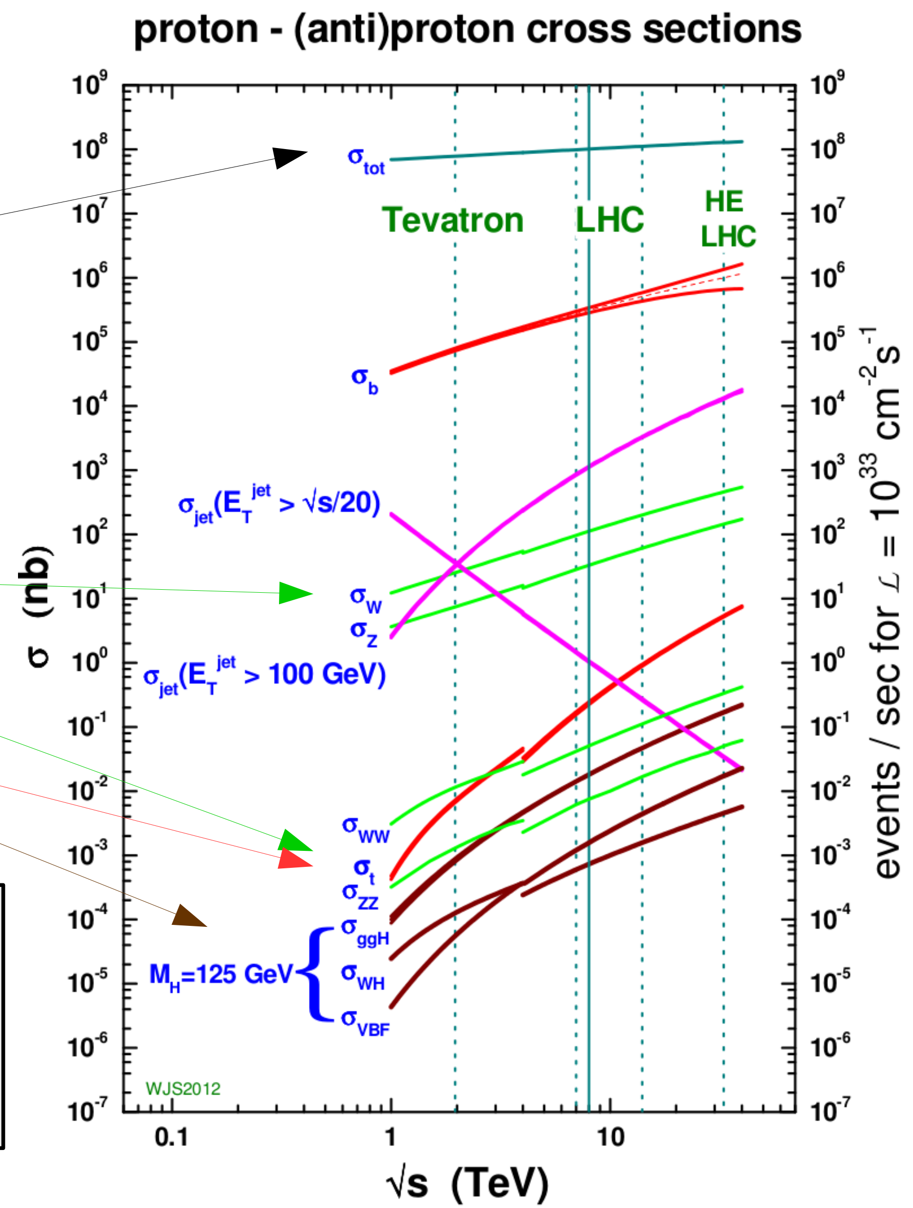
Optimization of the electron identification criterion for the 2015 ATLAS data taking

Sébastien Kahn

Importance of the leptons for LHC physics

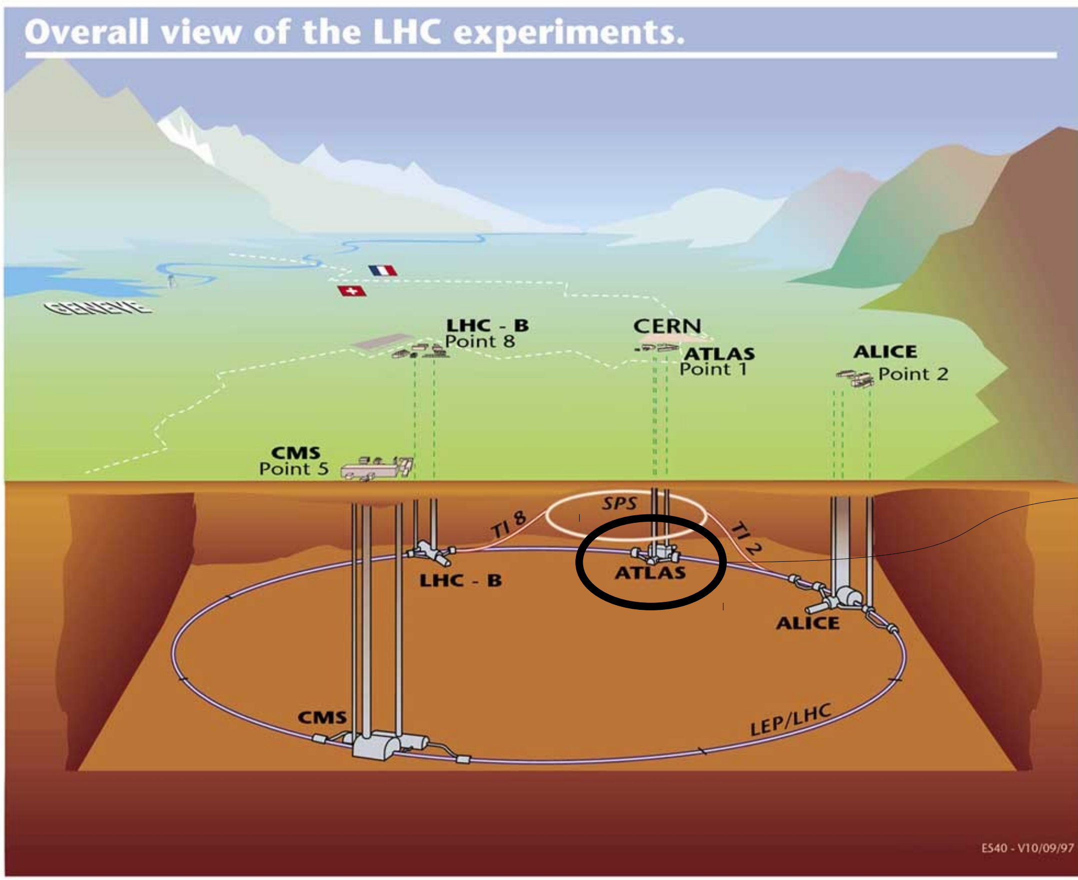
- **Leptons give a very different experimental signature from the one from QCD processes**
  -> Very clear experimental signature
- **Cross section of those processes at least 10^6 smaller than the one form QCD**
  -> Very useful to define triggers
- **Leptons can tag processes of high interest :**
  - **Z/W physics :** Z(+jets) / W(+jets)
    Dibosons
  - **Top physics :** tt(+jets) , single top
  - **Higgs :** H -> ZZ*-> 4l / H - > WW* -> 2l2ν
  - **New physics :** SUSY / exotic



Electron marker of interest in the harsh pp collision hadronic environment
-> Identifying electrons is crucial for many physics analyses in LHC experiment

Zoom on ATLAS Detector

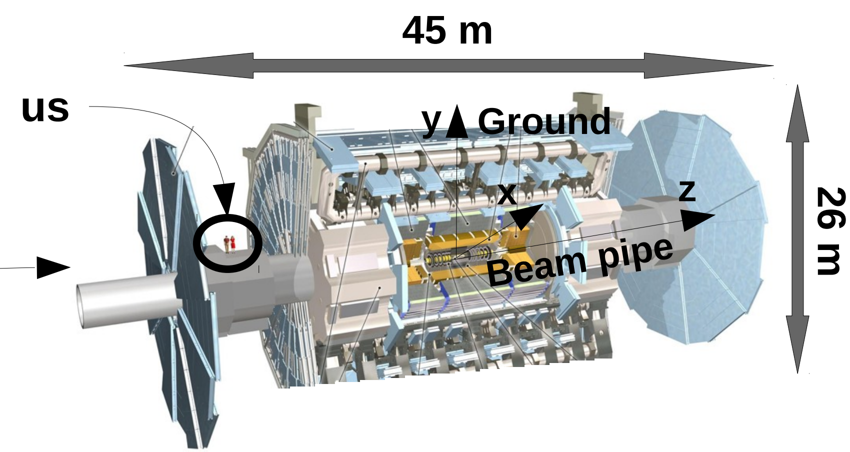
- **Produce pp collision at 13 TeV in 2015 :**



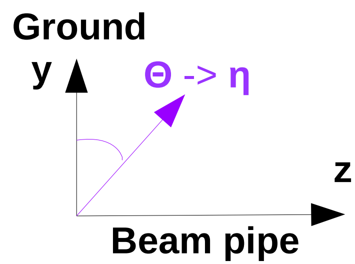
Let's have a closer look to ATLAS

- **4 detectors :**
  - **- Direct discovery :** ATLAS / CMS
  - **- b physics :** LHCb
  - **- nuclear physics :** ALICE

- **Let's zoom in the ATLAS detector**



- **ATLAS angular coordinates :**

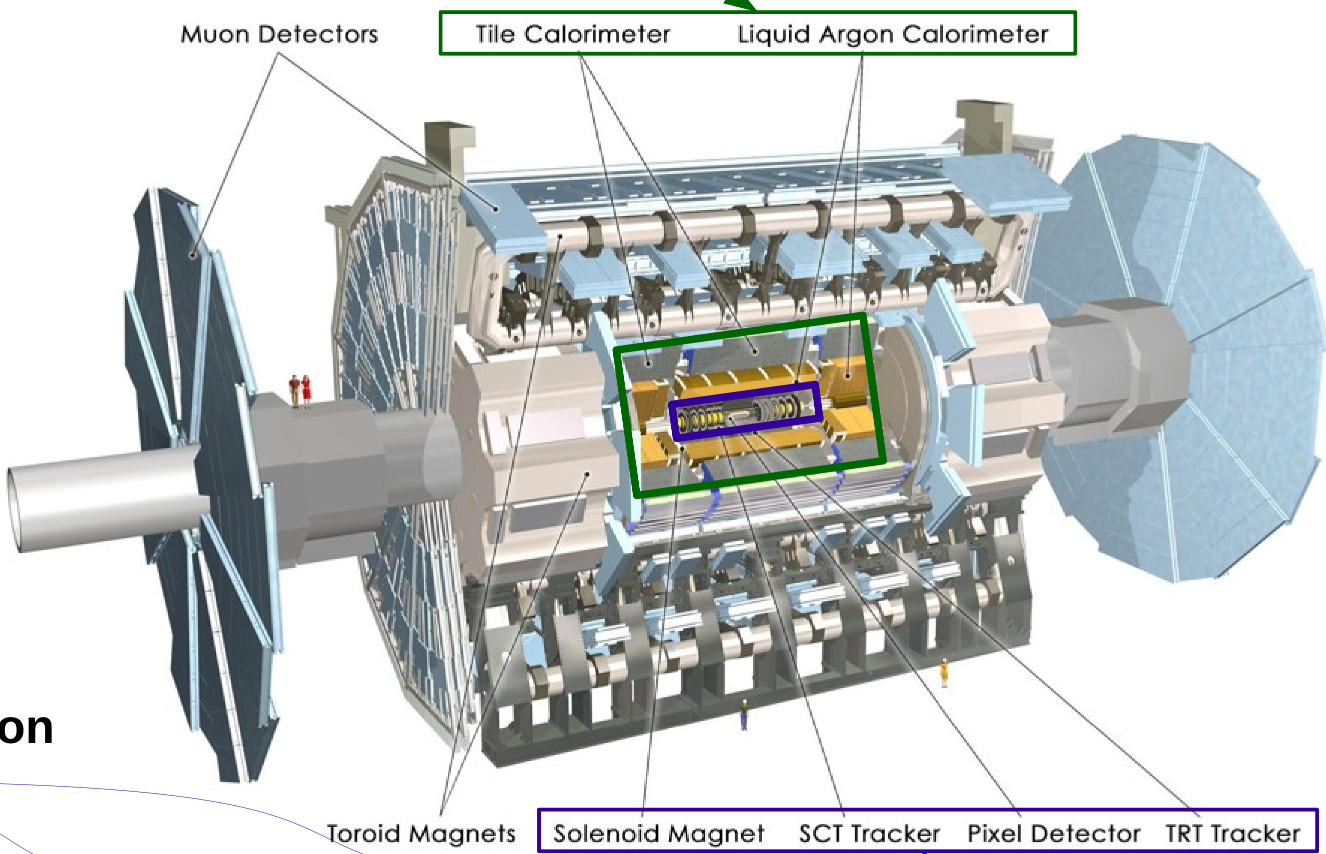


η used for the mapping of the detector

$$\eta = -\ln\left[\tan\frac{\theta}{2}\right]$$

How to detect electron using the ATLAS detectors

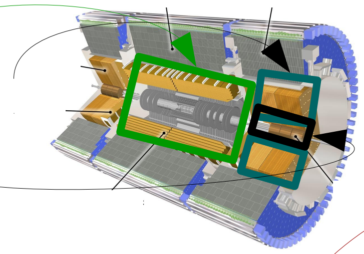
- **Using the showering process :**
  -> Calorimeters
  - Stops the electrons and Measure their **energy**
  - Give **shower shape** information
- **Using the track :**
  -> Inner Tracker
  - Reconstruct the **track** of the electron
  - Measure the **charge**
  - Identify the **primary vertex**
- **Using the transition radiation**
  -> TRT tracker
  - Additionnal e / π discrimination



The ATLAS detector gives a large panel of information to identify electrons

The electromagnetic calorimeter

- **Global geometry :**
  - **Barrel : |η| < 1.475**
  - **End-cap :** 1.375 < |η| < 3.2
  - **Forward :** 3.2 < |η| < 4.9

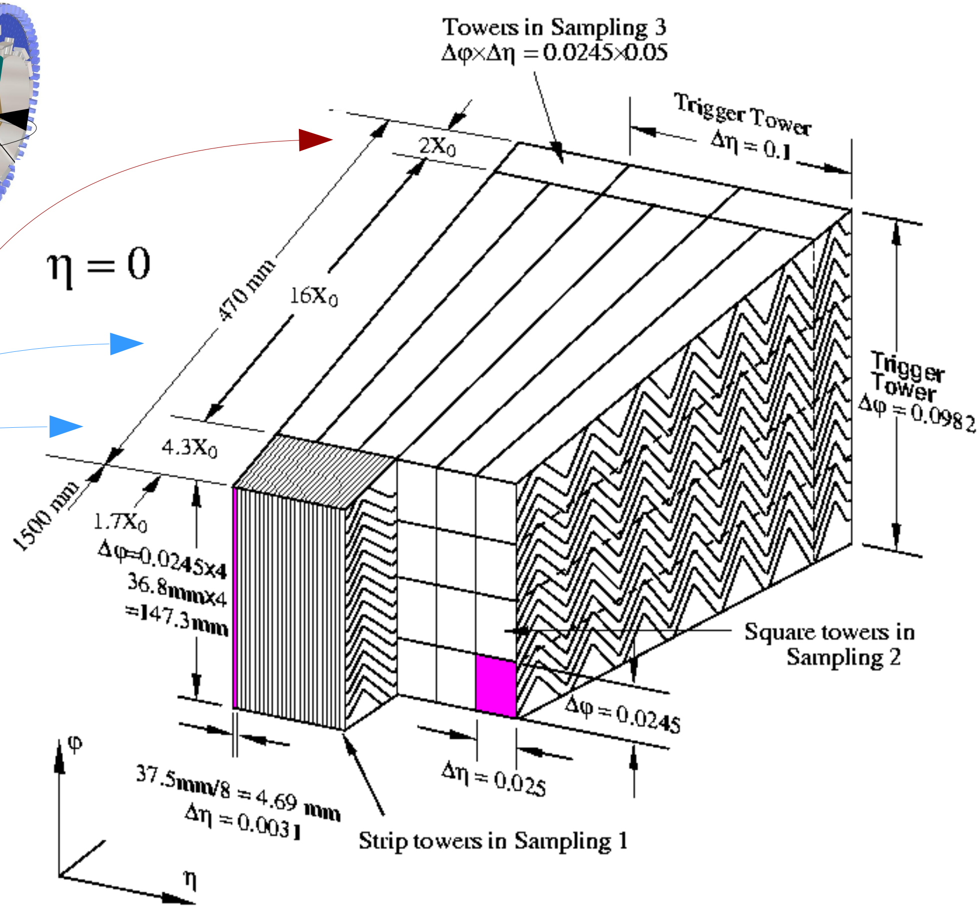


- **Operating principle :**
  - Passive material : Pb
  - Active material : liquid argon
  - Accordion structure
    - -> Excellent hermiticity along Φ

