FLUKA Update

Ethan Cline

DarkLight Collaboration Meeting, TRIUMF

May 30, 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

FLUKA Input Deck

- Majority of FLUKA input deck written by Mina Nozar (Has retired)
- I received some on-the-job training from Luca Egoriti (Still at TRIUMF)
- Two DarkLight relevant input decks are in use
  - Current ARIEL Beam Dump Setup to verify current simulation can replicate previous results
    https://github.com/DarkLight-EXP/ARIEL-BD-FLUKA
  - Modification of Beam Dump into DarkLight setup
    https://github.com/DarkLight-EXP/DarkLight-BD-FLUKA

Using FLUKA

- FLUKA can be run on any laptop, but use server for rapid prototyping and cluster for statistics
- Currently use SBU server for plots shown here, FLUKA and flair compile nicely
- FLUKA compiles on MIT/SBU cluster, not on CEDAR
- Flair only compiles on MIT cluster

FLUKA Importance for DarkLight

- Two primary FLUKA uses for DarkLight
  - To get approval to put material in the electron beamline and demonstrate we can run safely
  - To determine the amount of shielding needed for the experiment detectors and electronics

FLUKA for Safety Approval

- FLUKA used to assess safety of the beam dump
- Also used to characterize background in the hall
- **Does not include any sort of target in the beamline!**
- Written by Mina Nozar
- Approved April 2014

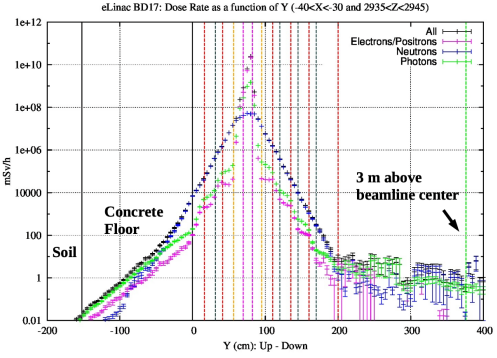


Figure from safety report

FLUKA from Safety Approval

- All results from Mina can be reproduced using FLUKA input deck within statistics
- Good baseline for comparisons!
- Still working on beautifying plots, multiple plots on same figure, etc.
- In principle all shapes from previous slide are reproduced, but can't quite figure out how to overlay them nicely

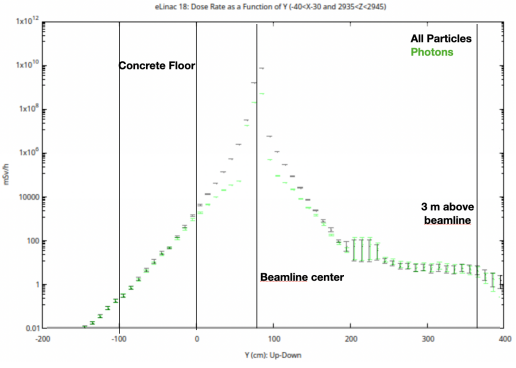
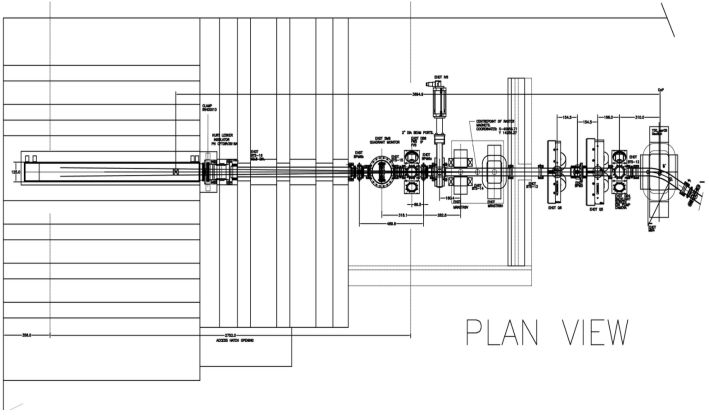


