MINERvA::Tracking Prototype Momentum Reconstruction and Particle ID of hadrons using MC data

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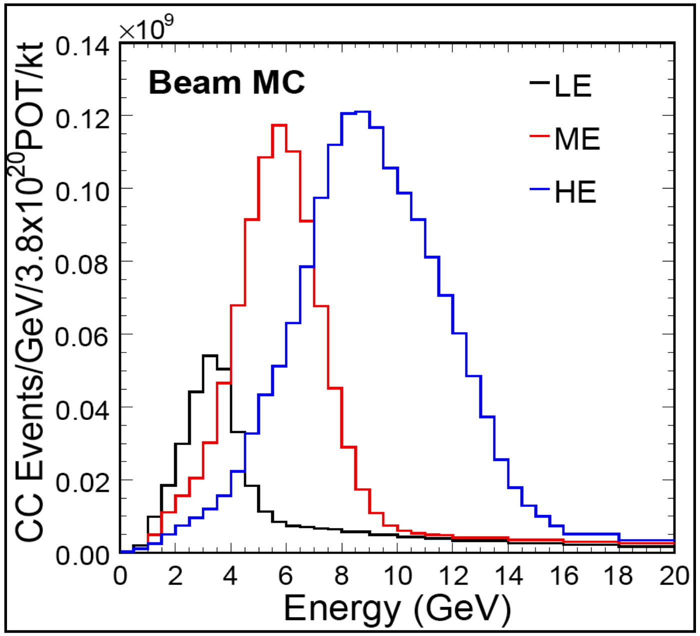
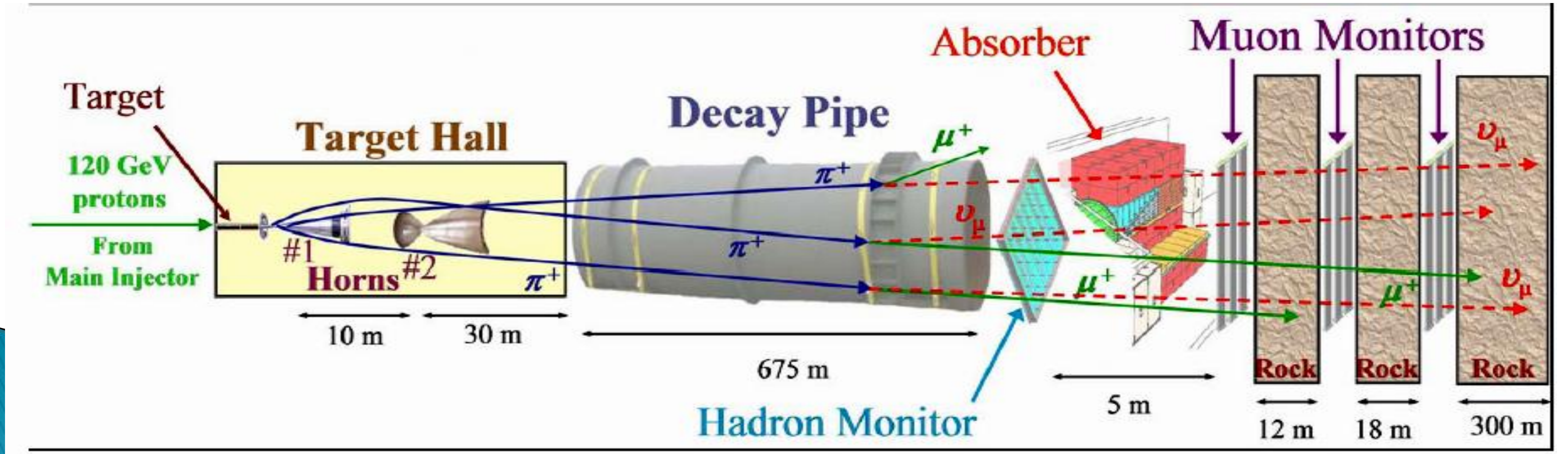
Hampton Group Meeting
Nov. 3, 2009

NuMI Beam

- Movable graphite target for flux studies
- Reversible horn current allows for ν_μ or ν_μ-bar beams
- Variable beam energy
- 92.9% ν_μ, 5.8% ν_μ-bar, and 1.3% ν_e in low energy (LE) configuration



