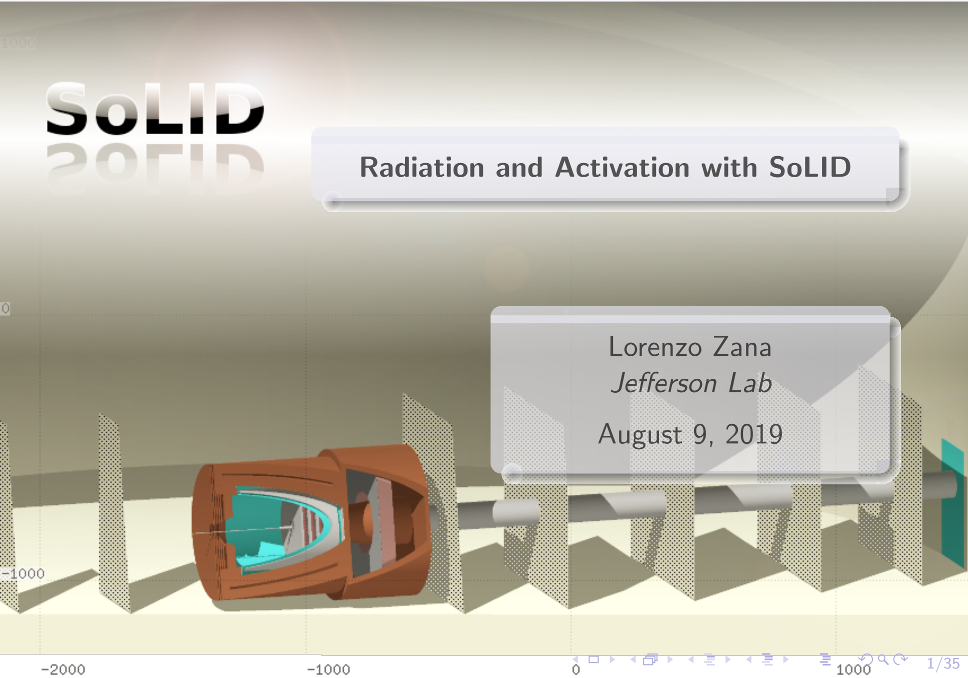


SoLID

Radiation and Activation with SoLID

Lorenzo Zana
Jefferson Lab

August 9, 2019

Simulation: Two Simulation packages

Advantages

- Two simulation packages with independent code base.
- Independent cross checks both in geometry and in physics modeling.
- Unique capabilities expanding the overall reach.

Simulation: Two Simulation packages

FLUKA

- Easier tools to directly determine Full Radiation quantities.
- Established tool in determining activation estimates.

GEANT4

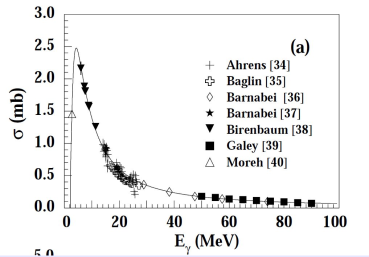
- Better for particular tasks in order to simplify the Shielding design (like vertex, energy reconstruction on particle fluxes over regions of interest).
- Established framework from other part of the simulation project of SoLID

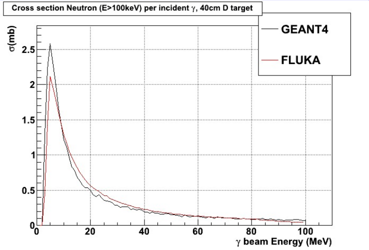
Neutron Photo-production on Deuterium

From all the different SoLID configurations, the Deuterium target is expected to have the highest radiation inpact

Neutron Photo-production on Deuterium

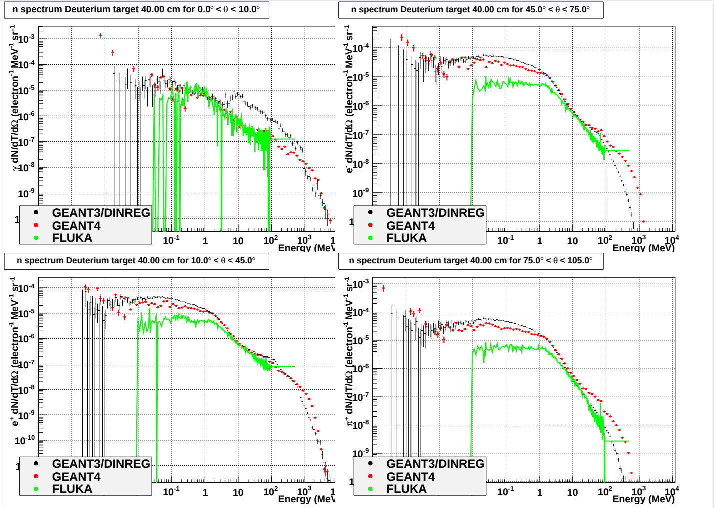
Comparison with real cross section for FLUKA and GEANT4 for Neutron Photo-production on Deuterium





