Performance of electron identification in ATLAS experiment with $Z \rightarrow e^+e^-$ events

CPPM seminary, Dec 12th

J.Maurer

Introduction

- Subject of my PhD: “Search for new physics in ATLAS experiment in channels involving electrons and missing transverse energy”
- A first-step was the good understanding of objects using data collected since last year

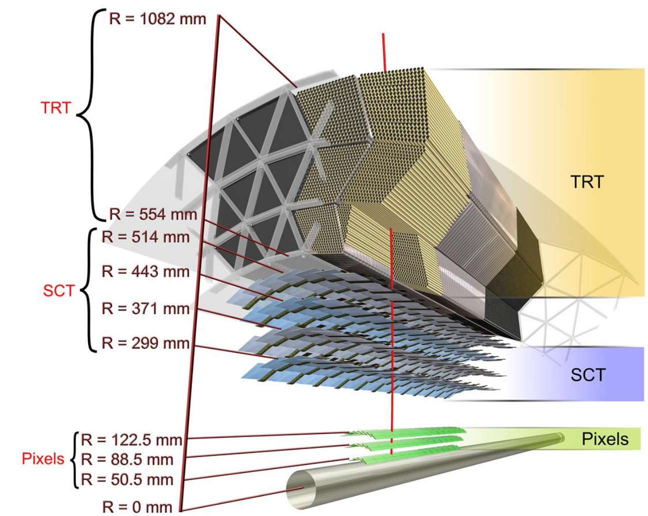
  → I worked on electron performance, and more specifically in measurement of electron identification in data

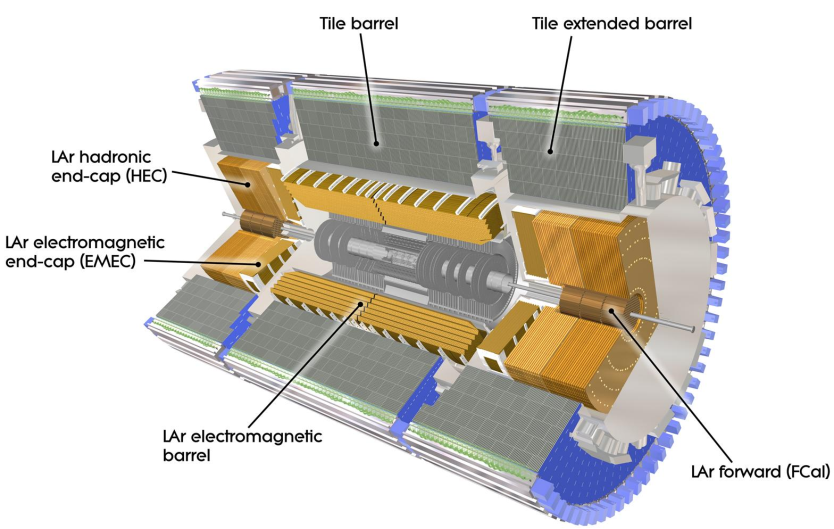
  → I could benefit from CPPM ATLAS group expertise on that topic, in particular from my supervisors (Fabrice Hubaut / Pascal Pralavorio)

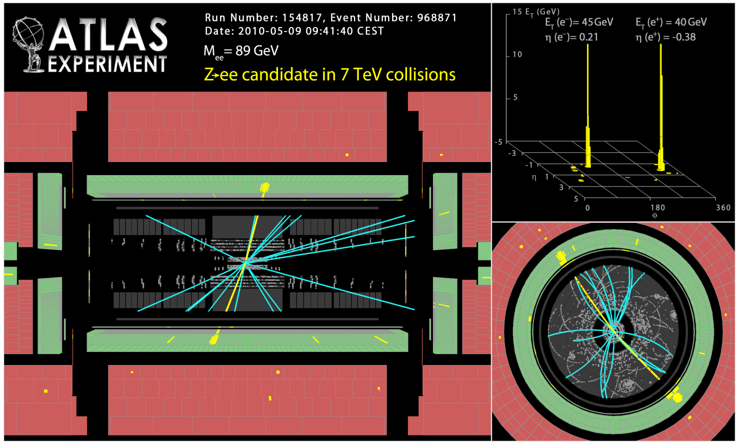
- Overview of the talk:
  - Electron reconstruction/identification in ATLAS
  - Tag&probe methodology for data-driven efficiency measurements
  - A few results with 2011 data

