Inclusive analysis of $B \to X_u \ell \nu_\ell$ and $|V_{ub}|$determination at Belle II

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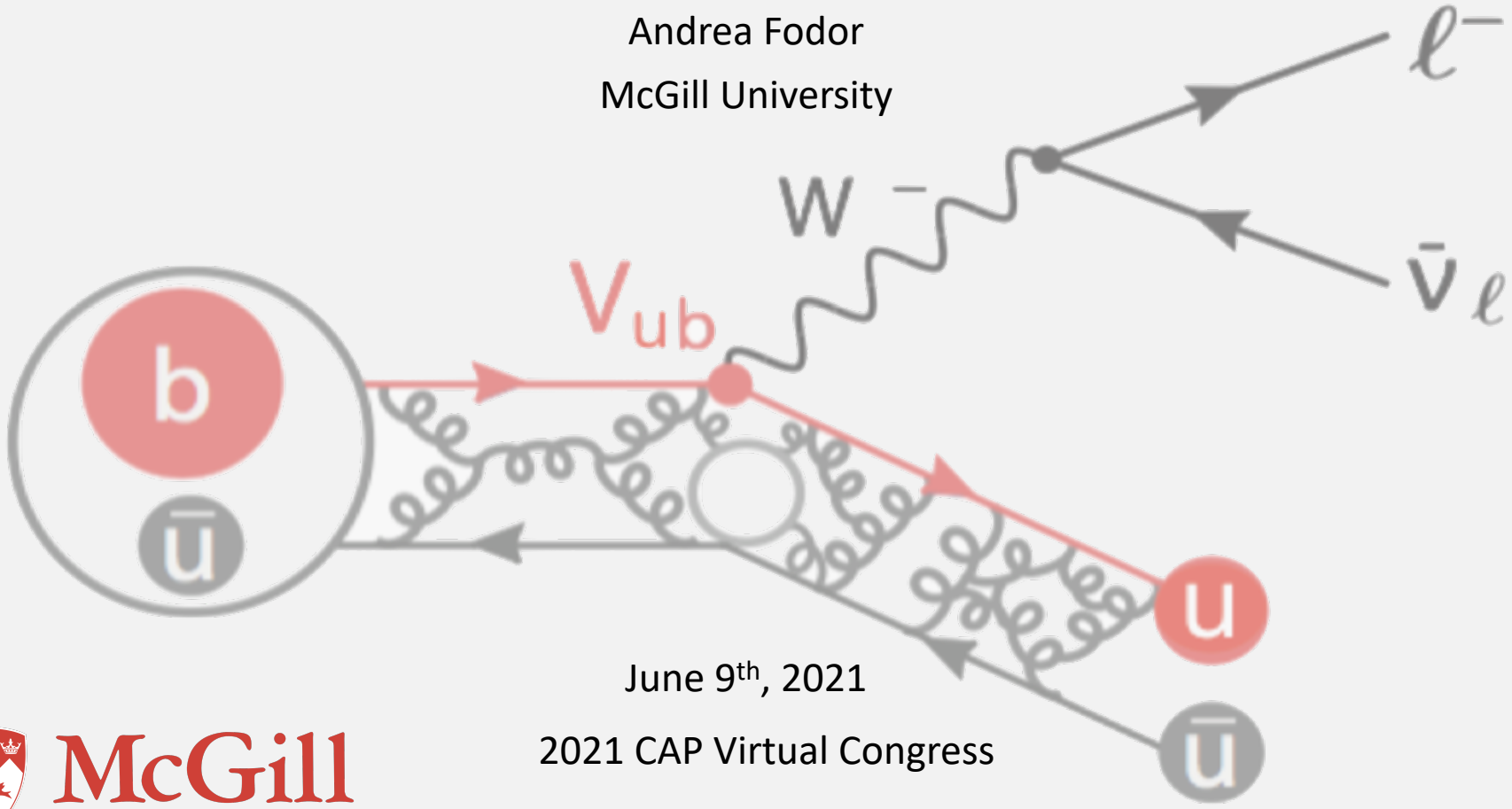
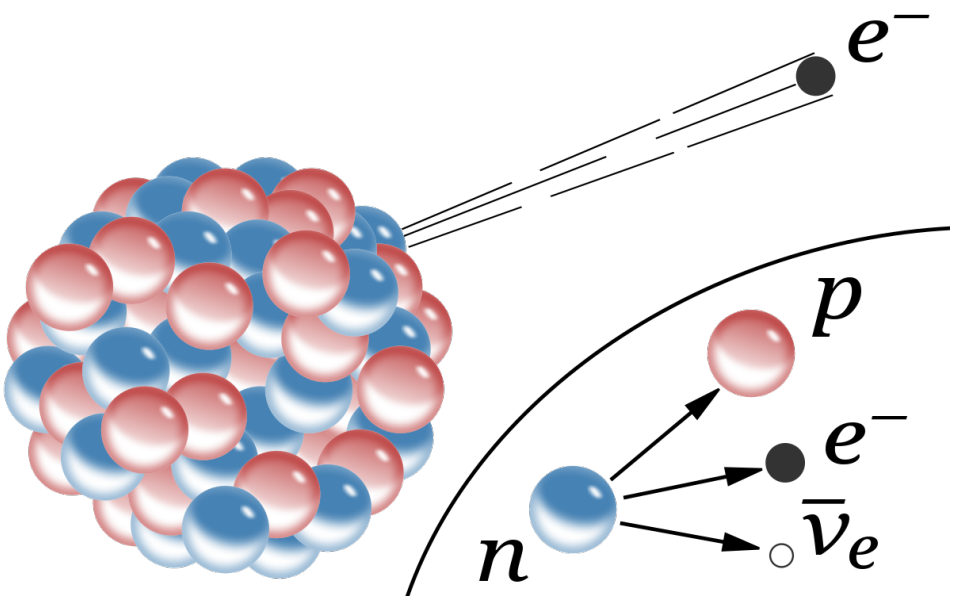


