ATLAS Searches for Higgs Boson Decays to BSM Dark-Z Bosons in Four-Lepton Final States

Theodota LAGOURI [1]
on behalf of the ATLAS Collaboration
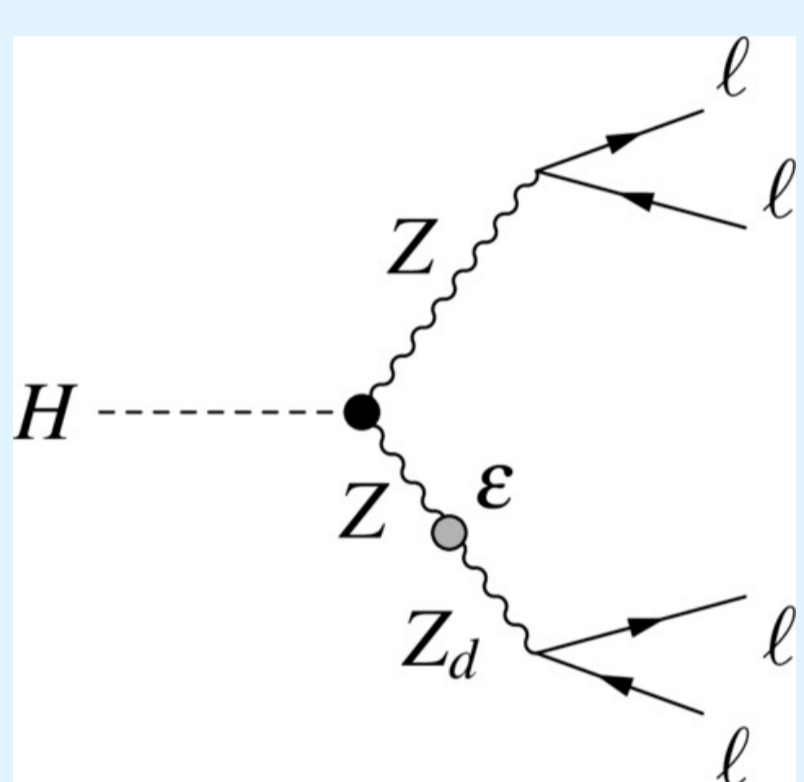ICNFP 2021 23 August-2 September, Crete, Greece
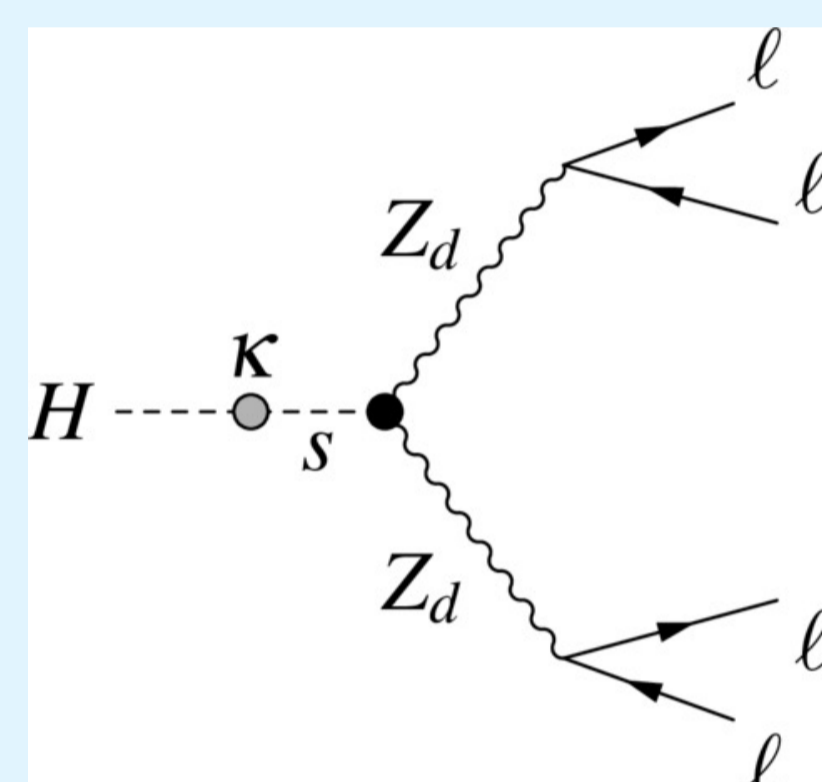
ATLAS-CONF-2021-034

