Search for the scalar boson in the diphoton channel in ATLAS

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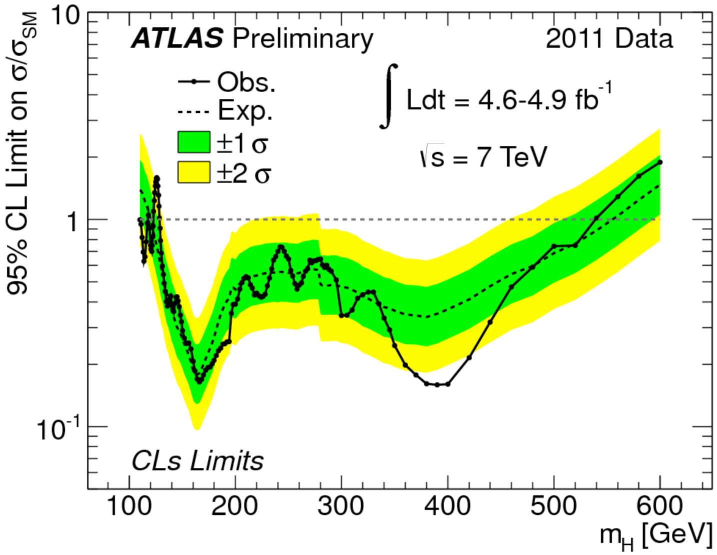
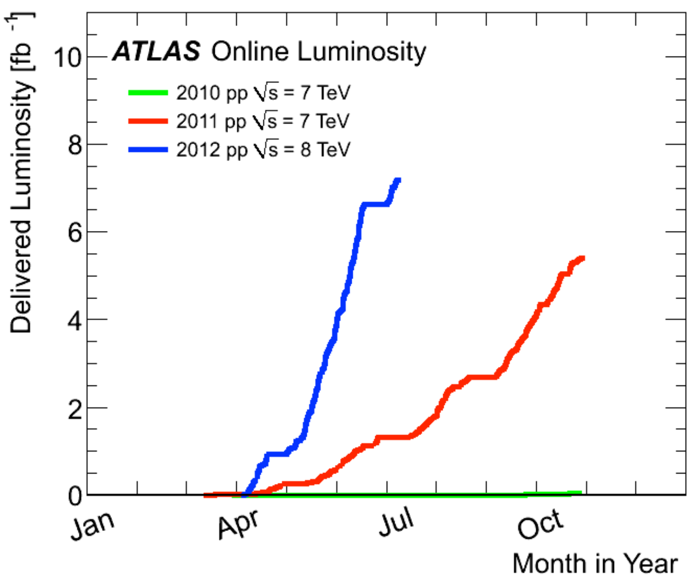
On behalf of the *ATLAS* Collaboration

Introduction





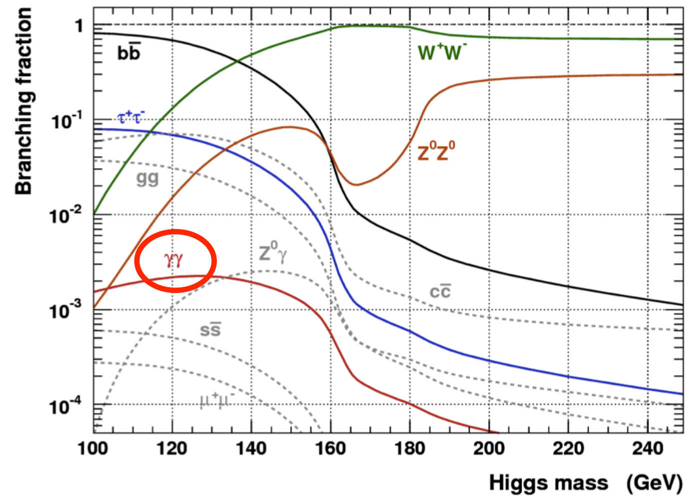
Moriond 2012 (~5 fb^{-1} at 7 TeV):

- Only mass range not excluded at the 99% CL is 115 − 130 GeV!
- Close to 3σ local excess around 126 GeV (mainly from $H \rightarrow \gamma\gamma$)

Result presented today:

- Improved analysis of 7 TeV dataset
- Combined result with new 8 TeV dataset (~11 fb^{-1} in total)

H → γγ at the LHC

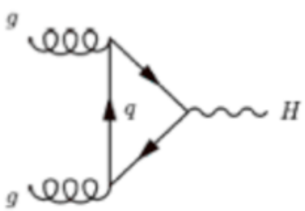


Within the SM, small BR ~0.2%

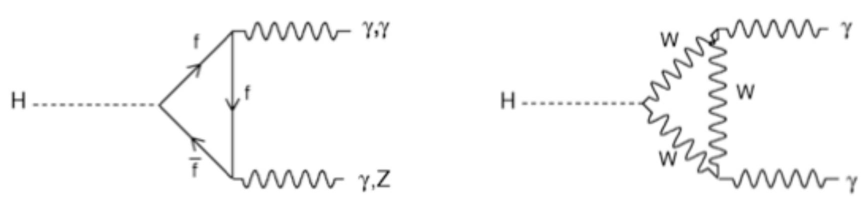
→ Compensate with high mass resolution (1−2%)

Main production and decay through loops

- Sensitive to beyond SM physics
- σ(gg→H) known at NNLO, uncertainty *O*(15%)



gluon-fusion production



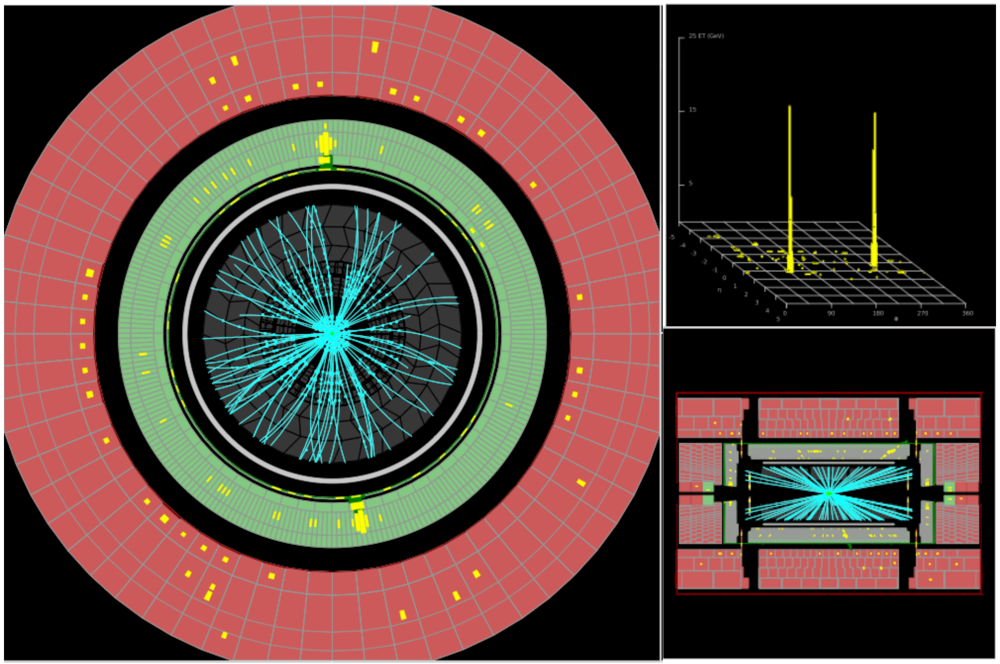
decay to γγ

Large event yield due to the large gluon-fusion production rate, simple signature, effective triggering, simple analysis selection

~40% final selection efficiency ~200 events in 11/fb S/B ~10%

Relevant analysis aspects

Clean discovery channel: Select events with two isolated high p_T photons. Look for bump in steeply falling diphoton mass spectrum



$p_{T1} > 40$ GeV, $p_{T2} > 30$ GeV

Relevant aspects:

- Photon identification / background rejection
- Good diphoton mass resolution
- Background estimation / signal extraction

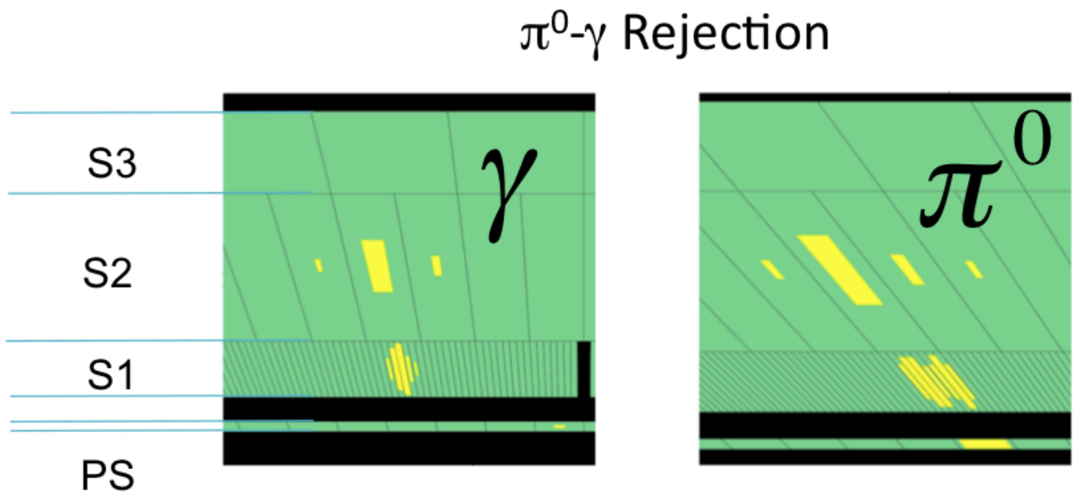
Main focus in past months/year:

- Further optimise analysis using 2011 data, keep 2012 data blinded
- Prepare for 2012 pileup challenges

Photon selection I.

