FLUKA Update

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DarkLight Collaboration Meeting, TRIUMF

November 15, 2023

FLUKA

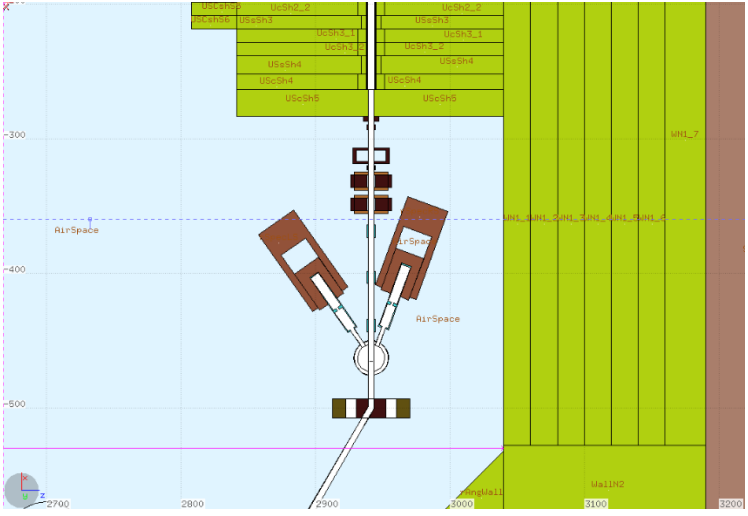
- Monte-Carlo for calculations of particle transport
- Fortran77 based
- Individual simulations defined and steered through "input deck"
- Geometry visualization and general use through flair program
  - Compiling with external magnetic fields, and combining independent runs is described in the flair interface
  - In principle all flair commands can be replicated on the command line, but this is extremely discouraged

"Format is not free...even in the free format..."
-FLUKA Manual

Current Status

- Beam optics in place
- Dose in the hall WITHOUT DarkLight target remains essentially unchanged with new optics
- Dose in the hall WITH DarkLight target is high, but should be safe outside the hall.
  - One location of concern
  - Additional concrete can be added
- Detector shielding underway

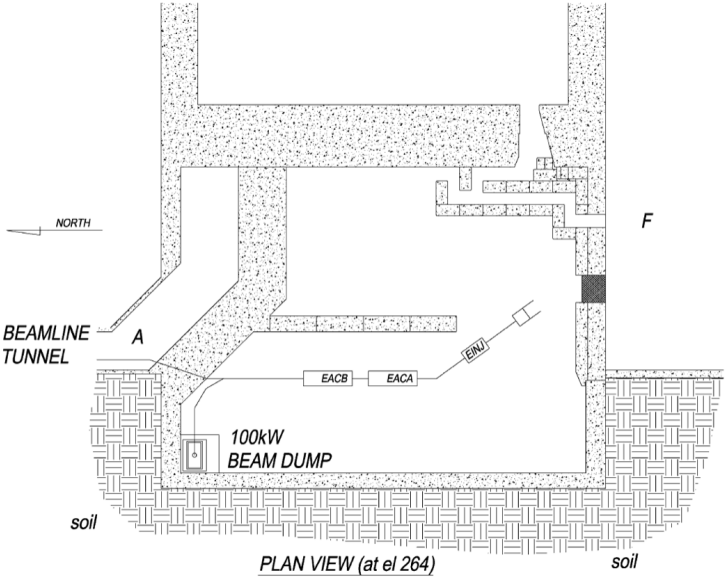
Spectrometers in FLUKA



Important Numbers

- Outside the hall, ambient dose should be below 5 μSv/h
- FLUKA tracks neutrons down to 10 μeV, gammas to 1 keV
- Run FLUKA with 32 MeV beam, 312.5 μA current, 10 kW
- Dose linearly proportional to current, not beam energy
- Informally, Rad Safety indicated FLUKA always overestimated dose by "large margin"

