Search for $B^+ \to K^+ \nu\nu$ decays with an inclusive tagging using B2BII

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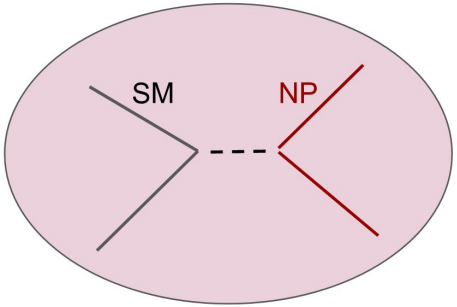
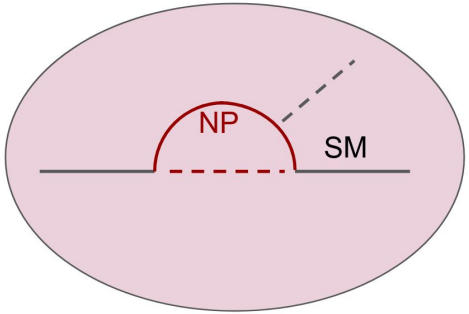
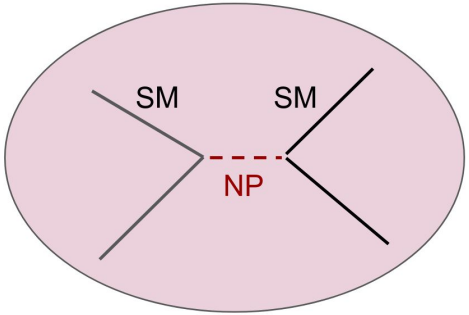
Indirect search for New physics







Energy frontier (CMS, ATLAS):

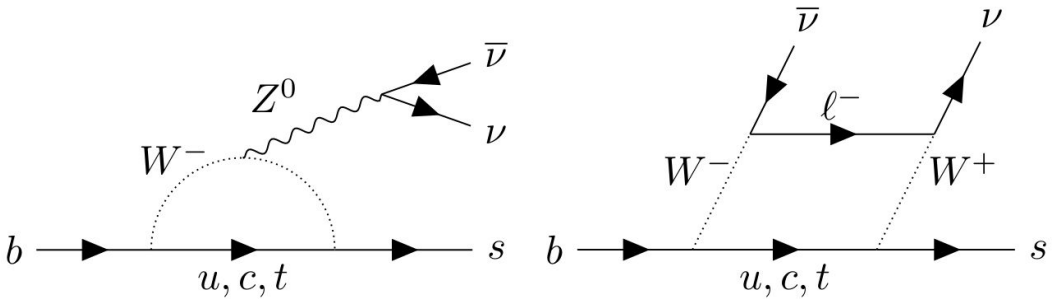
- Direct production of new physics (NP) particles
- Limited by beam energies

Intensity frontier (B-factories, LHCb):

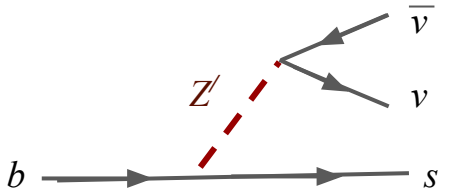
- Indirect searches for a deviation from SM expectations
- Offers a complimentary approach in NP searches
- Sensitivity to very high scales: recent observation of "Flavour Anomalies"

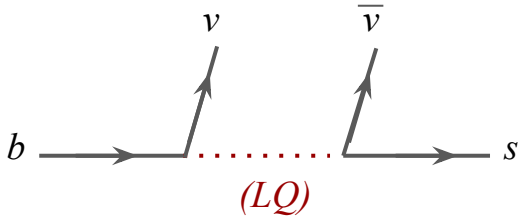
LHCb, arXiv:1705.05802, arXiv:2103.11769
Belle, arXiv:1904.02440, arXiv:1908.01848

$B^+ \to K^+ \nu\nu$ decays: Motivation



- Flavour changing neutral current; highly suppressed in the SM
- Theoretically clean in the absence of charged leptons in the final state
- Sensitive to potential new physics contributions:
  - Mediators in loops or new tree level diagrams
  - Sources of missing energy





PRD 106, L031703 (2022), PRD 98, 055003 (2018), PRD 102, 015023 (2020) , axions PRD 101, 095006 (2020)

Motivation (cont.)

