STXS and differential cross section measurements at CMS, bosonic channels

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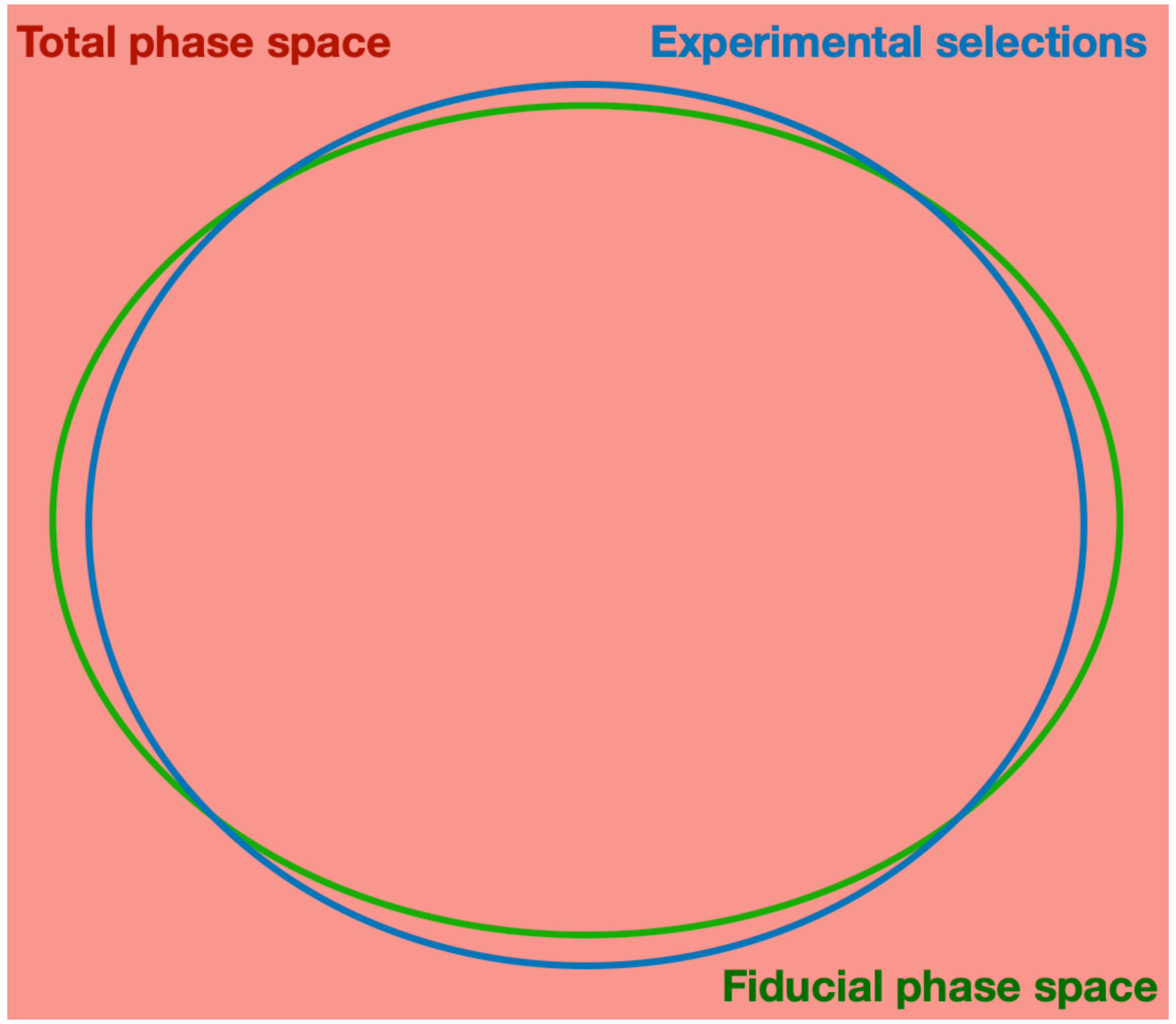
Differential cross sections and STXS

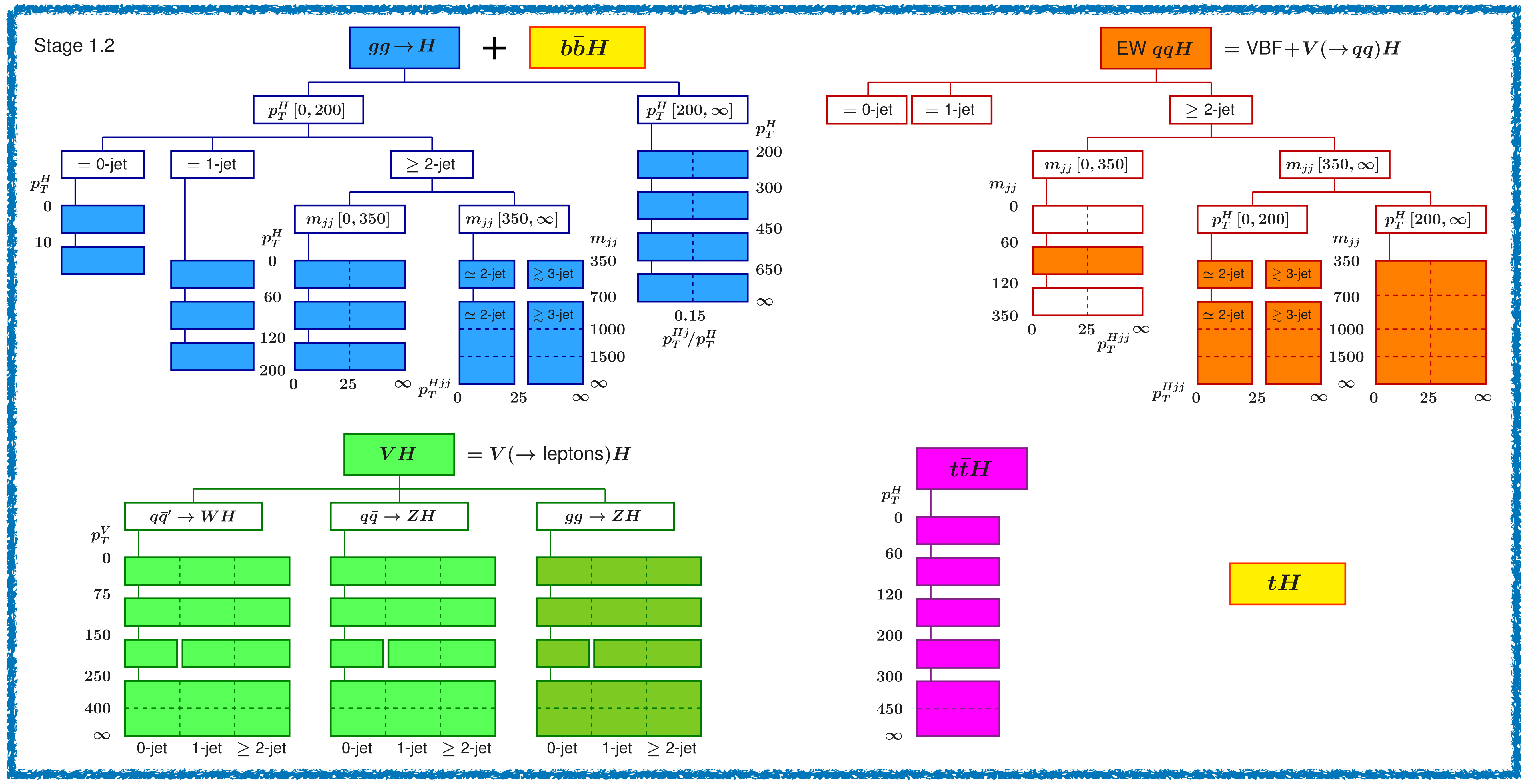
Fiducial Cross Sections

Allows a characterisation of the Higgs boson in different regions while being as model-independent as possible



Simplified Template Cross Sections

Maximise sensitivity to isolate BSM effects while reducing theory dependence



JHEP 07 (2021) 027

CMS Higgs results in the bosonic channel

$H \to \gamma\gamma$

Run 2 STXS
JHEP07(2021)027

Run2 differentials
(JHEP07(2023)091)

13.6 TeV differentials
CMS-PAS-HIG-23-014

$H \to ZZ$

Run 2 STXS
Eur. Phys. J. C **81**, 488 (2021)

Run 2 differentials
(JHEP08(2023)040)

13.6 TeV differentials
CMS-PAS-HIG-23-013

$H \to WW$

Run 2 STXS
Eur. Phys. J. C **83**, 667(2023)

Run 2 differentials
JHEP03(2021)003

Run 2 combinations refer to Massimiliano Galli's talk at 11:10 in this session

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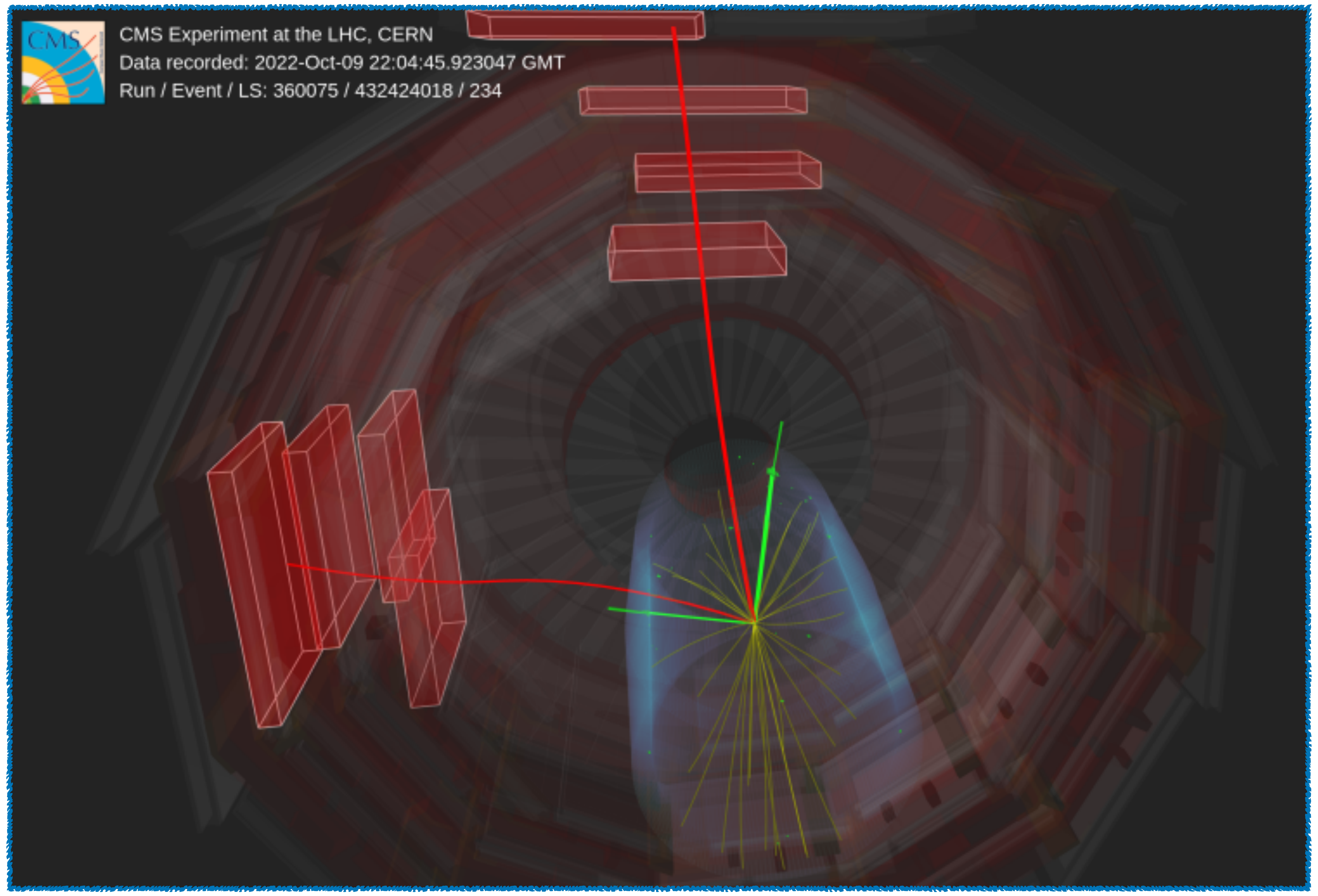
JHEP03(2021)003

