EURISOL targetry challenges

EURISOL shall deliver beams of 3 orders of magnitude higher intensity than 1999 yields.

- Design of “oven + heat-transport system” target containers dissipating a direct GeV p-beam dc-power of > 100 kW to produce spallation generated RIBs.
- Computational optimization of the wall material and target geometry of a chosen element from a “target vessel, transfer line & ion-source” system to improve the release efficiency.
- Improve ion-source efficiencies and beam purity.
- Design high power density spallation n-sources (10 MW/I)
- Design actinide targets intercepting efficiently the neutrons generated by high power density n-sources.
Introduction to ISOL RIB facilities

Isotope Separation On Line

- ISOLDE
- TRIUMF
ISOLDE target handling.

Class A laboratory

$\Sigma_{\text{Isotopes}} (\text{Activity}/\text{LA}) > 10'000$
ISOL "Thick" targets

Pre-Separation, Separation, Extraction, beam optics

Target material 5-200 g/cm²
“Oven - Radiator” (Ta,Mo,Nb, C …)

Ionisation
Molecular transport
Effusion
Diffusion
Nucl. reaction

Ion-source & Transfer line
(Ta,Mo,Nb, C …)

+/− 8V 500A
+/− 9V 1000A

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ISOLDE Front-End
Technical design

Strategy: 2 FE + 1 spare
Production needs: 1 FE/3 years
“Minor” repair after 1 year of cooling

5×10^{19} p/y
5 MGy/y

Faraday cup & QP triplet Section

Exchangeable Target and Ion-Source coupling section

x-y Electrostatic steering + z Movement

Quick exchange of spare parts

External alignment

S. Marzari & ATB-IF

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6 \leq Z \leq 92 \quad \text{Target materials}

- **Spallation, Fragmentation & fission**

- **25 Elements,**
  - ~ 40 compounds:
    - Oxides, Carbides
    - Molten metals, - salts
    - Thin foils, Powders

- **Target thickness:** 4-220 g/cm²
  - Cross section $\sigma(E_{\text{proton}})$

- **Beam power for ISOL-RIB production:**
  - Liquids (1-2 kW), Solids (5 kW),
  - Ta, Nb, SiC (20-30 kW @ TRIUMF)
Ta + 1 GeV p, CASCABLA, A. Junghans

1 GeV proton induced Spallation

- 181-Ta 1.0 GeV
- Nat. & stable

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Chemically selective RIB Ion-sources

Surface ion-source
Negative ion-sources
FEBIAD ion-sources
RILIS, Elements available 2004
ECR 1+

H

Li Be

Na Mg

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 Ti Pb Bi Po At Rn

Fr Ra Ac

La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lw

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Ion-sources efficiencies

Electron Affinity [0-4 eV]  Ionisation potential [4-25 eV]

- LaB$_6$-surface
- KENIS
- W-surface
- ECR
- FEBIAD
- RILIS

Ionisation efficiency

- 100.0%
- 10.0%
- 1.0%
- 0.1%

Ionisation potential [4-25 eV]

- ECR ?
- Negative
- Plasma
- Surface

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Release efficiency

effusion, diffusion

![Graph showing count rate versus time delay](image)

- **Data**
- **Bg & Coll. Corr.**

- $^{25}$Na (59.6s)
- UC-118 2100°C
- $^{32}$Na (13.5 ms)
- $^{33}$Na (8.2 ms)

.....
Half lives

- < 1s
- < 1 min
- < 1h
- < 1 day
- < 1 week
- < 1 month
- < 1 year
- > 1 y
- Nat. & stable
ISOLDE yields: ~750 RIBs produced (1963-2004)
EURISOL -- EURISOL DS

- 4 years EU project published end 2003;
- Conclusion: RIB yields enhancement predicted (vs. 1999 data) by factors of 2 to 4 orders of magnitude!
- 2005 EURISOL-DS to address the remaining technological challenges
EURISOL target stations

