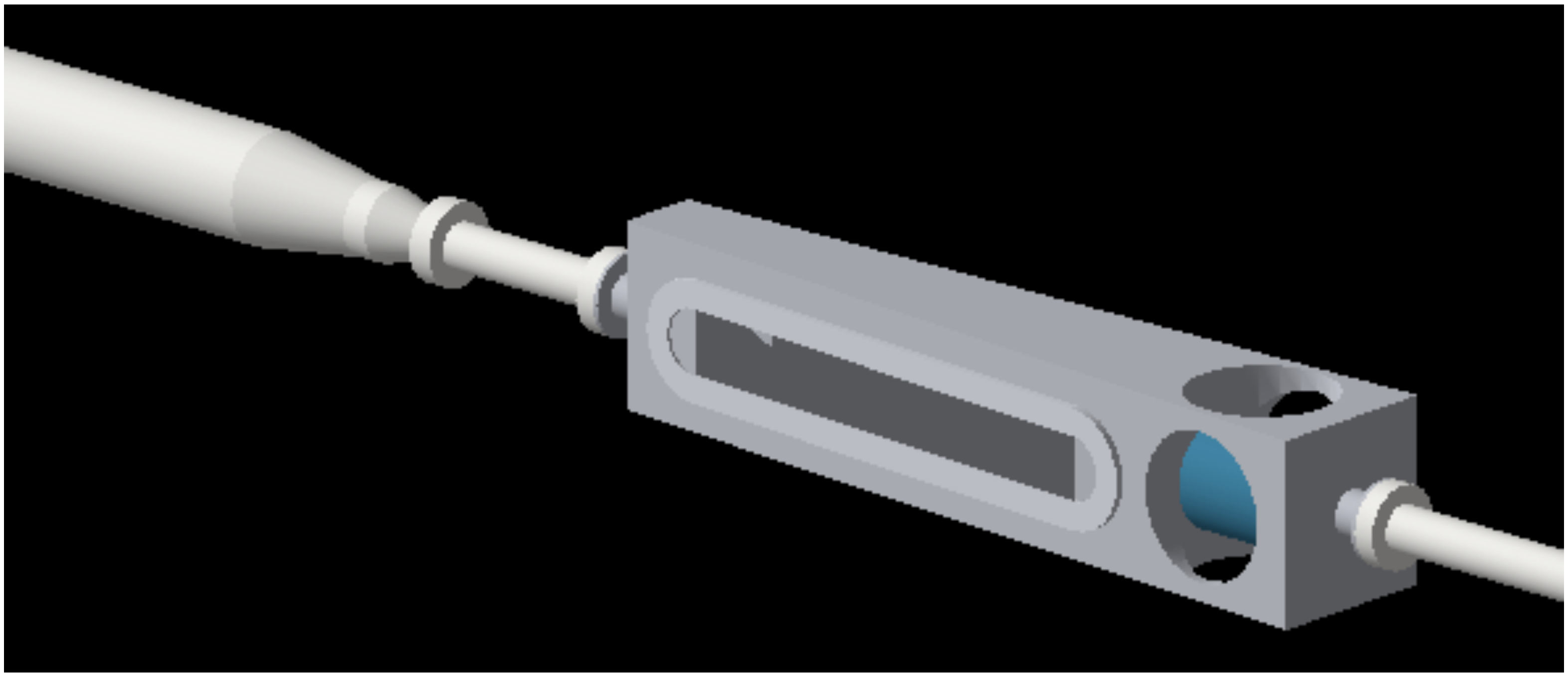
Synchrotron, Beam Halo and Collimator Studies

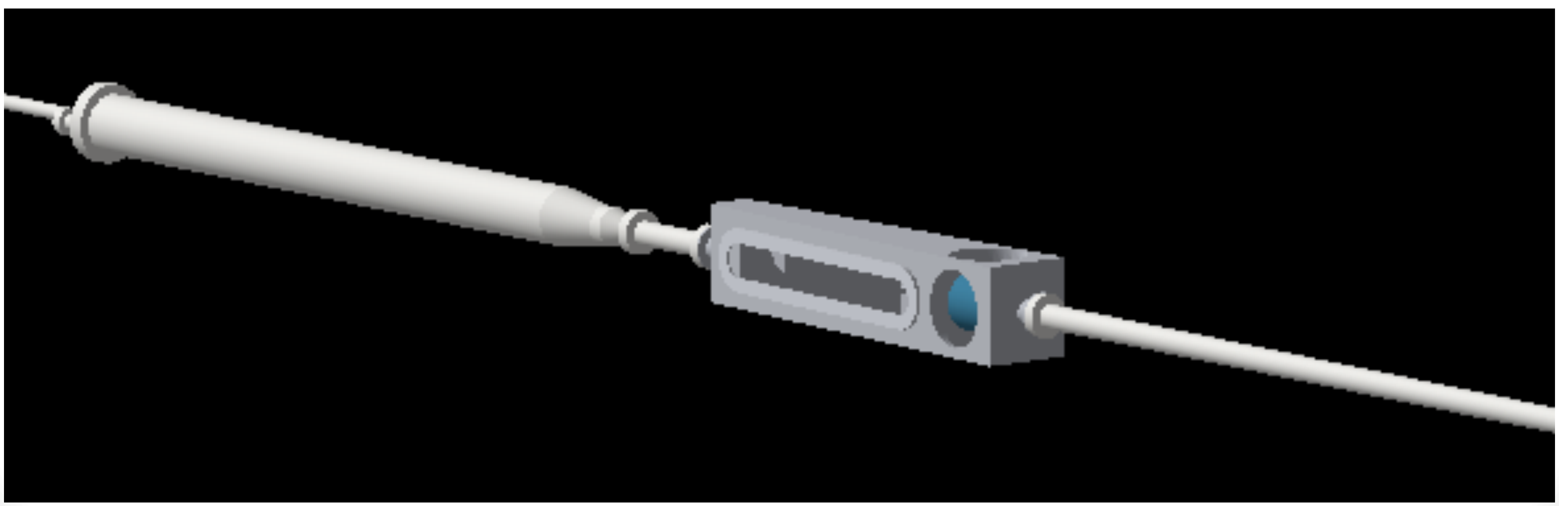


Axel Schmidt

26 April, 2010

Monte Carlo Simulation

- Realistic Scattering Chamber
- Virtual “sphere detector” tracks counts particles as a way of measuring radiation flux
- No other detectors or geometries
- OLYMPUS magnetic field



Generated Electron Profile

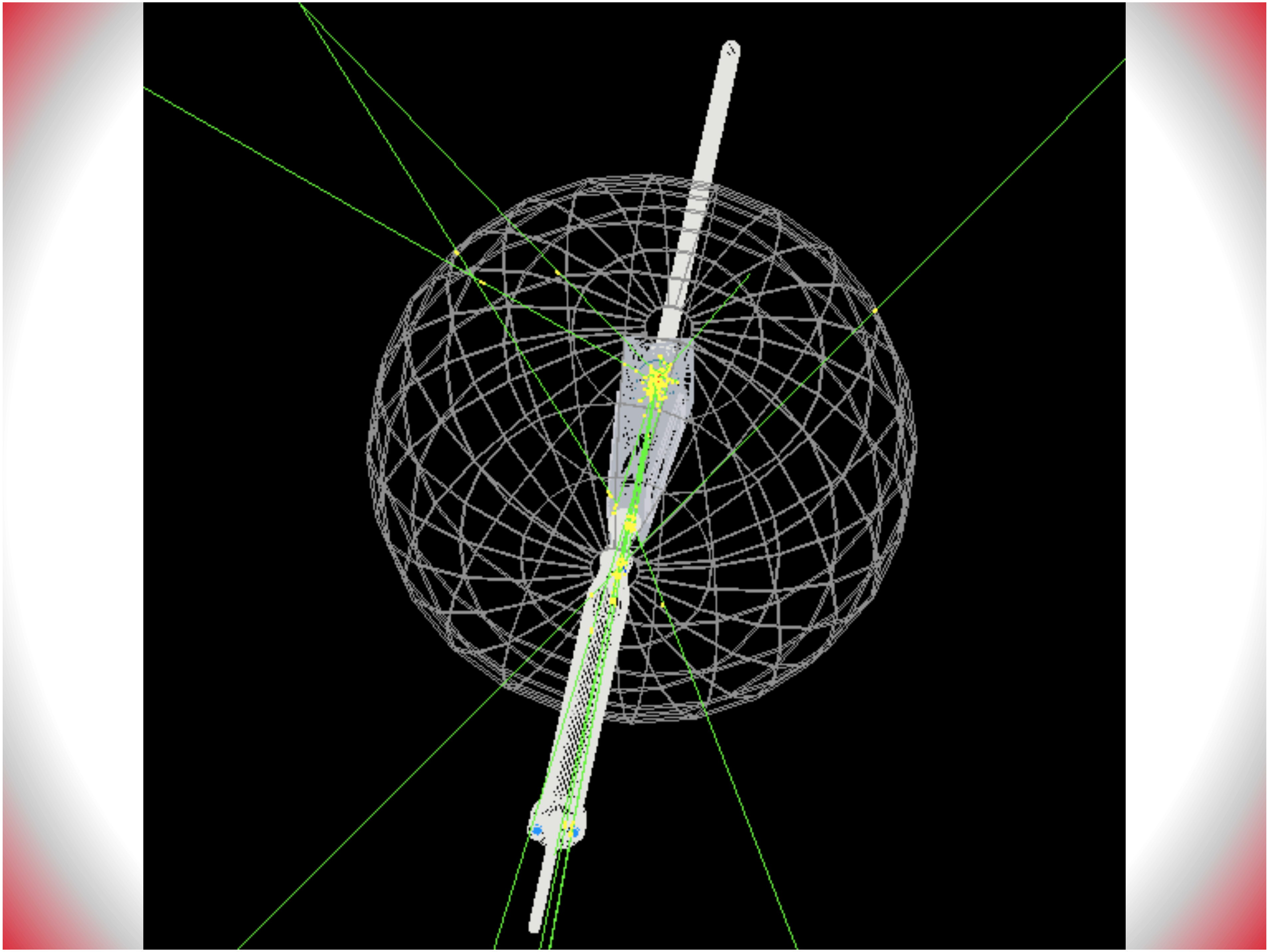
- What are the position and momentum distributions of electrons that hit the collimator?
  - This is a difficult question to answer.
  - Let's assume that total beam is made up of:

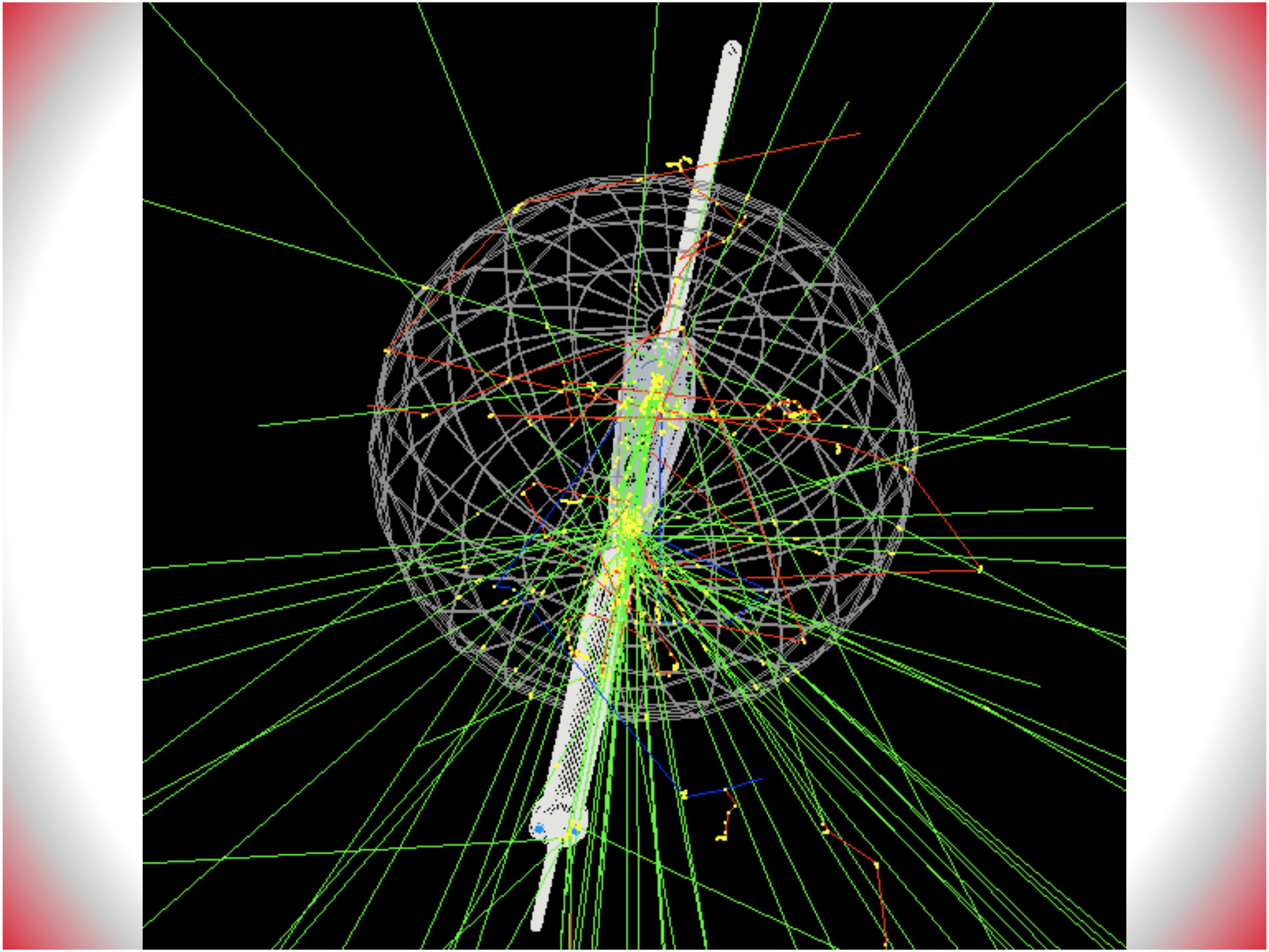
$$\textit{Total Beam} \quad = \quad \textit{Beam} \quad + \quad \textit{Halo}$$

    where beam is described by a perfect Gaussian scaled with the local beta function.
  - The "Beam" part will not hit the collimator.
  - What is the size of the Halo?

