THE MULTI MEGAWATT TARGET STATION INTEGRATION OF THE MAFF/PIAFE FISSION TARGET DESIGN (*)

C. Kharoua[a], R. Rocca[a], O. Alyakriskiy[b], M. Ashrafi-Nik[c], M. Barbui[b], J. Freibergs[d], F. Groeschel[c], M. Gross[e], A. Herrera-Martinez[a], Y. Kadi[a], J. Lettry[a], M. Lindroos[a], F.Nebel[f], F. Negoita[g], Y. Romanets[h], K. Samec[c], L. Serbina[g], Luigi Tecchio[b], P.Thirolf[f], P. Vaz[h], L. Zanini[c]

[a]European Laboratory for Nuclear Research (CERN), Geneva, Switzerland; [b]National Institue of Nuclear Physic (INFN), Legnaro, Italy;
[c]Paul Scherrer Institute (PSI), Villingen, Switzerland; [d]Institute of Physics at the University of Latvia (IPUL), Riga, Latvia;
[e]Ludwig Maximilians University (LMU) and [f]Technical University of Munich (TUM), Munich, Germany;
[g]National Institute of Physics and Nuclear Engineering (NIPNE), Bucarest, Romania;
[h]Insttute of Technology and Nuclear (ITN), Lisbon, Portugal;

Abstract

The European Isotope Separation On-Line facility (EURISOL) is set to be the 'next-generation' European ISOL Radioactive Ion Beam (RIB) facility. It will extend and amplify current research on nuclear physics, nuclear astrophysics and fundamental interactions beyond the year 2010.

In EURISOL, four target stations are foreseen, three direct targets of approximately 100 kW of beam power and one multi-MW liquid metal proton-to-neutron converter, all driven by a high-power proton or light ion linear accelerator. In the multi-MW target assembly, high-intensity RIBs of neutron-rich isotopes will be obtained via induced fission reaction in several actinide targets surrounding a liquid metal spallation neutron source.

This article summarises the work carried out within Task 2 of the EURISOL Design Study, with special attention to the coupled neutronics of the liquid converter and fission target (MAFF/PIAFE design like) and the overall performance of the facility, which will sustain fast neutron fluxes of the order of 10^{14} n/cm^2/s/MW of beam. The production of radionuclides in the actinide targets as well as in the liquid metal is also evaluated, showing that an in-target production of 10^{13} Sn^{132}/s per actinide target can be achieved.

Some of the greatest challenges in the design of high power spallation sources are the high power densities, entailing large structural stresses, and the heat removal, requiring detailed thermo-hydraulics calculations.

Alternatively, a windowless target configuration has been proposed, based on a liquid mercury transverse film design. With this design, higher power densities and fission rates may be achieved, also avoiding the technical issues related to the beam window.

INTRODUCTION

The scientific case for high-intensity RIBs using the ISOL method includes (a) the study of atomic nuclei under extreme and so-far unexplored conditions of composition (i.e. as a function of the numbers of protons and neutrons, or the so-called isospin), rotational angular velocity (or spin), density and temperature; (b) the investigation of the nucleosynthesis of heavy elements in the Universe, an important part of nuclear astrophysics; (c) a study of the properties of the fundamental interactions which govern the properties of the Universe, and in particular of the violation of some of their symmetries; (d) potential applications of RIBs in solid-state physics and in nuclear medicine. These cases require a 'next generation' infrastructure such as the proposed EURISOL [1] facility, with intensities several orders of magnitude higher than those presently available, allowing the study of hitherto completely unexplored regions of the Chart of the Nuclei.

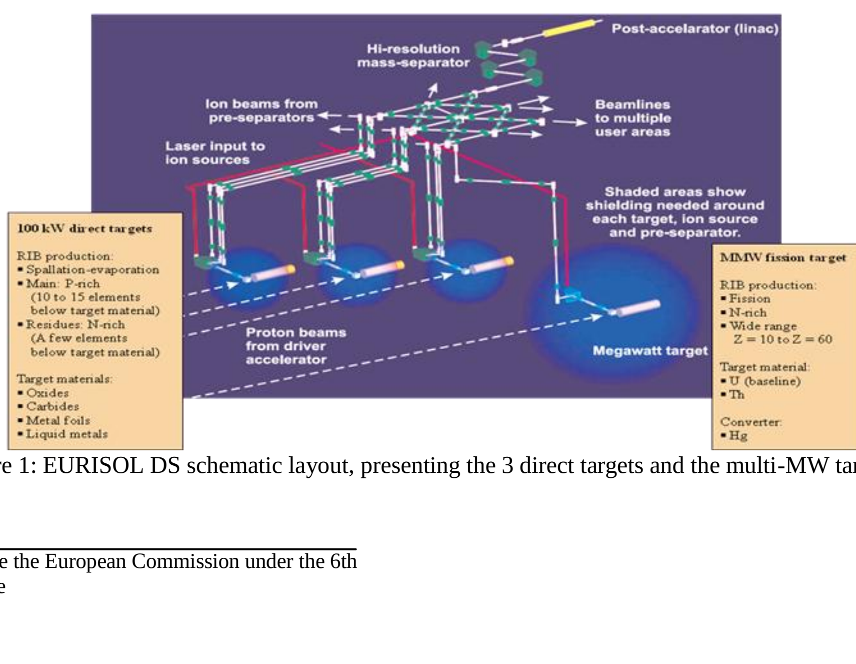

Figure 1: EURISOL DS schematic layout, presenting the 3 direct targets and the multi-MW target station