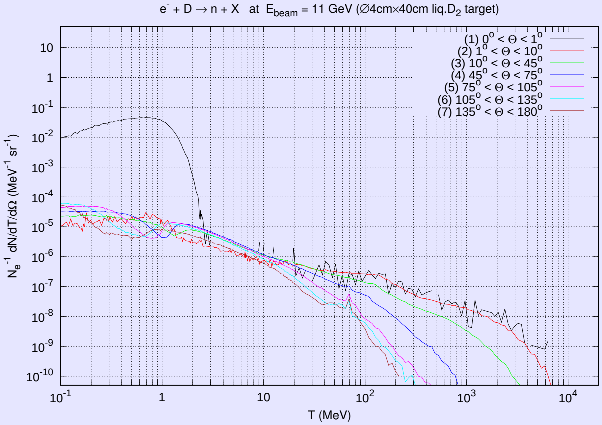
Neutron Full Production from electron beam

NEUTRON 40cm Deuterium $\frac{d^2N}{dT\,d\Omega}$

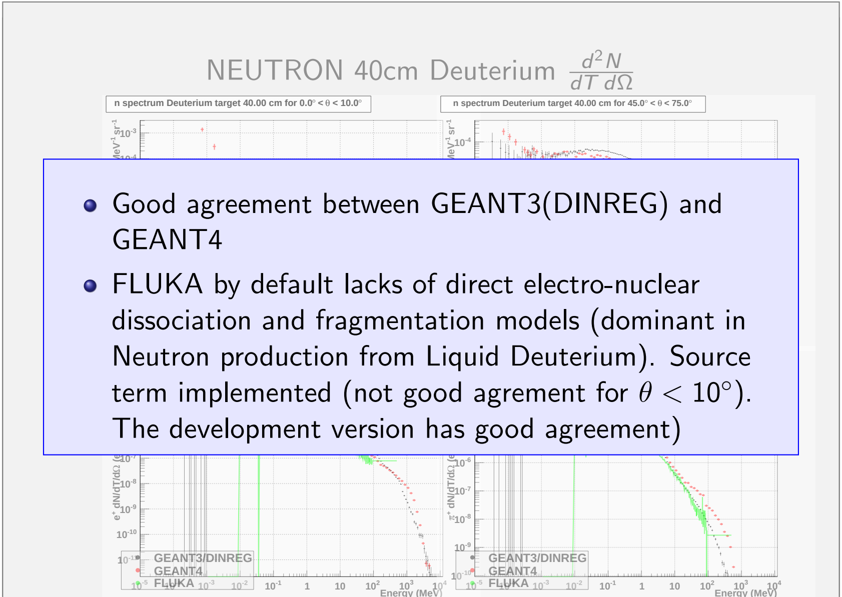


Neutron Full Production from electron beam

NEUTRON 40cm Deuterium $\frac{d^2N}{dT\,d\Omega}$ Fluka Dev version



Neutron Full Production from electron beam



- Good agreement between GEANT3(DINREG) and GEANT4
- FLUKA by default lacks of direct electro-nuclear dissociation and fragmentation models (dominant in Neutron production from Liquid Deuterium). Source term implemented (not good agrement for $\theta < 10^\circ$). The development version has good agreement)

Radiation inside the Magnet

Shielding inside the Magnet: PVDIS configuration

- Shielding inside the Magnet will be based on Borated Polyethylene
- This Shielding is expected to give the best results in mitigating the expected background radiation spectrum.
- Shielding is placed filling the space between the baffles, covering the coils on the section of the magnet outside the baffle region and in the downstream region in the available space.

