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*Latest results on the Higgs boson in the **diphoton** Channel*

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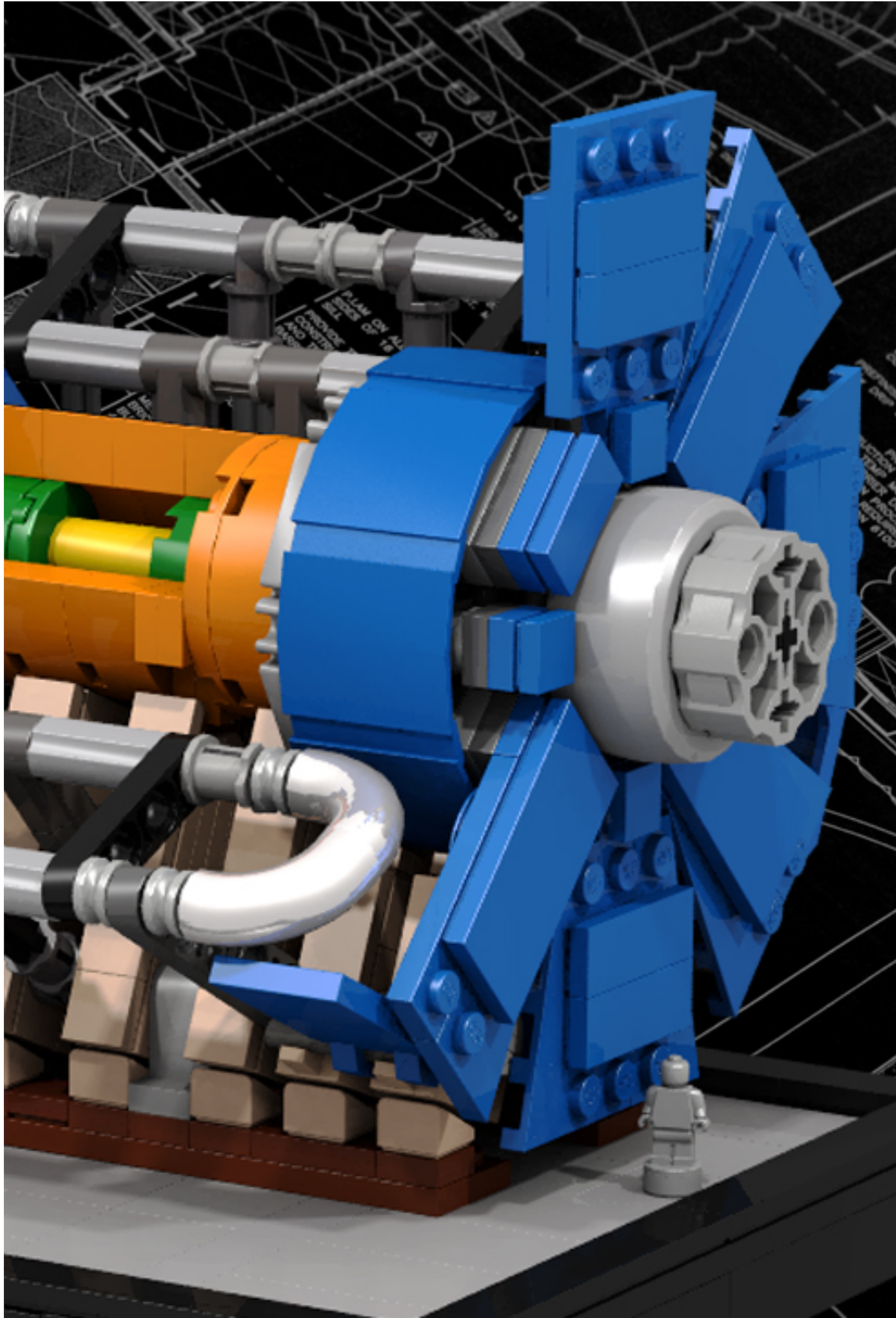
*on behalf of the **ATLAS** collaboration*

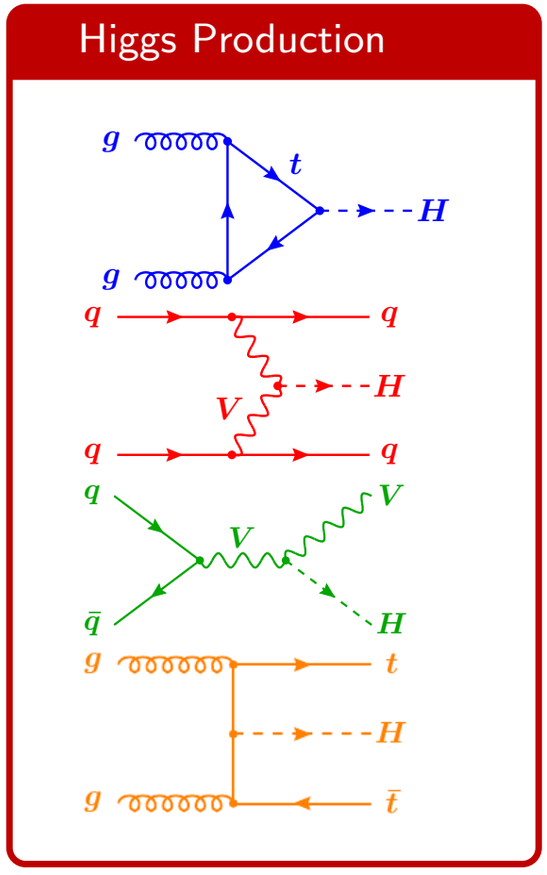
SUSY 2015, Lake Tahoe

ATLAS EXPERIMENT



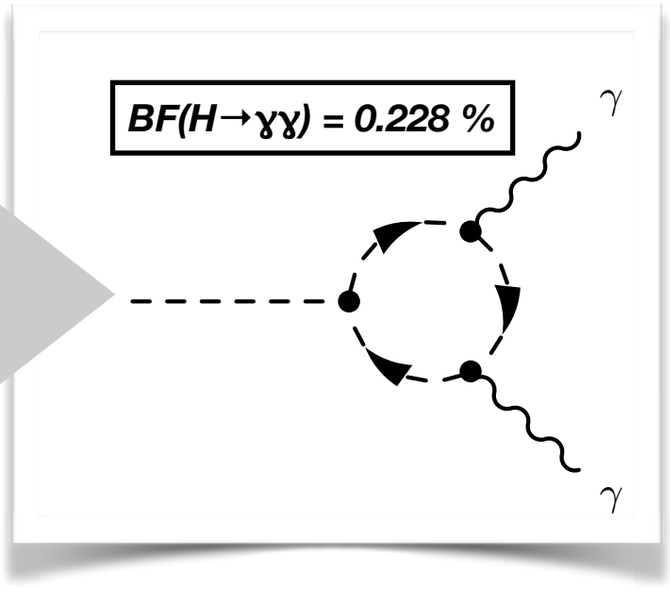
Probing the Higgs Boson in the diphoton channel

- Higgs Boson's discovery 2012 put mass generation of the Standard Model on firm footing.
- More and more transition from discovery to precise measurements; characterizing *Higgs production, decay and mass.*
- For general properties see talk from Peter Rados (Monday), ttH talk from Julian Bouffard (Tuesday), Couplings talk from Mairo Lacer (Tuesday), High mass talk from Graham Cree (Friday).



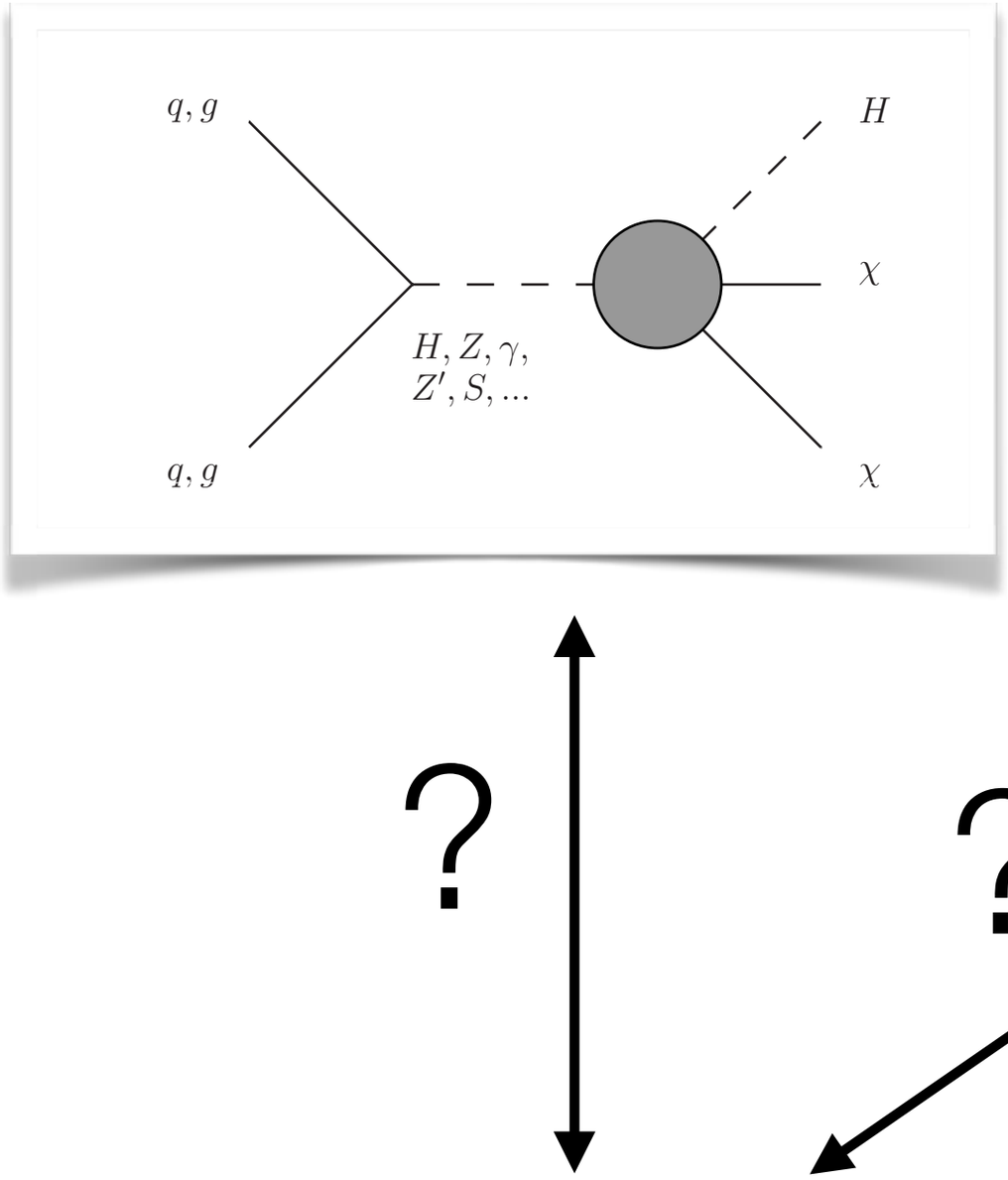
H→γγ decay is a rare process in the SM:

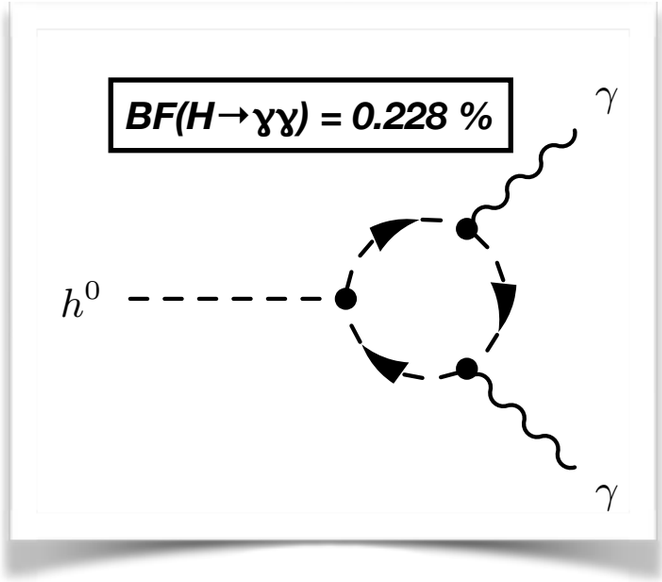
H



Loop induced as photons do not directly couple to the Higgs

Connection to supersymmetry and Unification and fundamental Interactions?

