Overview

Advances in science and technology in the field of neutron science have been dominated by a fruitful combination of major international facilities supported by networks of smaller regional facilities. Recent advances in accelerator technology and neutronic design have made it possible to construct small-scale accelerator-driven neutron facilities that would be able to play a significant role in neutron technology and science. The neutron applications using compact accelerator driven neutron sources are now becoming more and more important since it can cover various fields such as material science, engineering, nuclear physics, cancer therapy, soft error, cultural heritage and so on, and therefore they would play a more significant role in the future.

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 were held in Beijing (China) 2011, Bloomington (U.S.A) 2012, Bilbao (Spain) 2013, Sapporo (Japan) 2014, Legnaro (Italy) 2015, and Xi’an (China) 2016.
PROGRAM COMMITTEE

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Xuewu WANG  Tsinghua University, China,
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Luis RODRIGUEZ PALOMINO
Javier SANTISTEBAN
Ivan SIDELNIK
Miguel VICENTE ALVAREZ
Preface

Neutron beam techniques have been making key contributions to our scientific knowledge and technological development for several decades now. Those techniques are well established, after continuous development that has led to a significant improvement in experimental capabilities. Such evolution benefited greatly from a synergistic combination of large scale facilities and small neutron sources, which in turn became increasingly useful in terms of neutron flux after developments in accelerator technology and the production, transport and detection of slow-neutrons.

The Union for Compact Accelerator-driven Neutron Sources – UCANS – was established at the end of the ICANS-XIX meeting in Grindelwald, Switzerland, in March 2010. Its main purpose is to provide a platform for discussions and exchange of ideas and experiences among groups interested in building or operating small neutron facilities based on accelerators. The interest is prompted by the fact that applications that use compact accelerator-driven neutron sources are becoming more and more important by their own merit.

In the UCANS-VI meeting held in Xi’an (China, 2016), the UCANS Executive Committee decided that the 7th. International Meeting of the Union for Compact Accelerator-driven Neutron Sources will be held in San Carlos de Bariloche, Río Negro, Argentina (https://en.wikipedia.org/wiki/Bariloche). As a result, for the first time an UCANS meeting is being held in the Southern Hemisphere, and we are very proud and excited for such a distinction.

It is a pleasure to acknowledge support from the Argentine Atomic Energy Commission (CNEA) and INVAP S.E., the highly successful state-owned nuclear and space technology company.

We wish to thank you for coming from far away countries to participate in UCANS-VII, hoping that we all benefit from a combination of good neutron science and a lovely natural environment.

Rolando Granada
Chairman
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<th>Sunday 11</th>
<th>Monday 12</th>
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<th>Wednesday 14</th>
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<td>8:55 – 9:20</td>
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<td>A2 Shvetsov</td>
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<td>9:20 – 9:45</td>
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<td>A4 Kobayashi</td>
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<td>10:10 – 10:35</td>
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<td>B1 Zakalek</td>
<td>F10 Ke</td>
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<td>10:35 – 11:10</td>
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<td>11:10 – 11:35</td>
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<td>E1 Y. Yang</td>
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<td>11:35 – 12:00</td>
<td>G1 Otake</td>
<td>E2 Hong</td>
<td>H2 H. Iwashita</td>
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<td>12:00 – 12:25</td>
<td>I1 Granada</td>
<td>E3 Shvetsov</td>
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<td>E5 Zeinalov</td>
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<td>CANS Projects and Innovative Instrumentation</td>
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<td>Other applications of CANS</td>
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<td>Nuclear Astrophysics and Nuclear Data</td>
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<td>Medical applications</td>
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<td>Computer simulations and data-analysis software</td>
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<td>Education</td>
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## Programme

### Sunday, March 11, 2018

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<tr>
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<tbody>
<tr>
<td>16:50 – 18:30</td>
<td>Registration</td>
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<tr>
<td>18:30 – 20:30</td>
<td>Reception</td>
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### Monday, March 12, 2018

#### Opening Session
Chair: Rolando Granada

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 1: CANS Projects and Innovative instrumentation</th>
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<tbody>
<tr>
<td>8:30 – 8:55</td>
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<tr>
<td>8:55 – 9:20</td>
<td>F1 Christiane Alba-Simionesco Update on SONATE, the French Compact Neutron Source Project</td>
</tr>
<tr>
<td>9:20 – 9:45</td>
<td>F2 David V. Baxter Update on LENS for 2018</td>
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<tr>
<td>9:45 – 10:10</td>
<td>F3 Michihiro Furusaka Upgrade of Hokkaido University neutron source (HUNS)</td>
</tr>
<tr>
<td>10:10 – 10:35</td>
<td>F4 Ferenc Mezei The industrial CANS project LvB at Martonvásár, Hungary</td>
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<tr>
<td>10:35 – 11:10</td>
<td>Coffee Break</td>
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#### Session 2: CANS Projects / Material Characterization

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<tr>
<th>Time</th>
<th>Session 2: CANS Projects / Material Characterization</th>
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<tbody>
<tr>
<td>11:10 – 11:35</td>
<td>F5 Javier Santisteban LAHN: The Argentinean Neutron Beams Laboratory Project</td>
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<tr>
<td>11:35 – 12:00</td>
<td>G1 Yoshie Otake RIKEN Accelerator-driven compact neutron sources and its quantitative analysis methods</td>
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<tr>
<td>12:00 – 12:25</td>
<td>I1 Rolando Granada Neutron Scattering Kernels and Cross Sections for Cold Moderator Materials</td>
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<tr>
<td>12:30 – 13:55</td>
<td>Lunch</td>
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#### Session 3: Moderator neutronics / Optical devices

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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>14:00 – 14:25</td>
<td>C1 Yannick Beßler Engineering studies on second generation of ESS low dimensional cold moderator for full power operation</td>
</tr>
<tr>
<td>14:25 – 14:50</td>
<td>C3 Yutaka Yamagata Development of cold neutron source using methyl-benzene derivatives for compact neutron source</td>
</tr>
<tr>
<td>14:50 – 15:15</td>
<td>D1 Yoshihisa Iwashita Magnified neutron imaging using refractive optics</td>
</tr>
<tr>
<td>15:15 – 15:40</td>
<td>D2 Sheng Wang The Portable Neutron Imaging Facility and its Experiment Study Based on D-T Neutron Source of Compact Accelerator</td>
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<td>15:40 – 16:05</td>
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<tr>
<td>16:10 – 16:50</td>
<td>Coffee Break + POSTER SESSION</td>
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<tr>
<td>16:50 – 18:30</td>
<td>Round Table</td>
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</table>
## Session 4: Accelerators and beam optics / Target radiation damage

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
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<tbody>
<tr>
<td>8:30 – 8:55</td>
<td>Nicolas Chauvin</td>
<td>IPHI, a high intensity proton accelerator for neutron production</td>
</tr>
<tr>
<td>8:55 – 9:20</td>
<td>Valerii Shvetsov</td>
<td>Current status of the IREN resonance neutrons source</td>
</tr>
<tr>
<td>9:20 – 9:45</td>
<td>Yoshiaki Kiyanagi</td>
<td>Present Status of Nagoya University Accelerator Driven Neutron Source, NUANS</td>
</tr>
<tr>
<td>9:45 – 10:10</td>
<td>Tomohiro Kobayashi</td>
<td>Development of transportable neutron source prototype RANS-II</td>
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<tr>
<td>10:10 – 10:35</td>
<td>Paul Zakalek</td>
<td>Mechanical stability of a target for a compact accelerator based neutron source</td>
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### Coffee Break

## Session 5: Neutron detectors

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<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
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<tbody>
<tr>
<td>11:10 – 11:35</td>
<td>Yigang Yang</td>
<td>The progress of a honeycomb neutron convertor based neutron detector</td>
</tr>
<tr>
<td>11:35 – 12:00</td>
<td>Seung-Woo Hong</td>
<td>Detecting neutrons with a MICROMEGAS detector</td>
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<tr>
<td>12:00 – 12:25</td>
<td>Valerii Shvetsov</td>
<td>Measurement of the energy dependence of the neutron counters sensitivity at the neutron beams of the electrostatic generator</td>
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### Lunch

### Free Afternoon

### Conference Dinner
## Session 6: CANS Projects and Innovative instrumentation

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<tr>
<td>8:30 – 8:55</td>
<td>F6</td>
<td>Pierfrancesco Mastinu</td>
<td>The SPES project at the INFN- Laboratori Nazionali di Legnaro</td>
</tr>
<tr>
<td>8:55 – 9:20</td>
<td>F7</td>
<td>Yoshiaki Kiyanagi</td>
<td>Neutronic performance of a beam line for imaging at the electron Linac Facility in Kyoto University Research Reactor Institute</td>
</tr>
<tr>
<td>9:20 – 9:45</td>
<td>F8</td>
<td>Thomas Gutberlet</td>
<td>NOVA ERA - A compact neutron source for universities</td>
</tr>
<tr>
<td>9:45 – 10:10</td>
<td>F9</td>
<td>János Füzi</td>
<td>Compact equipment for neutron source imaging</td>
</tr>
<tr>
<td>10:10 – 10:35</td>
<td>F10</td>
<td>Jianlin Ke</td>
<td>Conceptual design of an accelerator-driven 10-14MeV neutron source</td>
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<td>10:35 – 11:10</td>
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<td>Coffee Break</td>
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## Session 7: Other applications of CANS

