Electron performance in the ATLAS experiment

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Outline

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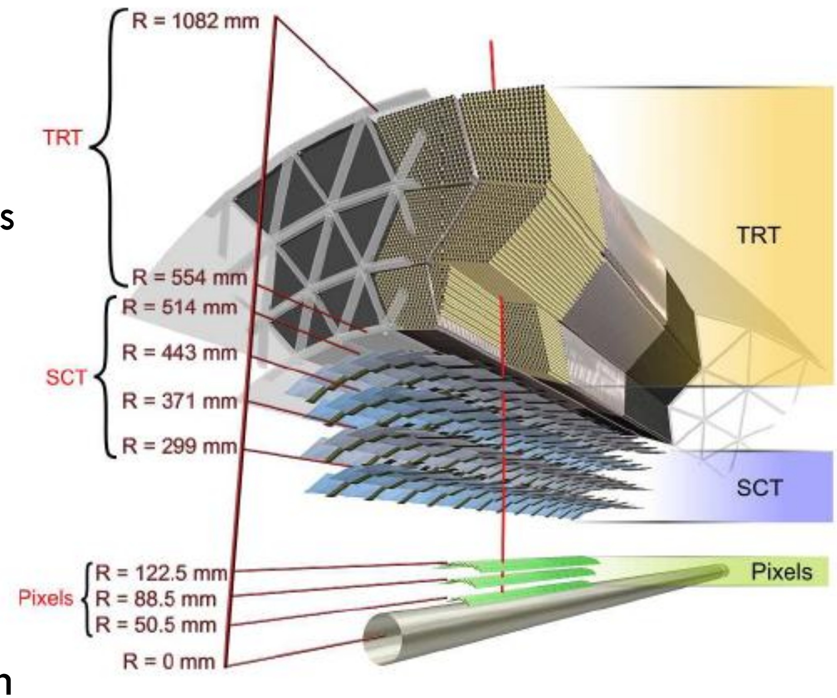
  - The ATLAS Liquid argon calorimeter
- Electron reconstruction
- Electron calibration
- Uniformity checks on $\pi^0 \rightarrow \gamma\gamma$
- Electron identification
  - MC/data comparisons of identification variables
- J/ψ observation
  - Performance checks on J/ψ (plans)
- $W \rightarrow e\nu$ plans for performance studies

The Transition Radiation Tracker (TRT)

- The Inner detector consists of three independent but complementary sub-detectors.
  - At inner radii, high-resolution pattern recognition capabilities using discrete space-points from silicon pixel layers and stereo pairs of silicon microstrip layers
  - At larger radii, the transition radiation tracker (TRT), layers of gaseous straw tube elements interleaved with transition radiation material.

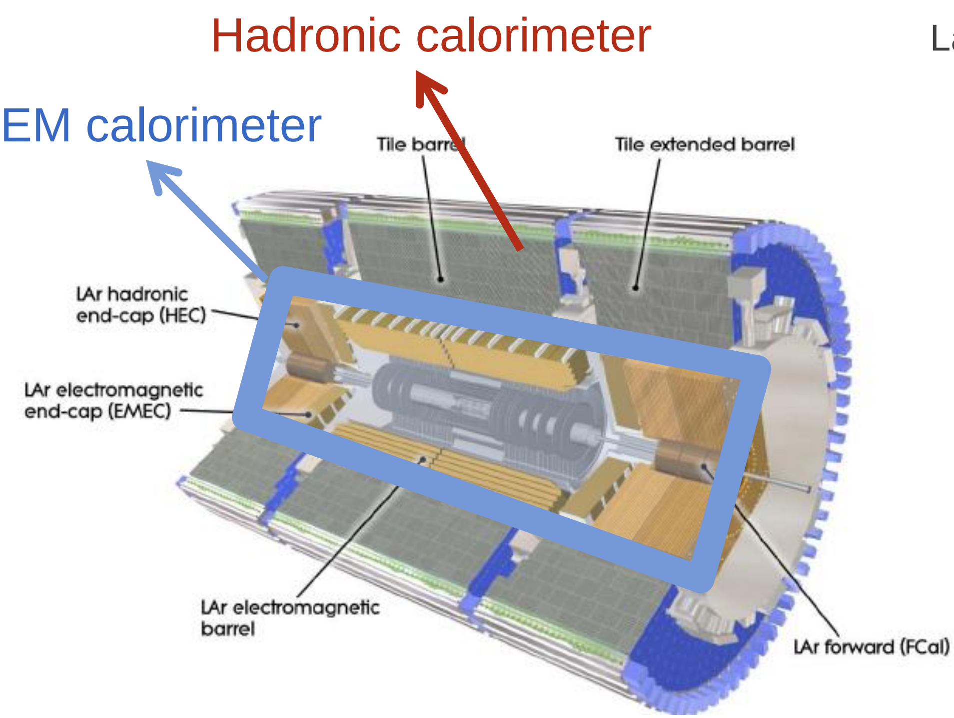


A charged track of 10 GeV pT in the barrel inner detector (η = 0.3).

