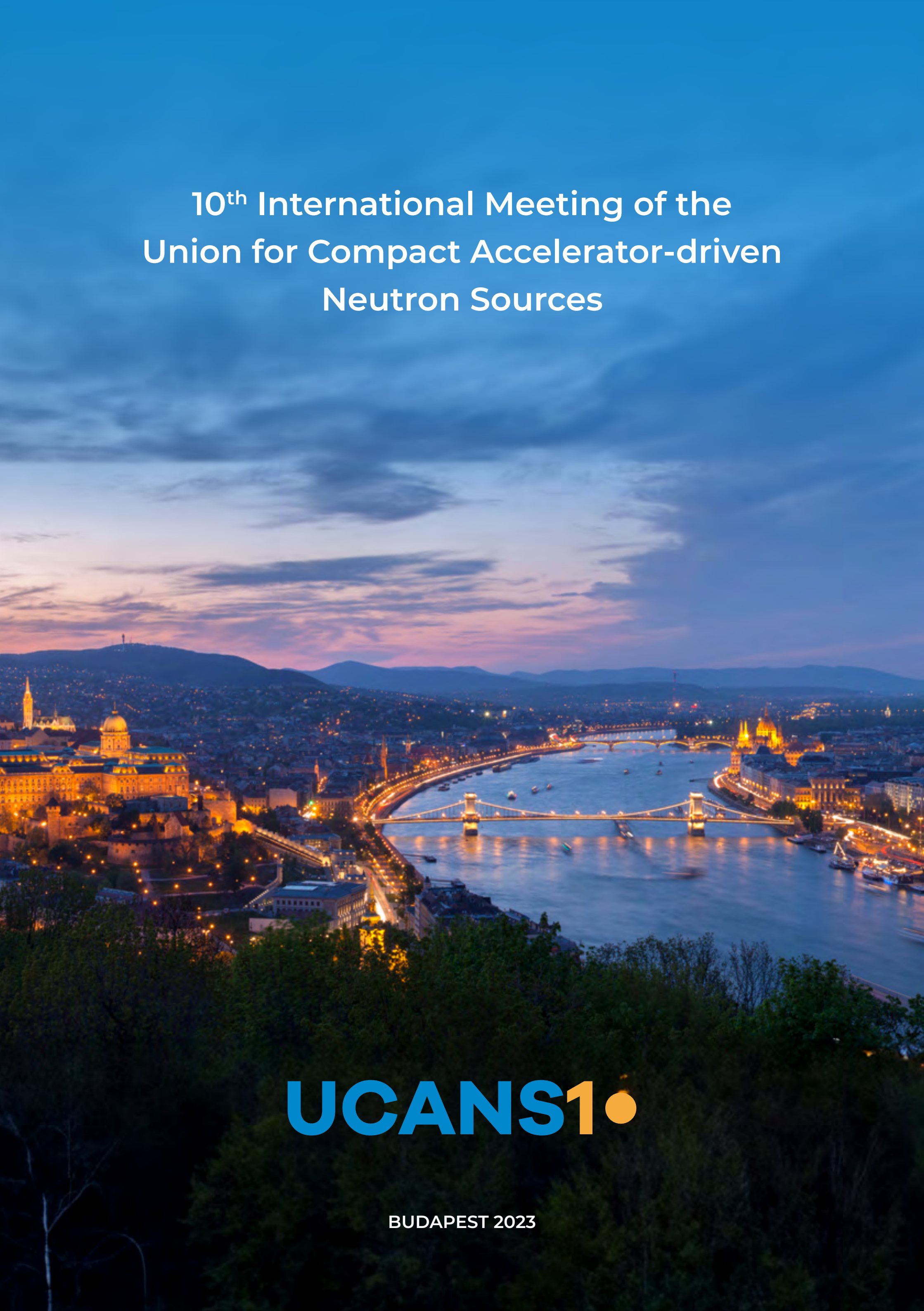
10th International Meeting of the Union for Compact Accelerator-driven Neutron Sources



UCANS10

BUDAPEST 2023

UCANS10

10th International Meeting of the Union for Compact Accelerator-driven Neutron Sources

ORGANIZED BY:

UCANS

MIRROTRON
THE WORLD OF NEUTRON

HUN REN

UCANS10

WELCOME

On behalf of the Local Organizing Committee, we warmly welcome you to the 10th Annual Meeting of the Union for Compact Accelerator-driven Neutron Sources in the beautiful city of Budapest.

The Union for Compact Accelerator-driven Neutron Sources was formed in 2010 to support the ongoing development of small accelerator-based neutron sources around the world. Since then, fruitful meetings have been held in Beijing (China) 2011, Bloomington (U.S.A) 2012, Bilbao (Spain) 2013, Sapporo (Japan) 2014, Legnaro (Italy) 2015, Xi´an (China) 2016, Bariloche (Argentina) 2018, Paris (France) 2019 and online hosted by Riken (Japan) 2022.

Mirrotron and HUN-REN Centre for Energy Research are proud to have the opportunity of organizing the 10th Annual Meeting of UCANS in Budapest. We are happy to be able to meet colleagues from around the world in person again.

We look forward to four days of exciting talks, posters, and discussions as well as a visit to Mirrotron's LvB CANS in Martonvásár, the first privately operated CANS facility in Europe. (LvB also refers to composer Ludwig van Beethoven who was a frequent visitor at the castle of Martonvásár in the early 1800s.)

It is our honor to host the first award ceremony of the John M. Carpenter Prize, established by UCANS in commemoration of our colleague 'Jack', taking place as part of the closing session of the event.

We would like to thank all of the conference participants for their contributions which are the foundation of this conference. We hope that you will have a productive and pleasant time at UCANS 10.

The Local Organizing Committee

EXHIBITORS AT UCANS10

DAICO MFG CO.,LTD.

JCNS Jülich Centre for Neutron Science

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Time	Speaker name	Title	Affiliation	Type	Page No.
15:00	Natko Skukan	Neutron Science Facility of the IAEA	IAEA	Contributed	**41**
16:00	Ulrich Rücker	Thermal moderator-reflector assembly for HBS	JCNS	Contributed	**42**
16:20	Dong Won Lee	Development status and application plan of 30 MeV cyclotron based neutron source in Korea	KAERI	Contributed	**43**
16:40	Wen Wang (subst. for Chao Liu)	Development of HINEG Series High Intensity Steady Neutron Generators	IANS	Contributed	**44**
Wednesday 18 October 2023 9:00-12:45 Section 4: Technologies (Accelerators and beam optics, Target development and moderator neutronics)					
9:00	Masahiro Okamura	RFQ linear accelerators for compact neutron production system	BNL	Keynote	**45**
9:35	Luyu Ji	The development of the Compact Accelerator-driven Neutron Source at CIAE	CIAE	Contributed	**46**
9:55	Ilan Eliyahu	200kW High Power liquid GaIn metal targets for neutron production at SARAF	SOREQ	Invited	**47**
10:20	Petr Konik	Coupling neutron moderators and optics	BNC CER	Contributed	**49**
11:15	Luca Zanini	Moderator developments in HighNESS and feedback to compact sources design	ESS	Invited	**50**
11:40	Yun Chang Shin	Compact ultracold neutron source for low-energy accelerator-driven neutron sources	IBS	Contributed	**51**
12:00	Kazuo Muramatsu (subst. for Yujiro Ikeda)	Exploring a new application of RANS cold neutrons for increasing cold neutrons with flower shaped graphene reflector	RIKEN	Contributed	**52**
12:20	Rosta László	Cold moderator developments for the new generation neutron sources	BNC CER	Contributed	**53**
Wednesday 18 October 2023 14:00-17:00 Section 5: Facilities/Projects II. (CANS projects and facility developments)					
14:00	Hirotaka Sato	Recent achievements of the Hokkaido University Neutron Source (HUNS) facility with cold/thermal/epithermal/fast neutrons	Hokkaido Univ.	Keynote	**54**
14:35	Xuewu Wang	CANS Projects in China	Tsinghua Univ.	Invited	**55**
15:00	Paul Zakalek	JULIC Neutron Platform, a testbed for HBS	JCNS	Contributed	**56**
16:00	Frédéric Ott	The ICONE project: towards a new neutron source in France for materials science and industry.	LLB	Contributed	**57**
16:20	Luis A. Fernandez	The neutron source target proposal for the ARGITU project	ESS Bilbao	Contributed	**58**
16:40	Cheolmin Ham	Recent progress of Nuclear Data Production System at RAON	IRIS	Contributed	**59**
Thursday 19 October 2023 9:00-10:45 Section 6: Nuclear Physics (Nuclear astrophysics and other neutron applications, Nuclear data measurements and evaluation)					
9:00	Moshe Friedman	Simulating Stars in the Lab - the 7Li(p,n) Reaction as an Intense Quasi-Stellar Neutron Source	Hebrew Univ.	Keynote	**60**
9:35	Rolando Granada	A new neutron scattering kernel for superfluid helium	CNEA	Contributed	**61**

Time	Speaker name	Title	Affiliation	Type	Page No.
9:55	Norberto Schmidt	On the comparison of the experimental neutron cold spectra obtained for various para- and ortho-hydrogen ratios against Monte Carlo simulations with different codes and nuclear data libraries	JCNS	Contributed	**62**
10:15	Douglas Di Julio	Advances in nuclear data development for moderator and reflector design at the European Spallation Source	ESS	Contributed	**63**

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3	Canyu Wang	The Design Status of DTL in SYSU-PAFA	IFCEN	**68**
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5	Junyang Chen	Investigation of Pancake-like Moderator-Reflector Structure for the High Brilliance Neutron Source (HBS)	JCNS	**70**
6	Mina Akhyani	A high brilliance spallation source optimized for one single instrument	EPFL	**71**
7	Pulin Bai	Optimized beam shaping assembly for 13 MeV proton accelerator-based neutron source	Tsinghua Univ.	**72**
8	Yuxuan Lai	The optimization of target station for bimodal neutron and photon imaging	Tsinghua Univ.	**73**
9	Octavio González del Moral	Conceptual insight into the moderators of ARGITU: A preliminary neutronics study	ESS Bilbao	**74**
10	Norberto Schmidt	Development of an Epithermal and Fast Neutrons Target-Moderator-Reflector Unit for the HBS	JCNS	**75**
11	Takuma Tashiro	Improvement of arrangement and size of a neutron production target for a higher intensity electron accelerator-driven pulsed neutron source	Hokkaido Univ.	**76**
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12	Tomohiro Kobayashi	Compact neutron monitoring system using solar cell	RIKEN	**78**
13	Yuxuan Lai	Realization of neutron sensitive microchannel plate imaging detector with a cross-strip readout	Tsinghua Univ.	**79**
14	Yasuki Okuno	Signal characteristics for pulsed neutron beam flux in organic-inorganic halide perovskite solar cells based detector	RIKEN	**80**
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15	David Baxter	Design of SANS Instruments at CANS Facilities	Indiana Univ.	**82**
16	Weihnang Hong	The Progress of Grazing-incidence Focusing Small-Angle Neutron Scattering (gif-SANS) Instrument at CPHS	Tsinghua Univ.	**83**

Poster No.	Name	Title	Affiliation	Page No.
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19	Norberto Schmidt	Conceptual design of neutron imaging instruments for the High Brilliance Neutron Source	JCNS	**86**
20	Miki Takeda	Development of a thermal/epithermal/fast neutron and X-ray radiography system for element imaging	Hokkaido Univ.	**87**
21	Wen Wang	Development and Application of Compact High-resolution Neu-tron Radiography System	IANS	**88**
Nuclear data measurements and evaluation				
22	Monia El Barbari	Experimental and Simulation Analysis of Ethane as a Neutron Moderator at Various Cryogenic Temperatures	JCNS-HBS	**89**
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23	David McGinnis	An open-source, zero-code, full-stack, integrated hard-ware-software control platform for research facilities	BL Monitor	**90**
24	Frédéric Ott	Design of a high resolution diffractometer using statistical time modulation to exploit the long pulse structure at the ICONE HiCANS.	LLB	**91**
25	Mariano Andrés Paulin	Development of neutron reflectometry at a HiCANS: the HERMES instrument at the JULIC Neutron Platform	LLB	**92**
26	Zhen Yang	A Novel Pyroelectric Neutron Generator Using Laser Irradiation Heating and Ionization	IFCEN	**93**
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27	Ha Shuai	Accelerator-based Boron neutron capture therapy (BNCT) tech-nology development project at Martonvásár, Hungary	Mirrotron/ ELTE	**94**
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28	Jochen Fenske	An Engineering Diffractometer for the High Brilliance Neutron Source (HBS)	Hereon	**95**
29	Olga Sidorova	Digital investigation of the neutron detector	JNR/Dubna Univ.	**96**
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30	Axel Klix	The intense DT neutron generator of Technical University of Dresden	Karlsruhe Inst.	**97**
CANS projects and facility developments				
31	Shavkat Akhmadaliev	Ion accelerator based neutron source at HZDR	HZDR	**98**
32	Daniel Blanco Lopez (subst. for Felix Fernandez-Alonso)	The IKUR-FUN initiative in the Basque Country – Raison d'être and first steps	CFM/MPC	**99**

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34	Erik Iverson	Conceptual Design of the Moderator Test Station at the Spallation Neutron Source	SNS Oak Ridge	**101**
35	Tomoki Sebe	Estimation of neutron energy-dependent SEU cross sections of semiconductor devices without fast TOF-analysis function	Hokkaido Univ.	**102**
36	Doruntin Shabani	Investigation of the mutual influence of multiple extraction channels for accelerator-based neutron sources	Aachen Univ.	**103**
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37	Hidenori Iwashita	Low energy neutron-induced SEU cross sections and the need for thermal neutron irradiation using CANS	NTT	**104**
38	Masato Takamura	On-site application of neutron salt-meter RANS-μ for non-destructive inspection of concrete bridges	RANS View	**105**

ABBREVIATIONS

Aachen Univ.	Aachen University of Applied Sciences
AIST	The National Institute of Advanced Industrial Science and Technology (AIST)
BL Monitor	BL Monitor and Control AB
BNL	Brookhaven National Laboratory
CEA	CEA Paris-Saclay
CFM/MPC	MATERIALS PHYSICS CENTER, University of the Basque Country
CIAE	China Institute of Atomic Energy
CNEA	Argentine Atomic Energy Commission
Darmstadt Tech. Univ.	Technische Universitaet Darmstadt
ELTE	Eötvös Loránd University
EPFL	École Polytechnique Fédérale de Lausanne
ESS	European Spallation Source
ESS Bilbao	Consorcio ESS Bilbao
Hebrew Univ.	The Hebrew University of Jerusalem
Hereon	Helmholtz-Zentrum Hereon
Hokkaido Univ.	Graduate School of Engineering, Hokkaido University, Sapporo, Japan
HUN-REN CER	Hungarian Research Network, Centre for Energy Research
HZDR	Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden
IAEA	International Atomic Energy Agency
IANS	International Academy of Neutron Science,Chongqing
IBS	Institute for Basic Science, Daejeon
IFCEN	Sino-French Institute of Nuclear Engineering and Technology, Sun Yat-sen University
IFP, CAEP	Institute of Fluid Physics, China Academy of Engineering Physics
ILL	Institut Laue-Langevin
Indiana Univ.	Indiana University, Bloomington
INER	Institute of Nuclear Energy Research, Atomic Energy Council, Taiwan,
INPC, CAEP	Institute of Nuclear Physics and Chemistry, China Academy of Engineering Physics
IRIS	Institute for Rare Isotope Science, Institute for Basic Science, Korea
JCNS	Jülich Centre for Neutron Science
JCNS-HBS	Jülich Centre for Neutron Science, High Brillance Neutron Source
JINR University	Joint Institute for Nuclear Research/Dubna
KAERI	Korea Atomic Energy Research Institute
Karlsruhe Inst.	Karlsruhe Institute of Technology
Kyoto Univ.	Kyoto University
LLB	Laboratoire Léon Brillouin CEA-CNRS
Nagoya Univ.	Nagoya University
NTT Corporation	Nippon Telegraph and Telephone
SNS Oak Ridge National Laboratory	Spallation Neutron Source, Oak Ridge
SOREQ	Soreq Nuclear Research Center
Torino Univ.	Torino University
Tsinghua Univ.	Tsinghua University
Tsukuba Univ.	Tsukuba University

