Physics Performance vs Time Since Injection

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Belle II Trigger/DAQ Workshop
1 December 2022

HEPHY
INSTITUTE OF HIGH ENERGY PHYSICS

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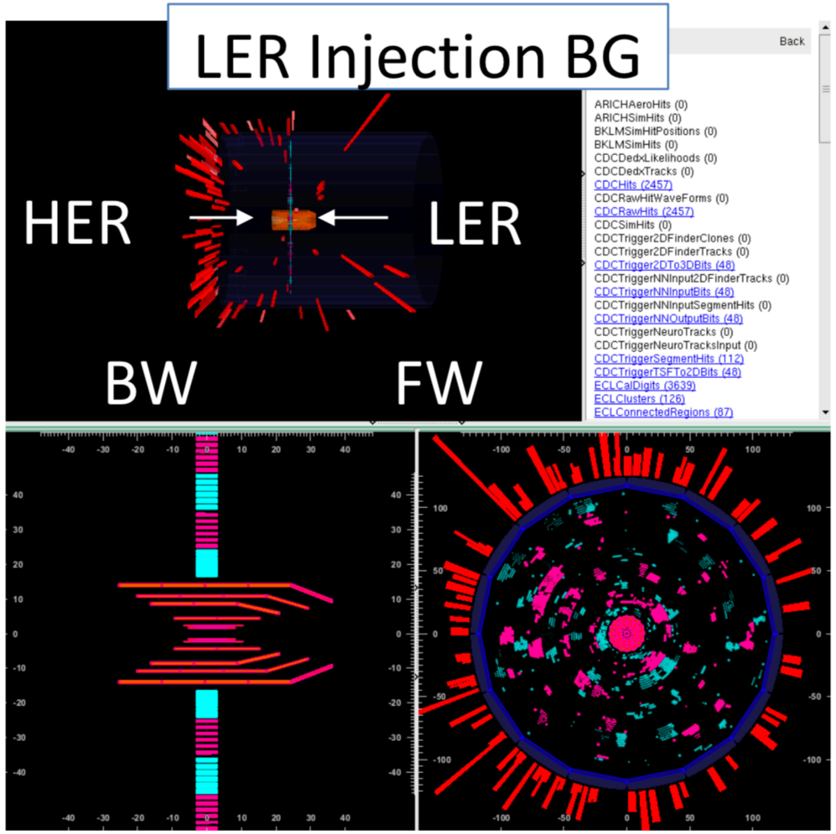
Belle II

- Toward end of 2022ab data taking period the luminosity/currents ramped up and we lost collimators, resulting in relatively high beam background conditions.

T. Koga



- Major beam backgrounds at SuperKEKB include: Touschek, beam-gas background, luminosity, synchrotron radiation, injection background and sudden beam losses.

- One of the most important / difficult tasks for SuperKEKB is to maintain stable injection background conditions.

- *Injection background*: Newly injected bunches are perturbed and oscillate in the horizontal plane around the main beam. This causes high background rates for several *ms* after injection.

  Dedicated trigger vetos avoid saturation of readout.

Time since injection

- With the most recent processing of the 2022ab data (buckets 26-36), analysts are now able to access in MDST the time after LER/HER injection.

- In the Physics Performance Group we have been characterising performance vs time since last injection. Some highlights from these studies will be shown in this talk:

    - CDC dE/dX
    - K_S^0 reconstruction
    - Slow pion tracking efficiency
    - π^0 reconstruction
    - Lepton ID
    - Hadron ID
    - L1 trigger rate

CDC dE/dx

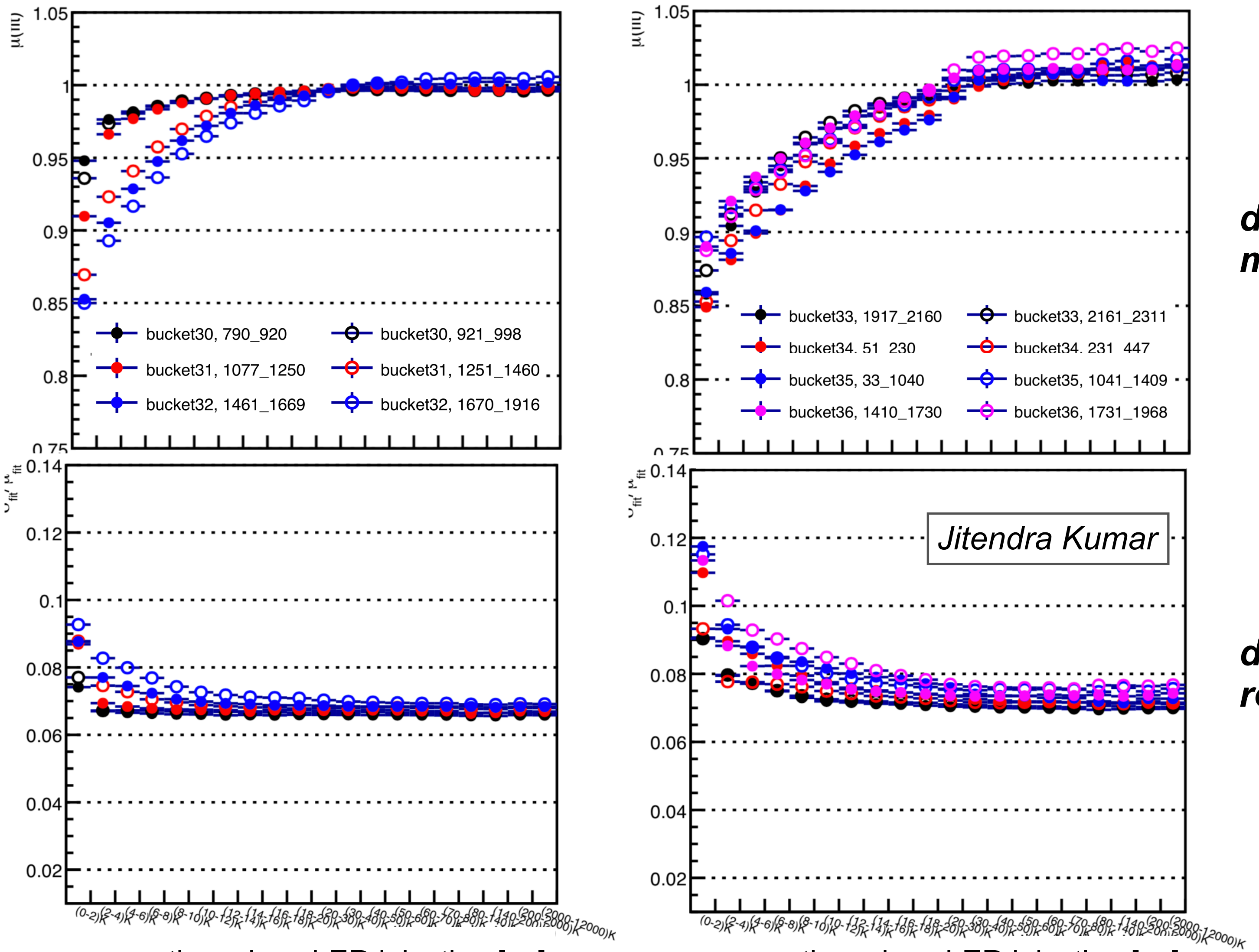
- Study of dE/dx mean and resolution vs time after injection, using radiative electrons.
- LER injection is shown here, which typically has the larger effect.

- <u>Early injection</u> (< ~20 ms):
  clear shift + degradation in resolution.
  Becoming worse in higher luminosity/current runs.

- <u>Later injection time</u>,
  stabilises to normal dE/dx ~ 1.0

⇒ dE/dx group has plans for calibration to recover the performance in future prompt and re-processed data (see backup slide for details).

