CERN

Target group: J.P. Ramos, S. Rothe, D. Leimbach, J. Ballof, F. B. Pamies, T. Stora, E. Barbero, B. Crepieux
Beam manipulation: T. Giles, S. Warren
RILIS: B. Marsh, K. Chrysalidis, S. Wilkins, C. Granados
ISOLTRAP: M. Mongeot, J. Karthein
SCK-CEN: D. Houngbo, L. Popescu, M. Dierckx
TRIUMF: L. Egoriti, A. Gottberg
ISOLDE: G. Neyens, K. Johnston, R. Catherall, A. Dorsival, A.P. Bernardes

João Pedro Ramos
http://www.joaopedroramos.com
joao.pedro.ramos@cern.ch/@kuleuven.be

GUI Meeting

3rd of June 2019

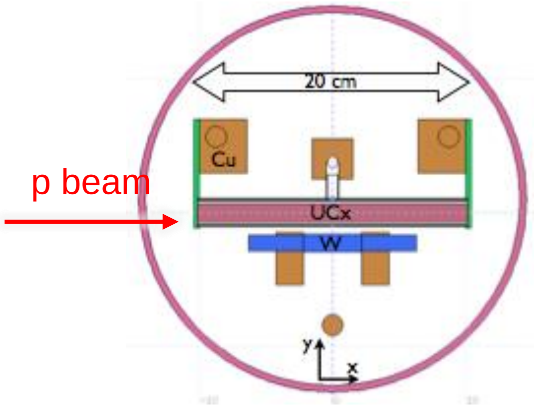
Results from tests with the new p2n converter

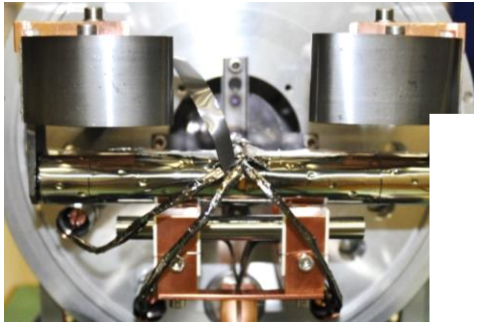
Simulations and concepts

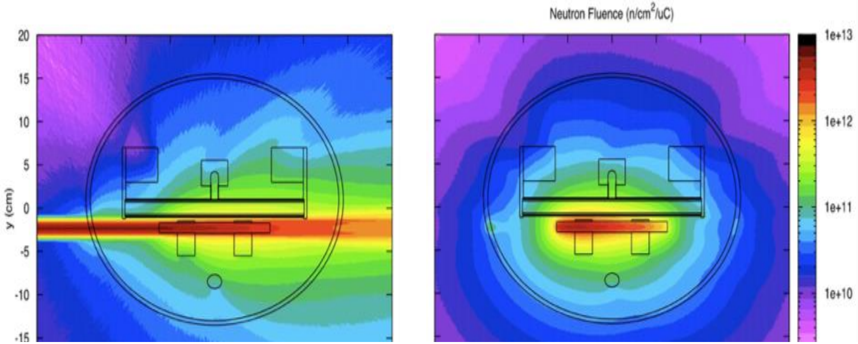
Offline developments

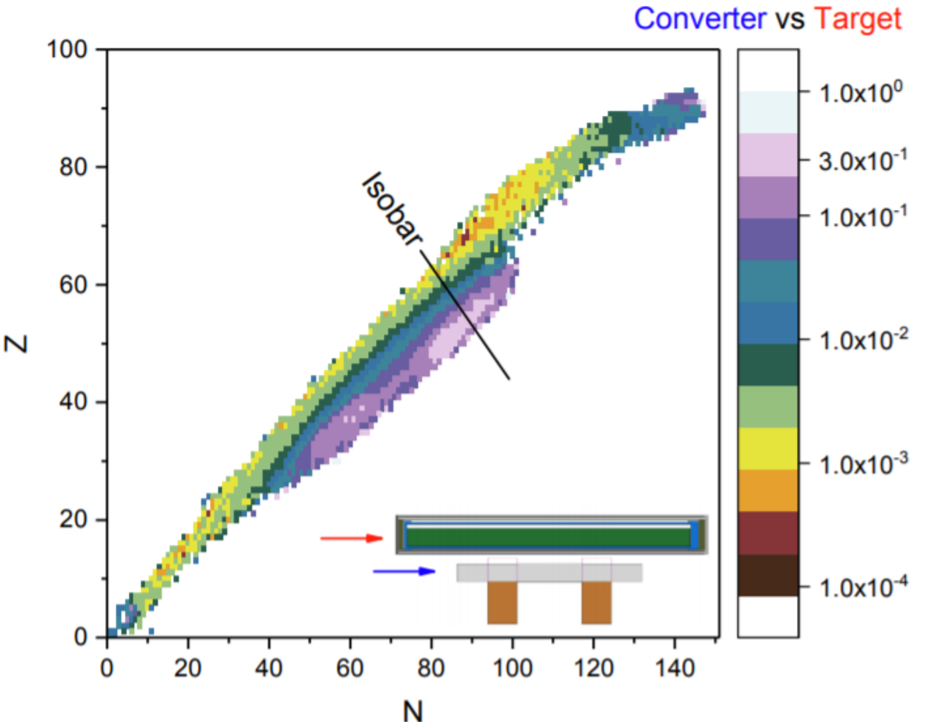
Online run

p2n-converter







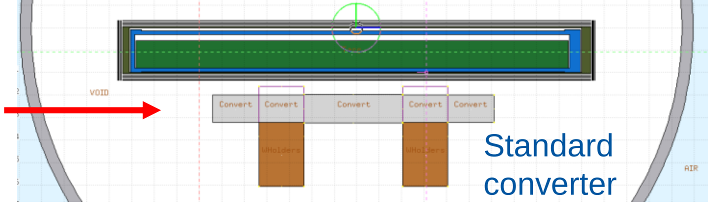


TRIUMF	ISOLDE	
500 MeV	1.4 GeV	2.0 GeV
100 μA	2.2 μA	(3 μA)
cw	pulsed	pulsed
50 kW	**3.1 kW**	**(6 kW)**
	8.0 GW	**(11.5 GW*)**

Collaboration s
two p2n-conve

- Improve the
- Design one

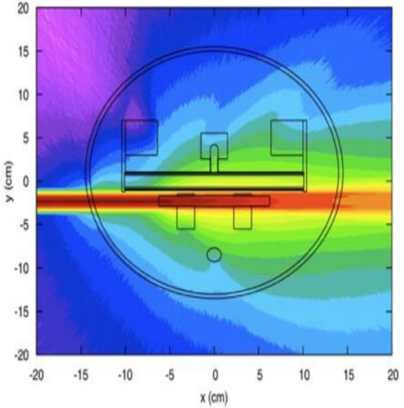
*assuming same bunch struc

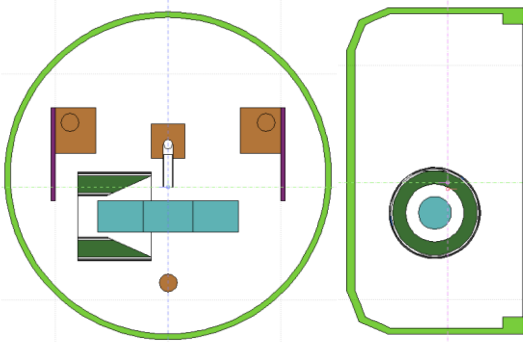


Concept history

Problem: scattered protons

isotope intensity loss (70-80%)

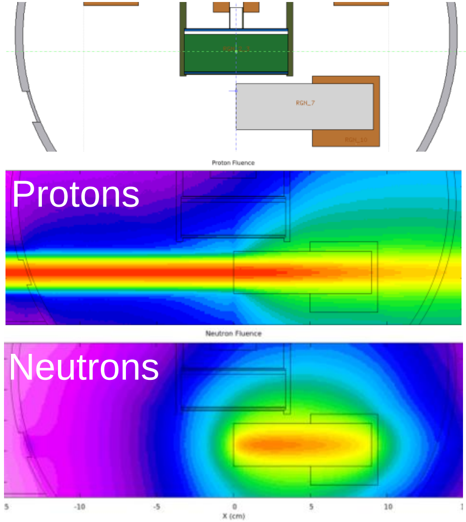




R. Luis, et al., , et al., EPJA 48 (2012) 90

Simple prototype was designed and tested

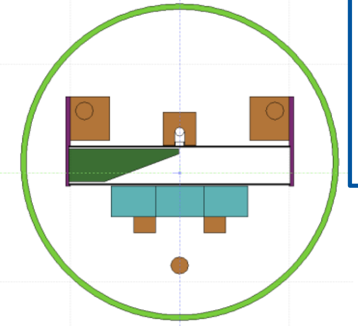
Low yields but
very high purity
Target oven could
not reach 2000 °C



A. Gottberg, et al., NIMB 336 (2014) 143–148.

Main ideas:

- **Thick converter** – reduce "proton cone"
- **Short target and shifted (annular)** – avoid the proton scattering zone



Converter optimization has two directions:

- Avoid as much as possible the scattered protons for **low proton flux**
- Have the converter as close as possible to the 2000 °C target for **high neutron flux**

Project management

This project used:

cern.ch/opense

Scientific project management framework

+

For development

Converter is very relevant:

- 53 INTC documents where p2n-converter is mentioned (up to March 2018)
- 10/83 INTC documents for 2016/2017 where p2n-converter is requested

3 boards (project steering and reporting):

- 20th March 2018
- 12th June 2018
- 25th October 2018
- Last board (soon)

Project board:

Person	Affiliation	Role
R. Catherall	CERN (EN/STI)	Chairperson/funding/expertise
G. Neyens	CERN (EP/SME)	Users representative
K. Johnston	CERN (EP/SME)	Users representative
T. Stora	CERN (EN/STI)	Technical expert
A.P. Bernardes	CERN (EN/STI)	Safety expert
A. Dorsival	CERN (HSE/RP)	Radioprotection expert
J.P. Ramos	CERN (EN/STI)	Project responsible/secretary

