ISOL Targets for HIE-ISOLDE with 6μA, 2GeV proton beam from PSB

HIE-ISOLDE
Design Study

Thierry Stora

Nov 2013

Presentation layout

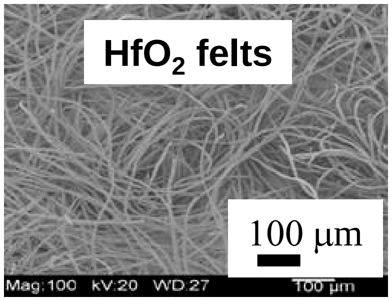
- HIE-ISOLDE physics requests, priorities for HIE-DS
- Yield vs integrated yields : target sintering, going to Linac 4 (6μA)
- New neutron converter for fission products
- Motivation to go for 2GeV
- Liquid metal target: LIEBE project

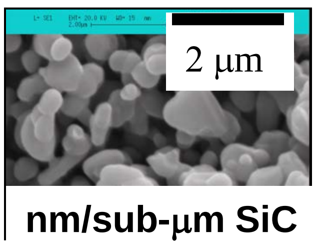
ISOLDE MEDICIS

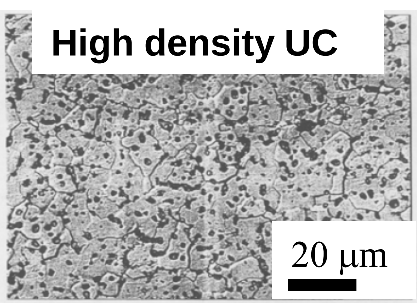
ISOLDE production units → HIE-ISOLDE ?

CERN EN STI

Transfer lines (>5)

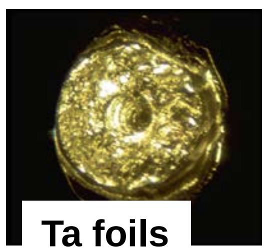


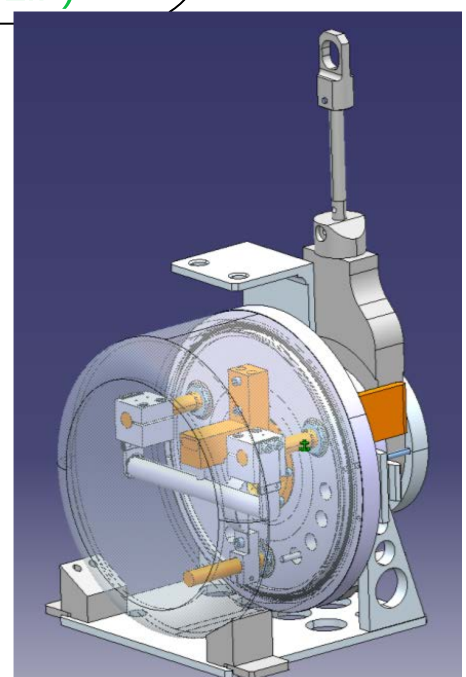




Target materials (30):

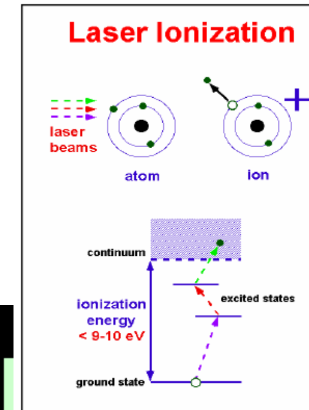
- Refractory oxides carbides (Al_2O_3, SiC, nano Y_2O_3)
- Solid metals (Ta, Nb, Mo)
- Molten metals (Pb, La, Sn)
- Molten salt (NaF-LiF)

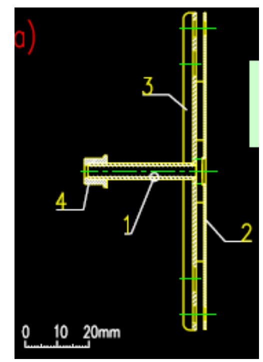


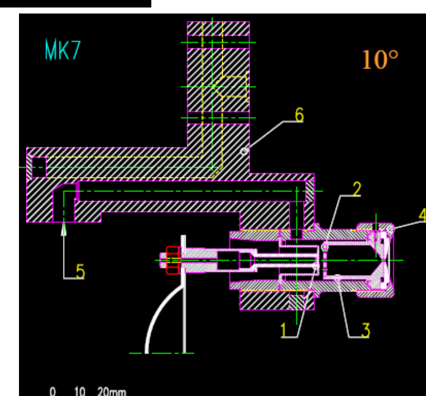


Ion sources (>5):

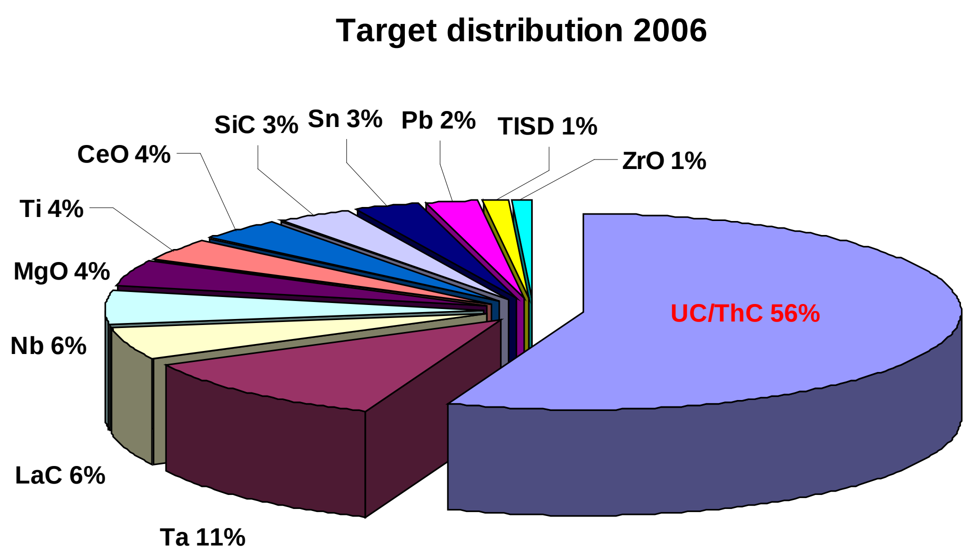
- Surface (W, Re, GdB6)
- FEBIAD, RF Plasma
- LIST



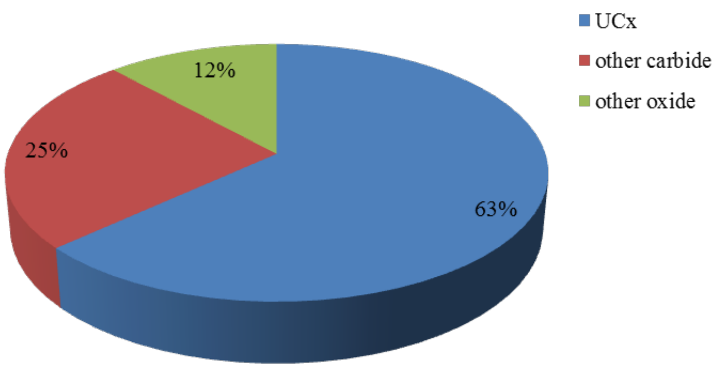




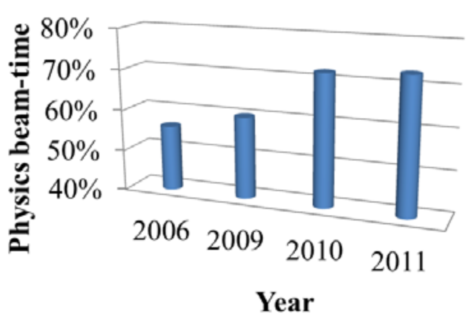
Target unit requests: ISOLDE and HIE-ISOLDE

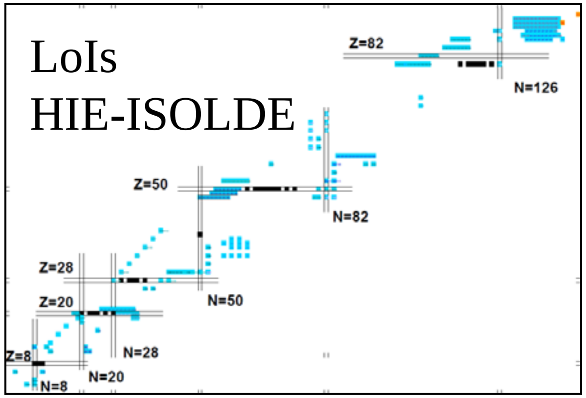


Allocated shifts for HIE-ISOLDE at INTC Jun 2013



12 UCx units / year (total ~25-30)





T. Stora

ISOLDE Beams
and production units

RIB intensity $[s^{-1}\ \mu A^{-1}]$

Proton beam Intensity $[s^{-1}\ \mu A^{-1}]$

Avogadro Numb.

