Use of TRT in Electron ID

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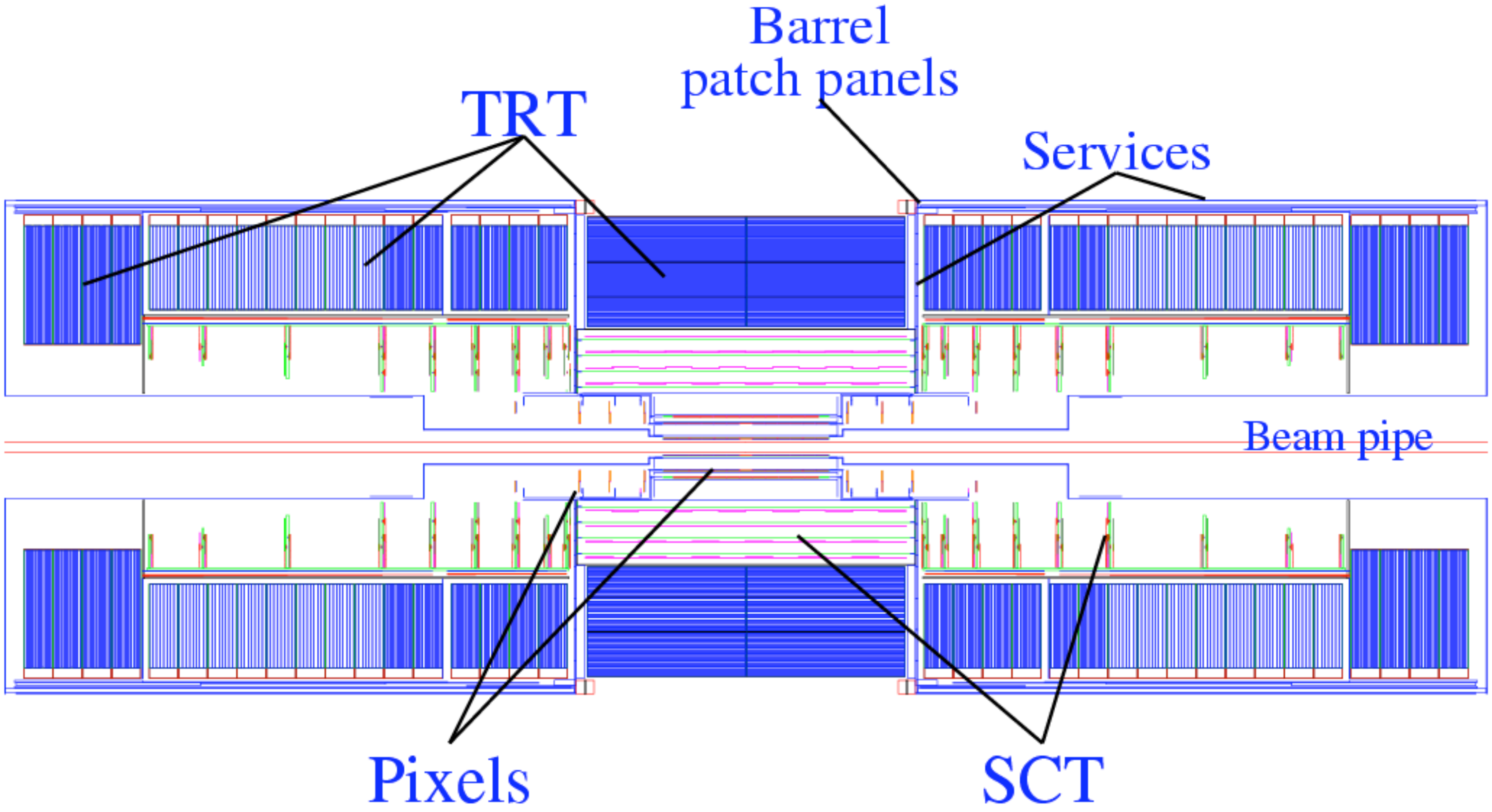
Introduction and Disclaimers

