Light Radioactive Beam Production via Two Stage Irradiation Setup

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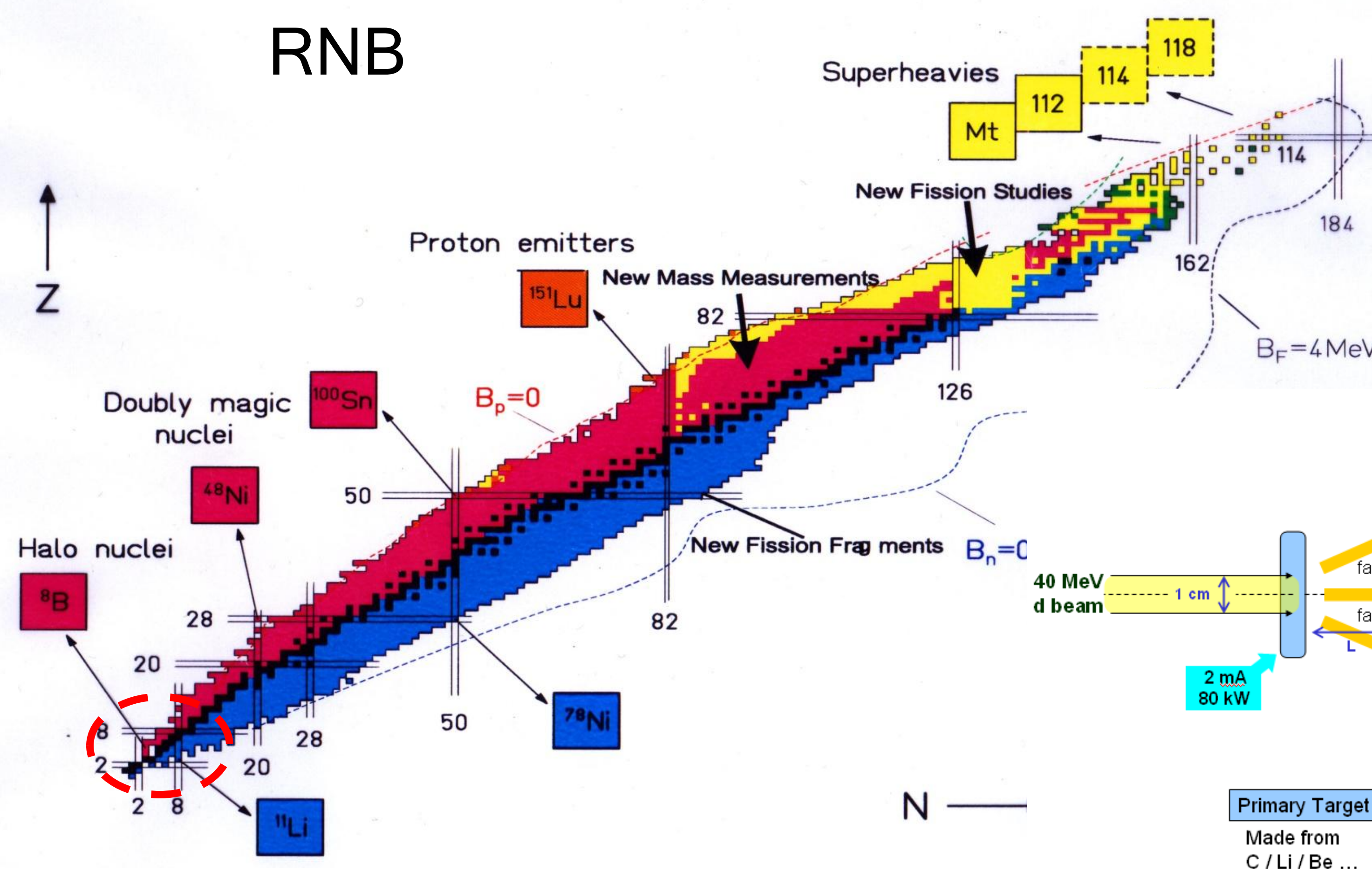
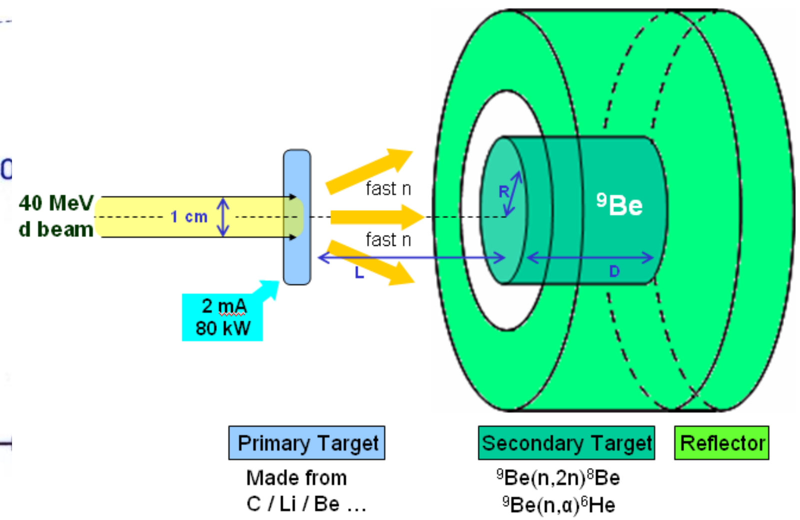
Objectives

RNB





High Yield Production of ^6He and ^8Li

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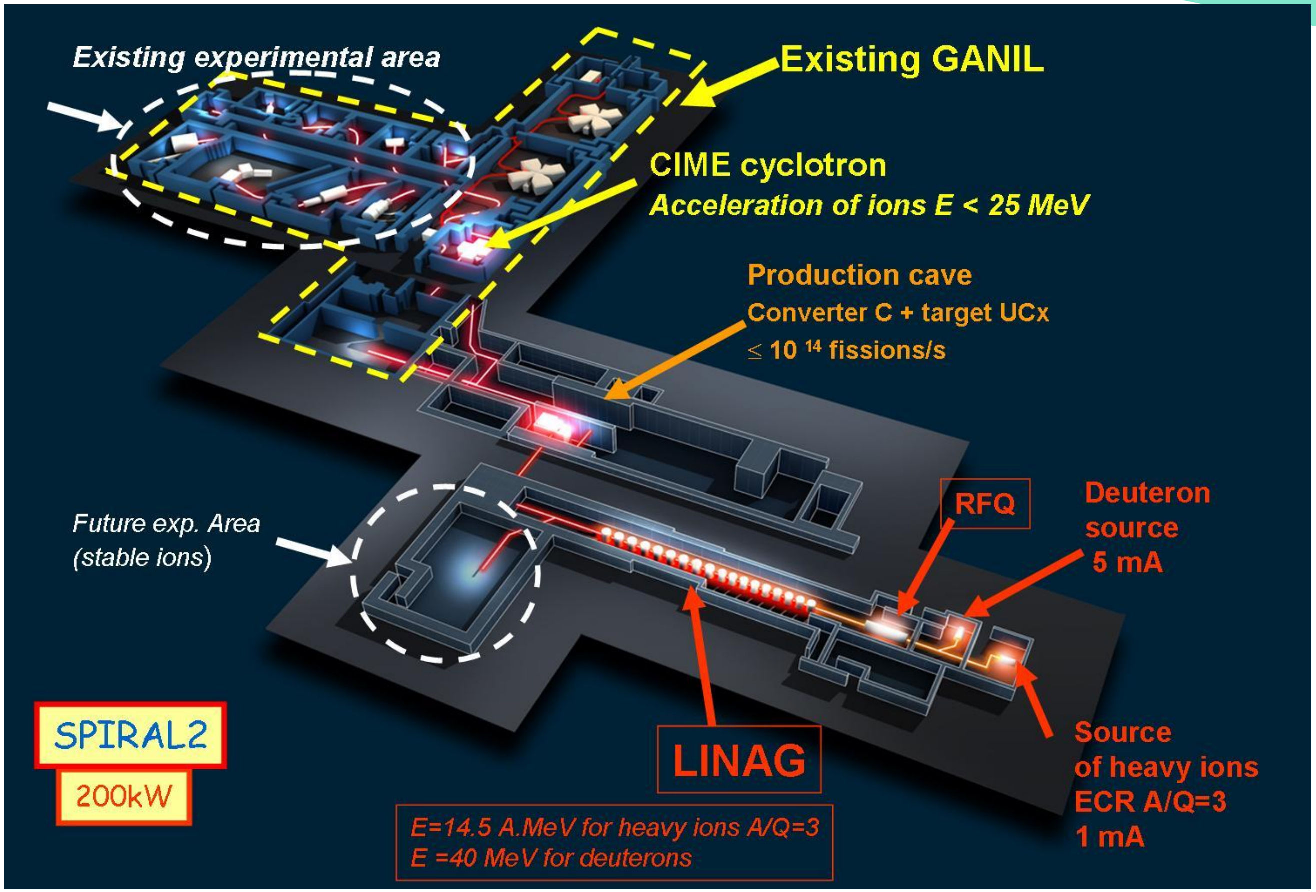
SPIRAL 2 - PP GANIL



