Physics Week Summary
Experiment

Akimasa Ishikawa
(KEK)

Physics Week

- Busy and fun week
  - 10 lectures
  - 6 talks
  - 7 posters
  - 4 panel discussions (including theory)
  - 1 tutorial
  - (only experimental ones)

- These are very educational for both students and staffs, and hopefully also for theorists.
- Since there are so many important talks and the time is limited, sorry if I skip your favorite

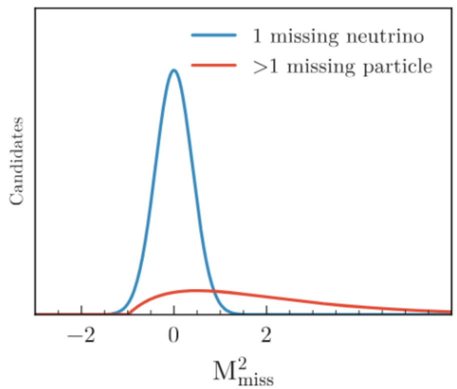
- Missing Energy Decays

- Tagging and Other Tools

- Missing Energy Decays at Other Experiments

Missing Energy Decays

Markus Prim



- Neutrinos (or dark matter) in the final states
  - Taus can be a source of neutrinos
  - Single neutrino → peak at 0 of missing mass squared
  - Multiple neutrinos → no peak

- EWP (Gaetano and Elisa)
  - $b \to s\nu\nu$, $b \to s\tau\tau$, $b \to s\tau l$
  - B→ invisible (2ν or 4ν or DM)
- Non-EWP (Markus)
  - $b \to cl\nu$, $b \to ul\nu$
  - $B \to D(*)\tau\nu$, $B \to \pi\tau\nu$
  - $B \to \mu\nu$, $B \to \tau\nu$

- Sensitive to new physics or CKM parameters

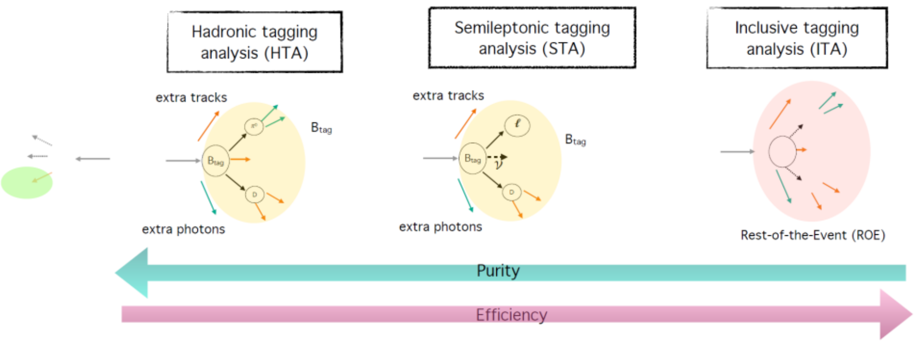
Elisa Manoni

Analysis Overview of Missing Energy EWP decays

- Analysis overview from alpha (tagging) to omega (systematics)
  - Three tagging methods, reconstruction, RoE, background suppression, efficiency calibration, fit, systematics
  - And future perspective
  - One missing item is limit setting → Diego's talk

Very useful lecture for people starting this kind of analyses

Tagging techniques



- So far, most of the analyses have been performed using HAD Full Event Interpretation (FEI)
- First STA results to come next year
- When applicable, ITA has proved to be more sensitive than HTA

Future perspective in systematics

We foreseen improvements on systematics related to:

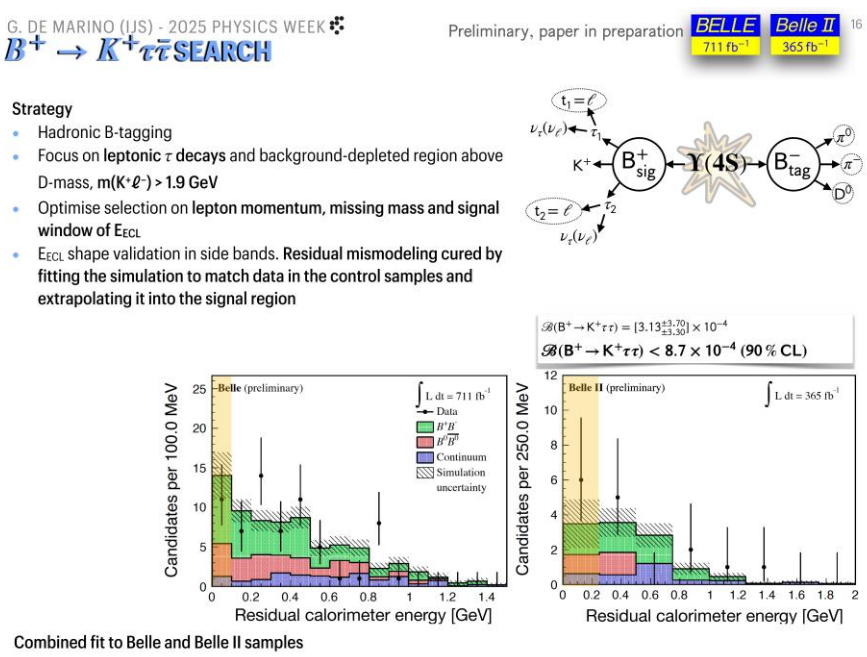
- background normalisations → generally, statistical in origin
- specific background modelling
- detectors performances (improvements in particle reconstruction and identification algorithms, usage of MCrd)
- simulated sample size → larger MC samples can be produced in a smart way (save to disk only skimmed events)

