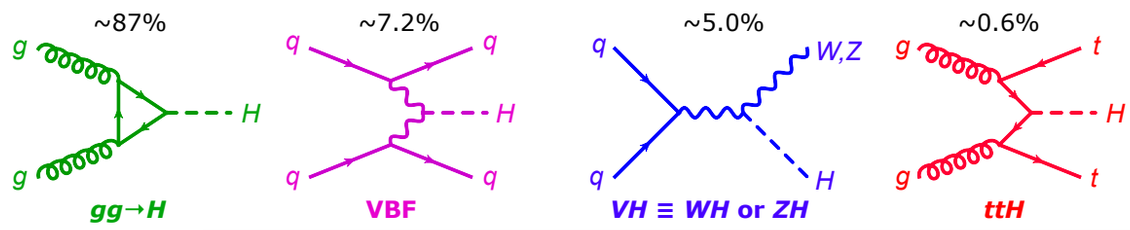
EPS Poster Session – Stockholm, July 18-24 2013

Property measurements of the Higgs boson in the $\gamma\gamma$ final state with the ATLAS detector at the LHC

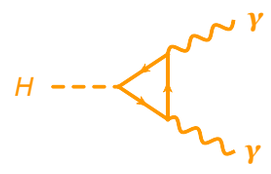
Higgs production at the LHC

Dominant production modes

- Gluon-gluon fusion, $gg \to H$
- Vector boson fusion, VBF
- Higgs strahlung, VH
- Top-antitop fusion, ttH

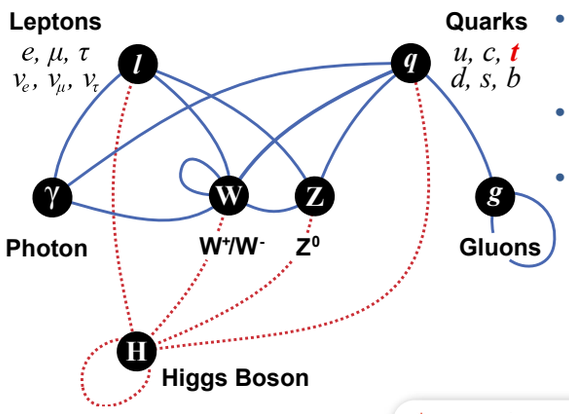


Higgs decay to $\gamma\gamma$



- via fermion loop
- BR($H \to \gamma\gamma$) = 0.228%
- To measure $H \to \gamma\gamma$, need detector with precise γ E-scale and resolution

Higgs in the Standard Model

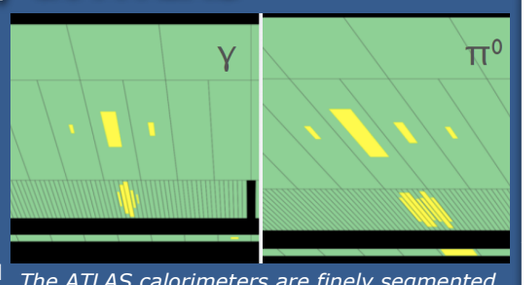


- Higgs boson couples to all massive, fundamental particles
- The Higgs boson can decay to $\gamma\gamma$ via a loop
- Properties to study:
  - Production rate and mass
  - Coupling strength to the other particles ------
  - Spin and parity
  - Kinematic properties*