Diffusion+ Effusion Efficiency

$$I = \int \sigma(E)\ \Phi(E, x)\ \rho(x)\ N/A\ dx\ \varepsilon_{diff+eff}\ \varepsilon_{ion}$$

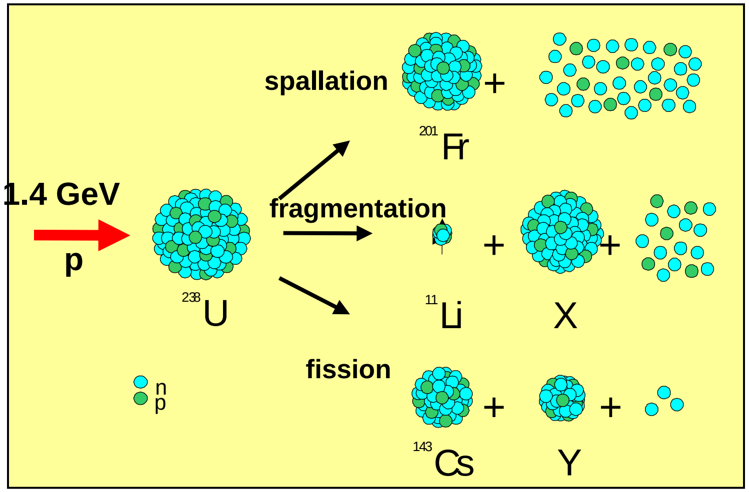
Cross section $[cm^2]$

Target density $[g\ cm^{-3}]$

Target Atomic Mass [g]

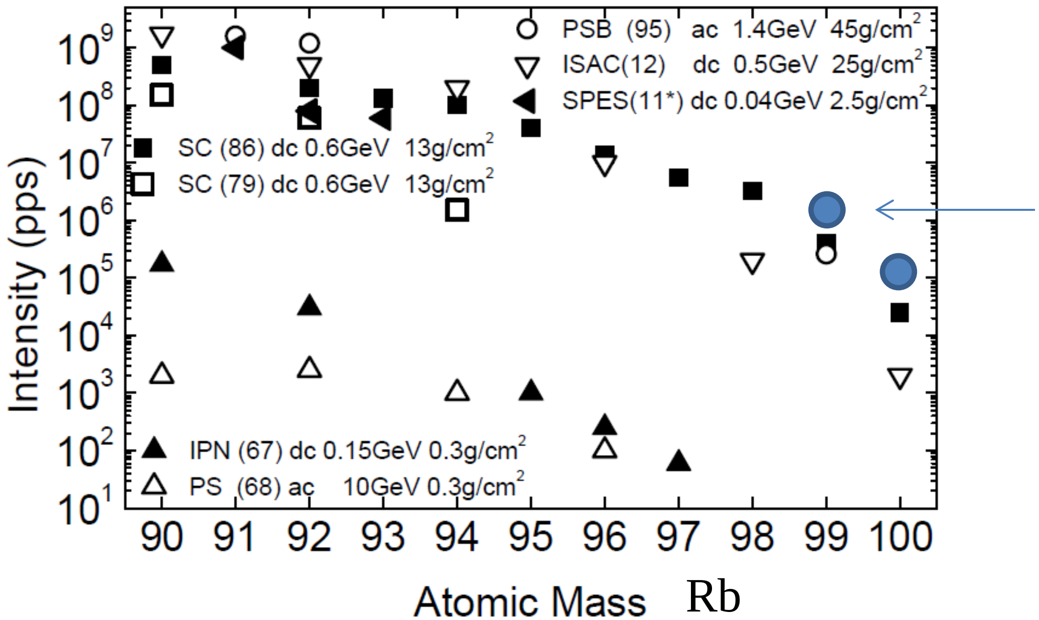
Ionization Efficiency

2 GeV !!!!



T. Stora

Rb intensities (not integrated)



(SPIRAL 2, RAON, ISOL@Myrrha not shown)

ISAC2/ARIEL should also gain

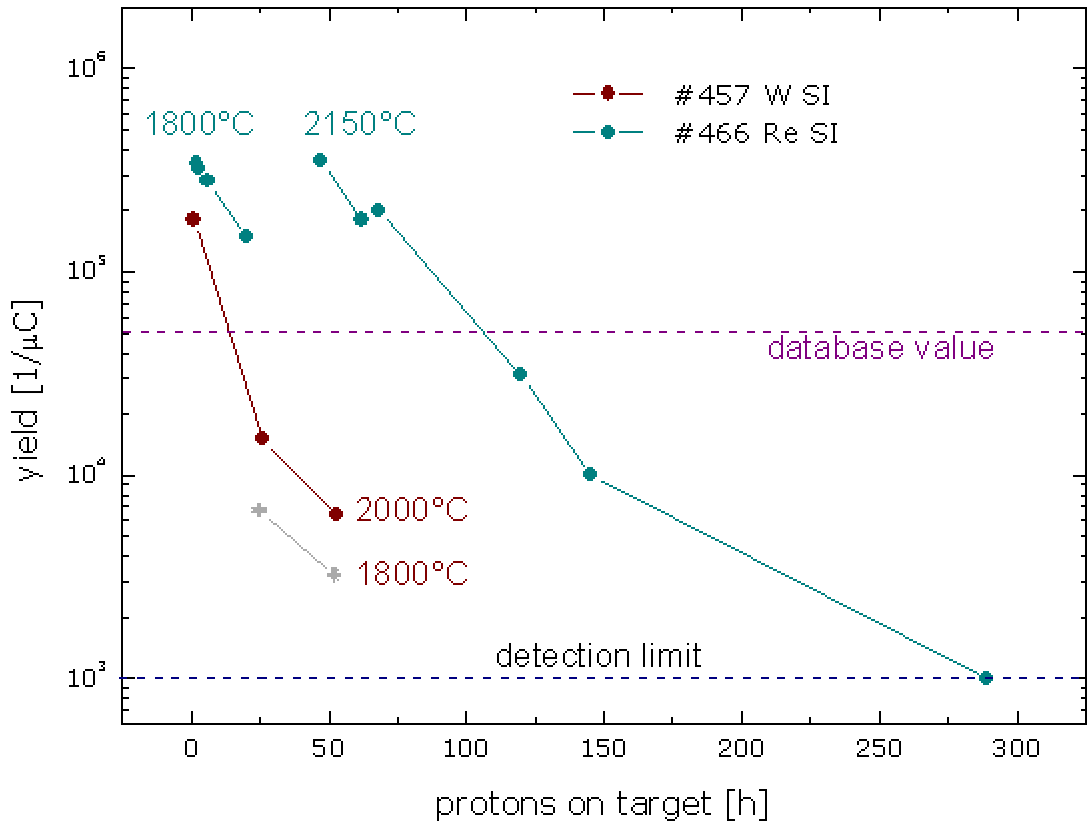
Figure of merit of a given radioactive ion beam facility:

- Diversity of available beams.
- Beam **intensity** (secondary ions/ primary beam μC).
- Beam quality, for instance **purity**, time structure and emittance.
- Facility down-time.
- Stability of beam intensity **over time**.

