The simulation of DarkLight experiment at ARIEL (TRIUMF)*

Chenxi Ma[1]

supervised by Jan C. Bernauer[1,3], Katherine Pachal[2], and Ethan Cline[1]

[1]Stony Brook University

[2]TRIUMF

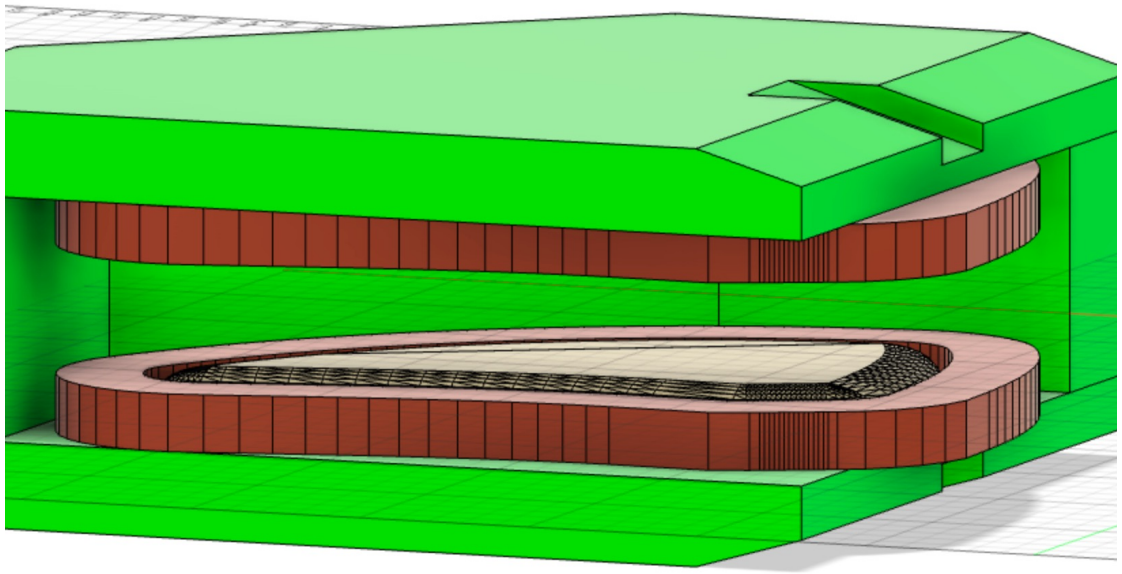
[3]RIKEN BNL Research Center

*This experiment has been supported by DOE, NSF, NSERC.

Introduction

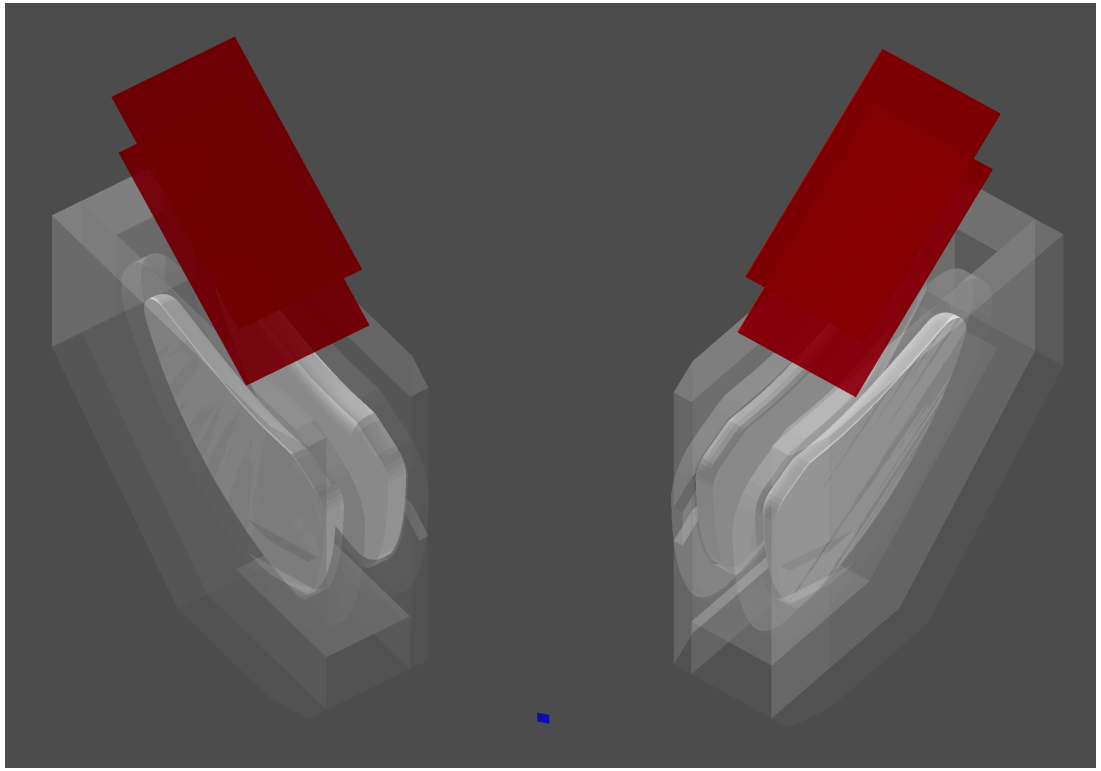
The DarkLight experiment aims to search for a new boson in the dark sector via electron scattering from a heavy target for evidence of new physics. Of particular interest is the mass range between 10 to 20 MeV. The experiment has been proposed to use the 30-50 MeV beam of the ARIEL facility at TRIUMF on a Tantalum target along with two magnetic spectrometers to detect the e+e- pair.