***lower background periods** (b30-32)* ***higher background periods** (b33-36)*

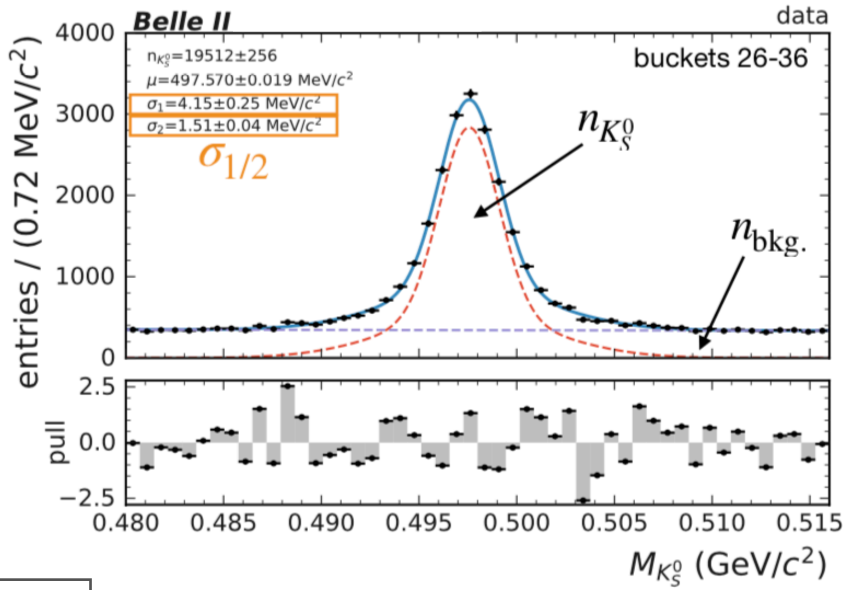


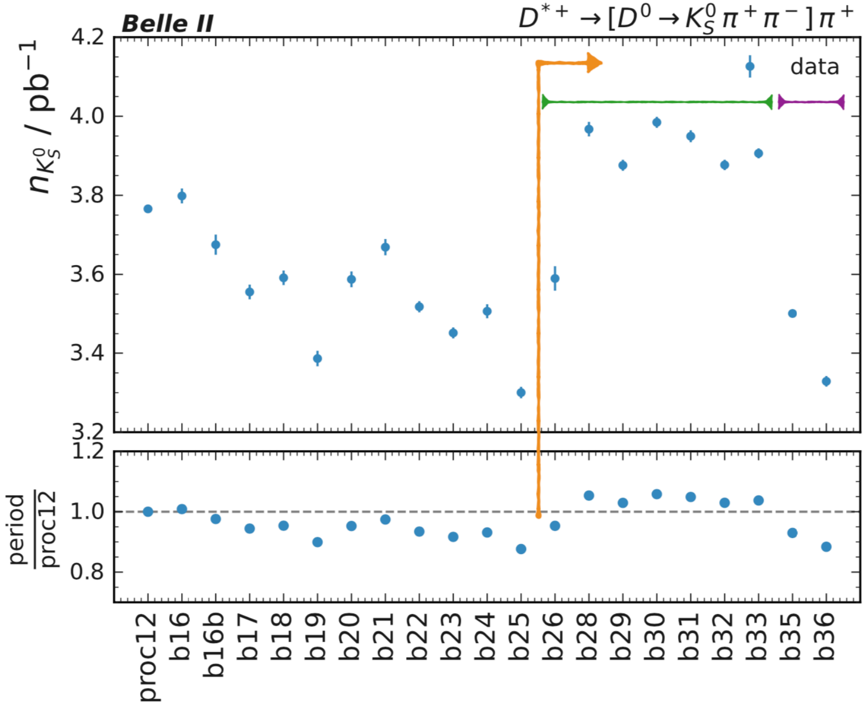
dE/dx mean

dE/dx resolution

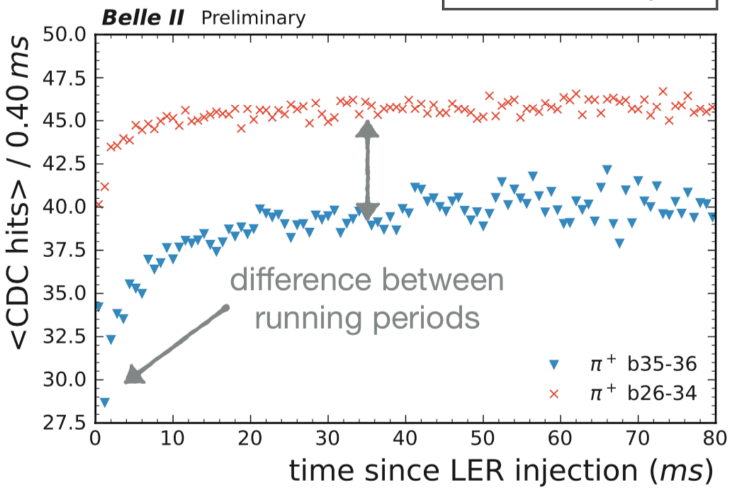
K_S^0 performance

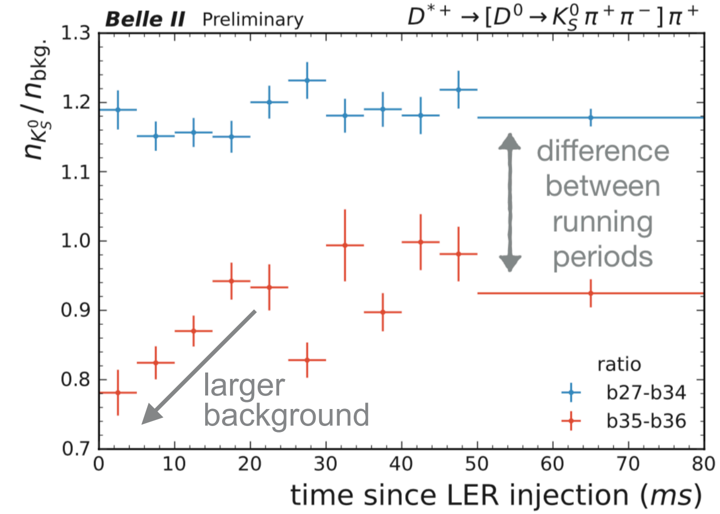
- K_S^0 reconstructed in $D^{*+} \to [\bar{D}^0 \to K_s^0\pi^+\pi^-]\pi^+$events.
  Fit the mass distribution — double gauss (signal) & first oder polynomial (bkg).
- Split into low (b26-34) and high (b35-36) beam background running periods.
  - Lower K_S^0 yield at higher backgrounds.
    More displaced vertex → more dependent on CDC tracking → lower efficiency.
  - Close to LER injection: reduced # CDC hits, clear trend to larger bkg rates





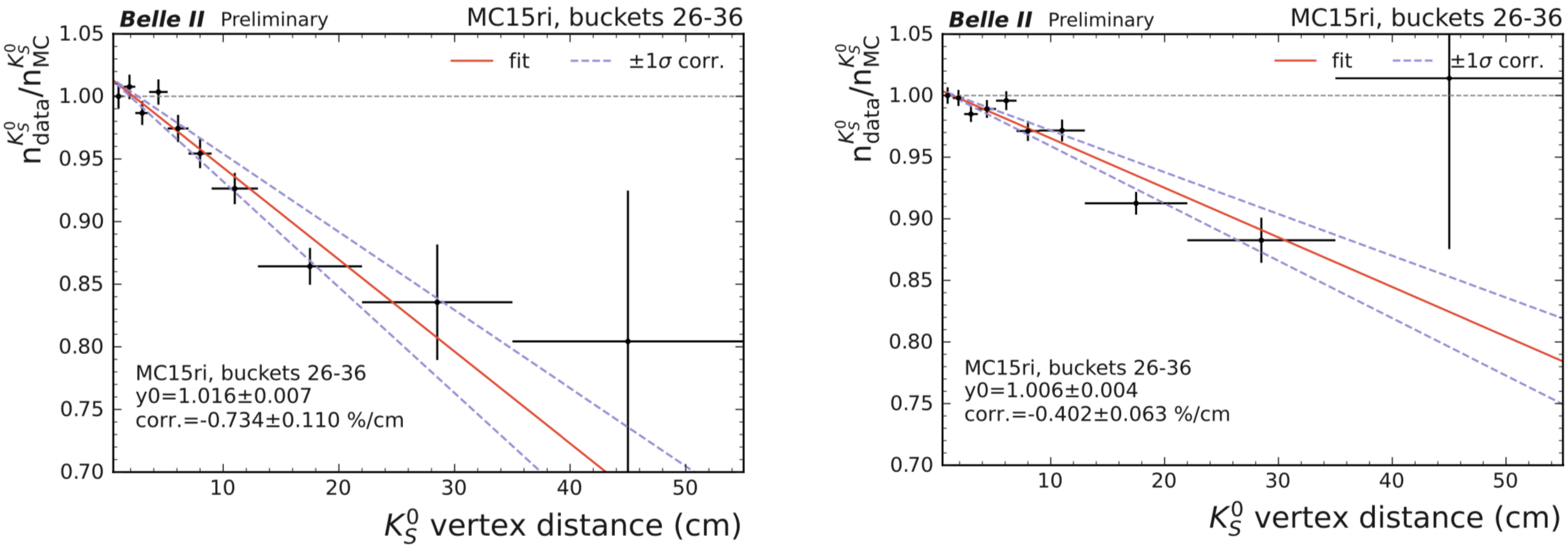
Sascha Dreyer





- Data/MC agreement is much better for large times after LER injection.
- We are planning to bin K_S^0 efficiency corrections and systematics in ~2 bins of time after injection.

