G4 simulation for Axial Form Factor Experiment

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Inaugural Axial FF Collaboration Meeting

Sep 14th 2024

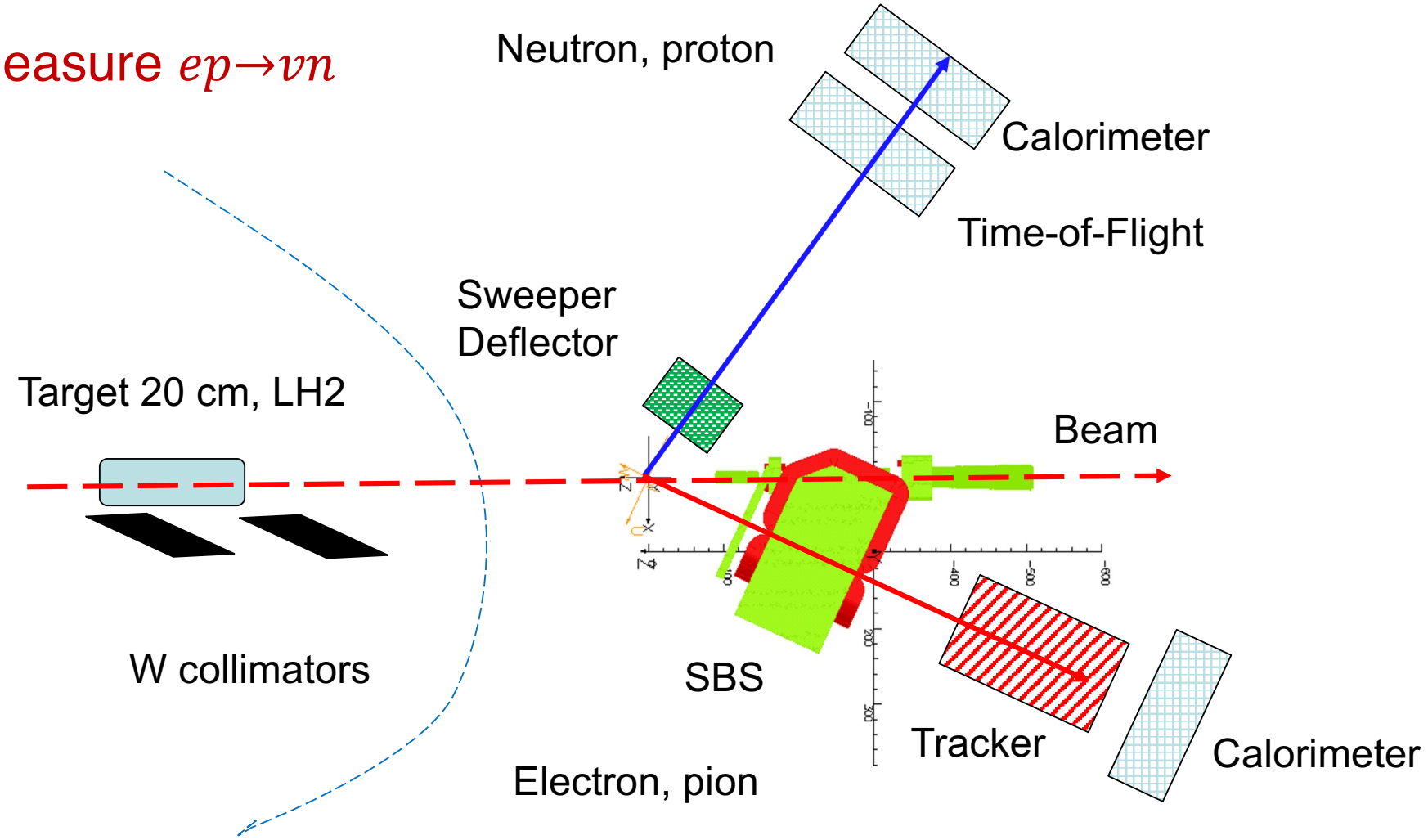
SHANDONG UNIVERSITY

Outline

- Overview of desired simulation framework
- Neutron energy deposition on Time-of-Flight (TOF) detector
- Beam-on-target simulation
- Task list and workforce

Overview of Experimental Apparatus

Need to measure $ep \rightarrow vn$



Overview of Experimental Apparatus

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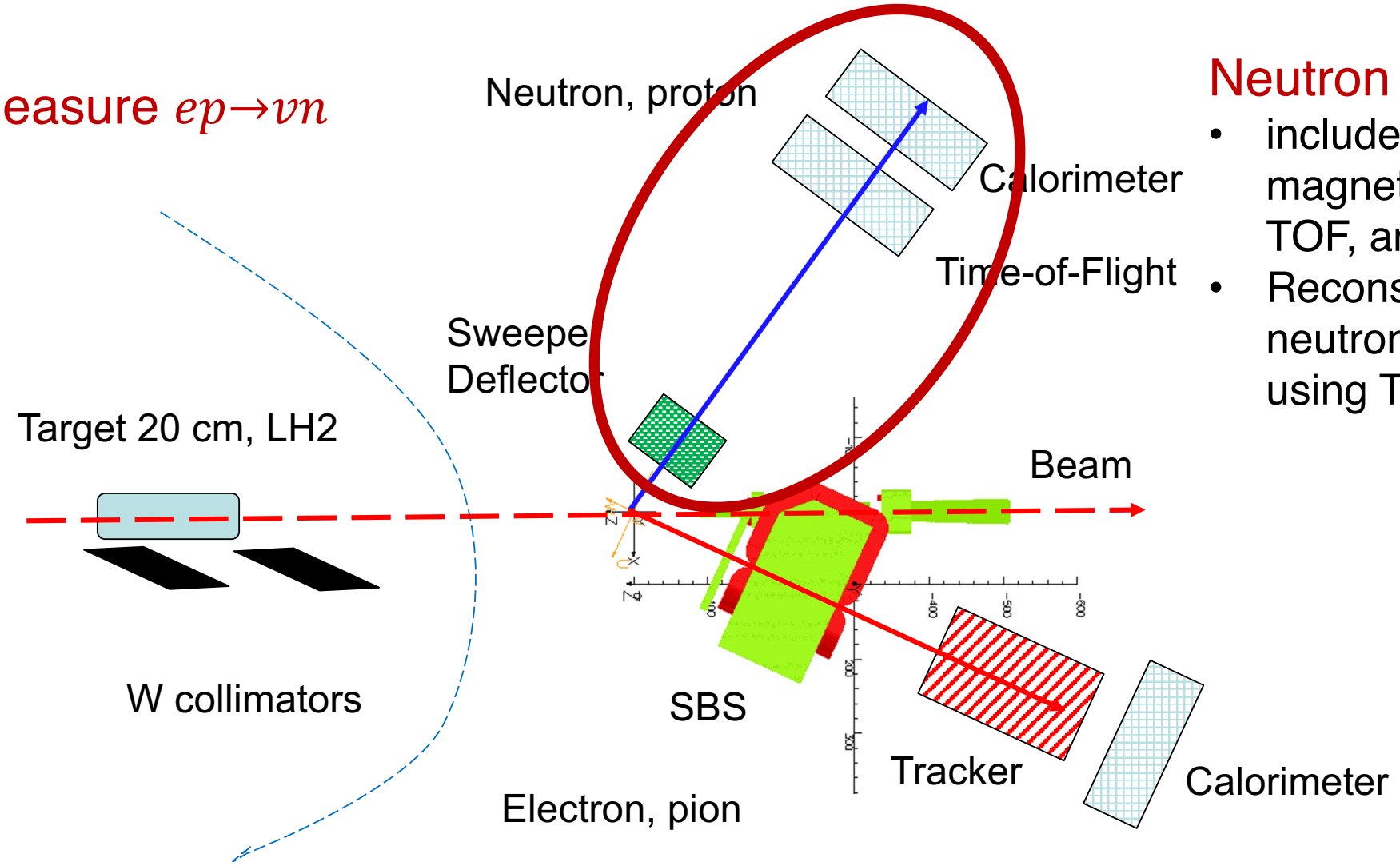
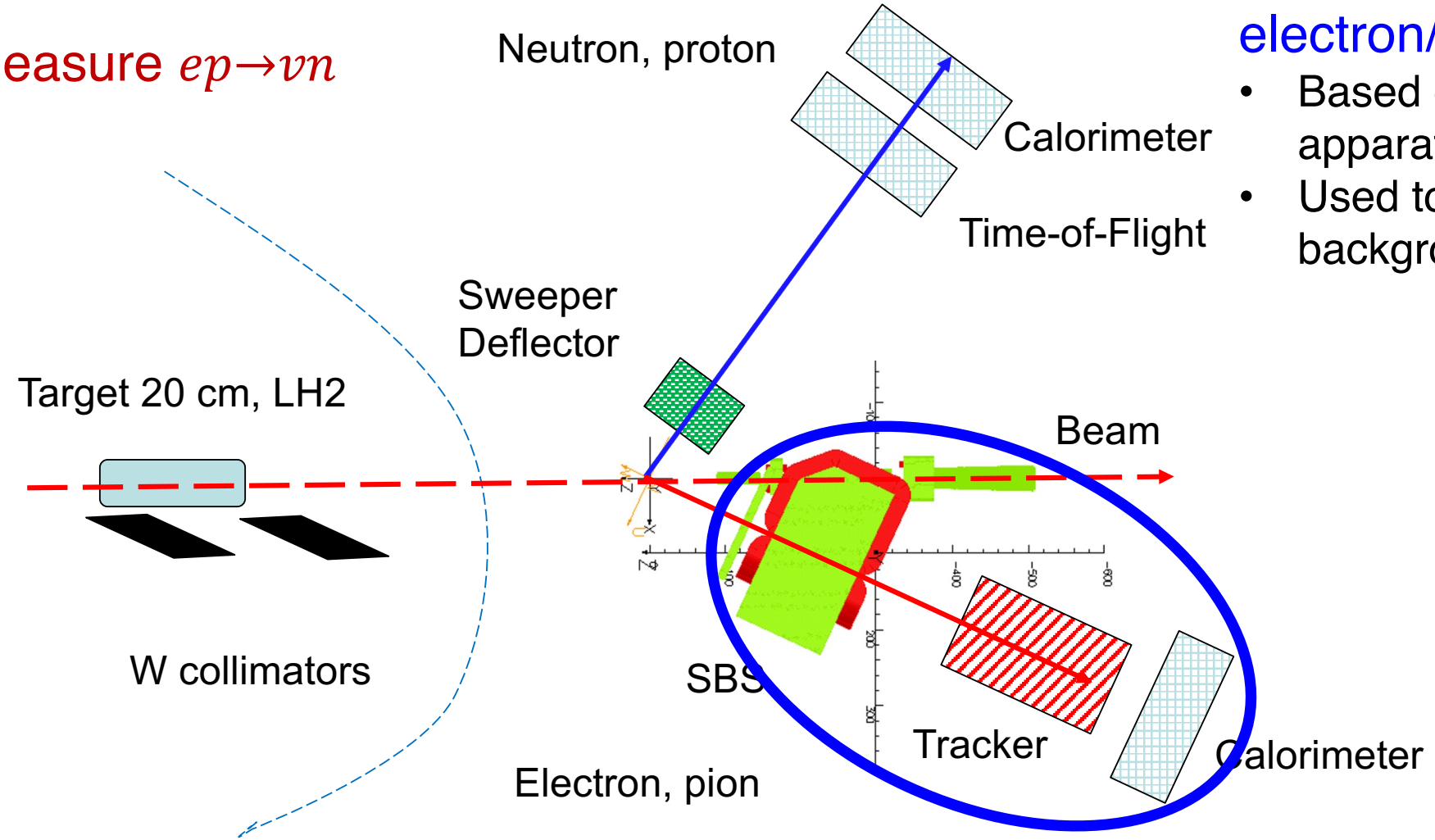


Neutron arm:

- include sweeper magnet, scintillator TOF, and Hcal
- Reconstruct neutron p and θ using TOF

