CERN

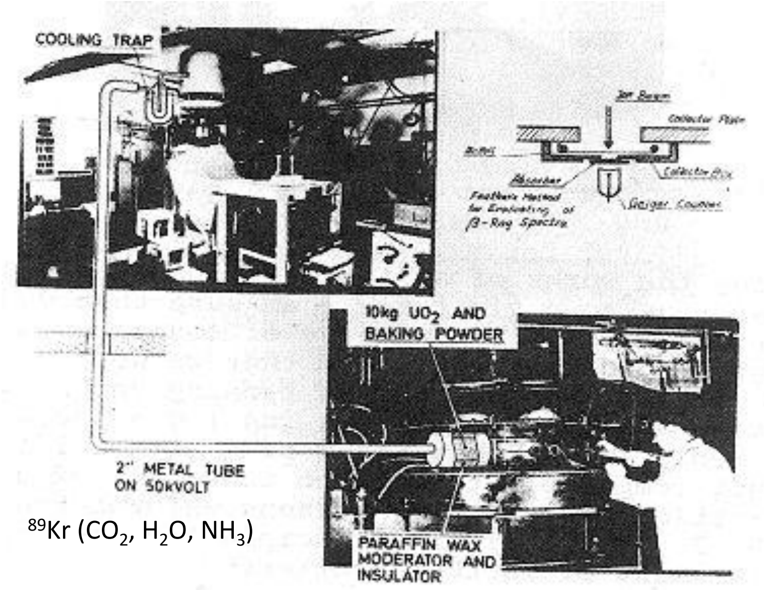
PBC workshop – porous (nano)materials exposed to proton beams

Thierry Stora

Medicis.cern

ISOLDE "0"

O.Kofoed-Hansen
K.O. Nielsen
Dan. Mat.Fys.Medd. 26, no. 7 (1951)



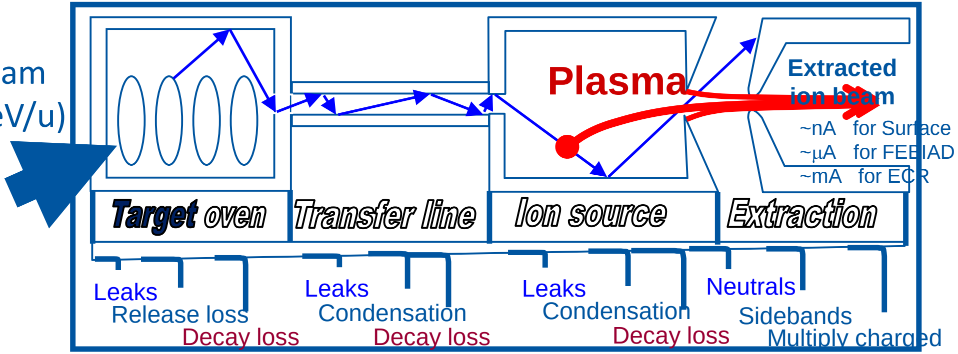
^{89}Kr (CO_2, H_2O, NH_3)

