# Prospects for $H \rightarrow \gamma\gamma$ analysis at ATLAS

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On behalf of the ATLAS collaboration
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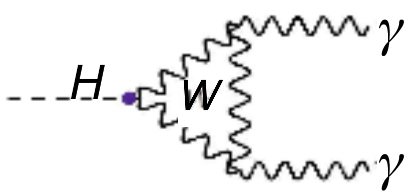
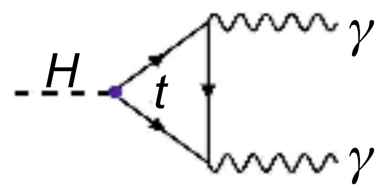
# Introduction

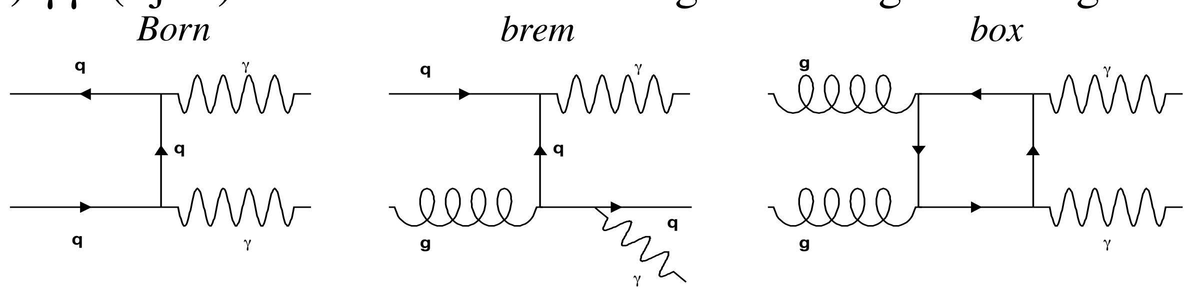
**Signal**: Higgs decays to two photons through top/W loop. Branching ratio for Higgs at 120GeV/c$^2$ is $2.2 \times 10^{-3}$ , $\sigma_{H\to\gamma\gamma} \simeq 30\,fb$ at $\sqrt{s} = 7\ TeV$




**Background**: invariant mass range [100, 150] GeV + kinematic cuts

(1) γγ (+jets) : about 3 orders of magnitude larger than signal.




(2) reducible: one or more jets misidentified as photons.

$$\gamma - jet(s)\ \ (\sigma \approx 10^3 \cdot \sigma_{\gamma\gamma(+jets)})$$

$$jet(s) - jet(s)\ \ (\sigma \approx 3\times 10^6 \cdot \sigma_{\gamma\gamma(+jets)})$$