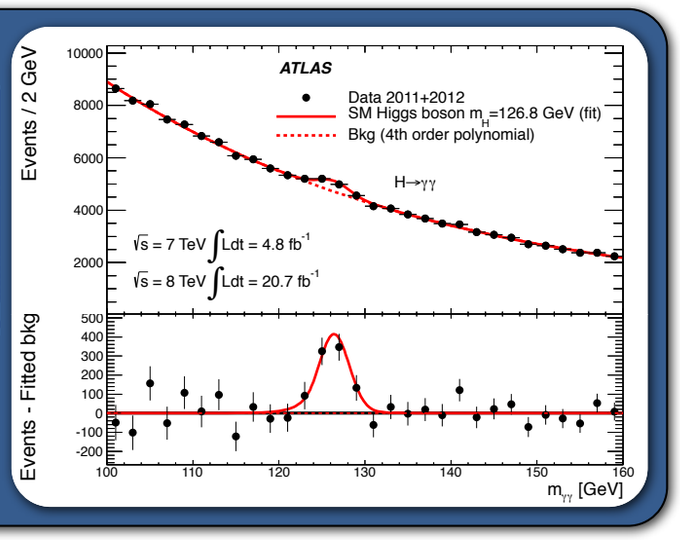
*see poster presented by James Saxon

Measuring $H \to \gamma\gamma$ at ATLAS

- The Higgs Boson decays to two photons 0.23% of the time
- Distinct $m_{\gamma\gamma}$ resonance peak expected on top of smooth background
- Selection:
  - Diphoton trigger
  - Two isolated photon with good shower shape (see right) and p_T > 40 (30) GeV, $|\eta|$<2.37
- Backgrounds:
  - Promt diphoton production
  - γ+jet and dijet (fake photons)



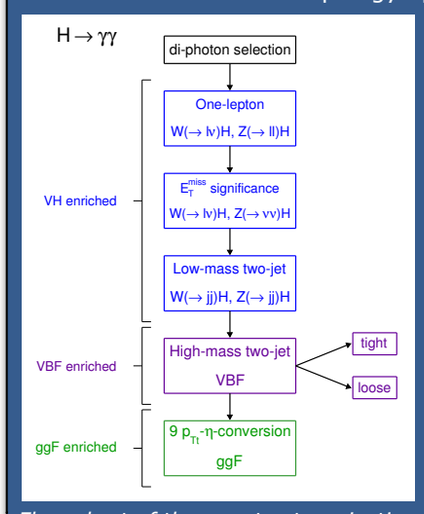
The ATLAS calorimeters are finely segmented and can effectively distinguish between isolated photons and backgrounds like $\pi^0 \to \gamma\gamma$



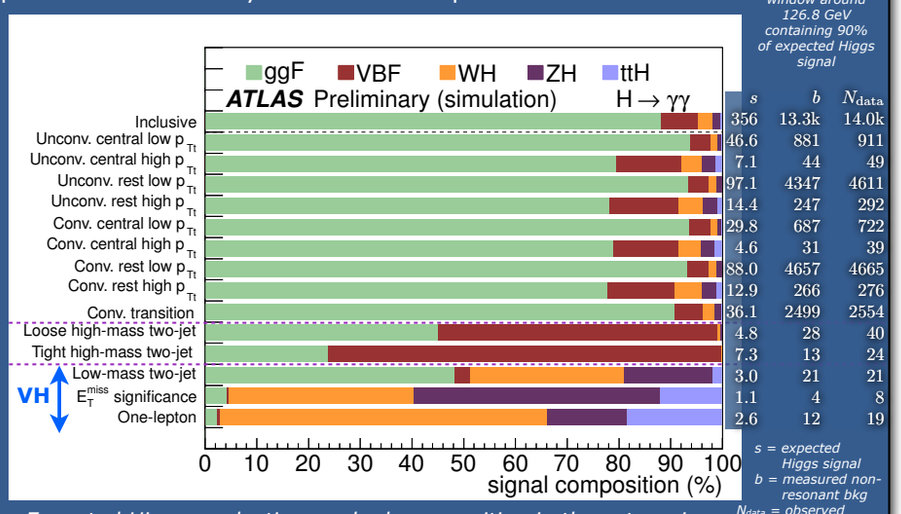
Diphoton invariant mass distribution. The resonance peak of the new boson is observed at $m_{\gamma\gamma}$ =126.8 GeV.

Analysis optimization

- The dataset is split into ***14 event categories***: different s/b optimizes overall sensitivity; selection based on topology optimize the sensitivity to the different production modes



Flow-chart of the event categorization.



