Two Stage ^{8}Li RIB Production System at SARAF

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FUNTRAP12, WIS

3/12/2012

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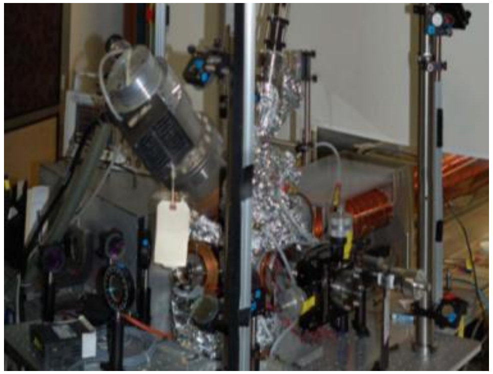
WEIZMANN INSTITUTE OF SCIENCE

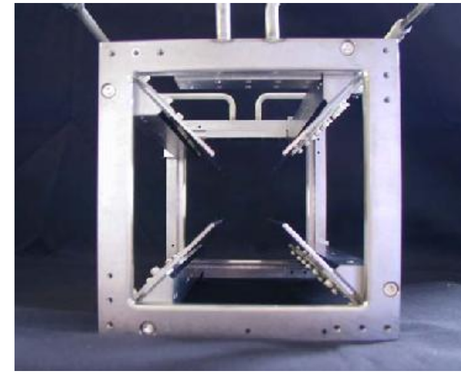
SOREQ

Trapping of ^{6}He and ^{8}Li



^{6}He MOT trap, Argonne @GANIL

^{6}He electrostatic trap, WIS



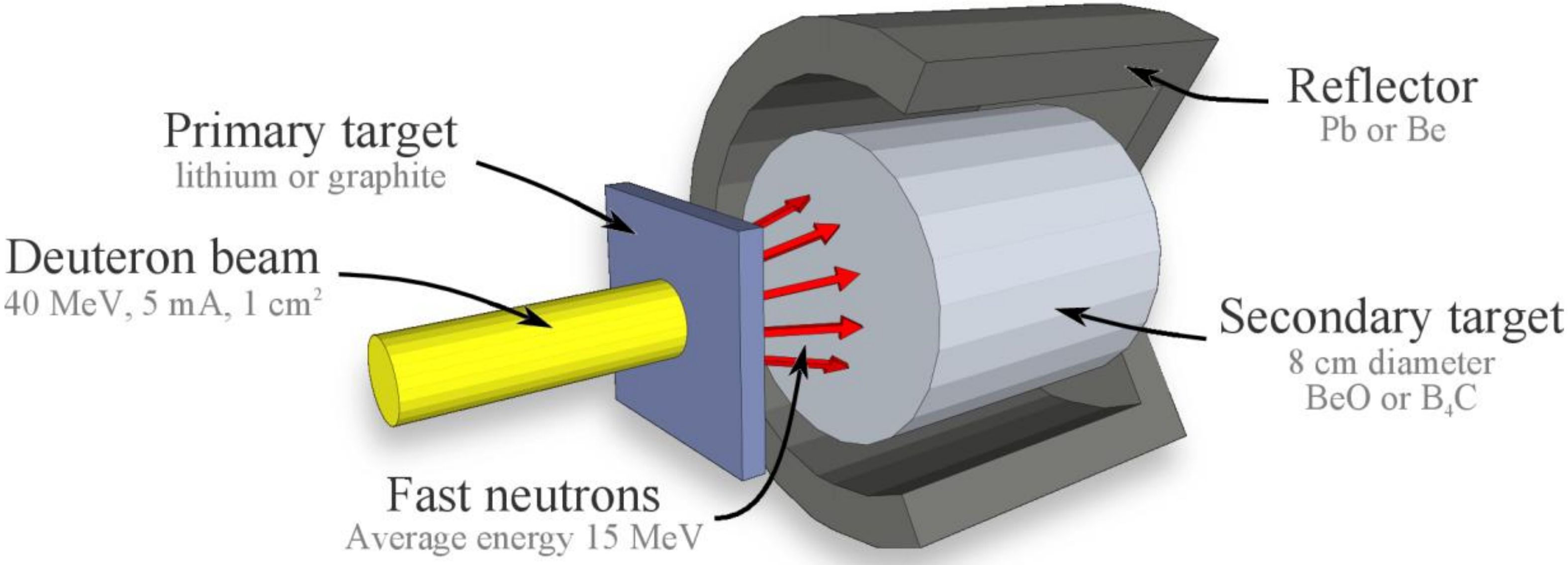
^{8}Li Paul-Trap, Argonne

- The name of the game is ***Efficiency***
- We need **higher production rates**
- New generation of multi mA **deuteron LINACs** (SARAF, SPIRAL2, IFMIF)
- Presenting the ***Two-stage*** **irradiation concept** for light RIB production

Outline/TODO

- ❑ Calculate the production numbers
- ❑ Optimize the irradiation scheme
- ❑ Measure the extraction efficiency
- ❑ Test the full system integration
- ❑ Summarize

