

# How $J/\psi$ enabled one of the most precise measurements at the LHC

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# LHC & ATLAS program

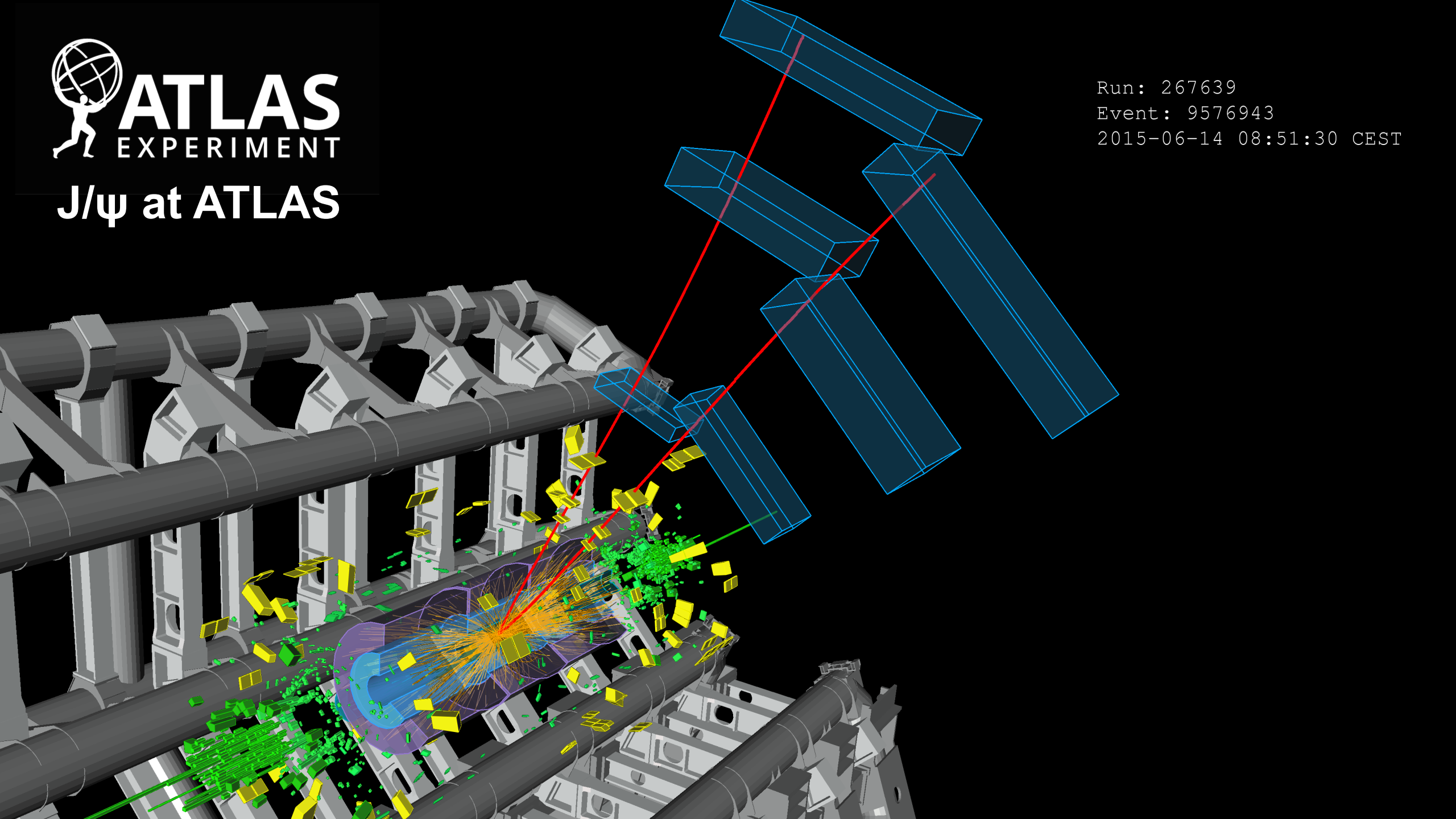
- LHC is a proton-proton collider at CERN - Highest energies every probed
  - **We at BNL work on the ATLAS detector!**
- With the large collected dataset is an opportunity to probe an extensive range of physics **including  $J/\psi$** 
  - Higgs boson discovery and further measurements is one of the primary goals



