Improving Calorimeter-Based PID

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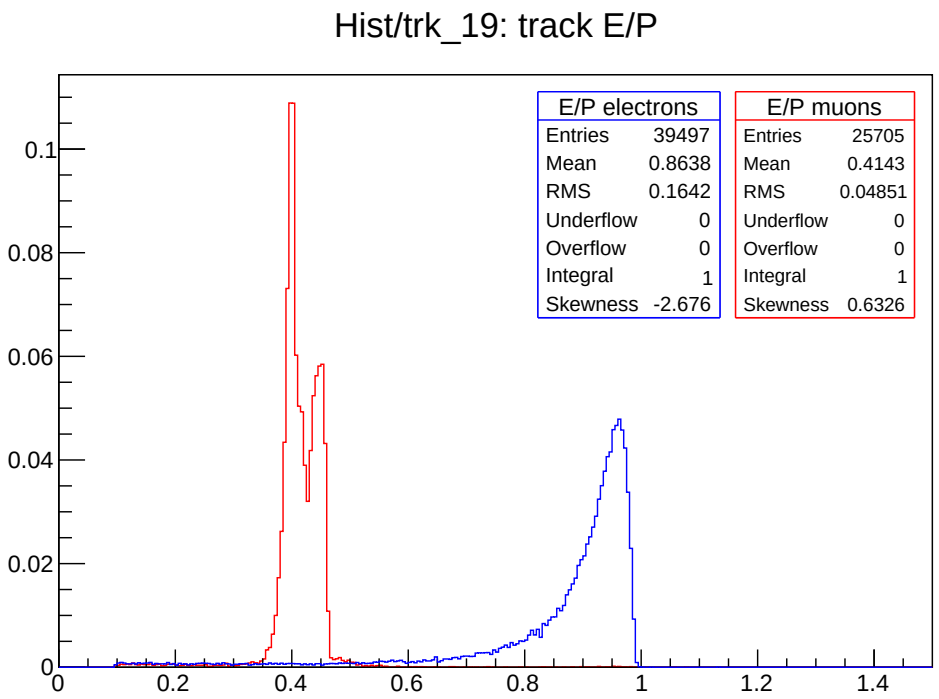
Introduction

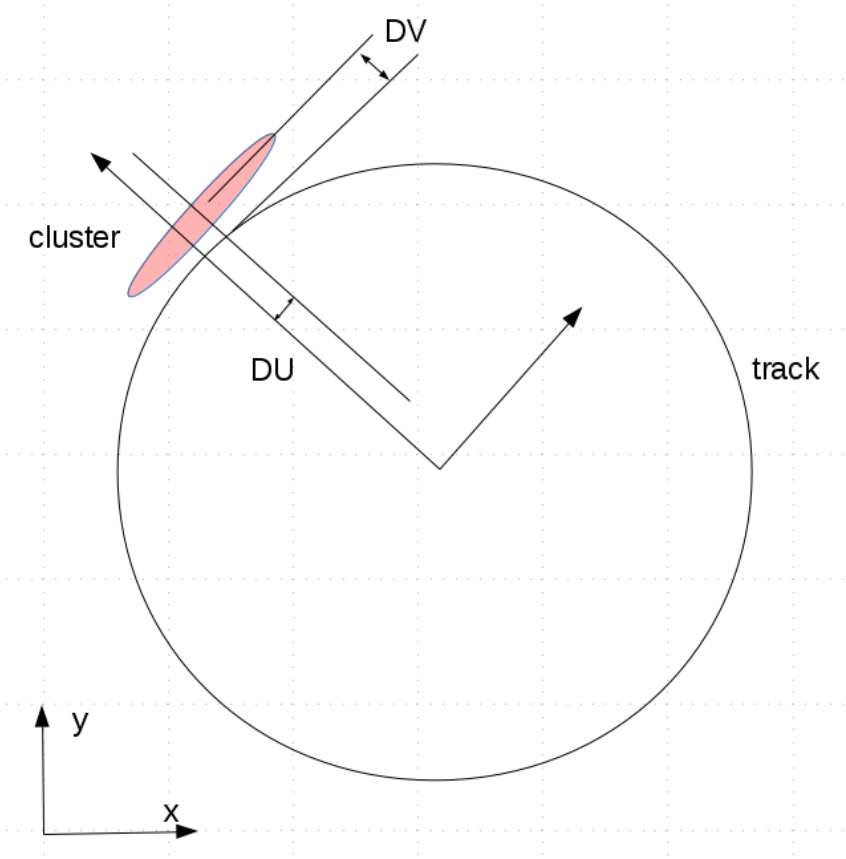


- **AIM:** to measure $\mu \rightarrow e$ conversions. So need to distinguish these conversion electrons from background in the detector.
- A lot of this background is muons
- Current PID uses E/P information for muons and electrons (left)
- Electrons (blue) peak at ≈ 1, muons (red) peak at ≈ 0.4. This is as expected for straight forward relativistic calculations

