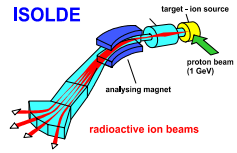
EURISOL

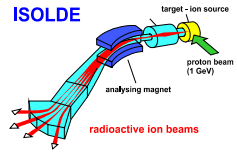


ISOLDE EURISOL R&D for ISOL facilities

H. L. Ravn/CERN, EP

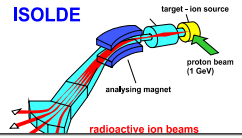
http://cern.ch/Helge.Ravn/files/RIA_Workshop/

EURISOL R&D and EU designstudy



Name of Participating Organization	Role in Project
GANIL, Caen, France	LSF-IHP
CUT, Göteborg, Sweden	OTHER
KULeuven, Leuven, Belgium	OTHER
GSI, Darmstadt, Germany	LSF-IHP
INFN, Legnaro, Italy	OTHER
IPNO, Orsay, France	OTHER
CEA/DAPNIA,Saclay, France	OTHER
ISOLDE/CERN, Genève, Switzerland	LSF-IHP
JYFL, Jyväskylä, Finland	LSF-IHP
RAL, Didcot, United Kingdom	OTHER

EURISOL Project



European Isotope Separation On-Line Radioactive Nuclear Beam Facility

EURISOL index	*(This page)*
EURISOL project	*What is EURISOL? Find out here!*
EURISOL details	*The EURISOL contract and Participating Institutions.*
Meetings	*The 5 EURISOL Task Groups: Dates, notes and presentations*
1st Town Meeting	*Held in Orsay, France, in 2000*
2nd Town Meeting	*Held in Abano Terme, Italy, 2002*
3rd Town Meeting	*Held in Orsay, France, in May, 2003*
Mailing list	*Join our mailing list for regular updates*
Links	*Related sites and documents*
GANIL home page	*Back to GANIL*

http://www.ganil.fr/eurisol/index.html

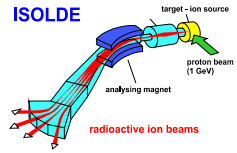
3rd EURISOL TOWN MEETING: Orsay, France, 12 & 13 May 2003.
PRESENTATIONS

Note: if you did not receive the ANNOUNCEMENTS by e-mail, then you are probably not on the *EURISOL Mailing List*!

Draft Reports of the TASK GROUPS (still being revised):

- Key Experiments Task Group Draft Report (30 Mbytes)
- Driver Accelerator Task Group Draft Report (7.9 Mbytes)
- Target & Ion Source Task Group Draft Report (11 Mbytes)
- Post-Accelerator & Mass Spectrometer Task Group Draft Report (13 Mbytes)
- Instumentation Task Group Draft Report (4.5 Mbytes)

EURISOL Layout of the EURISOL Targetstations



Driver accelerator 5 MW, 1-2 GeV proton LINAC

Post-accelarator (linac)

Hi-resolution mass-separator

Ion beams from pre-separators

Beamlines to multiple user areas

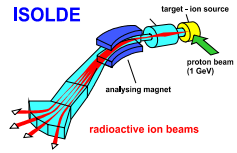
Laser input to ion sources

Shaded areas show shielding needed around each target, ion source and pre-separator.

Proton beams from driver accelerator

Megawatt target area

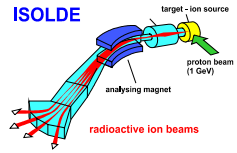
EURISOL



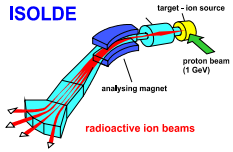
Overview

- Introduction to European RIB facilities EURISOL and networks
- Key experiments
- R&D topics planned for Driver Accelerator
- **R&D topics planned for the Target & Ion Source**
- R&D topics planned for Post-Accelerator & Mass Spectrometer
- R&D topics planned for Instumentation
- Relevance to RIA and Suggestions to international collaboration

The EURISOL-ISOLDE development programme



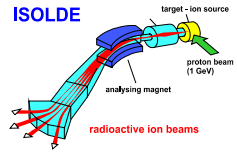
EURISOL

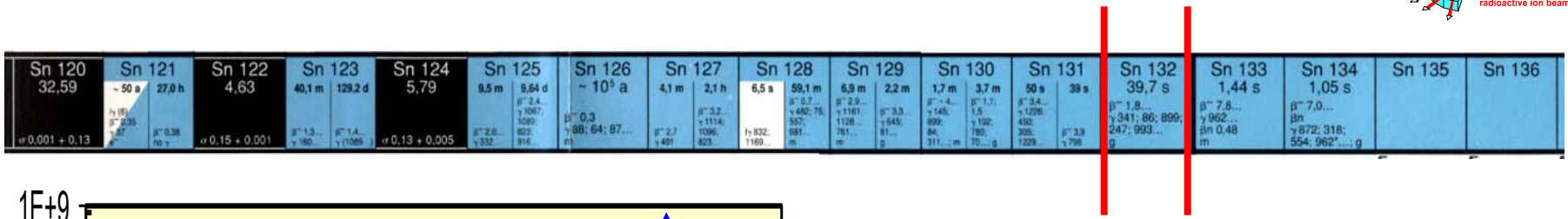


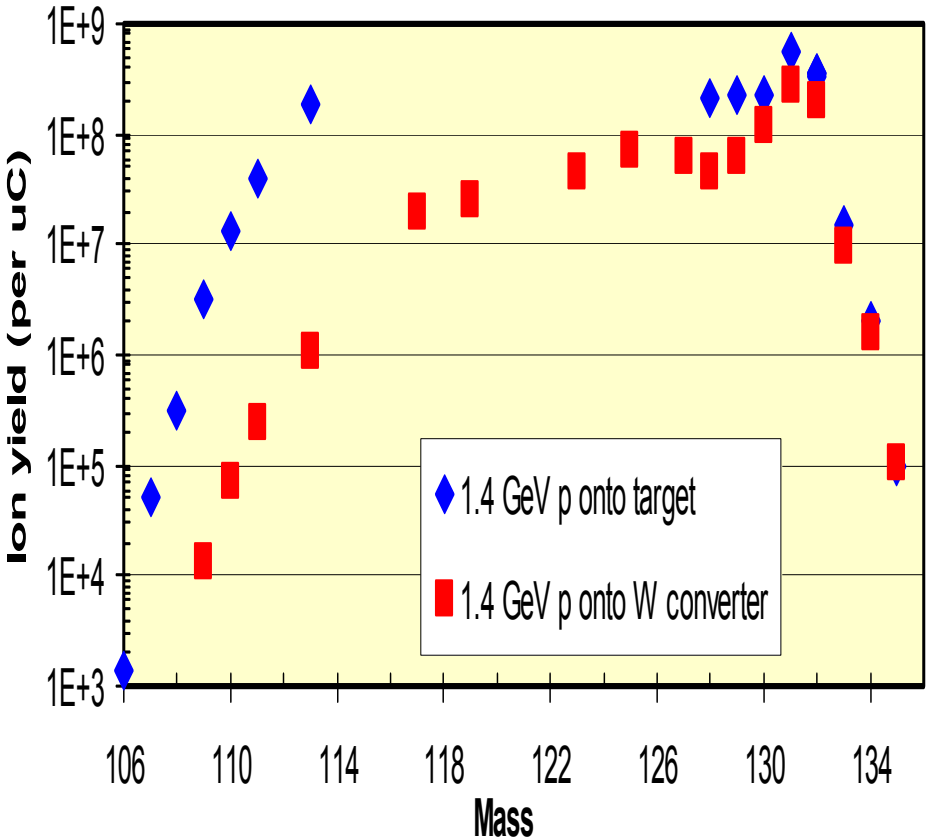
Determination of parameters for yield extrapolations

	On-Line data from CERN/ISOLDE							**Extrapolations to a uA on converter**			**4000**
	Element	**Isotope**	**Half-life**	**Measured yield [at/uC]**	**In-target production yield [at/uC]**	**Improvement factor due to the target optimization**	**Yield after target optimization [at/uC]**	**Expected improvement in ionization efficiency**	**Injected radioactive ion beam intensity [1/s]**	**EURISOL gain factor**	**Accelerated radioactive ion beam intensity [1/s]**
UC	**Ga**	**74**	8.12 m	**1.90E+05**	2.72E+07	10.00	1.90E+06	7.15E+01	**5.43E+11**	1.43E+06	**1.85E+10**
converter		**75**	126 s	**2.20E+05**	3.19E+07	10.00	2.20E+06		**6.29E+11**	1.43E+06	**2.14E+10**
surface ionization		**76**	32.6 s	**2.10E+05**	3.15E+07	10.00	2.10E+06		**6.01E+11**	1.43E+06	**2.04E+10**
		77	13.2 s	**1.80E+05**	2.87E+07	1.00	1.80E+05		**5.15E+10**	1.43E+05	**1.75E+09**
		78	5.09 s	**1.40E+05**	2.54E+07	1.00	1.40E+05		**4.00E+10**	1.43E+05	**1.36E+09**
		79	2.847 s	**1.00E+05**	2.07E+07	1.00	1.00E+05		**2.86E+10**	1.43E+05	**9.72E+08**
		80	1.697 s	**4.00E+04**	9.83E+06	1.00	4.00E+04		**1.14E+10**	1.43E+05	**3.89E+08**
		81	1.217 s	**1.00E+04**	2.83E+06	1.00	1.00E+04		**2.86E+09**	1.43E+05	**9.72E+07**

EURISOL Sn yields from a UC target







Today at ISOLDE:

$^{132}Sn^{+}$ intensity: **5.0E8 per s**

with 2.5 μA of 1.4 GeV protons

onto 12.7 mm W converter

(release efficiency about 80%)

EURISOL:

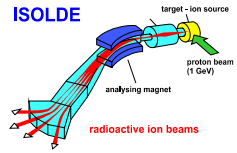
1.0 GeV protons instead of 1.4 GeV	0.7
1 mA protons	400
circular target	10
RILIS improvement	5
Total	14000

Expected intensity:

7E12 per s = 1 μA $^{132}Sn^{+}$

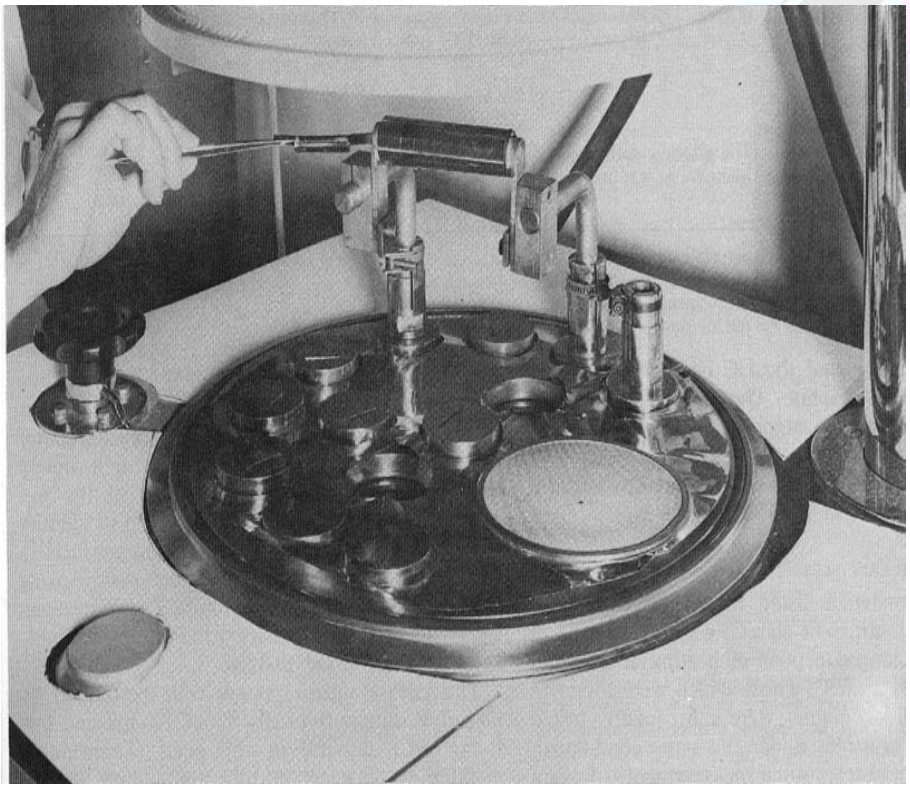
Ref. Ulli Koester

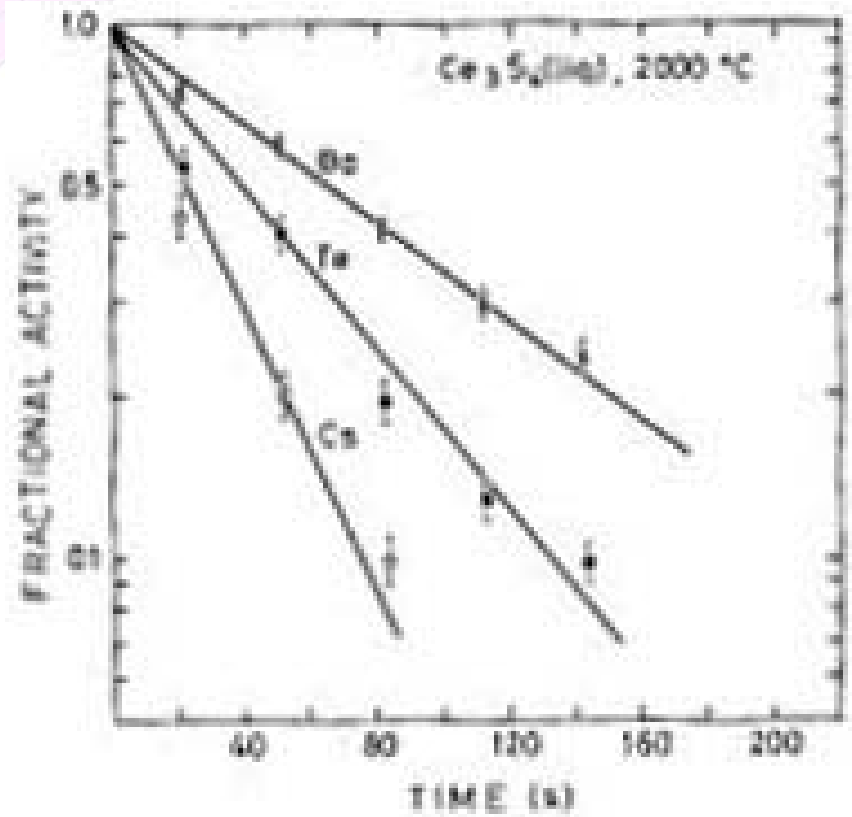
Target materials and release



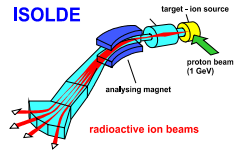
- Uranium oxide, Uranium carbide
- UC_x fibres
- Molten metals,
- Metal foils and powders
- Metal oxides, carbides, and sulphides

