Photon performance and search for the Higgs boson in $H \rightarrow Z\gamma \rightarrow ll\gamma$ decay mode

Giovanni Marchiori, Kun Liu, Yanwen Liu

08/04/2014

7th FCPPL workshop @ Clermont-Ferrand

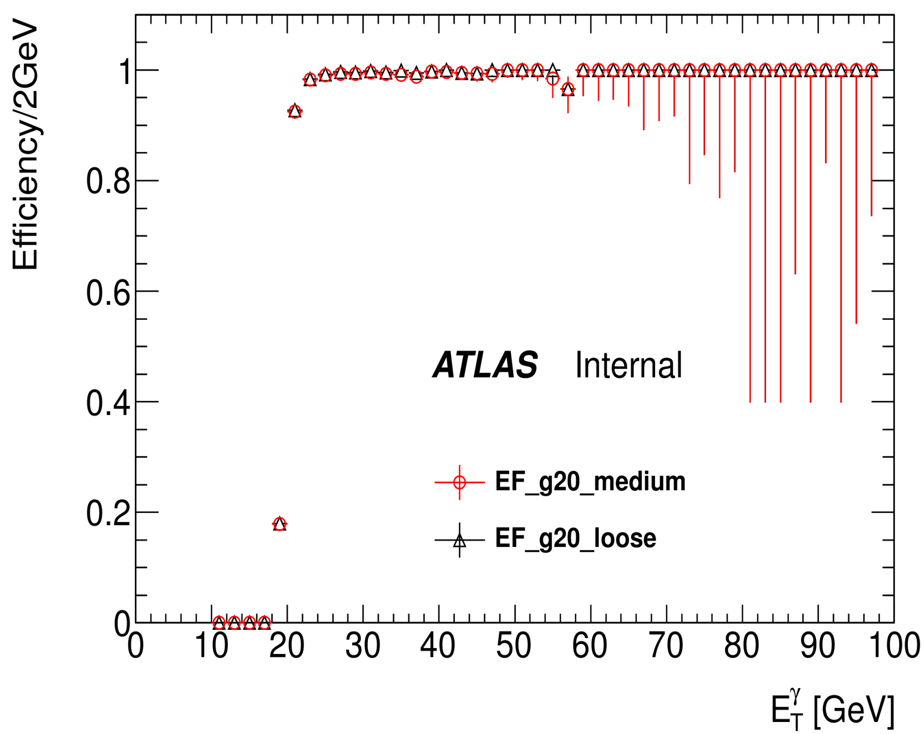
Introduction

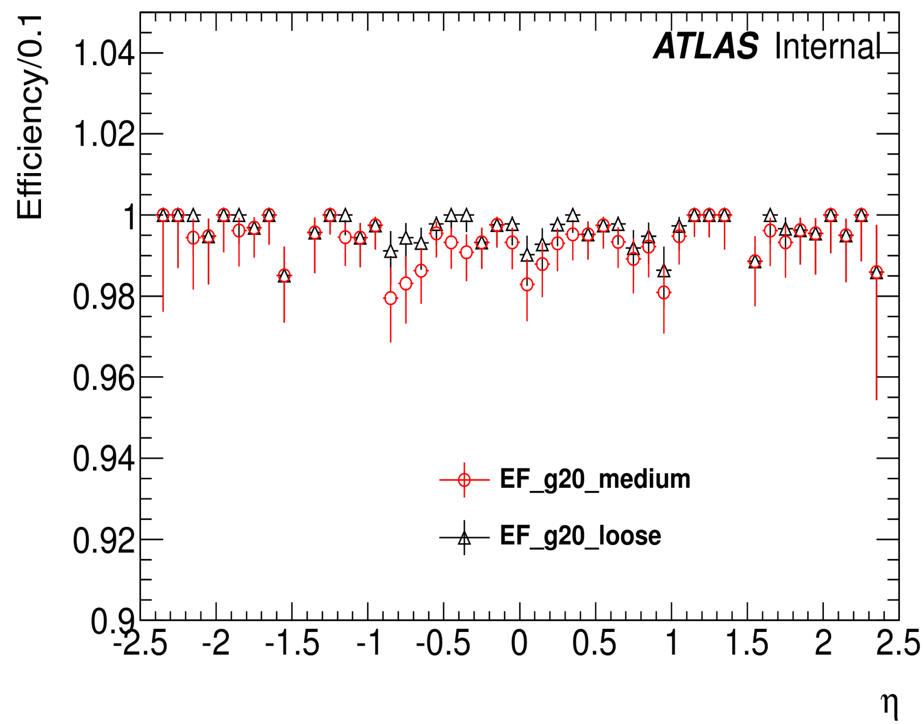
- Photon trigger efficiency measurement
- Photon identification efficiency measurement
- Latest results on the Higgs coupling measurement in $H \to \gamma\gamma$ channel
- Search for the Higgs boson in $H \to Z\gamma \to ll\gamma$ decay mode

Photon trigger performance

- For the high pile up condition in 2012 data, we proposed the medium photon trigger: optimize the criteria used in previous trigger, study new variables which are robust against pile up.
- Trigger efficiency is measured using photons from radiative Z decays.

- The results are used in the H → γγ analysis. In parallel, the measurement is included in the trigger performance paper (in preparation).





Photon identification (ID) efficiency measurement

- Photon off-line identification efficiency is measured with three data-driven methods. It's uncertainty is reduced by combination of the three methods.
- We contributed two of them:
  – radiative Z decays: using pure photons selected from radiative Z decays
  – matrix method: measuring photon purity of two samples: passing ID and inclusive sample.