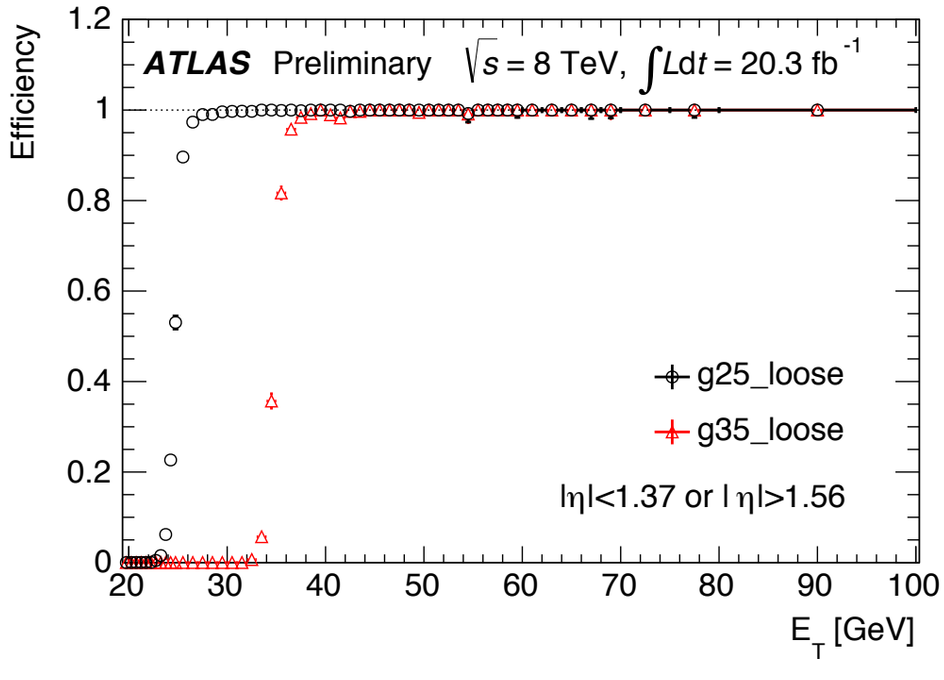




Loop induced as photons do not directly couple to the Higgs

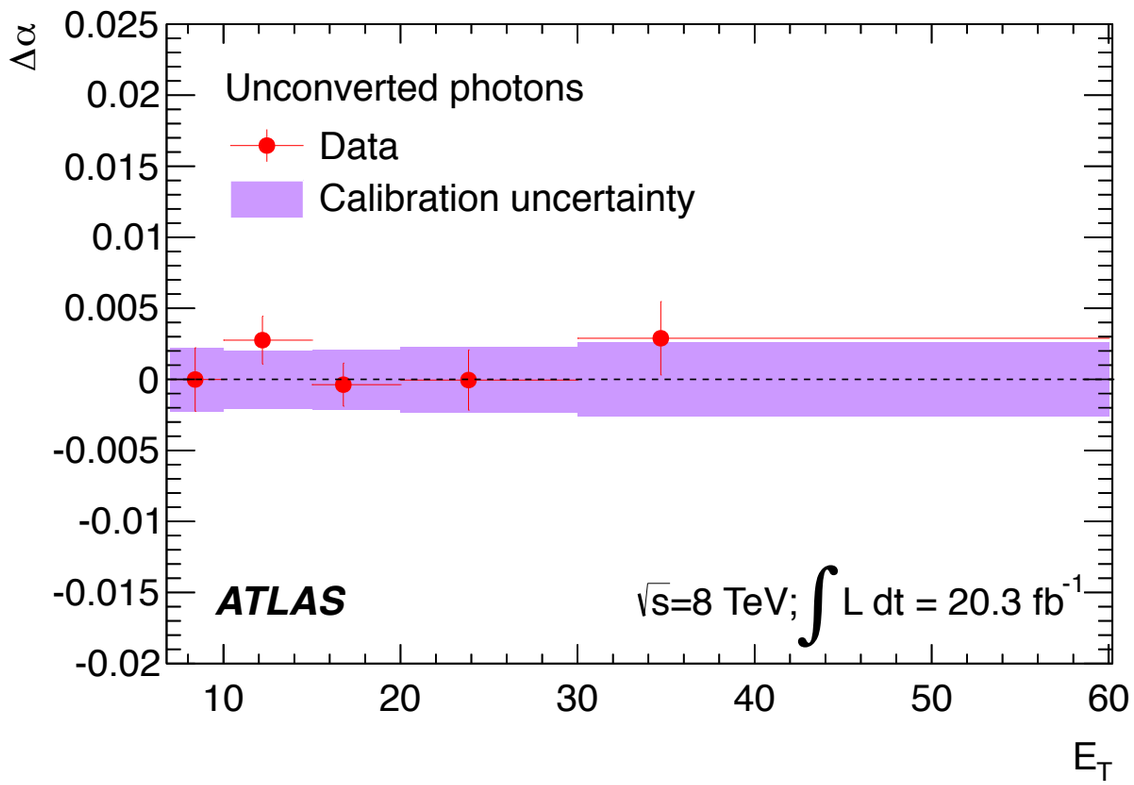
Probing the Higgs in the diphoton channel

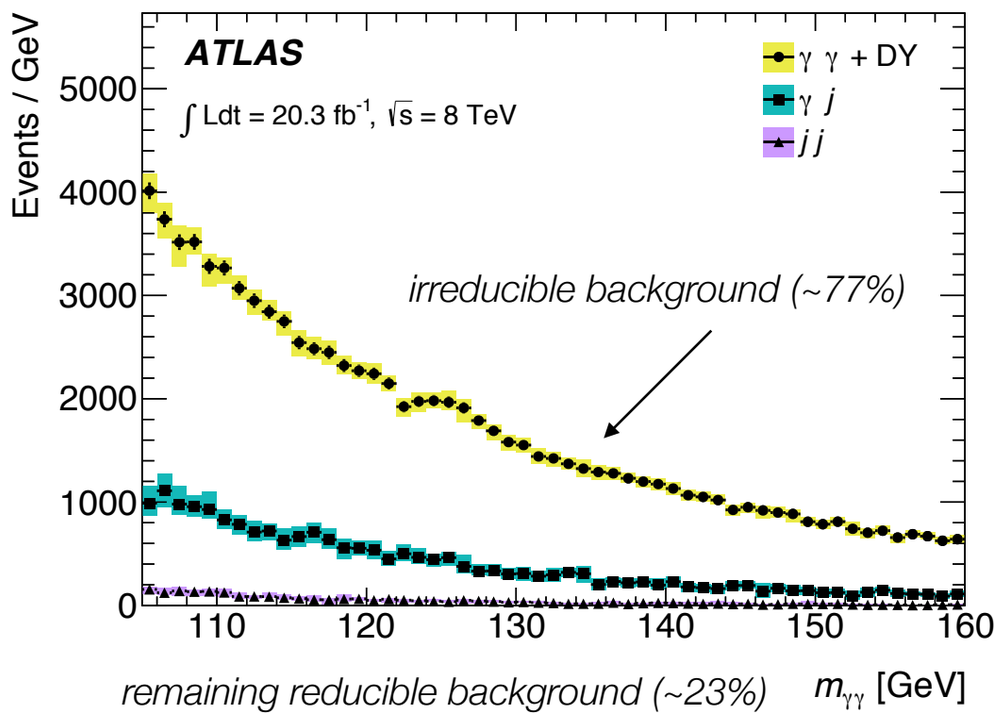
- Events selected by dedicated diphoton triggers
- Photon energies calibrated using energy scale derived from $Z \rightarrow e^+e^-$ and others processes.



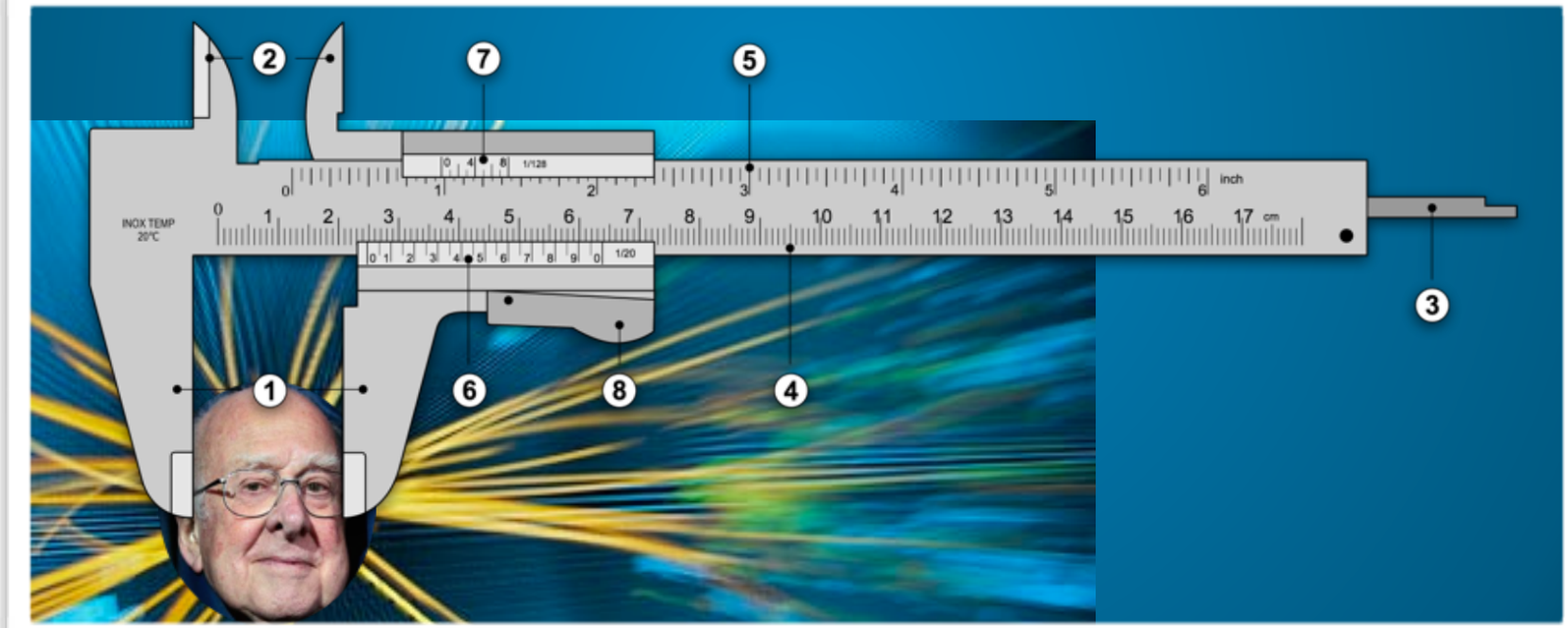
Invariant Mass: $m_{\gamma\gamma} = \sqrt{2E_1E_2(1-\cos\alpha)},$

Opening angle with respect to their production vertex





Towards Higgs precision Physics



Present three recent results and a short status report on Run 2:

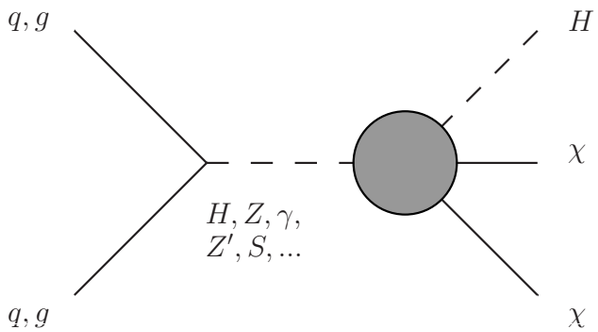
I. Search for Dark Matter in Events with Missing Transverse Momentum and Higgs boson decaying to two photons
II. Inclusive and differential Higgs boson cross section measurements
III. Constraints on non-SM Higgs boson interactions with fiducial cross sections.
IV. In case you missed it — Run 2 started!

Dark Matter Search with Missing Transverse Momentum in the Higgs Boson to Diphoton Channel

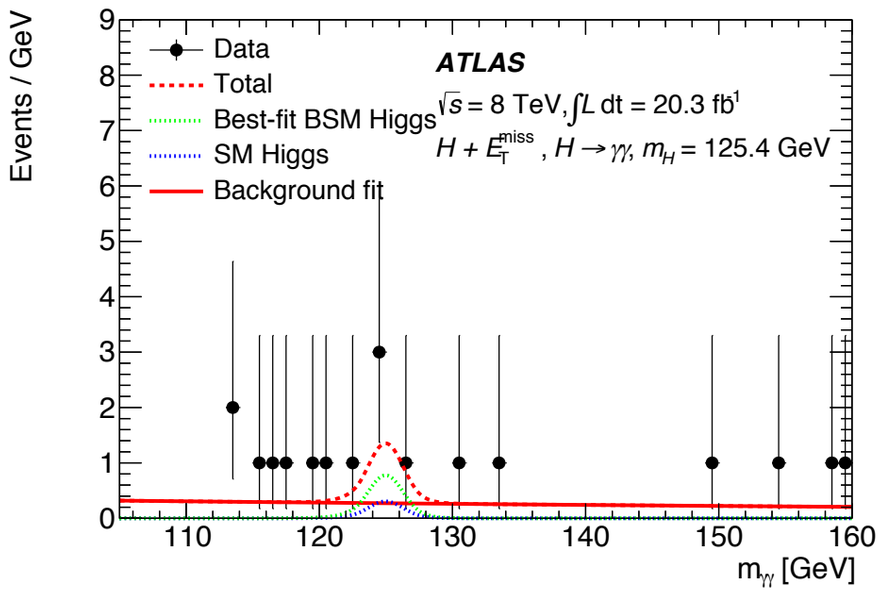
http://arxiv.org/abs/1506.01081
Accepted by PRL

