

**GANIL**  
GRAND ACCELERATEUR NATIONAL D'IONS LOURDS



# Radioactive ion beam production at other facilities

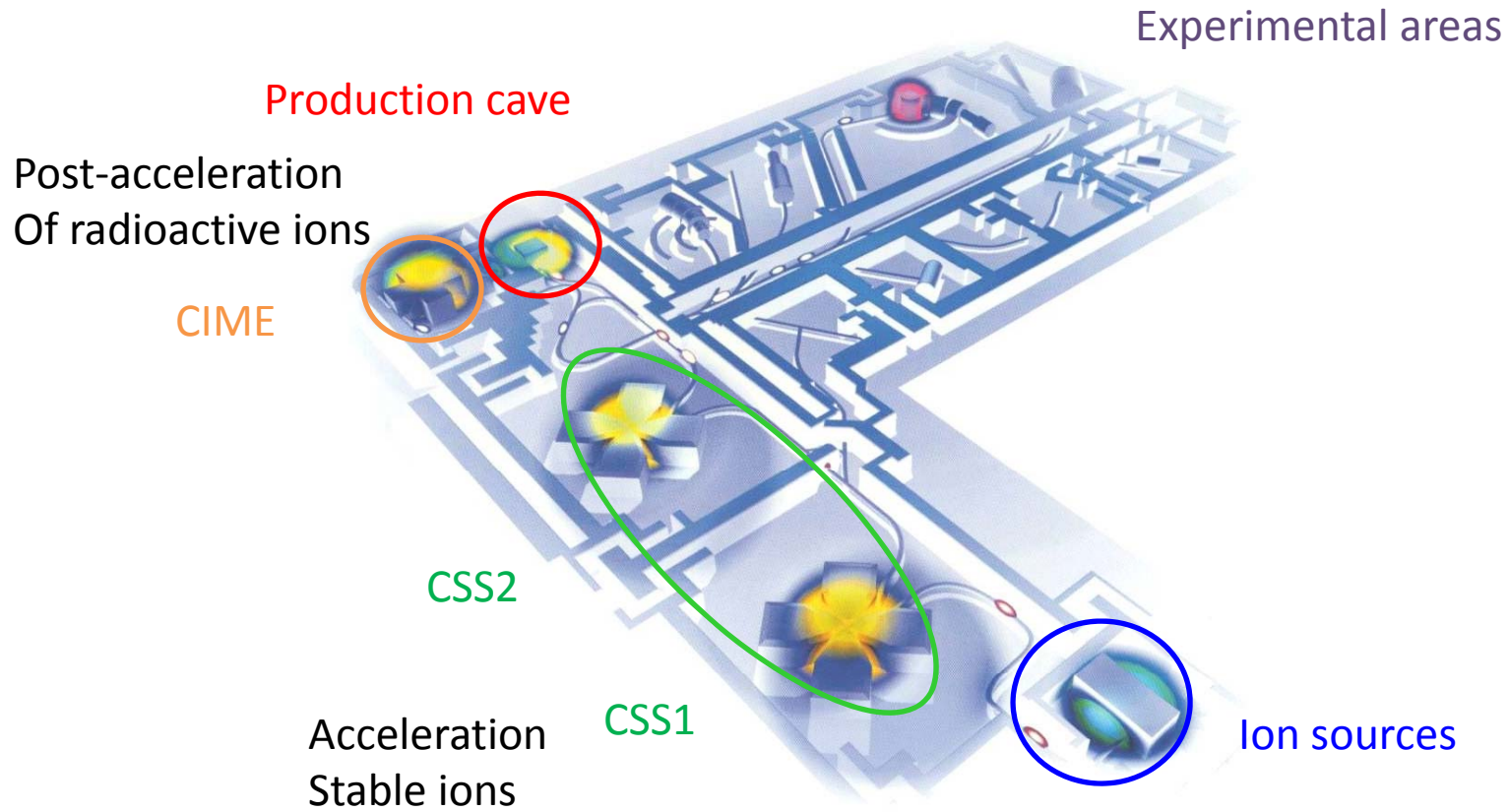
P. Delahaye, GANIL

And M. Hass, Weizmann Institute/SOREQ

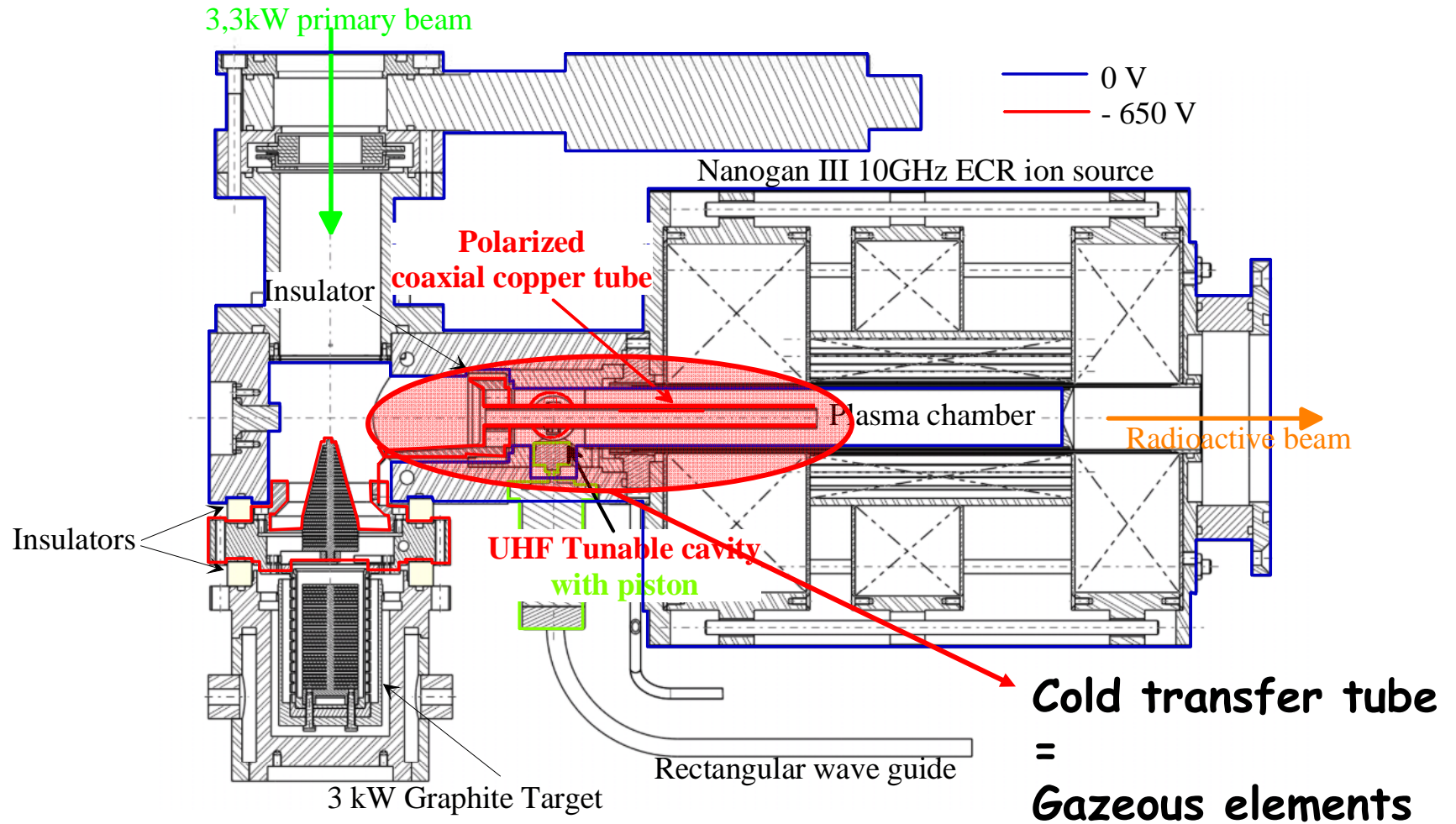
# GANIL – SPIRAL 1

- Most intense beams of  ${}^6\text{He}$  and  ${}^{18}\text{Ne}$
- ${}^6\text{He}$ 
  - $2 \cdot 10^8/\text{s}$  at low energy,  $3 \cdot 10^7$  post-accelerated
  - ${}^{13}\text{C}$  beam 75A MeV on a graphite target (1.5 - 3kW)
- ${}^{18}\text{Ne}$ 
  - $10^7/\text{s}$  at low energy (2+),  $3 \cdot 10^6$  post-accelerated
  - ${}^{20}\text{Ne}$  beam 95A MeV on a graphite target (1.5 - 3kW)
- Graphite target, very efficient ionization with an ECR source

