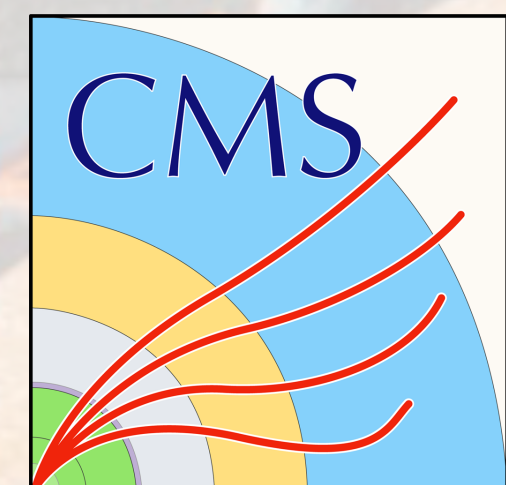


# The new frontier

Inclusive and differential Higgs boson cross sections at  $\sqrt{s} = 13.6 \text{ TeV}$

**Alessandro Tarabini** on behalf of the CMS collaboration  
(ETH Zürich, IPA)

2024 LHC Days  
30/09/2024



**ETH** zürich

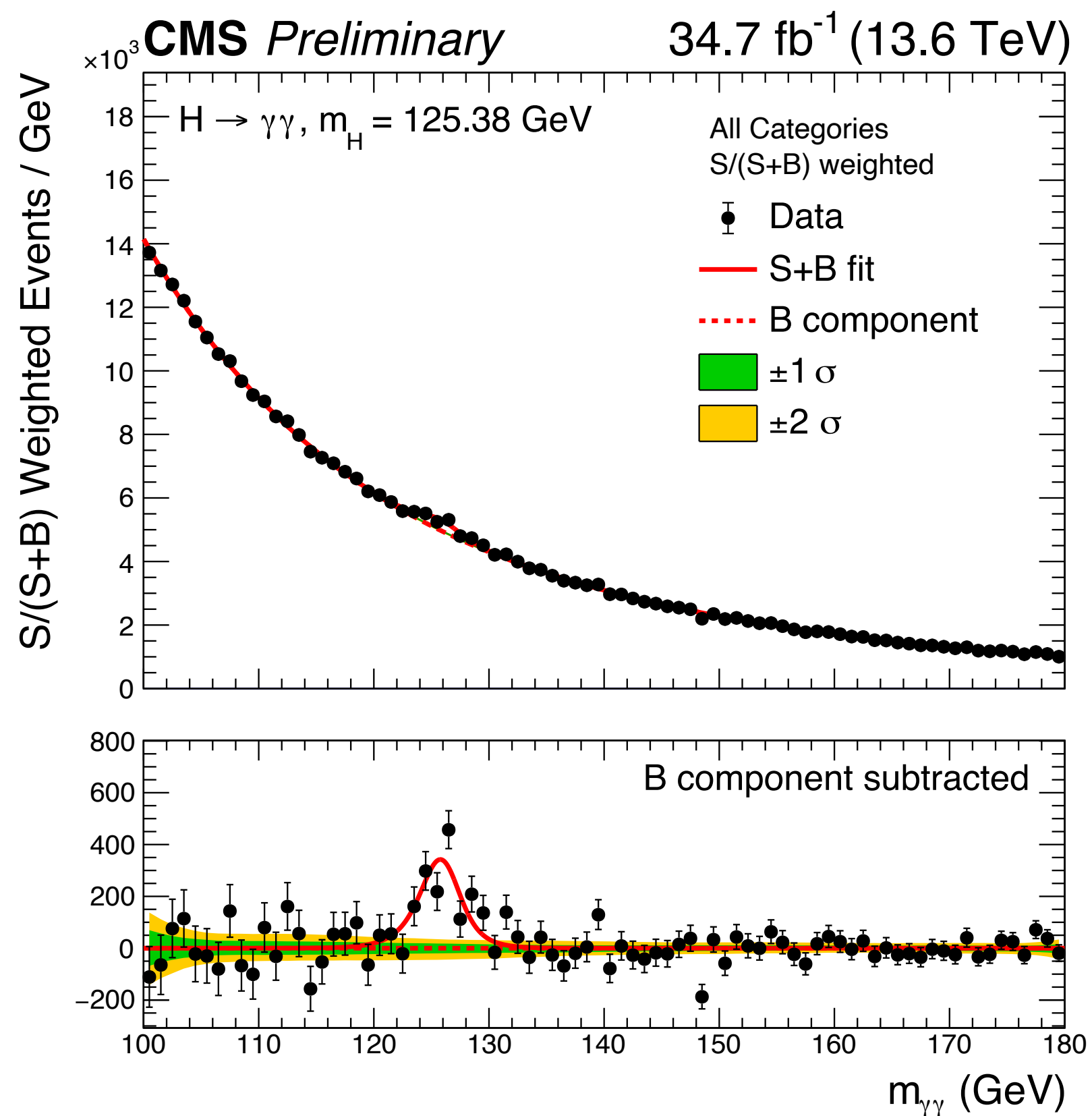


# The two high-resolution channels

$$H \rightarrow \gamma\gamma$$

The diphoton decay channel provides a **clean and clear signature** with two isolated photons, forming a **narrow peak** over a **smoothly falling background** due to the excellent photon energy resolution

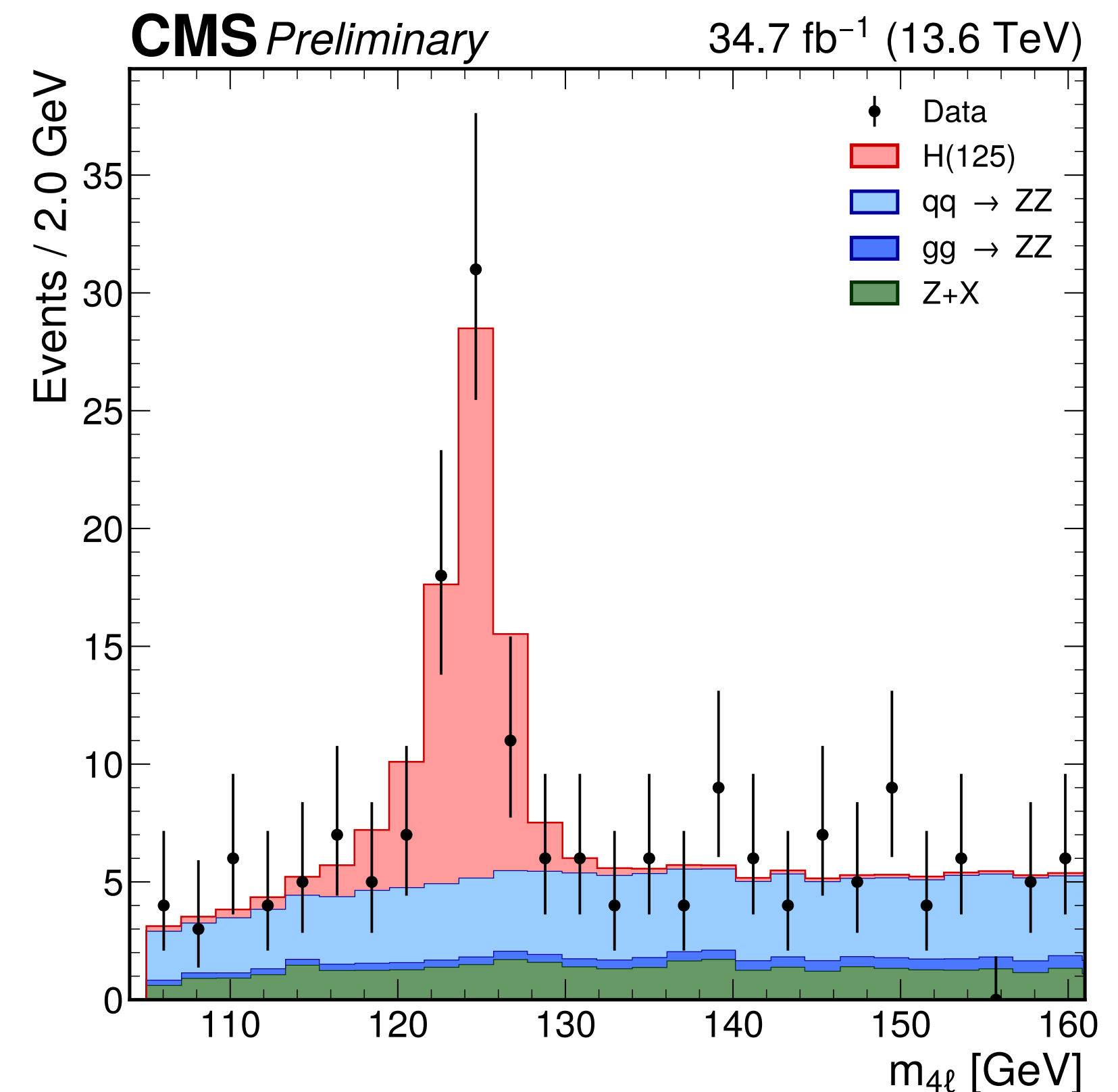
Backgrounds: QCD  $\gamma\gamma$  production,  $\gamma$ +jet, jet-jet