Inclusive and differential cross section measurements

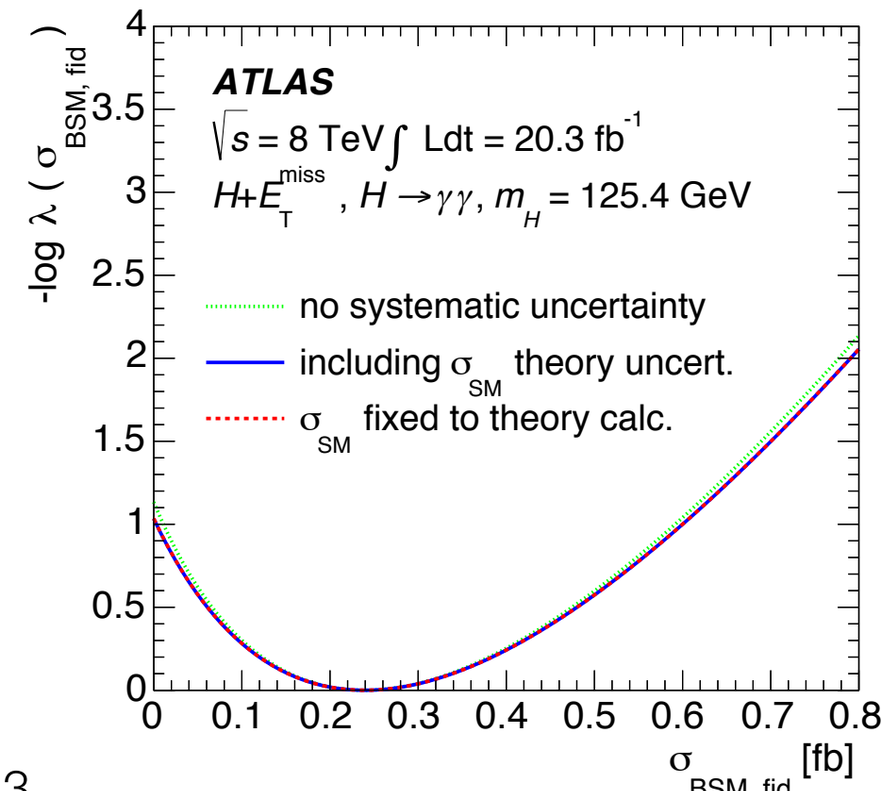
- Analysis idea:
  - Look for an excess in Higgs boson to diphoton Events associated with Missing transverse momentum.



$$E_T^{\text{miss}} > 90\,\text{GeV}, p_T^{\gamma\gamma} > 90\,\text{GeV}$$



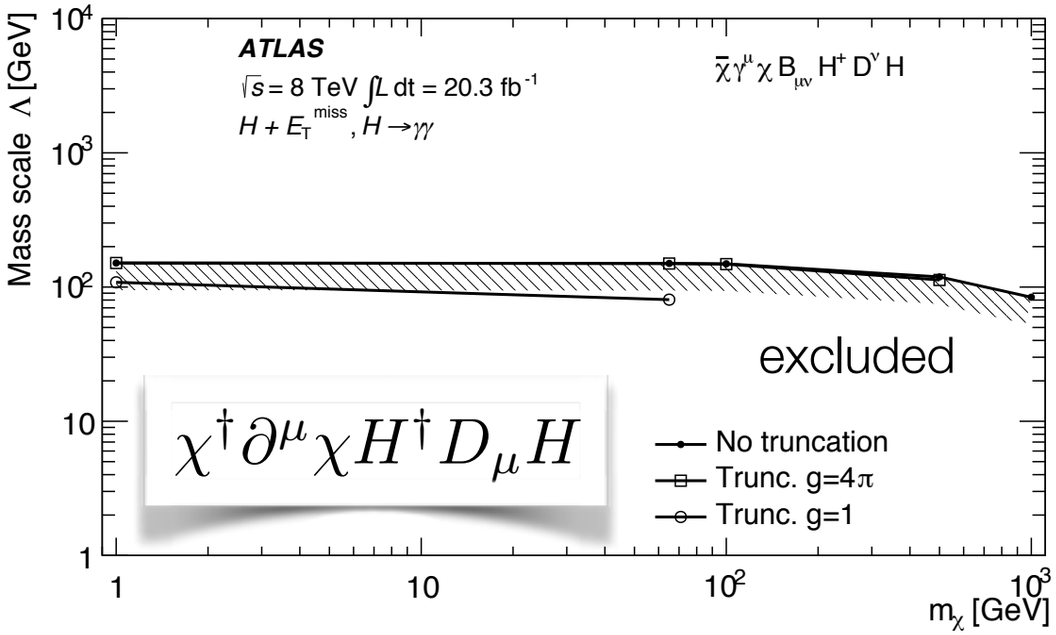
'Subtract' Standard Model signal

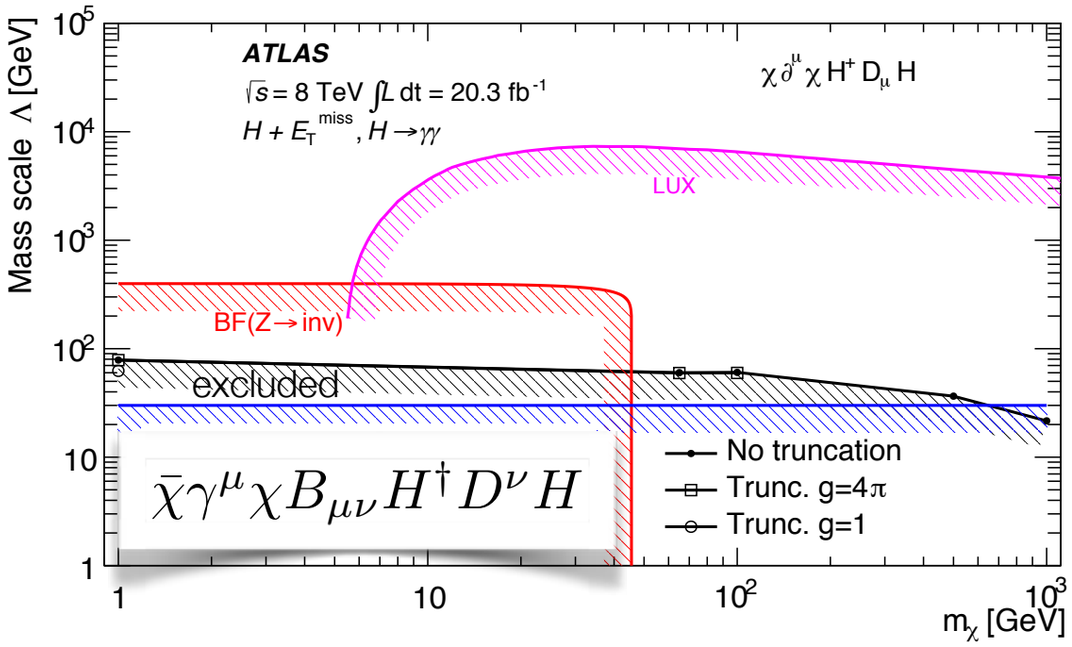


Expect ~1+1 signal+bgk events in the peak region, but see ~3.

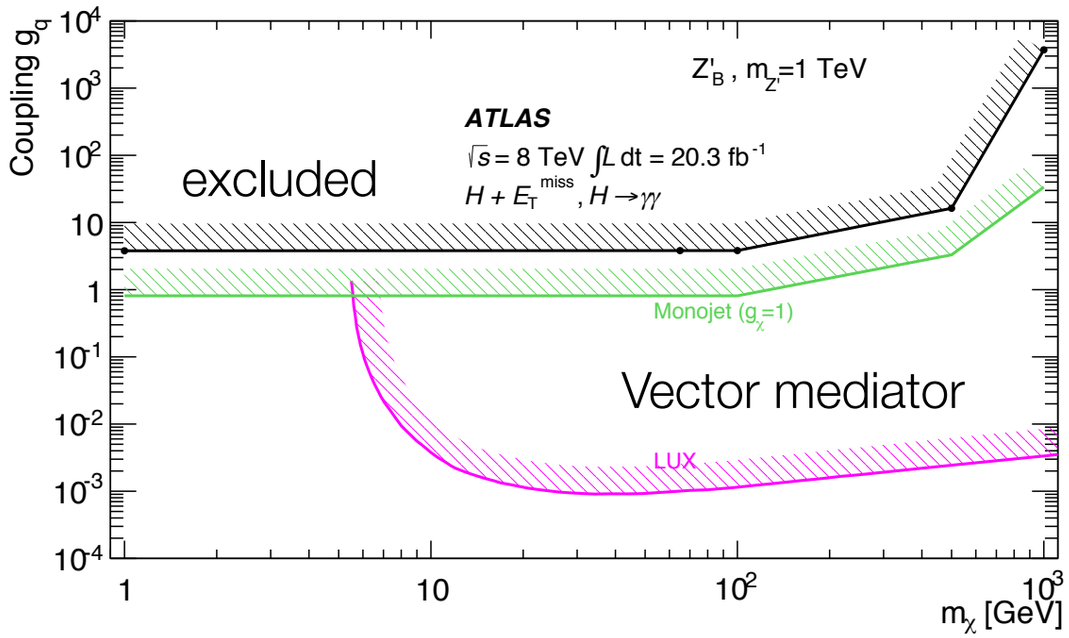
Inclusive and differential cross section measurements

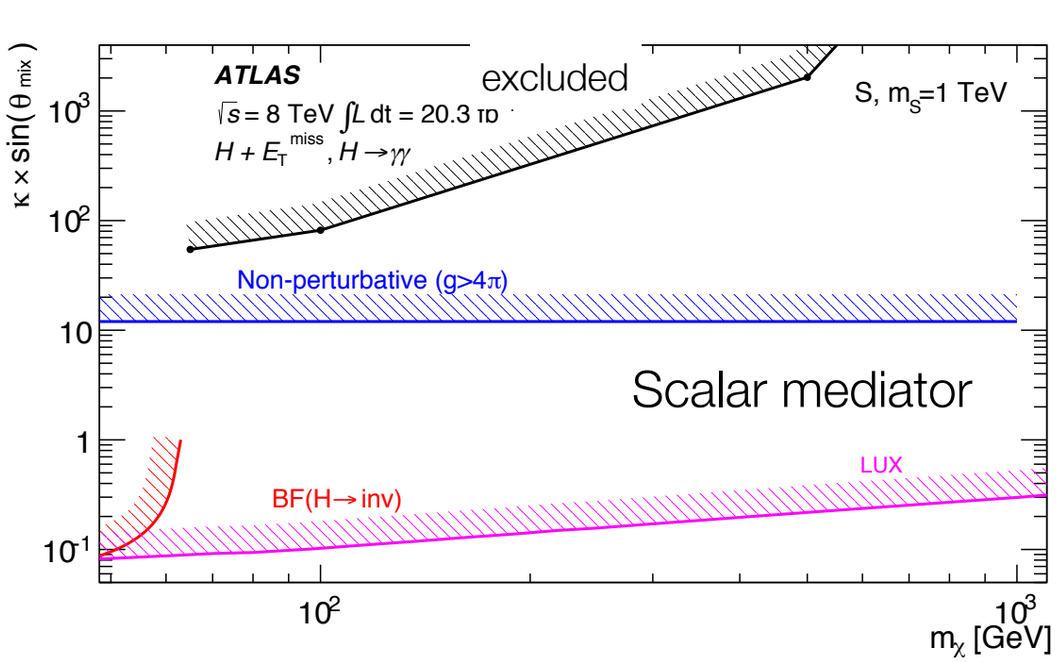
EFT Limits:





Simplified Model Limits:





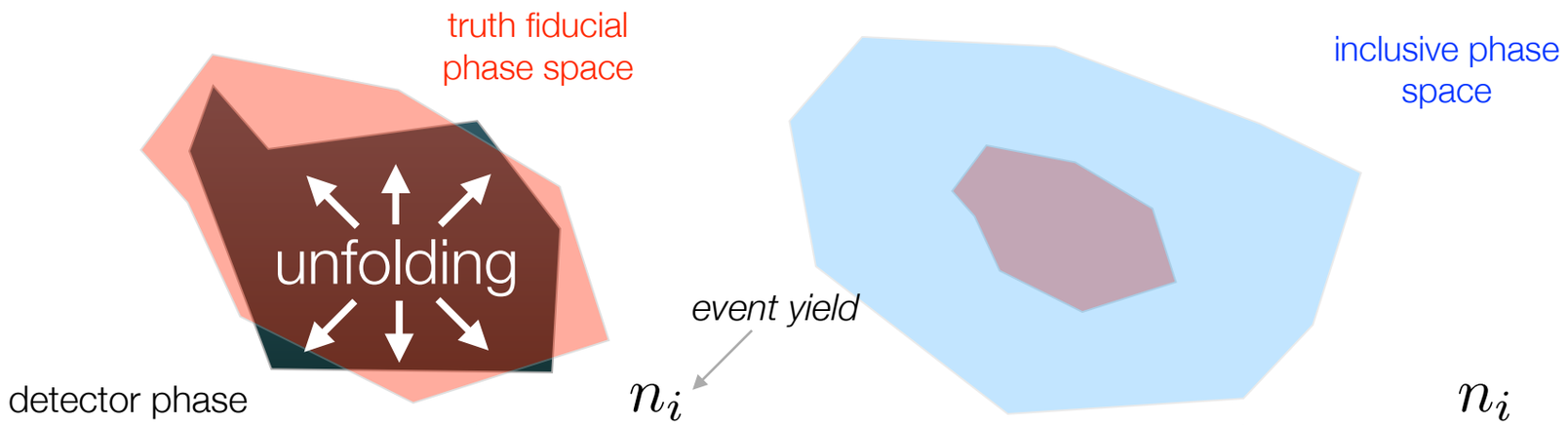
Very statistically Limited at this point, will be very interesting with full Run II data.