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<th>Presenter</th>
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<tbody>
<tr>
<td>11:10 – 11:35</td>
<td>H1</td>
<td>Gentaro Funatsu</td>
<td>Progress in the ITU-T’s standardization of Soft Error Test of network equipment using Compact Accelerator-driven Neutron Sources</td>
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<tr>
<td>11:35 – 12:00</td>
<td>H2</td>
<td>Hidenori Iwashita</td>
<td>Radioactivation characteristics evaluation of electronic equipment in soft error test using accelerator-driven neutron sources</td>
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<tr>
<td>12:00 – 12:25</td>
<td>H3</td>
<td>Hiroki Mori</td>
<td>Evaluation of Acceleration Factor in a Soft Error Test Using 18MeV Proton Accelerator Facility</td>
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<td>12:30 – 13:55</td>
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<td>Lunch</td>
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## Session 8: Education / Neutron detection

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<tr>
<td>14:00 – 14:25</td>
<td>L1</td>
<td>Hirohiko M. Shimizu</td>
<td>An Effort to Improve the Terminology for Neutron Beam Users</td>
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<td>14:25 – 14:50</td>
<td>E4</td>
<td>Roberto Mayer</td>
<td>Neutron Counting Absolute Method</td>
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<tr>
<td>14:50 – 15:15</td>
<td>E5</td>
<td>Shakir Zeinalov</td>
<td>Twin ionization chamber with position sensitivity for neutron induced fission investigations</td>
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<tr>
<td>15:15 – 15:40</td>
<td>E6</td>
<td>Ivan Sidelnik</td>
<td>Neutron detection capabilities of Water Cherenkov Detectors</td>
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<td>15:40 – 16:05</td>
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<td>16:10 – 18:30</td>
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<td>Coffee Break + POSTER SESSION</td>
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<td>18:30 – 20:30</td>
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<td>Executive Committee Meeting</td>
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**Thursday, March 15, 2018**

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<td>Round Table</td>
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<td>10:30 – 11:00</td>
<td>Closing Session</td>
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<td>POSTERS</td>
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<tr>
<td>B2</td>
<td>Development and test of the compact neutron source target at KAERI</td>
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<tr>
<td>D3</td>
<td>A test experiment of a focusing SANS instrument with an ellipsoidal Neutron supermirror designed for RIKEN Accelerator based Neutron Source</td>
</tr>
<tr>
<td>D4</td>
<td>Mass Production of Supermirror Segments for Fully-revolved Ellipsoidal Neutron-focusing Mirror Assembly</td>
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<tr>
<td>E7</td>
<td>Thermal neutron detector based on COTS CMOS imagers and a conversion layer containing Gadolinium</td>
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<tr>
<td>E8</td>
<td>Luminescent and scintillating properties of lanthanum fluoride nanocrystals in response to gamma/neutron irradiation: codoping with Ce activator, Yb wavelength shifter, and Gd neutron captor</td>
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<tr>
<td>F11</td>
<td>Progress of Neutron Sources and Opportunities for CANSs in China</td>
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<td>G2</td>
<td>Measurements of total cross sections using the VESUVIO Spectrometer</td>
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<tr>
<td>G3</td>
<td>Design, manufacturing and testing of the passively cooled Irradiation module of ESS</td>
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<tr>
<td>L2</td>
<td>EDUCATION at a CANS</td>
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<tr>
<td>I2</td>
<td>Contribution of Centro Atómico Bariloche to the thermal scattering libraries in ENDF/B-VII.0 and JEFF 3.3</td>
</tr>
<tr>
<td>I3</td>
<td>Evaluated Thermal Neutron Scattering Cross Sections for Liquid Hydrogen and Deuterium with Application to Neutron Sources</td>
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Abstracts
A1 - IPHI, a high intensity proton accelerator for neutron production by Nicolas Chauvin | nicolas.chauvin@cea.fr

Event: UCANS-VII
Topic: Accelerators and beam optics

N. Chauvin (on behalf of the IPHI team), F. Iguaz-Gutierrez, C. Lahonde-Hamdoum, A. Letourneau, A. Marchix, T. Papaevangelou, L. Segui, H. Tran, G. Tsiledakis
CEA, IRFU, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France.

J. Darpentigny, A. Menelle, F. Ott
CEA, LLB, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France.

Over the last years, CEA-Saclay has been strongly involved in R&D activities dedicated to accelerated high intensity proton and deuteron beams.
In particular, the high power proton injector IPHI has been conceived, developed and build with the ultimate goal of accelerating a 100–mA continuous beam to 3–MeV. This machine is composed by a high intensity ECR ion source, a low energy beam line, a 352–MHz Radio-Frequency Quadrupole and a medium energy transport line equipped with diagnostics.

In 2016, the IPHI facility has been successfully commissioned with a low duty cycle (around 0.1 %) proton beam of 80–mA. After a technical shut-down, IPHI was restarted by the end of 2017. In January 2018, an experiment has been performed to determine various particle yields resulting from the bombardment of a Beryllium target with the 3–MeV protons beam accelerated by IPHI.

In this paper, the complete IPHI facility will be described and the current performances will be exposed and discussed. The setup of our recent experiment will also be presented. The fast neutrons yield and its angular dependence was determined as well as the gamma rays yield. The various sources of background noise on time-of-flight $^3$He detectors was also measured to assess the shielding requirements for future neutron scattering spectrometers. The measured data are compared with Monte Carlo simulations of the experimental setup using Geant4 and MCNP.
The IREN facility is an intense resonance neutron source developed for fundamental and applied investigations in neutron nuclear physics by means of high resolution neutron spectroscopy methods in a neutron energy range from eV to tenth of keV. The IREN is based on an electron linear accelerator (LUE-200) with an S-band traveling wave accelerating structure. A massive target made of a material with a high atomic number (tungsten or natural uranium) serves as a nonmultiplying neutron producing target. The electron beam produced by the LUE-200 linear electron accelerator hits the target and undergoes there a conversion into neutrons (e-gamma-n reaction).

Current state of the IREN facility as well as the experimental program will be presented.
A3 - Present Status of Nagoya University Accelerator Driven Neutron Source, NUANS  
by Yoshiaki Kiyanagi | kiynagi@phi.hys.nagoya-u.ac.jp

Yoshiaki Kiyanagi, Kazuki Tsuchida, Daiki Furuzawa, Kazuya Sato, Atsushi Yamazaki, Sachiko Yoshihashi, Kenichi Watanabe, Akira Uritani, Yoshiyuki Tsuji, Tatsuya Tsuneyoshi  
Graduate School of Engineering, Nagoya University (Japan),  
Go Ichikawa, Yusuke Tsuchikawa, Katsuya Hirota, Ikuya Ito, Masaaki Kitaguchi, Hirohiko M. Shimizu  
Graduate School of Science, Nagoya University (Japan)

An accelerator driven neutron source is under construction at Nagoya University. There are two beam lines. The first beam line is used for the primary aim, namely, engineering feasibility study of a boron neutron capture therapy (BNCT) system. At the second beam line, physics and engineering applications are performed.

An electrostatic proton accelerator with 2.8MeV and 15 mA was installed. The first beam line was constructed and a proton beam of about 2 mA was transported successfully. We use Be targets at the second beam line and also at the first beam line at beginning. They were already manufactured. A Li target is used to obtain full neutron intensity at the first beam line. It is a shield type compact target with emboss structure. It was indicated that the cooling power with the use of a mechanism to enhance turbulent flow was enough at the full power operation. A filling system of Li is under testing. A beam shaping assembly (BSA) with a nozzle for BNCT has been designed. The BSA will make a patient setting easier and a patient more comfortable during irradiation. Designed performance fulfilled the IAEA recommendation.

We already got a license to produce the neutrons. However, to perform the neutron experiments, we are now constructing a shield room to set up the BSA. After completion of the room, we set up the first beam line completely and construct the second beam line.  
In the presentation, outline of NUANS, accelerator status, target development, BSA design are explained.
B1 - Mechanical stability of a target for a compact accelerator based neutron source

by Paul Zakalek | p.zakalek@fz-juelich.de

Event: UCANS-VII
Topic: Target radiation damage and heat removal

JCNS-2, Forschungszentrum Jülich GmbH, 52428 Jülich, Germany

T. Gutberlet
JCNS at MLZ, Forschungszentrum Jülich GmbH, Lichtenbergstr. 1, 85748 Garching, Germany

Recent developments indicate that compact accelerator based neutron sources (CANS) are becoming more important as can be seen in developing projects like Jülich project HBS and the Saclay project SONATE. At such a source, neutrons are produced by protons or deuterons at an energy level of a few 10 MeV impinging on a target of a low Z-material. The neutron yield depends strongly on the target performance which directly depends on the cross sections involved and the power deposited. At a CANS optimized for high brilliance, the power is deposited in a small volume and the mechanical stability of the target is a limiting factor.

Mainly three effects need to be addressed: First, the temperature rise throughout the target due to the heat deposition density for which the cooling has to be adjusted accordingly. Second, static stress affecting the target because of the pressure difference between the accelerator vacuum and cooling fluid pressure. Third, additional stress induced by the temperature gradient. All these effects show specific dependencies on fundamental target parameters like target thickness, diameter, deposited power and pressure difference.

