Search for Higgs bosons decaying into $\mu^+\mu^-$ in $pp$ collisions at $\sqrt{s}=13$ TeV with the ATLAS detector

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**Introduction**

- H$\rightarrow\mu^+\mu^-$ decay mode is rare (branching ratio is only $2.2 \times 10^{-4}$), but an important channel to study the Higgs properties
  - Direct measurement of Higgs coupling to the second generation of fermions
  - This decay mode has not been observed yet
- Search in Run 1: using the data with a total integrated luminosity of 24.8 fb$^{-1}$; the observed (expected) upper limit on signal strength $\mu_S(\sigma_{obs}/\sigma_{SM})$ was set at 7.0 (7.2) at 95% C.L.
- With the increased luminosity and center of mass energy at Run 2, there will be much higher sensitivity for this search

**Analysis Overview**

- Major contributions come from ggF and VBF Higgs production modes; VH mode contribution is small
- Data sample: $L = 13.2$ fb$^{-1}$ recorded at 13 TeV
- Dominant background is Drell-Yan process
- General event selection:
  - Two single $\mu$ triggers with $p_T > 24$ for isolated muons or 50 GeV for muons without isolation requirement
  - Leading $\mu$ $p_T > 25$ GeV, subleading $\mu$ $p_T > 15$ GeV
  - $E_T^{miss} < 80$ GeV; b-jet veto
  - Signal region: $m_{\mu\mu}$ within 110-160 GeV
- Events selected into VBF category if passing dedicated BDT criteria
- Non-VBF events sorted into six other categories based on $p_T$, $ll$, and $\eta$ regions of the muons
- Fit the $m_{\mu\mu}$ spectrum with analytic function to extract signal strength — fully data driven method

**Signal and Background Modeling**

- Signal model: sum of a Crystal Ball (CB) function and a Gaussian (GS) function
  $$P_S(x) = f \cdot CB(x,m,\sigma_{CB},\alpha,n) + (1-f) \cdot GS(x,m,\sigma_{GS})$$
- Background model: sum of a Breit-Wigner (BW) convolved with a GS and an exponential function divided by $x^3$
  $$P_B(x) = f \cdot BW(M_{BW},\Gamma_{BW}) \cdot GS(\sigma_{BG}^B)(x) + (1-f) \cdot e^{-x^3}/x^3$$

**Discriminant Distributions and Event Yields**

- Event yields for expected signal, background and observed data within a window of $120 < m_{\mu\mu} < 130$ GeV

**Systematic Uncertainties**

- Systematic uncertainty on spurious signal
  - Fit simulated background $m_{\mu\mu}$ distributions to check any potential bias coming from background analytic modeling
  - The impact of background mismodeling on the upper limit on signal strength $\mu_S$ is 4% for $m_H = 125$ GeV

**Results**

- Significant improvement on $\mu_S$ for $m_H = 125$ GeV compared with Run 1 result!
- Combining with Run 1 data, the observed (expected) upper limit on $\mu_S$ is 3.5 (4.3)