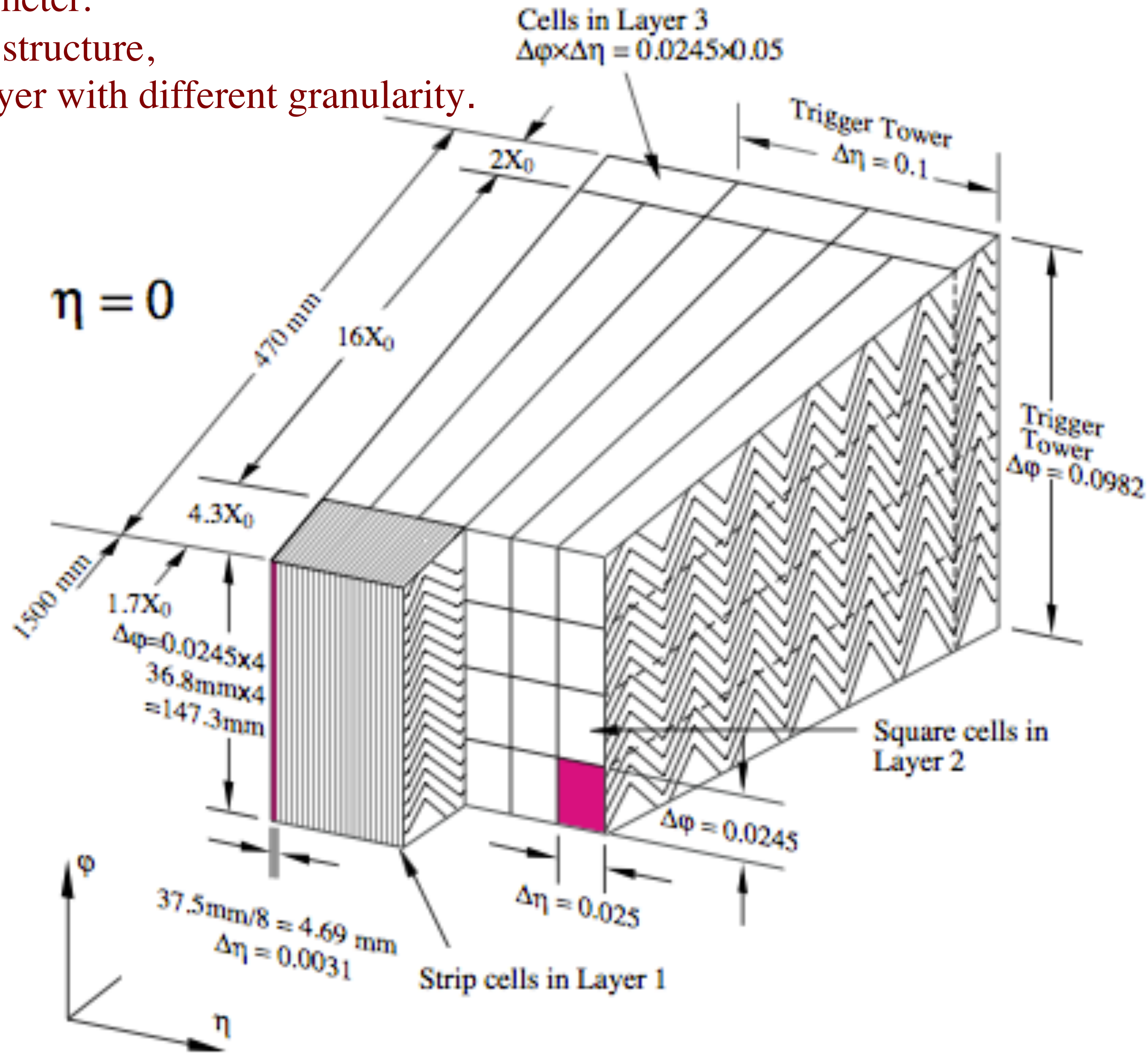
(3) Drell-Yan process: electrons misidentified as photons.

Need good photon reconstruction/identification.

Need good energy/direction measurement, since Higgs in this mass region is a narrow resonance.

# Photon identification / isolation

EM Calorimeter:
Multi-layer structure,
Different layer with different granularity.



# Photon identification / isolation

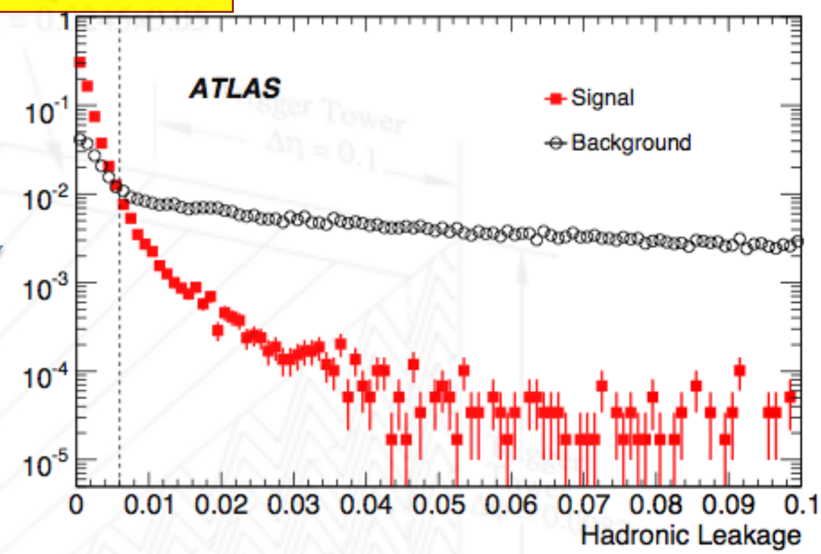
Photon identification: use shower shape variables

See more information in
M.Aurousseau's talk in this workshop

Information from tracker used to classify electron, photon and photon conversion.