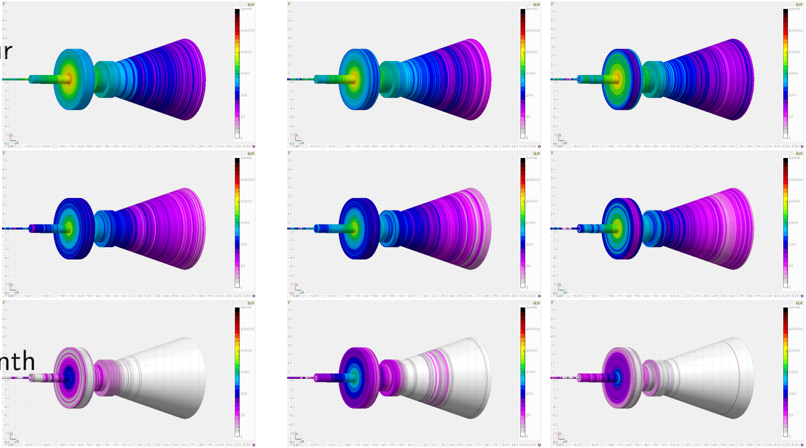
Baffle: Different Material Activation

LEAD COPPER TUNGSTEN

1hour

1day

1month



Baffle: Different Material Activation

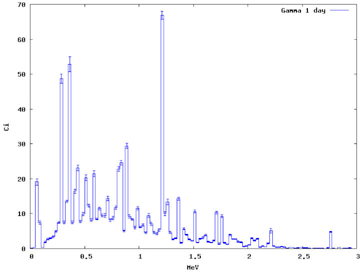
Baffle's material Activation

- Different material were tested for the first 3 layers of baffle/shielding
- At this presentation just shown the first baffle, but material dependence is comparable also for the other baffles analyzed
- Copper shows a longer decaying time for the activated isotopes (after 1month radiation is ¡ 1 order of magnitude respect to Lead and Tungsten)

Change of SoLID config: baffle activation for PVDIS

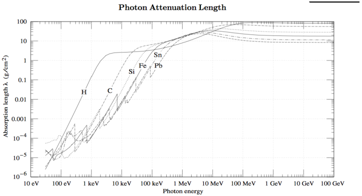
Goal for activation $\Rightarrow < 10 mrem/h$

Copper 1st baffle:
Gamma Spectrum after 1day



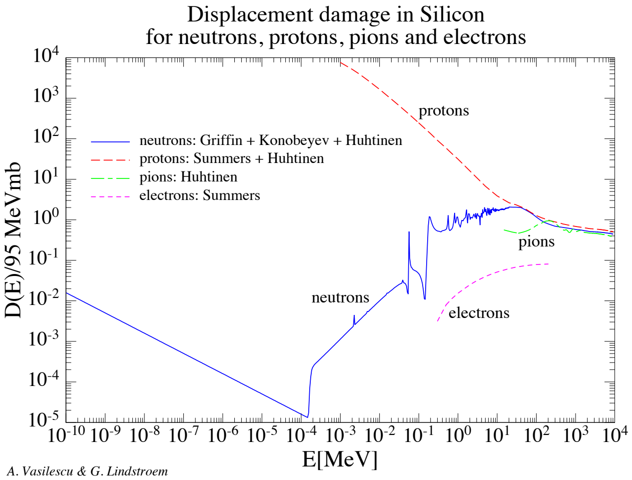
$\sim 8cm$ of Lead for goal

- factor of $\sim$ 20 reduction
- (Real baffle has 50% of this activation)



Displacement damage in Si, NIEL

(Non Ionizing E-Loss) for e^-, p, π, n

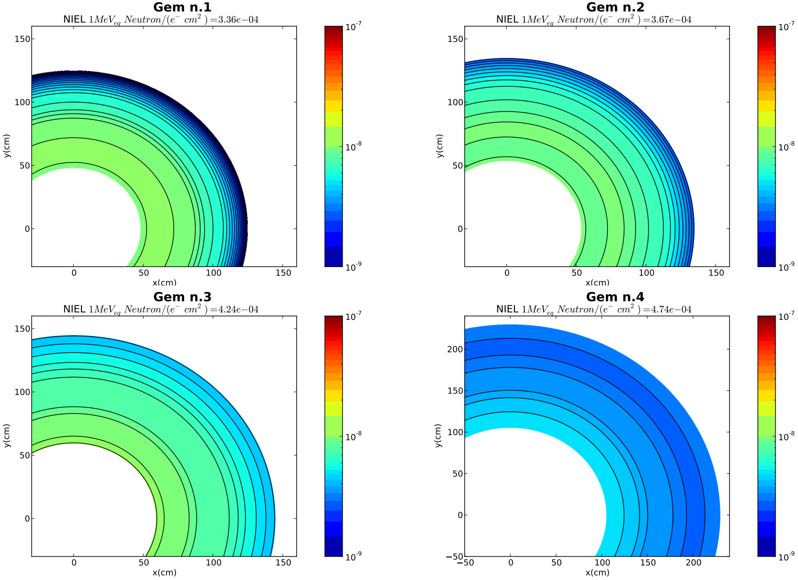


Displacement damage in Si, NIEL

What is a tolerable level for APV25 (GEM) ?