- This talk will focus on rejecting pions using the TRT.
- My studies have not used the EM calorimeters.
  - All of my work has focused on using the TRT to directly identify electrons and more importantly to reject pions.
  - In practice one will use both the LAr and TRT to identify electrons. The TRT can provide a substantial addition pion rejection factor particularly for lower energy tracks (less than 20-30 GeV) where the LAr has less ID power.
  - The TRT will be most useful in modes requiring identification of multiple electrons within a single event.
    - If one of the electrons is low energy there is a good chance of confusing it with a pion.
- All of the plots were made using GEANT3 and atlsim.
  - We need to redo this work using GEANT4 and Athena.

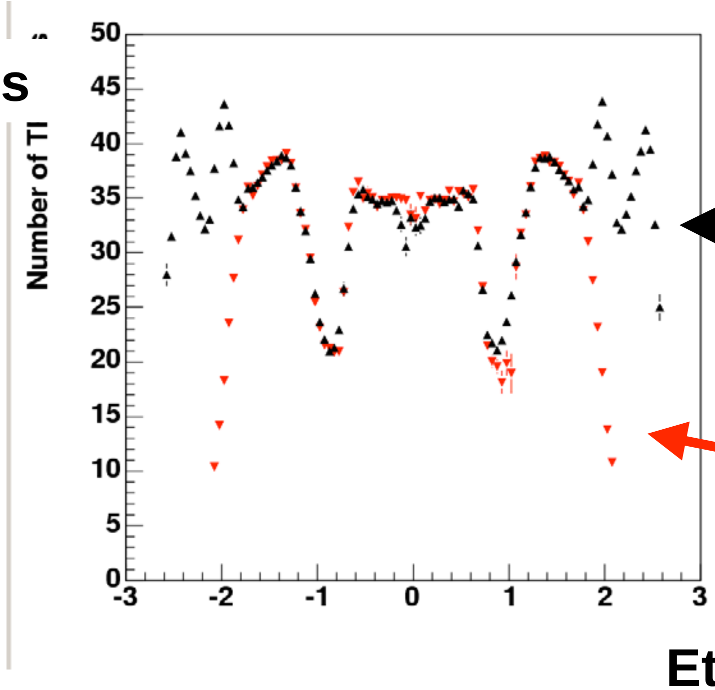
The Inner Tracker



Inner Detector Simulation Layout

Inner Detector Layout	DC1	DC2	Initial
B-layer radius	5 cm	5 cm	5 cm
2nd pixel layer & disk, forward TRT wheels	Present	Present	Absent
Longitudinal pixel size in b-layer	300 um	400 um	400 um

Number of TRT Hits



DC2 Layout

Initial Layout

Eta

Inner Tracker Particle ID

- The Inner Tracker aids in ID in several ways:
  1. Matching tracks to EM showers in the calorimeters.
     - EM showers with a track pointing at them are electrons.
     - EM showers without a track pointing at them are photons.
  2. Finding detached vertices caused photon conversions in the mass of the Inner Tracker.
  3. Directly identifying electrons using the TRT using Transition Radiation (TR) photons.
- Theoretically there are two ways that the TRT can identify electrons and reject pions:
  1. By using the pulse width generated by a tracks crossing a straw as a measure of the ionization deposited by a track.
     - This has been to be shown to not work with the current electrons.
  2. By looking for large pulses caused by Transition Radiation X-Rays made in radiators between the TRT straws.

Transition Radiation

- The TRT is constructed with the space between the straws is filled with material having many layers. High energy particles passing through these layer boundaries produce Transition Radiation (TR) photons with an energies of ~5-10 keV.
- The TRT gas is 70% Xe (Z=54) and TR photons interacting in it are largely absorbed producing a large energy deposit.
  - A MIP deposits an average of ~1.8 keV of energy crossing a TRT Straw.
- The separation is not perfect because:
  - The pion energy spectrum exhibits a long Landau tail of large energy deposits.
  - The pions knock-on δ-electrons that cause large deposits.

