NNV ANNUAL MEETING, LUNTEREN

MEASURING THE HIGGS BOSON LIFETIME

OFFSHELL HIGGS → ZZ → LLVV ANALYSIS AT ATLAS

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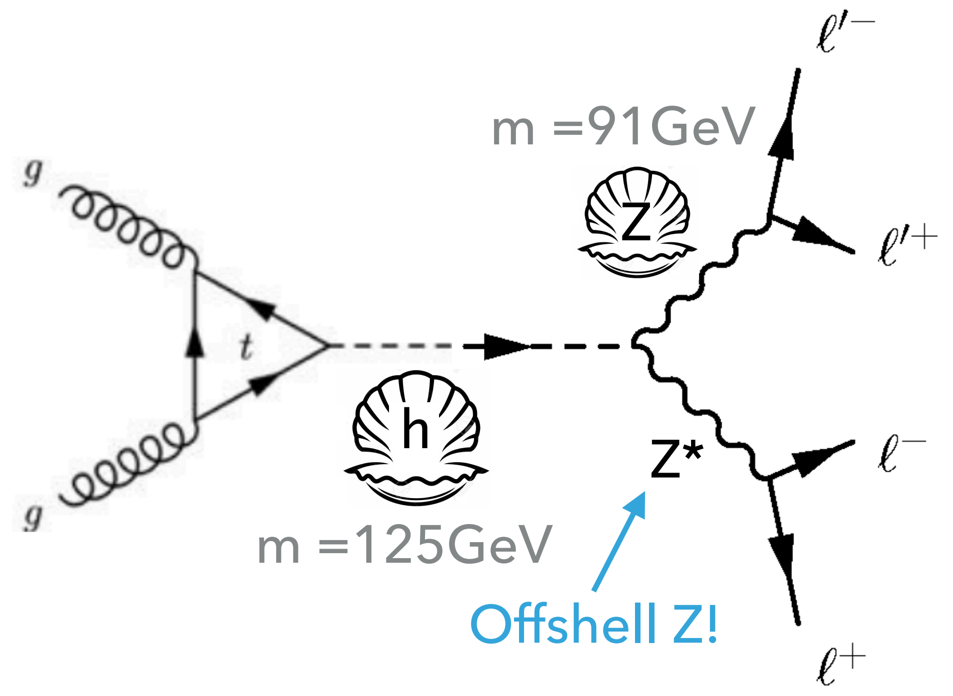
ATLAS DETECTOR

- General purpose particle detector at the Large Hadron Collider (LHC)

HIGGS LIFETIME

- In 2012, the Higgs Boson was discovered by ATLAS+CMS
- Completed the set of Standard Model particles
- We want to know and test its properties, e.g. the lifetime
- If the lifetime differs from the prediction, this will indicate physics beyond the Standard Model
- Onshell Higgs production at the LHC, mainly $gg \rightarrow h$



ONSHELL: MEASURING THE HIGGS WIDTH

- Higgs lifetime can be measured directly from the width of the mass peak

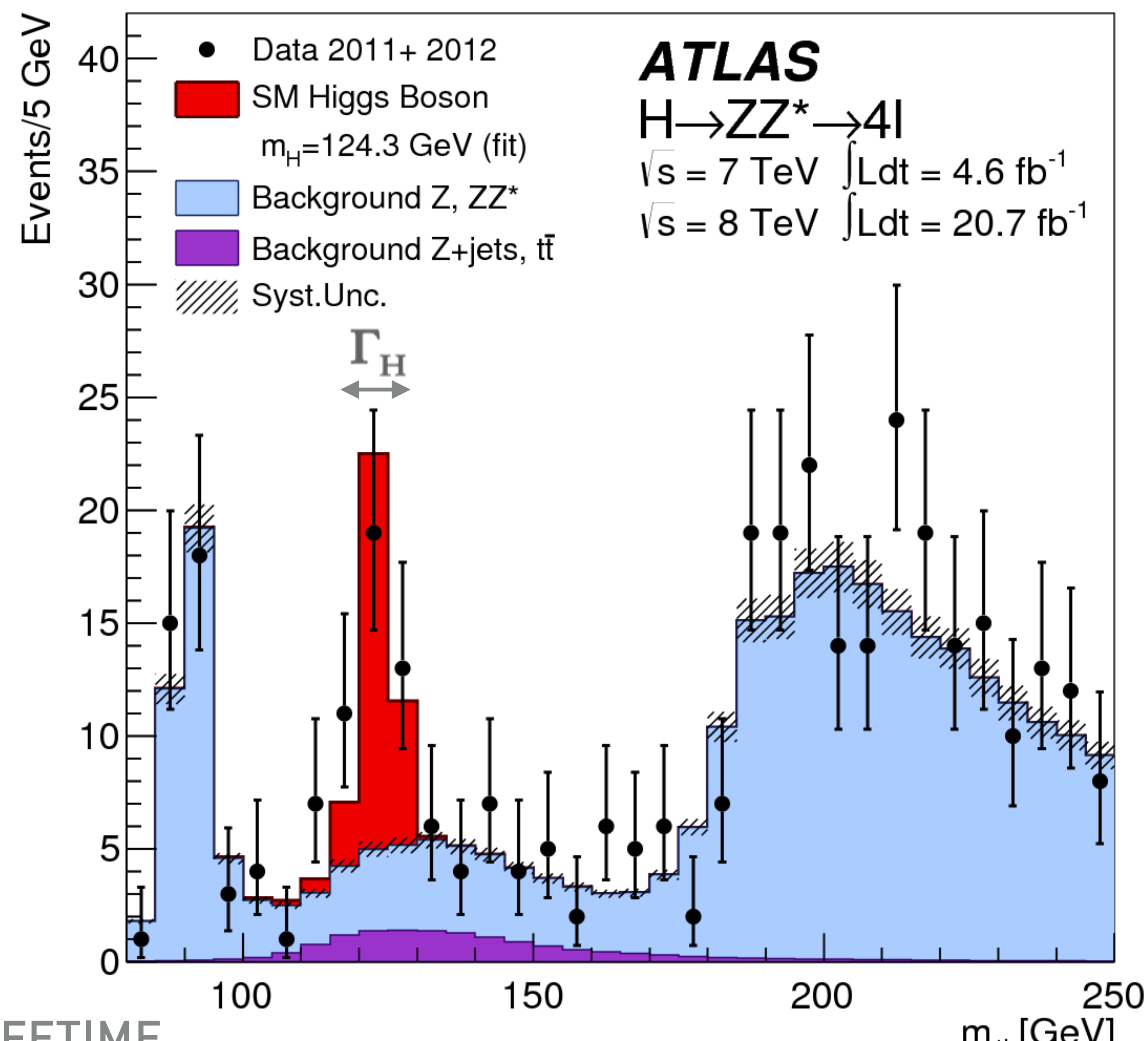
- ATLAS Measurement

  Γ_H < 2.6 GeV

SM prediction

  Γ_H ~ 4.1 MeV

- Limited by detector resolution



MEASURING THE HIGGS WIDTH

Onshell

$$\frac{d\sigma^{pp\to H\to ZZ}_{on-shell}}{dM^2_{ZZ}} \sim \frac{g^2_{Hgg}g^2_{HZZ}}{m^2_H\Gamma^2_H}$$