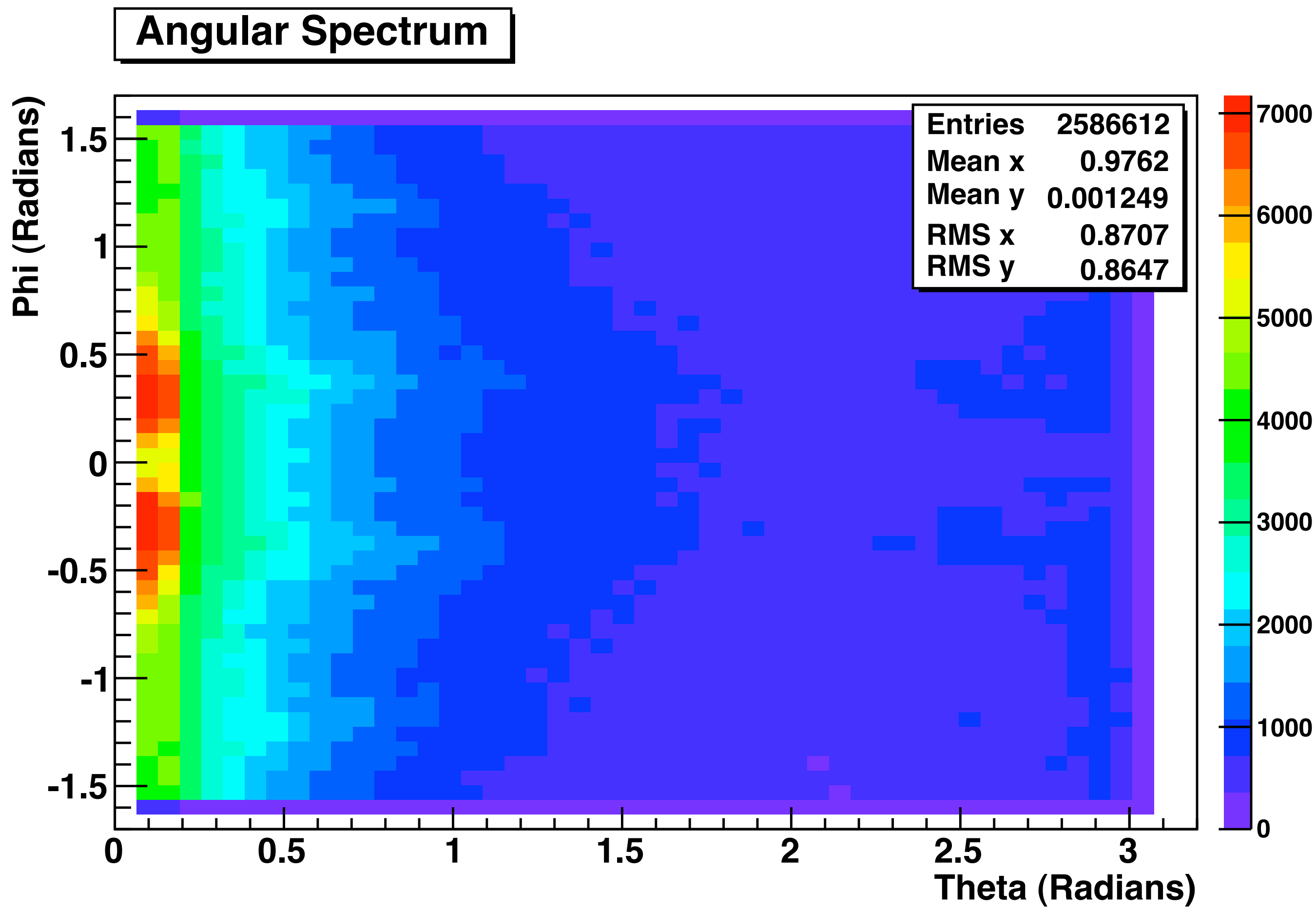
Estimating the Beam Halo

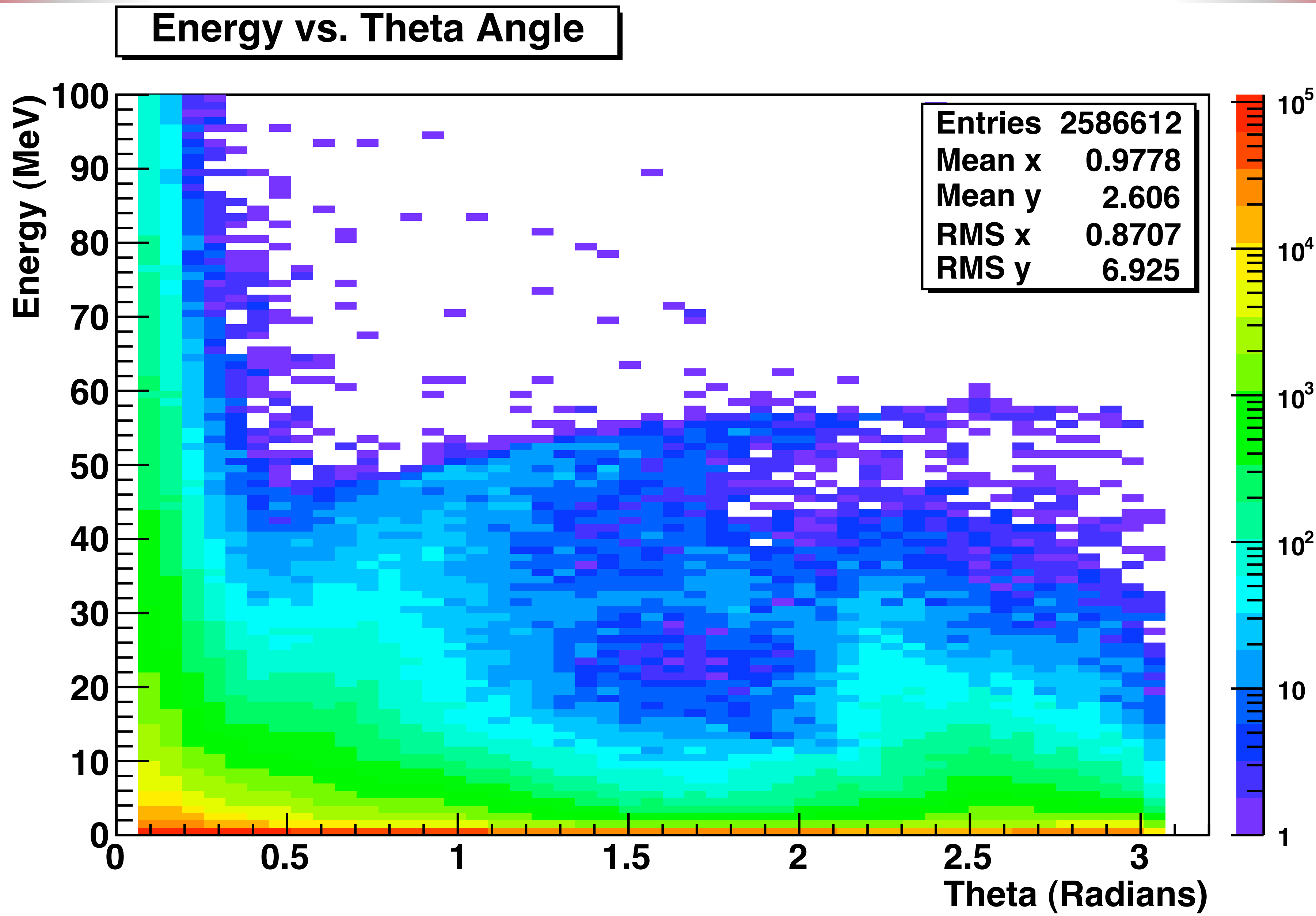
- Dominant contribution from electrons Bremsstrahlung-scattered by beam gas.
- I take calculations by Uli Kötz from Dec. '09
  - Rate of 110 kHz hitting the collimator
  - Assume position spread and energy spread scale with energy
- No angular spread (yet).

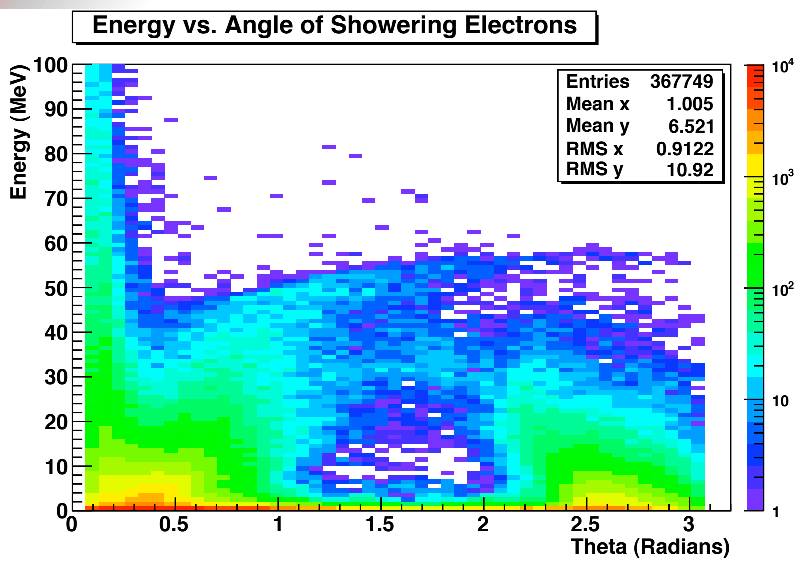


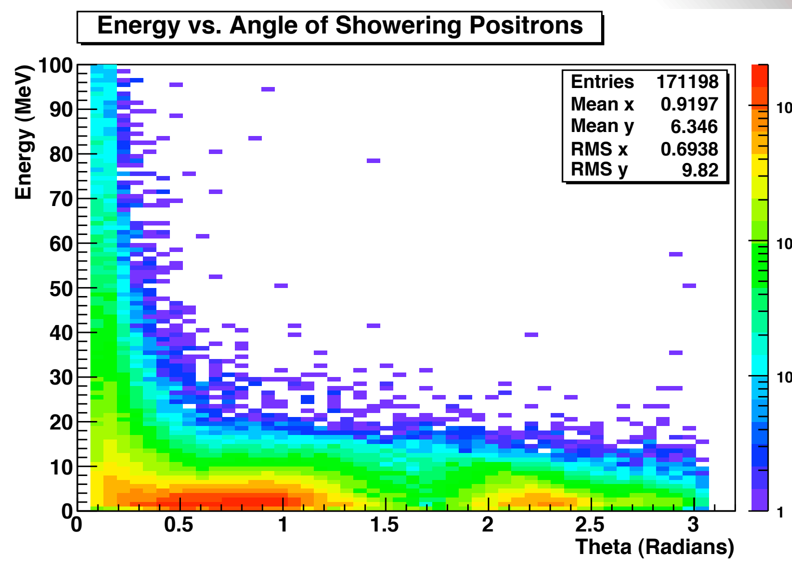


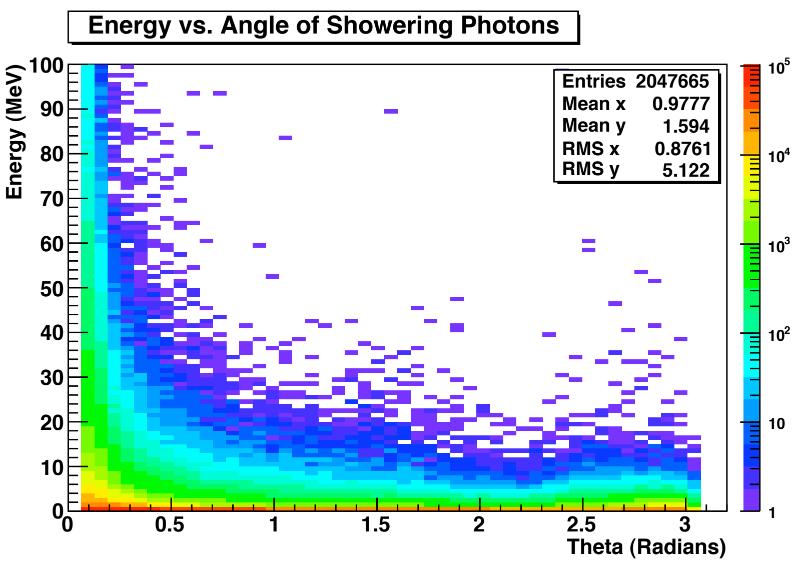
Simulation Results
110,000 events (1 s) @ 2.0 GeV




Energy vs. Theta Angle
Entries 2586612
Mean x 0.9778
Mean y 2.606
RMS x 0.8707
RMS y 6.925
Energy (MeV)
Theta (Radians)
0
10
20
30
40
50
60
70
80
90
100
0.5
1
1.5
2
2.5
3
1
10
10^2
10^3
10^4
10^5





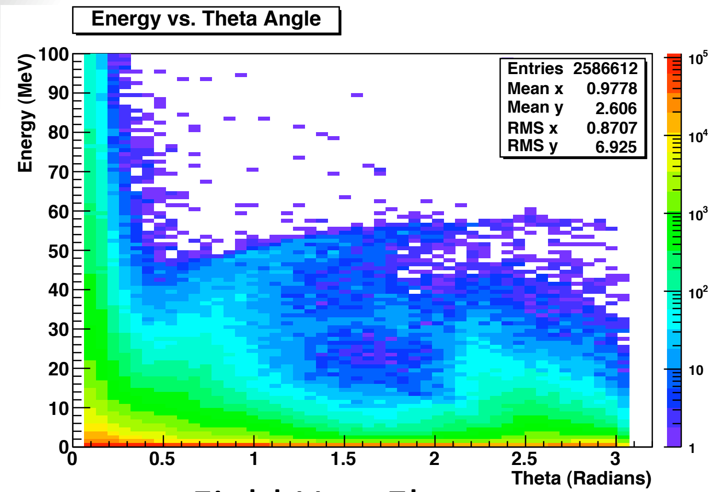


The dominant source of radiation is bremsstrahlung photons.

