

Performance of Particle Identification with the ATLAS Transition Radiation Tracker

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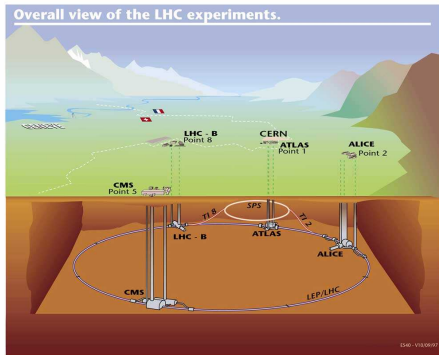
University of Pennsylvania

DPF 2011

Outline

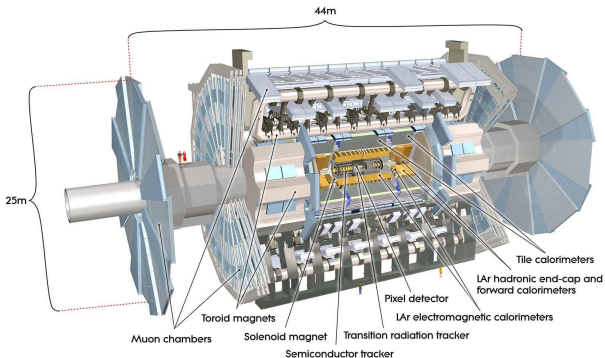
- The LHC, ATLAS and the TRT
- Transition Radiation
- Particle ID using the TRT High-threshold
- Validation of Hardware Settings
- Time over Threshold
- Combination of HT and ToT

LHC



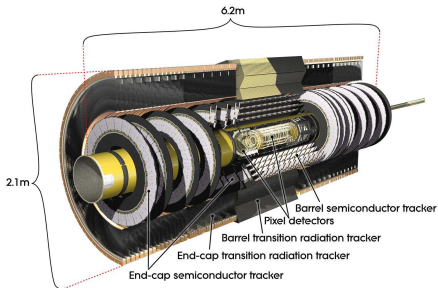
- 27 km circumference
- 7 TeV \sqrt{s} , 14 TeV designed
- Designed instantaneous luminosity of 10^{34} , 10^{32} reached in 2010
- Bunch spacing 150 ns or greater in 2010, design 25 ns spacing
- 4 main experiments

The ATLAS Experiment



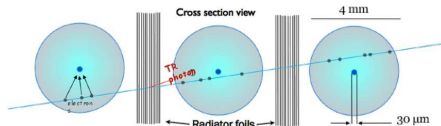
- ~3000 Scientists from ~200 institutes and ~40 countries
- General Purpose Detector
- Precision Tracking in a 2T magnetic field
- Electromagnetic and Hadronic Calorimetry
- Muon Spectrometry

- Outermost sub-detector of the ATLAS Inner Detector
- Combination straw tracker and particle ID from Transition Radiation
- Nearly 300,000 straws organized into a barrel section and two end-caps
 - Straws in the Barrel arranged parallel to the beampipe
 - Straws in the End-caps arranged in wheels radially perpendicular to the beampipe
 - End-caps sub-divided into A and B-type wheels, which differ in spacing between straw layers
- Active Gas Mix of 70% Xe, 27% CO₂, 3% O₂



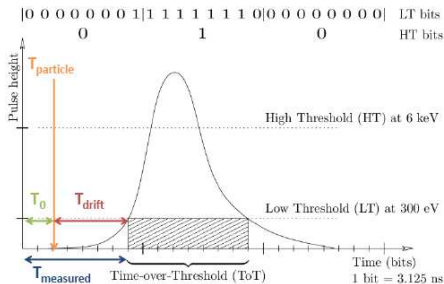
Transition Radiation

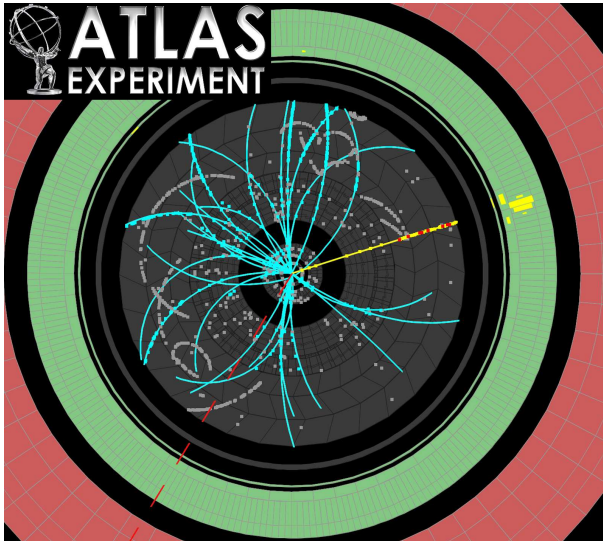
- Produced by highly-relativistic charged particles crossing boundaries with differing dielectric constants
- Radiators in the TRT:
 - Regular foils between straw layers in endcap
 - Oriented fibers interwoven between straws in barrel
- Useful for electron ID due to small mass electron mass compared with hadrons
- Up to particle energies of a few hundred GeV only Electrons produce significant amounts of TR
- Xenon active gas chosen for its absorption efficiency of TR photons of 6-15 keV, produces large energy deposition the straw