- I will be discussing new methods to add to the likelihood, and improvments to the current E/P information

Improvements to Δu and Δv

- Particle spirals through the tracker, then collides with calorimeter and deposits energy, creating clusters
- Need to match tracks to clusters for PID



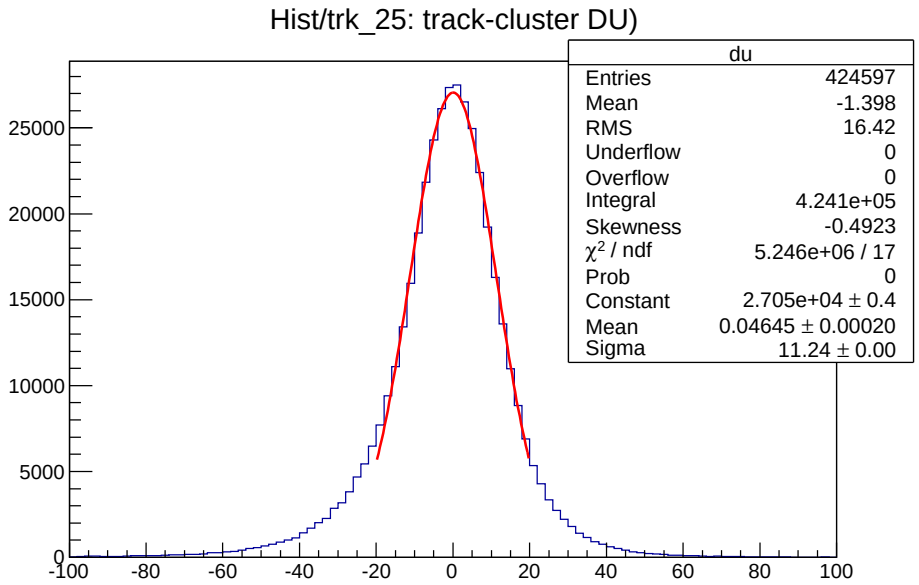
- u and v are the coordinates of the cluster
- Δu and Δv are the residuals in u and v, i.e. difference between cluster coordinate and reconstructed track coordinate:

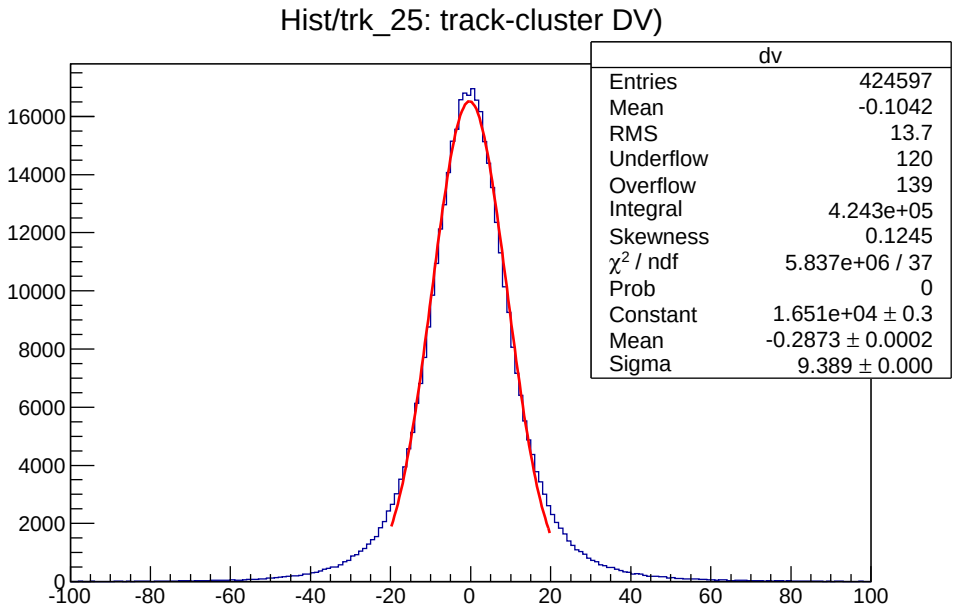
$$\Delta u = u_{track} - u_{cluster}$$

- Ideally, would like $\Delta u = 0$ and $\Delta v = 0$
- Δu is in the direction of the track, Δv is orthogonal to it

