Tracking for taggers

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Far-backward meeting

Introduction

- Mechanism for cluster finding and track fit for tagger detectors will be shown here
- Series of steps connect detector signals to the original scattered electrons:
  1. Hits as fired pixels in tracking planes
  2. Clusters are formed out of hits in the planes
  3. Detector tracks are found from the clusters
  4. Scattered electrons are reconstructed from detector tracks
- Item (4), and briefly (1) was discussed last time: indico.bnl.gov/event/15498/
- Tracks for electron reconstruction were obtained with help of truth MC as points in counting planes belonging to the electron
- Realistic implementation for tracking and clustering will be shown here for items (2) and (3)
- Simulation of 5M events of quasi-real photoproduction was used to obtain the results

Geometry layout to test the tracking

- 4 planes for each tagger ordered in increasing z, convenient for the used fit procedure

- The planes are perpendicular to the beam as an approximation to detector at an angle
- Plane spacing along z is 30 cm
- Each plane is made of Si, 50 µm thick
- Segmentation is done to pixels of 200×200 µm^2
- Output is deposited energy in each pixel (hit)
- The hit is primary if primary electron makes a step in the pixel

Figure: Tagger 1

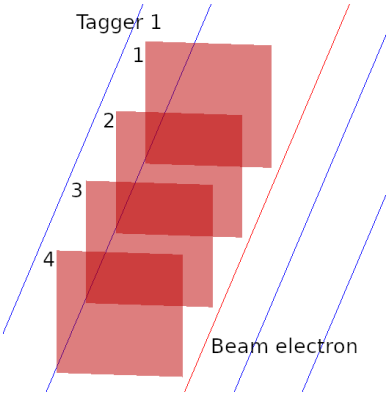
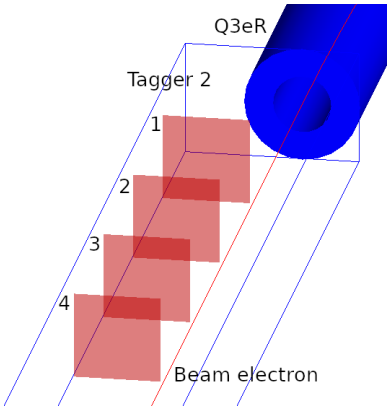


Figure: Tagger 2

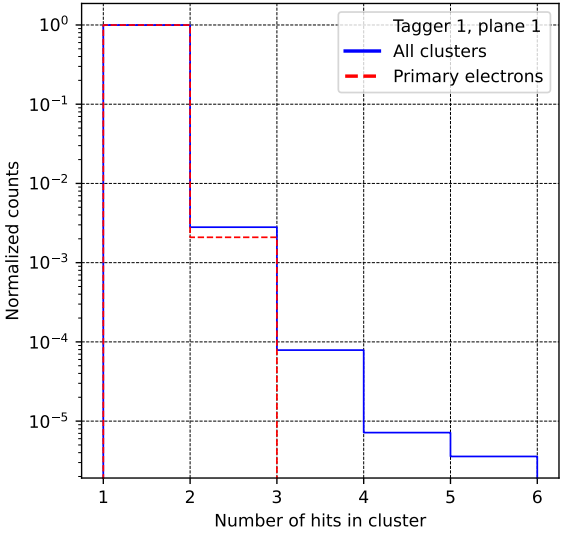


Cluster finder

- Energy deposition caused by a single electron is shared by neighboring pixels in general
- Adjacent pixels (hits) with energy deposition are grouped to form clusters in a series of steps:
  1. Threshold of 0.4 keV is applied to each hit
  2. Seed for cluster is found as a hit with the highest energy deposition
  3. All hits neighboring the seed are found
  4. Cluster is formed by the seed hit and its neighboring hits
  5. All hits in the cluster are removed from the finder
  6. Next seed is found from the remaining hits and the process repeats
- The steps to find clusters are performed for each detector plane separately
- Position of the cluster is obtained as energy-weighted average in x and y along the detector plane
- Energy of the cluster is a sum of energies in hits in the cluster

