PROCEEDINGS OF THE EURISOL-NET MEETING ON R&D

CERN

June 27-28 2011

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Introduction

EURISOL-NET: Task 1 working group meetings held at CERN on June 28-29, 2011

Milestone M-NA03-1.2

1st working group meetings: identification of main common R&D issues

The first working group meetings of task 1 (Coordination and dissemination of R&D for ISOL facilities) of the EURISOL-NET network of ENSAR were held at CERN on June 28 and 29, 2011. They were attended by 42 participants from 15 institutions. Eighteen oral presentations were given concerning the main R&D issues pertaining to EURISOL currently investigated in the laboratories participating in the network. The work can be classified in 5 categories:

Neutron converters: After the conclusion of the MEGAPIE project at PSI work is proceeding on the definition of high power targets for the ESS and MYRRHA projects. A test bench for high power targets is being studied in the framework of the TIARA project.

Development of fission and other target materials; study of release properties: Uranium Carbide material for ISOL targets is being developed at CERN, IPN Orsay and LNL Legnaro, in particular in the framework of the ACTILAB JRA of ENSAR**.**

Improvement of Ion Source performances: Ion Sources and charge breeders are being developed at JYFL, IPN Orsay and at GANIL in the framework of the EMILIE project funded under the auspices of NuPNET.

Beam manipulation and purification: Advances made at CERN, JYFL and LNS Catania were discussed.

Superconducting Linear Accelerator Technology and beam diagnostics: SCRF development related to SPIRAL2 and EURISOL is carried out at IPN Orsay while compact integrated beam diagnostic systems developed at CERB, LNS Catania and NASU, Kiev were presented.

This document contains short summaries of the talks that were presented which give a comprehensive overview of the EURISOL related R&D currently being carried out.

Yorick Blumenfeld	Yacine Kadi
EURISOL-NET activity leader	Task 1 leader

Timetable

Monday 27th June

13:30 ENSAR and EURISOL-NET, Y. Blumenfeld

13:45 EURISOL-NET Task 1 R&D Coordination, Y. Kadi

14:00 Optimization Studies of the CERN-ISOLDE neutron converter – fission target system, T. Stora

14:20 Designing Safety into a High-Power Neutron Spallation Source, Y. Kadi

14:40 Converter targets for high power spallation neutron sources, E. Noah

15:00 Recent results on development of the SPES production target, A. Andrighetto

15:20 The R&D on target material at IPNO, E. Cottereau

15:40 Latest progress for the RIB production for the future activities at GANIL/SPIRAL2, H. Franberg Delahaye

16:00 Uranium Carbide Material Developments at CERN-ISOLDE, A. Gottberg

16:20 Coffee break

16:50 Status of R&D on ion sources at IPNO, C. Lau

17:10 Status of the EXCYT facility at INFN-LNS, L. Celona

17:30 Recent ion source related research and development work at JYFL, P. Suominen

17:50 Metallic beams and charge breeding, H. Franberg Delahaye

19:30 Dinner

Tuesday 28th June

08:30 Low intensity beam diagnostics at INFN-LNS, L. Cosentino

08:50 Ion beam production and manipulation at IGISOL, A. Jokinen

09:10 Beam Manipulation and Purification at ISOLDE and REX-ISOLDE, F. Wenander

09:30 Superconducting Radio-Frequency Recent Developments at IPN Orsay, S. Bousson

09:50 SRF activities at CERN, M. Pasini

10:10 High intensity beam diagnostics system based on novel metal micro-detectors, O. Kovalchuk

10:30 Beam diagnostics developments for the HIE-ISOLDE linac, F. Zocca

10:50 Coffee Break

11:20 Discussion/Conclusions

Converter targets for high power spallation neutron sources

Author: E. NOAH

Abstract:

The last decade has seen the commissioning and operation of two spallation neutron source facilities, SNS and J-SNS, where the mercury neutron converter targets receive pulsed proton beams in the MW range. The European Spallation Source planning first neutrons for 2019 has been exploring a range of targets and is converging towards the choice of a baseline target and a back-up solution. This paper presents the target selection process, describing requirements for an ESS target and outlining the advantages and disadvantages of the various neutron converter targets considered.

Talk summary:

The precursor to the European Spallation Source project, the German SNQ project in the 80’s, had planned a rotating water-cooled target with an incident beam of 5 MW. Since then several high power (~MW) converter targets have come into operation:

- SINQ at PSI from 90’s: water-cooled solid rod bundles (“cannelloni”).
- SINQ at PSI in 2006: Liquid LBE MEGAPIE target.
- SNS at ORNL from 2006: Liquid Hg target.
- J-SNS at JAEA from 2008: Liquid Hg target.

Recent operational experience from the above spallation sources was integrated into the design process for the target station of the European Spallation Source project. In addition, the proton beam parameters were changed, rather than the short-pulse sub-μs length, a longer pulse length > 1 ms was adopted. In 2010, a wide range of target solutions was explored by the ESS central team in Lund along with collaborating institutes across Europe (ESS-Bilbao, FZJ, KIT, PSI, CRS4, IPUL) within the framework of the Target Station Concept Selection (TSCS) process. Amongst the many criteria used to compare solutions, the driving ones are:

- Safety
- Scientific performance
- Maintainability/availability
- Cost

Liquid metal targets

There are considerable challenges for Hg targets: maintenance of loop components was found to be difficult due to their contamination/activation even after draining of the Hg, the high vapour pressure of Hg leads to spreading of activity over large areas during target exchanges, and potential high release of activity in accidental scenarios. The main drawback is the inability to demonstrate a disposal path for the irradiated Hg at the end of the facility lifetime. The requirement by permanent waste repositories to solidify any liquid waste into a stable solid matrix cannot to date be met for Hg. Solutions have been explored but are not considered mature enough, they also tend to be very expensive, due to the large final volume of waste. The ESS project saw a risk in not being able to license a Hg high power spallation target in Europe. For this reason, other liquid metals were considered. The favored candidate is lead-bismuth eutectic (LBE) due to the experience accumulated in its use (coolant in Russian Alpha-class nuclear submarines, MEGAPIE project). Non-negligible amounts of the ⍰-emitting Polonium are produced in LBE. For this reason other lead-based alloys were also considered, including lead gold eutectic (LGE) although preliminary tests of corrosion effects were inconclusive.

<u>Solid targets</u>

Stationary solid targets were considered but discarded because of the requirement to ensure passive cooling of the remanent decay heat. Rotating targets were re-explored for ESS and either water-cooled or gas-cooled rotating tungsten targets are being actively studied as potential baseline targets.

<u>Outlook for EURISOL mMW converter target</u>

Hg is most likely not licensable in Europe. Other target concepts should be considered for EURISOL, analyzing the design methodologies applied at PSI, SNS, J-SNS, ESS and adapting these to the specific requirements of the EURISOL converter target (neutron spectrum and flux, safety: proximity of fissile material at temperatures > 2000°C).

EURISOL Network Activity on Neutron Converter Studies

Author: Y. Kadi

Technical context surrounding the EURISOL Network Activity on Neutron Converter Studies

Results from previous undertakings by research institutes across Europe funded through the FP6 program have proven the theoretical and experimental basis for high-power spallation neutron sources. Two such programs, Megapie[1] and Eurisol[2], have played a fundamental role in articulating the case for continued technological development in this field.

Within the EURISOL Design study, the target complex was one of the key elements of the EURISOL facility, which was the subject of intense design work and preliminary prototyping. The 4 MW mercury converter was to be set up in a target station where it would be utilised in conjunction with a uranium target to create exotic isotopes by rapid fission. The converter was based on a circulating metal loop exposed to direct proton beam irradiation. First prototypes were developed and tested off-line, from which relevant experience was gained. At the present stage, several issues are yet to be addressed, such as the impact of beam irradiation parameters on the liquid metal loop operation. Likewise, the target development will necessitate further research in the field of heat exchange with liquid metal, irradiation, corrosion and fatigue testing of materials.

Achieving the design of the full scale target for EURISOL will require several partial tests: first of sub-components, irradiation at lower power, through to instrumentation tests, and finally full scale tests. In order to better ascertain the needs for testing a high-power target, various existing and projected facilities have to be examined and their characteristics evaluated. These issues will be partly addressed in the WP9 task of the TIARA project

Target Development Requirements

The neutron source used for Megapie and Eurisol both contained liquid metal. The experience from both these experiments is of particular value for deriving a safer reliable high-power spallation neutron source. As illustrated below, the two sources each explored advanced aspects of this technology.¨

Megapie was the first source operating with liquid metal under irradiation. Eurisol explored high velocities with liquid metal on very thin surfaces for the beam window allowing higher

1 http://megapie.web.psi.ch/
2 http://www.eurisol.org/site02/index.php

heat depositions and therefore a higher neutron flux. The lessons learnt from this experience are summed up in the Table below.