Δu and Δv distributions

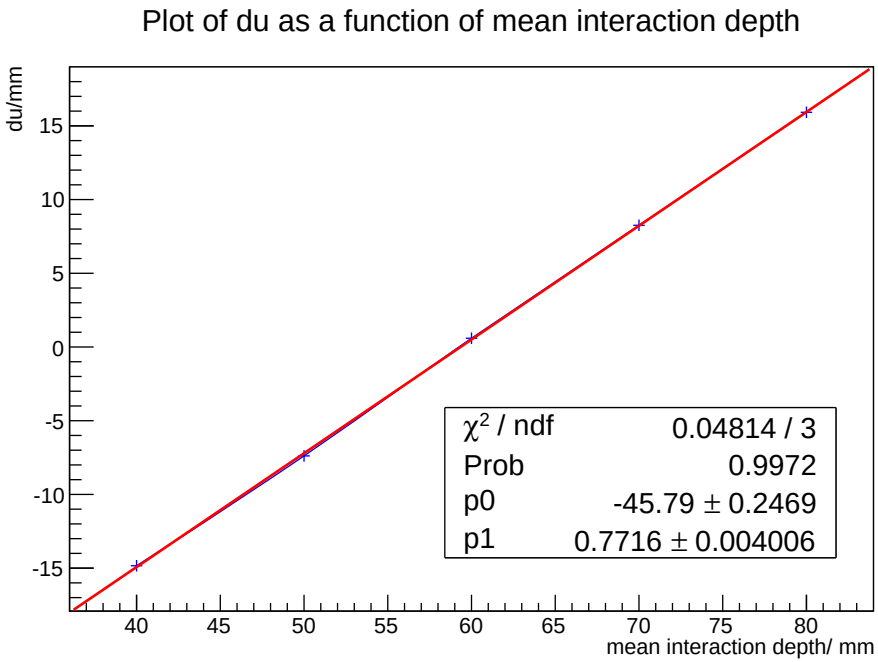
- The depth of extrapolation of the track in the calorimeter is called the interaction depth
- Would expect Δu (and maybe Δv) to depend on interaction depth

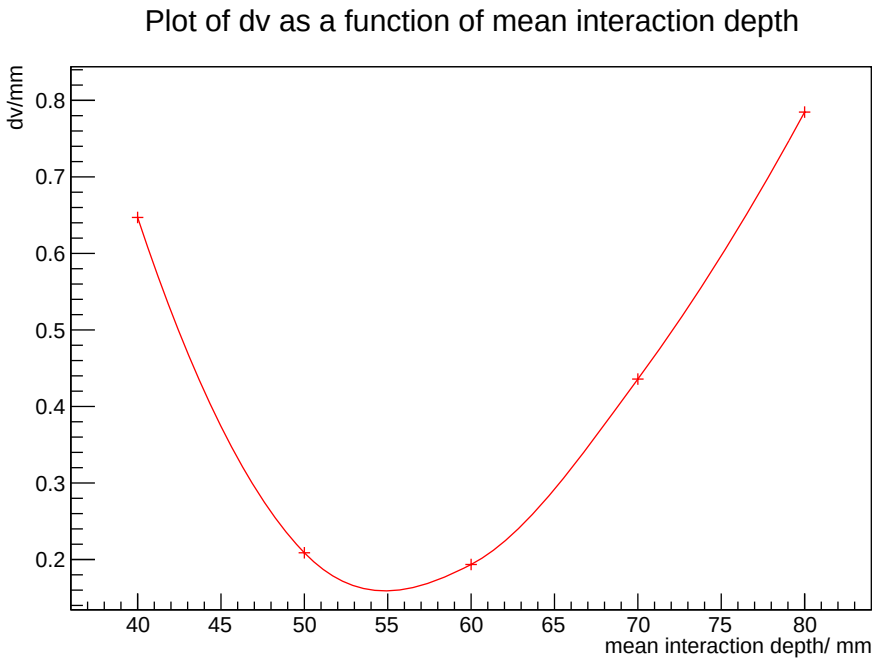




- Therefore, aim is to find an optimum interaction depth, i.e. for which $\Delta u = 0$
- I changed interaction depth in the range 40-80mm, and for each point plotted the mean
- (Note: these plots show Δu and Δv for the final interaction depth)

