Measurement of the $H \to ZZ^* \to 4\ell$ cross-sections in pp collisions at $\sqrt{s} = 13.6$ TeV with the ATLAS Detector

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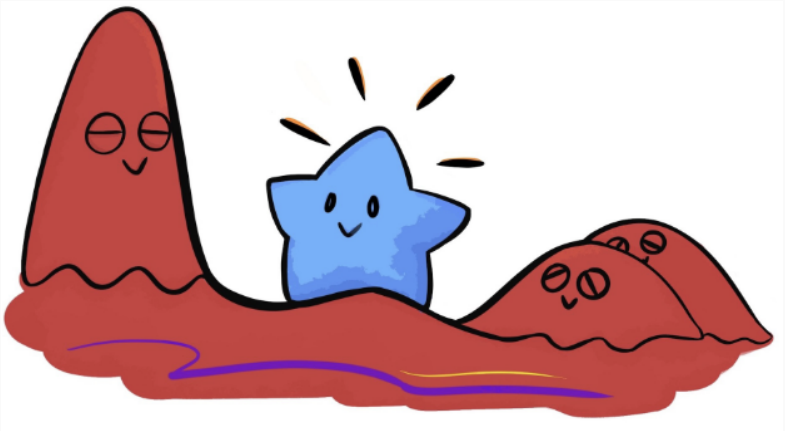


Introduction

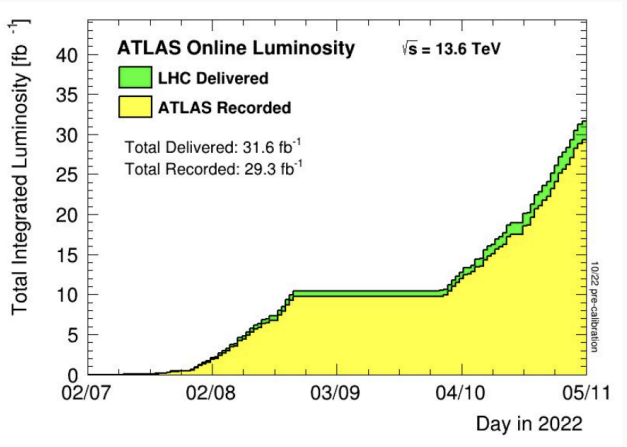
Motivation

The Run 3 operations at LHC

- new world-record energy scale - **13.6TeV**
- Commissioning of new detector: NSW
- 2022 dataset: 29fb^{-1} with muon trigger

First round of Run3 *HZZ** Analysis

- *HZZ** 4l channel shows excelent S/B
- Cross section measurement
  - $H \to ZZ^* \to 4\ell$ cross section
  - total $pp \to Higgs$ cross section
  - Basic setup for the following Run3 analysis



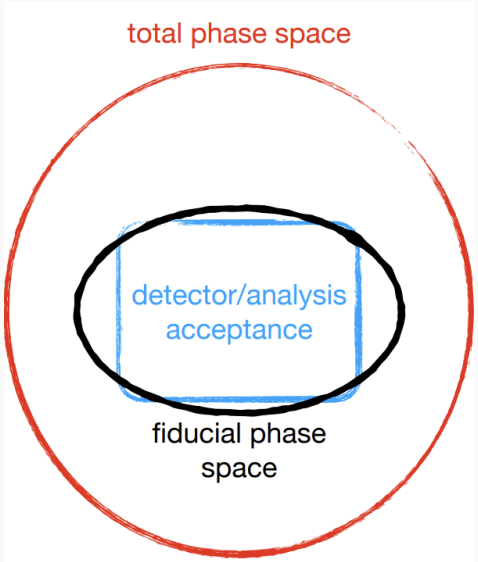
Overview of Analysis Strategy

Fiducial cross section: most **model indenpendent** way to measure Higgs@LHC

- Minimizing **acceptance** and **extrapolation** effects

Extraction of Fiducial XS:

- fitting binned m_{4l} spectrum



Irreducible background:

- ZZ^*: **qqZZ, ggZZ**
- **ttll, triboson**

Reducible background: 2 prompt leptons + 2 leptons from **Heavy Flavor/fake**

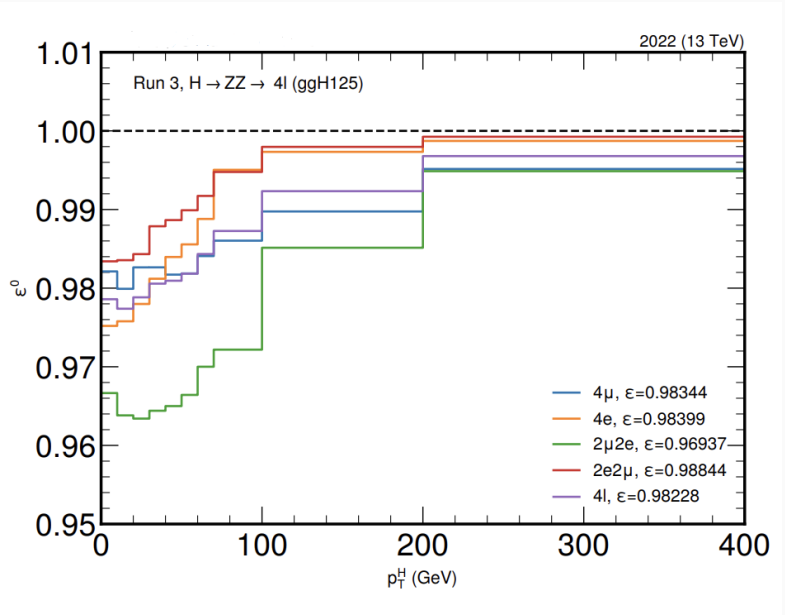
- Z + $\mu\mu$
- Z + ee

Event Selection

Object Reco and Trigger

Object definition:

- **Electron**:
  - Loose identification
  - Loose isolation
  - E_T > 7GeV, $|\eta|$ < 2.47
- **Muon**:
  - Loose identification
  - Loose pflow isolation
  - p_T > 5GeV, $|\eta|$ < 2.5



Trigger:

- lowest un-prescaled triggers available
  - single lepton threshold: 24GeV(26GeV) for μ(e)
  - multi-lepton threshold: down to 6GeV
- trigger matching applied

Selection of Quadraplet

Same flavor opposite sign pairs of leptons: 4μ, 4e, 2μ2e, 2e2μ

- p_T threshold: **20GeV**, **15GeV**, **10GeV**, **5(7)GeV** for μ(e)
- leading lepton pair: [50GeV, 106GeV]
- subleading: upper boundary 115GeV:
  - **dynamic lower boundary**
  - 12GeV for m_{4l}<140GeV
  - linearly rise to 50GeV for m_{4l}=190GeV

if multi quads pass the selection:

- Based on Z mass and signal efficiency
- extra lepton p_T > 12GeV: ME based selection