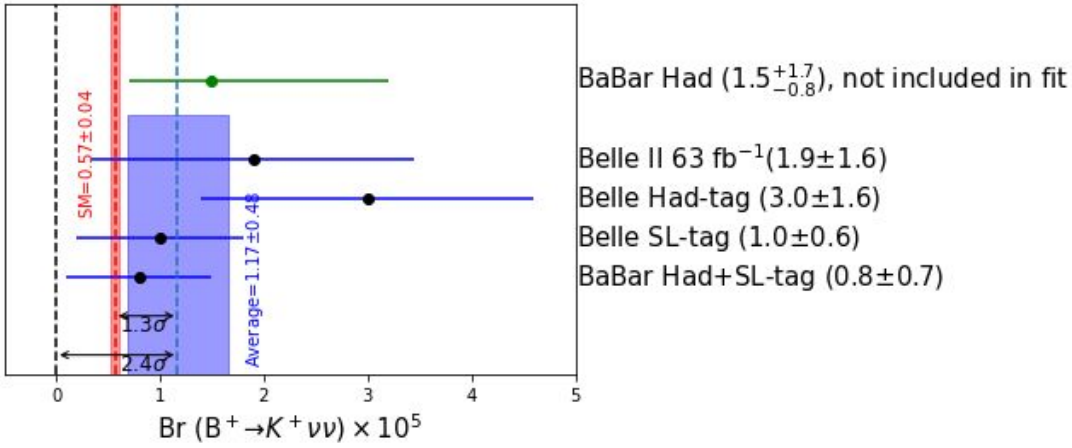
- Theory prediction:

  BR = (5.67±0.38)×10^{-6}

  (**HPQCD22**, https://arxiv.org/abs/2207.13371)

- Not observed yet experimentally
  - Searches from BaBar, Belle and Belle II

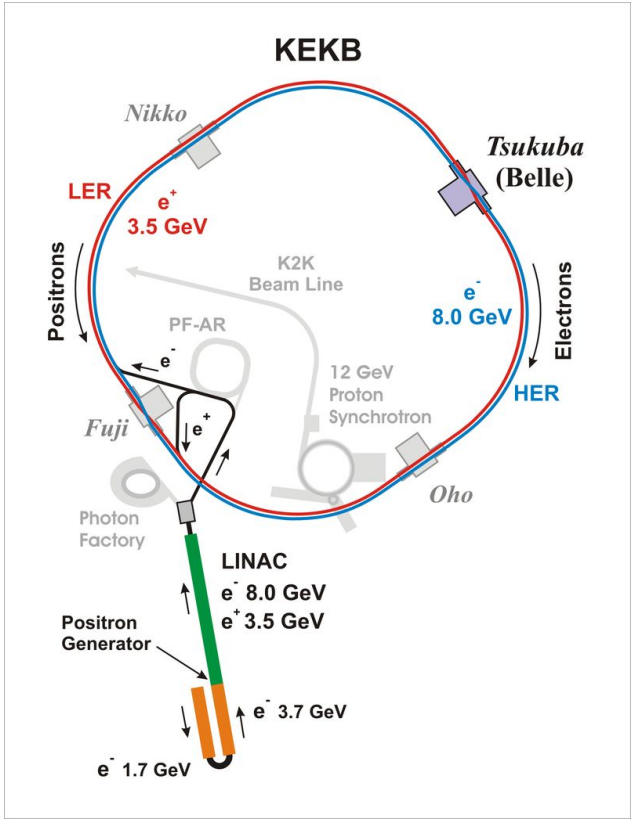
- Very hard/impossible at hadron collider; Belle/Belle II is in a unique position to do this measurement



