Study the Radiation of A1N|D2N Experiment Using FLUKA

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March 19, 2018

Outline

Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

1) Experiment run condition:

30 uA, 11 GeV electron beam
12 amg gaseous helium3 target
~30 gauss holding field
A1N: <700 hours
D2N: <1000 hours

2) Geometry

3) FLUKA simulation result

4) Conclusion

Everything is safe!
Far below radiation budget!
All electronics and equipment are safe!

This talk will address this item: →

Hall C A_1^n (E12-06-110) and g_2^n (E12-06-121)
Experiment Readiness Review
Jefferson Lab March 2, 2018

Charge

1. What are the running conditions for both experiments? Please state clearly the maximum current being used and the target dimensions.
2. What is the operational status/performance requirements of the equipment needed by the experiments. Precisely:
   a) 3He target
   Provide the targets configuration needed, performance requirements and status.
   b) Laser system
   Provide the laser system configuration needed, the operation and safety (including documentation) and status.
   c) Moller and Compton beam polarimeters
   Demonstrate that polarimetry is expected to provide a precision of $\Delta P_b/P_b < 1\%$
   If the above elements are not already operational, what are the completion/commissioning schedules, tasks and user commitment?
3. Are the polarized target running configurations affected by the spectrometer fields? If yes, have the fringe field effects been properly mitigated?
4. Has the entire beam line, spectrometers, detector configuration been defined, including ownership, maintenance and control during beam operations?
5. Are the responsibilities for carrying out each job identified, and are the manpower and other resources necessary to complete them on time in place?
6. Are the beam commissioning procedures and machine protection systems sufficiently defined for this stage?
7. Are the radiation levels expected to be generated in the hall acceptable? Is any local shielding required to minimize the effects of radiation in the hall equipment?
8. What is the status of the specific documentation and procedures (COO,

Radiation at Site Boundary

Hall: C **RADIATION BUDGET FORM** *page:* 1 of 1

Exp. # Pol.He3 **rev:** **run dates: 2019** **name of liaison: B. Sawatzky**

E12-06-107,E12-06-121

setup number			1	2	3	4	5	6	
beam	energy	GeV	11.0	11.0	11.0	2.2	2.2	2.2	*totals:*
	current	uA(CW)	30.0	30.0	50.0	30.0	30.0	50.0	
exp't	element		He-3	N	C	He-3	N	C	
target	thickness	mg/cm2	50	465	200	50	465	200	
add'l	element		Si	Si		Si	Si		
target 1	thickness	mg/cm2	24	24		24	24		
add'l	element		O	O		O	O		
target 2	thickness	mg/cm2	28	28		28	28		
add'l	element		Be	Be	Be	Be	Be	Be	
target 3	thickness	mg/cm2	155	155	155	155	155	155	
time	run time	hours	1568	10	10	24	9	10	1631
	(100% eff.)	days	65.3	0.4	0.4	1.0	0.4	0.4	68.0
	installation	hours							0
	time	days	0.0	0.0	0.0	0.0	0.0	0.0	0.0
dose rate at	method 1	urem/hr	0.43	1.31	1.01	0.66	2.03	1.52	
the fence post	method 2	urem/hr							
(run time)	conservative	urem/hr	0.43	1.31	1.01	0.66	2.03	1.52	
dose per setup		urem	678	13	10	16	18	15	750.3
% of annual dose budget		%	6.8	0.1	0.1	0.2	0.2	0.2	7.503
									% of allowed dose for the total time: 40.298
									% of allowed dose for the run time only: 40.298

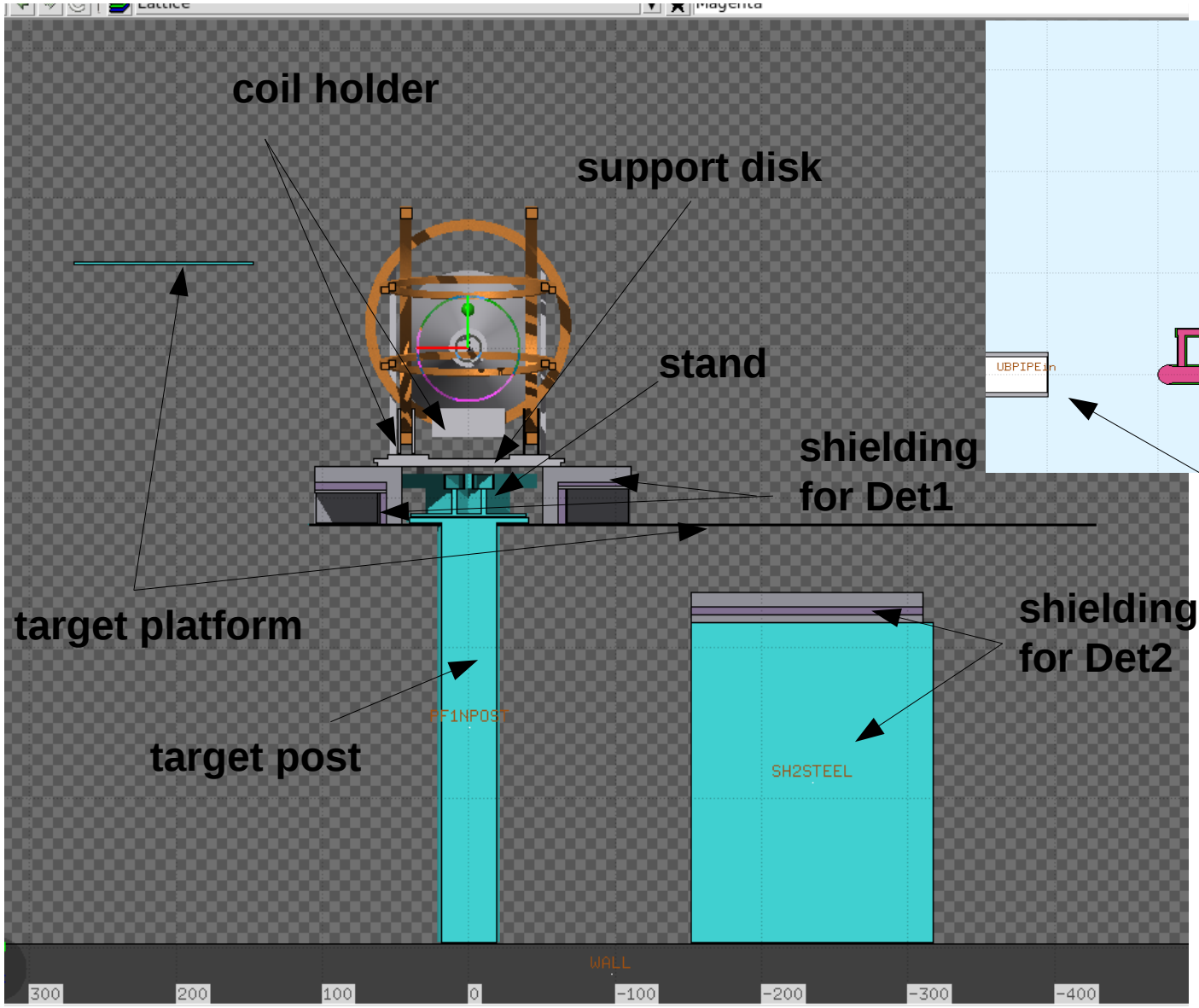
If > 200%, discuss result with Physics Research EH&S officer