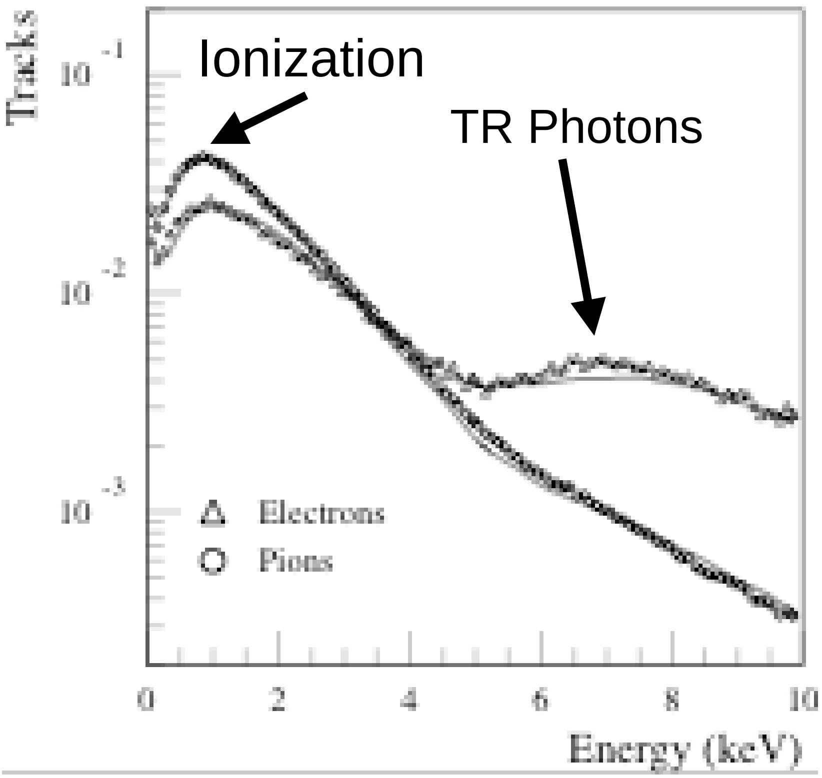
Simulating Straw Tube Response

- The straw tube response to an electron depends on both ionization (dE/dx) deposits and TR while the response to a pion depends only on ionization. It is not enough to only simulate the TR production in the radiators and absorption in the gas.
- Electrons with a Lorentz $\gamma > 1000$ generate simulated Transition Radiation photons. All particles have there ionization deposits simulated carefully.
  - Ionization is done with the Photo Absorption Ionization (PAI) model.
    - A special purpose PAI model was written by Pavel Nevski for GEANT3/atlsim.
    - Thomas Kittelman (NBI) translated Pavel's PAI model into C++ for use with the current C++ digitization. We have also used the native GEANT4 PAI model written by Vladimir Grischine of the GEANT4 team.
  - The TR photons are simulated as a single cluster in the TRT gas.
    - Pavel also wrote a the TR model used for GEANT3/atlsim (the TR model creates hits not digitizations).
    - The TR model for GEANT4 was written by Mogens Dam (NBI). We have also tried various TR models written for GEANT4 by Vladamir.

