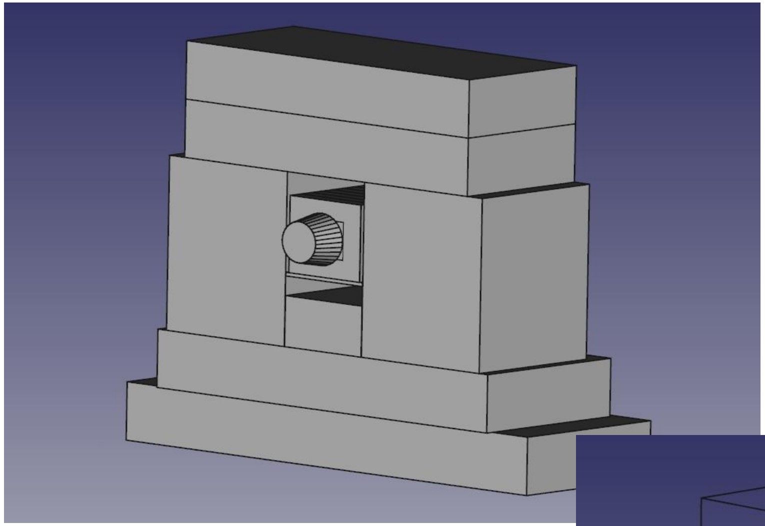
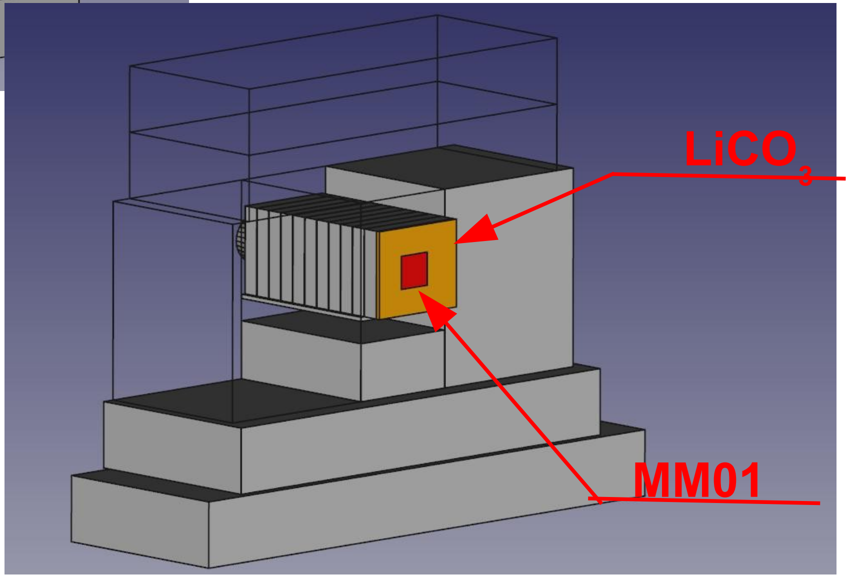
Fluka simulations for DY 2018 run

