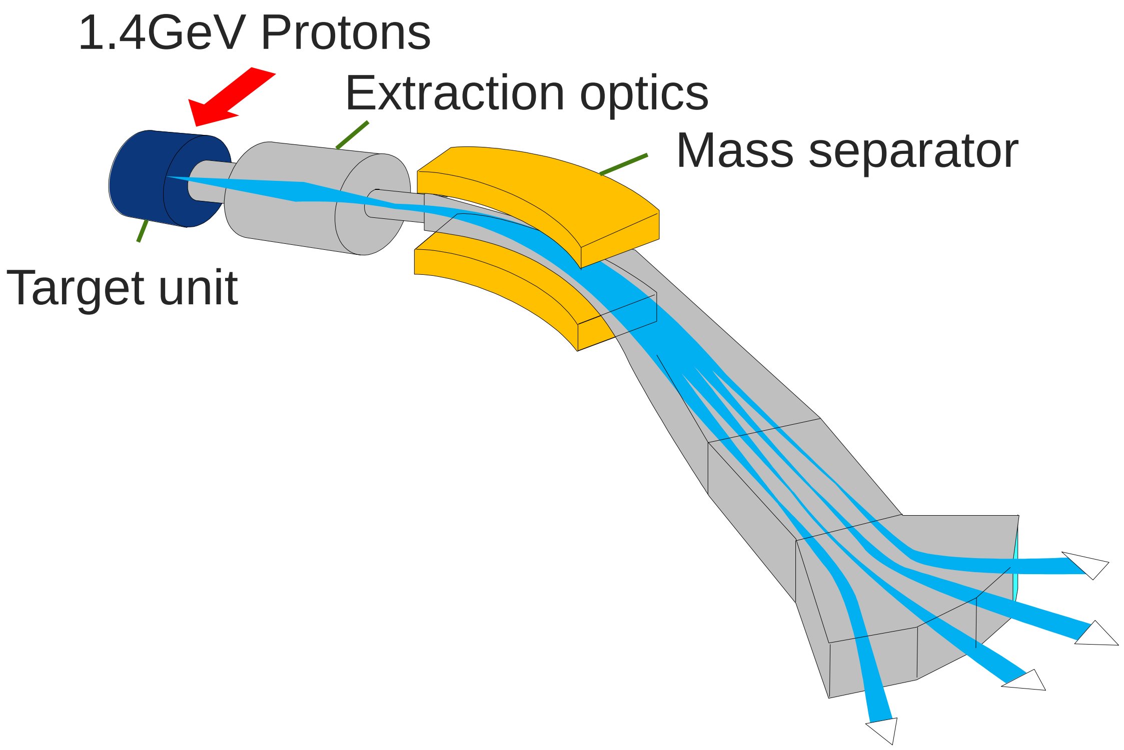
Targets for an EPIC project.

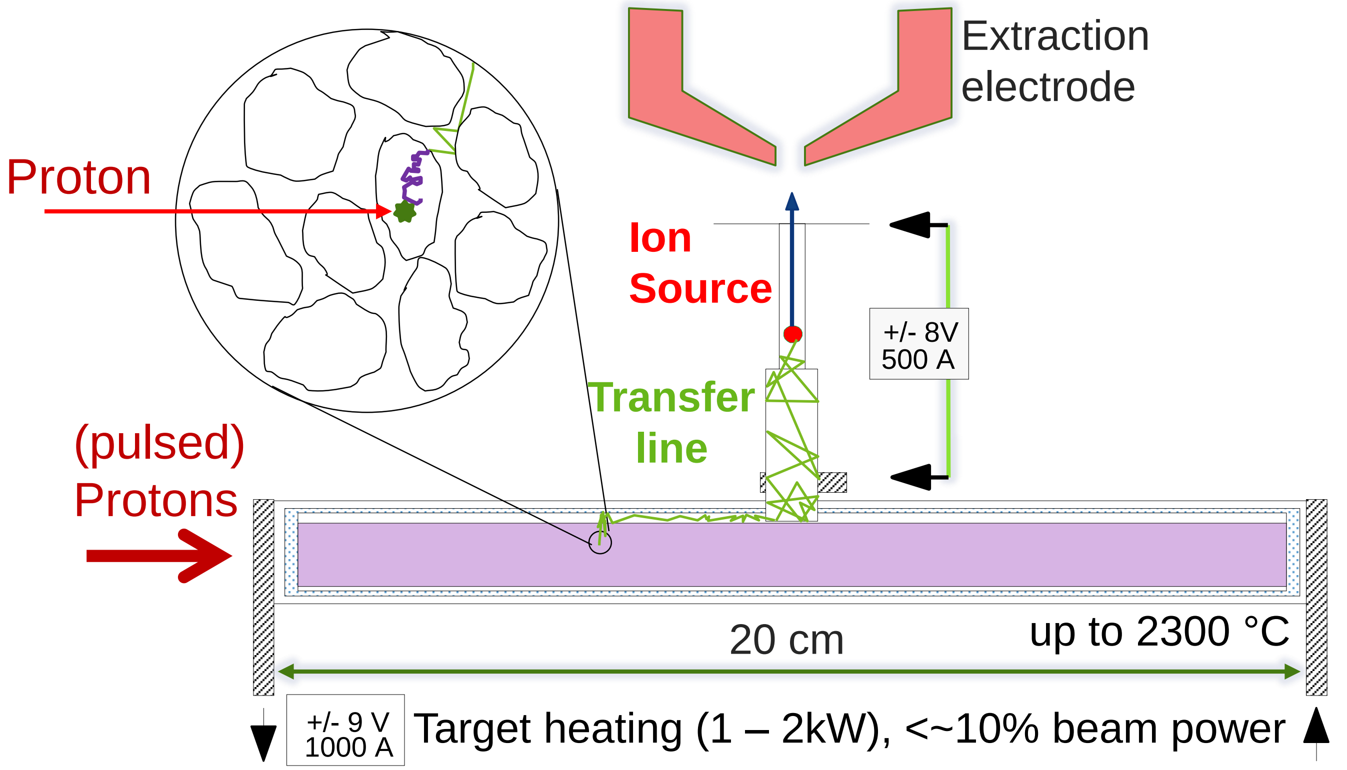
Sebastian ROTHE
for the ISOLDE target and ion source development teams