TIME	MONDAY (16.10)	TUESDAY (17.10)	WEDNESDAY (18.10)	THURSDAY (19.10)	FRIDAY (20.10)
		Session 2: Applications	**Session 4: Technologies**	**Session 6: Nuclear Physics**	**Optional Visit**
9:00-10:45		**Yoshié Otake** RIKEN (keynote) **Alain Menelle** LLB (inv.) **Ryu Kiuchi** NTT **Ke Jianlin** INPC CAEP	**Masahiro Okamura** BNL (keynote) **Luyu Ji** CIAE **Ilan Eliyahu** SOREQ (inv.) **Petr Konik** HUN-REN CER	**Moshe Friedman** Hebrew Univ. (keynote) **Rolando Granada** CNEA **Norberto Schmidt** JCNS **Douglas Di Julio** ESS ERIC	**Optional visit to Budapest Neutron Centre and Mirrotron's Neutron Optics HQ & labs**
10:45-11:15		Coffee break	Coffee break	Coffee break	
11:15-12:45		**Young-soon Bae**, DawonMedax (inv.) **Hiroaki Kumada** Tsukuba Univ. **Ettore Mafucci** Torino Univ. **Javier Dawidowski** CNEA	**Luca Zanini**, ESS (inv.) **Yun Chang Shin** IBS **Kazuo Muramatsu** (subst. for Y. Ikeda) Incubation All. **László Rosta** HUN-REN CER	**John M. Carpenter-prize ceremony** **Closing session** **Group photo**	
12:45-14:00	**Welcome & Registration 12:45-13:40** **Opening session 13:40**	Lunch included on site	Lunch included on site	Lunch included on site	
	Session 1: Instrumentation	**Session 3: Facilities/Projects**	**Session 5: Facilities/Projects**	**LvB CANS visit**	
14:00-15:30	**Jörg Voigt** JCNS (keynote) **Koichi Kino** AIST (inv.) **Sheng Wang** INPC CAEP	**Hirohiko Shimizu** Nagoya Univ. (keynote) **Mario Perez** ESS Bilbao **Natko Skukan** IAEA	**Hirotaka Sato** Hokkaido Univ. (keynote) **Xuewu Wang** Tsinghua Univ. (inv.) **Paul Zakalek** JCNS	**Visit to LvB CANS Martonvásár**	
15:30-16:00	Coffee break	Coffee break	Coffee break		
16:00-17:00	**Oliver Zimmer** ILL (inv.) **Yoshihisa Iwashita** Kyoto Univ. **Stefan Scheuren** Darmstadt Techn. Univ.	**Ulrich Rücker** JCNS **Dong Won Lee** KAERI **Wen Wang** (subst. for Chao Liu) IANS	**Frédéric Ott** CEA **Luis A. Fernandez Barrio** ESS Bilbao **Cheolmin Ham** IRIS		
17:00-18:00	Posters and Discussion	Posters and Discussion	Posters and Discussion		
18:00-19:00		**UCANS Board Meeting**			
19:00-21:00		**UCANS 10 Scientific Program Committee Dinner**	**Social Dinner**		
21:00-22:00					

Speaker name	Affiliation	Title	Time	Type
Bae Young-soon	Dawon-Medax	Boron neutron capture therapy using LINAC-driven epithermal neutron beam in Korea	Tue, 11:15	Invited
Dawidowski Javier	CNEA	Determination of effective temperatures through affordable concurrent techniques in CANS	Tue, 12:20	Contributed
Di Julio Douglas	ESS	Advances in nuclear data development for moderator and reflector design at the European Spallation Source	Thu, 10:15	Contributed
Eliyahu Ilan	SOREQ	200kW High Power liquid GaIn metal targets for neutron production at SARAF	Wed, 9:55	Invited
Fernandez Luis A.	ESS Bilbao	The neutron source target proposal for the ARGITU project	Wed, 16:20	Contributed
Friedman Moshe	Hebrew Univ.	Simulating Stars in the Lab - the 7Li(p,n) Reaction as an Intense Quasi-Stellar Neutron Source	Thu, 9:00	Keynote
Granada Rolando	CNEA	A new neutron scattering kernel for superfluid helium	Thu, 9:35	Contributed
Ham Cheolmin	IRIS	Recent progress of Nuclear Data Production System at RAON	Wed, 16:40	Contributed
Konik Petr	HUN-REN CER	Coupling neutron moderators and optics	Wed, 10:20	Contributed
Iwashita Yoshihisa	Kyoto Univ.	Update of Magnetic Optics for Neutron Beams	Mon, 16:25	Contributed
Ji Luyu	CIAE	The development of the Compact Accelerator-driven Neutron Source at CIAE	Wed, 9:35	Contributed
Jianlin Ke	INPC, CAEP	Development and applications of compact deuterium-deuterium neutron generator at INPC, CAEP	Tue, 10:20	Contributed
Kino Koichi	AIST	Status and imaging examples of the compact electron accelerator-driven neutron facility AISTANS	Mon,14:35	Invited
Kiuchi Ryu	NTT	Possibility of evaluating the cosmic proton environment for CANS using clarifying the relationship between neutron- and proton-induced SEU cross sections	Tue, 10:00	Contributed
Kumada Hiroaki	Tsukuba Univ.	Neutron beam performance of iBNCT001, a linac-based neutron source for neutron capture therapy in Tsukuba project	Tue, 11:40	Contributed
Lee Dong Won	KAERI	Development status and application plan of 30 MeV cyclotron based neutron source in Korea	Tue, 16:20	Contributed
Mafucci Ettore	Torino Univ.	Development of a Neutron Capture Therapy Compact Spectrometer	Tue, 12:00	Contributed
Menelle Alain	LLB	CANS and industrial applications	Tue, 9:35	Invited
Muramatsu Kazuo (subst. for Yujiro Ikeda)	RIKEN	Exploring a new application of RANS cold neutrons for increasing cold neutrons with flower shaped graphene reflector	Wed, 12:00	Contributed

Speaker name	Affiliation	Title	Time	Type
Okamura Masahiro	BNL	RFQ linear accelerators for compact neutron production system	Wed, 9:00	Keynote
Otake Yoshie	RIKEN	RIKEN Accelerator-driven compact neutron sources, RANS, and their applications	Tue, 9:00	Keynote
Ott Frédéric	LLB	The ICONE project: towards a new neutron source in France for materials science and industry.	Wed, 16:00	Contributed
Perez Mario	ESS Bilbao	The European Low Energy accelerator-based Neutron facilities Association (ELENA) – Current Status and Perspectives	Tue, 14:35	Contributed
Rosta László	HUN-REN CER	Cold moderator developments for the new generation neutron sources	Wed, 12:20	Contributed
Rücker Ulrich	JCNS	Thermal moderator-reflector assembly for HBS	Tue, 16:00	Contributed
Sato Hirotaka	Hokkaido Univ.	Recent achievements of the Hokkaido University Neutron Source (HUNS) facility with cold/thermal/epithermal/fast neutrons	Wed, 14:00	Keynote
Scheuren Stefan	Darmstadt Tech. Univ.	Demonstration of non-destructive, isotope-sensitive material characterization using a laser-based neutron source	Mon, 16:45	Contributed
Schmidt Norberto	JCNS	On the comparison of the experimental neutron cold spectra obtained for various para- and ortho-hydrogen ratios against Monte Carlo simulations with different codes and nuclear data libraries	Thur, 9:55	Contributed
Shimizu Hirohiko M.	Nagoya Univ.	A Quantitative Description of Supply and Demand Relationship of Neutron Beam Use - Numeracy for Applications of Neutrons	Tue, 14:00	Keynote
Shin Yun Chang	IBS	Compact ultracold neutron source for low-energy accelerator-driven neutron sources	Wed, 11:40	Contributed
Skukan Natko	IAEA	Neutron Science Facility of the IAEA	Tue, 15:00	Contributed
Voigt Jörg	JCNS	An Instrumentation Suite for HBS	Mon, 14:00	Keynote
Wang Sheng	INPC, CAEP	Improvements of fast neutron tomography based on compact accelerator of D-T neutron source	Mon, 15:00	Contributed
Wang Wen (subst. for Chao Liu)	IANS	Development of HINEG Series High Intensity Steady Neutron Generators	Tue, 16:40	Contributed
Wang Xuewu	Tsinghua Univ.	CANS Projects in China	Wed, 14:35	Invited
Zakalek Paul	JCNS	JULIC Neutron Platform, a testbed for HBS	Wed, 15:00	Contributed
Zanini Luca	ESS	Moderator developments in HighNESS and feedback to compact sources design	Wed, 11:15	Invited
Zimmer Oliver	ILL	Nested mirror optics – the next generation of neutron delivery systems?	Mon, 16:00	Invited

John M. Carpenter Prize

The John M. Carpenter Prize was established by the Union for Compact Accelerator-driven Neutron Sources in 2023, in commemoration of the inspiring scientist and colleague 'Jack' Carpenter, co-founder of UCANS who passed away in 2020. The prize will be awarded bi-annually to an outstanding member of the CANS community in recognition of his or her fundamental achievements and contributions in the field of CANS research and applications.

In 2023, the monetary award of the prize is generously sponsored by RANS View Corporation Japan and HUN-REN Centre for Energy Research Hungary.

The presentation of the 2023 John M. Carpenter Prize will take place within the closing session of the UCANS 10 meeting on Thursday 19. October starting at 11:15.

Visits and social dinner

UCANS 10 SOCIAL DINNER

Wednesday, 18. October 2023

Start: 19:00 End: 22:00
Venue: Vén Hajó Restaurant (Kossuth Museum Boat)
Address: 1052 Budapest, Vigadó 2nd pier
Travel: Individually (public transport/walking/taxi)

VISIT TO LvB CANS MARTONVÁSÁR

Thursday, 19. October 2023

Start: Hotel Lobby at 14:15 (Mercure Hotel Castle Hill)
End: Déli Station at 18:19
Travel: By train (28 minutes) + Walk (15 minutes)
Group tickets pre-purchased by Mirrotron

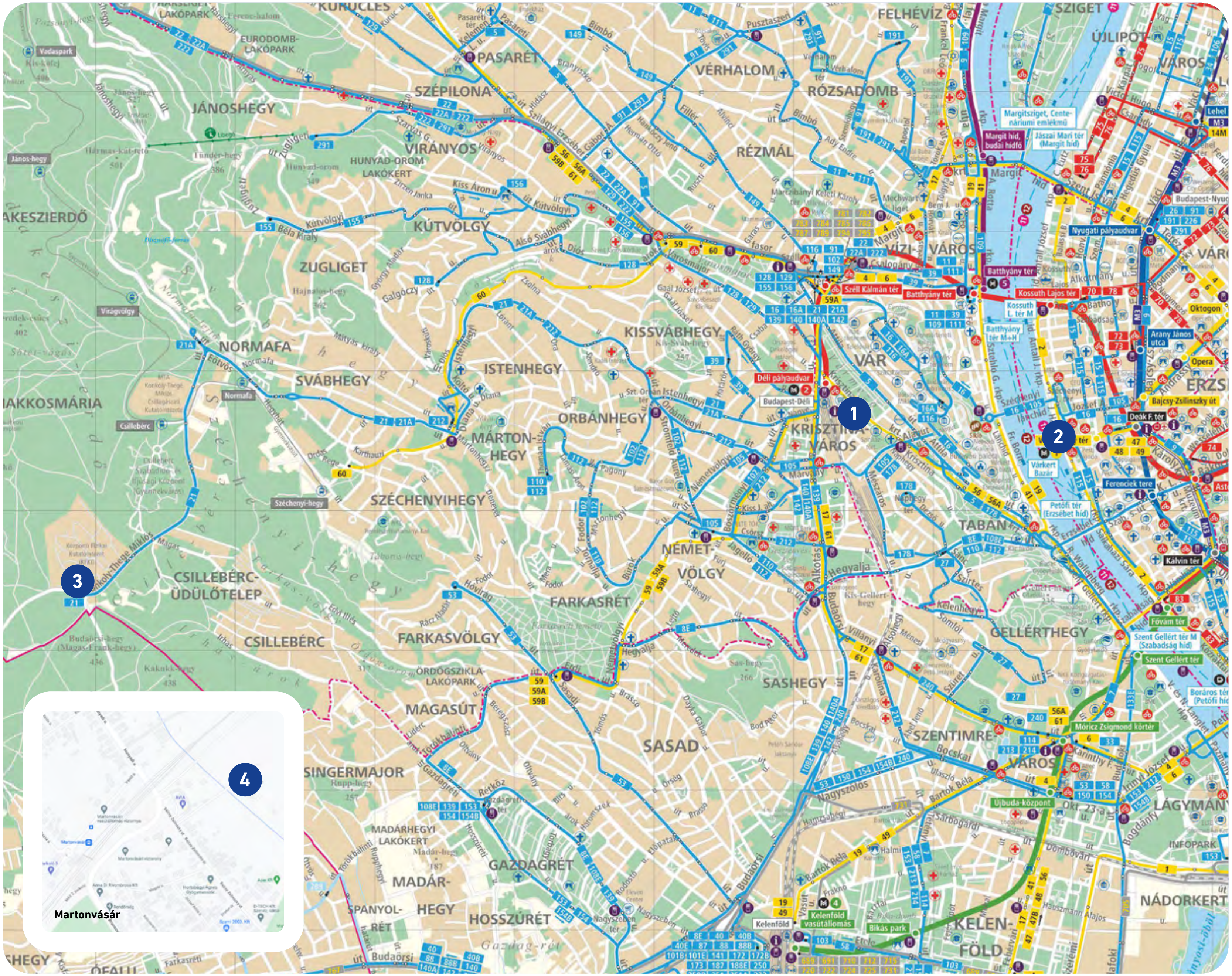
Departure	Arrival
Meeting point: Hotel Lobby at 14:15 Train from Déli Station at 14:40 (TRAIN 4616)	Martonvásár at 15:08
15 minutes walk to destination (arrival 15:25) LvB CANS Presentations and discussion (15:30-16:45) Refreshments (16:45-17:15) 15 minutes walk back to the train station (17:15-17:30)	
Train from Martonvásár Station at 17:48 (TRAIN 4643)	Déli Station at 18:19

OPTIONAL VISIT TO BNC (BUDAPEST NEUTRON CENTRE) AND MIRROTRON'S NEUTRON OPTICS HQ & LABS

Friday, 20. October 2023

Start: Hotel Lobby 8:00 (Mercure Hotel Castle Hill)
End: Hotel Lobby 12:20
Travel by: Charter buses (20 minutes) (license No.: MUE-240 and NSY-222 Mercedes-Benz Tourismo buses)

Departure	Arrival
Meeting point: Hotel Lobby at 7:50 – BUS	KFKI Campus at 8:20 (Konkoly-Thege Miklos út 29-33.)
Budapest Neutron Centre, Mirrotron's Neutron Optics HQ, Mirrotron's production labs (9:00-12:00)	
KFKI Campus at 12:00 – BUS	Hotel Lobby at 12:20



GOOGLE MAPS ROUTE
1 Mercure Hotel Castle Hill

GOOGLE MAPS ROUTE
2 Vén Hajó Restaurant

GOOGLE MAPS ROUTE
3 Budapest Neutron Centre Mirrotron

GOOGLE MAPS ROUTE
4 LvB CANS Martonvásár

ORAL PRESENTATIONS

- **Section 1: Instrumentation**
  Neutron imaging and analytics, Neutron detection and neutron optics, Innovative instrumentation, Computer simulations and instrument performance
  MONDAY 16 OCTOBER 2023 14:00-17:00

- **Section 2: Applications**
  Potentials for industrial applications, Neutron scattering and material characterization, Medical applications
  TUESDAY 17 OCTOBER 2023 9:00-12:45

- **Section 3: Facilities/Projects I.**
  CANS projects and facility developments
  TUESDAY 17 OCTOBER 2023 14:00-17:00

- **Section 4: Technologies**
  Accelerators and beam optics, Target development and moderator neutronics
  WEDNESDAY 18 OCTOBER 2023 9:00-12:45

- **Section 5: Facilities/Projects II.**
  CANS projects and facility developments
  WEDNESDAY 18 OCTOBER 2023 14:00-17:00

- **Section 6: Nuclear Physics**
  Nuclear astrophysics and other neutron applications, Nuclear data measurements and evaluation
  THURSDAY 19 OCTOBER 2023 9:00-10:45

Time of presentation:
16.10.2023. 14:00 - 14:35

An Instrumentation Suite for HBS

Jörg Voigt[1], Klaus Lieutenant[1]

[1] Jülich Center for Neutron Science, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

ABSTRACT

High Current Accelerator driven Neutron Sources (HiCANS) are considered as the next generation medium flux neutron facility taking over the role of today's national neutron sources. The High Brilliance Source HBS will provide dedicated target stations delivering ~ 100 kW, where the instruments around the target station define the pulse and spectral properties of the neutrons source. Recently, we have finished the technical design report for the HBS comprising of four volumes, covering "Accelerator", "Target", "Instrumentation" and "Infrastructure" [1]. I will present the instrumentation suite that has been explored in the Volume "Instrumentation" by a large group of instrument developers from JCNS and other facilities. They show, that the HBS can host a competitive instrument suite, which is able to cover the future requirements of the neutron community.

REFERENCES

[1] T. Brückel, T. Gutberlet, Ser. Ed., Technical Design Report HBS (2023)

Time of presentation:
16.10.2023. 14:35 - 15:00

Status and imaging examples of the compact electron accelerator-driven neutron facility AISTANS

Koichi Kino[1,2]

[1] National Institute of Advanced Industrial Science and Technology (AIST)
[2] Innovative Structural Materials Association (ISMA)

ABSTRACT

AISTANS (Analytical facility for Industrial Science and Technology using Accelerator based Neutron Source)1-3) is a compact accelerator-based neutron facility at AIST (National Institute of Advanced Industrial Science and Technology) Tsukuba in Japan. AISTANS can provide a thermal-cold pulsed neutron beam from the decoupled solid-methane moderator. Various neutron measurement methods are available at AISTANS, although the electron linear accelerator, neutron source, and neutron beamline, which are the main components of AISTANS, are optimized for Bragg-edge imaging aiming.

Samples aimed at developing structural materials for transportation vehicles have been investigated at AISTANS using neutron Bragg edge imaging, neutron radiography, and neutron Computed Tomography imaging. The large-scale samples included a door panel, transmission (gearbox), and suspension components. Materials joined together using glue, welding, and friction stir welding were imaged for same and dissimilar materials. Some samples were also measured using X-rays also to demonstrate the usefulness of neutron beams for nondestructive analysis. Recently, neutron diffraction measurement became available by developing a diffractometer utilizing the short neutron pulse from the decoupled solid methane moderator.