Photon reco and selection based on longitudinal and lateral shower profile

- Shower shape variables in S2
- Fine S1 granularity ~0.003 in η
- Calorimeter based isolation



→ *New:* NN based photon selection (+8-9% efficiency w/ same jet-rejection)

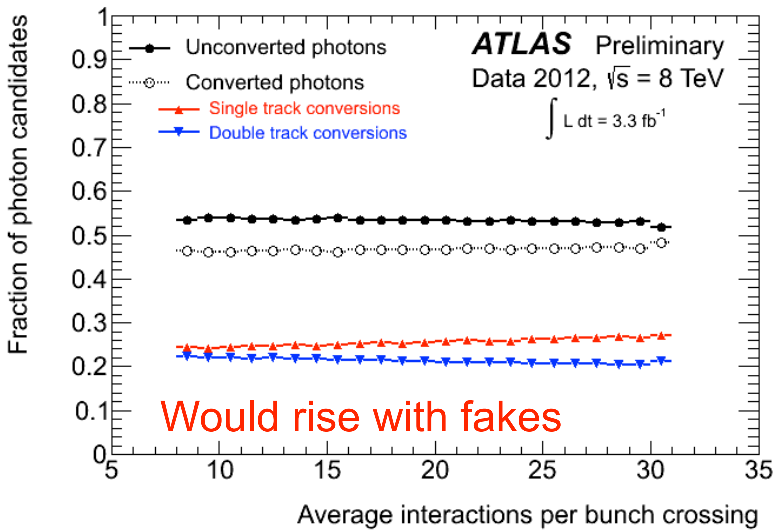
(So far only used in the 2011 selection.)

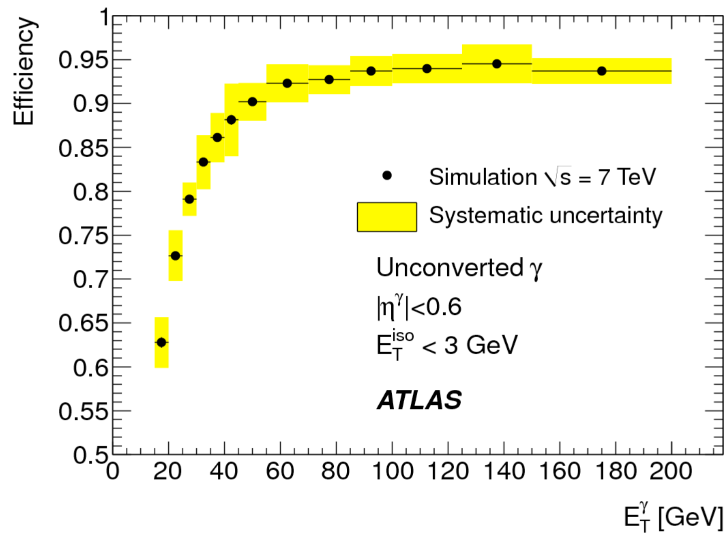
→ *New:* Improved isolation with pile-up robust noise subtraction algorithm

Photon selection II.

Conversion reconstruction in the inner detector crucial for this analysis

- Apply dedicated identification criteria and calorimeter energy correction
- *New:* more robust conversion finding for high pileup





Photon selection efficiency cross-checked with several data based methods

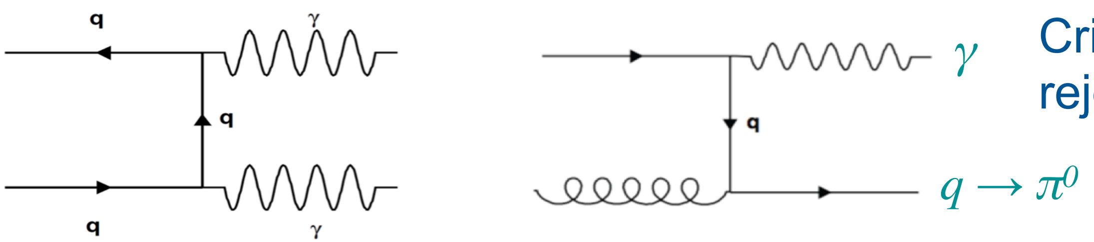
($Z\rightarrow ll\gamma$ events, $Z\rightarrow ee$ extrapolating e to γ, isolated direct γ events)

Typical uncertainty ~5% (gives dominant uncertainty on signal yield ~10%)

Diphoton selection

Main backgrounds

- Irreducible: SM $\gamma\gamma$ production
- Reducible: γj, jj production with $q/g \rightarrow \pi^0$



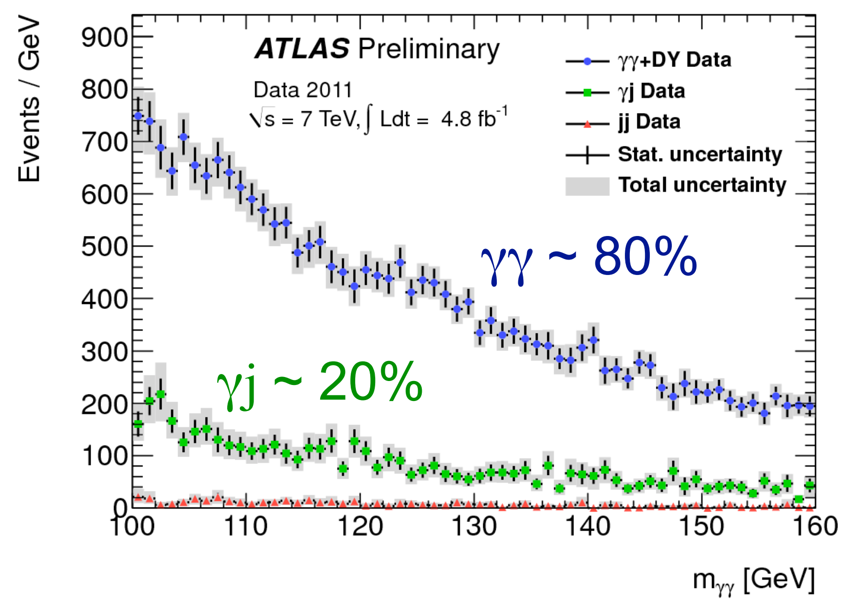
Irreducible

Reducible

Critical to reach rejections $O(10^4)$

Estimate diphoton sample composition with different data based methods

$\gamma\gamma$ purity: (80/75 ± 4)%
in 2011/2012 selection



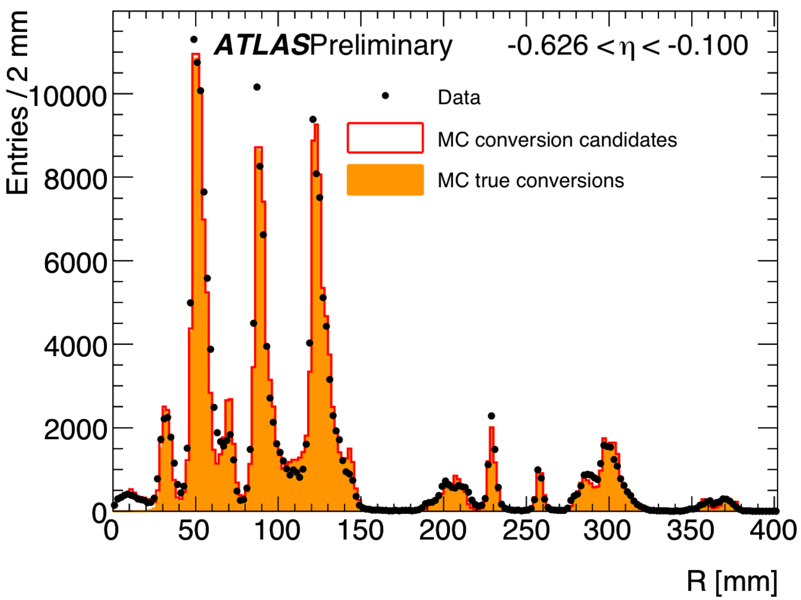
Photon energy calibration

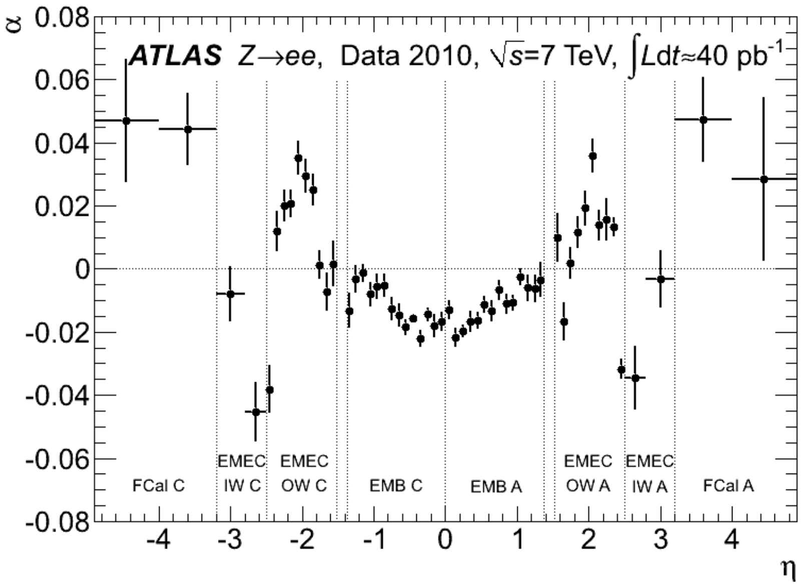
MC based calibration at cluster level tuned in test beam

