Commissioning of the Charged Lepton Identification with Cosmic Rays in ATLAS

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on behalf of the ATLAS collaboration

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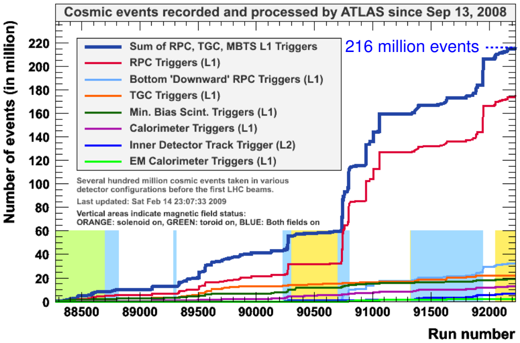
Outline

1. Cosmic rays in ATLAS
2. Commissioning of the muon identification with cosmic rays
3. Commissioning of the electron identification with cosmic rays
4. Commissioning of the τ identification with cosmic rays

Cosmic rays in ATLAS

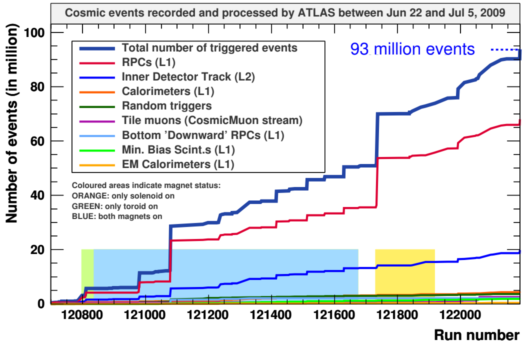
Cosmic ray data taking periods in ATLAS

Fall 2008



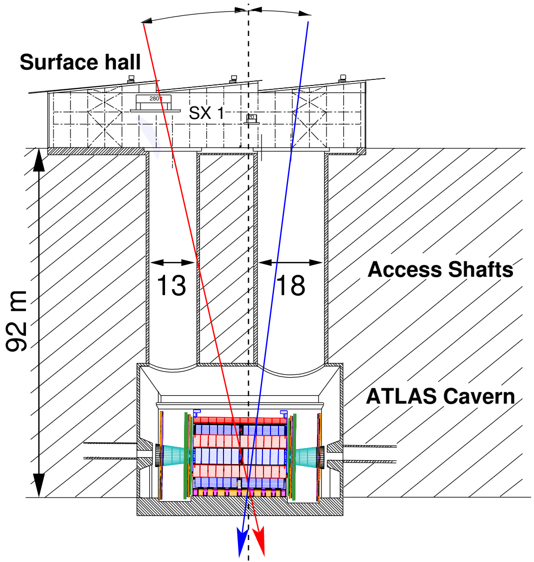
- 216 million events with different detector configurations.
- ~ 20 million events with magnets turned on.
- Period used for the commissioning of e, μ and τ identification.

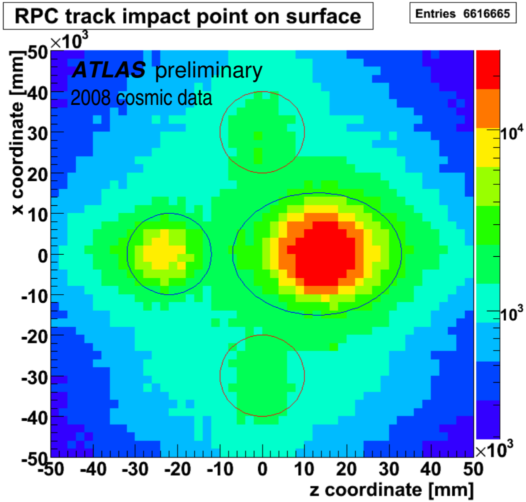
Summer 2009



- 93 million events with different detector configurations.
- ~ 20 million events without magnetic field used for muon spectrometer alignment.
- ~ 20 million events with magnets turned on used for the commissioning of the muon identification.

