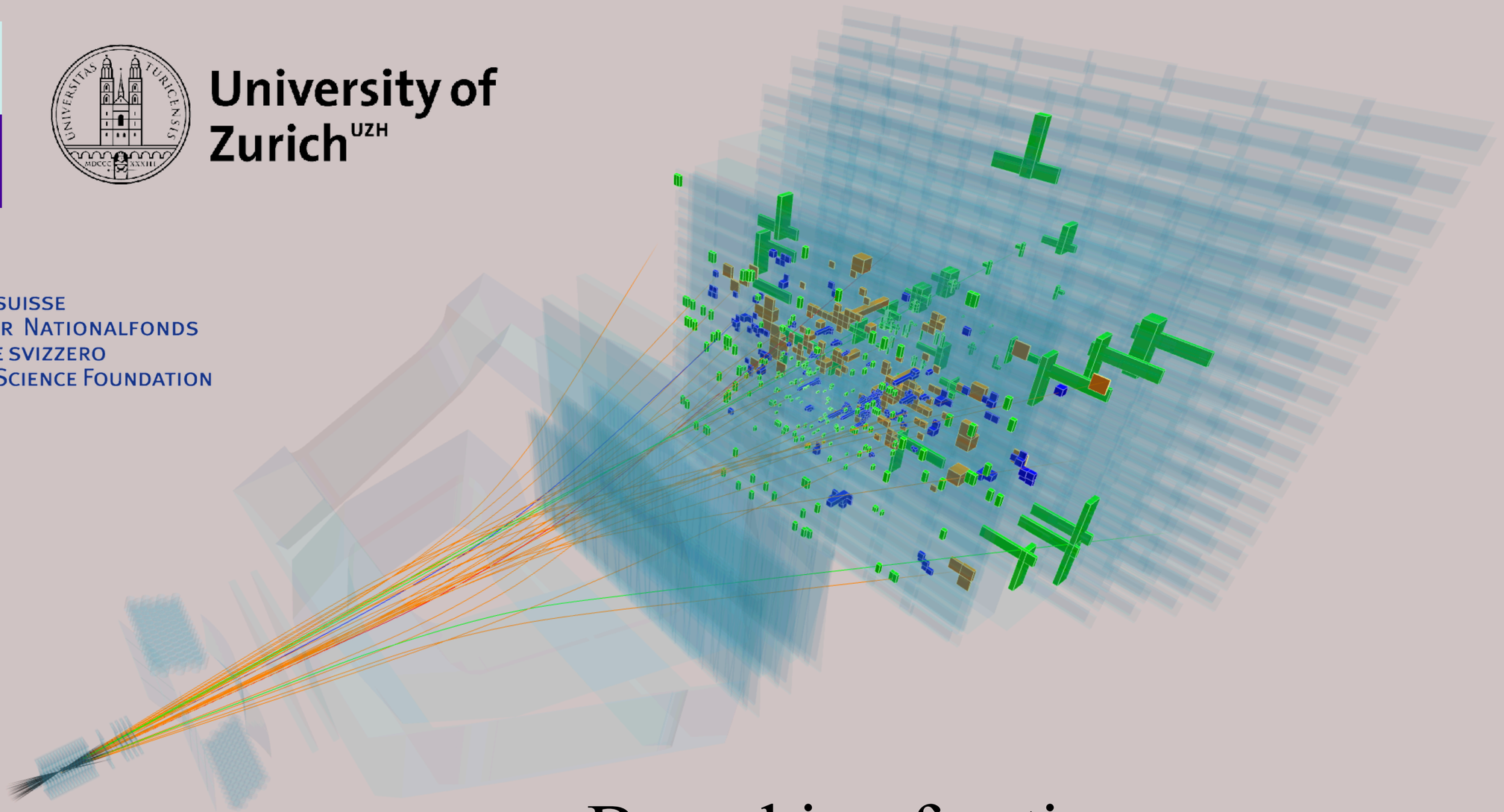
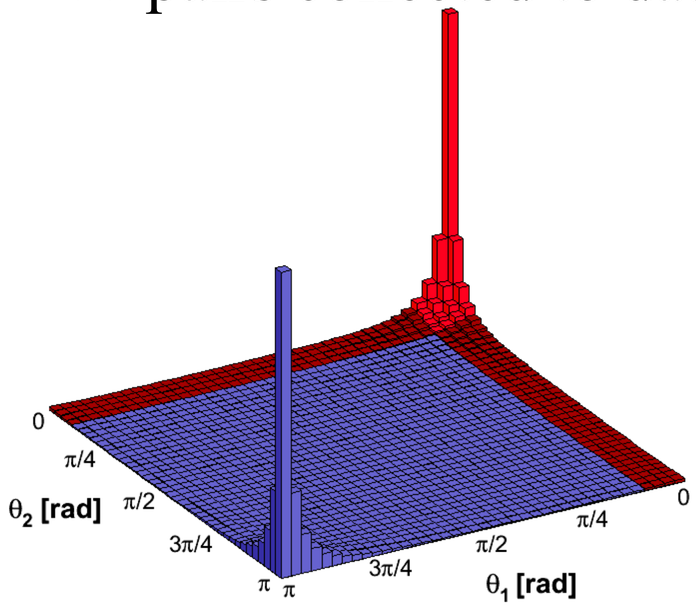