In this presentation, the status of AISTANS and recent measurement examples at AISTANS will be shown.

This is partly based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

REFERENCES

[1] K. Kino et al., European Physical Journal Plus (2022) 137:1260.

[2] K. Kino et al., Nuclear Instruments and Methods in Physics Research,A 927 (2019) 407-418.

[3] B.E. O'Rourke et al., Nuclear Instruments and Methods in Physics Research,B 464 (2020) 41–44.

Time of presentation:
16.10.2023. 15:00 - 15:20

Improvements of fast neutron tomography based on compact accelerator of D-T neutron source

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ABSTRACT

Neutron imaging team at INPC of CAEP has constructed several neutron radiography systems based on compact accelerator of D-T neutron sources since several years ago [1-3]. The maximum D-T neutron yield is 1.7×10^{11} neutrons/s, and neutron source's size is about 10mm. Thermal and fast neutron radiography, thermal and fast neutron tomography have been all tested at these systems, and the resolution of fast neutron radiography is better than 1mm in the previous system.

Recently, with new setup of rotating tritium target, D-T neutron source could supply longer lifetime up to several ten hours. A new scanning system was built and applied to large detection applications [4], and an improved square imaging system was developed at the same time. However, because of low detection efficiency, the raw pictures of fast neutron radiography were still poor. In order to promote the images' quality of raw projection images, a pro-dealing method was applied to wipe high brightness noise from different time series images. Furthermore, a noise2noise deep learning technology explored by nVidia [5] was used to improve SNR of pro-dealing images. With SART reconstruction method, the fast neutron tomography of scanning imaging system and square imaging system were both obviously improved. Each fast tomography costed about 10 hours. Flaws of diameter 2mm hole and width 0.3mm slit in light materials covered by heavy materials were reconstructed clearly.

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Time of presentation:
16.10.2023. 16:00 - 16:25

Nested mirror optics – the next generation of neutron delivery systems?

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ABSTRACT

Neutron delivery from a neutron source to its attached instruments is key for its efficient exploitation in successful experiments. Nested mirror optics (NMO) offer a viable and flexible solution for this task, offering several advantages with respect to traditional neutron transport systems. Provided the direct view onto the moderator emission surface is not obstructed by shielding structures, a condition that is most easily fulfilled for UCANS, NMO are able to image a well-defined volume of beam phase space with large solid angle from the moderator onto a target, such as a sample for neutron scattering. In contrast to neutron guides, each of the NMO's individual mirrors reflects neutrons only within a narrow range of finite angles. Due to this geometrically well-defined reflection kinematics, NMO can tailor the beam divergence and, using supermirrors with well-selected broadband or bandpass reflectivity, also the spectrum customized to the needs of experiments, resulting in qualitatively new experimental opportunities. NMO can produce clean beams without optical elements close to the source and the target, which also leads to a number of practical advantages. The current status of development includes first experimental demonstrations of small-scale elliptic and parabolic NMO prototypes, performed at the instruments MIRA at FRM2 and BOA at PSI. Within the HighNESS project, two proposals were made for NMO neutron transport from a future liquid-deuterium moderator at the ESS to an in-beam source for ultracold neutron production in superfluid helium, and to a detector for an experimental search for neutron-to-antineutron oscillations.

Time of presentation:
16.10.2023. 16:25 - 16:45

Update of Magnetic Optics for Neutron Beams

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[1] KEK

ABSTRACT

Magnetic optics makes enables efficient use of precious neutrons. It uses the electromagnetic force among four forces in the universe. It is specifically the interaction between the magnetic dipole moment of the neutron and the magnetic field. The strong force, on the other hand, is used in reflectors such as neutron guides and diffractive optics, where neutrons are absorbed or scattered by materials and surfaces.

While magnetic fields of the strength currently available are not very strong compared to devices that use strong forces, they are advantageous because they are more tolerant of neutron transmission losses. We have been developing magnetic neutron focusing lenses and have demonstrated their application to SANS focusing and magnification imaging. We have also recently begun development of a magnetic neutron guide. These activities will be reported.

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Time of presentation:
16.10.2023. 16:45 - 17:05

Demonstration of non-destructive, isotope-sensitive material characterization using a laser-based neutron source

Stefan Scheuren[1], Marc Zimmer[2], Annika Kleinschmidt[3,4], Nikodem Mitura[1], Alexandra Tebartz[1], Gabriel Schaumann[1], Torsten Abel[1], Tina Ebert[1], Markus Hesse[2], Sero Zähter[2], Sven C. Vogel[5], Oliver Merle[6], Rolf-Jürgen Ahlers[6], Serge Duarte Pinto[7], Maximilian Peschke[8], Thorsten Kröll[1], Vincent Bagnoud[1,3], Christian Rödel[1], and Markus Roth[1,2]

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ABSTRACT

Laser-driven neutron sources (LDNS) have garnered a lot of attention for their compact size, relatively low cost and high application potential[1,2,3]. Here we present the design and optimization of a LDNS in the epi-thermal and thermal energy range.

We have utilized the PHELIX ultra-short pulsed laser system (~103J at ~500fs) at GSI to accelerate both protons and deuterons. The ion acceleration took place in the target normal sheath acceleration (TNSA) regime and the accelerated ions reached energies exceeding 50MeV. These ions were subsequently converted into neutrons using beryllium and lithium fluoride discs, resulting in an average primary neutron yield of 10^{10} neutrons per shot [2]. We optimized the moderator and beamline for experiments in the energy region from 0.5 to 10eV in order to conduct neutron measurements on static samples [2]. These measurements include neutron resonance spectroscopy (NRS) on a 2.7mm thick tungsten sample, in a time-of-flight configuration. Besides several tungsten isotopes we were able to detect a tantalum impurity (2%) in the sample. We further conducted a simplified variant of neutron resonance imaging (NRI), with samples of indium and cadmium using the time-of-flight technique [2]. The final part of the talk will give an outlook for future developments and applications of LDNS. This outlook will focus on low energy, high average power ultra-short pulse laser systems and their potential as drivers of compact, mobile LDNS.

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16.10.2023. 16:45 - 17:05

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Time of presentation:
17.10.2023. 09:00 - 09:35

RIKEN
Accelerator-driven compact neutron sources, RANS, and their applications

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ABSTRACT

RIKEN Accelerator-driven compact neutron source, RANS, has been operated since 2013[1]. There are two major goals of RANS research and development. One is to establish and realisation of CANS models that can be easily operated, non-destructively measured, and quantitatively evaluated, as a floor-standing type for industrial use as non-destructive analysis equipment. Another goal is to invent a novel transportable compact neutron system for the preventive maintenance of large-scale construction such as a bridge. As of April 2023, two accelerator-based compact neutron source systems, RANS (7 MeV Proton, Be target) and RANS-II (2.49 MeV proton, Li target), as well as RANS-μ (252Cf) which has started real bridge measurements, are in constant operation. In addition, RANS-III, a transportable compact neutron system for non-destructive inspection of bridge decks, is being developed for onboard use. There are more than six kinds of instruments, and neutron measurements are available with RANS and RANS-II. The transmission imaging[2], neutron diffractometer towards stress measurement [3], small angle scattering instruments with thermal and/or cold moderators at RANS, fast neutron scattering time-of-flight imaging [4,5], neutron activation analysis with RANS and RANS-II, and neutron-induced prompt gamma-ray analysis with RANS, RANS-II, and RANS-μare available. As an example of the results, the neutron diffraction technique for the measurement of retained austenite volume fraction has been newly developed by using RANS, which allows us to perform the "on-site" measurement with an accuracy of 1%. Retained austenite is one of the key factors that dominate the mechanical properties of an advanced high-strength steel sheet. The visualisation of water retention leading to the deterioration of grading inside floor slabs and the deterioration of suspension bridge cable anchorage has been developed into a quantitative assessment in RANS-II with the advancement of measurement technology. RANS-μ is a non-destructive, quantitative evaluation of salinity inside concrete bridges to a depth of 7 cm, and has already been used to measure salinity in more than two outdoor bridges. The RANS project is challenging the deployment of the technology for non-destructive detection inside concrete structures into space, as it will enable water exploration and elemental exploration on the Moon and Jupiter.

Time of presentation:
17.10.2023. 09:00 - 09:35

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Time of presentation:
17.10.2023. 09:35 - 10:00

CANS and industrial applications

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ABSTRACT

Due to the interesting properties linked to thermal neutron interaction with matter, the use of neutrons for specific characterizations of materials are of interest for society and industry [1]. In the neutron scattering area, one can think to nuclear and magnetic phase diagram determination of new materials, small angle scattering characterization of nanostructures, or texture and stress characterization in metallurgy. Reflectivity measurements will be done for quality control of neutron guides. Neutrons will also enable imaging of light material within heavy ones and prompt and delayed gamma activation analysis can be used for composition measurement on industrial conveyers.

However, current neutrons sources are mainly large infrastructures. The access to beam time can be delayed, expensive and difficult to obtain which prevent a larger use of them by industry.

Having a closer look, the needs of industry and academic areas are a bit different. At the contrary of research use that quite often needs a high flux to solve their problems, this is most of the time not the case for industry that may obtain the answers to their questions with instruments having a limited flux. For that sake, CANS appear to be the good solution since they should be able to provide the main criteria required by industry:

- Working instruments with scientist able to provide high qualified support
- Available beam time all around the year
- Affordable prices
- Sufficient flux to obtain good quality data

Examples of expected CANS use by industry will be given.

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Time of presentation:
17.10.2023. 10:00 - 10:20

Possibility of evaluating the cosmic proton environment for CANS using clarifying the relationship between neutron- and proton-induced SEU cross sections

Ryu Kiuchi [1], Hidenori Iwashita[1], Yoshiharu Hiroshima[1], Tomoki Sebe[2], Hirotaka Sato[2], Takashi Kamiyama[2], Michihiro Furusaka[2] and Yoshiaki Kiyanagi[2]

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ABSTRACT

Single event upset (SEU) testing and evaluation by proton irradiation is essential for electronic devices used in the space environment. However, because proton beams have low transmission power, their testing is limited to directly irradiating individual devices in system, and system-level testing is not possible because of the overlap of multiple electronic boards. On the other hand, neutron beams, which have high penetrating power, are relatively easy to test at the system level. Therefore, if the relationship between neutron- and proton-induced SEU cross sections can be clarified, it will be possible to evaluate the effects of proton-induced SEU in the system from the results of neutron-induced SEU tests. We have previously measured continuous neutron energy-dependent SEU cross sections in a white pulsed neutron source using the TOF method [1]. In this study, we measured proton-induced SEU cross sections at monoenergetic proton sources of 10 MeV, 20 MeV, 30 MeV, and 65 MeV for the measured semiconductor devices at Takasaki Ion Accelerators for Advanced Radiation Application (TIARA) of Takasaki Institute of Advanced Quantum Science, QST, Japan. Then, we compared them with the neutron-induced SEU cross sections. As a result, it was found that the proton-induced SEU cross section of about 10 MeV is lower because the proton beam is shielded due to Coulomb barrier by the cover over the memory. However, in the higher energy region is almost the same value as that of the neutron induced SEU cross section. Therefore, soft-error tests using neutron beams may be used to evaluate the proton-induced SEU effects at the system level. This finding suggests that the compact accelerator-driven neutron source can be used in the space research field.

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Time of presentation:
17.10.2023. 10:20 - 11:15

Development and applications of compact deuterium-deuterium neutron generator at INPC, CAEP

Jianlin Ke[1], Baili Liu[1], Benchao Lou[1], Yonghong Hu[1], Taiyan Liu[1], Jie Yan[1], Chunlei Wu[1], Jinyang He[1], Qinlong Zhang[1]

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ABSTRACT

Compact deuterium-deuterium (D-D) neutron generators are widely used in neutron activation analysis, neutron detector calibration, neutron radiation, neutron imaging and so on. Compared with radio-isotopic neutron generator and deuterium-tritium (D-T) neutron generator, D-D neutron generator has many advantages. Firstly, D-D neutron generator is safer. It is nearly free from tritium contamination and can be turned off in the case of installation and transportation. Secondly, the deuterium in the target can be complemented by the incident deuterium ions, thus the lifetime of the D-D neutron generator is generally very long. Thirdly, the D-D neutron generator does not require complex maintenance, as its components are replaceable and stops emitting when turned off.

Three generations of compact D-D neutron generator, with the neutron yield of about 1×108n/s, have been developed at Institute of Nuclear Physics and Chemistry, CAEP, China. The Characteristics of these neutron generators are introduced in this paper. The design of a compact D-D neutron generator, with the neutron yield of 5×10^{9}n/s is also introduced. The applications of the D-D neutron generators in industrial material analysis and neutron detector calibration are also introduced.

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Time of presentation:
17.10.2023. 11:15 - 11:40

Boron neutron capture therapy using LINAC-driven epithermal neutron beam in Korea

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ABSTRACT

Boron neutron capture therapy (BNCT) has been attractive radiation cancer therapy as a new radiation modality because it can selectively destroy cancer cells while maintaining the healthy state of surrounding normal cells. Many experimental trials have demonstrated significant BNCT treatment efficacy using neutron beams from research reactors. However, nuclear reactor technology cannot be scaled to sites in hospitals delivering patient treatment. Therefore, compact accelerator-based neutron sources that could be installed in many hospitals are under development or have even been commissioned at many facilities around the world. In Korea, a radiofrequency (RF) LINAC-based BNCT (A-BNCT) facility is installed and under operation for human clinical trials carried by DawonMedax (DM). It provides the highly efficient production of an epithermal neutron beam with an optimized neutron energy spectrum range of 0.1 ~ 10 keV with a 10-MeV and 20-kW proton beam from the LINAC, and the irradiation port epithermal neutron flux is higher than 1 x 10^9 n/cm^2s. Comprehensive verification and validation of the system has been conducted with the measurement of both proton and neutron beam characteristics. Significant therapeutic effects from BNCT have been confirmed by DM in both in-vitro and in-vivo non-clinical trials. Further, during exposure to epithermal neutrons, all other unintended radiation is controlled to levels recommended by International Atomic Energy Agency (IAEA). The A-BNCT facility is now in operation for the first phase of human clinical trials. Recently, the first three patients are treated. This paper presents the characteristics and technology issues of DM LINAC-driven neutron source for BNCT.

Time of presentation:
17.10.2023. 11:40 - 12:00

Neutron beam performance of iBNCT001, a linac-based neutron source for neutron capture therapy in Tsukuba project

Hiroaki Kumada[1], Yinuo Li[1], Kiyoshi Yasuoka[1], Susumu Tanaka[1], Kei Nakai[1], Takashi Sugimura[2], Masaharu Sato[2], Toshikazu Kurihara[2], Hideyuki Sakurai[1] and Takeji Sakae[1]

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ABSTRACT

Boron neutron capture therapy (BNCT) is the next generation of radiotherapy that combines neutrons and boron drugs. iBNCT project headed by the University of Tsukuba has developed “iBNCT001”, a demonstration device for the linac-base neutron source for BNCT [1]. iBNCT001 has adopted an RFQ and a DLT type linac as the proton beam accelerator. The linac accelerates protons of the average current of 2 mA to 8 MeV and then generates high-intensity neutrons by irradiating the protons to the beryllium target. The high-energy neutrons emitted from the beryllium reduce the energy by passing through a moderator and an epithermal neutron beam is finally released from the beam aperture. University of Tsukuba plans to conduct a clinical trial for a malignant brain tumor in the near future. To confirm the practicality and therapeutic applicability of the neutron beam of iBNCT001, we have performed various characteristic measurements of the neutron beam.

In the experiment with a rectangular water phantom simulated a human head, two-dimensional distributions for thermal neutron flux and gamma-ray dose rate which are important factors to determine the dose in BNCT, have been measured in the phantom. In the measurement of the thermal neutron flux, we confirmed that the maximum thermal neutron flux in the phantom was approximately 1.4 × 10^9 (n/cm^2/s). The neutron intensity has sufficient performance to complete irradiation in around 30 minutes under the protocol of the BNCT for malignant brain tumors. And we confirmed that the beam can deliver the thermal neutrons requiring the treatment to a depth of 6 cm or more in the phantom. These results demonstrated that our equipment could produce a neutron beam that is applicable to BNCT. Furthermore, we measured leakage radiation emitted from outside of the beam aperture and residual gamma rays after irradiation, etc. The results were verified to be small enough to be safe for patients as well as medical staff. Based on these results, we are

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preparing to begin a clinical trial on phase 1 of malignant brain tumors after going through several procedures.

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Time of presentation:
17.10.2023. 12:00 - 12:20

Development of a Neutron Capture Therapy Compact Spectrometer

E. Mafucci[1,2], M. Costa[1,2], E. Durisi[1,2], V. Monti[1,2], R. Bedogni[3], A. Calamida[3], A. Fontanilla[3], S. Bortolussi[4,5], I. Postuma[4,5],S. Altieri [4,5], N. Protti[4,5]

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ABSTRACT

In recent years, the introduction of accelerator-based BNCT facilities has led to a significant increase in interest from the medical and scientific communities.
Monitoring and characterization of neutron beams and intercomparison of different facilities are becoming mandatory [1]. This stimulates the development of dedicated dosimetry and spectrometry techniques. This work aims to present a novel compact spectrometer with an isotropic response called Neutron Capture Therapy- Activation Compact Spectrometer (NCT-ACS), funded by INFN, highly sensitive in the energy interval ranging from thermal to 100 keV and suitable for in-phantom irradiation.
The detector geometry is composed of a spherical moderator shell containing different material foils exhibiting neutron radiative capture resonances covering the wide energy domain for BNCT. This contribution will first focus on the extensive simulations work that have been performed to optimize the geometry of the detector, its materials composition, and its response; following by the main experimental results that have been obtained.
Irradiation and activation measurements on a first prototype have been performed at the electron Linac facility installed at the university of Turin, where a well-known epithermal neutron field can be produced. The materials activation was measured using a HPGe and a LaBr(Ce) detectors, opportunely calibrated for the spectrometer geometry. A careful analysis of the activation gamma spectra has been performed to correctly estimate the statistic and systematic uncertainties. The Turin epithermal neutron spectrum was then obtained using an unfolding code and a comparison with a standard Bonner Sphere Spectrometer (BSS) was performed. The agreement between the two measurement is within the 10%, providing a proof of the NCT-ACS working capability. More details will be provided in the presentation.
A compact multi-material spectrometer for in-phantom measurement will be a novelty for the BNCT applications, with the aim to contribute to the beam quality assurance.

