Performance of Particle Identification of the Atlas Transition Radiation Tracker

Elizabeth Hines
for the Atlas Collaboration
TRDs for the 3rd Millennium
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The ATLAS Transition Radiation Tracker

- Operates as both a straw tracker and a TRD
- Active Gas of 70% Xenon used for efficient absorption of TR photons
- Electronics employ a two-level threshold
  - Low Threshold for Tracking of ~300 eV
  - High Threshold of about 6-7 keV for detection of large energy deposits from TR photons
W→ev candidate in 7 TeV collisions

\[ p_{T}(e^+) = 34 \text{ GeV} \]
\[ \eta(e^+) = -0.42 \]
\[ E_{T}^{\text{miss}} = 26 \text{ GeV} \]
\[ M_{T} = 57 \text{ GeV} \]
Selection

- Electrons from 2 sources
  - Tag and probe using photon conversions in min-bias
    - Abundant in early data – provides lots of statistics quickly for electrons up to ~20 GeV
  - Tag and probe using Z boson decays
    - Ability to probe higher momenta

- Pions from min-bias tracks
  - Veto electrons from conversions
  - Veto low momentum protons and kaons using dE/dx measurement in the Pixel detector
A Word On Purity of Samples

- First estimated from Monte Carlo
- Purity of Conversion Electron Selection is >99%
  - Contamination worst at high $\eta$ and highest momenta probed
- Purity of Pion Sample is ~85% in total
  - Primarily from Protons and Kaons, $p>$2 GeV – not a problem since all hadrons behave similarly at this momenta
  - Contamination from electrons <0.5%
Cross Checks on Purity

- Pion sample also taken from K short decays
  - Purer sample (>98% pion), results in good agreement confirm no significant dependence on hadron type for $p > 1$-2 GeV
- All samples also tested with a data driven method
  - Results in good agreement with Monte Carlo predictions
- For Z-sample only data driven method is used – shows purity of >99%
Turn On Curves

- Turn on behavior of TR is clearly visible as a function of Lorentz gamma
- Data is out performing MC expectations in the endcaps
- Only prototype barrel modules were available in the ATLAS Combined Test Beam, decreased ability to tune end-cap simulation as accurately before collision data
TR also shows interesting dependence on the detector structure

- “Build-up effect” between detector modules (in barrel) and wheels (in end-cap) reflect passive material between detecting elements
In contrast, hadron candidates do not see this “build up” effect (no TR photons) – only differences in track lengths in straw leading to higher ionization on average.

Can be used to refine particle ID.
Validation of Hardware Settings

- Thresholds are adjustable through on-detector electronics, measured in Digital to Analogue Converter setting (DAC Counts)
- The initial high-threshold setting used was the value that gave maximum separation power in the combined test-beam
- The variation across the detector taken was into account by use of electronic noise scans
- Special run was taken Summer 2010 where thresholds were changed during the run on the fly
- A total of $20 \text{ nb}^{-1}$ were taken at nominal, ±15, ± 25, and -8 DAC Counts
- Dependence on hardware threshold not well modeled in the simulation, so validation must be performed using real data.

Electrons

Pions

ATLAS Preliminary
Data 2010 (\sqrt{s}=7 TeV)

4 < p < 20 GeV
- Barrel
- End-cap A-wheels
- End-cap B-wheels

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Electron HT probability vs. Difference in TRT high threshold [DAC counts]
Pion HT probability vs. Difference in TRT high threshold [DAC counts]
The results of the test show that PID performance is stable for 2010 settings and lower, but degrades for higher settings.

The decision was made to lower slightly for 2011 in order to ensure stable data conditions.

The data was also used to refine chip-level high-threshold equalizations across the detector.
- Satisfied that hardware settings are optimal – proceed to detailed studies of the TR performance
- Concentrating on electrons that are above the TR threshold, good separation is seen in the fraction of HT hits
- Vary a cut on high-threshold fraction and see what the efficiency is for electron and pion candidates to pass this cut (Electron efficiency and Pion Mis-ID probability).
- Use finer $\eta$ binning than previous plots, since high threshold response is greatly dependent on $\eta$.
- Errors here are statistical only – no systematics for contamination taken into account.
- As expected end-caps outperform barrel.
And combining the two:

\[ \text{ATLAS Preliminary} \]
\[ \text{Data 2010 (\sqrt{s} = 7 \text{ TeV})} \]
\[ 4 < \mathbf{p} < 20 \text{ GeV} \]

- |\eta| < 0.6
- 0.6 < |\eta| < 0.8
- 0.8 < |\eta| < 1.0
- 1.0 < |\eta| < 1.2
- 1.2 < |\eta| < 1.4
- 1.4 < |\eta| < 1.6
- 1.6 < |\eta| < 1.8
- 1.8 < |\eta| < 2.0

Pion mis-identification probability vs. Electron efficiency
Using the 90% electron efficiency as benchmark point
- Using 90% electron efficiency as a benchmark point, determine pion mid-ID probability.
- Pion rejection factors >10 seen everywhere except transition region between barrel and endcap.
- Greatest rejection of >100 in the most efficient regions of the endcap B-type wheels.
Preview of Coming Attractions:

- Full PID power of the TRT exploits the combination of HT information with the additional separation power of Time over Threshold
  - Full talk by Jean-Francois Marchand on Friday on the use of ToT
Summary and Conclusions

- Particle ID with the ATLAS TRT is performing very well
  - Even exceeding MC expectations in several ranges of $\eta$
- Pion rejection factors of 10-100 obtained for high-threshold cuts giving 90% electron efficiencies
- Detailed studies with Z-$\rightarrow$ee data coming from 2011 $\sim$100x statistics from 2010