Software Improvement for Liquid Argon Neutrino Oscillation Physics

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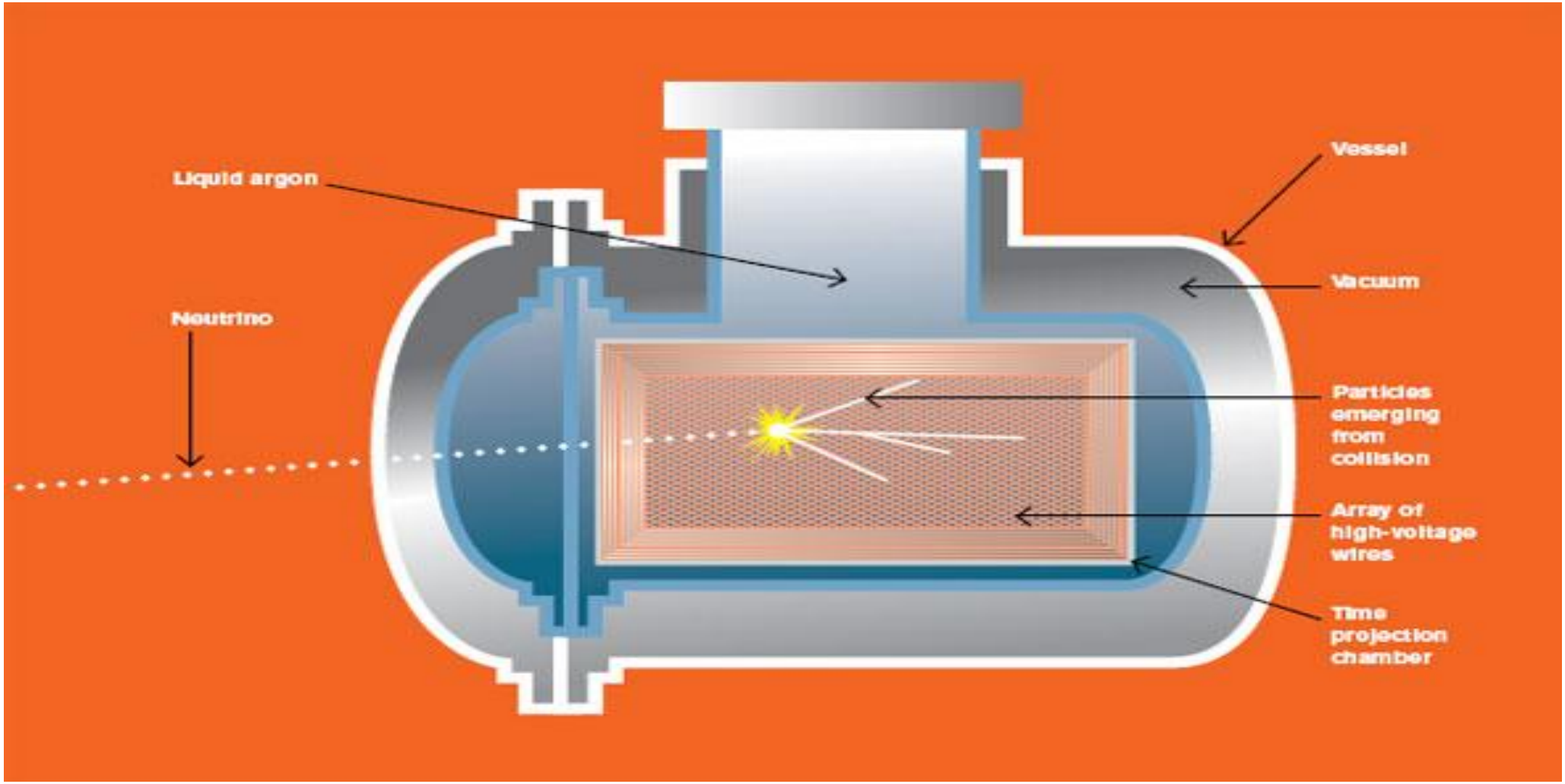
LArTPC

- **L**iquid **Ar**gon **T**ime **P**rojection **C**hamber
- Reasons for using Argon
- Purpose of LArTPC experiments

ArgoNeuT

- How does it work?



Neutrino Beam Physics

- What are neutrinos?
  - Why neutrinos?
- Neutrino oscillations
  - What is neutrino mixing?

Challenges in Programming

- Learning to use C++
- Programming within a framework (LArSoft)
- Programming for detector independence

Calculating Resolutions

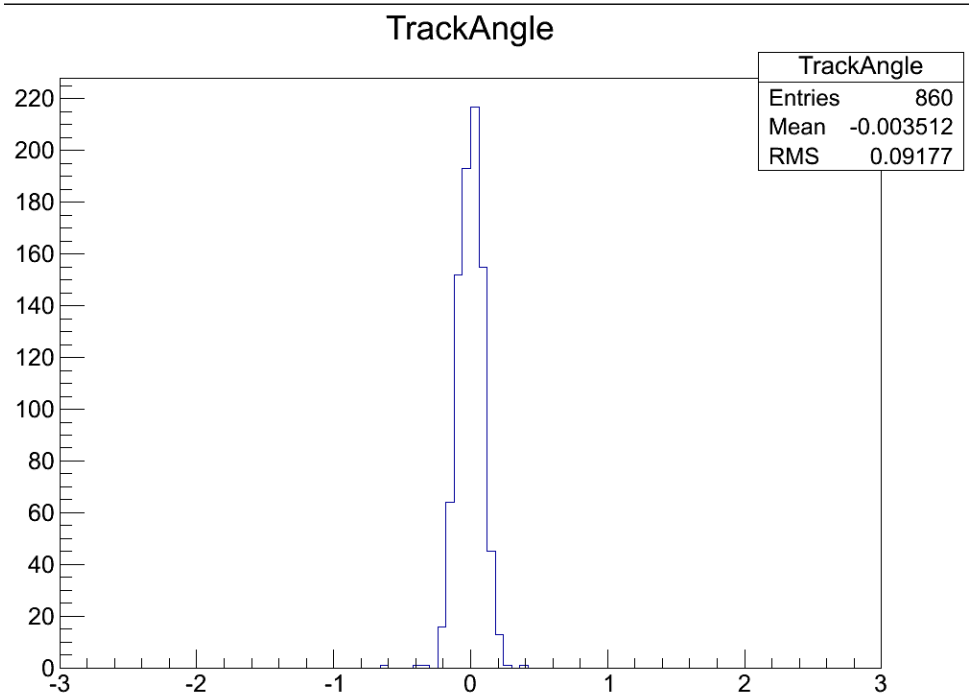
By Deana Del Vecchio

Goals:

- Calibrating the uncertainty of the timing differences between wires

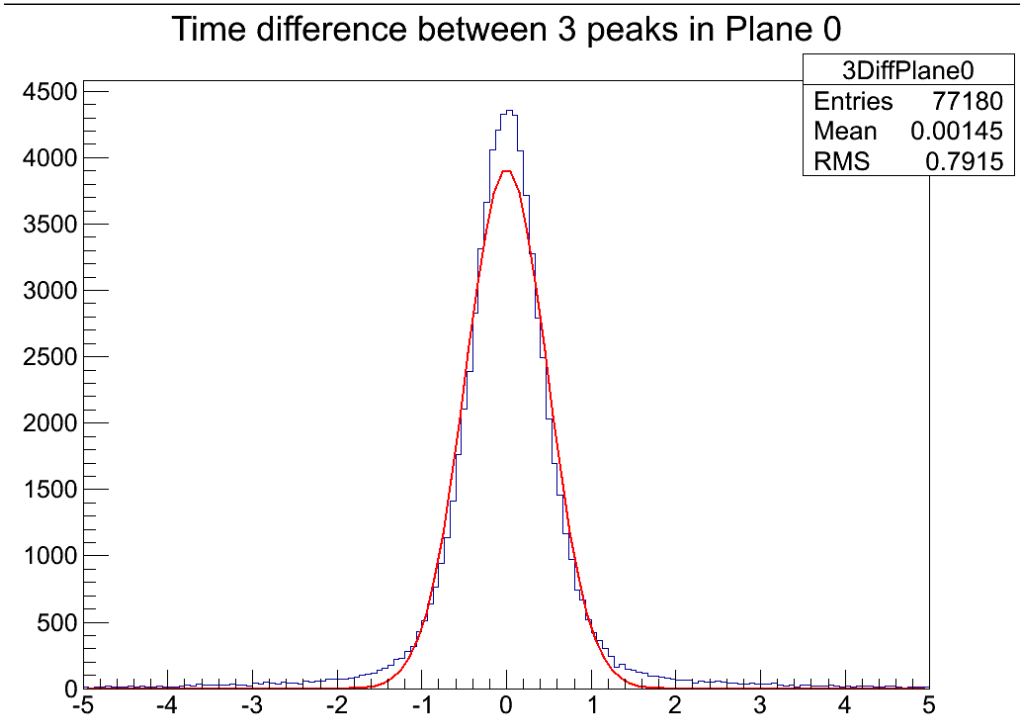
- Calculating the angular resolution between track like objects