Two-stage irradiation setup

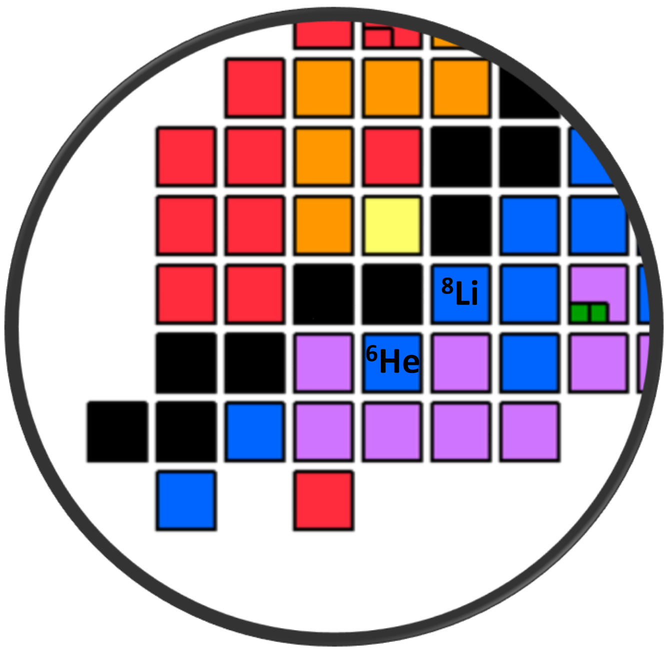


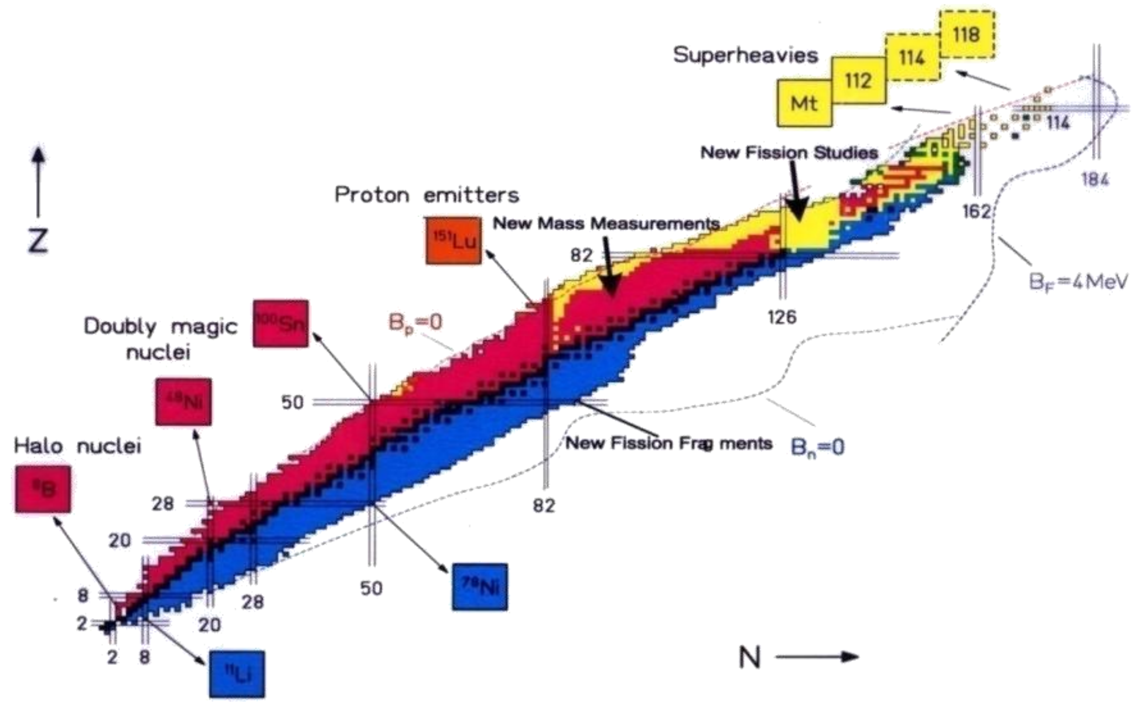
- Physical separation of heat removal and isotopes extraction issues
- Orders of magnitude increase in radioisotopes yields

Study and development of an efficient production scheme for light RIB using the two-stage irradiation method

Background

High yield production of ^{6}He (807 ms) and ^{8}Li (838 ms) RIB





Motivation:

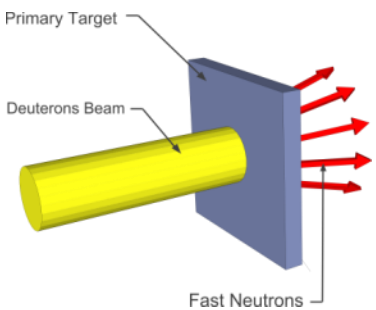
Development of an efficient RIB production scheme for different scientific applications