Electron reconstruction

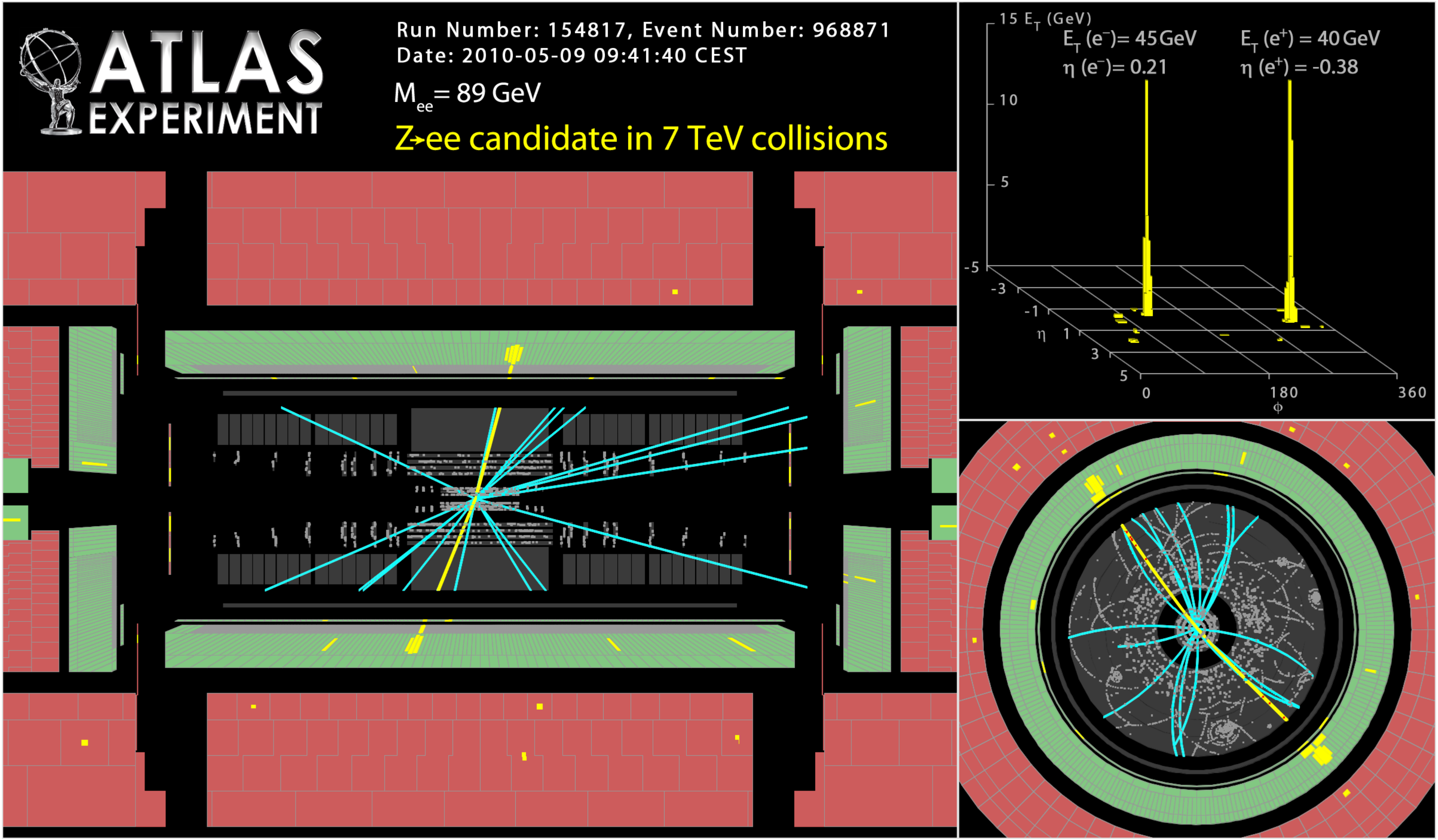
- Main electron features: charged, light particles, highly interacting with material
- Therefore, reconstruction of electron candidates combines:
  - A track in the inner detector
  - An energy deposit in the electromagnetic calorimeter
  - A reasonable matching between these 2 objects
    → track must be extrapolated to calorimeter,
    accounting for material and magnetic field





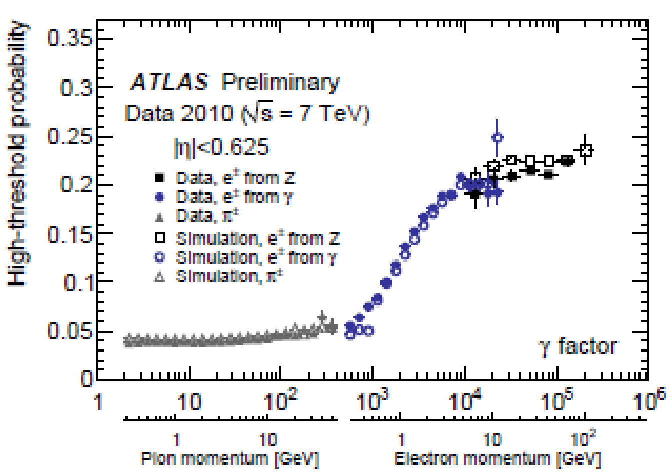


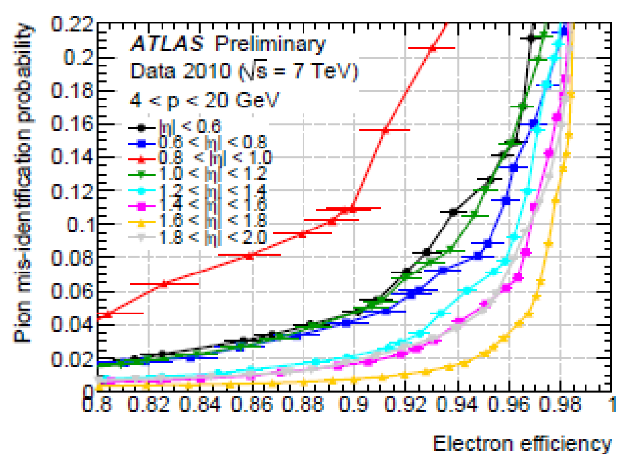
Electrons in $Z \to e^+e^-$ candidate



Electron identification

- Current method: orthogonal cuts on several discriminating variables
→ cuts optimized as a function of pseudorapidity and transverse momentum
→ simple but robust, compared to more advanced PID tools (NN,BDT...)
- Shower shape variables: electron have narrow and early showers
→ lateral width, fraction of energy leaking in hadronic calorimeter...
→ benefit from the high granularity in η of the first layer of the EM calorimeter
- Isolated electrons are produced in the primary vertex of the interaction
→ good track quality (number of high-precision hits), early track (hit in B-Layer)...
- Good matching between cluster and track: Δη, Δφ, E[cluster] / p[track]...
- Track/calorimeter isolation not part of standard identification cuts, but added on top
- Discrimination between particles provided by the Transition Radiation Tracker
→ X-ray photons emitted, depending on Lorentz factor