T. Stora

Integrated yield
UCx stability over run

30Na beams



T. Stora

ISOLDE

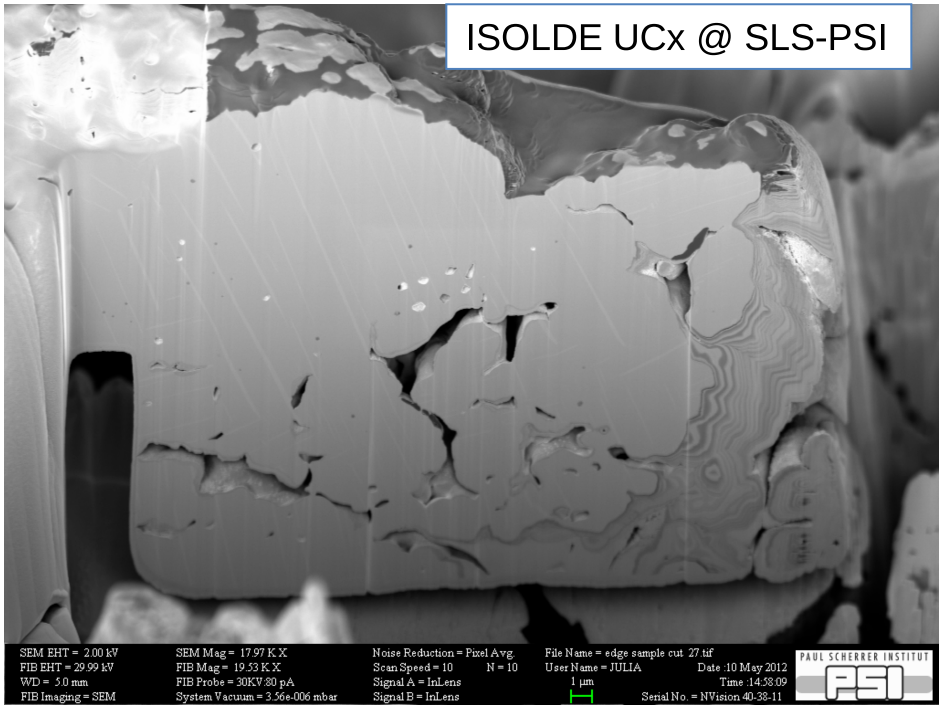
MEDICIS

ENSAR ActILab

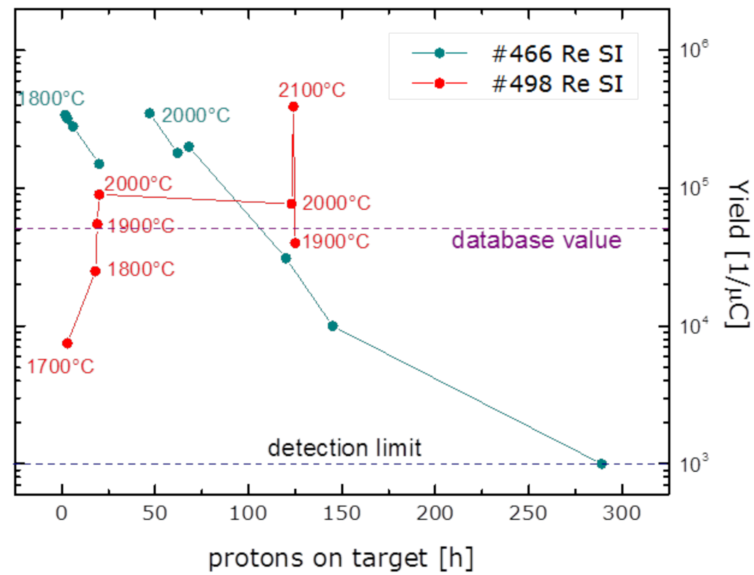
CERN EN STI

Tests of nanoUCx UC498@CERN and @IPNO

ISOLDE UCx @ SLS-PSI



IS540

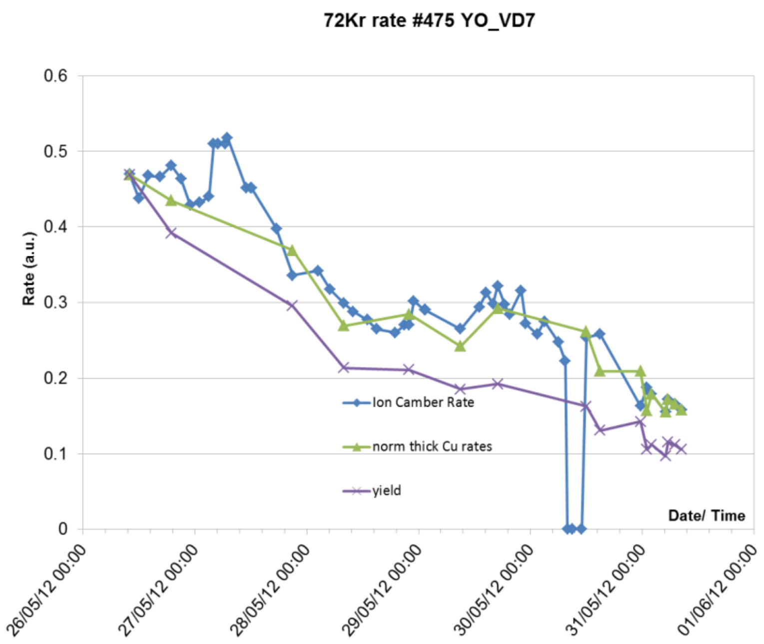


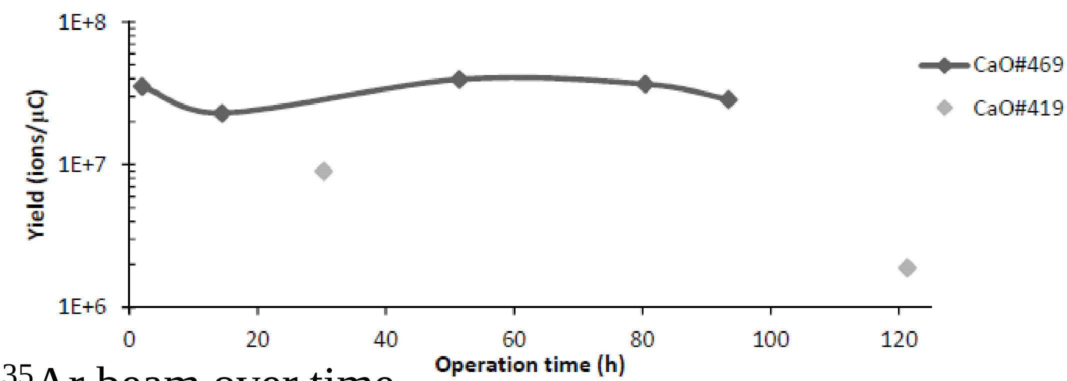
New UCx less prone to sintering: should be capable of withstanding higher beam pulse intensity

T. Stora

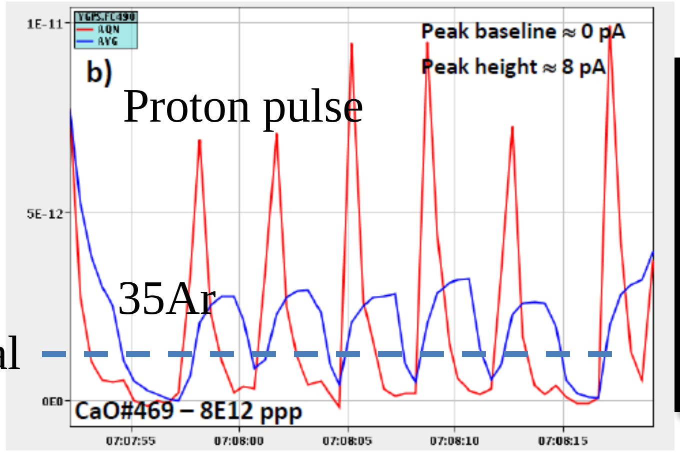
Other targets – pulsed nature of the beam

