University of Victoria

Studies of Cluster Counting for use in SuperB Drift Chamber dE/dx measurements

Sam Dejong
University of Victoria

SuperB Canada

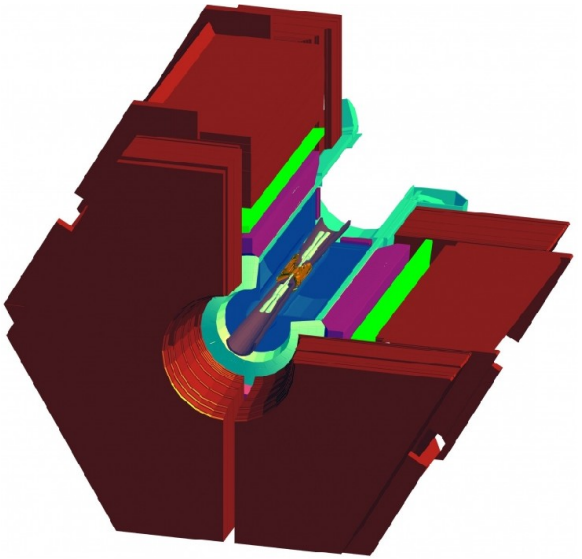
- Victoria
  - M. Roney (PI), R. Kowalewski, R. Sobie, S. Dejong, A. Beaulieu
- UBC
  - C. Hearty, T. Mattison, J. McKenna, R. So, J.F. Caron
- Montreal
  - J.P. Martin, P. Taras
- McGill
  - P. Patel, S. Robertson, A. Warburton, D. Swersky, D. Lindermann, R Cheaib.

Outline

- The SuperB Experiment
- Drift chamber theory
- Cluster counting
- Garfield Simulation Software
- UVic Chamber
    - Simulation results
    - Cluster counting studies
- TRIUMF Testbeam
- Conclusion

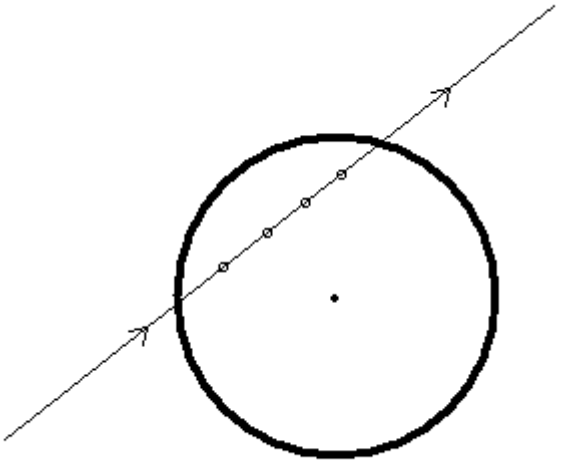
The SuperB experiment

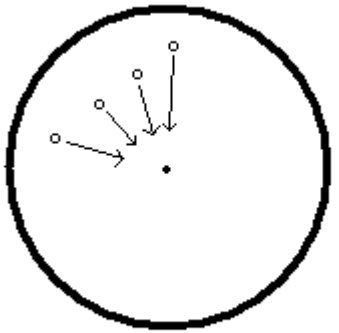
- Next generation high luminosity antisymmetric e+e- collider to be built outside of Rome
    - For study of flavour and electroweak physics
- 1.5T solenoid magnet allows tracking of charged particles as they pass through the detector
    - Allows measurement of momentum
- Ionization measured in drift chamber
    - Allows measurement of velocity
- With β and p, can identify mass



Drift Chamber

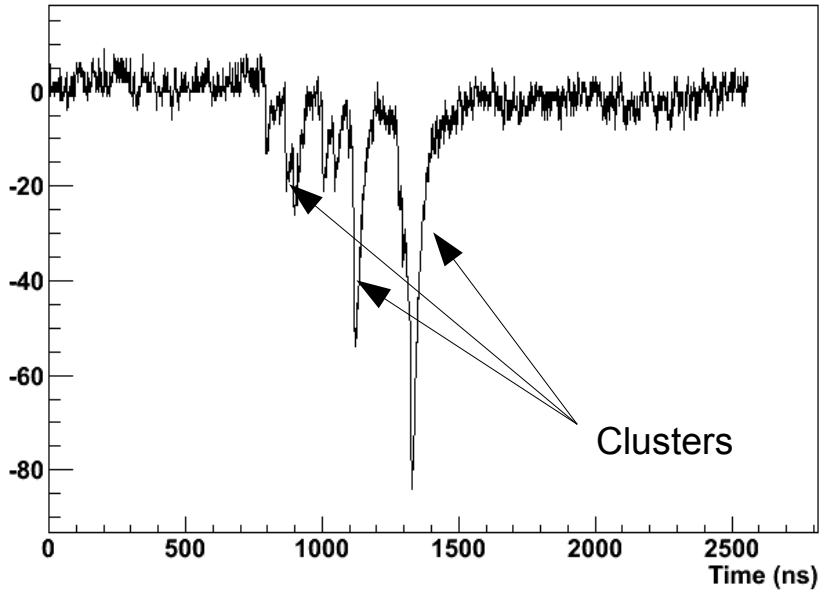
- Charged particle deposits energy via ionization
- Spatial distribution of ionization is Poisson
- Ejected electron ionizes gas around it, forming clusters of electrons that drift toward anode
- Electron drift times give position of initial track for a known time to distance relation
- Number of clusters is a direct measurement of $(dE/dX)_{ionization}$

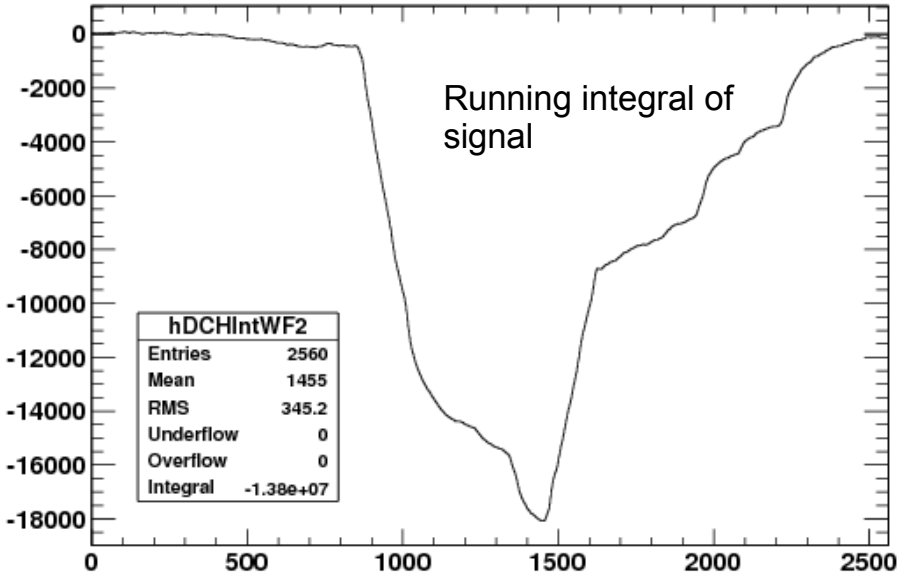




Drift Chamber

- Traditionally dE/dx measurements integrate all charge deposited on the wire as a proxy for number of clusters
  - Fluctuations in gas gain and number of primary electrons degrades measurements
  - Counting primary ionization (clusters) reduces spread around the mean, improving particle identification