Measurement of the total and differential Higgs boson production cross section

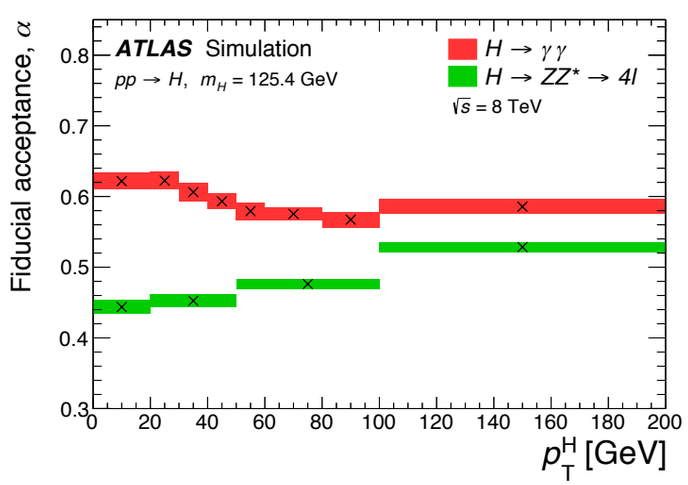
http://arxiv.org/abs/1504.05833
Accepted by PRL

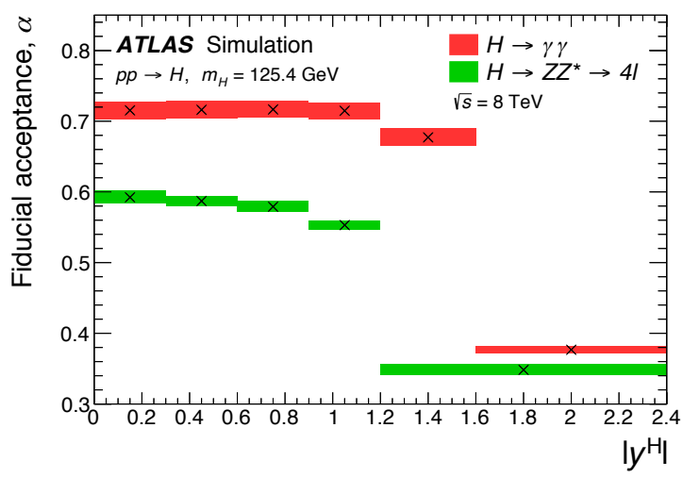
Inclusive and differential cross section measurements

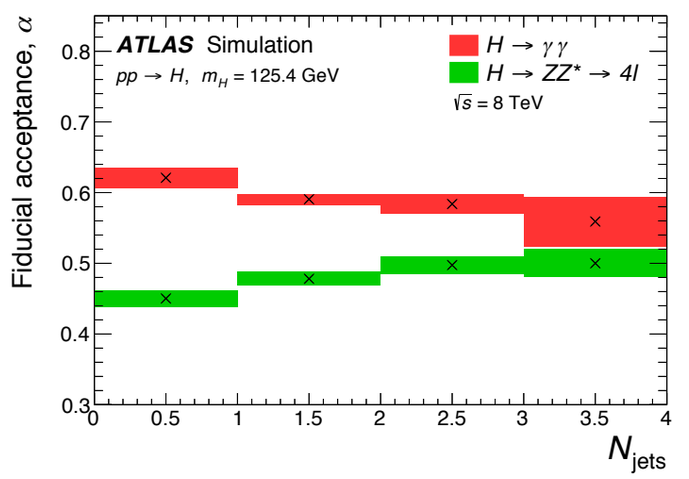
- Analysis idea:
  - Combine H→γγ and H→ZZ*→4l fiducial event yields by accounting for the difference in branching fraction and acceptance



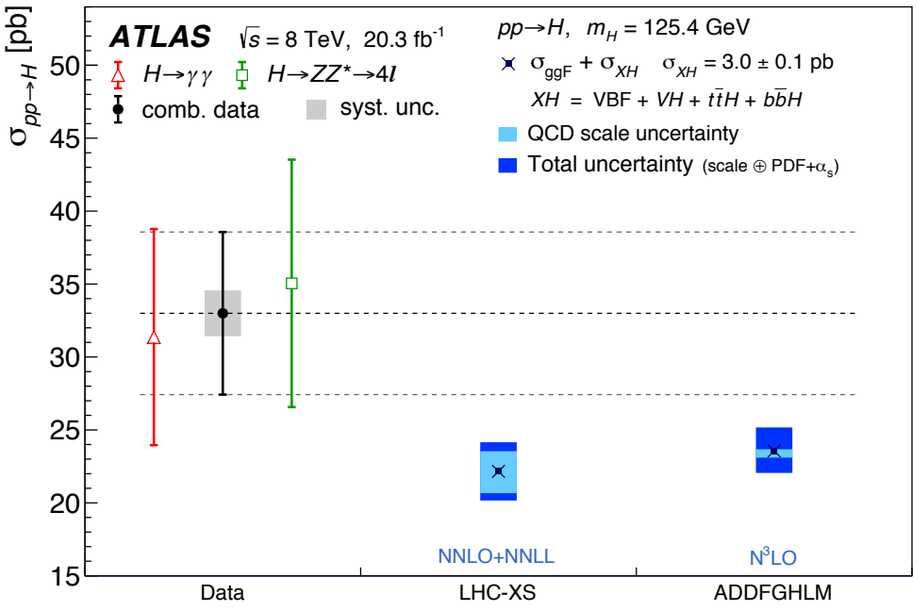
➡ Can also be done for differential distributions, e.g. Higgs boson pT spectrum

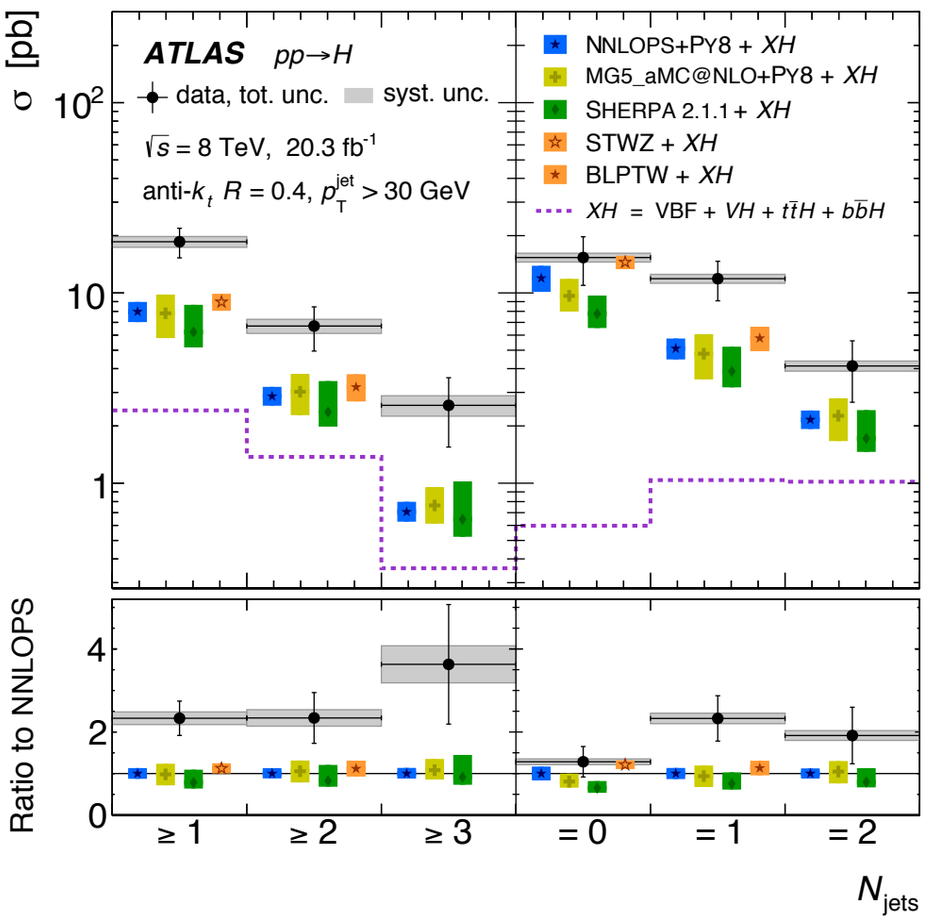






Inclusive and differential cross section measurements





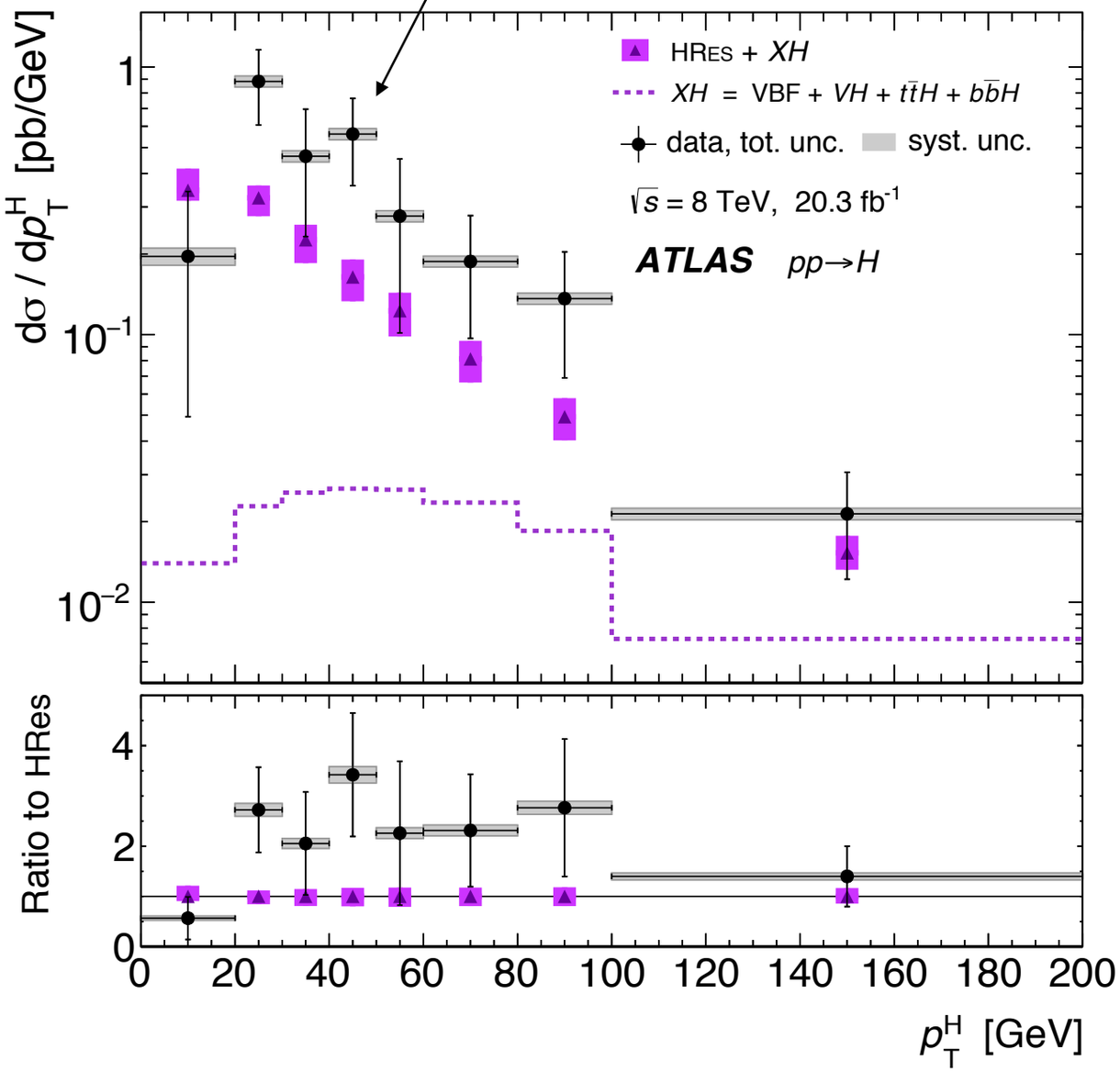
- Inclusive cross section result:
  - Compared to **N3LO** result from Anastasiou et al. http://arxiv.org/abs/1503.06056
  - Good agreement between channels.
  - Cross section a bit high in comparison to SM