Cosmic rays in ATLAS

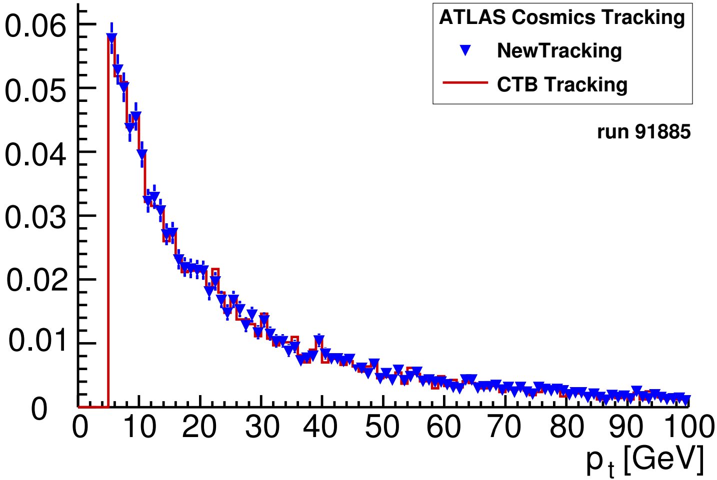




- Mainly muons flying through the access shafts are detected by ATLAS.

⇒ Commissioning of identification algorithms restricted to the barrel region.

P_t Cosmics Spectrum | ATLAS Preliminary

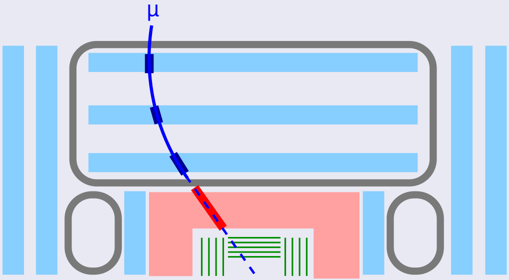


- Typical cosmic ray momentum spectrum with fall-off at large momenta.
- Substantial muon rate up to ∼100 GeV.

Commissioning of the muon identification with cosmic rays

Muon identification

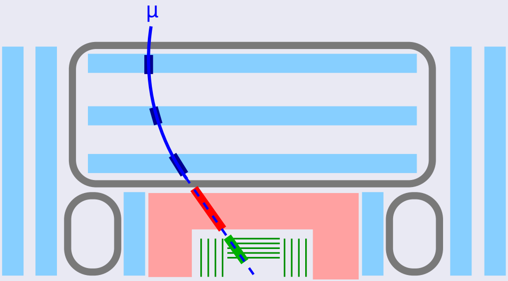
Stand-alone muons



Measurement of the muon momentum in the muon spectrometer

corrected for the energy loss in the calorimeters.

Combined muons



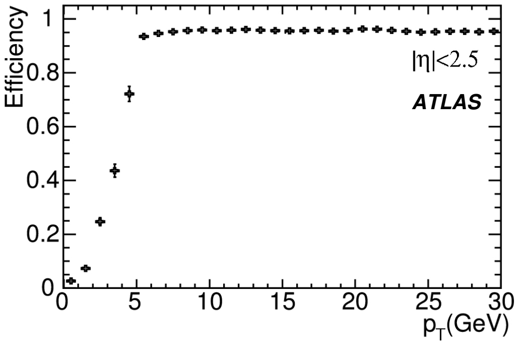
Measurement of the muon momentum in the muon spectrometer

corrected for the energy loss in the calorimeters

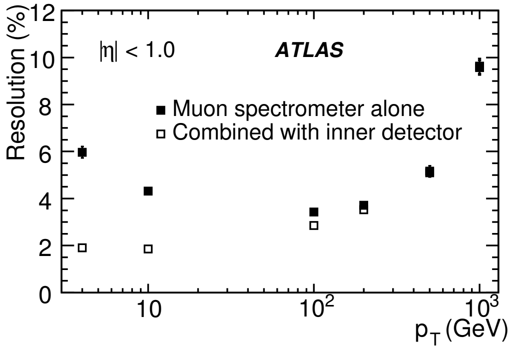
and combined with the momentum measurement in the inner detector.

