Energy of EM shower with cosmic ray background

V. Galymov

SB Meeting

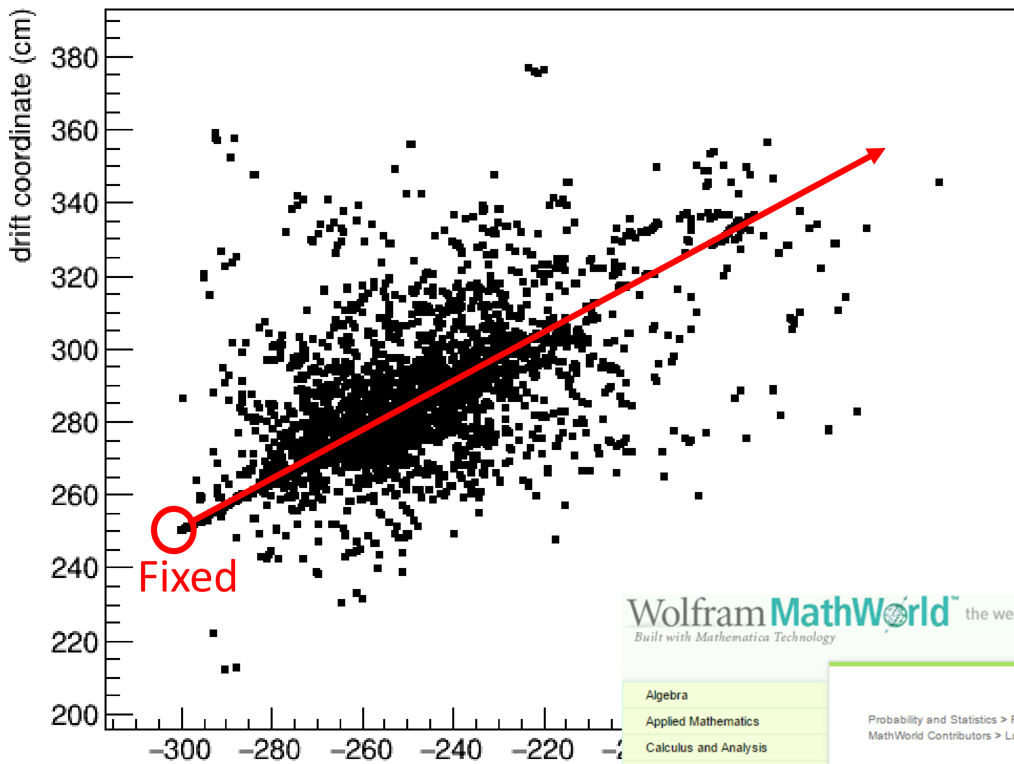
Introduction

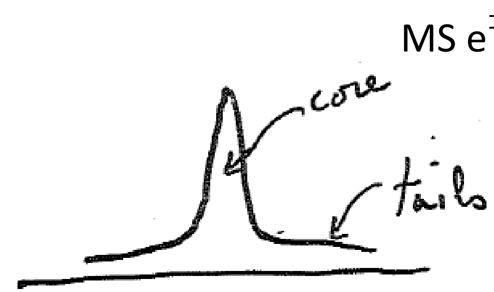
- The cosmic ray background expected in WA105 will generate a significant activity in the TPC
- The energy deposited by these cosmics will affect calorimetric energy measurement for the beam events
- First look at this potential problem for EM showers
  - The shower is compact and its development can be parametrized, so a good starting point

EM shower “reconstruction”

- Fix vertex to the beam entry point
- Find angle of the shower (could also fix to the beam angle in principle)
- Make association of hits to the shower in each view

Shower direction

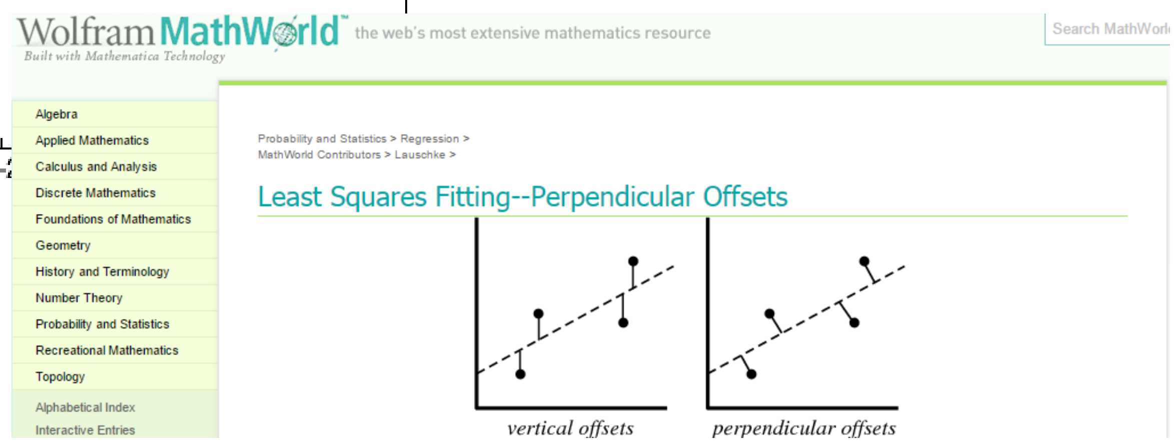




Compton scattered soft γs

Weighted LSQ fitting perpendicular offsets

The weight is the hit charge → to give more significance to the shower core



Shower hit association

Pick hits in a cylinder along shower axis defined by the vertex and the projected direction angle θ in a given view

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x - v_x \\ y - v_y \end{pmatrix}$$

Apply longitudinal and lateral cuts to select hits:

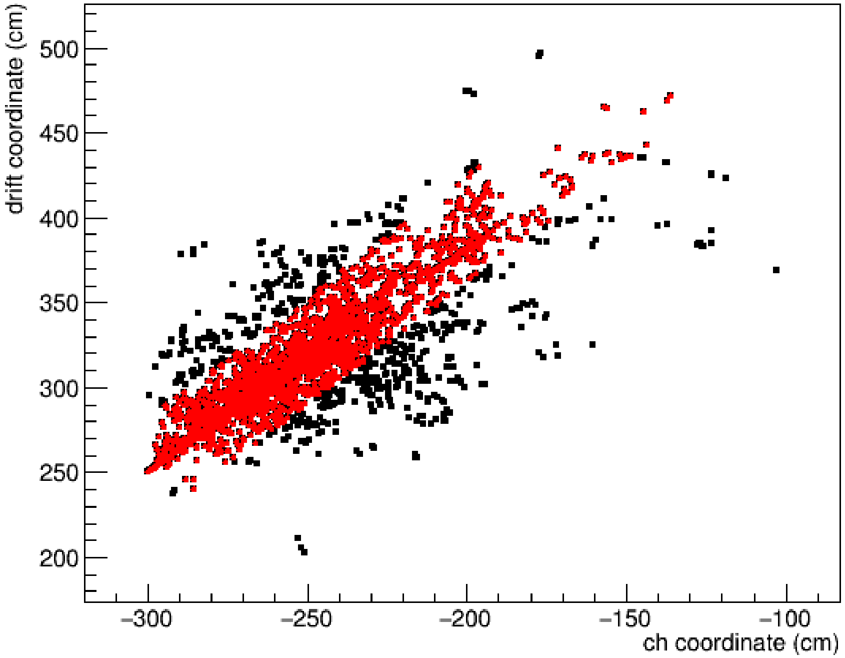
1. $0 \le x'/X_0 \le n$
2. $0 \le |y'|/R_M \le m$

Radiation length: $X_0 = 14.0$ cm
Moliere radius: $R_M = 9.0$ cm

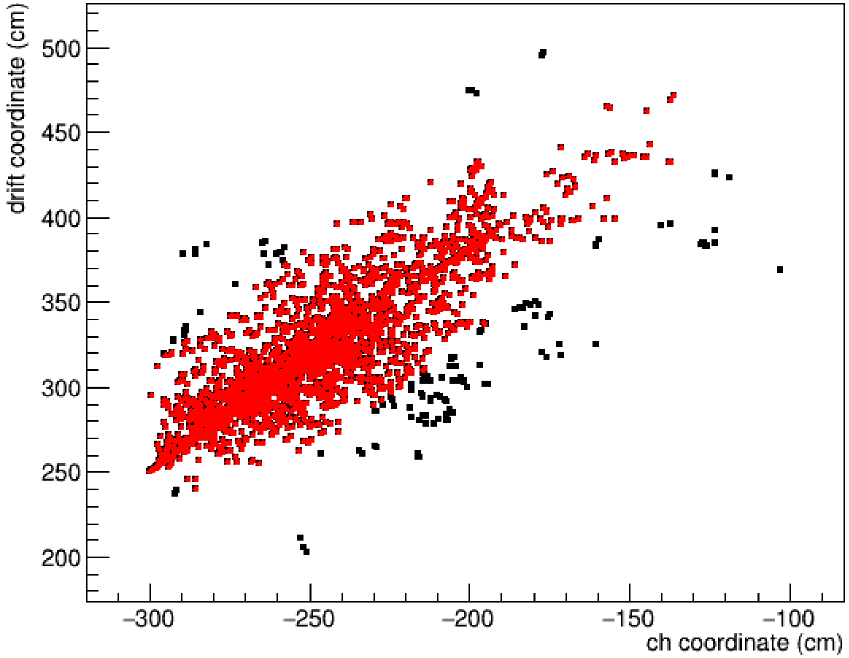
Shower hit association

Single 3GeV electron events

$0 \leq x' \leq 20X_0;\ 0 \leq |y'| \leq 2R_M$



$0 \leq x' \leq 20X_0;\ 0 \leq |y'| \leq 4R_M$



~95% of reconstructed charge is associated to the shower

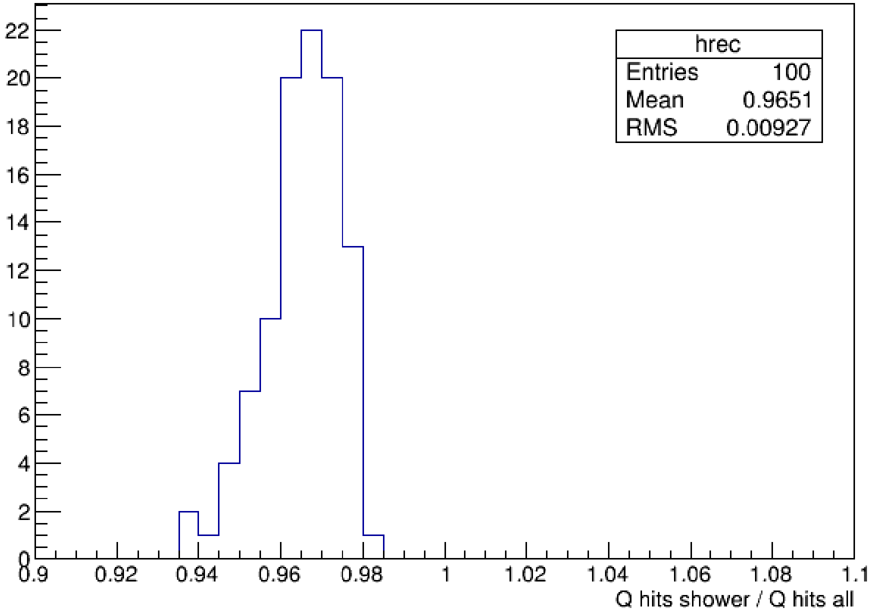
➔ No hits from low energy photons dominating lateral profile at large radii