Uncertainty on Wires

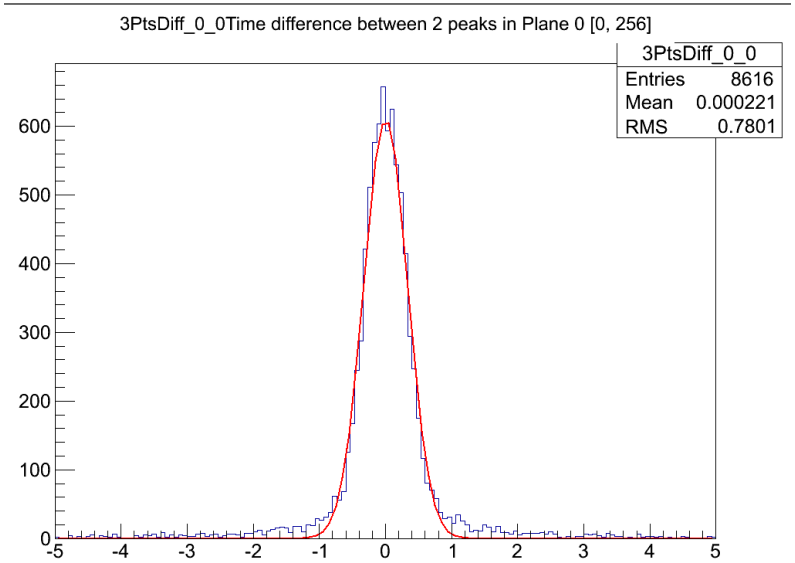


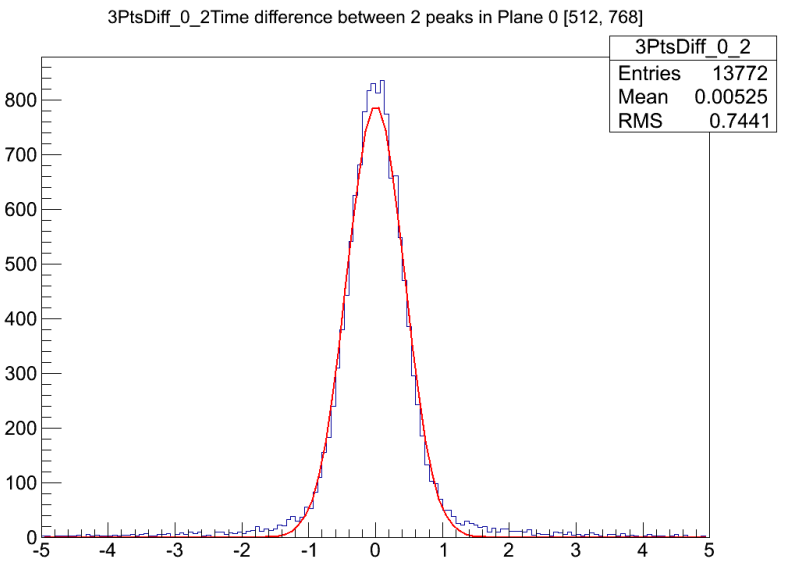
Spread in the angles

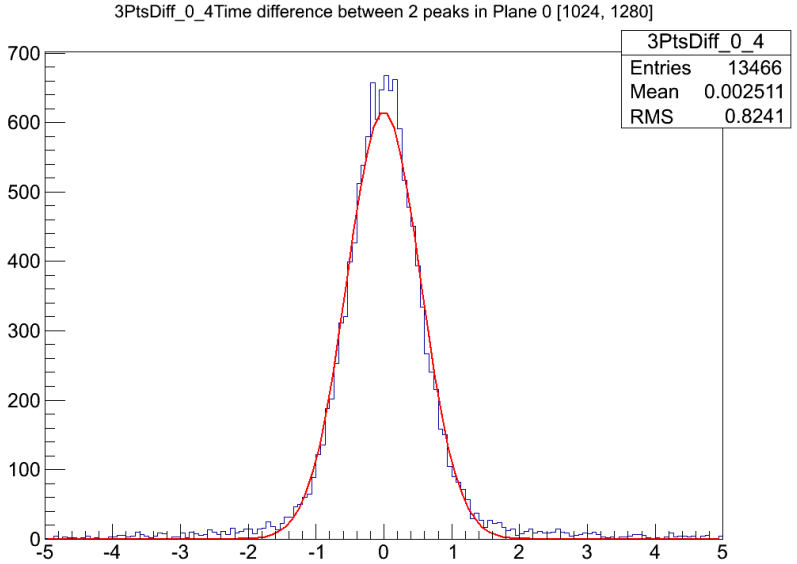
Timing difference between hits on three consecutive wires

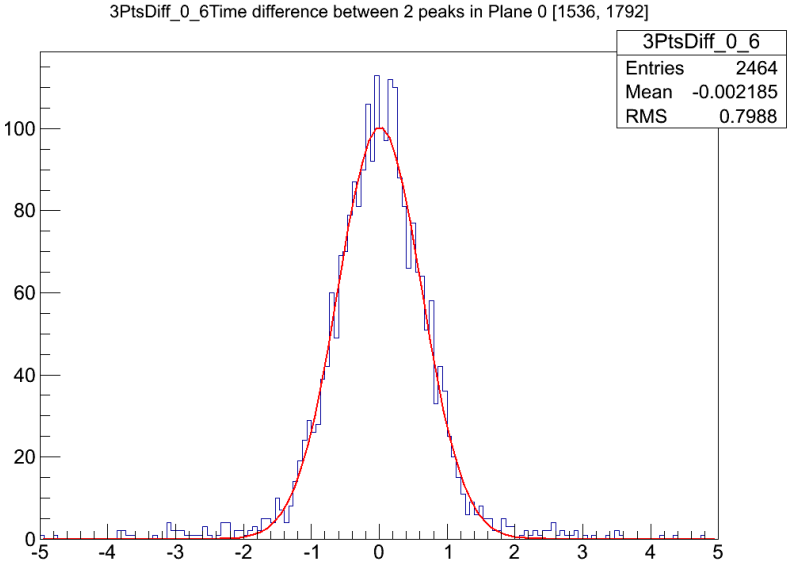


Timing spread (1,3,5,7)





