Search for the Higgs Boson in the $\gamma\gamma$ Channel

with 1.1 fb^{-1} of Data Taken in 2011 with the ATLAS Detector

Marumi Kado

Laboratoire de l'Accélérateur Linéaire (LAL)
IN2P3, CNRS

On behalf of the ATLAS Collaboration

International Europhysics Conference on High Energy Physics

European Physical Society

HEP 2011

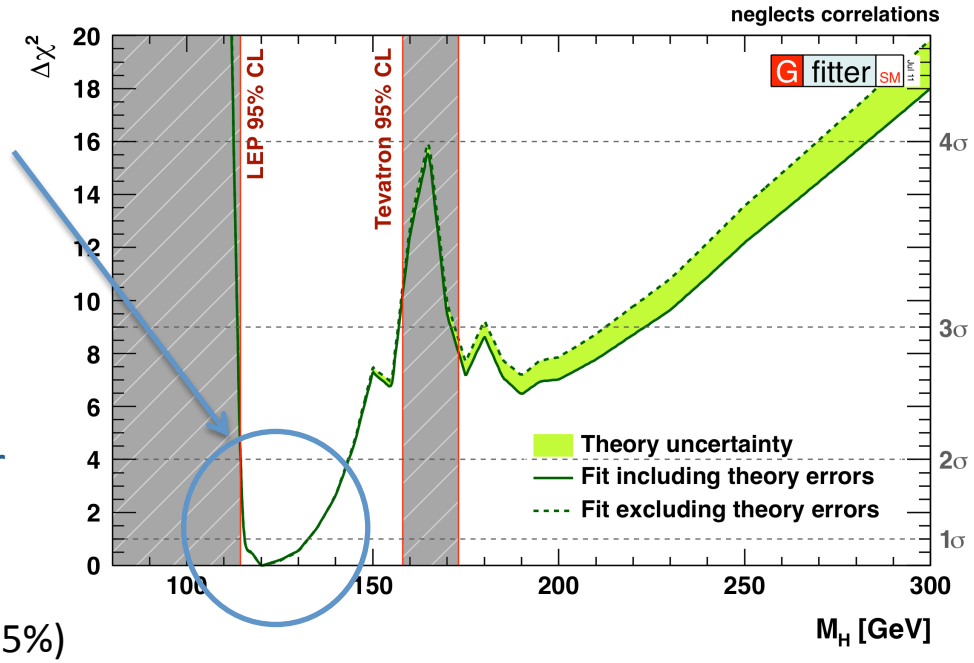
Relevance of the γγ Channel

- Dominant Channel in the very low mass range (110-125 GeV)

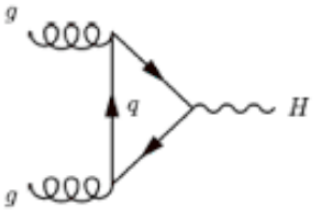
See combination talk by K. Cranmer

- Despite the low branching (~0.2%) large event yield.

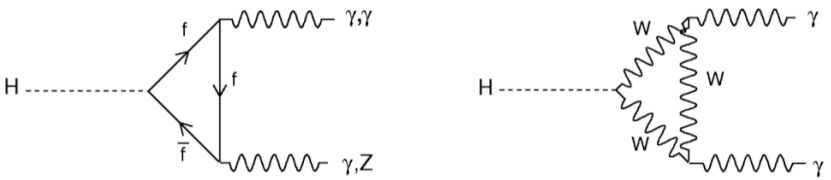
- Main production and decay processes occur through loops :



known at NNnLO, still rather larger uncertainty O(15%)



A priori potentially large enhancement…



… Not so obviously enhanced (e.g. SM4)

Still e.g. NMMSSM (U. Ellwanger Phys.Lett. ***B 698****, 293-296,2011) up to x6 at low masses, Fermiophobia…*

- If observed implies that it does not originate from spin 1 : Landau-Yang theorem

L. Landau, Dokl. Akad. Nauk. , USSR **60**, 207 (1948) and C. N. Yang, Phys. Rev. **77**, 242 (1950).

Simple Signature Channel

Very simple signature
(and analysis selection)

Two tightly identified and isolated photons with :

$$p_{\perp}^{\gamma_1} > 40\ GeV/c$$

$$p_{\perp}^{\gamma_2} > 25\ GeV/c$$

$$|\eta_{1,2}| < 1.37 \quad \text{and} \quad 1.52 < |\eta_{1,2}| < 2.37$$

Photon Identification based both on the lateral and longitudinal segmentation of the calorimeter

Photon Reconstruction

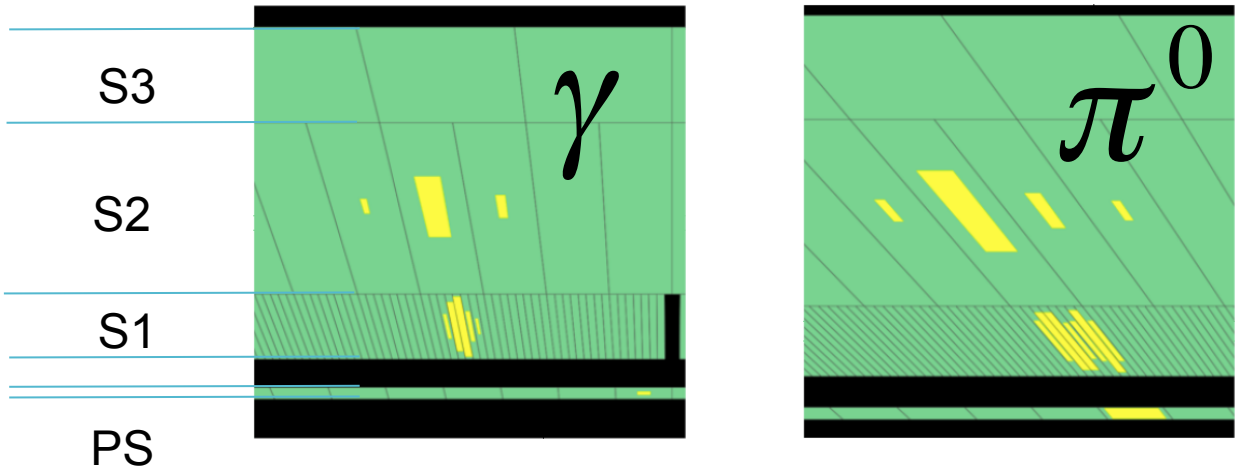
Longitudinal segmentation :

Energy reconstruction

Photon Cluster based on 3x5 (unconverted γ) and 3x7 (converted γ)

- for barrel photons -

π^0-γ Rejection



Lateral segmentation :

- Shower shape variable in S2
- Fine S1 granularity ~0.003 in pseudo rapidity
- Excellent γ-π^0 rejection
- Simple cuts technique

Photon isolation :

- Calorimeter based (0.4 cone)
- Out-of-(inner)-cone leakage corrections
- Underlying event and pile-up (PU) correction event based (using a Jet-Area type of algorithm)