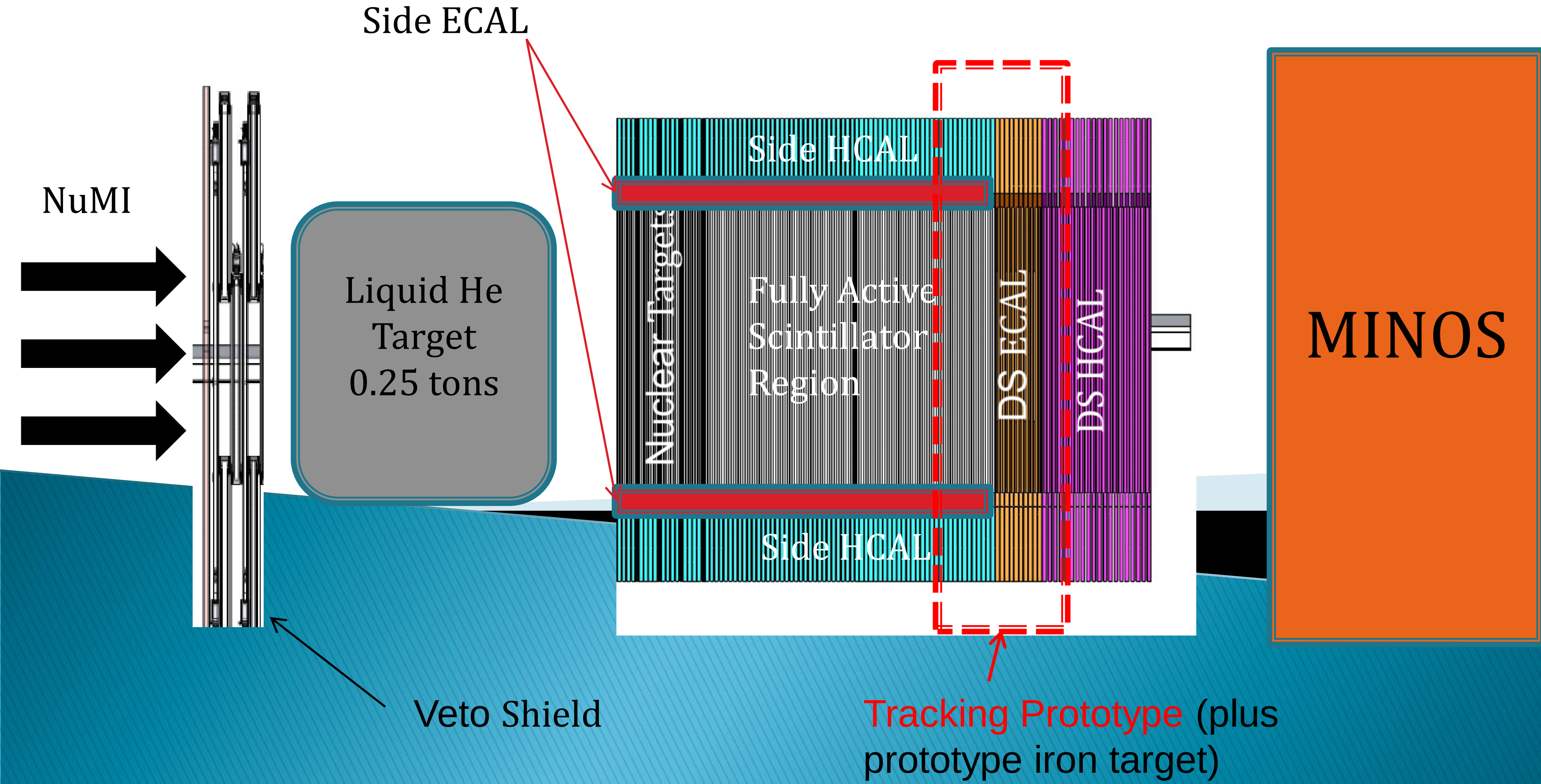


Pictures/plots retrieved from http://www-numi.fnal.gov/talks/postedtalks.html

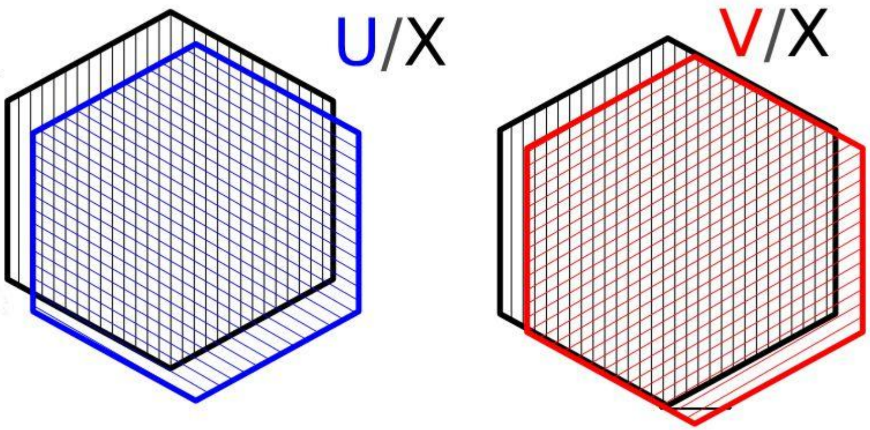
MINERvA Diagram

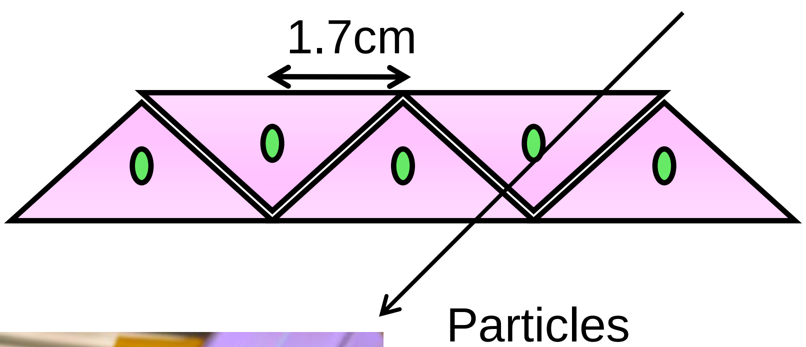
	Module/Frame	Scintillator Planes
Nuclear Targets	18	36
Active Target	60	120
DS ECAL	10	20
DS HCAL	20	20
Totals	108	196

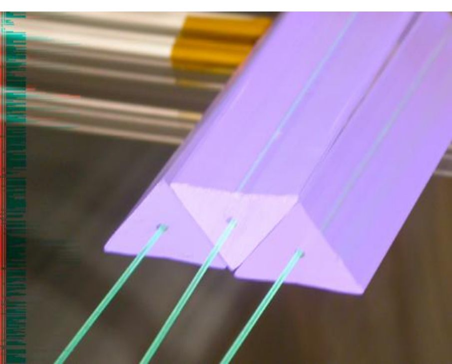
MINERvA: Main INjector ExpeRiment for ν-A



Detector Design

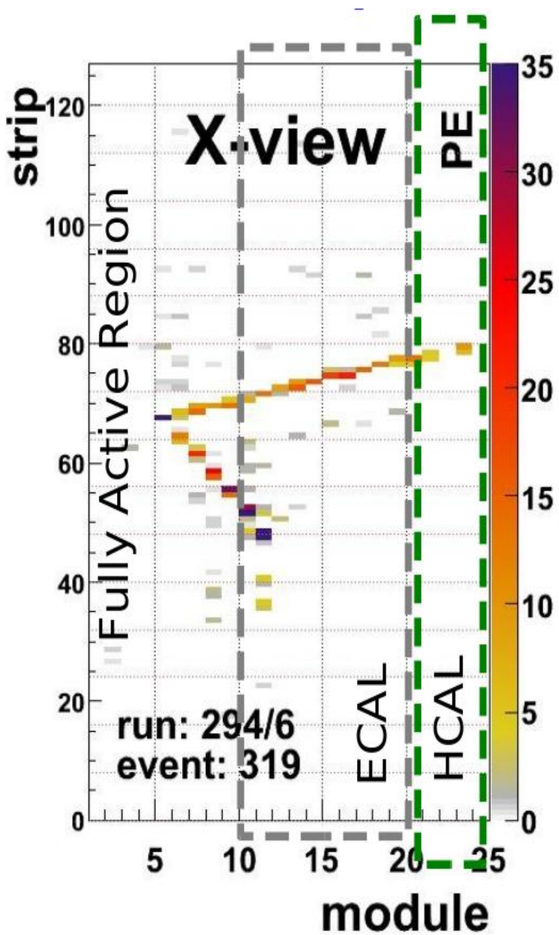


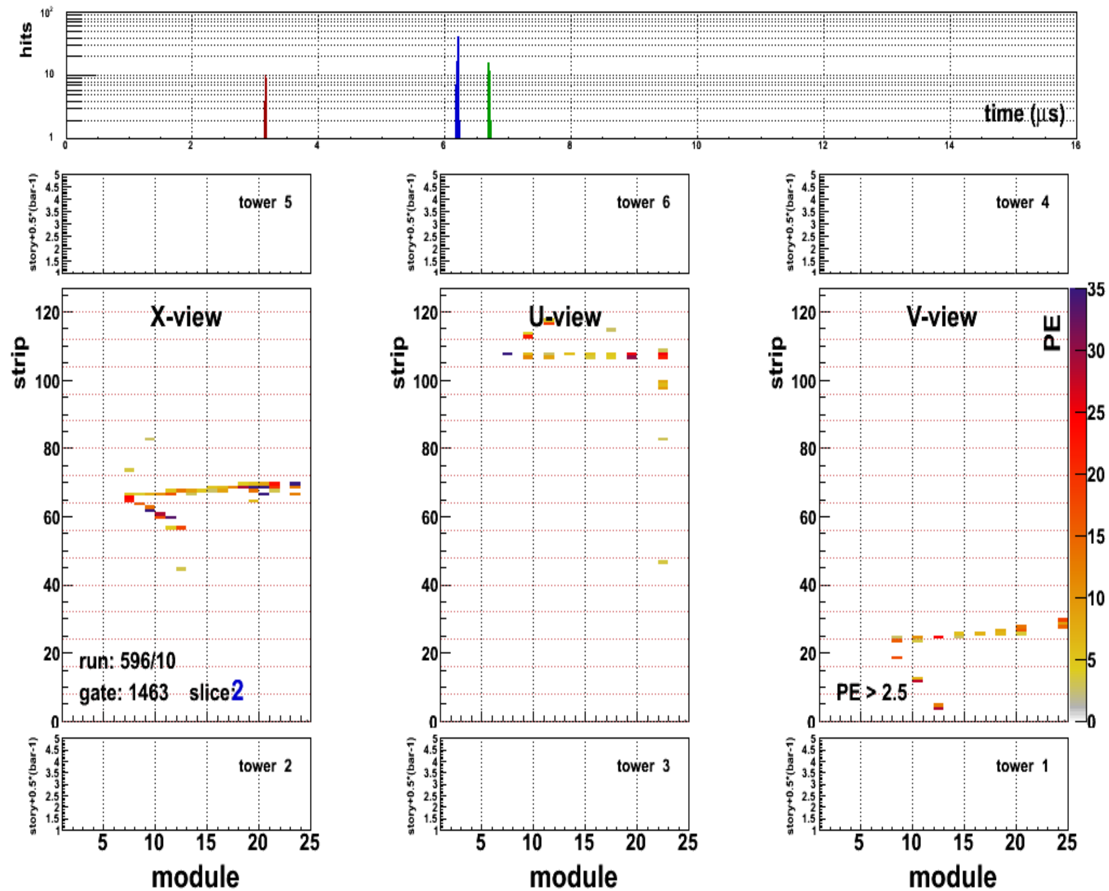




1	22	u x	Tracker Modules
2	21	v x	
3	20	u x	
4	19	v x	
5	18	u x	
6	17	v x	
7	16	u x	
8	15	v x	
9	14	u x	
10	13	v pb/x	
11	12	pb/v pb/x	DS ECAL Region
12	11	pb/u pb/x	
13	10	pb/v pb/x	
14	9	pb/u pb/x	
15	8	pb/v pb/x	
16	7	pb/u pb/x	
17	6	pb/v pb/x	
18	5	pb/u pb/x	
19	4	pb/v pb/x	
20	3	pb/u x	
21	2	steel v	HCAL
22	1	steel x	

Events: Quasi-elastic Candidates





M. Kordosky

$\nu_\mu + n \to \mu^- + p$

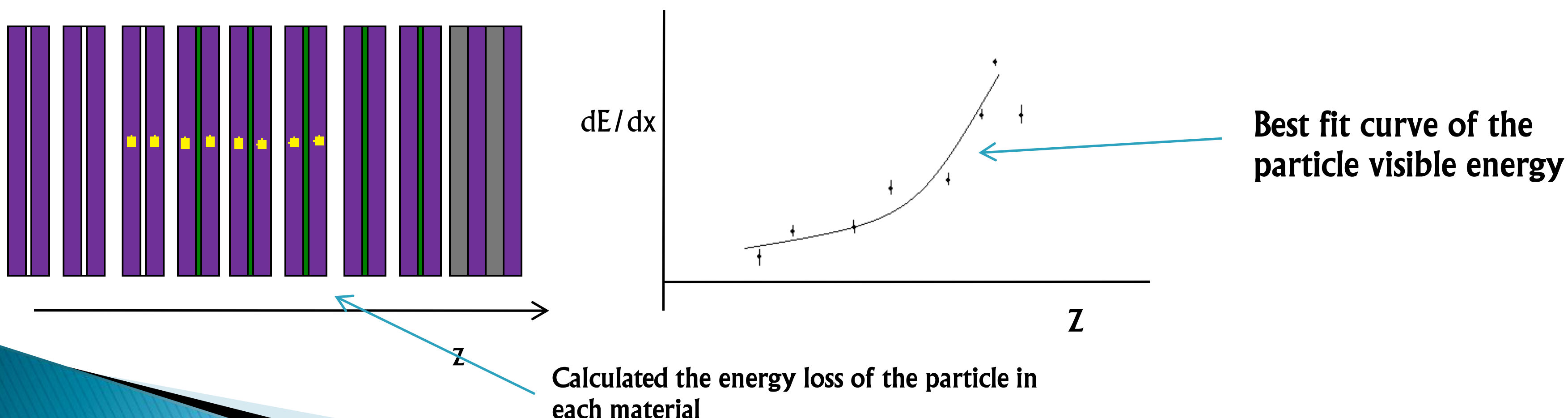
Two different events: Both have long track exiting detector (muon) and short contained track with increased dE/dx at endpoint (proton)