- **Structure : 3 layers**
  - **Pre-sampler**
  - **1st layer :**
    - fine η binning
    - -> good γ / π^0 discrimination
  - **2nd layer :**
    - fine Φ binning
    - deep layer
    - -> Most of the energy deposit
  - **3rd layer :**
    - -> coarser η and Φ binning

LATERAL INFO

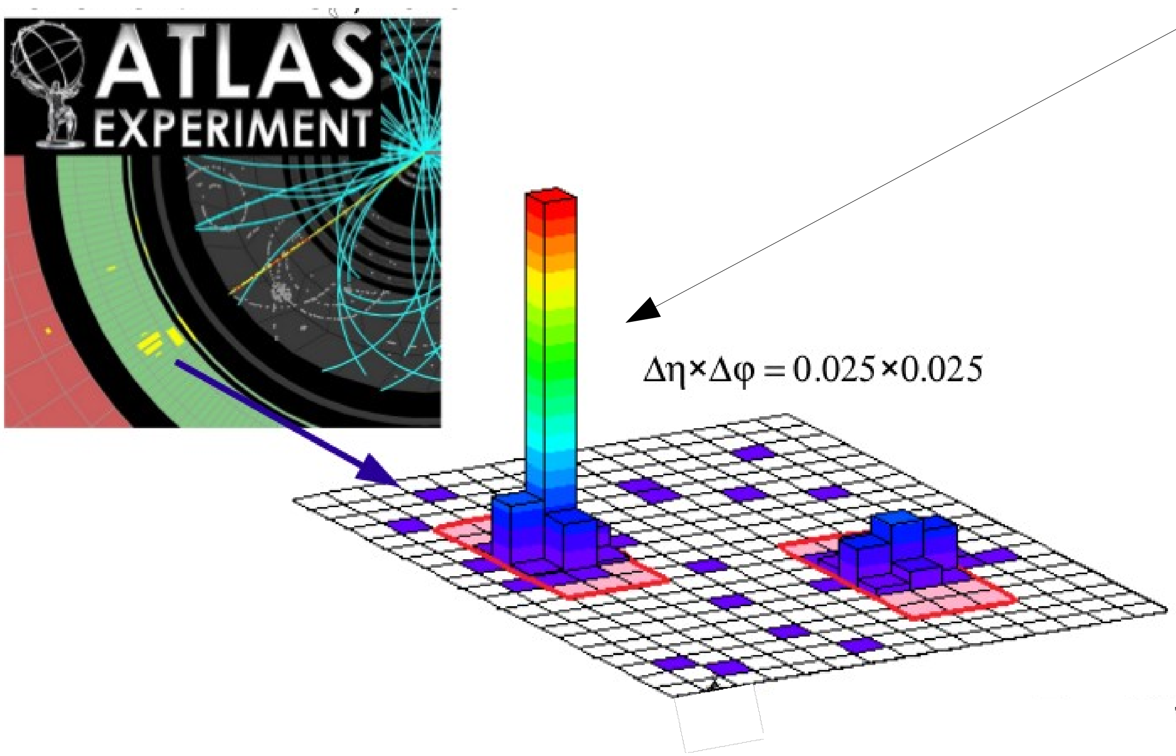
LONGITUDINAL INFO



Large granularity, with transverse and longitudinal segmentation
-> Very useful for electron identification

Electron reconstruction

W -> eν event



- **Step 1 : Identification of energy clusters**
  in the electromagnetic calorimeter
  in a fixed ΔΦ and Δη window (in red)

- **Step 2 : Association of a track with the cluster**
  - found track :
  -> electron
  - No track found
  -> photon

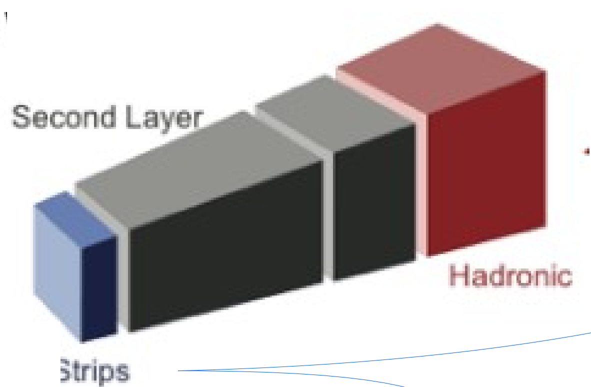
- **Step 3 : Computation od the final physical parameters**
  ex : 4 momentum / charge etc ...

- **Hadrons are ~10^6 more abudant that electron in LHC.**
  -> Not enough rejection with the reconstruction

Further discrimination is needed
-> electron identification

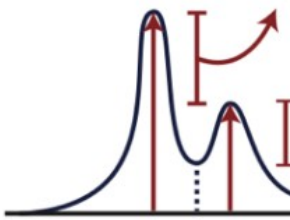
Electron identification variables
1st layer

Calorimeters information



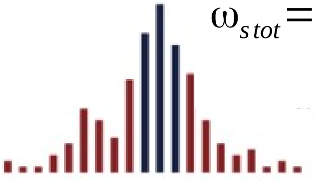
Get information from the transverse profile of the shower in layer 1

$$E_{\text{ratio}} = \frac{E^{S1}_{\text{max},1} - E^{S1}_{\text{max},2}}{E^{S1}_{\text{max},1} + E^{S1}_{\text{max},2}}$$



$$\Delta E = E^{S1}_{\text{max},2} - E^{S1}_{\text{min}}$$

Detect the single structure in the lateral shower shapes



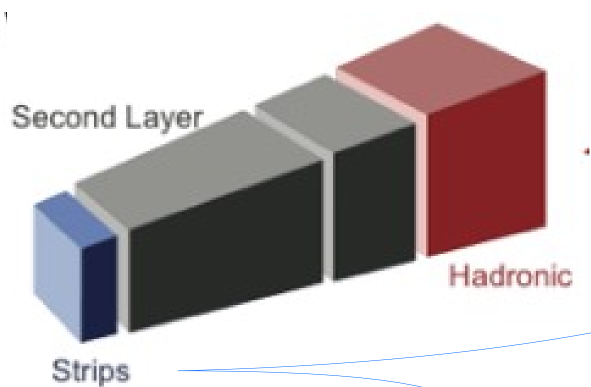
$$\omega_{stot} = \sqrt{\frac{\sum E_i (i - i_{max})^2}{\sum E_i}}$$

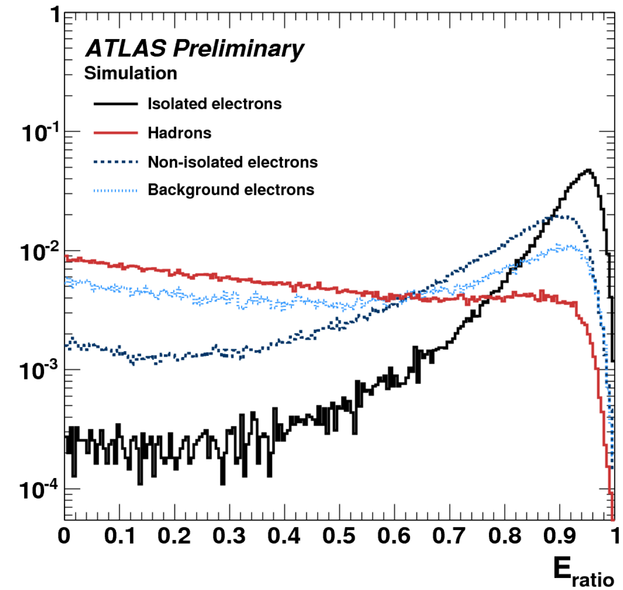
ωstot uses 20 strips in η

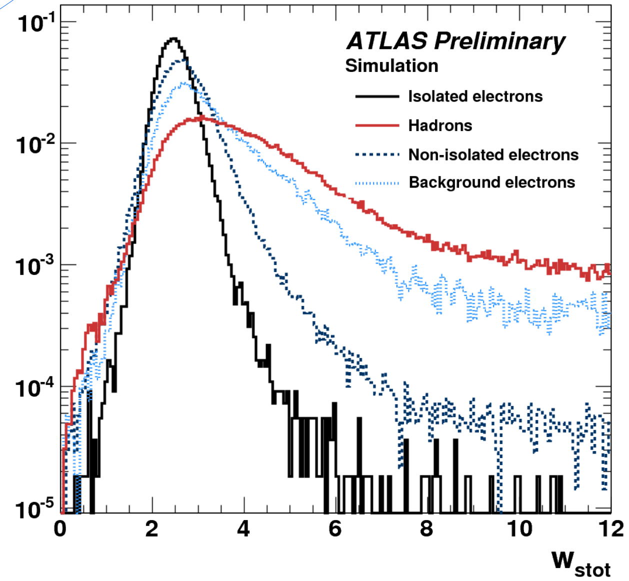
Measure the sharpness of the lateral shower shape

Electron identification variables 1st layer

Calorimeters information





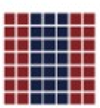


Good discriminating power

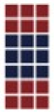
Electron identification variables 2nd layer

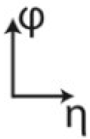
Measure the lateral spread out of the shower in η and Φ

$$R_\eta = \frac{E^{S2}_{3\times7}}{E^{S2}_{7\times7}}$$



$$R_\phi = \frac{E^{S2}_{3\times3}}{E^{S2}_{3\times7}}$$

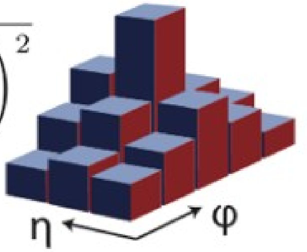




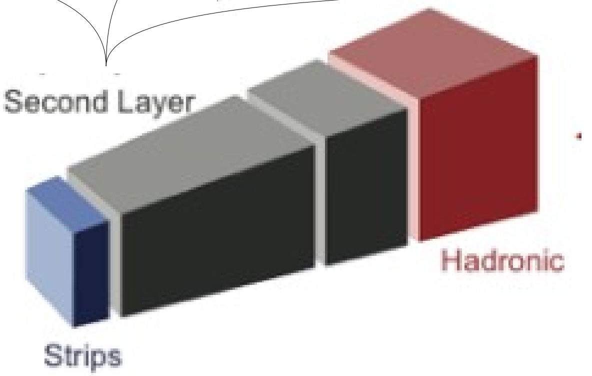
Measure the sharpness of the lateral shower shape

$$w_{\eta,2} = \sqrt{\frac{\sum E_i \eta_i^2}{\sum E_i} - \left(\frac{\sum E_i \eta_i}{\sum E_i}\right)^2}$$

Width in a 3×5 (Δη×Δφ) region of cells in the second layer.

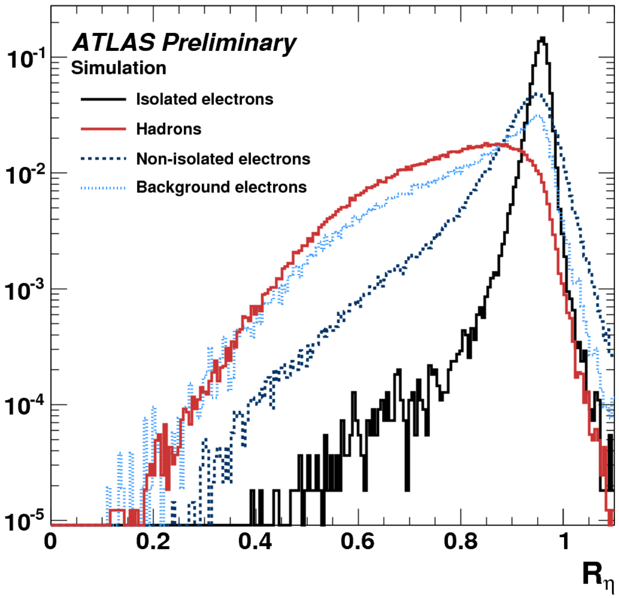


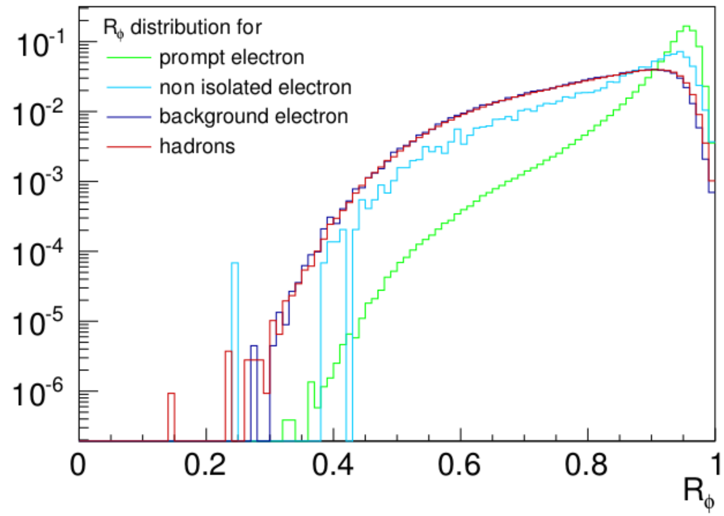
Calorimeters information

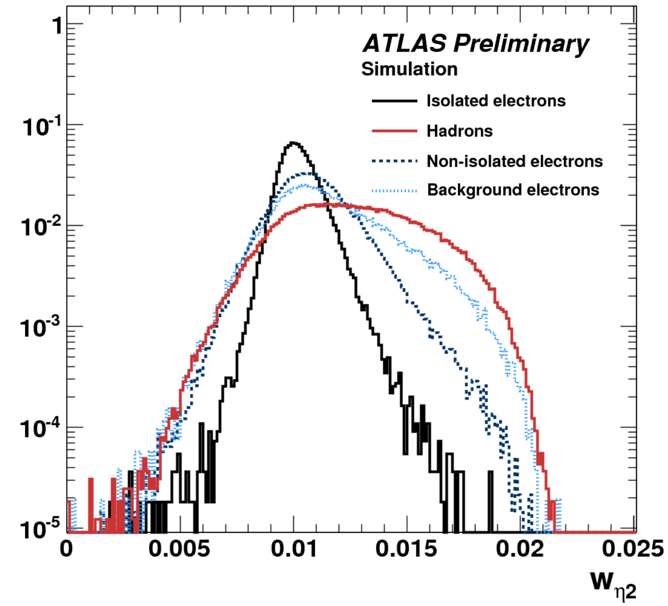


Get information from the transverse profile of the shower in layer 2

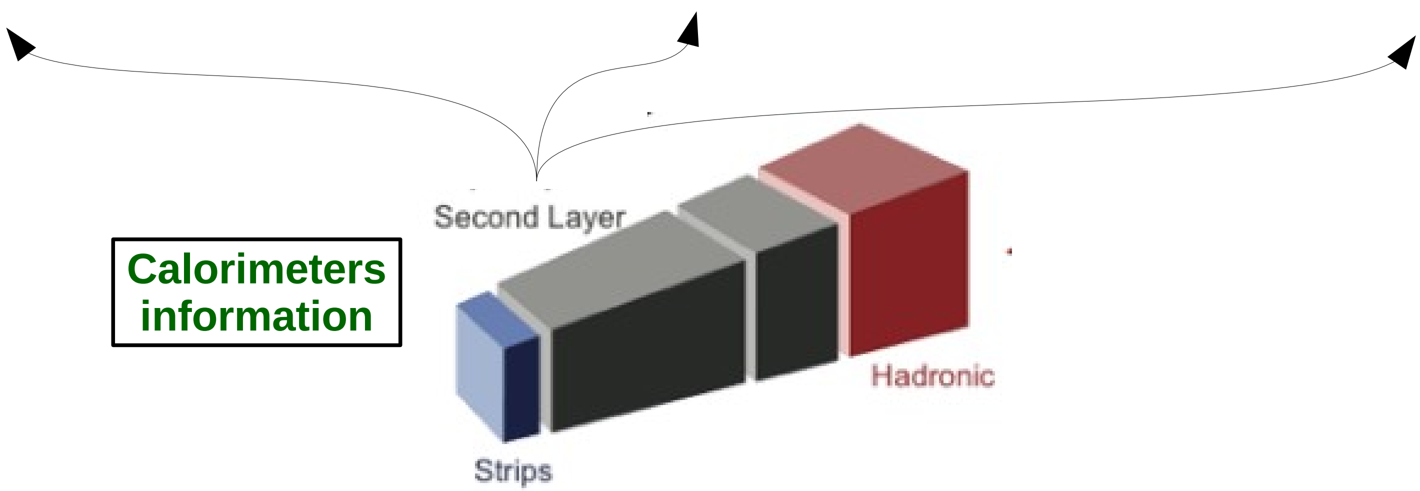
Electron identification variables 2nd layer