ENGINEERING
DEPARTMENT

ISOLDE: Isotope Separation On Line

Adapted from
J. P. Ramos | 17/09/2018
ISOLDE EMIS2018





1. Production
2. Diffusion
3. Effusion
4. Ionization
5. Mass Separation
6. Transport

$$Beam\ Intensity = \sigma . j . N_t . \varepsilon$$

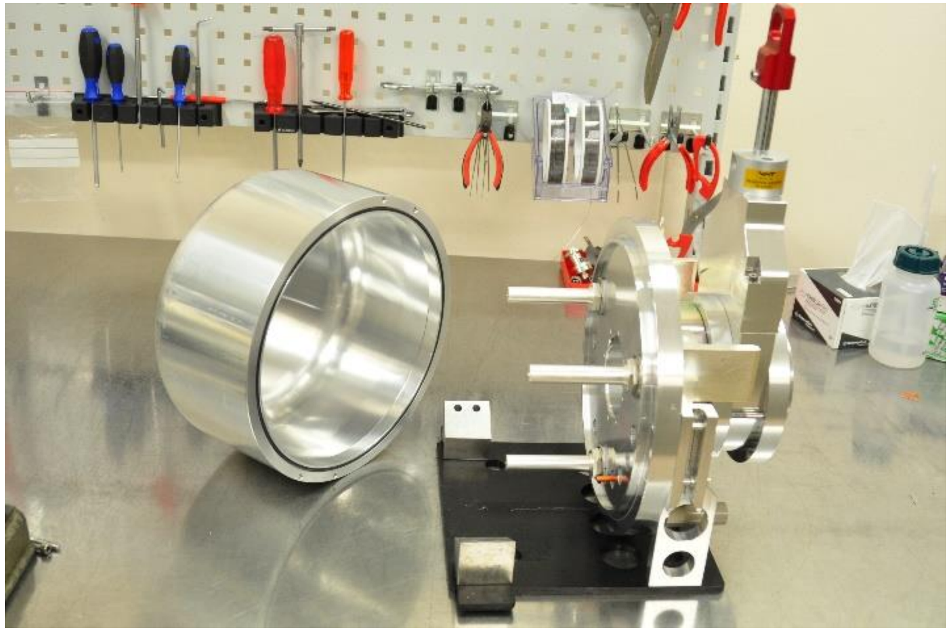
$$\varepsilon = \varepsilon_{diff}\varepsilon_{eff}\varepsilon_{is}\varepsilon_{sep}\varepsilon_{trans}$$

N_t – Nr of exposed atoms [dim]
j – Proton flux [cm^{-2}]
σ – Cross section [mb]
ε – Efficiency [%]

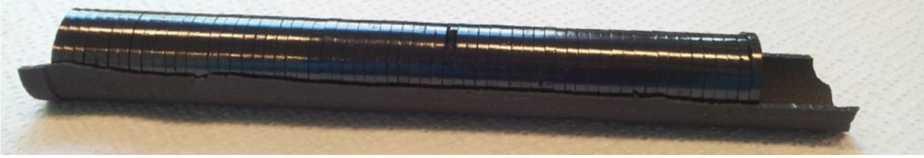
ISOLDE Target assembly

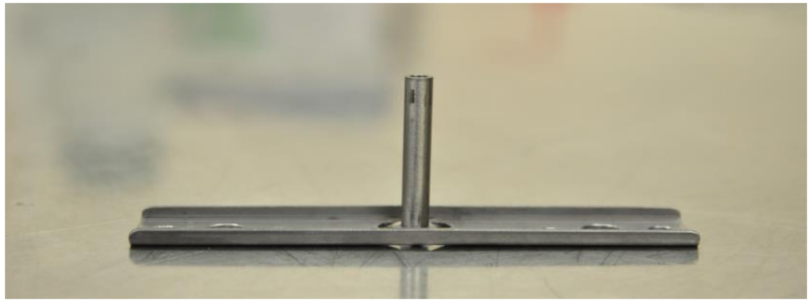
Target Container + transfer line

(Plasma) ion source



Target base





Target material

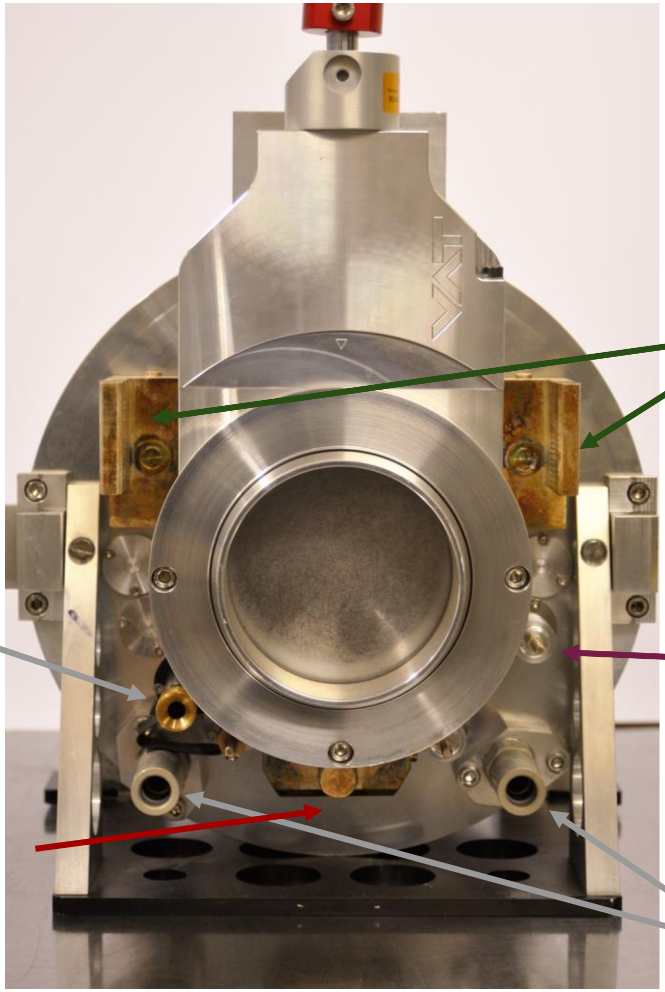
Surface/Laser ion source

Images: A. Viéitez

Feedthrough connections

Frontend side

Target side



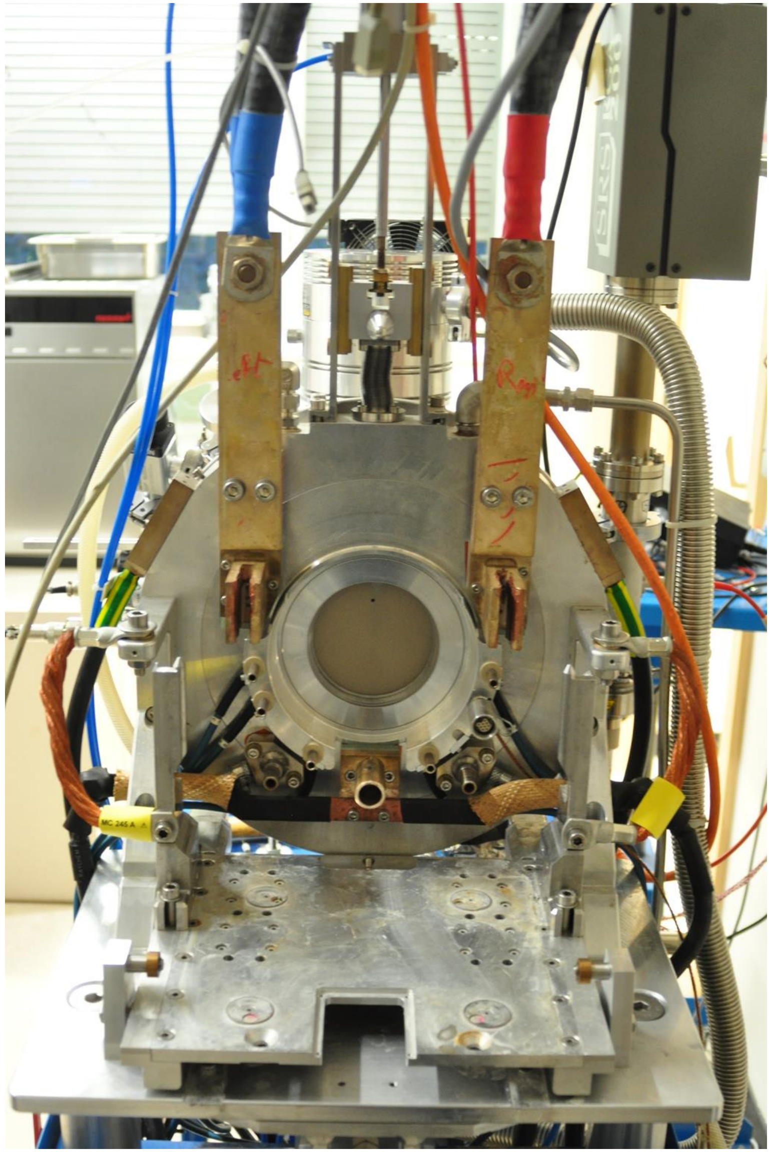
Target heating

Gas injection

Oven (mass marker)