Methods for Momentum Reconstruction

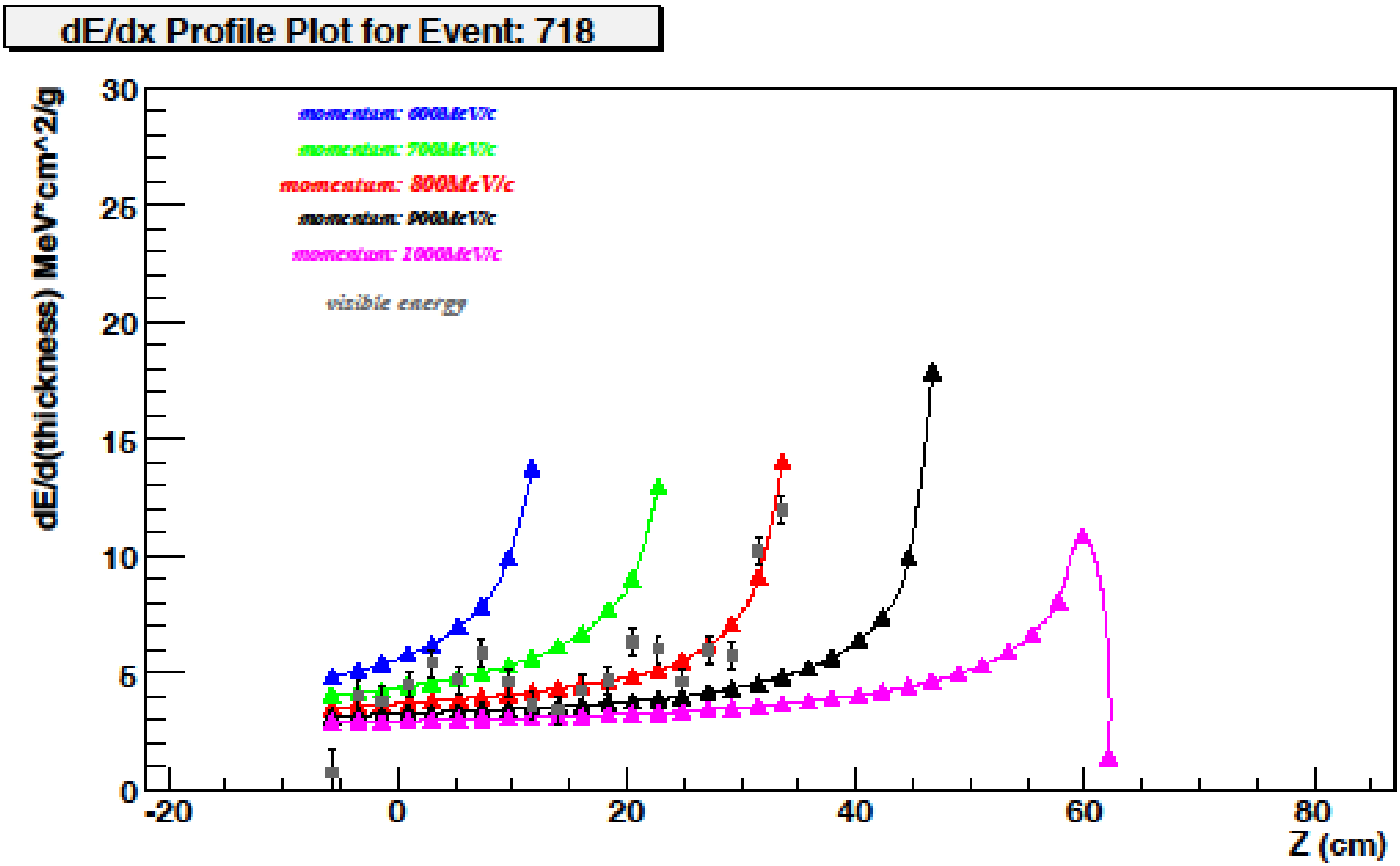
- Sum the total reconstructed track's visible energy to estimate the initial momentum, used the estimate initial momentum to calculate missing non-visible energy, and then iterate the initial and missing momentum to correct for the momentum.
- Using the range tables, find the range of the reconstructed track in all material and then trace it back to a reconstructed momentum.
- Fit the reconstructed track's visible energy dE/dx profile to an expected energy loss profile.

Momentum Reconstruction Method

- Fitted the dE/dx profile of the reconstructed track's visible energy to a calculated <dE/dx>avg profile of a particle's visible energy for various incident momenta, where the path length of the materials and the vertex plane depended on the trajectory of the reconstructed track and the <dE/dx>avg per material was calculated at the z position in each layer.
- Used the chi squared test search algorithm to find the best fitted incident momentum for the reconstructed track.



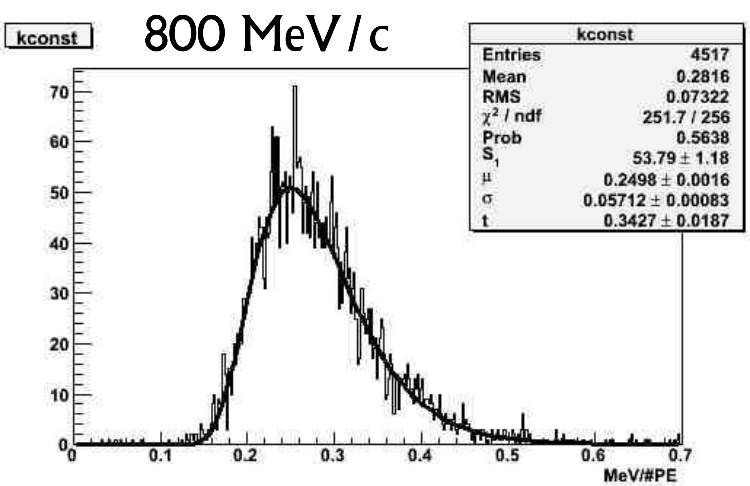
dE/dx profile plot

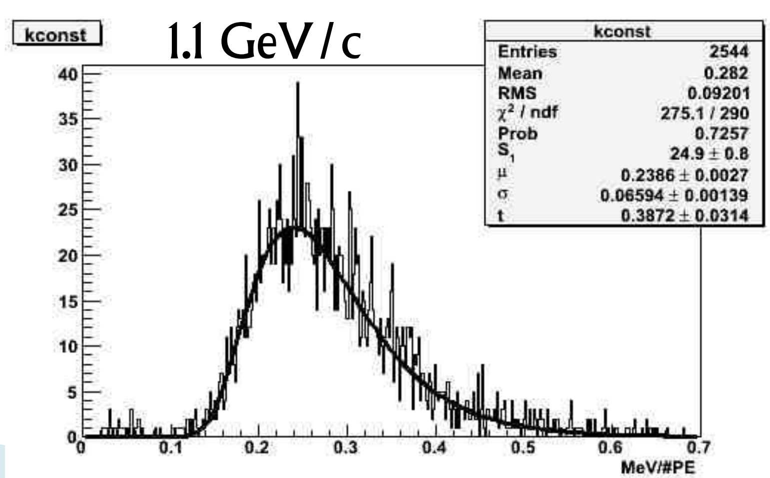


Converting from PE to MeV: Using mono-energetic straight going through proton tracks