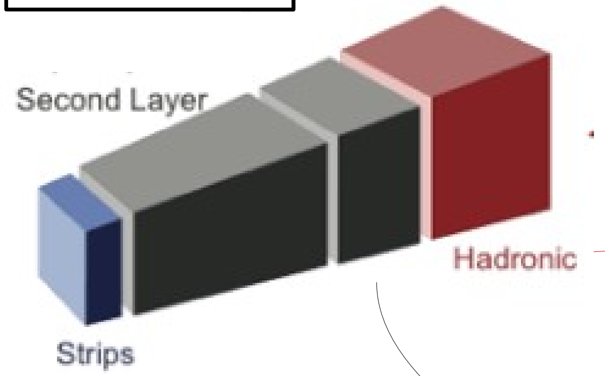


Calorimeters information



Electron identification variables
Shower depth

Calorimeters information



$$R_{\mathrm{Had}} = \frac{E_T^{\mathrm{Had}}}{E_T}$$

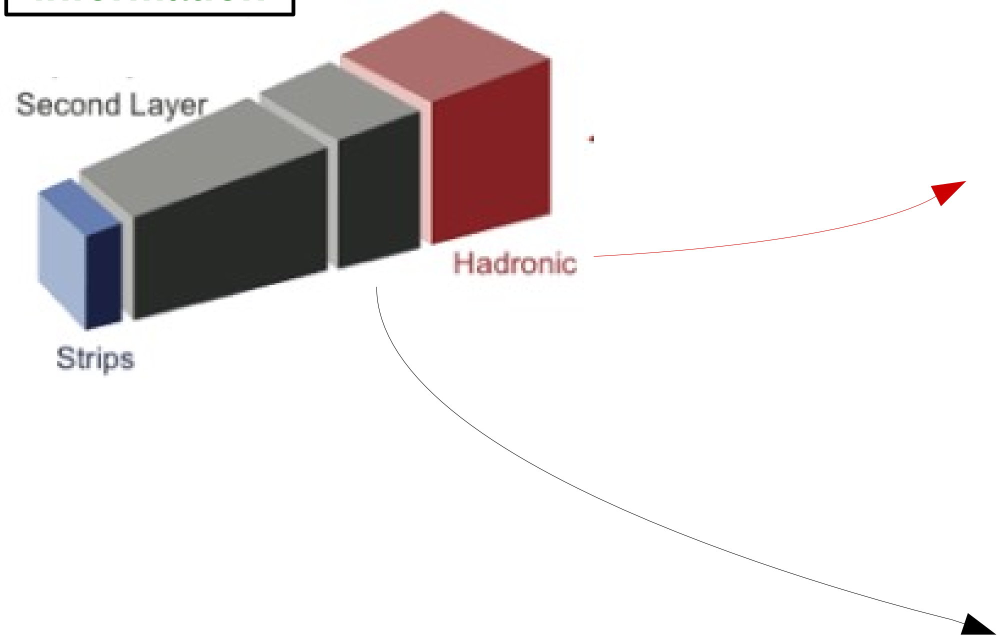
Measure the leakage in the hadronic calorimeter

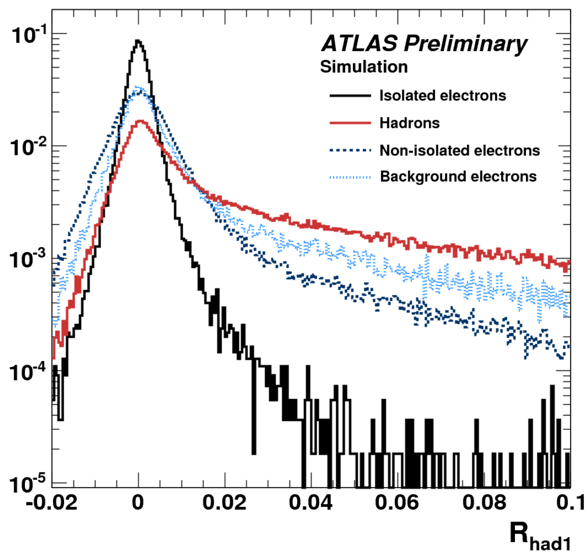
$$f_3 = \frac{E_{S3}}{E_{eCal}}$$

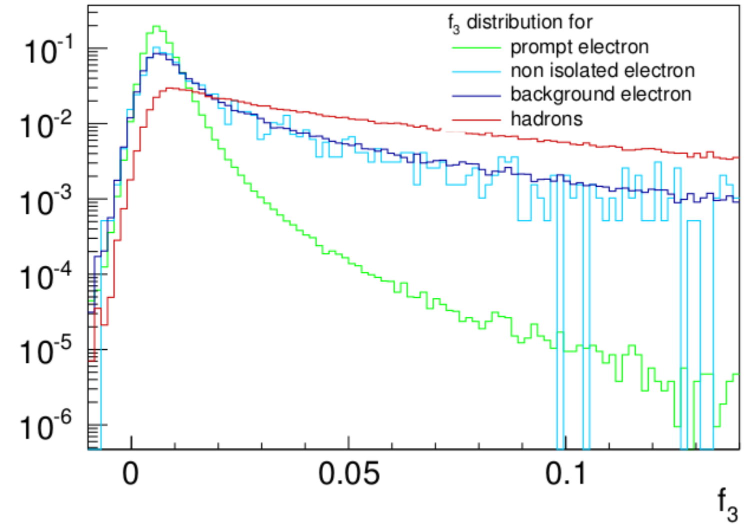
Get the longitudinal info from the third layer

Electron identification variables
Shower depth

Calorimeters information

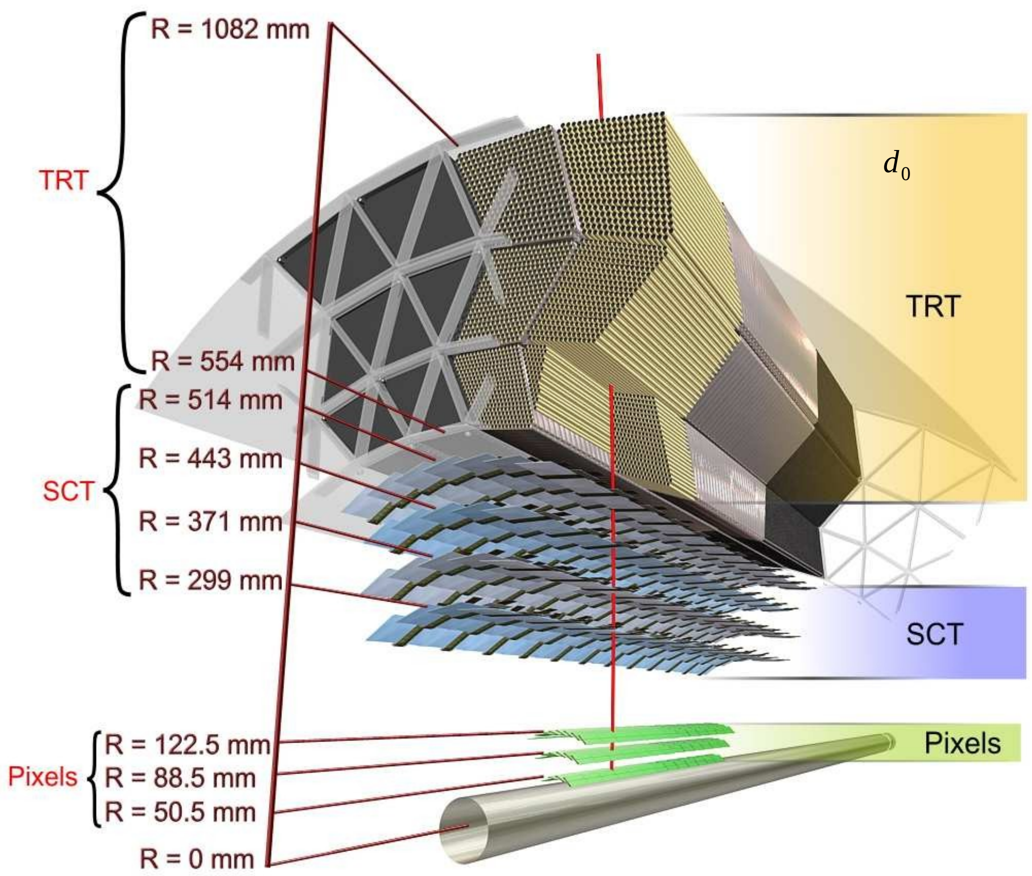


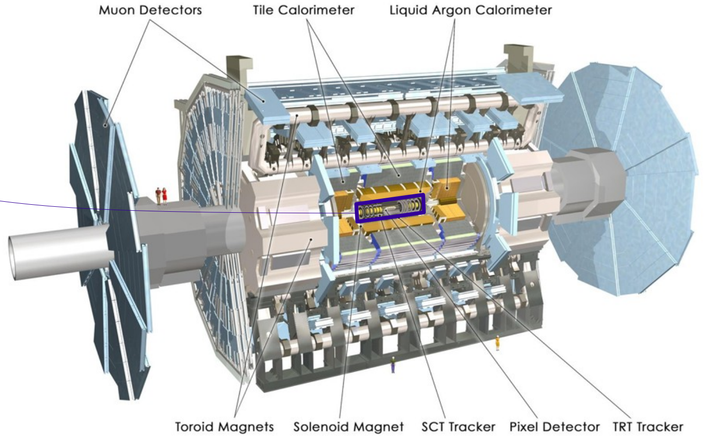




Electron identification variables inner tracker

Tracking information





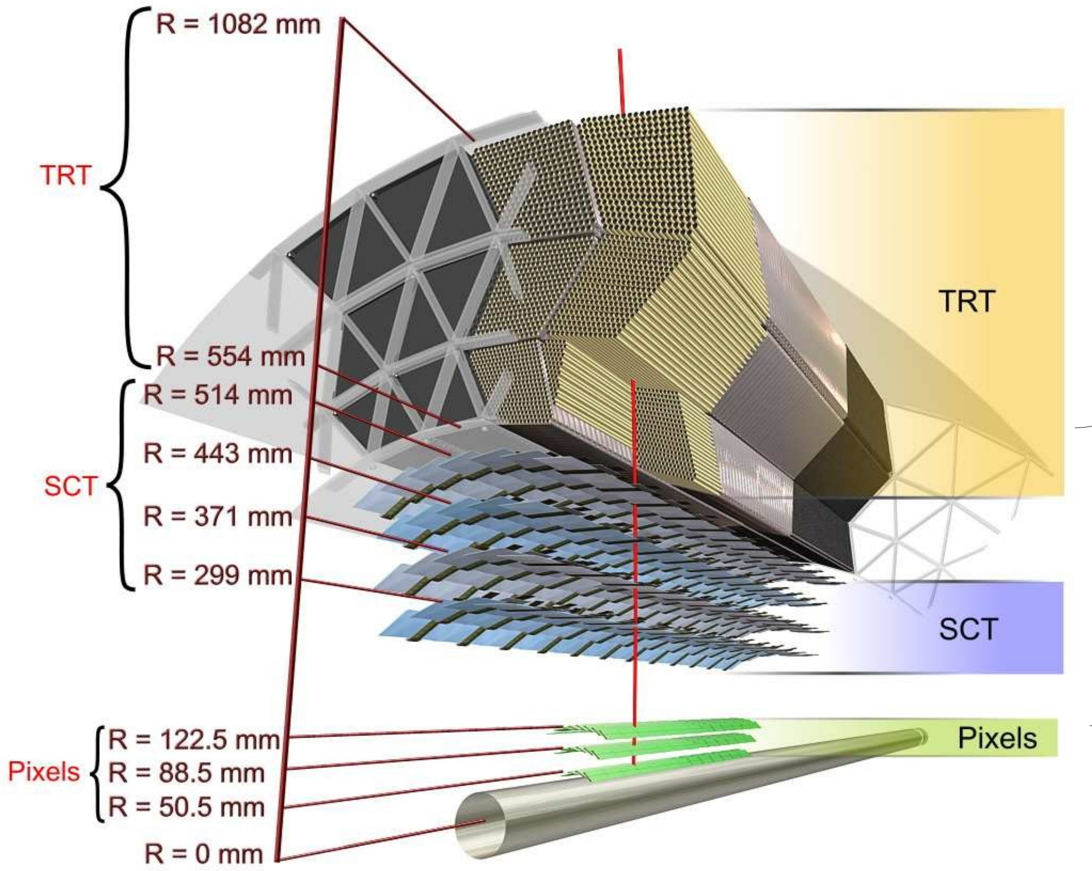
Fraction of high threshold hits In TRT

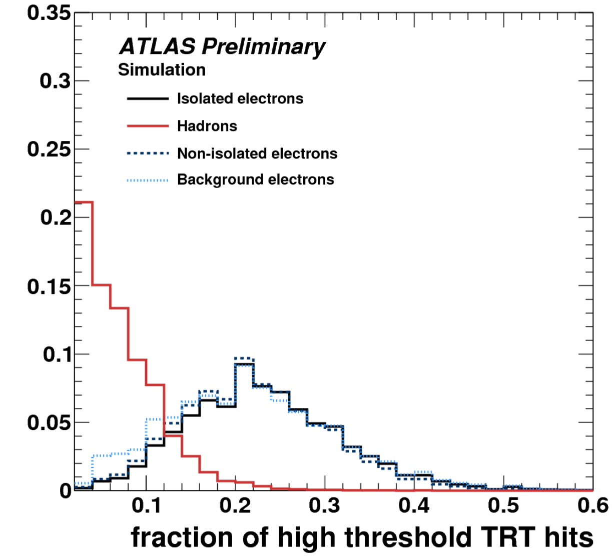
Number of hits in the tracker (track quality)

