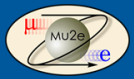
WP2: Mu2e-II and Mu2e Targetry updates

S. E. Müller

Helmholtz-Zentrum Dresden-Rossendorf

aMUSE General Meeting Workshop, *September 17, 2024*



HZDR

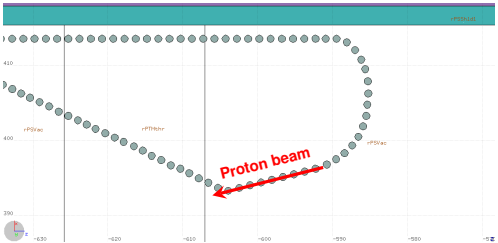
DRESDEN concept

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

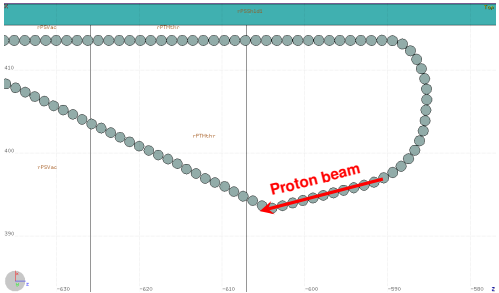
New PT conveyor target positions

Spline-parameterization of sphere trajectories allows to more realistically model the sphere positions when changing sphere radii:

Old design (tungsten):



New design (tungsten):



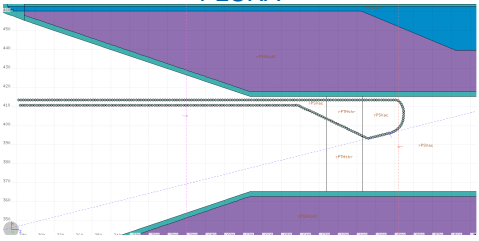
Added feeding and draining lines for design with carbon spheres (which was limited to only the spheres interacting wth the beam).

New PT conveyor target positions

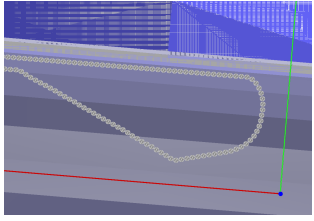
New conveyor target designs have been implemented with FLUKA and GEANT4 (Michael MacKenzie, Northwestern University, also corresponding `gdml`-files):

333 tungsten spheres with 6.3mm radius:

FLUKA

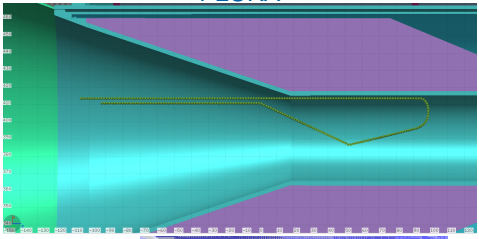


GEANT4



274 carbon spheres with 7.5mm radius:

FLUKA



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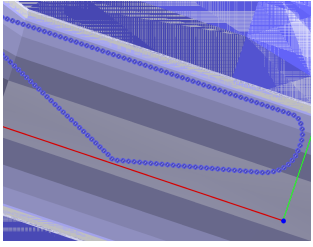
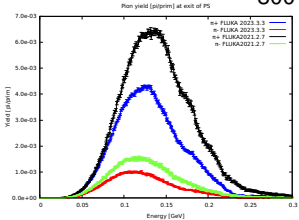
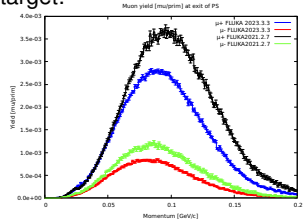


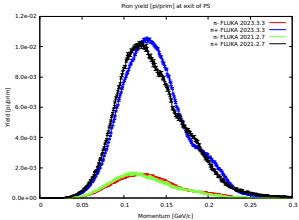
FLUKA Pion and Muon yields with Tungsten and Carbon targets

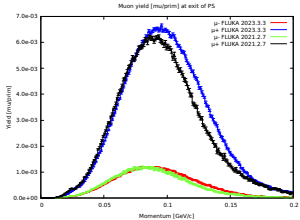
800 MeV protons on tungsten target:





800 MeV protons on carbon target:



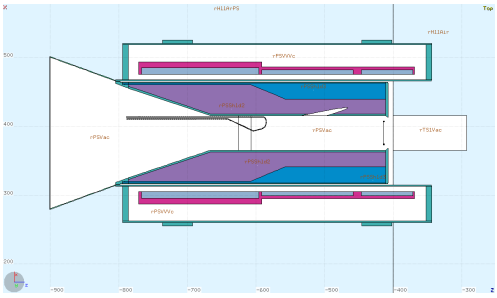


Results do not change much for carbon target design, but are lower by $\sim$ 30% for tungsten target - reason has probably been understood (**not** due to a change in **FLUKA** physics, but geometry had been changed for tungsten target).