Line heating

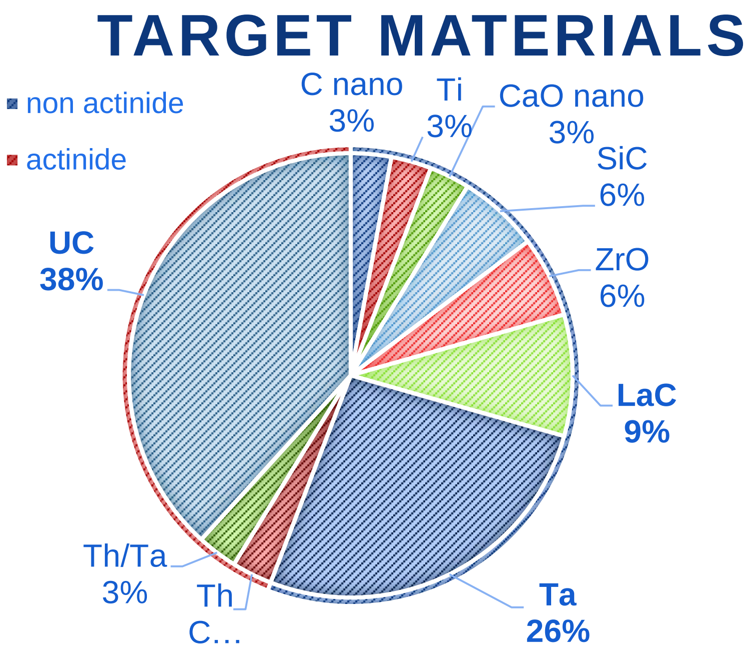
Water circuit connectors

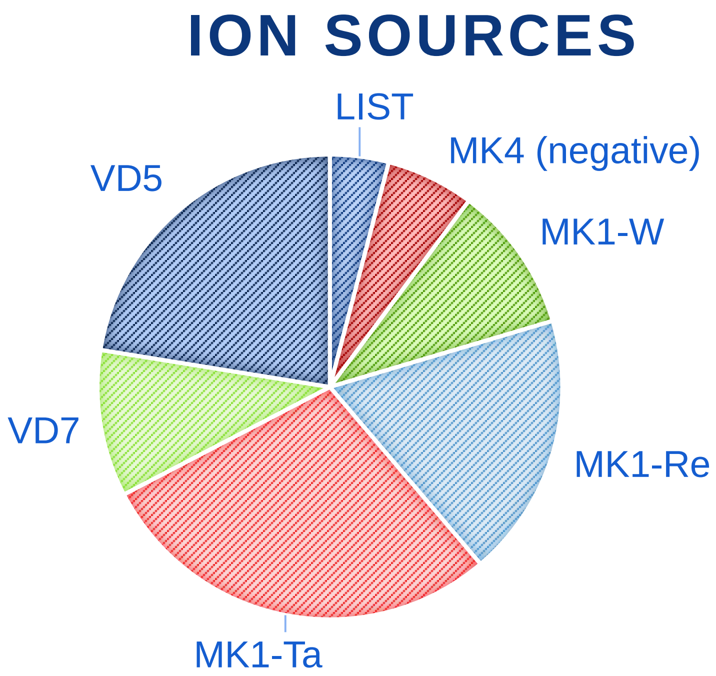


A. Viéitez

ISOLDE Target Production 2018

29 ISOLDE targets





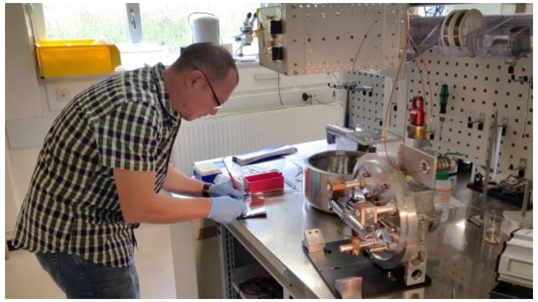
Total targets assembled end of 2018 : 49

- **Delivered to ISOLDE**: **29**
- Delivered to MEDICIS: 10 + 2 in December
- Used for development: 8 (16%)

- **10 different materials**
- Mostly carbides and metal foils
- Most popular: **uranium carbide**

- ***7 different ion sources***
- LIST and negative ion source back in action

ISOLDE Target Production Team 2018



Bernard Crepieux

- Assembly -

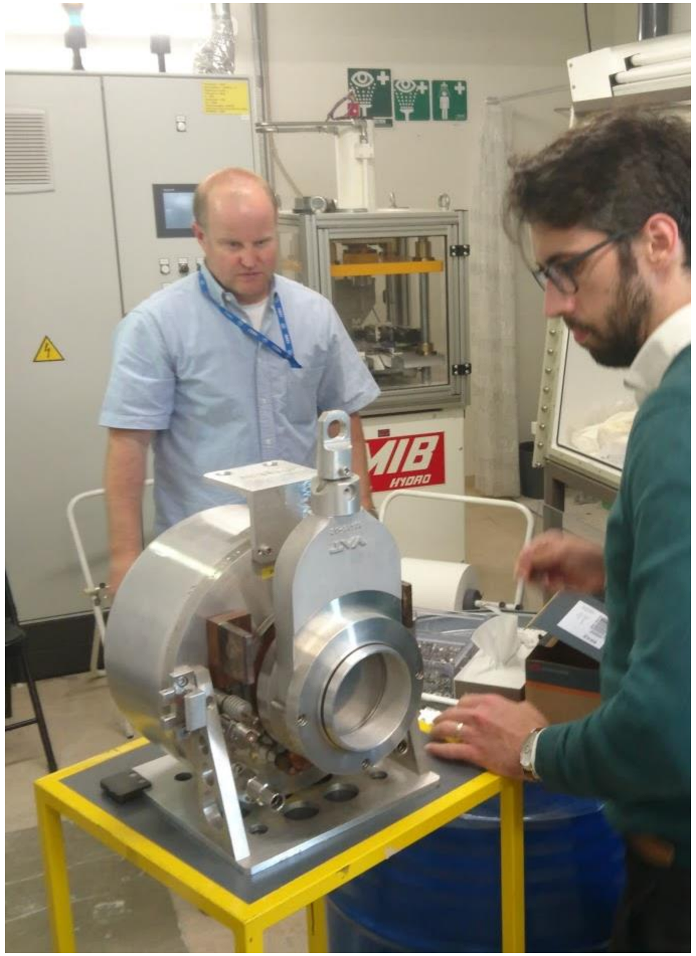
Andres Viéitez Suárez

- Assembly -

(Left the team summer ‘19)