- The TRT provides discrimination between electrons and pions over energy range between 1 and 200 GeV using transition radiation in foils and fibres. Two thresholds: the lower set to register minimum-ionising particles and the higher intended for transition radiation (TR) photon interactions.

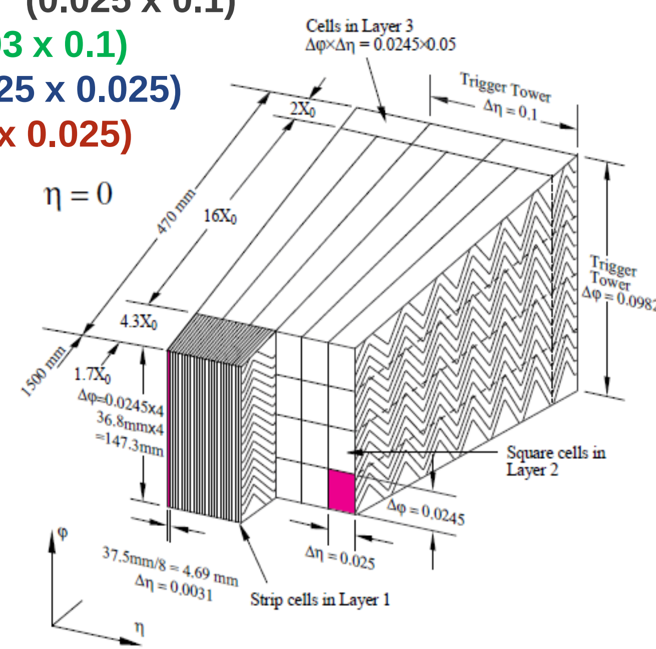
The Liquid Argon (electromagnetic) Calorimeter

- Lead-liquid argon detectors with accordion shape absorbers and electrodes. This geometry allows the calorimeters to have several active layers in depth:
  - three in the precision-measurement region ($0 < |\eta| < 2.5$)
  - two in the higher-η region ($2.5 < |\eta| < 3.2$) and in the overlap region between the barrel and the end-caps.
- In the precision measurement region, an accurate position measurement is obtained by finely segmenting the first layer in η.



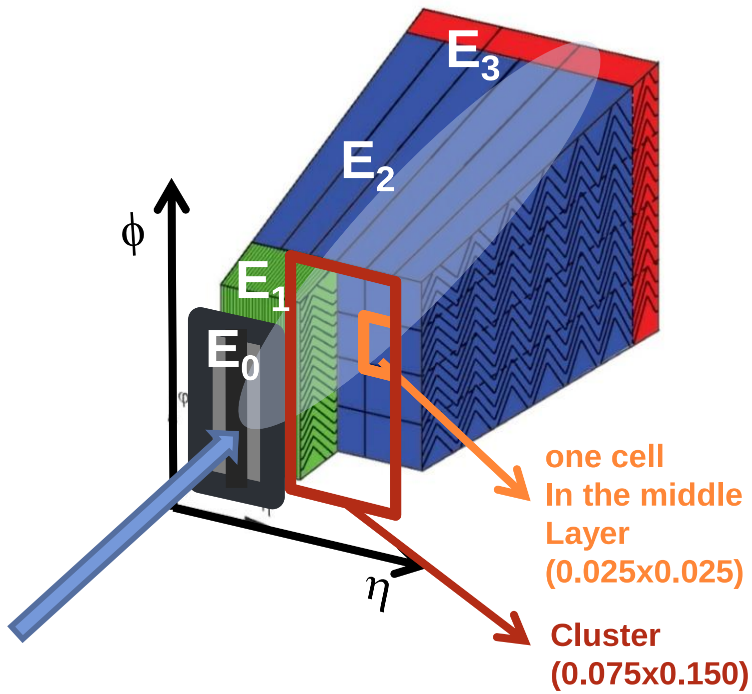
Layers and granularity ($\Delta\eta x \Delta\phi$):

Presampler (0.025 x 0.1)
Strips (0.003 x 0.1)
Middle (0.025 x 0.025)
Back (0.05 x 0.025)



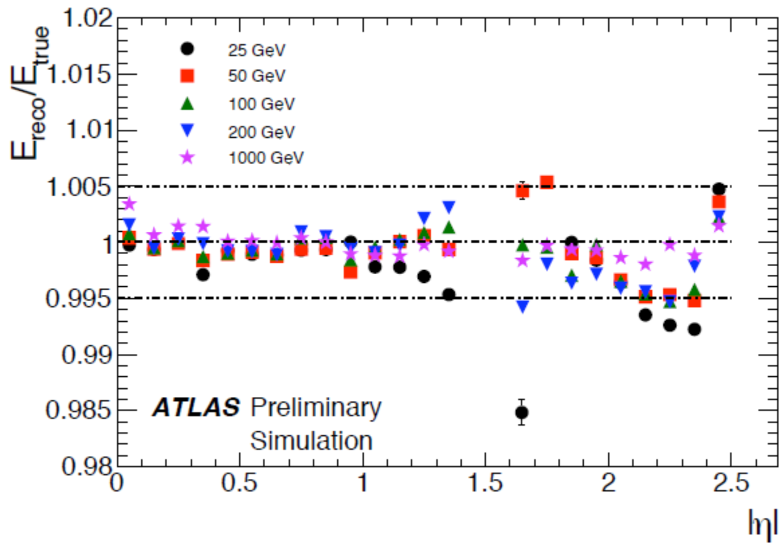
Electron reconstruction & identification