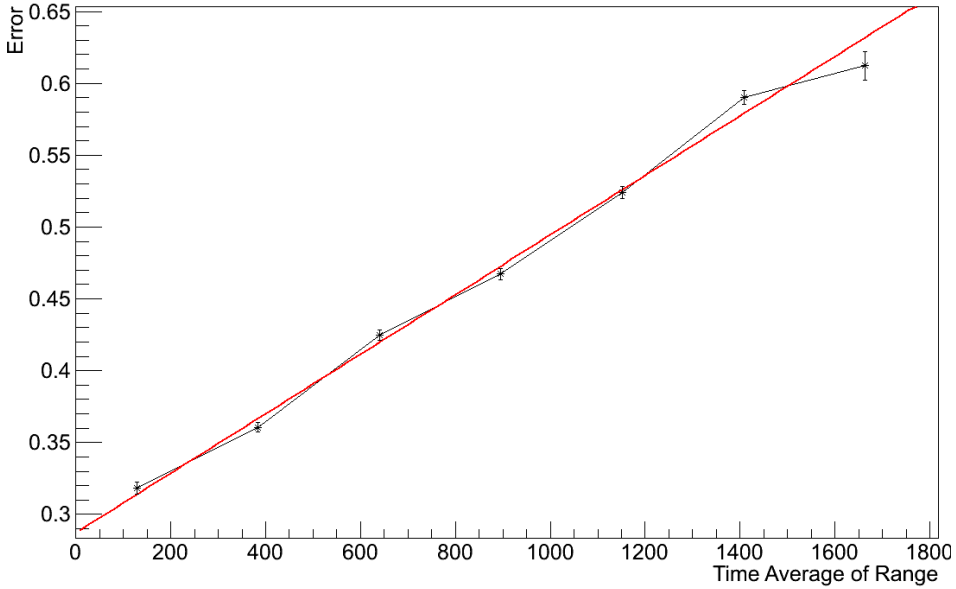




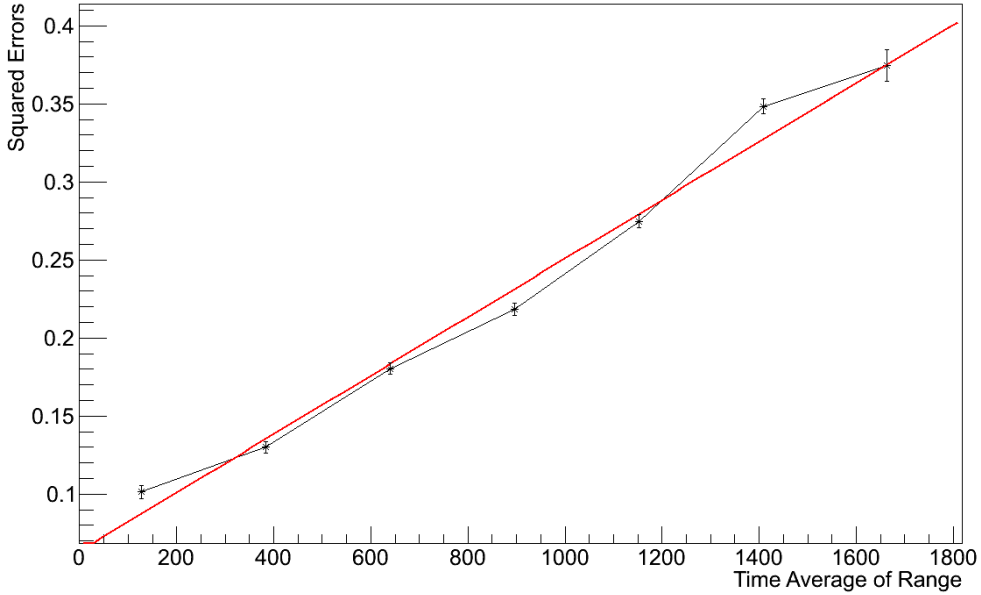
The Uncertainty

Graphs of the Error VS The Timing

Error

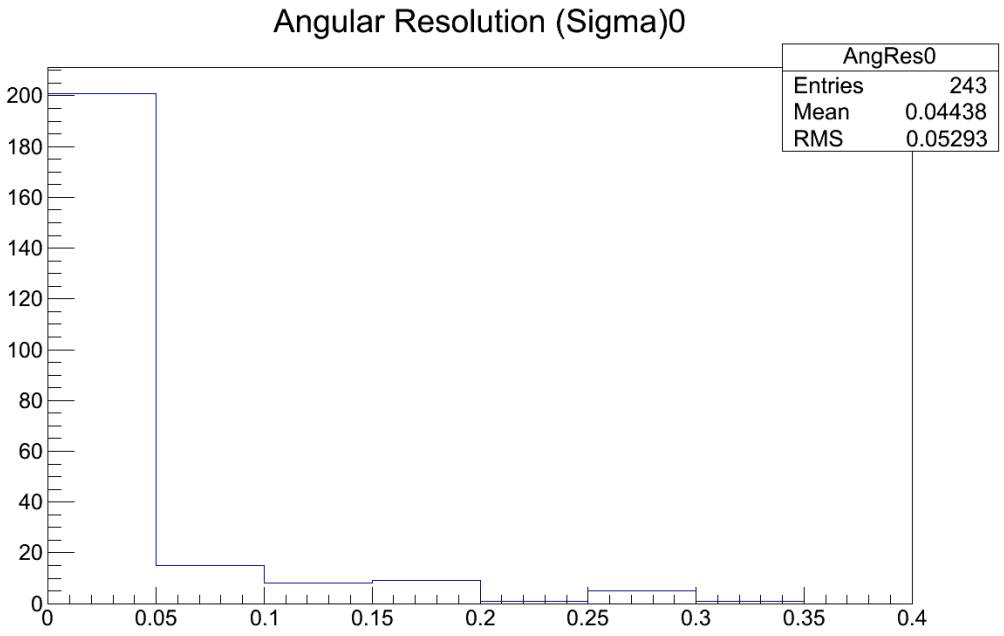


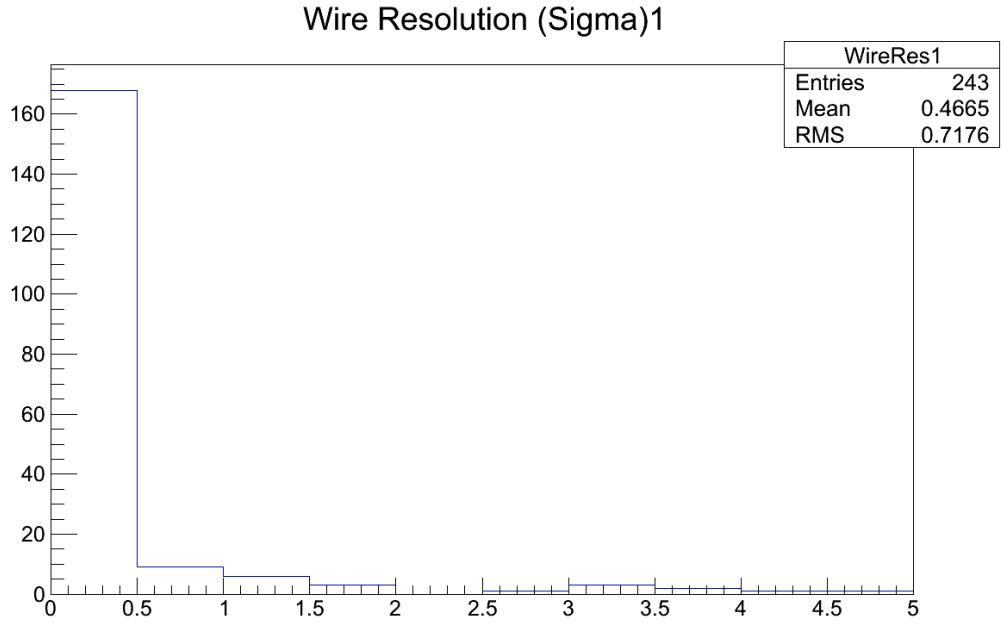
Squared Error



Differentiating between tracks

Can differentiate two track-like objects within .032 radians (~1.8°) and within 1 wire





Testing the Feasibility of Neutron Source for LArTPC in MicroBooNE Experiment and Birk's Constant Calibration

Big Picture

- Working in Liquid Argon Time Projection Chamber (LArTPC)
- All data simulated and analyzed in LArSoft program
- Testing the charge deposition of protons to measure Birk's Constant

During The Summer

- Programming in LArSoft
- Simulated experiments
- Tested saturation limits

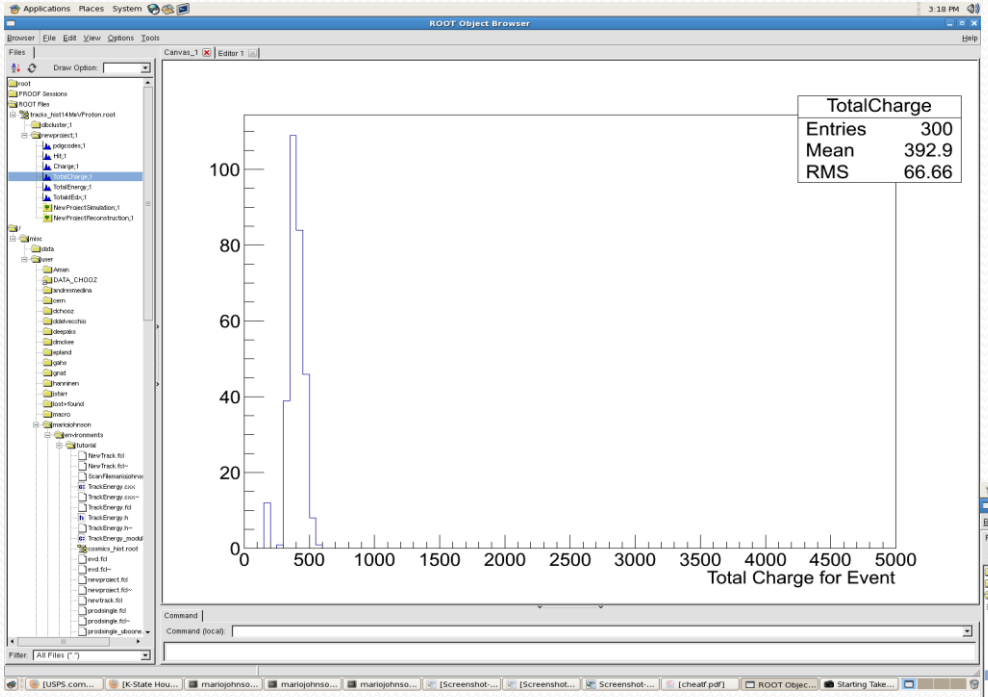
Reasons for Research

-
- Studying the relationship between neutron energy, proton energy and measured charge in the detector
- No naturally occurring proton sources
- Need different $\frac{dE}{dx}$ values (i.e. lower value for Muons and higher values for Protons)