Need accurate material description for $e \rightarrow \gamma$ extrapolation

(Cross checked with photon conversions, hadronic interactions, EM shower shapes and E/p, …)

Energy scale corrections from Z decay to electrons (scarce γ calibration signal)

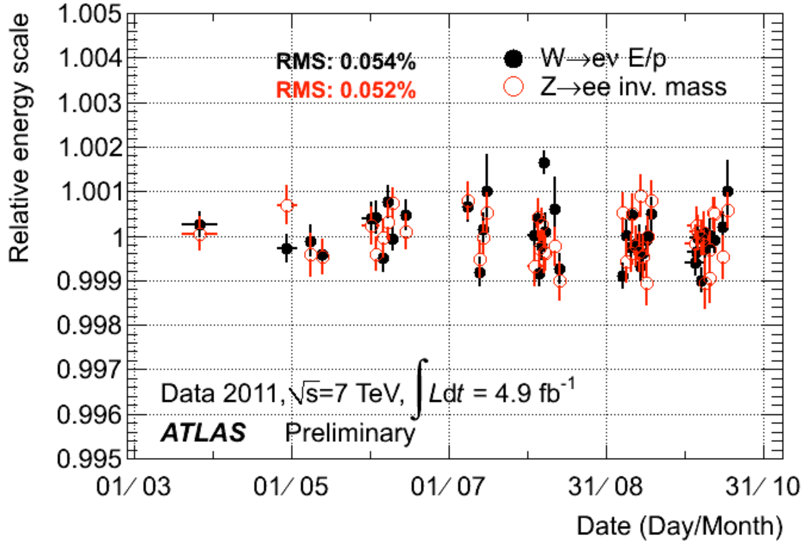


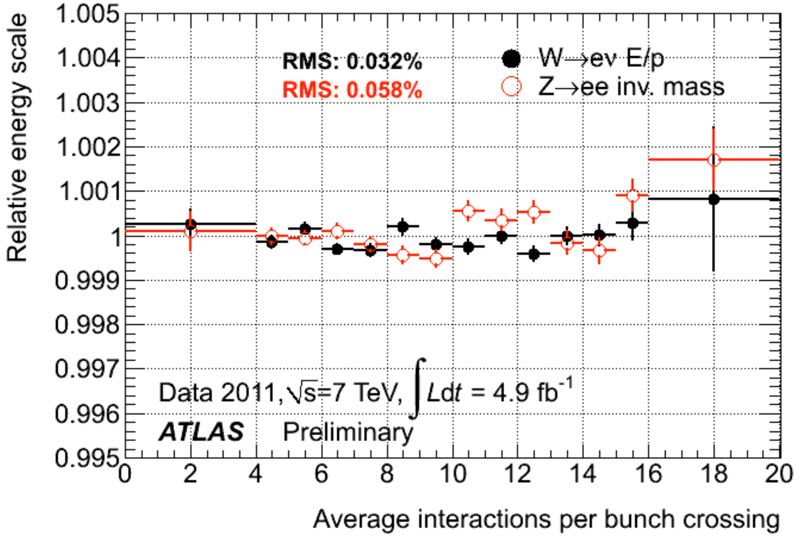


Calibration checks

In-situ energy calibration results and their stability checked with different methods (E/p with W $\rightarrow e\nu$, J/$\psi \rightarrow$ ee)

Stability of EM calorimeter response vs time/pile-up better than 0.1%





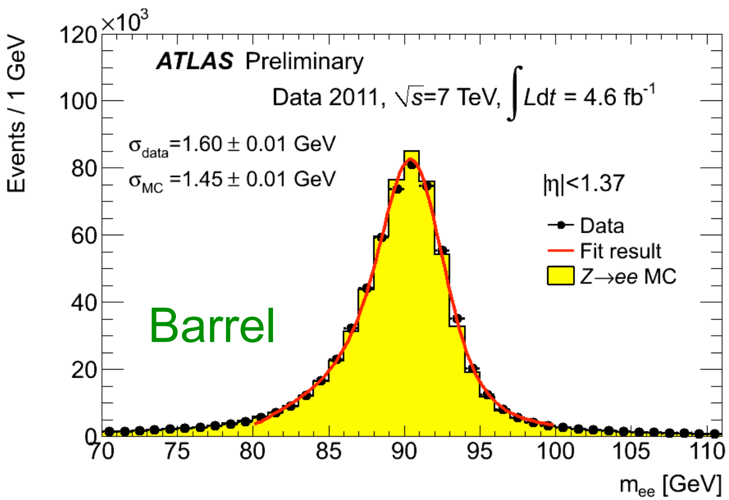
Uncertainty on the diphoton mass scale 0.6% (correlated between 7/8 TeV data)

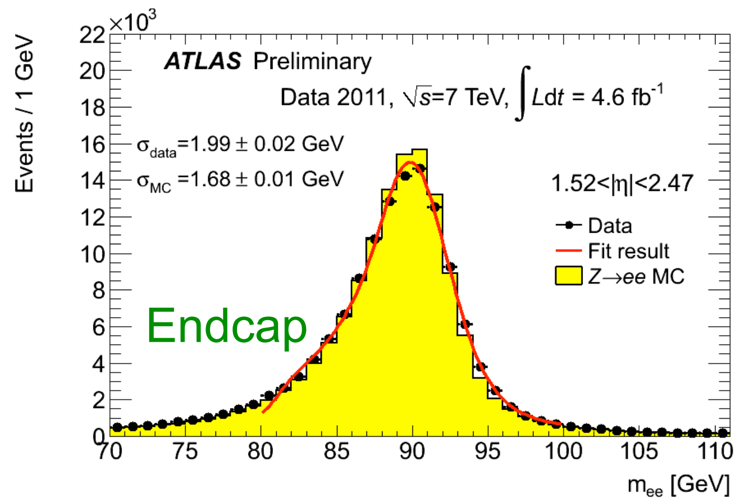
- Material effects (separately for volumes before and after $|\eta| = 1.8$)
- Presampler scale (separately for barrel and end-cap)
- Uncertainty on the in-situ calibration method

Photon energy resolution

Resolution corrections to the MC derived from Z decay to electrons

- Add effective constant term to perfect MC resolutions through smearing
- 1% in barrel, 1.2 − 2.1% in endcap





Uncertainty on photon energy resolution:

- Uncertainty on sampling term (from test-beam)
- Uncertainty in ‘effective’ constant term
- Uncertainty on e→γ extrapolation (material upstream calorimeter)

→ 12% uncertainty on diphoton mass resolution

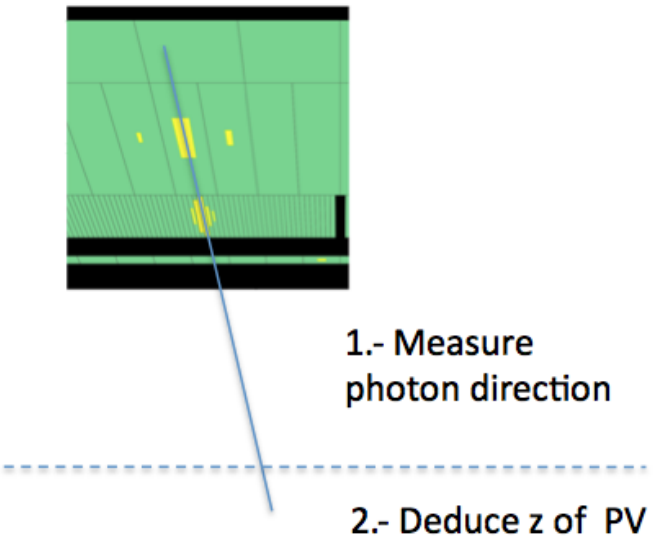
Photon polar angle measurement

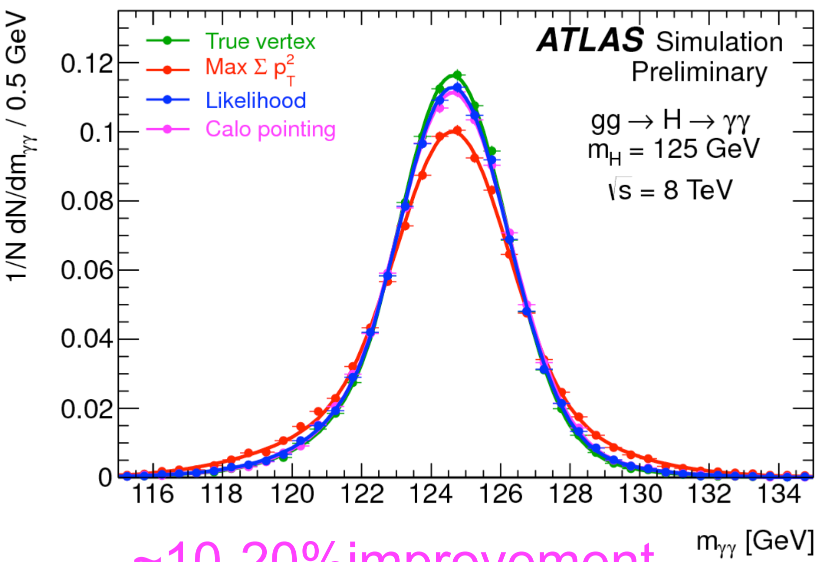
Important ingredient for mass resolution