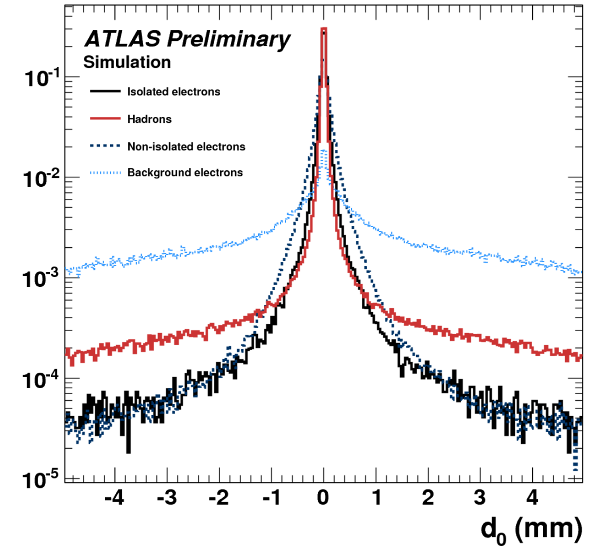
d0 : Transverse impact parameter

Electron identification variables inner tracker

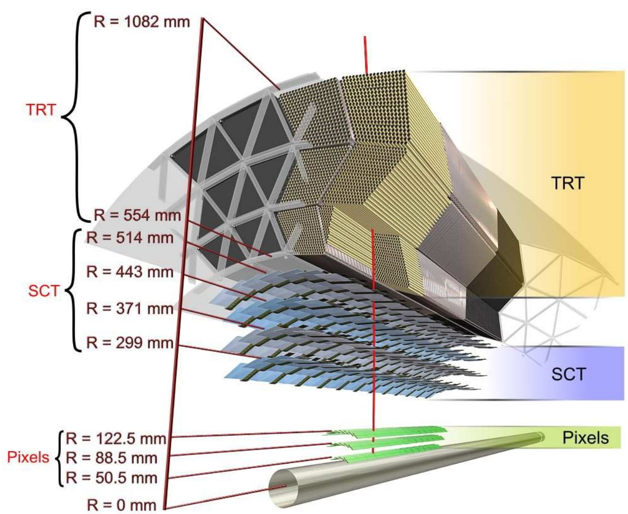
Tracking information

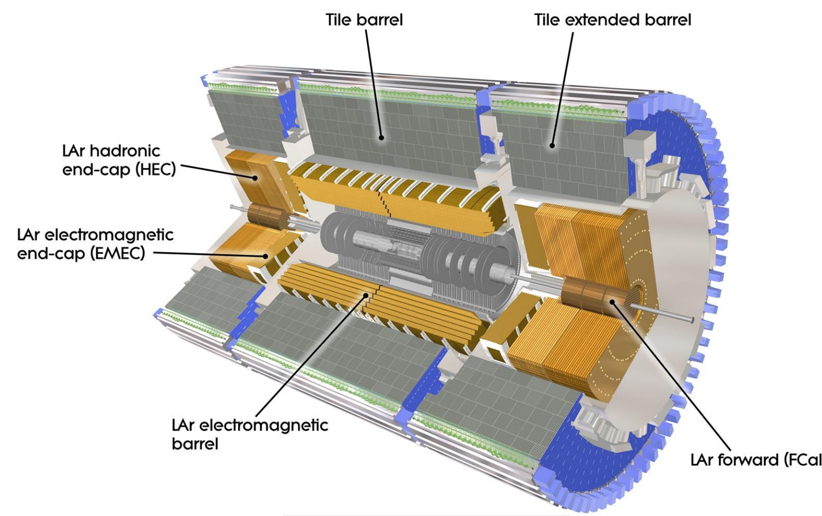






Electron identification variables track-cluster matching



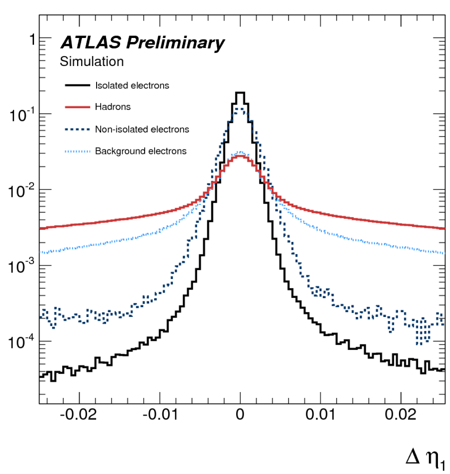


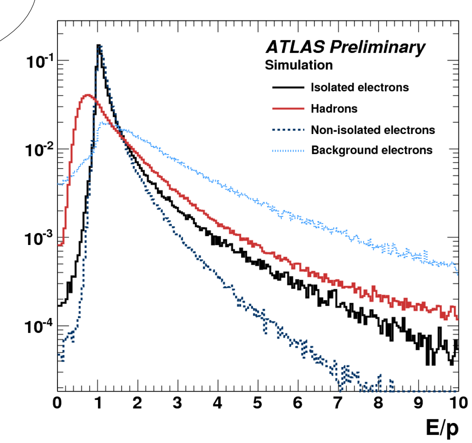
Tracking information

Calorimeters information

Track-Cluster matching

Position	**Δη ΔΦ**
Energy	**E/p**

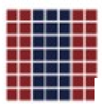




Electron Identification variables Summary

- **Here is a small presentation of the calorimeter based electron identification discriminating variables :**

$$R_\eta = \frac{E^{S2}_{3\times7}}{E^{S2}_{7\times7}}$$



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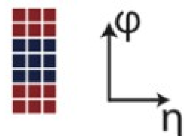
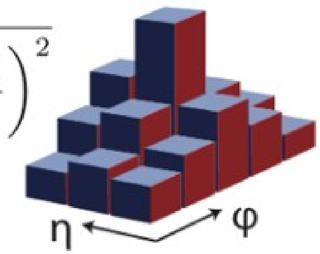
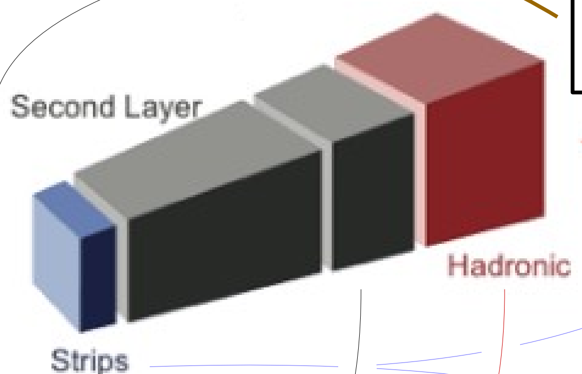


$$w_{\eta,2} = \sqrt{\frac{\sum E_i \eta_i^2}{\sum E_i} - \left(\frac{\sum E_i \eta_i}{\sum E_i}\right)^2}$$

Width in a 3×5 (Δη×Δφ) region of cells in the second layer.



Calorimeters information



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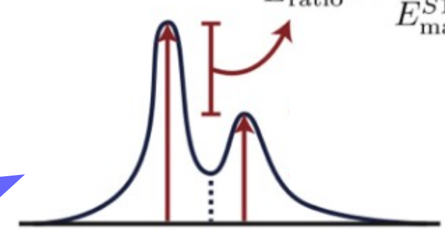
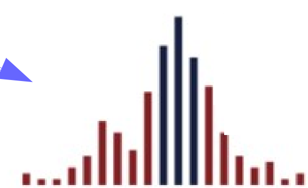


Track-Cluster matching

Position	**Δη ΔΦ**
Energy	**E/p**



$$\omega_{s\,tot} = \sqrt{\frac{\sum E_i (i - i_{max})^2}{\sum E_i}}$$

ωstot uses 20 strips in η

Tracking information

TRT	$F_{HT} = \frac{n_{TRT\ \ HT\ \ hits}}{n_{TRT\ \ Hits}}$
Silicone tracker	$n_{Si\ \ Hits}$ $n_{Pix\ \ Hits}$ $n_{b\ \ layer\ \ Hits}$

$$R_{\text{Had}} = \frac{E_T^{\text{Had}}}{E_T}$$

$$f_3 = \frac{E_{S3}}{E_{eCal}}$$

A large variety of information exploiting the full power of the detector

Electron identification

- **Use different discriminating variables to reach further discrimination from background**
- **Wide variety of analysis in ATLAS**
  - Some are limited by **statistics**
    -> high **signal efficiency** is needed
  - Some are limited by the **fakes** electrons
    -> high **background rejection** is needed
- **To better cope with needs of the analysis 3 identification criterion are defined :**
  -> Loose / Medium / Tight
- **2 different strategy :**
  - Likelihood PID :
    -> Good performances
    -> Sensitive to mis-modeling

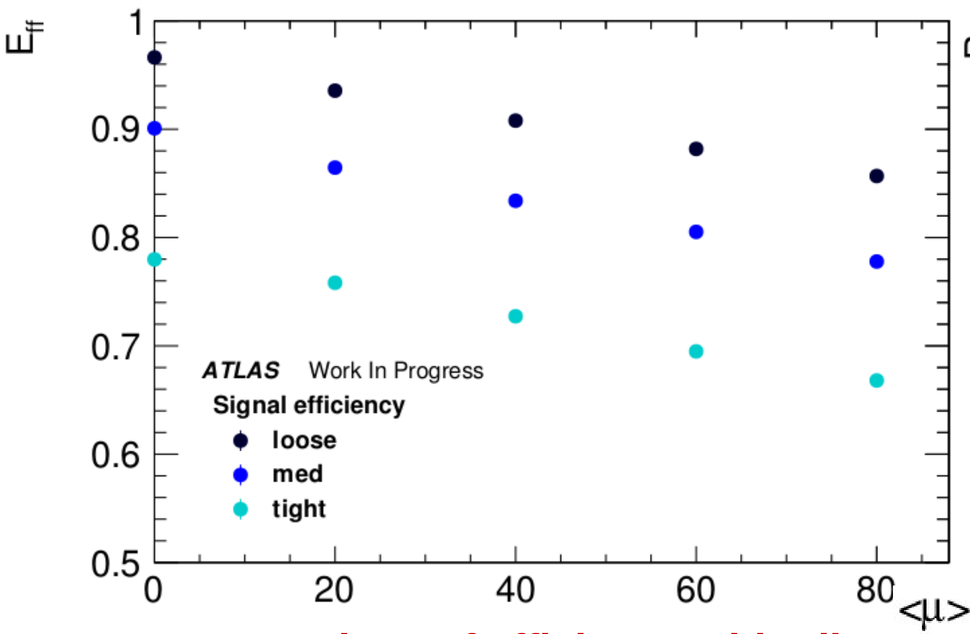
    Good for later data taking
  - Cut Based PID :
    -> More robust to mis-modeling
    -> Worse performances

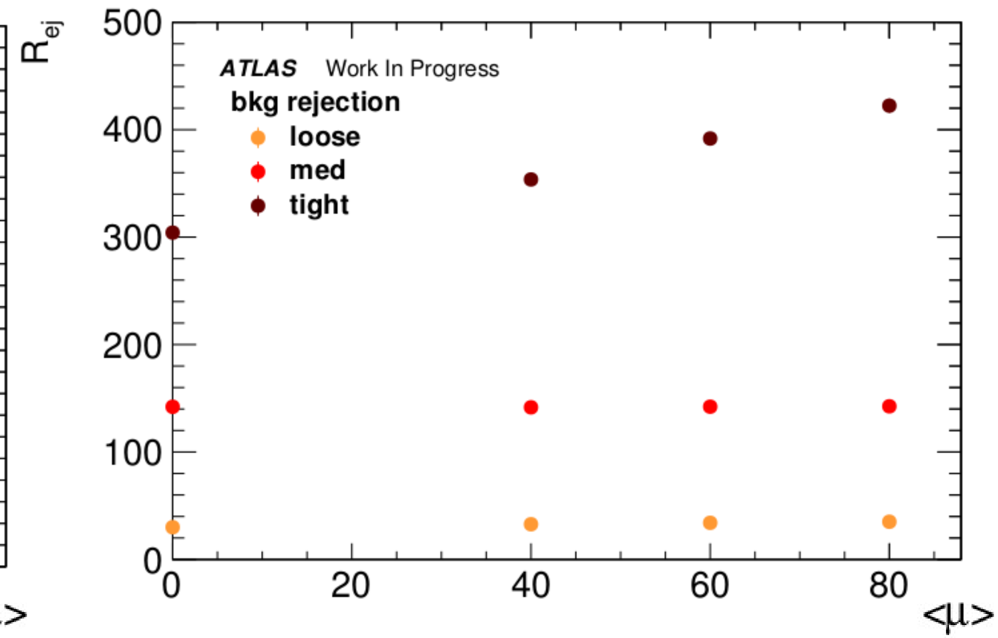
    Good for early data taking
- **In 2015 the LHC will produce collision at higher energy / luminosity**

Is the 2012 cut-based menu adapted for run 2 high luminosity configuration ?

Why re-optimizing
The electron identification

- **Here are the offline performances of the 2012 identification menu :**





Important loss of efficiency with pile-up :
<mu> = 0 -> <mu> = 40 : ~ 5 % of loss

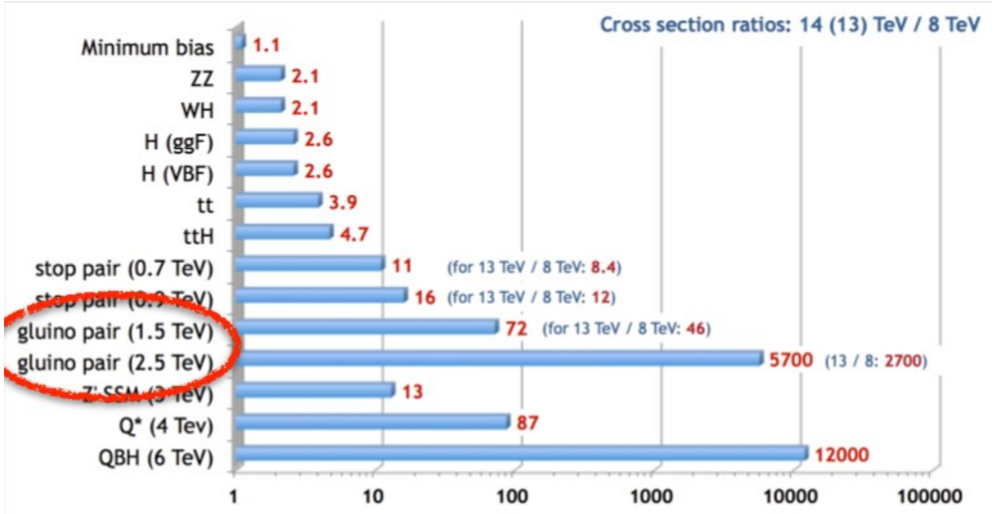
Acceptable background rejection

- **Online performances :**
  - The allowed bandwidth for single electron trigger for 2015 : **~200 Hz.**
  - The energy and the luminosity will both increase
    - -> 2015 trigger rate **4-5 time higher**
    - -> 2012 single electron trigger in 2015 high lumi/Energy conditions : **~ 1 kHz**

The 2012 identification menus needs to be re-optimized for 2015 high luminosity conditions

Optimization method (1)
Pile-up robustness

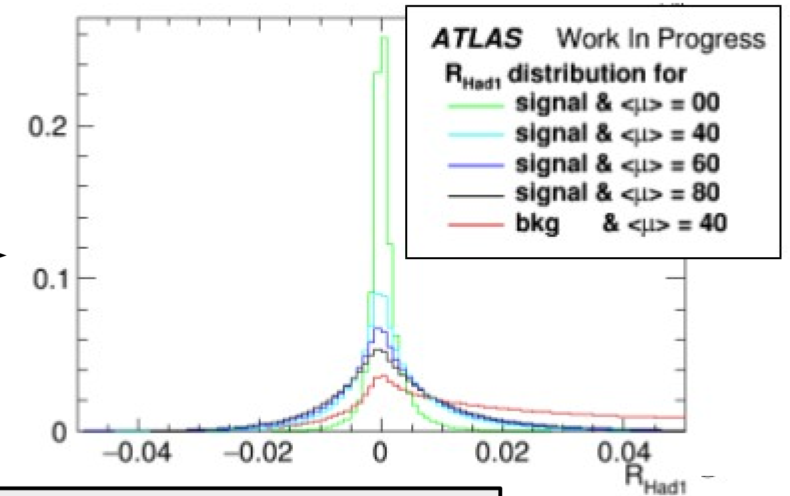
- **Rise of energy in 2015 to 13 TeV**
  -> Very important rise of production cross section for new physics particle (heavy)
  -> Many new physics can be **quickly** probed using very **simple analysis**



- **Very quick result are wanted**
  -> Menu have to be **simple** to use for analysers
  -> Pile-up is varying during the data taking

We want a pile-usp independent menu

- **To have pile-up robust menus, we have :**
  -> Identified the worst pile-up offenders
  -> Optimized them independently focusing pile-up robustness



We have then menu particularly adapted for new physics searches with early 2015 data