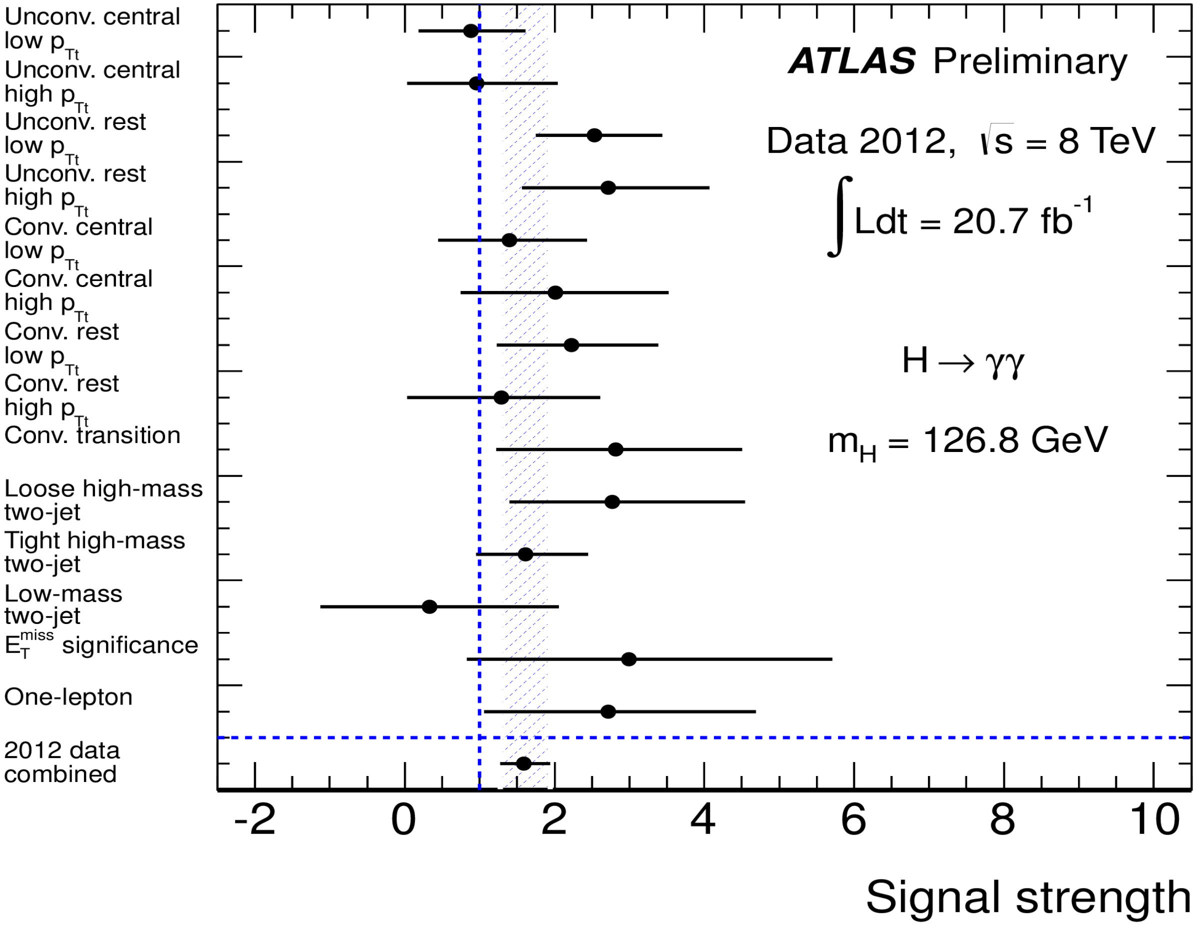
- The results are being finalized and being used in the $H \rightarrow \gamma\gamma$ analysis.
  In parallel, a photon performance paper is preparing based on the photon identification efficiency measurements.

Coupling measurement in $H \rightarrow \gamma\gamma$ channel (Moriond-2013)

- Using m_H= 126.8 GeV and using only 2012 data set

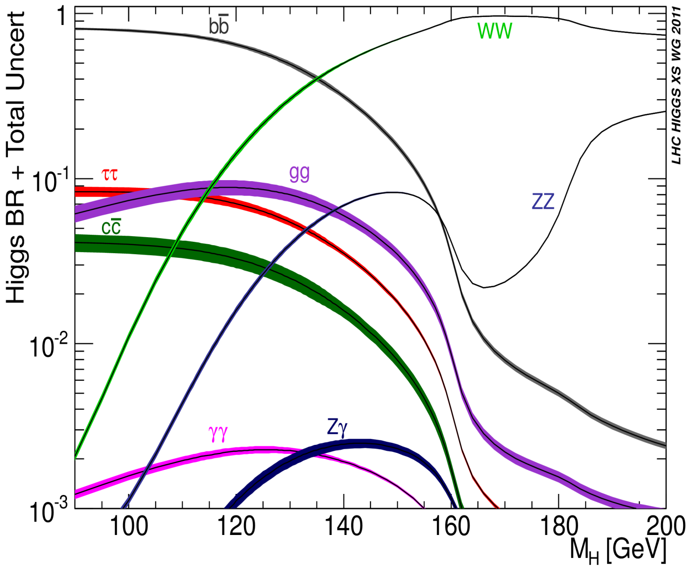
- Inclusive signal strength (μ) : $1.65 \pm 0.24(\text{stat})^{+0.25}_{-0.18}(\text{syst})$
  2.3 σ deviation from the Standard Model.