Abstract

ATLAS searches for a BSM light boson using events where a Higgs boson with mass 125 GeV decays to four leptons are reported. This decay is presumed to occur via an intermediate state which contains one or two on-shell, promptly decaying bosons: $H \to ZX/XX \to 4l$, where X is a new dark vector boson Z_d (or a pseudo-scalar a), with an invariant mass between 1 and 60 GeV. These exotic Higgs decays searches use 139 fb^{-1} of p-p collision (Run-2) data at $\sqrt{s}$=13 TeV collected with the ATLAS detector at the LHC. The results are found to be consistent with SM background predictions and both fiducial model independent limits as well as limits with interpretations in specific benchmark theory models are set.
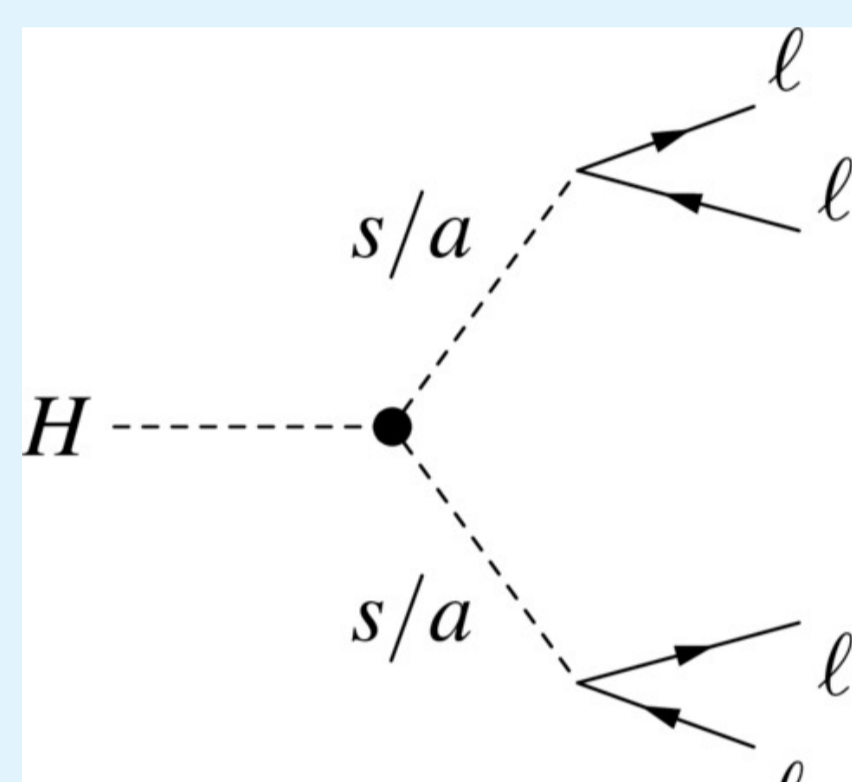
Introduction & Motivation

- B(Higgs → BSM) could be as large as $O(10\%)$
- Dark sector interactions could be mediated by a new massive $U(1)$ gauge boson Z_d
- It could couple to SM Higgs via mixing with Z boson or
- Dark sector Higgs S could mix with SM Higgs Boson