$$m_{\gamma\gamma}^2 = 2E_1E_2(1-\cos\theta)$$

Beam spot spread ~5-6 cm, assuming detector centre origin adds 1.4 GeV in mass resolution (equivalent to intrinsic CAL resolution)

Resolution with pointing ~1.5 cm, better when conversion vertex used





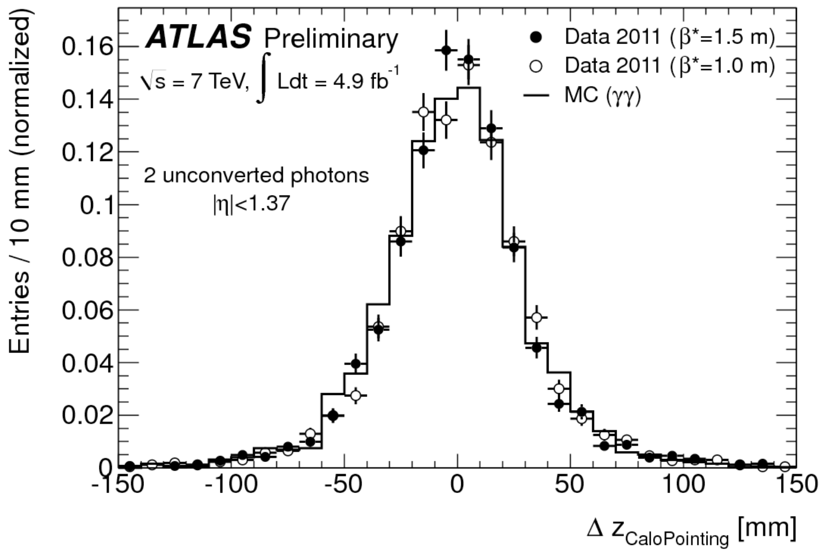
~10-20%improvement

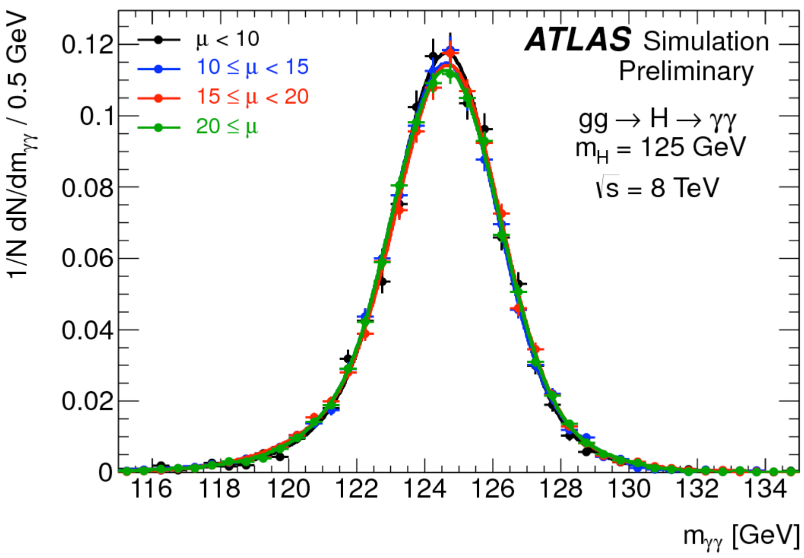
Primary vertex selection

Identify specific vertex with Likelihood combining information from pointing and track based vertex selection (needed to reject jets from pile-up)

Check pointing resolution in data with electrons, where track gives ‘true’ angle

Mass resolution pile-up robust with pointing



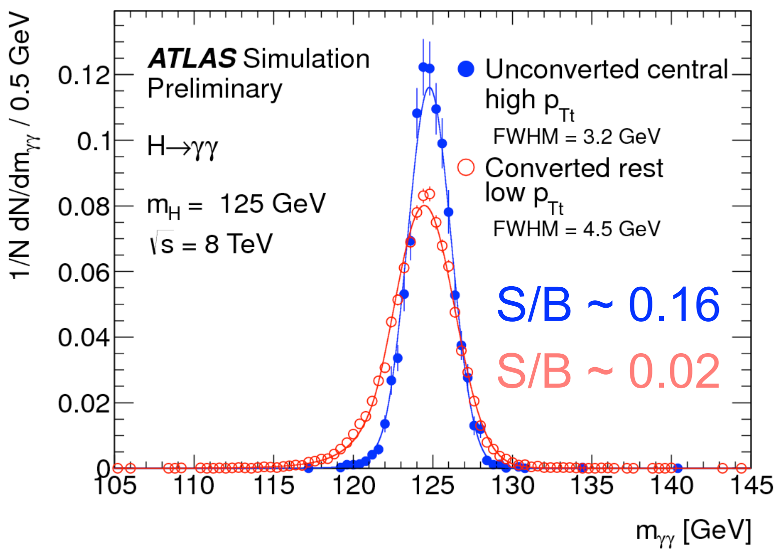


Events categorisation

Separate events into categories with different S/B and resolutions, based on:

- *New:* Vector boson fusion (VBF) signature category
- Presence of photon conversions
- Photon impact point on CAL
- Diphoton p_T related variable

→ 25% increase in expected sensitivity



Examples:

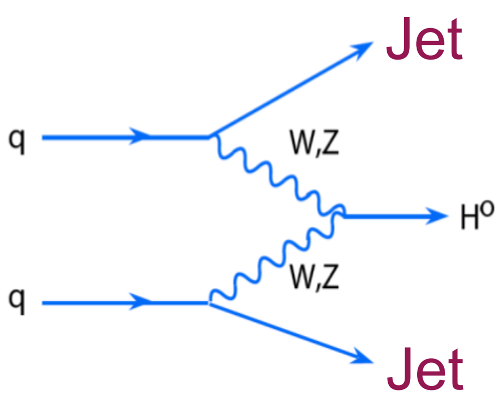
- Both γ unconverted and central, high $\gamma\gamma$ p_T
- At least one γ converted and not central, low $\gamma\gamma$ p_T

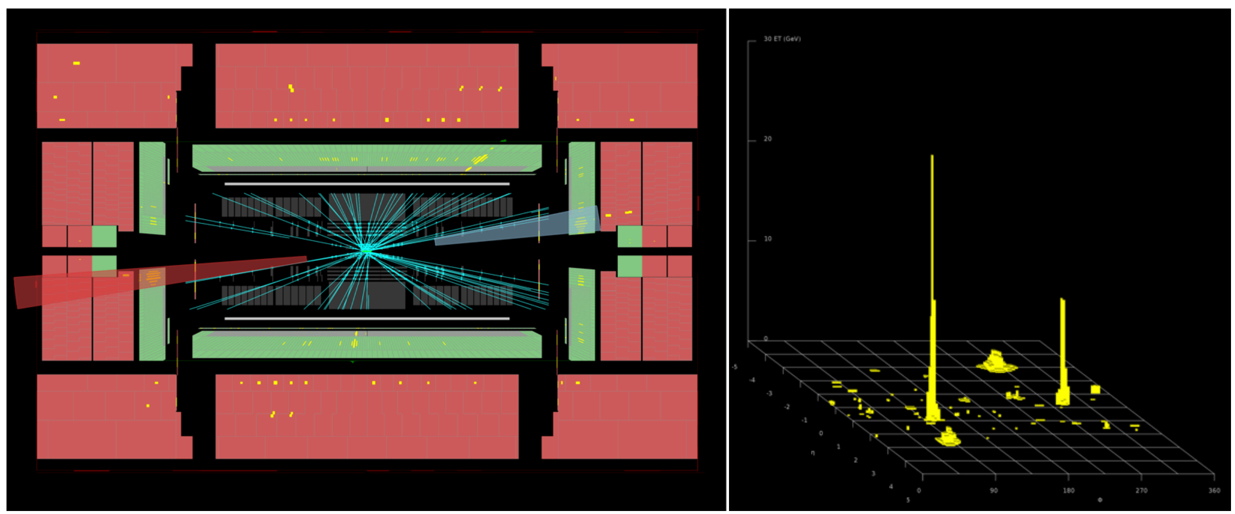
Signal model: sum of Crystal Ball and Gaussian functions