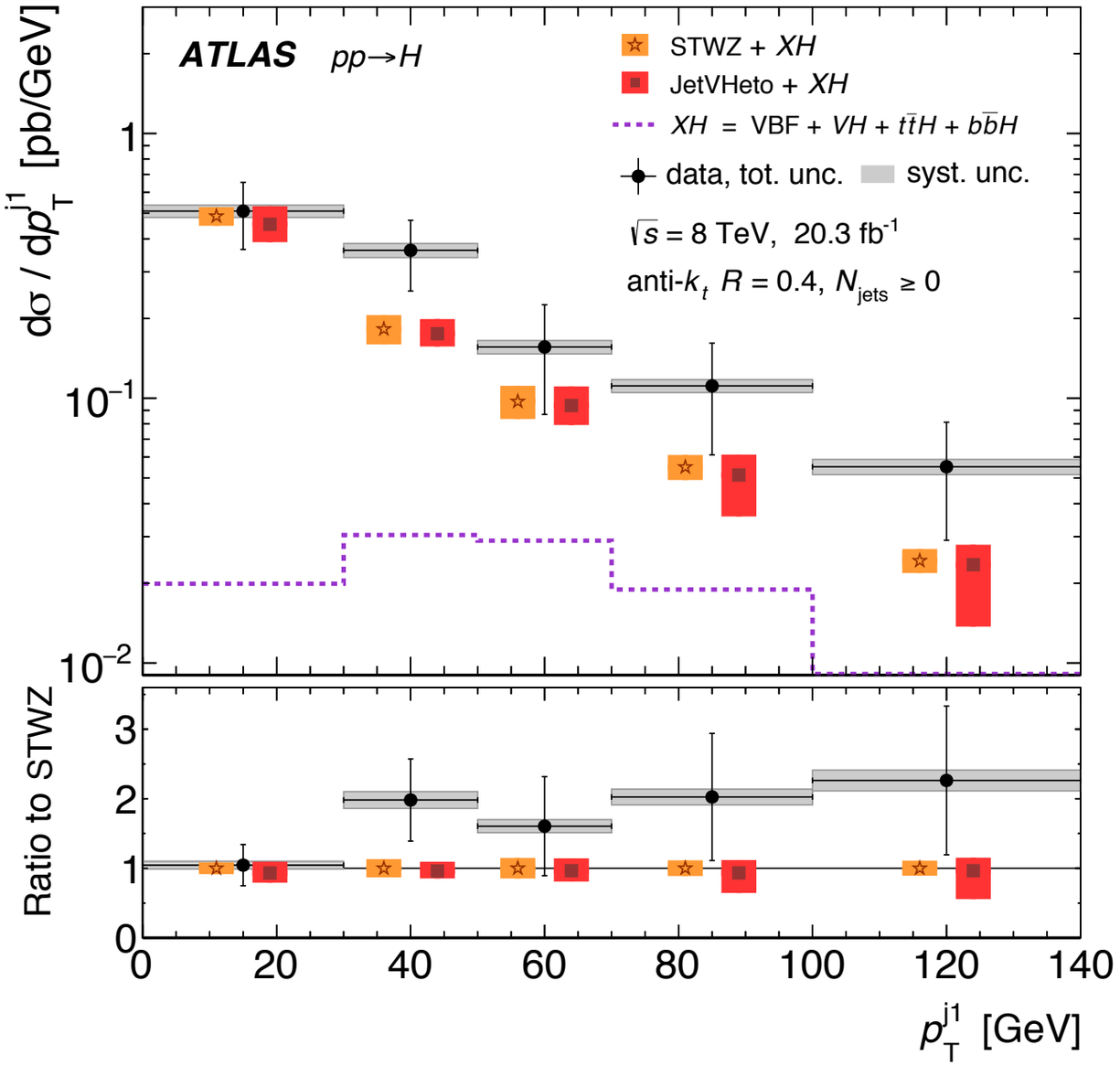
- Inclusive and Exclusive Jet cross sections

Total cross-section calculations	
LHC-XS [10]	NNLO+NNLL [a,b,c]
ADDFGHLM [27–30]	N^{3}LO [a,b,c]
Analytical differential cross-section predictions	
HRes 2.2 [20, 21]	NNLO+NNLL [a,e,f]
STWZ [31], BLPTW [32]	NNLO+NNLL [c,d,e,g,h]
JetVHeto 2.0 [33–35]	NNLO+NNLL [a,c,e]
Monte Carlo event generators	
SHERPA 2.1.1 [36, 37]	$H+0,1,2$ jets @NLO [i,j]
MG5_aMC@NLO [38, 39]	$H+0,1,2$ jets @NLO [i,k,l]
Powheg Nnlops [40, 41]	NNLO$_{\geq 0j}$, NLO$^{e,l,m}_{\geq 1j}$

Inclusive and differential cross section measurements

A bit more boosted than expected.





Constraining non-SM Higgs boson interactions using differential cross sections

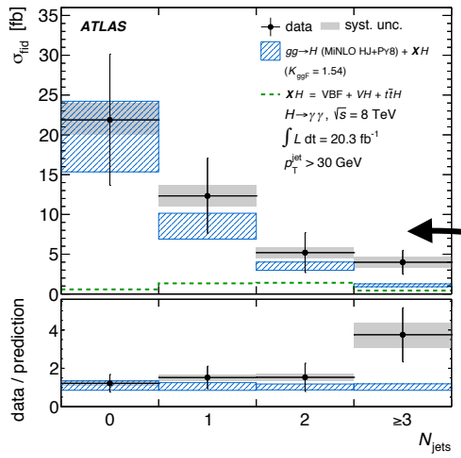
http://arxiv.org/abs/1508.02507
Submitted to PLB

Effective Field Theory Analysis of differential cross sections

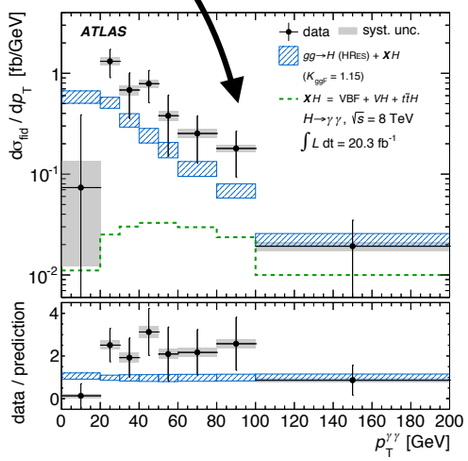
- Analysis idea:
  - Simultaneous analysis of several differential cross sections to probe for New Physics.
  - **Problem**: all measured from same data → need statistical correlations.

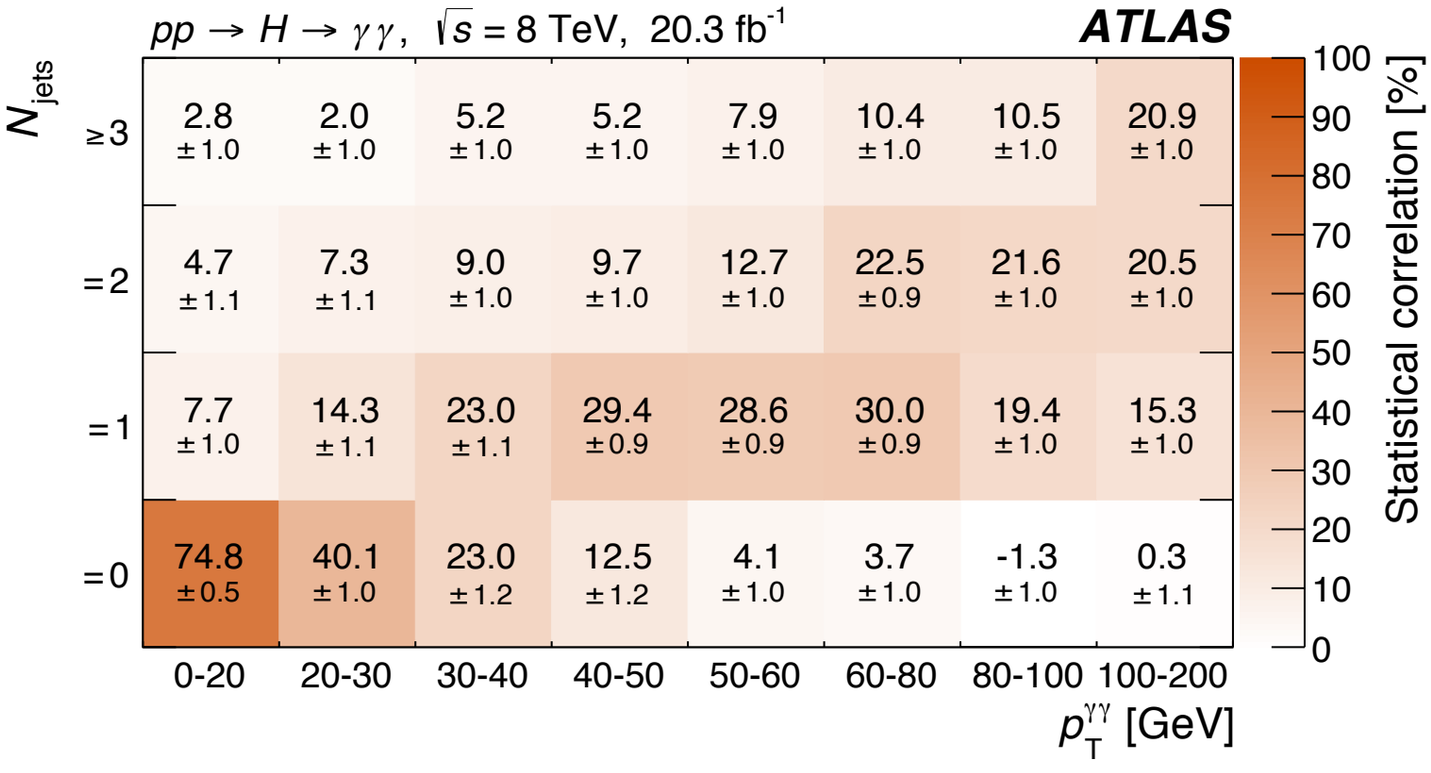
Can be obtained using **bootstrapping** approach

i.e. exploit large amount of background to estimate correlations.



$\rho = ?$





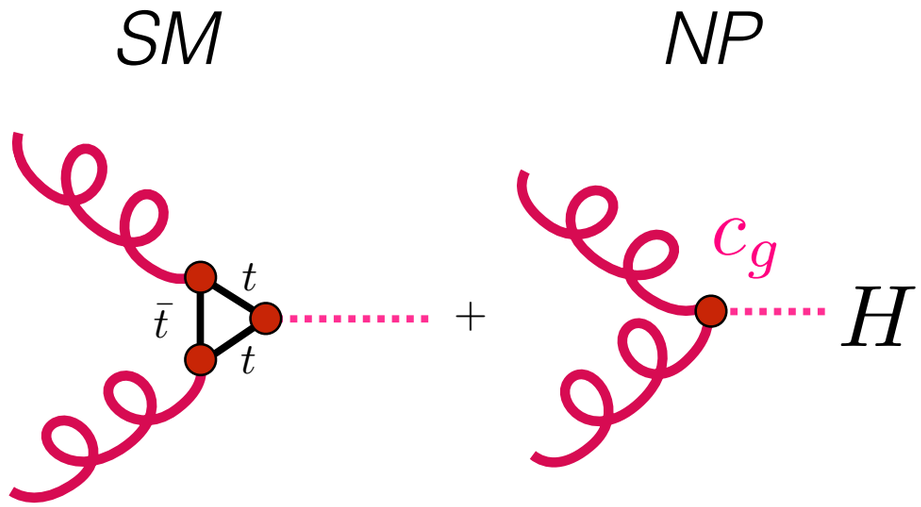
Effective Field Theory Analysis of differential cross sections

- Effective Field theory:

  Strongly **I**nteracting **L**ight **H**iggs

  arXiv:1303.3876

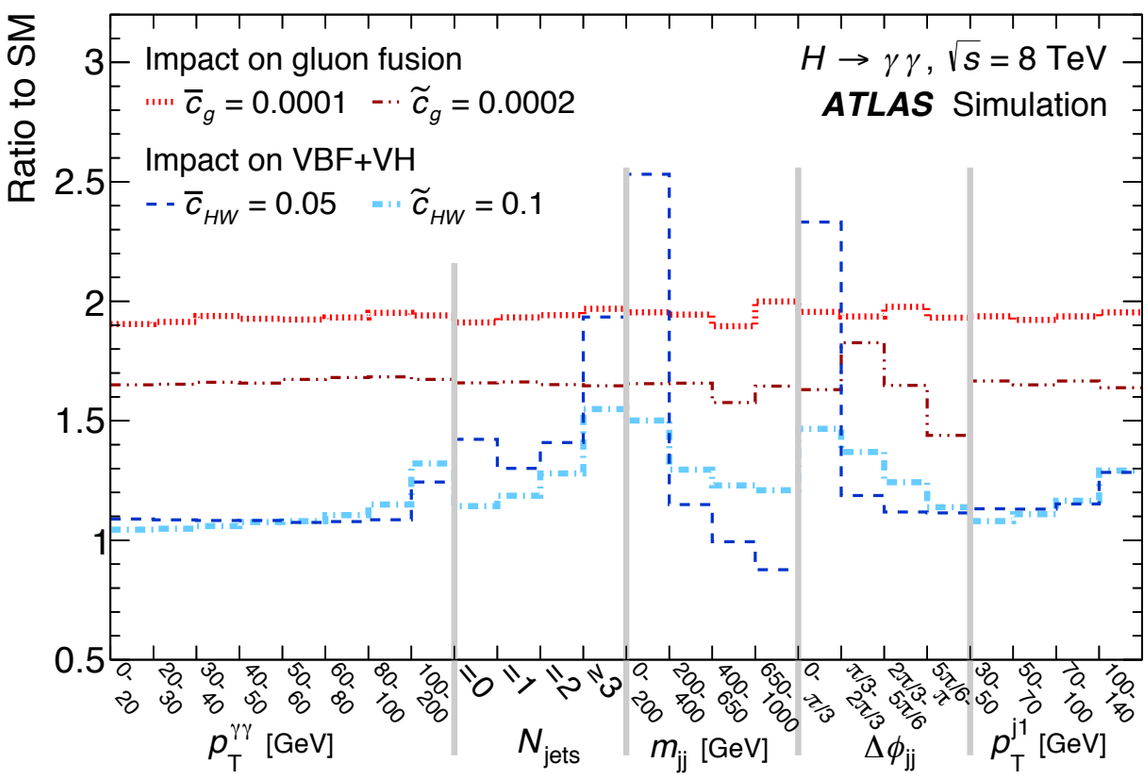
  arXiv:hep-ph/0703164

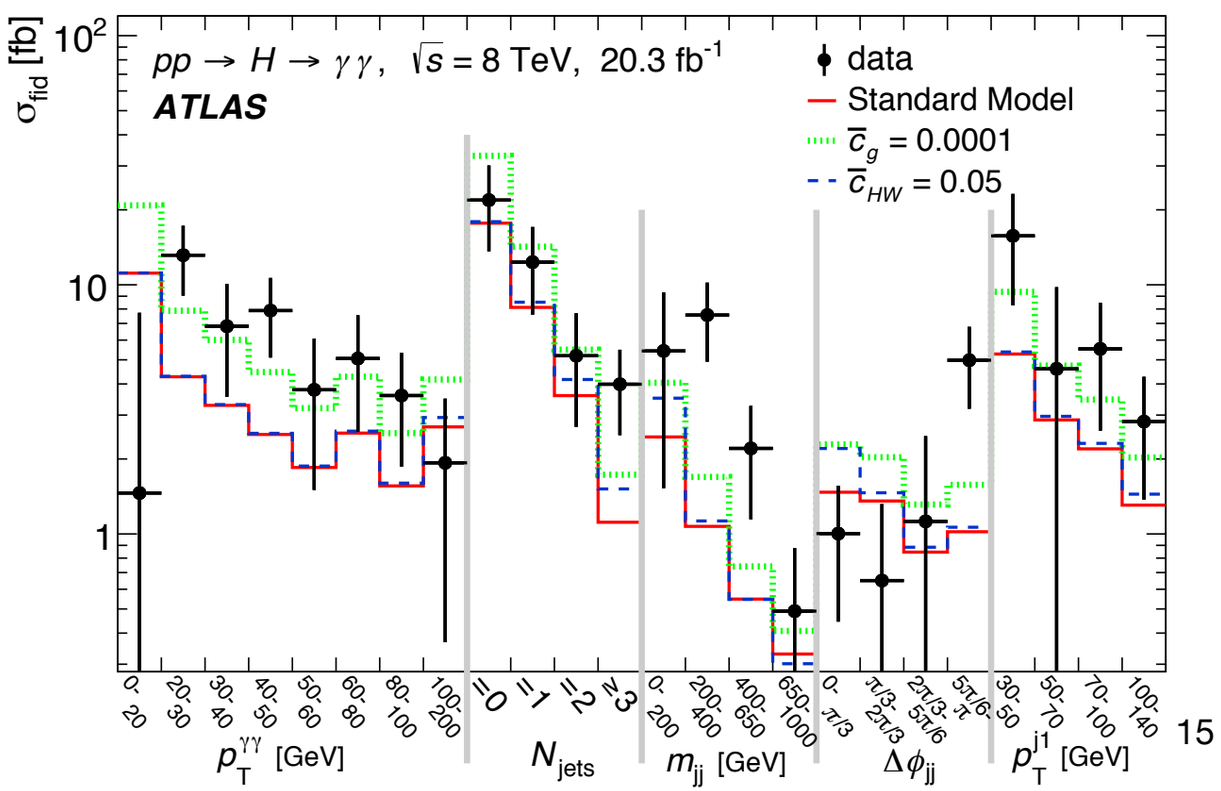


➡ Extends SM by adding point-like interactions

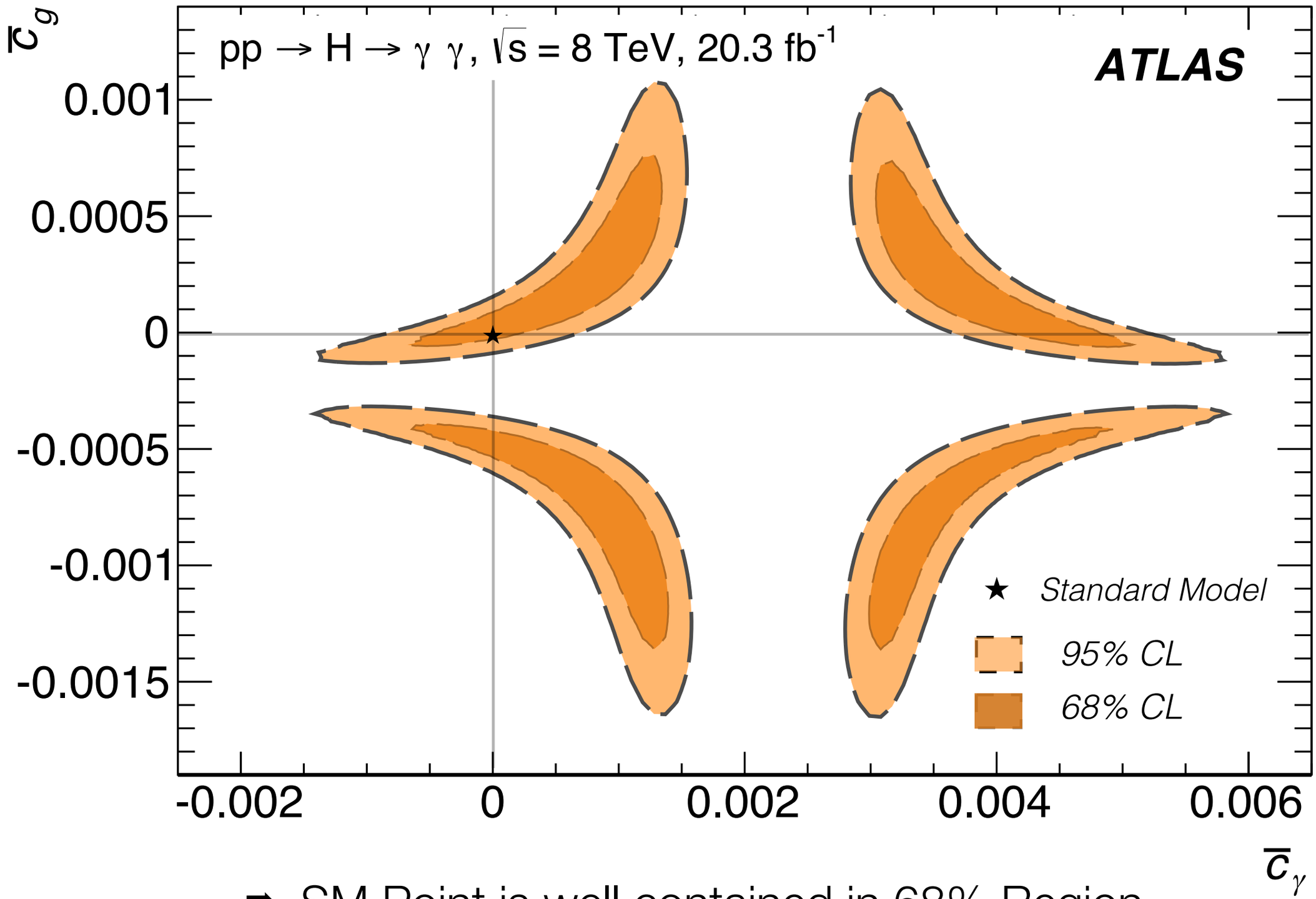
$$\mathcal{L} = \bar{c}_\gamma \mathcal{O}_\gamma + \bar{c}_g \mathcal{O}_g + \bar{c}_{HW} \mathcal{O}_{HW} + \bar{c}_{HB} \mathcal{O}_{HB} + \tilde{c}_\gamma \mathcal{O}_\gamma + \tilde{c}_g \mathcal{O}_g + \tilde{c}_{HW} \mathcal{O}_{HW} + \tilde{c}_{HB} \mathcal{O}_{HB},$$

Data points published on HepData
http://arxiv.org/abs/1407.4222
JHEP09(2014)112



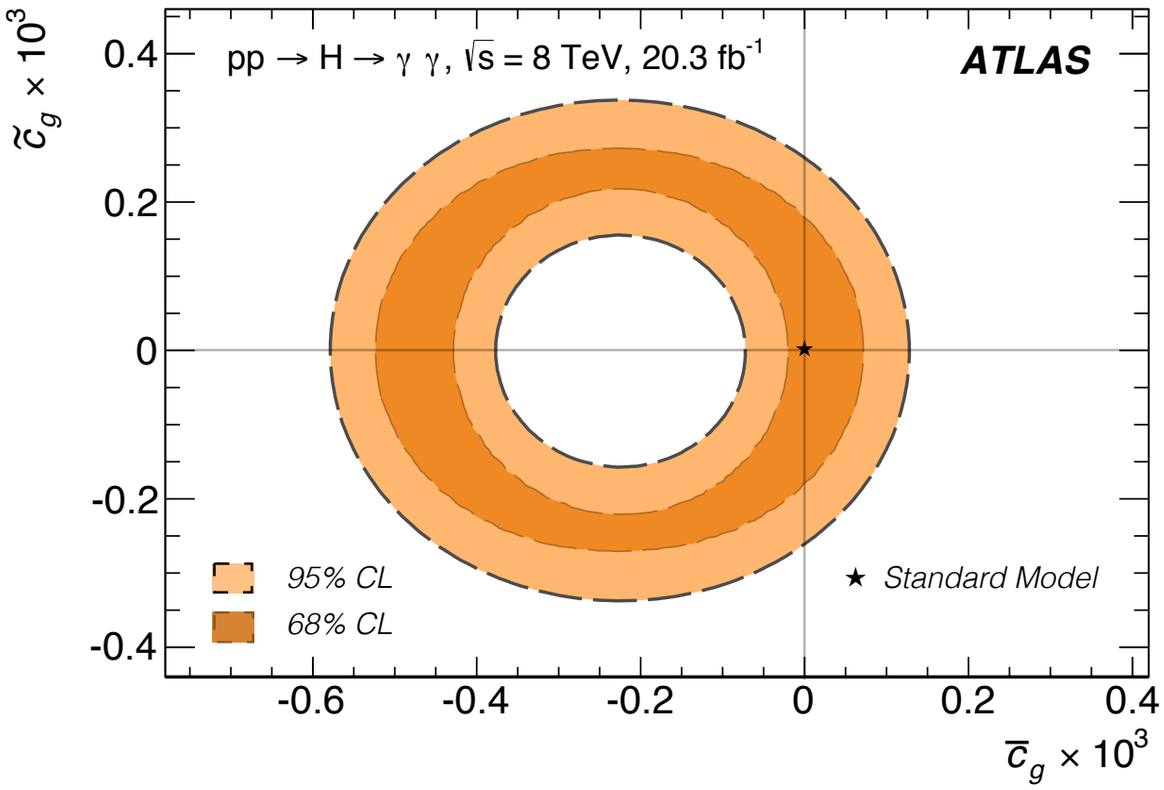


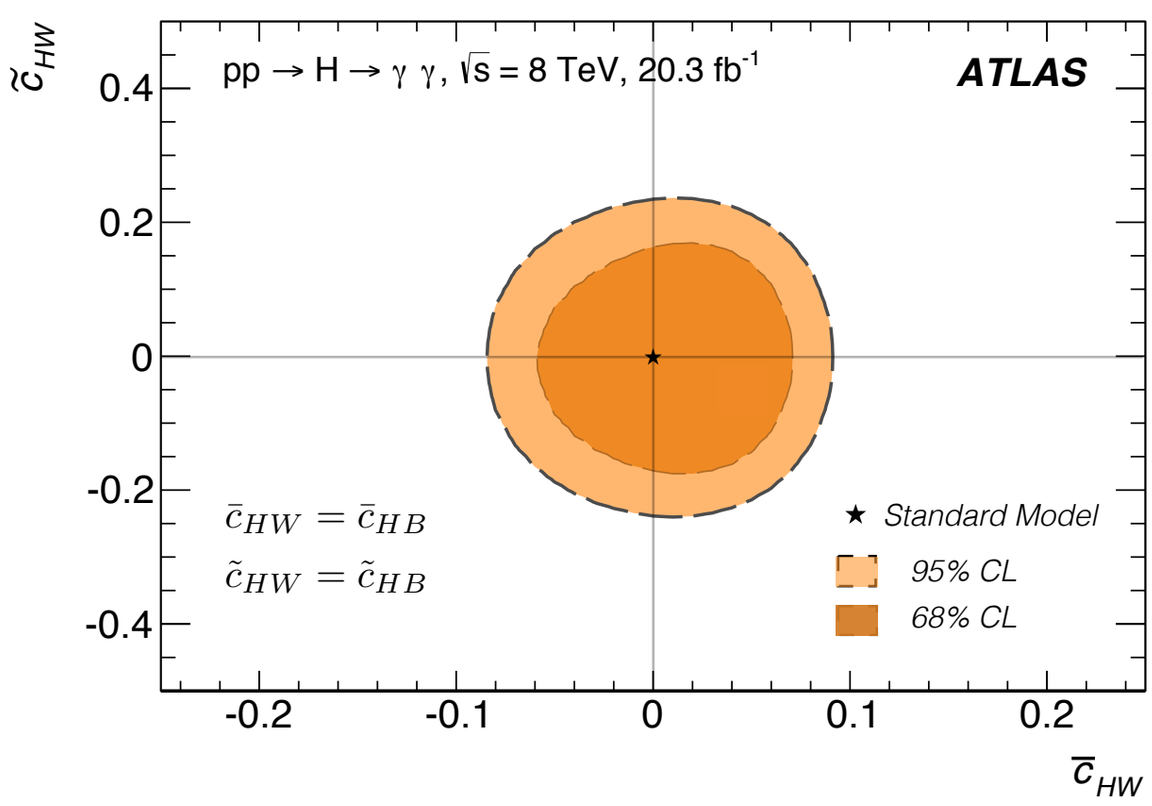
Limits on $\bar{c}_g$ and $\bar{c}_\gamma$



➡ SM Point is well contained in 68% Region

Other operators:





- No significant deviation from SM observed.