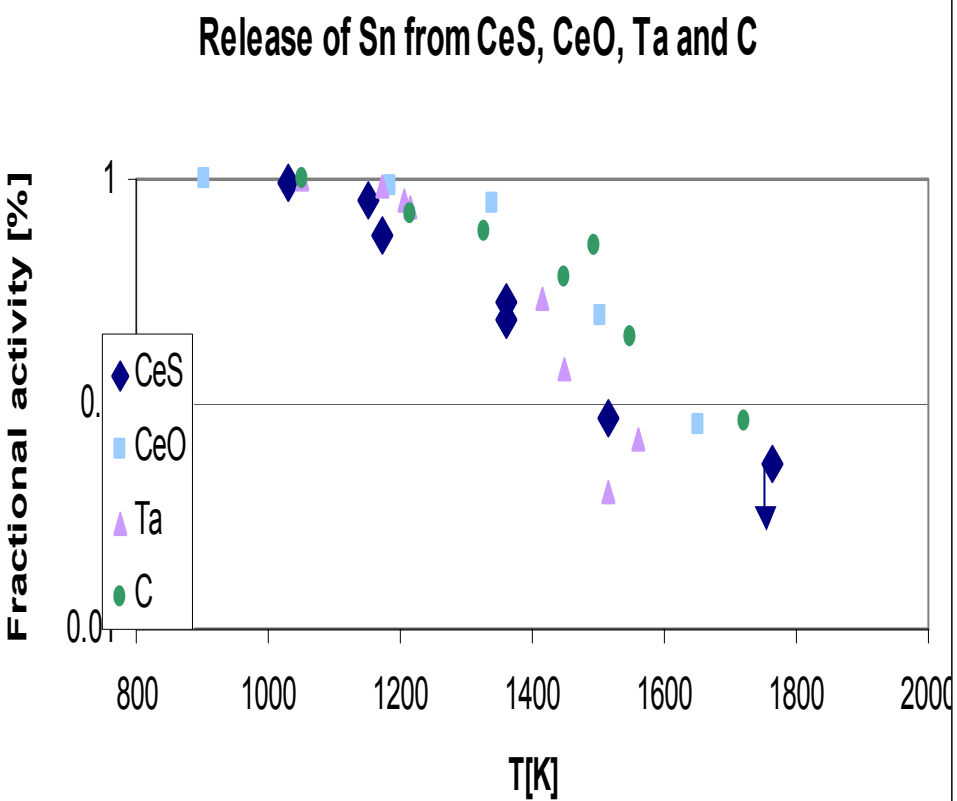
- High temperature refractory material
- Condensed phase diffusion and desorption
- Gas phase effusion
- Chemistry



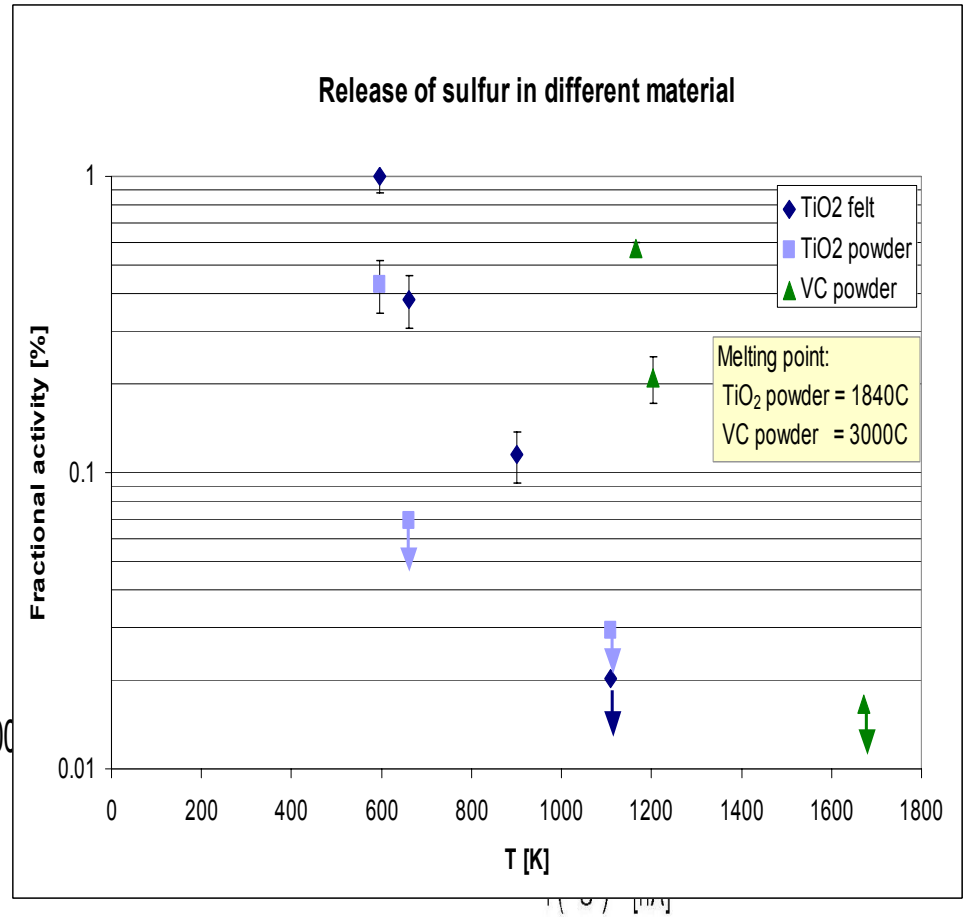


New targets for making beams of the elements C, O, N, Si, S, Ge and Te

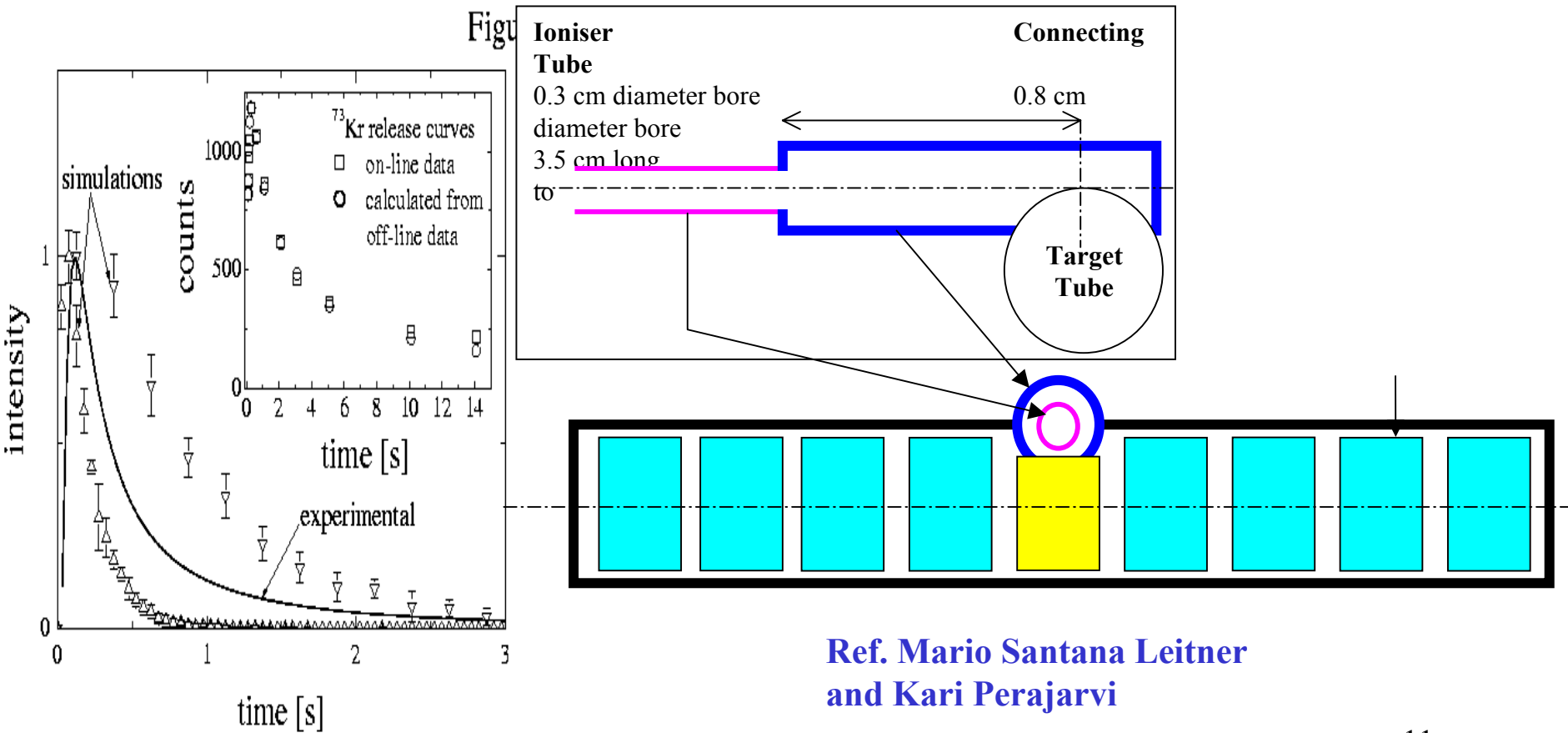




Ref. Angelique Joinet

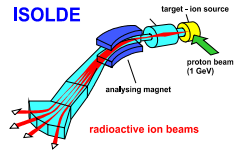


Monte Carlo code for prediction of the decay losses in new target geometries

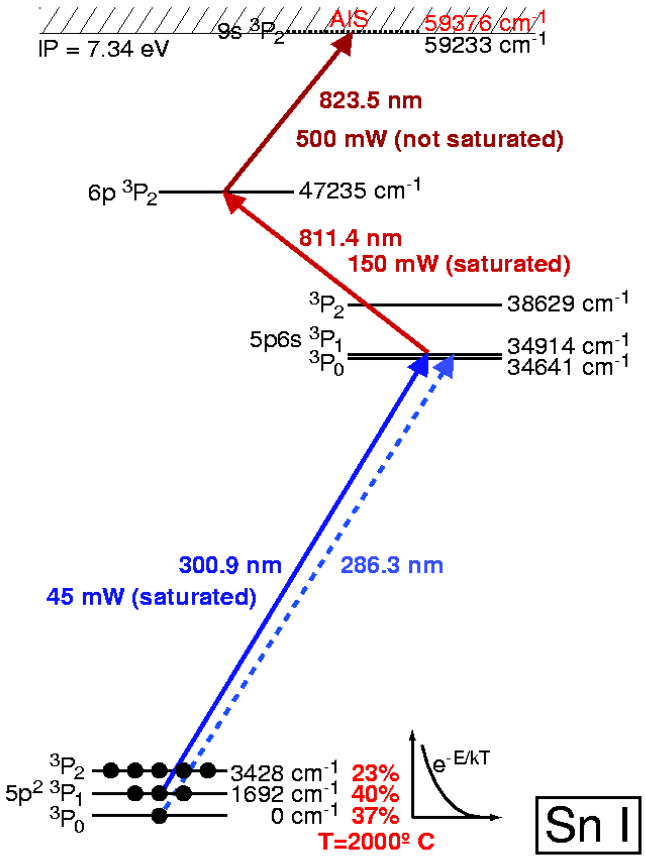


Ref. Mario Santana Leitner and Kari Perajarvi

Resonant ionization laser laser ion source RILIS of Tin

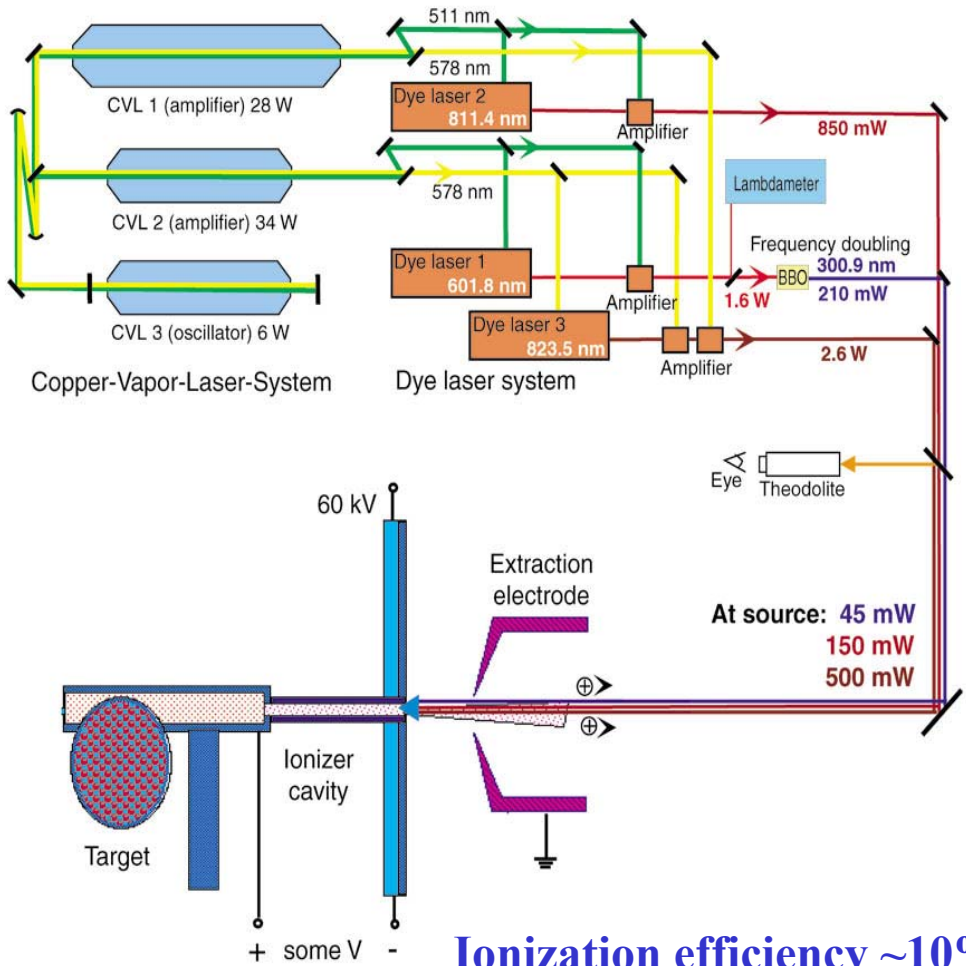


Ionization scheme for Tin



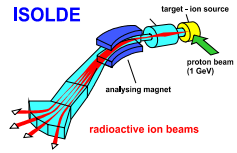
Three fine structure components of the ground state are thermally populated, but only one can be excited at a time. A second UV laser (dotted line) could roughly double the efficiency.

