WP6.4 – Effects of neutrons on MgB_2: neutrons, α and Li contribution to the DPA.

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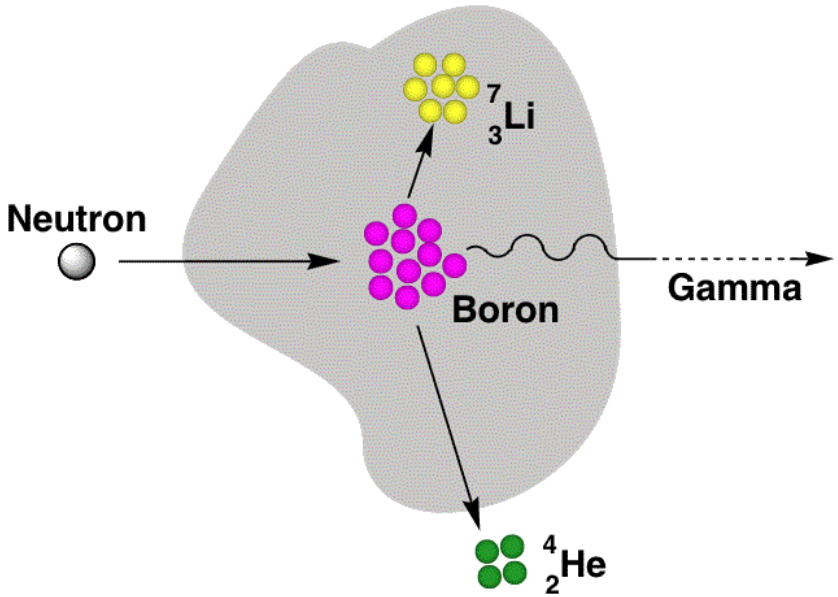
Outline

- Cronological development of the study on B
- Consumption evaluation
- Irradiation test simulation
- What is the relative α and Li importance to DPA ?

^{10}B n Capture Reaction

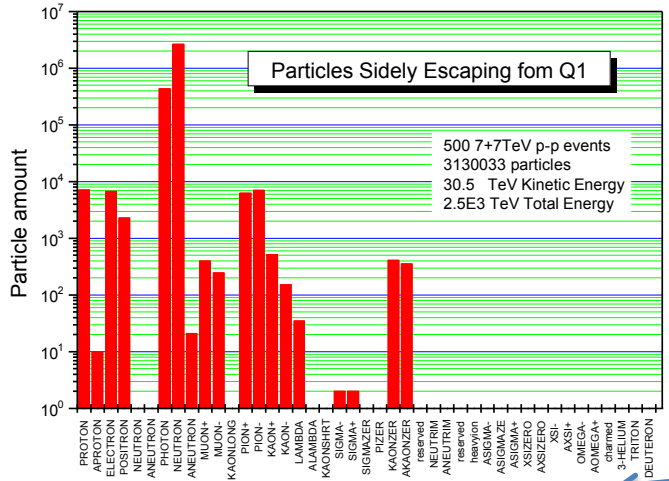
$$n + {}^{10}_{5}B \rightarrow {}^{11}_{5}B^{*} \begin{cases} {}^{7}_{3}Li + \alpha \quad (6\%) \\ \quad 1.015\,MeV + 1.777MeV \\ {}^{7}_{3}Li^{*} + \alpha \rightarrow {}^{7}_{3}Li + \gamma + \alpha \quad (94\%) \\ \quad 0.84\,MeV \quad + \quad 0.48\,MeV \quad + \quad 1.47MeV \end{cases}$$