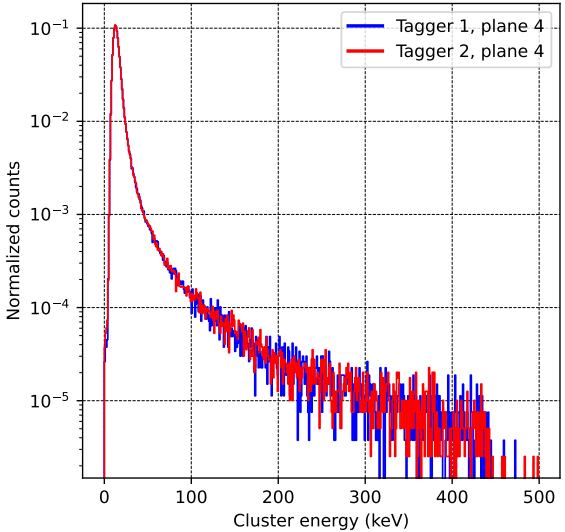
Number of hits in clusters

- Example on number of hits forming a cluster is shown for plane 1 in tagger 1, works similar for the rest
- The cluster is associated with primary electron if all its hits correspond to primary electron
- Background (non-primary) hits and clusters are caused by scattering in magnets material
- Clusters by primary electrons are more localized, 1 or 2 hits only



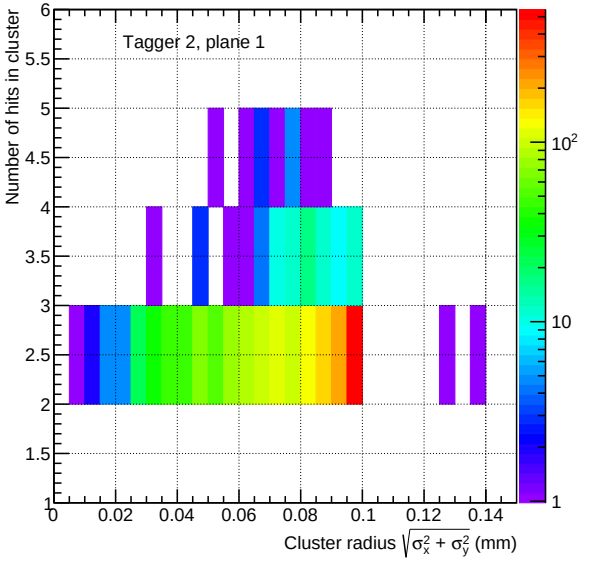
Cluster energy

- Energy of cluster is a sum of energies in hits in the cluster
- Shown for plane 4 in both taggers, works similar for the rest



Cluster size

- Cluster size is taken as uncertainty in energy-weighted average used in cluster position
- The radius combines uncertainty in x and y as $\sqrt{\sigma_x^2 + \sigma_y^2}$
- Shown in relation to number of hits in cluster for plane 1 in tagger 2, works similar for the rest



Detector frame for track fit

- Points for the track are given by clusters in each detector plane
- Detector planes 1 – 4 are spaced by distance L, pixel size in each is d
- The planes are aligned and centered along z (drawing on the right)
- Track is given by slope angle θ_x, θ_y and intercept position x_0, y_0:

$$x = x_0 + z \times \tan\theta_x$$
$$y = y_0 + z \times \tan\theta_y$$

- In the detector frame it is possible to obtain analytic formula for the slope and intercept