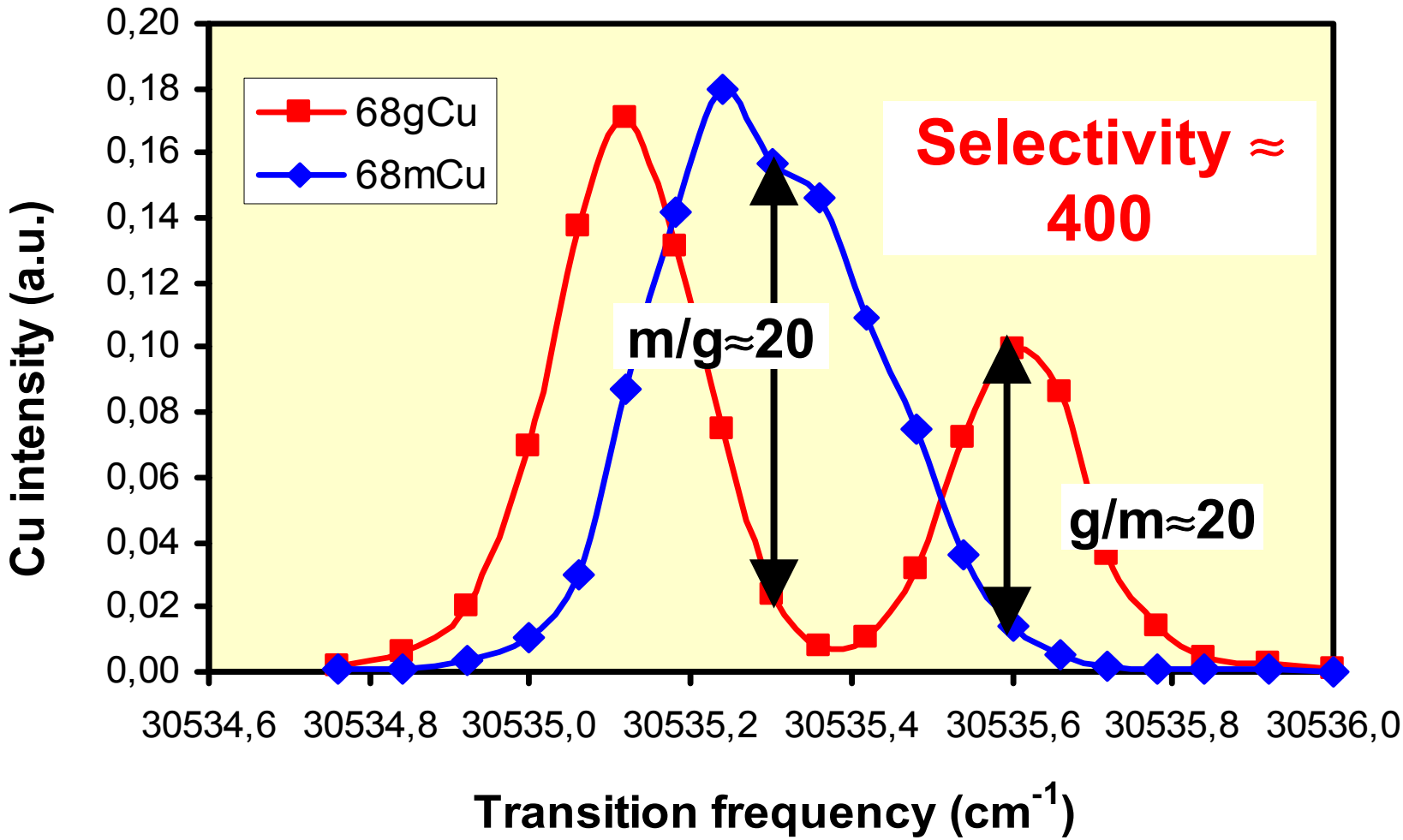
Ref. Ulli Köster



Ionization efficiency ~10%

Separation of Cu isomers with the ISOLDE RILIS

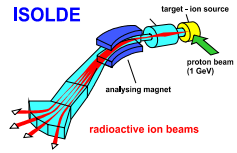




Ref. Ulli Köster

EURISOL

RILIS elements



Resonance Ionization Laser Ion Source, using Copper Vapor Lasers

elements ionized with ISOLDE RILIS

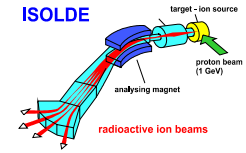
tested ionization scheme

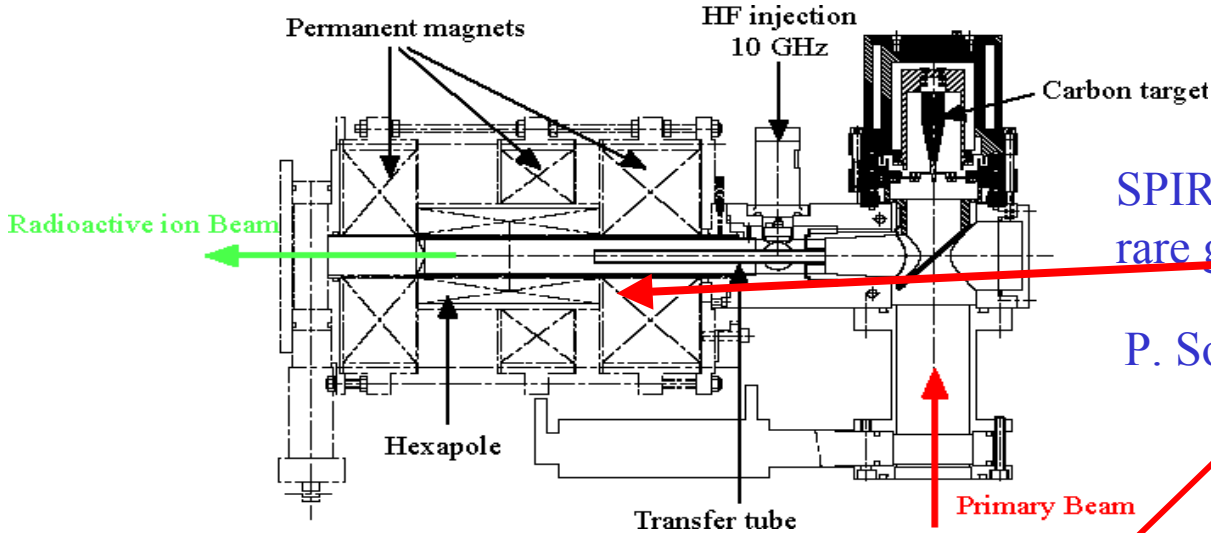
possible ionization scheme (untested)

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110	111	112						

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

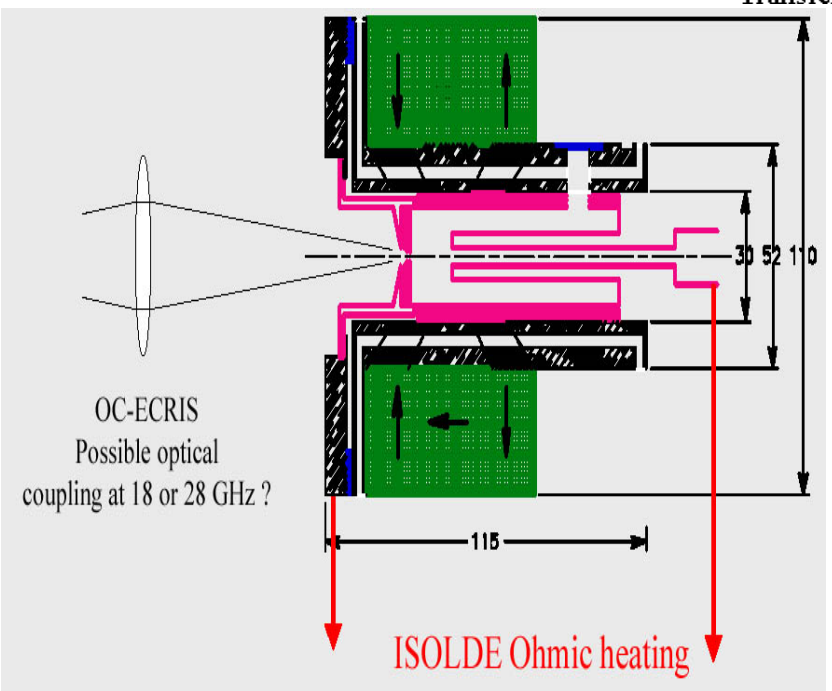
ECR ion sources

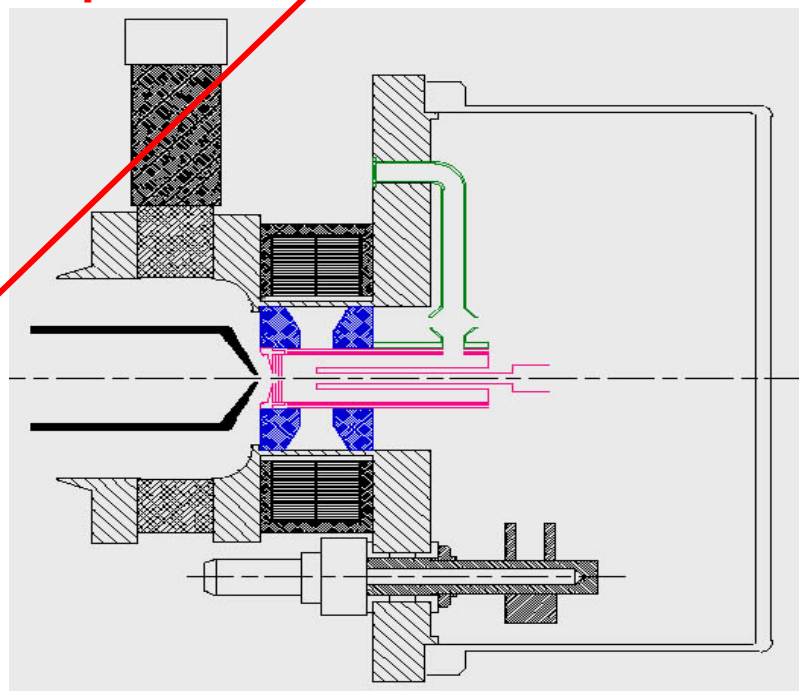




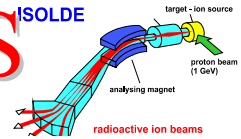
SPIRAL ECR source for rare gases

P. Sortais suggestions for R&D





EURISOL GANIL/ISOLDE MONOECRIS



Design principle

- Permanent magnets
- RF=2.45 GHz, <50 W
- Simple
- Radiation sensitive

ISOLDE construction team

+ **Jacques Lettry Fredrik Wenander**

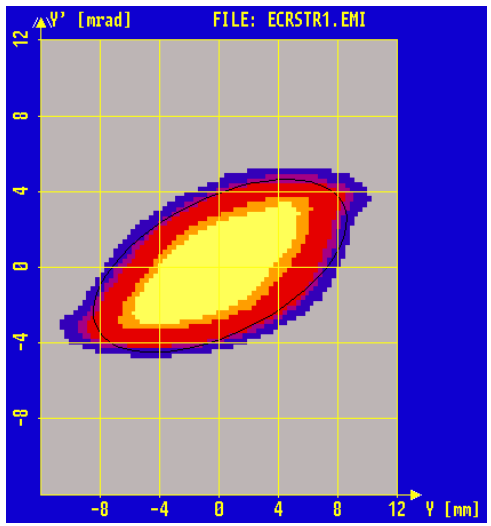
* Original design GANIL's MINIMONO, G. Gaubert, P. Jardin, R. Leroy

Expected performances

- **Aimed for noble gases and N_2 and S_2**

	Efficiency	$T_{response}$(50%)
He	0.01% to 20%	20 ms
Ne	0.05% to 35%	30 ms
Ar	7.0% to 95%	40 ms
Kr	40% to 95%	40 ms

Measured beam phase-space



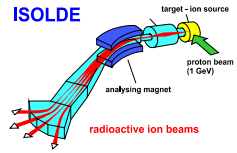
43 π mm mrad (95%) at 30 keV

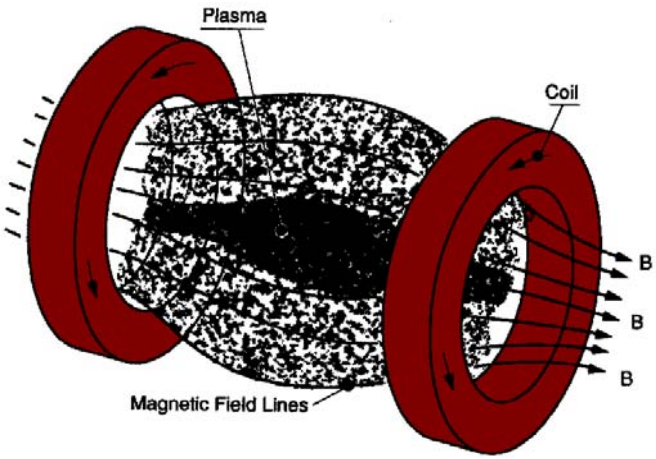
Within standard target unit

Present status

- Plasma ignited
- Beam extracted
- Ar^+ efficiency of 25%
- Severe sparking problems!
- Upgrade power supplies
- Complicated puller design
- Off-line tests October
- On-line next year?