Overview of Experimental Apparatus

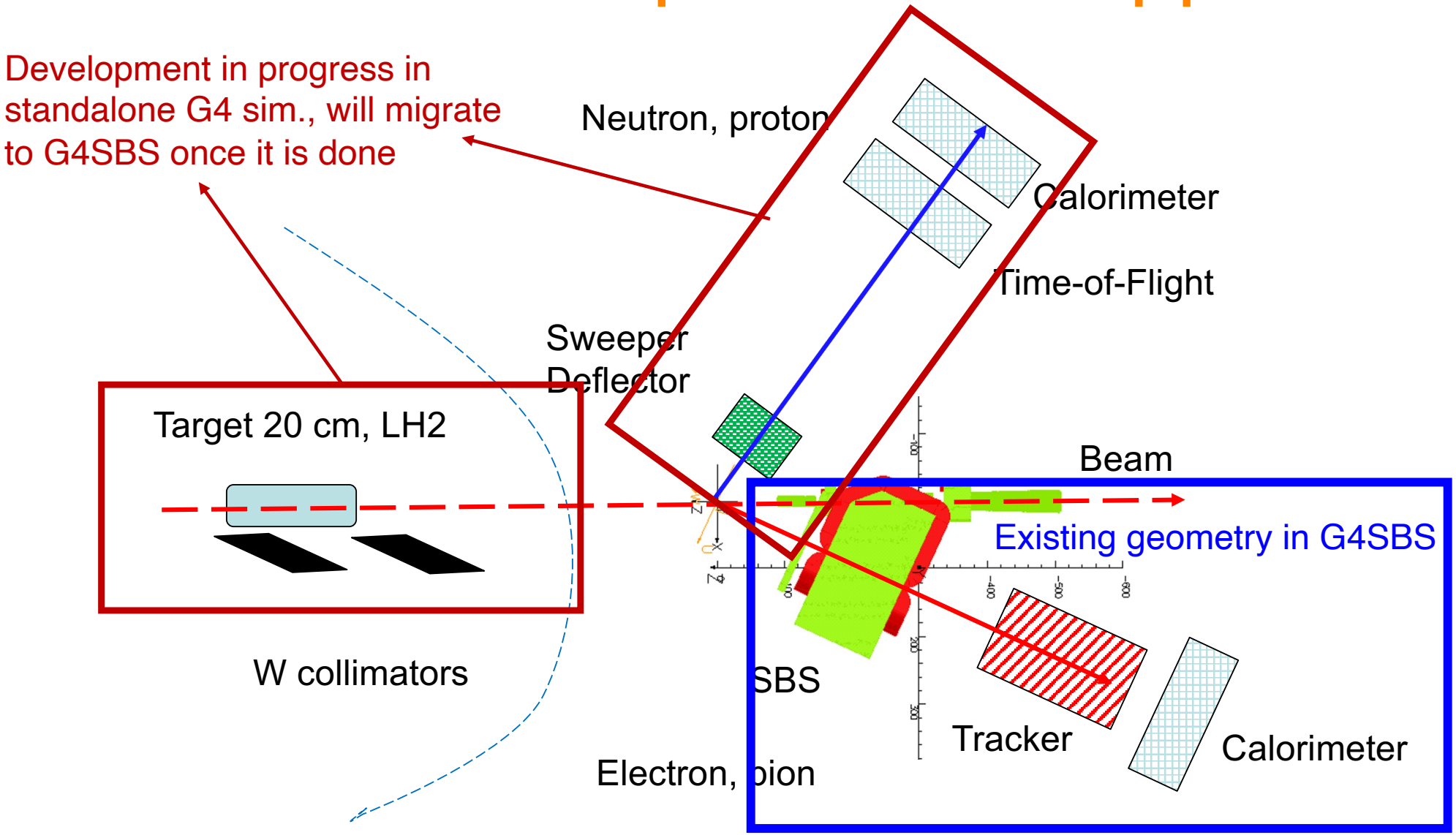
Need to measure $ep \rightarrow vn$



electron/pion arm:

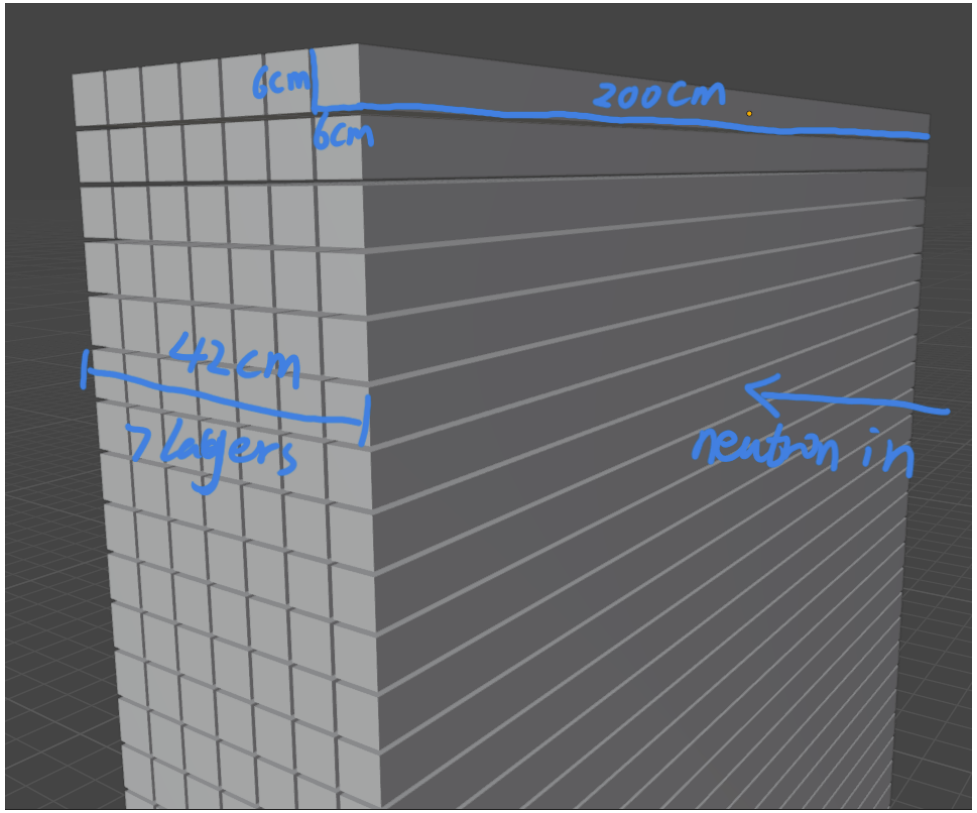
- Based on SBS apparatus
- Used to veto background

Overview of Experimental Apparatus

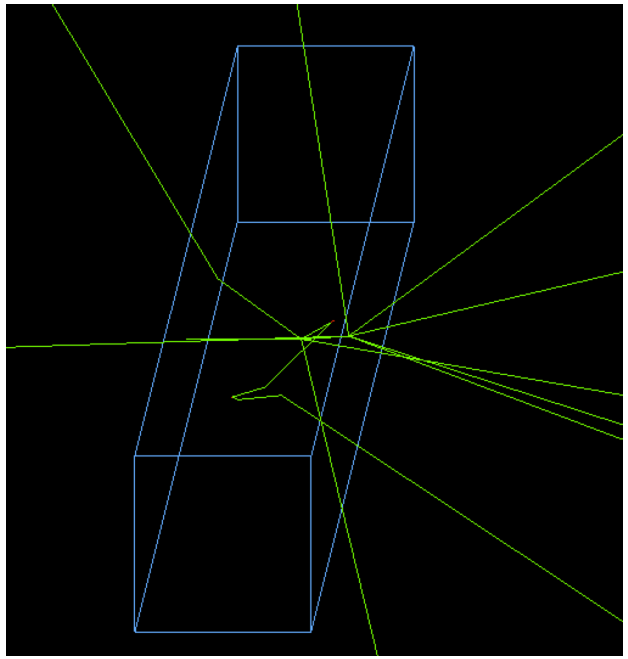


Simulation Setup for EDep in TOF

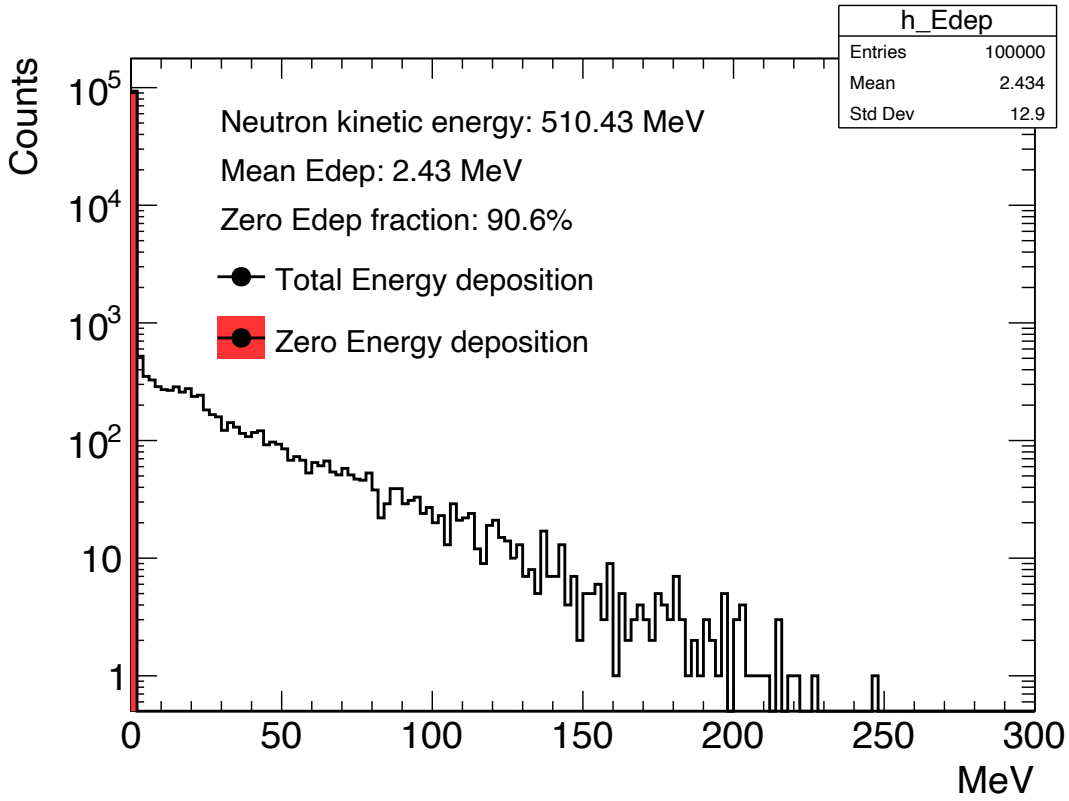
- Particle gun: neutron
  - Total energy: 1.45 GeV corresponding momentum ~1.1 GeV
  - Direction: +z direction
- Physics list: FTFP_BERT (a build-in list)
- Detector geometry
  - Module material: BC408 (a plastic scintillator made by Luxium solutions)
  - Single module: x-y-z = 200-6-6 (cm)
  - Module array:
    - 7 layers in z
    - Each layer: 1 module in x and 140 modules in y
    - 980 modules in total