- CMS Silicon STRIP Tracker (the APV25 chip was designed for this detector) total fluence expected to peak around $2.4x10^{14}\frac{1MeV_{eq}N}{cm^2}$
- Our flux is ($2000h$ at $100\mu A$) $2.4x10^{14}\frac{1MeV_{eq}N}{cm^2} \Rightarrow 5.3x10^{-8}\frac{1MeV_{eq}N}{e^- cm^2}$
- The APV25 chips will be placed in the outer layer of the GEM

PVDIS $1MeV_{eq}$ $\frac{N}{e^{-}cm^2}$ WITH SHIELDING (ABS/SHLD = POLY)



Radiation on SIDIS

Neutron radiation dominates the PVDIS configuration.
What is the comparison with SIDIS?

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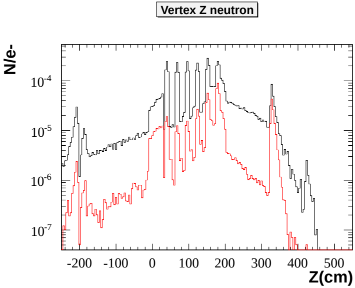
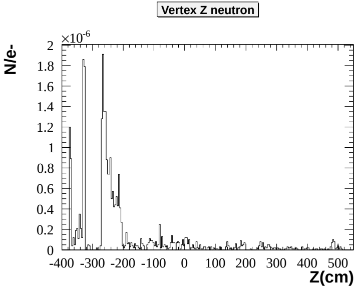
PVDIS

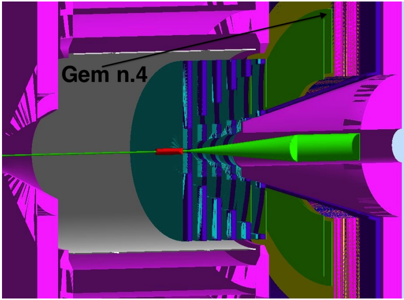


SIDIS

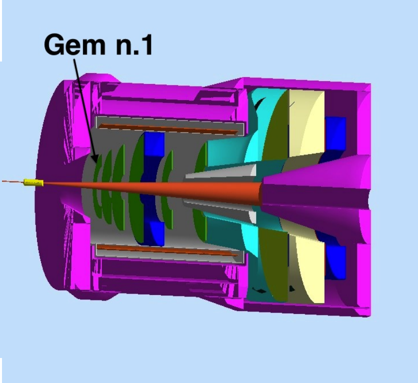


Radiation on SIDIS

PVDIS



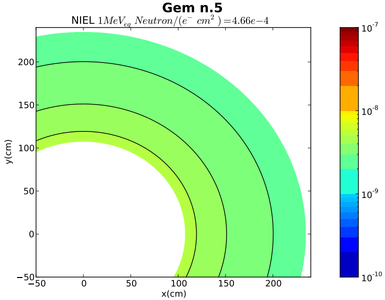
SIDIS



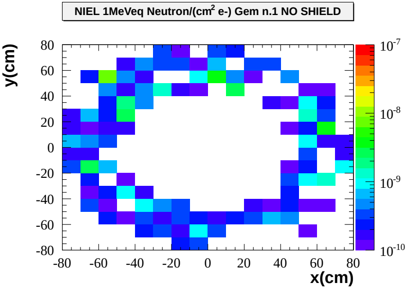
Radiation on SIDIS

What is the comparison for 1MeV eq radiation in the gems?

PVDIS Gem n.5



SIDIS Gem n.1

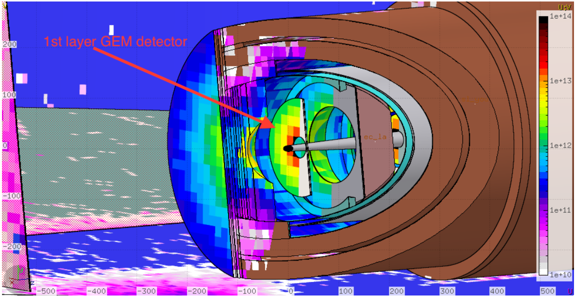


Radiation GEM detector for (J/Ψ)

Accumulated fluence in the Hall

Accumulated $\left(\frac{1MeV_{eq}Neutron}{cm^2}\right)$ for 60 days, $3\mu A$ beam at 11GeV