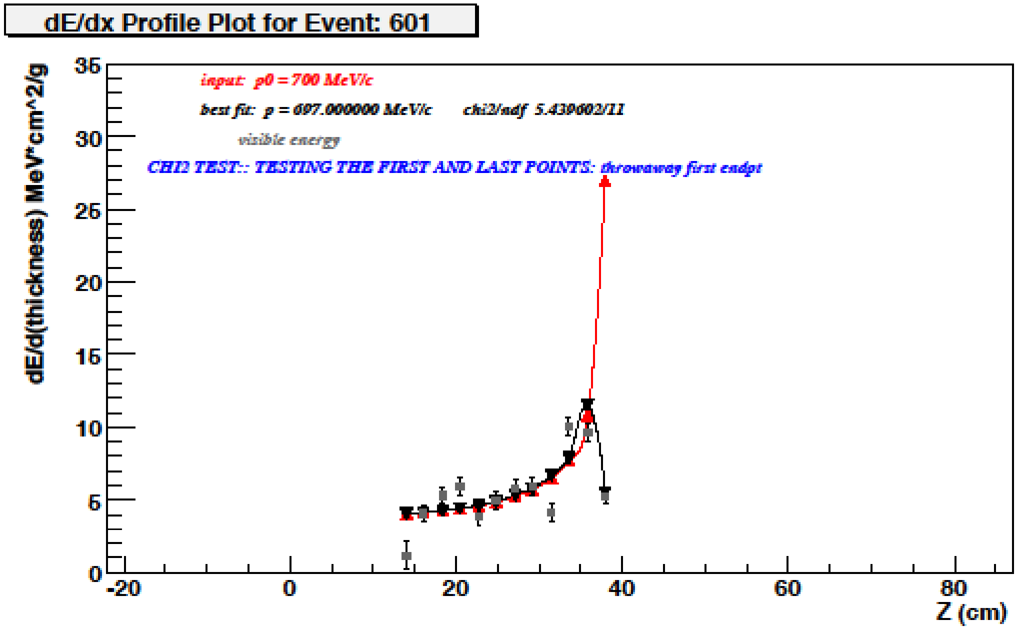
- Using the ParticleCannon, generated individual proton data files at the face of the TP of a momentum which equal only 700MeV/c , 800MeV/c, 900MeV/c, 1.0GeV/c, 1.1GeV/c, 1.2GeV/c or 1.3 GeV/c.
- In principal, we can take the ratio of the expected <dE/dx>avg and measured energy (cluster PE) per plane to find a conversion constant from MeV to PE
- Used the Bethe-Bloch to calculate the expected visible <dE/dx>avg and Birk's Law to correct for the expected <dE/dx>avg per plane scintillator light output response, where the birk's constant was obtained for Sim. $k_i = \frac{\Delta E_{avg_i}(1 + k_b(\frac{dE}{dx})_{avg_i})}{Clus\_PE_i}$, excluding the first and last node on a reconstructed track.
- Took the average of the mean of the data from each distribution.

$$0.28276\frac{MeV}{PE} \pm 0.003525$$



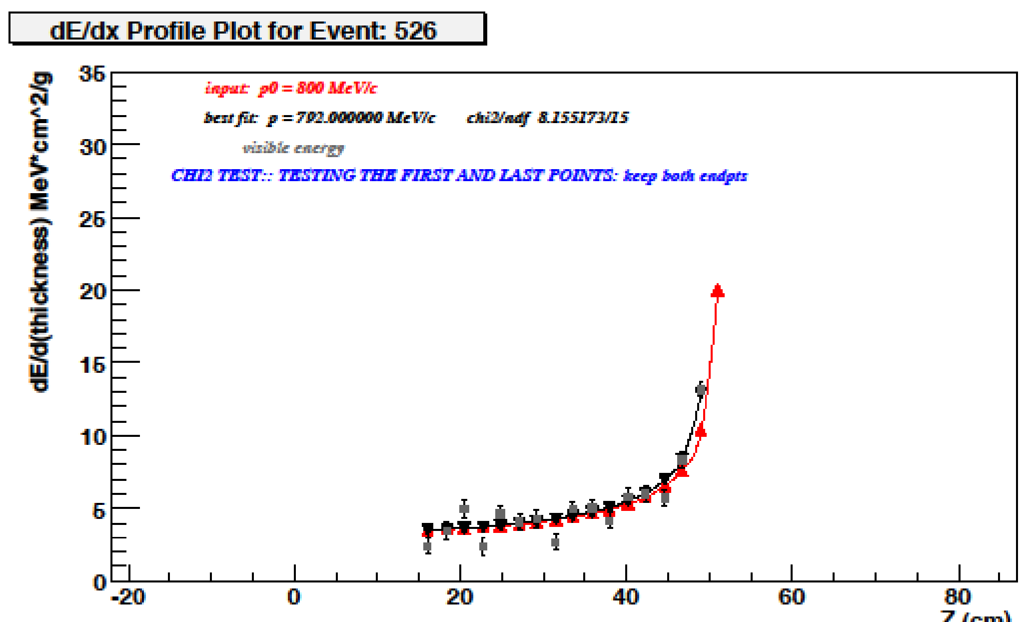


Examples of dE/dx Profile Fits

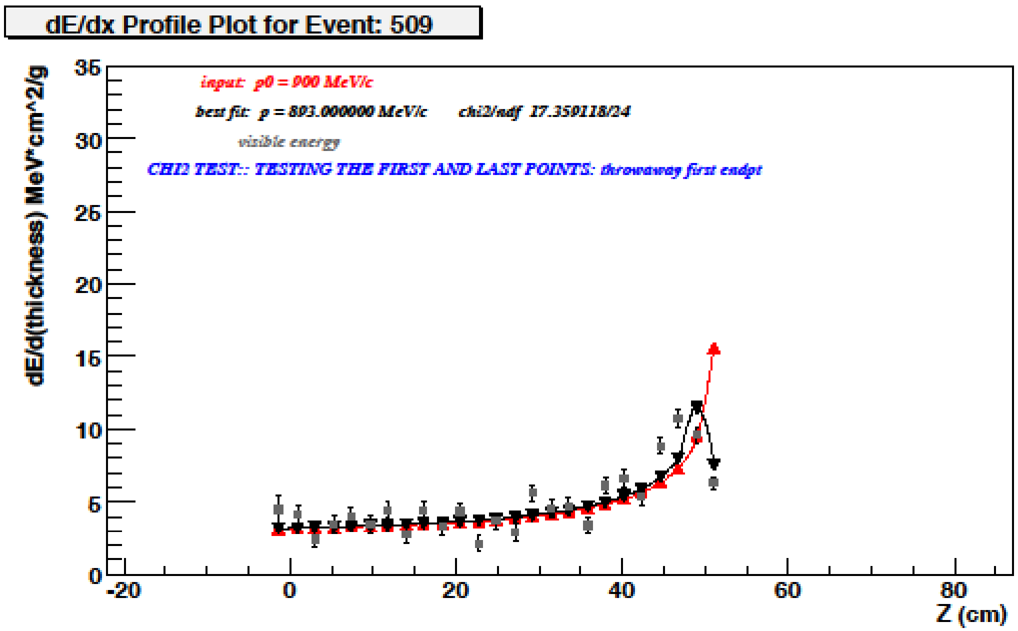


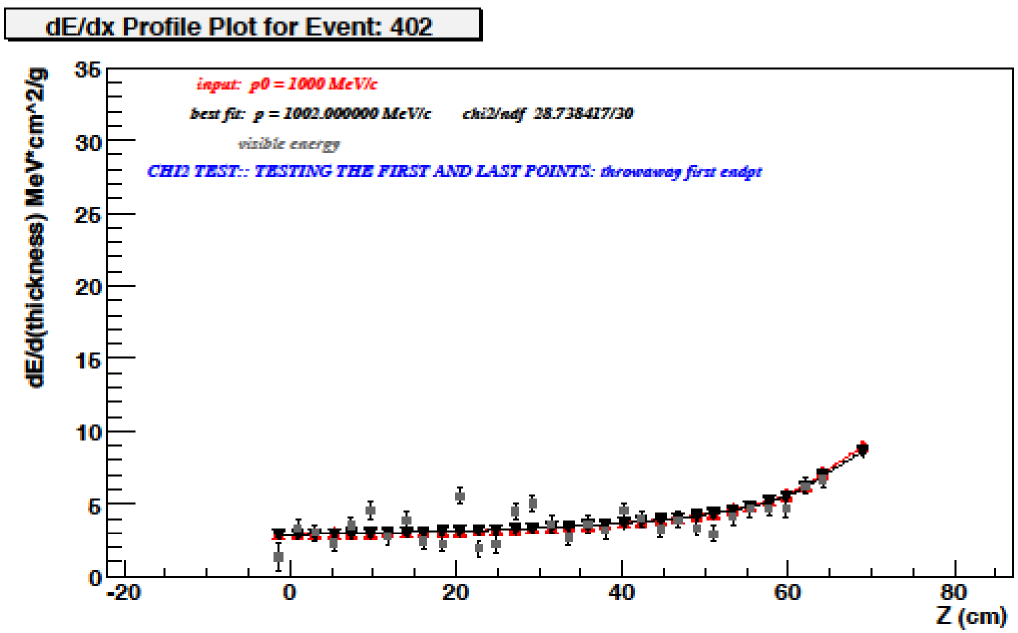
- ➢visible energy: reconstructed track's dE/dx, where the error bars correspond to an approximated width of the energy straggling plus an estimated 5% error due to the optical model
- ➢input p0: the generated momentum
- ➢best fit p: the reconstructed momentum from the best chi^2 value
- ➢path length is calculated from the reconstructed track's trajectory
- ➢ Chi2 test: tests the vertex's plane and the last plane energy deposition of a recon trk

- ➢theta: 3degrees to 33degrees
- ➢Generate vertices X and Y with the fiducial volume
- ➢Z: -20.8cm to 19.2cm