Important Locations



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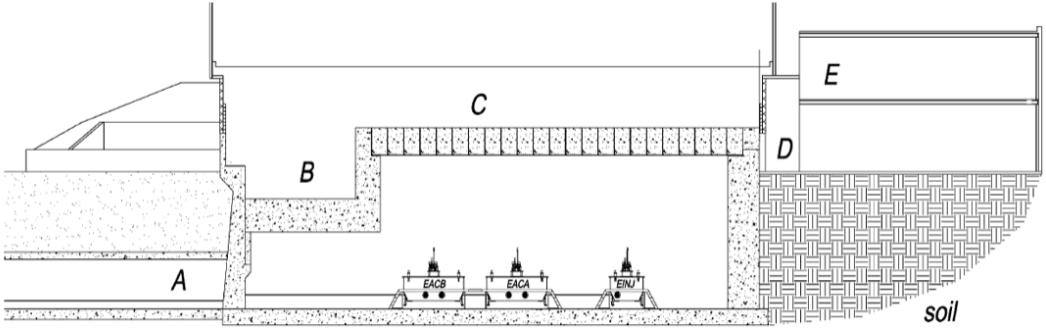


ELEVATION VIEW (LOOKING EAST)

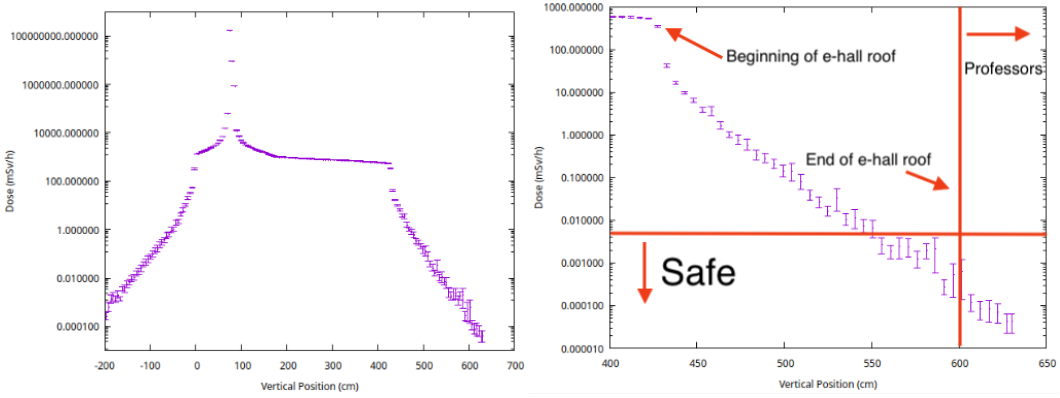
Important Locations

- Locations C, D, E1, E2, and F see no measurably increased dose
- Far away, shielding through air, concrete
- Additional dose from DarkLight comes from γ, e, and n
  - γ and e are forward peaked, A, D, E1, E2, and F are backward
  - n are isotropic, but much lower in dose
- Location A is listed as low-occupancy, but is close to the dump, and an opening in the shielding extends towards it
  - This is where the future ARIEL beamline will extend, and is where the current proton beamline sits
  - Is this really low occupancy? Is TRIUMF allowing personal to walk directly next to a running electron/proton beamline?
  - Does this area need to be reclassified?
- Location B sees increased dose

Important Locations - Location B

Don't irradiate: undergrads, grads, postdocs, professors, passersby, etc.

Average Dose in Location B

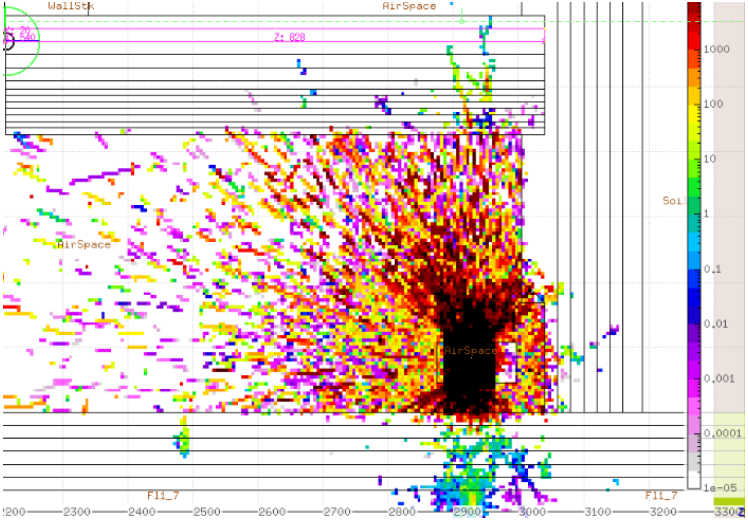


Left: Average Dose as a function of vertical position. **Right:** Zoomed in version of same plot.

