Search for Higgs Boson in Diphoton Final State with the ATLAS Detector

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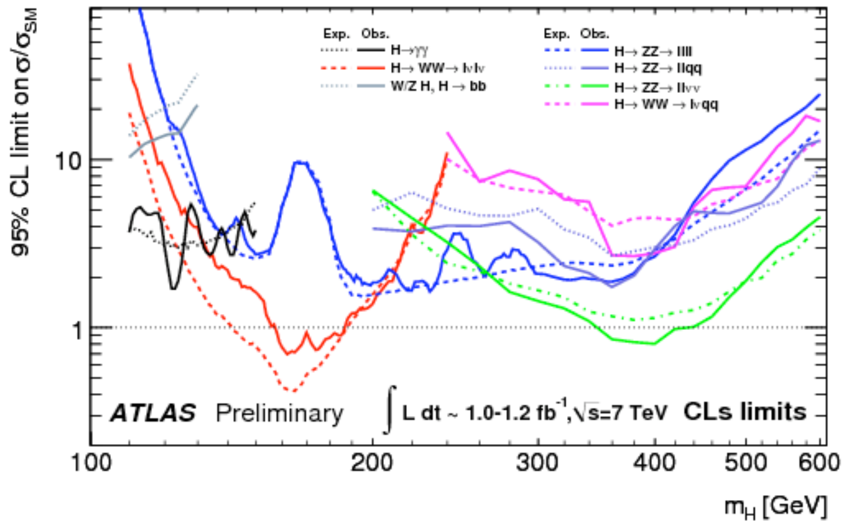
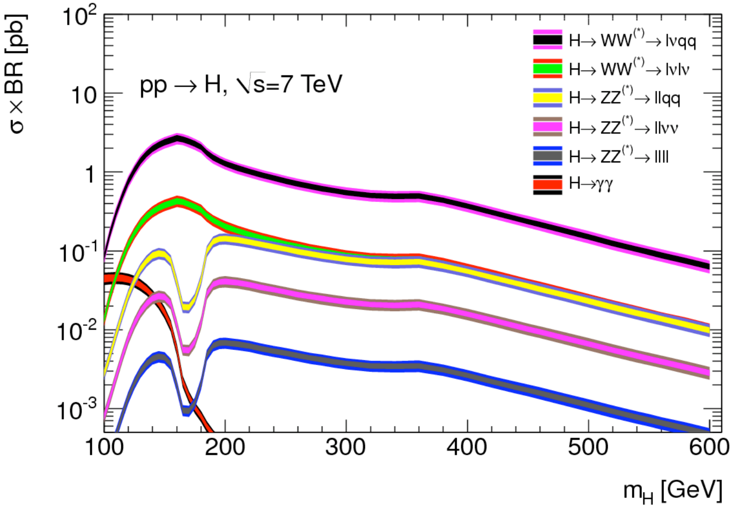
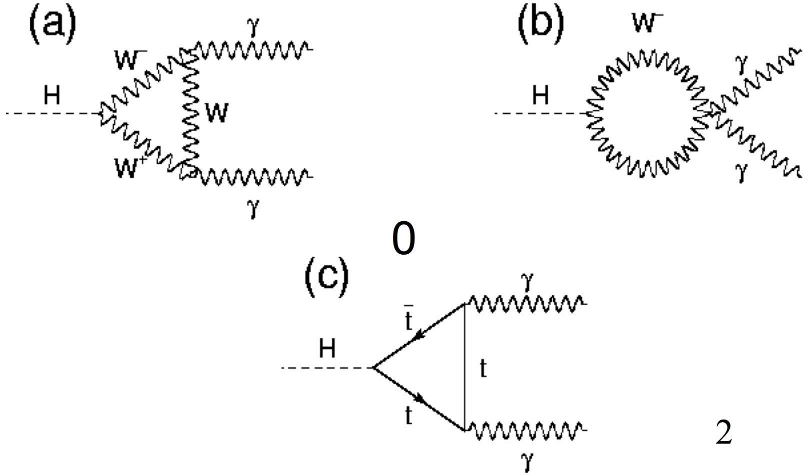
H → γγ

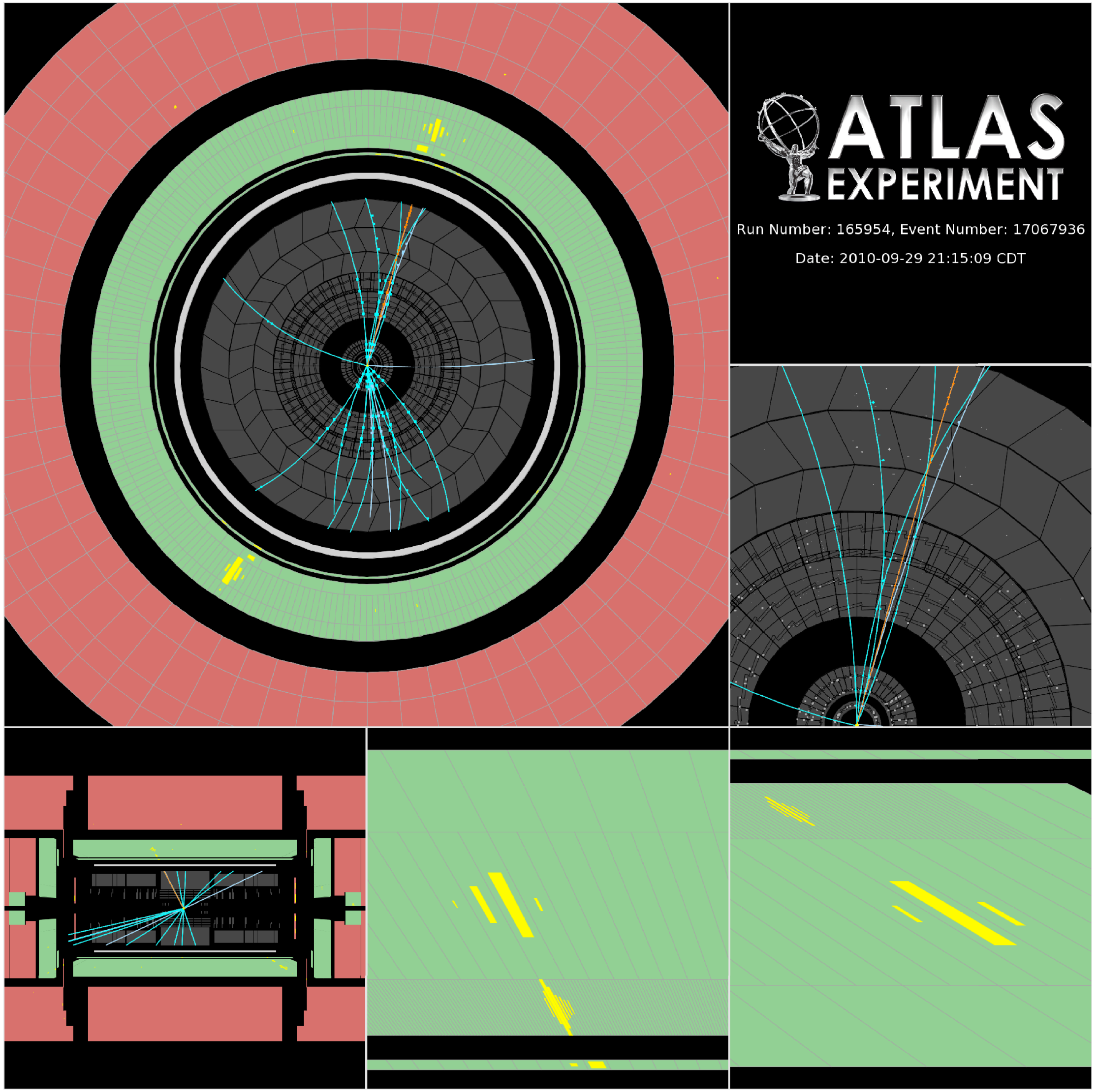
- Most sensitive channel in low mass region at LHC (mH<130GeV)
- Higgs decays to γγ through a top/W loop
  - No coupling between H and γ→ Possible enhancement in BR due to new physics.
  - BR could also be suppressed when new physics(e.g. MSSM) opens other decay channels.
- Signature: diphoton resonance on top of QCD backgrounds, which also offers the possibility of a precise measurement of Higgs mass.