Figure from me, using Mina's input deck

FLUKA for DarkLight

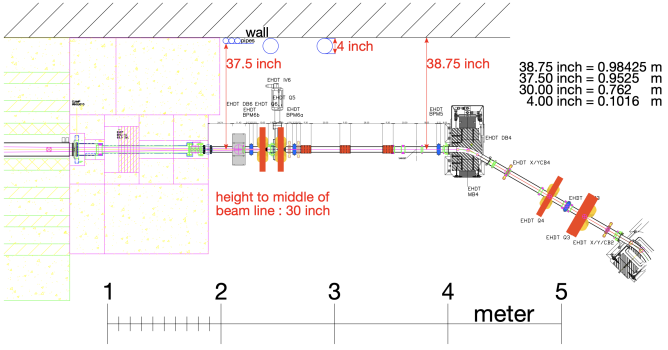
- Have good starting point from Mina
- What Mina simulated and got approved is not what was built
- Need to modify beamline to DarkLight configuration
  - Remove some shielding, remove beamline elements, add new magnetic field
  - Add target!



Top view from Mina, closely resembles what was built, but not quite

FLUKA for DarkLight

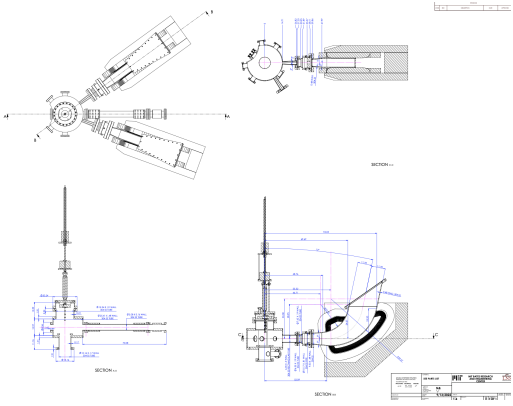
- Beamline elements moved!
- Shielding removed!
- Target implemented!
- Begun implementing DL chamber



Top view of DL configuration from Stephanie. Almost completely implemented!

FLUKA for DarkLight

- Have implemented DL chamber and collimator
- Need to bring beam dump and beam line up to existing spec!
- Need to implement detectors, spectrometers, concrete shielding for hut
- Have schematic from Chris, need time and motivation to finalize
- Don't need complete and final details to begin assessing background!



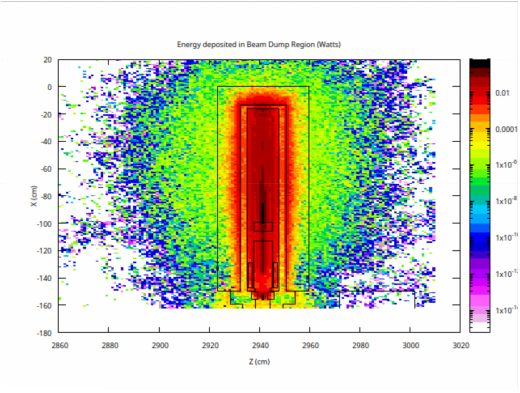
Chamber and spectrometer schematic from Chris

Results from FLUKA

- Caveats on results
  - 20 cm of shielding near the beam dump is not in FLUKA
  - There is an extra 13 cm of beamline **upstream** of the DL target
  - The magnetic field parameterization in FLUKA still needs tweaking, cf Aveen's talk
  - Beam not as focused as it should be!
- Using 30 MeV beam
- Using 330 μA beam
- DarkLight target is 1 μm thick