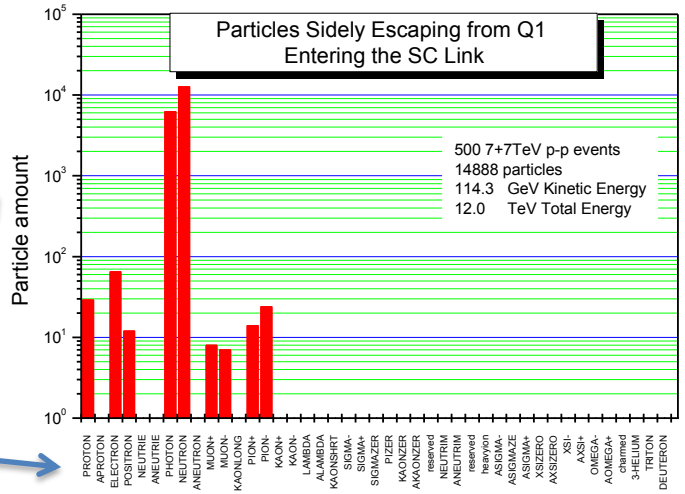


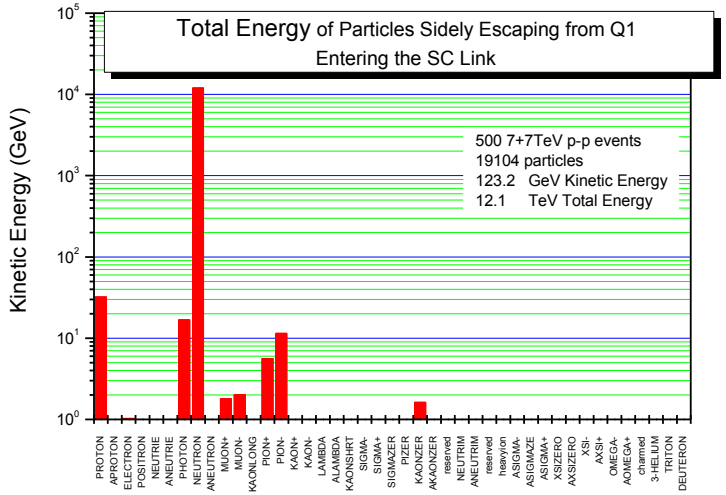
How many neutrons impinge on how many ^{10}B nuclei ? (and react)

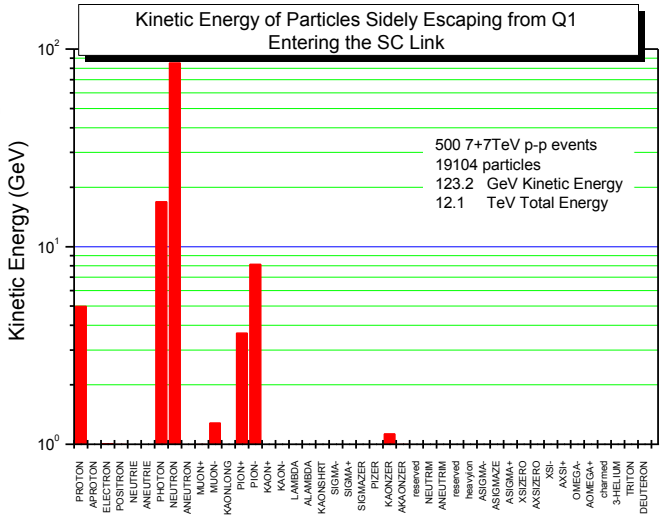
Particles entering the SC Link

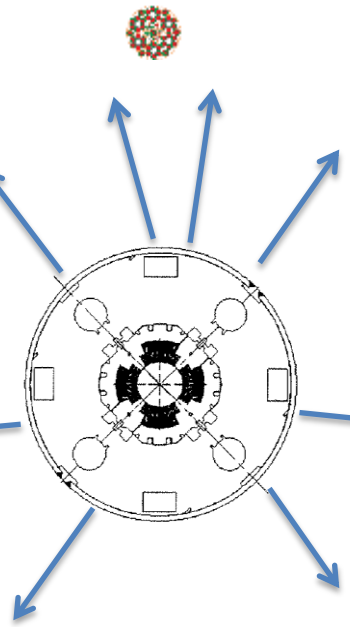
(1 m above Q1)