Relevance	Relevant Safety Guideline
System	Multiple containment strategy is vital Natural circulation is of little value Leaks must not flow into the path of the beam Leak analysis and mitigation strategy in place No organic cooling liquid inside source Development using multi-physics analysis
Component	Calibrated electro-magnetic pumps are reliable High-grade finishes reduce drag losses T91 /316 stainless steel are an appropriate choice
Signal	Diversify flow-meter instrumentation Instruments in- and outside of source (beam) Ensure leak detection using diverse sensors Pressure transducers and TCs are resilient

Table 1: Summary of Experimental feedback from Eurisol and Megapie programs

The lessons learnt indicated that a liquid metal target, although more complex, is undoubtedly an avenue worth investigating. It offers the possibility of allowing a more compact design through a far high power deposition whilst at the same time retaining much of the activity with the liquid metal. This last topic was the subject of a detailed investigation in the post-Megapie phase, which indicated that unless high temperature were attained, there was no danger of any release of Polonium, it remained bound to the Lead-Bismuth Eutectic.

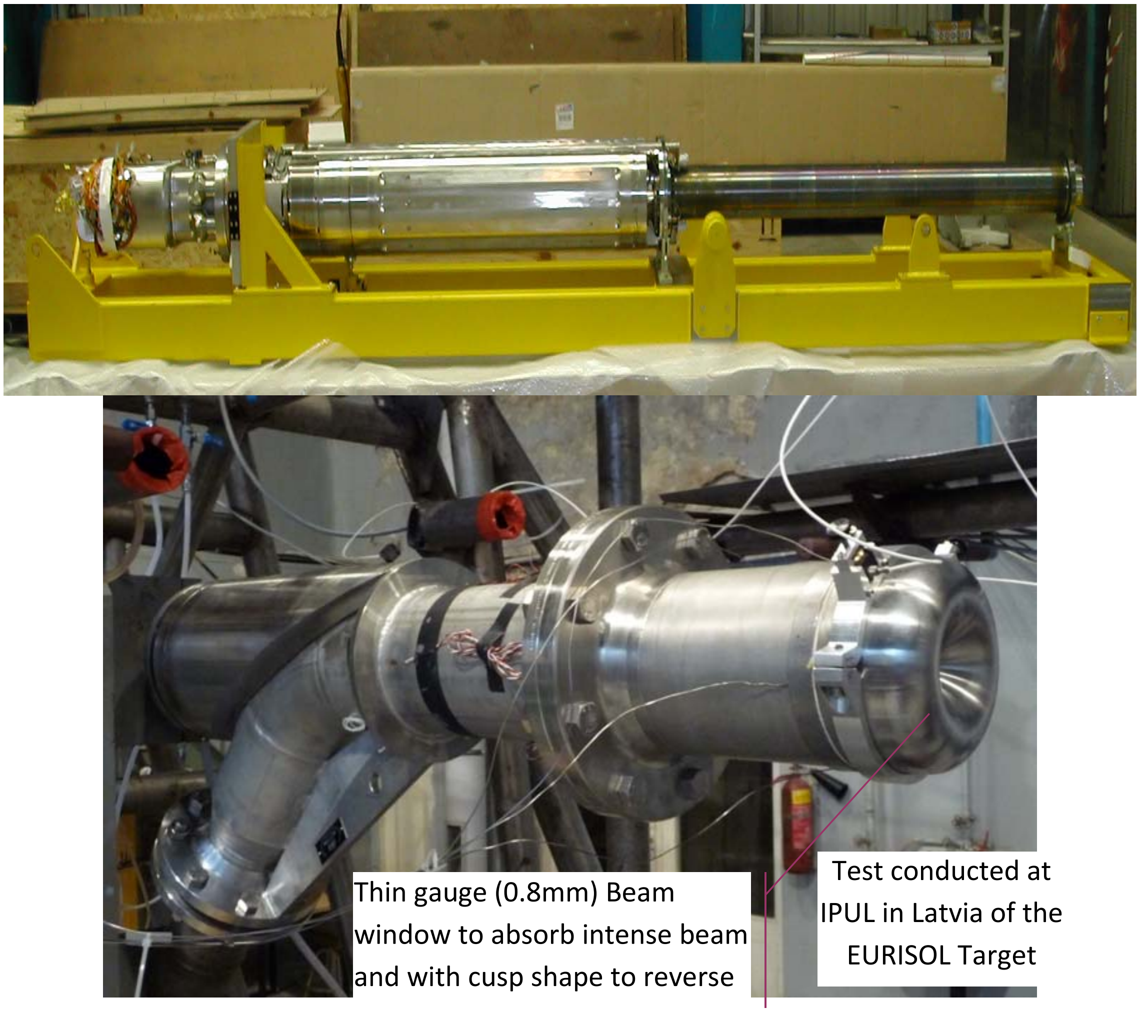


Figure 1: Liquid metal neutron source Megapie (top), Eurisol on test stand (bottom)

Improvements in target design

The schematic in *Figure 2* below highlights how an improved safety-enhanced liquid metal source may be built, taking on board combining these experiences However it should be pointed out that the design would also work using a solid target placed in the main spallation zone (blue circle) cooled by heavy water. The advantages of compactness still pertain although power density will evidently be less, licensing on the other hand would be facilitated. Both options will be studied. A further advantage of the proposed design lies in the fact that it is easily scalable to different power levels by simply adapting the lengths of the heat exchanger main corpus. In addition due to its compactness it may be positioned horizontally or vertically.

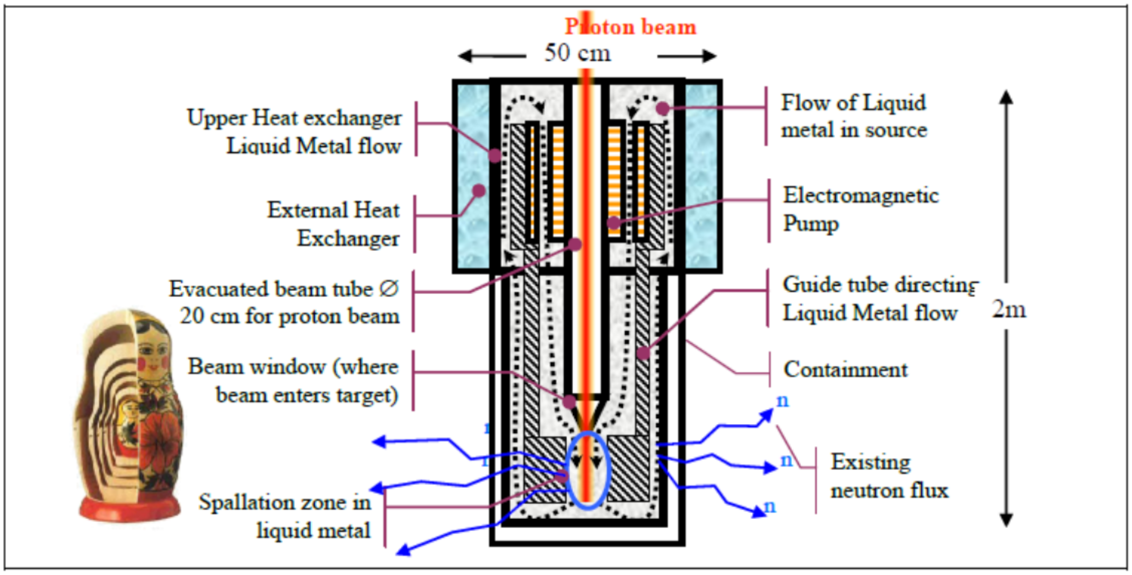


Figure 2: Proposed layout of a compact liquid metal neutron source

Note: the design would also allow a solid target in the spallation zone (blue circle) cooled by heavy water, albeit at lower power levels.

A possible design shown in *Figure 3:* following theses general principles is proposed as a guide to obtaining development costs, a task which has been entrusted by one on the main industrial partners contacted for the task, Škoda JS. The design features a succession of independent sub-assemblies fitting into each other allowing rapid disassembly.

The innermost component is the beam conditioning which comprises quadrupoles for focusing the beam just before it enters the target through the beam window, such that when the beam first enters the assembly through the beam tube lid at the top, the beam footprint can still be quite large reducing stresses and temperatures on that containment barrier. This component slides into the beam tube.

The beam tube comprises at its lower end the beam window. In case of rupture of the beam window the liquid in the target would simply flood the beam tube but without directly impinging on the containment, a marked improvement over previous designs. The beam tube and beam window are the inner wall of the target proper and also house the electromagnetic pump at the upper end which can be entirely withdrawn from the beam tube and is thus distinct from the target facilitating its maintenance. The target itself is a closed circuit with a guide tube separating the down-coming cool fluid cooling the beam window from the upcoming heated fluid which is directed to the heat exchanger manifold.

The target-side heat exchanger channels are separated from the containment-side matching cooling channels by a 1 mm helium-filled gap at 0,5 Bar which serves as a protection barrier and leak detector. The containment with its integrated cooling jacket at the top is the last and outermost component serving to contain any spillage. It is far less exposed to direct spill products than Megapie and is not directly traversed by the beam except the upper lid.

Testing requirements

Testing liquid metal sources require setting up a liquid metal loop with all measurement devices required for measuring pressure, temperature flow and local velocities where needs. Prior experience gained in this respect indicates that selecting specific components for dedicated tests such as the beam window is a proven way forward. In a graded approach aimed at minimising risk, integral testing is required only once the component testing is successful.

In order to proceed in a cost-efficient manner, the different aspects of target testing have been broken down into separate testing requirements to avoid replicating large facilities or placing such high demands on the proposed facilities, that they would make the project unaffordable. Each requirement can thus be assigned to a specific facility. Where compatibilities exist, adaptations are to be made; otherwise a dedicated facility would have to be built. By focusing on a particular testing requirement, it is however far more likely that an existing facility may accommodate the specific testing needs, failing which the purpose-built facility which would have to be built would focus on a narrower set of objectives and thus be cheaper.