Beta beam

Fundamental interactions

Astrophysics

n spectrum of d-Li with 40 MeV



$4 \cdot 10^{14}$ n/sec/mA

<En> = 15 MeV

IFMIF
国際核融合材料照射施設

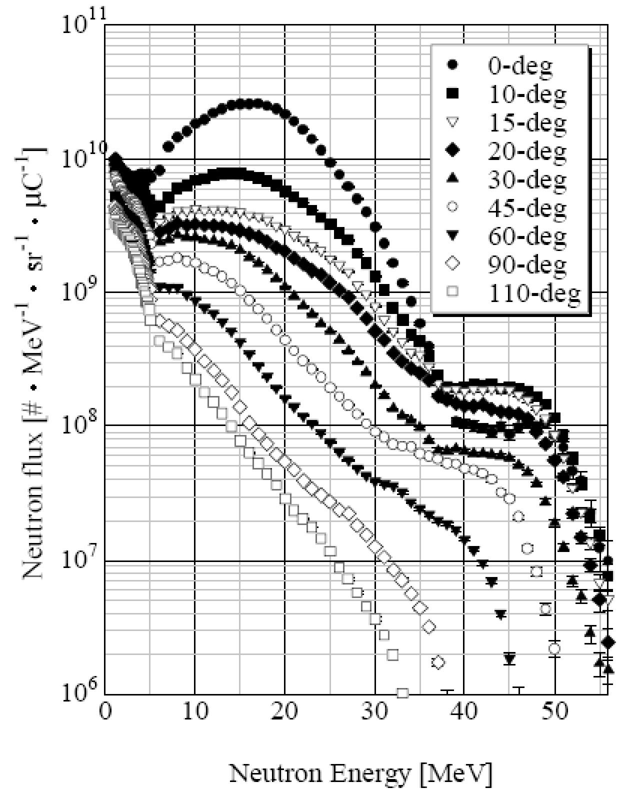
40 MeV , 250 mA
Lithium Converter

Spiral2

40 MeV , 5 mA
Graphite Converter

SARAF

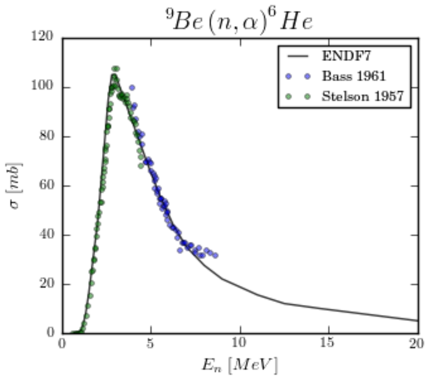
40 MeV , 4 mA
Lithium Converter

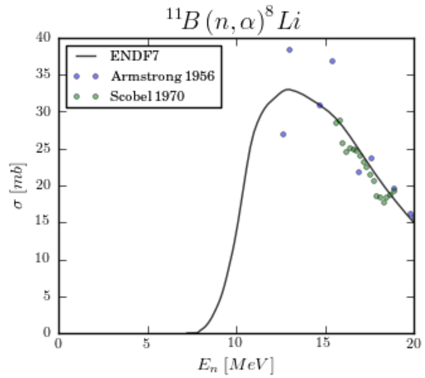


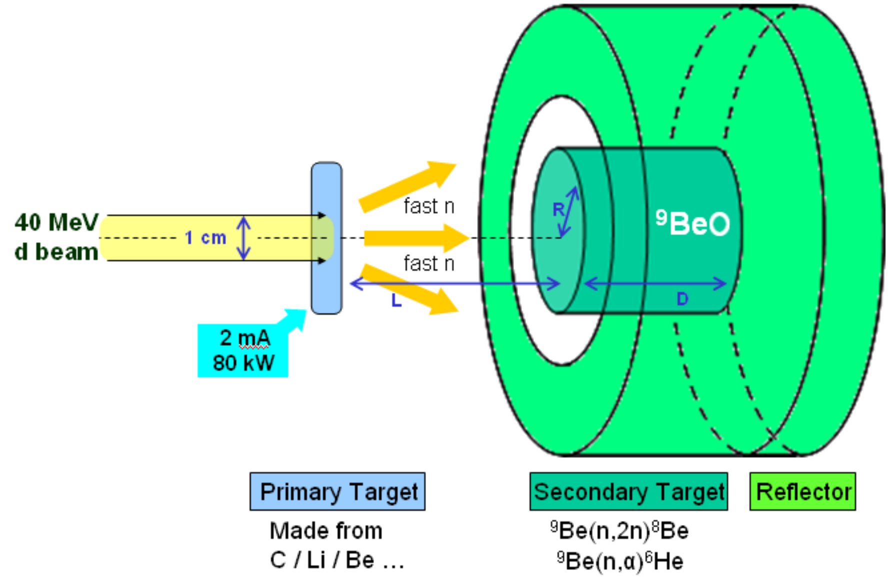
Other possible converters: Beryllium, Water, Heavy water

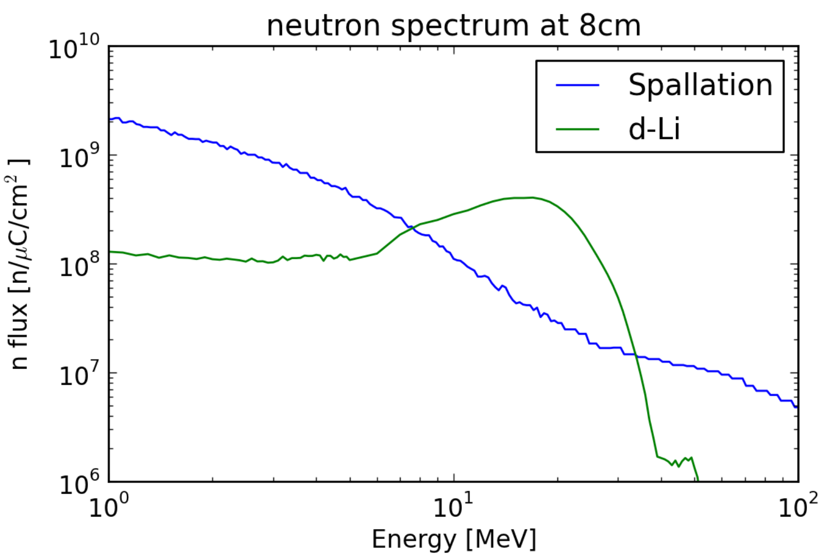
M.Hagiwara et al. *Fus. Sci. Tech.*, **48** (2005).

Optimization Calculations









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

Material	Reaction	half life $[msec]$	Yield $\left[\frac{10^{12}\ atoms}{mA\ sec}\right]$
BeO	$^{9}Be(n,\alpha)^{6}\mathbf{He}$	807	2.53
	$^{9}Be(n,p)^{9}\mathbf{Li}$	178	0.033
	$^{16}O(n,p)^{16}\mathbf{N}$	7130	0.9
B_4C	$^{11}B(n,\alpha)^{8}\mathbf{Li}$	838	0.87
	$^{11}B(n,p)^{11}\mathbf{Be}$	13810	0.14
	$^{12}C(n,p)^{12}\mathbf{B}$	20	0.24
	$^{13}C(n,p)^{13}\mathbf{B}$	17	$6.63{\cdot}10^{-4}$

The above yields are for porous targets, R=4 cm, D=8 cm, L= 1 cm

Outline/TODO

- ☑ Calculate the production numbers
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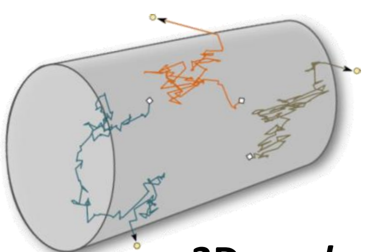
- ☐ Summarize

