Modular RICH Simulation with Magnetic Field On

Cheuk-Ping Wong
Georgia State University

10-02-2015

Content

1. **Comparison to field-on and field-off simulations**
2. **Single Muon simulation**
3. **10,000 Muons simulation**

   momentum distribution of e^- study

Modular RICH Detector

Silica Aerogel (SiO_2) -- Radiator

- Density 0.02 g/cm3
- Refractive index: n=1.025

Fresnel lens -- Focus Cherenkov radiation on the photonsensor

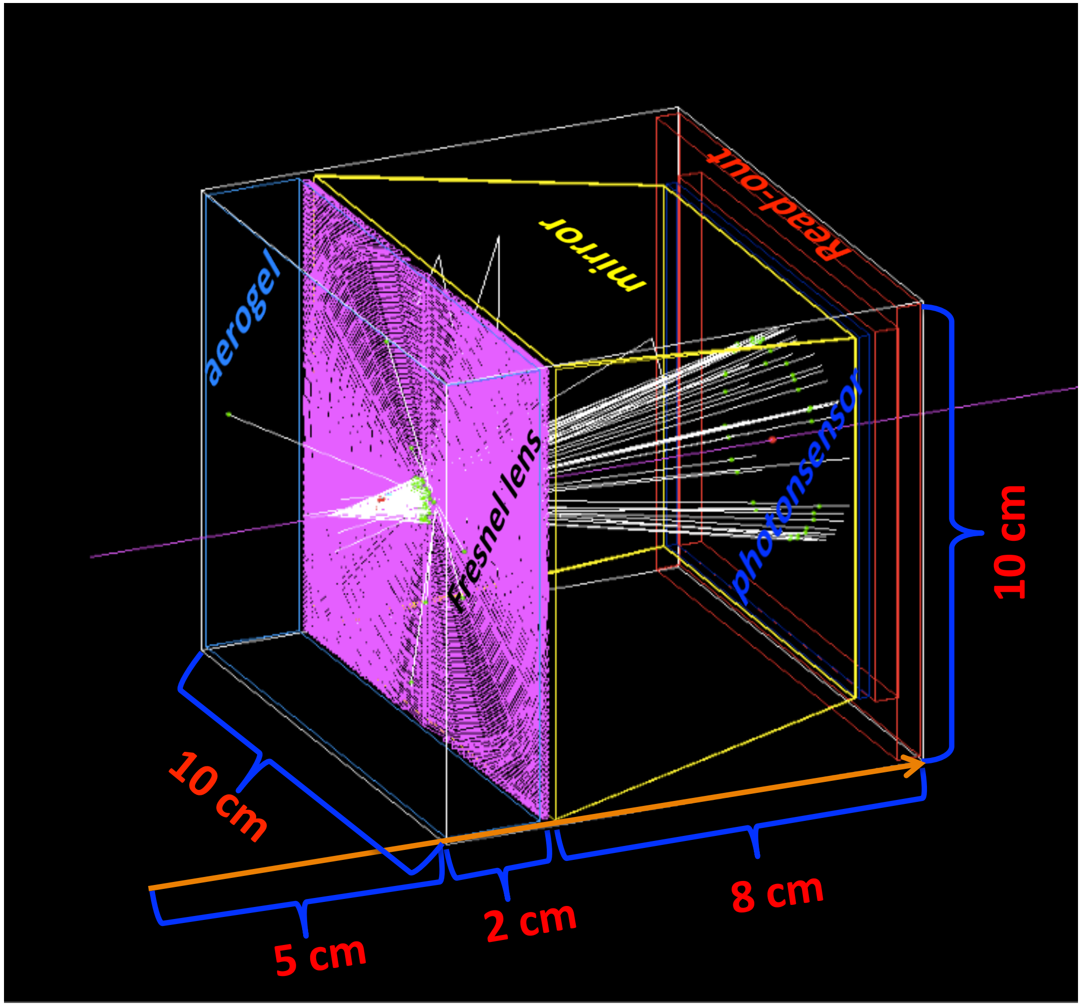
- Acrylic, C5H8O2, 1.19 g/cm3
- Four sections, G4Polycon
- 100 grooves

Mirror -- Reflector

- Four sections: left, right, top and bottom
- Reflectivity index : 0.95

Photosensor & Readout

- Block of aluminum



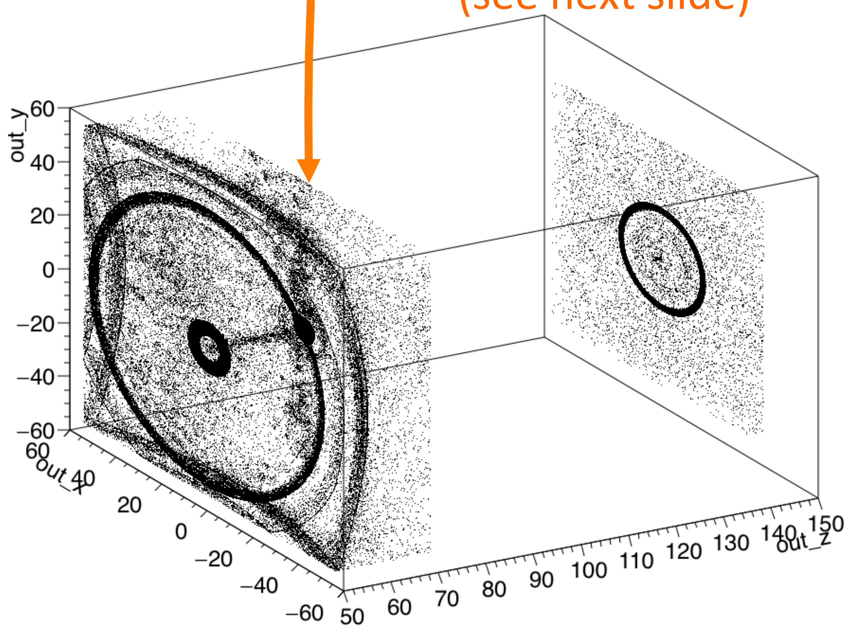
1. Comparison to field-on and field-off simulations

- In the next two slides, we compare the patterns of photon hits on the Fresnel lens ,and the photonsensor, in field-**on** and field-**off** simulations
- Simulation setup
  - 9 GeV pion
  - 10,000 events
  - Hall frame dimension (x, y, z)=(0.5, 0.5, 0.5)m
  - Magnetic field
    - Left column : $(B_x, B_y, B_z)=(0,1.5, 0)$ T
    - Right column : field-Off

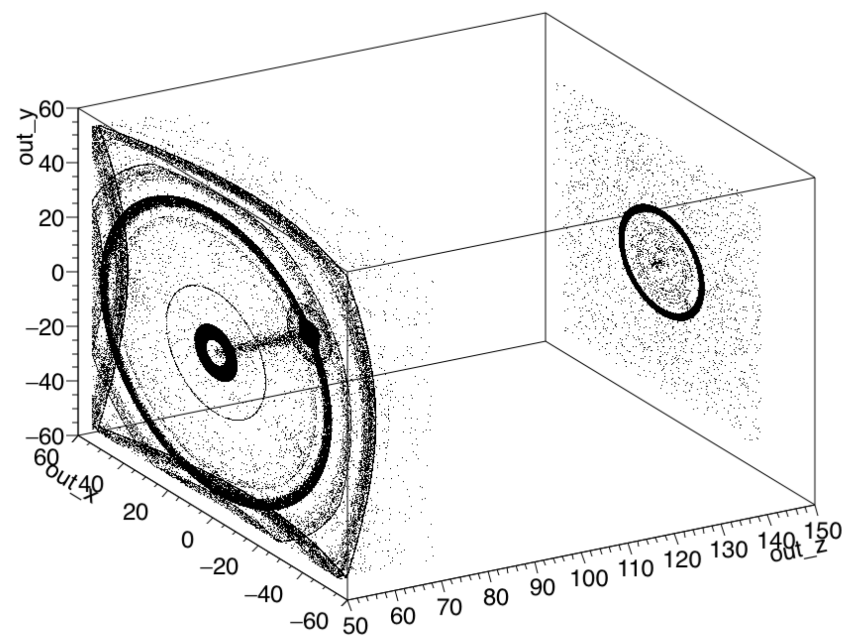
All Hits in Modular RICH Detector

Field On

A vertical band formed by photon hits on Fresnel lens (see next slide)

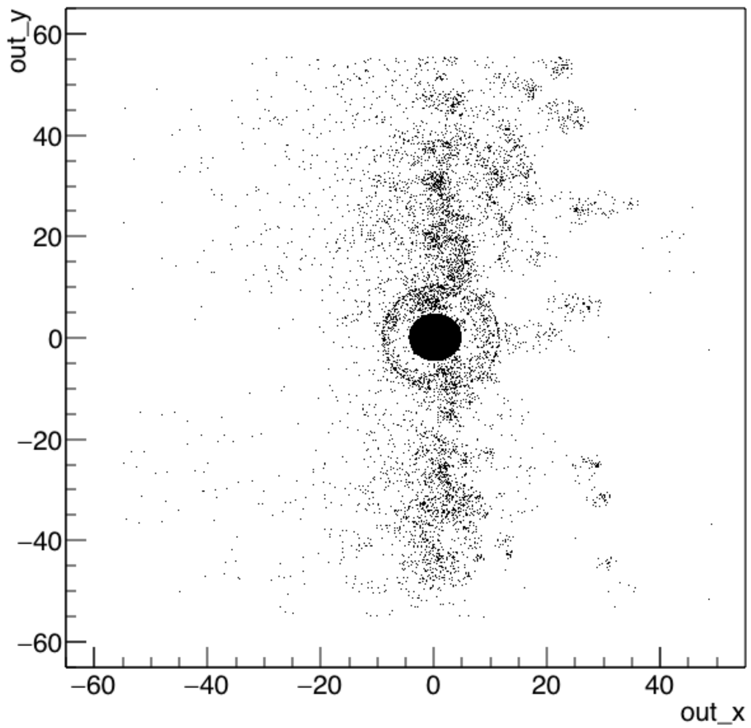


Field Off



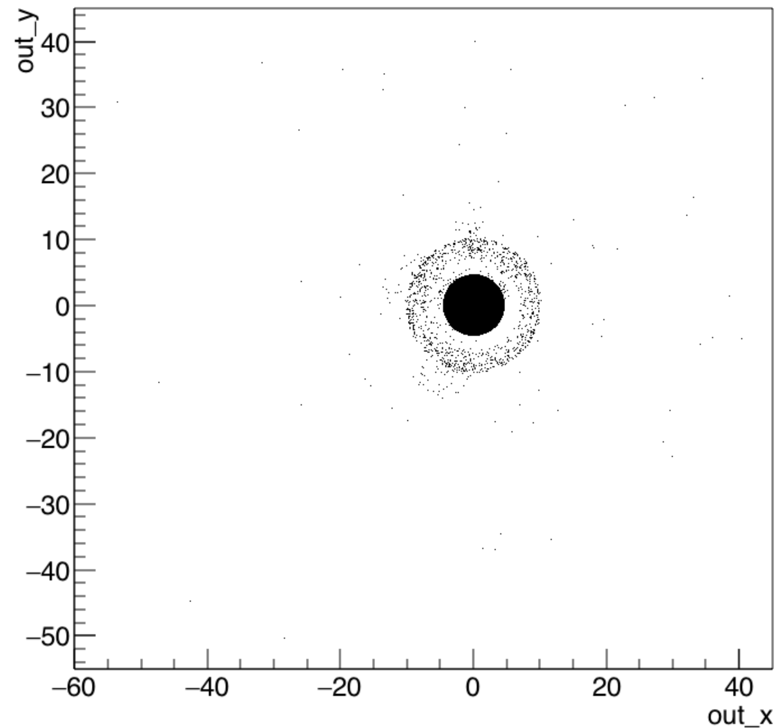
Photon Hits on Fresnel Lens

Field On



- We still saw a vertical band
- 737864 entries

Field Off



732482 entries

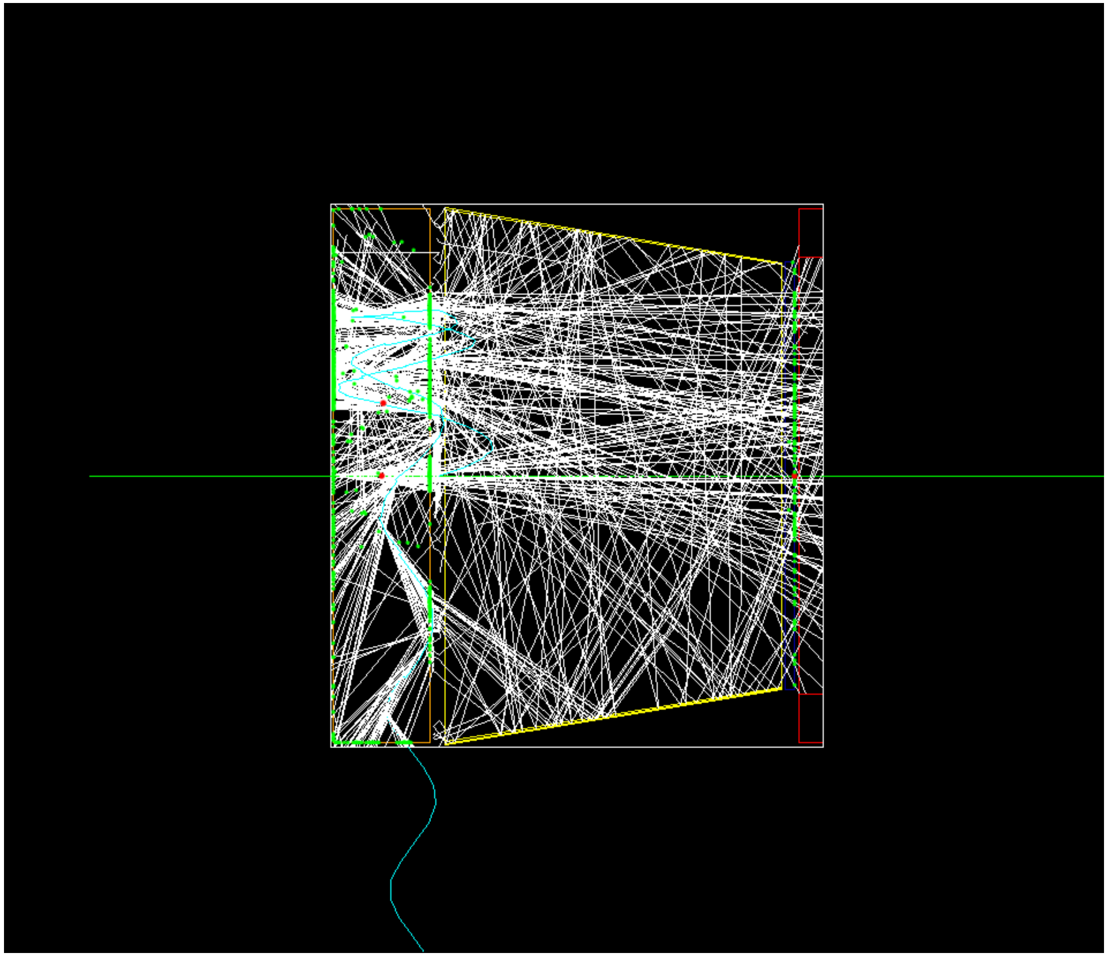
2. Single Muon simulation

- In order to study the cause of the vertical band, we changed beam from pion to muon as it has minimal interaction with the detector
- Simulation Setup
  - 9 GeV Muon
  - Single event
  - Magnetic B-field $(B_x, B_y, B_z)=(0, 1.5, 0)$ T
  - Hall frame dimension $(x, y, z)=(0.5, 0.5, 0.5)$m