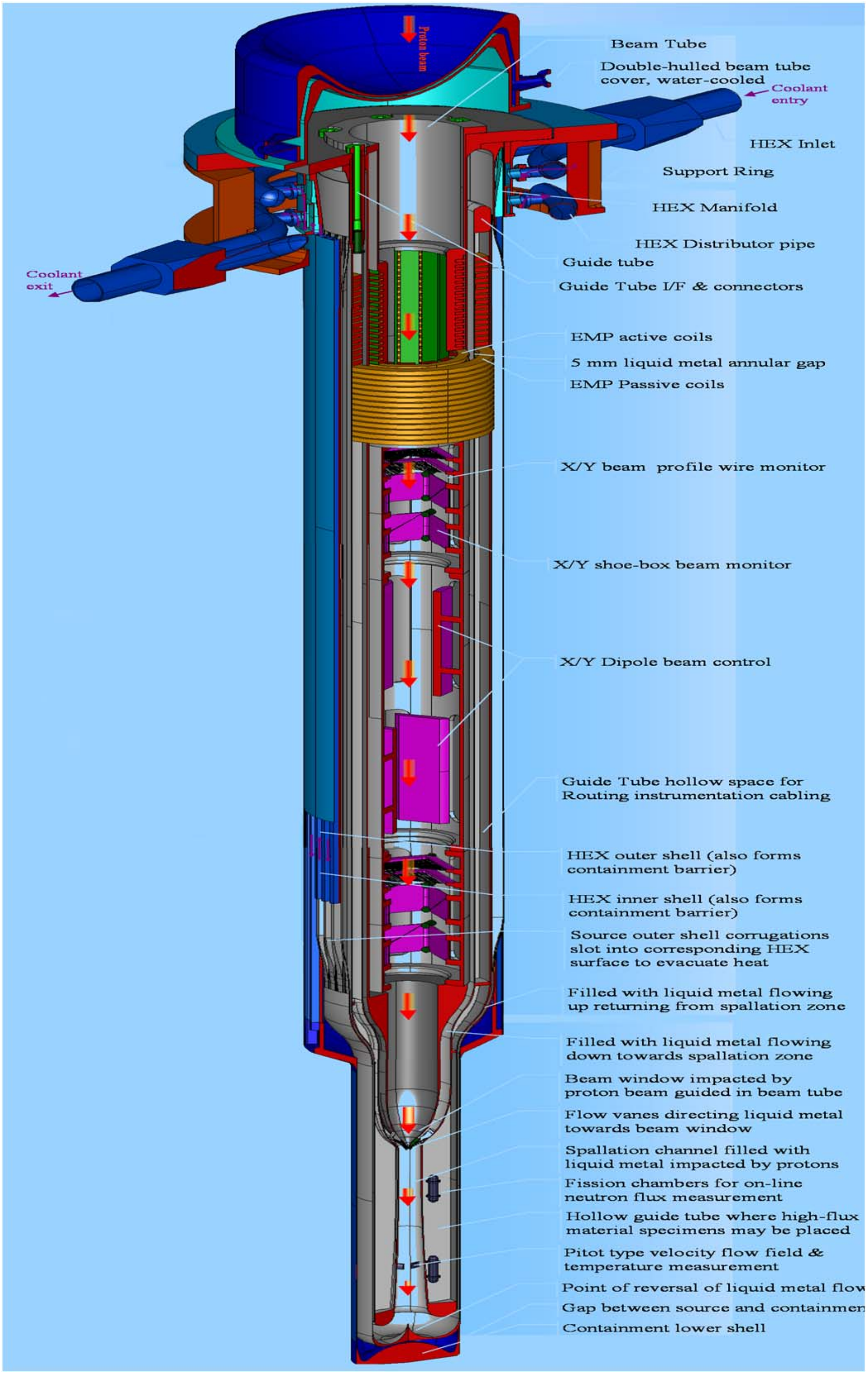
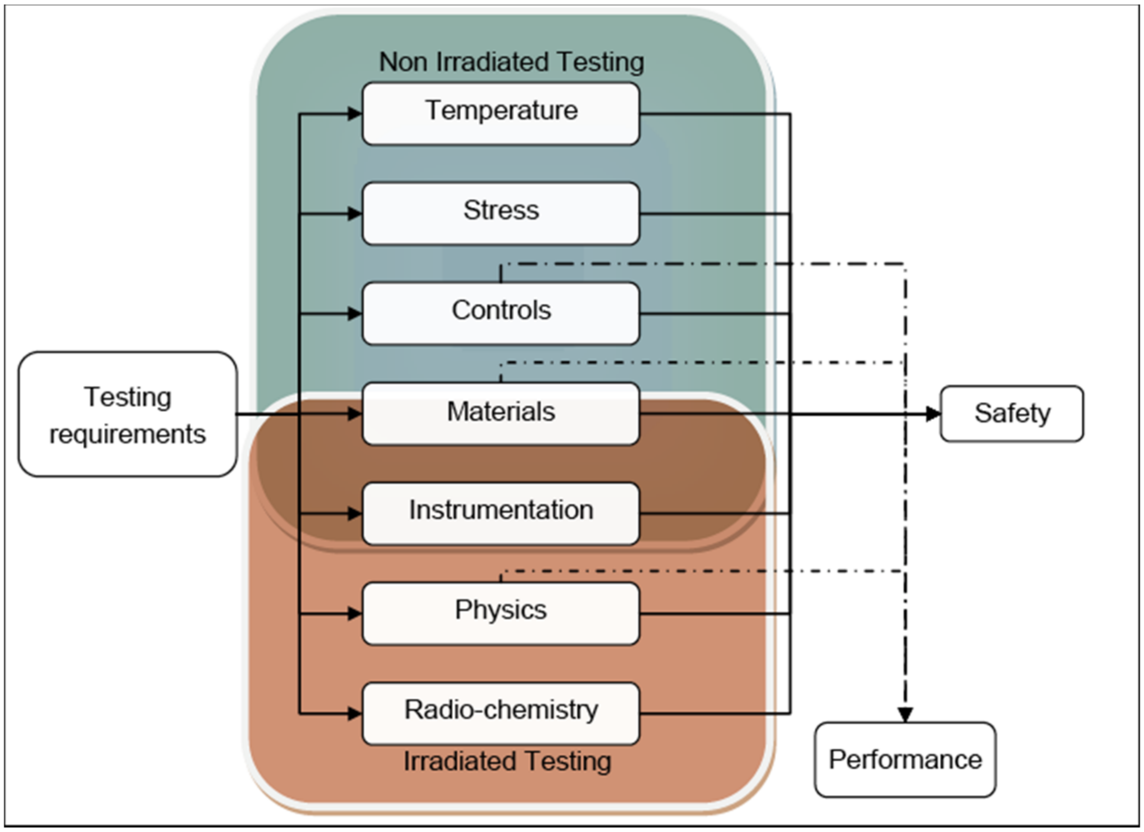


Figure 3: Conceptual Design for an optimised neutron source acc. K. Samec



Component testing

Component testing is of particular relevance to liquid metal targets as the coolant used in the target is unfamiliar. Hence it is recommended to break down the overall task into distinct phases which focus on particular aspects of thermo-hydraulics, thermo-mechanics, coupling fluid/structure etc. For this reason it is necessary first to construct a smaller liquid metal loop where certain components may be tested. As such, the liquid metal development includes also the development of components which cannot be bought off-the-shelf.

A sub-scale loop for component development and testing, fundamental thermal-hydraulics and physics investigation involves:

- Liquid metal loop 16 bar rated tightness.
- Pumps rated at 1 l/s (for LBE at 10 [kg/m3]).
- Heat exchangers able to handle 100 kW.
- Flow meter.
- Pressure taps and Pitot tube locally.
- Thermocouples mounted in LM stream

- ❖ Data acquisition through appropriate gas-tight connectors to all sensors. Separate low-frequency multi-channel acquisition from fast acquisition on a few selected channels. (may be common with solid target development)
- ❖ Control and power.
- ❖ Adequate data storage.

Once the sub-scale loop is operating, dedicated tests for evaluating physical phenomenon such as cavitation, fluid-structure interaction or technological test such as sensor development may be envisaged.

Integral testing

The need for integral testing is justified by ensuring the proper functioning of complex machinery once it has been assembled. In many ways this reassembles large scale testing in the nuclear industry, the reason for which an industrial partner has been sought.

For testing under thermal-hydraulic conditions, the partner found to be most willing and able to provide this capability in Central Europe, Skoda JS could ensure testing of the neutron target using their extensive facilities (see below in *Figure 4*) which have been used to test components up to reactor size.