Average Dose vs Specific Dose

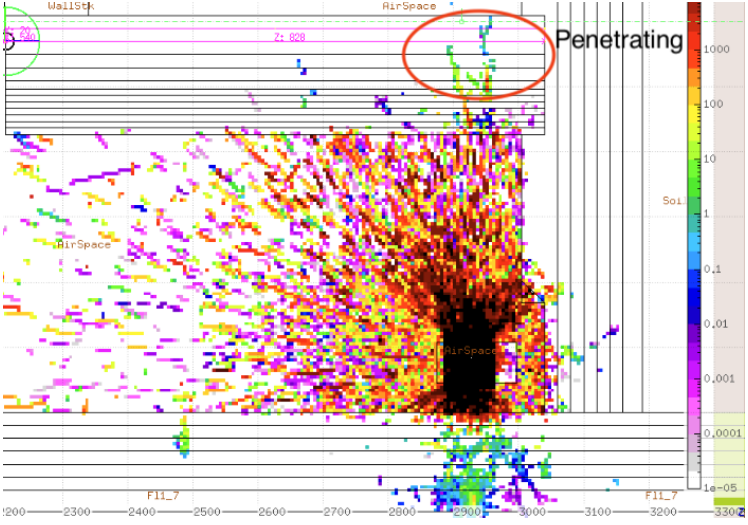
- While the average dose is safe, the specific dose is not
- Location B is ≈ 64 m^2, larger than the average person's footprint
- Certain spots can have slightly higher dose, beyond safety limits

Average Dose vs Specific Dose



Downstream cutaway of beamline

Average Dose vs Specific Dose



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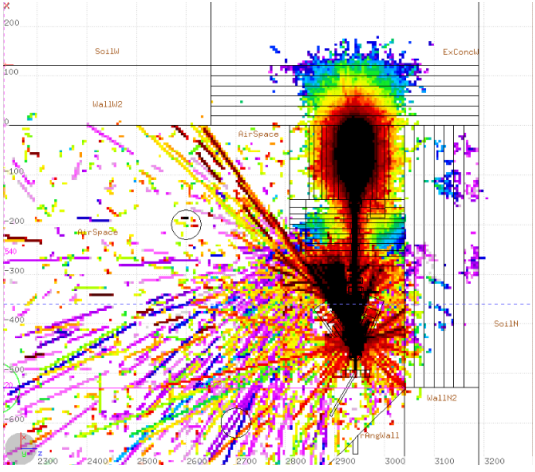
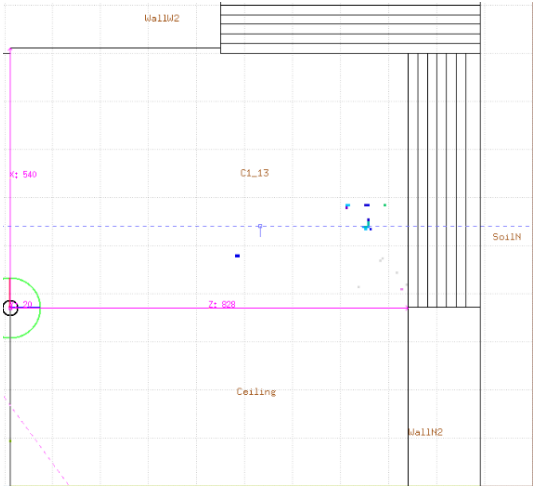
Average Dose vs Specific Dose