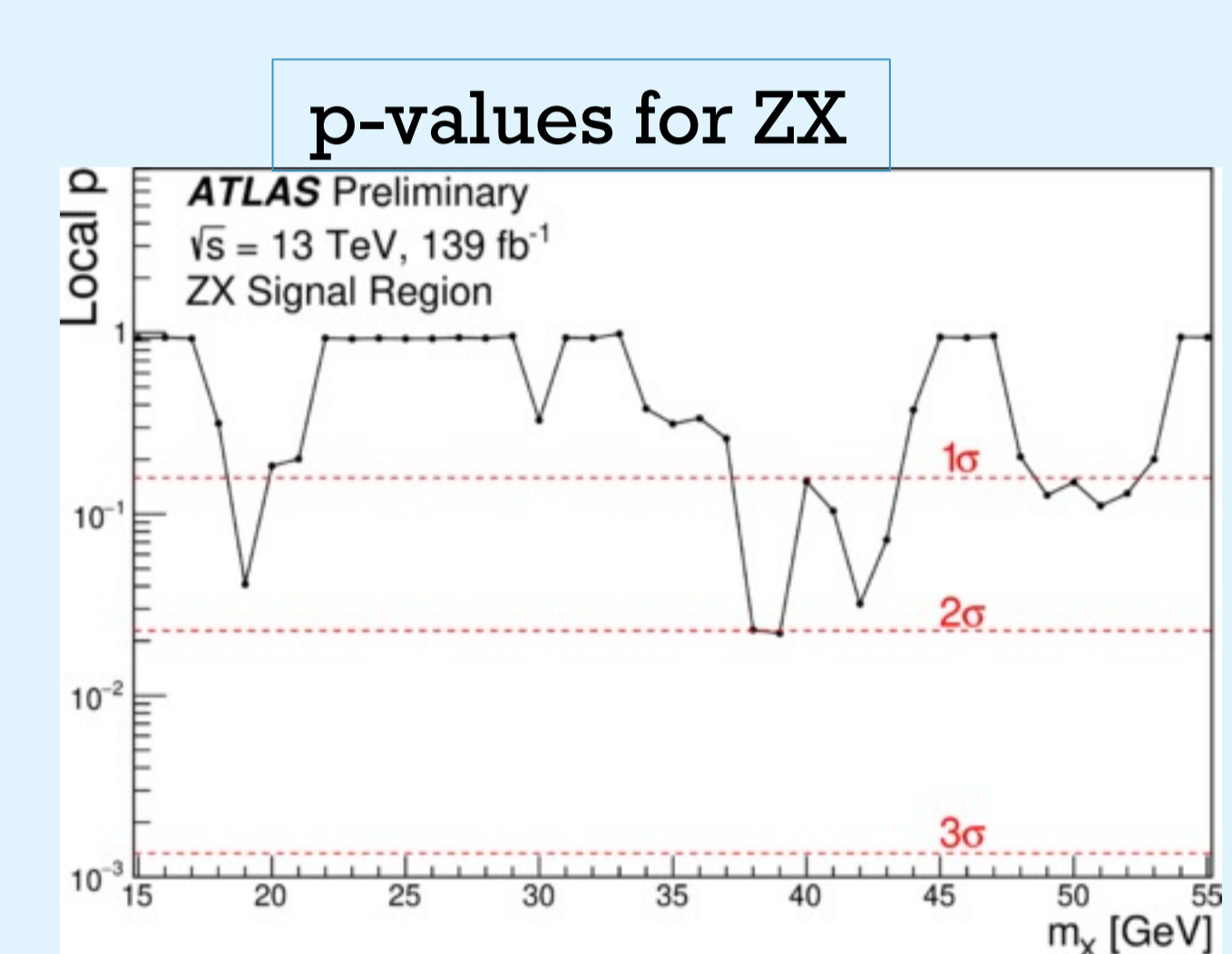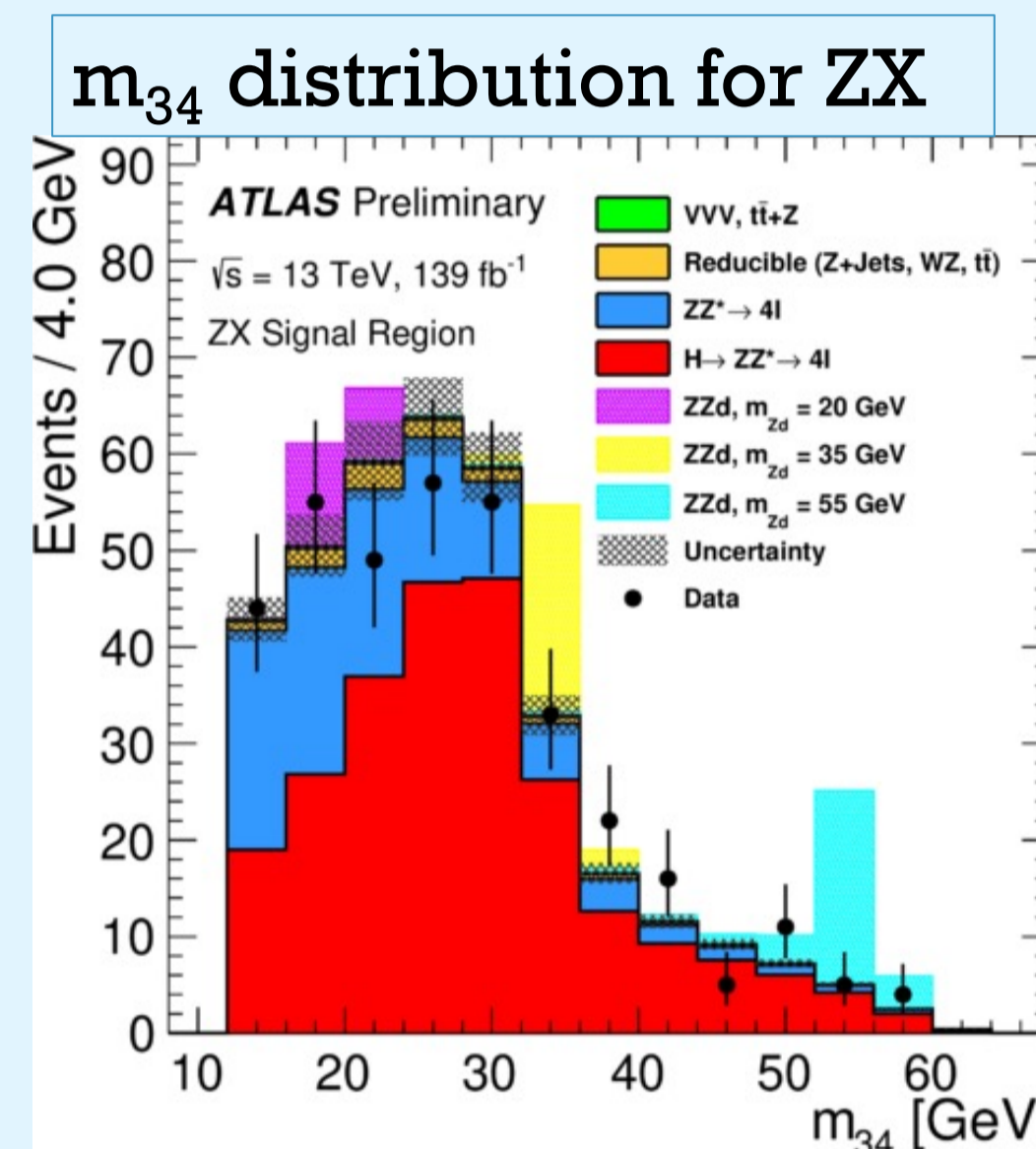Kinetic mixing parameter ϵ (controls coupling between Z_d & SM Z)