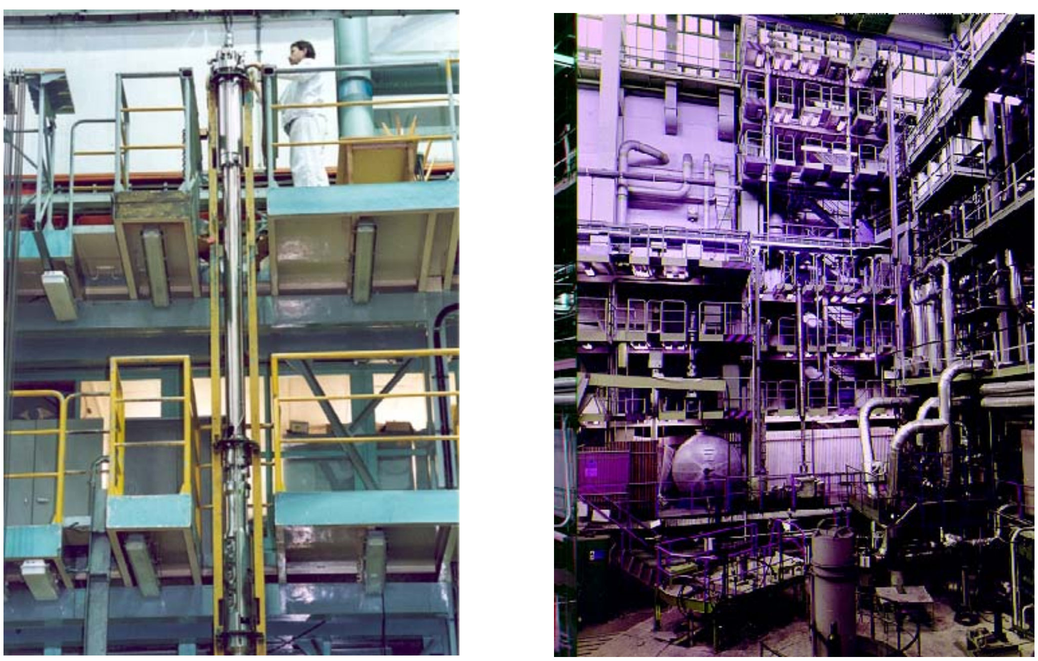


Figure 4: Thermal hydraulic test facility available at ŠKODA Jaderné Strojírenství)

For testing under irradiation, a flexible solution has to be found as many advanced facilities in the world have a tight schedule foe their own internal operations. An integrated spallation target in a representative test is possible using higher power facilities with which the research community has developed historical ties such as JINR-Dubna in Russia and where energies up to 1 GeV may be reached.

Conclusions

The report has specified the essential needs for a high-power target station development based on the latest developments in this field. The definition of the needs is based on practical recent experience in target development which is very diverse in terms of the design solutions envisaged. The specification in the current document does not pre-empt the choice that will be made by the designers for the target design. Instead a wide field of possible collaborations has been sought, in order to give target designers of the future the greatest possible choice for testing their future designs.

Ideally both solid and liquid metal targets should be developed in parallel so as to promote dissemination of knowledge. Some of the facilities may then be shared between a solid target testing station and a liquid metal target testing station if both options are pursued.

The possibility of developing liquid metal (LM) target has been frequently mentioned as a viable option for high-power targets. Solid target development is evolving currently as well, in the quest for ever higher power densities. The attractions of LM must be set against the increase in overall specification demands which are most likely to lead to a cost increase over a purely solid target development program.

Therefore it will be necessary when deciding upon which facilities are to be built, to examine the different target design options as outlined in the introductory part of this report and carry out a rough trade-off study to ensure the merits of liquid-metal technology are worth the additional investment their development will require. First and foremost the limitations imposed on the beam size and power if a solid target were to be selected must be compared against foreseeable demands, to check whether the current and foreseeable solid target development technology may be reaching its limits –or not.

The TIARA work package WP9 within EUCARD will give a clearer idea of the cost for the various testing facilities. Only then will it be possible from a project management point of view to direct further development of the targets testing station in a cost-efficient manner consistent with prioritizing resource allocation to areas most likely to enhance significantly the technology base.

Actinide targets at IPNO

Author: E. Cottereau

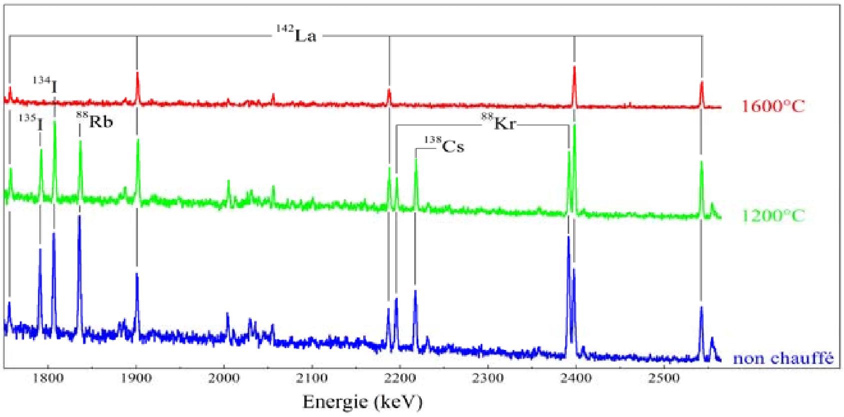
The Institut de Physique Nucléaire Orsay (IPNO) is strongly involved in the study of actinide targets for the production of neutron rich radioactive beams by the ISOL method (isotope separation on line) through active collaborations. IPNO has taken part in EURISOL-DS and is currently in charge of UC_x target developments within the Spiral2 project. An efficient collaboration has been set up with the Sciences Chimiques material laboratory of the University of Rennes (France). A MoU is being established between IPNO and Legnaro (Italy) within the SPES project. Experimental work is performed within the MoU existing between IPNO and Triumf (Vancouver, Canada). Lastly but not the least, IPNO is an active partner of both the ENSAR ActILab project and the Eurisol-net working group. Unfortunately, IPNO's ANR project Priscus was not granted this year.

The aim of the work pursued at IPNO is to increase the target density while improving the release properties. Different precursors are studied for the carboreduction process (uranium oxide and oxalate) along with the arc melting process of uranium and graphite. In parallel, studies on the electrochemical treatment of UCx material are starting in order to deal with the disposal of the targets. Construction is scheduled to start in September 2011 to extend the target laboratory at IPNO. This will enable us to separate the activities dealing with U at room temperature and at 2000°C. An air treatment unit will also be added.

Other fission materials will be investigated including binders for pressed powders, sol-gel synthesis in complex fluids and nanostructures. IPNO participated in the release tests at Isolde of the new dense UC target previously tested at Gatchina.

Characterizing the structure of the UCx targets is essential in order to gain a better understanding of their behavior. An experimental procedure was set up to test the release properties of single UCx pellets. This allows to discriminate between the various prototypes of UCx pellets leaving the on line experiment to the most promising of them. Two pellets of the same composition are irradiated together with neutrons delivered at the ALTO facility in IPNO. These neutrons result from the break-up of 20 nA 27 MeV deuterons impinging on a graphite converter. The activity of each pellet is then measured by gamma spectrometry. One of the pellet is then heated to 1200°C for one hour. Then once again the activity of each pellet is measured. The tests at 1200°C were carried out to demonstrate the feasibility of such a procedure.

The elements to be measured were chosen according to their lifetime, the heating time and the time it takes to transfer the pellets from the irradiation chamber to the furnace. The following elements were chosen after simulation calculations: Kr, Sr, Y, Ru, Sn, Sbn Te, I, Xe, Cs, La and Ce. The following figure shows the evolution of the intensity of some □ rays after heating at 1200°C and 1600°C.



A chamber is under development to test the release properties at 2000°C under vacuum.

Finally, the structural stability of the pellets after heating for over 400 hours was studied with MEB micrographs. Conclusions on the first samples were hard to draw because of the heterogeneity of the surface of the pellets.

<u>**Uranium Carbide Material Developments at CERN-ISOLDE**</u>

Author: A. GOTTBERG

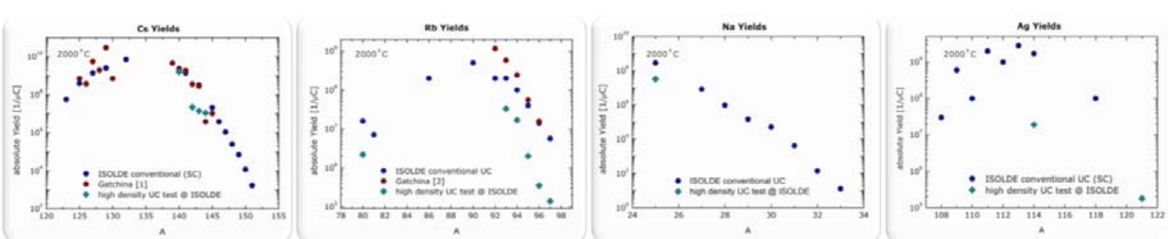
Abstract:

UCx targets have long been used in ISOL-type facilities to deliver a large range of different radioisotopes. Such targets are also central in the operation of next generation facilities, such as SPES, HIE-ISOLDE, SPIRAL2, and ultimately EURISOL. Within the FP7-ENSAR Joint Research Activity ActILab a large collaboration, including members from CERN, GANIL, INFN, IPNO and PSI, is working on novel and innovative technologies to further improve the performance of this promising target material. Activities at CERN involve the exploration of new kinds of material synthesis, online tests of recent types of actinide targets and finally comprehensive studies of structural, crystallographic and chemical evolution during target operation.