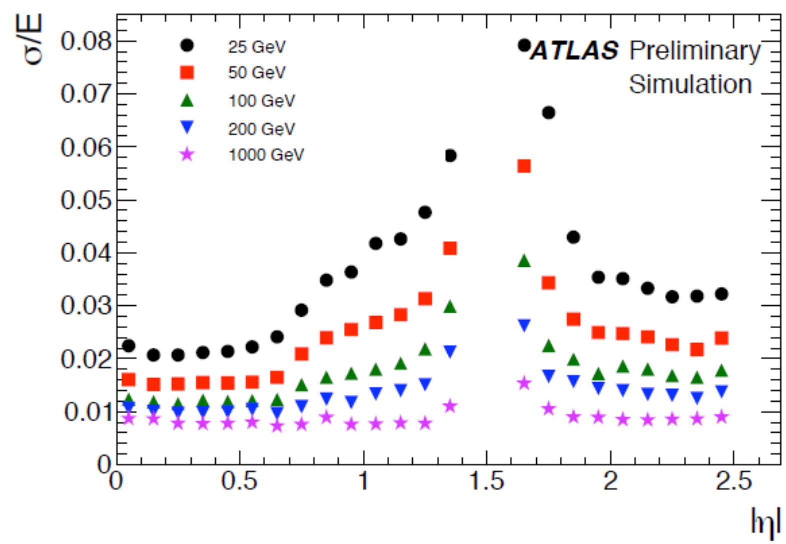
- The first stage of the search for EM objects is to look for significant deposits in the EM calorimeter cells inside a window as it is moved across the detector.
- An electron candidate is defined by:
  - one or more reconstructed tracks matched to a cluster (energy deposit) in the electromagnetic calorimeter (The best track is the one with an extrapolation closest to the cluster barycenter (weighted mean position) of the shower in the second layer of the calorimeter)
- The energy, position recomputed in an adapted window size dependent on the position of the electron candidate (central part, end-caps).
- The electron energy
  - the sum of the weighted energies each compartment
  - corrections for shower depth, lateral and longitudinal leakage, local modulations, etc...



Electron calibration scheme

- The electron/photon calibration scheme used is based on the full Monte-Carlo truth information of energy losses inside the detector ("calibration hits"). Three terms are added up to recover the initial electron energy. They are parametrized as a function of the measured energies in the presampler and calorimeter:
  - The energy deposited in the material in front of the electromagnetic calorimeter.
  - The energy deposited by the shower in the calorimeter.
  - The energy leakage at the back.
- This calibration is optimised mainly for high pT electrons (especially above 20 GeV)
- In situ calibration in data will be performed using J/ψ, Z and W to electron events, which will allow to refine the calibration in place now.





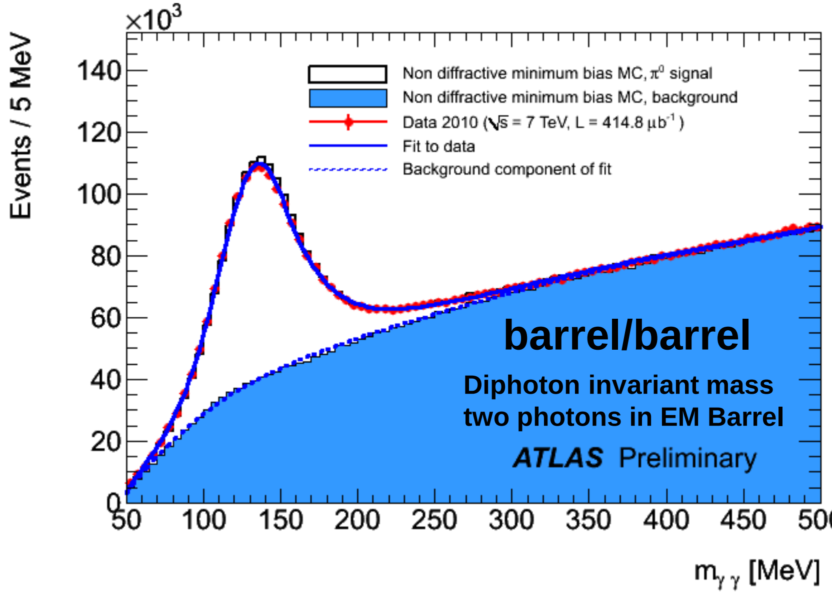
π^0 (first uniformity/energy scale checks of the EM calorimeter)