- Overview
- Neutron capture
- Simulations
- Suggestions
- conclusions

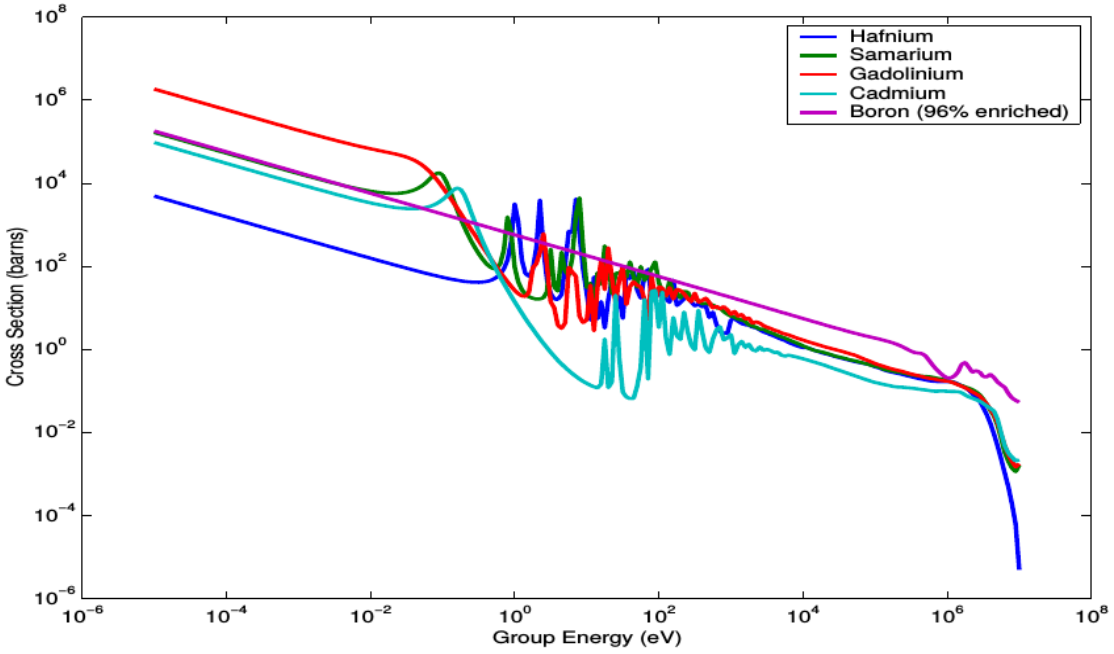


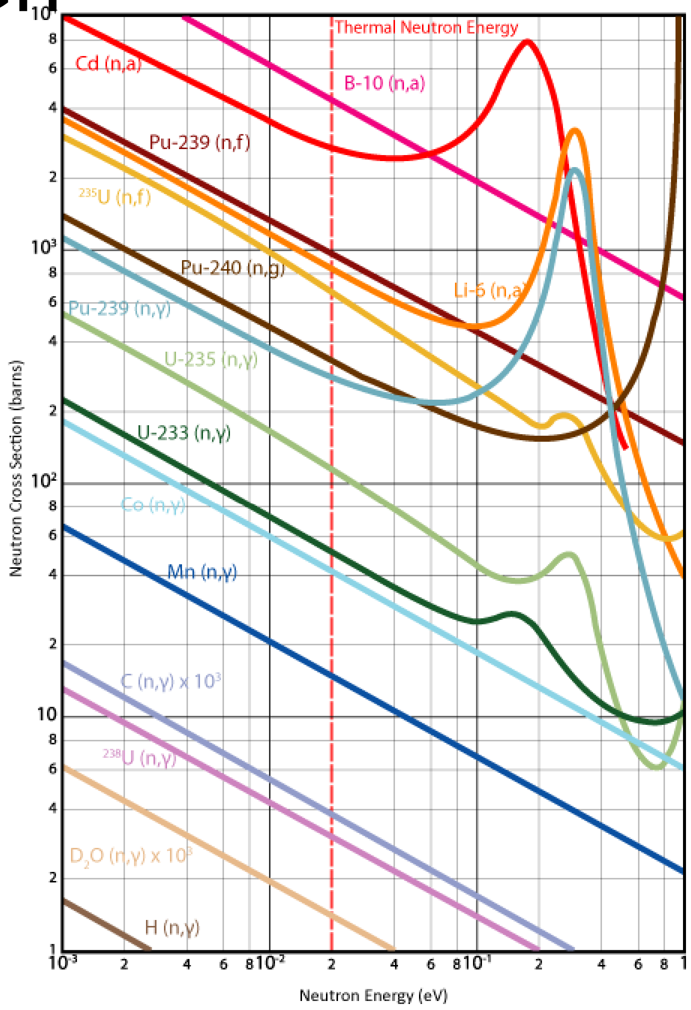


Neutrons capture materials possible candidates

- The neutrons absorber candidate are:
  - ^{6}Li
    - Cross section at 2200 m/s: 940 barn
    - Natural abundance: 7,5%
    - $^{6}Li+n\rightarrow t(2.05\,MeV)+\alpha(2.73\,MeV)$
  - ^{10}B
    - Cross section at 2200 m/s: 3839 barn
    - Natural abundance: 19.9%
    - $^{10}B+n\rightarrow {}^{7}Li(0.84\,MeV)+\alpha(1,47\,MeV)\ldots(93.7\,\%)$
    - $\quad\hookrightarrow {}^{7}Li\rightarrow {}^{7}Li(1.02\,MeV)+\gamma(1.78\,MeV)$
    - $^{10}B+n\rightarrow {}^{7}Li(1.02\,MeV)+\alpha(1.78\,MeV)\ldots(6.3\,\%)$
  - ^{113}Cd
    - Cross section at 2200 m/s: 20600 barn
    - Natural abundance: 12.2%
    - Many with γ and α emission
  - ^{155}Gn and ^{157}Gn
    - Cross section at 2200 m/s: 61100 and 259000 barn
    - Natural abundance: 14.8% and 15.7%
    - Many with γ and α emission

Possible alternatives
Li – B – Cd - Gn





Neutrons absorption cross section (thermal neutrons)

	Composition/Z	A	Neutrons absorption cross section at 2200 m/s [barn]	Density [g/cm³]	Mean free path [cm]
^{6}Li	Z = 3	6.015	940	0.534	$1.99*10^{-2}$
^{7}Li	Z = 3	7.016	0.0454	0.534	$4.81*10^{2}$
^{10}B	Z = 5	10.013	3835	2.08	$2.08*10^{-3}$
^{11}B	Z = 5	11.004	0.0055	2.08	$1.60*10^{2}$
^{155}Gd	Z = 64	134.95	61000	7.88	$4.66*10^{-4}$
^{157}Gd	Z = 64	136.94	259000	7.88	$1.11*10^{-4}$
nat Gd	^{155}Gd(14.8%)+^{157}Gd(15.7%)	157.25	42568	7.88	$7.78*10^{-4}$
nat Li	^{6}Li(7.4%)+ ^{7}Li(92.6%)	6.94	70.5	0.534	$3.06*10^{-1}$
nat B	^{10}B(20%)+^{11}B(80%)	10.81	767	2.08	$1.13*10^{-2}$
$LiCO_3Si$	^{6}Li(95%)+^{7}Li(5%)			1.36	$1.15*10^{-1}$
Borated Polyeth	B(30%)+PolyEth(70%)			1.19	$4.04*10^{-2}$

Macroscopic cross section and mean free path

Macroscopic cross section (so called ???**)**

$$\Sigma = \sum_i P_i N_i \sigma_i$$

P_i = percentage in mass of ith element

N_i = number of nuclei per cm^3 of the i^{th} element

σ_i = microscopic cross section of i^{th} element

$$N_i = \frac{\rho * N_A}{M}$$

ρ = density [g/cm^3]

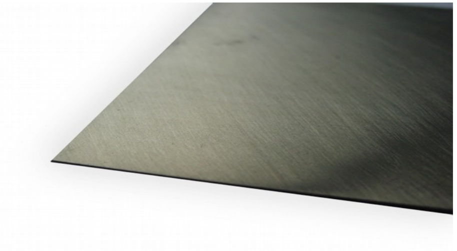
N_A = Avogadro number ($6.022*10^{23}$ atoms/mole)

M = atomic weigth [g/mole]