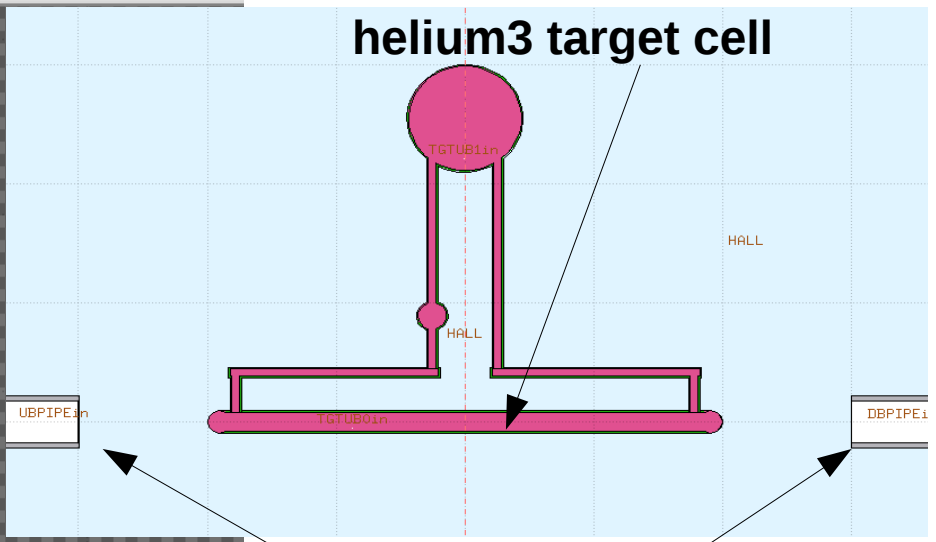
date form issued: January 22, 2018 *authors:* P. Degtiarenko

We are far below dose budget!
Nothing to worry about!