Ermanno Barbero

- Machining artist -



Michael ‘Mike’ Owen

- Assembly -

EPIC Baseline

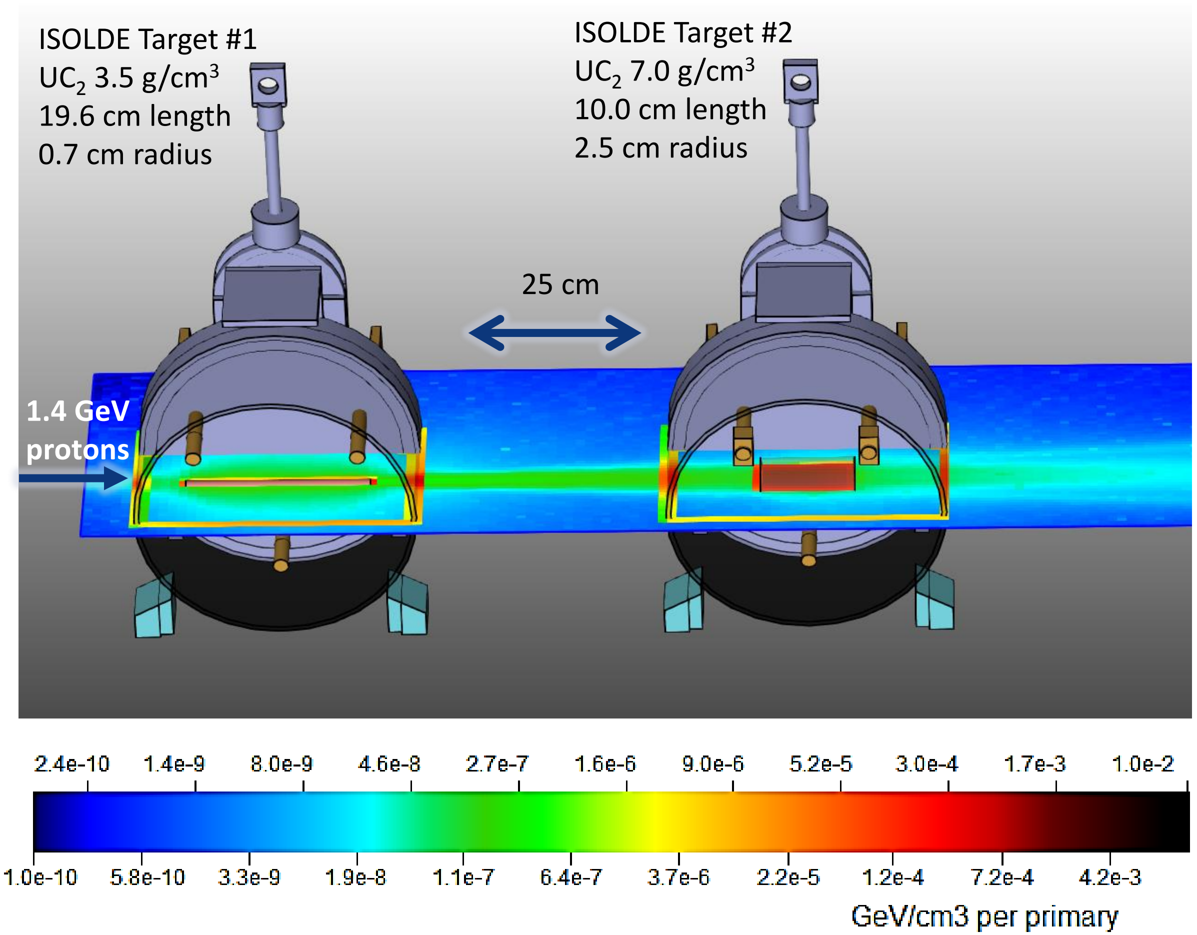
- Energy upgrade : 2 GeV (+ 40%)
  - power deposition

In-target production aspects
-> see talk by JPR

- Intensity upgrade : BTY : 4uA (ppp x 2)
  - Mitigate (Peak) power deposition, shocks ?
  - Impact on target lifetime ?

1.4 GeV -> 2.0 GeV - Uranium Carbide

ALL PARTICLES



E_{dep} at 1.4GeV

Target type#1(radius) – Target type#2(radius)	#1 - #2 W_{total} per µA 5 cm	#1 - #2 W_{total} per µA 25 cm	#1 - #2 W_{total} per µA 100 cm
UC_2(0.7) - Ta(2.5)	**106** - 88	109 – 69	105 - 32
UC_2(0.7) - UC_2(2.5)	107 - 153	107 – 121	106 - 57
UC_2(0.7) - UC_2(0.7)	107 – 16	107 – 7	107 – 1.5
UC_2nano(0.7) - UC_2(2.5)	**32** - 203	31 – 197	32 – 130
UC_2nano(0.7) - UC_2(0.7)	31 - 51	31 - 30	32 - 7

E_{dep} at 2GeV

Target type#1(radius) – Target type#2(radius)	#1 - #2 W_{total} per µA 5 cm	#1 - #2 W_{total} per µA 25 cm	#1 - #2 W_{total} per µA 100 cm
UC_2(0.7) - Ta(2.5)	**117** - 108	117 - 96	118 - 50
UC_2(0.7) - UC_2(2.5)	116 - 186	117 - 165	118 – 85
UC_2(0.7) - UC_2(0.7)	118 - 26	117 – 13	117 – 2.5
UC_2nano(0.7) - UC_2(2.5)	**33** - 244	33 - 235	32 – 186
UC_2nano(0.7) - UC_2(0.7)	32 - 70	33 - 46	33 - 13

11% increase for micro UCx
3% increase for nano UCx

FLUKA Simulation: Ch. Duchemin

1.4 GeV -> 2.0 GeV - Liquid targets

E_{dep} in Pb and Sn
Incident proton beam with an energy of 1.4 GeV and 2GeV

Material (diameter in mm, length in mm, density in g/cm³)	Watts per µA All particles	Watts per µA Protons only
Pb (δ=10 mm, l=20 cm, ρ=11.3 g/cm³) 1.4 GeV 2.0 GeV	286 354	171 187
Sn (δ=10 mm, l=20 cm, ρ=7.3 g/cm³) 1.4 GeV 2.0 GeV	221 255	144 151

Tab.1: Deposited energy in the whole target volume from all particles and from protons only in Watts from an incident proton beam intensity of 1 µA. The relative uncertainties on the values range from 0.02% to 0.6%). 1.4 GeV and 2.0 GeV have been considered.

Ratio of the E_{dep} in Pb and Sn
2 GeV/1.4 GeV

Material (diameter in mm, length in mm, density in g/cm³)	All particles	Protons only
Pb (δ=10 mm, l=20 cm, ρ=11.3 g/cm³) 2.0 GeV/1.4 GeV	1.24	1.10
Sn (δ=10 mm, l=20 cm, ρ=7.3 g/cm³) 2.0 GeV/1.4 GeV	1.15	1.05

Tab.1: Ratios of the deposited energy from all particles and from protons only between a 2 GeV and 1.4 GeV incident proton beam.