^{72}Kr from sub-µm Y_2O_3 vs ^{35}Ar from nano CaO

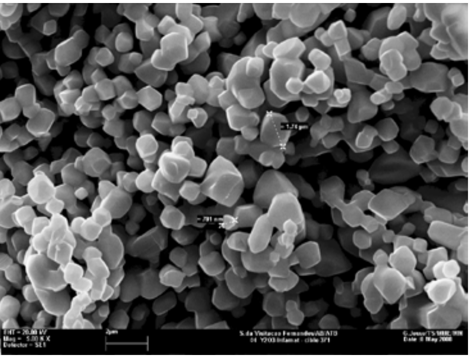


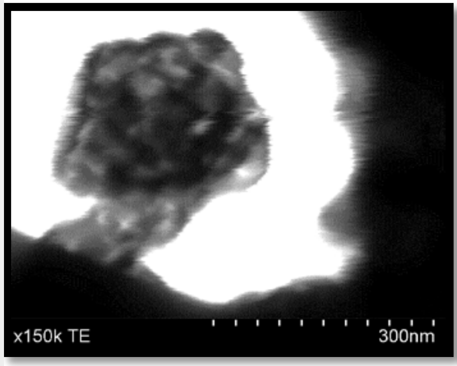


^{35}Ar beam over time



Hypothetical impurity



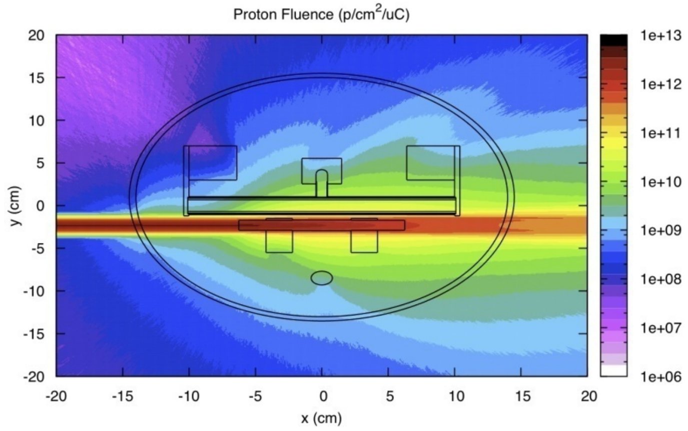


See presentation M. Czapski

T. Stora

Improvement of neutron converter

Improvement of fission product yields (for ex. ^{80}Zn, ^{130}Cd) and further reduction of isobaric contaminants (^{80}Rb, ^{130}Cs)