Courtesy to Pavel

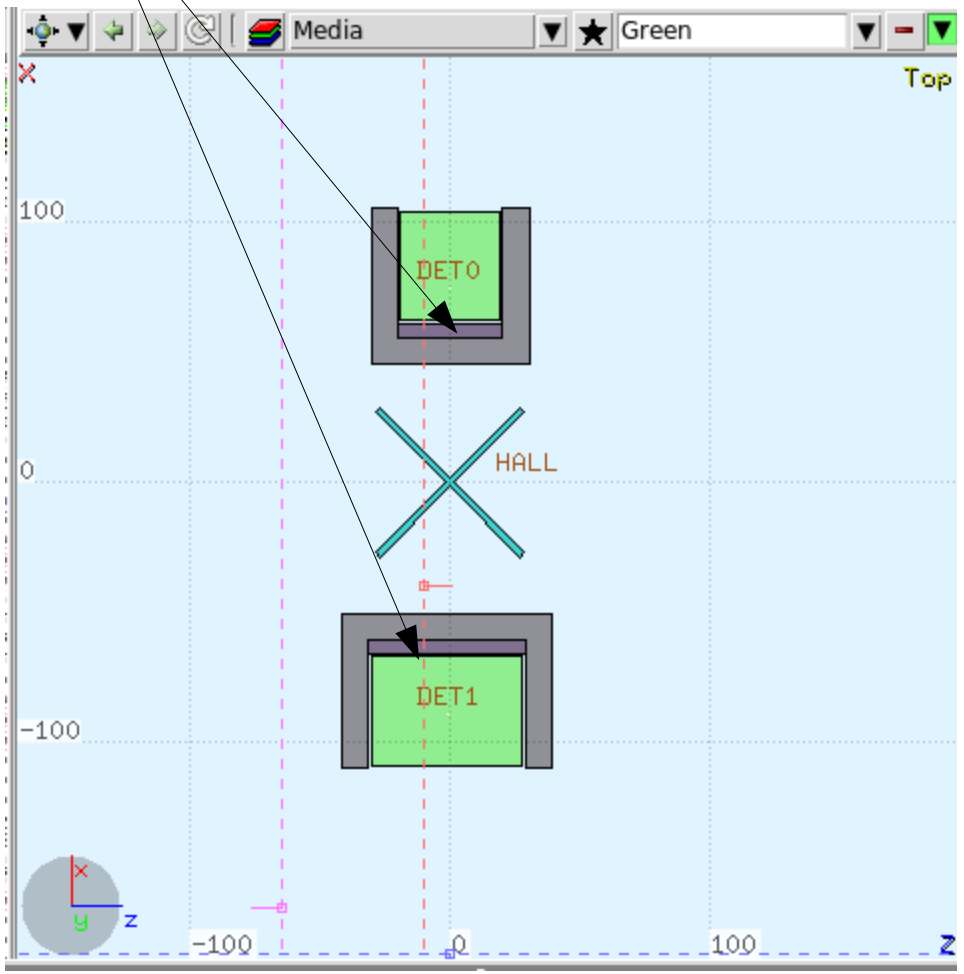
Geometry: 3D view

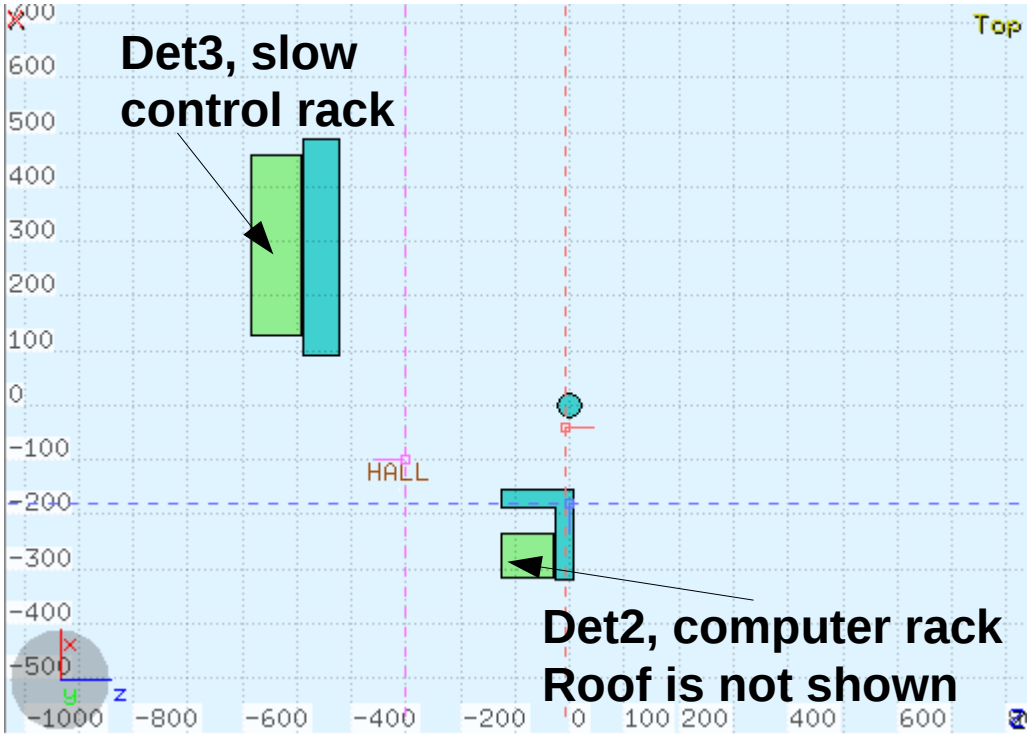




Shielding

Det0, Det1: NMR|EPR|PNMR
Add plastic layer in the inner wall and roof





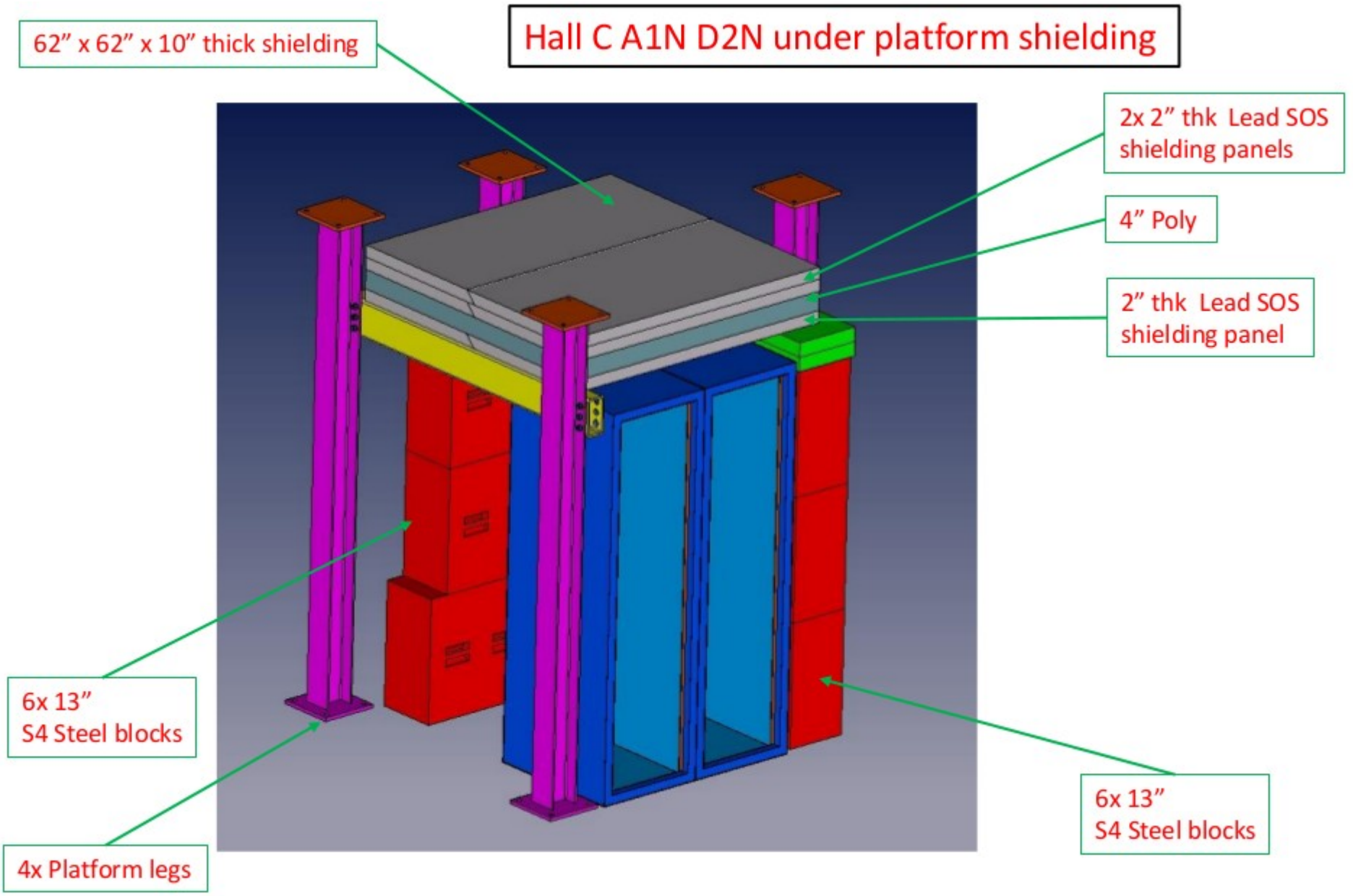
Det0: 4“ thick lead at sides and top, with 2” plastic padding.

Det1: 4“ thick lead at sides and top, with 1” plastic top padding and 2” side padding.

Det2: 4” lead + 4”plastic + 2”lead at top, 13” thick steel in sides (left and down)

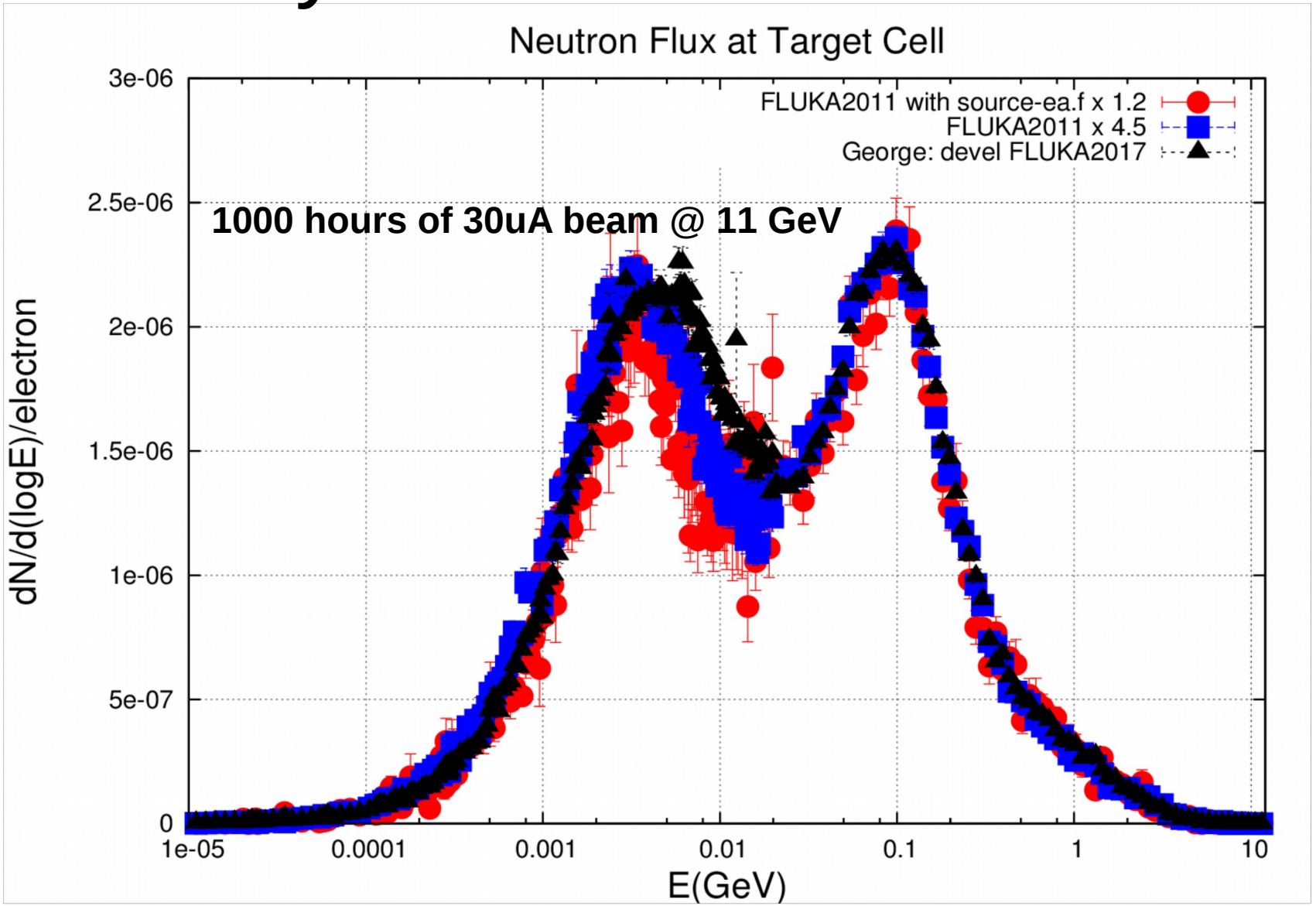
Det3: 26” thick steel at down side

CAD Model: Shielding at Det2(1)



Courtesy to Bert Metzger

New Physics: Add eN Contribution



Current release of FLUKA (version 2011) does not include electro-nuclear cross session, while the developed version (2017) does. Source_ea.f from Pavel is added to version 2011 to account for eN contribution. (Only works for thin target.)