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Time of presentation:
17.10.2023. 12:20 - 12:40

Determination of effective temperatures through affordable concurrent techniques in CANS

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ABSTRACT

The study of the interaction of neutrons with materials in the epithermal energy range is of interest in various fields of pure and applied physics. As a research tool, techniques involving epithermal neutrons have been used to study the kinetic energies of the atoms that make up the material. From the point of view of Nuclear Engineering, this is the range of energies that are necessarily traversed in moderation processes. From the point of view of applied physics, it is an essential range for the design of neutron sources associated with compact accelerators. It is therefore not surprising to find projects involving the use of epithermal neutrons in different contributions to this conference. It is also worth to mention that the studies that can be performed in this range of neutron energies are a distinctive feature of accelerator-based sources, as opposed to reactor-based ones.

The effective temperatures of atoms differ from thermodynamic temperatures, and are determined not only by thermodynamic temperatures but also by the dynamics of matter, so that experimental neutron techniques, which allow the densities of vibrational states to be known, make it possible to evaluate them. However, in this case it is an indirect relation that allows access to these values by calculation. Yet, there are techniques that allow direct experimental access to these quantities. We refer to Deep Inelastic Neutron Scattering (DINS) and Neutron Transmission (NT). Both techniques can be performed on the VESUVIO spectrometer (ISIS, UK) during the same experiment, which eliminates the need to deal with different experimental set-ups when comparing data. Although ISIS is a large neutron source, it should be mentioned that these techniques were successfully carried out at the now defunct LINAC in Bariloche (Argentina), both by proof of concept and by providing competitive data to obtain relevant physical conclusions.

In this talk we will show this capability through combined DINS and transmission experiments performed at ISIS and Bariloche in molecular liquids. We will show the different steps involved in the processing of the information and comment on the different possibilities for future use.

Time of presentation:
17.10.2023. 14:00 - 14:35

A Quantitative Description of Supply and Demand Relationship of Neutron Beam Use -Numeracy for Applications of Neutrons-

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ABSTRACT

Slow neutrons are widely used in material researches since neutrons have the same order of mass as atoms and they are extremely useful probes that can simultaneously cover both temporal and spatial scales in material researches. However the slow neutron beam is inevitably sparse because no practical deceleration method other than moderation by a neutron moderator is known and accordingly their phase space density becomes very low. To compensate for this disadvantage and to meet the increasing demand for neutrons, there is no doubt that increasing the neutron source intensity is a direct solution, but it is not easy to further increase the size of large facilities or to build additional large facilities in a short period of time. Another solution is to improve the neutron utilization efficacy by improving the neutron beam transport optics and detector performance. As a result, the possibility of practical use of small-scale neutron sources has been recognized, and momentum to consider the use of accelerator-driven compact neutron sources with a large degree of freedom in installation has increased, which led to the establishment of the Union of Compact Accelerator-driven Neutron Sources. It is important to remember the essential fact that the neutron intensity of such sources is lower than large neutron facilities and the employment of single compact source would enforce a limited variation of achievable researches, a limited quality of the measurement data. Therefore, it was strongly recognized that it is essential to quantify the purpose of neutron-based measurement and to clarify the procedure to evaluate the degree of achievement of the purpose.

An attempt to evaluate the over-all performance of neutron measurements integrating the charactersitics of neutron moderators, upstream transport optics, downstream transport optics, detectors, signal processing, and data analysis was initiated, and a framework for quantitative expression is being developed. The question then becomes how to quantitatively express the degree to which the objectives of individual measurements have been achieved. An attempt to quantitatively describe the degree of achievement of the objective of each measurement is currently in progress, using small-angle neutron scattering as an example. In this presentation, this attempt will be introduced s an example to start the discussion toward a numeracy applicable to the general cases of neutron beam use.

Time of presentation:
17.10.2023. 14:35 - 15:00

The European Low Energy accelerator-based Neutron facilities Association (ELENA) – Current Status and Perspectives

Mario Perez[1], Thomas Brückel[2], Thomas Gutberlet[3], Alain Menelle[4]

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[4] LLB

ABSTRACT

The European Low Energy accelerator based Neutron facilities Association (ELENA - www.ELENA-neutron.eu) promotes the development of Compact Accelerator driven Neutron Sources (CAN S) and High Current Accelerator driven Neutron Sources (HiCANS) in Europe. As of today, it represents 7 projects and 8 institutions from major European countries: Italy, Spain, France, Germany, Norway, Sweden, Hungary and Israel. HBS, ICONE and ARGITU are examples of HiCANS with an instrument performance equal to or exceeding that of medium size research reactors, while LvB is a CANS project serving industry.

The members of ELENA strongly believe that decisive action is required now if we don't want to be limited with only four major sources (ESS, ISIS, SINQ and MLZ) in the future for about 5000 European neutron users a situation which will not allow most of these users to maintain a strong research program with neutrons. The situation is even more serious if we consider the downtimes for maintenance, technical problems and upgrades as the last years have shown, where sometimes only one of the remaining major sources was in operation. Such a situation is prohibitive for doctoral projects, where students typically need at least a few days beam times per year for three years. Having only very few sources makes the ecosystem extremely vulnerable.

An overview of the ELENA association and on going projects will be given, presenting the potential of HiCANS as an opportunity to regain a strong, diverse, and healthy neutron landscape. At UCANS the community shall be informed first hand about these prospects in order to gather support for a rejuvenated European neutron ecosystem.

This work is part of the collaboration within ELENA and LENS on the development of HiCANS.

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Time of presentation:
17.10.2023. 15:00 - 15:20

Neutron Science Facility of the IAEA

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ABSTRACT

The Nuclear Science and Instrumentation Laboratory (NSIL) of the Physics Section, Division of Physical and Chemical Sciences (NAPC) at the IAEA, has expanded its capabilities in neutron analytical techniques via the establishment of a Neutron Science Facility (NSF) at the IAEA Seibersdorf Laboratories, Austria [1]. The facility is based on three compact neutron generators, one Deuterium-Deuterium (DD) generator, with its intensity of 5E6 n/s and two Deuterium-Tritium (DT) generators, with their intensities of 2E8 and 5E8 n/s in 4π respectively. The new facility primarily serves educational demonstrations of research and applications using neutrons, like general neutron instrumentation, neutron activation analysis, neutron radiography-tomography, delayed neutron counting and radiotracer production in small quantities for training purposes, and some others. In this talk we aim to present the design, construction, and commissioning of the facility the trainings already developed as well as future plans.

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Time of presentation:
17.10.2023. 16:00 - 16:20

Thermal moderator-reflector assembly for HBS

Ulrich Rücker[1], Ivan Pechenizkiy[1], Jingjing Li,[1] Junyang Chen[1], Egor Vezhlev[1], Paul Zakalek[1], Jörg Voigt[1], Thomas Gutberlet[1] and Thomas Brückel[1]

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ABSTRACT

The thermal moderator is the key component in a research neutron source to convert the primary neutrons which typically have energies in the MeV regime into useful neutrons for investigations that shall have energies well below 1 eV. In the case of a HiCANS as HBS, the thermal moderator has to be optimized according to the compact target size and to the proton pulse lengths at the different target stations. Extraction channels in the thermal moderator are used to either place cold sources feeding instruments that need a cold neutron spectrum or to extract thermal neutron beams from the volume of highest thermal neutron flux density. Requirements of restricted space, neutron transparency of the main structural materials, the technically demanding flowing liquid thermal moderator material, the complex nature of intense thermal and induced mechanical loading, industry-standard requirements for operational safety, etc. impose important boundary conditions on the design of the thermal moderator.

Here, we present the details of a thermal moderator design serving up to 12 instruments at a target station operated at 96 Hz. The thermal moderator consists of a combined welded complex-profiled Al vessel containing 12 thin-walled cast extraction channels arranged in 2 levels. The vessel is filled with H2O as moderator material which is pumped for cooling purposes. The entire system is surrounded by a lead reflector and arranged on top of the compact Ta target. We show the results of simulations concerning the neutronics and the thermal behaviour of this thermal moderator-reflector assembly.

This work is part of the collaboration within ELENA and LENS on the development of HiCANS.

Time of presentation:
17.10.2023. 16:20 - 16:40

Development status and application plan of 30 MeV cyclotron based neutron source in Korea

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[2] QBeam Solution, Republic of Korea

ABSTRACT

In Korea, neutron sources and related research facilities are being developed and utilized for the commercialization of fusion energy, the development of future and in-service nuclear power plants, and various industrial applications. Neutron beam research using HANARO, a research reactor, imaging, isotope production, and neutron irradiation experiment of materials are underway. Acceleration tests for neutron irradiation experiment using a heavy ion accelerator (KAHIF) are underway.

Recently, 30 MeV cyclotron-based neutron source development is completed the neutron generation preliminary evaluation is in progress, in which the existing cyclotron was used, and TMRS and new instrumentation devices are added. After the preliminary test, neutron imaging and neutron irradiation tests will be conducted in conjunction with the related facilities.

Time of presentation:
17.10.2023. 16:40 - 17:00

Development of HINEG Series High Intensity Steady Neutron Generators

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ABSTRACT

Neutron sources are the important experimental platform for the R&D of advanced nuclear energy systems, especially for the development for fusion systems. Series High Intensity Steady Neutron Generators (HINEG) have been developed in China for different missions including neutronics design validation, materials & components irradiation test, nuclear waste burning and nuclear technology applications, etc. HINEG includes three phases: HINEG-I, HINEG-II and HINEG-III. This contribution reports on the recent progress and status of HINEG projects.

HINEG-I includes two sources, HINEG-Ia and HINEG-Ib. HINEG-Ia, which has already operated, is a D-T fusion neutron source with the yield of 6.4×10^{12} n/s, and has been coupled with the Lead-based Zero Power Reactor CLEAR-0. HINEG-Ib is a cyclotron-based neutron source with neutron yield more than 10^{14} n/s and is under construction now. HINEG-I aims to be a platform for support fusion neutronic design, and the fission reactor shielding design validation. It also can be used for extended nuclear technology applications, such as radiotherapy, radiography, isotope production, etc. Series experiments have been carried out on HINEG-I, including neutronics performance test of TBM blanket, measurement of leakage spectra from Pb and Pb-Bi, irradiation damage testing for laser crystal, etc.

HINEG-II includes two sources, HINEG-IIa and HINEG-IIb. HINEG-IIa is a high-voltage electrostatic accelerator based D-T neutron source with neutron yield over 10^{13}n/s. HINEG-IIb is a cyclotron-based spallation neutron source with neutron yield more than 10^{15}n/s. These two sources are aimed to provide multi-type of neutron spectrum including fusion-like neutron spectrum and high neutron intensity for radiation damage mechanism study, advanced reactor technology validation, and extended nuclear technology application research, etc. The design and key components manufacture of HINEG-IIa have been finished, the construction and assembly are on-going. For HINEG-IIb, the design and key technologies R&D are on-going.

HINEG-III is high flux steady state neutron source with the intensity of 10^{17}-10^{18} n/s. It will be coupled with a subcritical reactor with neutron flux higher than 10^{15} n/cm^2/s. HINEG-III is a multi-purpose neutron irradiation platform for irradiation testing of fuel, material and components for advanced reactors. The conceptual design of HINEG-III is on-going.

Time of presentation:
18.10.2023. 09:00 - 09:35

RFQ linear accelerators for compact neutron production system

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ABSTRACT

There are two accelerator systems that show promise as CANS assuming lithium and beryllium target. One is a single-ended electrostatic accelerator and the other is a linear accelerator based on an RFQ. Here we discuss the design requirements and operation of the RFQ, considering only neutron production. Usually, the transverse emittance requirements are not strict because the accelerated beam only needs to reach the neutron production target. However, in many cases, a high average current is required, so excellent heat removal performance is required. Frequency selection and macro-pulse length are also important considerations. Large acceptances should be employed to ensure robust long time operational performance. The talk will first discuss the design of an RFQ using a proton beam, followed by an introduction to the features of a neutron generator using a lithium beam under development at BNL.

Time of presentation:
18.10.2023. 09:35 - 09:55

The development of the Compact Accelerator-driven Neutron Source at CIAE

Luyu Ji[1], Fengping Guan[1], Shizhong An[1], Sumin Wei[1], Jiansheng Xing[1], Bin Ji[1], He Zhang[1], Shigang Hou[1], Peng Huang[1], Xia Zheng[1], Huaidong Xie[1], Zhe Wang[1], Junyi Wei[1]

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ABSTRACT

Boron neutron capture therapy (BNCT) is a cancer treatment modality based on the nuclear capture and fission reactions. For the application of BNCT, a compact proton cyclotron is developed at China Institute of Atomic Energy (CIAE). A compact magnet with a radius of 880 mm is adopted in this cyclotron. The negative hydrogen ion beam is provided by an external multi-cusp ion source and injected into the cyclotron by an electrostatic inflector. A 14 MeV, 1mA proton beam is extracted by a carbon foil. The beryllium target is used as the neutron production target and the BSA is designed to produce the required high-flux collimated and thermalized neutron beam. The design of this facility and results of beam commissioning will be described in this paper.

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Time of presentation:
18.10.2023. 09:55 - 10:20

200kW High Power liquid GaIn metal targets for neutron production at SARAF

Ilan Eliyahu[1], Sergey Vaintraub[1], Eyal Reinfeld[1], Nadav Goldenberg[1], Herzel Isyakov[1], Noam Tamim[1], Eli Shvero[1], Dany Kijel[1], Yossi Luner[1], Israel Mardor[1], Arik Krisel[1]

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ABSTRACT

The Soreq Applied Research Accelerator Facility (SARAF) is based on a proton/deuteron RF superconducting linear accelerator [1, 2]. Phase II of the project is underway and includes the development of the accelerator to its final specifications: an energy of 40MeV proton/deuteron, and a current of 5mA. One of the main challenges for all these facilities is building a target that can withstand the high-power beam and be a powerful neutron source.

The targets are designed to stop the beam with a maximum power of 200 kW. To avoid radiation damage and improve heat transfer, we designed a liquid metal target, based on our prior experience with the liquid lithium jet target (LiLiT). The liquid metal target material is Gallium Indium (Ga-In) 83.2% gallium and 16.8% indium atomic ratio. The design is based on a high-velocity windowless Ga-In jet that generates a stable 6 mm-thick film [3] flowing at a velocity of up to 5 m/sec into a concave supporting wall. The film is thick enough to stop the 40MeV proton/deuteron beam, and the velocity is enough to absorb and remove the full beam power without boiling and cavitation in the film. Among the advantages of using Ga-In are good heat transfer, low to no radiation damage, simplicity of adjustments to size and shape of the impacting beam, low melting temperature of ~15°C and low chemical hazard risk.

The main Ga-In target component is a loop of circulating liquid metal. An electromagnetic (EM) induction pump drives the liquid Ga-In flow from the reservoir through the pipes (1.5" in diameter) to the vacuum chamber, where a nozzle forms the thin film. The Ga-In then falls back into the reservoir. The system is fabricated mainly with stainless steel 316L, except for the vacuum gaskets that are made of nickel. Both materials are compatible with Ga-In.

The expected neutron and isotope production yield from Proton and Deuteron beams in the 20-45 MeV range on thick liquid Gallium-Indium and Lithium targets were recently measured at the COSY (Cooler Synchrotron) accelerator facility at Forschungszentrum Julich GmbH [4]. Several prototypes of Ga-In targets were built in recent years and successfully tested at SARAF accelerator with a 3.7 MeV and 1.2 mA deuteron beam and a 1.27 MeV 5 mA proton beam. We are currently in the manufacturing stage of the full-power (200 kW) system, which will be installed in SARAF Phase II during 2023.

Time of presentation:
18.10.2023. 09:55 - 10:20

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Time of presentation:
18.10.2023. 10:20 - 10:40

Coupling neutron moderators and optics

Petr Konik[1] and Alexander Ioffe[2]

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ABSTRACT

In the last decade, low-dimensional neutron moderators made from almost pure para-hydrogen (pH2) have been introduced [1]. Thanks to large difference in scattering cross-sections of thermal and cold neutrons in pH2, moderators in the form of tubes or disks provide significant brightness improvements over traditional voluminous cold moderators. According to the study by the ESS [2], potential gains of up to 2-3 times in the useful neutron flux are possible when the moderator height is reduced from 12 cm to 3 cm, especially for high-resolution instruments that use well-collimated beams. However, the small size of the moderators in some cases makes it difficult to properly illuminate the sample, leading to non-uniform divergence profiles. Therefore, larger neutron moderators with reduced brightness are preferred for some instruments.