~99% of reconstructed charge is associated to the shower

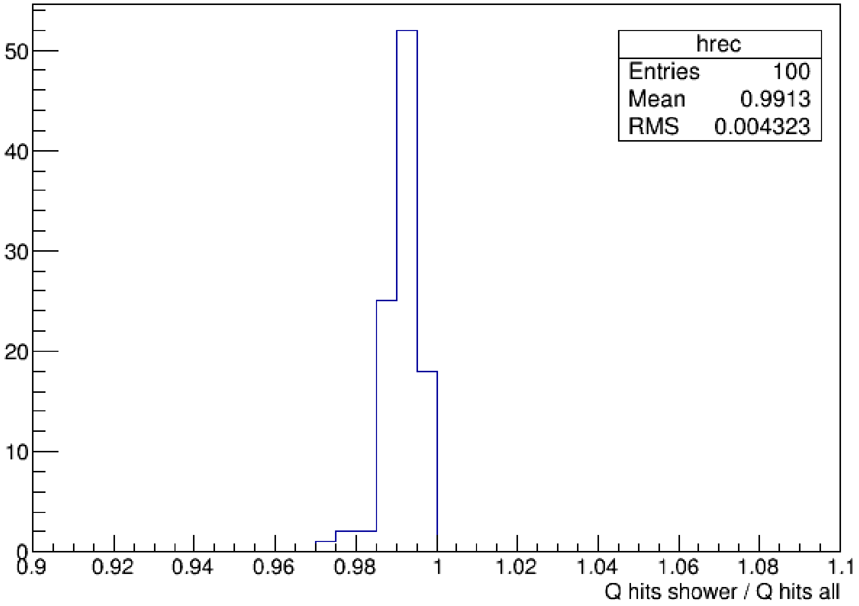
Shower hit association

Single 3GeV electron events

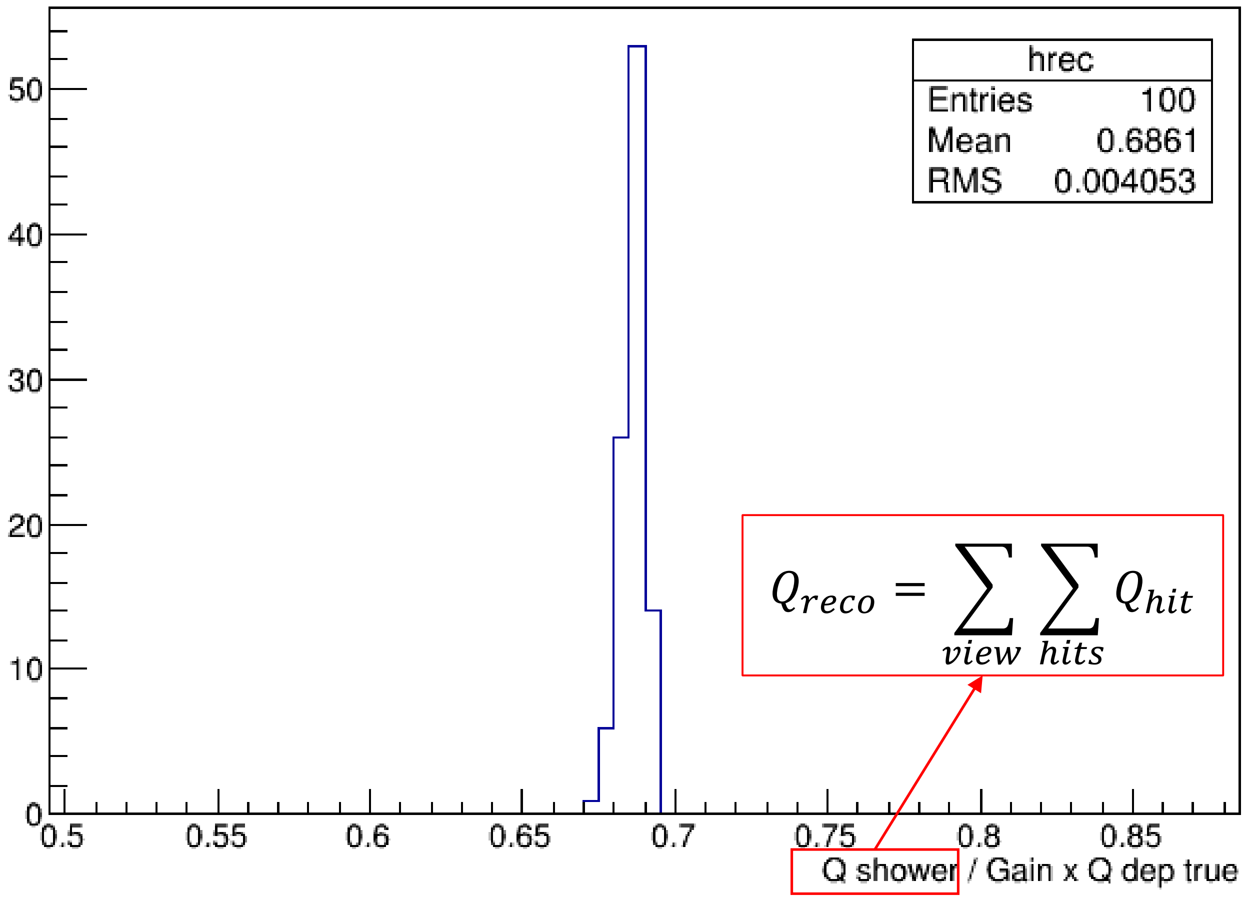
$0 \le x' \le 20X_0;\ 0 \le |y'| \le 2R_M$