At the UCANS VII we will present the target concept for a compact accelerator based neutron source aimed for a power level of 1 kW. We will show the parametric study of the mechanical stability including the temperature rise and the induced stress and derive the mentioned dependencies. From these derived dependencies, we will extrapolate the mechanical parameters for a target working at a higher power.
B2 - Development and test of the compact neutron source target at KAERI by Dong Won LEE

dwlee@kaeri.re.kr

Event: UCANS-VII

Topic: Target radiation damage and heat removal

Dong Won LEE, Sun-Ho KIM, Bongki JUNG, Doo-Hee CHANG, Hyung Gon JIN, Seok Kwan LEE, Suk-Kwon KIM, and Chang Wook SHIN

Korea Atomic Energy Research Institute (KAERI)

We have developed the compact D-D neutron sources with ion beams for the various application such as radiotracing isotope production, radiography, and so on, in which the various targets were considered in parallel. Among them, solid target with water coolant was designed and fabricated, and it was tested under the high heat flux test with KoHLT-EB (Korean Heat Load Test facility with Electron Beam) at KAERI (Korea Atomic Energy Research Institute) before assembling with the ion beam for investigate its integrity under the heating condition. Test conditions were prepared with the preliminary analysis and compared with the test results. From this results, the design was optimized and optimized target design was proposed.
C1 - Engineering studies on second generation of ESS low dimensional cold moderator for full power operation by Y. Beßler |
y.bessler@fz-juelich.de

Event: UCANS-VII
Topic: Moderator neutronics

Y. Beßler, M. Butzek, F. Hanusch, G. Natour
Forschungszentrum Juelich GmbH, Juelich, Germany
M. Kickulies, D. Lyngh, L. Zanini
European Spallation Source ERIC, Lund, Sweden

Studies have shown that low-dimensional moderators can improve the neutron brightness by more than a factor of two, compared to the common volume moderators. ESS will therefore be equipped with such a moderator. Due to ramp up of the accelerator the first generation will operate under partial load of less than 1 MW proton beam power, with the so-called butterfly-2 moderator (BF2), consisting of two separate aluminum vessel filled with liquid hydrogen. Further parametric studies have shown that geometrical optimizations can lead to an additional gain of cold brightness of up to 30% for several beamlines, which resulted in the butterfly-1 (BF1) moderator (single vessel) neutronic design. Therefore, the BF1 cold moderator should be used in the second generation of ESS. The following paper will cover the verification of the technical feasibility of the optimized neutronic design. The transient fluid dynamic simulations will be in the focus of this work. Based on the existing requirements, a theoretical maximum allowable beam power will be estimated. Local boiling phenomena and pressure waves by pulsed heat will be analyzed as well.
C2 - Determination of the para-hydrogen concentration in the ISIS moderators by Goran Skoro

Skoro | goran.skoro@stfc.ac.uk

Event: UCANS-VII
Topic: Moderator neutronics

Goran Škoro, Giovanni Romanelli, Svenir Rudić, Robert Bewley, Steven Lilley, John Webster, Felix Fernandez-Alonso,
Maciej Krzystalniak, David Haynes and David Jenkins
ISIS Neutron and Muon Source, STFC, RAL (United Kingdom)

A reliable estimate of the level of para-hydrogen concentration in the hydrogen moderators is of crucial importance for the current projects at ISIS Neutron and Muon Source: complete refurbishment of the first target station (TS-1) and modification/upgrade of the hydrogen moderator at the second target station (TS-2).

We will present an overview of a number of different studies performed in an attempt to characterize para/ortho hydrogen fractions in TS-1 liquid hydrogen moderator: using the data from LOQ (one of the instruments served by TS-1 hydrogen moderator) incident beam monitor collected over last 10 years; using the diffraction setup added to CRISP instrument to measure pulse widths as a function of wavelength over a cycle; comparing the shape of the experimental time-of-flight data from the OSIRIS instrument with corresponding simulation results and even performing hydrogen-grab tests at Oxford University (Ritchie group) using Cavity Ring-Down Spectroscopy.

As a conclusion, the results of most recent experimental characterisation of hydrogen samples from TS-1 and TS-2 moderators will be summarized. This new approach is based on the direct measurement of neutrons transmission through thin hydrogen samples (with different para-hydrogen fractions) using VESUVIO instrument at ISIS, combined with measurements of thermal conductivity of the (same) hydrogen samples using para-hydrogen gauge (and a para-hydrogen generating cell) specifically built for use on ISIS beam-lines.
C3 - Development of cold neutron source using methyl-benzene derivatives for compact neutron source by Yutaka Yamagata |
yamagata@riken.jp

Yutaka Yamagata, Shin Takeda, Takuya Hosobata, Toshihide Kawai
RIKEN Center for Advanced Photonics RIKEN(Japan)
Masahiro Hino, Yutaka Abe,
Kyoto University (Japan)
Hirota Katsuya, Hirohiko M. Shimizu,
Nagoya University (Japan)
Yasuo Wakabayashi, Tomohiro Kobayashi, Atsushi Taketani, Yoshie Otake
RIKEN Center for Advanced Photonics, RIKEN (Japan)

A cold neutron source is being developed for the realization of safe and easy-to-use compact accelerator-driven neutron sources using methyl-benzene derivatives. It uses closed-cycle helium cryo cooler and closed methyl-benzen cold moderators. It is free from explosive gases and requires small maintenance operation. A monte-carlo simulation using PHITS code with scattering kernel of mesitylene was conducted. The performance estimation, pre-moderator and moderator dimension optimization, radiation shielding evaluation and pulse characteristics of coupled, decoupled and poisoned moderator was conducted. Based on those simulations, the cold source was attached to RIKEN compact accelerator-driven neutron source (RANS) and its performance was tested experimentarily. The comparison and discussion with experimental results are made.
D1 - Magnified neutron imaging using refractive optics by Yoshihisa Iwashita |
iwashita@kyticr.kuicr.kyoto-u.ac.jp

Event: UCANS-VII
Topic: Optical devices

Y. Iwashita¹, R. Katayama¹, Y. Fuwa², T. Ishida³ and K. Kino⁴
¹ Institute for Chemical Research, Uji, Kyoto University, Japan.
² Kyoto University Research Reactor, Kumatori, Kyoto University, Japan.
³ Hokkaido University, Sapporo, Japan
⁴ National Institute of Advanced Industrial Science and Technology, Japan

The modulating sextupole magnetic lens is a powerful device for making use of precious neutrons generated with a compact neutron sources. It can focus wide wavelength range of neutrons in pulsed neutron beams. The focusing is realized by modulating the focusing strength synchronized with their TOF information. The refraction lens has no material that may scatter neutrons in the bore and the straightforward optical axis eases its mechanical alignment compared with the mirror devices, whose angle error of the downstream axis is twice as much as the angle alignment error. The simple focusing principle of the refraction lens is suitable for the neutron imaging with neutrons. A series of trial imaging experiments is under going at HUNS at Hokkaido Univ. The status will be presented.
D2 - The Portable Neutron Imaging Facility and its Experiment Study based on D-T Neutron Source of Compact Accelerator by Sheng Wang | mritn5851@gmail.com

Sheng Wang, Wei Yin, Bin Liu, Hang Li, Yong Sun, Chao Cao, Yang Wu, Heyong Huo, ShiLei Zhu, Benchao Lou, Chunlei Wu, Bin Tang
Institute of Nuclear Physics and Chemistry, Chinese Academy of Engineering Physics (CAEP), China

The neutron imaging team at INPC of CAEP constructed portable multi-use neutron imaging facility based on of D-T neutron source compact accelerator. The facility includes fast neutron imaging module and thermal neutron imaging module, and off-line detection method based on NIP or film, on-line detection method based on scintillator screen cooperated with CCD camera could be chosen. The neutron imaging facility is composed of portable compact accelerator of D-T neutron source, moderator of tungsten –steel-polyethylene, carrying system and detection system. The accelerator composed of high frequency ion resource of deuterium, eliciting and focusing department, accelerate tube, high voltage power of 280KV and neutron target of tritium. The highest neutron flux intensity is $1.7 \times 10^{11}$/s.

The thermal neutron imaging module has been applied on detection of residual material in the nickel alloy blade and detonator of aviation application. We carried out fast and thermal neutron radiography and thermal neutron tomography based on this facility. The highest fast neutron radiography resolution is 0.5mm with CCD system (0.3mm with film system), and the highest thermal neutron radiography is 0.06mm with CCD system (0.05mm with film system). Especially, we carried out neutron tomography experiment at this facility, and the object is made of aluminum, polyethylene and gadolinium. With collected 181 images of rotation from 0º to 360º, the reconstructed results show that this facility could be used for thermal neutron tomography and multi-material objects could be reconstructed clearly(smallest line of gadolinium 0.2mm was reconstructed clearly).
D3 - A test experiment of a focusing SANS instrument with an ellipsoidal neutron supermirror designed for RIKEN Accelerator based Neutron Source by Shin Takeda

| s-takeda@riken.jp

S. Takeda, T. Hosobata, Y. Yamagata
RIKEN (Japan)

M. Hino
Kyoto University Research Reactor Institute (Japan)

T. Ishida, J. Yamada, M. Furusaka, M. Ohnuma
Hokkaido University

Small angle neutron scattering (SANS) is a very popular method among various material research fields and a SANS instrument would be a fine application at compact accelerator driven neutron sources (CANS), which numbers of facilities are increasing. A compact SANS instrument with focusing optics is a good candidate for such instruments at CANS. The combination of SANS and focusing optics have been discussed by Glinka et al [1] which conclude the benefit of such a combination is a much more compact layout for low-q measurements. A compact experimental layout also allows a higher-repetition rate at pulsed neutron sources and wide Q-range measurements.