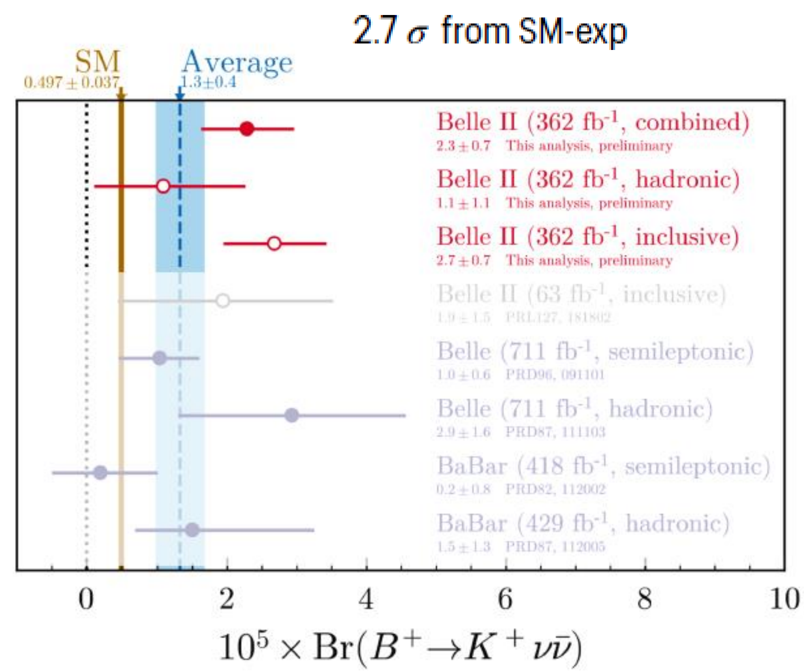
Source	Impact on σ_μ
Normalization of $B\bar{B}$ background	0.90
Normalization of continuum background	0.10
Leading B-decay branching fractions	0.22
Branching fraction for $B^+ \to K^+ K^0_L K^0_L$	0.49
p-wave component for $B^+ \to K^+ K^0_S K^0_L$	0.02
Branching fraction for $B \to D^{**}$	0.42
Branching fraction for $B^+ \to K^+ n\bar{n}$	0.20
Branching fraction for $D \to K^0_L X$	0.14
Continuum-background modeling, BDT_c	0.01
Integrated luminosity	<0.01
Number of $B\bar{B}$	0.02
Off-resonance sample normalization	0.05
Track-finding efficiency	0.20
Signal-kaon PID	0.07
Photon energy	0.08
Hadronic energy	0.37
K^0_L efficiency in ECL	0.22
Signal SM form-factors	0.02
Global signal efficiency	0.03
Simulated-sample size	0.52

Summary of Missing Energy EWP Decays

- Summarize the on-going/published analyses
  - B→K(*)$\nu\nu$, B→Xs$\nu\nu$
  - B→K(*)$\tau\tau$, B→K(*)τl
  - B→K + invisible

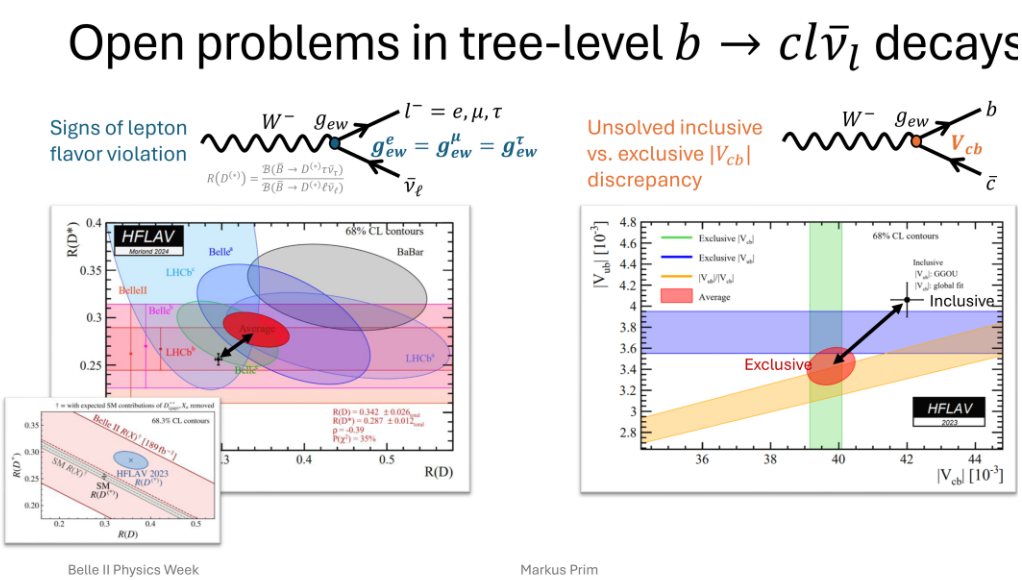
$B^+ \to K^+\nu\nu$ 2.7σ deviation from SM
Best limits on $B \to K^+\tau\tau$ and $B \to Xs\nu\nu$





Lecture on Non-EWP Missing Decays

- Informative lecture on analysis overview of (semi)leptonic decays
- Showed current problems
  - Lepton Flavor Universality Violation in B→D(*)τν 3.8σ deviation from SM
  - inclusive VS exclusive in b→clν and b→ulν



Take-aways

Key variables

- M^2_{miss}
- $\cos\theta_{BY}$
- E_{ECL} (when analyzing τ)