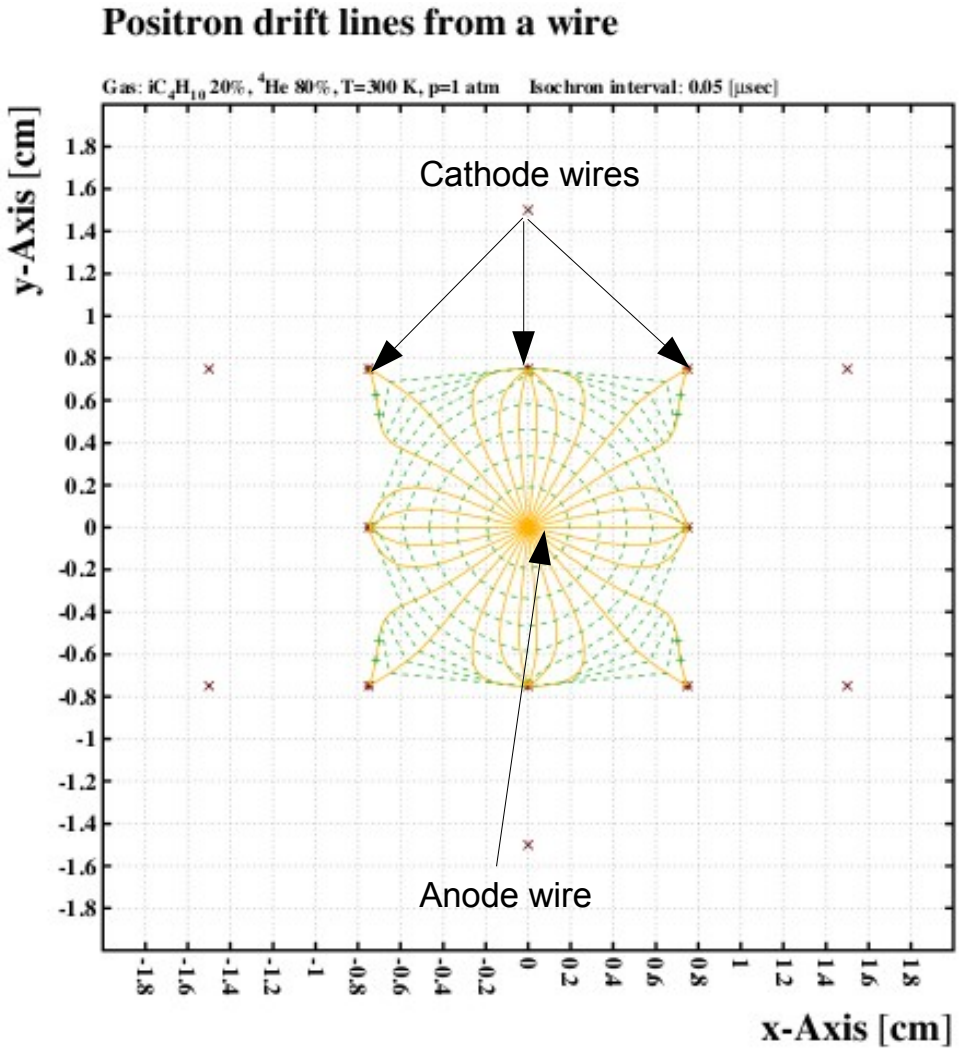
Cluster Counting

- Electrons in same cluster arrive at anode at approximately the same time
- Pulses from different clusters must not overlap in time
- Charge should be collected in less than ~1μs
- A large number of clusters is needed to reduce statistical error
- Density of clusters in track must be low enough to see individual clusters

The SuperB Experiment: Drift Chamber

- Will use a rectangular configuration of wires in the chamber
- Fewer wires than a typical hexagonal arrangement

~40 layers of sense wire



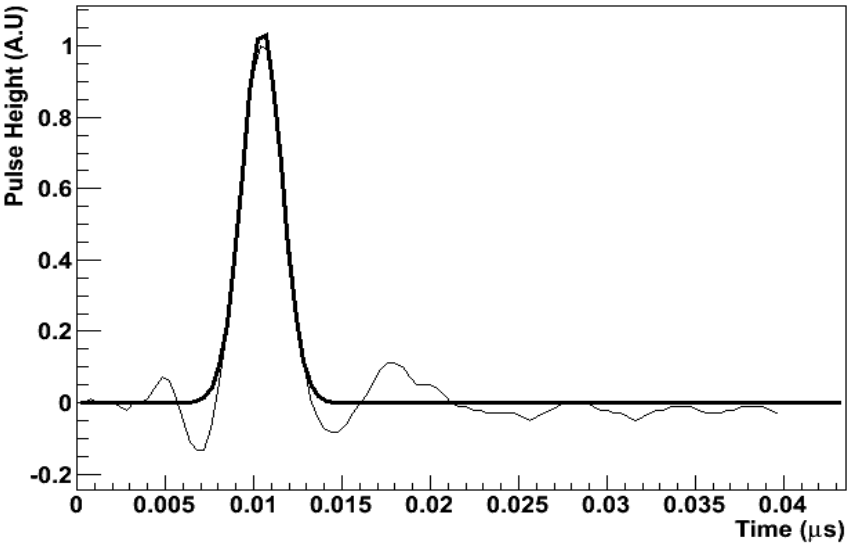
Helium-Isobutane (C_4H_{10})

- Low Z gases minimize multiple scattering, allowing precise measurement of momentum
- High ionization potential helium
  - Fewer clusters, so larger gap between them
- Most ionization is from Isobutane
- Low drift velocity
  - Amplifies cluster separation
- High ion mobility
  - Clear up space charge region quickly