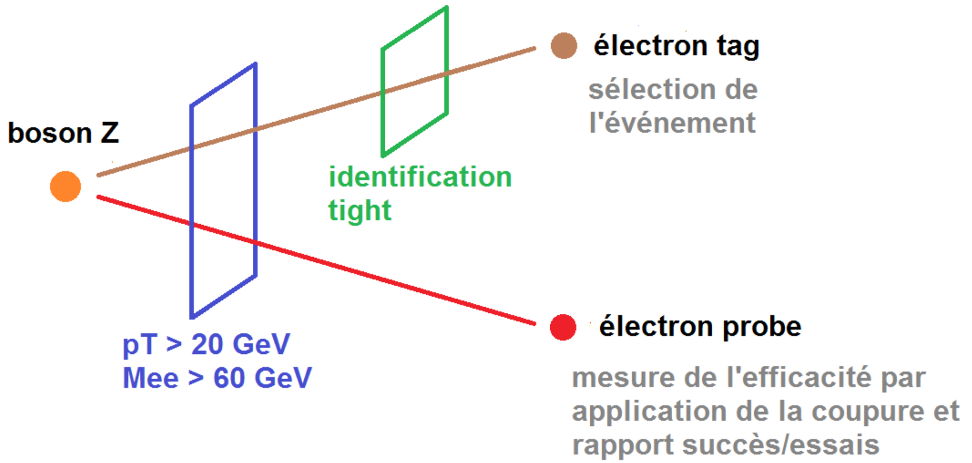




Cuts gathered to provide 3 levels of identification:
Loose (~95% efficiency)
Medium (~90% efficiency)
Tight (~80% efficiency)