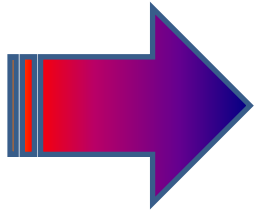
# GANIL – SPIRAL 1



# Gaseous elements with Nanogan 3 and cold transfer tube



# Graphite targets



Projectile  
fragmentation!



**Ne, Ar, Kr, N, O, F**

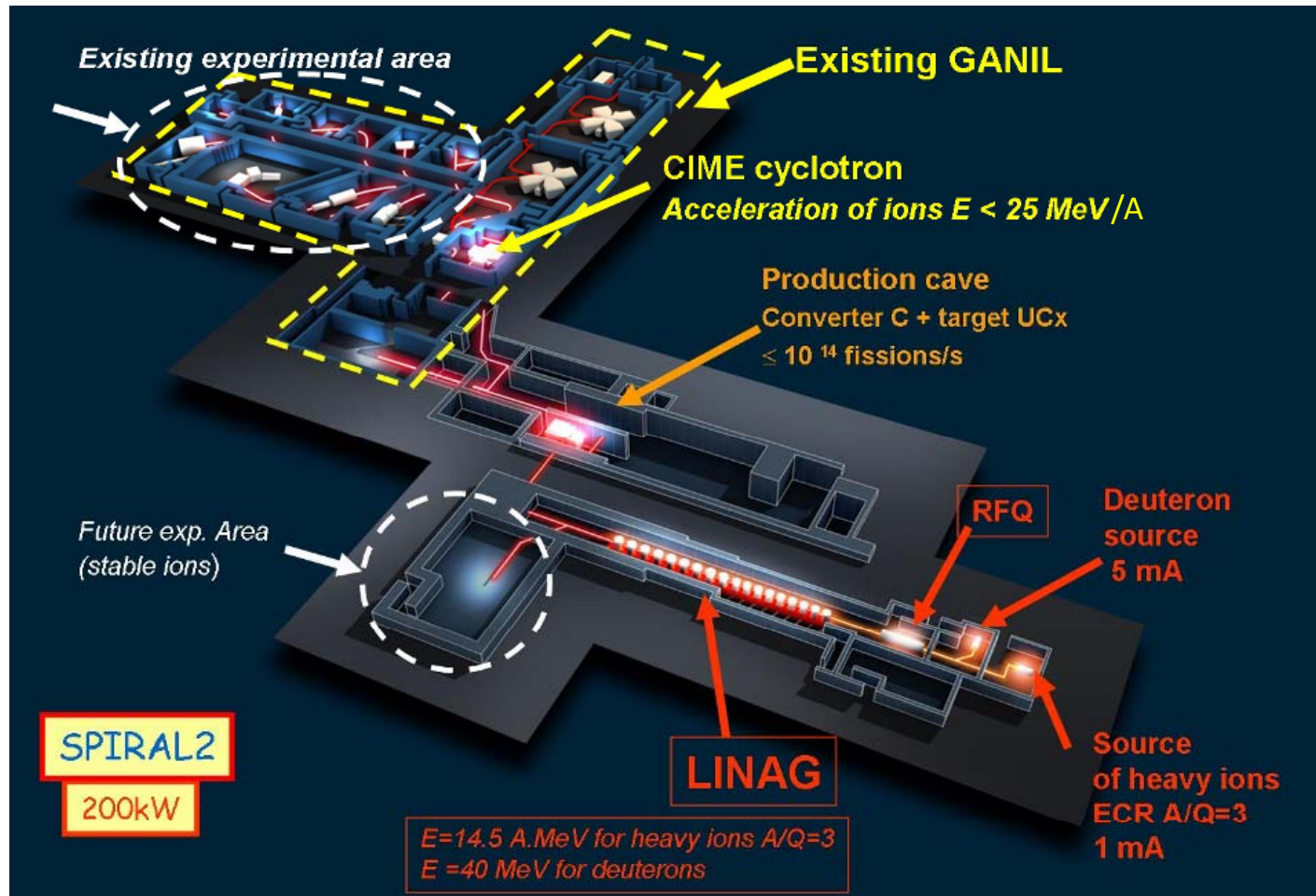


**He**

# Projects at SOREQ and GANIL

- GANIL - SPIRAL 1: new target materials for target fragmentation and fusion – evaporation
- GANIL – SPIRAL 2:
  - UCx targets with 5mA 40 MeV d hitting a neutron converter in  $^{12}\text{C}$
  - Fusion – evaporation and transfer reactions with light - or medium heavy - intense beams
- SOREQ - SARAF:
  - Phase 1: 2mA 5 MeV d on neutron converter (Li)
  - Phase 2: 2mA 40 MeV d on neutron converter (Li)

