1st Exploratory Workshop

Exotic Radionuclides from Accelerator Waste for Science and Technology (ERAWAST)

15th - 17th November 2006

Villigen (Switzerland)

1. Executive summary

This ESF-sponsored Exploratory workshop aimed to search for potential collaboration partners and establish an international network for the exploitation of accelerator waste materials with regard to the use of exotic radionuclides in basic science and for technological and medical applications was hold in Villigen (Switzerland) from 15th -17th Nov. 2006. 30 participants from 12 countries decided to create an international collaboration. 25 talks were given pointing to the various possibilities of application in the fields of basic nuclear physics, nuclear astrophysics, Laser based Resonance Ionisation Mass Spectrometry (RIMS), Accelerator Mass Spectrometry (AMS) and radiopharmaceutical science as well as possibilities for preparative separation of the wanted isotopes. Talks given by the participants lasted 20 min, followed by 10 min of discussion. At the end of every workshop-day, one hour was reserved for further discussions. The workshop had an international dimension represented by colleagues from the US and India.

The workshop, executively sponsored by the ESF, was hosted by the RadWasteAnalytics Group of the Laboratory for Environmental and Radiochemistry of the Paul Scherrer Institute under the leadership of Dr. Dorothea Schumann and the co-convenors Prof. Frank Rösch (Uni Mainz), Dr. Franz Käppeler (FZ Karlsruhe), Dr. Zsolt Fülöp (ATOMKI Debrecen) and Dr. Gunther Korschinek (TU Munich). Participants from outside were accommodated at "Schloss Böttstein", a wonderful hotel in the near neighbourhood of PSI. All lunches as well as the dinner on 15th November were served at PSI canteen. At the beginning of the workshop on Wednesday (15th November) morning, the participants were welcomed by the Vice-director of PSI, Prof. Dr. Heinz Gäggeler, who expressed the high interest of PSI in the proposed activities. On Thursday, 16th, a visiting tour of the PSI accelerator facilities including the 590-MeV ring cyclotron and the neutron spallation source SINQ was performed, competently guided by the head of the Department for Condensed Matter Research with Neutrons and Muons, Dr. Kurt Clausen, followed by a workshop dinner at Schloss Böttstein. The workshop ended on Friday 17th November, at noon.

2. Scientific content

The participants in total presented 25 talks, which were divided into 6 topics. In topic 1 the radionuclide production facilities were introduced. In the contributions of the PSI staff members Y. Dai, J. Neuhausen and D. Schumann the possibilities of producing mainly long-lived radionuclides in accelerator facilities were explained and expected amounts of interesting isotopes from the now existing PSI accelerator waste were estimated. U. Köster from ILL Grenoble then talked about isotope production in high flux reactors with following electromagnetic recoil separator, a method well-suited for gaining short-lived neutron-rich nuclei and, therefore, ideally completing the palette of production possibilities.

Topic 2 was dedicated to analytics and separation techniques as well as theoretical predictions for the estimation of the radionuclide inventory. It could be shown by the colleagues of PSI (M. Wohlmuther, D. Schumann), that calculations and chemical analysis of a copper beam dump, foreseen for preparative separation, are in good agreement. First examples for chemical separation technique were presented. Prof. Lahiri (Saha Institute, Kalkutta) presented in his talk a broad spectrum of separation works useful for several purposes in possible future joint projects. The opportunities of mass separation using ISOL technique were discussed by L. Fraile (CERN/ISOLDE, Geneve). A very valuable comment concerning this subject came from A. Lefebvre-Schuhl (IPN Orsay) proposing the French facility for special separation purposes, like for instance separation of iron isotopes.

The following sessions dealt with possible applications of rare isotopes. Topic 3 covered nuclear and basic physics research. C. Geppert (GSI, Darmstadt) and K. Wendt (Uni Mainz) spoke about application of special ultra-rare trace isotopes in laser based spectroscopic investigations, a very young but prospective analysis method. One talk was given on proton-neutron interaction at the proton dripline near ^{44}V (A. Krasznahorkay, ATOMKI, Debrecen) and one contribution concerning theoretical predictions on α-particle semi-microscopic optical potential for low energies and medium mass nuclei (M. Avrigeanu, University of Bucharest).