VBF signature category

To enhance and separate sensitivity to Higgs production in VBF, separate events consistent with VBF signature

- Two high pT jets from the PV and $\Delta\phi_{\gamma\gamma\text{-}jj} > 2.6$
- Separated in rapidity: $\Delta\eta_{jj} > 2.8$ and $m_{jj} > 400$ GeV





VBF purity ~70% of total signal contribution in this selection category

Large uncertainties on selected gluon-fusion events due to uncertainties on the perturbative calculation (25%) and UE model (30%)

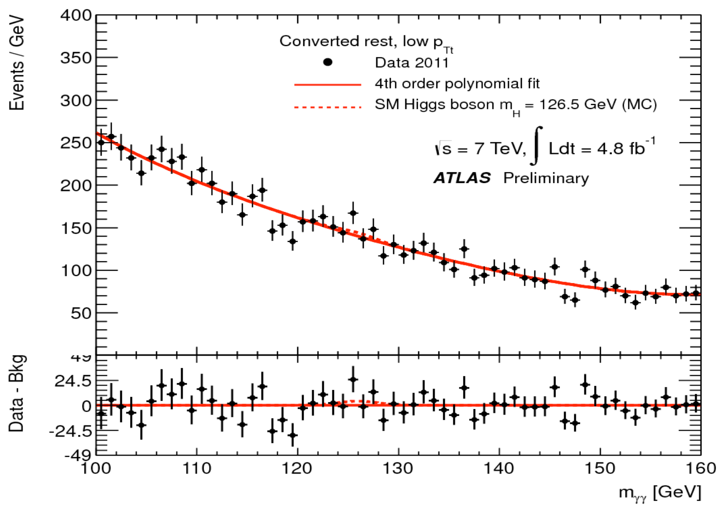
Background model

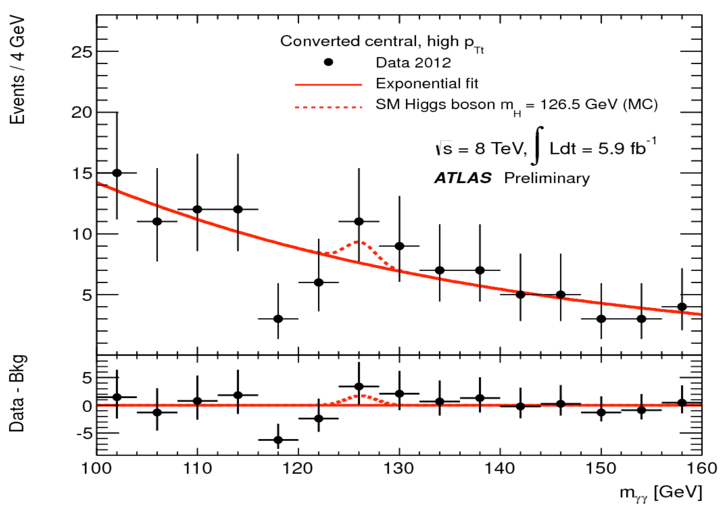
To choose a fit model for each category, use:

- Several different high statistics simulations with and w/o parameterised corrections for detector resolution and acceptance
- Data driven background estimates/cross checks

→ Require that for each of these the fit bias is <10% of expected signal or <20% of √B at any mass point in the search range