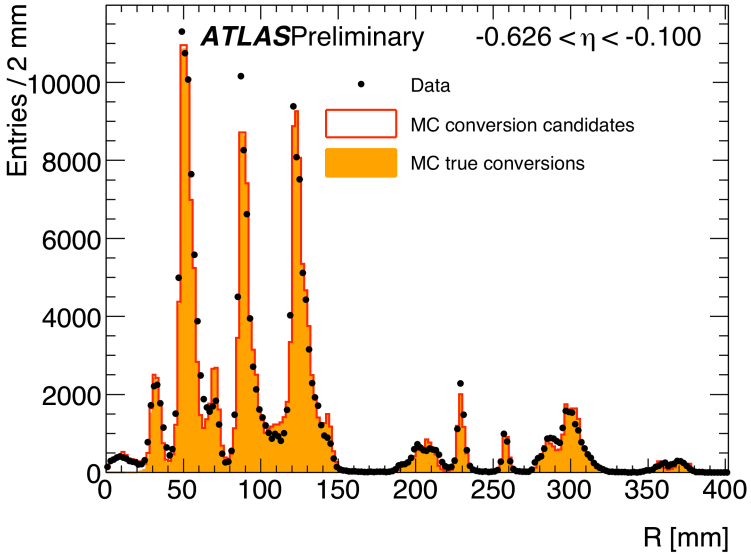
Photon Energy Calibration

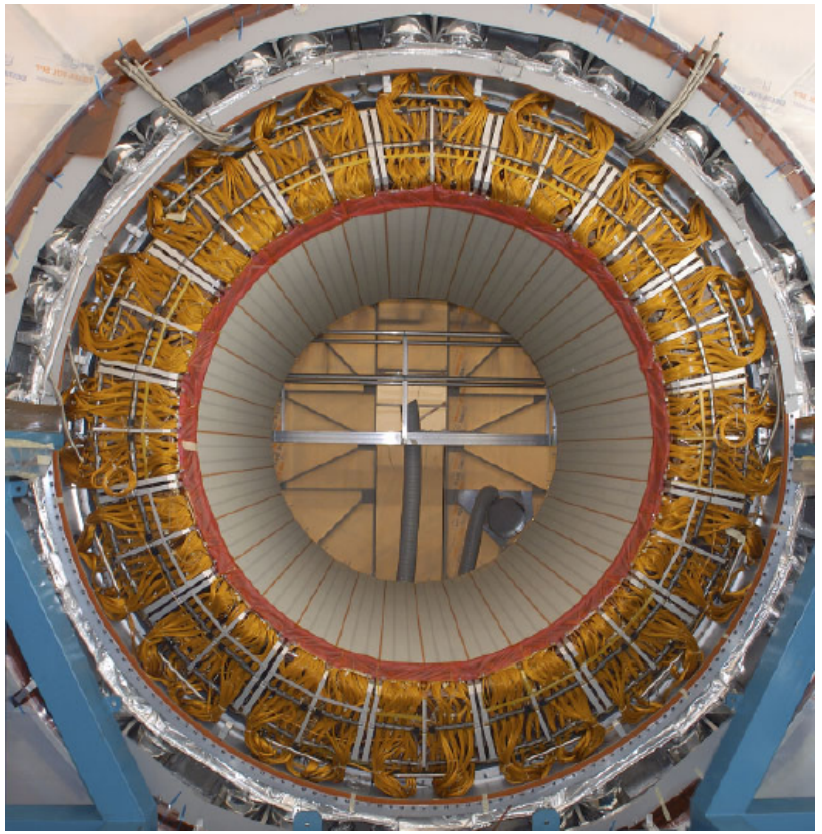
The Electromagnetic Calorimeter Uniform by Construction

- Crack-less Accordion geometry

SA constant term : ~0.5% (per TB module)

- γ Calibration : MC based calibration (EM Calorimeter full simulation tuned in Test Beam) and accurate material description upstream (Verified with in situ measurements).





(Conversions, e^- shower shapes, energy flow, E/p distributions, etc…)

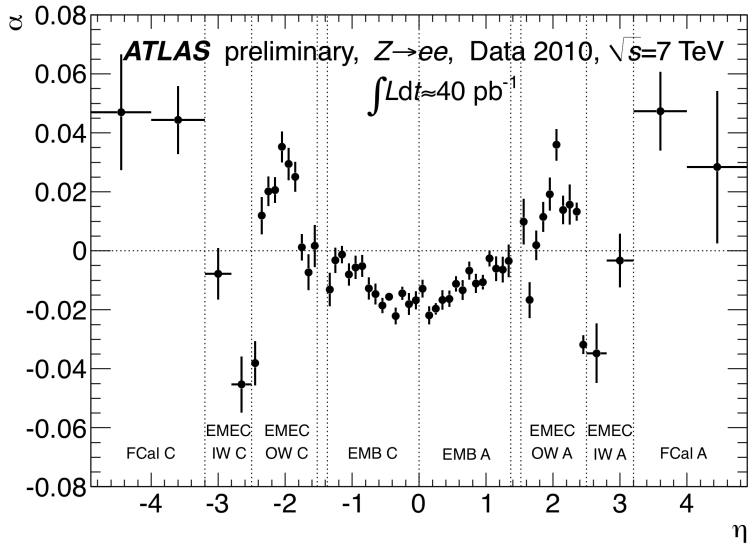
Energy scale calibration from Z decays to electrons

… In absence of a significant γ calibration signal*

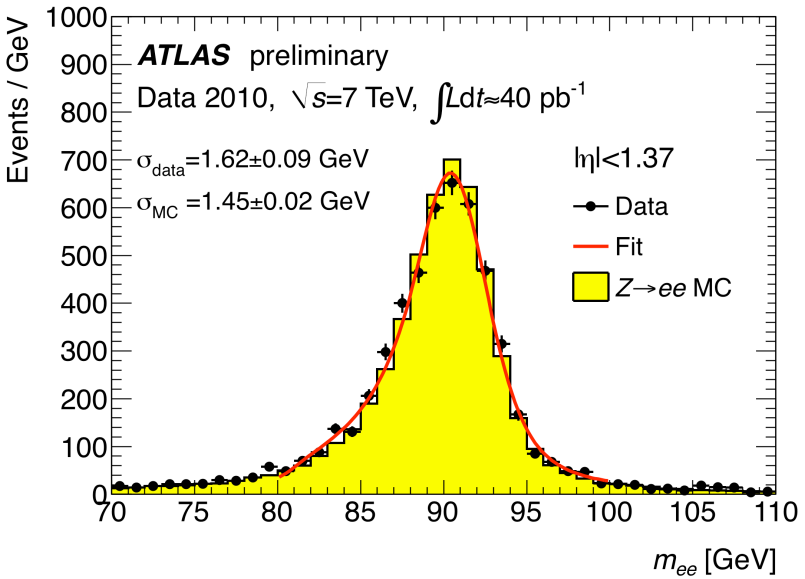
- After MC based calibration, apply electron energy scale corrections from a global fit to the 2010 data (Z to e^+e^-) .