Magnets, Target, and Focal Plane Detectors in GEANT4



- CAD model of the magnet
  - Contains geometry information
  - Consists of coils, polepieces and yokes
  - Can be converted to STL file and then imported to GEANT4

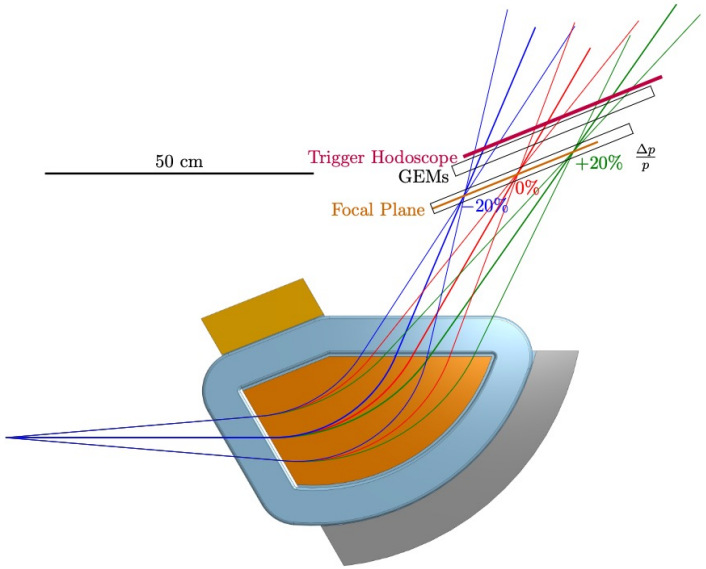
Magnets, Target, and Focal Plane Detectors in GEANT4

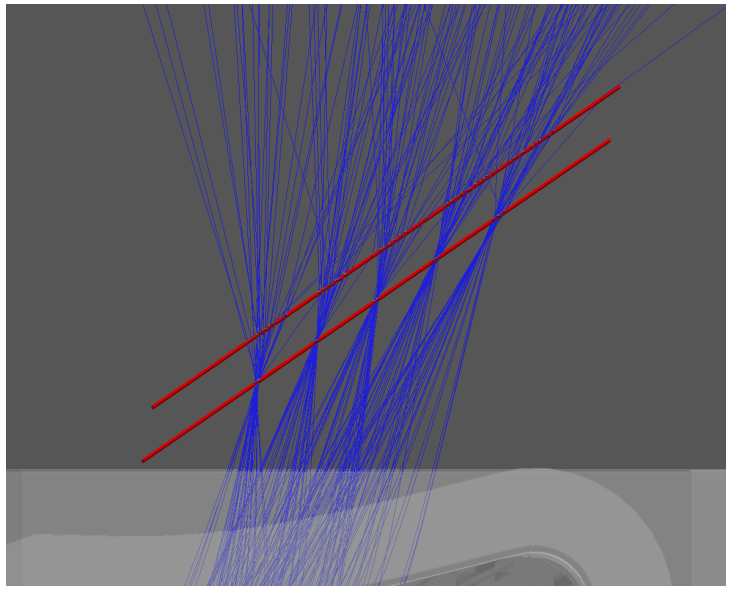


- Visualization of the model
  - Magnets were imported to GEANT4 as G4TessellatedSolid objects
  - Materials were set
  - Thin foil target and focal planes were added