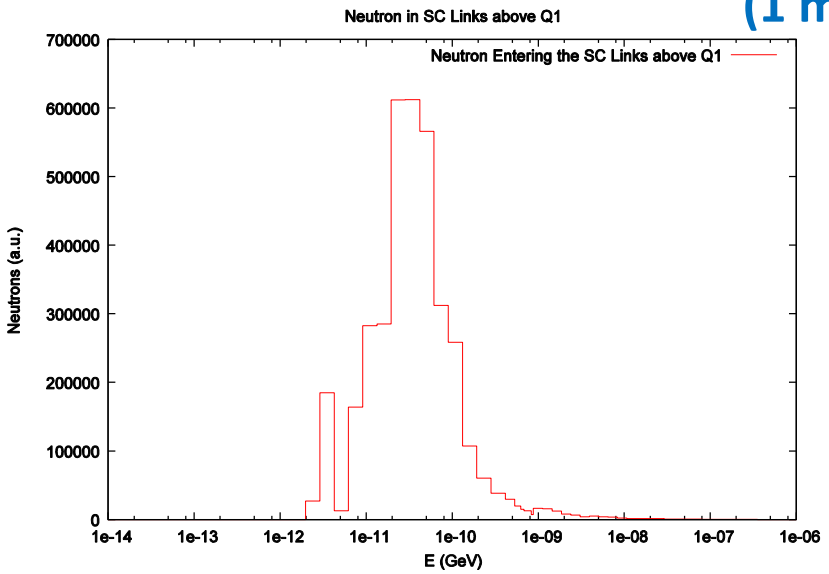




Data refer to 500 p-p 7 TeV events

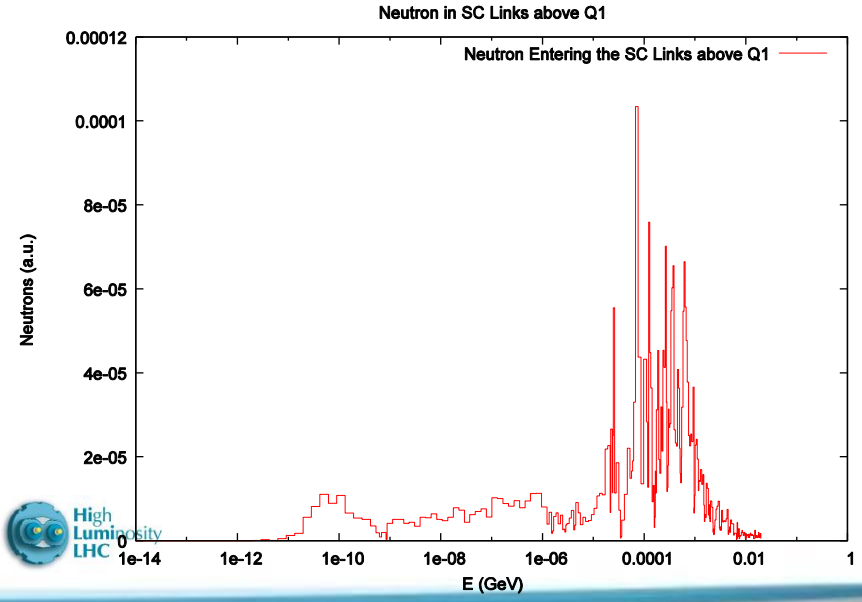
Neutrons Entering the SC Link

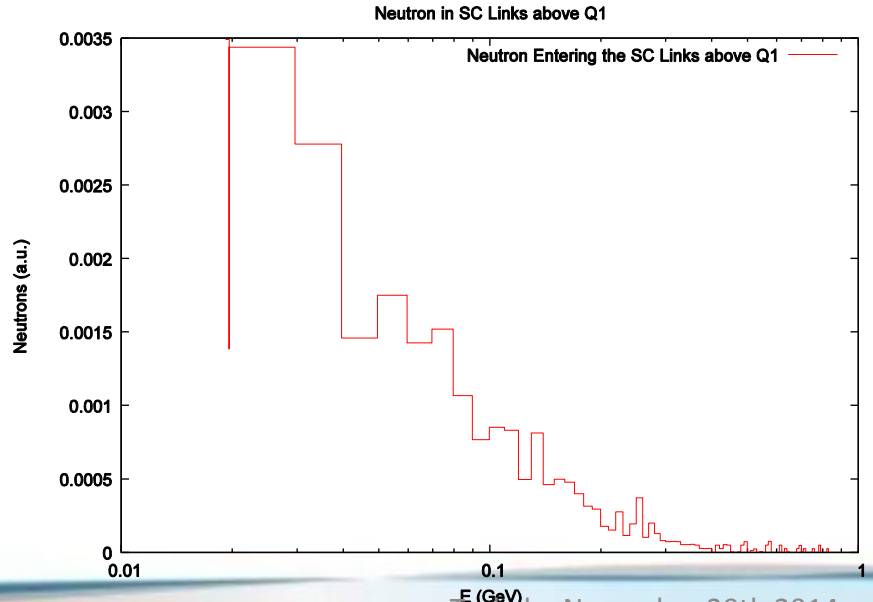
(1 m above Q1)