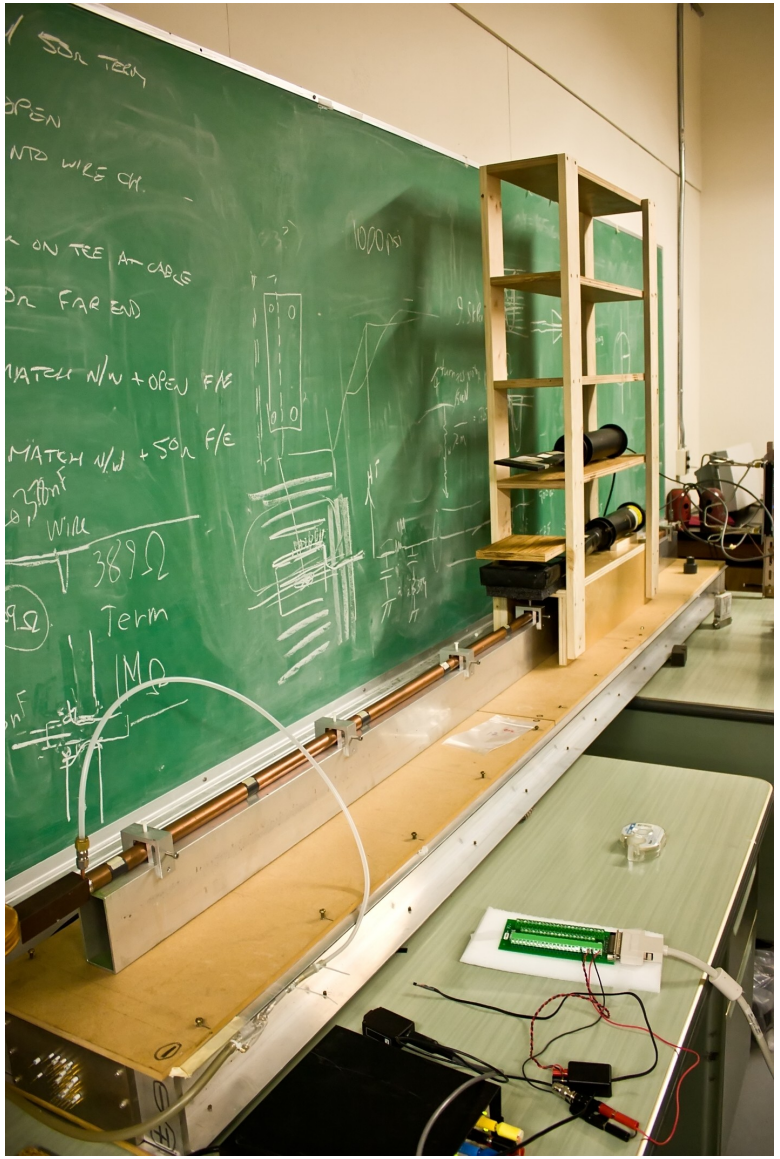
Garfield Simulation Software

- Software to simulate gaseous detectors
- Allows control over gas mixture, chamber geometry, transfer function of electronics, etc.
- Garfield simulation of UVic chamber was done
- http://garfield.web.cern.ch/garfield/

Preamp Transfer Function

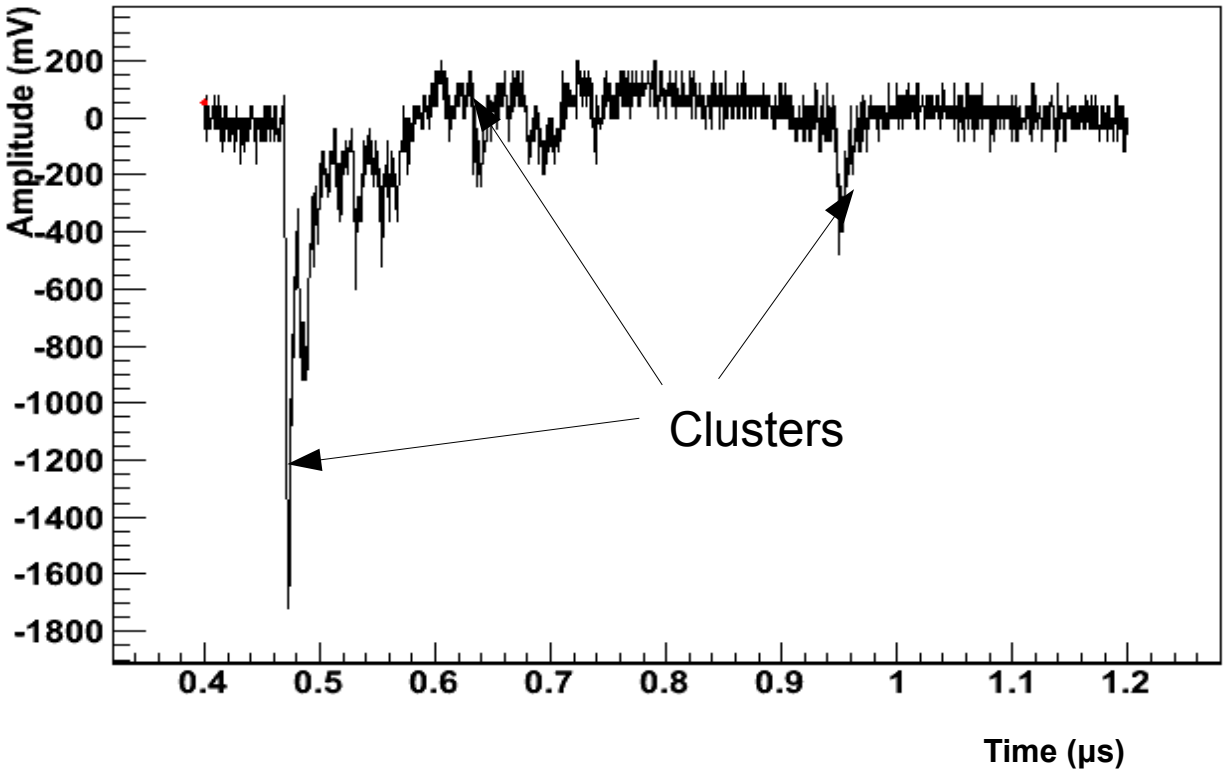


UVic Chamber



- 2.7m long copper tube, diameter of 2cm
- 20μm W anode wire
- Ran with various gas mixtures:
  - 70% He, 30% Isobutane
  - 80% He, 20% Isobutane
  - 90% He, 10% Isobutane
- Cosmic rays used
- Commercial Wentec 1GHz preamp