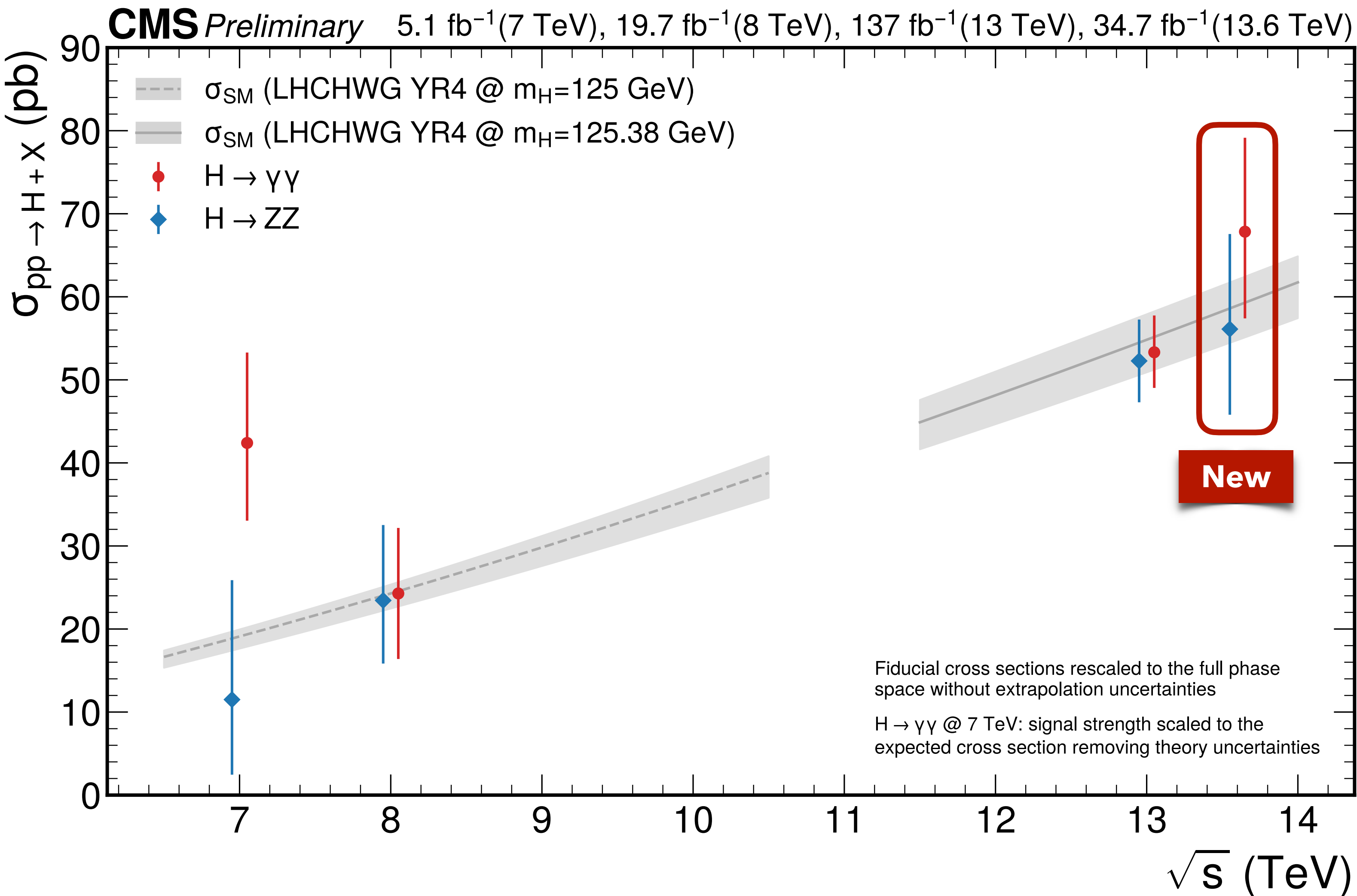
$$H \rightarrow ZZ \rightarrow 4\ell$$

The four-lepton decay channel, despite its **small branching ratio** ( $\sim 0.028\%$ ), offers a **narrow peak** over a **flat background** across **three possible final states** ( $2e2\mu, 4e, 4\mu$ )

Backgrounds: non-resonant ZZ production ( $q\bar{q} \rightarrow ZZ, gg \rightarrow ZZ$ ) and Z+X (Z+jets,  $t\bar{t}$ +jets, ...)



# Exploring new frontiers



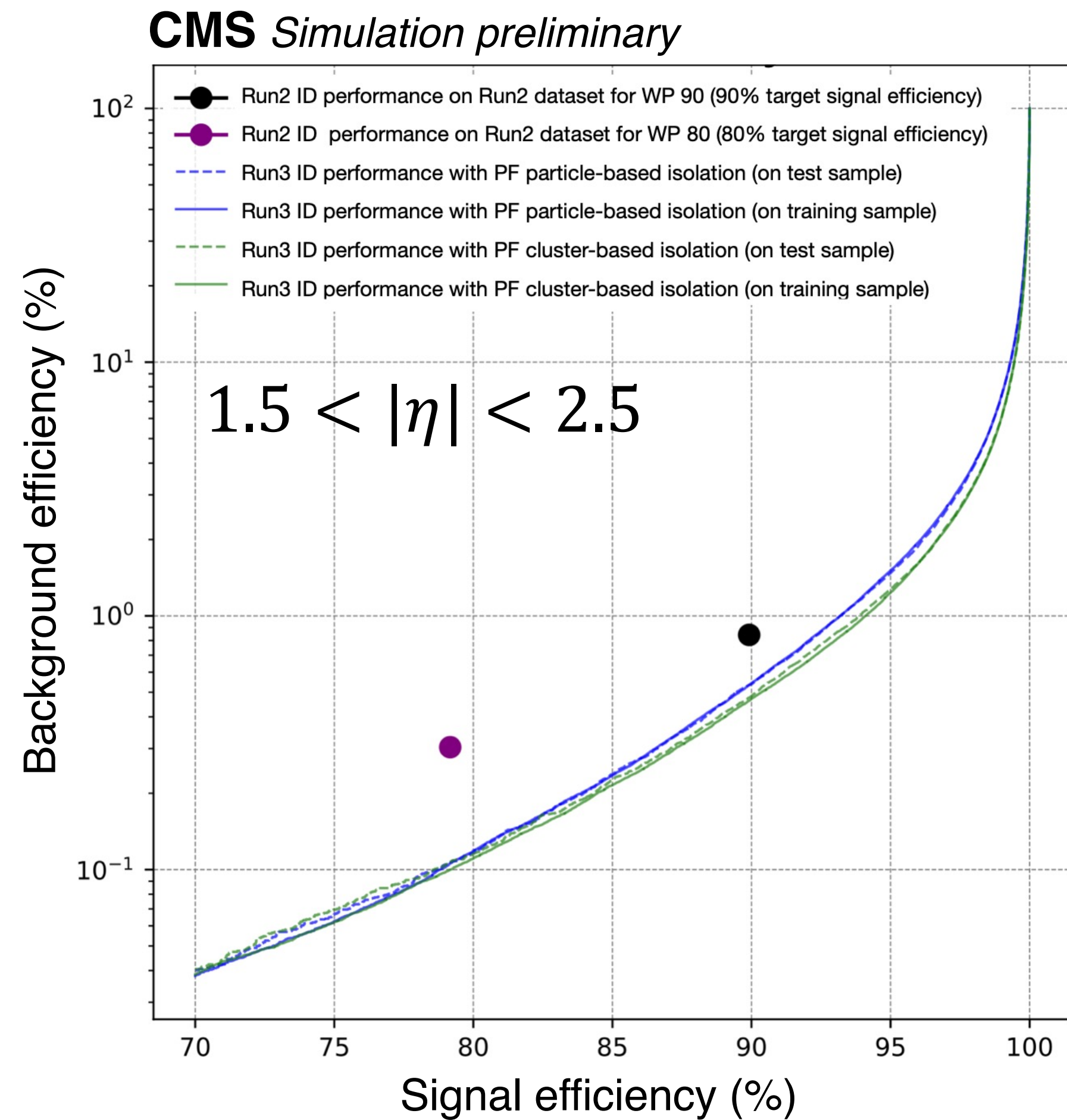
## First Higgs results from the CMS collaboration with Run3 data