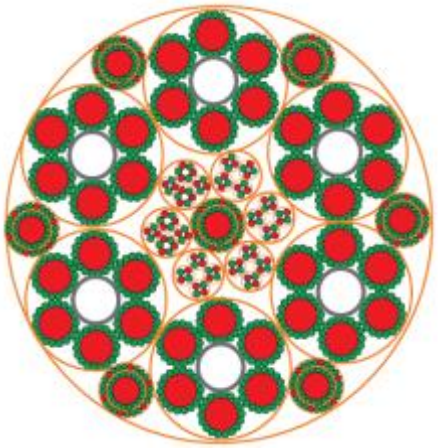
From the previus plot follows

$$12707 \ \frac{3\times10^{17}}{500} \sim 7.6 \times 10^{18} \quad \text{Neutrons}$$





Number of ^{10}B Target in the SC Link



Φext ~ 65 mm

Cu

MgB_2 , Φ = 0.85 mm

18 MgB_2 wires
Φ = 6.5 mm

Considering 1 m Link length
S=33.2 cm^2
Being M=45.93 g/mol the MgB_2 molar mass and
ρ=2.57 g $cm^{-3}$the density

Material composition of the cable

MATERIAL	ATOM CONTENT	PARTIAL DENSITIES (g/cm^3)
MAGNESIUM	0.1225	0.2192
BORON	0.24501	0.195
COPPER	0.48231	2.2563
HYDROGEN	2.03E-02	1.51E-03
CARBON	4.88E-02	4.31E-02
NITROGEN	4.07E-03	4.19E-03
OXYGEN	1.02E-02	1.20E-02
HELIUM	8.89E-03	2.62E-03
IRON	4.05E-02	0.16655
NICKEL	5.55E-03	2.40E-02
CHROMIUM	1.19E-02	4.55E-02

$$\frac{\rho}{M}A = \frac{2.57}{45.93}6.022 \cdot 10^{23} = 3.37 \cdot 10^{22}$$

Pure MgB_2 atoms cm^{-3}

$$3.37 \cdot 10^{22} \times 33.2 \times 100 \times 2 \times 0.245 \times 0.2 = 1.1 \times 10^{25}$$

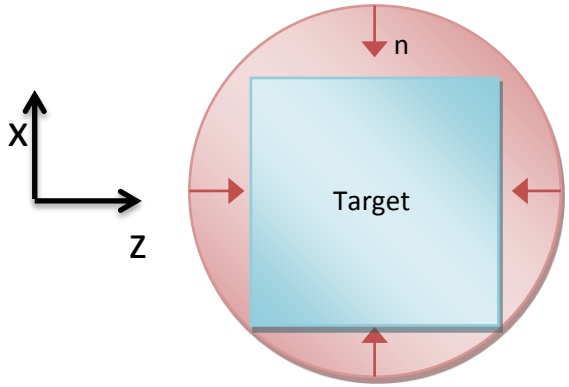
^{10}B atoms m^{-1}

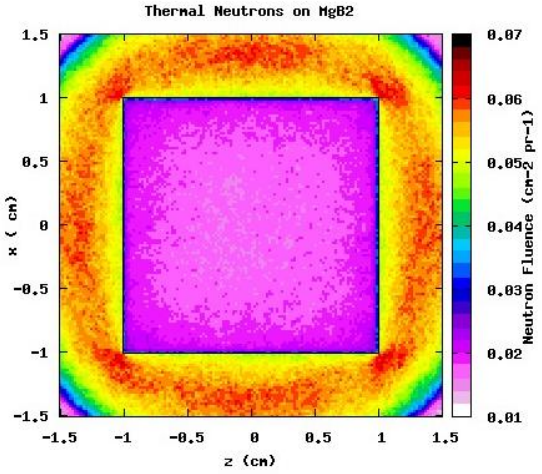
Much higher than 7.6 x 10^{18} and even supposing 1 capture reaction per neutron the ^{10}B consumption is negligible