# Spiral2



# SARAF - Soreq

deuterons / protons  
linear accelerator

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

40 MeV at Phase 2  
with 6 SMs (2013)

2 mA current

- Nagler, LINAC2008
- Piel, EPAC2008
- Pekeler, LINAC2006



2008

40 MeV , 2 mA  
Lithium Converter



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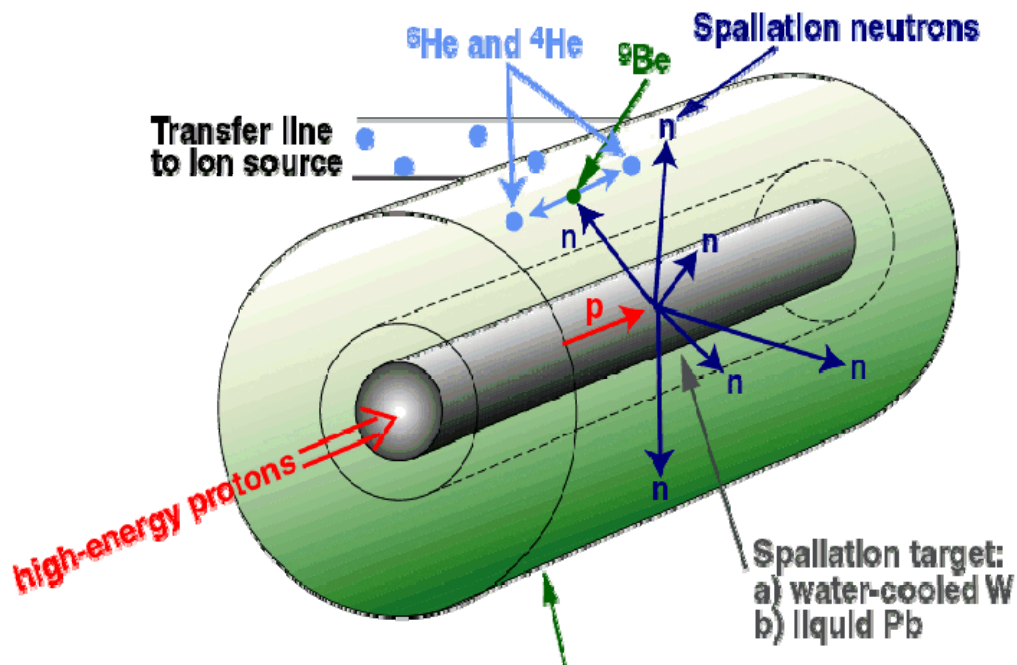
# What interests for beta-beams?

- Development of light RIBs for nuclear physics
  - Joint (SOREQ+GANIL) development and tests of BeO targets with ISOLDE for high intensity  ${}^6\text{He}$  beams
  - SOREQ: tests of a BN target for  ${}^8\text{Li}$  production
  - GANIL: possibilities for testing (production) diffusion, effusion and ionization of  ${}^8\text{B}$  and  ${}^8\text{Li}$  beams at SPIRAL 1

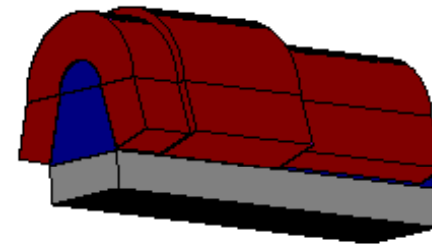
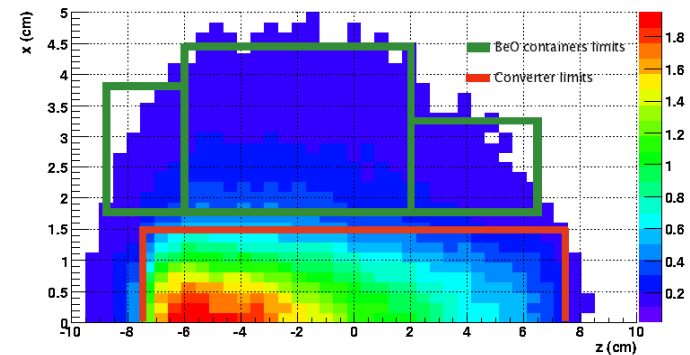
# BeO and ${}^6\text{He}$ : EURISOL



Converter technology:  
(*J. Nolen, NPA 701 (2002) 312c*)



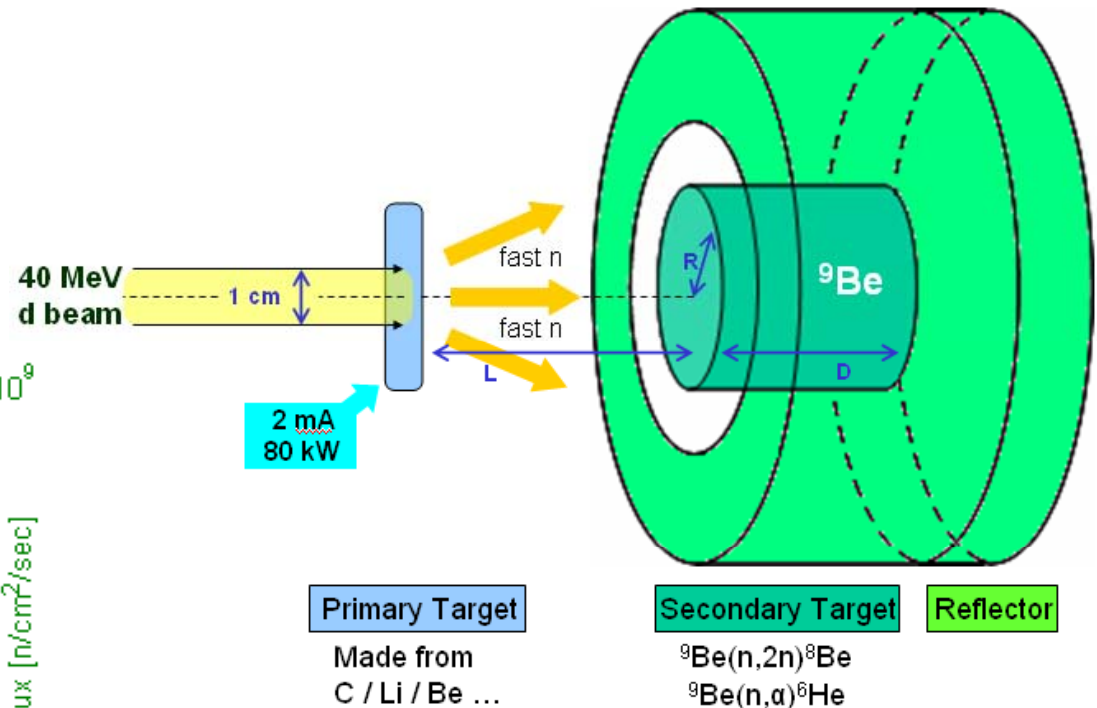
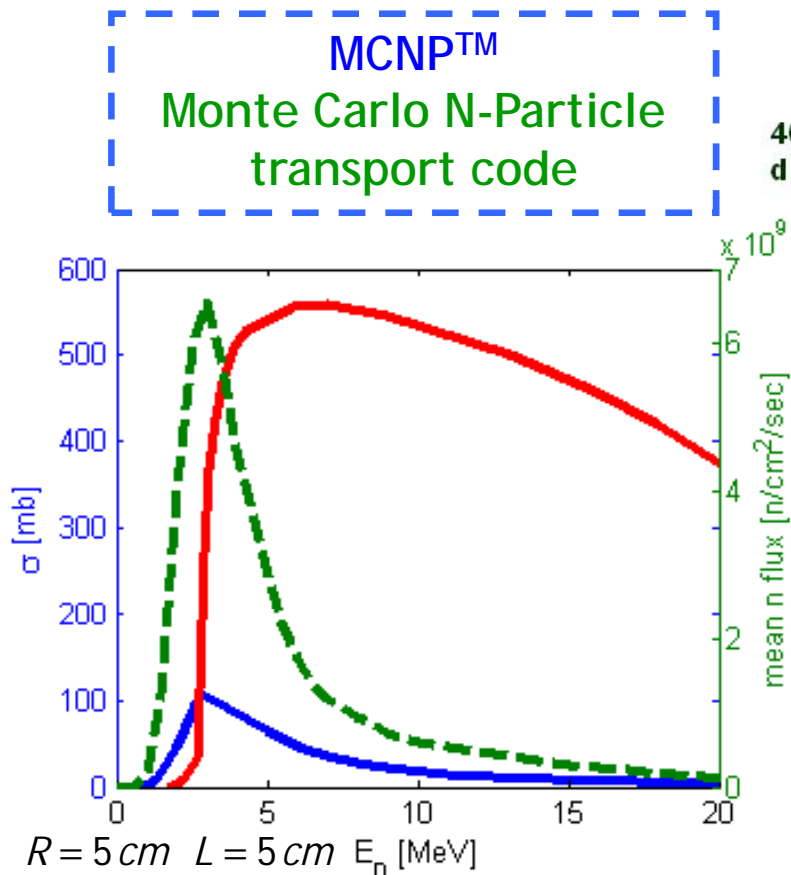
CEA Saclay Optimized Geometry