Selection of Quadraplet

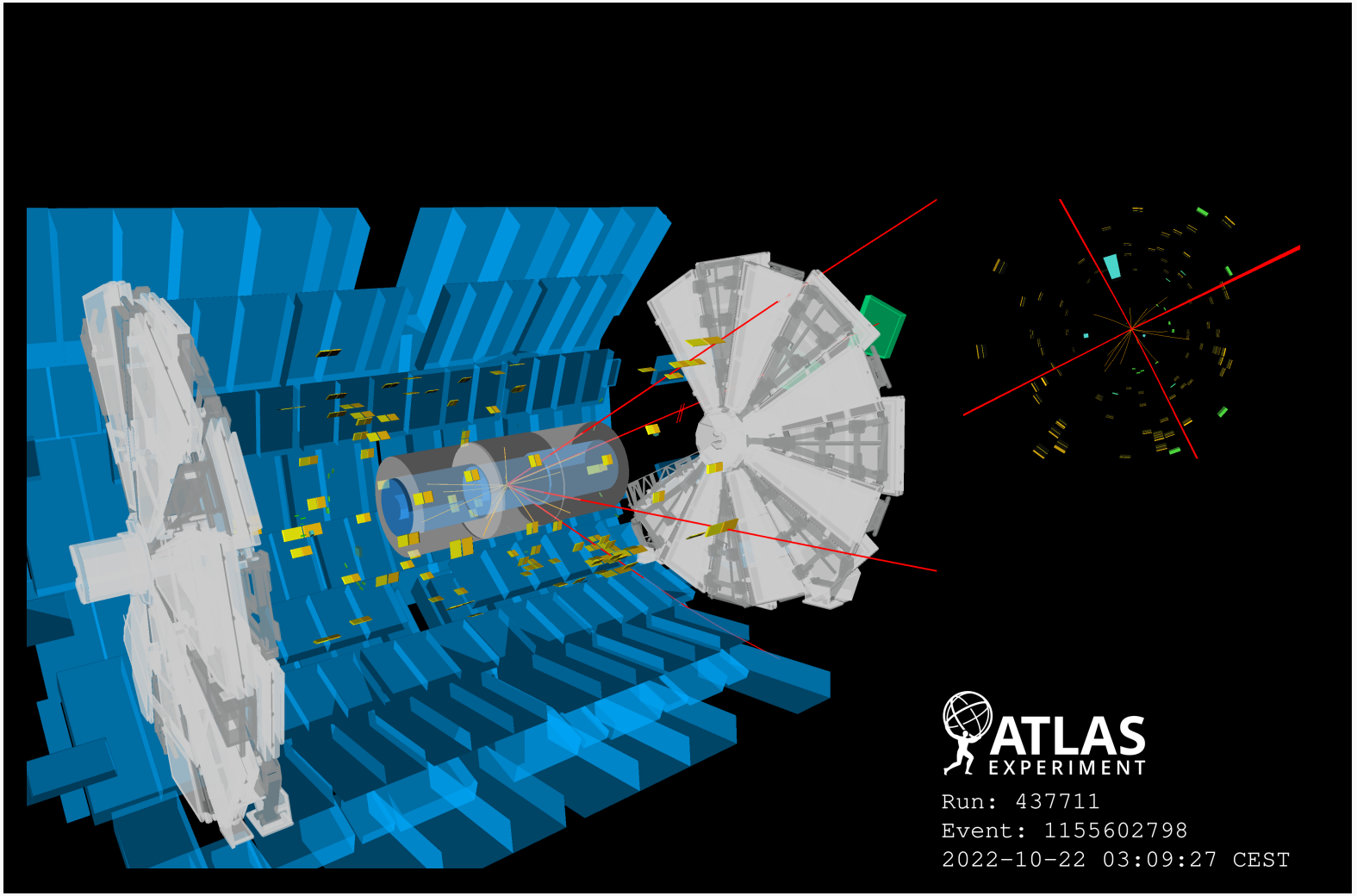


Figure 1: Candidate of an HZZ event in 4μ channel, with m_{4l}=125.6GeV

Background Estimation

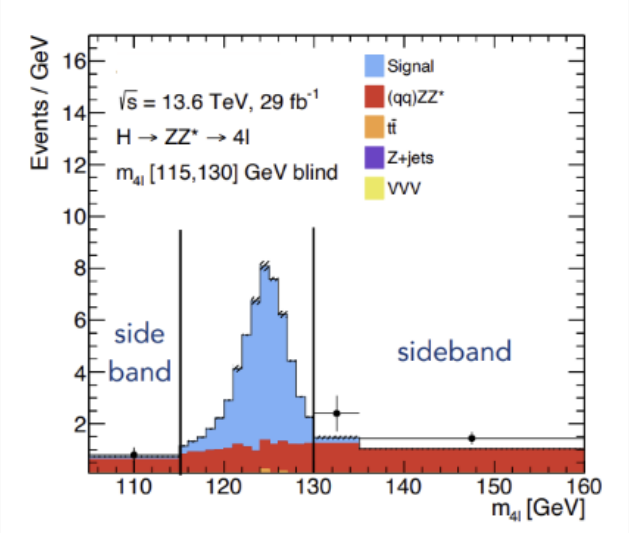
Irreducible Background

Major irreducible background process:

- ZZ^* production via $q\bar{q}$
- ZZ^* production via gluon fusion
- triboson: from mc
- ttZ: from mc

Simultaneous extraction of normalization in sideband:

- For reduction of theoretical systematic on qqZZ and ggZZ
- sideband: [105GeV, 130GeV] and [130GeV, 160GeV]