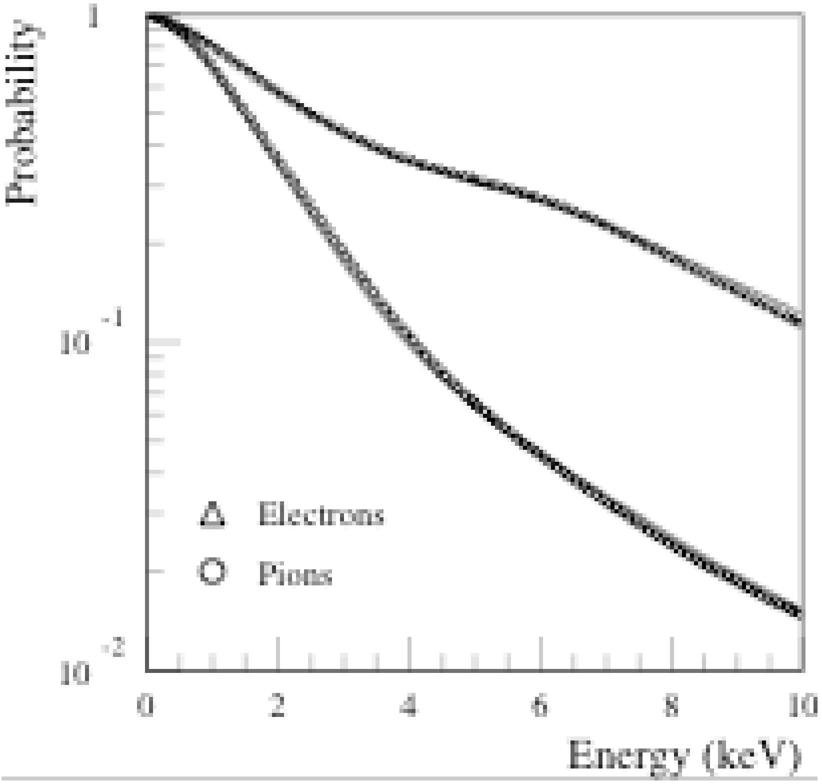
Identifying Electrons with the TRT

- Each TRT straw has two discriminator thresholds:
  1. A lower one set to ~200-300 eV that is used to measure drift time and provide the spatial resolution needed to use the TRT for particle tracking.
     - The low level discriminator measures the drift time with 3.125 ns bins.
  2. A higher one set to ~5000 eV that is used for pion rejection.
     - The high level discriminator is fired ~25% of the time by a 20 GeV electron and ~3-4% of the time a 20 GeV pion.
- The TRT is designed so that a stiff track usually crosses ~35 straws as it passes through the TRT.
  - Treating the hits on a track as combined ensemble leads to a pion rejection factor of order 100.
    - The rejection factor varies with pseudo-rapidity and track energy.