- Coarse corrections averaged in ϕ

- Resolution correction derived from a comparison of the MC to the data in electrons.



- Energy scale and resolution corrections do not necessarily apply to photon : taken into account in material effect systematic uncertainty.



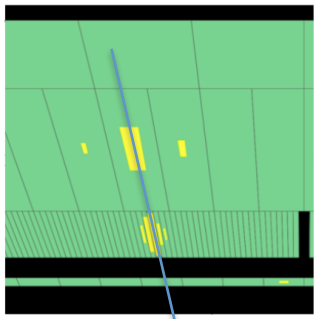
* Zγ events are still too scarce and low E_T

Reconstruction of the Angle in Space

- IP spread of 5.6 cm : assuming (0,0,0) adds ~1.4 GeV in mass resolution

(equiv. to the calo. $M_{\gamma\gamma}$ resolution itself).

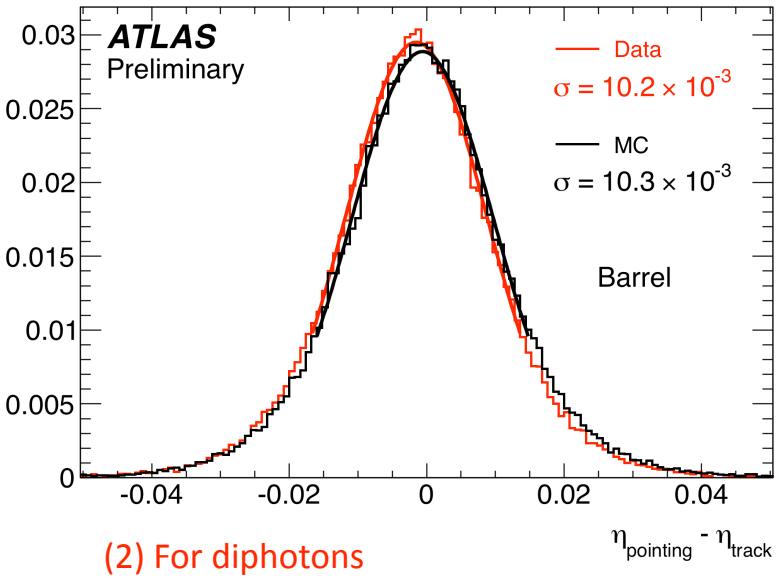
- Can use conversion as well
- Recoil tracks (less effective with large PU)



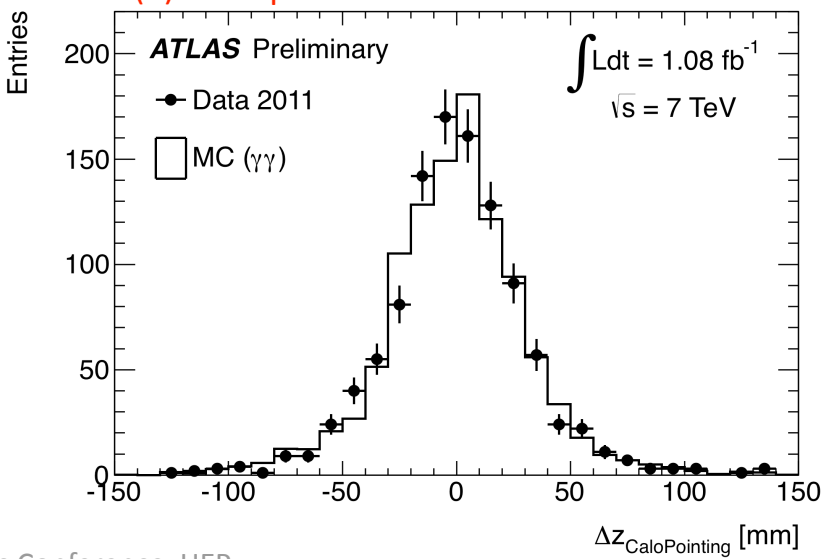
1.- Measure photon direction

2.- Deduce z of PV

(1) For electrons



(2) For diphotons



- Resolution with pointing ~1.6 cm
- Effective gain with O(10) PU events ~10%

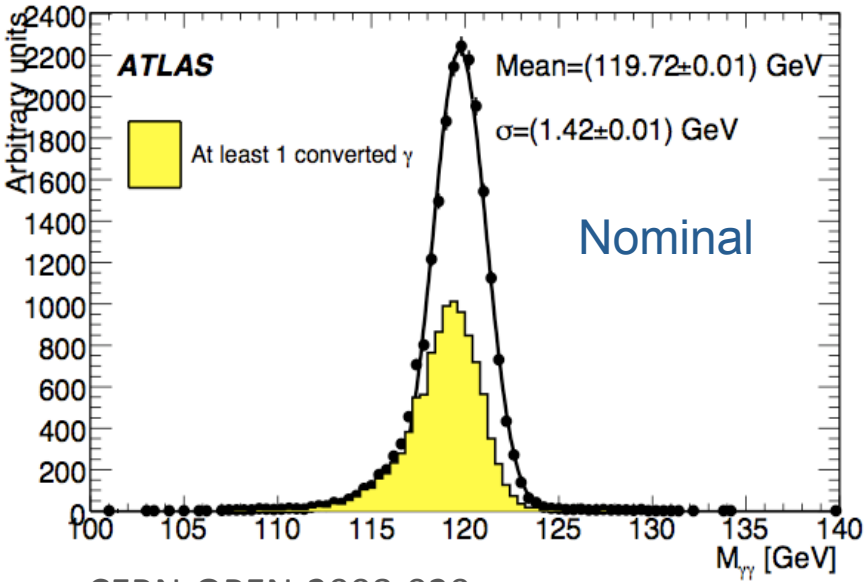
Reconstructing the diPhoton Invariant Mass

- Primary vertex reconstruction :
  - Photon calorimeter pointing
  - Use conversion tracks when available

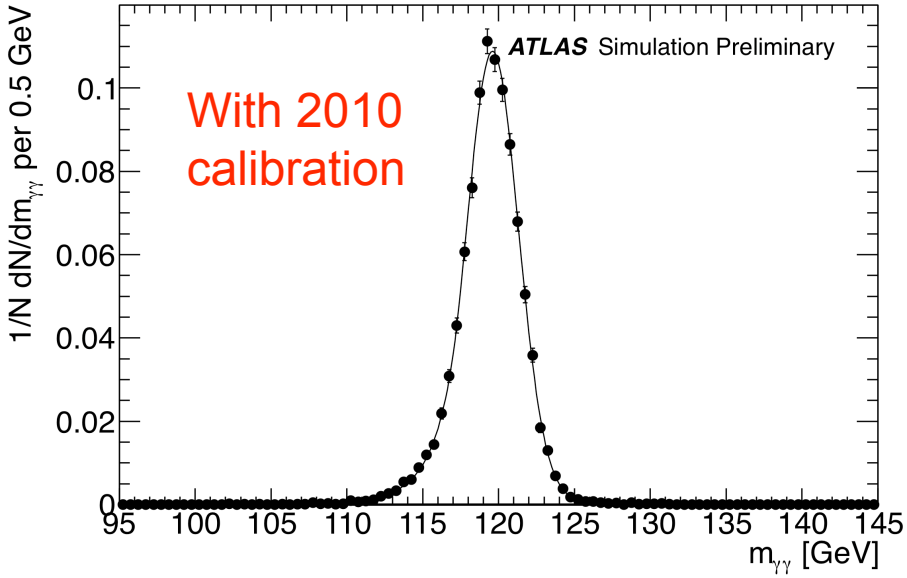
} Robust against PU

- Energy scale calibration from Z to electrons applied
- Crystal Ball + Gaussian model with narrow widths (of the core of the distribution) :