Mean free path

$$\lambda = \frac{1}{\Sigma}$$

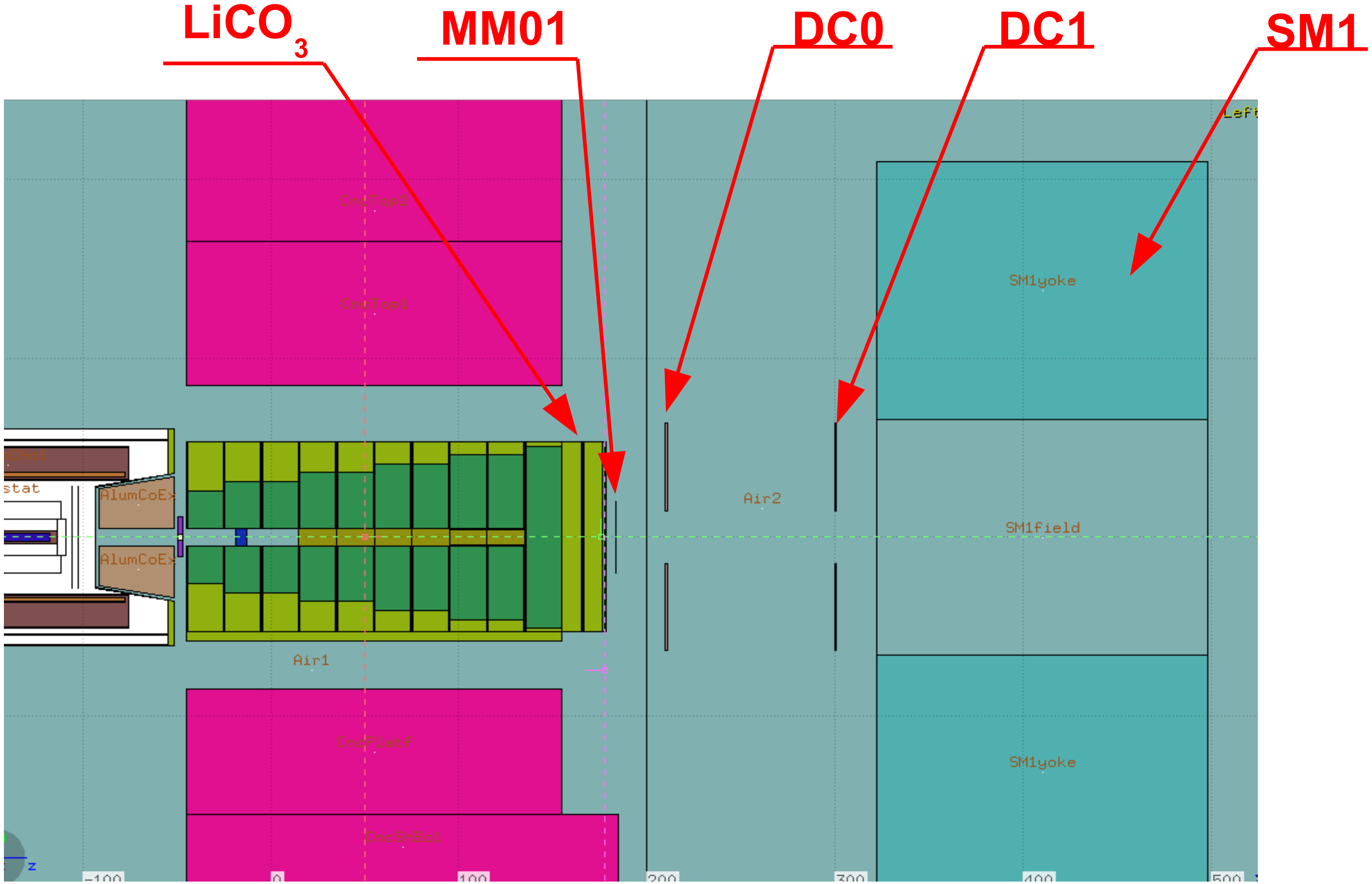
gadolinium



- is a silvery-white, malleable, and ductile rare earth metal
- is believed to be ferromagnetic at temperatures below 20 °C and it is strongly paramagnetic above this temperature.
- demonstrates a magnetocaloric effect whereby its temperature increases when it enters a magnetic field, and decreases when it leaves the magnetic field.
- Melting point: 1312 ^{o}C
- Density: 7.9 g/cm^3
- Commercial material
- Non toxic
- Is widely used as a burnable absorber in nuclear power plants; gadolinium is very effective in compensation of the excess of reactivity

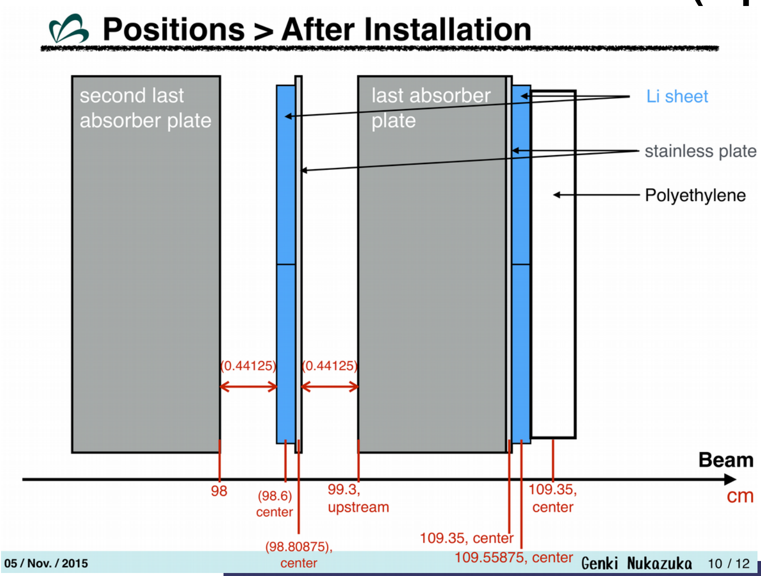
Check of availability, costs and delivered shape with specialized technicians and / or engineer. Check for enriched ^{157}Gn

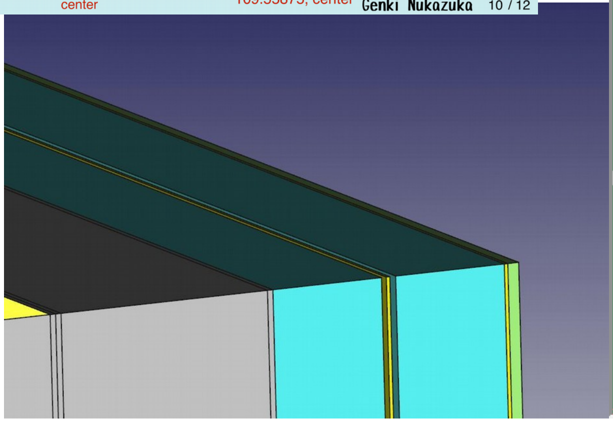
Configuration of 2015 run

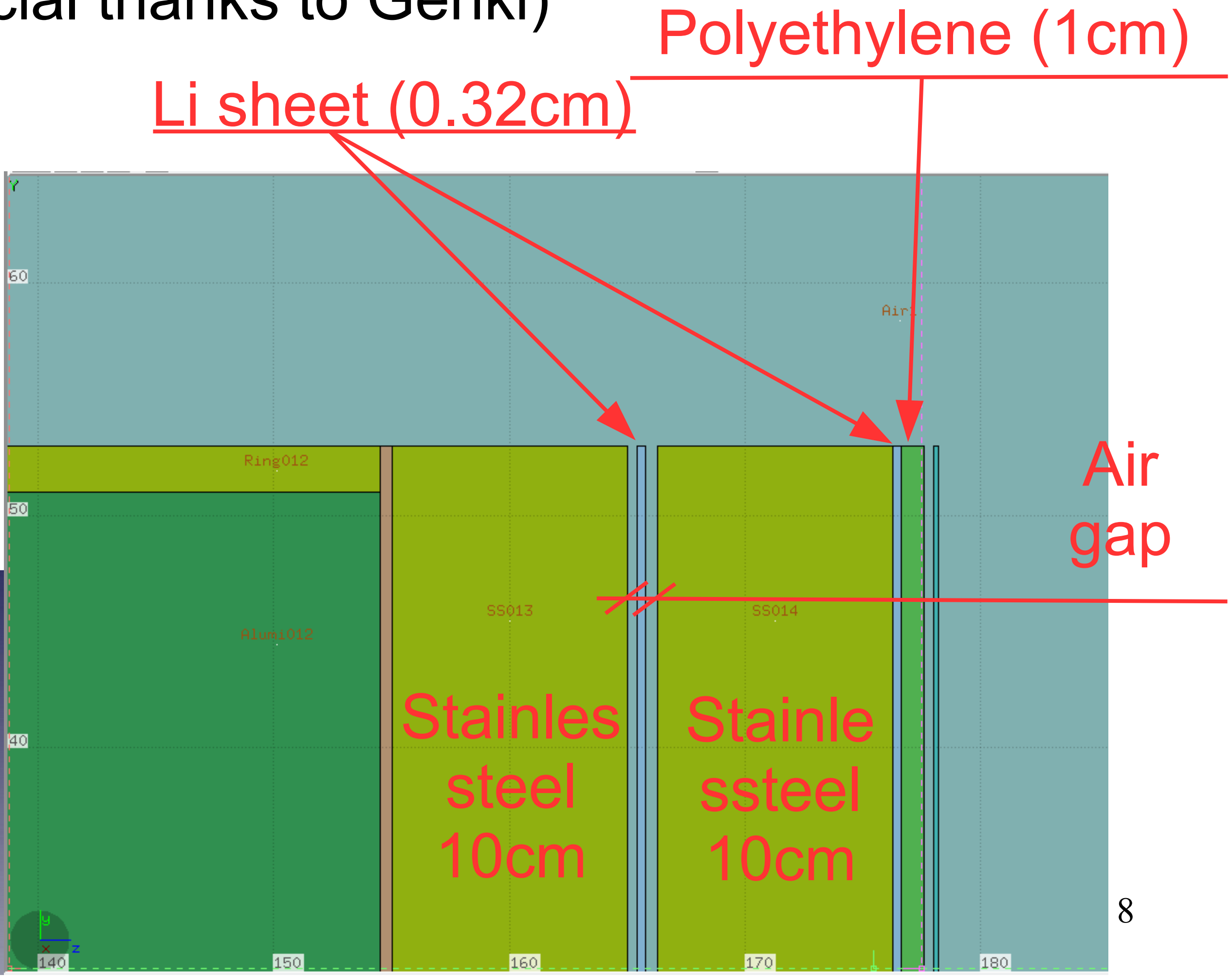


Run 2015 geometry

(special thanks to Genki)