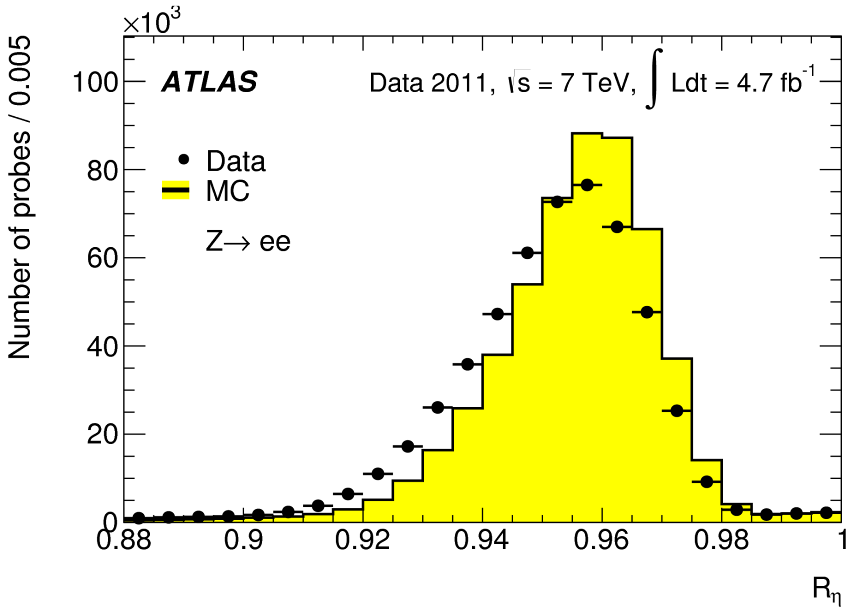
Optimization method

- **We need to use high pile-up Monte Carlo samples :**
  - Electron signal : Zee at <μ> = 0 / 20 / 40 / 60 / 80 and Bs = 25 ns
  - Background sample : JF17 at <μ> = 0 / 20 / 40 / 60 / 80 and Bs = 25 ns

- **However, important shower shapes mis-modeling seen in Run 1 :**
  - Data → Monte Carlo shifting computed with 2012 data applied **(See ref n°2, slide 11)**
  - Loosen some potentially problematic cuts

- **The cuts are optimized using an algorithm that uses :**
  - The TMVA Cuts method
  - Further manual tuning

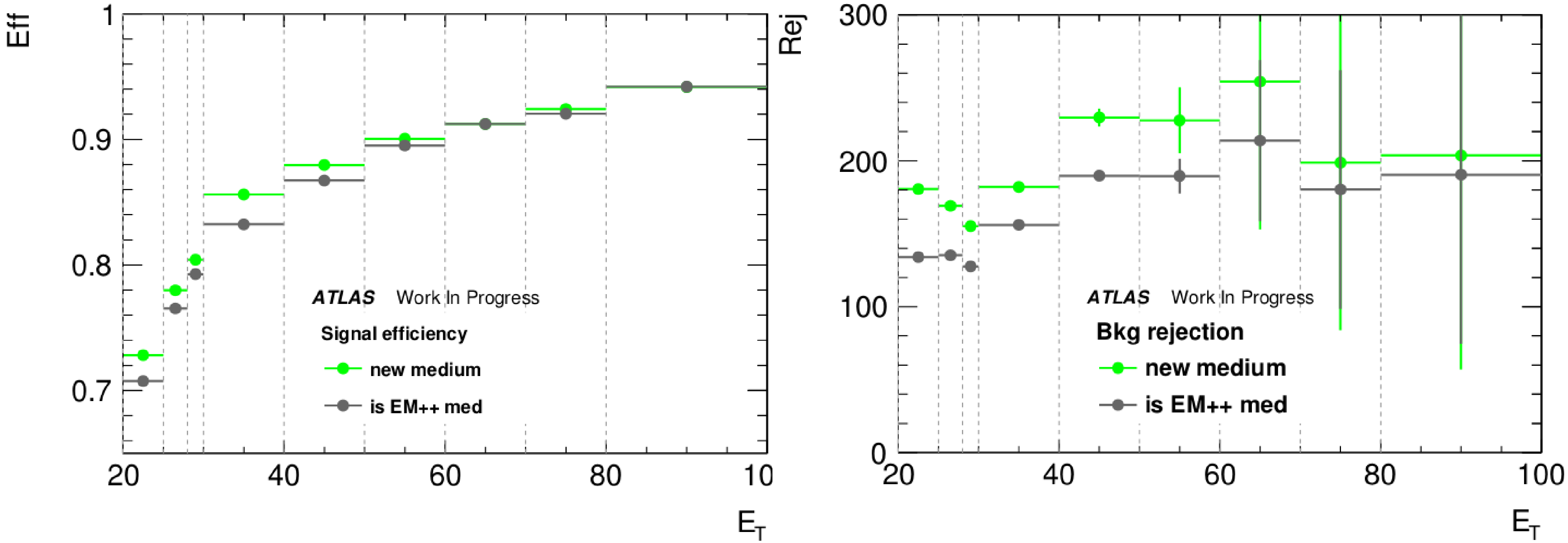
- **This optimization has been performed for :**
  - 10 η bins (|η| < 2.47)
  - 7 Et bins (Et > 20 GeV)



After one year of work to develop the tools, extract and test the menus, we propose the following re-optimized menus

Medium menu
Performance @ <μ> = 40

- **Status of the re-optimization for the medium menu :**

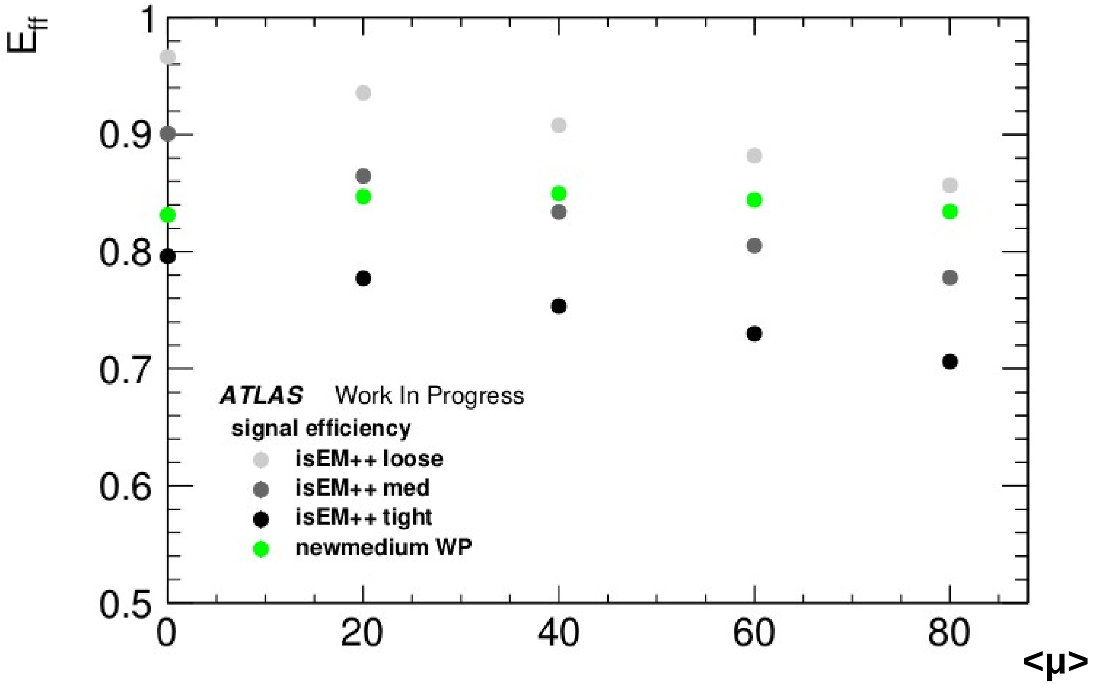


See back-up for :
- the cut content
(slide 30)

- Much better rejection
- Better efficiency for Et < 50 GeV
- Equivalent efficiency for Et > 60 GeV

Medium menu
pile-up robustness

- **Here is the Et / η pile-up robustness :**

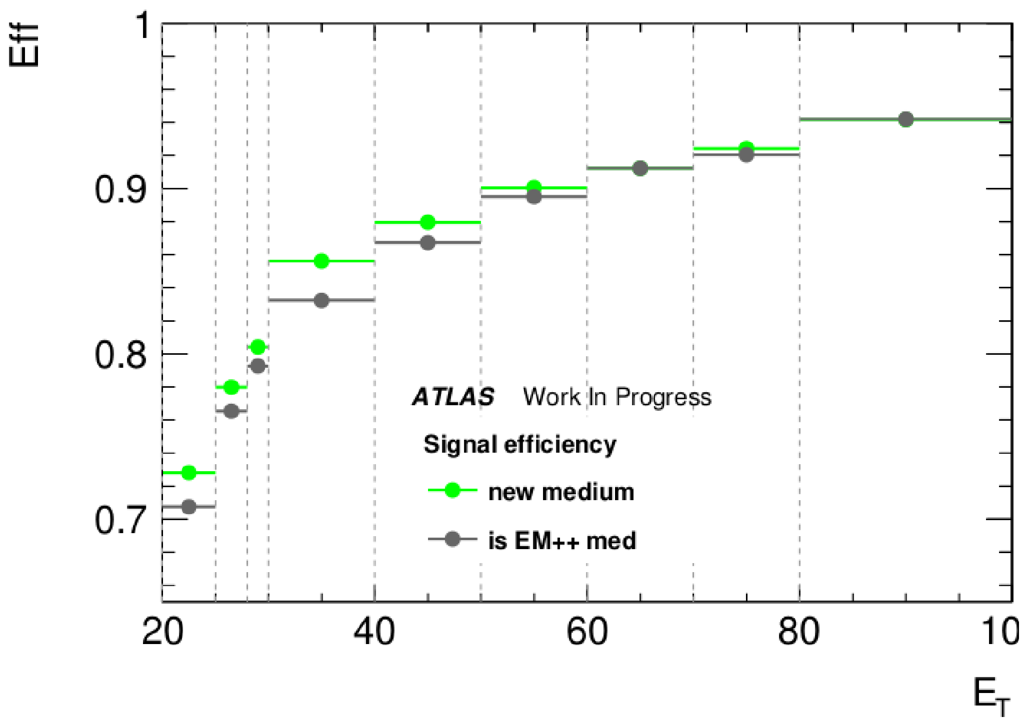


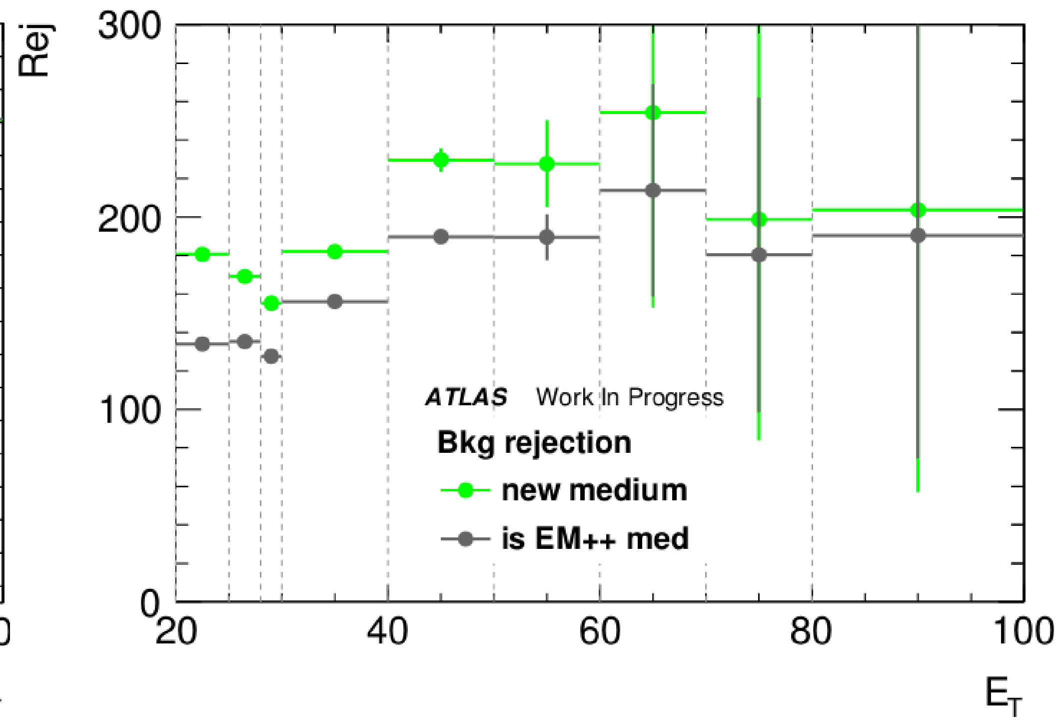
See back-up for :
- the cut content
(slide 30)

Better pile-up robustness

Medium menu
Performance @ <μ> = 40

- **Status of the re-optimization for the medium menu :**





See back-up for :
- the cut content
(slide 30)

- Much better rejection
- Better efficiency for Et < 50 GeV
- Equivalent efficiency for Et > 60 GeV

Tight menu
Online performances @ <μ> = 40

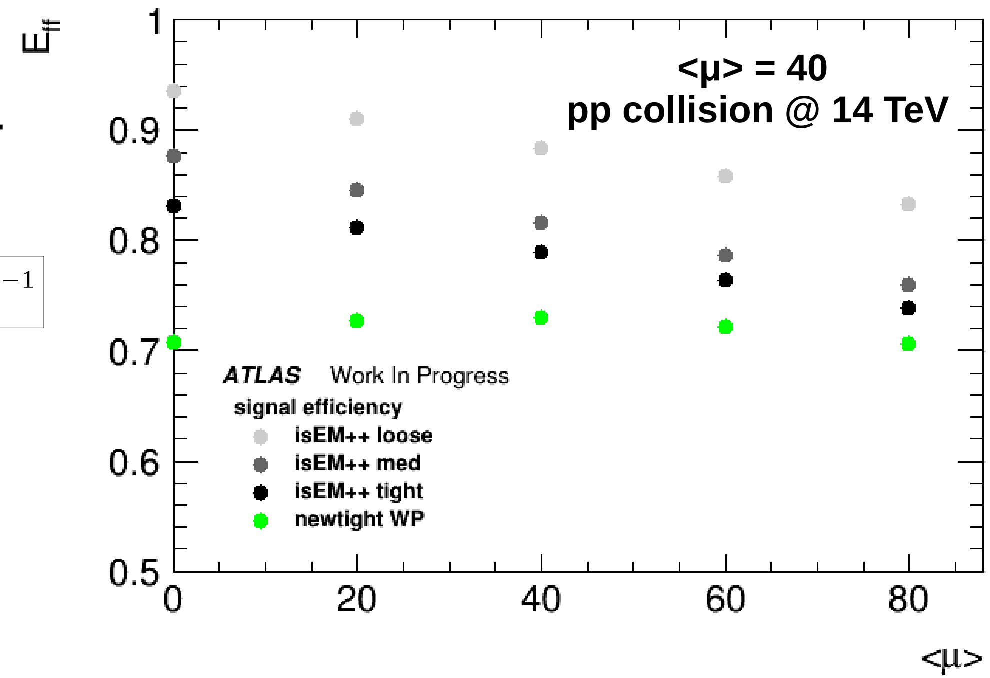
- **The Et[20,30] GeV bin of the tight menu is used to define the run2 unprescaled single lepton trigger.**
- **Un-prescaled electron trigger at Run1**
  - trigger item : e24_medium_vhi
  - Et thershold : 24 GeV
  - loose isolation cut
  - **Rate : ~ 1 kHz**

$$L = 2.10^{34}\,cm^{-2}\,s^{-1}$$

- **Rising to higher Et threshold :**
  - Et theshold : 24 -> 28 GeV
  - **Rate : 590 Hz**
- **Re-optimized trigger item**
  - **trigger item : e28_tight_vhi :**