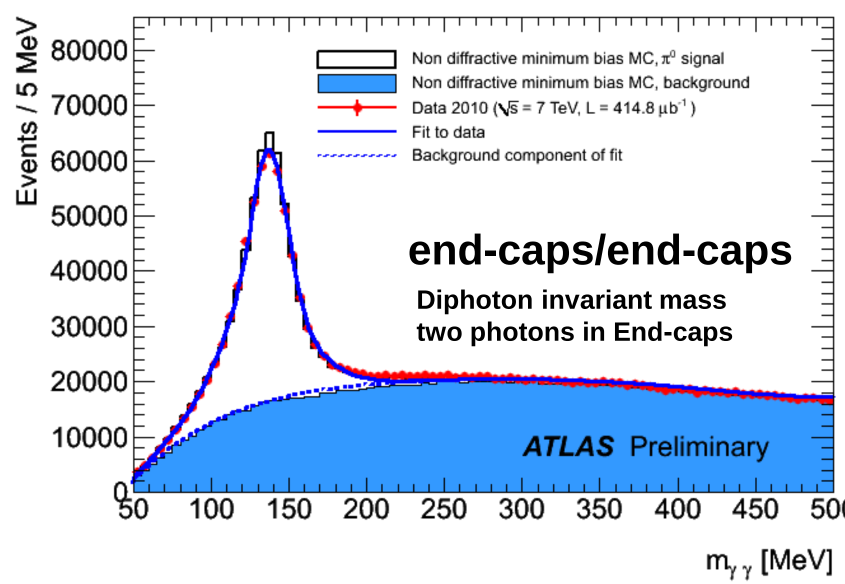
- Integrated luminosity ~425 μb^{-1}
- Selection:
  - ET(cluster) > 400 MeV
  - PT(pair) > 900 MeV
  - E1(cluster)/Etot(cluster) > 20 %
  - Track-veto

$m_{\pi 0}$(PDG) = 134.9767 MeV

Region		Fitted mass [MeV] (from global fit)	Resolution [MeV] (from Gaussian fit)
All	Data	135.04 +/- 0.04	20.11 +/- 0.05
	Monte Carlo	135.76 +/- 0.04	19.09 +/- 0.04
	|Data-MC|/MC	0.5 %	5.3 %
Barrel	Data	134.24 +/- 0.05	23.85 +/- 0.11
	Monte Carlo	134.89 +/- 0.05	23.07 +/- 0.10
	|Data-MC|/MC	0.5 %	3.4 %
Endcap	Data	136.71 +/- 0.04	16.12 +/- 0.05
	Monte Carlo	136.92 +/- 0.05	15.11 +/- 0.03
	|Data-MC|/MC	0.1 %	6.7 %

The agreement between data and MC is better than 1% for the $\pi 0$ mass, and better than 10% for the resolution

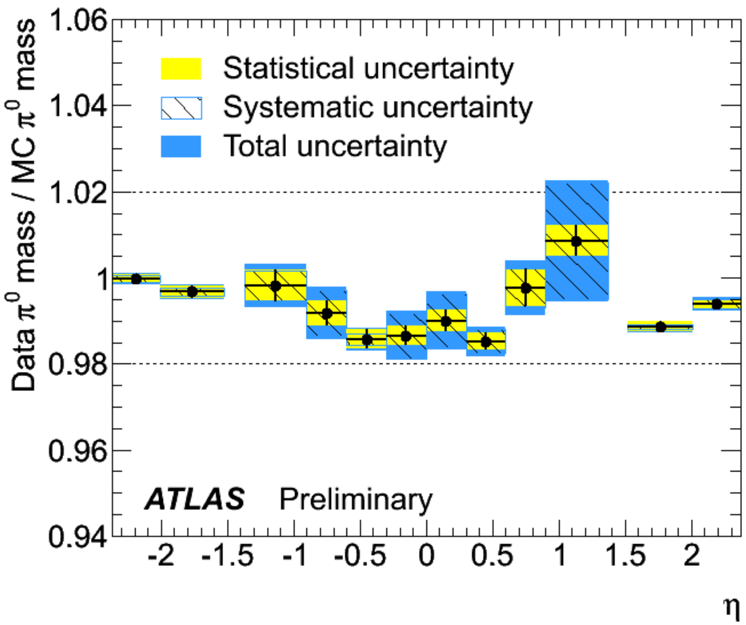




π^0 (first uniformity/energy scale checks of the EM calorimeter) (2)

Uniformity in η

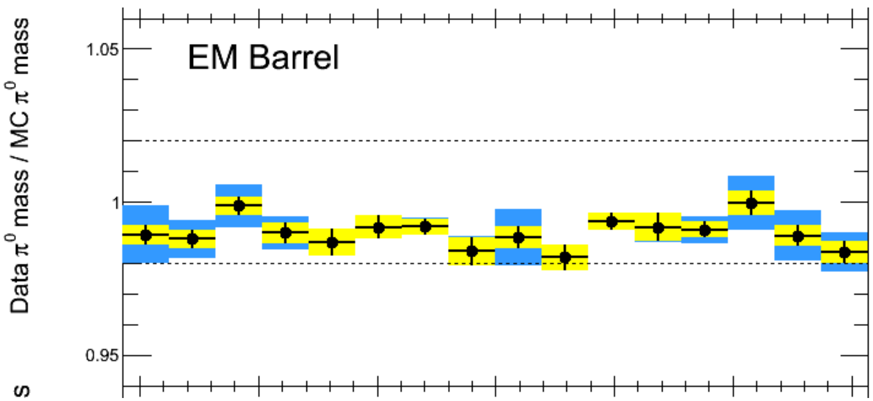
Fitted mass in data, normalized to Monte-Carlo, as a function of η (integrated over ϕ). The overall uniformity along is better than +/-2%. At low energies, material differences between data and MC can have non-negligible effects