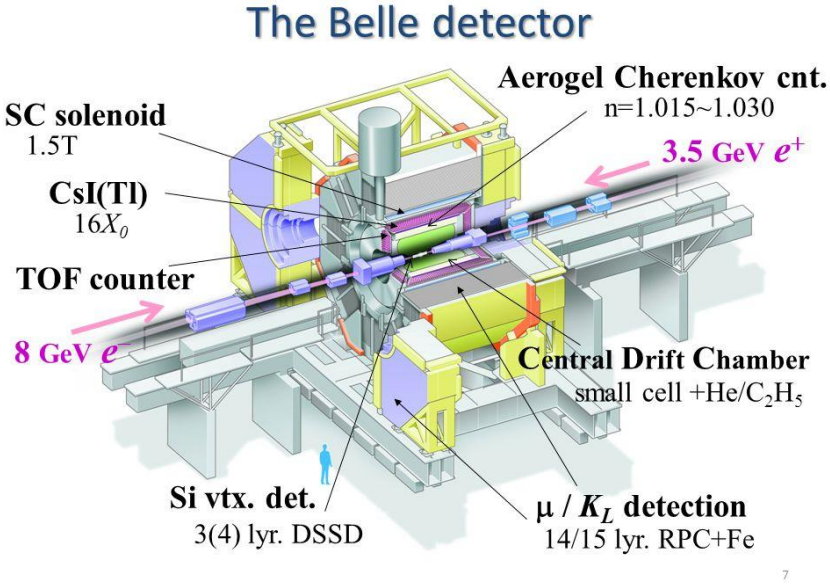
PRL **127**, 181802
PRD **87**, 111103
PRD **96**, 091101
PRD **87**, 112005

- **An inclusive analysis with the full Belle data would provide a more precise measurement**

KEKB and Belle detector

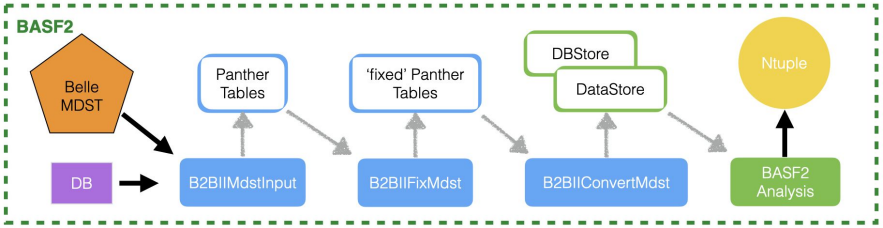


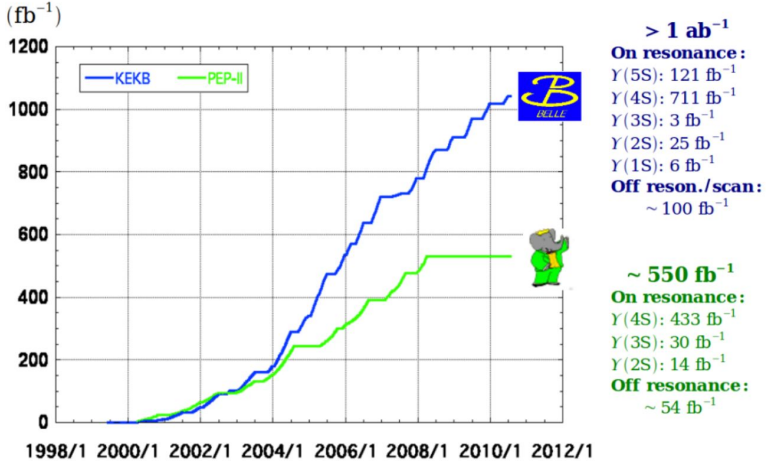
- e^- (8 GeV) →← e^+ (3.5 GeV)
- $\sqrt{s}$ = 10.58 GeV = m(Y(4S))



Why Belle ?