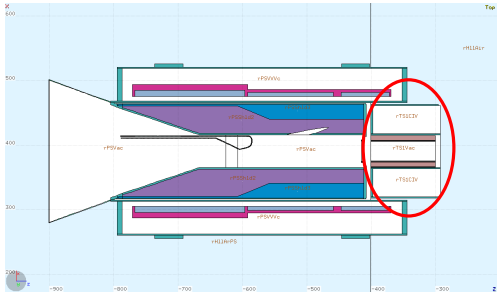
FLUKA Pion and Muon yields with Tungsten and Carbon targets

Collimator at entrance of Transport Solenoid was added to geometry:

Old geometry without collimator:



New design with collimator:



The collimator is taking out a fraction of the particles going from Production Solenoid to Transport Solenoid.

- looks everybody else was scoring particles entering the Virtual Detector volume from the PS, while I was scoring particles exiting the Virtual Detector volume into the TS
- I reached out to Michael MacKenzie and Vitaly Pronskikh to confirm (no answer yet)

New prototype of conveyor target

A new prototype for the conveyor target has been built by Euclid Techlabs.

- Layout more close to what is projected in the simulations
- Sprocket drive to drive the spheres

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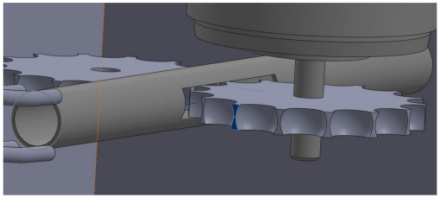

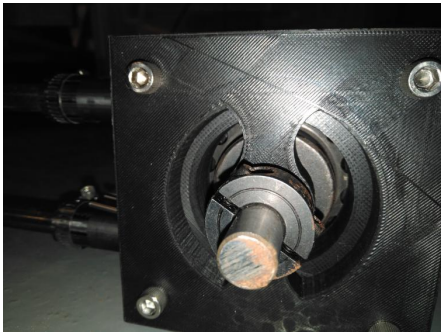

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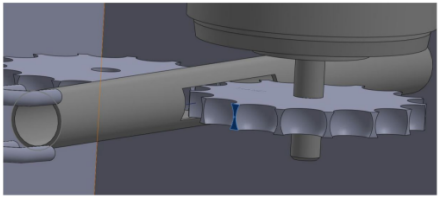
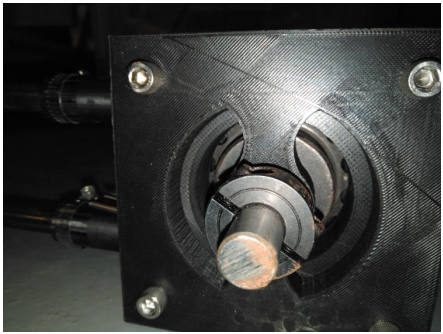


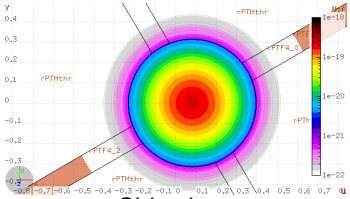


Many more ideas on target design following discussions at targetry session of “Workshop on a Future Muon Program at Fermilab” (Caltech, Mar 27 - 29, 2023)

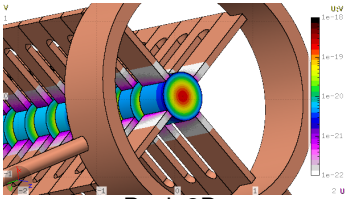
DPA simulations for the Mu2e hayman target