Energy Deposit and Probability

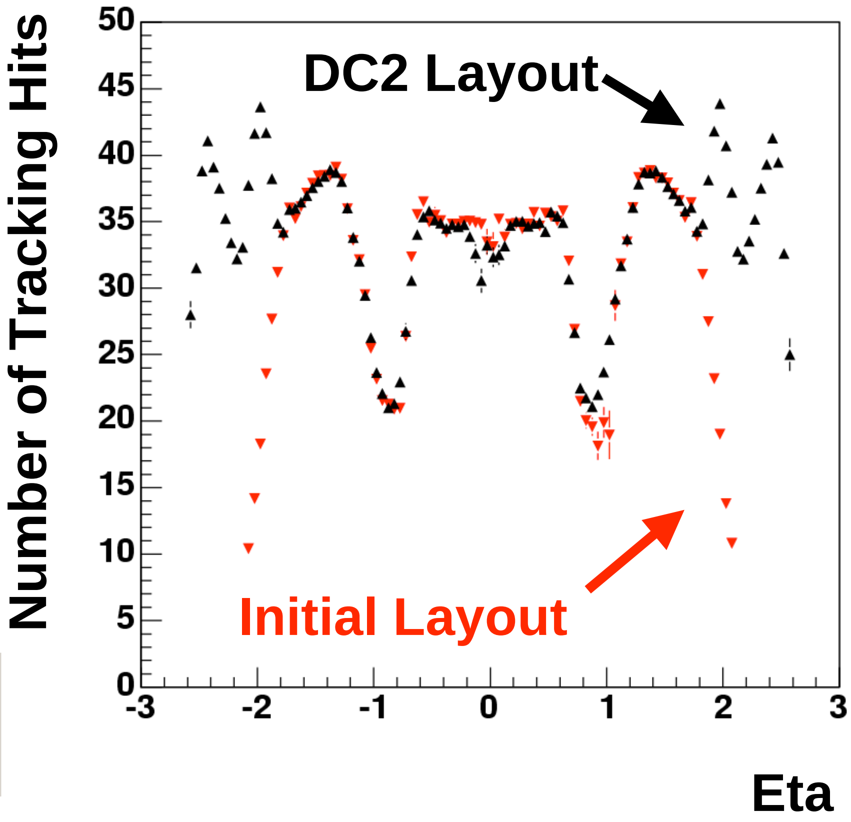


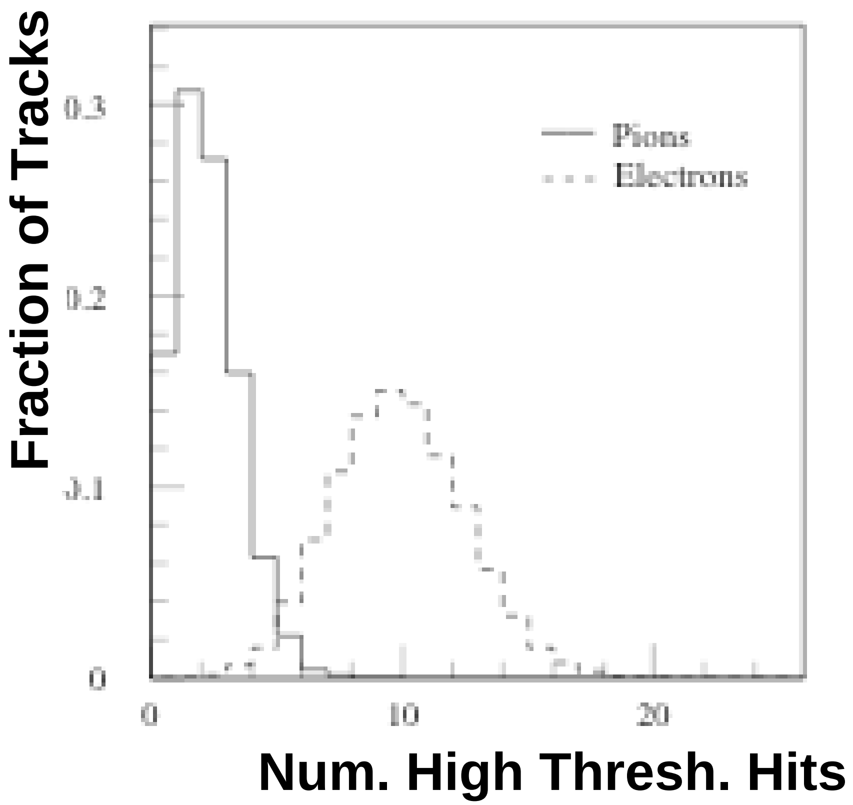
Raw energy deposition spectra for e and π (testbeam data).



Probability that e and π have an energy deposition larger than a given threshold (testbeam data).

