[JRJC 2015] Instrumentation/Performances

Electron reconstruction Efficiency Measurements In ATLAS at 13TeV

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Overview

Contents

Reference for the method established with 2010-2012 LHC data at 7/8 TeV

2011 measurements: EPJC74(2014)74

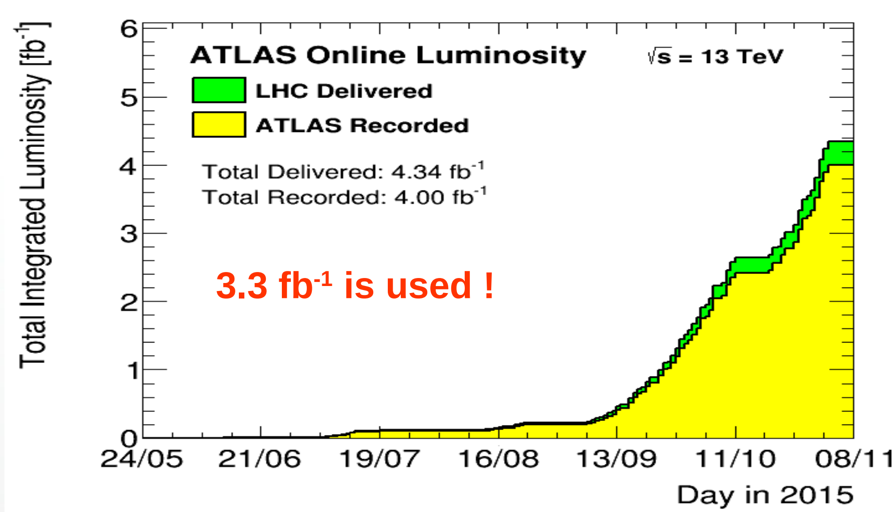
2012 measurements(Reference):ATLAS-CONF-2014-32

2010 measurements: Eur.Phys.J.C.72(2012)74

"Mesure des performances de reconstruction des électrons et recherche de Supersymétrie dans les canaux avec deux leptons de même charge dans les données du détecteur ATLAS": Julien Thesis

- **Qualification Task**:

Reconstruct an electron and calculate its efficiency using Tag&Probe method with Zee sample for run2(2015).

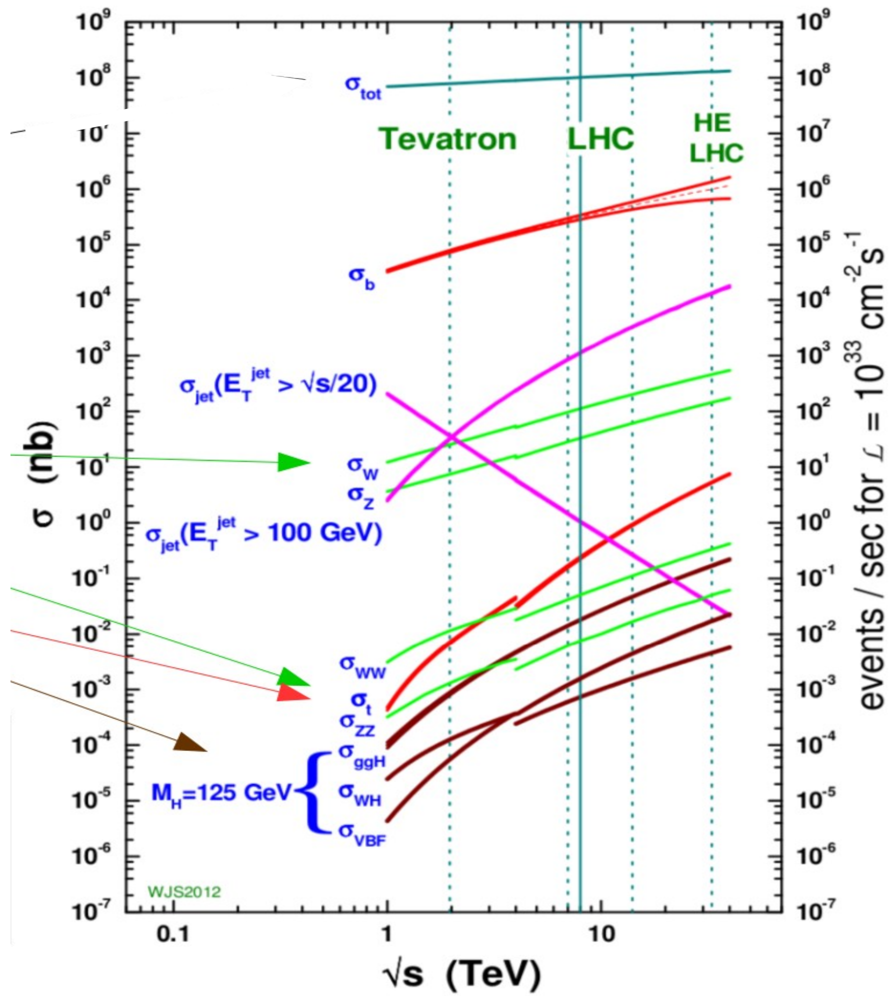


Importance of the leptons for LHC physics

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

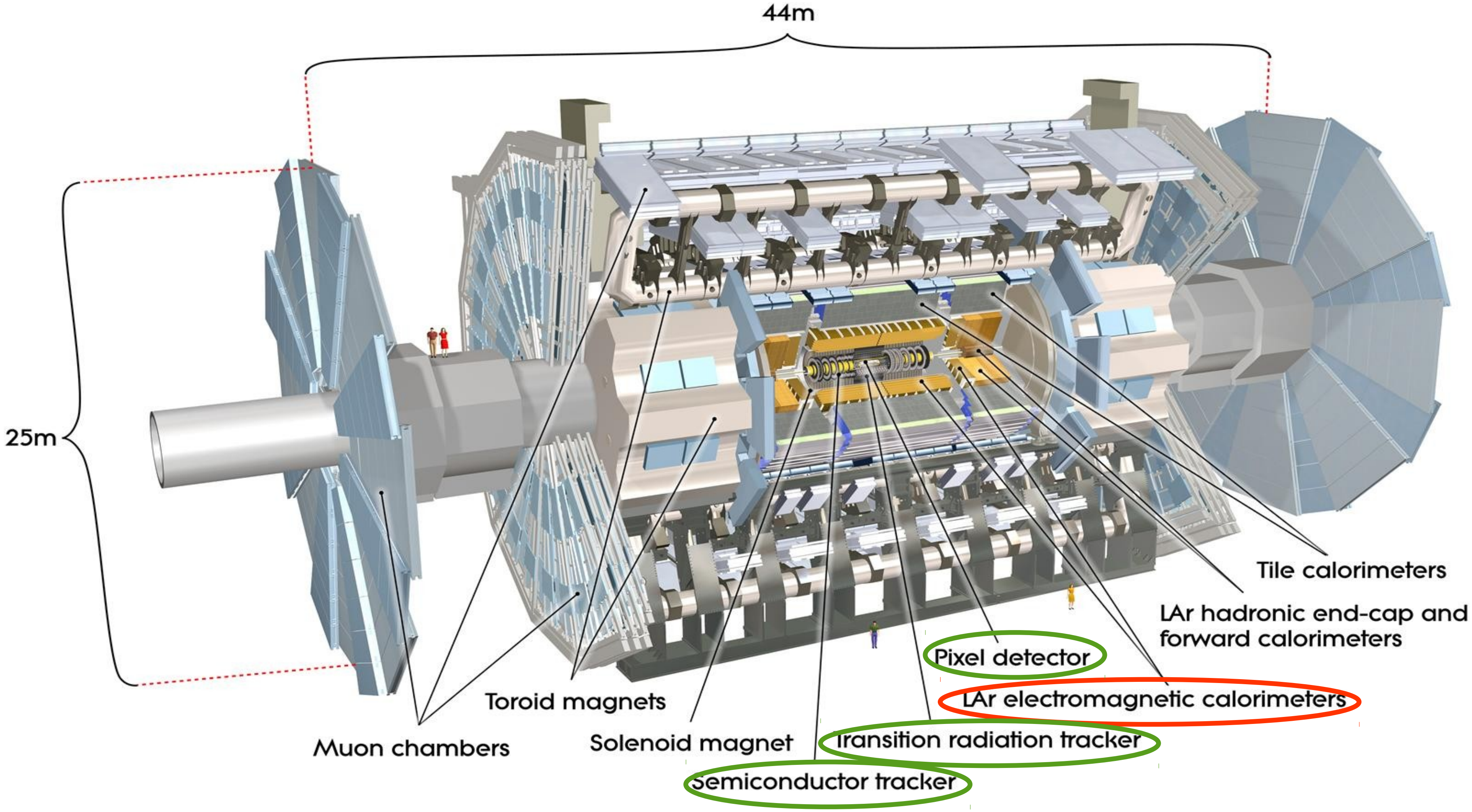
- Clear experimental signature.
- Cross Section $\geq 10^{-6}\sigma(QCD)$.
  - -> Very useful to define triggers
- Tag processes of high interest :
  - – Z/W physics : Z(+jets) / W(+jets)/ Dibosons.
  - – Top physics : tt(+jets) , single top.
  - – Higgs : H -> ZZ*-> 4l / H - > WW* -> 2l2ν.
  - – New physics : SUSY / exotic.