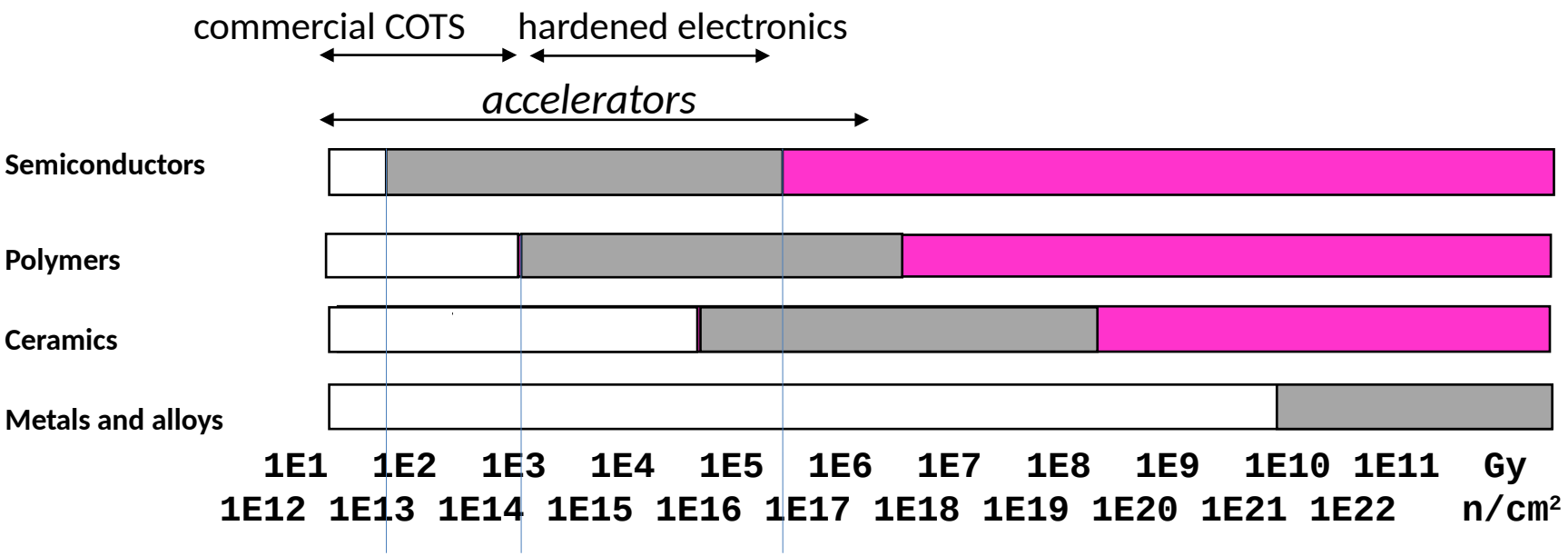
Courtesy to George and Pavel

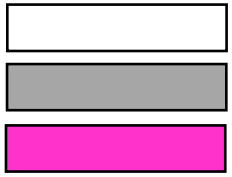
Radiation Damage Chart (Approximate)

Dose & Displacement Damage

Radiation Damage to Materials/Electronics

!!! A Rough Overview Only !!!

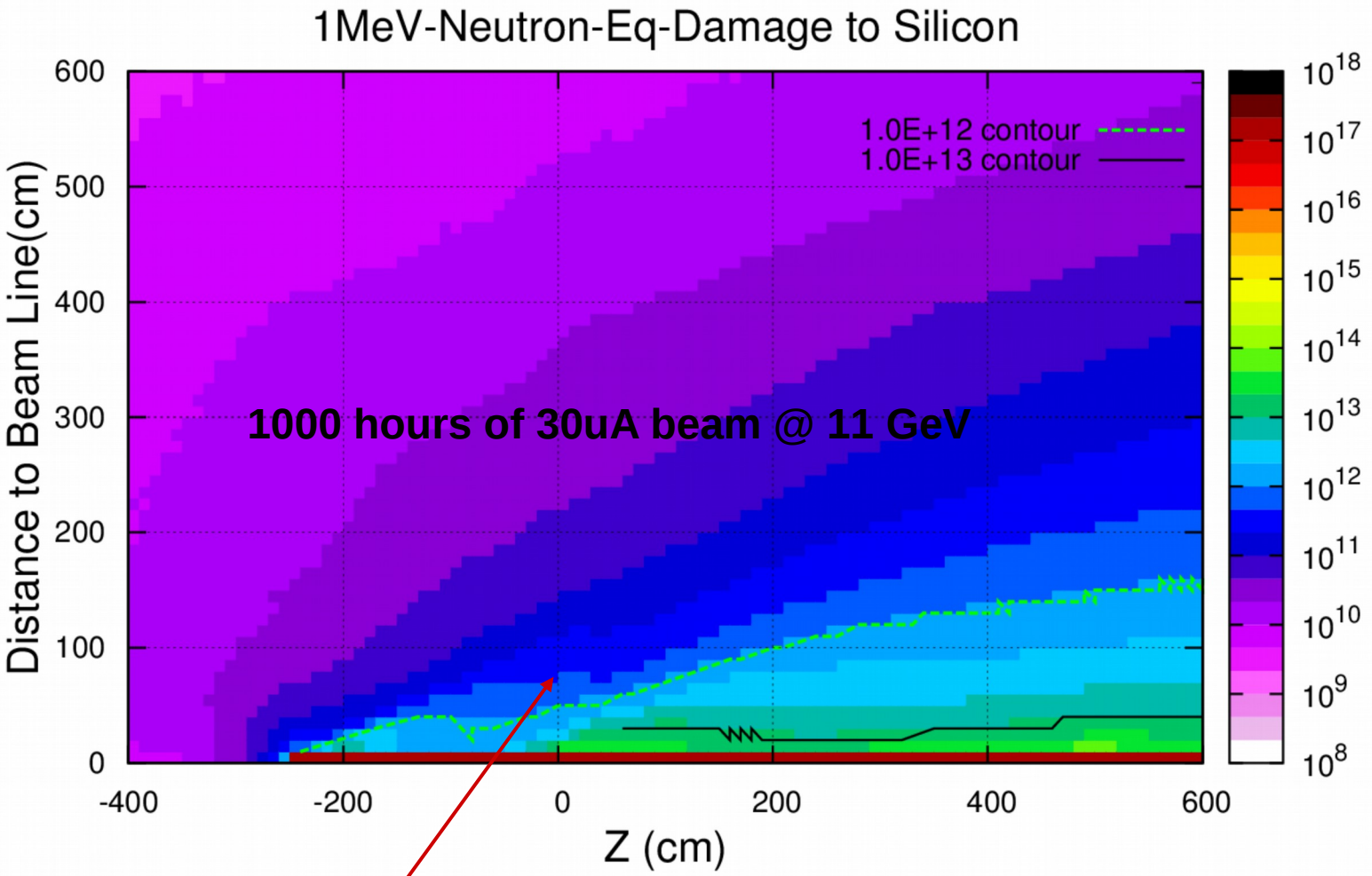




- no damage
- mild to severe damage
- destruction

!!! Assumption !!!
(depends on particle energy spectra)
1 neutron (1MeV) /cm² ~ 3.3E-11 Gy