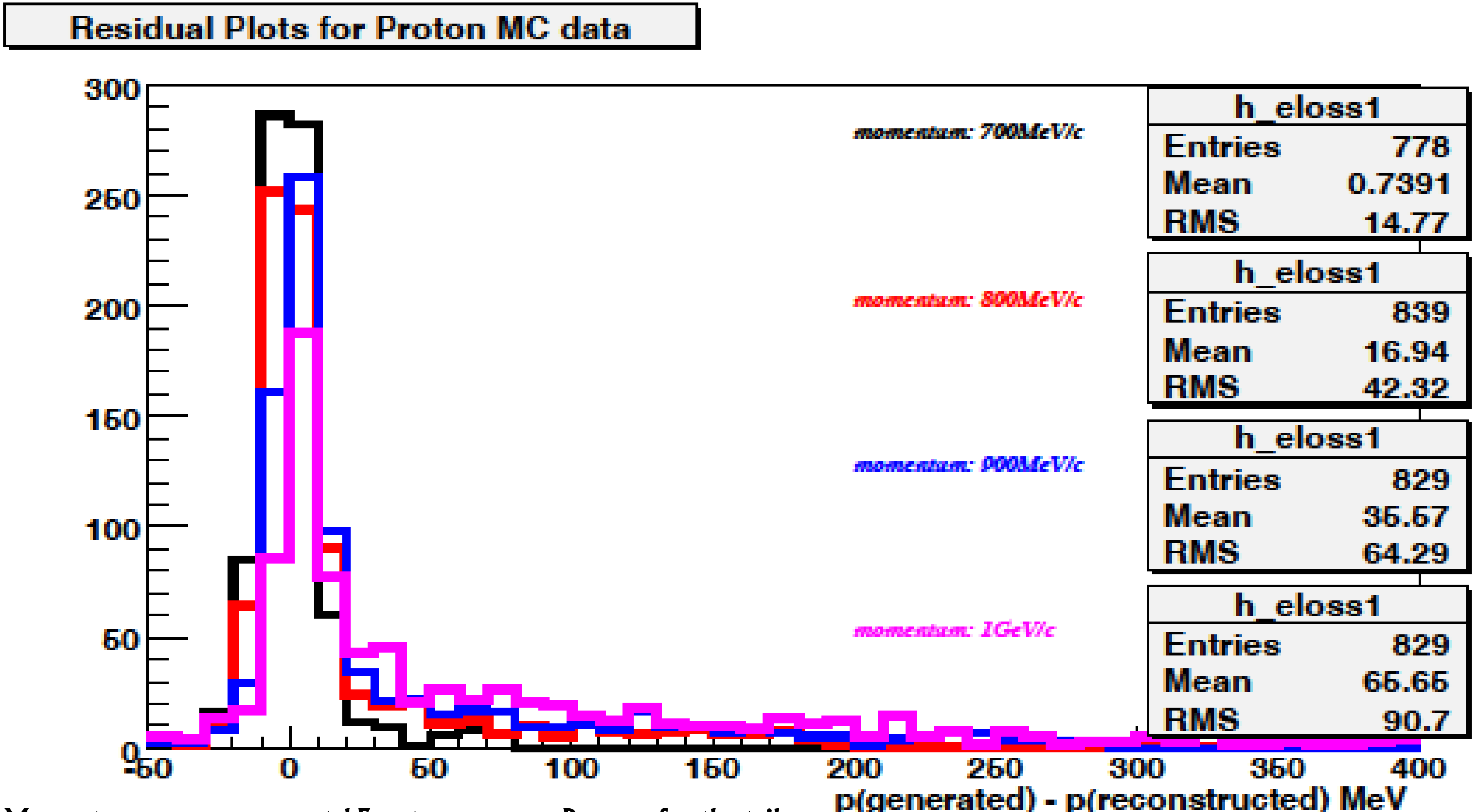


Examples of dE/dx Profile Fits





Momentum Residuals



Momentum	trkEvents
700MeV/c	778/1000
800MeV/c	839/1000
900MeV/c	829/1000
1GeV/c	829/1000

Reasons for the tails

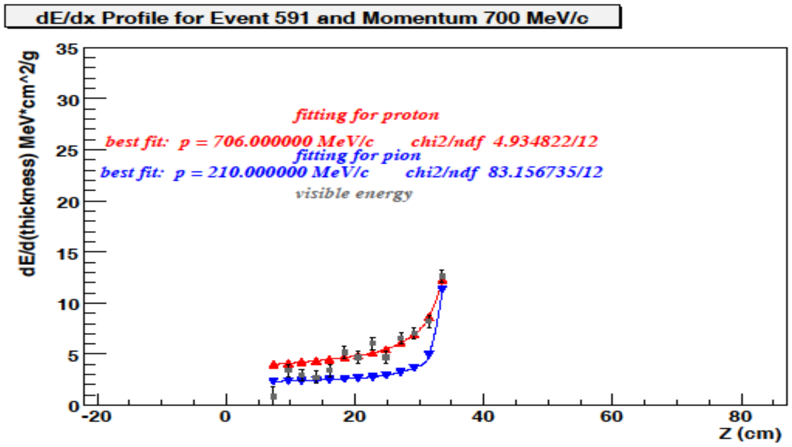
- Energy straggling
- Secondary Nuclear interaction

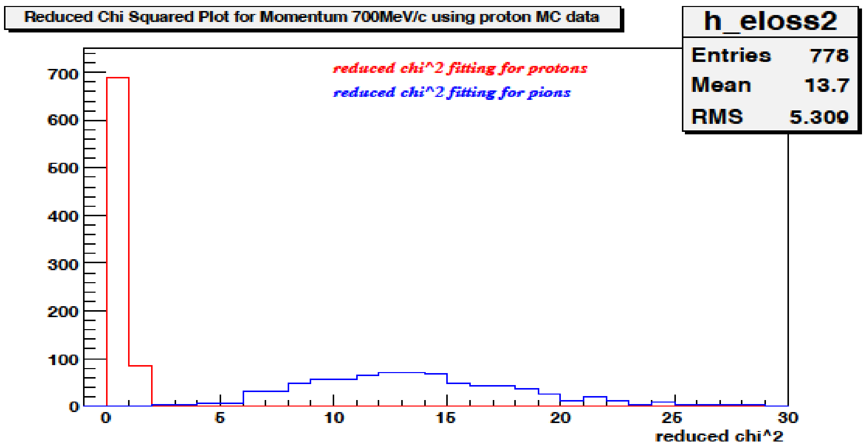
Probability of Nuclear Interaction in the SCINTILLATOR

- 20cm => 20%
- 30cm => 32%
- 40 cm => 40%

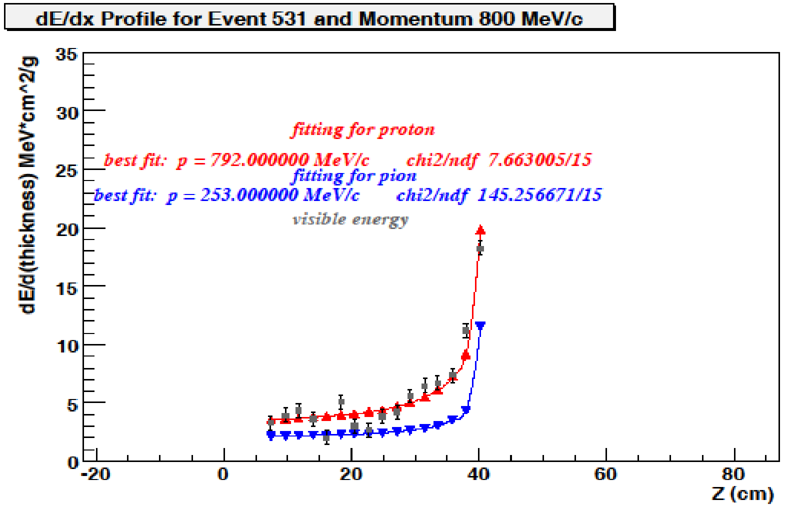
- Using the dE/dx profile plots, can one discriminate proton from pion, by changing the mass from proton to pion?