Neutron Energy Deposition in a Single Module



Example of an event



- Average energy deposition: 2.43 MeV
- 90% neutrons with 0 energy deposition

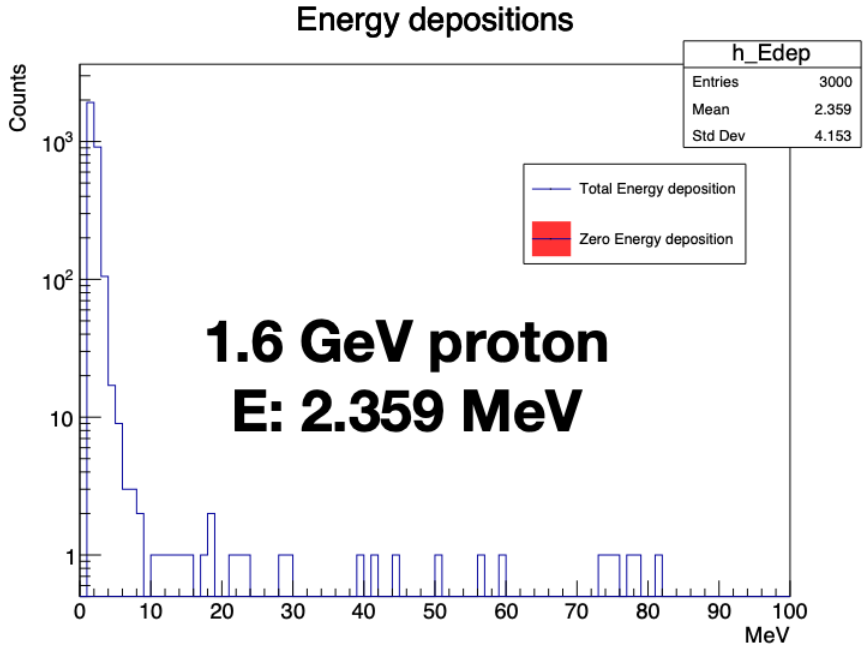
Validation of TOF Module EDep

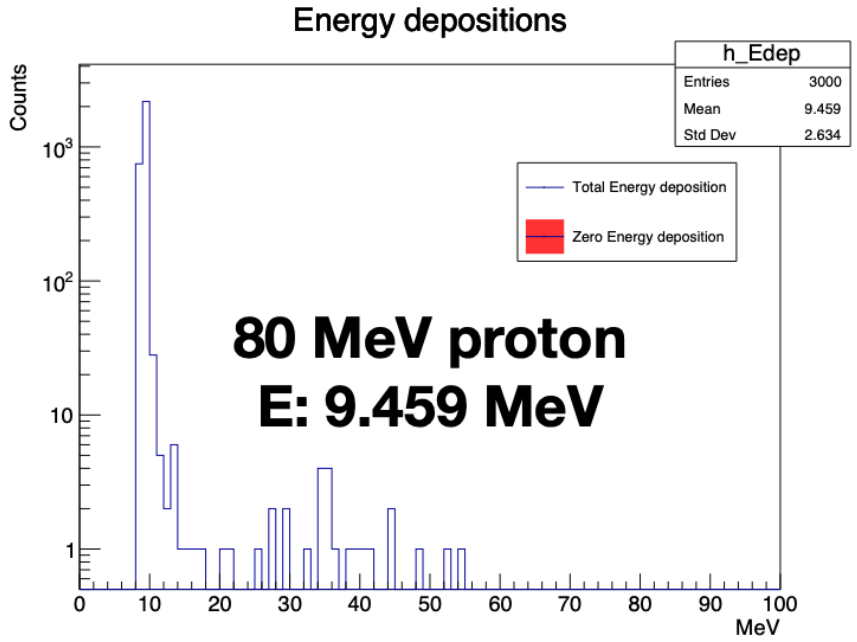
- Proton energy deposition with 10mm scintillator
  - 1.6 GeV(kinetic energy) proton: 2.02 MeV
  - 80 MeV(kinetic energy) proton: 9.09 MeV

According to LISE++ calculation, the deposition energy of 10 mm thickness of plastic scintillator irradiated by 1.6 GeV proton is 2.02 MeV and the deposition energy of 80 MeV proton is 9.09 MeV[9]. The absorbed dose is the average radiation

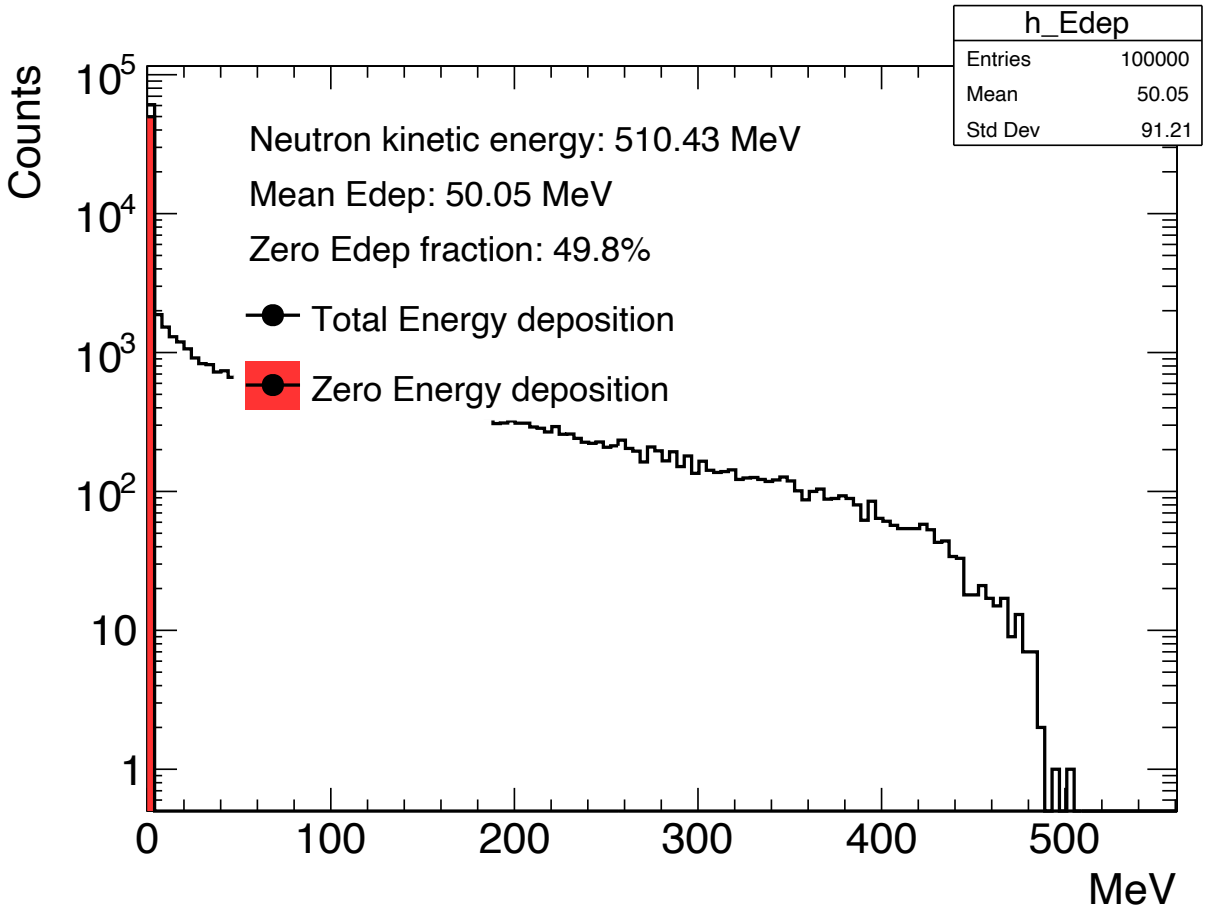
- Simulation results: slightly larger values

2309.04164

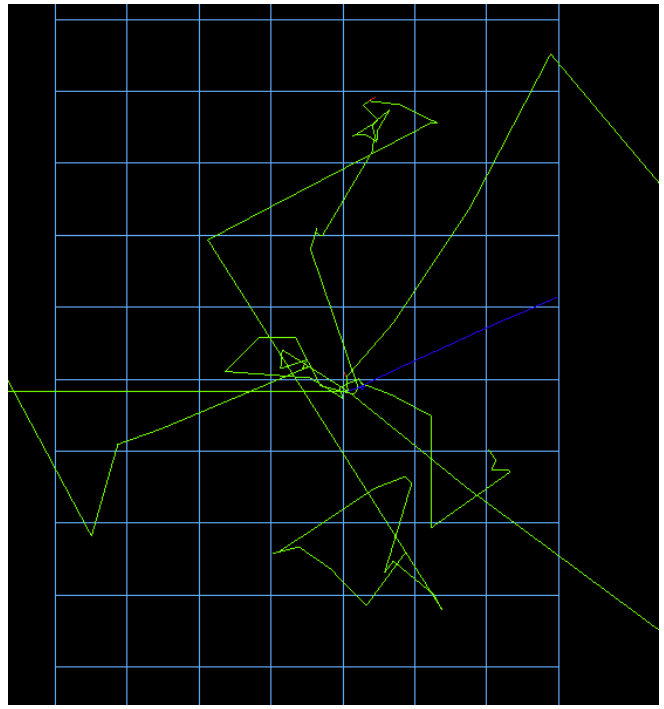




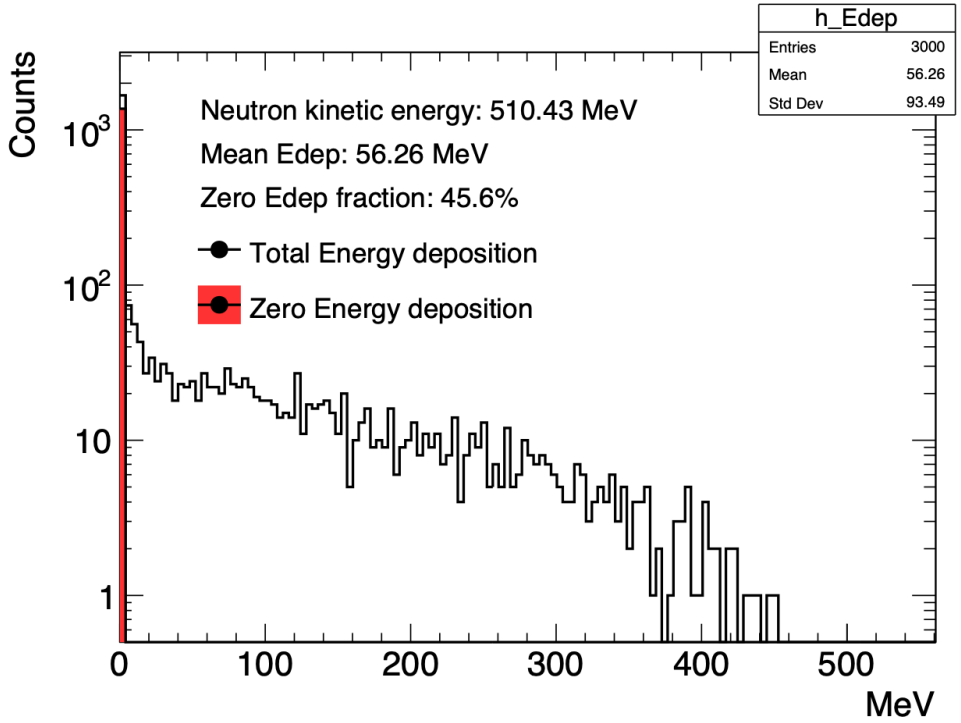
Neutron Energy Deposition in Module Array



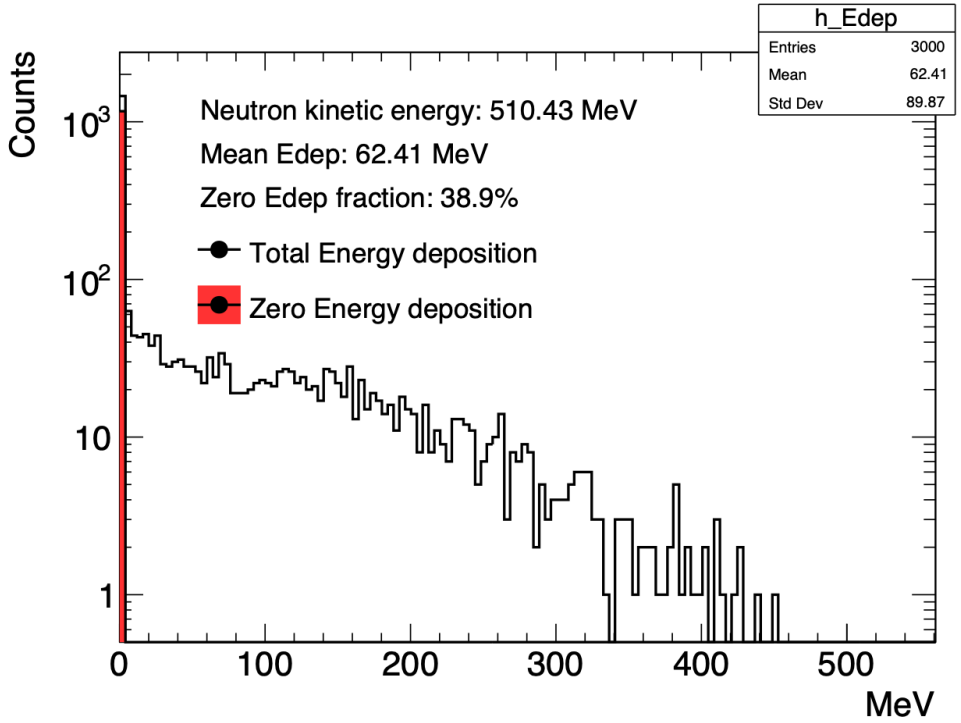
- ~50% neutrons with 0 energy deposition