June 9th, 2021

2021 CAP Virtual Congress

Introduction

- β decay of the neutron – the same type of interaction as $B \to X_u \ell \nu$ decay



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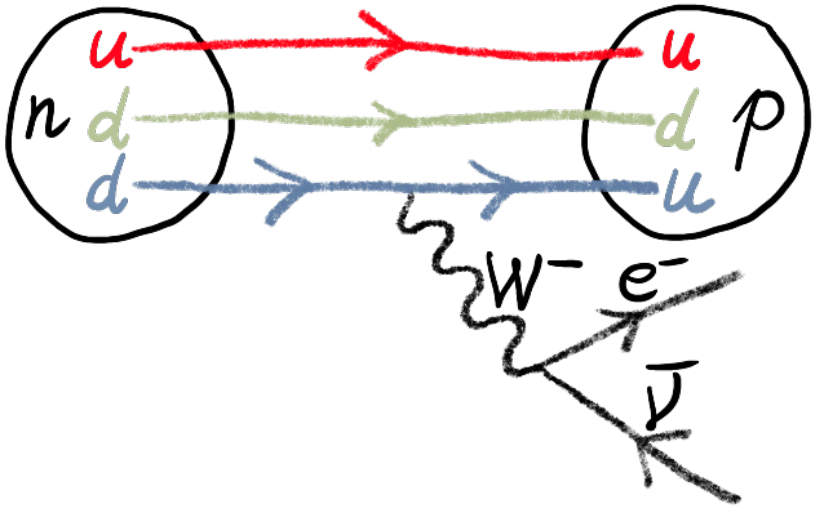
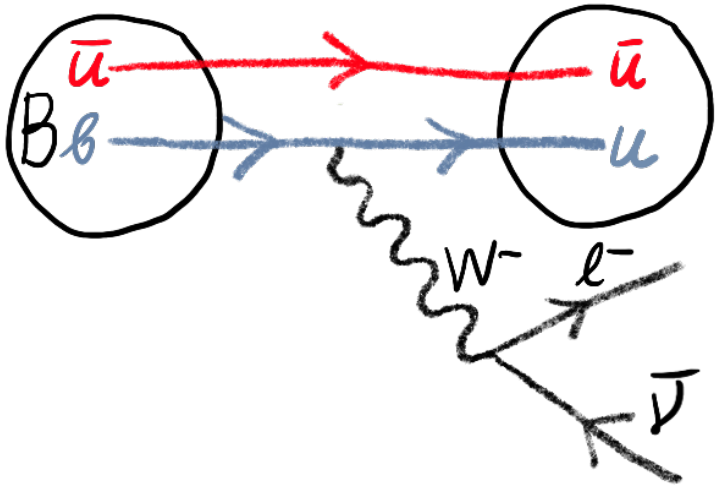
  - Both are governed by the weak force





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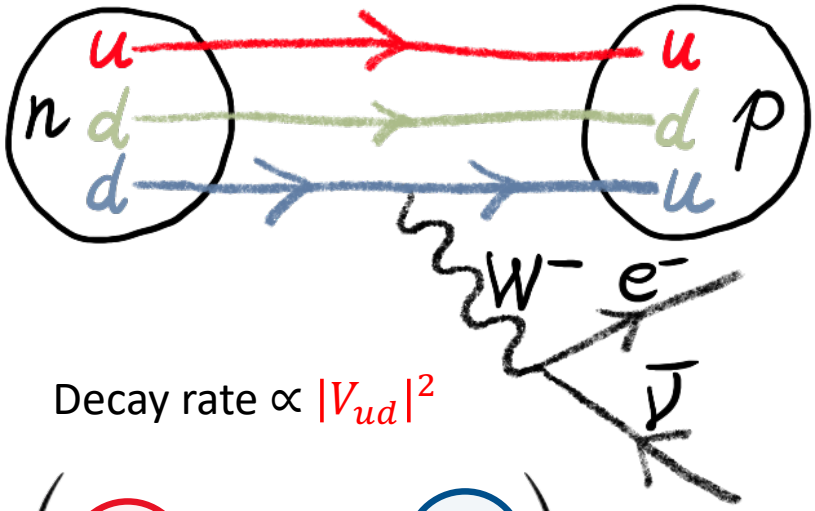
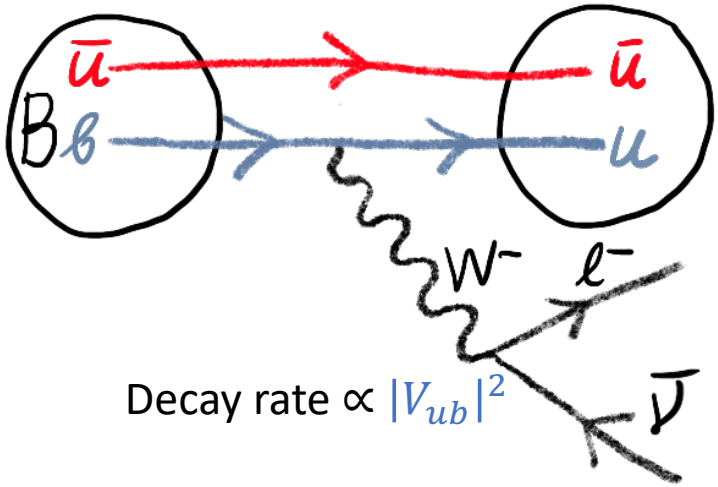