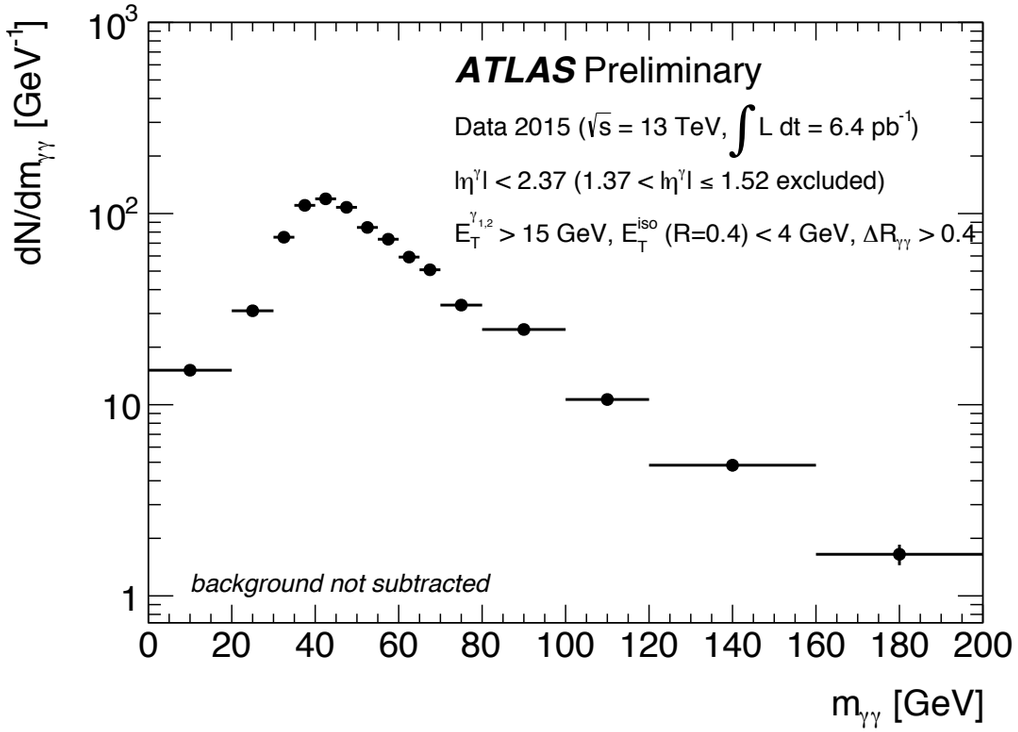
Coefficient	95% $1 - CL$ limit
$\bar{c}_\gamma$	$[-7.4, 5.7]\times10^{-4} \cup [3.8, 5.1]\times10^{-3}$
$\tilde{c}_\gamma$	$[-1.8, 1.8]\times10^{-3}$
$\bar{c}_g$	$[-0.7, 1.3]\times10^{-4} \cup [-5.8, -3.8]\times10^{-4}$
$\tilde{c}_g$	$[-2.4, 2.4]\times10^{-4}$
$\bar{c}_{HW}$	$[-8.6, 9.2]\times10^{-2}$
$\tilde{c}_{HW}$	$[-0.23, 0.23]$

Run 2 & Summary

Summary and Run 2

- Showed you many exciting Run 1 results using the Higgs boson to diphoton channel.
  - Transition from discovery to more precision results.
  - Probe the SM character by performing as model independent measurements as possible.
  - Excluded large non-SM contributions of individual operators.
    - All measurements are consistent with the SM.
  - Information public so that outsiders can perform similar tests.

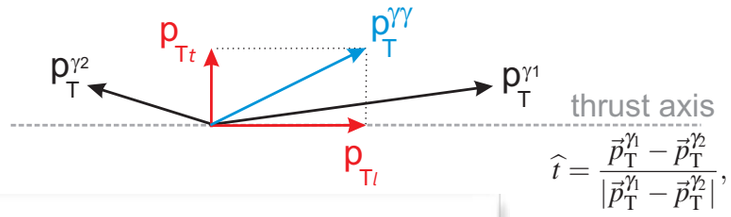
- Started Run 2 data taking
  - Diphoton mass distribution (background is not subtracted)
- Excited to get 13 TeV results!

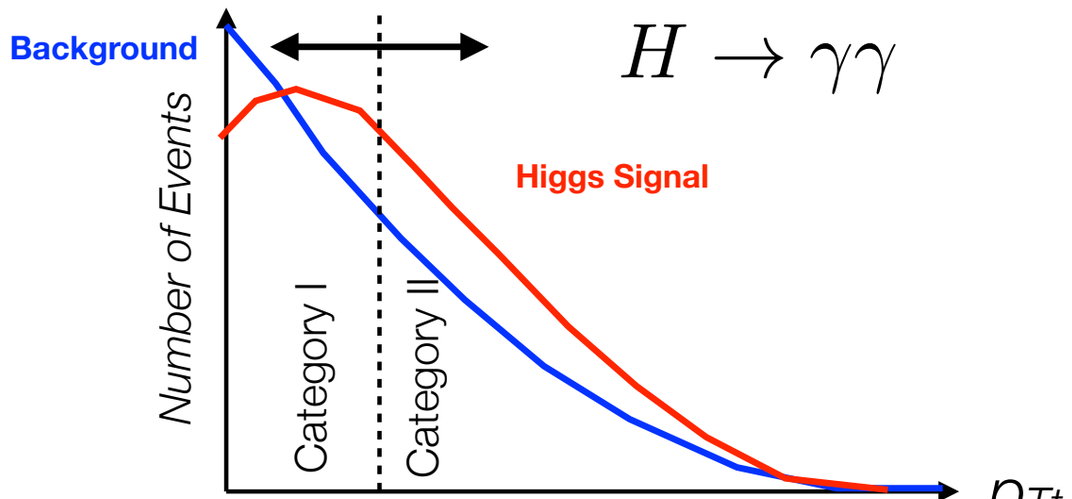


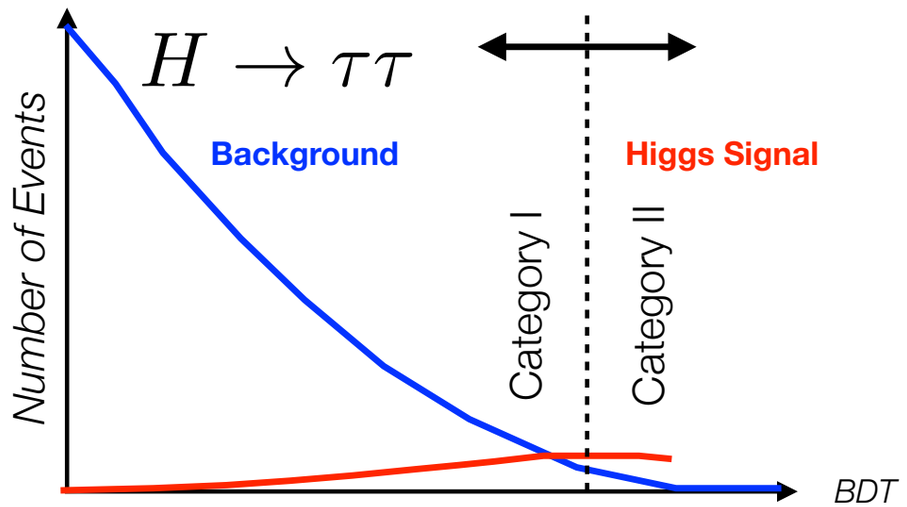
Backup

Differential and Fiducial cross section measurements

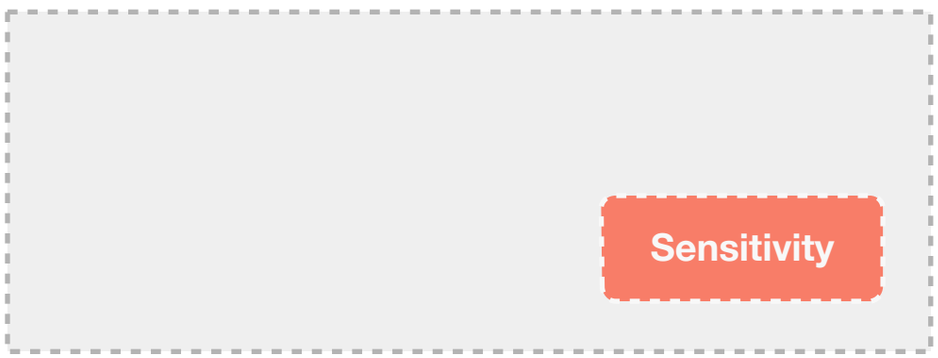
How did we find the Higgs?







- In a signal strength fit, category II gets more weight than category I due to the higher expected S/B
- Events from a very specific region of phase space can get very high weight in a combined fit.



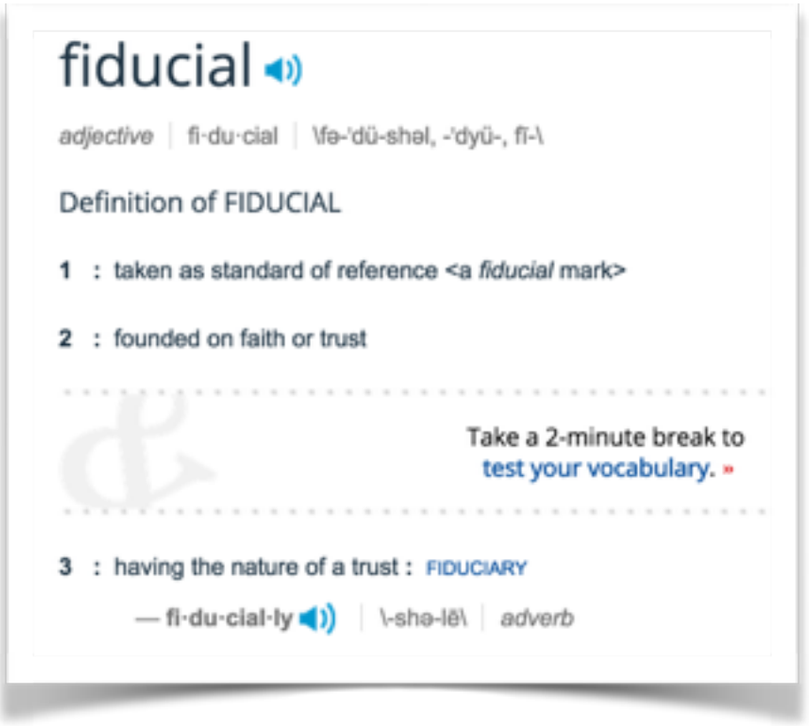
Problem:

i. if efficiencies are modelled wrong, get a biased result

ii. Pretend to measure all of phase space, but effective sensitivity from a small, very specific region.