- **Data** : ~2 times BaBar and Belle II (pre LS1)
- Ideal environment to search for decays with missing energy in the final state:
  - clean event environment and well defined initial state
  - good & efficient reconstruction of decays with neutrals
- **B2BII**
  - Use Belle data with the analysis software and algorithms developed for Belle II





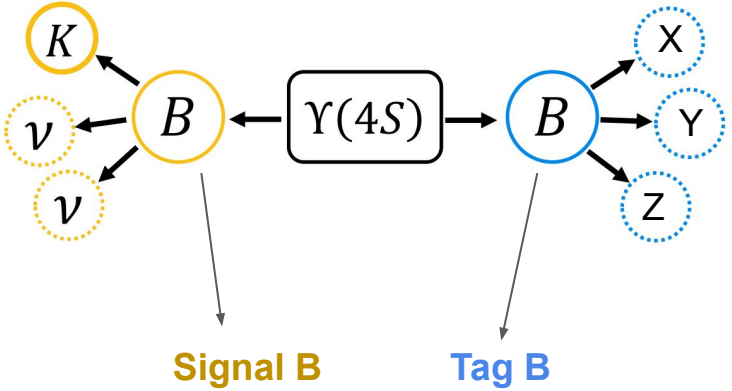
Belle II pre-LS1 : ~426 fb^{-1}

- An **inclusive tagging** approach not yet exploited with Belle data would provide a more precise measurement

Inclusive tagging

- Explicit reconstruction of the second B meson suffers in signal efficiency
  - Semileptonic tag:
    signal efficiency of ~0.2%
    (Belle, PRD 96, 091101 (2017))
  - Hadronic tag:
    signal efficiency of ~0.04%
    (BaBar, PRD 87, 112005 (2013))

Semi-leptonic/hadronic tag

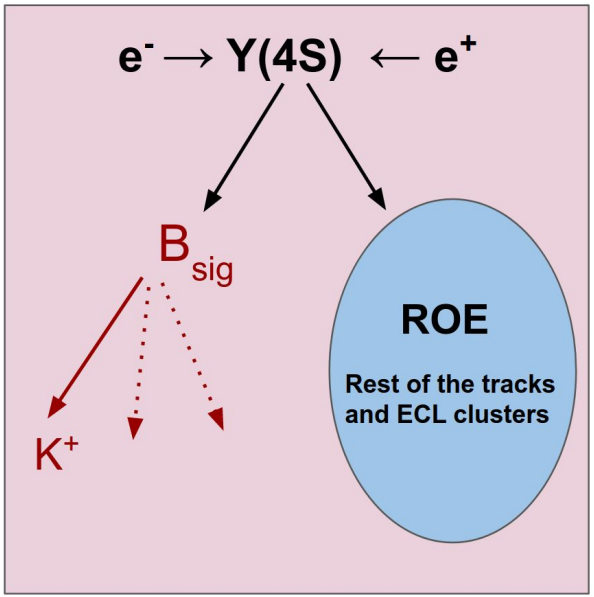


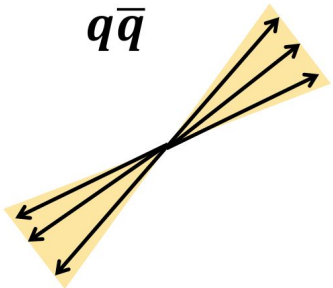
Inclusive tagging

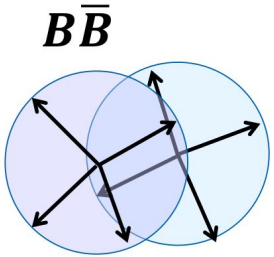
- Explicit reconstruction of the second B meson suffers in signal efficiency