- Centre-of-mass energy @ **13.6 TeV**
- Analysed **2022 data**, corresponding to **34.7 fb<sup>-1</sup>** (13.8 fb<sup>-1</sup> ReReco + 20.9 fb<sup>-1</sup> Prompt)
- Higher PU and higher instantaneous luminosity
- Results published for ICHEP2024:
  - Hgg: <https://cds.cern.ch/record/2904882>
  - HZZ: <https://cds.cern.ch/record/2904969>

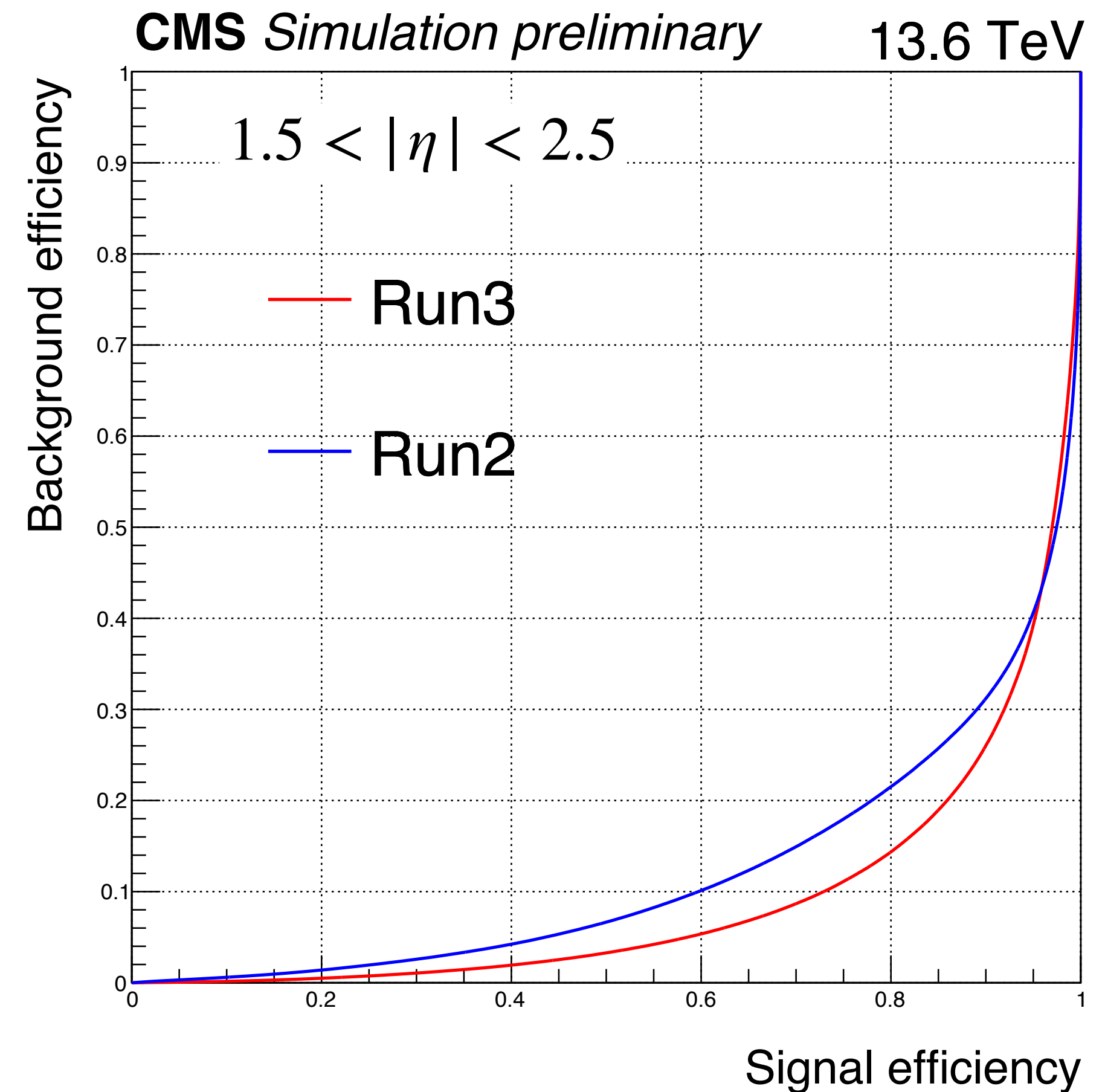