Decay rate $\propto |V_{ud}|^2$



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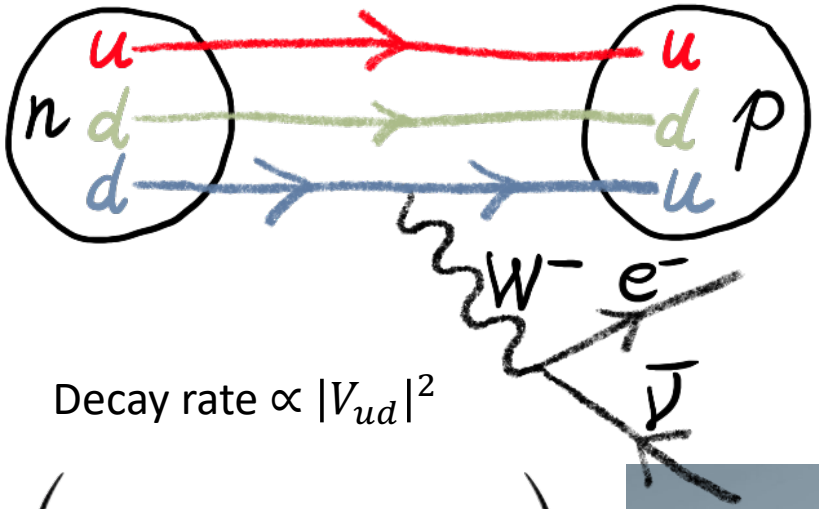

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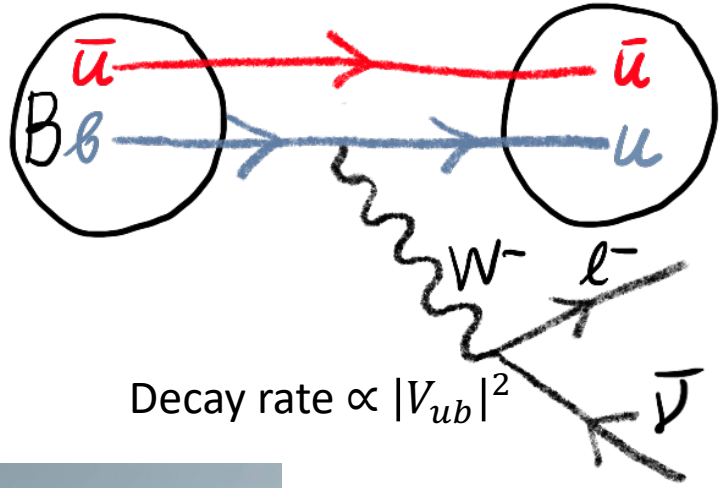

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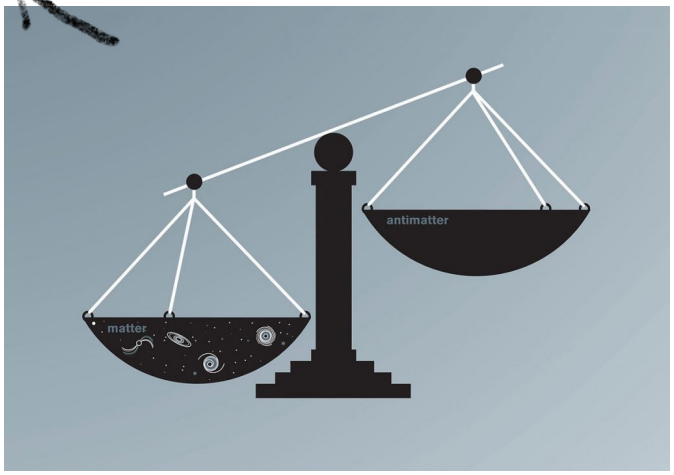
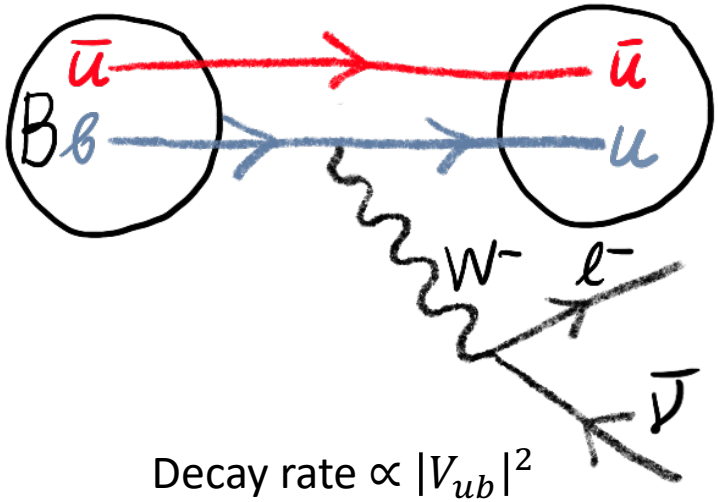