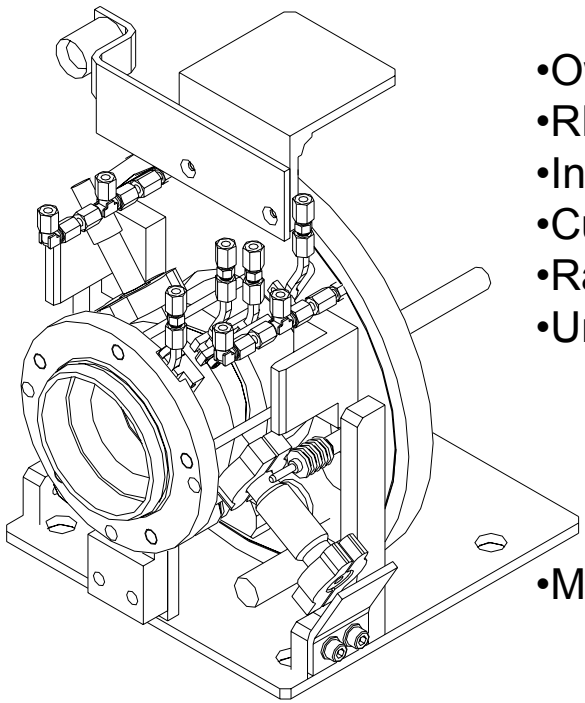
ISOLDE MONOECRIS II





Magnetic confinement (2 coils)
+ RF (2.45 GHz) + Support gas
=>
Hot electrons that ionise
atoms/ moleules

Prototype of coil for B-field generation



Within standard target unit

Design principle

- Own ISOLDE design
- RF=2.45 GHz
- Innovative cavity design
- Current coils
- Radiation robust
- Unknown:
  - functioning
  - efficiency
  - response
  - stability
- Modify
  - on-line extraction?
  - pumping?

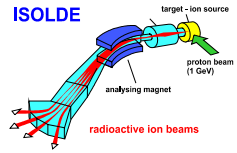
Present status

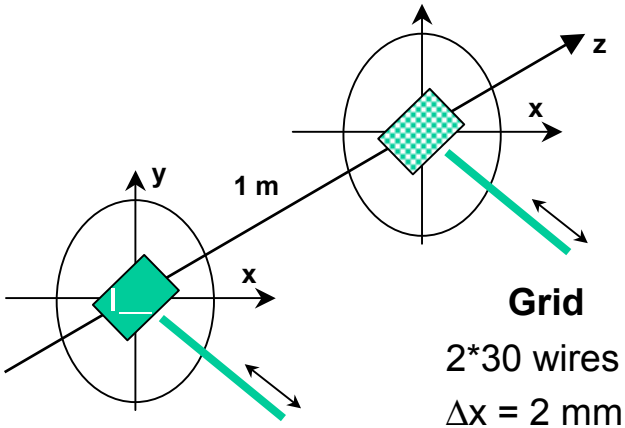
- Under construction
- Prototype tests Jan/Feb

Design and construction

- Fredrik Wenander
- Jacques Lettry
- Nicola Chritin
- Ermanno Barbero
- W. Pirkl

Emittance meter





Grid

2*30 wires

Δx = 2 mm

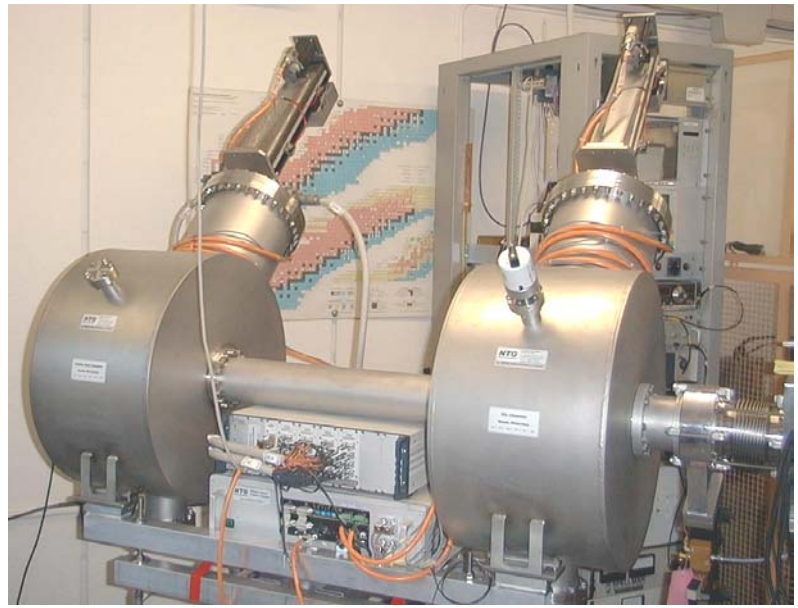
7 intermediate steps => angular resolution 0.25 mrad

ϕ_{wire} = 0.2 mm

Slits

width = 0.2 mm

step length > 10 μm



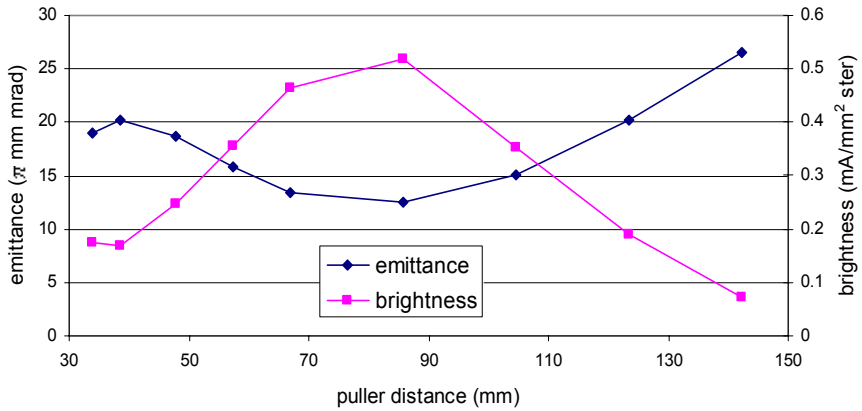
Features

- Measures the transverse phase spaces
- Tilted 45° → ε measured at the same z pos. no rotation of the device
- ε limit ~ 0.1 mm·mrad
- Current limit ~ 1nA
- Gateable 1 - 1000 ms

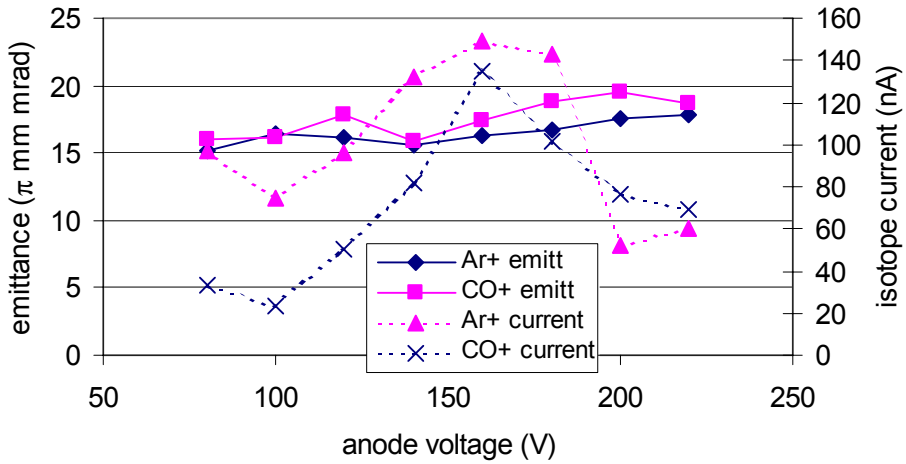
Emittance programme

1. Determine the emittance for the different ISOLDE ion sources.
2. Investigate the parameter influence on the emittance.
3. Improve the emittance.
4. Emittance-characterise each newly built target unit.

Emittance results



95% geo emittance and brightness (top) and currents (bottom) as functions of puller position for a surface ion source.



95% geo emittance and isotope current vs. anode voltage

General conclusions

- Puller position important for emittance
- ε varies with selected ion mass
- No space-charge for I_{total}<3 uA

Surface ioniser

- ε independent on ionisation potential
- Emittance dependent on surface ioniser tube temperature

Plasma ioniser

- ε varies with the pressure
- ε varies slightly with anode potential
- etc etc

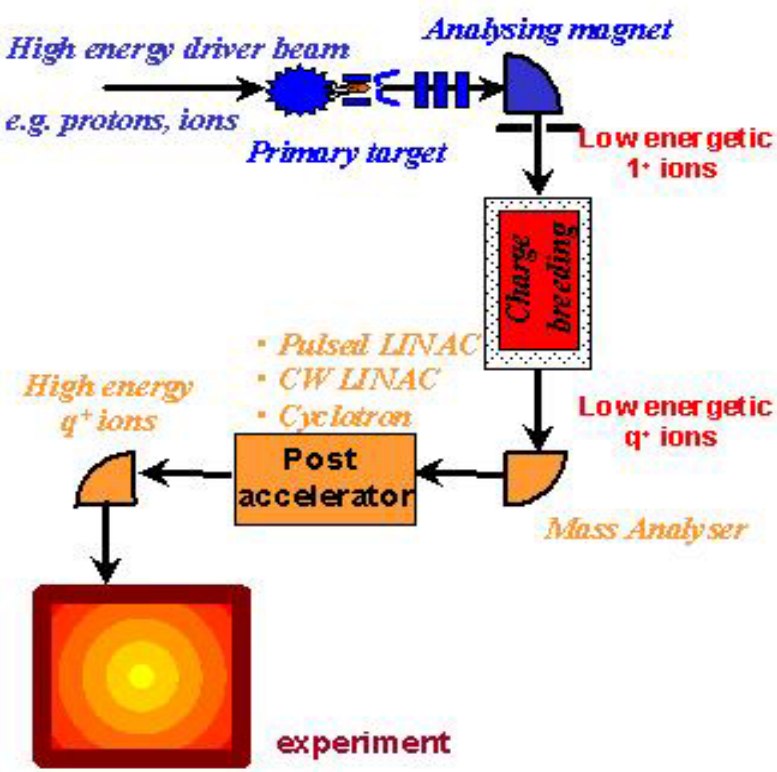
Optimum cold plasma ion-source emitt.
~6 π·mm·mrad (95% geo, 60 kV)
for typical operation conditions

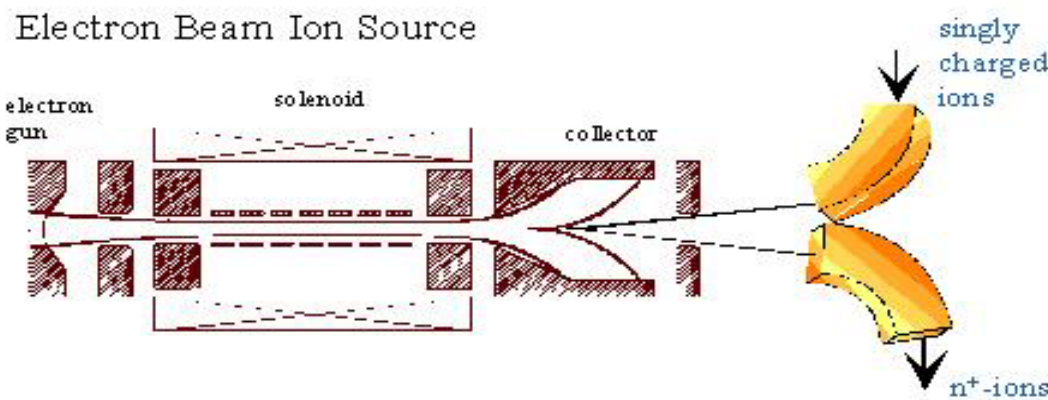
Optimum surface ioniser emitt.
~10 π·mm·mrad (95% geo, 60 kV)
typical conditions (3 mm tube)

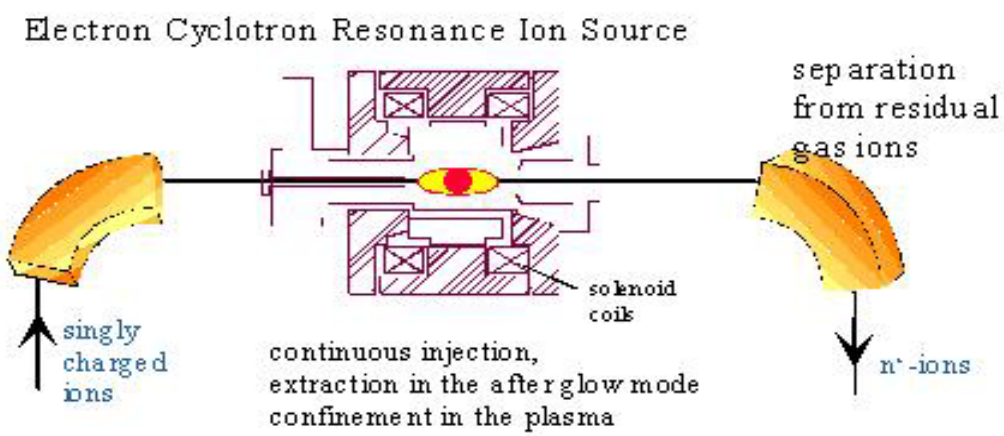
F. Wenander et al., Transverse Emittance Investigation of the ISOLDE Target Ion Sources Proc. of EMIS 14, to be published in Nucl. Instr. Meth. B.