Secondary n's + fission
BUT
Also light RIB's

$^{11}B(n,\alpha)^{8}Li$

$^{8}Li \rightarrow \beta^-$

$t_{0.5}$= 838 ms

$^{9}Be(n,\alpha)^{6}He$

$^{6}He \rightarrow \beta^-$

$t_{0.5}$= 807 ms

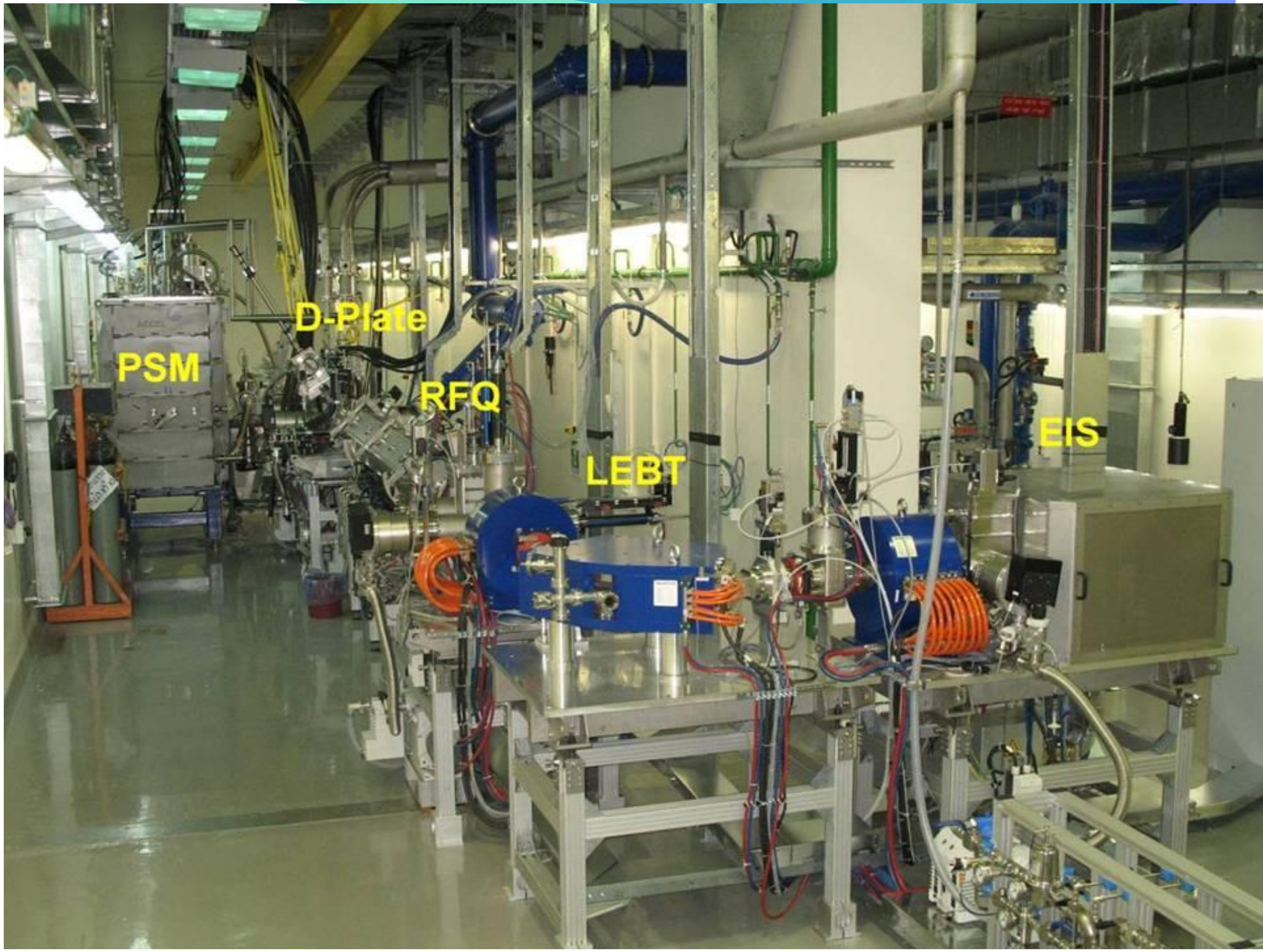
SARAF - Soreq

deuterons / protons
linear accelerator

5 MeV at Phase 1
with only 1 PSM (2008)

40 MeV at Phase 2
with 6 SMs (2013)

2 mA current



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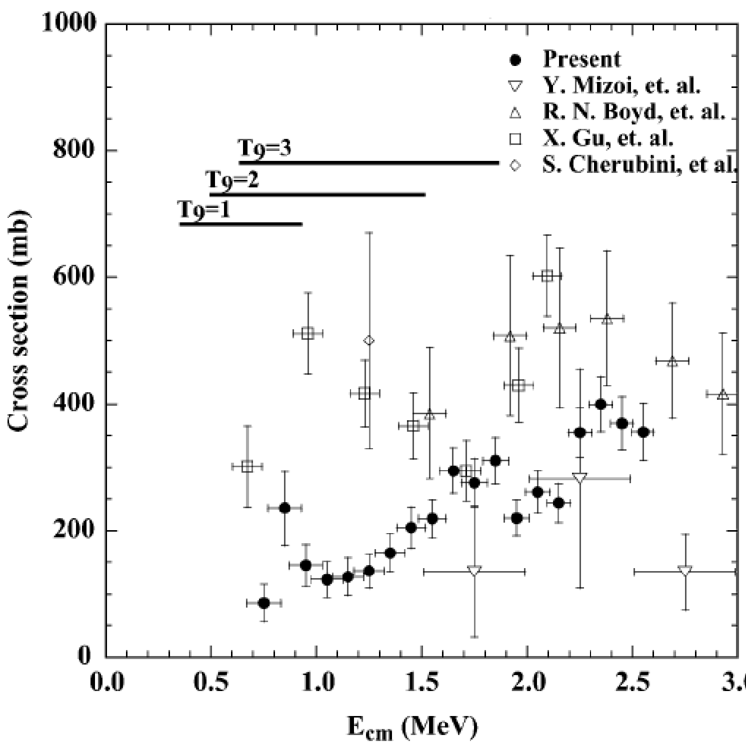
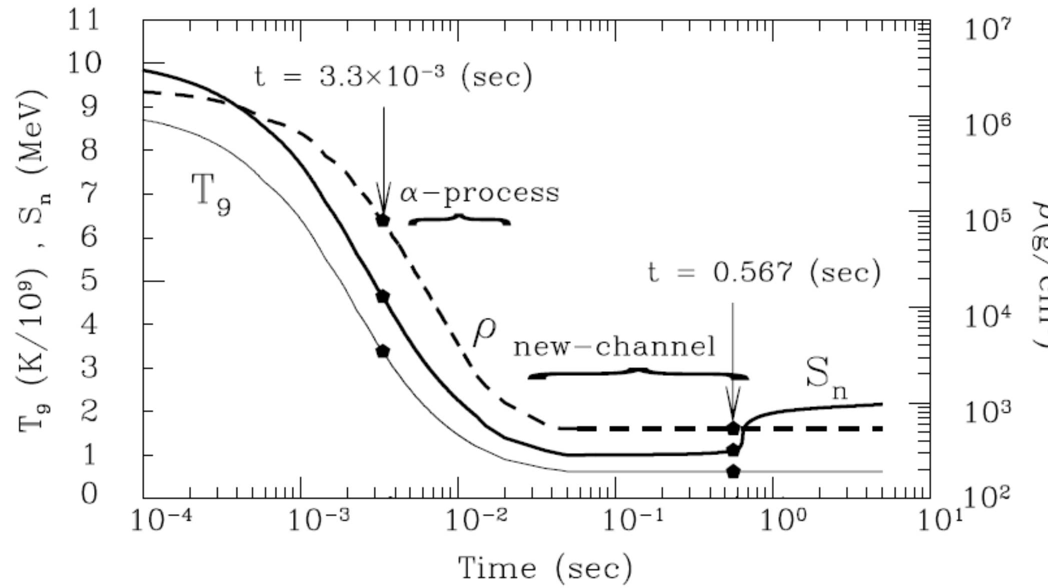
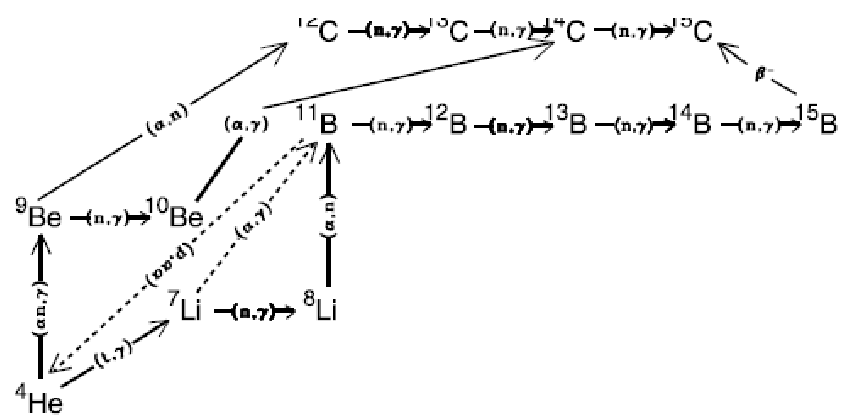
Astrophysics and Nuclear Physics with Light RIB