Uniformity in ϕ

Region	RMS (%)
EMEC-C (-2.37 < eta < -1.52)	0.65 +/- 0.11
EMB (-1.37 < eta < 1.37)	0.47 +/- 0.08
EMEC-A (1.52 < eta < 2.37)	0.71 +/- 0.13

RMS of the distribution of mass(Data)/mass(MC) projected along . The uniformity is 0.65% in EMEC-C, 0.47% in EMB, and 0.71% in EMEC-A, which is of the order of what is expected at initial stage.



Fitted mass in data, normalized to Monte-Carlo, as a function of ϕ (integrated over η), in EM barrel calorimeter

Electron identification

- The electron identification variables include calorimeter, tracker and combined calorimeter/tracker information. Three reference sets of cuts have been defined with increasing background rejection power: loose, medium and tight:

  - **Loose:** Shower shape variables of the second calorimeter layer and hadronic leakage variables.

  - **Medium:** Loose + Shower shape variables in the first layer of the calorimeter, track quality requirements, track-cluster matching ($\Delta\eta$) and transverse impact parameter cut.

  - **Tight:** Medium + track-cluster matching ($\Delta\phi$), E/p, number of TRT hits, fraction of TRT high threshold hits, b-layer hit requirement (Depending on the analysis, a robust tight requirement is applied, where cut choices and thresholds are based on the current understanding of the detector performance.)

A look at electron candidates for 1 nb^{-1} of data in 7 TeV collisions

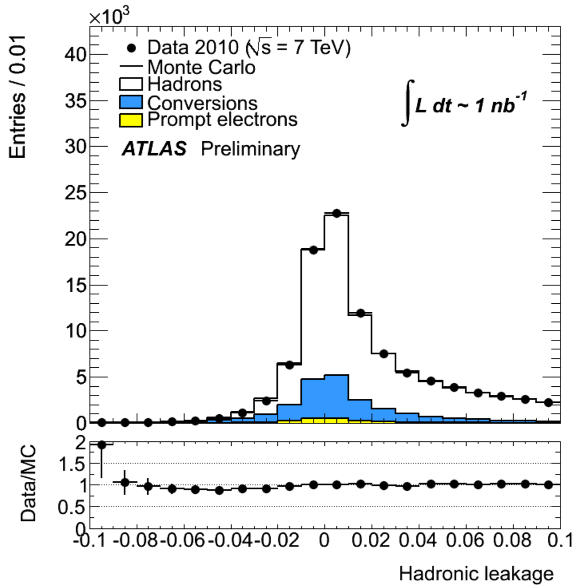
- Preselection:
  - Cluster ET > 5 GeV
  - |eta|<2.0 (excluding 1.37 < |eta| < 1.52)
  - Number of silicon hits >= 4, number of TRT hits > 10
- Number of electron candidates found: 128909
- Composition of obtained inclusive electron sample
  - **Hadrons**
  - **Conversions**
  - **Prompt Electrons**
- Applying standard identification selection criteria

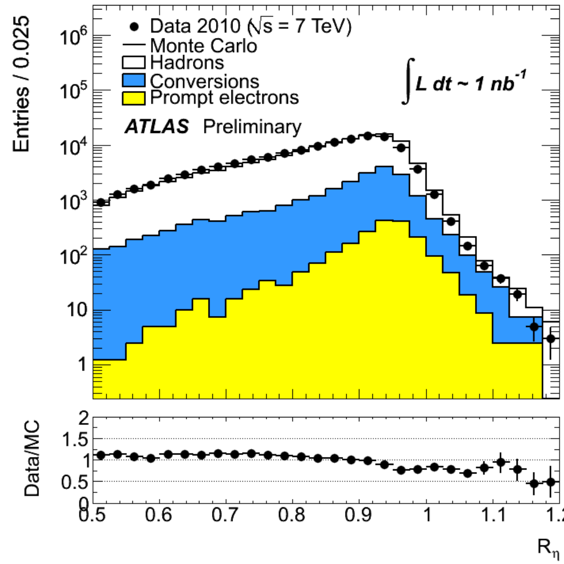
Composition of electron sample after each standard selection criteria (as extracted from MC after normalisation to data)