Simulations: Optimization Calculations

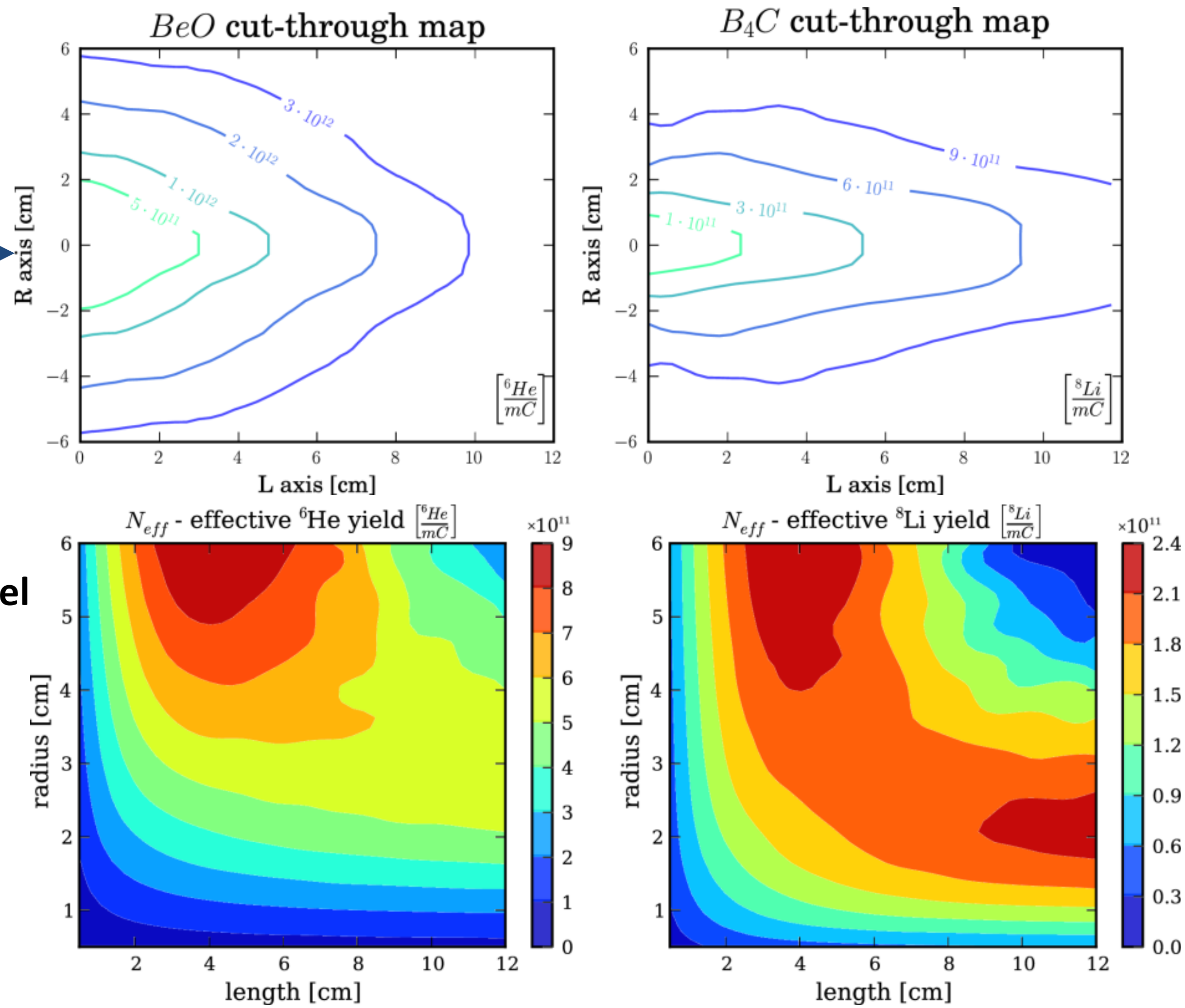
MCNP - Monte Carlo Neutron transport code

Fast n



3D *random-walk* model

The optimal target geometry maintains the balance between high production and fast effusion time



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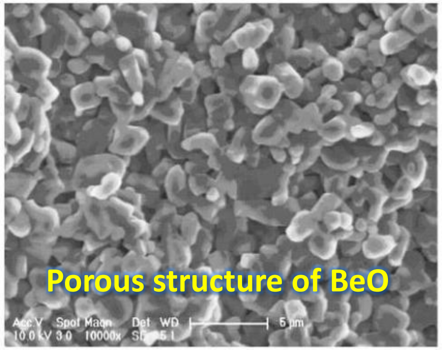
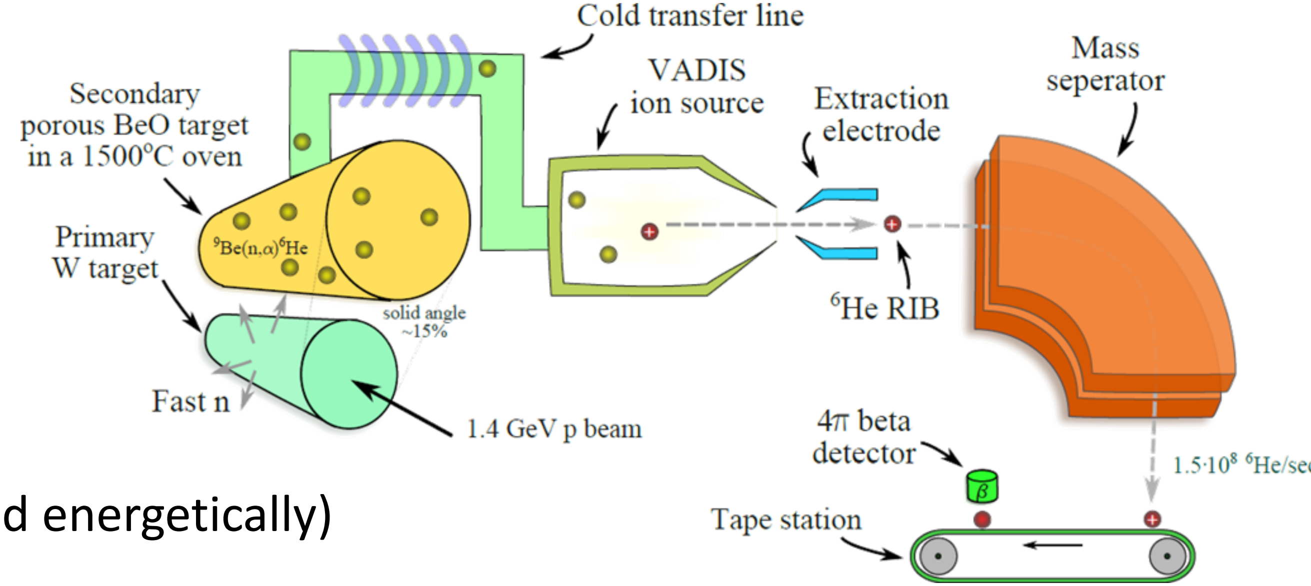
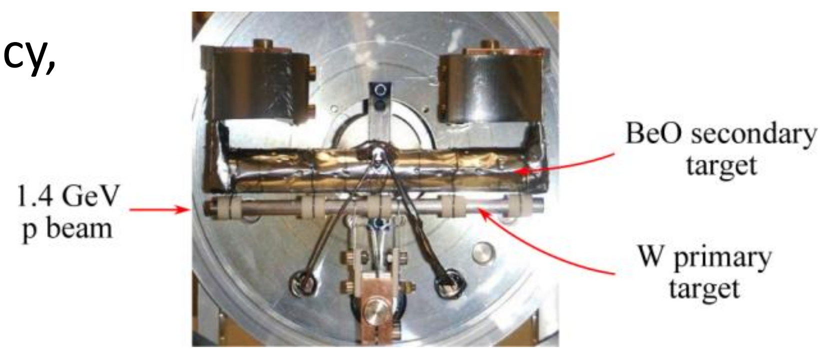
^{6}He experiment at ISOLDE