Funding (resources)	EN/STI-RBS
Users	EP/SME (representing EP/UIS)
Regulators	HSE/RP and ISOLDE safety
Expertise (feasibility)	EN/STI-RBS
Project manager	Appointed project responsible

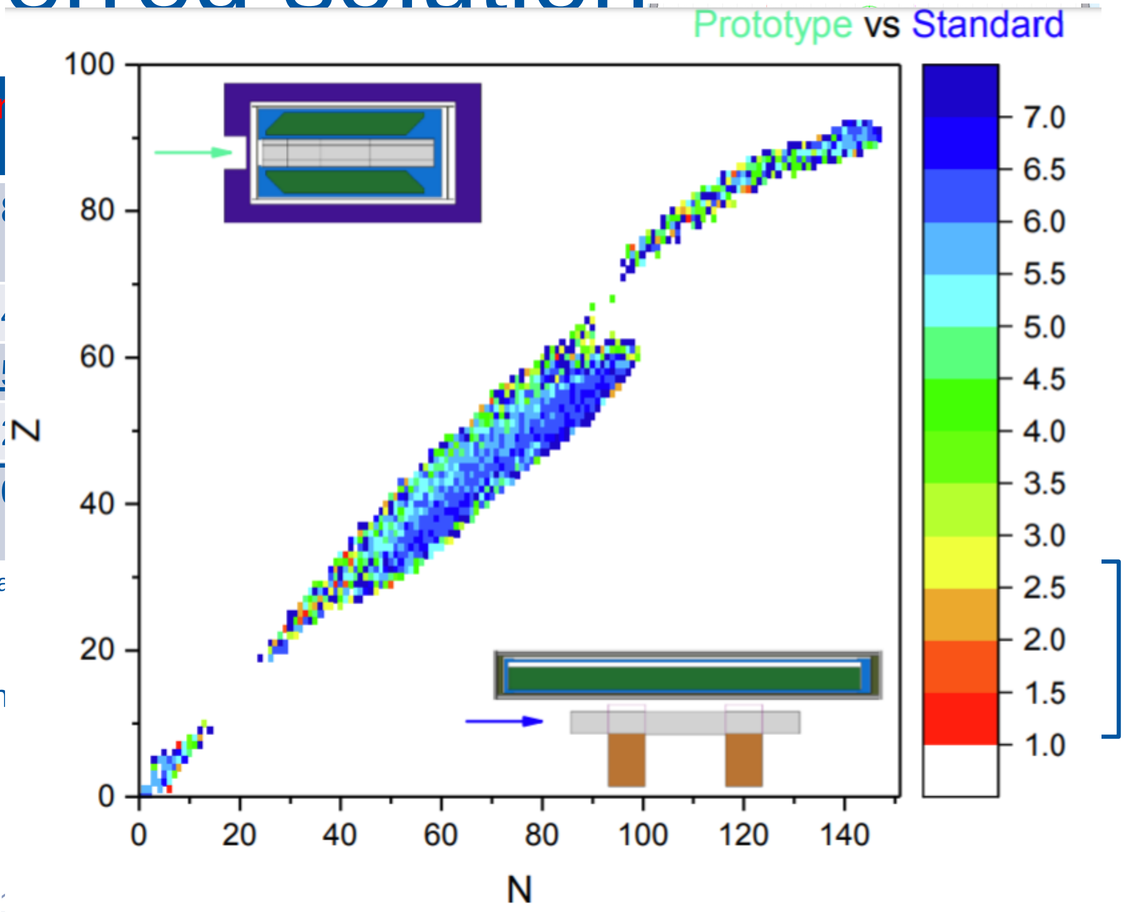
Strategic decisions

Analysis – preferred solution

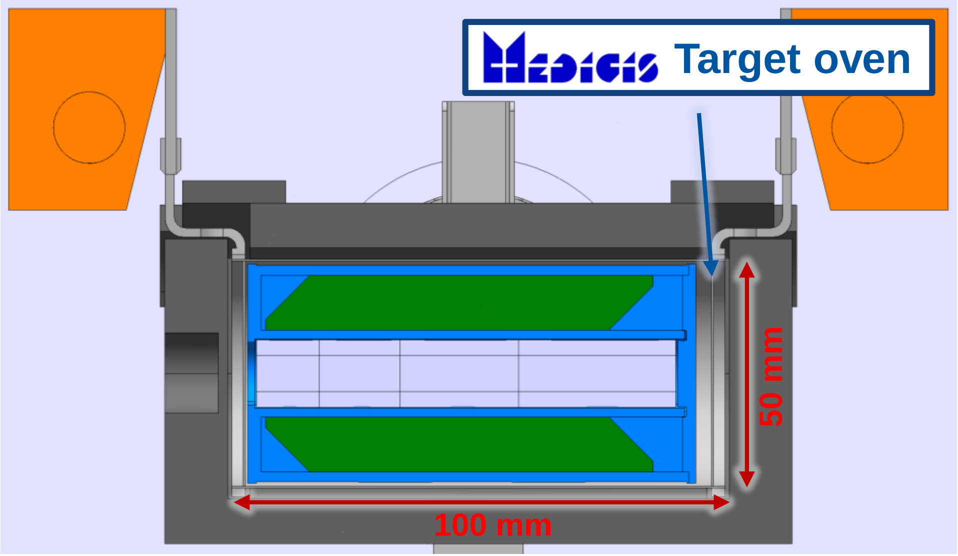
	n-ind fissions (/s)	p-in
Standard converter	7.05E10	1.2
Raul	5.01E10 (0.71)	1.4
Compromise*	1.57E11 (2.23)	1.1
High Intensity*	4.19E11 (5.94)	5.8
(TRIUMF concept)	3.85E11 (5.46)	3.1

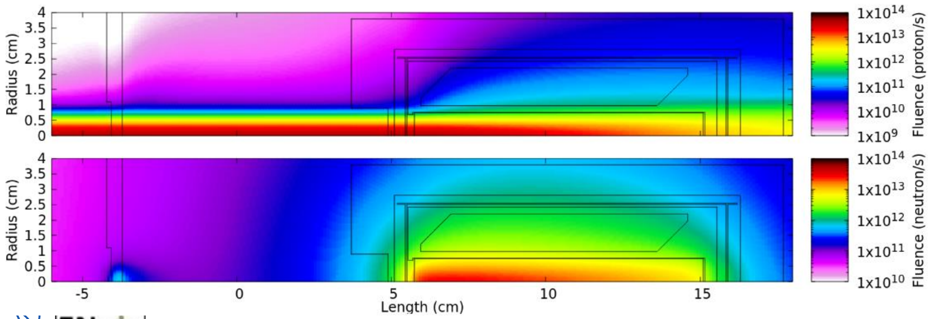
*for new prototypes assumed smaller density (material manua pressed but powder manually compacted

Brings roughly 2 – 4x more yield in all isotopes than

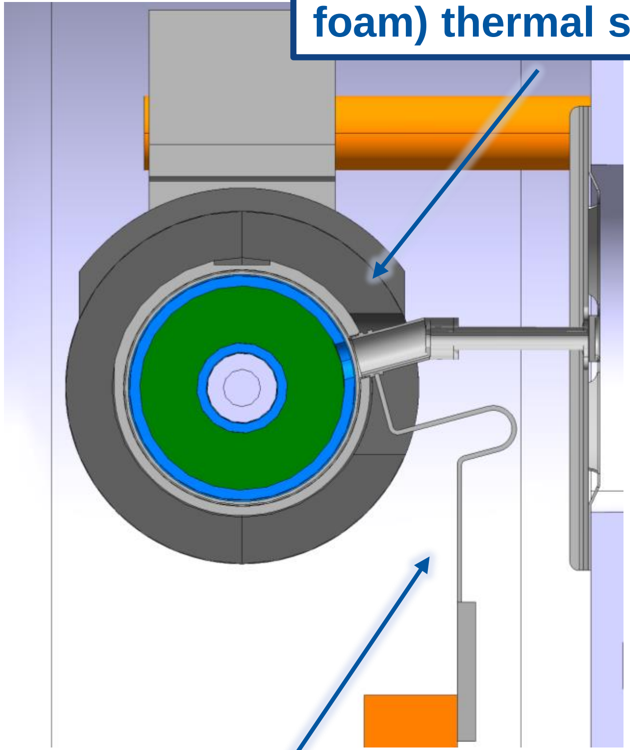


The final concept





Sigratherm (graphite foam) thermal shielding



SPES exotic beams for science

transfer line design

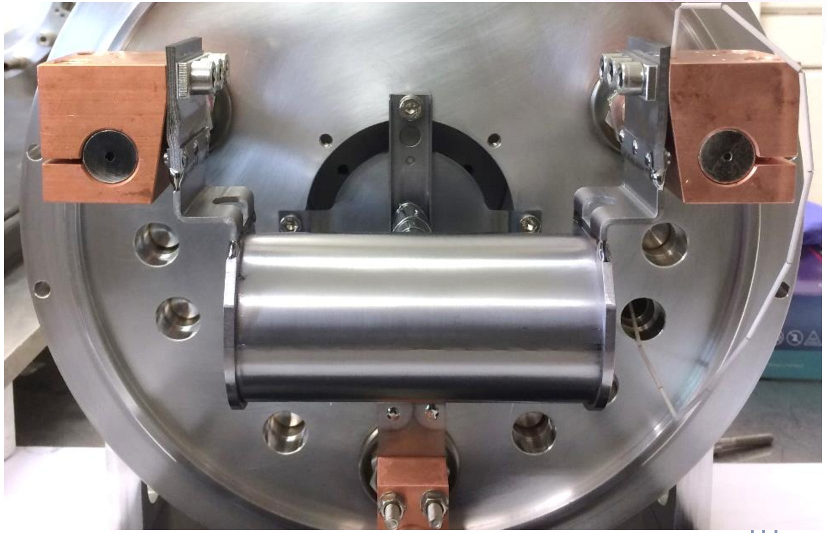
J.P. Ramos, et al., EMIS 2019 Proceedings, to be published