Birk's Constant Calculation

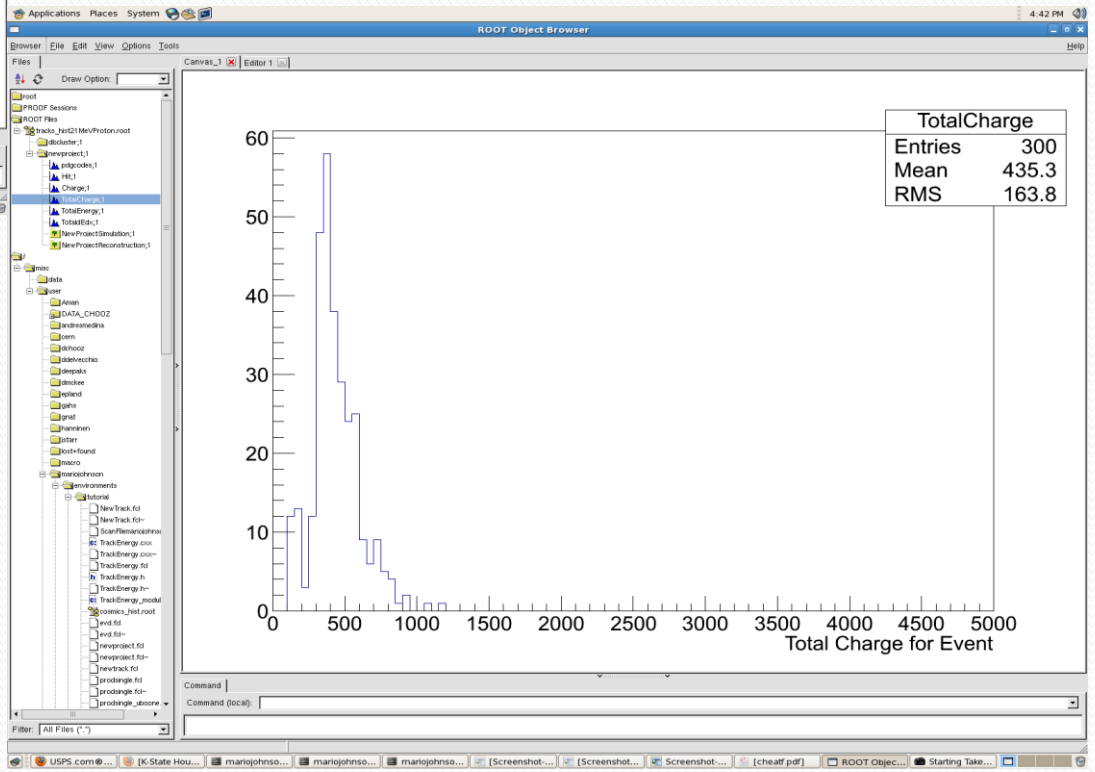
- $\Delta Q_0 = C \cdot \left(\frac{dE}{dx}\right) \cdot \Delta x$
- Ideal Situation:
  - $\Delta Q_D = k \cdot \Delta Q_0$
- Actual Situation:
  - $\Delta Q_D \approx k \frac{\Delta Q_0}{1 + K_B \cdot \Delta Q_0}$
    - K_B = Birk's Constant