The two sessions on Thursday (Topic 4 and 5) were dedicated to nuclear astrophysics research. Talks on cross section measurements with neutrons (F. Käppeler, Karlsruhe, R. Reifarth, LANL, Los Alamos) as well as on the use of exotic radionuclides in connection with radioactive ion beam technologies were given. Besides the use of ^{7}Be beams for astrophysically relevant studies (M. Hass, Weizmann Institute, Rehovot, L. Gialanella, INFN, Napoli) which represent already well-established technologies, also future ideas for

application at the n_TOF facility (A. Mengoni, CERN, Geneve) and at the planned new accelerator facility in Frankfurt were presented (M. Heil, Darmstadt). Two very interesting experiments using ^{10}Be and possibly ^{44}Ti as radioactive ion beam at the facility UCL (A. Sanchez, UCL, Louvain-la- Neuve, A. Murphy, Uni Edinburgh) for basic nuclear physics and astrophysical investigations were also introduced as examples for projects realizable already in the near future.

Accelerator Mass Spectrometry, radio-pharmaceutical application and related science were the topics of the last session on Friday morning. F. Rösch reported on the possibilities for so-called "radionuclide-generator-systems" and their application for medical purposes. Three talks were given on the potential of AMS-measurements to contribute to basic nuclear research and the possible role of exotic radionuclides within these studies (G. Korschinek, G. Rugel, TU Munich, A. Wallner, Uni Vienna). At the end, U. Köster pointed to some other exotic radionuclides, available from accelerator waste, like several Ar isotopes, which are worth considering for scientific experiments.

The participants discussed problems concerning the organisation of joint experiments, physical and chemical consistence of desired radionuclides, time schedules, acquisition of other interested institutions like the Rutherford Appleton Laboratory in the UK, Triumf in Canada as well as the possibilities of further networking. The participants agreed to establish and international network on the exploitation of accelerator waste and organise several actions for joint experiments and collaboration, which are described in detail in the next section.

3. Assessment of the results, contribution to the future direction of the field, outcome

After lively and constructive discussions, the participants decided to create an international network to support the collaboration between the interested partners. As the first and probably most important action, an application for an ESF-funded Research Network Programme was launched (ERIMAST - Exotic Radionuclides from Irradiated Material for Science and Technology; Ref. No. 06-RNP-069). This RNP shall provide the ERAWAST-community with the necessary communication tools and financing of short- and mid-term visits for the next 4 years (from 2008).

Additionally, a number of further actions were defined, which are listed and explained in detail in the following:

1. Bi- or multilateral collaborations which can be started in the near future (2007-2008), with PSI being able to provide the necessary isotopes from a copper beam dump and irradiated graphite targets:

    1) Laser based investigations and analytics of ultra rare trace isotopes (University of Mainz, Germany in collaboration with Nagoya University, Japan and University of Jyväskylä, Finland)

    2) $^{60}Fe(n,\gamma)^{61}Fe$ at stellar energies: Astrophysical quests and experimental challenges (Forschungszentrum Karlsruhe, Germany)

    3) Spectroscopy of ^{10}Be on the search for the beryllium halo nuclei charge radii (GSI Darmstadt, Germany)

    4) ^{7}Be for measuring the cross section of the $^{7}Be(p,\gamma)^{8}B$ reaction (Weizmann Institute Rehovot, Israel, ISOLDE/CERN Switzerland)

    5) ^{7}Be for ion-implantation at ISOLDE/CERN to study the half-life in various media and to perform 7Be(n,p) emission channeling experiments at ILL Grenoble

    6) A new ^{10}Be beam at CRC/UCL (Université catholique Louvain, Louvain-la Neuve, Belgium)

    7) ^{44}Ti abundance as a probe of nucleosynthesis in core collapse supernovae (University of Edinburgh, UK; UCL, Belgium)

8) Model studies with a $^{44}Ti/^{44}Sc$ radionuclide generator (University of Mainz, Germany)

9) Half-life measurement of ^{60}Fe and ^{53}Mn (Technical University of Munich, Germany)

10) Proton-neutron interaction at the proton dripline near ^{44}V (ATOMKI, Debrecen, Hungary, in collaboration with RCNP, Osaka, Japan)

11) AMS measurements with an ^{26}Al standard (ETH Zürich, Switzerland, University of Vienna, Austria)

2. Plans for collaboration in a longer time scale (start 2009 and later); these joint experiments depend on construction of new facilities as well as changing and development of new equipment on the user site and development of separation techniques either from the lead targets, special irradiations at SINQ or from beam dumps with high amounts of activity:

    1) Branchings in the s-process path (GSI Darmstadt, Germany)

    2) Neutron capture on radioactive isotopes for astrophysics (Los Alamos National Laboratory, USA)

    3) Perspectives for measurements of neutron reaction cross sections of rare radioactive isotopes at CERN n_TOF (CERN, Switzerland)

    4) Half-life measurements of long-lived rare earth isotopes (Technical University Munich, Germany)

    5) Construction of a $^{44}Ti/^{44}Sc$-generator for animal and clinical application (Uni Mainz)

    6) Development of a ^{26}Al beam for nuclear astrophysics (Université catholique Louvain, Louvain-la Neuve, Belgium; TUM Munich, Germany)

    7) Irradiation of special samples in the SINQ target - Bi for the production of ^{205}Pb (Los Alamos National Laboratory, USA), enriched ^{34}S for the production of ^{32}Si (University of Vienna, Austria). The target material will be positioned within the next 2 week for irradiation in 2007/8. The samples can be provided after a cooling time of about one year (e.g. from 2009).

3. Long-lived radionuclides are also produced in the irradiation of samples at the instruments LOHENGRIN and GAMS of the Institute Laue Langevin (Grenoble,

France). Some of these radionuclides produced in (n,gamma) reactions can complement those provided by PSI. Bilateral collaborations can be established.

4. The problem of isotopic mass separation needs further discussion - in particular for the study of ^{60}Fe production at stellar energies. Maybe the facilities at CERN (Switzerland) or CSNSM and IPN Orsay (France) could be an option.

5. The Saha Institute of Nuclear Physics (Kolkata, India), the University of Mainz (Institute for Nuclear Chemistry, Mainz, Germany) and PSI (Villigen, Switzerland) will discuss in the near future possible collaboration concerning chemical separation techniques.

6. Other nuclide production facilities shall be contacted for a possible collaboration (TRIUMF, Vancouver, Canada; Rutherford Appleton Laboratory, UK; SNS, Oak-Ridge, USA).

7. Other institutes and universities acting as users shall be included (1. Italy: colleagues from INFN Sezione di Napoli will try to get in contact with other interested institutes; 2. Institutions which did not participate in the ERAWAST workshop but showed interest in participating in the ERIMAST project).

8. A dedicated ERAWAST-webpage will be installed, all talks given at the workshop will be provided as PDF-files (presently: workshop web-page. http://lch.web.psi.ch/radwaste/workshop/index.html).

9. In the frame of the ERAWAST collaboration, several applications for joint projects are envisaged (7th framework of EC, national funding and others).