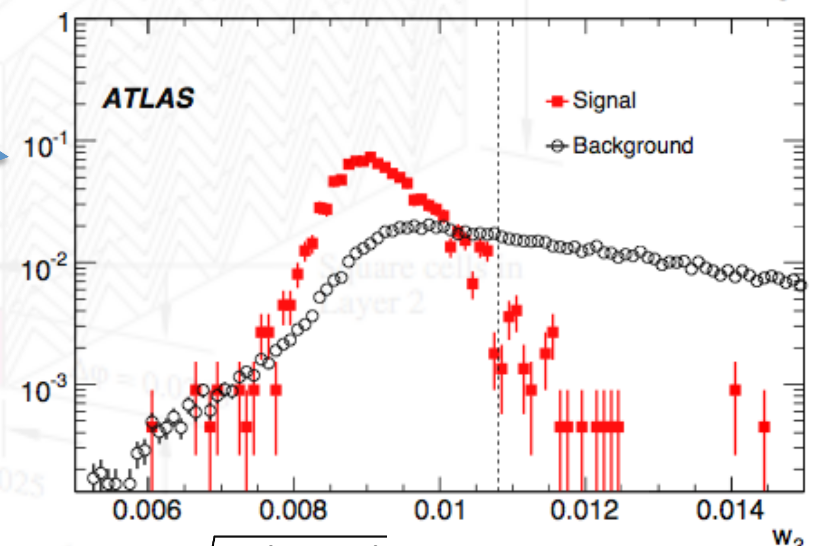
1. hadronic calorimeter

   reject energetic jets with bigger energy leakage into hadronic calorimeter than photon.




2. middle layer of EM calorimeter (e.g : shower width)

   reject jets with wide showers.




3. first layer of EM calorimeter:

   Good segmentation allows better $\pi^0/\gamma$ discrimination.

Photon isolation: use tracks

Sum of tracks $p_T$ (w/ $p_T > 1$ GeV) in a cone ( $\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2}$ ) of 0.3 around the photon smaller than 4 GeV. (conversion track veto in cone of 0.1)

# Invariant mass reconstruction

**Photon energy reconstruction:**

$$E = a + b \cdot E_{PS} + c \cdot E_{PS}^2 + d \cdot (\sum_{i=1,3} E_i)$$

✧Taking into account of the corrections on:

Energy loss in front of the calorimeter

Longitudinal leakage

Energy loss outside the cluster.

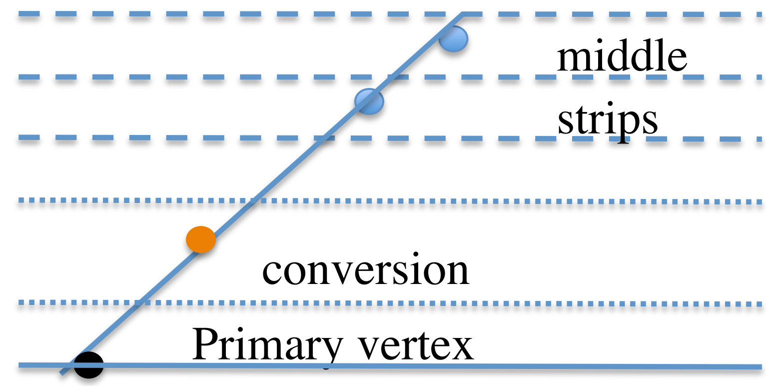
✧Different weights for unconverted and converted photon.

**Photon direction reconstruction, using:**

✧ Multi-layer structure of EM calorimeter.

✧ Conversion vertex when possible.

✧ Reconstructed primary vertex position.