Common problems / systematics

- Modelling:
  - Gap, Resonances ($b \to c\ell\bar{\nu}_\ell$)
  - Hybrid MC, Interference ($b \to u\ell\bar{\nu}_\ell$)
- MC statistics when using tag-side reconstruction
- Particle identification

Tagging and Other Tools

- Crucial for analyses on missing energy decays

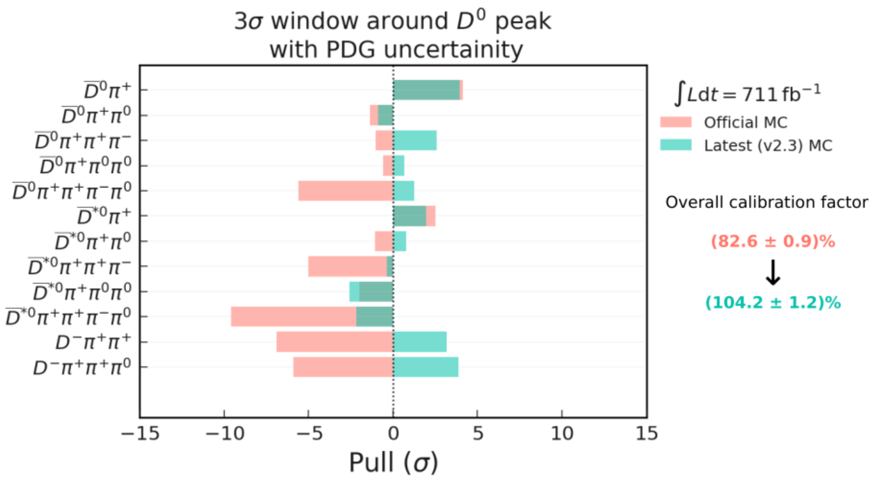
Karim Trabelsi

Improvement of MC Modeling and Hadronic FEI reconstruction

- 12 exclusive B→D $n\pi$ decays cover 90% of the hadronic FEI efficiency
  - Tuning of the decay table improve the calibration factor from 0.82 to 1.06
- Selection for slow π^0 from D^{*0} too tight for tagging
  - The efficiency is improved by 30% with the same purity
  - Avaialble for release-8

Pulls of calibration factors

Another way to visualize the improvement in the calibration factors:



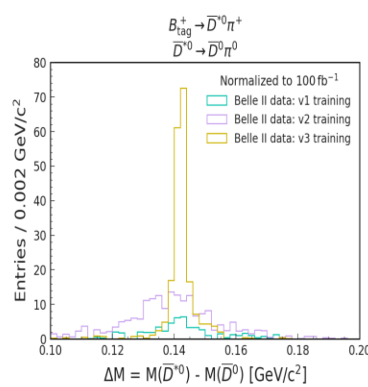
improving description of hadronic B decays ⇒ improve B-tagging efficiency

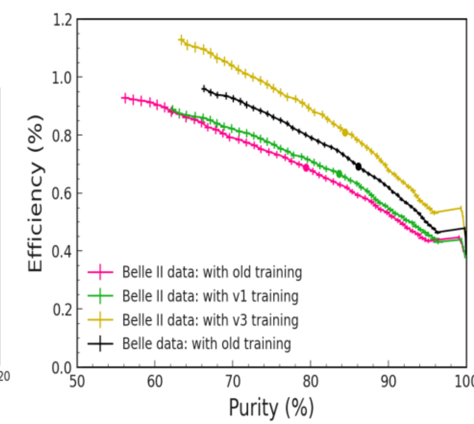
37

$D^{*0} \rightarrow D^0 \pi^0$ reconstruction

Optimize ΔM for D^{*0} reconstruction

Along with looser preselection for photons, mass-constraint is applied for π^0 candidates in Belle II.
This will improve ΔM distribution which is used in preselection and training for D^{*0}.
Retraining FEI provides expected results:





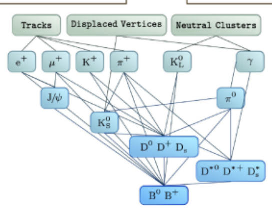
48

Inclusive Tagging for B→Kνν analysis

- New tagging technique developed for B→Kνν analysis
  - Everything optimized for signal
  - Better efficiency while low purity
  - Careful checks and calibration are required
- First evidence for B→Kνν with combination of analysis with hadronic FEI

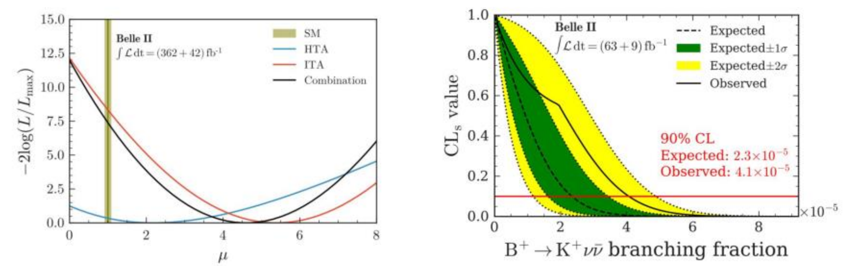
Tagging methods at Υ(4S) factory

Hadronic tagging	Semileptonic tagging	Inclusive tagging
ε <1%	ε ~ 1%	ε > 1%
highest purity	High purity	Lowest purity
Best Kinematic constraints	Partial constraints	Beam constraints only