Ohmic target heating nominal ~2kW

Beam heating LPb 1uA@ 2GeV: 350W

24% increase for LPb

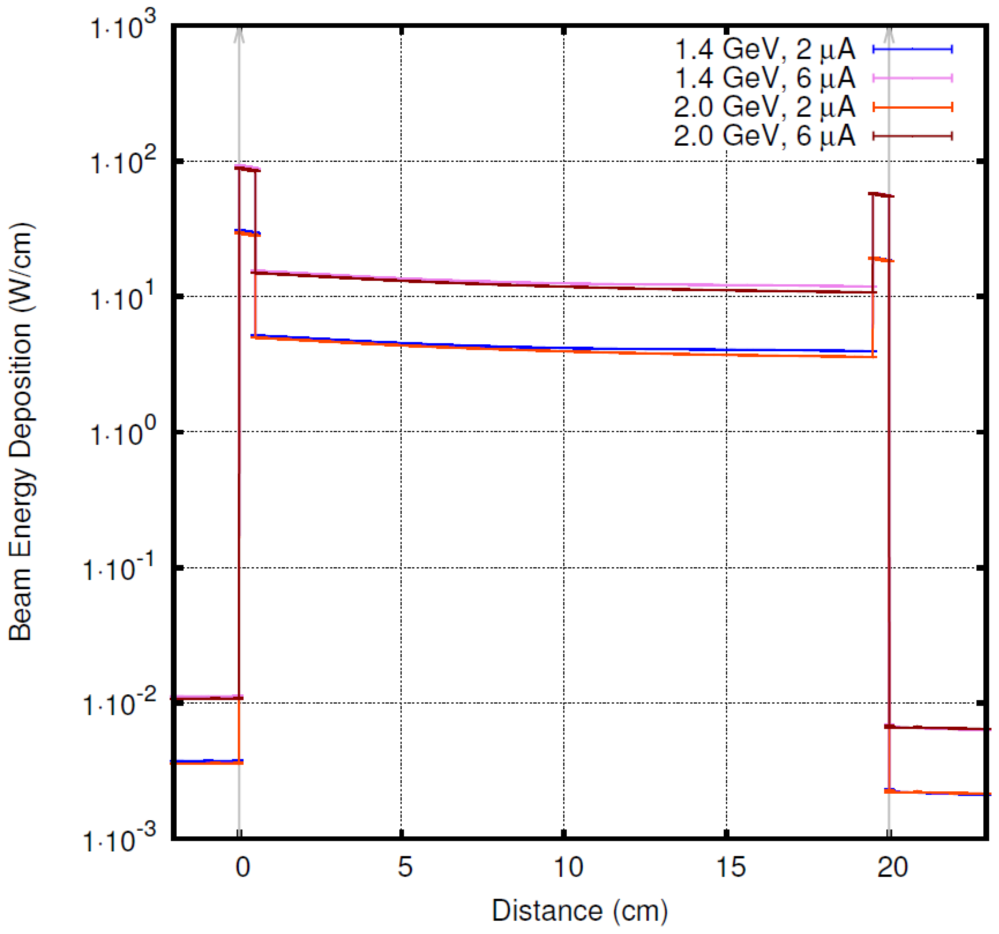
15% increase for LSn

Can be mitigated through reduced heating.

FLUKA Simulation: Ch. Duchemin

Power deposition higher intensity

Beam energy deposition for a standard UC2-C target @ 50g/cm2

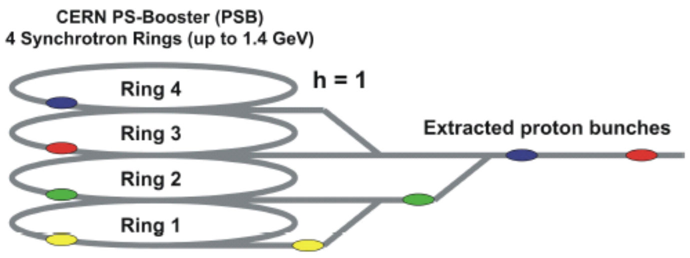


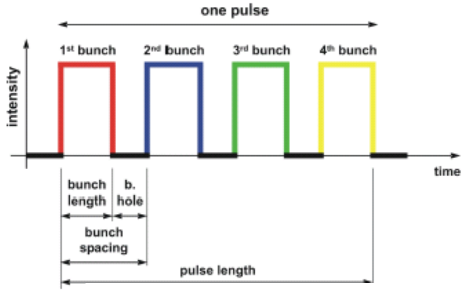
→ Higher intensity can be mitigated

To be considered:

- Individual target dose
- Frontend dose, if #(FE) constant

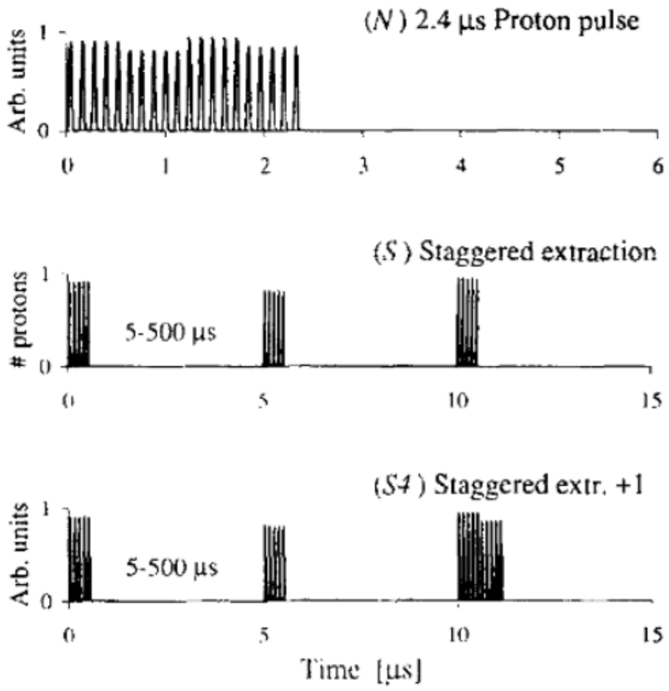
STAGISO vs NORMISO – Release Profile





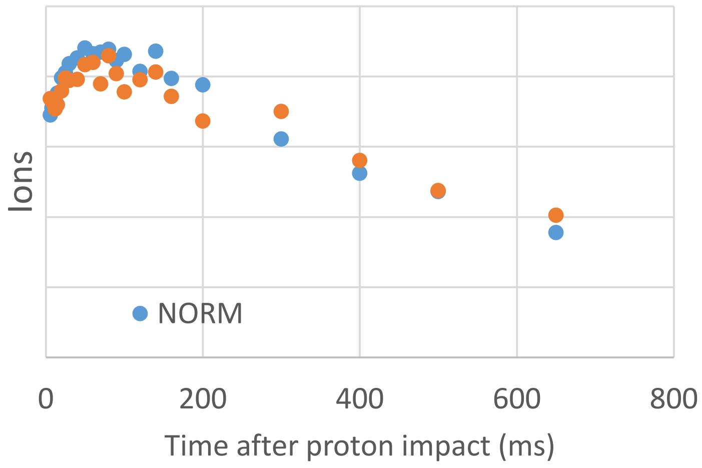
Booster pulse pictures from PhD Thesis, R. Wilfinger