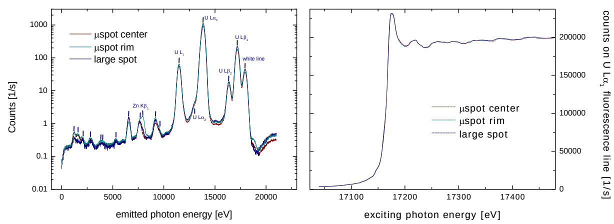
In 2009 more than 70% of the target units used for ISOLDE operation were UCx based. The strong interest in this particular target material arises from the large number of different isotopes strongly produced by CERN's high energy pulsed proton beam through fission, fragmentation, and spallation.

Although the success of this target material is unchanged throughout the last decades and its preparation has not been changed considerably, yet only little is known about the material's chemical and geometrical microstructure before and after irradiation and its contribution to the release properties.

In order to address these questions systematically the ActiLab collaboration was founded. In this framework a well-defined fine-grained Uranium Monocarbide with high density (12.7 g/cm^3) was studied online in a standard ISOLDE target geometry. The measured yields from the high density UC target at ISOLDE are comparable to the ones gained in Gatchina [1,2] after correcting for geometry and proton intensity. But despite its large thickness (241 g/cm^2) this target was found to deliver comparable absolute yields for the studied isotopes of Cs, Rb, Fr, K, Na, and Ag (partly shown in the charts below) compared to conventional ISOLDE UCx targets with smaller thickness (45 g/cm^2)[3]. This observation indicates, that in the case of the high-density material only a small fraction actually contributes to the release of isotopes.



To achieve better knowledge about the influence of the material's microscopic structure on the release properties advanced spectroscopic techniques are applied, both before and after proton irradiation while operation of the material in a target unit. In that way first tests using µ-spot extended X-ray absorption fine-structure spectroscopy have been successfully performed on the high-density material, reveling the chemical and crystallographic details on the µm-scale (see the X-ray fluorescence spectra (left) and the EXAFS spectra (right) below).



[1] V. N. Panteleev, *et al.*, Eur. Phys. J. A **42**, 495-501 (2009)

[2] V. N. Panteleev, EMIS-15, June 25, 2007

[3] ISOLDE Yield Database, http://oraweb.cern.ch/pls/isolde/querz_tgt

Recent results on development of the SPES production target

Author: A. Andrighetto

During the meeting of Eurisol-net working group, the status regarding the R&D activities in target and ion-source of the SPES RIB facility has been presented.

The SPES project at Laboratori di Legnaro of INFN (Italy) is concentrating on the production of neutron-rich radioactive nuclei by the Uranium fission at a rate of 10^{13} fission/s. The emphasis to neutron-rich isotopes is justified by the fact that this vast territory has been little explored, at exceptions of some decay and in-beam spectroscopy following fission. The Radioactive Ion Beam (RIB) will be produced by ISOL technique using a 8kW proton beam that induced fission on a Direct Target.

The most critical element of the SPES project is the Multi-Foil Direct Target which consists on seven UCx discs of 40 mm. diameter each, and about 1 mm. thick. Up to day the SPES target represents an innovation in term of capability to sustain the primary beam power. The design is carefully oriented to optimise the radiative cooling taking advantage of the high operating temperature of a ISOL target (up to 2200^{o}C).

First of all the experimental test e results on thermal behavior of the target system dissipating 10 kW of power has been presented. During the talk has been also presented the developments on the fabrication, characterization, and on-line testing of uranium carbide targets. In particular it has been presented the recent yield measurement performed at HRIBF (ORNL), using the SPES UCx target prototype irradiated by a 40 MeV, 50nA proton beam. During the measurement several n-rich isotopes have been collected: the ion beam intensity reached are in good agreement with the Montecarlo calculation. These experimental yields have been published recently. Next the activity concerning the production of some dedicated targets for p-rich beams production, like LaCx, BC4 and ZrC carbides it has been presented.

Developments related to the +1 ion-sources activity using both surface and plasma ion source techniques have been reported. In addition the preliminary result on 'no-selective' photoionization technique developed at LNL using a Excimer laser, in order to ionize Aluminum isotopes, it has been shown. Finally recent experimental test concerning the vertical handling of the SPES target chamber has been presented: the test performed in the LNL front-end laboratory, testify the feasibility of the proposed SPES handling architecture, which consists on the use of two dedicated devices (horizontal and vertical handling apparatus).

Recent ion source related research and development work at JYFL

Author: H. Koivisto

During the EURISOL-NET meeting the most important work of the JYFL ion source group was described. That included for example the beam transport and metal ion beam production. The presentation included also aspects, which are important to the production of radioactive ion beams like basic research of ion source plasmas. The ARC-ECRIS can offer an interesting option for the charge breeding and beam merging.

The presentation described the new possibility to produce ion beams from the refractory elements. The JYFL ion source group has noticed that the microwave power can be coupled to the sample of interest resulting in the vigorous heating of the sample. Further studies and development will be performed to determine the feasibility of the method. A status of the inductively heated oven was also given.

The experiments performed by the group have shown that the space charge compensation plays a crucial role in the beam transport and consequently methods to improve the compensation are sought. This is a key issue when the beam intensity of medium charge states like Ar^{8+} after the JYFL K130 cyclotron is increased.

The studies involving in the Bremsstrahlung, UV and visible light spectroscopy were described. The motivation of the work is to define the parameters affecting the breakdown process of the ion source plasma. The results can be used to optimize the time-structure of extracted ion beams. In addition, the work can possibly help enhancing the H^- surface production.

As a last item the ARC-ECRIS concept was described. The first prototype was designed, constructed and tested by the JYFL ion source group. As a consequence of encouraging results comprehensive design study was carried out. According to the study the ARC-ECRIS operating at 14 GHz and 42 GHz using copper wires or NbTi superconducting wires, respectively, are feasible. Funding to realize 14 GHz ECRIS have actively been sought.

Metallic beams and charge breeding collaborative R&D

Author: P. Delahaye

SPIRAL Upgrade at GANIL: « hoplites » project

Metallic beams from a FEBIAD

VADIS from ISOLDE (**ongoing, first results**)

1+ n+ for SPIRAL with an ECRIS

Phoenix ECRIS from Daresbury, tested at CERN, on a design from LPSC, recently given to GANIL

upgrade with the help of LPSC and ANL (**ongoing**) **Submitted to the French national Research Agency: ANR**

Target development

Nb, Y_2O_3 … targets with the help of ISOLDE (**not yet started)**

Charge breeding for future ISOL facilities: « EMILIE » project:

Test of a CW EBIS charge breeder concept

A Paul trap as debuncher

REXEBIS –like charge breeder

Partnership between GANIL, CERN ISOLDE, JYFL, LPC Caen and CSNSM Orsay

Optimization of the SPIRAL 2 Phoenix ECRCB from LPSC

INFN as task leader (A. Galata), optimization initiated for the SPES project

LPSC, GANIL, JYFL and Warsaw as partners

Submitted to Nupnet << EURISOL R&D>>

Evaluation by NUPNET: end of July 2011

Status of R&D on ion source at IPNO

Author: C. Lau

IPNO achieves various studies and developments on ion sources in the framework of European projects for future facilities and for the operation of ALTO facility. Most of these developments are dedicated to ion sources for the production of radioactive beams. Developments on ion sources for stable beams have also been programmed, in particular for the national ANDROMEDE project. This short status report will focus on the radioactive ion sources developed at the ALTO facility of IPNO.

The IRENA ion source

For Spiral2 project, IPNO is developing a plasma ion source called IRENA (Ionization by Radial Electron Neat Adaptation). This prototype has been designed to operate under the high level of radiation generated in the Spiral2 irradiation conditions to produce the neutron-rich radioactive beams. This constraining irradiation conditions being a closer step towards the facility designed for EURISOL, a study has been achieved to integrate the IRENA prototype to EURISOL operation, particularly for the multi-mega-watt target station. First IRENA prototypes have been manufactured and tested at the ALTO off-line isotope separator. The preliminary results were quite promising according to estimations worked out during the design, the total extracted currents being comparable to standard FEBIAD used at ISOLDE CERN and ALTO. Furthermore, the first ionization efficiencies obtained for stable Ar are already higher than a few percents. However, none of these results were obtained in operation conditions. Indeed, due to high voltage issues, the off-line separator could not deliver beams over 20 kV. The identification of the various high voltage issues has leaded us to the decision of designing a new extraction electrode. During the design, IPNO has benefited from ISOLDE CERN collaboration. Indeed, even if the specifications are different: small volume of the vacuum chamber, need for a fast withdrawal of the electrode etc., data supplied by ISOLDE CERN were very helpful. The assembly of the new electrode is planned for the end of autumn 2011.

The RILIS in collaboration with ISOLDE-CERN

For the ALTO facility, in collaboration with ISOLDE CERN, IPNO should start soon the operation of a laser ion source. The exploitation of the laser installation will start with the production of neutron-rich Ga beams. The engineer in charge of the lasers at ALTO has been trained at ISOLDE CERN on dye laser techniques, and also has taken part in an experiment.

The submitted NUPNET EURIMIS proposal

In the framework of the first NuPNET call, IPNO has submitted a proposal involving 5 European laboratories: CERN, IFJ (Poland), IPNO (France), LNL-INFN (Italy), SLCJ (Poland). The proposal named EURIMIS (EURIsol Multi-megawatt Ion Sources) is a program for the development of ion source prototypes intended for the EURISOL multi-mega-watt target station. It consists in four work packages, for an overall budget of 320 k€.