Proton-(anti)proton Cross Sections



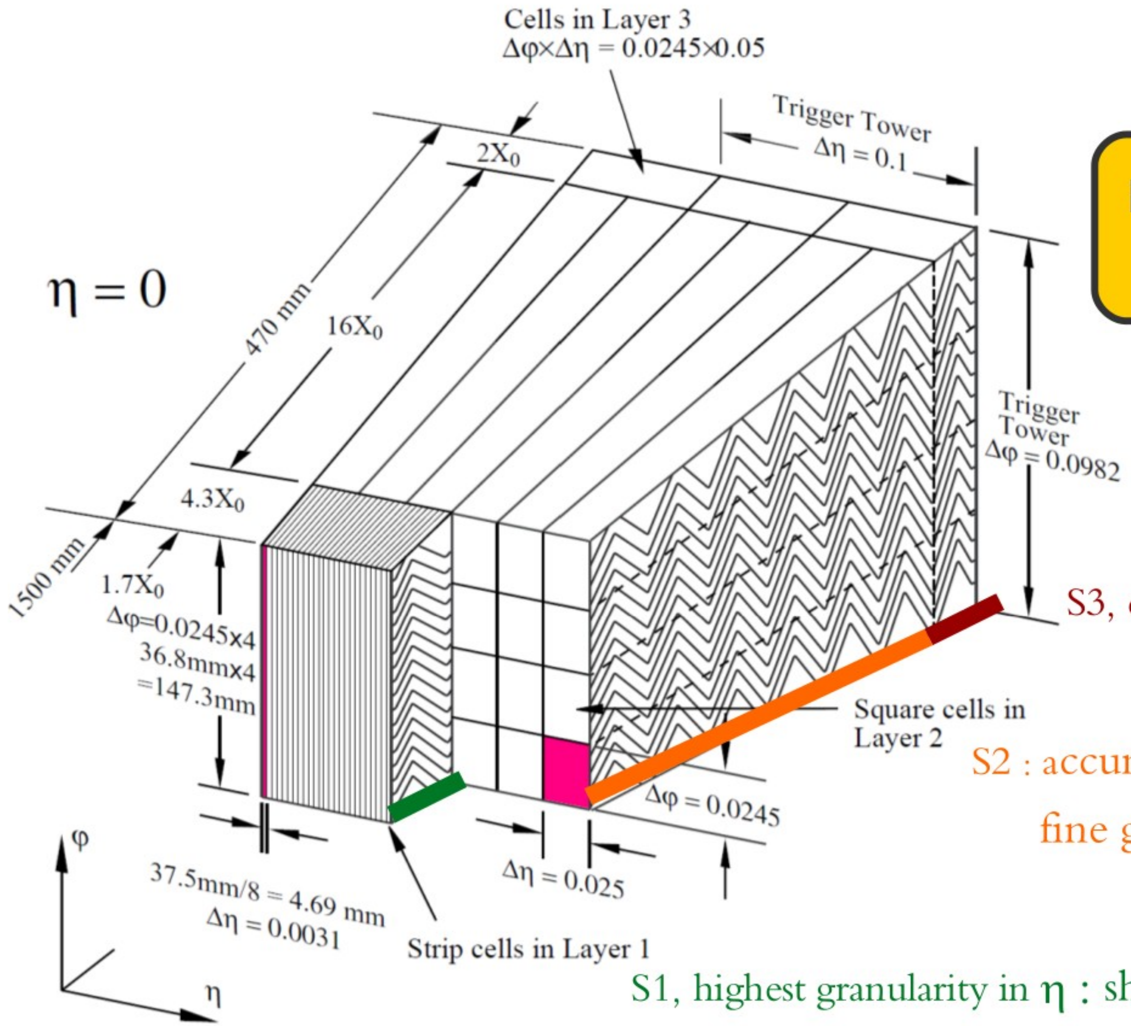
ATLAS Detector

The remarkable discovery of the Higgs boson in the experimentally harsh LHC environment would not have been possible without the deep understanding of the detector performance and optimisation of the reconstruction and identification algorithms.



EM Calorimeter at ATLAS

Large shower shapes for the charged particles at the passage through the calorimeter



High segmentation : high resolution
3 layers (S1-3) + pre-sampler (PS)

S3, coarser granularity : collects only the tail shower E

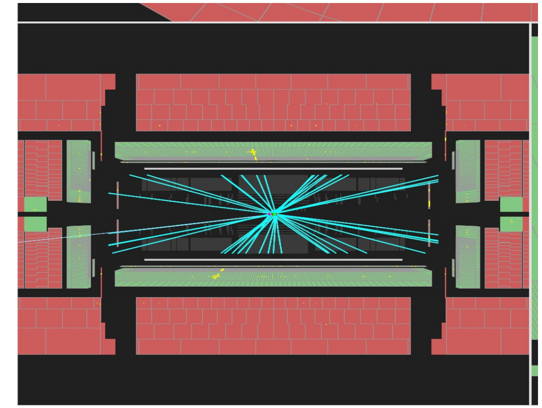
S2 : accumulates most of the EM shower energy

fine granularity $\Delta\eta\times\Delta\varphi = 0.025\times0.025$ ($|\eta|<2.5$)

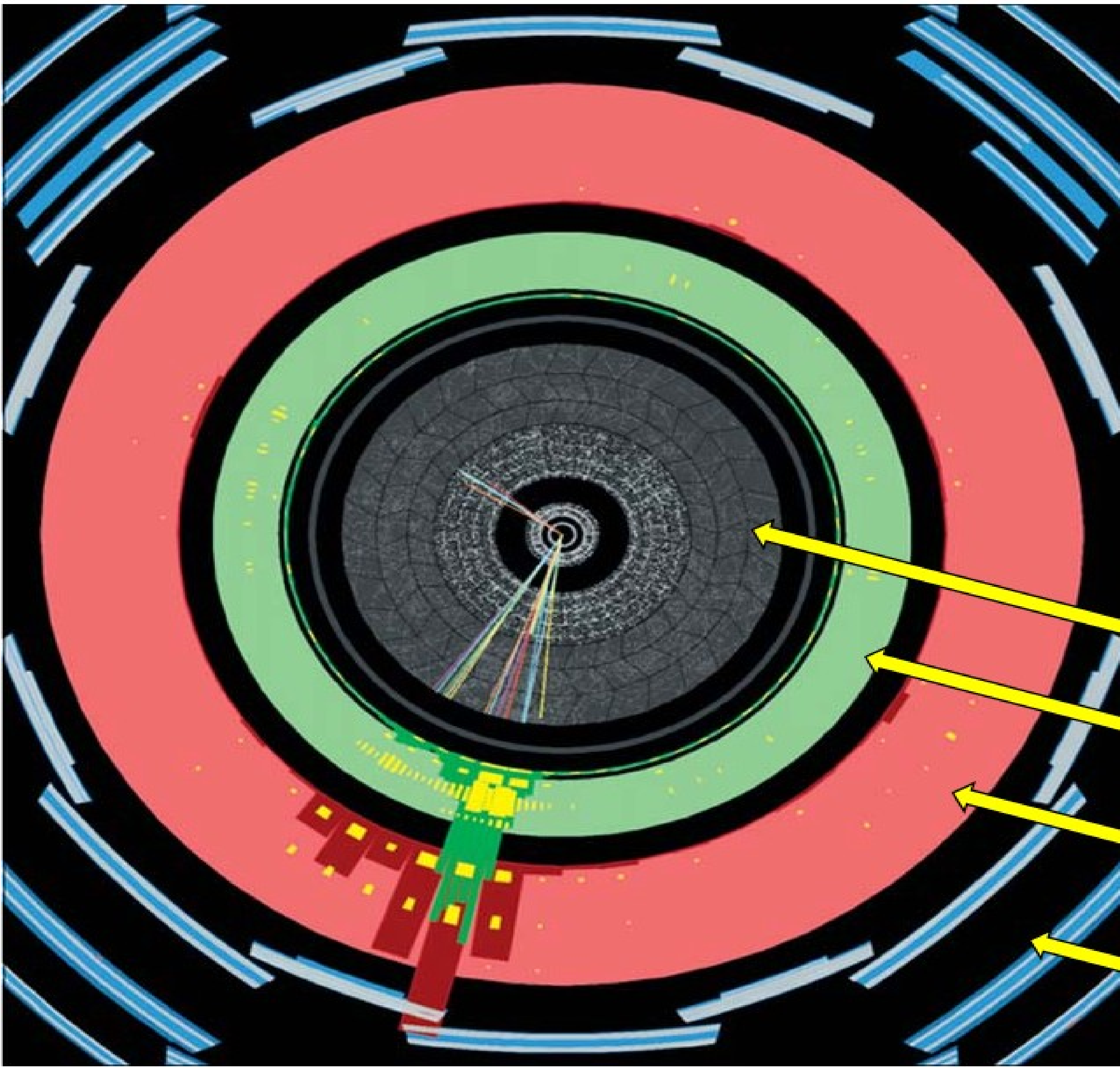
S1, highest granularity in η : shower shape & η measurements