10 MeV deuterons
d-to-n converter (Be)
n moderator (wax)
UO_2 (10 kg)
Baking powder

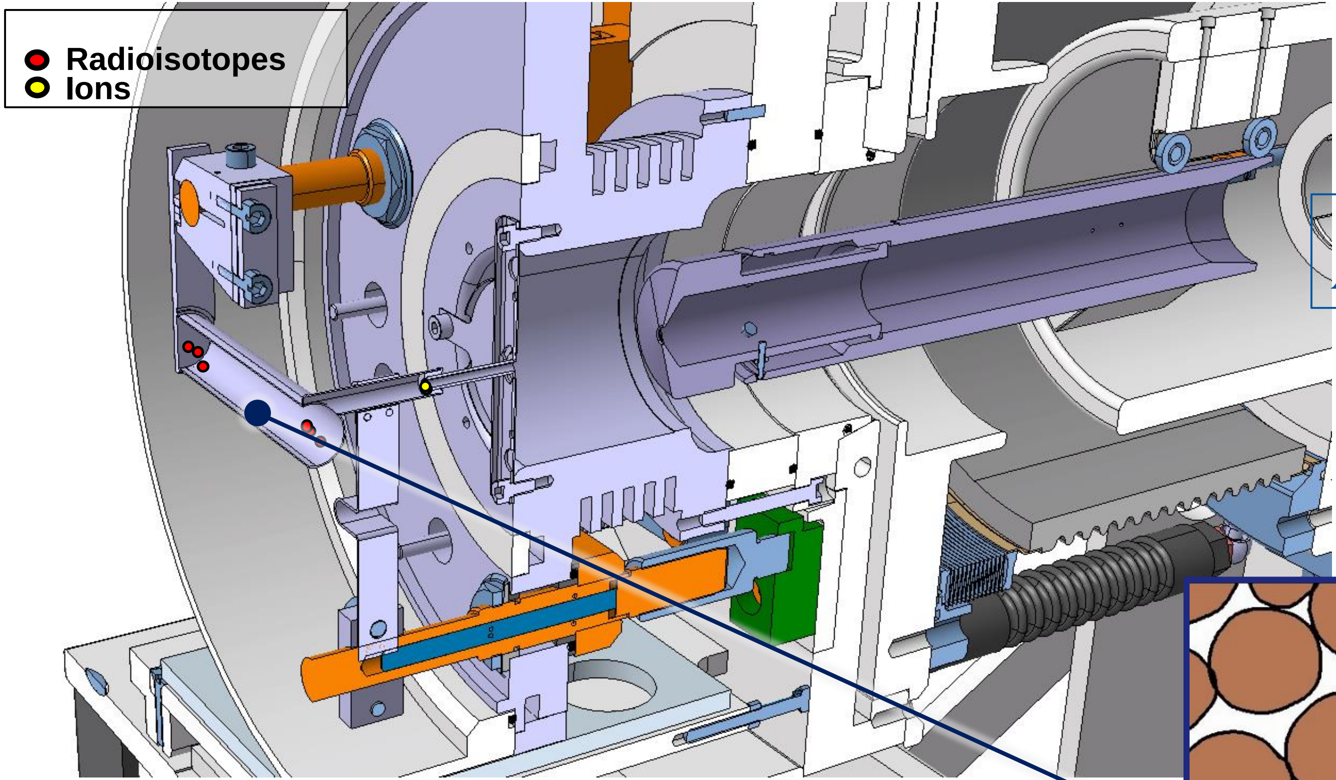
CERN 76-13, 3rd conf. nuclei far from stability

Principles of radioactive beam production

Primary beam
(MeV/u-GeV/u)
Or
neutrons

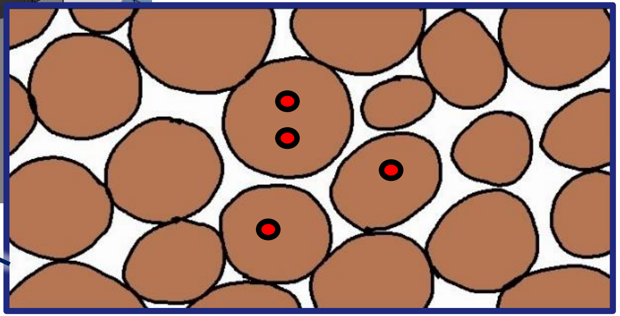


H. Ravn and W. Brian
"On-line mass separators." Treatise on heavy ion science. Springer US, 1989. 363-439.



*Standard ISOLDE target unit with **surface** ion source*

$$I_{RIB}(pps) = \sigma_i(E^*) \cdot N_{target} \cdot I^* \cdot \varepsilon$$
$$A=(1-e^{-\lambda t})\, I_{RIB}$$



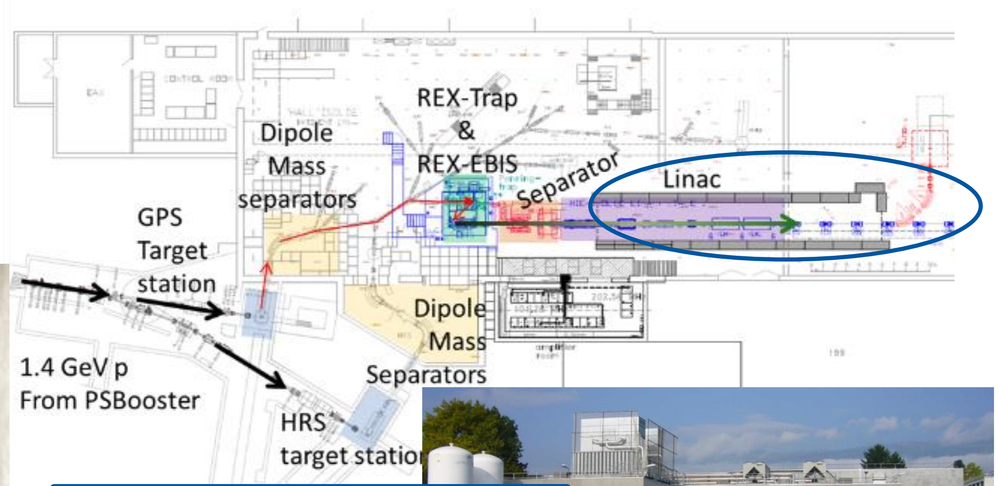
Principle of isotope release and ionization