Results

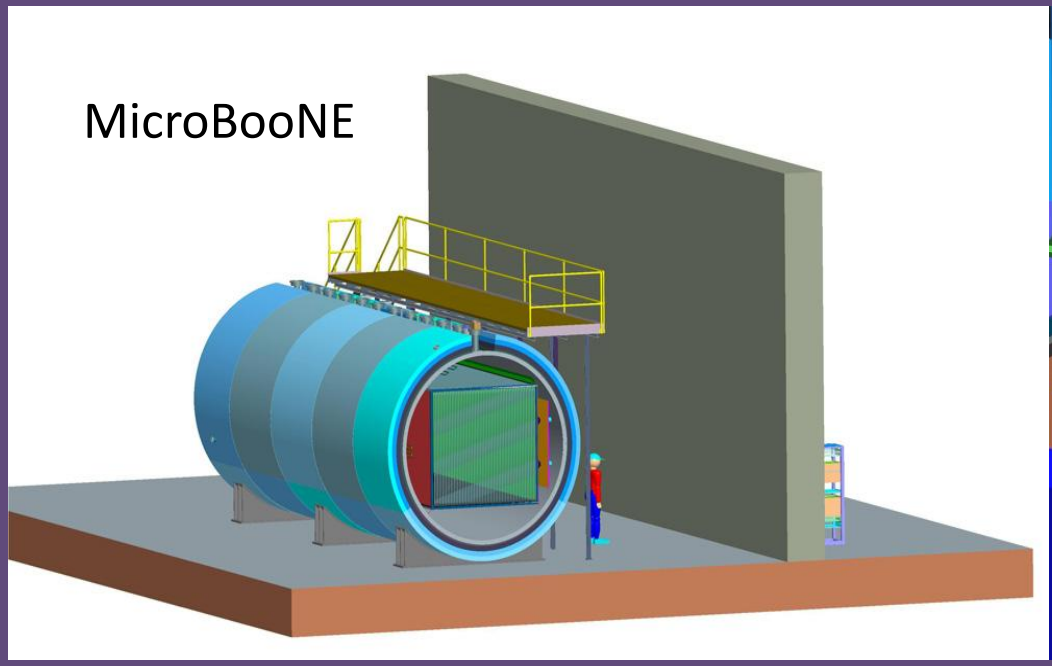


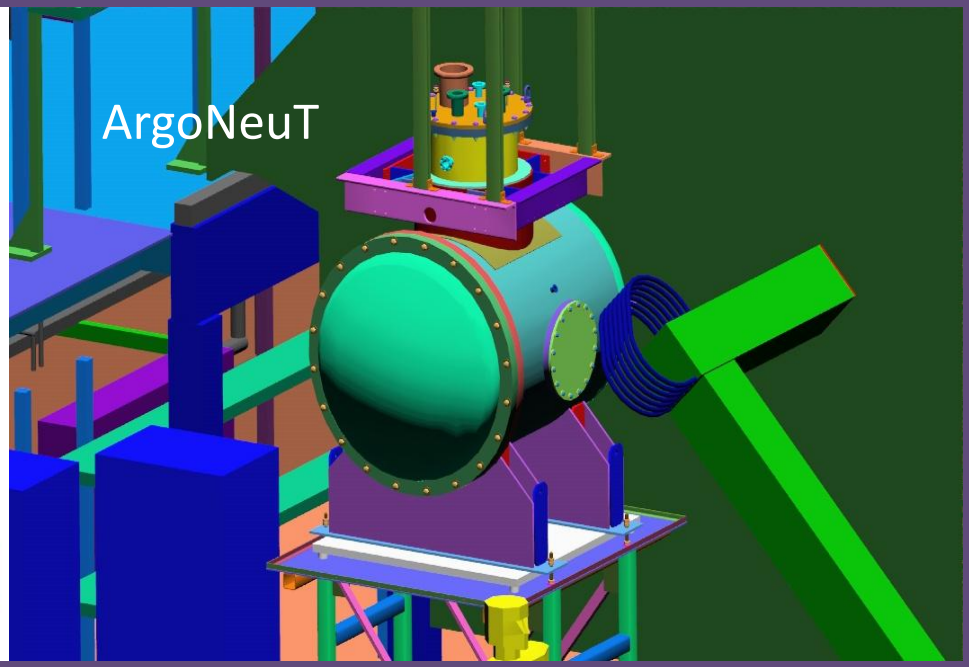
← 14 MeV Proton Total Charge

21 MeV Proton Total Charge →



Particles ID Identification for Tracks in LArTPC

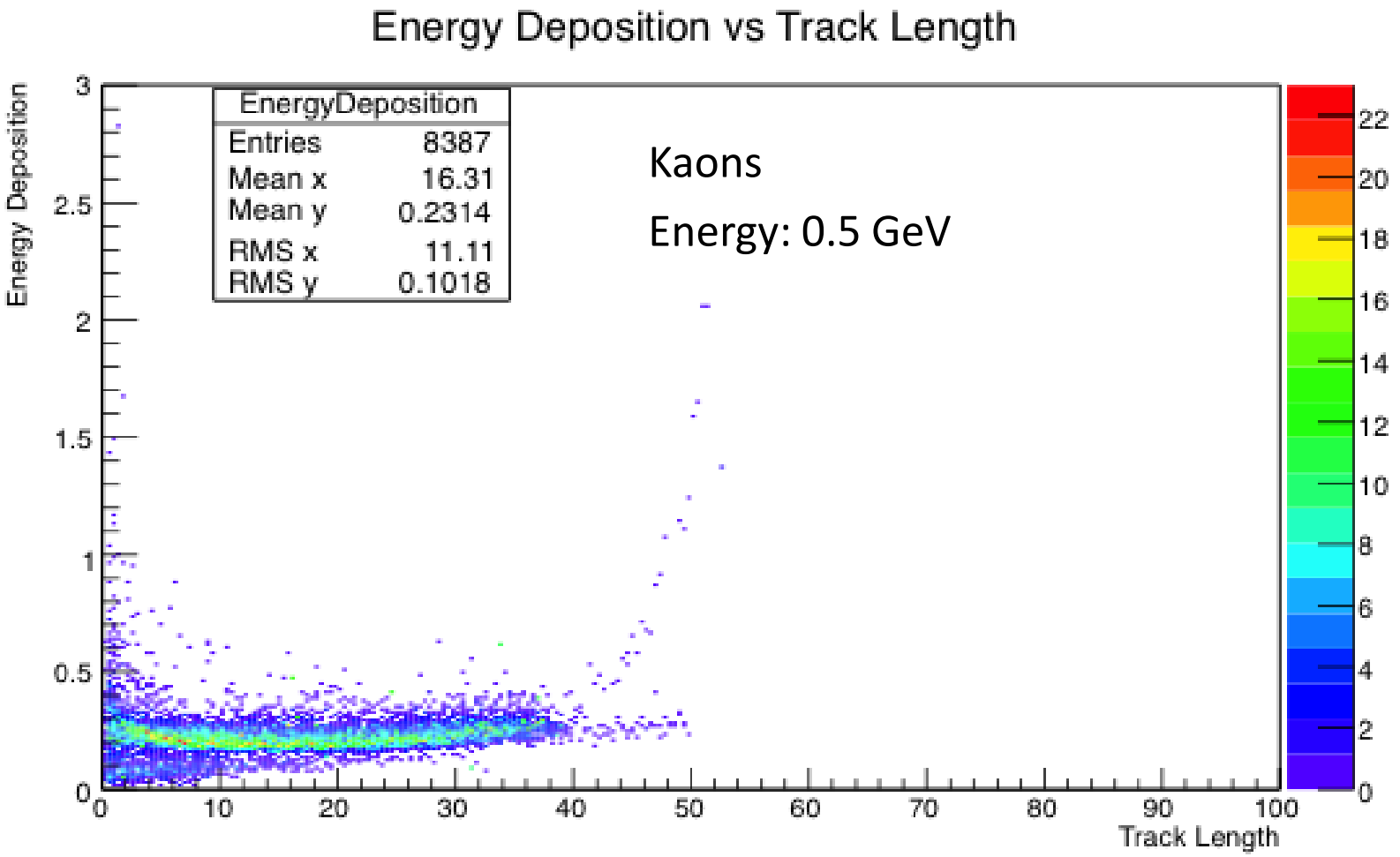


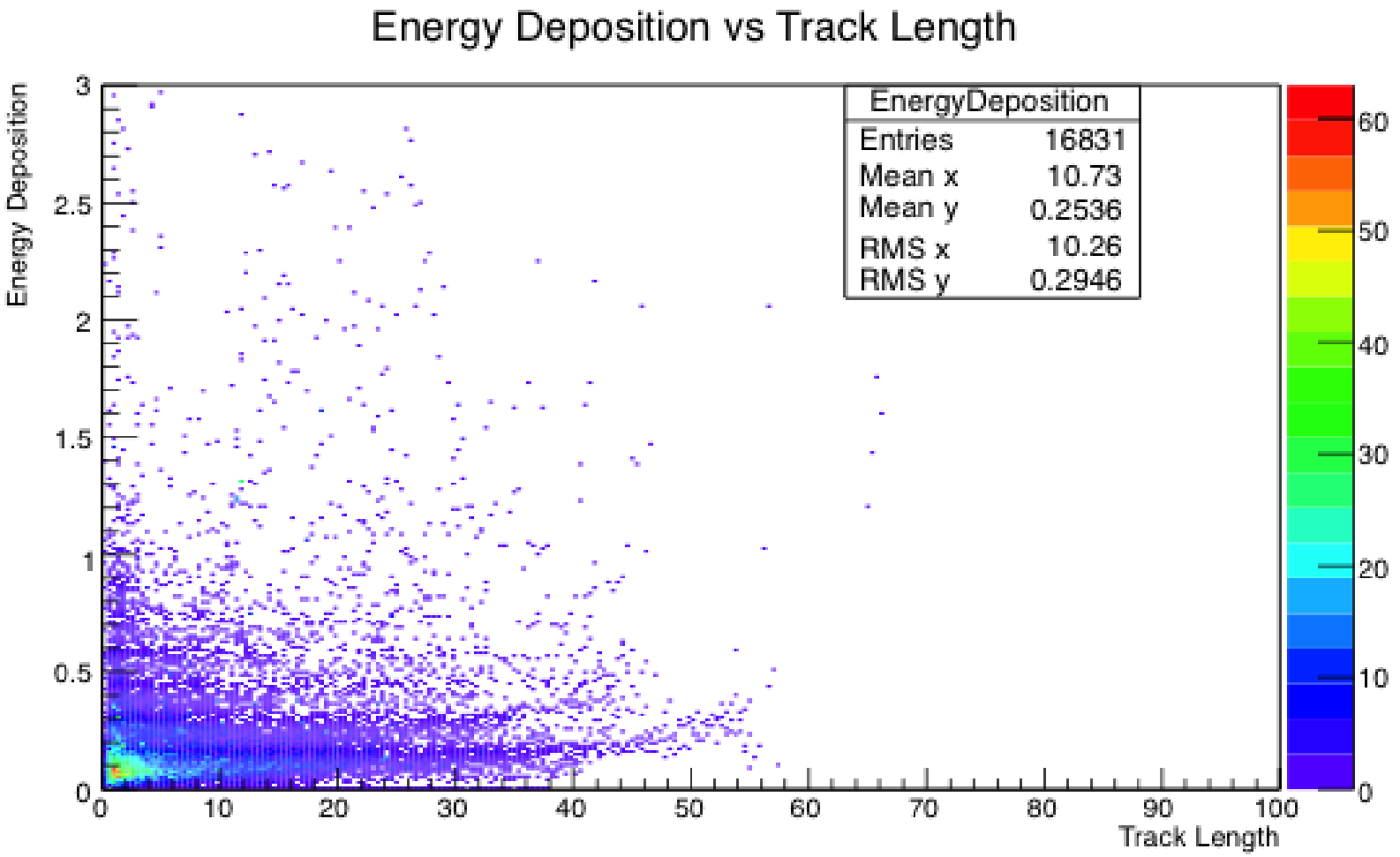


What have I been trying to do in the past 9 weeks?