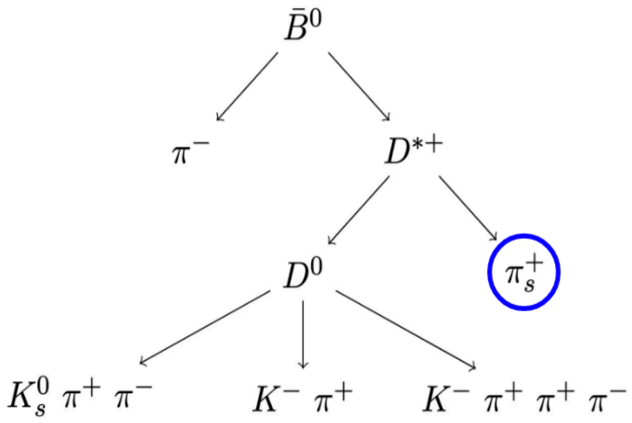
Sascha Dreyer

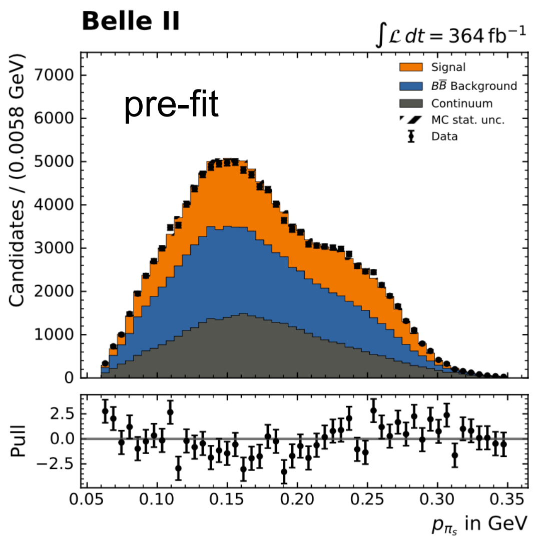


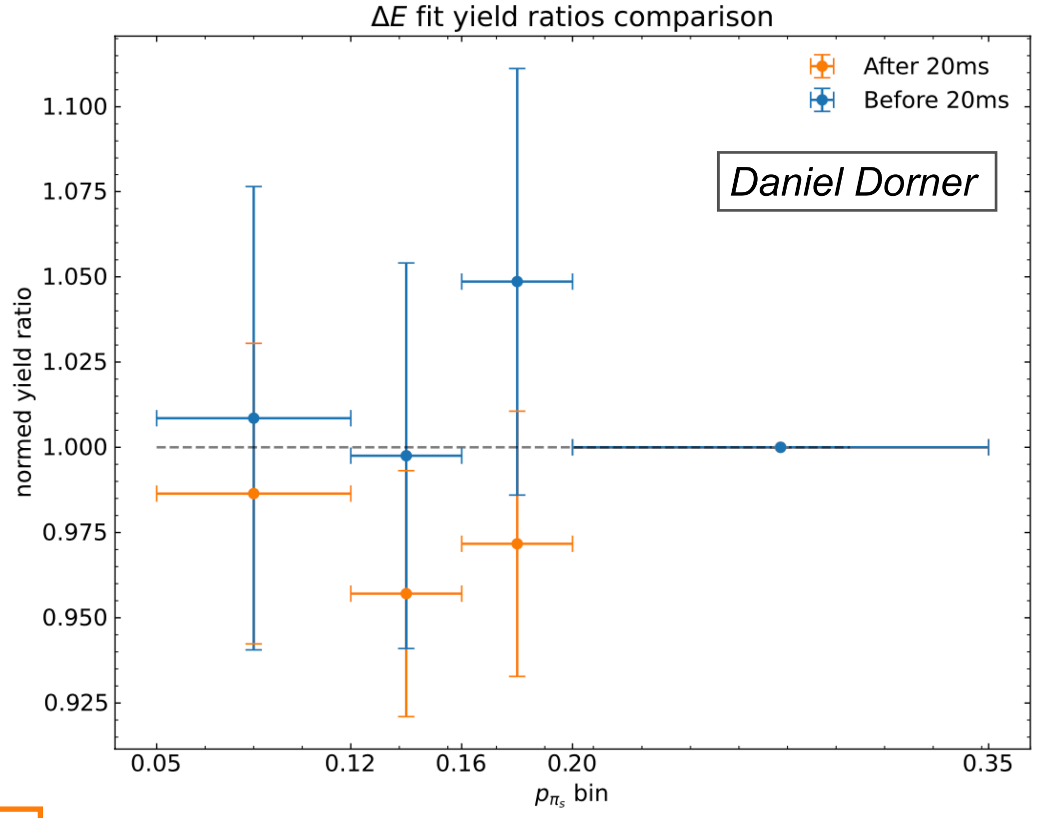
$< 20\,ms$ after injection

$> 20\,ms$ after injection

- Measurement of relative slow pion efficiency in two bins of time since injection → before and after 20 ms. One dimensional fit in 9 bins of ΔE for 4 bins of $p_{\pi s}$.







- Consistent results before and after within (large) statistical uncertainties.

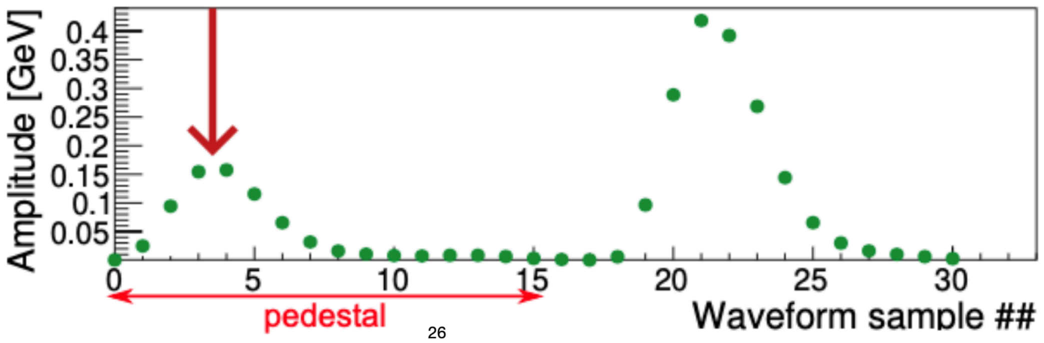
Before 20ms weighted average: $(101.718 \pm 3.571_{stat} \pm 0.305_{sys})\%$	After 20ms weighted average: $(96.982 \pm 2.268_{stat} \pm 0.291_{sys})\%$

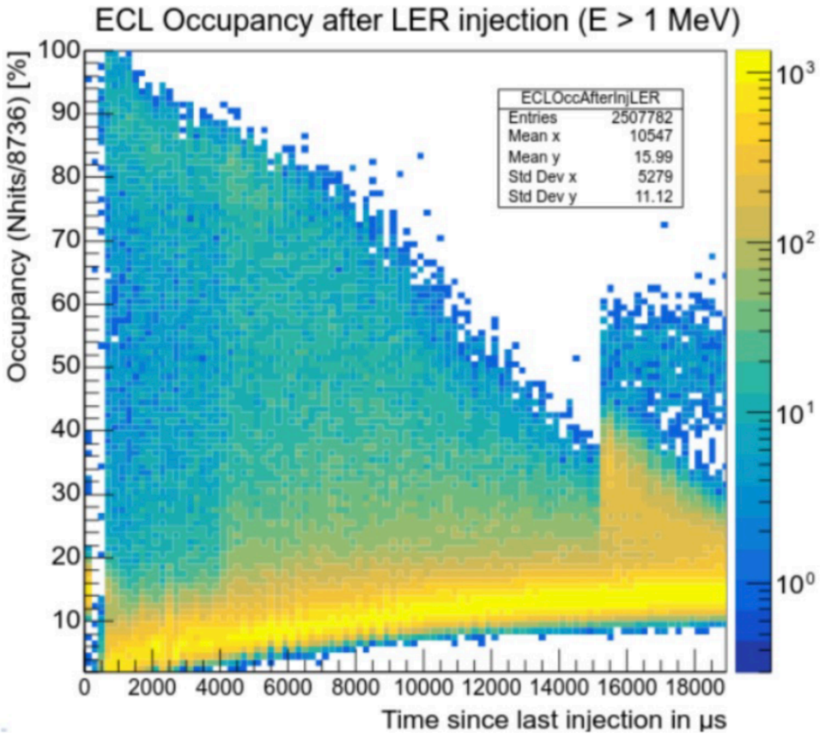
π^0 performance

- Injection background causes loss of ECL data for low-energy hits.

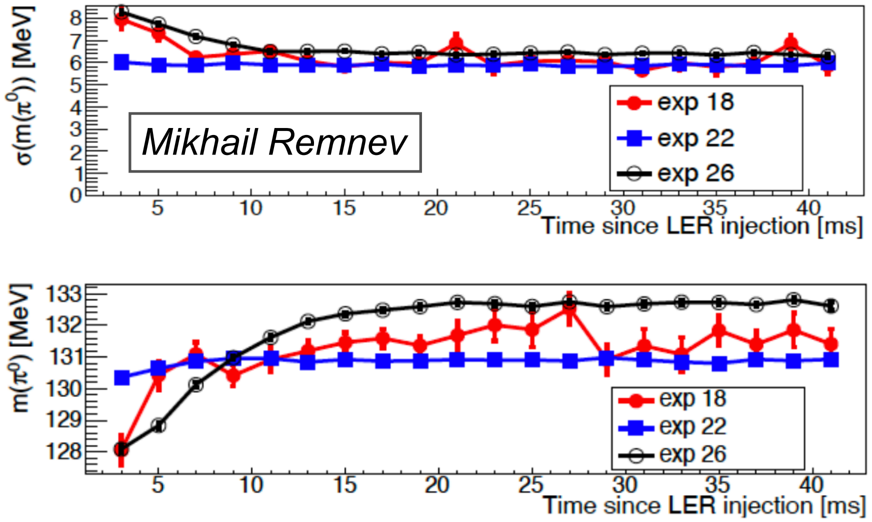
  Higher pedestal → lower amplitude → more hits below the 1 MeV threshold are discarded.

- Recent data had a noticeable decrease of occupancy soon after LER injection (first ~10 ms).