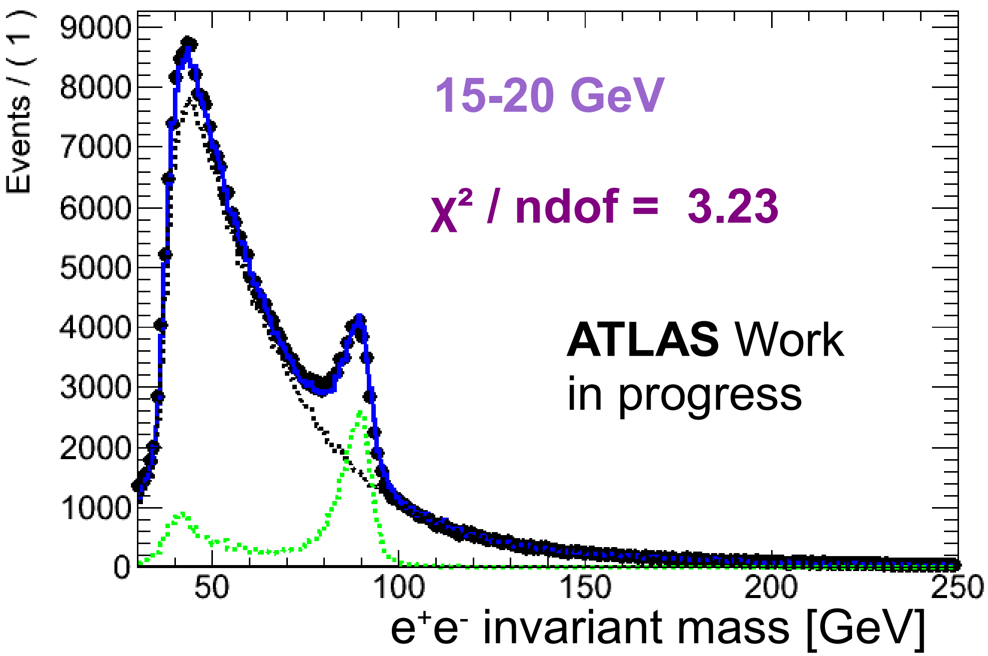
Tag&probe method

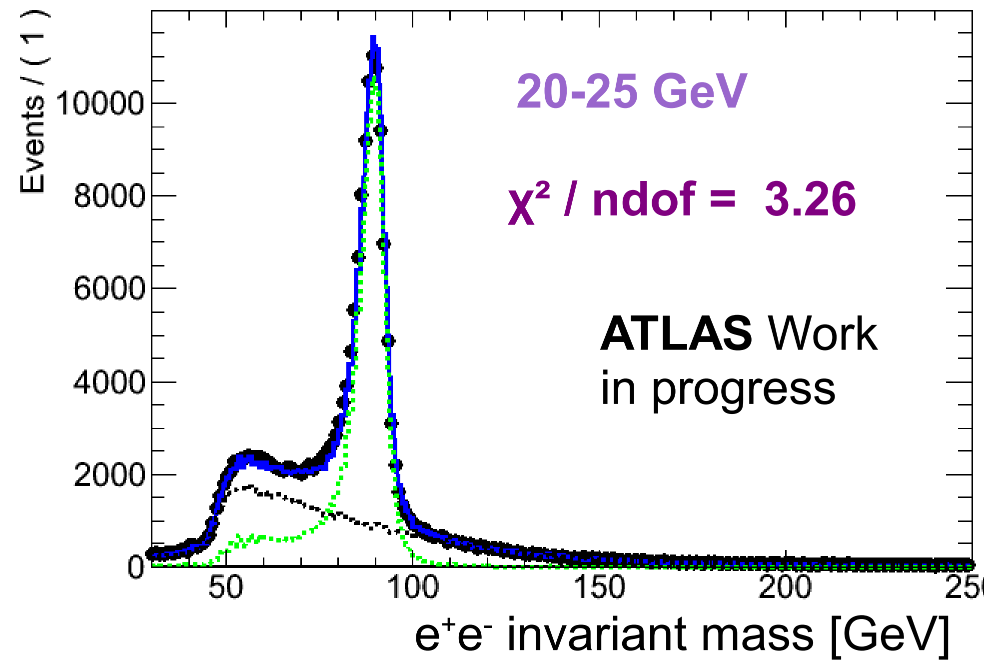
- Electron identification efficiency knowledge is mandatory to measure cross-sections, compute expected/exclusion limits...
  → a good precision is needed (ex. H → ZZ → 4l)
- Description of real detector by simulation not perfect → need to measure ID efficiency in data, to correct MC previsions
- Data-driven: requires selection of an unbiased sample of electrons, on which efficiency measurement can be performed

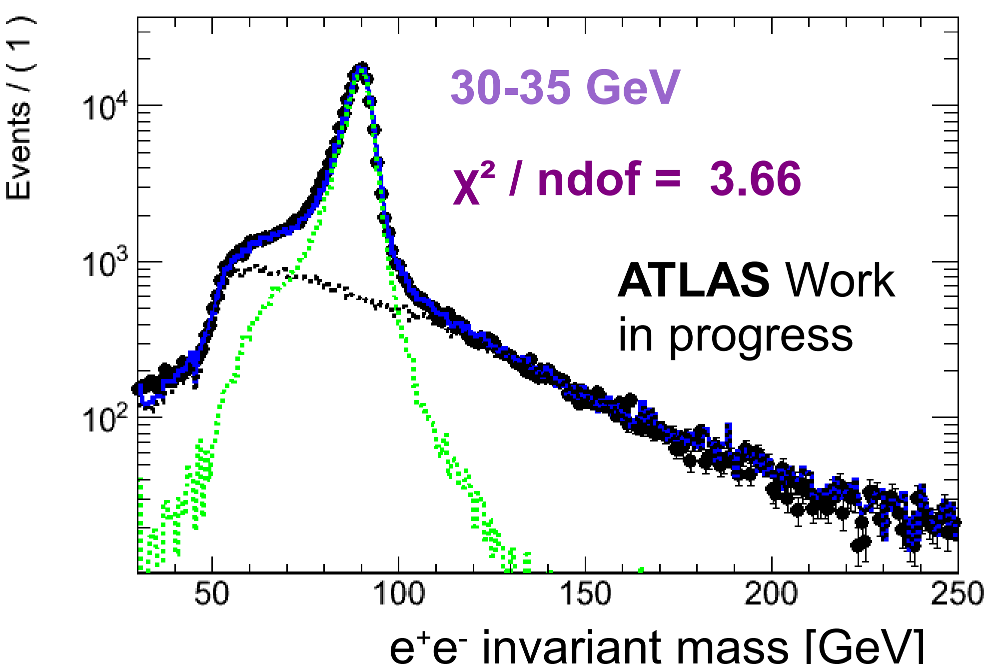


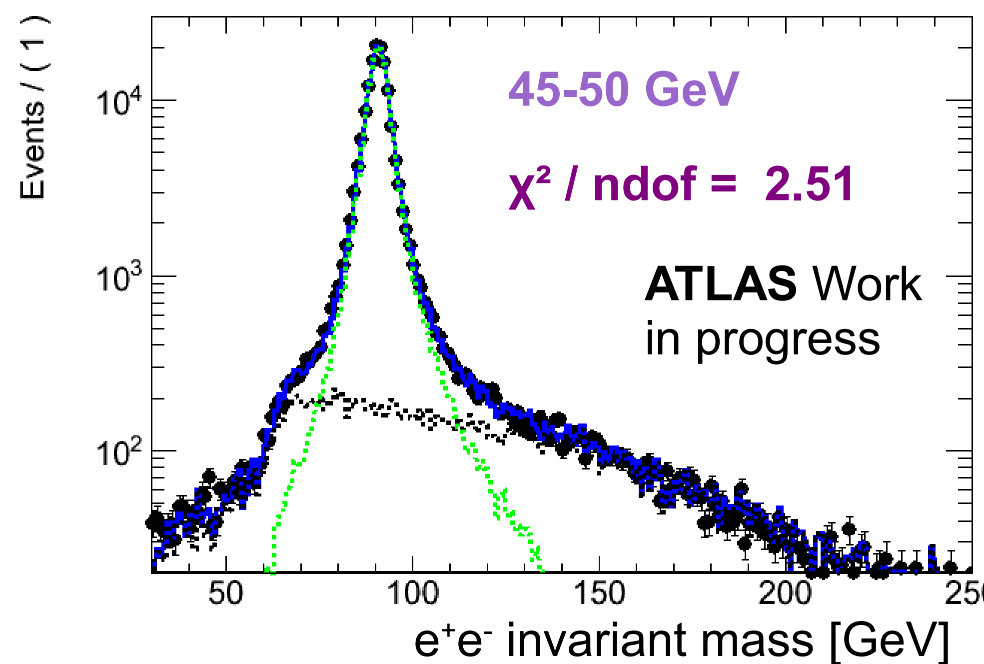
- Such selection can be done with “tag and probe” method on Z → e^+e^- events:
  - Severe identification cuts are applied on one electron (“tag”)
  - Only kinematical cuts are applied on the second electron (“probe”), leaving it unbiased; efficiency of a given cut can be measured as pass/pass+fail ratio
  - Selecting such events with invariant mass close to the Z one (91.19 GeV) allows to provide a sample with purity > 90%
- Taking into account the remaining 10% background properly is the main issue...