Neutron Energy Deposition with Iron Plates



1 iron plate in front of 1st layer of array



1 iron plate each in front of the 1st and 2nd layers of array

- Adding iron plate (2cm thickness) in front of some layers
- Average energy deposition increases by ~6MeV per iron plate.
- Neutron detection efficiency increases by ~5% per iron plate

Setup for Beam-on-Target Simulation

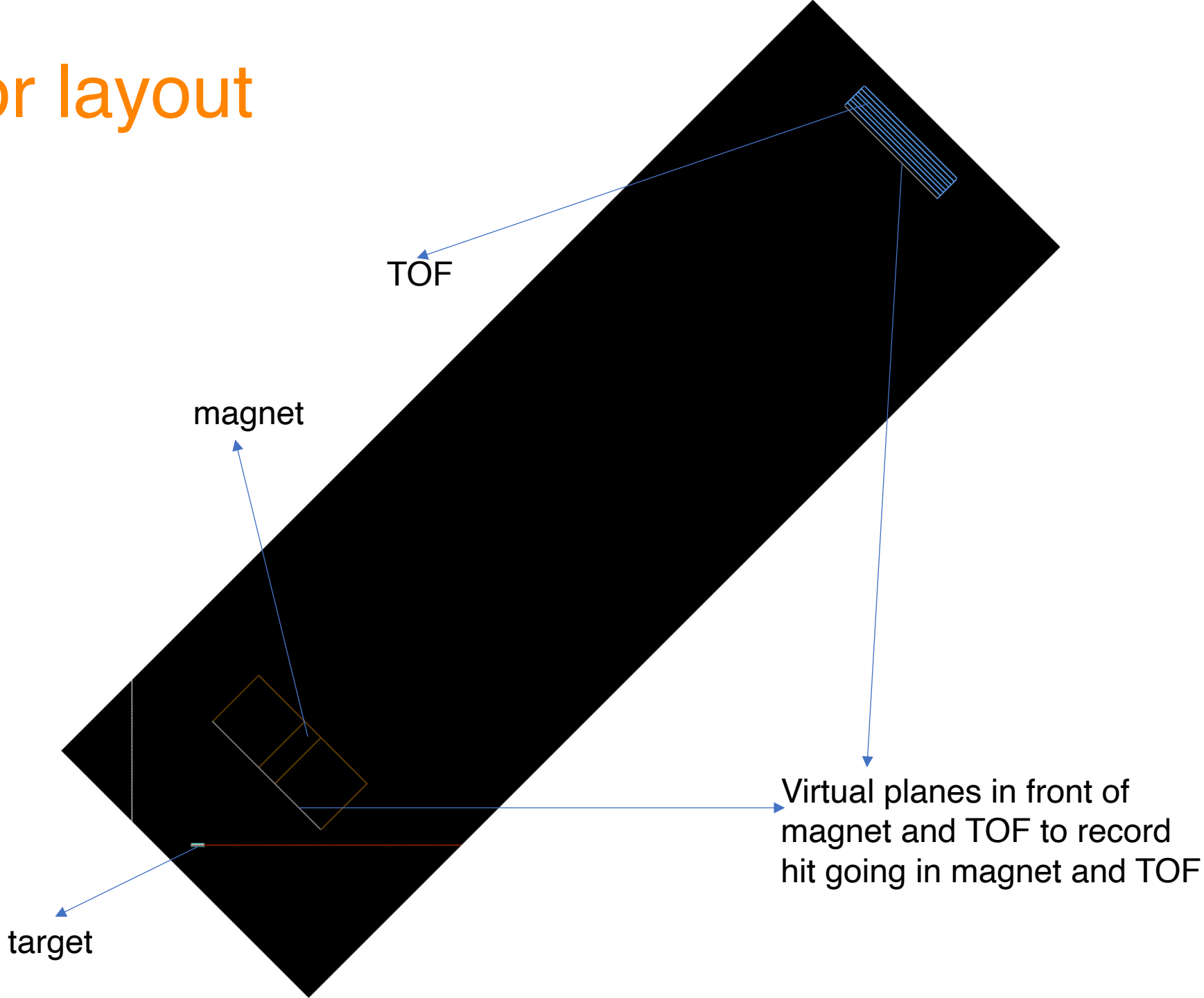
- Particle gun: 2.2GeV electrons along +z direction
- Physics list: FTFP_BERT (a build-in list)
- Detector geometry: LH2 target + neutron arm (magnet + TOF) filled with air
  - Neutron arm is rotated by 45° around y-axis with respect to the target

Target: LH2
- Container: aluminum, 2 inch diameter, 20cm long
- beam windows are 0.15 mm
- thickness of the cell side wall is 0.25 mm.
- Placed in a vacuum beampipe

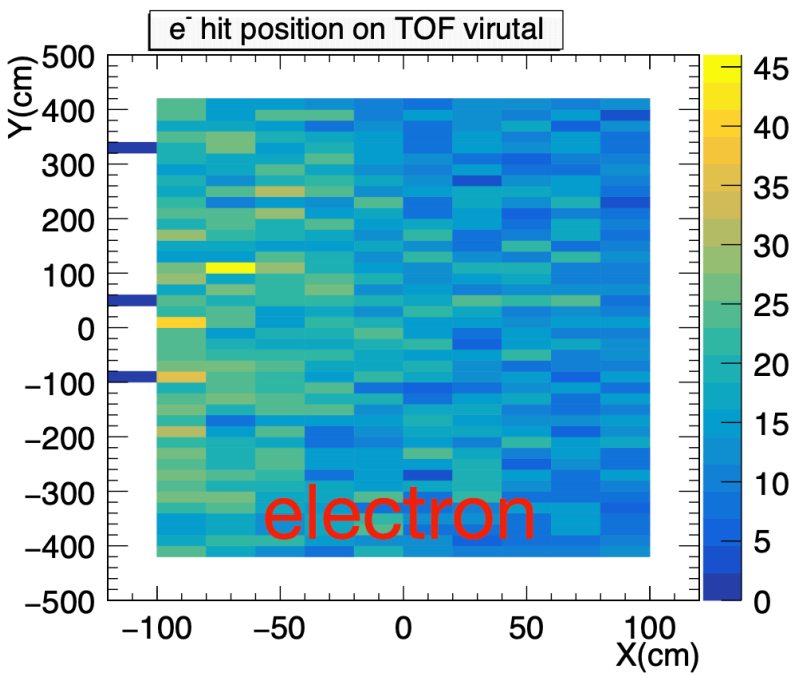
Magnet:
- BField: 0.5T in y
- BField area (x-y-z): 34-142-100 (cm) filled with air and surrounded by iron wall in x-y direction
- Thickness of Iron Wall: 100 cm in x and y direction
- 1.5 m away from the target

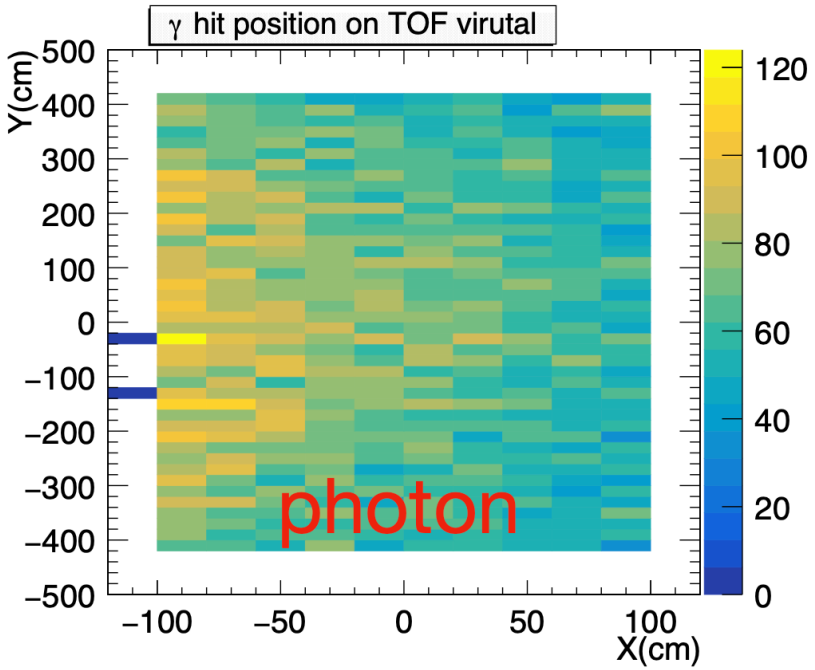
TOF:
- Material: BC408
- single module x-y-z: 200-6-6 (cm)
- Array of modules x-y-z: 200-840-42 (cm)
- number of modules x-y-z: 1-140-7, totally 980 modules
- 15 m away from the target
- No iron plates