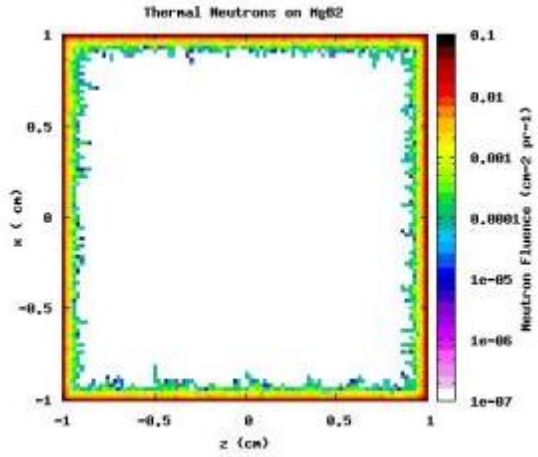
Neutrons on MgB_2 Simulations

- MgB_2 with natural composition of B (80% ^{11}B – 20% ^{10}B)

Thermal Neutrons (isotropic source) **TARGET (2x2x2 cm^3)**

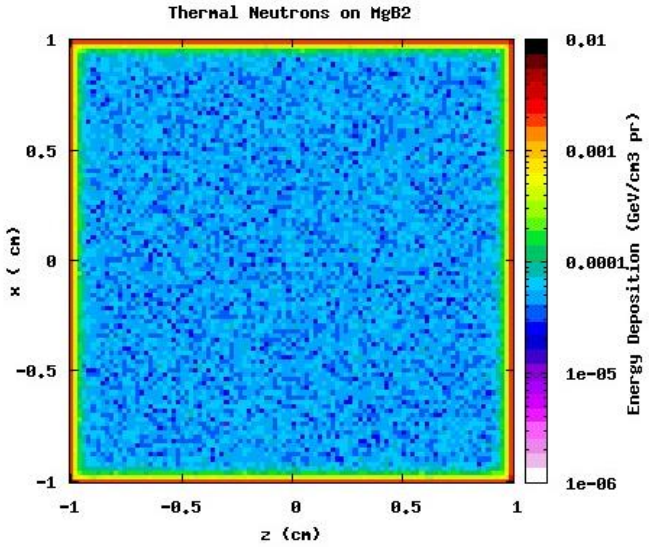




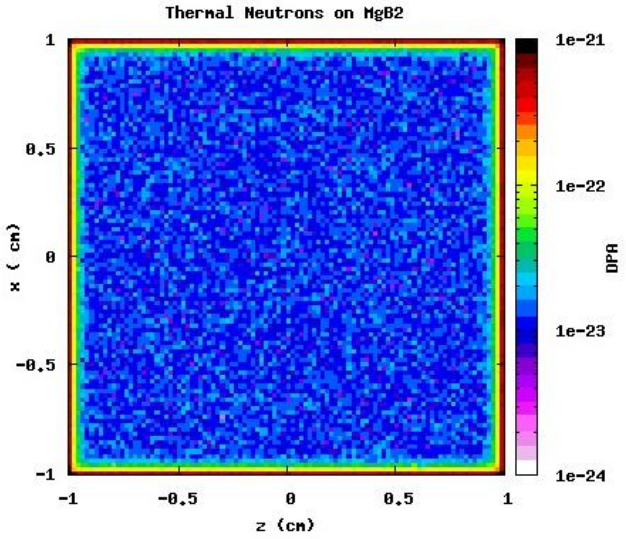


Central section: neutrons react at the surface

Energy Deposition and DPA



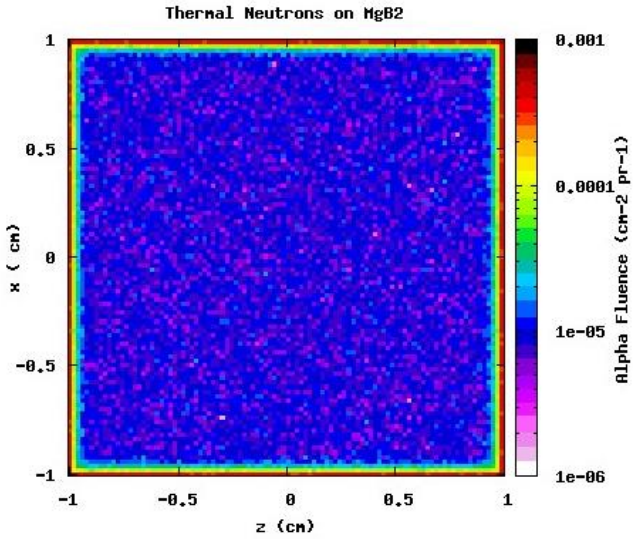
Energy Deposition
1.11E-03(±0.03%) GeV/pr