Expected performance of the muon identification

Identification efficiency



Momentum resolution



- Efficiency: 95% for $p_T > 5$ GeV. (Fake rate $\sim 0.1\%$.)
- Inefficiency due to uninstrumented areas of the detector.

- Resolution 2% for $p_T < 100$ GeV.
- Excellent resolution $< 10\%$ up to 1 TeV.
- Resolution at high p_T given by the muon spectrometer.

Expected performance of the muon identification

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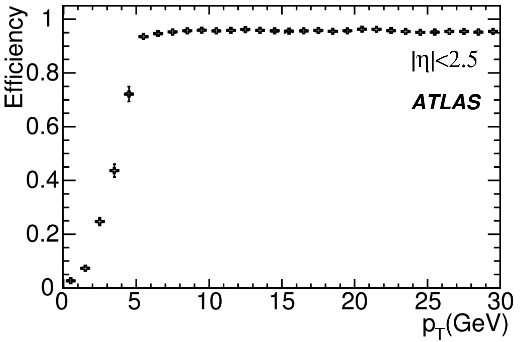
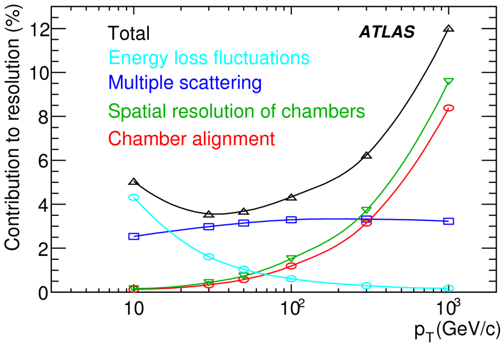


Momentum resolution



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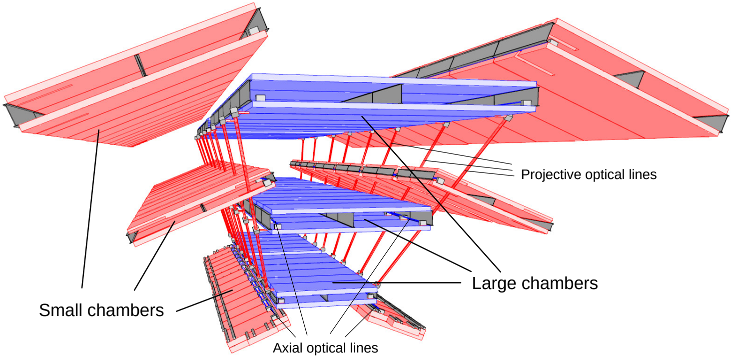
- Muon chamber alignment crucial at high P_T.

Alignment concepts for the ATLAS tracking detectors

Inner detector. Alignment with tracks by minimizing track residuals.

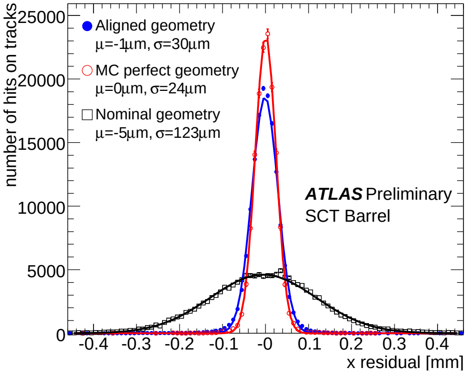
Muon spectrometer. Combination of track based and sensor based alignment.

Sketch of barrel sectors of the muon spectrometer



- Movements of the chambers are monitored with μm precision by a system of optical sensors.
- Relative positions of the chambers are measured with straight muon tracks (obtained with turned off magnetic field).