# Performance of EM objects in Run 3

**Stable physics performance** during Run 3 data taking and **high quality** prompt calibration and reconstruction

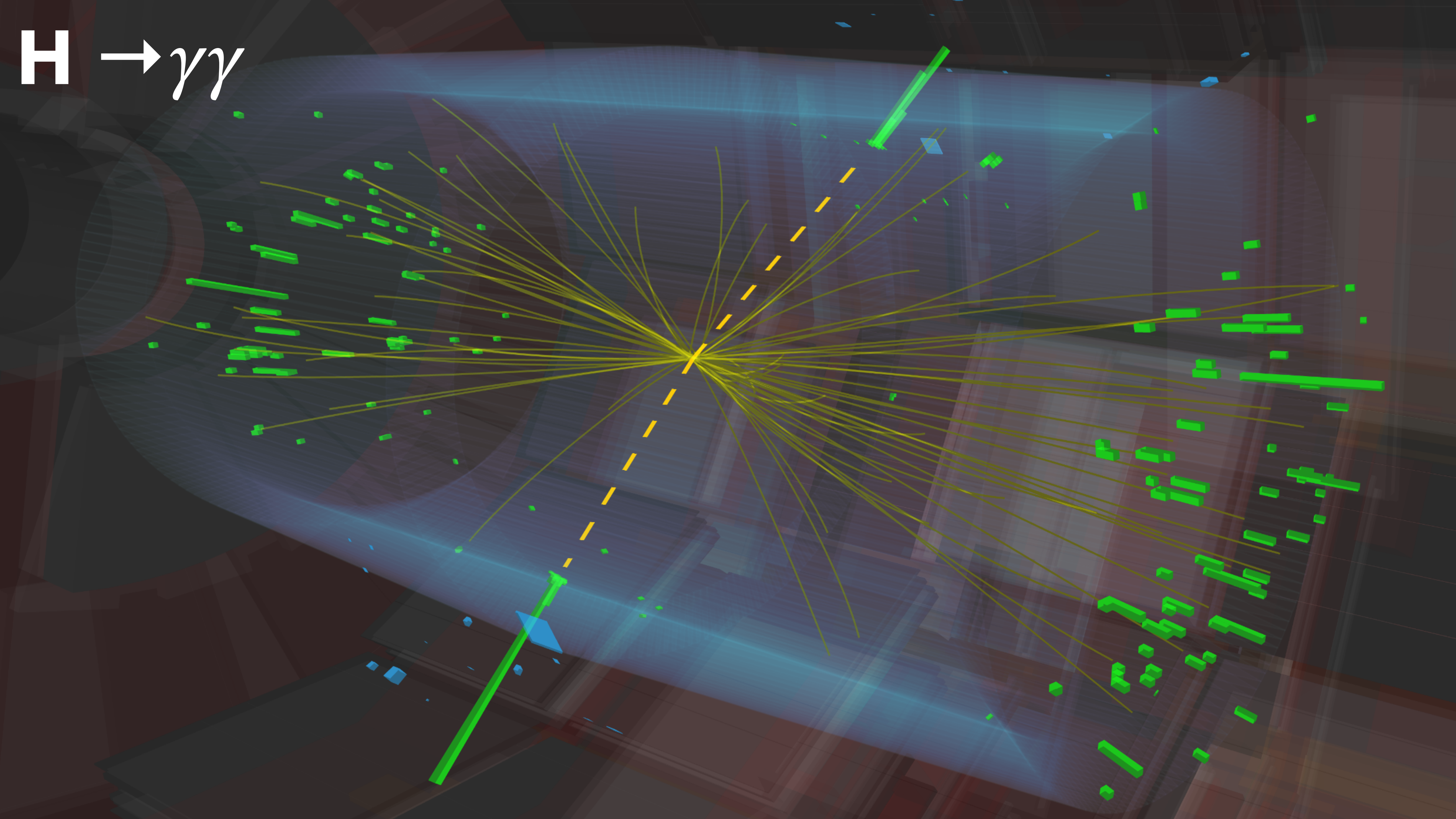
## BDT-based electron ID



## BDT-based photon ID



$H \rightarrow \gamma\gamma$



# One flow to correct them all

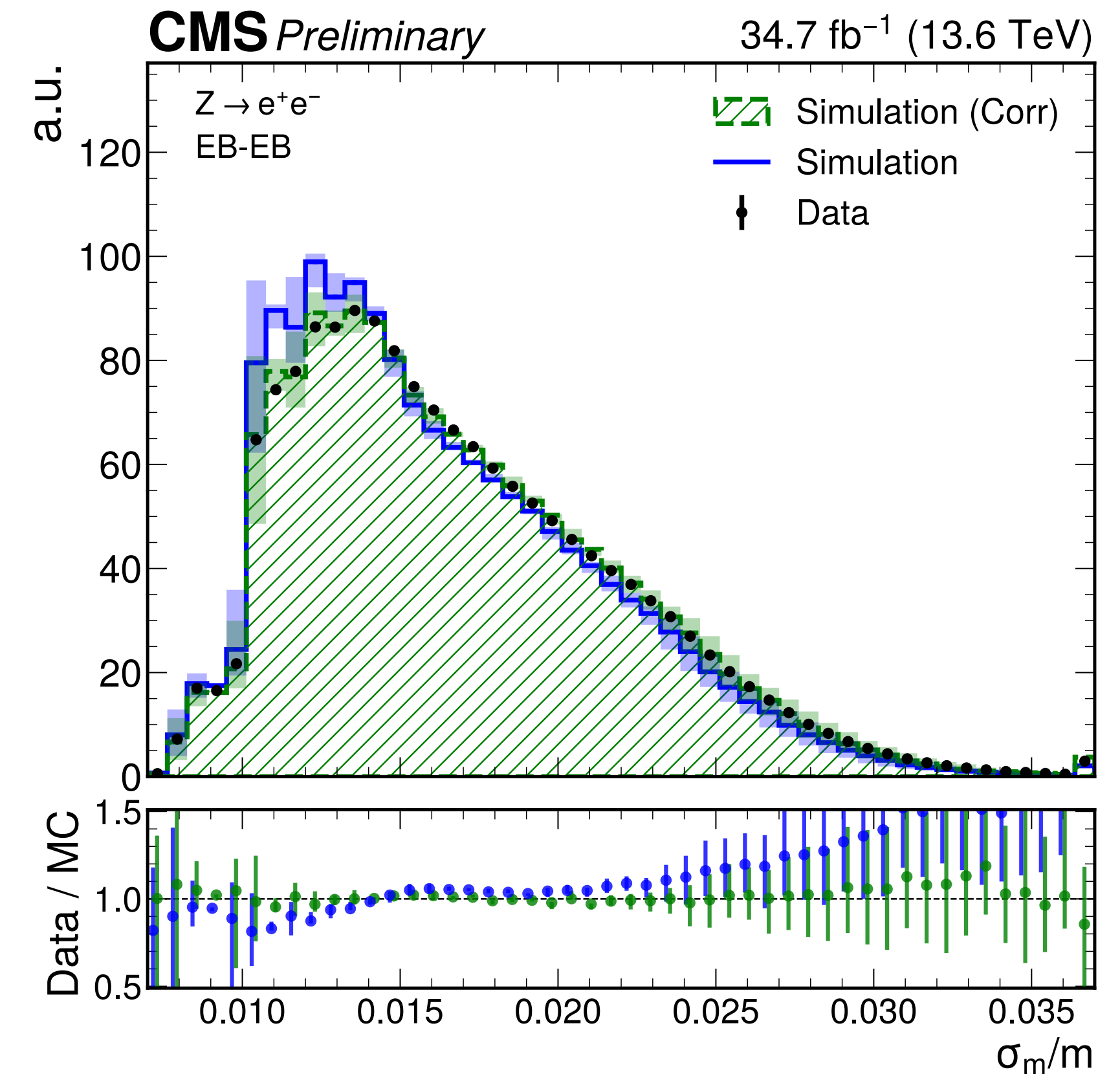
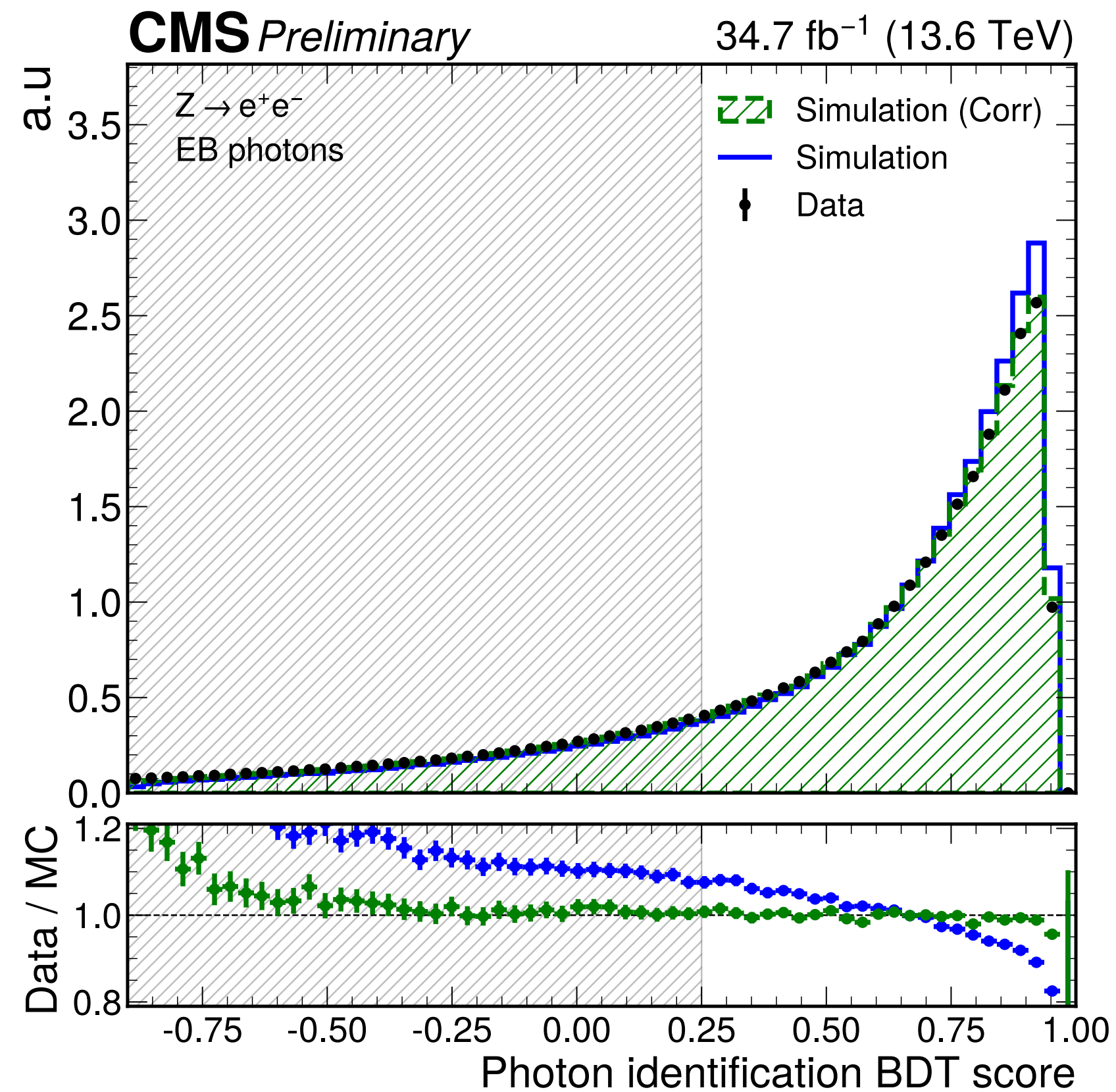
$H \rightarrow \gamma\gamma$