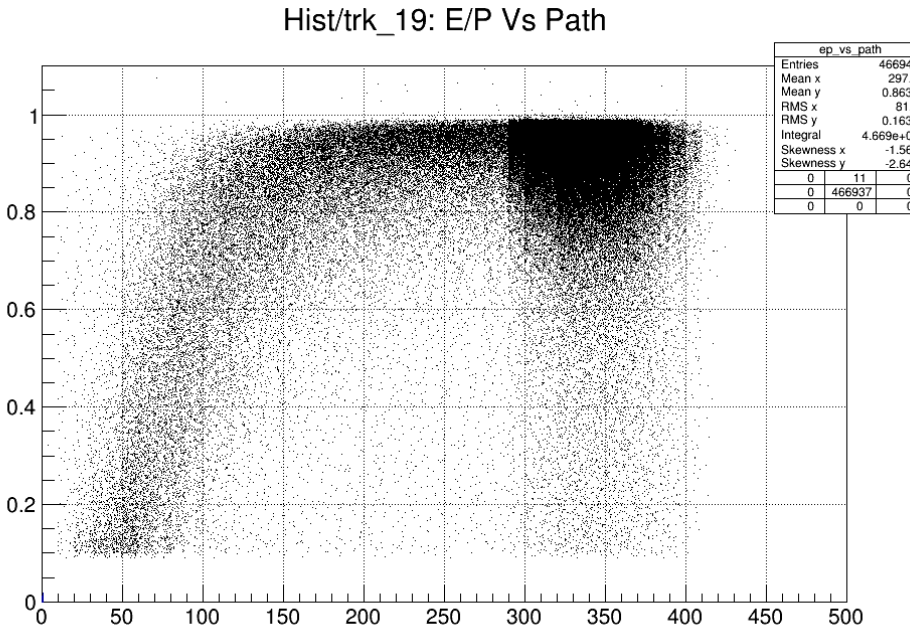
Δu and Δv vs interaction depth

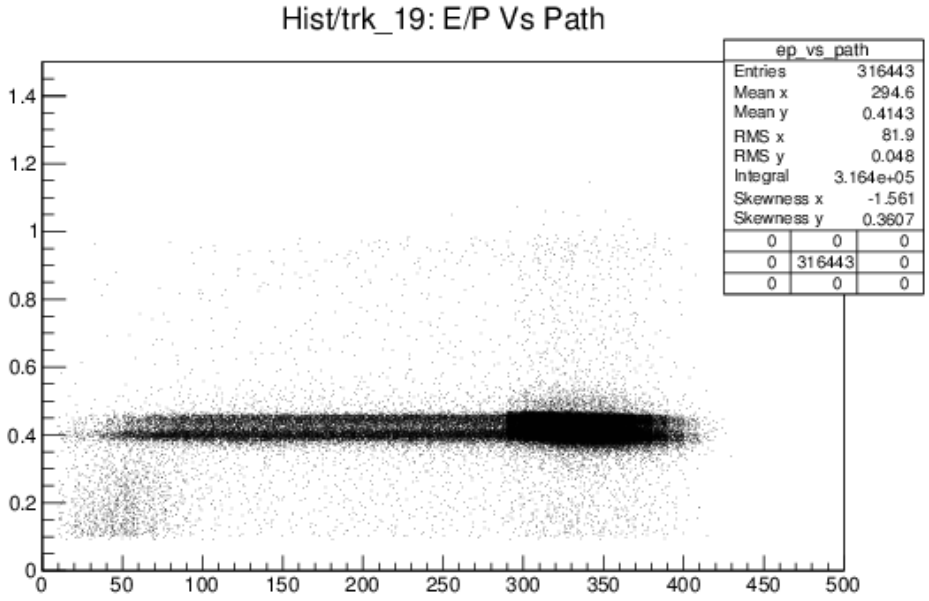




- I then plotted Δu and Δv as functions of interaction depth
- Δu plot has expected linear shape, zero at 59mm
- The shape of Δv is due to a second order effect due to geometry and direction of the track. Much smaller than Δu effect.
- Minimum in Δv at 55mm
- It is actually surprising that the minimum in Δv is so close to the zero in Δu
- Final optimum mean interaction depth: **59mm**