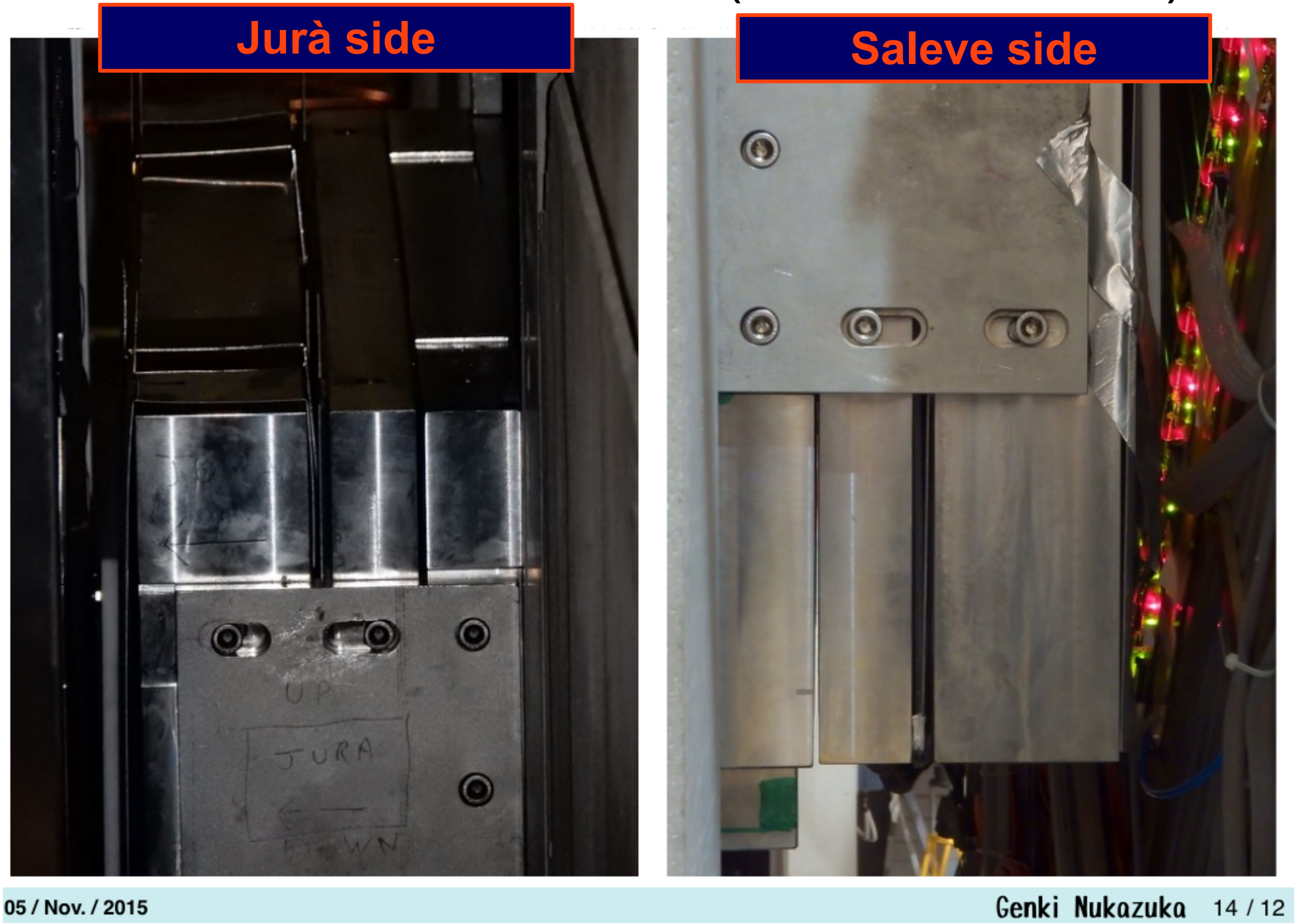






Pictures

(thanks to Genki)



2015 run guidelines

Maximum flexibility to control the particle flux downstream using different stainless steel thickness

0 cm
5 cm
10 cm
15 cm
20 cm

Material budget
(thanks to Genki)

Specification of Li_2CO_3 & Si Rubber Sheet

- Dimension : 59 cm × 55 cm × 0.3175 cm
- Density : 1.36 g/cm^3

	A	Z	Mass ratio (^{6}Li vs ^{7}Li)	Mass ratio (Li_2CO_3)	Mass ratio (Li_2CO_3 vs Si)	Mass ratio
^{6}Li	6	3	95.00	18.79	30	5.354
^{7}Li	7	3	5.00			0.282
C	12.01	6		16.25		4.876
O	16.00	8		64.96		19.49
Si	28.09	14			70	70.00

~~05 / Nov. / 2015~~ → updated on 02 / Dec. / 2015 Genki Nukazuka 5 / 12

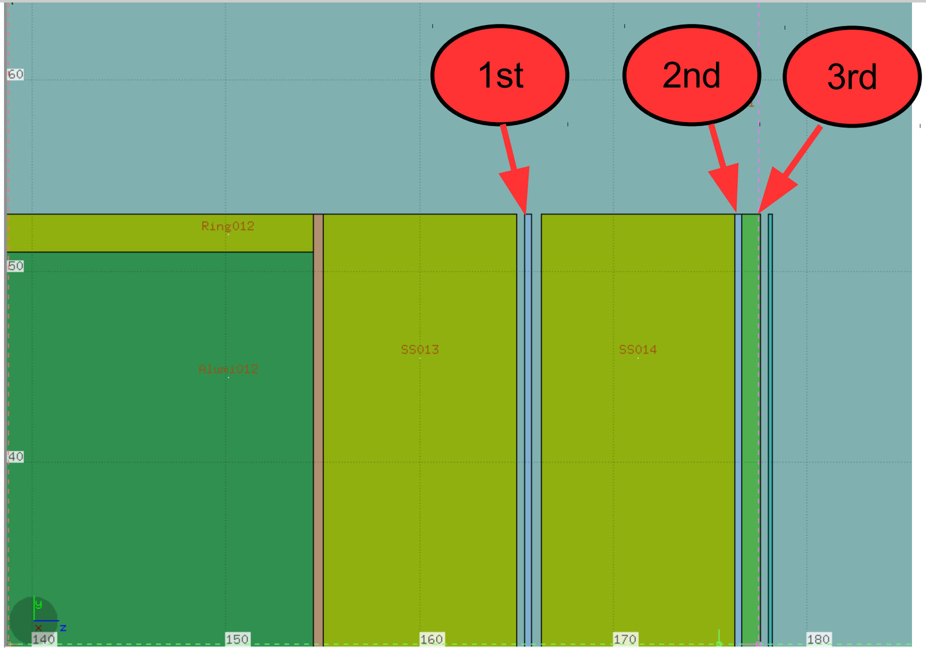
Polyethylene

n * (C_2H_4)

