The study of the rare decays $B^0_{(s)} \to \mu^+\mu^-$ at $\sqrt{s}$ = 13 TeV with the ATLAS detector

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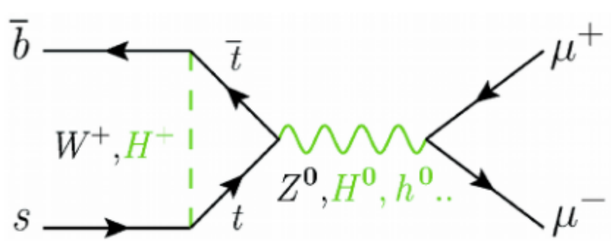
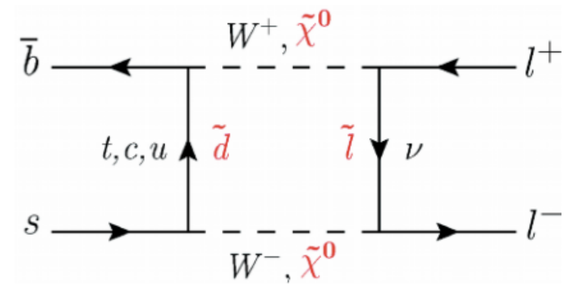
ATLAS EXPERIMENT

- Strongly suppressed flavour-changing neutral-current processes, predicted in the Standard Model (SM)
  - $\mathcal{B}(B^0_s \to \mu^+\mu^-) = (3.66 \pm 0.14) \times 10^{-9}$
  - $\mathcal{B}(B^0 \to \mu^+\mu^-) = (1.03 \pm 0.05) \times 10^{-10}$





- Deviations from the SM prediction may indicate new physics that involves non-SM heavy particles.
- The branching fractions are measured relative to the reference decay mode $B^\pm \to J/\psi\,(\to \mu^+\mu^-)K^\pm$.

world averages, PDG: $(1.010 \pm 0.029) \times 10^{-3}$ X $(5.961 \pm 0.033) \times 10^{-2}$

$$\mathcal{B}(B^0_{(s)} \to \mu^+\mu^-) = N_{d(s)} \frac{\mathcal{B}(B^+ \to J/\psi\, K^+) \times \mathcal{B}(J/\psi \to \mu^+\mu^-)}{\mathcal{D}_{\text{ref}}} \times \frac{f_u}{f_{d(s)}}$$

$B^0_{(s)}$ yield from UML fit to $m_{\mu\mu}$ data

HFLAV average: $f_s/f_d = 0.256 \pm 0.013$; $f_u/f_d = 1$ the ratio of the hadronisation probabilities of a b-quark into B^+ and $B^0_{(s)}$

$$\mathcal{D}_{\text{ref}} = N_{J/\psi K^+} \times (\varepsilon_{\mu^+\mu^-}/\varepsilon_{J/\psi K^+})$$

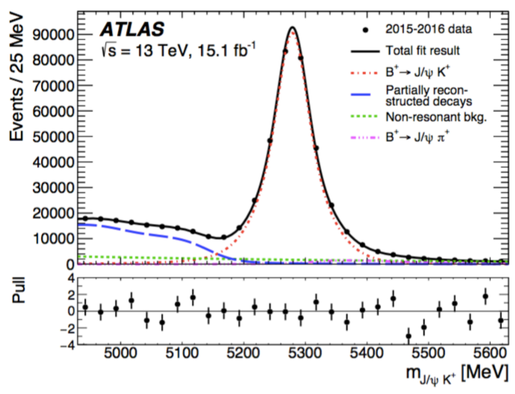
Reference channel yield from UML fit to $m_{J/\psi K}$

Ratio of efficiencies evaluated on MC tuned to data

- Blinded dimuon invariant mass region [5166 MeV, 5526 MeV].

Reference channel

- $B^\pm$ yield is extracted from unbinned extended maximum-likelihood fit to the $J/\psi K^\pm$ invariant mass:
  - $B^+ \to J/\psi K^+$ and $B^+ \to J/\psi \pi^+$ decays: modelled by the sum of Johnson S_U and Gaussian functions.
  - Partially reconstructed $B \to J/\psi X$ decays: combination of Fermi-Dirac and exponential functions.
  - Continuum background: modelled by exponential function.



- $B^\pm$ yield: 33435 ± 0.3% (stat) ± 4.8% (sys)

Background processes

Continuum background

- consists of muons from uncorrelated hadron decays.
- Boosted Decision Tree (BDT) to reject this background is trained on sideband data.

Partially reconstructed B decays

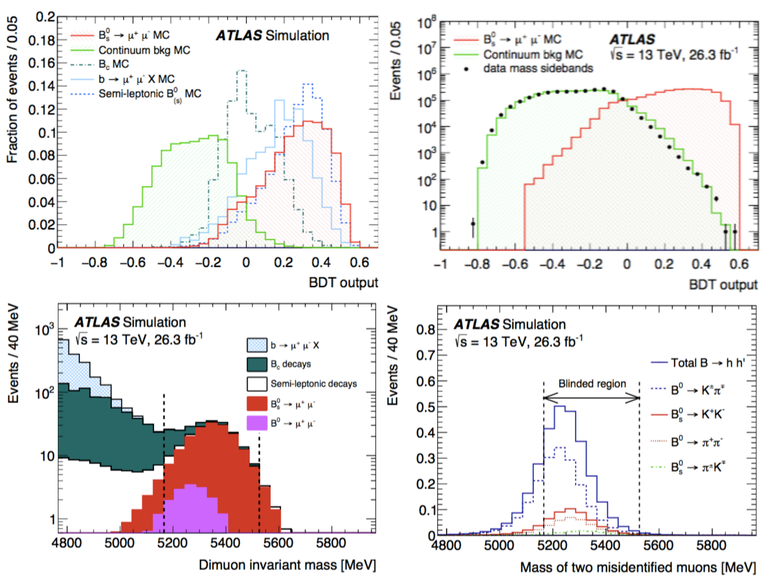
- same-vertex ($B \to \mu^+\mu^- X$), same-side ($b \to c\mu\nu \to s(d)\mu\mu\nu\nu$) and B_c decays.
- exponential in the low mass sideband.

Semi-leptonic B decays

- $B^0 \to \pi^-\mu^+\nu$, $B^0_s \to K^-\mu^+\nu$, $\Lambda^0_b \to p\mu^-\bar{\nu}$
- charged hadron misidentified as muon.

Peaking background $B \to hh'$

- both hadrons misidentified as muons.
- presents in the $m_{\mu\mu}$-signal region.

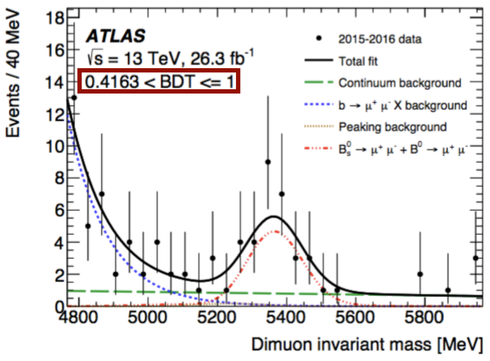


Efficiency ratio

- Estimated from MC in fiducial region with
  - $p_T(B) > 8$ GeV, $|\eta_B| < 2.5$
  - $p_T(\mu_L) > 6$ GeV, $p_T(\mu_T) > 4$ GeV, $|\eta_{\mu L,T}| < 2.5$
  - $p_T(K) > 1$ GeV, $|\eta_K| < 2.5$
- $\varepsilon_{J/\psi K}/\varepsilon_{\mu\mu} = 0.1176 \pm 0.0009$ (stat) ± 0.0047 (sys)

Signal yield

- Extracted with unbinned maximum-likelihood fit to $m_{\mu\mu}$ simultaneously across four intervals of BDT
  - each of 18% of signal MC events.
  - BDT boundaries: 0.1439, 0.2455, 0.3312, 0.4163, 1.



- Extracted (expected) yields
  - $N_s = 80 \pm 22$ (91), $N_d = -12 \pm 20$ (10)

Results

- Branching fractions using 2015+2016 data

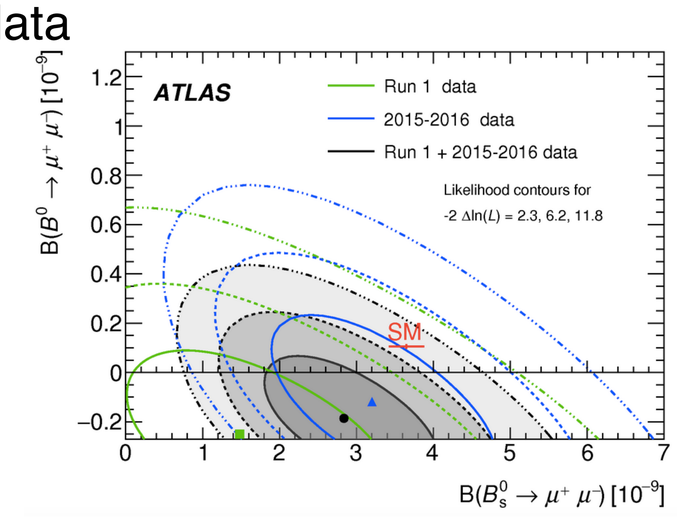
$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = \left(3.21^{+0.96+0.49}_{-0.91-0.30}\right) \times 10^{-9}$$

$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 4.3 \times 10^{-10} \quad @\ 95\%\ \text{CL}$$

- Combination with Run1

$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = \left(2.8^{+0.8}_{-0.7}\right) \times 10^{-9}$$

$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 2.1 \times 10^{-10} \quad @\ 95\%\ \text{CL}$$



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