- Not geometrically (and energetically) optimized
- First measurement of the extraction efficiency, by applying two independent methods
- First measurement of ISOLDE spallation neutron spectrum
- **The most intense ^{6}He beam ever produced**



T. Stora, E. Noach, R. Hodak, T. Y. Hirsh, et al., EPL, **98,** 32001, 2012.

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SARAF phase I

***S**oreq **A**pplied **R**esearch **A**ccelerator **F**acility*

2010
Phase 1 - 5 MeV 2 mA

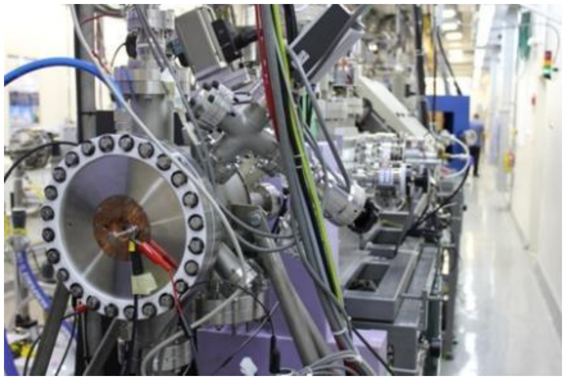
2016
Phase 2 - 40 MeV 4 mA

5 MeV deuterons → Primary Target → Fast neutrons → Secondary Target → ^{8}Li RIB → Efficiency measurement

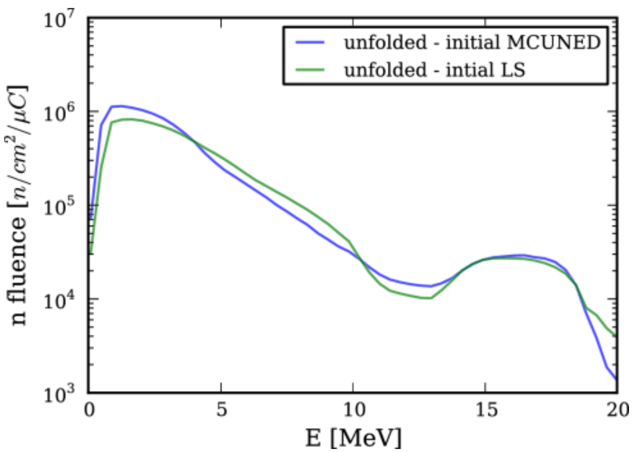
LiFTiT

***Li**thium **F**luoride **T**h**i**ck **T**arget*

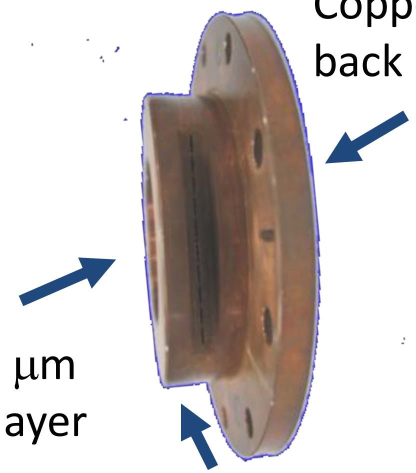
- 10^{12} n/sec/mA, Isotropic
- Fast neutrons of up to 20 MeV
- First physics experiment in SARAF phase 1
- 4.76 MeV d beam 0.1 mA @ 1% DC