- The partner B-meson (“tag”) is an important part of data analysis at Υ(4S) factory
- It can be reconstructed explicitly in one of the hadronic or semileptonic decay mode its properties can be used inclusively
- The approaches differ in efficiency, purity, and kinematic constraining power

Result representation



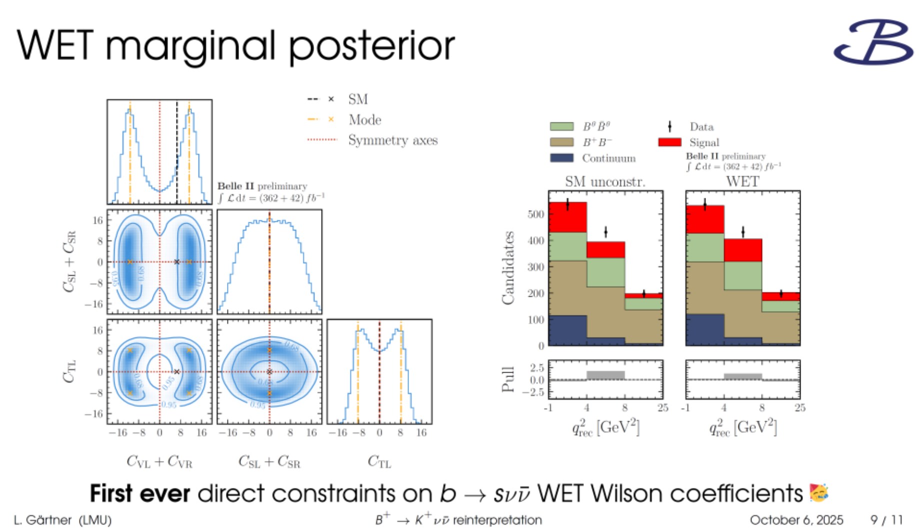
- Signal significance can be determined using log-likelihood scan
- Hadronic tag analysis (HTA) provides a cross check and improved accuracy
- If no significant signal is observed, set limits
- Likelihoods (and example code how to use them) should become public after paper is accepted

32

Lorenz Gärtner

Reinterpretation framework and application to B→Kνν

- Reinterpretation framework developed
- Provided reinterpretable likelihood for B→Kνν
  - To be shown also on HEPdata



Charm Tagging Tool

- Tagging using recoil mass against charm hadron + fragmentation particles
- Demonstrated at Belle with $D_s \rightarrow l\nu$, and $D \rightarrow$invisible etc.
- ccFEI under development is 3.5 times better than the tool at Belle
- Very promising for missing energy charm decays!

ccbarFEI

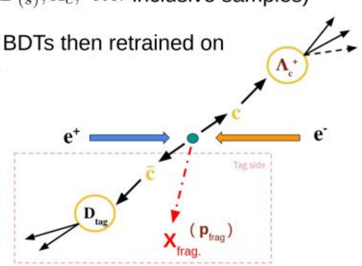
→ FEI is existing tool that is trained to efficiently reconstruct hadronic B decays.

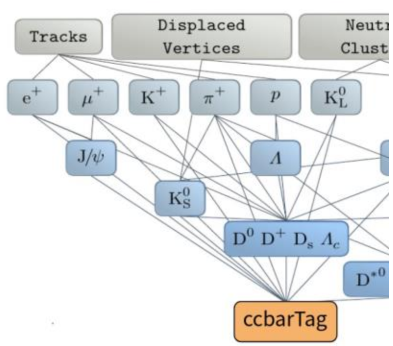
→ in the chain it is already reconstructing various charm states

→ idea of ccbarFEI is to adjust FEI to reconstruct charm tags (the recoil of which is a single $D_{(s)}$,

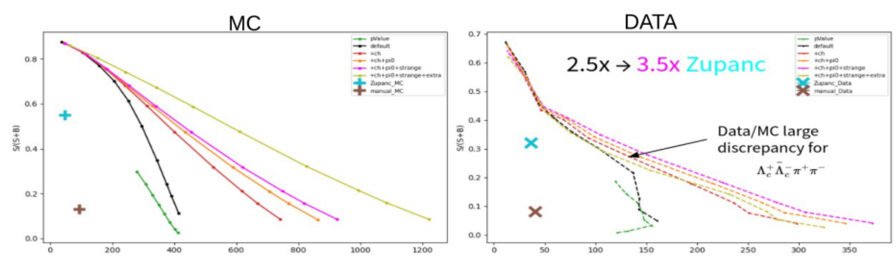
→ target B modes in the last step of FEI are replaced with a list of target ccbar tags (specific for $D_{(s)}, \Lambda_c$, etc. inclusive samples)

→ all stages of BDTs then retrained on ccbar events





Comparison with ccbar tag reconstruction from previous measurements



	Yield MC	Purity MC	Yield Data	Purity Data
Zupanc	48	55 %	36	33 %
Kristof	94	13 %	41	8 %
ccbarFEI > 0.2	295 (455)	50 (47) %	102 (150)	30 (28) %
ccbarFEI > 0.5	159 (183)	77 (75) %	44 (50)	46 (45) %

→ there is ~ factor 4 difference in the inclusive Λ_c yield between data and MC

→ still yield is improved compared to Zupanc analysis for 2.5x using "simple" modes only, and 3.5x using more modes (at same purity)