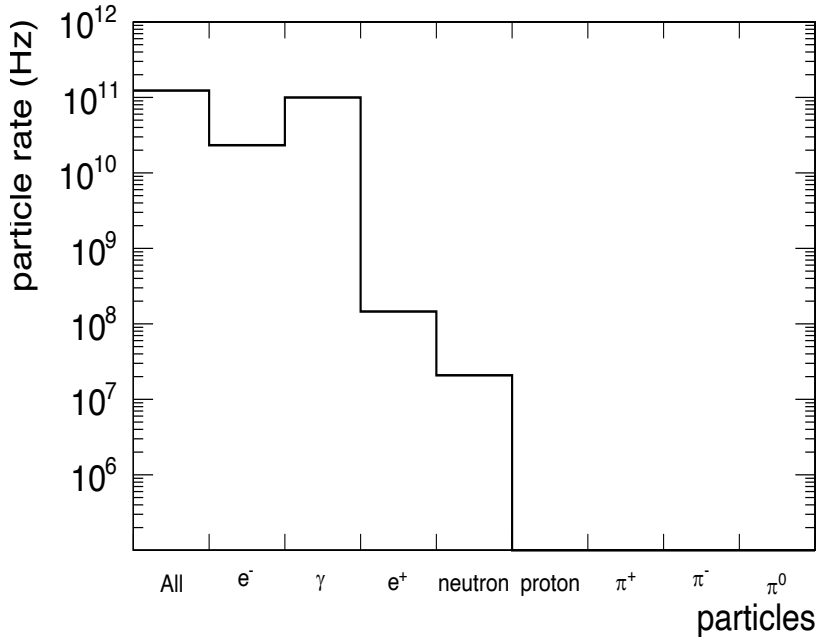
Detector layout



Hits x-y Distribution on Virtual Plane at TOF

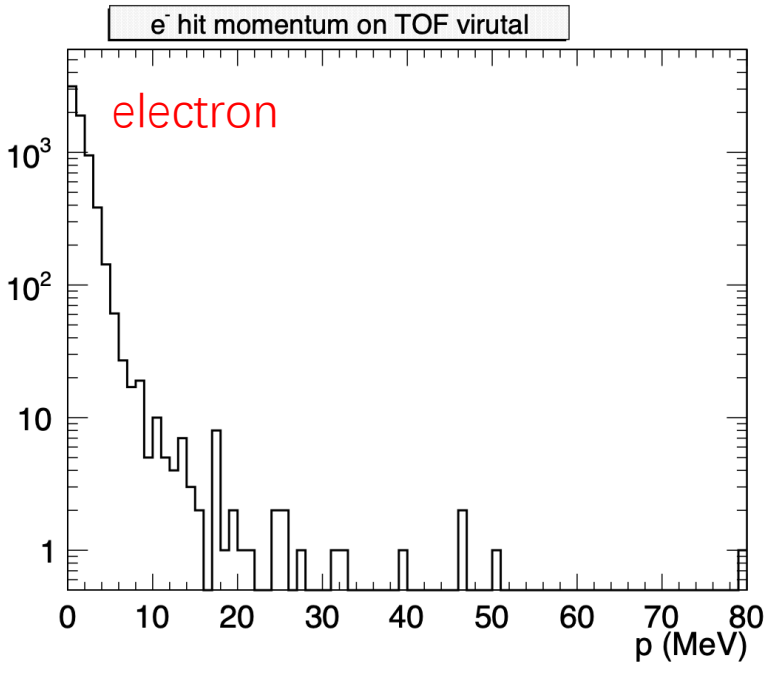


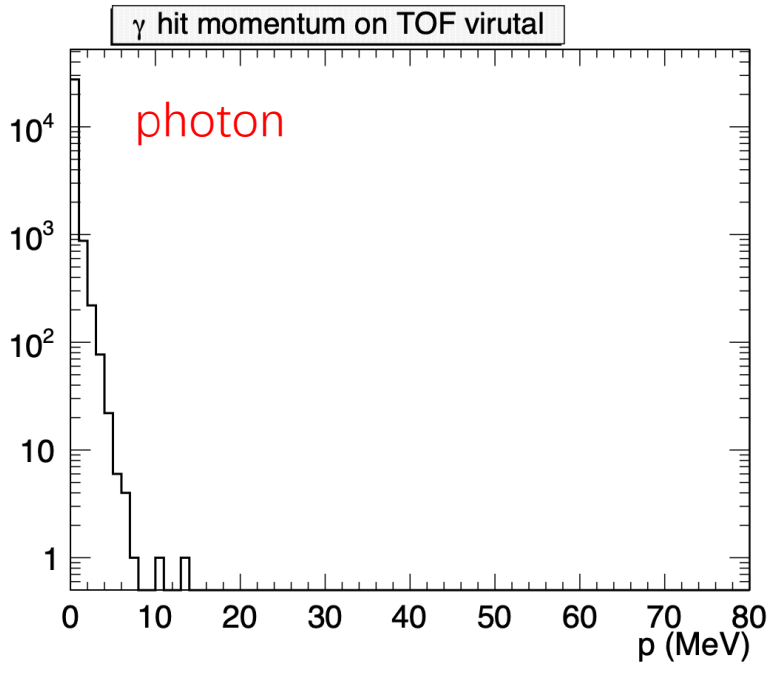


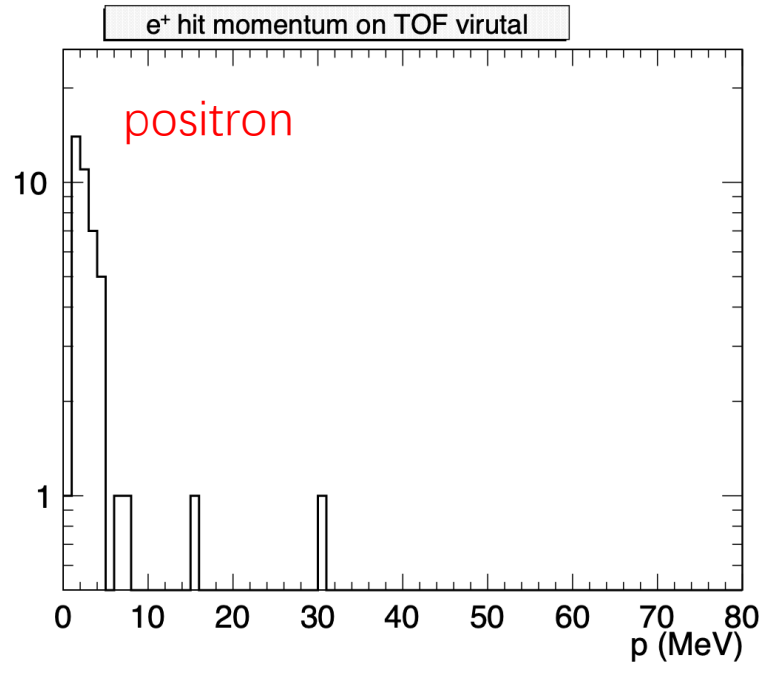


- No energy cut applied
- Two dominant sources: electron and photon
- Number of particles is much smaller than that goes into magnet

Momentum Distributions on TOF Virtual Plane

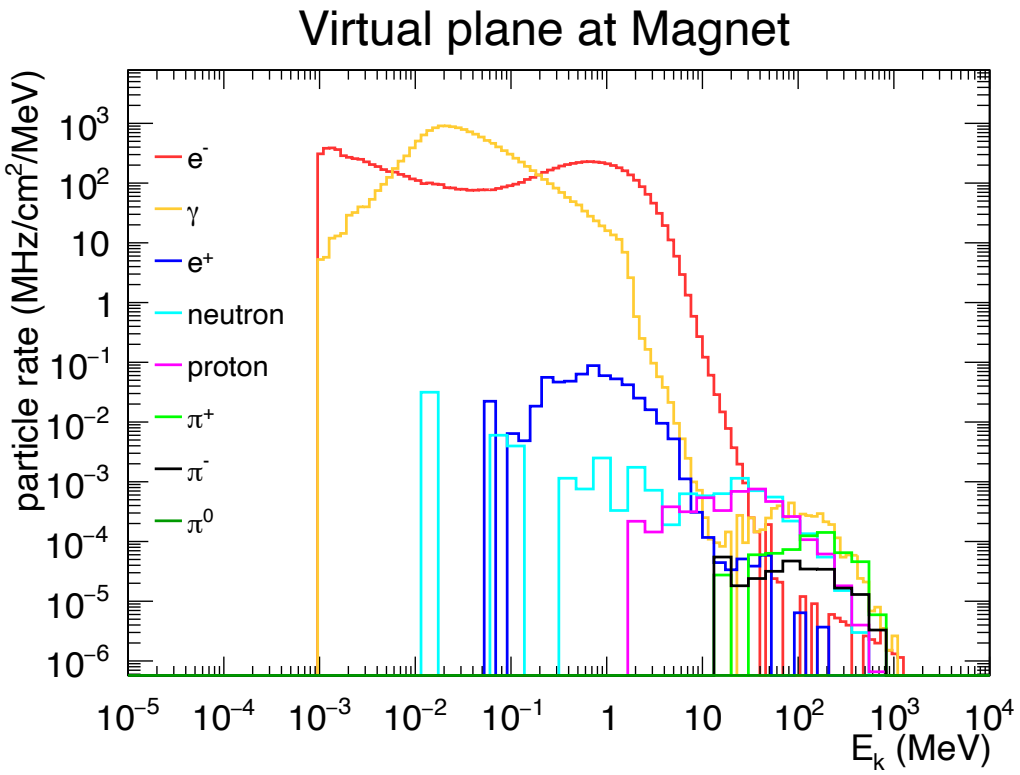


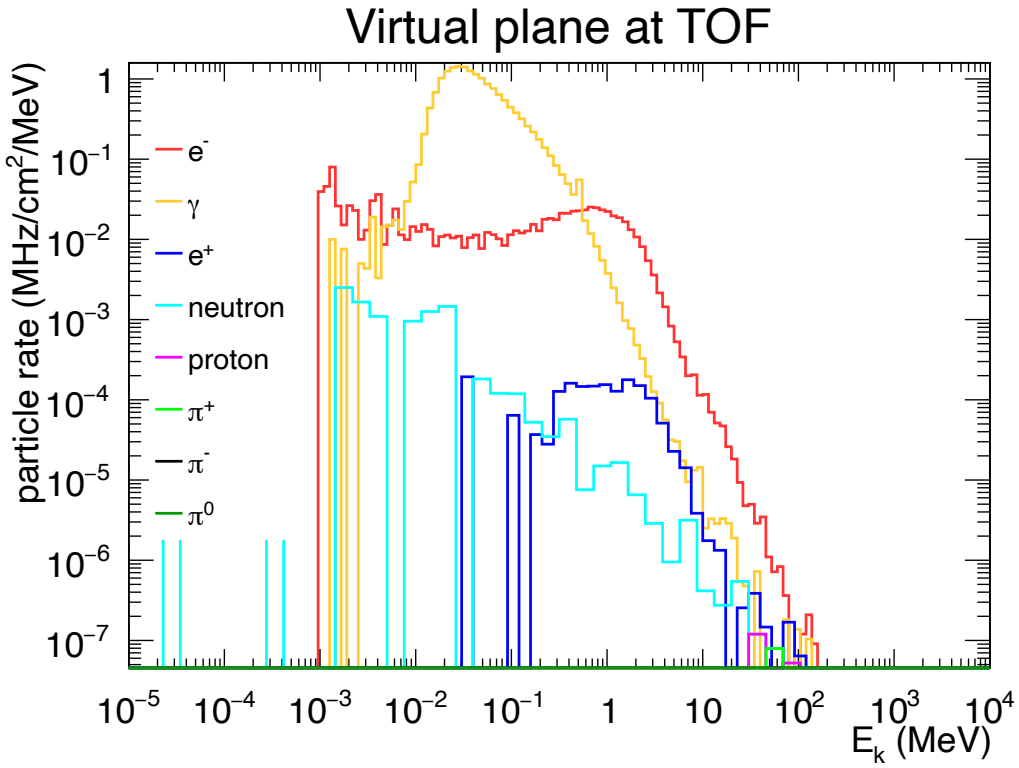




- Most of them are low momentum particles

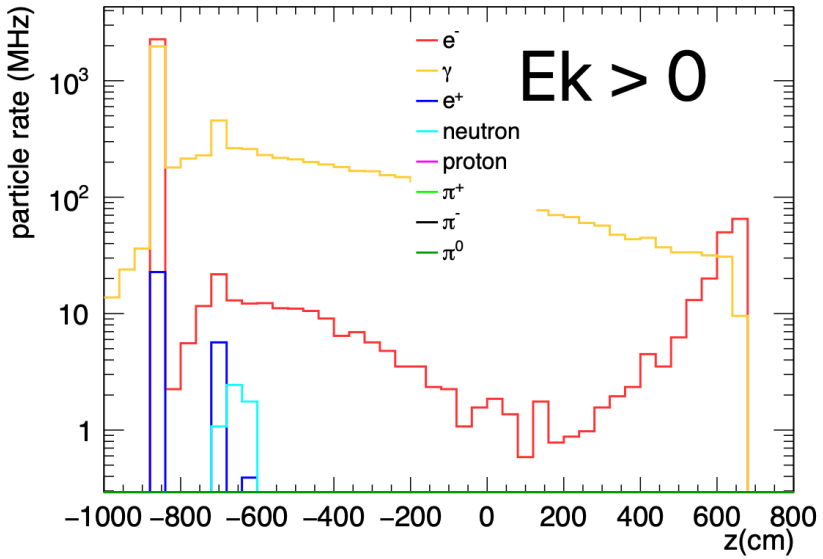
Particle Rate vs Ek on Virtual Detectors