- ID identification for Tracks.
- Figure out the particles that are inside the detector in a particular event.
- Why Kaons?
  - Measurement of cosmogenic kaon backgrounds for proton decay searches

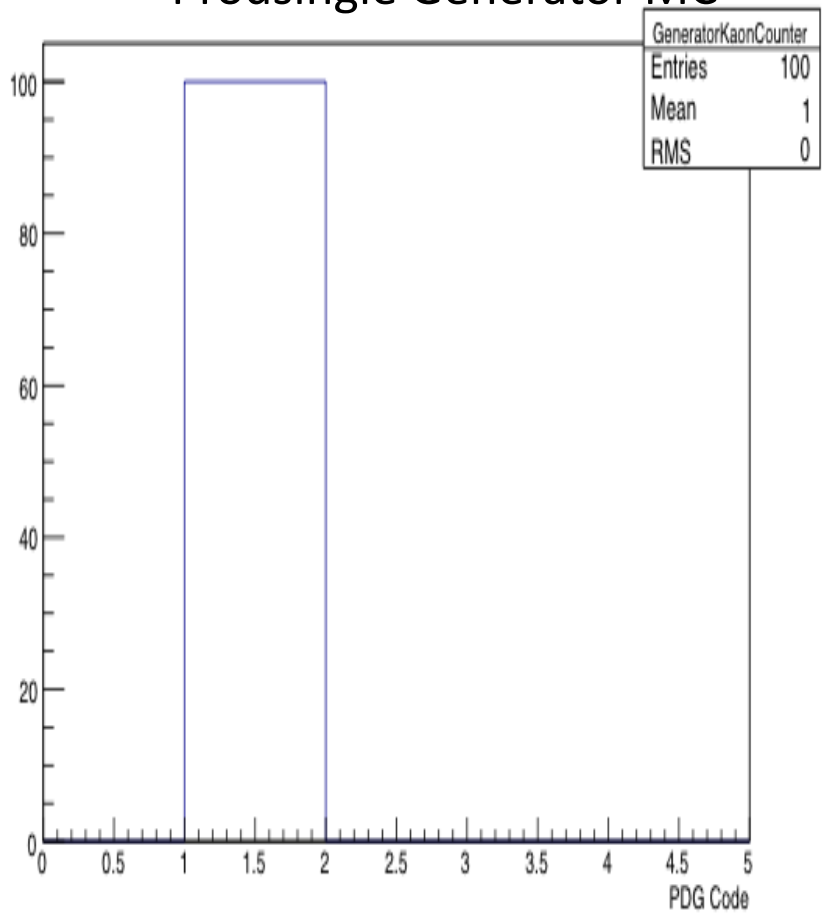
Results


Energy Deposition vs Track Length
EnergyDeposition
Entries 8387
Mean x 16.31
Mean y 0.2314
RMS x 11.11
RMS y 0.1018
Kaons
Energy: 0.5 GeV
Energy Deposition
Track Length
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22

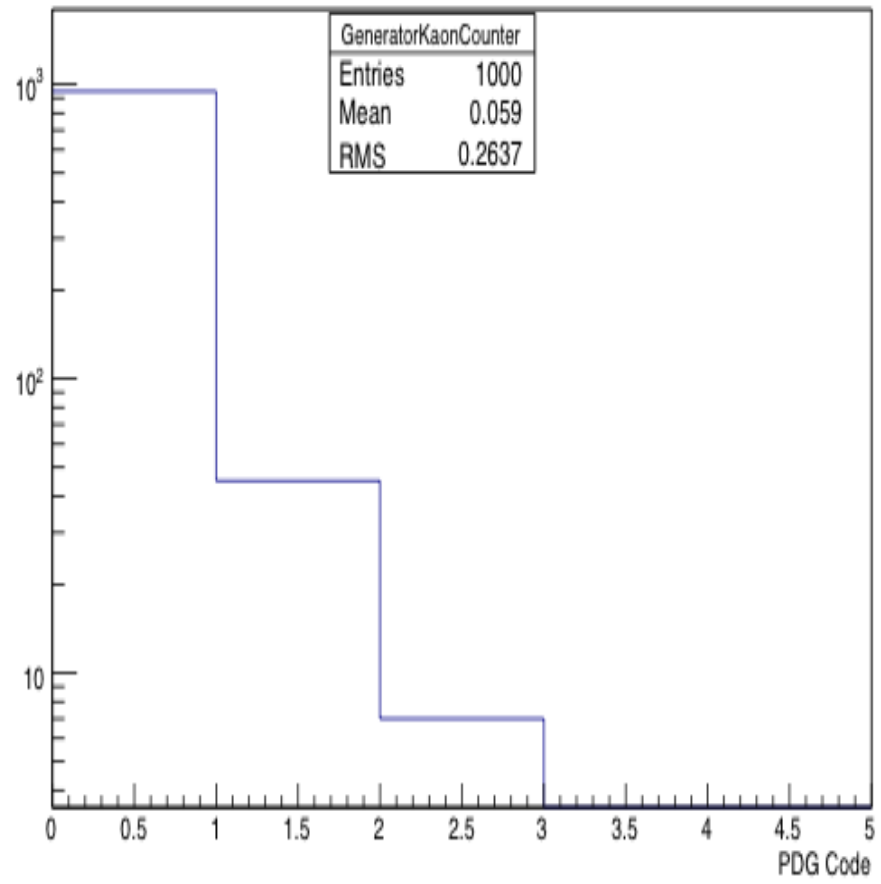

Energy Deposition vs Track Length
EnergyDeposition
Entries 16831
Mean x 10.73
Mean y 0.2536
RMS x 10.26
RMS y 0.2946
Energy Deposition
Track Length
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60
70
80
90
100
0
10
20
30
40
50
60

