Differential cross sections of the Higgs boson measured in the diphoton decay channel with the ATLAS detector using 8 TeV proton-proton collision data

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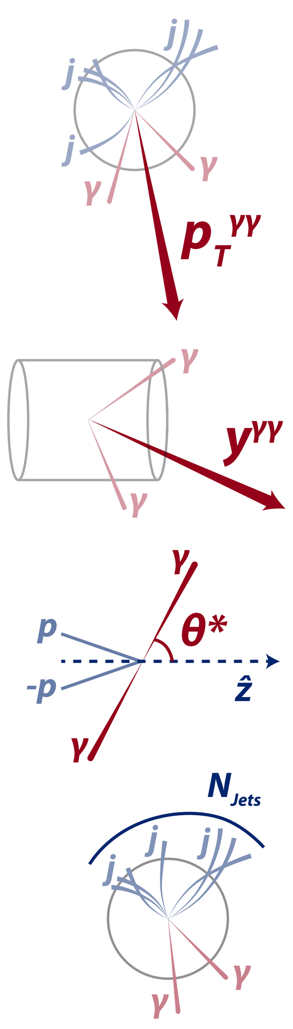
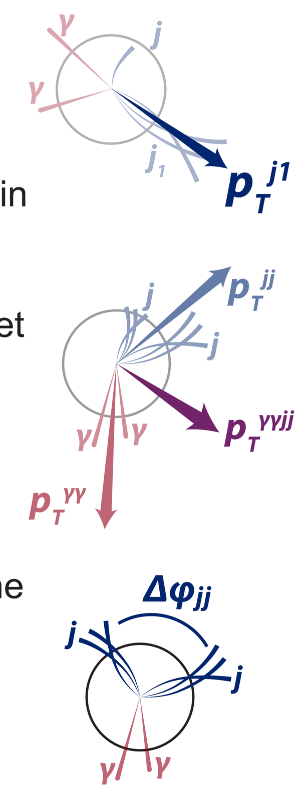
With its high signal selection efficiency and straightforward signal extraction, the diphoton decay channel is well suited to probe the underlying kinematic properties of Higgs boson production and decay. Measurements are made for several diphoton and jet distributions for isolated photons within the geometric acceptance of the detector and corrected for experimental acceptance and resolution. The dataset used corresponds to 20.3 fb^{-1} of proton-proton collisions, produced by the LHC in 2012. Results are compared to particle-level theoretical predictions.

Selected Variables and Motivation



The variables selected are particularly sensitive to QCD in Higgs boson production, to potential BSM Higgs models, and to the spin and CP eigenvalue of the Higgs boson.

- The transverse momentum of the diphoton system, $p_T^{\gamma\gamma}$, is sensitive to the description of QCD in ggH production. With the rapidity $|y^{\gamma\gamma}|$ and the Higgs boson mass, it defines the Higgs boson kinematics.
- The rapidity, $|y^{\gamma\gamma}|$, is in principle additionally sensitive to the PDFs of the incoming protons.
- The helicity angle $|\cos\theta^*|$ in the Collins-Soper frame has been used in $H\to\gamma\gamma$ spin analyses. The extraction in this analysis is model-independent.
- The jet multiplicity, N_{Jets}, is tied to the relative rates of the five production modes (*ggH*, VBF, *WH*, *ZH*, *ttH*), and to the description of QCD in ggH. This also allows the 'jet veto fraction' $\sigma_{N_{Jets}=i}/\sigma_{N_{Jets}\geq i}$ to be calculated.
- The transverse momentum of the hardest parton emission, p_T^{j1}, is of fundamental theoretical interest in *ggH* production.
- The transverse momentum of the Higgs boson + dijet system (for events with ≥ 2 jets), $p_T^{\gamma\gamma jj}$, is a powerful variable for VBF analyses. Its effectiveness is presently limited by large theoretical uncertainties.
- The angular separation between the highest p_T jets, $\Delta\phi_{jj}$, is sensitive to the spin and CP eigenvalue of the Higgs boson. It also responds to higher-order calculations that describe the angular correlations using the matrix element instead of parton shower algorithms.



Definition of the Fiducial Region

Event and Photon Selection:

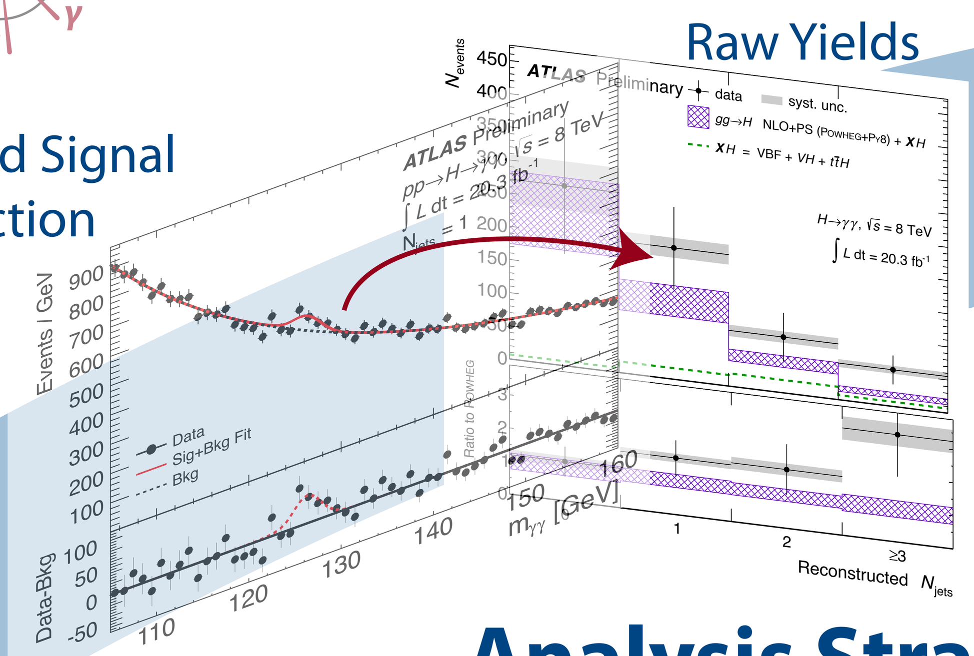
- Two isolated photons are selected within $|\eta| < 2.37$ (excluding $1.37 \leq |\eta| < 1.56$ in reco.).
- The diphoton invariant mass $m^{\gamma\gamma}$ must lie between 105 GeV and 160 GeV, and the ratio $p_T^{\gamma}/m^{\gamma\gamma}$ must exceed 0.35 (0.25) for the leading (subleading) photon.