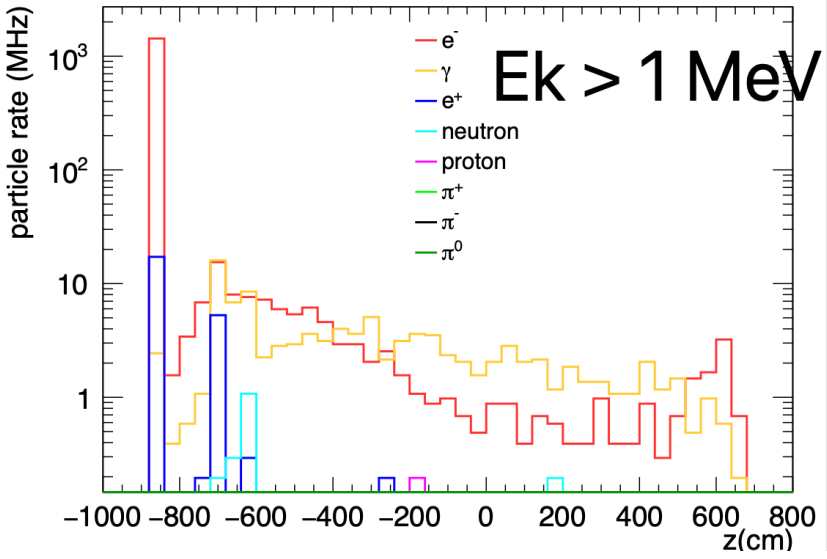


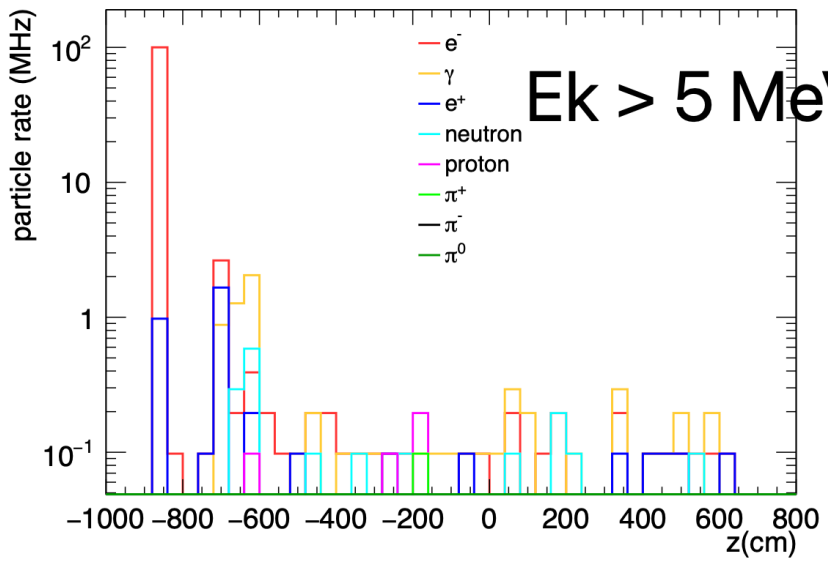


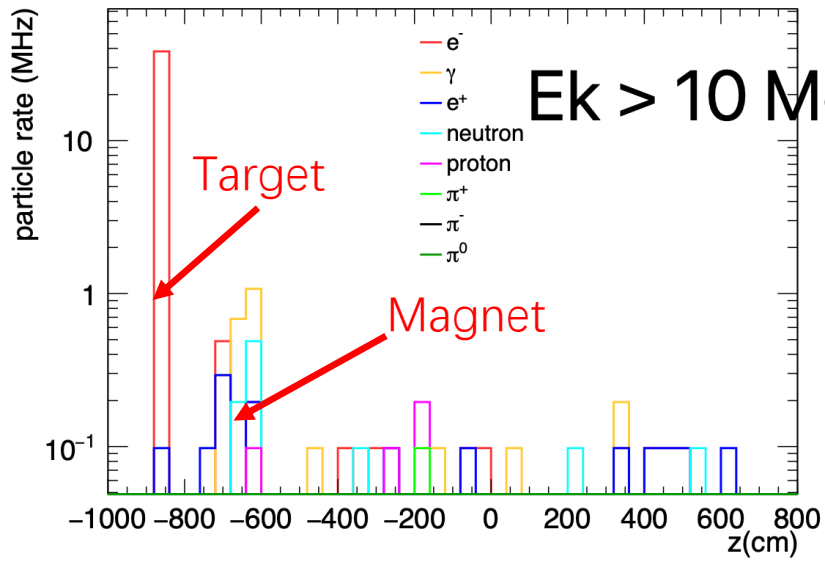
- No energy deposition cut on TOF module
- Most of them are below 10 MeV
- Bumps around ~100 MeV on virtual 1 but not for virtual 2

Vertex z Distributions on Virtual Plane at TOF



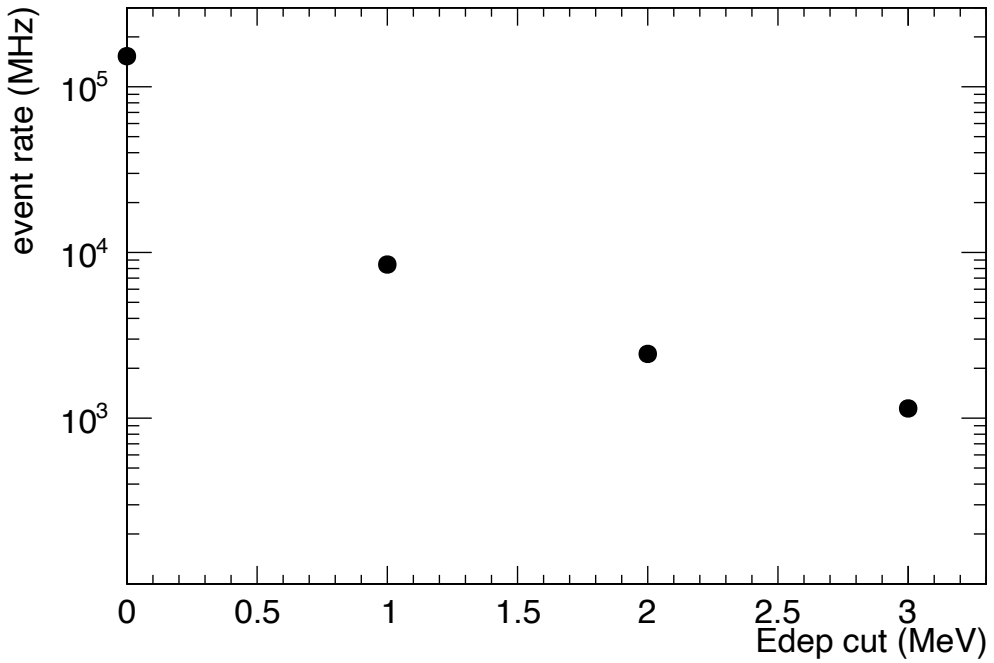


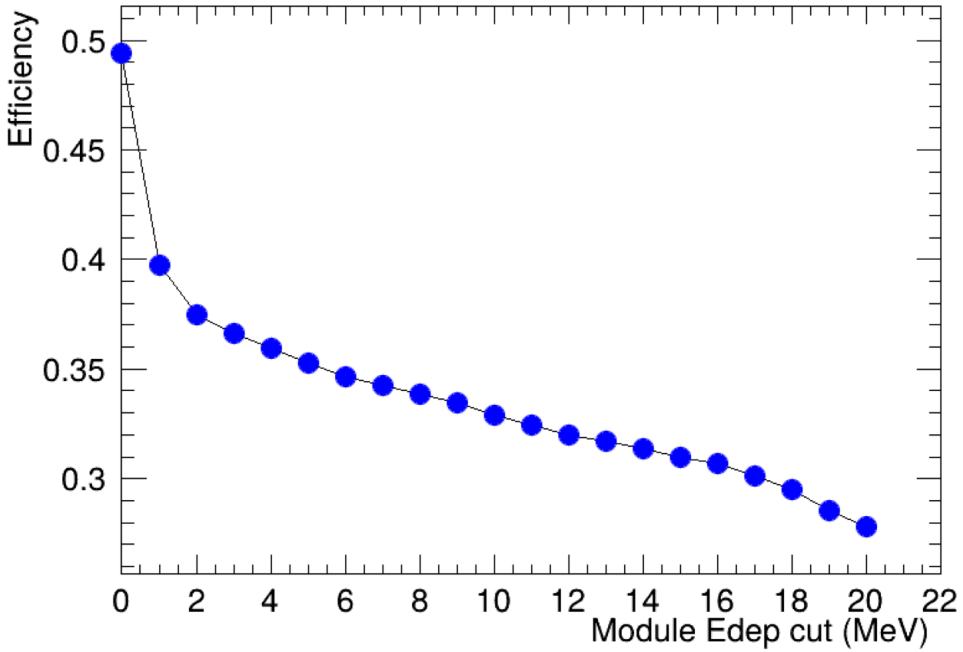




- Z-axis along the neutron arm
- Large fraction contributions from non-target region
- Energy deposition cut help to reduce non-target contribution
- See many electrons generated directly from target, very odd

Event Rate and Neutron Detection Efficiency





- Events are selected with TOF module energy deposition > threshold
- Events rate are sensitive to the energy deposition cuts
- Neutron detection efficiency is not strongly dependent on cuts

Task List and Workforce

- For G4 simulation:
  1. Full neutron arm geometry in G4 (end of Sep.)
  2. Optics photon simulation for neutron TOF (Mid of Oct.)
  3. Migration to SBS simulation (Nov.?)
  4. Geometry and detector optimization

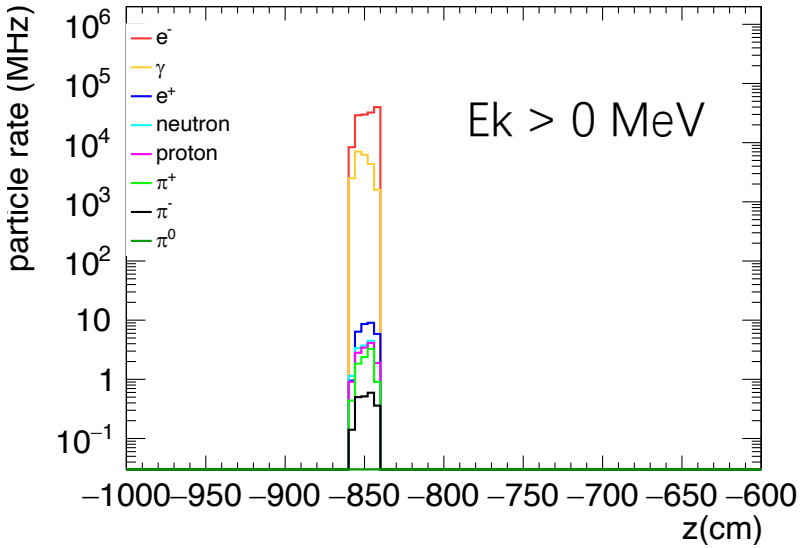
- For various MC generator (might need exclusive ones):
  1. Elastic ep (many such generators avilable, i.e. esepp)
  2. signal generator for ep->nv (need help, put should be straight forward)
  3. electro and photo production of pion generators from ep (need help)
  4. background generator for eAl (quasi-elastic, inelastic, need help)

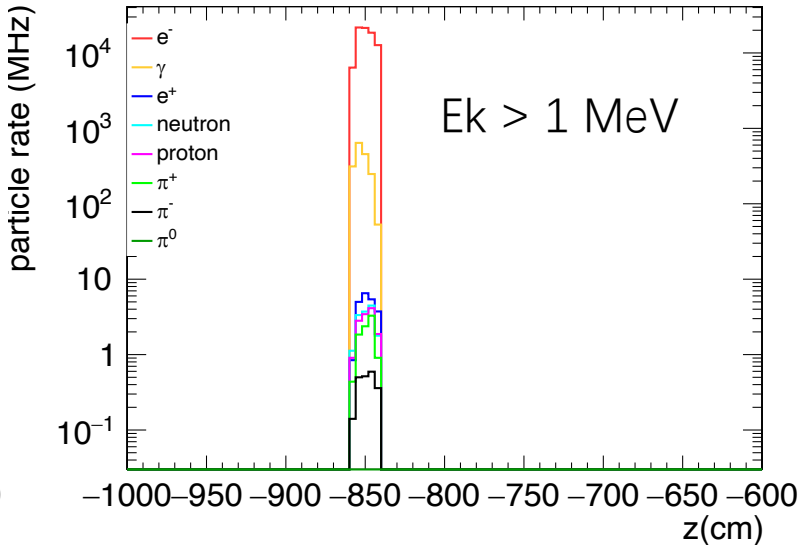
- Current workforce:
  - On G4: Yi Yu, WX (SDU), Jimmy Caylor (JLab)
  - On generators: WX + some possible students (SDU)

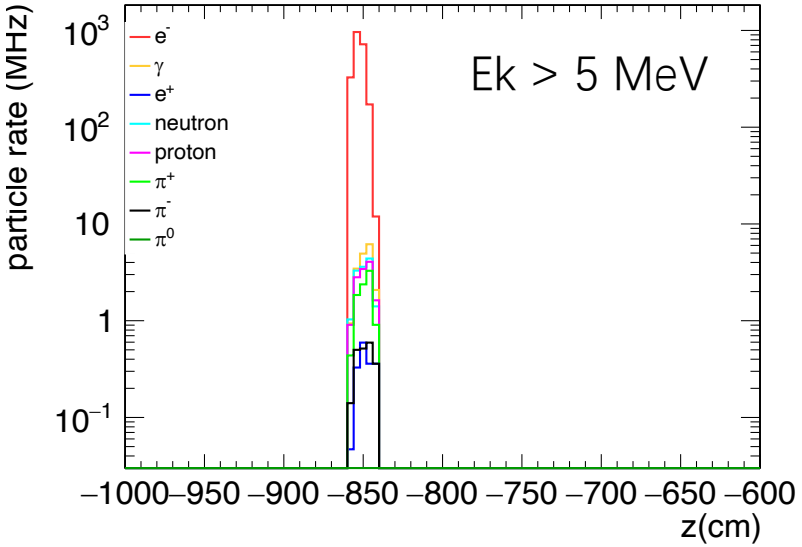
- Helps are much needed and appreciated!