Simulations and concept

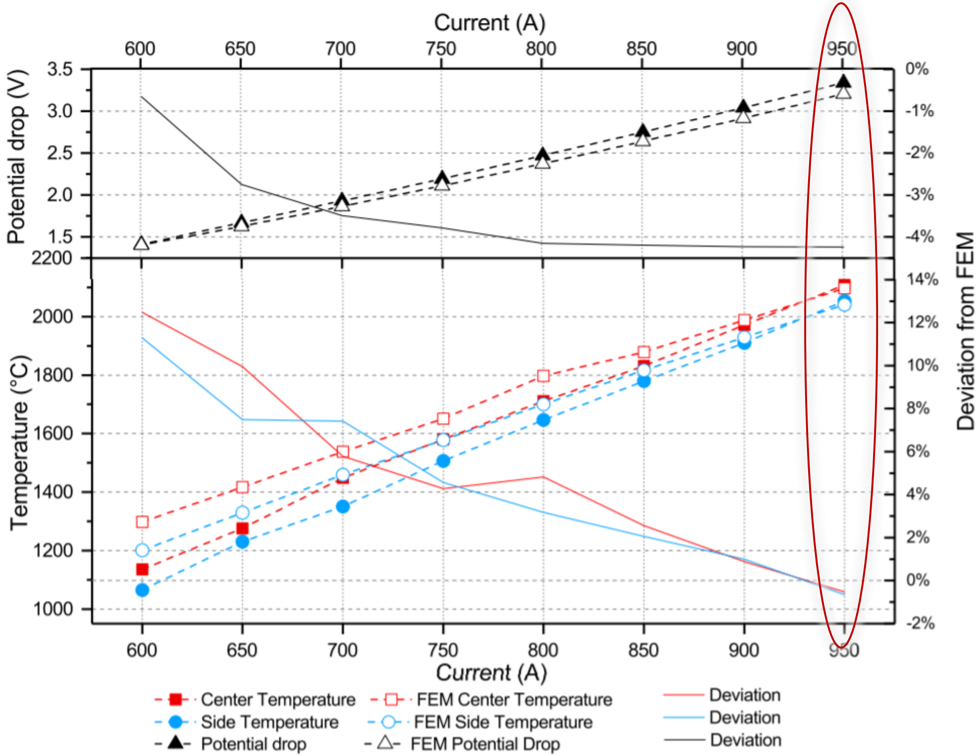
Offline developments

Online run

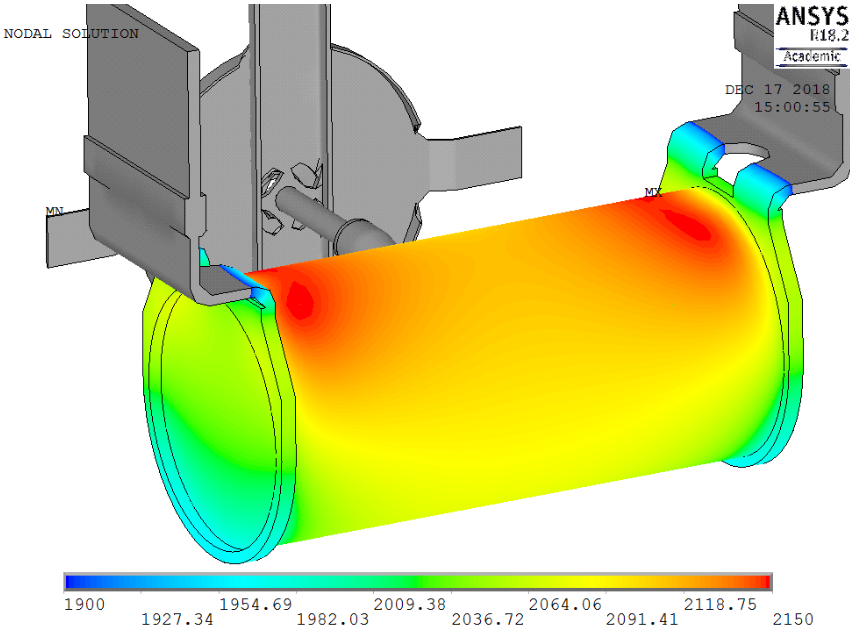
Material acquirement



Oven tests



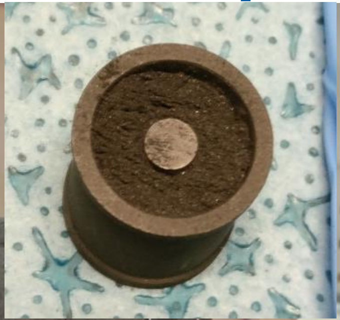
Current (A)
600
650
700
750
800
850
900
950
Potential drop (V)
3.5
3.0
2.5
2.0
1.5
2200
2000
1800
1600
1400
1200
1000
Temperature (°C)
0%
-1%
-2%
-3%
-4%
14%
12%
10%
8%
6%
4%
2%
0%
-2%
Deviation from FEM
Current (A)
Center Temperature
Side Temperature
Potential drop
FEM Center Temperature
FEM Side Temperature
FEM Potential Drop
Deviation
Deviation
Deviation



NODAL SOLUTION
ANSYS
R18.2
Academic
DEC 17 2018
15:00:55
MN
MX
1900
1927.34
1954.69
1982.03
2009.38
2036.72
2064.06
2091.41
2118.75
2150

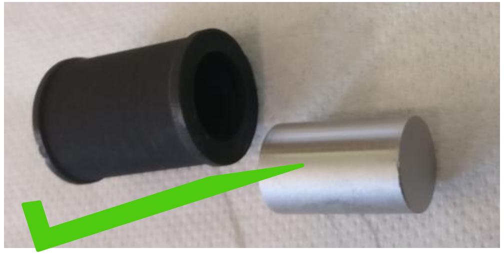
Material compatibility

W not water cooled, but at >2000 °C)