*Work supported by the the European Commission under the 6th Framework Programme

The main components of the proposed facility are: a driver accelerator, a target/ion-source assembly, and a mass-selection system [2]. As shown in Figure 1, the proposed ISOL facility would use both three 100 kW proton beams on a thick solid target to produce RIBs directly, and a liquid metal 1–5 MW 'converter' target (studied under task 2 of EURISOL [3]), similar to intense spallation neutron sources such as ESS[4], SINQ[5] and SNS[6], to generate high neutron fluxes which would then produce RIBs by fission in secondary actinide targets.
Since the purpose of the facility is to produce radioisotopes, maximizing the yield of such isotopes (e.g. Ni-74, Ga-81, Kr-90 or Sn-132) is the main objective. In the case of the proton-to-neutron converter this implies increasing the neutron yield and reducing the parasitic absorptions in the converter. The compactness and efficiency of the spallation target is mandatory in order to minimize the total inventory of material in the facility and attain the specified neutron flux and fission density.

Several concepts and configurations were studied for the integration of the mercury converter and its fission targets. The study of the mercury jet proposed in the EURISOL-RTD [7] has rapidly demonstrated the considerable number of obstacles to produce such a jet and new proposals for the converter have lead to the two actual designs: the Coaxial Guided Stream (CGS) design and the Windowless Transverse Mercury Film (WTMF) design (Figure 2). The baseline design is the so called CGS one.

Figure 2: The CGS (left) and WTMF (right) design for the spallation target

Similarly different concepts have been studied for the fission targets. In the first configuration it was proposed to use large targets of Uranium carbide as shown on Figure 3. This design results in high thermal stress (as evaluated in [8]). The large quantity of ^{238}U will produce a non-negligible quantity of ^{239}Pu and a dedicated licensing of the facility. The IAP (International Advisory Panel [9]) pointed out the need to decouple the mercury target from the actinide targets and to place the sensitive equipments (like the ion source) away from the harsh radiation environnement. In this respect, we proposed the MAFF/PIAFE [10] design.

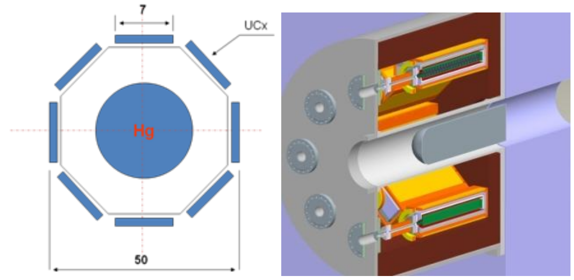

Figure 3: Layout of the UCx target and ion source around the CGS converter [11]

Figure 4 shows a proposal for the layout of the Multi MegaWatt (mMW) target Station. The six beam lines are coming from the different fission targets placed around the converter. The converter is positioned in front of the proton accelerator. As the spallation target is producing a high neutron flux, irradiation port as well as a neutron facility have been included in this layout (Figure 4). This will allow to make use of this powerful neutron source.

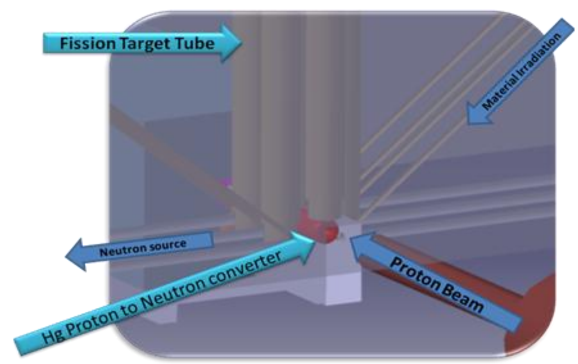

Figure 4: Close view of the spallation target surrounded by the MAFF/PIAFE fission target tube

This article will first go through the calculation showing the behaviour of the converter (neutronics and CFD - Computational Fluid Dynamic). The two designs proposed for EURISOL spallation target will be exposed here. This will lead to the coupled analysis of the converter and the fission targets with special attention to the neutronics yields and thermal behavior of these actinide targets.

THE PROTON TO NEUTRON CONVERTER, THE COAXIAL GUIDED STREAM (CGS) DESIGN

A key parameter in the design of the experiment is the power density, since it will determine the maximum beam intensity that the system can withstand, which in turn is correlated with the fission rates. As elaborated in [12], the energy deposition peaks at ~2 cm after the interaction point, reaching 1.9 kW/cm^3/MW of beam, and decreases rapidly. The beam window is enduring less heat deposition (~900

W/cm^3/MW of beam). These power densities require an inventive liquid mercury flow design and a careful choice of beam window material.

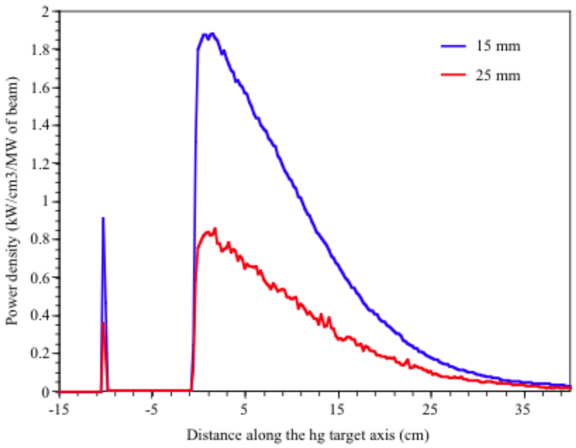

Figure 5: Power density distribution for the considered beam widths, along the beam axis and around the window.