Will be covered in this talk

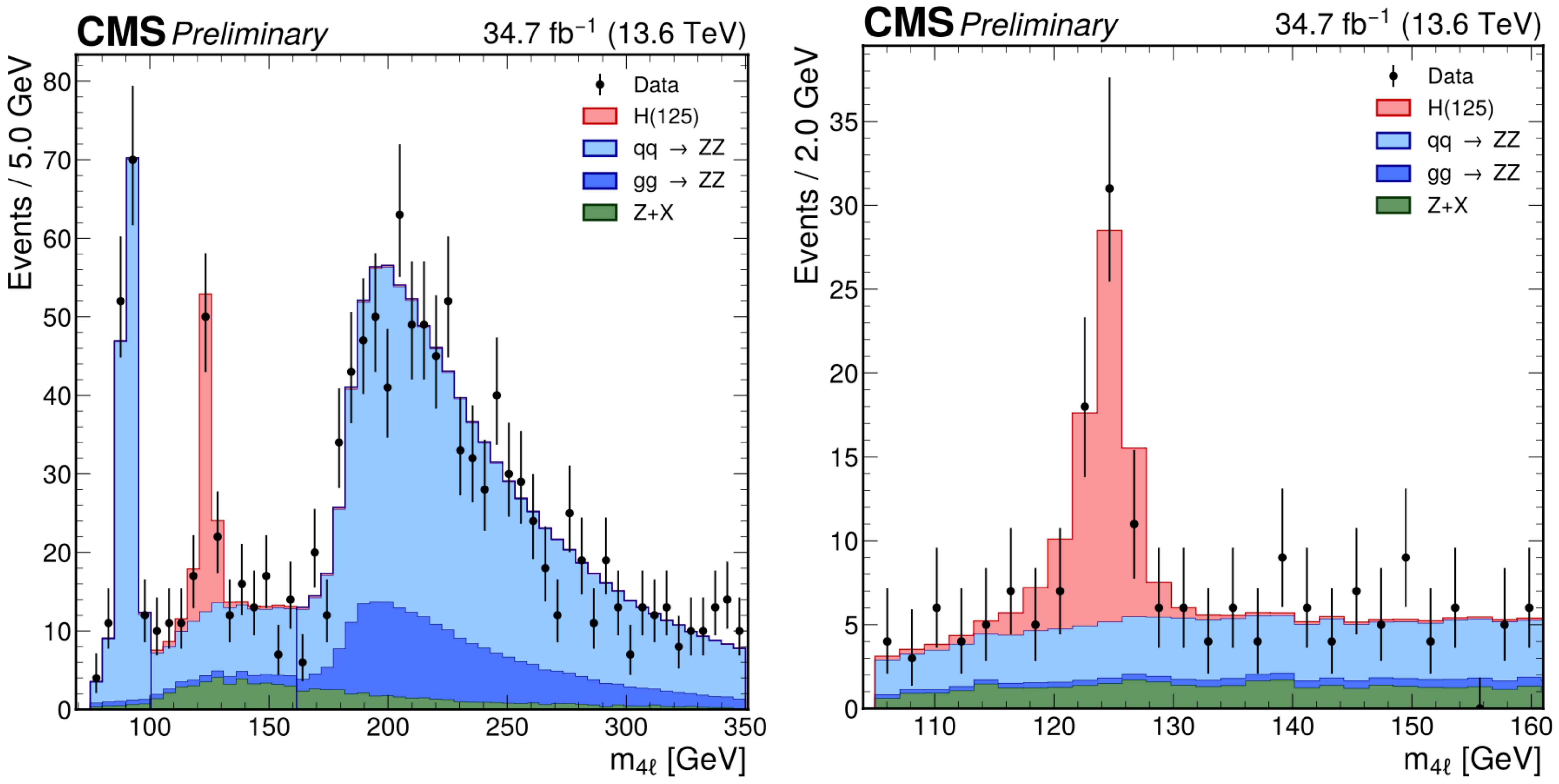
$H \rightarrow ZZ \rightarrow 4\ell$ measurement

CMS-PAS-HIG-24-013



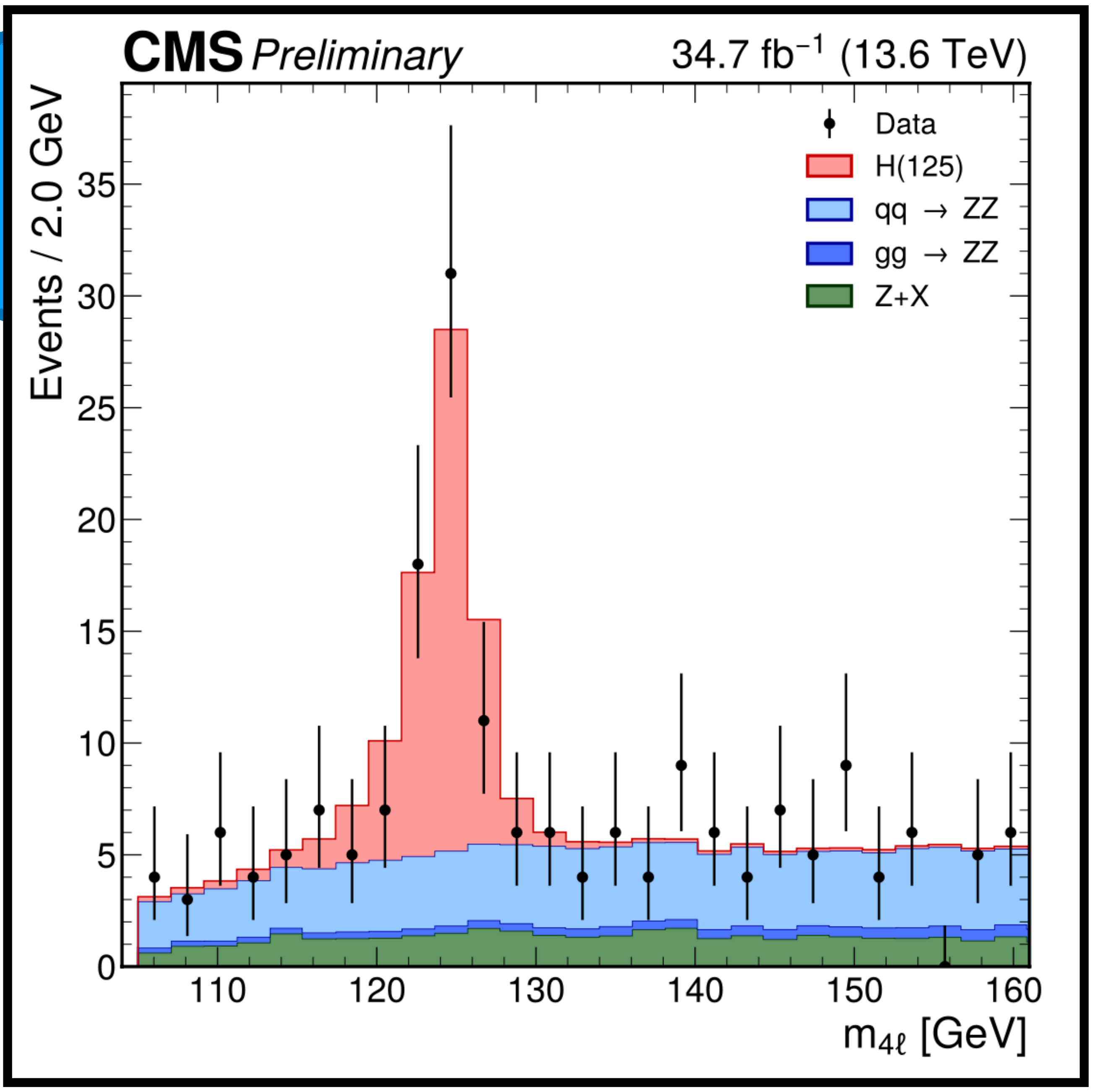
Electron BDT with a better performance w.r.t Run 2

Low BR but clean final state and high S/B



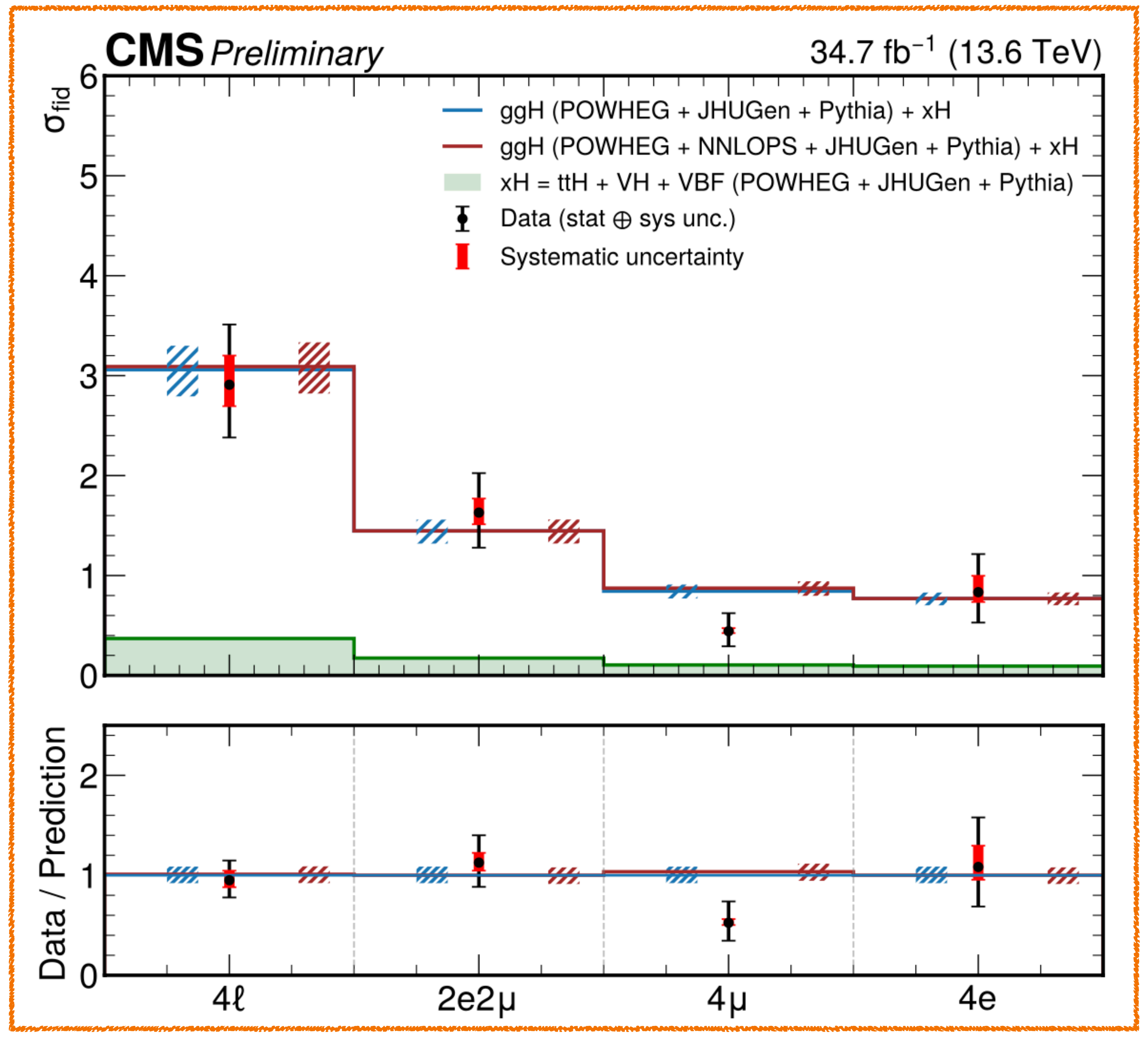
- Precise identification and calibration of low p_T muons and electrons is crucial
- Z peak used for e and μ calibration, Low p_T muons benefits from J/ψ
- Dedicated BDT for low pt electrons and usage of "tracker" muons

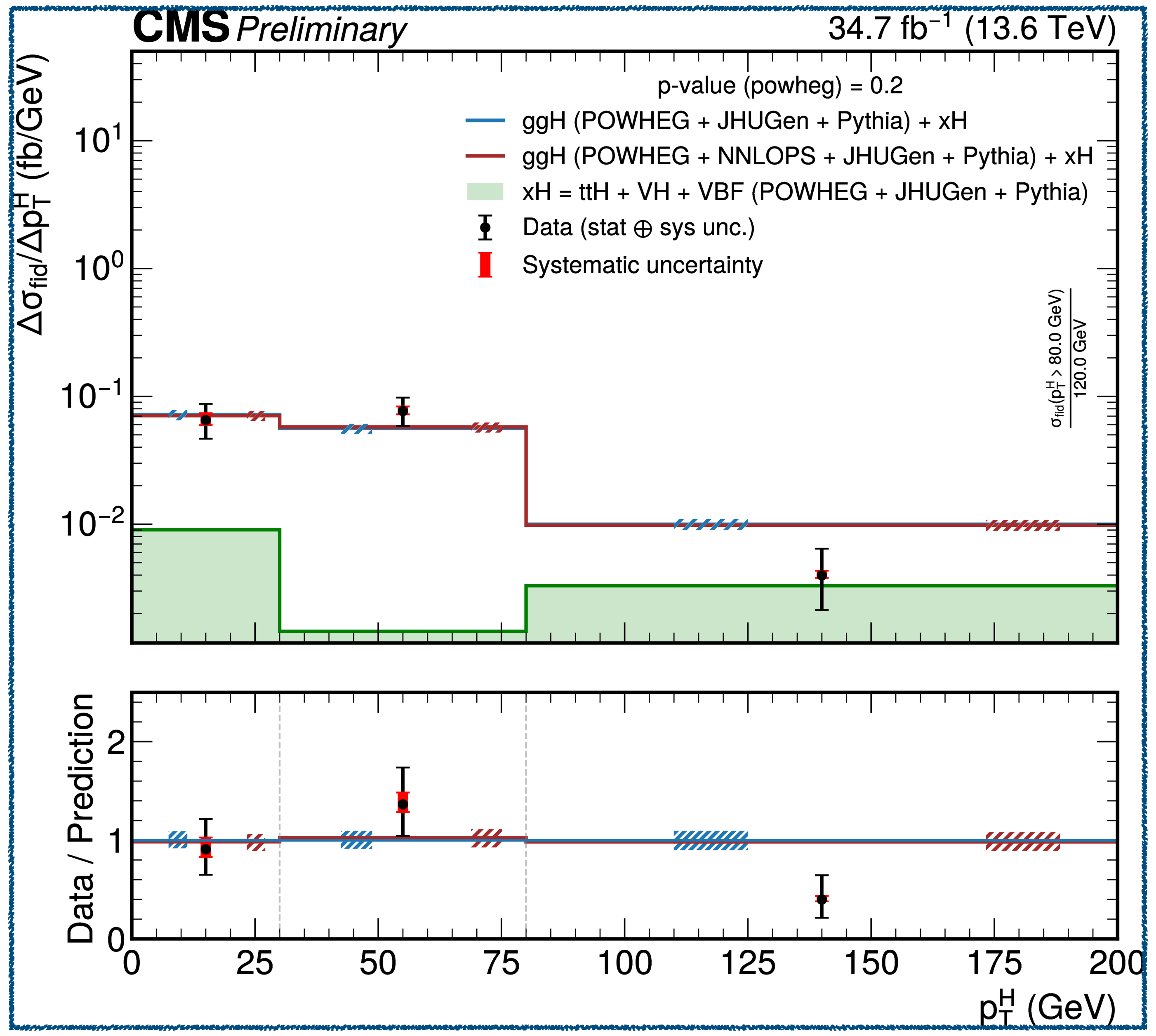
$H \rightarrow ZZ \rightarrow 4\ell$ measurement