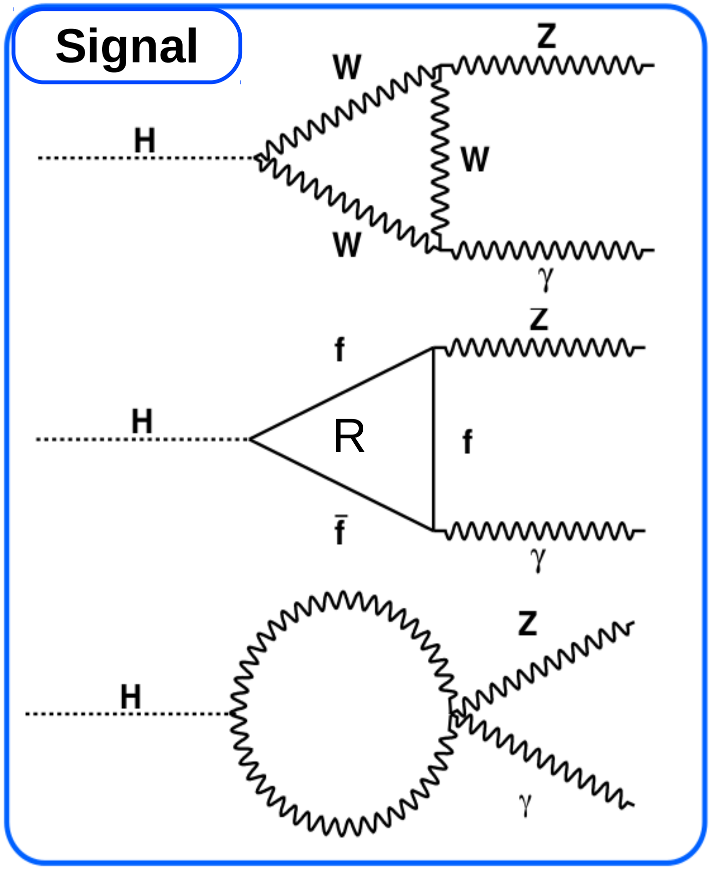
- μ in each category :

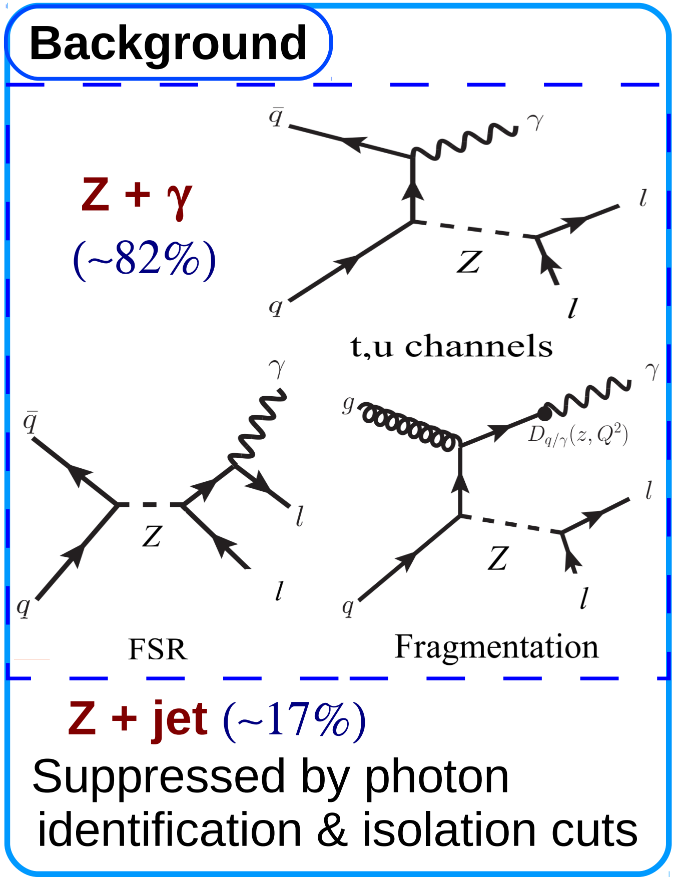


Search for the Higgs Boson in $H \rightarrow Z\gamma \rightarrow ll\gamma$ mode

- In the Standard Model, H → Zγ is rare decay, and proceeds mainly through loops (mostly W-loop).