**Invariant mass fit:**

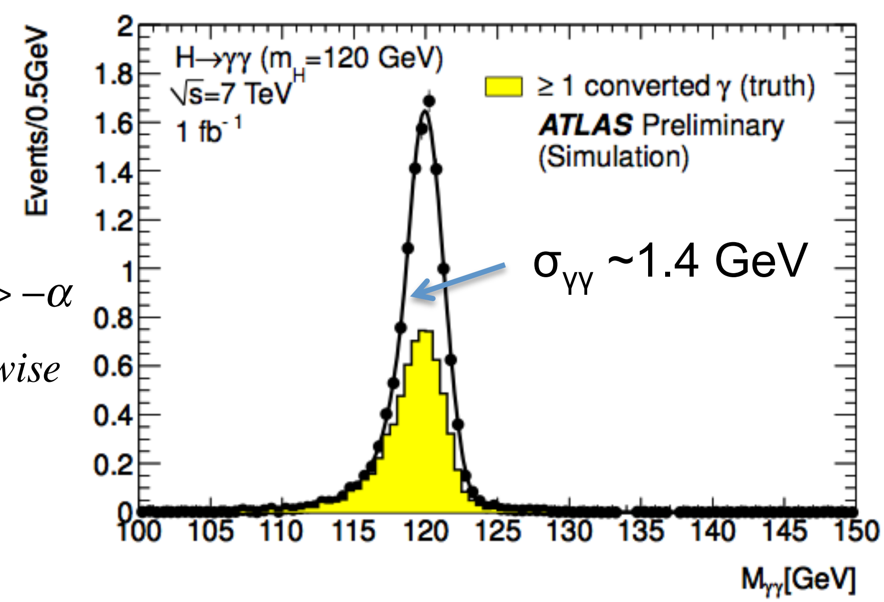
**Signal** : Crystal ball + Gaussian

Describe the core and the left tail

For outlying events, 3-4%

$$P_S(M_{\gamma\gamma}) = \begin{cases} \exp(-t^2/2), & \text{for } t > -\alpha \\ (n/|\alpha|)^n \cdot \exp(-|\alpha|^2/2) \cdot (n/|\alpha| - |\alpha| - t)^{-n}, & \text{otherwise} \end{cases}$$

**Background**: a simple exponential with slope ξ = -0.029



# Inclusive analysis

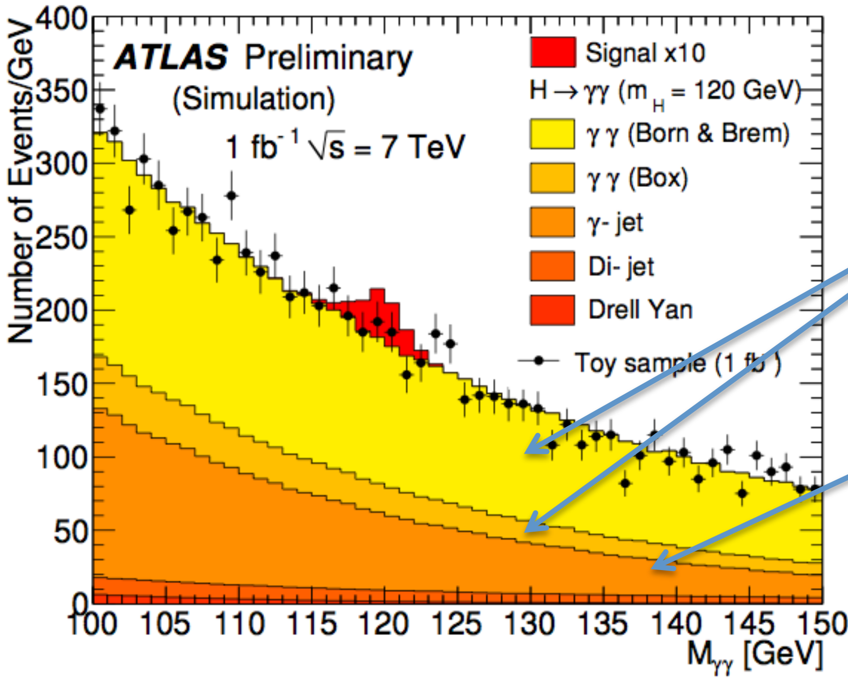
Trigger selection: two photons $E_T > 20$GeV.

At least two reconstructed photons:

1. $|\eta| < 2.37$ and exclude the transition region between barrel and endcap ( $1.37 < |\eta| < 1.52$ )
2. Pass photon selection on shower shape
3. Pass track isolation