Event Display – Side View

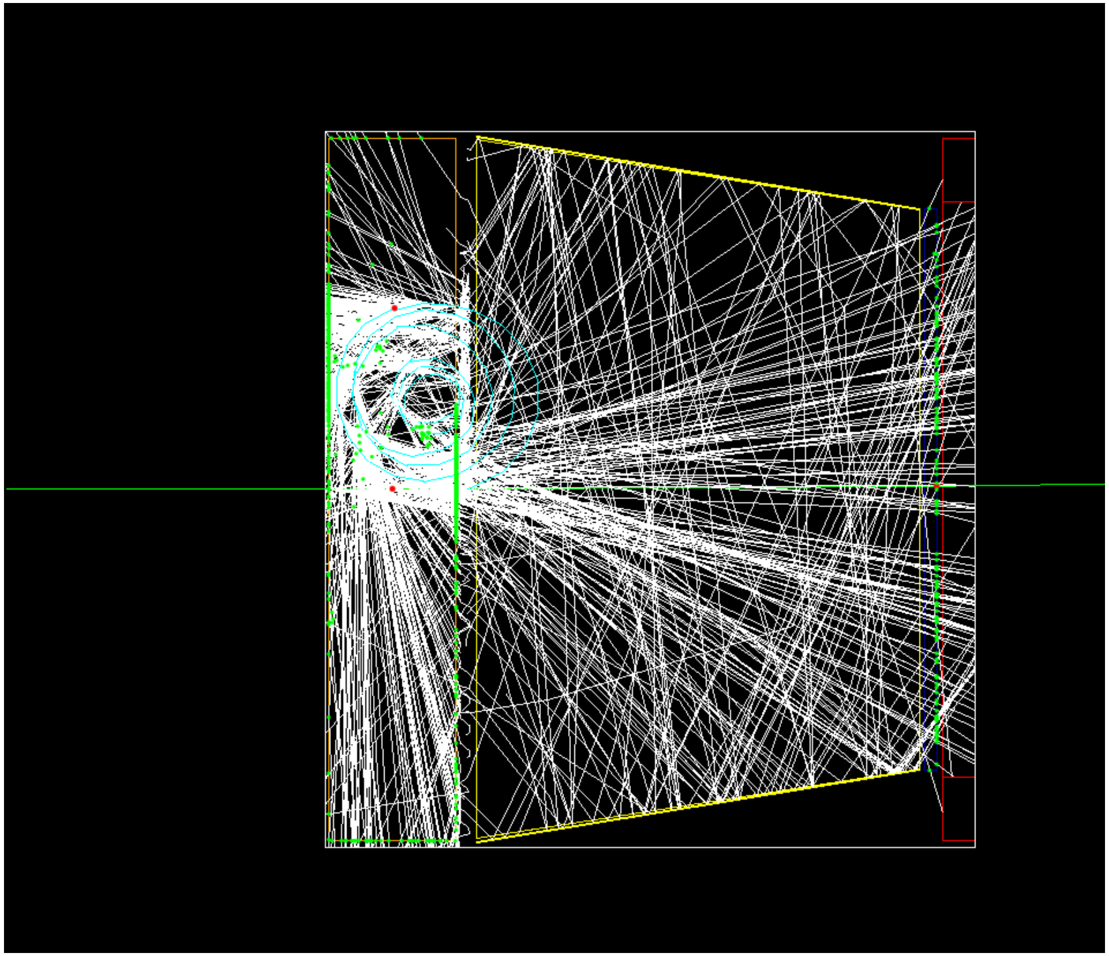
- Electron spirals (cyan lines) which propagate in y-direction emitted Cherenkov radiation
- The frequency of having electron(s) is low! One per ~80 runs (single event)

* I set the grooves of Fresnel lens invisible on the event display



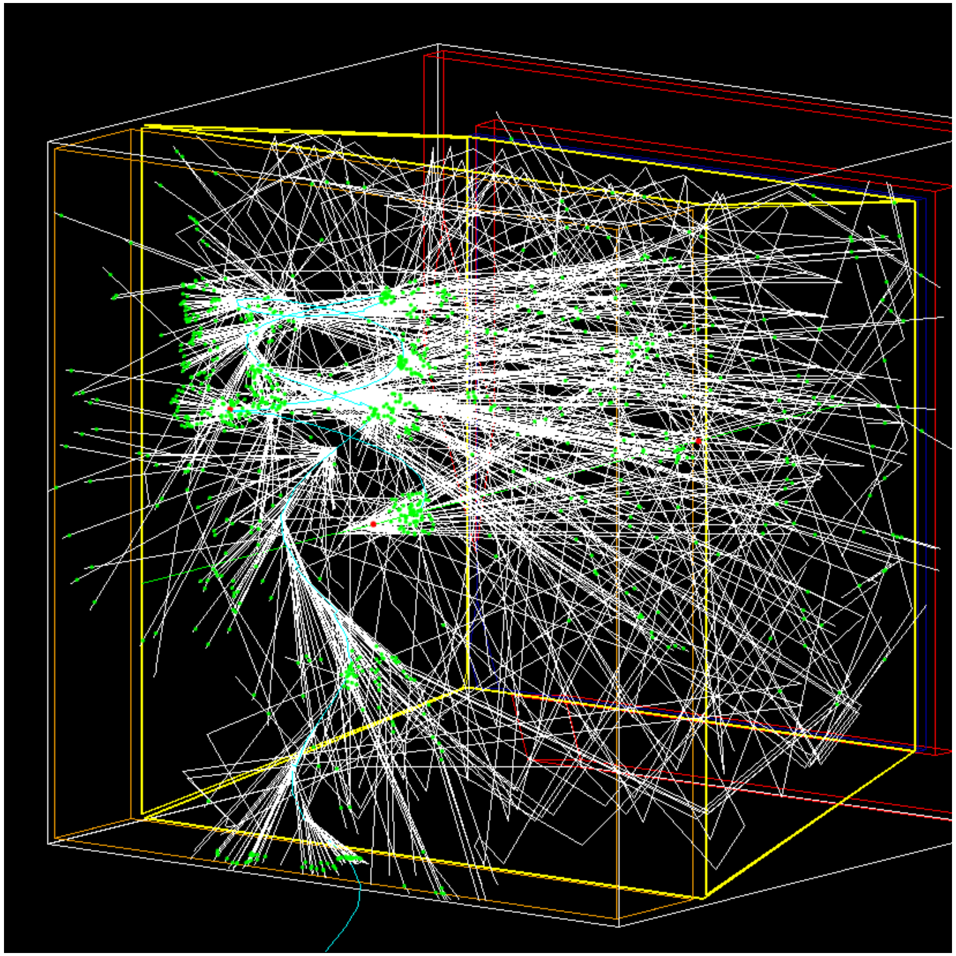
Event Display – Bird View

Electron spirals (cyan lines) which propagate in y-direction emitted Cherenkov radiation

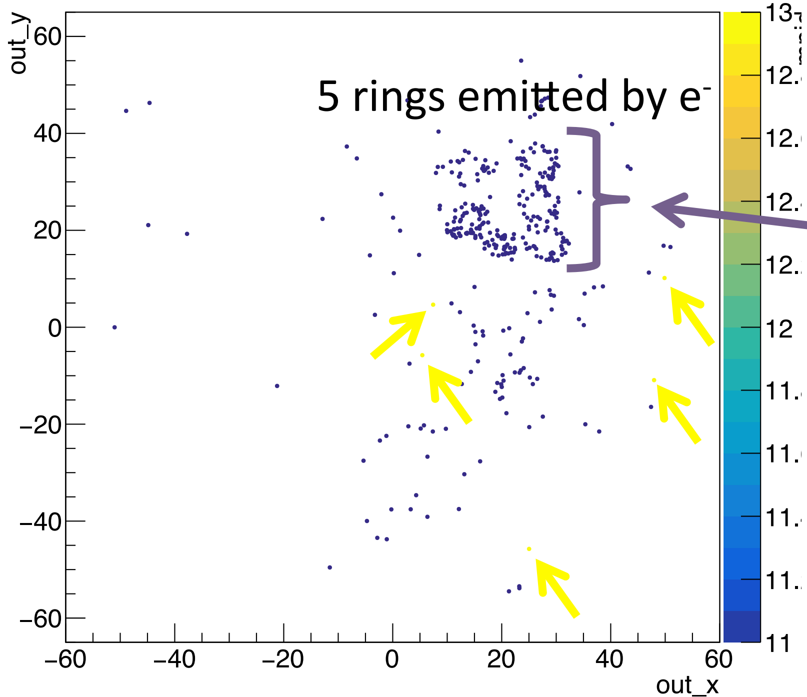


Event Display -- Front

- Electron spirals (cyan lines) which propagate in y-direction emitted Cherenkov radiation
- Radiation (photons) was emitted along the electron spiral trajectory (see back up slide)
  - Cherenkov ring (may not be a perfect circle) appeared on the front of the aero gel and on the Fresnel lens

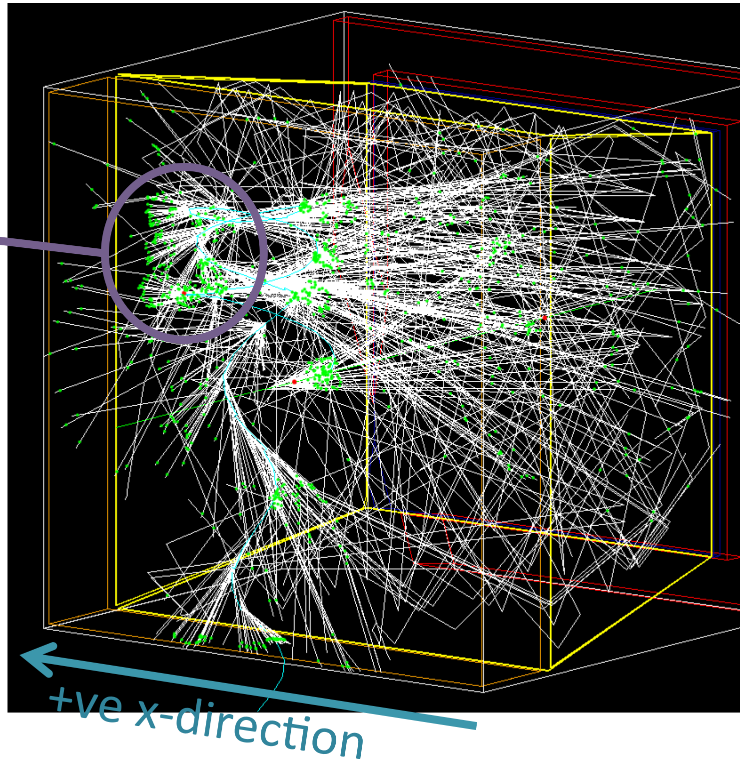


mpid of Photon Hits on the Aero Gel



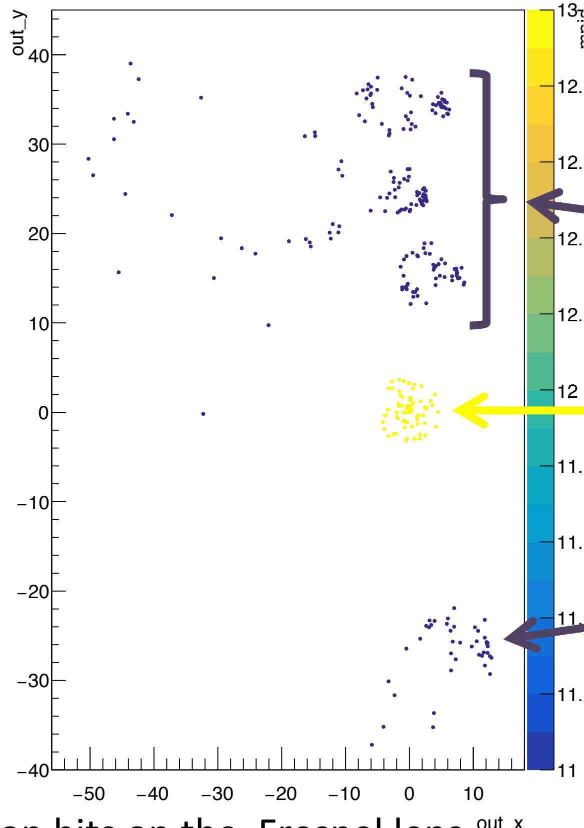
Photon hits on the aero gel

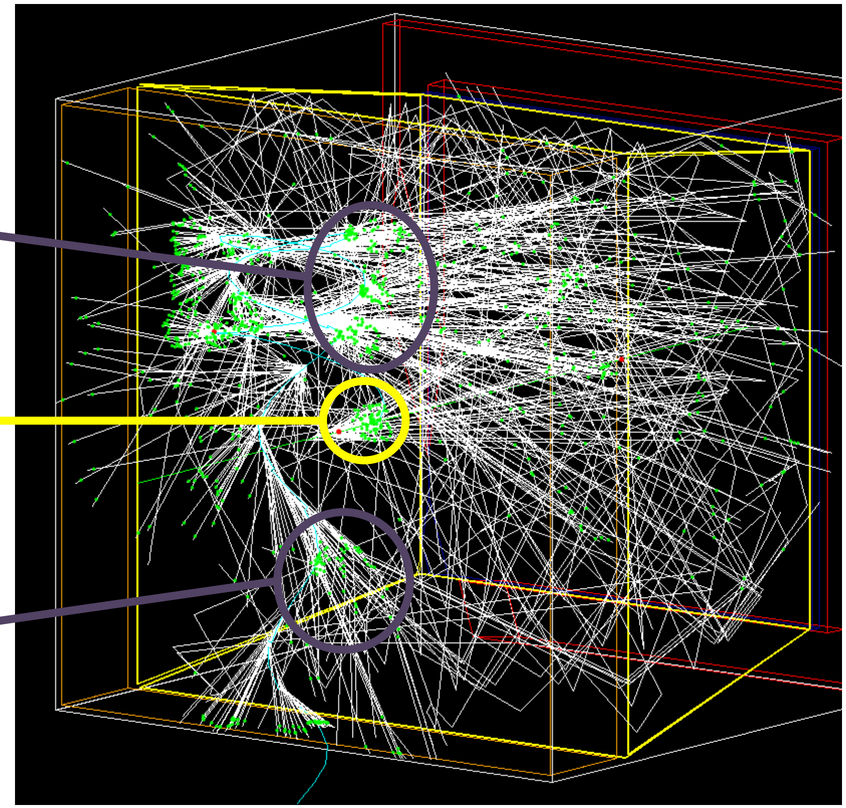
- Y-axis – y-position of photon hit
- X-axis – x-position of photon hit
- Color – mpid
    - Purple – mpid=11 → e^-
    - Yellow – mpid=13 → μ^-



Front view on the event display

mpid of Photon Hits on Fresnel Lens





Photon hits on the Fresnel lens

- Y-axis – y-position of photon hit / X-axis – x-position of photon hit
- Color – mpid
  - Purple – mpid=11 → e^-
  - Yellow – mpid=13 → μ^-