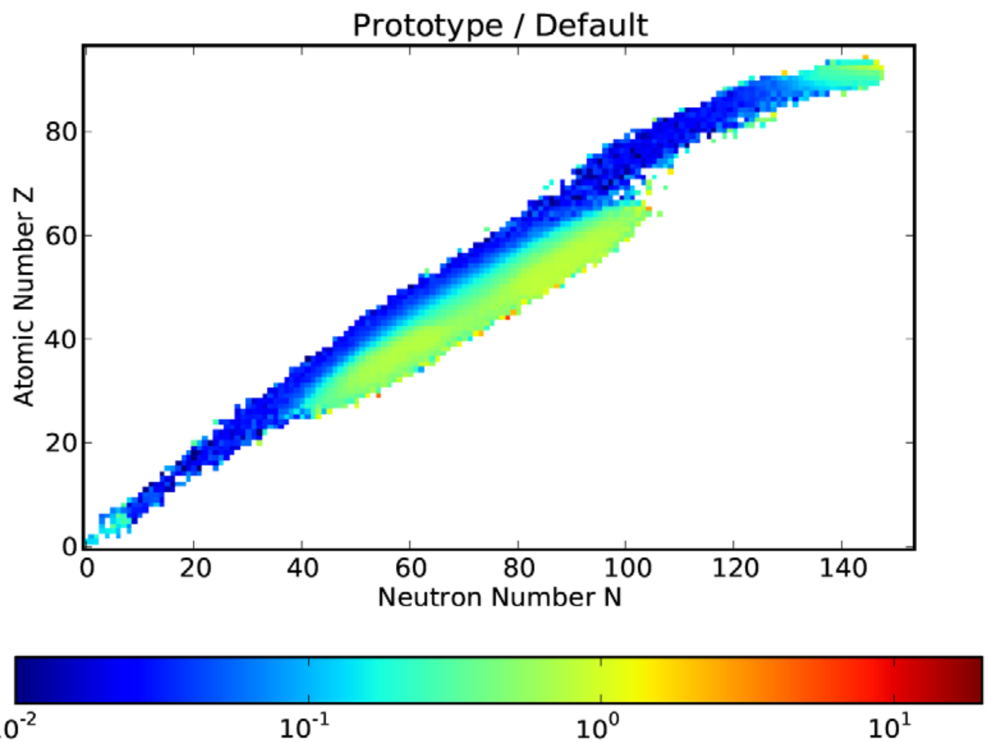


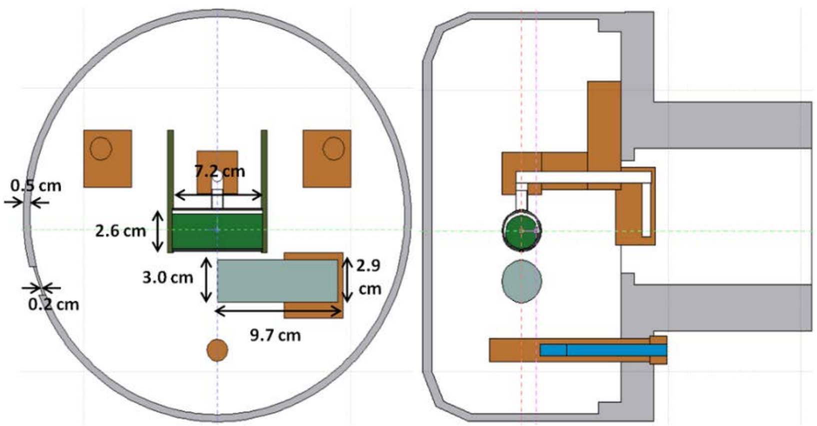
R. Luis et al.
Eur. Phys J. A
2012

See presentation S. Cimmino

T. Stora

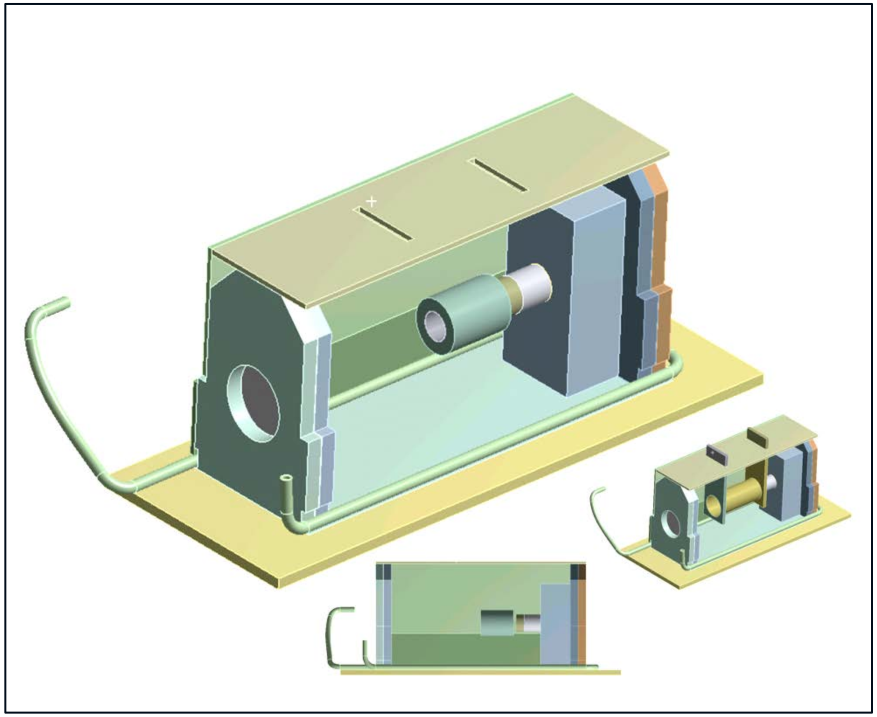
Neutron converter

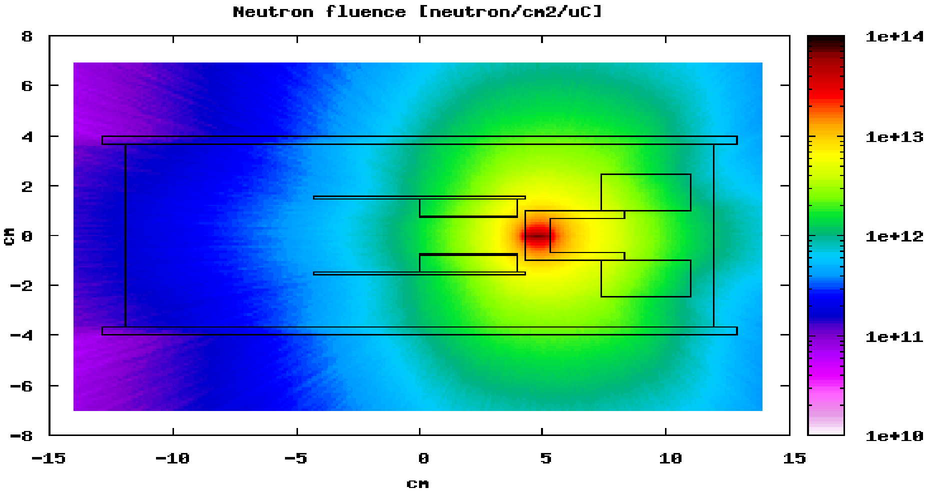




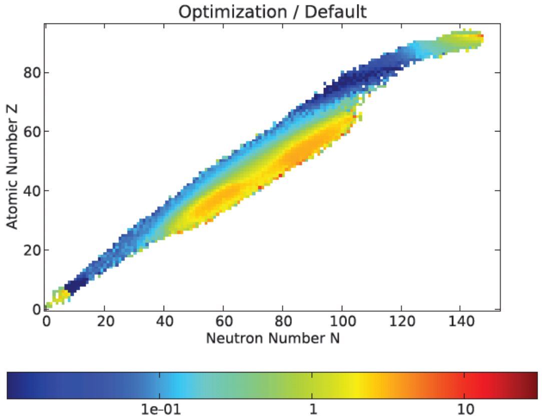
(1st version at ISOLDE:
A. Gottberg, T. Mendonca, R. Luis et al.
Experimental tests of an advanced neutron-to-neutron converter at ISOLDE-CERN, ready for Subm. To NIMB)

Neutron converter v2.0





Goal : R. Luis et al.
Eur. Phys J. A 2012



S. Cimmino et al.
In collaboration with TRIUMF, P. Bricault

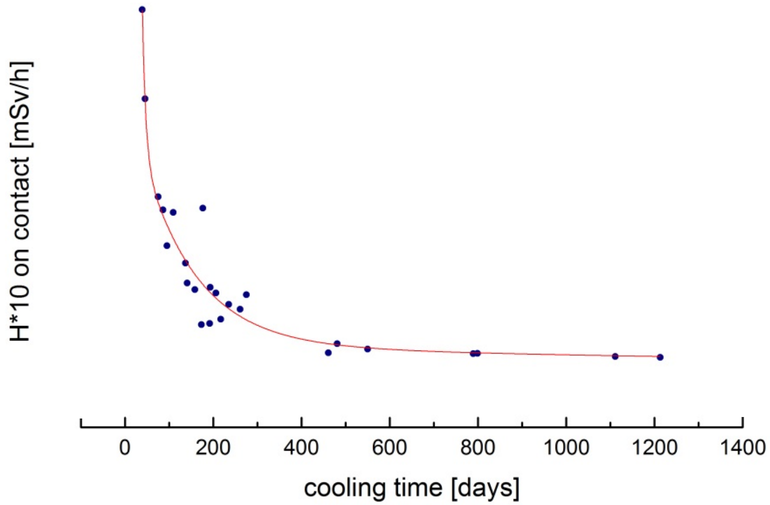
ActILab

Tests of nanoUCx UC498@CERN and @IPNO

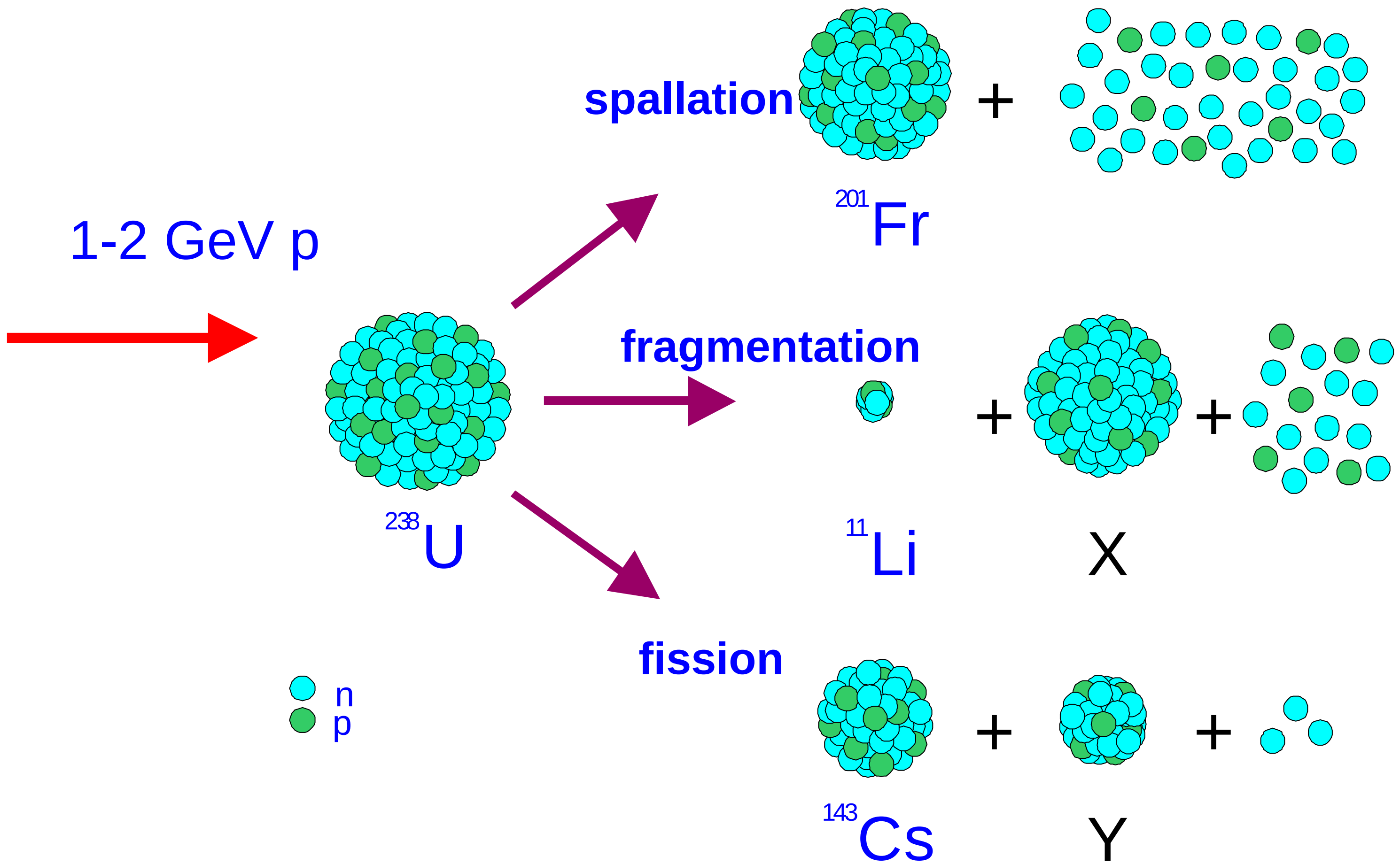
New UCx Target : ~ 50% standard ISOLDE target density

→ One needs to revisit the max # proton on UCx target for dismantling compatibility

→ Nuclearisation of targets, improvement of safety : Presentation by S. Cimmino



T. Stora


1-2 GeV p
238U
n
p
spallation
+
201Fr
fragmentation
+
+
11Li
X
fission
+
+
143Cs
Y