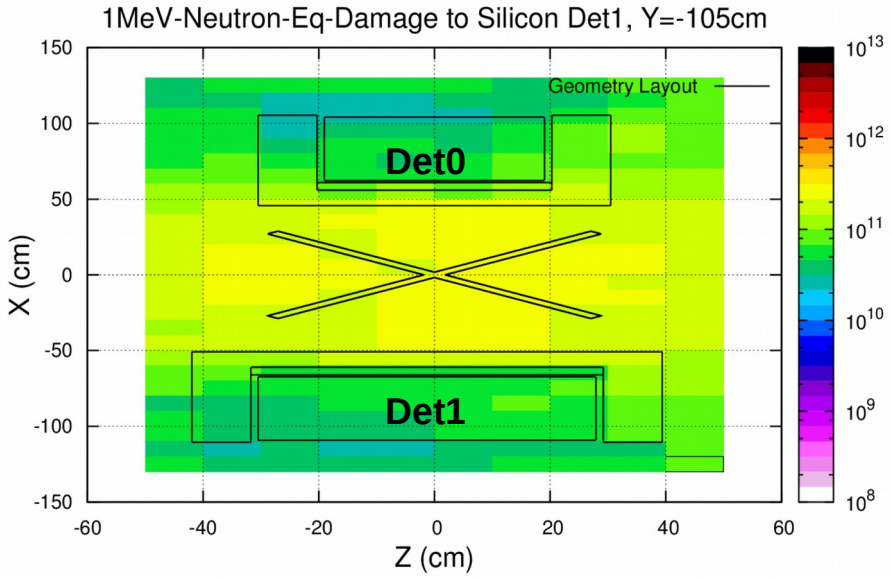
1 MeV Neutron Equivalent Damage

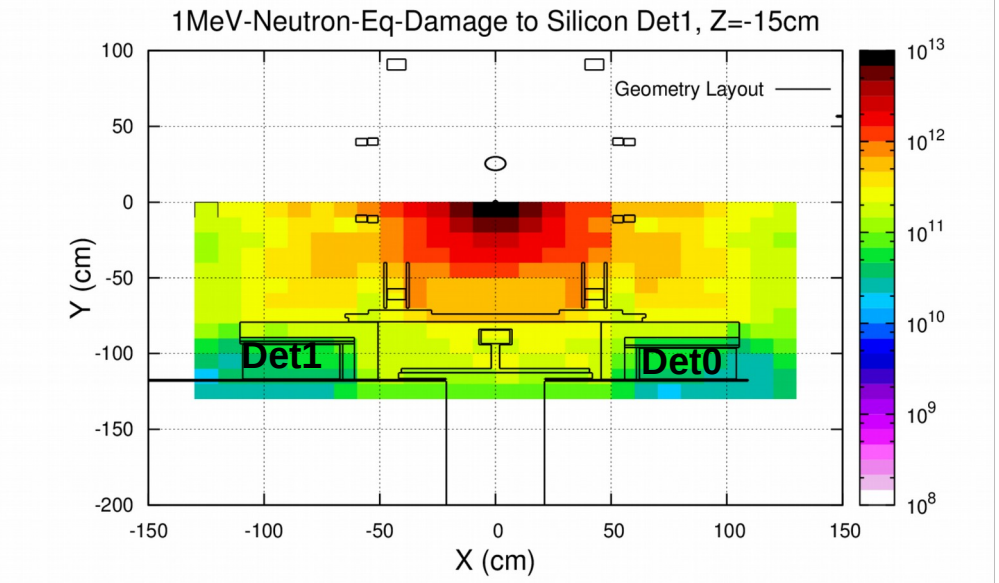


Electronics shows damage when the 1MeV-Neutron-Equivalent dose is accumulated to 10^13 neutron per cm^2.

Det0 and Det1 is about 95 cm below the pivot. This area is pretty safe.

