

Higgs to two photons with the



S. Laplace

(LPNHE - IN2P3/CNRS/Univ. P6 & P7)

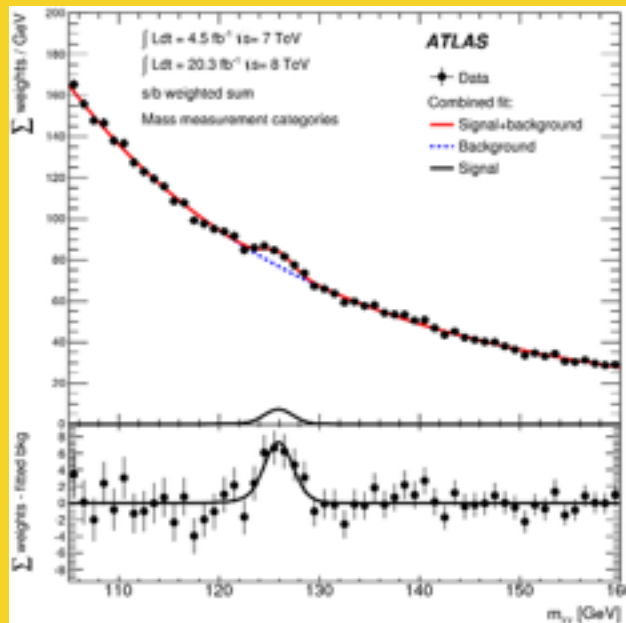
on behalf of the ATLAS collaboration

ICHEP conference, Valencia (Spain), July 3rd, 2014



New results with the $H \rightarrow \gamma\gamma$ channel

Higgs Boson Mass

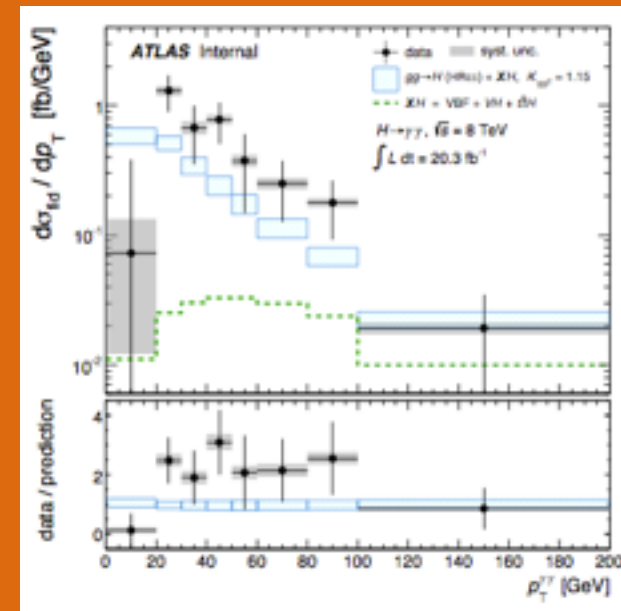


arxiv: 1406.3827
 submitted to PRD

supersedes previously published result

(poster A. Gabrielli,
 talk R. Harrington)

Fiducial and Differential cross-sections

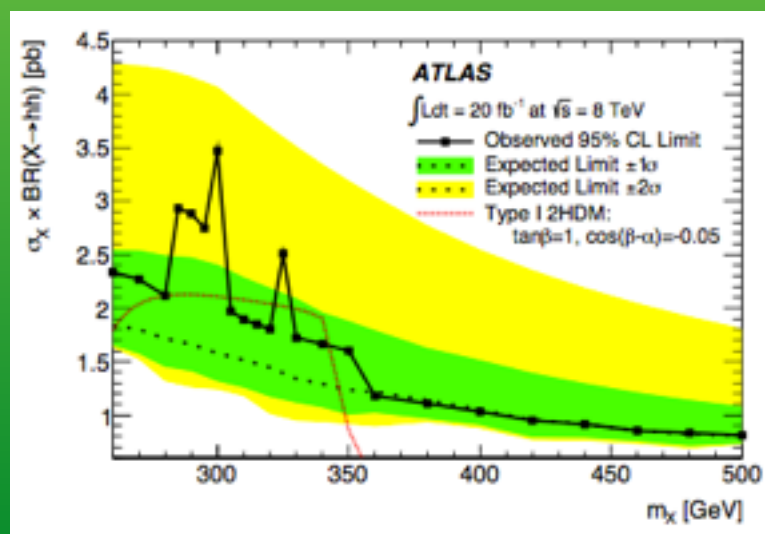


submit soon to JHEP

supersedes previously preliminary result

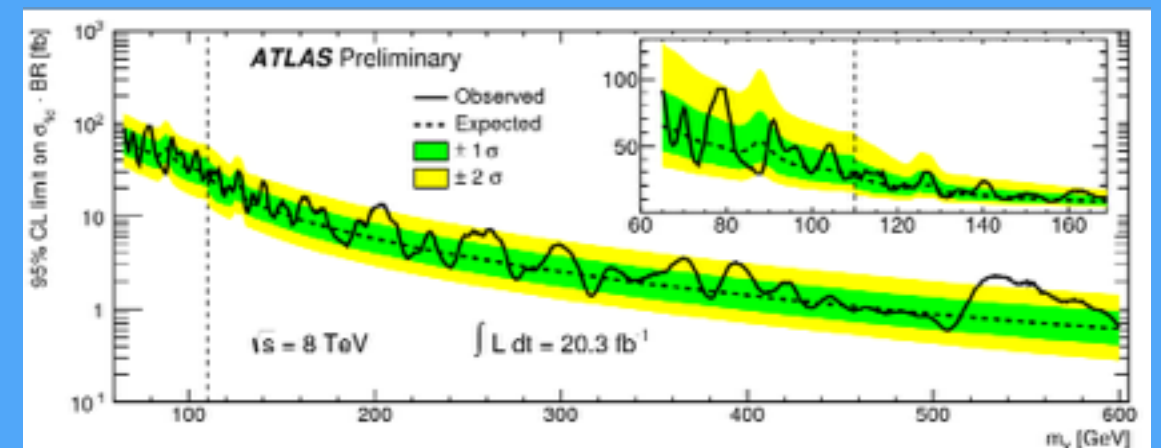
(poster Y. Huang)

Resonant and non-resonant $hh \rightarrow \gamma\gamma + bb$



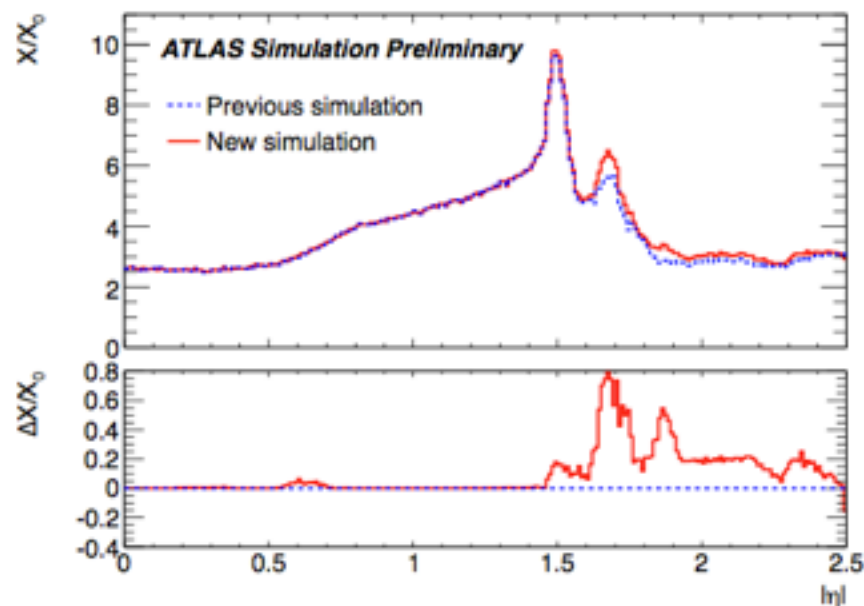
arxiv: 1406.5053
 submitted to PRL

New resonance search CONF-HIGG-2013-13, submit soon to PRL

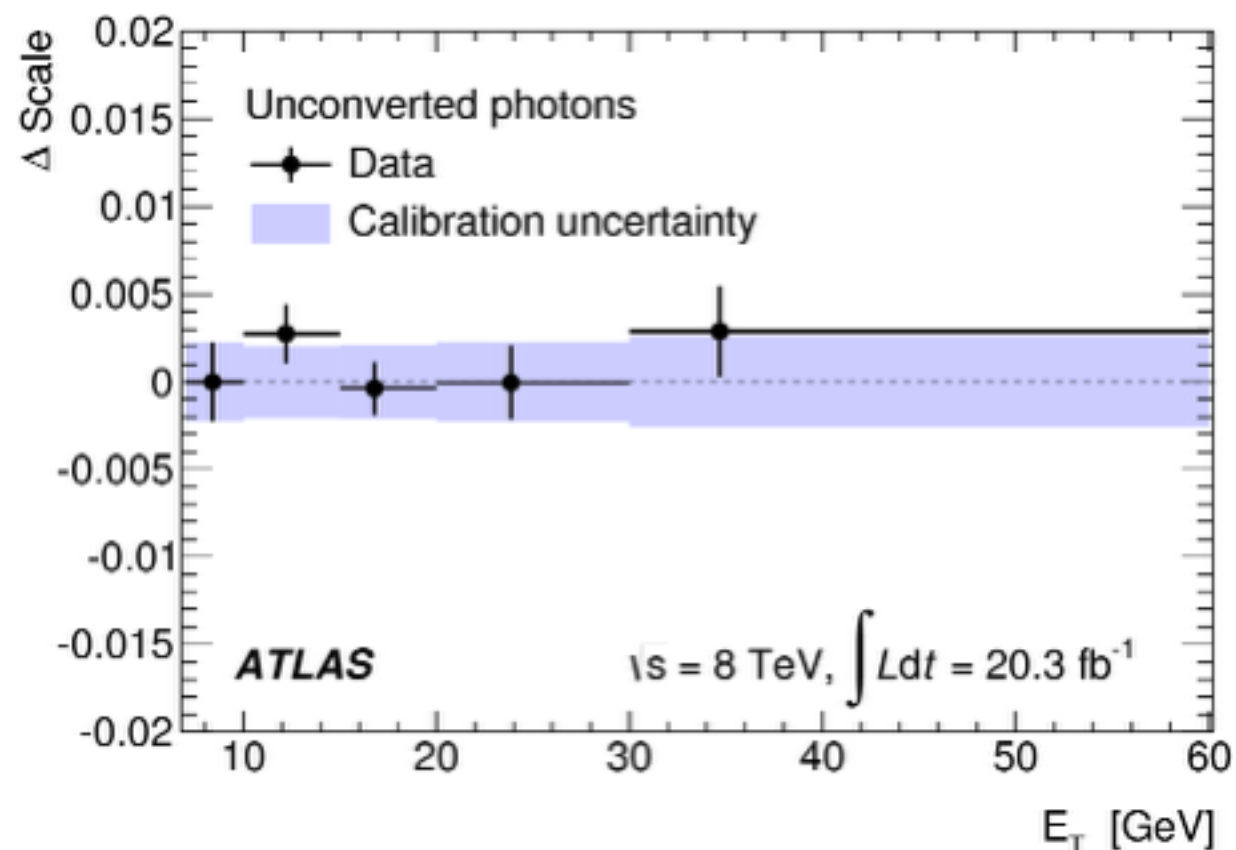
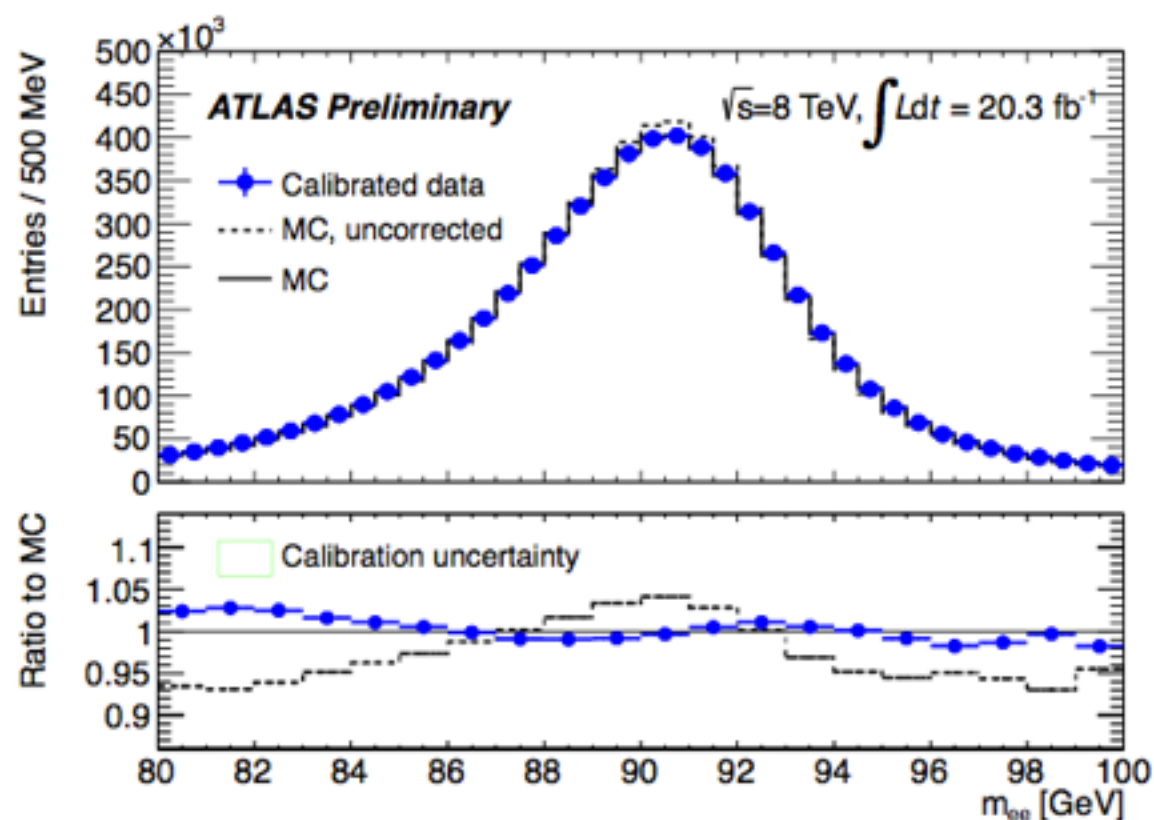