Gain in yield for 2GeV

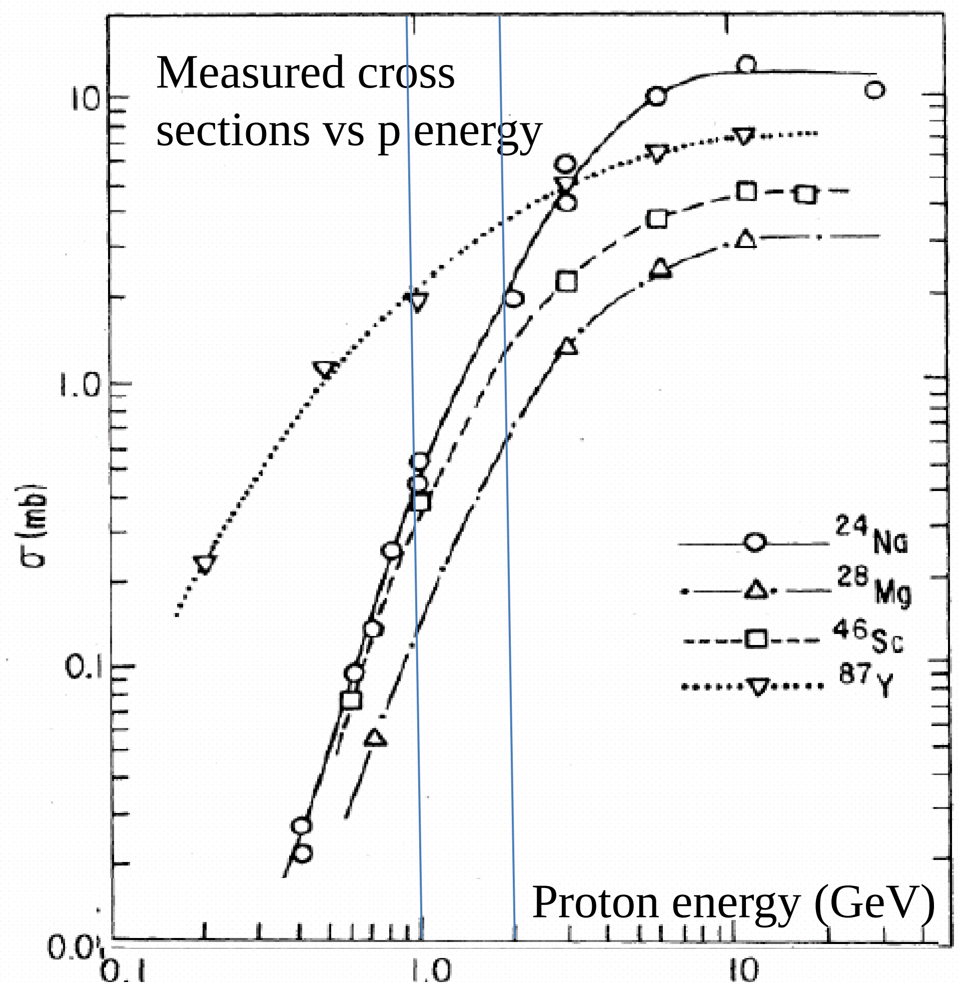
- Yield: $Y = I\,X\,\sigma\,\varepsilon_{rel}\,\varepsilon_{ion}\,\varepsilon_{sep}\,\varepsilon_{transp}$

Proton beam intensity (I)

Target thickness (X)

Production cross section (σ)

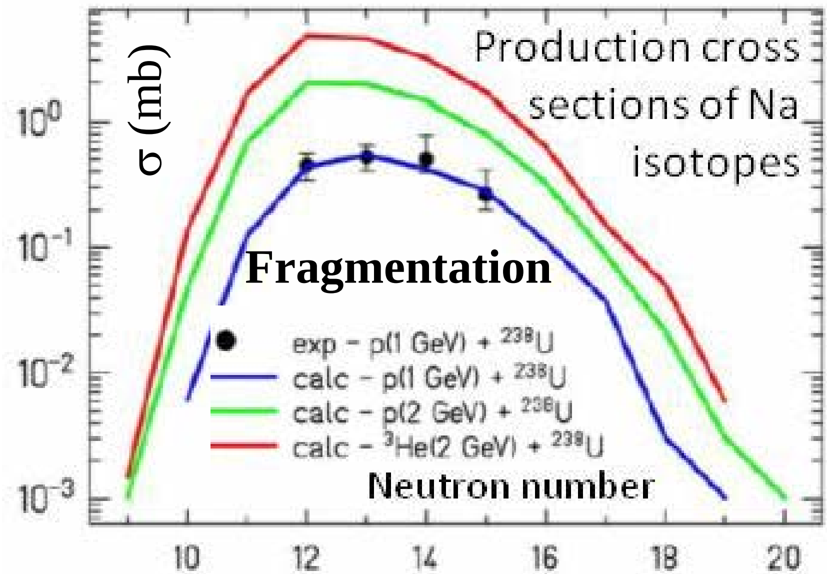
Efficiencies (release, ionization, mass-separation, transport)

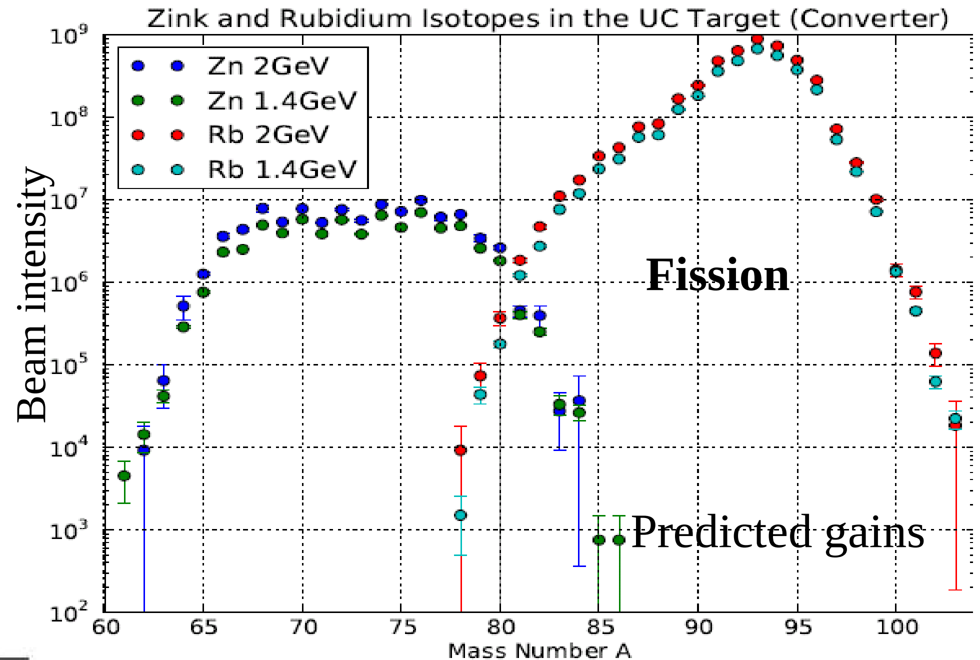


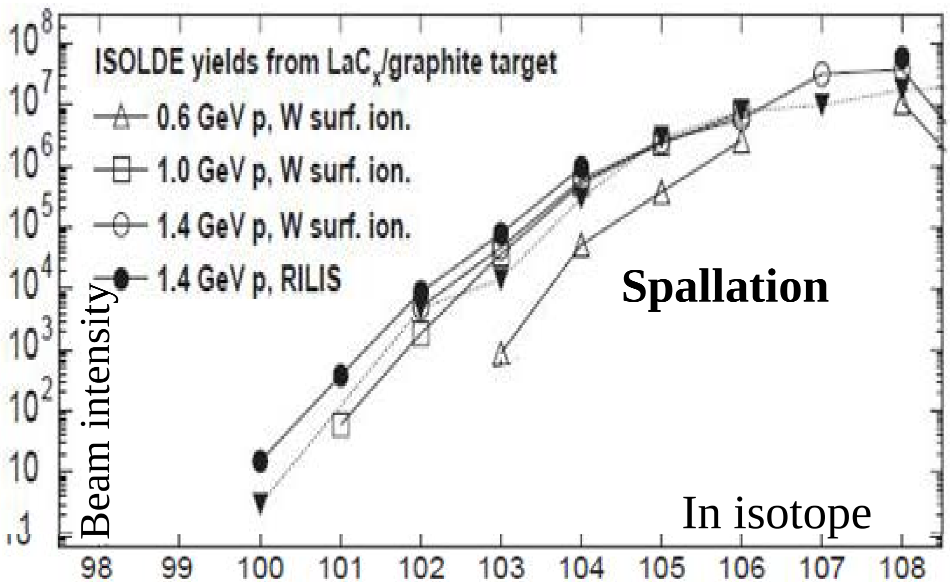
- Increase in proton energy from 1/1.4 GeV to 2 GeV will **increase the cross section** (σ), and thus **the yield**