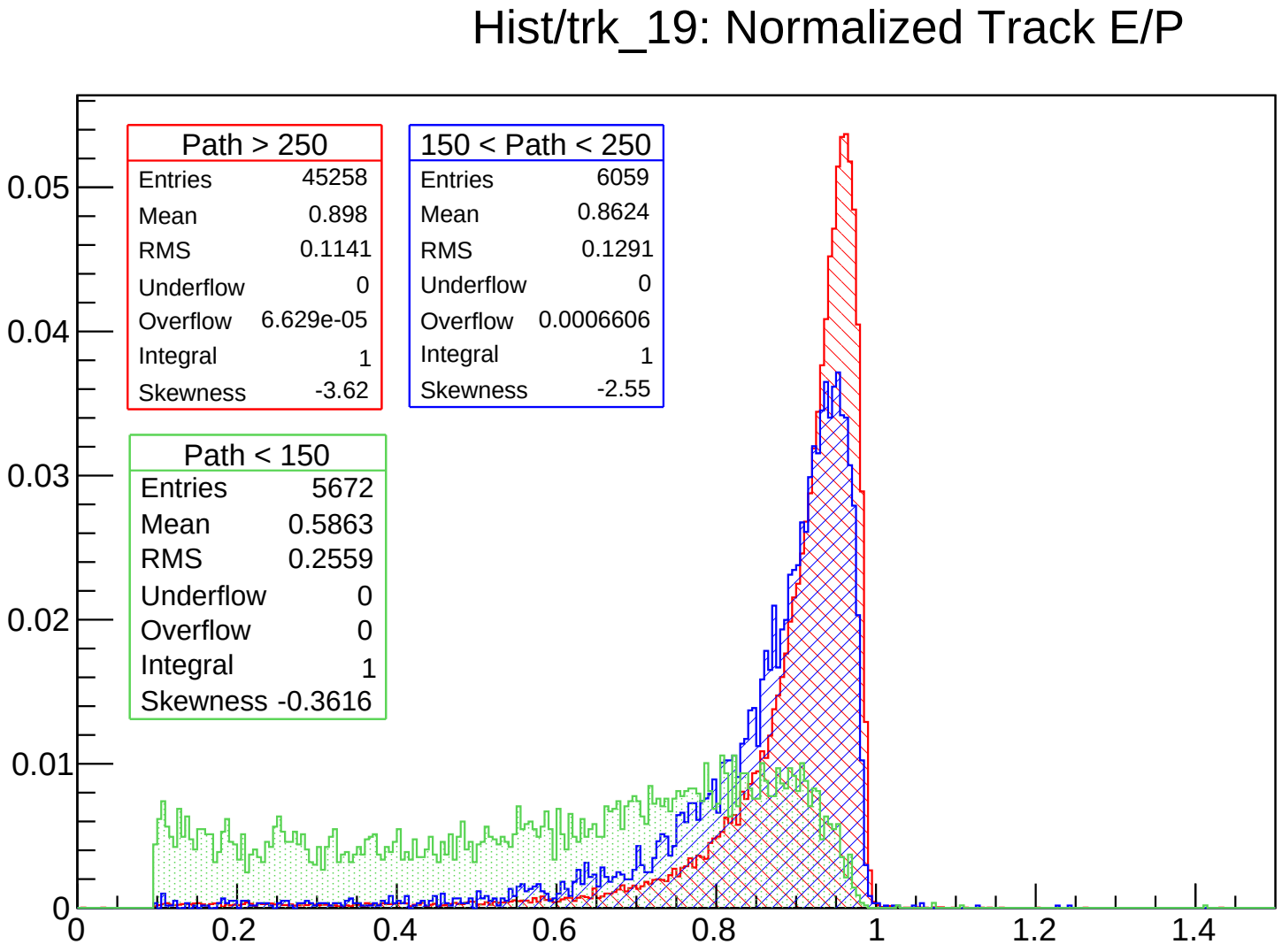
E/P dependence on the track path





- Track path is distance particles travel in the calorimeter
- Electrons (left) show expected max at ≈ 1, muons (right) show expected max at ≈ 0.4
- Both 105 Mev/c
- Long tail at low E/P values for electrons
- Mainly due to particles hitting edges $\rightarrow$ travel less far $\rightarrow$ deposit less energy
- Suggests some correlation between E/P and path length