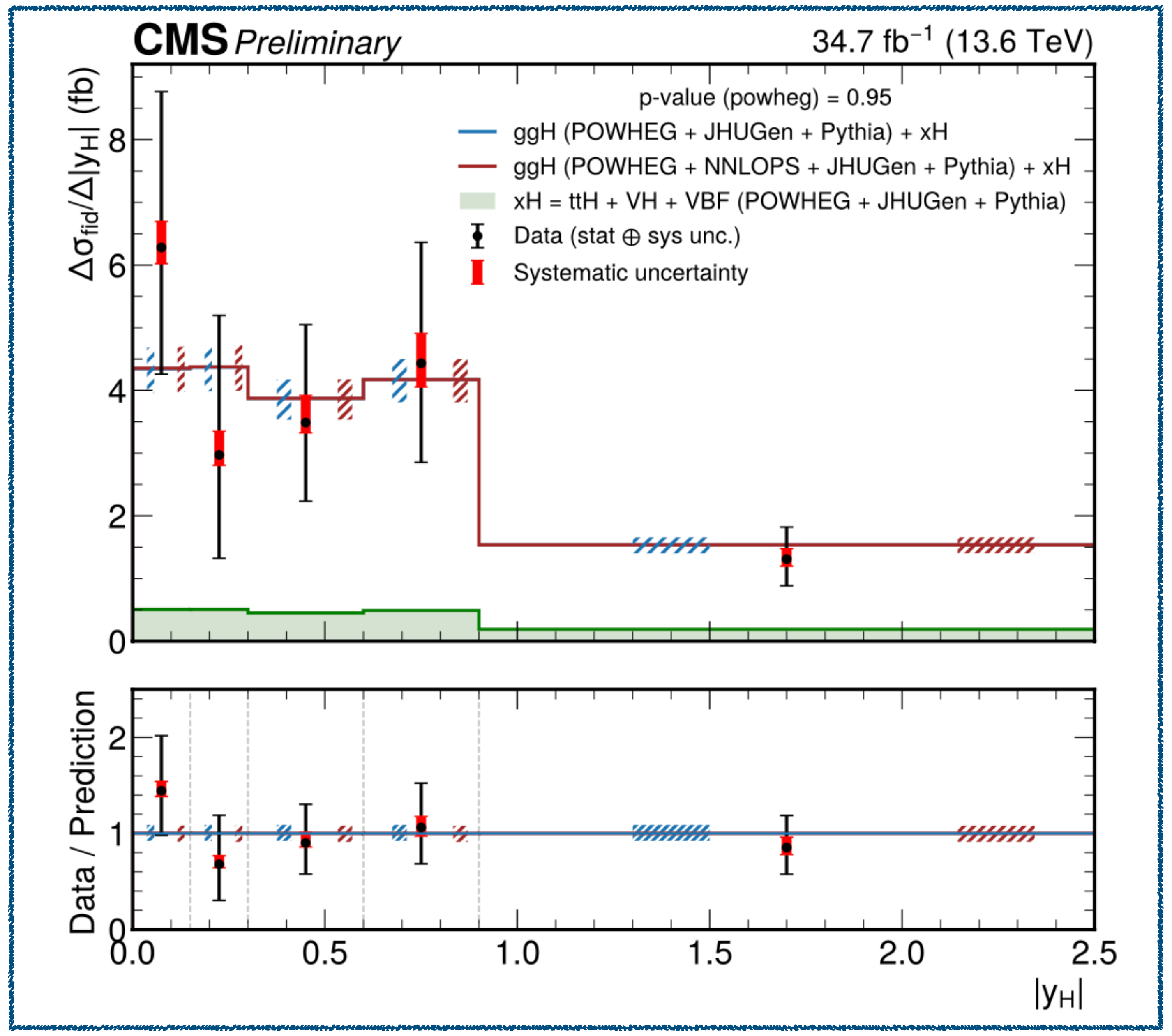


- The measurement is performed using an unbinned maximum likelihood fit to the data
- Largest source of experimental uncertainty being the electron efficiency

Inclusive fiducial cross sections	
Observed	Expected
$2.94^{+0.53}_{-0.49}(stat.)^{+0.29}_{-0.22}(syst.)$ fb	$3.09^{+0.27}_{-0.24}$ fb

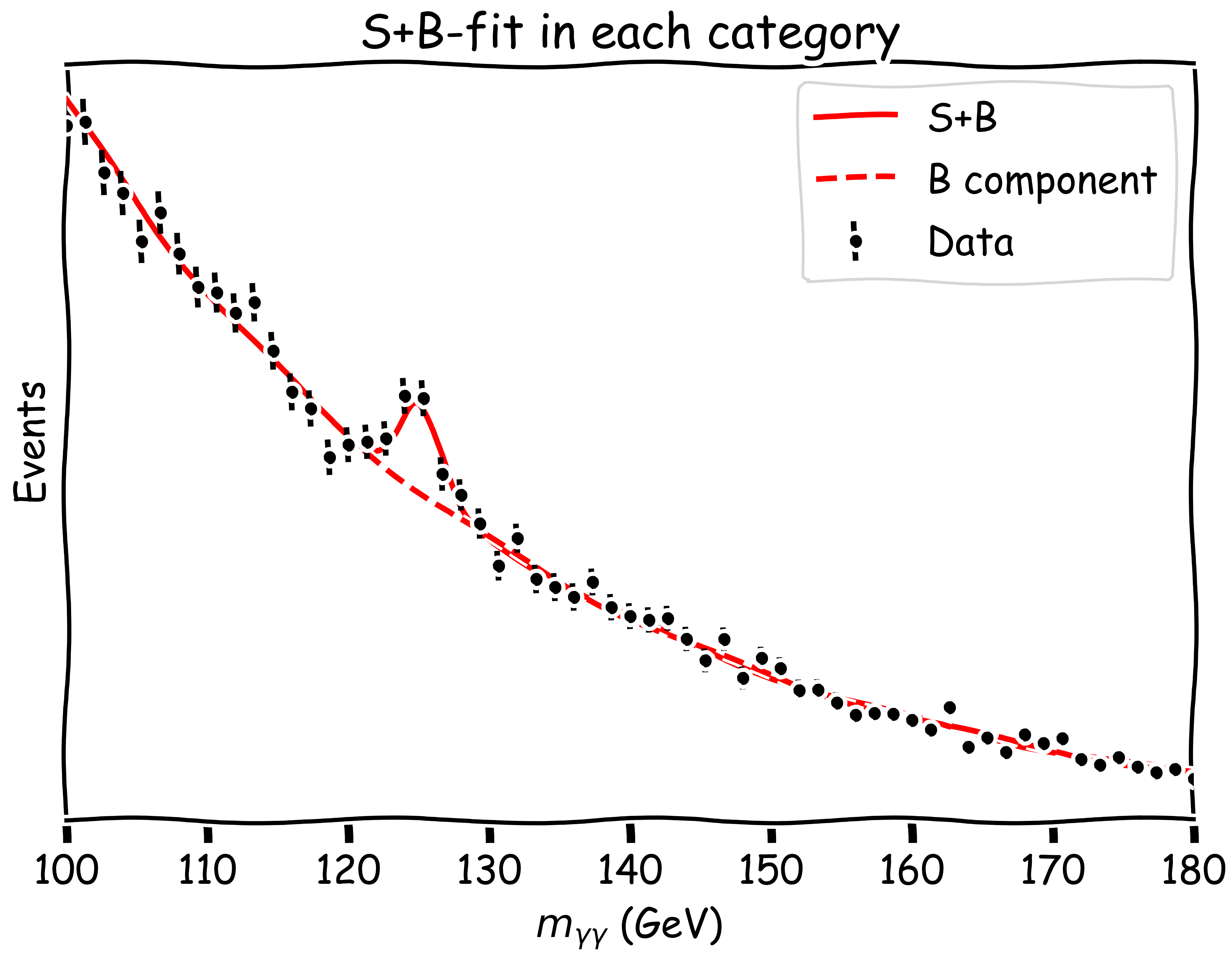






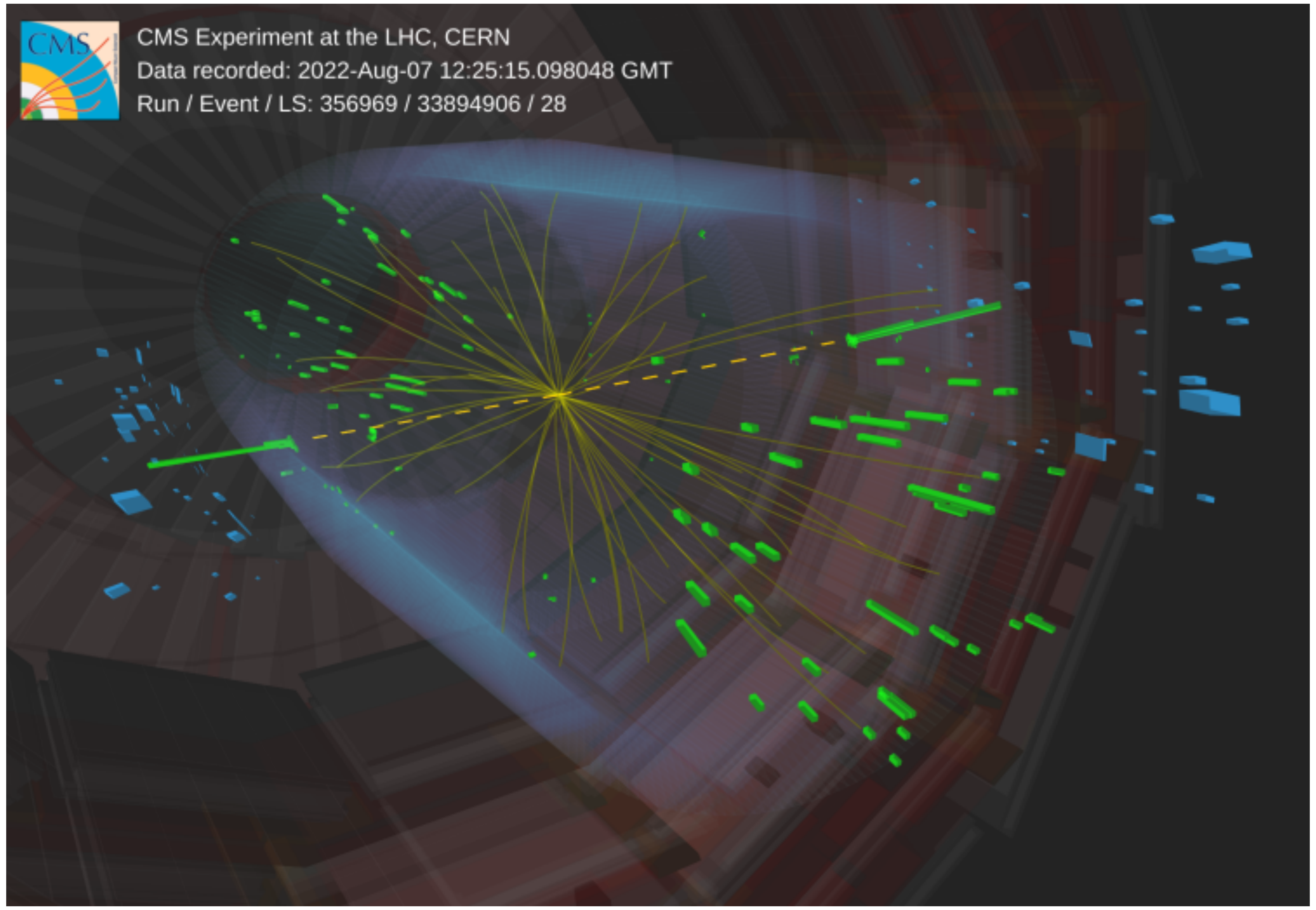
$H \to \gamma\gamma$ at 13.6 TeV

CMS-PAS-HIG-23-014



- Sharp peak over a smoothly falling background
- Mass resolution has an important role in the analysis