Simulations by the FNAL targetry group for the Mu2e hayman target gave up to 250 DPA (locally concentrated) per year of running. I re-checked using my **FLUKA** model:

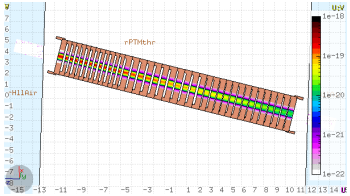
Front view



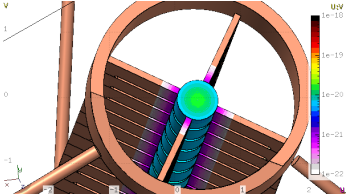
Front 3D



Side view



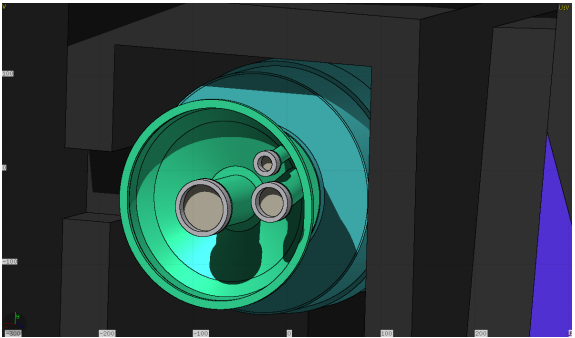
Back 3D



With a maximum value of 3×10^{-19} DPA/proton, 5.5×10^{12} prot/sec and 1.5^{7} sec/year, I get 22 DPA/year at the hottest spot.

Updated PS endcap geometry

The PS endcap had been updated from a flat design to a curved one, adding a big central window tube, flanges and additional ports. I have added this now to the FLUKA simulation:



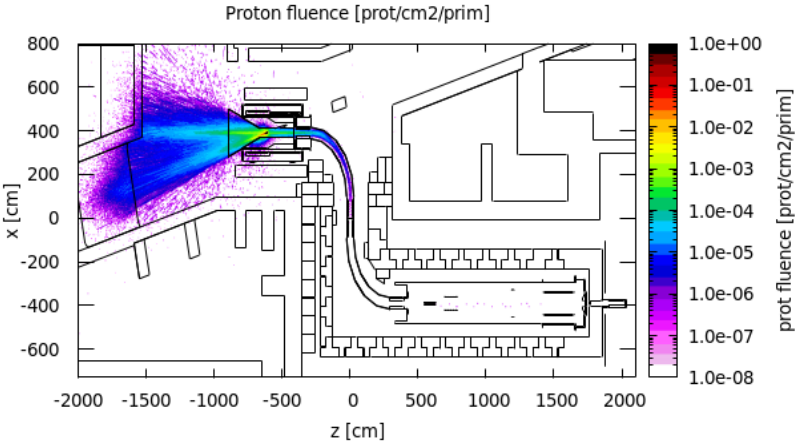
- Does not change muon stopping rates at Stopping Target, but may have an effect on shielding calculations

Bringing FLUKA to `fermigrid`

- **FLUKA 2023.3.3** has been packaged for **ups** with help from Ray Culbertson and Rob Kutschke from **MU2E**
  - I provide `.tgz` packages for upcoming respins or releases of **FLUKA**
  - Did for **FLUKA 2024.1.0**
- **Mu2e** magnetic fieldmaps for **FLUKA** now available at `/cvmfs/mu2e.opensciencegrid.org/DataFiles/BFieldMaps/Mau13/FLUKA/`
  - `PSMap.bin, TSuMap_swap_TS_14_15.bin, TSdMap.bin, DSMap.bin, DSSweepExtension.bin`
- Can now run **FLUKA** simulations on `fermigrid`
  - Lot of things to be learned and understood...
  - One event (POT) takes about 10 seconds (with magnetic field, without magnetic field it is about 3-4 seconds)
- In the meantime, **MU2E** has moved to Almalinux 9 and **SPACK** instead of Scientific Linux 7 and **ups** ...
  - Work in progress to package **FLUKA** for **SPACK**

First results from the grid

After some initial difficulties, I managed to launch 200 jobs of 5 $\times$ 500 events each (of which 164 came back, so I have 410 000 events). **FLUKA** postprocessing routines are used for standard **FLUKA** scoring, and a **ROOT** `TSelector` was used to process **ROOT**-files.