(poster Z. Barnovska)

Higgs Boson mass: a new photon calibration



- Improved simulation of detector geometry
- New MVA calibration: 10% improvement on $m_{\gamma\gamma}$ resolution
- 1-2% precision on $E_{1/2}$, 5% on E_{PS}
- 0.2-0.5% energy scale uncertainty for photons (checked on $l\gamma$ events)



Higgs Boson mass measurement

- 7+8 TeV data, two isolated photons with $p_{T1,2}/m_{\gamma\gamma} > 0.35, 0.25 + \eta_{\gamma}$ acceptance
- Dedicated analysis with categories based on conversions, η_{γ} and p_{Tt} , to minimize expected $\sigma(m_H)$
- Dominant systematic uncertainty: energy scale

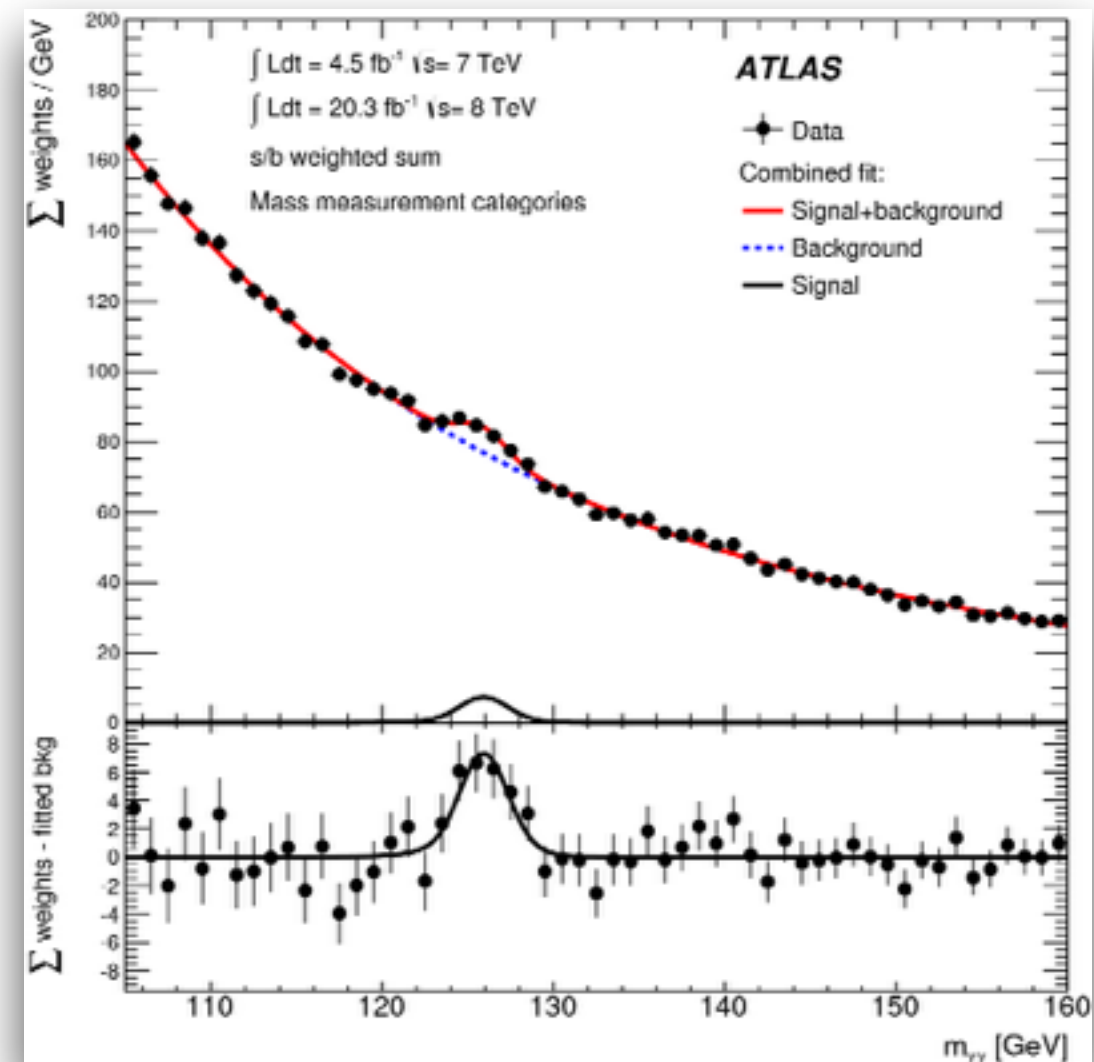
$$m_H = 125.98 \pm 0.42 \text{ (stat)} \pm 0.28 \text{ (syst)} \text{ GeV} \quad (\mu = 1.29 \pm 0.30)$$

to be compared with:

The previous measurement: $126.8 \pm 0.2 \pm 0.7 \text{ GeV}$

- observed shift (0.8 GeV) consistent with expected shift $-0.45 \pm 0.35 \text{ GeV}$
- syst. error decreased by factor 2.5
- stat. error:

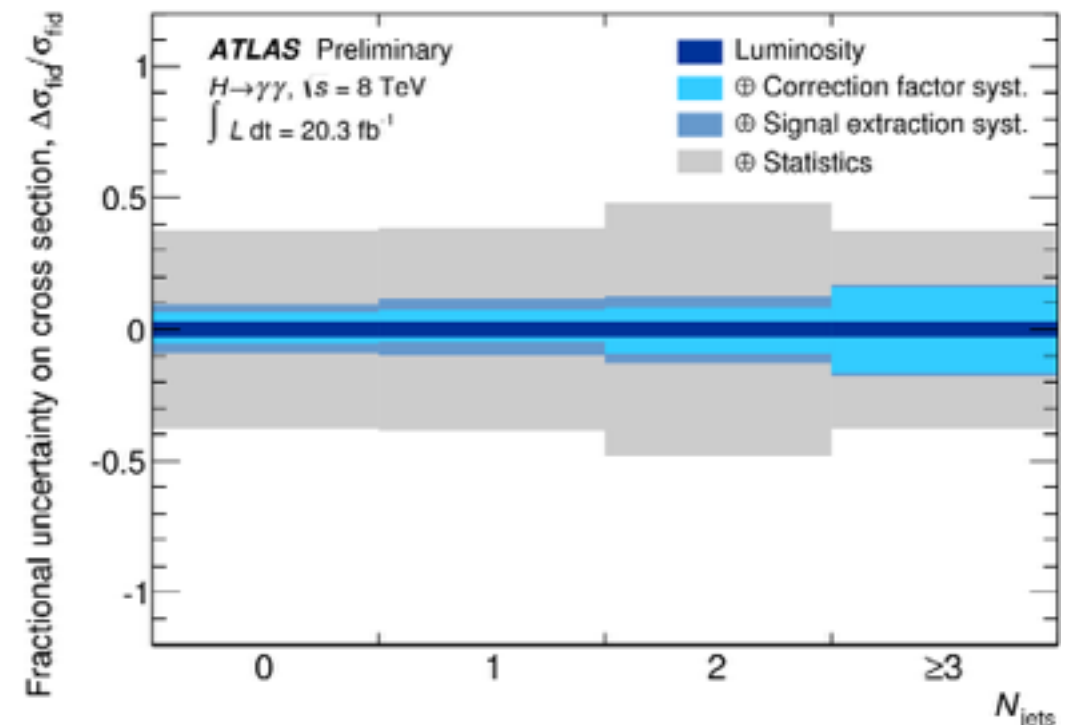
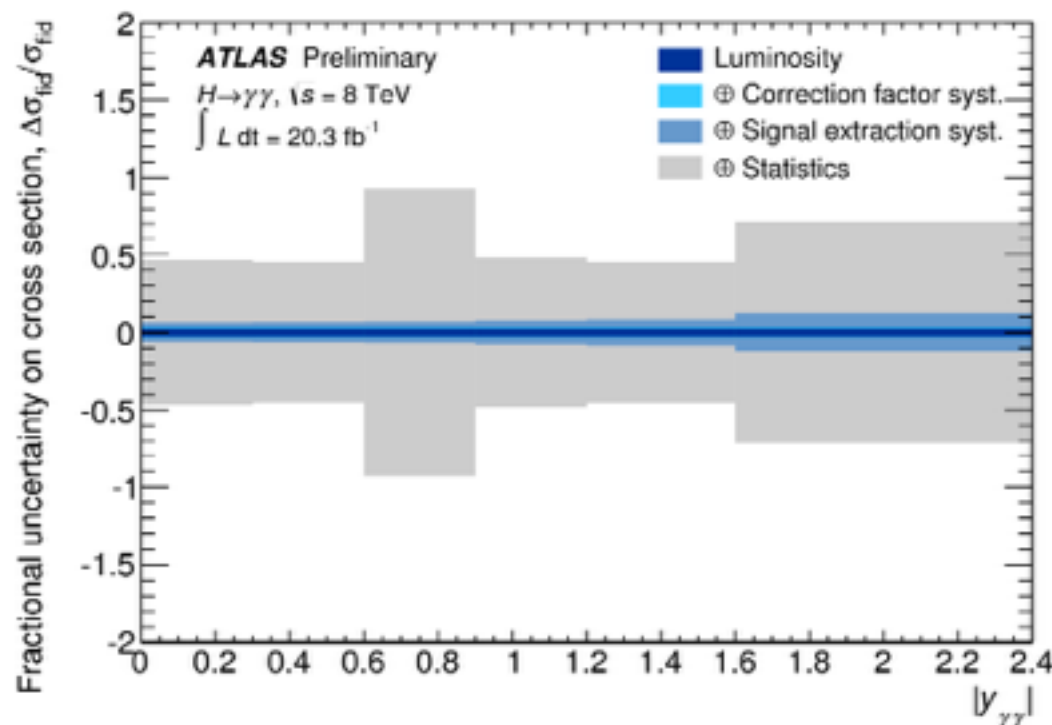
	μ	Exp. σ	Obs. σ
Previous	1.55	0.33 GeV	0.24 GeV
Current	1.29	0.35 GeV	0.42 GeV



Fiducial and Differential cross-sections

- Probe **theoretical modeling** of Higgs Boson production mechanisms and **BSM**
- Two kinds of cross-section measurements:
 - **7 fiducial regions**: inclusive, 1,2,3 jets; VBF enhanced; 1 lepton, $E_{T\text{miss}} > 80$ GeV
 - **12 differential distributions**: Higgs kinematics, jet activity, spin/CP, VBF
- 8 TeV data only, isolated photons with $p_{T1,2}/m_{\gamma\gamma} > 0.35, 0.25 + \eta_\gamma$ acceptance
- In each region/bin, obtain **signal yield** through $m_{\gamma\gamma}$ fit, add **correction factor** c_i to unfold from detector to particle level ($c_i = 66\%$ in inclusive case)
- **Systematics** \ll statistical uncertainties in all cases
 - Dominated by signal extraction (energy scale, resolution, ...)
 - Jet energy scale becomes important for large jet multiplicities

$$\sigma_i = \frac{\nu_i^{\text{sig}}}{c_i \int L dt}$$



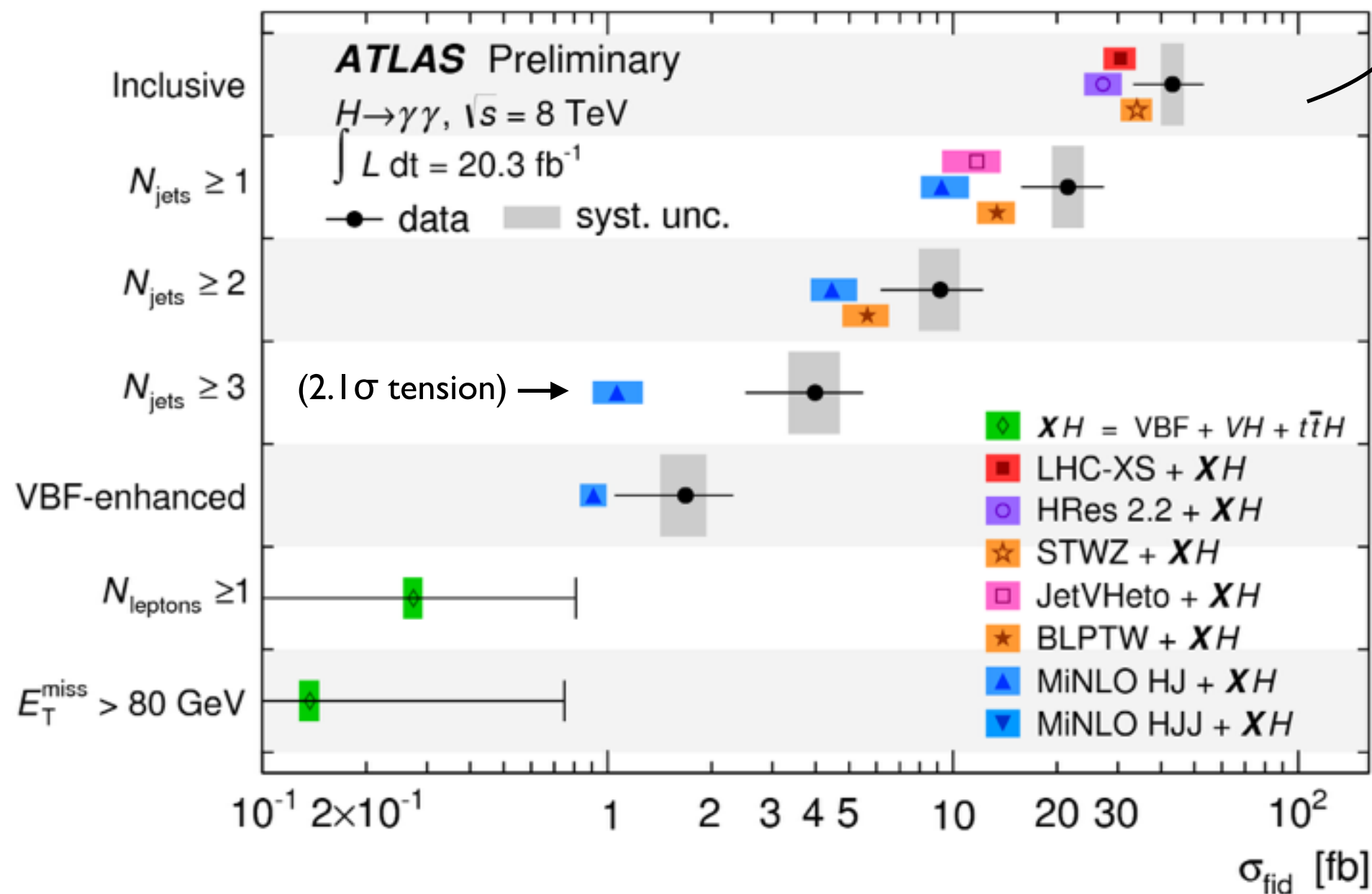
Theoretical predictions

Name	Parton Shower	fiducial region	diff. XS	QCD Precision	Quark mass in loop	EW Prec.
Powheg+Py8	Pythia 8	inclusive	all	NLO(0j) + PS	$m_t=\infty, m_b=0$	-
MINLO HJ	Pythia 8	inclusive 1 jet	all	NLO(0,1j) + PS	$m_t=\infty, m_b=0$	-
MINLO HJJ	Pythia 8	inclusive 2 jets	all	NLO(2j) + PS	$m_t=\infty, m_b=0$	-
LHC XS	-	inclusive		NNLO+NNLL	finite m_t, m_b, m_c	NLO
STWZ (SCET)	-	inclusive		NNLO+NNLL'	$m_t=\infty, m_b=0$	-
HRes	-	inclusive	kinematics of Higgs + decay	NNLO+NNLL	finite m_t, m_b	-
BLPTW (SCET)	-	1 jet 2 jets		NLO + NNLL' approx. NLO +	$m_t=\infty, m_b=0$	-
JetVHeto	-	1 jet		(N)NLO + NNLL	finite m_t, m_b	-

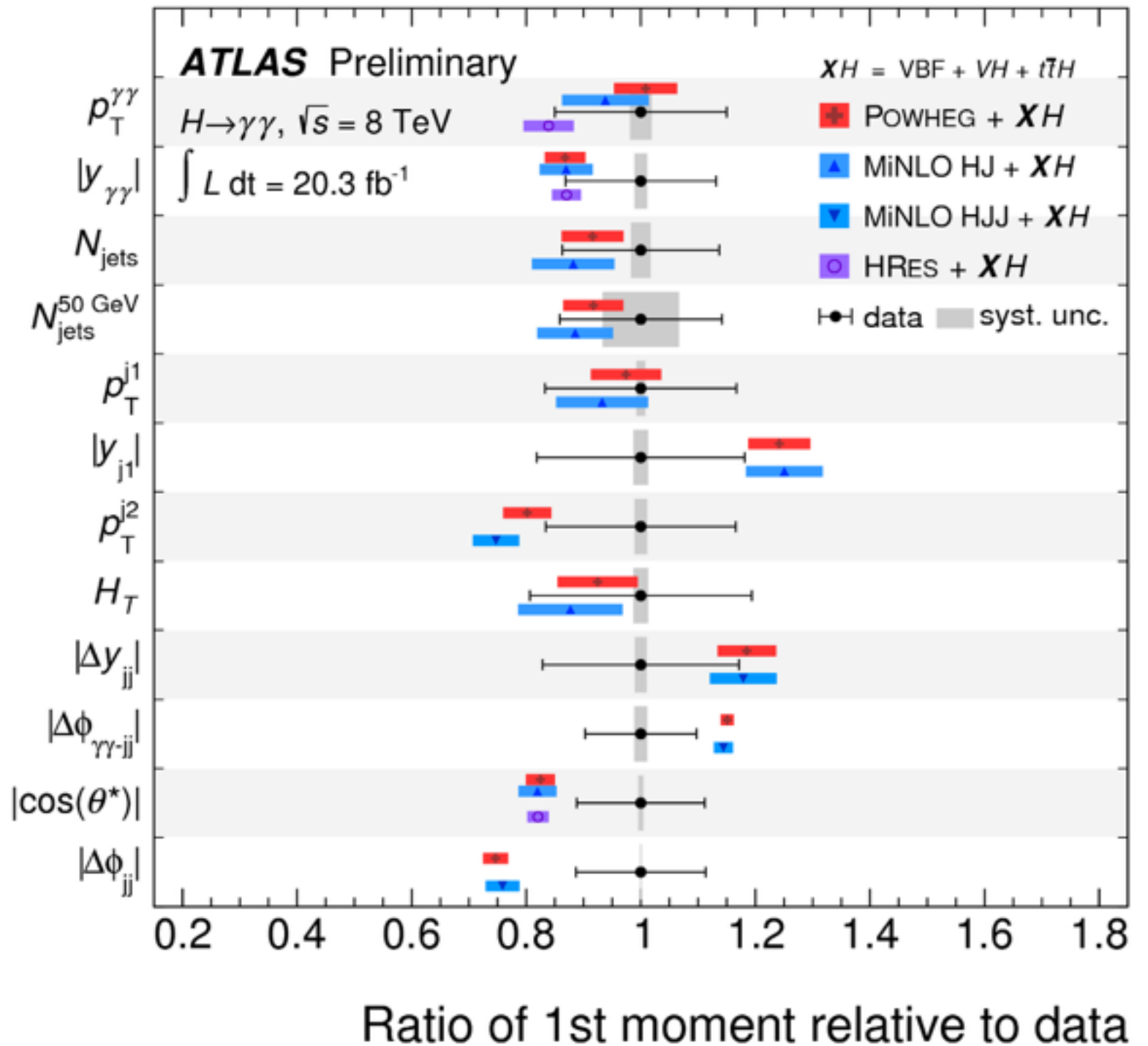
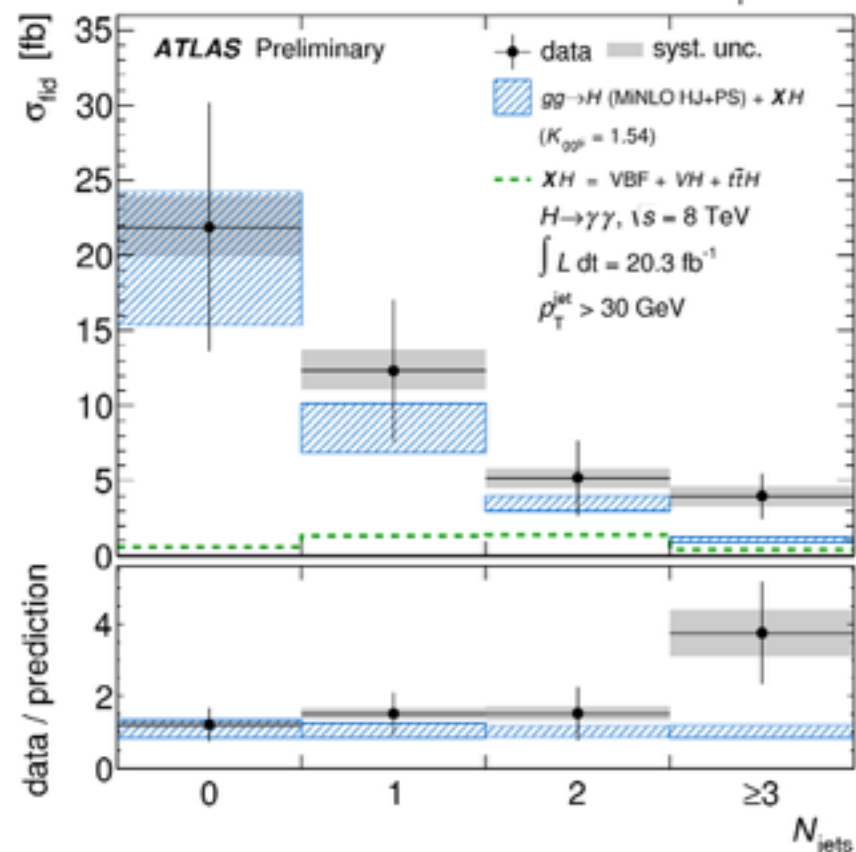
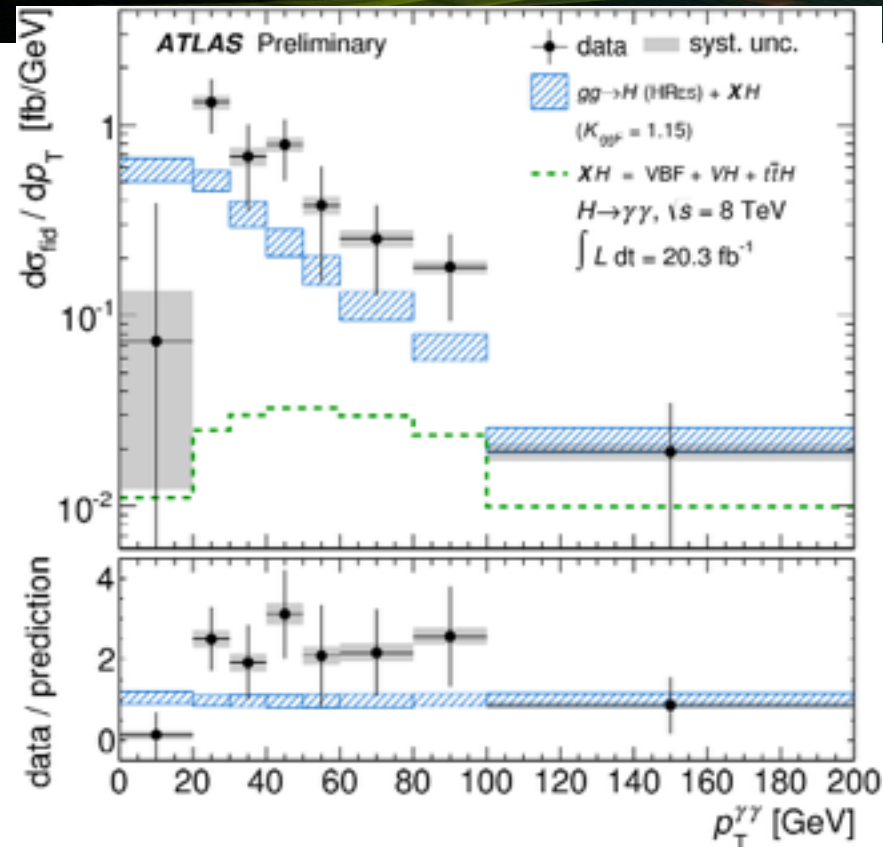
Fiducial cross-sections

$$\sigma_{\text{fid}}(pp \rightarrow H \rightarrow \gamma\gamma) = 42.7 \pm 9.3 \text{ (stat)}^{+3.2}_{-2.9} \text{ (syst)} \pm 1.2 \text{ (lumi)} \text{ fb}$$

($\times 1.4$ LHC-XS prediction)



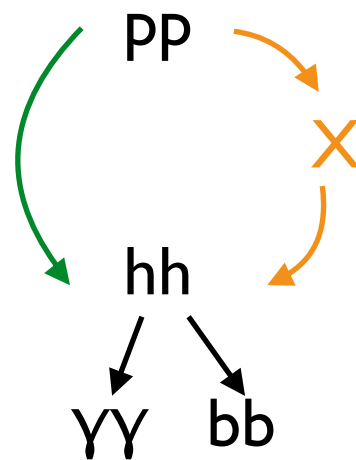
Differential cross-sections



$$hh \rightarrow \gamma\gamma + bb$$

- 8 TeV data only; baseline selection:
 - two isolated photons with $p_{T1,2}/m_{\gamma\gamma} > 0.35, 0.25 + \eta_\gamma$ acceptance
 - two b-tagged jets with $|\eta| < 2.5$, $p_{T1,2} > 55, 35$ GeV and $95 < m_{jj} < 135$ GeV ($\sigma(m_{jj}) = 13$ GeV)

Non resonant
SM hh, enhanced tthh
(composite models), ...



Resonant
 $X = (\text{SM } h,) \text{ H, G, radion, stoponium, ...}$
 $m_X = 260 \text{ to } 500 \text{ GeV}$

Simultaneous fit of $m_{\gamma\gamma}$ in signal region (2 b-jets) + control region CR (<2 b-jets)

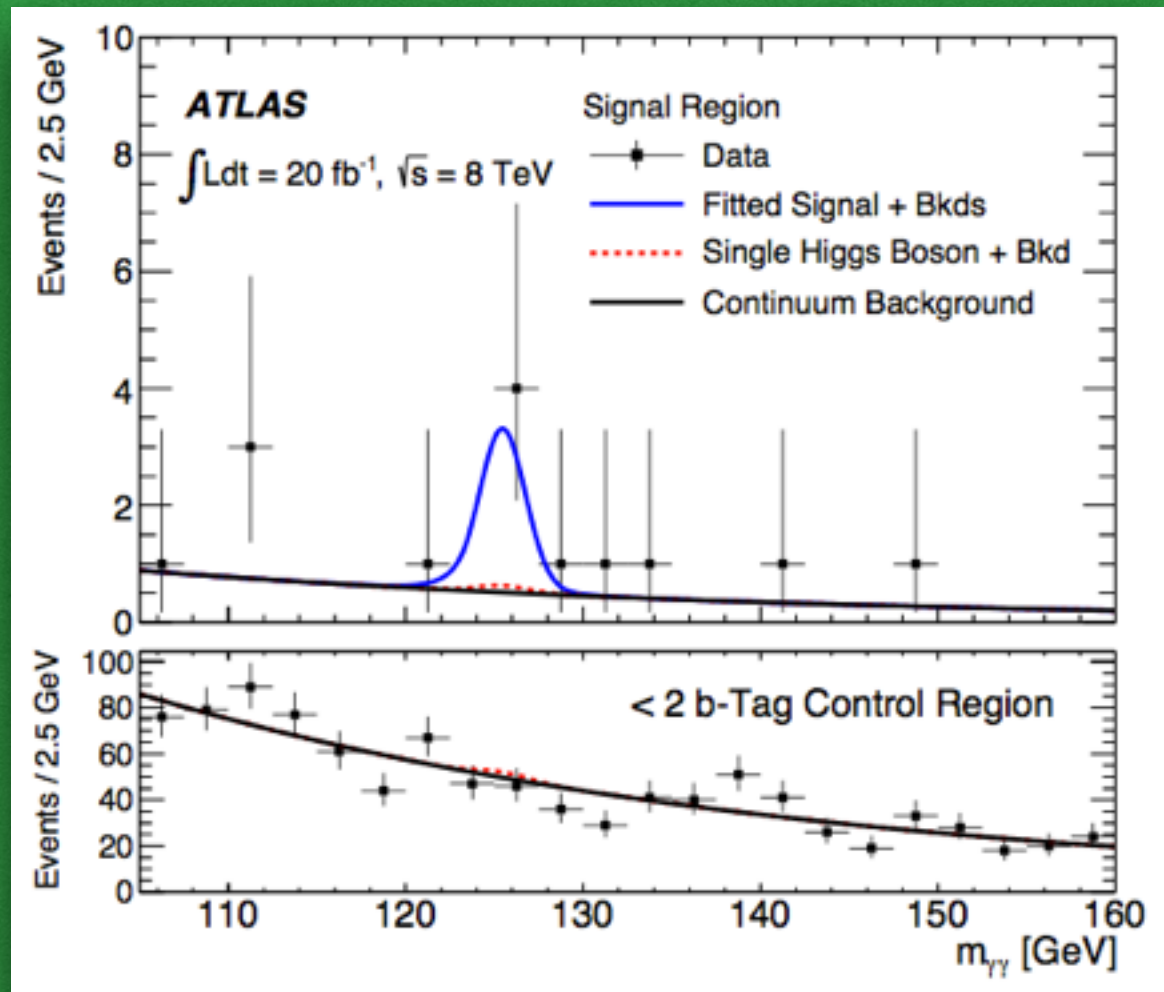
- signal modeled as in mass analysis (Crystal Ball + Gaussian)
- background modeled by exponential

Counting experiment; additional cuts:

- $m_{\gamma\gamma} (= 125.5 \text{ GeV}) \pm 2\sigma(m_{\gamma\gamma})$
with $\sigma(m_{\gamma\gamma}) = 1.6$ GeV
(bkg acceptance $\epsilon_{m_{\gamma\gamma}} = 13\%$)
- $m_{\gamma\gamma bb} (= m_X) \pm \Delta$
with $\Delta = 17/60$ GeV at $m_X = 260/500$ GeV
(bkg acceptance $\epsilon_{m_{bb\gamma\gamma}} = 8-18\%$)

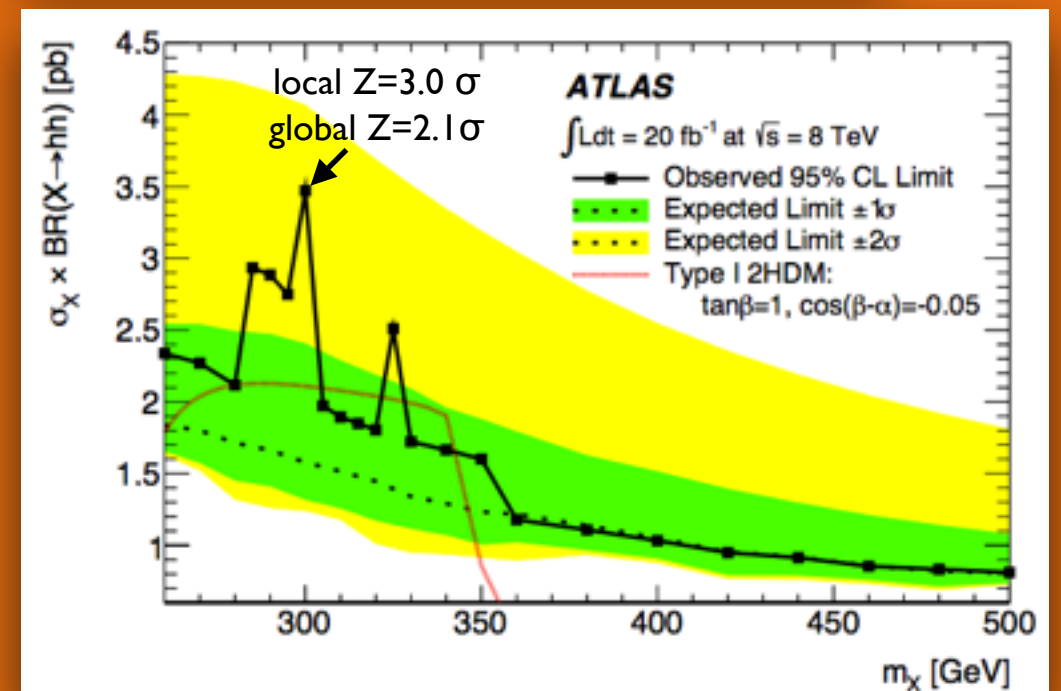
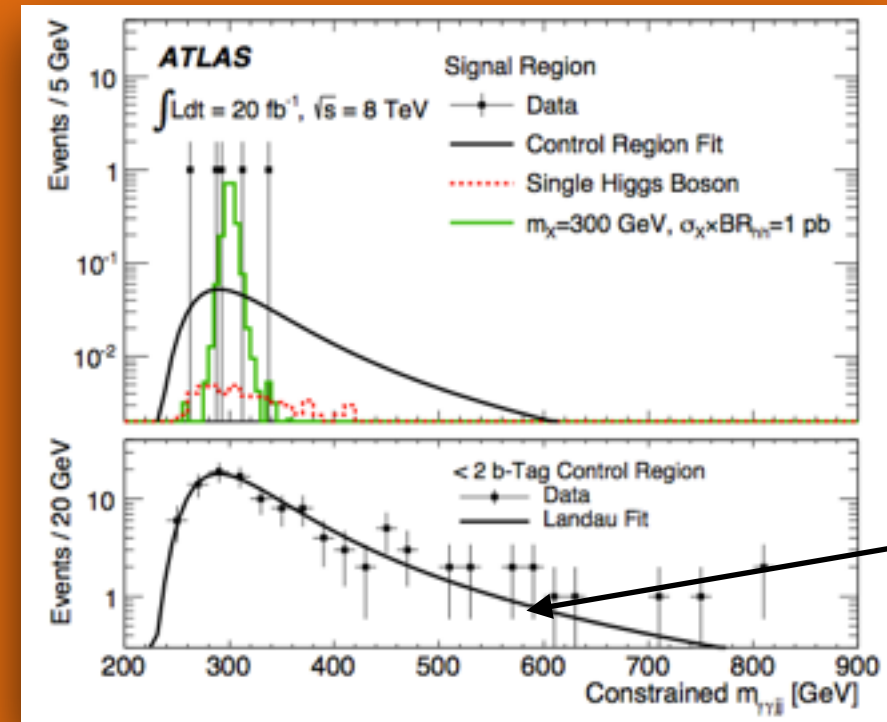
both analyses are largely statistically limited

$hh \rightarrow \gamma\gamma + bb$



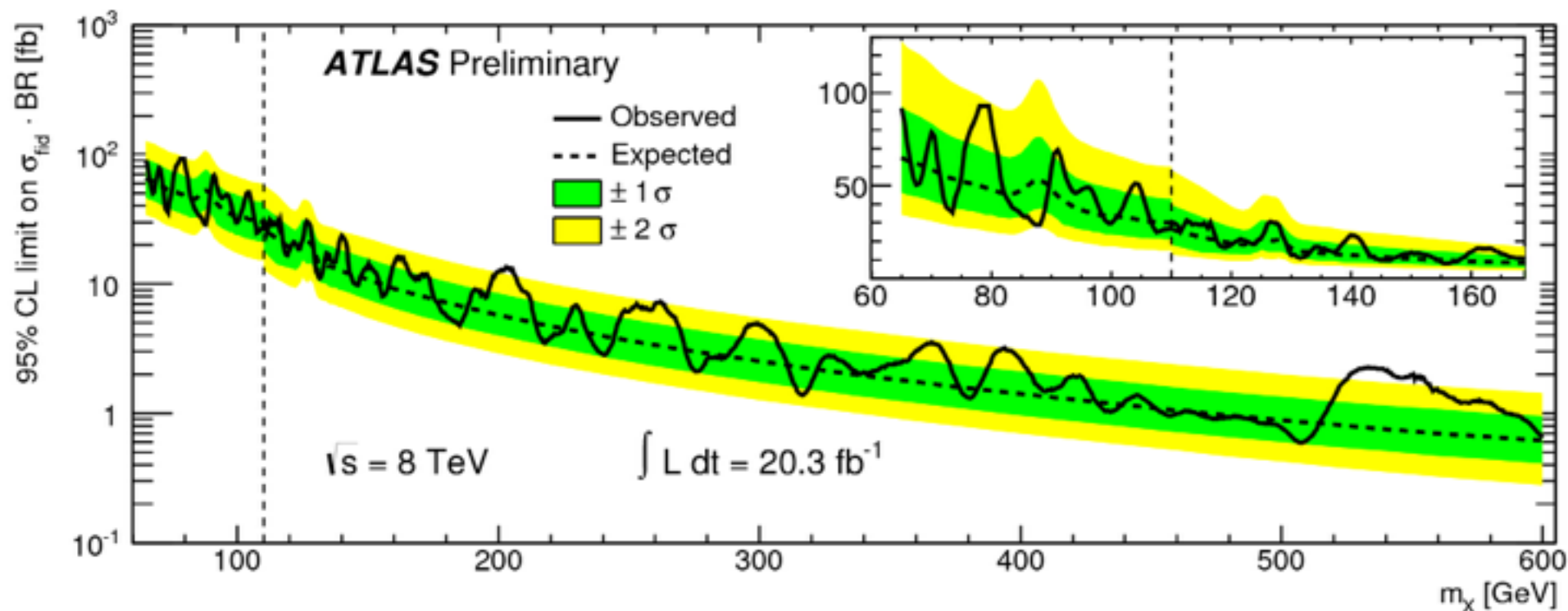
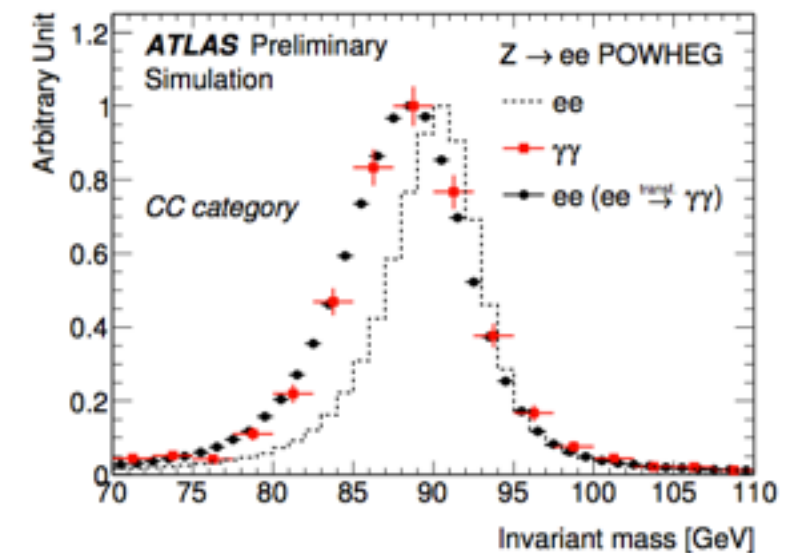
N_{exp} (bkg+single h)	N_{obs}	Sig.	95% CL limit on $\sigma(hh)$ [pb]
1.5	5	2.4σ	1.0(exp)/2.2(obs)

(in $125.5 \pm 2 \sigma$)



search for a narrow resonance decaying into $\gamma\gamma$

- 8 TeV data only; two isolated photons with $p_{T1,2} > 22$ GeV + η_γ acceptance
- Low mass: challenging Drell-Yan background
- High mass (+ $p_{T1,2}/m_{\gamma\gamma} > 0.4, 0.3$): continuum bkg extracted using analytical fit in a sliding window



No excess seen:
model-independent limit
on fiducial cross-section

Conclusions

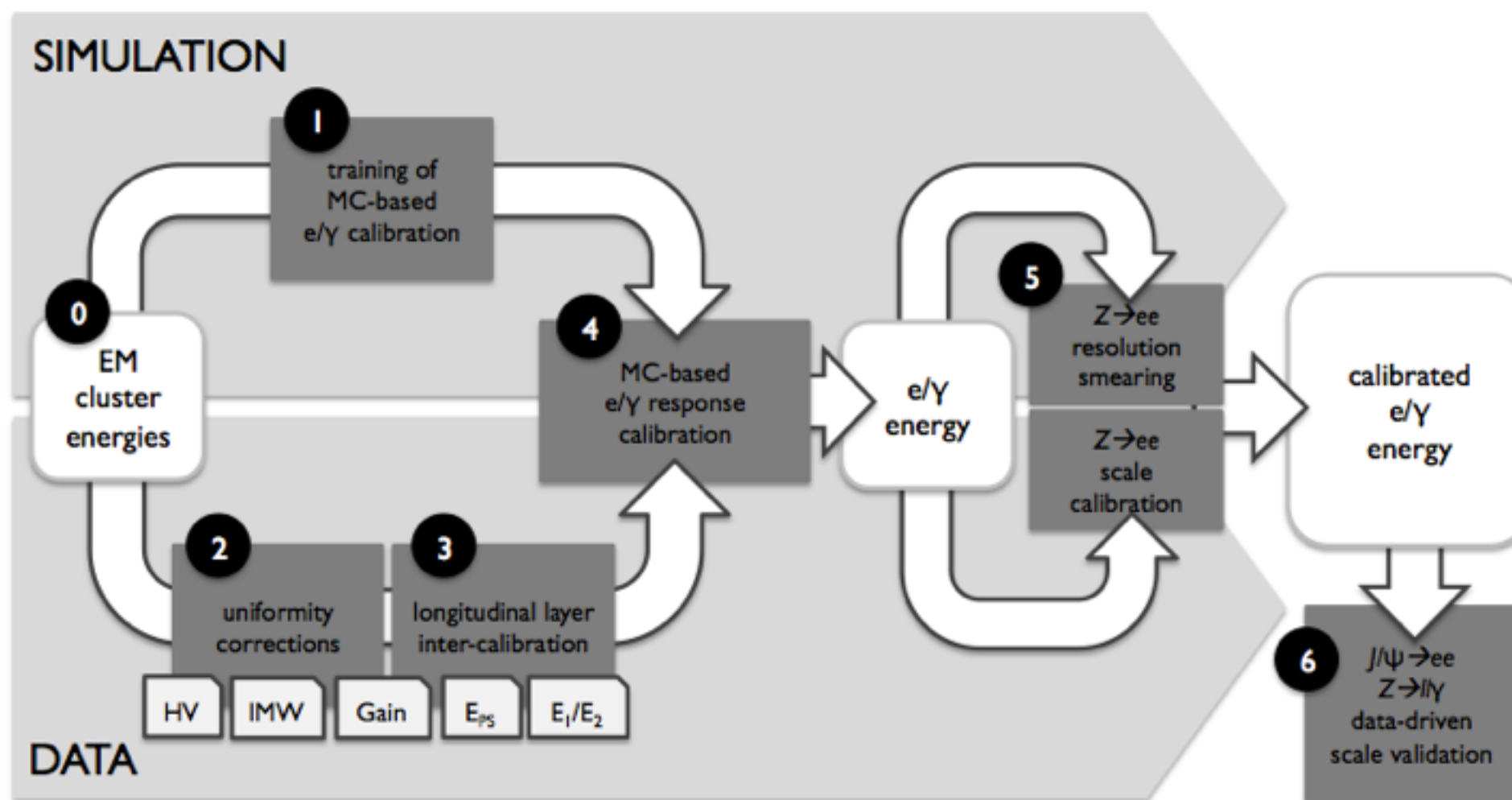
- This talk:
 - Updated mass and differential cross-section results supersede earlier results:
 - impressive improvement of m_H systematic uncertainty !
 - New results on fiducial cross-sections, double higgs production and new resonance search
 - $H \rightarrow \gamma\gamma$ also used as a new physics search channel
- See also talk on ttH including new $ttH(\gamma\gamma)$ result by E. Shabalina
- Several other updated and new $H \rightarrow \gamma\gamma$ results in the coming weeks !



Backup

Higgs Boson mass: a new photon calibration

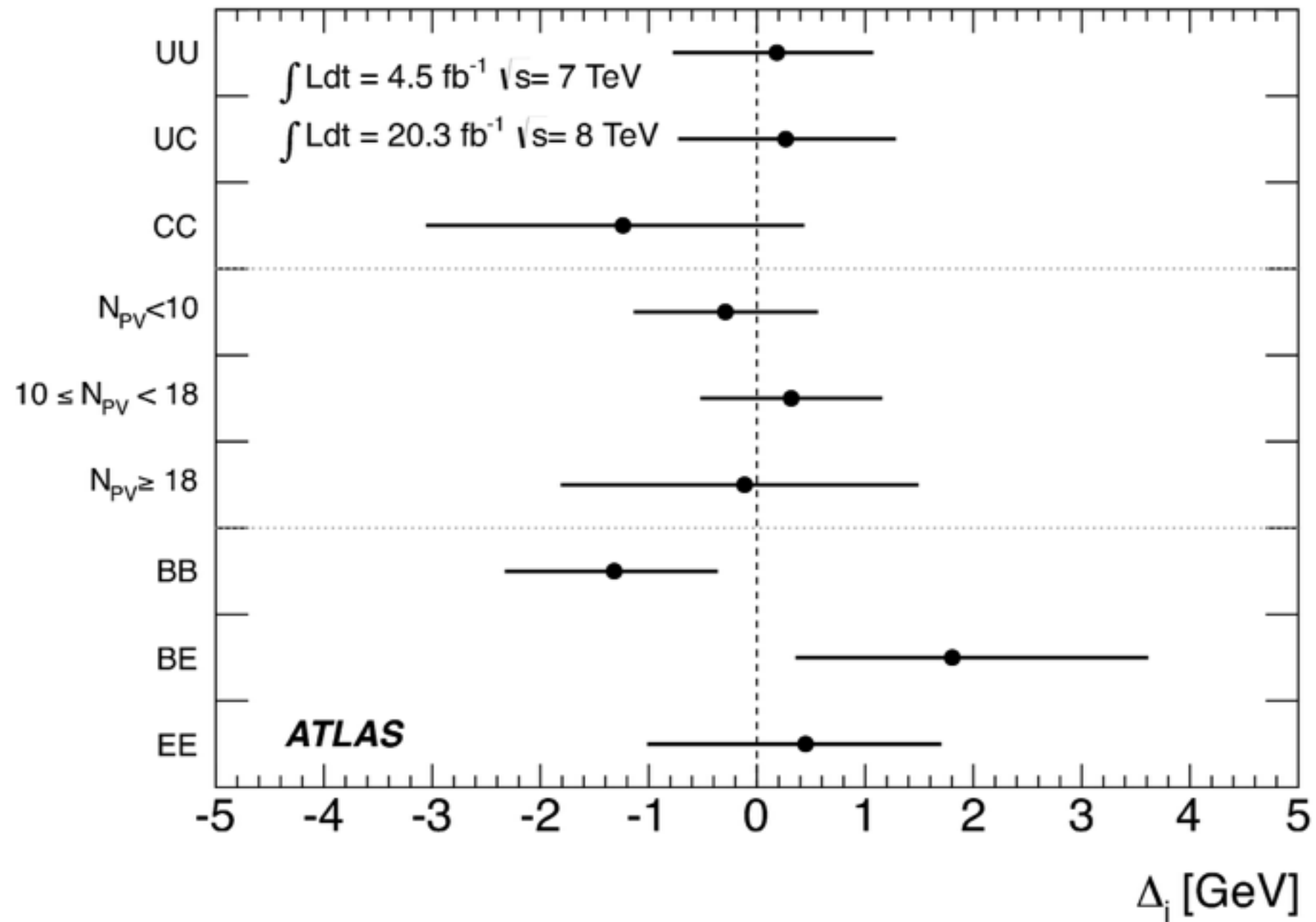
See talk of JB Blanchard



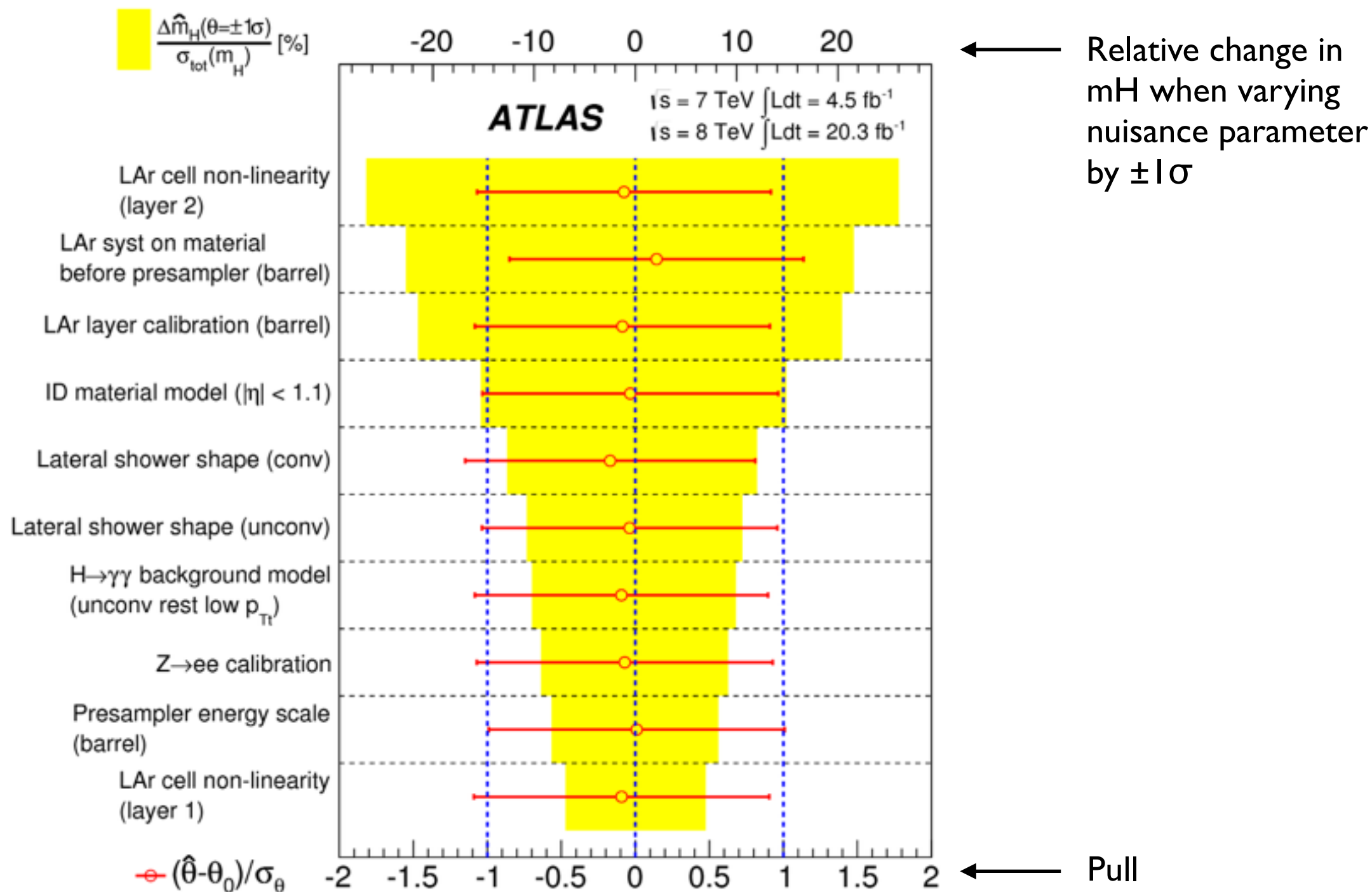
Higgs Boson mass: selection of vertex

- Neural network with:
 - pointing from calorimeter + track of converted photons
 - average beam spot position
 - *these two yield a 15mm resolution in the z direction: photon direction impact on m_{γγ} resolution already negligible*
- three additional variables to better fight pile up:
 - $\text{sum}(p_T)$
 - $\text{sum}(p_T^2)$
 - $\text{deltaPhi}(\gamma\gamma\text{-tracks})$
 - *this selects true PV with 93% efficiency*

Higgs Boson mass



Higgs Boson mass

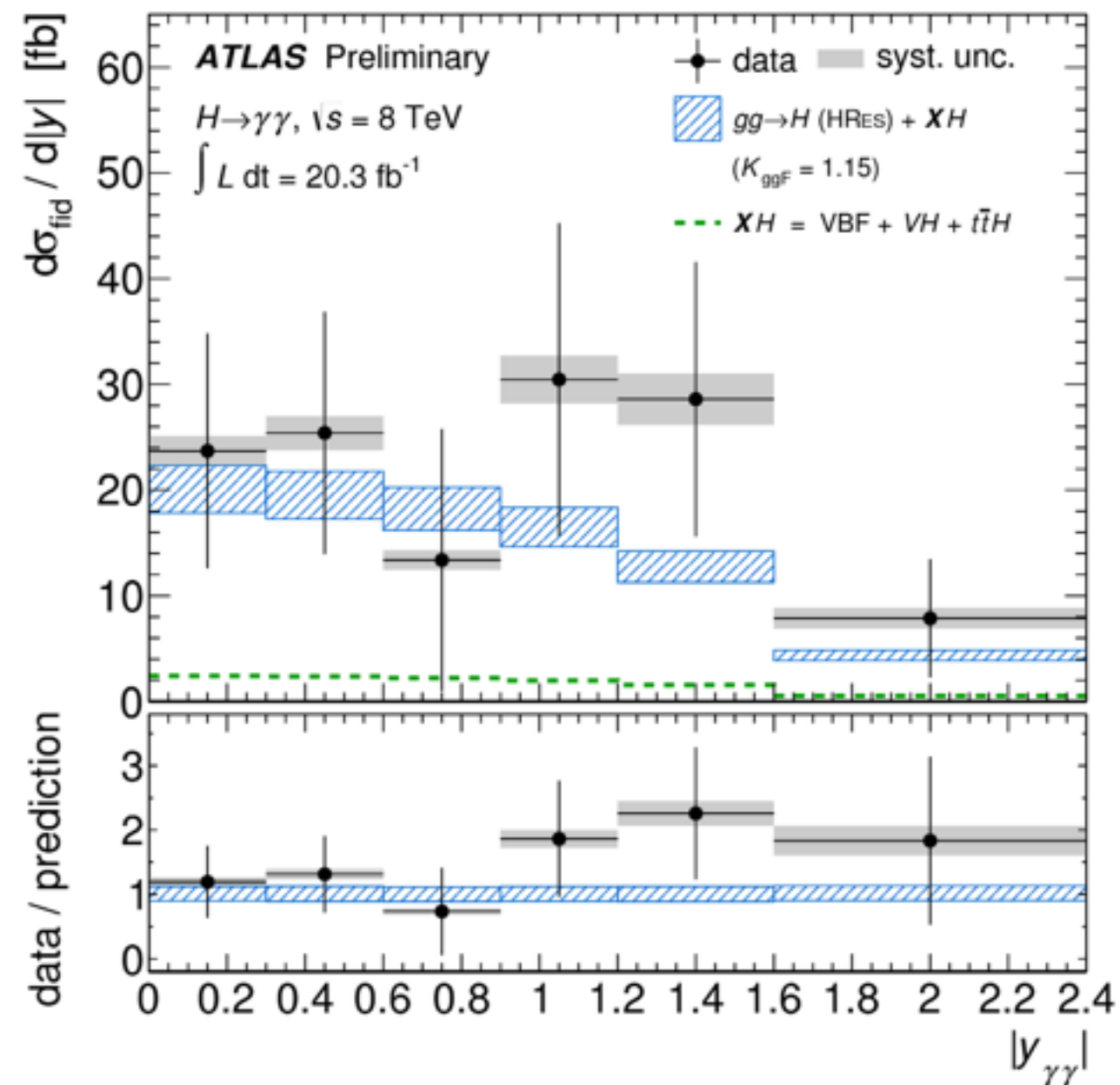
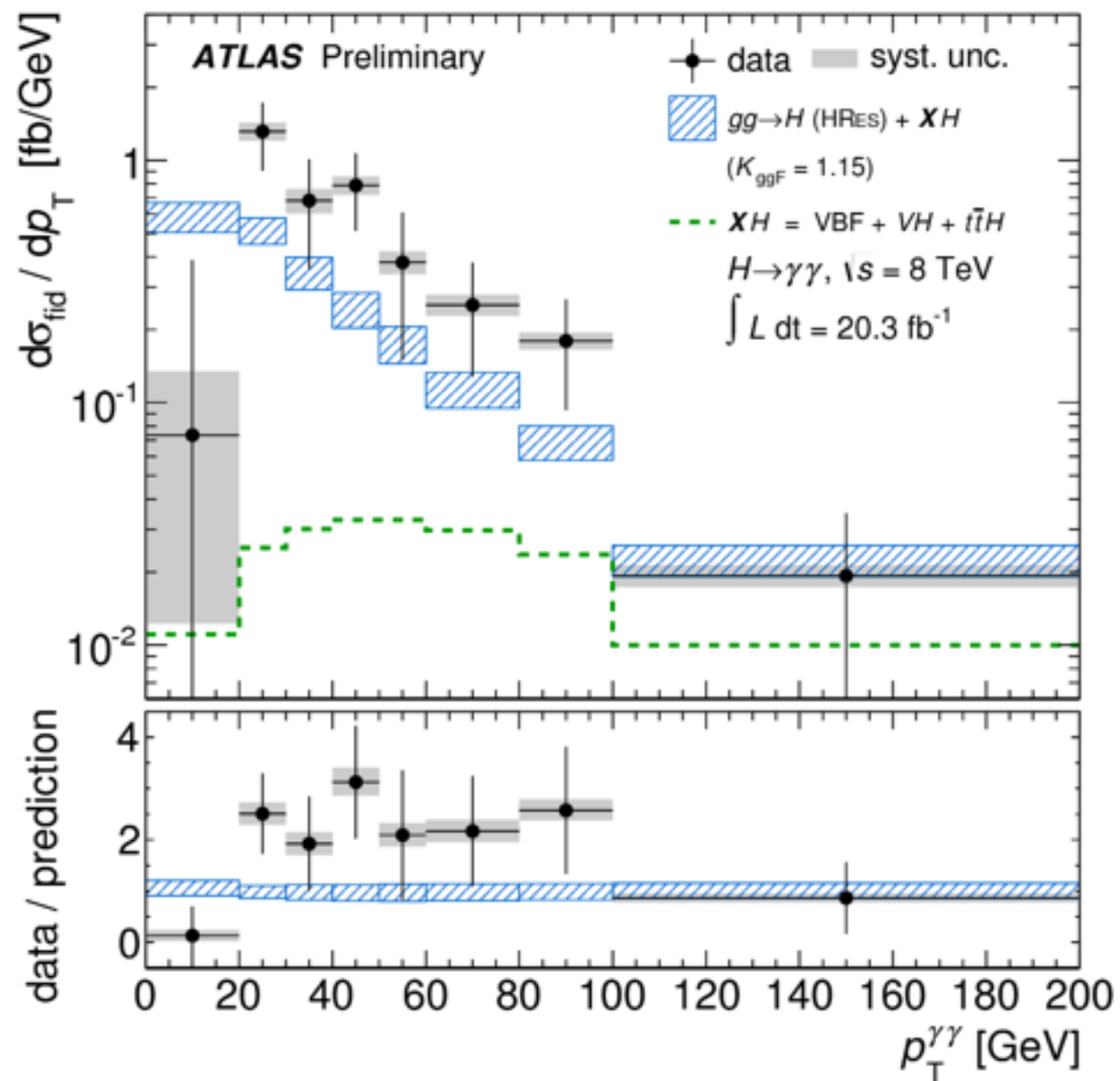


Higgs Boson mass

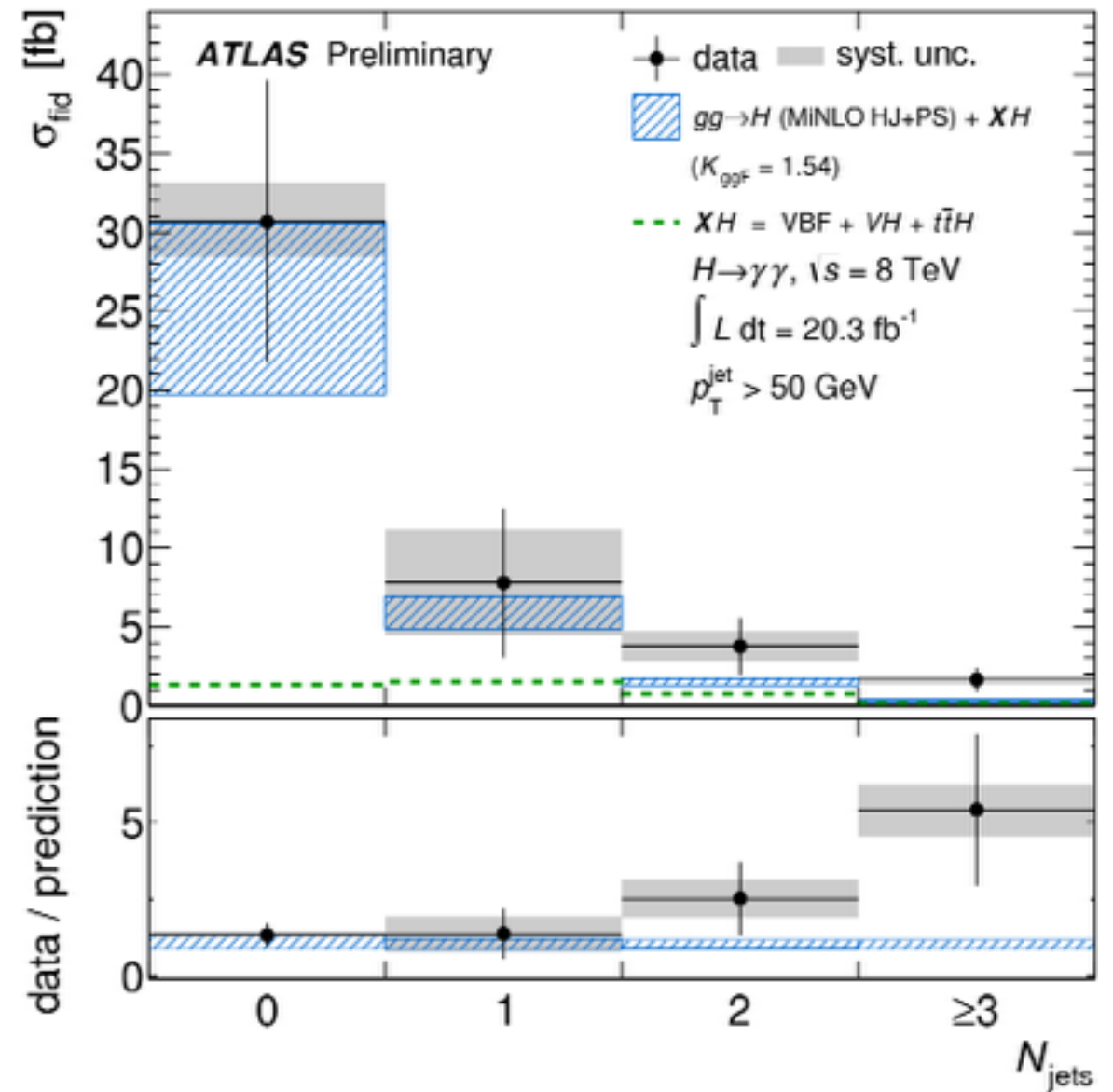
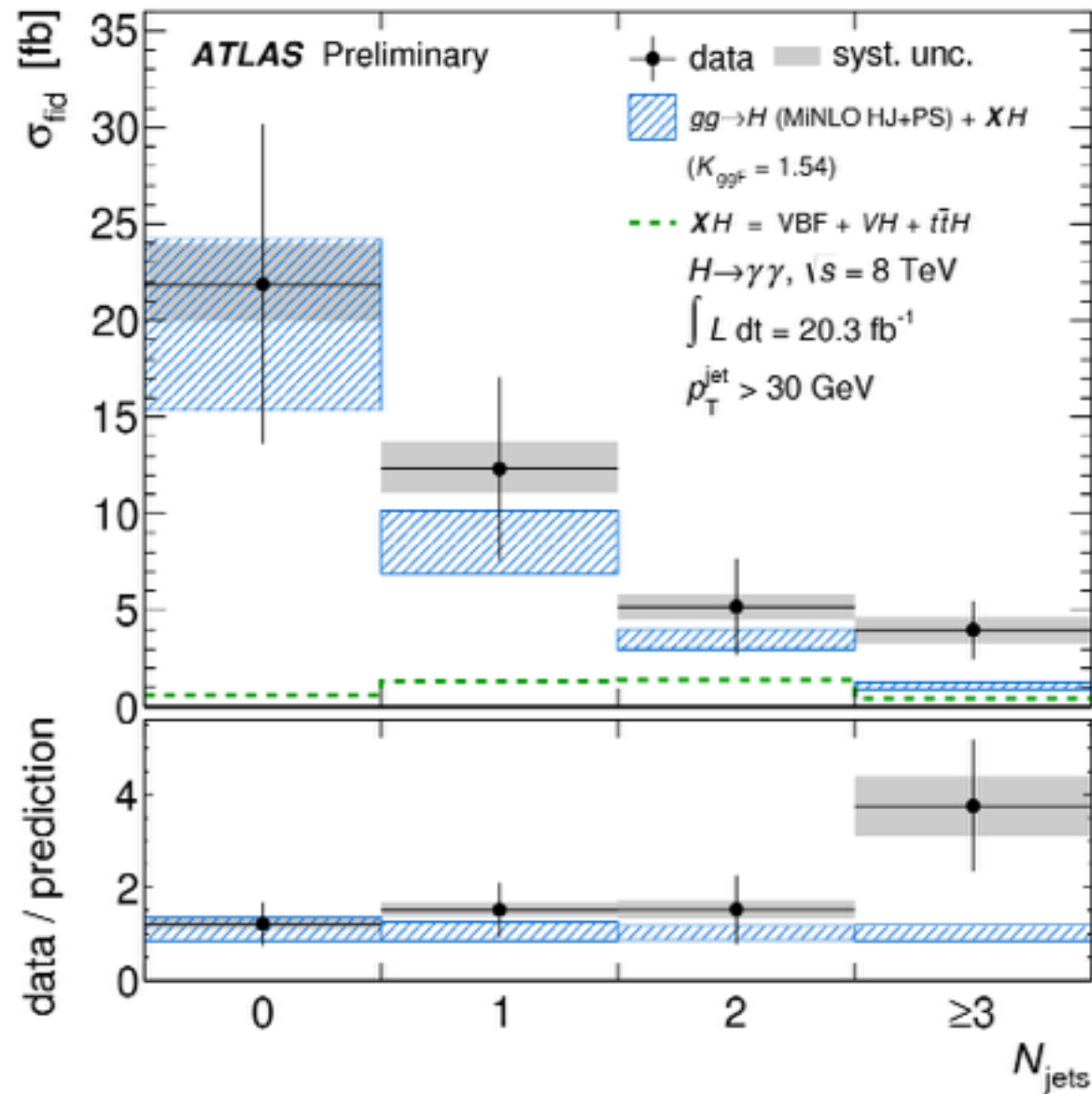
Table 2: Summary of the relative systematic uncertainties (in %) on the $H \rightarrow \gamma\gamma$ mass measurement for the different categories described in the text. The first seven rows give the impact of the photon energy scale systematic uncertainties, grouped into seven classes.

Class	Unconverted					Converted				
	Central		Rest		Trans.	Central		Rest		Trans.
	low p_{Tl}	high p_{Tl}	low p_{Tl}	high p_{Tl}		low p_{Tl}	high p_{Tl}	low p_{Tl}	high p_{Tl}	
$Z \rightarrow e^+e^-$ calibration	0.02	0.03	0.04	0.04	0.11	0.02	0.02	0.05	0.05	0.11
LAr cell non-linearity	0.12	0.19	0.09	0.16	0.39	0.09	0.19	0.06	0.14	0.29
Layer calibration	0.13	0.16	0.11	0.13	0.13	0.07	0.10	0.05	0.07	0.07
ID material	0.06	0.06	0.08	0.08	0.10	0.05	0.05	0.06	0.06	0.06
Other material	0.07	0.08	0.14	0.15	0.35	0.04	0.04	0.07	0.08	0.20
Conversion reconstruction	0.02	0.02	0.03	0.03	0.05	0.03	0.02	0.05	0.04	0.06
Lateral shower shape	0.04	0.04	0.07	0.07	0.06	0.09	0.09	0.18	0.19	0.16
Background modeling	0.10	0.06	0.05	0.11	0.16	0.13	0.06	0.14	0.18	0.20
Vertex measurement	0.03									
Total	0.23	0.28	0.24	0.30	0.59	0.21	0.25	0.27	0.33	0.47

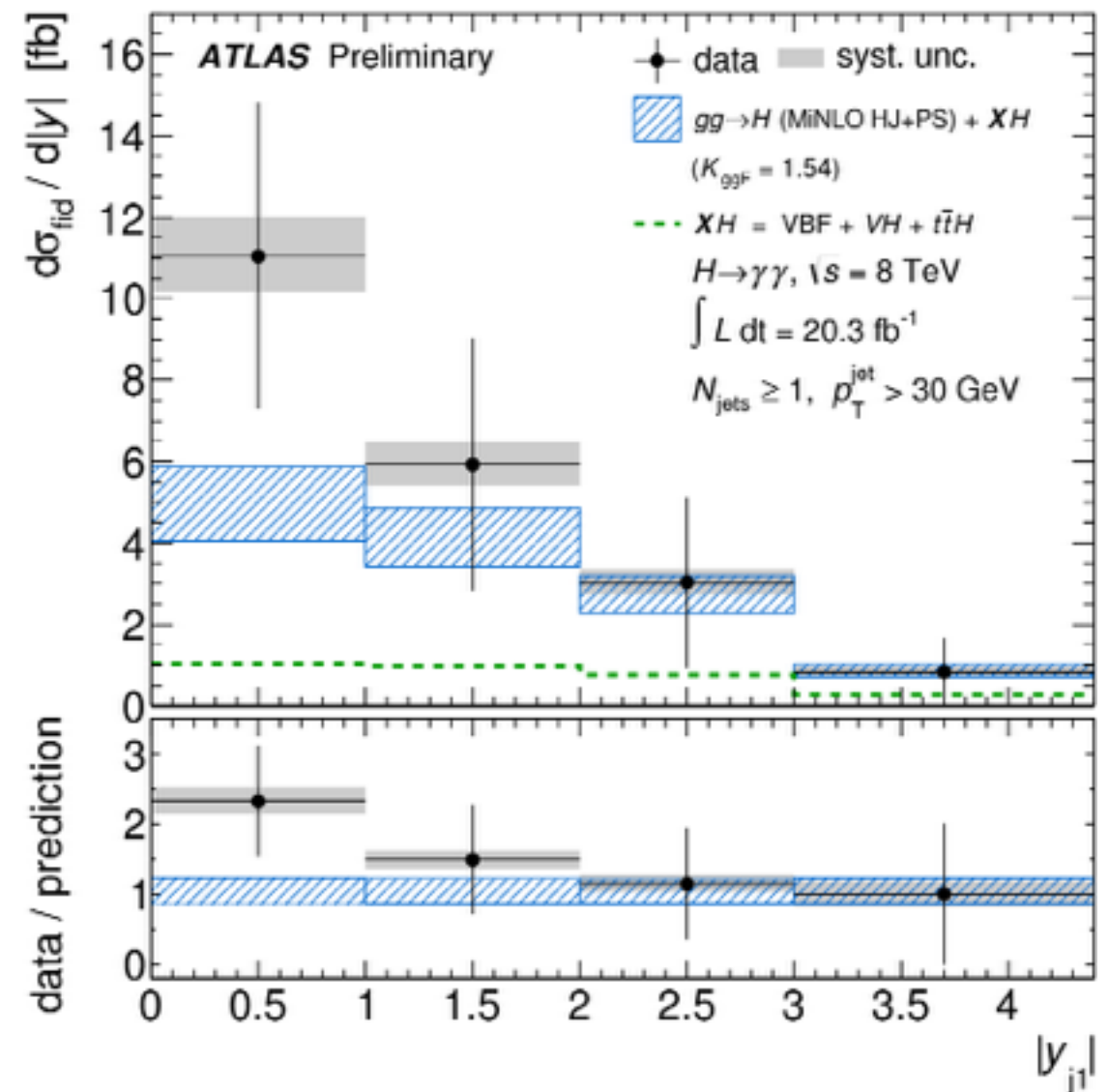
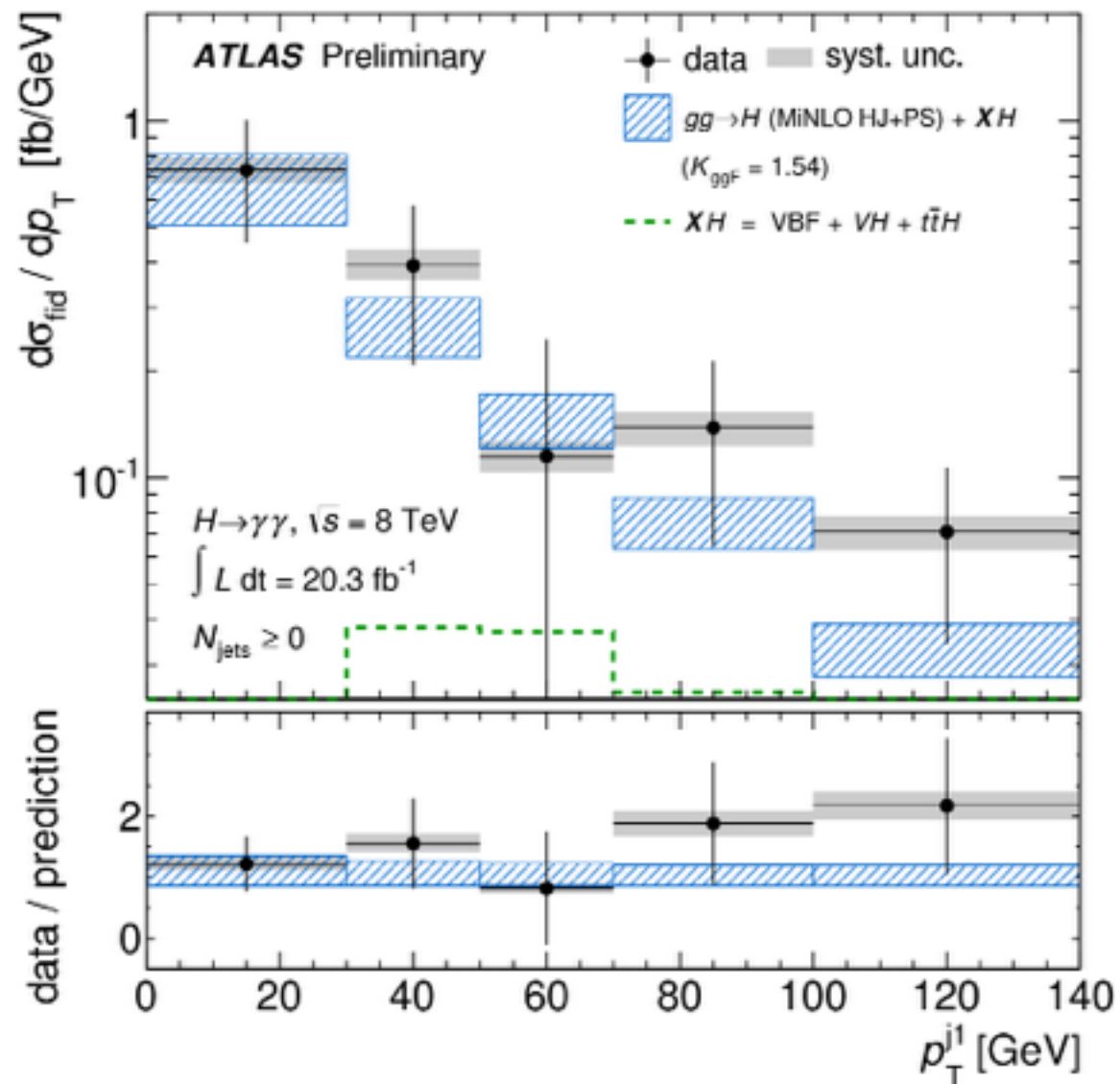
Diff. cross-sections



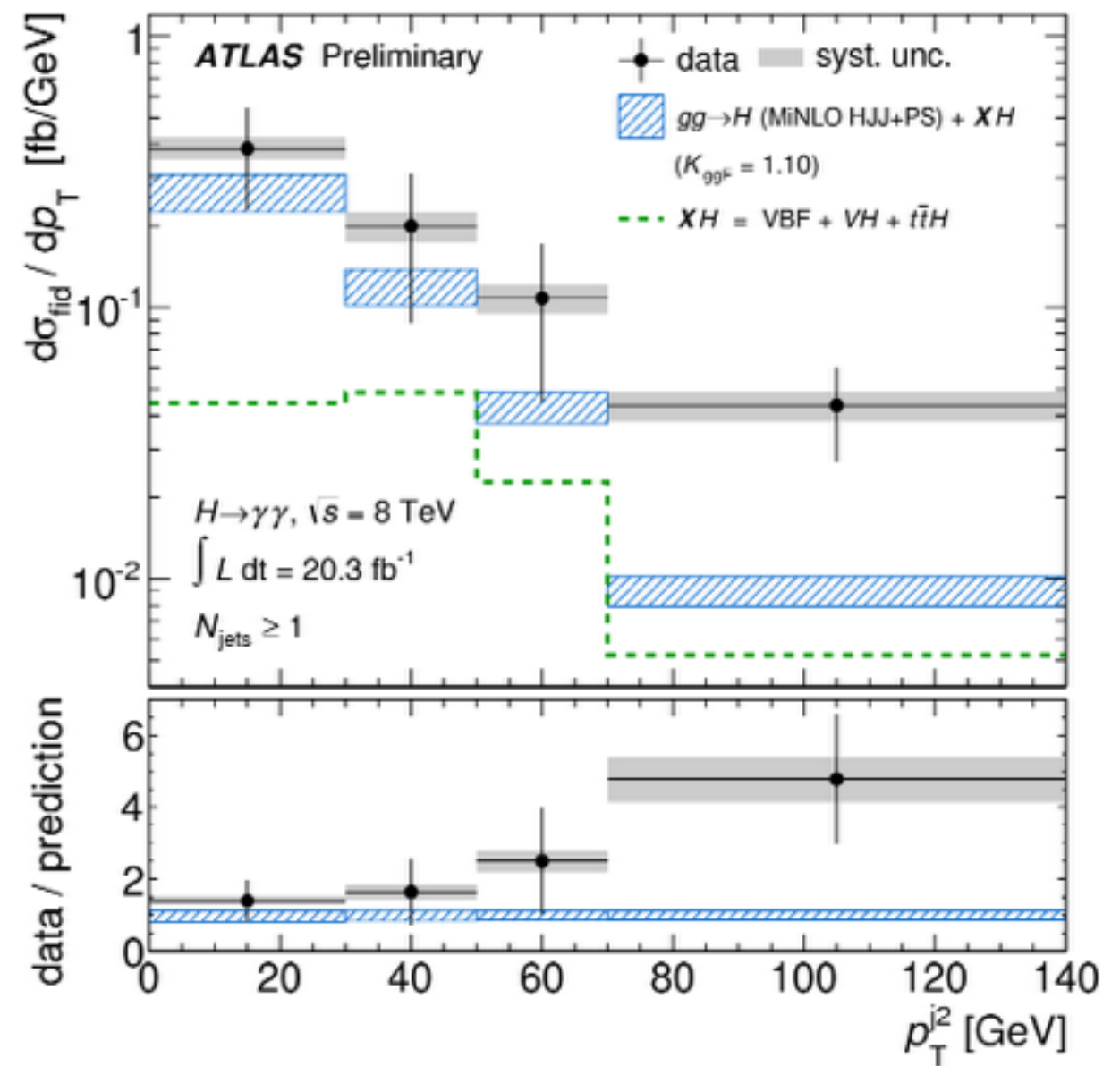
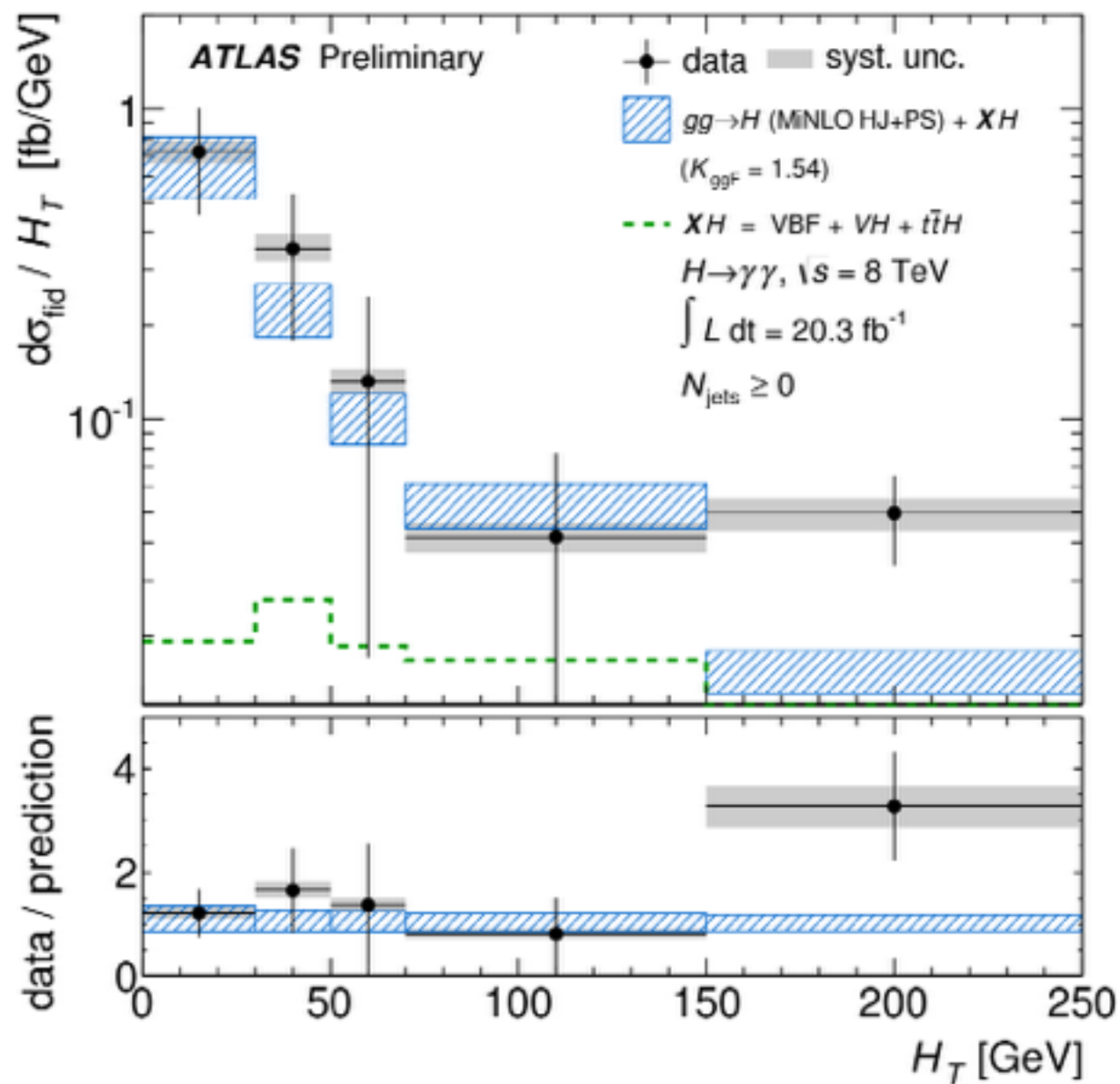
Diff. cross-sections



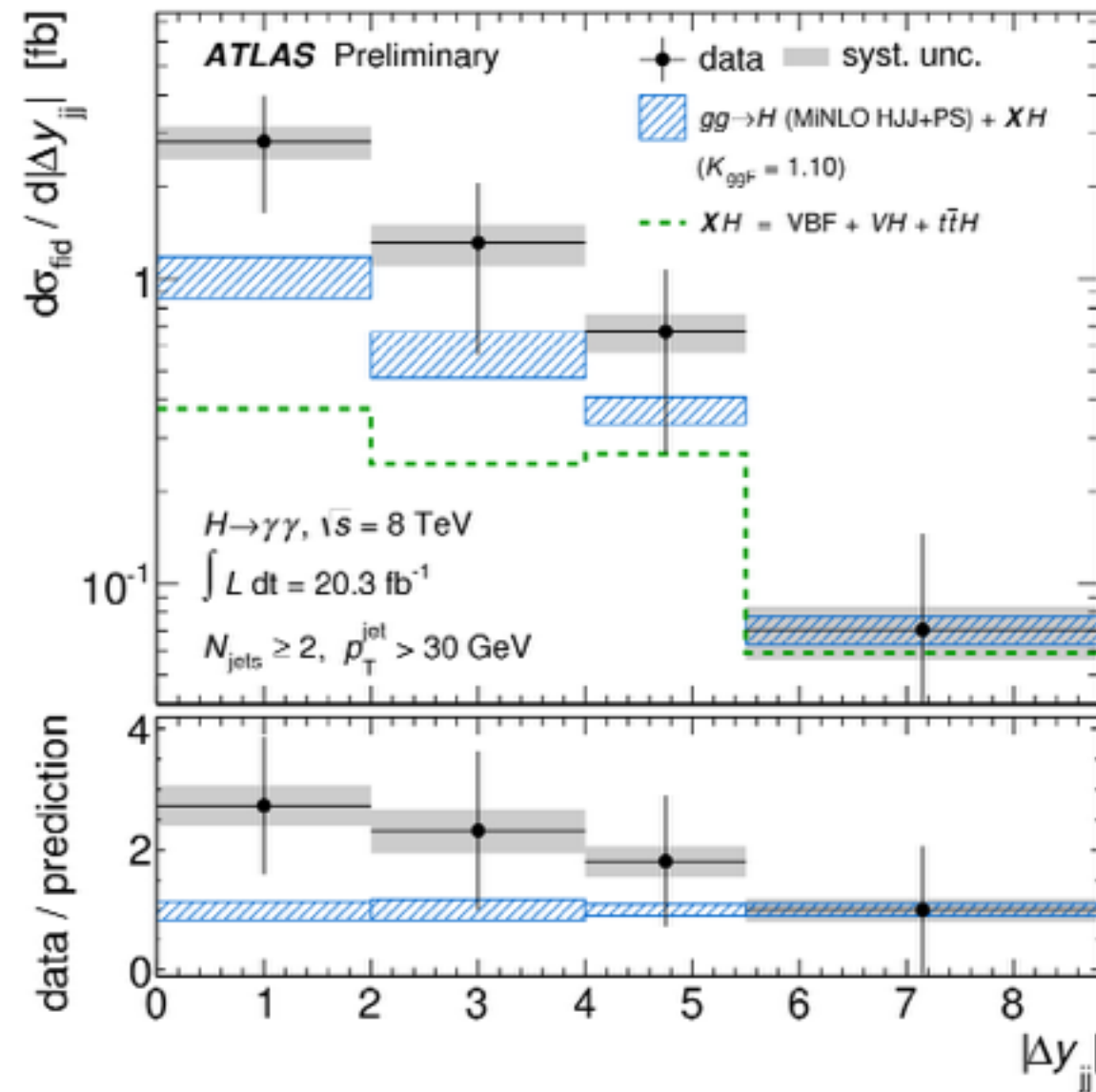
Diff. cross-sections



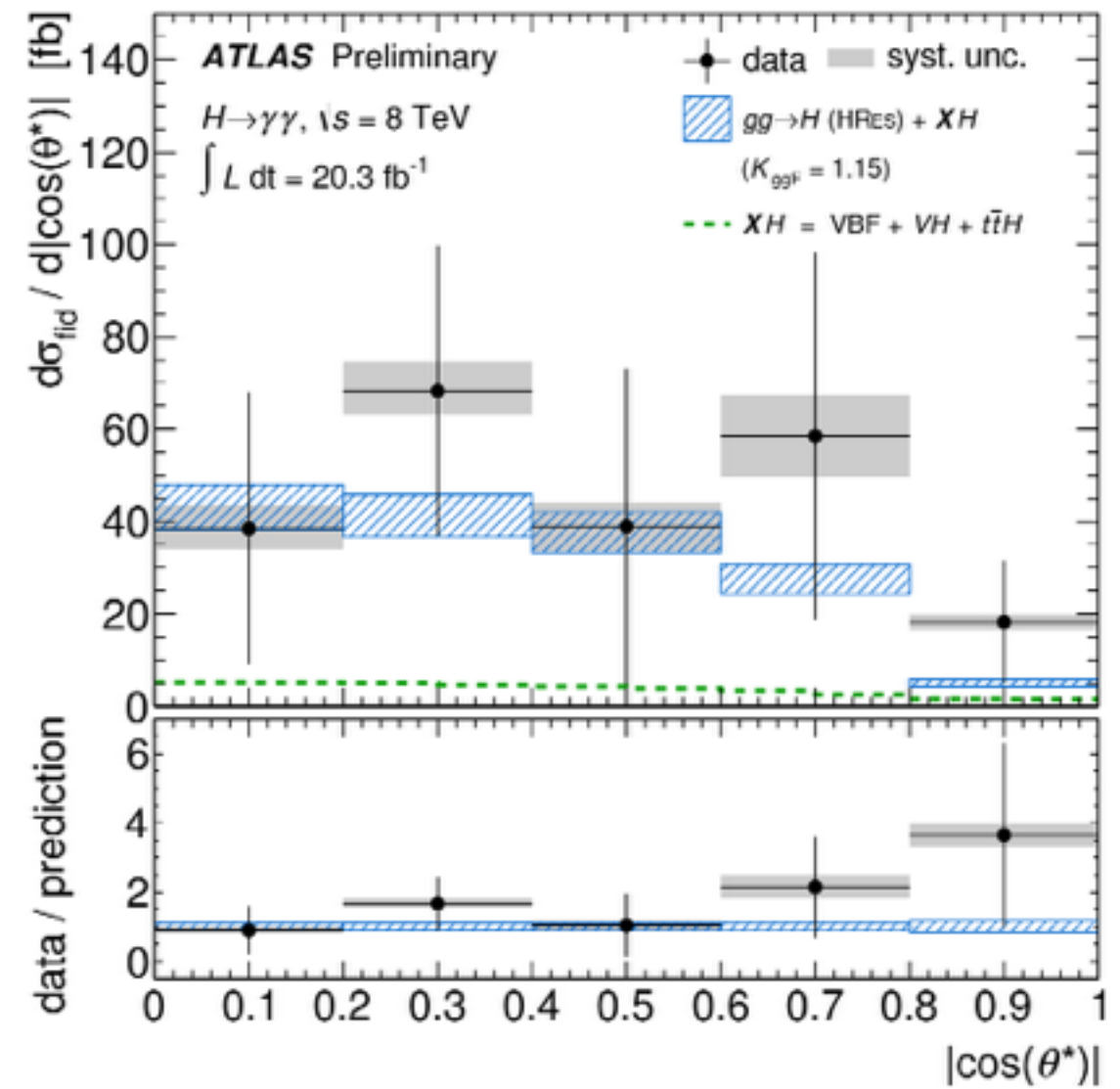
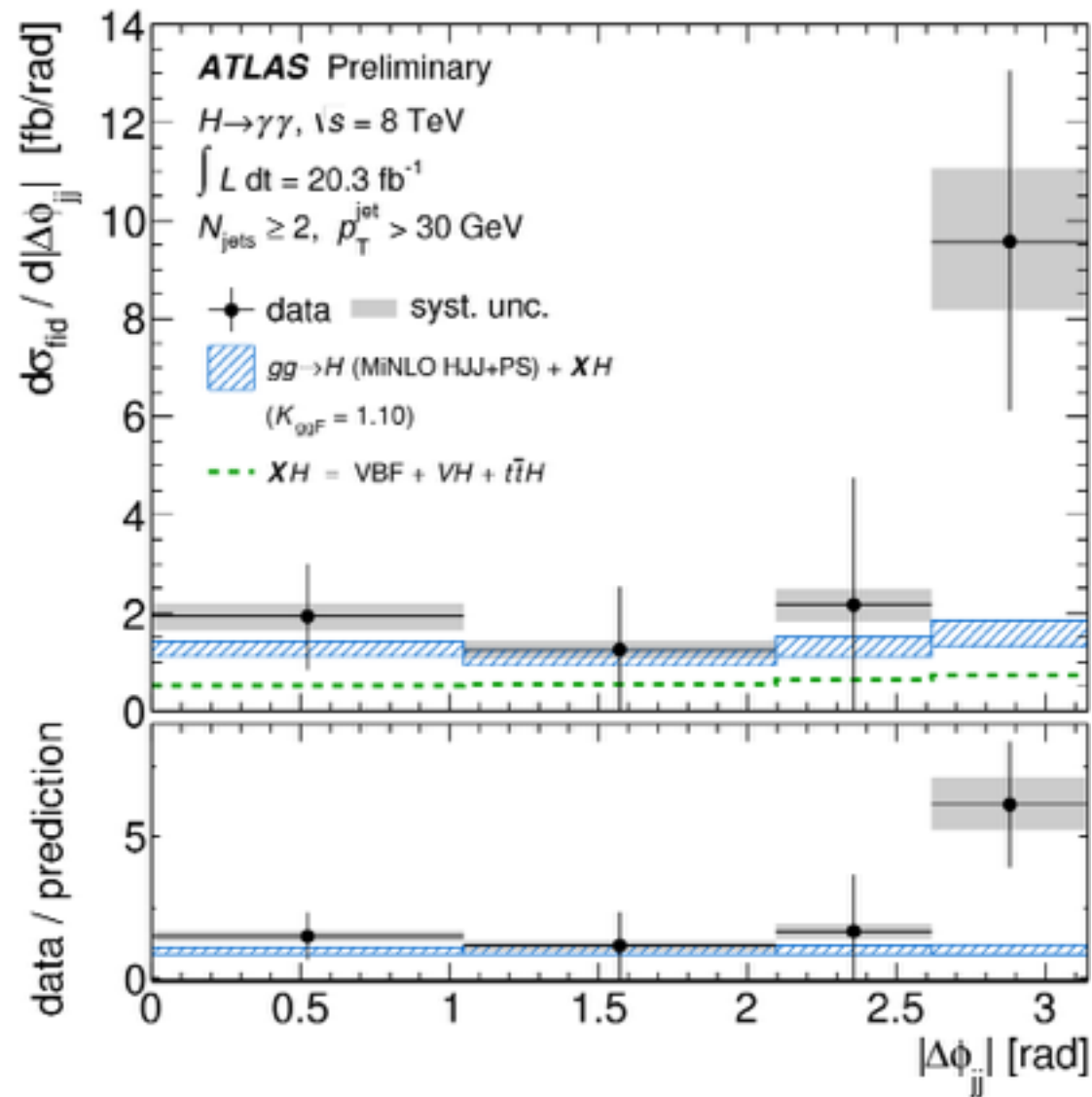
Diff. cross-sections



Diff. cross-sections



Diff. cross-sections




$$hh \rightarrow \gamma\gamma + bb$$

- Very small SM rate, possible enhancements:
 - Non resonant production:
 - Higgs Boson self-coupling altered (turned off, flipped sign)
 - direct $t\bar{t}hh$ coupling in composite models
 - addition of light colored scalars in the SM
 - Resonant production:
 - gravitons, radions
 - hidden Higgs sector mixing with the observed Higgs
 - 2HDM $H \rightarrow hh$
- Two benchmark models generated using MADGRAPH5:
 - Non resonant: SM di-higgs production (including interference between trilinear Higgs boson couplings and box diagrams)
 - NLO cross-section: 9.2 fb
 - Resonant: gluon initiated narrow width resonance
- Backgrounds:
 - Non resonant: diphoton, photon+jet, $t\bar{t}$ (di-electron faking di-photon)