The challenges



A display of an event where two photons were produced.

- **The signature is simple, but there are big challenges**
- **To reconstruct the a narrow peak:**

  → Good photon energy resolution.

  → Precise position measurement.

- **To suppress the huge QCD background**

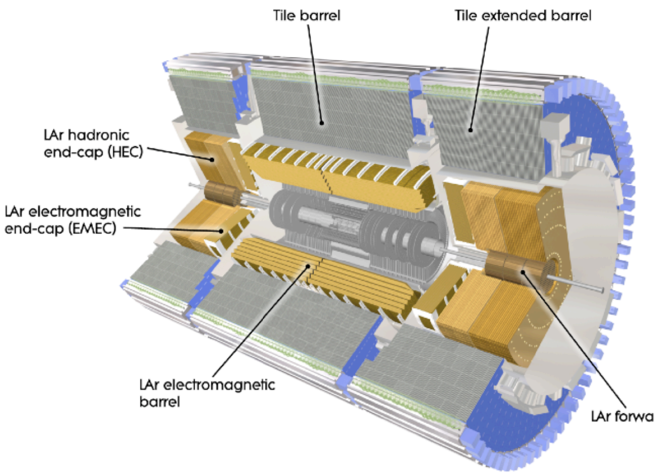
  → Strong photon-jet separation power

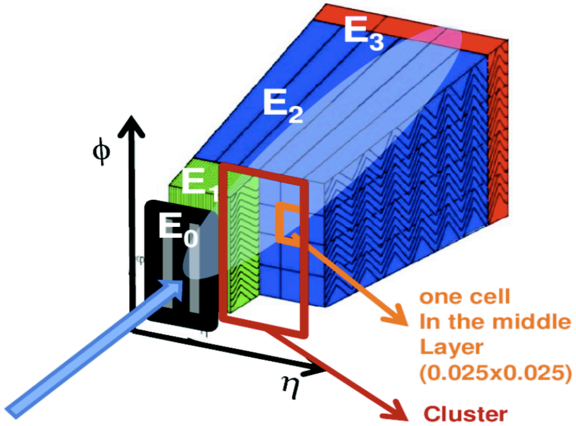
- **To maximize the search sensitivity**

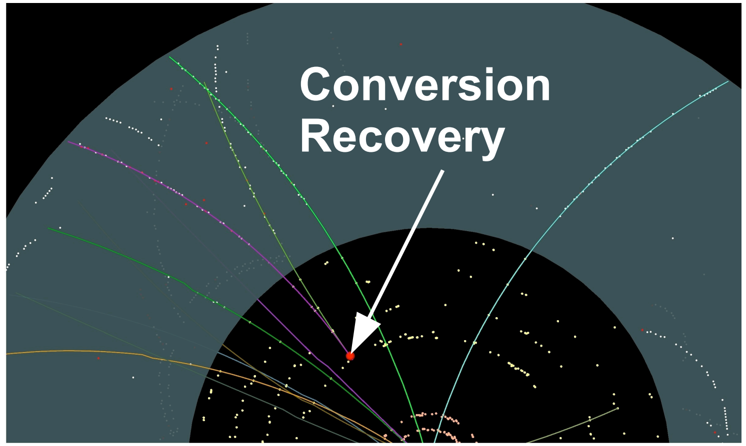
  → Good understanding the signal property and the background composition.

  → Develop sophisticated search strategy

Photon Reconstruction

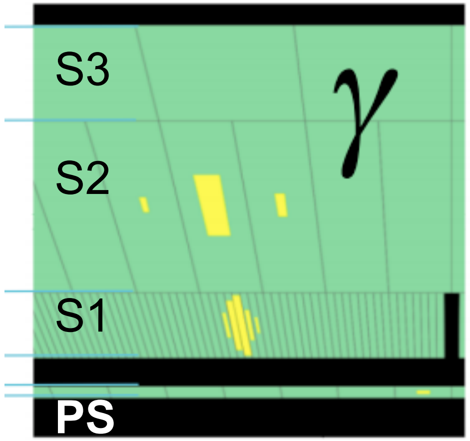


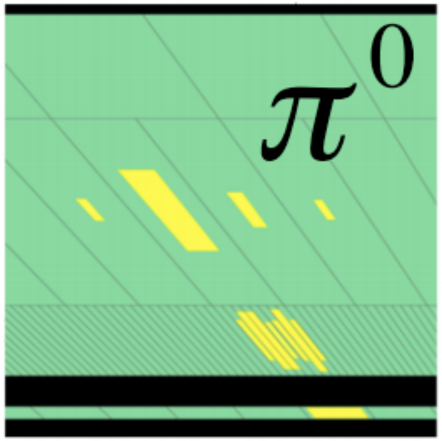


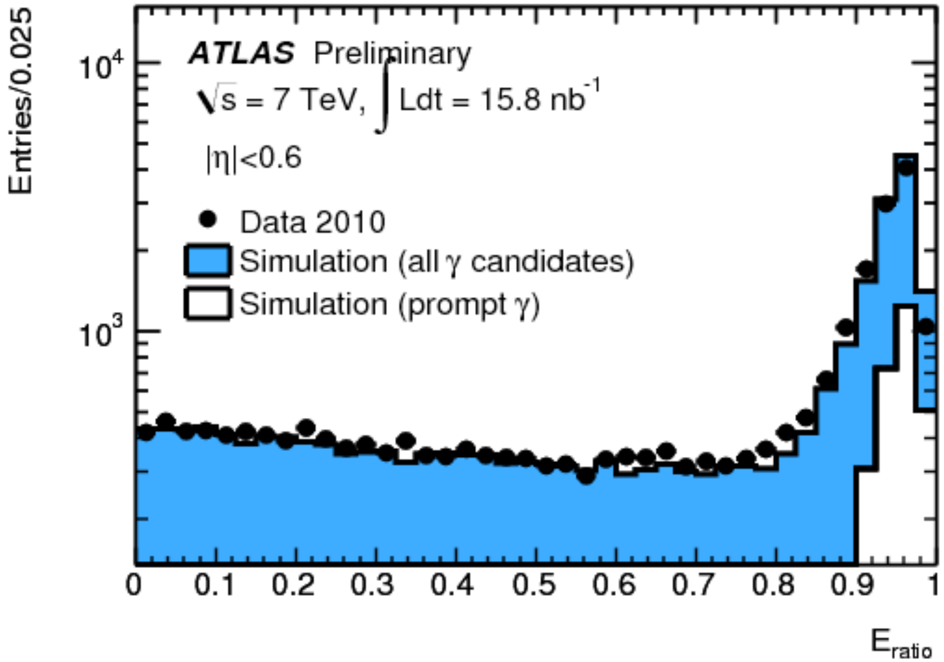


- Liquid Argon EM Calorimeter with accordion geometry covers $|\eta| < 3.2$. The fine granularity for $|\eta| < 2.5$ allows precision measurements of EM objects.
- Four layers perform energy/position measurements and provide information for particle identification.
- Electrons from photon conversion are "recovered", i.e. classified as photon candidates.