Transition Radiation

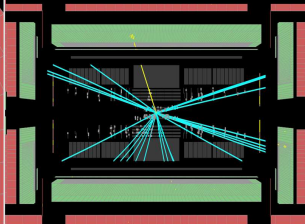
- TRT utilizes a two-threshold read-out
 - Low-threshold of 300 eV for tracking
 - High-threshold of 5-6 keV for detection of TR photons
- Low-threshold information available 8 times per BC (3.12 ns)
- High-threshold information every BC (25 ns)





Run Number: 152409, Event Number: 5966801

Date: 2010-04-05 06:54:50 CEST



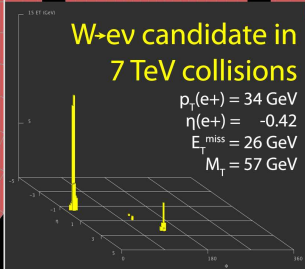
W \rightarrow ev candidate in 7 TeV collisions

$$p_T(e^+) = 34 \text{ GeV}$$

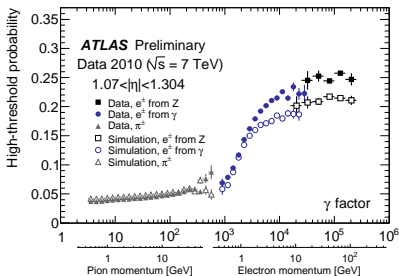
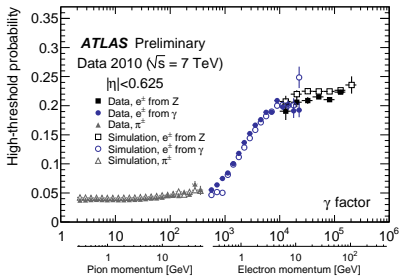
$$\eta(e^+) = -0.42$$

$$E_T^{\text{miss}} = 26 \text{ GeV}$$

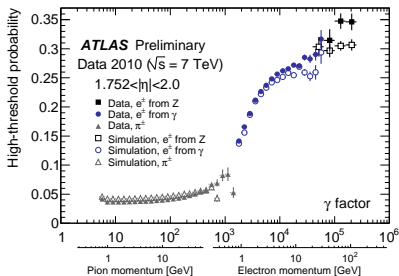
$$M_T = 57 \text{ GeV}$$



Turn-on Curves

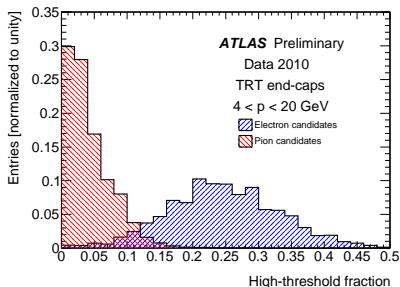
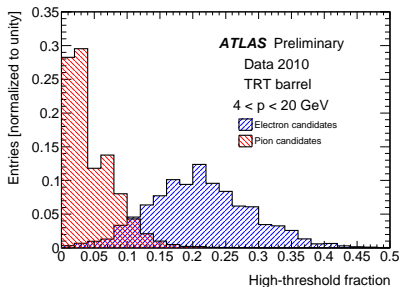


- Electrons from:
 - Photon Conversion
 - Z boson decays
- Pions from min-bias tracks, veto on photon candidates
- Onset of Transition Radiation is clearly visible as a function of Lorentz Gamma
- Exceeding MC expectation in the end-caps!