CKM matrix describes the matter-antimatter asymmetry in the Standard Model; free parameter in the SM

Previous measurements

- $|V_{ub}|$ measurements:
  - Inclusive analysis – outgoing meson not specifically reconstructed
  - Exclusive analysis – final state with specific meson is reconstructed
- Previous results show 2σ tension between these two measurement approaches



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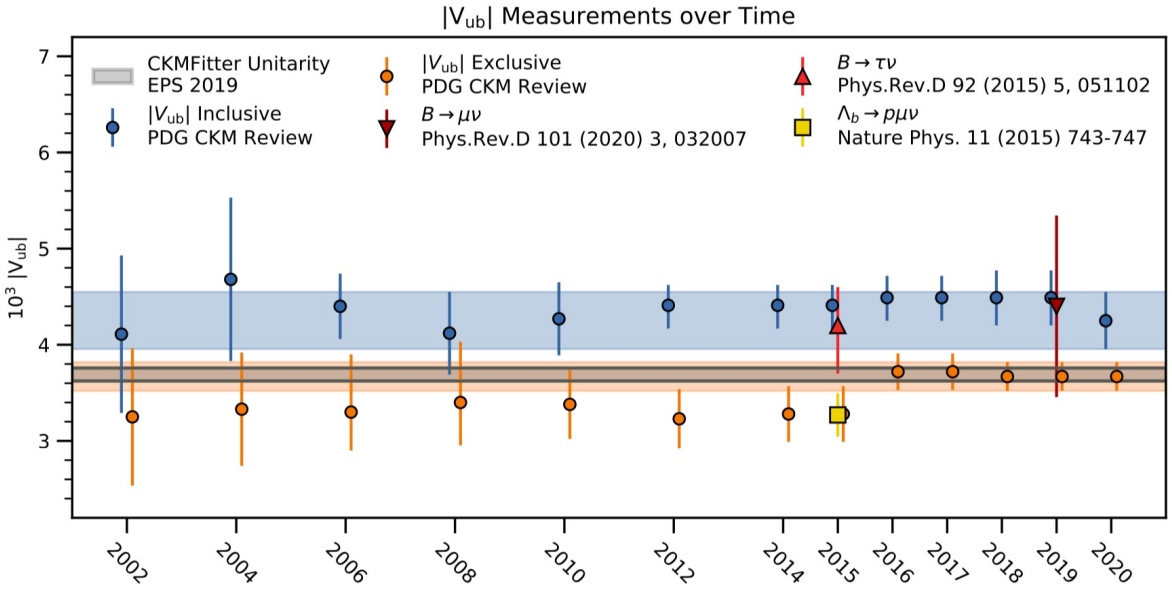
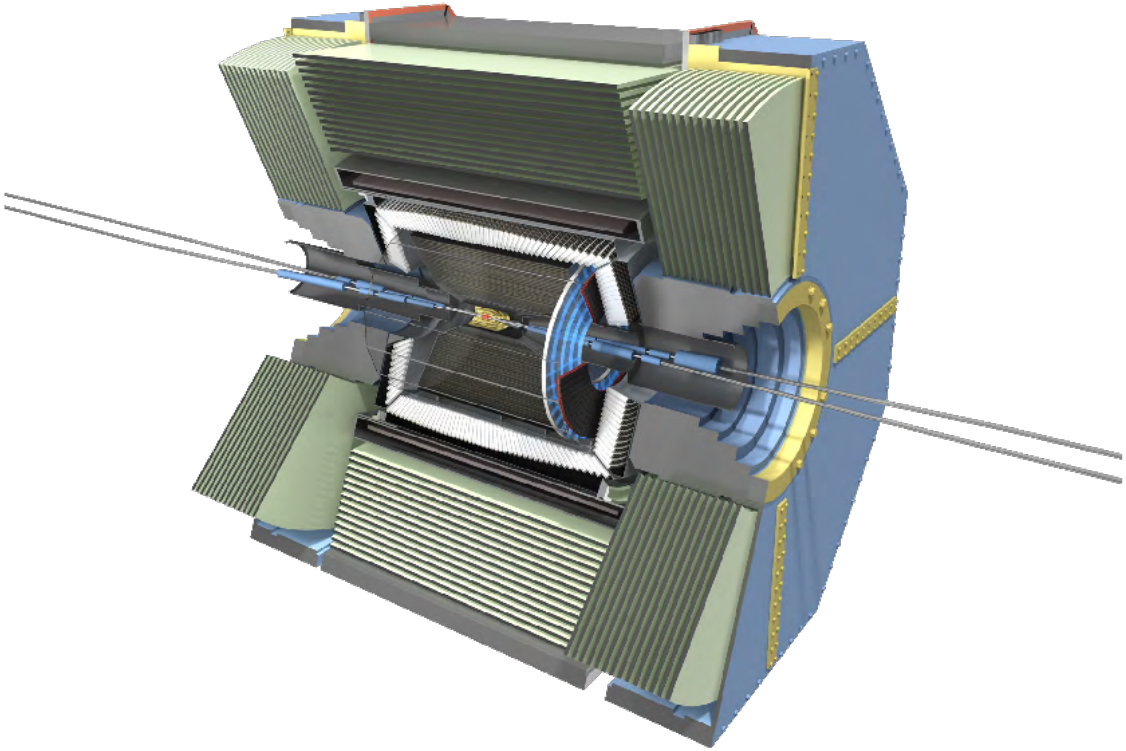