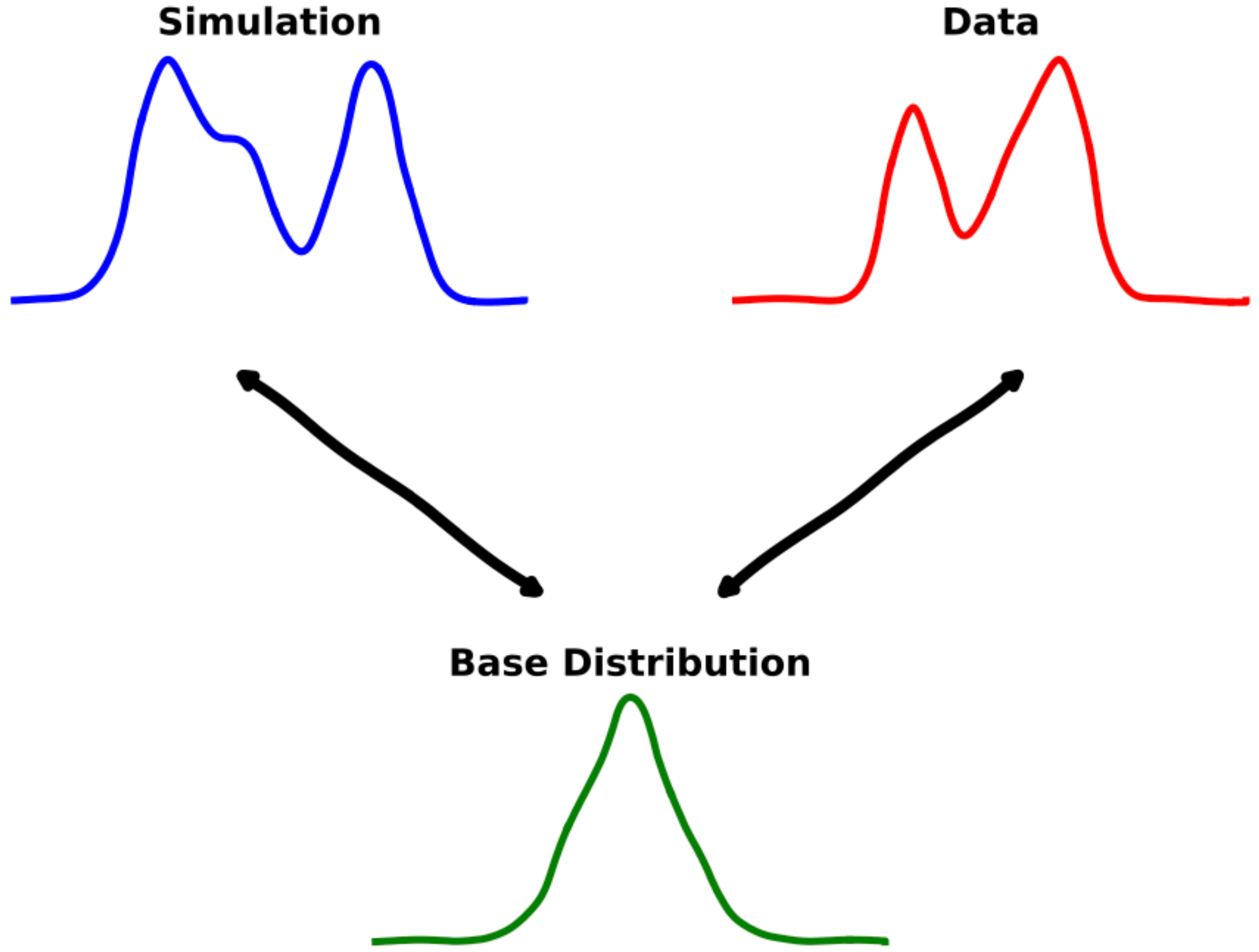
New columnar analysis framework, processing lightweight datasets

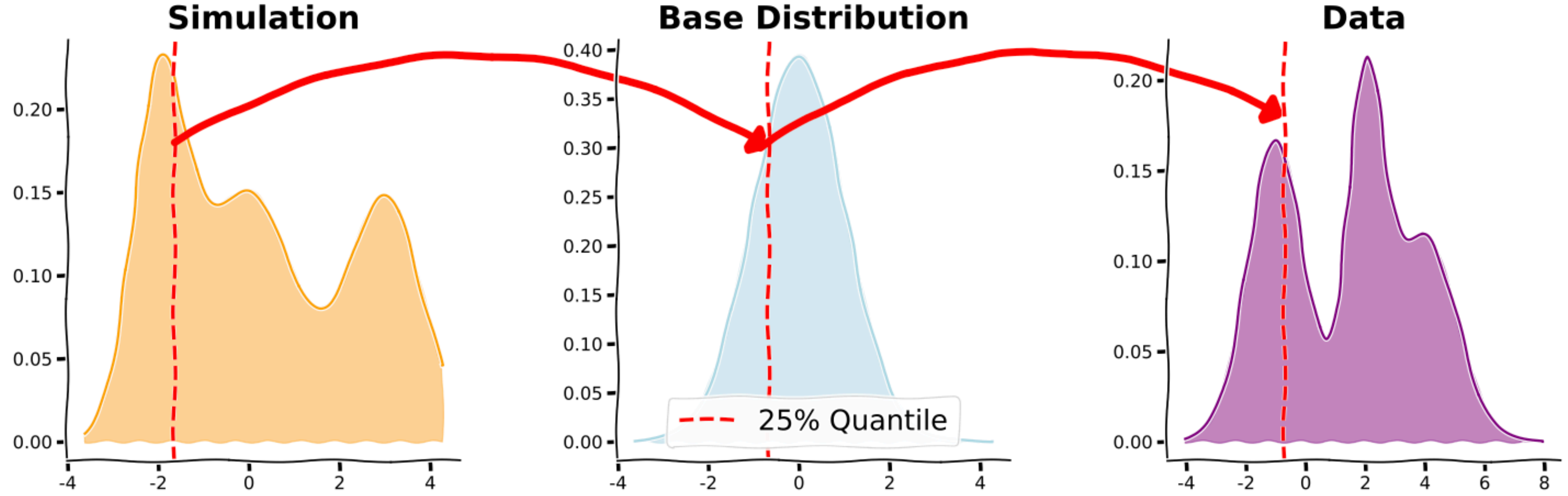


Suppression of non prompt photons done by a BDT

σ_m/m and Photon identification score correction

- Largest source of systematics in past analyses were related to the mismodeling of the ID inputs and σ_m/m
- A new method based on a single normalising flow is used to perform the ID inputs and σ_m/m corrections
- The method is capable of correcting non-continuous distributions, such as isolations





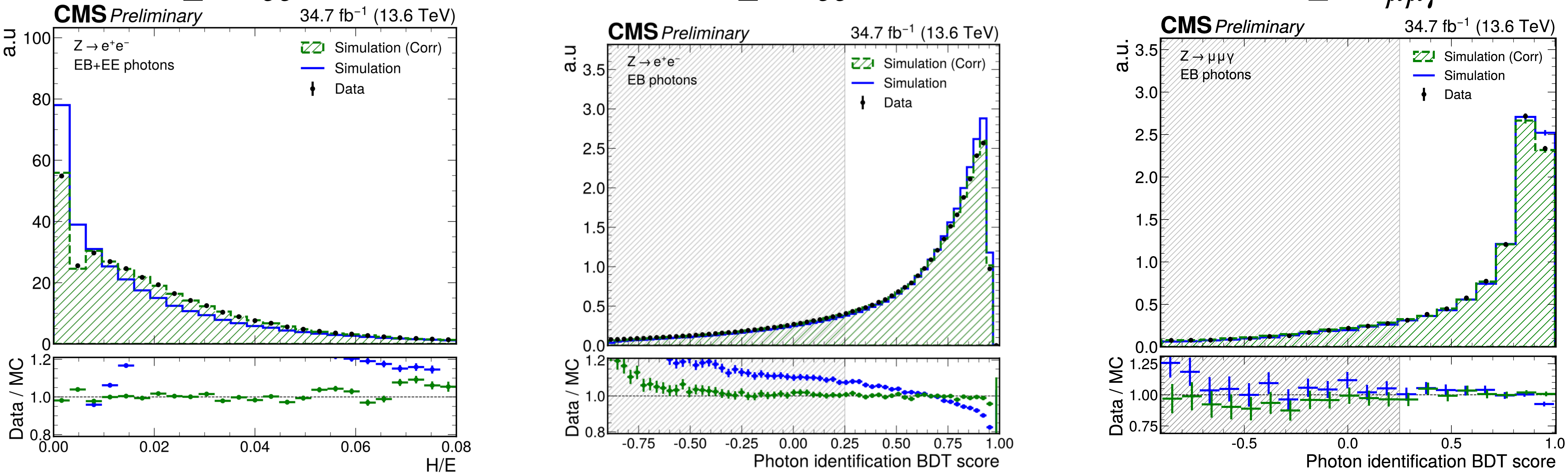
CD et al. Comput.Softw.Big Sci. 8 (2024) 1, 15

More details in the plenary talk by Davide and Johannes talk on Friday at 11

Photon ID and σ_m/m categorisation

- Flow model is trained using $Z \rightarrow ee$ probes
- Excellent agreement in the individual variables and the photon ID inputs (impact of 1%) and σ_m/m
- Besides the marginal distributions, the correlations also improve

$Z \rightarrow ee$ $\quad$ $Z \rightarrow ee$ $\quad$ $Z \rightarrow \mu\mu\gamma$