Photon Identification



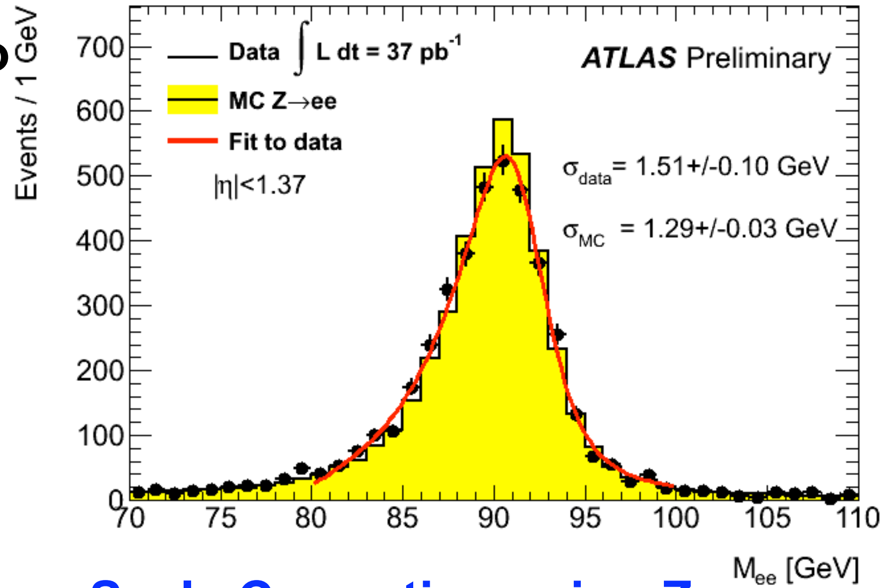




- Photon showers are generally narrower than those of fake, which mostly are photons from pi0.
- Take advantages of fine granularity of four layers to design **shower shape** variables.
- A combination of shower shape cuts is defined to identify photon candidate.

Photon Energy Calibration

- **Photon energy calibration includes two steps:**
  - **MC based Calibration**
    - **MC full simulation is tuned with Test Beam data.**
    - **An accurate description of materials is confirmed by measurements in data.**



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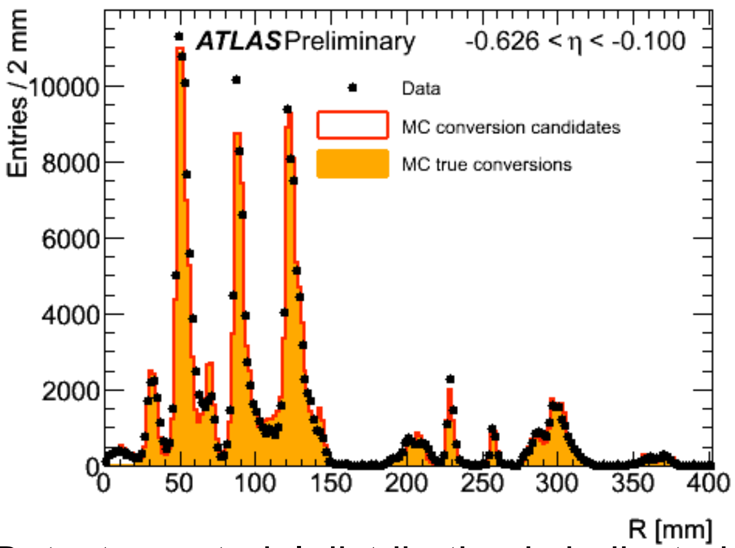
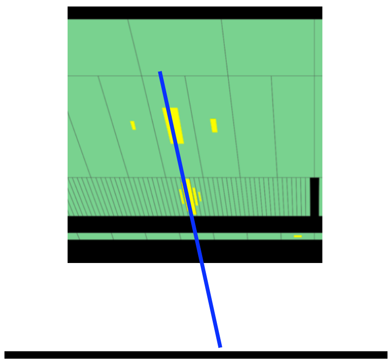


Detector material distribution is indicated from distribution of conversion radius. Data and MC agree fairly good.

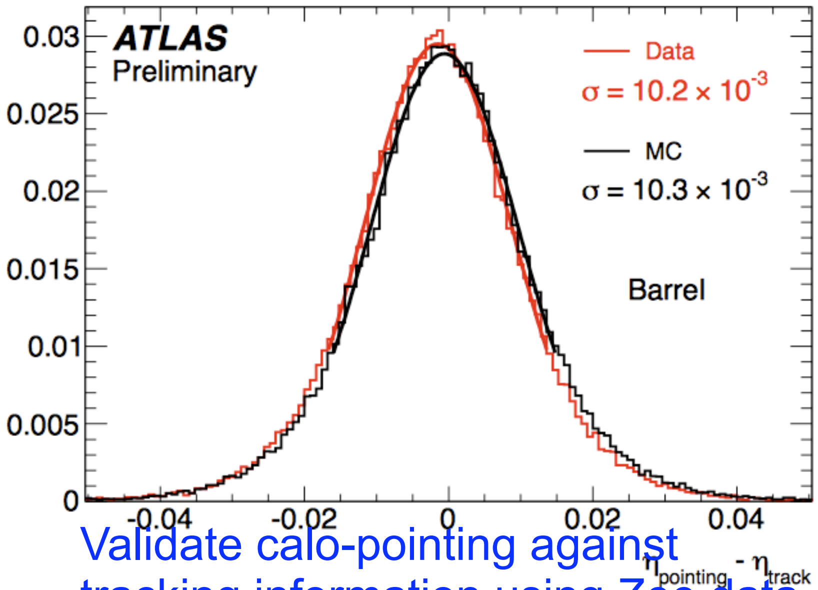
- **Energy Scale Correction using Z → ee data**
  - **Energy scale correction is applied to data. The correction is obtained from a global fit to the 2010 data (Z to e+e-) .**
  - **The extrapolation of energy scale correction from electron to photon is treated as an uncertainty.**
  - **MC energy is smeared to match the energy resolution determined from data**

Vertex of Photon Pairs

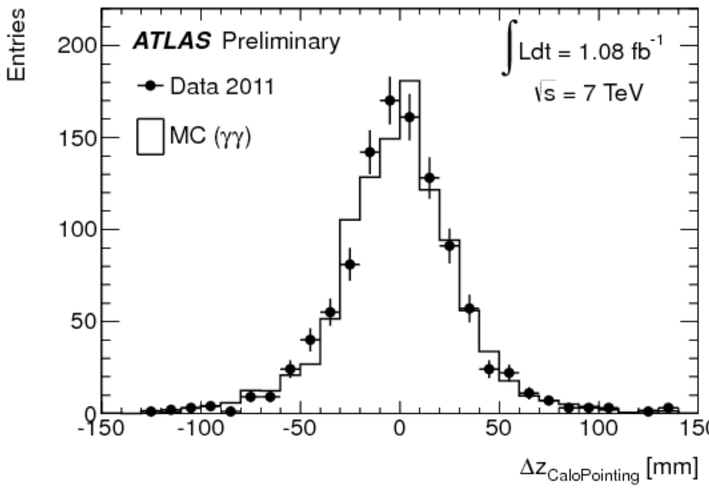
- Interaction Point' spread ~ 5.5 cm → Assuming photons come from origin (0,0,0) introduces ~ 1.4 GeV to the mass resolution.
  - Tracks from underlying event are used to find the primary vertex. Performance is reduced when large pile-up is present.
  - Additional information is used to improve the vertex measurement:
    - Converted photon: the tracking information of electrons from photon conversion could be used.
    - Unconverted photon: extrapolate from energy barycenters in calorimeter to IP.