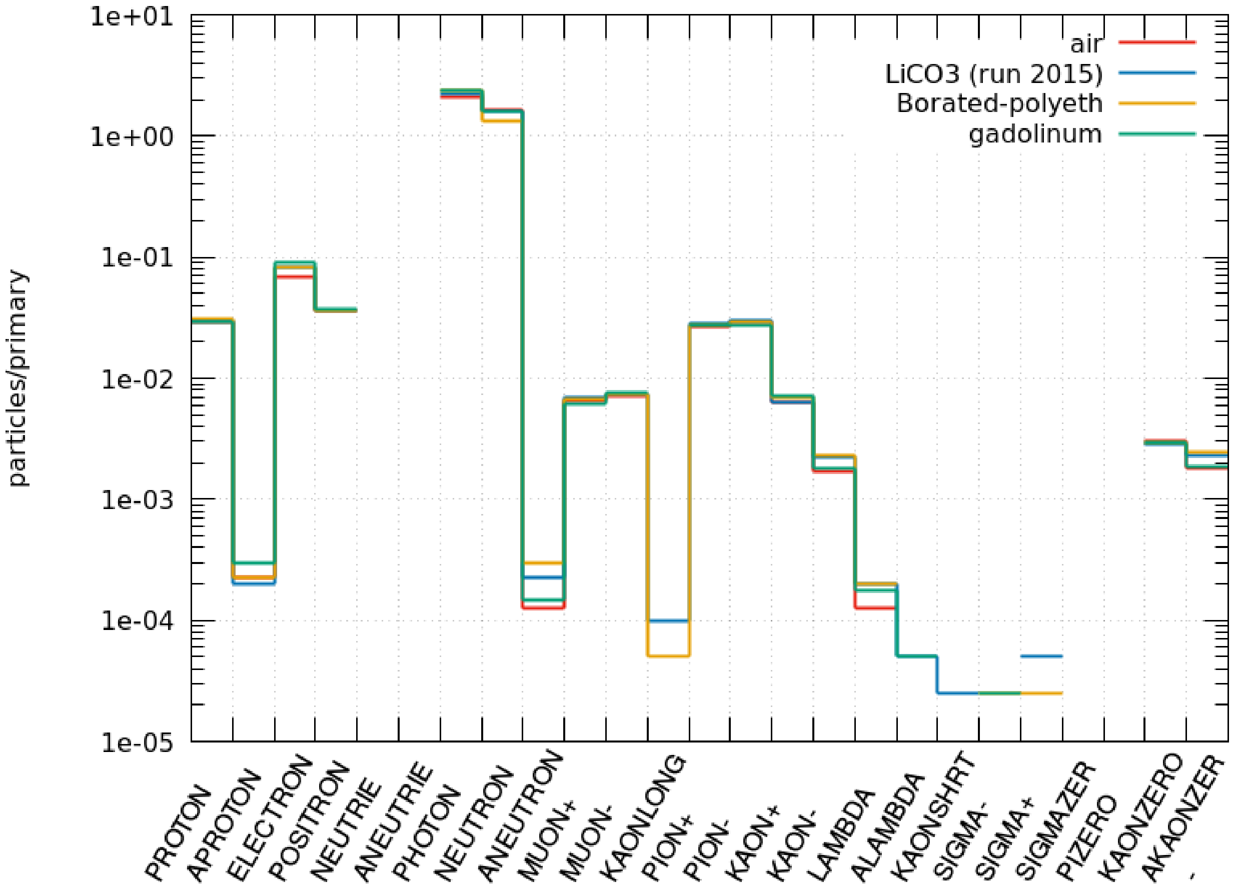
Density: 0.94 g/cm^3

Simulations

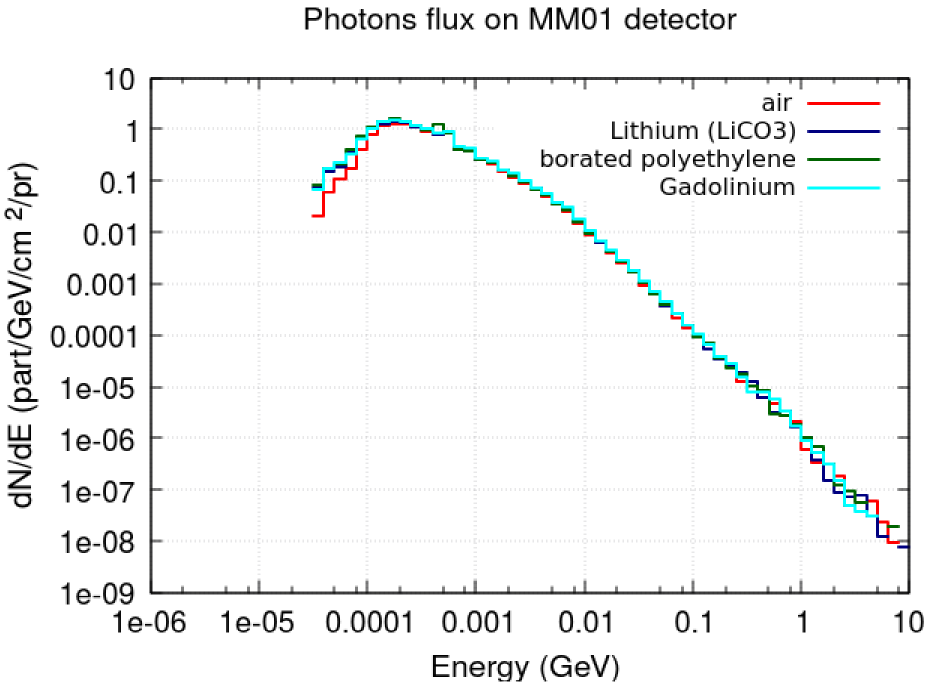
name	Additional sheet	1st sheet	2nd sheet	3rd sheet
		cm	cm	cm
MM01-ntg-10	Air (2015 configuration)	0.32 air	0.32 air	1 air
MM01-ntg-11	Lithium carbonated + polyethylene	0.32 Li	0.32 Li	1 polyeth
MM01-ntg-12	Borated polyethylene (B = 30%)	0.32 Bpol	0.32 Bpol	1 Bpol
MM01-ntg-13	gadolinium + polyethylene	0.32 Gd	0.32 polyeth	1 polyeth