- 3×100 kW direct irradiation
- Fissile target surrounding a spallation n-source
  - >100 kW Solid converters (RAL 800 kW operational)
  - 4 MW Hg-jet
Top view

Beam distribution

Target stations

3 × 100 kW

Target handling

4 MW

Target station

~1 GeV p-driver

Experimental hall

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100 kw direct irradiation

- Target Materials: > 25
  - Thickness, Heat transport, dose rate
  - Diffusion and Effusion delays
- Chemical nature of the target: 6
- Oven Materials: 4
- Elements to be produced: > 70
- Transfer line: 4
  - Drift fields
- Ion source: 5
  - Stabilisation of the production (Std. eff., life time, reproduce on-line the best off-line results).
  - Radiation Hardness.
  - Selectivity vs. isobars.
- Maintenance, vacuum vessel, pumps, radioactive Waste handling.
TEST cases 100 kW direct

- **Targets**
  - Actinide target (carbide)
    - UC$_2$+C, ThC$_2$+C
    - W-converter, Moderator & Reflector
  - Metal foil target (solid)
    - Ta, Nb
  - Oxide powder of fiber
    - BeO + converter
    - Insulating materials low dE/dx
    - Low density
  - Molten metal (Liquid)
    - Vapor condensation

- **Ion-sources**
  - Mono ECR
  - RILIS, Surface
  - FEBIAD

- **Elements**
  - He, Li, Be, Hg ...

Synergy with $\beta$-beam

Spin off is expected on:
- Similar target materials
- Elements from the same chemical group
SiC Triumf

Nanowires

Nanoholes

ISOLDE Physics Seminar, 15 Feb. 2005

Thomas AGNE (CERN/UnS)
Confinement of the activity, RIB-selection

Mass separator

Confinement of radioactive gases (cold trap)

Target station
Chemically selective ion-source (RILIS)
Target plugs
Actinide target

• Cylindrical, donut or C-shaped optimized vs. n-flux … and target exchange.
• Target material: Test of the release properties of high density UC$_2$ vs. UC$_2$+C powder
• Thermal equilibrium issue: the target is kept at 2200°C while its inner or close by placed Hg-n-spallation source Has to evacuate ~1 MW.

Synergy with SNS, SPIRAL II and SPES
Competitive method: high flux reactors
$^{235}$U-fission at MAAF

1 Target ?
5 Ion-sources
1 Front-end
p- or n-induced fission

Fission probability

- 238U, 1.4 GeV p,f (2.59 barn) CASCABLA
- 238U, 600 MeV p,f (2.25 barn) CASCABLA
- 235U, Thermal n,f (582 barn)
Spallation n-sources

- Cooled Ta or W-rods
- Hg stream or confined Hg-jet

- Engineering study of the thermal hydraulics, fluid dynamics and construction materials of a window free liquid-metal converter.
- Study of an innovative waste management in the liquid Hg-loop e.g. by means of Hg distillation.
- Engineering design and construction of a functional Hg-loop.
- Off-line testing and validation of the thermal hydraulics and fluid dynamics.
- Detailed planning and proposal for subsequent in-beam test in collaboration with other Hg target users.
- Engineering design of the entire target station and its handling method.
The yields of very n-rich isotopes obtained via neutron induced fission of Th or U are close to those of high energy protons.

Further developments:
Geometrical optimum and n-reflectors

**UC₂ + W-converter**

**Kr, Xe and Cs yields, Ta-W converter**

**Cs-yields UC₂-183**

- p+ on UC-target
- p+ on Ta-converter
- Ratio

**Spallation**  
**Fission**
Conclusion

• The EURISOL-DS-targetry group proposes:
  – 4 test cases to define the front-end of the 100 kW target stations (T3).
  – Investigation of a spallation n-source based on Hg loop (4 MW) (T2) and cooled solids (<1 MW) (T4).
  – Compare yields of high-density and powder of actinide carbides (T4).

• Decision on EU-funding of the EURISOL-DS project in June 2004.
T3 – direct target

Total estimated Cost (k€): 2439
Contribution from UE (k€): 890