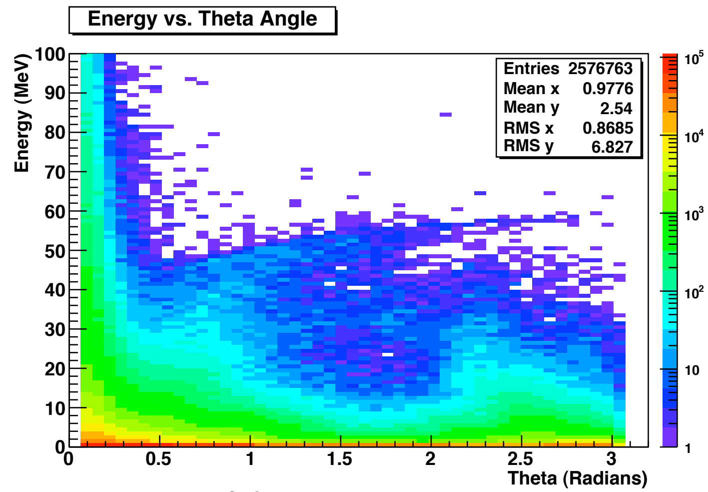
The radiation is sharply peaked in the forward direction.

The magnetic field causes spiraling of particles through the sphere.