$^{4}He(^{8}Li,n)^{11}B$ reaction

Ishiyama et al., Physics Letters B 640 (2006) 82-85







Terasawa et al. , Astrophysical J., **562**:470-479, 2001 November 20

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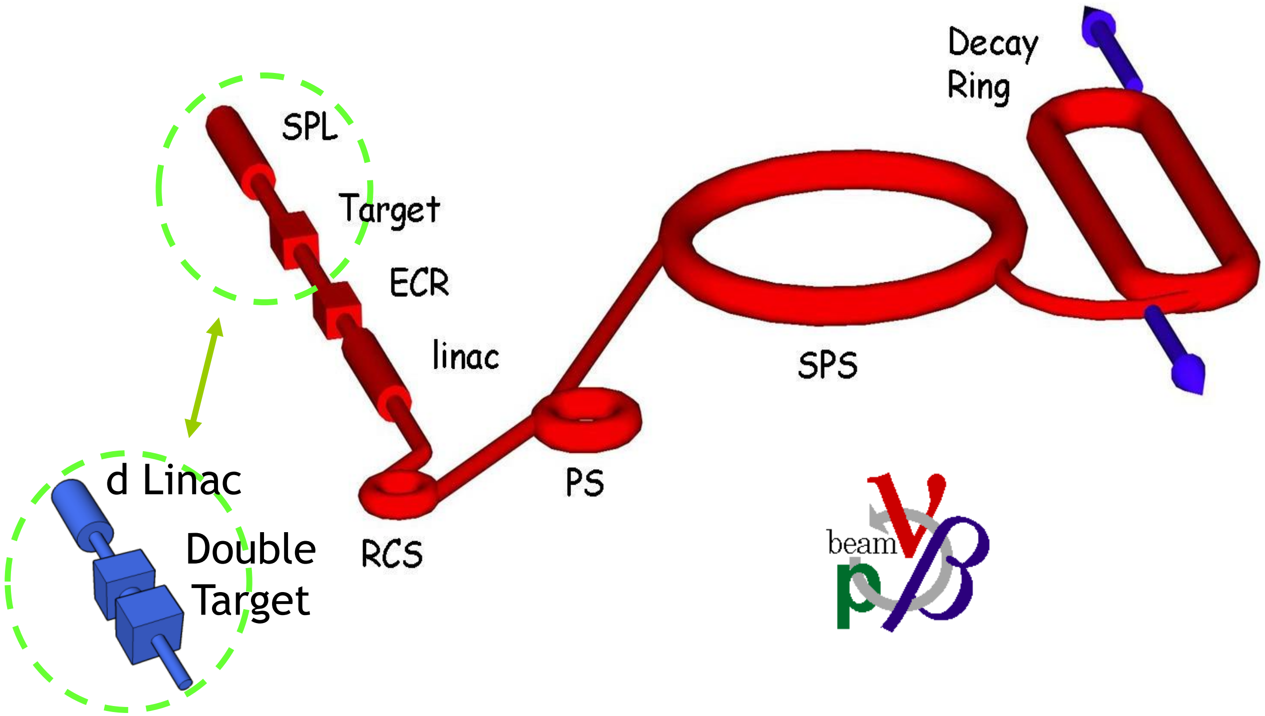
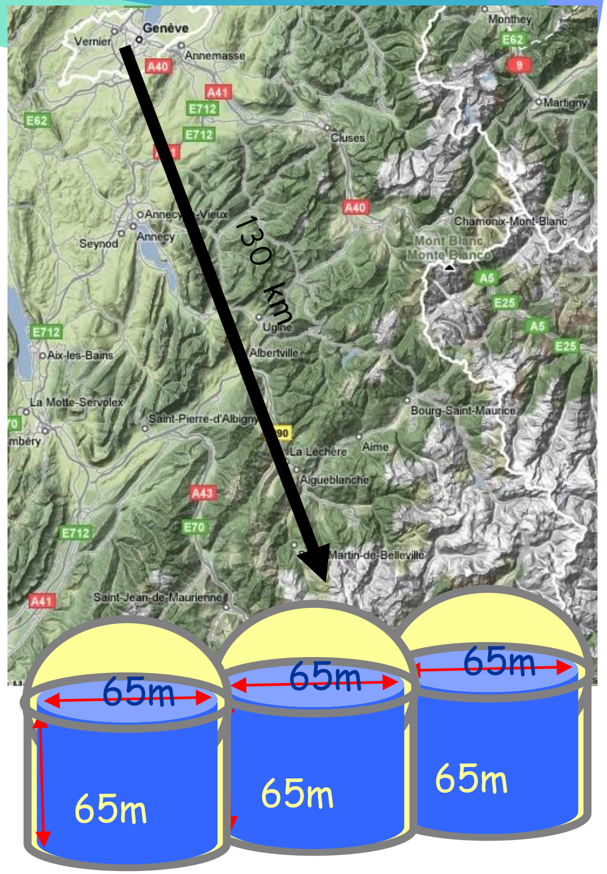
Beta Beam

^{6}He, ^{8}Li [$\bar{\nu}$)
^{18}Ne [ν]





P.Delahaye, "The beta-beam project in the EURISOL context",*Quantum Seminar, Mainz* (2006)
http://beta-beam.web.cern.ch/beta-beam/

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Neutron Spectrum from a 40 MeV Deuteron Beam on a Thick Lithium Target

$E_d = 40\ MeV$

$n = 8 \cdot 10^{14}\ n/sec \quad for\ 2\ mA$

$n/d = 0.064$

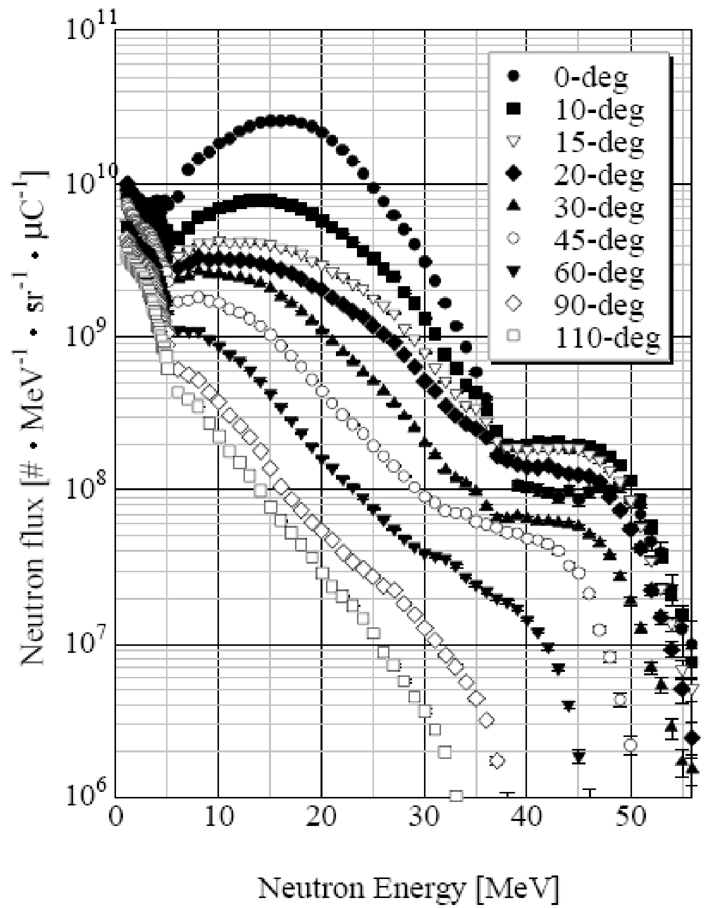
$Q\ value\ for\ ^7Li(d,n)^7Be \rightarrow 15.03\ MeV$

IFMIF 国際核融合材料照射施設 — 40 MeV , 250 mA Lithium Converter

Spiral2 — 40 MeV , 5 mA Carbon Converter

SARAF — 40 MeV , 2 mA Lithium Converter

Other possible converters:
Beryllium, Water, Heavy water



M.Hagiwara et al. *Fus. Sci. Tech.*, **48** (2005).

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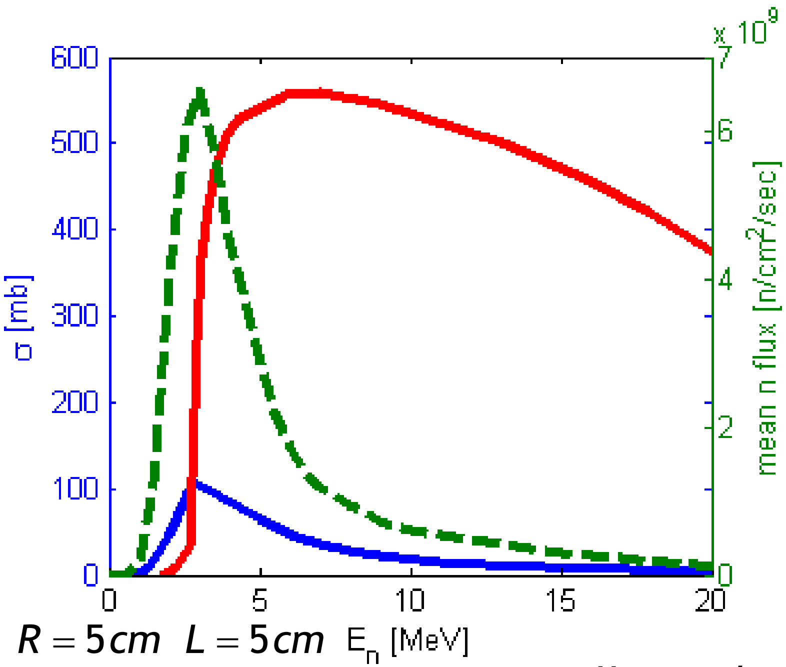
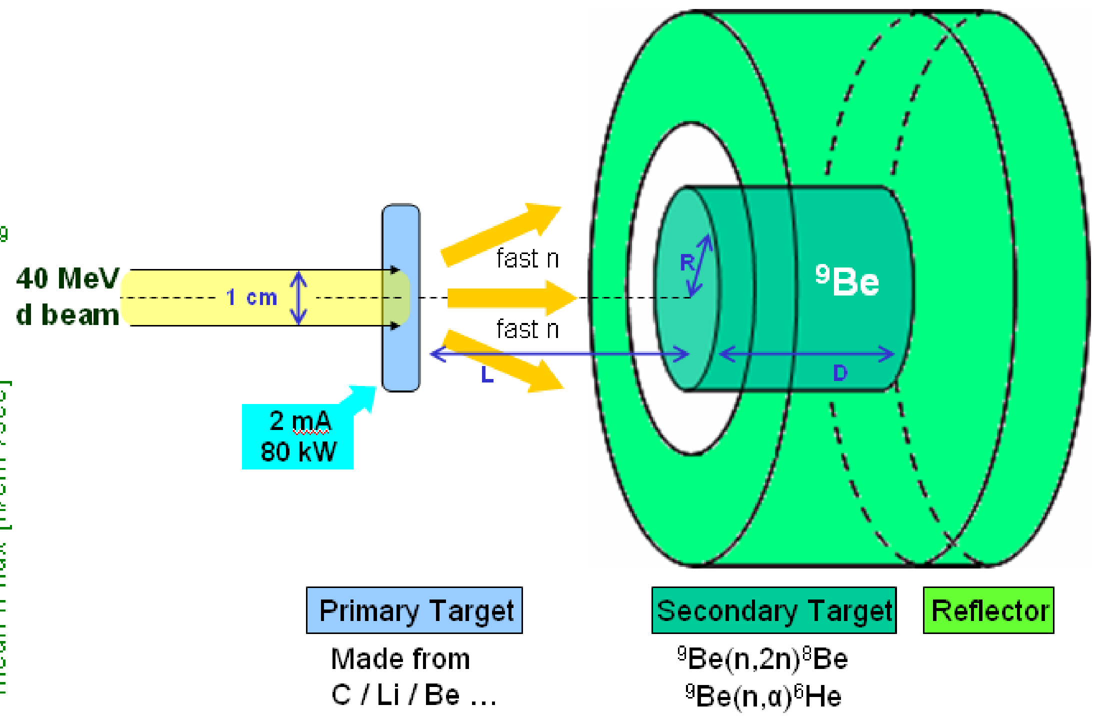
Optimization Calculations

MCNP™

Monte Carlo N-Particle transport code



$R = 5cm \quad L = 5cm$



Hass et al., J. Phys. G: Nucl. Part. Phys., 35, 014042 (2008).

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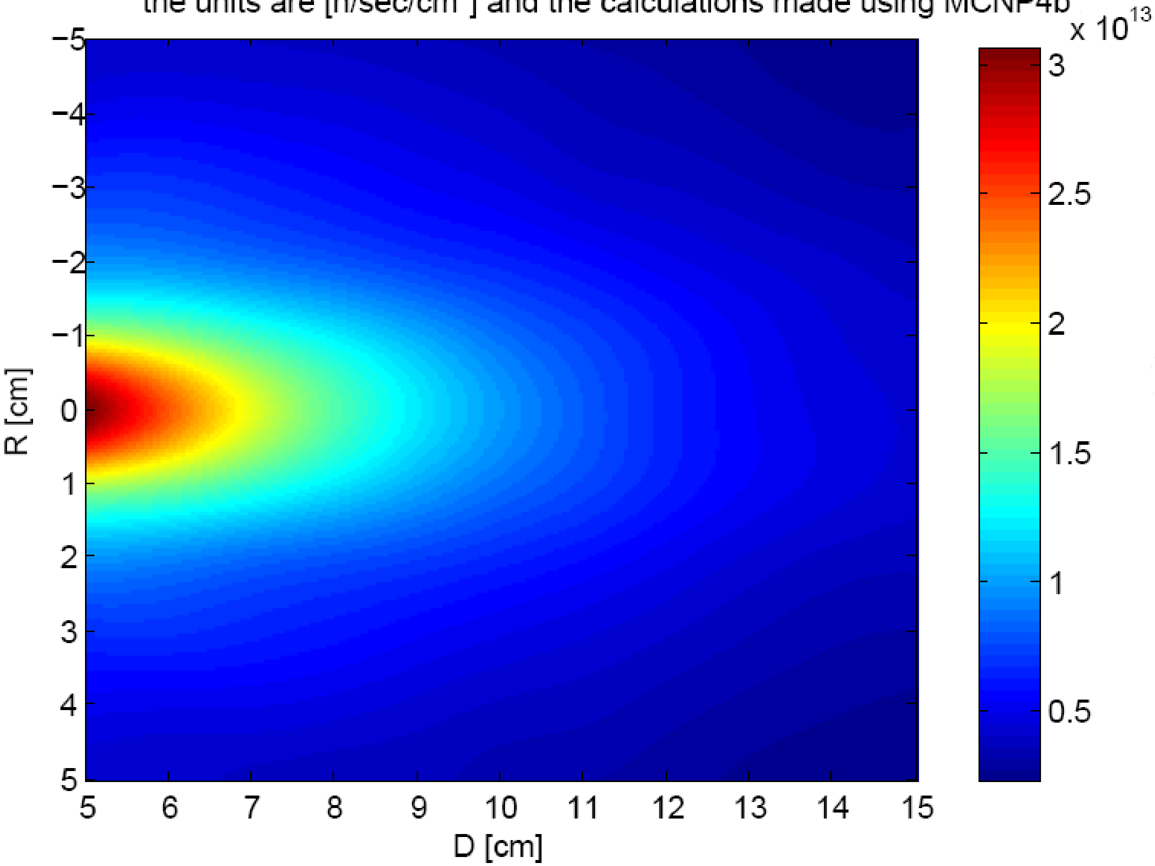
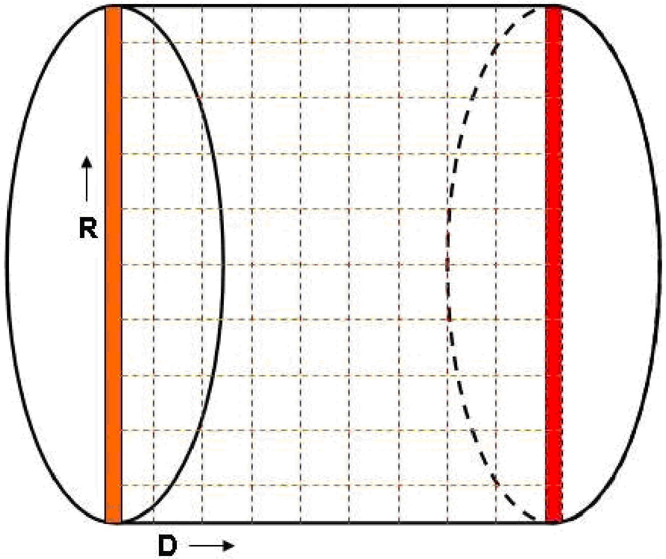
Simulations: 2D Slice Inside The Secondary Target

Mean neutrons flux on ^{9}Be target by bombard of 40 MeV and 2 mA deuterons beam on thick Lithium target. this is a 2D slice in the middle of the target. the units are [n/sec/cm^2] and the calculations made using MCNP4b





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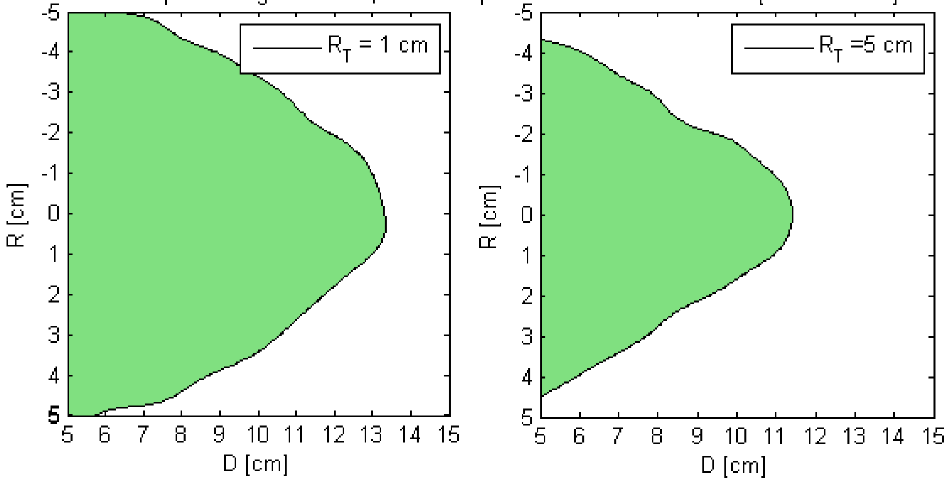
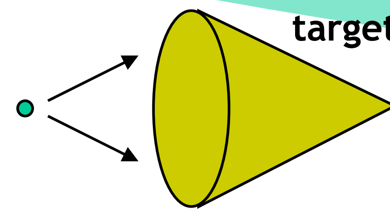
Simulations:

^{6}He Production Inside a 2D Slice of the target

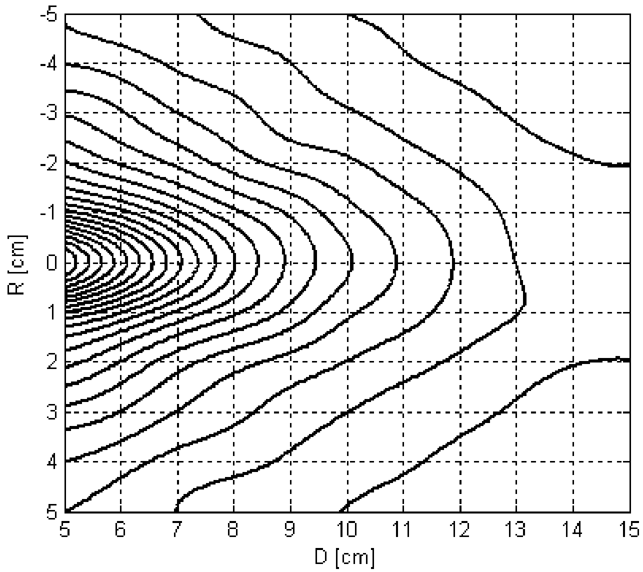
^{6}He yield density distribution [^{6}He/sec/cm^3] inside a 2D slice of the target for two positioning distances, the line represents a value of 1.3*10^{10} [^{6}He/sec/cm^3]

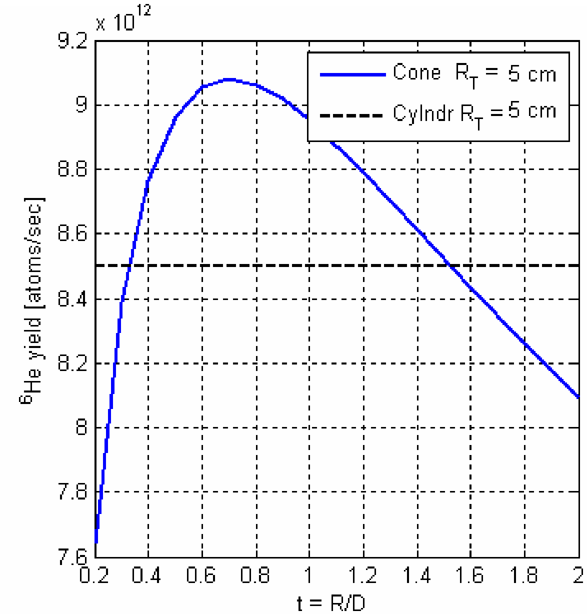


Cone shaped target



^{6}He production yield distribution inside 2D slice for R_T = 1 cm





^{6}He production yields for a constant target volume and for different R to D ratios
These results are for a 785.4 cm^3 cone target and for R_T = 5 cm

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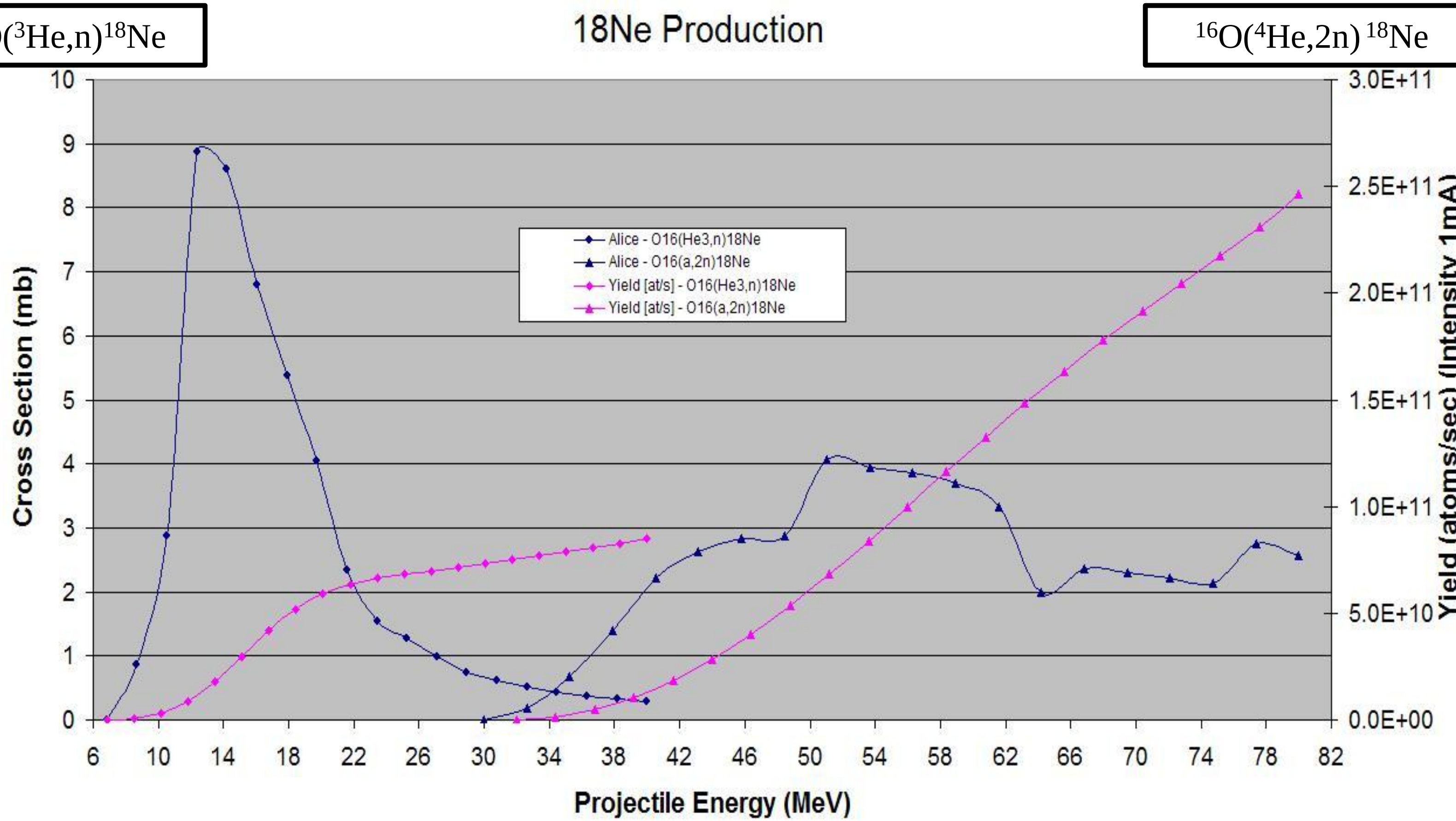
What about ^{18}Ne?..

$^{16}O(^{3}He,n)^{18}Ne$

$^{16}O(^{4}He,2n)^{18}Ne$



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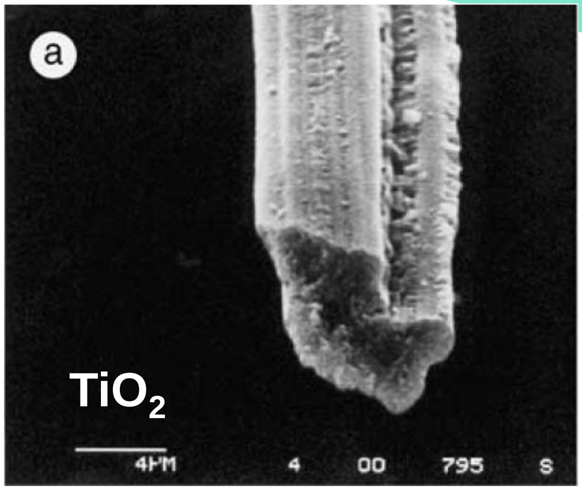
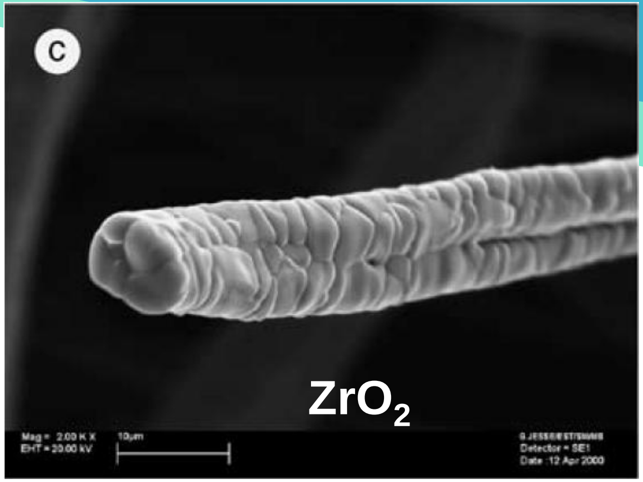
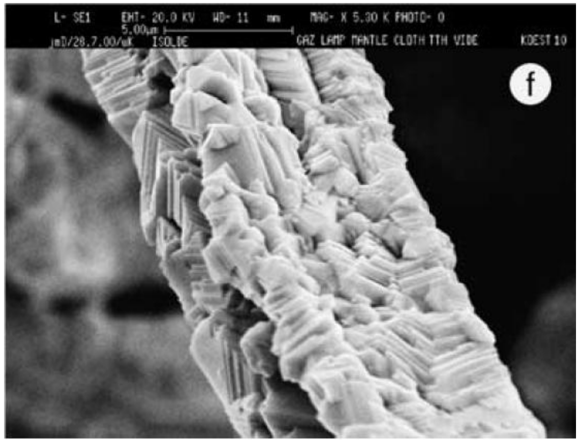
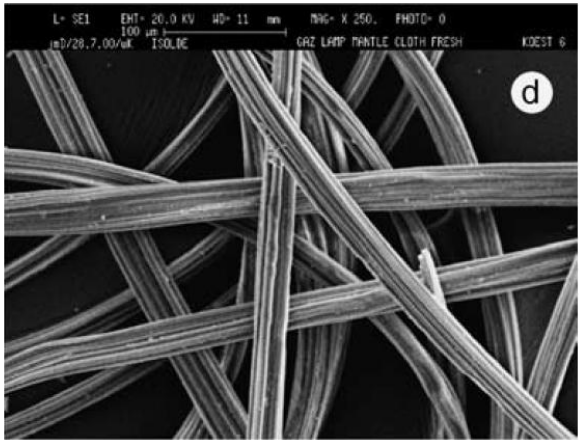
Oxide Fibers









BRUSH
CERAMIC PRODUCTS

- BeO 2 mm disks
- 23 mm diameter
- Purity of 99.9% BeO
- ~500 ppm impurities
- 50%-75% density
- Grain size 20 micron

BeO, the most refractory Be compound (melting point 2520 °C), in form of fibers should provide an ideal target. For all oxide fiber targets discussed in this article >80% of the produced [6]He is released before its decay. BeO, which can be heated to even higher temperatures, should thus guarantee an efficient release also from large volume targets.

For short-lived isotopes of Cu, Ga and Xe the zirconia and ceria targets respectively provided significantly higher yields than any other target (metal foils, oxide powders, etc.) tested before.

U. Koster, "Oxide Fiber Targets at ISOLDE" ,Nuc. Ins. Meth. Phys. Res. B 204 (2003)

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Expected yields

^{6}He

- **Expected Yields for a BeO target (useful for RNB extraction):**
- **SARAF** (40 MeV, 2 mA): **$8 \cdot 10^{12}$** [^{6}He/sec]
- **SPIRAL2** (40 MeV, 5 mA): **$2 \cdot 10^{13}$** [^{6}He/sec]

^{8}Li

SPIRAL2 (40 MeV, 5 mA): **$2 \cdot 10^{12}$** [^{8}Li/sec]

Expected yield at SPIRAL2 for "just" neutrino production - $2 \cdot 10^{14}$ [^{6}He/sec]
NO technological difficulties (like efficiencies of ionization, extraction…

Present and Future test Experiments

$^{27}Al(n,\alpha)^{24}Na$ — γ	↔	$^{27}Al(n,\alpha)^{24}Na$
NG — Production		Monte Carlo Simulations

↓

$^{11}BN(n,\alpha)^{8}Li$ — β	↔	$^{11}BN(n,\alpha)^{8}Li$
NG / Phase 1 — Production extraction		Monte Carlo Simulations

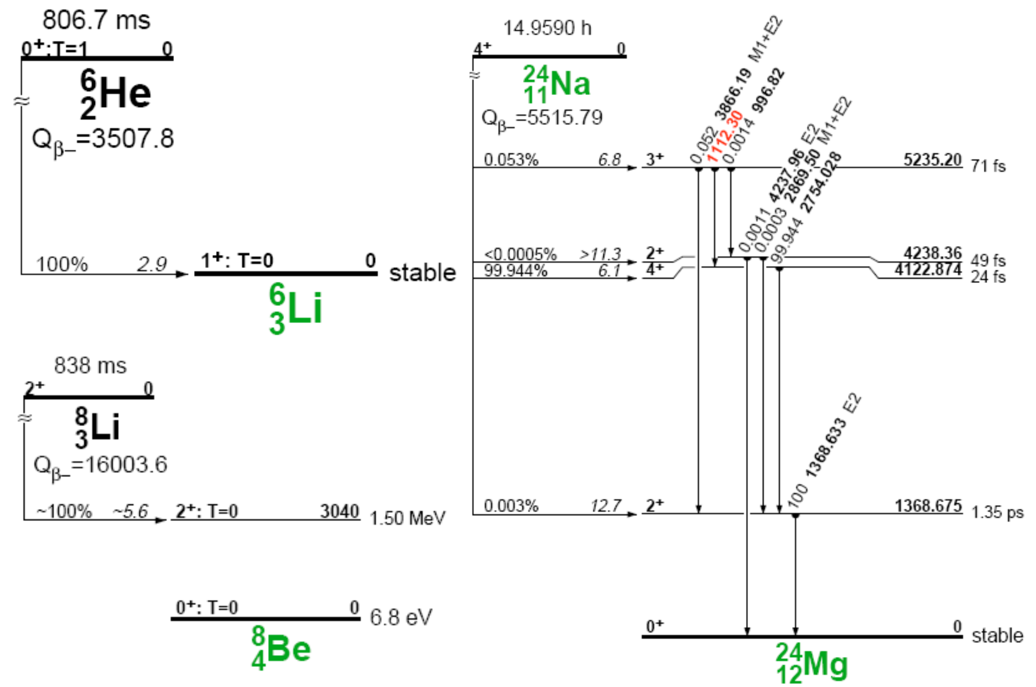
↓

$^{9}BeO(n,\alpha)^{6}He$ — β	↔	$^{9}BeO(n,\alpha)^{6}He$
Phase 1 / Ganil / ISOLDE — Production extraction		Monte Carlo Simulations

↓

beam

^{6}He production and extraction numbers



15.2.2008 Aluminum cubes irradiation experiment number 1.
Preliminary experiment for verification of target geometry in compare to Monte Carlo simulations.

28.4.2008 Aluminum cubes irradiation experiment number 2.
Preliminary experiment for verification of target + reflector geometries in compare to Monte Carlo simulations and previous experiment.

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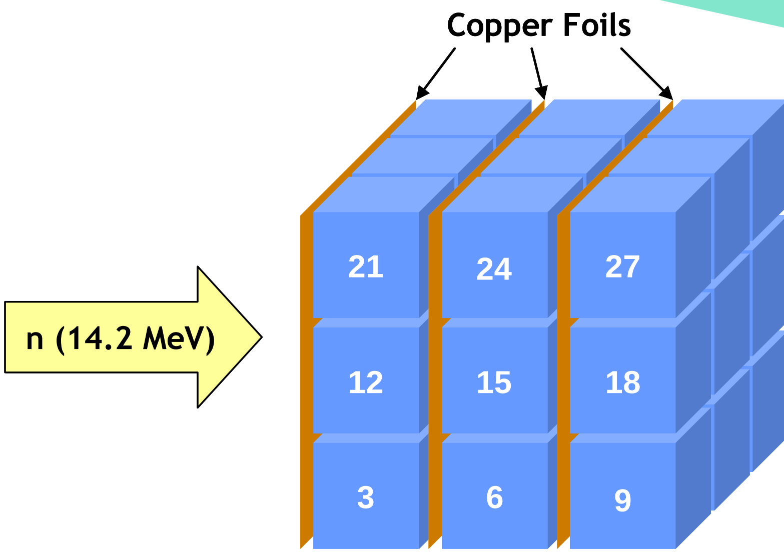
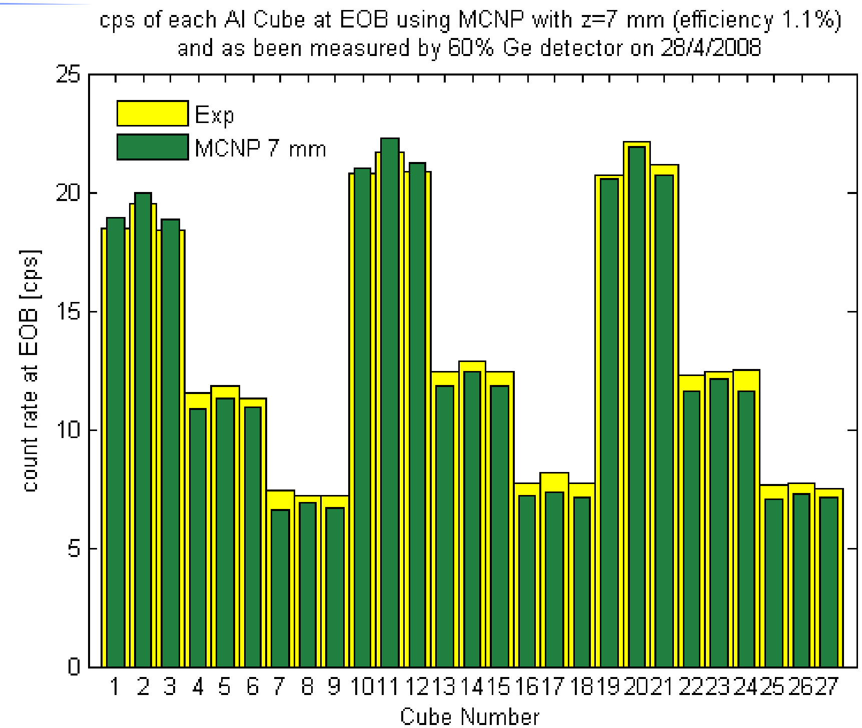
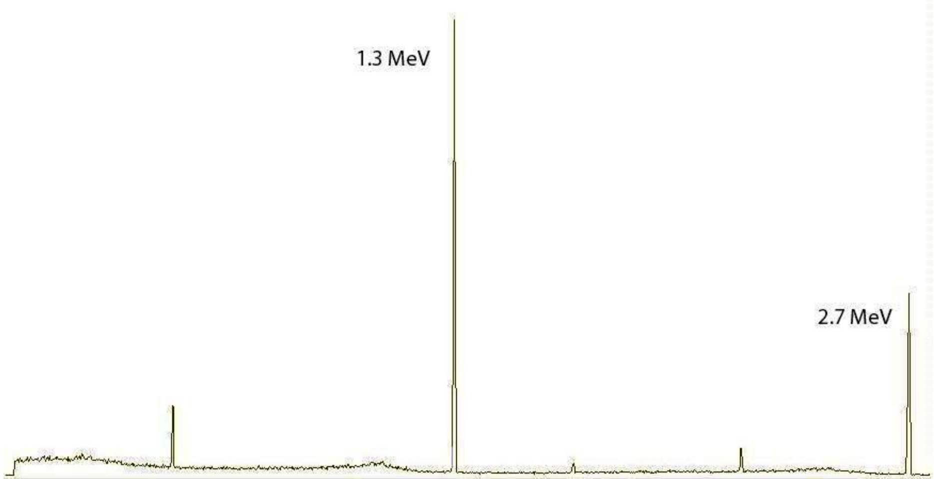
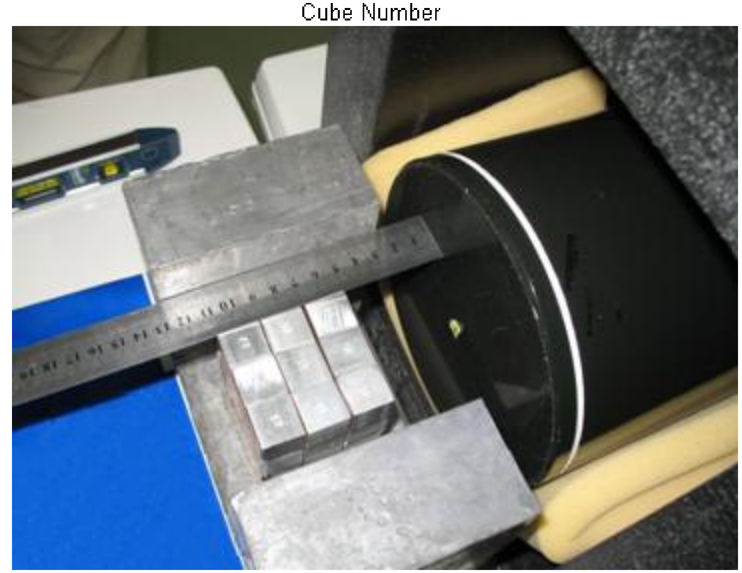
Aluminum Cubes Experiment









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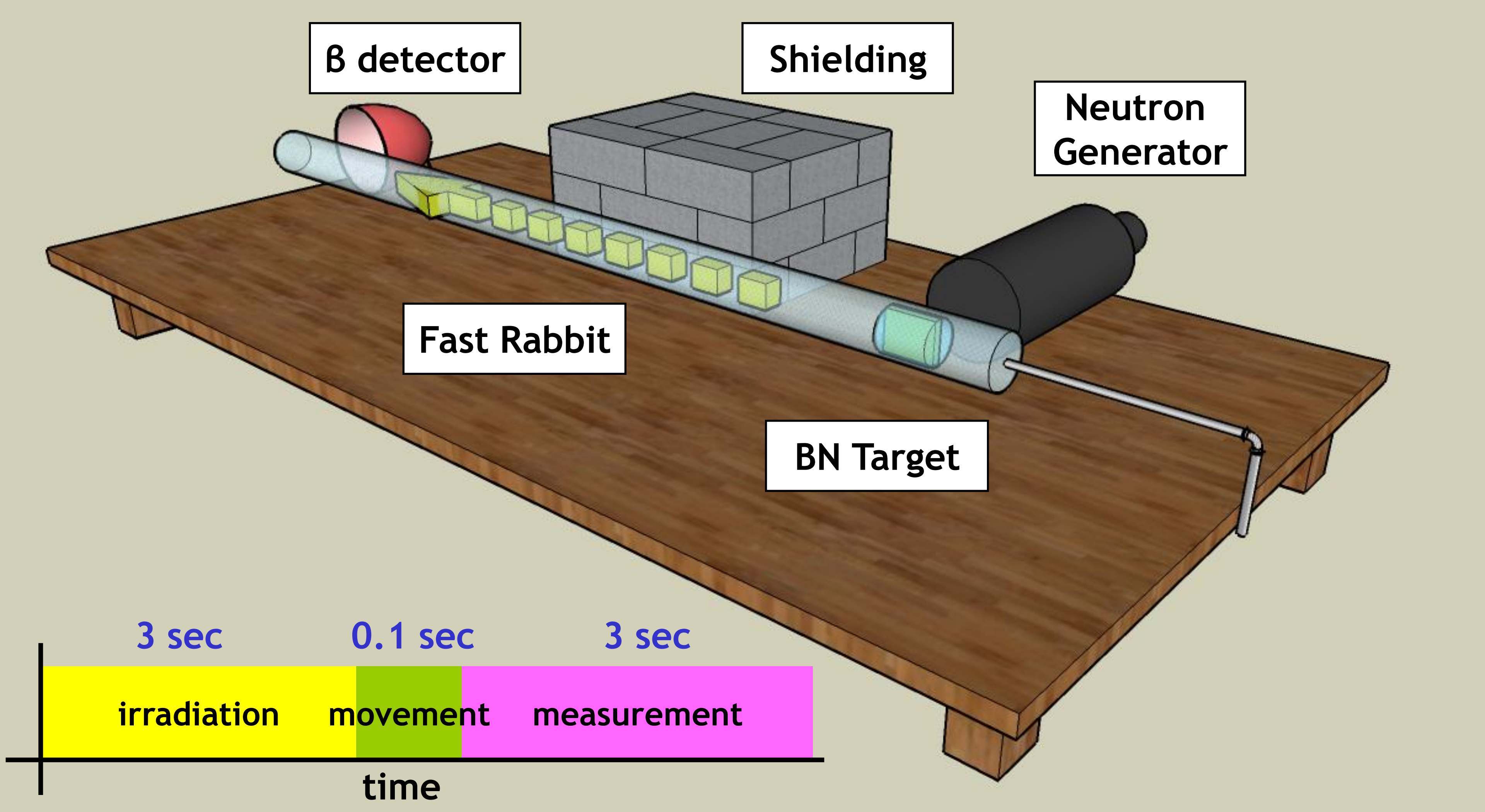
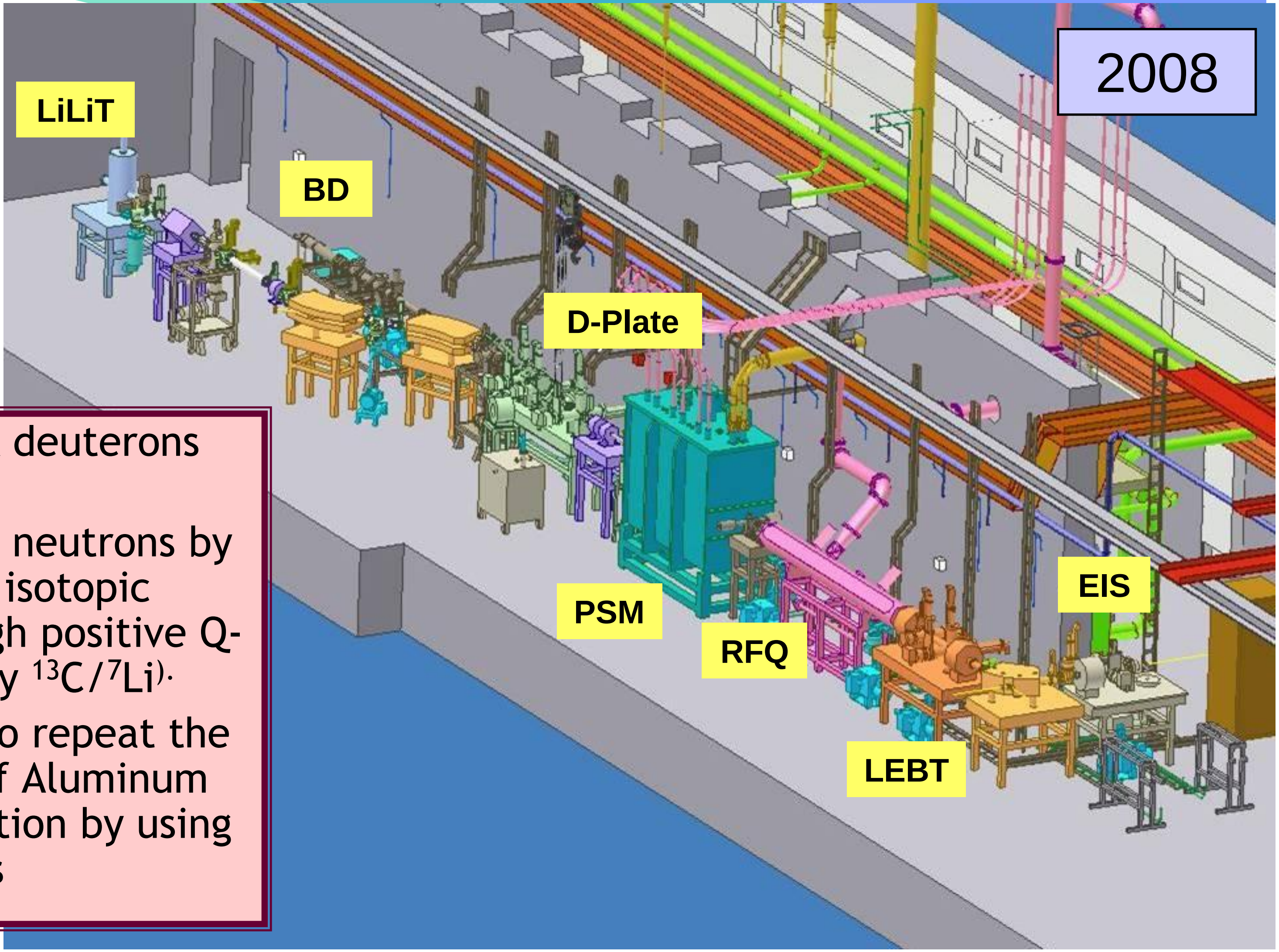
^{8}Li Production Experiment



SARAF Phase I



5.2 MeV and 2 mA deuterons beam.

Production of fast neutrons by placing a light isotopic target with high positive Q-value (probably $^{13}C/^{7}Li$).

We are planning to repeat the experiments of Aluminum and BN irradiation by using these neutrons

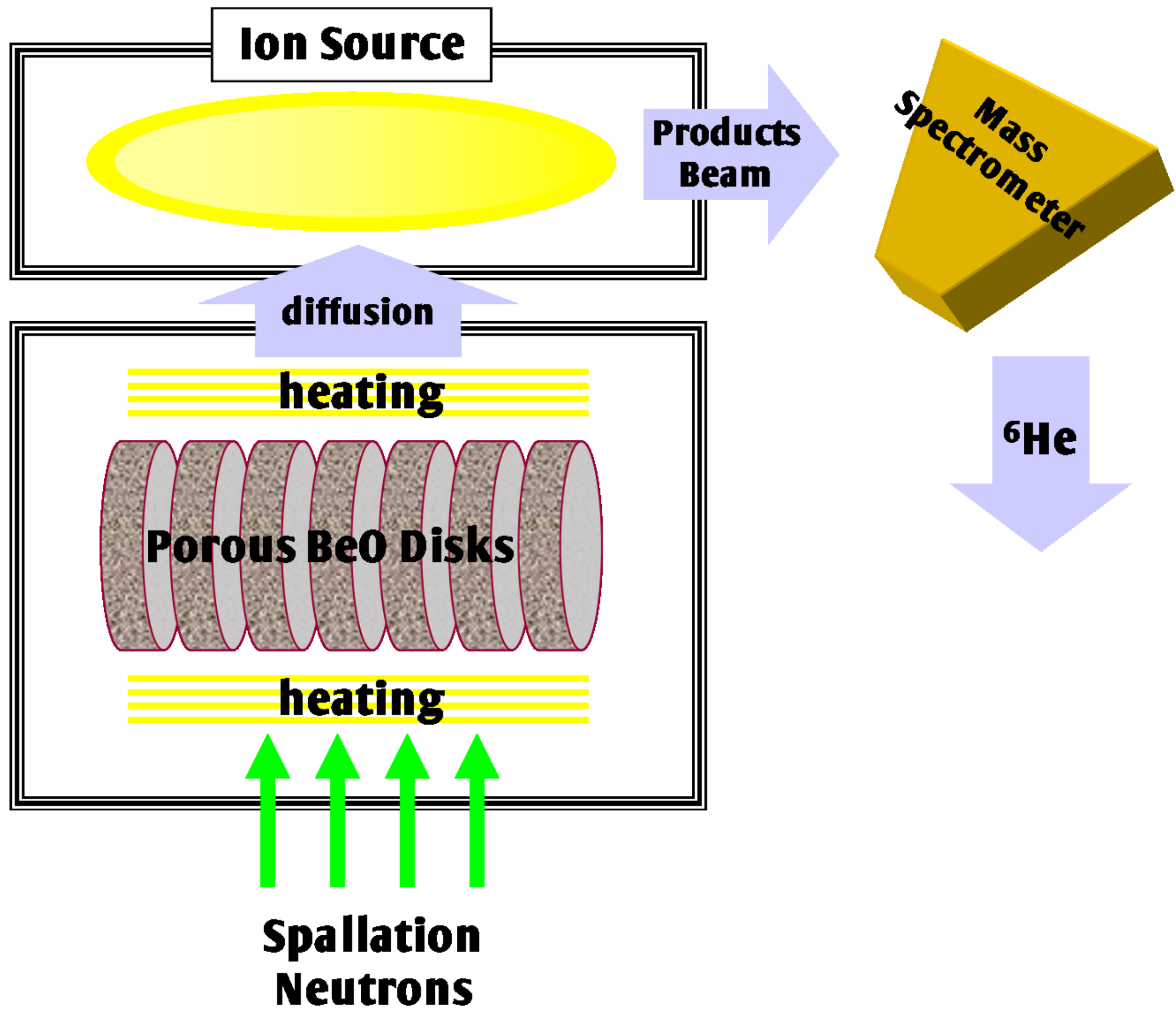
Proposed ISOLDE Porous BeO Experiment

Option for experiment at Ganil:

Production and extraction of ^{8}Li ⇨

Boron-Nitride powder target ⇨

Fast neutrons from $^{12}C(^{12}C,n)$ reactions ⇨



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Summary

1. Presented simulations and tests for production of secondary-neutron induced RIB production.
2. Planned future experiments – including extraction and ionization yields.
3. Towards a specific design of a target for SPIRAL2 and/or SARAF.
4. β-Beams?...

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ISOLDE

Mats Lindroos

Theirry Stora

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