T. Stora et al, EURISOL-TN03-25-2006-0003    N Thollieres et al. EURISOL-TN03-25-2006-0004

- Preferred to direct irradiation (heat transfer and efficient cooling allows higher power)
- ${}^6\text{He}$  in target yield is  $\sim 2 \times 10^{13}$  ions/s (dc) for  $\sim 200$  kW on target
- Use of a 4MW target is a priori possible

# SARAF and GANIL Optimization Calculations (SOREQ/WI)

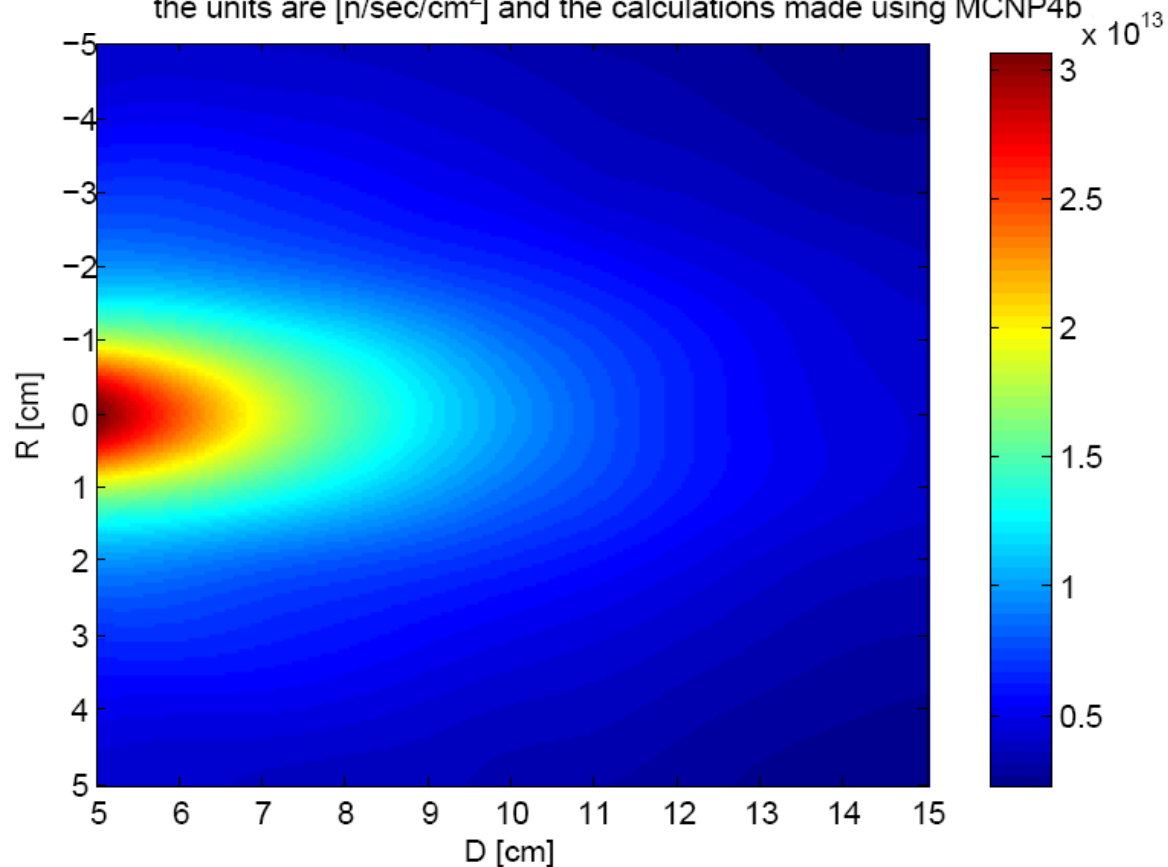
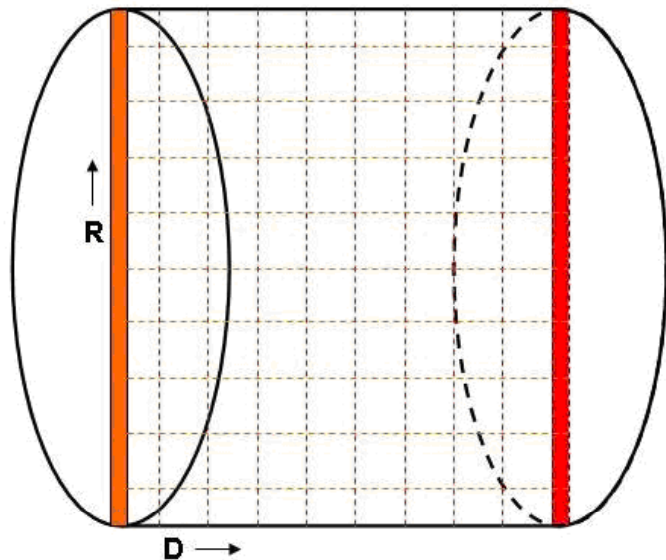


Expected in target yields for BeO:  
 SARAF (40 MeV, 2 mA):  $8 \cdot 10^{12}$  [ ${}^6\text{He}/\text{sec}$ ]  
 SPIRAL2 (40 MeV, 5 mA):  $2 \cdot 10^{12} - 2 \cdot 10^{13}$  [ ${}^6\text{He}/\text{sec}$ ]  
 Expected in target Yields for a BN target:  
 SARAF (40 MeV, 2 mA):  $2 \cdot 10^{12}$  [ ${}^8\text{Li}/\text{sec}$ ]