The residual small bias is taken into account as systematic uncertainty

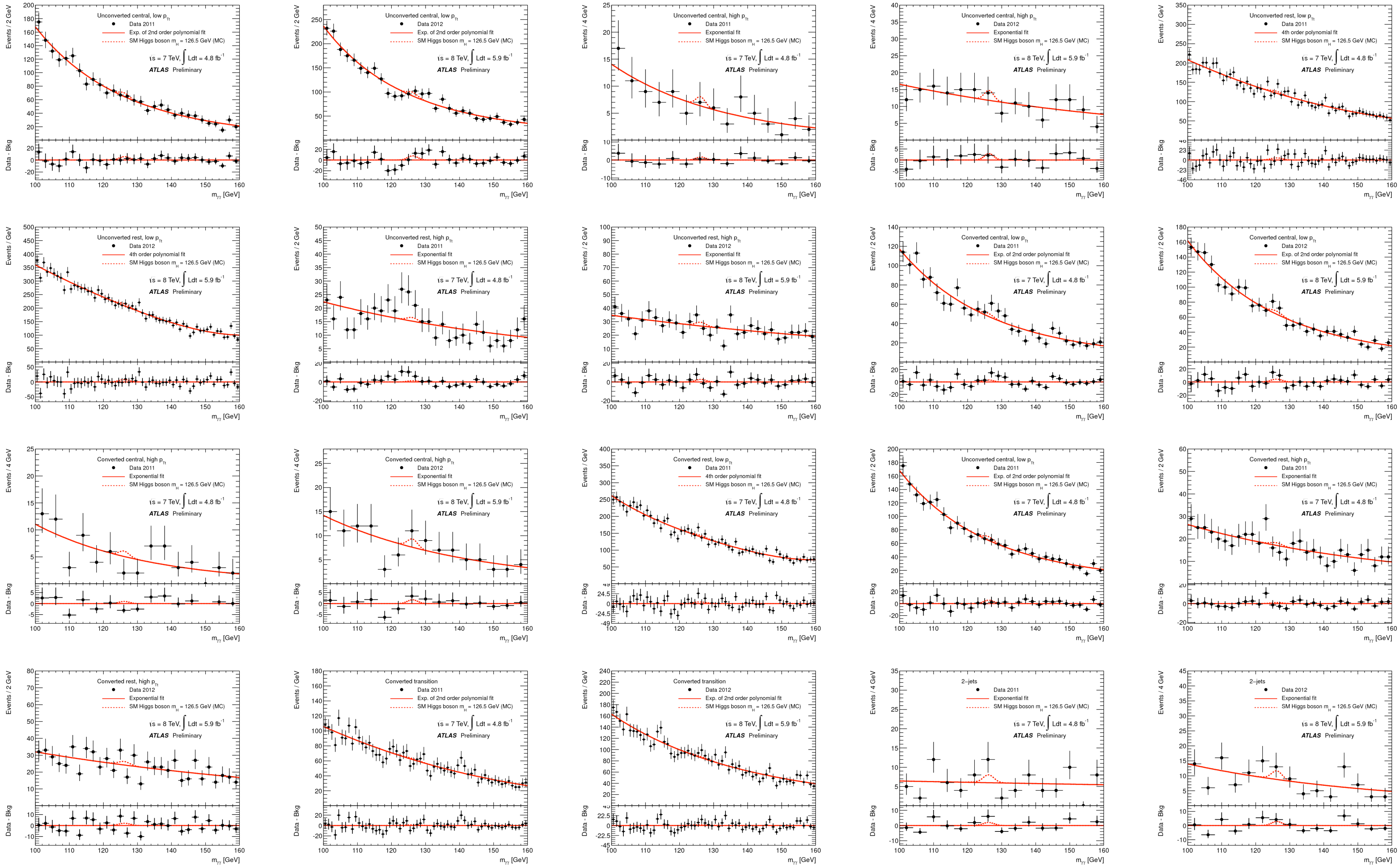




Higher stat. categories: polynomial based, lower stat. categories: exponential

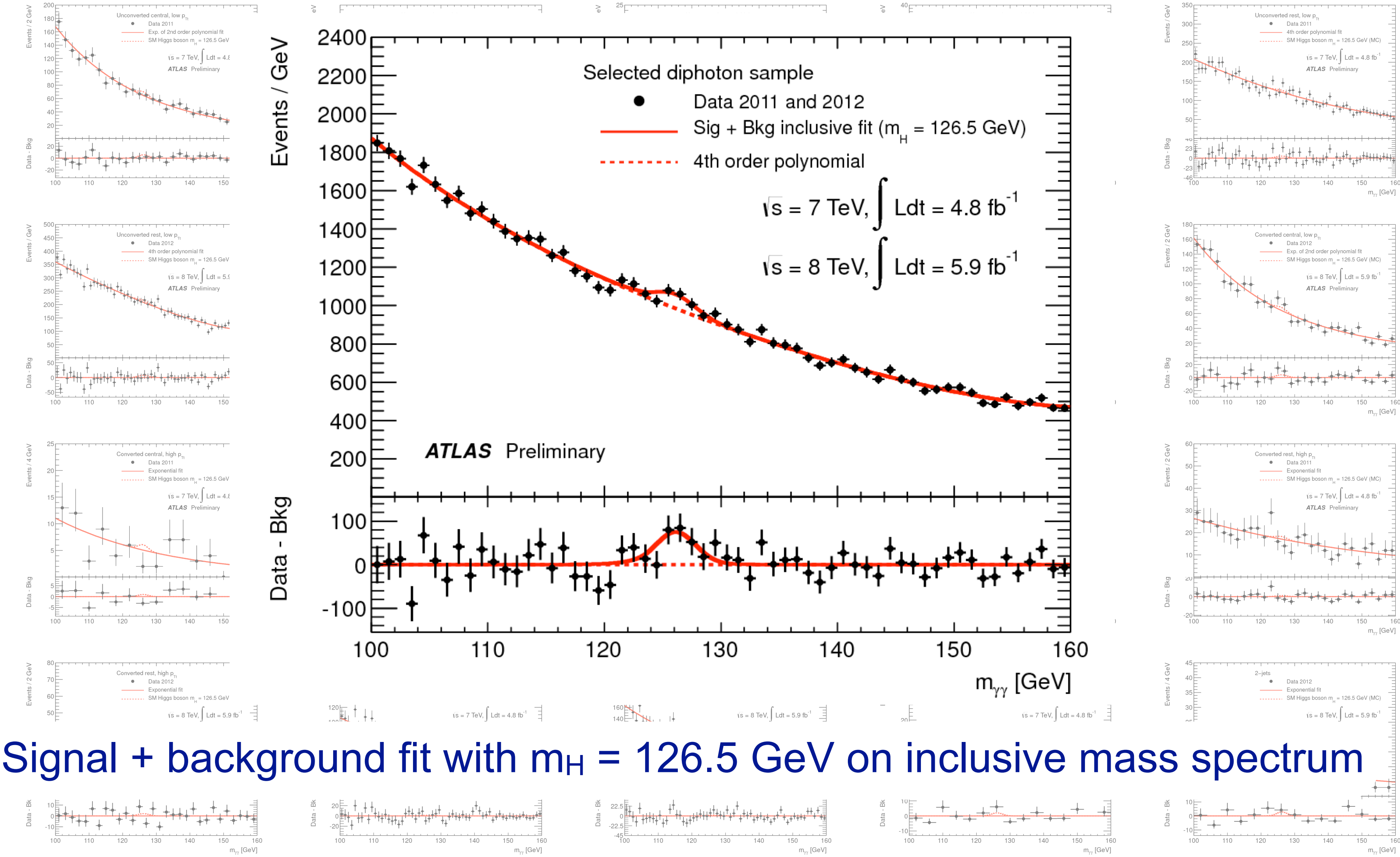
Mass spectrum

Mass spectra of the individual categories consisting the final result



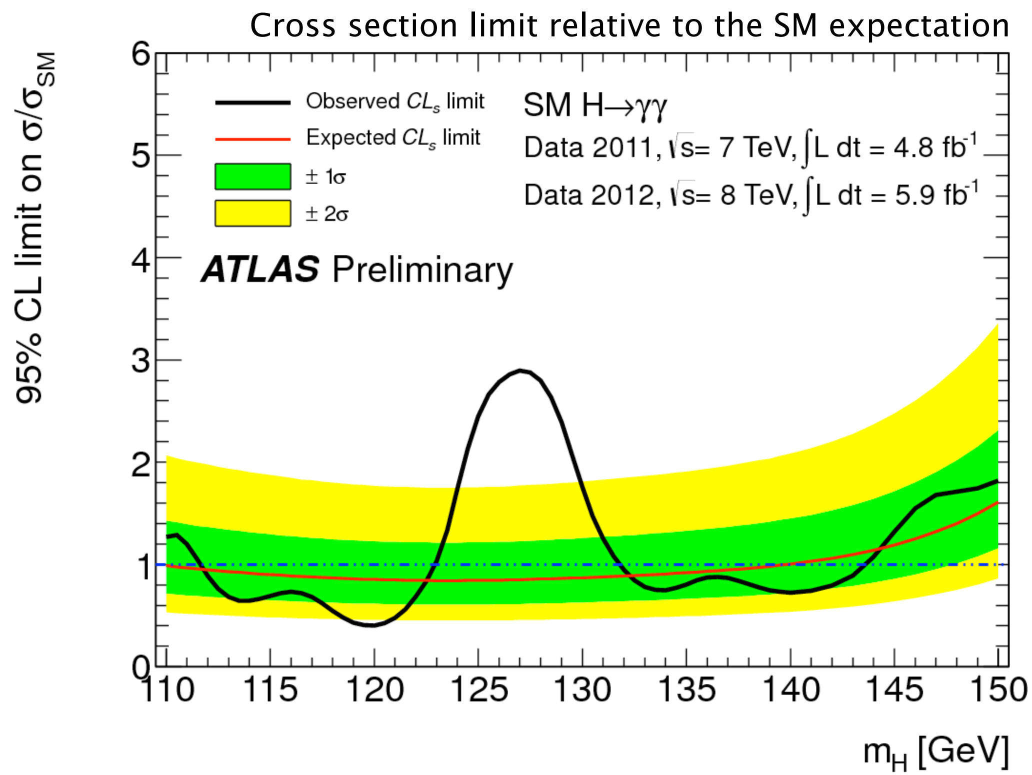
Mass spectrum

After final selection 59059 events in the combined dataset



Signal + background fit with m_H = 126.5 GeV on inclusive mass spectrum

Exclusion limits

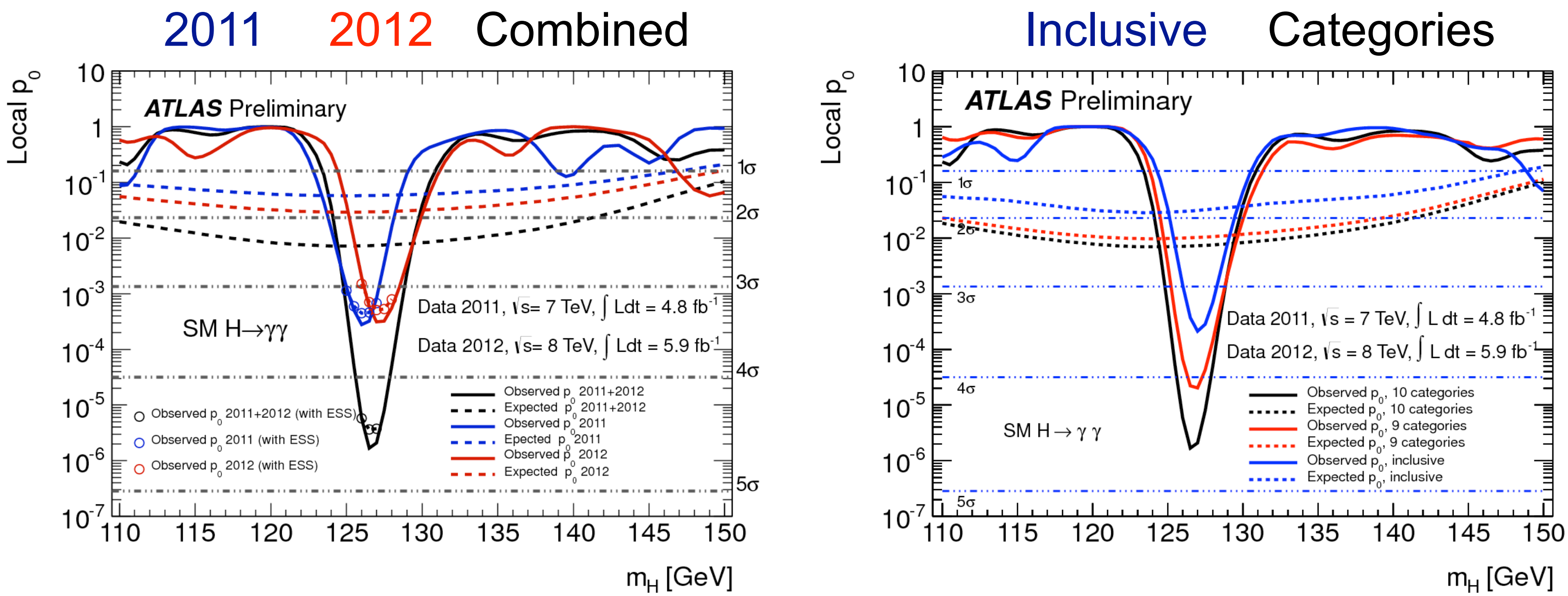


Sensitivity below SM expectation in whole search range up to 140 GeV

Excluded at 95% CL: 112-122.5 GeV, 132-143 GeV

Excess around $m_{\gamma\gamma}$ ~126 GeV

Quantifying excess



Maximum deviation from background only expectation at $m_{\gamma\gamma}$ = 126.5 GeV

→ Local significance 4.5σ (expected from SM Higgs 2.4σ)