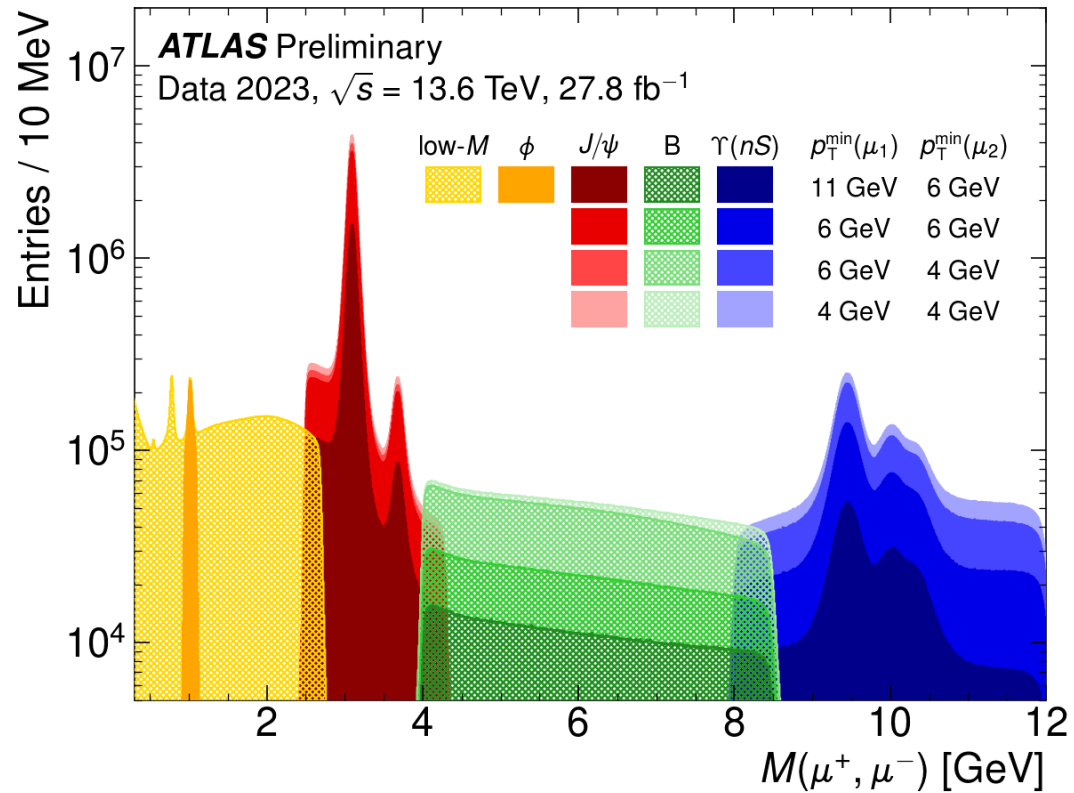


# J/ $\psi$ at ATLAS

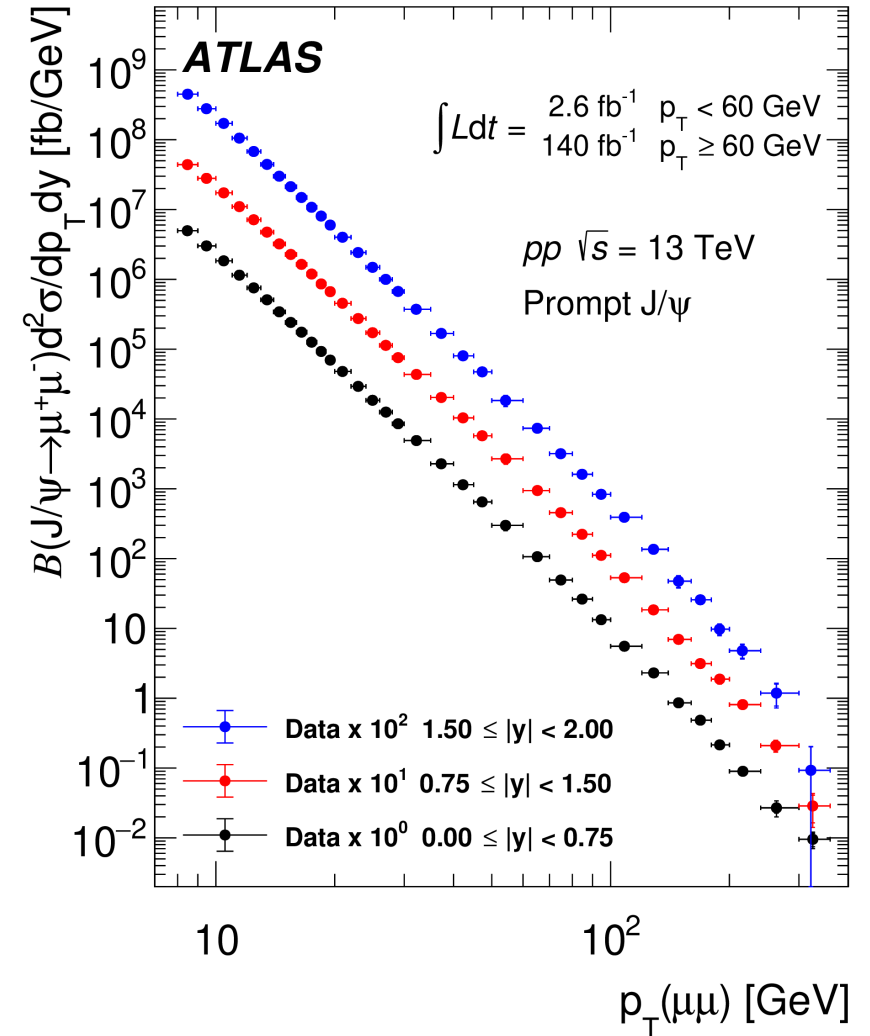
Run: 267639  
Event: 9576943  
2015-06-14 08:51:30 CEST