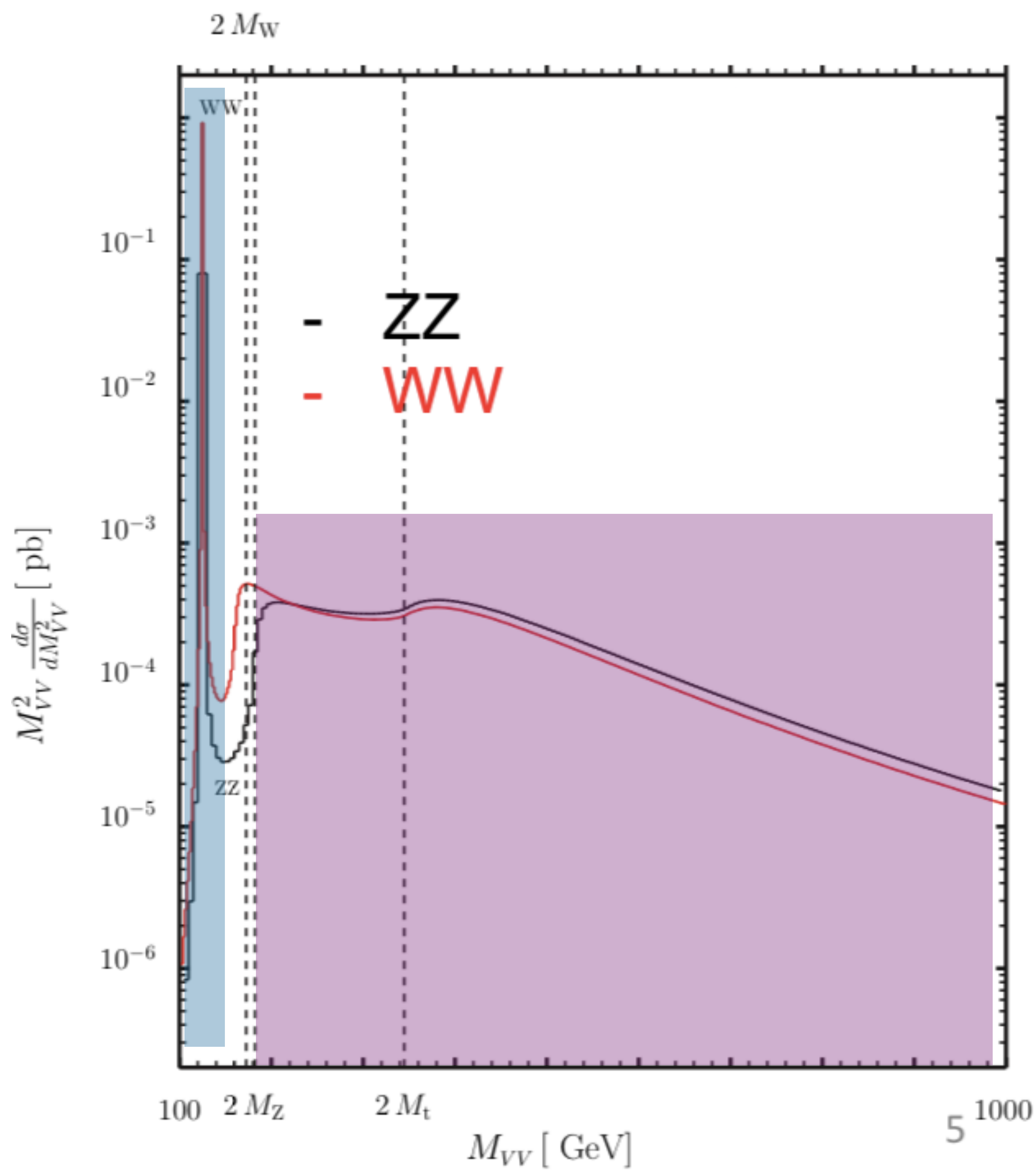
$$\div$$

Offshell

$$\frac{d\sigma^{pp\to H\to ZZ}_{off-shell}}{dM^2_{ZZ}} \sim \frac{g^2_{Hgg}g^2_{HZZ}}{\left(M^2_{ZZ}-m^2_H\right)^2}$$