Alignment of the inner detector with tracks



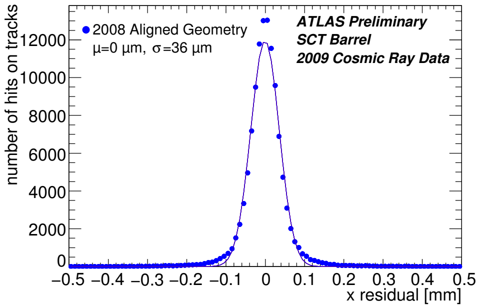
Ideal geometry (MC)

24 μm residual width.

Track alignment with 2008 data

30 μm residual width.

$\Rightarrow$ Alignment accuracy $\lesssim 18\ \mu$m.



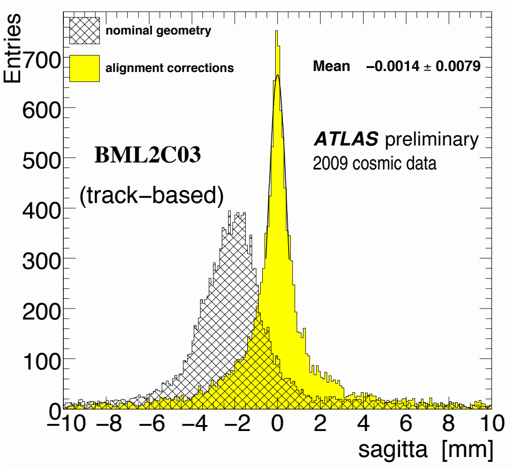
Track residual in 2009 data with 2008 alignment constants

Residual with: 36 μm.

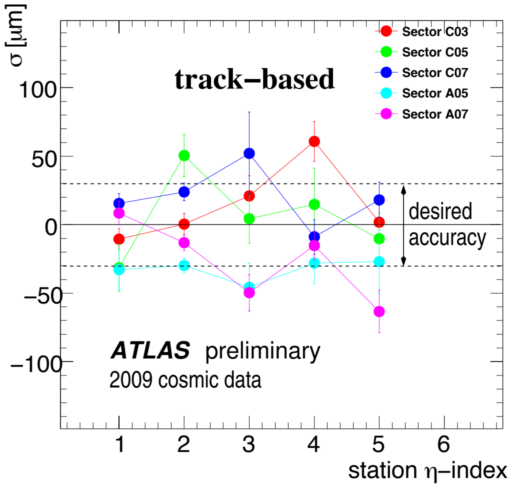
$\Rightarrow$ Geometry stable on the level of 20 μm.

Alignment of the muon spectrometer

Alignment accuracy for one chamber



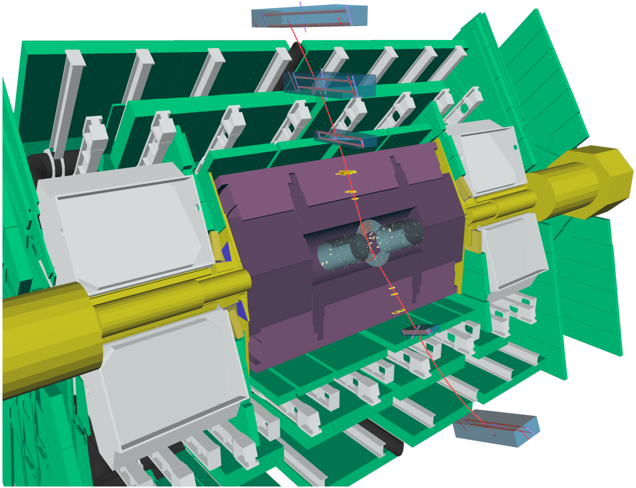
Alignment accuracy in top part

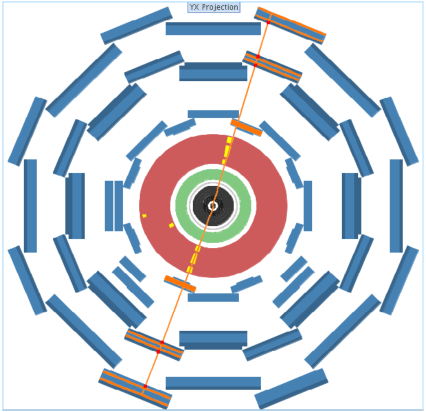


- Accuracy of nominal geometry ~1 mm consistent with mechanical alignment accuracy.
- Alignment accuracy after track alignment:

  Top part: < 100 μm. Bottom part: < 200 μm.
- Desired accuracy of 30 μm requires higher statistics (recorded in 10/2009).