$0 \le x' \le 20X_0;\ 0 \le |y'| \le 4R_M$



Comparison to true Edep



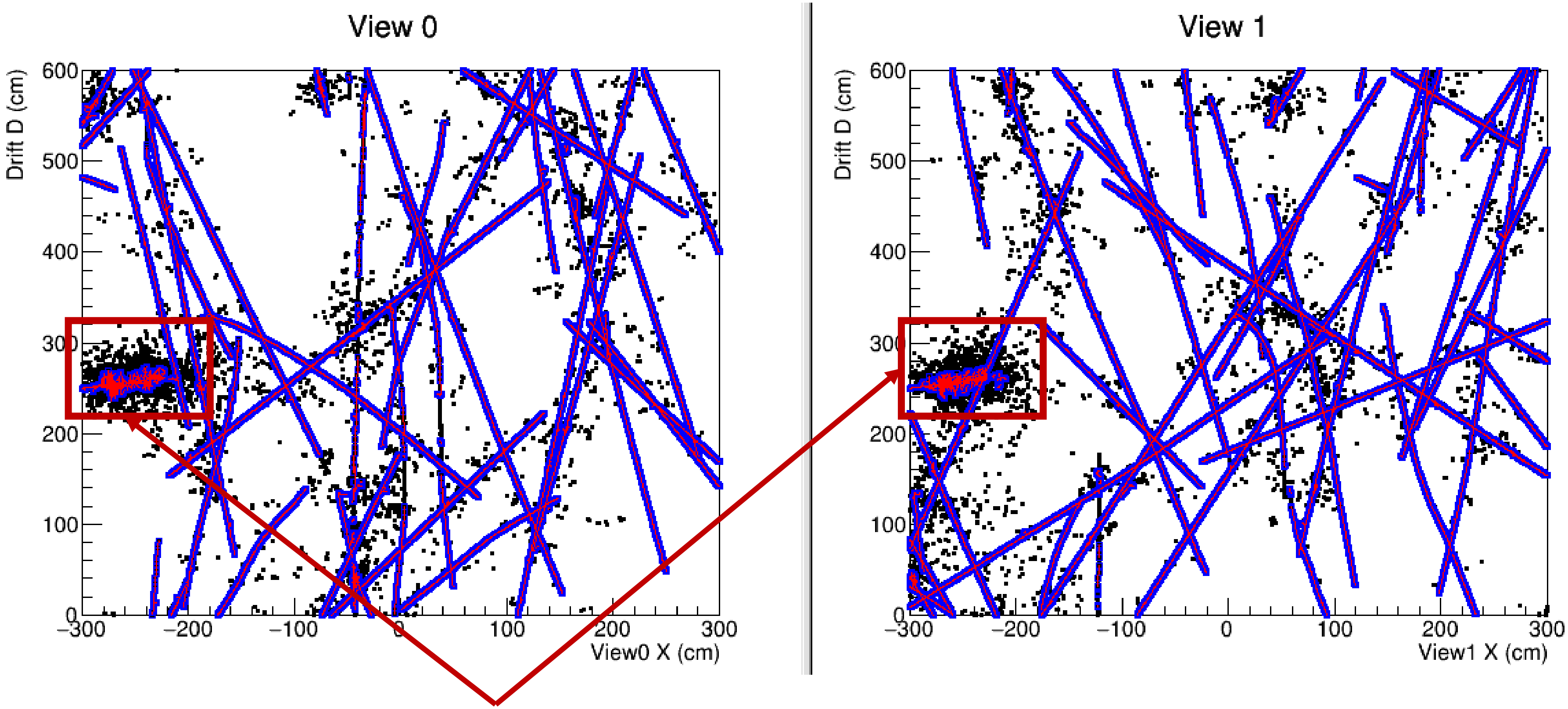
No recombination correction is applied

LEM gain of 20 is assumed

No electron lifetime attenuation / diffusion effects

No LEM border effects are included

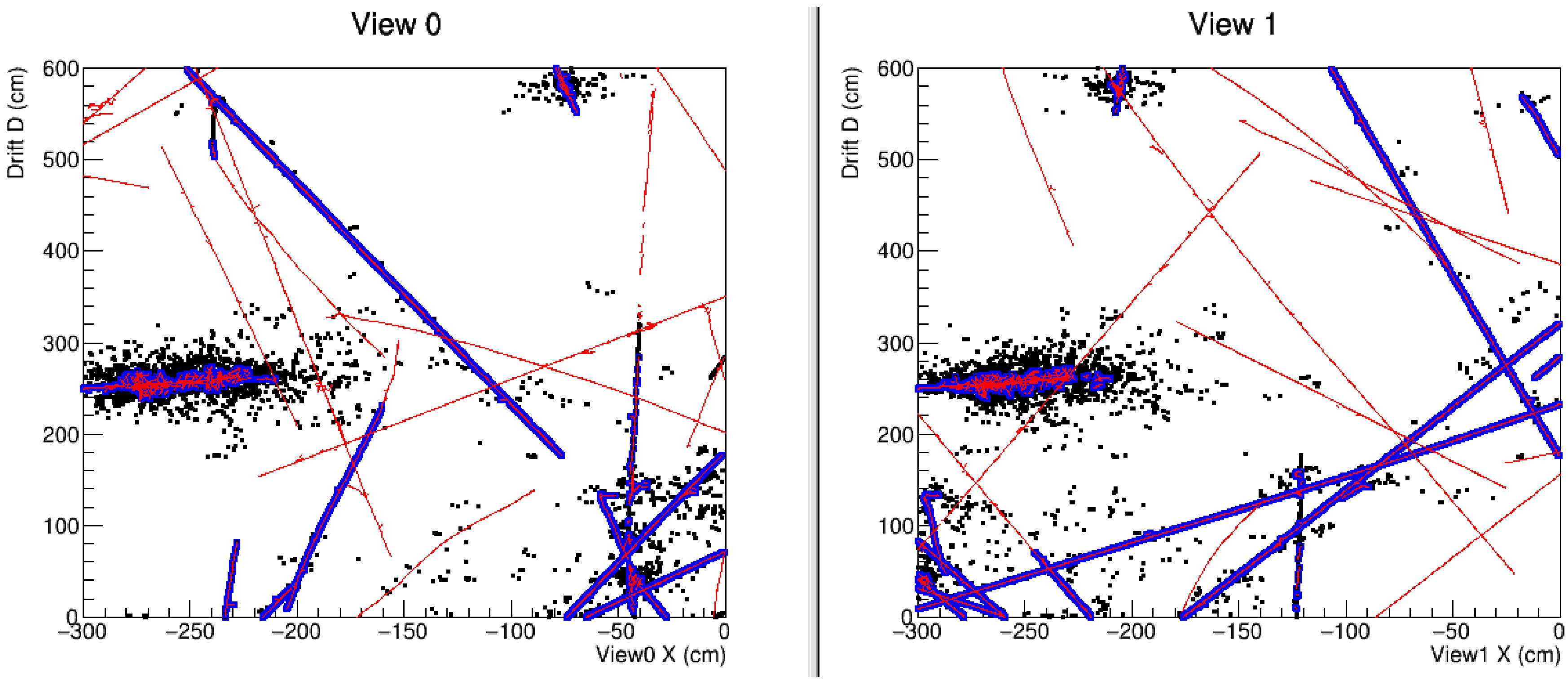
CR background overlap



Shower from 3 GeV electron

CR background overlap

For compact showers can look into just single 3x3 m^2 CRM to avoid too many overlaps (3 m is ~21 X_0)