- Effect is clearly seen in π^0 mass peak and resolution, particularly for the most recent higher background period (**exp26**).

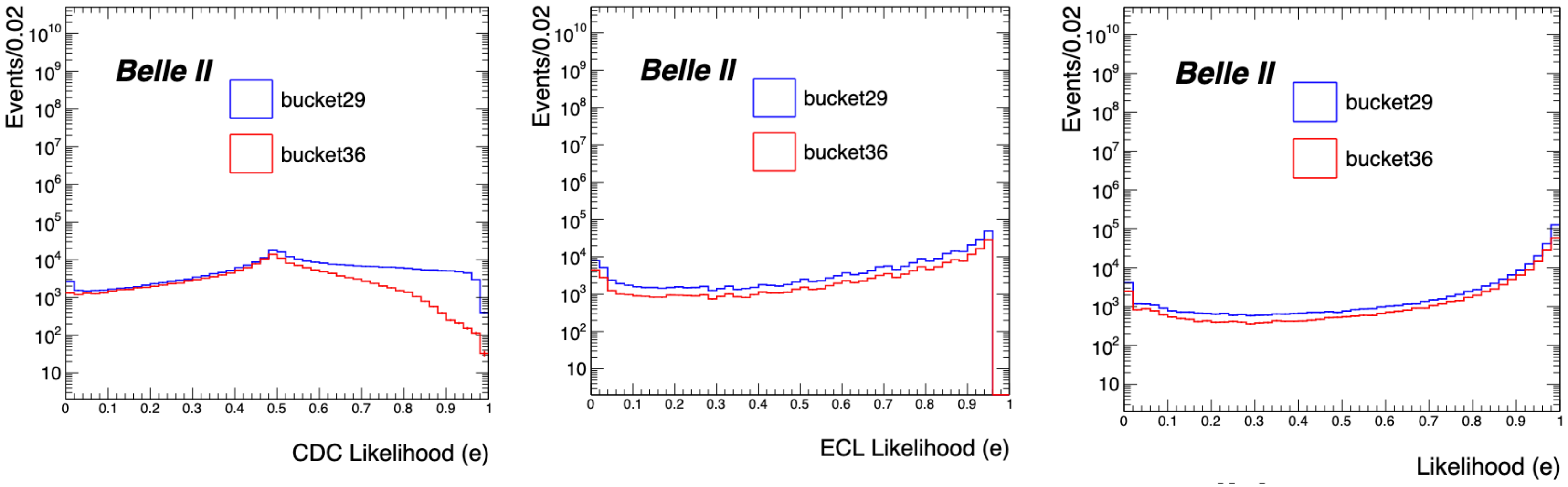


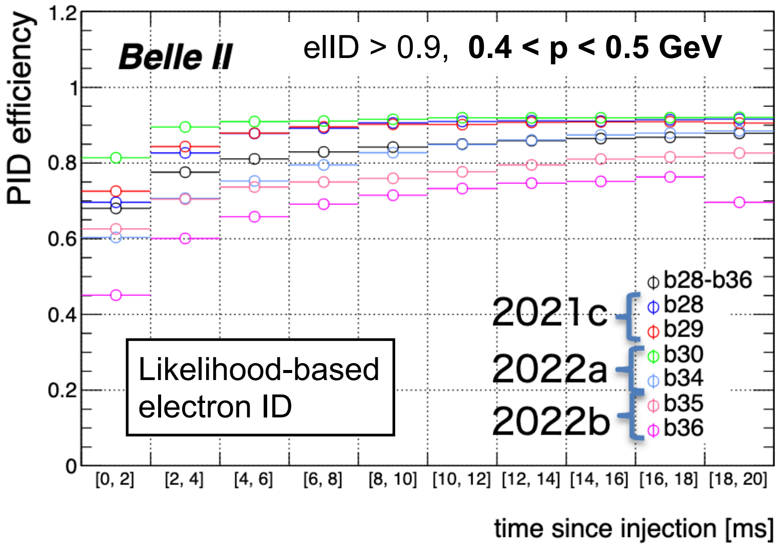
- $\sigma(\pi^0)$: **6 MeV→ 8 MeV**
- $M(\pi^0)$: **133 MeV→128 MeV**

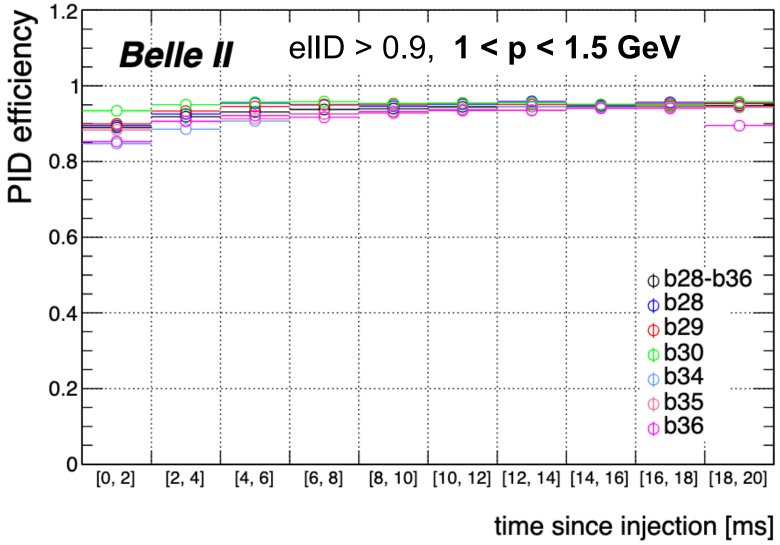
- To reach more comprehensive understanding, plan to visit more data samples

Kenta Uno

- Study of electronID likelihoods in lower (b29) and higher (b36) background periods, with 2-photon events.
- CDC likelihood is severely affected by the variations of background conditions.
- Some effects are seen also on the ECL likelihood.



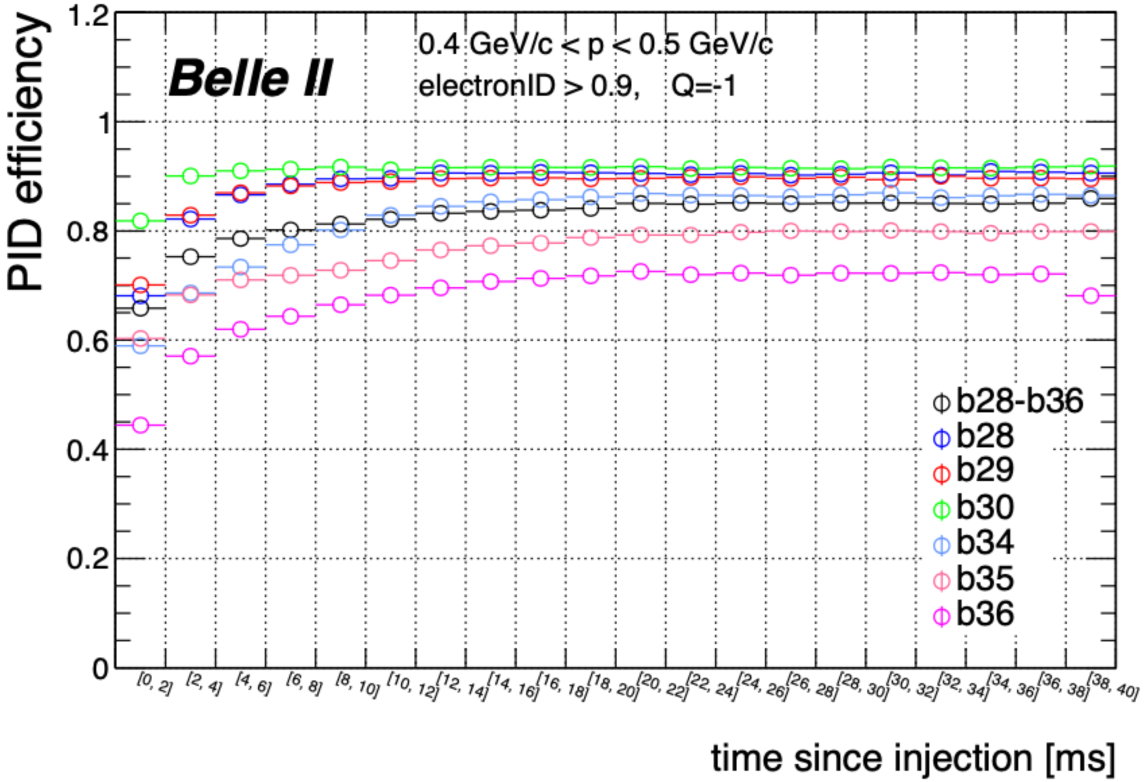




- Injection backgrounds have significant impact on efficiency, particularly at low momentum (drop of up to 40% in b36).
- Similar trend at high momentum, but the degradation is smaller.