Charge state breeding

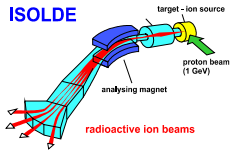
Charge breeding scenarios





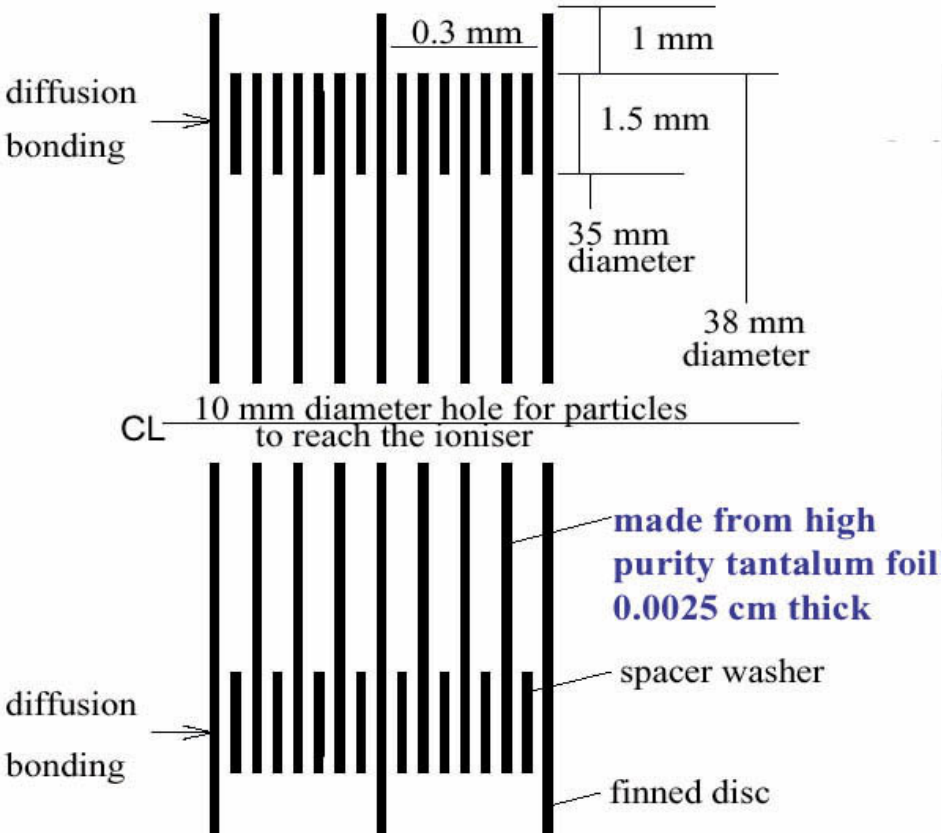


High power targets

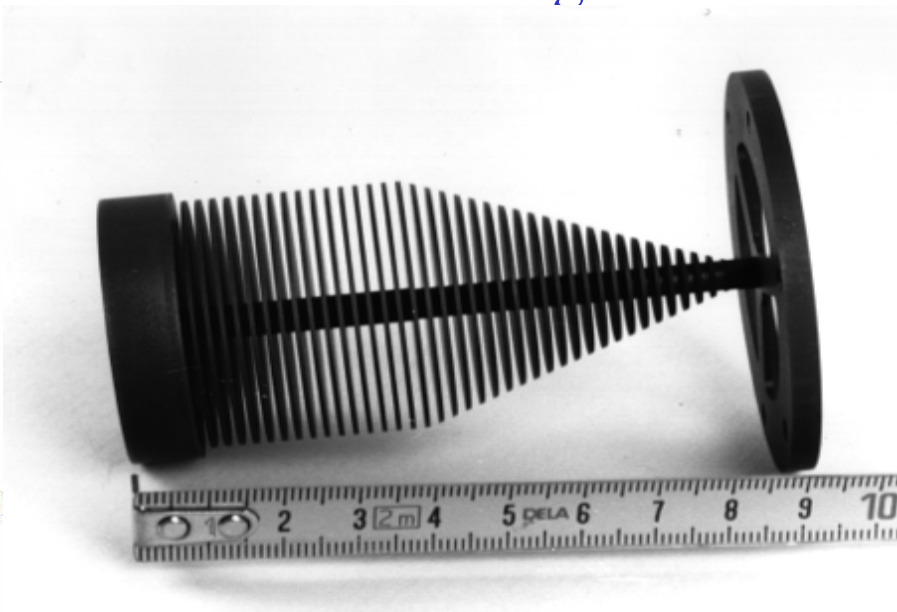


Power density of 300 to 3000 W/cm^3

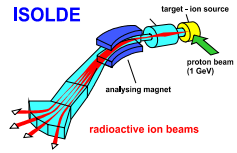
30kW RIST Ta target

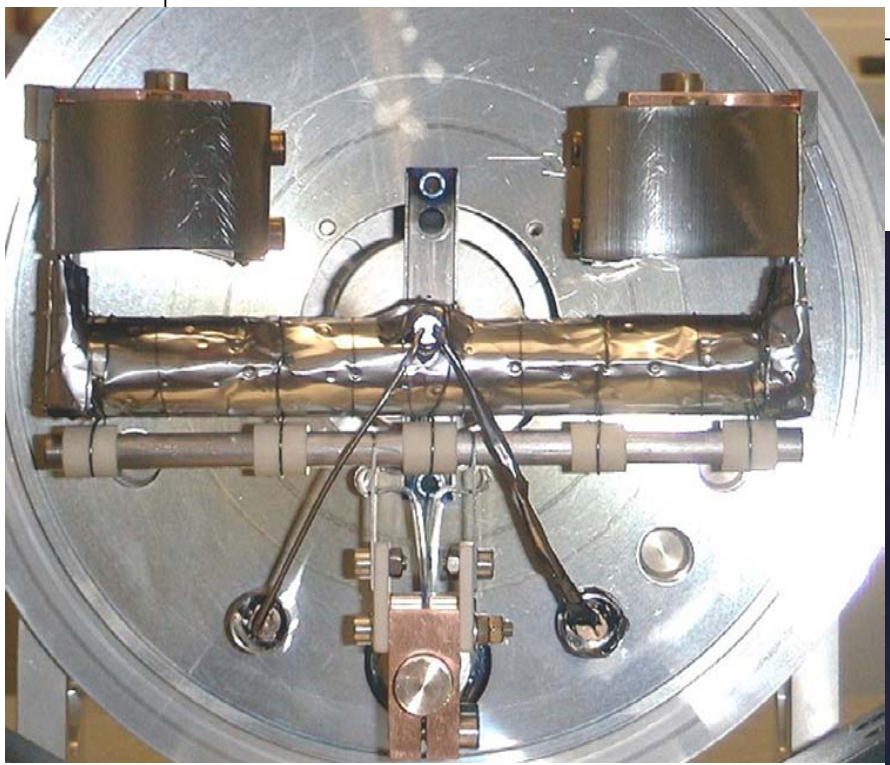


6kW GANIL C target



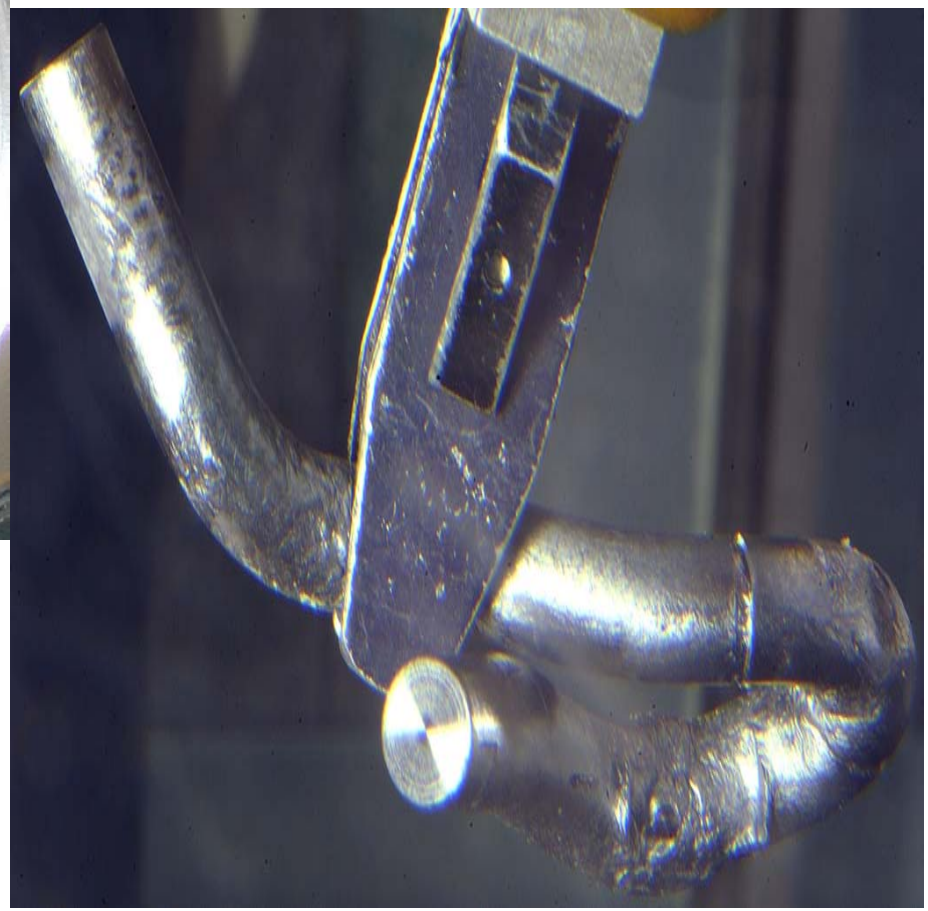
ISOLDE converter targets





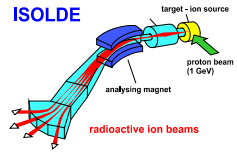
Ta-converter mounted below the UC target before irradiation

Ta-rod after irradiation with 6E18 protons in 2.4 μs pulses of 3E13



EURISOL

1 MW target for 10^{15} fissions per s



Fission products

$^{238}UC_2$

Spallation neutrons

Transfer line to ion source

n

n

n

p

n

n

n

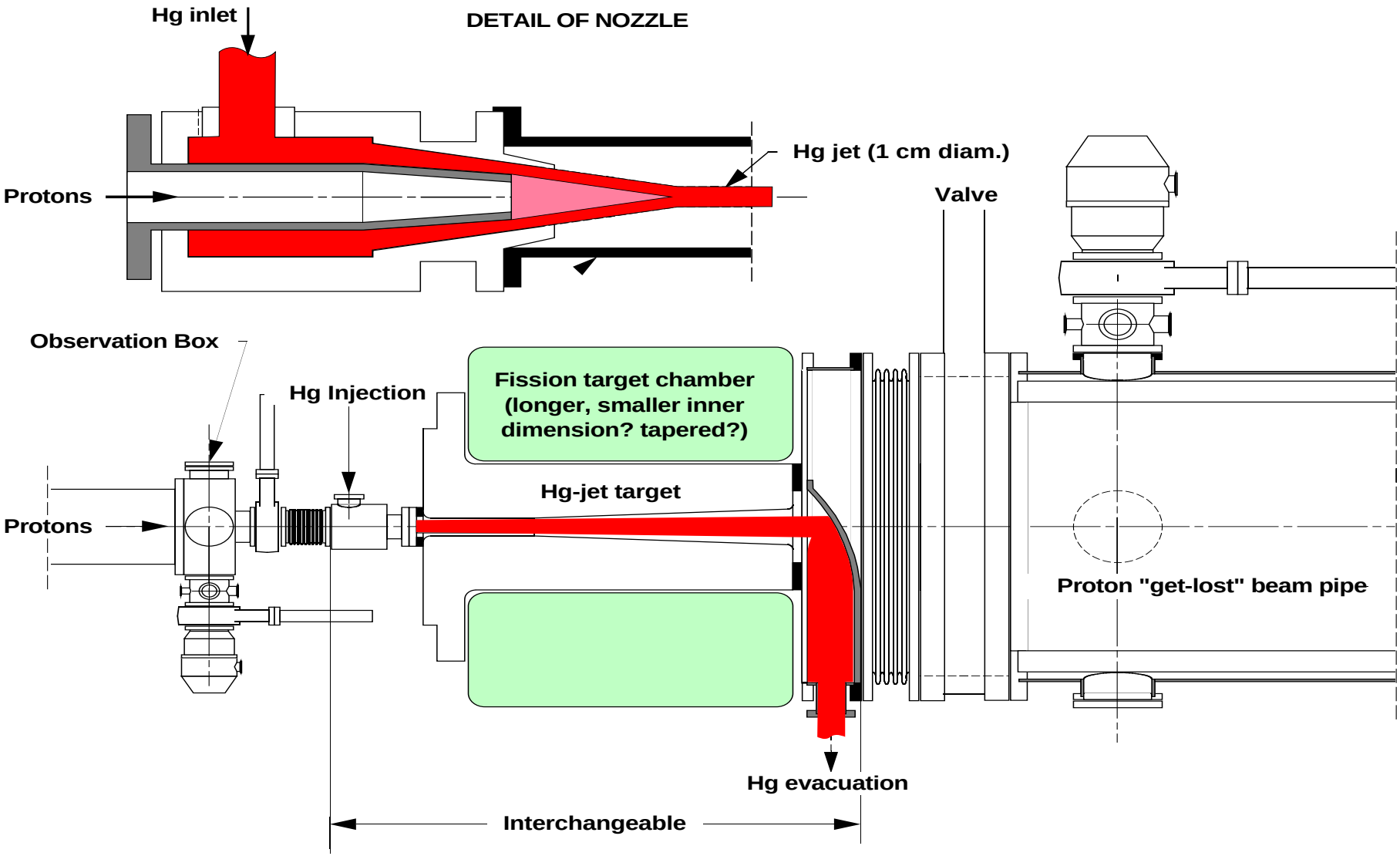
high-energy protons

Spallation target:
a) Watercooled W
b) Hg-Jet

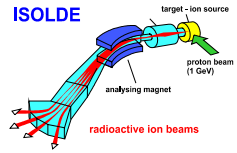
Ref. Ulli Koester

ISOL target surrounding a spallation neutron source

Mercury-jet p-n converter



EURISOL EUROPEAN ISOL-RIB FACILITIES and R&D networks



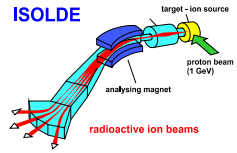
- **ARENAS Louvain-laNeuve**
- **ISOLDE CERN**
- **SPIRAL GANIL**
- **EXCYT Catania**
- **MAFF Munich**
- **SPES Legnaro**

- **EU-network TARGISOL**
- **EU-network Charge breeding**
- **EU-network LASER**
- **EUnetworkSAFERIB**

Meetings

Numerous workshops have been and will continue to be organised by the various EU networks and the Design Study.
US participants are also invited