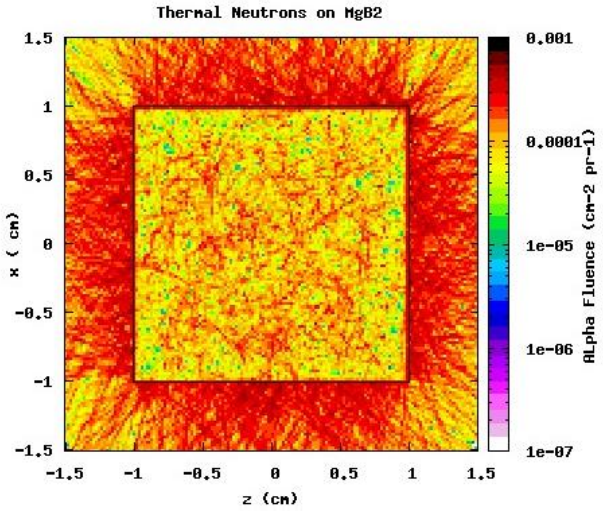


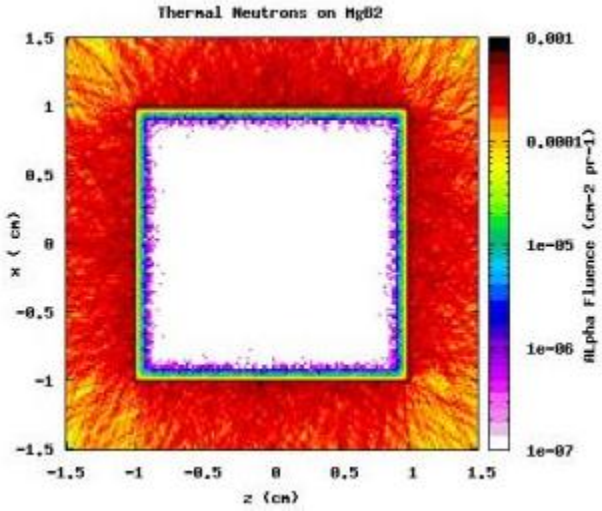
DPA
2.93E-22 (±0.03%)

DPA is related to Energy Deposition

α Fluence



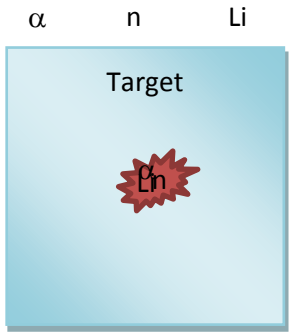


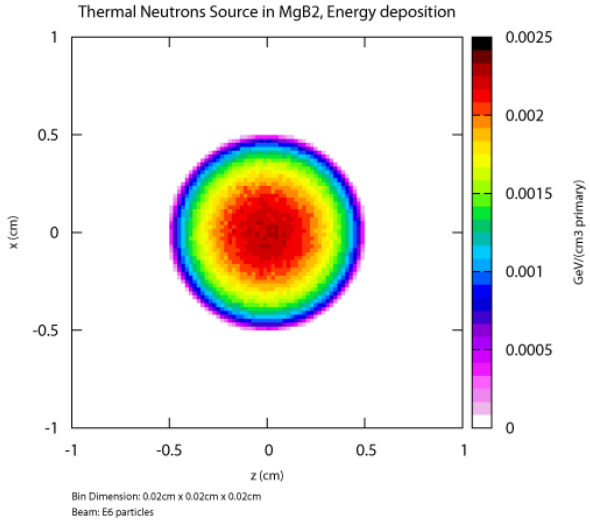


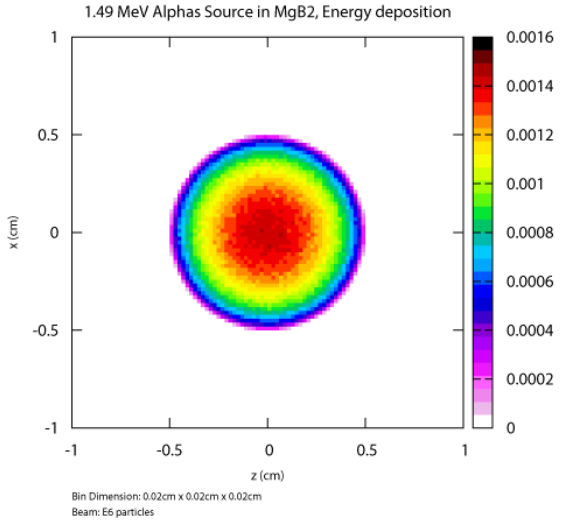
Reactions occurring at the surface cause a high fluence of alfa particle outside