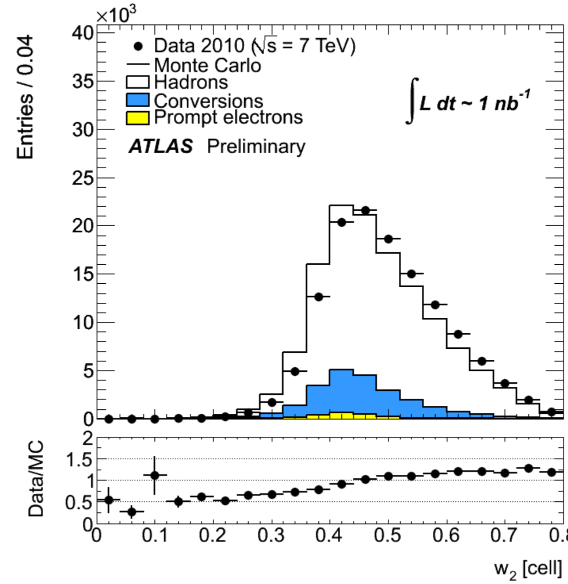
- **Preselected:**
  - Hadrons – (82.1 ± 0.1)%
  - Conversions – (16.3 ± 0.1)%
  - Prompt electrons – (1.6 ± 0.1)%
- **Loose:**
  - Hadrons – (67.5 ± 0.3)%
  - Conversions – (28.4 ± 0.3)%
  - Prompt electrons – (4.1 ± 0.1)%
- **Medium:**
  - Hadrons – (66.5 ± 0.5)%
  - Conversions – (22.8 ± 0.4)%
  - Prompt electrons – (10.7 ± 0.3)%
- **Tight:**
  - Hadrons – (29.6 ± 1.1)%
  - Conversions – (22.4 ± 1.0)%
  - Prompt electrons – (48.1 ± 1.2)%

Monte-Carlo/data comparisons for various identification variables

- On all electron candidates (variables used in the "loose" selection):
  - The fraction of the cluster energy deposited in the first layer of the hadronic calorimeter (or hadronic leakage)
  - Ratio in η of cell energies in 3 x7 versus 7x7 cells.
  - Shower width in the second layer of the calorimeter



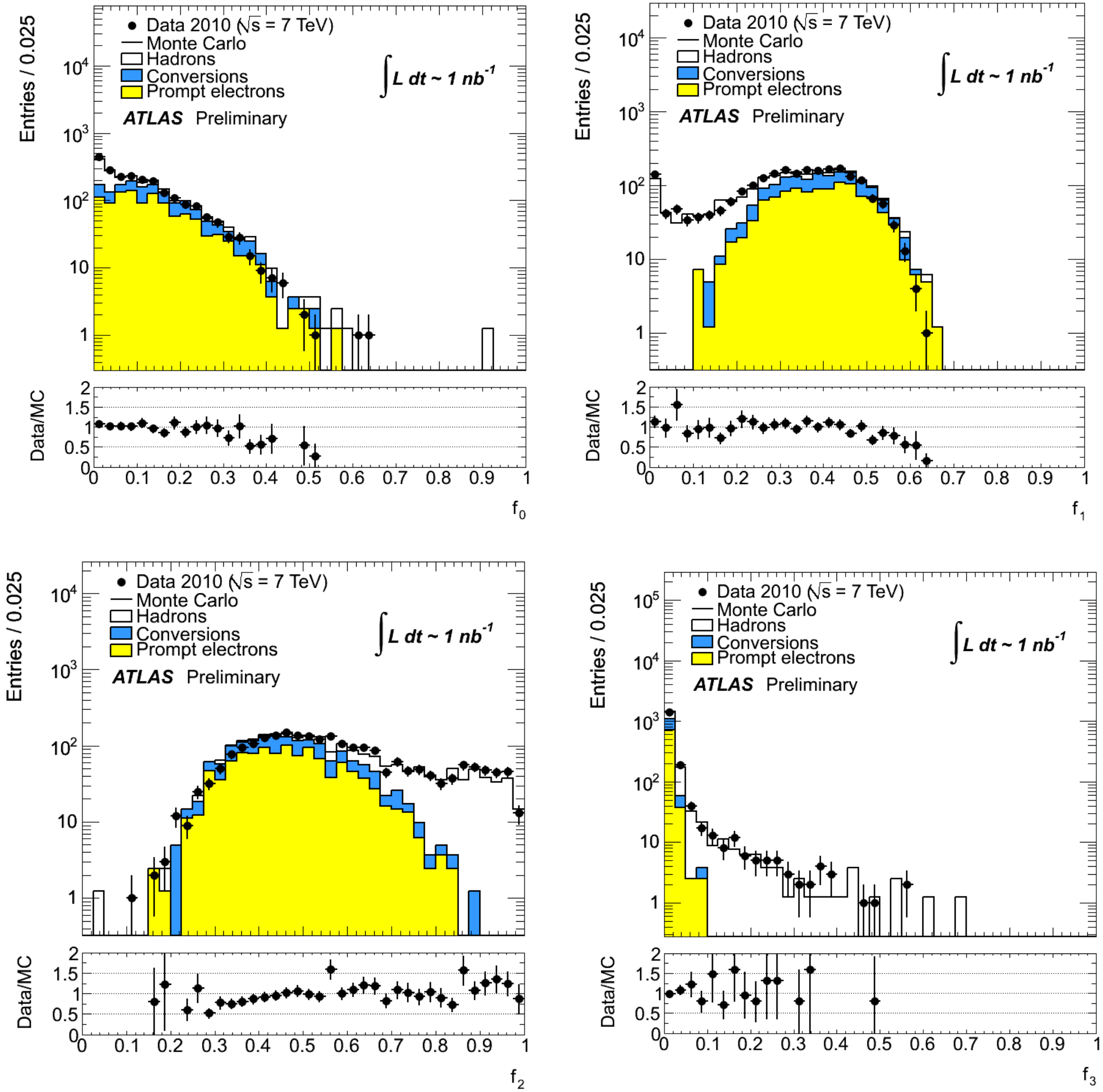




  - Hadronic leakage dominated by noise at these low energies (good agreement)
  - Small shifts observed in other variables (under study, cross-talk, material effects?)

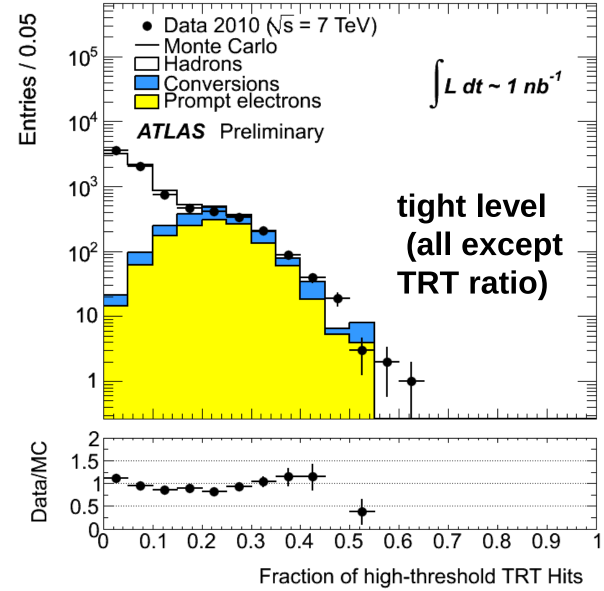
Fraction of energy in each EM calorimeter layer (after tight selection)

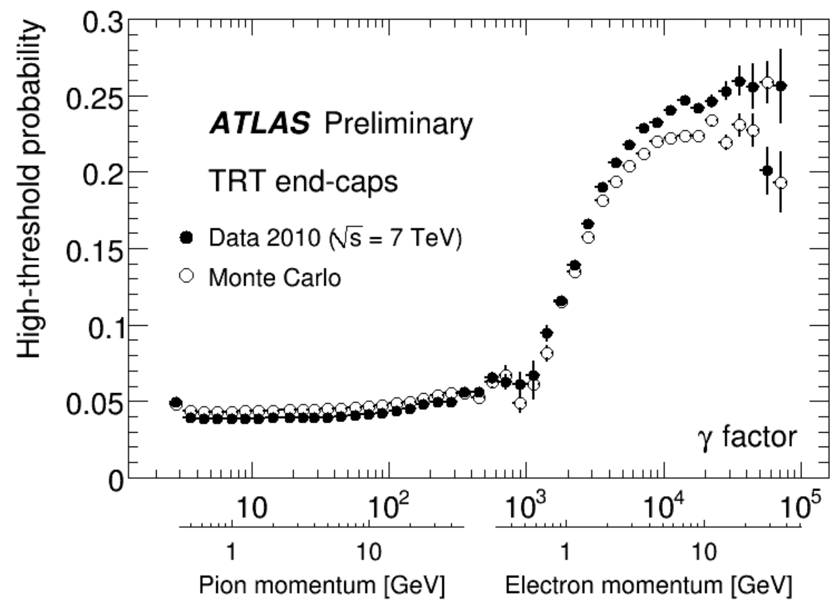
- The longitudinal segmentation of the electromagnetic calorimeter can be used to further separation between hadrons and prompt electrons /electrons from conversions.
- This is highlighted on the upper right plots representing the fraction of energy in the first sampling.



Extraction of the composition of the inclusive electron spectrum

- The electron candidate data sample is expected to consist predominantly of three components:
  - charged hadrons faking electrons
  - electrons from photon conversions
  - prompt electrons (mainly from b,c decays)
- Method to separate these components :
  - Separate electrons (prompt/conversion) from hadrons. Based on the measured fraction of high-threshold TRT hits
  - Separate conversions from prompt electrons using the innermost pixel layer (B-layer).
- The method has successfully been tested in the 900 GeV collisions to separate hadrons from photon conversions.
- This study is ongoing on the 7 TeV data to possibly extract the b,c→e component and measure cross-sections

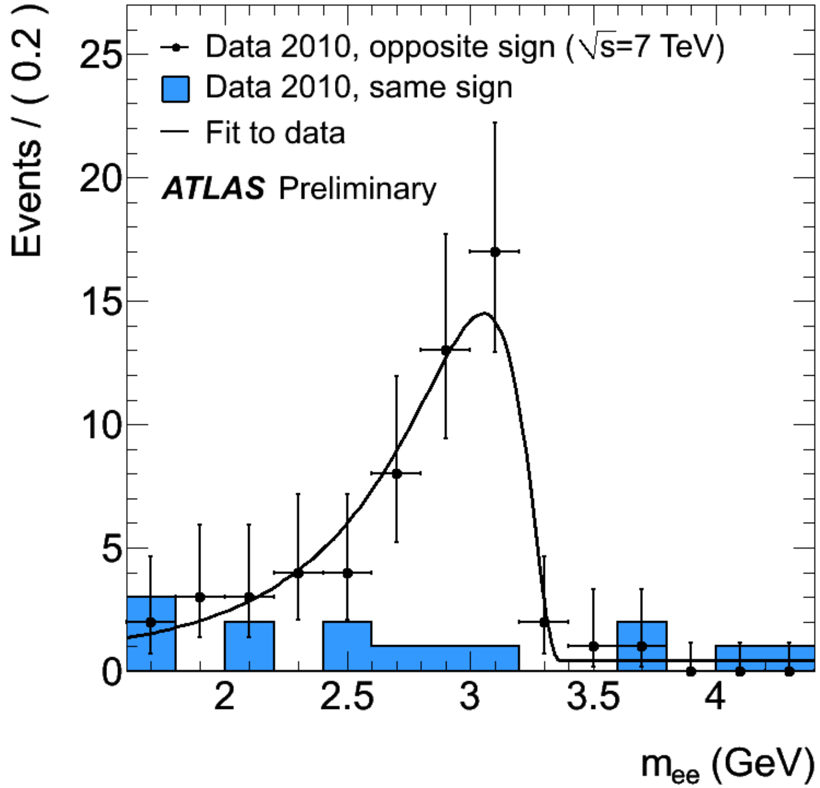




$J/\psi \rightarrow ee$ (observation)

- Integrated luminosity used: ~6.3 nb^{-1}
- Calo triggered events, energy deposit greater than 3 GeV
- Stricter requirements on fraction of high threshold TRT hits (compared to standard "tight" selection). This allows to have a very clean peak with very low background.
- The invariant mass is computed using only the track parameters.
- The track momenta are not corrected for Bremsstrahlung effects.
- The data are fitted with the Novosibirsk function for the signal plus a straight line for the background.

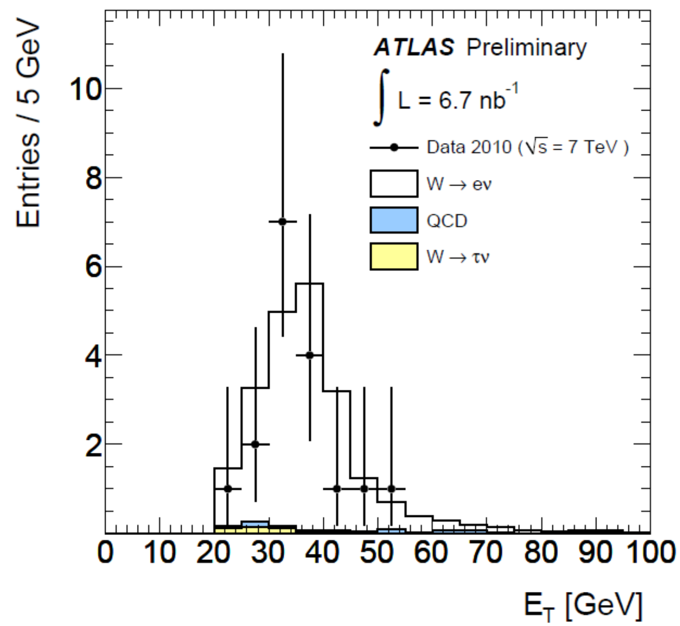
Result of the fit:
Signal: 52 +/- 8 events
Background: 6 +/- 4 events
Fitted Mass: 3.05 +/- 0.07
Fitted Width: 0.27 +/- 0.05



$J/\psi \rightarrow ee$ & $W \rightarrow e\nu$ (plans for performance studies)

- $J/\psi \rightarrow ee$
  - Study Bremsstrahlung recovery through refitting of tracks using GSF (Gaussian Sum Filtering)
  - Using calorimeter information for the computation of the invariant mass.
    - Checking uniformity, energy scale
  - Study of shower shapes used in electron identification (towards understanding of efficiency)
  - Tag & probe to measure efficiency.

- W->eν
  - There is a dedicated talk on the first W/Z observation in this conference.
  - In 6.3 nb^{-1} integrated luminosity we find 17 $W \rightarrow e\nu$ candidates.
  - With increasing available data, we will move to electron performance studies:
    - Shower shapes
    - E/p studies: uniformity, energy scale
    - With the help of J/ψ events, we can have a first look at linearity..



Conclusions

- First results on 7 TeV electron candidates very encouraging.
  - Very good agreement is seen in data/MC comparisons.
  - Gained important knowledge on the identification variables used in the electron selection.
  - The versatility of the ATLAS detector allows to have very good particle identification with the combined use of independent sub-detectors. Very confident that ATLAS will be able to extract the various components of the inclusive electron spectrum, obtain pure samples of b,c electrons as well as isolated electrons and quickly measure efficiencies and cross-sections.
- Uniformity checks of the EM calorimeter with π^0 give a uniformity of better than 0.7% over ϕ in barrel and end-caps.
- With more J/ψ, Ws and Zs to come, we will be able to check the uniformity of the response of the electromagnetic calorimeter versus η, ϕ and energy over the full accessible range using the available methods that have been tested over the years in simulation and test-beams.