# J/ψ at ATLAS



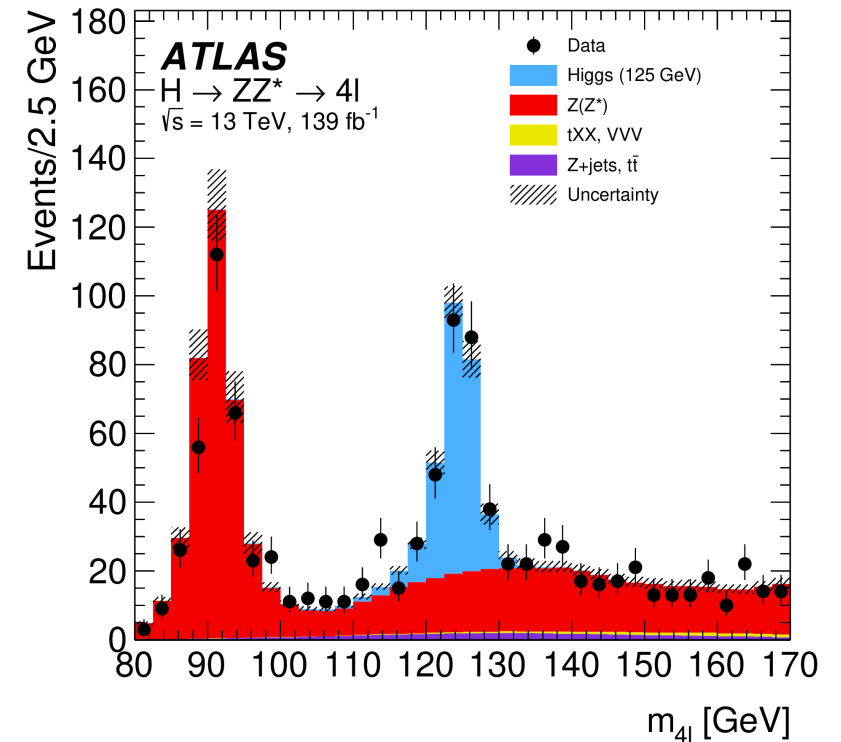
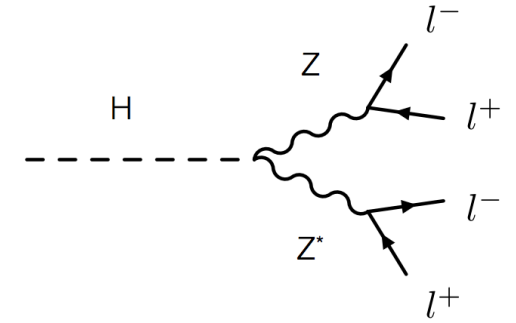
Dedicated triggers at ATLAS to select  $J/\psi$  events - [link](#)



Measurements spanning orders of magnitude - [link](#)