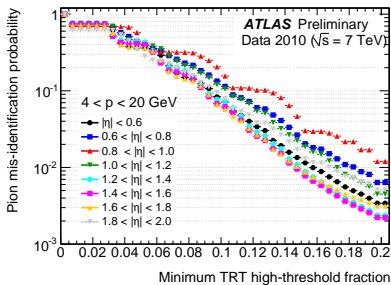
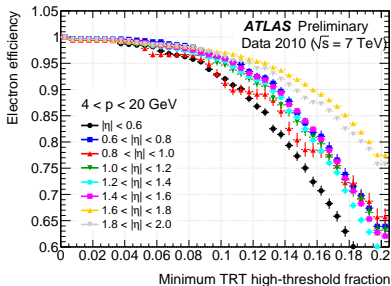


High-threshold fraction

- Plot HT ratio for each track, $4 < p < 20$ GeV, past the rise in the turn-on curve
- Good separation seen between Pion Candidates and Electron Candidates
- HT hits for pions due predominantly from large ionization deposits in the Landau tail



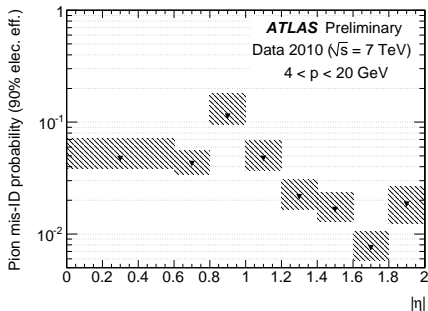
High-threshold fraction



- Due to geometrical effects and differing radiators, high-threshold response for both electrons and pions is highly dependent on η
- Vary a cut on minimum high-threshold fraction and determine efficiency for electrons to pass, and the pion mis-ID rate
- Electron efficiencies highest in the B-wheels, as expected from the turn on curves

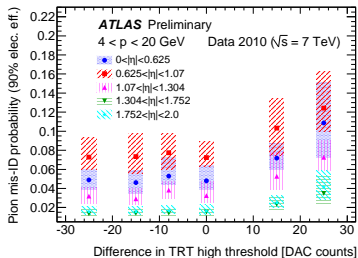
Pion Rejection

- As a benchmark, selected minimum HT cut that gives 90% electron efficiency, determine the fraction of pion candidates that also pass this cut
- Rejection factors ~ 10 across entire detector
- Rejection factors ~ 100 in best areas - Endcap B-type wheels
- PID largely uncorrelated with shower shape variables in the calorimeters



- Thus can be used as a powerful complement for increased purity of sample or estimation of fake rates

Validation of Hardware Settings

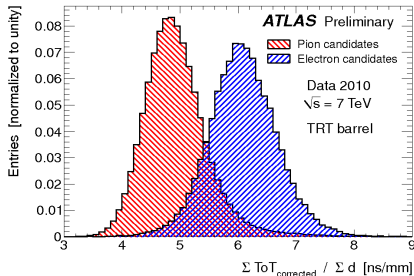


- Thresholds adjustable on on-detector electronics, measured in Digital to Analogue Converter setting (DAC Counts)

- High-threshold initially set at value that gave maximum separation power in the combined test-beam
- Variation in the detector taken into account by use of electronic noise scans
- Special run taken Summer 2010 where thresholds were changed during the run on the fly
 - A total of 20 nb⁻¹ taken at nominal, ± 15 , ± 25 , and -8 DAC Counts
- PID performance seen to be constant for lower settings, and poorer for higher settings
- Settings lowered slightly in Fall 2010 to ensure stability

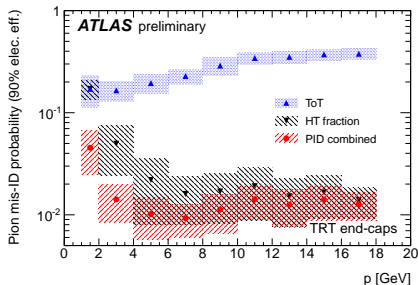
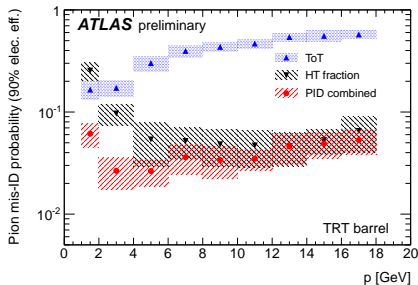
Time over Threshold

- Electrons on average have more primary ionizations along its path through the active gas
 - Leading edge on average closer to true distance of closest approach to the straw (slightly earlier)
 - Trailing edge on average closer to straw wall (slightly later)
 - Combine so that time the signal (ToT) is over threshold is higher for electrons
- Corrections made to correct for path length in the straw differing as a function of track to wire distance and Z-dependence
- Is also used in searches for exotic highly-ionizing particles



Combination of HT and ToT

- Construct individual likelihood functions containing the information from the HT and ToT (excluding HT hits). Two likelihoods are independent, so simple combination possible
- Time over Threshold enhances electron identification for momenta less than ~ 10 GeV
- Particularly useful since this is where separation from high-threshold is the poorest



Summary

- Particle ID with the TRT is performing well, and even exceeding expectations from simulation
- Pion rejection factors of 10-100 possible with 90% electron efficiency from cutting on high-threshold fraction
- Including ToT information increases separation power for $p < \sim 10$ GeV