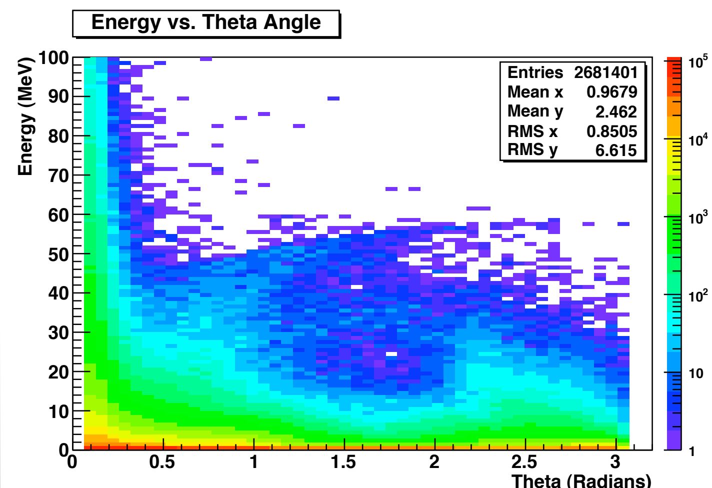
All four field/beam configurations



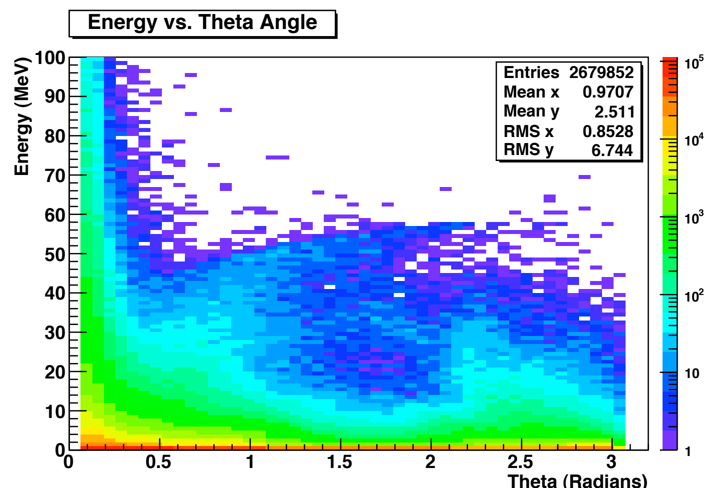
Field Up - Electrons



Field Up - Positrons

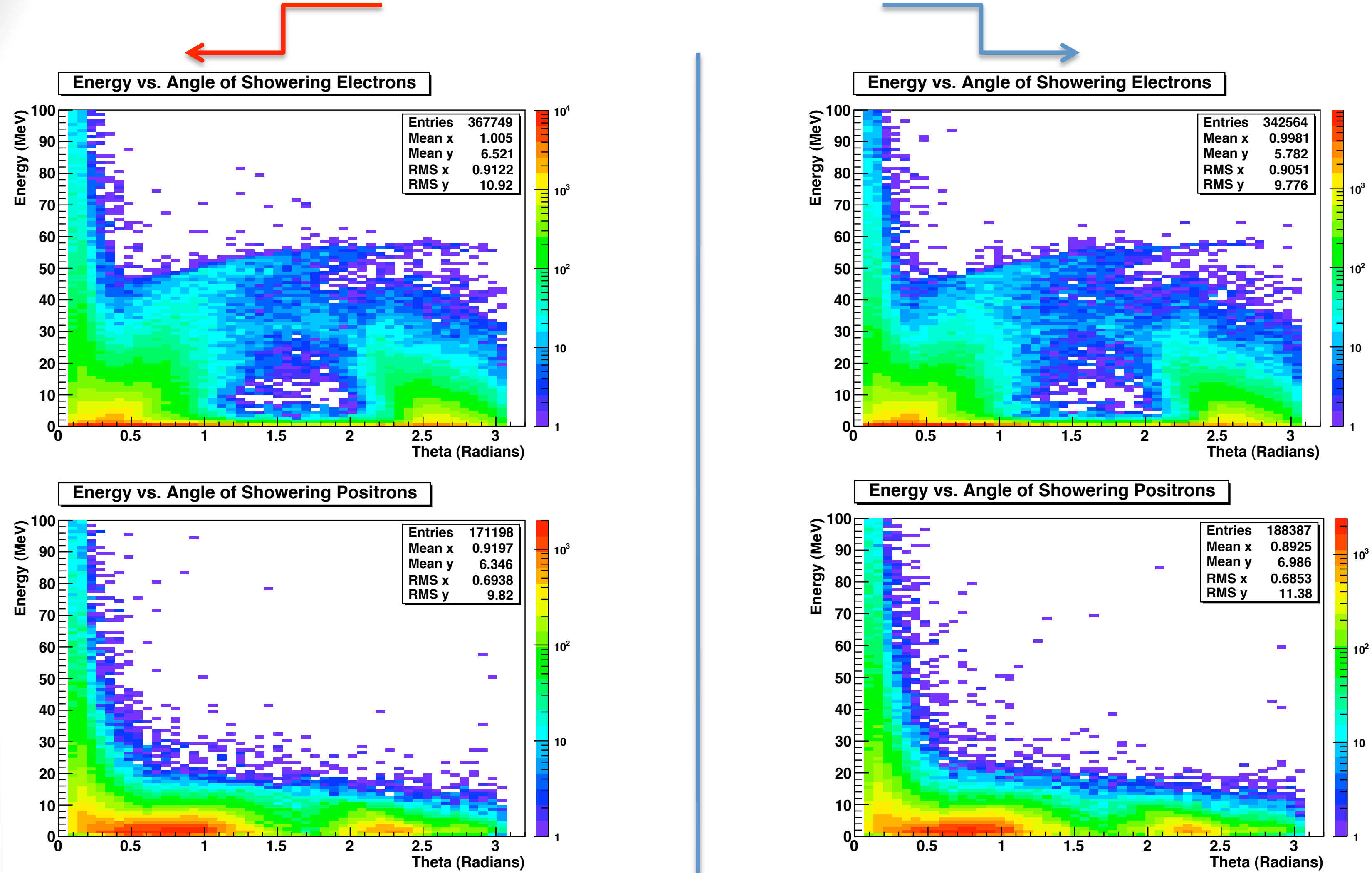


Field Down - Electrons



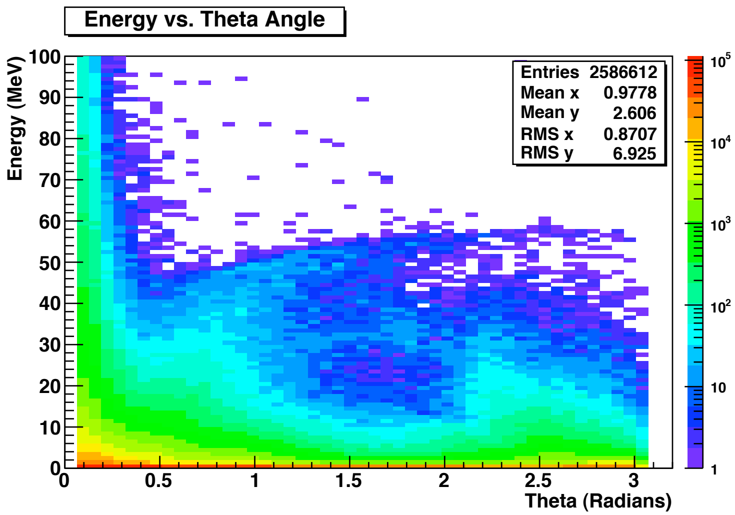
Field Down - Positrons

Electron Beam vs. Positron Beam

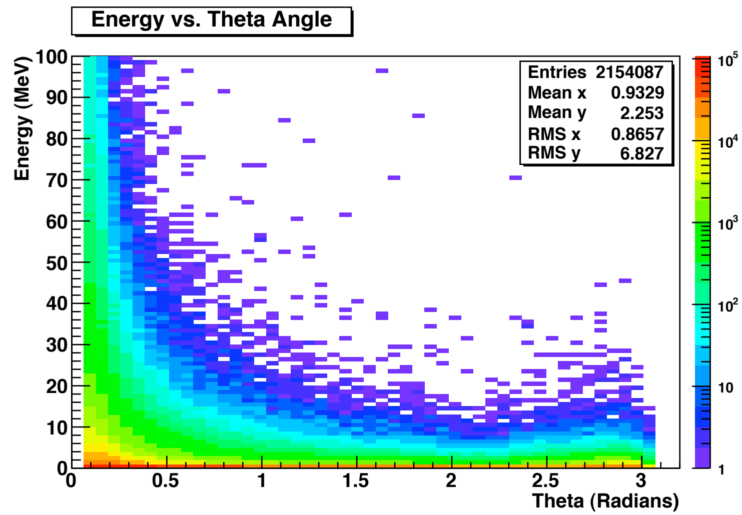


Electrons radiation still dominates positron radiation!

The effect of the magnetic field



Field Up (Electrons)



No Field (Electrons)

- This higher radiation rate with the field on is caused by particles cycling and crossing the sphere many times.
- These "medium energy" particles may cycle for a while and then end up in a detector but can do so only once.
- I need to find a good way to handle these cases.

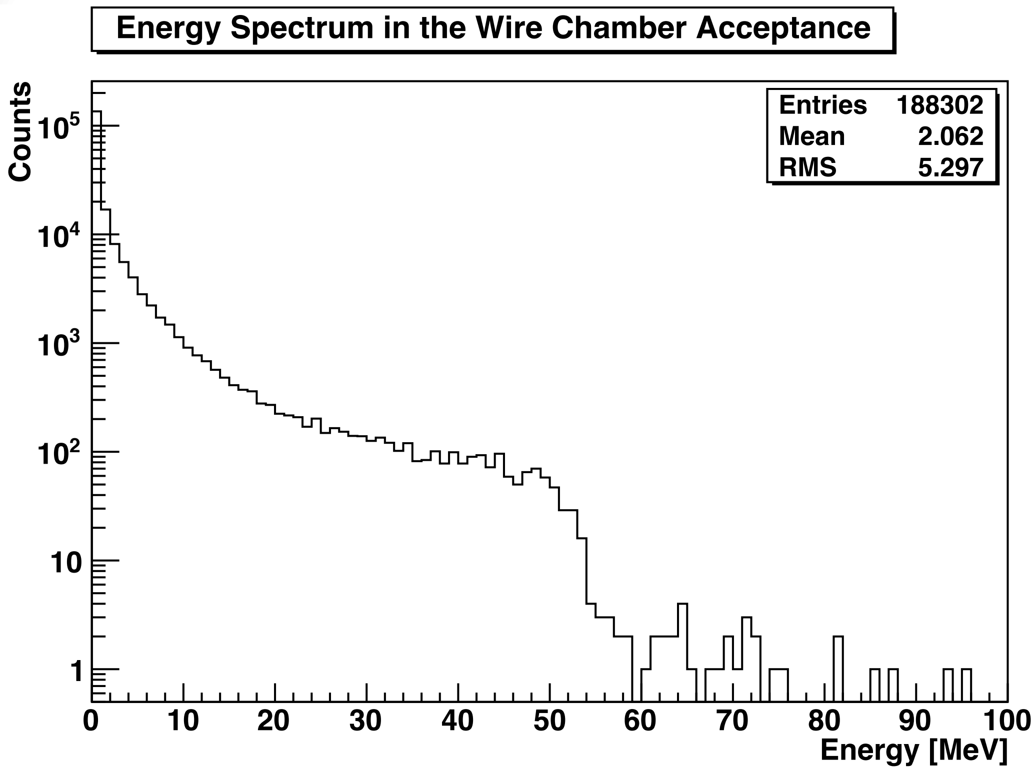
Making a Rate Estimate

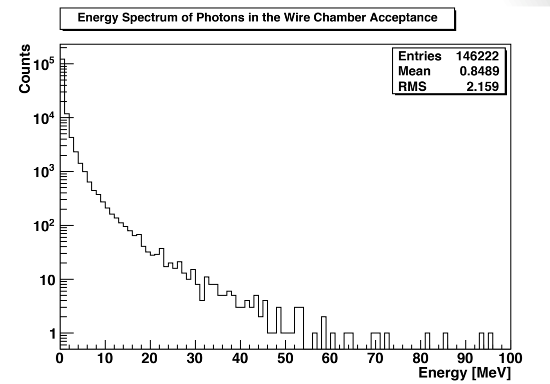
- Assuming ≈110 kHz rate of halo particles hitting the collimator:
- Measure the rate of particles passing through angular acceptances of the different detectors
  - Wire Chambers:
    - 20˚ - 80˚ in theta, ± 15˚ in phi
  - Luminosity Monitors
    - 10.3˚ - 13.2˚ in theta (10 cm at 12˚), ± 1.5˚ in phi

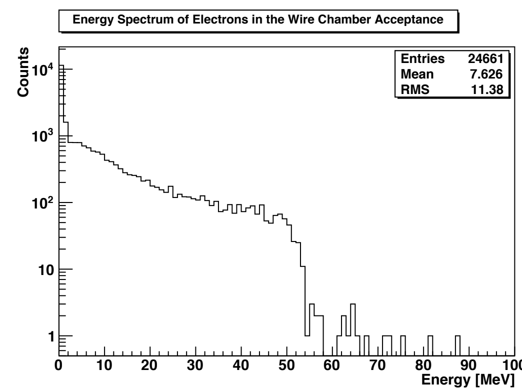
Field / Beam Configuration	↑ / e-	↓ / e-	↑ / e+	↓ / e+	No Field e-	No Field e+
Wire Chambers	188 kHz	209 kHz	189 kHz	207 kHz	154 kHz	157 kHz
Lumi Monitors	2.59 kHz	2.63 kHz	2.61 kHz	2.64 kHz	2.44 kHz	2.48 kHz

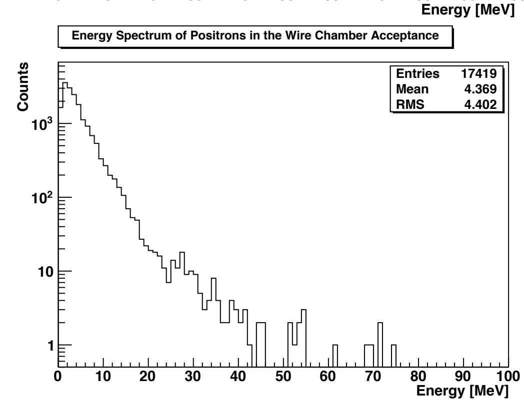
Energy Spectra in Wire Chambers

(Field Up / electrons)









188 kHz total:

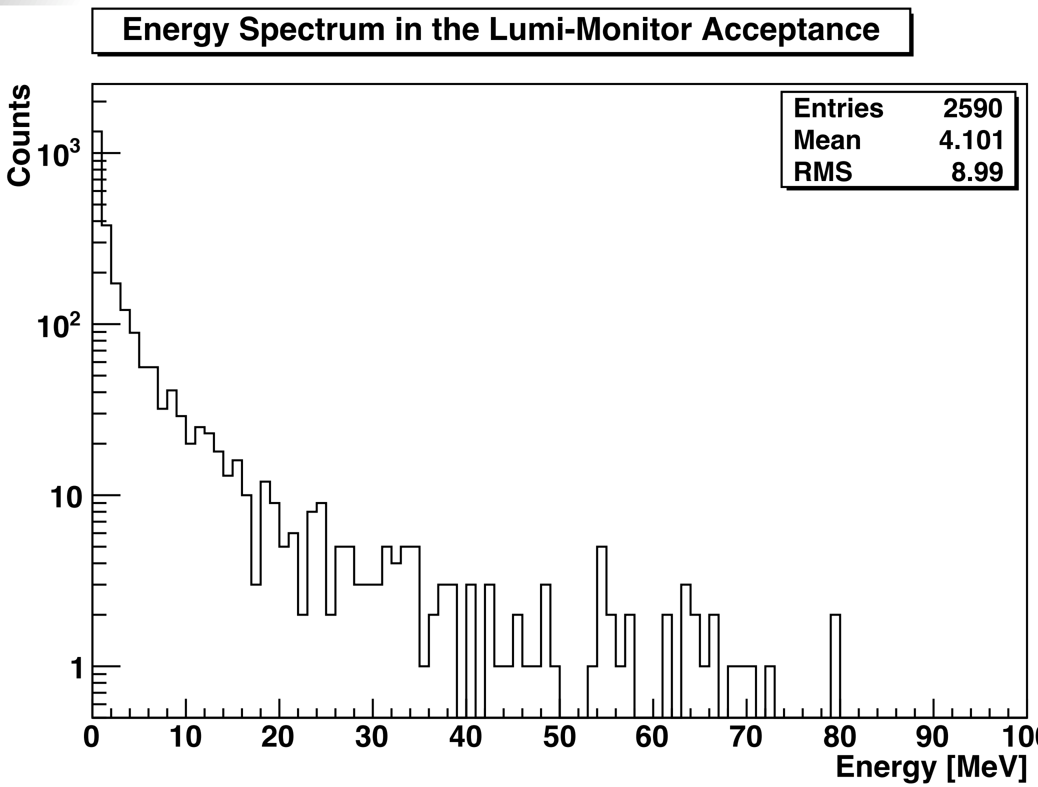
- 146 kHz photons
- 25 kHz electrons
- 17 kHz positrons

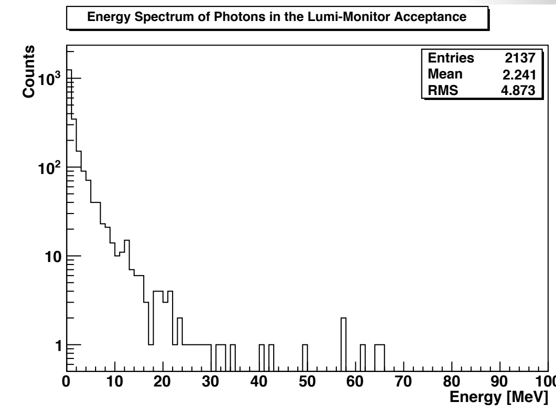
Mostly low energy

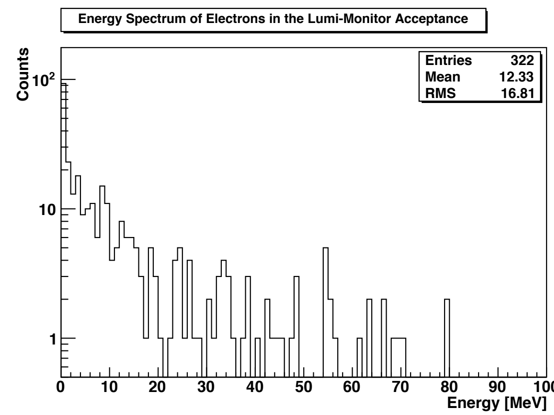
< 50 MeV

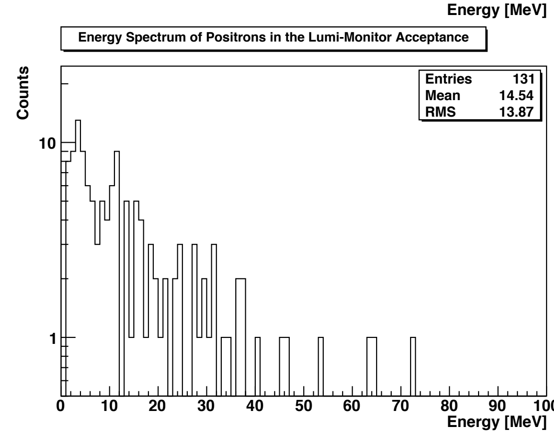
Energy Spectra in the Lumi-Monitors

(Field Up / electrons)









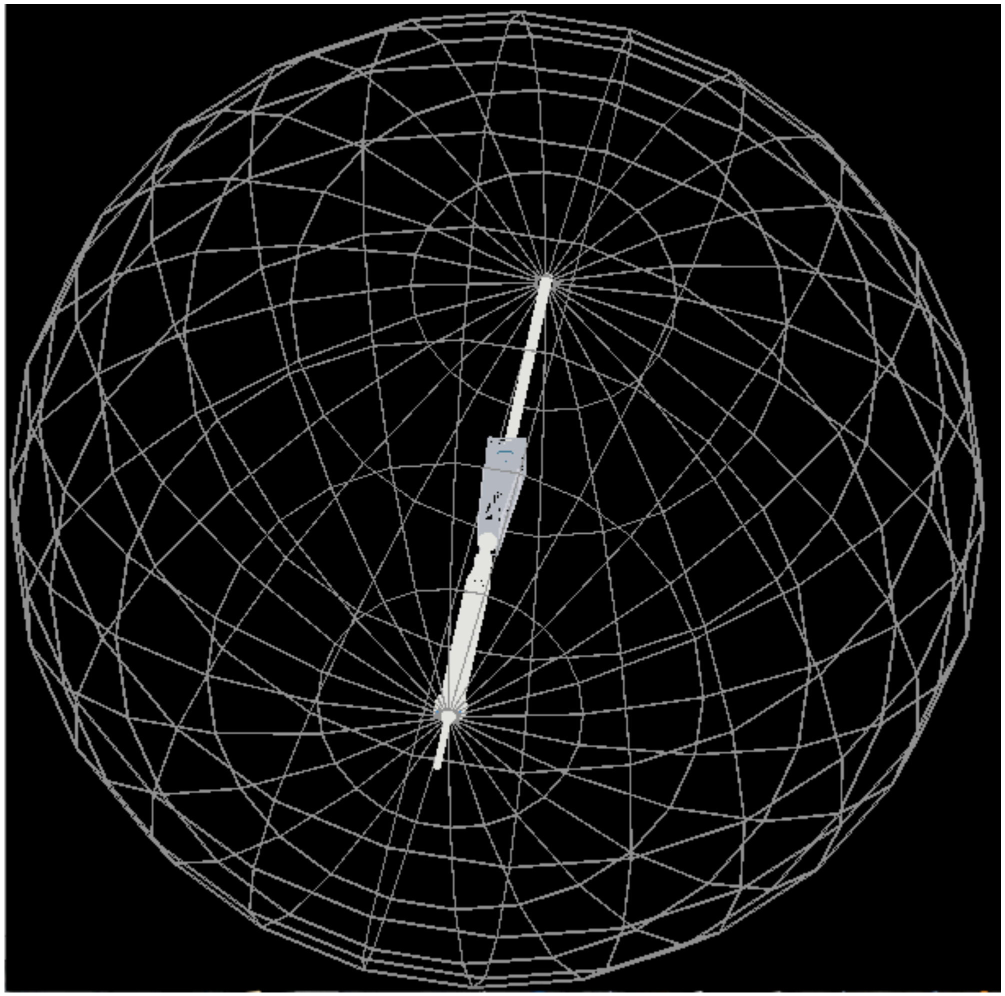
2.59 kHz total:

- 2.13 kHz photons
- 0.32 kHz electrons
- 0.13 kHz positrons

Also low energy
< 20 MeV

Radiation Flux at the Möllers

- To make this estimate: we need a bigger sphere (3.2 m)