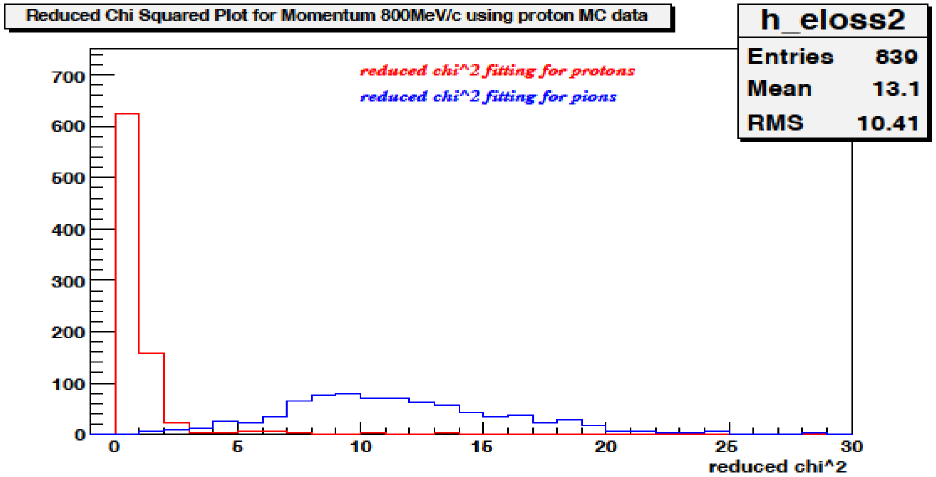
Discrimination of Protons and Pions





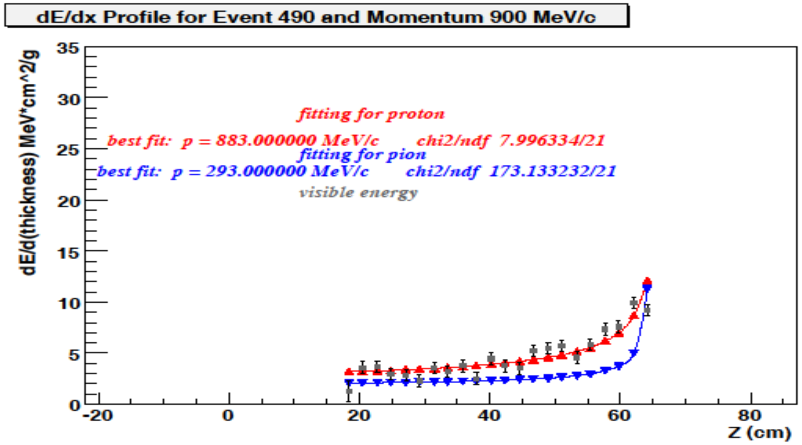
In an event by event comparison of reduced chi squared:
Total Events = 778
Protons = 778 Pions = 0 Efficiency = 100%

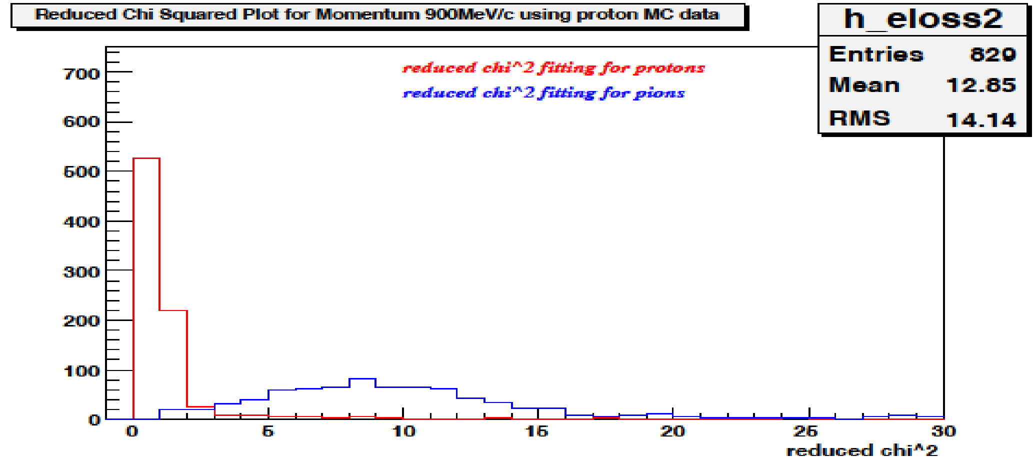




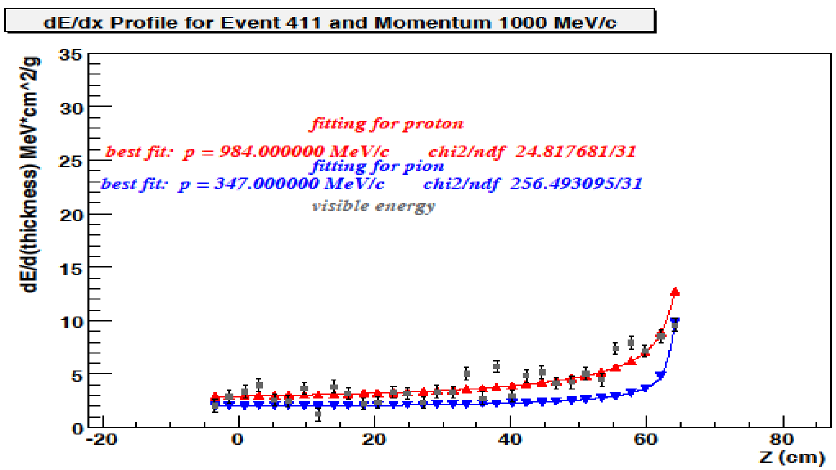
In an event by event comparison of reduced chi squared:
Total Events = 839
Protons = 839 Pions = 0 Efficiency = 100%

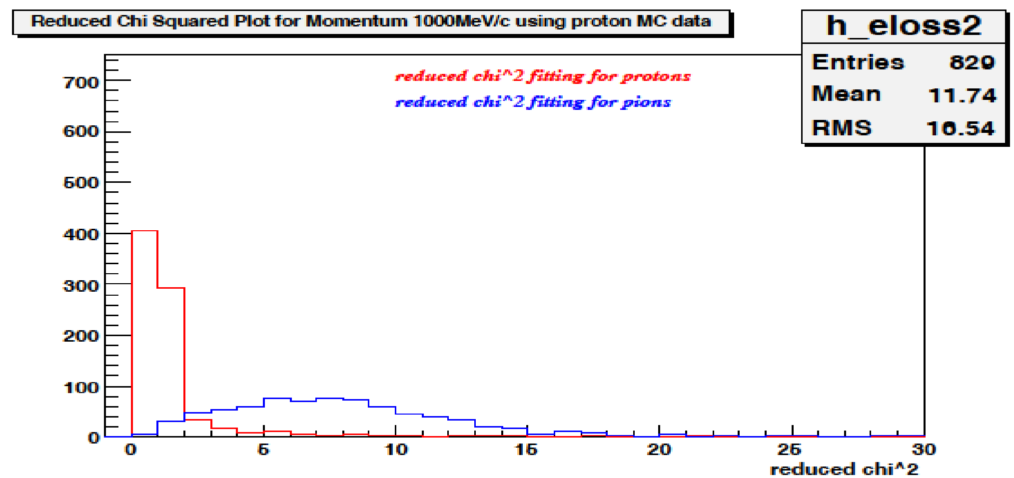
Discrimination of Protons and Pions





In an event by event comparison of reduced chi squared:
Total Events = 829
Protons = 826 Pions = 3 Efficiency = 99.6%

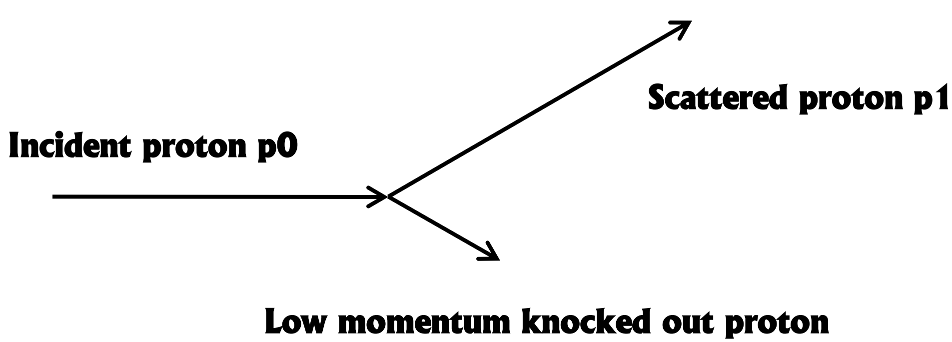




In an event by event comparison of reduced chi squared:
Total Events = 829
Protons = 824 Pions = 5 Efficiency = 99.4%

Secondary Nuclear Interaction

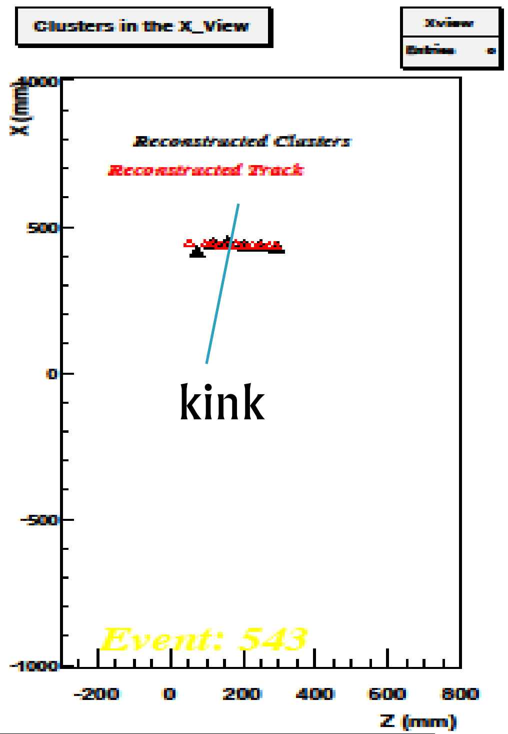
Proton to proton collision (p->2p)