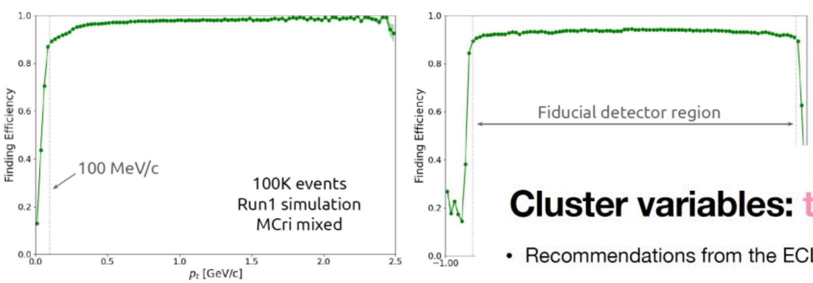
Bianca Scavino
Eldar Ganiev
Alessandro Gaz

Tracking/Photons/E_{extra}/PID

- Full use of Belle II detector is one of the keys for missing energy decays.
  - Lectures on Tracking/Photons/E_{extra}/PID

Tracking performance in MC

- **Finding efficiency** vs p_t and cosθ (not including detector acceptance)
  - Above 90% for most of the phase space covered by the detector (**average: 92%**)
  - **Drop** for low pt (<100 MeV/c) → small number of hits, larger multiple scattering, ..



Cluster variables: the good

- Recommendations from the ECL group
- All shower shapes depend on the particle energy and the beam backgro (and detector reconstruction details) => **Always check data-simulation agreement, energy and beam background dependency!**

- clusterAbsZernikeMoment40
- clusterAbsZernikeMoment51
- clusterE1E9
- clusterE9E21
- clusterLAT
- clusterSecondMoment
- clusterDeltaLTemp
- minC2TDist
- clusterE
- clusterTheta
- clusterPhi
- clusterTiming (current default recommendation abs(clusterTiming)<200)
- clusterPulseShapeDiscriminationMVA (only if clusterHasPulseShapeDiscrimination is non zero)

By T. Ferber

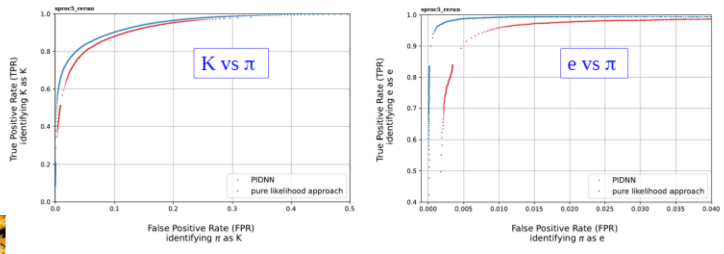
more details here

variable definitions here

37

Performance

PIDNN vs **likelihood**



- In *general* PIDNN variables give **clear advantage** over the likelihood;
- However, it is not guaranteed that this is true *everywhere*, there are some corners of the phase space where the likelihood works somewhat better. Please spend some time and check what works best for your analysis!

October 9th 2025 28

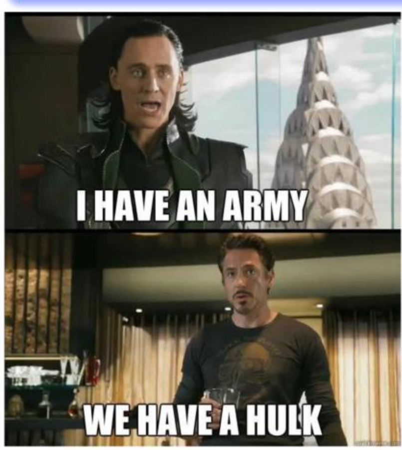
Missing Energy Decays at Other Experiments

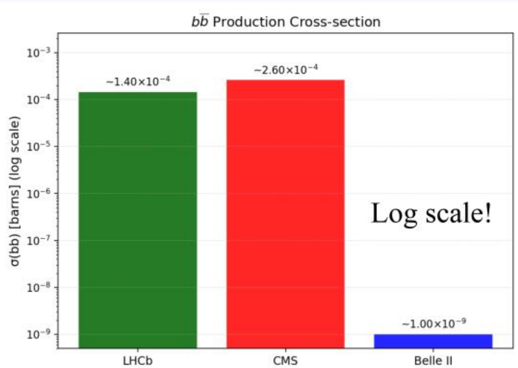
- Interplay and/or competition

LHCb : Tough Competitor

- Many particles produced from fragmentation makes analysis harder but huge cross section of b quark and vertexing allows better results
  - 10 times better limit on $B \to K^{*0}\tau\tau$ than Belle II
- Run3 with higher lumi and better trigger

But…





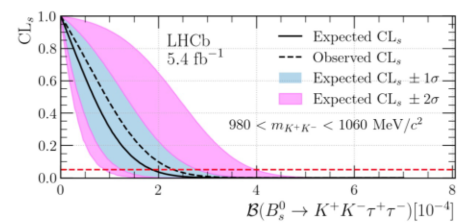
$b\bar{b}$ production 5 orders of magnitude higher at LHC!