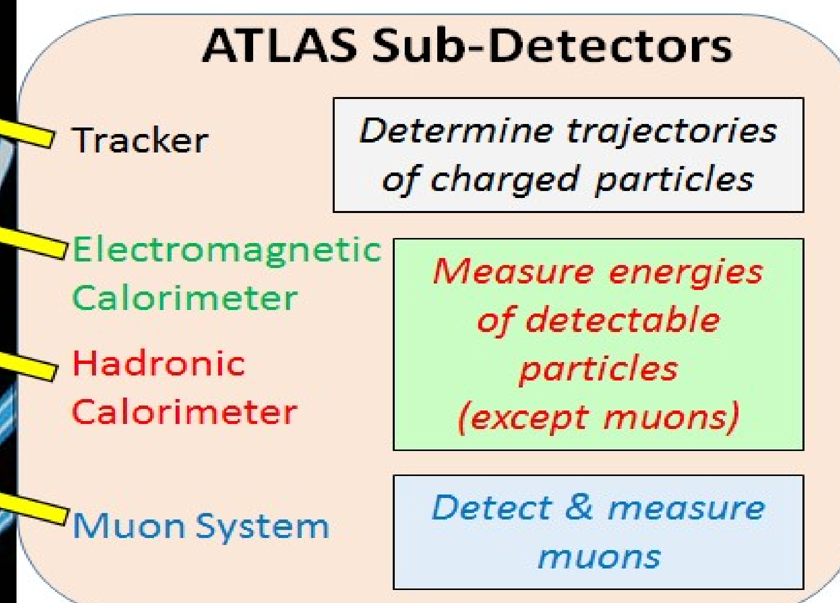
Accordion geometry : a full coverage and a very good uniformity in φ

Object Reconstruction at ATLAS

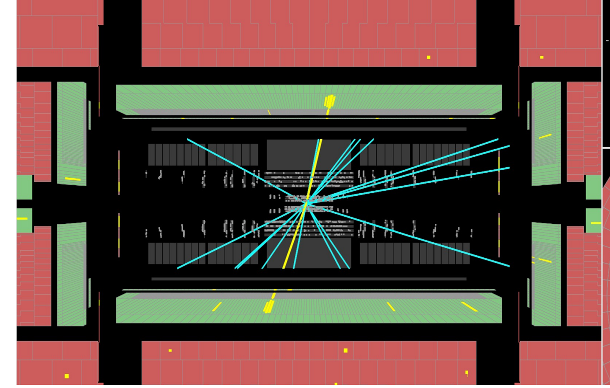


- An object is reconstructed using energy deposits in the calorimeter (clusters), and/or tracks that provide information on the particle's origin and direction (its momentum).



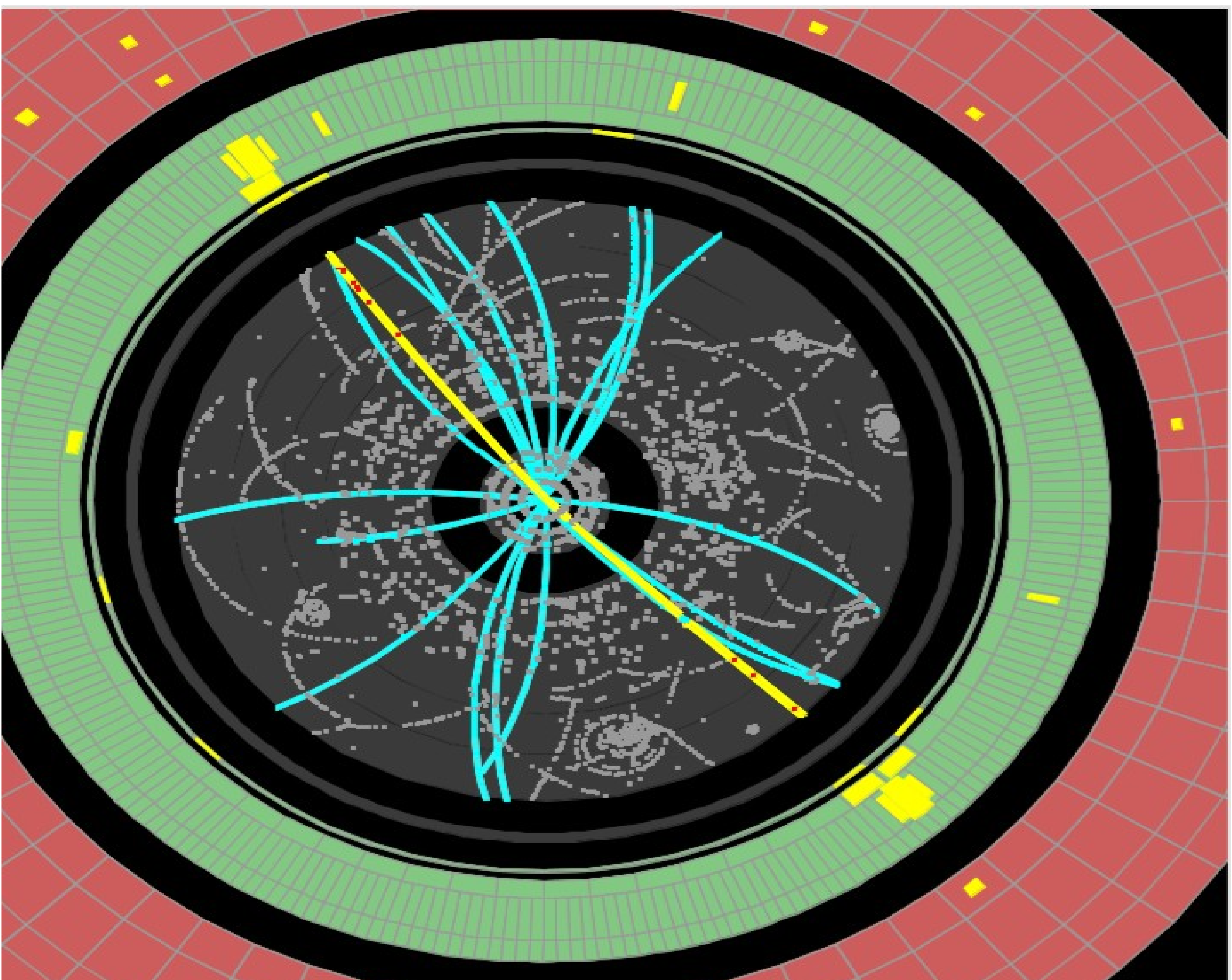


Electron Reconstruction at ATLAS

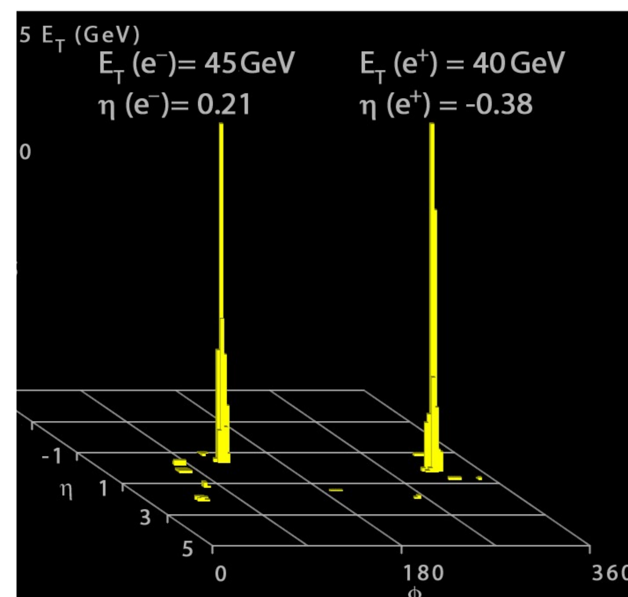


Z → ee candidate

M_{ee}=89 GeV



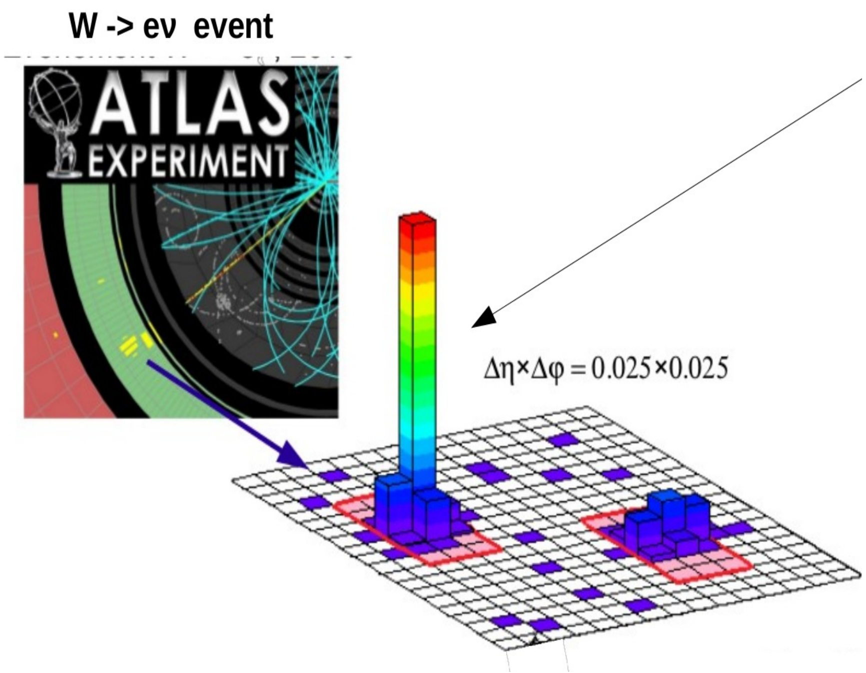
- An electron is reconstructed using energy deposits in the calorimeter (clusters), matched with tracks that provide information on the particle's origin and direction (its momentum).