$\sigma \sim 1.4$ GeV



$\sigma \sim 1.7$ GeV



CERN-OPEN-2008-020

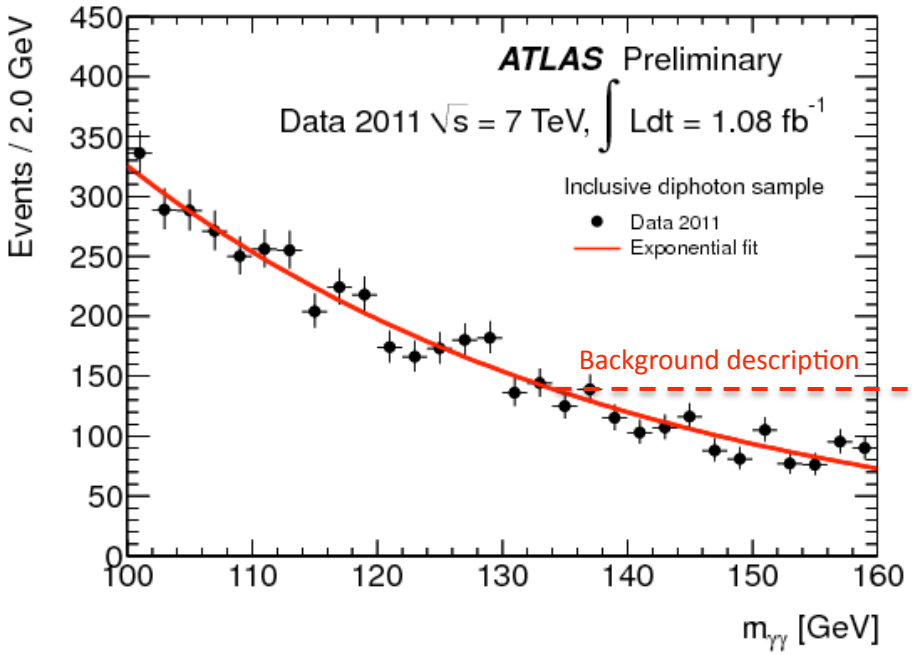
The Analysis

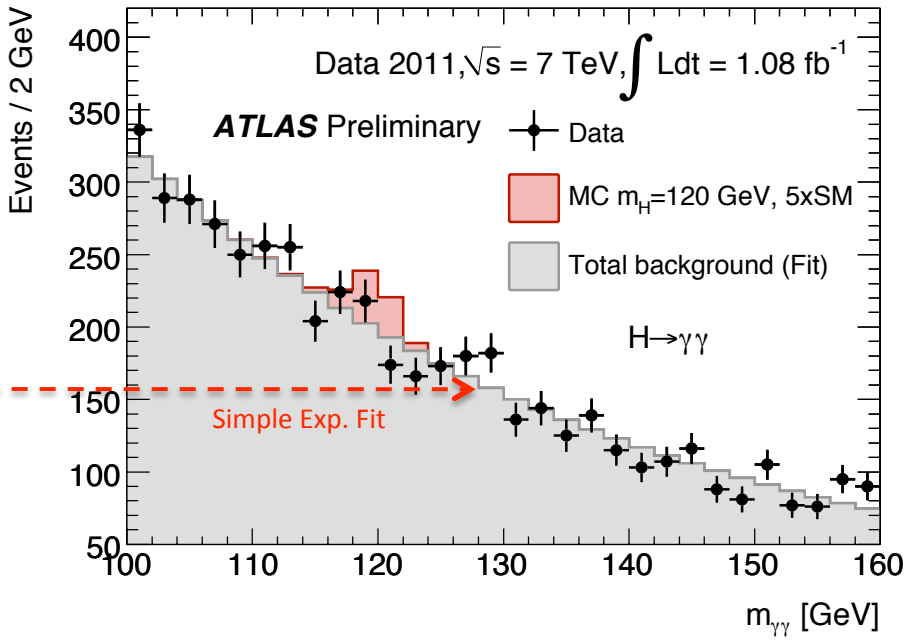
The Dataset

- Primary trigger selection : 2 photons E_T> 20 GeV
- Lumi block based data quality selection
- Event based DQ selection
- Photon based DQ selection

Integrated luminosity of : **1.08 fb^{-1}**

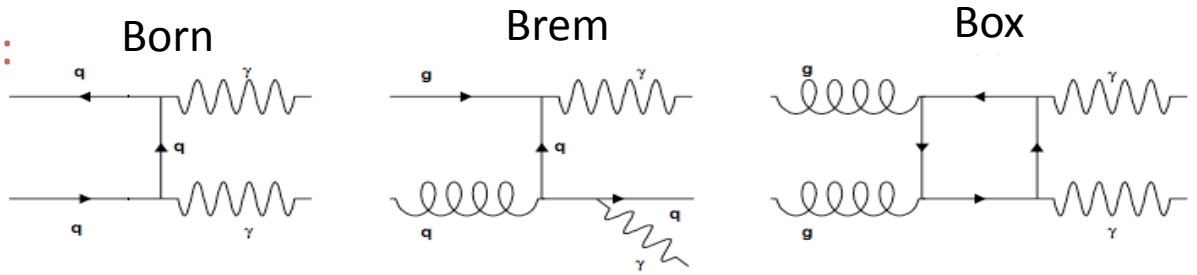
Inclusive Mass Spectrum





Main Backgrounds

Irreducible backgrounds :



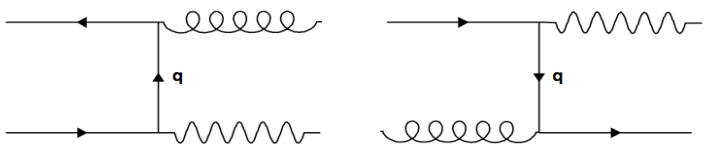
- Born and box Best estimate by parton-level resummed NLO ResBos

- The brem is in principle reducible in practice not, and it is a process difficult to simulate

Best estimate by parton-level NLO fixed order Diphox (T. Binoth,J.Ph. Guillet et al.)

Now SHERPA (Gleisberg, Hoeche et al.)

The Reducible backgrounds : Critical to reach jet rejections O(5000)



Final state parton(s) fragments into a leading π^0

Best estimate by parton-level fixed order NLO JetPhox (S. Catani, M. Fontannaz et al.)