Number of Hits

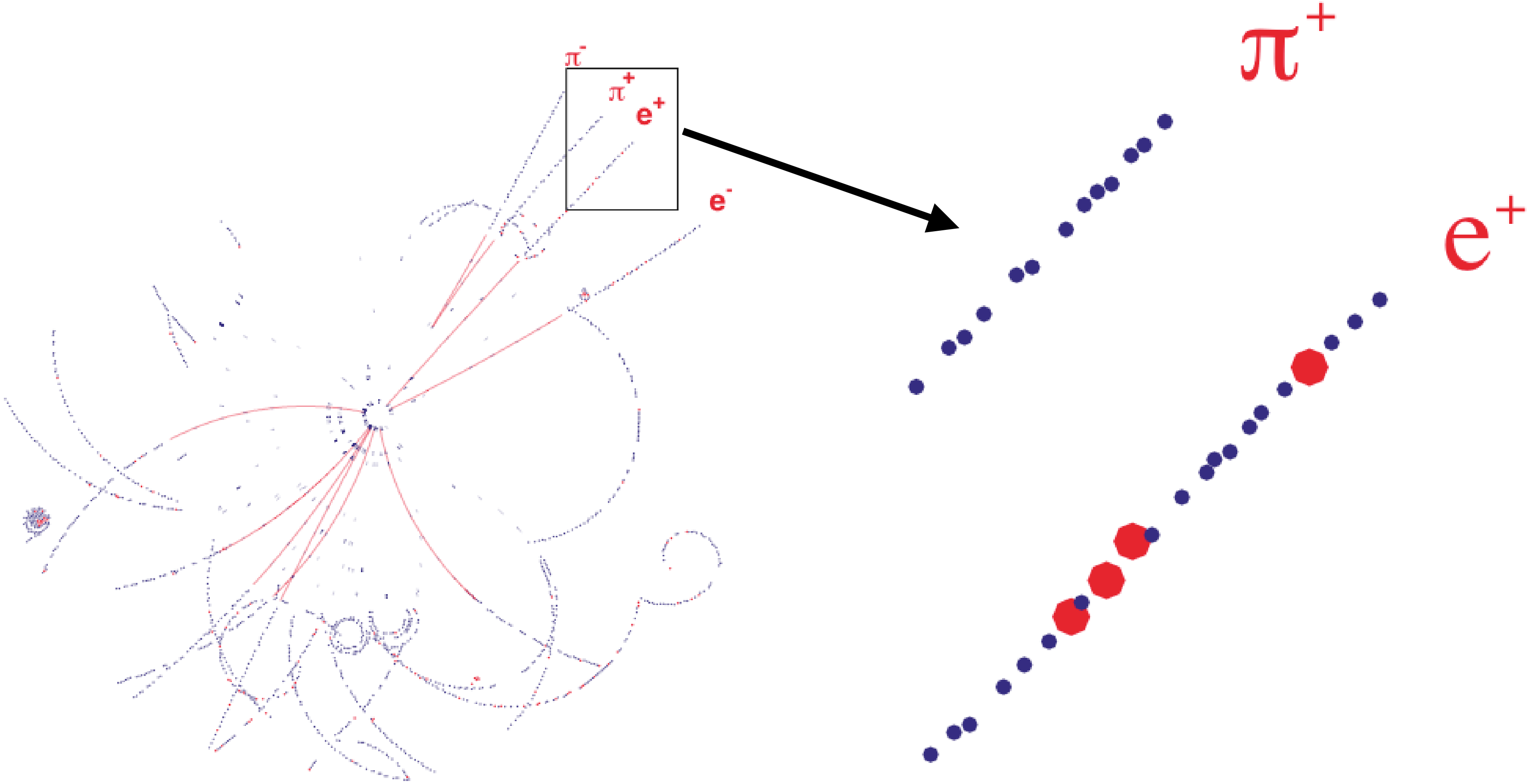




Recent Monte Carlo Studies by Davide Costanzo using GEANT4.