Symbolic plot of calo-pointing.



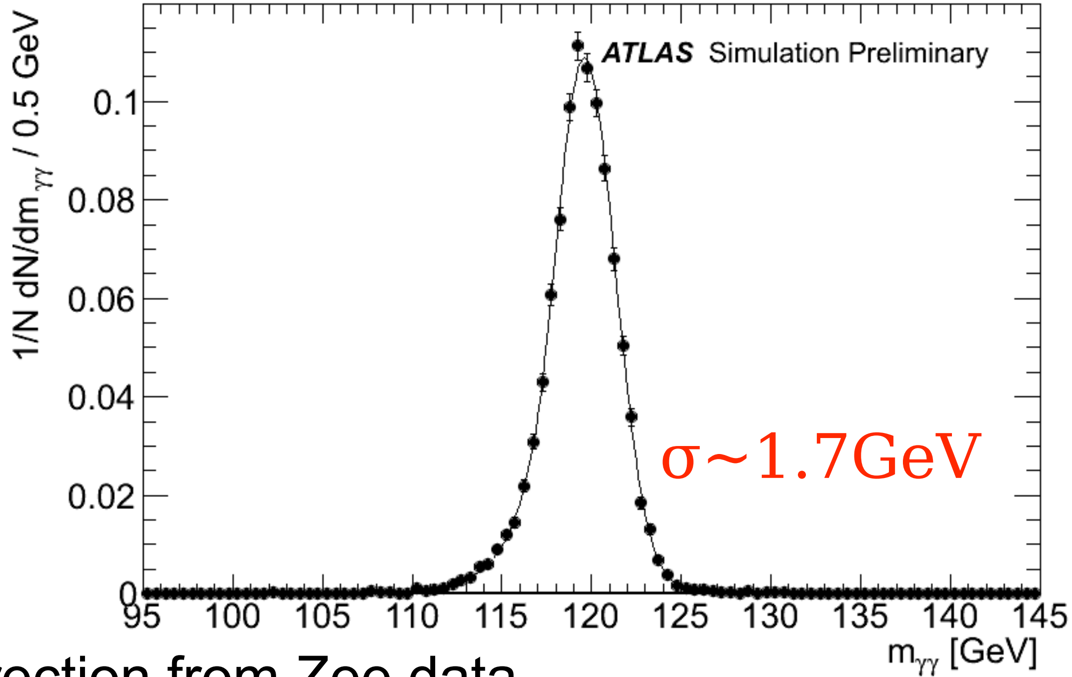
Validate calo-pointing against tracking information using Zee data



ΔZ between two photons. Data and MC agree well.

Reconstruction of γγ Invariant Mass

Distribution of the reconstructed diphoton invariant mass of a simulated 120 GeV mass Higgs boson signal



- Energy correction from Zee data.
- Primary vertex correction → Conversion tracks, calorimeter pointing ~ 10% improvement.
- Signal is fitted by Crystal Ball(core) + Gaussian(tail) function.

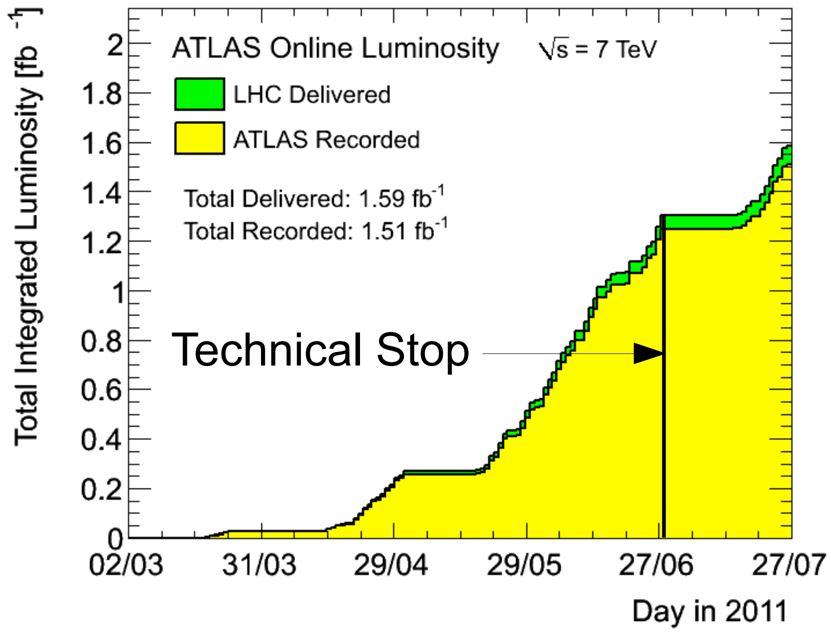
"Crystal Ball" $N \cdot \begin{cases} e^{-t^2/2} \\ (\frac{n_{CB}}{\alpha_{CB}})^{n_{CB}} \cdot e^{-\alpha_{CB}^2/2} \cdot (\frac{n_{CB}}{\alpha_{CB}} - \alpha_{CB} - t)^{-n_{CB}} \end{cases}$

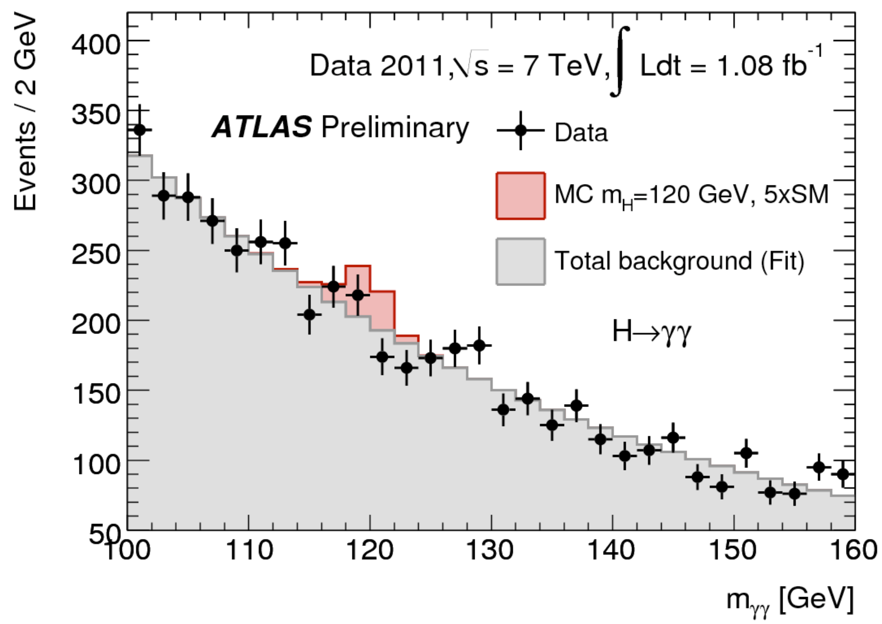
where $t = (m_{\gamma\gamma} - \mu_{CB}))/\sigma_{CB}$