9

Results

[LHCb-PAPER-2025-048]

- Normalisation channels: $B^0 \to J/\psi K^*$ and $B_s^0 \to J/\psi\phi$.
- Limits obtained in all bins of $m(K^+K^-)$ and $m(K^+\pi^-)$.
- **Dominant systematics: Modelling of the bkg shapes.**



$$\mathcal{B}(B^0 \to K^{*0}\tau^+\tau^-) < 2.8 \times 10^{-4}\ (2.5 \times 10^{-4}) \text{ at } 95\%\ (90\%) \text{ CL},$$
$$\mathcal{B}(B_s^0 \to \phi\tau^+\tau^-) < 4.7 \times 10^{-4}\ (4.1 \times 10^{-4}) \text{ at } 95\%\ (90\%) \text{ CL}.$$

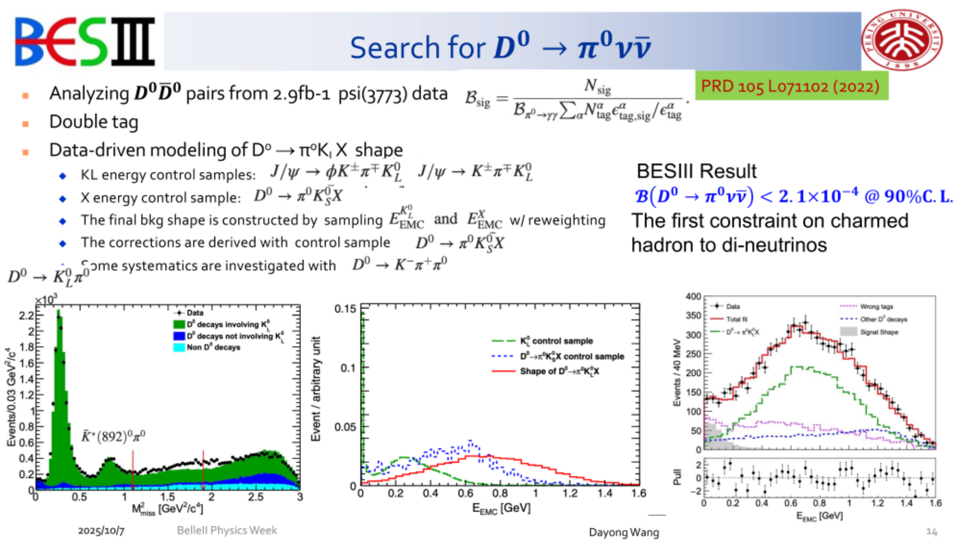
Limit 10x better than Belle-II!

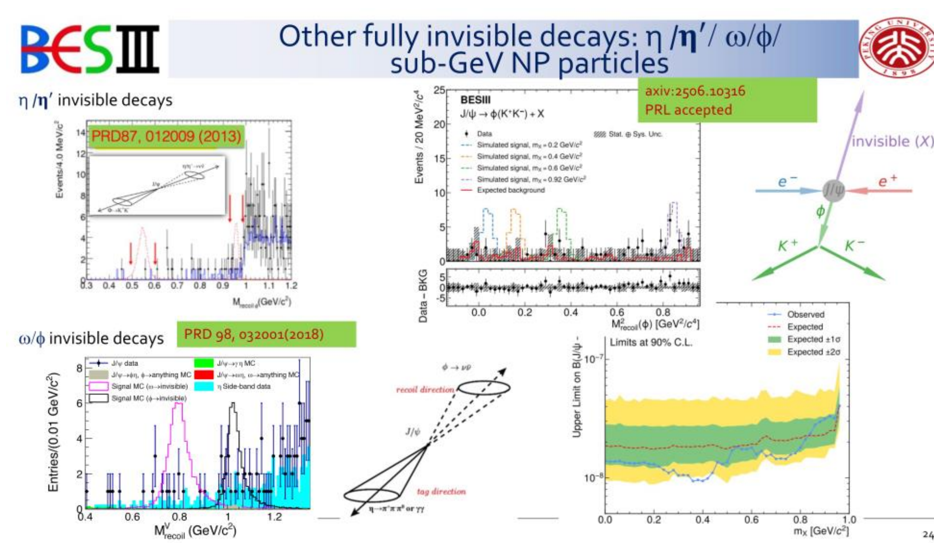
Limits 3x better on $|C_9^{\tau\tau}|$ than prev. LHCb limit.

07.10.25 34

BESIII

- So many results on missing energy decays
  - Not only charm (golden $D^0 \to \pi^0 \nu\nu$) but also dark sector
- Another 5+ years of operation should improve the limits

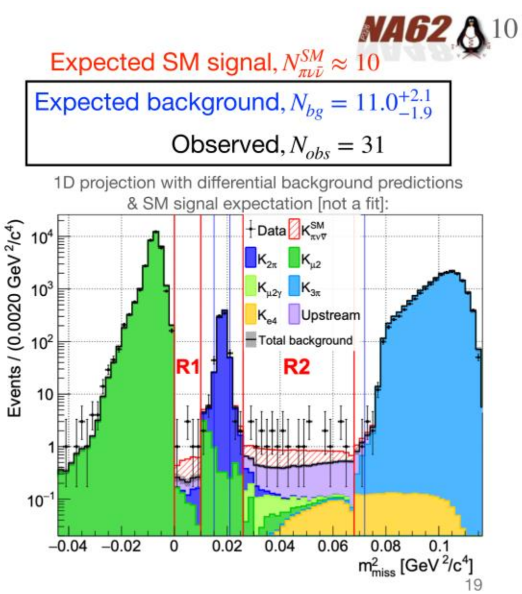




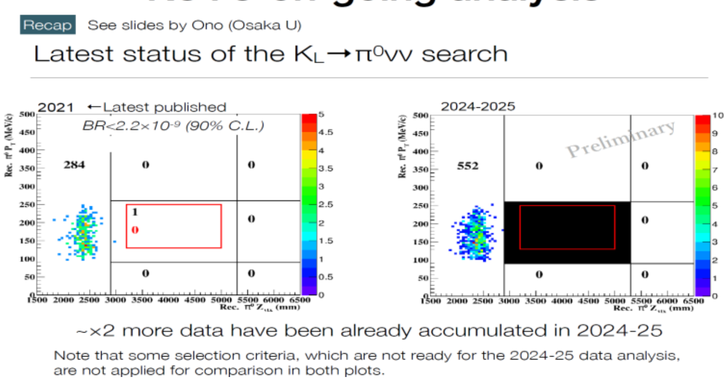
- Operation for another 5+ years foreseen
  - BEPCII-U upgrade going on well
  - Plenty of opportunities ahead
  - Synergy with theorists, BELLE-II and other experiments