Simulation of Magnetic Field

- A magnetic field map was calculated via ANSYS Maxwell
- It then was applied to GEANT4 simulation by doing trilinear interpolation
- Field overlapping between two magnets was calculated





Sensitive Detectors

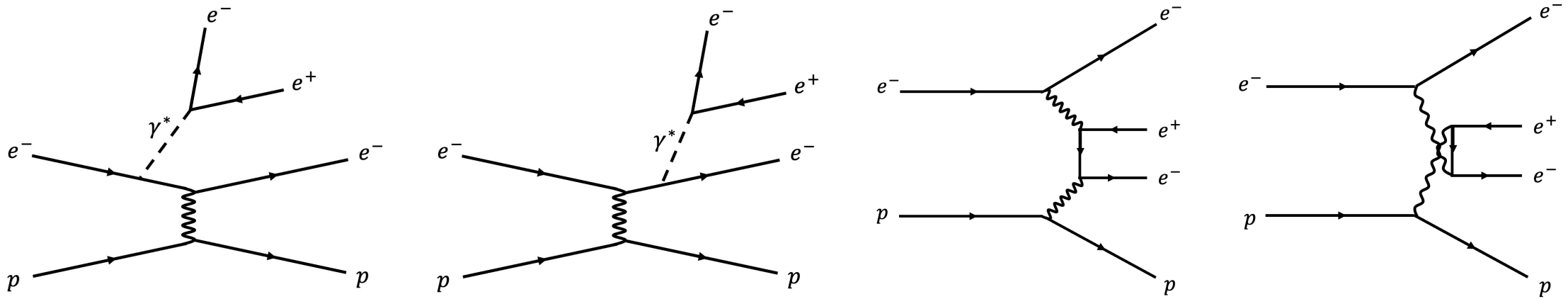
- We've made the focal planes sensitive to store hits information
- Hits data: x, y, dx, dy, p, Θ, Φ
- We use transfer functions

$$\mathrm{f_i} = \sum_{\mathrm{a,b,c,d}} \alpha_{\mathrm{a,b,c,d}} \mathrm{x^a} \cdot \mathrm{y^b} \cdot \mathrm{dx^c} \cdot \mathrm{dy^d}$$

  to reconstruct p, Θ, Φ
- Then reconstruct $\mathrm{m_{\gamma'}}$
  - $\mathrm{p_{\gamma'}} = \mathrm{p_{e^-}} + \mathrm{p_{e^+}}$
  - $\mathrm{m_{\gamma'}^2} = \mathrm{p_{\gamma'}^2}$

Signal and Irreducible Background

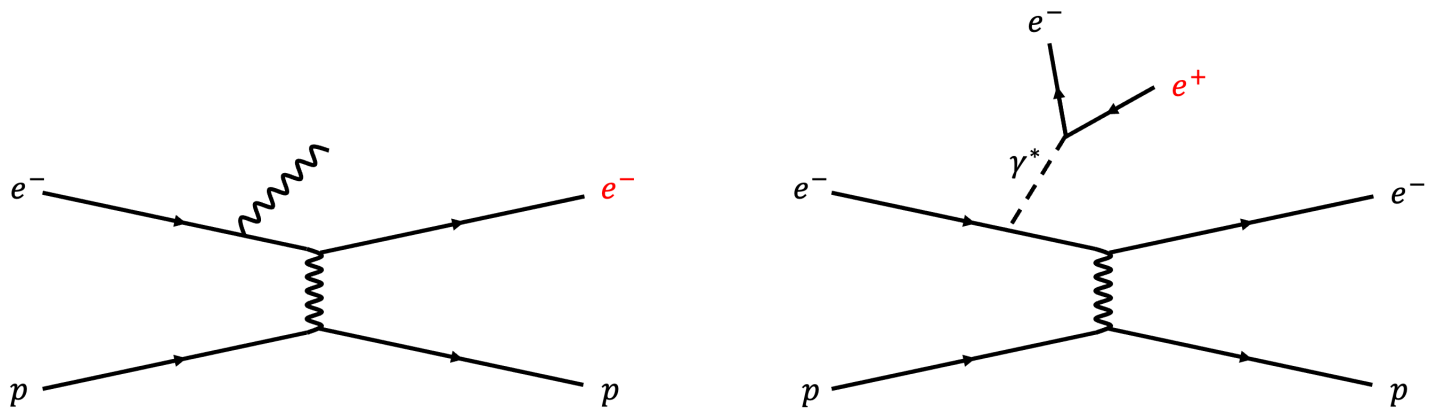
- MainzGen (arXiv:1303.2540, T. Beranek et al.)
  - Can generate signal events
  - Can give $\mathbf{B_{irred}}$
  - We can obtain signal by applying scaling factor $\frac{\Delta\sigma_{\gamma'}}{\Delta\sigma_{\gamma^*}} = \frac{3\pi}{2N}\frac{\epsilon^2}{\alpha}\frac{m_{\gamma'}}{\delta m}$