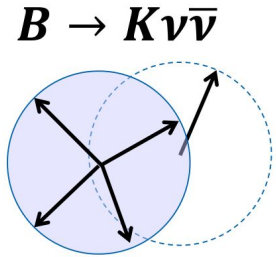
- A novel approach tested successfully with early Belle II data (Phys. Rev. Lett. **127**, 181802)

  - No explicit reconstruction of the tag side
  - Exploit distinct topology and kinematics to achieve higher signal efficiency (~4%)





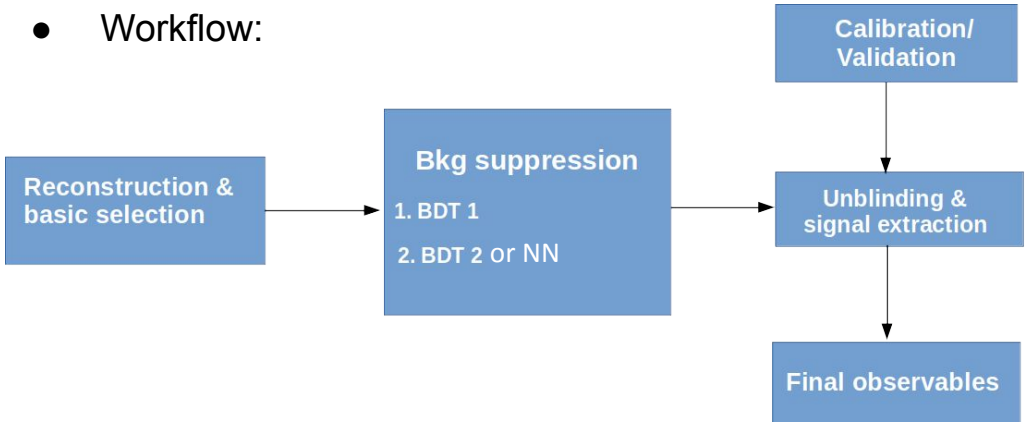




Analysis overview

- Goal: Measure $B^+ \to K^+ \nu\nu$ branching fraction using with the full Belle data
  - Hopefully best parameter estimation from a single experiment: observation of the process?

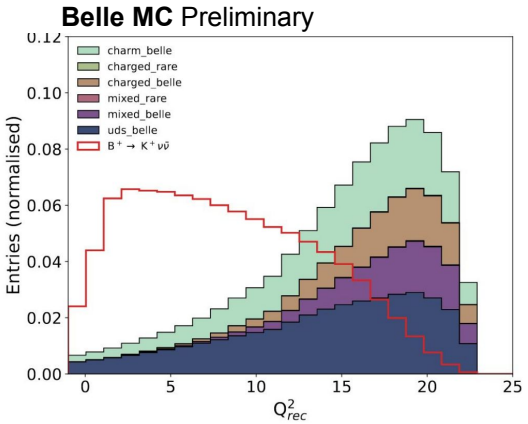
- Workflow:

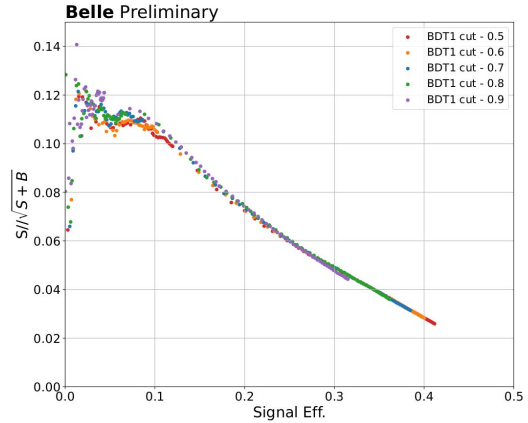


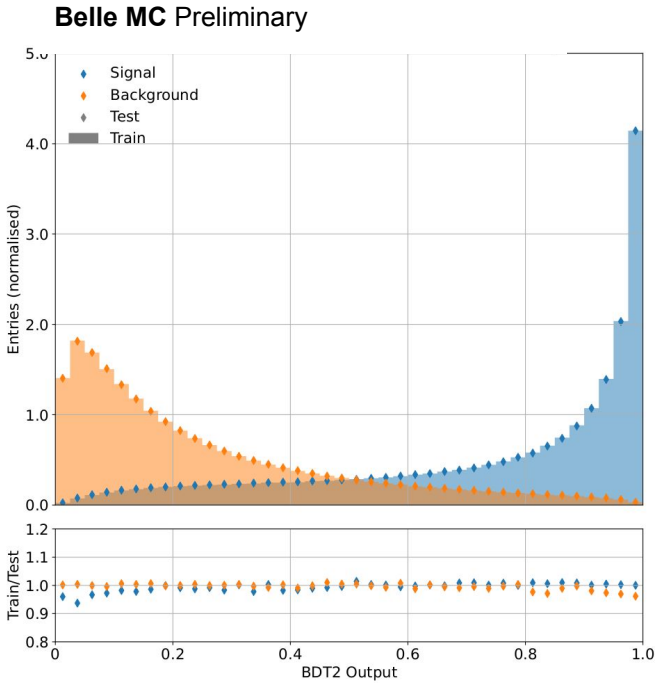
- Select highest p_T track as signal kaon candidate
- Choose one B candidate per event with lowest reconstructed $q^2 = M_B^2 + M_K^2 - 2M_B E_K^*$
- 2-step MVA for bkg suppression and signal selection (topology, rest-of-event, missing energy, vertex separation,…)
- Validation using off-resonance data and $B^+ \to K^+ J/\psi(\to \mu^+\mu^-)$ decays where the muons are removed to mimic signal
- A binned maximum likelihood fit to extract signal

Current status and plans

- Very preliminary plots using Monte Carlo samples





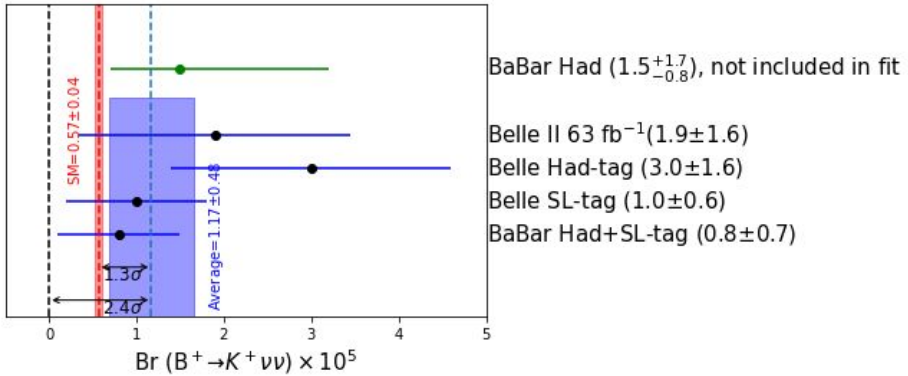


- Baseline selection and background suppression using MC samples
- Further optimization and control sample checks ongoing
- Analysis note under preparation
- Targeting Moriond 2023

Summary

- The decays of B-mesons with missing energy provide an indirect prob for NP
- An **inclusive tagging** approach, not yet exploited with Belle data would provide a more precise measurement on B.F. ($B^+ \to K^+ \nu\nu$)

  - Belle provides ideal event environment with ~2 times the BaBar/Belle II (pre-LS1) data
  - The B2BII enables us to use the advanced analysis softwares and algorithms being developed for Belle II
  - The analysis is currently blind: preliminary selection, background suppression and signal extraction procedure are being developed using simulated samples
  - Targeting to have the preliminary results by Moriond 2023



→ Belle II inclusive tagging provide a competitive result already with 63 fb^{-1}

→ With more than 10 times data, we expect a much better precision


THANK
YOU !