EURISOL DS PROJECT

Task#2: MULTI-MW TARGET DESIGN

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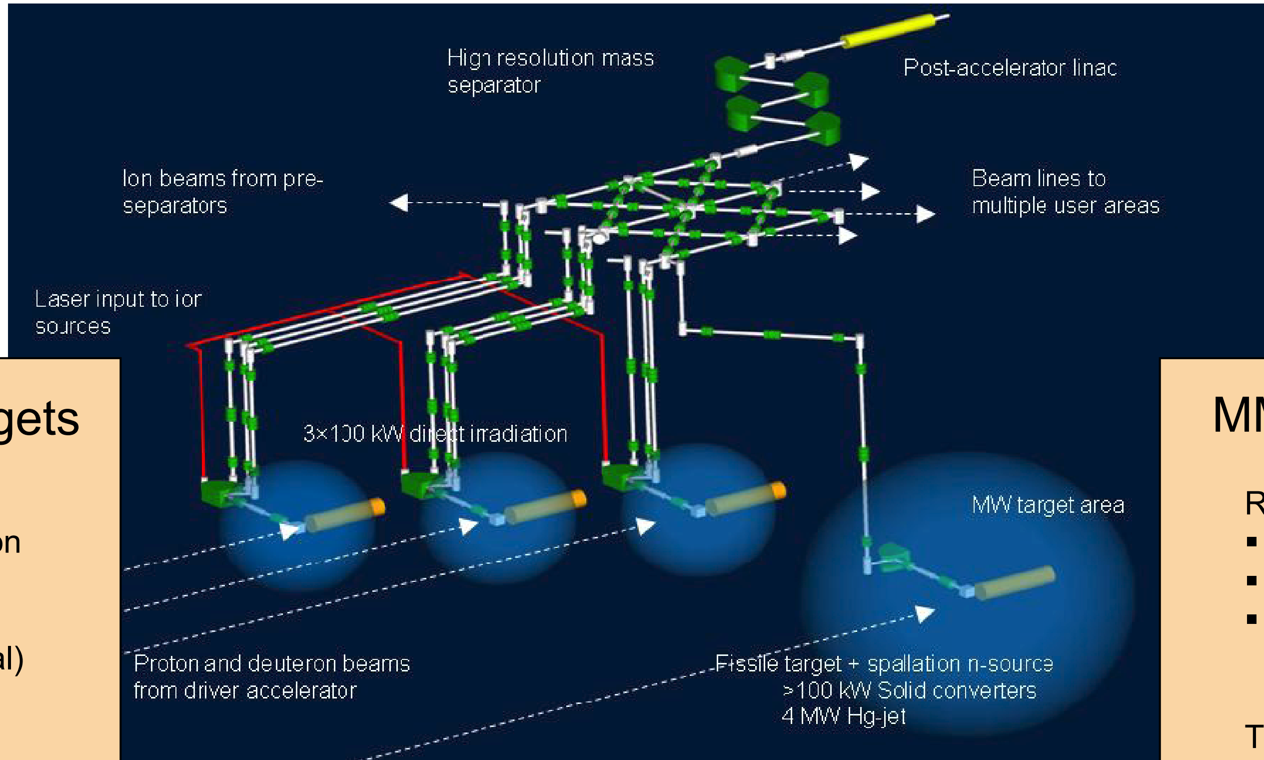
EURISOL Target Stations

EURISOL
Design Study



100 kW direct targets

RIB production:
- Spallation-evaporation
- Main: P-rich
  (10 to 15 elements
  below target material)
- Residues: N-rich
  (A few elements
  below target material)

Target materials:
- Oxides
- Carbides
- Metal foils
- Liquid metals

Participants:
~20 institutions

Contributors:
~20 institutions

EU suport (~30%):
~9.2 MEuros

Duration:
2005-2009

12 Tasks are active

MMW fission target

RIB production:
- Fission
- N-rich
- Wide range
  Z = 10 to Z = 60

Target material:
- U (baseline)
- Th

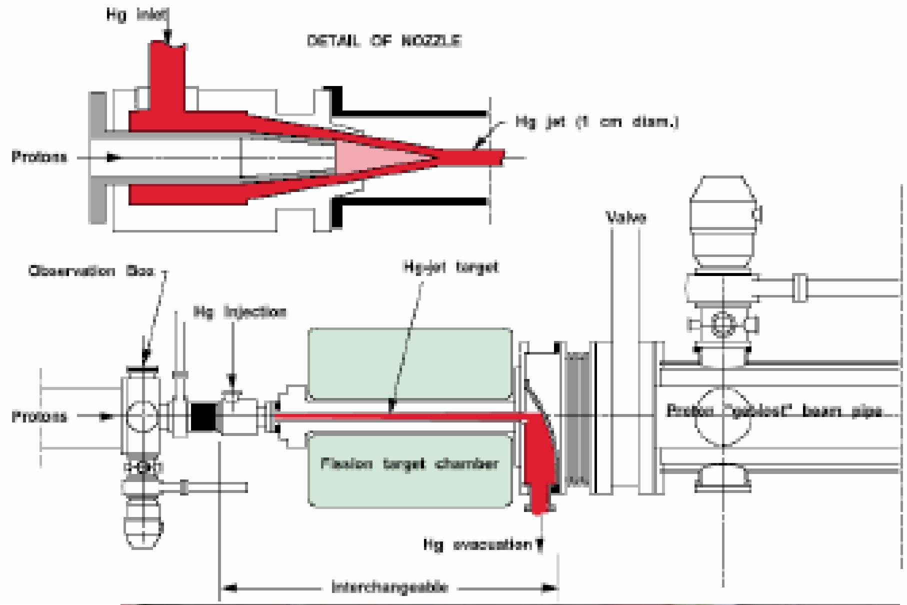
Converter:
- Hg

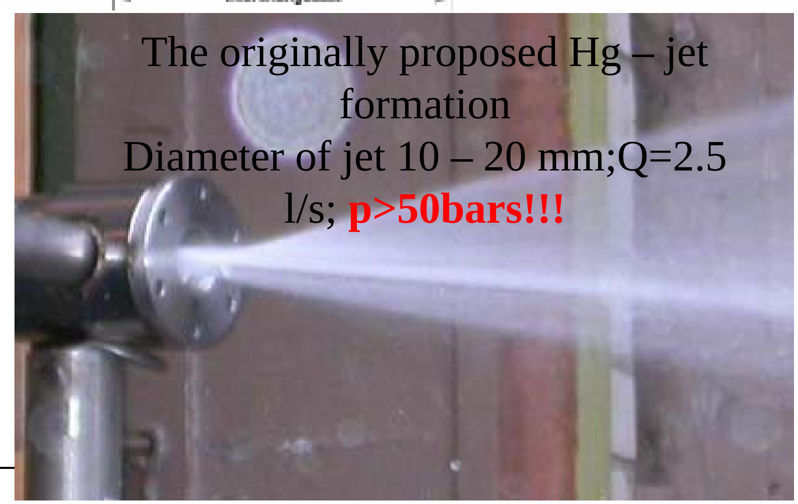
EURISOL-DS Targetry Challenges

EURISOL Design Study

EURISOL shall deliver beams 3 orders of magnitude higher intensity than in presently operating facilities.

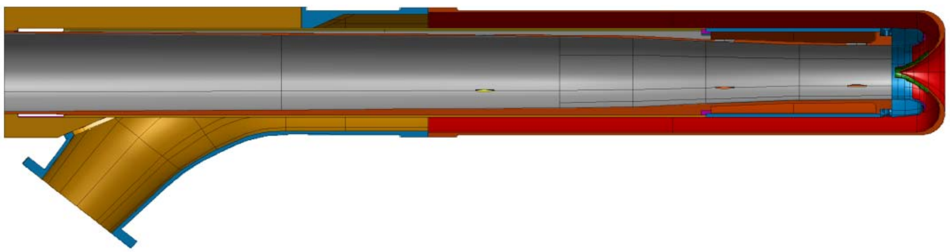
Parameter	Symbol	Units	Nval	Range
Converter Target material	Z_{conv}	-	Hg (liquid)	LBE
Secondary Target material	Z_{targ}	-	UC_x, BeO	
Beam particles	Z_{beam}	-	Proton	
Beam particle energy	E_{beam}	GeV	1	2
Beam current	I_{beam}	mA	4	2 – 5
Beam time structure	-	-	CW	50Hz 1ms pulse
Gaussian beam geometry	σ_{beam}	mm	15	< 25, parabolic
Beam power	P_{beam}	MW	4	< 5
Converter length	l_{conv}	cm	45	85
Converter radius (cylinder)	r_{conv}	cm	8	4 – 15
Hg temperature	T_{conv}	°C	150 – 200	<< 357
Hg flow rate	Q_{conv}	ton/s	0.1 – 0.2	<< 1
Hg speed	V_{conv}	m/s	~5	<< 15
Hg pressure drop	ΔP_1	bar	1 – 2	< 10
Hg overpressure	ΔP_2	bar	5 – 7	< 10
UC_x temperature	T_{targ}	°C	2000	500-2500





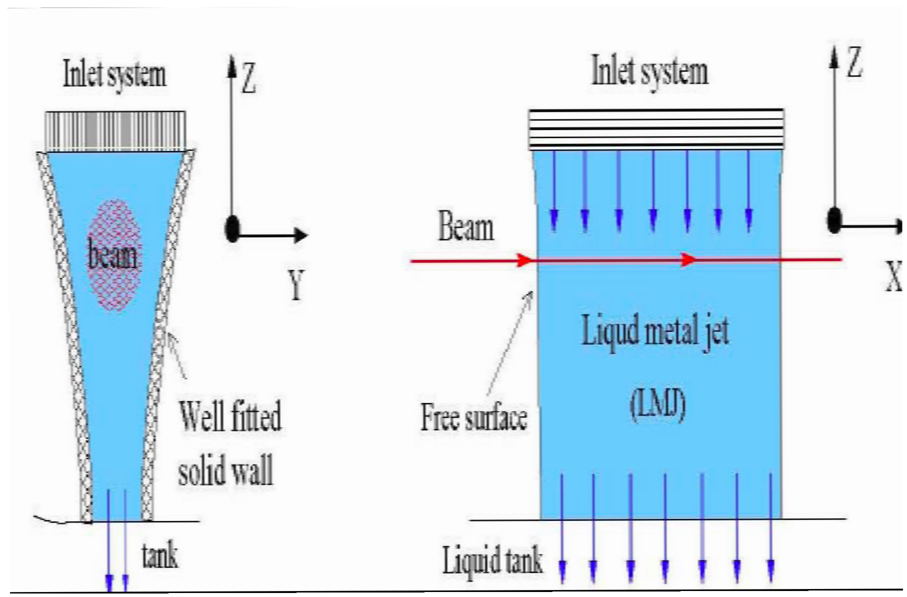
Task#2 – Multi-MW Liquid Hg Target

- Compact Hg-loop with beam widow
- Confined transverse film windowless



Deliverables:

1. Engineering study of the thermal hydraulics, fluid dynamics and construction materials of a window or window-free liquid-metal converter.
2. Study of an innovative waste management in the liquid Hg-loop e.g. by means of Hg distillation.
3. Engineering design and construction of a functional Hg-loop.
4. Off-line testing and validation of the thermal hydraulics and fluid dynamics.
5. Engineering design of the entire target station and its handling method