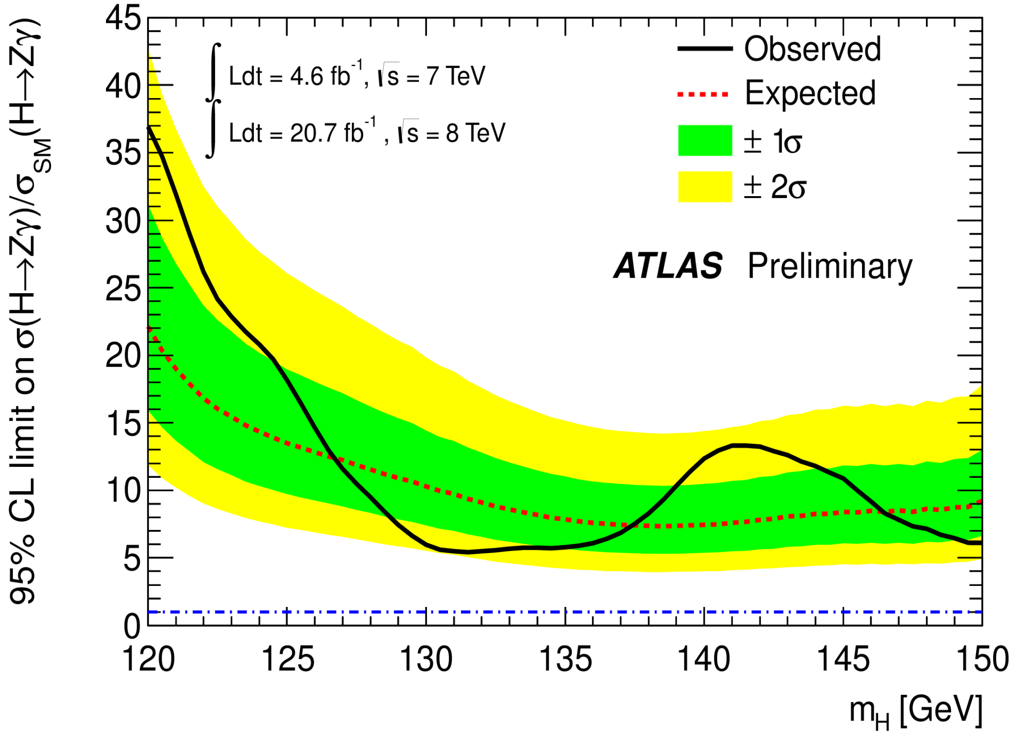




- Why the H → Zγ channel is interesting ?
  - -- decay rate can help determine whether the new boson is the SM Higgs boson
  - -- measurement of $\Gamma_{Z\gamma}$ provides information on the underlying dynamics of the Higgs sector
  - -- sensitive to potential heavier new particles in the loops

The first preliminary analysis was published in 2013

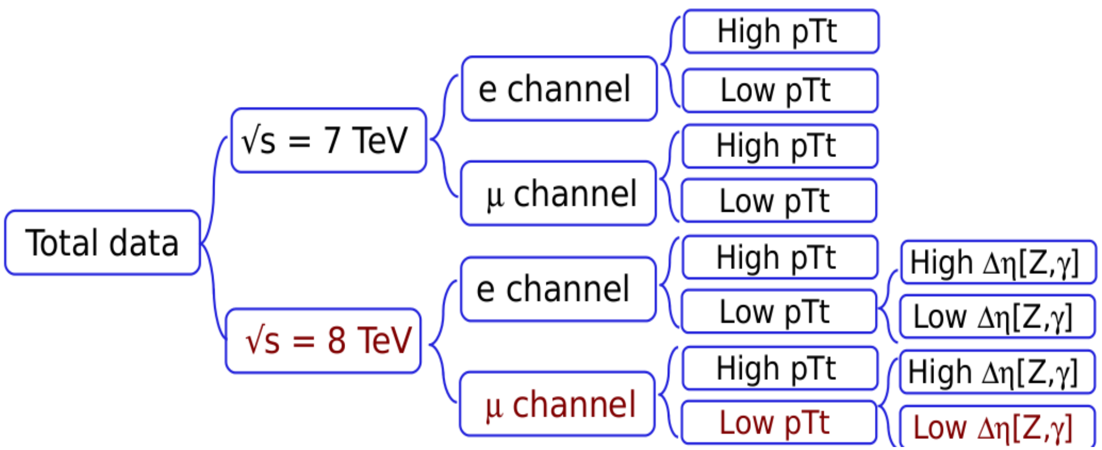
- **Study was done using full run I data set.** Events are classified in four categories based on lepton flavor (μ or e) at $\sqrt{s}$ = 7 TeV or 8 TeV.
- Using $\Delta m(M_{ll\gamma} - M_{ll})$ as discriminating variable, the exclusion limit was set on Higgs mass in the range [120, 150] GeV.
  - expected limits vary between 7.3 and 22.1 xSM
  - observed limits vary between 5.4 and 36.9 xSM

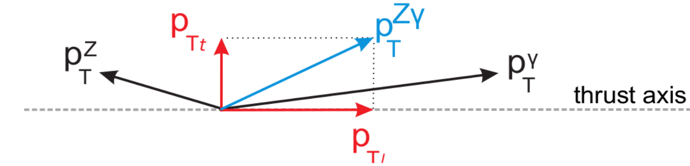


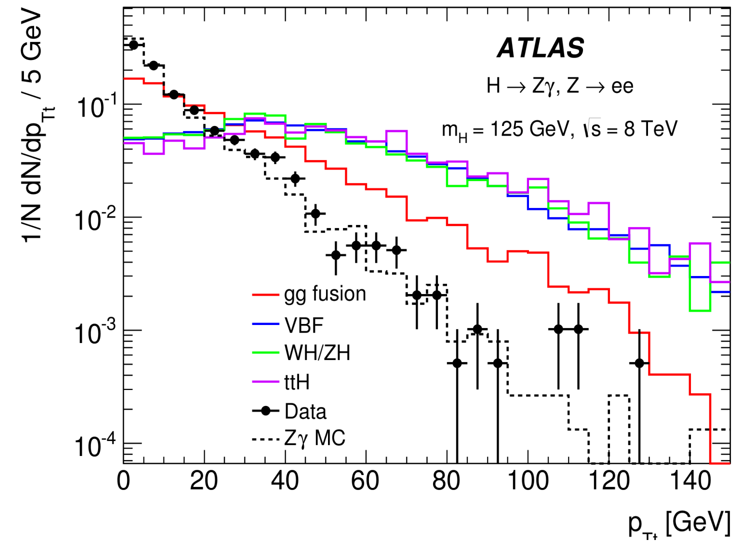
- Our goal after this conference note was to improve the analysis as much as possible and publish as soon as possible.