The Analysis

Data Sample

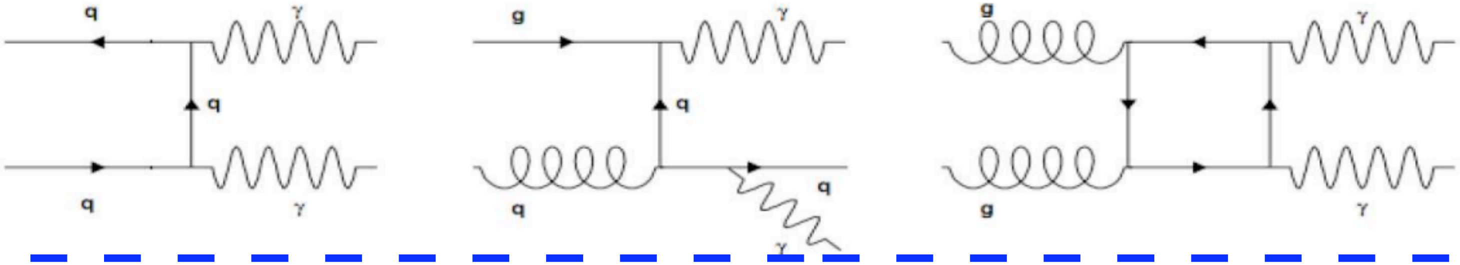
- Data with good quality ~ 1.1fb^{-1} .
- Event is triggered by 2 photons, E_T> 20GeV.
- Selection
  - Good object quality
  - Tight identification requirement
  - P_{T1} > 40GeV, P_{T2}>25GeV,
  - |eta|<1.37 or 1.52<|eta|< 2.37
  - Isolation Energy < 5GeV



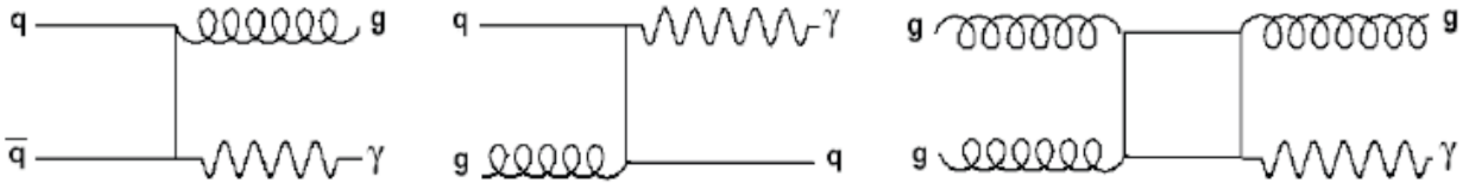


Backgrounds

Irreducible background: SM diphoton production



Reducible background: photon+jets production

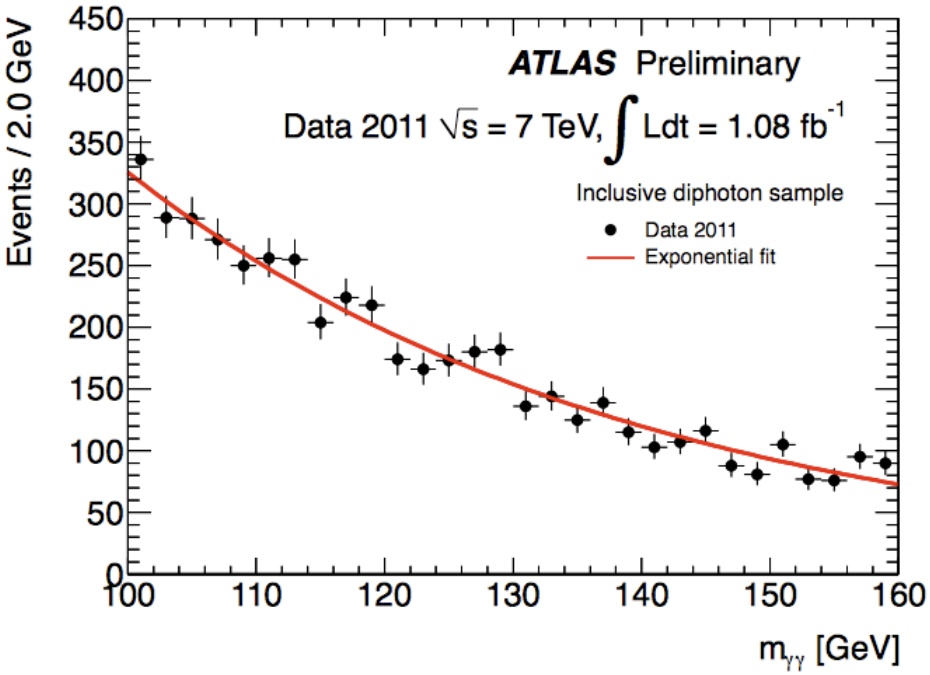


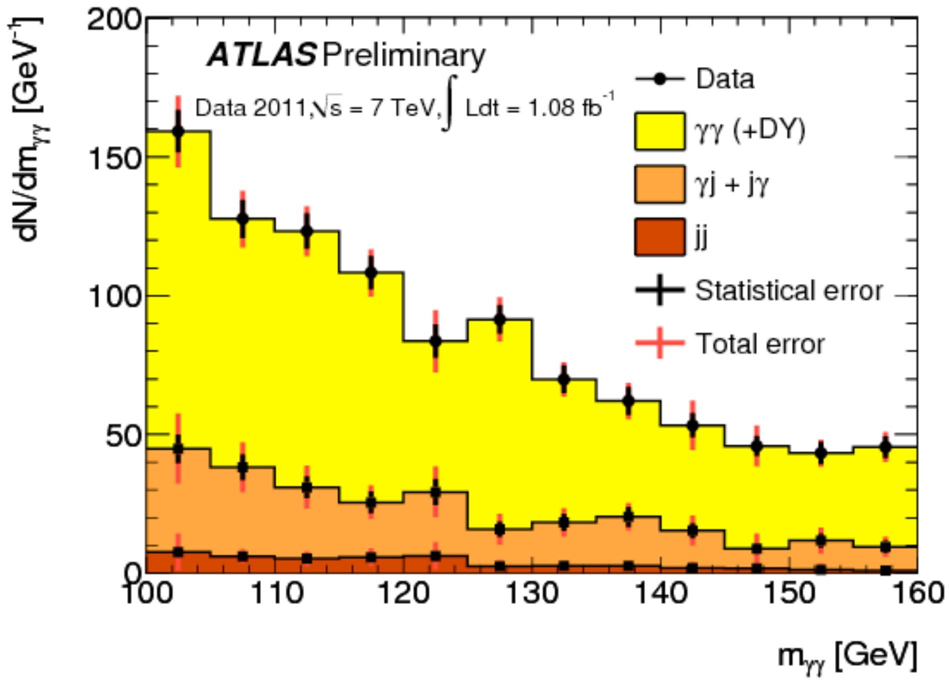
where a jet is misidentified as a photon (mostly, a pi0)

Both processes have fragmentation contributions and theoretical prediction is sensitive to parton isolation.