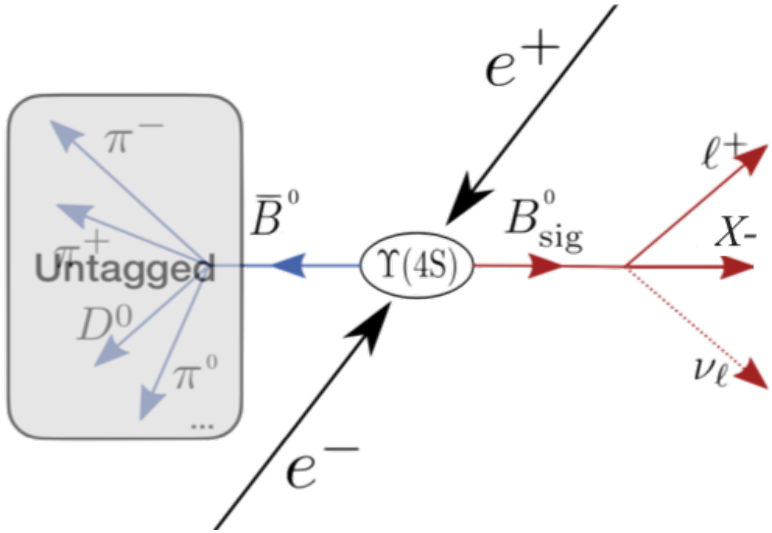
Belle II experiment and SuperKEKB

- Belle II is a B meson factory ($\sim 1.1 \cdot 10^9\ \bar{B}B$ pairs per ab^{-1})
- SuperKEKB is an electron - positron collider located at KEK Laboratory in Tsukuba, Japan
  - High Energy electron ring - **7 GeV**
  - Low Energy positron ring - **4 GeV**
  - ➢ $B\bar{B}$ pairs copiously produced
- Record-breaking luminosity - ideal for precision measurements



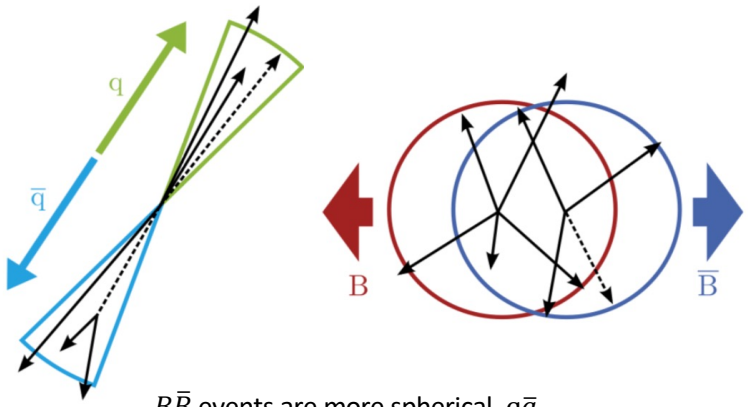
$B \to X_u \ell \nu$: Analysis approach

- Using the **untagged** analysis approach, the companion B meson is not reconstructed
- **Inclusive** analysis approach: *only the outgoing lepton is selected (electron or muon)*
- Use Monte Carlo simulation to estimate the selection efficiency and understand the **backgrounds**
- Extracting the yield of signal decays using the lepton momentum distribution