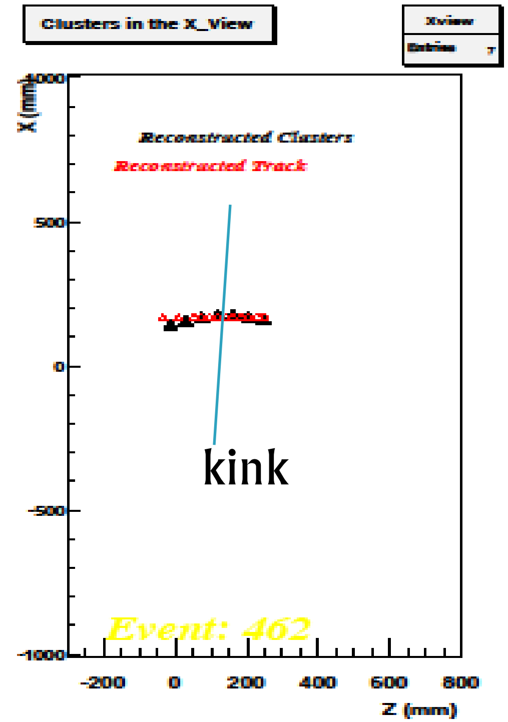


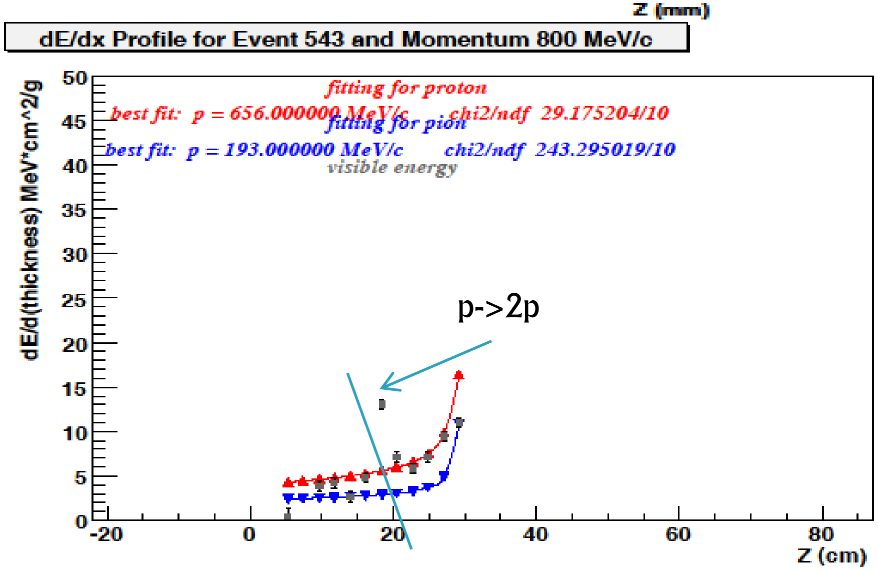
Evidence of p->2p

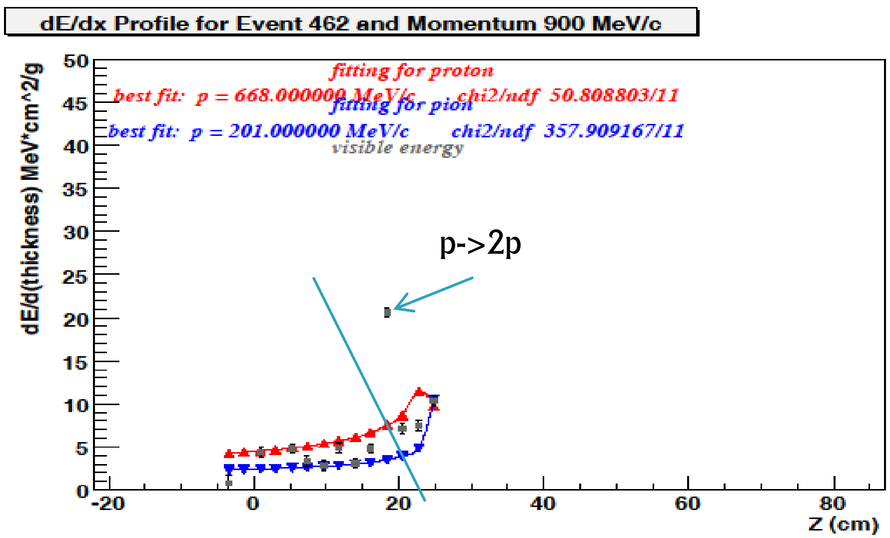
- Kink in the reconstructed track
- Low momentum knocked out proton will deposit energy in very few layers
- Around the kink in the track you will see a very large energy deposition
- The scattered proton will have a lower momentum