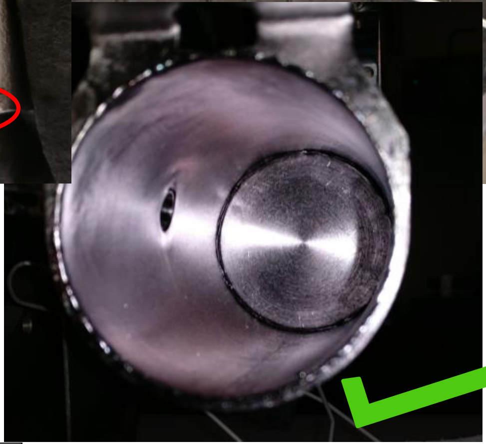


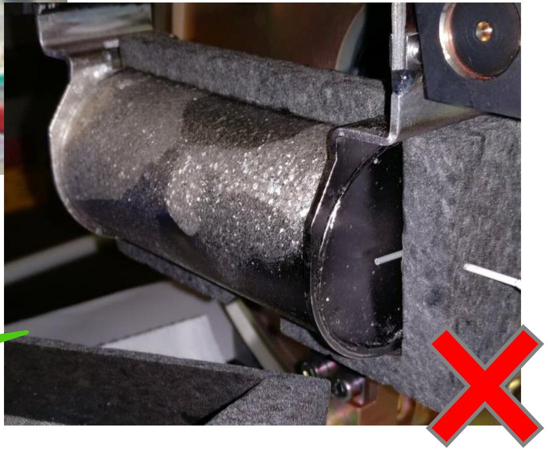
Before – UO_2 + 4C

After – UC_2+2C



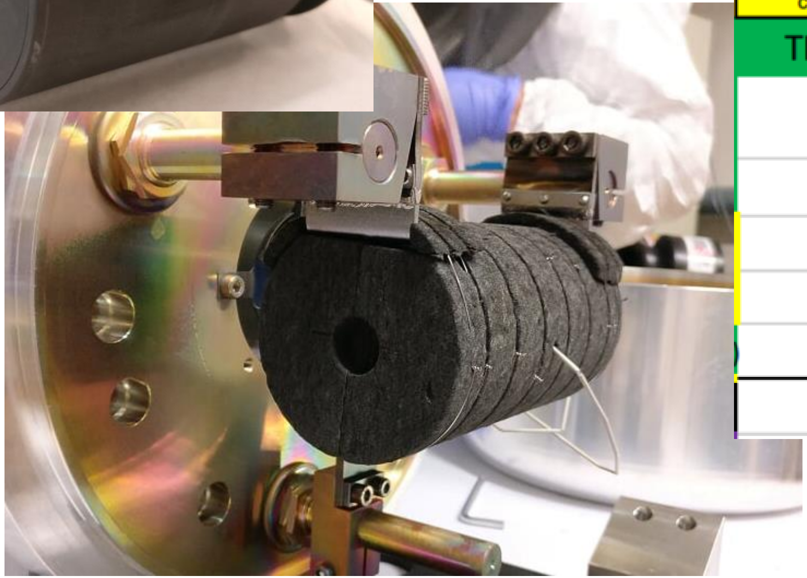
After (2200 °C – 16 h) – no change





Use standard (tilted) UCx pellets

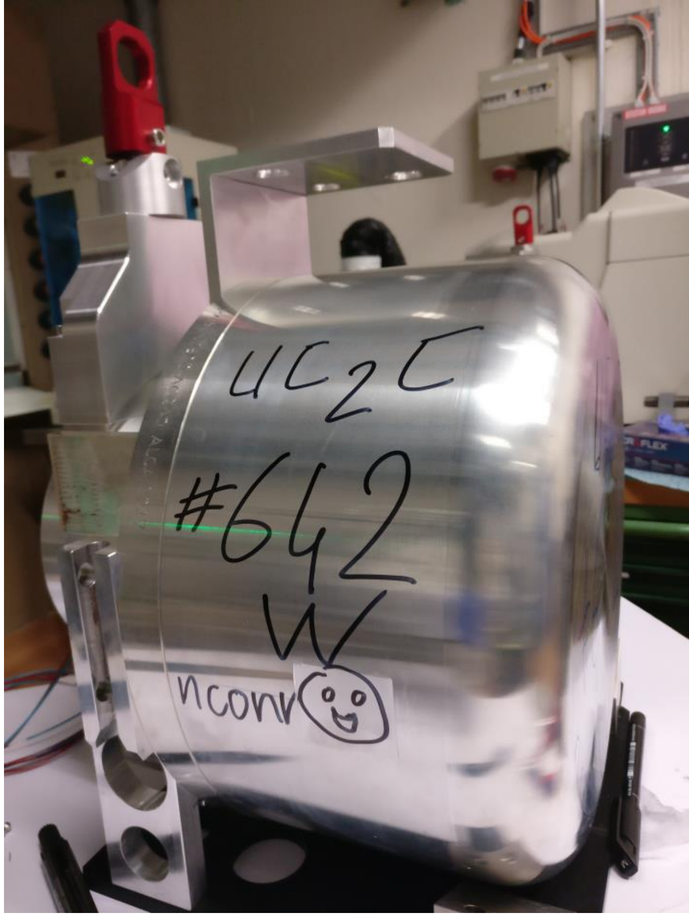
Online target ready



Offline tests successful

HRS

44	45
#642 UC n(ew)-conv	TISD 5
TISD	TISD
	#672 CaO VD7
	WISArD LOI172
	RILIS: for TISD



W ion source installed

Everything up to here is published

Online run

Simulations and concept

Online run

ARTICLE IN PRESS

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Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/nimb

ELSEVIER

BEAM INTERACTIONS WITH MATERIALS AND ATOMS

Design and tests for the new CERN-ISOLDE spallation source: an integrated tungsten converter surrounded by an annular UC_x target operated at 2000 °C

J.P. Ramos[a,*], M. Ballan[e], L. Egoriti[b,c], D. Houngbo[d], S. Rothe[a], R.S. Augusto[a,f,1], A. Gottberg[b], M. Dierckx[d], L. Popescu[d], S. Marzari[a], T. Stora[a]

[a] European Organization for Nuclear Research (CERN), Esplanade des Particules 1, 1211 Genéve 23, Switzerland
[b] TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia V6T 2A3, Canada
[c] University of British Columbia, Department of Chemistry, Vancouver, British Columbia V6T 1Z1, Canada
[d] SCK·CEN, B-2400 Mol, Belgium
[e] INFN, Laboratori Nazionali di Legnaro, viale dell'Universitá 2, 35020 Legnaro (PD), Italy
[f] Ludwig-Maximilians-Universität Munich Faculty of Physics, Schellingstrasse 4, 80799 Munich, Germany

ARTICLE INFO

Keywords:
Spallation neutron source
Proton-to-neutron converter
Isotope separation on-line (ISOL)
ISOLDE
Radioactive ion beams (RIB)

ABSTRACT

The production of high intensity and isobarically pure neutron-rich fission fragments is of high importance for the physics research program of the ISOLDE facility at CERN. This is typically done in a two-step method where a tungsten converter, positioned parallel and below the UC_x target, is irradiated with 1.4 GeV protons. This will produce spallation neutrons which irradiate a UC_x target producing the isotopes of interest. Currently, the in-target production is limited by the geometrical overlap of the neutron fluence and the target material and suffers from low production yield. In this work, a prototype is proposed where the tungsten converter is positioned in the center of an annular UC_x target. FLUKA simulations were conducted to optimize the geometry, maximizing the production of isobarically pure neutron-rich fission fragments which determined that a large diameter target is necessary (5 cm). Thermo-electric ANSYS® simulations were conducted in order to develop a large Ta target oven which can reach 2000 °C and tests were conducted to benchmark the simulations. A prototype design was validated, for ISOLDE operation, with offline tests which shows that the tungsten-graphite-tantalum assembly is fully stable up to 2200 °C.

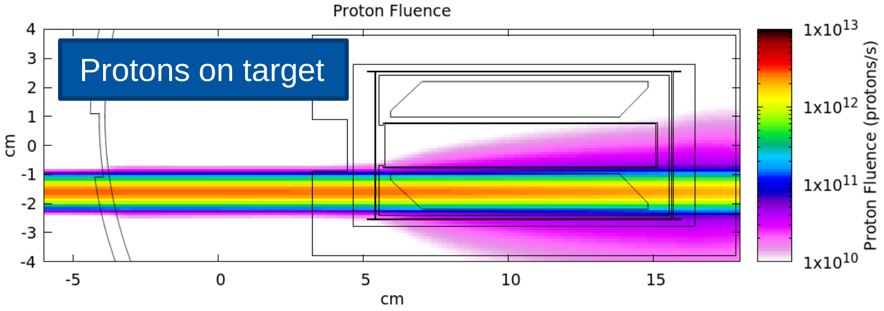
https://doi.org/10.1016/j.nimb.2019.04.060

Online run

Run split in two

First part:
- Proton scan
- Cs yields
- Rb yields

Second part (laser ionized)
- Zinc
- Gallium
- Indium
- High proton intensity tests



Measure full isotope chains

Protons on target and on converter

Laser on/off

> 100 yields

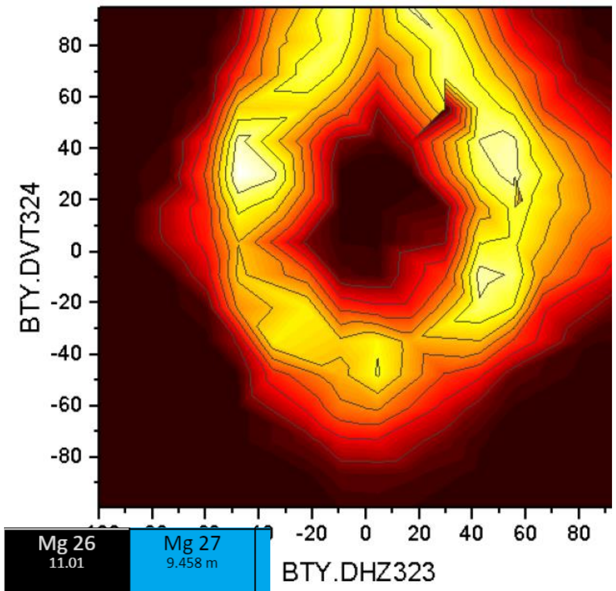
<u>Gamma detector was broken – only beta detector was available</u>