Normalized E/P for electrons for different path lengths



Improvement to E/P likelihood

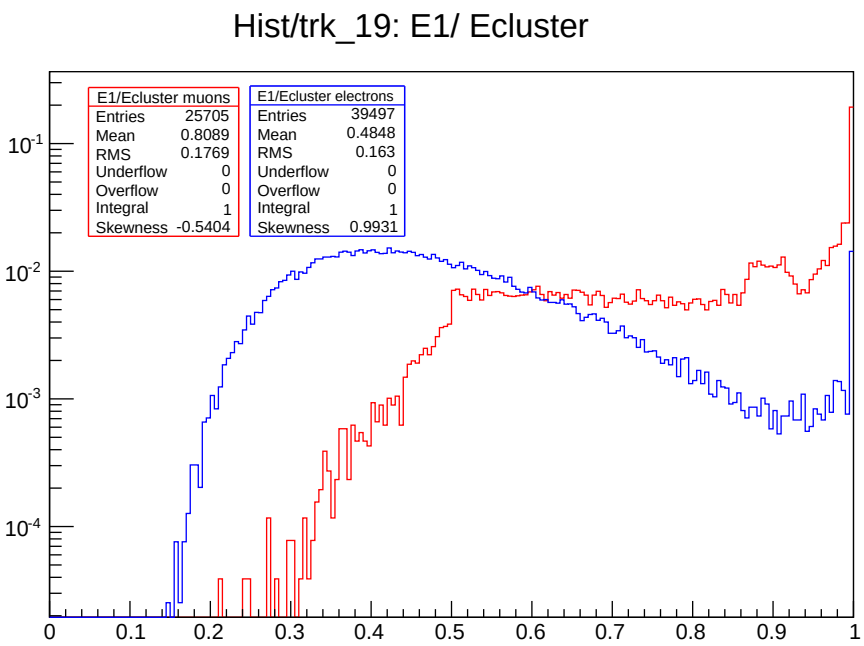
- Recall: currently use E/P to distinguish electrons and muons
- Long electron tail is a problem as harder to distinguish electrons from muons
- Most of tail made up of $E/P < 150mm$
- The E/P part of calorimeter PID likelihood becomes a function of trajectory length, S:

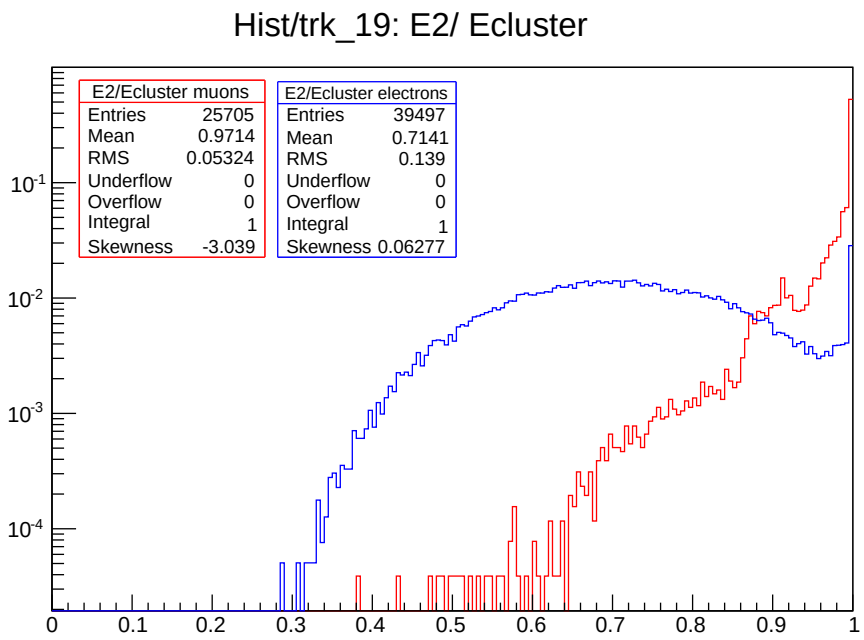
$$\ln L_{e,\mu} = \ln \frac{L_e}{L_\mu} = \ln P_{e,\mu}(\Delta t) + \ln P_{e,\mu}(E/P, S)$$