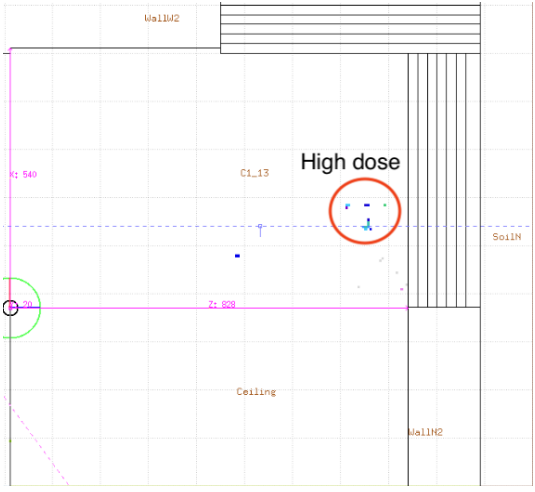
Top-down view of experiment at beam height. Note asymmetry due to spectrometers.

Average Dose vs Specific Dose



Top-down view of experiment at professor height.

Average Dose vs Specific Dose

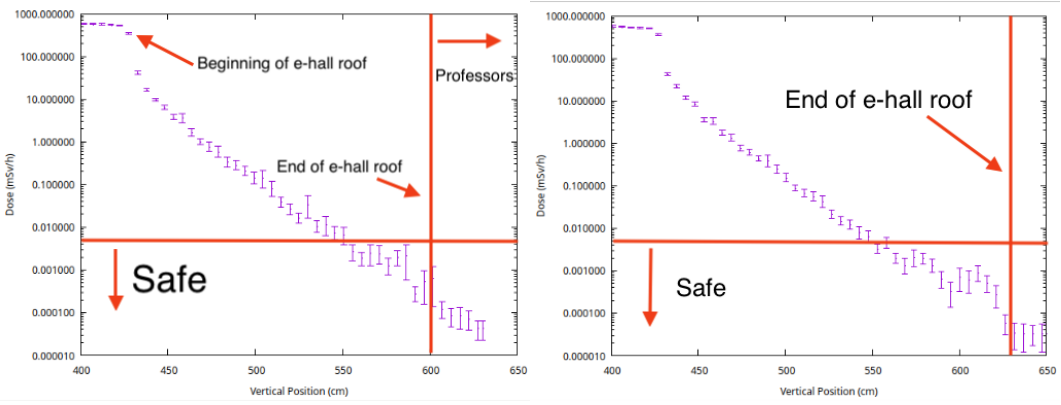


Top-down view of experiment at professor height.

Solution

- Add additional 30 cm of concrete on top of roof
- Concrete blocks already exist
- Sits on top of trap door to access area, weight is not an issue, will just take longer to open door
- Doug Preddy(?) is in charge of making this access, needs a crane anyway

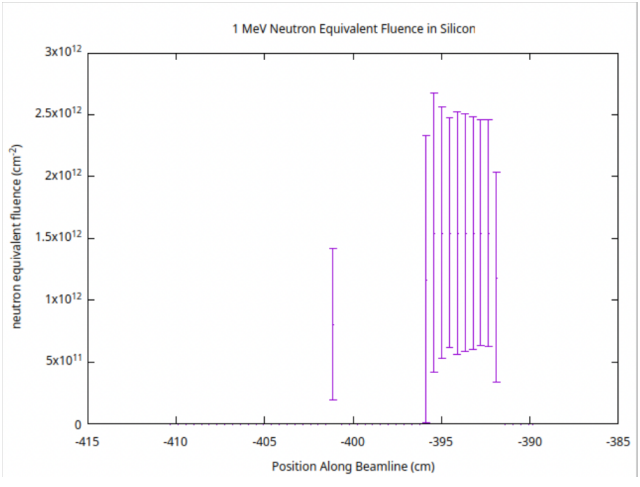
Solution



Left: Average Dose as a function of vertical position. **Right:** Same, but including additional 30 cm of concrete.

Work in Progress

- Investigating neutron damage in silicon
- FLUKA provides special scoring detector for 1 MeV equivalent neutron fluence
- Unsure of damage, scoring is cm^{-2}/e
- Converted to total neutrons in 1000 h of beam time
- Poor statistics in this simulation, this is why there are blank regions in plot



Summary

- Dose under control from human safety perspective
- DarkLight safety report being written, due to be submitted by end of year
- ARIEL extension safety report submitted by end of January
- Focused study on detector radiation damage underway