The ATLAS Transition Radiation Tracker

Performance with First High-Energy
Proton-Proton and Pb-Pb Collisions

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Outline

- Introduction
- Design
- Operation
- Tracking Performance
- Transition Radiation
- Particle ID Performance
- Heavy-Ion Collisions
- Summary

The ATLAS Detector

The ATLAS Inner Detector

Three Parts of the ATLAS ID

Pixel: silicon pixels (→ Tayfun's talk)

SCT: silicon stereo-strips (→ Vasiliki's talk)

TRT: straw-tube tracker (this talk)

- drift tubes (4 mm diameter) with central wire
- good single-point resolution (around 120 μm)
- long lever arm for wide-range p_T measurement
- continuous tracking (typically > 30 hits per track)
- high tolerance against radiation doses
- extra feature: electron identification

Alignment: putting it all together (→ Vicente's talk)

TRT Geometry — View

Endcap

Barrel

TRT Geometry — Numbers

TRT Barrel

- **longitudinal** straws (along the beam axis) of 1.5 m length
- three layers of 32 modules each, **52 544** straws
- wires electrically split, read out on both sides
- ranging from $r = 0.5$ m to $r = 1.1$ m, covering $|\eta| < 1$

TRT Endcap A and C

- **radial** straws (perpendicular to the beam axis) of 0.4 m length
- 8 inner wheels, 12 outer wheels per side, **122 880** straws
- wires read out at their outer end
- ranging from $|z| = 0.8$ m to $|z| = 2.7$ m, covering $1 < |\eta| < 2$

TRT Straws

Structure

- wound Kapton tube ($d = 4 \text{ mm}$) with glued carbon fibre reinforcement
- gold-plated tungsten wire ($d = 31 \text{ }\mu\text{m}$)

Electrical supply

- straw wall at -1530 V
- central wire at ground
- proportional counter mode

Gas filling

- Xe-CO₂-O₂ mixture (70 : 27 : 3)
- X-ray absorber plus quenchers

Particle Detection

Signal formation

- charged particles ionize the gas
- electrons drift towards the wire
- gas amplification avalanche
- first arrival determines drift time

Signal readout

- signal gets amplified
- sampled in 24 time bins of 3.12 ns
- each time bin compared against threshold (300 eV): 24-bit pattern
- buffered in 6- μ s readout pipeline
- passed on to central ATLAS DAQ

Calibration Procedure

T_0 calibration

- defines offset between start of readout and arrival of particles
- accounts for time of flight, signal propagation, clock offsets
- daily jitter on the level of 100 ps

$R(t)$ calibration

- relates measured drift time with distance of closest approach
- depends on active gas mixture, voltage, magnetic field
- very stable over time, due to “Gas Gain Stabilization System”

Position Resolution (1)

TRT yields avg. of 30 position measurements for each track

- **barrel: 118 μm** residual
- **endcaps: 132 μm** residual
- recent improvements from wire-by-wire **alignment**

Position Resolution (2)

Residuals vs. momentum

- increases for low momenta due to stronger scattering

Residuals vs. vertices

- number of reconstructed primary vertices in event
- cut for $p_T > 10$ GeV
- absolute effect is small

Tracking Efficiency

Do we see a hit where we'd expect to see one?

- averaged over all straws of a detector region
- known-dead straws excluded (approximately 2% of all)

Yes, we do most of the time!

- better than 94% in the plateau (with 2% noise occupancy)
- drops due to geometrical and reconstruction effects

Momentum Resolution

TRT contributes significantly to Inner Detector tracking

- large **number of hits**
- long **lever arm**
- particularly helpful for high transverse momenta

ID tracking is performing well

- close to ideal Monte Carlo
- **alignment** is important!
- here: $Z \rightarrow \mu\mu$ invariant mass

Transition Radiation

What is it?

- charged particles can emit photons at **material boundaries** ($\epsilon_1 \neq \epsilon_2$)
- effect depends on $\gamma = E / m$
- typical photon energies 5–30 keV (from gas–plastic transition)

How do we use it?

- many thin **radiator** fibres/foils increase emission probability
- xenon gas acts as X-ray **absorber**
- **ternary** readout electronics register high-threshold hits (6 keV) sampled in 25-ns time bins

Particle Identification (1)

High-threshold probability

- electron-hadron discrimination using transition radiation (up to energies of 150 GeV)
- works best in the endcaps (more, regular radiators)

High-threshold fraction

- fraction of HT hits per track
- electrons from conversions
- momentum range 4–20 GeV

Particle Identification (2)

Time over (low) threshold

- depends on energy deposition dE/dx of traversing particle
- depends on β (Bethe-Bloch)
- divided by transverse path length of track in the straw
- corrected for hit position along the straw

Combining HT and ToT

- yields additional information to improve the particle ID

Heavy-Ion Collisions

Heavy ions are a challenge!

- thousands of tracks
- avg. occupancy around 50%, peak values up to 90%
- large event data sizes
- preview of high-lumi LHC

The TRT can deal with them

- lossless data compression
- tracking and reconstruction adapted to high occupancies
- TRT improves track finding and momentum resolution also in heavy-ion events

Summary

The ATLAS TRT provides **tracking** and **identification** of charged particles

With the latest alignment and calibration constants, spatial residuals of **118 μm (barrel)** and **132 μm (endcaps)** can be achieved

TRT tracking improves overall **momentum resolution**, transition radiation improves **electron identification**

Heavy-ion collisions show that the TRT is **ready** for high occupancies at LHC's ever-increasing luminosities

References

Images and plots:

- [atlas.ch](#) Multimedia (slide 2, 3, 4, 6, 8)
- [TRTPublicResults](#) TWiki (slide 12, 13)
- [ApprovedPlotsID](#) TWiki (slide 14)
- [InDetTrackingPerformanceApprovedPlots](#) TWiki (slide 14, 18)
- [EventDisplayHeavyIonCollisions](#) TWiki (slide 18)
- [ATLAS-CONF-2011-006](#) (slide 10)
- [ATLAS-CONF-2011-012](#) (slide 6, 11)
- [ATLAS-CONF-2011-128](#) (slide 16, 17)

Related presentations:

- [ATL-INDET-SLIDE-2011-200](#)
- [ATL-INDET-SLIDE-2011-254](#)