Longitudinal shower containment

electrons

The lateral shower profile is dominated by low energy photons that travel far from the shower axis, so only the depth of the shower changes with energy

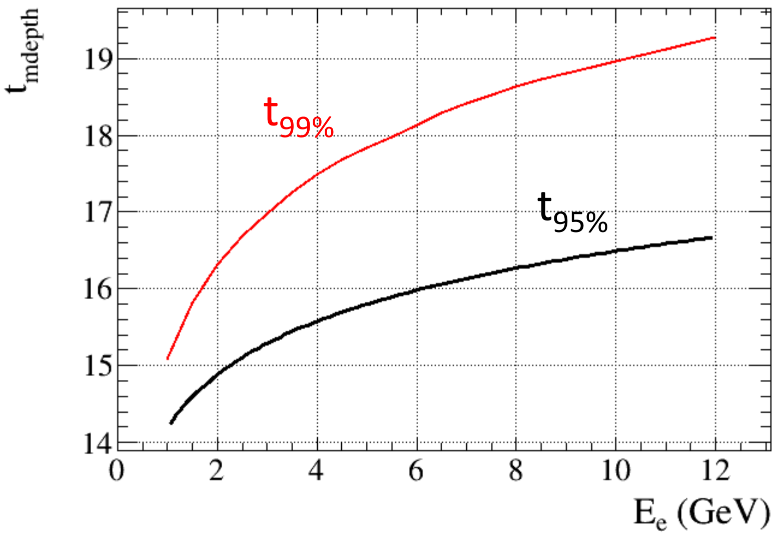
Longitudinal profile parametrization (PDG recommended):

$$\frac{dE}{dt} = E_0 b \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$

$t_{\max} = (a-1)/b$

b ~ 0.5

E. Longo and I. Sestili, Nucl. Instrum. Methods 128, 283 (1975).



Shower maximum in units of X_0

$$t_{max} = \ln\left(\frac{E}{30.5\ \text{MeV}}\right) - 0.5$$

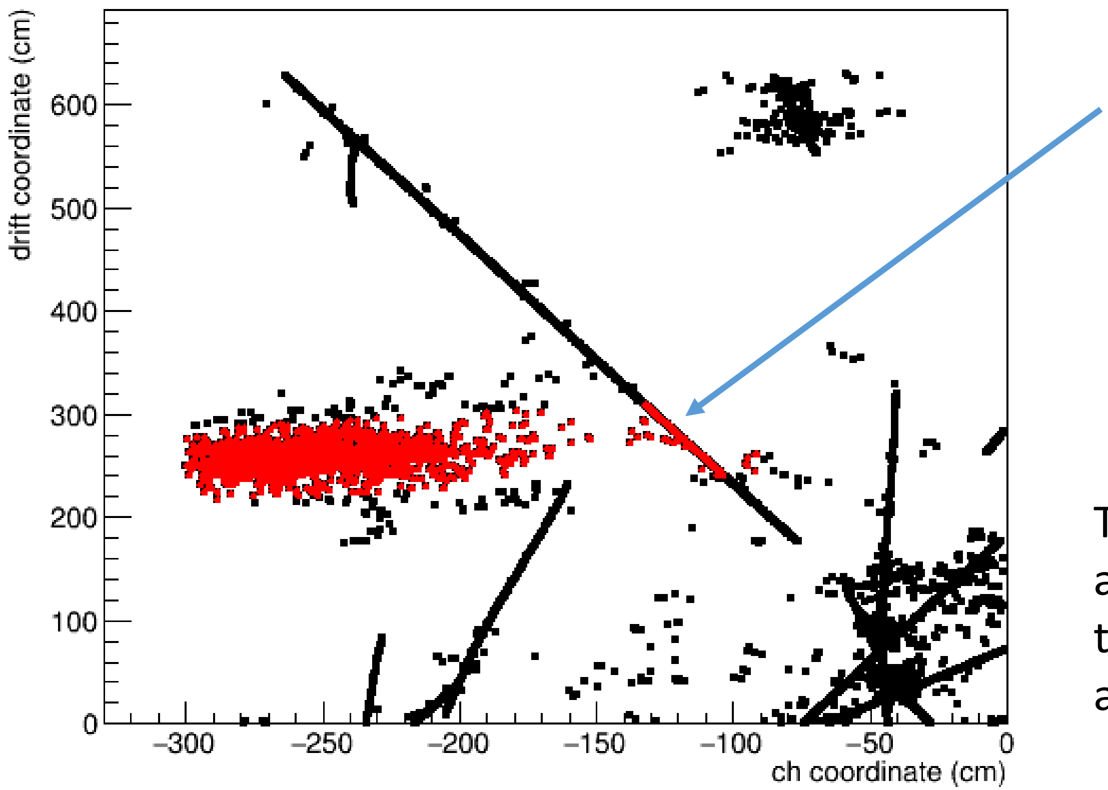
$$t_{95\%} \approx t_{max} + 0.08Z + 9.6 = \ln\left(\frac{E}{30.5\ \text{MeV}}\right) + 10.5$$

To get >99% containment:

$t \approx 15$ (~210 cm) for $E_e = 1$ GeV; $t \approx 19$ (~270 cm) for $E_e = 10$ GeV