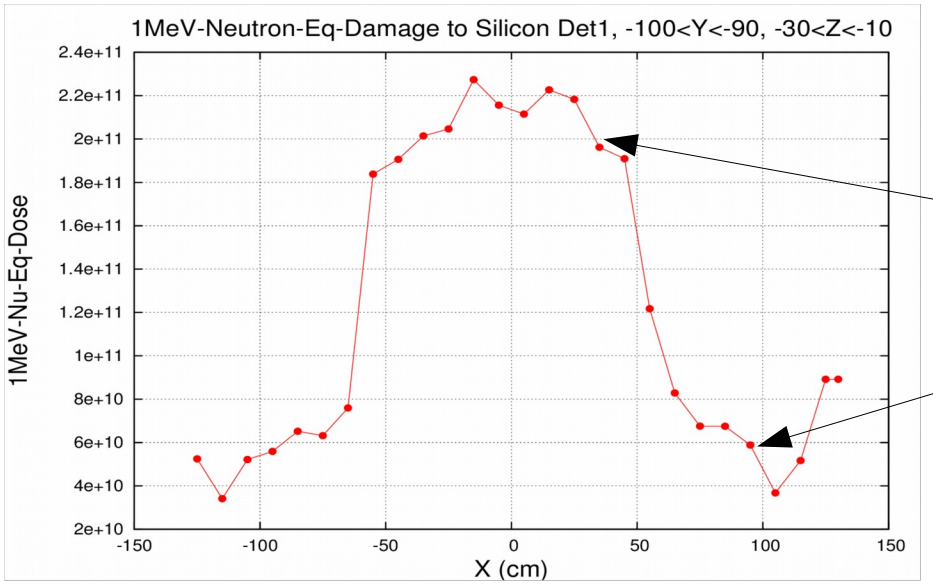
1Mev-Nu-Eq Damage @ Det1





shielding

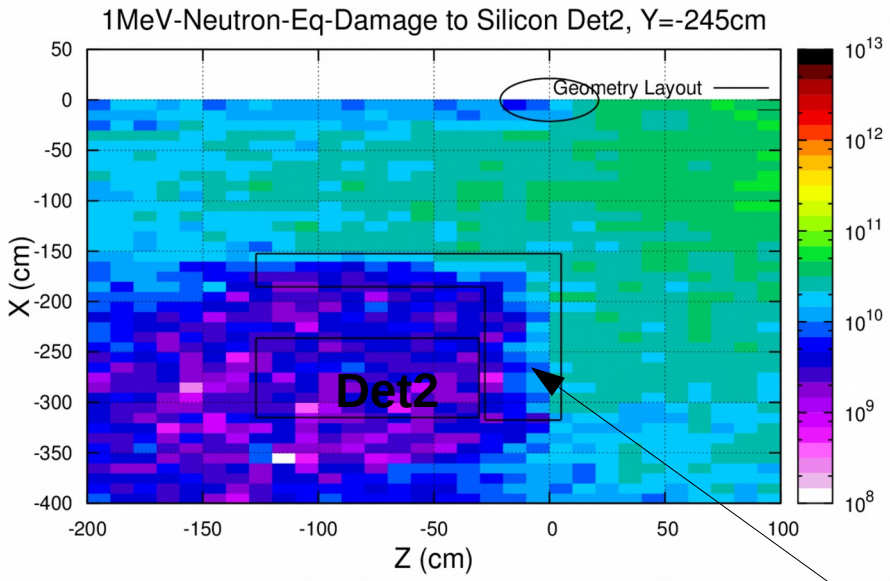
1000 hours, 11 GeV, 30uA e- beam

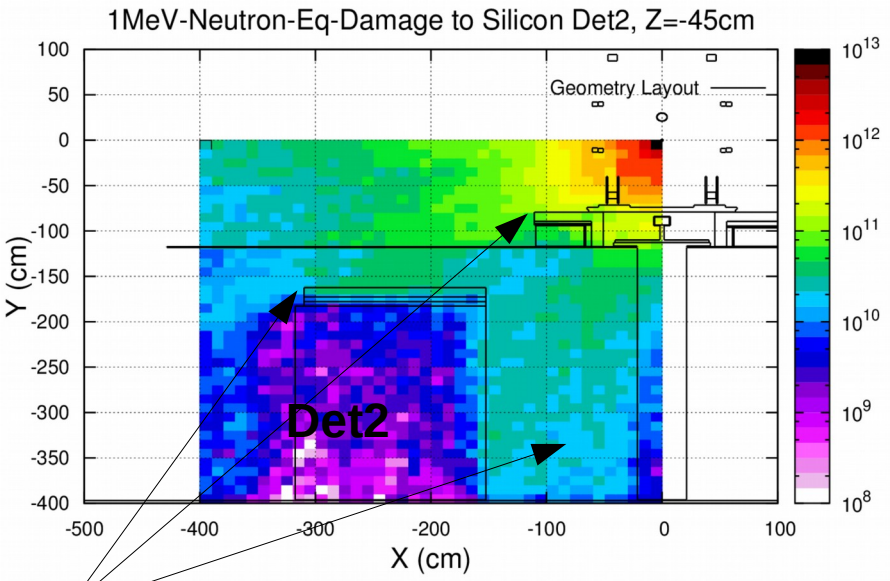


Not covered by shielding

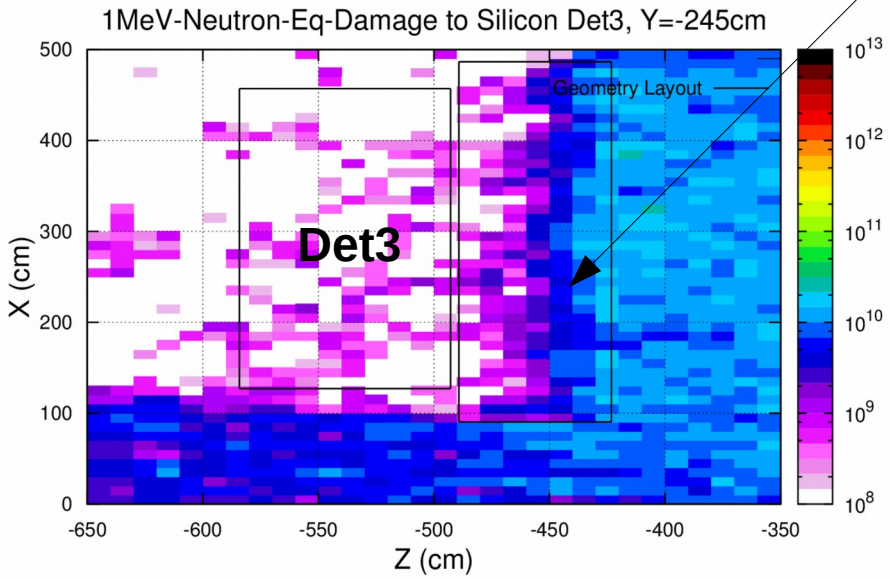
Covered by shielding,
Dose is reduced by ~75%!

