Towards a measurement of $B \to \pi\tau\nu$ and R(π)

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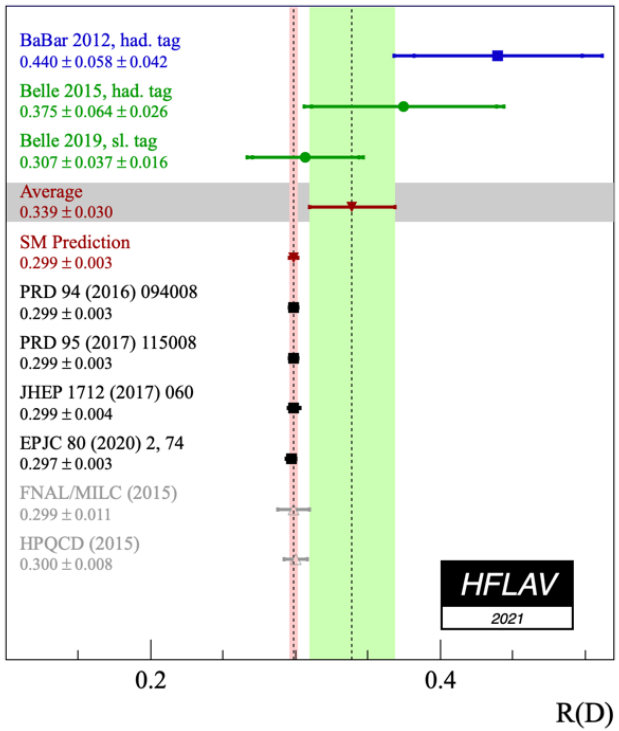
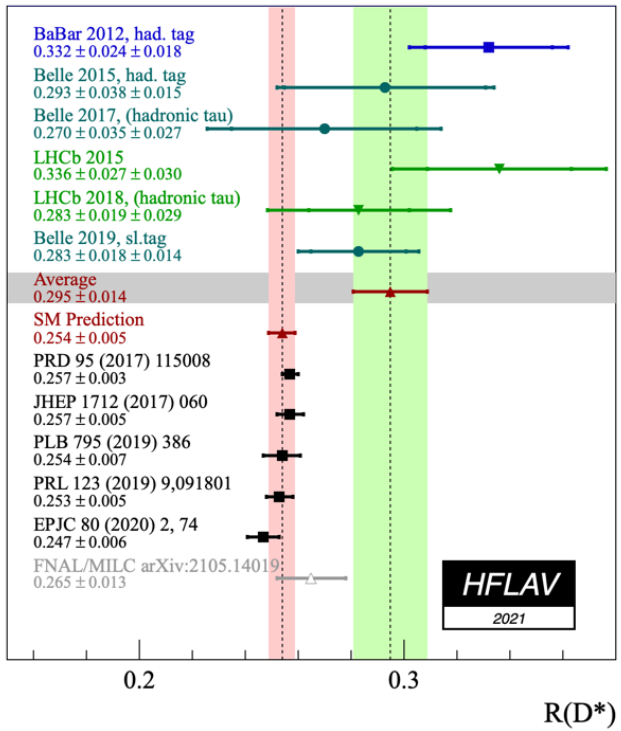
Research Aims

- Belle II Experiment main aim to search for new physics through the study of rare decays
- Aim for this project: Measure ratio of branching fractions $R(\pi) = \frac{\mathcal{B}(B \to \pi\tau\nu)}{\mathcal{B}(B \to \pi\ell\nu)}$ for $\ell = e, \mu$
- SM Prediction: 0.641 ± 0.016
- Current upper bound of $\mathcal{B}(B^0 \to \pi^- \tau^+ \nu) = 2.5 \times 10^4$ at 90% CL done with hadronic tagging at Belle
- Perform such measurement with the use of semileptonic tagging

Motivation: Similar Measurements



(a) $R(D)$ Measurement



(b) $R(D^*)$ Measurement

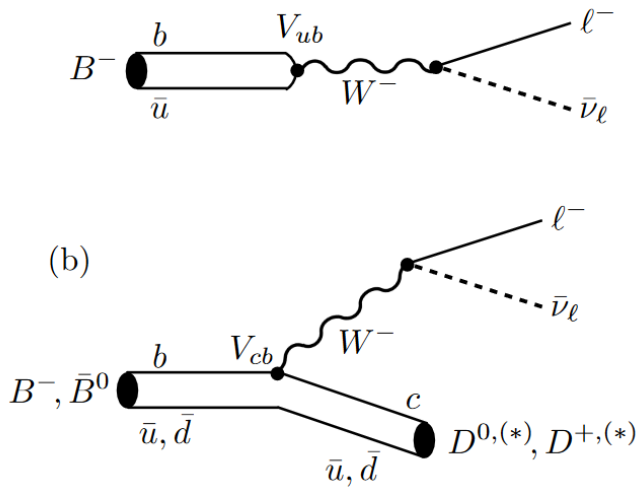
- Tension in both similar measurements for $R(D), R(D^*)$ exceeding 1.4σ and 2.8σ
- Possibility of seeing similar phenomenon for light mesons requires more statistics

Theoretical Background

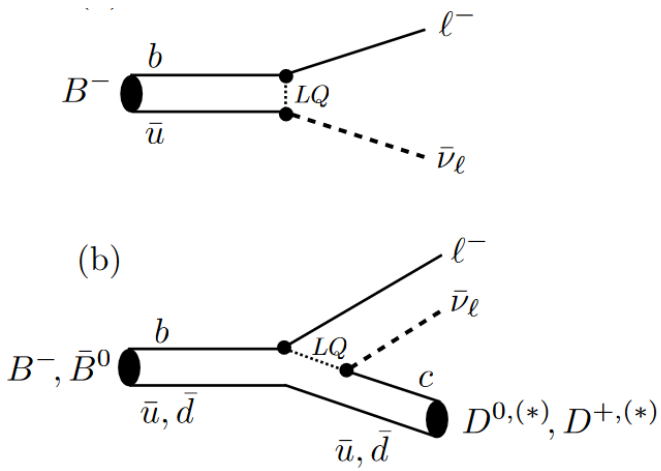
SM Differential Decay Rate $B \to \pi \ell \nu$:

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2 |V_{ub}|^2 |p_\pi| q^2}{96\pi^3 m_B^2} \left(1 - \frac{m_\ell^2}{q^2}\right)^2 \left[H_0^2(q^2) \left(1 + \frac{m_\ell^2}{q^2}\right) + \frac{3m_\ell^2}{2q^2} H_t^2(q^2) \right]$$

- Helicity amplitudes are functions of the form factors $f^{+/0}(q^2)$ parametrised in q^2: in terms of the 4-momentum transfer to the lepton
- Extensions to SM will change this term by modifying the helicity amplitudes



(a) Feynman Diagram under SM



(b) Possible leptoquark contributions

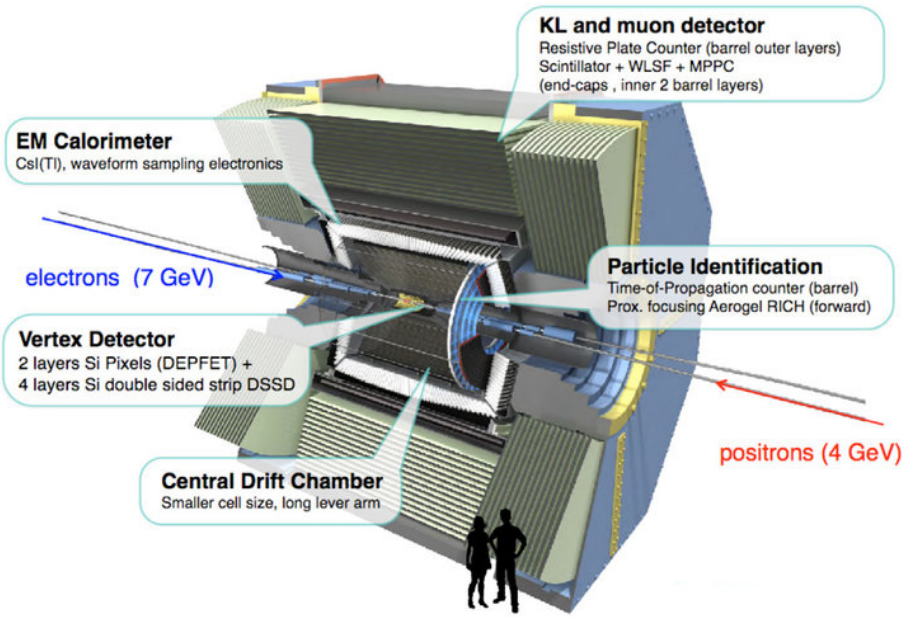
Current Plan

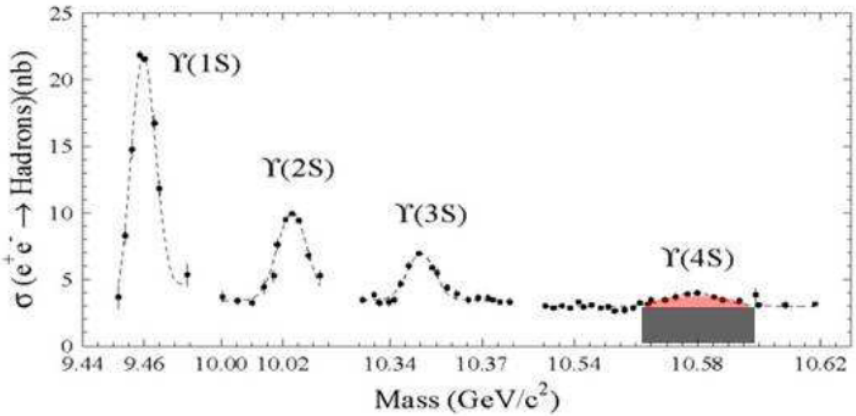
- Develop criteria to identify reconstructed $B \rightarrow \pi\tau\nu$ and exclude background events
- Develop proper method of identifying and reconstructing tau leptons

Backup Slides

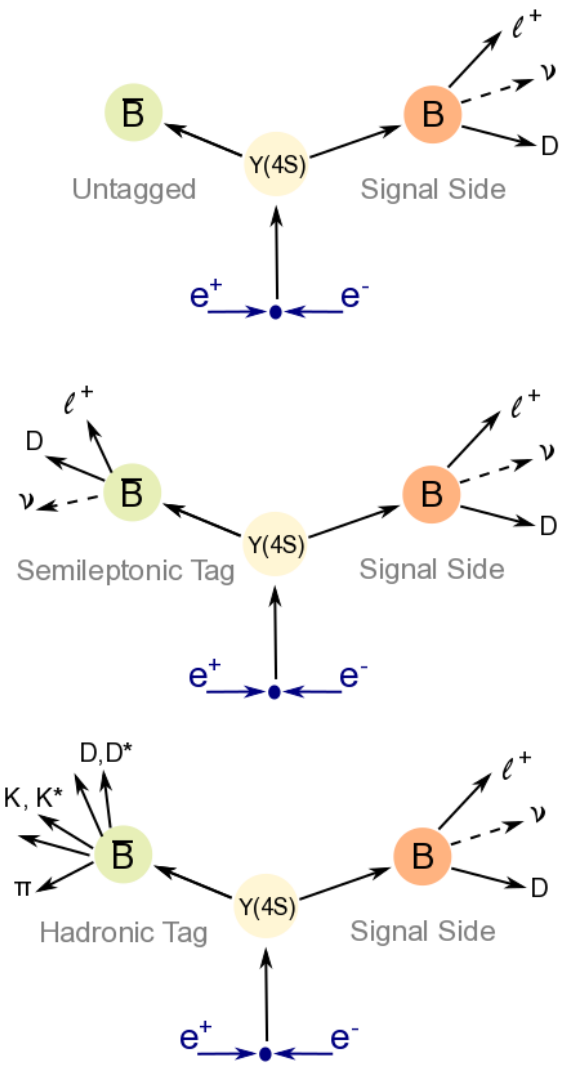
Belle II Experiment

- SuperKEKB collides asymmetric beams of 7 GeV electrons and 4 GeV positrons
- Centre of mass frame corresponds to Upsilon $\Upsilon(4S)$ resonance at 10.58 GeV, which decays to $B\bar{B} > 96\%$ of the time
- Aim over experiment lifetime to achieve an integrated luminosity of 50ab^{-1} corresponding to 52.5 billion $B\bar{B}$ pairs





Tagging Analysis



- Selecting $\Upsilon(4S)$ candidates with our signal B meson and a tag B meson which decays in a pre-defined way
- Higher degree of tag knowledge improves the kinematic information of our signal B meson and reduces background
- Semileptonic tagging is employed as it provides a middle ground between untagged and hadronic tagging analyses

Full Event Interpretation

- Since the decay is well known, it is useful in calibrating FEI
- Machine learning algorithm which reconstructs tag B mesons with a hierarchical approach
- Reconstructed tags have an output variable of signalProbability between 0 and 1 to indicate how background-like or how signal-like the B_{tag} is respectively
- Tagging efficiency of semileptonic tag $\varepsilon \approx \mathcal{O}(1\%)$