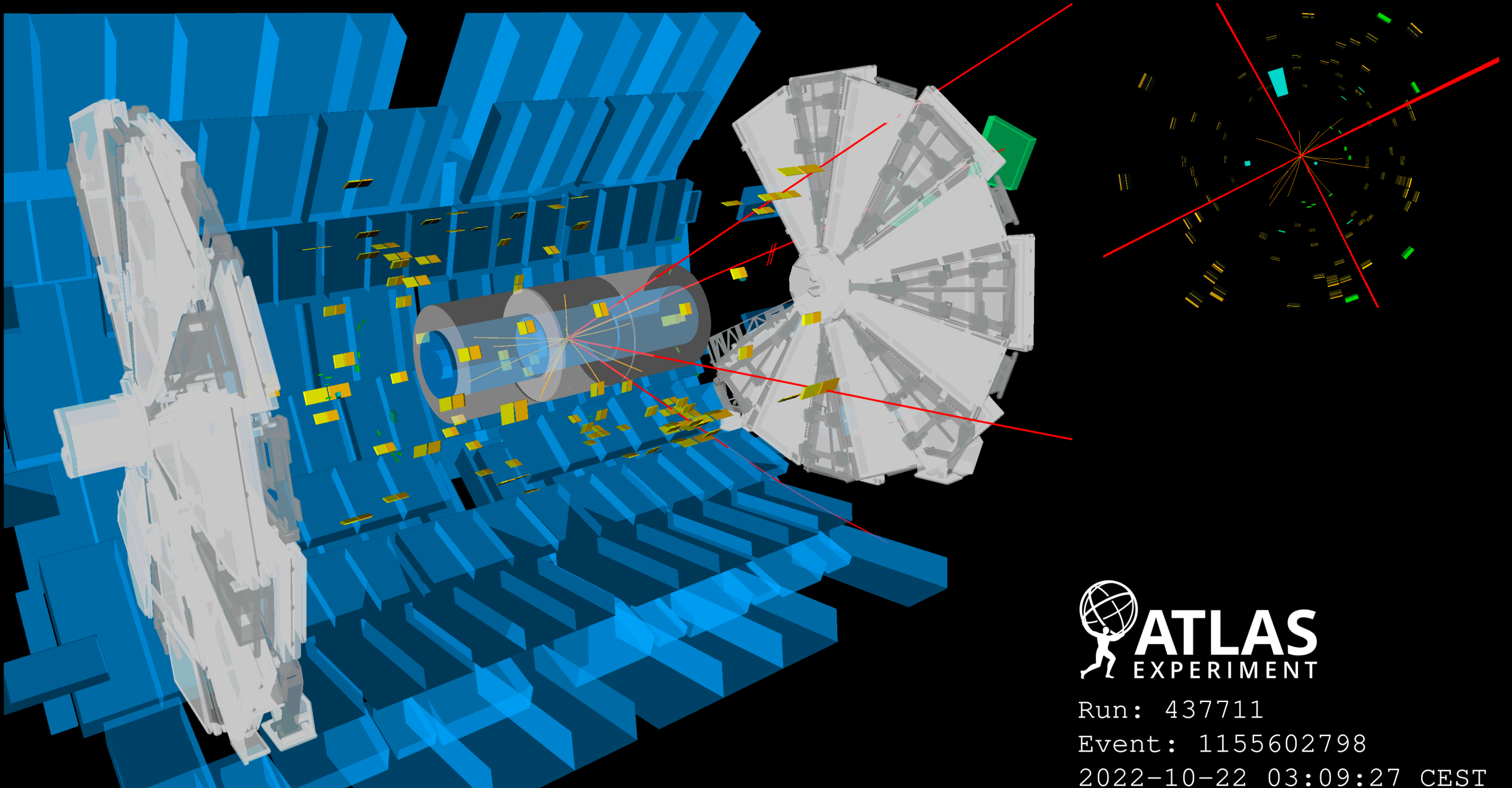
# Higgs mass measurement

- Higgs mass is the only free parameter in the Higgs sector in the SM
  - Once specified, Higgs sector has unique theoretical predictions
- $H \rightarrow ZZ^* \rightarrow 4l$ : 'The Golden Channel' for Higgs mass measurement
  - Fully reconstructable
  - Extremely sensitive to detector performance