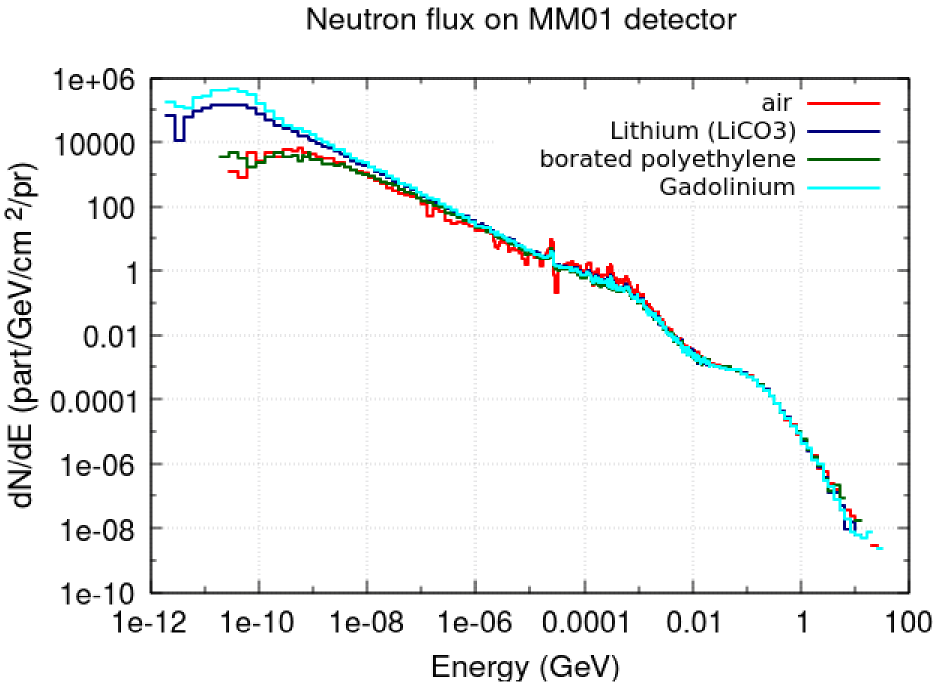


MM01
flux of various particles



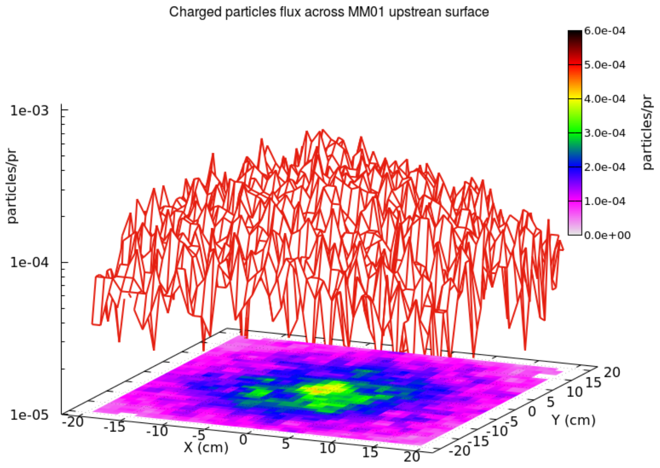
MM01
Energy of particles

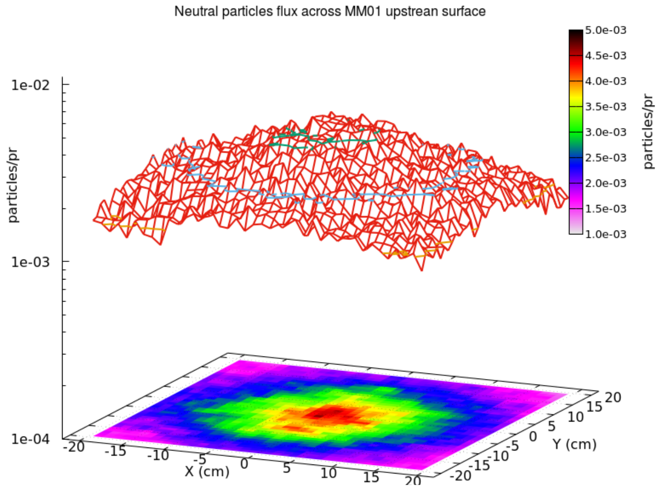




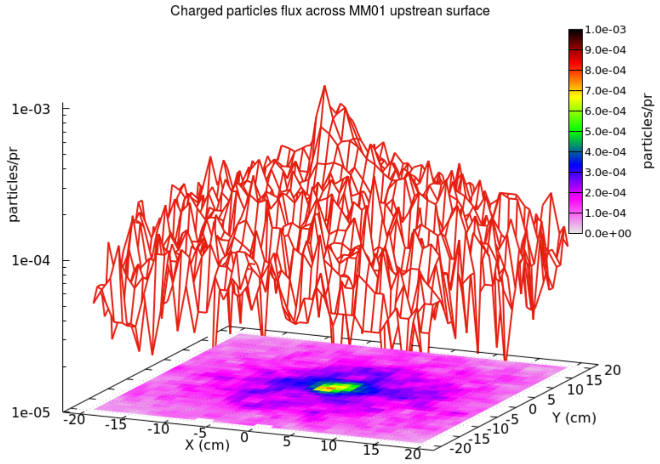
MM0-ntg-10 and 11 crossing point

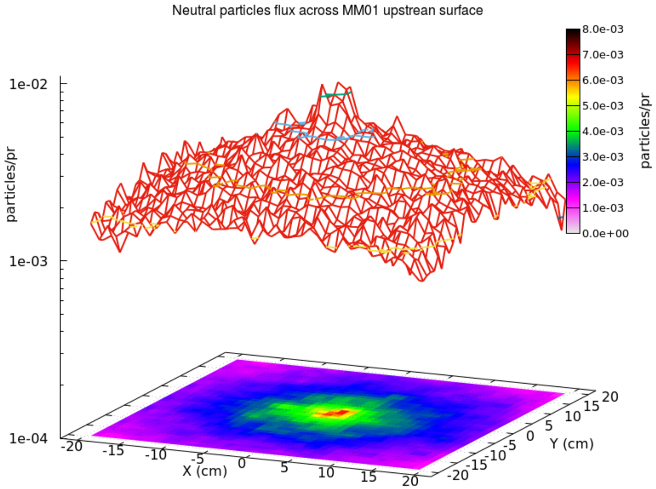
10 air



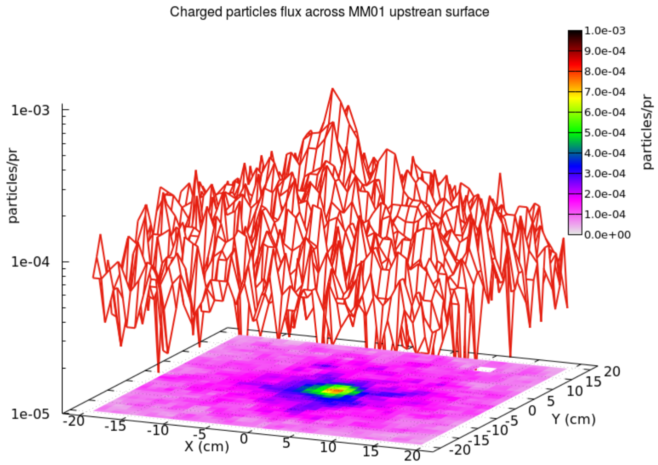


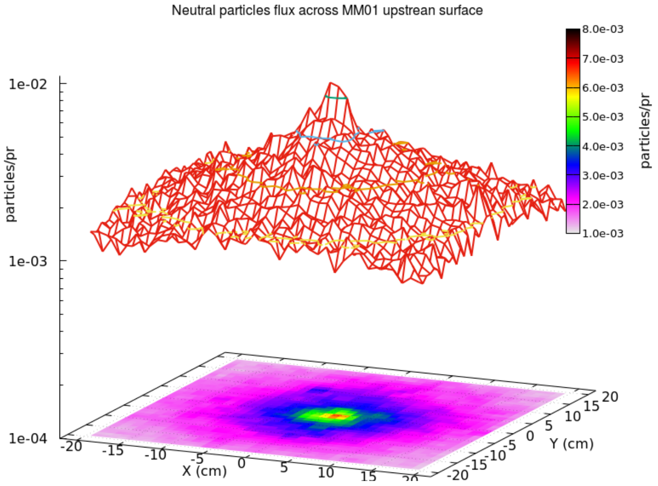
11 Li





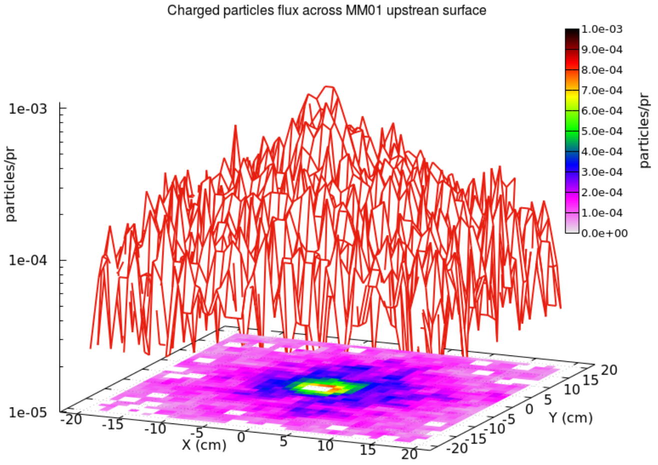
MM0-ntg-12 and 13 crossing point

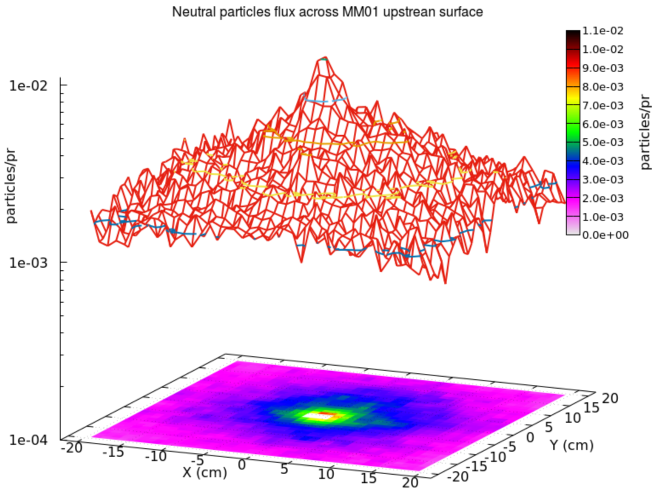




12 Borated polyethylene

13 gadolinium polyethylene





Summary of simulations

simulation	Additional sheet	Thickness [cm]	phot/Pr	neutron/Pr	e^-/Pr/cm^2	charg/Pr
MM01-ntg-10	Air (run 2015)	0.32+0.32+1	2.145	1.762	0.109	0.219
MM01-ntg-11	Carbonated Lithium + polyethylene (run 2015)	0.32+0.32+1	2.259	1,600	0.119	0.230
MM01-ntg-12	Borated polyethylene (B = 30%)	0.32+0.32+1	2.383	1.328	0.108	0.230