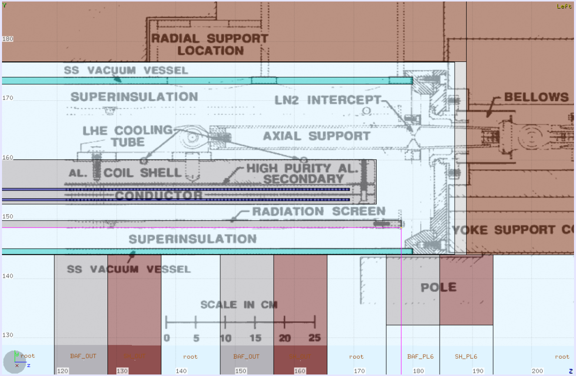
- The GEM readout system was developed to sustain $2.4x10^{14}\left(\frac{1MeVNeutron}{cm^2}\right)$
- Radiation is well below the threshold for the electronics



Lifetime on NbTi superconductor carried by SoLID

Updated Coil design to CLEO

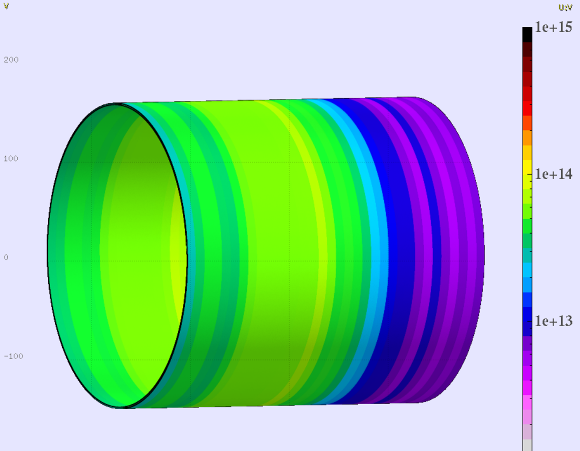
The PVDIS configuration with Deuterium target present the main source for neutron fluxes on the coils



Lifetime on NbTi superconductor carried by SoLID

Expected PVDIS neutron fluence $\frac{N}{cm^2}(E > 1MeV)$

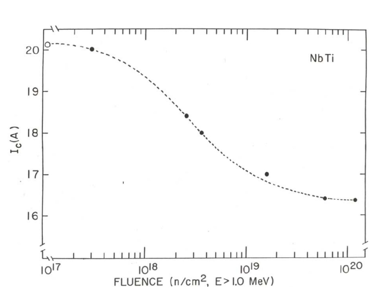
Dose for 2000h at $100\mu A$ (Flux on coils)



Lifetime on NbTi superconductor carried by SoLID

Expected PVDIS neutron fluence $\frac{N}{2}(E > 1MeV)$

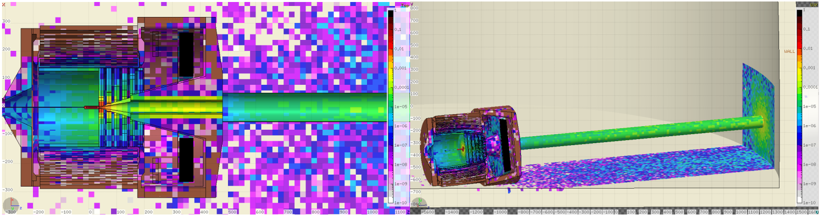
Dose



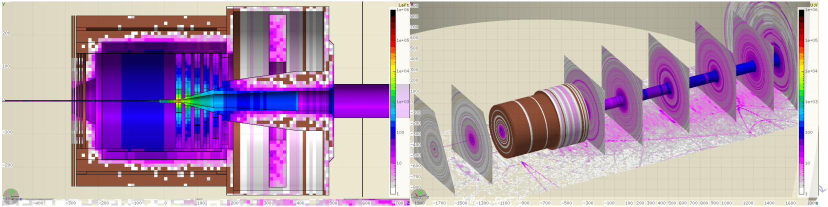
- A reduction of $\sim 20\%$ in I_c is expected in the range $2x10^{17} < \frac{N}{cm^2} < 2x10^{19}$
- **The expected accumulated fluence for PVDIS is $< 10^{14} \frac{N}{cm^2}$**