Novelty

**Photon mismodelling in the simulation** is a non-negligible source of systematic uncertainty

Event categorisation based on  $\sigma_m/m$  and the **photon ID BDT score** and mismodelling between data and MC in these variables can lead to large source of uncertainty

**Shower shape** and **isolation** observables (inputs to photon ID BDT), as well as the **energy resolution**  $\sigma_E$  ( $\rightarrow \sigma_m/m$ ) are corrected with a novel method based on a **single normalising flow** [Paper]

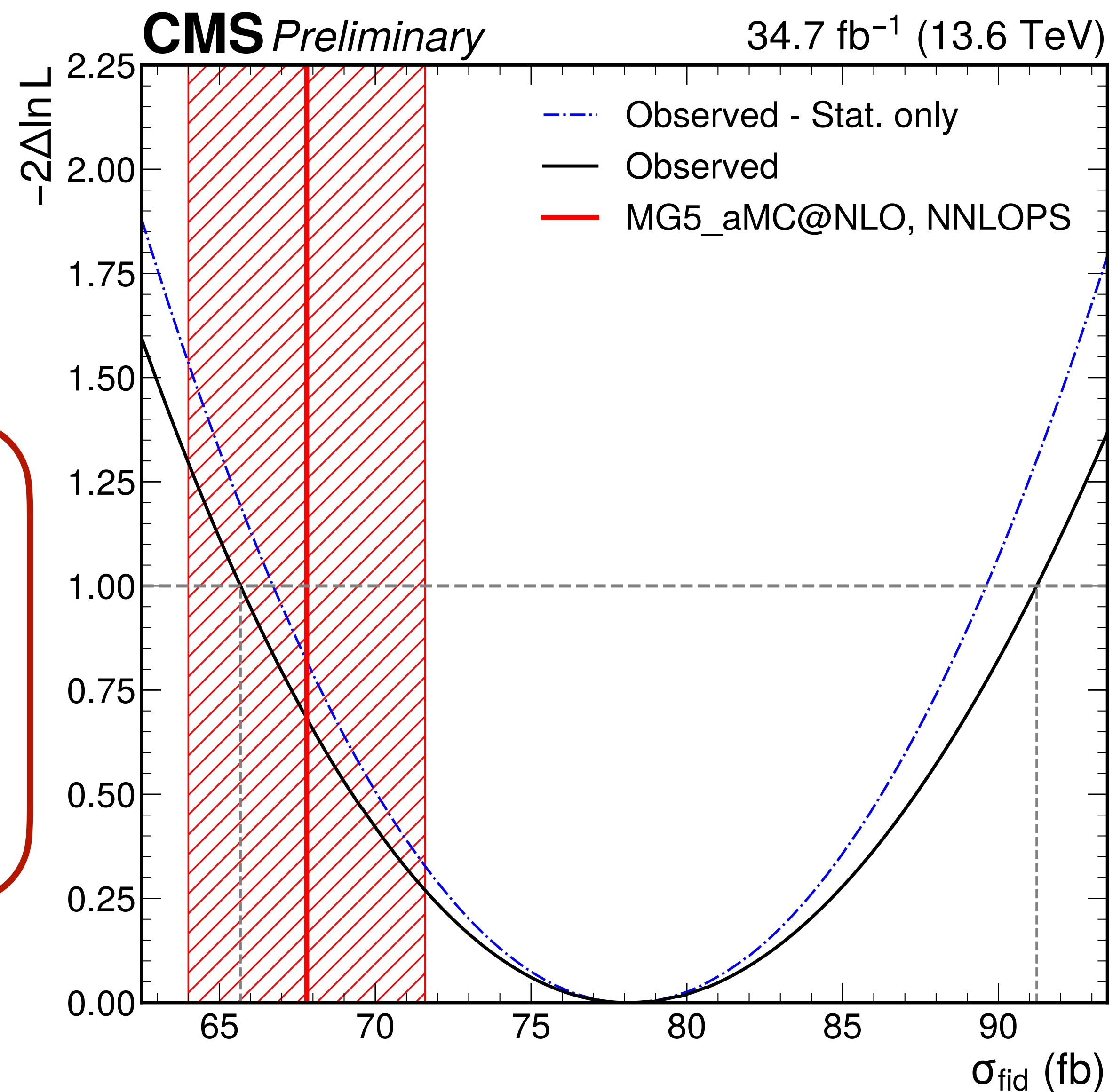


# Inclusive cross section

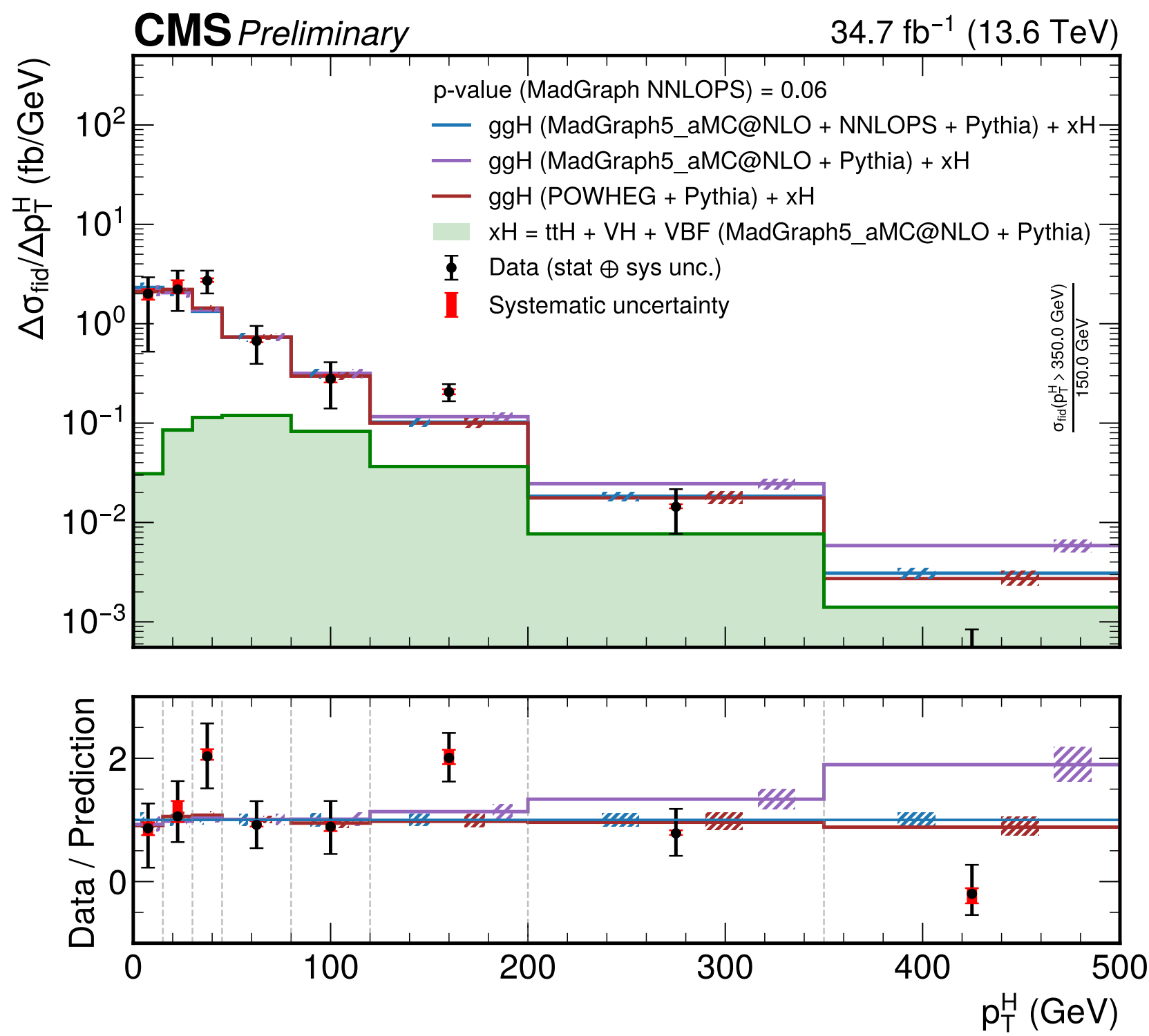
$H \rightarrow \gamma\gamma$

$$\sigma_{\text{fid}} = 78 \pm 11 \text{ (stat.) } \begin{matrix} +6 \\ -5 \end{matrix} \text{ (syst.) fb}$$