MM01-ntg-13	Gadolinum+ polyethylene	0.32 + 1.32	2.411	1.616	0,127	0.234

Neutral = neutrons + photons + other

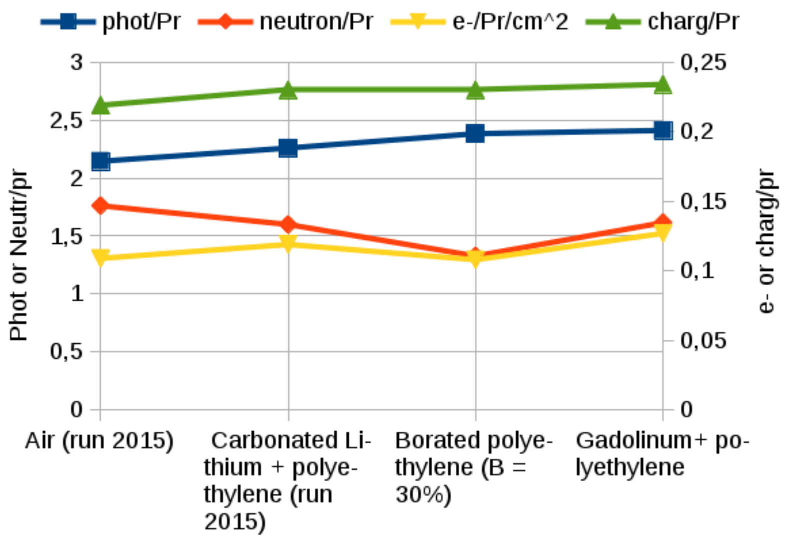
Check with standard flka scoring

Neutrons crossing MM1

- Lithium -9%
- Borated polyethylene -25%

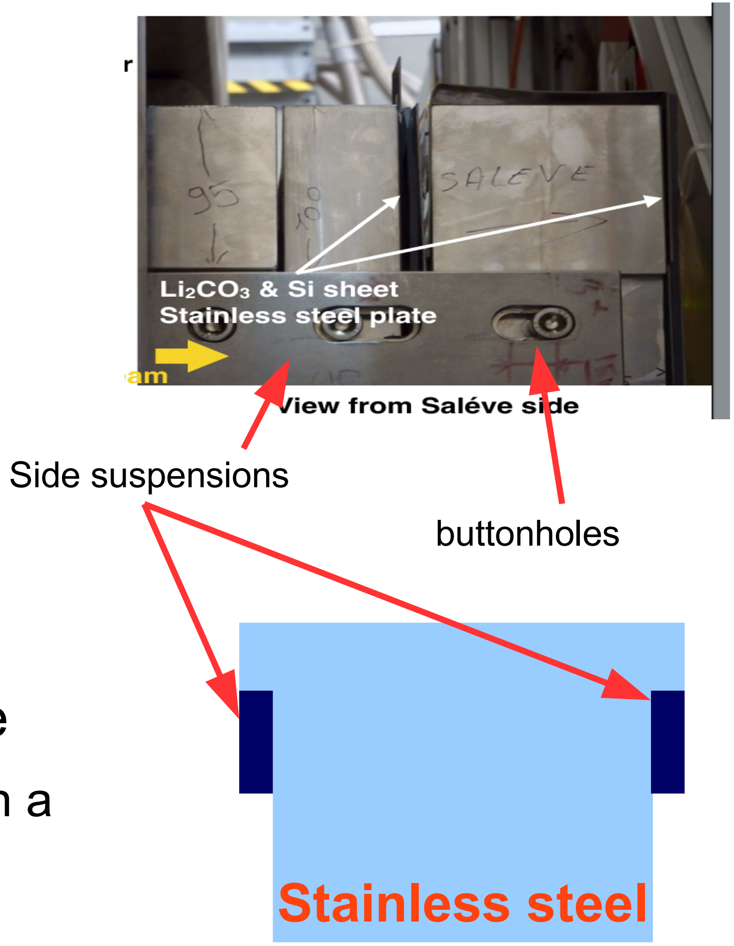
Photons crossing MM1

- Lithium +5%
- Borated polyethylene +11%



Suggestions
from cheap to expensive

- Reshouffle the downstream stainless steel layers
  - Motivation: leave more material in the neutron source direction
    - Now: 5cm + 5cm + airgap + 10cm
    - Reshouffled: 10cm + 5cm + airgap + 5cm
  - Check the side bar suspensions and its buttonholes
- Remove the downstream Li layer and polyethylene
  - Simply wrong: always, put the moderator first and then a neutron absorber
- Replace the side suspensions with longer one
  - Leave more air gap between the last two layers
- Use natural borated polyethylene instead of Li