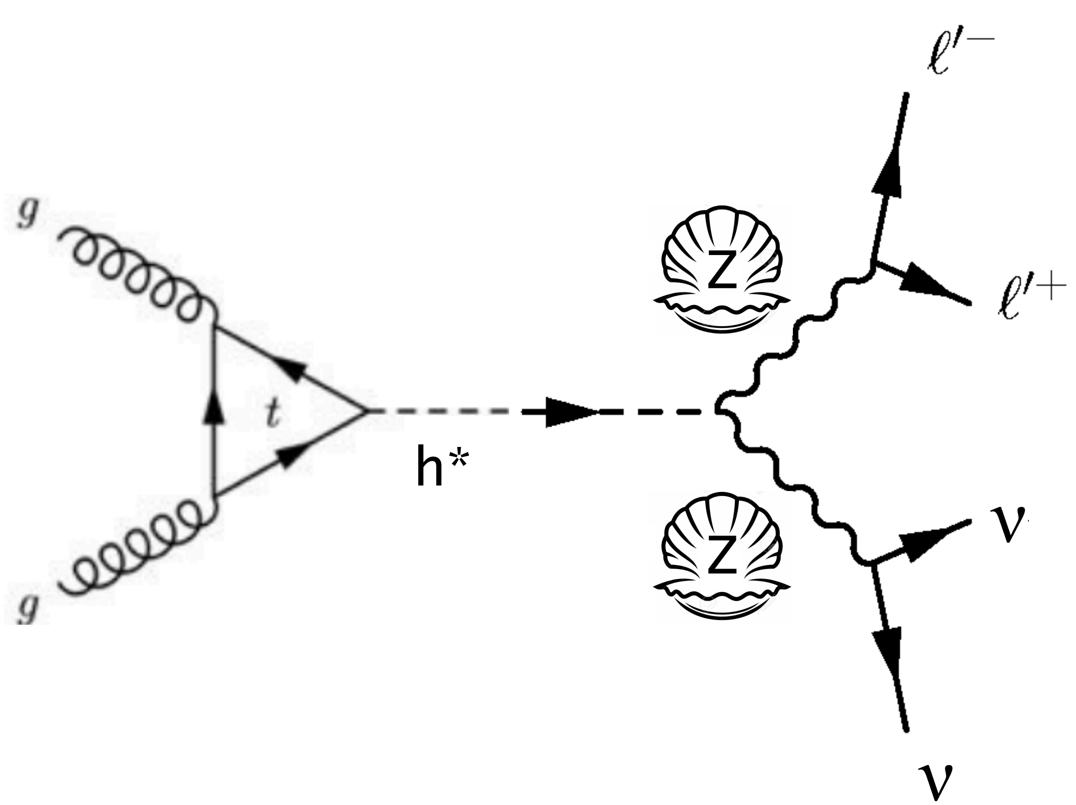
$$\downarrow$$

$$\frac{\sigma_{offshell}}{\sigma_{onshell}} \propto \Gamma_H$$



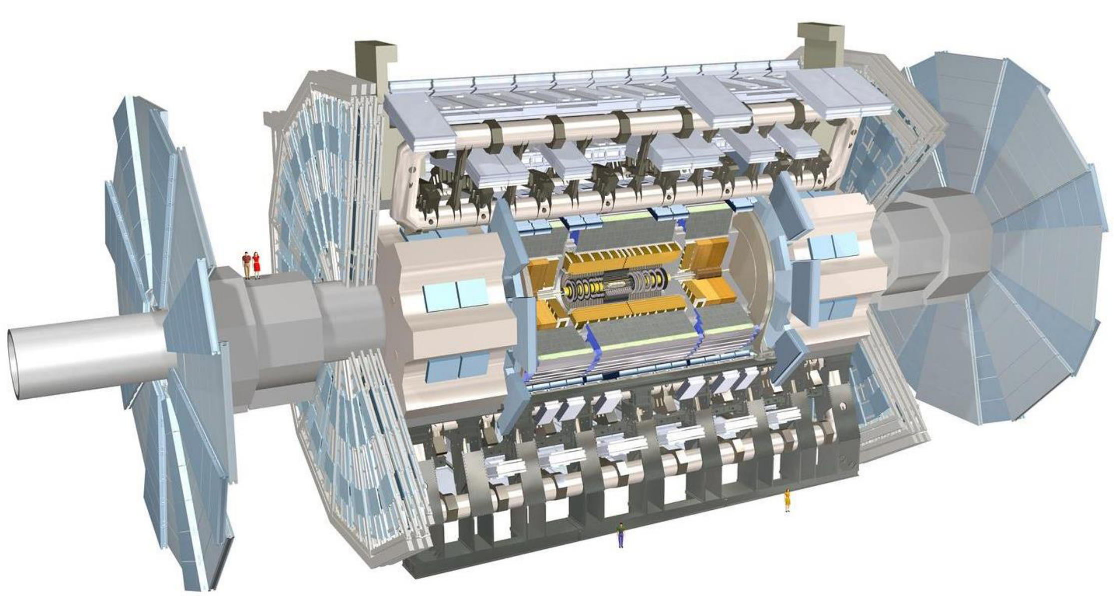
OFFSHELL MEASUREMENT

- Energy range from 300 GeV to 2 TeV
- Higgs → llνν analysis is complementary to Higgs → 4l
- Higher yield, due to higher branching ratio
  - BR(ZZ→llνν) ~ 6 BR(ZZ→4l)

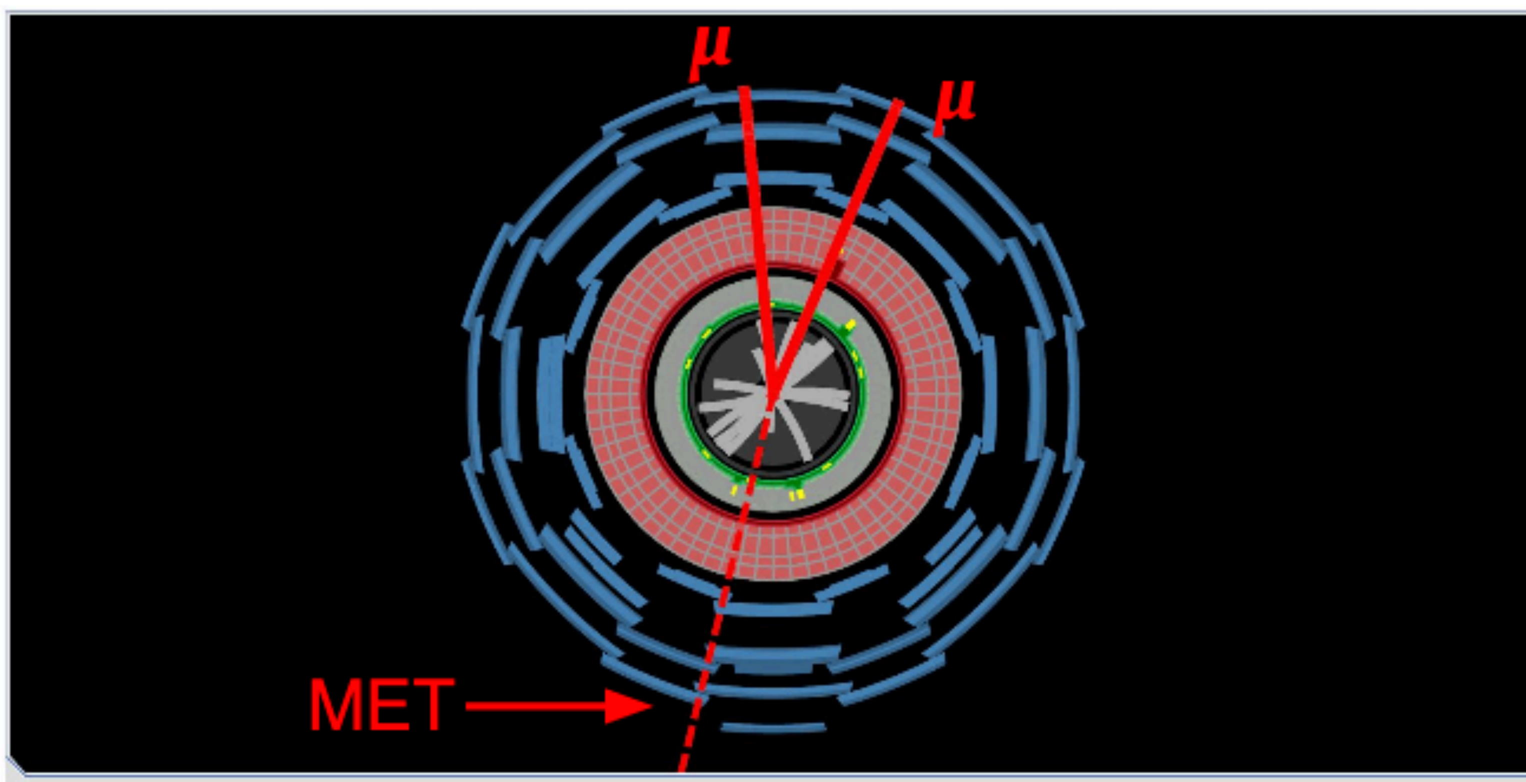


MISSING TRANSVERSE ENERGY (MET)