Radiation Flux at the Möllers

- Define an angular region: 1.3˚ ± 1 mrad

  = 3.38 E-5 srad

  1 sec of beam yields ≈ 70000 counts

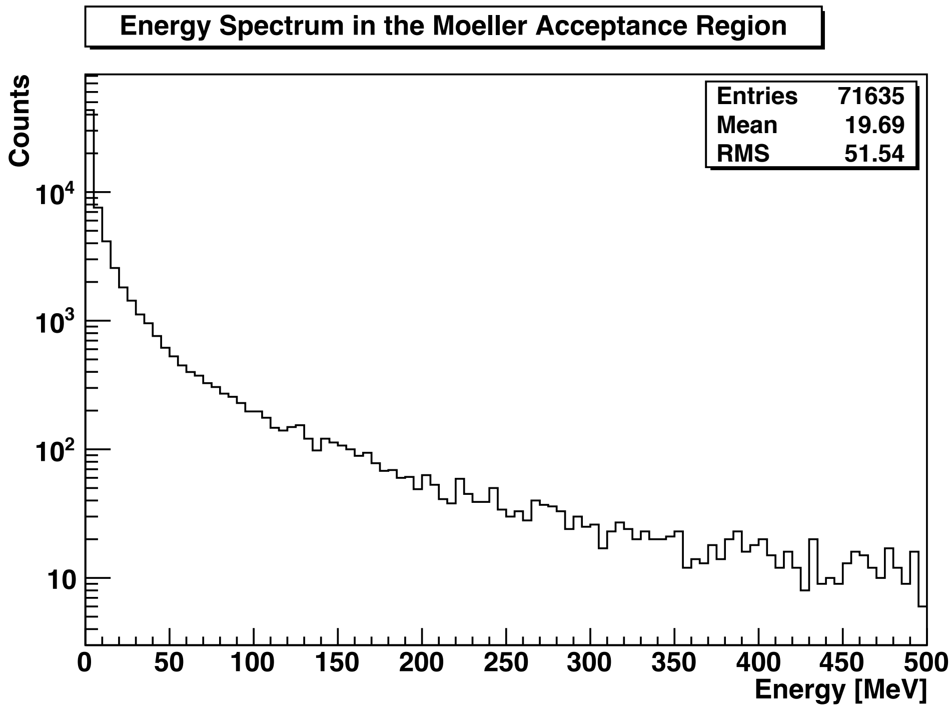
  < 70 kHz in Möllers

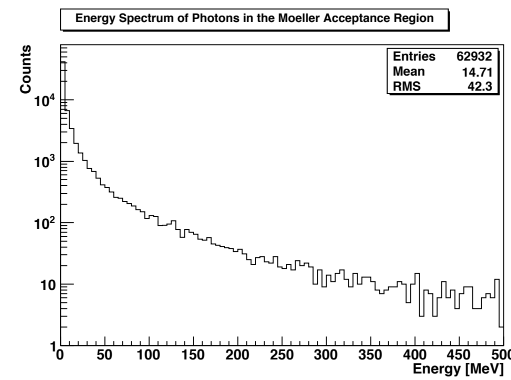
Radiation Flux at 1.3˚ (GHz/srad)

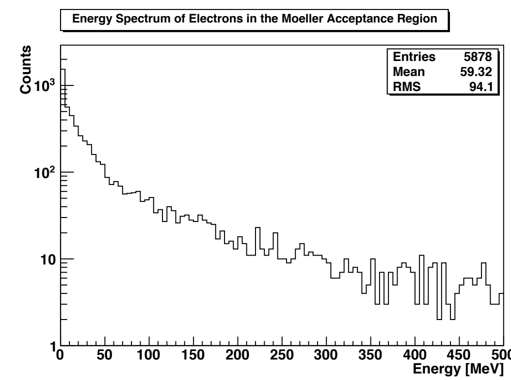
Beam Particle	**Field Up**	**Field Down**	**No Field**
electrons	2.12	2.09	2.09
positrons	2.10	2.07	2.09

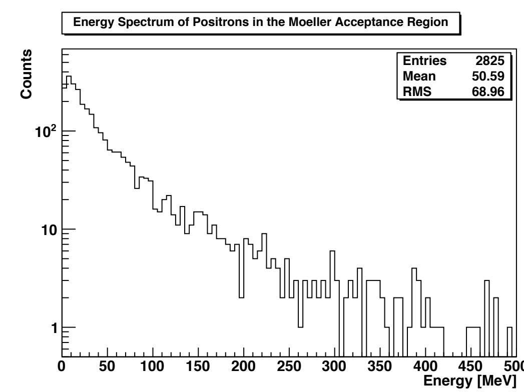
Energy Spectrum at 1.3°

(electrons / field up)





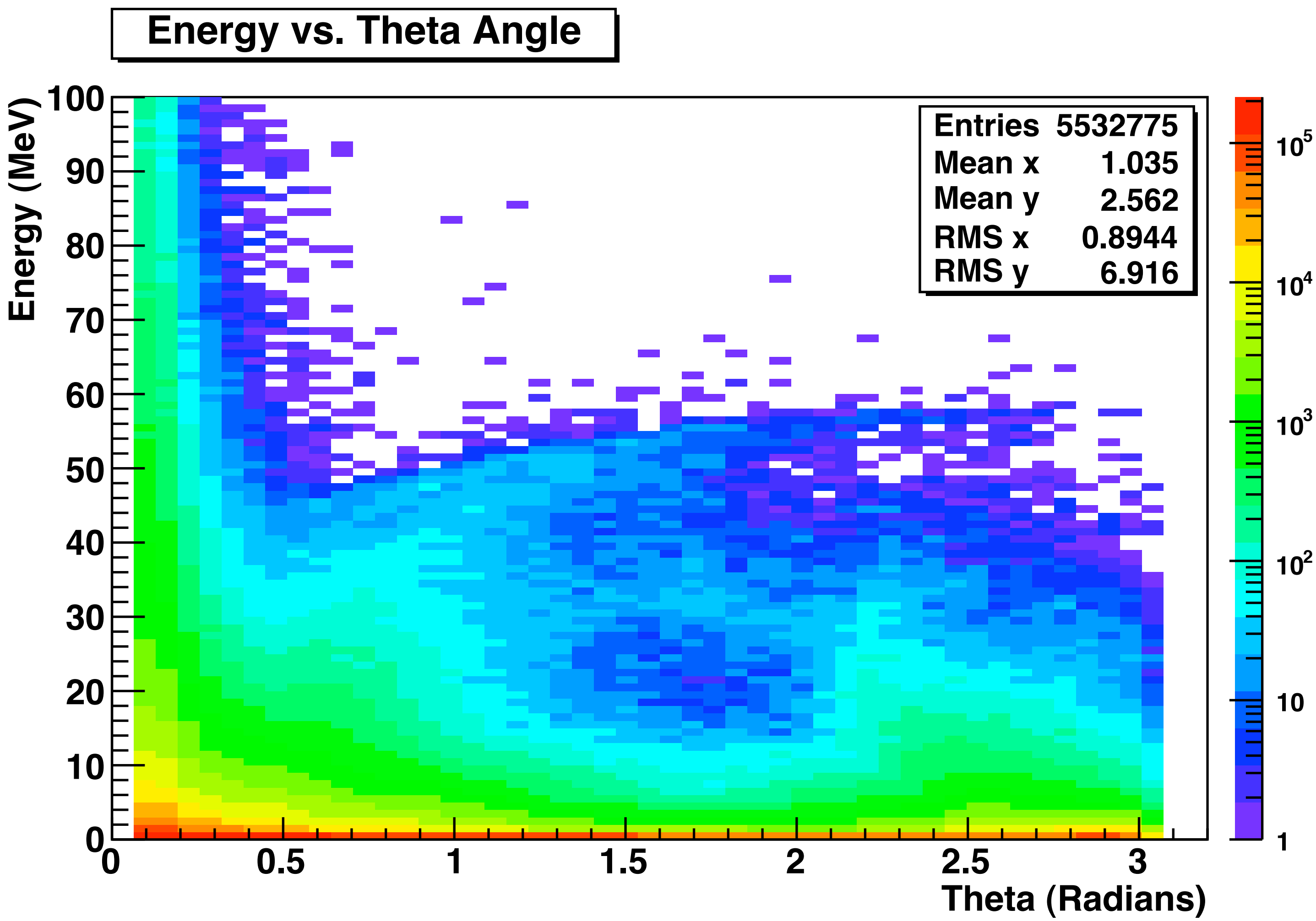




Photons are still the dominant contribution.
There is some high-energy radiation here!