diagrams of irreducible background

Random Coincidences Background

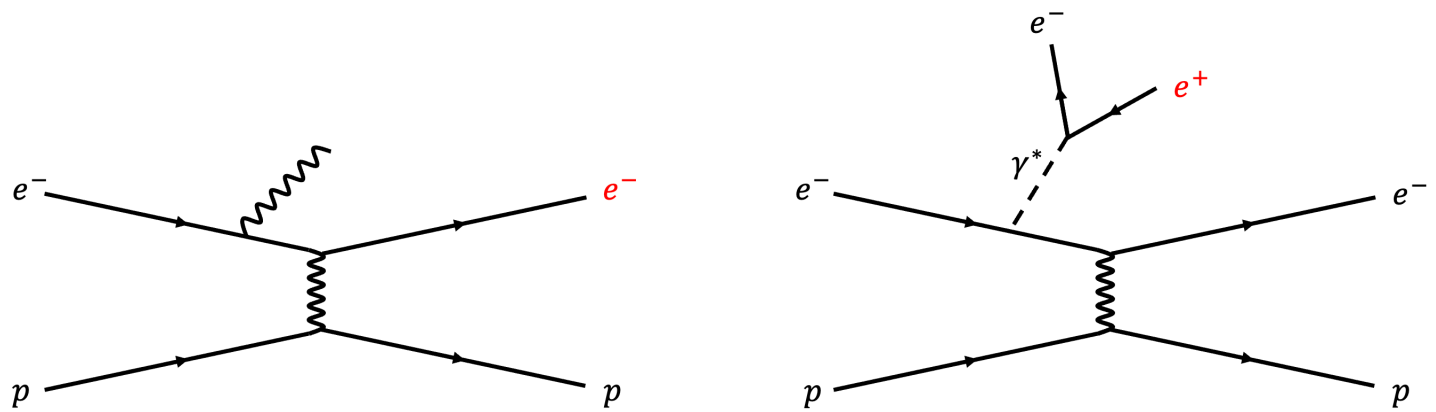
- MainzGen (arXiv:1303.2540, T. Beranek et al.)
  - Can give half of random coincidences background
- RadGen from OLYMPUS (https://link.aps.org/doi/10.1103/PhysRevLett.118.092501, B.S. Henderson et al.)
  - Can do the other half of random coincidences background



random coincidences background

Random Coincidences Background

- Mix the data from RadGen and MainzGen to obtain random coincidences background



random coincidences background

Resolution of p, Θ, Φ without multiple scattering(msc) on focal planes

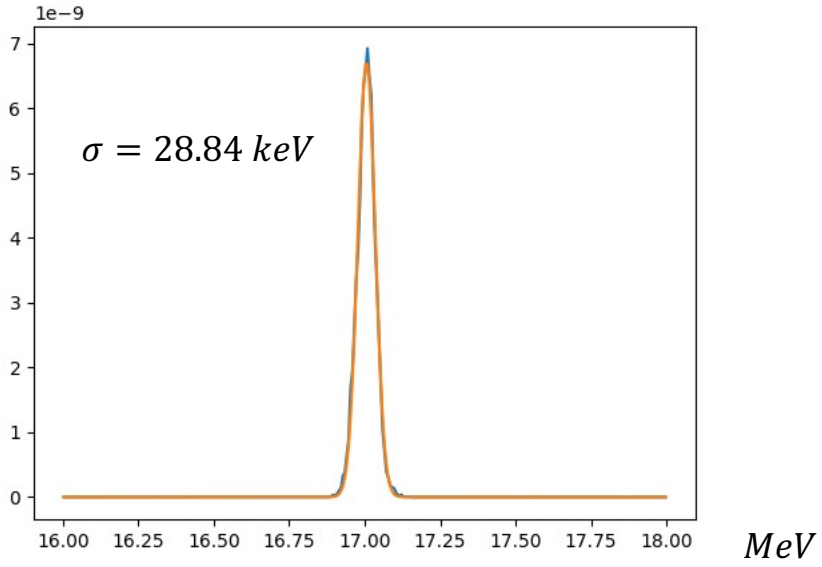
	e^- spectrometer	e^+ spectrometer
p	$26\ \mathrm{keV}$	$36\ \mathrm{keV}$
Θ	$0.033\ \mathrm{deg}$	$0.032\ \mathrm{deg}$
Φ	$0.014\ \mathrm{deg}$	$0.014\ \mathrm{deg}$