To determine the optimal moderator size, we have developed a new approach that takes into account instrument parameters such as sample size and angular resolution. It is based on phase space considerations and extensive Monte Carlo simulations have been conducted to validate it. This method is particularly useful for designing new neutron instruments and neutron sources.

We also present a new analytic approach to calculate the brightness of para-H2 moderators. It is shown that the brightness gain is the near-the-surface effect, so that a narrow cold moderator shaped as elongated rectangular parallelepiped provide a substantially higher cold neutron brightness. The obtained results are in excellent agreement with MCNP calculations.

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Time of presentation:
18.10.2023. 11:15 - 11:40

Moderator developments in HighNESS and feedback to compact sources design

L. Zanini[1], M. Akhyani[2], M. Bertelsen[1], Y. Bessler[3], T. Brys[1], A. Chambon[4], J. I. Marquez Damian[1], B. Folsom[5], V. Nesvizhevsky[6], B. Rataj[1], N. Rizzi[4], V. Santoro[1], H. Shuai[7], M. Strothmannc, A. Takibayev[1], R. Wagner[6], O. Zimmer[6] and the HighNESS collaboration

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ABSTRACT

The main, high-brightness neutron source for ESS is based on the low-dimensional moderator concept, and will serve the initial suite of neutron scattering instruments. In the HighNESS project, several design options have been identified and investigated for a second source for ESS, intended to be complementary to the primary one. In this project, more emphasis was dedicated to the design of high-intensity sources, delivering Cold, Very Cold (VCN), and Ultra Cold Neutrons (UCN). Some of the outstanding results of the project, completed in September 2023, include: a cold moderator based on liquid deuterium capable of delivering an intensity close to a factor 10 greater than the ESS upper moderator; a VCN moderator based on solid deuterium at 5 K, surrounded by nanodiamond layers, delivering a brightness above 40 Å an order of magnitude higher than a conventional cold moderator placed in the same location; and several design options for UCN sources based on the use of superfluid helium and solid deuterium. The use of these new sources would have a major impact on fundamental physics experiments and neutron scattering techniques. In this paper we summarize the main results of the source designs in HighNESS, and investigate the possible impact that these concepts can have for compact sources, with particular emphasis on VCN sources.

Time of presentation:
18.10.2023. 11:40 - 12:00

Compact ultracold neutron source for low-energy accelerator-driven neutron sources

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ABSTRACT

The concept of a small-scale, pulsed-proton accelerator-based compact ultracold neutron (UCN) source is presented. The essential idea of the compact UCN source is to enclose a volume of superfluid 4He converter with a super-cold moderator in the vicinity of a low-radiation neutron production target from (p, n) reactions. The super-cold moderator should possess an ability to produce cold neutron flux with a peak brightness near the single-phonon excitation band of the superfluid 4He converter, thereby augmenting the UCN production in the compact UCN source even with very low intensity of neutron brightness. The performance of the compact UCN source will be presented in terms of the UCN production and thermal load in the UCN source.

Time of presentation:
18.10.2023. 12:00 - 12:20

Exploring a new application of RANS cold neutrons for increasing cold neutrons with flower shaped graphene reflector

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ABSTRACT

As it is identified that slow neutron reflecting materials such as super-mirrors play important role to increase neutron intensity from moderators at any neutron source facility, we have been investigating performance of nano-sized carbon materials, such as nano-sized graphene as well as nanodiamond, whether they have potential high reflection capability for low energy neutron. In particular, the experimental studies were carried out on multi-layered graphene materials at RANS cold neutron under a slit collimation geometry, and SANS system of iMATERIA at J-PARC. We have measured relatively high total scattering cross section of graphene to those of graphite in a neutron energy less than 5 meV down to 2 meV by neutron transmission technique incorporated with cold neutrons from a mesitylene moderator.[1] The transmission data showed that coherent neutron scattering process dominates cross section at around and below meV.[2] Also, size of the graphene was confirmed by SANS measurements. It was indicated that the nano-graphene made by HIP with a proper condition could have advantageous character as reflection materials which lead to increasing extracted neutrons. Based on this exciting result, we propose a concept of cold neutron beam intensifier, in other word, a new neutron reflection system like a super-mirror by applying a designated graphene base. This paper describes prospect of the nano-size graphene materials optimized to exhibit large scattering cross section and be applied as cold neutron intensifier in various type of neutron source configurations.

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Time of presentation:
18.10.2023. 12:20 - 12:40

Cold moderator developments for the new generation neutron sources

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ABSTRACT

Cold neutron moderators have been developed since over 60 years at reactor source facilities to shift the spectral distribution of neutrons towards lower energies, i.e. increase the flux of the longer wavelength neutrons for their efficient use in materials research. Cryogenic moderators and in particular liquid hydrogen turned out to be the most efficient media for this purpose. During the past decades several attempts were made to improve the neutronics performance, increase the safety or reduce the costs of such installation. Various materials (D_2, D_2O-ice, methane, mesithelene etc.), geometrical configurations (e.g. half-hollow sphere) and cryogenic regimes (direct condensation) were tried. A major breakthrough in cold neutron moderator developments has been achieved by the invention of the para-hydrogen effect applied to low-dimensional geometries [1]. The most significant application of this advancement is the design and construction of a 'pancake' or 'butterfly moderator' for ESS. Monte-Carlo simulations have shown that if para-hydrogen is used as moderator material, these novel moderators can increase significantly the brightness, desired by most types of neutron instruments. Various designs were extensively studied by simulations, however, few experiments are available to validate them. Difficulties in experimental investigation of moderator properties can be overcome by the dedicated Test Facility installed at a radial channel of the 10 MW Budapest Research Reactor [2]. This beamline with unusually hard neutron spectrum is targeted on a Be-disc installed in a lead reflector, placed close to the channel exit. Neutrons scattered inside the Pb reflector block are slowed-down in the cryogenic moderator cell tested, which is installed in the vicinity of the Be-block. Cold neutrons leaving the cryogenic moderator (e.g. a tube-type Al-alloy vessel filled with liquid p-hydrogen) through a collimator, are measured by a camera obscura system with time-of-flight option [3] using a pinhole-chopper-2D detector assembly. This system enables to measure the spatial and spectral distribution of neutrons emerging from the moderator, thus its various features are characterized. The neutronic performance of the Test Facility as well as spectral measurements of various moderator configurations and their comparison with neutronics model calculation are described.

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Time of presentation:
18.10.2023. 14:00 - 14:35

Recent achievements of the Hokkaido University Neutron Source (HUNS) facility with cold/thermal/epithermal/fast neutrons

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ABSTRACT

Hokkaido University Neutron Source, HUNS, has three types of short-pulsed neutron sources and a high energy X-ray source driven by 32 MeV-3.2 kW electron LINAC [1]. The facility was built in 1973, the accelerator was replaced in 2018, and the electron guide cavity was replaced in 2020. In addition, the facility building will be renewal in 2024. In our presentation, various projects and facility developments of HUNS will be reported in detail.

HUNS has cold, thermal and fast neutron sources. The cold neutron source is a coupled-type 20 K solid CH4 moderator, and is used for the TOF small-angle neutron scattering (TOF-SANS) instrument, iANS (intermediate-Angle Neutron Scattering). iANS and X-ray machines (diffractometer, SAXS and USAXS) are collaborated each other, and are utilized for materials science and industrial applications of steels, light metals, cements, foods and so on. The thermal neutron source can be changed between coupled-type and decoupled-type of 300 K polyethylene moderator. The thermal neutron source is used for developments of neutron optical devices and detectors. The coupled thermal neutron source is used for epithermal neutron resonance absorption imaging. The decoupled thermal neutron source system with a supermirror guide tube and a grid collimator is powerful for Bragg-edge/dip neutron transmission imaging, and is utilized for materials science, industrial applications and international collaborations of steels, batteries, nuclear materials, cultural heritages, thermography [2] and so on [3]. X-ray imaging system and machine learning technologies sometimes assist neutron imaging. The fast neutron source, a Pb neutron production target, is used for acceleration experiments of cosmic-ray neutron-induced soft errors and single event effects. Furthermore, recently, new collaboration works on beam irradiation are developing and planning; 32 MeV electrons, MeV-class X/γ-rays and also neutrons are used for astrophysics and medical biology.

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Time of presentation:
18.10.2023. 14:35 - 15:00

CANS Projects in China

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ABSTRACT

There are three grand national neutron sources in operation in China, including, China Spallation Neutron Source (CSNS), China Advanced Research Reactor (CARR) and China Mianyang Research Reactor (CMRR). Chinese Neutron Scattering Society (CNSS) was formally established as a branch of the Chinese Physical Society (CPS) in 2012, which is a good situation for developing of neutron science and technology.

There are several projects with Compact Accelerator-driven Neutron Source (CANS) in operation, in construction or in proposal in China, such as, the Compact Pulsed Hadron Source (CPHS) and e-LINAC driven bimodal source in Tsinghua University, the Peking University Neutron Imaging Facility (PKUNIFTY), the RFQ-based Boron Neutron Capture Therapy (BNCT) supported by CSNS, the electrostatic accelerator-based BNCT (AB-BNCT) of NeuBoron, the intense neutron generator and RFQ-based BNCT of Lanzhou University, the CANS and neutron radiography facility of China Academy of Engineering Physics, the CANS and RFQ-based BNCT in Xi'an Jiaotong University, and so on. The progress of the CANS projects in China will be presented.

The trend and opportunity of CANS projects will be discussed, especially several AB-BNCT projects have been launched or proposed in recent years.

Time of presentation:
18.10.2023. 15:00 - 15:20

JULIC Neutron Platform, a testbed for HBS

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ABSTRACT

The High-Brilliance neutron Source (HBS) project [1] develops a High-Current Accelerator-driven Neutron Source (HiCANS) with a pulsed proton beam, a peak current of 100 mA and an average power at the target of 100 kW. The concept of such a HiCANS was published some years ago [2] indicating the feasibility of such a facility with all of its components: high-current accelerator, target station with integrated moderator-reflector assemblies and neutron instruments. All components require engineering development and testing. The JULIC Neutron Platform was thus developed as a testbed for all components and the investigation of their interplay.

The JULIC Neutron Platform uses a cyclotron providing a tunable pulsed proton beam with a low current but a variable frequency and pulse length to a spacious experimental area. A target station shielding is placed in its center with an empty inner core of 1 m^3, able to accommodate different moderator-reflector assemblies as well as cryogenic moderators. The target station uses a tantalum target for the conversion of protons to neutrons and has eight spacious flexible ducts where moderator plugs for neutron extraction or blind plugs are placed.

First beam on target was achieved in December 2022 with three instruments in operation: reflectometer, diffractometer and detector test stand. Further beamtime in 2023 is planned in order to investigate different cryogenic moderators, to estimate the performance of such a HiCANS and to perform further experiments.

At UCANS, we will present the JULIC Neutron Platform, the experiments performed and the possibilities it offers.

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Time of presentation:
18.10.2023. 16:00 - 16:20

The ICONE project: towards a new neutron source in France for materials science and industry

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ABSTRACT

The European landscape of neutron facilities is evolving quickly with the closure of a number of aging research reactors: for example the reactor Orphée in France, BER in Berlin and Kjeller in Norway closed in 2019. While the European Spallation Source (ESS) should start later in this decade, its capacity will not be sufficient to replace the closed facilities. Hence, the Laboratoire Léon Brillouin (LLB), operated by the CEA and the CNRS in France, is developing the technologies necessary to build a new type of neutron source using low energy proton accelerators: High Current Compact Accelerator driven neutron sources (HiCANS).

We will describe the ideas driving the design of HiCANS and present the potential capabilities of such sources. Since 2018, the CEA has been engaged in an experimental research program around the IPHI accelerator and has demonstrated a number of technologies on the IPHI – Neutrons platform. We will report on the recent progress in the field of neutron producing targets, the first diffraction measurements on the DIoGENE instrument and the developments around cold moderators.

The long-term goal is to eventually build a user facility, ICONE, which would offer a suite of 10 neutron scattering instruments to the French community. We aim at achieving performances comparable to the instruments which were operated around the Orphée reactor.

This work is part of the collaboration within ELENA and LENS on the development of HiCANS. It has been funded by the "CANS Inflexion" program at the CEA and the "IPHI-Neutron" SESAME project of the Ile de France region.

Time of presentation:
18.10.2023. 16:20 - 16:40

The neutron source target proposal for the ARGITU project

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ABSTRACT

The ARGITU project [1] is one of the initiatives framed within the joint European strategy to develop the next generation of high-current accelerator-driven neutron sources (HiCANS)[2] claim to cover the gap of neutron production in Europe created by the shutdown of research reactors. The ARGITU project is one of these initiatives to build a regional neutron source in the Basque Country area (Spain). This envisioned facility, a high current proton beam (beam pulse: 1.5 ms, beam current: 32 mA, repetition rate: 30 Hz, energy: 31.5 MeV) hits a beryllium target, producing neutrons by nuclear processes that can serve to run a suite of up to four neutron scattering instruments.

The accelerator is based on ESS-Bilbao ion source facility that will be upgraded with the completion of the RFQ (already on manufacturing phase) and new DTL tanks to achieve final energy. The proton beam will target a beryllium plate cooled with water. Vanadium is proposed as backing material due to its favorable combination of mechanical properties and hydrogen diffusion, which helps to prevent blistering [3]. The elevated heat deposition forces a complex design of the cooling system to avoid high thermal stress while keeping the cooling supply requirements as low as possible. Moreover, guaranteeing contact between materials is another critical aspect of the design, given the thermal expansion difference.

The relative compact dimensions of the target station as well as the use of low activation materials will minimize the requirements on services like remote handling, lifting devices, cooling supply etc… But enhance the challenge of miniaturization of the target-reflector-moderator system.

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Time of presentation:
18.10.2023. 16:40 - 17:00

Recent progress of Nuclear Data Production System at RAON

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ABSTRACT

A fast neutron facility, called Nuclear Data Production System (NDPS) [1], was constructed for nuclear science and applications at RAON (Rare Isotope Accelerator complex for ON-line experiments) in Korea. NDPS provides neutron beams not only for nuclear data measurements but also for other applications. NDPS is designed to provide both white and mono-energetic neutrons, using 98 MeV deuteron and 20 – 83 MeV proton beams with a thick graphite and thin lithium targets, respectively. Neutron energy is determined by employing the time-of-flight (TOF) technique, along with a pulsed deuteron (or proton) beam with a repetition rate of less than 200 kHz. Fast neutrons are produced in the target room and are guided to the TOF room through a 4 m long neutron collimator consisting of iron and 5 % borated polyethylene. In the TOF room, a gas-filled Parallel Plate Avalanche Counter (PPAC) with a ^{232}Th layer and EJ-301 liquid scintillation detectors are installed to measure the neutron flux. The beam commissioning for NDPS is scheduled for 2024. The recent progress of NDPS will be reported, together with our plan.

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Time of presentation:
19.10.2023. 09:00 - 09:35

Simulating Stars in the Lab - the $^{7}Li(p,n)$ Reaction as an Intense Quasi-Stellar Neutron Source

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ABSTRACT

Neutron-induced reactions play a key role in various scenarios of stellar nucleosynthesis. The s-process takes place during different stages in the life cycle of low-mass AGB and massive stars, at typical temperatures of ≈0.1-1 GK, and is responsible for about half the abundance of ≈A>60 isotopes in the galaxy. During core-collapse supernovae, neutron-induced reactions on proton-rich nuclei enhance destruction rates of relatively long-lived isotopes hence affecting the nucleosynthesis trajectories of the p- and the νp-processes, and changing the final abundances of key isotopes such as ^{26}Al and ^{56}Ni in supernovae ejecta. Those reactions occur at much higher temperatures of 1.5-3.5 GK.

Experimental studies of neutron-induced reactions in stellar environments require intense neutron sources at energies of 1-2000 keV. While the neutron Time-of-Flight (TOF) has proved to be a very successful tool for such measurements, they are limited to neutron fluxes around 10^6 n/s/cm^2 at the relevant energies. Alternatively, the $^{7}Li(p,n)$ and the $^{18}O(p,n)$ reactions at specific proton energies proved successful in producing quasi-Maxwellian neutron energy distribution with effective temperatures of 0.3 GK and 0.06 GK, respectively. For the ^{7}Li case, a 100-μA proton beam at E^p = 1912 keV will produce a quasi-Maxwellian neutron flux of ≈10^9 n/s/cm^2, which is a huge improvement over the neutron TOF facilities.

Soreq Applied Research Accelerator Facility (SARAF, Israel) is a linear accelerator capable of producing a 5-mA proton beam, resulting in an order of magnitude improvement in neutron flux over VdG machines. The SARAF intense proton beam required the development of the Liquid-Lithium Target (LiLiT) to serve as a quasi-stellar neutron source, capable of dissipating a continuous beam power of up to ≈10 kW and providing the most intense neutron source for s-process measurements.

We will report on the successful physics program conducted with LiLiT in the last decade, and describe future plans to utilize the $^{7}Li(p,n)$ reaction as an intense quasi-stellar neutron source at temperatures of 1.5-3.5 GK, relevant for explosive stellar environments.