new menu Rate : 290 Hz

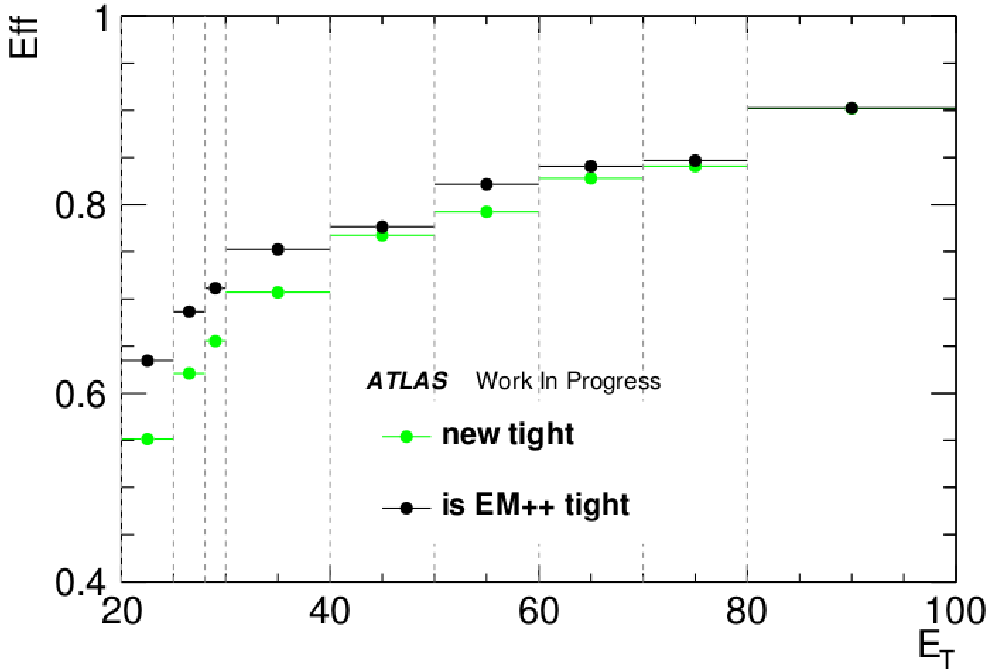
- **Pile-up dependency :**

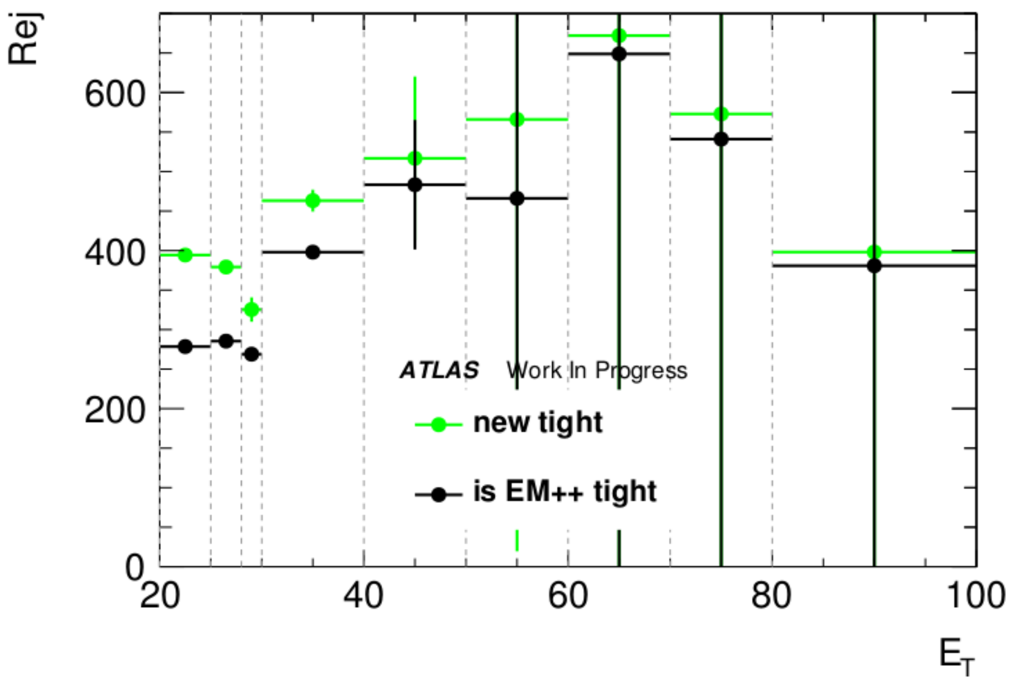


- The trigger rate is now acceptable
- Better pile-up robustness

Tight menu
Offline performances @ <μ> = 40

- **Menu's performances driven by trigger rate requirements**
  → lower offline efficiency



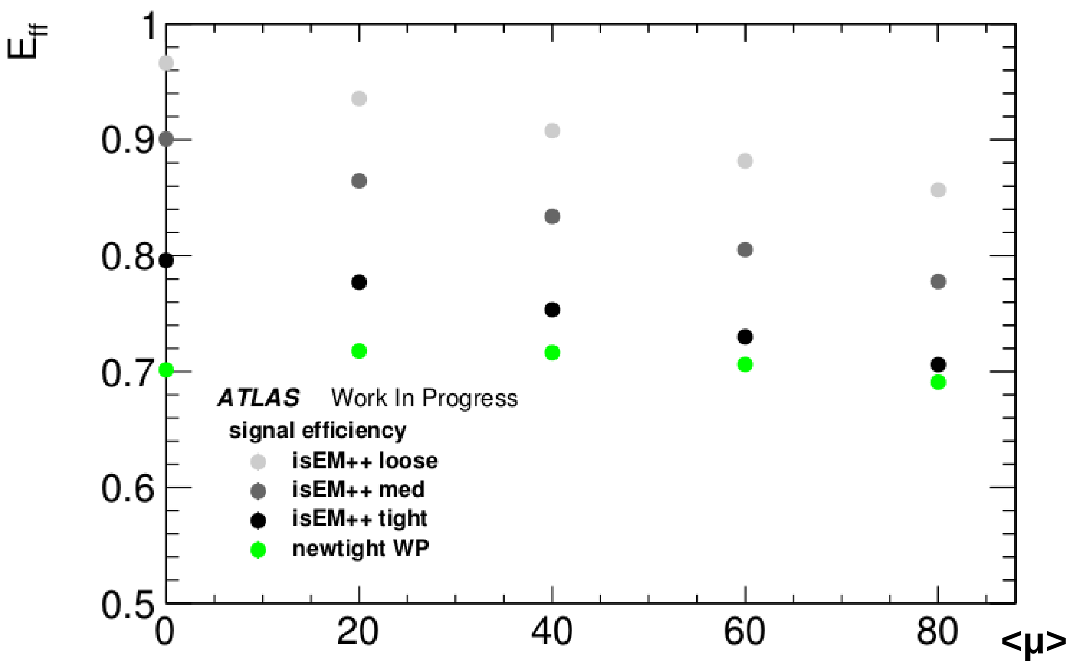


See back-up for :
- the cut content
(slide 19)

Tighter menu

Tight menu offline
pile-up robustness

- **Here is the pile-up robustness for two differents Et bins :**

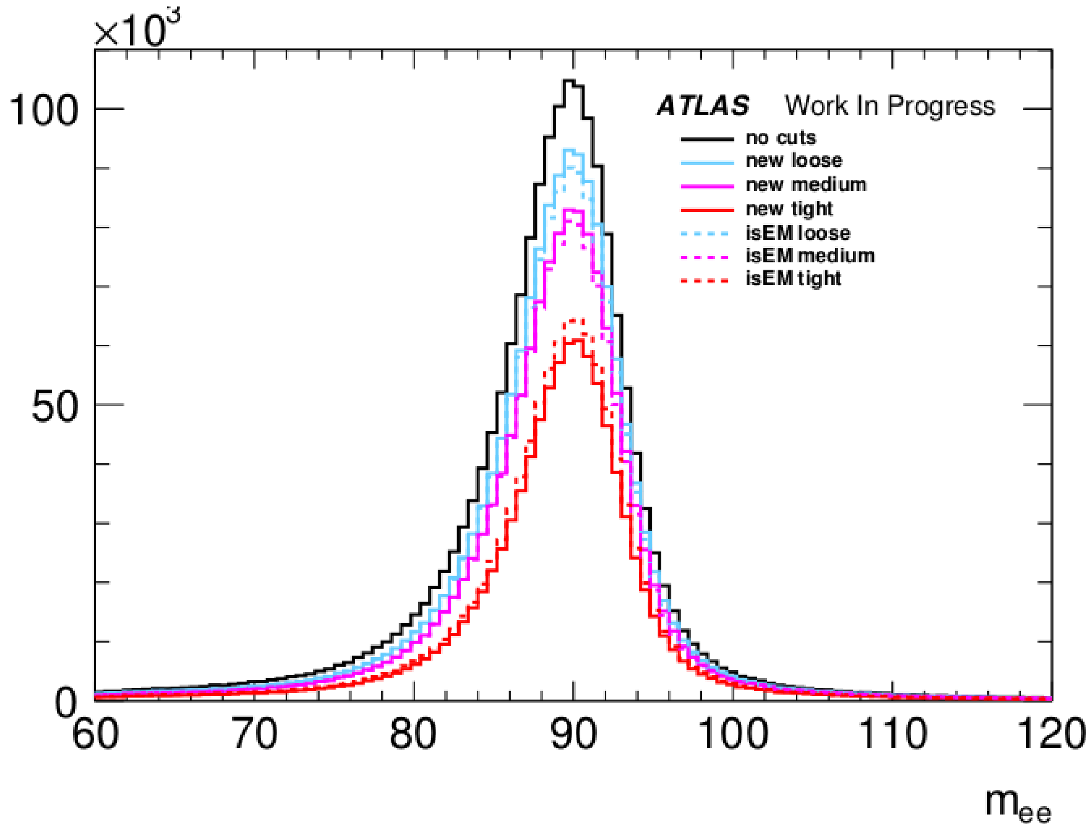


See back-up for :
- the cut content
(slide 19)

Better pile-up robustness

Are our menus degrading the physical content ?

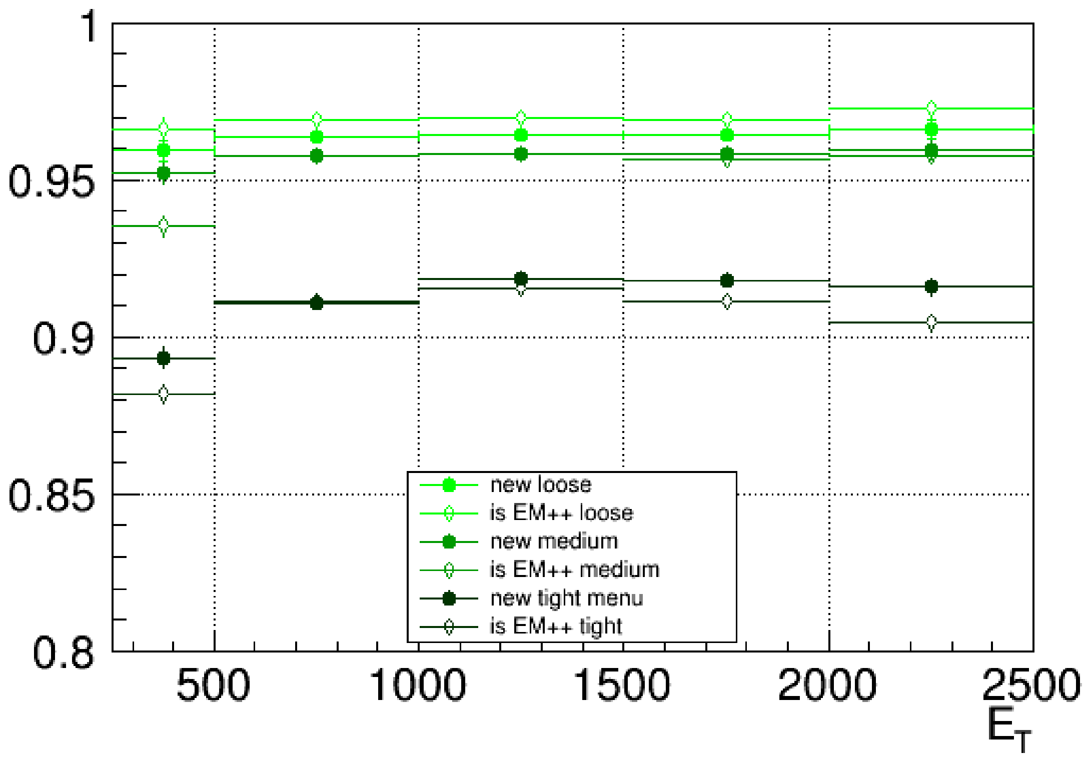
- **Invariant mass of electron pairs coming from a Z -> ee process**



No drop of efficiency @ very high Et
-> Very important for new physics

Are our menus adapted for new physics searches ?

- **New physics searches are crutial for the begining of the 2015 data taking**
- **Many new physics signals are tagged with very high Energy leptons**
  -> We want to keep high efficiency for TeV electrons



No drop of efficiency @ very high Et
-> Very important for new physics

Conclusions

- **We have re-optimized a full set of cut-based electron identification menus for 2015 high energy / luminosity conditions**
  - Those menus have globally better performances than 2012 electron identification menu at high pile-up configuration.
  - They should be robust with respect to mis-alignment/modeling issues.
  - They have an improved pile-up robustness.
  - The very hight Et efficiency is not harmed.

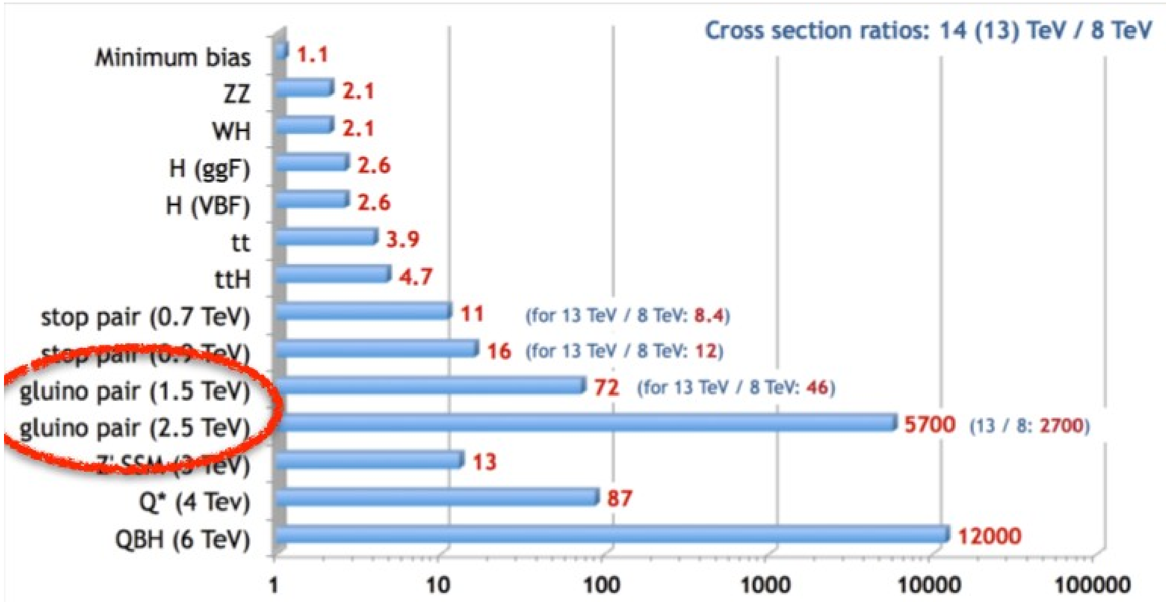
Reference to previous talks on back-up (slide 32)

- The final menus are now beeing implemented in the online/offline ATLAS software
- They will be used in all the ATLAS analyses involving electrons
(together with a Likelihood menu)

Outlook
2015 data taking is coming !