- No transverse momentum (to the beam) in collision
- ATLAS measures momentum of all particles in 4π circumference
- Undetected particles generate missing transverse momentum
  - This we can measure!
- Allows us to ‘detect' neutrinos

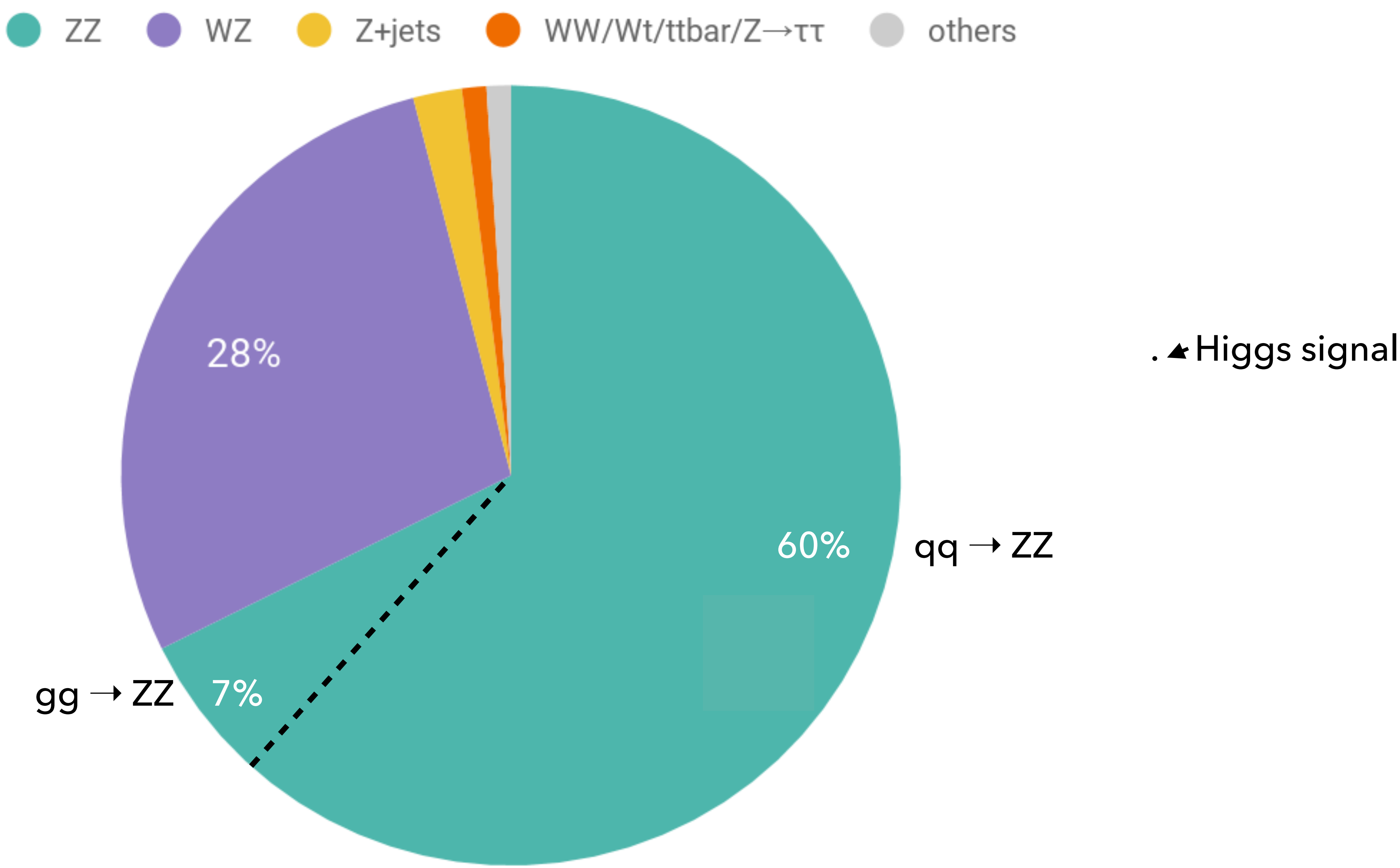


Candidate high-mass H(ZZ) event:



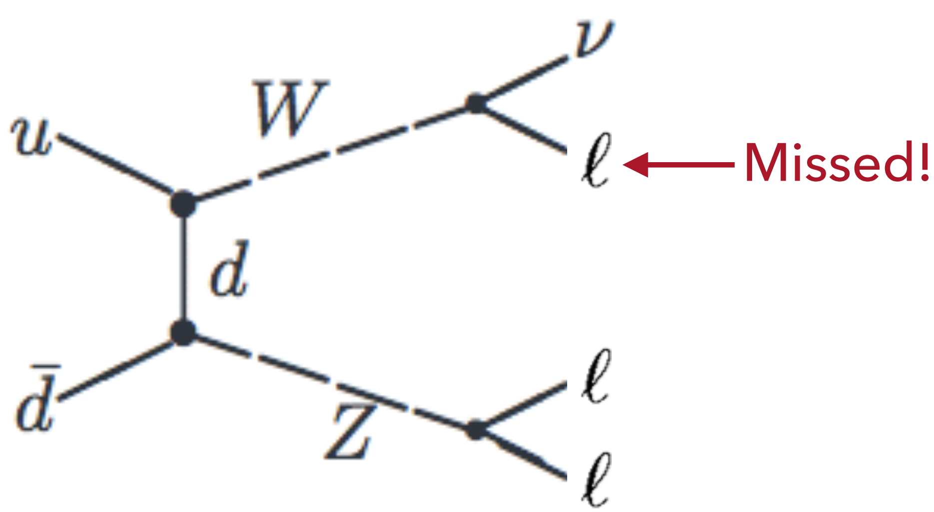
BACKGROUNDS

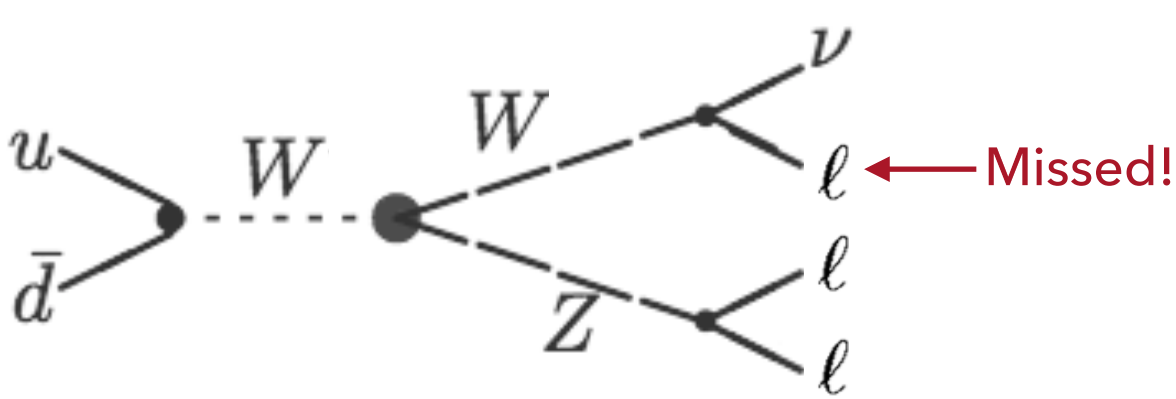
- Backgrounds can have the same signature (ZZ, WW), missing particles (WZ) or fake MET (Z+jets)

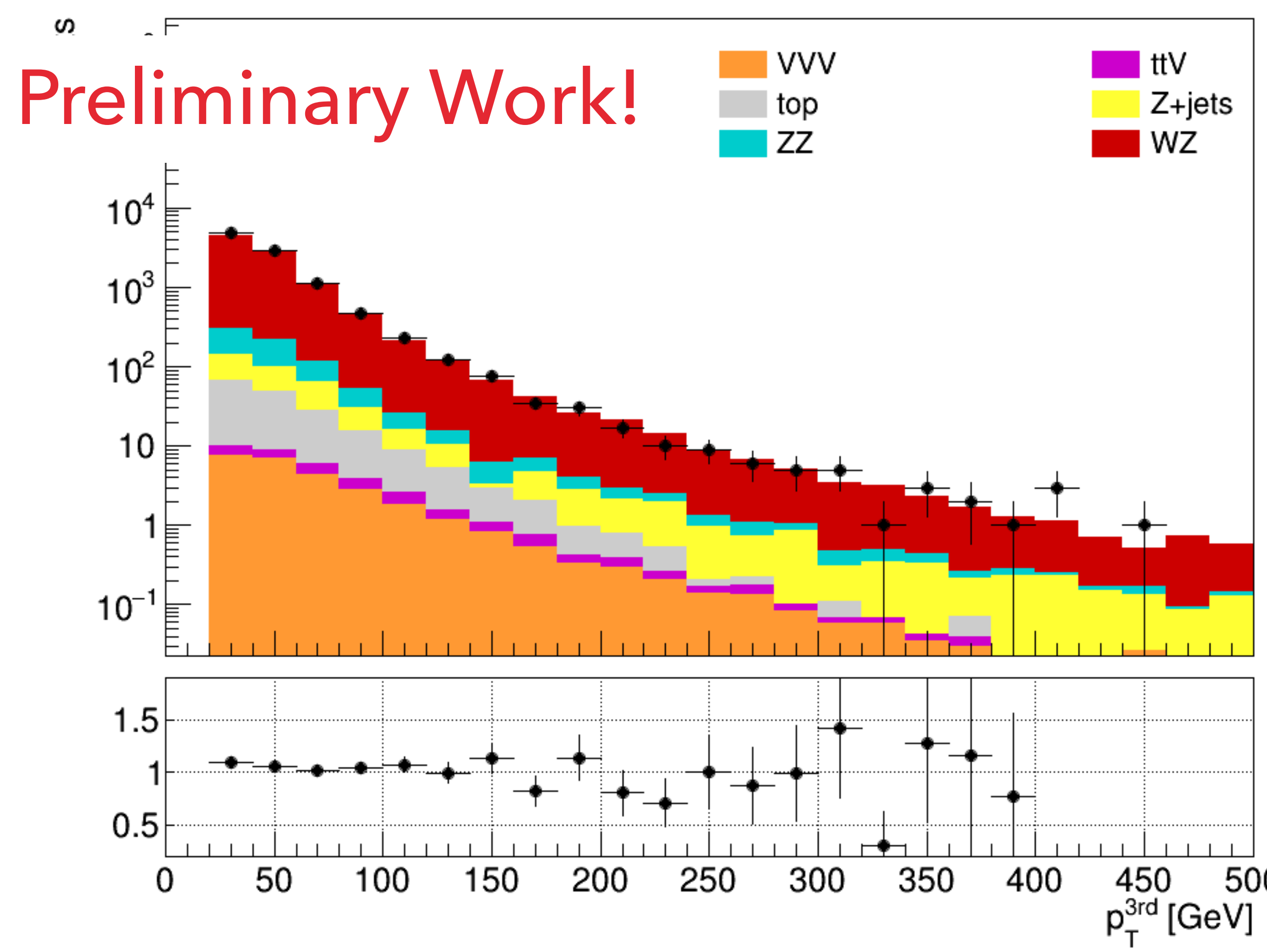


WZ: CONTROL REGION

- WZ backgrounds arise when we miss the lepton from the W decay
- We need to test our understanding of the WZ process
- Define a 'control region' where we select events with 3 leptons: >90% WZ!