Ion beam production and manipulation at IGISOL

Author: A. Jokinen

IGISOL-facility in the Accelerator Laboratory relies on the ion guide technique developed early 80's in the University of Jyväskylä. In the ion guide technique, reaction products recoiling out from the target matrix are stopped in a noble gas, usually He. During the slowing down process, the charge state of ions is reset mainly to 1+. The process is universal and very fast, thus being an interesting alternative for conventional ion source techniques, which usually suffer from physical and chemical selectivity. Ion guide technique has been developed over years and its variations have been implemented worldwide. At JYFL we continue developing and improving the ion guide technique. Our recent studies have concentrated on the laser ionization both in the gas cell but also in the gas jet evacuating the gas volume.

In the production side IGISOL-facility together with sensitive counting of ions with Penning trap has been applied for yield measurements of fission process. This program will be continued in the new IGISOL coming on-line in 2012. In connection to move of the IGISOL-laboratory to new location, preparations for the neutron-conversion target have been started allowing yield measurements of neutron induced fission in the future.

The extracted ion beam from IGISOL-separator can further be manipulated in a various way. A radiofrequency ion cooler and buncher has been developed and fully utilized at JYFL. The recent innovation deals with an optical pumping in the cooler. In this method ionic state of ions of interest is manipulated in such a way, that more efficient transition for further studies can be utilized. This technique has allowed, for example, a collinear laser spectroscopy of some refractory elements, like Y and Mo at JYFL.

In the ion trap technology, we have developed new purification technique called Ramsey-cleaning and multi-injection method to improve measurement efficiency especially for low duty cycle measurements. Both techniques have been employed in measurements requiting extreme precision, like QEC and half-life measurements for super allowed beta decay and double beta decay Q-value measurements. In the near future we will investigate new extraction methods from the Penning trap to improve ion beam properties after the trap.

Beam Manipulation and Purification at ISOLDE and REX-ISOLDE

Author: F. Wenander

At ISOLDE and REX-ISOLDE a large number of projects are on-going in order to improve the beam characteristics of the low-energy and post-accelerated beams. The area covers as diverse topics as low-intensity beam identification, beam purification methods in REXTRAP, development of polarized beams and, charge breeder upgrade plans among other things. A brief overview of some of these beam manipulation and beam purification activities at ISOLDE and REX-ISOLDE will be given.

To suppress isobaric contaminants present in the ISOLDE beam the inherent mass-resolving power of REXTRAP can be used before the beam is charge bred and post-accelerated. The concept has been evaluated during two campaigns. The main result obtained is an optimal mass resolution of 3E4 for 39K for a suppression factor of 98%. It was furthermore shown that the transverse phase space cooling in the trap during this process was sufficient for injection into the successive charge breeder REXEBIS. A total transmission efficiency of 2.5% was achieved for this particular case. Nevertheless, disturbing space charge effects occurred for more than 1E6 ions/bunch (including the contaminants). For instance, spurious double peaks in the cyclotron resonance scan occurred, and the positive results (as well as anomalies) were not fully reproducible. With the recent upgrade of the auxiliary systems for REXTRAP the situation should have improved as the control of the RF settings is made easier and, there now exists a possibility to apply rotating wall excitation in addition to the quadrupolar and dipolar excitations among other things. For the future mass-resolving tests on real beams are expected as well as a follow-up of the rotating wall cooling tests.

The beam identification of the post-accelerated beams is presently performed by the users, by means of a gas-Si telescope detector. The setup has the capability of resolving elements within an isobar up to approximately Z=40. There are discussions about detaching the beam identification from the users and handing it over to the ISOLDE/REX responsible. The use of a monolithic silicon telescope detector from ST Microelectronics from Catania will be investigated. SRIM simulations suggest that Sr and Rb should be resolved in such a device. An initial test with a Sr-Rb cocktail beam is foreseen for the fall.

A test campaign in order to evaluate the suitability of diamond detectors for current amplification, particle counting and energy measurements at REX-ISOLDE has been performed. Single- and poly-crystalline CVD detectors were tried out by E. Griesmayer, Bergoz Instrumentation in collaboration with REX-ISOLDE. Different stable beams were post-accelerated to 1.9 and 2.8 MeV/u. With the sCVD detectors counting rates up to 1E7 particles/s could be demonstrated. In favorable situations an energy resolution of 1.1% (1 sigma) was achieved. The time structure of the accelerator RF was clearly visible, suggesting a time response <1 ns. The results from the pCVD diamond detectors were less convincing as for example the current amplification mode could not be used due to strong variations in the leakage current. The low beam energy (a few MeV/u) means that the impinging particles are stopped within the detectors and this most likely deteriorates the crystal behavior. A follow-up of the applicability of diamond detectors at REX-ISOLDE and the HIE-ISOLDE linac will be done by M. Parlog.

For particle counting in the ISOLDE low-energy (<60 keV) beam lines a Multi-Channel Plate (MCP) can be used. The detector being capable of counting also stable beam particles complements the radioactive beam measurements performed at the tapestation. A fast, low-ringing MCP (Hamamatsu, F9890-13S221) geared towards time-of-flight applications has been ordered. The MCP has a low-resistance extended gain, thus allowing for counting rates up to 1E6 particles/s. The MCP is foreseen to be installed after the tapestation and first results are hoped for before the end of the year.

A superconducting solenoid identical to the one at REXEBIS has been recuperated from the Manne Siegbahn Laboratory. The solenoid is under re-commissioning, i.e. being cooled down and tested at CERN for the moment. It will act as a spare solenoid for REXEBIS in case of failure and, as a test bench for new electron beam gun designs and cathodes. A new IrCe cathode type has been purchased and a matching gun is being designed. The setup, called the TwinEBIS testbench, could in an extension serve as a provider of highly charged to test for example the EMILIE cw trap suggested within the NUPNET network.

With TwinEBIS alternative solutions for a more reliable operation of REXBIS can be tested. However, the main charge breeding parameters cannot be improved as they are strongly connected to the magnetic field strength and its configuration. Thus, within the HIE-ISOLDE project a design study of an upgraded breeder will be performed. The performances required from a point-of-view of increased REX-ISOLDE beam energy and increased beam intensity from ISOLDE will be considered. In addition, the specific requirements of the Test Storage Ring at ISOLDE will be addressed.

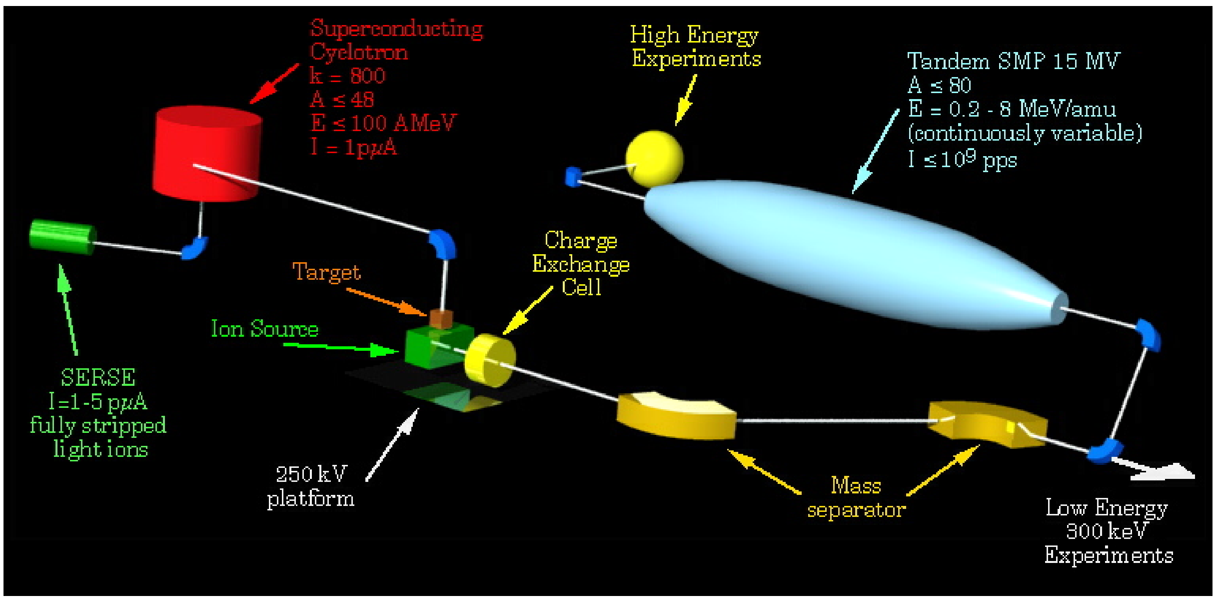
In the presentation several related topics were omitted, such as the production of post-accelerated polarized beams using the tilted foils technique, improvement of the High Resolution Separator and results from the new fast tape station.

Radioactive Ion Beam-s at LNS

Author: L. Celona

Radioactive ion beams are produced at INFN-LNS by mens of two facilities the EXCYT facility (EXotics with Cyclotron and Tandem) and the upgraded FRIB facility (In fliht scheme).

The aim of the EXCYT (EXotics with CYclotron and Tandem) facility is the production and acceleration of radioactive ion beams (RIBs). A primary beam provided by the K-800 superconducting cyclotron will produce, in a target-ion source complex (TIS), the required nuclear species which can be used for low energy experiments (up to 300 keV) or at higher energy by post-accelerating them with the 15 MV tandem.