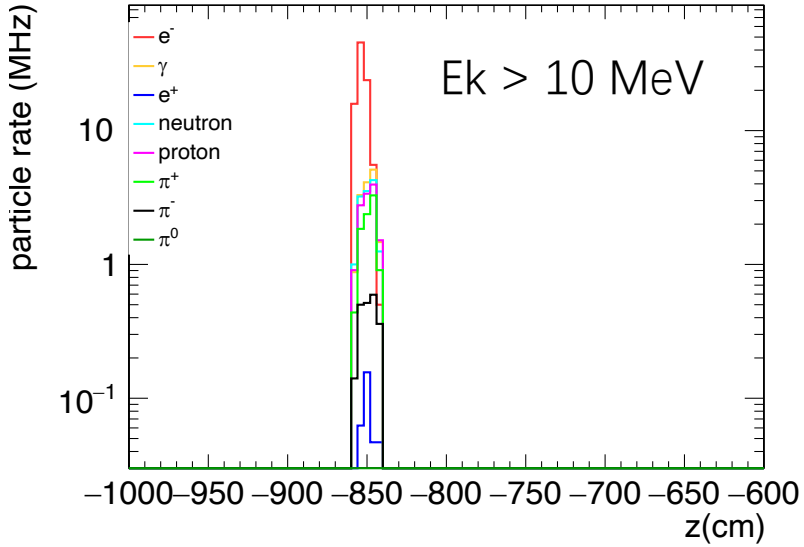
Backup

Vertex z distributions on virtual plane at magnet



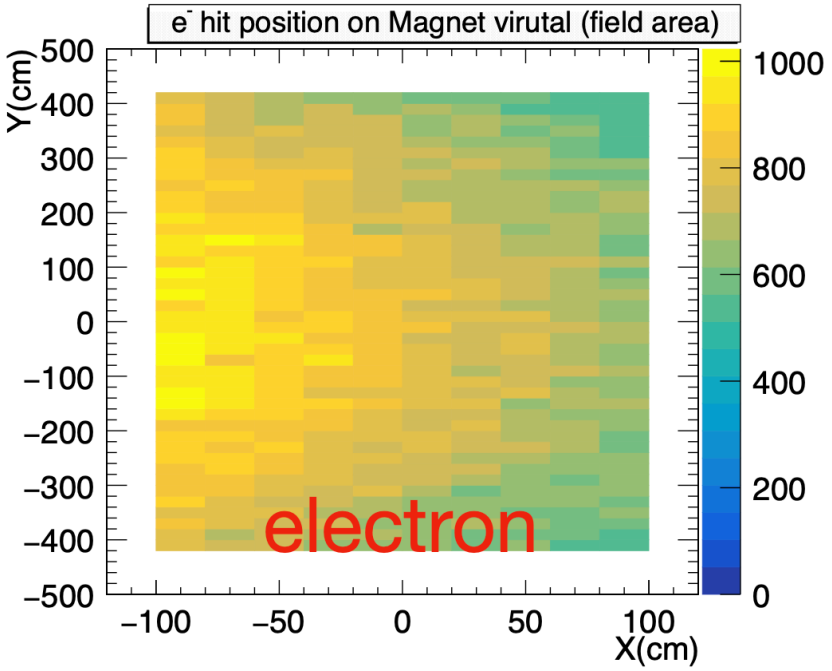


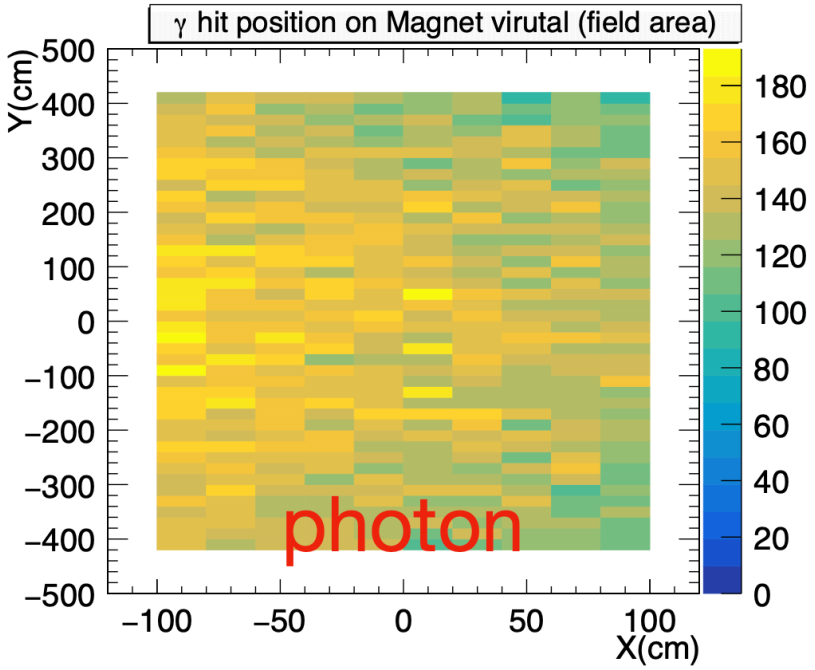


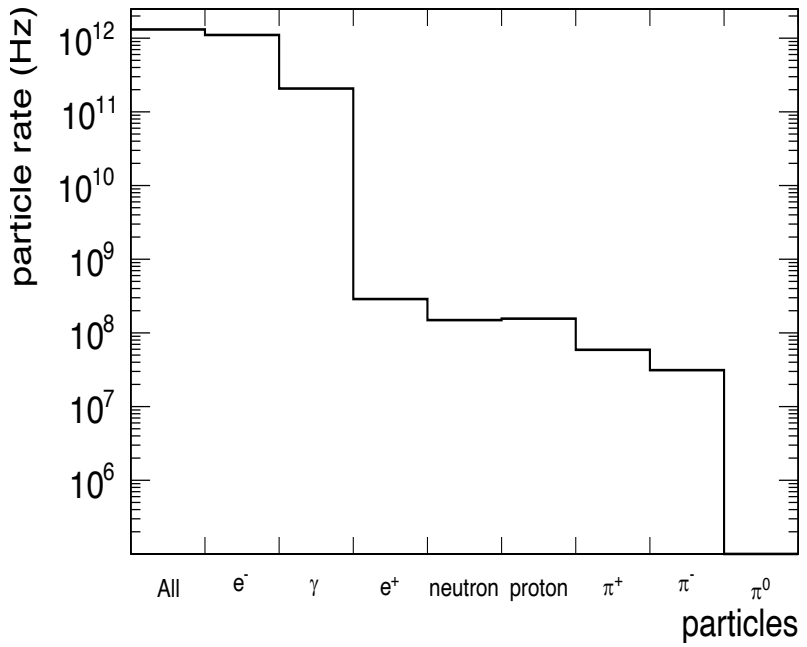


- All the detectors are placed in vacuum
- All particles are generated at target region as expected