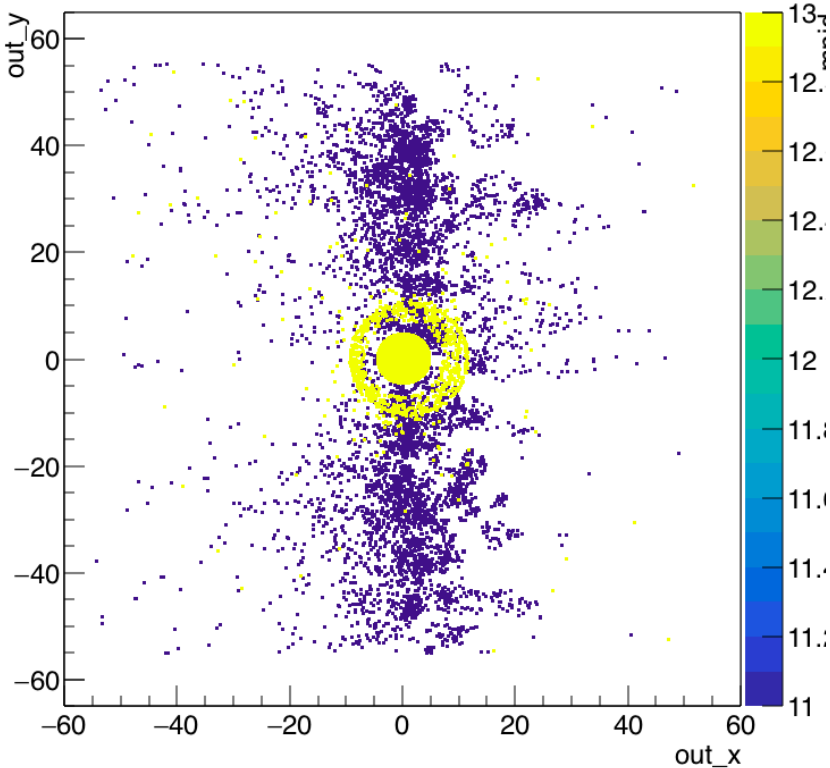
3. 10,000 Muons Simulation

e^- momentum distribution study

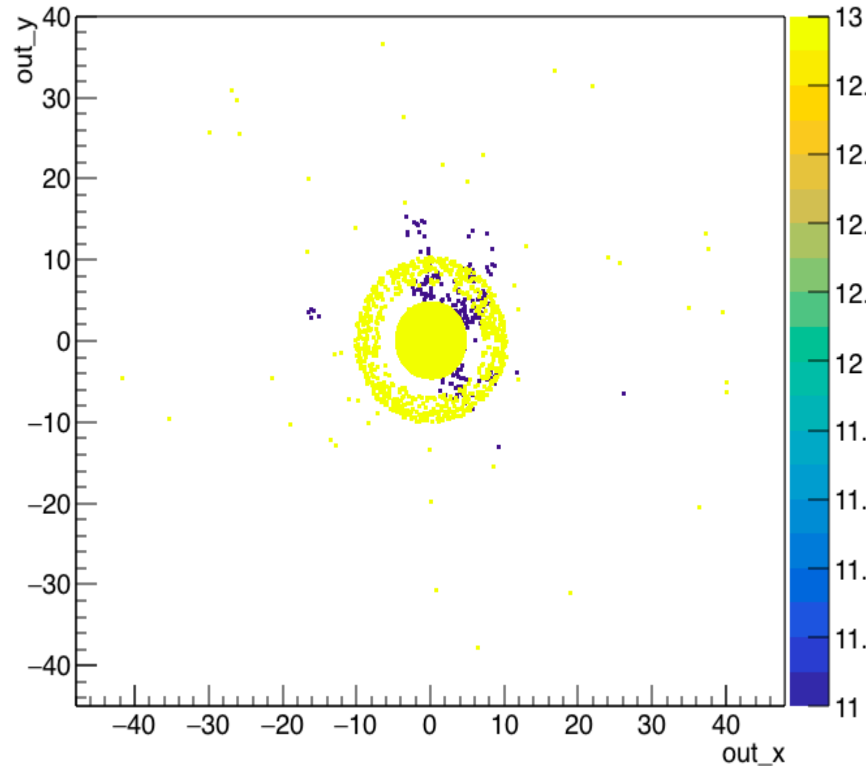
- In the next two slides, we are comparing the momentum distribution of e^- generated inside aero gel, in field-on and field-off simulation
- Simulation Setup
  - 9GeV Muon
  - **10000 events**
  - Hall frame dimension (x,y,z)=(0.5, 0.5, 0.5)m
  - Magnetic field
    - Field-On $(B_x, B_y, B_z)=(0, 1.5, 0)$T
    - Field-Off

mpid of Photon Hits on Fresnel Lens

Field On



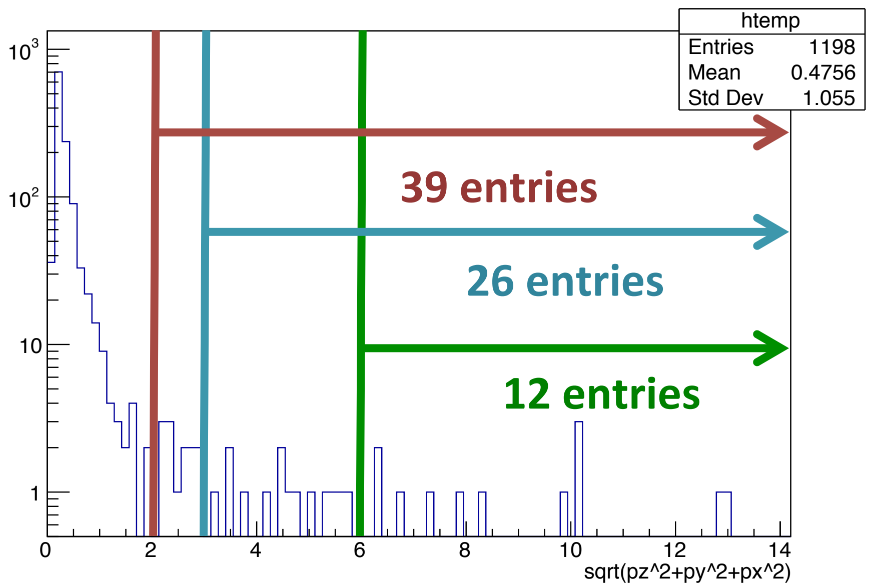
Field Off



- Y-axis – y-position of photon hit
- X-axis – x-position of photon hit
- Color – mpid : Purple – mpid=11 → e^-
  Yellow – mpid=13 → μ^-

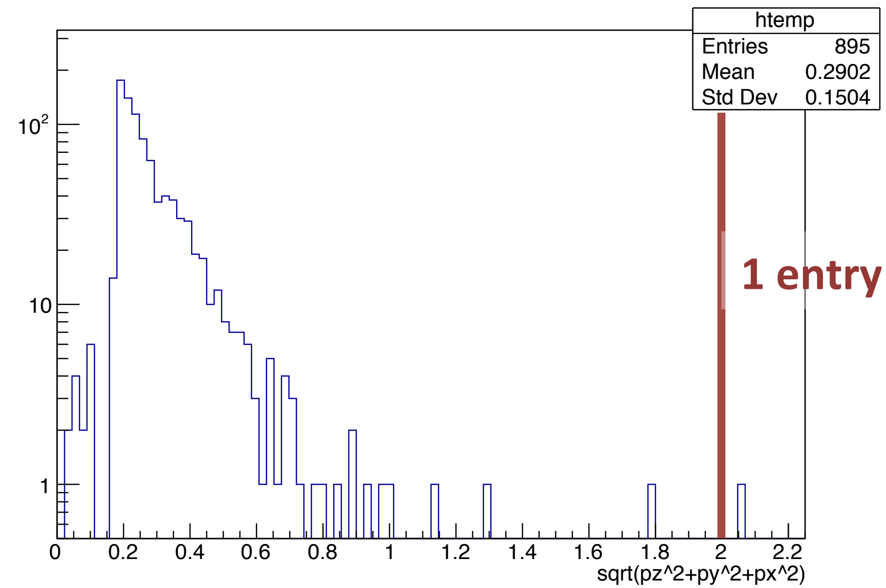
Linear Momentum Distribution of Electron Hits in Aero Gel

Field-On



Total e- hits in aero gel =1198
P > 2 MeV : 39 entries
P > 3 MeV : 26 entries
P > 6 MeV : 12 entries

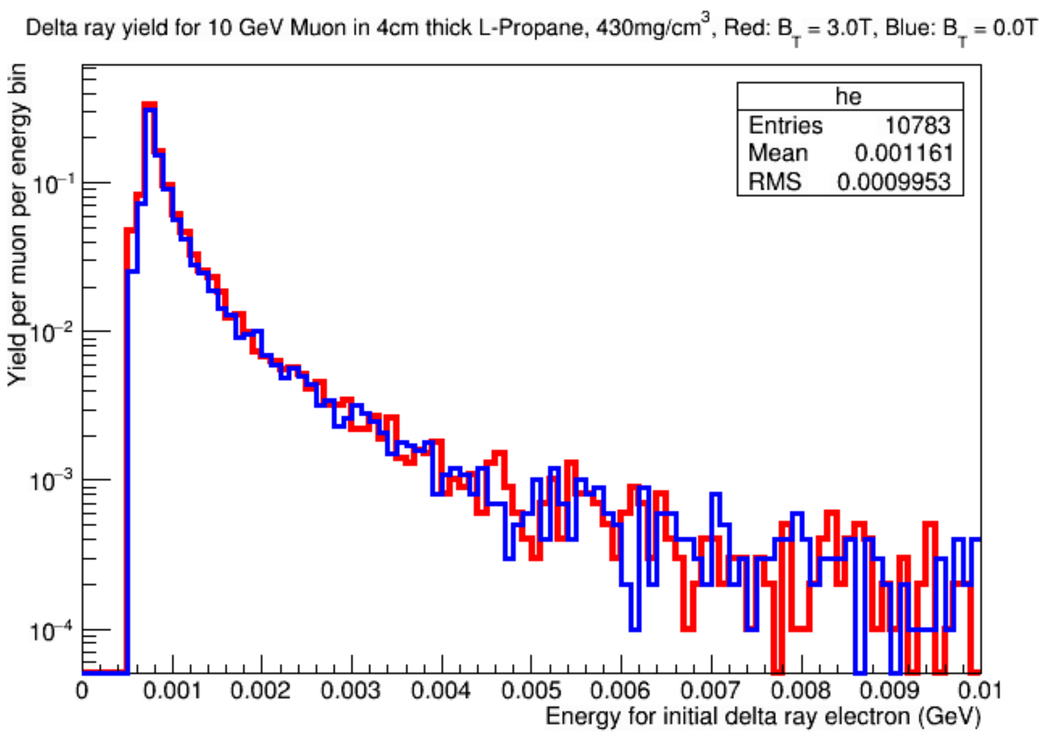
Field-Off



Total e- hits in aero gel = 895
P > 2 MeV : 1 entries
P > 3 MeV : 0 entries
P > 6 MeV : 0 entries

More e^- hits in aero gel if magnetic field is on (due to e^- spiral?)
More high momentum (P>2 MeV) e^- hits in aero gel if magnetic field is on.

Yield of delta ray e^- vs. Energy of initial ray e



Yield of delta ray e^- vs. Energy of initial ray e^- from ePHENIX simulation

However, Jin shown that energy of delta ray e^- should be independent on magnetic field

Summary

- e^- "generated" inside the aero gel moves in a spiral trajectory and emits Cherenkov radiation
- Why e^- generated in the aero gel had higher linear momentum (P>2 MeV) if magnetic field is on?

Back Up

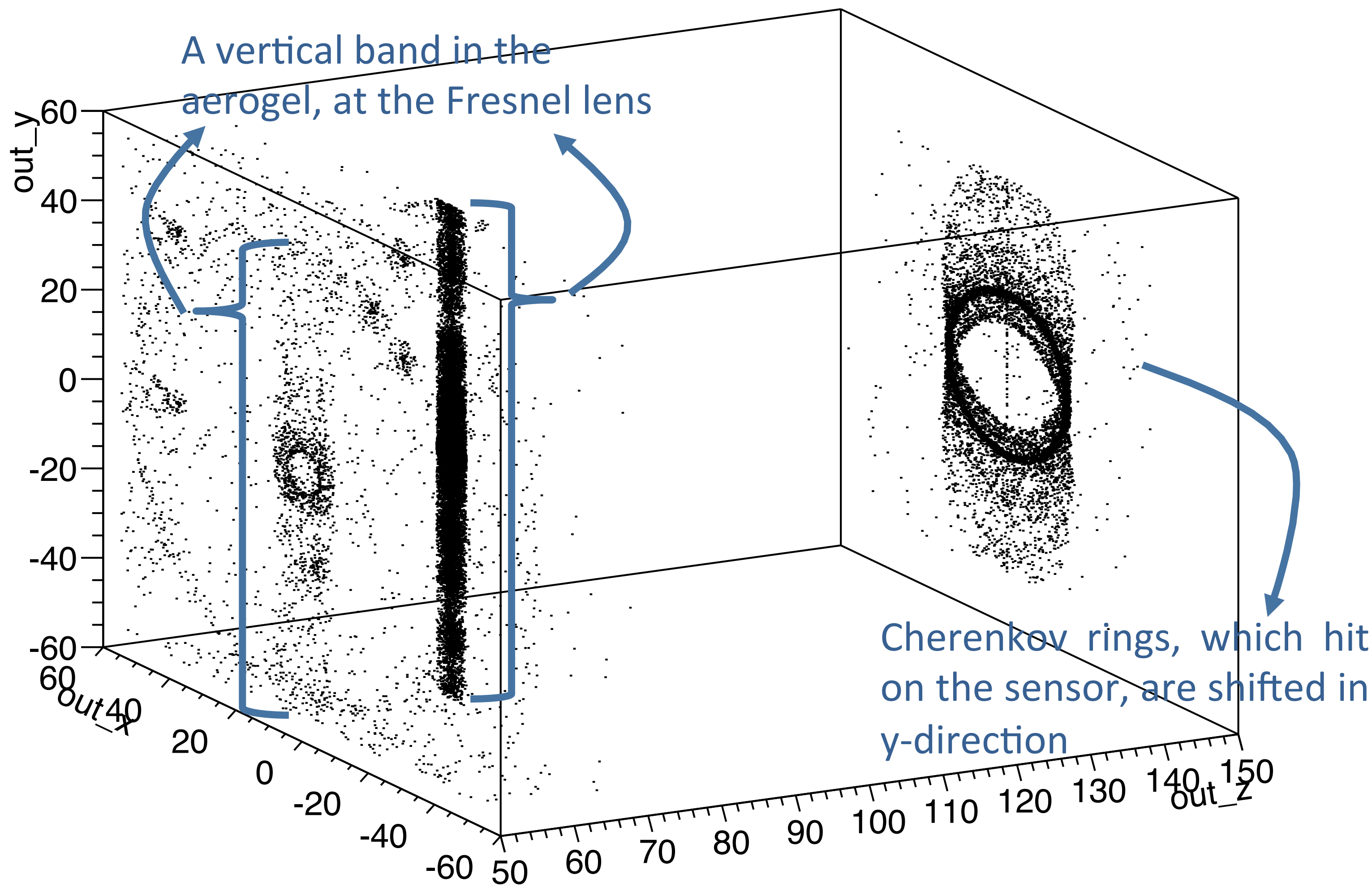
If we just plug Magnetic field in

- **Simulation Setup**
  - 9GeV Pion
  - 100 events
  - Magnetic field $(B_x, B_y, B_z)=(0, 1.5, 0)T$
  - Hall frame dimension