Dark Higgs S, coupling κ (controls coupling between S and H)

2HDM+S model allow Higgs to couple to a new low mass (pseudo)scalar s (α) states

ZX Overview

- Quadruplet ranking (if more than one quadruplet in event):
  - In order $4\mu > 2e2\mu > 2\mu2e > 4e$
  - Resolve ambiguities by:
    - smallest $|m_Z - m_{12}|$, smallest $|m_Z - m_{34}|$
- One di-lepton pair m_{12} compatible with Z boson mass
- Signal region: the other di-lepton pair m_{34}
- 50 GeV< m_{12} <106 GeV & 12 GeV < m_{34} < 115 GeV
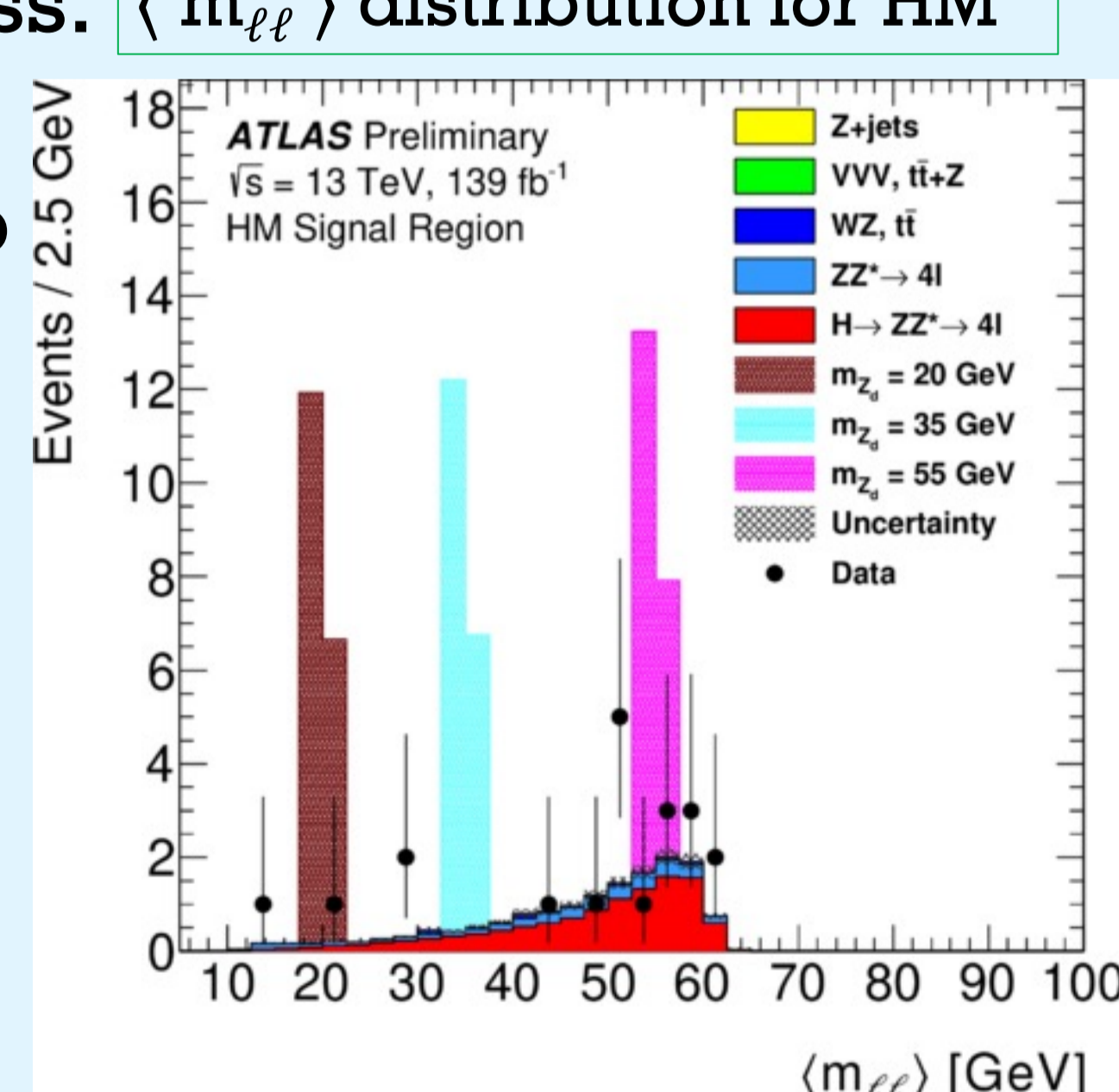