Global significance (including LEE) 3.6σ

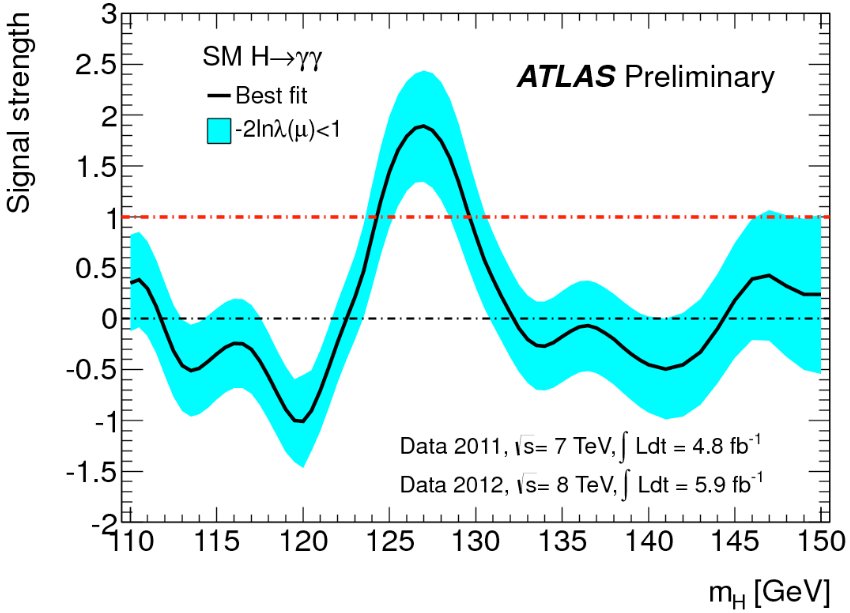
Excess consistent in both datasets, and in inclusive analysis without categories

Best-fit signal strength

Fit S+B hypothesis to observed data, allow signal strength to vary

→ Obtain best-fit signal strength

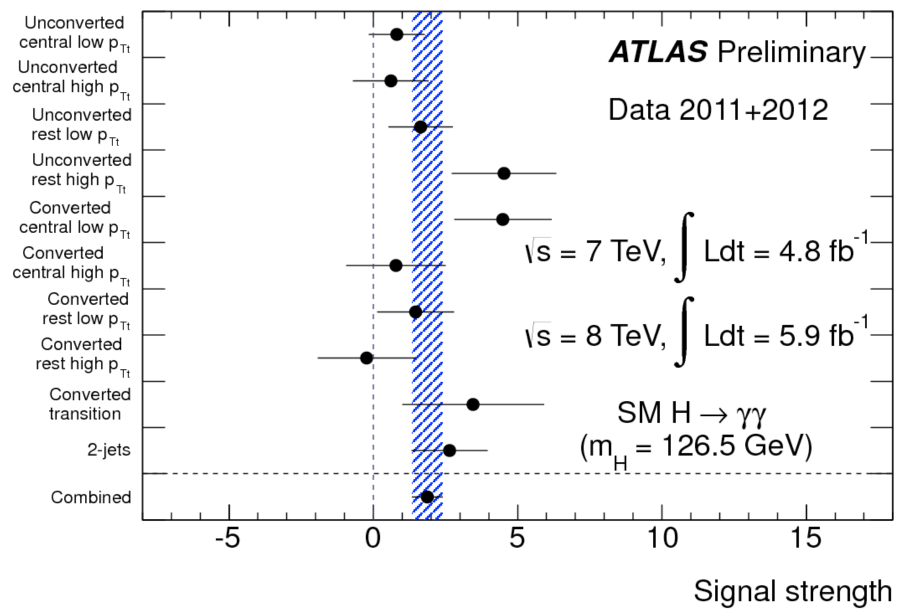
Best-fit signal strength



Best fit for m_H =126.5 GeV

$\mu = 1.9 \pm 0.5$

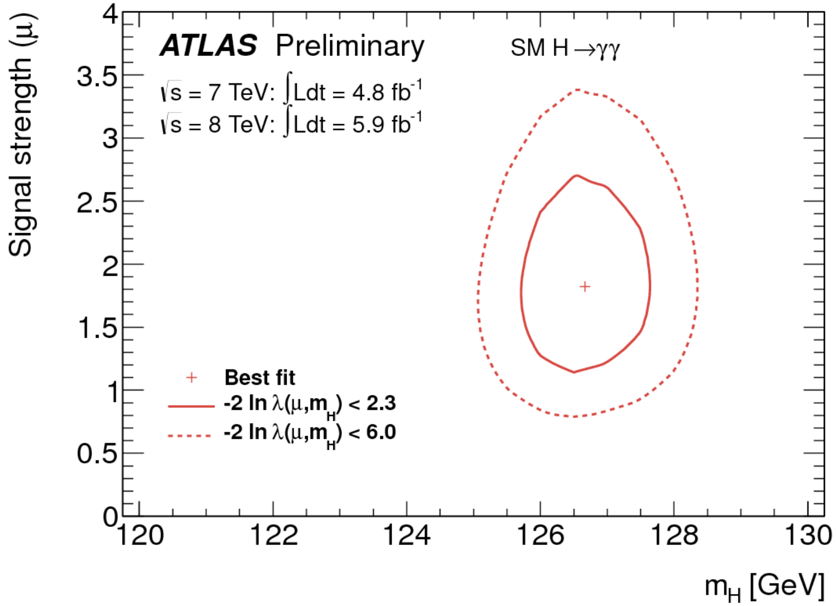
Per category



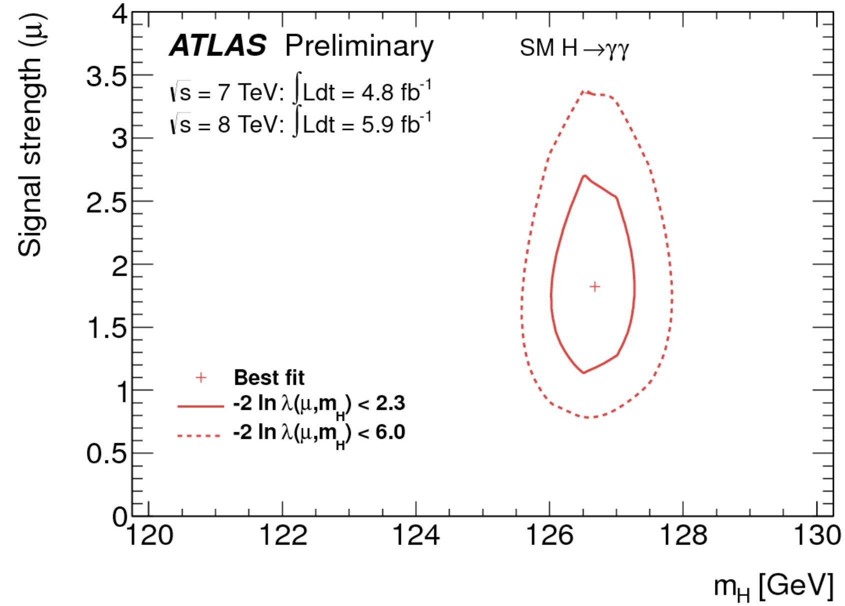
Consistent results from different categories

Best-fit signal strength vs mass

With ES systematic uncertainty



Without ES systematic uncertainty



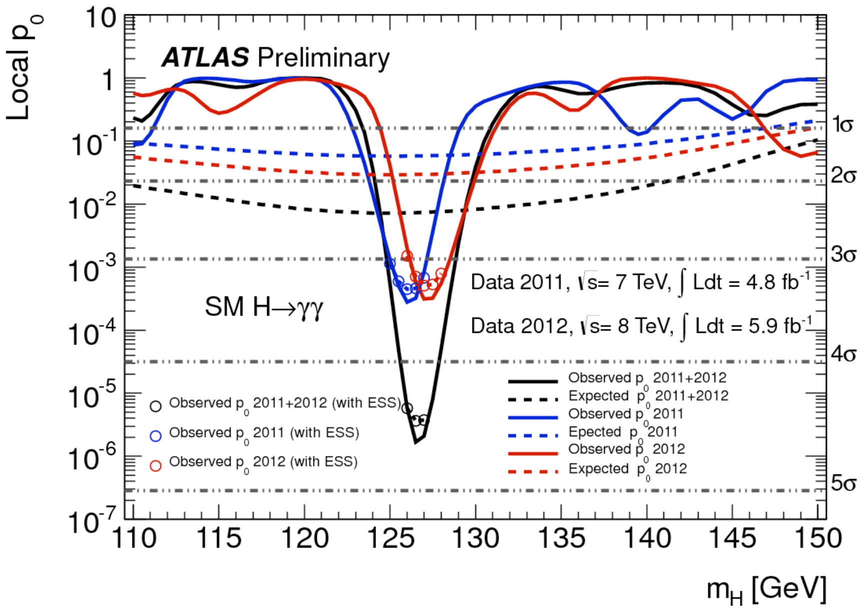
Likelihood contours in the (μ, m_H) plane

Uncertainty on best fit position for m_H mainly depends on the statistical uncertainty and energy scale systematics

Conclusions

Observation of a narrow excess in the diphoton mass spectrum around 126.5 GeV with a local significance of 4.5σ (global 3.6σ)

Excess is consistently observed in 2011 and 2012 datasets, in the sharing among categories and in the inclusive analysis



Not from spin 1 decay (Landau-Yang theorem)

Next steps: establish the true nature of symmetry breaking with property measurements → ~126 GeV is the ideal place for the diphoton decay mode!