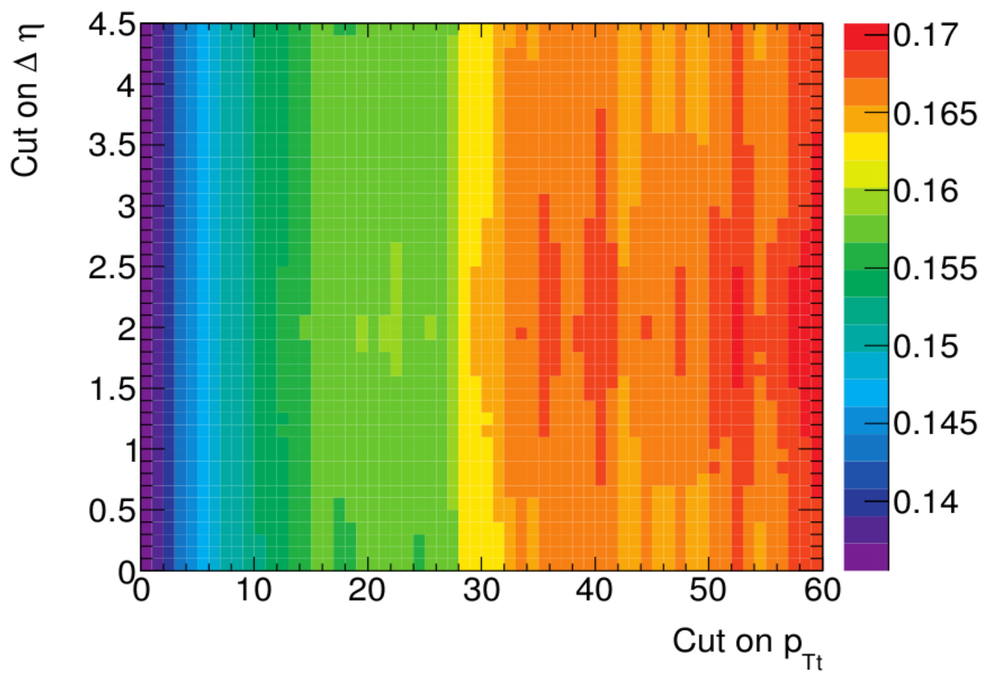
The optimized analysis was published as paper in 2014

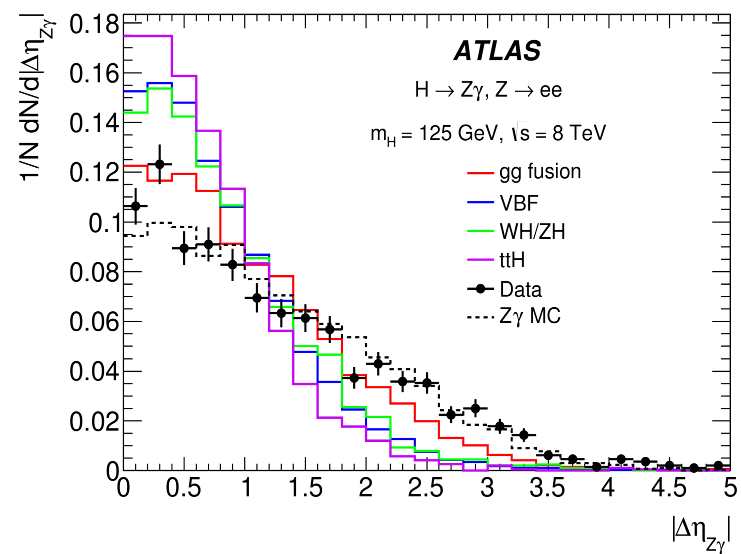
- The events are classified in 10 categories, in order to enhance the analysis sensitivity, based on the kinematic variables:











Parametrization(bkg extracted in data fit)