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

# SOREQ/WI: neutron flux simulation

Mean neutrons flux on  $^9\text{Be}$  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  $[\text{n}/\text{sec}/\text{cm}^2]$  and the calculations made using MCNP4b



2D slice inside the secondary target

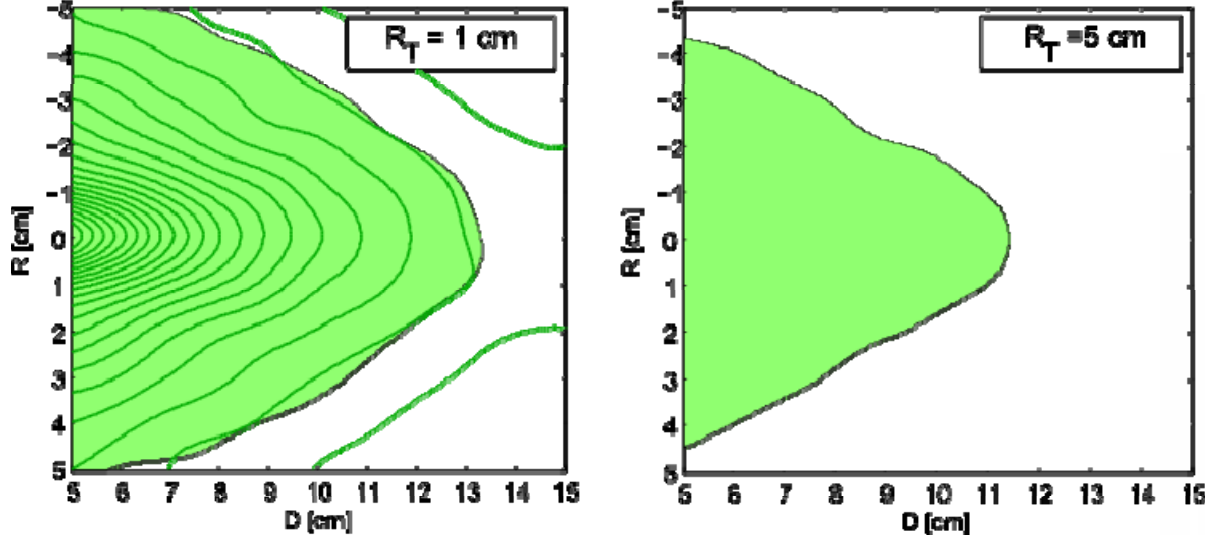


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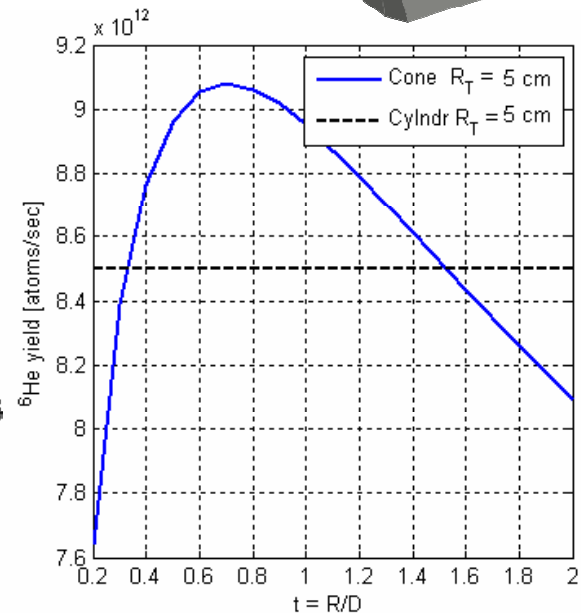
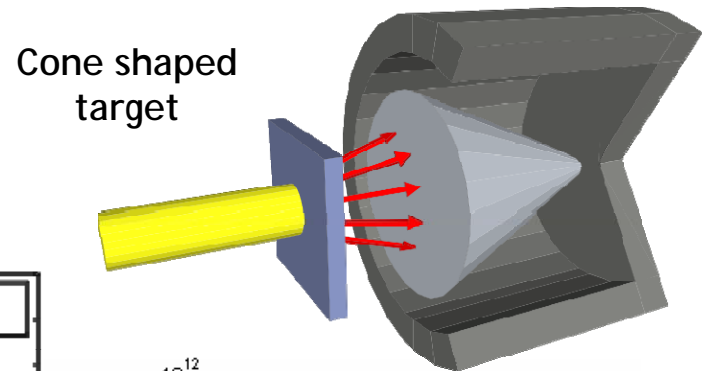


# SOREQ/WI: target geometry

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



2D slice of the target



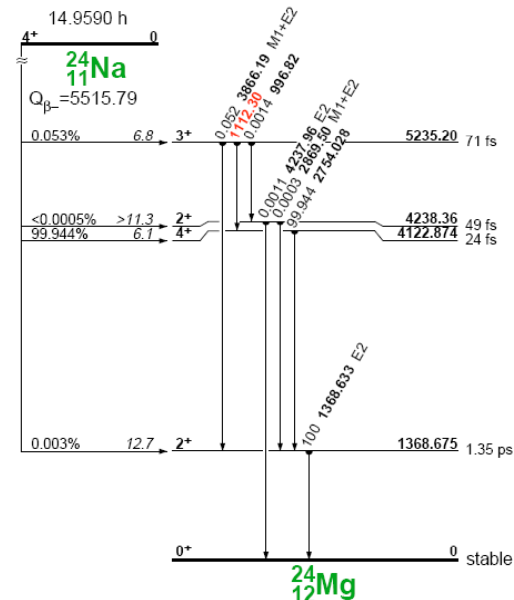
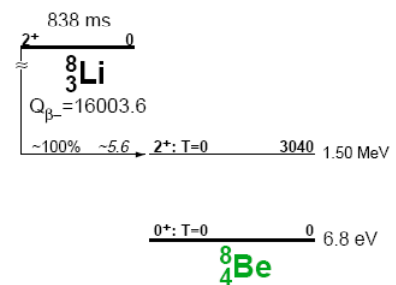
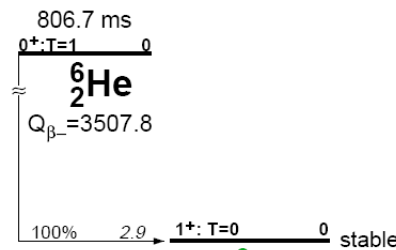
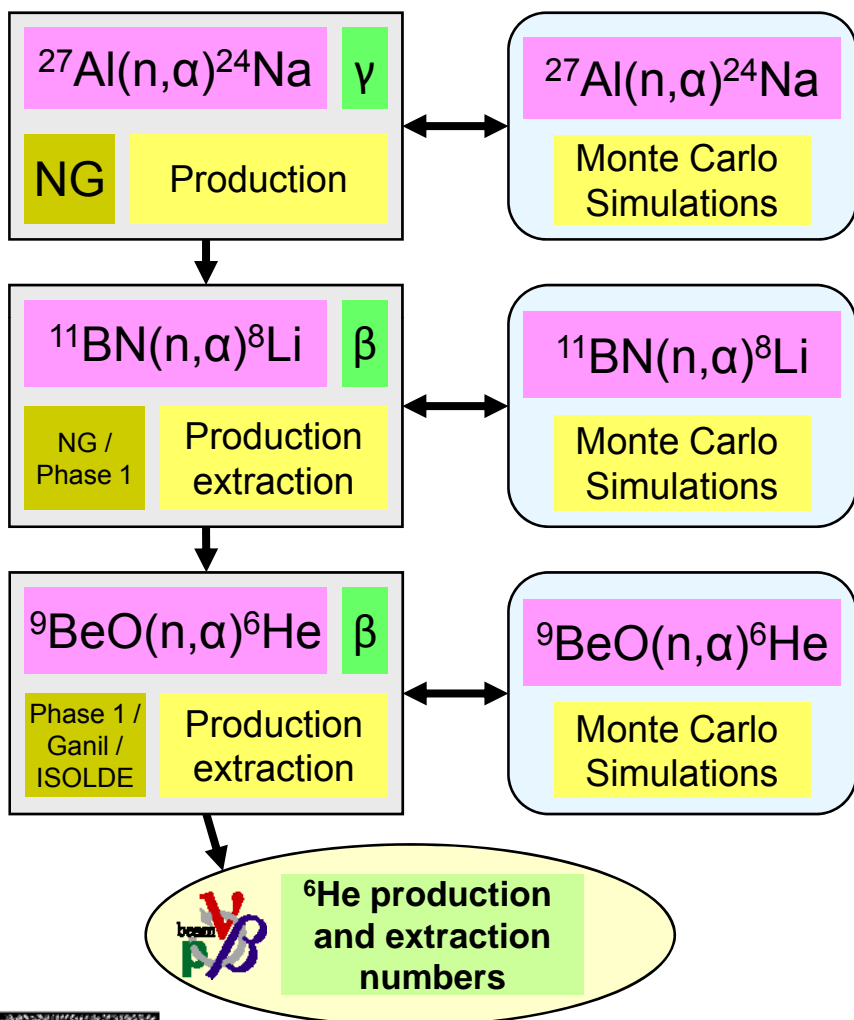
$^6\text{He}$  production yields for a constant target volume and for different R to D ratios. These results are for a  $785.4 \text{ cm}^3$  cone target and for  $R_T = 5$  cm