However, for low-q measurements the optics discussed in the paper view only a small area of the cold neutron source, leaving a large portion of the emitted neutrons unused. For more efficient use, the moderator can be modified to a more optimal shape, such as the low dimensional moderator proposed by Mezei et al [2] or the grooved shaped moderator proposed by Kiyanagi [3].

At RIKEN, we are developing a mirror-based focusing SANS instrument and cold neutron source designed for RANS, a compact neutron source at RIKEN. A test experiment for the mirror performance was operated at Hokkaido University Neutron Source (HUNS) using a supermirror with an ellipsoidal figure. The mirror substrate was manufactured at RIKEN by applying a technique which uses metallic material as the substrate and the supermirror coating process was operated at Kyoto University Research Reactor Institute using an ion sputtering instrument. A minimum q-range of 3.0×10-2 nm-1 was obtained with a 2.5 m long experimental layout. The mirror performance was reasonable and is expected to be feasible
for focusing SANS use.

Neutron-focusing optics can greatly enhance the capability of compact accelerator-driven neutron sources, as the focusing of neutrons onto samples or detectors enables efficient utilization of the limited neutron flux. In this presentation, we report on our ongoing development for an assembly of neutron-focusing supermirrors, whose surface is a fully-revolved ellipsoid.

The neutron-focusing mirror assembly under development is composed of 54 supermirrors deposited on segments with partial ellipsoidal surfaces. The supermirror as a whole is 900 mm in length when assembled on a unique cage-like structure. Such large assembly is realized by the fabrication technique established in our previous works, using metal substrates with nickel-phosphorous electroless plating [1,2]. The metal substrates provide great design freedom with good machinability while the platings assure form accuracy and surface smoothness. Mass production of the segments are in progress in divisional cooperation; pre-forming of ellipsoidal surfaces and supermirror deposition are done at KURRI, and precise form adjustment and polishing of substrates are done at RIKEN. After struggling on prototypes, ellipsoidal substrates with roughness of approximately 0.2~nm in root mean square are constantly being produced, to which deposition of supermirrors up to $m=5$ has been accomplished.

Although the current optical design of this supermirror assembly is optimized for a neutron resonance spin echo spectrometer (VIN ROSE at BL06 in J-PARC/MLF), the mechanical design concept is applicable to the supermirrors for compact sources, not only as focusing devices but also as neutron guides. Considering that the accessibility to the moderator is one of the advantage of compact sources, such supermirrors may be used near the moderator for beam shaping. We trust that the design concept of our supermirror assembly provides a
variety of choices in the design of beamlines at compact neutron sources.

E1 - The progress of a honeycomb neutron convertor based neutron detector

by Yigang Yang | yangyigang@mail.tsinghua.edu.cn

Yigang Yang
Tsinghua University

A newly designed neutron detector is developed in Tsinghua in order to replace the $^3$He counter. The honeycomb neutron convertor is used to absorb thermal neutrons and produce electron-ion pairs in the working gas filled in holes of the honeycomb structure. An electrical field is applied to drive the electrons outside that are in turn multiplied by a GEM (gas electron multiplier) detector. The WSA (wedge and stripe anode) electrode is placed behind the GEM to collect the electron cloud induced by each incident neutron. The temporal and spatial information of the incident neutrons can thus be acquired by analyzing the different fractions of electrons collected by the W, S and Z sub-electrodes of the WSA electrodes, respectively. This detector has been tested with the neutron beam delivered by a 7MV photoneutron source at Tsinghua University and a 45 MV photoneutron source at Hokkaido University, respectively, demonstrating that a 6 mm spatial resolution can be realized. This detector also showed an anisotropy of neutron sensitivity, which can help suppress the detection of spurious neutrons that produce the unwanted background events in the neutron scattering. The principle and experimental evaluation of this detector will be presented in detail in this paper.
E2 - Detecting neutrons with a MICROMEGAS detector by Seung-Woo HONG | swhong@skku.ac.kr

Seung-Woo HONG
Department of Physics, Sungkyunkwan University, Suwon 440-746, Republic of Korea

A MICROMEGAS detector is a gaseous particle detector that can detect charged and neutral particles. In the past, we used our MICROMEGAS to detect α particles and calibrated the detector by changing the energy of α particles.

Recently, we used our MICROMEGAS to detect thermal neutrons generated by the MC-50 Cyclotron of the Korea Institute of Radiological Medical Sciences (KIRAMS). Neutrons are produced by bombarding a 1.05cm thick beryllium target with protons from the MC-50 cyclotron. A continuous energy spectrum of neutrons is produced. We used as a converter in our MICROMEGAS detector a thin film of 10B deposited on the cathode of the detector. α and 7Li produced by the 10B (n,α) 7Li reaction can be detected by our MICROMEGAS. Monte Carlo simulations are performed to compare the experimental results with the simulation results. Two distinct peaks are detected in the experiments and are identified as peaks produced by α and 7Li. The calibration of the energy spectrum and the estimation of the detection efficiency can be done by comparing the experimental results with the simulation results.
E3 - Measurement of the energy dependence of the neutron counters sensitivity at the neutron beams of the electrostatic generator by Shvetsov V.N. | shv@nf.jinr.ru

Shvetsov V.N., Krylov A.R., Pikelner L.B., Kobzev A.P., Timoshenko G.N.
Joint Institute for Nuclear Research (Russia)
Mitrofanov I.G.
Russian Space Research Institute (Russia)
The sensitivity of the neutron ³He-counter within the polyethylene moderator was tested in energy range 0.2 - 1.0 MeV with the neutron beam of electrostatic generator. For the monoenergetic neutron production the p + ⁷Li = n + ⁷Be reaction was used. The high-pressure ³He-filled reference counter was applied for the neutron beam spectrometry and for the neutron flux measuring. The technique of the experiment and the data processing are described. The good agreement between the experimental and calculated results is obtained. Monoenergetic neutrons were used for calibration of the High Energies Neutrons Detector (HEND) - one from the set of scientific instruments, installed on board of Mars Odyssey spacecraft.
E4 - Neutron Counting Absolute Method

R.E. Mayer | mayer@cab.cnea.gov.ar

R.E. Mayer, I.J. Rios
Centro Atómico Bariloche, Comisión Nacional de Energía Atómica, Argentina

The absolute counting of neutrons at energies where detectors are partially transparent to the incident beam, usually leads to the numerical evaluation of detector efficiency or resort to comparison with standards. A new method may, in many cases, allow to avoid this step through application of the “Influence Method” recently developed.

This method exploits the influence of the presence of one detector in the count rate of another detector, when they are placed one behind the other. It is conceived for the absolute determination of a nuclear particle flux in the absence of known detector efficiency and without the need to register coincidences of any kind. The method defines statistical estimators for the absolute number of incident particles and for the efficiency. It also provides expressions for the uncertainty of the statistically correlated variables thus defined.

The philosophy of the method is to deal with a problem with a number k of unknowns, through the employment of k detectors (whenever possible), placed in such a way that their successive influences yield correlated measurements. Thus, for some needs, its expressions were extended for that arbitrary number k.

For time-of-flight determinations the method is particularly useful, given the fact that the efficiency measured for each of the approximately monoenergetic time bins is a particular constant for each of them. The latter is nevertheless not the most usual case. Where the beam entails a whole energy spectrum, the method provides a weighted mean efficiency. Nevertheless, the efficiency is not needed because there is always an expression for the absolute number of neutrons in the beam.

The method has also found application for the experimental assessment of the “space charge effect”, which diminishes gas multiplication in proportional counters undergoing irradiation by intense radiation bursts. Under those conditions, individual neutrons are not distinguished and, instead, the whole piled up electric charge is registered. The more intense the radiation burst, the more intense the accumulated positive ions charge accumulated in the counter and more shielded the electric field will appear, with the ensuing diminution of the “gas multiplication”. 
E5 - Twin ionization chamber with position sensitivity for neutron induced fission investigations by Shakir Zeinalov | zeinal@nf.jinr.ru

Shakir Zeinalov, Pavel Sedyshev, Olga Sidorova, Valery Shvetsov
Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Joliot-Curie 6, Dubna, Moscow region 141980, Russian Federation
Leonid Svetov
Dubna International University of Nature, Society and Man, Dubna, Moscow region 141980, Russian Federation

In this work we report the recent achievements in design of twin back-to-back ionization chamber (TIC) for fission fragment (FF) mass, kinetic energy and FF orientation. Correlated FF kinetic energies, their masses and the angle of the fission axes in 3D Cartesian coordinates can be determined from analysis of the heights and shapes of the pulses induced by the fission fragments on the anodes of TIC. Anodes of TIC were designed as consisting of isolated Δ-shaped strips connected to nodes of the chain filter, made of serially connected two-port networks. Double charge division method was implemented by digitizing four waveforms at the endpoints of the chain filters. It was shown how the fission fragments emission point on the target plane may be determined using the measured data. Position sensitive neutron induced fission detector for neutron imaging applications with both thermal and low energy neutrons was found as another possible implementation of the designed TIC. Preliminary measurements with the thermal neutron induced fission were done with RC chain filters and the results were demonstrated.
E6 - Neutron detection capabilities of Water Cherenkov Detectors by Ivan Sidelnik

sidelnik@cnea.gov.ar

Event: UCANS-VII
Topic: Neutron detection

Ivan Sidelnik\textsuperscript{2,3}, H. Asorey\textsuperscript{1,2,3}, N. Guarin\textsuperscript{3}, F. Alcalde\textsuperscript{2,3}, L. H. Arnaldi\textsuperscript{1,3}, J. Lipovetzky\textsuperscript{1,2,3}, M. Pérez\textsuperscript{1,3}, M. Sofo Haro\textsuperscript{2,3}, M. Gómez Berisso\textsuperscript{2,3}, J.J. Blostein\textsuperscript{2,3}

\textsuperscript{1} Comisión Nacional de Energía Atómica (CNEA), Argentina
\textsuperscript{2} Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina
\textsuperscript{3} Instituto Balseiro, Univeridad Nacional de Cuyo

In this work we show the neutron detection capabilities of a water Cherenkov detector (WCD). This type of detector is used in different big observatories, such as The Pierre Auger Observatory in Argentina, and the Latin American Giant Observatory (LAGO) across the Andes, for the study of cosmic rays in a very wide energy range.

The experiments presented here were performed by using a single and simple, one PMT, WCD and $^{241}$\textsuperscript{241}AmBe and $^{253}$Cf neutron sources, using only pure water without additives as the detection volume. Different neutron moderators and shielding configurations and distances have been explored. We show that fast neutrons from the $^{241}$\textsuperscript{241}AmBe and $^{253}$Cf sources, as well as thermal neutrons coming from a neutron moderator and exhibiting different spectral characteristics, can be detected and identified over the flux of atmospheric particles background. The characteristic pulse-height histogram shapes are recorded as a clear signature of neutrons with energies lower than $\approx$ 11 MeV, which is the maximum neutron energy experimentally available with the sources we used. This was verified for different experimental conditions and even with detailed simulations based on Geant4, that corroborate neutron detection capabilities in the energy range from meV to GeV, depending only on the geometry of the active detection volume. Using a 1-ton detector, we estimate from our measurements a neutron detection efficiency at the level of $10 \pm 5$.

Being the active volume a cheap and easily accessible material, the results obtained in this work are of great interest for the development of large neutron detectors for different applications, at a small fraction of the cost of current technologies. Of special importance are those related with space weather phenomena as well as those for the detection of fissionable or fusionable special nuclear materials.
E7 - Thermal neutron detector based on COTS CMOS imagers and a conversion layer containing Gadolinium by Martín Pérez | ing.perezmartin@gmail.com

Event: UCANS-VII
Topic: Neutron detection

Martín Pérez, Jerónimo Blostein, Fabricio Alcalde Bessia, Aureliano Tartaglione, Iván Sidelnik, Miguel Sofo Haro, Sergio Suárez, Melisa Lucía Gimenez, Mariano Gómez Berisso, José Lipovezky
Comisión Nacional de Energía Atómica (Argentina)
Consejo Nacional de Investigaciones Científicas y Técnicas (Argentina)

In this work we will introduce a novel low cost position sensitive thermal neutron detection technique, based on a Commercial Off The Shelf CMOS image sensor covered with a Gadolinium containing conversion layer. The feasibility of the neutron detection technique implemented in this work has been experimentally demonstrated. A thermal neutron detection efficiency of 11.3% has been experimentally obtained with a conversion layer of 11.6 micrometers. It was experimentally verified that the thermal neutron detection efficiency of this technique is independent on the intensity of the incident thermal neutron flux, which was confirmed for conversion layers of different thicknesses. Based on the experimental results, a spatial resolution better than 25 micrometers is expected. This spatial resolution makes the proposed technique specially useful for neutron beam characterization, neutron beam dosimetry, high resolution neutron imaging, and several neutron scattering techniques.
E8 - Luminescent and scintillating properties of lanthanum fluoride nanocrystals in response to gamma/neutron irradiation: codoping with Ce activator, Yb wavelength shifter, and Gd neutron captor by Iván Sidelnik | sidelnik@cnea.gov.ar

I. Sidelnik 1,2, J.M. Vargas 1, L.A. Rodríguez Palomino 1, D. Rondón Brito 3, R.E. Mayer 2,4 and J.J. Blostein 1,2

1 Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Centro Atómico Bariloche, Av. Bustillo 9500, 8400, S. C. de Bariloche, Rio Negro, Argentina
2 Instituto Balseiro, Centro Atómico Bariloche, Universidad Nacional de Cuyo, Av. Bustillo 9500, 8400, S. C. de Bariloche, Rio Negro, Argentina
3 Instituto Venezolano de Investigaciones Científicas (IVIC), 1020, Altos de Pipe, Miranda, Venezuela
4 Comisión Nacional de Energía Atómica, Centro Atómico Bariloche, Av. Bustillo 9500, 8400, S. C. de Bariloche, Rio Negro, Argentina

A novel concept for gamma radiation detection and spectroscopy, and detection of thermal neutrons based on co-doped lanthanum fluoride nanocrystals containing gadolinium is presented. The trends of colloidal synthesis of the mentioned material, LaF₃ co-doped with Ce³⁺ as the activator, Yb³⁺ as the wavelength-shifter and Gd³⁺ as the neutron captor, is reported. Nanocrystals of the mentioned material were characterized by transmission electron microscopy, X ray diffraction, energy dispersive X ray spectroscopy, optical absorption, and photoluminescence spectroscopy. Gamma detection and its potential spectroscopy feature have been confirmed. The neutron detection capability has been confirmed by experiments performed using a ²⁵²Cf neutron source.
F1 - Update on SONATE, the French Compact Neutron Source Project by Christiane Alba-Simionesco | christiane.alba-simionesco@cea.fr

Event: UCANS-VII
Topic: CANS Projects and Innovative instrumentation

Christiane Alba-Simionesco
CEA, France

In order to prepare a future coherent landscape of neutron sources around the ESS flagship, various European countries are currently working hard on the design of low energy, accelerator based neutron sources of powers of the order of a few kW. In France the LLB is leading a project called SONATE. It aims at building a full scale neutron scattering infrastructure for Material Sciences with up to 10 spectrometers at the horizon 2025-2030; the performances are expected close to the current LLB spectrometers around the Orphée reactor to allow the current very large user community to pursue their research activities. The working plan to get this source and the instrumental program are presented, as well as the results of recent tests on various targets performed on the IPHI accelerator at Saclay with our colleagues from CEA/IRFU.

Figure: Current artist view of the Sonate project at the horizon 2025.
The Low Energy Neutron Source at Indiana University has been running since late in 2004 and has had an impact on the International Neutron Sciences community in a variety of areas over that time. This has ranged from the significant number of students who have complete PhD’s associated with the facility, the interest it has helped spark in CANS facilities in general, and the innovations in moderator and instrument design that have been developed at LENS. Over the last few years, we have undergone significant changes to the control systems at LENS (both for the accelerator and on the instrumentation side) from legacy systems to ones controlled by EPICS. I will review some of these updates, with an emphasis on what lessons our experience may provide for other facilities, and I will report on our most recent experiments with moderator spectra and the physics that can be accessed using the Magnetic Wollaston Prisms developed at LENS.
F3 - Upgrade of Hokkaido University neutron source (HUNS) by Michihiro Furusaka

michifurusaka@icloud.com

Event: UCANS-VII
Topic: CANS Projects and Innovative instrumentation

Michihiro Furusaka
Faculty of Engineering, Hokkaido University

The electron linac driven neutron source at Hokkaido University (HUNS) had been running for more than 40 years since 1974. In late October this year, we shutdown the accelerator and already removed the old accelerator. Our new linac is being installed at the same place where the old linac was sitting.

The accelerator used to deliver about 1.2 kW of beam power at 34 MeV and 50 Hz. It will be upgraded to 3 kW with 35 MeV of energy at 100 Hz. It will have two accelerator tubes of 3 m each, each driven by 7.5 MW klystrons. It has a 3 MeV injector that has an electron source, pre-buncher, buncher, followed by accelerator cavities. It is sharing 2.5 MW of RF power out of the 7.5 MW power with the first accelerator tube.

The beam transport section and the two target systems remain the same as before. One is a coupled cold mesitylene neutron source and a decoupled polyethylene thermal source.