An iterative design process was necessary in order to reduce the large thermal stresses in the beam window (above the 200 MPa limit for martensitic steel T91, below 2 dpa) and the temperature gradient. Finally, these stresses were reduced to ~150 MPa for a beam of 4 MW [13].

This peak stress is acceptable under the provision of a dose limited to 2 dpa. This limitation brings on operational difficulties as it may require a frequent change of the window. Hence it has been suggested that the stress be further lowered through an increase in the beam diameter from 15 mm to 25 mm (defined as the standard deviation of the beam profile).

Figure 5 shows a comparison of power densities for both cases. There is a 2.6 reduction factor gained by the beam enlargement, and a decrease in temperature gradients, proven by the more homogenous power distribution for a 25 mm σ beam. The first peak power is in the small window separating the accelerator and the converter. The converter window is placed at the abscisse 0.

Once the beam window was optimised, the liquid mercury flow inside the target container was recalculated to minimise pressure losses while ensuring adequate cooling of the window and preventing vaporization and cavitation in the back-swept surfaces. Several design changes were performed to improve the flow, such as the use of annular blades along the beam window to accelerate the flow, increase the local cooling and reduce the pressure drop at the 180-degrees turn.

With this design and a bulk pressure of 7.5 bar, the maximum temperature in the beam window is ~200 °C and the maximum von-Misses stress is 135 MPa. The mercury peak temperature is 180 °C (at the beam axis, 2 cm away from the interaction point) and the maximum velocity is 6 m/s in the channels formed by the flow-guides and the walls, at the 180-degrees turn.

Figure 6 represents the temperature distributions within the structural materials and in the flowing mercury. Note the sharp temperature gradient in the beam window, main source of difficulties in the design of this element.

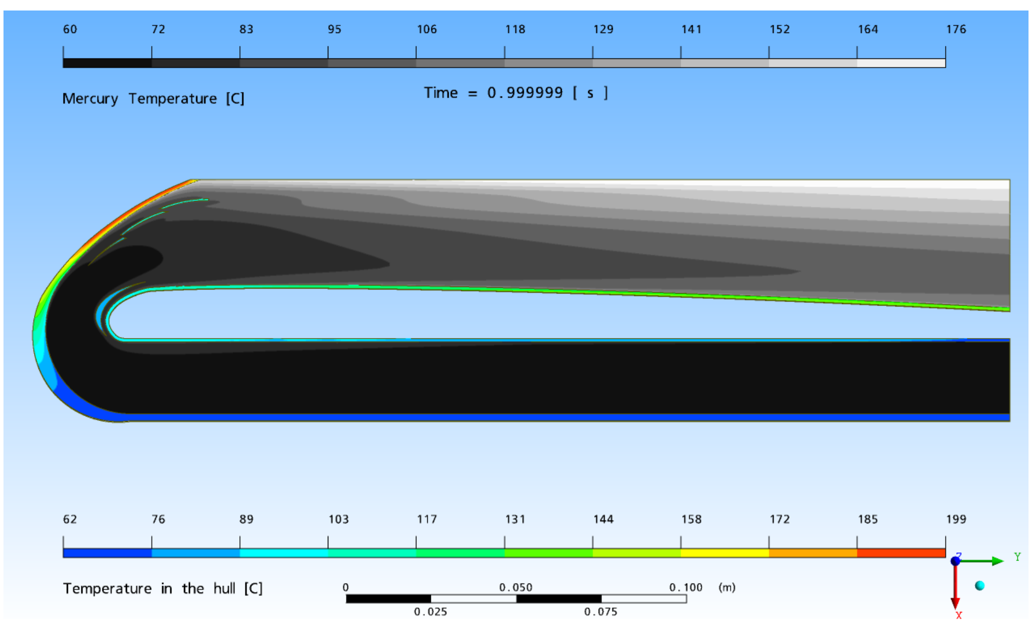

Figure 6: Temperature distribution in the mercury (grey scale) and in the structure (color scale) obtained with ANSYS CFX.[13]

ALTERNATIVE WINDOWLESS TRANSVERSE MERCURY FILM (WTMF) FOR THE SPALLATION TARGET DESIGN

An alternative and innovative windowless design was also developed, to avoid the technical difficulties related to the beam window, also presenting several advantages in terms of neutronics. The transverse mercury film would fall by gravitation, interacting with the proton beam to produce spallation neutrons and efficiently removing the beam power with reasonable flow rates. The most relevant benefit of such design is the brief exposition of the liquid metal to the proton beam, thus permitting an accurate control of the temperature increase in the liquid metal. This is also achieved by setting the local velocity by varying the pitch between flow-guides depending on the beam cooling requirements [14].

Figure 7 shows the basic layout of such a design, where the proton beam path is represented by a red line. The liquid metal flows through the upper tube, and the fins guide the falling mercury. Below the interaction point, the mercury is recovered, pumped to the auxiliary circuit some 10m away, where the volatile separator, the magnetic pump and the mercury reservoir are placed. It was evaluated, with a total mercury flow-rate of about 12 l/s, a temperature increase of the mercury of about 117.5 K for a heat deposition density on the beam center line of 25 kW/cm^3.