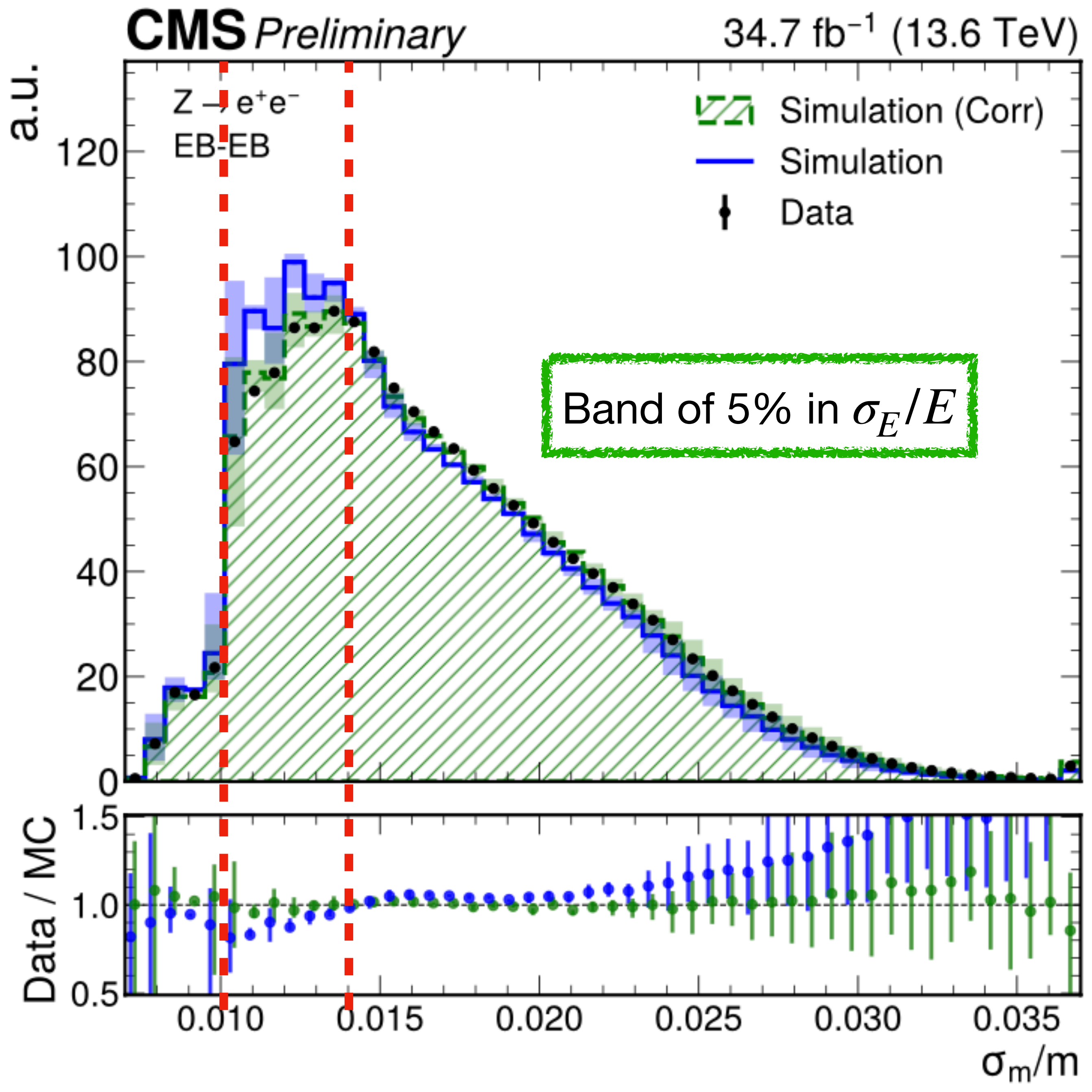


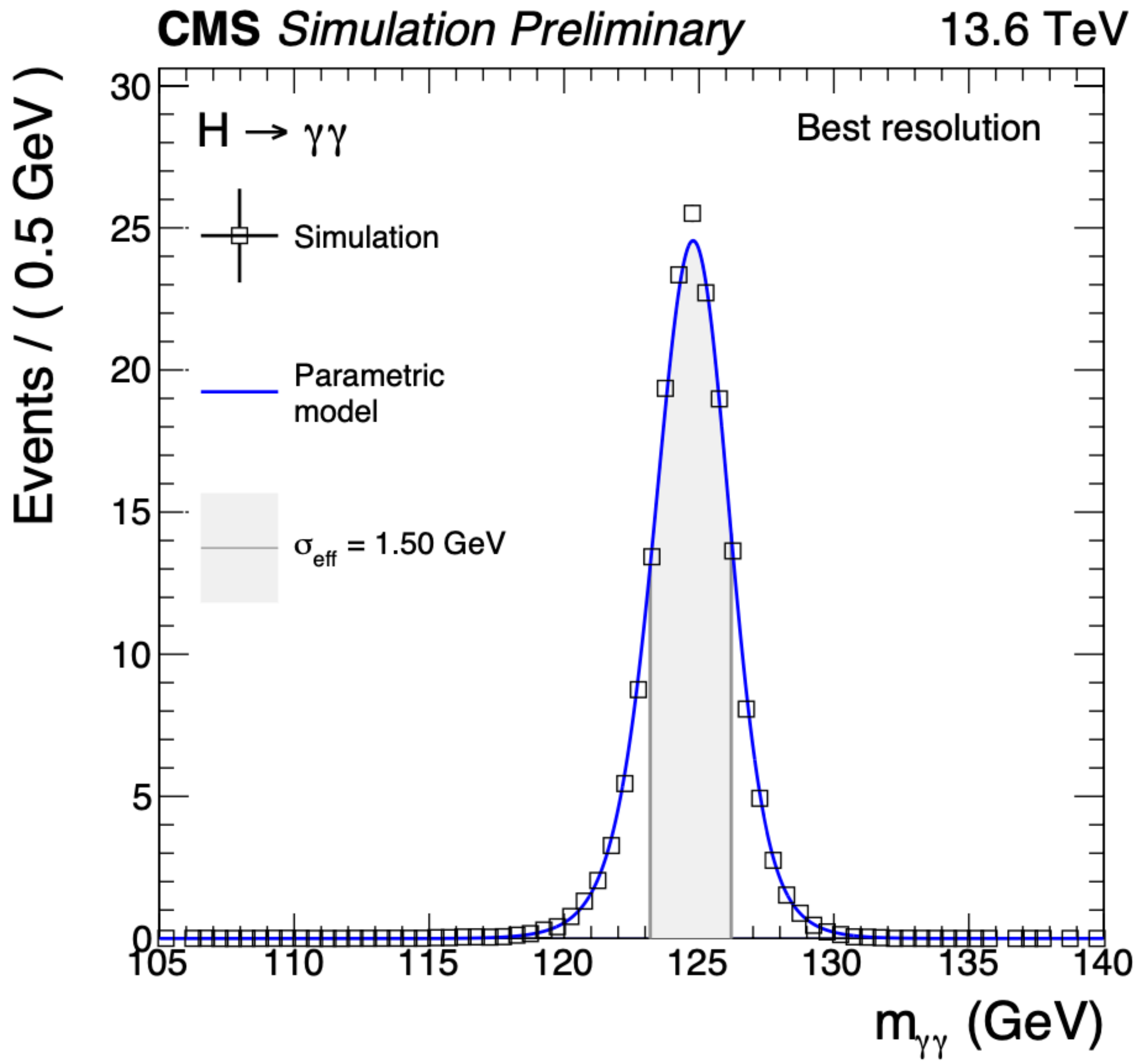
Validation with real photons

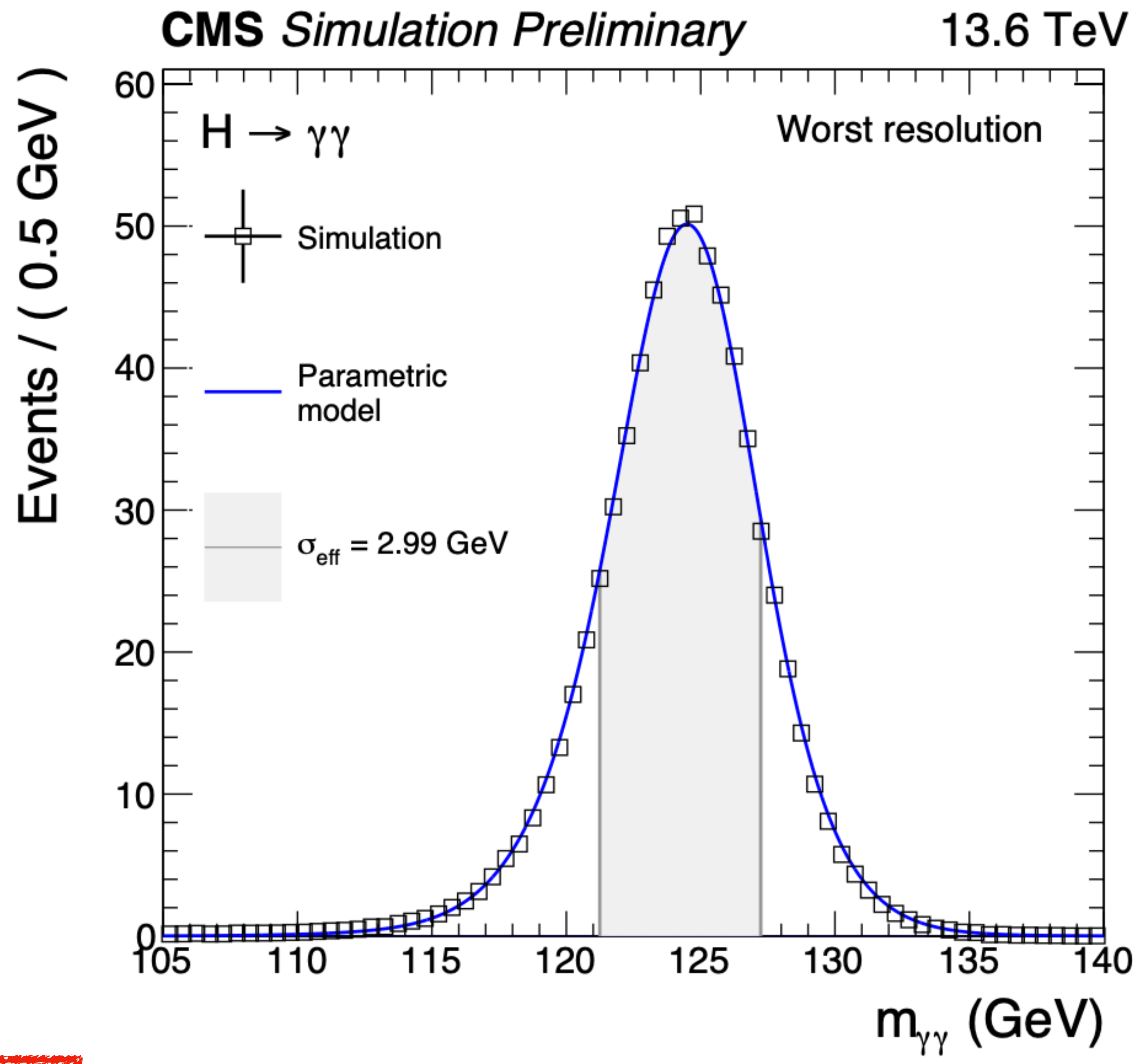
Signal and background models

$$\frac{\sigma_m}{m} = \frac{1}{2}\sqrt{\left(\frac{\sigma_{E_1}}{E_1}\right)^2 + \left(\frac{\sigma_{E_2}}{E_2}\right)^2}$$

- Signal and background models are constructed using parametric functions
- Due to calorimeter resolution, σ_m/m is decorrelated w.r.t $m_{\gamma\gamma}$ distribution in order to have a smoothly falling background
- σ_m/m boundaries are defined by optimizing the expected significance







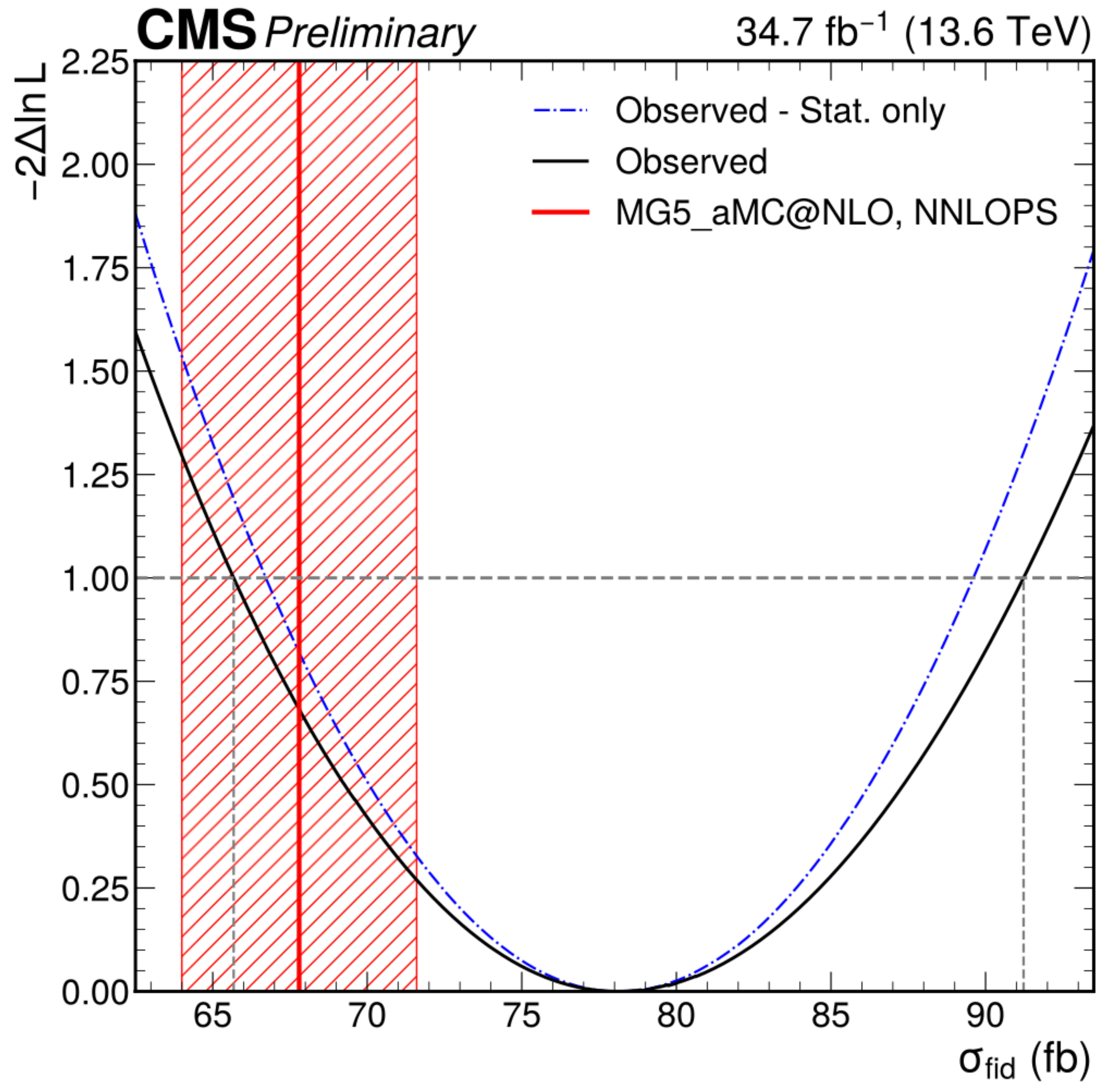
2018 UL best category resolution was 1.48 (JHEP07(2023)091)