    $(x, y, z)=(100, 100, 100)m$

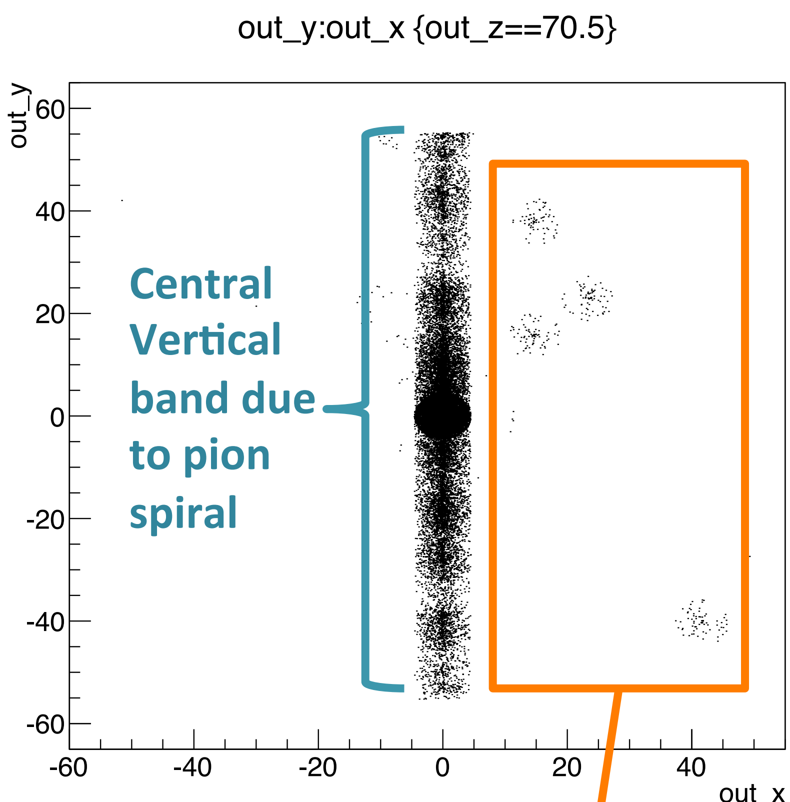
If we just plug Magnetic field in

Position of Hits in Modular RICH Detector



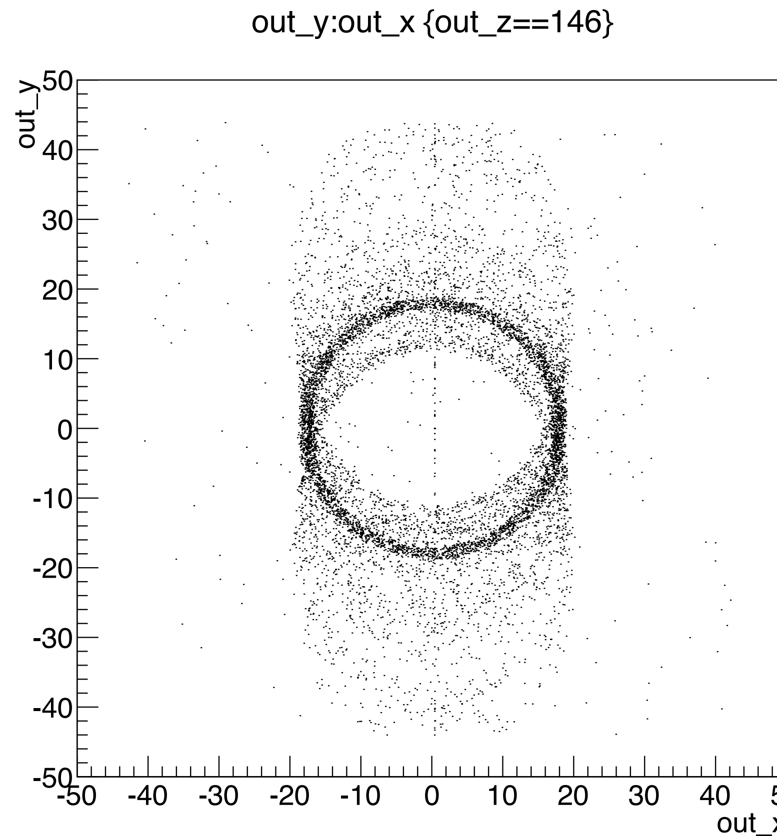
If we just plug Magnetic field in

Hits on Fresnel lens and Photonsensor



Hits on Fresnel lens

e^- generated inside the aerogel



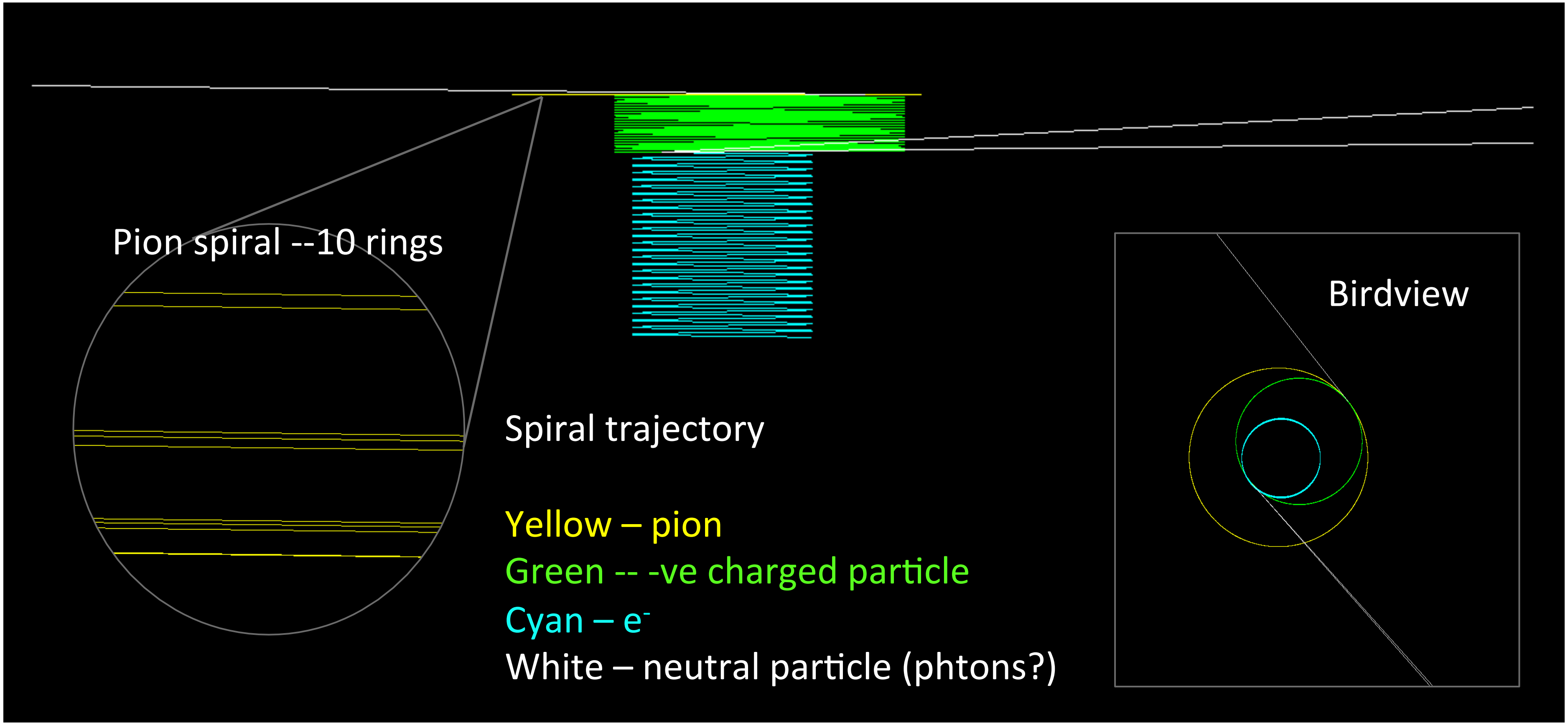
- Hits on Photonsensor
- Shift of Cherenkov rings due to pion spiral

Simulation without Detector

- First, put the detector away
- Simulation Setup
  - magnetic field – $(B_x, B_y, B_z)=(0, 1.5, 0)$T
  - 9GeV Pion was shot from the center of the lab frame
  - Number of Events – 1 event
  - **Removed detector**
  - Hall frame dimension

    $(x, y, z) = (100, 100, 100)$m

Simulation without detector



Simulation without detector

Single event, different momenta

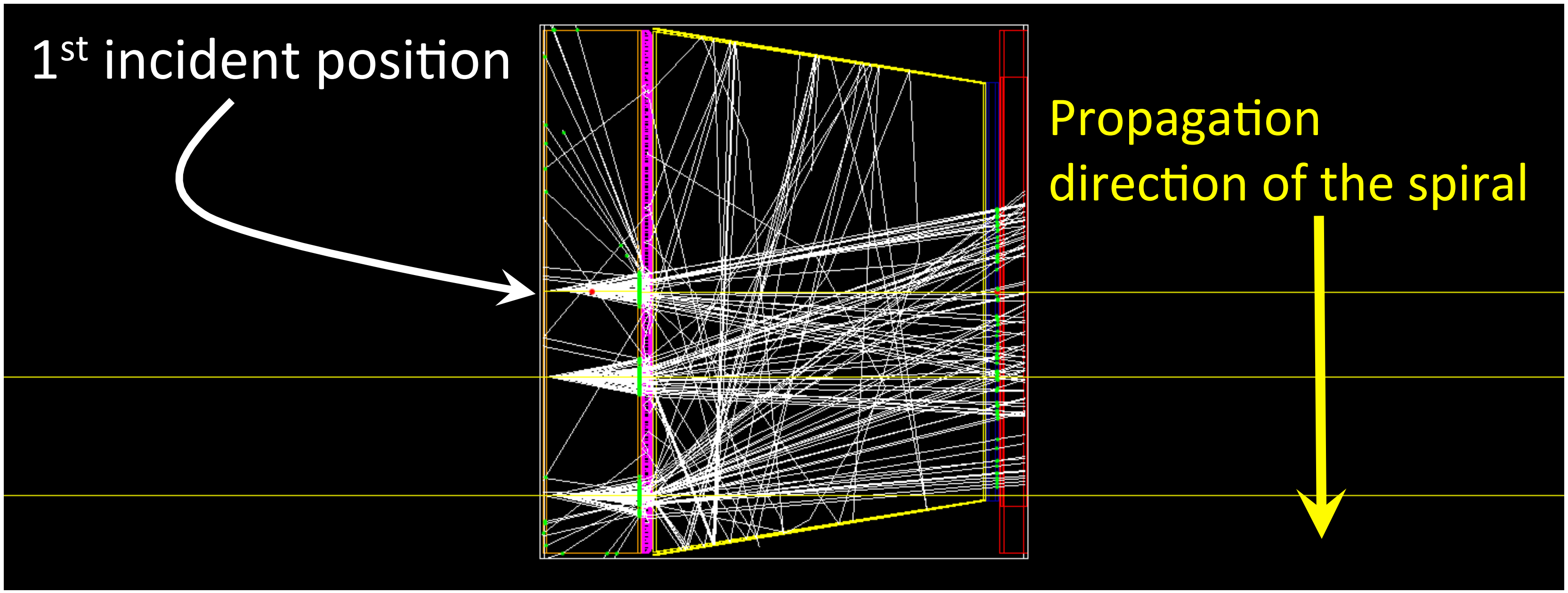
Stronger the magnetic field, larger the ring radius

Simulation with Detector

- Now, let's put the detector back
- Simulation Setup
  - magnetic field – $(B_x, B_y, B_z)=(0, 1.5, 0)T$
  - 9GeV Pion was shot from right in front of the aero gel
  - Number of Events – 1 event
  - Hall frame dimension

    $(x, y, z) = (100, 100, 100)m$

Simulation with Detector

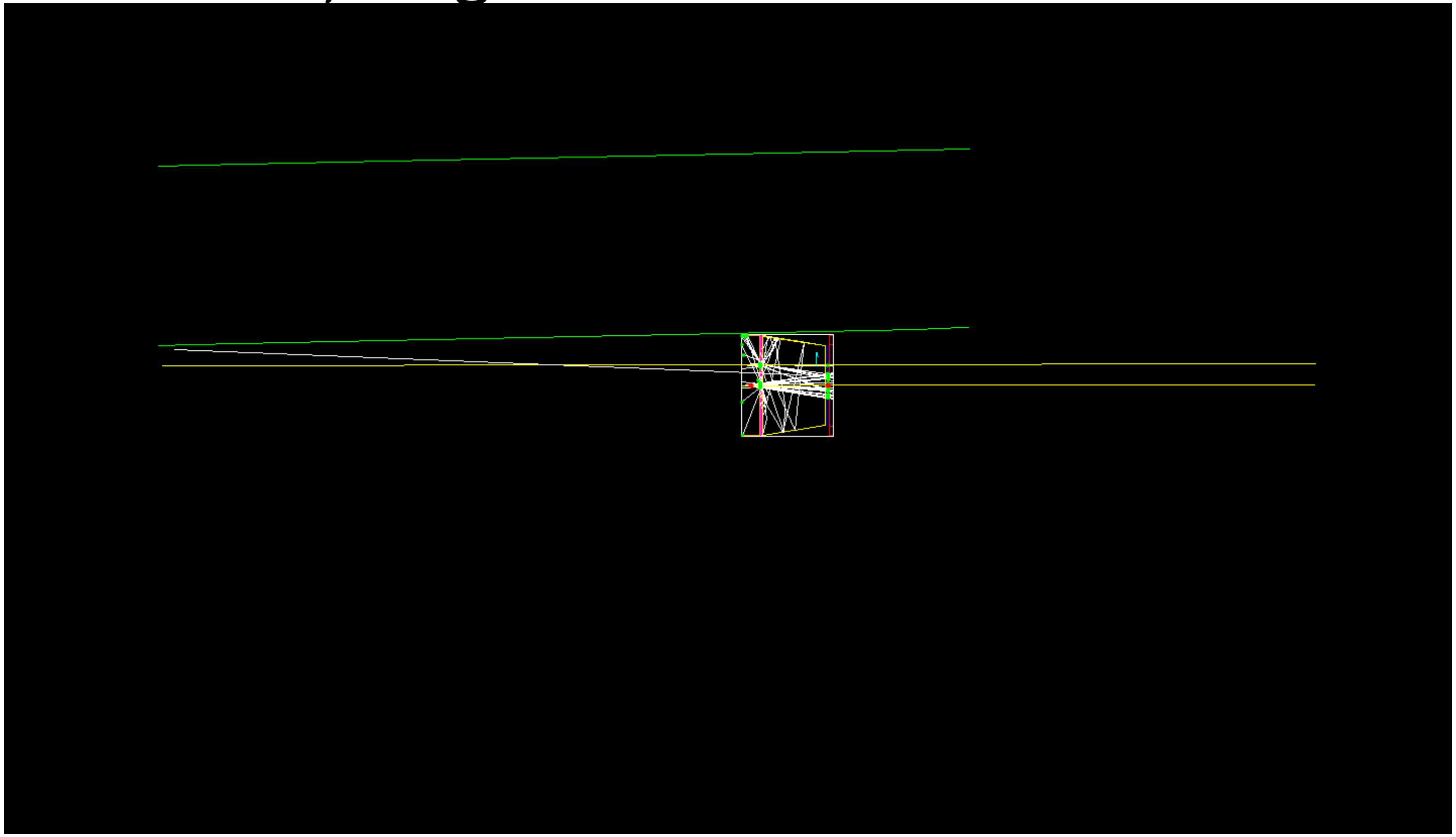


- In the simulation , when the particle reaches the boundary of the hall frame, it will be killed.
  ➔ To avoid the returned pion hit, we need to reduced the hall frame dimension.