Performance measurements

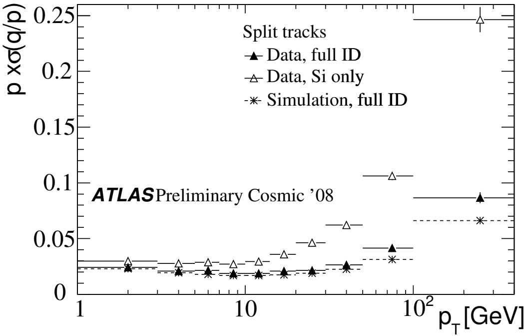




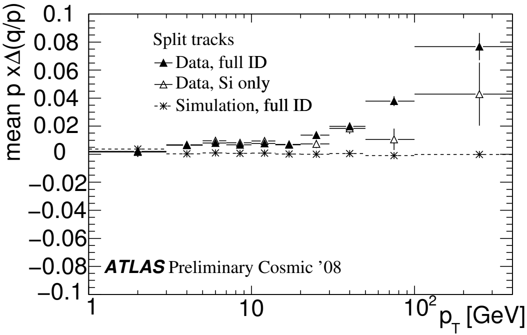
Technique for performance measurements

- Select tracks pointing to center of the ATLAS detector.
- Split the tracks into a bottom and a to track to immitate a dimuon event in pp collisions.
- Compare the top and bottom track.

Momentum resolution



Momentum bias

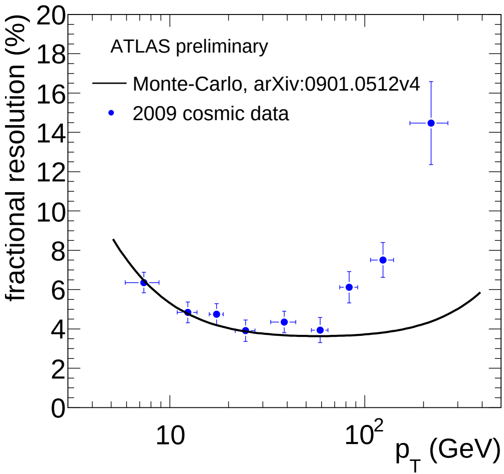


Present alignment accuracy (limited by available statistics) leads to

- a degradation of the momentum resolution by ∼20%,
- momentum bias of $\lesssim 2\%$ up to $p_T = 100$ GeV.

⇒ Performance close to nominal for $p_T^{\mu} < 100$ GeV.

Momentum resolution of the muon spectrometer



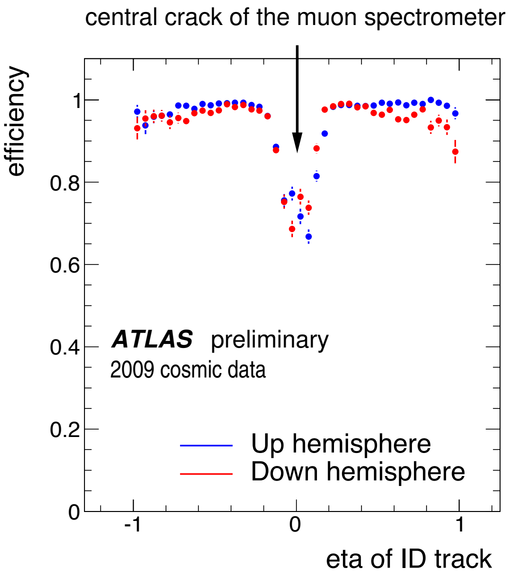
- $p_T \lesssim 100$ GeV: measured resolution compatible with expectation.
- $p_T \gtrsim 100$ GeV: significant degradation of the momentum resolution.
- Main sources of the degradation:
  - Limited alignment accuracy to be improved with high statistics of new cosmic muon data.
  - Limited timing resolution (cosmic muon events are asynchronous with the artificial LHC clock used as timing reference).