The nuclear experimental programme started in July 2006 with the experiments BIGBANG and RCS using the post-accelerated 8Li ions. Since then 8Li, 9Li and 21Na beams have been already produced and in the near future production of oxygen, fluorine and chlorine beams have been planned, according to the experimental proposals, with beam intensities ranging between 104to 106 pps and at the typical energies of our tandem. Developments in different fields are ongoing in order to optimize the performance and increase the yield of the species produced. For this purpose different activities are going to start in collaboration with SPES project people to better understand the diffusion–effusion process occurring in the target. New materials and geometries are under investigation to increase the production and the ionization efficiency. Moreover, several alternative solutions are taken into account to directly produce negative ions. Finally a brief overview of the new FRIBS facility (commissioned on this March) with the preliminary results obtained has been given.

Superconducting Radio-Frequency Recent Developments at IPN Orsay

Author: S. Bousson

Abstract :

IPN Orsay is strongly involved in several R&D programs and projects based on SCRF cavities, which are the framework for many developments on superconducting cavity technology. For the Spiral-2 project, IPNO is in charge of the high energy part of the linac, composed of 14 quarter-wave SC cavities resonators. All series cavities have been tested and the first series cryomodule is currently being tested. Within the EURISOL-DS EU program, spoke cavities have been developed for the intermediate energy part of the linac. The last prototype, a triple-spoke resonator has been designed and fabricated and is currently being prepared for chemical treatment. Within the FP7 EUCARD program, two developments are performed: - a 700 MHz, 5 cells, beta 0.65 elliptical cavity for the SPL has been designed and will be fabricated - a new test cavity and associated test-stand has been developed in order to measure and characterize the fundamental properties of new superconducting thin films. In this paper, we will report on the recent achievements on these ongoing SCRF activities.

One page summary:

SCRF development is one of the major technical activity of the IPN Orsay laboratory. Two main activities are directly directed towards developments for EURISOL, and many of the others are relevant for EURISOL and exhibit a strong synergy for the future European facility for radioactive ion beam production.

During the EURISOL-DS, the program on spoke developments ended with the launch in the industry of the triple spoke cavity fabrication. The choice of the cavity type and beta is the results of the optimization of the EURISOL linac performed during EURISOL-DS, as well as the cavity RF and mechanical design. After 18 months of fabrication time by the SDMS Company (France), the cavity was received in IPNO in April 2011, with its helium tank already welded to it. The cavity will then be chemical etched by a mixture of fluorhydric, nitric and phosphoric acid to remove ~120 µm of niobium on the cavity inner surface. After a high pressure rinsing with ultrapure water at 100 bars and assembly in the IPNO ISO 4 clean room, the cavity will be tested at 4.2 K and 2K in a vertical cryostat in September 2011.

Another activity directly linked to EURISOL has started in early 2011: TIARA. This EU program, today in its preparatory phase, is aiming at the development of a pan-European, distributed, multipurpose test infrastructure for Accelerators R&D. In this program, the WP9 is dedicated to infrastructures relevant for Eurisol, i.e. a multi-MW target test platform and a versatile cryomodule for low beta superconducting cavity testing. IPN Orsay is developing this test cryomodule, which will have the capability to host several type of fully equipped (with coupler, He tank and tuner) low beta cavity: half wave, quarter-wave, spoke…

Most of the SCRF group resources are today dedicated to the SPiral-2 project. IPN Orsay is responsible for the high energy part of the superconducting linac based on beta 0.12 quarter-wave resonators. All 16 series cavities have been fabricated and tested in vertical cryostat at 4.2 K. They all performed above specifications (Eacc = 6.5 MV/m and 10 W maximum of dissipated power), with 50% margin in average on the accelerating field and a factor 3 better on the losses. One key preparation step to achieve these high performances was to bake the cavities at 120°C during 48 hours in the clean room after the high pressure rinsing: the benefit was a reduction by a factor 2 on the RF losses of the resonators. The next step now is to assemble the seven cryomodules for the high energy part of the linac (12 MeV – 40 MeV), each housing 2 cavities and their ancillaries like the cold tuning system (for the in-situ cavity frequency regulation) and the RF power coupler.

Intensive R&D is also being carried out on three other high power proton linacs: MYRRHA, ESS and SPL. The MYRRHA project is the demonstrator for an accelerator Driven System (ADS) for nuclear waste transmutation. This facility, to be constructed in Mol (Belgium) is supported by an R&D program within the 7th European framework program called MAX, leaded by IPN Orsay. One of the technical objectives of MAX is to perform reliability studies of accelerators components. A 704 MHz cryomodule housing one elliptical cavity has been designed and constructed in collaboration with INFN Milano. Reliability tests at full power (80 kW) and nominal operating temperature (2K) will be performed at Orsay.

For ESS (European Spallation Source), IPN Orsay is responsible for the study and development of the intermediate energy section of the linac (50 MeV – 200 MeV), based on superconducting double spoke resonators. An RF study of the cavity is under progress, aiming at optimizing the cavity surface fields to reach the 8 MV/m of accelerating field with enough margins. Two cavity prototypes will be fabricated and RF tested during the ESS technical design report (TDR) phase (January 2011 – January 2013).

SPL (Superconducting Proton Linac) at CERN is in an early stage of development, and supported by the special contribution of France to CERN. In that framework, IPN Orsay is designing a half-length cryomodule to host four beta 0.92 elliptical cavities. Innovative solutions have been used for this module, like the mechanical support of the cavities by the power couplers. The conceptual design is now achieved and the aim is to be ready for tendering at the beginning of next year. The other participation of IPNO to SPL is thru the EUCARD European program in which IPN Orsay is developing a beta 0.65 five cells elliptical cavity. The design is achieved and the call for tender has been launched.

Even if all these high power proton accelerators have each some specific features (duty cycle, reliability requirements, cavity gradients…), important synergies on the cavity developments are existing between ESS, EURISOL, SPL and MYRRHA: the progress and achievements that will be done for each project, especially at IPN Orsay, will indeed benefit to all.

Beam diagnostics developments for the HIE-ISOLDE linac

Author: Francesca Zocca

In the framework of the High Intensity and Energy (HIE)-ISOLDE project for the superconducting upgrade of the REX-ISOLDE linac at CERN, an R&D program has been launched including also beam diagnostics developments. A staged construction of a superconducting linac based on sputtered quarter-wave cavities is foreseen downstream of the present normal conducting linac. The main tasks of the HIE-REX beam instrumentation involve the measurement of beam intensity, position, transverse profile, transverse emittance, energy (both in relative terms for cavity phase up and in absolute terms), longitudinal profile and emittance. For intensity, position and transverse profile a diagnostic box is foreseen in each of the inter-cryomodule regions of the linac, and will contain slits, Faraday cups and current-sensitive devices for the lowest intensity beams, while for the transverse emittance measurement an emittance meter is foreseen at the end of the linac. For longitudinal profile measurements aimed at the cavity phase-up, the prototype of a solid state detector monitor is being developed to be placed downstream of the HIE-REX superconducting modules. The number of cavities used to post-accelerate ions at ISOLDE will increase from 5 to 34 with the HIE upgrade, motivating the development of a quick, and eventually automated, solution for tuning the phases of the superconducting cavities.

In this framework a silicon monitor prototype has been tested in a diagnostic box of the REX linac, downstream of the 9-gap resonator. The purpose of this test was the investigation of the monitor performances in terms of cavity phase scanning and longitudinal beam profile measurements. The prototype monitor consisted of a 50mm^2 300 μm-thick partially-depleted Passivated Implanted Planar Silicon (PIPS) detector. An actuator could place the detector on the beam line to directly stop the beam, so that the particle total energy and time of arrival were measured. Tests were performed with a stable ion beam composed of carbon, oxygen and neon ions accelerated at energies from 300 keV/u to 2.82 MeV/u. The beam intensity had to be strongly attenuated in order to reduce the particle count rate on the silicon detector. The monitor is in fact intended for single-particle detection in order to perform a pulse-height energy spectroscopy of the beam particles. Different attenuation methods were investigated and beam intensities as low as a few pps could be reached by means of perforated copper foils. The energy measurements performed allowed for beam spectroscopy and ion identification with a resolution of 1.4 to 0.5 % rms in the measured energy range. The achieved resolution is suited for a fast phase tuning of the cavities, which was demonstrated with the third REX 7-gap resonator. The time structure of the beam, characterized by a bunch period of 9.87 ns, was measured with a resolution better than 200 ps rms. A Time-of-Flight phase-up procedure has also been demonstrated and is a viable option should a chopper be incorporated in the HIE-REX upgrade and the bunch spacing increased.

Diagnostic Devices for Radioactive Ion Beams at INFN - LNS

Author: L. Cosentino

Radioactive ion beams are produced at INFN - Laboratori Nazionali del Sud (LNS) by means of the two operating accelerators, the Tandem and the Superconducting Cyclotron (CS), originally designed to accelerate stable beams. Both the ISOL (Isotope Separation On Line) and the IFF (In-Flight Fragmentation) methods are exploited to produce RIBs in two different ways at different energies: in the first case, the Cyclotron is the primary accelerator and the Tandem accelerates the secondary beams, while in the second case radioactive fragments are produced by the Cyclotron beam in a thin target with energies comparable to the primary beam energy. The ISOL facility is named EXCYT (Exotics at the Cyclotron and Tandem) and was commissioned in 2006, when the first radioactive beam (^{8}Li) has been produced. The IFF installation is named FRIBs (in Flight Radioactive Ion Beams), and it has started to produce radioactive beams in 2001, placing a thin target in the extraction beam line of the Cyclotron. Both the facilities require high efficiency beam diagnostics, that taking into account the low intensity of the beams (< 10^{6} pps), allows to acquire in real time all the beam parameter useful to optimize the beam transport: beam imaging, intensity, isotope identification.