U. Koester, Eur. Phys. J. A15, 255 (2002)

Cross section/yield increase





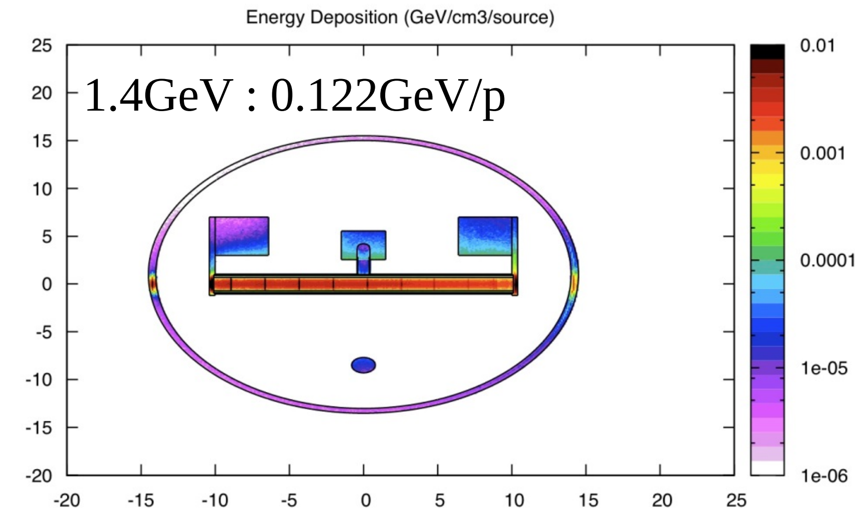


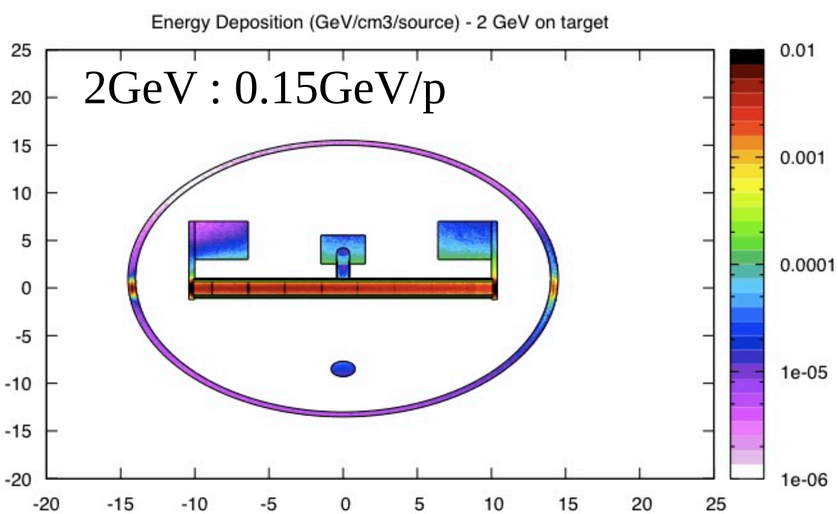
Expected gains:

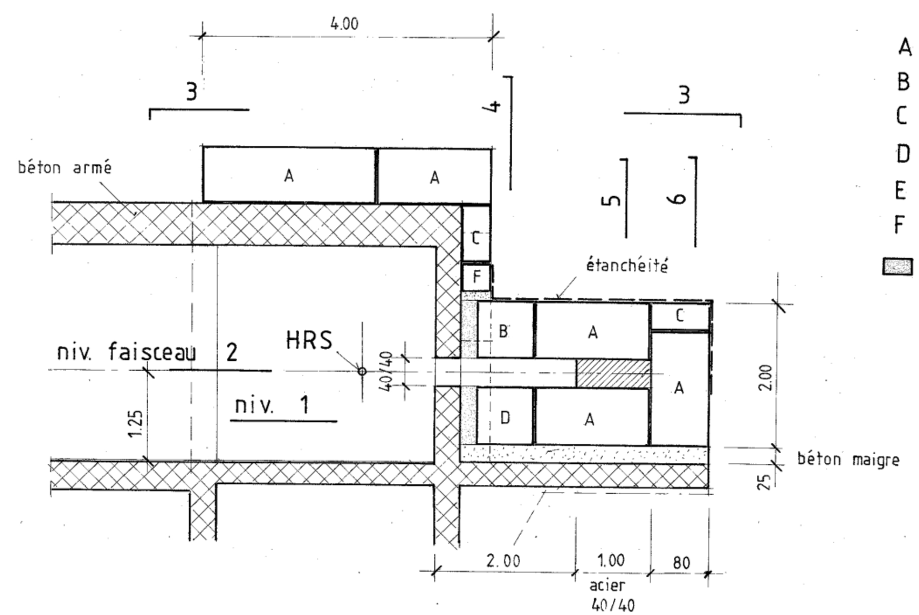
- fission products:1.4 on average;
- fragmentation products: x2 to x5;
- spallation products: over x6

2GeV proton driver will better recreate the EURISOL aims

Targets 2GeV vs 1.4 GeV



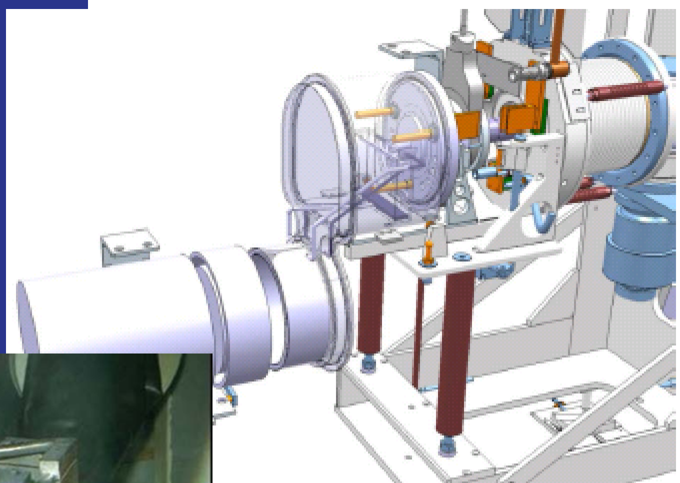




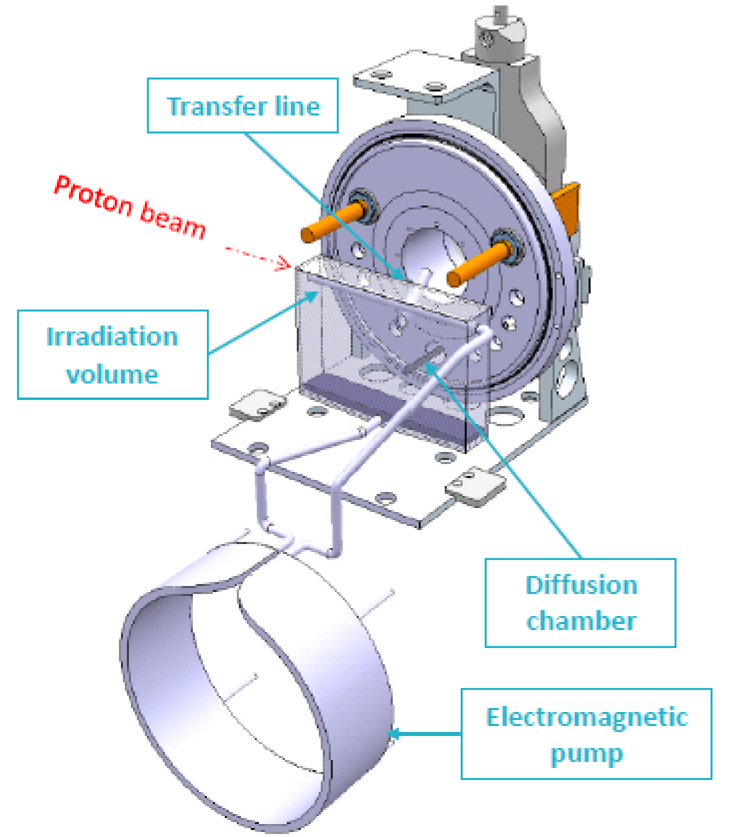
See presentation V. Troncale, A. Polato, L. Morejon