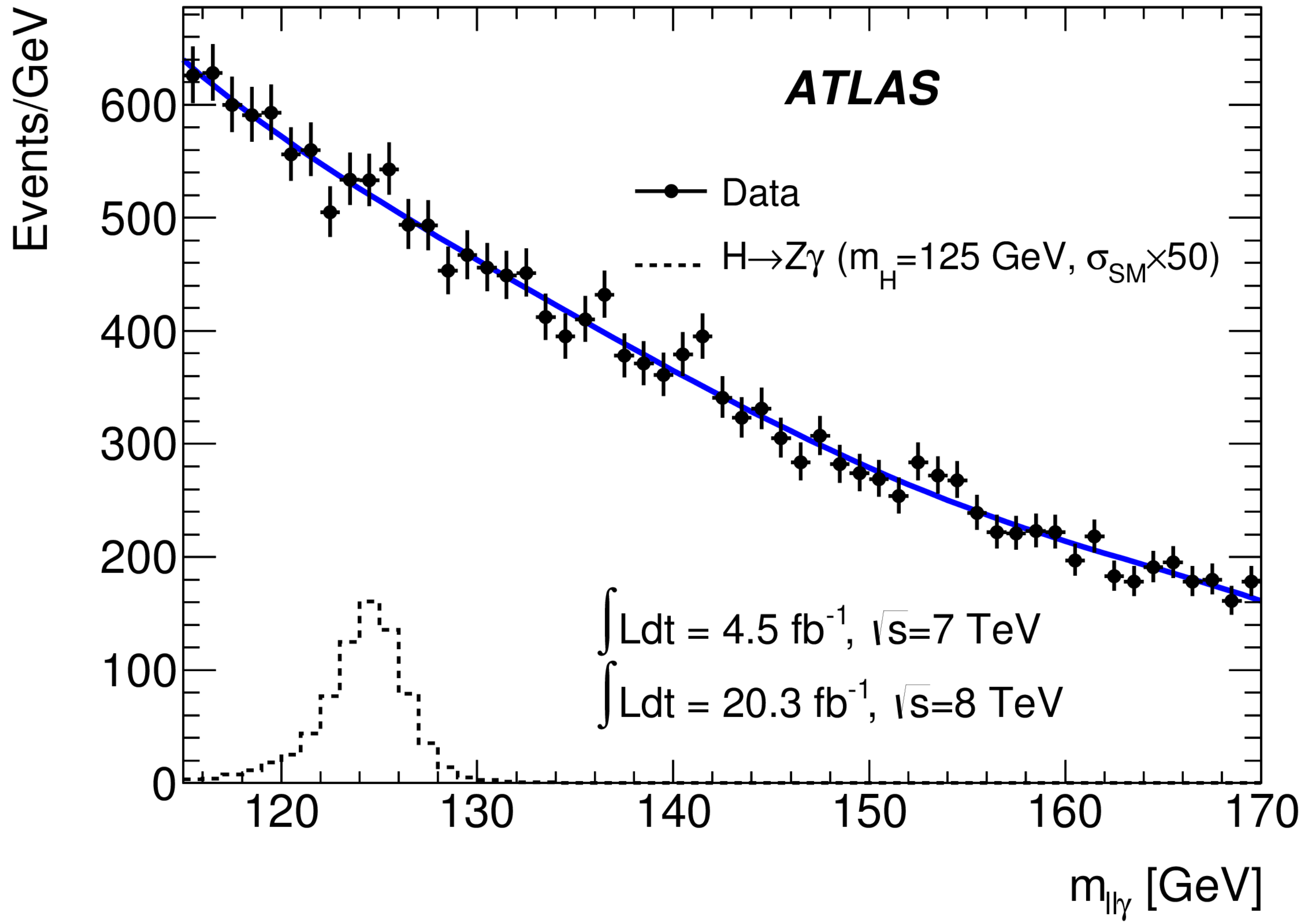
- Expected signal and background yields in [-5, +5] GeV mass window at 125 GeV

$\sqrt{s}$ [TeV]	ℓ	Category	N_S	N_B	N_D	$\frac{N_S}{\sqrt{N_B}}$	FWHM [GeV]
8	μ	high p_{Tt}	2.3	310	324	0.13	3.8
8	μ	low p_{Tt}, low $\Delta\eta$	3.7	1600	1587	0.09	3.8
8	μ	low p_{Tt}, high $\Delta\eta$	0.8	600	602	0.03	4.1
8	e	high p_{Tt}	1.9	260	270	0.12	3.9
8	e	low p_{Tt}, low $\Delta\eta$	2.9	1300	1304	0.08	4.2
8	e	low p_{Tt}, high $\Delta\eta$	0.6	430	421	0.03	4.5
7	μ	high p_{Tt}	0.4	40	40	0.06	3.9
7	μ	low p_{Tt}	0.6	340	335	0.03	3.9
7	e	high p_{Tt}	0.3	25	21	0.06	3.9
7	e	low p_{Tt}	0.5	240	234	0.03	4.0

- High pTt categories have better S/B and signal resolution than low pTt ones.

Background only fit on data

- Summing of background shape(fitted on data in each category) and signal shape in all categories are illustrated with inclusive data distribution.