10. An announcement on ERAWAST will be made in Nuclear Physics News, the magazine of NuPECC

Final program

Tuesday; 14.11.06

	Arrival	
20.00	Welcome Apèro at Schloss Böttstein	

Wednesday, 15.11.06

8.45-9.15	Registration	
9.15	Welcome and introduction	
9.30	Information on the European Science Foundation	
9.45-11.45	**Topic 1: Radionuclide production possibilities**	
	Chair: G. Korschinek	
	D. Schumann (PSI)	Accelerator waste at PSI
	Y. Dai (PSI)	The SINQ spallation source at PSI
	U. Köster (Grenoble)	Multi-neutron-capture for gamma-ray spectroscopy and more
	J. Neuhausen (PSI)	EURISOL and the possibilities for nuclide production from liquid Hg-targets
11.45-13.00	Lunch	
13.00-15.00	**Topic 2: Analytics and separation techniques**	
	Chair: F. Rösch	
	M. Wohlmuther (PSI)	Calculation of residue nuclide production in accelerator waste
	D. Schumann (PSI)	Chemical separation techniques
	L. Fraile (CERN)	Mass separation at CERN ISOLDE
	S. Lahiri (Saha Inst.)	Possible Role of "Saha Institute of Nuclear Physics - Radiochemistry group" in ERAWAST project
15.00-15.30	Coffee break	

15.30-17.30 **Topic 3: Nuclear and basic physics**

Chair: Z. Fülöp

C. Geppert (GSI)	Spectroscopy of ^{10}Be on the search for the beryllium halo nuclei charge radii
M. Avrigeanu (Uni Bucharest)	α-particle semi-microscopic optical potential for low energies and medium-mass nuclei
A. Krasznahorkay (ATOMKI)	Proton-neutron interaction at the proton dripline near 44V
K. Wendt (Uni Mainz)	Laser Based Investigations and Analytics of Ultra rare Trace Isotopes

17.30-18.30 Round table discussion I

18.30- Dinner at PSI Oase

Thursday, 16.11.06

8.15-10.15 **Topic 4: Astrophysics I - Cross section measurements**

Chair: Z. Fülop

F. Kaeppeler (FZK)	^{60}Fe(n,gamma)^{61}Fe at stellar energies: Astrophysical quests and experimental challenges
M. Heil (FZK)	Branchings in the s-process path
M. Hass (Weizmann Inst.)	^{7}Be for measuring the cross section of the ^{7}Be(p,γ)^{8}B reaction
R. Reifarth (Los Alamos)	Neutron capture on radioactive isotopes for astrophysics

10.15-10.45 Coffee break

10.45-12.45 **Topic 5: Astrophysics II - Radioactive beams**

Chair: F. Kaeppeler

A. Sanchez (UCL)	A new ^{10}Be beam at UCL
A. Murphy (Uni Edinbough)	^{44}Ti Abundance as a Probe of Nucleosynthesis in Core Collapse Supernovae

	L. Gialanella (INFN)	Production and Applications of a ^{7}Be radioactive beam using a 3 MV Tandem Accelerator
	A. Mengoni (CERN)	Perspectives for measurements of neutron reaction cross sections of rare radioactive isotopes at CERN n_TOF
12.45-14.00	Lunch	
14.00-17.00	Visit of PSI accelerator facilities	
17.00-18.00	Round table discussion II	
19.00	Workshop dinner at Schloss Böttstein	

Friday, 17.11.06

8.15-11.15	**Topic 6: Applications: AMS, Radiopharmacy and others**	
	Chair: D. Schumann	
	F. Rösch (Uni Mainz)	New radionuclide generators based on long-lived parent radionuclides
	A. Wallner (Uni Wien)	Availability of radionuclides for AMS – from calibration to applications
	G. Korschinek (TUM)	AMS and radionuclides from a beam dump
9.45-10.15	Coffee break	
	G. Rugel (TUM)	Half-life measurement of ^{60}Fe
	U. Köster (Grenoble)	^{39}Ar and ^{42}Ar: too valuable for ventilation!
11.15-12.15	Round table discussion III and workshop summary	
12.15-13.30	Lunch	
13.30	Departure	

Participants

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Statistical information

Country	Number of participants
Germany	8
Switzerland	6
France	4
Austria	2
Belgium	1
Italy	2
United Kingdom	1
Hungary	2
Romania	1
Israel	1
USA	1
India	1

4 participants were female, 26 male.

5 were PostDocs.