Hits x-y distribution on virtual plane at Magnet

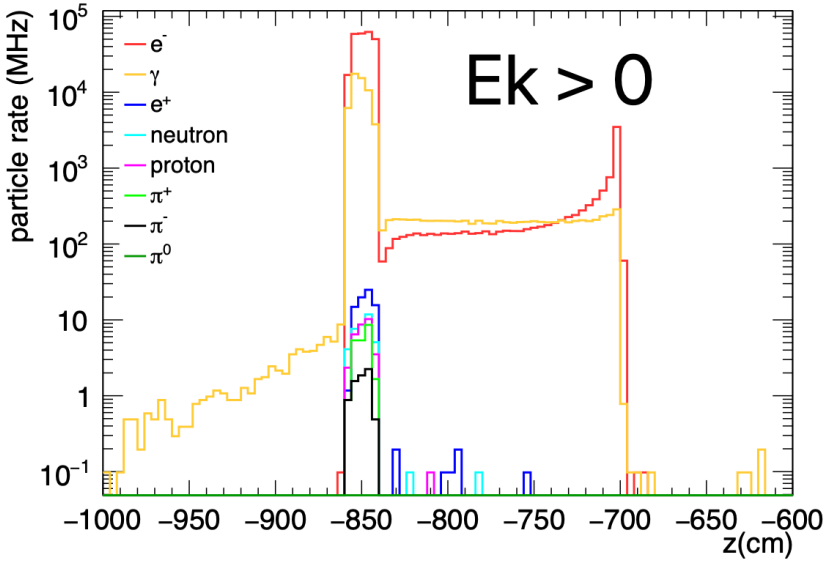


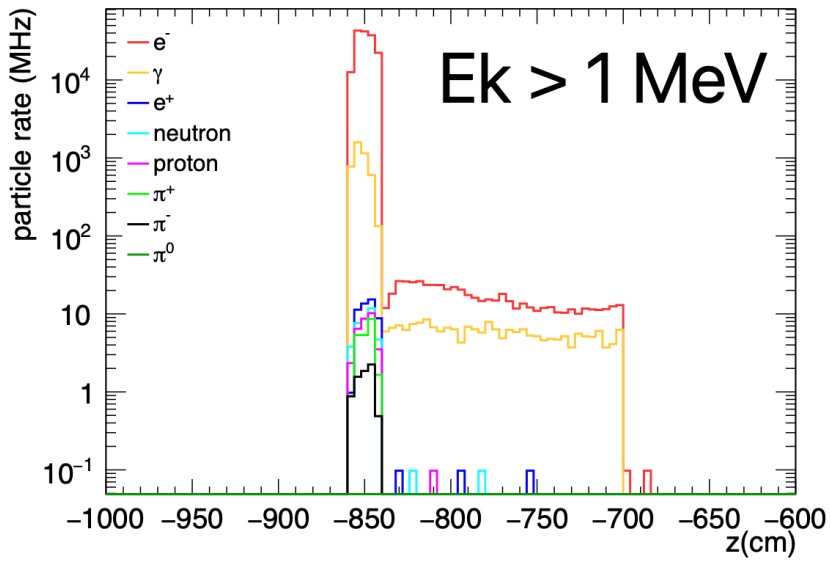


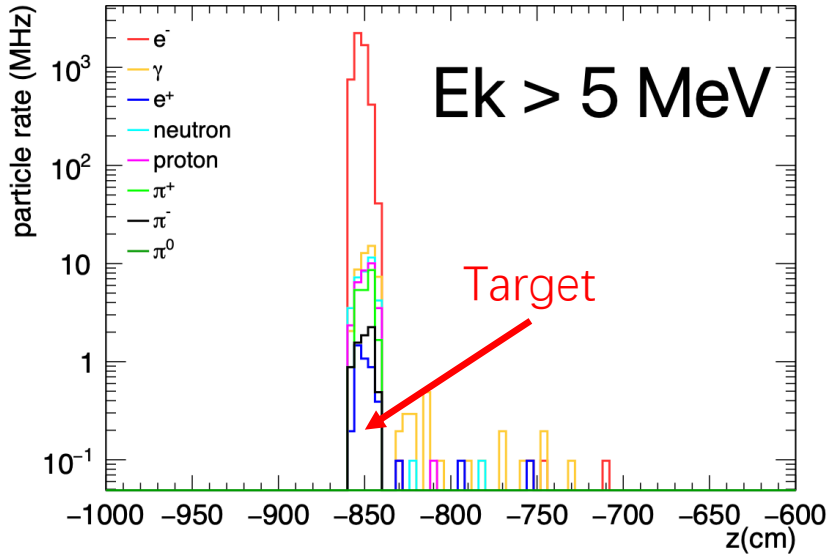


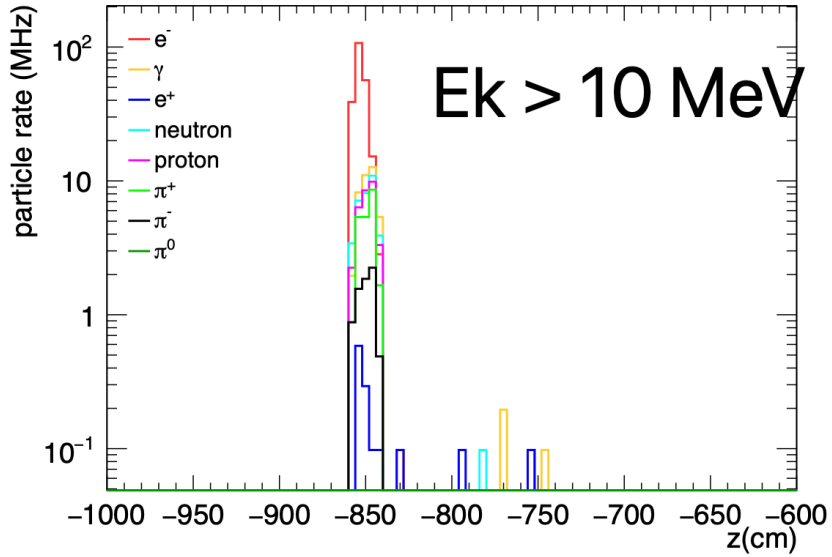
- Total events: 1.8×10^{8} electrons
- Time scale: 288ns assuming 100μA
- The coordinates are rotated with the +z being direction of neutron arm
- No energy cut applied
- Two dominant sources: electron and photon

Vertex z Distributions on Virtual Plane at Magnet



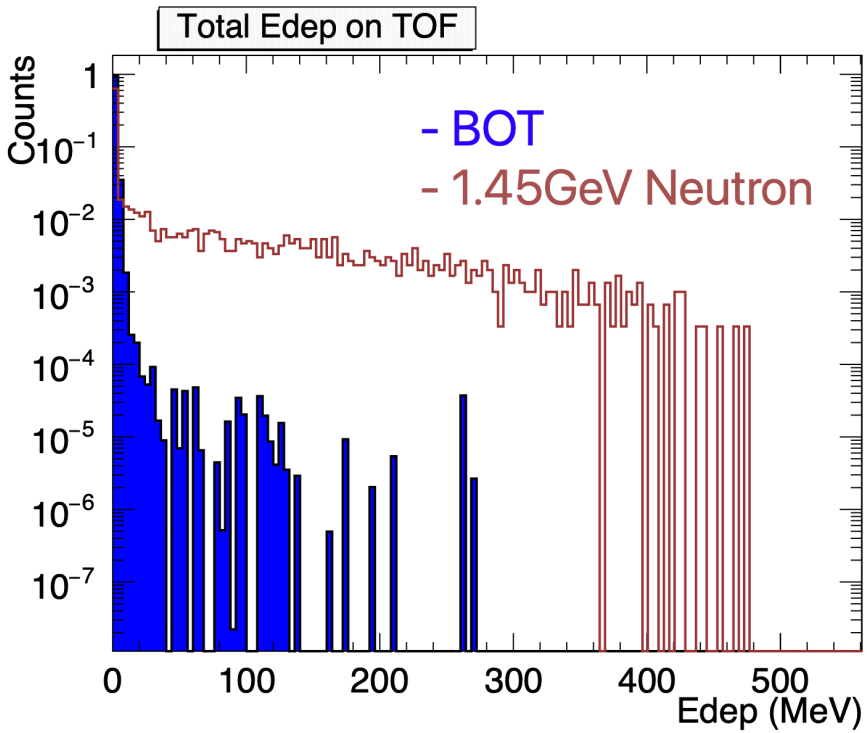


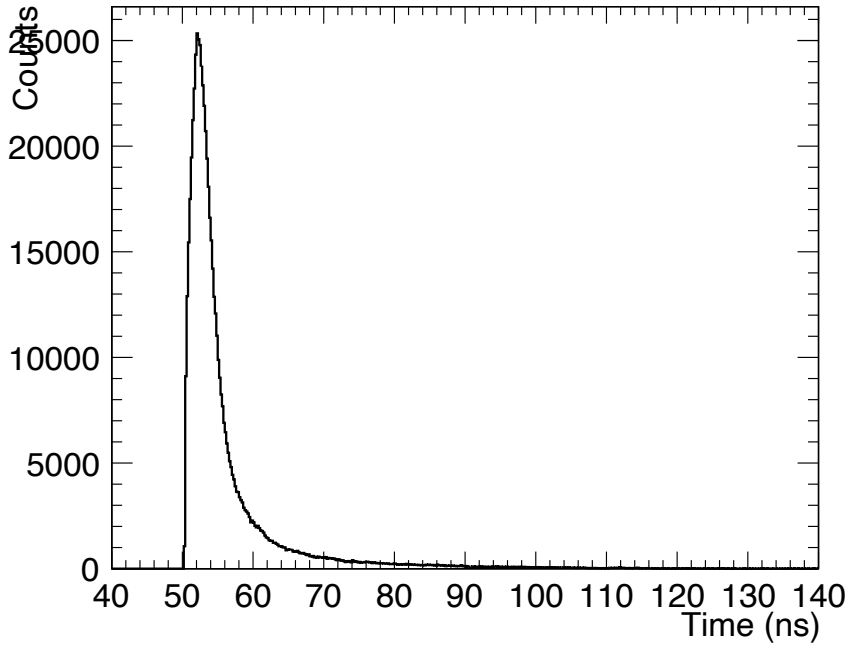




- Most particles are generated at target region
- A flat distribution at non-target region

Energy Deposition and Timing

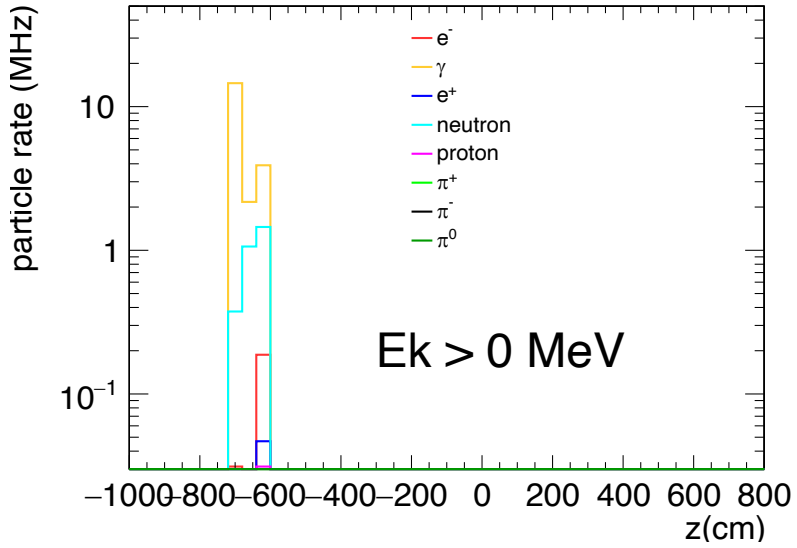


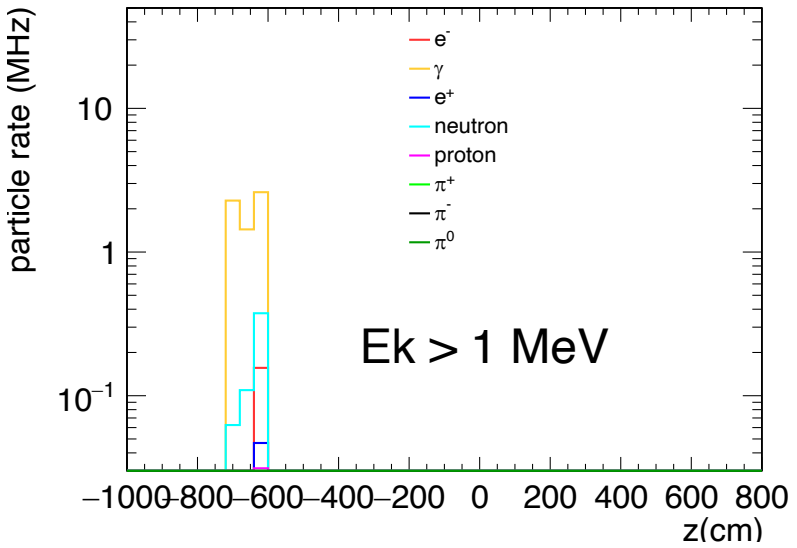


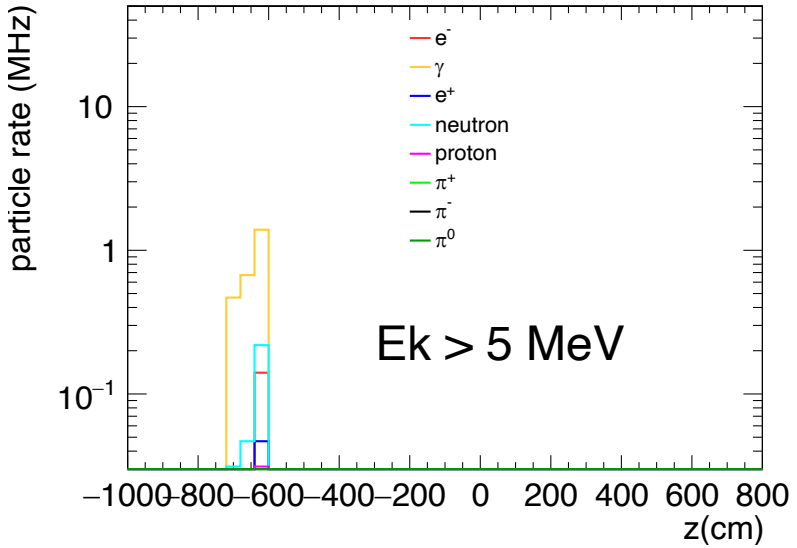
- Energy deposition for beam-on-target (BOT) simulation is generally small
- The time of BOT energy deposition peaks around 55ns with a long tail

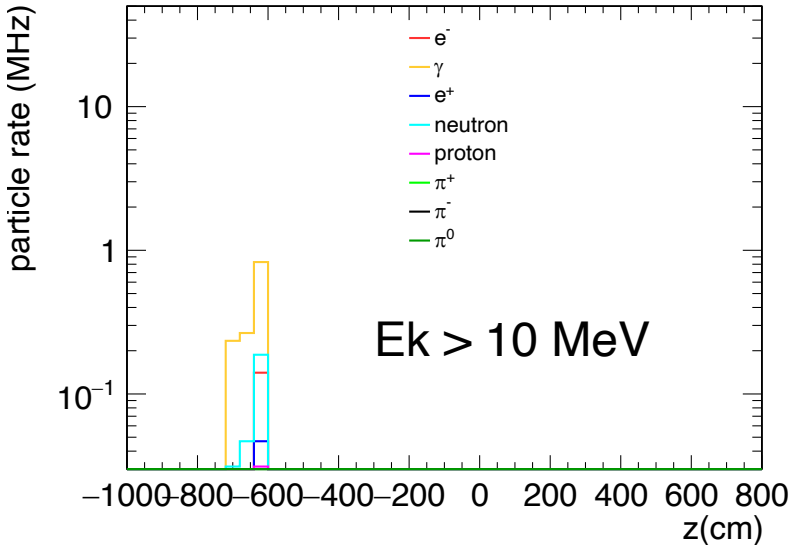
Vertex z Distributions on Virtual Plane at TOF

(replace air with vacuum)









- Z-axis along the neutron arm
- All the detectors are placed in vacuum
- All particles are generated at magnet region

- Electrons from target no longer show up, indicate that many electrons from target may bounce into TOF through MS with air
- Should be able to reduce with proper shielding