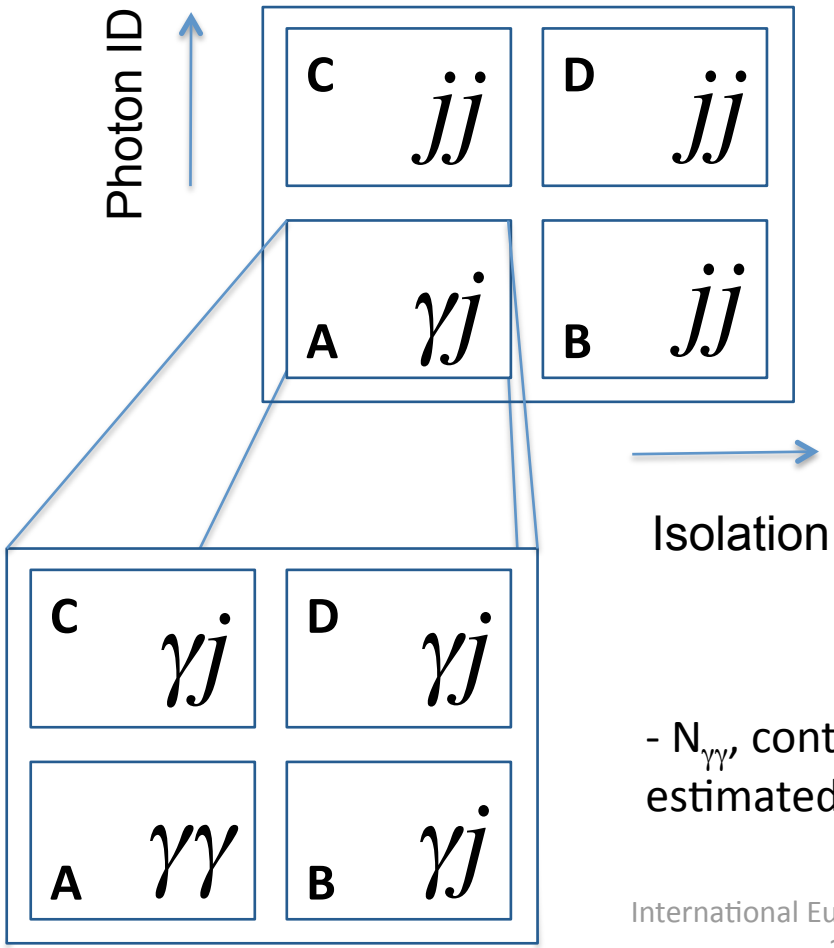
Also note : large difference Pythia vs. Herwig in the leading $\pi 0$ fragmentation

Background Estimates in Data

- Apply the side-band method on each photon separately

- Allows to estimate $N_{\gamma\gamma}$, $N_{\gamma j}$, and N_{jj}

$$N_A - N_A^{sig} = N_B \times \frac{N_C}{N_D}$$



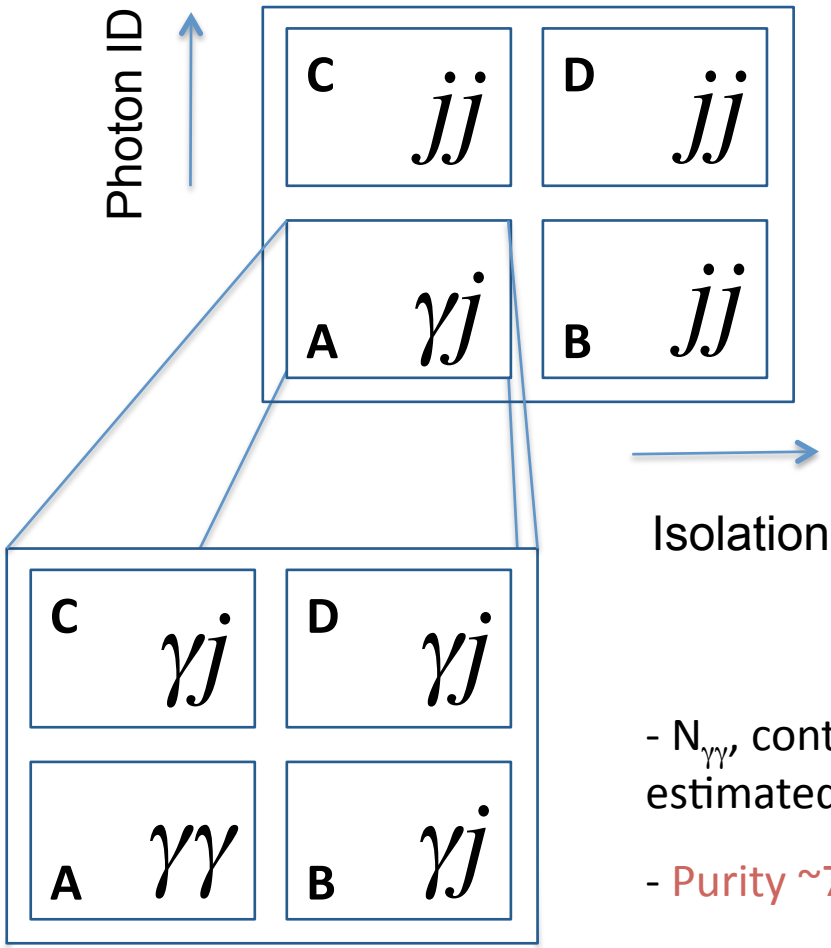
- $N_{\gamma\gamma}$, contains also bkg. From fake electrons (mostly DY) : estimated on Z to electrons events.