CR background overlap

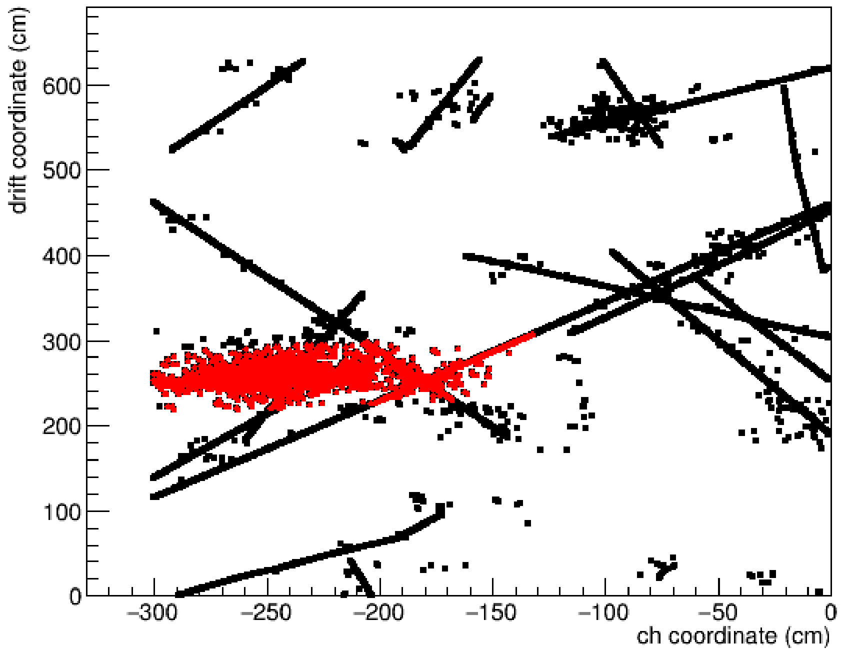
$0 \leq x' \leq 20X_0;\ 0 \leq |y'| \leq 4R_M$

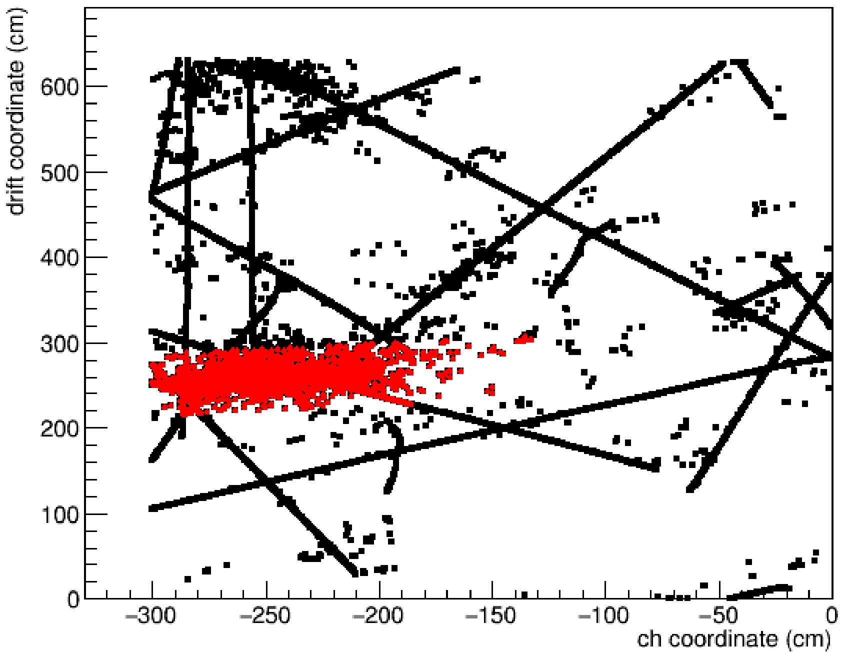


The hits associated with the CR tracks could be removed However the nearby activity would remain

To minimize pick-up of the activity from CRs need to put a tight cut on shower dimensions as a function of beam energy

CR background overlap

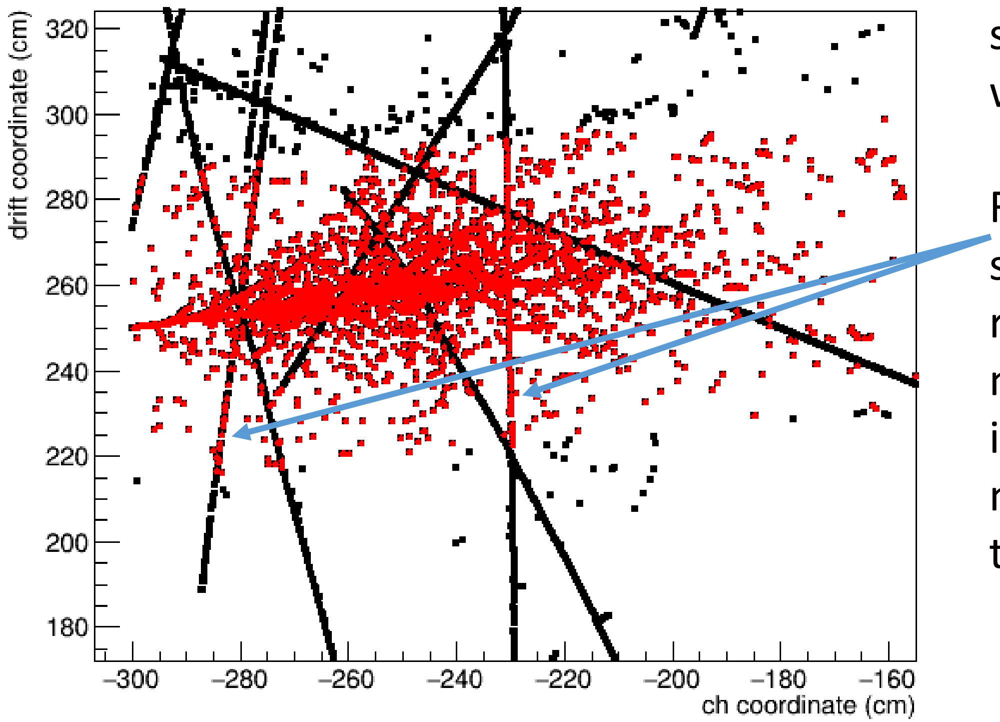




Cases where comics go directly into the shower would be the problem for calorimetric energy measurement