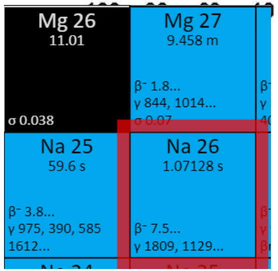
FCup and ISOLTRAP

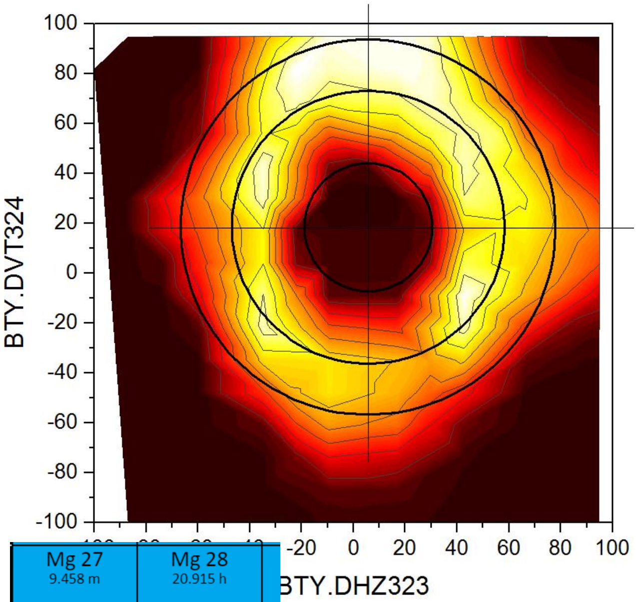
Proton scan

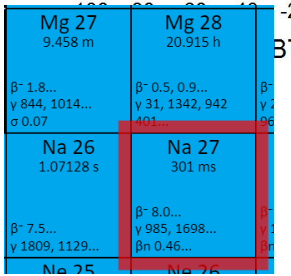
Converter
H: 20, V: 0

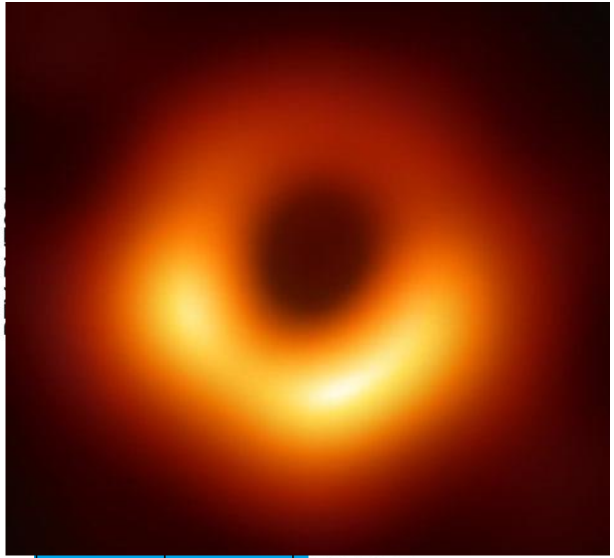
Target
H: 60, V: 0

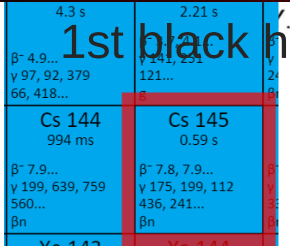












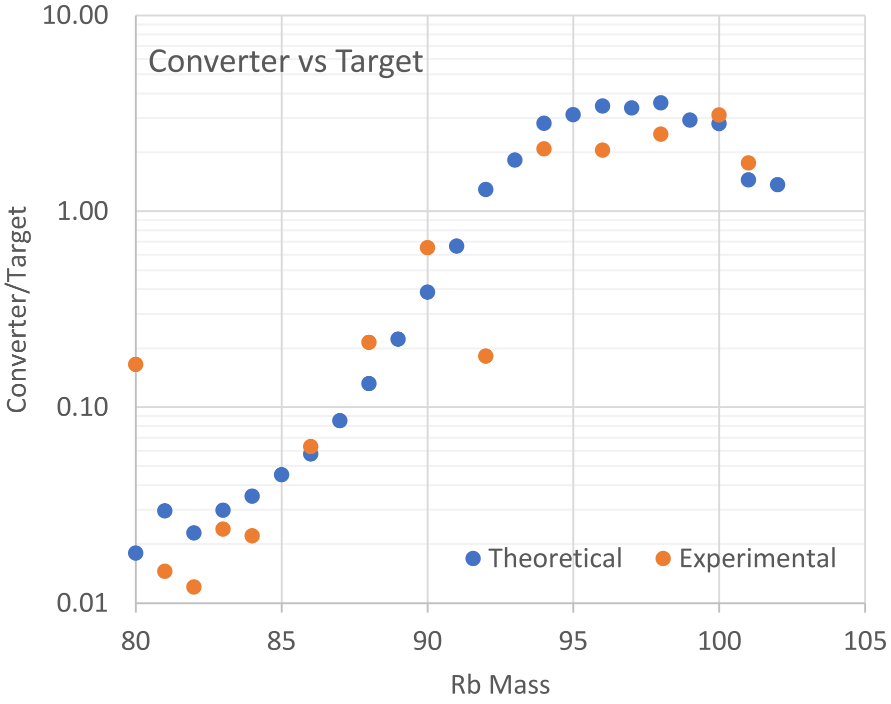
1st black hole picture

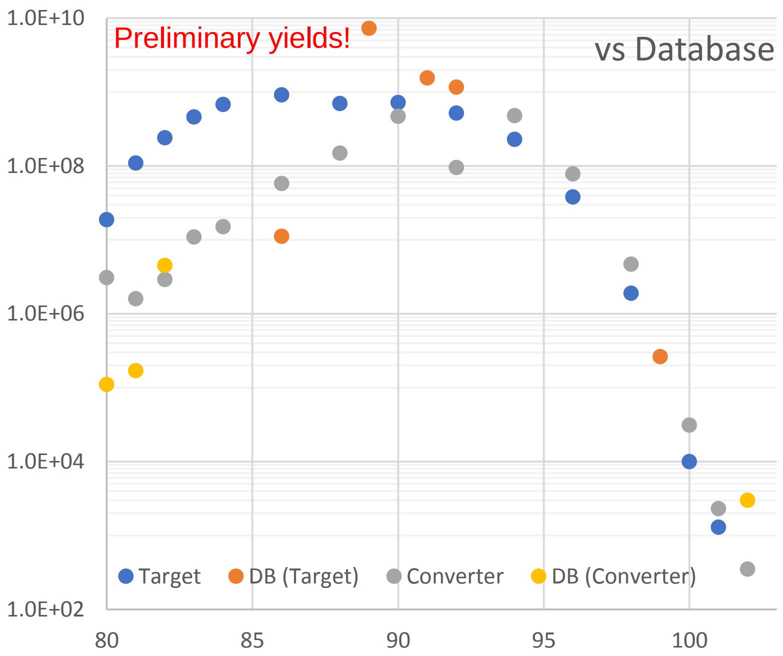
J.P. Ramos, et al., to be published.

Rb yields

Target
2000 °C (850A)

W ion source
~2150 °C (255A)





ISOLTRAP – Rb/Sr > 10

T_b = 688 °C

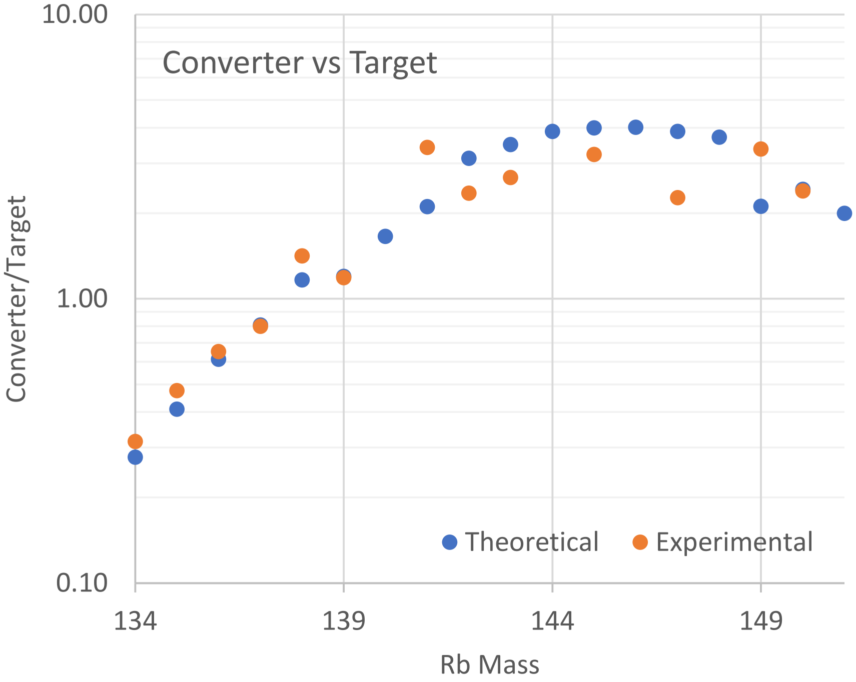
$T_{P=1Pa}$ = 161 °C

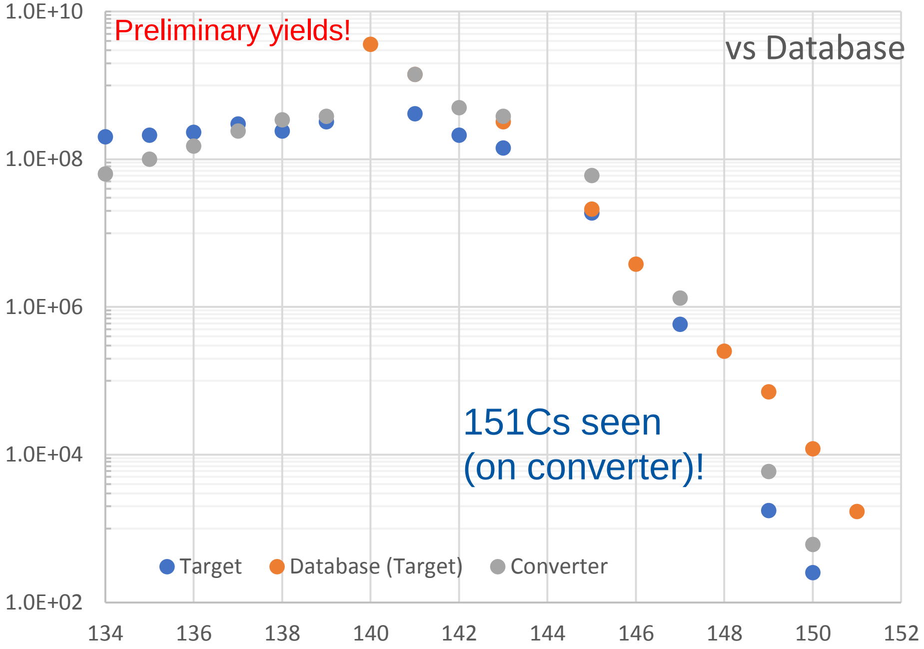
J.P. Ramos, et al., to be published.

Cs yields

Target
2000 °C (850A)

W ion source
~2150 °C (255A)





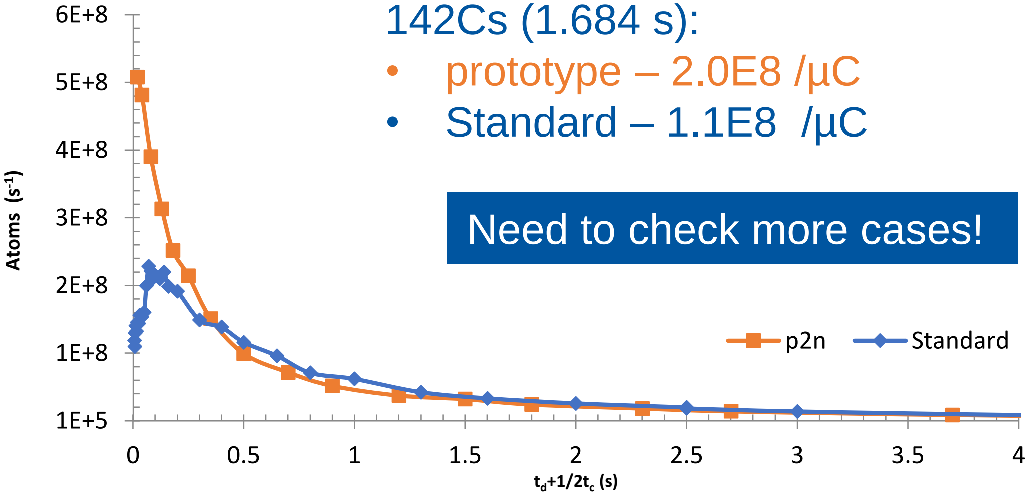
ISOLTRAP – Cs/Ba ~ 10, Cs/La > 100

T_b = 671 °C

$T_{P=1Pa}$ = 145 °C

J.P. Ramos, et al., to be published.