Simulation with Detector

More captures from event display

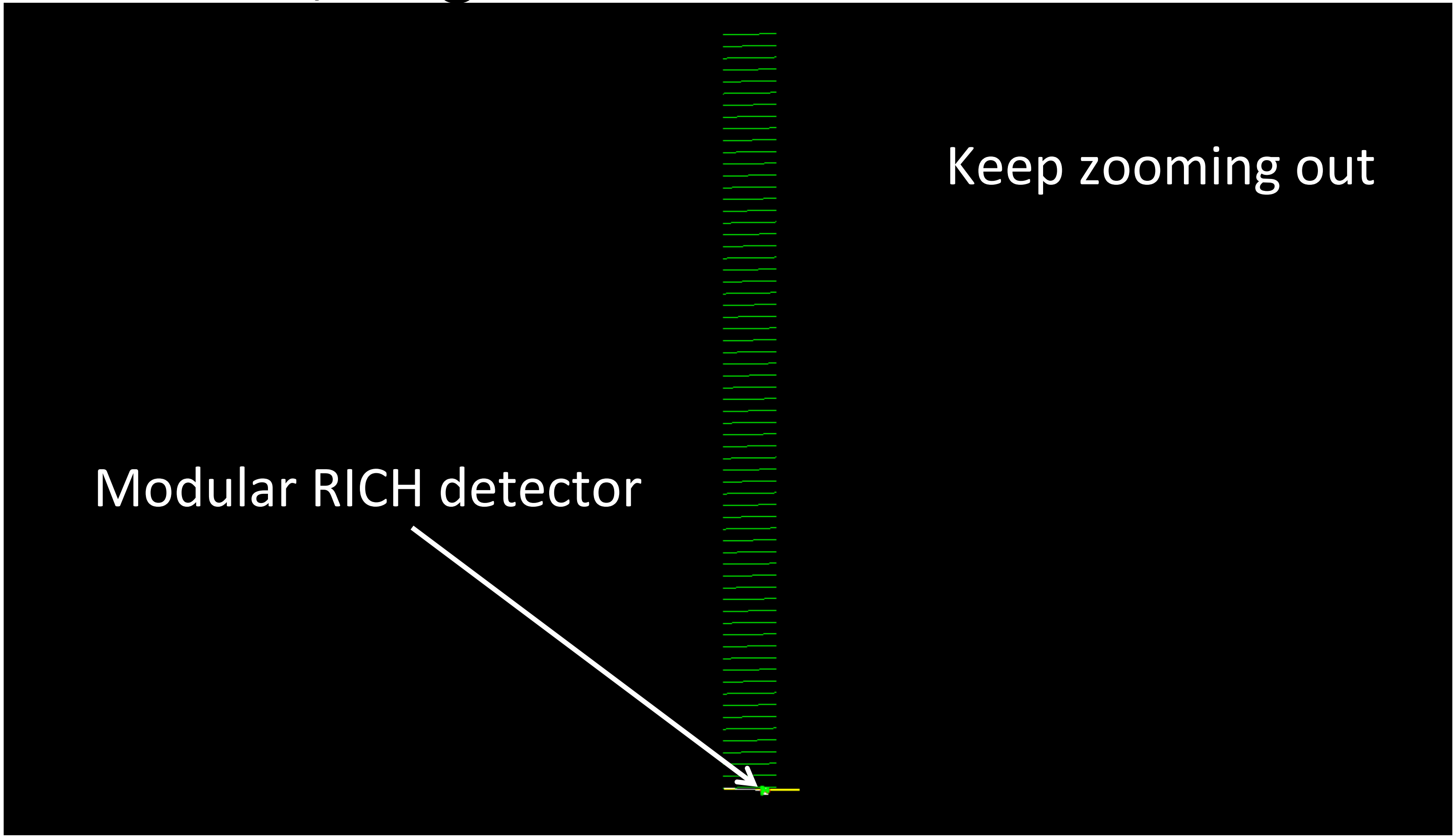
- 1GeV Pion, single event



Simulation with Detector

More captures from event display

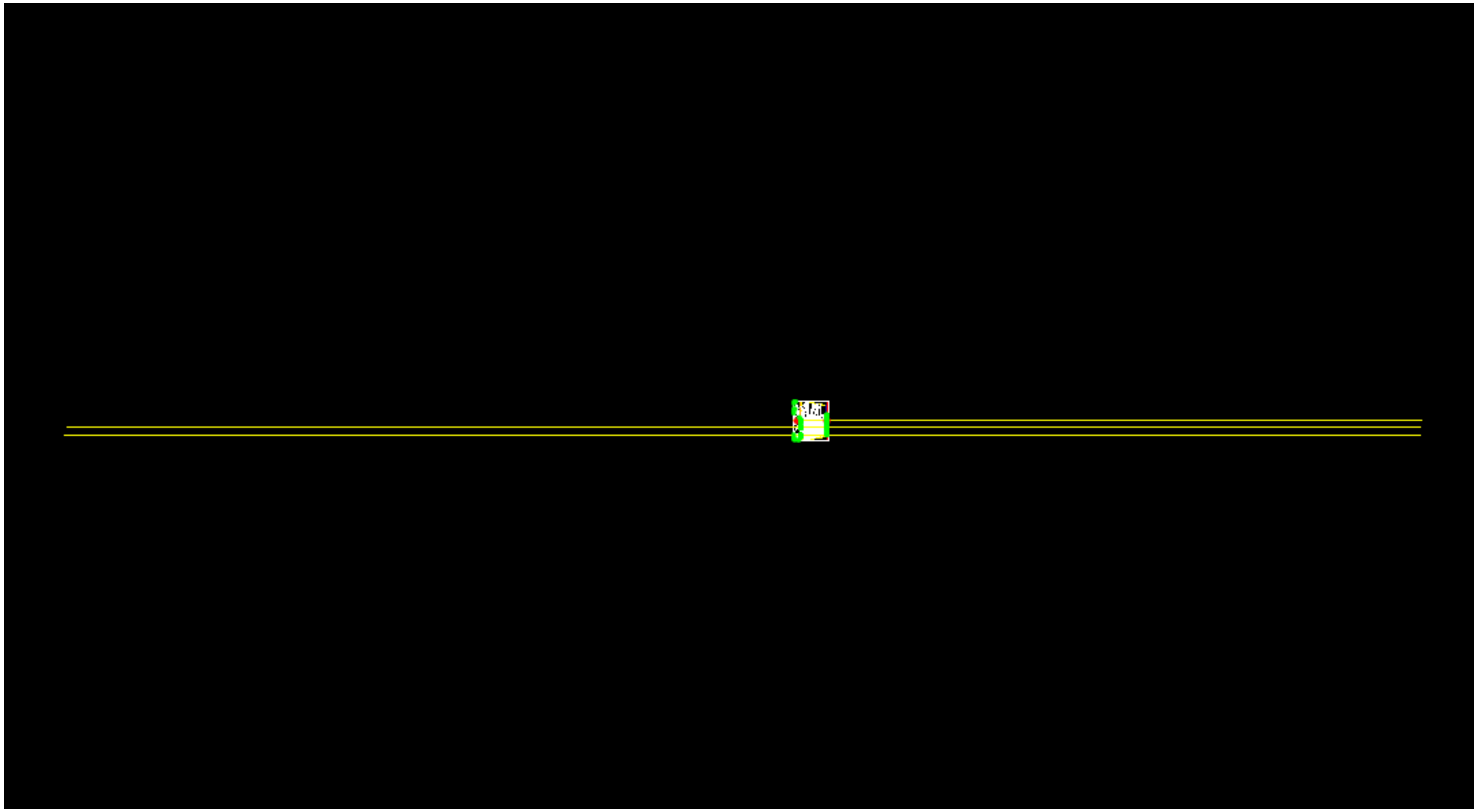
- 1GeV Pion, single event



Simulation with Detector

More captures from event display

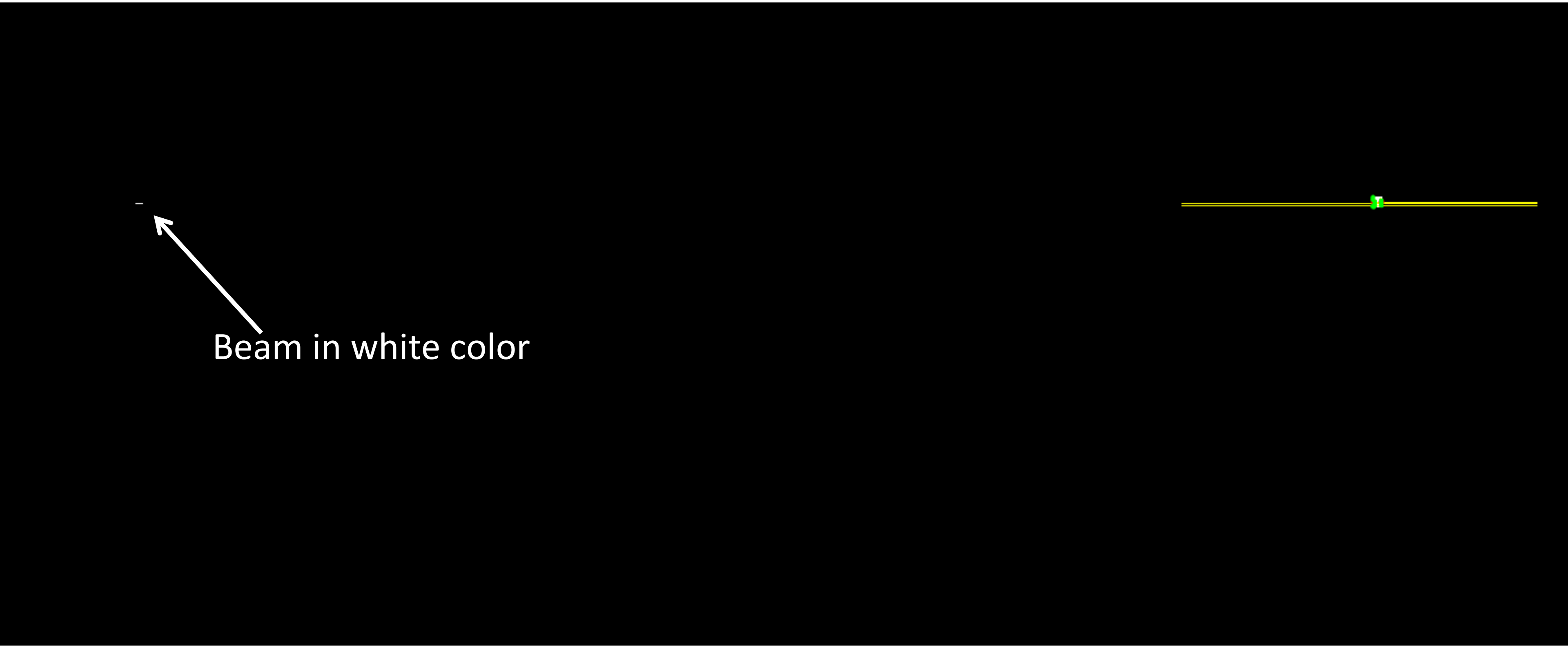
- 9GeV Pion, single event



Simulation with Detector

More captures from event display

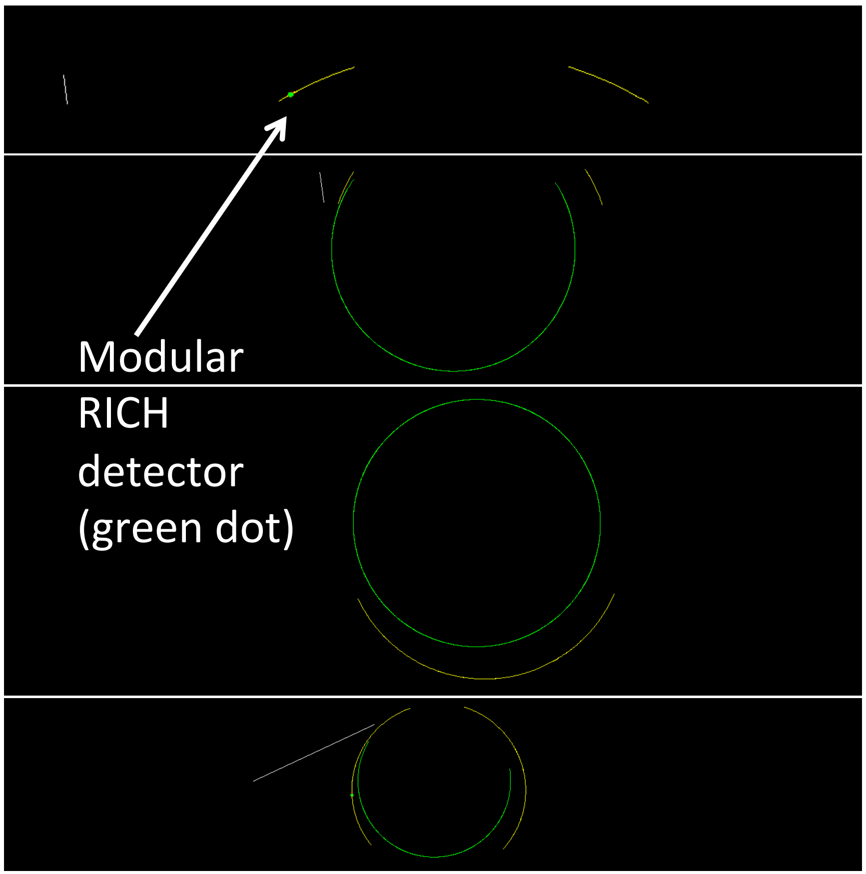
- 9GeV Pion, single event



Simulation with Detector

More captures from event display

- 9GeV Pion, single event

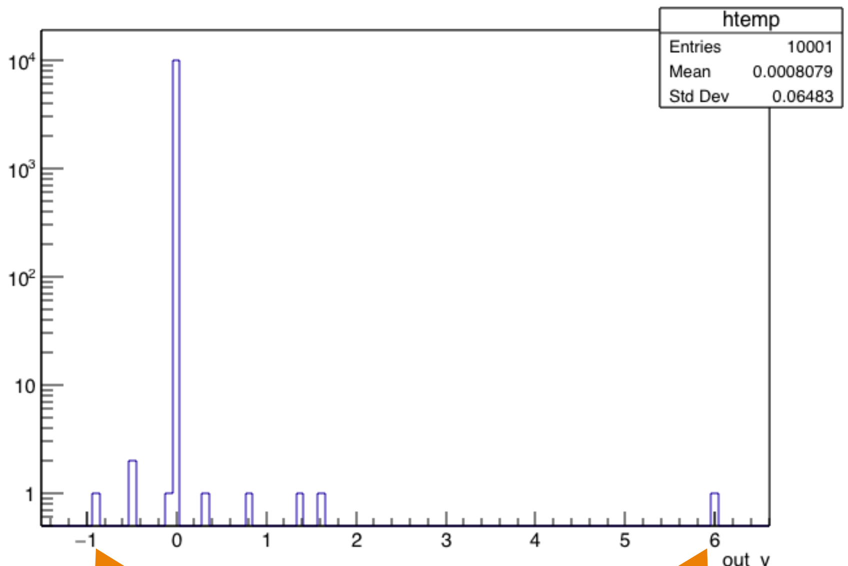


- You can see full circle of different spirals.
- I cannot make both yellow and green circles full at the same time. It looks like that the plane of the green circle is not parallel to the yellow one.
- These four captures are not shown in same scale.