PbBi Alternative – Neutron Balance

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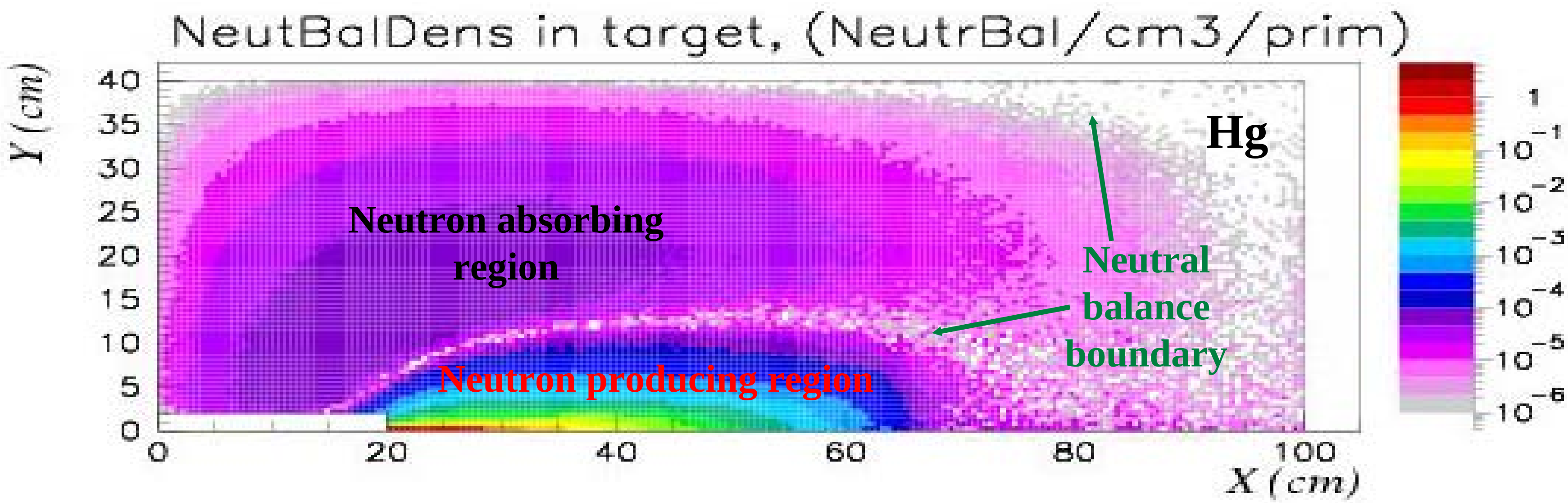
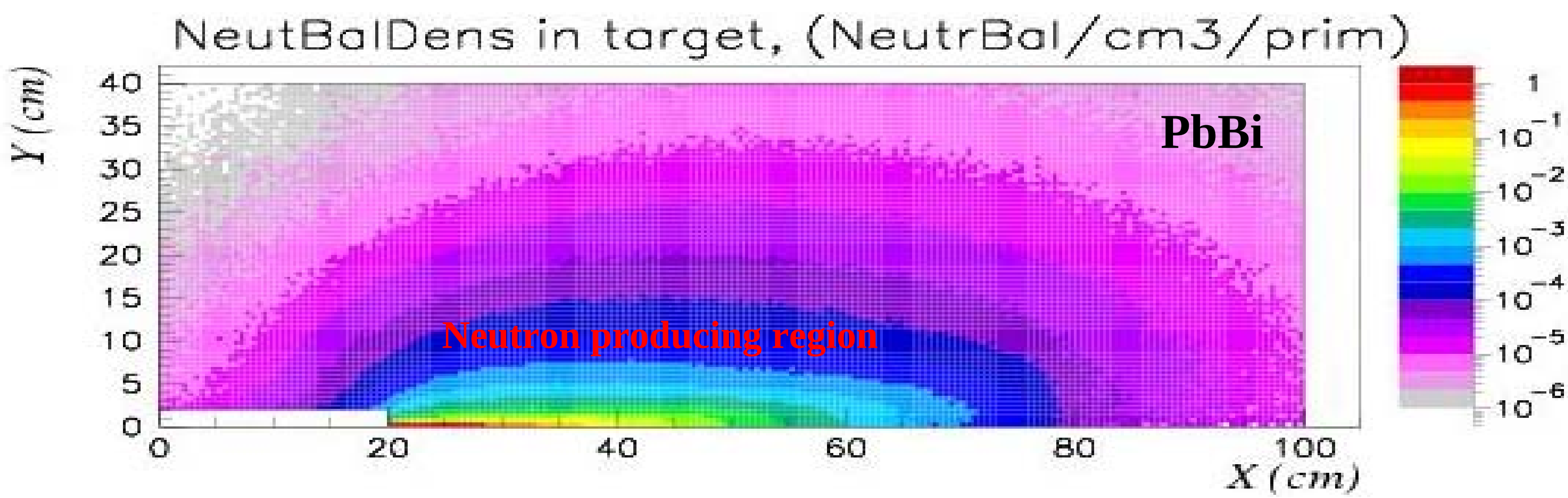
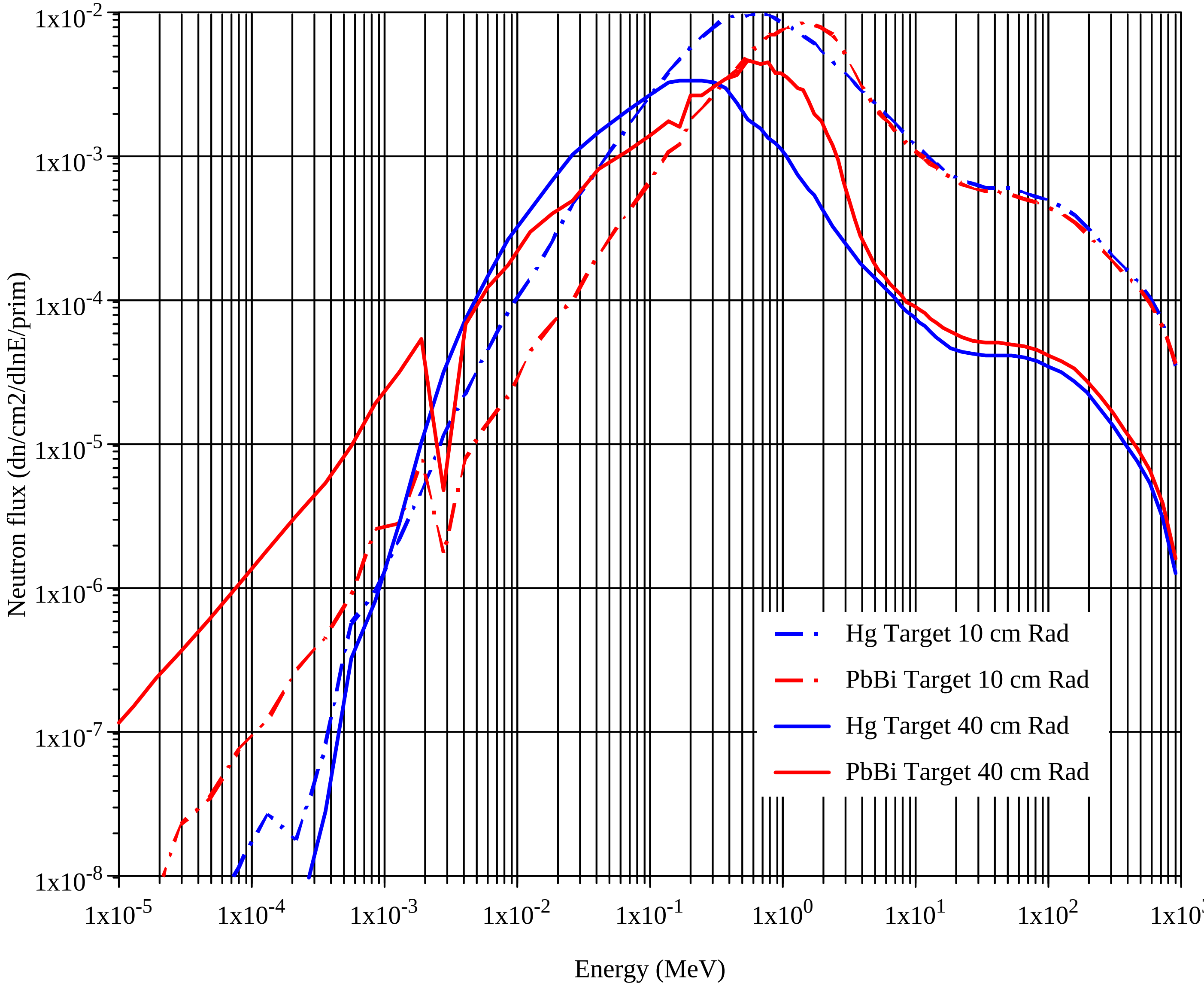




PbBi Alternative – Neutron Spectrum

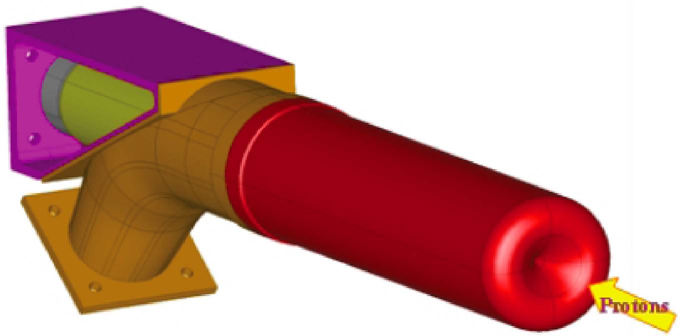


180º Coaxial Bend Target

PSI PAUL SCHERRER INSTITUT

Basic performances of the target

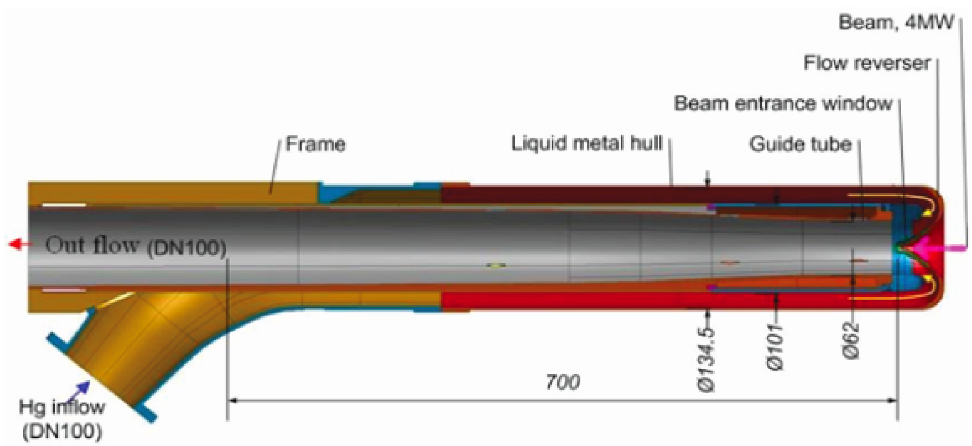
TM-34-07-05 K.Samec /Design of the EURISOL converter target. – PSI 2007

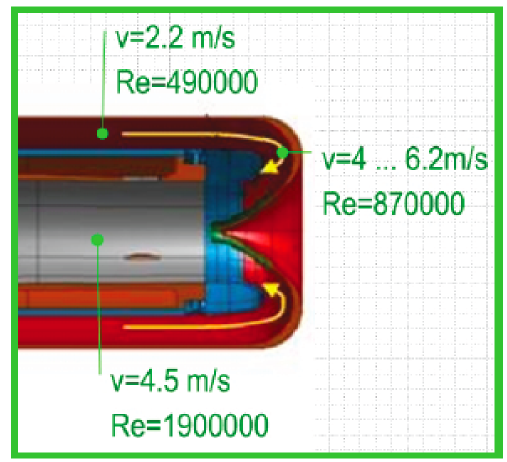


4MW thermal power

Parameter	symbol	value	unit
Liquid compound	Hg	13.5	kg/l
Flow rate	ϕ	172	kg/s
Entrance temperature	T_{in}	< 60	C
Exit temperature	T_{out}	< 180 > 150	C
Pressure drop	ΔP	< 5	Bar
Static pressure	P_0	< 5	Bar