EURISOL



CERN baseline scenario for a Neutrino Factory

Repetition rate, pulse duration: 50 Hz, 3.3 ms

Pulse intensity 10^{14}/pulse

Beam power 4 MW

Heavy element target absorbing 1 MW beam power

2.2 GeV Superconducting H⁻ Linac

Bunch compressor ring

Accumulator ring

Target

Horn

44/88 MHz capture, cooling, acceleration

2-10 GeV recirculator

10-50 GeV recirculator

Muon decay ring

Bow-tie on inclined plane

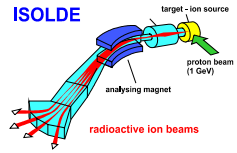
ν

ν

cdj

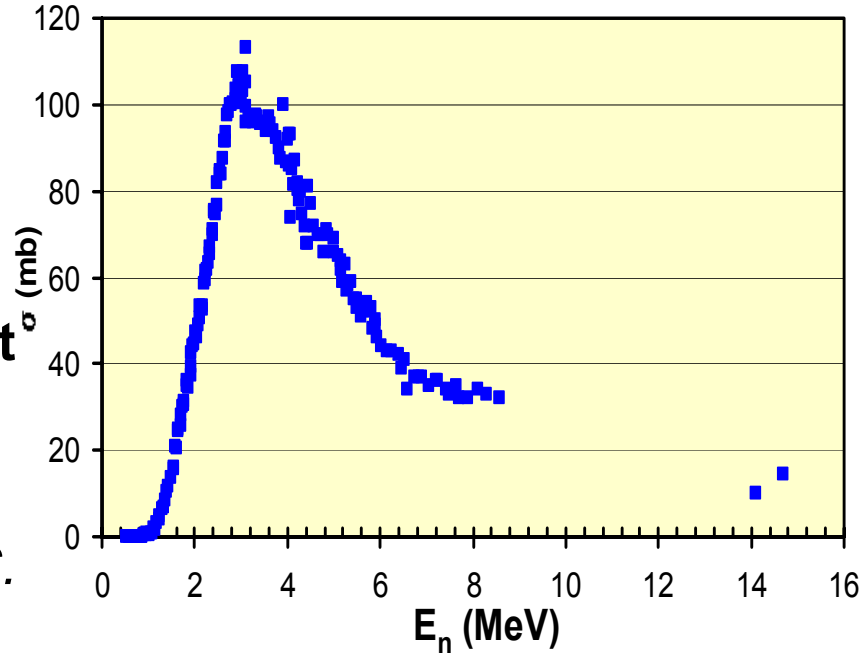
10^{21} neutrinos/year

^{6}He production by ^{9}Be(n,α)



^{9}Be(n,α)^{6}He reaction favorable:

- **Threshold: 0.6 MeV**
- **Peak cross-section 105 mb**
- **Good overlap with evaporation part of spallation neutron spectrum: $n(E) \sim \sqrt{E} * \exp(-E/E_e)$**
- **E_e: 2.06 MeV for 2 GeV p on Pb** *G.S. Bauer, NIM A463 (2001) 505*
- **BeO very refractory**

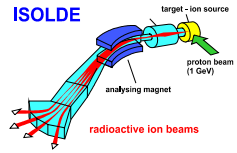


^{6}Li(n,p)^{6}He reaction less interesting:

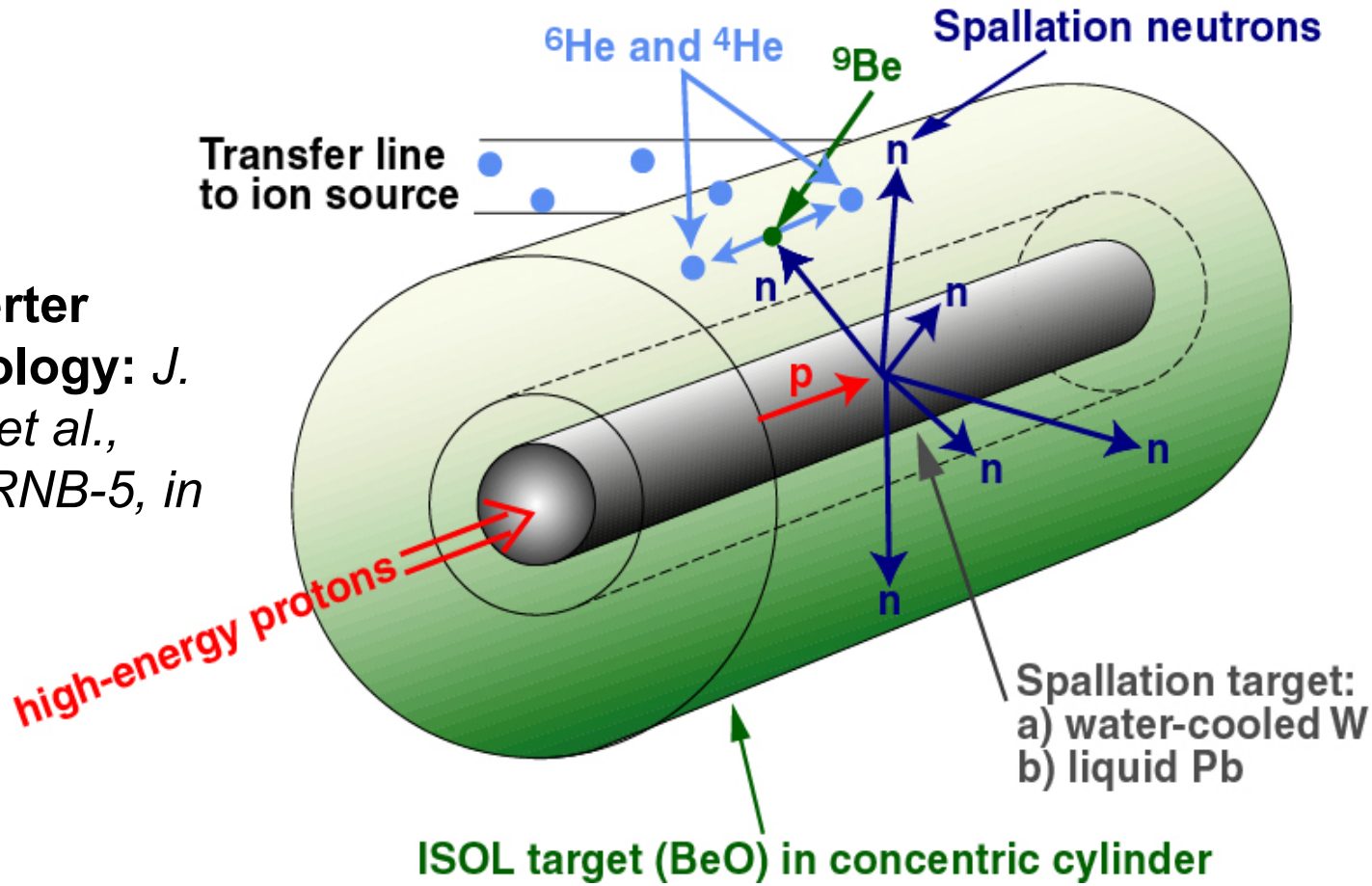
- **Threshold: 2.7 MeV**
- **Peak cross-section 35 mb**
- **Li compounds rather volatile**

Ref. Ulli Koester

^{6}He production by ^{9}Be(n,α)

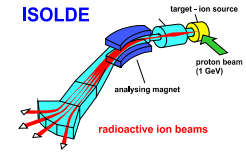


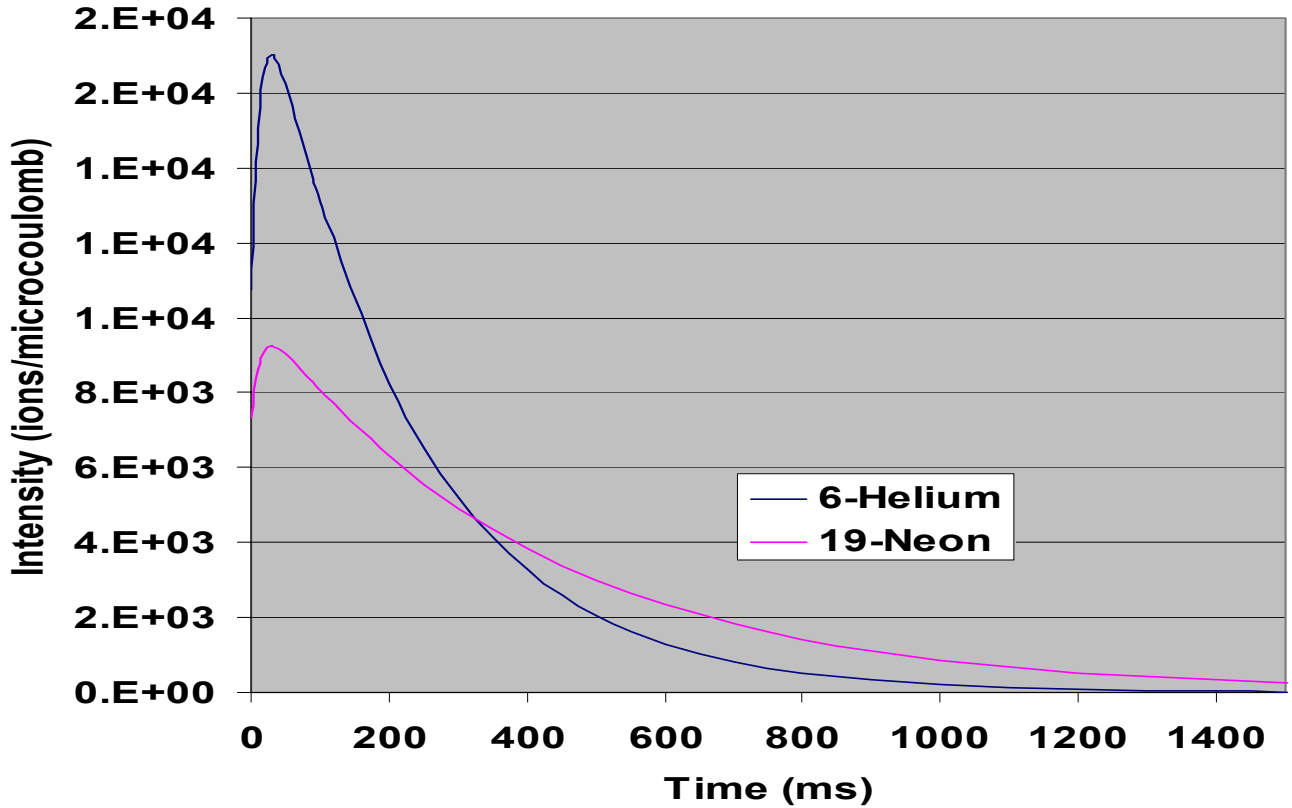
Converter technology: *J. Nolen et al., NPA, RNB-5, in press*.



Ref. Ulli Koester

He and Ne beam intensities

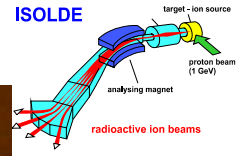




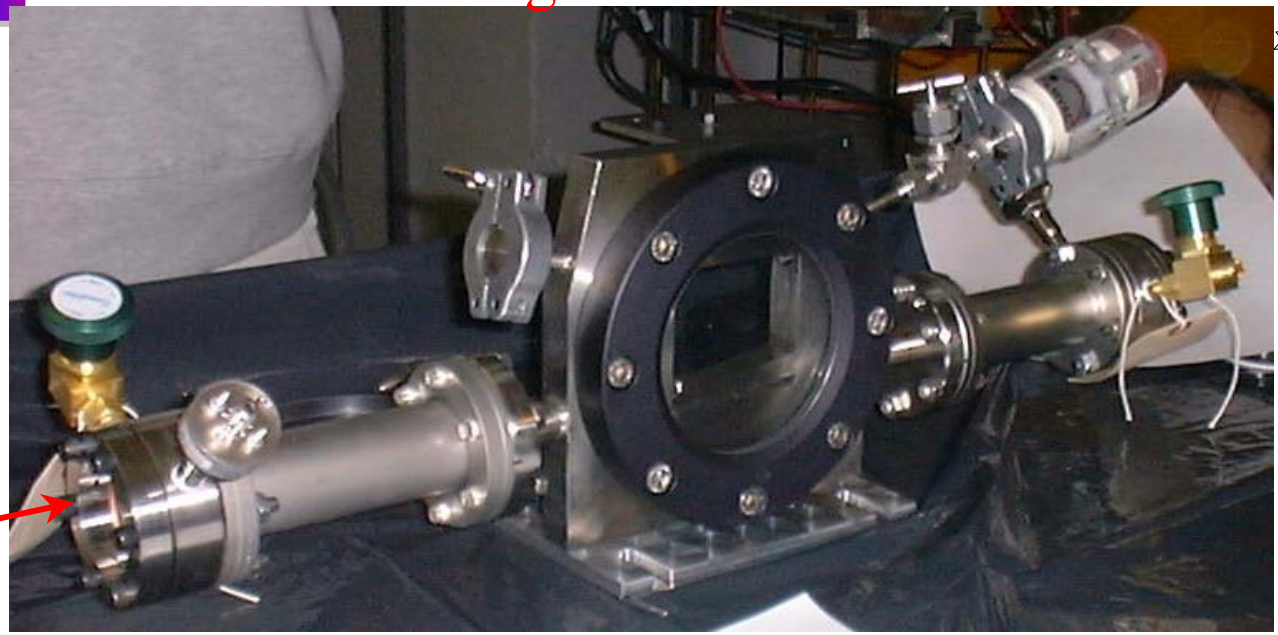
Target element and technique	Target thickness	Cross section	Proton driver beam		Rate in target	Transfer	6-He Beam
	g/cm2	cm2	Energy (GeV)	Intensity (mA)	atoms/s	efficiency	ions/s
MgO target technology presently operating	3	1.00E-27	1	0.004	1.86E+09	0.025	4.65E+07
BeO technology improved with known technique and SPL	30	1.00E-26	1	0.1	4.65E+12	0.25	1.16E+12
New BeO target technology to be developed for SPL	30	1.00E-26	2.2	2.5	3.14E+14	0.25	7.84E+13
Mercury-jet target technology to be developed for SPL	800	2.60E-26	2.2	2.5	9.75E+14	0.05	4.88E+13
			Spallation neutrons (n,α)				
BeO with converter technology under development and SPL	3	6.80E-25	2.2	2.5	2.13E+15	0.25	5.33E+14