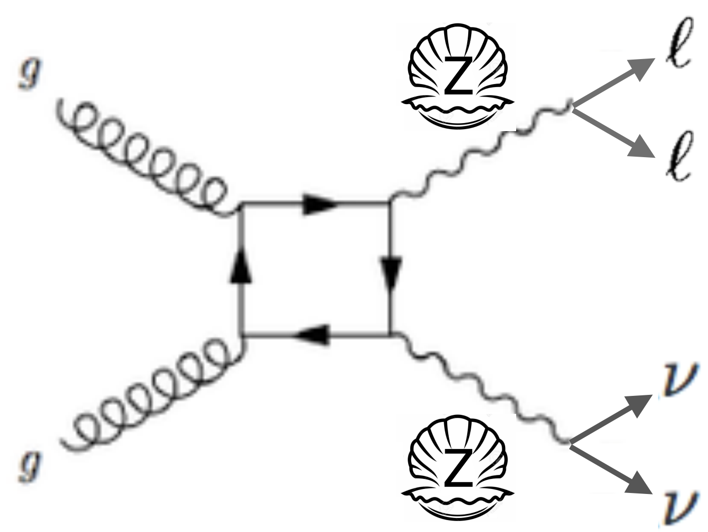


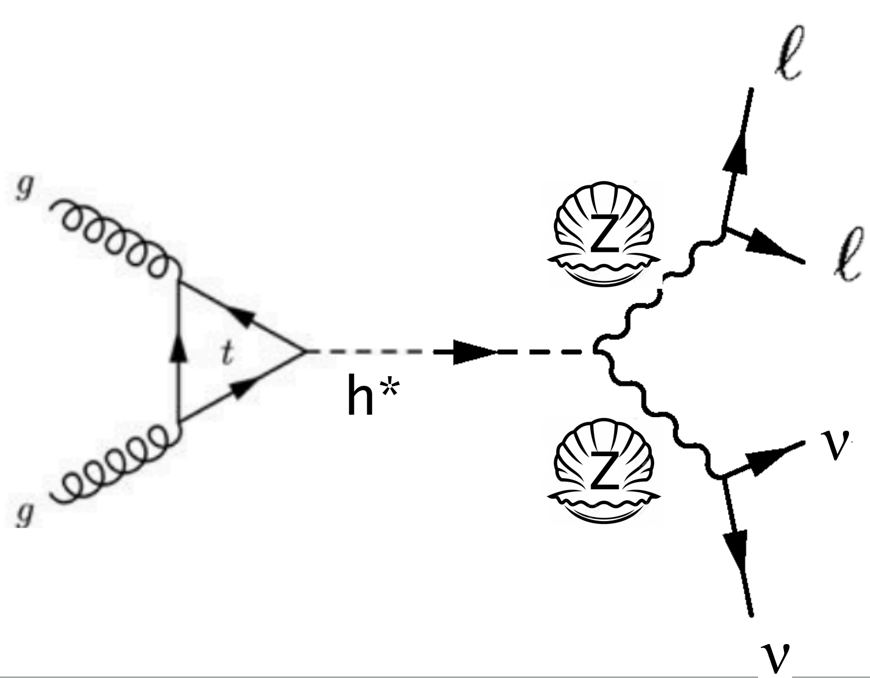


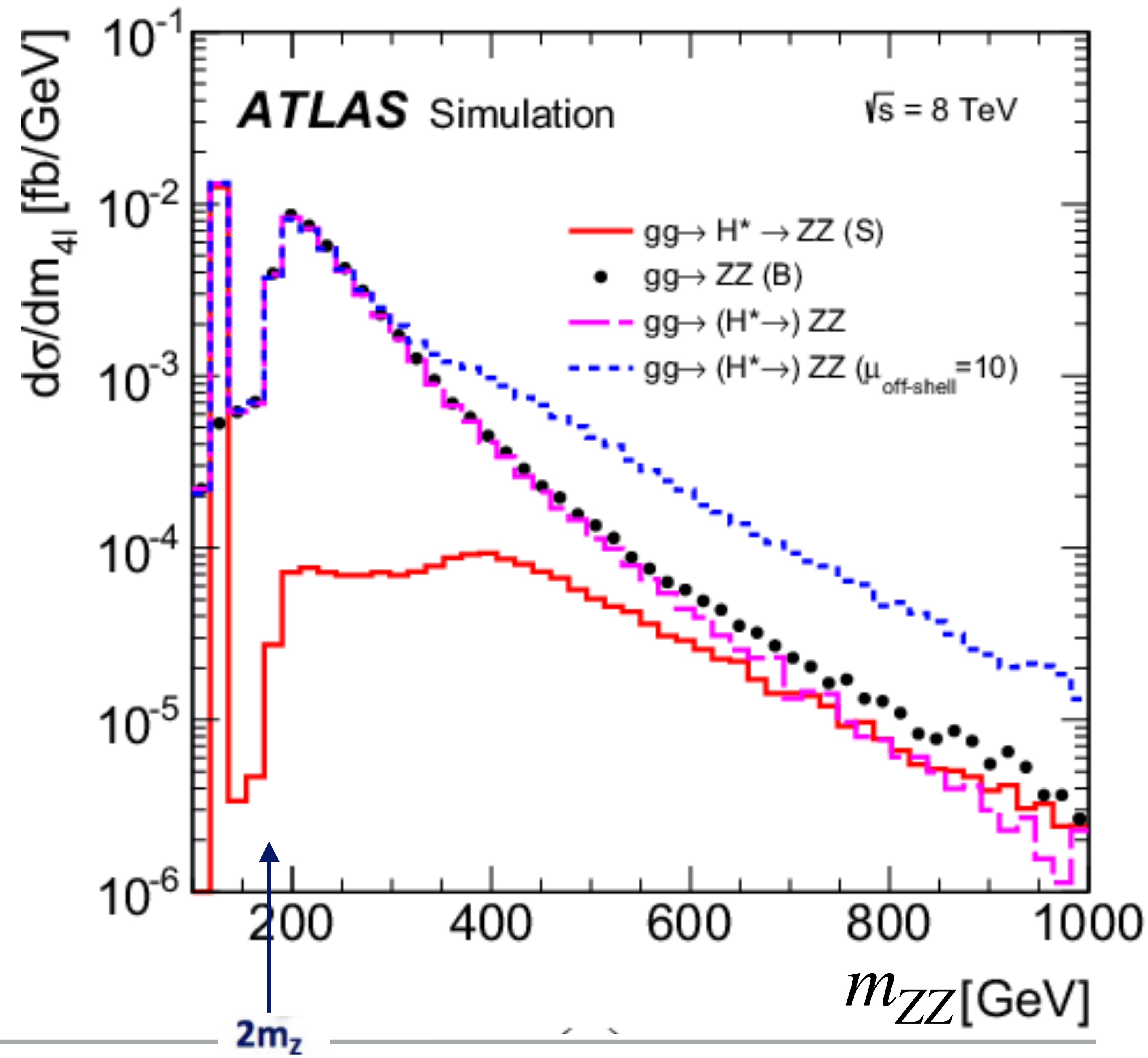


ZZ: INTERFERENCE

- Signal and Background cannot be distinguished, due to negative interference
- We measure a deficit in ZZ events, the size of the deficit depends on the Higgs Width!