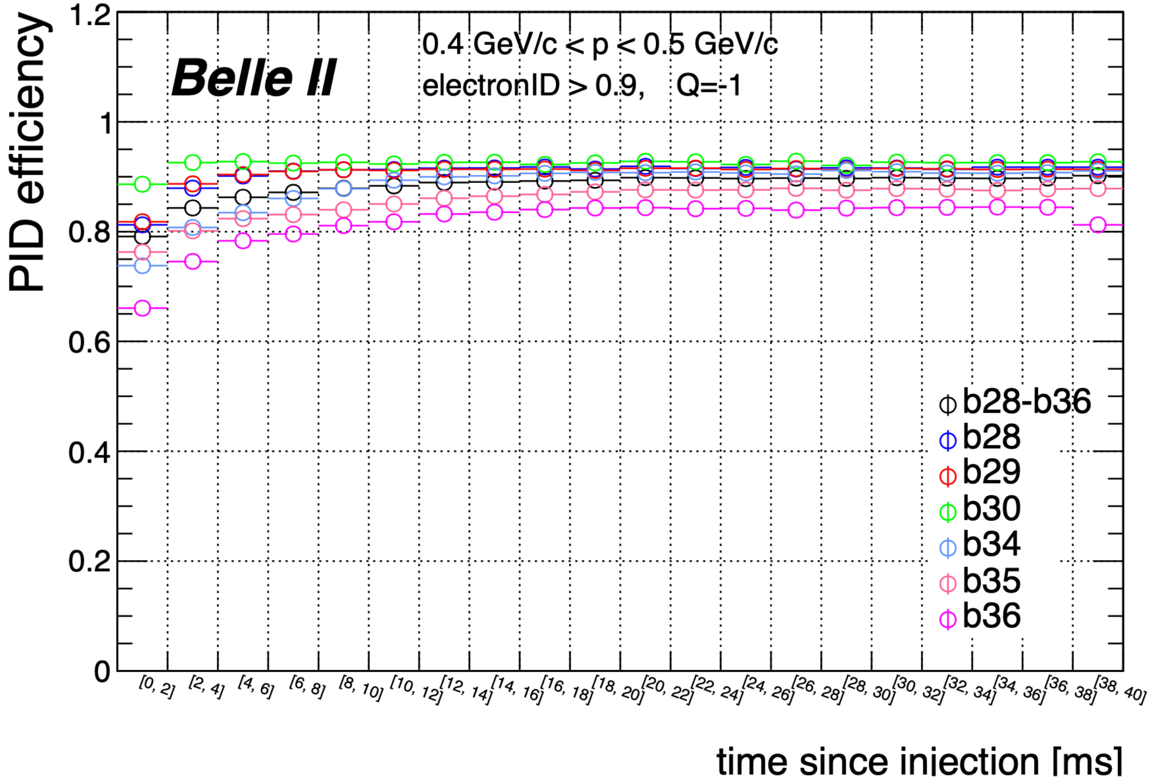
LH vs BDT: low momentum

Likelihood-based electron ID



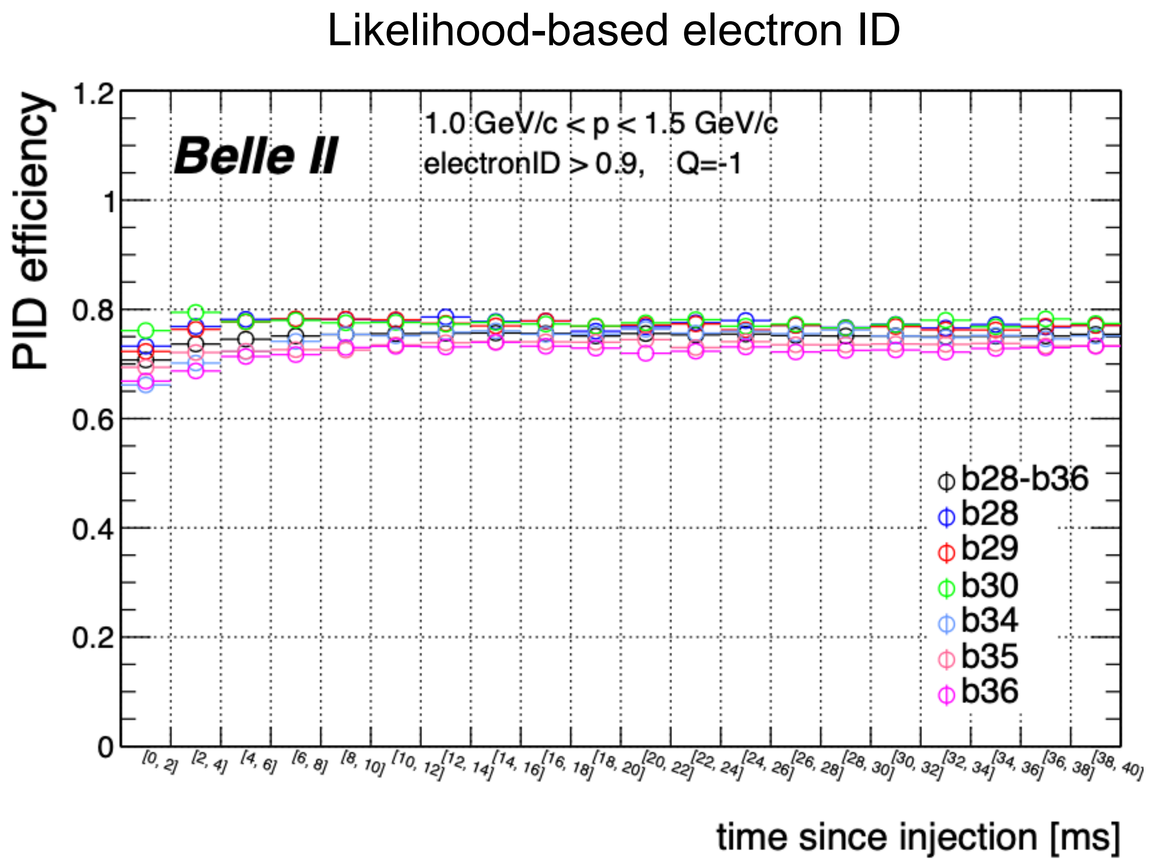
BDT-based electron ID

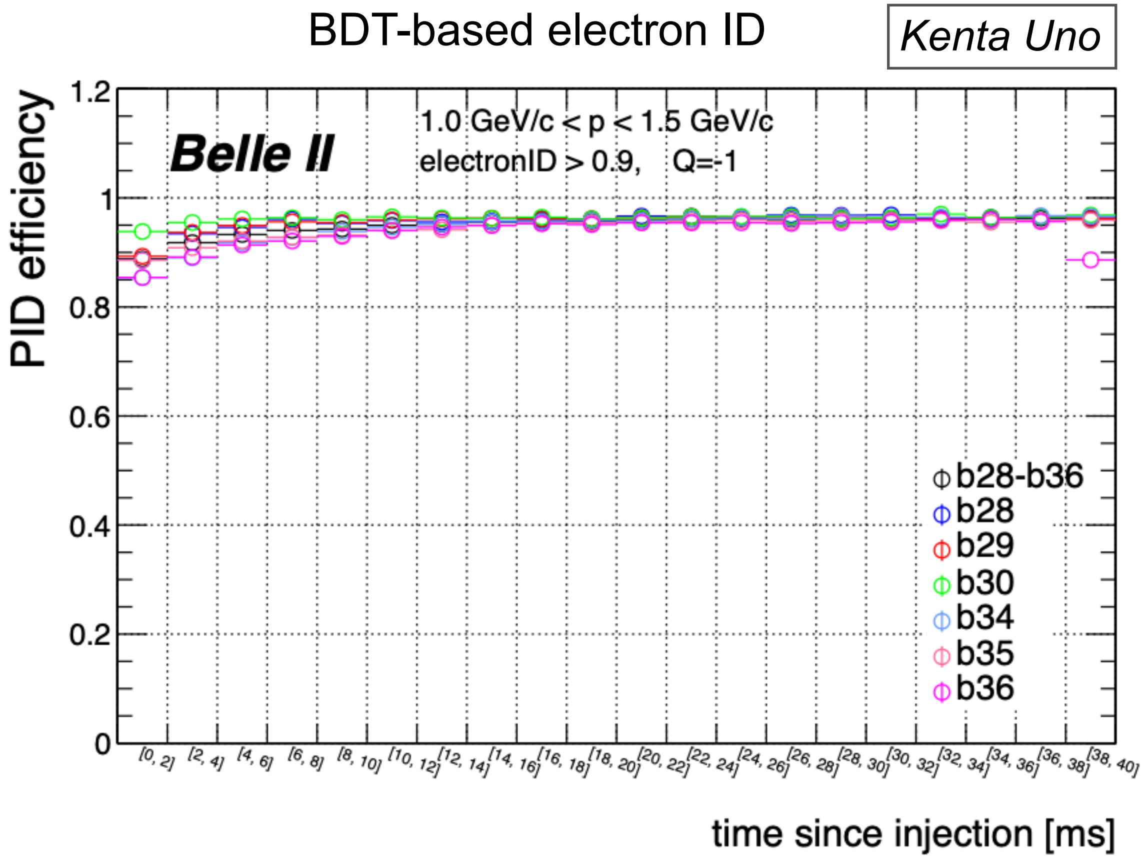
Kenta Uno



⇒ Large effect for low momentum tracks. BDT is more robust against injection backgrounds.