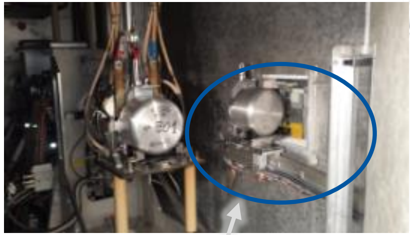
Isolde and MEDICIS

R. dos Santos Augusto, et al. "CERN-MEDICIS (medical isotopes collected from ISOLDE): a new facility." Applied Sciences 4.2 (2014): 265-281.

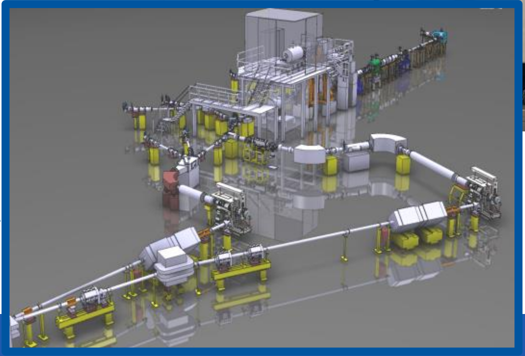
M. Borge, "Recent Highlights of the ISOLDE Facility." Journal of Physics: Conference Series. Vol. 580. No. 1. IOP Publishing, 2015.

Isotope mass separation at CERN





2nd target +
Radiation hard conveyor



CERN-MEDICIS:
Class A lab &
Offline mass separation for medi
isotopes
(1st tests in 2016
Plan start up end 2017)

HIE-ISOLDE:
Superconducting
post-accelerator
(1st beam in 2015)

ISOLDE Beam and production units

RIB intensity [s^{-1} μA^{-1}]

Proton beam Intensity [s^{-1} μ A^{-1}]

Avogadro Numb.

Diffusion+ Effusion Efficiency

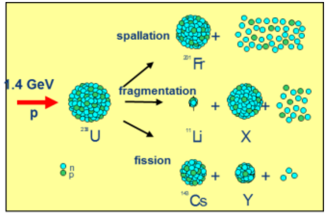
$$I = \int \sigma(E)\, \Phi(E, x)\, \rho(x)\, N/A\, dx\, \varepsilon_{diff+eff}\, \varepsilon_{ion}$$

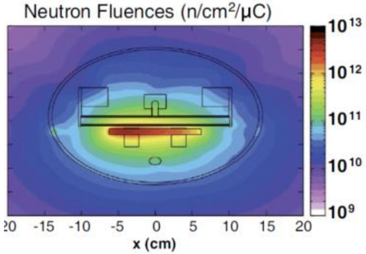
Cross section [cm^2]

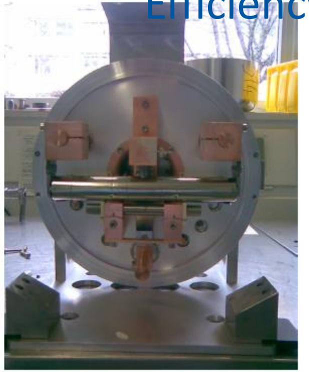
Target density [g cm^{-3}]

Target Atomic Mass [g]

Ionization Efficiency







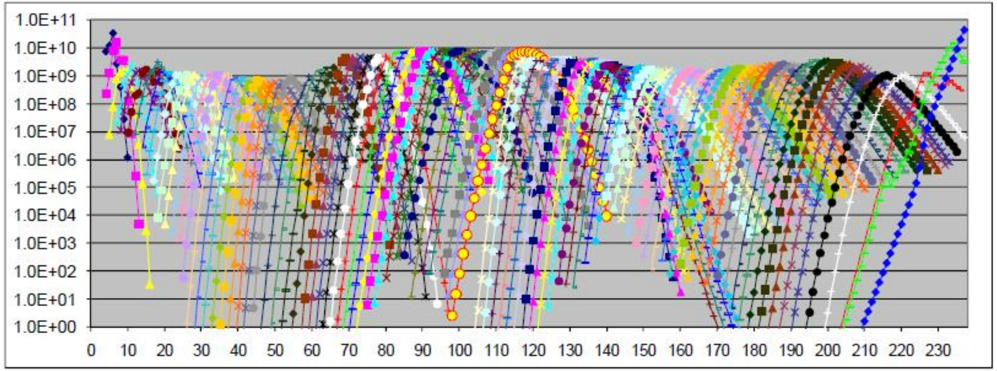
T. Stora "Recent developments of target and ion sources to produce ISOL beams." NIMB317 (2013): 402-410.

