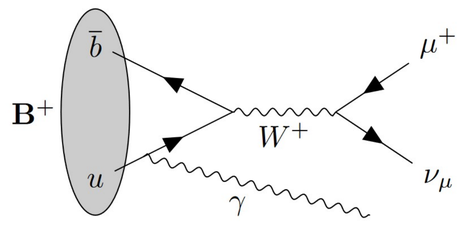
Search for the decay $B^+_{(c)} \to \mu^+\nu_\mu\gamma$

Fabian Glaser[1,2], Martino Borsato [3], Marie-Hélène Schune[2]
[1] Universität Heidelberg, Physikalisches Institut, Germany,
[2] Université Paris-Saclay, CNRS/IN2P3, IJCLab, Orsay, France,
[3] Milano-Bicocca University, INFN Sezione di Milano, Italy

Why $B^+ \to \mu^+\nu_\mu\gamma$?

- Decay has **never been observed**
- **Golden mode** to probe B^+ meson substructure
- Emission of γ probes first inverse moment λ_B of the B meson Light Cone Distribution Amplitude
- Value of λ_B not well known
- **Vital theory input** for QCD factorization schemes and non-perturbative calculation of B meson decays



Leading order Feynman diagram for the decay $B^+ \to \mu^+\nu_\mu\gamma$.

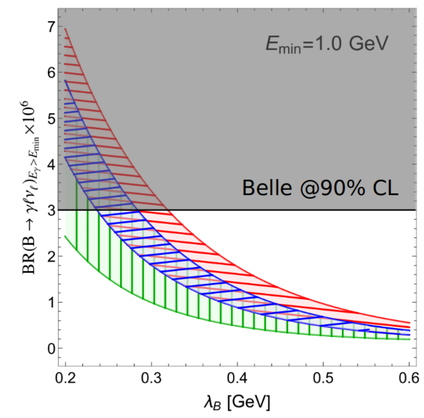
On the decay $B_c^+ \to \mu^+\nu_\mu\gamma$

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

Current experimental limit

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

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



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

JHEP 07 (2018) 154
PRD 98, 112016 (2018)

Reconstruction at LHCb

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

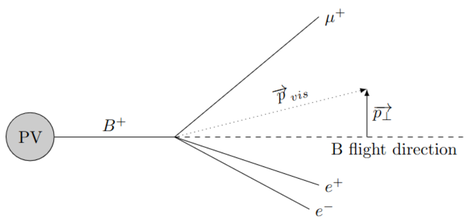
Photon Reconstruction

- 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

$$m_{corr} = \sqrt{m^2_{vis}(\mu^+\gamma_{ee}) + p^2_\perp} + p_\perp$$



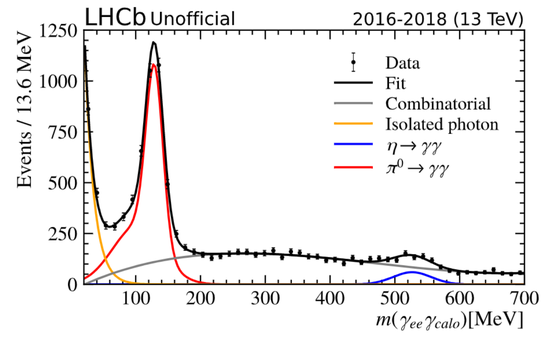
Background modelling

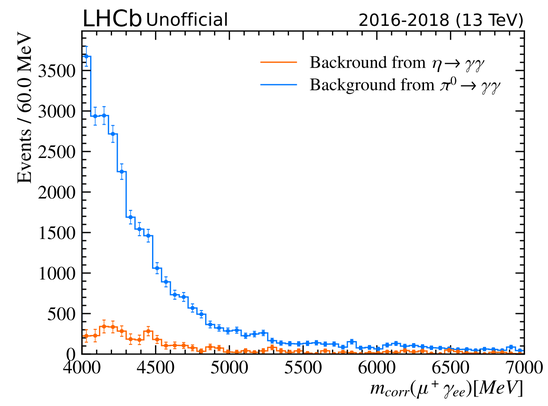
Analysis Strategy

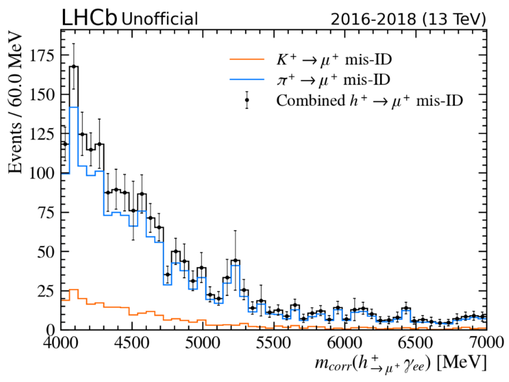
- Use data recorded with LHCb from 2016-2018 corresponding to $\mathcal{L}_{int} = 5.4\,\text{fb}^{-1}$
- Search for signal by binned template fit in m_{corr}
- Generate data-driven **background templates**

Background from $\pi^0/\eta \to \gamma_{ee}\gamma$

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







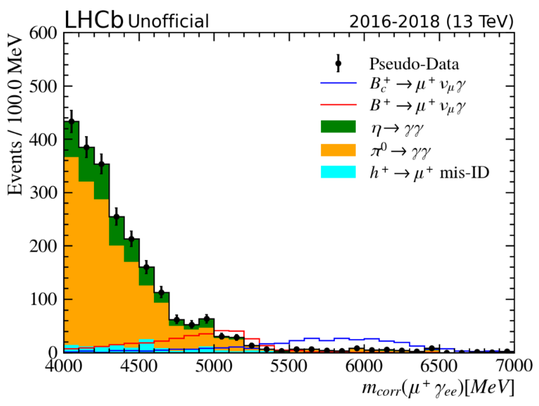
Background from $h^+ \to \mu^+$mis-identification

- 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 $\mathcal{B}(B^+ \to \mu^+\nu_\mu\gamma)$
- Optimisation performed on pseudo-experiments
- Generate background only pseudo-data from derived templates
- Fitting with signal shapes for $B^+_{(c)} \to \mu^+\nu_\mu\gamma$
- Signal selection **not yet finalised**

WORK IN PROGRESS



Background-only pseudo-data and signal shapes with arbitrary normalisation.

Outlook

- Search for $B^+_{(c)} \to \mu^+\nu_\mu\gamma$ 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 $\mathcal{B}(B^+ \to \mu^+\nu_\mu\gamma)$ soon to be evaluated

13th LHC students poster session, Nov. 27th 2023

fabian.christoph.glaser@cern.ch