The diagnostic system we have developed for the low-energy beam line (< 300 keV) of the EXCYT facility is called LEBI: Low Energy Beam Imager/Identifier. Such a compact multisensor device allows to cover the needs of the excyt beam transport procedures. It is basically made of two components. One used for the beam imaging that is based on a scintillating screen (5×5 cm^{2} area, 1 - 2 mm thick) made of Cesium Iodide doped with Thallium, CsI(Tl), chosen since its light yield (6 x 10^{4} photons/MeV) is far higher than the ordinarily used phosphor screens. Such a screen is placed at an angle of 45° with respect to the beam axis and is watched by a high sensitivity CCD camera. The second component is used to detect the beta particles emitted as a consequence of the radioactive decay of the isotopes present in the beam. It can measure the beam rate and can identify the beta-emitting radioisotopes by means of their half-life and their beta energy spectrum. The detector is a plastic scintillator BC408 optically coupled to a short photomultiplier tube, that is placed inside the vacuum chamber and is powered by an active voltage divider installed outside. The CsI(Tl) and the plastic scintillator are mounted on the same holder, mechanically fixed to a steel rod that can slide vertically by means of a pneumatic actuator. Depending on the application (stable beam imaging, radioactive beam imaging, beam identification/counting), the device can be inserted in beam in three different operating positions or removed. For acquiring the transversal 2D profile of a stable pilot beam the actuator is slid in, so that the CsI(Tl) screen can directly intercept the beam. Part of the energy released by each particle inside the screen is converted into scintillation light, thus the beam produces a light spot with a shape corresponding to its transverse profile. A shielding grid made of thin metallic wires set at ground potential, is on top of the scintillator front face, in order to prevent charging effects.

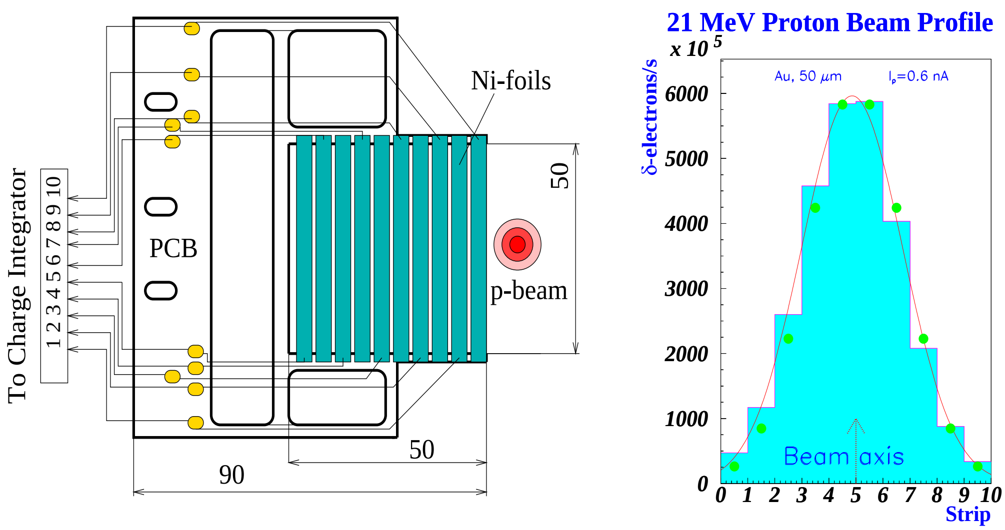
When operating with radioactive beams, and in particular if the beam or some contaminant has a somewhat longer decay time (several seconds or more), one would like to prevent its implantation onto the screen that would result in a long and impractical afterglow. For this reason an additional position of the screen was foreseen, allowing the beam to be implanted on a thin (6 μm) aluminized mylar tape that covers the lower half of the CsI(Tl) screen surface. Whenever needed, the tape can be rolled horizontally by means of a stepper motor, thus providing the screen with a fresh radiation-free portion of tape. The radiation emitted by the decay of the implanted beam particles (mainly β and γ rays), crosses the scintillating screen thus producing the beam image. In order to work in the plastic scintillator mode, the LEBI support rod is placed in the third position. The radioactive beam is implanted onto the thin aluminum reflecting layer used to wrap the plastic scintillator. Roughly 50% of the beta particles emitted by the radioactive species decay interact with the scintillator, thus producing a fast light pulse that is converted into an electrical pulse by means of the PMT. Its output is split along two paths; one goes to a discriminator for the pulse counting, the other to a spectroscopy amplifier for the acquisition of the energy spectrum. The population/decay curves of the radioisotopes is reconstructed by using a multichannel scaler. For beam species involving gamma decay channels, LEBI can be supplemented with one or two high purity coaxial germanium detectors (HPGe).

For the accelerated beams, recent diagnostics has been implemented in order to work with the EXCYT and FRIBs RIBs. More than 20 devices have been installed in the diagnostics points along the LNS beam line, with sensitivity down to the single particle. In each diagnostic point two devices have been installed, each one moved by means of its pneumatic actuator, avoiding the risk of collision between them by means of an anti-collision system. A device consists of a plastic scintillators BC408 (τ_{decay} = 2.1 ns, 5 x 5 x 1 cm^3) coupled to a Hamamatsu R1924A PhotoMultiplier. This detector is fast enough in order to be able of counting the beam particles hitting the scintillator and thus providing the measurement of the beam intensity. The second device consists of a position sensitive silicon detectors (PSSD), that is able of measuring the X-Y coordinates for each beam particle with a resolution within 2mm, therefore allowing the reconstruction of the transversal beam profile very quickly, that is watched in a monitor in real time by the accelerator crew. For all the devices the parameters such as the gains, discrimination thresholds, etc, can be very easly managed from the accelerator consolle. A VME acquisition system collect all the signals (more than 80) coming from the detectors, allowing to measure for each ion beam both the energy released in the detectors and the arriving time. For the PMT based device, an on-board electronics in every diagnostics point implements a leading-edge discriminator, that allows to select the pulses produced by the beam, by setting a threshold directly by the user interface in the consolle, where the beam rate is also showed. The output of such discriminator is also used for the time of flight measurements. This electronics also implements a charge integrator that with a suitable shaping time allows the acquisition of the energy parameter, useful for the identification of the isotopes present in the beam, by means of the energy loss (ΔE) vs. time of flight (Tof) plot. Concerning the PSSD based device, five signals are collected by each detector, the four electrodes of the anode for the coordinate reconstruction and the one of the cathode for the energy/timing parameter. Each signal is sent to a preamplifier placed in air, whose output is amplified by one of the shaping amplifier installed along the beam line, and then sent to the corrispondent ADC channel of the acquisition system. By the same amplifier the fast outputs corresponding to the cathode signals have been sent to the leading edge discriminator of the acquisition system for the trigger of the system itself and possibly used for the timing. The shape distortion that typically affects the response of such devices, has been corrected by means of an algorithm developed by us, that is fast enough to guarantee a real time vision of the beam profile.

High intensity beam diagnostics system based on novel metal micro-detectors

Author: O. Kovalchuk

Physics principle and production technologies have been developed at KINR for the new type detectors of the charged particles as well as synchrotron radiation – Metal Foil Detectors (MFD). Micro-strip MFDs – Micro-strip Metal Detectors (MMD) 0.5 – 1.0 micro-meter thick were used for the beam profile monitoring of the synchrotron radiation as well as for the charged particles: HERA-B Luminosity monitoring, LHCb Radiation Monitoring system, BPM for 21 MeV proton beam (tandem MPIfK), BPM for the LHCb (ST) test beam studies, 21 KeV,



Synchrotron BPM at HASYLAB, 5 MeV Electron beam BPM at KINR, 150 KeV Synchrotron BPM at ESRF.

The current technology allows for production of the thin Ni-strips with a pitch of about few micrometers, providing high position resolution. The main technical features of the MMD: High Radiation tolerance (> 100 MGy); Low thickness of sensors (~1 µm); Low operation voltage (20 V); Perfect spatial resolution (10 µm); Stable operation at X-ray intensity up to 10^{16} photons·s^{-1}·mm^{-2} and proton beam intensity up to 10^{10} protons·s^{-1}·mm^{-2}. Conversion factor of MMD – electrons/particle: ranges from 0.1 (for MIP) to few hundreds (for the fast Heavy Ion), noise – Determined by the connecting cable and readout electronics – ENC: 100 – 500 electrons. Metal detectors are suitable for measuring and imaging beams of charged particle in the energy range from KeV to TeV as well as synchrotron radiation.

In comparison with the latest developments in beam profile monitoring based on the silicon micro-strip or micro-pixel detectors Metal Micro-strip Detectors have an advantage of being extremely thin and semi-transparent device. MMD could be used as a feedback element for stabilizing and/or focusing charged particles beams.