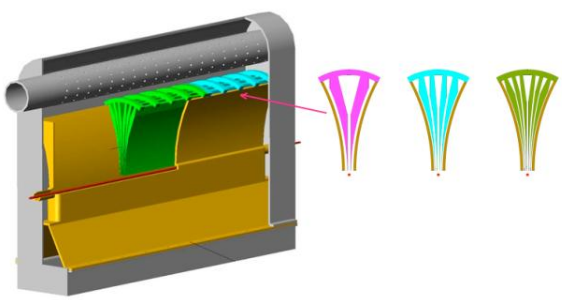

Figure 7: Schematic view of the liquid metal transverse flow target, including the variable pitch flow-guide segments to regulate the flow rate for different power densities.

The technical simplicity of the system, in particular of the beam-target interaction as a free surface, facilitates its operation for extended periods of time by eliminating the need to exchange targets every few months, due to beam window radiation damage and aging [6]. Moreover, the reduced thickness of the film produces a harder neutron spectrum and permits the positioning of flat actinide fission targets closer to the interaction point. This increases the fission density rates and reduces the higher actinide production, by favouring fission rather than capture reactions. The film is decoupled in two regions, a central one (~1 cm thick), receiving the impact of the beam and flowing at high speed, and an external one confining the former (~1.5 cm thick on each side), to avoid high-energy escapes and maximise the production of spallation neutrons.

Figure 8: Film formation against inlet design

Figure 8 illustrates the experimental results of different inlet geometries of the film former. These different prototypes were tested on a liquid metal loop, set up at the Institute of Physics and the University of Latvia (IPUL, Riga). It is an Indium-Gallium-Tin (InGaSn) loop.

The film behaviour and flow stability seem compatible with the EURISOL design requirements, although further tests, involving larger mass flows and heat deposition, should be performed. In order to test the feasibility of the proposed design, a scale model of the transverse film target is being developed and will be constructed and tested with mercury.

PROTOTYPING AND TESTNG OF THE CONVERTER DESIGNS

The Institute of Physics of the University of Latvia is one of the main research centers in the field of MHD (Magneto-Hydro-Dynamics) technology which has been involved in both theoretical and applied studies and experimental work.

The Institute possesses a special mercury laboratory complex including a 350m^2 experimental hall. The

amount of Hg in use reaches 13 tons, almost 1m^3 of mercury.
At this mercury laboratory it is planned to test the WTMF design as well as the CGS design. The MEGAPIE target of the SINQ facility have also been prototyped and tested in this laboratory.

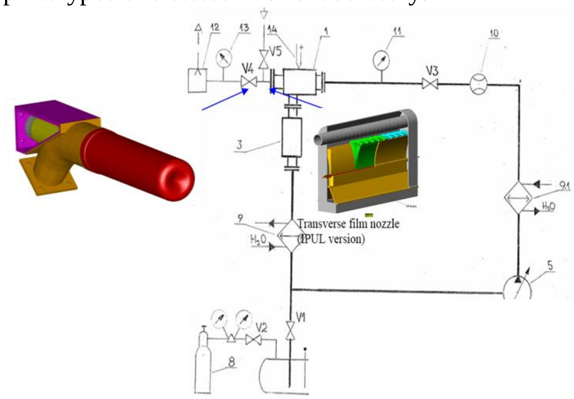

Figure 9: Scheme of the mercury loop

Figure 9 shows the scheme of principle of the mercury loop with the incorporation of the two different prototypes.
In this experimental project, one of the main concerns is the integration of the instrumentation. It is foreseen to measure velocity, pressure and HTC (Heat Transfer Coefficient) in order to validate the design choices.

ANALYSIS OF THE CONVERTER COUPLED WITH THE MAFF/PIAFE FISSION TARGET DESIGN

A thorough study of a preliminary Multi-MW target configuration, optimised for maximum neutron production and complete proton beam containment inside the Hg target, was presented in [12] and [15]. These studies showed that large fission rates (~10^{15} fissions/s) could be obtained with reasonable fission target volumes, i.e. one to five litres of depleted Uranium and led to the development of two technically feasible configurations (CGS and Hg-Jet Option). Both solutions were characterized by fast neutron spectra necessary to achieve the targeted fission rate in ^{238}U and required a fuel mass in the order of 1 kg.
Safety considerations related to the production of significant quantities of ^{239}Pu and concerns about specific isotope production rates, which are not only proportional to fission rates but also affected by neutron energy and release efficiency, suggested undertaking further developments of the design. In order to address these issues the integration of a MAFF/PIAFE configuration in the EURISOL target station has been considered.

In the MAFF design a fission rate of 10^{14} fission/s is reached by using a reduced (~ 1g) amount of ^{235}U within a reactor, which suggested that our targeted fission rate could be reached with a fuel mass of 10 g if a suitable thermalization of the neutron was achieved. The feasibility of this solution from the point of view of neutronics and isotope production is presented in this section.
The main goal of this study was to optimize the moderation of the neutron flux in the fission targets. It has been decided not to modify the design of the spallation target (CGS configuration, [12]), but rather achieve the moderation locally around the fission targets with the twofold purpose of minimising parasitic capture in Hg and realize a modular configuration (i.e. the moderation of each target can be fine tuned according to the fuel employed).

The simulations were carried out using the Monte Carlo particle transport code FLUKA [16]. The model geometry is shown in Figure 10. The position of the targets was chosen on the base of the neutron flux distribution as calculated in a previous study [12].