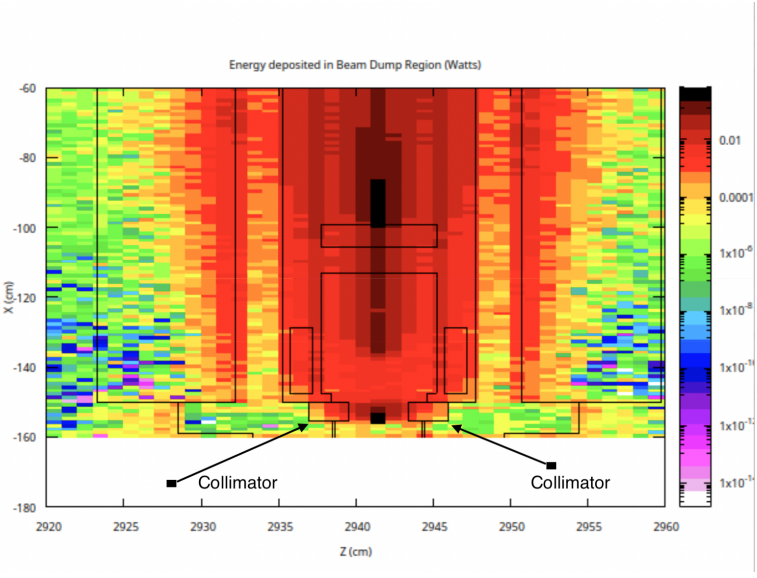
Results from FLUKA: Heating the Collimator

- Aluminum collimator implemented into FLUKA (Donut with square hole)
- Some beam will be absorbed into collimator
- How much heating will collimator experience?
- Some confusion on FLUKA units, but seems to be in GeV/e



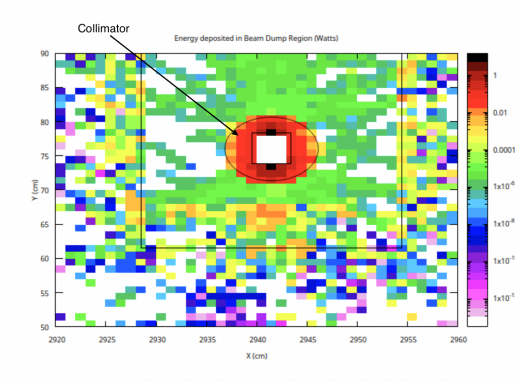
Top-down view of energy deposited into beam dump