m34 distribution for ZX

p-values for ZX

Analysis Overview
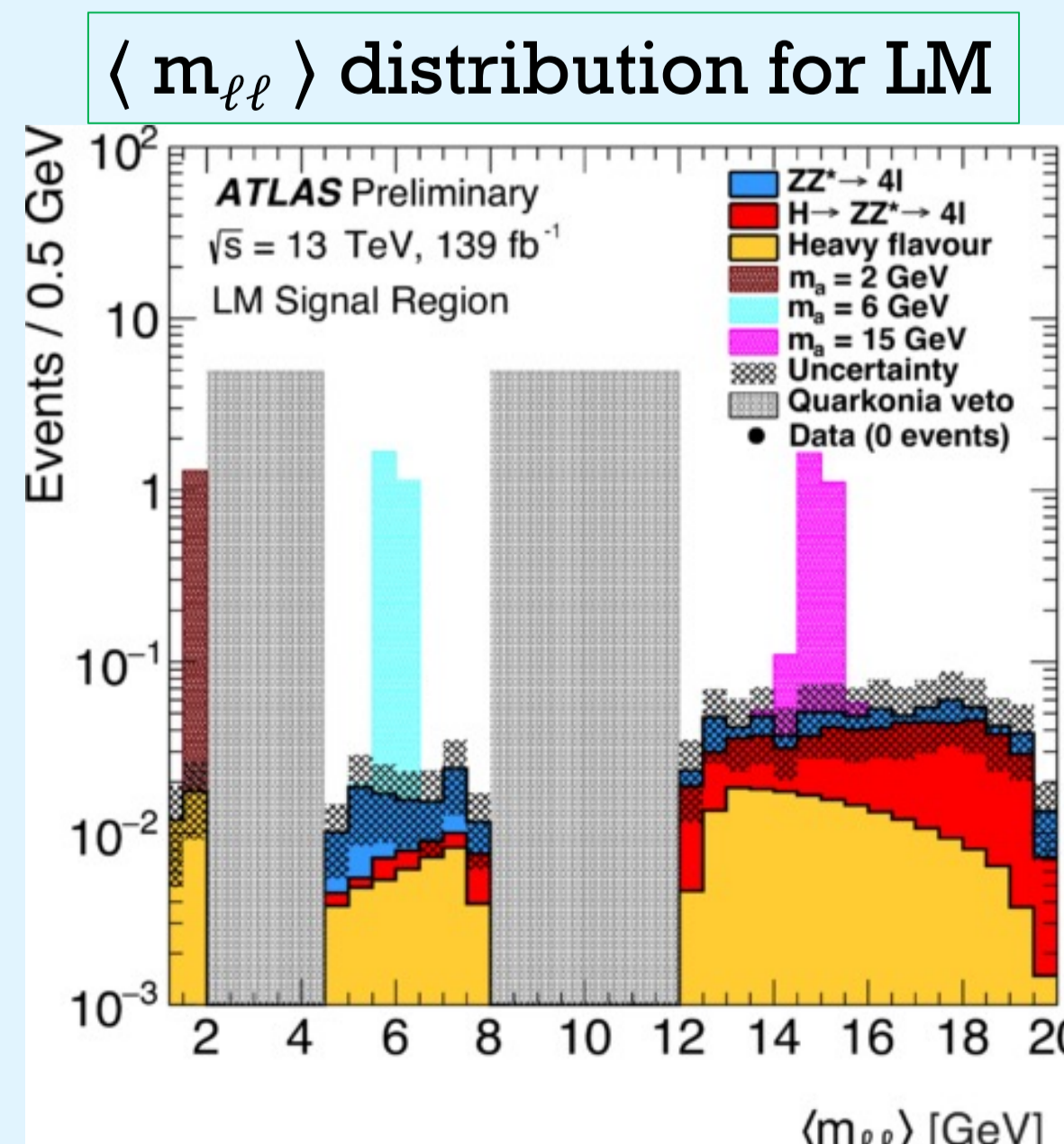
- Search for exotic decays of the Higgs in four lepton final states, 3 channels, where ℓ= e, μ
  1. High-mass (HM): H→XX→4ℓ, 15 GeV< m_X < 60 GeV
  2. Low-mass (LM): H →XX →4μ, 1 GeV< m_X < 15 GeV
  3. ZX channel: (ZX) H→ZX→4ℓ, 15 GeV< m_X < 55 GeV
- Select two pairs of prompt Same Flavor Opposite Sign (SFOS) leptons ($|m_{12} - m_Z| < |m_{34} - m_Z|$)
- Four-lepton invariant mass: 115 $GeV < m_{4\ell}$ < 130 GeV

HM Overview

- Similar di-lepton invariant mass:
  - smallest $\Delta m_{\ell\ell} = m_{12} - m_{34}$
- Veto Z bosons (applied also to alternative pairings)
- Veto quarkonia
- Signal region: $m_{34}/m_{12} > 0.85 - 0.1125 f(m_{12})$
- 1D display of signal region: $<m_{\ell\ell}> = 1/2 (m_{12} + m_{34})$