Release properties



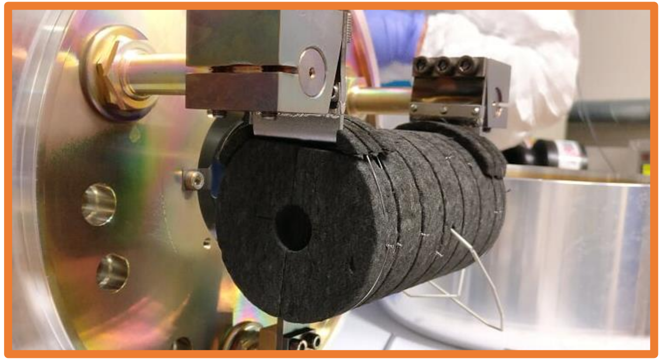
142Cs (1.684 s):

- prototype – 2.0E8 /µC
- Standard – 1.1E8 /µC

Need to check more cases!

- Diffusion should not be affected (same material, same pellets)
- Effusion is affected (larger volume, annular shape)

- Temperature inhomogeneities of 200 to 300 °C
- Target volume is 60 cm^3

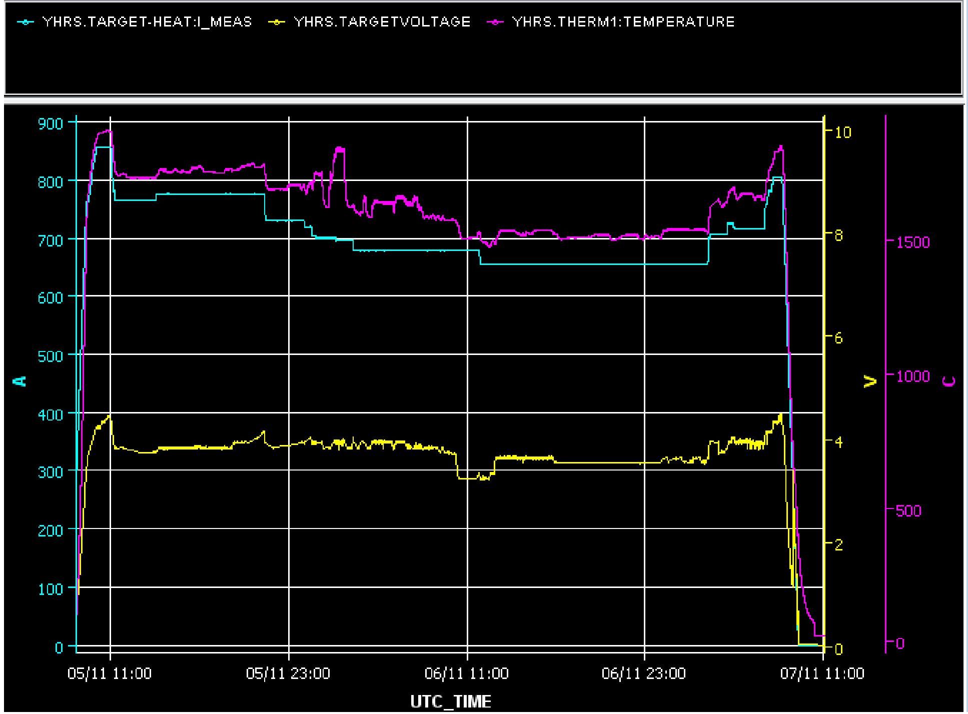


- No cold spots
- Large target volume (200 cm^3)
- Anular target

2nd part of the run

Target heating issues:

- Voltage increased continuously (container failure sign)
- Decreased target current to keep voltage stable (same power)
- Target temperature was heavily influenced



<u>Another large target was irradiated and tested at MEDICIS</u>

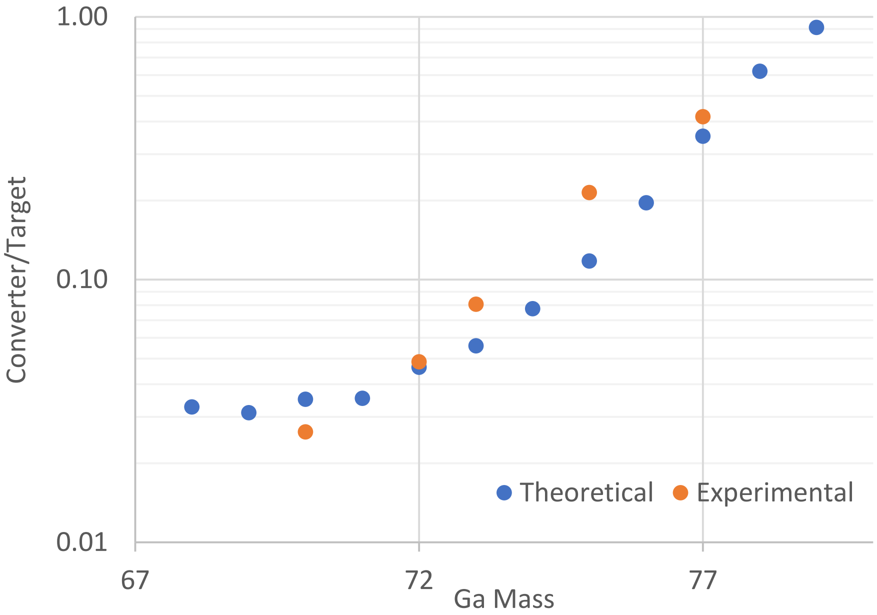
- Failure of the target oven (brough to >2300 °C)

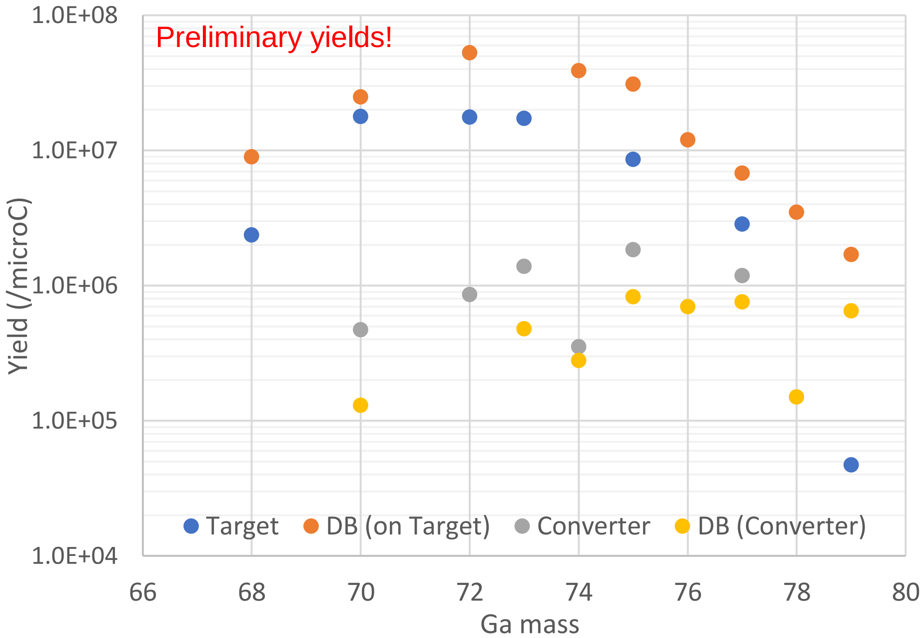
Can affect the reliability of the yields taken after (laser ionized Ga, In, Zn)

Ga yields

Target
1444 to 1764 °C (665 to 775A)

W ion source
~2150 °C (255A)





Laser enhancement was only x4.3 (expected 40-50)!
Optimization done on radioactive (peak)!