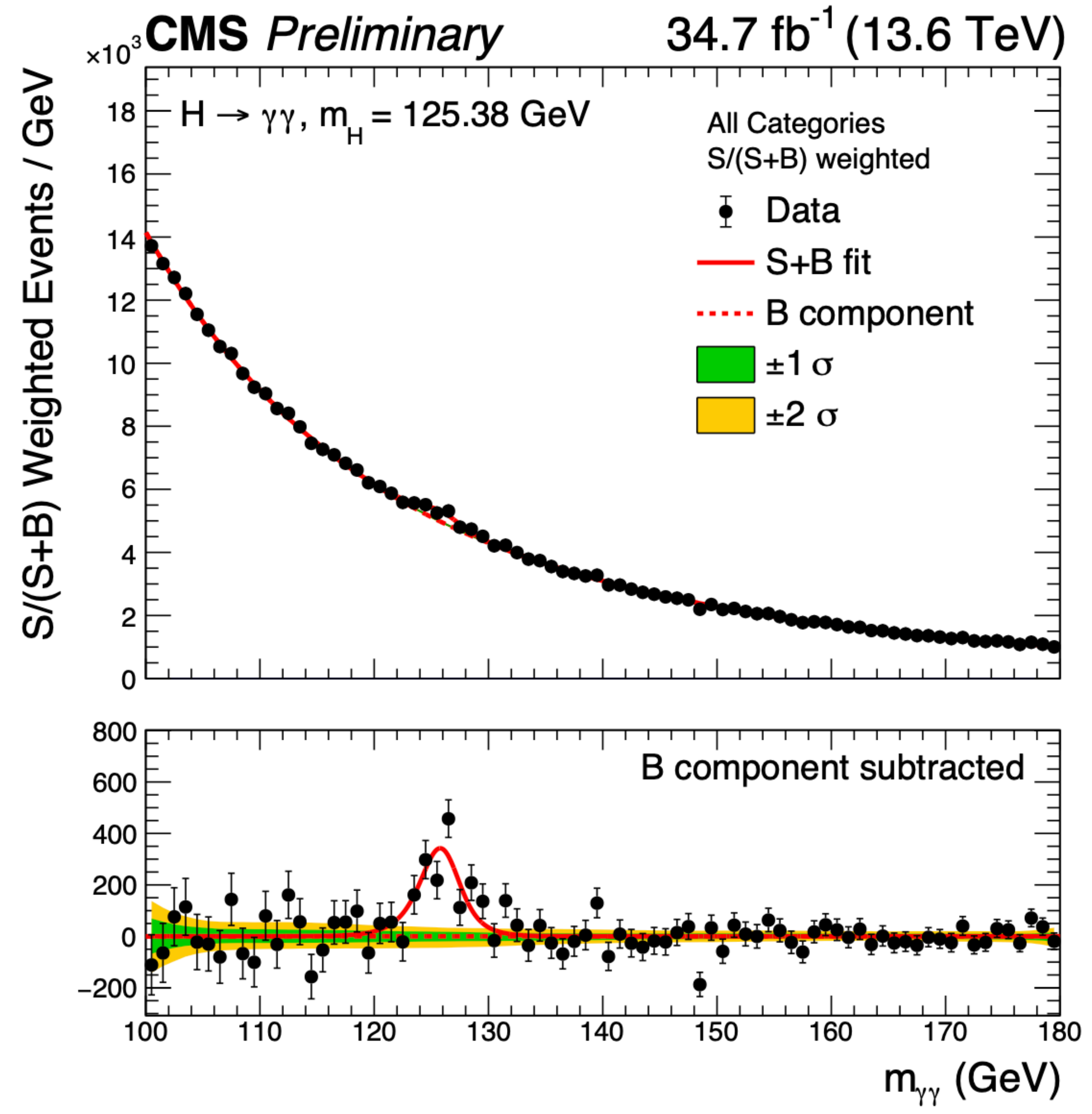
The $H \to \gamma\gamma$ measurement

- A new fiducial requirement on geometric mean is applied: $\sqrt{p_T^{\gamma_1} p_T^{\gamma_2} / m_{\gamma\gamma}} > 1/3$
  - Improved perturbative convergence in phase space (2106.08329)

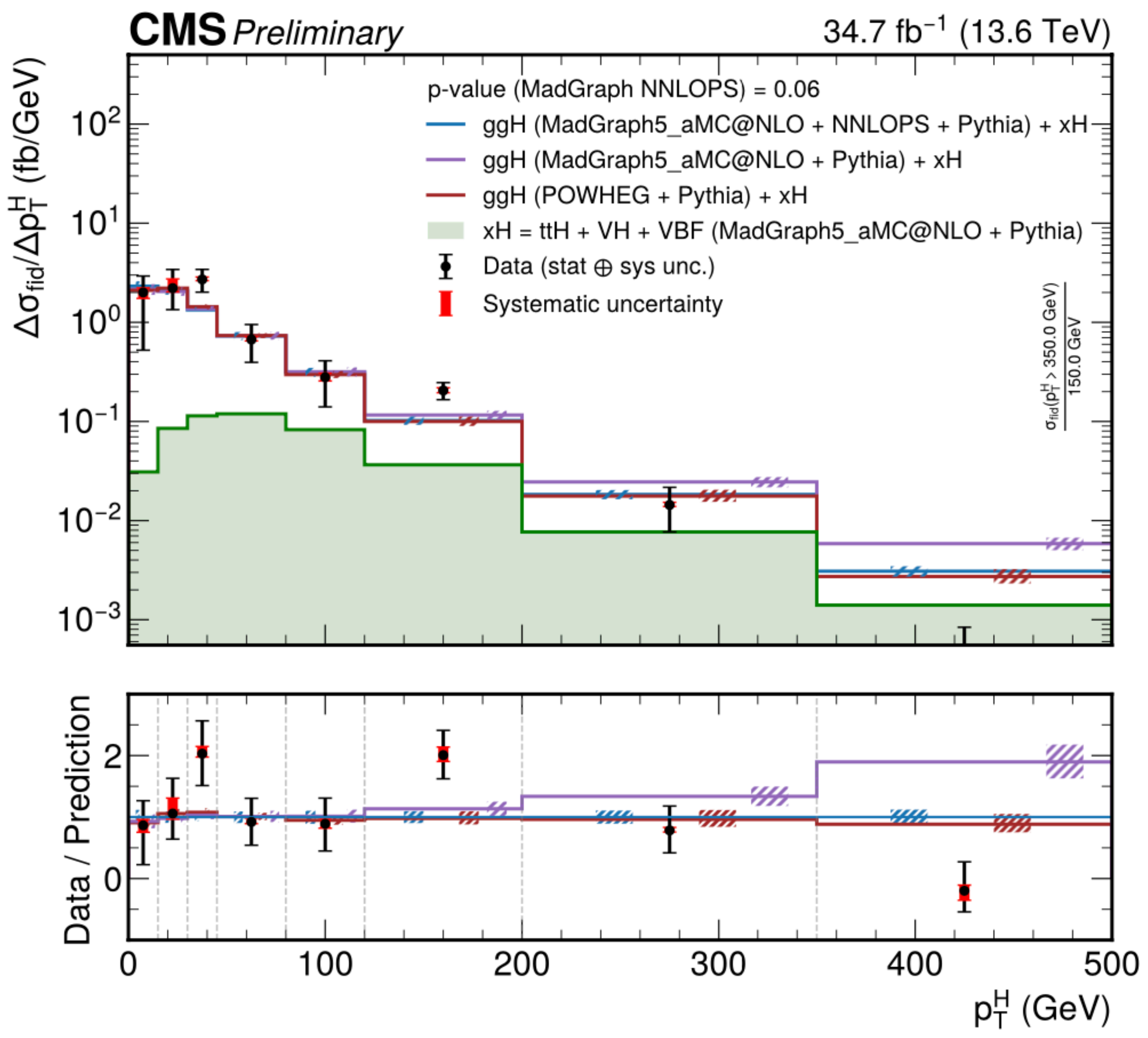
Inclusive fiducial cross sections	
Observed	Expected
$78^{+11}_{-11}(stat.)^{+6}_{-5}(syst.)$ fb	67.8 ± 3.8 fb

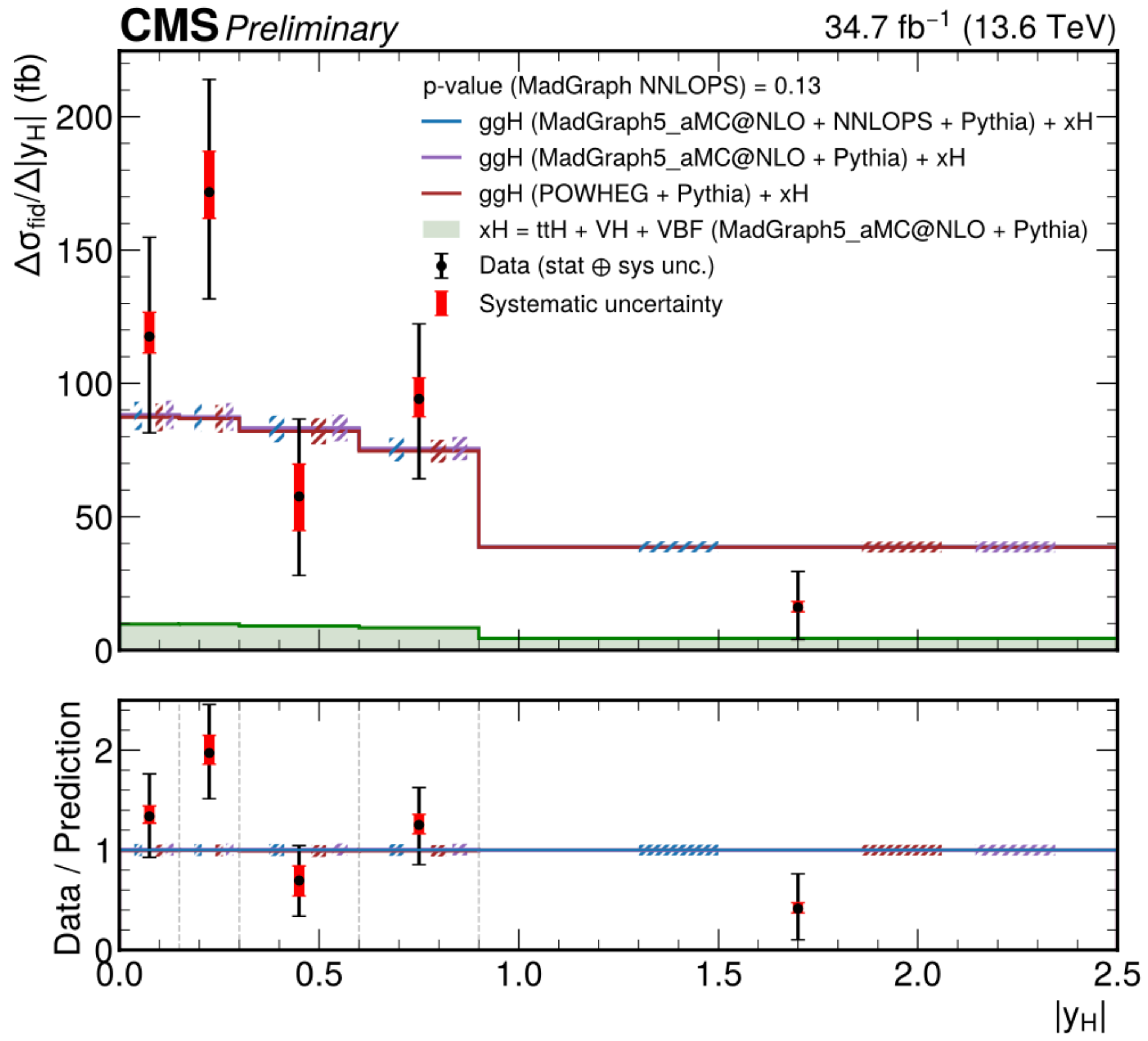
Systematic uncertainty	Magnitude
Photon energy scale and resolution group	$+5.8\% / -4.9\%$
Category migration from energy resolution	$+3.5\% / -3.9\%$
Integrated luminosity	$\pm 1.4\%$
Photon preselection efficiency	$\pm 1.4\%$
Energy scale non-linearity	$+0.8\% / -1.6\%$
Photon identification efficiency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