\*  $R_T$  stands for the distance between the two targets





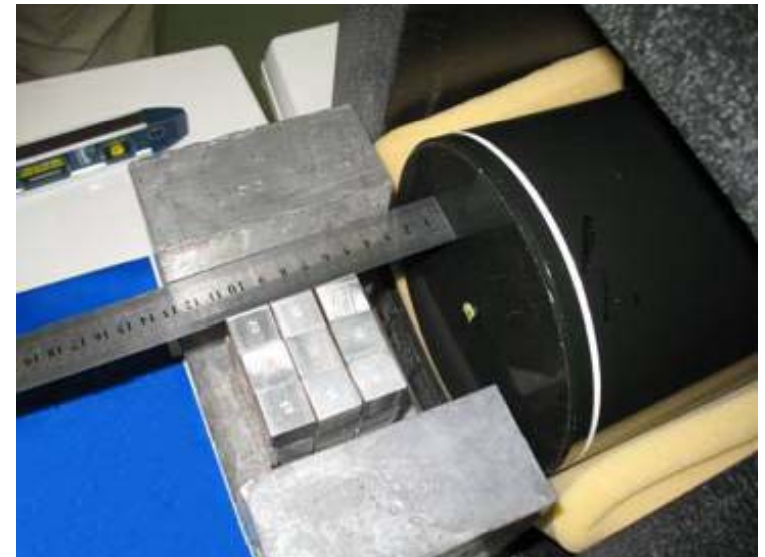
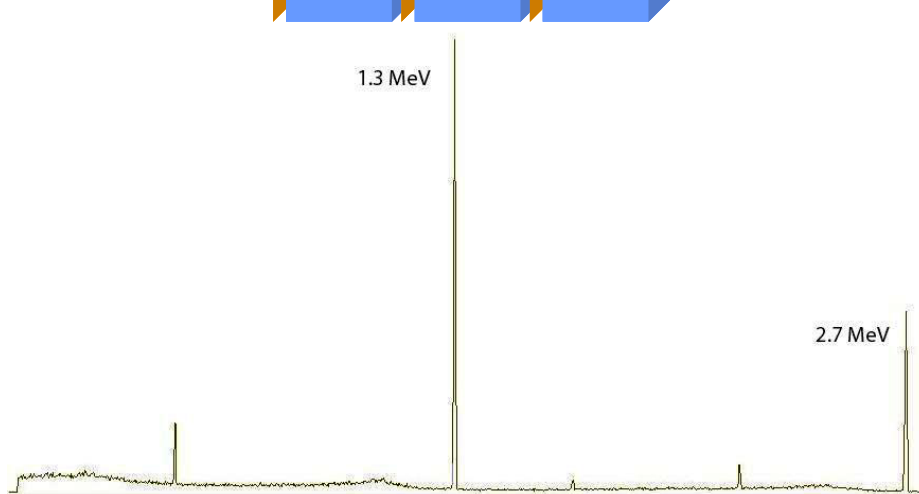
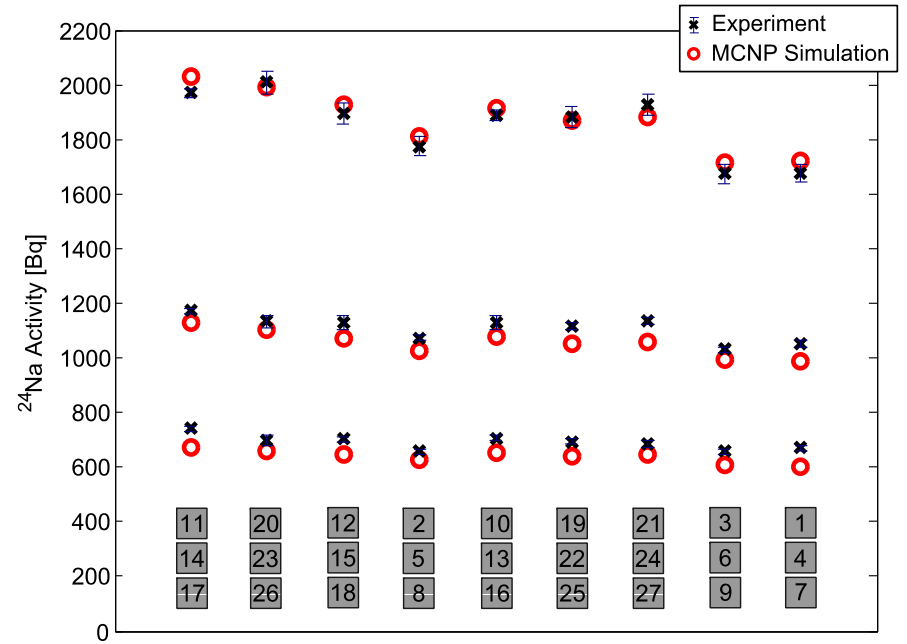
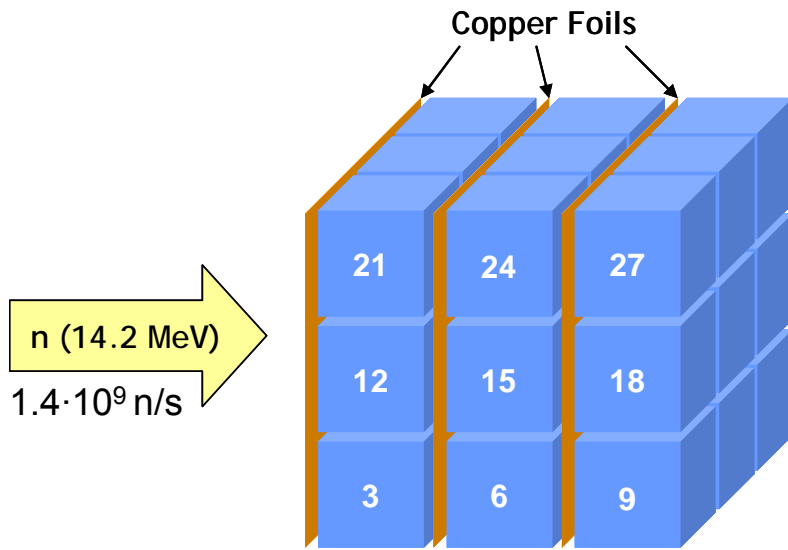
# Plans SOREQ