Genie and Prodsingle

Prodsingle Generator MC

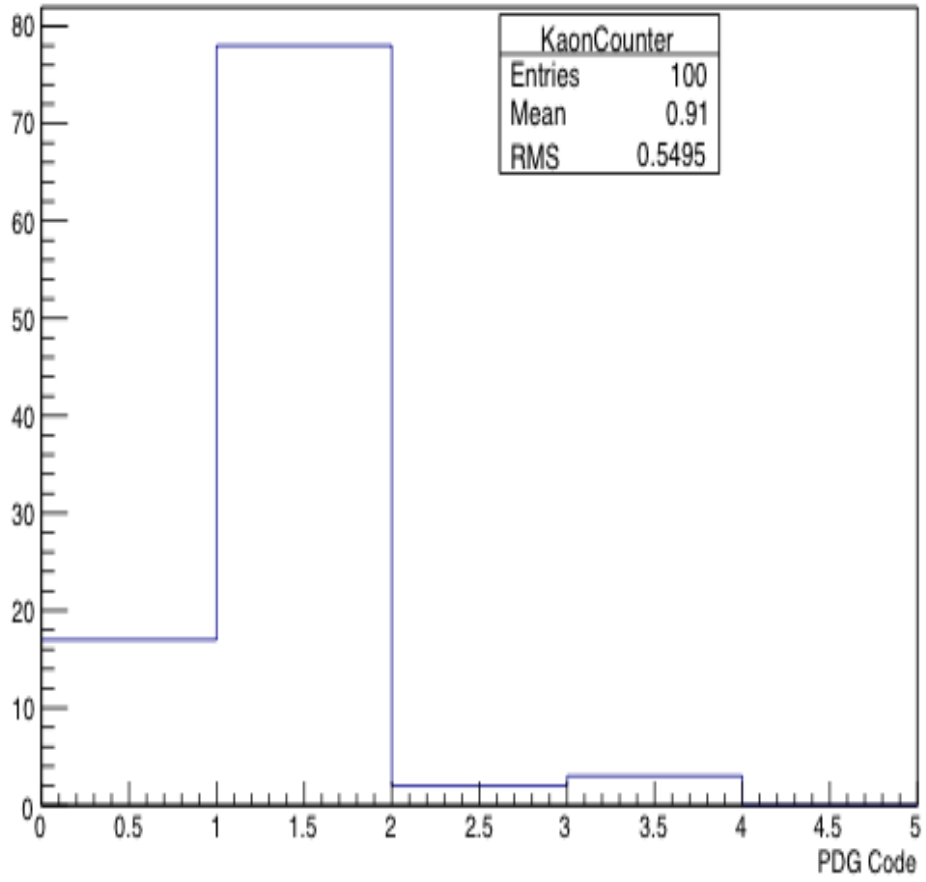


Genie Generator MC

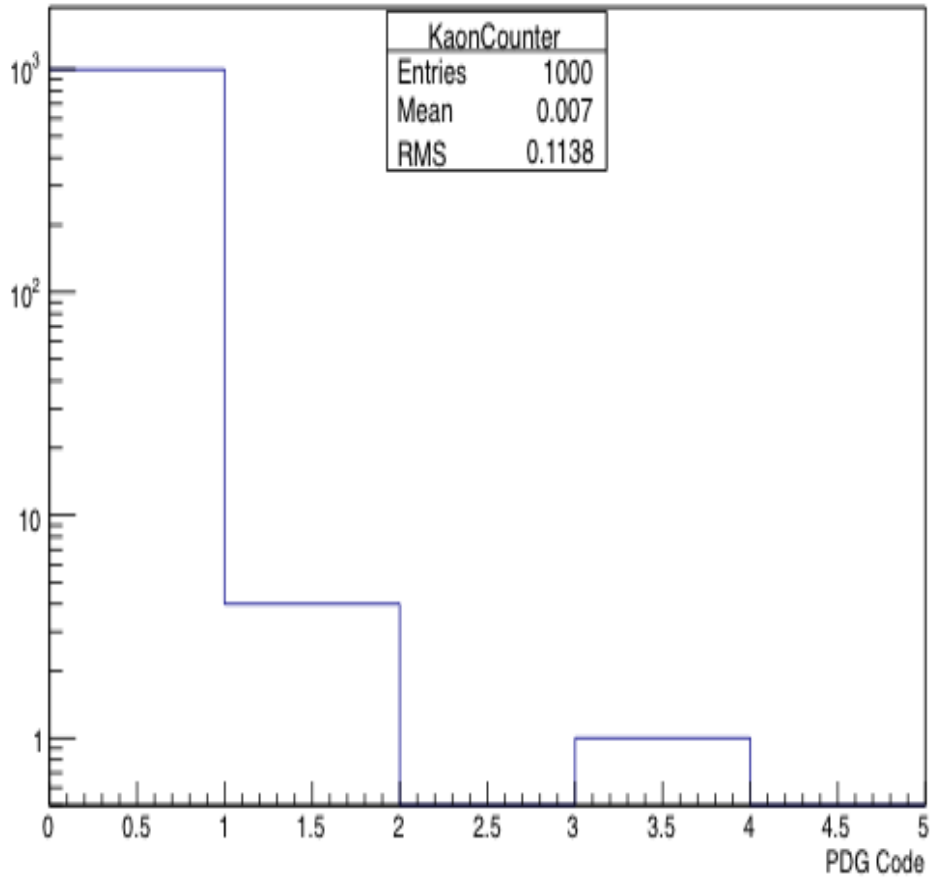


Kaon Count

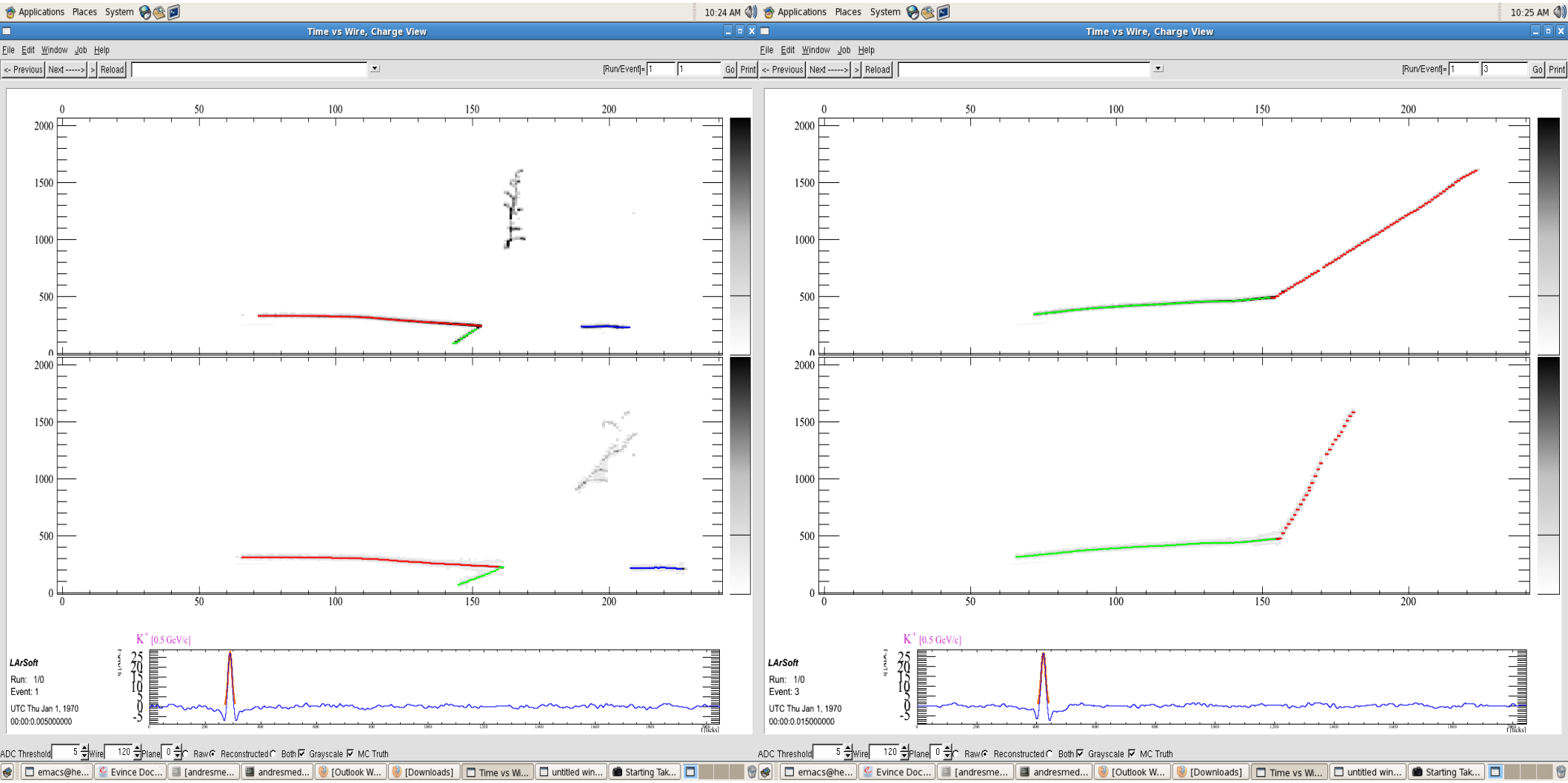
Prodsingle



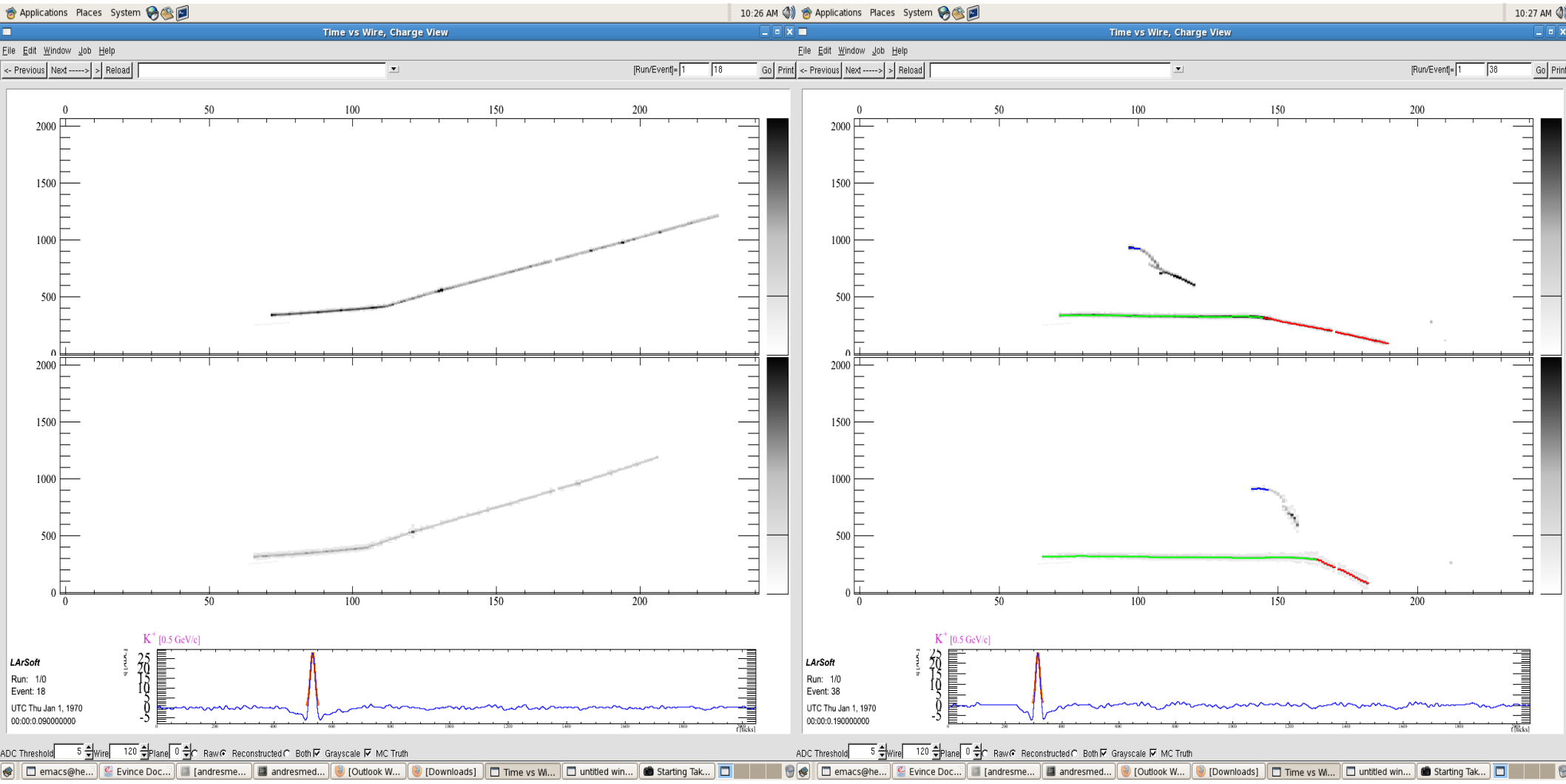
Genie



Event Display



Continue


Applications Places System
10:26 AM
Time vs Wire, Charge View
File Edit Window Job Help
<-- Previous Next -----> Reload [Run/Event]= 1 18 Go Print
LArSoft
Run: 1/0
Event: 18
UTC Thu Jan 1, 1970
00:00:0.090000000
K+ [0.5 GeV/c]
ADC Threshold 5 Wire 120 Plane 0 Raw Reconstructed Both Grayscale MC Truth
Applications Places System
10:27 AM
Time vs Wire, Charge View
File Edit Window Job Help
<-- Previous Next -----> Reload [Run/Event]= 1 38 Go Print
LArSoft
Run: 1/0
Event: 38
UTC Thu Jan 1, 1970
00:00:0.190000000
K+ [0.5 GeV/c]
ADC Threshold 5 Wire 120 Plane 0 Raw Reconstructed Both Grayscale MC Truth

Problems with the Track and Possible Solution

- The Track Identifier is not working well
- Use others trackers such as Bezier Track

In Conclusion…

- Deana has developed an angular and timing resolution filter for the framework