HUNS has also been used routinely now for research, such as, small-angle neutron scattering experiment for nanoscopic structure characterization and Bragg-edge transmission experiments characterizing Battery materials.
F4 - The industrial CANS project LvB at Martonvásár, Hungary by Ferenc Mezei | ferenc.mezei@esss.se

Event: UCANS-VII
Topic: CANS Projects and Innovative instrumentation

Ferenc Mezei

European Spallation Source ESS, POB. 176, 22100 Lund, Sweden
MIRROTRON Ltd, Brunszvik u 2, 2462 Martonvásár, Hungary

The construction of a compact neutron source for commercial use has started in Nov. 2017 in the town of Martonvásár, 35 km West of Budapest by an industrial consortium led by Mirrotron Ltd. The other members of the consortium are the Energy Research Center of the Hungarian Academy of Sciences and evopro Innovation Ltd. The project’s application for Hungarian government regional industrial development funds has been awarded for 75% of the costs of the neutron source (premises, accelerator and target station). This CANS will consist of a linear proton accelerator producing > 2.5 MeV energy, 20 mA current proton beams, initially in 1 - 2 ms long pulses and in CW mode in longer term. On the one hand, fast neutrons produced in the target by the proton beam will be extracted in a flexible cross section not moderated beam in the forward direction with respect to the proton beam. On the other hand, a thermal - cold bi-spectral low dimensional “tube” moderator will produce several moderated beams in roughly perpendicular directions to the proton beam. Adjacent water and liquid para-hydrogen moderators will compose the bi-spectral moderator in the middle of an efficient reflector inside the shielded target station. The first applications implemented as separate projects run by various investors will include test of reflectivity of neutron mirrors, neutron radiography and powder diffraction. On longer term it is envisaged to develop CW operational capability for providing adequate neutron beams for healthcare use of neutron irradiation.
F5 - LAHN: The Argentinean Neutron Beams Laboratory Project  
by Javier Santisteban |  
J.R.Santisteban@cab.cnea.gov.ar

Event: UCANS-VII  
Topic: CANS Projects and Innovative instrumentation

Javier Santisteban, Karina Pierpauli, Gabriela Aurelio, Florencia Cantargi, Miguel Vicente Alvarez, Aureliano Tartaglione

Comisión Nacional de Energía Atómica

The RA-10 is a 30 MW multi-purpose reactor under construction in Ezeiza, Buenos Aires, designed to satisfy national and regional demand for radioisotopes, nuclear materials testing and neutron beams research. The reactor will start operations on 2021, it will have a liquid deuterium cold source and a large guide hall for instruments. Since 2016 the National Atomic Energy Commission has started a project called "The Argentinean neutron beams laboratory for the RA-10 reactor" (LAHN); aimed at implementing state-of-the-art instruments, developing a user community and the laboratory sta. Two instruments are being designed for the rst stage of this laboratory: (i) a neutron imaging instrument on a cold beam; and (ii) a multi-purpose diractometer on a thermal beam, optimized for non-destructive studies on large objects. Both instruments will be placed on the reactor face, in order to exploit very intense, undisturbed, neutron beams. Besides this, an ambitious program has started to popularize neutron techniques in Argentina and create new users. A second phase for the project is being evaluated, taking into consideration the demands of the local and regional scientific community. In this work, the present state of the project is described, providing details of the instruments design and the strategies implemented to develop the Argentinean users community.
F6 - The SPES project at the INFN-Laboratori Nazionali di Legnaro by Pierfrancesco Mastinu | INFN-LNL

Event: UCANS-VII
Topic: CANS Projects and Innovative instrumentation

Pierfrancesco Mastinu
INFN- Laboratori Nazionali di Legnaro

SPES is a multi-disciplinary project focused on the development of an up-to-date ISOL facility for the production and reacceleration of exotic beams. The SPES project is in the construction phase at the Legnaro National Laboratory (LNL) of INFN.

SPES will provide a Radioactive Ion Beam facility for the study of neutron rich unstable nuclei of interest to nuclear and astro-nuclear physics. At the same time, it will host a laboratory for research and production of radioisotopes to be applied in nuclear medicine and a fast-neutron facility.

SPES is based on a dual exit high current Cyclotron, with proton beam energy 35-70 MeV and 0.2-0.5 mA on each exit. One of the two ports will drive an ISOL system with an UCx Direct Target able to sustain a power of 10 kW and to produce neutron rich ions at intensities one order of magnitude higher than existing facilities. The second proton beam port will be used for applied physics: radioisotope production for medicine and neutrons for material study.

The neutron facility will offer an atmospheric-like and quasi-monochromatic neutron beams, beyond of the straightforward proton beam. These beams will integrate the proton and heavy ions facilities presently operating at the LNL for radiation damage studies on semiconductor detectors and electronic devices.

The layout of SPES was designed in such a way to operate two targets at the same time distributing the beam according to a schedule that minimizes the radiation problems. The following target caves are under installation: two ISOL target caves, three caves for radioisotopes production and developments, a target area for cross section measurement and an area for neutron production and material study.

The status of the SPES project will be presented.
F7 - Neutronic performance of a beam line for imaging at the electron linac facility in Kyoto University Research Reactor Institute by Yoshiaki Kiyanagi | kiynagi@phi.hys.nagoya-u.ac.jp

Event: UCANS-VII
Topic: CANS Projects and Innovative instrumentation

Yoshiaki Kiyanagi, Akira Uritani, Kenichi Watanbe
Graduate School of Engineering, Nagoya University (Japan)

Yoshiyuki Takahashi, Tadafumi Sano, Junichi Hori, Ken Nakajima
Research Reactor Institute, Kyoto University (Japan)

A neutron beam line at the Kyoto University electron linac, KURRI-LINAC, has been updated for a project called N-DeMAIN (Development of Non-Destructive Methods Adapted for Integrity test of Next generation nuclear fuels). As a non-destructive method, neutron resonance transmission analysis is adopted for identification and quantification of nuclides in the fuels.

We redesigned a target-moderator-reflector system (TMRS) to suit for the imaging since it had been designed for nuclear data measurements. We first considered position of a moderator to obtain highest neutron intensity since the neutron beam line exists at an angle of 135° with respect to the electron beam line. We found that epithermal neutron intensity was much higher when the moderator was put near the target. However, it causes flight time difference of neutrons due to position dependent flight path of the moderator surface. Simulation results showed distortion of emission time distribution. However, the effect on a resonance peak was not so large. Simulations were performed to check performance of a collimator system. A measured neutron spectrum was almost the same as that of a simulation one. This indicates that the beam line was constructed as designed.

Here, we explain neutronic design studies and performance of the TMRS and the collimator system, and introduce some results of test experiments.

Acknowledgement
The authors thank Ms. Harada for her contribution to simulation calculations. Present study includes the result of “Development of Non-Destructive Methods Adapted for Integrity test of Next generation nuclear fuels” entrusted to the Kyoto University by MEXT Japan.
F8 - NOVA ERA - A compact neutron source for universities by Thomas Gutberlet | t.gutberlet@fz-juelich.de

Event: UCANS-VII
Topic: CANS Projects and Innovative instrumentation

Thomas Gutberlet
Forschungszentrum Jülich GmbH

Neutron scattering has proven to be one of the most powerful methods for the investigation of structure and dynamics of condensed matter on atomic length and time scales. A severe drawback in using neutrons is the limited possibilities to access neutrons offered via nuclear research reactors or accelerator driven spallation sources, which are costly to build and to operate. To offer neutrons more easily accessible for science, training and industrial use is a challenge. The concept of a compact accelerator based neutron source is a new approach to tackle this challenge with the aim to bring neutrons to the users on demand and cost effective.

Compact accelerator based neutron sources (CANS) produce neutrons by the nuclear reaction between a low energy proton beam and light elements as beryllium or lithium. Depending on the power of the accelerator and the number of target stations and instruments such a source can be equivalent to small and medium flux reactor or spallation based neutron sources. With the aim to design CANS to be operated at universities, research institutes or industry laboratories a conceptual design report has been developed at JCNS for a small neutron source named NOVA ERA (Neutrons Obtained Via Accelerator for Education and Research Activities). Such a neutron source can be built at low cost with low maintenance efforts and without nuclear licensing procedure as small accelerator facility. Main features of this new concept will be presented and discussed.
F9 - Compact equipment for neutron source imaging by János Füzi | fuzi.janos@wigner.mta.hu

Event: UCANS-VII
Topic: CANS Projects and Innovative instrumentation

J. Füzi, V. Heirich, Z. László, A. Len, J. Orbán, L. Rosta
Wigner Research Center for Physics (Hungary)
J. Janik
Centre for Energy Research (Hungary)

A compact, mobile equipment for energy sensitive imaging of neutron sources has been developed and tested at the Budapest Research Reactor. The key components are a mask with pinhole and chopper unit respectively a four-layer, double readout solid boron converter neutron detector. Neutron adsorber materials, system geometry and parameters have been optimized to accommodate the high count rate and good spatial and time resolution required by the intended application. An unexpected hysteresis effect has been observed in the brightness of the Budapest Research Reactor thermosiphon liquid Hydrogen cold moderator. Direct imaging of the moderator showed that liquefaction is incomplete when performed with reactor at full power, in contrast to the case when Hydrogen in the moderator cell is liquefied with stopped reactor.
F10 - Conceptual design of an accelerator-driven 10-14MeV neutron source

by Jianlin Ke | kejianlin@caep.cn

Jianlin Ke, Chunlei Wu, Meng Liu, Xiaohai He, Benchao Lou, Qinlong Zhang, Yan Li
Institute of Nuclear Physics and Chemistry, CAEP, Mianyang 621900, China

Yuanrong Lu
State Key Laboratory of Nuclear Physics and Technology, Institute of Heavy Ion Physics, Peking University, Beijing 100871, China

Zhihui Li
Institute of Nuclear Science and Technology, Sichuan University, Chengdu 610065, China

An accelerator-driven neutron source is being designed at Insititute of Nuclear Physics and Chemistry, with the neutron energy of 10-14 MeV. The neutrons are generated by deuterons bombarding heavy water jet target. The accelerator is combined with a radio frequency quadrupole (RFQ) accelerator and a drift tube linac (DTL), which can deliver an 11 MeV deuteron beam. The neutron source mainly consists of ECR (electron cyclotron resonance) ion source, LEBT (low energy beam transportation), RFQ cavity, MEBT (medium energy beam transportation), DTL cavity, HEBT (high energy beam transportation), heavy water jet target, RF transmitter and control system. This paper will introduce the conceptual design of this neutron source.
There are three grand national neutron sources in operation or in construction in China, including, China Spallation Neutron Source (CSNS) which got its first neutron beam in August, 2017, China Advanced Research Reactor (CARR) which got critical in 2011 and is expected to start operation in 2018, China Mianyang Research Reactor (CMRR) which started operation since 2013. The recent progress of the three grand neutron source of China will be introduced.