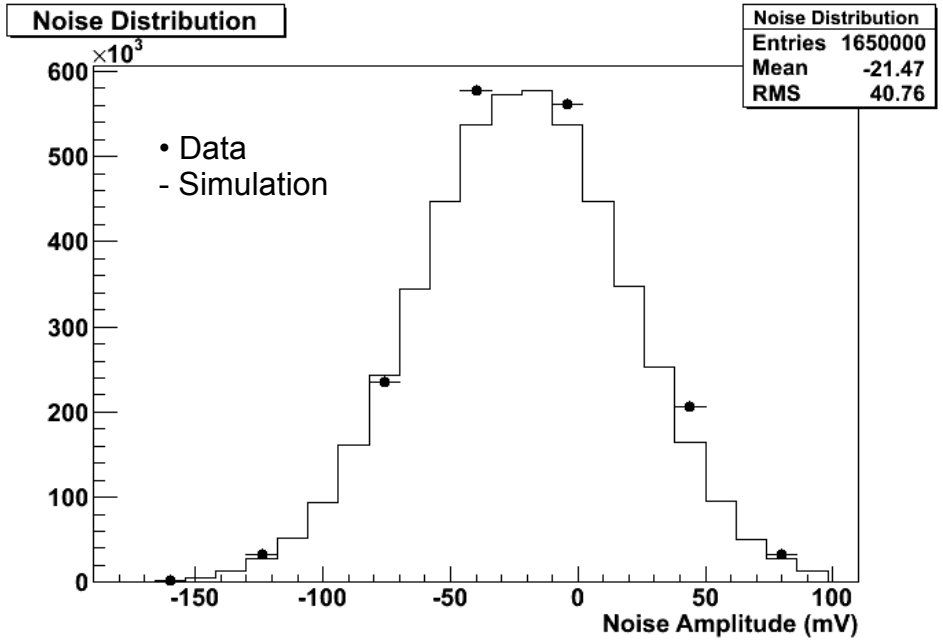
Sample trace from UVic chamber

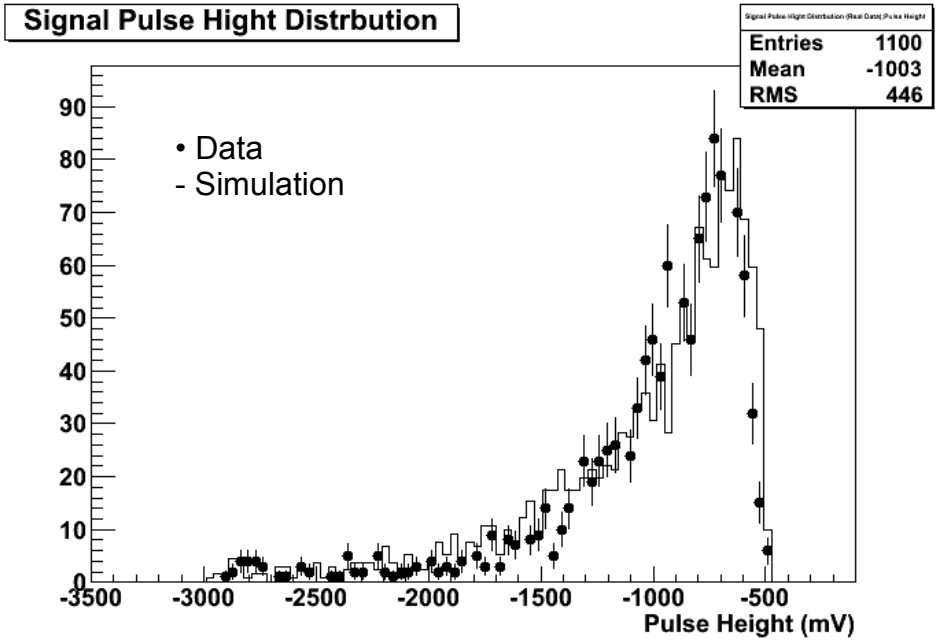


From cosmic ray

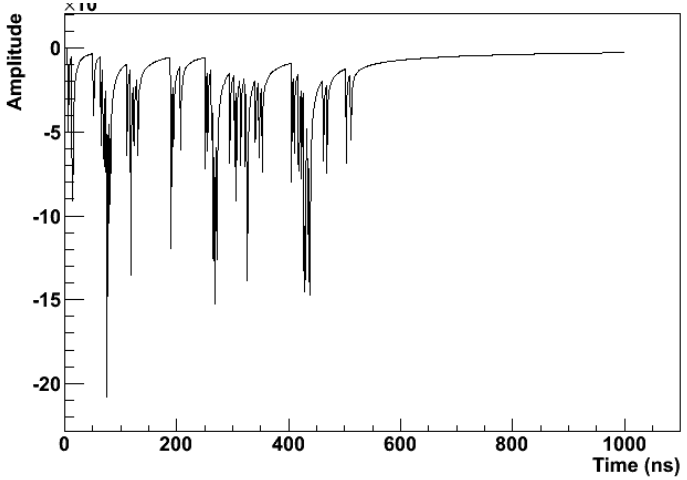
Tuning Garfield

- Garfield signal and noise distributions were tuned based on real data

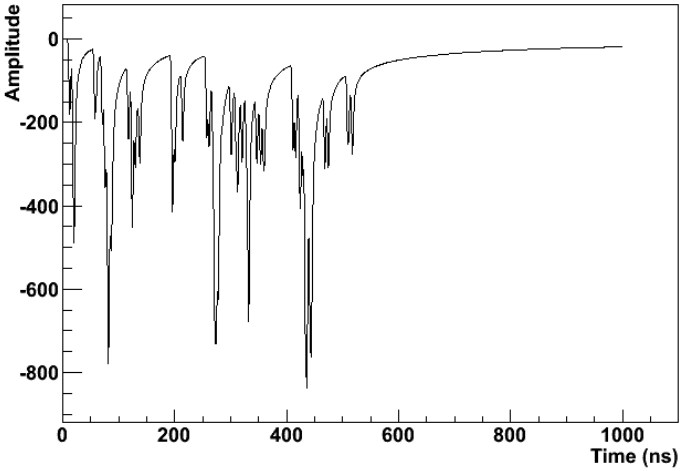




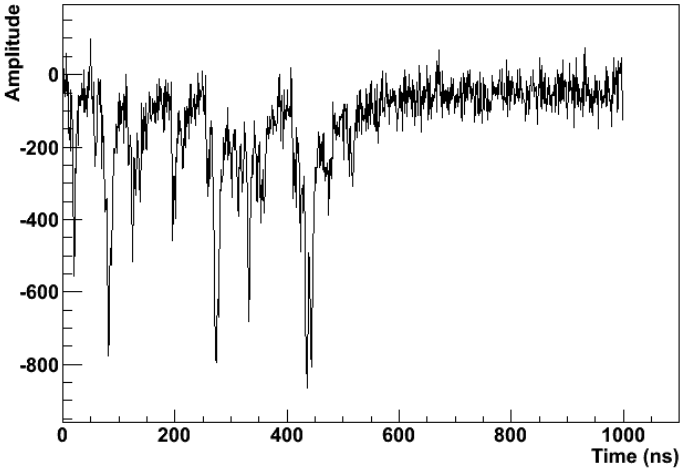
Sample trace from Garfield



Raw Signal generated by Garfield

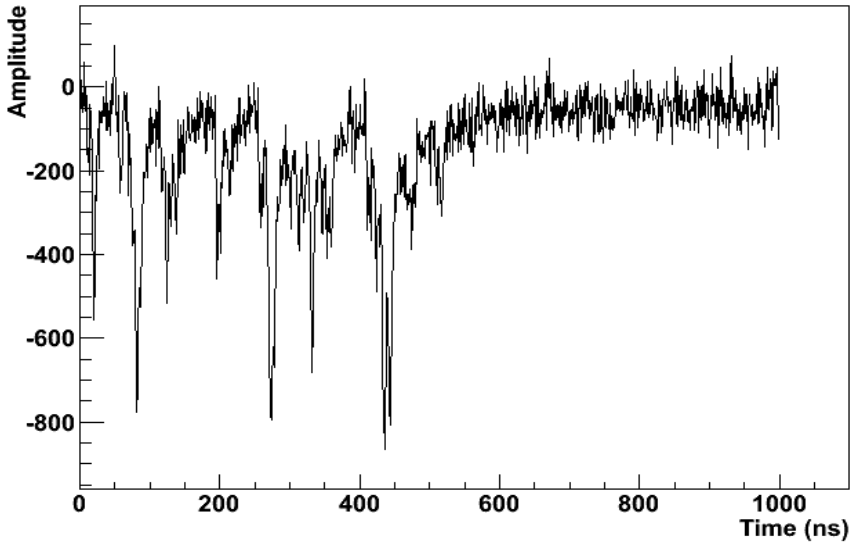


Preamp response added

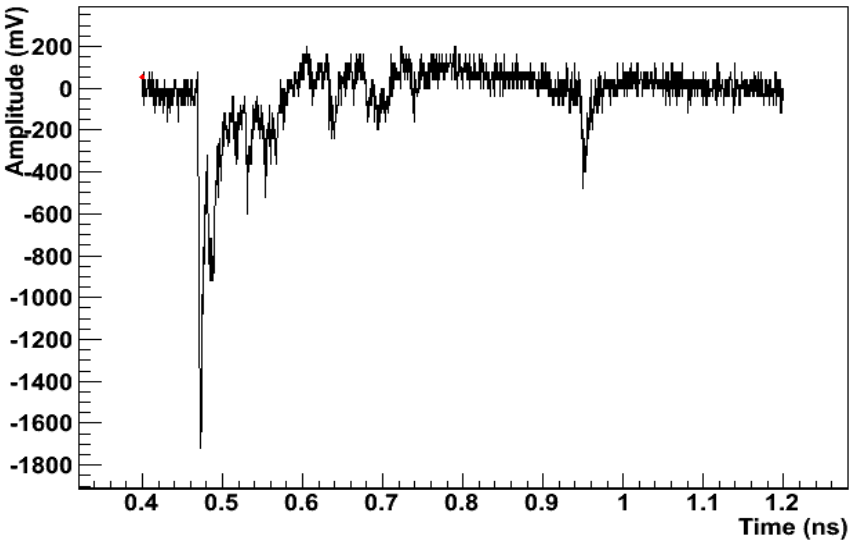