Results from FLUKA: Heating the Collimator

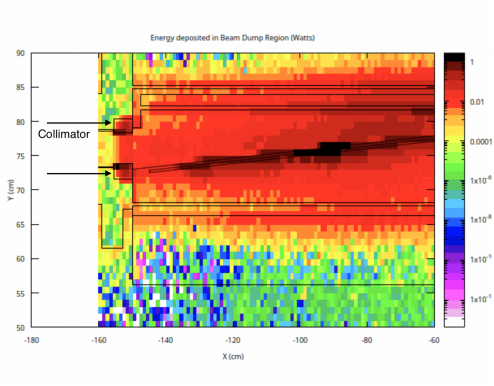


Top-down view of energy deposited in collimator

Results from FLUKA: Heating the Collimator



Looking down the beampipe view of collimator

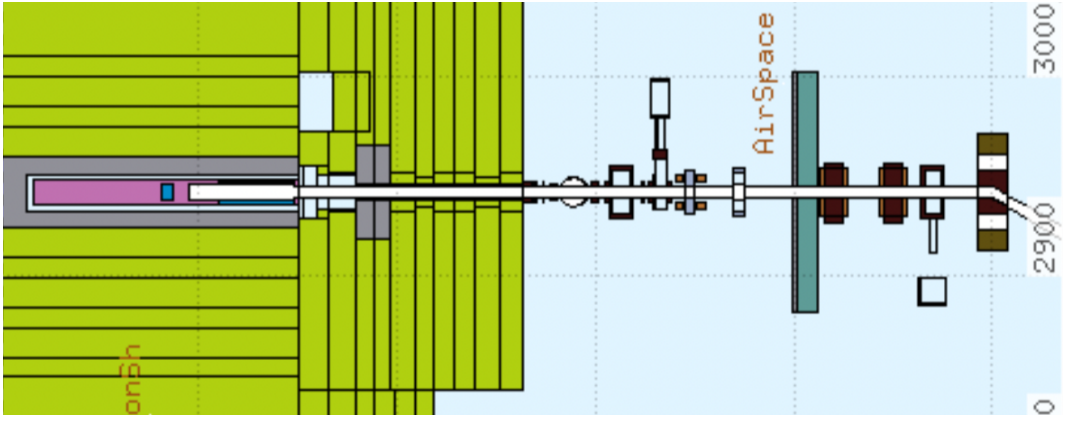


Side view of collimator

Results from FLUKA: Heating the Collimator

- Collimator receives ≈20-50 W from beam across surface
- This is with *improper beam tune*, once beam parameterization fixed, will reduce heat load

FLUKA Setup: Current Configuration

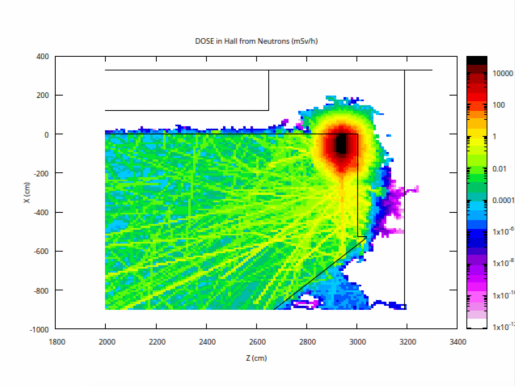


Results from FLUKA: Background from Beam

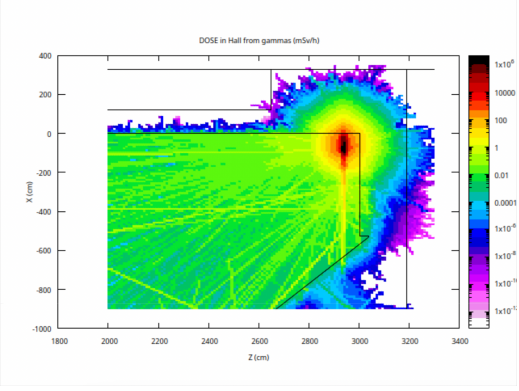
Date	Beam energy (MeV)	Beam power (kW)	γ dose (mSv/h)	n dose (mSv/h)
Oct 14 (1)	29.3	0.9	8	1.1
Oct 14 (2)	29.42	2.1	15	2
Oct 20	29.75	6	9	2
Oct 27	29.4	1.1	5	1.1

Measured rates from Kate/Tomas/Mike last fall. Without target.

Results from FLUKA: Background from Beam



Dose from neutrons



Dose from gammas

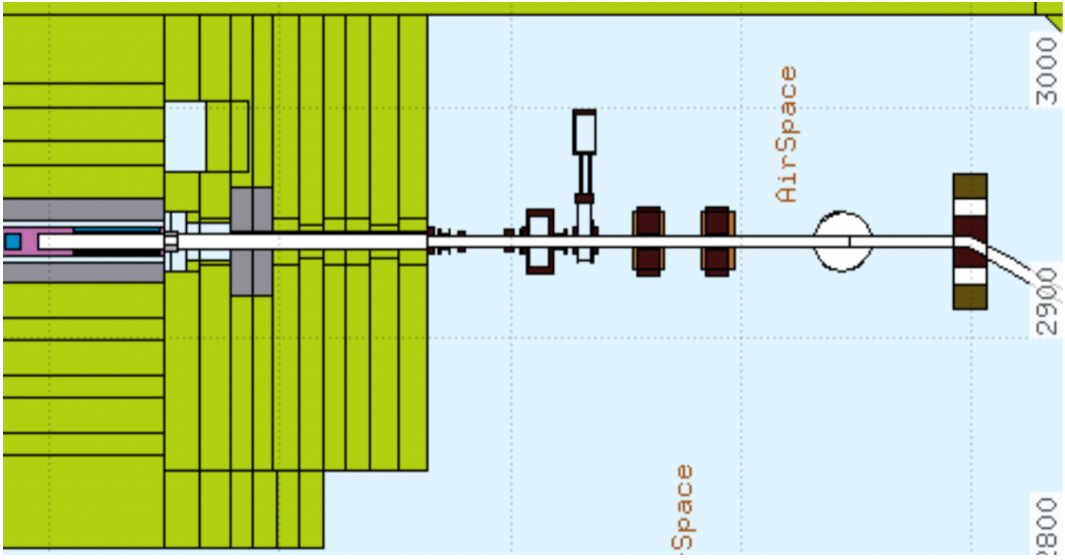
Results from FLUKA: Background from Beam

Measurements in the hall indicate 1-2 mSv/h of neutron dose
FLUKA estimates at a similar location $\approx$0.1 mSv/h neutron dose

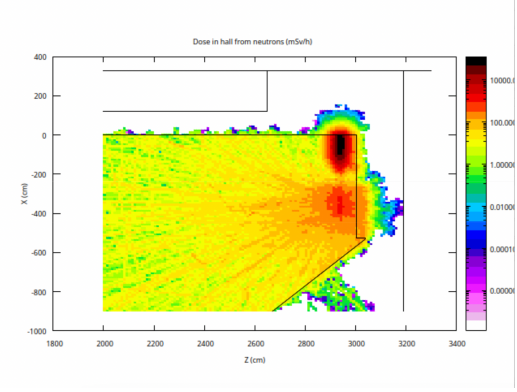
Measurements in the hall indicate 5-15mSv/h of gamma dose
FLUKA estimates at a similar location $\approx$1 mSv/h gamma dose

FLUKA indicates a total dose, including electrons, of $\approx$1.5 mSv/h
Conclusion - Measurement limited by statistics (50 M events), extremely sensitive to placement of detector

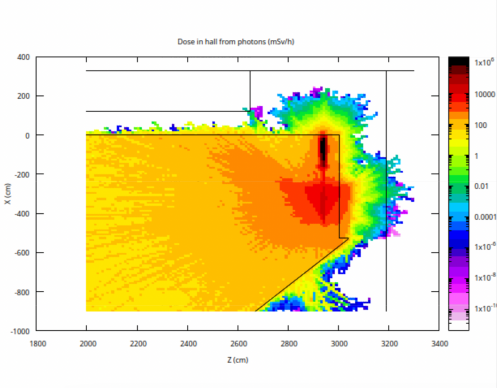
FLUKA Setup: DL Configuration



Results from FLUKA: Background from Target



Dose from neutrons



Dose from gammas

Results from FLUKA: Background from Target

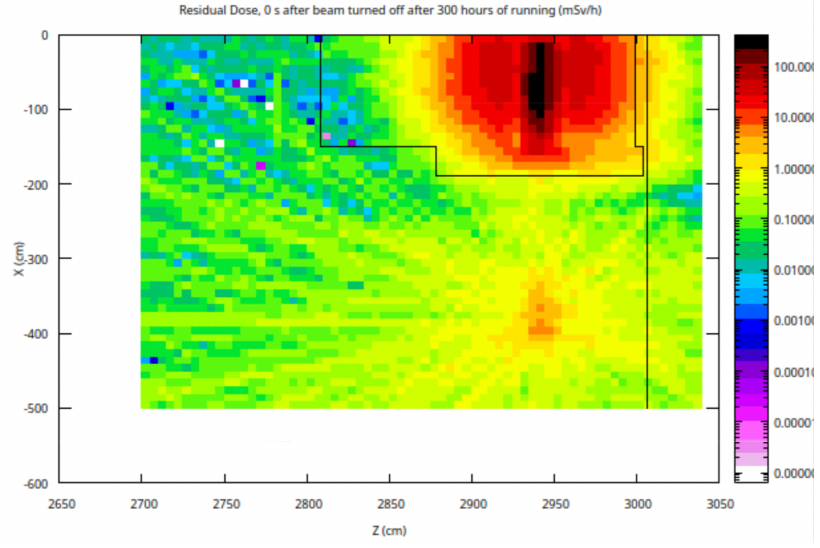
Including target increases background from $\approx$0.1 mSv/h $\rightarrow$ $\approx$10 mSv/h neutron dose