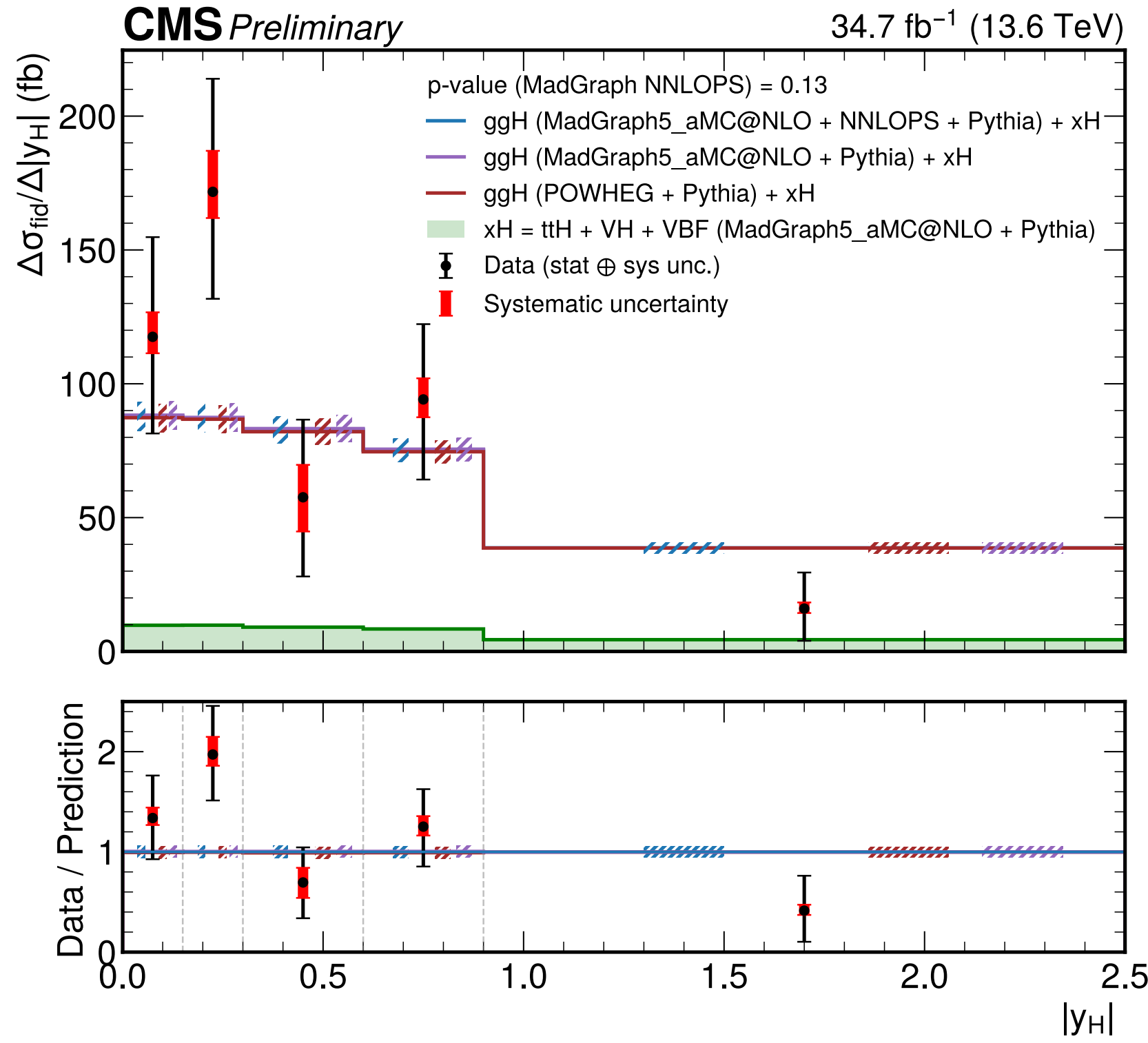
Systematic uncertainty	Magnitude
Photon energy scale and resolution group	+5.8% / - 4.9%
Category migration from energy resolution	+3.5% / - 3.9%
Integrated luminosity	$\pm 1.4\%$
Photon preselection efficiency	$\pm 1.4\%$
Energy scale non-linearity	+0.8% / - 1.6%
Photon identification efficiency	$\pm 1.0\%$
Pileup reweighting	$\pm 0.8\%$



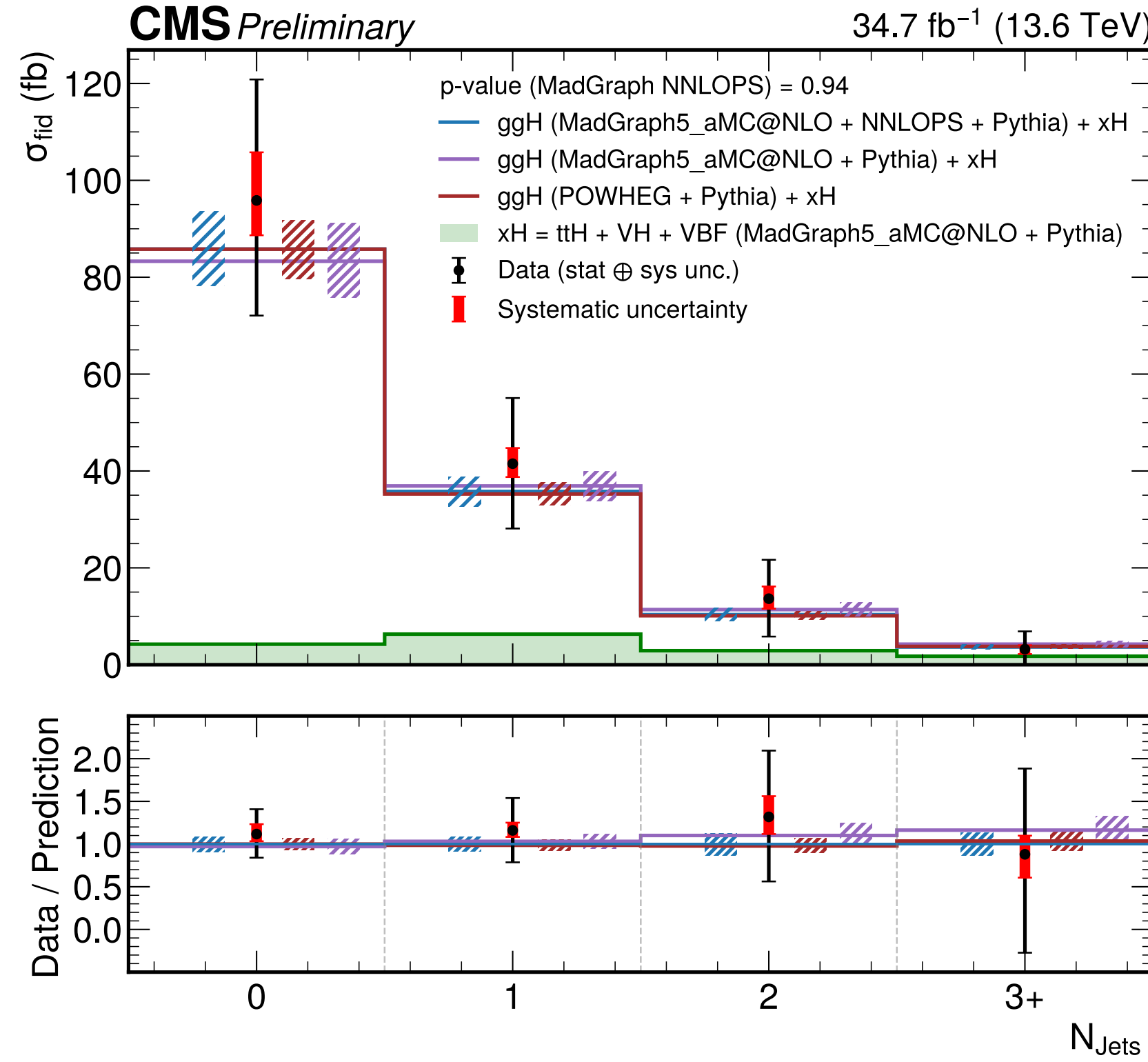
**Transverse momentum of the Higgs boson**