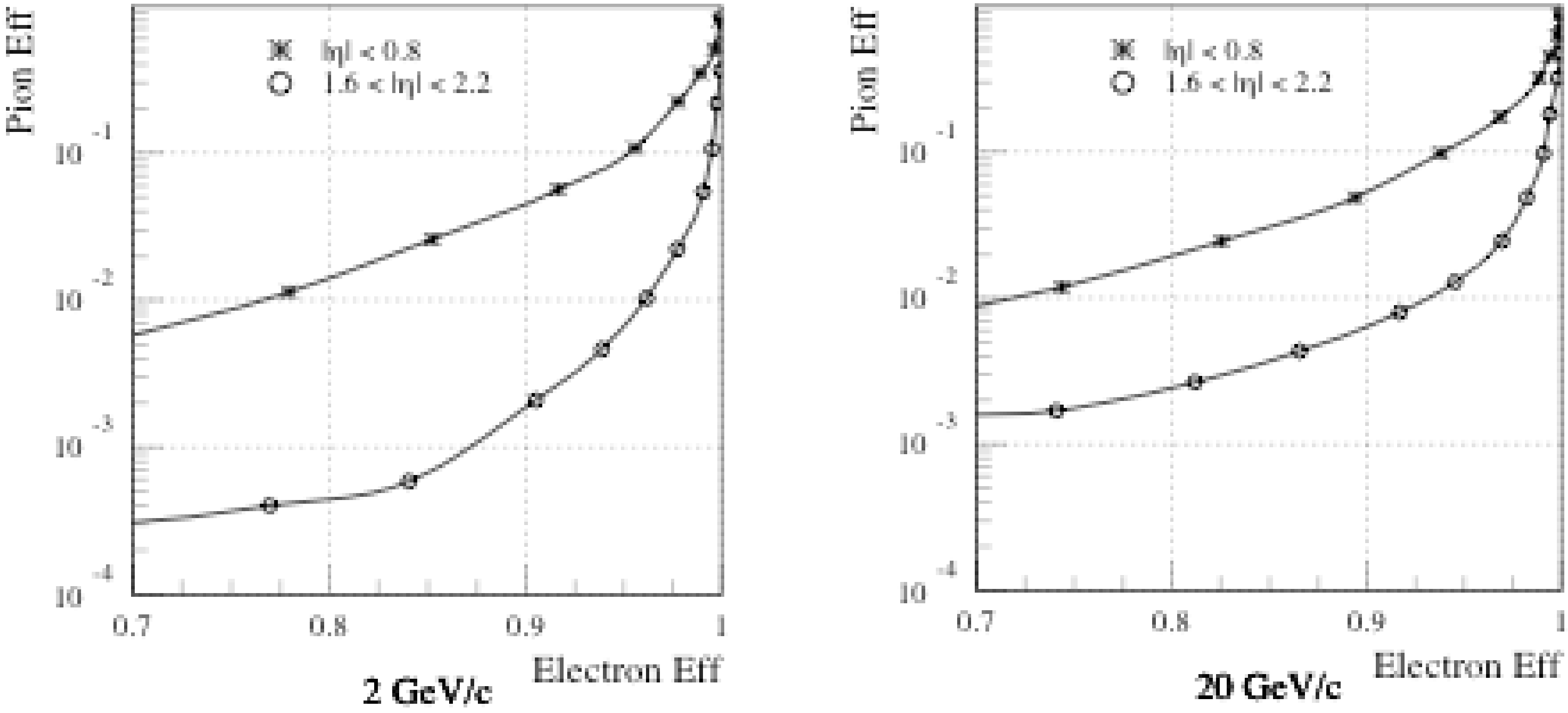
5 GeV Testbeam data grouped to emulate tracks with 35 hits.

Cartoon of How it Works



Display of a simulated $B^0_d \rightarrow J/K^0_s$ event in the ATLAS barrel TRT, at low luminosity (plot from thesis of A. Manara).

Pion Rejection Factors



2 GeV/c

20 GeV/c

Plots of the fraction π being identified as e versus the fraction of e being identified as e for tracks with p_T 2 GeV/c and 20 GeV/c (atlsim).

Summing Up

- The TRT can contribute substantially to electron identification.
- Many things remain to be studied:
  - The affect of luminosity on the electron identification.
    - Pile-up increases the probability of a pion track being measured with large pulse height because more than one track will contribute to the pulse height in the readout of a single straw.
  - We need to validate the GEANT4 simulation.
    - In the end, we used ionization models developed within the TRT community to model dE/dx (PAI) and TR for the hits. We completely recalculate the energy deposition in the digitization. These models have undergone much work in the last couple of years.
    - There are many, many results from testbeam and GEANT3 simulations to compare to. However we have not made the comparison in several years and things have evolved considerably.