R. Luis, et al. "Optimization studies of the CERN-ISOLDE neutron converter and fission target system." The European Physical Journal A 48.6 (2012): 1-11.

The « ISOL » filter

Isotope mass separation online

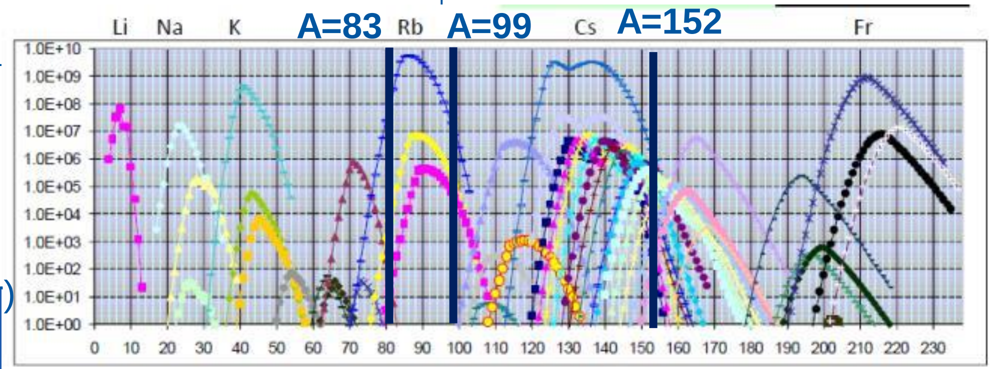
In-target production rate



1000+ isotopes
(for 73+ elements)
“online”

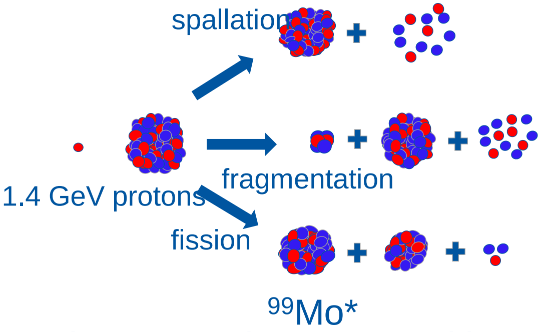
$I_{[pps]} \sim \Phi_{[pps]}\ \sigma_{[barn]}\ N_{[g/cm2]}\ \varepsilon_{[\%]}$