Measure Higgs mass in the  $H \rightarrow ZZ^* \rightarrow 4l$  channel

# $H \rightarrow ZZ^* \rightarrow 4l$ Candidate event



 **ATLAS**  
EXPERIMENT

Run: 437711

Event: 1155602798

2022-10-22 03:09:27 CEST

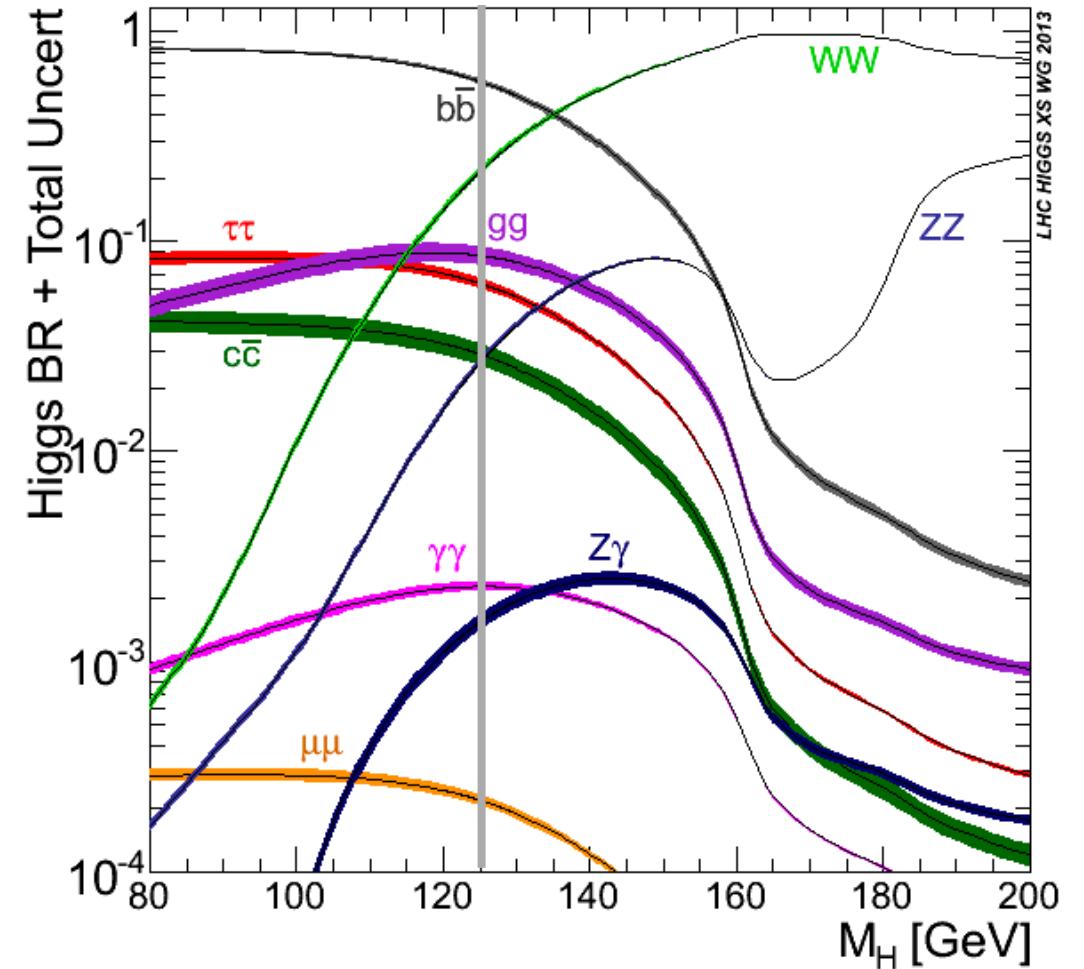
# How accurate do we need to be?