N_{evts} in a $m_{\gamma\gamma}$ window around 126.8 GeV containing 90% of expected Higgs signal

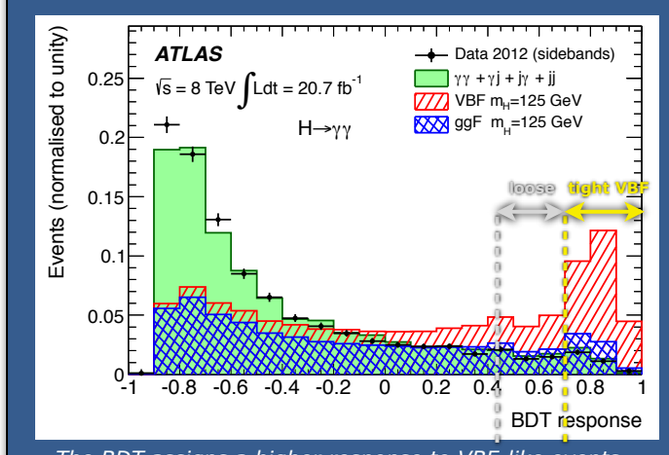
	s	b	N_{data}
Inclusive	356	13.3k	14.0k
Unconv. central low p_{Tt}	46.6	881	911
Unconv. central high p_{Tt}	7.1	44	49
Unconv. rest low p_{Tt}	97.1	4347	4611
Unconv. rest high p_{Tt}	14.4	247	292
Conv. central low p_{Tt}	29.8	687	722
Conv. central high p_{Tt}	4.6	31	39
Conv. rest low p_{Tt}	88.0	4657	4665
Conv. rest high p_{Tt}	12.9	266	276
Conv. transition	36.1	2499	2554
Loose high-mass two-jet	4.8	28	40
Tight high-mass two-jet	7.3	13	24
VH Low-mass two-jet	3.0	21	21
VH E_T^{miss} significance	1.1	4	8
VH One-lepton	2.6	12	19

s = expected Higgs signal
b = measured non-resonant bkg
N_{data} = observed data

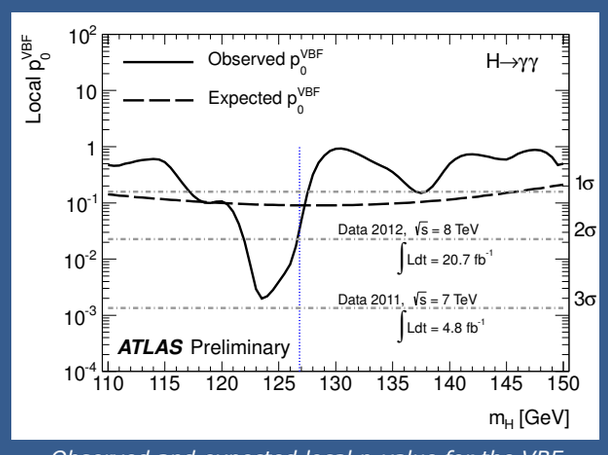
Expected Higgs production mode decomposition in the categorizes.

Vector boson fusion (VBF)

- Higgs bosons produced via VBF have ***two associated forward jets***
- This distinct topology allows for better discrimination against backgrounds
- A multivariate analysis based on boosted decision trees is used to better measure the VBF Higgs rate



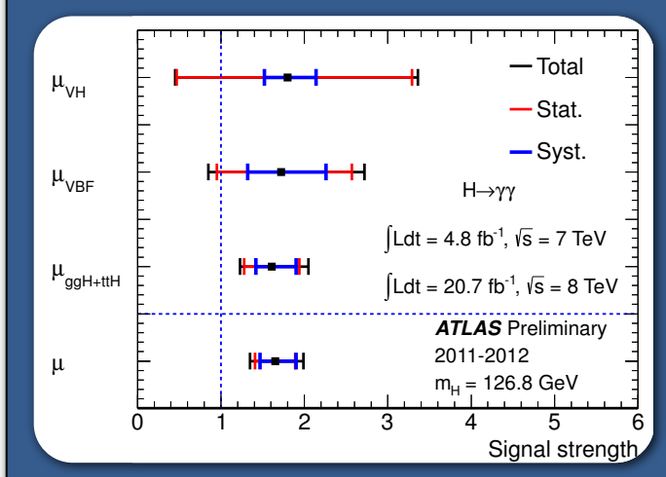
*The BDT assigns a higher response to VBF-like events. The **loose** and **tight** VBF categorizes defined from **0.44 < BDT < 0.7** and **BDT > 0.7**, respectively.*