Subtracting CR background

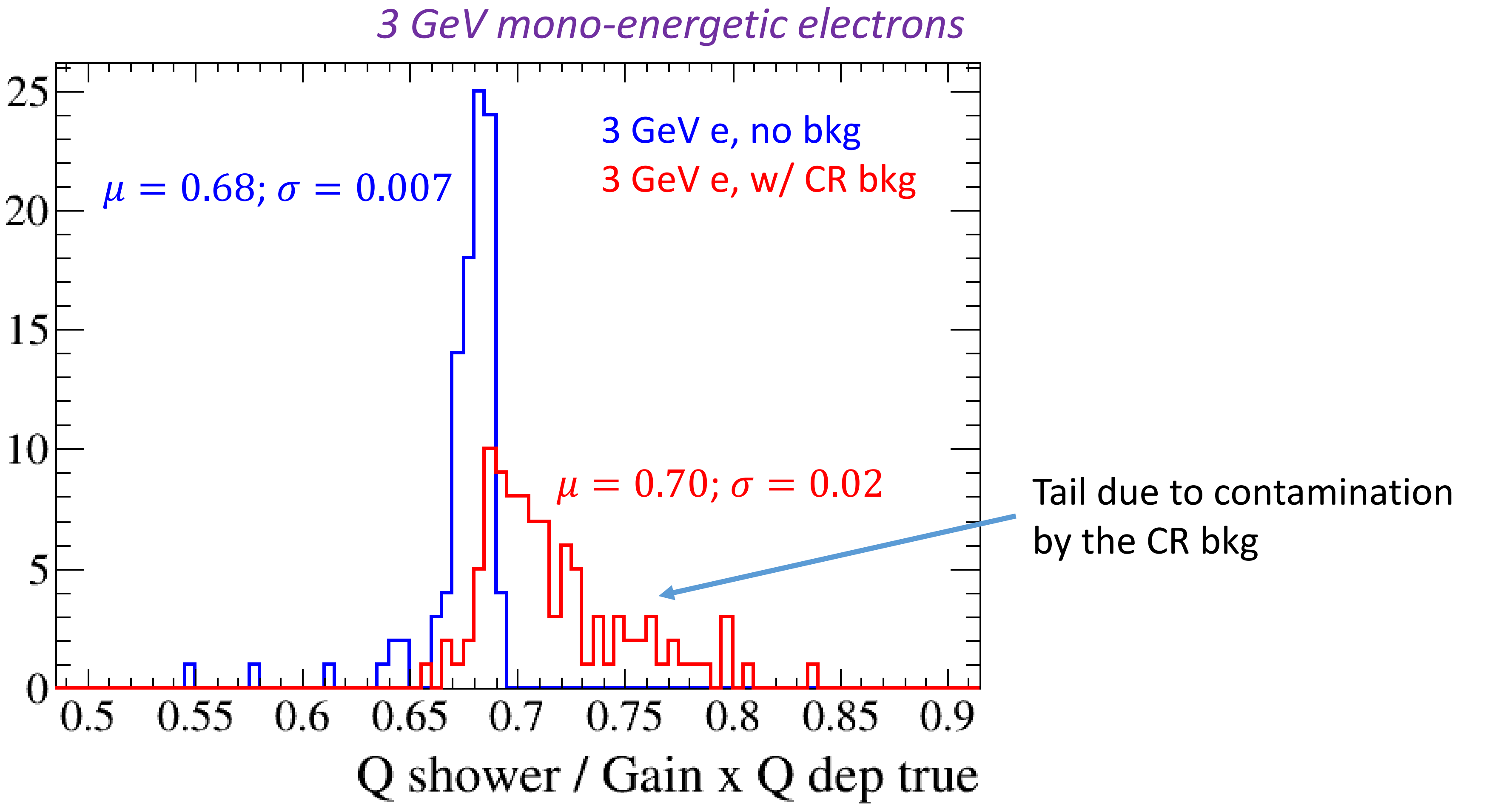
Remove hits associated to tracks whose either endpoint is outside of the region for the shower search defined by $0 \leq x'/X_0 \leq n; 0 \leq |y'|/R_M \leq m$



In red are the hits associated to the shower after removing hits associated with CR tracks

For downward going muons producing several hits on the same channel in rapid succession some of the hits are not correctly assigned to the track (or, if the track is not well reconstructed, not assigned at all); these are assigned to the shower