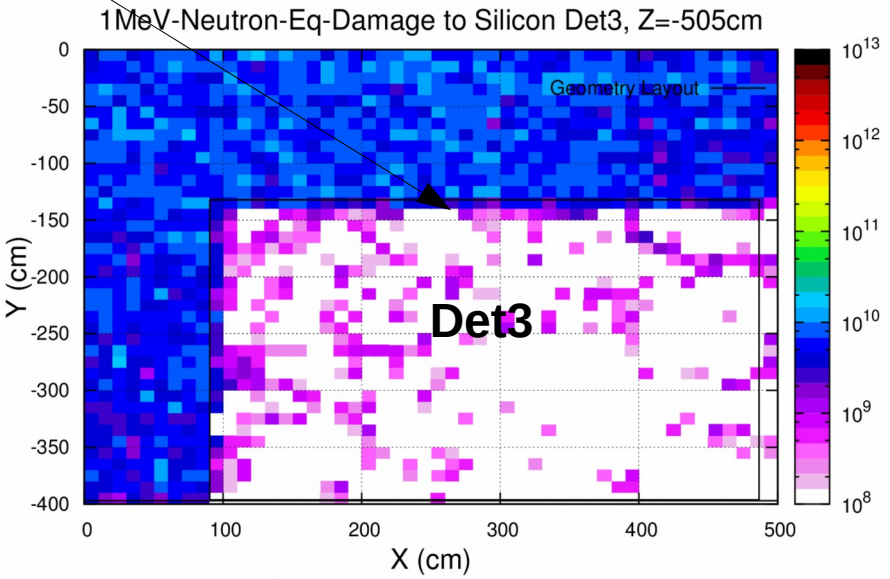
1Mev-Nu-Eq Damage @ Det2 and Det3





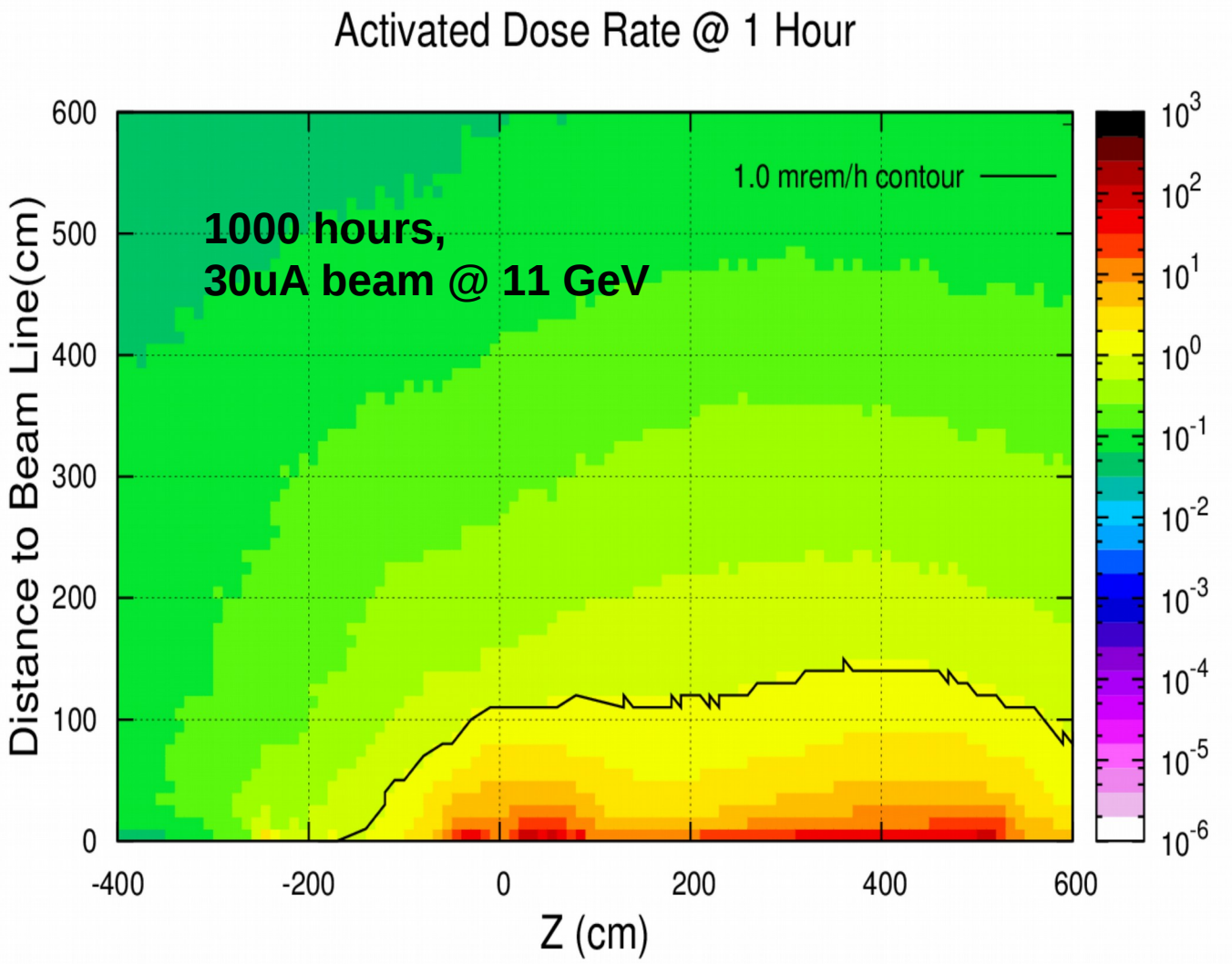
shielding





1000 hours, 11 GeV, 30uA e- beam

Dose Rate from Activation @ 1 hour



After beam is shut down for 1 hour, dose rate is ~1 mrem/h at 1.1 m away from beam line.

Summary

1) FLUKA simulations have been performed assuming 1000 hours of 30 uA electron beam at 11.0 GeV on helium3 target. The following shieldings are included:

   Det0: 4“ thick lead at sides and top, with 2” plastic padding at top and beam side.
   Det1: 4” thick lead at sides and top, 1” thick plastic at top and 2” plastic at beam side.
   Det2: 4” lead + 4”plastic + 2”lead at top, 13” thick steel in sides (left and down).
   Det3: 26” thick steel at down side.

2) Radiation damage after 1000 hours of beam time:

At Det0 and Det1 location, the shielding will reduce the 1-MeV-N-Eq. damage by 75%. The dose is ~6×10^{10} 1-MeV-N-Eq/cm^2. (Electronics will show damage when dose reaches ~10^{13}).

At Det2 and Det3 location, the 1-MeV-N-Eq. dose is below 10^{10}

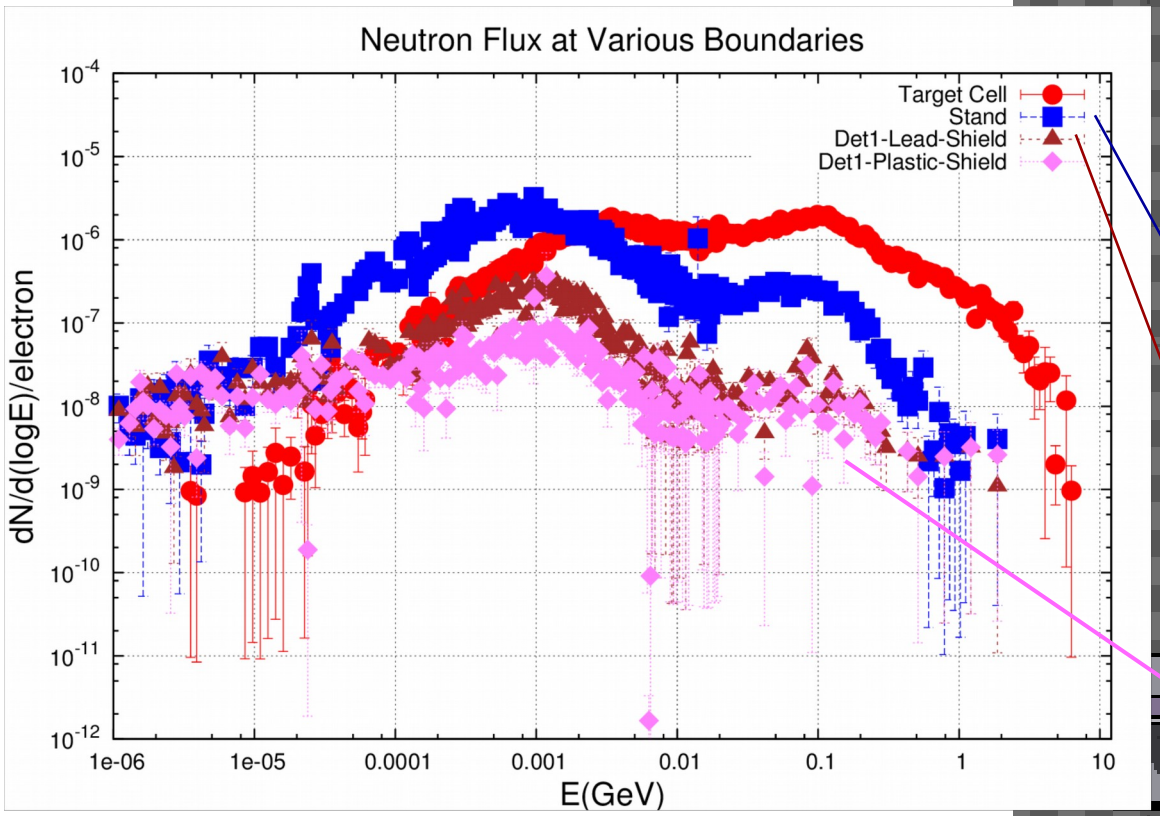
The designed shielding works very well!