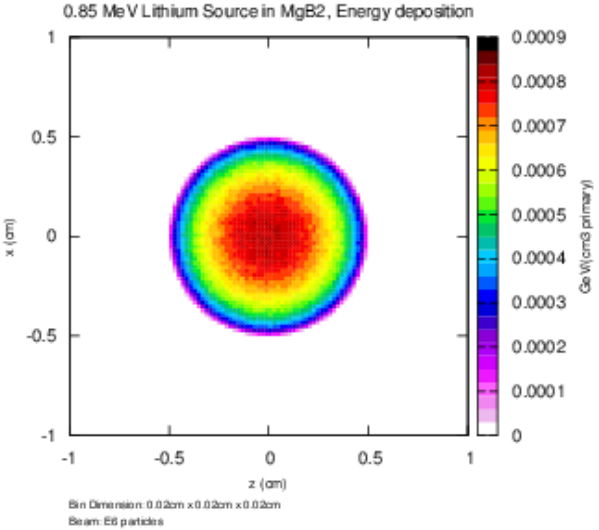
Single contribution (of α and Li)

Simulation with single internal isotropic source

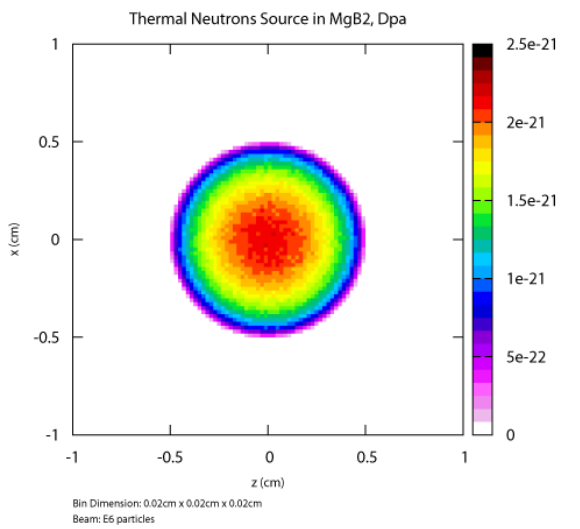


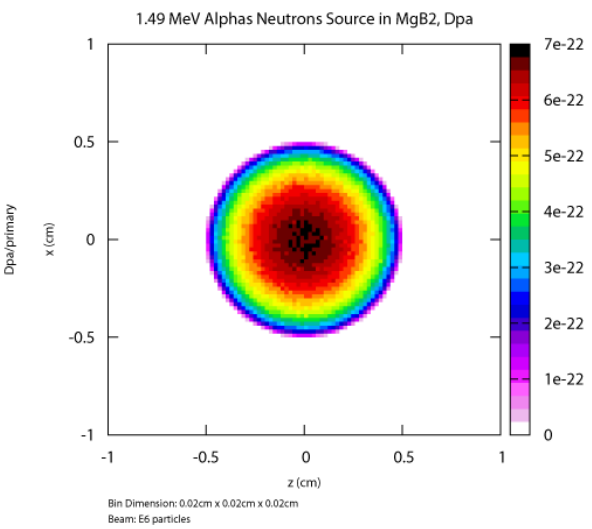


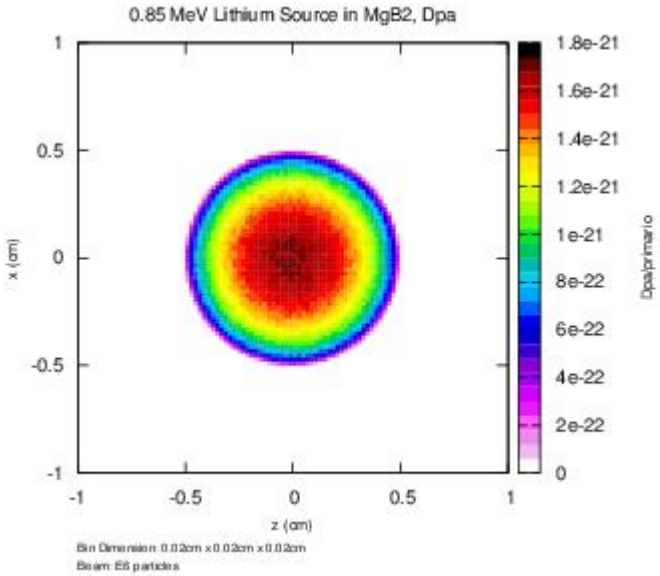




Single contribution (of α and Li)