Experimental precision on  
best measured Higgs production rate  
~6%

~0.2% uncertainty on Higgs mass

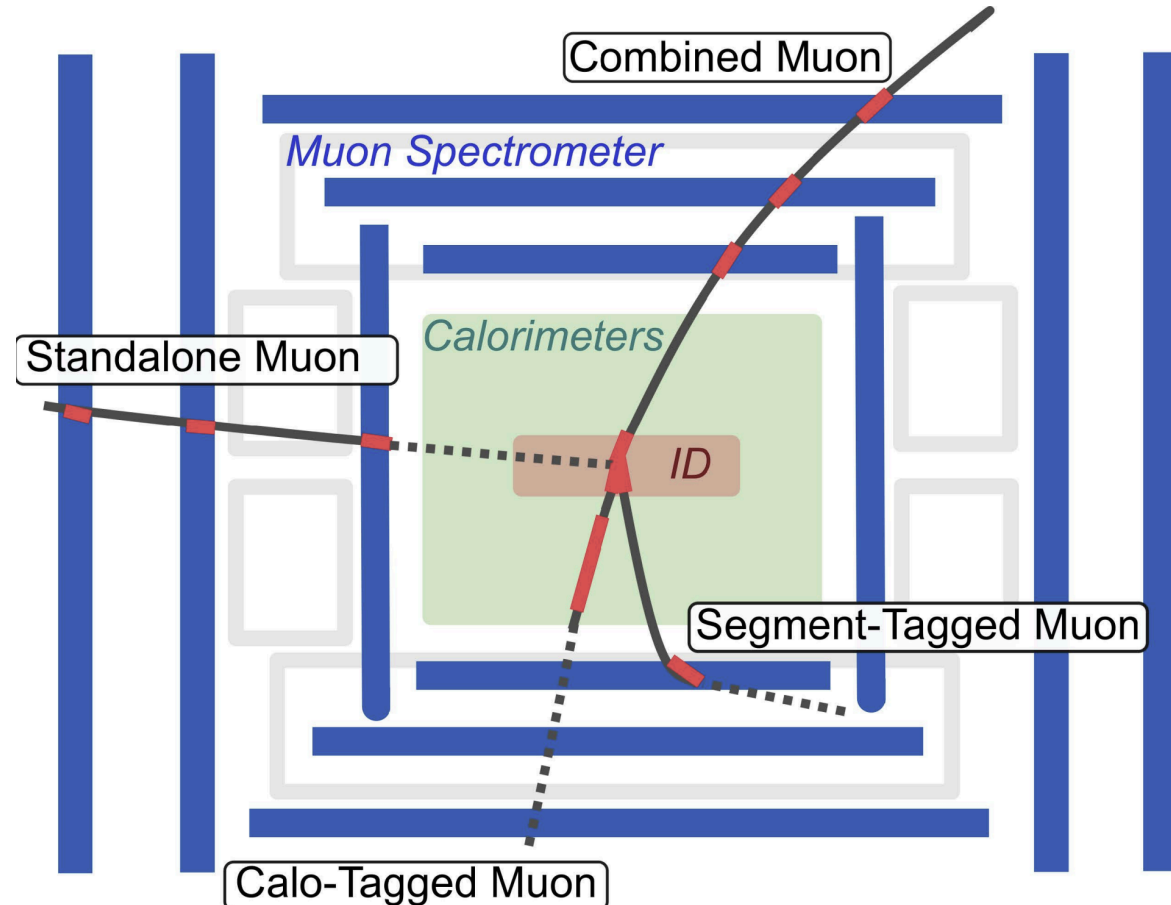


4% uncertainty the predicted rate



# Muons: Not all of them are the same

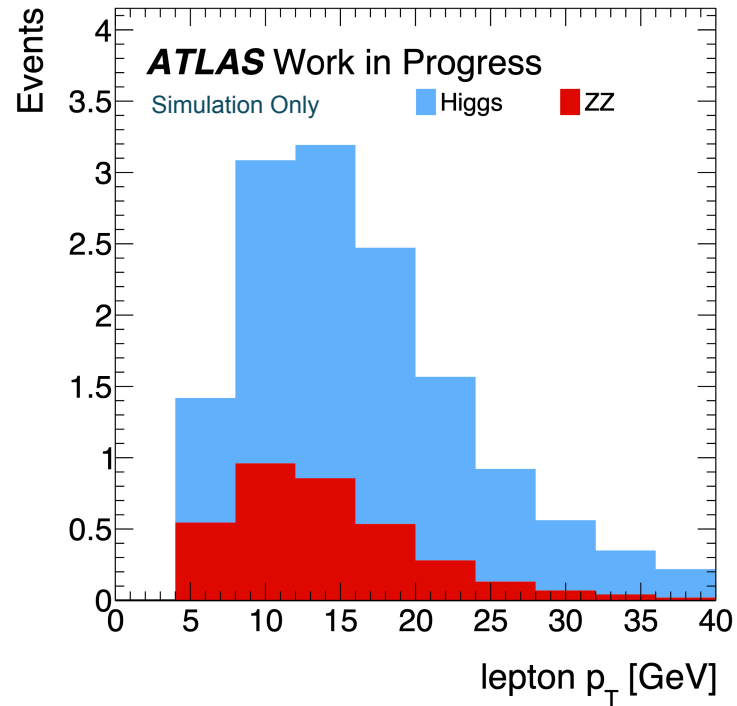
- $H \rightarrow ZZ^* \rightarrow 4\mu$ : The most sensitive channels for the Higgs mass measurement
  - Significantly dependant on muon performance in ATLAS
- Many different 'types' of muons exist within the detector
  - Different algorithms, with different response with momentum and geometrical position
- Need a 'standard candle' to probe the full phase space for muon performance



