# *b*-hadron FCNC decays at LHCb

## CLHCP 2023

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on behalf of the LHCb Collaboration

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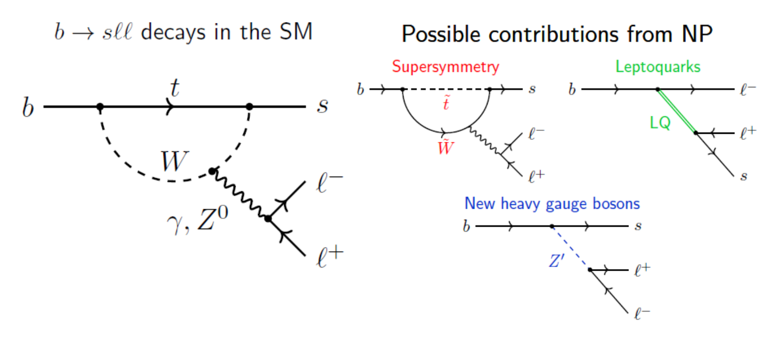
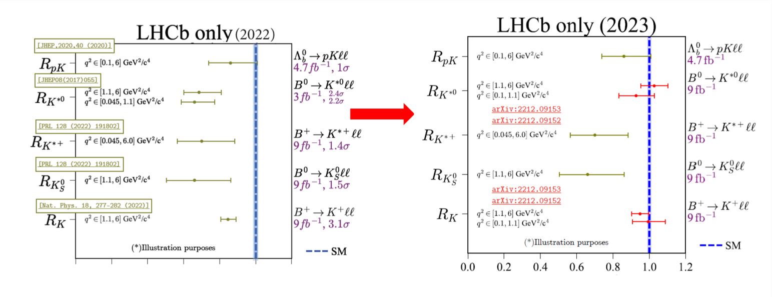
- FCNC ($b \to s\ell^+\ell^-$) heavily suppressed in the SM
- New heavy particles can significantly contribute and affect decay rates, angular distributions, and rate asymmetries

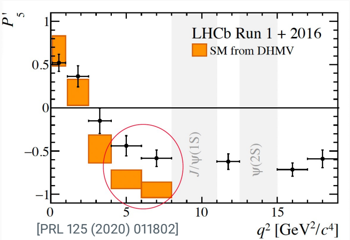


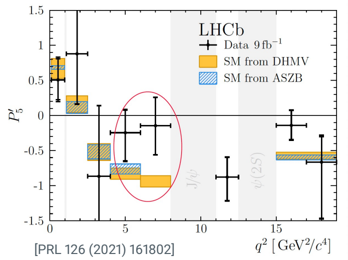
- Test LFU using ratios of branching fraction $R_X = \frac{B(b \to s\mu^+\mu^-)}{B(b \to se^+e^-)}$
- Status late 2022 showed an intriguing pattern of tension to SM
- $R_X$ ratio extremely well predicted in SM, any departure from unity is a clear sign of New Physics
- Now: agreement to SM driven by latest LHCb measurement



# $b \to s\mu^+\mu^-$ angular analysis

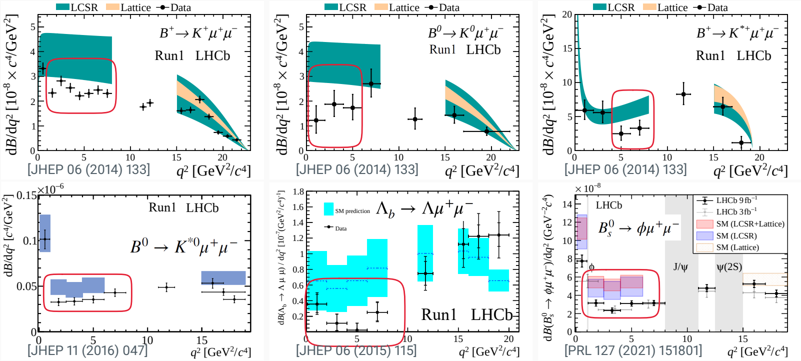
- Optimised variables where form factors cancel at leading order : $P'_5 = \frac{S_5}{\sqrt{F_L(1-F_L)}}$ [JHEP, 05 (2013) 137]
- Local tension of $2.5\sigma$ and $2.9\sigma$ in bins of [4.0,6.0] and [6.0,8.0] $\mathrm{GeV}/c^2$ for $B^0 \to K^{*0}\mu^+\mu^-$ [PRL 125 (2020) 011802]
  - New unbinned analysis result reduce the tension to $1.8\sigma$
- Similar trend in $B^0 \to K^{*+}\mu^+\mu^-$ [PRL 126 (2021) 161802]
- Update using the full LHCb Run 1+2 data sample ongoing



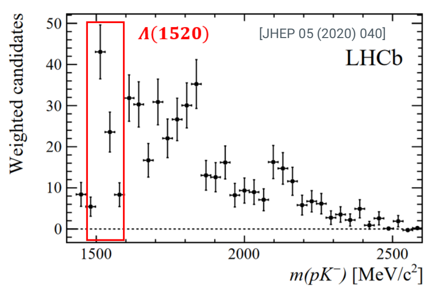



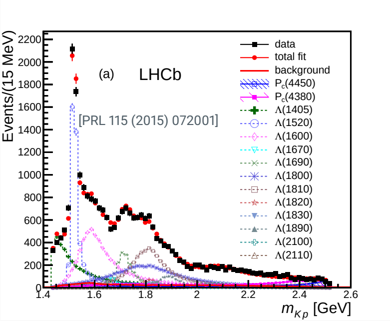
# $b \to s\mu^+\mu^-$ differential decay rates

- Data consistently below SM predictions (particularly at low $q^2$)
- Tensions at 1–3 level, SM predictions exhibit sizeable hadronic uncertainties $\sigma_{th} \sim O(20-30\%)$ (form factors, charm-loop)
- Anomaly or a common issue with hadronic contributions from SM ?



- $\Lambda_b^0 \to pK^-\mu^+\mu^-$ first observed at LHCb with Run1 data ($3\,\mathrm{fb}^{-1}$) [JHEP06(2017)108]
- LFU test with $\Lambda_b^0 \to pK^-\ell^+\ell^-$ decays at low $q^2$ ([0.1-6.0] $\mathrm{GeV}^2/c^4$) with Run1 and 2016 data ($4.7\,\mathrm{fb}^{-1}$) [JHEP 05 (2020) 040]
- Rich resonance spectrum in the $pK^-$ system, but the $\Lambda(1520)$ stands out due to its narrow width

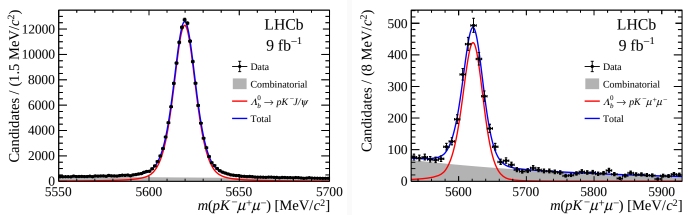


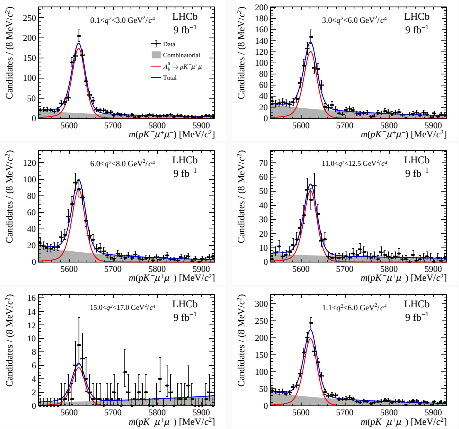
# Measurement of $d\mathcal{B}(\Lambda_b^0 \to \Lambda(1520)\mu^+\mu^-)/dq^2$ [PRL 131 (2023), 151801]

- Measure the $\mathcal{B}(\Lambda_b^0 \to \Lambda(1520)\mu^+\mu^-)$ in bins of $q^2$ with full Run1+Run2 data [9 fb$^{-1}$]
- Normalization of the branching fraction is done through the corresponding $J/\psi$ decay mode

$$\left\{\frac{d\mathcal{B}[\Lambda_b^0 \to \Lambda(1520)\mu^+\mu^-]}{dq^2}\right\}_{q^2_{\rm min}}^{q^2_{\rm max}} = \frac{1}{(q^2_{\rm max} - q^2_{\rm min})} \frac{\mathcal{B}(\Lambda_b^0 \to pK^- J/\psi)\mathcal{B}(J/\psi \to \mu^+\mu^-)}{\mathcal{B}[\Lambda(1520) \to pK^-]} \times \frac{N_{\Lambda(1520)\mu^+\mu^-}}{N_{pK^-J/\psi}} \frac{\varepsilon_{pK^-J/\psi}}{\varepsilon_{\Lambda(1520)\mu^+\mu^-}}$$

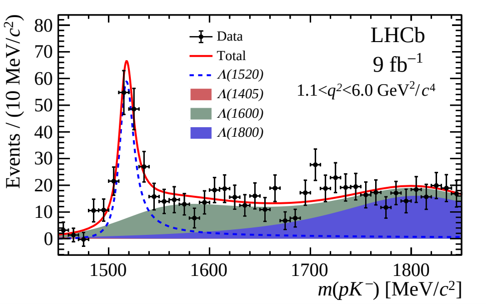


- Fit to the $m(pK^-\mu^+\mu^-)$ distribution in regions of $q^2$ outside the $J/\psi$ and $\psi(2S)$ resonances
- Clear signal peak in all regions
- Using sPlot method to get the signal-only $m(pK^-)$ distribution

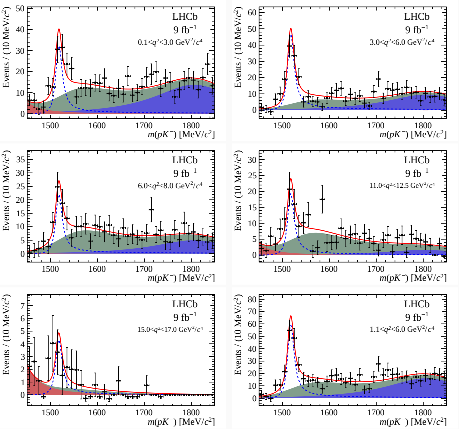


# Measurement of $d\mathcal{B}(\Lambda_b^0 \to \Lambda(1520)\mu^+\mu^-)/dq^2$ [PRL 131 (2023), 151801]

- Consider $\Lambda(1405)$, $\Lambda(1520)$, $\Lambda(1600)$, $\Lambda(1800)$ resonances
- Relativistic Breit-Wigner lineshapes used
- Mass resolution so good that it only matters for $\Lambda(1520)$
- Uncertainty in resonance parameters and interference treated as systematics

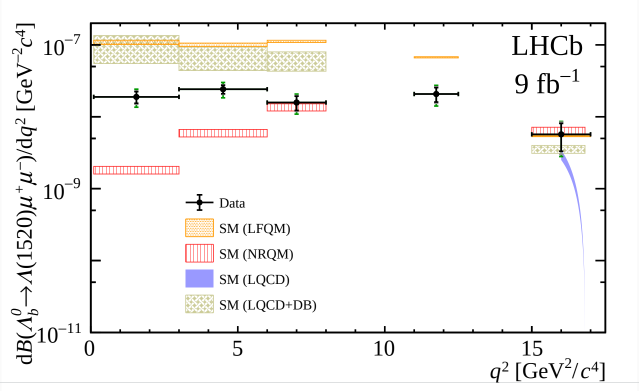


- Clear $\Lambda(1520)$ peak in all regions
- Not isolated as the $K^*$ in $B^0 \to K^{*0}\mu^+\mu^-$
- Still promising for angular analysis

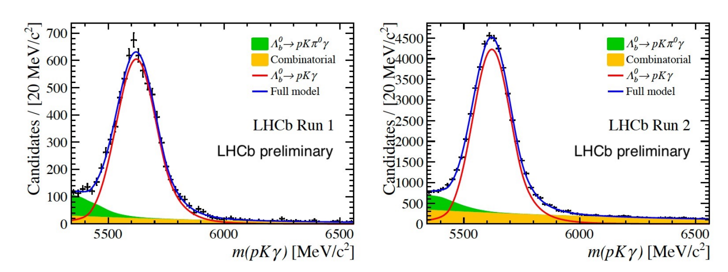


# Measurement of $d\mathcal{B}(\Lambda_b^0 \to \Lambda(1520)\mu^+\mu^-)/dq^2$ [PRL 131 (2023), 151801]

- Branching fraction measurement dominated by statistical uncertainty
- Comparison to the theoretical predictions is made in all $q^2$ regions
- Results are consistent with SM at high $q^2$, large difference between predictions at low and middle $q^2$, indicating that consolidation on the theory side is required to be conclusive

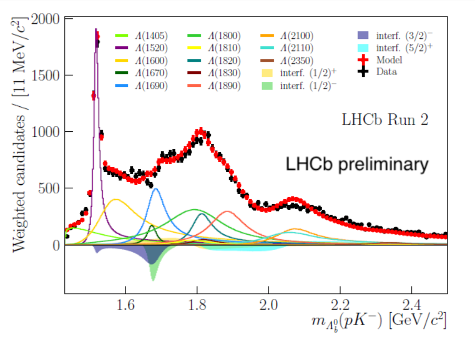


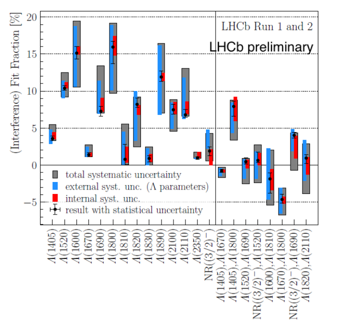
- Obtained 50K signal candidates from the full LHCb data [9 $\text{fb}^{-1}$]
- Fit to the $m(pK^-\gamma)$ distribution to disentangle the signal and the backgrounds using the sPlot method
- Fit was done separately for Run 1 and 2 due to the different trigger configurations



# Amplitude analysis of $\Lambda_b^0 \to pK^-\gamma$ [LHCb-PAPER-2023-036 in preparation]

- Best model containing all the well-established Λ states with $L \leq 3$ plus a non-resonant component with $J^P = 3/2^-$
- Dominant contributions from $\Lambda(1800)$, $\Lambda(1600)$, Λ(1890) and $\Lambda(1520)$
- Uncertainty entirely dominant by external inputs (mass and width of the Λ resonance)



# Summary

- Presented recent results for rare beauty baryon decays
  - First measurement of $d\mathcal{B}(\Lambda_b^0 \to \Lambda(1520)\mu^+\mu^-)/dq^2$
  - First amplitude analysis of $\Lambda_b^0 \to pK^-\gamma$
- Current measurement limited by external inputs (still experimental)
- Theoretical effort is necessary to converge on the understanding of Λ resonances such as in $\Lambda_b^0 \to \Lambda(1520)\mu^+\mu^-$
- Complementary angular analysis is on the way

Thanks!

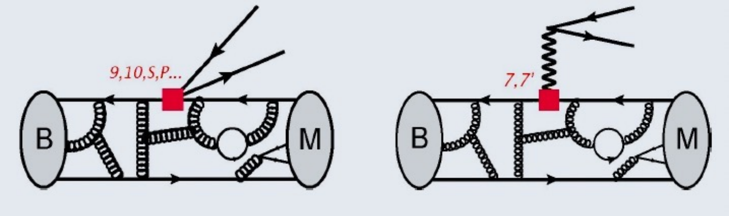
# Backups

# SMEFT

- Model-independent description in effective field theory

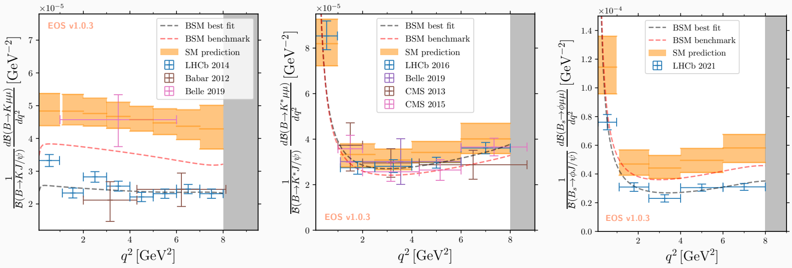
$$\mathcal{H}(b \to s\ell\ell) = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_{i=1}^{10} C_i(\mu) O_i(\mu)$$

- With Wilson coefficient $C_i$ and local operator



# Dispersive analysis

- Extrapolate the LQCD from high $q^2$ to low $q^2$
- Apply dispersive bounds for form factor constraints
- The optical theorem gives a shared bound for all the $b \to s$ processes (more measurement more constraint)
- Tension reduction in $B^+ \to K^+\mu^+\mu^-$, persists in $B^0 \to K^{*0}\mu^+\mu^-$ and $B_s^0 \to \phi\mu^+\mu^-$



# Dispersive analysis - *b*-baryon sector

- Agrees well for $\Lambda_b^0 \to \Lambda\mu^+\mu^-$
- Undershoot the data for $\Lambda_b^0 \to \Lambda(1520)\mu^+\mu^-$