Invariant mass distributions



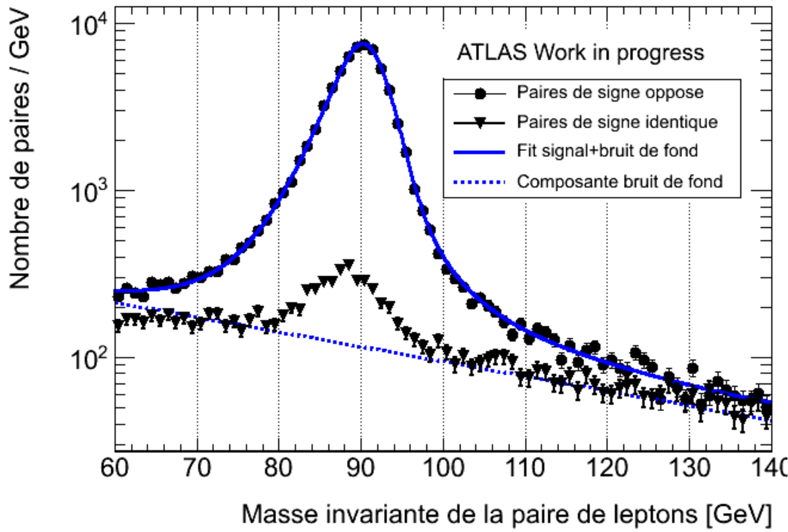




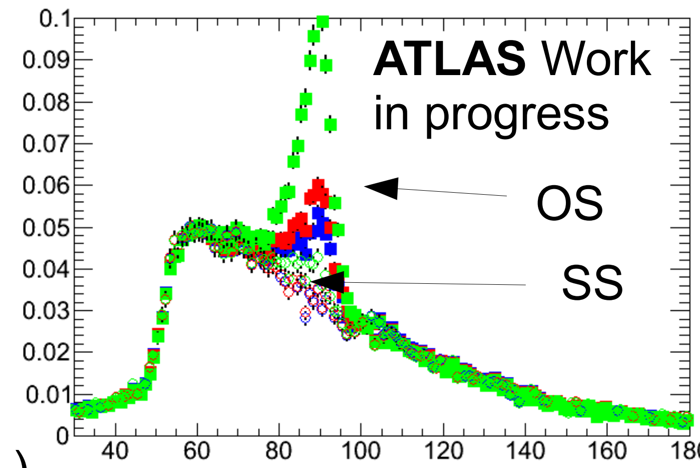


Background subtraction

- Several methods tested to perform signal extraction
- Useful tool: distribution of same-sign events, with exact same selection (kinematics, identification)
- Early method: linear extrapolation under the peak from sidebands of SS distribution
  → extrapolation required because of small charge mis-identification for electrons



- Baseline: combined fit of invariant mass
  - Signal: MC template / Breit-Wigner*Crystal-ball(resolution)
  - Bkg: (single-sided) exponential
- Background template: using SS distribution again, but after applying ID anti-cut on probe to keep only bkg
  - Normalized using high-tail (mostly bkg)
    → no dependency to signal description required
- A combination of the last two has been used in the last release of efficiencies (used for Higgs results tomorrow...)