Noise added

Simulation and real trace



Simulated trace



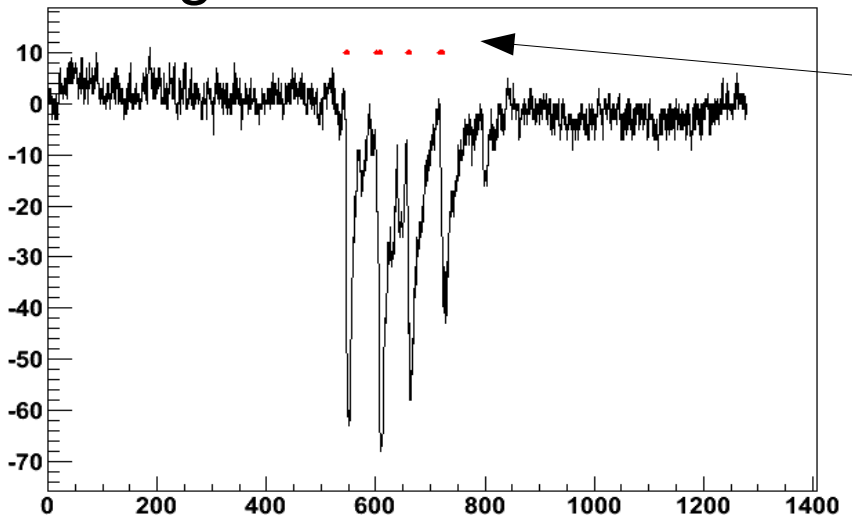
Real trace

Cluster counting Algorithm

- Algorithm takes the difference between a time bin and the average of previous 5 time bins

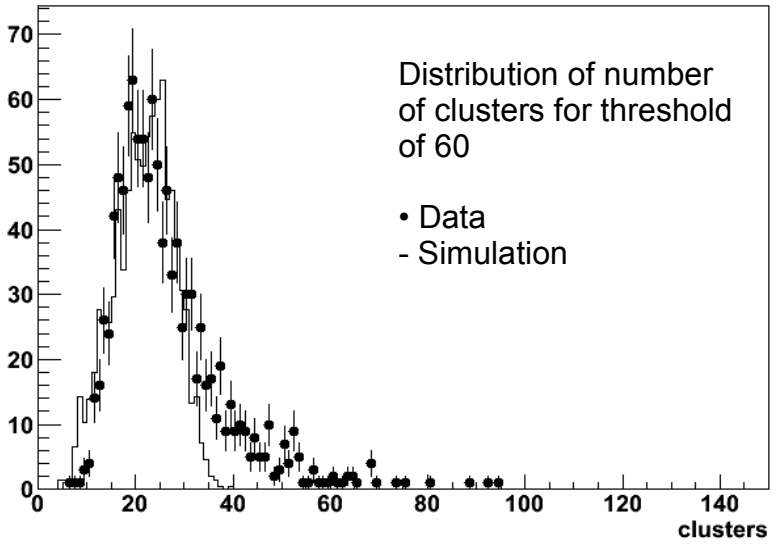
$$a_i = v_i - \frac{(v_{i-1} + v_{i-2} + v_{i-3} + v_{i-4} + v_{i-5})}{5}$$

- If a_i is above a certain threshold, a cluster is detected
- If time bin is above threshold, next bins are ignored until they fall below threshold again