**Absolute value of the rapidity of the Higgs boson**

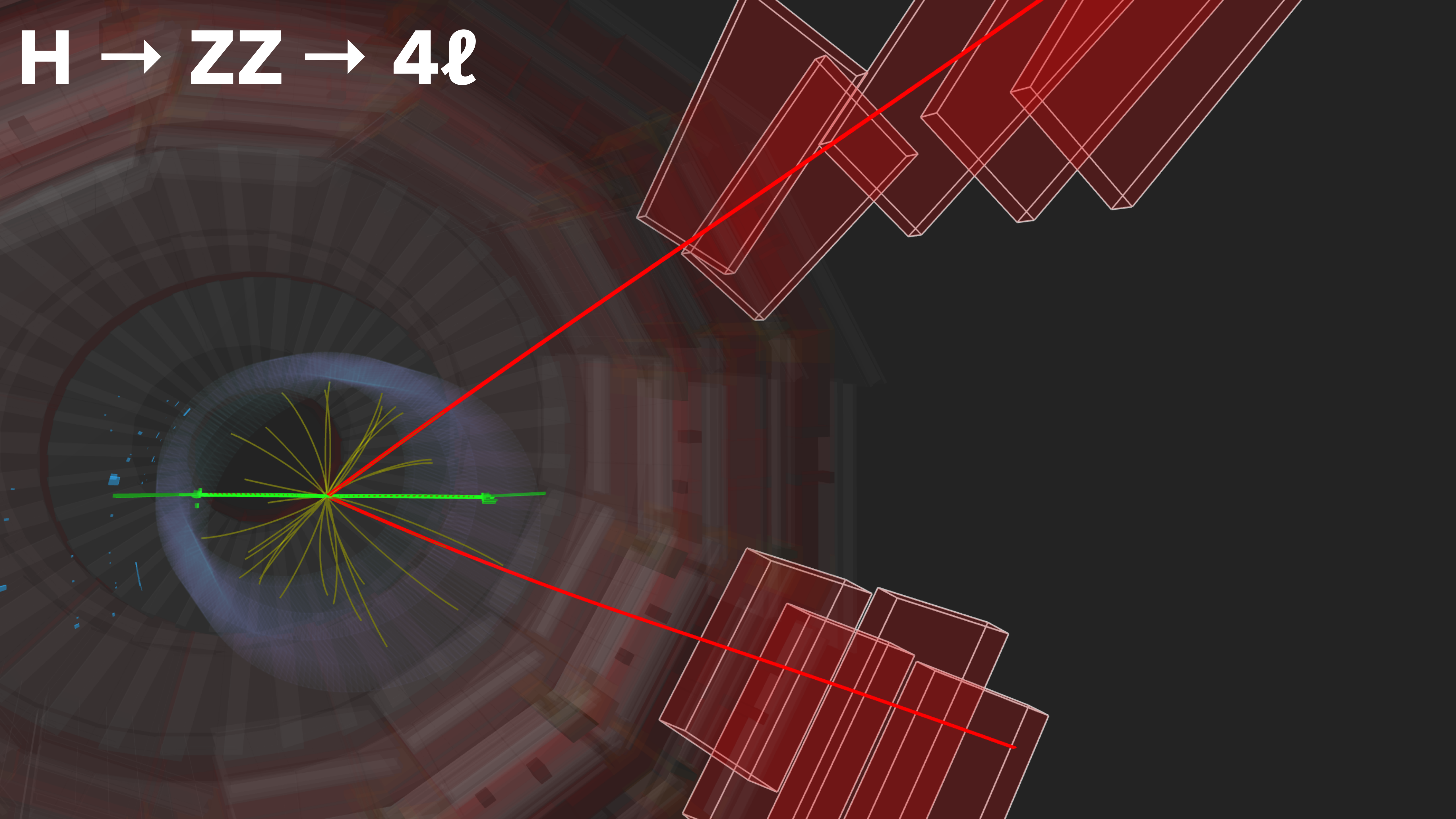


**Number of associated jets**



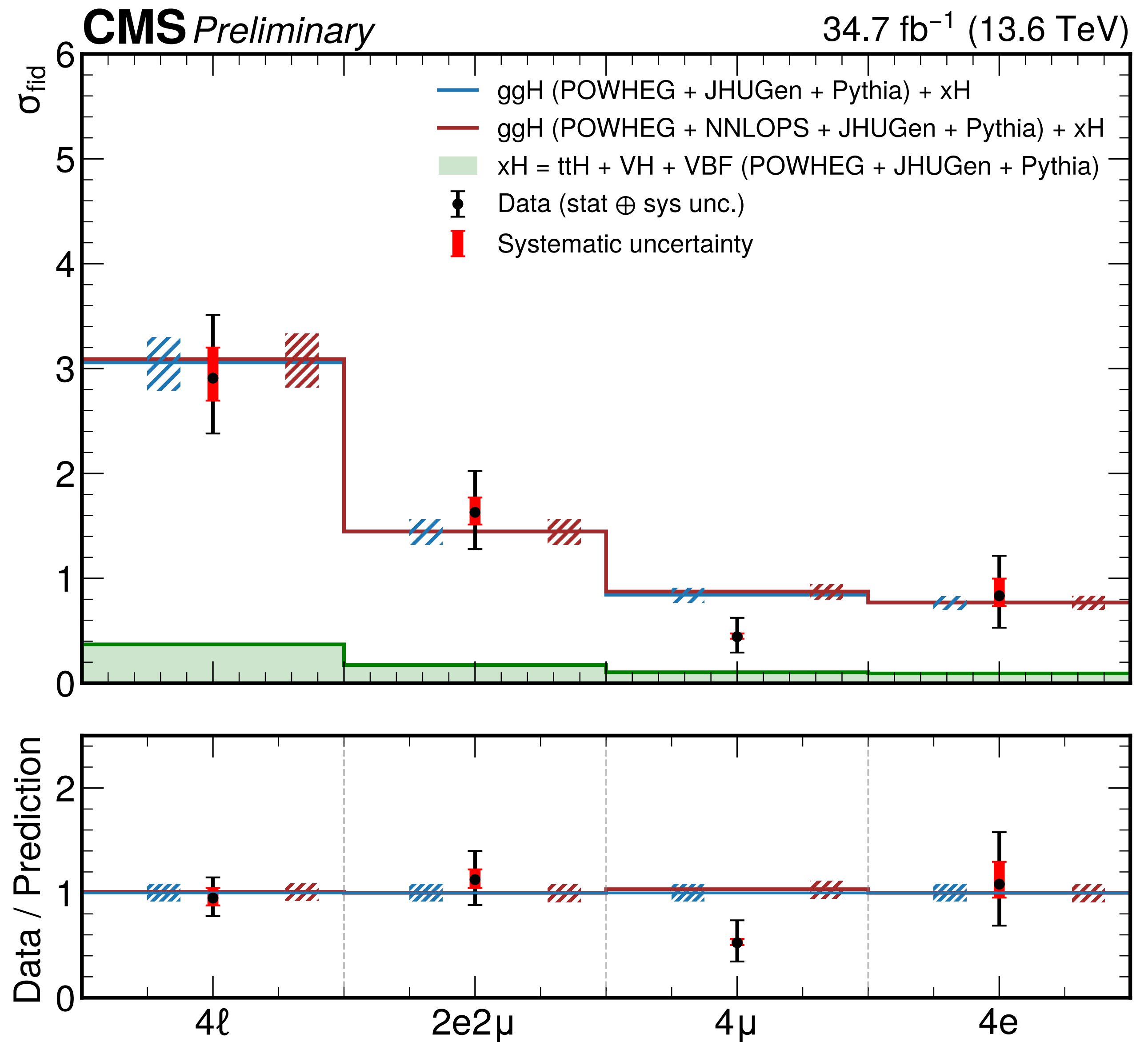


**H → ZZ → 4ℓ**



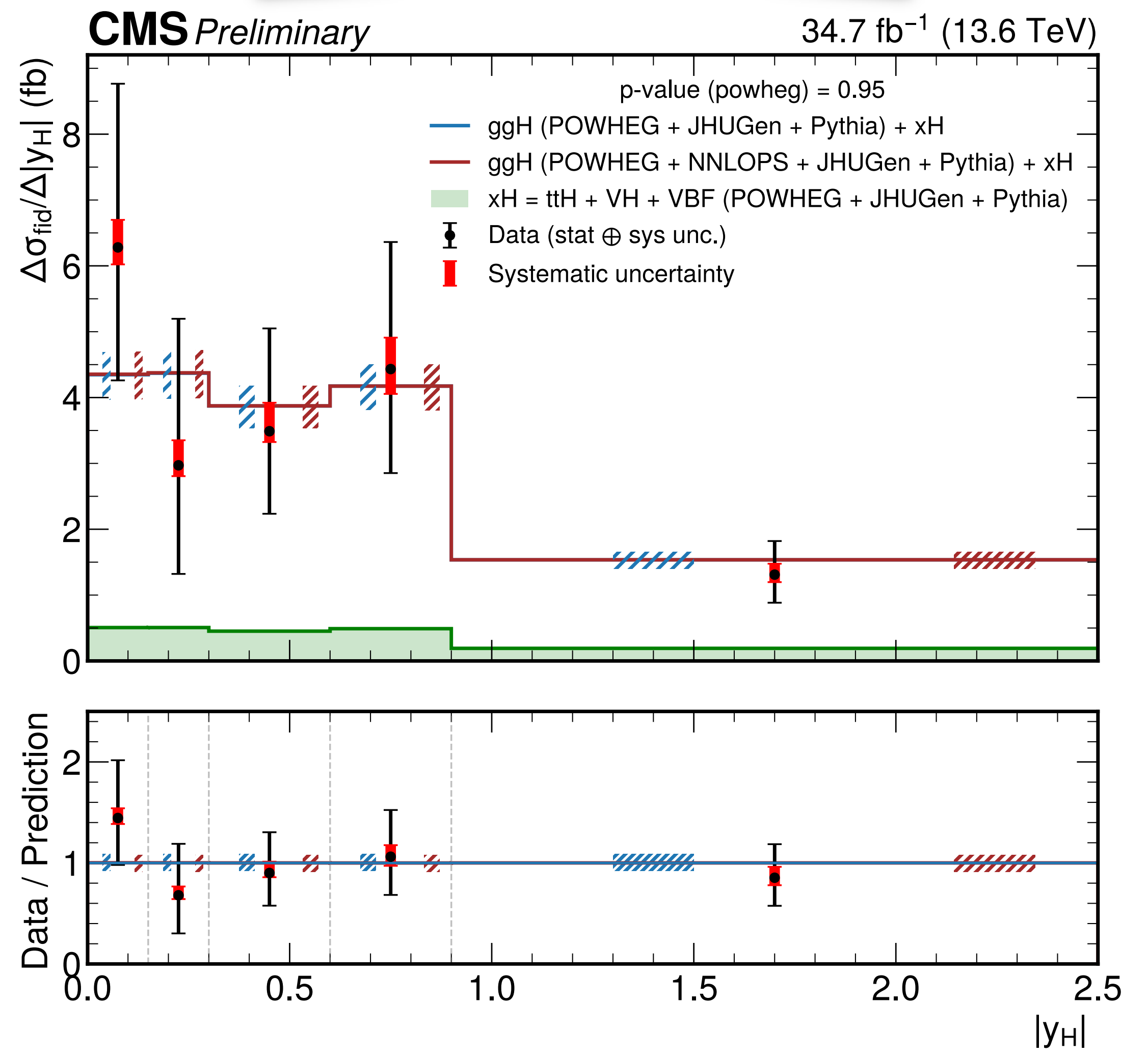
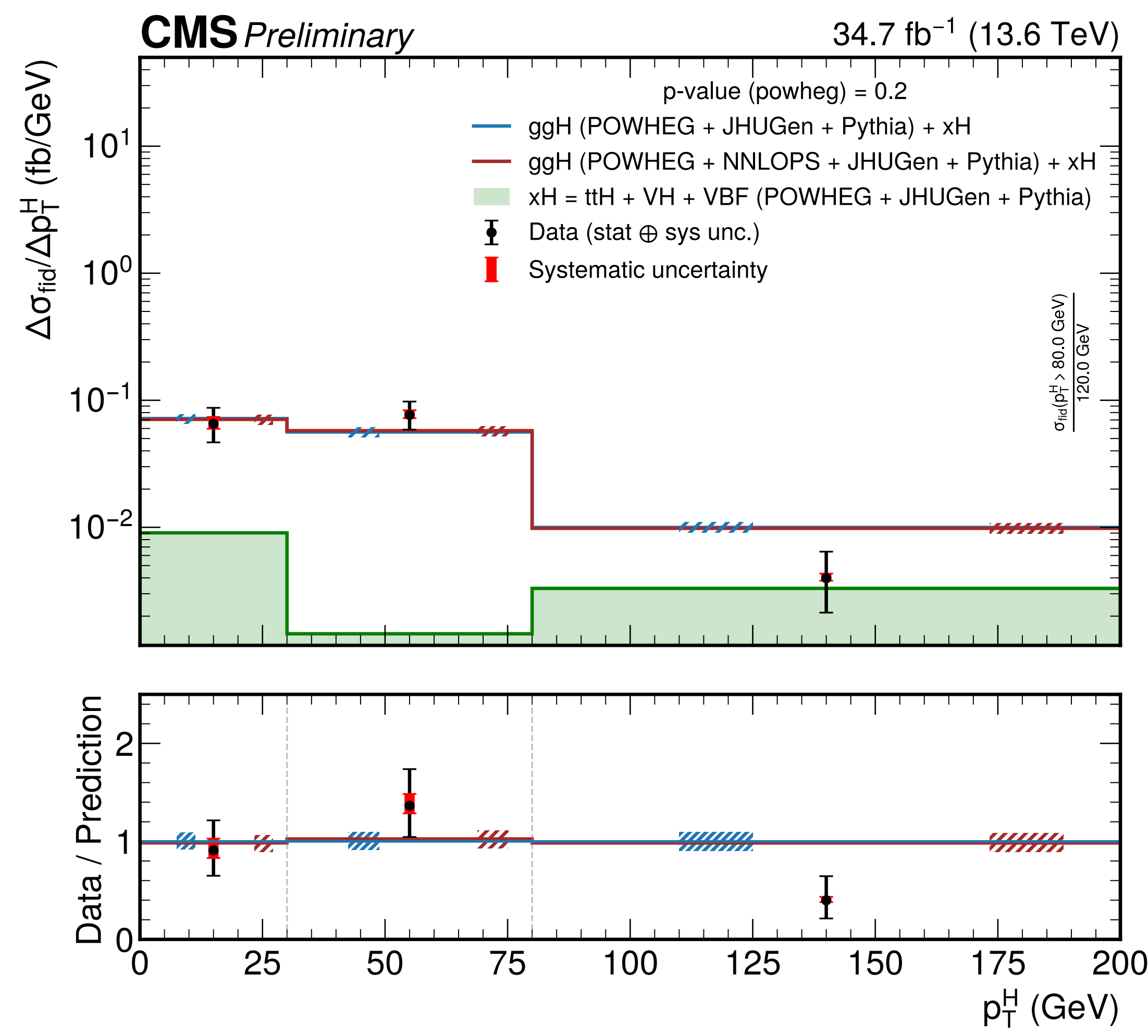
	$\sigma_{fid}$ (fb)
2e2 $\mu$ (fb)	$1.63^{+0.37}_{-0.33}$ (stat.) $^{+0.14}_{-0.12}$ (syst.)
4 $\mu$ (fb)	$0.46^{+0.18}_{-0.15}$ (stat.) $^{+0.03}_{-0.02}$ (syst.)
4e (fb)	$0.83^{+0.34}_{-0.29}$ (stat.) $^{+0.16}_{-0.10}$ (syst.)
Inclusive (fb)	$2.94^{+0.53}_{-0.49}$ (stat.) $^{+0.29}_{-0.22}$ (syst.)

- Overall, same strategy as in the Run2 measurement
- **Electron efficiency** is the most relevant systematic uncertainty
- Excellent **validation of muon and electron performance** of CMS in Run 3



**Transverse momentum of the Higgs boson**

**Absolute value of the rapidity of the Higgs boson**



# Summary

**Presented the first Higgs results from the CMS collaboration with Run3 data at  $\sqrt{s} = 13.6$  TeV**

Inclusive and differential Higgs boson cross sections in the **diphoton** and **four-lepton** channel

Novel method based on normalising flows to improve data/MC agreement in the diphoton channel

Pilot analyses showing that CMS is ready for important Higgs results with Run 3 data

## **First sneak peek at Run3 data**

Run3 data collection is still ongoing and, together with Run2 data, will give us the possibility to probe the Higgs sector with an unprecedented precision