**Why \( B^+ \to \mu^+ \nu_\mu \gamma \)?**

- Decays have never been observed
- Golden mode to probe \( B^+ \) meson substructure
- Emission of \( \gamma \) probes first inverse moment \( \lambda_B \) of the \( B \) meson Light Cone Distribution Amplitude
- Value of \( \lambda_B \) not well known
- Vital theory input for QCD factorization schemes and non-perturbative calculation of \( B \) meson decays

On the decay \( B^+_s \to \mu^+ \nu_\mu \gamma \)

- CKM favoured by \(|V_{ub}|^2/|V_{ub}|^2\) but production cross section much smaller
- Effects cancel to yield approximately the same rate as for \( B^+ \to \mu^+ \nu_\mu \gamma \)

**Reconstruction at LHCb**

- Extremely difficult to reconstruct at hadron colliders, deemed impossible
- Challenging yet possible at LHCb

**Photon Reconstruction**

- Select signal candidates from displaced \( B \) vertices
- Crucial to require \( \gamma \to e^+e^- \) conversion for vertex reconstruction
- Conversion in LHCb’s Vertex Locator provides excellent vertex resolution

**Neutrino Recovery**

- At LHCb cannot constrain neutrino momentum from initial kinematics
- Correct for momentum imbalance \( p_\perp \) perpendicular to \( B \) flight direction

\[
m_{corr} = \sqrt{m_{vis}^2 (\mu^+\nu_\mu) + p_\perp^2 + p_\perp}
\]

**Background modelling**

**Analysis Strategy**

- Use data recorded with LHCb from 2016-2018 corresponding to \( L \text{int} = 5.4 \text{ fb}^{-1} \)
- Search for signal by binned template fit in \( m_{corr} \)
- Generate data-driven background templates

**Background from \( \pi^0/\eta \to \gamma e\gamma \)**

- By far the dominant source of background
- Select \( \pi^0/\eta \to \gamma ee/\eta \) in data using additional calorimeter photon \( \gamma_{\text{calo}} \)
- Correct efficiency of finding additional photon
- Representative of all \( \pi^0/\eta \to \gamma ee \gamma \) backgrounds including physics and combinatorial components

Background from \( h^+ \to \mu^+ \) mis-identification

- Control sample without PID requirement on the muon track
- Generate template for \( \pi^+ \to \mu^+ \) and \( K^+ \to \mu^+ \)

**Optimising signal selection**

- Maximise sensitivity to \( B(\bar{B}^+ \to \mu^+ \nu_\mu \gamma) \)
- Optimisation performed on pseudo-experiments
- Generate background only pseudo-data from derived templates
- Fitting with signal shapes for \( B^+_s \to \mu^+ \nu_\mu \gamma \)
- Signal selection not yet finalised

**Outlook**

- Search for \( B^+_s \to \mu^+ \nu_\mu \gamma \) can be done at LHCb
- Pushing the limits of the LHCb experiment
- Analysis strategy and background modelling in place
- Selection of signal candidates still ongoing
- Expected sensitivity towards \( B(\bar{B}^+ \to \mu^+ \nu_\mu \gamma) \) soon to be evaluated

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**Current experimental limit**

Belle searched for \( B^+ \to \ell^+ \nu_\ell \gamma \) using \( \ell = e, \mu \) to find an upper limit of

\[
B(\bar{B}^+ \to \ell^+ \nu_\ell \gamma) < 3.0 \times 10^{-6} \text{ @90\%CL}
\]

Branching ratio prediction for \( \bar{B}^+ \to \mu^+ \nu_\mu \gamma \) superimposed with the experimental limit from Belle. The colored bands correspond to different theory models.

**Search for the decay \( B^+_c \to \mu^+ \nu_\mu \gamma \)**

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