Z + $\mu\mu$ Background Estimation

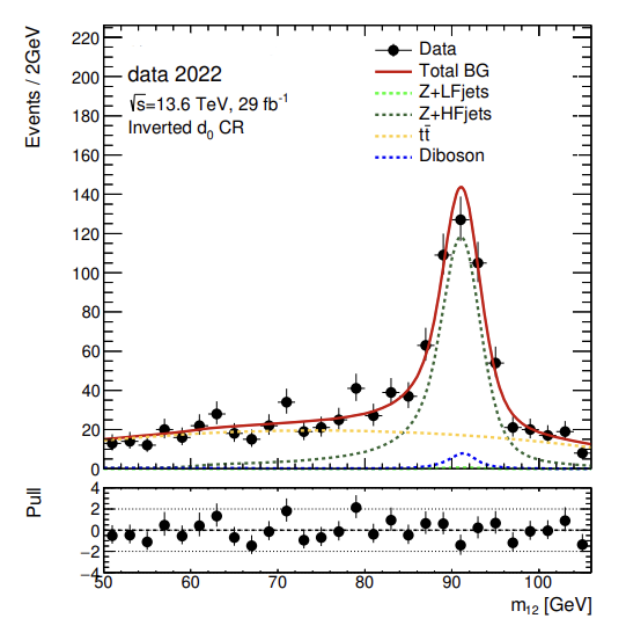
leading components: Z + **H**eavy **F**lavor, other contributions: Z+LF, ttbar, WZ
Unbinned simultaneous fit on m_{12} shape in 4 orthogonal CRs(different cuts on subleading pair):

- **Invert d0 in sub pair**: HF enriched
- **Invert Isolation in sub pair**: LF enriched
- **Same Sign in sub pair**: ttbar enriched
- **Different flavor in leading pair**: all Bkgs

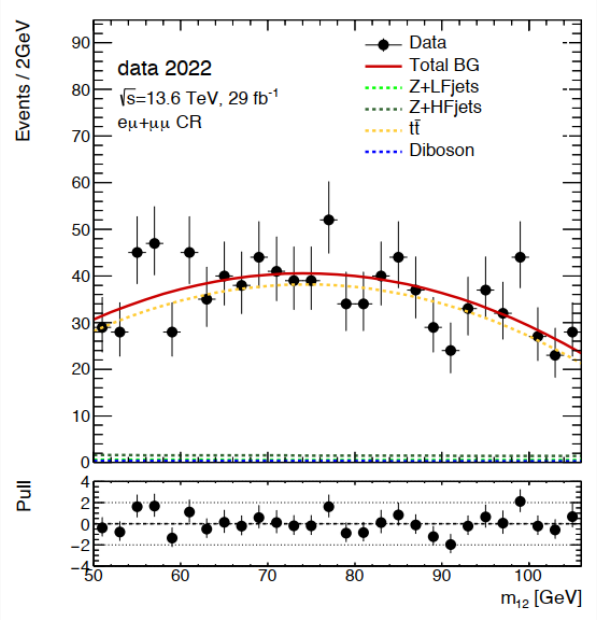
Z + $\mu\mu$ Background Estimation

Relaxed Iso/d0 CR: similar cut on SR, but **without cuts on Iso, d0 and vertex**.

- validation region
- not orthogonal to SR, not included in fitting.
- SR yields extrapolated from this region.



(a) Inverted d_0 region



(b) Different flavor region

Z + *ee* Background Estimation

estimate performed in 3l+X CR:

- similar to nominal 4l selection
- relaxed ID cut on lower pt electron in sub-lead pair
- same sign requirement in sub-lead pair to keep orthogonality

Origin of X:

- semi-leptonic decay of heavy quark(**q**): from mc
- light jet faking electron (**f**)
- photon conversion (γ)

Fitting number of pixel layer hits to get **f** and γ from data
Extrapolation from 3l+X CR to SR

- transfer factor evaluated from Z+X dedicated control sample
- As a function of X pT

Fiducial Cross Section Measurement

Fiducial Definition and Fitting Strategy

Fiducial region: defined in truth level for stable leptons, but very close to detector acceptance.

$$N_i(m_{4\ell}) = \sum_i \epsilon_i \times (1 + f_i^{nofid}) \times \sigma_i^{fid} \times \mathrm{PDF}(m_{4\ell})_i \times \mathcal{L}_{\mathrm{int}} + N_i^{bkg}(m_{4l}) \ ,$$

$$\sigma_i^{fid} = \sigma_i^{total} \times A_i \times Br_i$$

- i: 4μ, 4e, 2μ2e, 2e2μ
- A_i = Acceptance = N_{fid}/N_{total} around **50%**
- ϵ_i = reco efficiency = $N_{reco\&fid}/N_{fid}$ around **25%-50%**
- f_i^{nofid} = fiducial leakage = 1 - $N_{reco\&fid}/N_{reco}$ around **1%**
  - fraction of events outside fiducial region, but fall in reco-level signal region