Nuclear Interaction Candidates

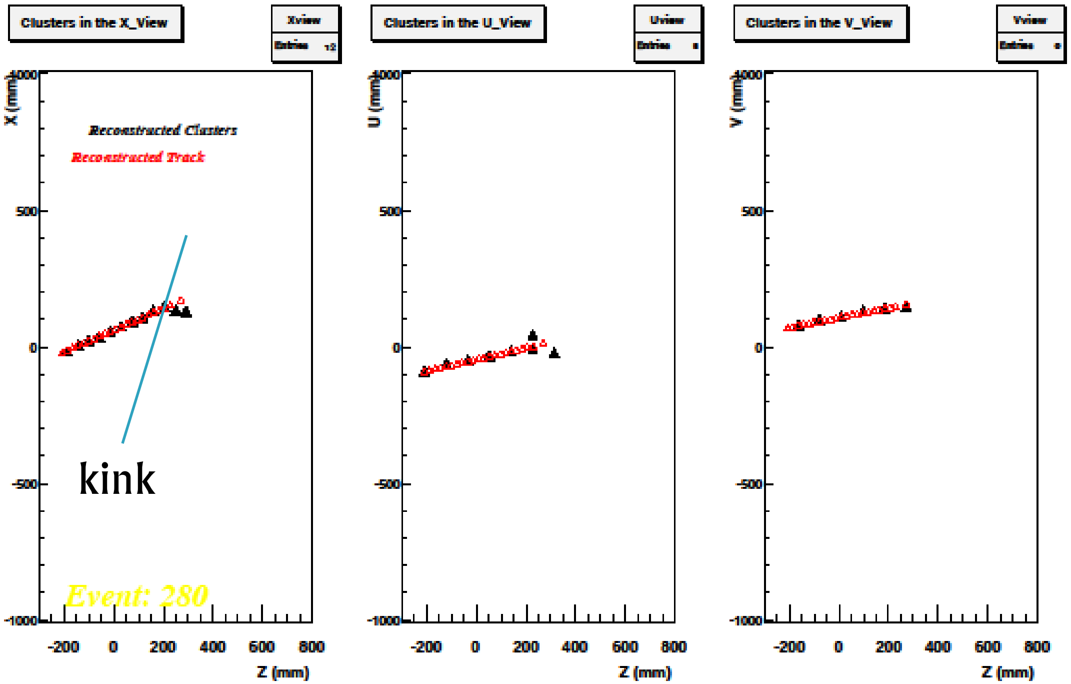


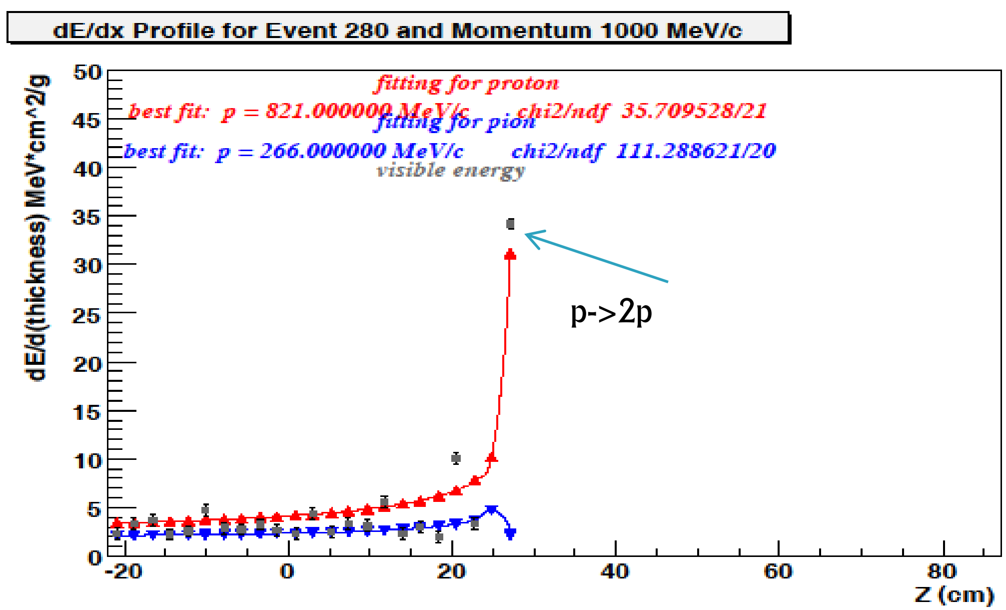




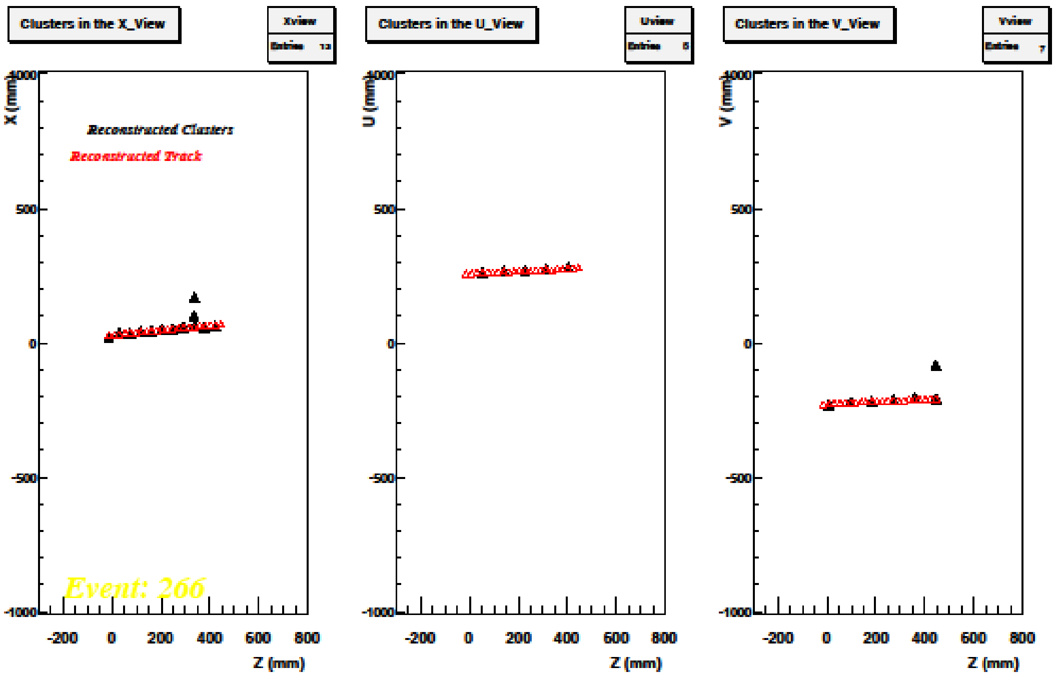


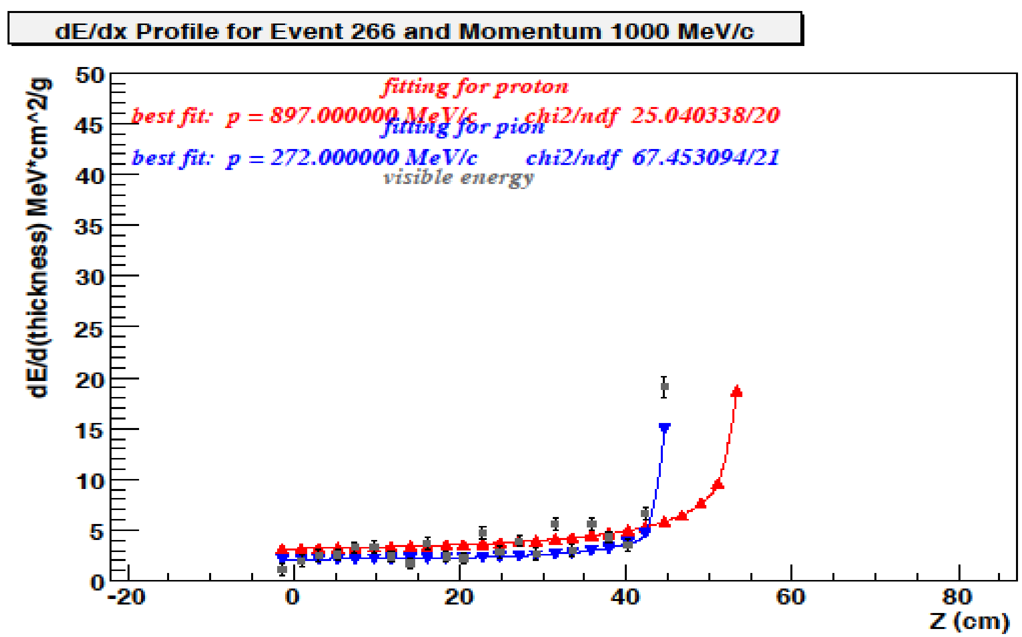
Nuclear Interaction Candidates



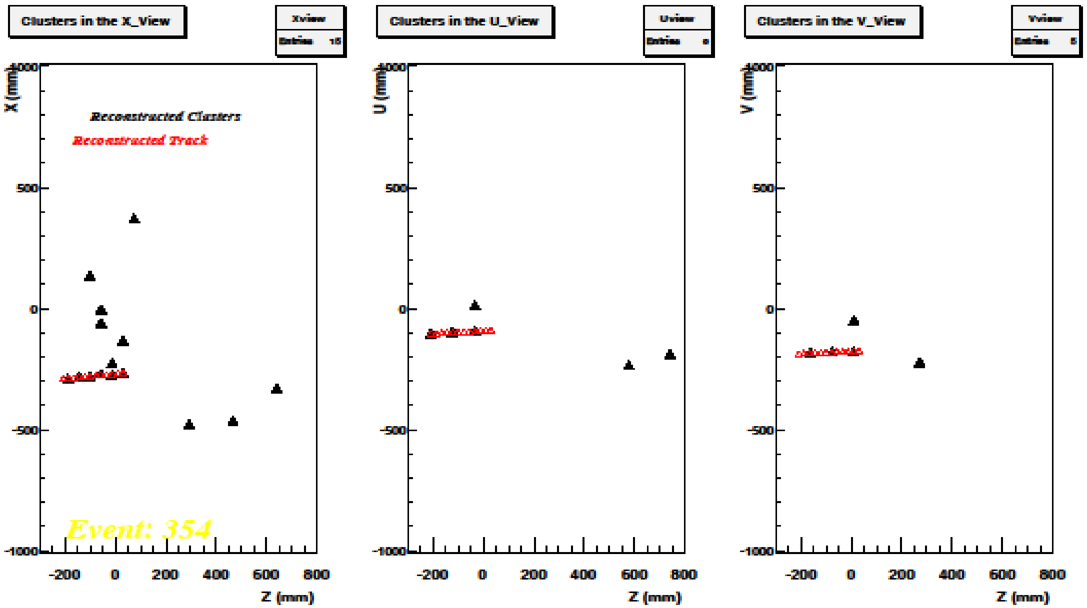


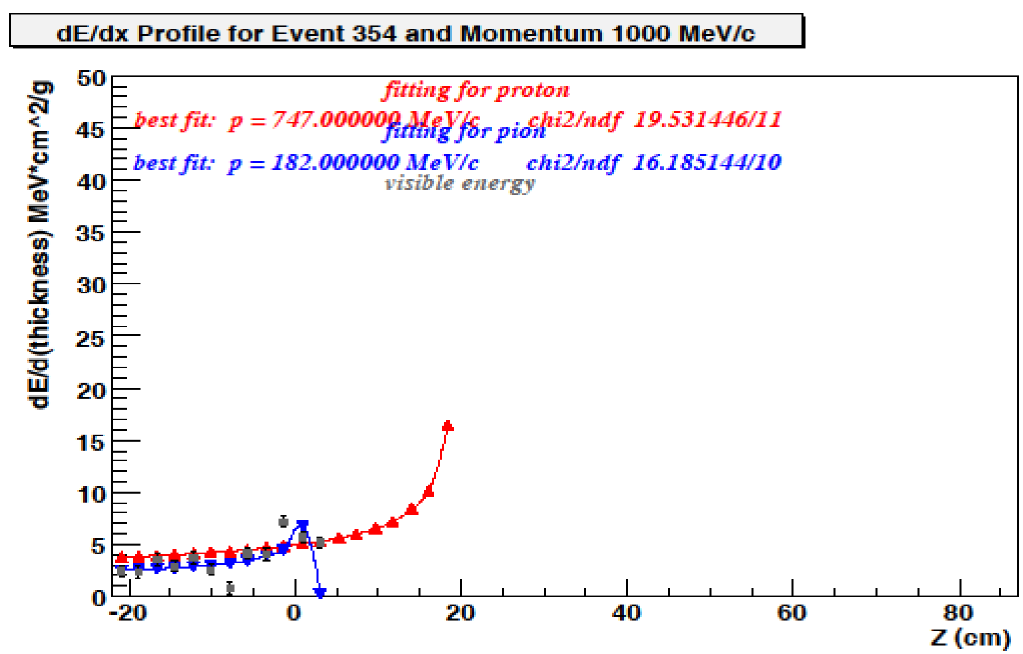
Proton that could look possible like a Pion





Proton that looks like a Pion





EnergyLoss Tool

- Input: track (nodes, clusters, clusterPE)
- Output: reconstructed momentum, mass
- May work for proton, pion, and muon tracks leaving the HCAL rear or side providing if there is enough information
- Working with Benjamin to implement it into the KalmanFilter Tool

Improvement to the EnergyLoss Tool

- Develop an algorithm which recognizes reconstructed tracks that includes secondary nuclear interaction.
- Study the momentum of the reconstructed track before and after the interaction.
- Can we do kinematics for p->2p collisions?