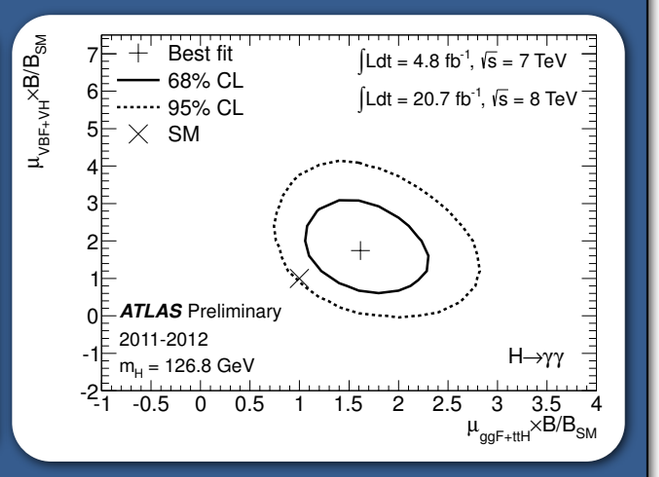
Observed and expected local p-value for the VBF Higgs production. At the measured Higgs mass (blue dashed line) a 2σ excess is observed.

Couplings

- Dedicated event categories optimized to measure different Higgs production modes ($gg \to H$, VBF, VH)
- ttH & $gg \to H$ (VBF & VH) production sensitive to Higgs coupling to top quarks (W/Z bosons)
- The cross section of each production modes can be measured separately or simultaneously by introducing individual signal strength parameters that float in the signal extraction fit

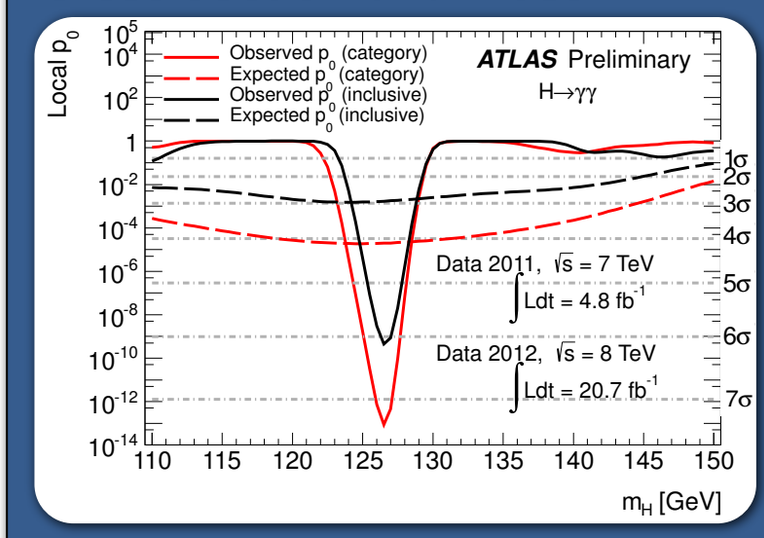


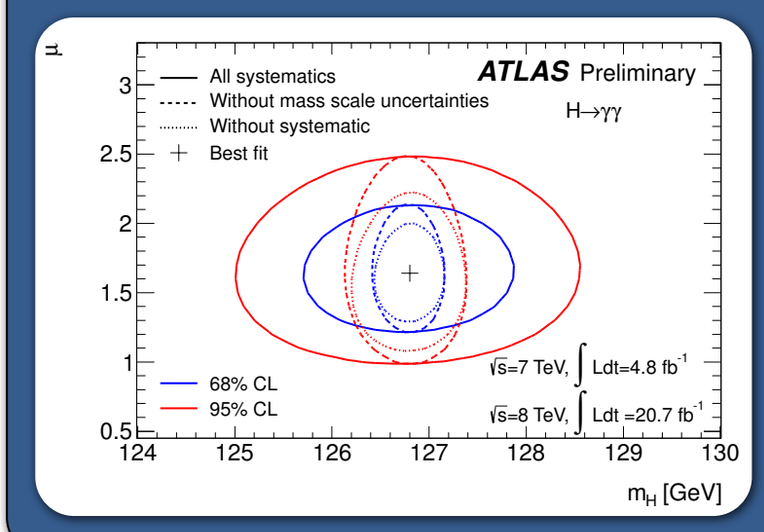
Measurements of the ratio of observed Higgs boson cross section to the Standard Model expectation for various Higgs production modes separately.