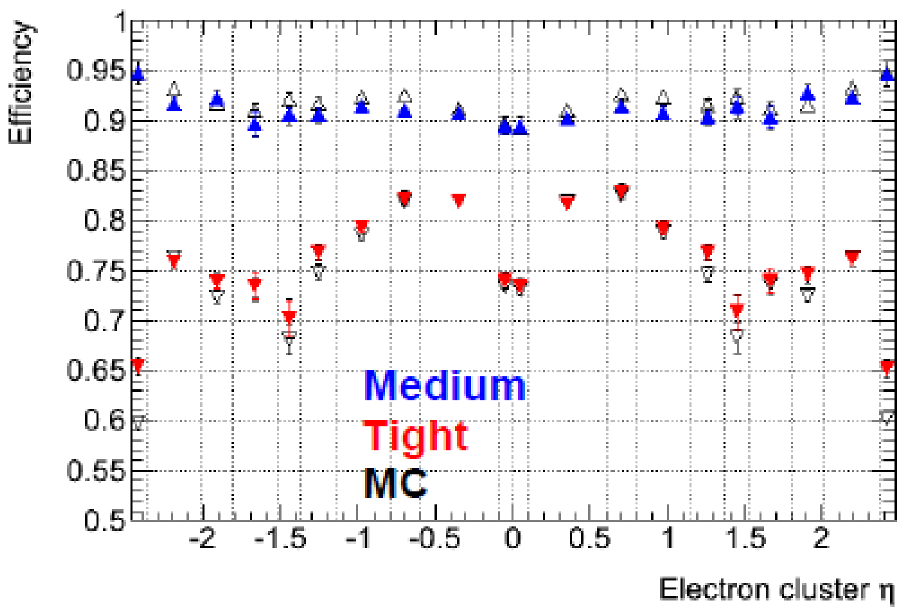


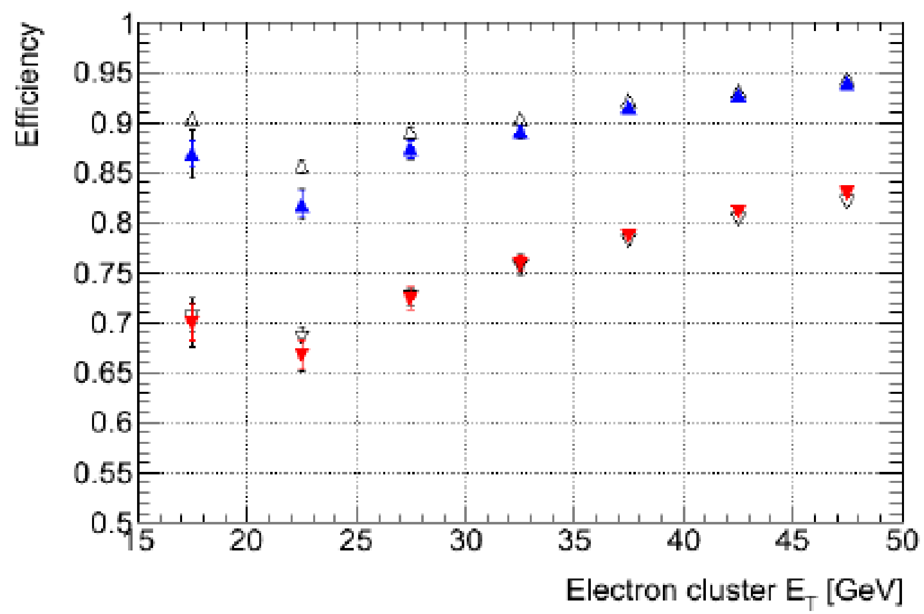
Some results

- Efficiencies measured on data and MC, ratio ("scale factor") provided to physics analyzes to correct MC
- Until now, measurements only performed in 1D (as a function of η or pT)

  → cross-checks performed in 2D; in most cases, the approximation
  SF(η,pT) ~ SF(η) * SF(pT) / <SF> is valid

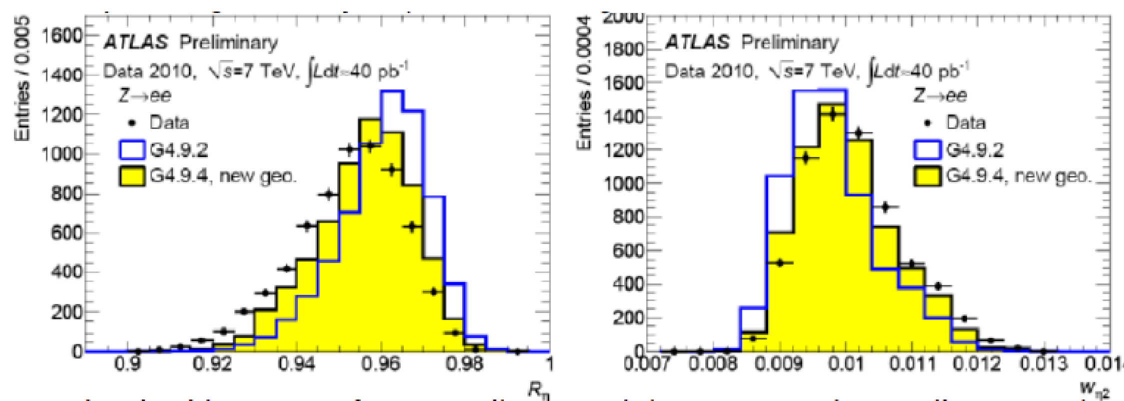
- Showing here efficiencies on data/MC for 2 levels of identification