Intensity
Purity

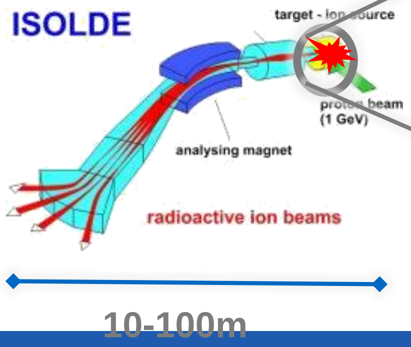


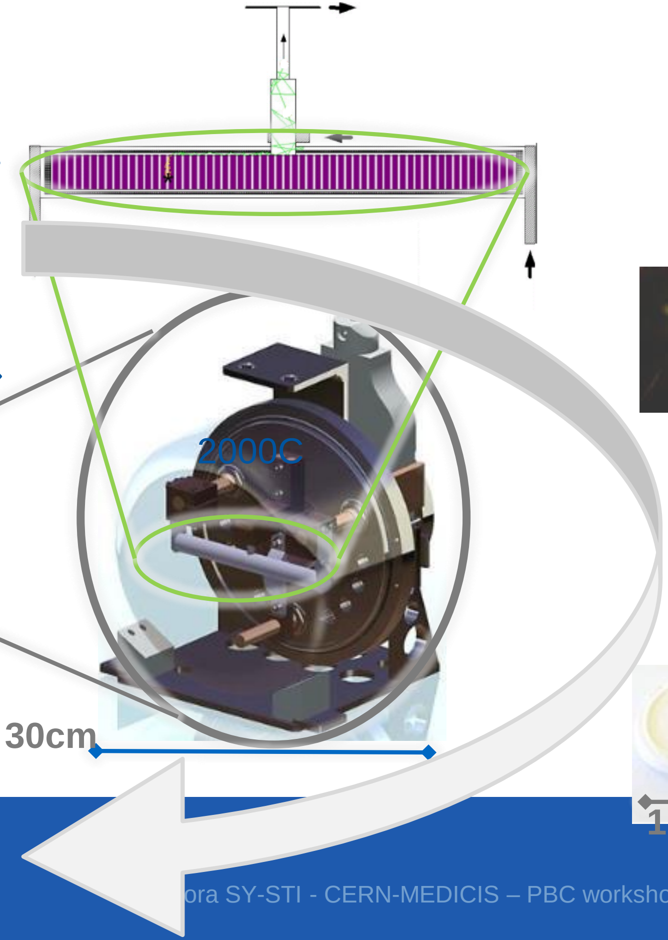
Beam production rate
(Mass separation filter)

From production to beam formation



*we don't mean it's « competitive » in this context



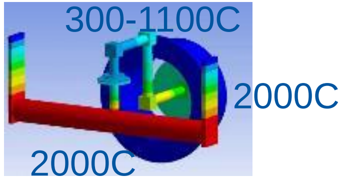


From production to beam formation

Target (Nb/ZrO_2 by reactive brazing); Operation at 1400C

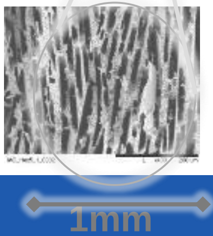
EURISOL-DS Final Report, J. Cornell Ed, GANIL (2009)

E. Bouquerel, et al. "Beam purification by selective trapping in the transfer line of an ISOL target unit." NIMB 266.19 (2008): 4298-4302.

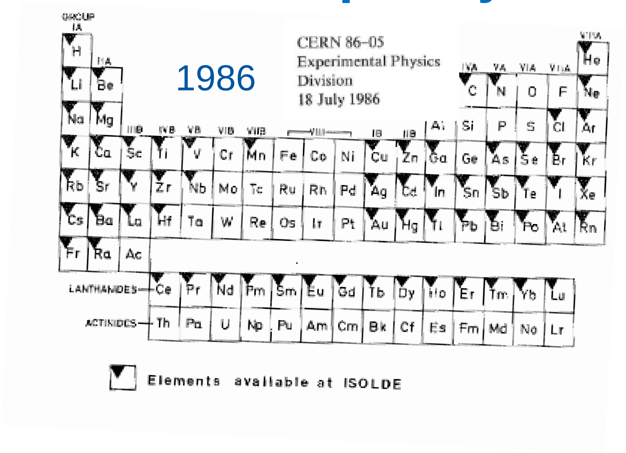


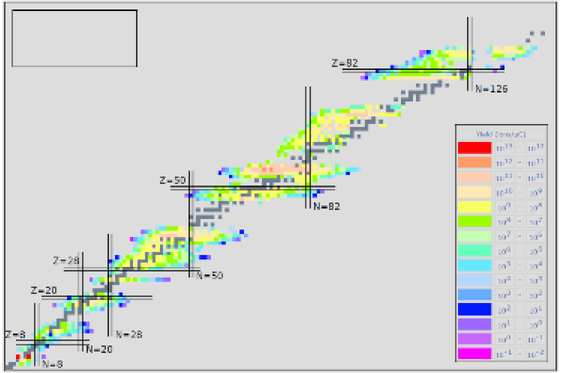
Al_2O_3 with uniaxial porosity

M. Czapski, et al. "Porous silicon carbide and aluminum oxide with unidirectional open porosity as model target materials for radioisotope beam production." NIMB317 (2013): 385-388.