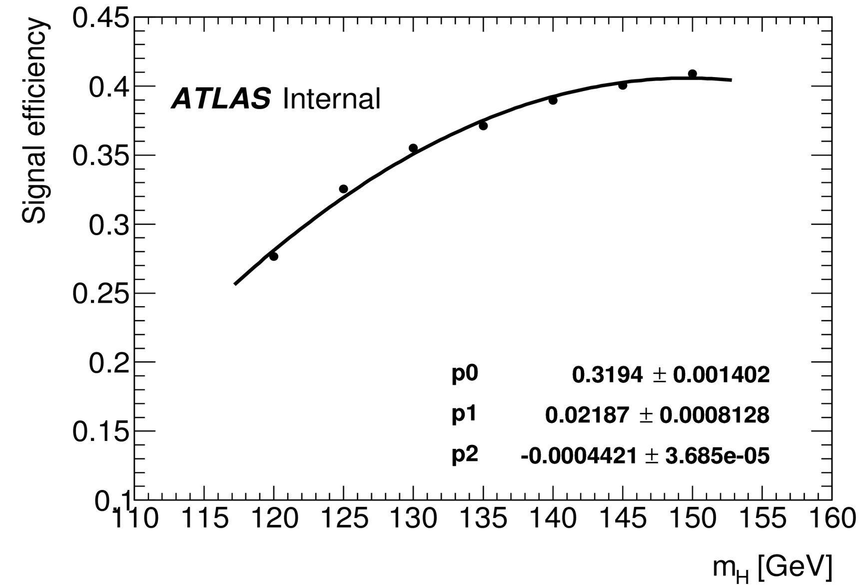


Signal yields and parameters interpolation

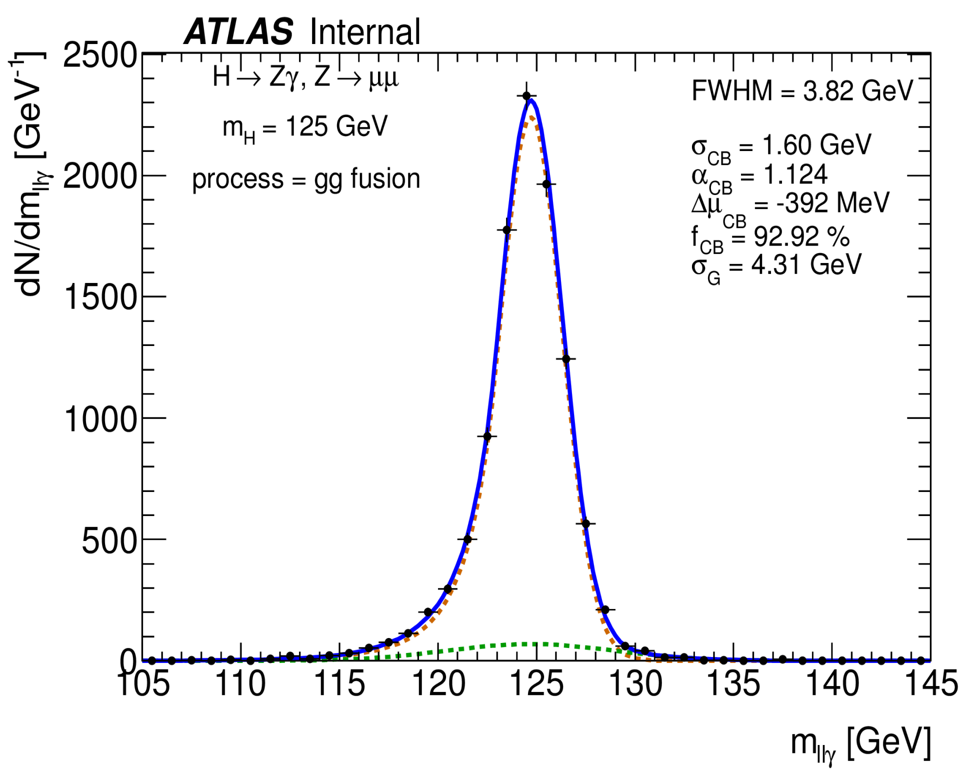
- **Expected signal yields:**

$$N_{i,\ell}(m_H) = \int \mathscr{L}\,dt \times \sigma_i(m_H) \times \mathscr{B}_{H\to Z\gamma}(m_H) \times \mathscr{B}_{Z\to\ell\ell} \times \varepsilon_{i,\ell}(m_H)$$

Higgs BF and cross section is taken from theory, while the efficiency is evaluated in signal MC plus parabolic interpolation with 0.5 GeV mass step.



- **Signal model: Crystal ball + Gaussian**



Systematic uncertainty

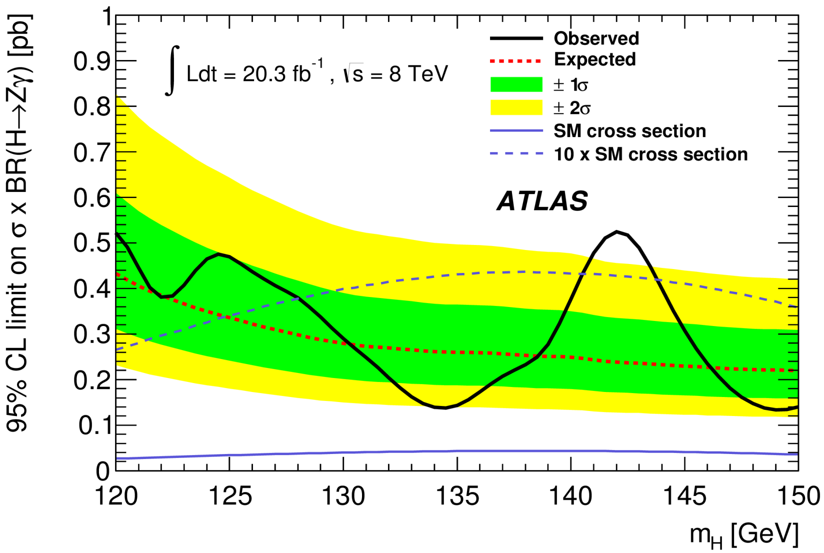
- **Experimental uncertainties** on
  - signal yields: are dominated by the uncertainties of luminosity (~3%), photon identification and electron reconstruction & identification (~3%). The total relative uncertainty on the signal efficiency in each category is within 5%.
  - single peak position (0.2 GeV) is dominated by photon energy scale; width of signal mass is dominated by the photon and electron energy resolution (~3-10%) and muon resolution (1.5 %)