Ab.13 l/s





Task#2 – Multi-MW Liquid Hg Target

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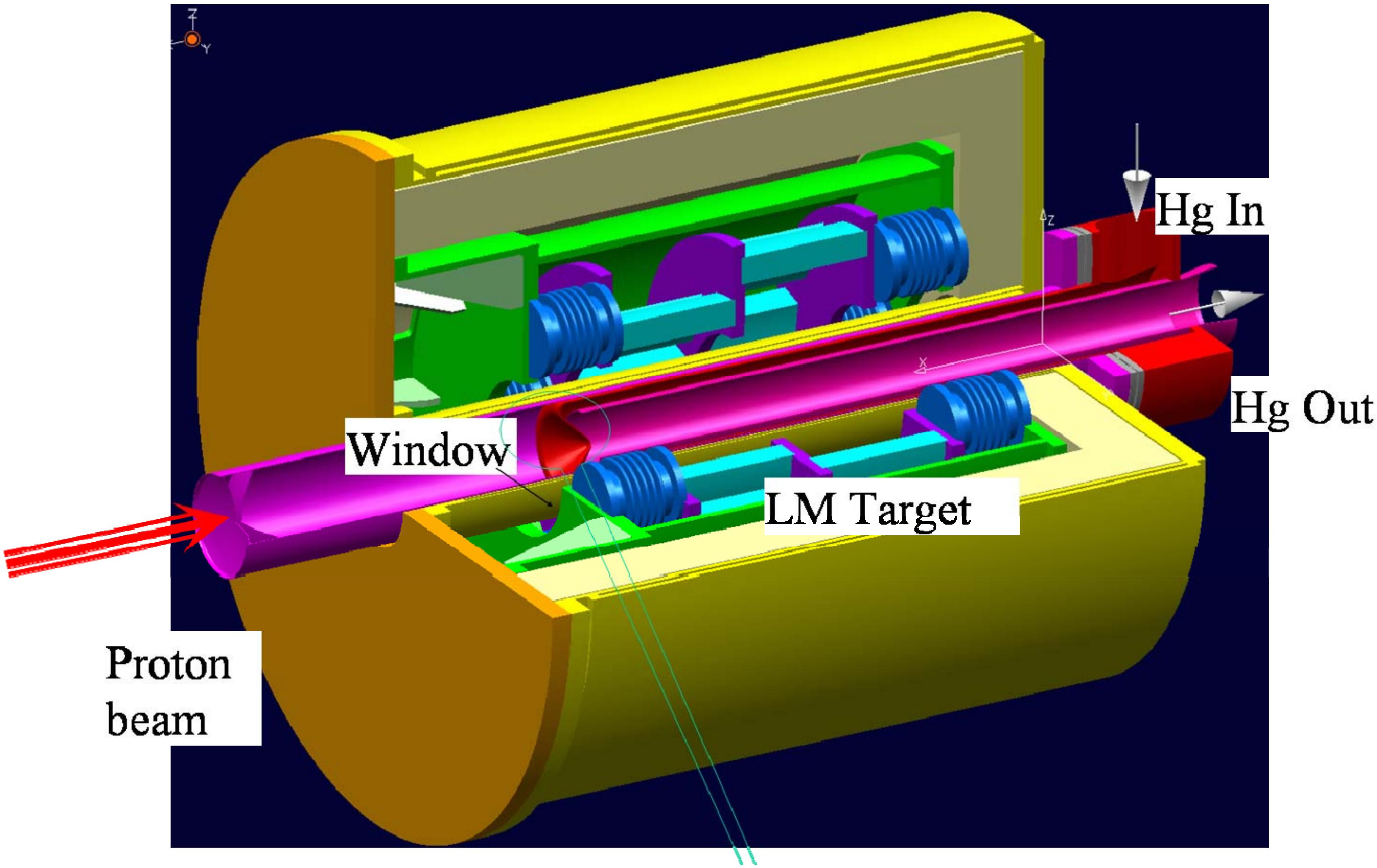
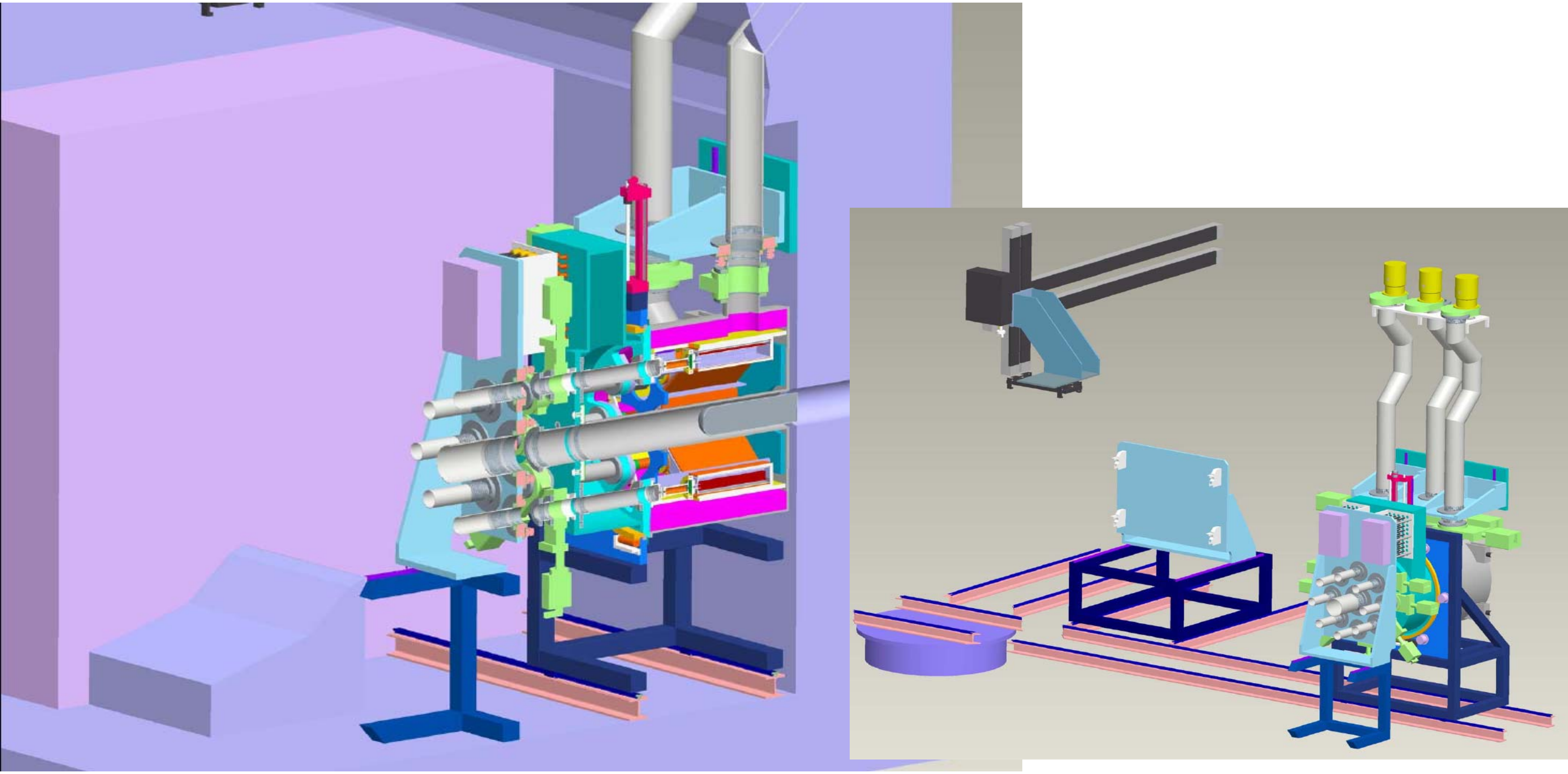
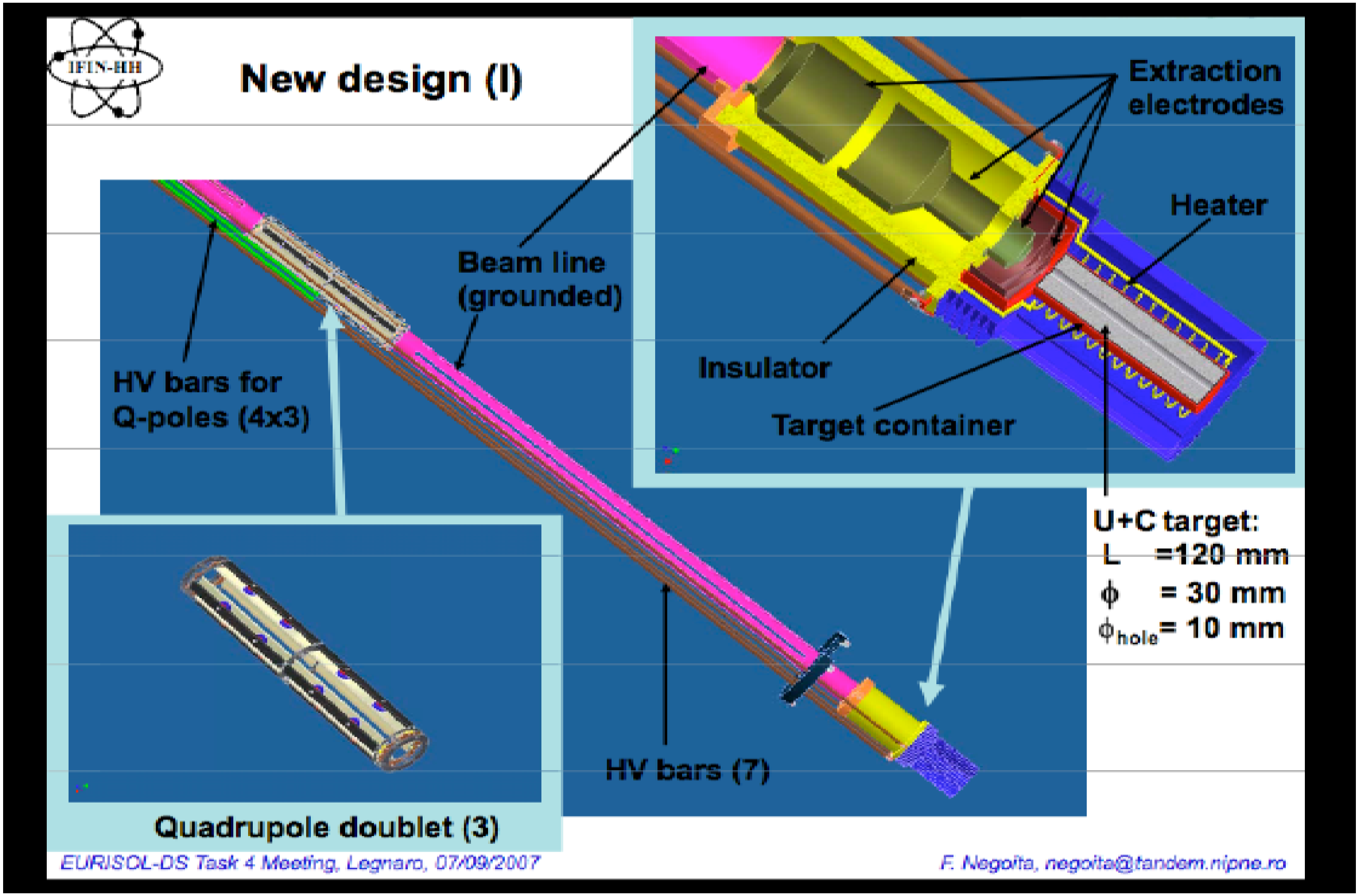
Hg converter and secondary fission targets