All channels fitted simultaneously

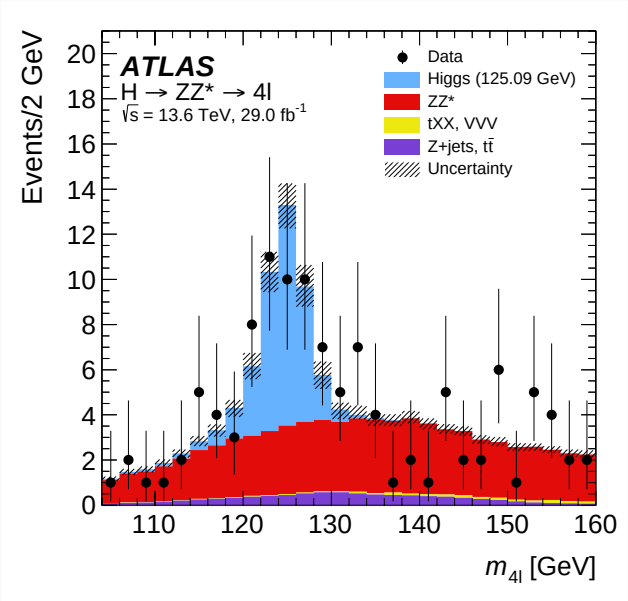
Post-fit Result

$H \to ZZ^* \to 4\ell$ cross-section:

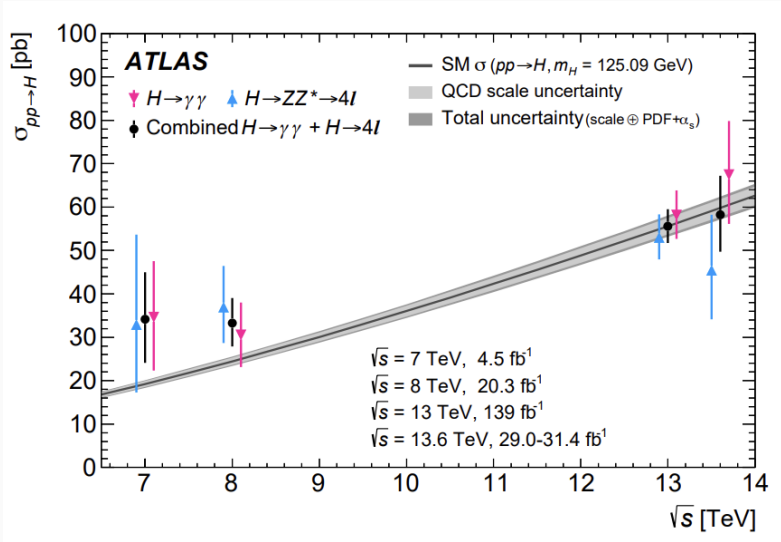
- σ_{fid} = 2.80 $\pm$ 0.70 (stat.) $\pm$ 0.21 (syst.) fb
- $\sigma_{fid,SM}$ = 3.67 $\pm$ 0.19 fb

Total $pp \to H$ cross-section:

- σ_{total} = 46 $\pm$ 12 pb
- Combination with $H\gamma\gamma$: σ_{total} = 58.2 $\pm$ 8.7 pb