Resolution of p, Θ, Φ with msc

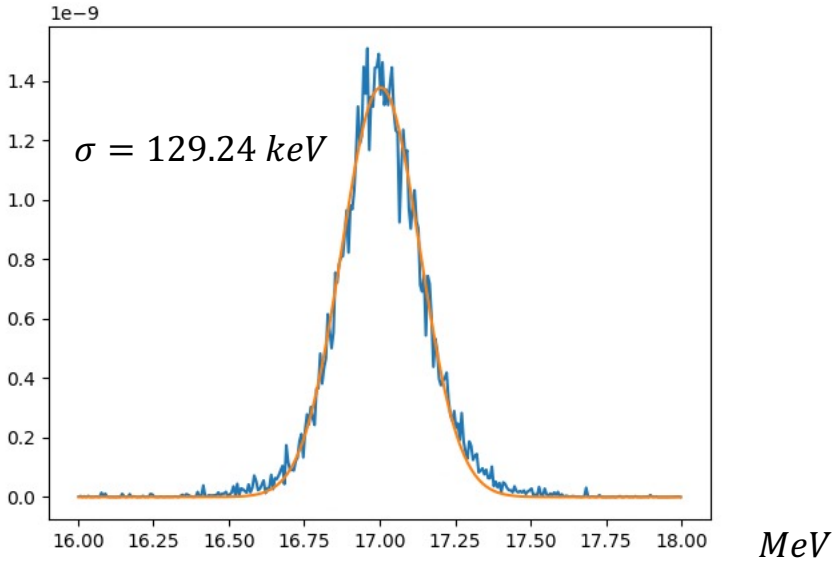
	e^- spectrometer	e^+ spectrometer
p	76 keV	39 keV
Θ	0.486 deg	0.261 deg
Φ	2.472 deg	1.896 deg