2.3 µs in NORM
16 µs in STAG

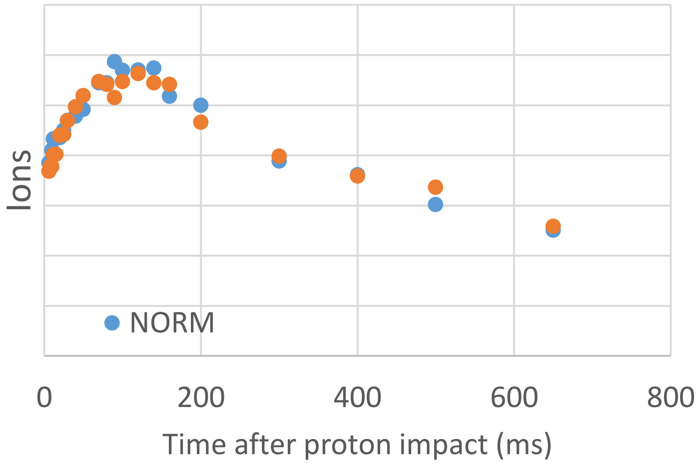


J. Lettry, *et al.* Nucl. Instr. Meth. B, 126 (1997), p. 170

142Cs release on Converter



142Cs release on Target



Release curves measured on:

- GPS and HRS
- Target and Converter
- 26Na and 142Cs

<u>Complete study to be published soon.</u> J.P. Ramos

➡ STAGISO can be used as standard

Assumption 1: Fixed Target production budget

- 2018: 39 target assemblies for ISOLDE
  - Exceptionally due to LS2
  - made by 3 technicians -> ~ 13 targets / technician /a

- Since 2019
  - Reduced back to 2 technicians -> ~26 targets /a is reasonable
  - actually **27 targets /a** promised to ISOLDE physics

- Also to be considered: Material costs, storage capacity, dismantling, waste treatment, disposal

EPIC effects : 4 uA & 27 Targets

- Intensity increases by x2 while # targets (27) constant
  - dose / target increases

  - Expected **increase in radioactive inventory** /target

➡ Targets shall be less affected by PoT

Constraint 2: Current Target design & operation

- Currently typical target exchange after ~ 10 d
- Reasons for frequent changes
  - Target material ageing ~ Time x temperature ➡ Target material development
  - Ion source degradation ~ Time x temperature ➡ Ion source development
  - Target dose limits ~ PoT, ~ target Z, ~ target dens. ➡ Target material development
  - Schedule ➡ Optimise operation paradigm
    - new user / new target policy
    - Target/ion source custom made for requested isotope

EPIC Targets

- Targets shall be less affected by PoT
- Improve overall target lifetime
- Target material development
- Ion source development
- Optimise operation/production paradigm

It is imperative to include Target and Ion Source development in EPIC

EPIC target and ion source development

- Materials
- Ion Sources
- Target bases
- Operation cycle

ISOLDE target materials

Material requirements

- High **production cross section** of the isotope(s) of interest
- Stability at **high temperatures**
- Chemically **stable and inert**
- Resistance to radiation damage
- Rapid **diffusion** and **effusion** rates of the element(s) of interest

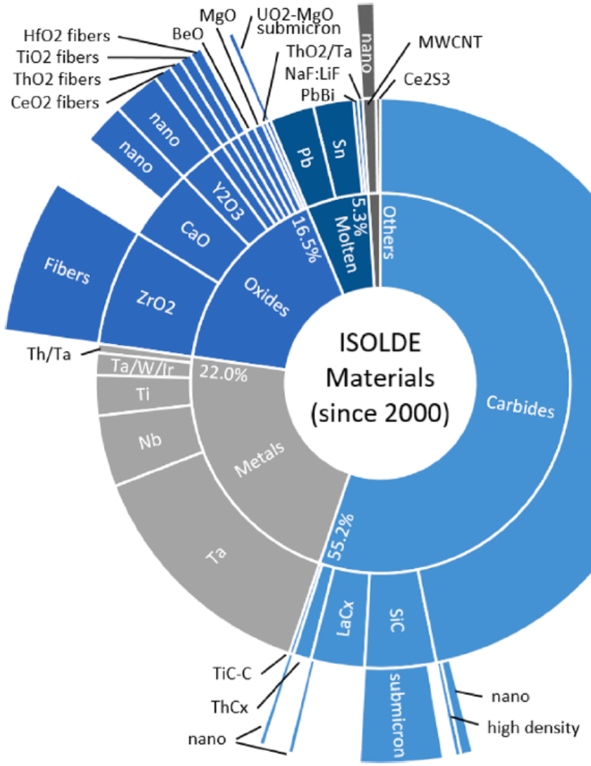
Operation temperature limitations:

- **Sintering** (preserve target microstructure)
- Limited reactivity with surrounding materials
- Reduced stable beam contaminants (chemical impurities)
- Moderate equilibrium vapor pressure compatible with ion source (10^{-2} Pa)

João Pedro Ramos | 07/09/2017

MEDICIS-Promed Specialized Training on Radioisotope Production

Number of targets in the last 16 years at ISOLDE:



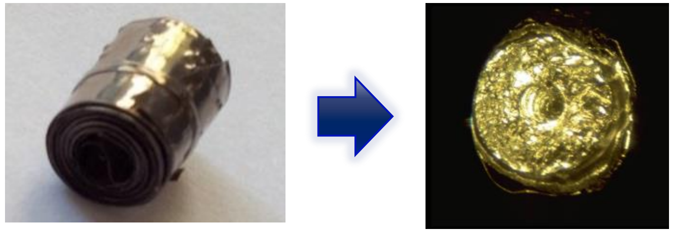
João Pedro Ramos: Thick solid targets for the production and online release of radioisotopes
The importance of the material characteristics – A review

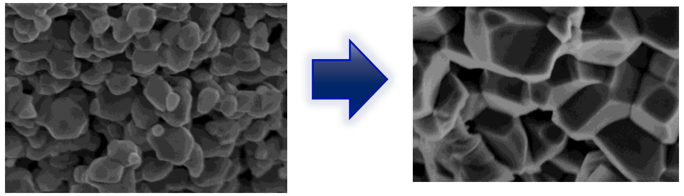
Most prominent Uranium Carbide

Target material ageing

- Liquid targets – do not age
- Metal foil targets – sinter (time@temperature)
  - define operation conditions to prevent sintering
  - Stabilize through separation layers or coatings etc.

- Carbide or oxide targets can be stabilized through matrix
  - Fibers
  - Nano materials



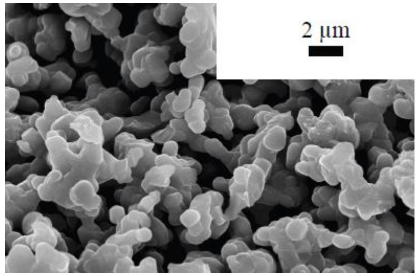


Figures: João Pedro Ramos | 07/09/2017
MEDICIS-Promed Specialized Training on Radioisotope Production

Nanomaterials at ISOLDE

SiC - S. Fernandes, et al.