Kinematic cut: $p_T^{\gamma 1} > 40\ GeV,\ p_T^{\gamma 2} > 25\ GeV$

Two photon invariant mass range: [100, 150] GeV



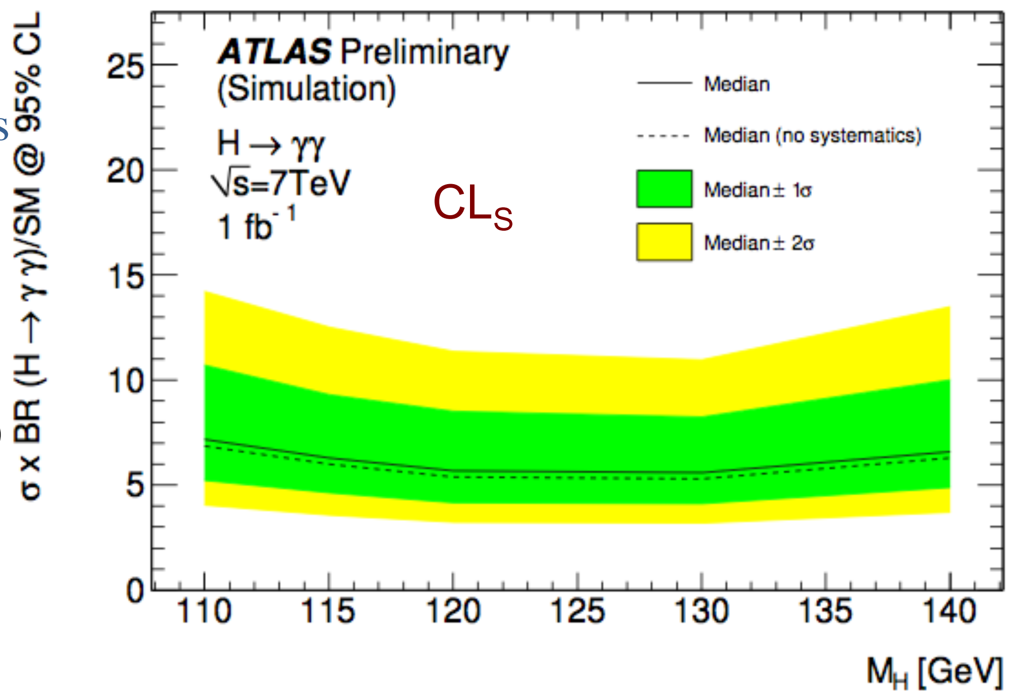

After the selection listed above, the main background is $\gamma\gamma$ (+jets), around 65%.

$\gamma$ +jets and jet(s)+jet(s) together contribute to around 34%.

Drell-Yan process contributes to 1%.

# Exclusion limit

A simple and robust analysis based on $1fb^{-1}$ (expected at next year) of data at $\sqrt{s}$ = 7 TeV: Inclusive analysis uses only invariant mass as the discriminating variable.




**Likelihood Model:**

$$L(\mu, N_B, \xi) = \mu N_S P_S(M_{\gamma\gamma}) + N_B P_B(M_{\gamma\gamma}, \xi)$$

$\mu$ : signal strength parameter.

$N_B, \xi$ : nuisance parameters.

**Take into account of the following systematics uncertainties:**

**for signal:**

✧Resolution for invariant mass (+13%)

✧Photon efficiency (-1%)

✧Luminosity (-10%)

**For background:**

✧Systematic uncertainty automatically included by nuisance parameters $N_B, \xi$

Limits at 95% CL, $1fb^{-1}$, 7TeV

| $m_H$ (GeV) | 110 | 115 | 120 | 130 | 140 |
|---|---|---|---|---|---|
| μ | 6.8 | 5.9 | 5.3 | 5.1 | 6.0 |