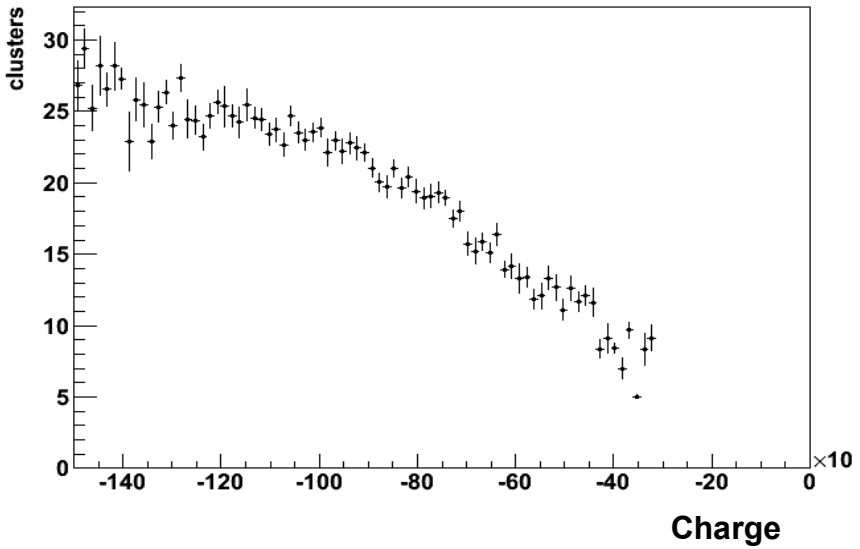
Analysis of UVic chamber

- Simulated and real data
- Larger tail in real data
    - Issue with noise tuning?
- Close agreement between simulation and data for threshold of 60mV.

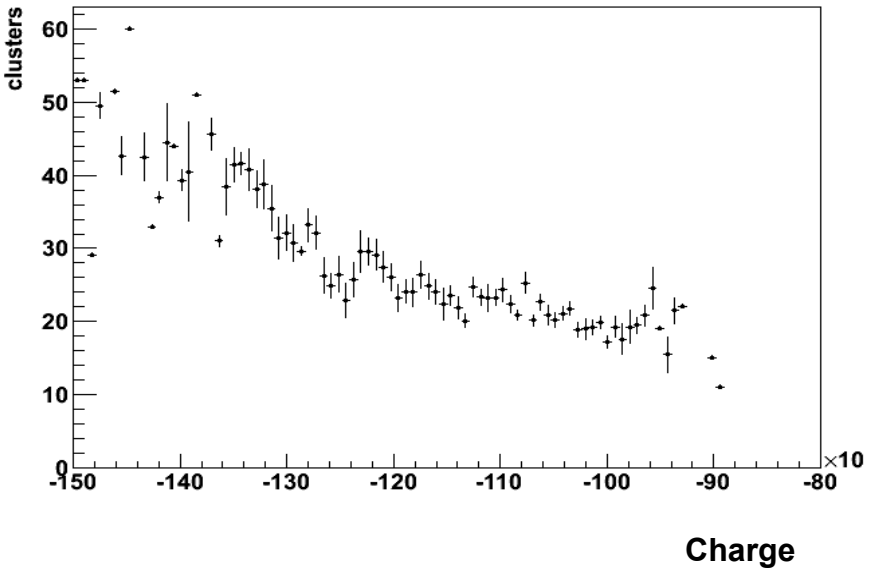


Cluster Number vs. Integral

Simulated Data



Real Data



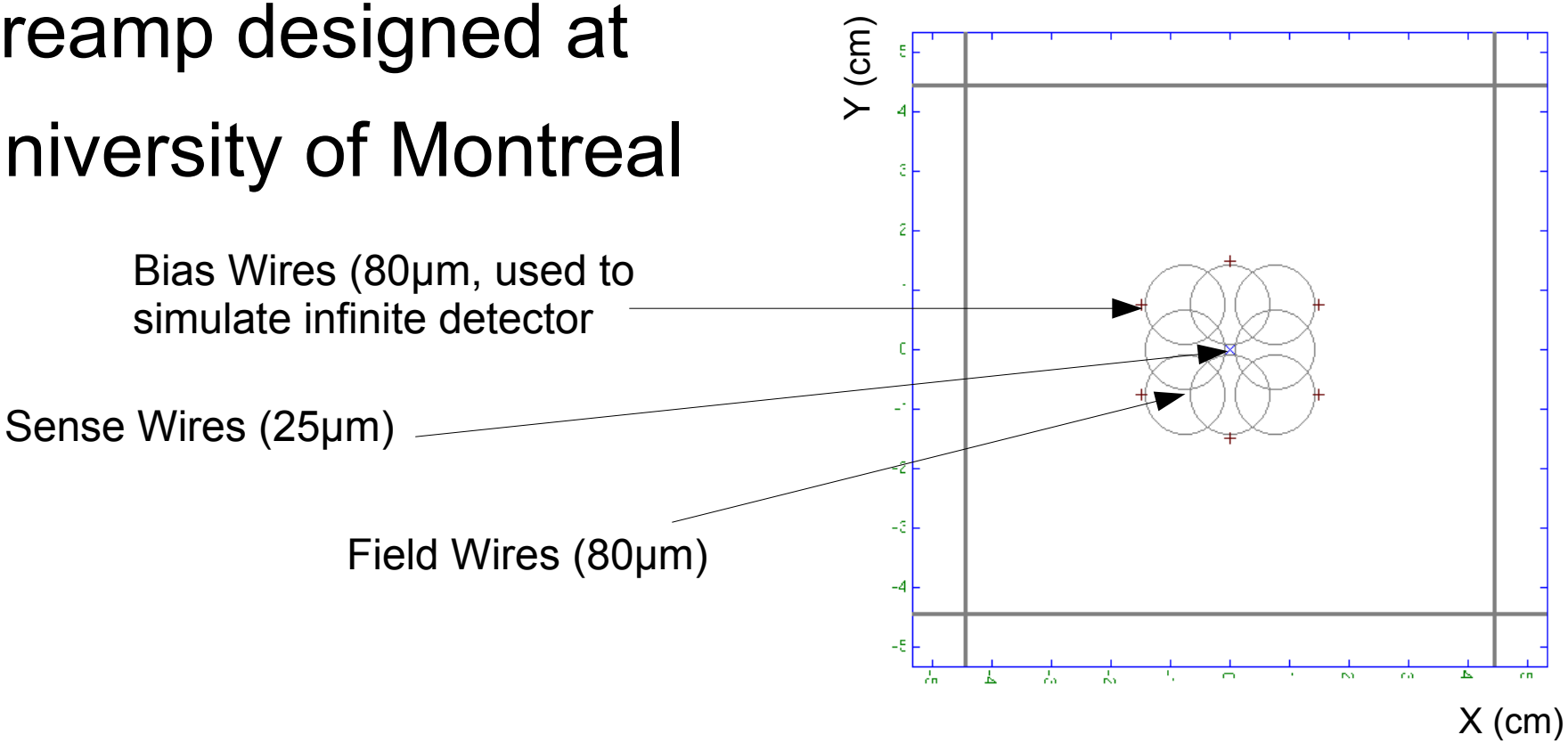
Threshold of 60mV

TRIUMF Test beam

- Test chamber set up in M11 (Muons, Pions, and electrons) beam at TRIUMF
- Testbeam run in late November 2011
- Run at various momenta
- Various Gas mixtures:
  - 80% He, 20% Isobutane
  - 90% He, 10% Isobutane
  - 95% He, 5% Isobutane