	Max Dpa [dpa/primary] ± Err%	Mean Dpa [dpa/primary] ± Err%
Alpha	$1.86 \cdot 10^{-21} \pm 6.1$	$8.94 \cdot 10^{-23} \pm 0.03$
Lithium	$4.58 \cdot 10^{-21} \pm 6.8$	$2.215 \cdot 10^{-22} \pm 0.03$
Neutron	$5.94 \cdot 10^{-21} \pm 5.8$	$2.797 \cdot 10^{-22} \pm 0.03$

Single contribution (of α and Li)

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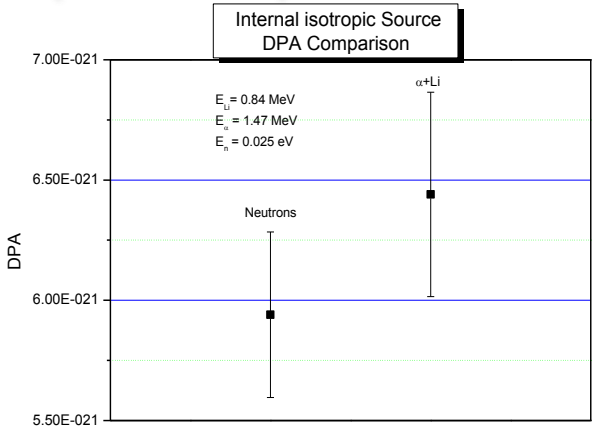


Max DPA : α+Li = $1.86 \cdot 10^{-21} + 4.58 \cdot 10^{-21} = 6.44 \cdot 10^{-21}$

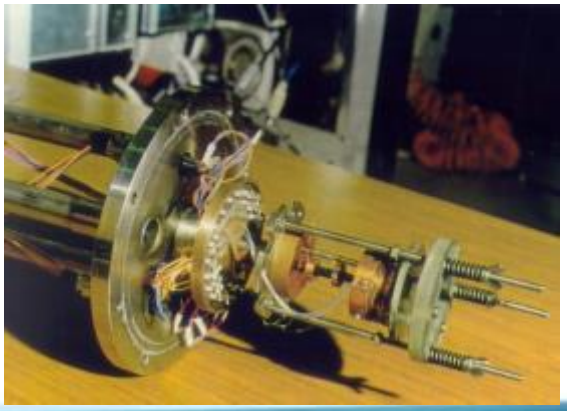
Mean DPA : α+Li = $8.94 \cdot 10^{-23} + 2.215 \cdot 10^{-22} = 3.109 \cdot 10^{-22}$

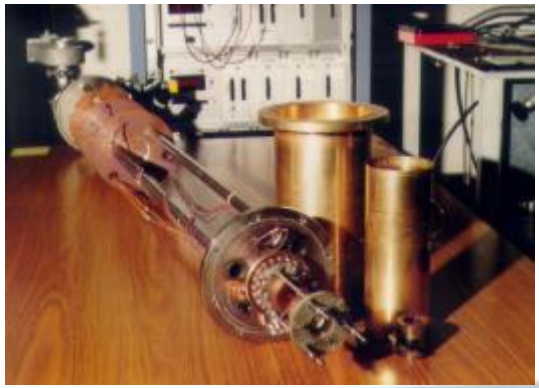
The contribution to DPA from alpha and Lithium is overestimated because we assume that every neutron reacts with ^{10}B realizing one Li and one alpha particle. Actually it not always happens (only 94%)

The study shows that the Lithium contribution to DPA is higher than alpha one being about 71.3% (and 28.7% from alpha).
Massive and slow particles induce more DPA

Conclusions and Perspectives

- MgB_2 neutron *damage* is not a concern about the performance of the SC Links.
  - Irradiation tests vs. simulations comparison
  - Code benchmarking and **correlations with DPA**
- WP6.4 is Energy Deposition and Material Studies Thermal conductivity measurements





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