Expected momentum resolution for first LHC data with improved alignment:

- $p_T < 100$ GeV: nominal resolution of 4%.
- p_T=1 TeV: 20% instead of nominal 10%.

$\Rightarrow$ No degradation of the standard-model physics potential!

Reconstruction efficiency of the muon spectrometer



Analysis technique

- Use inner detector tracks to tag muons.
- Measure how often this tracks are reconstructed in the muon spectrometer.

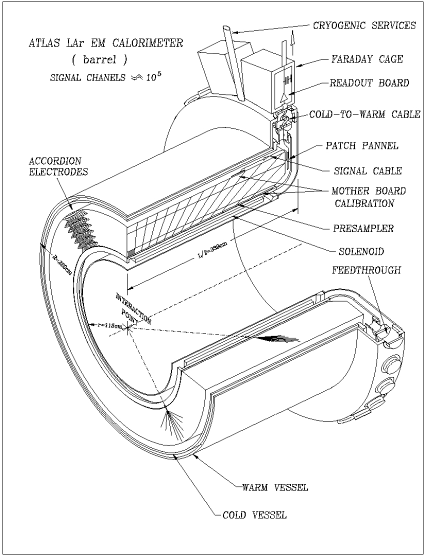
Results for $p_T^\mu > 6$ GeV

- Efficiency as expected.
- Inefficiencies related to the acceptance gaps of the spectrometer:
  - $\eta \sim 0$: hole for cables to the inner detector and calorimeters.
  - Bottom: Lower efficiency due to feet of the detector.

Muon reconstruction commissioned for standard-model physics studies!

Commissioning of the electron identification with cosmic rays

Electron identification in ATLAS



Loose cuts

- Electromagnetic cluster fully contained in the LAr ECAL.
- A track associated with this cluster.
- Lateral shower shapes compatible in middle calorimeter with electron.

Additional medium cuts

- Use lateral shower shape in first layer with fine granularity in along η.
- Inner detector track hit requirements to suppres electrons from converted photons.

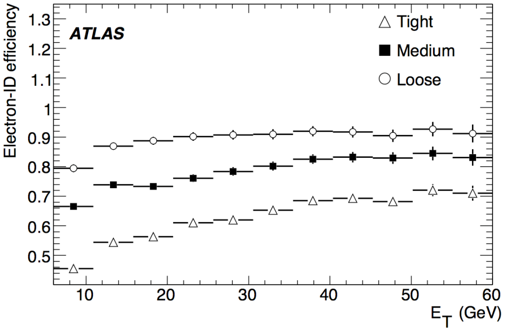
Additional tight cuts

- Stricter inner detector track hit requirements.
- Isolation requirements.
- Use of transition radiation in the transition radiation tracker.