Other background processes:
Di-jet production: both jets are misidentified as photons.
Drell-Yan: both electrons are misidentified as photons.

Composition of the Sample





Fraction of each major background in the sample selected is estimated in a fully data-driven way. The right plot shows the estimated number of events for each background in different mass bins.

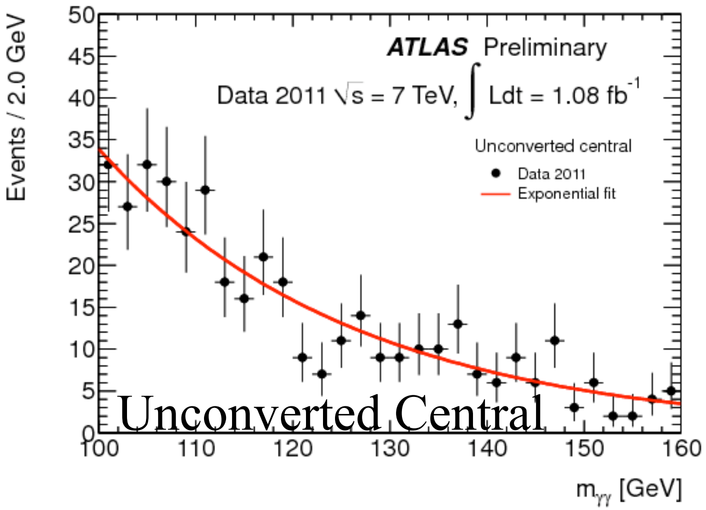
Genuine diphoton events are the dominant component, ~ 70%
Photon+Jets events constitutes ~23%
Drell-Yan ~2%, Dijets ~5%

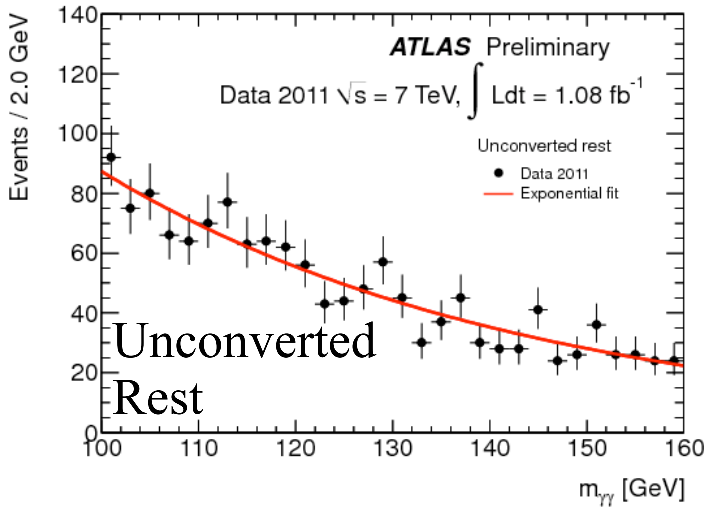
Search Strategy

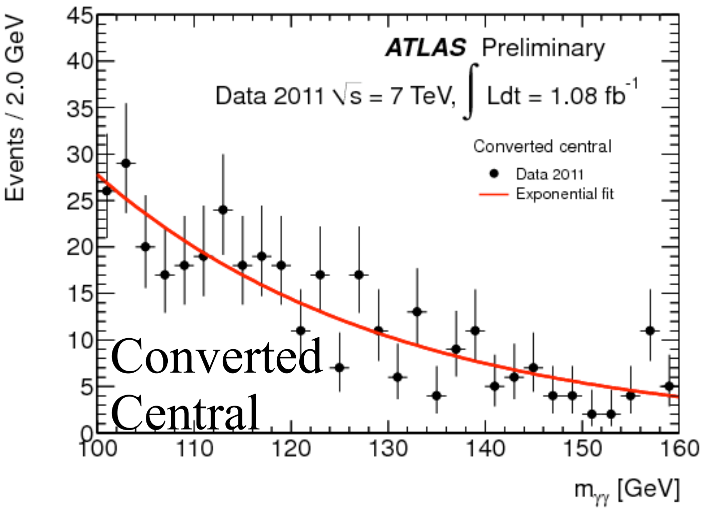
- Categorize data sample according to conversion status and eta region in the detector.
  - To make S/B uneven in various sub-samples
  - To take advantage of certain detector region where resolution is better.
- Five categories:
  - 1.Unconverted-central: 2 UC In the central barrel calorimeter ($|\eta|<0.75$)
  - 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 in the barrel/end cap transition region($1.3< |\eta|<1.75$)
  - 5.Converted–rest: all other events with at least 1 Conv.
- The expected improvement with respect to inclusive analysis is about 5-15%, depending on mass point.

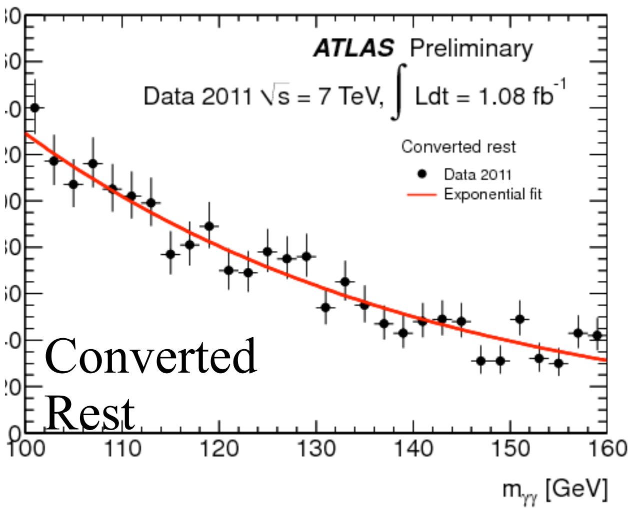
Data Sample in Five Categories

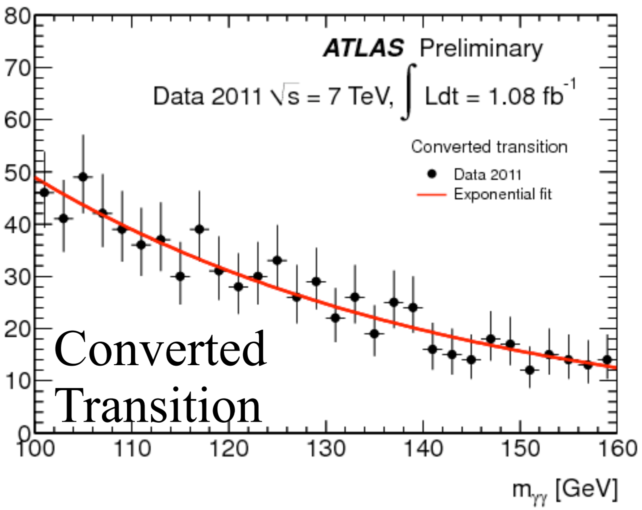
Invariant mass distributions in five categories