New isotopes by mass separation (ISOL)





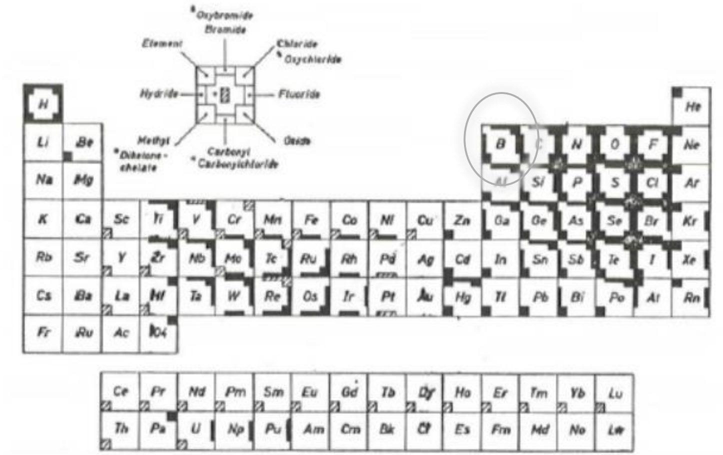
2012 And more recently

We don’t evaporate/release refractory elements in atomic form

T. Sato, et al. "Measurement of the first ionization potential of lawrencium, element 103." Nature 520.7546 (2015): 209-211.

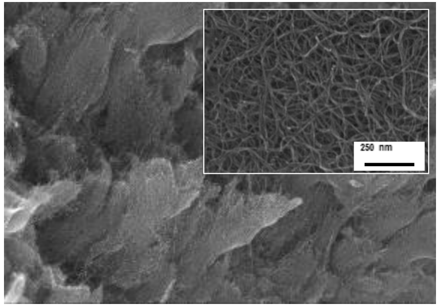
Case studies :1st Boron $^{8}BF_2^+$ from carbon nanotubes

$^{8}BF_2^+$ (T1/2 880ms) produced
from multiwall carbon nanotube target (fast diffusion)
and SF_6 reactive gaz injection (volatile BF3 molecule)



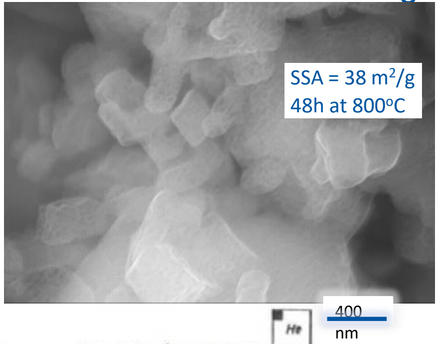
C. Seiffert, Production of radioactive molecular beams for CERN-ISOLDE.
PhD thesis TU Darmstadt, CERN (2015)
Manuscript in preparation

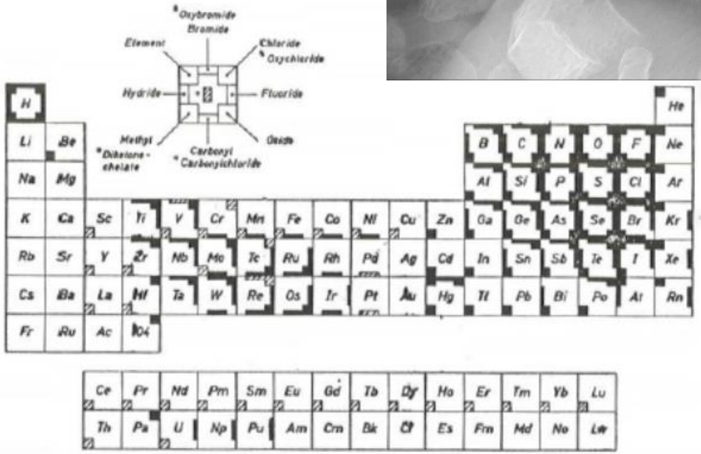
MWCNT

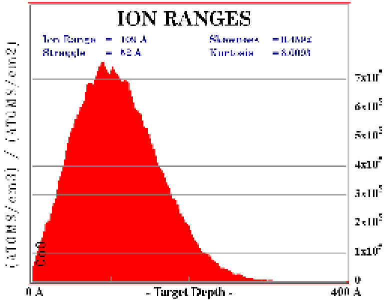


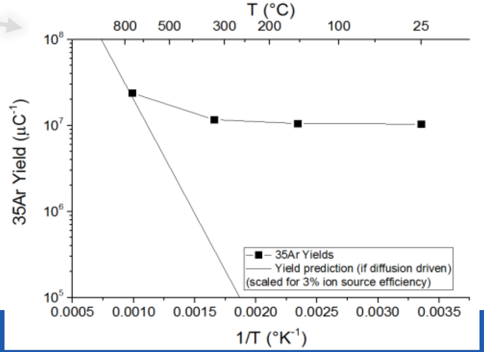
Case studies : $^{35}Ar^{+}$ from cold nanostructured targets

Fast release of ^{35}Ar from cold nanostructured CaO targets:
Recoil into nanomaterial