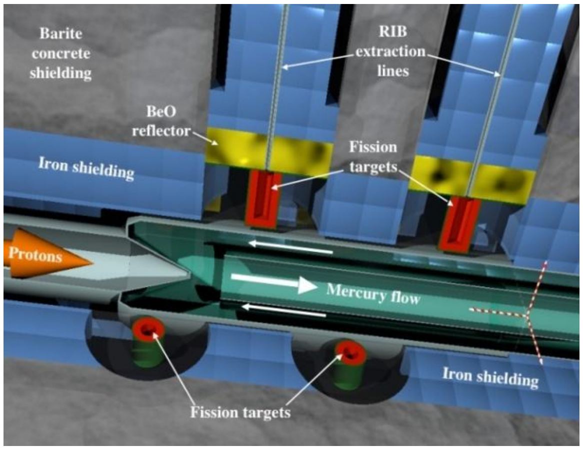

Figure 10: Schematic representation of the baseline mMW target station

The moderator materials considered were amongst most commonly used materials in nuclear reactors: H_2O, D_2O and Graphite. For each combination of moderator and shielding materials the following issues and topics were determined: the neutron flux distributions in the spallation target and fission targets, fission rate and energy deposition in the fission targets. For radiation protection purposes, the neutron flux escaping the system through the shielding walls and points of connection of the body tubes with external elements of facility were also estimated.

The analysis of the fission rate indicates a better performance when water is used as moderator material coupled with the iron shielding (Table 1).

Table 1: Comparative study of moderator and shielding

Moderator	Shielding	Fission in the target [fiss/s/4 mA]
H_2O	Iron	**4.9 x 10^{14}**
D_2O	D_2O	1.5 x 10^{14}
D_2O	Iron	1.3 x 10^{14}
Graphite	Graphite	9.6 x 10^{13}
Graphite	Iron	8.9 x 10^{13}

Following these results a study to compare different fuels and to estimate the effect of the fission target container material on the fission rate in the system has been performed. Four different fuels were considered: natural Uranium, Thorium and highly enriched Uranium dispersed in two different graphite matrices [10]. Their characteristics are summarized in Table 2.

POCO foam was preferred to MKLN graphite for its higher mass content of ^{235}U per unit volume and for its low density and open porosity which allow increasing the release efficiency of the fission target by enhancing diffusion and effusion. The fissile material for the POCO fuel is highly enriched ^{235}U uranium, having an atomic relative content of 10^{-5} ^{238}U and 0.99999 ^{235}U and a density of 19.05 g/cm^3.

Table 2: Fission material characteristics

	Density [g/cm^3]	Main isotope	U/C or Th/O mass	atom content [at %]
MKLN	1.6	^{235}U	0.05	0.25
POCO	0.4	^{235}U	0.5	2.49 ^{235}U
$^{nat}UC_3$	3.0	^{238}U	6.6	0.17 ^{235}U 24.83 ^{238}U
ThO_2	9.86	^{232}Th	6.4	33.33 ^{232}Th

Nine cases were studied, comprising several combinations of fuel and target container material, as summarized in Table 3.

Table 3: Comparative study of fuel and container materials

Fuel	Container	Fission Rate per target [fiss/s/4 mA]
POCO	Tantalum	1.8 x 10^{15}
	Tungsten	1.9 x 10^{15}
	Rhenium	4.9 x 10^{14}
$^{nat}UC_3$	Tantalum	3.8 x 10^{14}
	Tungsten	4.1 x 10^{14}
	Rhenium	1.3 x 10^{14}
ThO_2	Tantalum	5.8 x 10^{13}
	Tungsten	5.8 x 10^{13}
	Rhenium	5.8 x 10^{13}

The results show that POCO and natural Uranium give one order of magnitude higher fission rates than Thorium. Nonetheless Thorium is a fuel of interest because of its species production of isotopes and chemical nature.

The calculation also shows that the estimated fission rates obtained with natural Uranium and POCO are enhanced by a factor 4 using a Tungsten or Tantalum container instead of Rhenium, while the fission rate with the Thorium fuel has a consistent value with all containers.
This is due to the high capture cross section of Rhenium (85±5barns [19]) at thermal energies compared to the other materials (Ta~22±1barns and W~18.5±0.5barns [19]) and to the high energy fission threshold of Thorium. The effect of neutron absorption in the container on the energy spectrum within the fission target can be observed in Figure 11.

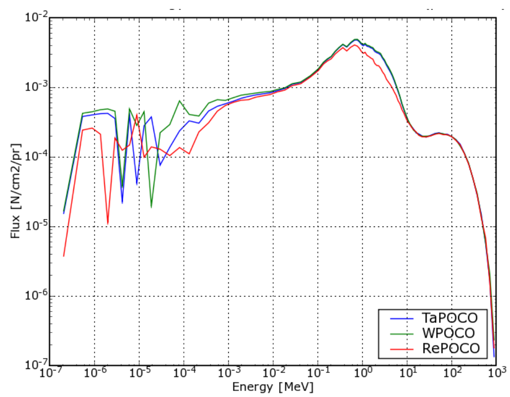

Figure 11: Neutron flux spectrum in the POCO fission target for different container materials

The detailed isotopic distribution of the fission fragments has been assessed, allowing the prediction of in-target RIB intensities for specific isotopes. The production rates for several reference isotopes [2] are reported in Table 4. The use of depleted uranium carbide and thorium oxide entails a reduction in the production of asymmetric fission fragments in the region of mass number 90 and 140, but also an increase of up to one order of magnitude in the yields of isotopes in between the aforementioned regions, as may be observed in Figure 12.