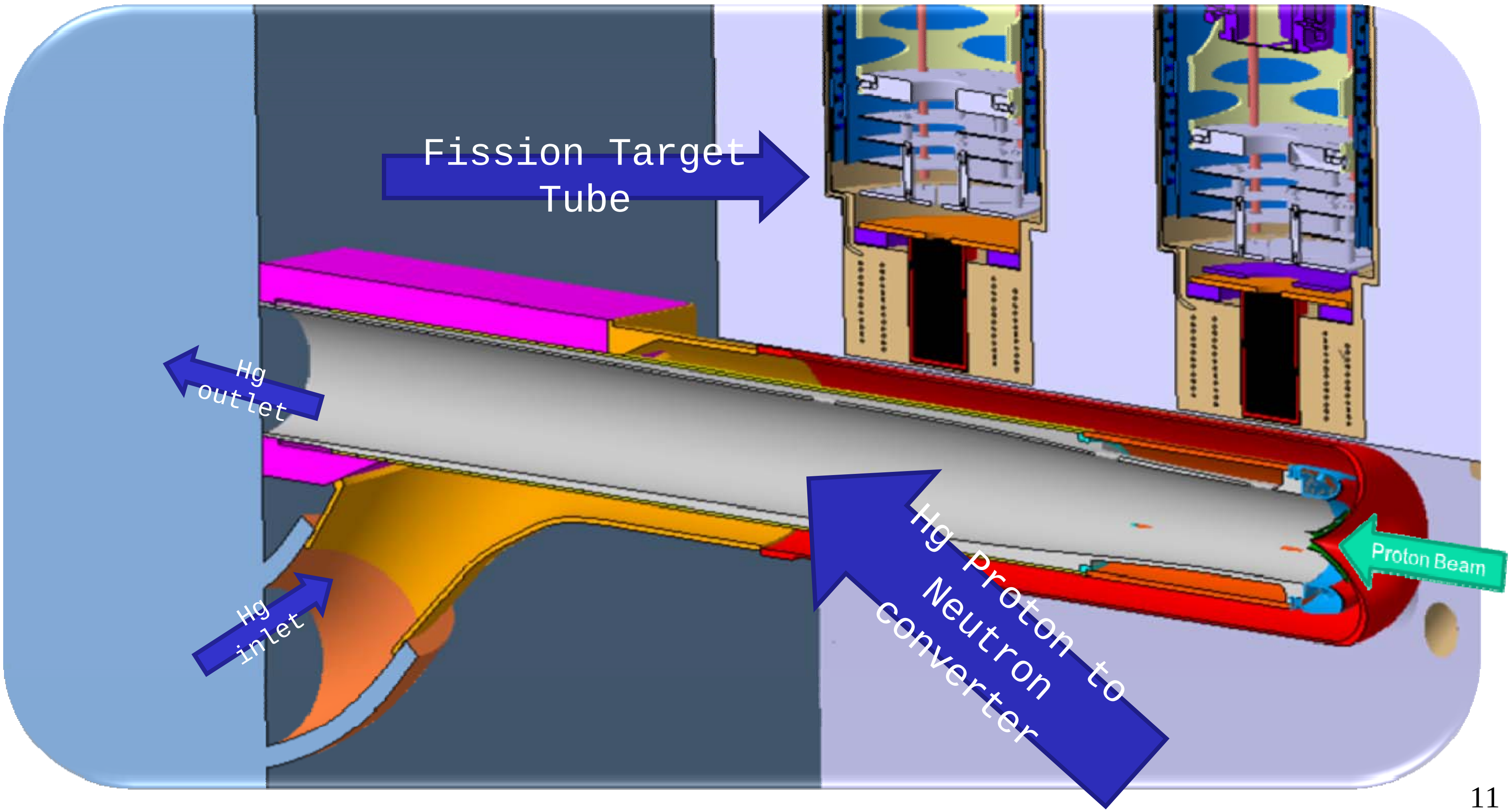
Task#4 – Fission Target



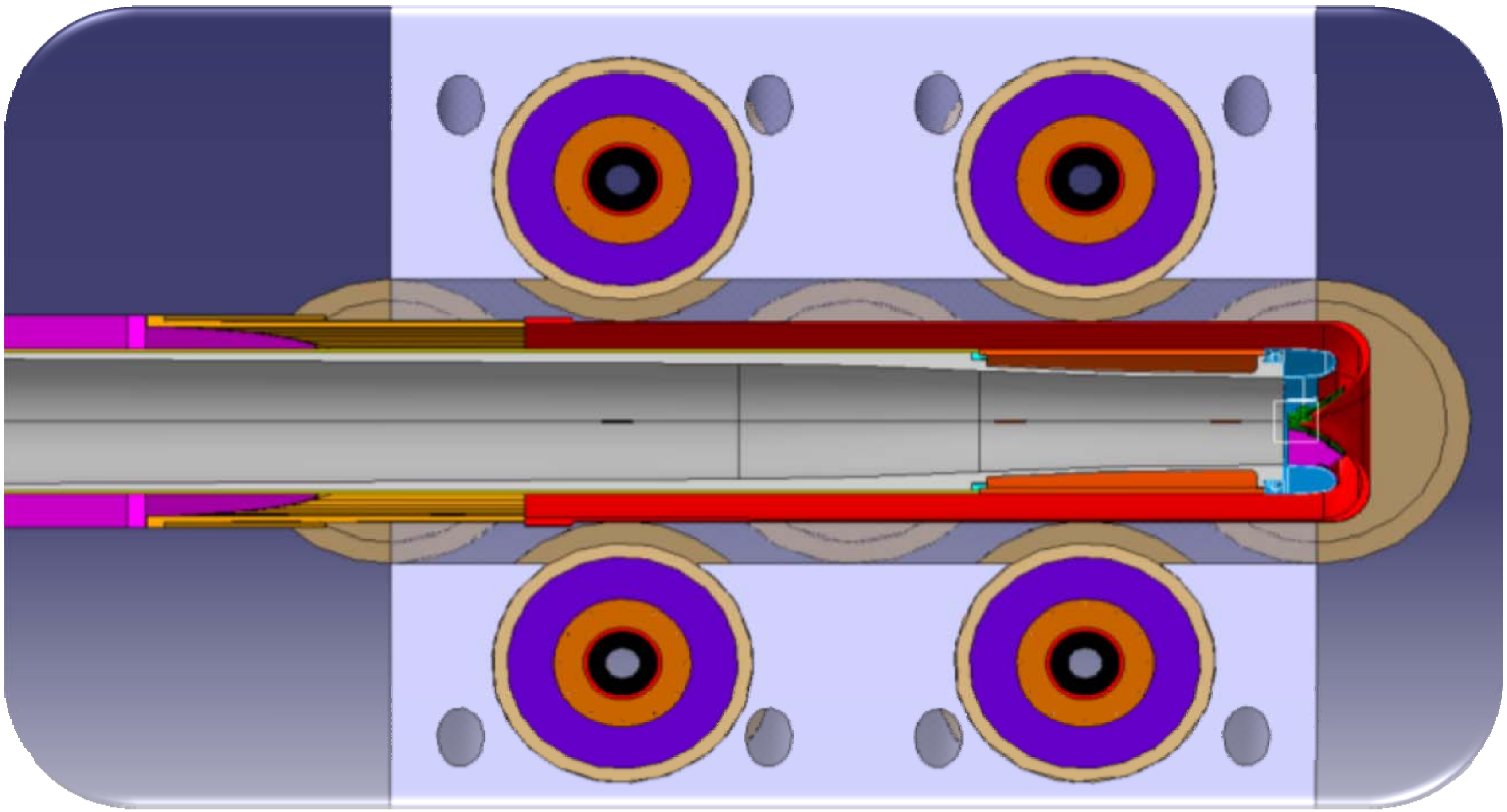
Task#2 – 3D view of the fission target



MAFF Fission Target Integration



MAFF Fission Target Integration



Multi-MW facility Layout

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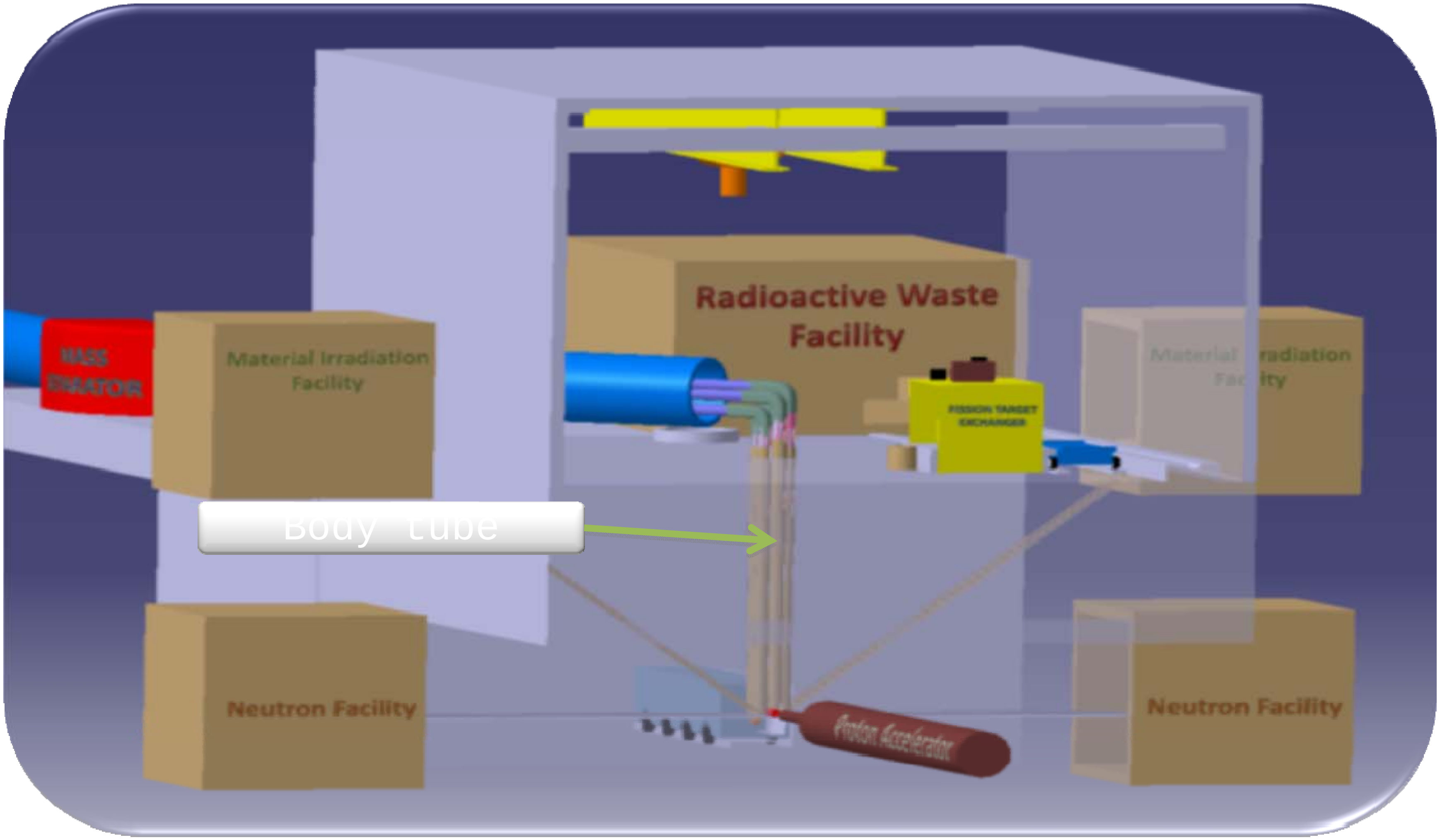
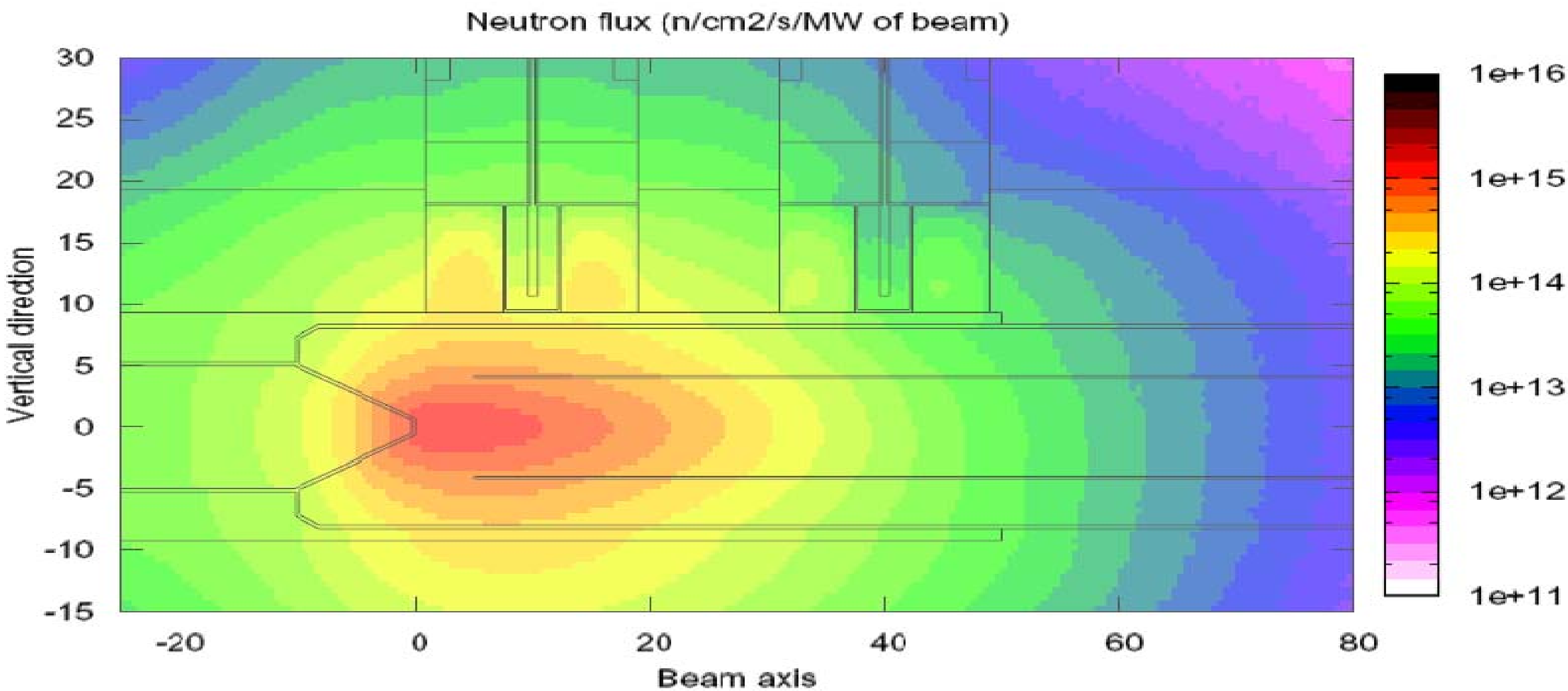
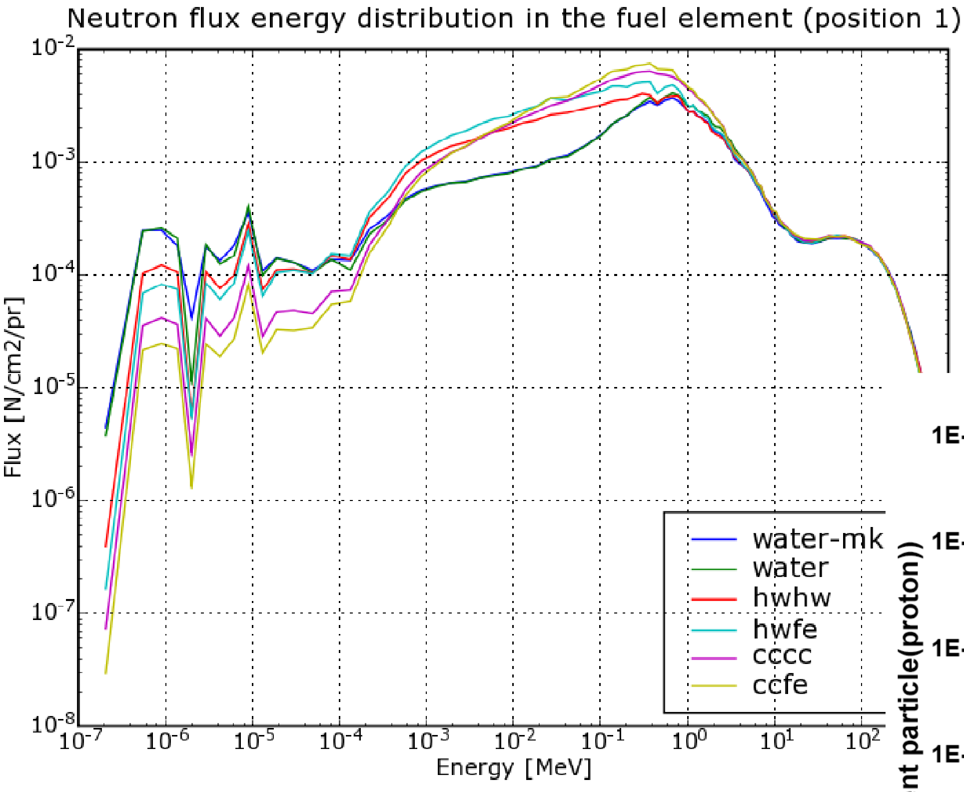
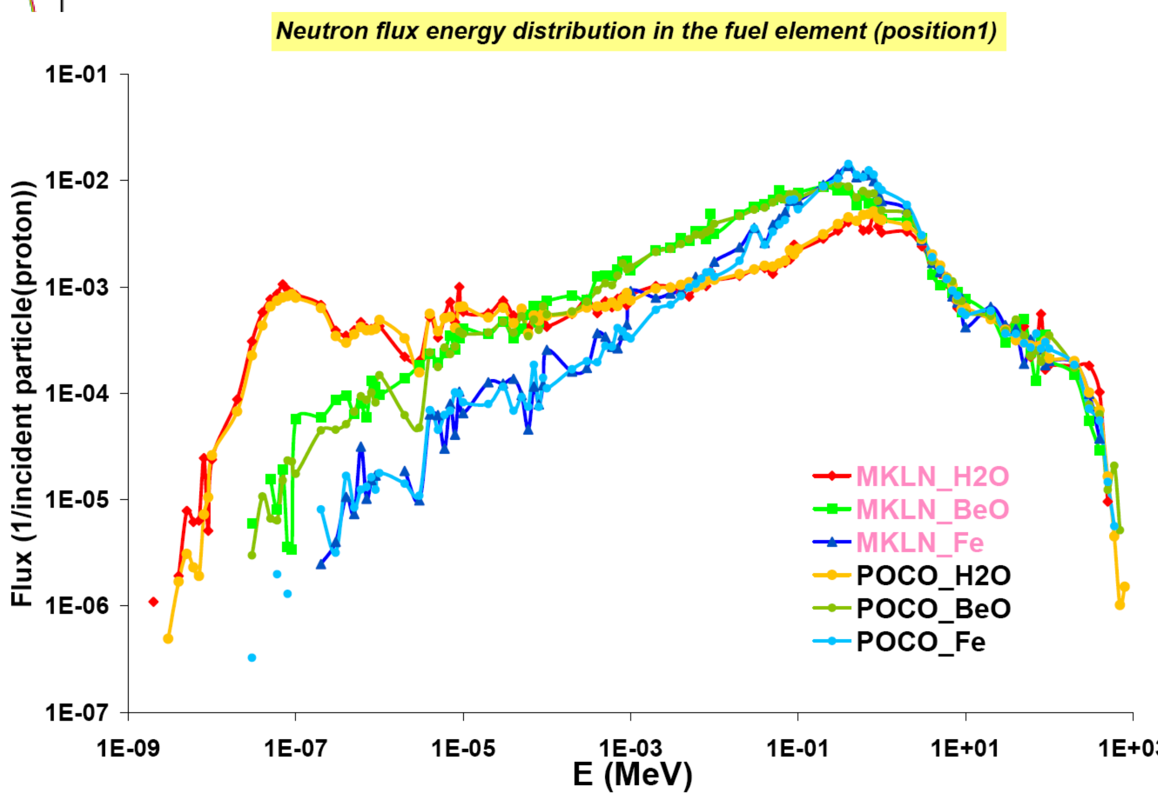