SoLID PVDIS: Power and Activation

$E_{dep}(W)/cm^3$ PVDIS, Liquid D target $(100\mu A)$

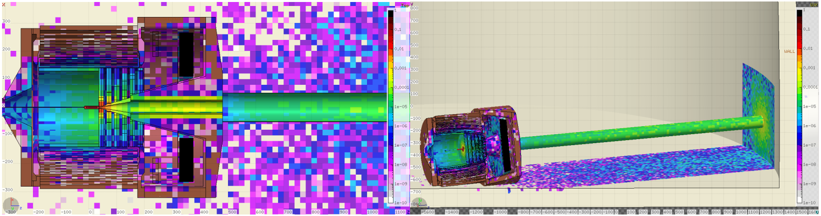


$Dose_{eq}(mrem)/h$ after $1hour$ from beam exposure (1 Month running time)

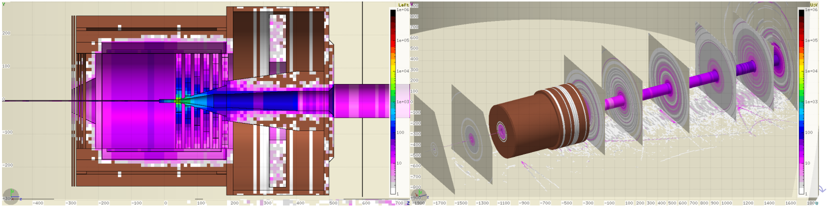


SoLID PVDIS: Power and Activation

$E_{dep}(W)/cm^3$ PVDIS, Liquid D target ($100\mu A$)

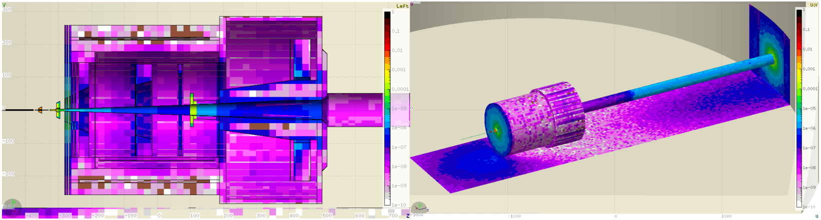


$Dose_{eq}(mrem)/h$ after $1day$ from beam exposure (1 Month running time)

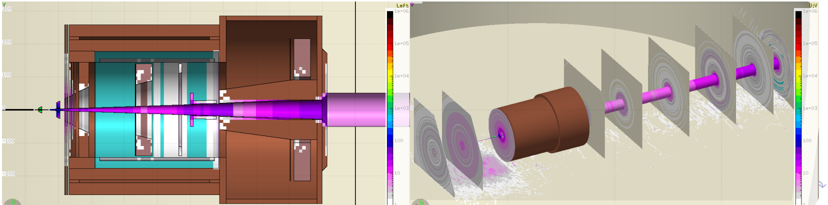


SoLID SIDIS: Power and Activation

$E_{dep}(W)/cm^3$ SIDIS, Liquid ^3He target ($15\mu A$)

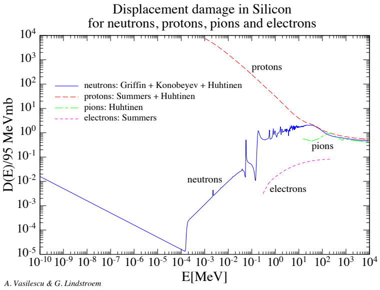


$Dose_{eq}(mrem)/h$ after $1hour$ from beam exposure (1 Month running time)

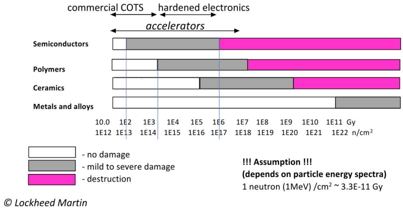


Radiation Estimates and Tolerance

Radiation Estimates

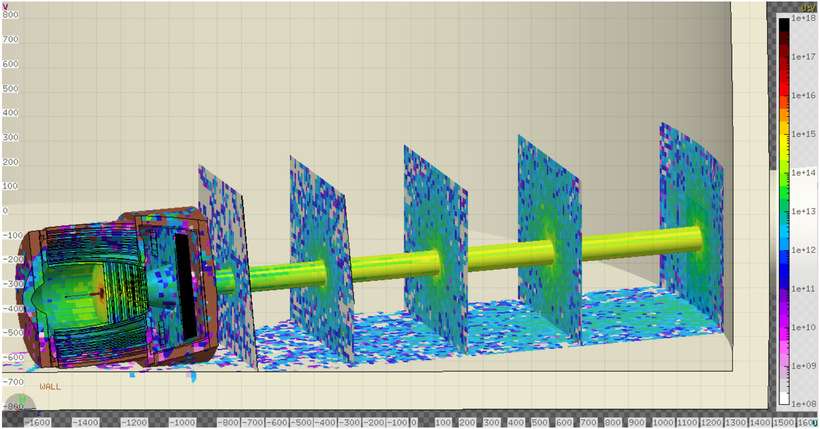


Tolerance (guideline)