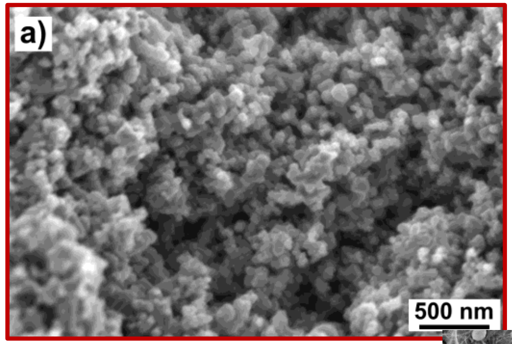
2010



***submicron**

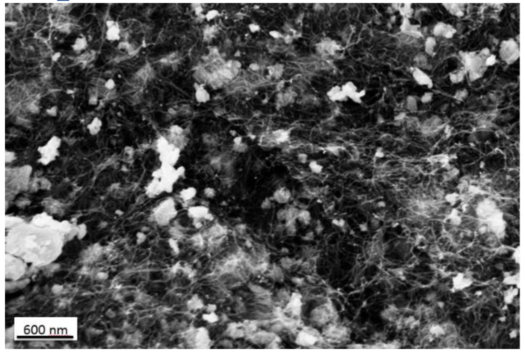
TiC+CB – J.P. Ramos, et al.

Nov- 2014



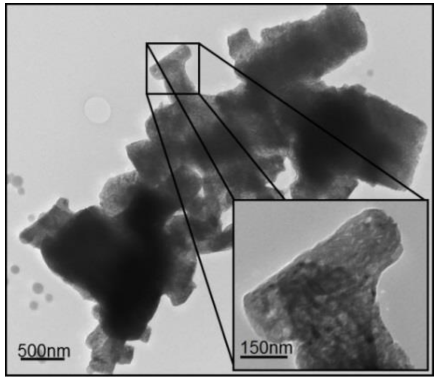
UC_2 + 2C – A. Gottberg, et al.

Nov - 2014



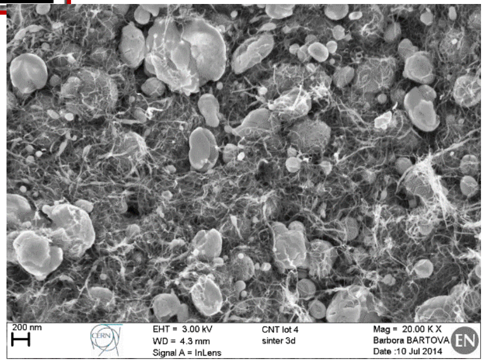
***1st nanomaterial at ISOLDE**

2011



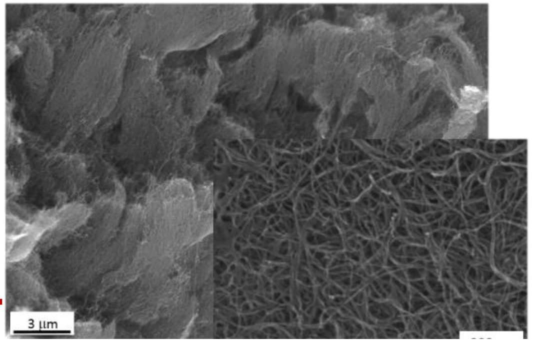
CaO – J.P. Ramos, et al.

Nov- 2014



LaC_2 + 2C – J. Guillot, et al.

Apr- 2015



MWCNT – C. Seiffert, et al.

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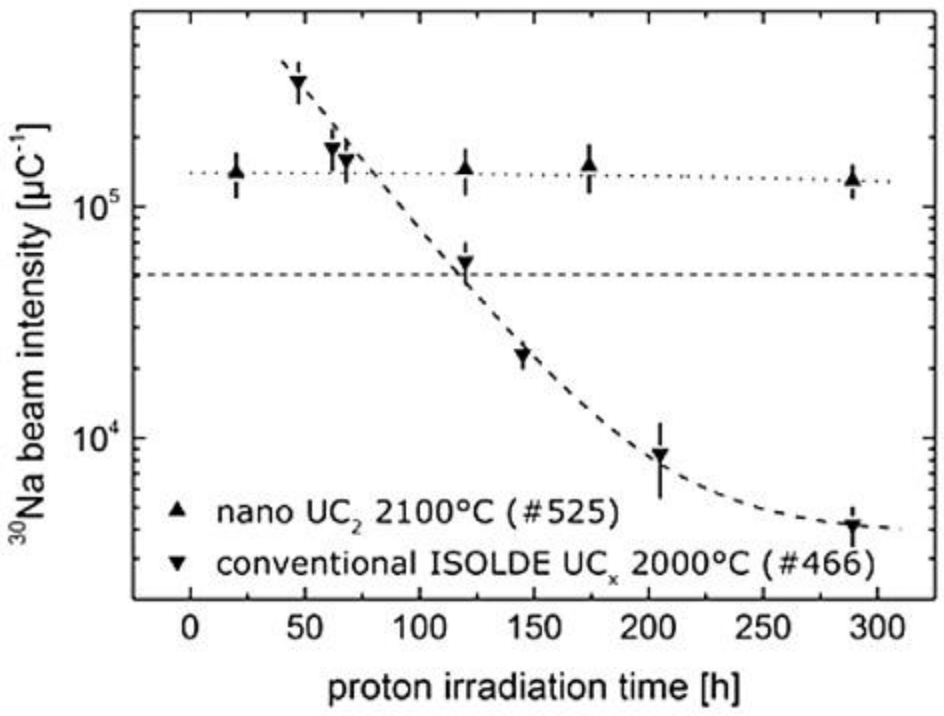
Nano UCx



Database value

A. Gottberg / Nuclear Instruments and Methods in Physics Research B 376 (2016) 8–15

Typical target densities:

- HD UC – 13.2 g/cc
- Standard – 3.2 g/cc
- Nano – 1.9 g/cc

-> Nano UC targets are lighter (60%)
-> less secondary particles, less damage

Hint on longer material life times

Reduced dose through reduced density

Class A nano-actinide lab in construction

Develop nano actinide production and handling

Targets need to be tested ONLINE

➡ Additional yield station for GLM suggested

21

Ion sources

- MK1- Ta (+RILIS)used 50-70 % of the time
- Rest shared between FEBIAD type plasma sources + few other sources

- FEBIAD weaknesses identified and some already addressed

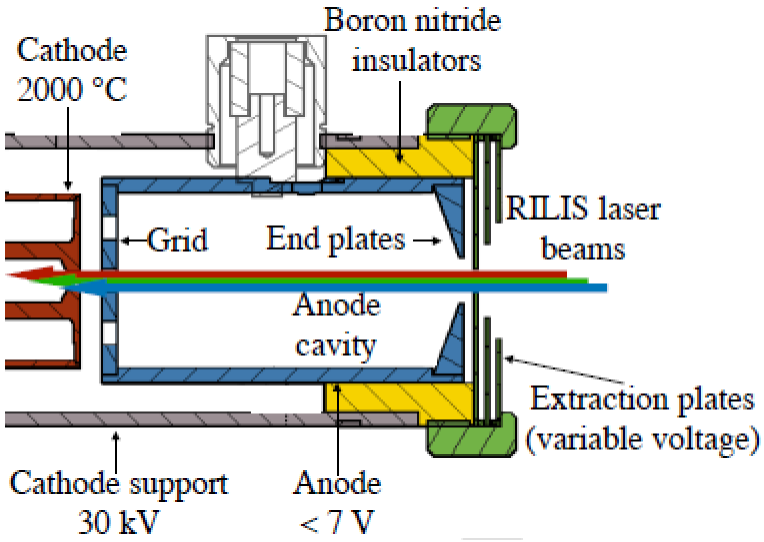
FEBIAD developments

SPES FEBIAD design

http://eurisol-jra.in2p3.fr/wp-content/uploads/sites/3/2019/02/ENSAR2_D14-2-Deliverable_final-V01.pdf

CERN VADLIS 2.0

Yisel Martinez Palenzuela, diss.