NEUTRON FLUX





Neutron flux energy distribution in the fuel element (position 1)
Flux [N/cm2/pr]
Energy [MeV]
water-mk
water
hwhw
hwfe
cccc
ccfe



Neutron flux energy distribution in the fuel element (position1)
Flux (1/incident particle(proton))
E (MeV)
MKLN_H2O
MKLN_BeO
MKLN_Fe
POCO_H2O
POCO_BeO
POCO_Fe

FISSION DENSITY

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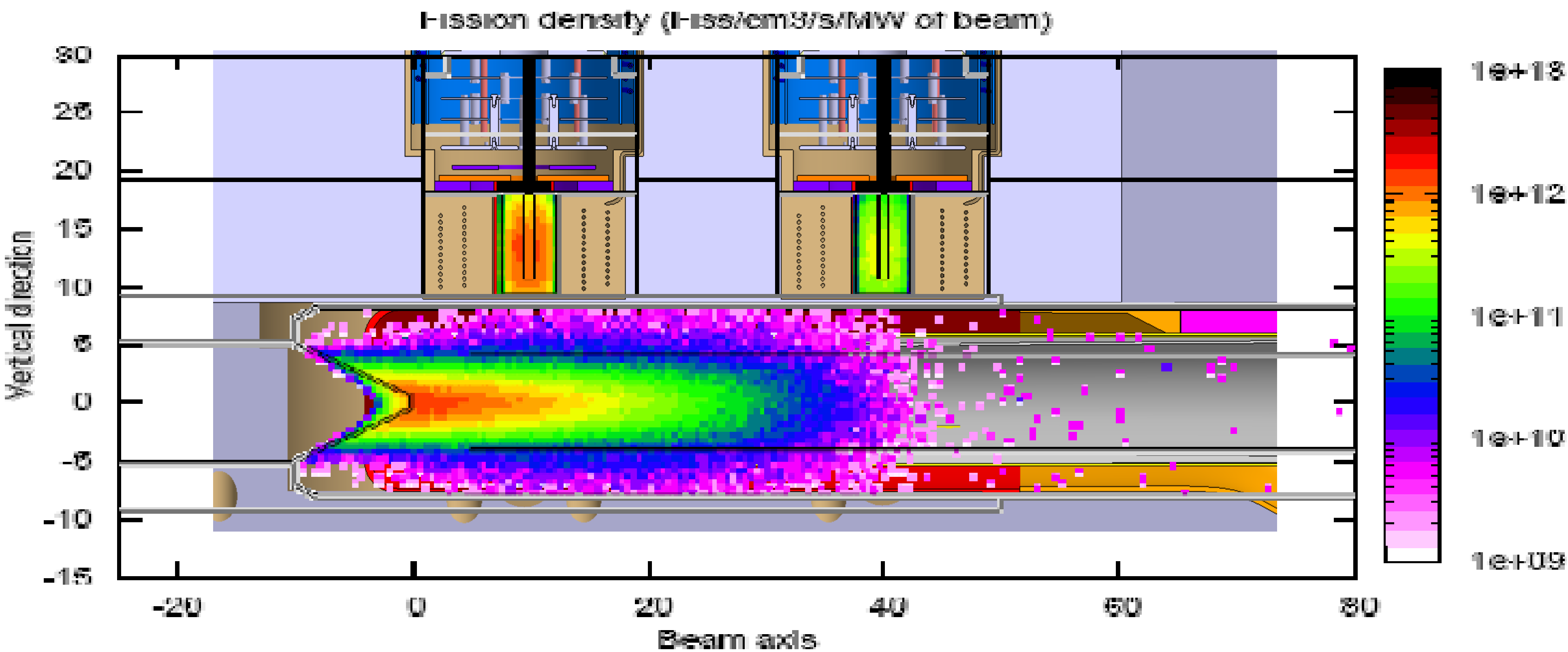
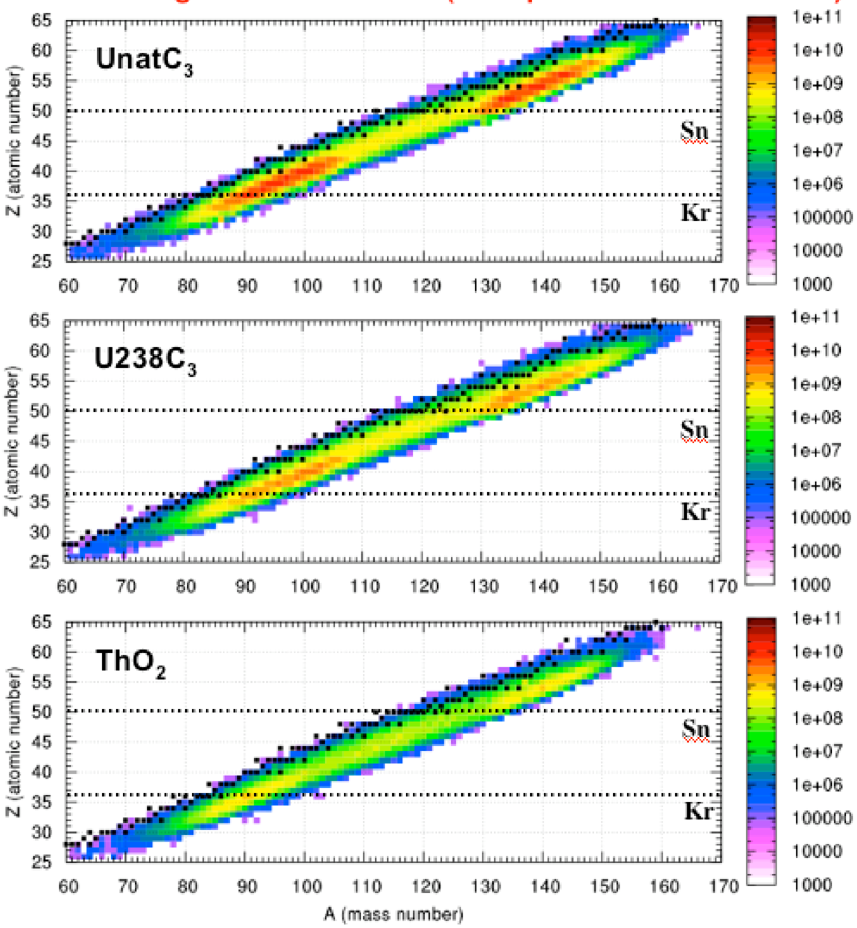
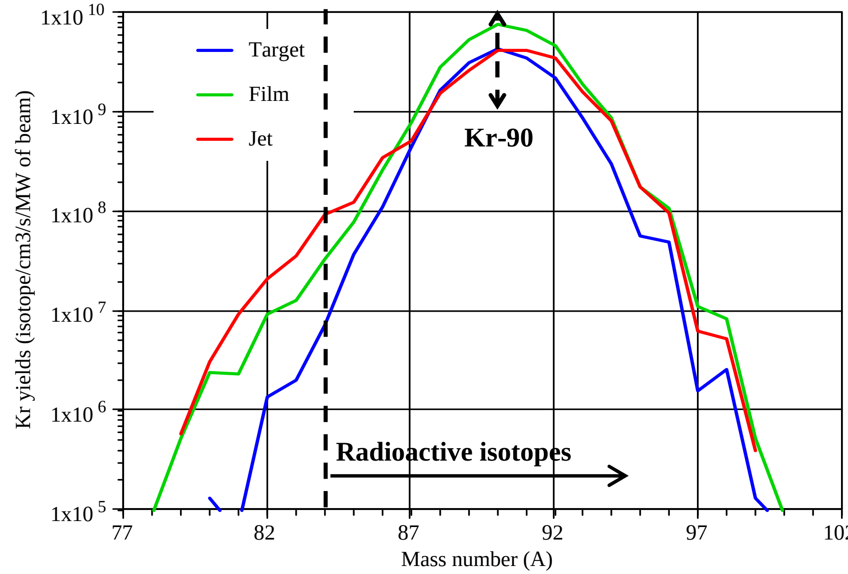


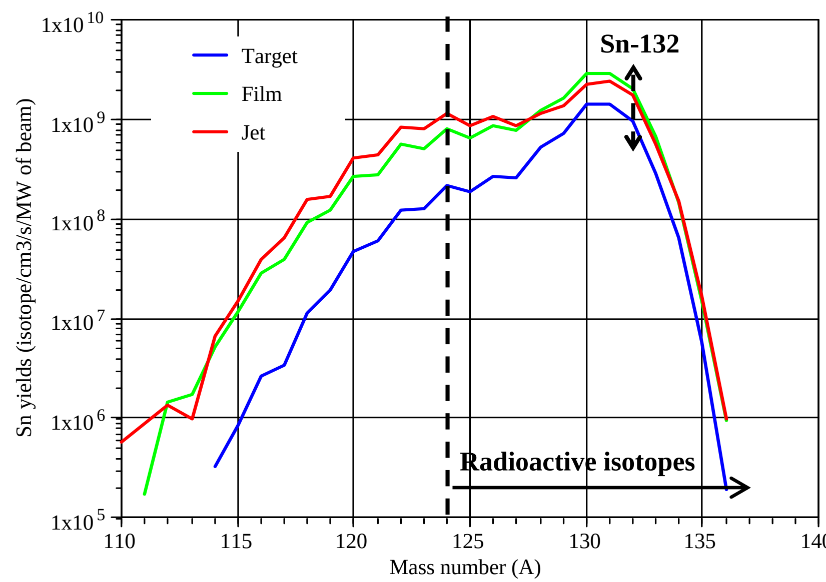
Task#2 – Radioactive Ions Production

Large RIB production for the proposed neutron-rich isotopes.
Clear advantage in using natural uranium.
Possibility of investigating the lower end of the *terra incognita*, e.g. Nd-157, Tb-167