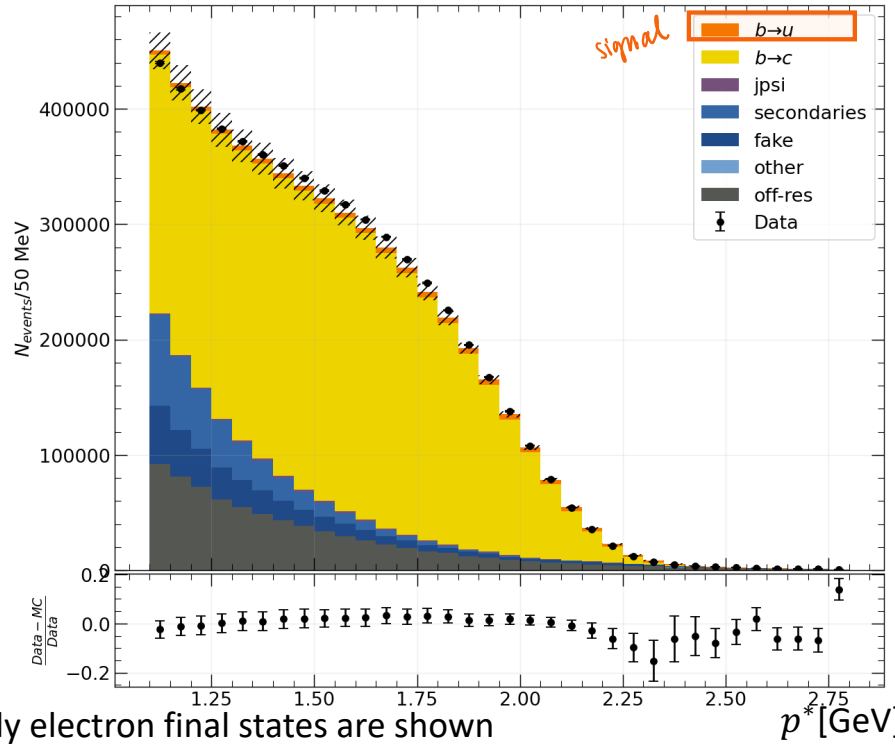


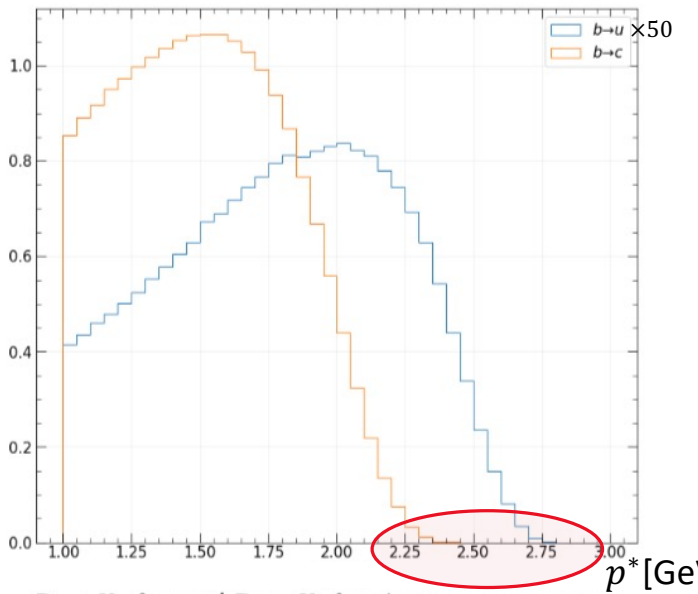
$B \to X_u \ell \nu$: Backgrounds

- Backgrounds from continuum events suppressed by using the event shape variables
- Looking in the **endpoint region of the lepton momentum** in the CM frame to avoid the dominant background from the decay $B \to X_c \ell \nu$