⟨ m$_{\ell\ell}$ ⟩ distribution for HM
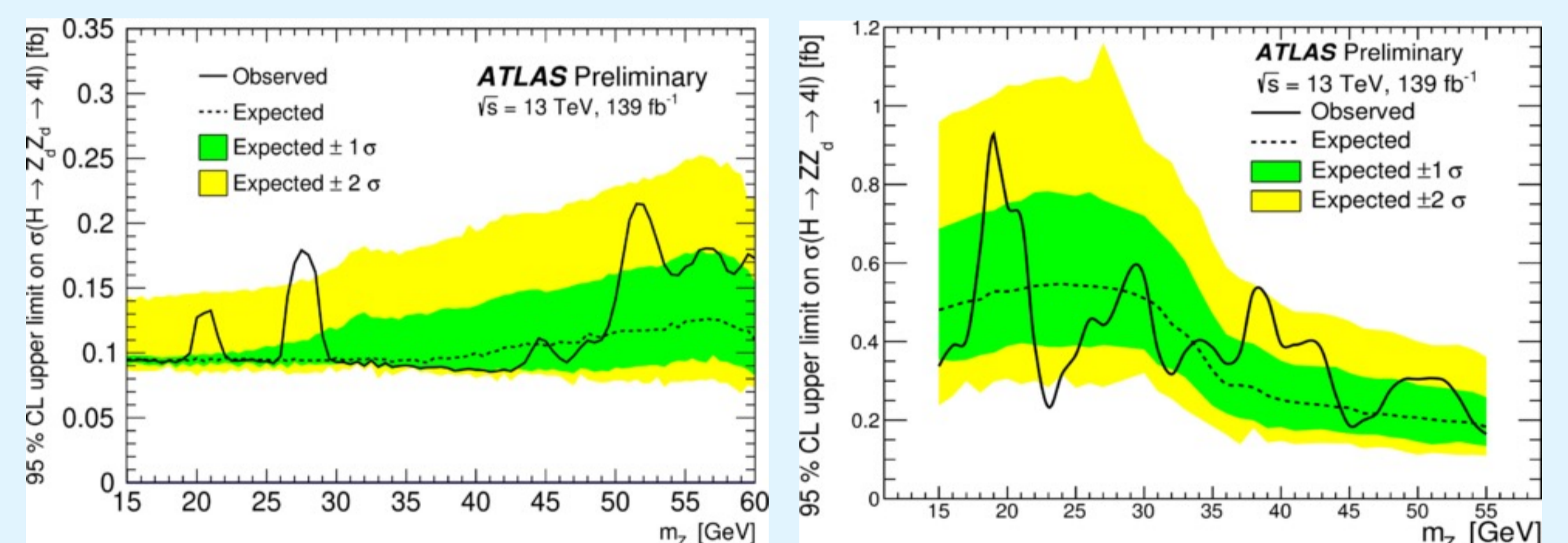
LM Overview