# Conclusion

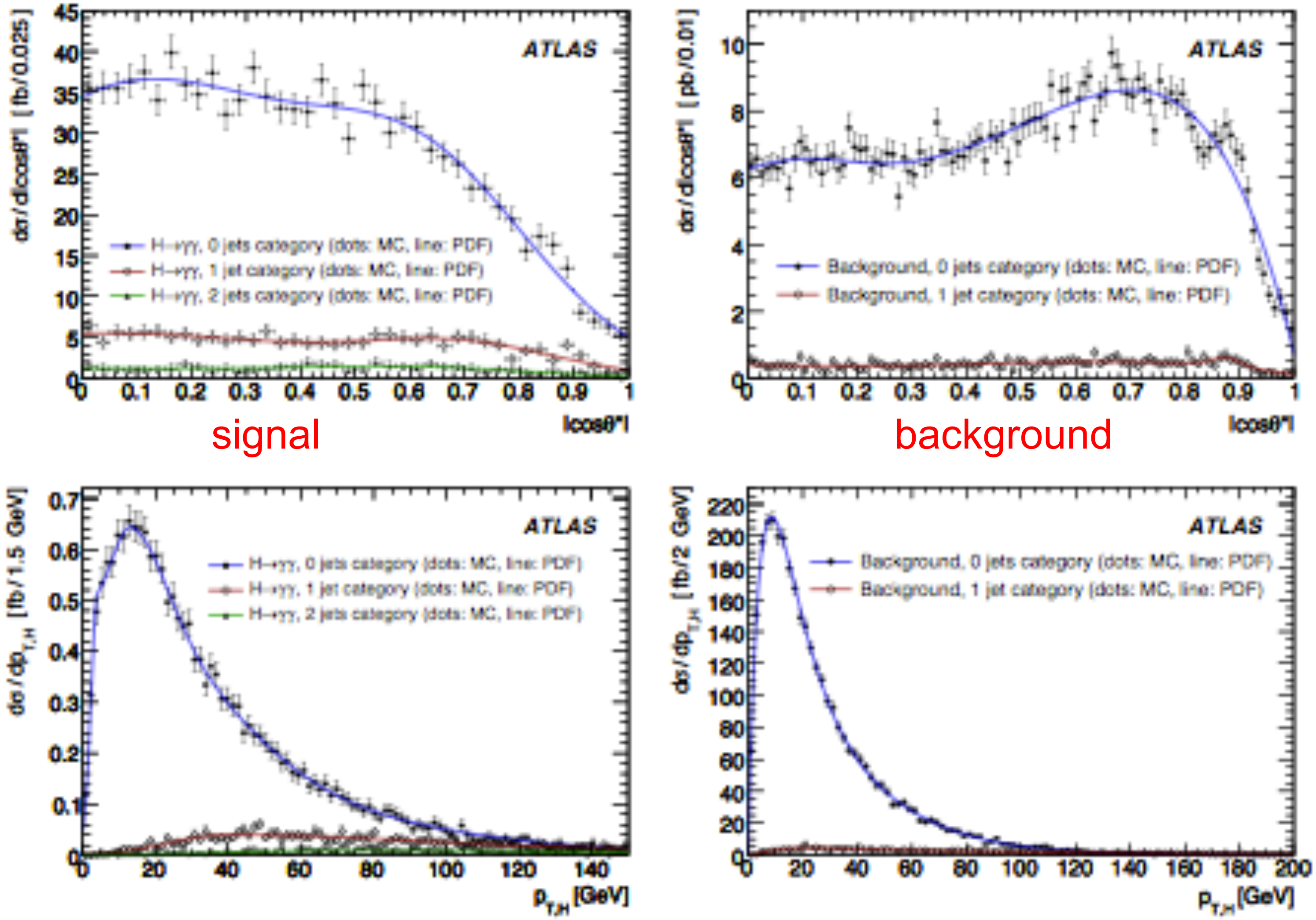
An inclusive analysis of $H \rightarrow \gamma\gamma$ based on Monte Carlo simulation at ATLAS has been presented.

The expected exclusion limit was evaluated by $CL_S$ and $CL_{S+B}$ (in backup) methods, using two photon invariant mass as the discriminating variable.

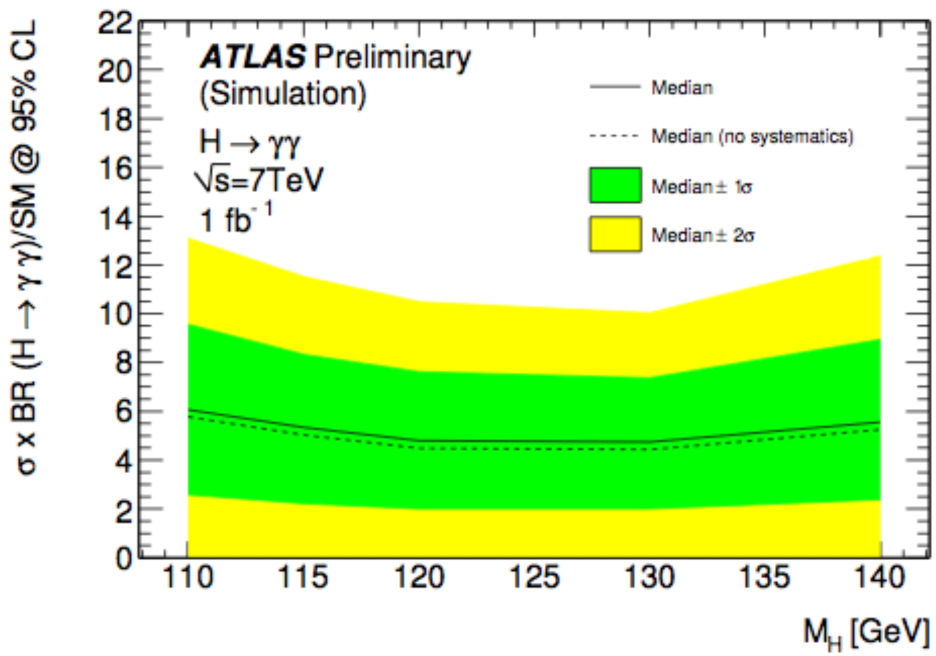
We could exclude 5.3 times the SM prediction of $\sigma$ x $BR(H \rightarrow \gamma\gamma)$, for Higgs mass at 120 GeV/$c^2$ with 1 $fb^{-1}$ of data at $\sqrt{s}$ = 7 TeV.