Time of presentation:
19.10.2023. 09:35 - 09:55

A new neutron scattering kernel for superfluid helium

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ABSTRACT

We present the development of a model to describe the interactions of neutrons in superfluid He-4 at temperatures below 1.3 K. The model was constructed based on the separation of the single-phonon and multi-phonon excitations at low temperatures. Below around 3.4 Å^{-1}, the single-phonon excitations are described exactly by the dispersion relation, while the multi-phonon excitations and the single-phonon excitations above this limit, are included using the phonon expansion approach in the Gaussian approximation. A frequency spectrum, derived from the experimentally observed phonon-roton excitations, is used throughout the calculation, except in the single-phonon term over the momentum transfer range where the quasiparticle dispersion curve exists. The model can be used to calculate UCN production from down-scattering processes, as the exact dispersion curve is included, and can also be used for the design of optimized target/moderator geometries at a neutron source as the first and second sum rules are well satisfied. We demonstrate that the approach reproduces very well the measured total cross sections, scattering functions, and ultra-cold neutron production spectrum, including both the single-phonon and multi-phonon components.

We have modified the software NJOY to include this description, making it possible to create thermal scattering libraries in the ACE format to be used in Monte-Carlo simulation of the production of ultra-cold neutrons from ^{4}He superfluid.

Time of presentation:
19.10.2023. 09:55 - 10:15

On the comparison of the experimental neutron cold spectra obtained for various para- and ortho-hydrogen ratios against Monte Carlo simulations with different codes and nuclear data libraries

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ABSTRACT

The High Brilliance Neutron Source (HBS) project aims to develop a High-Current Accelerator-driven Neutron Source (HiCANS) for neutron scattering, analytics, and imaging. It will feature several thermal and cold sources, including a liquid para-hydrogen moderator. At the Forschungszentrum Jülich, time-of-flight measurements were performed with the prototype of such a cryogenic moderator for different ratios between para- and ortho-hydrogen. In order to optimize the design of future instruments that will use this cold neutron source, accurate simulations of the neutron transport are necessary.

This work focuses on the comparison of various simulations performed against the cold spectra experimental results for the different para- and ortho-hydrogen ratios. Several Monte Carlo codes, including MCNP, PHITS, McStas, VITESS, and KDSource, with nuclear data from the ENDF/B-VII.1, JENDL-4.0 and JENDL-5.0 libraries were utilized. The simulations started with the comparison of the proton-neutron yield spectra, continued with coupling the event files before and after the modeling of the neutron guide, and ended with the time-distribution obtained at the detector. A good agreement between simulations and experiments was obtained.

The results provide insights into the strengths and limitations of each Monte Carlo code and nuclear data library combination. Not only the observed discrepancies are discussed, but also the potential sources of error are identified. Also, the conclusions will help to improve the accuracy and reliability of neutron cold moderator designs, especially for projects that will deploy a para-hydrogen cold source such as the HBS.

Time of presentation:
19.10.2023. 10:15 - 10:35

Advances in nuclear data development for moderator and reflector design at the European Spallation Source

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ABSTRACT

Available thermal neutron scattering data for neutronic design of neutron sources has been traditionally limited to a few selected materials, primarily due the main driver for these data being nuclear applications and also limitations in previously existing software. With the availability and development of recent software, such as NCrystal, the European Spallation Source is engaged in activities to develop new nuclear data, in particular with applications in cold, very-cold and ultra-cold neutrons sources in mind. In this presentation we will showcase some of the unique features of NCrystal, such as the ability to interface directly with a Monte-Carlo code, instead of a traditional nuclear data library, in addition to presenting results related to very-cold neutron reflector/moderator materials and also ultra cold neutron sources.

POSTER PRESENTATIONS

Beam acceleration test of 500 MHz-RFQ linac for transportable compact neutron source RANSIII

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ABSTRACT

A transportable compact accelerator neutron source system (RANS-III) has been under development for nondestructive inspection of large structural infrastructures using neutron measurement techniques. In RANS-III, Proton beam accelerated up to 2.49 MeV by a linear accelerator (linac) is irradiated to a lithium target to generate neutrons. The neutron beam is used to perform nondestructive inspection of infrastructure structures. Since RANS-III will be mounted on a vehicle for nondestructive inspection at outdoor sites such as bridges, a three-body structure 500 MHz RFQ linac was developed with the Tokyo Institute of Technology to reduce size and weight. Since the inner diameter of the accelerating cavity of an RFQ linac becomes smaller as the resonance frequency increases, the three-body 500 MHz RFQ linac has succeeded in reducing the inner diameter of the cavity by about 1/2 and the weight by about 1/3 (0.7 t) compared to the RFQ linac for RANS-II (200 MHz RFQ) [1]. After the fabrication of the 500 MHz RFQ linac, a beam acceleration test has been started. The accelerator system consists of the 500 MHz RFQ linac, a four RF system, a permanent magnet 2.45 GHz ECR ion source, a low-energy beam transport line (LEBT: a double Einzel lens), and a high-energy beam transport line (HEBT: doublet quadrupole magnets and a 90° bending magnet). At first, beam current from the RFQ linac was measured to improve the beam current by adjusting the alignment between the ion source and the RFQ linac, and the beam focusing condition of the double Einzel lens. Furthermore, by measuring the beam current of the proton beam accelerated to 2.49 MeV relative to the RF power, the RF power required to accelerate the beam in the RFQ linac was evaluated.
We will present about the accelerator system constructed for the beam acceleration test, the results of the beam acceleration test, and future development plans.

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A preliminary study on a intensity current narrow-pulse D-^{7}Li nuclear reaction neutron generator

Jie Li[1], Tao Wang[1], Zhijie Hu[1], Pan Dong[1], Jialong He[1], Feixiang Liu[1], Ping Liu[1]

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ABSTRACT

With the control of radioactive isotope neutron sources becoming more and more stricter, controllable neutron sources which can replace radioactive sources have become the focus of current research. Sealed D-T neutron tubes have been widely used as alternative radioactive sources, but tritium resources on Earth are very limited, and as a special nuclear material, it is also strictly controlled. The neutron spectrum produced by D-7Li nuclear reaction has the characteristics of continuous spectrum as the radioactive isotope neutron source such as AmBe source. At the same time, the D-7Li nuclear reaction neutron spectrum also has a high characteristic peak at 10MeV and 13.5MeV, because it is close to the D-T nuclear reaction single energy 14.1MeV neutron spectrum, it has the capability of D-T nuclear reaction fast neutron non-elastic scattering gamma element analysis, which can be used in the field of neutron logging and elemental analysis. The low frequency intensity current narrow pulse neutron source can directly obtain clean and separated inelastic scattering, capture and activation gamma spectra in pulsed neutron element analysis, therefore it can reduce background interference, improve characteristic gamma resolution for spectral resolution accuracy, and possibly it can reduce the neutron yield requirement. In this paper, a high current pulsed deuterium ion beam is proposed to generate neutrons by bombarding a lithium target. A D-7Li pulsed neutron source is designed, and a preliminary experimental study is carried out on a 100-200keV pulsed neutron experiment platform. Some of the new research results will be introduced in this report.

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The Design Status of DTL in SYSU-PAFA

Canyu & Wang[1], Liang & Lu[1] and Wei & Ma[1]

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ABSTRACT

The Particle Accelerator Facility at Sun Yat-sen University (SYSU-PAFA) can be used as compact accelerator driven neutron source. To meet the conditions for producing high-flux neutrons, a 200 MHz drift tube linac (DTL), operating under continuous wave (CW) mode, has been designed. PAFA-DTL, which adopts APF scheme, is expected to accelerate a 10 mA proton beam from 2.5 MeV to 8 MeV, and contains 31 acceleration cells with beam transmission efficiency reaches 100%. The total length of PAFA-DTL is 2.4 m. Interdigital H-mode (IH) structure is utilized in the PAFA-DTL cavity, which has achieved a high shunt impedance of 290 MΩ/m. Additionally, to ensure the stability of PAFA-DTL under CW operation, a low Kilpatrick factor (Kp) of 1.42 is obtained by adjusting the blending radius of the drift tubes (DTs) to reduce the risk of RF breakdown. Multi-physics analysis is also carried out to ensure that PAFA-DTL can operate safely and stably under CW mode. As a results, the maximum temperature during operation is lower than 328 K, and the corresponding frequency shift is -97 kHz, which can be tuned through the designed tuners. In this paper, the detailed design and results of PAFA-DTL, including beam dynamics, RF design and multi-physics analysis are presented.

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Design and optimization of a 200 MHz CW proton RFQ for SYSU

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ABSTRACT

The Sino-French Institute of Nuclear Engineering and Technology of Sun Yat-Sen University in China has developed a 200 MHz high intensity continuous wave (CW) radio frequency quadrupole (RFQ) accelerator as the low-energy injector for a proton accelerator facility [1]. This RFQ accelerator, employing a conventional four-vane structure, is capable of accelerating a proton beam from 20 keV to 2.5 MeV, with a beam current of 20 mA.
In the design of the beam dynamics, the transmission efficiency of 99.5% and low longitudinal emittance has been achieved. Moreover, the length of the vanes has been limited to less than 4 m. To ensure stable long-term operation, Pi-mode Stabilizer Loops (PISLs) have been implemented in the electromagnetic design. These loops enable a frequency separation of over 10 MHz and effectively remove the impact of dipole modes. Additionally, introduciton of the 48 tuners has provided a frequency tuning range of ±2 MHz, and the undercuts have been meticulously designed to ensure excellent field flatness along the longitudinal direction. The entire design work has been accomplished, and all design parameters meet the requirement of project well.

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Investigation of Pancake-like Moderator-Reflector Structure for the High Brilliance Neutron Source (HBS)

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ABSTRACT

The High Brilliance Neutron Source (HBS) project is developing a high-current accelerator-driven neutron source (HiCANS) to maintain a healthy neutron landscape in Europe. Despite the lower primary neutron yield of the nuclear reactions compared to reactor or spallation neutron sources, HiCANS achieve a competitive neutron brightness by a compact moderator and reflector design, which makes a large fraction of the primary neutron spectrum available for applications. The spectral and temporal, i.e. frequency and pulse length, characteristics of the neutron pulse are tailored to the instruments hosted at a target station.

Based on the 'pancake' and 'butterfly' moderator geometries developed for the European Spallation Source (ESS), we investigate a pancake-like structure by means of Monte Carlo simulations involving multi-parameter optimization routines. By increasing the interface area, we try to improve the coupling between thermal and cryogenic moderator. The extraction surfaces of the applied pancake-like geometry achieve a cold neutron flux of 85%-87% of a cylindrical para H2 moderator (length= 10 cm, diameter = 2.4 cm) with ideal coupling. The flux through the thermal extraction surfaces reaches 70%-79% in comparison to an ideal case with just a single extraction channel looking at the thermal flux maximum in the center of the thermal moderator. The optimized structure with up to six extraction channels looks therefore very promising for target stations that serve a large number of thermal and cold instruments. At this conference, we will present the results of our study of this moderator-reflector assembly.

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A high brilliance spallation source optimized for one single instrument

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ABSTRACT

Conducting neutron scattering experiments in the presence of high pulsed magnetic fields provides valuable information about the magnetic structures of materials. However, these experiments are challenging and time-consuming because the neutron count is typically low. To overcome this limitation, we propose the exotic concept of a specialized neutron source that is dedicated to increasing the neutron count and enhancing brilliance specifically for one single multi-purpose instrument. This source incorporates several key elements, including a spallation target station that is supplied by an existing high-energy proton accelerator at regular intervals of 5-10 minutes. The timing of these intervals is synchronized with the magnetic pulses, resulting in a significant reduction in average heat and radiation load. We have extensively investigated various geometries and materials for the target, moderator, and reflector to optimize brilliance and achieve maximum neutron count. Through an efficient transfer of neutrons, we aim to substantially increase the number of neutrons reaching the sample and enable the users to do diffraction and inelastic neutron scattering under very high pulsed magnetic fields.

Optimized beam shaping assembly for 13 MeV proton accelerator-based neutron source

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ABSTRACT

Accelerator based neutron source is the preferred choice for BNCT because of the potential for siting within a hospital. The primary aim of this study is to optimize the design of beam shaping assembly on the basis of IAEA recommendations, and to evaluate the in-phantom figures of merit for different epithermal neutron spectrum. In this study, the design of the beam shaping assembly is performed based on the primary neutron, which is produced by 13 MeV proton and beryllium target. For the purpose of deep-seated tumor treatment, we optimized three BSA models to obtain different epithermal neutron spectrum with harmful radiation components (fast neutrons, thermal neutrons and gamma ray) under the limit. Use of the higher neutron energy can improve thermal neutron distribution in deeper sites, but also creates the risk of higher damage within normal tissue. We use a modified Snyder head phantom to calculate the depth-dose distribution in the body. Several parameters, including advantage depth (AD), treatable depth (TD), treatment time (TT) etc., are calculated to evaluate the therapeutic effectiveness of these three BSA models.

The optimization of target station for bimodal neutron and photon imaging

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ABSTRACT

Bimodal neutron and photon imaging driven by a single electron linear accelerator has been realized and shown distinct advantages over conventional bimodal imaging systems[1]. However, this one-source-one-detector based bimodal imaging system was not yet fully optimized to improve its capability of material identification. In this study, the neutron converting target was investigated with the aid of Monte Carlo simulation, which reveals that using heavy metal(tungsten) rather than heavy water as gamma-to-neutron convertor may lead to a higher thermal neutron flux, when the electron's energy is larger than 18 MeV. The significant influencing factors for material identification, such as total thermal neutron flux, photon's spectrum and flux were optimized using multi-objective optimization method combined with Monte Carlo simulation. The optimized target station could deliver thermal neutron flux of higher than 10^5 cm^2/s with L/D = 100 based on an 18 MeV/8 kW e-LINAC. The photon's flux was tailored to about two orders of magnitude higher than that of neutrons, in order to compensate the relatively lower photon detection efficiency (about 1% of that for thermal neutrons) of neutron sensitive micro channel plate(nMCP) detector. In principle, different materials could be intrinsically identified by the F factor, which is the ratio between the energy averaged mass attenuation coefficient of imaging neutrons and that of imaging photons. Then additional optimization on photon's spectrum was conducted to expand the distribution of F factors for better material identification. The results present a 20% improvement of the standard deviation of F factors for elements with $Z < 92$ compared to present bimodal imaging system. And the inspecting time can be reduced by at least one order of magnitude.

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Conceptual insight into the moderators of ARGITU: A preliminary neutronics study

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ABSTRACT

This work reports on preliminary calculations of potential low-dimensional moderators for the high-current accelerator-driven neutron source (HiCANS) ARGITU [1]. Simulations start with the selection of materials, depending on the neutron energy range to be used for each instrument. Results evaluate the performance of water for thermal moderators to deliver neutrons for thermal instruments, whereas para-H2 and solid methane have been analyzed to deliver cold neutrons. Additionally, alternative concepts like using hybrid moderators (water/liquid methane) or reduced-size cold moderators (reduced-size para-H2) have been scrutinized for their use in bispectral instruments that require a wide range of intermediate neutron energies. The dimensions of the moderators have been refined to improve the neutron yield for the neutron wavelength range selected in each case. After that, a spaceefficient layout has been proposed to implement four moderators next to the Be target, linked to a preliminary suite of instruments that these moderators would serve. Although the eventual selection shall consider both the final instrument suite (that shall be agreed with the local scientific community), and the phase space volume required for such neutron instruments (that defines their neutron optics features), the results presented here represent a qualitative step towards the conceptual development of the ARGITU neutron source.

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Development of an Epithermal and Fast Neutrons

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ABSTRACT

The High Brilliance Neutron Source (HBS) project aims to develop a High-Current Accelerator-driven Neutron Source (HiCANS) for neutron scattering, analytics, and imaging. Fast neutrons with an average energy of 0.5 MeV will be generated by the interaction of 70 MeV, 100 mA proton beam with a tantalum target. Three target-moderator-reflector (TMR) stations will operate at different frequencies to deliver individually tailored beam characteristics for each instrument. For the low (24 Hz, 667 us) and medium (96 Hz, 167 us) frequency stations, the neutrons will be slowed down into the thermal and cold energy regimes, respectively, by corresponding moderator systems. In addition, a high-frequency mode can be adopted for a short pulse (~4-8 us) in one of the medium-frequency stations using an appropriate chopper system.

For this last case, it is desired to have an optimal epithermal and fast neutron flux, in order to carry out different experiments such as prompt gamma analysis based on inelastic neutron scattering (PGAINS), and resonance neutron imaging (RNI). These instruments will be well-suited for preservation of cultural heritage, characterization of archaeological objects, materials science, and study of large and dense objects such as batteries or aeronautical components.

Some of the most essential neutronic parameters for this kind of experiments are the integral epithermal neutron flux, the ratio over integral fast neutron flux, and the energy versus time neutron distribution. For the optimization of these different parameters, simulations with the PHITS Monte Carlo code were performed.

The objective of this work is the presentation of the conceptual design of an epithermal and fast neutron TMR unit for the HBS project, considering the choice of the coolant, moderator, and reflector materials.

Improvement of arrangement and size of a neutron production target for a higher intensity electron accelerator-driven pulsed neutron source

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ABSTRACT

At the pulsed neutron source facility based on an electron linear accelerator at Hokkaido University, HUNS (Hokkaido University Neutron Source), high wavelength-resolution time-of-flight (TOF) neutron imaging experiments are performed using a decoupled thermal neutron moderator system [1]. However, the neutron intensity is lower than that of a coupled moderator system due to the narrow neutron pulse. In order to increase the neutron beam intensity, we considered increasing the neutron intensity provided from a neutron production target located at the most upstream of a neutron beamline. In this study, we improved the target arrangement and size in the electron accelerator-driven pulsed neutron source system to realize a neutron source with not only shorter pulse but also higher intensity. Finally, the improved target system will be appropriately applied to the suitable moderator, reflector and beamline device systems.