**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.

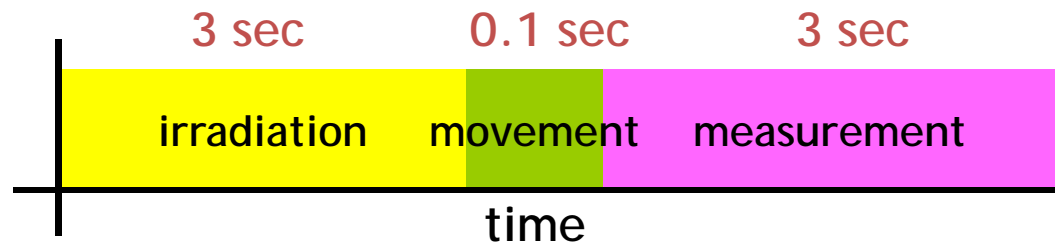
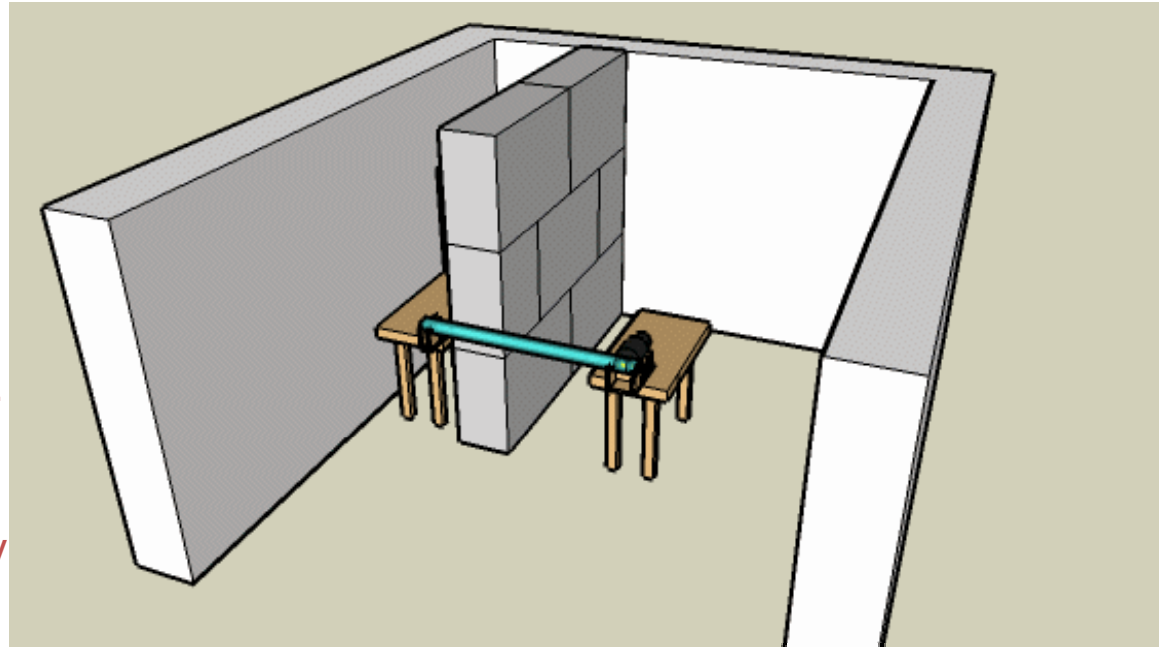
# Aluminum Cubes Experiment



T.Y.Hirsh et al. PoS(NUFACT08)090, 2008.

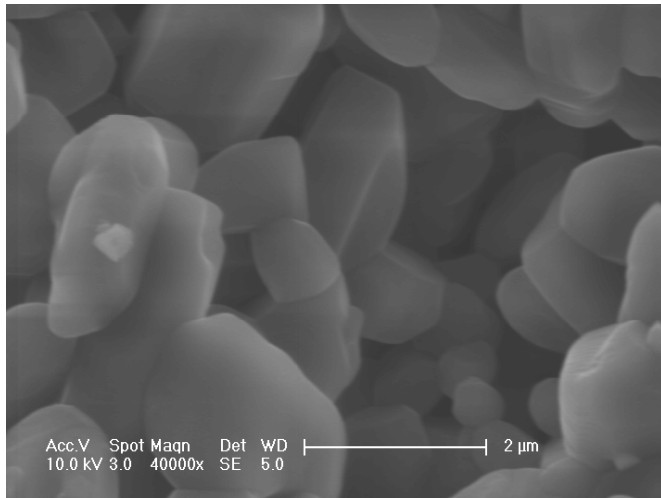
# $^8\text{Li}$ Production Experiment

- $^8\text{Li}$  production measurement.
- $^{11}\text{BN}(n,\alpha)^8\text{Li}$  by fast neutrons.
- Automatic measurement system using a fast air-pressure rabbit.
- Detection of betas from  $^8\text{Li}$  decay.
- A benchmark for simulations.
- $^6\text{He}$  production is also possible by replacing the target by  $\text{BeO}$ .