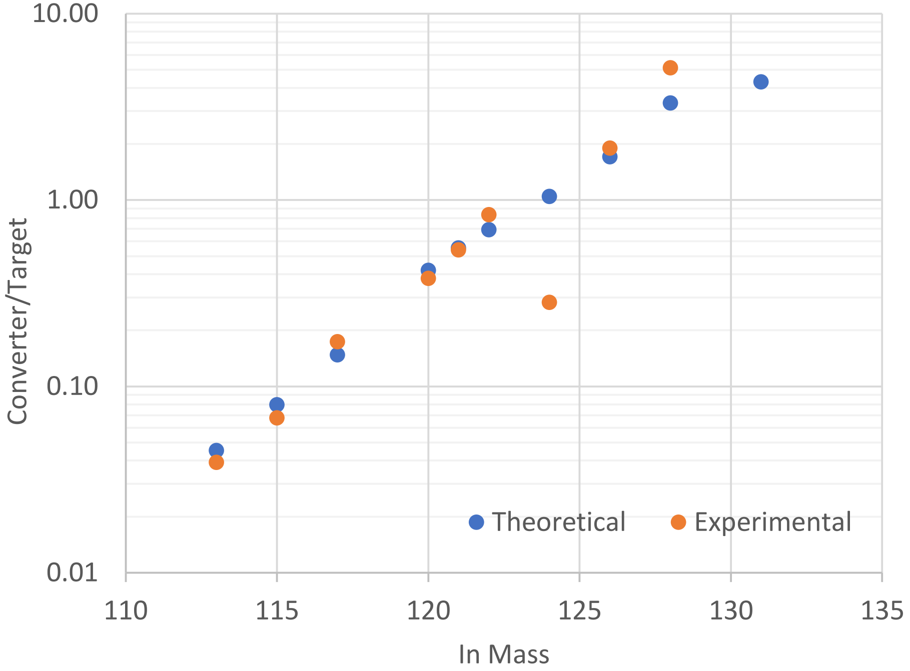
T_b = 2400 °C
$T_{P=1Pa}$ = 1037 °C

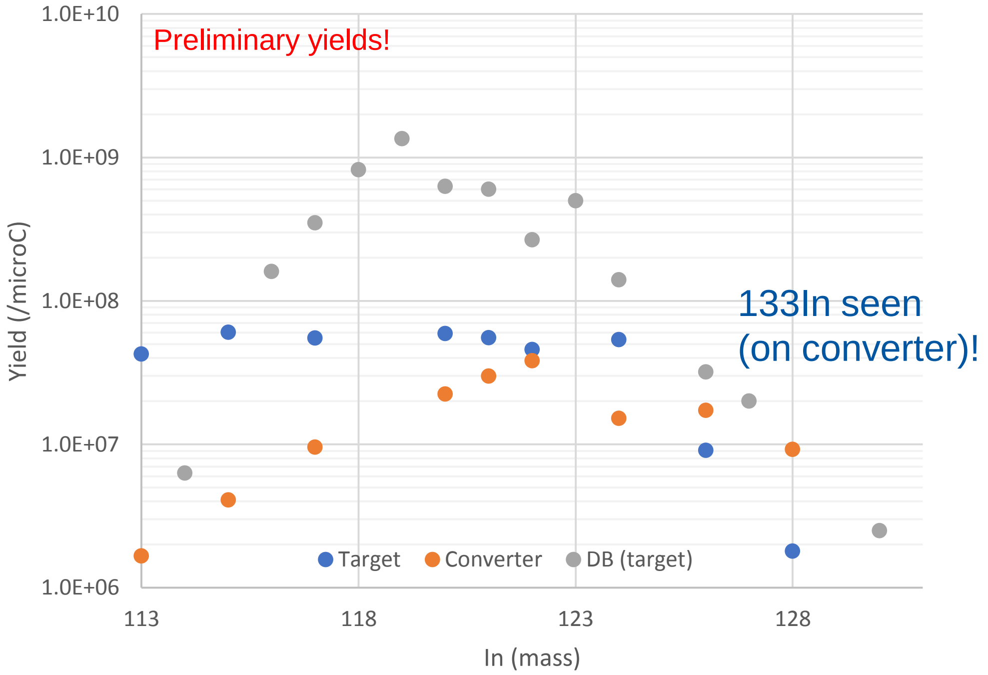
J.P. Ramos, et al., to be published.

In yields

Target
1406 -1476 °C (655 - 680A)

W ion source
~2150 °C (255A)





Laser enhancement was x4.9 from 113 In!
Optimization done on radioactive (peak)!

T_b = 2072 °C
$T_{P=1Pa}$ = 923 °C

J.P. Ramos, et al., to be published.

Zn yields

Target
1432 °C (655A)

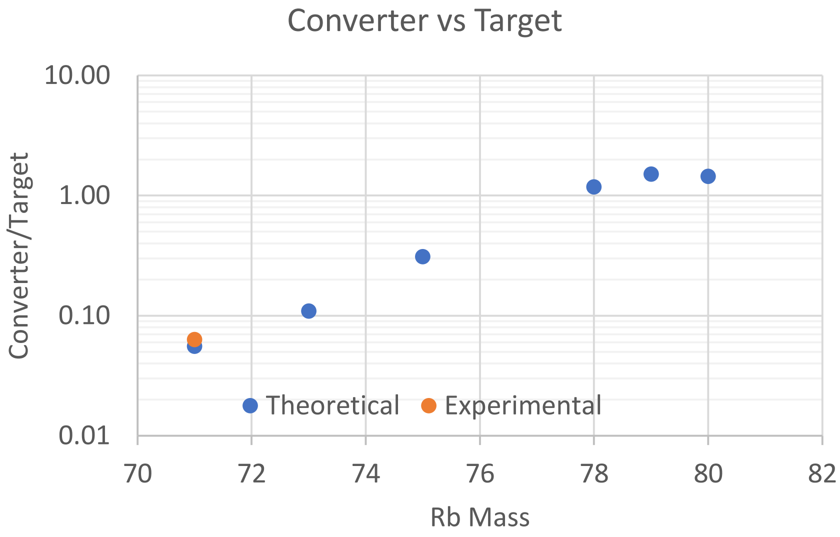
W ion source
~2150 °C (255A)

Data still in analysis…

Only 4 data points taken
Target was much degraded by then…

Example 75Zn (ISOLTRAP)
3.6E5 /µC
(DB 5.6E7 /µC)

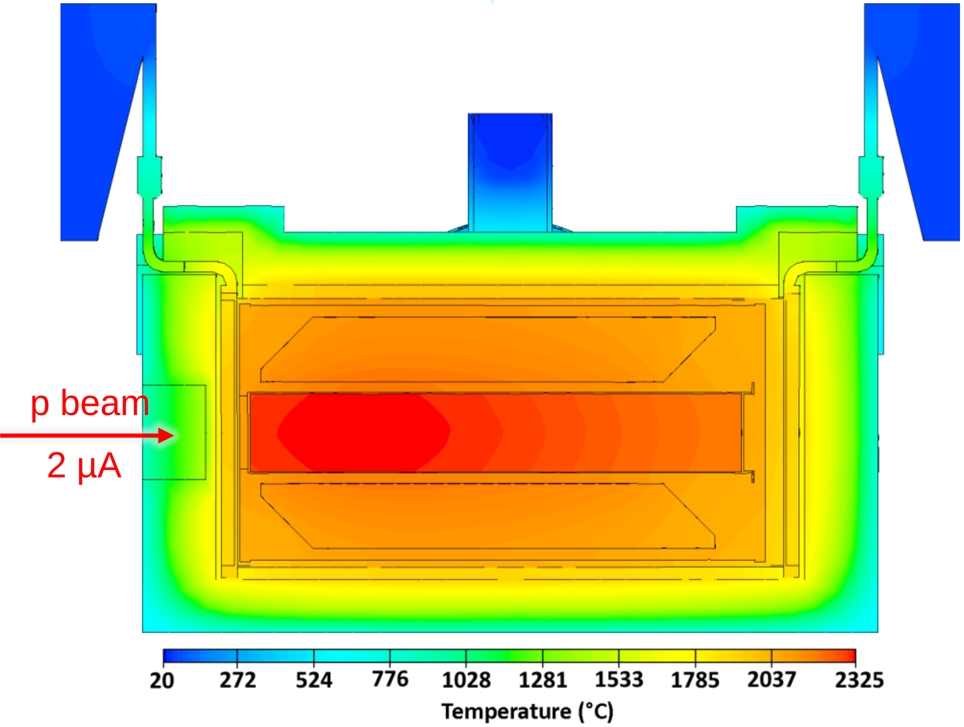
Low yields on Zn

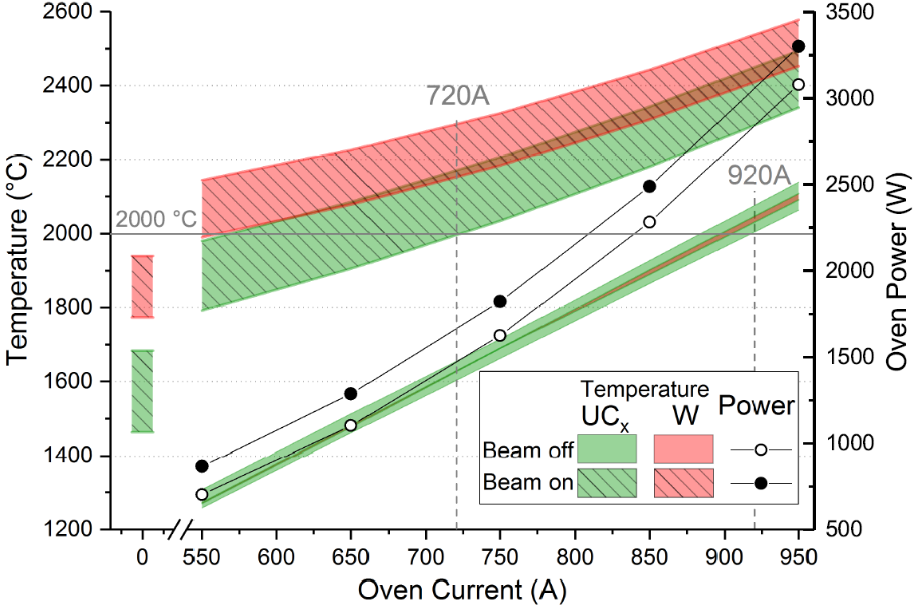


T_b = 907 °C
$T_{P=1Pa}$ = 337 °C

J.P. Ramos, et al., to be published.