Simultaneous rate measurement of production modes sensitive to W/Z-boson couplings (VBF+VH) vs quark couplings (ggF+ttH). The SM expectation is also shown.

Cross section and mass



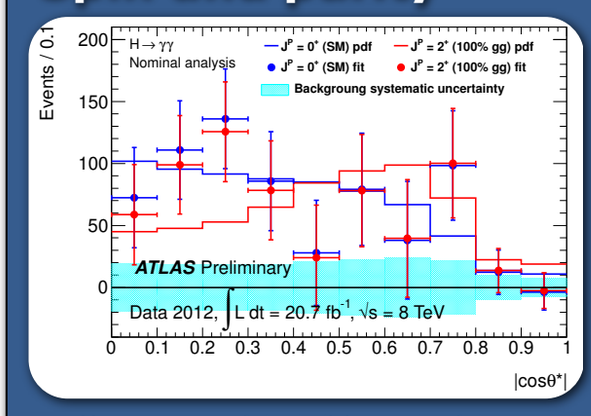


- Observed and expected p-value vs Higgs boson mass for $H \to \gamma\gamma$ using the full 2011 and 2012 ATLAS dataset
- An excess over background of 7.4 standard deviations is observed for a Higgs mass of 126.8 GeV
- The optimized event category analysis (red) significantly improve the results compared to using one inclusive category (black)
- The $H \to \gamma\gamma$ cross section in the fiducial region of: $p_{T\gamma}$ > 40 (30) GeV and $|\eta_\gamma|$ < 2.37 is measured to:

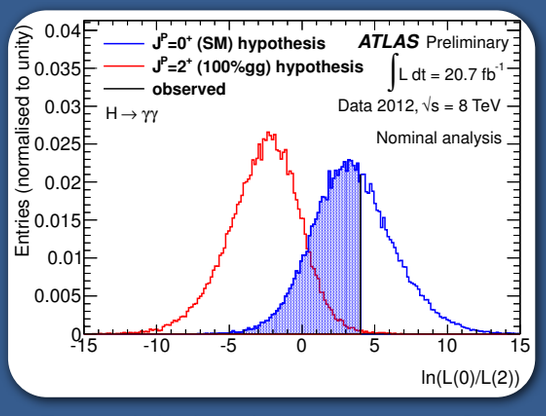
  σ_{fid} = 56.2 ± 12.5 fb

- Measured Higgs mass (x-axis) versus cross section ratio to the Standard Model (y-axis) with 68% (blue) and 95% (red) confidence contours
- The photon energy scale constitutes the main source of uncertainty

Spin and parity



Measurement of the helicity angle of the $\gamma\gamma$ decay products of new boson compared with predictions from spin 0 (blue) and spin 2 (red).



Test statistics for spin hypothesis tests. Data (black line) is less than 1% consistent with the $gg \to H$ spin 2 hypothesis (red).

Summary of ATLAS $H \to \gamma\gamma$ measurements

Preliminary results using the combined 2011 and 2012 dataset:

- Higgs mass: **126.8 ± 0.2(stat) ± 0.7(syst) GeV**
- Excess over background for this Higgs mass: **7.4σ** (expected: 4.3σ)
- Ratio of observed cross section to SM expected cross section: **μ = 1.55 ± 0.23(stat) ±0.21(syst)**, significance of deviation: **2.3σ**
- Couplings to quarks and V bosons: measuring each production mode separately
  - **$\mu_{ggF+ttH}$ = 1.6 ± 0.3(stat) ±0.3(syst)**
  - **μ_{VBF} = 1.7 ± 0.8(stat) ±0.5(syst)**, significance of excess: **2.0σ**
  - **μ_{VH} = 1.8 ± 1.5(stat) ±0.3(syst)**
- Spin 2 $gg \to H$ production excluded at 99.3% confidence level

Dag Gillberg, for the ATLAS Collaboration

ATLAS EXPERIMENT