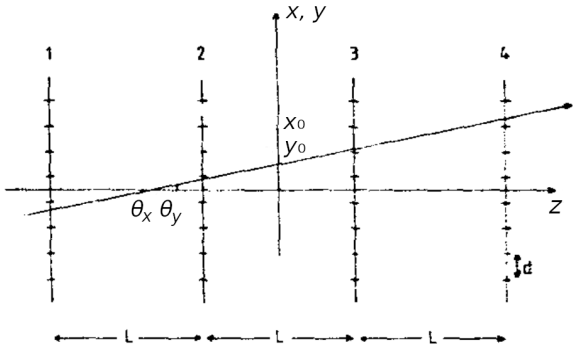


Figure: Detector frame centered in the middle of the planes

Track fit by a straight line

- Points measured by planes are x_1, x_2, x_3 and x_4 in x and similar y_{1-4} in y
- In Nucl.Instrum.Meth. 203 (1982) 291-297 it is shown for track slope and intercept:

$$x_0 = \frac{1}{4}(x_1 + x_2 + x_3 + x_4)$$

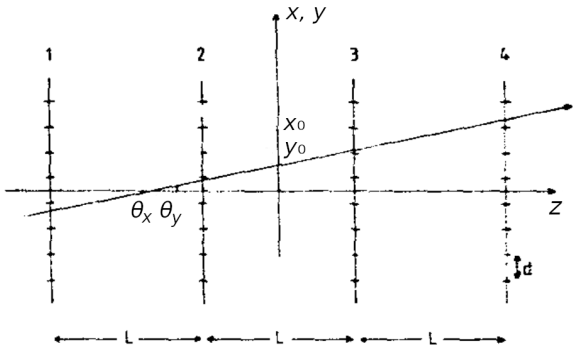
$$\tan\theta_x = \frac{1}{10L}(-3x_1 - x_2 + x_3 + 3x_4)$$

- Similar formula hold for y_0 and $\tan\theta_y$ out of y_{1-4}
- The fit has 2 degrees of freedom in x and y (4 points for 2 track parameters)
- It would work for 3 planes but the middle plane would not contribute to the slope

- Track as a straight line:

$$x = x_0 + z \times \tan\theta_x$$

$$y = y_0 + z \times \tan\theta_y$$



Tracks χ^2

- Set of points x_{1-4}, y_{1-4} has to satisfy $\chi^2_{x,y}/\text{ndf} < 4$ to form the track
- Example is shown for tagger 1, works same for tagger 2
- The track is primary if all its clusters are primary
- All primary tracks have $\chi^2_{x,y}/\text{ndf} < 1$

Figure: All tracks

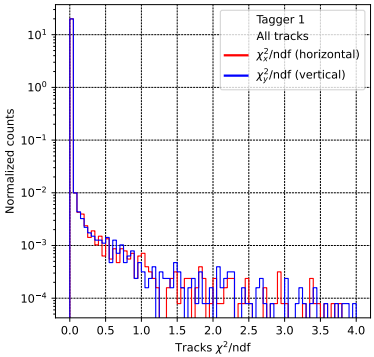
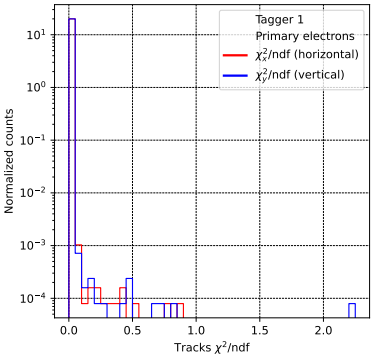


Figure: Primary electrons



Number of tracks per event

- In almost all cases the simulated electron is identified as a single primary track

Figure: Tagger 1

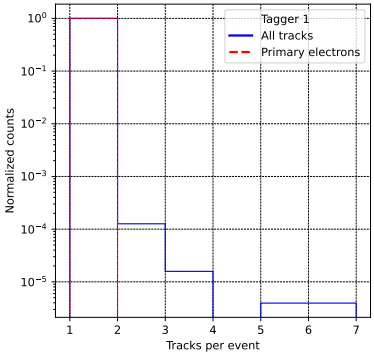
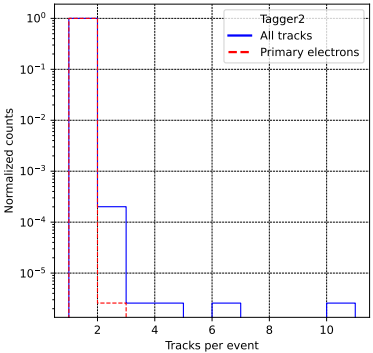