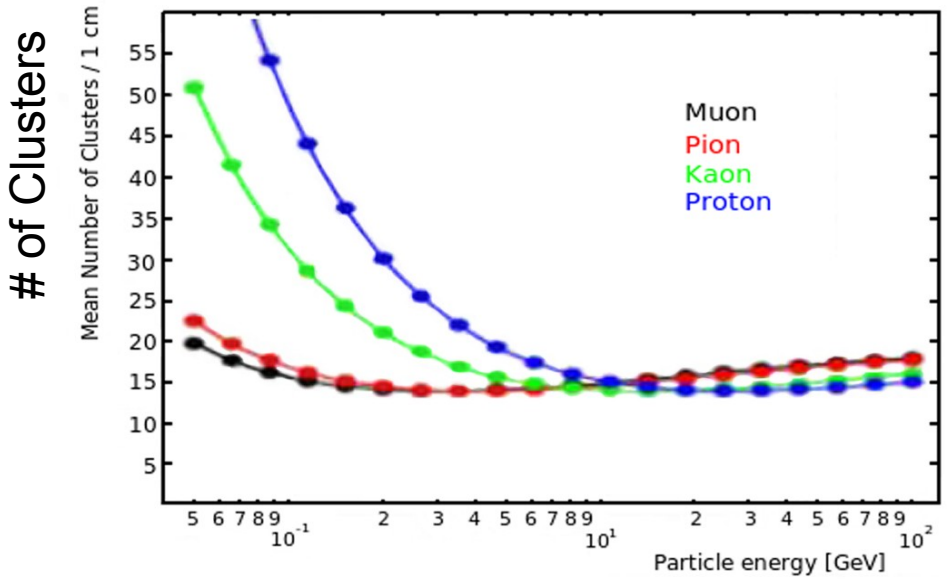
TRIUMF test chamber

- Used square chamber similar to possible SuperB chamber layout
- Preamp designed at
- University of Montreal



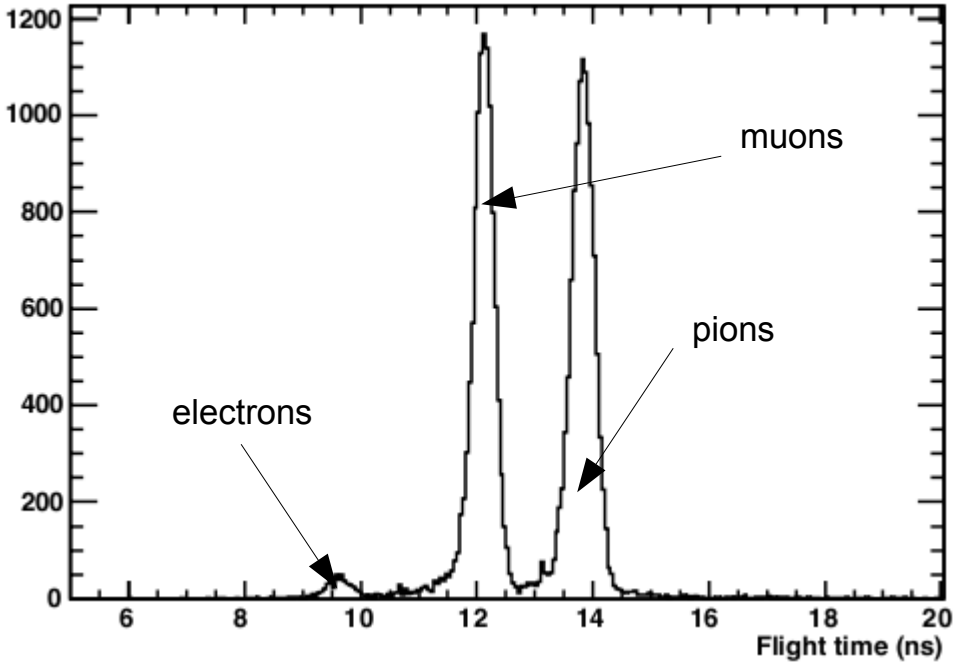
Momentum

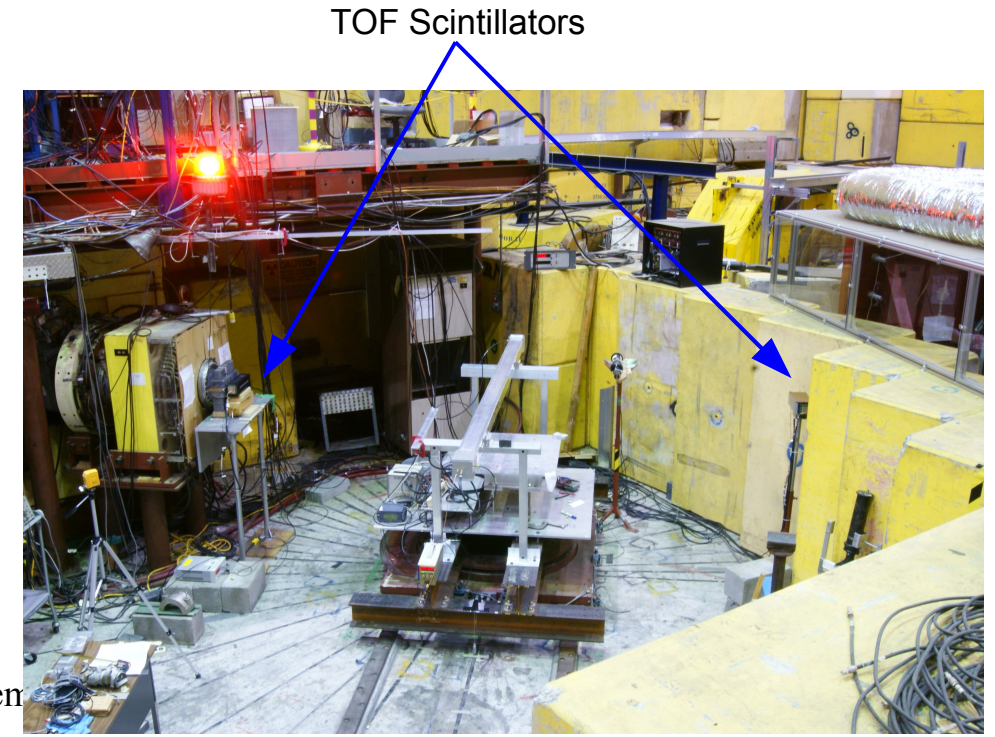
- At TRIUMF, momentum range from 120MeV/c to 400MeV/c was explored
- Separation of dE/dx curves for pions and muons is similar to kaons and pions at higher momenta