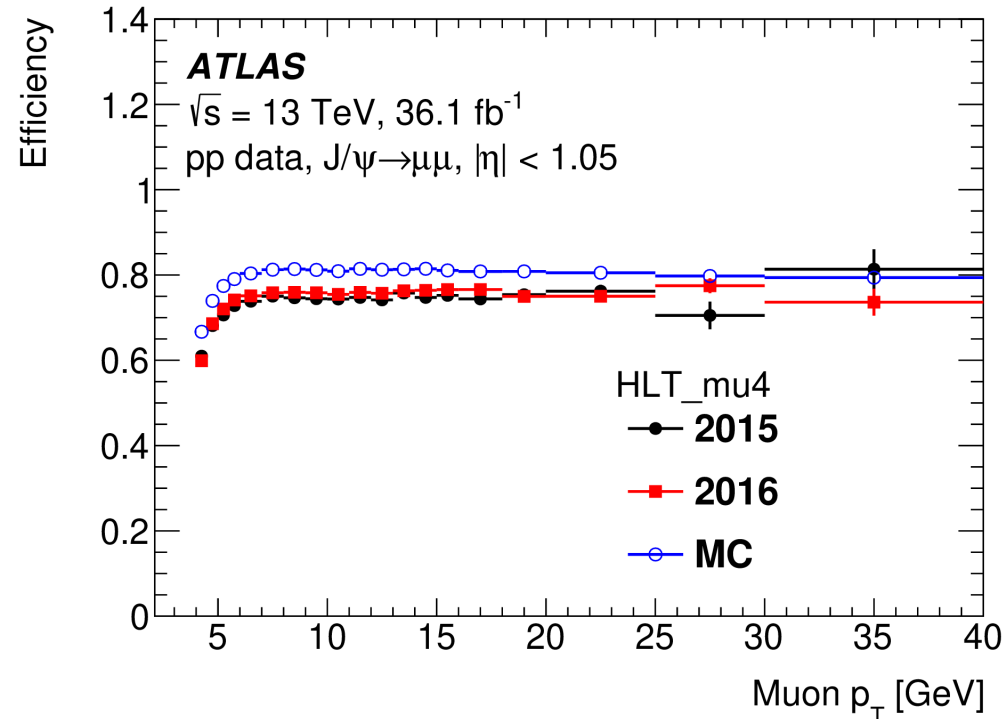


# J/ $\psi$ to the rescue!

Higgs boson has a relatively low momentum range...



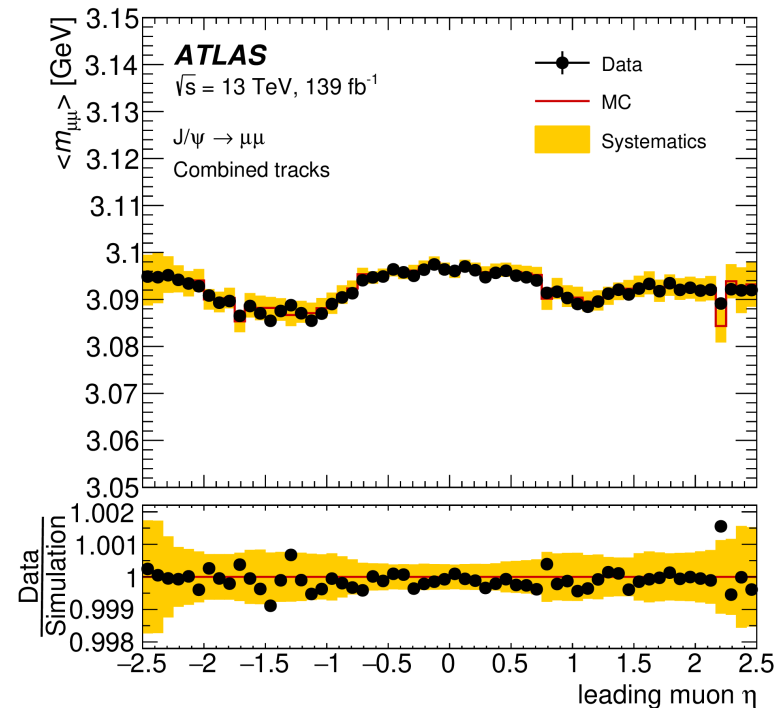
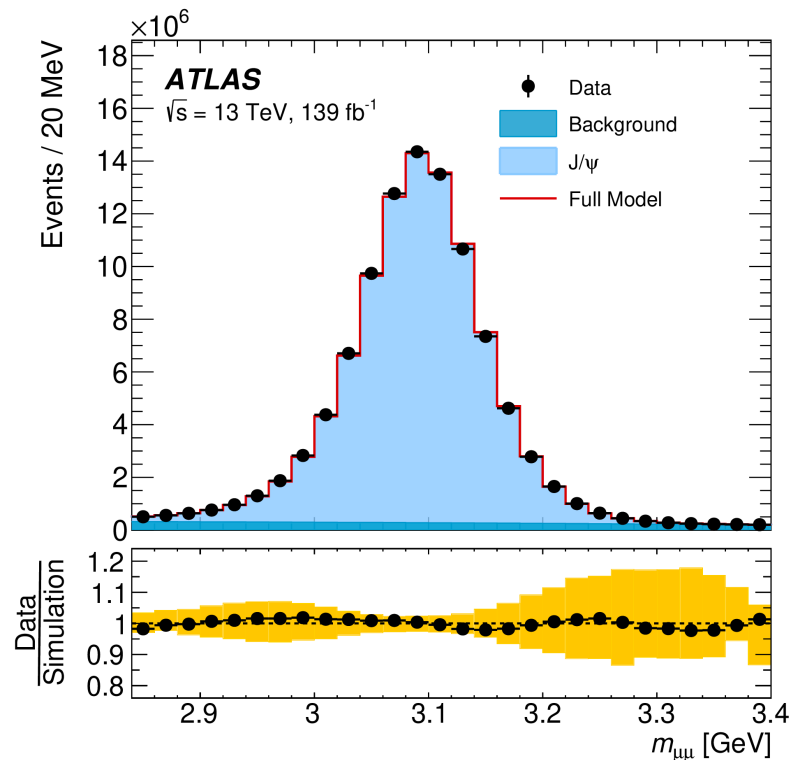
... which makes J/ $\psi$  an ideal candle - [link](#)