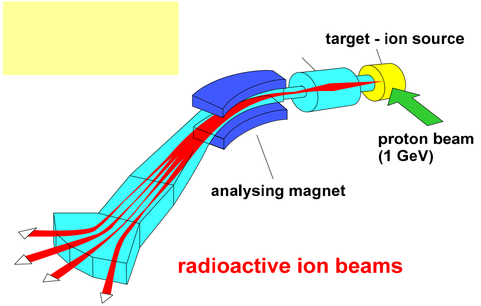






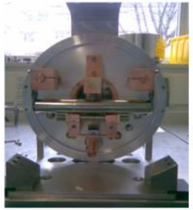
J. P. Ramos et al.

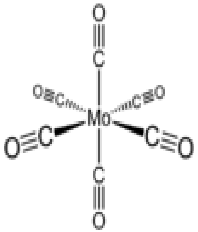
R&D towards Mo-99/Tc-99m mass separation at CERN-MEDICIS



- ^{238}U is fissioned by fast neutrons to produce Mo
- Requires the use of µm thick ^{238}U metallic foil target for fission recoil
- However Mo is a refractory element, it cannot be released in atomic form.
- Our plan: react it with CO gas. Forms a complex which is volatile.

- Method similar to that found in a neutron spallation facility (SNS, ESS, JSNS, ISIS, etc)





Formation of $Mo(CO)_6$ complex already achieved

J. Even, et al Radiochim Acta 2014

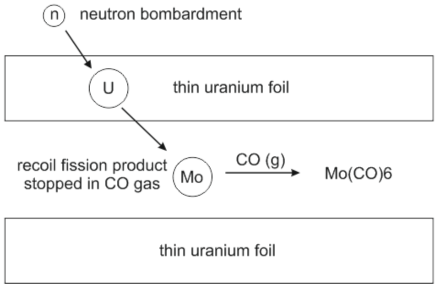
Transition metal carbonyl beams

Isotope production, carbonyl formation and extraction

Target concept

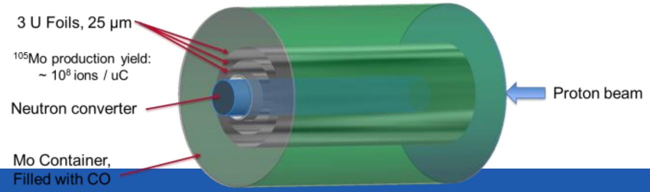
Diffusion and Effusion for refractory elements to slow.

➡ use fission recoil effect

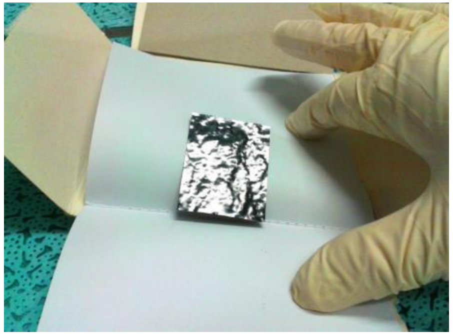


Protons induce plasma and destroy compounds

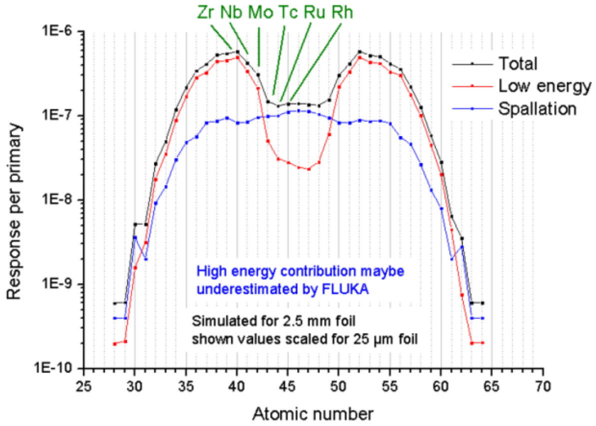
➡ use neutrons



Uranium foil



Production cross sections for ^{238}U (n,f)