There are also several compact accelerator-driven neutron sources in operation or in construction in China, such as, the Compact Pulsed Hadron Source (CPHS) in Tsinghua University, the Peking University Neutron Imaging Facility (PKUNIFTY), the RFQ-based BNCT supported by CSNS, the electrostatic accelerator-based BNCT of NeuBoron, the intense neutron generator of Lanzhou University, the compact accelerator-driven neutron source and neutron radiography facility of China Academy of Engineering Physics, the compact-accelerator driven neutron source in Xi’an Jiaotong University, and so on. The progress of these CANSs will be presented.

The opportunities for CANSs will be discussed while the grand national neutron sources and the CANSs are coming with great progress in China.
G1 - RIKEN Accelerator-driven compact neutron sources and its quantitative analysis methods  

by Yoshie OTAKE | yotake@riken.jp

Yoshie OTAKE
Neutron Beam Technology Team,
RIKEN Center for Advanced Photonics, RIKEN
(Saitama, 351-0198 Japan)

RIKEN has been operating the neutron source RANS (RIKEN Accelerator-driven compact Neutron Source) with 7 MeV proton linac and a beryllium target for 5 years [1]. There are two major goals of RANS research and development. One is to establish a new compact low energy neutron system of floor-standing type for industrial use. Another goal is to invent a novel transportable compact neutron system for the preventive maintenance of large scale construction such as bridges[2]. The water movement of different kinds of painted steel and different kinds of concrete blocks have been visualized and quantitatively analyzed [3]. The salt concentration estimation in the concrete samples has been estimated with prompt-gamma neutron analysis. The engineering diffraction method with compact source has successfully developed, and the texture evolution and austeninite volume fraction estimation for steel agree with those of J-PARC within 2% accuracy [4]. More compact source, RANS2 is currently under development with 2.49MeV proton linac.

G2 - Measurements of total cross sections using the VESUVIO Spectrometer by Luis Rodríguez Palomino

Palomino | rodrigl@cab.cnea.gov.ar

Event: UCANS-VII
Topic: Material characterization

L. A. Rodríguez Palomino, J. Dawidowski
Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Comisión Nacional de Energía Atómica, Universidad nacional de Cuyo (Argentina)

The measurement of total cross sections is an activity that was not usually contemplated in great neutron facilities, and historically it has been left for small sources. Its importance is key to Nuclear Engineering, which makes normal use of libraries, which are often not updated to the current experimental possibilities. The reason for having been left aside in large facilities, should be sought in the little access that Nuclear Engineers have had to them. The Bariloche LINAC team has a wide accumulated experience in Engineering and Physics interdisciplinary works, and the measurement of total cross sections has been one of its main working topics.

The recent upgrades in spectrometer VESUVIO (ISIS, Rutherford Appleton Laboratory, UK), allows good quality measurements of total cross sections, employing its transmission monitor. The recent policies in the management of its beam time, received favourably the development of proposals regarding Nuclear Engineering topics, thus opening new possibilities in the measurement of total cross sections, simultaneously with Deep Inelastic Neutron Scattering experiments, which allows to have a powerful tool for this discipline.

In this work we show the experimental results of the total cross sections of normal and deuterated alcohols measured in VESUVIO in a wide energy range ($10^3 - 10^2$ eV). Molecular Dynamics software (GROMACS) was employed to determine the vibrational spectra of the atoms that compose the system. With this information, the input parameters of the Granada's Synthetic Model was elaborated to calculate the neutron total cross-section of the samples. The samples studied were the hydrogenous 1-propanol, 2-propanol and n-butanol, 1-propanol (OD) and full deuterated 2-propanol and n-butanol. Good agreement between the experimental and calculated total cross-section were found.
G3 - Design, manufacturing and testing of the passively cooled irradiation module of ESS by Y. Beßler | y.bessler@fz-juelich.de

Event: UCANS-VII
Topic: Material characterization

Y. Beßler¹, M. Butzek¹, F. Hanusch¹, W. Beahr, G. Natour¹ and Y. Lee², M. Kickulies², D. Lyngh², L. Zanini², V. Santoro², G. Gorini³, G. Scionti⁴, F. Masi³,⁵, R. Senesi⁶,⁵

¹ Forschungszentrum Juelich GmbH, Juelich, Germany
² European Spallation Source ERIC, Lund, Sweden
³ Università degli Studi di Milano-Bicocca, Milano, Italy
⁴ Università della Calabria, Dipartimento di Fisica, Rende, Italy
⁵ CNR- IPCF, Sezione di Messina, Messina, Italy
⁶ Università degli Studi di Roma “Tor Vergata”, Dipartimento di Fisica, Centro NAST, Roma, Italy

Understanding the damage mechanism of structural materials under a high intensity fast neutron irradiation is important in determining the lifetime of functional systems in the vicinity of high power spallation target. Commonly used structural material in the spallation target environment is aluminum alloy due to its high strength and small neutron scattering cross-section. While the damage mechanism of aluminum alloys under thermal neutron irradiation in reactor environment is well known, there is lack of material data under fast neutron irradiation. Furthermore, the radiation damage in the welded region with or without filler materials has not yet been understood.

In order to understand the damage mechanism of aluminum alloys and selected fusion materials, a passively cooled irradiation module is designed and manufactured. This paper presents the design, manufacturing and testing of the helium filled passively cooled irradiation module. The module contains in total 120 welded and unwelded miniature specimens for tensile, bending and laser flash tests. These specimens are installed in a closed, double-walled, vessel. The vessel itself is located inside the pre-moderator, close to the spallation target, and will be cooled passively by the cooling water of the pre-moderator. Some of the installed samples are annealed and lose their strength properties exceeding a temperature of 130°C. Therefore, a helium atmosphere was used, which improve the heat conductivity inside the module. The irradiated samples will be retrieved for post irradiation examination, after the spallation target receives the accumulated proton beam dose of 27 GWh.
As more microfabricated and highly integrated semiconductor devices have been deployed in telecommunication equipment, soft errors caused by neutrons generated by cosmic rays have become more common and more significant. Soft errors occur when one or more bits within stored data on a device are reversed. This is temporary and can be repaired by restarting the device or overwriting data. To make highly reliable telecommunication equipment, measures taken to mitigate the impact of soft errors within a single semiconductor device cannot deal with all soft errors within actual equipment, which usually incorporates multiple devices. It is necessary to implement soft error measures for complete equipment systems. To improve the reliability of telecommunication equipment, we have conducted research into soft errors caused by neutrons. In 2013, it was assumed that soft errors could be caused using a compact accelerator-driven neutron source. Hence, soft error testing technology was jointly established at Hokkaido University’s compact accelerator-driven neutron source. This technology made it possible to test the soft error correction measures in equipment systems during their development [1](Figure 1), and it is now considered necessary to standardize this technology for the production of highly reliable telecommunication equipment. Now we are leading the effort to define quality standards for the International Telecommunication Union, Telecommunication Standardization Sector (ITU-T), which is the United Nations specialized agency. We have already submitted five new recommendations. One was approved as K.124 in Dec. 2016, and two were approved as K.130 and K.131 in Jan. 2018. The rest are expected to be approved in 2018. (Table 1)
Figure 1: Procedures for installation of soft error measures in development of equipment

Table 1: ITU-T Recommendation for soft error

<table>
<thead>
<tr>
<th>No</th>
<th>Title</th>
<th>Schedule</th>
</tr>
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<tr>
<td>K.124</td>
<td>Overview of particle radiation effects on telecommunications systems</td>
<td>Approved (Dec. 2016)</td>
</tr>
<tr>
<td>K.131</td>
<td>Design methodologies for telecommunication systems applying soft error measures</td>
<td>Approved (Jan. 2018)</td>
</tr>
<tr>
<td>K.130</td>
<td>Soft error test method for telecommunication equipment</td>
<td>Approved (Jan. 2018)</td>
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<td>K.soft_mes</td>
<td>Quality estimation methods and application guidelines for mitigation measures based on particle radiation tests</td>
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<td>Reliability requirement of particle radiation effect for telecommunication systems</td>
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H2 - Radioactivation characteristics
evaluation of electronic equipment in soft
error test using accelerator-driven
neutron sources by Hidenori Iwashita | iwashita.hidenori@lab.ntt.co.jp

H. Iwashita, H. Mori, G. Funatsu, K. Matsumura
Network Service Systems Laboratories, NTT (Japan)
H. Sato, T. Kamiyama, M. Furusaka
Faculty of Engineering, Hokkaido University (Japan)
Y. Kiyanagi
Graduate School of Engineering, Nagoya University (Japan)

In order to improve the reliability of electronic equipment against soft errors, application of soft-error testing in the development stage of electronic equipment has been started in order to confirm adequate failure handling at the time of occurrence of any soft error. Accordingly, we established soft error testing technology using a compact accelerator-driven neutron source at Hokkaido University. Especially at the system level of soft error testing, it is necessary to remove the equipment from the test site soon after testing in order to check accuracy by re-testing the equipment under test (EUT), but it is also necessary to keep the EUT in the test site until its radioactivity, produced by neutron irradiation, falls below a certain level. In this study, we use simulations to investigate the relationship between the number of soft errors occurring and the radioactivation characteristics of the materials used in electronic equipment, under various test conditions. To compare the radioactivation against the neutron energy spectrum, we simulated the radioactivation of EUT by high-energy and low-energy neutron sources using PHITS ver.3.02(Figure.1). This showed that radioactivation by a low-energy neutron source attenuates faster than that from a high-energy neutron source. Therefore, a low-energy neutron source is considered to be more useful in practical terms than a high-energy neutron source.
Neutron Sources