$B\bar{B}$ events are more spherical, $q\bar{q}$ events are more jet-like



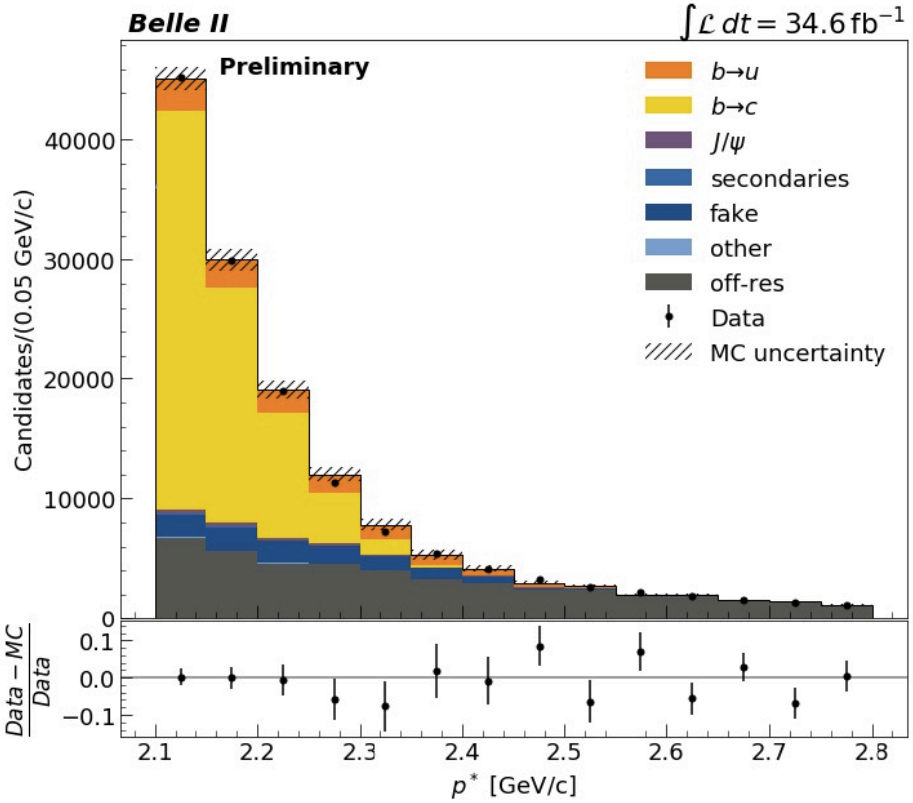


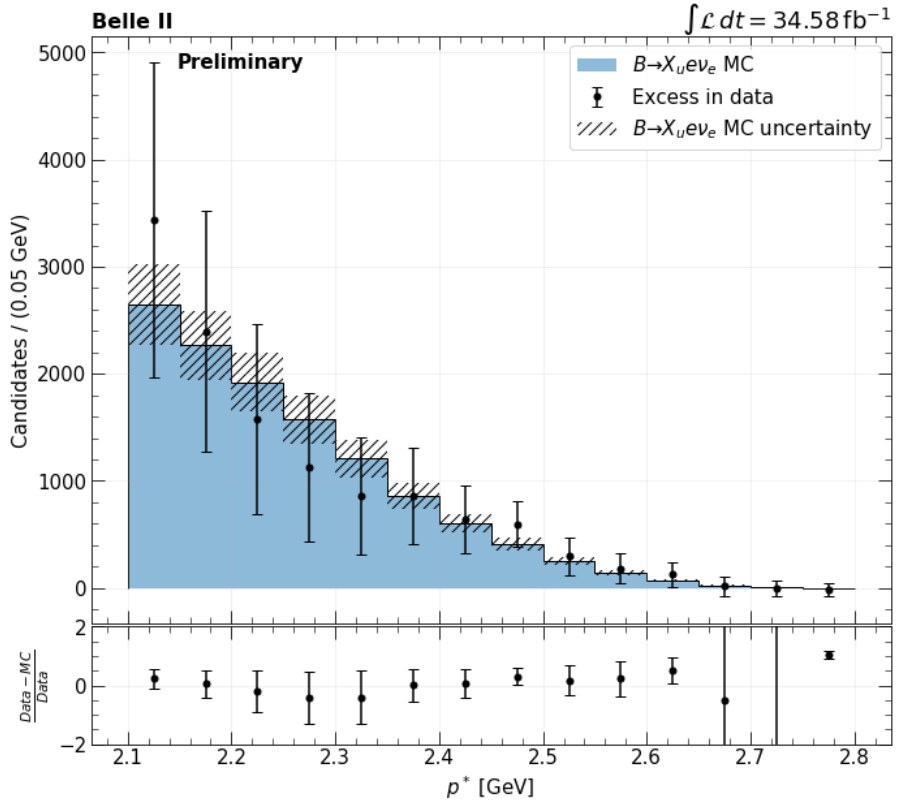
$B \to X_u \ell \nu$ and $B \to X_c \ell \nu$ electron momentum endpoints, truth MC

* Only electron final states are shown throughout this presentation

$B \to X_u \ell \nu$: Simulation vs. data

- Backgrounds from $B\overline{B}$ decays are estimated using a MC template fit
- Continuum and other $B\overline{B}$ contributions are subtracted in the endpoint region of the electron momentum [2.1, 2.8] GeV
- Observed $\boldsymbol{B \to X_u e \nu_e}$ **excess in data** $(> 3\sigma)$