T. Y. Hirsh et al., J. Phys, **337**, 012010 (2012)

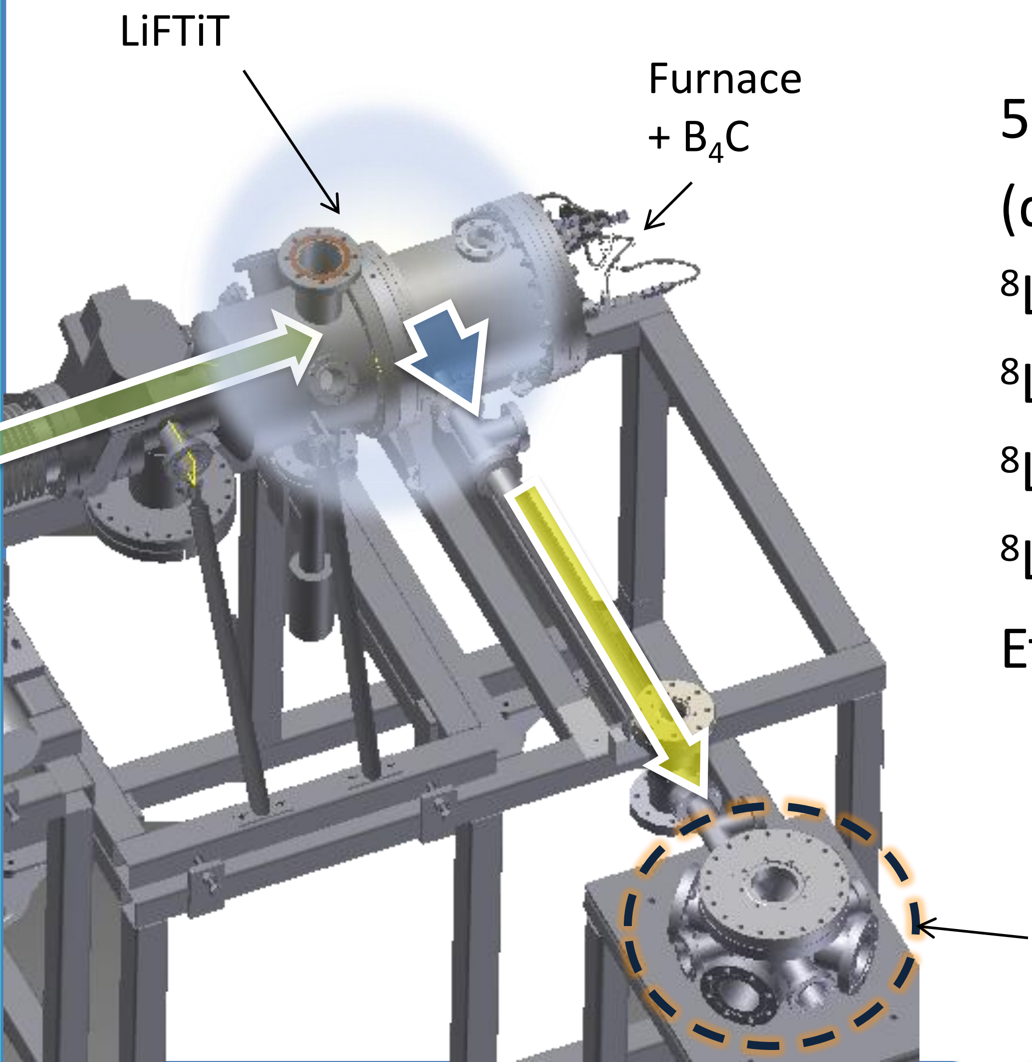


T. Y. Hirsh et al., PRSTAB, submitted (2012)



Based on *D. Petrich et al., "A neutron production target for FRANZ", (2009)*

The experimental setup @ Phase 1



5 MeV deuterons beam

(d,xn) reactions in LiFTiT

^{8}Li production inside B_4C target

^{8}Li diffuses out of the hot target

^{8}Li is ionized in the Re ionizer

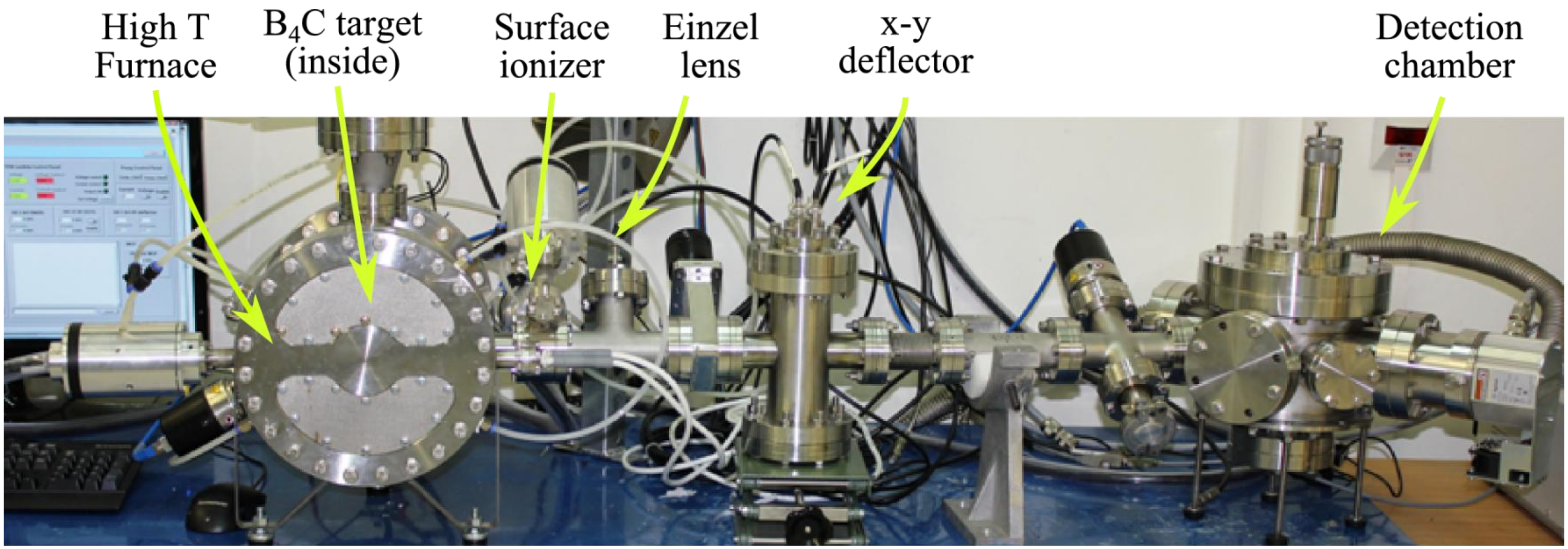
^{8}Li ions beam is delivered

Efficiency measurement

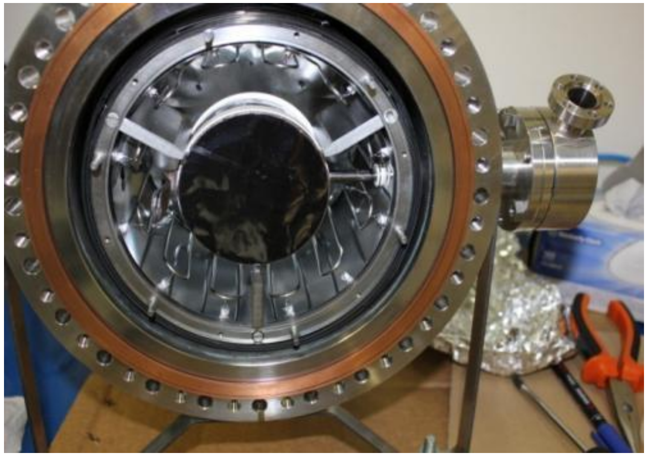
^{8}Li RIB test bench at SARAF

- Off-line apparatus that would be later be transferred to a beam line at SARAF, or as a preliminary test, a *d-t* neutron generator
- Calculated yields of 10^9 ^{8}Li/sec/mA already at phase 1

Material	Reaction	half life [msec]	Yield *LiFTiT* $\left[\frac{atoms}{mA\ sec}\right]$	Yield NG $\left[\frac{atoms}{sec}\right]$
BeO	^{9}Be(n,α)^{6}He	*807*	$3.8\cdot10^{10}$	$5.3\cdot10^{5}$
	^{9}Be(n,p)^{9}Li	*178*	$1.9\cdot10^{7}$	0
	^{16}O(n,p)^{16}N	*7130*	$9.7\cdot10^{8}$	$1.1\cdot10^{6}$
B_4C	^{11}B(n,α)^{8}Li	*838*	$1.2\cdot10^{9}$	$1.1\cdot10^{6}$
	^{11}B(n,p)^{11}Be	*13810*	$1.4\cdot10^{8}$	$1.5\cdot10^{5}$
	^{12}C(n,p)^{12}B	*20*	$1.2\cdot10^{8}$	$1.9\cdot10^{4}$
	^{13}C(n,p)^{13}B	*17*	$5.0\cdot10^{5}$	$3.3\cdot10^{1}$