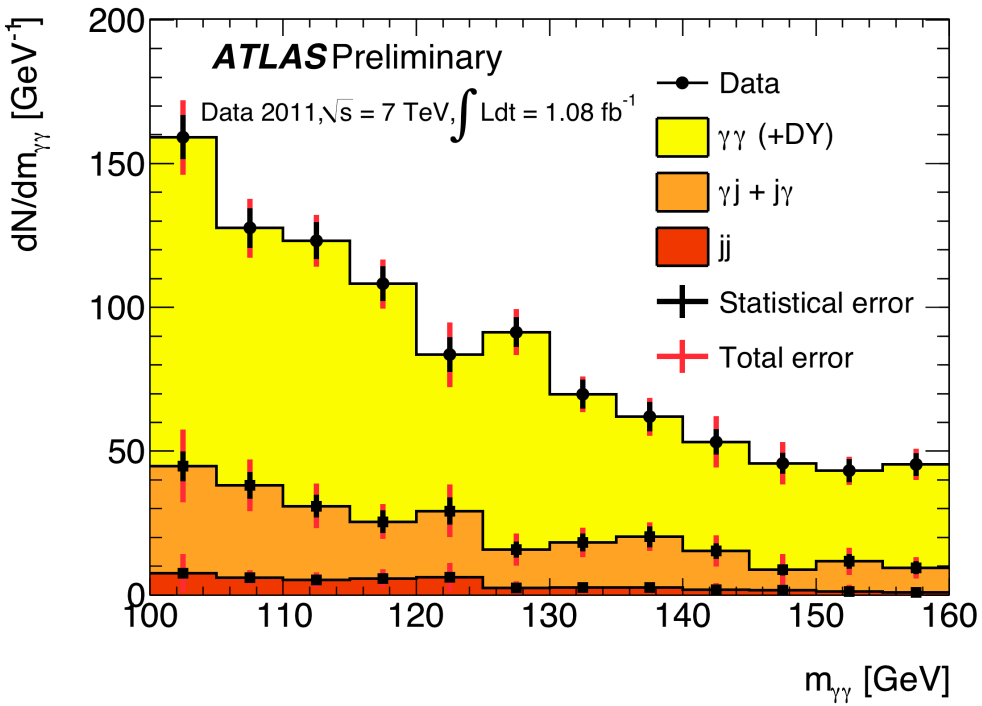
Background Estimates in Data

- Apply the side-band method on each photon separately

- Allows to estimate $N_{\gamma\gamma}$, $N_{\gamma j}$, and N_{jj}

$$N_A^{bkg} = \left(N_B - c_B N_A^{sig}\right) \times \frac{N_C - c_C N_A^{sig}}{N_D - c_D N_A^{sig}} \times \theta$$





- $N_{\gamma\gamma}$, contains also bkg. From fake electrons (mostly DY) : estimated on Z to electrons events (~2%).

- Purity ~70% (Confirmation of photon ID performance)

Analysis in Categories

1.- Unconverted-central: 2 UC In the central barrel calorimeter (|η|<0.75)

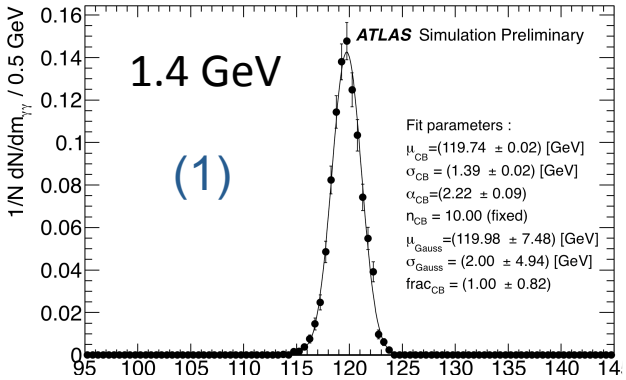
2.- Unconverted-rest: 2 UC , at least one not central

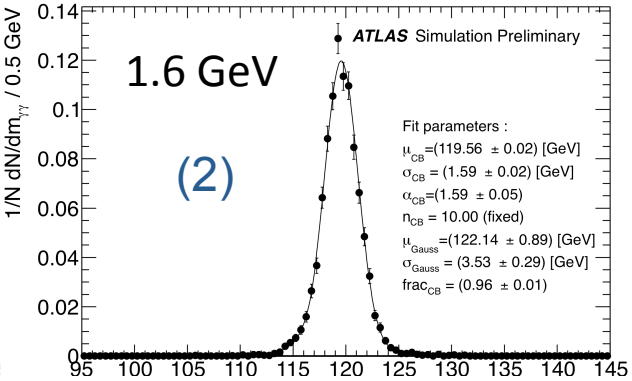
3.- Converted-central: at least 1 Conv., 2 central

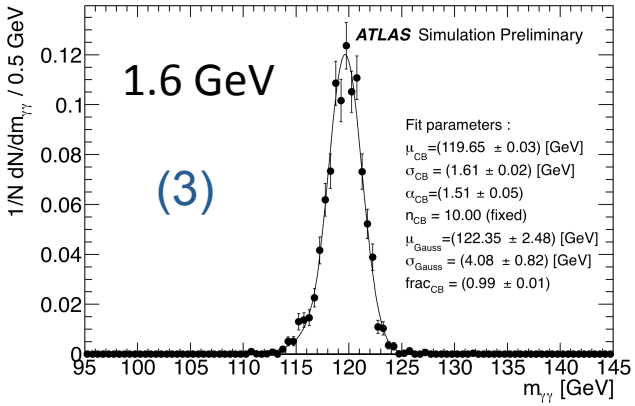
4.- Converted-transition: at least 1Conv. And 1 near the transition barrel/end-cap(1.3< |η|<1.75)

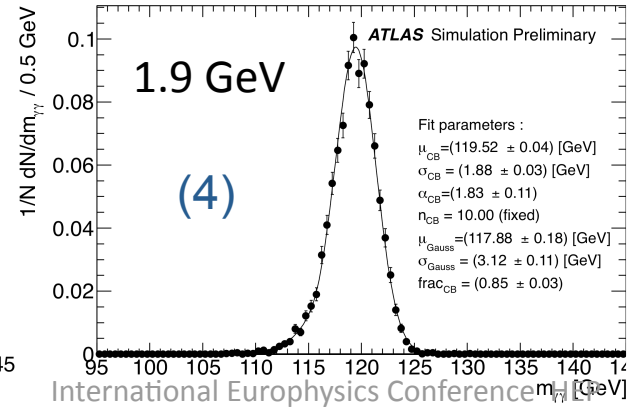
5.- Converted-rest: all other events with at least 1 Conv.

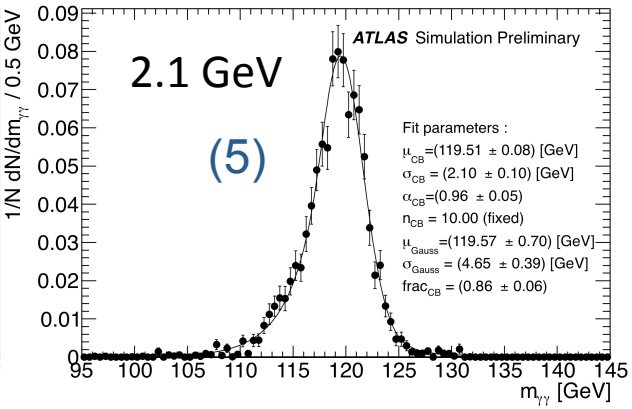
-Separate caegories in terms of resolution











Analysis in Categories

1.- Unconverted-central: 2 UC In the central barrel calorimeter (|η|<0.75)

2.- Unconverted-rest: 2 UC , at least one not central

3.- Converted-central: at least 1 Conv., 2 central

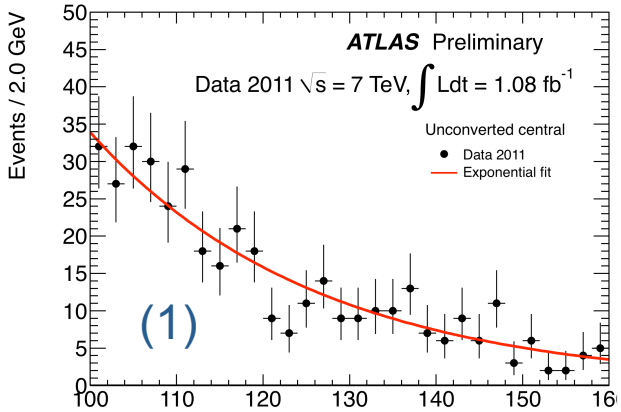
4.- Converted-transition: at least 1Conv. And 1 near the transition barrel/end-cap(1.3< |η|<1.75)