- This is a clear improvement to the likelihood

Cluster shape studies

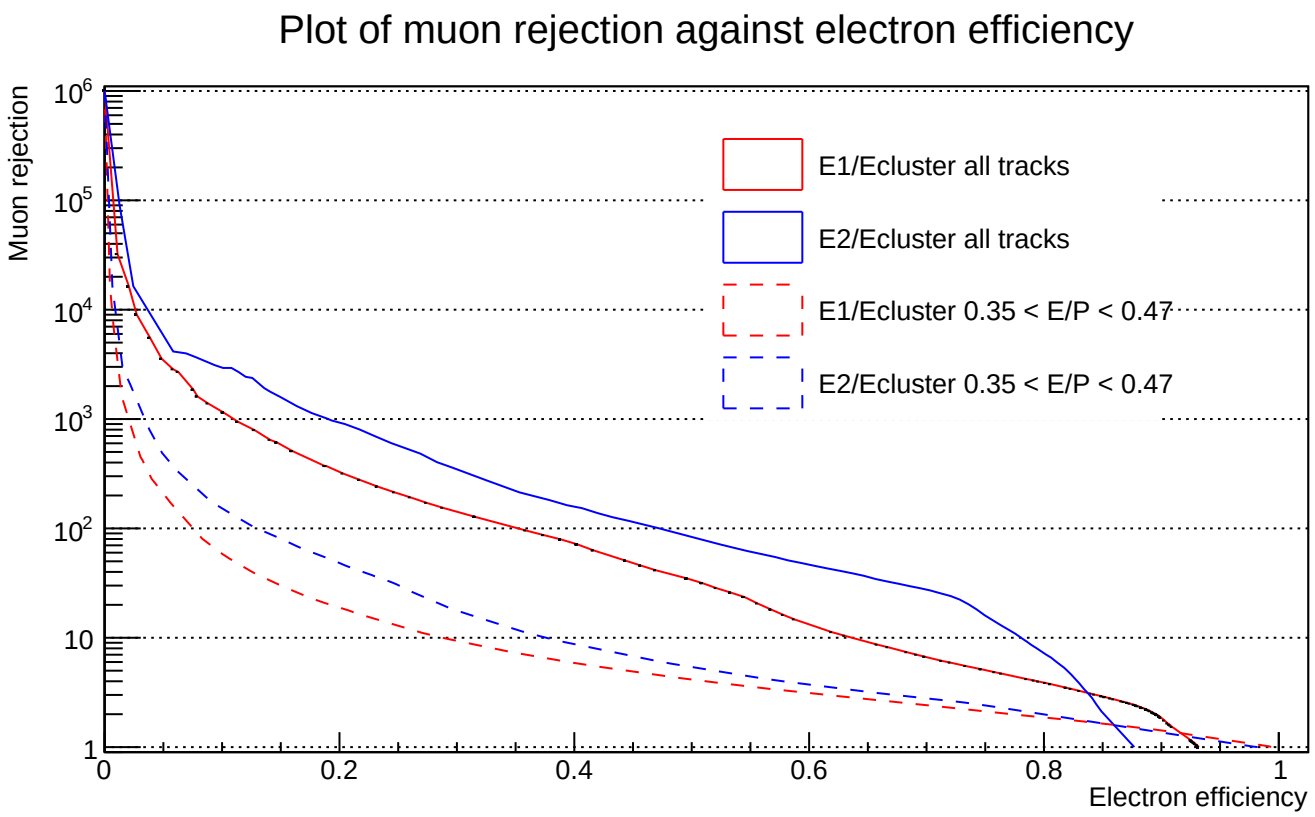
- This is a completely new study
- Particles deposit energy in the calorimeter and cluster shapes are related to energy distributions
- E_1/E_{cluster} is fraction of total cluster energy in highest energy crystal
- E_2/E_{cluster} is fraction of total cluster energy in two highest energy crystals