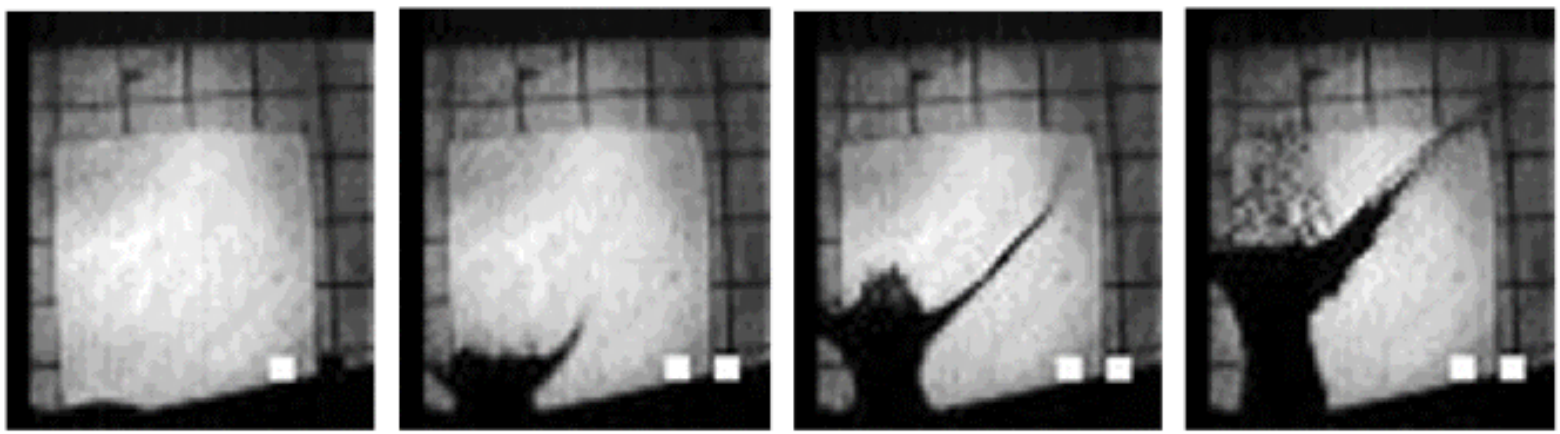
EURISOL

BNL E-951 trough test 8 kHz camera



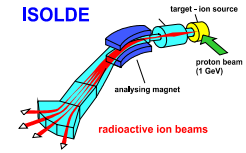
1st P-bunch
1.8×10^{12} ppb
150 ns

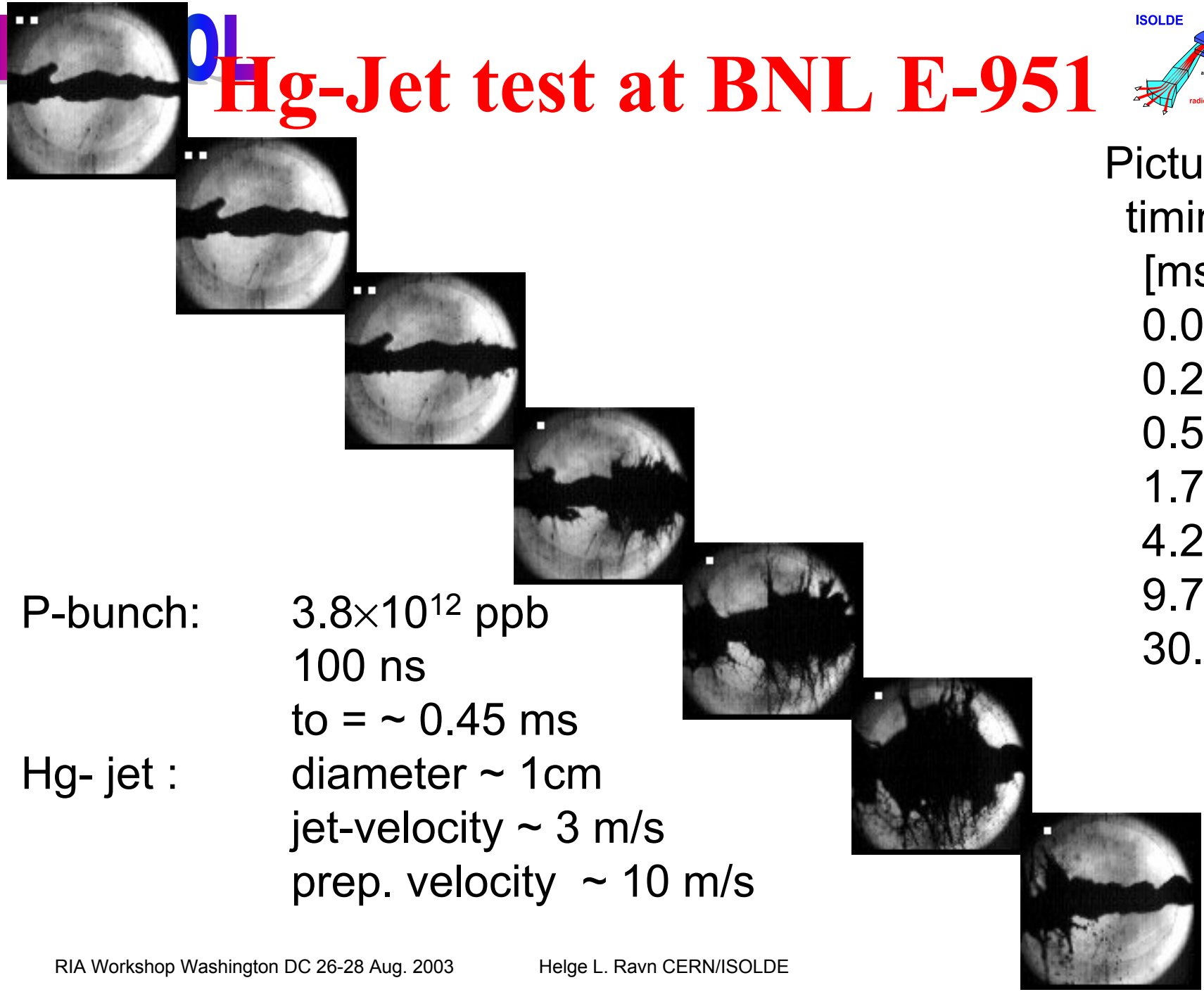




Timing : 0.0, 0.5, 1.6, 3.4 ms, shutter 25 μs V_{splash} ~20-40 m/s

Hg-Jet test at BNL E-951





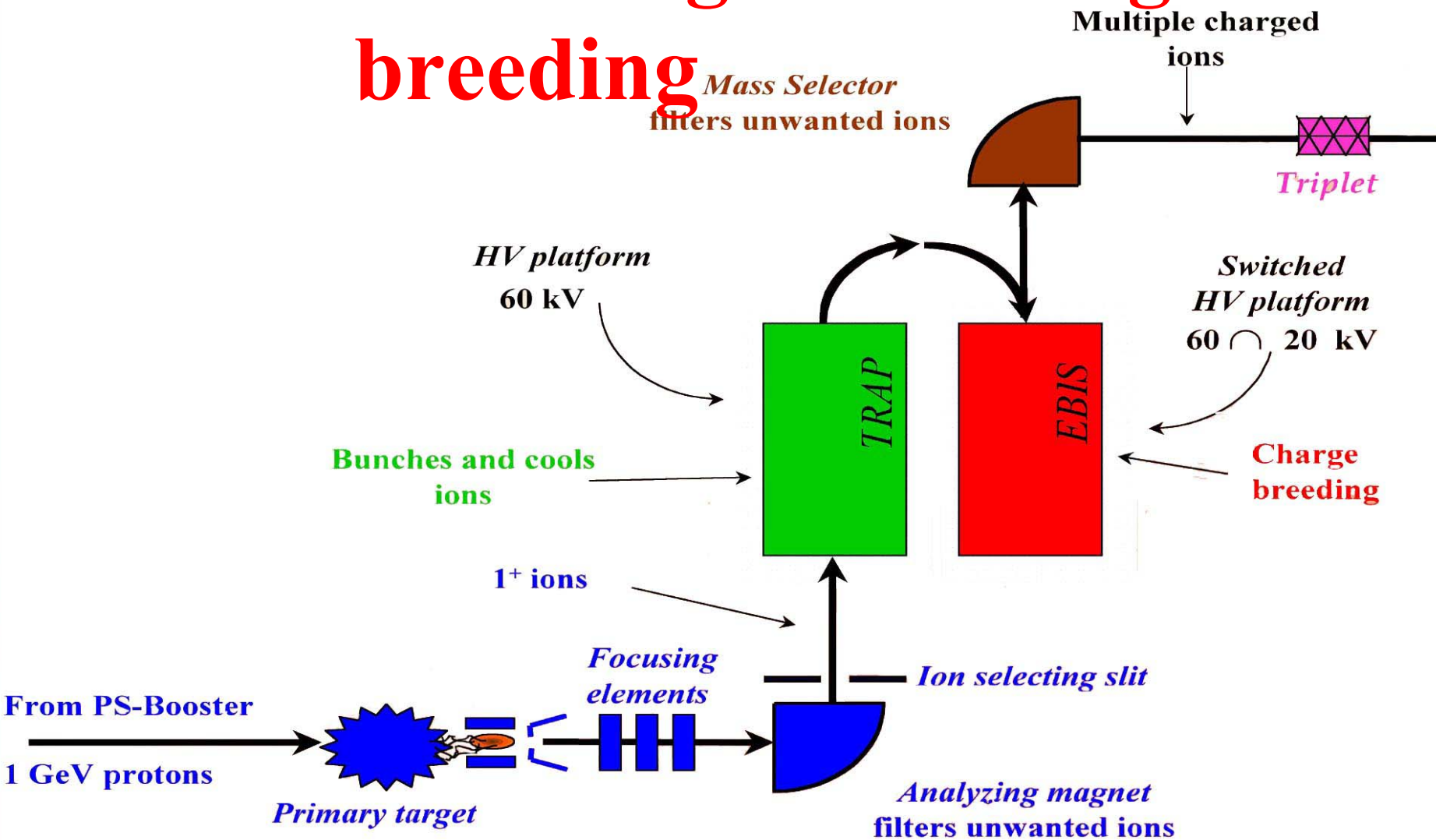
Pictures timing [ms]

0.00
0.25
0.50
1.75
4.25
9.75
30.0

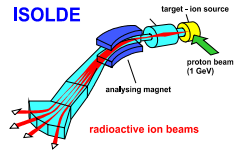
P-bunch: 3.8×10^{12} ppb
100 ns
to = ~ 0.45 ms

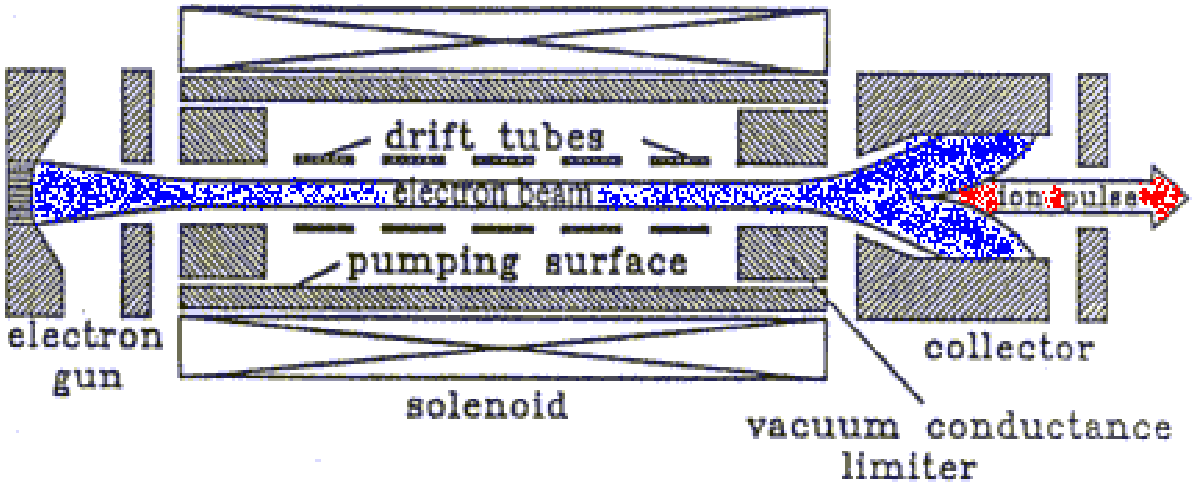
Hg- jet : diameter ~ 1cm
jet-velocity ~ 3 m/s
prep. velocity ~ 10 m/s

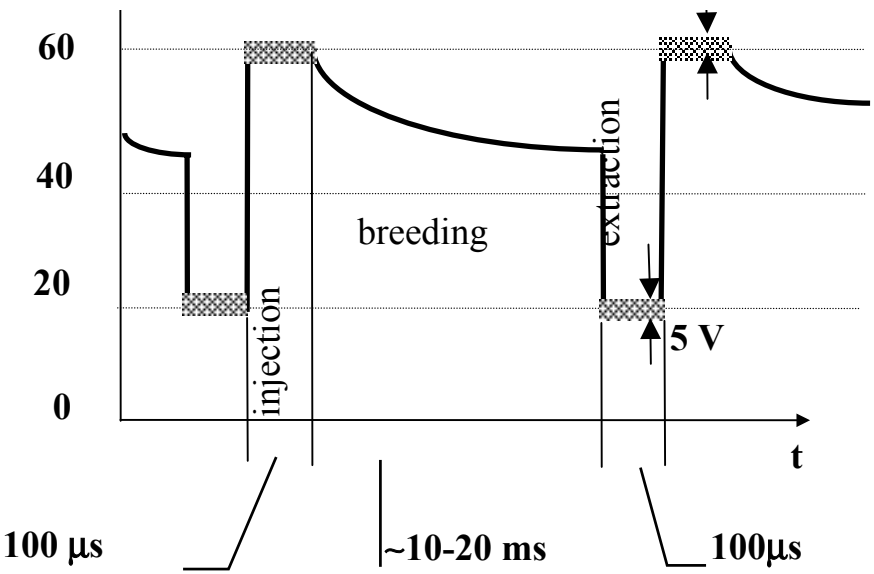
Bunching and Charge breeding



EURISOL REXEBIS







REX-EBIS CYCLE

- ***REX-EBIS data***

$B = 2$ T

$E_{electron} = 5$ keV

$\tau_{confinement} < 20$ ms

$I_e = 0.5$ A

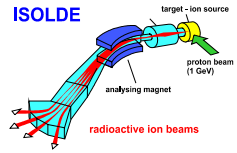
$j_e = 250$ A/cm^2

$L_{trap} < 0.8$ m

Warm bore

$q/A \sim 1/4$

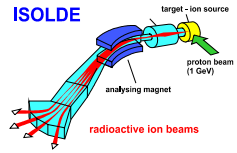
Why a Mercury-Jet



- High neutron yield (high Z)
- High source brightness (high density)
- Flowing liquid have excellent power handling capabilities
- No water radiolysis
- Liquid at ambient temperature (no liquid-to-solid phase change issues)
- Minimal waste stream (compared to solid alternatives)
- Passive removal of decay heating
- No dominant longlived radiotoxic products
- No confinement tubing (free flowing jet)
- No beam windows (differential pumping confinement)