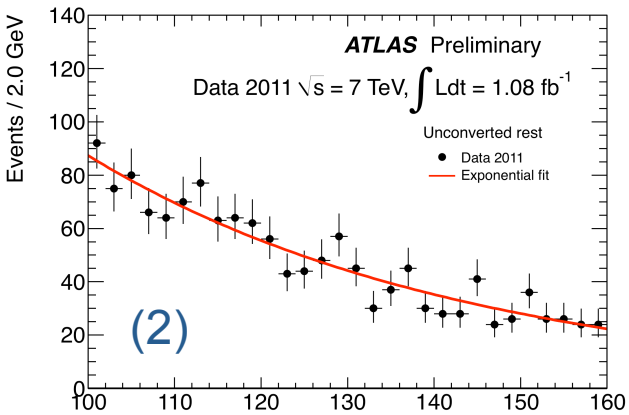
5.- Converted-rest: all other events with at least 1 Conv.

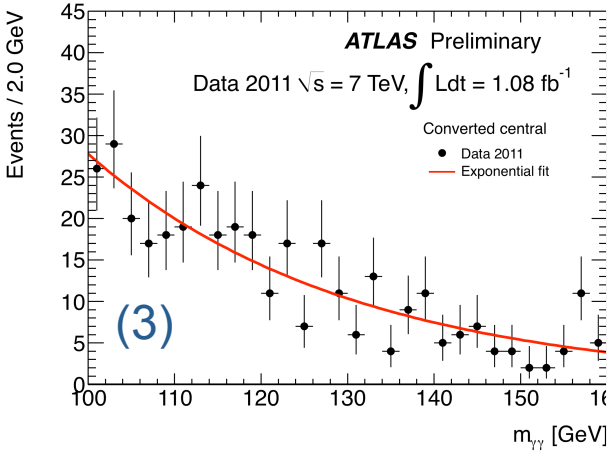
-Separate caegories in terms of resolution

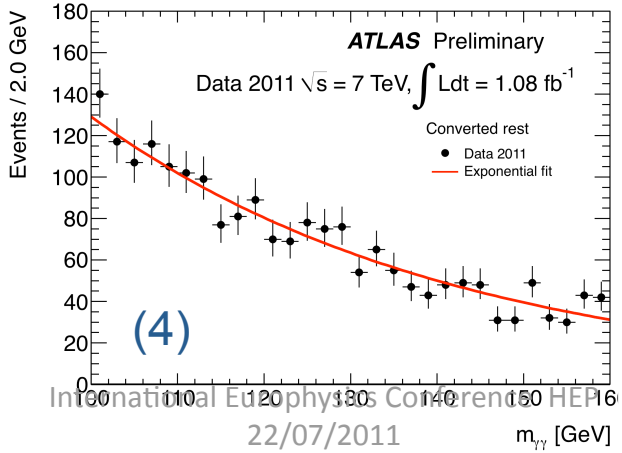
- Also in terms of s/b

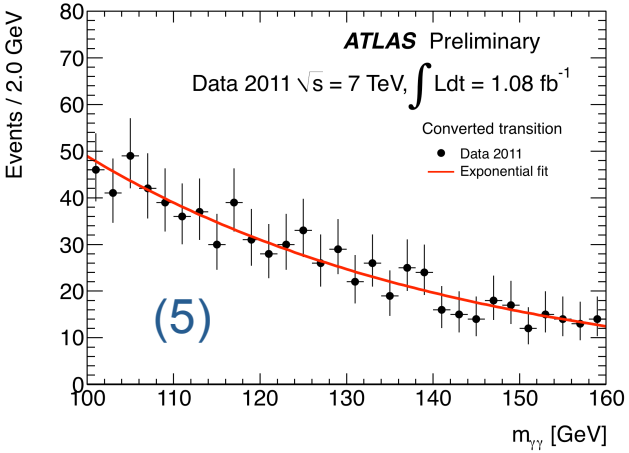
~15% Improvement











Systematic Uncertainties

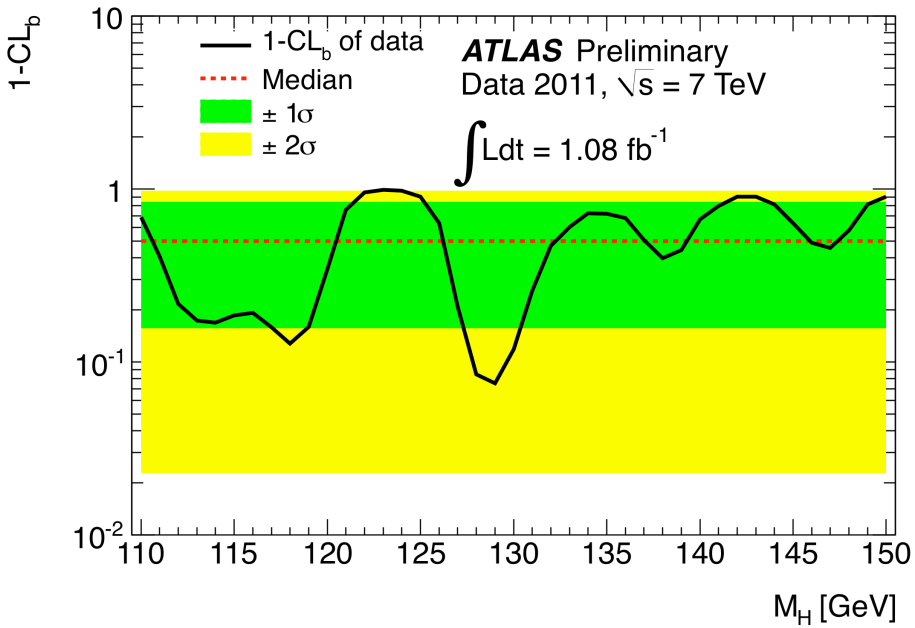
- Uncertainties on the signal yield : **Total ±12%**
  - Reconstruction and identification efficiency ±11%
  - Isolation cut efficiency : ±3%
  - Trigger efficiency : ±1%
  - Luminosity : 3.7%
  - Effect of $P_T^{\gamma\gamma}$ modeling on the kinematical cut acceptance : 1%

- Uncertainties on the invariant mass resolution : **Total ±14%**
  - Constant term of the cluster energy resolution : ±12%
  - Photon calibration arising in the extrapolation of the energy scale calibration of electrons : ±6%
  - Contribution of pileup fluctuations to the cluster energy measurement : < 3%
  - Photon angle measurements : 1%

- All systematic uncertainties are taken as fully correlated between the different categories (non-correlated systematic uncertainties negligible impact)