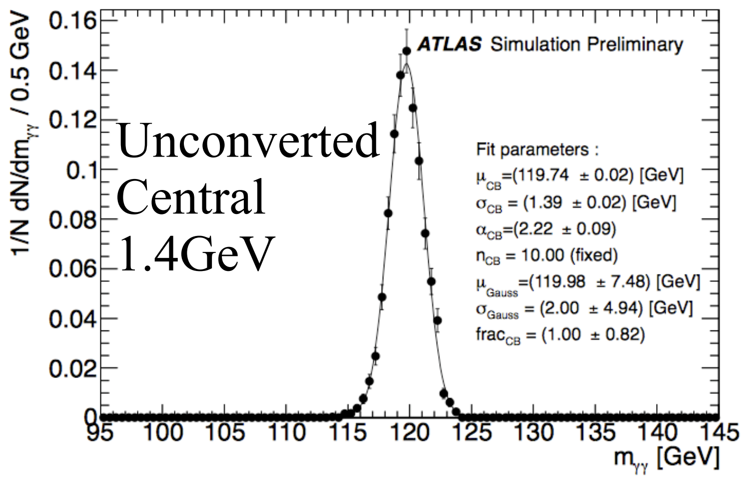


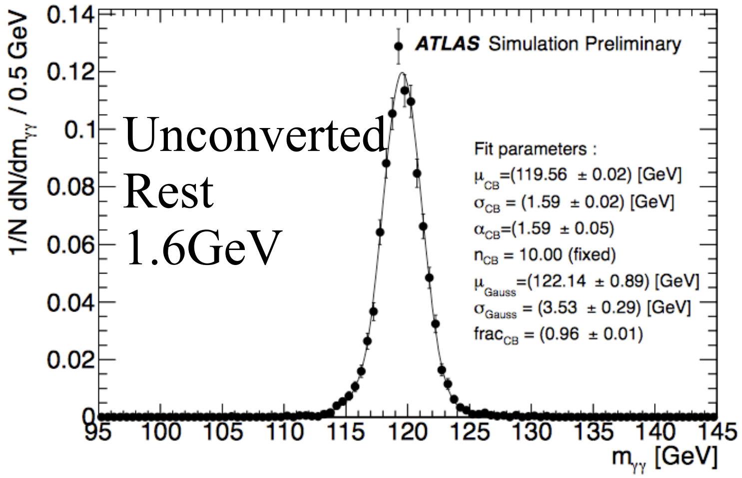


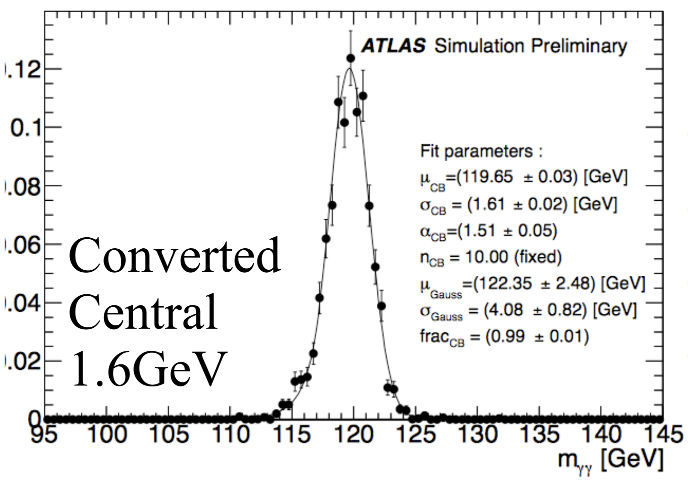


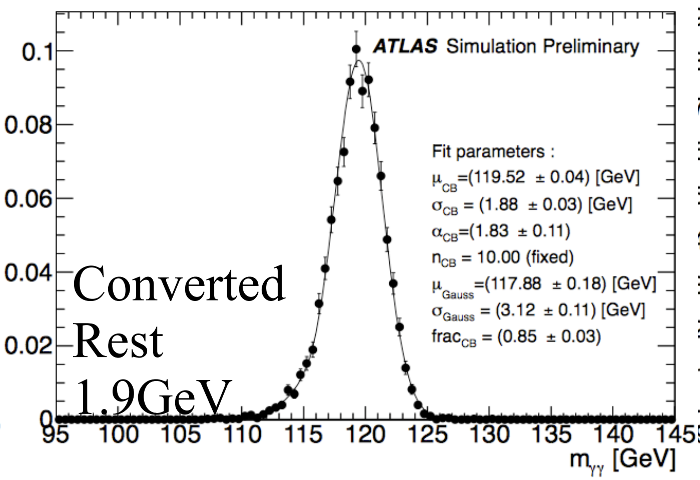
Signal in Five Categories

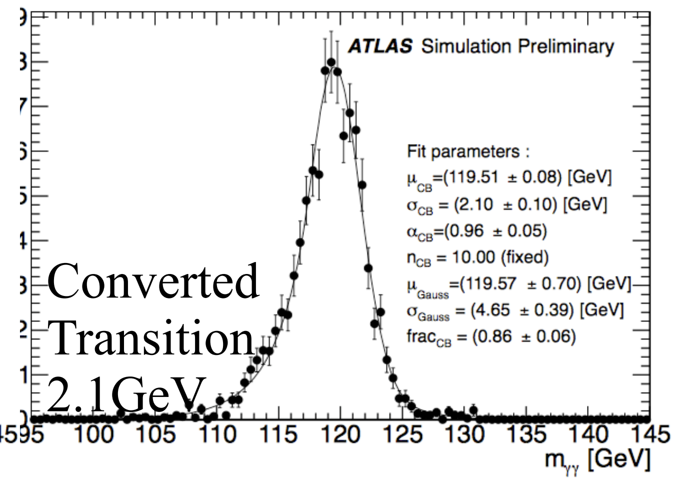
MC Higgs signal invariant mass distributions in five categories