(a) Post-fit m4l



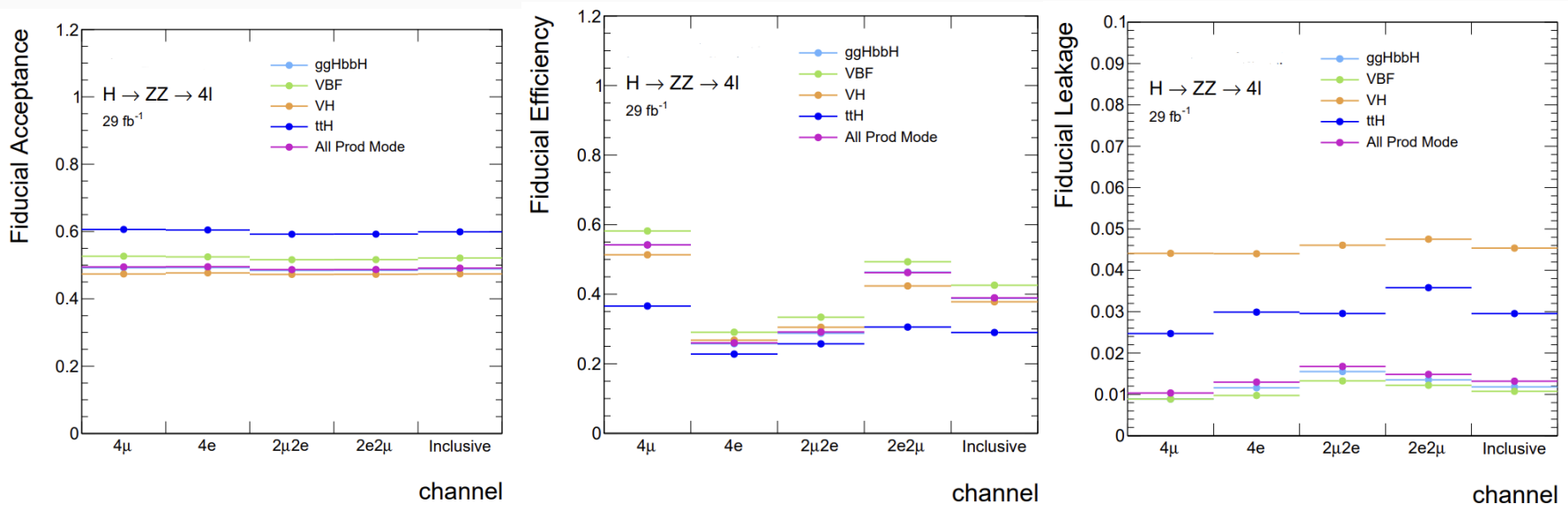
(b) Combination with $H\gamma\gamma$

Conclusion

Summary

Fiducial cross section of $H \to ZZ^* \to 4\ell$ measure@13.6TeV
Extrapolated to total phase space to measure total $pp \to Higgs$ cross section
All values compatible with standard model prediction

Acceptance, Efficiency and Fiducial



(a) Acceptance (b) Reco Efficiency (c) Fiducial Leakage

Backup

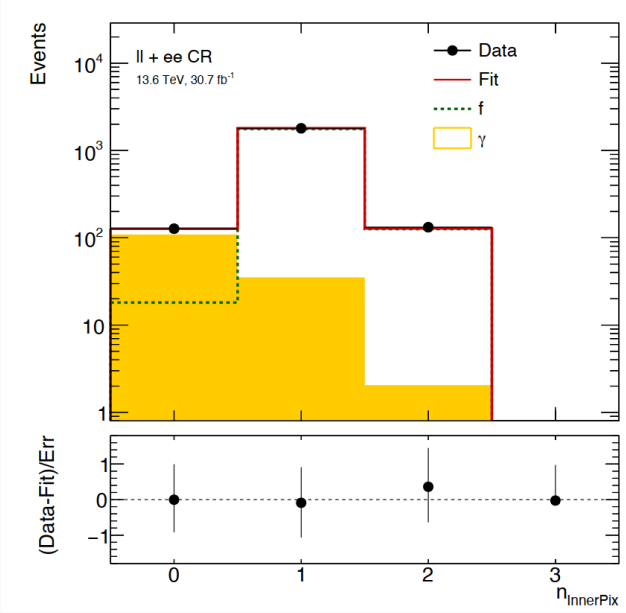


Table 1: Fit result for Zee bkg yields with statistical errors

type	data fit	ZZ^* + HF	efficiency[%]	SR yield
f	2168.8 ± 47.6	229.6 ± 3.0	0.18 ± 0.03	$3.52 \pm 0.14 \pm 0.54$
γ	171.2 ± 16.4	18.3 ± 0.4	0.55 ± 0.10	$0.83 \pm 0.15 \pm 0.04$
q	(MC-based estimation)			2.35 ± 0.73

type	data fit	extrapolation factor [%]	SR yield
ttbar	559 ± 21	0.28 ± 0.03	$1.54 \pm 0.06 \pm 0.15$
Z+jets (HF)	619 ± 45	0.38 ± 0.23	$2.36 \pm 0.17 \pm 1.40$
Z+jets (LF)	13 ± 10	1.5 ± 0.3	$0.19 \pm 0.14 \pm 0.04$)
Z+jets (HF+LF)	623 ± 35		$2.37 \pm 0.13 \pm 1.41$
WZ	MC-based estimation		0.26 ± 0.33