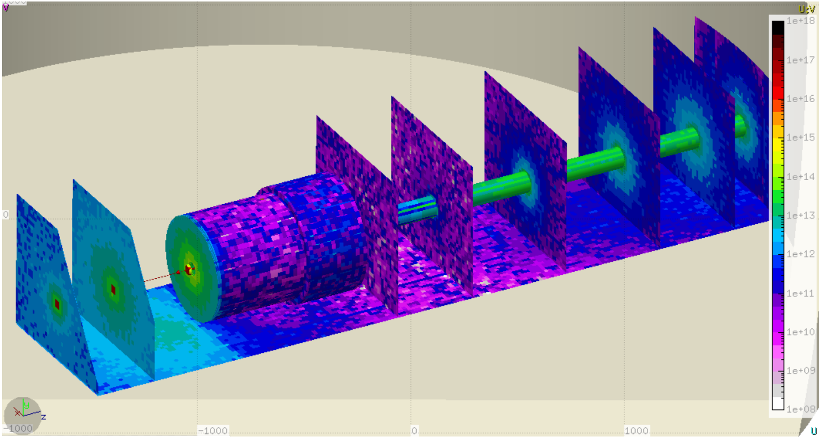
SoLID PVDIS: 1MeVeq Neutrons

$Neutrons(1MeV - eq)/cm^2$ PVDIS, Liquid D target
($100\mu A$ for $2000 hours$)



SoLID SIDIS: 1MeVeq Neutrons

$Neutrons(1MeV - eq)/cm^2$ SIDIS, Liquid ^3He target
$(15\mu A$ for $3000 hours)$

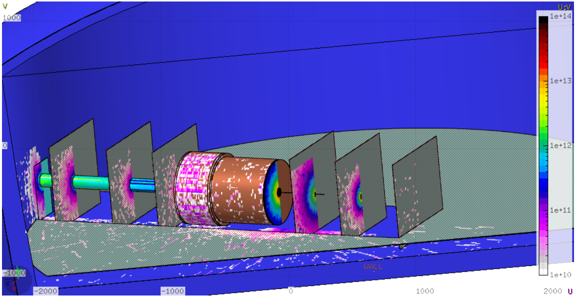


Radiation in the Hall (J/Ψ)

Accumulated fluence in the Hall

Accumulated $\left(\frac{1MeV_{eq}Neutron}{cm^2}\right)$ for 60 days, $3\mu A$ beam at 11GeV

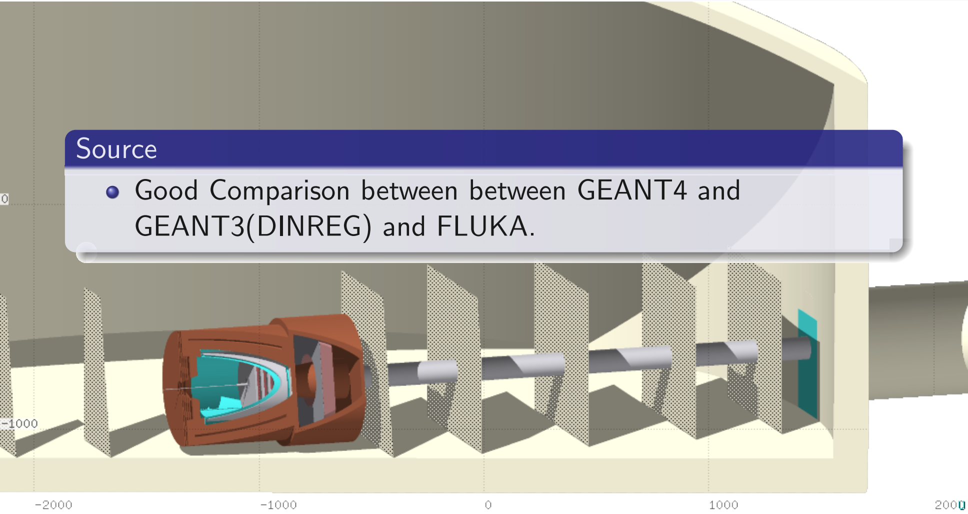
- 10^{13} $\left(\frac{1MeVNeutron}{cm^2}\right)$ as goal for safety
- Radiation in the Hall seems well under control



Conclusions

Source

- Good Comparison between between GEANT4 and GEANT3(DINREG) and FLUKA.