LH vs BDT: high momentum



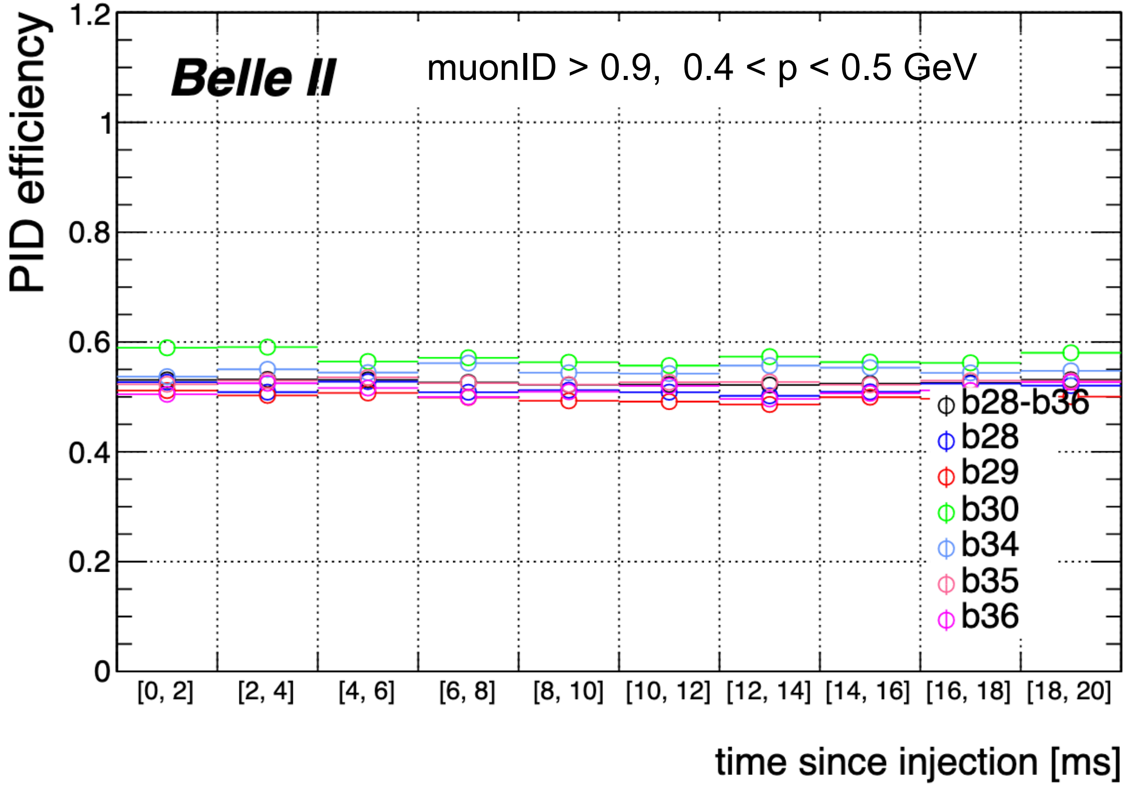


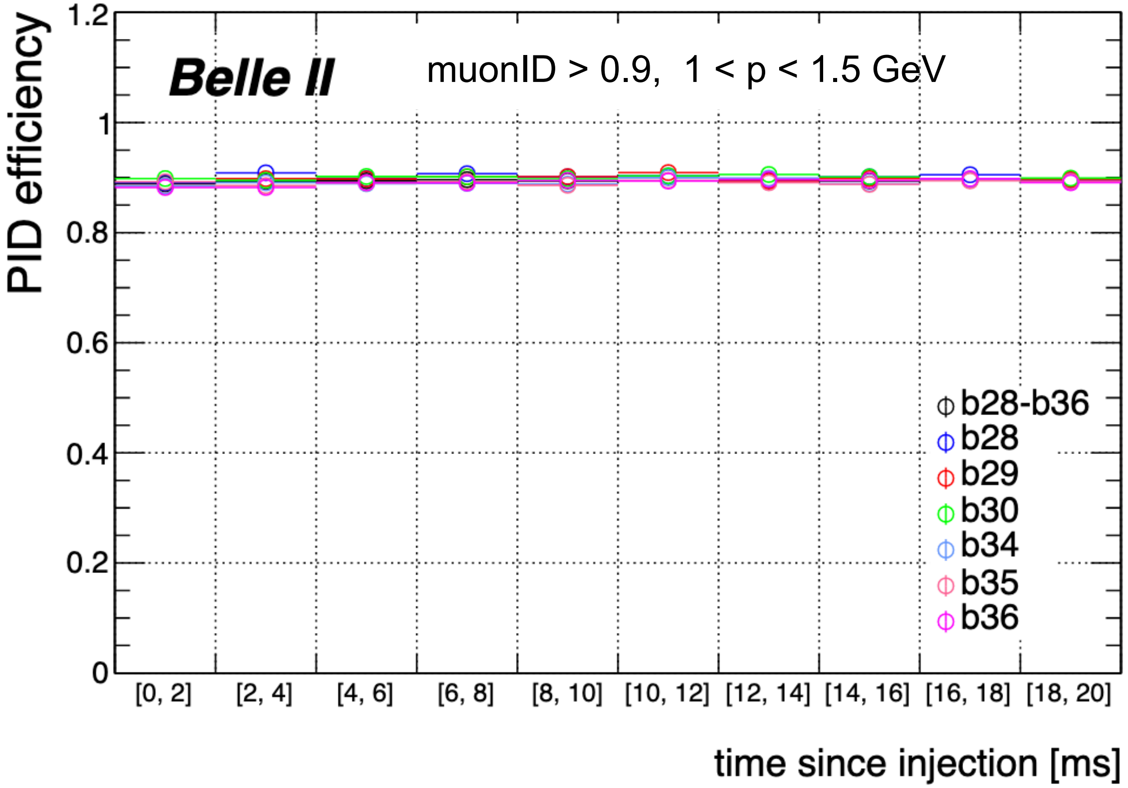
⇒ impact of injection backgrounds for high momentum tracks is smaller

Muon ID

- <u>Good news</u>: muonID is much more stable with increasing beam backgrounds and time since injection

Kenta Uno

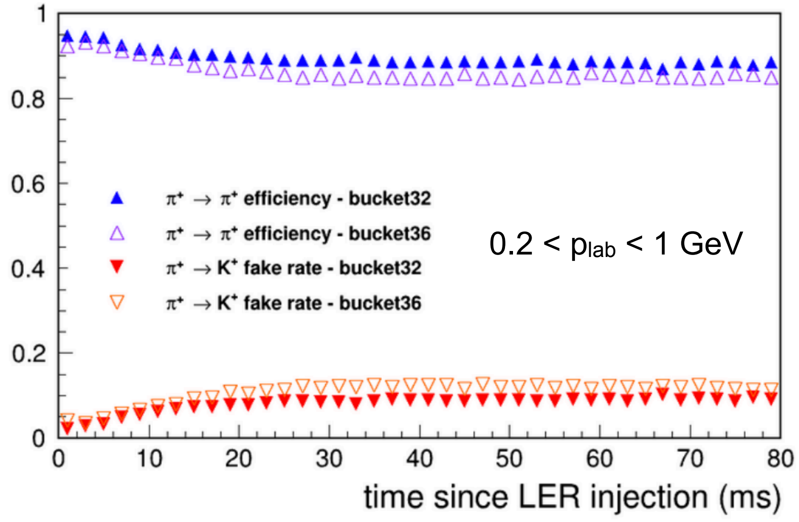


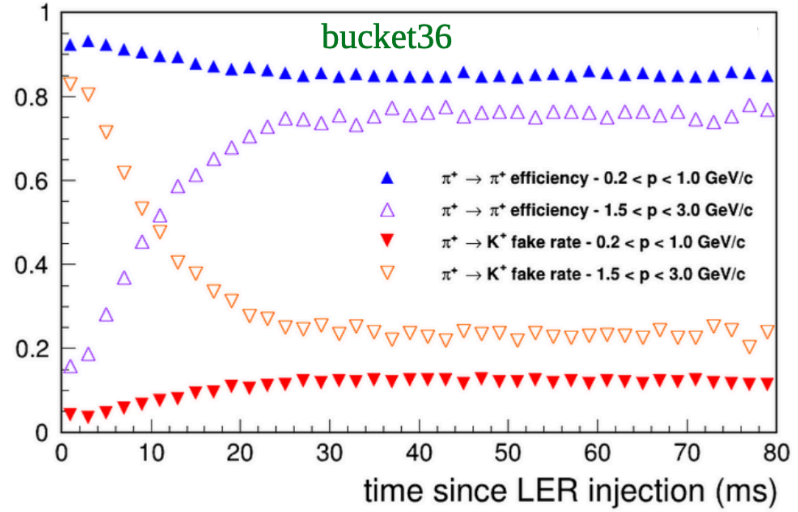


Ale Gaz

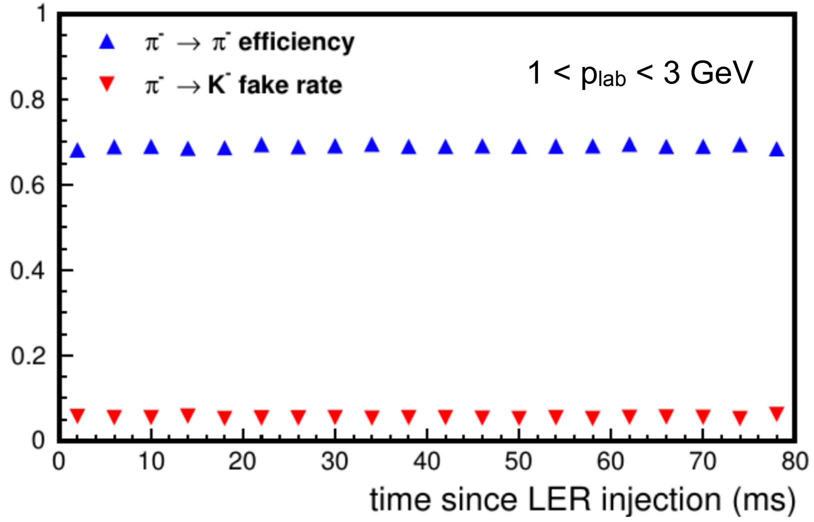
- Similar study for hadron ID, using $K_S^0 \rightarrow \pi^+\pi^-$events
- Also in this case the CDC is heavily affected by the background conditions
- Below (above) the crossing point of the dE/dx curves, particles are more pion(kaon)-like due to the shift to lower values of dE/dx at times close to the injection.
- The effect on TOP performance is much smaller and visible only for very high background buckets.