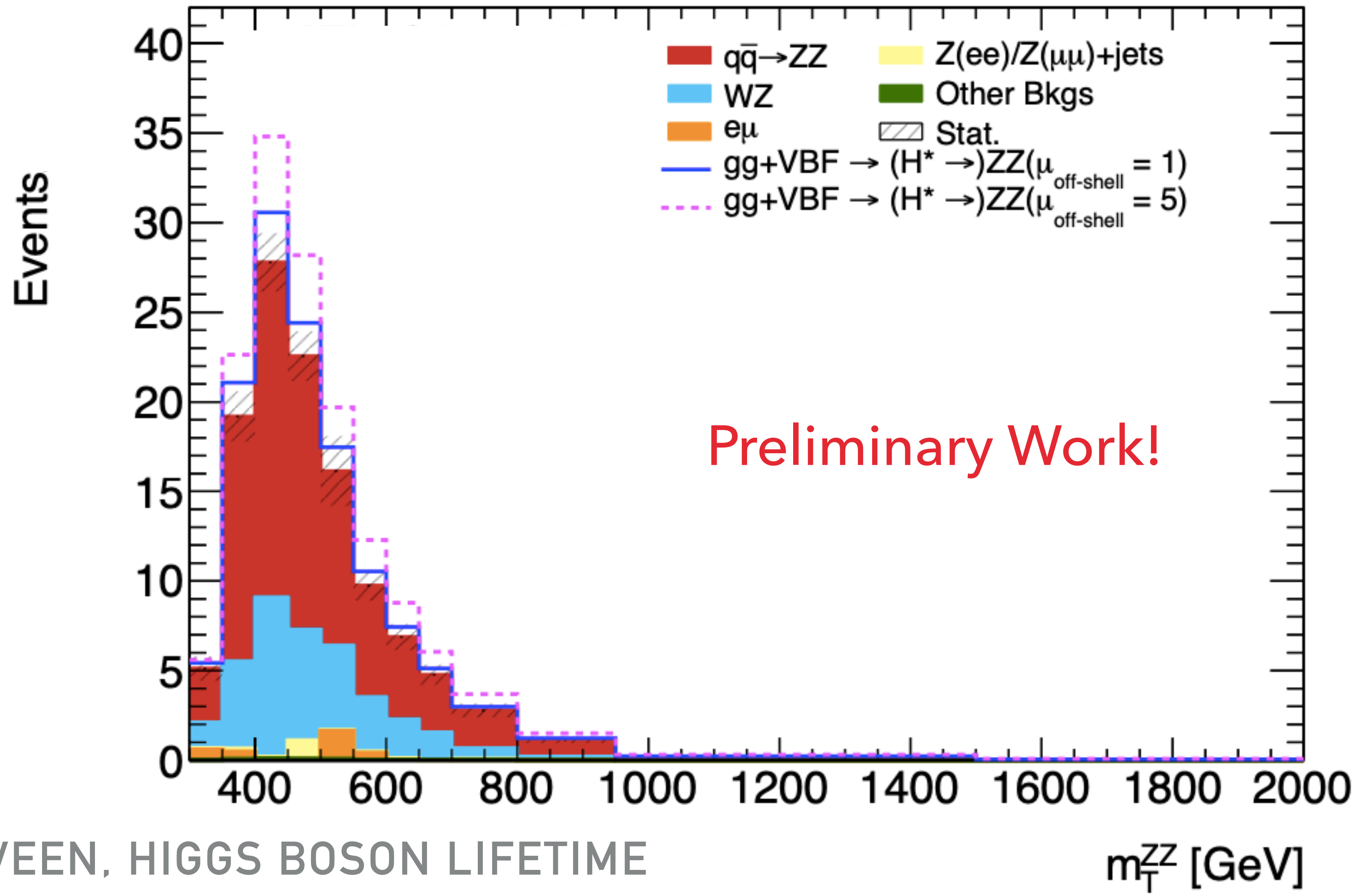




TRANSVERSE MASS

- We cannot reconstruct the neutrinos, instead of invariant ZZ mass, measure 'transverse mass'

$$m_{\mathrm{T}}^2 \equiv \left[\sqrt{m_Z^2 + |\vec{p}_T^{\,ll}|^2} + \sqrt{m_Z^2 + |\vec{E}_T^{miss}|^2}\right]^2 - \left[\vec{p}_T^{\,ll} + \vec{E}_T^{miss}\right]^2$$