Resolution of $\mathbf{m_{\gamma'}}$

- We use reconstructed momenta to reconstruct $\mathbf{m_{\gamma'}}$



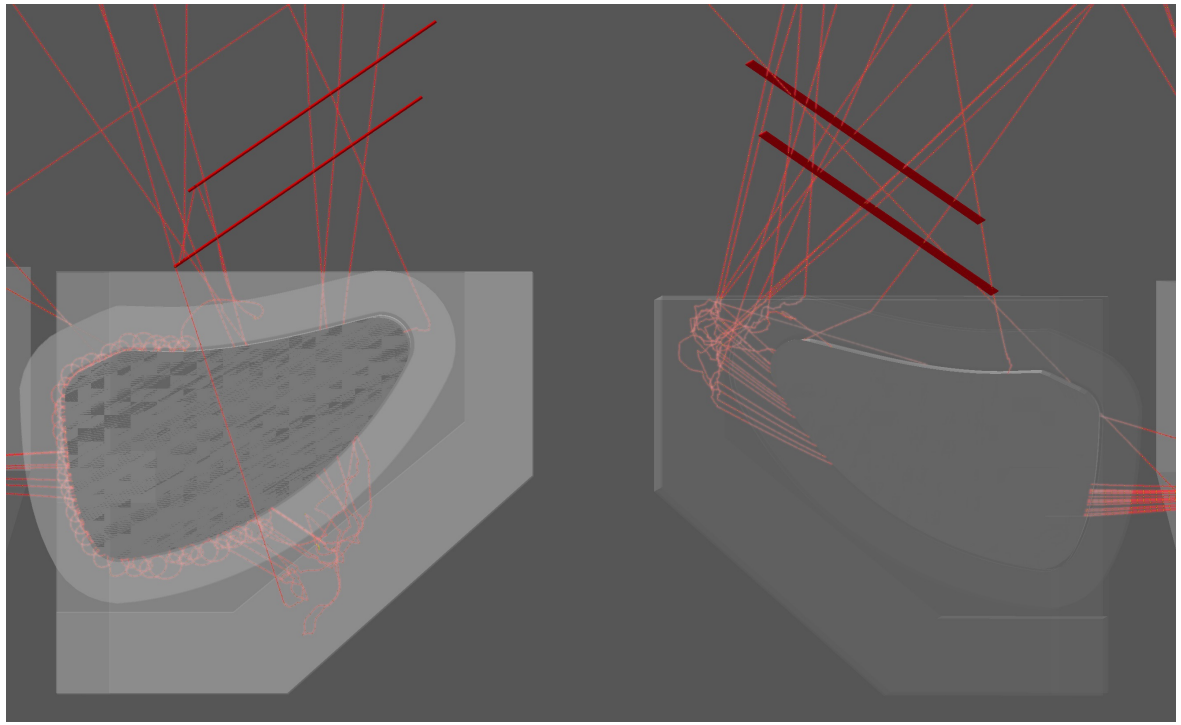
mass resolution without msc



mass resolution with msc

Electron Beam Background Analysis

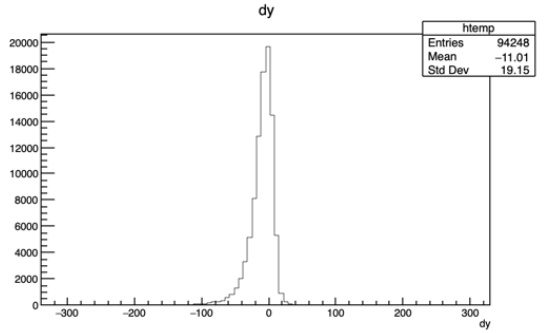
- Electron beam has a chance to hit magnets and then trigger focal plane detectors
- We've analyzed the case of $\mathbf{30\ MeV}$ beam of electrons hitting both magnets



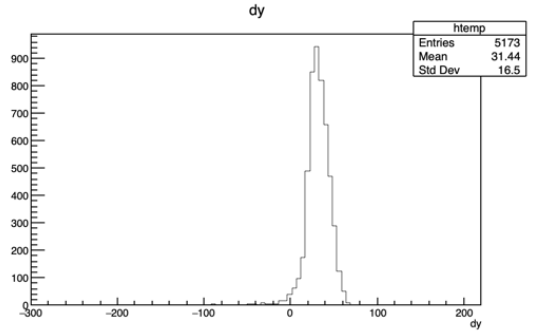
e^+ spect e^- spect

Electron Beam Background Analysis

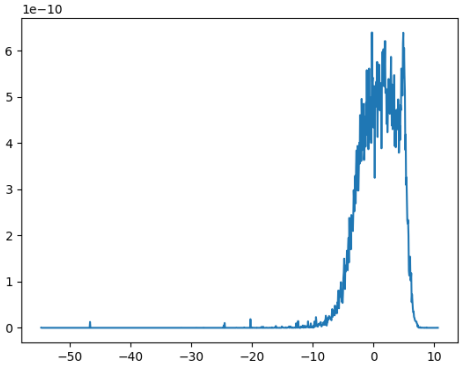
- Hits data shows distinct result from those of regular tracks
- We can make cuts based on this



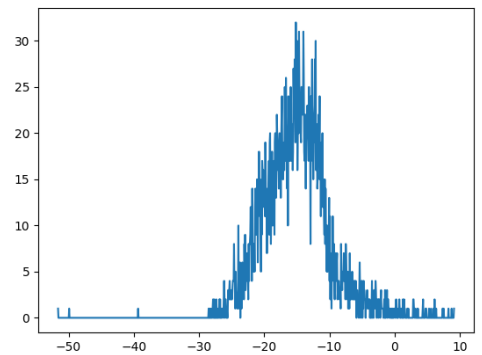
distribution of dy from regular tracks



distribution of dy from beam background



out-of-plane angle from regular tracks



out-of-plane angle from beam background

Projected Reach

- $\frac{S}{\sqrt{B}} = \frac{p_{sig}\mathcal{L}}{\sqrt{p_{irred}\mathcal{L}+p_{rand}\mathcal{L}^2}}$
- Choose ϵ^2 so that $\frac{S}{\sqrt{B}} > 2$