Shower energy

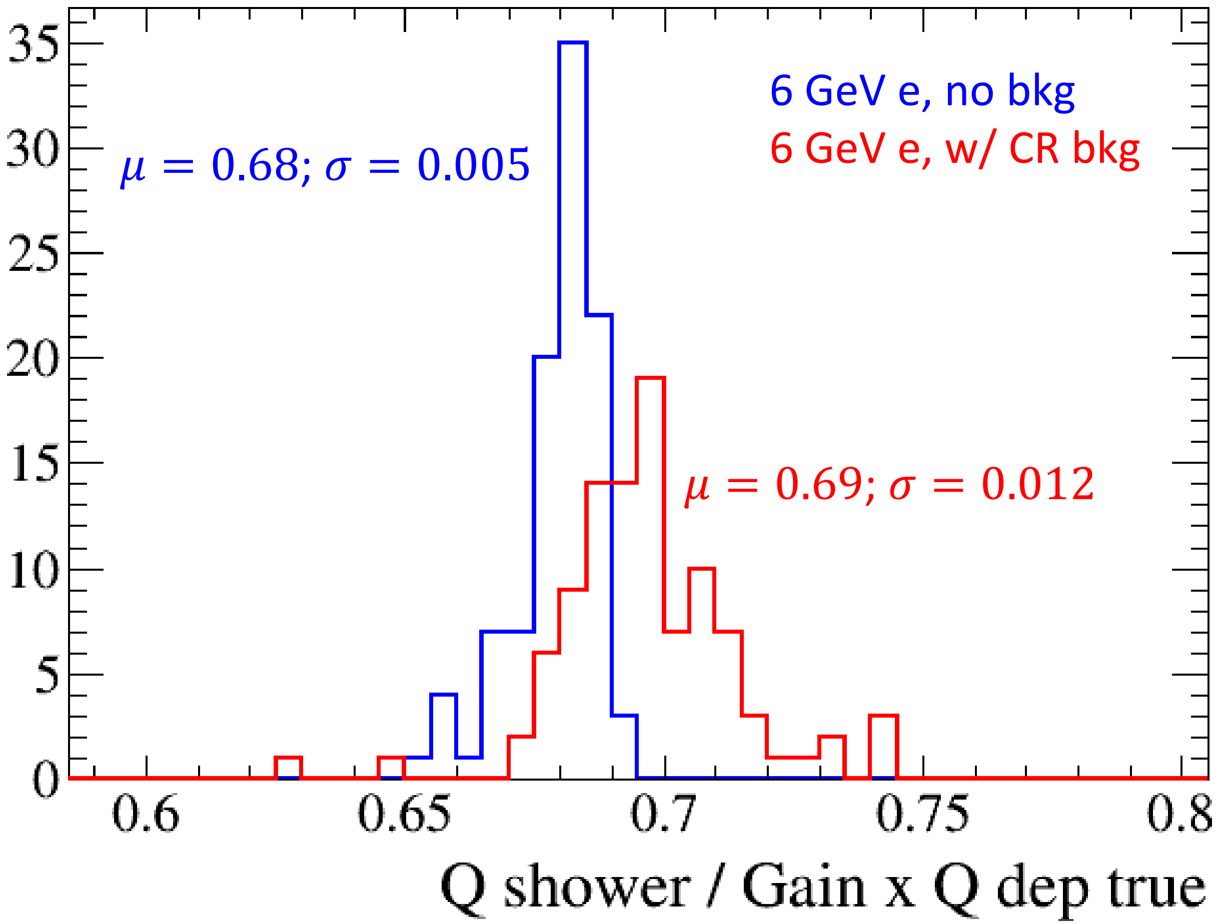


Since LAr is a homogeneous calorimeter, the stochastic term, $1\backslash\sqrt{E}$, in the intrinsic energy resolution is quite small ~$1\%\backslash\sqrt{E}$ (GeV)

The background introduces some bias ~3%
Worsens the resolution by a factor of ~3

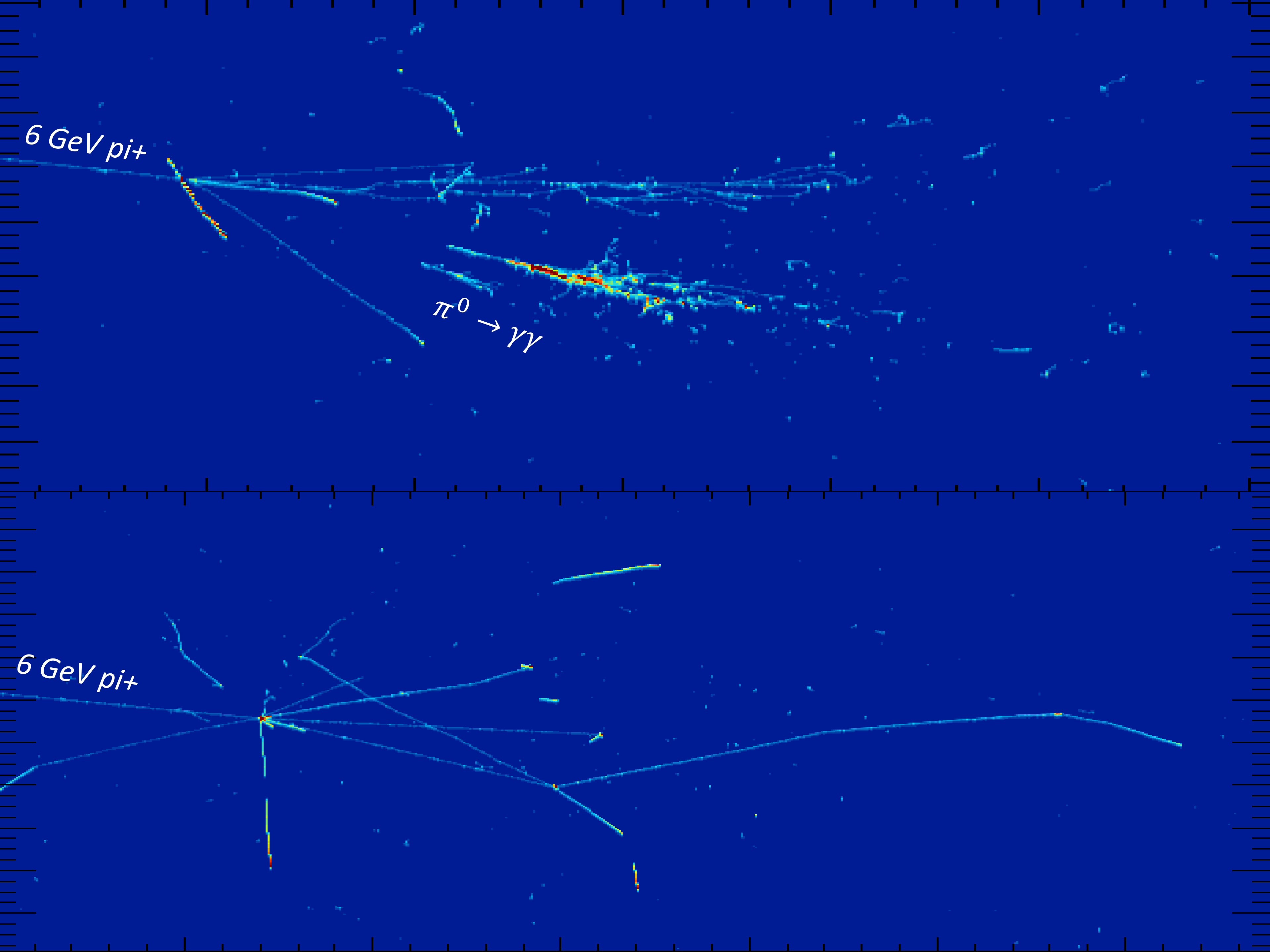
Shower energy

6 GeV mono-energetic electrons



Summary

- First look at reconstruction of the EM shower energy in presence of cosmic ray background
- The leftover charge from CRs appears to bias the energy reconstruction by 2-3% (at least for 3 – 6 GeV e)
- The resolution is also affected
- The effects are somewhat energy dependent
  - Energy of electron → shower depth in the detector → size of the volume within which CR overlap can happen
  - If the CR contribution does not vary significantly from one beam energy to other (the extent of the shower does not change substantially on the scale set by spatial density of CR events), then it becomes less significant as the energy of the electron increases
- On a different topic: for online reconstruction of CR need to develop veto regions from which CR tracks trajectories are not seeded
  - Avoid spending time looking in detail at the activity of the showers
  - For EM showers should be similar to putting a cylindrical volume cut described here
  - Could also work for HAD events (although $\lambda_I/X_0 \sim 6$, complex topologies) …


6 GeV pi+
$\pi^0 \rightarrow \gamma\gamma$
6 GeV pi+