Element composition of EUT

Radioactivation characteristics of EUT

<table>
<thead>
<tr>
<th>Unit</th>
<th>Element composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame of</td>
<td>Fe 35.0% C 0.04%</td>
</tr>
<tr>
<td>chassis</td>
<td>N 4.7% Si 0.5%</td>
</tr>
<tr>
<td>Gr 9.7%</td>
<td></td>
</tr>
<tr>
<td>Circuit</td>
<td>O 23.9% Mg 0.2%</td>
</tr>
<tr>
<td>package</td>
<td>H 2.2% Na 0.03%</td>
</tr>
<tr>
<td></td>
<td>S 8.5% K 0.03%</td>
</tr>
<tr>
<td>Si 4.1%</td>
<td>Cu 4.9%</td>
</tr>
<tr>
<td>Ca 0.8%</td>
<td>Br 1.3%</td>
</tr>
<tr>
<td>Al 0.6%</td>
<td>Sn 0.0%</td>
</tr>
<tr>
<td>B 0.2%</td>
<td>Mo 3.9%</td>
</tr>
</tbody>
</table>
H3 - Evaluation of Acceleration Factor in a Soft Error Test using 18MeV Proton Accelerator Facility by Hiroki Mori | mori.h@lab.ntt.co.jp

Event: UCANS-VII
Topic: Other applications of CANS

H. Mori, H. Iwashita, G. Funatsu, K. Matsumura
Network Service Systems Laboratories, NTT (Japan)

H. Sato, T. Kamiyama, M. Furusaka
Faculty of Engineering, Hokkaido University (Japan)

Y. Kiyanagi
Graduate School of Engineering, Nagoya University (Japan)

Soft error testing of electronic equipment can be performed at compact accelerator-driven neutron sources (CANS). The test reproduces soft errors in a short time by irradiating electronics with about few million times higher neutron intensity than the natural environment. This method is useful to verify measures for soft errors and to predict soft error occurrence rate.

It is important to know the acceleration factor FA defined as a ratio of the number of soft errors produced by CANS to that at natural condition during a certain time interval. Regardless of device types, FA can be assumed to be constant at high energy proton accelerator facilities since its neutron energy spectrum is almost the same as the natural environment, where difference of the neutron intensity is required information. On the other hands, FAs using CANS may be different among devices, because the neutron energy spectra at CANS are different from the natural environment. However, it is difficult to evaluate the soft error occurrence rate by considering the FA of each device because various kinds of devices are included in electronic equipment. Therefore, it is desired to evaluate the error occurrence rate estimated regardless of the variety of devices in electronic equipment, by setting a constant FA for each CANS.
Fig1. CANS of 18MeV proton accelerator facility condition
I1 - Neutron Scattering Kernels and Cross Sections for Cold Moderator Materials  
by J.R Granada | granada@cnea.gov.ar

Event: UCANS-VII  
Topic: Nuclear Astrophysics and Nuclear Data

J.R Granada, F. Cantargi, J.I. Márquez Damián, C. Helman  
Department of Neutron Physics - Centro Atómico Bariloche - CNEA

Cold neutrons are widely used in different fields of research such as the study of the structure and dynamics of solids and liquids, the investigation of magnetic materials, biological systems, polymer science, and a rapidly growing area of industrial applications. The development and optimization of advanced cold neutron sources require neutronic calculations involving thermal and subthermal neutron energies, which in turn demand the knowledge of reliable cross section data relative to the materials which conform the system under consideration. The compromise solution adopted in standard Nuclear Data Libraries involves the inclusion of scattering cross sections for a few common moderators at some selected temperatures, and data for any different material or physical condition must be ‘constructed’ from pieces of information.

We review the development of scattering kernels for a number of molecular systems of interest as cold moderator materials, both in liquid and solid phases at cryogenic temperatures, done at our laboratory during the last years. The importance of experimental data to validate the calculated cross sections and the generating scattering kernels is emphasized.
I2 - Contribution of Centro Atomico Bariloche to the thermal scattering libraries in ENDF/B-VIII.0 and JEFF 3.3 by

Jose Ignacio Marquez Damian | marquezj@cab.cnea.gov.ar

Event: UCANS-VII
Topic: Nuclear Astrophysics and Nuclear Data

José Ignacio Márquez Damián, Florencia Cantargi, Christian Helman, José Rolando Granada

Neutron Physics Department, Centro Atomico Bariloche, CNEA, Argentina, and CONICET, Argentina

On December 2017 and February 2018 a new version of nuclear data libraries JEFF and ENDF/B were released. These releases included an update of the thermal scattering sublibraries. The Nuclear Data Group at Centro Atomico Bariloche contributed with new evaluations to these libraries, including updates of existing evaluations and new materials, covering thermal moderators, neutron filters and cold moderators.

The thermal scattering sublibrary of ENDF/B-VIII.0 includes updated evaluations for two of the most important moderators in reactor physics: light and heavy water. These evaluations are based on previous work that combines molecular dynamics and experimental data.

In JEFF 3.3, the thermal scattering sublibrary now includes 7 new materials: room temperature neutron filters (silicon and sapphire), aromatic hydrocarbon cold neutron moderators (toluene and mesitylene), light water ice, and new evaluations of liquid hydrogen and deuterium in both para- and ortho- quantum states. Heavy water was also updated, using the same evaluation as ENDF/B-VIII.0.
I3 - Evaluated Thermal Neutron Scattering Cross Sections for Liquid Hydrogen and Deuterium with Application to Neutron Sources by Jose Rolando Granada

Granada | granada@cnea.gov.ar

Event: UCANS-VII
Topic: Nuclear Astrophysics and Nuclear Data

José Rolando Granada¹, Ariel Márquez², José Ignacio Márquez Damián¹, Florencia Cantargi¹, Christian Helman¹

¹Neutron Physics Department, Centro Atomico Bariloche, CNEA, Argentina, and CONICET, Argentina
²Reactor and Radiation Physics Department, Centro Atomico Bariloche, CNEA

We have used recent experimental and calculated information on the dynamics of liquid H₂ and D₂ to produce a new description of the interaction of slow neutrons with these cryogenic moderators. The molecular translational motion, for both diffusive and collective contributions, has been reanalysed and represented by a new spectral frequency distribution. Experimental structural studies on liquid hydrogen and deuterium were considered to produce a realistic structure factor, which was used within the Sköld approximation. With that information the calculation of the scattering laws was performed at different temperatures over the range corresponding to the liquid phase of para- and ortho-H₂ and D₂. The new scattering kernels were employed as input data to generate new cross section libraries using the NJOY code. The new libraries were used in Monte Carlo simulations to optimize the design of reactor cold neutron sources.
The advantage and applicability of slow neutron beam has been recognized more widely by the industrial community over material development, product inspection, medical application and so on. Consequently, the application-oriented neutron sources is more widely discussed on the basis of the applicability of compact accelerator-driven neutron sources and a few compact accelerator-driven neutron sources have been constructed or are under construction or planned in Japan.

Conventionally, technical skills and concepts of neutron utilization has been developed in research nuclear reactors and large-scale accelerator experimental facilities, in which general purpose beam utilization was highly preferred. Therefore, new concepts of neutron utilization are desired to evaluate the applicability of application-oriented compact accelerator-driven neutron sources quantitatively in comparison with the large-scale neutron facilities. Development of the terminology would contribute to enable the systematically quantified specification and characterization of neutron sources.

An effort to improve the neutron beam terminology is being attempted by The Fundamentals Working Group of The Japanese Society for Neutron Science under the collaboration with Particle Accelerator Society of Japan and the Japan Collaboration on Accelerator-driven Neutron Sources. Present status of the effort will be presented for a possible consideration on an international framework for enhancing efficient communications.
L2 - Education at a CANS by Roberto E. Mayer  
mayer@cab.cnea.gov.ar

R.E.Mayer

Centro Atómico Bariloche and Instituto Balseiro.
Comisión Nacional de Energía Atómica and Universidad Nacional de Cuyo

For over 30 years the Nuclear Engineering course of studies has benefitted itself from the continual use of our electron LINAC. This small accelerator allowed students to gain hands-on experimental experience, making an invaluable contribution to the deep understanding of Neutron Physics and Reactor Physics subjects of the curricula.

Some of the Nuclear Engineering most usual experiments included:

- Neutron Die-away Time as a function of paraffin moderator dimensions and as a function of light water moderator Poisoning with increasing concentrations of boric acid;
- Neutron Flux Distribution determination through activation probes employing the cadmium difference method;
- Total Cross Section time-of-flight measurement of indium resonances in the thermal range, with pulsed neutrons emerging from slab moderators of different thicknesses;
- Neutron Spectra Determination by Time-of-Flight
- Multiplication Factor of natural uranium fuel assembly for variable fuel pitch and simulating loss of light water coolant surrounding the fuel, while maintaining the presence of light water moderator.

Postgraduates have also employed this small facility for PhD and Master theses.