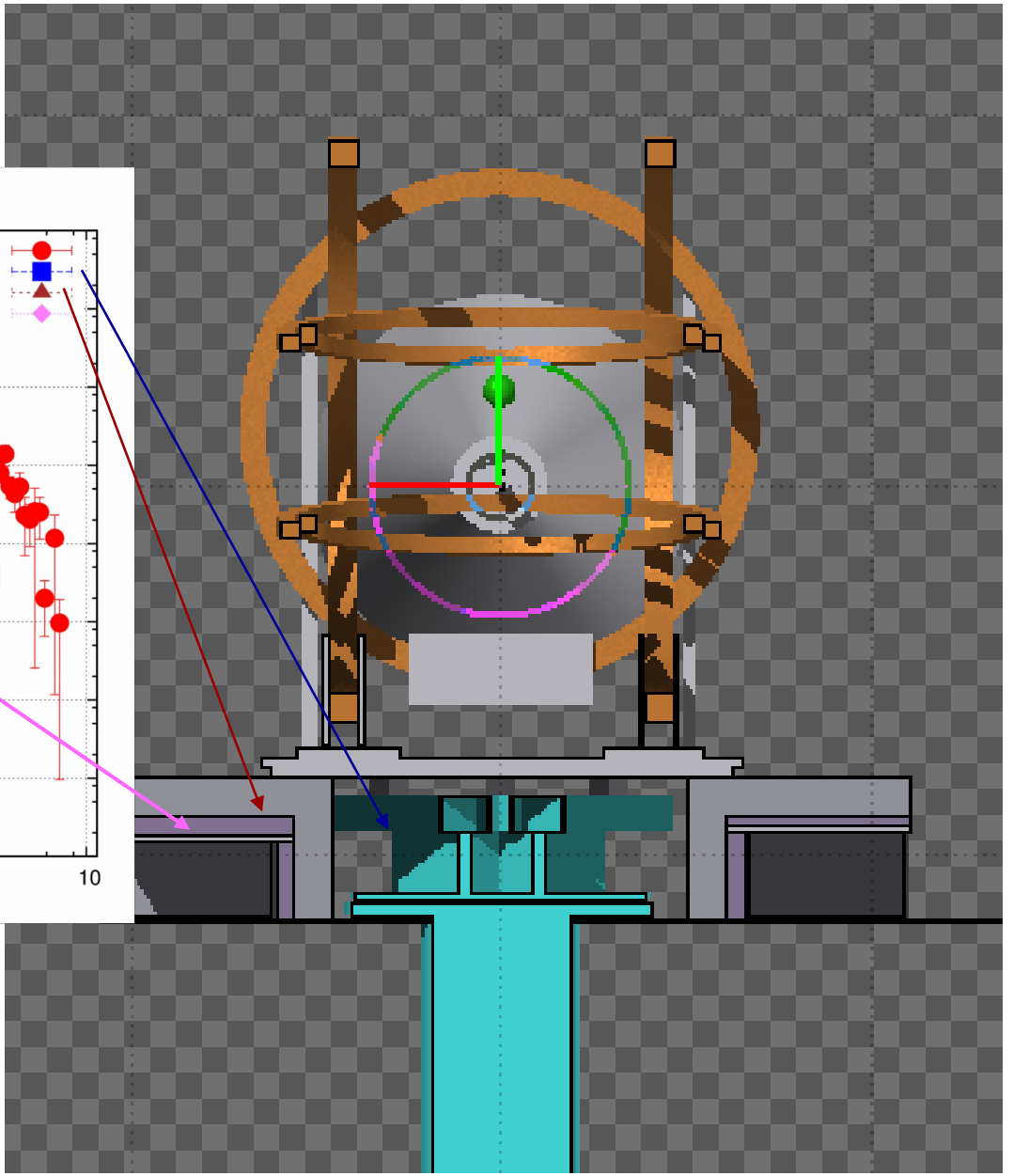
3) Dose rate from activation:

After 1 hour the beam is shut down, dose rate at the target area is ~1 mrem/h at 110 cm away the beam line.

4) Dose rate at site boundary is also far below radiation budget.

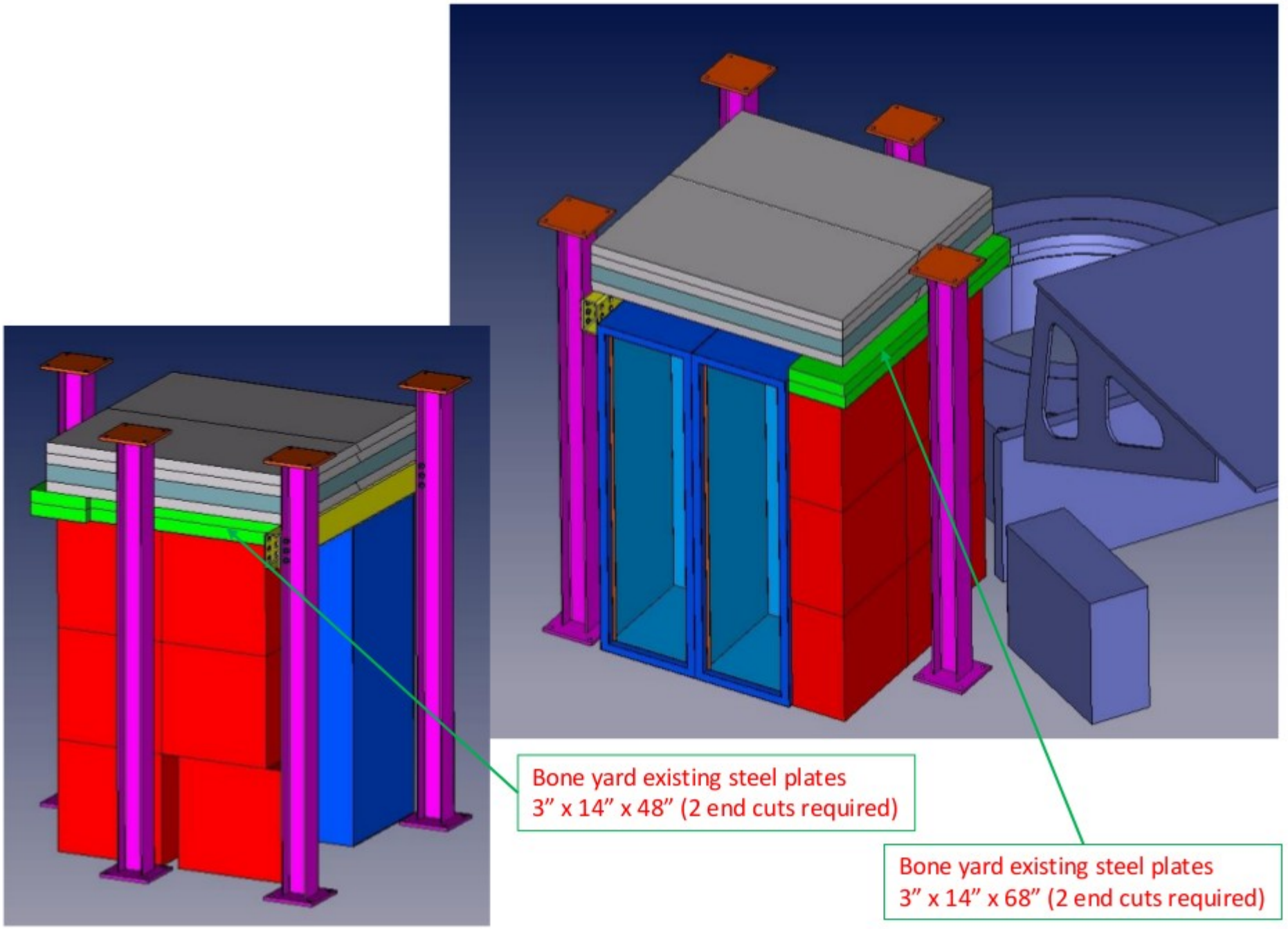
Neutron Flux after Shielding





11 GeV, 30uA e- beam

CAD Model: Shielding at Det2(2)



Courtesy to Bert Metzger

1MeV-Nu-Eq. Damage Convert Rules