- Mario has been developing ways to detect the energy deposition of particles and calibrating Birk's Constant
- Andres has been working on an identifier for particle tracks.

Acknowledgements

- Tim Bolton, Glenn Horton-Smith, David McKee
- Larry Weaver and Kristan Corwin
- National Science Foundation (NSF)
- Kansas State University and the High Energy Physics Group
- Fellow REU Students

Back up

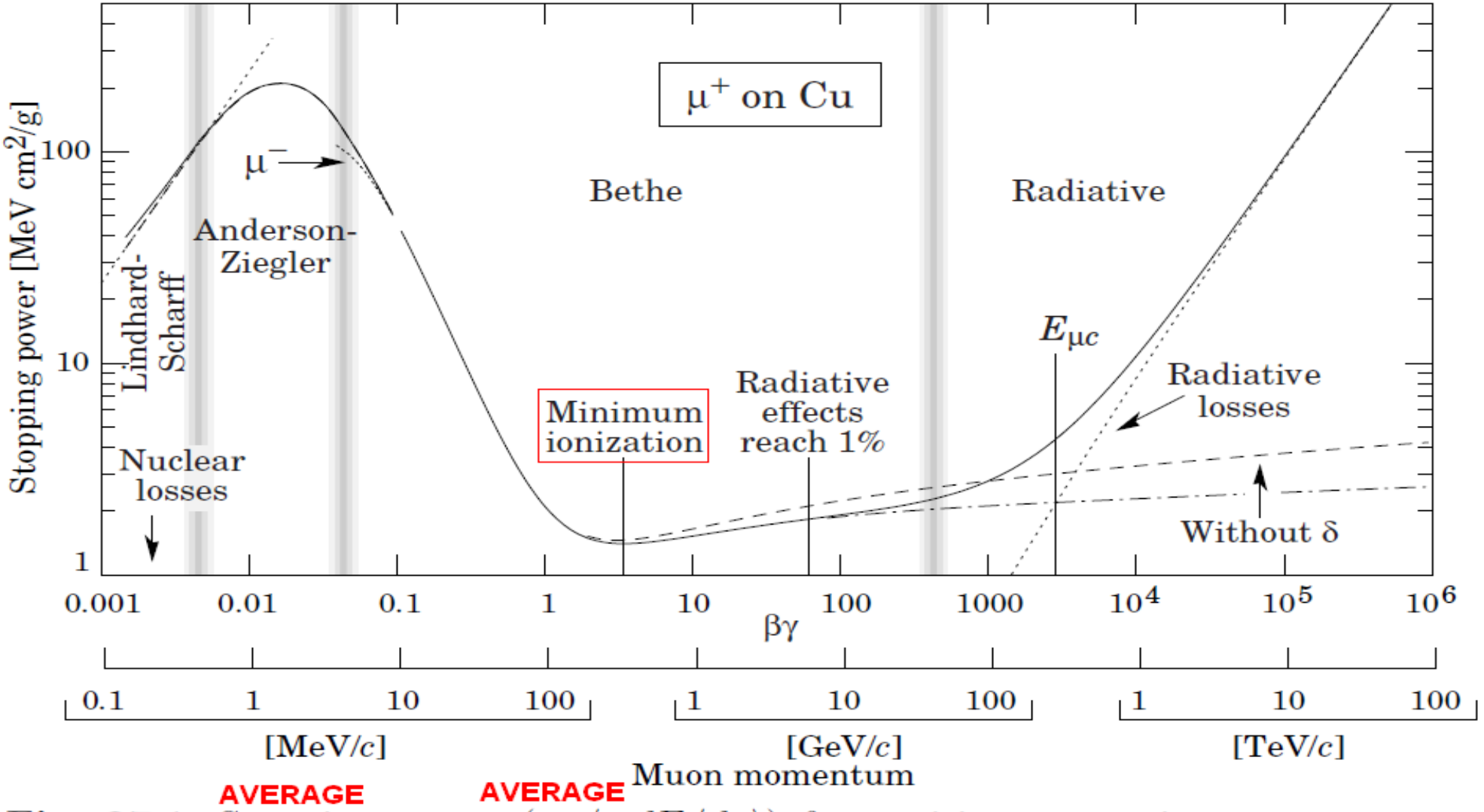


Fig. 27.1: Stopping power ($= \langle -dE/dx \rangle$) for positive muons in copper as a function of $\beta\gamma = p/Mc$ over nine orders of magnitude in momentum (12 orders of magnitude in kinetic energy). Solid curves indicate the total stopping power.

Bethe – Bloch Equation

$$-\frac{dE}{dx} = \frac{4\pi}{m_e c^2} \cdot \frac{nz^2}{\beta^2} \cdot \left(\frac{e^2}{4\pi\varepsilon_0}\right)^2 \cdot \left[\ln\left(\frac{2m_e c^2 \beta^2}{I \cdot (1-\beta^2)}\right) - \beta^2\right]$$

$\beta = v/c$
v = velocity of particle
E = Energy of particle
z = particle charge
x = distance particle traveled
c = speed of light

e = electron charge
m_e = electron rest mass
n = electron density of target
I = mean excitation of potential target
ε_0 = vacuum permittivity