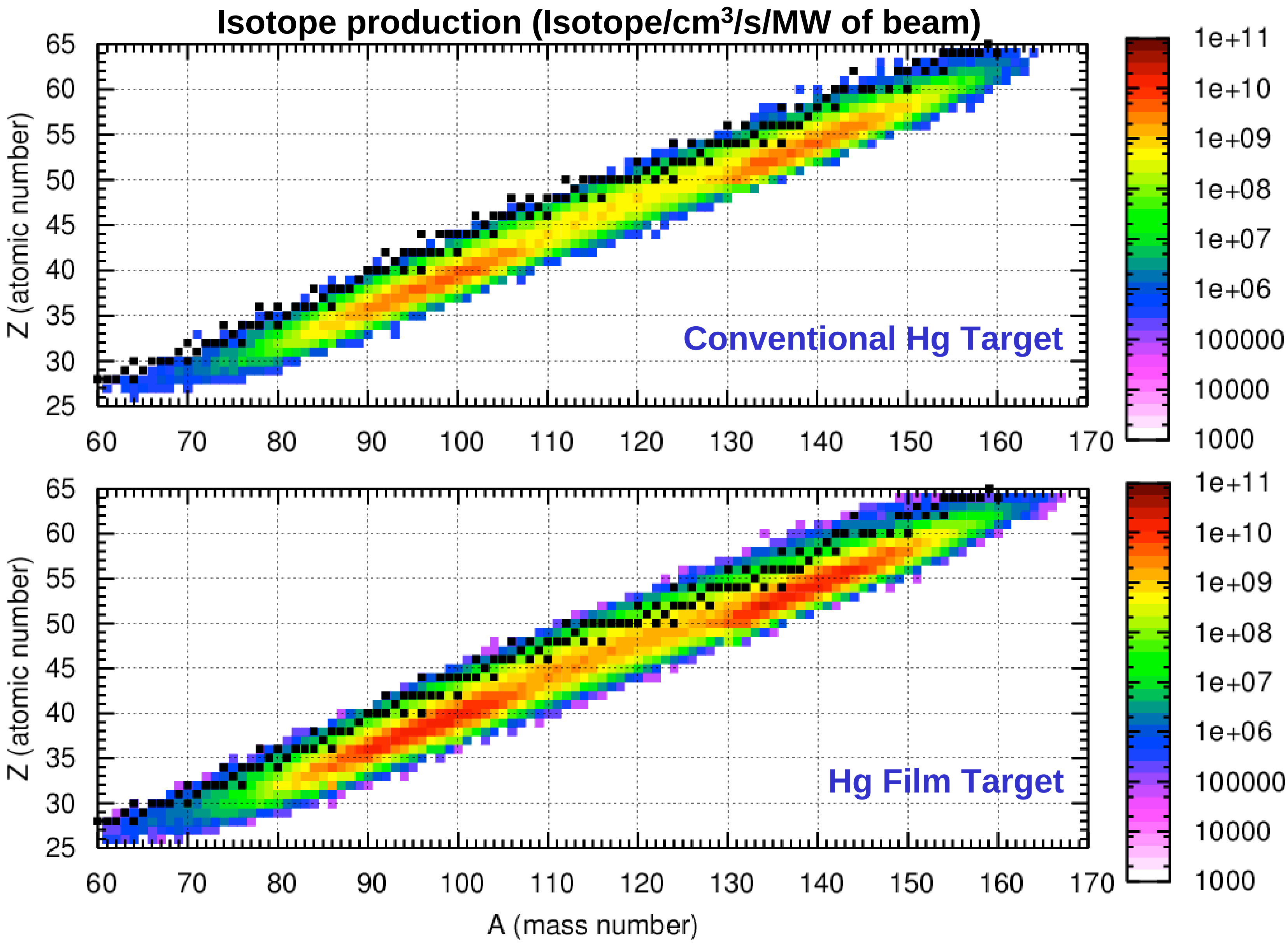
Fission fragment distribution (isotope/cm^3/s/MW of beam)







Radioactive Ions Production

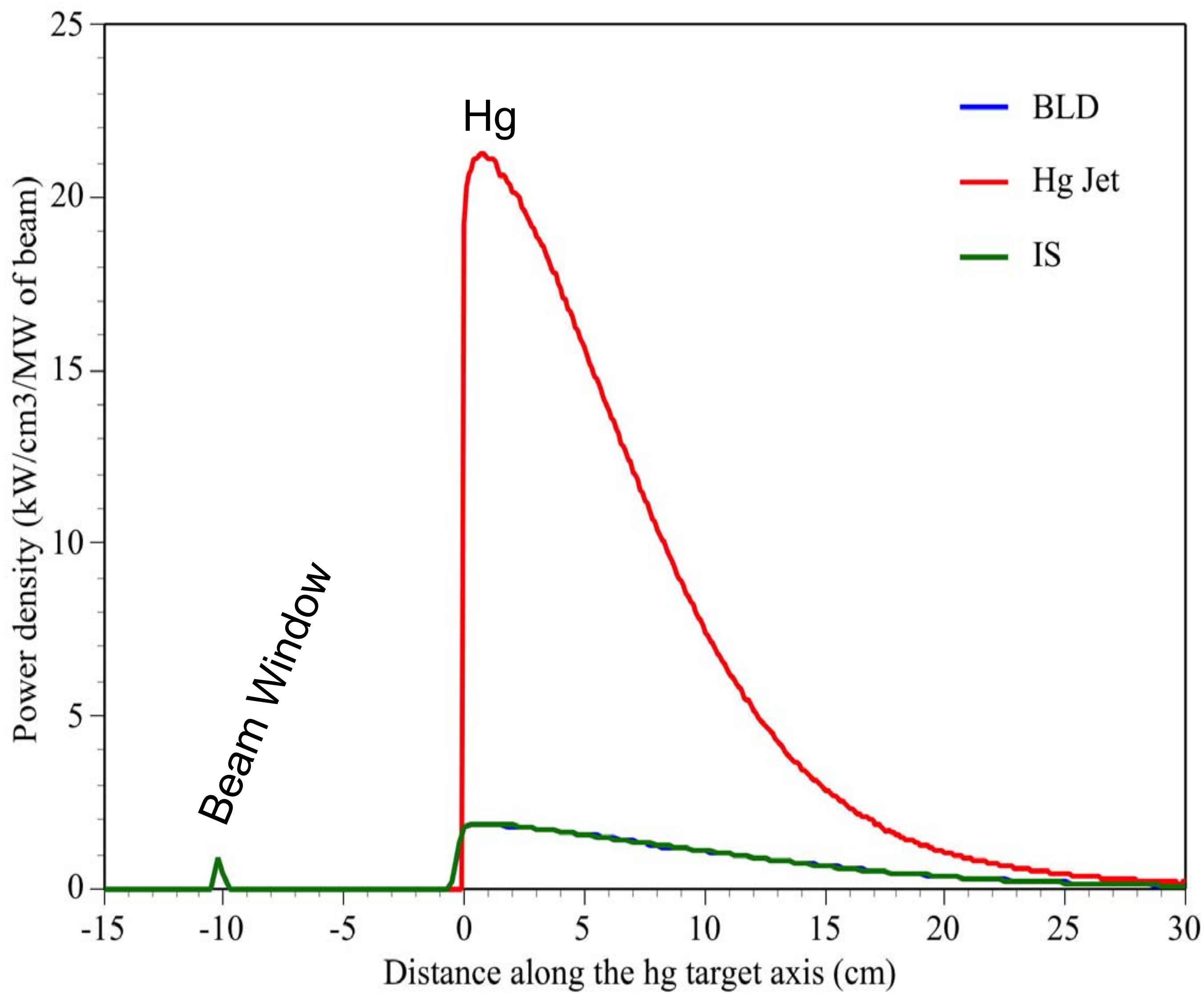


UC_3 Targets:

- **Natural Uranium (0.7% U-235)**
- **Density: 3 g/cm^3**

Power Densities

- More than one order of magnitude difference between the free surface Hg-J (~22 kW/cm³/MW) and the confined Hg targets (BLD, ~2 kW/cm³/MW)
- BDL and IS: Beam window suffering important power densities (~1 kW/cm³/MW → extra cooling plus radiation resistant material needed)
- Peak power densities similar to ESS and SNS



Liquid Hg Loop for tests of target mock-ups and other components

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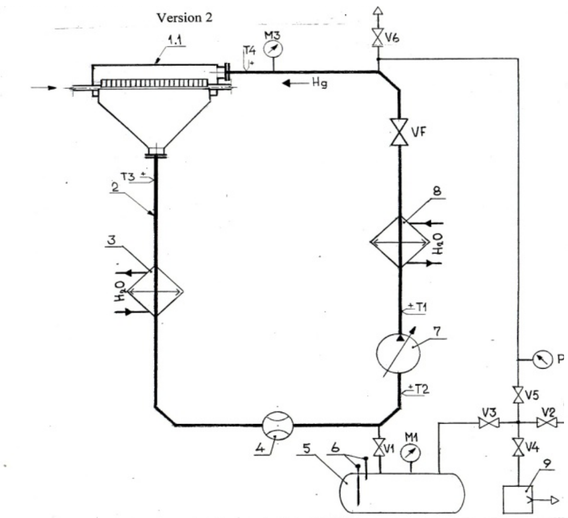
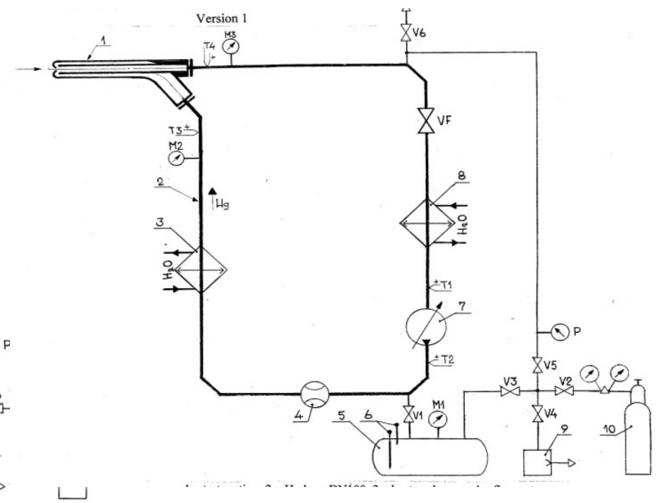
IPUL variant

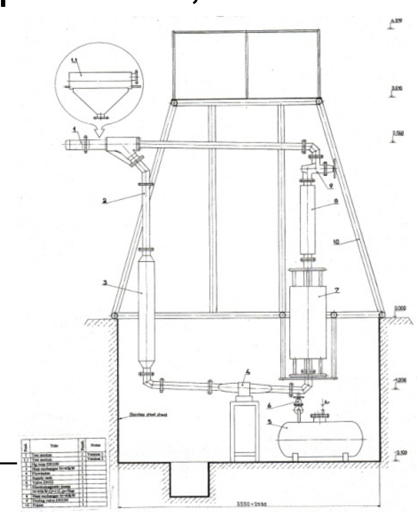


PSI variant



Existing Hg – loop in Institute of Physics (under reconstruction)(parameters of EMP p=4 bars; Q~12l/s

1 – test section; 2 – Hg loop DN100; 3 – heat exchanger; 4 – flowmeter;
5 – supply tank; 6 –level meter; 7 – electromagnetic pump; 8 – heat exchanger;
9 – vacuum pump; 10 – argon vessel; M1…M3 – pressure meter; P – vacuum gauge; T1…T4 – thermocouple; V1…V6 – valve; VF – dosing valve;



TASK #2 – Liquid Hg Loop @ IPUL

Experiments of Hg “curtain” in InGaSn Loop

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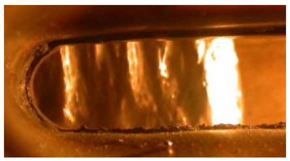
Transverse Hg – film



a

b

c

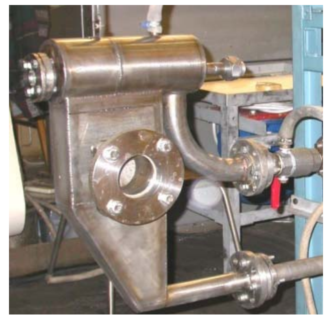
Modules of transverse film injectors

a

b

c

Test chambers



InGaSn test loop of transverse film target module

P=3 bar; Q~1.5 l/s

a – with rectangular cell inner structure
b – with round cell inner structure
c – with parallel separator inner structure