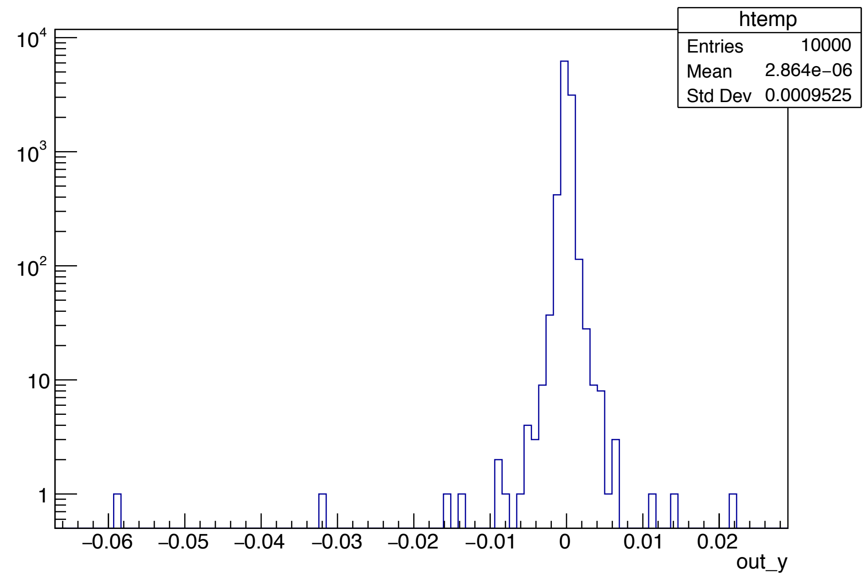
Reduce Hall Frame Dimension

Y-position Distribution of Pion Hits on Fresnel Lens

Field On



Field Off

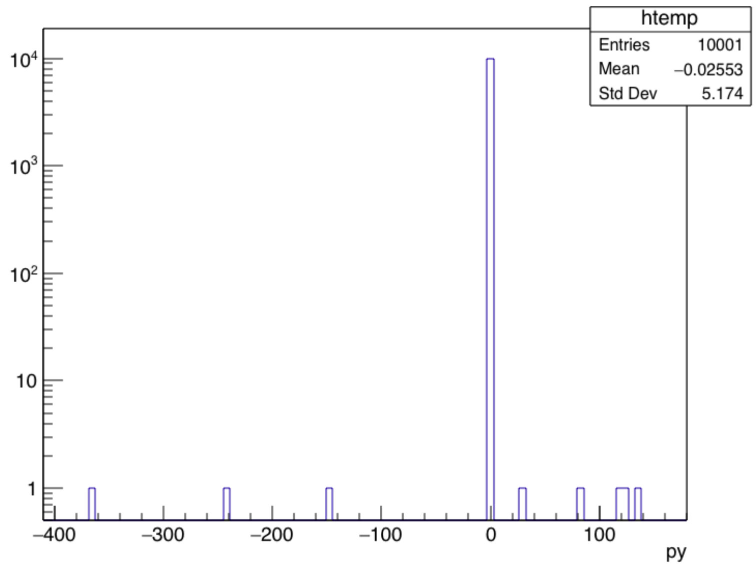


Pion hits spread wider in y-direction when field is on

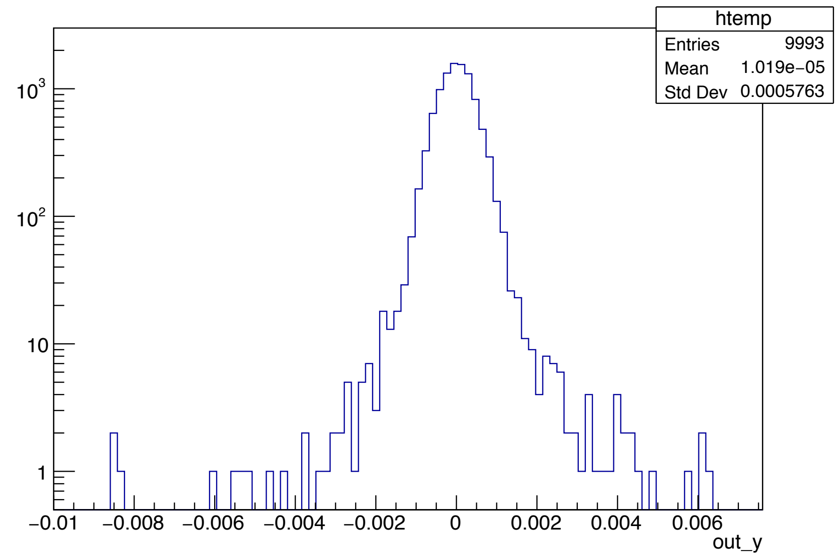
Reduce Hall Frame Dimension

P_y distribution of Pion Hits on Fresnel Lens

Field On



Field Off

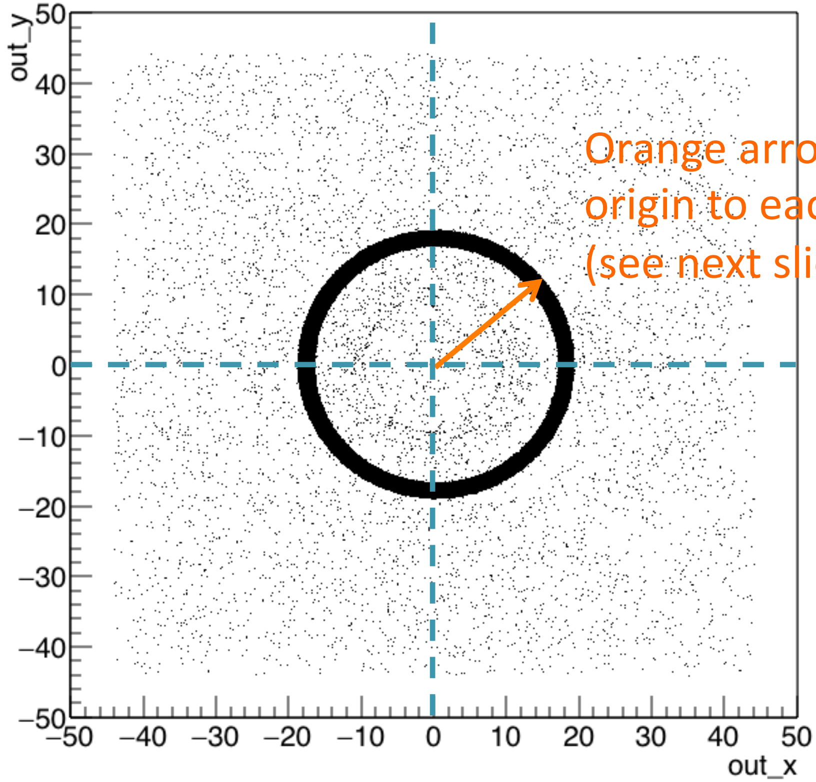


Few of the pions gained higher momentum in y-direction when By field is on

Reduce Hall Frame Dimension

Photon Hits on Sensor

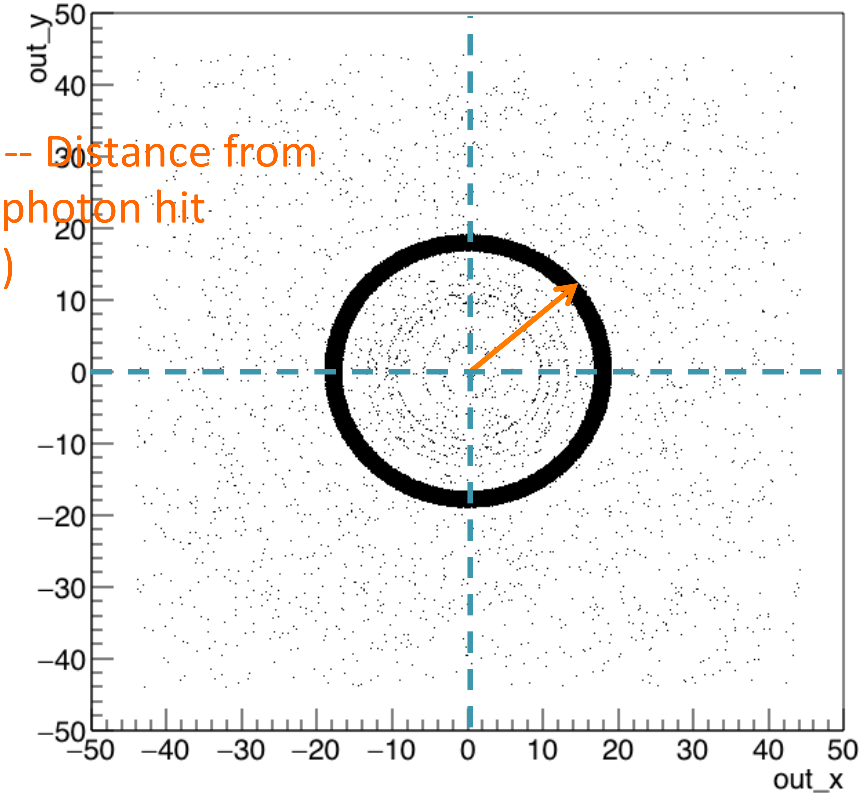
Field On



Orange arrow -- Distance from origin to each photon hit (see next slide)

Number of entries = 284411

Field Off

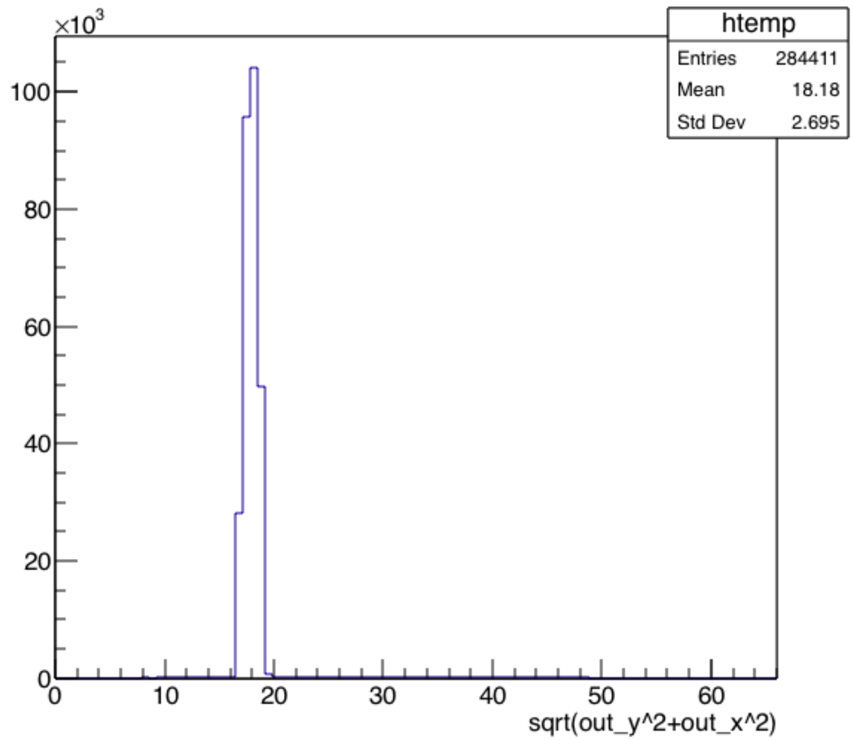


Number of entries = 280159

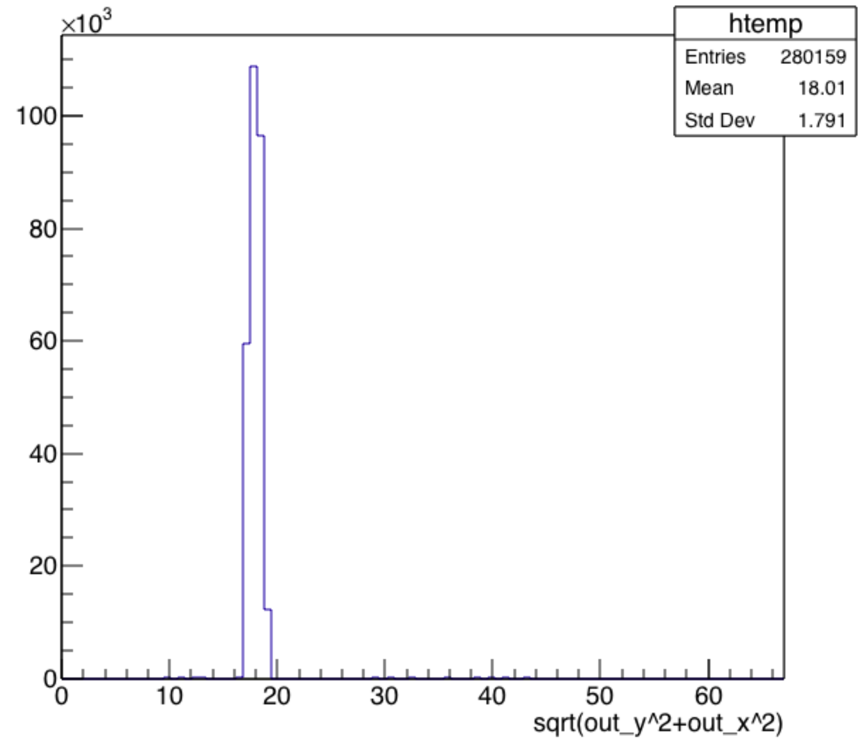
Reduce Hall Frame Dimension

Distance Distribution (from origin to each hit) of Photon hits on the Sensor

Field On



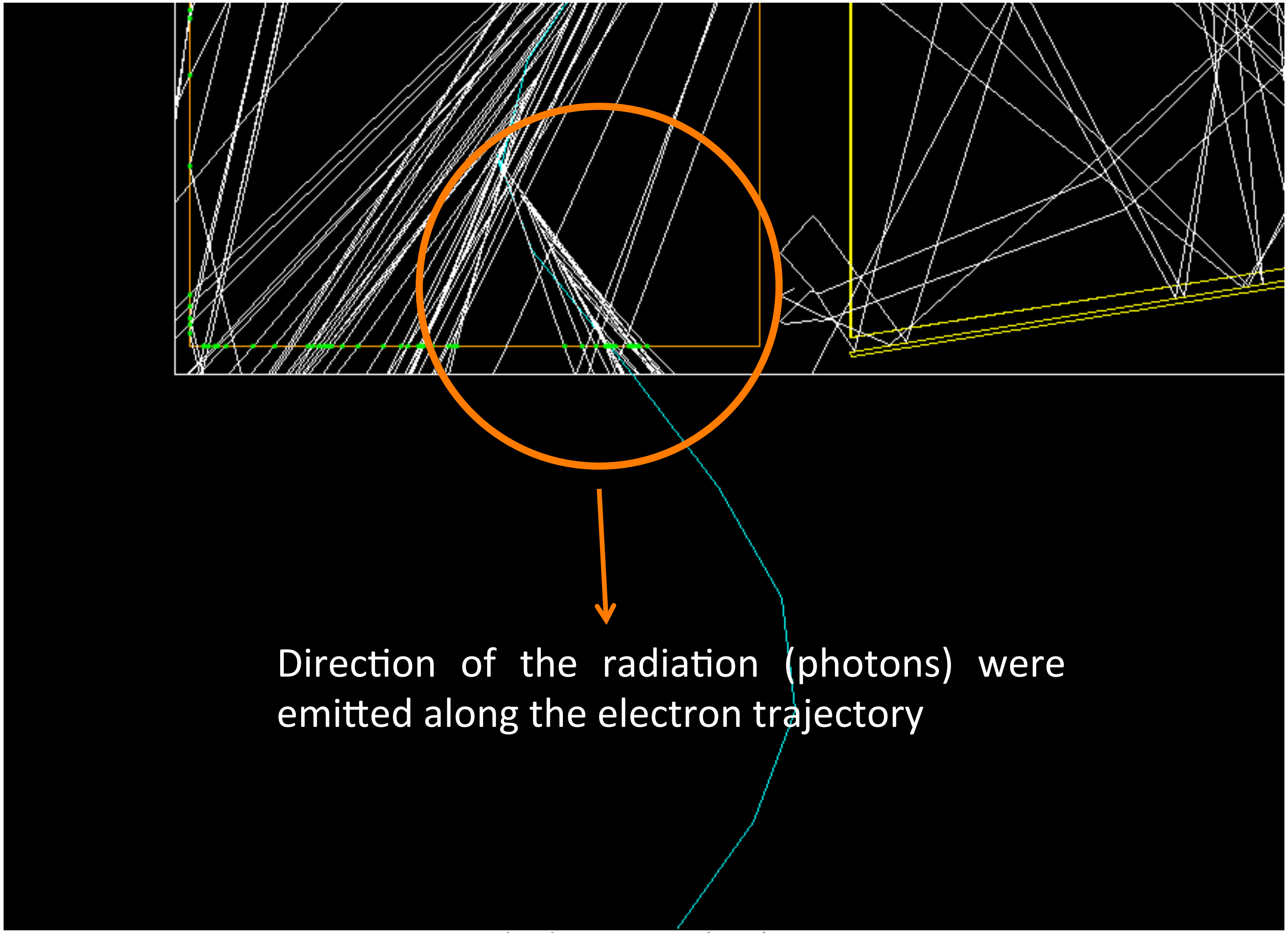
Field Off



Difference of mean between field-on and field-off= (18.18-18.01)/18.01=0.94%.
Difference of standard deviation = (2.695-1.791)/1.791=50.47%