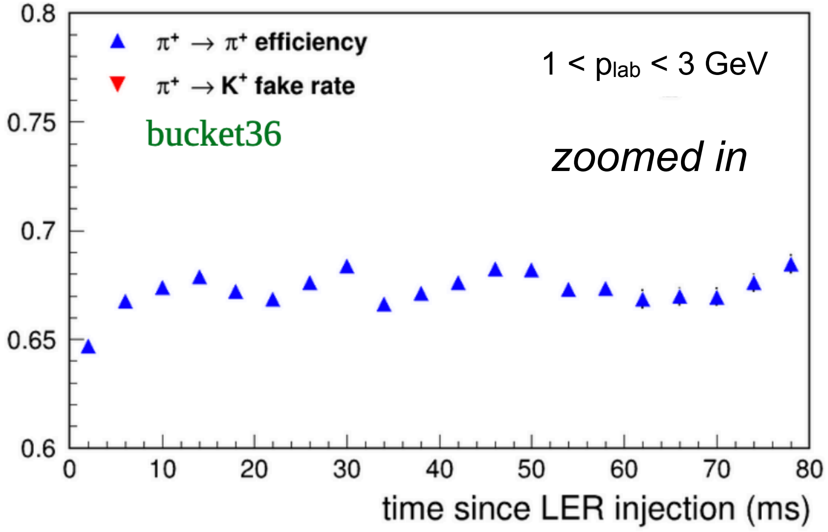
CDC only





TOP only



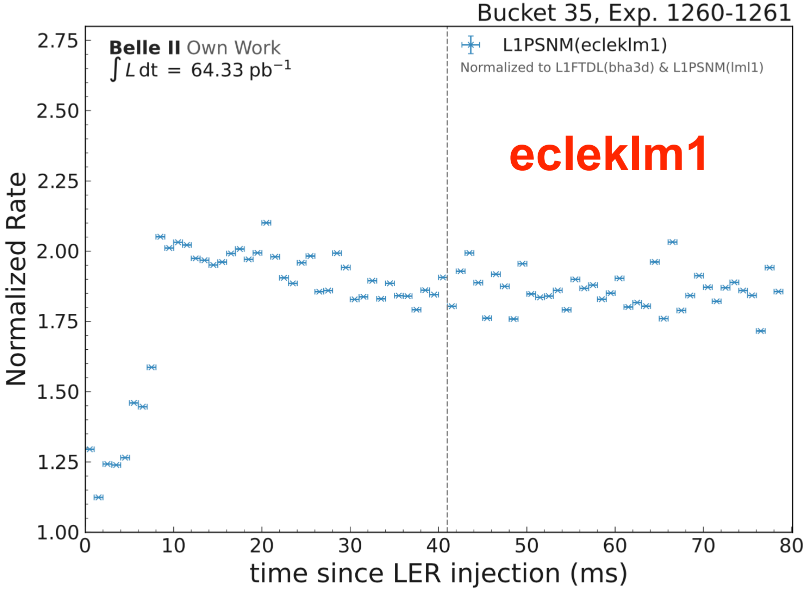


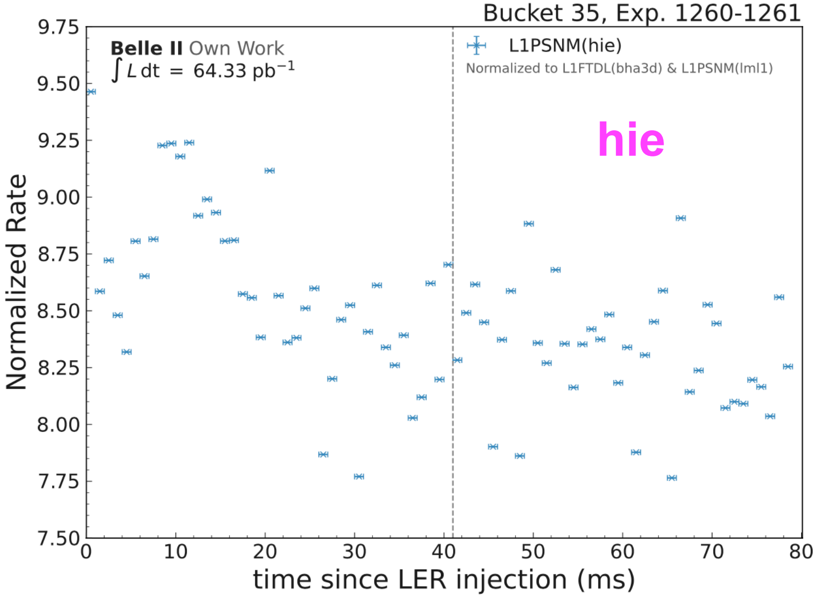
L1 Trigger Rate

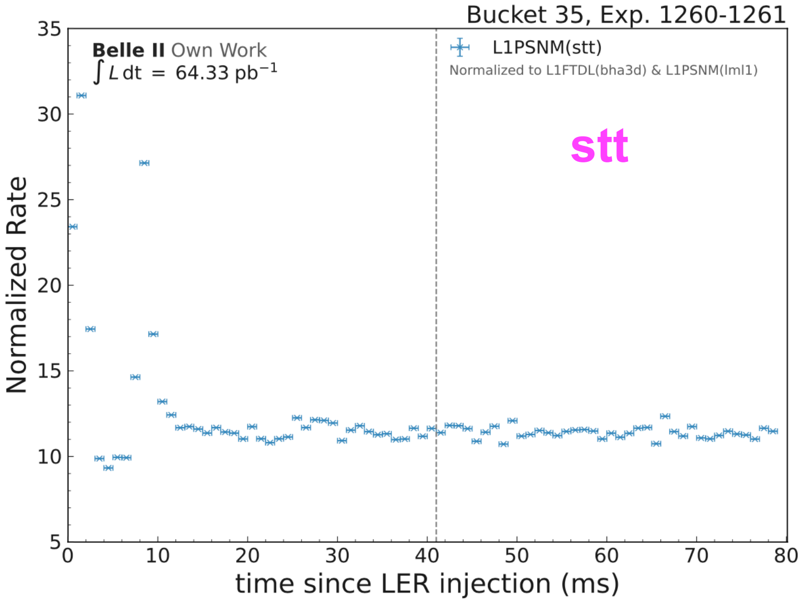
Isabel Haide

- Study of L1 trigger rate as function of time since LER/HER injection
- Data used: exp. 26, runs 1260-1261 (~64 pb^{-1}), with HLT in monitoring mode
- Rates normalized to L1FTDL(bha3d) and L1PSNM(lml1)
  → no reliance on tracking, mostly wide angle Bhabhas

Normalized Rate = $(N_{\mathrm{Bit}})/(N(\mathrm{L1FTDL(bha3d)\&L1PSNM(lml1)}))$







- Bits with **increasing** rate: ecleklm1, bwd_seklm, fwd_seklm, eklmhit
- Bits with **decreasing** rate: hie, stt, c2hie, cdcecl3, cdcklm1, cdcklm2, fyb, ggsel, lml16, syb, syo

L1 Trigger Rate

- Main trends:
  - LER injection suppresses standard 2D tracks, but increases short tracks
  - sst rate at 10 ms since LER is double that of the plateau rate
  - big decrease in KLM endcap near LER injection, but big increase in KLM barrel
  - standard ECL triggers (hie, lml1, lml2) have little sensitivity.
  - lml16 (0.5 GeV single cluster) does increase close to LER injection

- Complete set of plots from the study of *Isabel Haide* can be found here

Conclusion

- To adequately prepare for data taking after LS1 it is essential to characterise performance dependence on injection background levels.

- Main trends vs time since LER/HER injection:
  - In all cases studied so far we observe a larger dependence on LER injection
  - Injection backgrounds cause shift and worsening of dE/dx resolution.
  - Up to 40% degredation in electronID efficiency at low momentum. MuonID is stable.
    For hadronID, CDC is heavily impacted while TOP is stable.
  - Clear impact on K-short systematics and π^0 peak position and resolution.
  - Trigger Performance Group is monitoring L1 bit rates (see previous slide for main trends).

- If you have requests for further studies (e.g. those that can help in optimisation of injection veto) please let us know.