EURISOL

The ISOLDE target and ion-source system



Target unit for selective production of He, Ne, Ar, Kr, Xe and Rn beams

Vacuum chamber

Vacuum valve

Magnet

Water cooled transfer line

Plasma discharge ion source

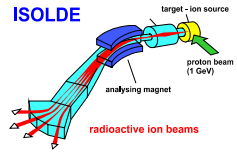
Target

Line current feed

0 2 4 6 cm

Separate systems developed for each element or group of elements

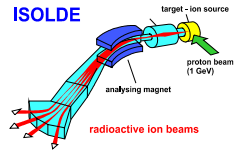
Mass transport



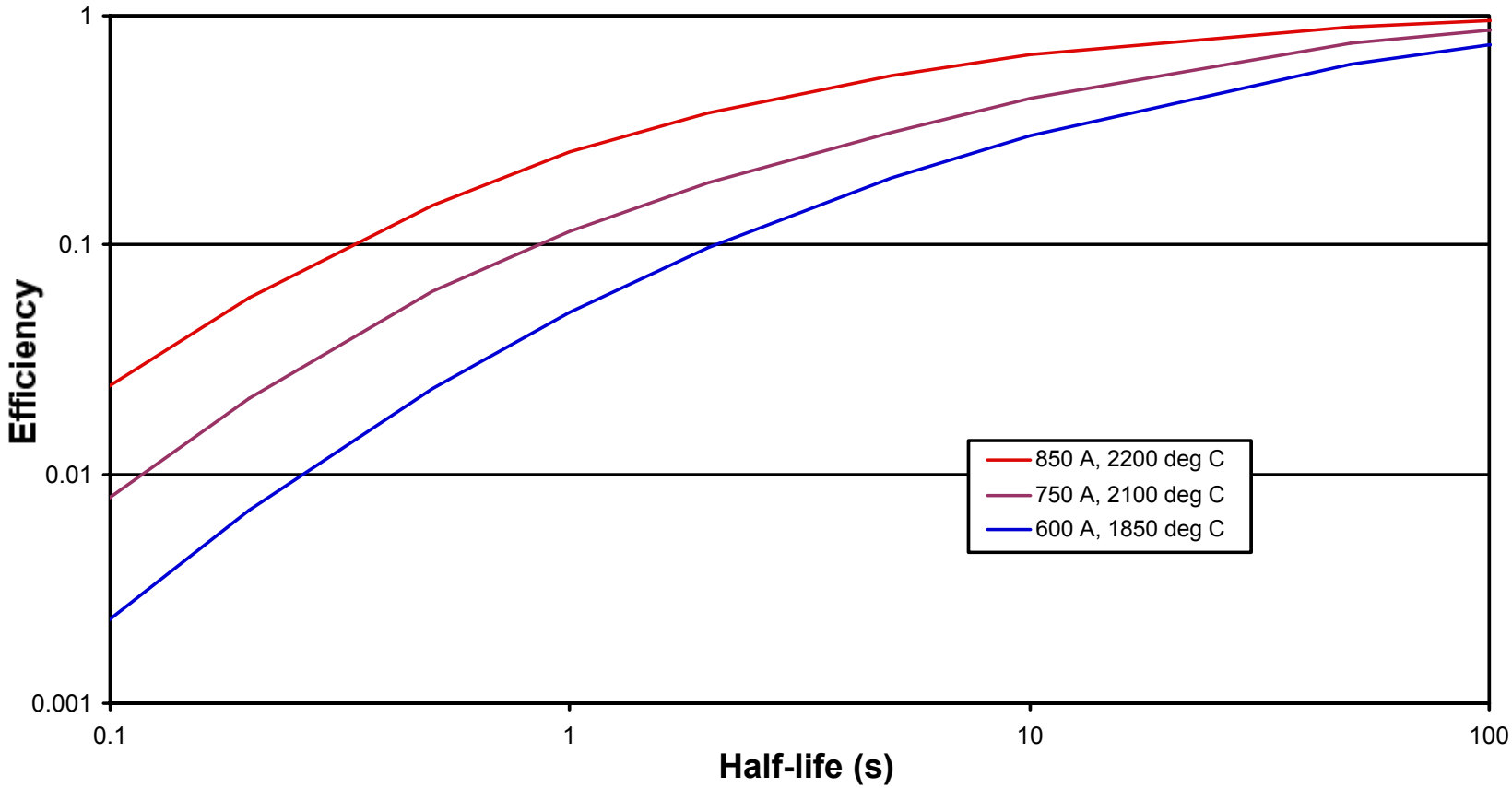
- $A = \Phi \ \sigma \ N \ \varepsilon_1 \ \varepsilon_2 \ \varepsilon_3$

- How to get the products out and transferred into an ion beam for separation and acceleration.
- Beam intensities and Target heat load Φ
- Production mechanisms and formation cross sections σ
- Uranium and Thorium target materials for neutron rich products N
- **Decay losses due to diffusion and effusion from the target to ion source ε_1 ε_2**
- **Acceleration efficiecy ε_3**

EURISOL Release efficiency ε_1 ε_2 determined by the decay losses

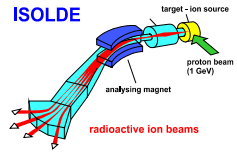


Release efficiency of tin from a UCx/graphite target

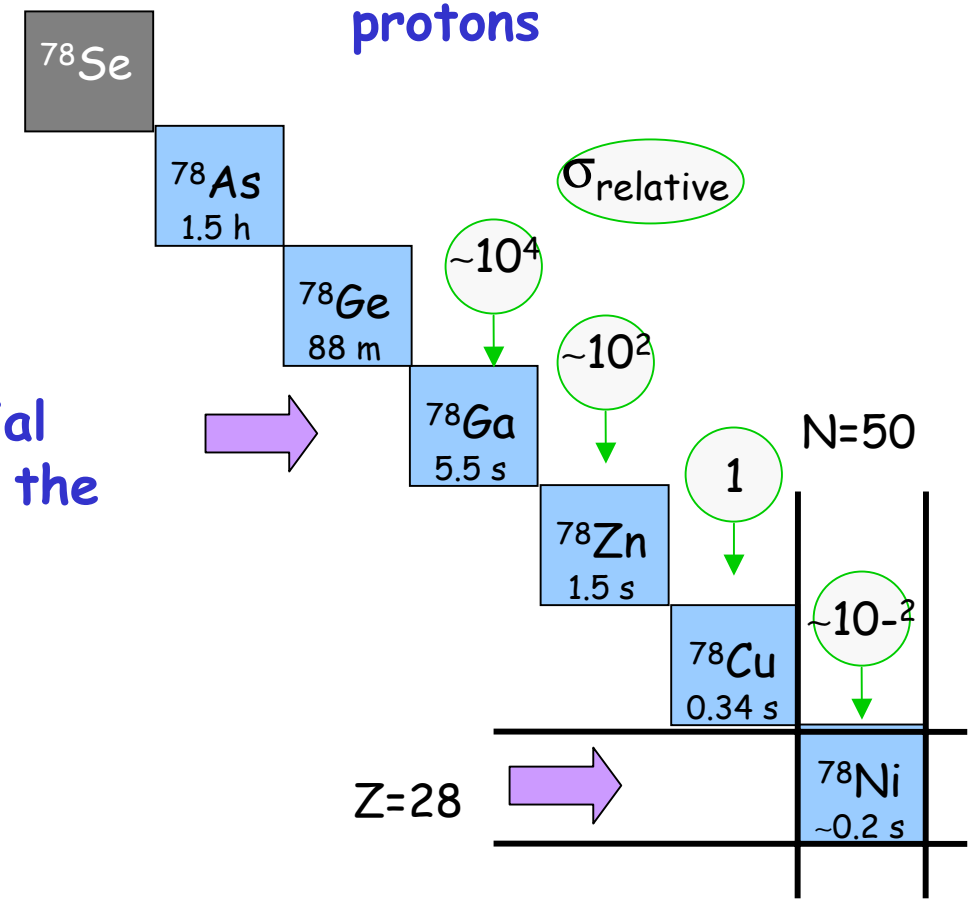


Ref. Ulli Köster

Selectivity of the RILIS



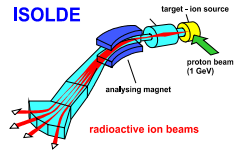
Fission of U with 1 Gev protons



Gallium with an ionisation potential of only 6eV is surface ionised in the Cavity.

Higher efficiency ~50%

Available at ISOLDE



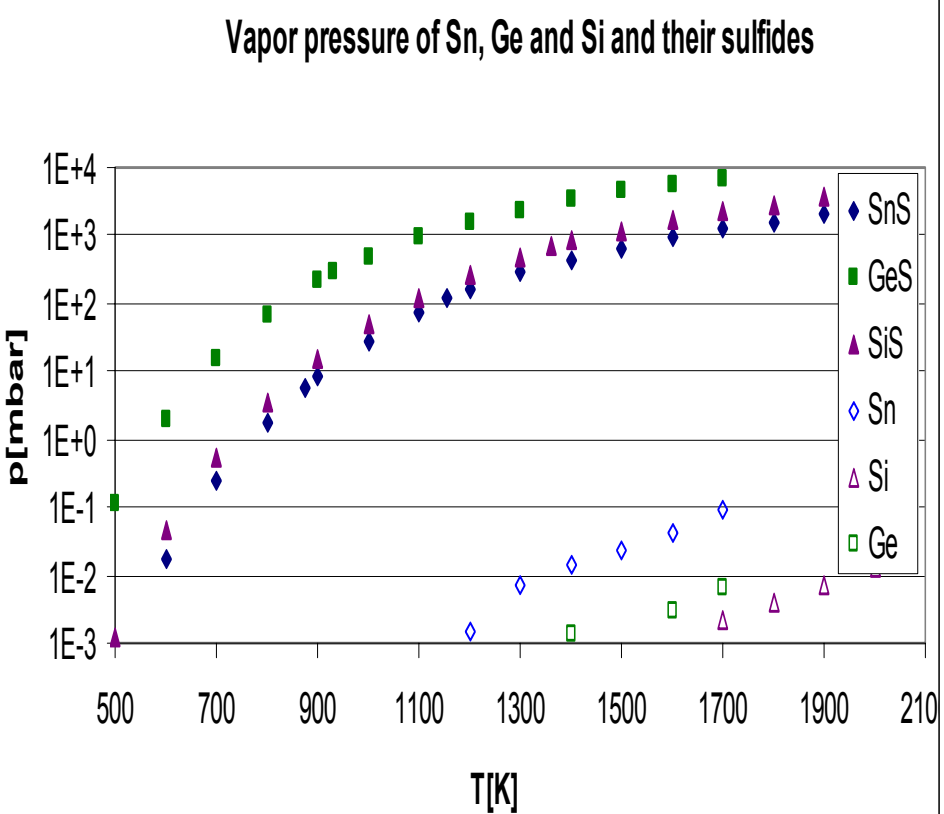
Presently 600 isotopic beams of 66 elements are available at ISOLDE

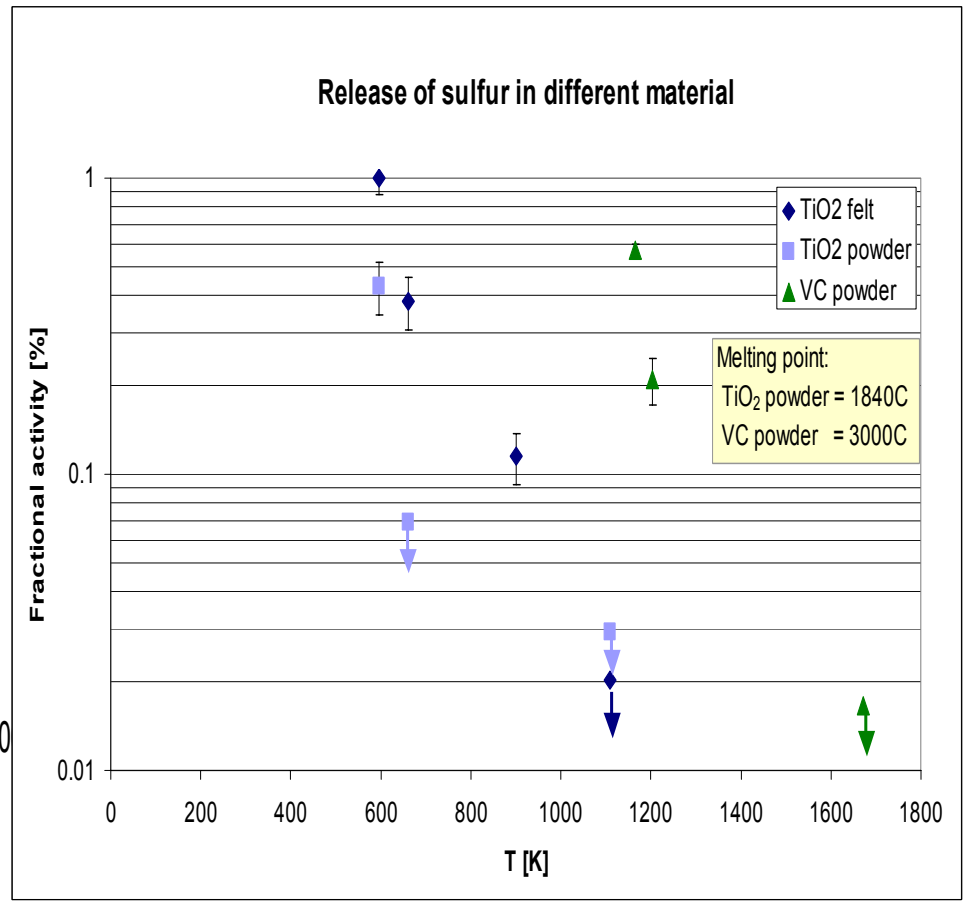
PERIODIC TABLE OF THE ELEMENTS

GROUP IA	IIA	IIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															
LANTHANIDES			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
ACTINIDES			Th	Pa	U	Np	Pu	Am	Cm	Dy	Cf	Es	Fm	Md	No	Lr	

Elements in bold characters areavailable as beams at ISOLDE

Sulphide chemistry of the Group 14 and 16 elements





Ref. Angelique Joinet