Differential and Fiducial cross section measurements

- Fiducial cross sections try to avoid such extrapolations

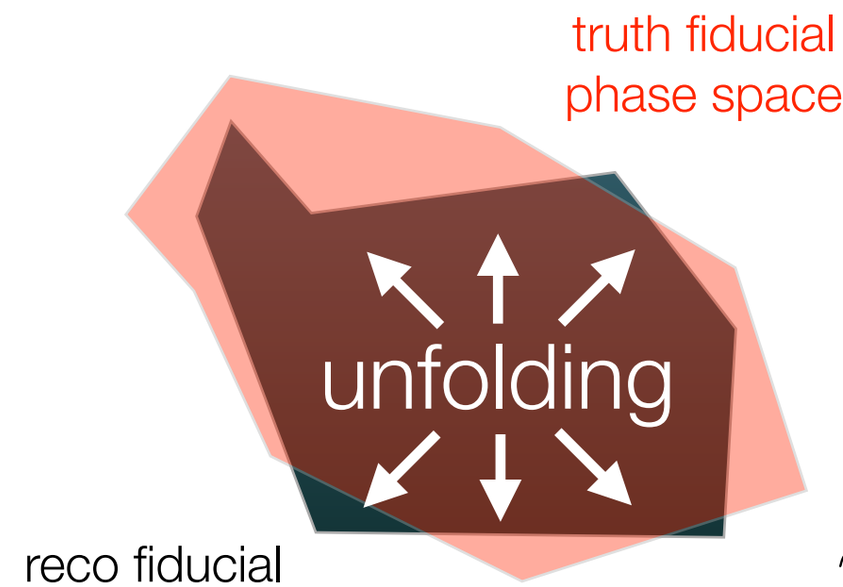


In particle physics

a fiducial cross-section is a cross-section measured only for the fiducial region, a clearly defined region in phase-space in which the detector operates with high efficiency, without extrapolating to regions where the experiment has no sensitivity.

To obtain a cross section, one needs to account for migrations in & outside the 'true' or 'truth' fiducial region.

This is called 'unfolding'

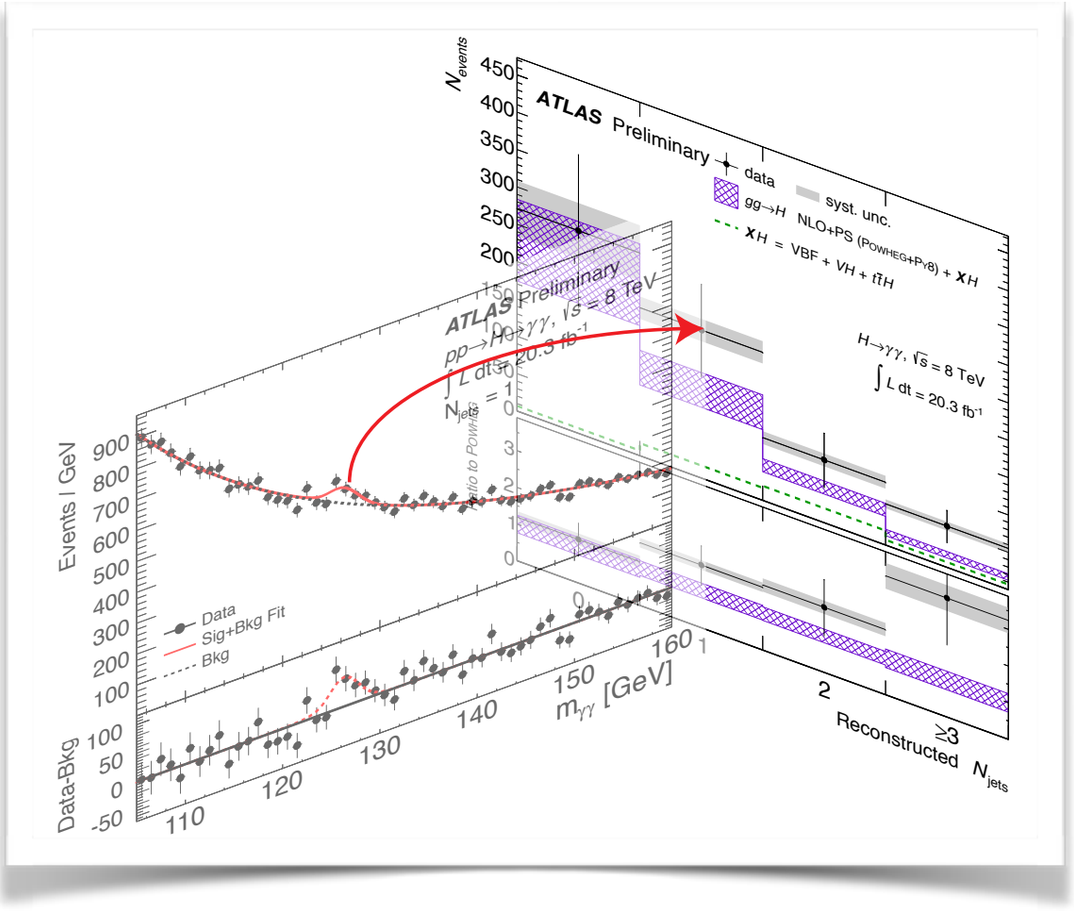


$$\sigma_i = \frac{n_i}{\mathcal{L}\, c_i}$$

Fiducial and Differential Cross Section Measurements in the diphoton channel

http://arxiv.org/abs/1407.4222
Published in JHEP09(2014)112

Differential and Fiducial cross section measurements



- Analysis idea straightforward:
  - Bin measured Candidates in observables of interest.
  - Perform Signal + Background fit in $m_{\gamma\gamma}$ to extract $H \rightarrow \gamma\gamma$ events.
  - Account for detector migration and overall efficiency effects and unfold yields into *truth fiducial region.*

cross section

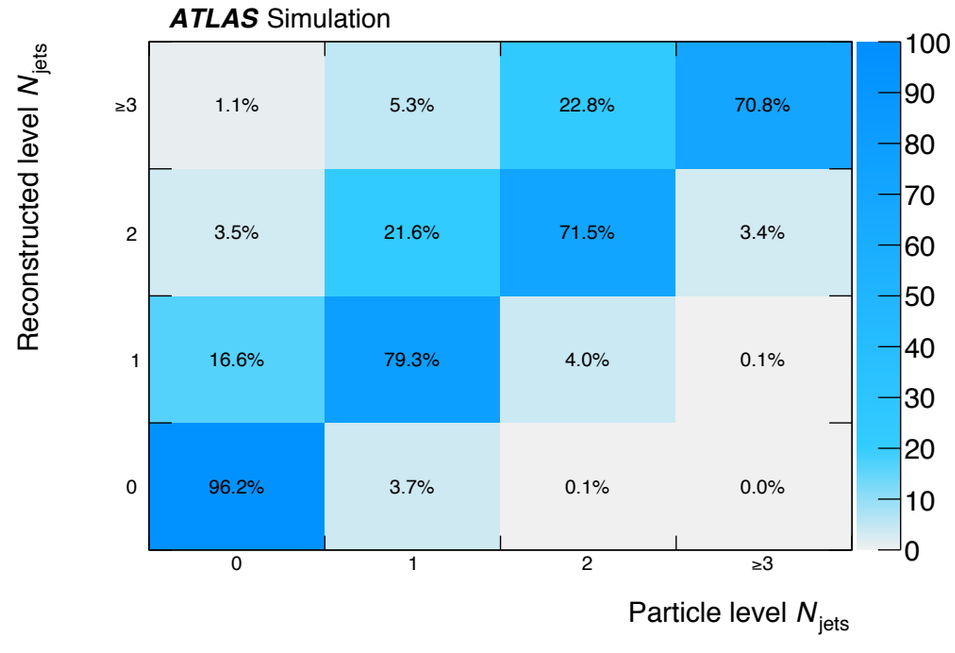
$$\sigma_i = \frac{\nu_i^{\mathrm{sig}}}{c_i \int \mathcal{L}\, \mathrm{d}t},$$

observed yield

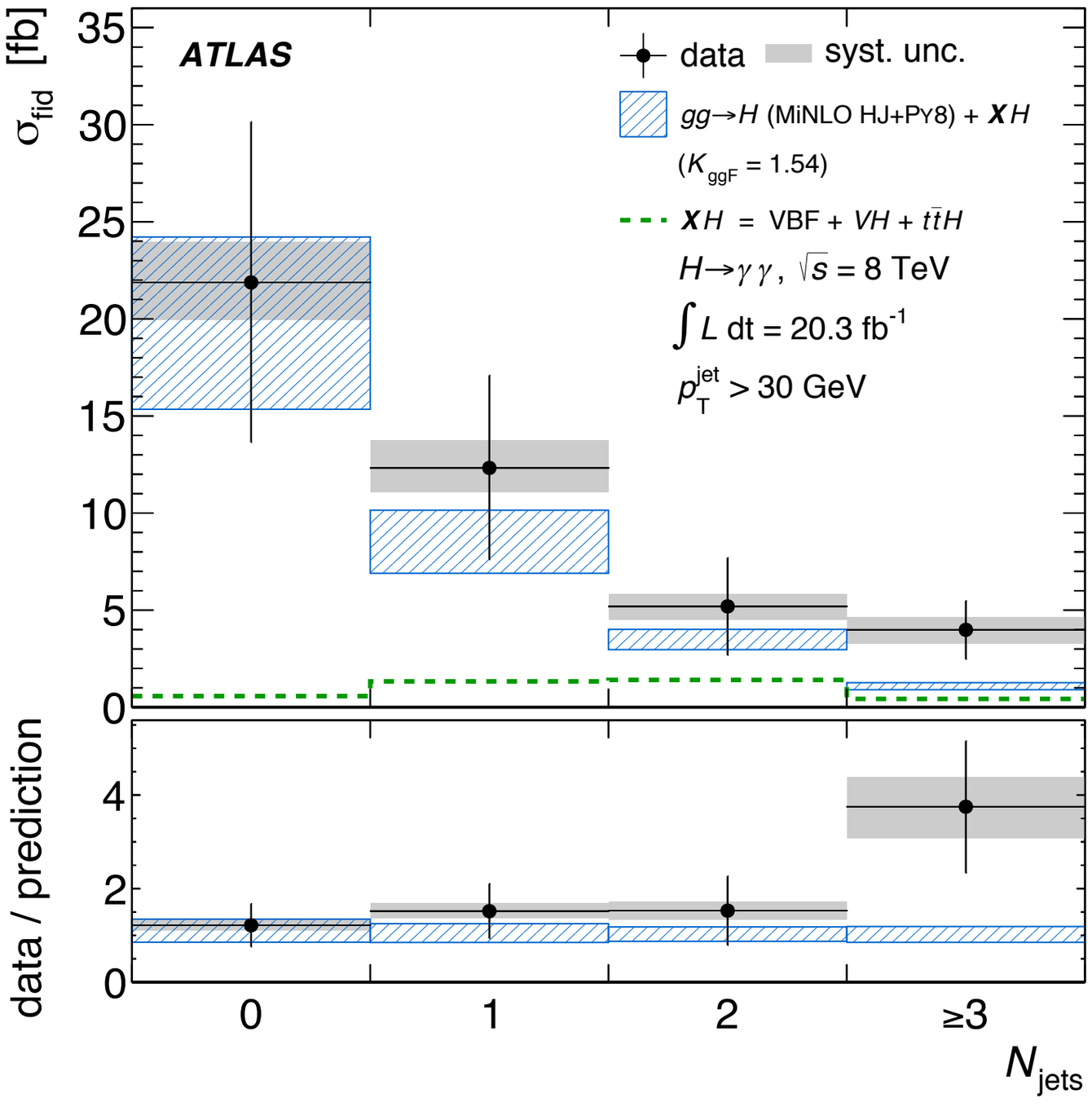
integrated luminosity

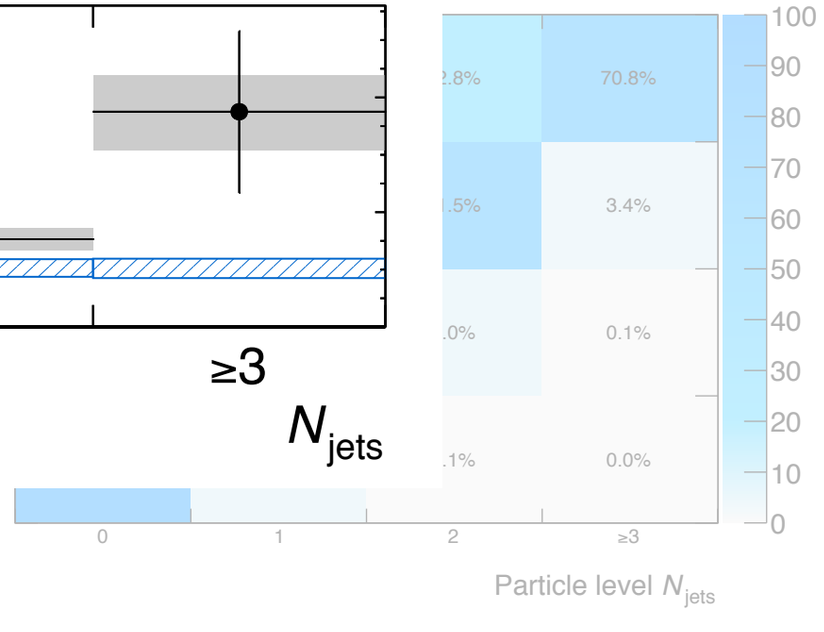
correction factor that accounts for migration

$$c_i = \frac{N_i^{\mathrm{true}}}{N_i^{\mathrm{reco}}}$$



Differential and Fiducial cross section measurements





forward:

ndidates in erest.

Background fit in

tor migration and ffects and unfold

cross section

$$\sigma_i = \frac{\nu_i^s}{c_i \int}$$

correction facto
accounts for migration

$$c_i = \frac{N_i^{\text{true}}}{N_i^{\text{reco}}}$$

Differential and Fiducial cross section measurements

- Measured *O(20)* observables and fiducial regions: