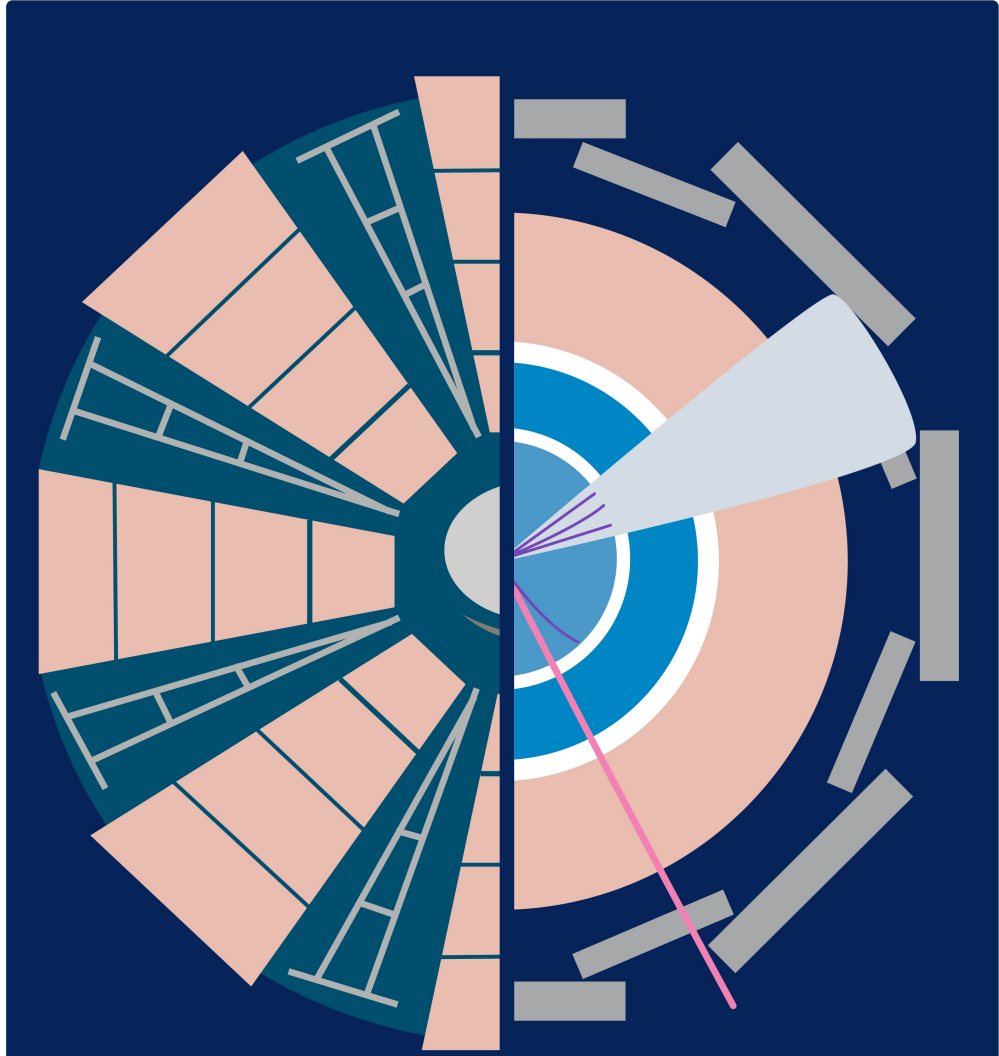
New ATLAS measurements at 13.6 TeV

Electroweak Interactions & Unified Theories
57th Moriond EW 2023 (18 - 25 March), La Thuile, Italy

Evgeniya Cheremushkina (DESY, Zeuthen, Germany)
on behalf of ATLAS collaboration



ATLAS EXPERIMENT

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

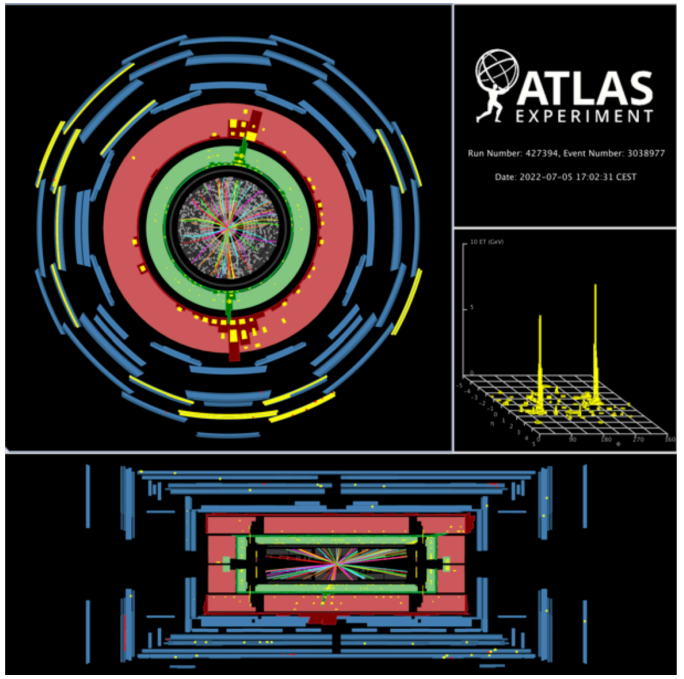
DESY.

Introduction

ATLAS measurements at the first year of Run-3

- Successful start of the Run-3 in 2022 with new pp energy at $13.6\ \mathrm{TeV}$;
- Various quick measurements are carried out:
  - To validate the detector and reconstruction performance for basic objects (e, μ, γ, jets…);
  - To test the SM predictions.

- **Recent results from the ATLAS experiment are presented for:**
  - Luminosity and detector performance;
  - $t\bar{t}$, Z inclusive cross-sections and $t\bar{t}/Z$ cross-section ratio measurement;
  - $H \to \gamma\gamma$ fiducial cross-section measurement.



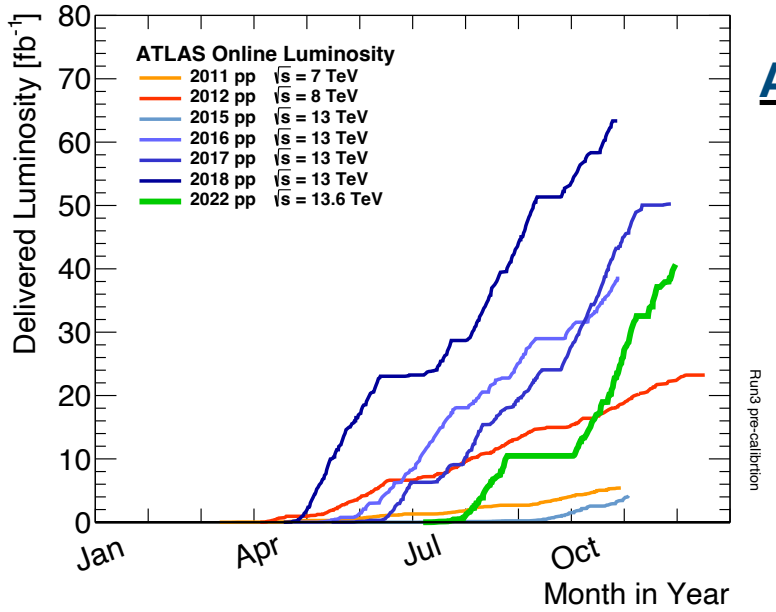
ATLAS operation at the first year of Run-3

Successful operational start in 2022

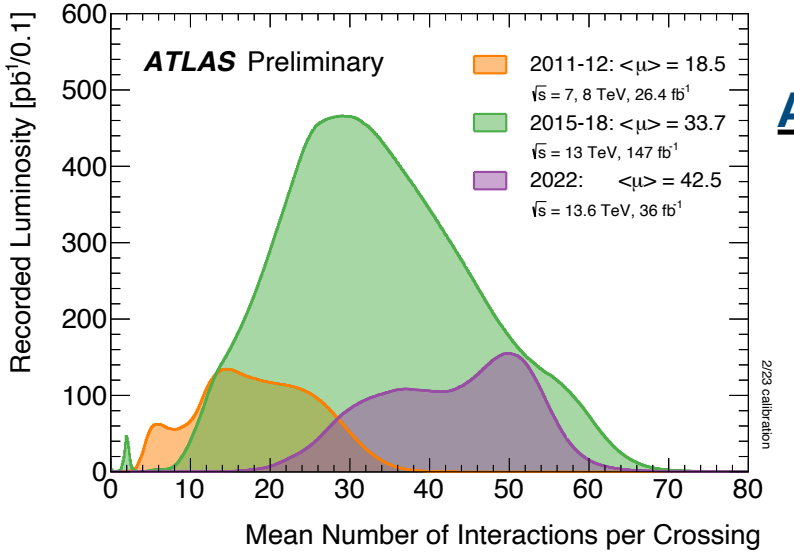
ATLASDetectorOperationRun3

Subdetector	Number of Channels	Approximate Operational Fraction	
Pixels	92 M	96.7%	Tracker
SCT Silicon Strips	6.3 M	98.3%	
TRT Transition Radiation Tracker	350 k	96.6%	
LAr EM Calorimeter	170 k	100%	Calorimeters
Tile Calorimeter	5200	99.2%	
Hadronic End-Cap LAr Calorimeter	5600	99.9%	
Forward LAr Calorimeter	3500	99.8%	
LVL1 Calo Trigger	7160	99.9%	
LVL1 Muon RPC Trigger	383 k	99.8%	Muon spectrometer
LVL1 Muon TGC Trigger	312 k	100%	
MDT Muon Drift Tubes	344 k	99.7%	
MicroMegas NSW	2.1 M	98.0%	
STGC NSW	358 k	99.2%	
RPC Barrel Muon Chambers	383 k	87.7%	
TGC End-Cap Muon Chambers	312 k	99.4%	
ALFA	10 k	100%	
AFP	430 k	100%	
LUCID	2x16	100%	
ZDC	2x20	100%	

ATLAS Lumi



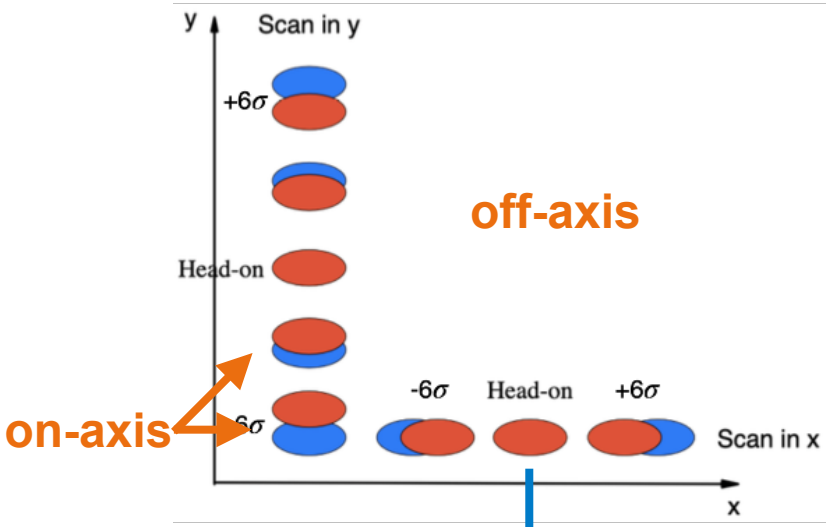
ATLAS Lumi



ATLAS Luminosity measurement

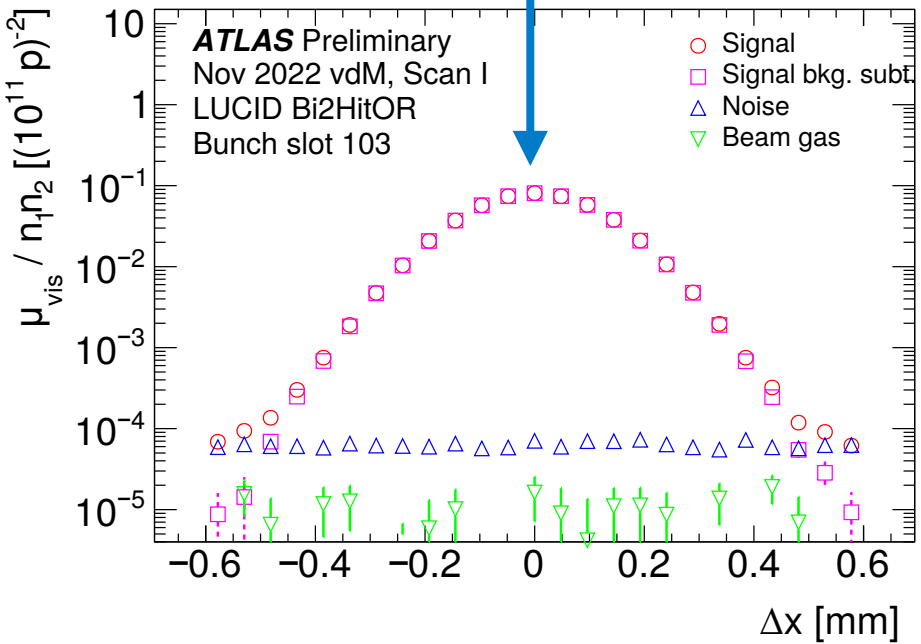
ATL-DAPR-PUB-2023-001

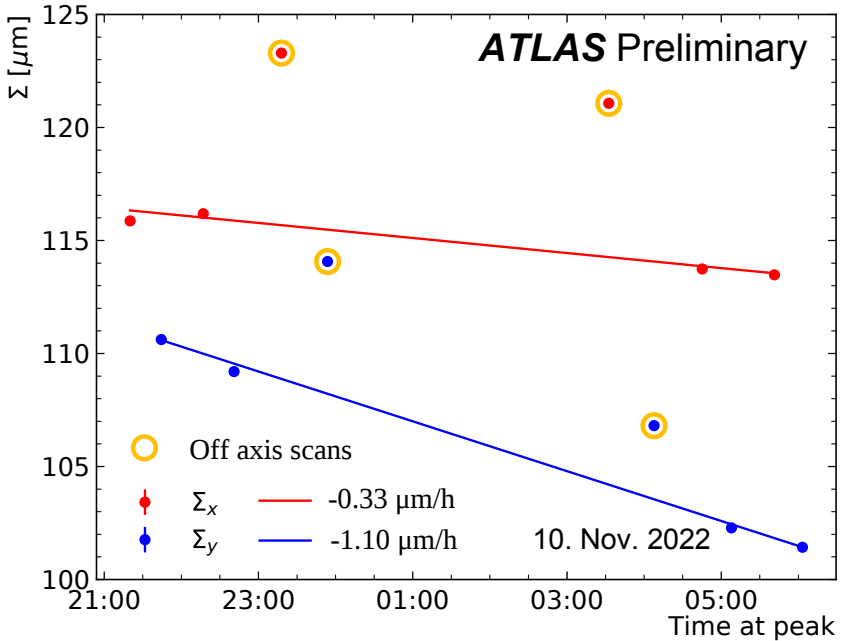
More details

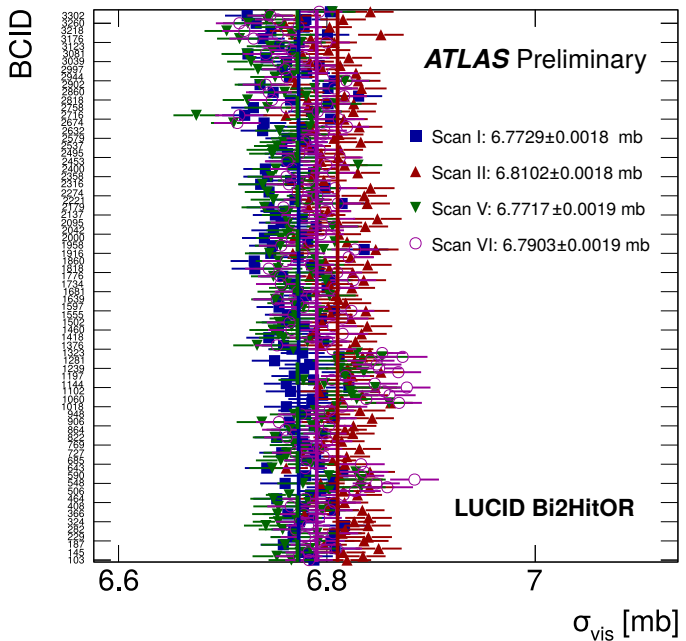


Van der Meer beam separation scan:

- Calibrations are done;
- First precise measurements of Luminosity;
- Non-factorisation correction - the largest impact;
- Uncertainty: ~2.2%.





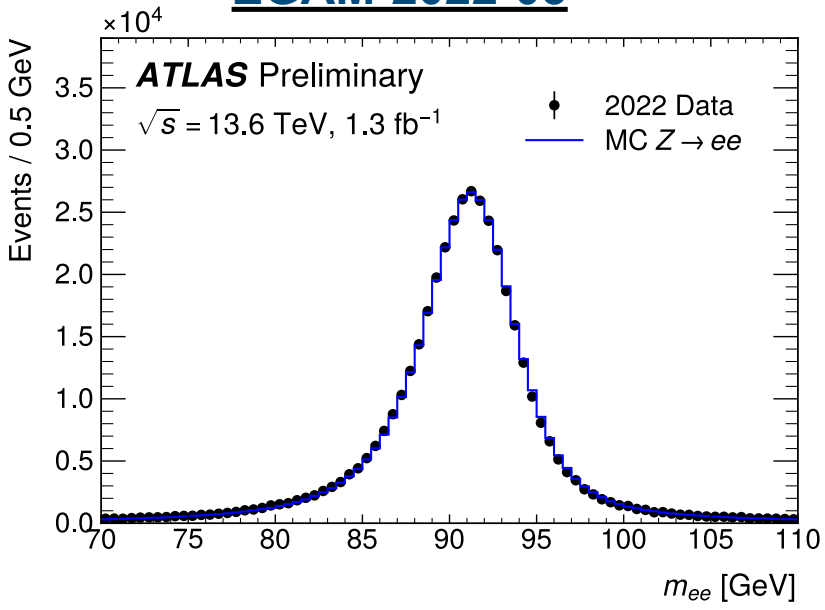


ATLAS performance at the first year of Run-3

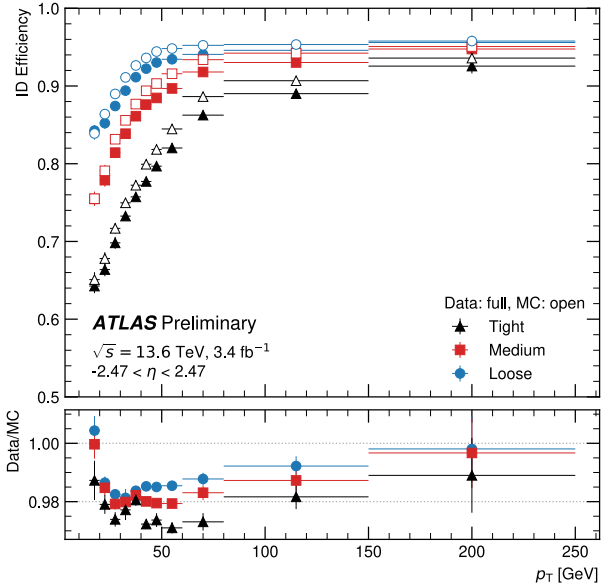
Electrons, flavour tagging

- **Invariant mass of opposite-sign electron candidates pairs:** 2 electrons with $p_{\mathrm{T}} > 27$ GeV and Medium likelihood identification;
- **Electron identification efficiencies:** in $Z \to ee$ events as a function of transverse momentum integrated over the full pseudo-rapidity range;
- **Number of b-tagged jets:** for different working points of the DL1d tagger in the opposite-sign $e\mu$ pair events.

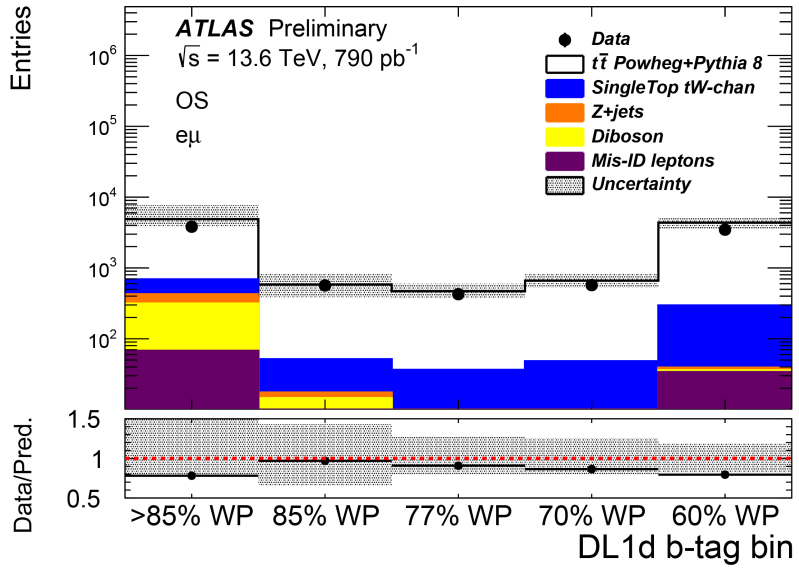
EGAM-2022-03



EGAM-2022-04



FTAG-2022-003

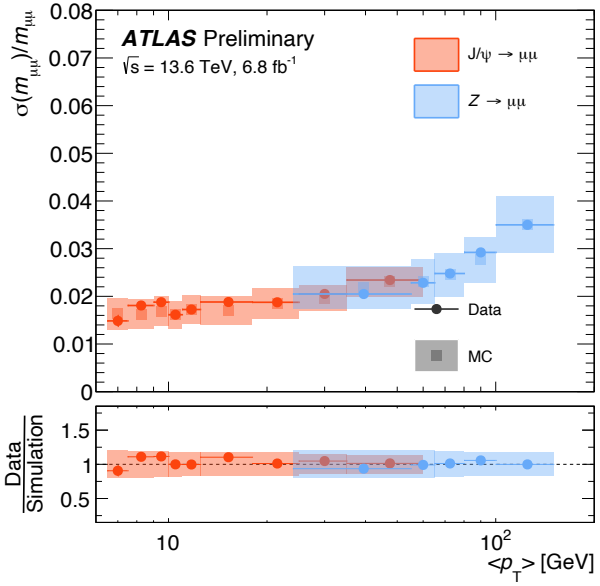


ATLAS performance at the first year of Run-3

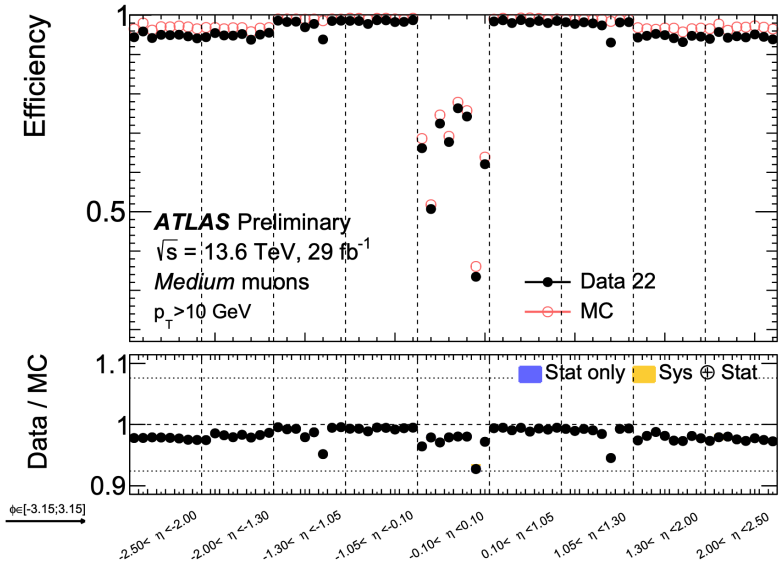
Muons

- **Dimuon invariant mass resolution divided by the particle's mass:** for combined muons from $J/\psi \rightarrow \mu\mu$ and $Z \rightarrow \mu\mu$ events as a function of the average transverse momentum;
- **Reconstruction and identification efficiency for muons:** in $Z \rightarrow \mu\mu$ events as a function of η and ϕ with Medium muon identification quality;
- **Event display for $Z \rightarrow \mu\mu$ candidate:** (Run 427394,Event 21060879) on 5 July 2022, when stable beams of protons at the energy of 6.8 TeV per beam were delivered to ATLAS for the first time by the LHC.

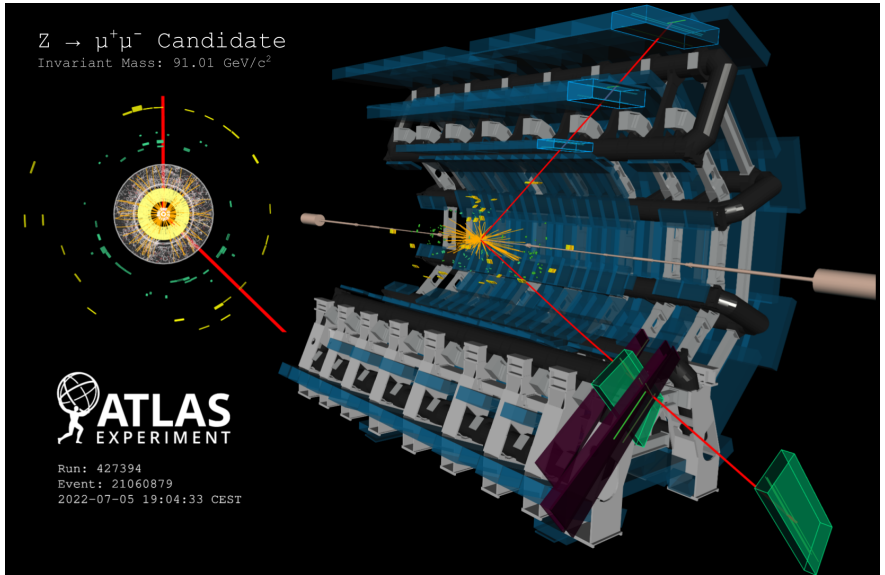
MUON-2022-02



PLOT-MUON-2023-01



UNSG-2022-85



Measurement of the $t\bar{t}, Z$ cross-section and $t\bar{t}/Z$ cross-section ratio in Run-3 with $11.3\ \mathrm{fb}^{-1}$

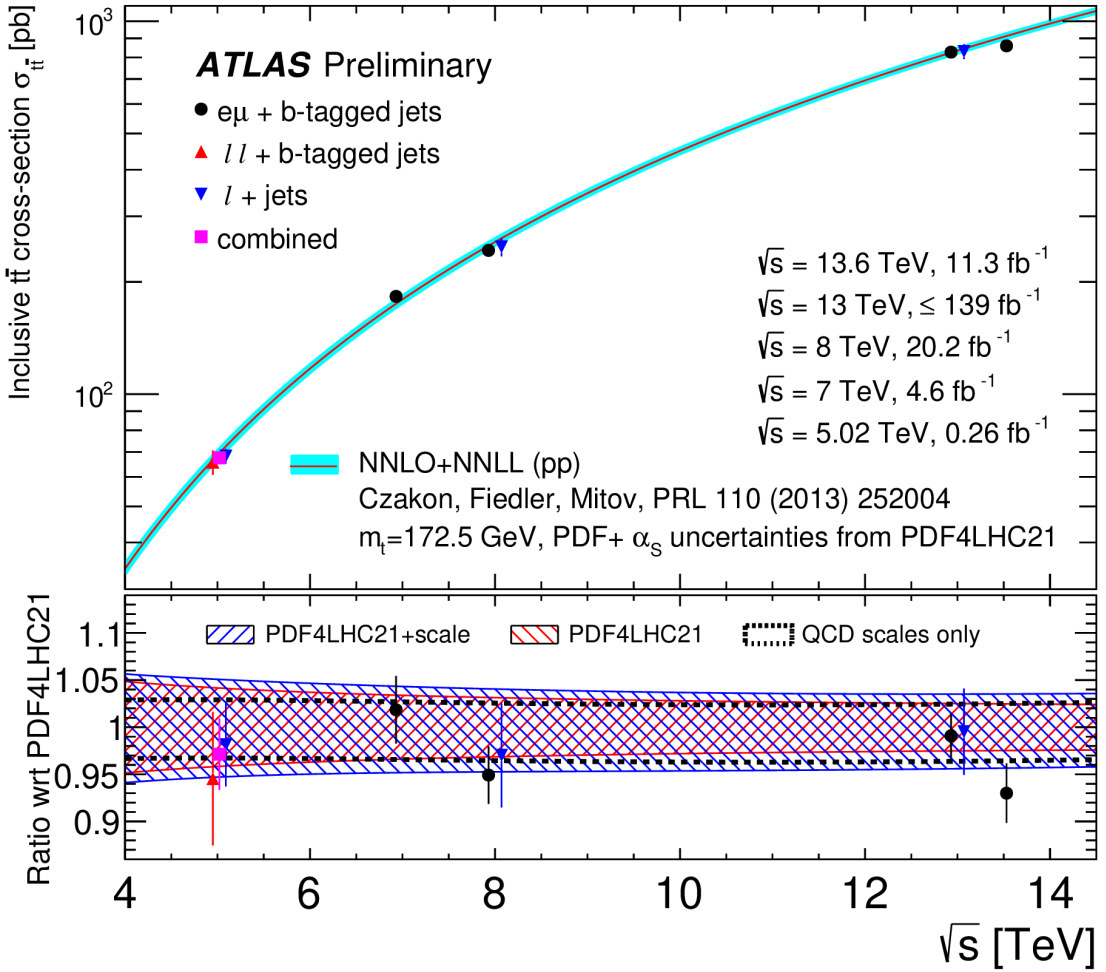
ATLAS-CONF-2023-006

$t\bar{t}/Z$ cross-section

Motivation

ATLAS-CONF-2023-006

- **Run 3 data at 13.6 TeV with $L = 11.3\ \text{fb}^{-1}$:**
  - MC, detector + software validation;
  - Strongly affected by the luminosity uncertainty (2.2%);
- **Measure inclusive $t\bar{t}$ cross-section:**
  - dilepton ($e\mu$, opposite sign) channel only;
- **Measure fiducial Z cross-section:**
  - $ee/\mu\mu$ (opposite sign) channels;
- **Measure tt/Z cross-section ratio:**
  - reduction of uncertainties;
  - sensitive to gluon/quark PDFs.



$t\bar{t}/Z$ cross-section

Analysis strategy

- **Fit:** $\sigma_{t\bar{t}}$, σ_Z and $R_{t\bar{t}/Z}$ in PL fits;
- **Regions:** ee, $\mu\mu$, $e\mu$ with $= 1b$-jet, $e\mu$ with $\geq 2b$-jets;
- **In-situ measurement of efficiency to reconstruct+tag exactly 1 b-jet: ϵ_b**

$e\mu$ events:

with $= 1b$-jet: $N_1 = L\sigma_{t\bar{t}}\epsilon_{e\mu}2\epsilon_b(1 - C_b\epsilon_b) + N_1^{\text{bkg}};$

Probability to reconstruct, select & b-tag the jet (fit parameter)

Correlation factor $C_b = \epsilon_{bb}/\epsilon_b^2$ (estimated from MC)

with $\geq 2b$-jet: $N_2 = L\sigma_{t\bar{t}}\epsilon_{e\mu}C_b\epsilon_b^2 + N_2^{\text{bkg}};$

Selection efficiency of $e\mu$ (no jets) (estimated from MC)

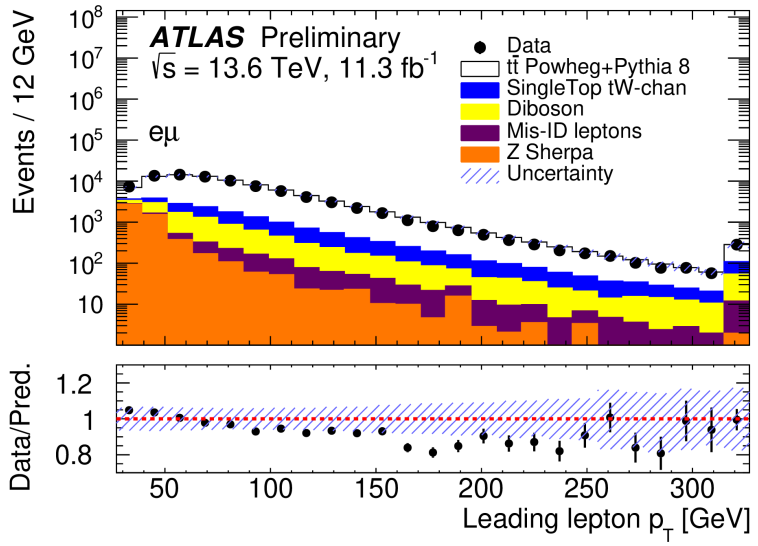
- **2 different profile Likelihood fits:** both using $t\bar{t}$ and Z boson events:

1. $\sigma_{t\bar{t}}$, σ_Z and ϵ_b estimation (3 NFs);
2. $R_{t\bar{t}/Z}$, σ_Z and ϵ_b estimation (3 NFs).

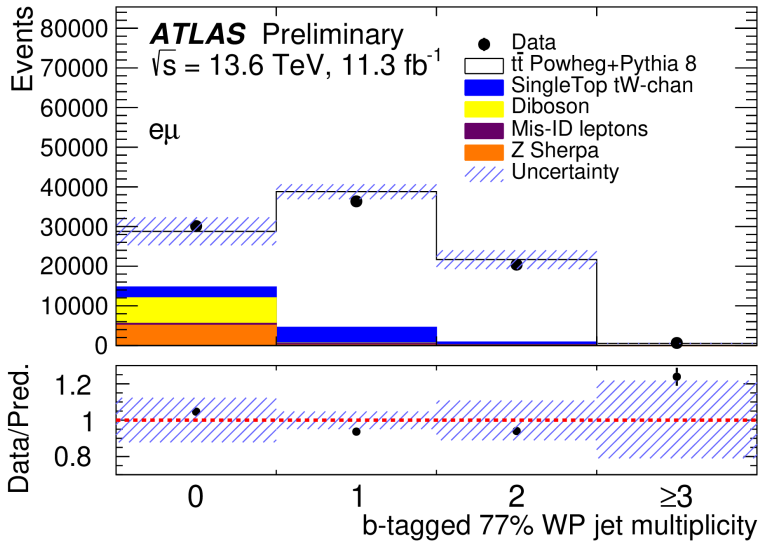
Guarantee that the fitted ratio is identical to the ratio of the fitted cross-sections.

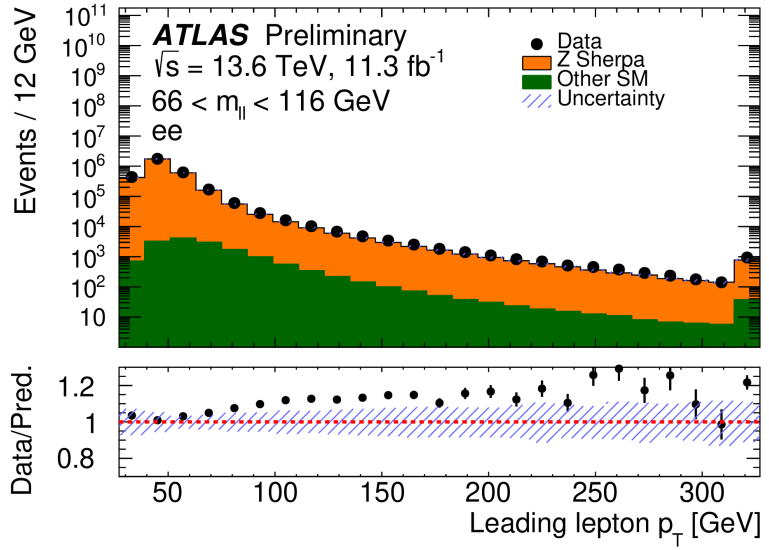
$t\bar{t}/Z$ cross-section

Data/MC comparison

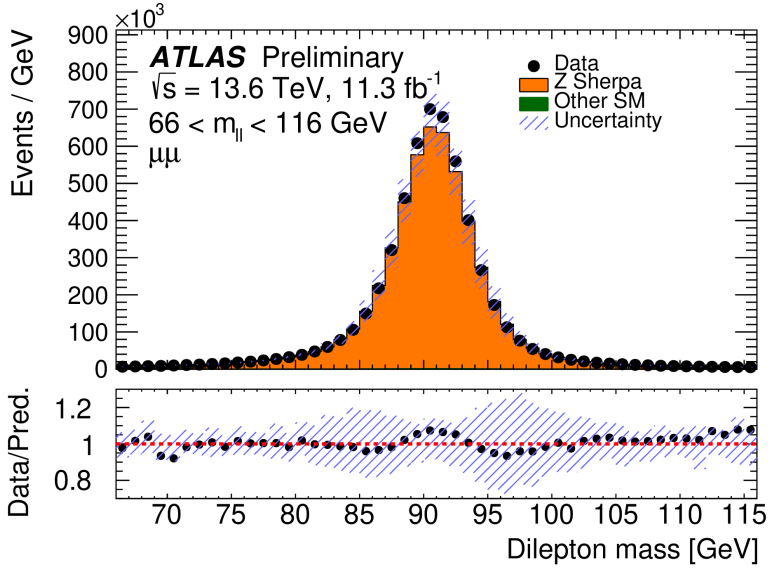


$e\mu$-channel



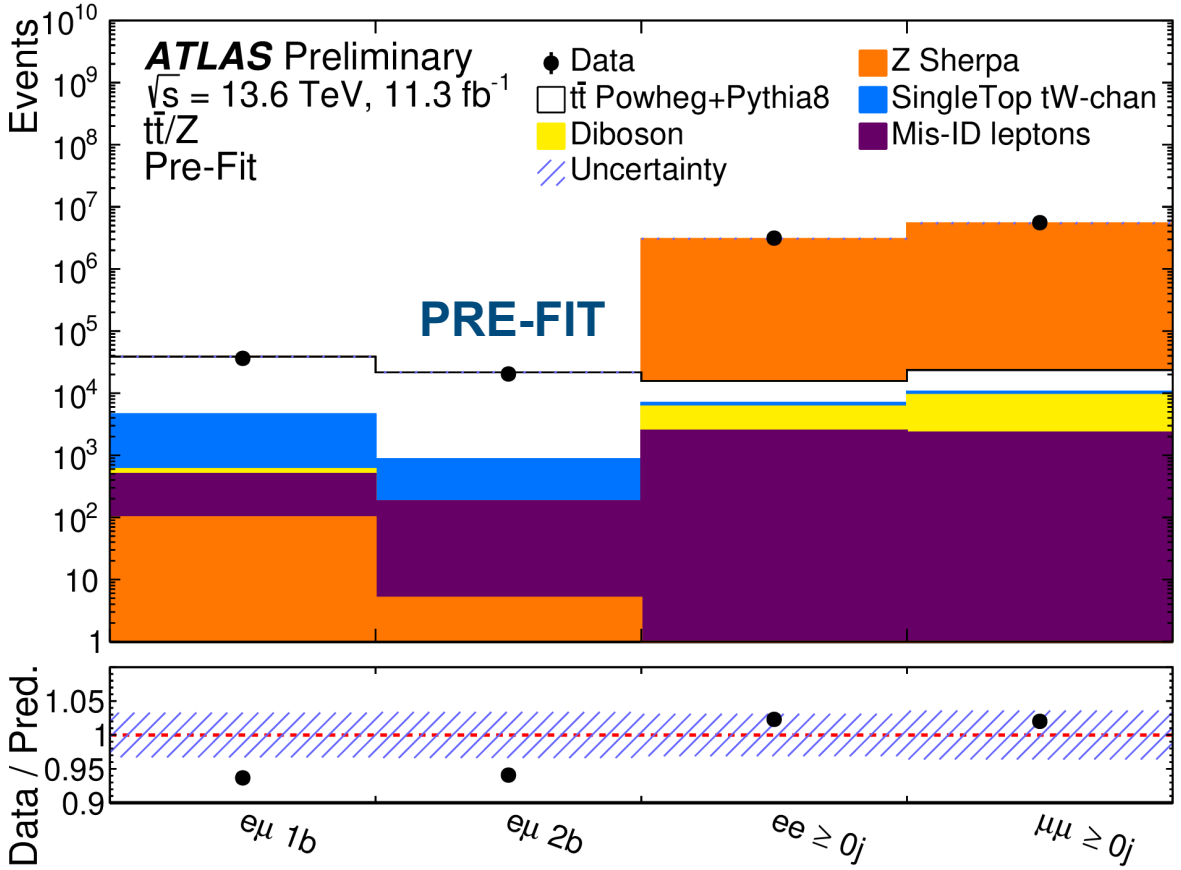


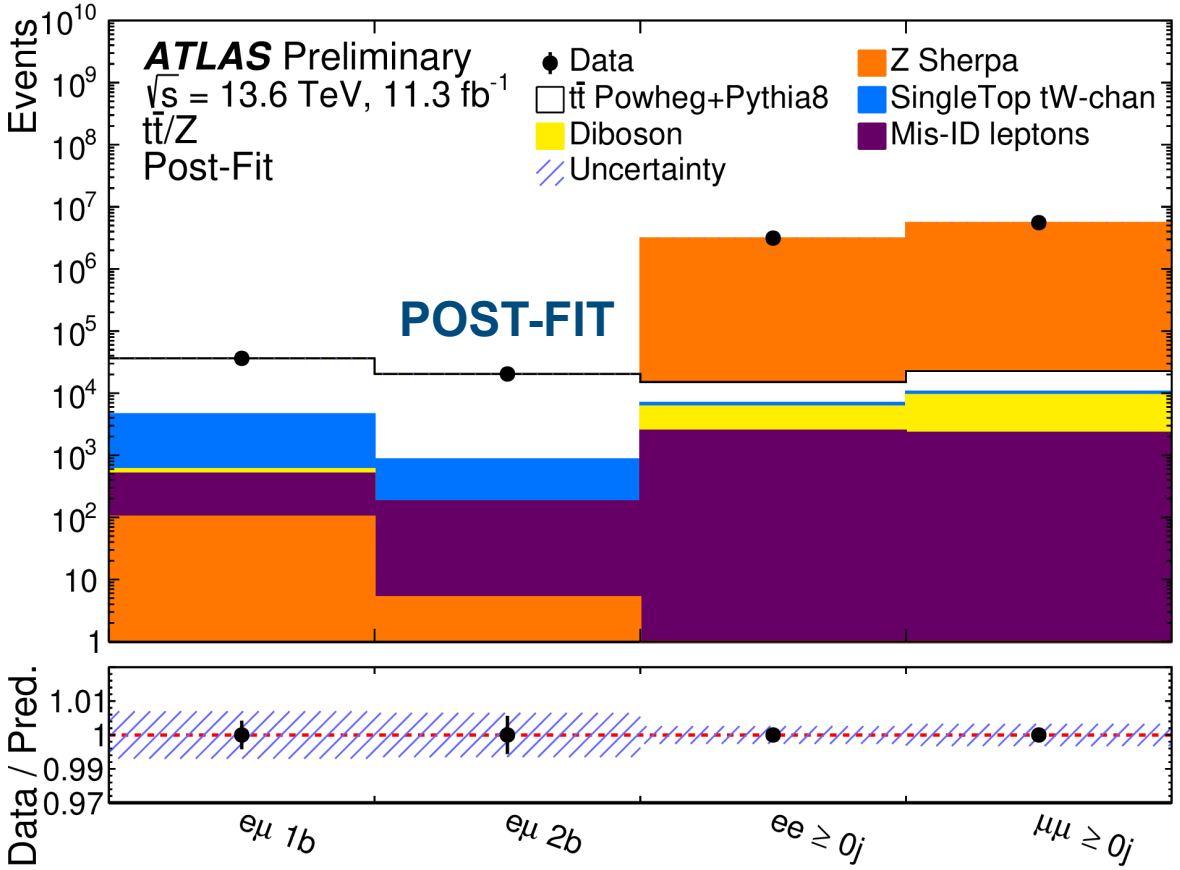
ll-channel



$t\bar{t}/Z$ cross-section

Event yields before- and after-fit



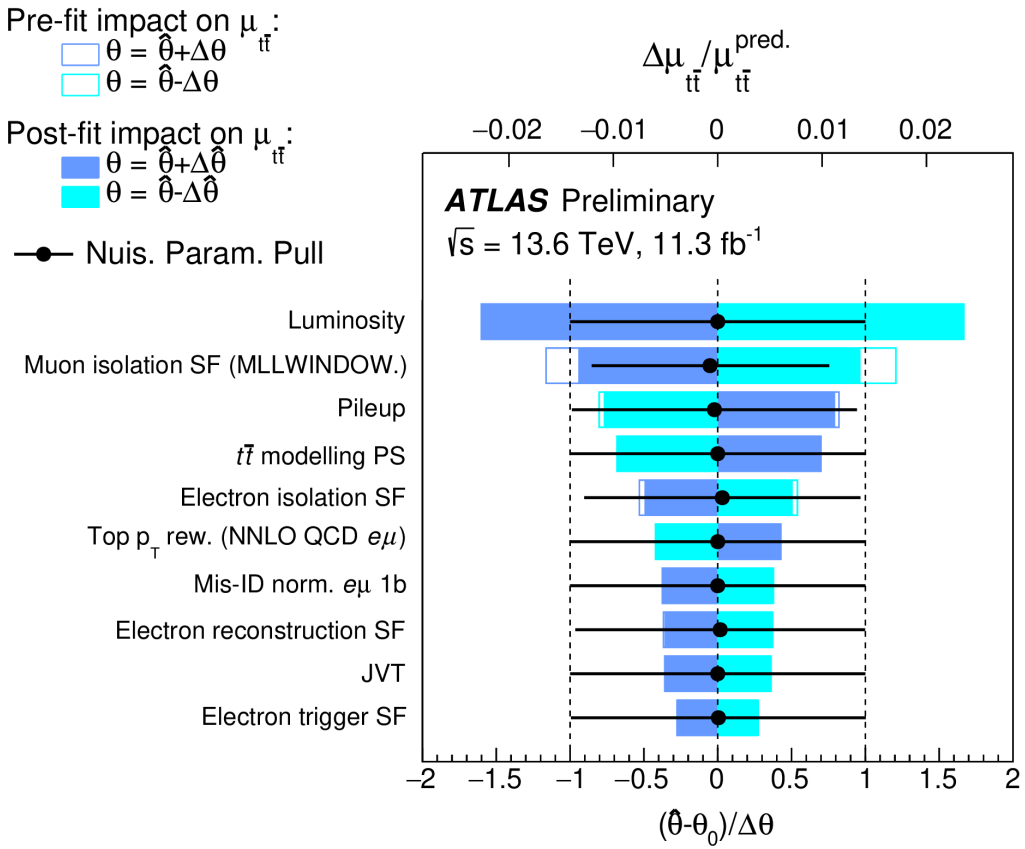


$t\bar{t}/Z$ cross-section

Systematic uncertainties

- Ranking plot shows the effect of the 10 most important systematic uncertainties on the measured $\sigma_{t\bar{t}}$, in the fit to data;
- Table shows the observed impact of the different sources of uncertainty on the measured $t\bar{t}$, Z cross-section and $R_{t\bar{t}/Z}$.

	Category	Uncert. [%]		
		$\sigma_{t\bar{t}}$	$\sigma^{\text{fid.}}_{Z\to\ell\ell}$	$R_{t\bar{t}/Z}$
$t\bar{t}$	$t\bar{t}$ parton shower/hadronisation	1.1	0.01	1.0
	$t\bar{t}$ scale variations	0.2	< 0.01	0.2
	Top quark p_{T} reweighting	0.6	0.02	0.5
Z	Z scale variations	0.2	0.5	0.3
Bkg.	Single top modelling	0.4	0.01	0.4
	Diboson modelling	0.1	0.06	< 0.01
	Mis-Id leptons	0.5	0.1	0.5
Lept.	Electron reconstruction	1.0	1.1	0.5
	Muon reconstruction	1.5	1.2	0.8
	Lepton trigger	0.4	0.7	0.8
Jets/tagging	Jet reconstruction	0.4	0.1	0.3
	Flavour tagging	0.2	0.01	0.2
	PDFs	0.4	0.2	0.4
	Pileup	1.1	1.1	< 0.01
	Luminosity	2.3	2.2	0.3
	Systematic Uncertainty	3.5	3.0	2.0
	Statistical Uncertainty	0.5	0.03	0.5
	Total Uncertainty	3.5	3.0	2.0



$t\bar{t}/Z$ cross-section

Results

- **Inclusive $t\bar{t}$ production cross-section:**

  $\sigma_{t\bar{t}} = 859 \pm 4(\text{stat.}) \pm 22(\text{syst.}) \pm 19(\text{lumi.})$ pb;

  $\sigma_{t\bar{t}}^{\text{theory}} = 924^{+32}_{-40}(\text{scale} + \text{PDF})$ pb;

- **Fiducial Z boson production cross-section:**

  $\sigma_{Z\to ll}^{\text{fid.}} = 751 \pm 0.3(\text{stat}) \pm 15(\text{syst}) \pm 17(\text{lumi})$ pb;

  $\sigma_{Z\to ll}^{\text{fid.,theory}} = 741 \pm 15(\text{scale} + \text{PDF})$ pb;

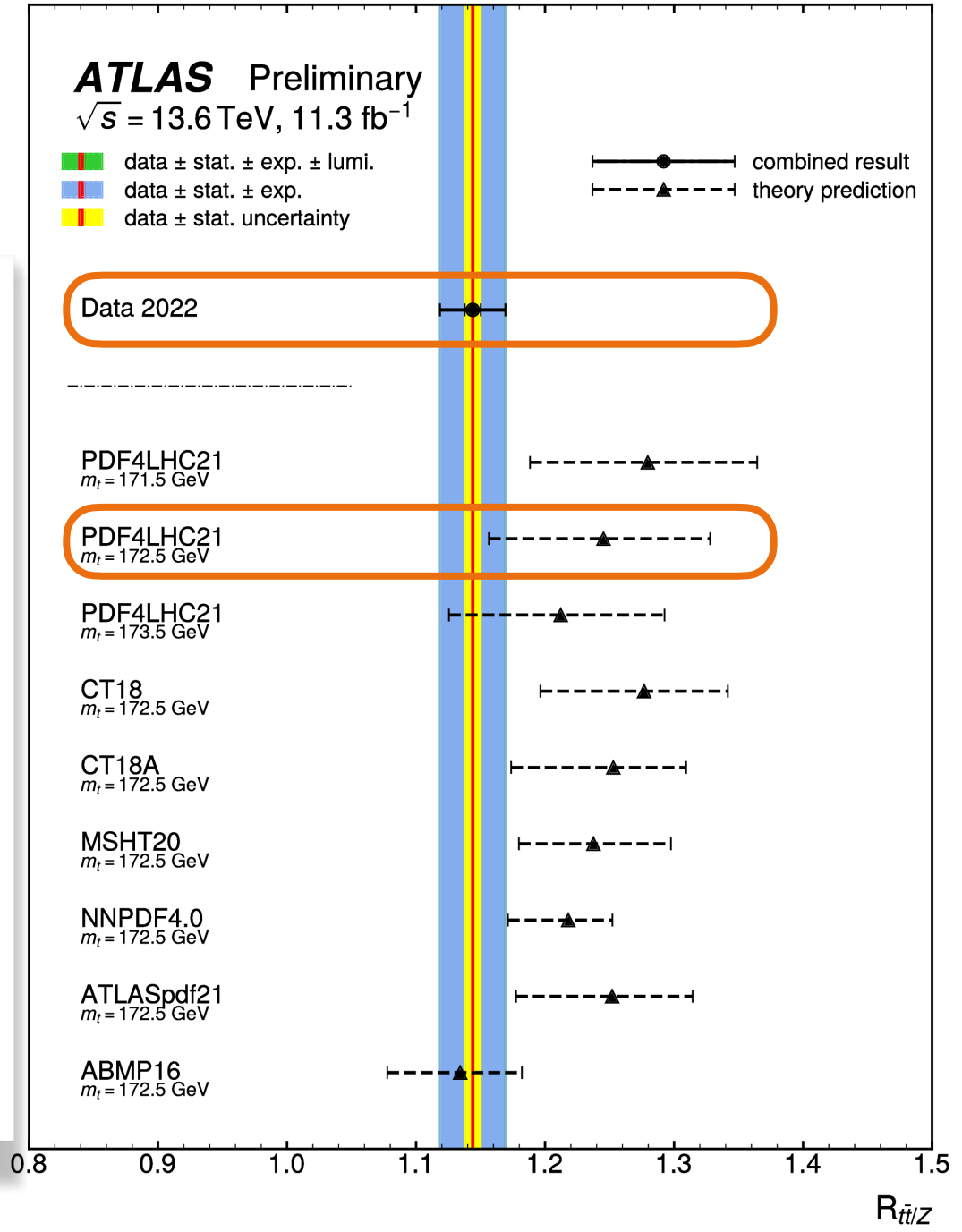
- **Reconstruction and b-tagging efficiency:**

  $\epsilon_b = 0.548 \pm 0.002(\text{stat.}) \pm 0.004(\text{syst.}) \pm 0.001(\text{lumi.})$

- **Ratio of the cross-sections:**

  $R_{t\bar{t}/Z} = 1.144 \pm 0.006(\text{stat}) \pm 0.022(\text{syst}) \pm 0.003(\text{lumi})$

  $R_{t\bar{t}/Z}^{\text{theory}} = 1.245 \pm 0.076(\text{scale} + \text{PDF})$



Measurement of the $H \to \gamma\gamma$ fiducial cross-section in pp collisions with $31.4\ \mathrm{fb}^{-1}$

ATLAS-CONF-2023-003

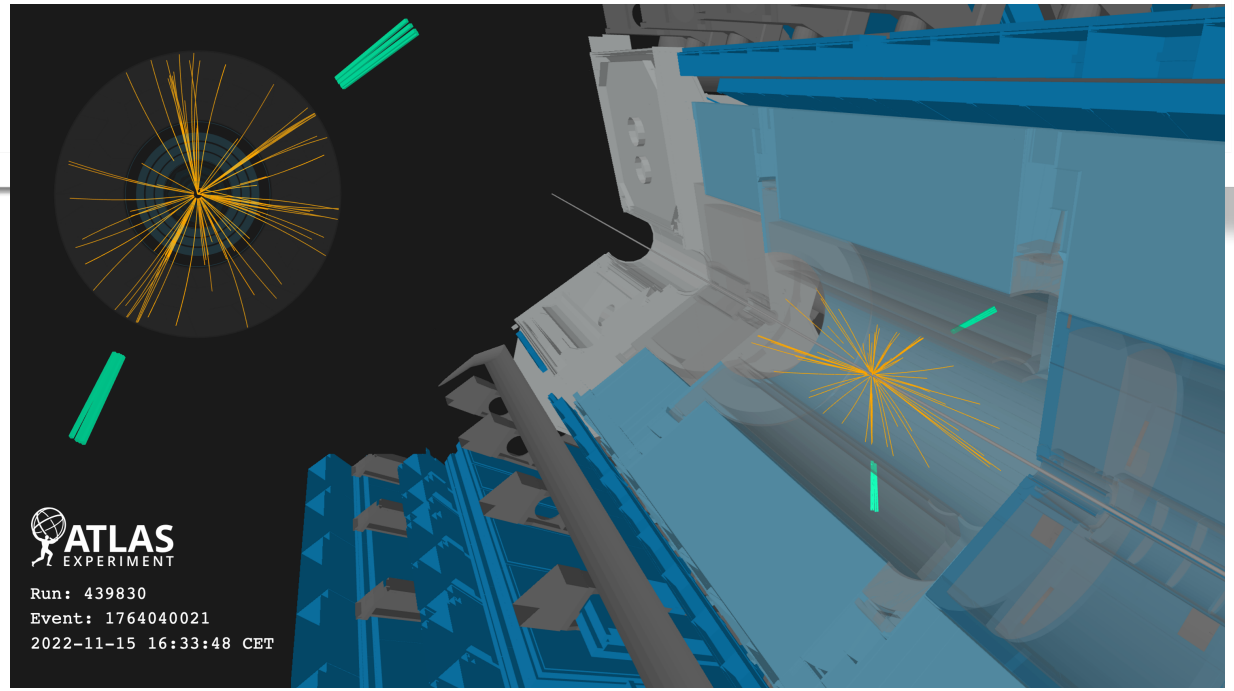
$H \to \gamma\gamma$ fiducial cross-section

Motivation

- First look at $H \to \gamma\gamma$ at 13.6 TeV:
  - Total $L = 31.4$ fb^{-1} of *pp* collision data;
  - Despite small $Br(H \to \gamma\gamma)$, low background & excellent $m_{\gamma\gamma}$ reconstruction and γ identification efficiency;
- Measuring of the **inclusive fiducial cross-section** $\sigma_{\text{fid}}(pp \to H \to \gamma\gamma)$:
  - Following the Run-2 analysis strategy;
- Extrapolation to the **full phase space** $\sigma(pp \to H)$.

ATLAS-CONF-2023-003

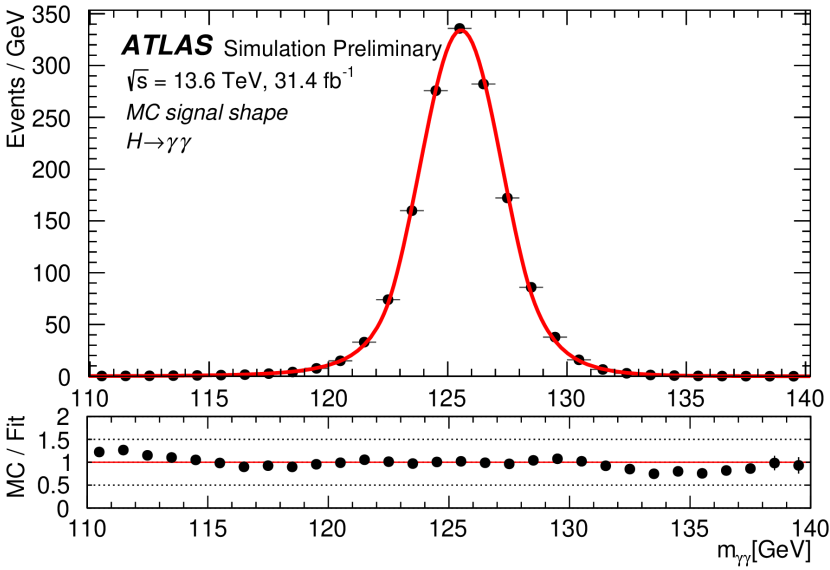
Event display: of $H \to \gamma\gamma$ candidate event (Run 439830, Event 1764040021) with $m_{\gamma\gamma} = 125.2$ GeV. The transverse momenta of the leading and sub-leading photons are 123.2 GeV and 98.5 GeV respectively. Both photon candidates are unconverted.

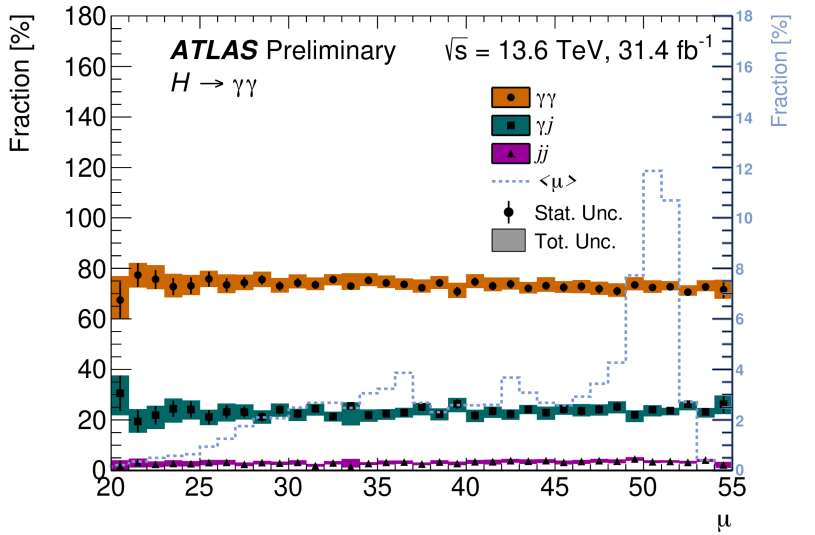


$H \to \gamma\gamma$ fiducial cross-section

Analysis strategy

- **Fiducial selection:** two isolated photons within detector acceptance, with cuts on $E_T^{\gamma_{\text{lead.(sublead.)}}}/m_{\gamma\gamma} > 0.35\ (0.25)$ and $105\ \text{GeV} < m_{\gamma\gamma} < 160\ \text{GeV}$;
- $\sigma_{fid}(H \to \gamma\gamma)$ **extracted by unbinned max LH fit to** $m_{\gamma\gamma}$ **spectrum:**
  - Signal shape parametrised by a double-sided Crystal Ball function;
  - Background shape parametrised by an analytical function (exponential of a second-order polynomial in $m_{\gamma\gamma}$) determined from a fit to MC template:
    - Accounts for prompt and isolated $\gamma\gamma$ production and $j \to \gamma$ fakes from γj (and $j\gamma$) + jj;
    - $\gamma\gamma$ component is estimated by new method based on smearing the generator-level MC using a normalising flow based on ML;
  - Systematic uncertainties on signal yield and signal $m_{\gamma\gamma}$ shape modelling, spurious signal (background modelling);
- **Extrapolation** of result to total phase space to extract the total $\sigma(pp \to H)$ based on acceptance corrections:
  - Additional systematic uncertainties on acceptance, as well as on the branching ratio.



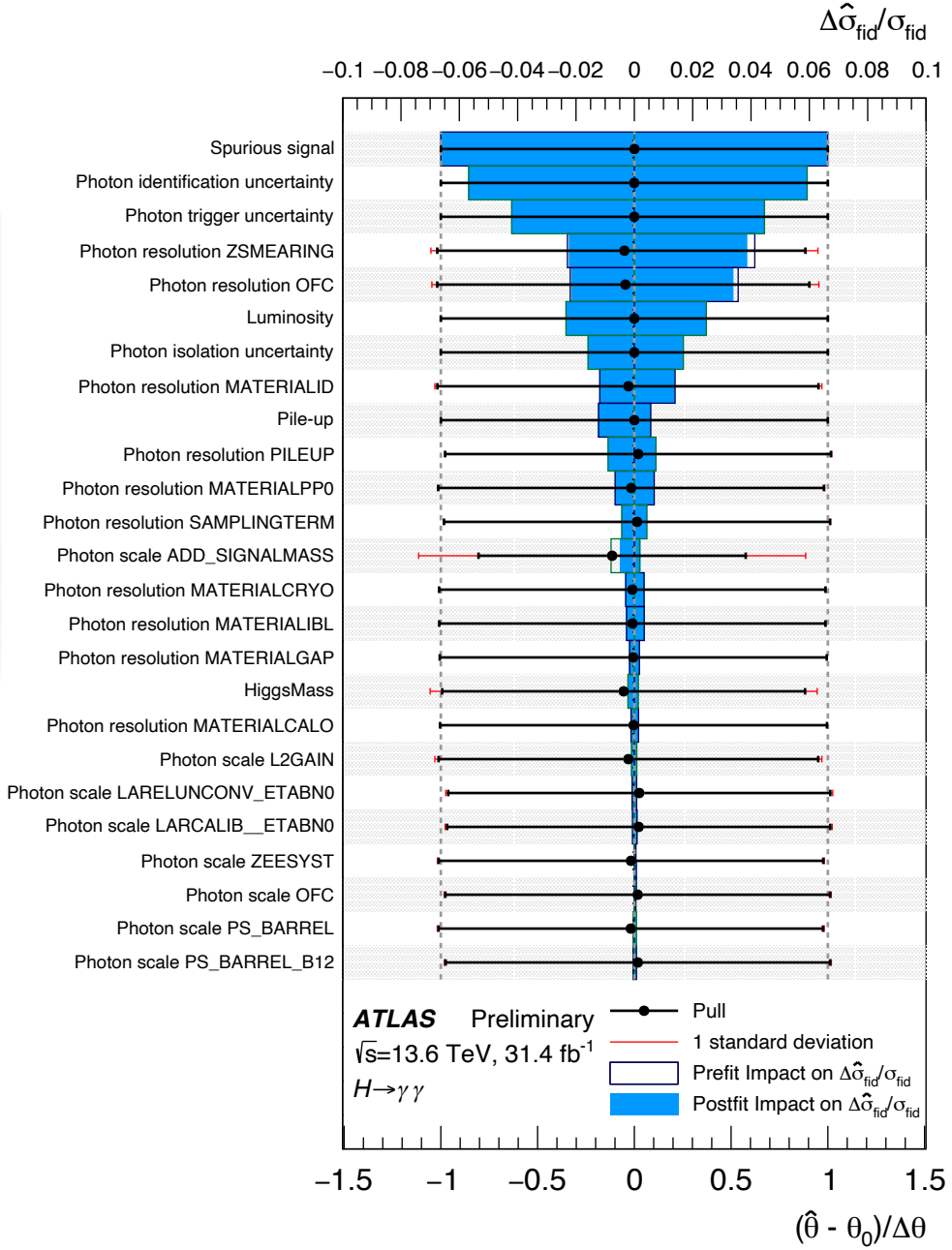


$H \to \gamma\gamma$ fiducial cross-section

Systematic and statistical uncertainties

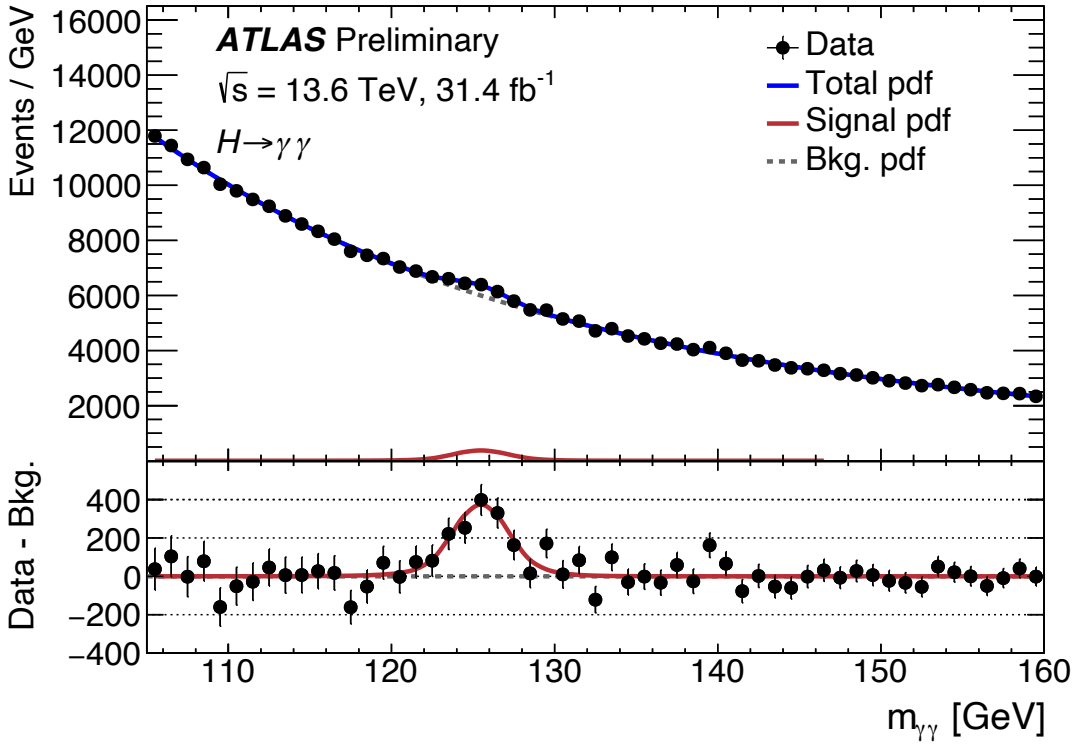
- Measurement limited by statistical uncertainty;
- Largest systematic uncertainties related to:
  Spurious signal, photon triggering, identification and isolation efficiency, and photon energy scale & resolution;
  - Many photon-related uncertainties conservatively extrapolated from Run-2 values.

Source	Uncertainty [%]
Statistical uncertainty	14.0
Systematic uncertainty	10.9
Photon trigger and selection efficiency	6.7
Background modelling (spurious signal)	6.0
Photon energy scale & resolution	5.5
Luminosity	2.2
Pile-up modelling	1.1
Higgs boson mass	0.1
Theoretical (signal) modelling	<0.1
Total	17.7



$H \to \gamma\gamma$ fiducial cross-section

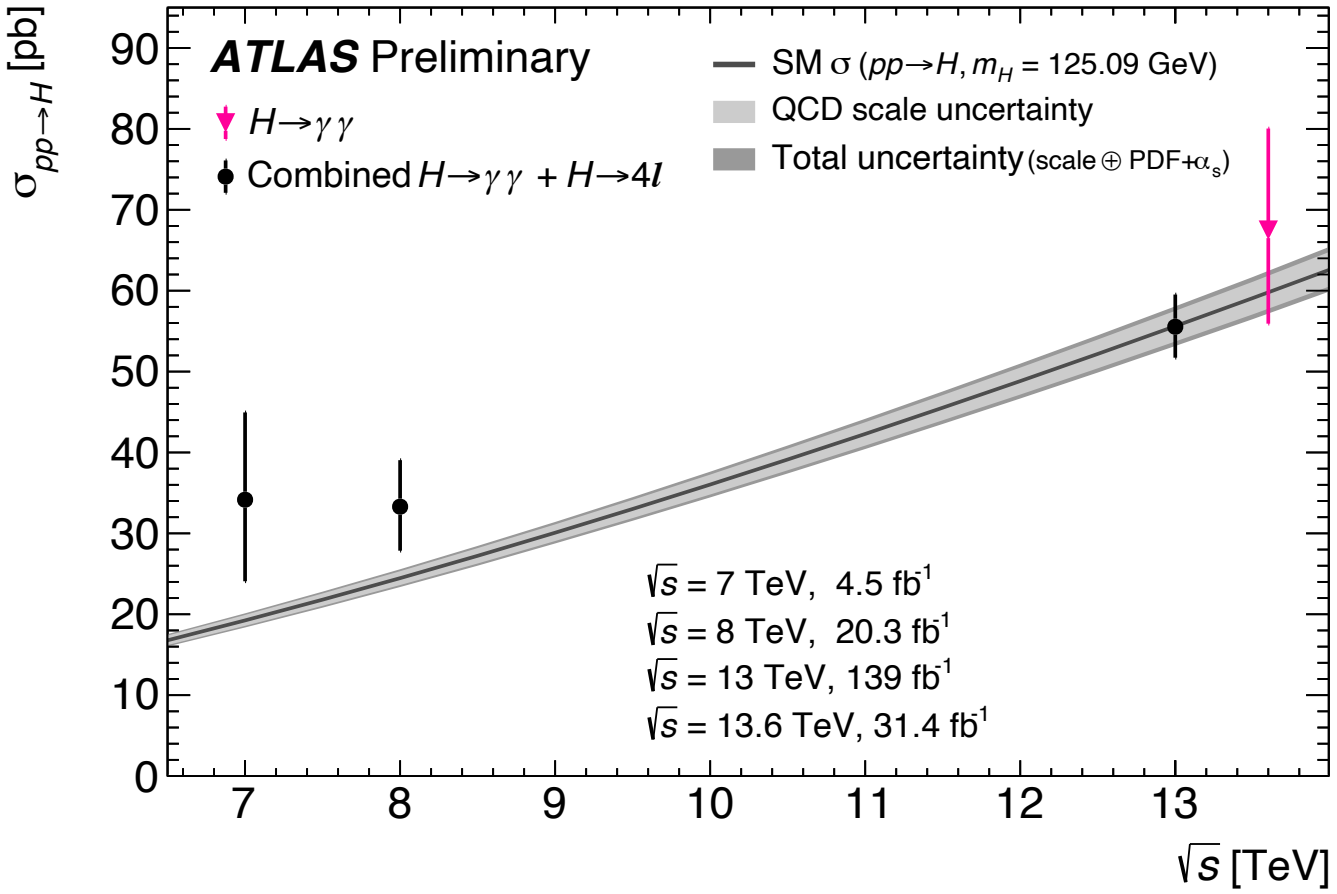
Fit result



- Result obtained from fit to $m_{\gamma\gamma}$ spectrum within $105\ \text{GeV} < m_{\gamma\gamma} < 160\ \text{GeV}$;
- $\sigma_{fid}(pp \to H \to \gamma\gamma) = 76^{+14}_{-13} = 76 \pm 11(\text{stat.})^{+9}_{-7}(syst.)\ \text{fb}$
- In agreement with $\sigma^{\text{theory}}_{\text{fid}} = 67.5 \pm 3.4\ \text{fb}$.

$H \to \gamma\gamma$ fiducial cross-section

Extrapolation to the full phase space

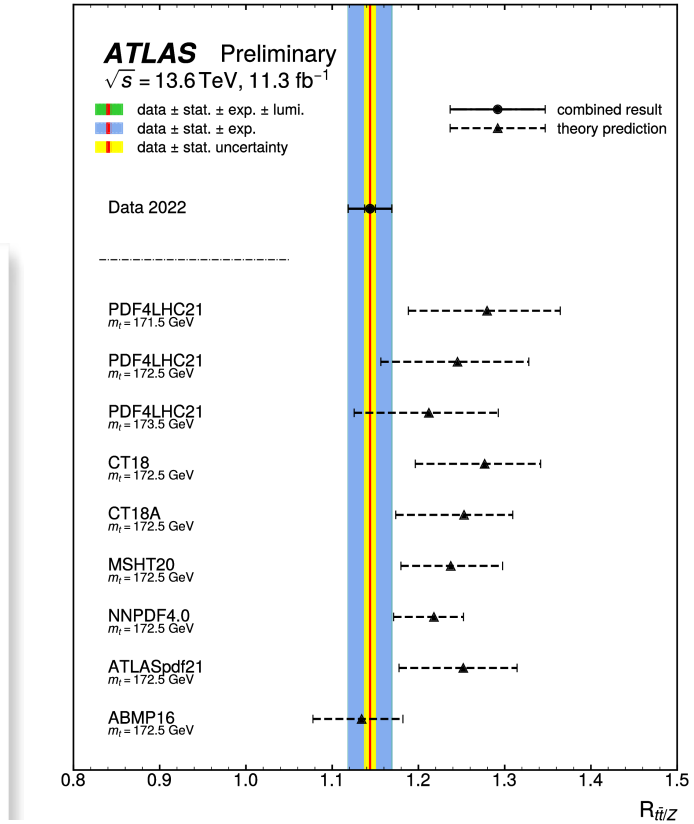


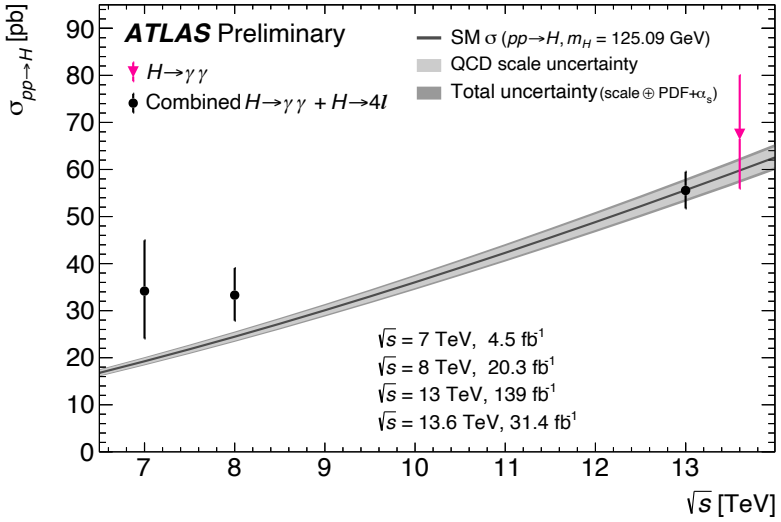
- Extrapolation:
  - Acceptance correction, with additional uncertainties including: missing orders, PDFs, PS modelling, α_s;
  - Uncertainty of 2.9% also considered on the $Br(H \to \gamma\gamma)$;
  - $\sigma(pp \to H) = 67^{+13}_{-12}$ pb;
  - $\sigma_{\mathrm{SM}} = 59.8 \pm 2.6$ pb;
- Full phase space result alongside combined $H \to \gamma\gamma + H \to ZZ^* \to 4l$ measurements at 7, 8, and 13 TeV.