Including target increases background from $\approx$1 mSv/h $\rightarrow$ $\approx$1000 mSv/h gamma dose

Including target increases total dose from $\approx$1.5 mSv/h $\rightarrow$ $\approx$10,000 mSv/h

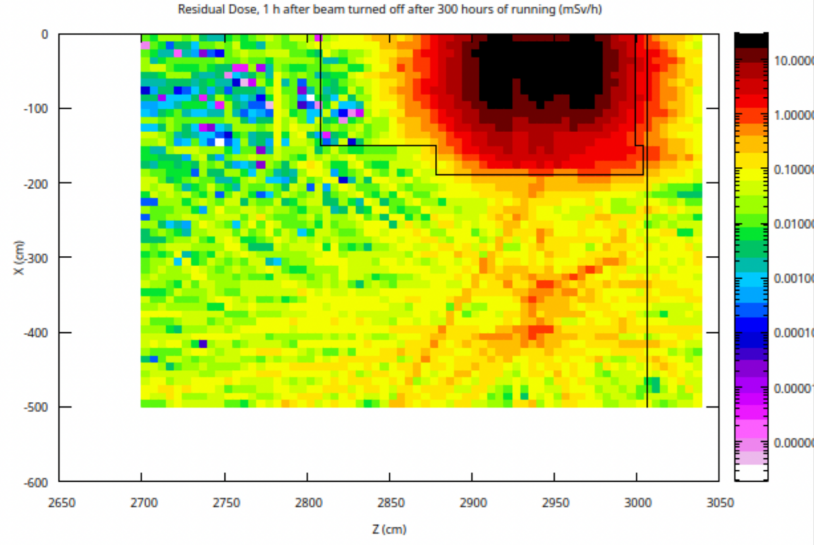
Conclusion - The beam focusing parameterization used in FLUKA is not quite right. Too much multiple scattering. Aveen is working on it. Not worried that it will impact experiment.

Results from FLUKA: Residual Dose



Residual Dose in hall after running beam for 300 hours and 0 s after beam turned off

Results from FLUKA: Residual Dose



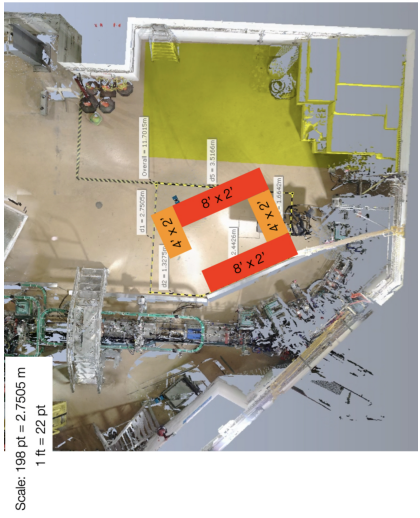
Residual Dose in hall after running beam for 300 hours and 1 h after beam turned off

Results from FLUKA: Summary

- Have modified beamline to be in DarkLight-like configuration
- Have include some parameterization of beam optics
- Current dose in hall unrealistically high according to FLUKA
- Measurements do not indicate significant problem
- Hall apparently safe to enter almost immediately after turning off beam (give the target an hour or so)
- More work to do!

Future Work

- Implement rest of DL chamber and apparatus
- Implement shielded electronics hut
- Finalize optics parameterization (hopefully this week)
- Compare to measurements in hall with target
- Write paper?



Future shielded electronics hut