Systematics

Uncertainty on Signal Yield ~ 12%

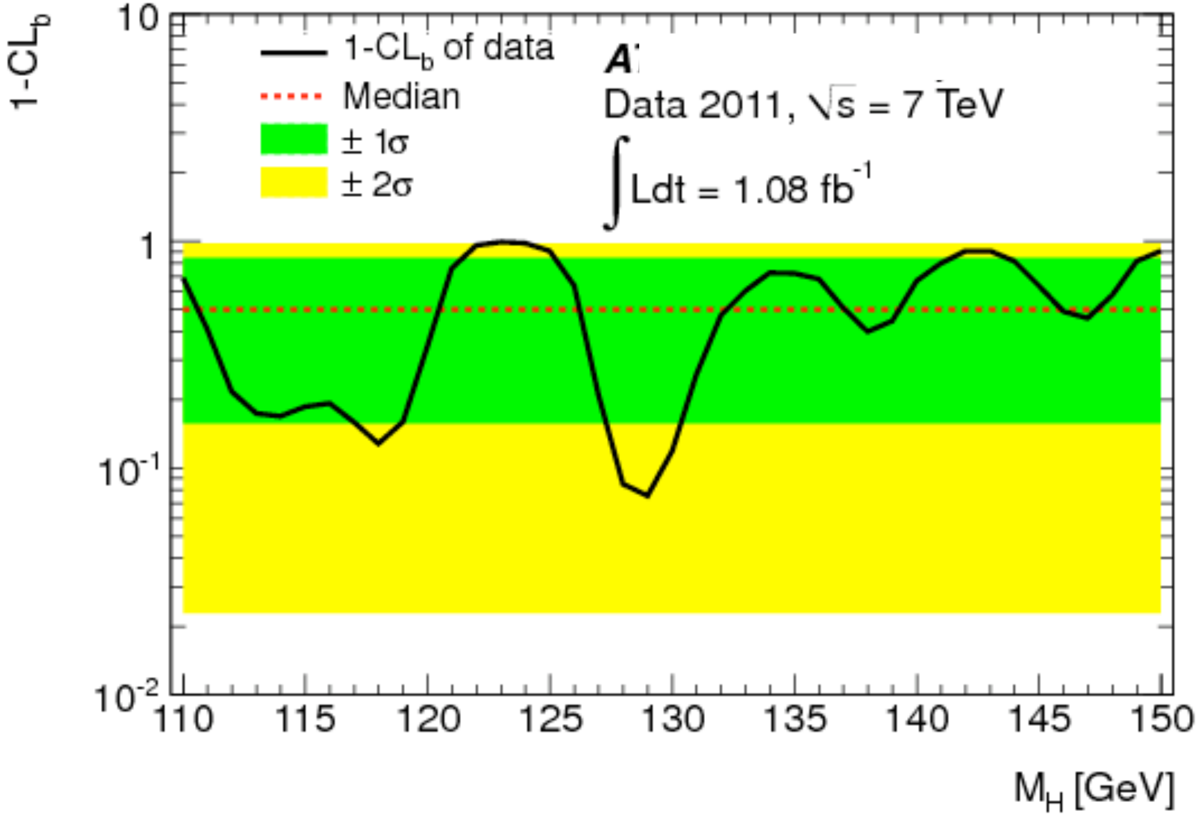
Reconstruction and Identification Efficiency	**11%**
Isolation efficiency	**3%**
Trigger efficiency	**1%**
Luminosity	**3.7%**
Higgs P_T reweighting (Reweight Powheg MC Higgs P_T to that of HqT)	**1%**

Uncertainty on Signal Resolution ~ 14%

Energy Calibration Uncertainty	**12%**
Energy correction extrapolated from $Z \rightarrow ee$ data	**6%**
Pile-up impact on energy measurement	**<3%**
Photon position measurement	**1%**

Uncertainty on background modeling is studied and found to have little impact on sensitivity.

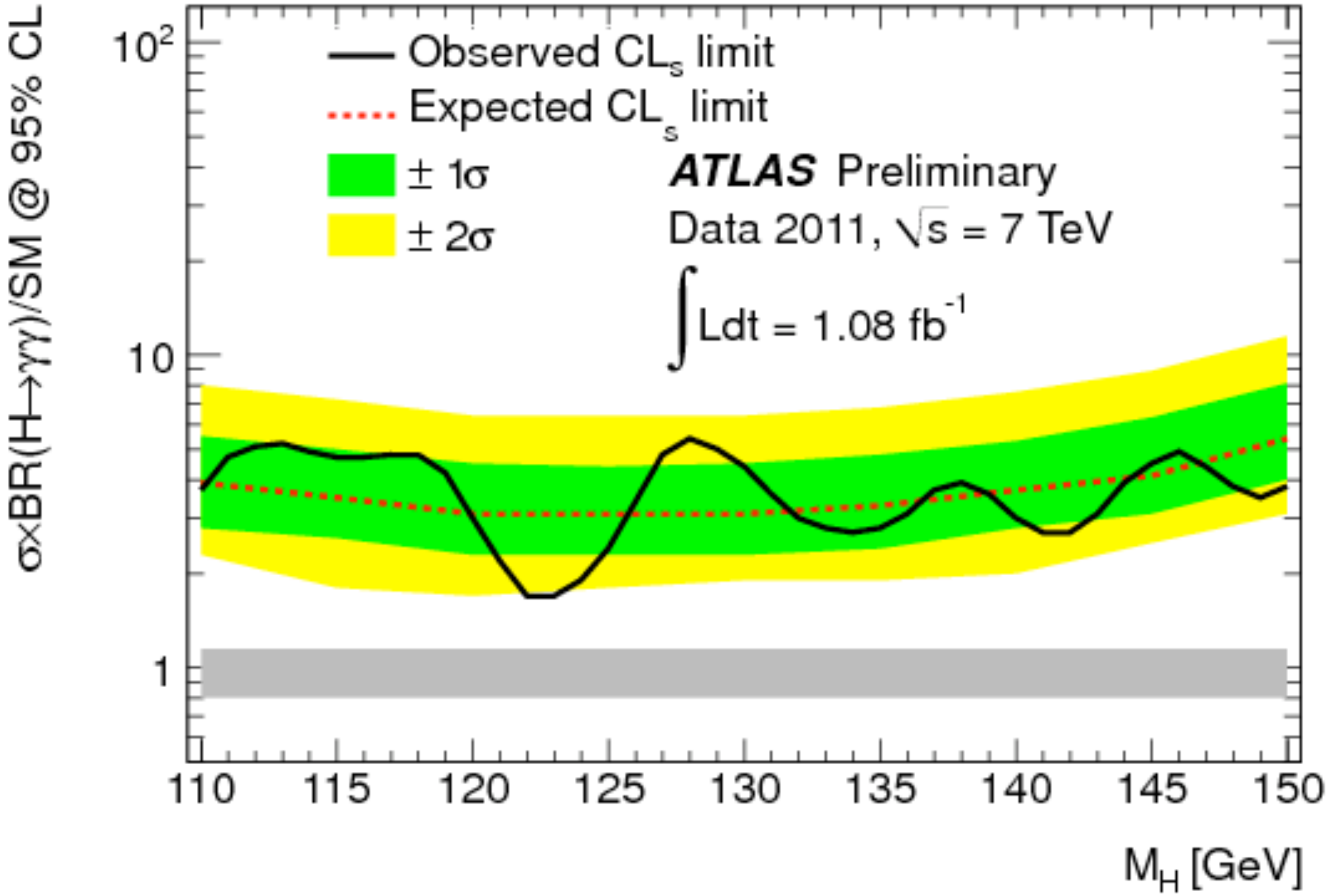
Any significant excess?



The largest excess is at 128GeV, and p-value of this excess is ~ 5%, well below 2sigma.

Limit on SM Higgs

Given the fact that no significant excess is observed, we set a limit on the SM Higgs production cross section.



The tightest CLs limit is observed at 122GeV and 123GeV where 1.6 times the SM expectation is excluded.
The least stringent CLs limit is observed at 128GeV where 5.4 times the SM expectation is excluded.

Conclusion and Outlook

- A new version of $H \rightarrow \gamma\gamma$ analysis using conversion and eta categories is designed and the expected sensitivity is improved ~ O(10)%, with respect to the inclusive analysis performed for previous conferences(Moriond and PLHC).
- A search for diphoton resonance in the mass region relevant to Higgs boson search is performed using $1.08 fb^{-1}$ collected by ATLAS detector this year. No significant excess is found.
- 1.6-5.4 X SM Higgs cross section is excluded in the mass region between 110GeV and 150GeV.
- Remarkable progress has been made since the start of 7 TeV run , but further improvements are still possible:
  - Jet category analysis
  - Additional discriminating variables.
  - WH,ZH,ttH analyses