Expected performance of the electron identification

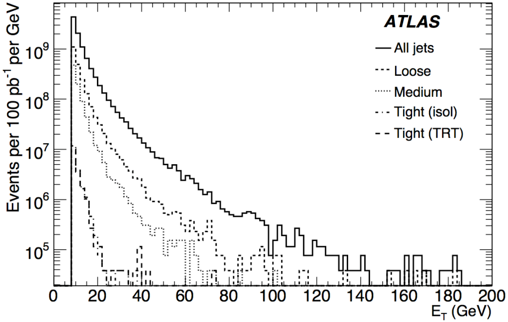
Identification efficiency

$H \to 4e$ events



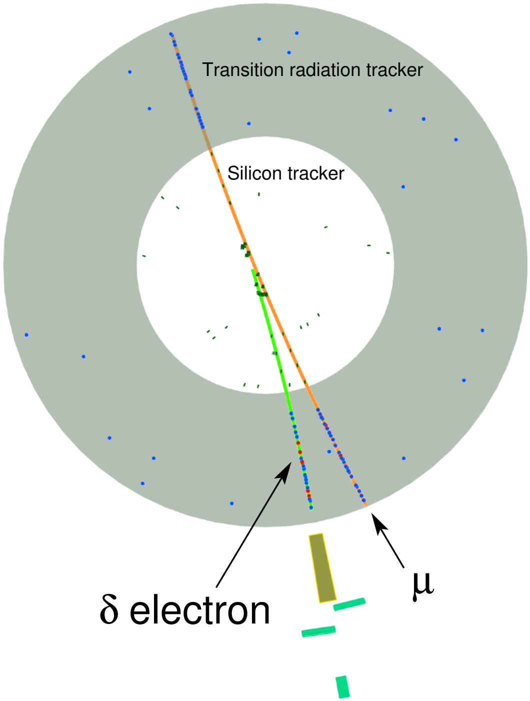
Jet rejection

Minimum bias events



Effiency of tight selection ∼65% at a jet rejection of ∼10000.

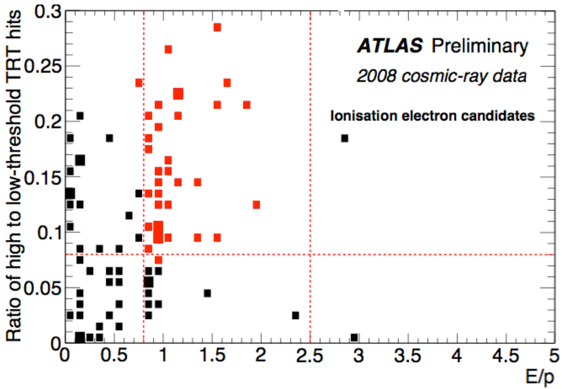
Commissioning of the $e^{\pm}$ identification with cosmic rays



Electron selection

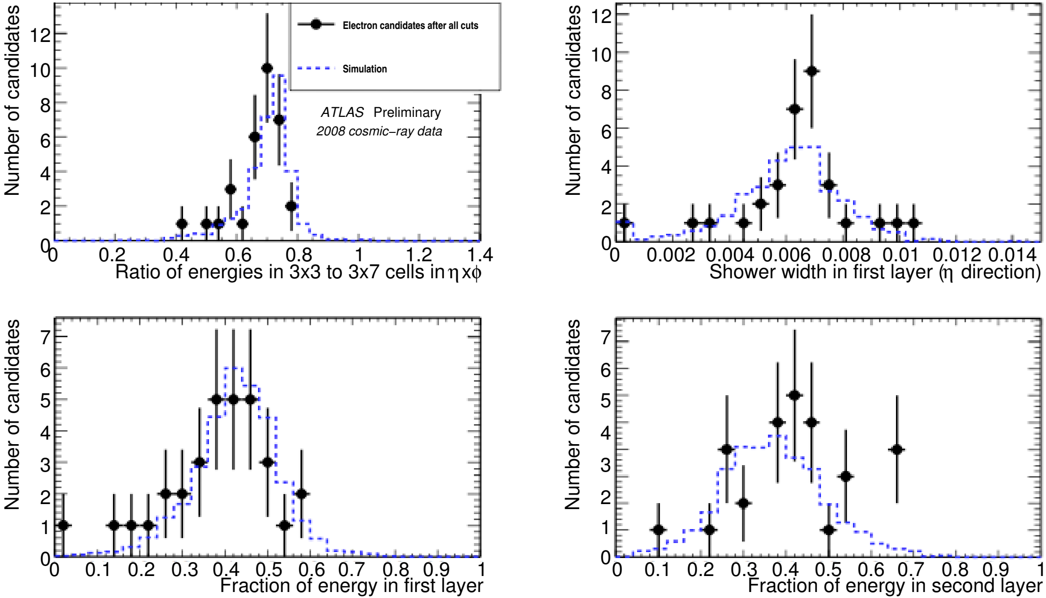
- Energy deposition in the e.m. calorimeter > 5 GeV which is larger than the energy loss of muons in the e.m. calorimeter.
- Apply medium electron identification cuts.
- Discriminants against muons:
  - $\frac{E}{p}$ ~ 1 for electrons.
    ~ 0 for muons.
  - Transition radiation.
    (Only muons with $E > 100$ GeV produce transition radiation.)