The target system was studied with simulation calculations using the particle transport Monte-Carlo code PHITS [2]. First, a flux trap-type target arrangement was investigated, in which multiple neutron production points are located close to the moderator by using a two-stage target. As a result, it was found that the photons, electrons, and positrons which contribute to neutron production are radially diverged by the front-stage target, and do not reach the rear-stage target sufficiently. Therefore, we investigated an arrangement in which an additional target was added between the front-stage target and the rear-stage target. As a result, photons, electrons, and positrons could be effectively utilized for neutron production. In addition, it was found that the target shielded the incident photons toward a neutron beamline by itself and suppressed the increment of the number of provided photons.

Then, we introduced another target arrangement. The target and the moderator were placed in series because of the proximity of the neutron production point to the moderator. In addition, the target was enlarged in size. This is because the increase in the volume of neutron production target increases the neutron intensity, while it increases the self-shielding effect for photons which are experimental background. As a result, the neutron

flux was 1.3 times higher than that of conventional system, while the photon flux was only 1.02 times higher than that. In addition to these results, the neutron pulse width was also evaluated. In the presentation, we will discuss the simulation calculation results and the experimental results of the new target arrangement and size in detail.

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Compact neutron monitoring system using solar cell

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ABSTRACT

We have developed a system that enables simple and real-time measurement of neutron intensity. We have already shown that solar cells can generate electric current output by electron, γ and α irradiations and operate as a dosimeter. In this study, we succeeded in adding sensitivity to neutrons by installing a boron converter on the 1 cm^2 cell area surface, which is made of InGaP, etc. The solar cell in contact with a boron sheet was enclosed in a resin case and installed near the RANS (RIKEN Accelerator-driven compact Neutron Source) beryllium target. A coaxial cable was used to connect to an ammeter installed outside the shielding, and the output was recorded every second. The output was on the order of nA, about 100 times larger than that without the boron converter. The output was compared with the average value of the proton current irradiated to the target , and it was confirmed that it was almost synchronized with the proton current. These results show that solar cells can serve as low-cost permanent neutron monitors and are expected to be further developed in the medical and nuclear fields in the future.

Realization of neutron sensitive microchannel plate imaging detector with a cross-strip readout

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ABSTRACT

The neutron/photon bimodal imaging technique puts forward higher demands for the counting rate and temporal resolution of imaging detector. However, the current cross delay line readout neutron sensitive microchannel plate (nMCP) detector can merely provide a throughput of ~100 kHz, which cannot meet the requirements when a high flux neutron source is utilized to conduct the bimodal imaging research. Benefitting from the large number of anodes, the cross-strip readout can realize an even higher throughput than cross delay line readout, with almost the same spatial resolution. In this study, we investigated the effect of cross-strip geometrical parameters on spatial resolution using Monte Carlo simulation combined with finite element method. The electronic system, including the preamplifier ASIC, ADC module and FPGA data processing module, was carefully designed and tested. The experimental results show that the spatial resolution of better than 100 μm could be achieved and the counting rate could be as high as MHz, which would be very promising to be used in the bimodal imaging system driven by a 18MeV/8kW electron linear accelerator.

Signal characteristics for pulsed neutron beam flux in organic-inorganic halide perovskite solar cells based detector

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ABSTRACT

Accelerator neutron sources are used in BNCT as a neutron source that can be installed in hospitals. The characteristics of the accelerator cause changes in neutron flux over time due to fluctuations in beam current and energy. Therefore, a method to measure the high flux direct neutron beam generated at the target with a detector is required. However, detectors have severe specification requirements such as signal saturation in high flux environments and degradation due to radiation damage. In a linear accelerator-based neutron source, the neutron is output as pulsed beam and is difficult to flux analysis because of count error of system by deadtime, etc.. We are aiming to develop a neutron detector based on solar cell, as a self-driven current-mode driven, for high flux radiation environment [1]. Organic-inorganic hybrid perovskite semiconductors have attracted worldwide attention in materials science and industrial applications such as solar cell and radiation detector, because of adjustable band gap, low-cost deposition process, and high defect tolerance[2]. Especially, defect tolerance is effective against defects caused by irradiation damage that caused in radiation environments and it is expected to be applied to radiation-resistant devices. Therefore, it will be possible to construct measurement systems that operate stably even in high-level radiation environments such as BNCT by utilizing perovskite solar cell devices with this high conversion efficiency and radiation tolerance. However, there is almost no neutron sensitivity in perovskite solar cell because the elements that compose perovskite do not have high neutron reaction cross sections. In this report, the neutron detector using perovskite solar cells is the designed and fabricated and the detection characteristics for pules neutron generated by RIKEN Accelerator-driven compact neutron systems (RANS) and RANS-II[3, 4]. In order to detect the neutron in perovskite solar cell, Boron Nitride as conversion films is deposited by containing on perovskite solar cells. The experimental results show that the detector induced current increases proportionally to the neutron flux estimated from the beam current in a pulsed neutron irradiation field.

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Design of SANS Instruments at CANS Facilities

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ABSTRACT

Small-Angle Neutron Scattering (SANS) is a ubiquitous technique at neutron scattering facilities throughout the world, and they are particularly attractive instruments to consider for a CANS facility as they are relatively simple in design, do not require high resolution, and can facilitate research across a wide swath of science. On the other hand, CANS facilities employ a fundamentally different primary neutron source than earlier generations of neutron facilities, and such CANS facilities must often be built within a different set of constraints than is typically seen at a major reactor or spallation source. We discuss briefly how these considerations may lead to minor variations in the design optimization for a CANS SANS instrument from the typical descriptions available from other facilities using the design of the instrument at LENS as an example [1].

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The Progress of Grazing-incidence Focusing Small-Angle Neutron Scattering (gif-SANS) Instrument at CPHS

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ABSTRACT

Small-angle neutron scattering (SANS), which is one of the most common and productive neutron scattering techniques, can be built based on compact accelerator-driven neutron sources (CANSs). However, the neutron current of compact sources is typically 2~3 orders lower than those of large facilities. This difficulty calls for novel neutron optics to realize a SANS spectrometer with high neutron current and wide Q-range.

The grazing-incidence focusing SANS (gif-SANS) at Compact Pulsed Hadron Source (CPHS) of Tsinghua University addresses the challenge of building high-performance SANS instrument based on CANSs. The gif-SANS has three modes applicable to different Q-range scenarios. A nested neutron-focusing supermirror assembly with a large collecting area and a He-3 LPSDs detector are employed to achieve ≥10^5 n/s neutron current at Q_{min}≤0.007 Å^{-1}. To extend the Q_{min} down to 10^{-3} Å^{-1}, a high-resolution neutron sensitive micro-channel plate (^{n}MCP) detector will be used. To achieve higher Q-range, gif-SANS is compatible with a pinhole design. By switching neutron optics and detectors, gif-SANS achieves a wide Q-range and a high neutron current gain with compact structure, allowing it to flexibly match different requirements.

In the last year, we have completed the overall preliminary design of the gif-SANS. In this year, we plan to complete the fabrication of major components. We have designed and manufactured a prototype device consisting of three shell semi-toroidal conical mirrors coated with m=3 Ni/Ti supermirror, and carried out performance tests based on this prototype. We have completed the design of the detector system and the bandwidth limiting neutron chopper, and are currently conducting prototype tests.

Neutron Scattering and X-ray Absorption Methods for Hydrogen Charging in Copper

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ABSTRACT

The corrosion of metal leads the mechanical properties degradation by the hydrogen embrittlement. The neutron scattering is more sensitive for the light elements than the X-ray methods. We used two analysis methods for electrochemical hydrogen charging in copper metals. The oxygen-free copper was analysis with small angle neutron scatting before hydrogen charging at -1.3 V vs. Ag/AgCl in 3.5 wt% NaCl solution for 200 and 300 seconds and the thermal charging at calculated 500ppm and 1000ppm hydrogen contents in the sealed quartz tube at 325oC about four for six hours. The X-ray absorption analysis with the in-situ electrochemical equipment for electrochemical hydrogen charging, also for thermal charging samples. Furthermore, the X-ray diffractometer would apply for these samples to comparison with the above-mentioned and the surface analysis methods, such as TEM, EBSD and Nano-Indentaion.

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Statistical Studies and Resolution Measurements on Digitalized Film Images in Neutron Radiography

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ABSTRACT

In the last years, neutron imaging facilities have implemented direct digital imaging systems such as imaging plates and CCD or sCMOS cameras coupled to a scintillator screen [1]. But for some applications, such as detection of micro cracks in large-size metallic or organic materials, these methods have some disadvantages, mostly related to their small field of view. On the other hand, the use of radiographic films, although an old technology restricted to 2D imaging, allows observing details with very good spatial resolution (<50μm) and over very large areas, which can compensate for their low efficiency. Within the HiCANS project ICONE, where it is foreseen that neutron radiography will be implemented to continue historical activities, radiographies were taken with films at PSI, on the NEUTRA beam line (providing thermal neutrons) in order to compare them to similar radiography films of the same objects taken at the Orphée nuclear reactor (providing cold neutrons) before its shutdown in 2019. Images were obtained with different neutron energy, different L/d and different fluence levels. High-resolution digitalization of the film was performed in order to apply quantitative measurements. We compared these images to those obtained with imaging plates or CCD cameras. A study on the quality and the statistics of the images after digitalization was done in order to quantify the evolutions of the contrast and the spatial resolution. Simulations were used to determine the resolving capacity of these images. With these results, it could be determined if the usage of films can complement modern neutron imaging methods depending on the needs.

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Conceptual design of neutron imaging instruments for the High Brilliance Neutron Source

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ABSTRACT

The High Brilliance Neutron Source (HBS) project aims to develop a High-Current Accelerator-driven Neutron Source (HiCANS) for neutron scattering, analytics, and imaging. Amongst the 25 instruments planned at HBS, there will be at least five different neutron imaging instruments: cold, diffractive, thermal, resonance/epithermal, and fast, covering the different neutron energy ranges.
These neutron imaging instruments will have different sample positions, which can be selected to optimize the flux, collimation, spatial, wavelength, and time resolutions. Each of these positions will be best suited for studies considering the specific energy ranges to investigate hydrogen in metals, strain phase mapping studies in engineering and energy conversion processes, archeological characterization, automotive and aerospace applications, or battery processes.
For the optimization of the required neutronic parameters, Monte Carlo simulations were performed, starting from the source and ending at the sample position. For the source simulations, the PHIT code was used, while VITESS and McStas performed the ray transport through the instrument. Also, an open-source code called KDSource was used to estimate the source distribution at a given point in the beam trajectory, and then resample new particles that respect the correlations of the original source.
The objective of this work is the presentation of the conceptual design of these instruments, the procedure for the simulations, the principal parameters, and the potential capabilities.

Development of a thermal/epithermal/ fast neutron and X-ray radiography system for element imaging

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ABSTRACT

Neutron and X-ray synergy imaging utilizes the elemental dependence of the reaction cross-section ratio of each radiation to materials (H. Hasemi *et al.*, IEEE Nucl. Sci. Symp. Conf. Rec., 2017). As a result, this method identifies elements on radiogram since the element-specific natural-logarithm ratio of the transmission of each radiation, which is dependent on only the cross-section ratio, is independent of the thickness and atomic number density. Thus, element imaging is possible by spatially matching images of each beam and obtaining an image of the cross-section ratio. However, a single information of the cross-section ratio may not be sufficient to uniquely determine an element, because there are element combinations which have the close ratio with each other. Therefore, we considered the use of multi-energy neutrons as way to improve the ability to identify elements. This is because multi-energy neutron imaging allows for multiaxiality of the cross-section ratio between radiations, e.g., thermal neutron and X-ray, epithermal neutron and X-ray, thermal neutron and epithermal neutron, and so on. For this purpose, it is preferable to obtain X-ray and multi-energy neutron images with the same radiation beam source, beamline, and detection system. We consider the use of HUNS at Hokkaido University as a facility capable of these radiation beam imaging because HUNS can provide high energy X-rays and cold/thermal/epithermal/fast neutrons. In this study, we conducted basic research for the development of a both X-ray and neutron imaging systems using an X-ray imaging plate (IP).
First, neutron imaging was done by an indirect neutron imaging method which imaging converter foils behind samples were activated on the neutron beamline. These converter foils were suitably selected for neutron energy in terms of activation level and decay time. Then, β-rays released from the foils were transferred to an X-ray IP off the beamline. Activations were achieved by 1/v absorption reaction for thermal neutrons, resonance absorption reaction for epithermal neutrons, and threshold nuclear reaction for fast neutrons. Activations between thermal neutrons and epithermal neutrons were separated by using a resonance filter composed of the same nuclide as the converter foil. In addition, high-energy X-ray imaging was achieved by X-ray IP direct imaging on the neutron beamline. In this presentation, we discuss methodology, various imaging results, and future works.

Development and Application of Compact High-resolution Neutron Radiography System

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ABSTRACT

Neutron radiography has been shown to be an effective diagnostic imaging tool in industrial NDT. The basic principle of neutron radiography is similar to that of X-ray radiography which both are transmission imaging techniques. However, the different interactions between neutrons and X-rays with matter make these two techniques largely complementary. X-rays interact with orbital electrons and are strongly linked to the physical density of the object being examined. However, neutrons interact with the atomic nucleus of an object rather than its orbital electrons, so they are not related to the electron density of the object, but rather its elemental composition. Neutron radiography has several outstanding advantages in detection, such as strong penetration ability, high sensitivity for light element detection, and high accuracy for component inspection and strong anti-interference ability. Neutron radiography has significant advantages in identifying the light materials in a metallic material packaging, as well as for penetration inspection of radioactive materials. It is also used for biological forensics and cultural heritage provenance studies.

To meet the urgent needs of the industrial NDT field, the Compact High-resolution Neutron Radiography System has been developed by FDS Consortium, with improvements in miniaturization of the high intensity neutron source, high efficiency collimation, and intelligent image processing technologies. It has some outstanding advantages, such as compact size, high resolution, intelligent and easy-to-use. It has been successfully applied to the non-destructive field of aerospace, energy equipment, circuit structures, power batteries, etc.

Experimental and Simulation Analysis of Ethane as a Neutron Moderator at Various Cryogenic Temperatures

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ABSTRACT

This abstract presents the results obtained by the High Brilliance Neutron Source (HBS) project at Forschungszentrum Jülich on the use of ethane as a neutron moderator material. The aim of the study was to conduct a detailed investigation on the behaviour of ethane as a cold moderator for neutrons and assess its performance at different cryogenic temperatures. The experimental measurements were carried out at temperatures of 170 K, 135 K, 100 K, 70 K, 50 K, 25 K, 15 K, and 10 K. The experimental data obtained from the measurements were then analysed and compared with simulation results using the PHITS (Particle and Heavy Ion Transport code System) code. A special phase analysis focusing on ethane's metastable phase was thoroughly analyzed and discussed which allowed for a comprehensive evaluation of the moderator's behaviour and its suitability for neutron moderation. The results showed that ethane exhibited notable changes in its response as the temperature changes. The findings from this study will contribute to the development of advanced neutron compact moderators and provide valuable information for optimizing neutron-based experiments and research facilities.

An open-source, zero-code, full-stack, integrated hardware-software control platform for research facilities

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ABSTRACT

Blinky-Lite is an open-source, zero-code, full-stack, integrated hardware-software control platform for research facilities. The platform is based on Edge computing technology designed by hardware engineers that can perform at any scale from home automation to particle accelerators. The platform was developed at the MaxIV Synchrotron Light Source and the European Spallation Source both located in Lund, Sweden. In this world of complex and costly particle accelerators, a strong 24/7 maintenance mindset is a must. It is essential to always understand the state of a machine remotely and to be able to securely troubleshoot it efficiently from anywhere in the world at any time.

Design of a high resolution diffractometer using statistical time modulation to exploit the long pulse structure at the ICONE HiCANS

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ABSTRACT

Low energy accelerator-driven neutron sources are intrinsically limited by the peak flux they can provide. A way to increase the total brilliance of the source is to increase the neutron pulse length. However, the efficient use of time-of-flight techniques on long pulse neutron sources is non trivial. The option chosen at ESS which is a very long pulse source is to build long instruments (up to 150 m) to be able to fully exploit the long pulse structure. Such a solution cannot be reasonably implemented on "Compact" accelerator-driven neutron sources, essentially for cost reasons. The Laboratoire Léon Brillouin is currently supporting the construction of a HiCANS source, the ICONE project, which would provide about 10 neutron scattering instrument to the French community. We are thus exploring the possibilities to maximize the performances of the instruments for the users.

We have investigated the possibilities of implementing statistical time modulation on a diffraction instrument to be able to use very long pulse structures. The current DIoGENE instrument [1] around the *IPHI – Neutrons* facility has limited performances due to a very short flight path. We will present Monte-Carlo simulations of the DIoGENE-DISChO instrument using statistical time modulation of long pulses and propose the design of a high-resolution powder diffractometer which could be installed on the long pulse target station of the ICONE source.