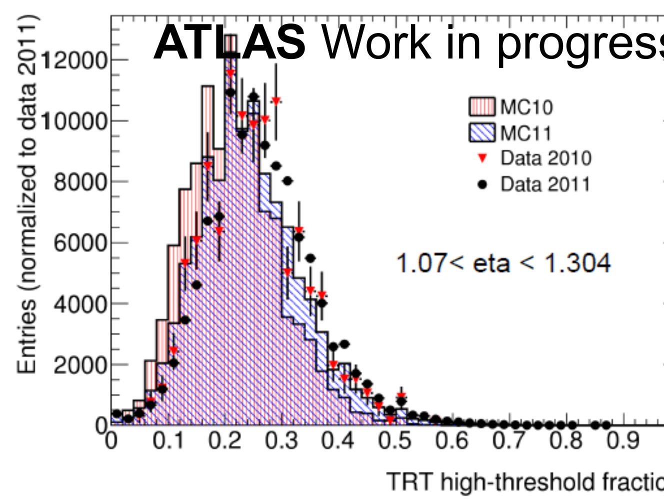


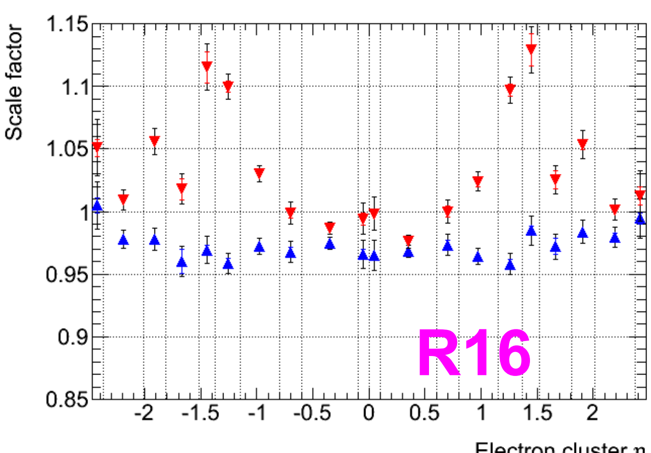
- Understanding of the detector at a few % level... cf next slide

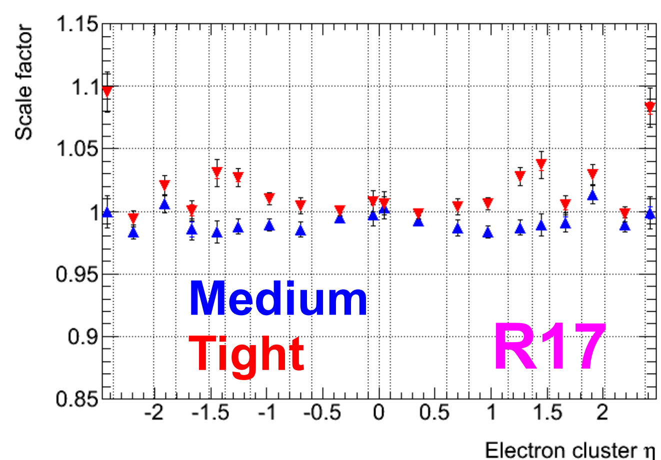
What is different in MC?



- Modeling of shower shapes was in significant disagreement when looking at first data
- Some part of the discrepancy attributed to modeling of EM calo absorber ()
  → refined description allowed better agreement
- Still discrepancies observed... also notified by ALICE/CMS
  → Geant4 collaboration investigating on shower model
- Another source: TR modeling not matching data
  → also isgnificant improvement observed after tune
- Below: data/MC ID scale factors for 2 versions of ATLAS reconstruction software

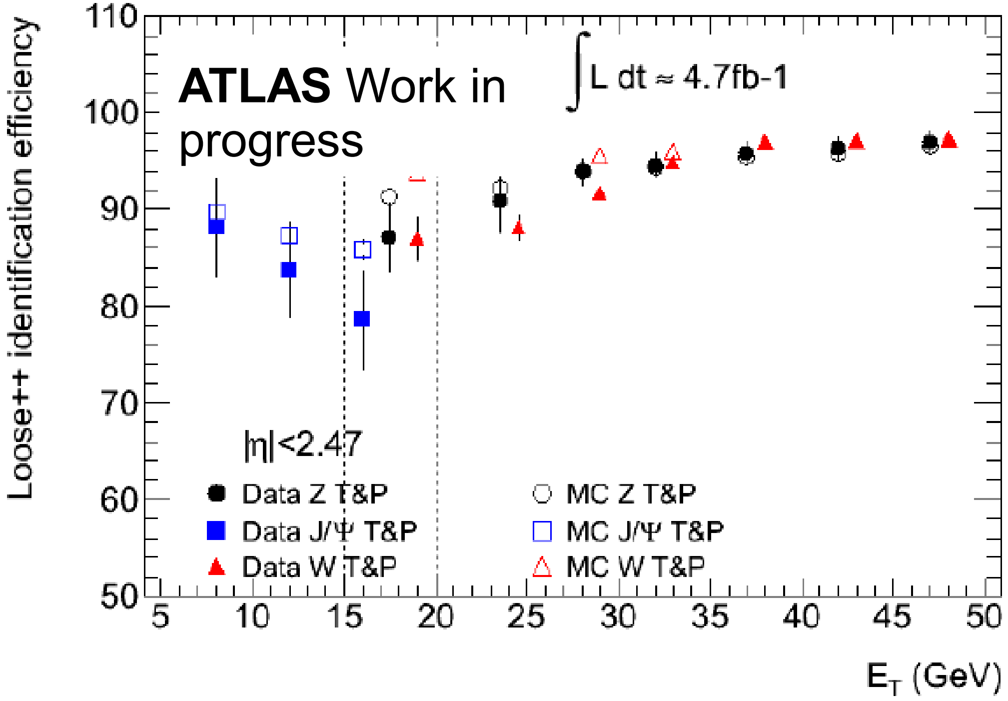






Comparison with other channels

- Efficiency also measured with other electron sources, to cross-check/extend range
- W→eν: severe cut on MET. More statistics than Z, but signal extraction more biased
- J/ψ→e^+e^-: similar to Z analysis at lower energy (but with complications...)