- J/ $\psi$  has a similar momentum range as the Higgs decay products
  - Makes it an ideal “standard” candle to probe for muon performance!

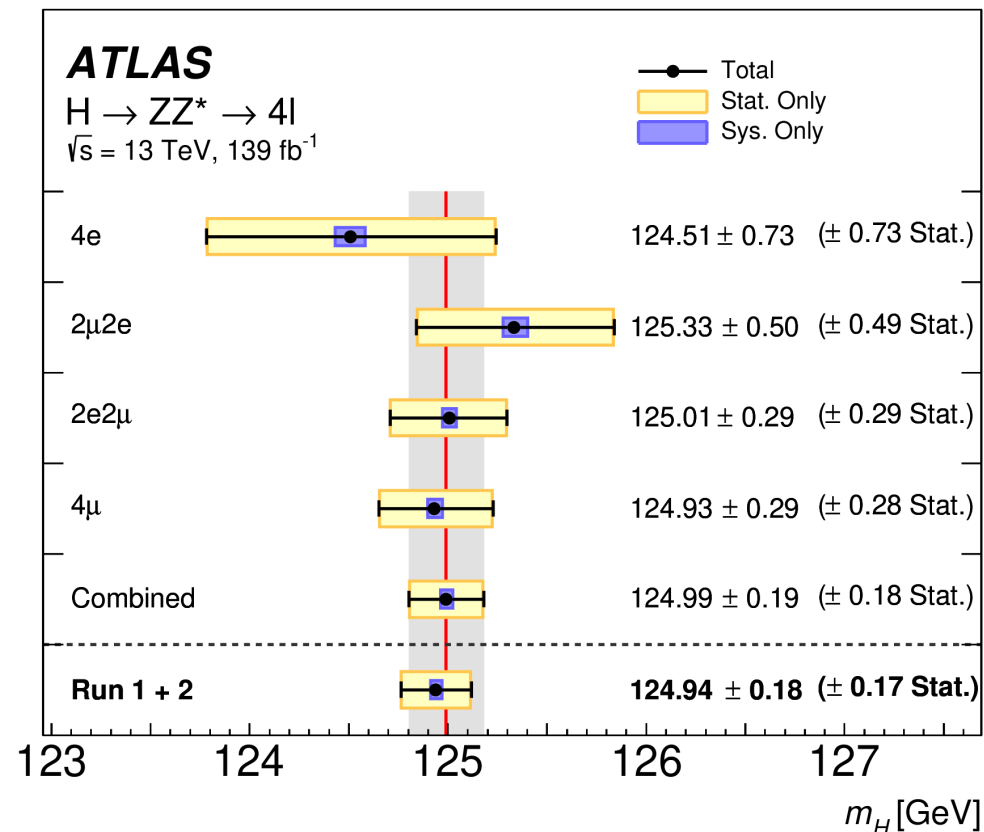
# Muon performance calibration

- Inclusion of  $J/\psi$  allowed for a precise calibration of muon performance in simulation
- Momentum scale uncertainties  $\sim 0.05 - 0.1\%$ 
  - The most precise determination of muon momentum scale across any LHC dataset



# Higgs mass

- Combine a few other ingredients - Most precise measurement of the Higgs mass with the ATLAS detector
- Systematics reduced from **half of statistical error** to **almost negligible levels**
  - 4x improvement in the muon related systematics uncertainties



Total error ~ 0.15%

# Conclusions

- LHC and ATLAS have an extensive physics program
  - These measurements require a precise understanding of the detector
  - ‘Standard candles’ are an established method for this
- **J/ψ continues to enable the latest progress in precision measurements in the Higgs sector!**