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Development of neutron reflectometry at a HiCANS: the HERMES instrument at the JULIC Neutron Platform

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ABSTRACT

High current Compact Accelerator-driven Neutron Sources (HiCANS) have risen as a possible answer to the drop in neutron availability in recent years due to the closure of various research reactors in Europe. Within this new trend, the Laboratoire Léon Brillouin (LLB) is currently evaluating the performance of neutron techniques around this novel type of source. HERMES [1] is a time-of-flight horizontal reflectometer that was operated by the LLB at the Orphée reactor [2] until 2019 and was mainly employed for soft-matter studies. Through a collaboration with the Jülich Centre for Neutron Science, HERMES was installed in 2022 at the JULIC neutron platform at Forschungszentrum Jülich. This platform is able to deliver neutron pulses in the 100 µs-2 ms range and is very well suited to evaluate the feasibility of reflectivity experiments at a HiCANS. Since its installation and first tests in 2022, several improvements have been planned and implemented at HERMES in order to exploit its maximum performance. Our current goal is to perform reflectivity experiments with supermirrors as a proof of concept, as the flux at the JULIC neutron platform is several orders of magnitude lower than the original Orphée flux or the one expected for a HiCANS. Nevertheless, Monte-Carlo simulations showed that an instrument as HERMES operating at a HiCANS could match the performance of similar instruments at medium power research reactors. This work is part of the collaboration within ELENA and LENS on the development of HiCANS. It has been funded by the "CANS Inflexion" program at the CEA and the "IPHI-Neutron" SESAME project of the Île de France region.

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A Novel Pyroelectric Neutron Generator Using Laser Irradiation Heating and Ionization

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ABSTRACT

Pyroelectric neutron generator is an ideal neutron calibration source for neutrino and dark matter detection [1]. This is due to its compact size, controllable neutron intensity, free of radioactive contamination and high-frequency noise interference. By using pyroelectric crystals to generate high-voltage electric fields, deuterons produced by ionization can be accelerated and bombard deuterium-rich targets, initiating deuterium-deuterium (D-D) nuclear reactions to create neutrons. The current pyroelectric neutron generators use field emission ionization to produce deuterons, which limits the beam current and acceleration voltage, thus limiting the neutron yield [2-4]. A novel pyroelectric neutron generator that uses a pulsed 1064 nm laser to irradiate a pyroelectric crystal covered with metal deuteride (LiTaO3-Mo-TiDx) simultaneously for heating and ionization was introduced in this paper. The effects of laser irradiation and heating law on the distribution of maximum electric potential and electric field, as well as beam parameters and neutron yields have been studied. Our goal is to develop a novel wireless pyroelectric neutron generator using laser remote heating and ionization.

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Poster No. **27**

Topic
Medical applications

Accelerator-based Boron neutron capture therapy (BNCT) technology development project at Martonvásár, Hungary

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ABSTRACT

An accelerator-based BNCT technology development project is underway to be built by Mirrotron Ltd. at Martonvásár, Hungary. The 2.5 MeV RFQ linac and the ECR ion source are already on site and are ready to enter the commissioning stage soon. Currently, the RFQ Linac is designed to operate in pulse mode with 1 mA time average proton beam. The proton beamline for BNCT development consists of a 90o bending magnet and a dipole. The proton beam hits the target within a 7 cm diameter circle (3 RMS size).
We have conducted preliminary simulations for the neutron beam shaping assembly design, assuming that a 10 mA 2.5 MeV proton beam bombards the 100 µm Li layer in 10 cm diameter disc shape. Neutron beam ports at various tilting angle were investigated and it is found that the neutron beam characteristics are similar at tilting angles from 0 degree to 60 degrees, while the fast neutron dose component slightly increases as the tilting angle increases. This provides us with the possibility to design an epithermal neutron source with multiple ports. Satisfying the criteria recommended by International Atomic Energy Agency (IAEA) [1], a 2-port epithermal neutron irradiator with symmetrical design can achieve the same neutron beam parameters at both ports. With slightly asymmetrical design and using dual moderator materials (half MgF2 and half AlF3), different neutron spectra can be achieved on the different ports. In this way, we can utilize neutrons more efficiently.

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Topic
Computer simulations and instrument performance

Poster No. **28**

An Engineering Diffractometer for the High Brilliance Neutron Source (HBS)

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ABSTRACT

The HBS is a high brilliance accelerator driven neutron source currently in the design process. It provides different target stations that follow the same duty cycle but offer different frequencies and pulse length. Cold and thermal moderators are used to adjust the neutron spectrum. The different target stations with their moderators thus allow choosing the parameters best fitting to an instrument or instrument class. We here present the design and expected performance of an engineering diffractometer for one of the target stations using a 96Hz pulse repetition. The by the PE moderator provided thermal neutron pulse has a length of about 250µs. To achieve a high resolution and make best use of the full pulse a wavelength frame multiplication (WFM) technique is used to extract four shorter sub-pulses. While the compact instrument design with a length of 21.8m is optimized for straining scanning measurements the design of the instrument will allow further the analysis of textures and the investigation of phase transitions.

Digital investigation of the neutron detector

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ABSTRACT

PFN emission of ^{235}U(n,f) reaction are under investigation in JINR for last 20 year. The recent achievements in experimental apparatus simulation are the subject of this presentation. The object of simulation is prompt fission neutron (PFN) detector used for resonance neutron induced fission of U-235. The neutron source was IREN facility and double ionization chamber (DIC) with Frisch grids was used for fission fragment spectroscopy. The PFN detector was multi detector system consisted of 32 BC501 scintillation liquid filled modules from the Sionix (Netherlands) company. Detectors were located on the sphere surface with 50 cm radius. Double Frisch gridded ionization chamber, used as fission spectrometer at the same time generated trigger signal for PFN registration apparatus. For each fission event the following simulated information was recorded: correlated fission fragments time mark, emission angle in respect to the selected coordinate frames along with the pulse heights and shapes of neutron detector signals. Multiple neutron scattering and the cross-talks were taken into account in order to evaluate contribution of those effects in the final results.

The intense DT neutron generator of Technical University of Dresden

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ABSTRACT

In the early 2000s the Technical University of Dresden has set up a new neutron laboratory with an accelerator-based intense DT neutron generator, TUD-NG. It provides a typical neutron yield at DT (deuterium-tritium) energies up to several 1011 s^{-1} and at DD (deuterium-deuterium) energies up to several 109 s-1. Operation can be in continuous and pulsed mode, the machine control provides microsecond and nanosecond pulsing. Accelerated deuterons with selectable energies between 100 keV and 325 keV bombard water-cooled solid targets containing tritium or deuterium. The maximum deuteron beam current achieved so far is approximately 8 mA at the target. The laboratory is licensed for a maximum DT neutron yield of 10^{12} s^{-1}. The setup of experiments is very flexible, and irradiations of materials and small samples at controlled temperatures up to several hundred degrees Celsius are possible.
The laboratory has been involved mostly in the European fusion research since its commissioning through close collaboration with Karlsruhe Institute of Technology. In the past, measurements were done on mock-ups of tritium breeding blankets and R&D work for the development of instrumentation for harsh environments. Other areas of work include nuclear cross section measurements and experiments related to the neutrino-less double-beta decay. Currently upgrades of the neutron generator and the measurement capabilities are underway. Two mobile high-purity germanium detectors were added as well as a compact electron spin resonance spectrometer suitable e.g. for dosimetry applications. New activity standards for dosimetry purposes with low uncertainty and traceable to national standards are available as well. Future plans for exploiting the TUD-NG capabilities will be presented.

Ion accelerator based neutron source at HZDR

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ABSTRACT

The Ion Beam Center (IBC) at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) is a unique user facility with decades of experience in materials research using ion beams of nearly all stable elements in a wide energy range from some eV up to 60 MeV. The IBC operates several electrostatic ion accelerators, ion implanters, low energy, highly charged, and fine focused ion beam systems including helium ion microscope. The IBC provides experimental equipment for materials modification via ion implantation and irradiation, all types of ion beam analysis of materials, surface processing by low-energy, highly-charged and focused ion beams, as well as for accelerator mass spectrometry (AMS). Continuous access to the IBC is provided via an online proposal procedure [1].

A new beamline with a neutron source will be installed at the 6 MV Tandetron. 12 MeV protons and 18 MeV helium ions can be used for production of neutrons using beryllium or vanadium targets. Neutrons provide information that cannot be obtained with other methods and open new opportunities for material analysis at IBC like imaging and 3D tomography with fast and thermal neutrons, prompt and delayed gamma neutron activation analysis (PGNAA & DGNAA), neutrons can be used in investigations of radionuclides production for radiopharmacology and in many other experiments and measurements.

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The IKUR-FUN initiative in the Basque Country – *Raison d'être* and first steps

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ABSTRACT

The IKUR 2030 Strategy was recently launched by the Department of Education of the Basque Government. An initial investment of 100 M€ over the period 2021-2030 has already been committed in four specific priority areas: neurobiosciences; quantum technologies; high-performance computing & artificial intelligence; and neutron & neutrino science. In this latter context, the IKUR-FUN initiative (from the Spanish *Fuente Ultracompacta de Neutrones*) was born in late 2022. Its primary *raison d'être* is predicated upon the pressing need to explore and assess in depth the requisite levels of neutron provision for academia and industry in the Basque Country, with an emphasis on capitalizing from the latest developments in increasingly compact neutron sources and the opportunities that they offer. To this end, a multidisciplinary working group has been assembled, with an initial focus on instrument development, sustainable materials, and industrial applications. This contribution describes the overall rationale and drivers behind the IKUR-FUN initiative and its first steps during these early days. Some of these include ongoing & mature research & development programmes in neutron and neutrino science by current IKUR-FUN actors, as well as joint scientific & technological demonstrators in close collaboration with existing neutron sources elsewhere in the world. These activities constitute a necessary first step towards a fully fledged business case in support of the (much-anticipated) arrival of neutrons to the Basque Country in the foreseeable future.

Neutron researches using cyclotron accelerator at INER

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ABSTRACT

This paper briefly descripts the status of cyclotron accelerators neutron source and the neutron techniques developed at the Institute of Nuclear Energy Research (INER) in Taiwan. At INER, two neutron projects are currently being executed. The first project is to make use of INER's 29-years-old 30MeV cyclotron TR-30 (made by TRIUMF, Canada) as a neutron source, two neutron applications like thermal neutron radiography and fast neutron soft error rate (SER) are being developed. In 2023, the 27MeV quasi-monoenergetic neutron source for SER testing had completed construction and testing, now the operation permission for services was attained. Another bi-functional neutron source that can provide both thermal and fast neutron is currently under test run, the operation goal for fast neutron is for 30MeV/20 A proton beam, for thermal neutron is 30MeV/200 A. The neutron target mentioned above is using the Beryllium (Be) metal.

The second project is a 4-year plan (2023-2026) involving securing a new 70MeV/1mA cyclotron with the civil-engineering construction of host building, and a neutron research laboratory was also proposed within. In early this year, a contract had been signed with a well-known cyclotron provider, the proton beam lower energy range had been extended to 28MeV. With the high power proton beam, makes a high emittance neutron source possible. Currently, two type of neutron sources are being developed, one is using the Tantalum (Ta) as neutron target material for the 70MeV/1mA case, the other is using the Beryllium (Be) as neutron target material for the 28.5MeV/400μA condition in order to co-exist with isotope production and to achieve the maximum beam time. As a startup, a thermal neutron diffraction station had been proposed and conceptual design is also under study. More detail and current status will be reported at the conference.

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Conceptual Design of the Moderator Test Station at the Spallation Neutron Source

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ABSTRACT

We describe a moderator test and development facility, the Moderator Test Station (MTS), under construction at the Spallation Neutron Source. We will leverage the Beam Test Facility (BTF) at the Spallation Neutron Source to provide a moderator neutronics test stand with which we will verify the anticipated performance gains expected and required from the innovative moderator concepts central to the SNS Second Target Station (STS) and the future of the First Target Station (FTS). These concepts include large-volume para-hydrogen moderators and the high-brightness tube moderators. The MTS will add to the existing BTF a proton beam chopper similar to that already used in the SNS at the RFQ exit (the so-called MEBT chopper), various proton beam transport components, a neutron-producing target, a cryogenic moderator test stand, a reflector-shielding assembly, and a performance assessment neutron beamline. The MTS will provide the ability to test a wide variety of moderators in a prototypic configuration, simultaneously measuring the neutronic performance of the moderator concept central to the anticipated STS gains and developing the instrumentation necessary to provide that performance in a production environment. The presentation will describe the MTS, its progress, and the way we optimize the prototypic nature of the moderators we will test.

Estimation of neutron energy-dependent SEU cross sections of semiconductor devices without fast TOF-analysis function

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ABSTRACT

In recent years, soft errors caused by cosmic ray neutrons on the ground have become an increasing problem. Therefore, it becomes important to design semiconductor devices, considering the soft error rate (SER) in actual field. Estimation of SER at various environments requires the data of the neutron energy-dependent single event upset (SEU) cross sections of semiconductor devices.

We have successfully measured such SEU cross sections for several FPGAs with the time-of-flight (TOF) method [1,2]. However, due to the limitation of error detection speed, only FPGAs are capable of TOF measurement of SEU cross sections above 1 MeV. In order to estimate SER for devices other than FPGAs (CPUs, SRAMs, DRAMs, Flash memories, etc.), it is necessary to investigate SEU cross sections for these devices as well.

It is difficult to directly measure energy-dependent SEU cross section from SER measured in an acceleration test using a neutron beam without the TOF method, because SER results from integration of energy-dependent multiplication between the SEU cross section of a particular device and neutron spectrum at the environment. As a solution, we have developed an inverse-problem analysis to estimate the neutron energy-dependence of SEU cross sections from measured data of SER and known neutron energy spectrum information. For the reliable analysis, we need numbers of SER responded for different incident neutron spectra. In our present study, at 18 MeV proton cyclotron neutron source facility, we changed incident neutron energy spectrum by changing neutron production targets, and estimated SEU cross sections for devices other than FPGAs.

In this presentation, we will report methodology, suitable method for changing neutron energy spectrum, experimental results of SER depending on the target and estimated results of SEU cross sections.

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Investigation of the mutual influence of multiple extraction channels for accelerator-based neutron sources

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ABSTRACT

Compact accelerator-based neutron sources (CANS) are an emerging technology that enables scientists to analyze the dynamics and structure of matter. One of these projects is the High Brilliance neutron Source (HBS) project, which aims to tailor the neutron beams to meet requirements for different instruments [1]. A key component in the optimization process is the development of the target-moderator-reflector (TMR) system, where the moderator plays an important role in accumulation, moderating, and emitting neutrons towards several instruments through extraction channels. This study investigates the mutual influences of several extraction channels on the neutron flux and the beam divergence compared to a one extraction channel system.

To understand the production, moderation and propagation of neutrons Monte Carlo particle-tracking codes, such as MCNP and PHITS can be used. Simulations using the PHITS program have first been performed for a single extraction channel system to observe moderator design effects on the beam divergence and the peak neutron flux emitted towards the instrument. Lastly, several arrangements of multiple extraction channels have been simulated to investigate the influence of additional extraction channels on the flux and the beam divergence.

The results achieved in this study show that the influence of multiple extraction channels on the thermal neutron flux is minimal depending on the amount of moderator material that is used and on the arrangement of the channels. The insights gained from this work contribute to the continuous development of the HBS project and provide helpful information for the optimization of such a neutron source and design of neutron extraction channels in forthcoming neutron source facilities.

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Low energy neutron-induced SEU cross sections and the need for thermal neutron irradiation using CANS

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ABSTRACT

Problems caused by cosmic neutron-induced soft errors in electrical devices are becoming increasingly common in various applications. Although soft errors were generally believed to occur with high-energy neutrons, we measured the effects of low-energy neutrons.

We had already performed a continuous observation of neutron-induced SEU cross sections over an energy range of 1-800 MeV at the Los Alamos Neutron Science Center (LANSCE). However, it is impossible to measure the neutron energy range below 1 MeV at LANSCE because the interval repetition of the proton/neutron beam pulse is so short and the neutron intensity below 1 MeV is very low. Therefore, we performed continuous observations of SEU cross sections for the energy range of 10 meV – 1 MeV at J-PARC (Japan Proton Accelerator Research Complex) [1].

As a result, we were able to clearly observe the effect on the cross section of the $^{10}B(n, \alpha)^{7}Li$ reaction below 0.1 MeV. Although these devices feature modern components without BPSG (borophosphosilicate glass), SEU cross sections in the thermal neutron energy region showed similar energy dependence to the boron capture cross section.

Hence, soft errors due to thermal neutrons still occur, and we believe that CANS is useful for soft error testing in the thermal neutron energy region.

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On-site application of neutron salt-meter RANS-μ for non-destructive inspection of concrete bridges

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ABSTRACT

Since collapse and many serious damages in concrete bridges due to chloride attack from the sea wind in coastal area or antifreezing agent in heavy snowfall area have occurred in the world, non-destructive on-site measuring techniques are required for the chloride ion concentration in concrete structures with a depth profile from the surface to the position of steel bar. Therefore, there are strong demands to solve above problems by applying non-destructive inspection methods to scan the elemental contents in large bulk such as concrete structures. We have developed a transportable neutron salt-meter, which we call "RANS-μ", where we combine 252Cf neutron source and a prompt gamma neutron activation analysis (PGNAA).

Trials of chloride detection measurement outdoors with 252Cf neutron source were performed on-site using real bridges in service as well as removal bridges damaged by chloride attack at an outdoor yard in Public Works Research Institute (PWRI) and a model bridge in Fukushima Robot Test Field. For these measurements, the results obtained by RANS-μ were compared with those of obtained by the chemical analyses of samples obtained by drill powder collection or core removal. From these comparisons, consistent results were successfully obtained.

We will also present the progress of practical applications and industrialization of RANS-μ promoted by Technology Research Association for Neutron Next Generation System (T-RANS) and the newly started venture company "Rans View".