Measurement of the Higgs mass in $H \rightarrow ZZ \rightarrow 4I$ in ATLAS with full Run 2 dataset

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Introduction and motivation

HZZ - fully reconstructed final states - from discovery to precision measurement!

Higgs mass (m_H) — crucial parameter in the SM

Precision measurement of mH required!

Enabled by improvements from analysis, theory & detector performance studies:

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- Additional statistics (full Run 2 dataset)
- Better theoretical modelling
- Data driven background estimates
- High precision lepton calibration





Object & event selection



Object & event selection





Analysis technique

Four-lepton invariant mass: m41

- Recover final state radiation
- Kinematic constraint of leading lepton pairs: Z-Mass Constraint
- Simultaneous fit in 4 final state categories (4µ, 4e, 2µ2e, 2e2µ)

Signal-background discriminant: D_{NN},

Input: 4I p_T & η , KD_{ZZ}, trained separately for same & mixed flavour final states <u>Per-event resolution</u>: σ_i , quantile-regression neural network output



Observables for 4I final state

Signal and background models

• <u>Goal</u>: capturing dependencies between m_{4I} , D_{NN} and σ_i into a 2D likelihood function

For signal:

$$P_s = P_s(m_{4l} | D_{NN}, \sigma_i, m_H) \cdot P_s(D_{NN} | m_H) \cdot P_s(\sigma_i)$$

 $\approx P_s(m_{4l} | D_{NN}, \sigma_i, m_H) \cdot P_s(D_{NN} | m_H)$

<u>m41</u>: Double-Sided Crystal Ball (DCB)

 Dependency on D_{NN}, σ_i and m_H absorbed by parametrisation in the DCB terms

D_{NN}: 2D PDFs

- Generated at $m_H = 124$, 125 and 126 GeV using ggH, VBF and VH
- Interpolated for variation in m_{H}

For background:

$$P_b = P_b(m_{4l}, D_{NN})$$

2D probability density function using kernel estimation



Statistical and systematic uncertainties



Leading uncertainties	Impact (MeV)
Statistical	±186
Muon momentum scale	±28
Electron energy scale	±19
Signal-process theory	±14

- Total observed uncertainty at 190 MeV (stat: 186 MeV)
- P-value between expected & observed uncertainty 0.28
- 50% reduction in muon momentum scale uncertainty!
- Remaining sources of systematics (luminosity, pileup, theory) < 5 MeV

Results



- Compatibility between channels ~ 0.8
- Final measured value from Run 2 -> **124.99 ± 0.19 GeV**
- Run 1 measurement in HZZ channel -> 124.51 ± 0.52 GeV
- Run 1+ 2 combination -> 124.94 ± 0.18 GeV, p-value = 0.4

Conclusion & Outlook

- Presented the most precise measurement of m_H in HZZ by the ATLAS collaboration
- Large statistical uncertainty reduction compare to Run 1, as well as systematic reduction from updated analysis techniques
- Statistically limited measurement, will benefit from more data!
- Exciting conclusion from Run 2 HZZ ==> looking forward to Run 3!

$m_H = 124.99 \pm 0.18 \ (stat) \pm 0.04 \ (sys) \ GeV$



Assuming natural unit: 1 GeV = 1 dollar

Thank you! Any questions?