Liquid Hg Loop – Transverse Film

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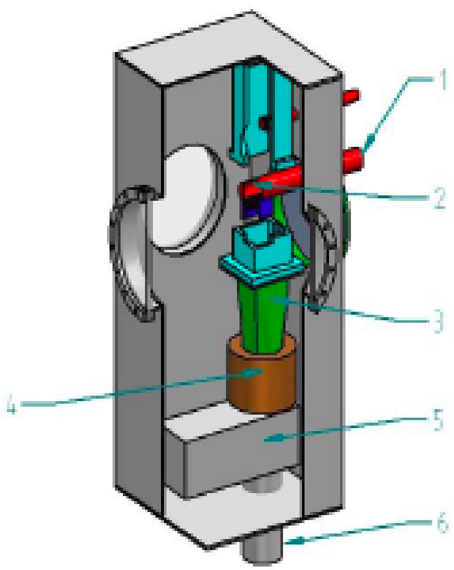
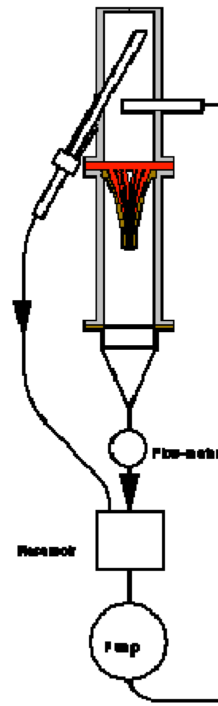
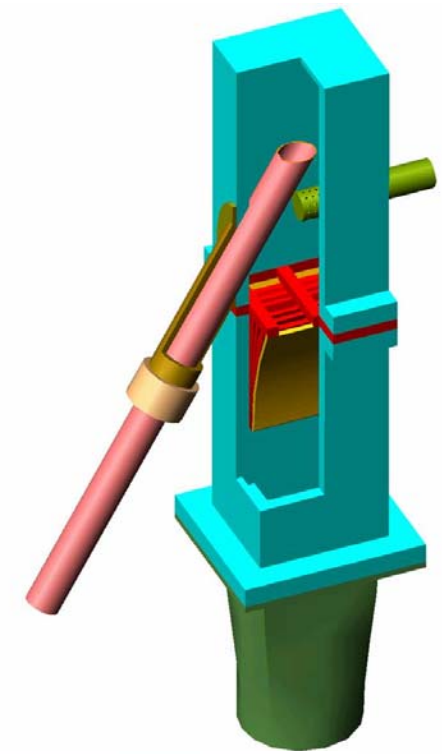


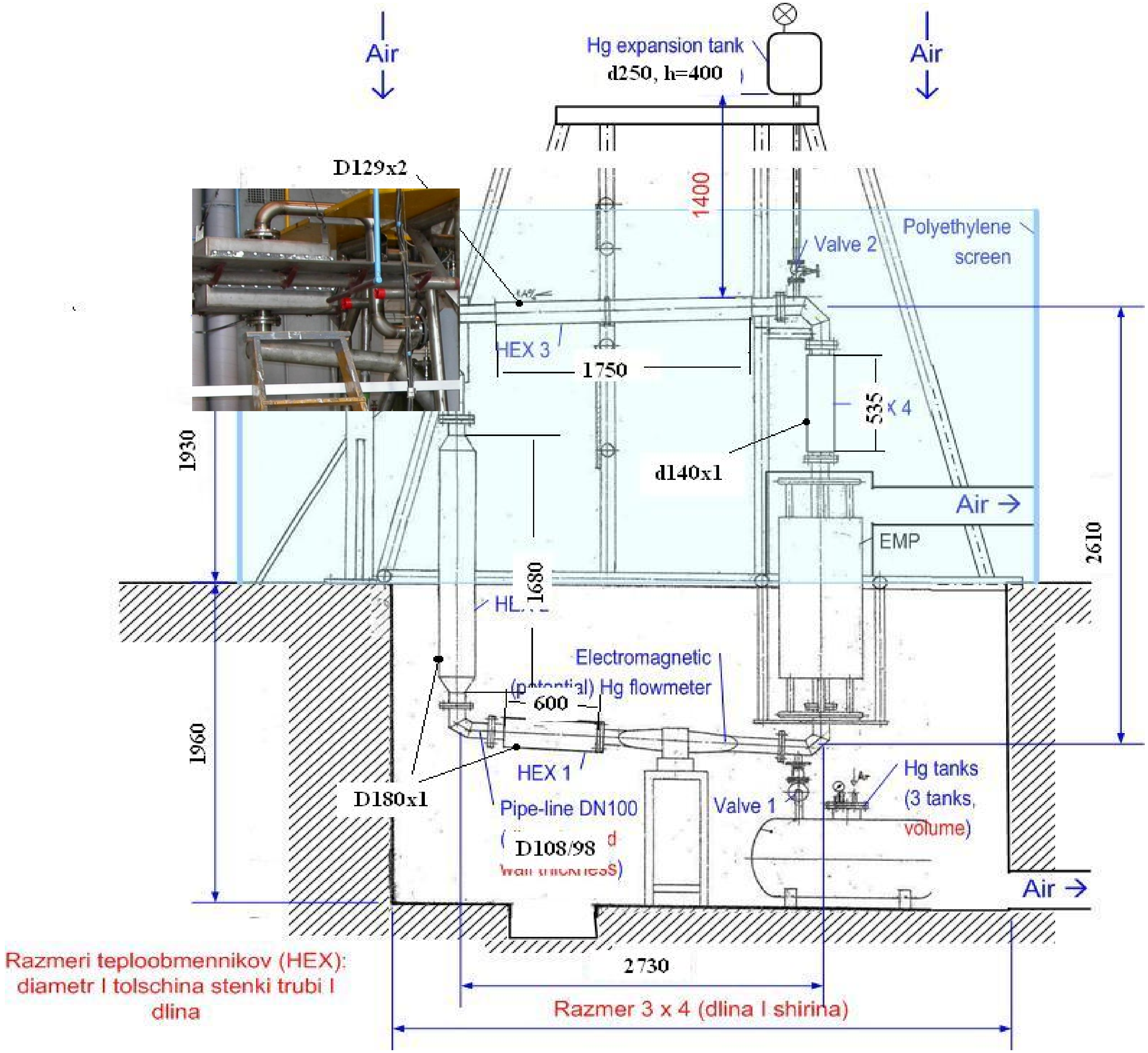
a) principle scheme

b) head of transverse film injector

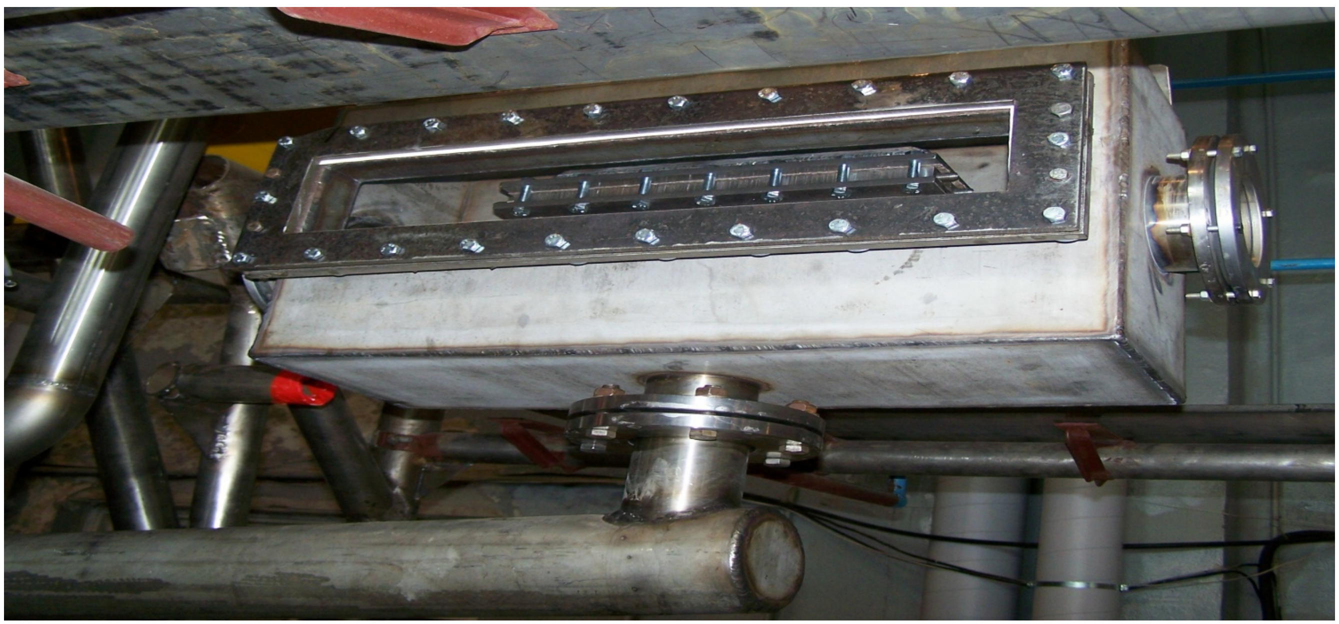
Fig.19
Experimental unit of transverse film injector
1 -inlet tube; 2-transverse film former; 3- liquid metal distributor; 4- flowmeter; 5- supply tank; 6- outlet tube.



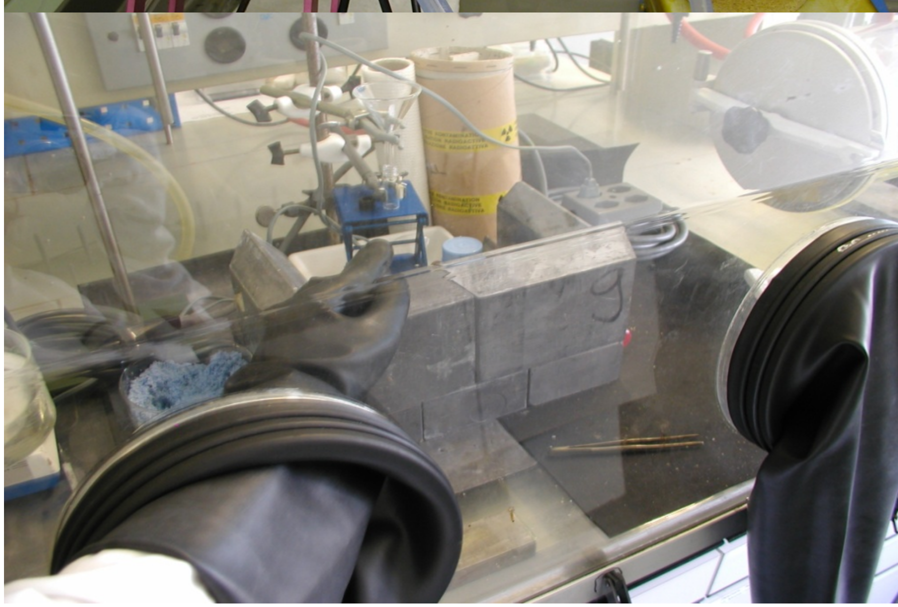




Air
Air
Hg expansion tank
d250, h=400
D129x2
1400
Valve 2
Polyethylene
screen
HEX 3
1750
535
d140x1
1930
Air
EMP
2610
1680
Electromagnetic
600
HEX 1
D180x1
Pipe-line DN100
D108/98
Valve 1
Hg tanks
(3 tanks,
volume)
1960
Air
2730
Razmer 3 x 4 (dlina I shirina)
Razmeri teploobmennikov (HEX):
diametr I tolschina stenki trubi I
dlina

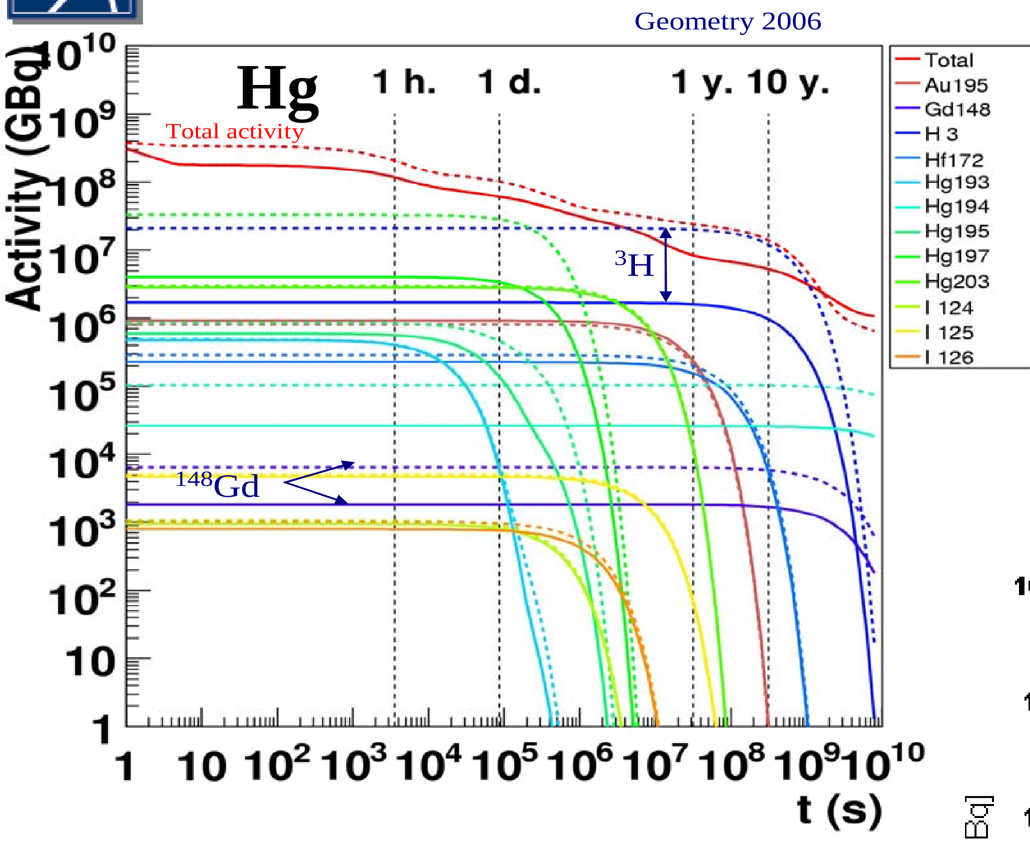


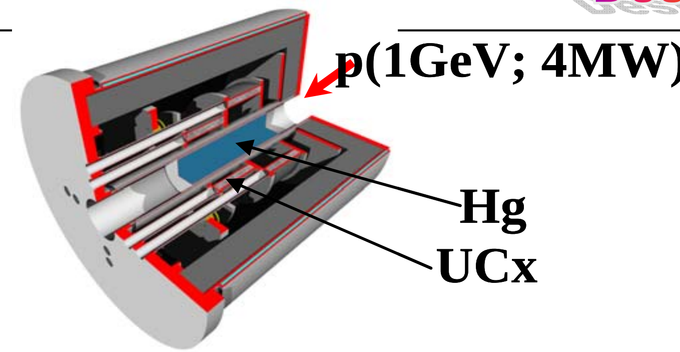
Task#2 – Hg Waste Management (D2)