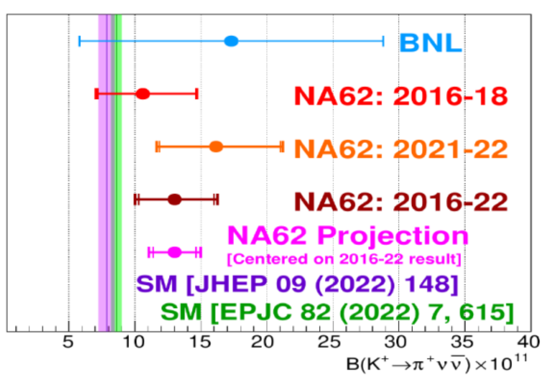
KOTO and NA62 : Interplay

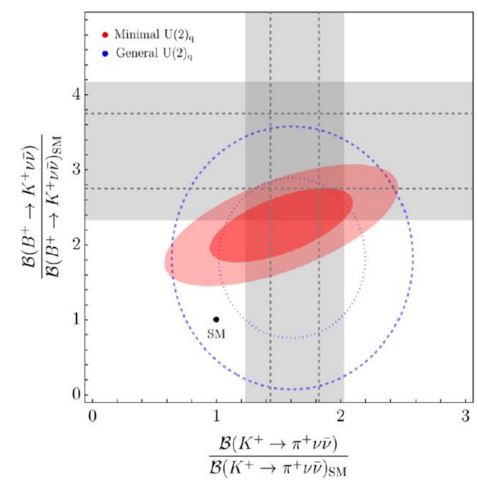
- First observation of dineutrino meson decays $K^+ \rightarrow \pi^+\nu\nu$ at NA62
  - 3 times larger data expected by 2026
- KOTO will reach to Grossman-Nir bound with 2024-25 data
  - Observation of KL → $\pi^+\nu\nu$ at KOTO II in 2030's



KOTO on-going analysis







FCC-ee or CEPC

- In 2040's, new collider should be in operation.
  - Electron-positron Higgs factory is the one of the promising future colliders in terms of physics
  - operation at Z-pole with high luminosity, copious number of b hadrons are produced.
- Uncertainty of B(B→Kνν) will be 0.5%.
  - This is great, but to me, far future.

$b \to s\nu\nu$

Existing FCC-ee sensitivity study for $B^0 \to K^+\pi^-\nu\nu$: arxiv:2309.11353
- using IDEA detector simulation
- perfect vertex seeding and PID, but expected to have small impact

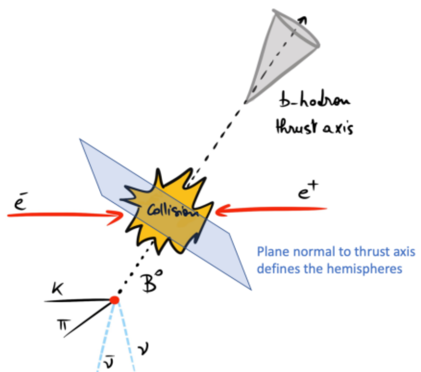
Discriminate from backgrounds using mainly:
- detached $K^+\pi^-$ vertex
- missing energy in signal hemisphere

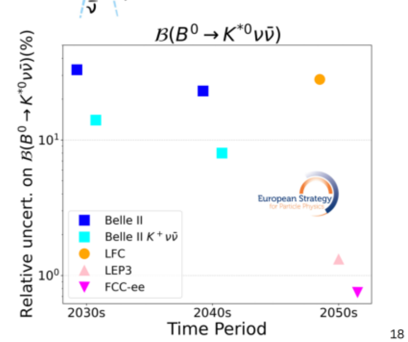
Expected precisions on BF substantially better than Belle II:

Belle II 50 ab^{-1}	$\sim 10\%$
FCC-ee:	$\sim 0.5\%$

(Note: note sure of how Belle II extrapolation is done here)

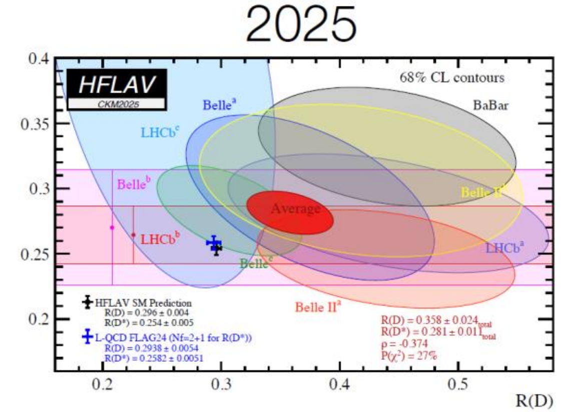
- Would allow more refined analysis to extract additional observables (f_L, $\mathrm{d}\Gamma/\mathrm{d}q^2$...)