(a)

Spin-off:

➡ potentially more robust anode mount.

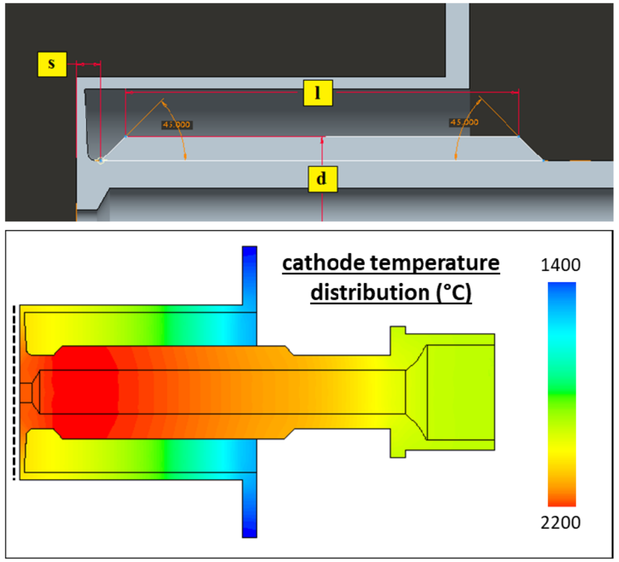


Figure 2. Optimized cathode design and focus on the related temperature field.

➡ Improved cathode design

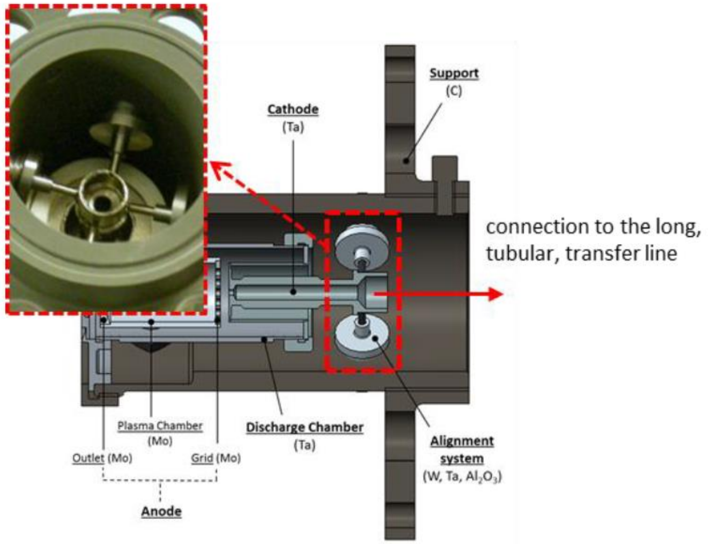


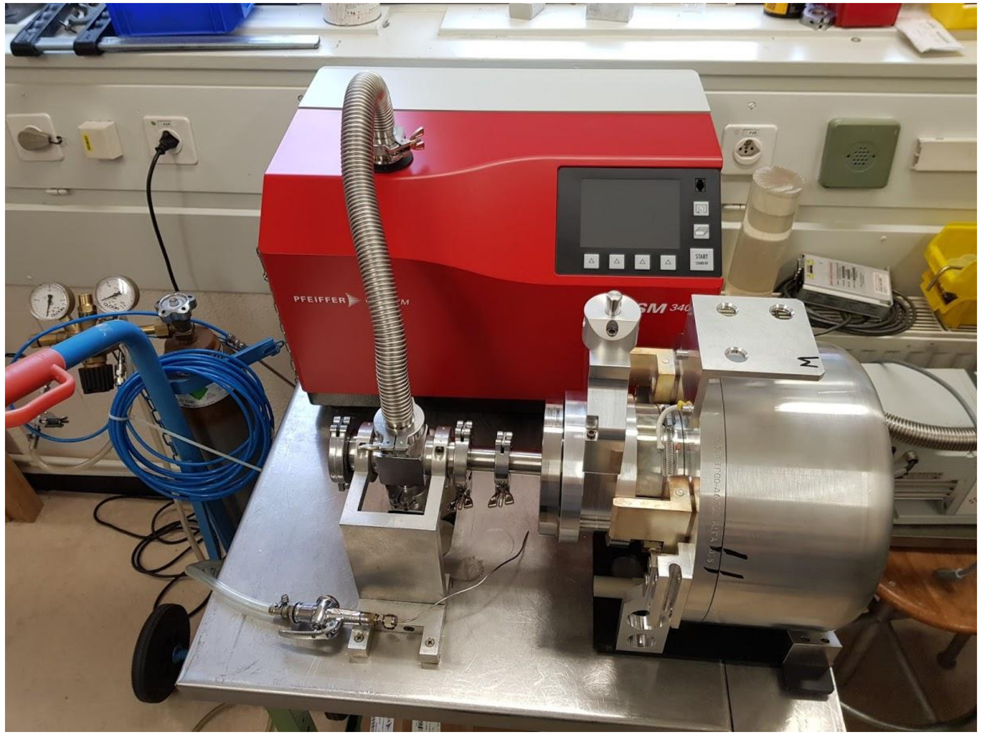
Figure 3. The cathode alignment system.

➡ Additional cathode fixation

➡ Long-term performance measurement required ONLINE

Target base

- Weak point seems to be the vacuum seals
- Require analysis of origin of leaks
- improve seals
  - Other polymers (PEEK, PC, …)
  - Metallic seals
  - Investigate all-metal VAT valve



➡ Leak test every target before dismantling

➡ Development required to improve durability

➡ Dismantling & Post mortem started in ISOLDE Hot cells

Ideas for scheduling, operation, production

- Facilitate scheduling of reused targets: measure yield for upcoming experiments foreseen on this target
- Identify and stock standard target/ion source combinations
  - -> more backups available
- Increase reliability
  - Move away from production to deadline
  - Test target base, plasma source separately, limit custom assembly to mass markers / gas leak / target material

Collaborate !

Many ISOL facilities face the same technical problems.

Ongoing and planned collaborations:

FEBIAD , Molecular Beams, Target heating concepts, Material compatibility, Actinide nano materials, …

… more to come !

THX to the colleagues interviewed:

Richard, Joachim, Jochen, Charlotte, David, Vassilis, Stefano, Nhat-Tan, Thierry, Gerda, Karl, Alberto, Bruce, Joao, Tom, Bernard, Mike, Simone …