Liquid euctectic Pb/Bi loop for EURISOL
LIEBE project

- PhD project of M. Delonca
- Online test in 2015

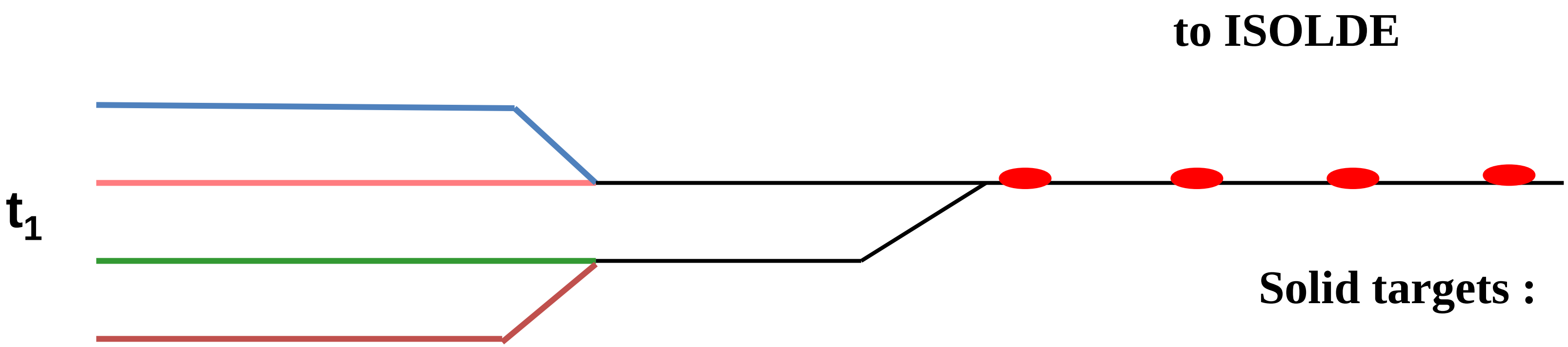


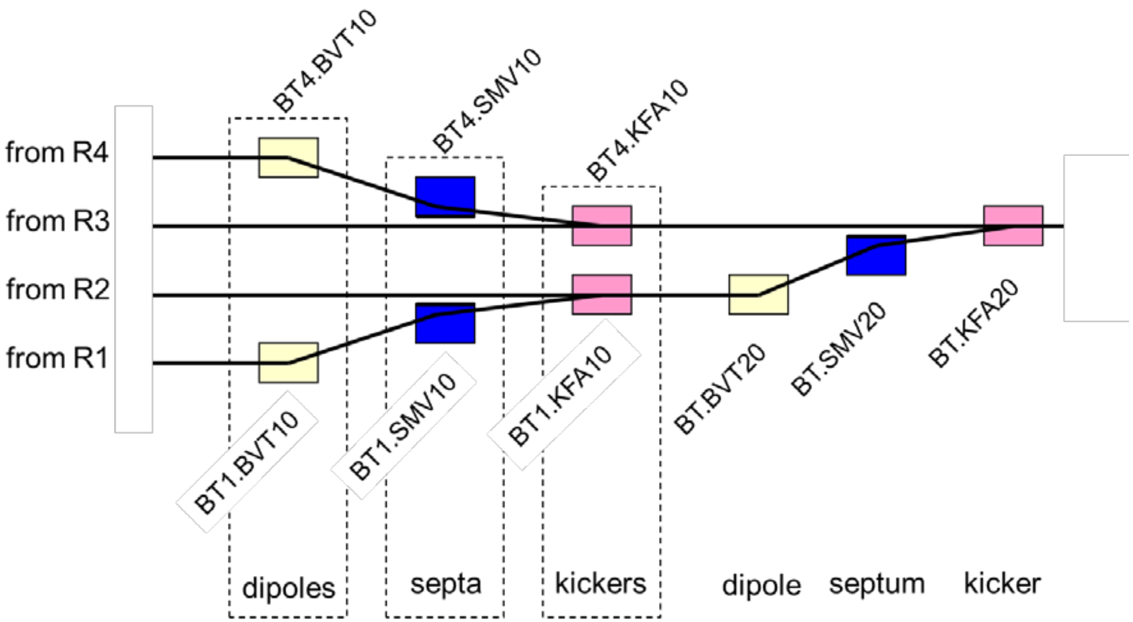
Liquid metal target: Cracked container welds



Courtesy of V. Barozier and M. Delonca

PSB time structure





Solid targets :

4 equidistant bunches

Bunch-length 250ns

Δt=572ns (157m)

Molten targets:

3 bunches
Δt=16 µs

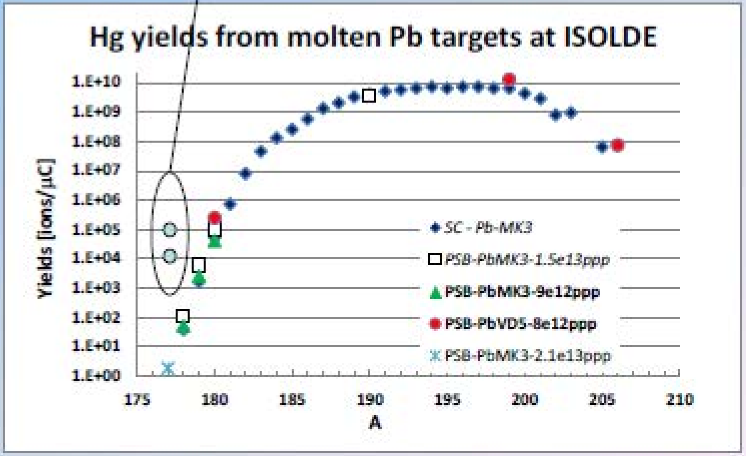
E. Siesling, K. Hanke BE/OP (from 2005, hope it is still up to date)…

Projected Hg beam intensities

177Hg Beam intensity at FRIB (400kW)
(accessed Oct 2012)

Beam		
AZ	209Bi	
Energy	210.2	MeV/u
Fragment		
Energy	160.4	MeV/u
B? (Q=Z)	4.204	Tm
Fast beam rate	3.37e+5	pps
Stopped beam rate	1.03e+5	pps
Reaccelerated beam rate	1.85e+4	pps

Beam intensity at EURISOL in pps:
X100 (100μA p beam)
X10 VADIS ion source
X20 release efficiency
X2 σ if 2GeV p
8% Post-acceleration
(~1/15 would be available at HIE-ISOLDE)



Team & Collaborations

- E. Barbero, B. Crepieux, M. Owen, S. Marzari: production, infrastructures

- C. Seiffert : Molecule evaporation (Gentner, CERN)

- R. Luis : Neutronics (ITN, Lisboa)
- R. Augusto : Fluka, MEDICIS (AdI, CERN)

- Dr. A. Gottberg : Target materials, incl. Uranium (ENSAR-FP7, ActILab).
- J. P. Ramos : Target nanomaterials (Univ. Aveiro)
- M. Czapski : Material analysis support (CATHI ITN Marie-Curie program)

- Dr. T. Mendonca : High power targetry
- S. Cimmino : Thermal management (CATHI ITN Marie-Curie program)

GANIL, IPNO, INFN, PSI (Uranium, ENSAR “ActiLab”), TRIUMF, JAEA
ITN (neutronics, UCx)
EPFL, Aveiro, ITN (materials)
ESS, CEA, SCK●CEN-Myrrha, SINP, PSI (high power targetry)

T. Stora

Conclusion

- 6μA, 2GeV protons for HIE-ISOLDE gives a competitive edge to the facility.
- Already some technical solutions for targets to cope with these new beam parameters are identified:
  - New UCx sinters less and new neutron converter: 60-70% of present beam requests for HIE-ISOLDE physics proposals
  - Circulating loop for liquid metal targets
  - The remaining oxides and carbides : Better insights in aging expected.
- Max number of protons on targets could be revisited: impact on operation
- staggered beam with 4 rings from PSB might be required for ALL targets
- Investigations for the target infrastructures will be key drivers (ventilation, beam dump, etc)

For complementary informations, see presentation at ISOLDE workshop by C. Seiffert

Thank you !