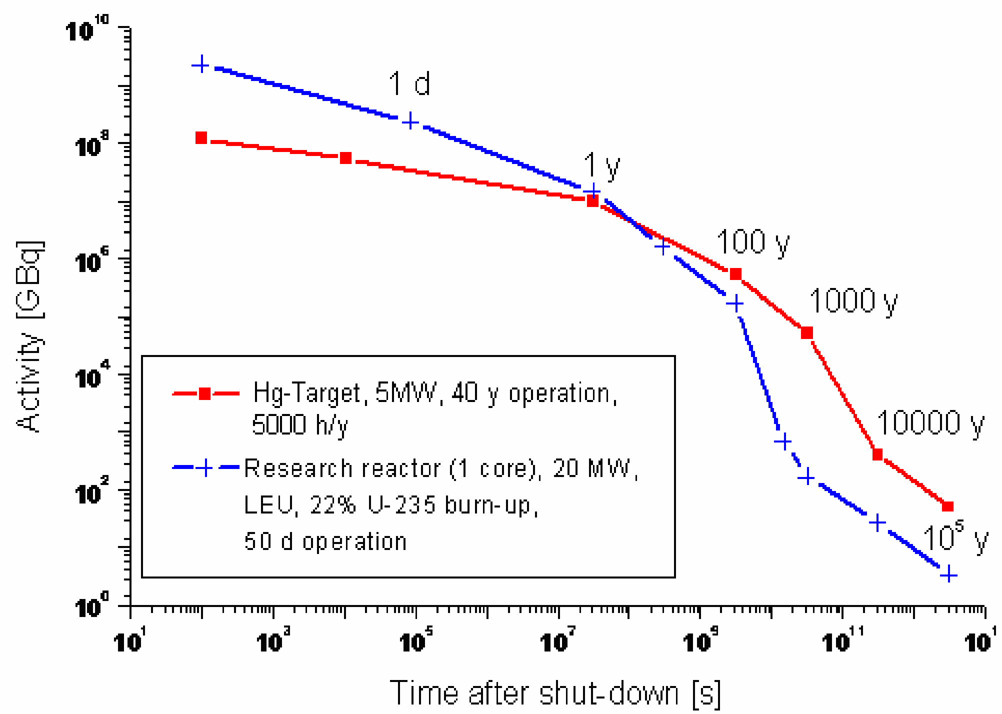
B) Activation of Hg

EURISOL Design Study





➩ Irradiation : 40 years operation, 5000 h/year, 4MW beam power

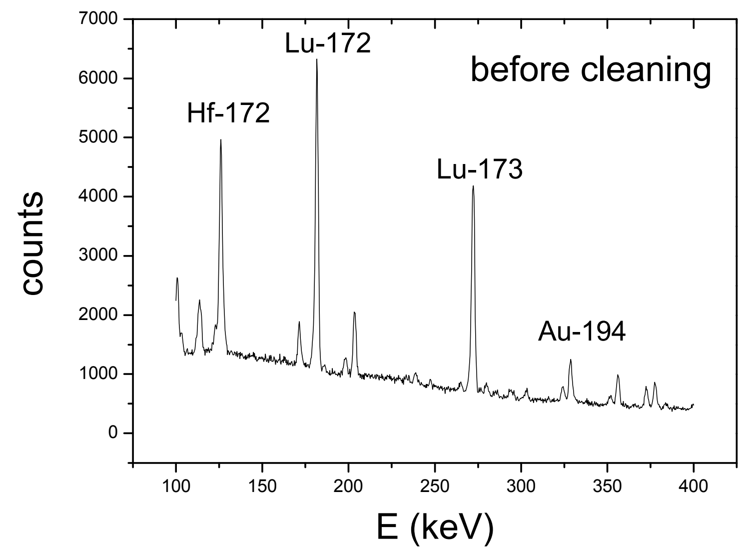


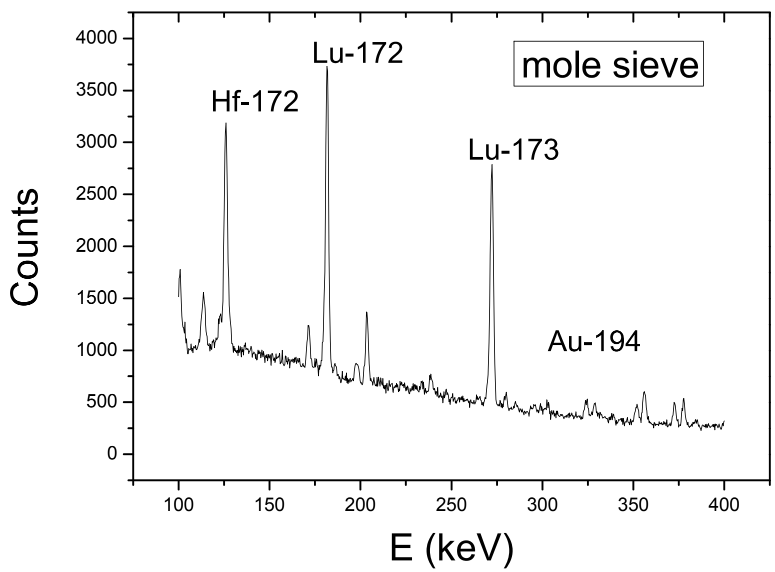
→ induced activity comparable to the research reactor + α emitters

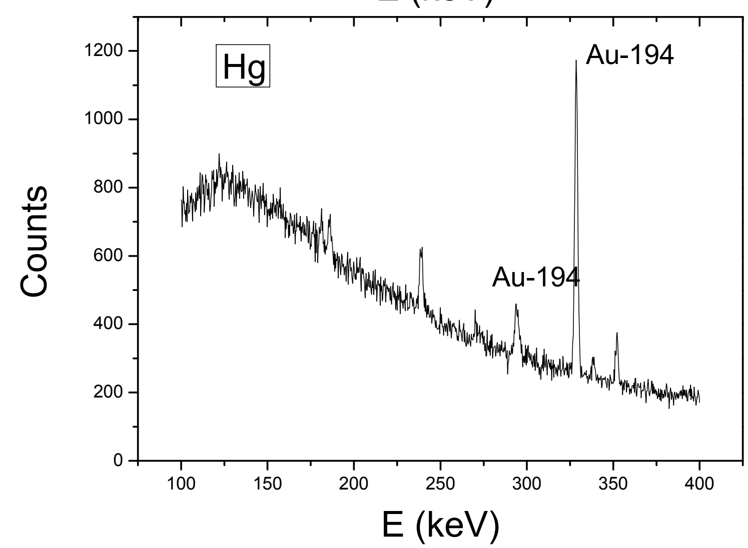
B. Rapp et al. (CEA)

Removal of Lu and Hf from CERN-Hg irradiated sample

- Hf and Lu present as an oxide deposit on Hg were removed by contacting the liquid metal with oxide materials with a rough surface:
- Sintered corundum
- Molecular sieve
- Oxides stick to the surface of these materials





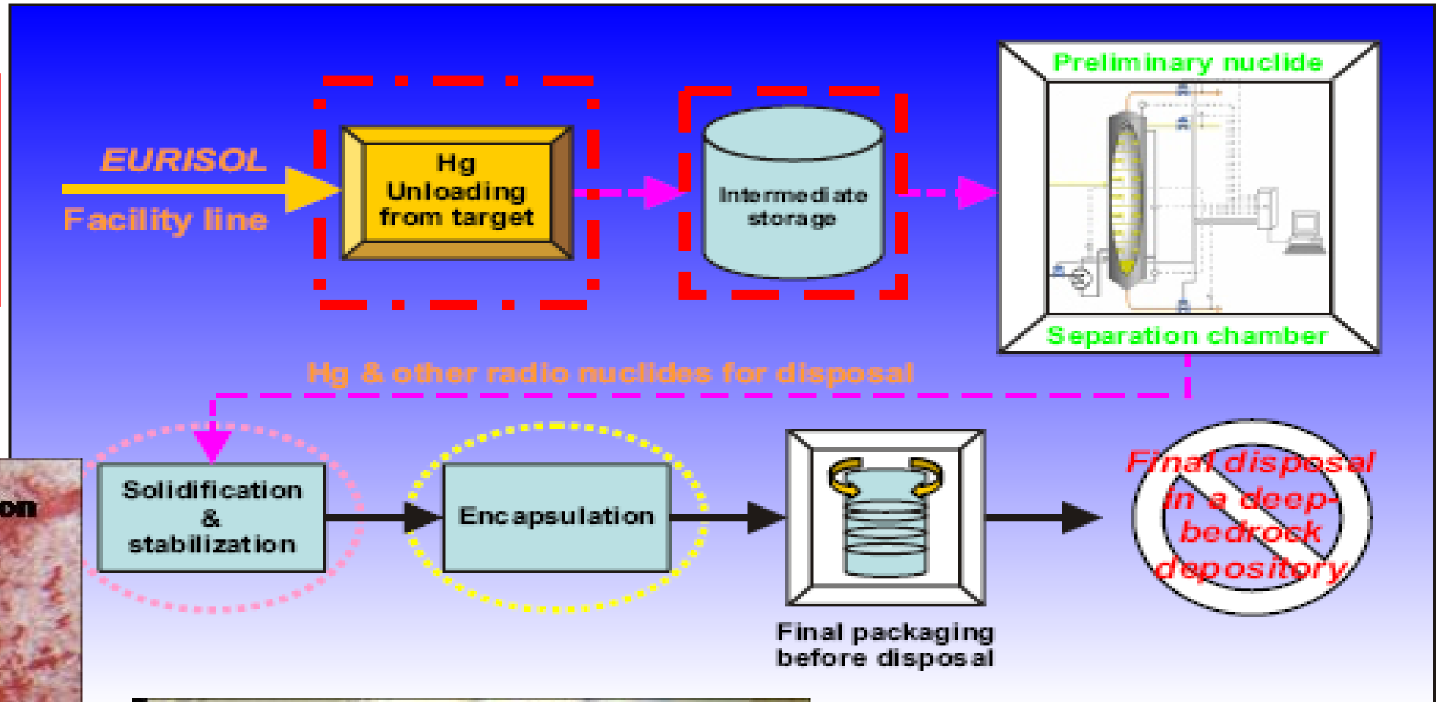


D) Disposal of liquid Hg

R. Moormann, Chiriki et al. (FZJ)

A schematic layout for liquid Hg-target disposal strategy

Chemical stabilization of Hg as an inorganic compound, e.g. HgS, HgSe, HgO, Hg_2Cl_2, $HgCl_2$



Extrapolation from laboratory scale to "industrial" scale still to be done

EURISOL Design Study

Task#2 – Milestone monitoring

No.	Milestones and expected result of this task:	Months due
M1	**Engineering study of the Hg converter**	
M1.1	Computation Hg fluid dynamics	7
M1.2	Study of a possible windowless Hg converter	9
M1.3	Decision on draft design parameters	14
M2	**Innovative waste management in the liquid Hg-loop**	
M2.1	Decision on optimum extraction method	29
M2.2	Full scale implementation of extraction method	39
M3	**Engineering design construction of a functional Hg loop**	
M3.1	Overall design and layout of Hg loop	26
M3.2	Design and construction of components	26
M3.3	Assembly of complete Hg loop with window free jet	36
M4	**Off line test of thermal and fluid dynamics**	
M4.1	Test of Hg loop components	31
M4.2	Operation of complete Hg loop with window free jet	43
M5	**Engineering design of a complete target station**	
M5.1	Study of HV platform and services	28
M5.2	Study of remote handling equipment	36
M5.3	Overall design of multi-MW target station	44

Done

In progress

Finalized

48 *Planned*

52 In progress

Thank you for your attention and to all contributors...