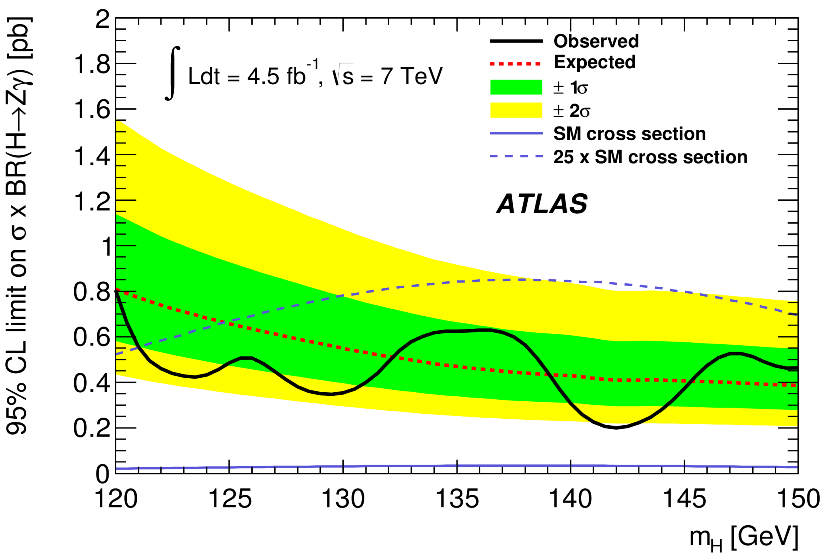
- **Theoretical uncertainties** on the production cross section: the choice of renormalization and factorization scales in the fixed-order calculations, the uncertainties on the PDFs and the value of α. It is more than two times larger the corresponding experimental uncertainty. The relative uncertainty on the $H \rightarrow Z\gamma$ branching ratio varies between 9% for m_H = 120 GeV and 6% for m_H = 150 GeV. An additional 5% uncertainty accounts the effect of the interference $H \rightarrow ll\gamma$ decay amplitudes ($H \rightarrow \gamma\gamma^* \rightarrow ll\gamma$, $H \rightarrow ll^* \rightarrow ll\gamma$).

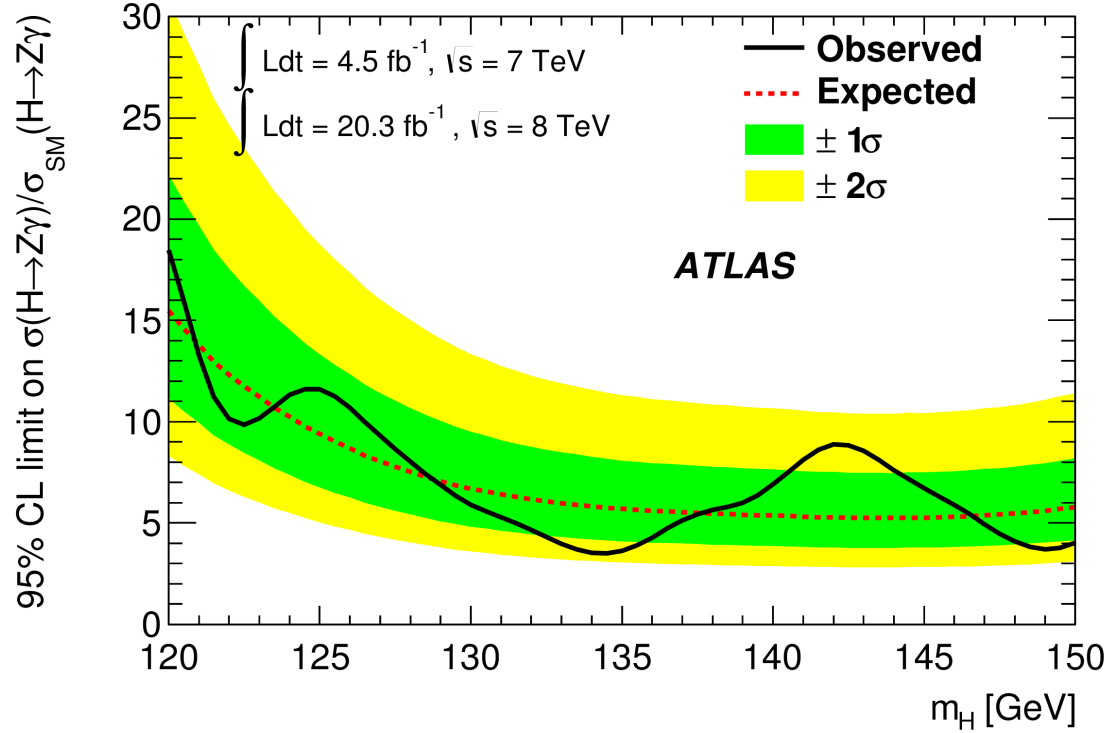
- **The Bias from background modeling:** the expected bias varies between 0.5 events in poorly populated categories and 8.3 events in highly populated ones.

95% C. L. limit

- The 95% C.L. limit is set on the production cross section times branching ratio (left), and on which is with normalized to the SM expected one (right).







- No excess with respect to the background is found in the llγ invariant-mass distribution.
- For a mass of 125.5 GeV, the observed 95% C.L. limit is 11 times the SM prediction.

Summary

- We were working on the photon performance measurements: photon trigger criteria optimization and ID efficiency measurements.
  Two performance papers are preparing.

- We leaded the research of the Higgs boson in $H \rightarrow Z\gamma$ mode. The paper has been published in PLB. No excess with respect to the background is found in the $ll\gamma$ invariant-mass distribution. For a mass of 125.5 GeV, the observed 95% C.L. Limit is 11 times the SM prediction.