conclusions

- No impressive neutrons reduction even with the best neutrons absorbers (in theory)
- No relevant difference in XY distribution
- For neutrons flux reduction, borated polyhethylene is better than carbonated lithium sheet
- For photons flux reduction, carbonated lithium is better tha borathed polyethylene
- Check of vertex, momentum resolution etc, must be done using the standard Compass simulations tools.

But the basic question is:
The high rates is due to neutrons or photons interaction?

γ interaction with matter

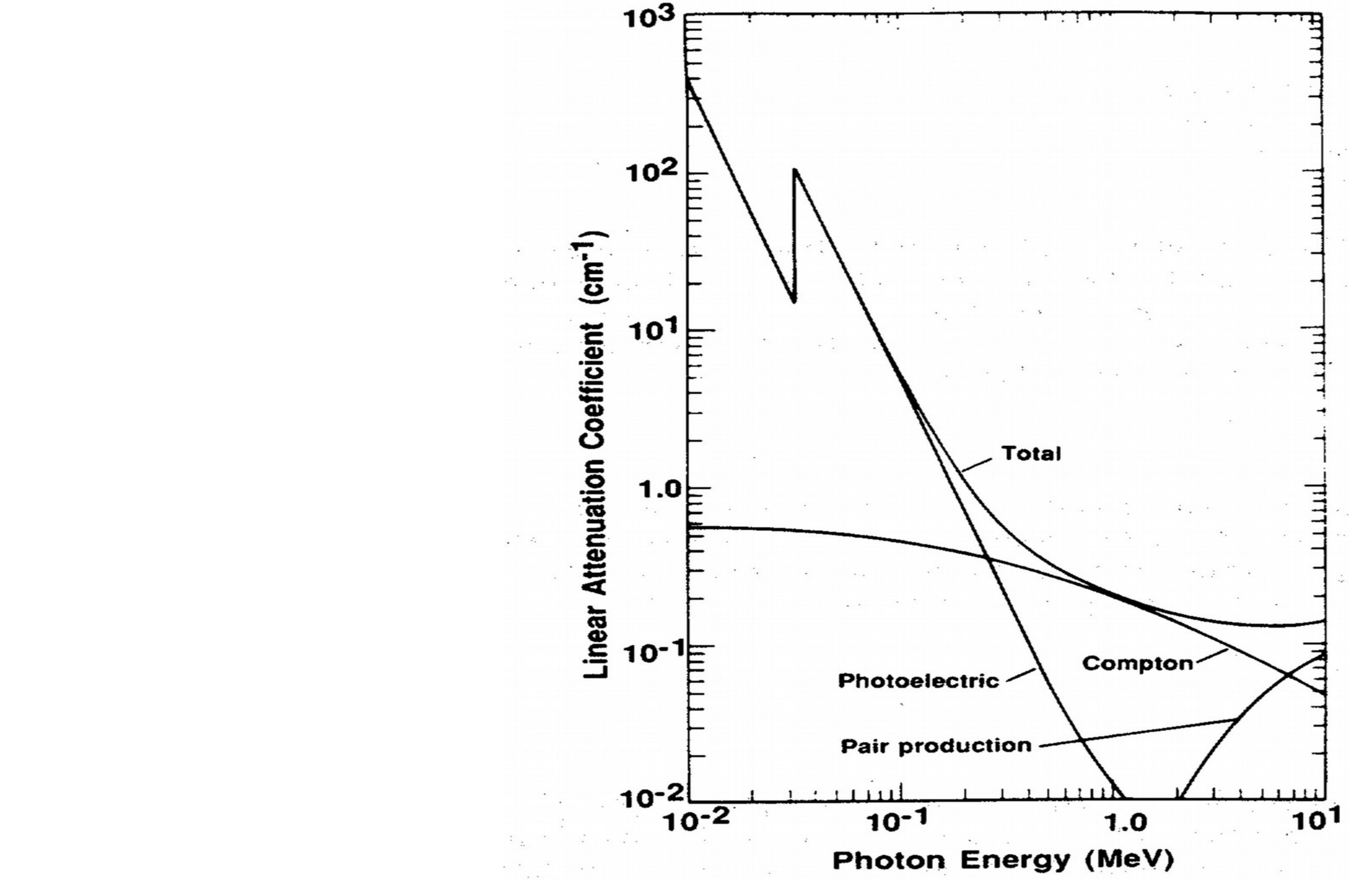


Fig. 2.3 *Linear attenuation coefficient of NaI showing contributions from photoelectric absorption, Compton scattering, and pair production.*

γ interaction with matter

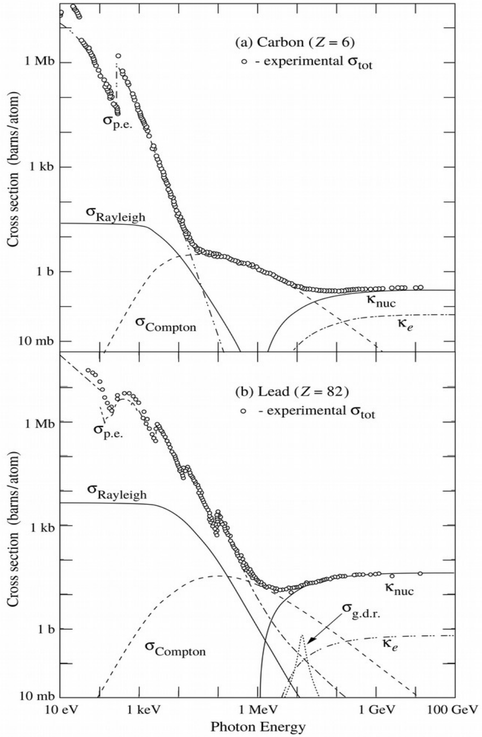


Figure 32.15: Photon total cross sections as a function of energy in carbon and lead, showing the contributions of different processes [51]:

$\sigma_{\text{p.e.}}$ = Atomic photoelectric effect (electron ejection, photon absorption)
σ_{Rayleigh} = Rayleigh (coherent) scattering–atom neither ionized nor excited
σ_{Compton} = Incoherent scattering (Compton scattering off an electron)
κ_{nuc} = Pair production, nuclear field
κ_e = Pair production, electron field
$\sigma_{\text{g.d.r.}}$ = Photonuclear interactions, most notably the Giant Dipole Resonance [52]. In these interactions, the target nucleus is broken up.

Original figures through the courtesy of John H. Hubbell (NIST).