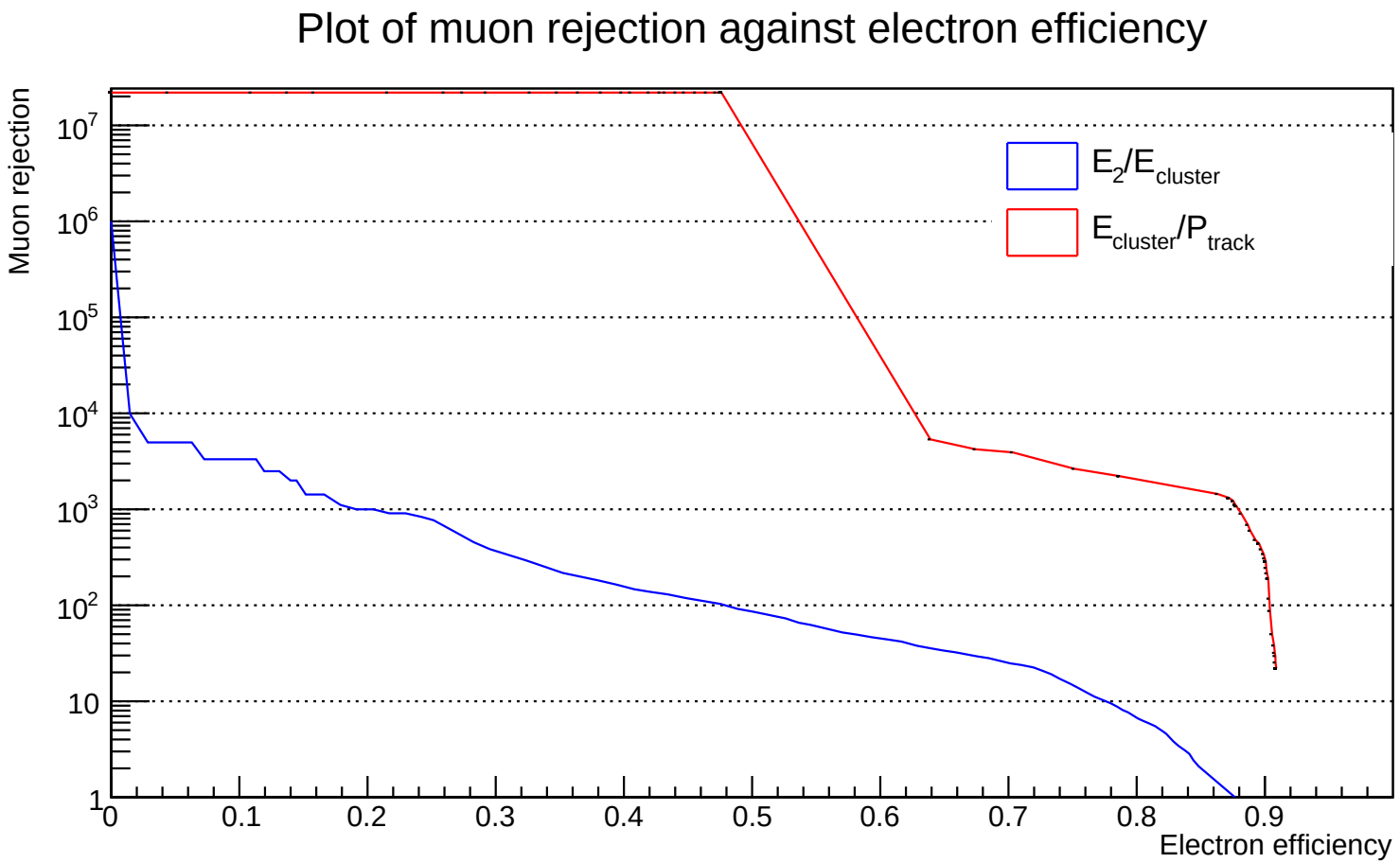
- E_1/E_{cluster} and E_2/E_{cluster} could both be useful...

Likelihood analysis for E/P range



- Muon rejection power an order of magnitude lower for E/P cut
- E_2/E_{cluster} better than E_1/E_{cluster} in both cases
- Clearly E_2/E_{cluster} of limited use **in addition** to E/P
- So which is better: E/P or E_2/E_{cluster}?

E_2/E_{cluster} vs E/P



- E/P above E_2/E_{cluster} in all places
- Note jump in E/P due to a single event
- Also, cluster shape depends on more free parameters such as energy cut off point
- Conclusion: E_1/E_{cluster} and E_2/E_{cluster} both less useful than E/P

Conclusions

- Mean interaction depth at which Δu is zero is **59mm**
- This is also very close to the minimum of Δv (second order effect)

- E/P is a function of path length in the calorimeter
- Tail in electron E/P made up almost entirely by short tracks which correspond to particles hitting the edge of the calorimeter
- Can improve likelihood in E/P by using path length

- E/P information is better than E_1/E_{cluster} and E_2/E_{cluster} information
- E_1/E_{cluster} and E_2/E_{cluster} of limited use in addition to E/P information