Table 4: In-target yields in a single Tantalum encased fission target for several relevant isotopes

Isotope	POCO [at/s/4mA]	$^{nat}UC_3$ [at/s/4mA]	ThO_2 [at/s/4mA]
^{74}Ni	9.72 x 10^{9}	8.77 x 10^{09}	**9.73 x 10^{10}**
^{81}Ga	7.70 x 10^{11}	7.70 x 10^{11}	6.23 x 10^{11}
^{90}Kr	**1.03 x 10^{14}**	2.10 x 10^{13}	2.95 x 10^{12}

^{99}Mo	**1.08 x 10^{14}**	2.27 x 10^{13}	1.53 x 10^{12}
^{132}Sn	3.19 x 10^{13}	1.68 x 10^{13}	1.58 x 10^{12}
^{214}Fr	na	2.50 x 10^{09}	**7.74 x 10^{10}**

As an example of isotope production peculiar to thorium oxide, the fission fragments distribution of Indium is shown in Figure 13.

These results highlight the complementarities of the three fuels and support the design choice of developing a modular target station.

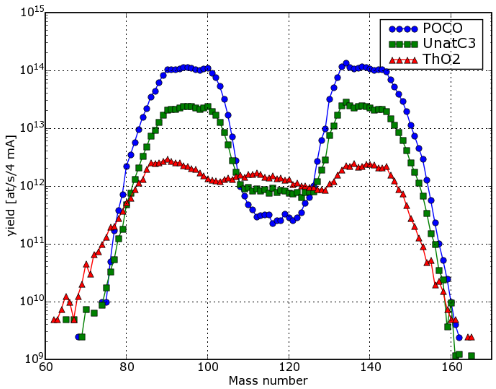

Figure 12: Isotopic yields obtained with the three fuels and Tantalum container as a function of mass number

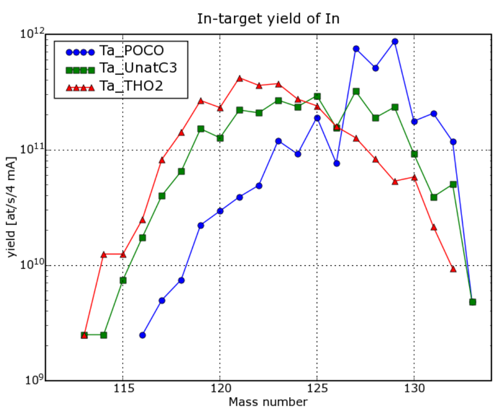

Figure 13: In-target Indium yield

PRELIMINARY THERMAL STUDY OF THE FISSION TARGET

The design of the fission target has been inspired by the MAFF/PIAFE [10] studies. The target is made of a graphite matrix impregnated with ^{235}U through a chemical process: a solution of Uranyl nitrate is impregnated in the porous graphite matrix, it is then converted into UO_2 (U_3O_8) by NO_x outgasing in a controlled heating system under vacuum and it is finally transformed into UC_x by further heating [10].

This fissile material is inserted in the fission target tube, which is the structure holding the beam optics, the ion source and the others ancillary equipments needed for the extraction of the isotopes (Figure 14). It is also used for extracting the heat through the cooling circuit, hereby designed as a simple coil (Figure 15). As previously mentioned in this article there are six fission target tubes placed around the spallation source (Figure 4). The graphite matrix impregnated with Uranium is a cylinder with a central hole for the fragment extraction as shown in Figure 15 and it is enclosed in a container made of Rhenium (other materials have been studied for the neutronics but only Re was considered for this thermal study). This container is seated on a support made also from Rhenium. This support is positioned on a Beryllium oxyde insulator, which is fixed to the fission target tube.

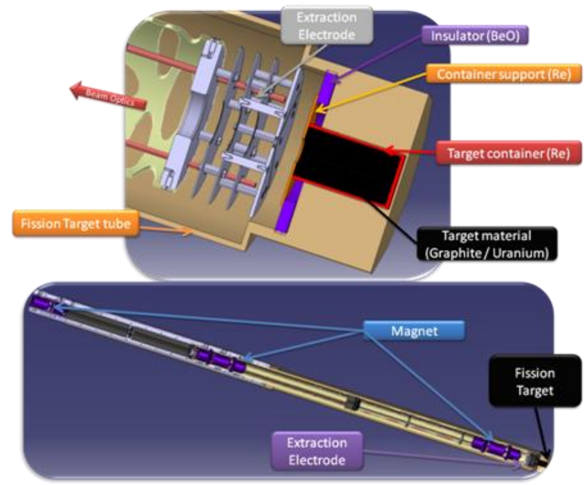

Figure 14: The Fission Target Tube

This study was carried out in order to assess the feasibility of integrating the MAFF/PIAFE design into the EURISOL Multi MegaWatt Target station. Table 2 below compares the parameters from both designs, MAFF against EURISOL.

	MAFF	EURISOL DS
Number of fission per second	10^{14} fission/s (thermal neutrons)	10^{15} fission/s (spallation neutrons)
Power induced in the target	3,2KW	32KW
Target volume	10cc	100cc
Power density	320W/cc	320W/cc
Material	PG 100 &150	PG 100 &150, POCO
Material conductivity	~80 W/m/K but unknown for high temperature and with U-content	~80-50 W/m/K but unknown for high temperature and with U-content

Table 5: Parameters comparison between MAFF and EURISOL

In the MAFF study it was shown that this target could be operated at 320 W/cm^3. Therefore, we chose to use the same power density with an increase by a factor 10 of the volume to produce the order of magnitude enhancement in the fission rate. The simulation and the modeling have been done using ANSYS [18]. Figure 15 shows the model used with the five main parts of it. Note that only the section (shown on Figure 15) of the fission target tube has been taken into account in order to have a simple and fast to solve model.