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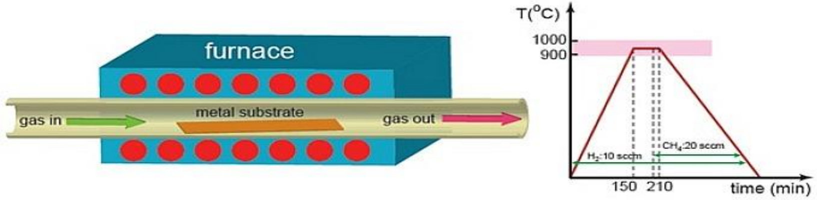
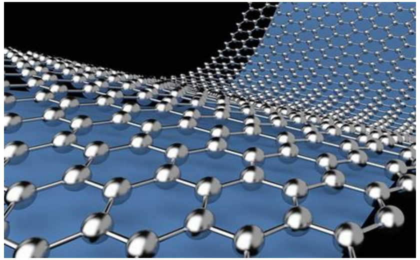
Growth of Graphene layers on Tantalum foils

Need to adjust the growth parameters





- Temperature – 800-1150°C
- Pressure – HV – ambient
- Carbon precursors ratio
- Time of growth
- etc.

Medicis Promed

MANCHESTER 1824

European Commission | Horizon 2020 European Union funding for Research & Innovation

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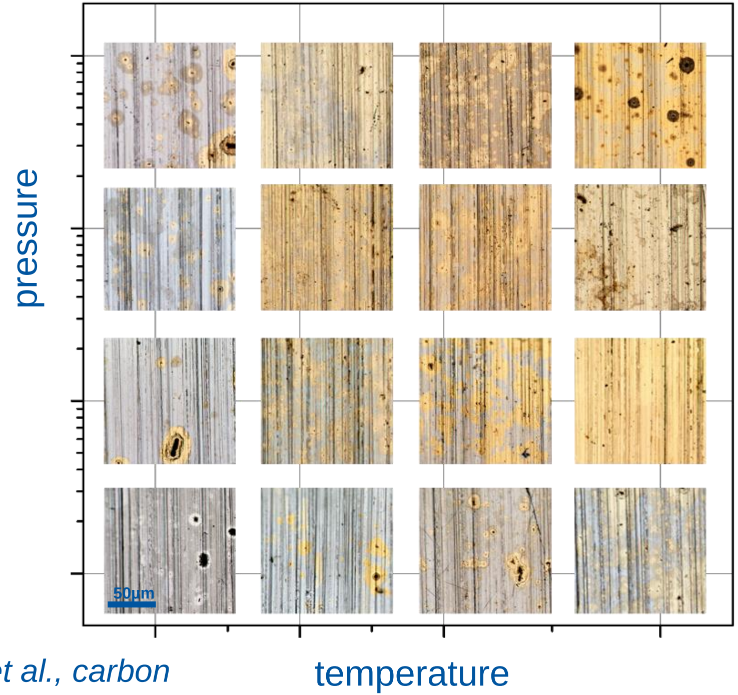
Graphene layers on Tantalum foils : preliminary results

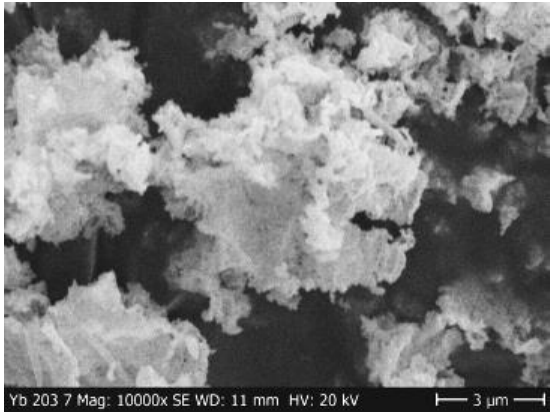


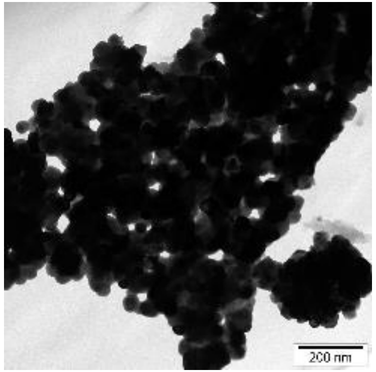
M. Nazarova et al., carbon

Comparison of pristine Tantalum
Vs graphene coated :
exposition to air for 3 hours
at increasing temperatures

R&D towards Mo-99/Tc-99m mass separation at CERN-MEDICIS

- Alternative target materials : towards submicron uranium-based materials
- Work has started as with lanthanide precursors via electrospinning





M. S. Henriques, et al. "Preparation of Yb2O3 submicron-and nano-materials via electrospinning." Ceramics International 41(9), 10795 (2015).

Thank you

question ?

Medicis.cern

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