Jet Selection:

- Jets are defined using the anti-k_t algorithm with distance parameter 0.4.
- The jet transverse momentum must exceed 30 GeV, and the rapidity $|y| < 4.4$.
- Reconstructed jets undergo several corrections for pileup.

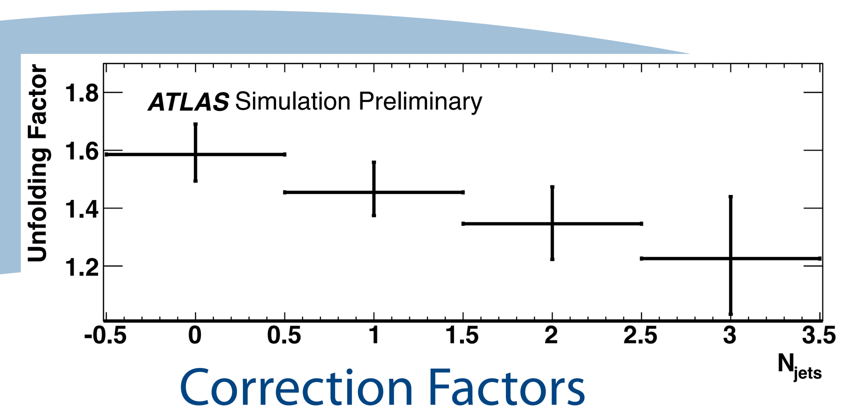
Binned Signal Extraction

Raw Yields



N_{Jets}

×



Correction Factors

Analysis Strategy

The Higgs boson decay to a pair of photons provides a clean resonance in the diphoton invariant mass, $m_{\gamma\gamma}$. The signal is thus straightforwardly separated from the continuum diphoton and photon-jet backgrounds using a signal plus background fit.

Signal and Background Modelling:

Signal: The signal is modelled as a **Crystal Ball** function plus a wide gaussian, and parameterized as a function of the Higgs boson mass.

Background: The background PDF for each bin of each observable is selected by requiring the measured signal in a fit to *background-only* simulation to be small.

- The largest measured signal in $119 < m_{\gamma\gamma} < 135$ GeV is assessed as an **uncertainty**.
- Ultimately, the second-order exponential e^{ax+bx^2} is used in every unfolded bin.

Signal Extraction: For each observable...

- Partition the dataset: e.g. N_{Jets} = 0, 1, 2, etc., or $20 < p_T^{\gamma\gamma} < 30$ GeV, etc.
- Extract the signal yields of all bins of an observable in a single pass, by performing a **simultaneous signal plus background fit** to all bins, in the diphoton invariant mass.
- This correlates nuisance parameters (NPs) and the Higgs boson mass m_H across bins.

Bin-by-Bin Correction Factors: For efficiencies, acceptances, and migrations...

- **Correction factors** are derived bin-by-bin as the ratio of the (fiducial) particle to reconstruction level yields, in simulated Higgs boson events, $c_i = n_i^{Particle}/n_i^{Reconstructed}$.
- Multiplying the extracted binned signal yields by these c_i, unfolds detector effects and restores **particle-level distributions**.
- **Uncertainties** are evaluated on these correction factors, to cover uncertainty in the sample composition (among Higgs production modes), generator bias, and shape.

Experimental Uncertainties: On the mass resolution and yields...

Yield: Luminosity (2.8%) and trigger efficiency (0.5%); photon identification (2.6-4.6%, depending on N_{Jets}), jet energy and resolution (3-15%, according to the bin).

Energy Resolution. The width of the fitted peak affects the extracted yield, and is subject to an uncertainty of 23-28%, according to the bin.

Results:

The unfolded distributions are presented. All observables are compared to POWHEG. The $p_T^{\gamma\gamma}$ and $|y^{\gamma\gamma}|$ are also compared to HRes1.0, while the others are compared to MINLO POWHEG HJ. Within the large statistical uncertainties, the theoretical predictions agree well with the data: the *p*-values of the χ² compatibility tests are presented below.

Probabilities from χ² Compatibility Tests

	N_{jets}	$p_T^{\gamma\gamma}$	$\lvert y^{\gamma\gamma}\rvert$	$\lvert\cos\theta^*\rvert$	$p_T^{j_1}$	$\Delta\phi_{jj}$	$p_T^{\gamma\gamma jj}$
POWHEG	0.54	0.55	0.38	0.69	0.79	0.42	0.50
MINLO	0.44	–	–	0.67	0.73	0.45	0.49
HRES 1.0	–	0.39	0.44	–	–	–	–

Poster is based on work described in ATLAS-CONF-2013-072. Further details and references for all generators and theoretical predictions may be found there.

Fiducial Differential Cross Sections