The main heat exchange occurs between the inner surface of the fission target tube and the outer surface of the container, through radiation. This was considered in order to minimize the temperature gradient inside the target, to reduce thermal stresses and, to avoid any cold spot and enhance the diffusion effusion process.

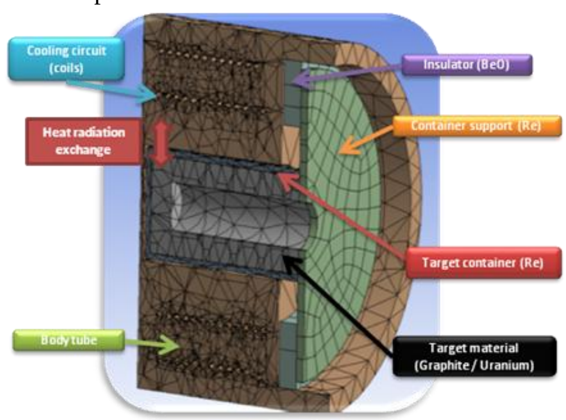

Figure 15: Cut view of the model

In order to estimate the worst cases and best cases, and due to the lack of known properties of the target material, two values for the thermal conductivity of graphite have been tested: a low conductivity at 45W/m/K and a high conductivity at 150W/m/K. It was also foreseen to evaluate the effect of the cooling system. Therefore different boundary conditions have been applied to the fission target tube or the coil: a "perfect" cooling system with the fission target tube at constant temperature (around 25°C) and a "standard" cooling where the heat is extracted through the coil.

Moreover, for each case the internal heat deposition has been introduced as uniform in the graphite and two values were tested.

For example, if we consider that one single target is producing 10^{15} fission/s; it means:

- 10^{15} x 2.10^8 eV/s in 100cm^3
- **320W/cm^3**

So the 2 values used for the simulation are 320W/cm3, 160W/cm3; respectively these values correspond to the hypothesis that the aimed fission rate (10^{15} fission/s) is achieved by one target or the combination of two targets.

Figure 16 shows the temperature map in the target and the Fission target tube for a uniform deposition of energy, equivalent to 10^{15} fission/s (320W/ cm^3). The heat generated by the fission in the target is extracted through the coils. The graphite chosen here has the lowest thermal conductivity.

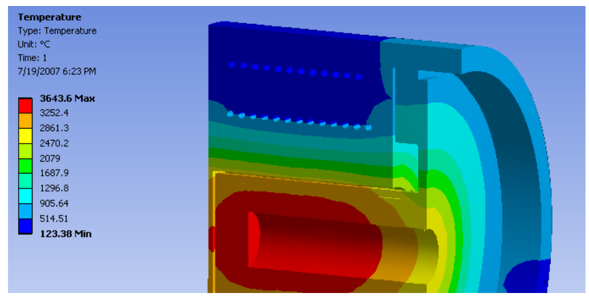

Figure 16: Temperature plot ("standard" cooling)

The temperature is too high (3600°C) for the application and the material. It is still probably possible to minimize it. As shown on Figure 17 the same condition applied with a perfect cooling system will bring the temperature down by nearly 800°C.

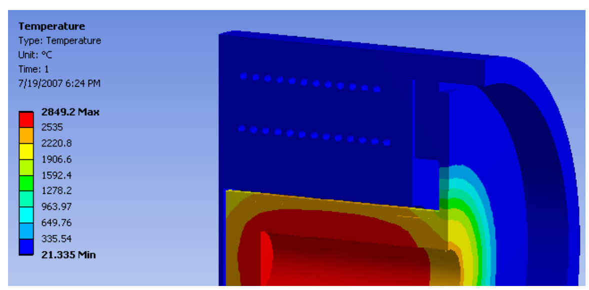

Figure 17: Temperature plot ("perfect cooling)

This temperature is still too high for the ISOL application. The required temperature is about 2200°C. By looking at the table 6 below, this condition can only be reached for the cases with a power deposition of 160W/cm^3 (5.10^{14} fission/s) or/and with a higher conductivity of the graphite.

Material conductivity	Energy deposition	Type of cooling	Maximum temperature
Graphite with Low Thermal conductivity	Full energy deposition in 1 target (32KW ~)	"Perfect"	2850°C
		"Standard"	3600°C
	Half energy deposition in 1 target (16 KW~)	"Perfect"	2160°C
		"Standard"	2430°C
Graphite with High Thermal	Full energy deposition in	"Perfect"	2550°C

conductivity	1 target (32KW ~)	"Standard"	3240°C
	Half energy deposition in 1 target (16 KW~)	"Perfect"	1990°C
		"Standard"	2220°C

Table 6 : Overview of the thermal analysis results

The several cases studied show that the integration of the MAFF/PIAFE target into EURISOL Multi Megawatt target station might be possible. But considerable studies, designs and simulations remain and will require a major effort to provide a final proposal.

For example in order to perform a full thermal analysis of the proposed design, the graphite material chosen, impregnated with the desired quantity of Uranium, needs to be fully analyzed and more realistic boundaries conditions applied.

The following properties need to be measured over the temperature range of the target usage condition (25°C up to 2500°C) and under radiation: specific heat, thermal conductivity, density, etc …

Chemical behavior of the desired material should also be studied.

A key parameter for all the design is the safety requirements and guide lines for both fission target and proton to neutron converter.