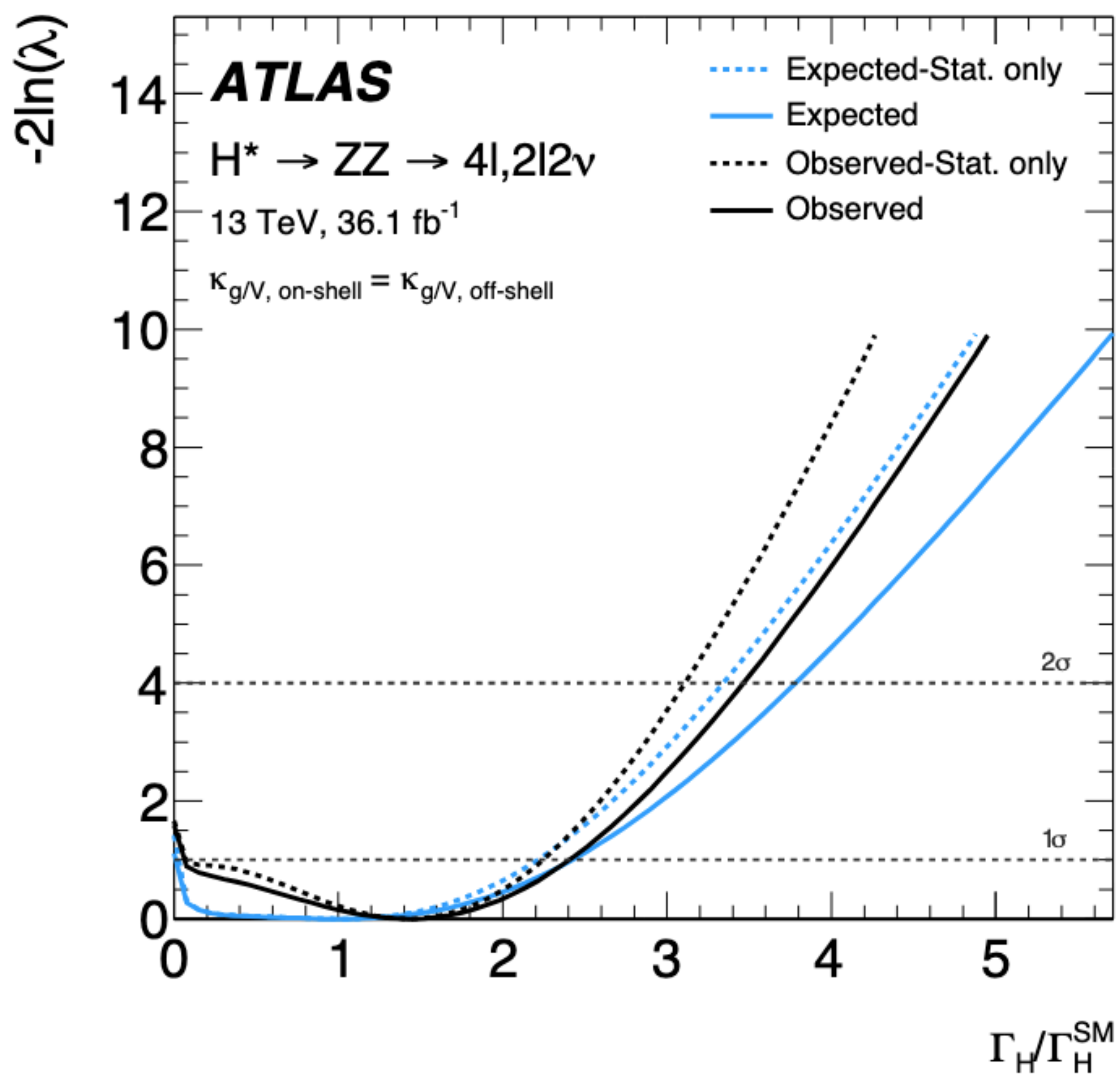


RESULTS

ATLAS (2015+16 data)

$\Gamma_H < 14.4$ MeV

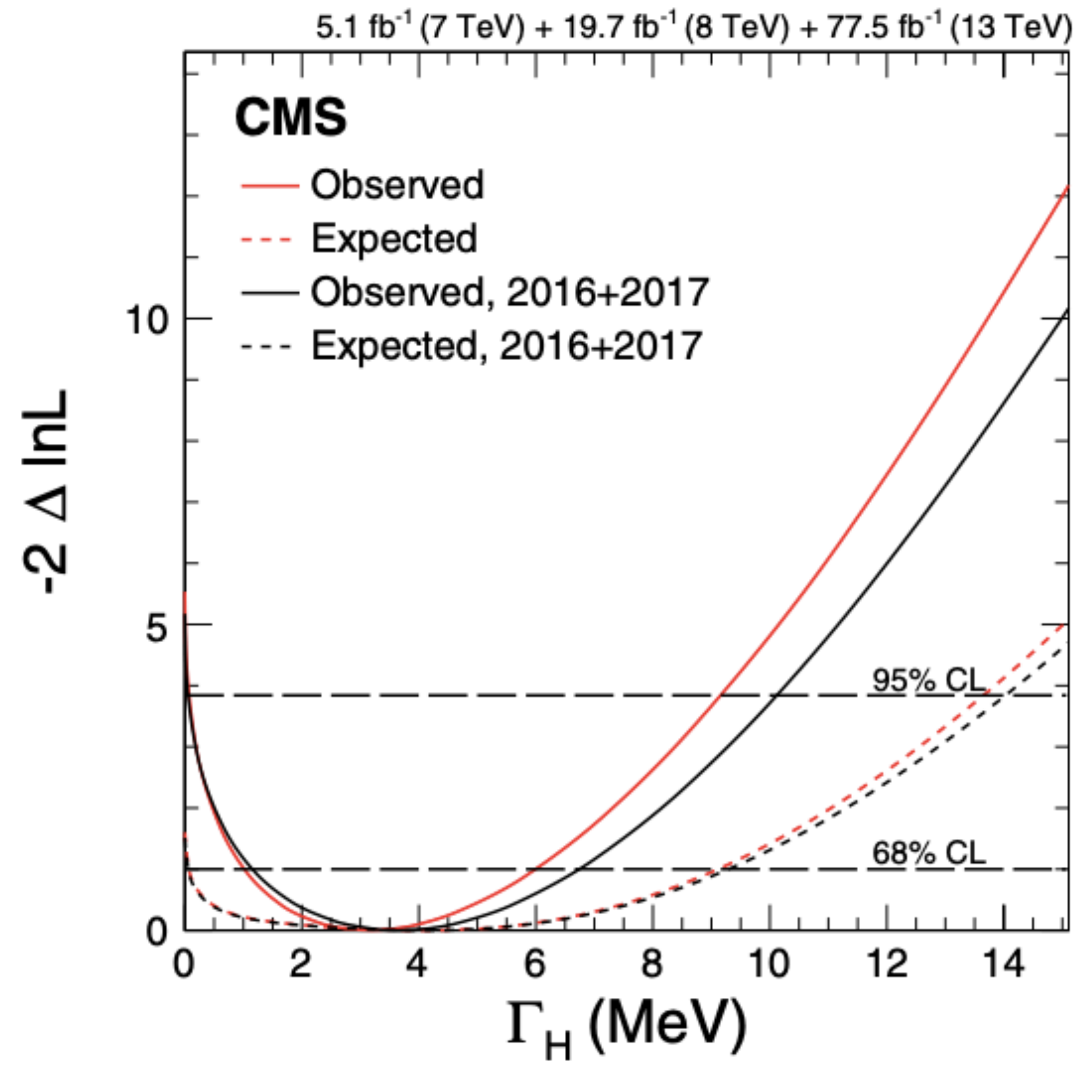
https://arxiv.org/abs/1808.01191



CMS (2015 +16 + 17 data)

$\Gamma_H = 3.2^{+2.8}_{-2.2}$ MeV

https://arxiv.org/abs/1901.00174



Stay tuned for the full run 2 (2015-18) data analysis

BACKUP

Event Pre-Selection
All_Good GRL events
Vertex with ≥ 2 tracks with $p_{\mathrm{T}} > 1$ GeV
Single lepton trigger (e or μ)
Event Selection
Two same flavour opposite-sign leptons (e^+e^- OR $\mu^+\mu^-$)
Veto of any additional lepton with Loose ID and $p_{\mathrm{T}} > 7$ GeV
$76 < M_{\ell\ell} < 106$ GeV
$E_T^{miss} > 175$ GeV
$\Delta R_{\ell\ell} < 1.8$
$\Delta\phi(Z, E_{\mathrm{T}}^{\mathrm{miss}}) > 2.7$
Fractional p_T difference < 0.2
$\Delta\phi(\mathrm{jet}(p_{\mathrm{T}} > 100\,\mathrm{GeV}), E_T^{miss}) > 0.4$
$E_T^{miss}/H_T > 0.33$
b-jet veto