Summary

- ATLAS **successfully operated** during the first data-taking year (2022) of the Run-3;
- **New** unprecedented **energy of** 13.6 TeV**;**
- **Total Luminosity** 31.4 fb^{-1};
- **Detector and object reconstruction performance** are validated;
- **Precise measurements** are done for various statistics taken during the beginning of Run-3 and show the **good agreement** with the theoretical predictions:
  - The luminosity uncertainty ~ 2.2%;
  - The obtained cross-sections for $t\bar{t}, Z$ and ratio of cross-sections $t\bar{t}/Z$;
  - Cross-section for $H \rightarrow \gamma\gamma$.

We are looking forward for more new results!





Thank you!









Backup

Contact

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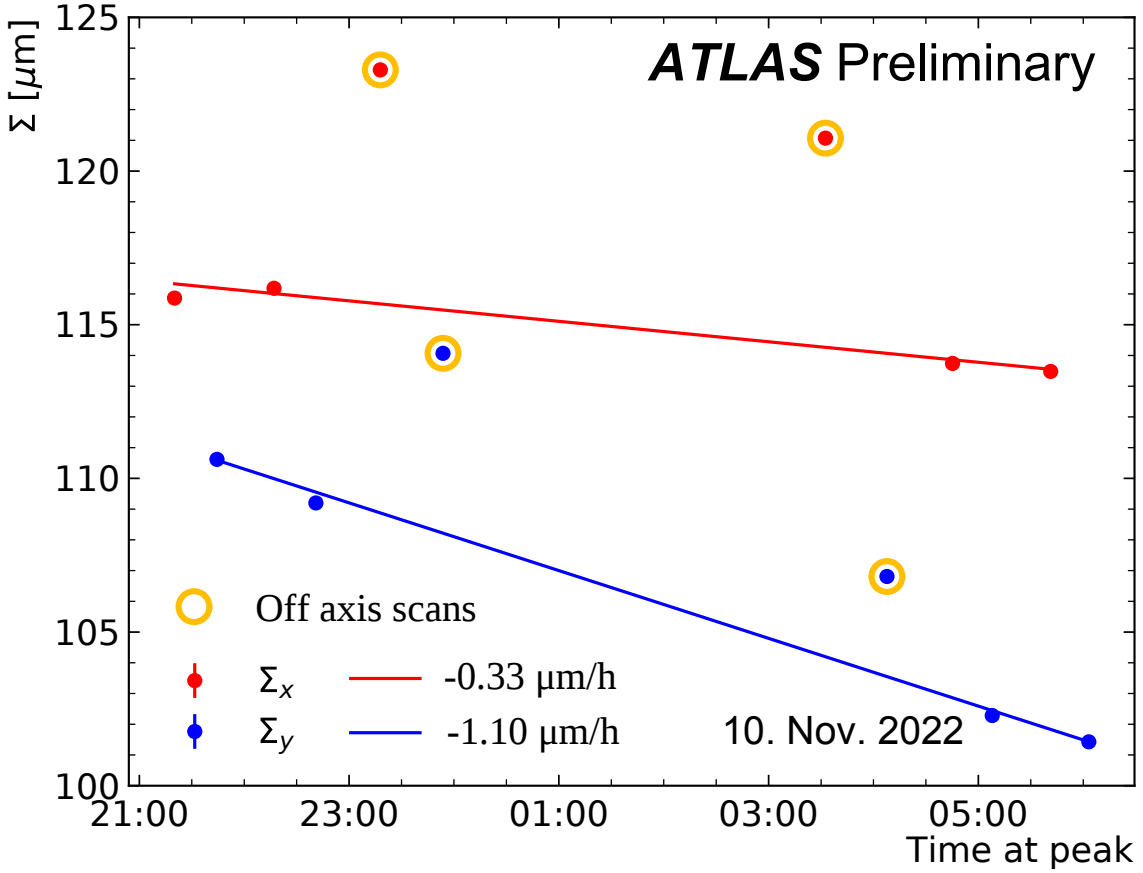
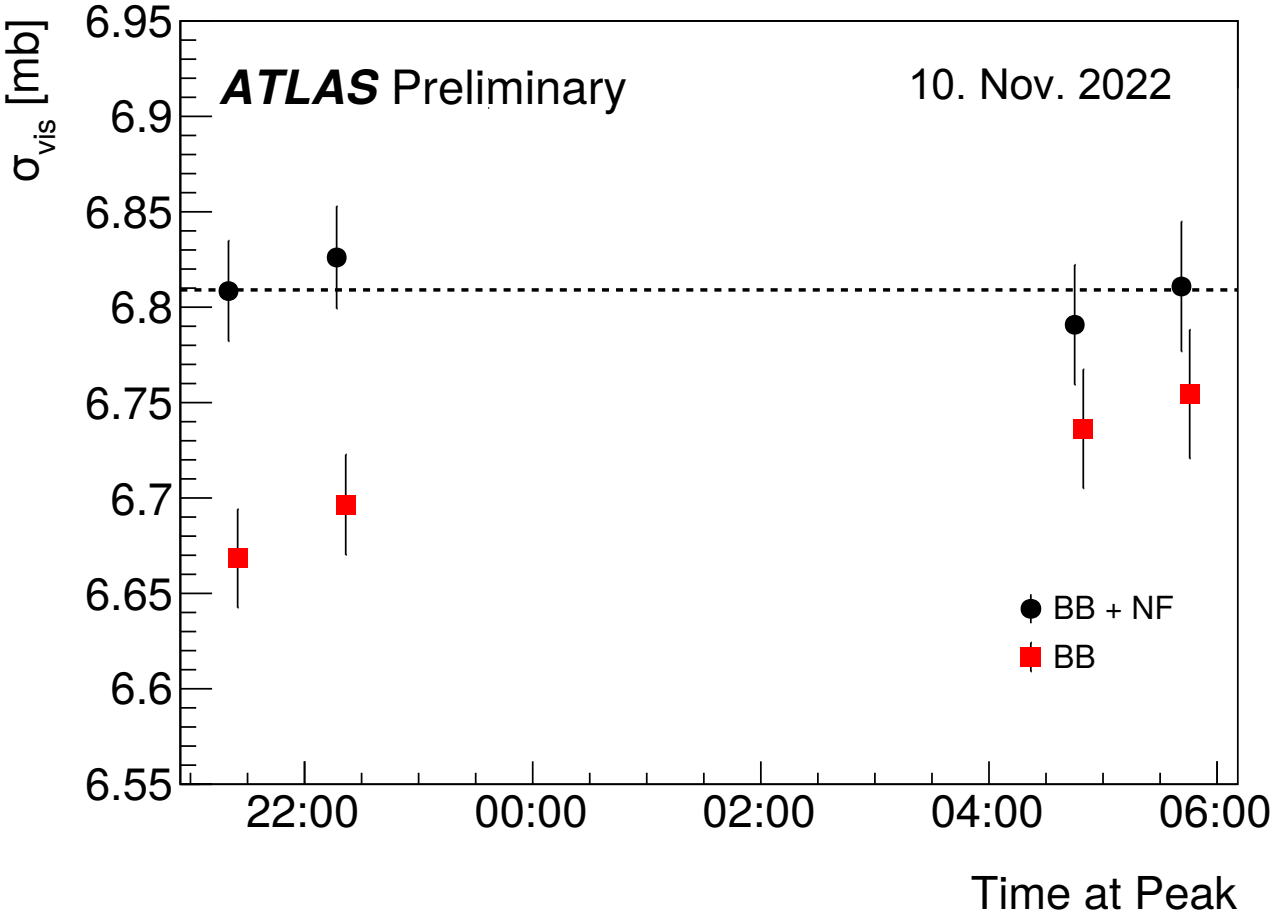
ATLAS Luminosity measurement

Non-factorisation correction





$t\bar{t}/Z$ cross-section

Simulated signal and background event samples

Process	Generator	Cross-section
tt	Powheg v2 + Pythia 8.307	NNLO+NNLL @ 13.6 TeV
Singletop	Powheg v2 + Pythia 8.307	tW: approximate N3LO (QCD), t-, s-channel: NNLO (QCD)
V+jets	Sherpa 2.2.12	MATRIX: NNLO (QCD) + NLO (EW) *Z+jets: born leptons, $m_{ll} > 10$ GeV,* *fiducial: $p_T > 27$ GeV, |eta|<2.5, $66 < m_{ll} < 116$ GeV*
Diboson	Sherpa 2.2.12	<= 1 additional parton: NLO (QCD) <= 3 additional parton: LO (QCD) No dedicated theory prediction yet, using k-factor from Run 2 + 50% uncertainty

$H \to \gamma\gamma$ fiducial cross-section

Simulated signal and background event samples

Process	Generator	Showering	PDF set	σ [pb] $\sqrt{s} = 13.6$ TeV
ggF + $b\bar{b}H$	Powheg Box v2 + MiNLO	Pythia 8.2	PDF4LHC21	52.7 ± 2.6
VBF	Powheg Box v2	Pythia 8.2	PDF4LHC21	$4.075^{+0.088}_{-0.089}$
WH	Powheg Box v2 + MiNLO	Pythia 8.2	PDF4LHC21	$1.453^{+0.029}_{-0.028}$
$q\bar{q} \to ZH$	Powheg Box v2 + MiNLO	Pythia 8.2	PDF4LHC21	$0.806^{+0.033}_{-0.029}$
$gg \to ZH$	Powheg Box v2	Pythia 8.2	PDF4LHC21	$0.136^{+0.034}_{-0.026}$
$t\bar{t}H$	Powheg Box v2	Pythia 8.2	PDF4LHC21	$0.569^{+0.040}_{-0.057}$
$\gamma\gamma$, $m_{\gamma\gamma} \in$ 90–175 GeV	MadGraph5_aMC@NLO	Pythia 8.2	NNPDF3.0	-