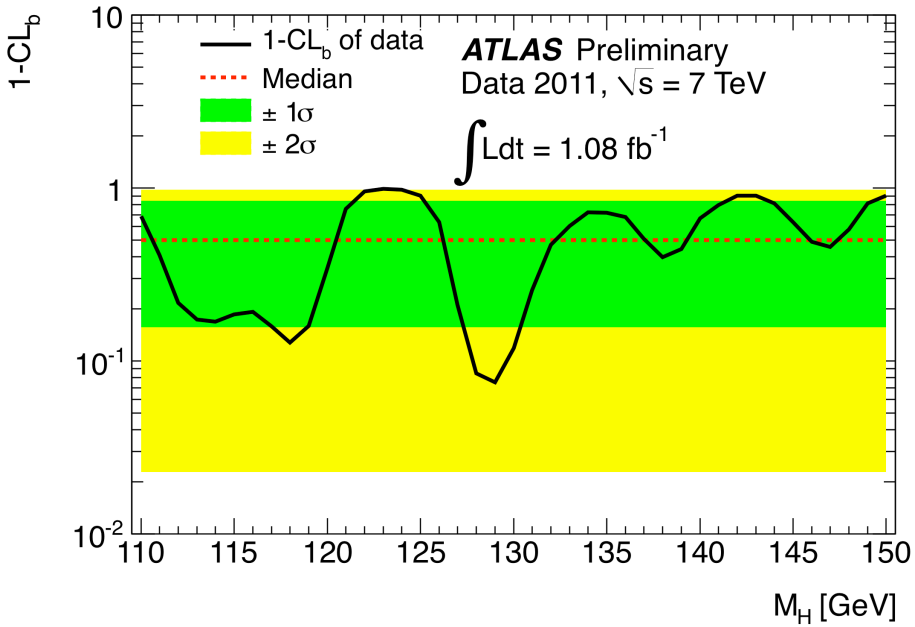
The H→γγ Results

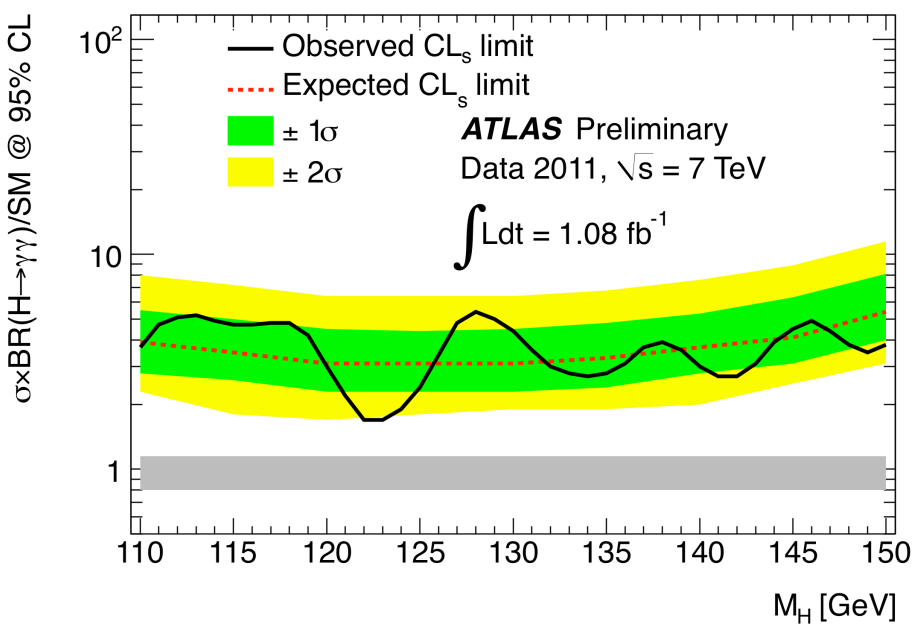
- Use a simple exponential model for the background
- Use Profile Likelihood test statistic to derive 95% CL limits and statistical significance 1-CL_b
- No significant excess observed



The H→γγ Results

- Use a simple exponential model for the background
- Use Profile Likelihood test statistic to derive 95% CL limits and statistical significance 1-CL_b
- No significant excess observed





- Use modified frequentist approach CL_s
- Sensitivity between 3 and 5 times NNLO standard model cross section
- Observed exclusion between 2 and 6 times the NNLO SM cross section

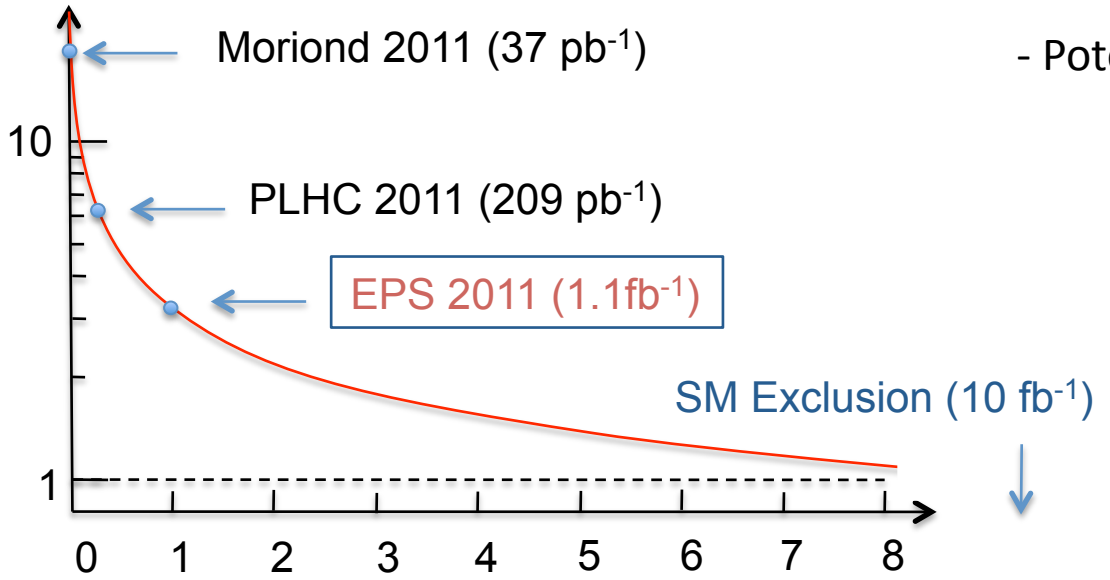
Conlusions and Outlook

- The Higgs to $\gamma\gamma$ analysis has been improved since Moriond 2011 and PLHC 2011 with the use of photon categories (in η and conversion status).

- This search is starting to reach a good sensitivity (~3 x NNLO SM cross section 95% exclusion).

- No significant excess observed and limits are set in agreement with the sensitivity.

- Expected sensitivity to SM exclusion ~10 x NNLO SM cross section.



- Potential improvements :
  - Use of discriminat such as $p_T^{\gamma\gamma}$ or $\cos\theta^*$
  - Use categories in numbers of jets
  - Exclusive channels (longer term)