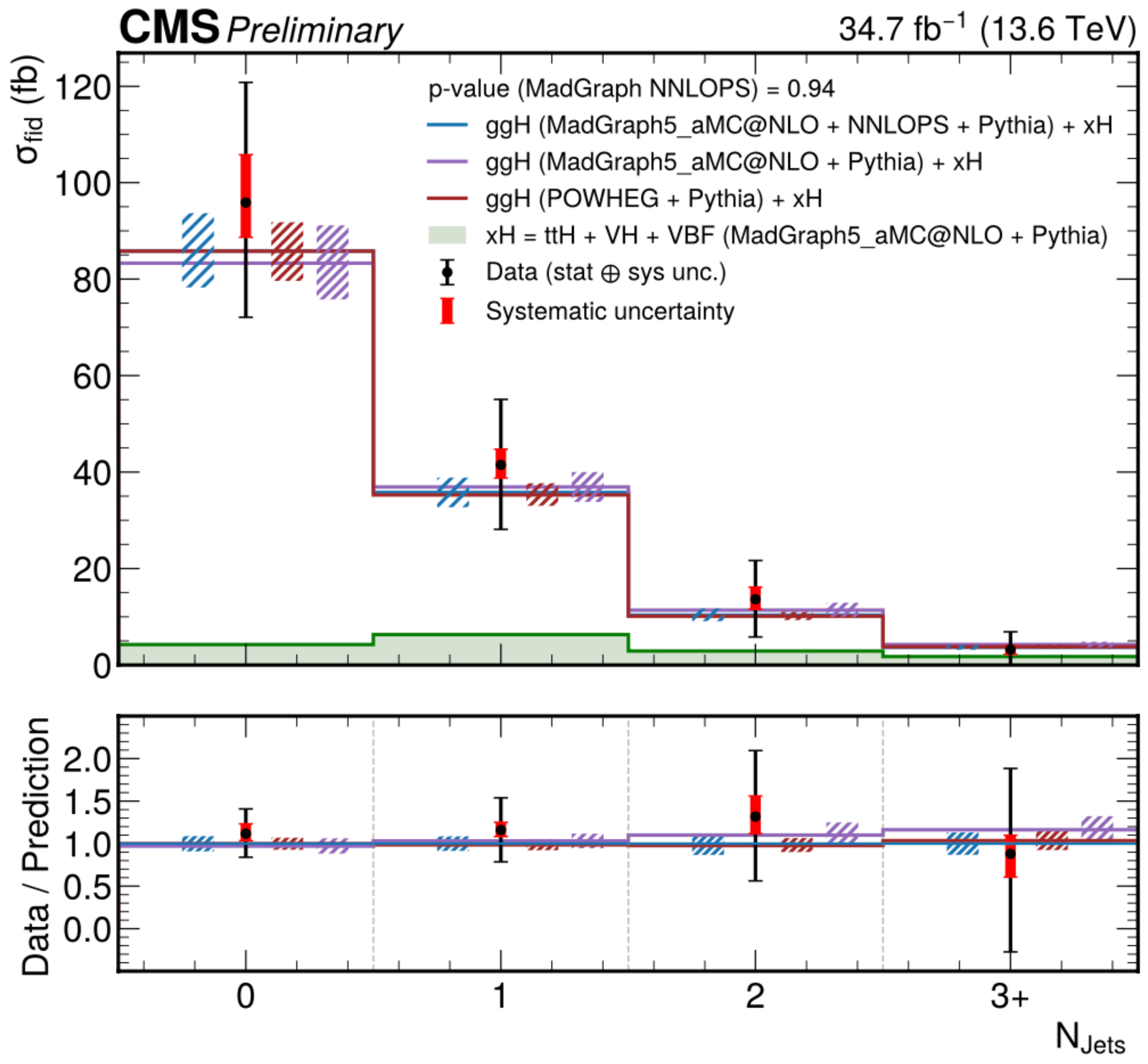




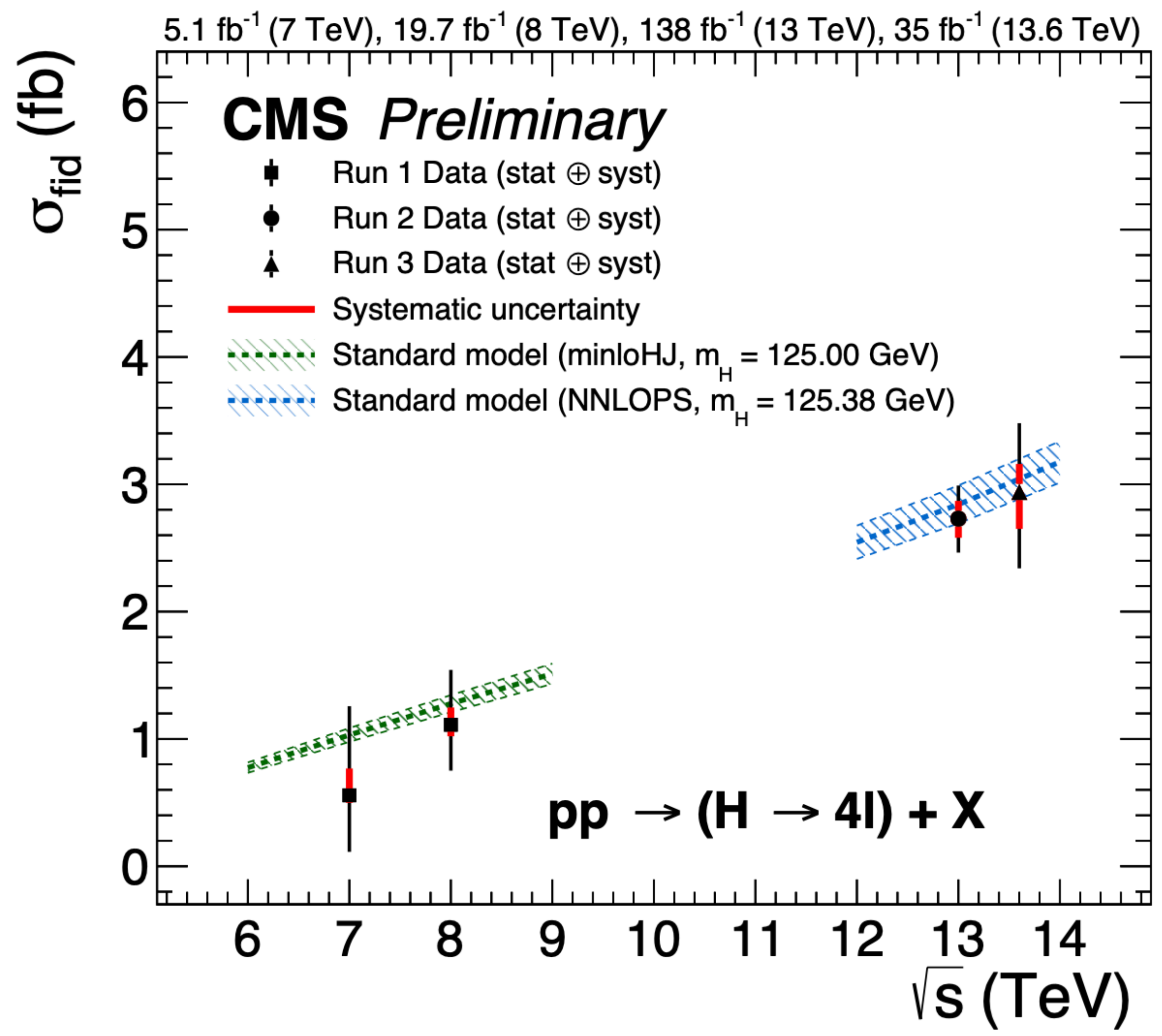
Differential cross sections

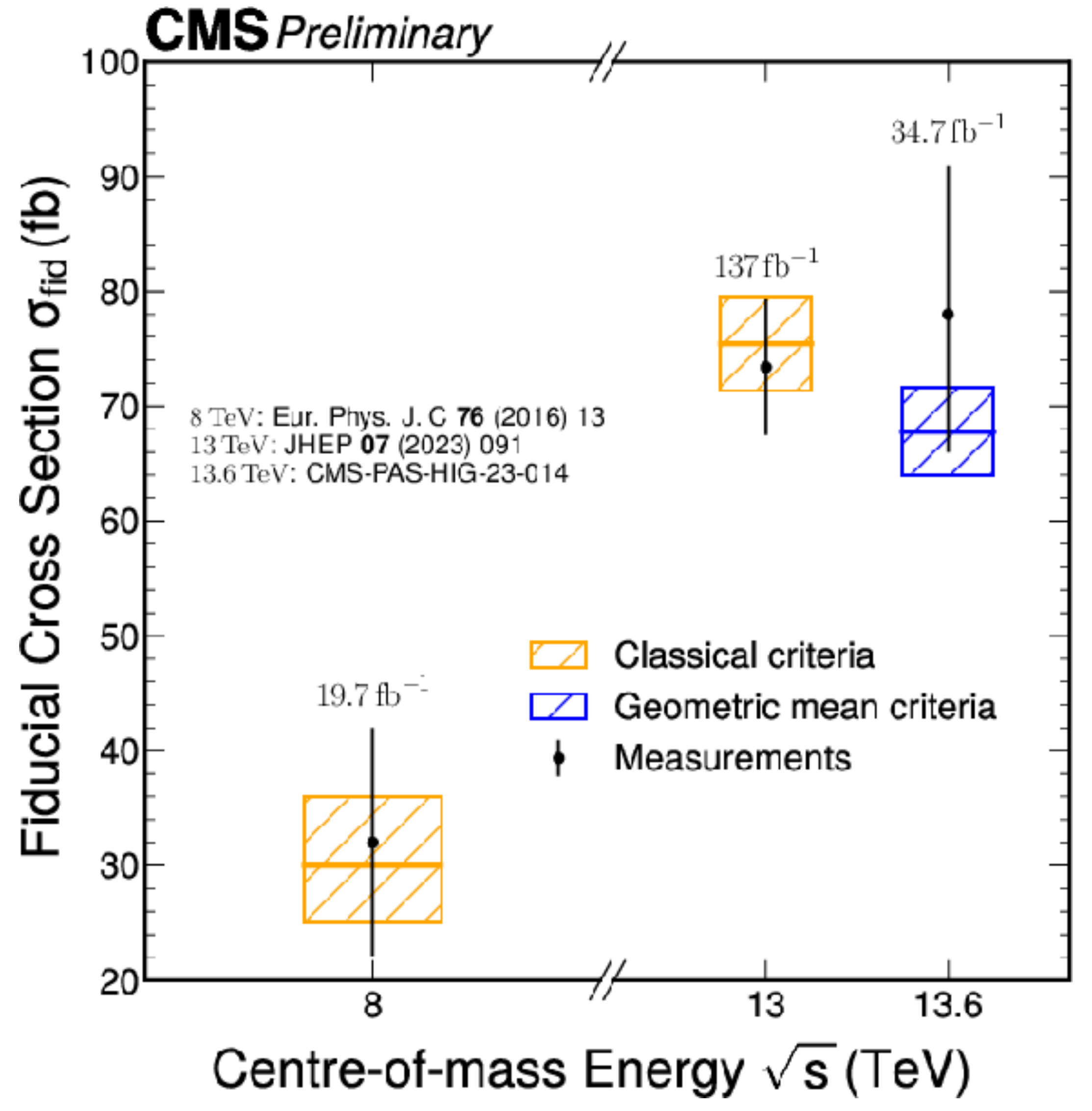






Summary





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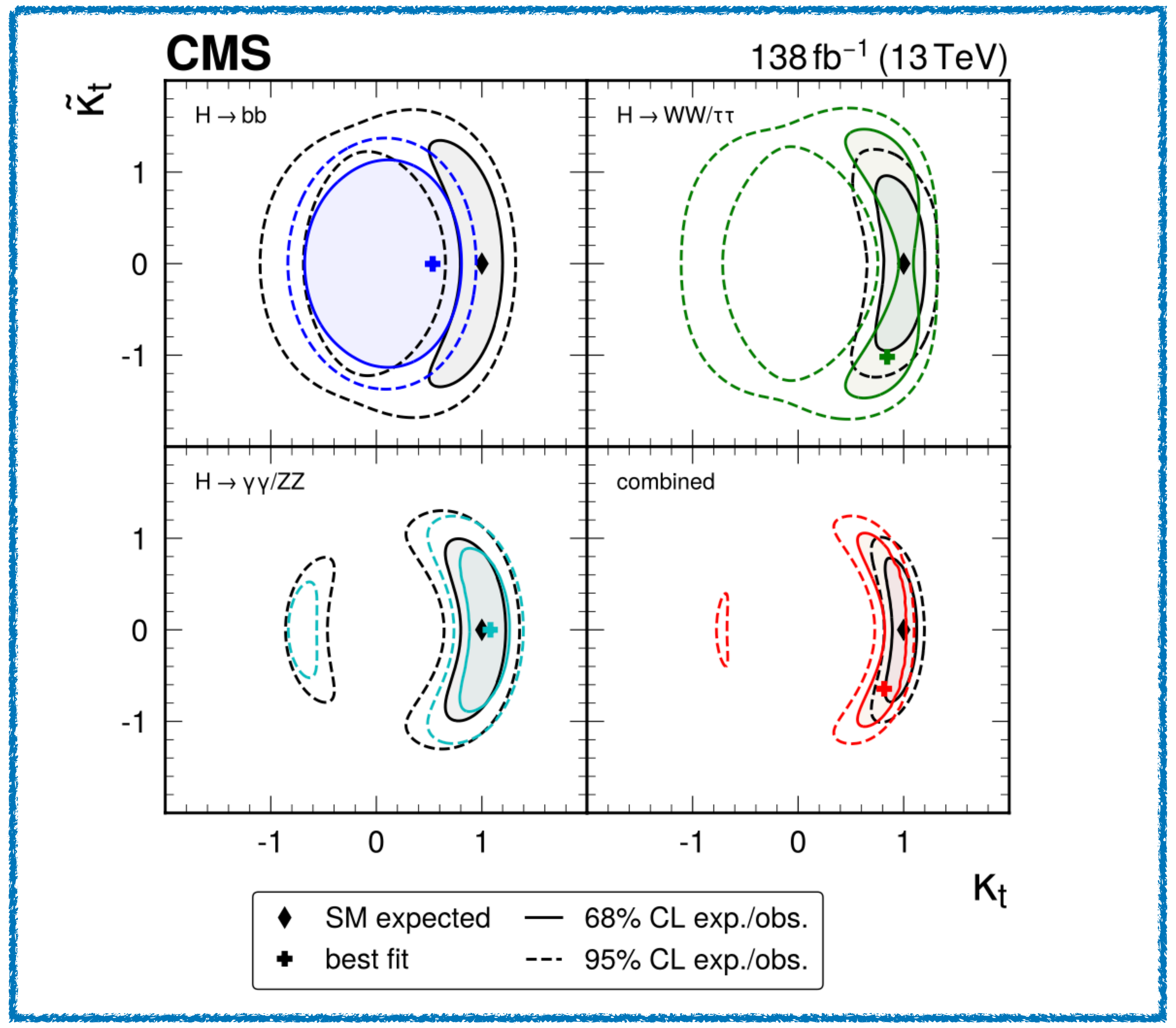
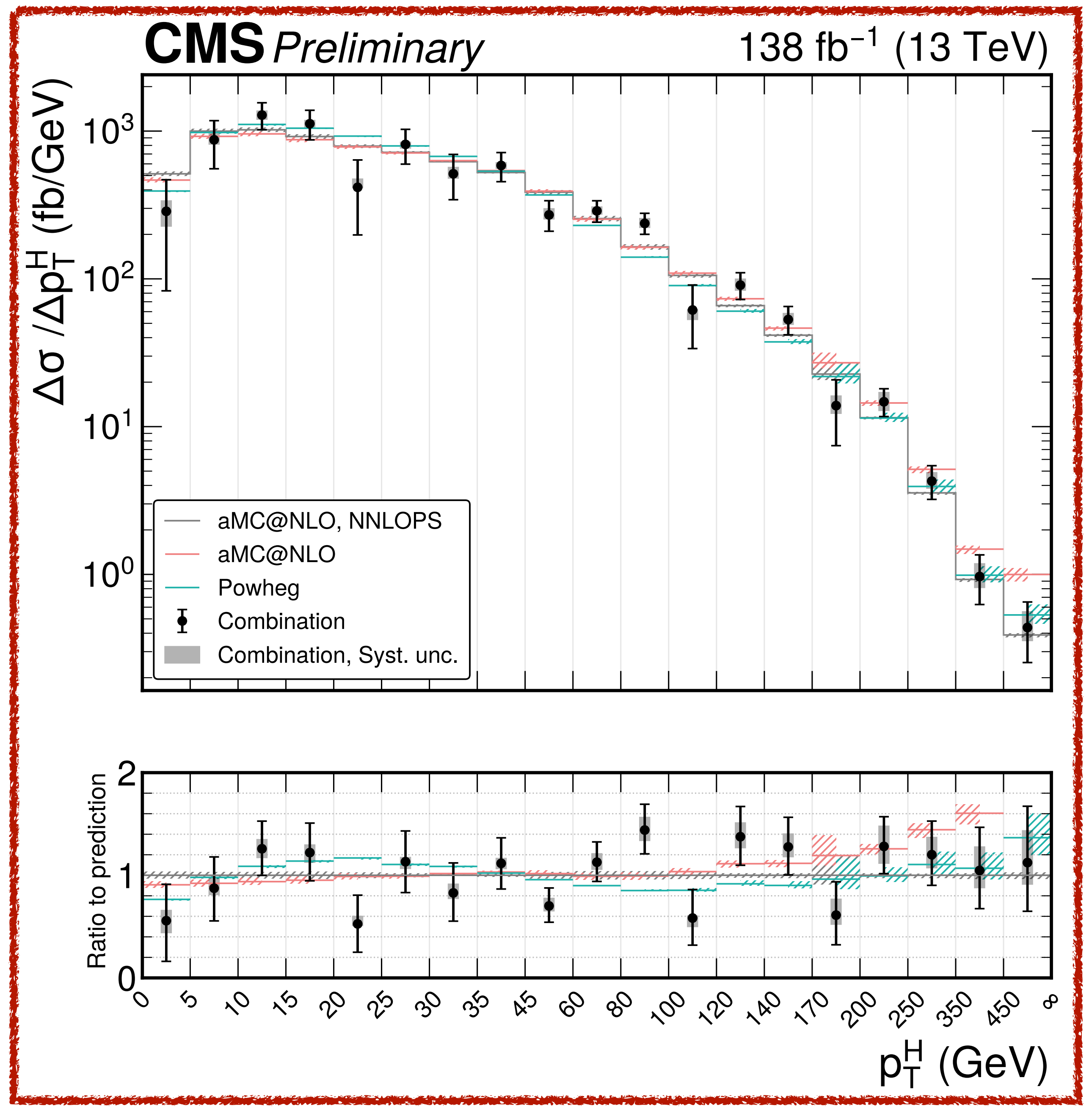