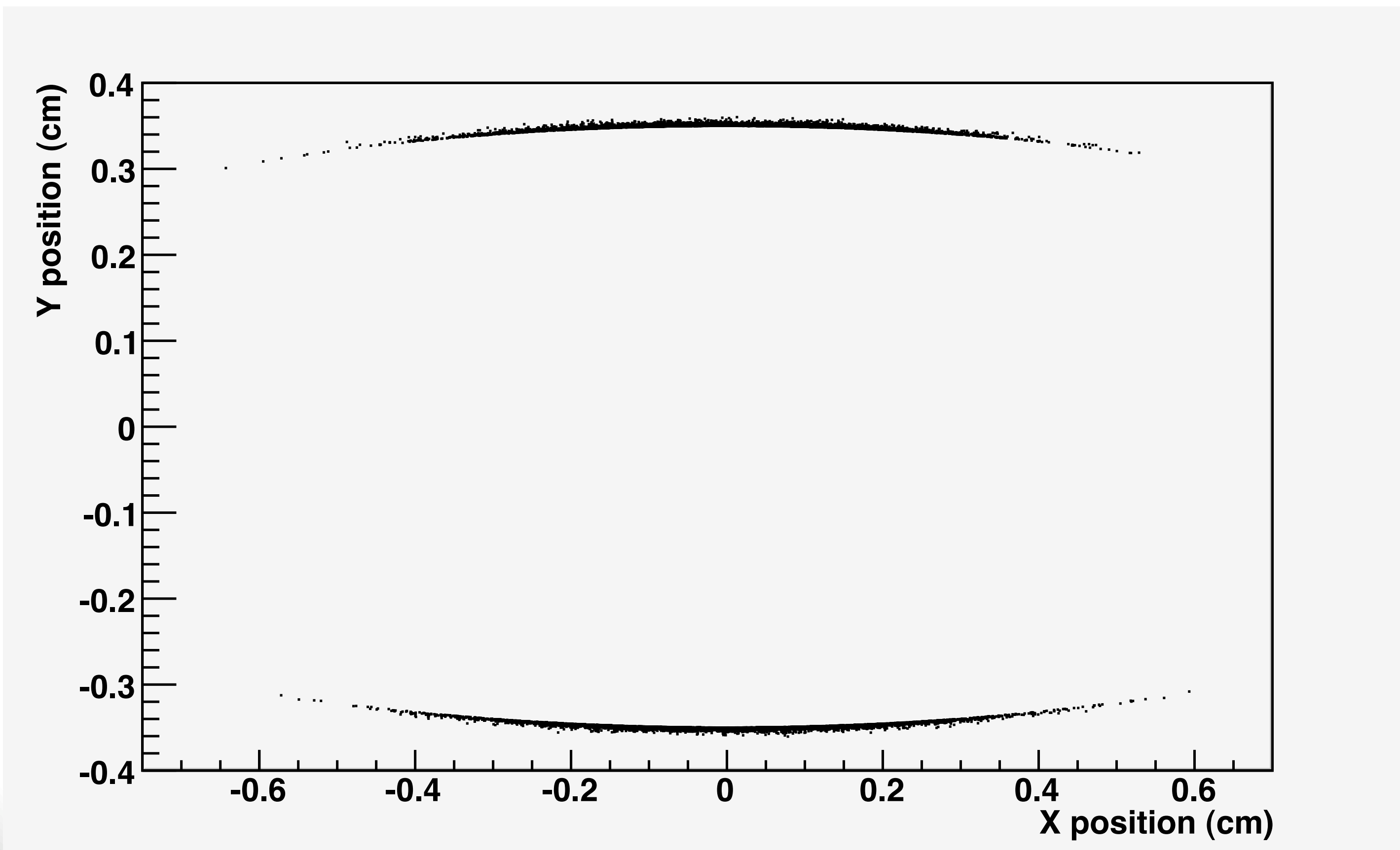
A quick look at 4.5 GeV

Similar spectrum, but the rate is about twice as high.
Higher energy radiation at low angles



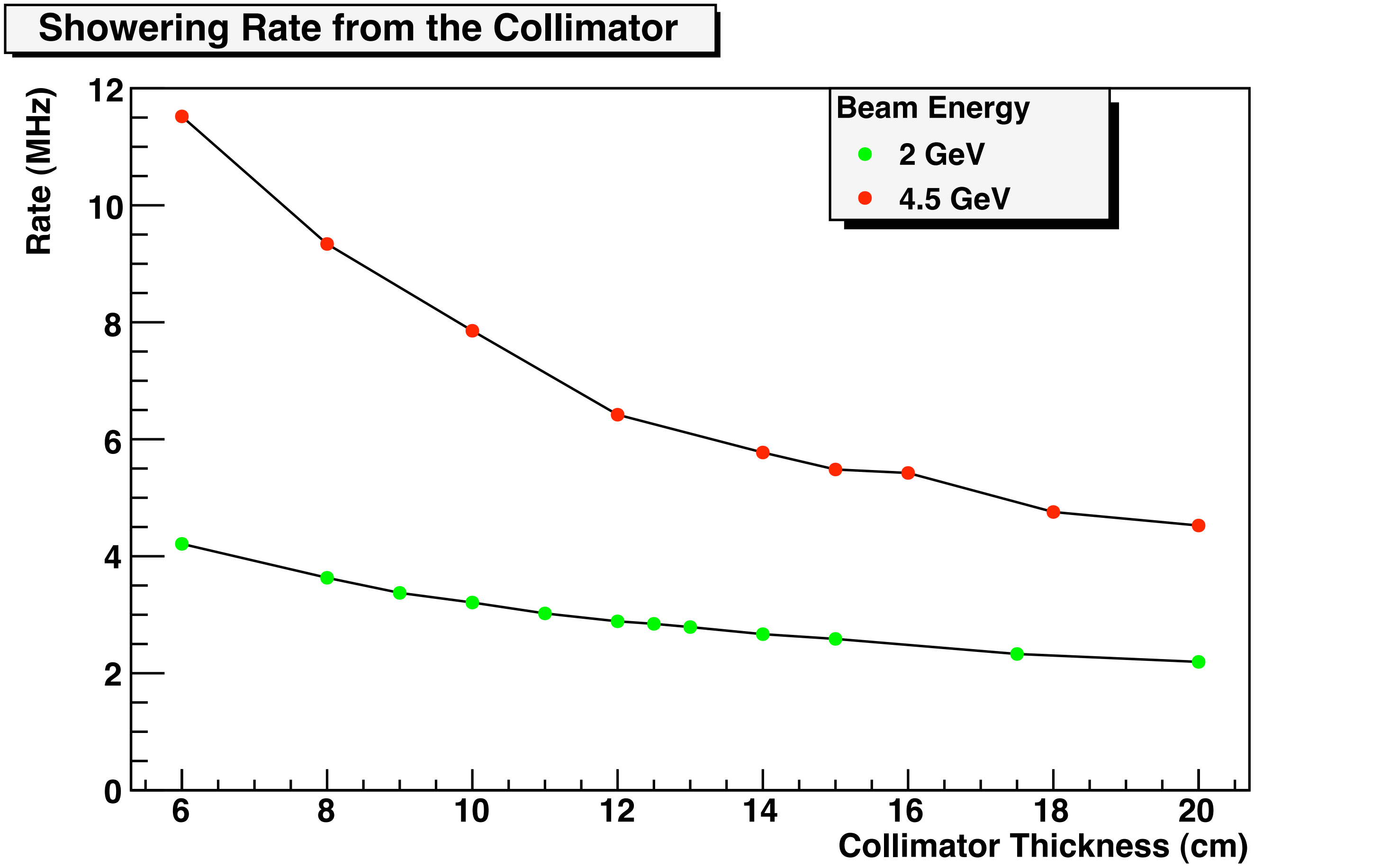
Collimator Studies

- Halo particles hit the vertical edges of the collimator aperture.



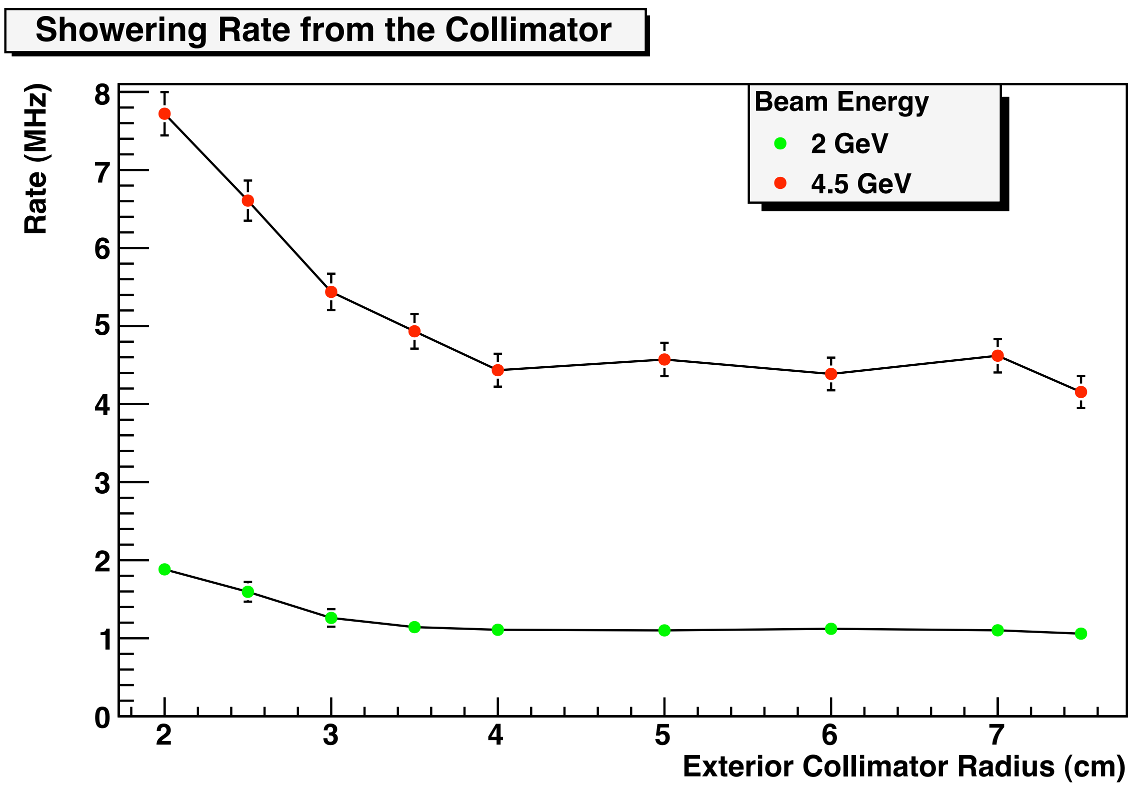
Collimator Thickness

- How thick does the collimator need to be?
  - Vary the thickness and look at the radiation response.



Collimator Radius Studies

- Angular spread in electron trajectories needed
- I've added some spread, but not in a realistic way
- Very large spread to get a conservative estimate



Things that need to be improved

the short-list

- I need to implement an accurate description of the beam halo size, energy, angular distributions
- Effectively account for particles spiraling through the sphere many times.
- More studies at 4.5 GeV
- Synchrotron radiation propagating through the collimator