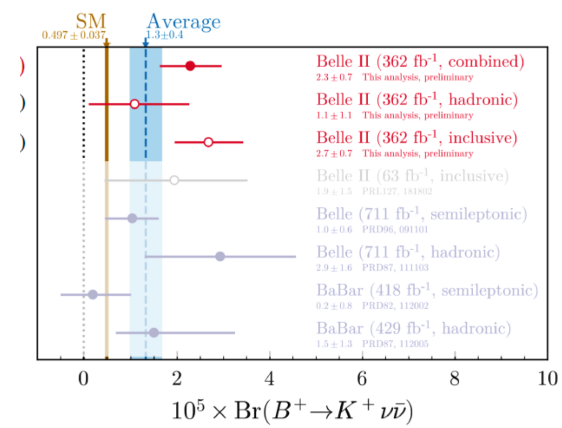
Personal View

Mirco Dorigo



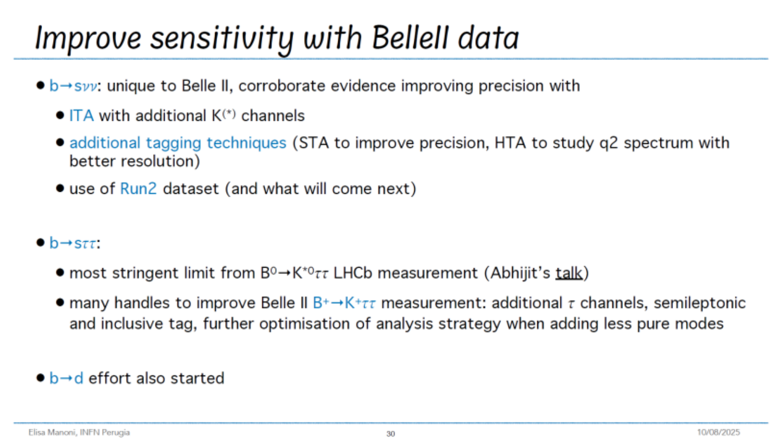
- Speakers have demonstrated that Belle II has a good capability to measure/search for missing energy decay modes
  - Evidence for B→Kνν, B→τν
  - Anomalies R(D*) 3.8σ, B(B→Kνν) 2.7σ

Gaetano de Marino



- To address the anomalies observed in the missing energy decays R(D*) and B(B→Kνν), analysis techniques should be further improved.

Elisa Manoni



Improve sensitivity with BelleII data

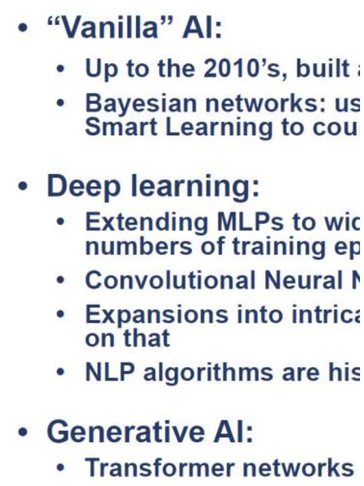
- b→sνν: unique to Belle II, corroborate evidence improving precision with
  - ITA with additional K(*) channels
  - additional tagging techniques (STA to improve precision, HTA to study q2 spectrum with better resolution)
  - use of Run2 dataset (and what will come next)
- b→sττ:
  - most stringent limit from B⁰→K*⁰ττ LHCb measurement (Abhijit's talk)
  - many handles to improve Belle II B⁺→K⁺ττ measurement: additional τ channels, semileptonic and inclusive tag, further optimisation of analysis strategy when adding less pure modes
- b→d effort also started

Elisa Manoni, INFN Perugia 30 10/08/2025

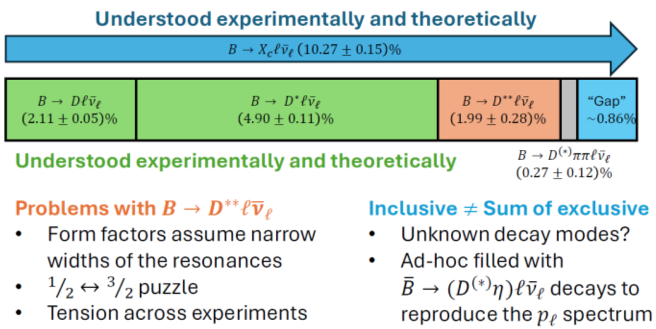
Personal View

- We can improve
  - Tagging tool/Background suppression
    - BDT based FEI → GraFEI → TrasnFEI? → ????
  - MC decay tables
    - Background modes involving K_S or protons, which act as proxies for K_L or neutrons
    - Measurement of b→c semileptonic gap modes
  - KL veto
    - No KL veto was used at Belle II
    - Development on-going and calibration is needed.
  - Detectors
    - Better tracking for slow pions
    - Better PID

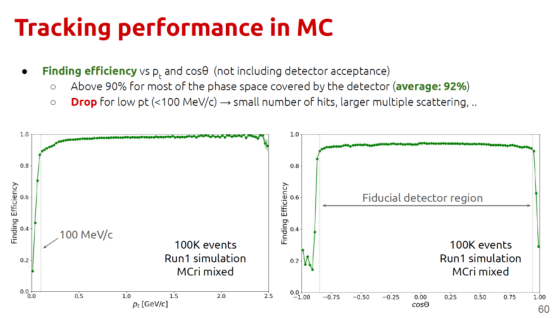
Adrian Bevan



Markus Prim



Bianca Scavino



No Summary for the Summary

backup

7 Posters

- B→K*$\tau\tau$, B→$\tau\tau$, and B→ K$\nu\nu$
- Inclusive Λ_c decays with FEI
- B→X(3872)K with FEI
- Radiative return for muon g-2
- Bremsstrahlung Recovery tool