- backup

# Other discriminants



# Results with $CL_{S+B}$ method

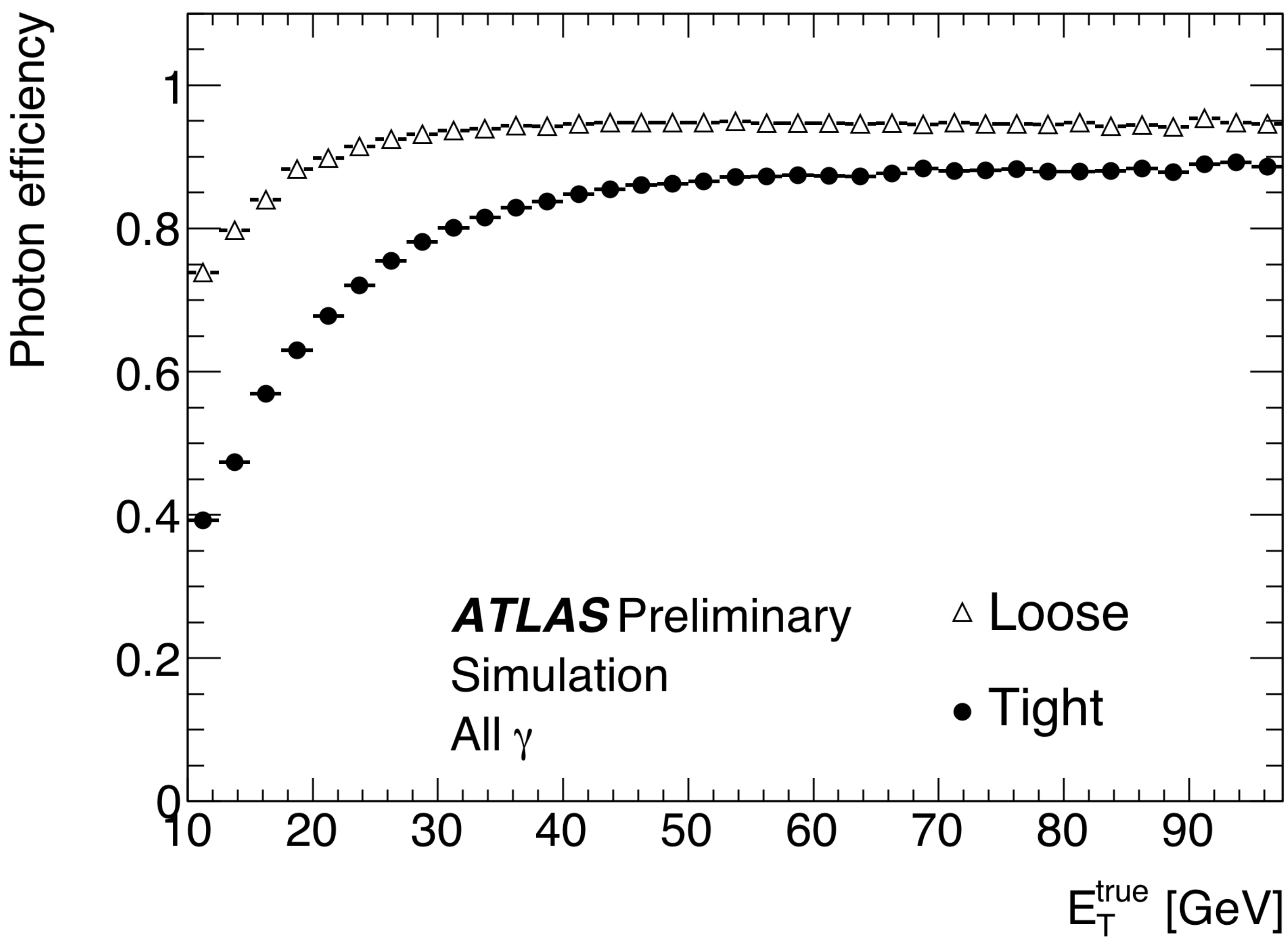



$CL_{S+B}$

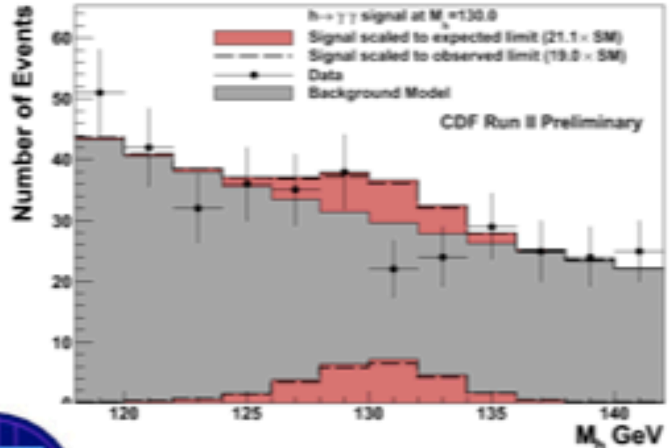
Limits at 95% CL, $1fb^{-1}$, 7TeV

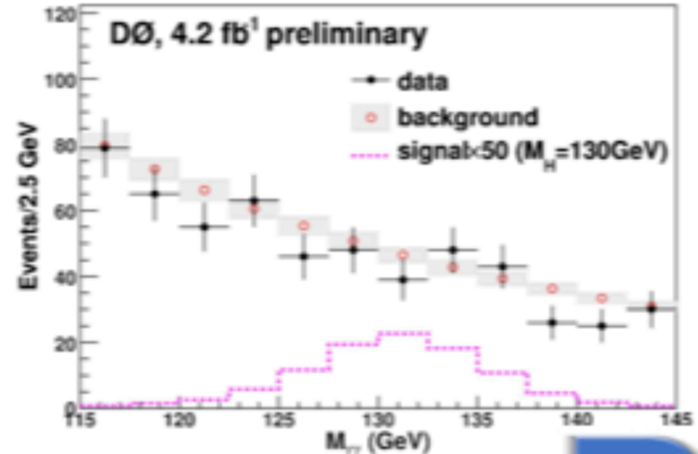
| $m_H$ (GeV) | 110 | 115 | 120 | 130 | 140 |
|---|---|---|---|---|---|
| μ | 5.8 | 5.0 | 4.6 | 4.4 | 5.2 |