- **The electron identification menus needs to be tested on early 2015 data**

- **The energy rise make room for very quick new physics discoveries :**
  example :
  the supersymetric partner of the gluon can be very quickly discovered or excluded
  -> New physics search very competitive at the begining of 2015 13 TeV data taking



I will start my analysis for search on supersymetric particles with 2 same sign leptons in the final state

Back-up

Reference to previous talks

- **Detailed performances of the isEM++ menu in high pile-up configuration :**

  For detailed study on which cuts are responsible of the pile-up dependency, see :
  https://indico.cern.ch/event/293488/contribution/1/material/slides/0.pdf

- **Data-MC Shifting tool :**
  - Presentation of the tool :

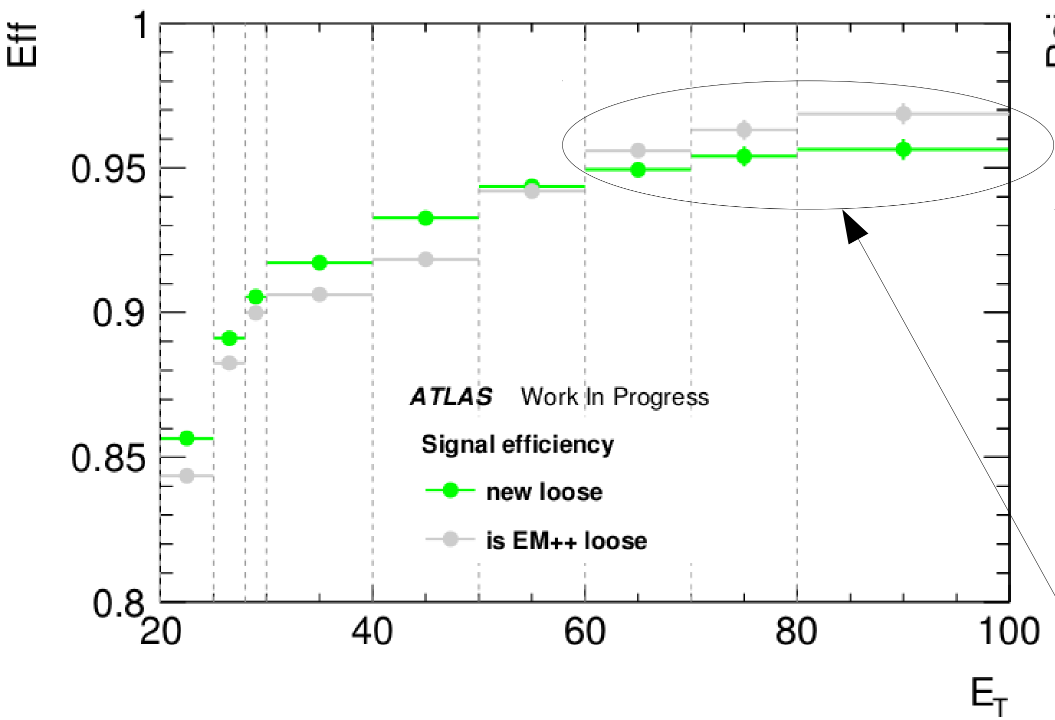
  See : Rob's presentation : https://indico.cern.ch/event/302354/
  And his tutorial : http://hn.hep.upenn.edu/Analysis/robflet/html/index.html

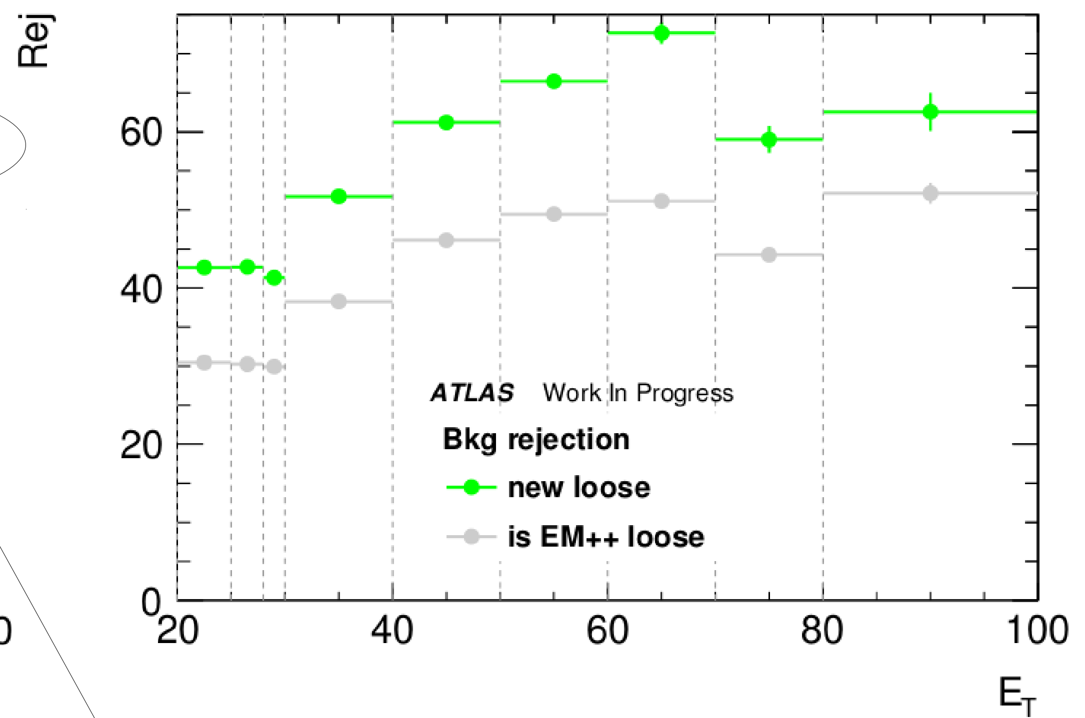
- **Egamma Workshop talk**

  https://indico.cern.ch/event/310874/session/5/contribution/9/material/slides/0.pdf

Loose menu
Performance @ <μ> = 40

- **Here is the status of the re-optimization for the loose menu :**



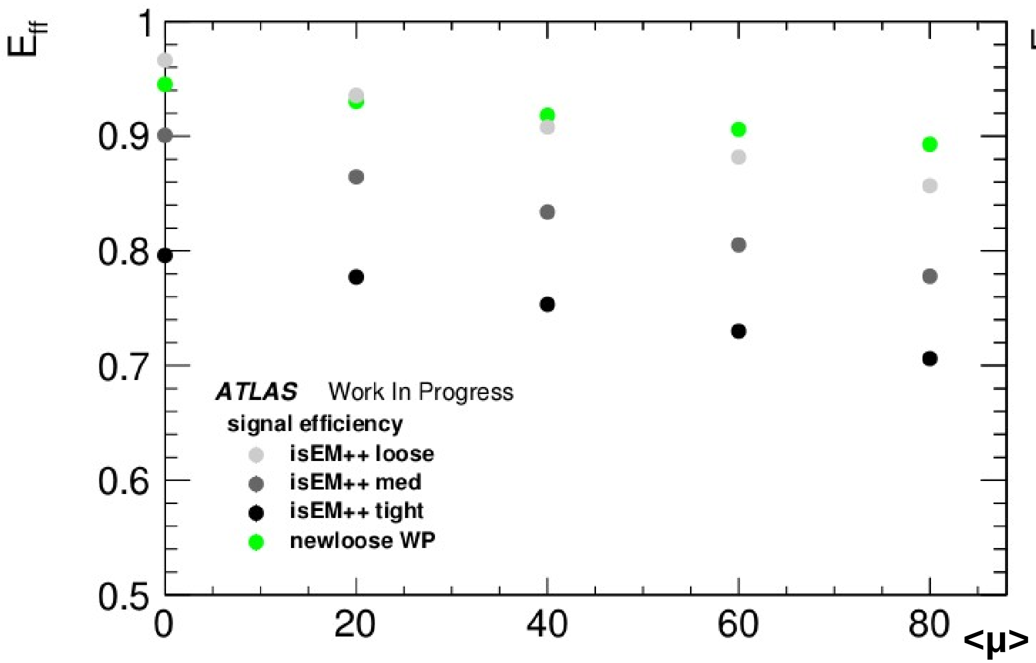


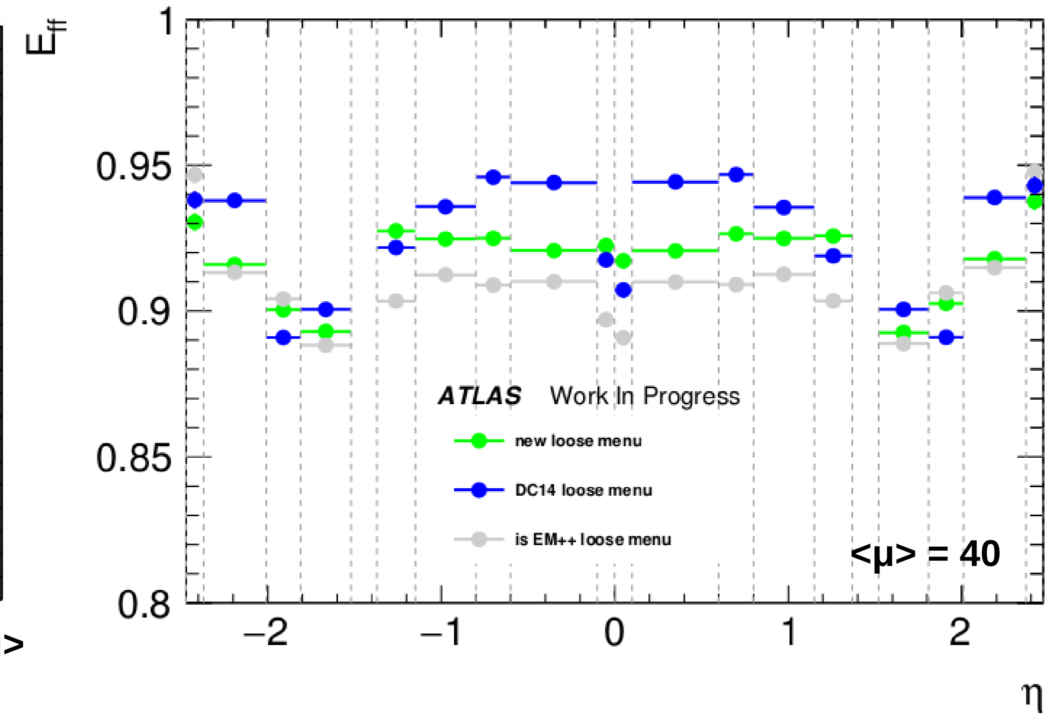
Due to nBlayer cut
-> under investigation

- Mutch better rejection
- Better efficiency for Et < 50 GeV
- worse efficiency for Et > 60 GeV

Loose menu
η dependency & pile-up robustness

- **Here is the pile-up robustness for two differents Et bins :**





See back-up for :
- the cut content
(slide 30)

Better pile-uprobustness

Cuts content

Loose menu

Used variables :
Shower shape : Eratio / ωstot / ωη2 / Rη / Rhad(1)
track-cluster matching : Δη
track quality : nSi / nPix / **nBlayer**

Medium menu

Used variables:
Shower shape : Eratio / ωstot / ωη2 / Rη / **RΦ** / f3 / Rhad(1)
TRT : F HT
track-cluster matching : Δη
track quality : nSi / nPix / nBlayer

Main changes :

- Rhad is looser
- F HT is now tighter and binned in Et
- Eratio is tigher for Et[20-30] GeV
- +1 on the nSi / nPix cuts
- d0 reasonably tighten

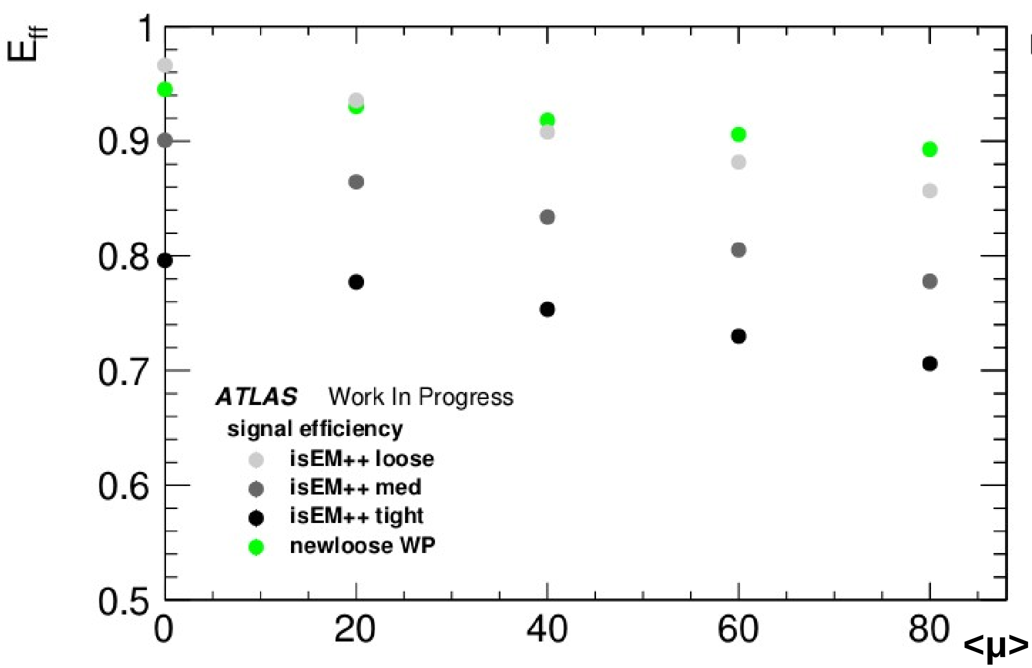
Tight menu

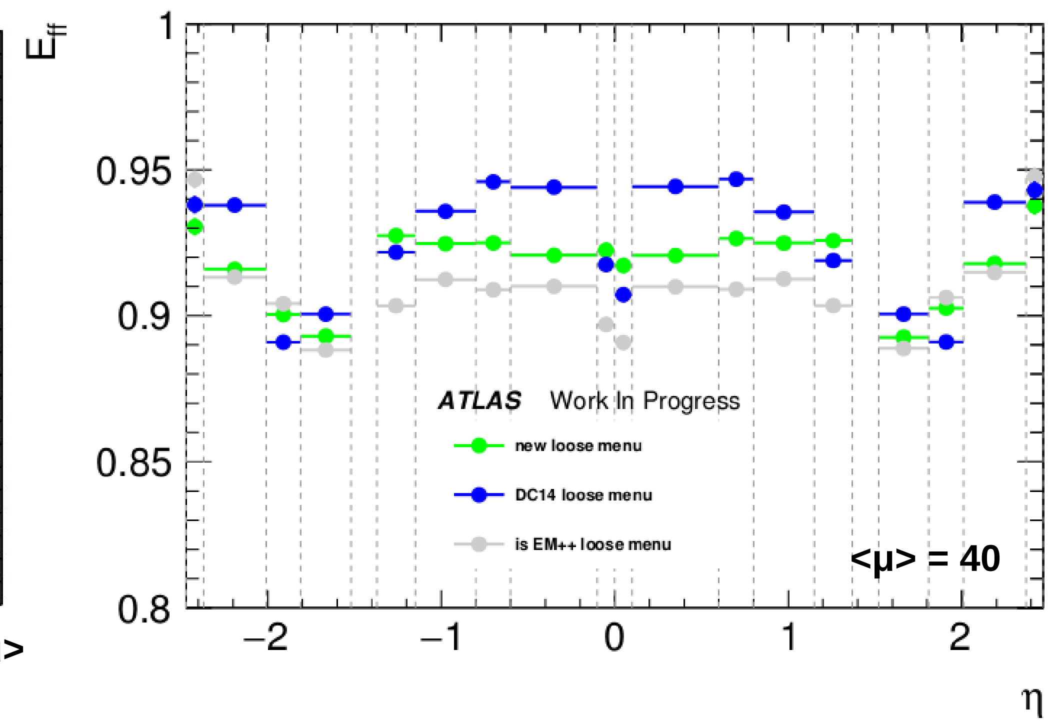
Used variables :
Shower shape : Eratio / ωstot / ωη2 / Rη / **RΦ** / f3 / Rhad(1)
track-cluster matching : Δη **/ ΔΦ / E/p**
TRT : F HT / nTRT
track quality : nSi / nPix / nBlayer

- **Green : New cuts with respect to 2012 isEM++ menus**
- **Red : Offline only cuts**