BACKUP

Channels analysed (non-exhaustive)

	Topic	Low multi or τ channels	Hadronic Channels
Tracking	Efficiencies, fast and slow, K_S	$\tau\tau$, $ee\gamma$	D^*, $B \to D^*h$
	Momentum scale and resolution	$\mu\mu$	D^*
Particle ID	Lepton ID efficiencies and mis-id	$ee(\gamma)$, $\mu\mu(\gamma)$, $eell$, $\tau\tau$	D^*, K_S, J/ψ
	Hadron ID efficiencies and mis-id	$\tau\tau$	D^*, Φ, Λ, K_S
Neutrals	Photon efficiency, energy and position resolution	$\mu\mu(\gamma)$	D^*, π^0
	π^0 efficiency and photon energy & position resolution	$\tau\tau$, $\Omega\gamma ISR$	D^*, π^0
	K_L efficiency	$\Phi\gamma$	D^*
Beam	Beam energies	$\mu\mu$	$B \to Dh$
	B-counting		$\Upsilon(4S)$ Inclusive
Analysis	FEI		$B_{FEI\text{-}tag}$ / $B_{SL\text{-}sig}$
	Flavour tagging		$B_{flav\text{-}tag}$ / $B_{flav\text{-}specific}$

dE/dx calibration for injection time

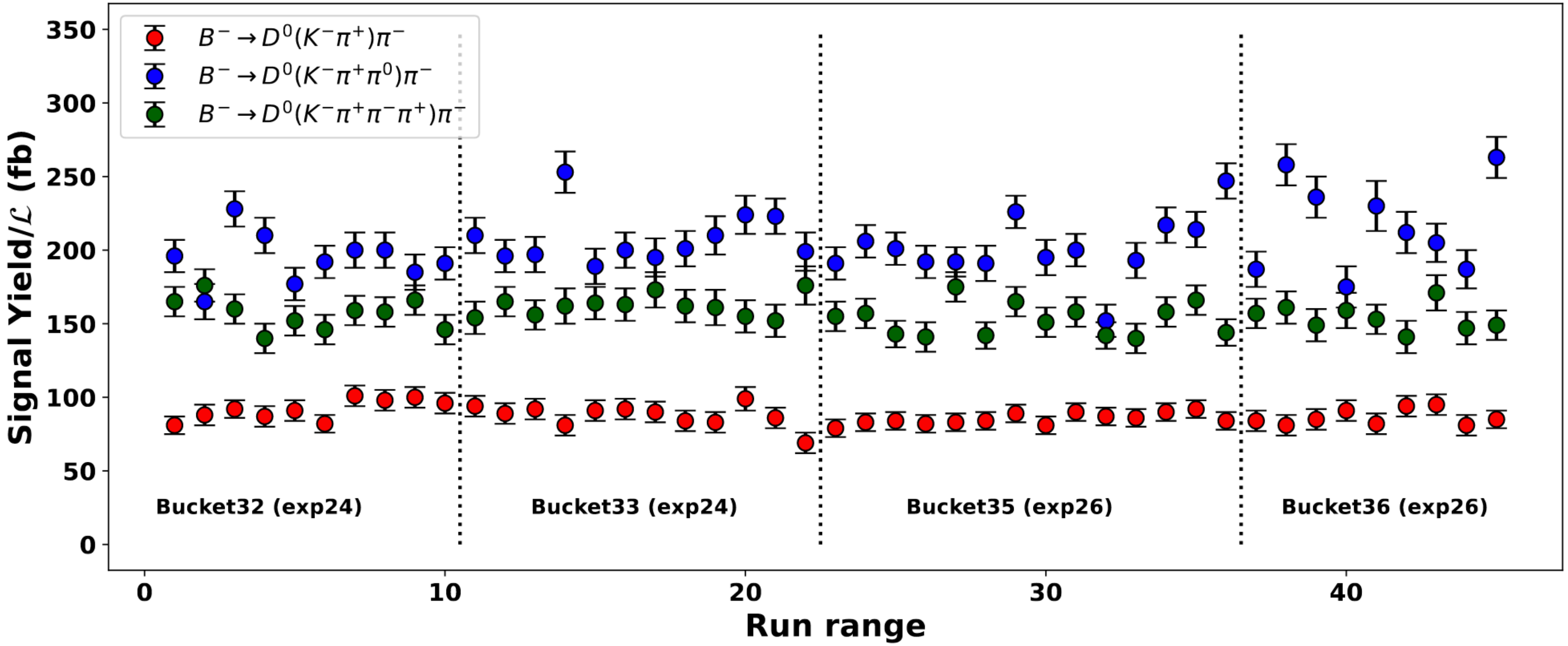
Jitendra Kumar

- New **calibration idea (airflow based)**
  - getting ready here; https://agira.desy.de/browse/BII-9560
  - gain vs injection time
    - ✴separate for HER and LER
    - ✴for a block of run (even splitting inside a bucket)
  - will be used for..
    - ✴future prompt calibrations via airflow
    - ✴and in major re-processing of current dataset
      - expecting performance recovery but not all. For example, poor resolution at initial time may remains and may be an additional calibration competent in future might is required (need more study)

Impact on Physics

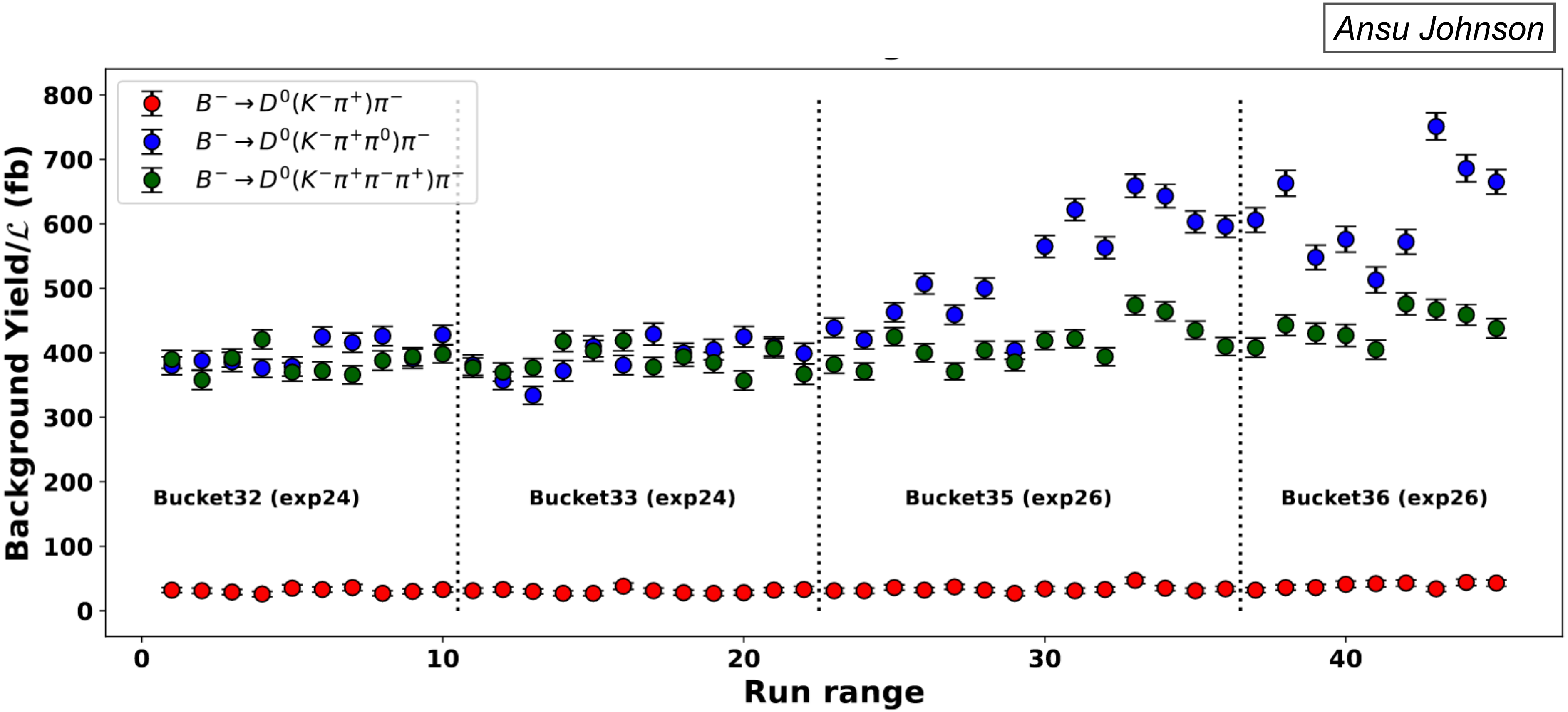
- Does the increased beam backgrounds at the end of 2022ab significantly effect B yields?
- Yields extracted from M_{bc} fits of fully reconstructed Bs

Ansu Johnson



- Good news: the high beam background doesn't seem to affect the $B^{\pm}$ signal yields much

Impact on Physics



- There is an increase in background yields, coming mostly from $D^0(K\pi\pi^0)$ mode.
- Likely coming from degradation in π^0 performance. Studies ongoing.
  Plan to retune π^0 reconstruction criteria for higher background conditions.