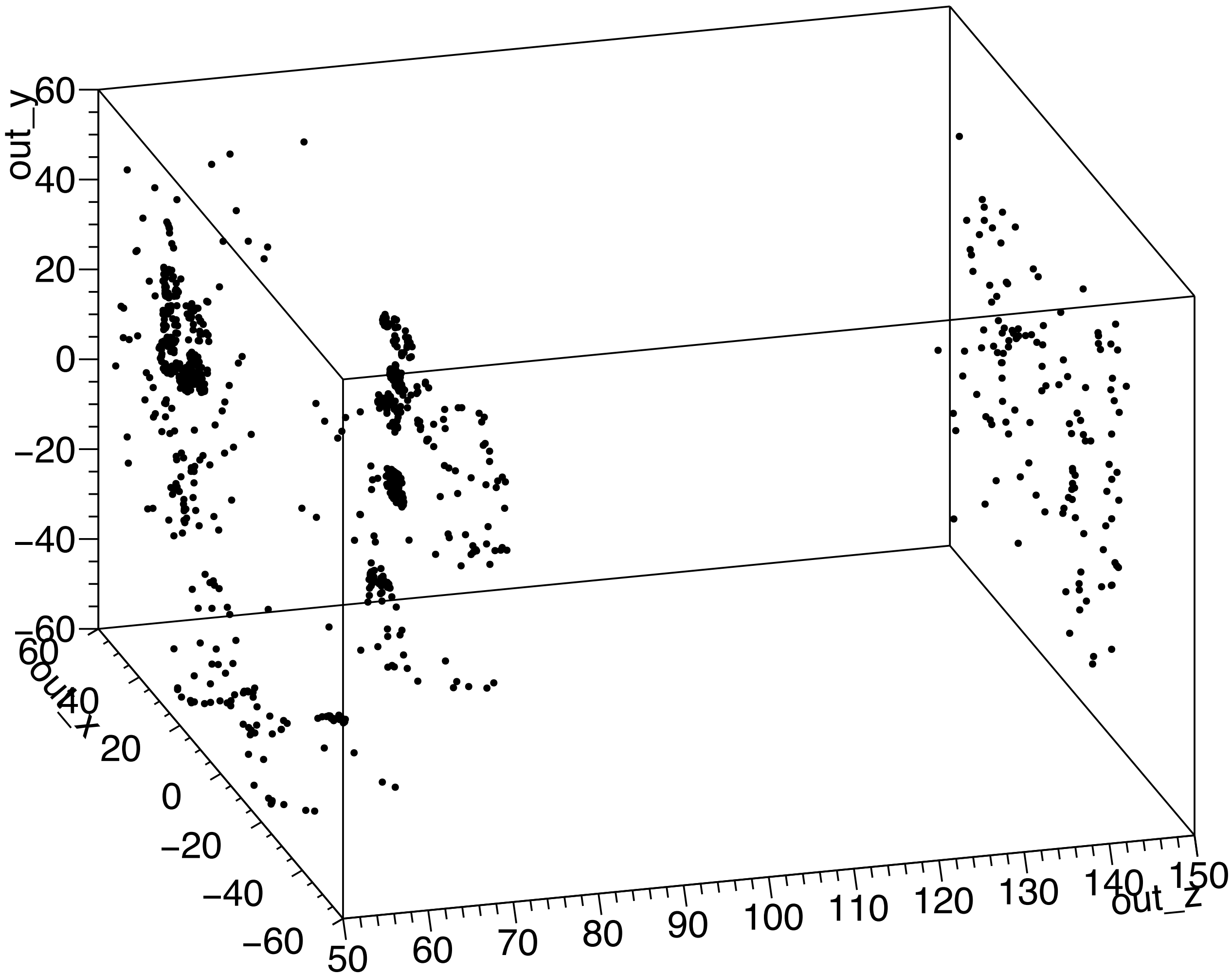
Single Muon simulation

Event Display



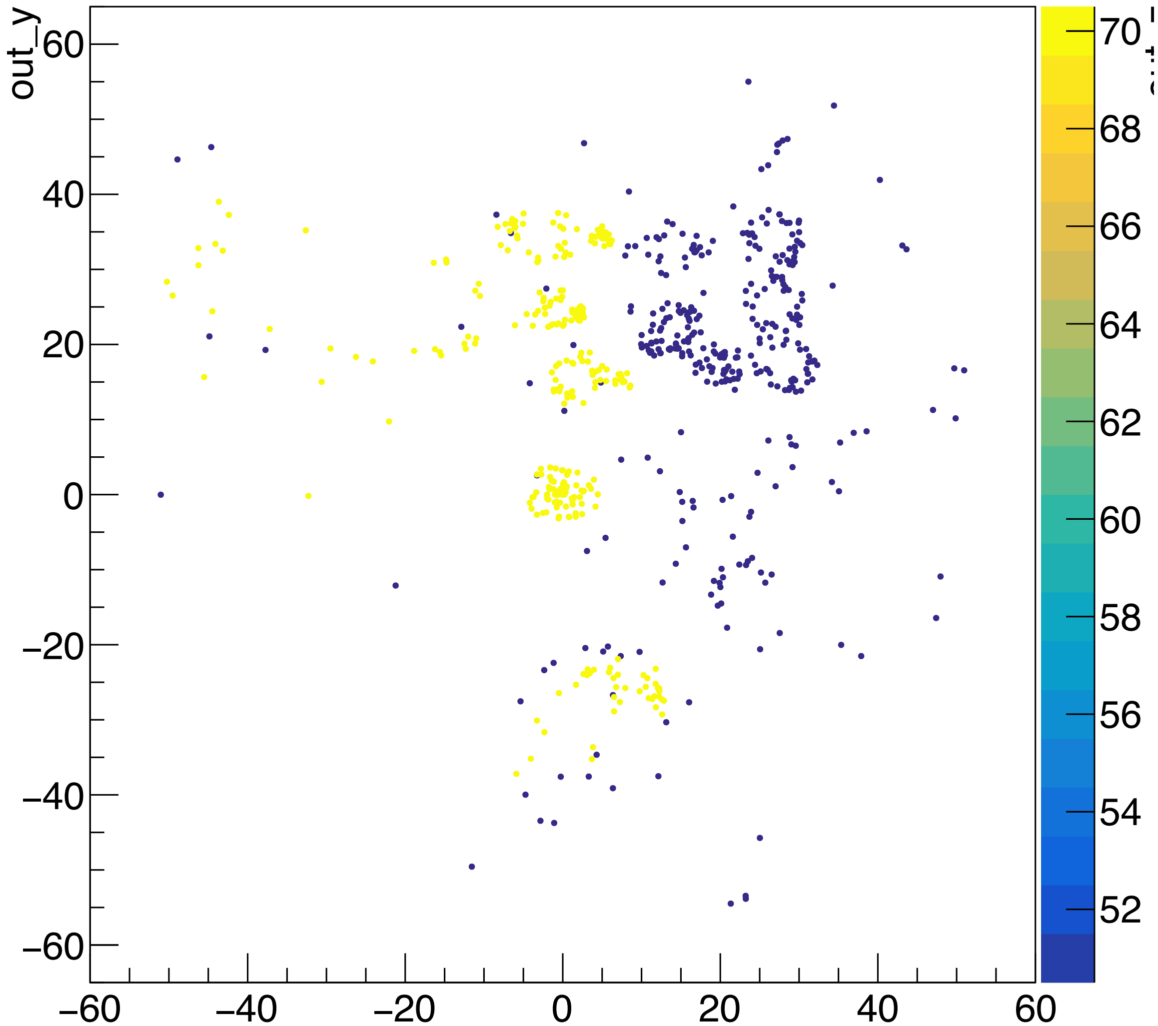
Single Muon simulation

All Photon Hits in Detector



Single Muon simulation

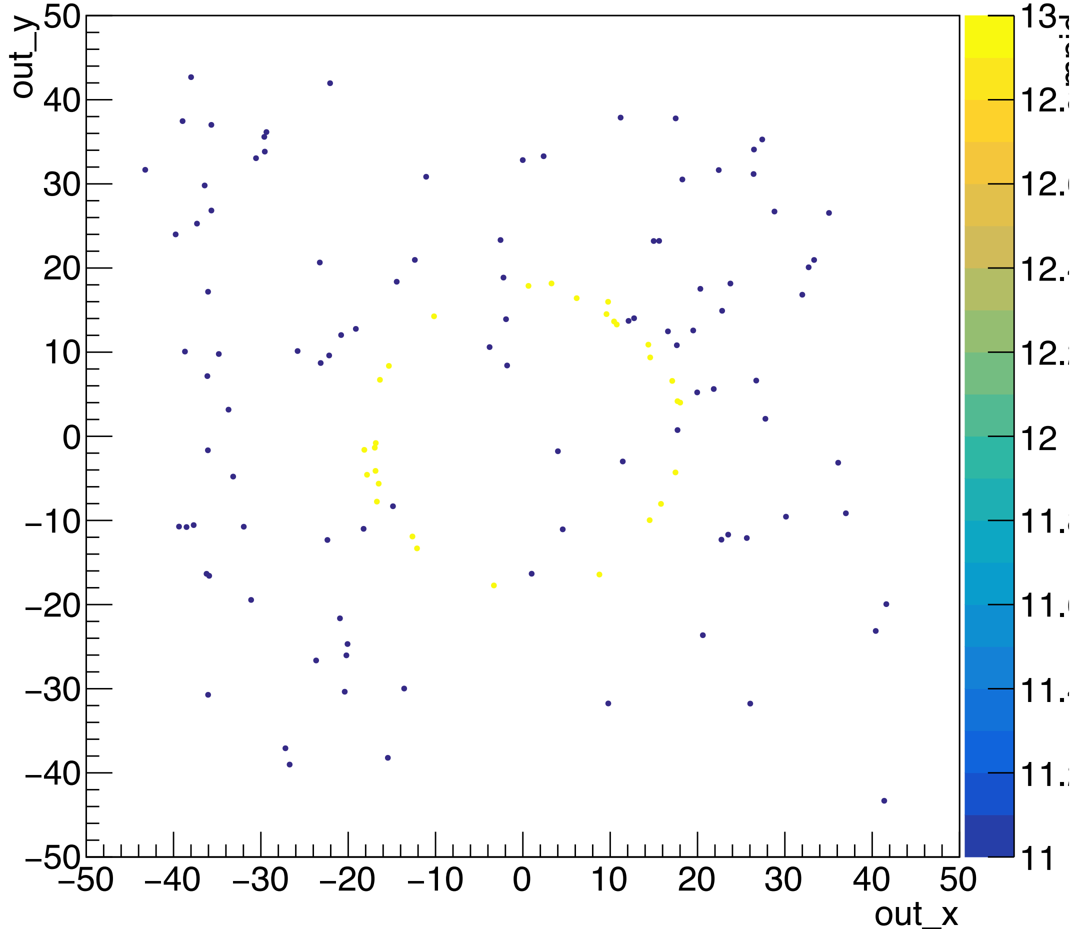
Position of Photon Hits on Aero Gel and on Fresnel Lens



- Overlay slide 12 on slide 13
- Y-axis – y-position of photon hit
- X-axis – x-position of photon hit
- Color – **z-position** of photon hits
  - Purple -- Photon hits on aero gel
  - Yellow– photon hits on Fresnel lens

Single Muon simulation

mpid of Photon Hits on the Sensor



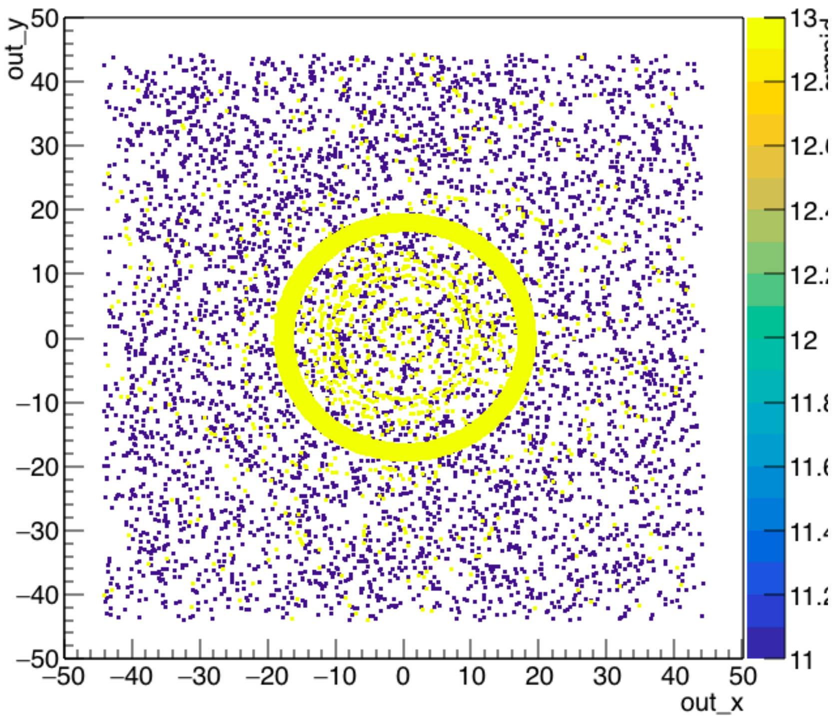
Mpid of photon hits on the photonsensor

- Y-axis – y-position of photon hit
- X-axis – x-position of photon hit
- Color – mpid
  - Purple – mpid=11 → e^-
  - Yellow – mpid=13 → μ^-