Loose menu
η dependency & pile-up robustness

- **Here is the pile-up robustness for two differents Et bins :**



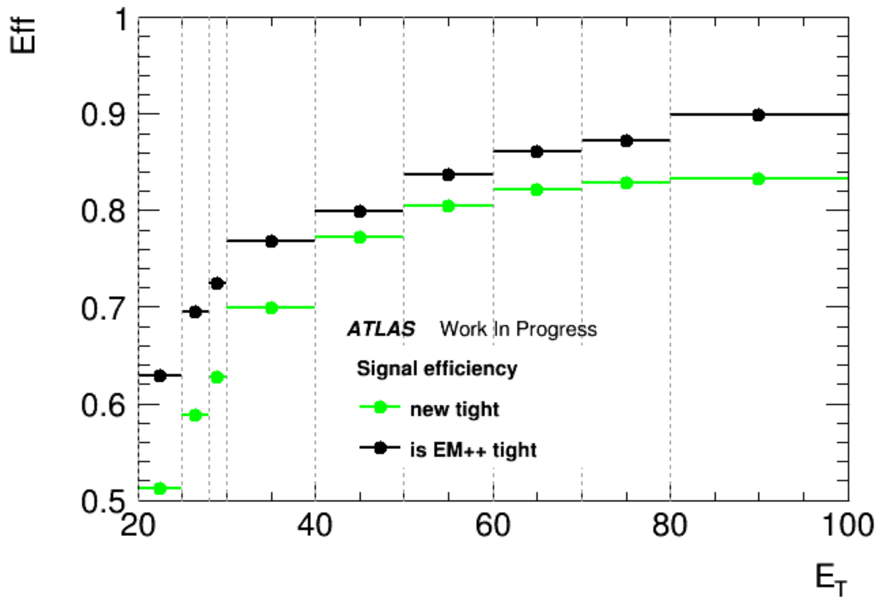


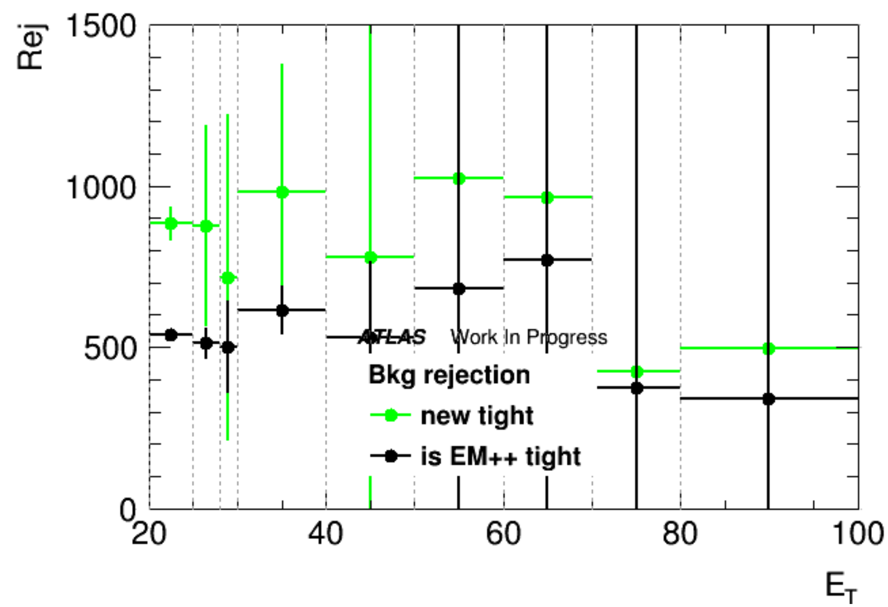
See back-up for :
- the cut content
(slide 30)

Better pile-uprobustness

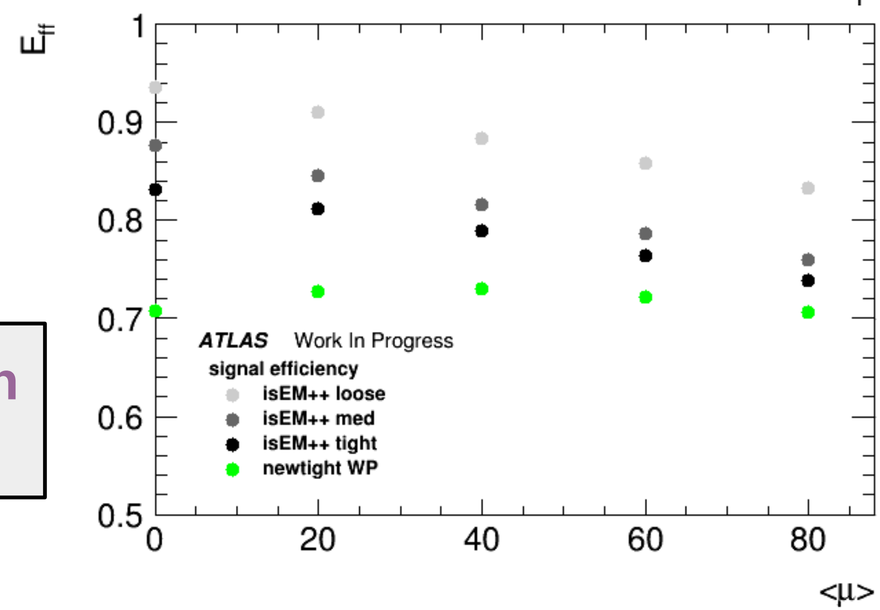
The new tight offline menu

- **Performance of the Et[20,30] GeV tight menu on offline varaibles (that defines the e28_tight trigger item:**



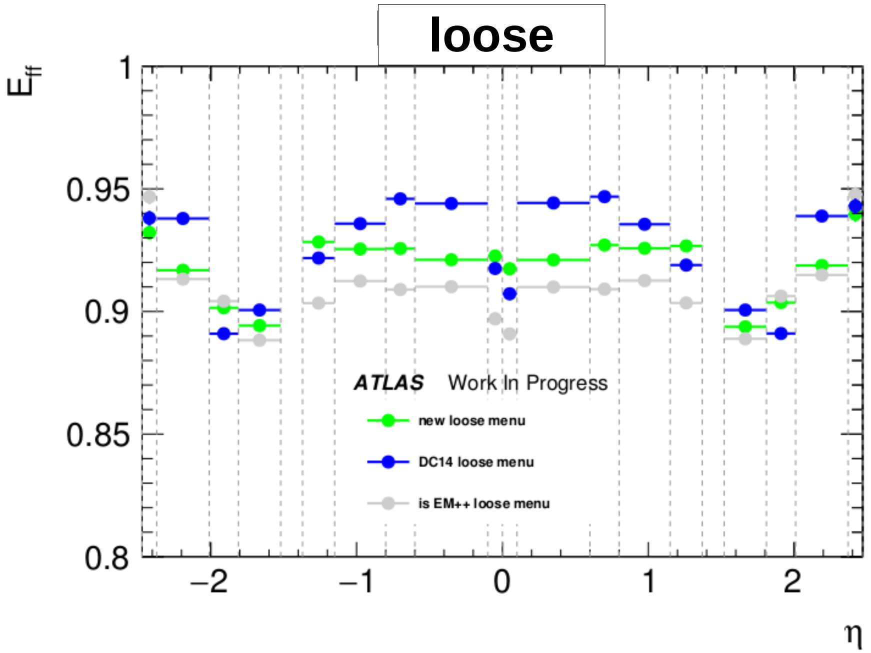


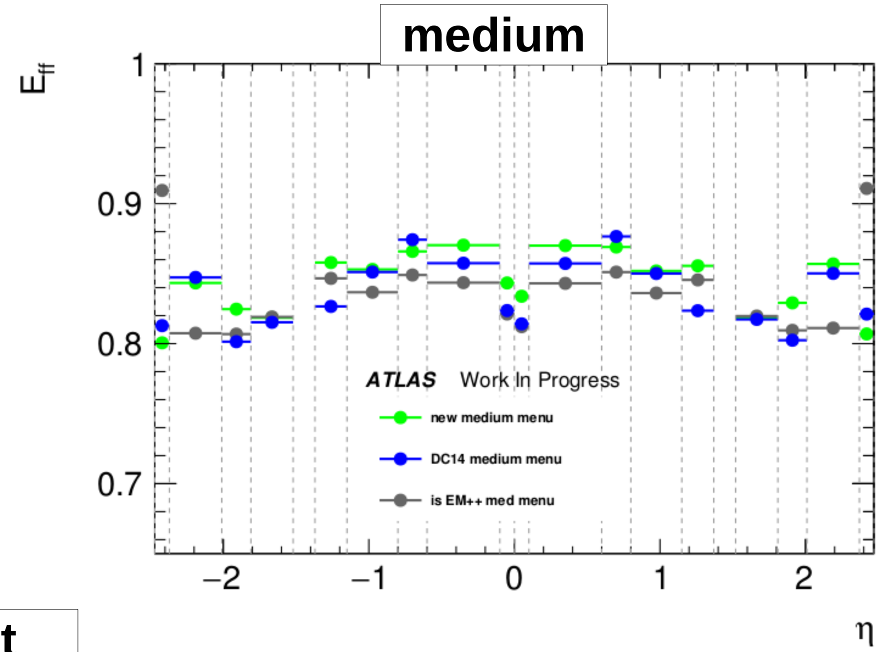
The isEM ++ tight curves are without offline cuts -> much closer to isEM++ medium menu

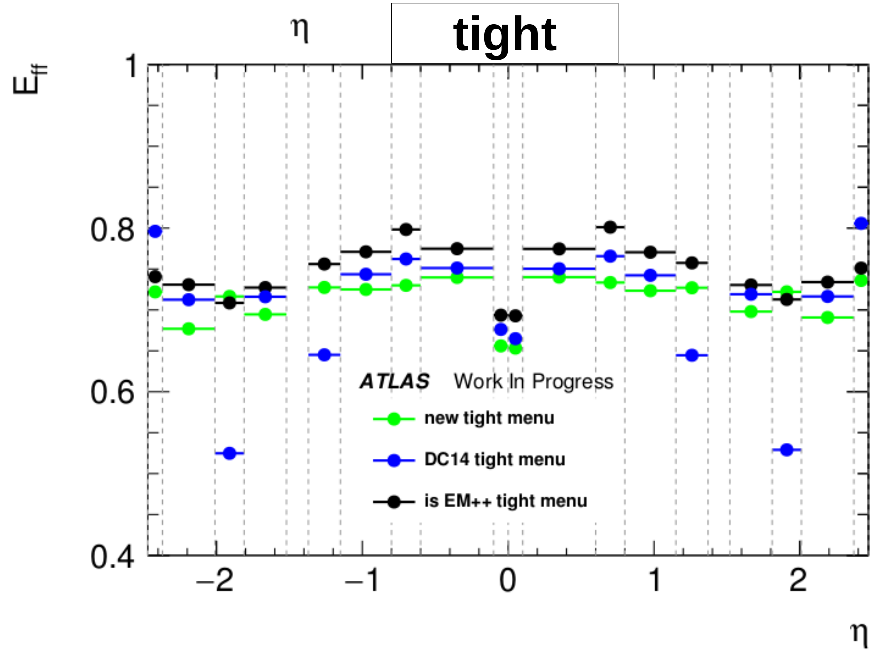


- manage to have a very high rejection
- Good pile-up robustness

η dependency of the menus



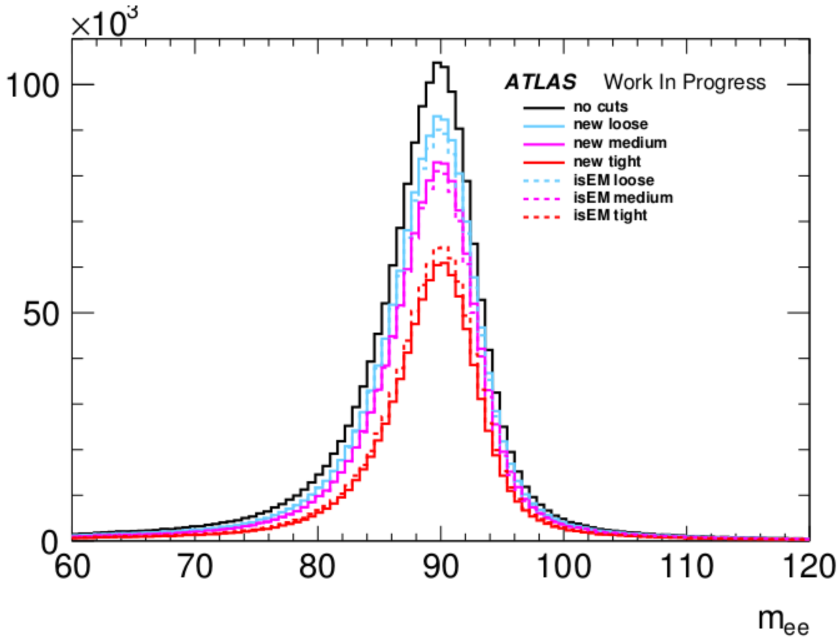




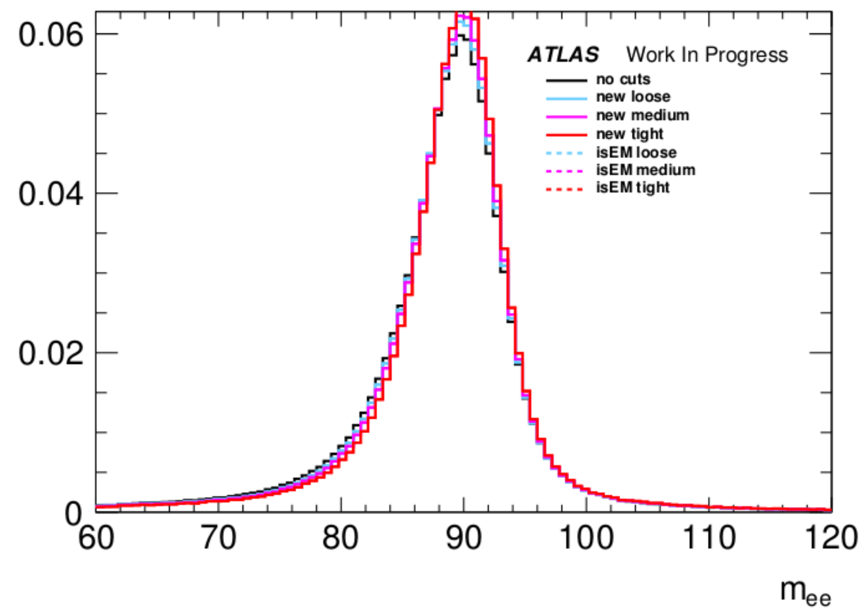
Acceptable η dependency

Check on mee

- **Invariant mass of 2 electrons computed on Zee electrons**

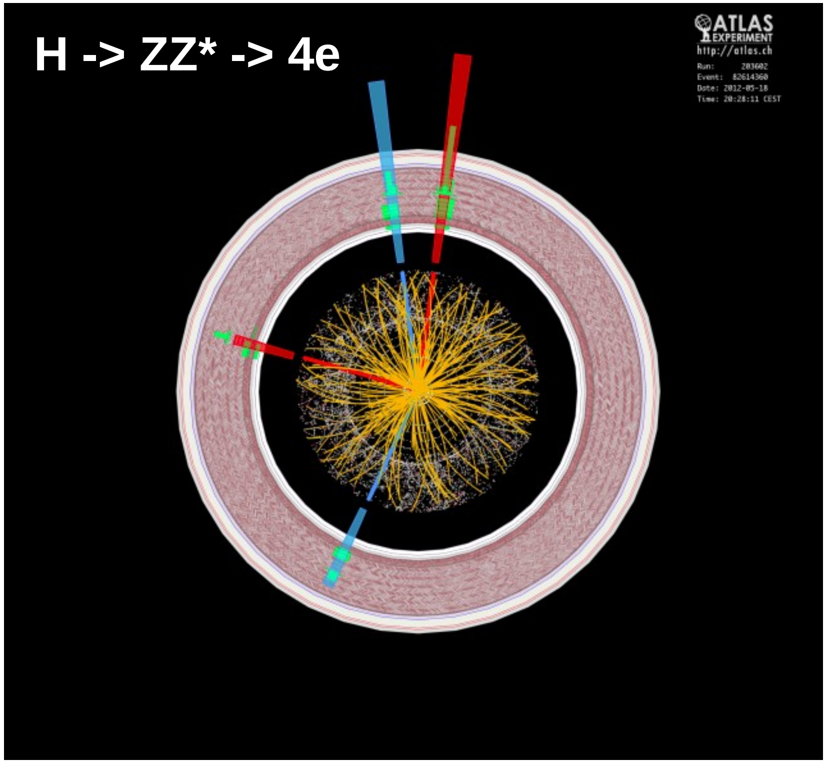


Normalized



No serious impact on the physics objects

H -> 4l event


H -> ZZ* -> 4e
ATLAS
EXPERIMENT
http://atlas.ch
Run: 203602
Event: 82614360
Date: 2012-05-18
Time: 20:28:11 CEST