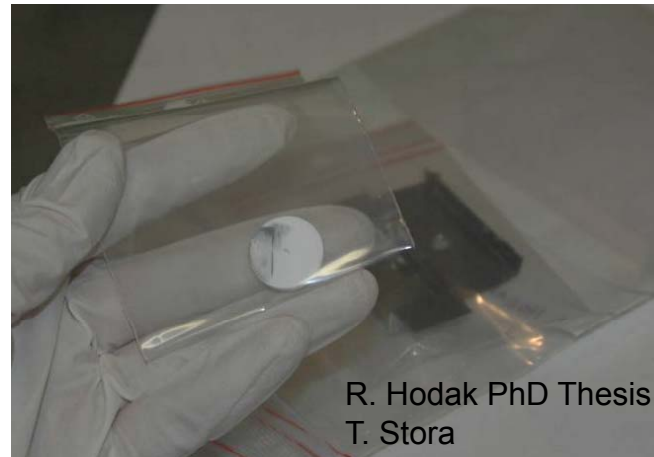


# Joint efforts BeO

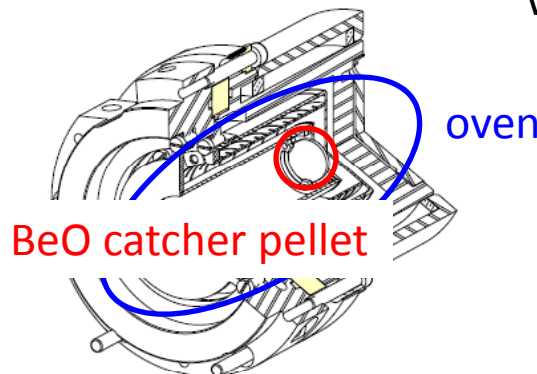
SEM BeO SOREQ/WI



Heating tests with Ta or Mo container at ISOLDE



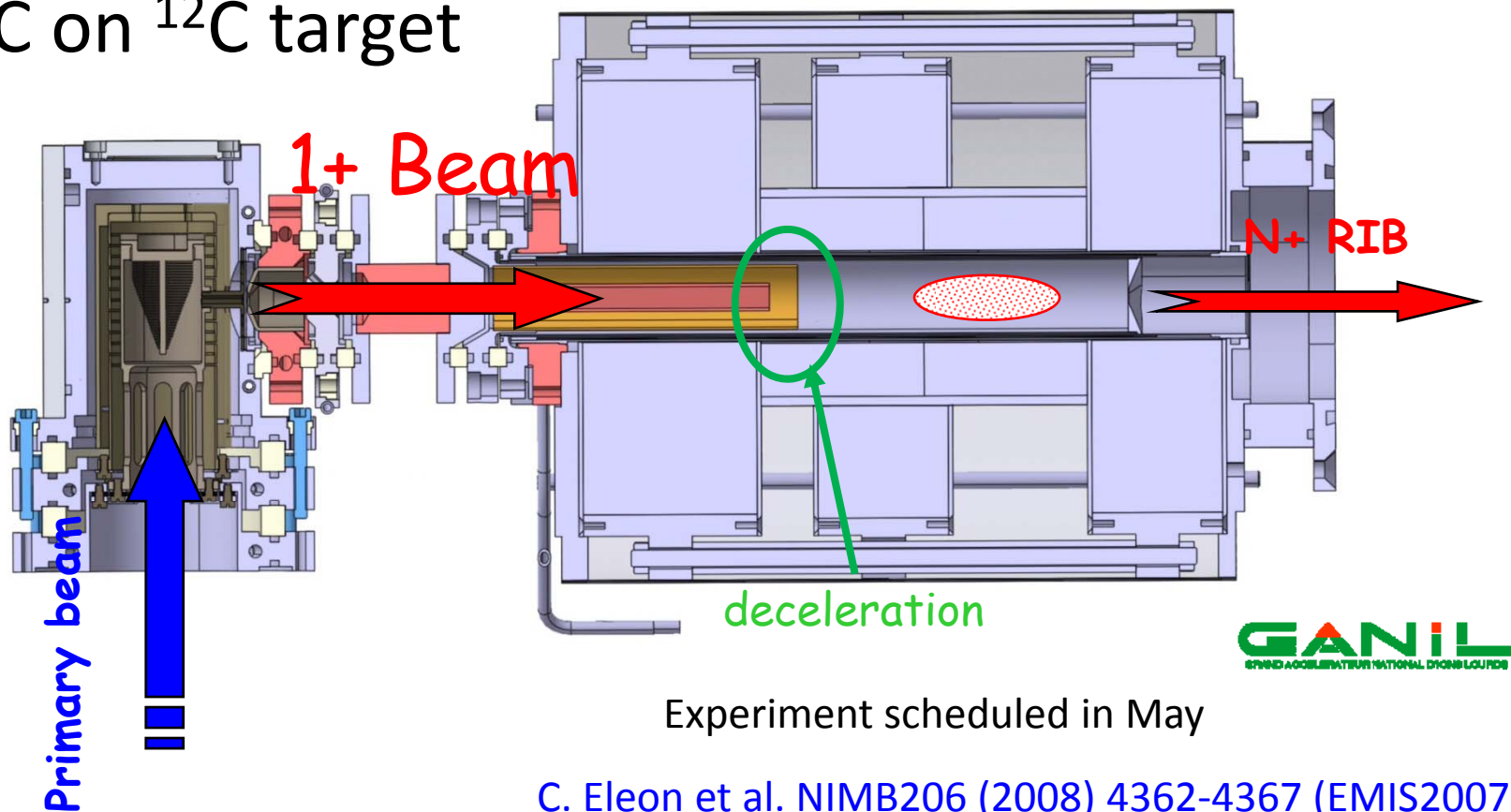
On line experiment foreseen mid of April with Ta converter



Diffusion and effusion test of  ${}^6\text{He}$  produced by SPIRAL 1 in a BeO pellet  
Target is becoming a catcher – experiment at SIRA for mid 2010  
Safety issues are being addressed

# Future possibilities GANIL SPIRAL 1

- $1+ N+ {}^8\text{Li}$  ions in “Nanonake”
- ${}^{13}\text{C}$  on  ${}^{12}\text{C}$  target



Experiment scheduled in May

C. Eleon et al. NIMB206 (2008) 4362-4367 (EMIS2007)  
C. Eleon et al RSI 79, 02A904 (2008)



# Testing a difficult beam: $^8\text{B}$

- Production using fragmentation of  $^{13}\text{C}$  on  $^{12}\text{C}$
- Flushing  $\text{CF}_4$  in the target surrounding to produce  $\text{BF}_3$
- Ionization in Nanogan (0 to N+)
  - Was already tested with  $^{32}\text{S}$  and  $^{36}\text{Ar}$  on graphite target but high background of  $^{24}\text{Na}$

# Summary

- In the frame of EUROnu
  - Production tests of  $^8\text{Li}$  from a BN target irradiated by fast neutrons at SOREQ with neutron generator and SARAF phase 1 (2009)
  - Production tests of  $^6\text{He}$  from a BeO target irradiated by fast neutrons at SOREQ from SARAF phase 1
  - Diffusion of  $^6\text{He}$  in BeO at GANIL (2010)
  - $^8\text{Li}$  (production) diffusion in graphite and ECR-ionization tests possible at GANIL (May – June 2009)
  - Possibility of testing diffusion and ECR-ionization of  $^8\text{B}$  in a parasitic beam time at GANIL (?)

# People and institutes



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Thanks a lot for your attention!

# What about $^{18}\text{Ne}$ ?..