Figure: Tagger 2



Track position

- Track intercept x_0, y_0 in detector frame is shown for both taggers

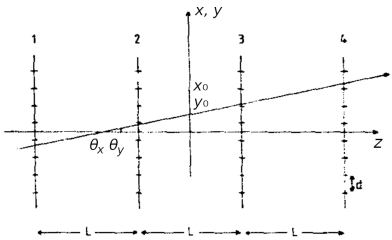


Figure: Tagger 1

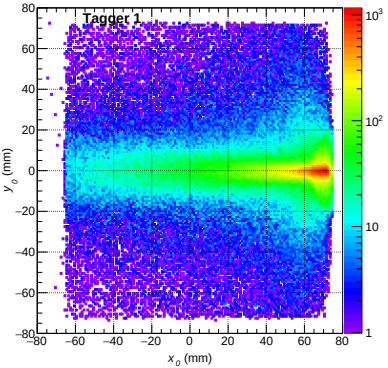
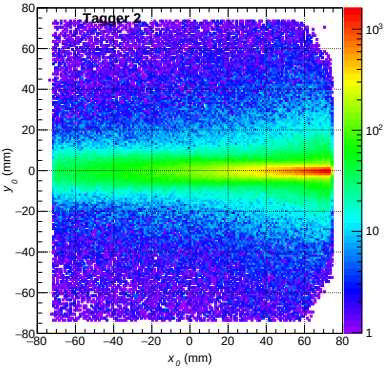


Figure: Tagger 2



Tracks horizontal angle

- Track horizontal slope θ_x in detector frame is shown for both taggers
- Large angles belong only to background clusters

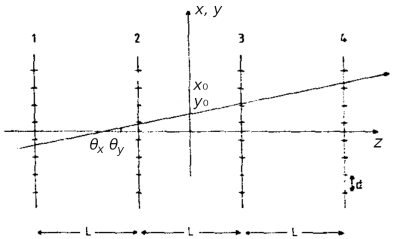


Figure: θ_x, tagger 1

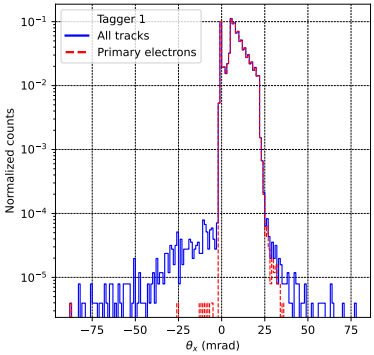
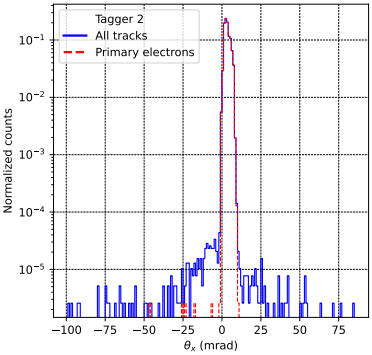


Figure: θ_x, tagger 2



Tracks vertical angle θ_y

- Track vertical slope θ_y in detector frame is shown for both taggers
- Large angles belong only to background clusters

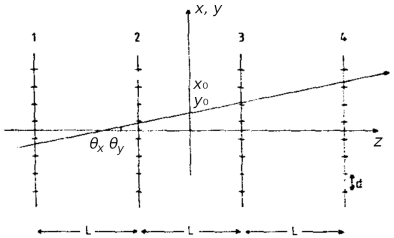


Figure: θ_y, tagger 1

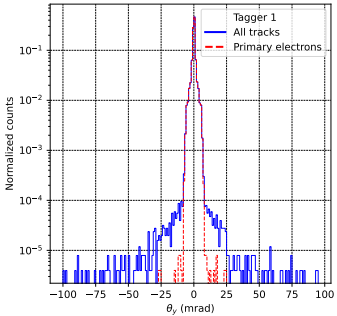
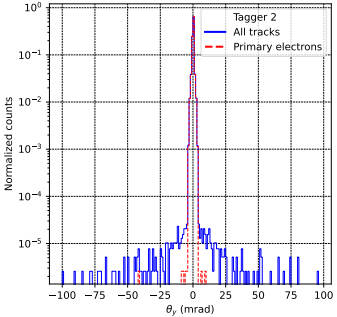