HIG-23-013



Fermionic Channels refer to Simone Gennai's talk tomorrow at 09:20

Run 2 combinations refer to Massimiliano Galli's talk at 11:10 in this session

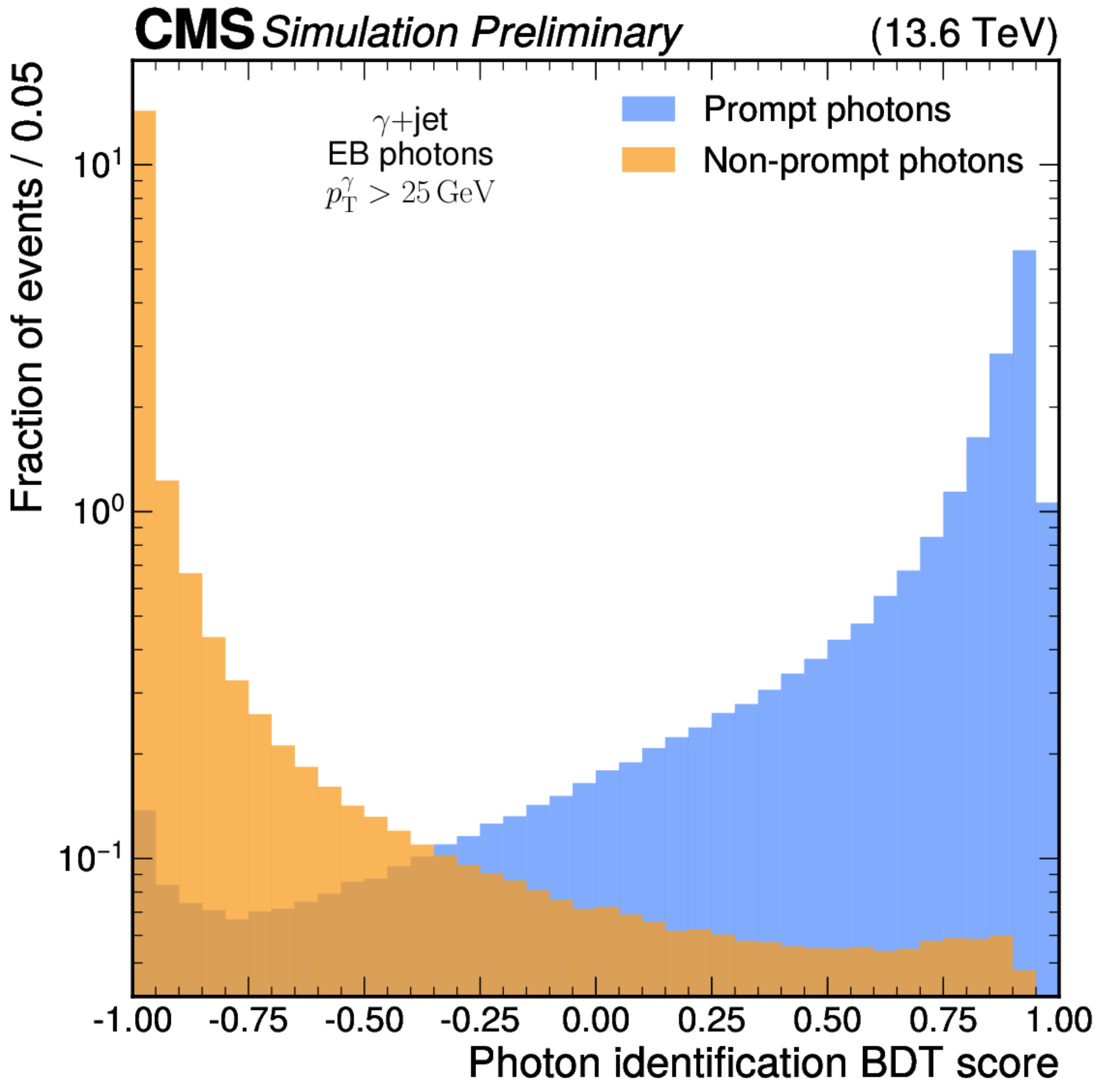
Backup slides

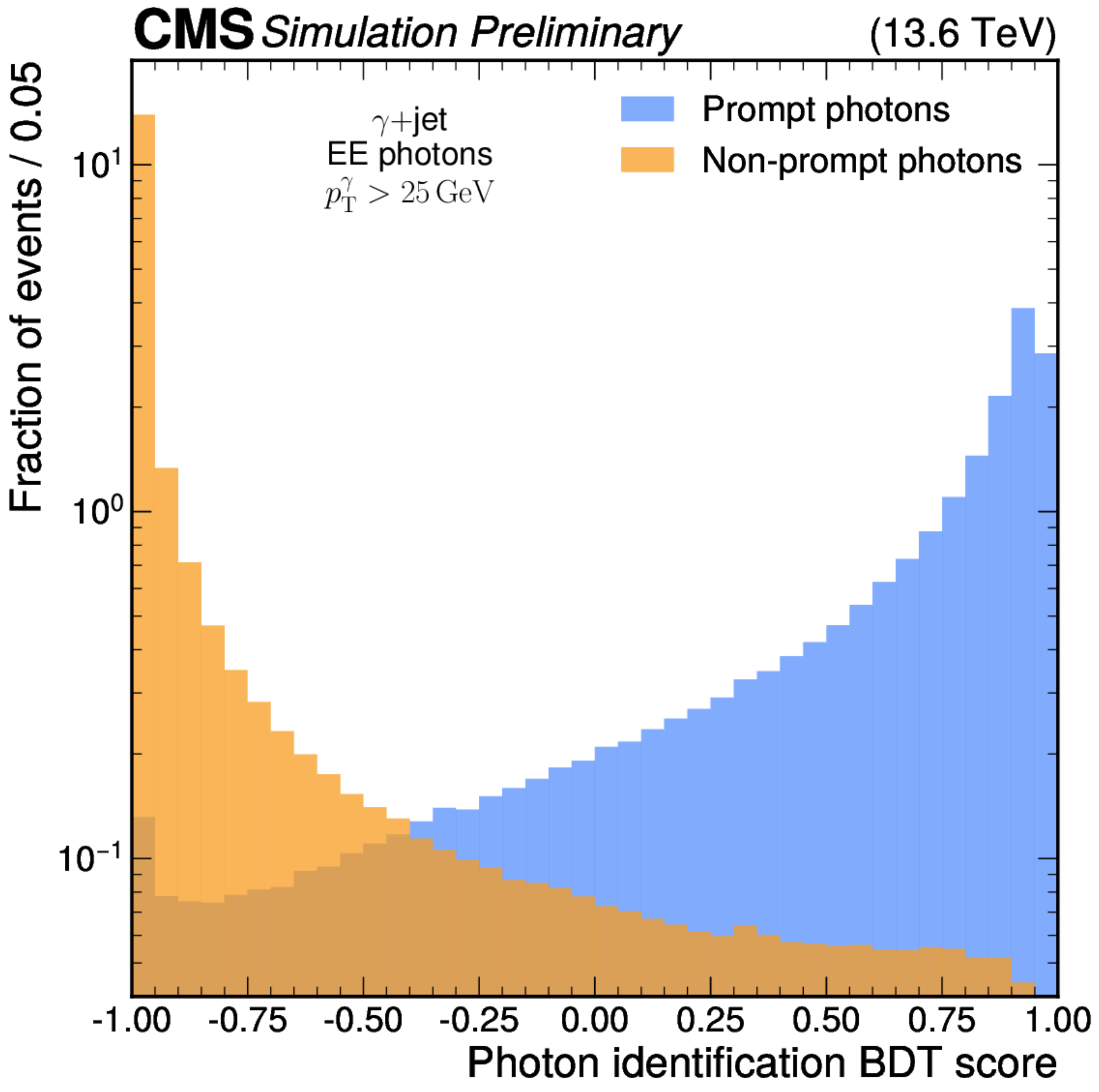
$H \rightarrow ZZ$ fiducial phase space

Table 12: Summary of requirements and selections used in the definition of the fiducial phase space for the $\mathrm{H} \rightarrow 4\ell$ cross section measurements.

Requirements for the $\mathrm{H} \rightarrow 4\ell$ fiducial phase space	
Lepton kinematics and isolation	
leading lepton p_{T}	$p_{\mathrm{T}} > 20$ GeV
next-to-leading lepton p_{T}	$p_{\mathrm{T}} > 10$ GeV
additional electrons (muons) p_{T}	$p_{\mathrm{T}} > 7(5)$ GeV
pseudorapidity of electrons (muons)	$\lvert\eta\rvert < 2.5(2.4)$
p_{T} sum of all stable particles within $\Delta R < 0.3$ from lepton	less than $0.35 \cdot p_{\mathrm{T}}$
Event topology	
existence of at least two SFOS lepton pairs, where leptons satisfy criteria above	
inv. mass of the Z_1 candidate	$40\,\mathrm{GeV} < m(\mathrm{Z}_1) < 120\,\mathrm{GeV}$
inv. mass of the Z_2 candidate	$12\,\mathrm{GeV} < m(\mathrm{Z}_2) < 120\,\mathrm{GeV}$
distance between selected four leptons	$\Delta R(\ell_i \ell_j) > 0.02$ for any $i \neq j$
inv. mass of any opposite sign lepton pair	$\mathrm{m}(\ell^+ \ell'^-) > 4\,\mathrm{GeV}$
inv. mass of the selected four leptons	$105\,\mathrm{GeV} < m_{4\ell} < 140\,\mathrm{GeV}$
the selected four leptons must originate from the $\mathrm{H} \rightarrow 4\ell$ decay	

$H \to \gamma\gamma$ photon ID





$H \to \gamma\gamma$ photon ID corrections