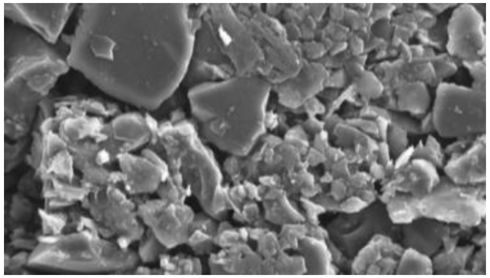
High temperature furnace

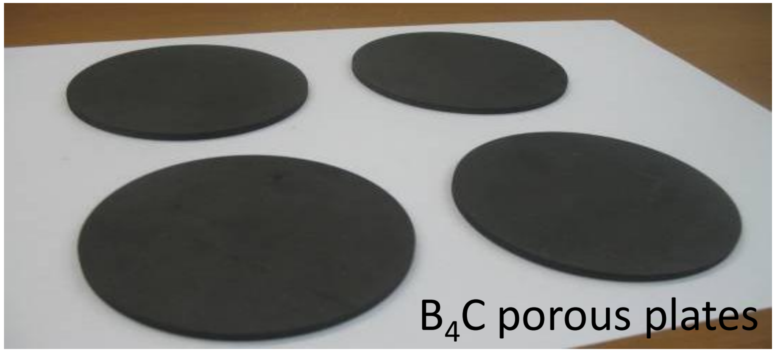


- Especially designed to maintain large ISOL targets in a uniform temperature of up to 1500°C
- Only a thin layer of molybdenum heat shield separates the primary and secondary targets
- Direct mount on top of LiFTiT

The B_4C target

- High porosity (65%)
- 1-5 micrometer grains
- Melting point 2300 °C
- High boron content

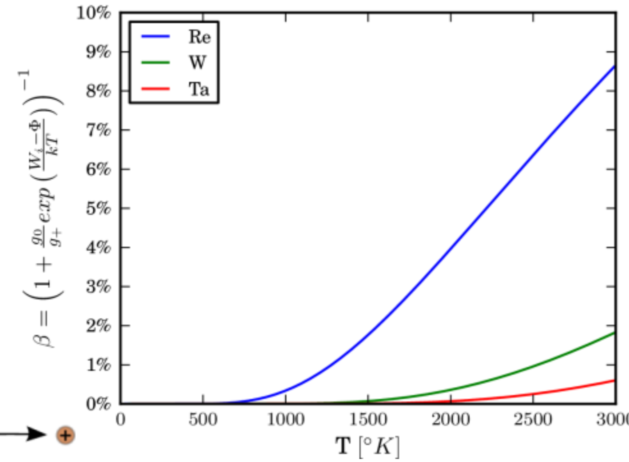


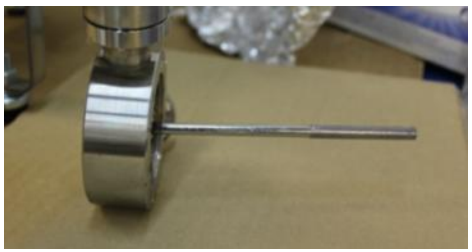


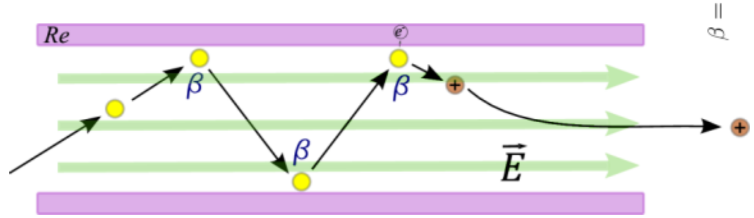
B_4C porous plates

Surface ionizer and beam line optics

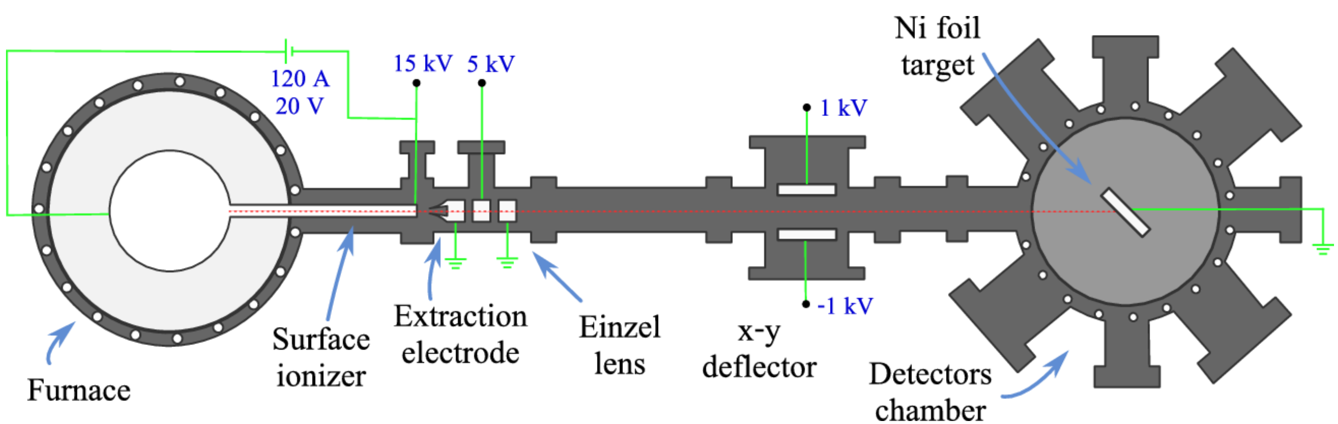
- Based on a recent study of our collaborators at GANIL
- A thin **rhenium** surface ionizer heated by a direct current
- Small voltage difference favors the ^{8}Li ions towards the exit





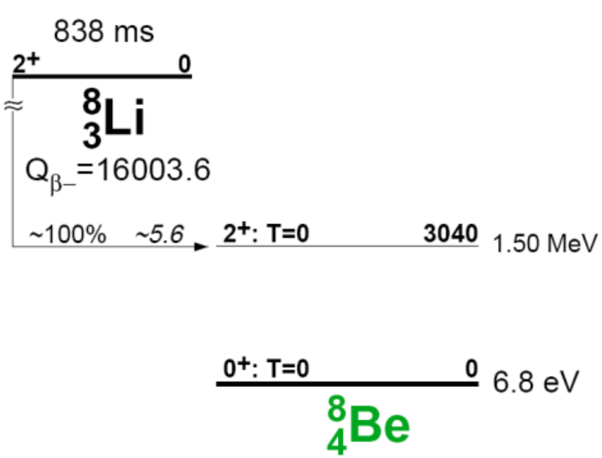


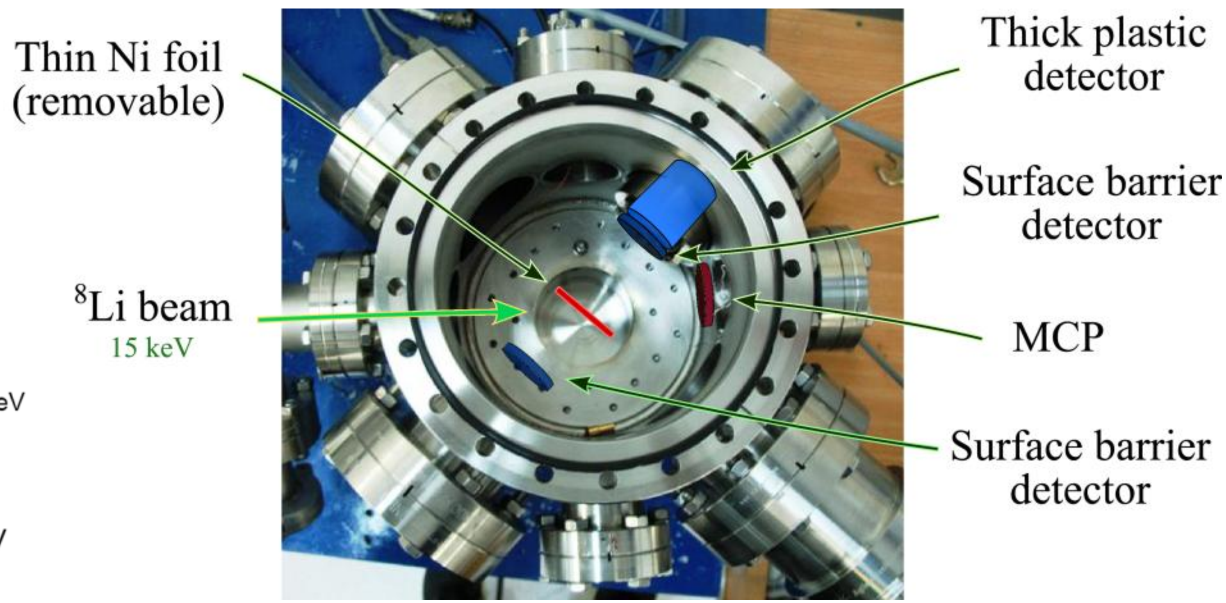
A. Pichard *et al.* Rev Sci Inst. 81(2) 02A908 (2010)



^{8}Li detection chamber

- Beta measurement using a dE-E telescope
- Alpha coincidence measurement of ^{8}Be - 2α decay
- An MCP detector to monitor the beam shape and intensity





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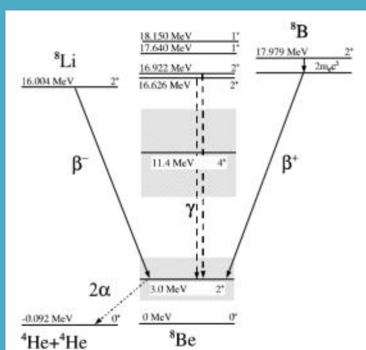
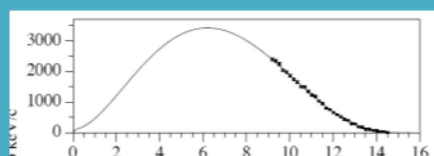
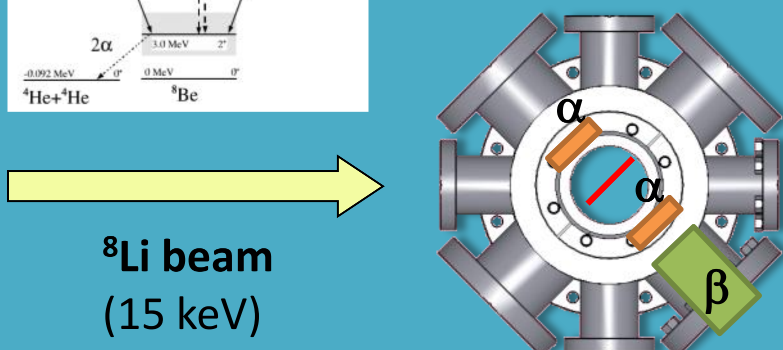
Near future applications

- Coincidence measurement of 2α from ^{8}Li->^{8}Be decay
- Simultaneously measure the high energy betas

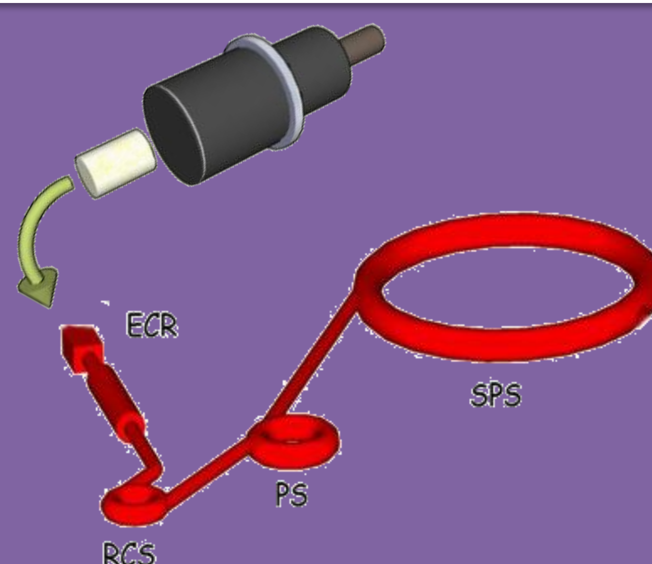






^{8}Li beam
(15 keV)

- Accelerate ^{6}He in CERN SPS
- Preliminary test of the β-beam concept
- Deliver our furnace to CERN to produce ^{6}He with an NG



Summary

The two-stage irradiation scheme is expected to provide orders of magnitude more ^{8}Li (and ^{6}He) RIB

These intense beams may allow the trapping of an intense light RIB for various experiments

A first full production and extraction experiment is planned to take place in the frame of SARAF phase I

Towards a specific design of a target for SPIRAL2 and/or SARAF

Outline/TODO

- ☑ Calculate the production numbers
- ☑ Optimize the irradiation scheme design
- ☑ Measure the extraction efficiency
- ☑ Test the full system integration
- ☑ Summarize

Acknowledgments

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