Figure: θ_y, tagger 2



Origin of peak in horizontal angles θ_x in tagger 1

- The peak in θ_x is caused by kinematics peak in cross section
- Potential for data-driven alignment

Figure: Cross section

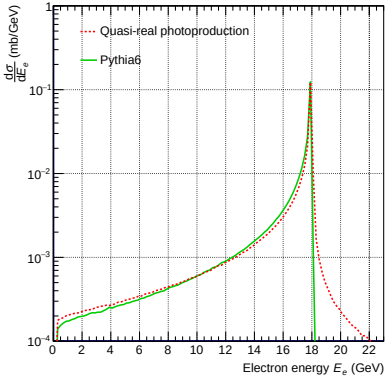


Figure: θ_x in tagger 1, close range

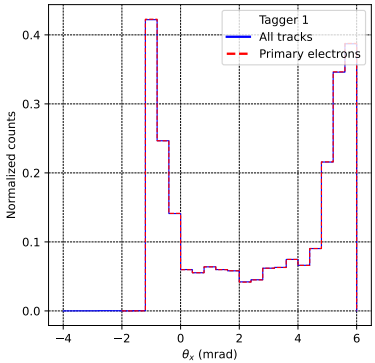
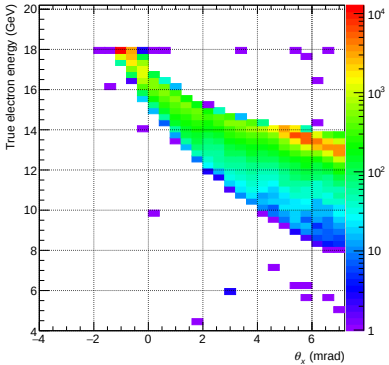


Figure: Energy and θ_x for tagger 1



Summary

- One photoproduction electron per event was simulated and corresponding detector track was found
- Next step is to simulate a bunch crossing with pileup of bremsstrahlung electrons
- A photoproduction electron has to be embedded in the bunch crossing
- The task is to separate all tracks in the bunch crossing and identify the photoproduction by Q^2
- Backup gives full account on tracking and clustering codes

Backup

Codes for MAPS, clustering and tracking

- MAPS tracking layer: github.com/adamjaro/lmon/blob/master/src/TrkMapsBasic.cxx
  github.com/adamjaro/lmon/blob/master/include/TrkMapsBasic.h
  github.com/adamjaro/lmon/blob/master/src/TrkMapsBasicHits.cxx
  github.com/adamjaro/lmon/blob/master/include/TrkMapsBasicHits.h
- Cluster finder:
  github.com/adamjaro/lmon/blob/master/roman_pots/src/TagMapsBasicPlane.cxx
  github.com/adamjaro/lmon/blob/master/roman_pots/include/TagMapsBasicPlane.h
- Tracking: github.com/adamjaro/lmon/blob/master/roman_pots/src/TagMapsBasic.cxx
  github.com/adamjaro/lmon/blob/master/roman_pots/include/TagMapsBasic.h
- Analysis over simulated data, run macro and example configuration:
  github.com/adamjaro/lmon/blob/master/analysis_tasks/src/AnaMapsBasic.cxx
  github.com/adamjaro/lmon/blob/master/analysis_tasks/include/AnaMapsBasic.h
  github.com/adamjaro/lmon/blob/master/analysis_tasks/run_macros/run_AnaMapsBasic.py
  github.com/adamjaro/lmon/blob/master/analysis_tasks/ini/AnaMapsBasic.ini