Electron candidates in ATLAS commissioning data



- Input for the analysis: $3.5 \cdot 10^6$ events with tracks in the inner detector.
- 85 ionization electron candidates.
- 36 candidates with $\frac{E}{p}$ and transition radiation compatible with electron hypothesis.

Shower shape variables for electron candidates



Shower shapes for electron candidates in agreement with simulation.

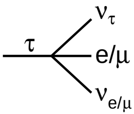
(More details on electron commissioning on J. Kraus' poster.)

Commissioning of the τ identification with cosmic rays

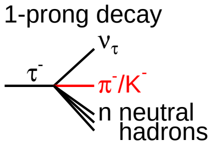
τ identification

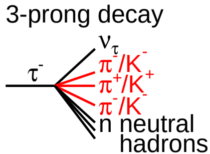
- τ leptons are identified through their decays.

35% leptonic decays



65% hadronic decays

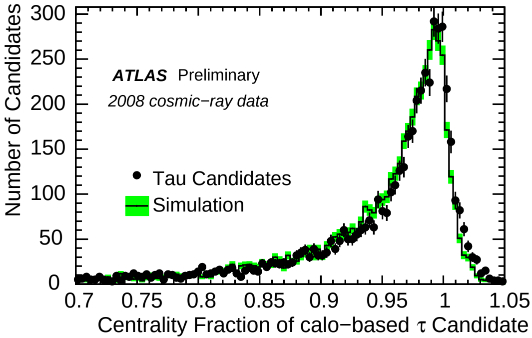




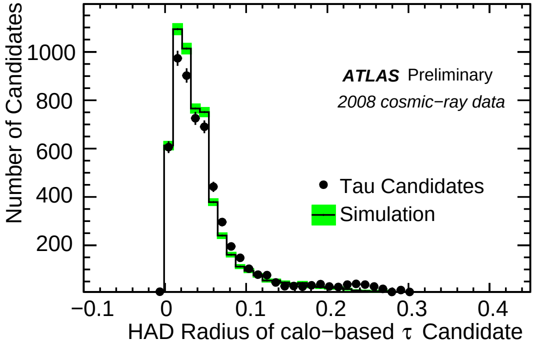
- Leptonic τ decays difficult to distinguish from primary electrons and muons.
  $\rightarrow$ Focus on hadronically decaying τ leptons.

Commissioning of the τ identification with cosmic rays

- No real τ leptons in ATLAS cosmic events.
- Highly energetic muons with accompanying bremsstrahlung photons or δ electrons can lead to fake τ candidates.
- Validation of the Monte-Carlo predictions for τ identification variables with cosmic events.



$E_T(\Delta R < 0.1)/E_T(\Delta R < 0.4)$



(Lateral shape of hadronic showers)

Agreement between real data and Monte-Carlo predictions!

Summary

Cosmic ray events recorded by the ATLAS detecotr in fall 2008 and summer 2009 were used to commission the charged lepton identification algorithms.

τ lepton identification

- No real τ leptons in cosmic events, but opportunity to study τ misidentification of muons.
- Measured distributions of τ identification variables for fake τ candidates are in good agreement with the Monte-Carlo prediction.

Electron identification

- δ electrons produced by highly energetic muons in the detector material have been identified successfully by exploiting the transition radiation detection capability of the inner detector.

Muon identification

- Muon tracks were used to align the inner detector and muon spectrometer:
  - Achieve alignment accuracy guarantees no degradation muon momentum resolution up to p_T=100 GeV and 20% resolution for p_T=1 TeV.
- Measured muon detection efficiency as expected.

ATLAS is ready for standard-model physics with leptonic final states at LHC.