# Photon identification efficiency

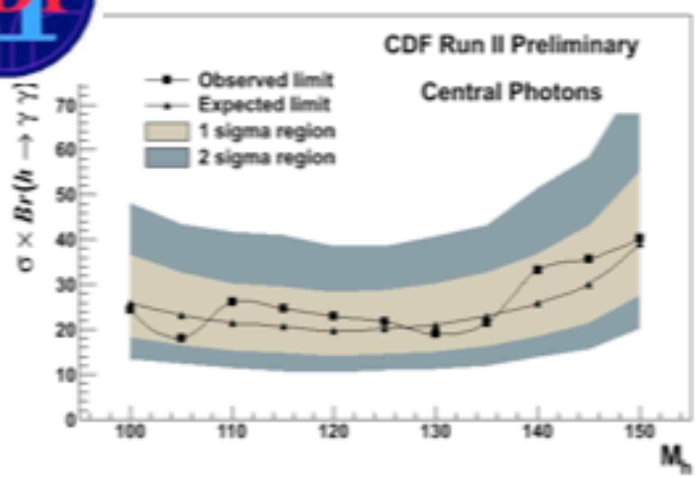


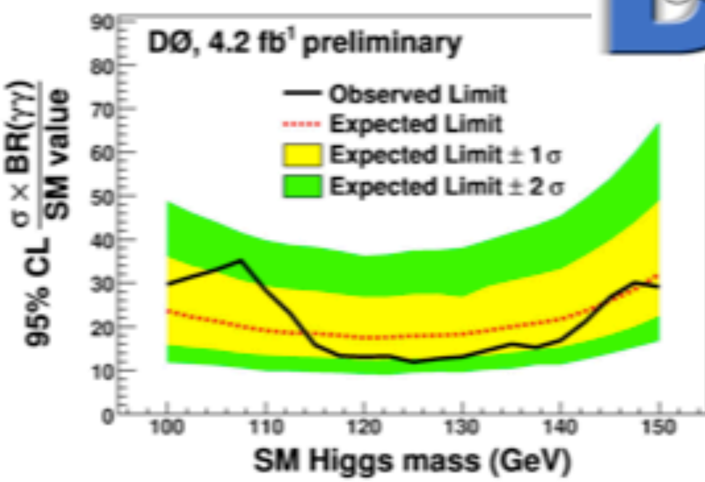
# SM Higgs limits




Limits for h→γγ (5.4 fb$^{-1}$)




The Mγγ spectrum in the search region is used to derive limits, which are a factor of ~20 above the SM expectation for $m_H$ = 100 ~ 140 GeV