Electron Reconstruction

Both charged particles and photons deposit energy in the Electromagnetic Calorimeter detector.

How could we distinguish between electron and other particles?



<u>Step 1</u> : Identification of Seed-clusters (energy clusters in a fixed $\Delta\Phi$ and $\Delta\eta$ window).

<u>Step 2</u> : Association of a track with the cluster.

- found track :

-> electron

- No track found:

-> photon

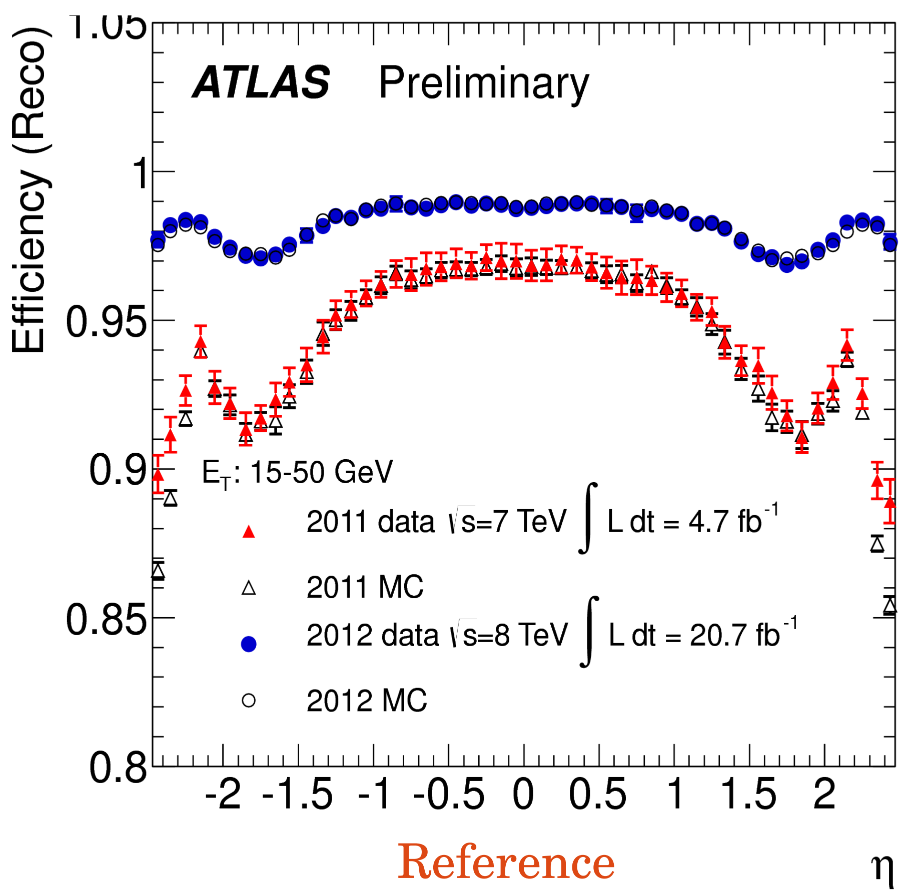
<u>Step 3</u> : Computation of the final physical parameters ex : 4 momentum / charge etc …

Improvement In Electron Reconstruction

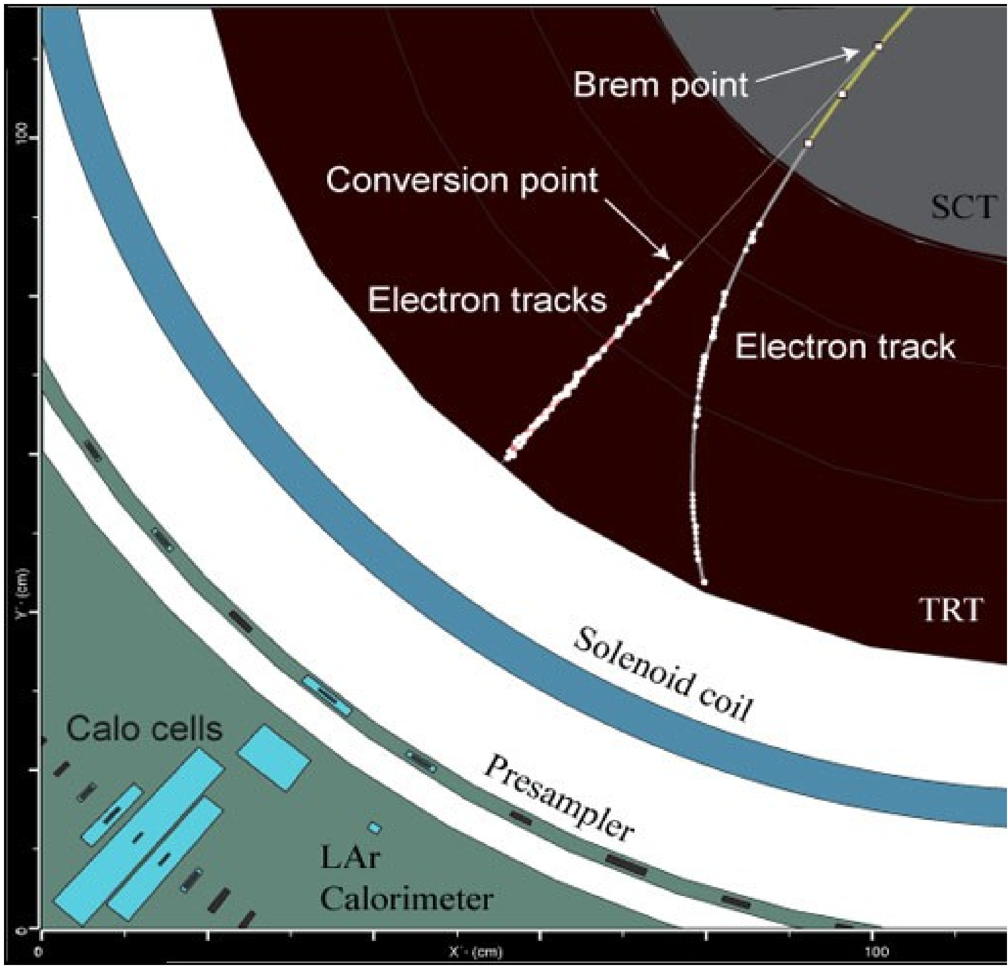
2012 New Algorithm!

Gaussian Sum Filter (GSF)

- improved track-cluster matching.
- Recovered efficiency losses due to electrons undergoing bremsstrahlung.



Reference



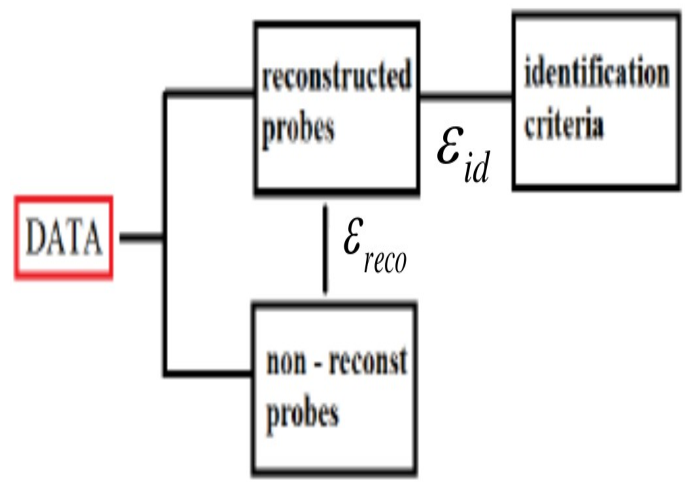
Electron reconstruction efficiency has increased by roughly 5%.

Electron Efficiency

$$\epsilon_{total} = \epsilon_{reco} \cdot \epsilon_{id} \cdot \epsilon_{trigger} \cdot \epsilon_{other}$$

$$\epsilon_{reco} = \frac{Cluster\ matched\ a\ track}{All\ Clusters}$$

$$\epsilon_{id} = \frac{Electron\ pass\ ID\ creteria}{Reconstructed\ electron\ candidates}$$



- **Run1 measurements with 2012 data:**
  - ε_{reco} → 95-99% in 10 × 50 (P_T , η) bins with 0.5-1.5% uncertainty.
  - ε_{ID} → 7 ID working points: Cut based (LH) Loose, Medium,(Very) Tight and Multilepton.

    → 96% (cut-based loose) and 78% (Very Tight LH) for electrons with 5–6 % (1-2%) uncertainty for electrons below (above) E_T =25 GeV.

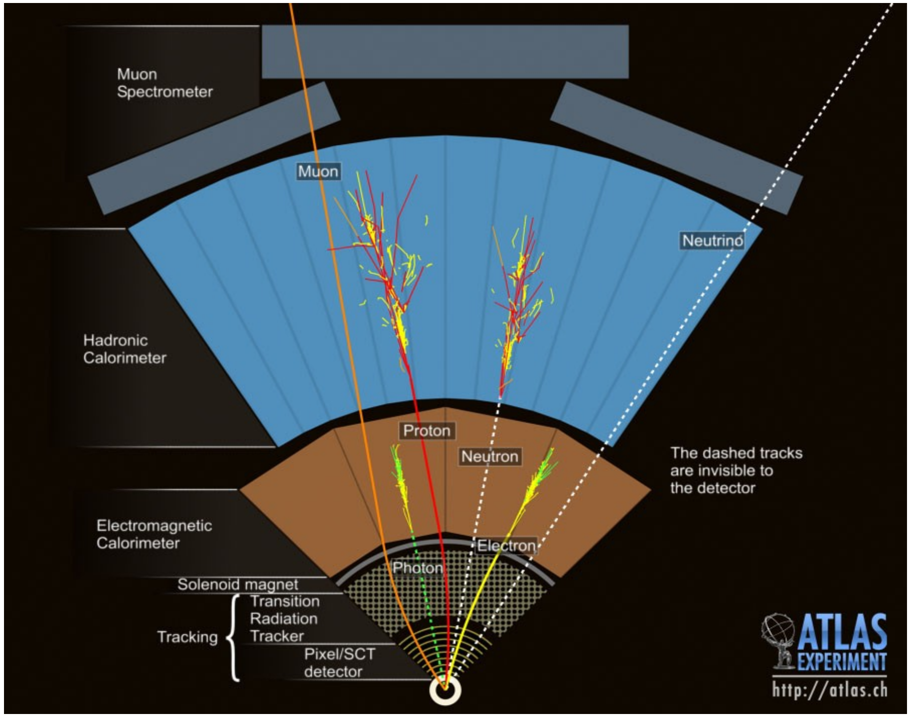
Electron Reconstruction Efficiency

$$\epsilon_{reco} = \frac{N^{PassTQ} - B^{PassTQ}}{\left(N^{PassTQ} - B^{PassTQ}\right) + \left(N^{FailTQ} - B^{FailTQ}\right) + \left(N^{Ph} - B^{Ph}\right)}$$

N/B: *Number of reconstructed/background probes.*

PassTQ/FailTQ: *Pass/Fail track quality requirements*

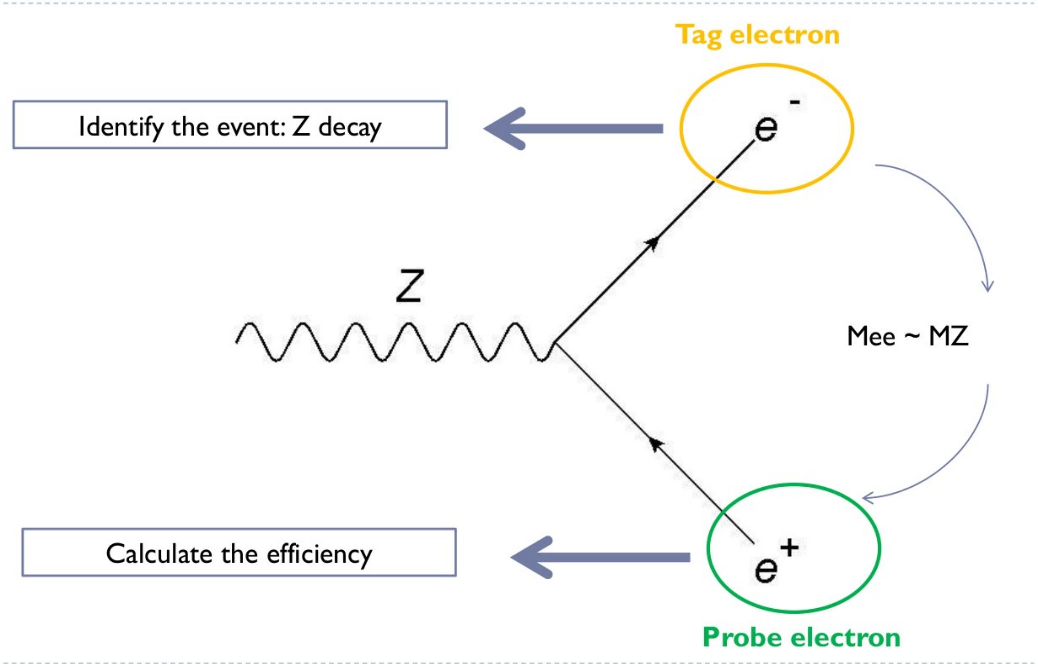
- Electron reconstruction efficiency at run2 is defined as the efficiency of reconstructing and matching a good quality track to the electron cluster.
- A good track quality requires the object to have at least 1 pixel hit and 7 silicon hits.



T&P method using Z→ee

- Data driven measurements are needed for % or sub-% level accuracy → T&P method!

  Need a sample enriched in well **isolated** electrons → Z → ee Standard Model processes



Tag electron : impose very strict selection criteria to suppress QCD background.

– Probe electron : used for the measurement,
and selected with loose requirements

Require tag-probe invariant mass to be close to Z mass → reject SM processes with non-isolated electrons.
Using electrons with $|\eta|<2.47$ (20 bins) ; $15 < p_T < 80$ GeV (10 bins).

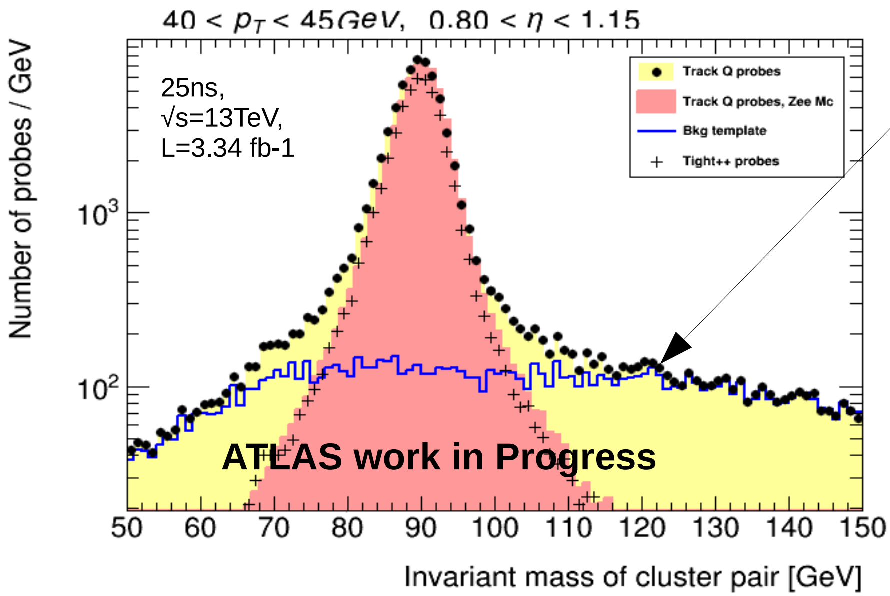
Reconstruction Efficiency: Background

$$B^{Pass} = B^{TemplP} \times \frac{B^{BaseP} - MC_{scale} \times N^{MC}_{tail}}{B^{TemplP}_{tail}}$$

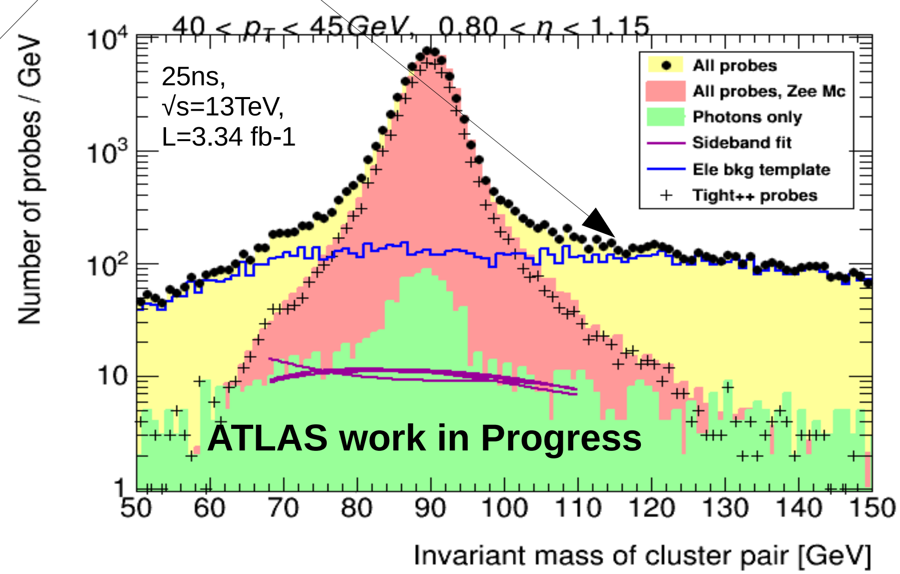
Reverting 2 ID cuts + isolation → Shape of the BKG

Normalization of BKG
in the control region (mee>120GeV)

Numerator

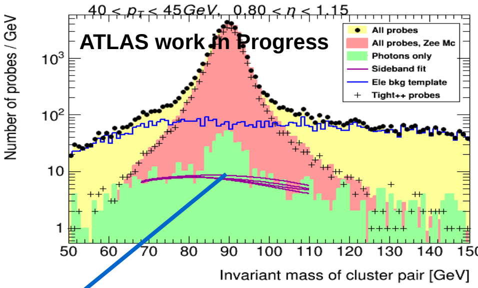


Denominator

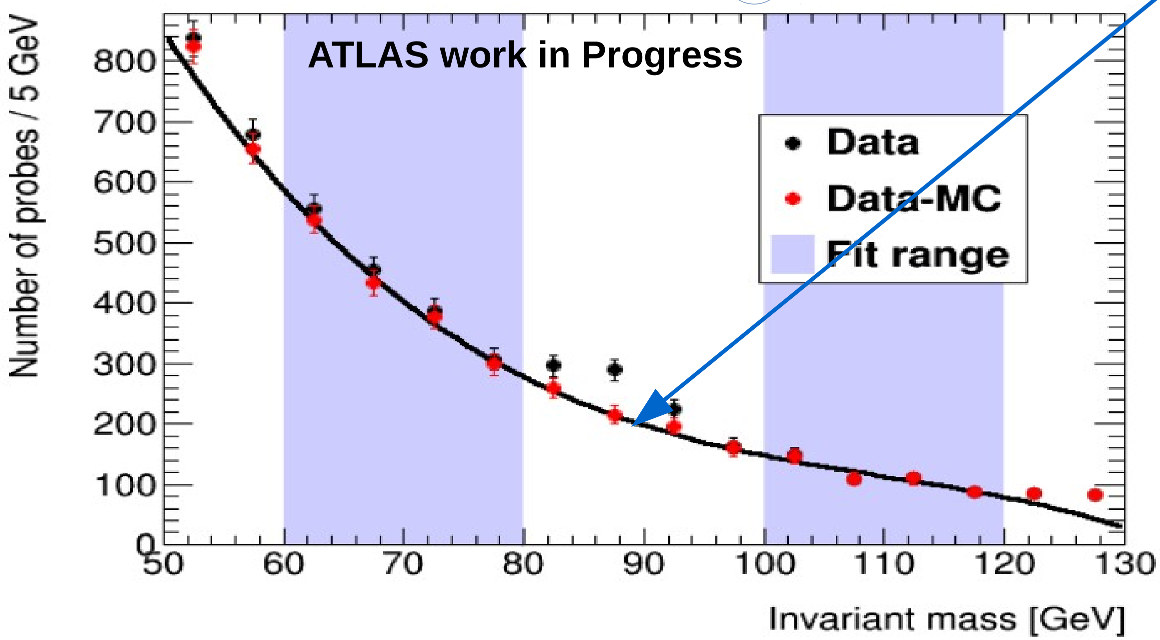


1. Electron Background: more background in the denominator.
2. shape after the background subtraction (yellow-blue) is signal-like.
3. The background subtraction works pretty well (the challenge of this analysis).
4. Photon Background: Fit 3rd order polynomial.

Photon Background



$$\cdot\Gamma \quad = N^{ph} - B^{ph}$$



1- Construct invariant mass between electron tag and photon probe.

2- Choose side band region.

3- Subtract the MC to exclude its contamination in the side band region.

4- Fit 3rd order polynomial (4 parameters) by minimizing χ^2(Fit data-MC).

5- Vary the side band definition to estimate the systematics.

Reconstruction Efficiency: Systematics

72 (3 × 3 × 2 × 4) variations are used for data, 9 (3 × 3) for MC

- **3 Tag identification variations :** LH Tight,LH Medium & topoetcone40 < 5 GeV or LH tight & topoetcone40 < 5 GeV.

- **3 invariant mass windows :**

[80,100] GeV . [75,105] GeV or [70,110] GeV.

- **2 electron bkgd. template variations:**

	Variation 1	***Variation 2***
pT<30 GeV	*!2loose & topoetcone30* $/p_T > 0.02$ $120\ GeV < m_{ee} < 250\ GeV$	*!2 loose & topoetcone30* $/p_T > 0.02$ $60\ GeV < m_{ee} < 70\ GeV$
p T >= 30 GeV	*!2 loose & topoetcone40* $/p_T > 0.05$ $120\ GeV < m_{ee} < 250\ GeV$	*! 2 loose & topoetcone40* $/p_T > 0.20$ $120\ GeV < m_{ee} < 250\ GeV$

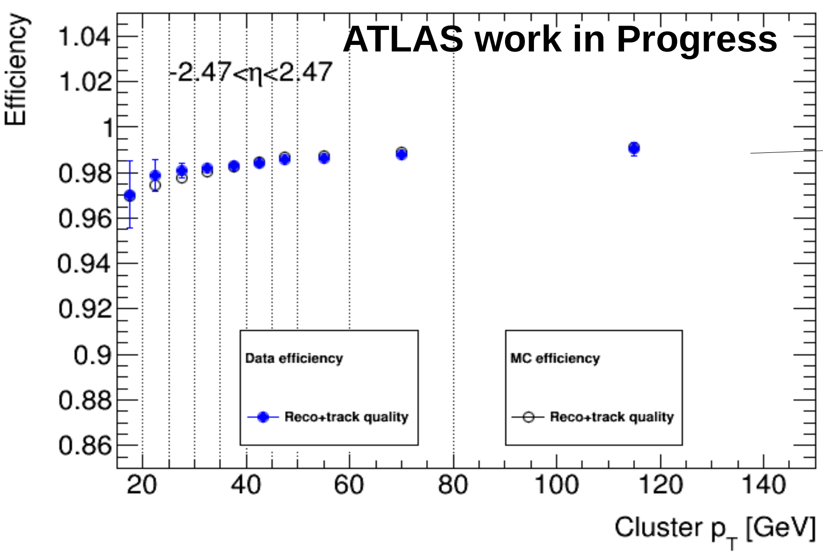
- **4 photon background configurations (GeV):**

{[70,80];[100,110]}, {[60.80];[100,120]},{[50.80];[100,130]},{[55,70];[110,125]}

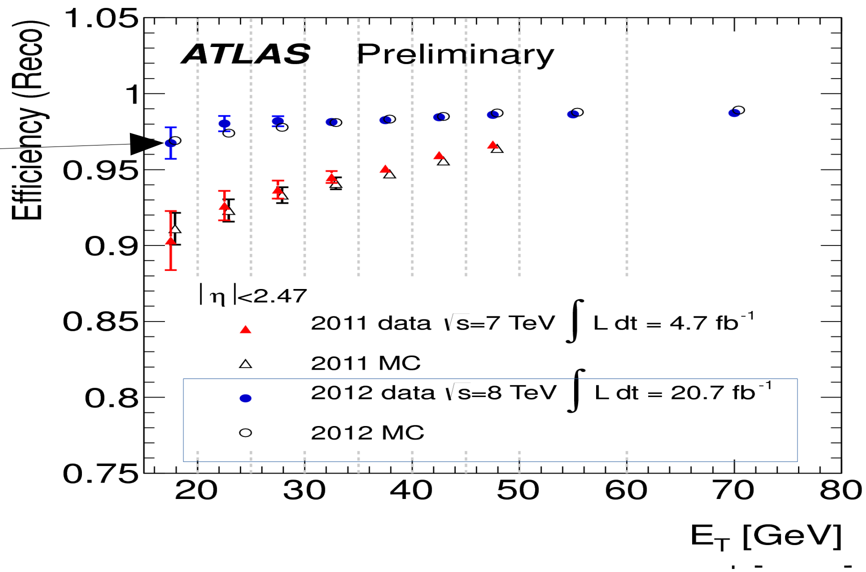
Reconstruction Efficiency: Measurements

Measurements performed in 200 bins here projected along pt.

2015 measurements (3.3 fb^{-1})



2012 measurements

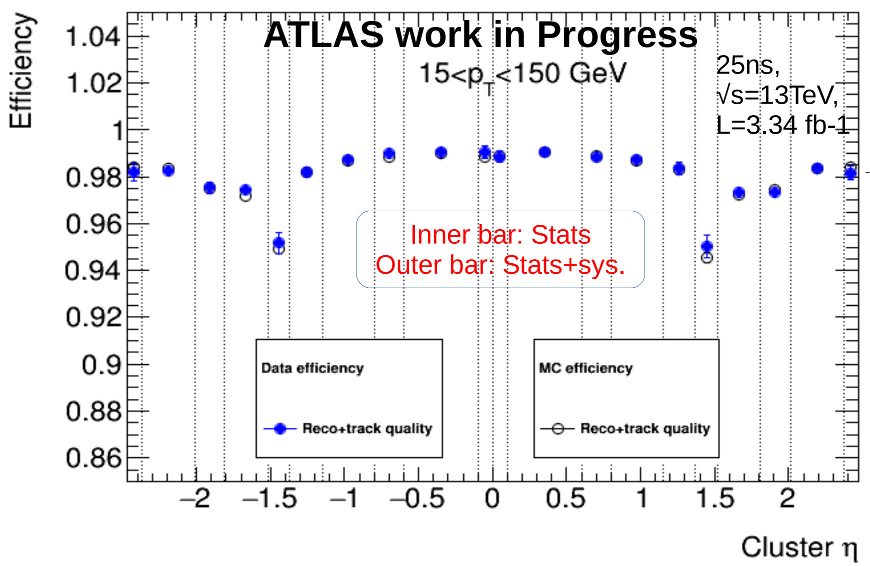


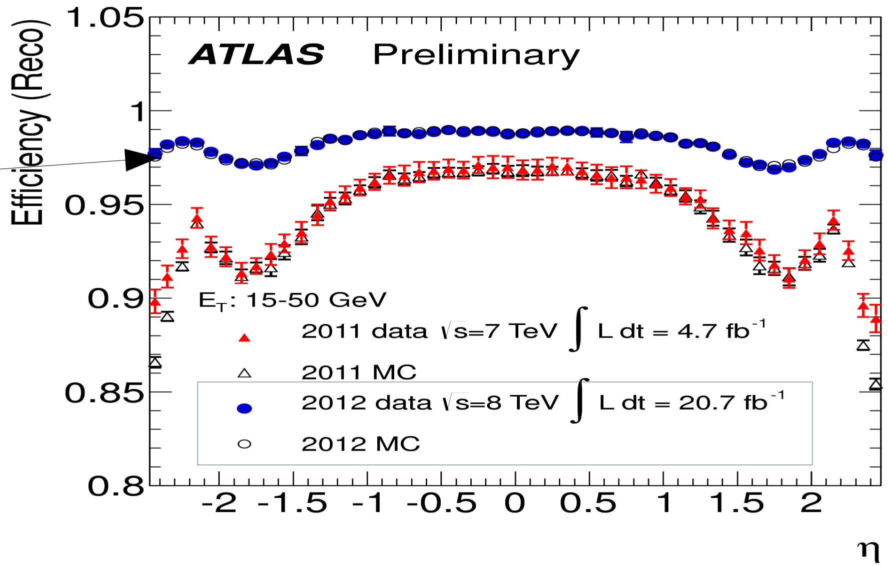
Very similar to the 2012 measurements

Reconstruction Efficiency: Measurements

Measurements performed in 200 bins here projected along eta.

2015 measurements (3.3 fb^{-1}) 2012 measurements

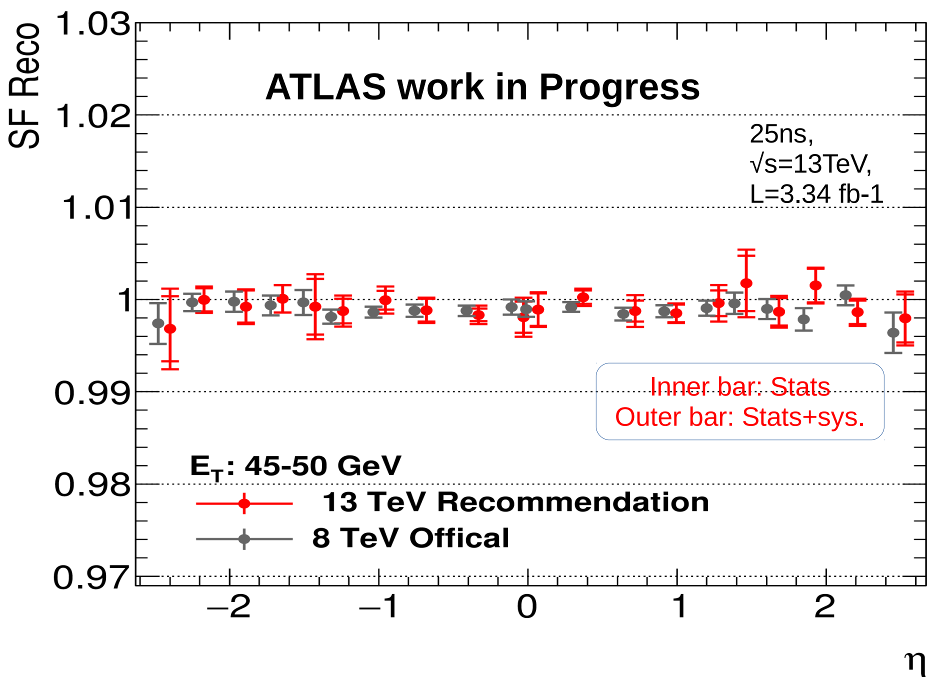




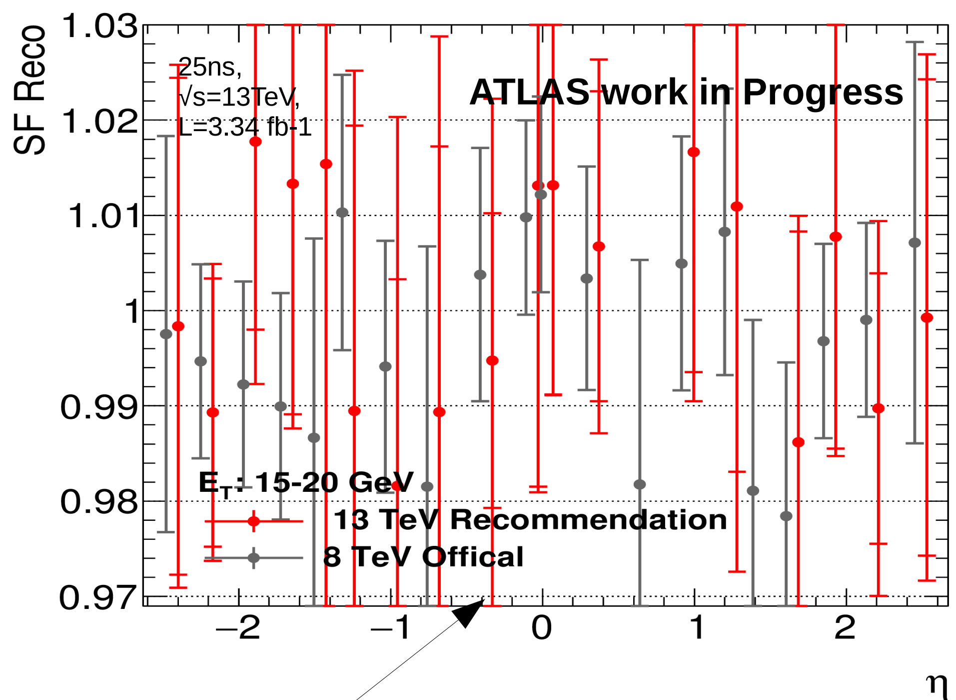
Very similar to the 2012 measurements except in the crack region where the efficiency decreases by ~2% in both data and MC.

Reconstruction Efficiency: Measurements

8/13 TeV SF Comparison At Z peak region



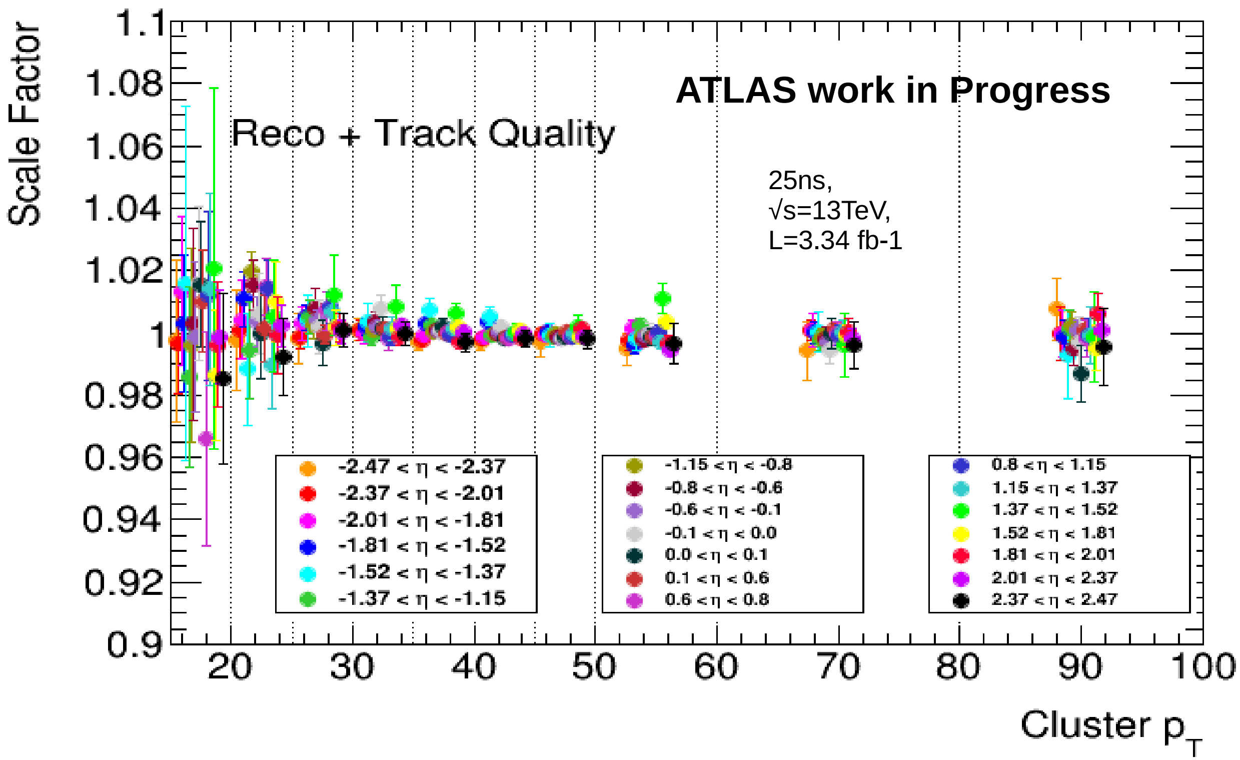
8/13 TeV SF Comparison At low E_T



in $E_T \sim 15 - 30$ GeV statistical uncertainties could be reduced by analyses using toys.

Reconstruction Efficiency: Measurements

Reco Scale Factor Summary



- SF are consistent with 1 in most bins.
- stat errors are dominating almost in all bins.

<u>Typical errors:</u>

- 0.1- 1.3% (0.0-0.6%) stat (sys.) errors at E_T>25 GeV and 0.3- 2.7% (0.1-3.7) at low E_T.

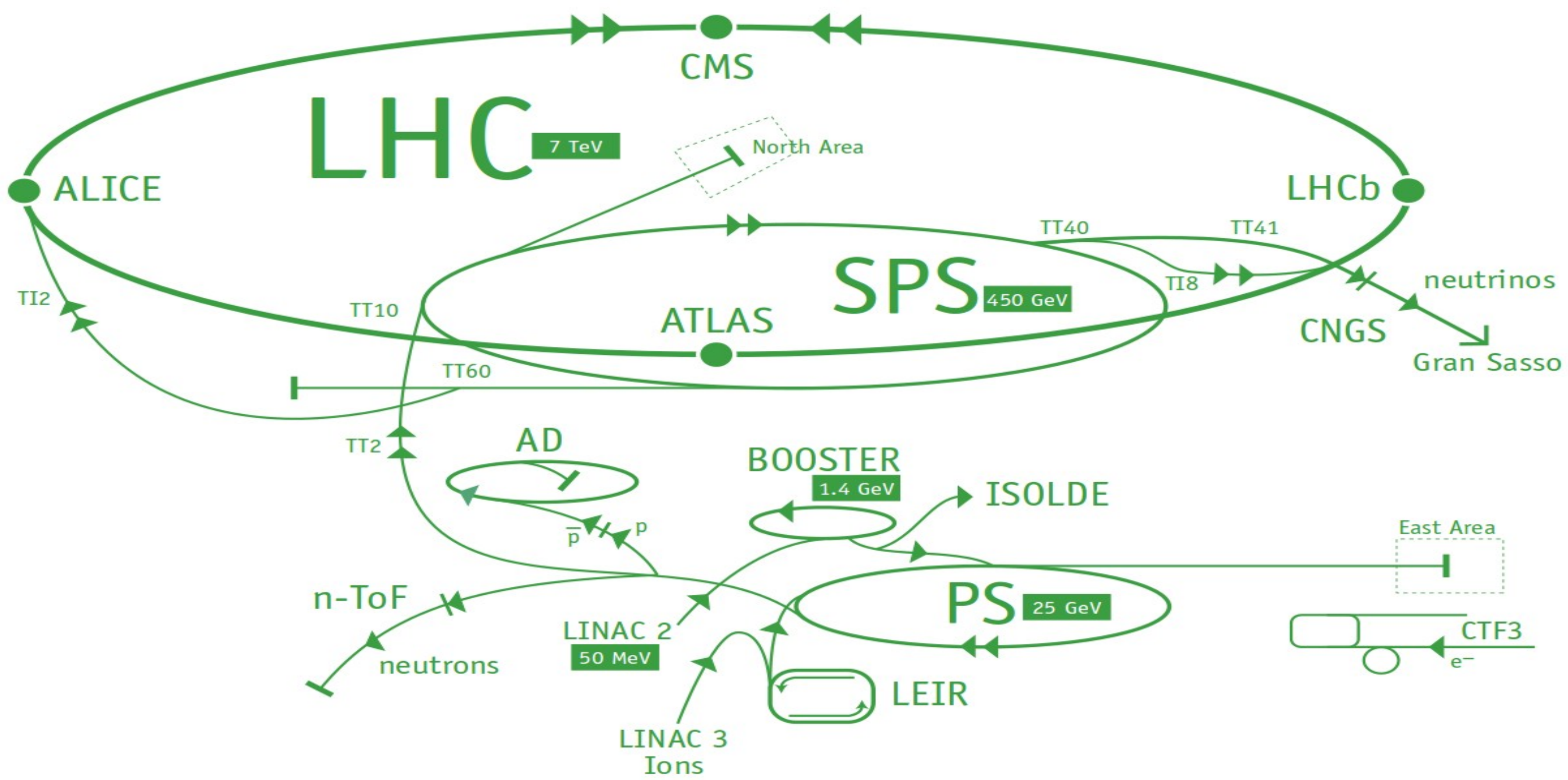
Conclusion

Electron reconstruction efficiency measurements with **the last data for 2015 with ~3.3/fb** is produced and corrections will be released soon by the Electron/Photon performance group, as recommendations to physics groups to finally be applied to MC electrons in order to account for the differences between simulation and data.

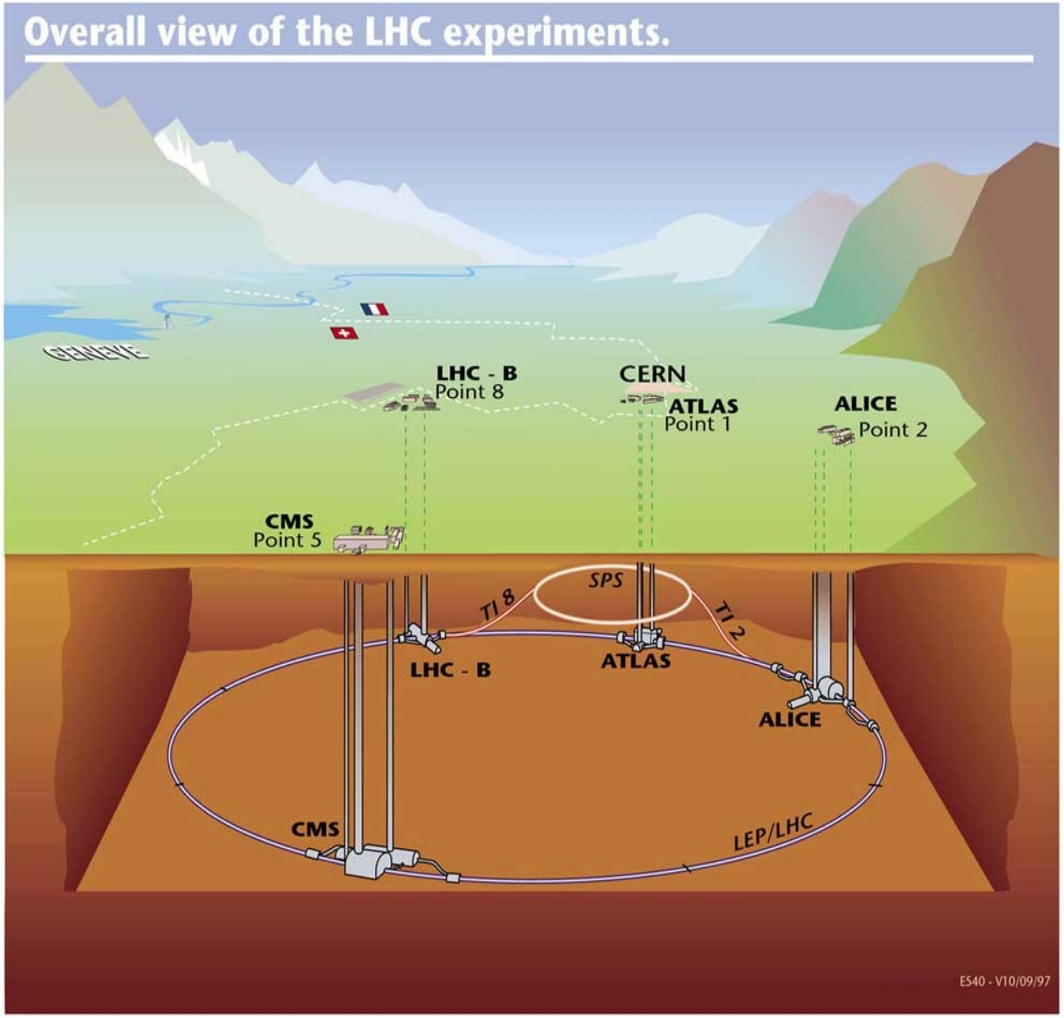
All scale factors are very close to one (i.e, we understand very well our MC)!

Back Up

CERN Accelerator Complex



LHC Experiment



<u>LHC accelerator</u>:

- § 27 km circumference: ring of superconducting magnets.
- § 96 ton of 1.9K(-271.3 °C) liquid helium to cool the magnet.
- § 100m depth.
- § 10000 magnets installation (2005-2007).
- § 120 MW electric consummation.
- § Pressure: 10 times more pressed than the moon.
- § 3.5 Billion Euros
- § Each proton beam: 2808 bunches, each bunch: 10^11 protons

<u>6 Detectors</u>: ATLAS, CMS, LHCb, ALICE, LHCf and TOTEM

- § Proton-Proton collision at 13TeV (June 2015), 8/7TeV(2010-2012).
- § Collision every 50ns.
- 600 million particle collisions per second.

1billion events/s → 100 events are selected by the trigger system.

<u>Goals:</u>

§ Higgs boson discovery.

§ Search for New physics such as: SUSY and extra dimensions.

§ Matter-antimatter asymmetry...