CONCLUSION

All the studies on the multi Megawatt target station and its ancillary equipments have significantly advanced in the last year. It was shown that the integration of the MAFF design for the fission target is compatible with the CGS converter design. Moreover the integration of such targets might be more suitable with a different configuration (like the WMTF design or the flat SNS target type) of the mercury converter.

The technical feasibility of such a mMW target assembly for EURISOL has been demonstrated by the Monte Carlo calculation for the neutronics but more calculations and experiments are needed to fully demonstrate the concept and especially a full thermo-mechanical study.

ACKNOWLEDGMENTS

We acknowledge the financial support of the European Commission under the 6th Framework Programme “Research Infrastructure Action-Structuring the European Research Area” EURISOL DS Project Contract no. 515768 RIDS. The EC is not liable for any use that may be made of the information contained herein.

We acknowledge the contribution from the MAFF project team and thank for their collaboration.

REFERENCES

[1] *EURISOL DS; European Isotope Separation On-Line Radioactive Ion Beam Facility Design Study*, EC – FP6 Research Infrastructure Action-Structuring the European Research Area, Project Contract no. 515768 RIDS; available at www.eurisol.org

[2] J. CORNELL (Ed.), *The EURISOL Report: A Feasibility Study for a European Isotope-Separation-On-Line Radioactive Ion Beam Facility*, GANIL, France, 2003.

[3] *Task2 of EURISOL DS; The Multi MegaWatt Spallation target;* Y. Kadi (task leader) www.eurisol.org/task2

[4] G. Bauer et al. (Eds.), ESS: A Next Generation Neutron Source for Europe, ISBN 090 237 6 500 and 090 237 6 659, ESS Council, March 1997.

[5] G. Bauer et al., *Target Options for SINQ – A Neutronic Assessment*, TM-36-97-04, Paul Scherrer Institute, Villingen PSI, Switzerland, 1998.

[6] The SNS Collaboration, *National Spallation Neutron Source Conceptual Design Report – Volume 1*, NSNS/CDR-2/V1, Oak Ridge National Laboratory, United States, May 1997.

[7] Co-ordinated by Prof. Jean Vervier (UCL, Louvain-la-Neuve, Belgium) and Edited by John Cornell (GANIL, Caen, France), *The EURISOL Report - RTD (Research and Technical Development)*, GANIL, December 2003, Caen, France

[8] E. Brun (PSI), K. Samec (PSI), L. Tecchio (INFN), *Detail thermal stress analysis of EURISOL Fission*, TM-34-07-02, Paul Scherrer Institute, Villingen PSI, Switzerland, 2006.

[9] Dr. Sytze Brandenburg (KVI/RuG), Prof. Witold Nazarewicz (University of Tennessee/ORNL), Dr. Paul. Schmor (TRIUMF), *The report of the International Advisory Panel,* IAP, 30 November 2007, CERN, Geneva, Switzerland

[10] H.J. Maier, D. Habs, M.L. Gross, R. Grossmann, O. Kester, F. Ospald, P. Thirolf, *"Target*

development for the Munich Fission Fragment Accelerator", Nuclear Instruments and Methods in Physics Research A 521 (2004) 54−58.
[11] Fission Target Design, L. Tecchio (INFN-Legnaro), F. Negoita, L. Serbina, E. Udup (NIPNE-Bucharest): Eurisol web site 04-25-2007-0009
[12] A. Herrera-Martínez, Y. Kadi, *EURISOL-DS Multi-MW Target: Neutronic Calculations for the Baseline Configuration*, CERN-AB-Note-2006-035 and EURISOL-DS/TASK2/TN-2006-05.
[13] M. Ashrafi-Nik, *Thermo hydraulic optimisation of the EURISOL DS target*, TM-34-06-0, Paul Scherrer Institute, Villingen PSI, Switzerland, 2006.
[14] J. Freibergs, E. Platacis, *Engineering design and construction of a function Hg-loop*, EURISOL DS Task 2 Internal Note, Institute of Physics at the University of Latvia (IPUL), 2007.
[15] A. Herrera-Martínez, Y. Kadi, *EURISOL-DS Multi-MW Target: Comparative Neutronic Performance of the Baseline Configuration vs. the Hg-Jet Option*, CERN-AB-Note-2006-037 and EURISOL-DS/TASK2/TN-2006-07.
[16] A. Fassò, A. Ferrari, J. Ranft, and P.R. Sala, *FLUKA: a multi-particle transport code*, CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773.
[17] A. Herrera-Martínez, Y. Kadi, M. Ashrafi-Nik, K. Samec, J. Freibergs, E. Platacis, *Engineering Design of the EURISOL Multi-MW Spallation Target*, in Proceedings of the OECD-organised 5th International Workshop on Utilisation and Reliability of HIgh Power Proton Accelerators, (HPPA5), SCK•CEN, Mol, Belgium, 6-9 May 2007 Also: CERN-OPEN-2007-016.
[18] C. Kharoua, Y. Kadi, *EURISOL-DS Multi-MW Target - Preliminary Thermal Study of the MAFF target concept, integrated into the Baseline Configuration,* CERN, Geneva, Switzerland, 2007
[19] Qivx Inc, www.qivx.com/ispt/q_ptw.php
[20] EURISOL Fission Target Design adapting MAFF concept, O. Alyakrinskiy, M. Barbui, L.B. Tecchio (INFN-Legnaro), F. Negoita, L. Serbina, E. Udup (NIPNE-Bucharest), Eurisol web site 04-25-2007-0010