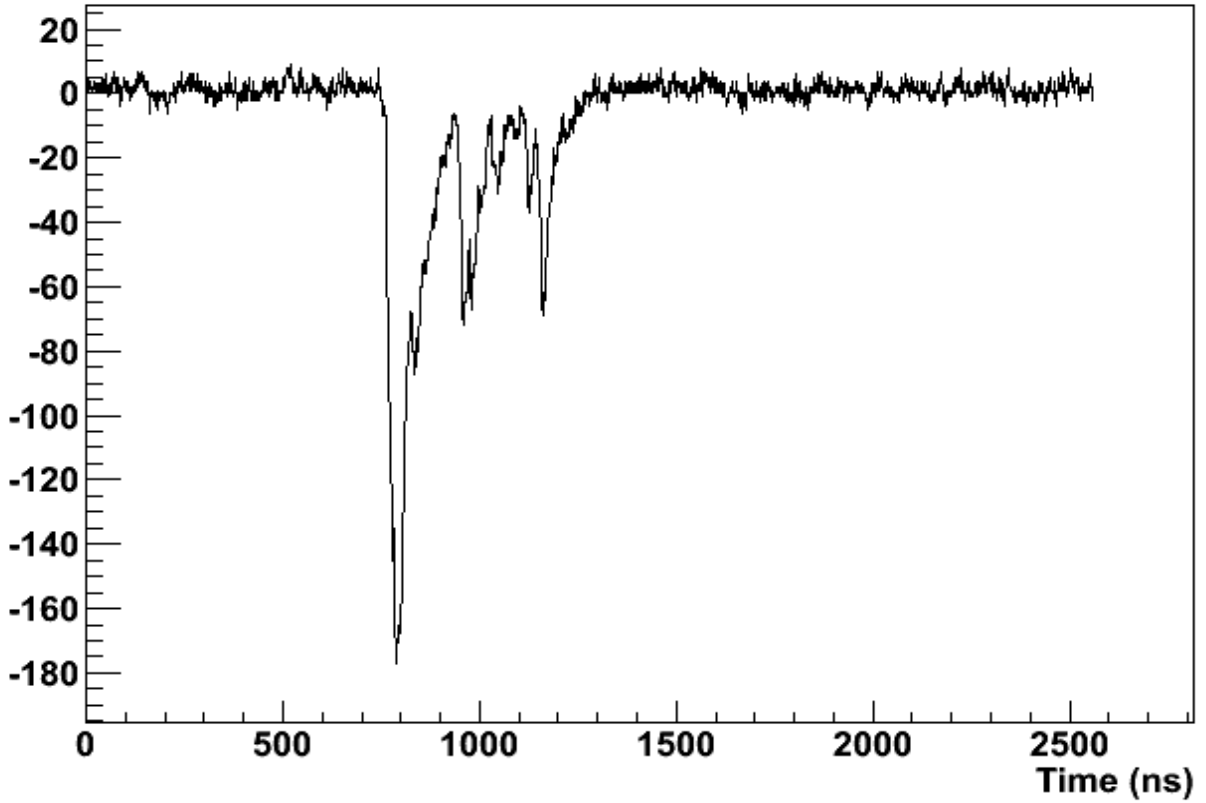
Time of flight

- Scintillators in front of and behind chamber used to calculate time of flight of particle
  - Allows identification of particles



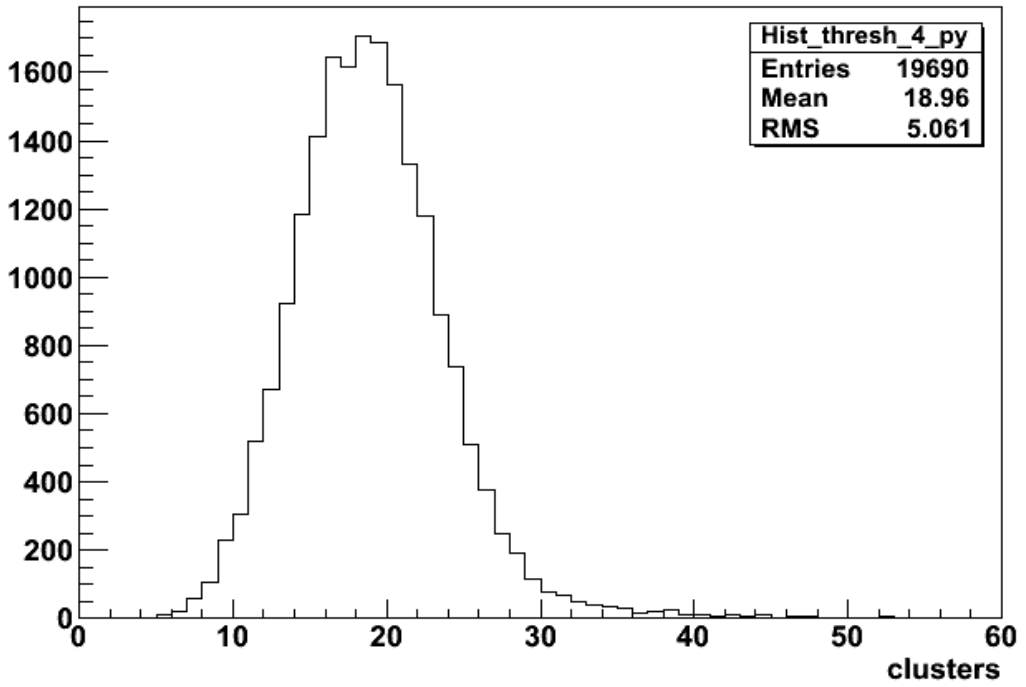


Sample trace from TRIUMF test beam



TRIUMF testbeam

- Analysis in progress
- Cluster distribution for 140MeV/c particles
- No particle ID done yet
- Counting algorithm applied



Conclusion/Future work

- Clusters visible in both UVic chamber and TRIUMF test chamber
- Qualitatively, simulation and data give similar waveforms
- Complete studies to determine of cluster counting will be used in SuperB DCH
- 5 cell x 5 cell prototype to be put in TRIUMF testbeam later this year