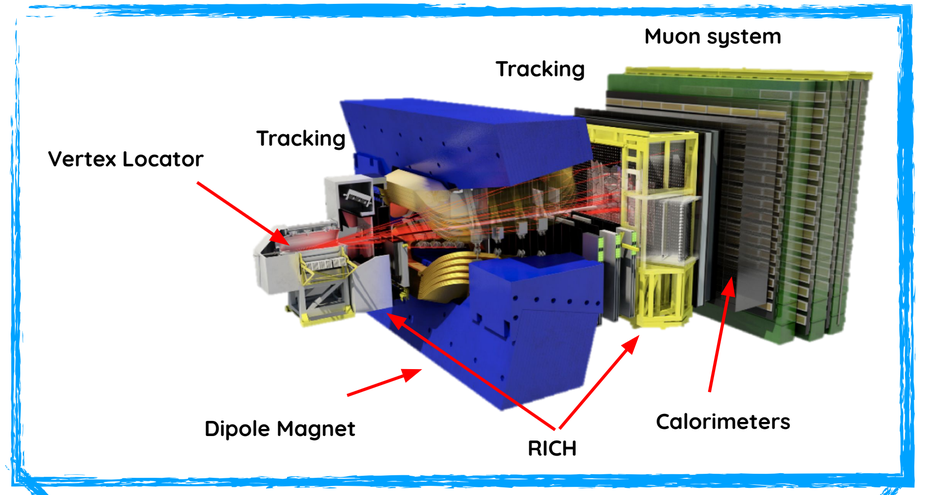
Martin Andersson

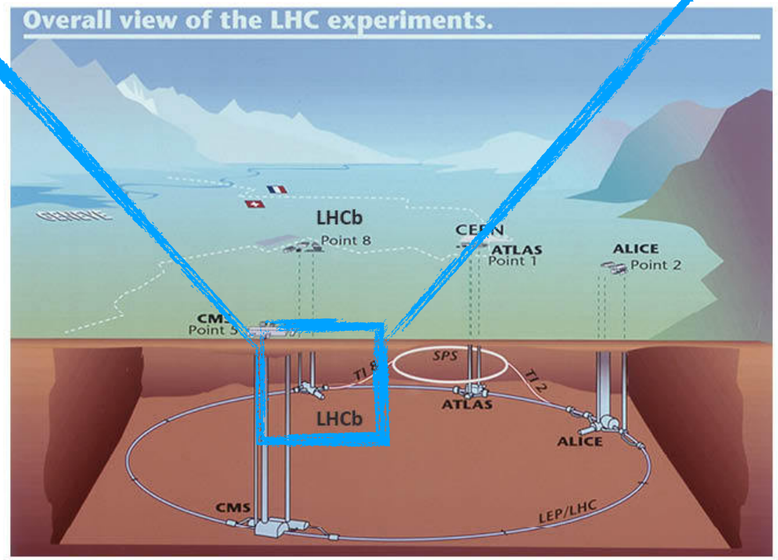
# Branching fraction measurement of the rare decay $B^0 \to K^+\pi^-\mu^+\mu^-$

# The LHCb experiment

- The LHC**b** is a dedicated flavour detector
- $b\bar{b}$ mostly produced in forward-backward region
- Around $10^{12}$ $b\bar{b}$ pairs collected to date



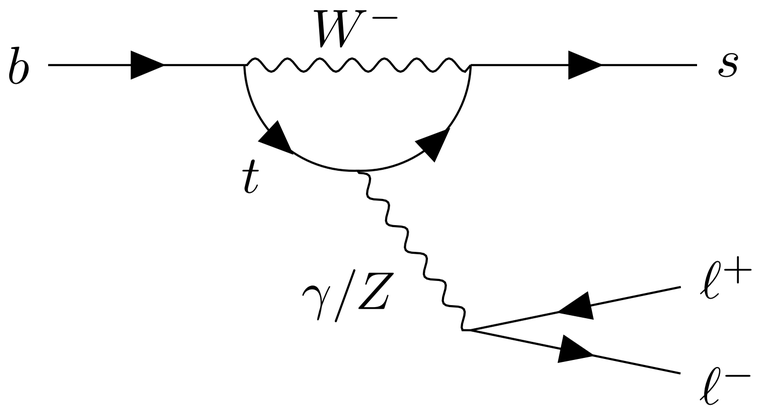




*Int. J. Mod. Phys. A* 30 (2015) 1530022

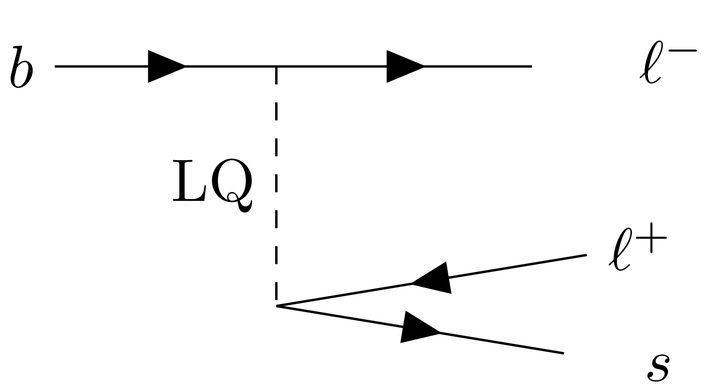
# $b \to s\ell\ell$ decays

- $b \to s\ell\ell$ is a Flavour Changing Neutral Current
  - Suppressed in the SM → New Physics contributions can compete with SM amplitudes

SM



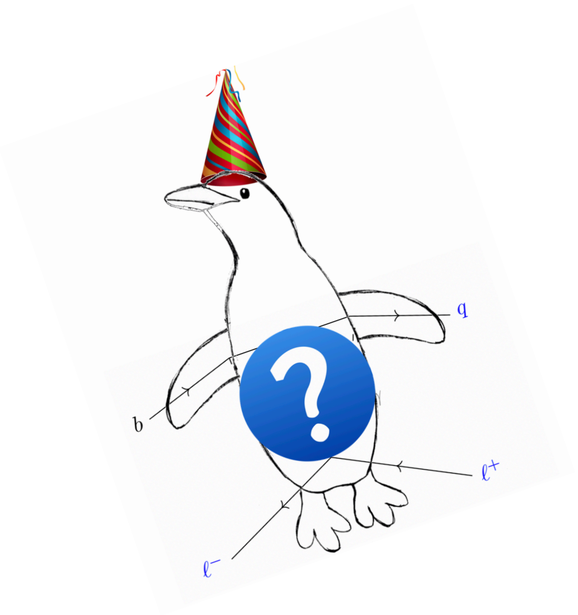

NP example

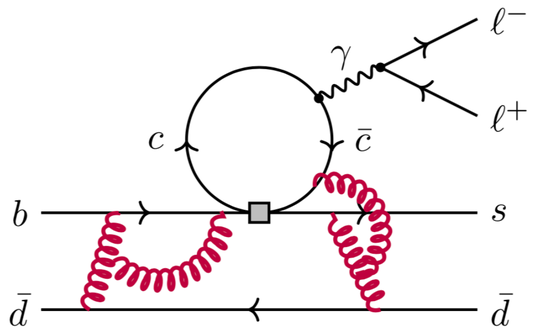


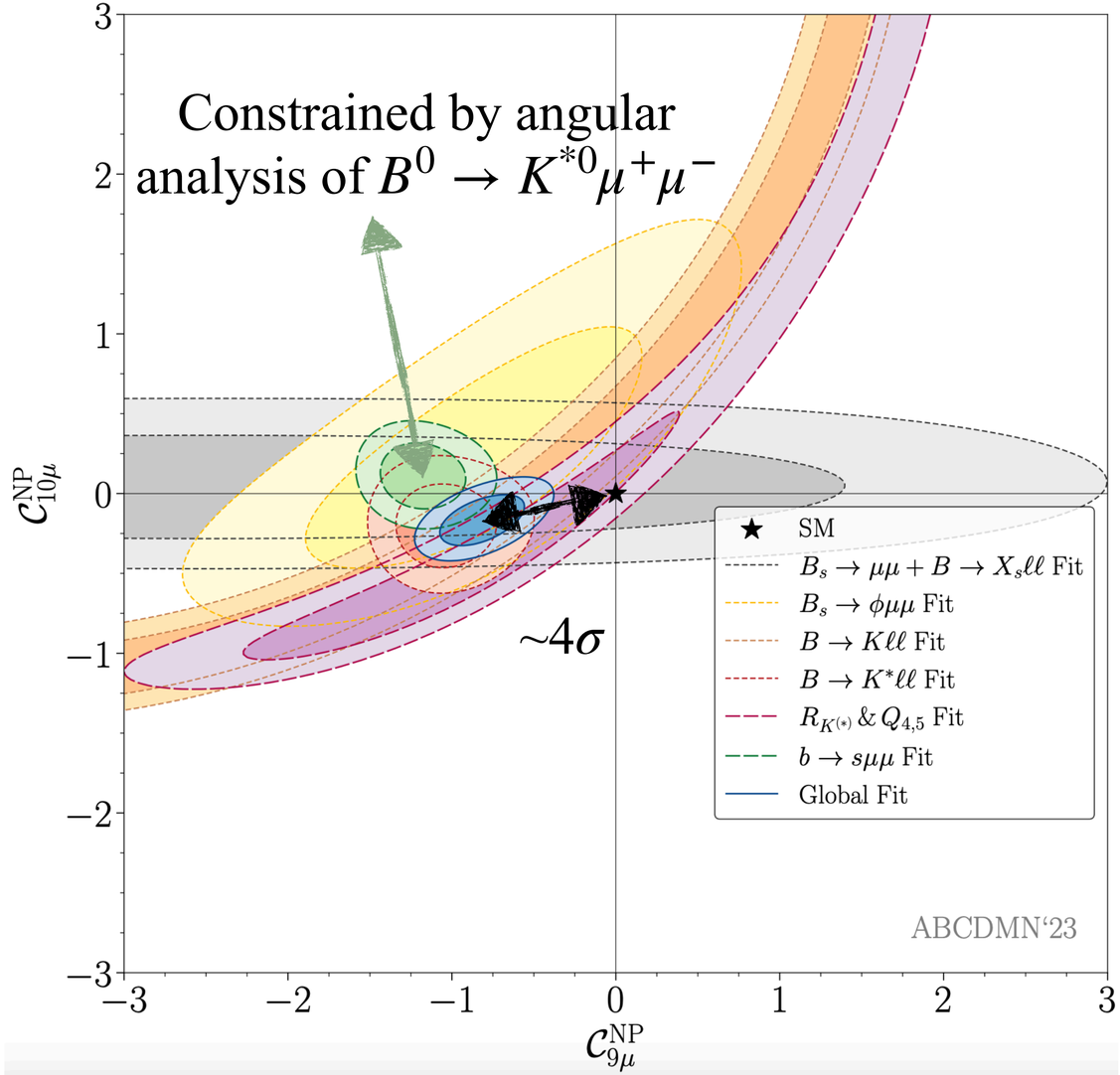

- New Physics contributions could therefore cause significant deviations of physical observables from their SM predictions

# Result of all $b \to s\ell\ell$ measurements

NP or missing SM effects?



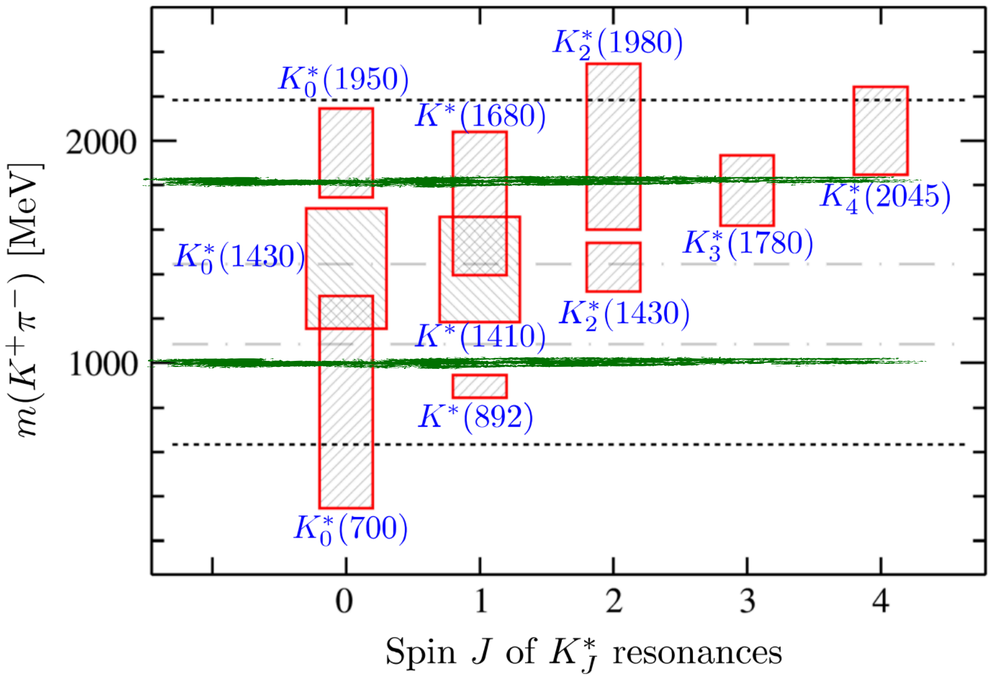



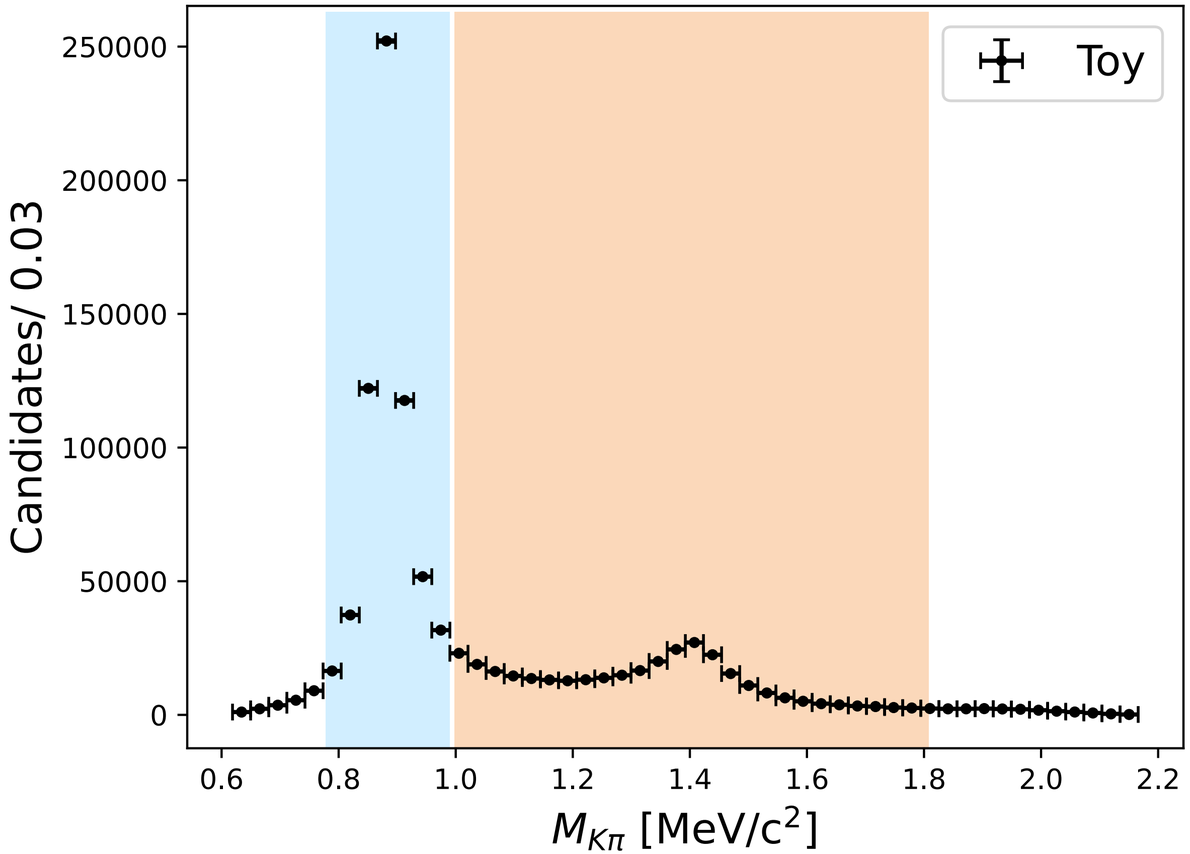

arXiv:2304.07330

# The high $m(K^+\pi^-)$ region

- Anomalies in this mode from previous slide are measured in the $K^{*0}(892)$ peak
- Upper region is currently not well constrained (arXiv:1609.04736) and composed of many resonances

PRL 122, 152002

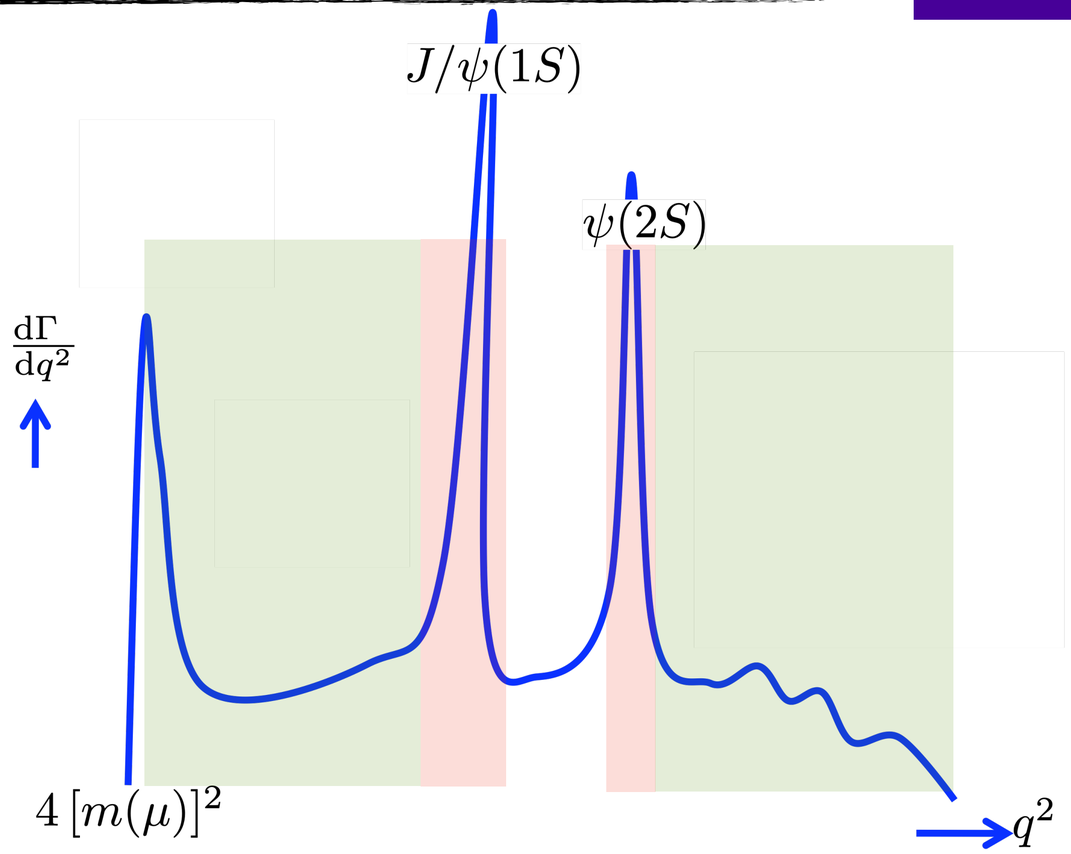


# Branching fraction measurement at high $K\pi$

- $\mathcal{B}(B^0 \to K^+\pi^-\mu^+\mu^-) = \dfrac{\Gamma(B^0 \to K^+\pi^-\mu^+\mu^-)}{\Gamma(B^0 \to X)}$

- Measure in $q^2$ bins across the full kinematic range
  - Theory predictions in high-$q^2$ suffer less from hadronic uncertainties arXiv:2305.03076
  - Charmonium resonances are vetoed




✓ $b \to s\mu\mu$ decays dominate

$q^2$ = [invariant mass of dimuon system]$^2$

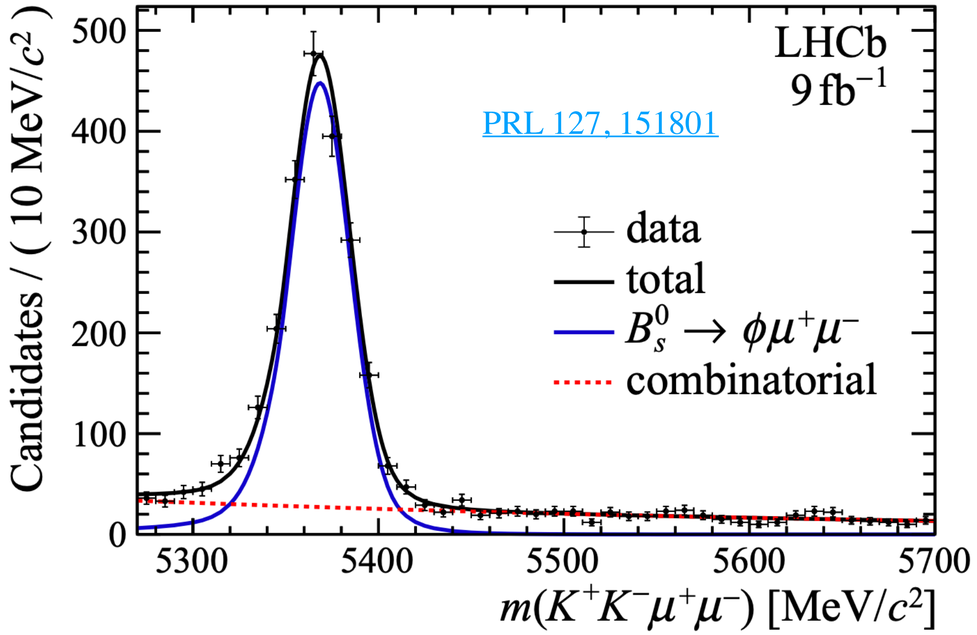
✗ $b \to s\bar{c}c[\to \mu^+\mu^-]$ decays dominate

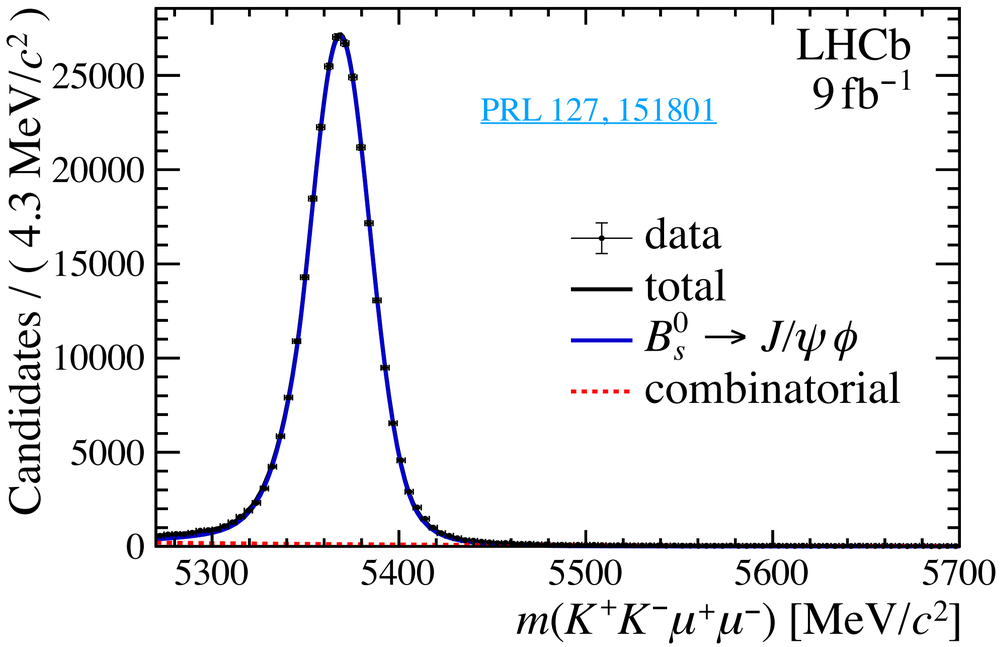
# Ingredients to branching fraction measurements

- Normalisation commonly done w.r.t. the $J/\psi$ mode at LHCb

$$\frac{d\mathcal{B}(B \to H\mu^+\mu^-)}{dq^2} = \frac{N(B \to H\mu^+\mu^-)}{N(B \to J/\psi H)} \cdot \frac{\epsilon(B \to J/\psi H)}{\epsilon(B \to H\mu^+\mu^-)} \cdot \frac{\mathcal{B}(B \to J/\psi H)\mathcal{B}(J/\psi \to \mu^+\mu^-)}{q^2_{max} - q^2_{min}}$$

Data fit | Simulation | Previous measurements

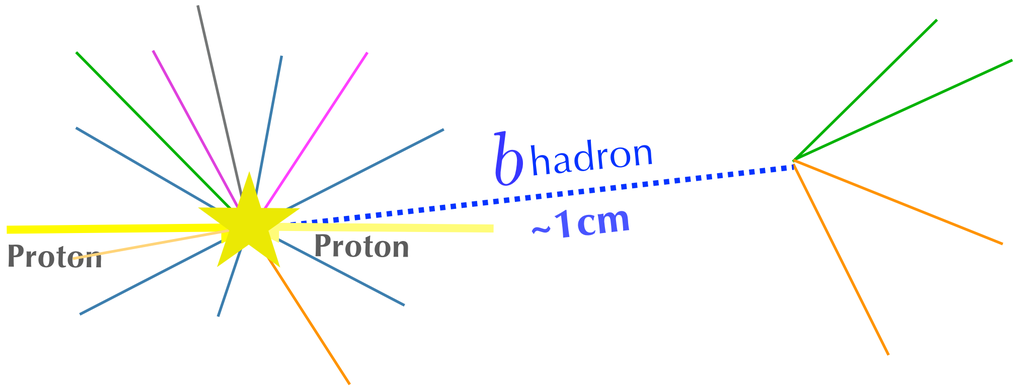


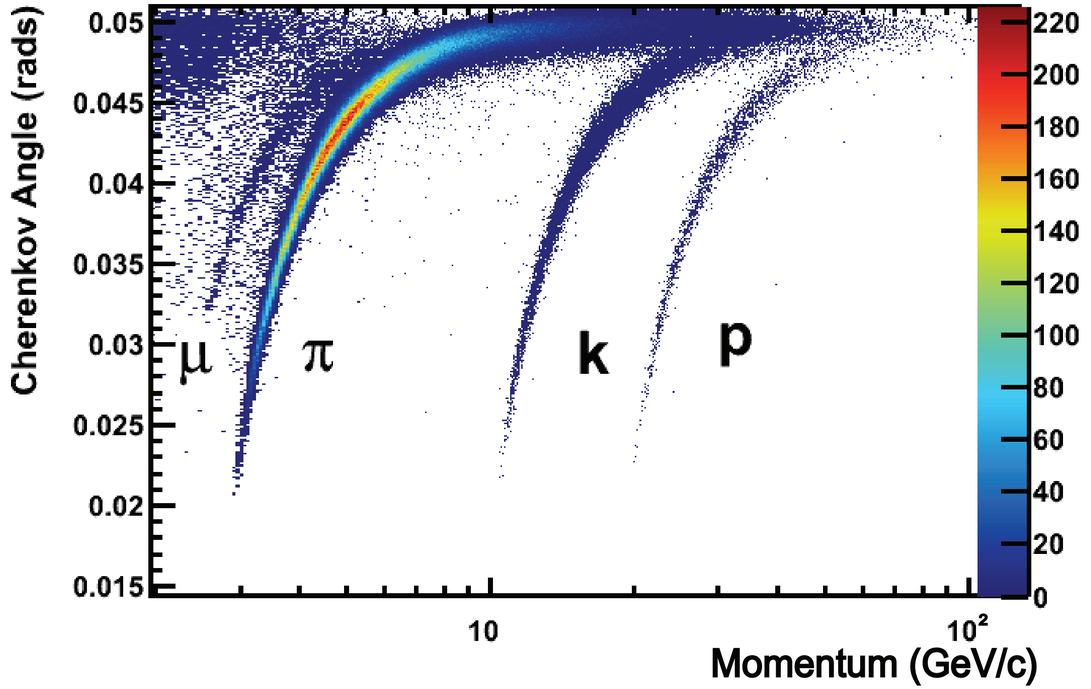

- Limited by the uncertainty on the normalisation channel

# General selection

- B-meson average flight before decaying



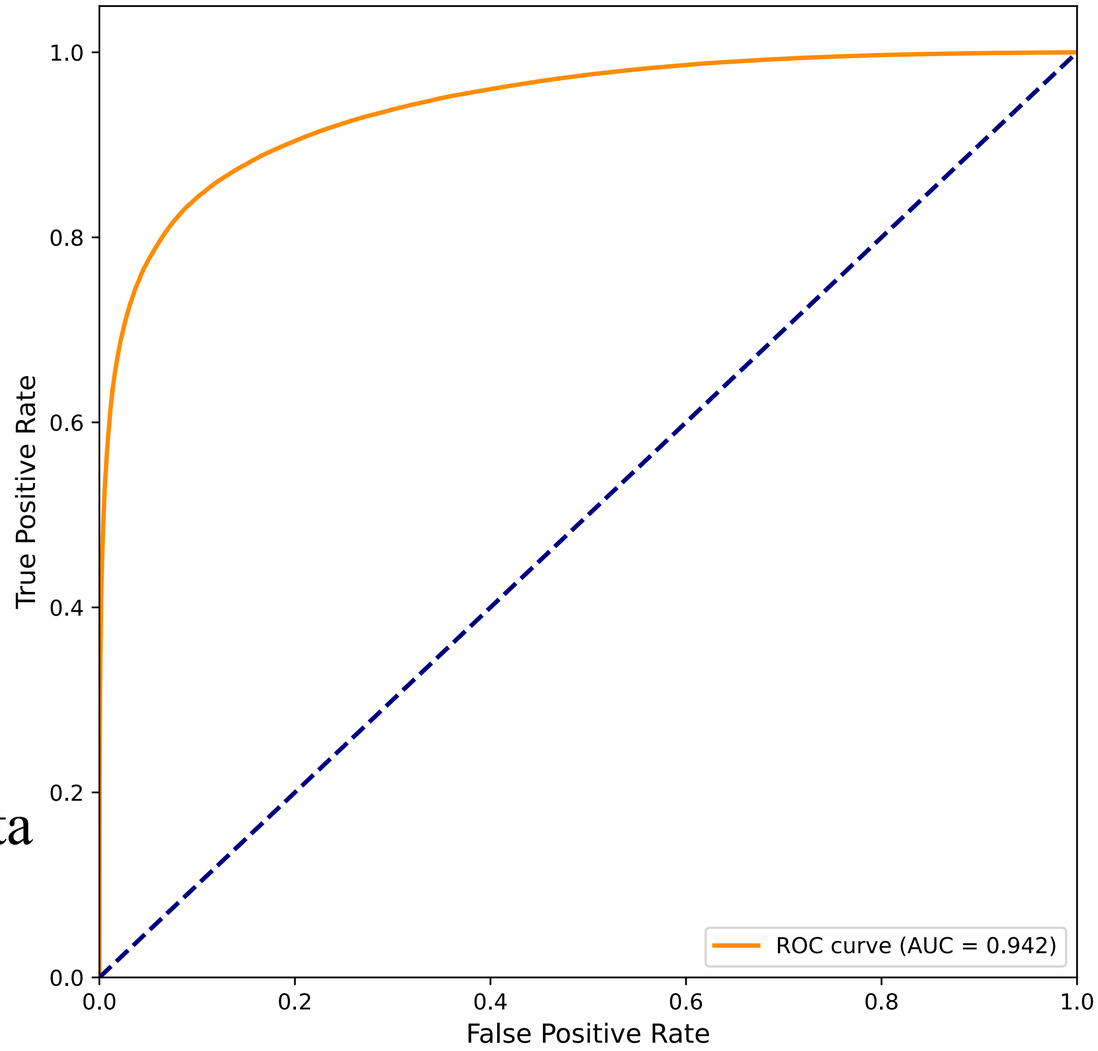

- High $P_T$ of daughter particles
  - $\mu$ : $P_T > 800$ MeV/c
  - $K^*$ : $P_T > 500$ MeV/c




- LHCb sub-detectors used for particle identification

# Multivariate classifier

- Done to reduce the combinatorial background
  - Originates from incorrectly vertexed tracks
- Want to discriminate between signal and combinatorial background
- Using ~20 weakly discriminatory variables to create 1 strongly discriminating variable
- Signal proxy: Background subtracted $B^0 \to J/\psi K^+\pi^-$ data
- Background proxy: $B^0 \to K^+\pi^-\mu^+\mu^-$ data above $m_{K\pi\mu\mu} > 5500$ MeV

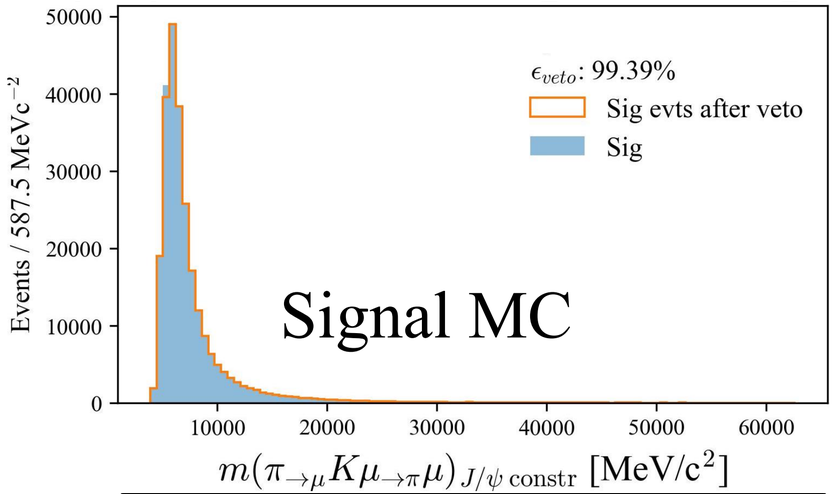


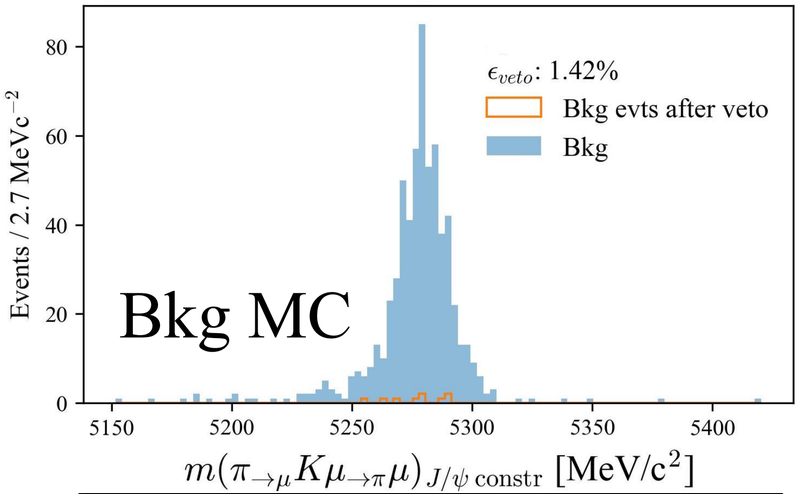
# Peaking backgrounds

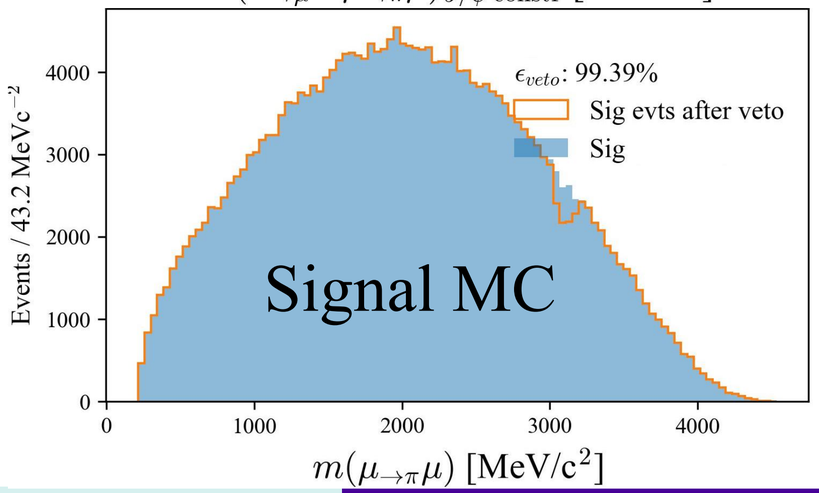
- Remaining backgrounds
  - Same topology as signal, sometimes much larger branching fractions
  - Need more dedicated selection
- Some examples:
  - $B^0 \to K^{*0}_{892}(\to K^+\pi^-)J/\psi(\to \mu^+\mu^-)$, hadron-lepton swaps
  - $B^+ \to K^+\mu^+\mu^-$, with additional random $\pi$
  - $B^0_s \to f^0_{980}(\to \pi^+\pi^-)\mu^+\mu^-$, $\pi$ mis-identified as $K$
- The contamination from these is studied using simulation

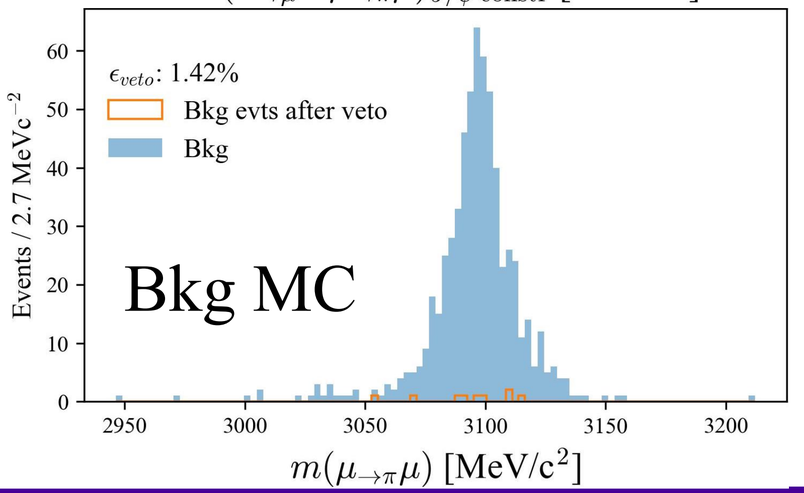
# Peaking backgrounds - an example

- A common swap in LHCb: $\pi \leftrightarrow \mu$
  - $B^0 \to K^{*0}_{892}(\to K^+\pi^-)J/\psi(\to \mu^+\mu^-)$, hadron-lepton swaps, large branching fraction!
- Events vetoed if:
  - $m(\pi_{\to\mu} K \mu_{\to\pi}\mu)_{J/\psi \text{ constr}}$ or $m(\mu_{\to\pi}\mu)$ in $m_B$ or $J/\psi$ respectively
    AND
  - lepton is hadron-like, or hadron is lepton-like
- Contamination: $0.8 \pm 0.2$ %



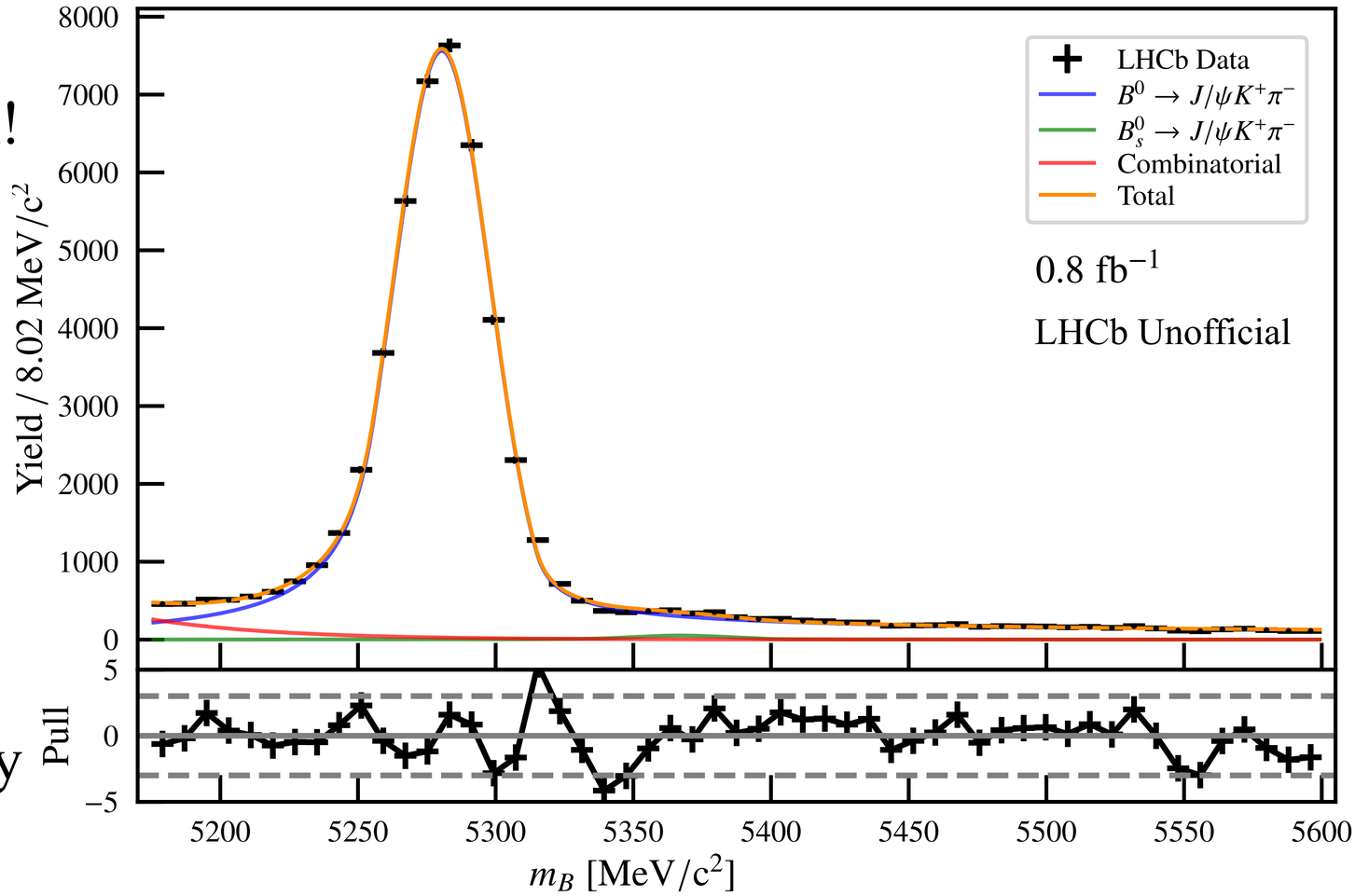
# Control mode $B^0$ mass fits

- Contamination from the studied backgrounds are $\lesssim 1\,\%$

- Clean enough data to fit the $J/\psi$ region!
  - Only signal and combinatorial background remains

- Signal modelled by a gaussian with exponential tails

- Combinatorial background modelled by an exponential

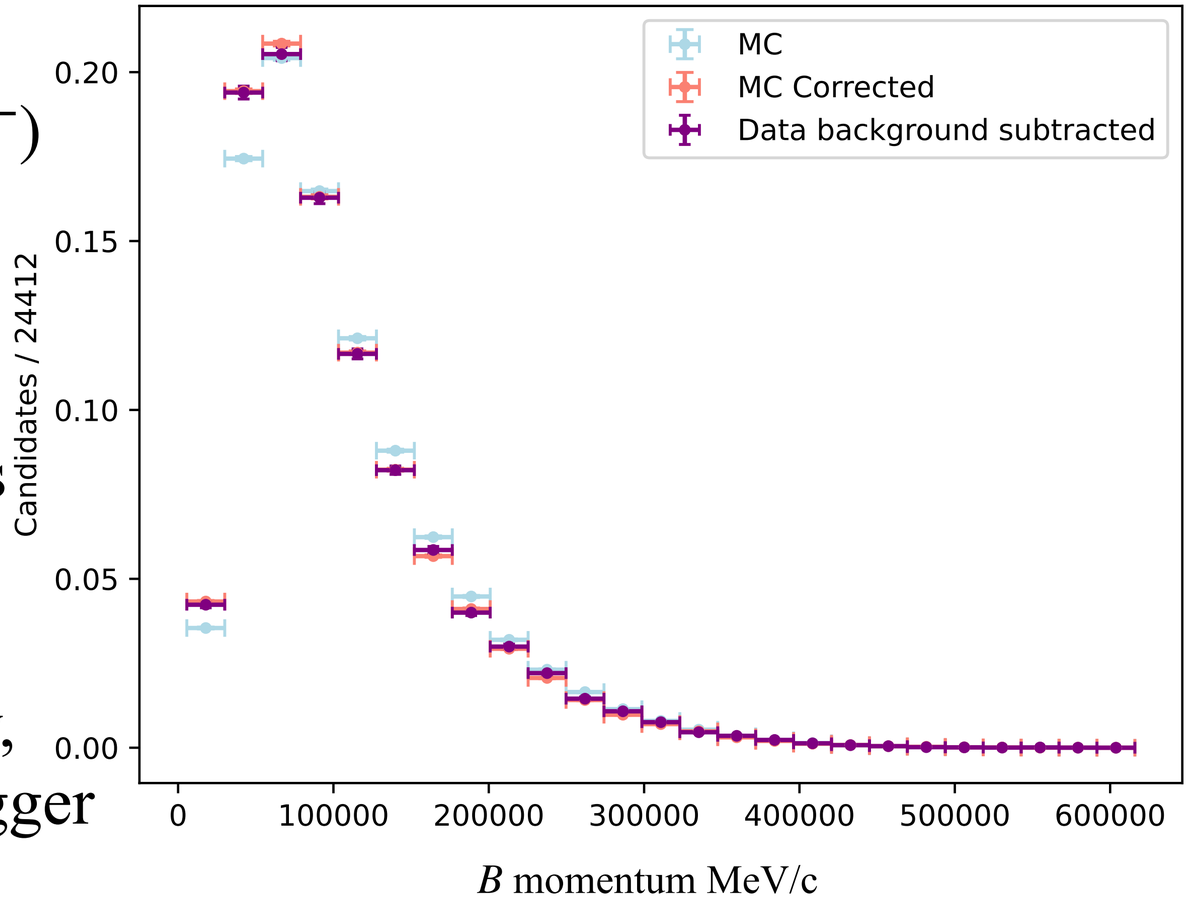


# Corrections to simulation

- Need to trust simulation to trust the evaluated efficiencies

- Corrections found from $B^0 \to K^{*0} J/\psi( \to \mu^+\mu^-)$
  - Per event weights found by comparing simulation and LHCb Data
  - Developed for the published $R_{K^{*0}(892)}$ analysis arXiv:2212.0915

- Need to correct B kinematics, event multiplicity, response of the PID detectors and hardware trigger



# Conclusion

- The set of anomalies observed in rare decays is still to be fully understood
  - Hadronic uncertainties are the limiting factors

- BF measurement in a rather unexplored region of high $m(K\pi)$ mass
  - Valuable contribution to the puzzle of the anomalies

- Next steps:
  - Some peaking backgrounds remain to be studied, finalise fit-model and evaluate systematics

Thank you for listening!