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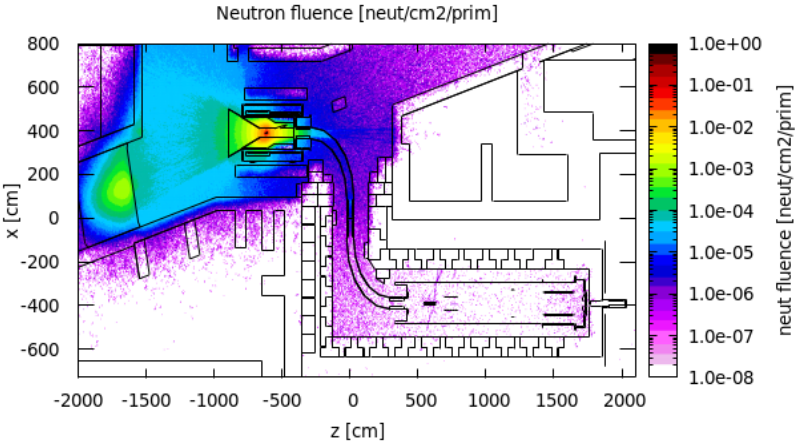

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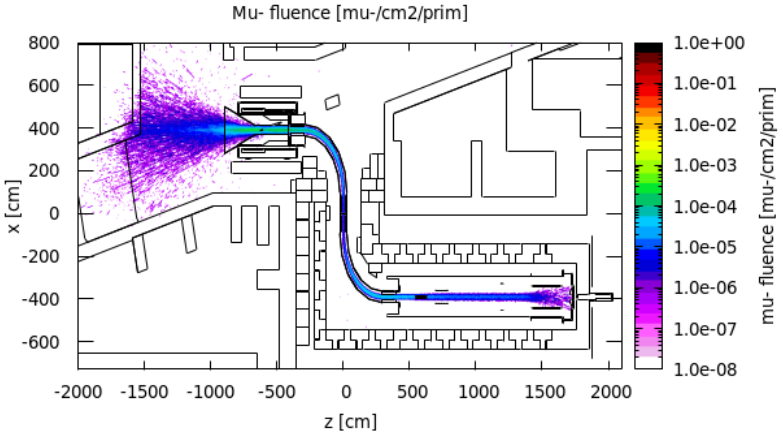


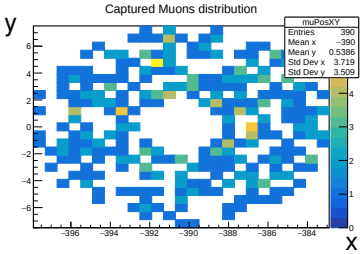
Stopped muons:

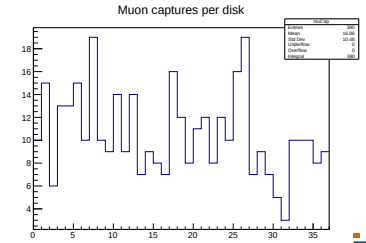
FLUKA allows to identify muons getting captured on the aluminum discs. I got 390 captured muons out of 410 000 primary protons.

Using the 0.6095 factor of muon captures per stopped muon, we get
0.00156 stopped muons per POT
which fits quite nicely with what can be found in **MU2E** literature:

- 0.0019 stopped muons per POT (TDR)
- 0.0016 stopped muons per POT (TDR target)
- 0.00156 stopped muons per POT (Tier 1)
- 0.00151 stopped muons per POT (Hayman 2)

More statistics is needed (of course).





Summary & Conclusion

- **MU2E-II** target models have been updated in the simulation
  - Better sphere alignment along path for tungsten spheres, feeding- and draining line spheres added for carbon design
  - Now repeat calculations done for SATIF workshop in 2022 and compare with GEANT4 and MARS codes
- New prototype of target for **MU2E-II** built by Euclid techlabs
  - Sphere trajectory closer to simulation design
  - Sprocket drive
  - Shelved momentarily due to lack of peoplepower
- Problem found with current **MU2E** hayman target design
  - Large radiation damage over 1 year of running found in simulation ($\sim$ 20 DPA)
  - Graphite target?
- Further improvements in **FLUKA** simulation
  - Endcap design in PS updated
  - Possibility to run **FLUKA** on `Fermigrid`