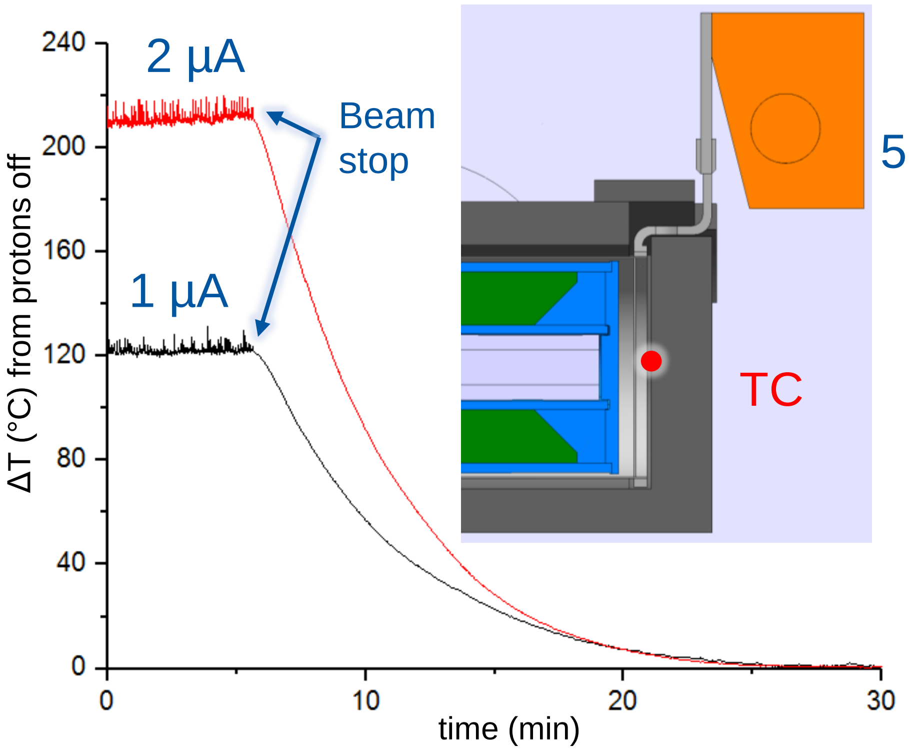
First high power target - simulations

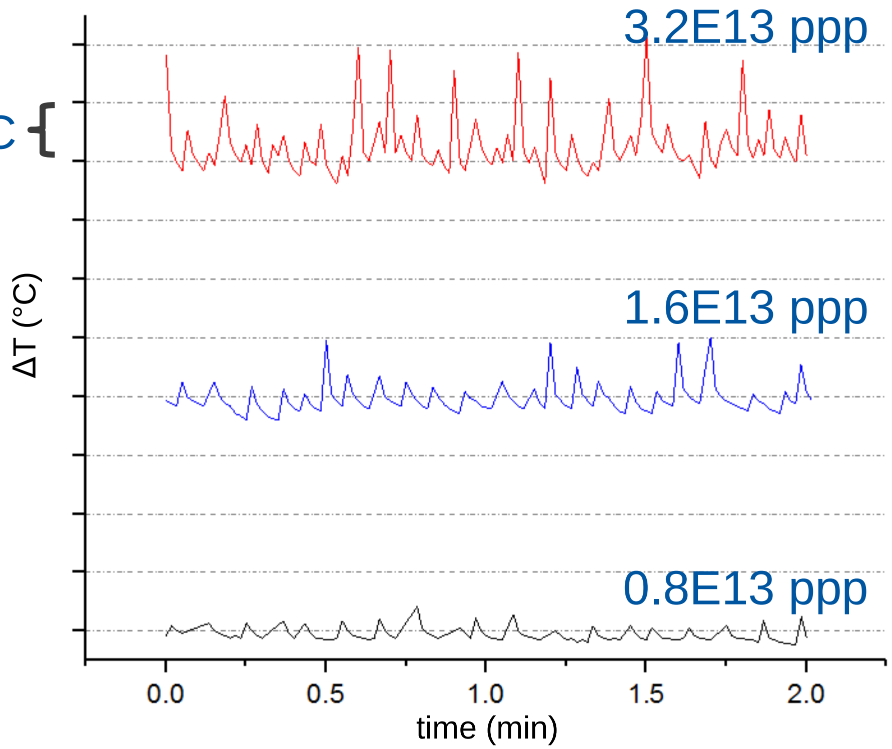




J.P. Ramos, et al., EMIS 2019 Proceedings, to be published

First high power target - data

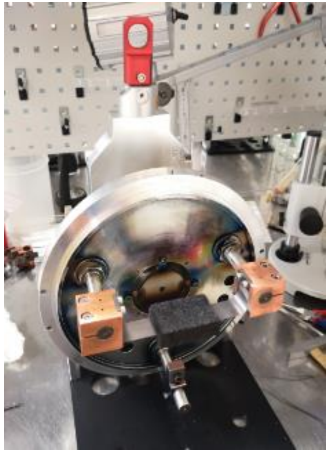


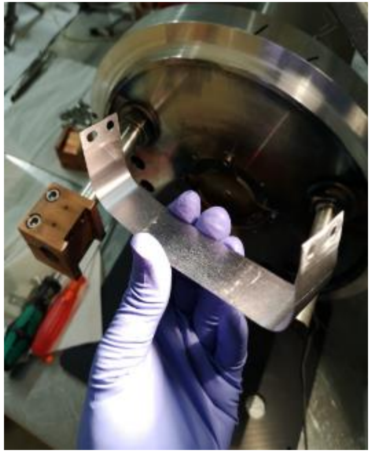


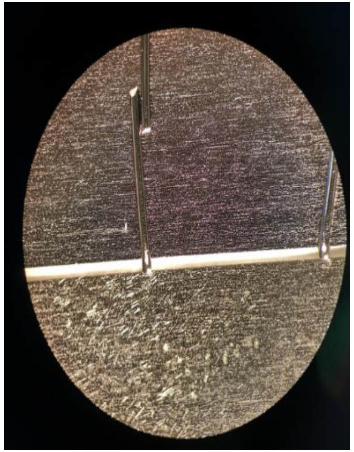
J.P. Ramos, et al., to be published.

Outlook

- **The target oven needs additional development**
  - Post-mortem analysis will be done (location TBD)
    - Two targets: p2nconverter + MEDICIS target
  - Already on-going by V. Samothrakis)

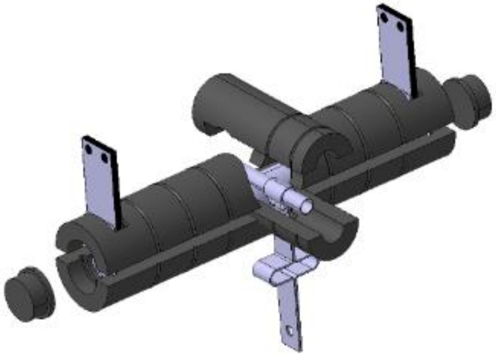






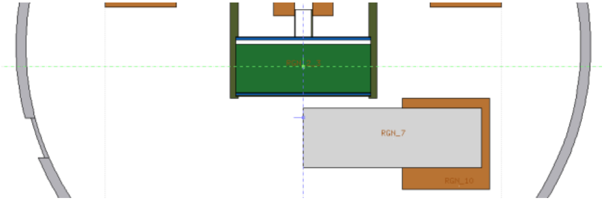
- Cu blocks optimization, current temperatures are 550 °C
- **Test again at ISOLDE** (perhaps with physics run for laser ionized species)

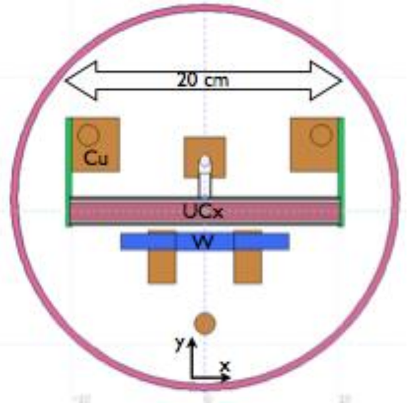
Thermal studies are bringing good outcome already for the standard ISOLDE targets



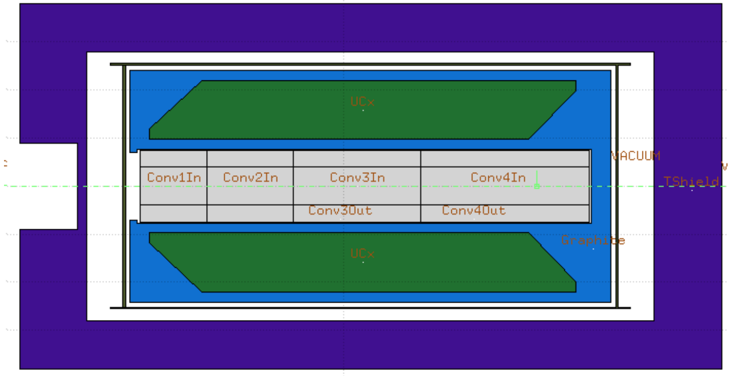
V. Samothrakis, et al.

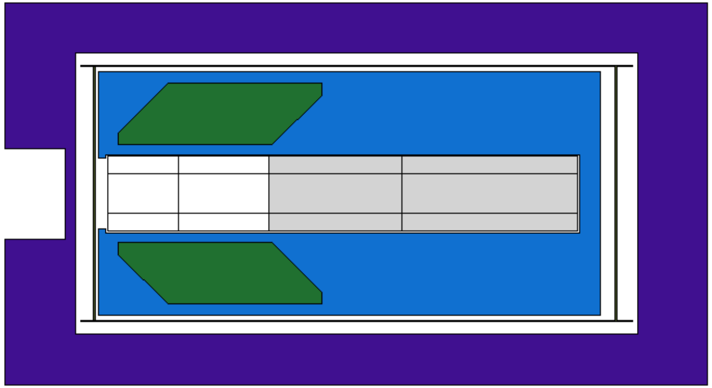
Outlook (2)





- **<u>Need for a high purity converter target</u>**
- Modular target personalized for user
  - can maintain current converter yield but <u>get a factor 4-10 in purity (maybe more?)</u>
  - Still have to run the simulations





Some cases are difficult (**Ni**, Co, Cu…)

- Have to go case by case

ThC$_x$ can help

- Target reduction
- Converter reduction
- Converter & target shift

Conclusions

- Cs and Rb yields were high and match predictions
- In, Ga and Zn were taken at low temperatures (and less optimized RILIS conditions)
- First high-power target of ISOLDE
  - Temperature needs to be adjusted if beam intensity changes
- Run data being analyzed with TRIUMF
  - Compare with more recent yields (a lot of data from SC)
- Current converter can use some extra development to be used as production target
  - Project spin-off (modular converter) with higher purity beams, personalized for user.

Thank you!

This project used:

openSE

cern.ch/opense

Scientific project management framework

Target group: J.P. Ramos, S. Rothe, D. Leimbach, J. Ballof, F. B. Pamies, T. Stora, E. Barbero, B. Crepieux, V. Samothrakis
Beam manipulation: T. Giles, S. Warren
RILIS: B. Marsh, K. Chrysalidis, S. Wilkins, C. Granados
ISOLTRAP: M. Mongeot, J. Karthein
SCK-CEN: D. Houngbo, L. Popescu, M. Dierckx
TRIUMF: L. Egoriti, A. Gottberg
MEDICIS-Promed (SPES): M. Ballan, S. Marzari
ISOLDE: G. Neyens, K. Johnston, R. Catherall, A. Dorsival, A.P. Bernardes

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