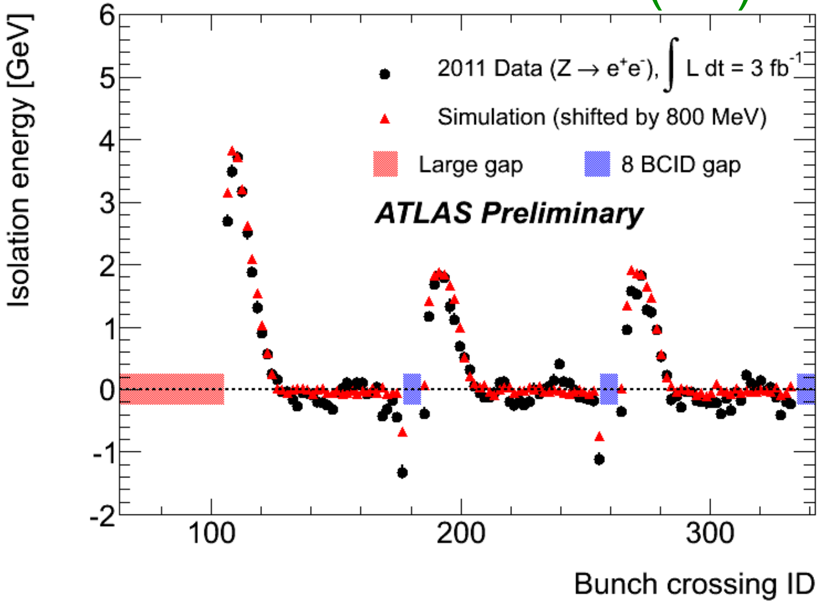
Backup

Photon isolation

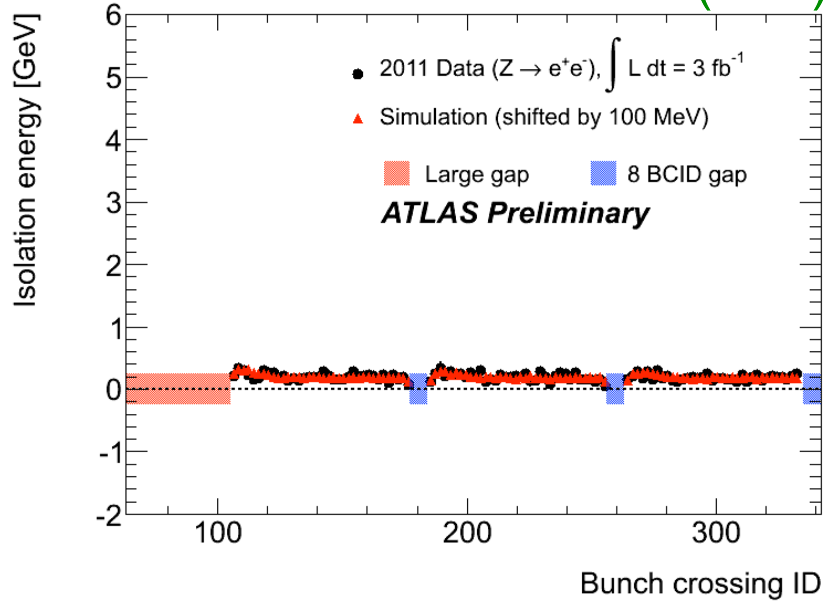
Calorimeter based isolation: E_T < 4 GeV inside cone $\Delta R < 0.4$ around γ

- Corrected for pileup and underlying event contributions by subtracting ambient energy density event-by-event
- *New:* improve pileup robustness with topological clusters which are based on calo cells with significant signal over noise ratio
- Good stability with position of colliding bunches in train → robust with pileup

Cell-based isolation (old)



Cluster-based isolation (new)



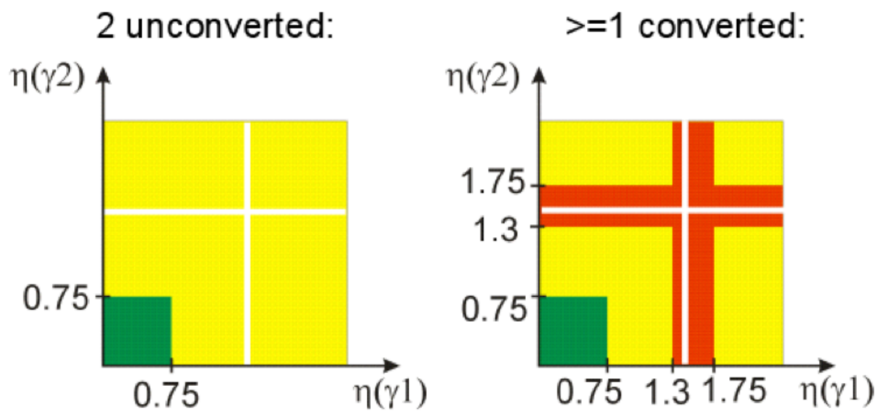
Photon based categories

Both unconverted:

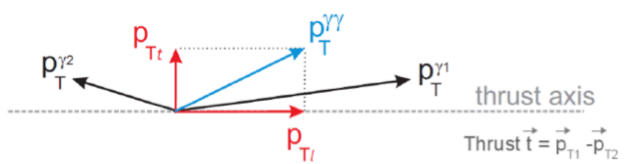
- Central
- Rest

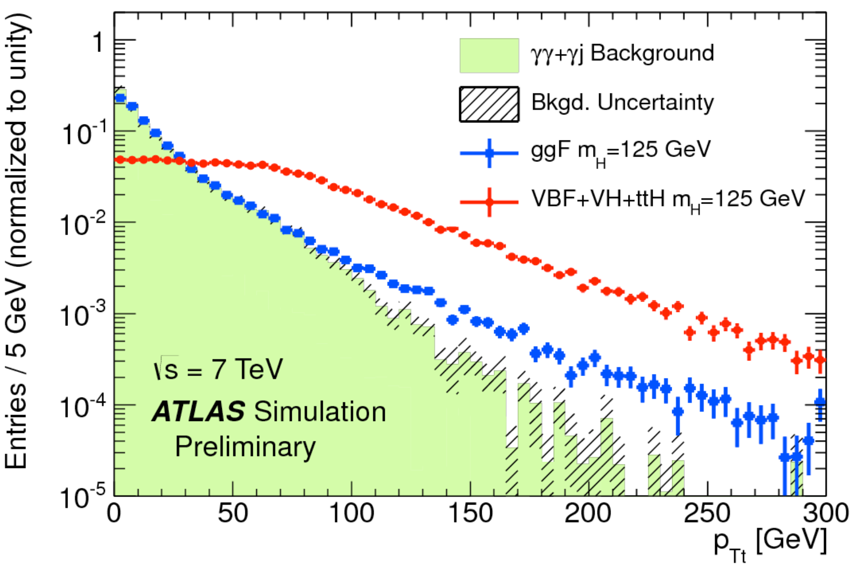
At least one converted:

- Central
- Transition
- Rest



Central and Rest divided into $p_{Tt} < 60\,\mathrm{GeV}$ and $p_{Tt} > 60\,\mathrm{GeV}$





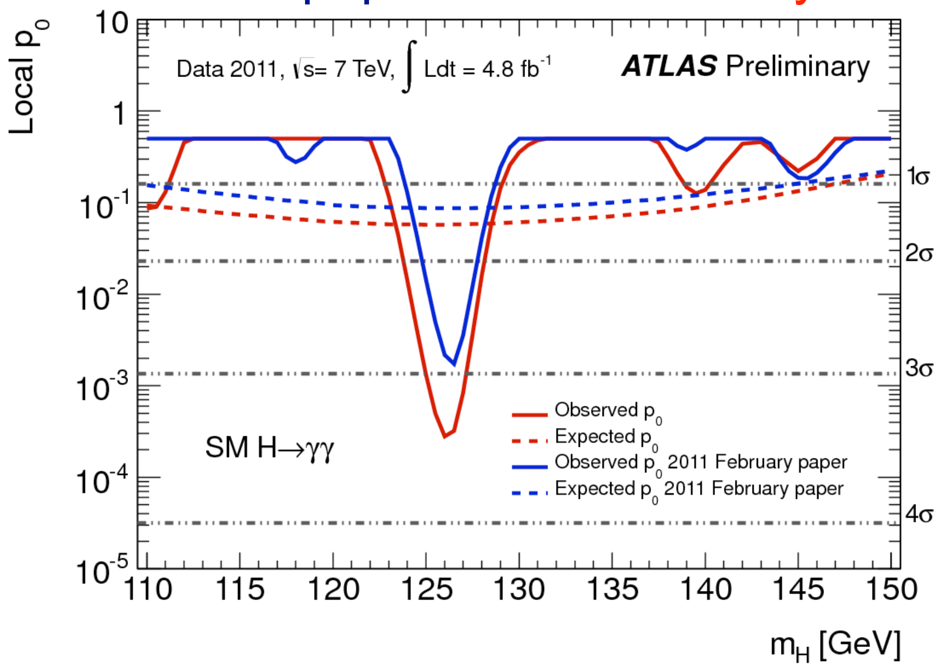
p_{Tt} vs p_T:

- Better detector resolution
- Retains monotonically falling $m_{\gamma\gamma}$ distribution

7 TeV dataset

New analysis of 7 TeV dataset consistent with published result

Febr. paper   New analysis



15% improvement in expected sensitivity:

- Mainly due to improved photon identification and isolation calculation
- Also, VBF category and higher p_{Tt} and sub-leading photon cuts

Best-fit signal strength for separate datasets