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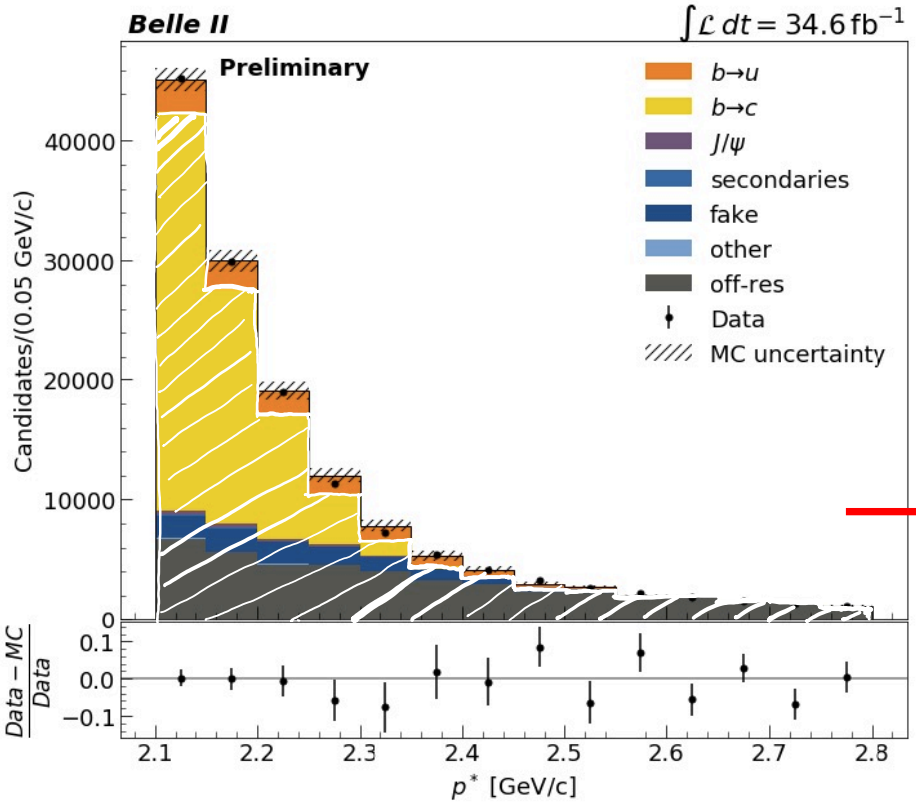
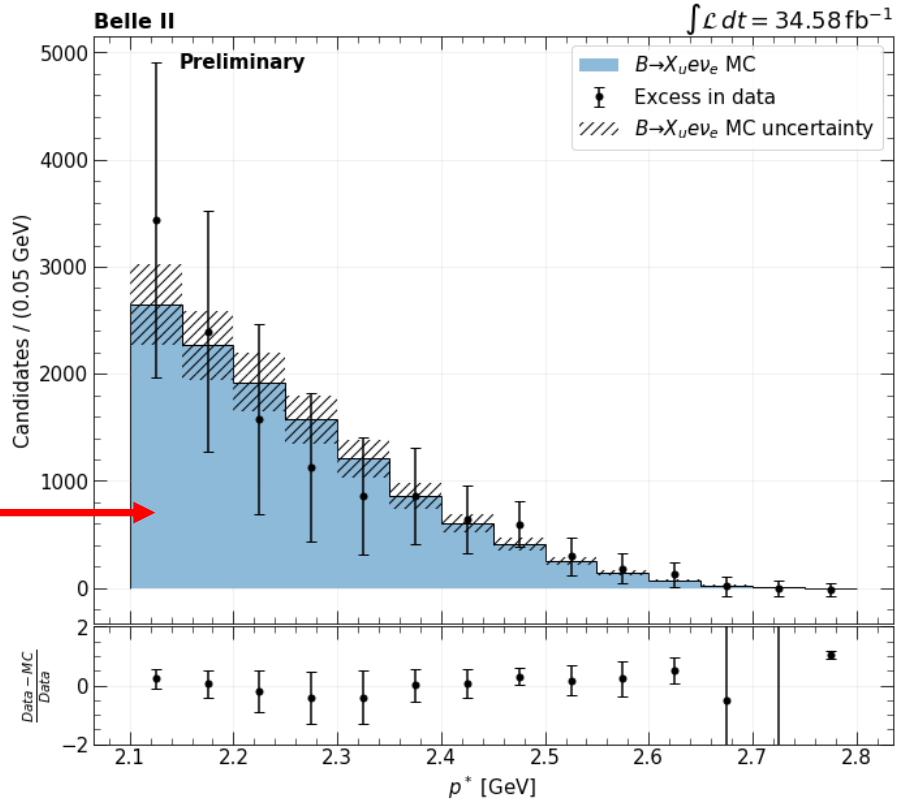
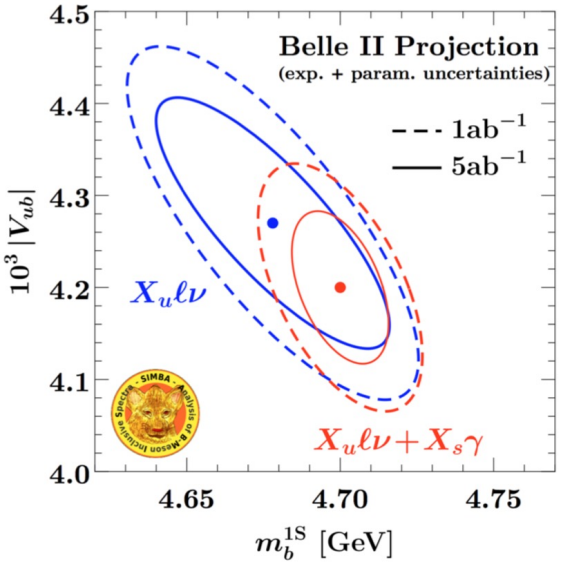




Final remarks

Significant improvement is expected with higher luminosities and better understanding of the detector's performance.

- Currently improving the suppression of $B \to X_c \ell \nu$ backgrounds
- One of the goals of the Belle II experiment is to resolve the discrepancy between inclusive and exclusive $|V_{ub}|$ measurements
  - ➢ New physics?
  - ➢ Better understanding of background processes?
  - ➢ Refining the theoretical approach?



	Statistical	Systematic (reducible, irreducible)	Total Exp	Theory	Total
$\|V_{ub}\|$ exclusive (had. tagged)					
711 fb^{-1}	3.0	(2.3, 1.0)	3.8	7.0	8.0
5 ab^{-1}	1.1	(0.9, 1.0)	1.8	1.7	3.2
50 ab^{-1}	0.4	(0.3, 1.0)	1.2	0.9	1.7
$\|V_{ub}\|$ exclusive (untagged)					
605 fb^{-1}	1.4	(2.1, 0.8)	2.7	7.0	7.5
5 ab^{-1}	1.0	(0.8, 0.8)	1.2	1.7	2.1
50 ab^{-1}	0.3	(0.3, 0.8)	0.9	0.9	1.3
$\|V_{ub}\|$ inclusive					
605 fb^{-1} (old B tag)	4.5	(3.7, 1.6)	6.0	2.5–4.5	6.5–7.5
5 ab^{-1}	1.1	(1.3, 1.6)	2.3	2.5–4.5	3.4–5.1
50 ab^{-1}	0.4	(0.4, 1.6)	1.7	2.5–4.5	3.0–4.8

Expected performance of Belle II experiment for $|V_{ub}|$ measurements

PTEP 2019 (2019) no. 12, 123C01.



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