⟨ m$_{\ell\ell}$ ⟩ distribution for LM

No events observed
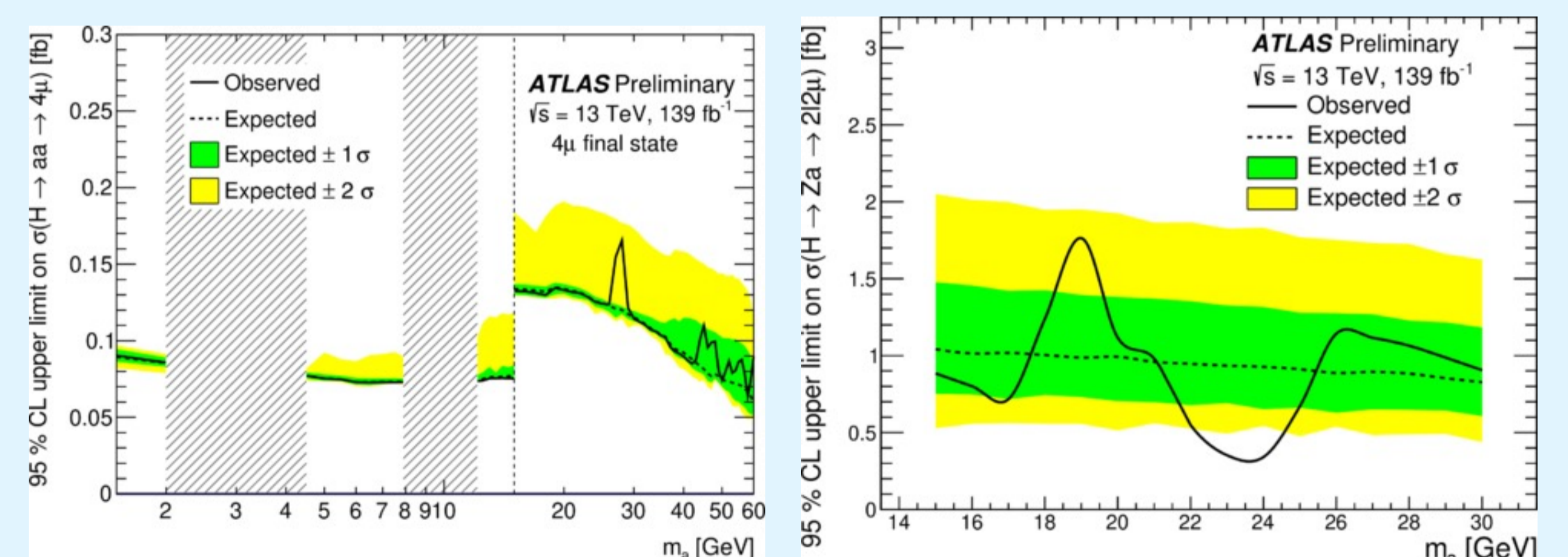
- No Z-veto
- Extended quarkonia veto:
  - $m_{\ell\ell} \notin$ [2 GeV, 4.4 GeV]
  - $m_{\ell\ell} \notin$ [8 GeV, 12 GeV]
- Narrower Higgs mass window:
  - 120 GeV < $m_{4\ell}$ < 130 GeV
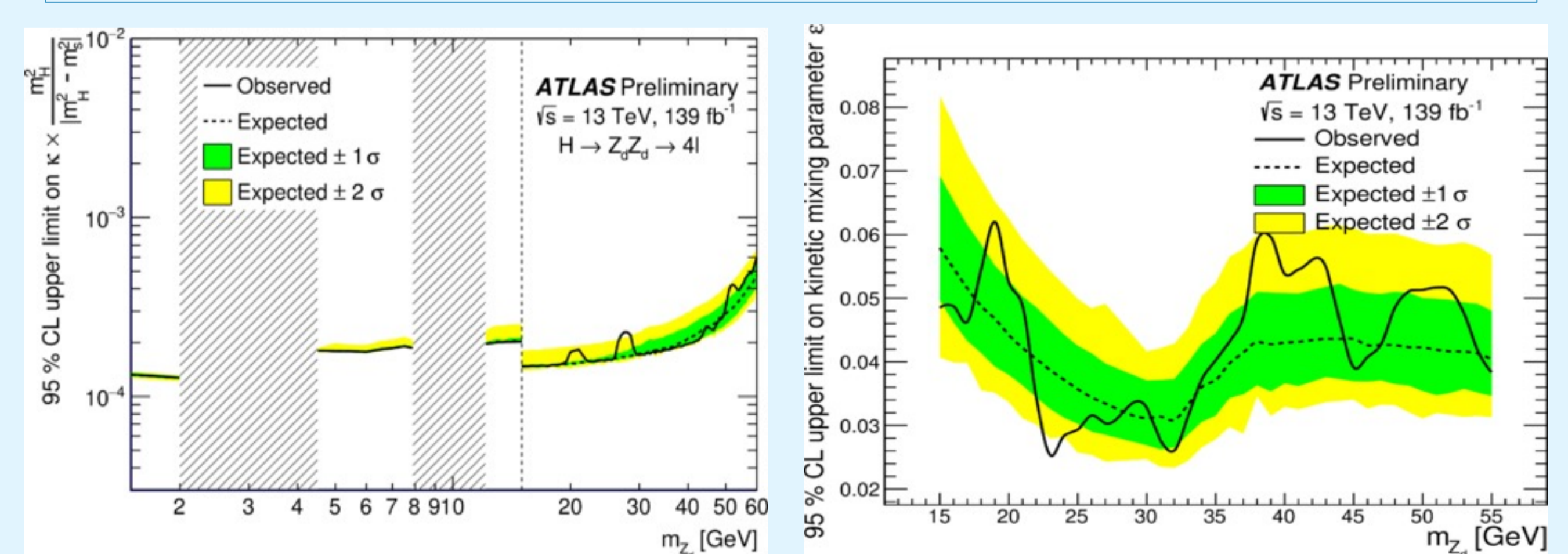- Signal region requirement:
  - $m_{34}/m_{12} > 0.85$

Analysis Results

Limits at 95% CL on $\sigma(H \to Z_d Z_d \to 4\ell)$ and $\sigma(H \to ZZ_d \to 4\ell)$

Limits at 95% CL on $\sigma(H \to \alpha\alpha \to 4\mu)$ and $\sigma(H \to Z\alpha \to 2\ell2\mu)$

Limits on Higgs mixing parameter κ' and Z_d mixing parameter ε

Conclusions

- No significant excess observed above SM background predictions
- Upper limits set on fiducial ($H \to XX / ZX$) and total cross sections ($H \to Z_dZ_d / ZZ_d \to 4\ell$ and $H \to aa / Za \to 4\mu$)
- Interpretations (HAHM, 2HDM+S) provided on mixing parameters: higgs coupling parameter κ, Z_d kinetic mixing ε, Z-Z_d mass mixing δ

References:
1. JHEP 06 (2018) 166
2. Phys. Rev. D 92 (2015) 092001
3. ATLAS-CONF-2020-027

(1) Affiliation: UTA, Chile