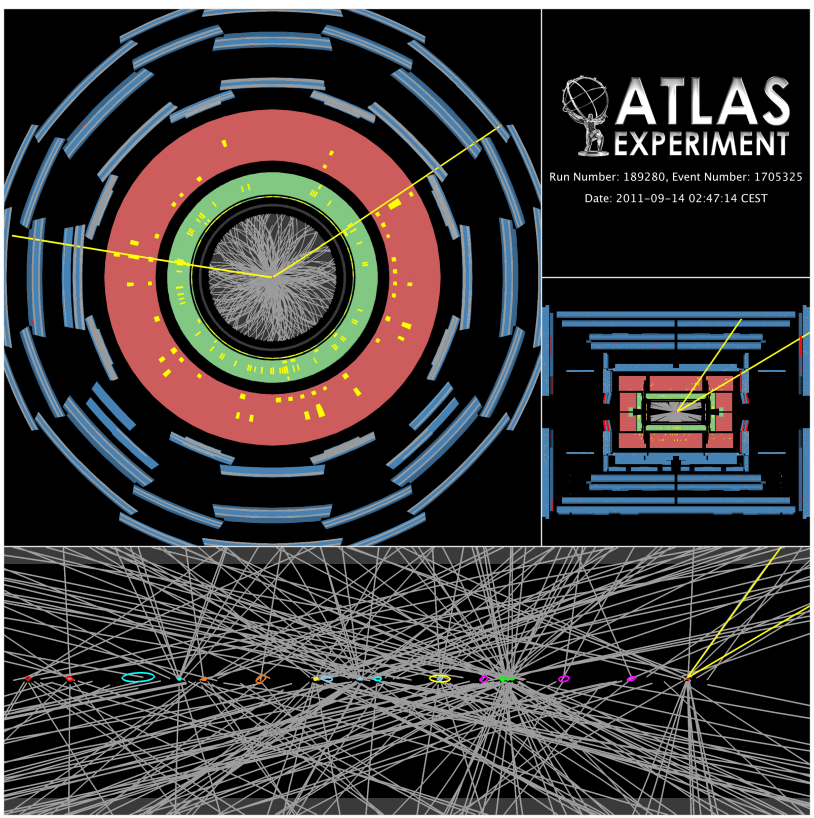


- Efficiencies (η,pT)-dependent, only scale factors can be compared directly
- But different kinematic distributions still imply artificial discrepancies → some differences are reduced when comparing values in 2D-bins

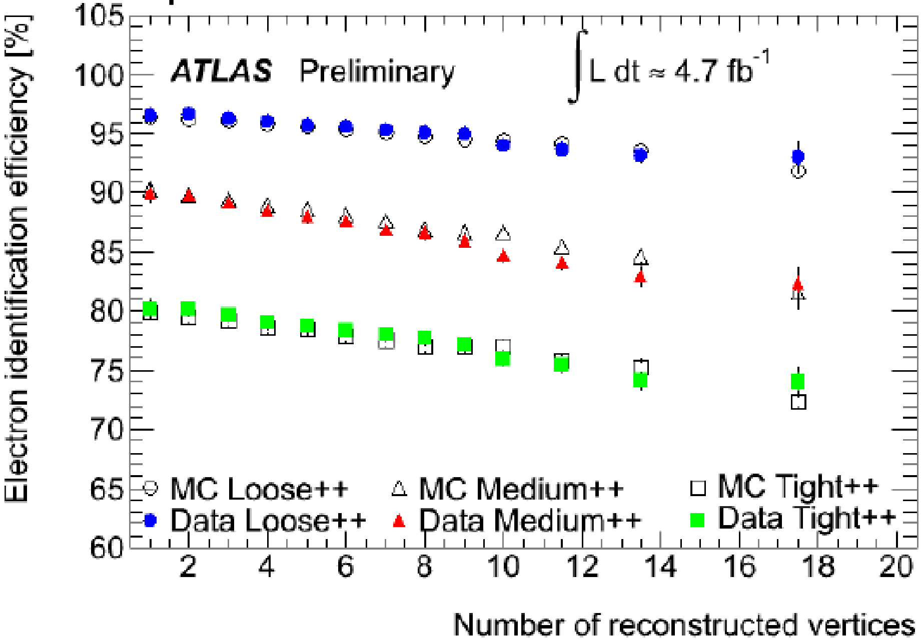
- Combination → at high pT, total uncertainty <1% in central region

Dependency to pile-up

- With the high-luminosity provided by LHC, additional constraints are present → multiple simultaneaous interactions (up to 15 in average, in last 2011 period)
- Presence of extra activity in detectors can impact on behaviour of algorithms, such as the profile of the discriminant variables used for electron identification
- Taken into account in the systematics (~0.5% effect on the scale factors), but interesting to monitor: bottom right plot shows evolution of ID efficiency with number of reconstructed vertices in the event.



- Significant loss of efficiency with increase of pile-up; but well-modeled by MC
- Mainly due to noise in hadronic calorimeter → re-optimization of cuts needed...



Conclusion

- Electron identification on ATLAS is performing well, reflecting the good understanding of the detector → only a few discrepancies remain, and are actively studied
- Measurement of associated efficiencies are performed using well-known tag&probe technique, with contributions from different channels to cover full kinematical range
- I have been involved in the measurements using Zee events:
  - Development of alternative methods for cross-check/improvement
  - Required assessment of systematics: selection, closure-test...
  - Also worked on reconstruction efficiencies, closely related topic
- Allowed me to take an active role in the ATLAS collaboration quickly

- Moving now to more physics-oriented topic:
  - SUSY searches in channel 1 electron + MET + jets
  - I will be implied in particular on estimation of QCD background
    → improvement at low pT is required, to reach compressed spectra
  - The knowledge accumulated during my work on electrons will be useful...