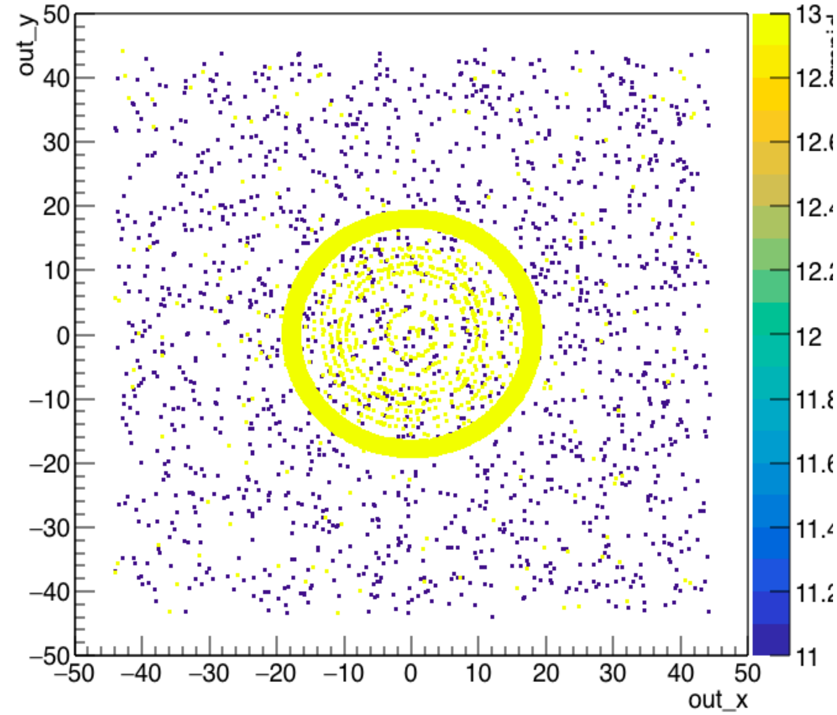
10,000 Muons Simulation

mpid of Photon Hits on Sensor

Field On



Field Off

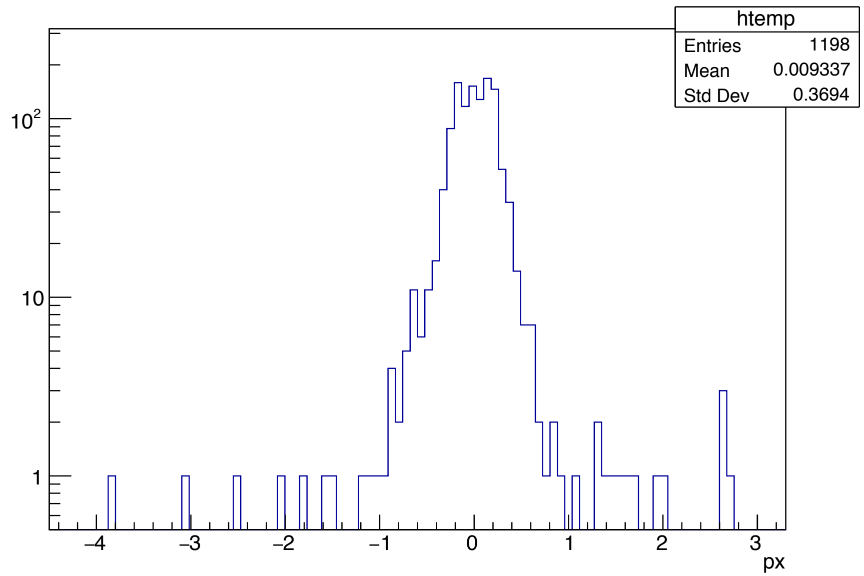


- Y-axis – y-position of photon hit
- X-axis – x-position of photon hit
- Color – mpid : Purple – mpid=11 → e^-
  Yellow – mpid=13 → μ^-

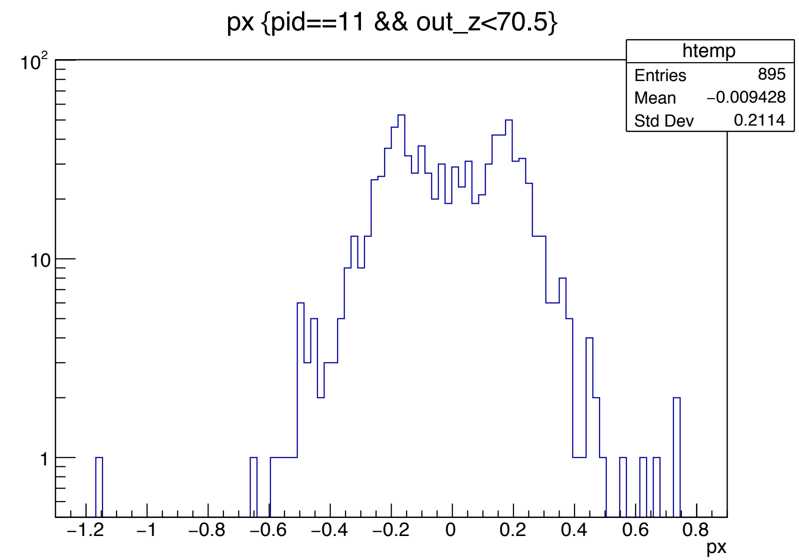
10,000 Muons Simulation

P_x Distribution of Electron Hits inside Aero Gel

Field-On



Field-Off



$|P_x|>=2$: 8 entries

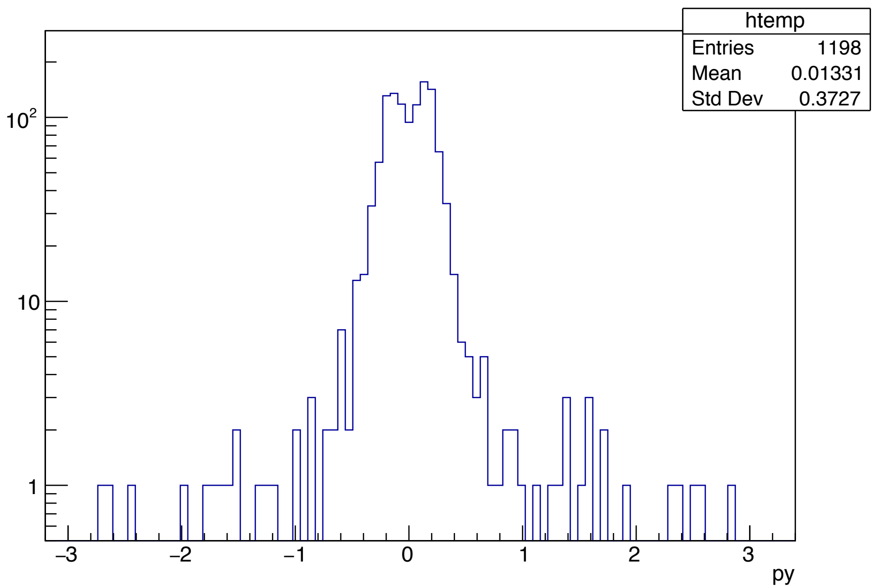
$|P_x|>=2$: 0 entries

* Cherenkov radiation threshold for electron particle : P≈2.3MeV

10,000 Muons Simulation

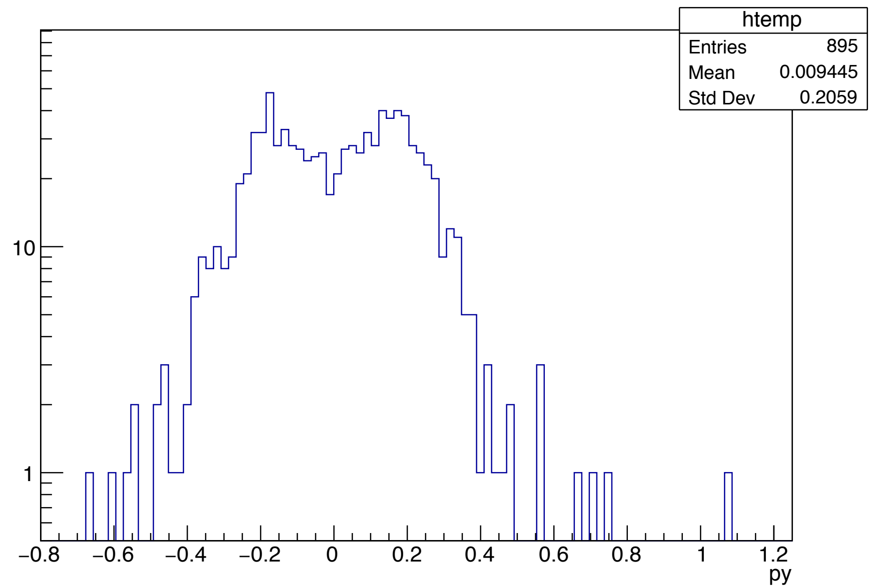
P_y Distribution of Electron Hits inside Aero Gel

Field-On



$|P_y|>=2$: 8 entries

Field-Off



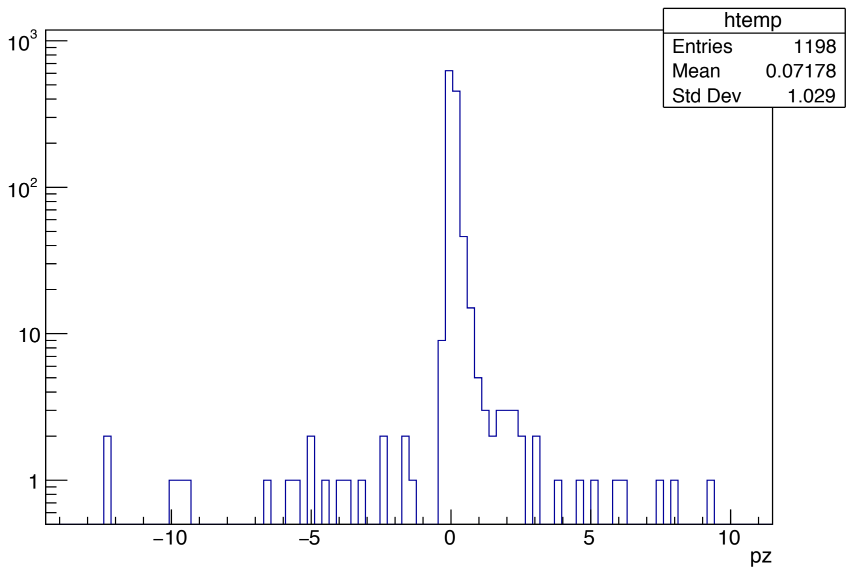
$|P_y|>=2$: 0 entries

*Cherenkov radiation threshold for electron particle : P≈2.3MeV

10,000 Muons Simulation

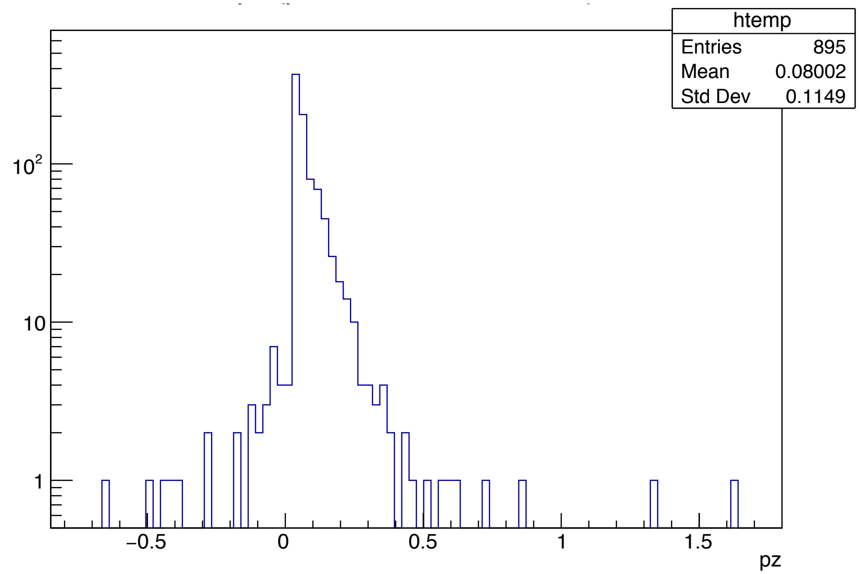
P_z Distribution of Electron Hits inside Aero Gel

Field-On



$|P_z|>=2$: 32 entries

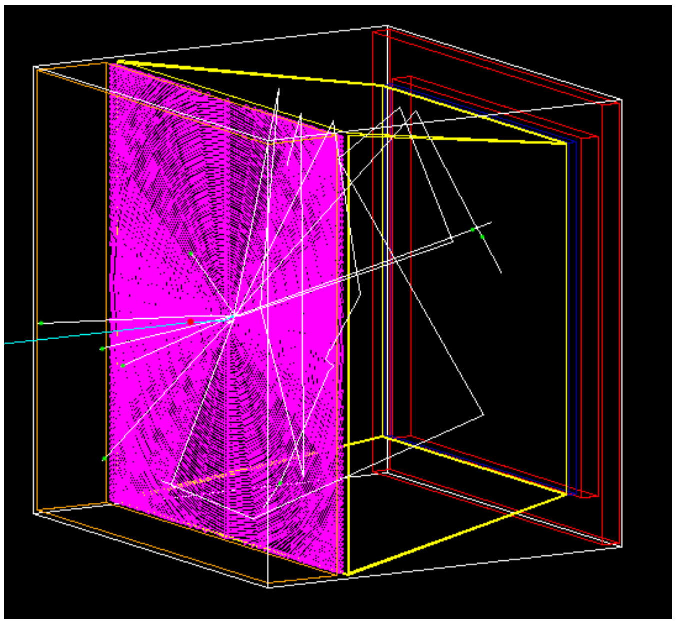
Field-Off



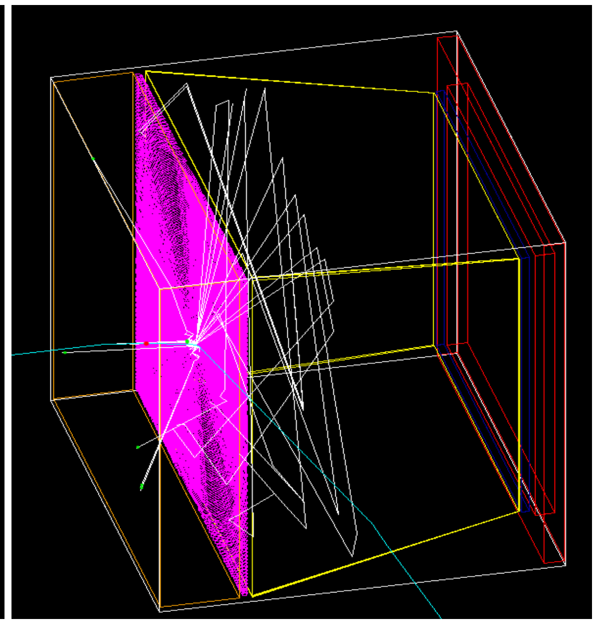
$|P_z|>=2$: 0 entries

*Cherenkov radiation threshold for electron particle : $P \approx 2.3$MeV

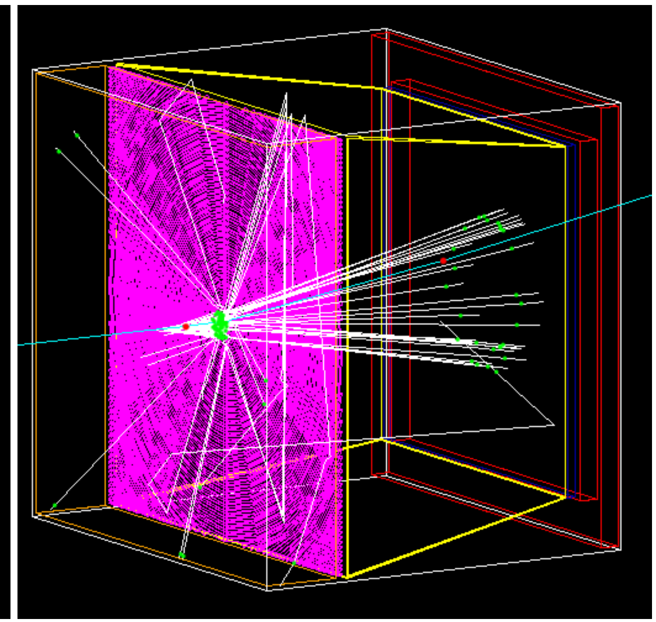
Field-Off, Single Electron with different momentum



1 MeV single electron



2.3 MeV single electron



6 MeV single electron

Cherenkov radiation threshold for electron particle : P≈2.3MeV