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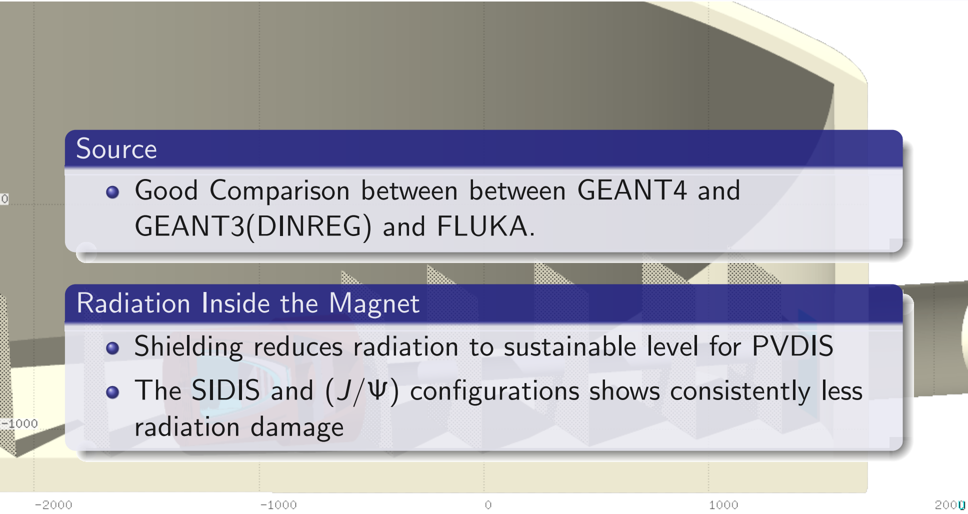


Source

- Good Comparison between between GEANT4 and GEANT3(DINREG) and FLUKA.

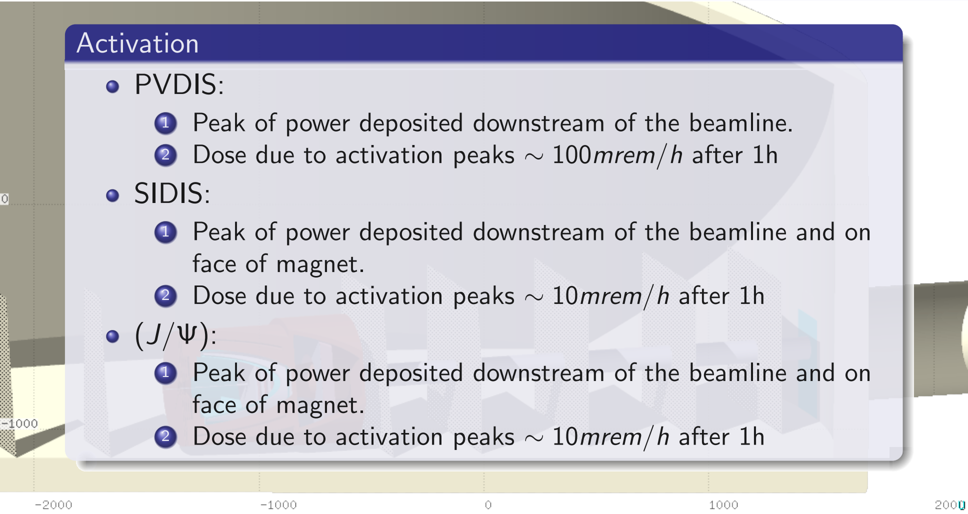
Radiation Inside the Magnet

- Shielding reduces radiation to sustainable level for PVDIS
- The SIDIS and (J/Ψ) configurations shows consistently less radiation damage

Conclusions

Activation

- PVDIS:
  1. Peak of power deposited downstream of the beamline.
  2. Dose due to activation peaks $\sim 100 mrem/h$ after 1h
- SIDIS:
  1. Peak of power deposited downstream of the beamline and on face of magnet.
  2. Dose due to activation peaks $\sim 10 mrem/h$ after 1h
- (J/Ψ):
  1. Peak of power deposited downstream of the beamline and on face of magnet.
  2. Dose due to activation peaks $\sim 10 mrem/h$ after 1h



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- (J/Ψ):
  1. Peak of power deposited downstream of the beamline and on face of magnet.
  2. Dose due to activation peaks $\sim 10 mrem/h$ after 1h

Radiation in the Hall

- PVDIS: Problems if electronics installed in area surrounding downstream beamline $\sim 10^{15} \frac{N_{1MeVeq}}{cm^2}$