

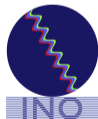
Wire-by-Wire Tracking Efficiency Plots

New Diagnostic for the Belle II Central Drift Chamber

Lessons from INO

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February 03, 2026



Introduction

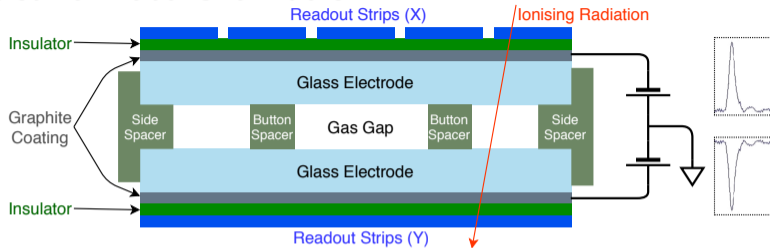
- Large detectors are often monitored as black boxes.
 - If the output of individual boxes look reasonable, we assume the internals are fine.
- This breaks down when local failures produce global bias.
- In multi-detector systems,
 - one detector can silently compensate for another,
→ creating false confidence in overall performance.

Bottom line

In an enterprise setup, even acceptable lemonade must be traceable to its lemons.

A familiar precedent: Resistive Plate Chambers

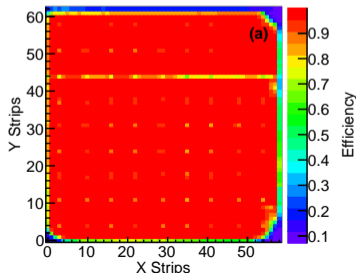
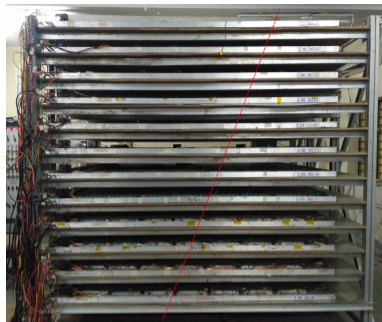
- RPCs are mostly operate in avalanche or streamer mode
 - each mode has different checks and bounds.



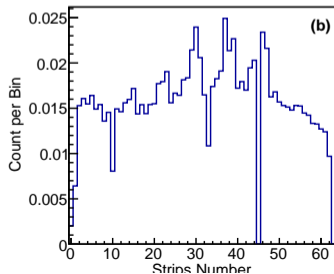
- In this work, the focus is on *avalanche mode*.
 - a highly statistical process.
 - energy deposition does not translate linearly to collected charge.
- Single-strip monitoring therefore focuses on:
 - pulse shape (during development),
 - noise rate and time-over-threshold (during operation).
- These validate the individual strip and electronics; but not detection efficiency.
- Efficiency is instead measured via *extrapolation in a multi-detector setup*.

RPC stack: efficiency as a standard diagnostic

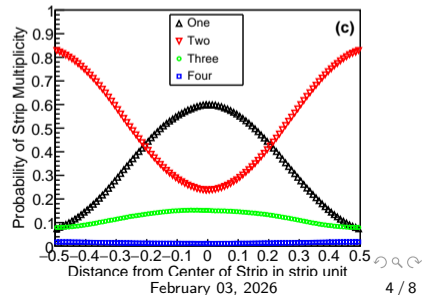
- A multi-layer setup provides the reference tracks.
- Detection efficiency is simply defined as
 - observed hits over expected hits from extrapolation,
 - which quantifies the *overall performance* of a layer.
- Strip hit counts identify *dead and noisy channels*.
- Cluster multiplicity probes the *gain and operating point*.
- For more, check out **Pethuraj's** slides presented yesterday.



Mondal (SSS Defence)



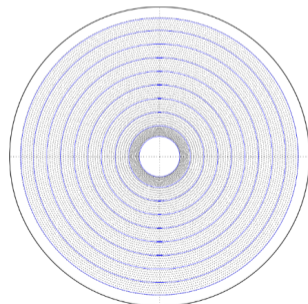
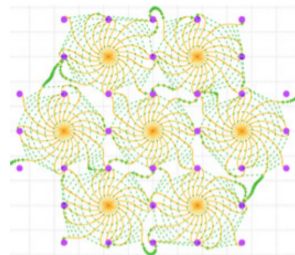
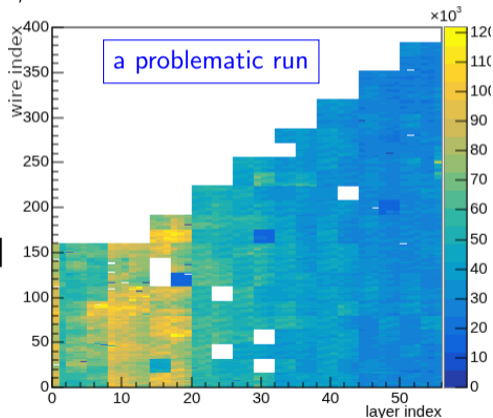
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Central Drift Chamber: wire health

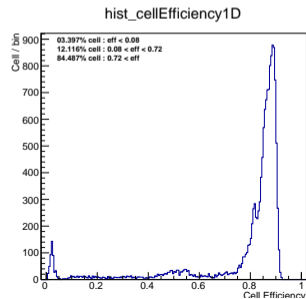
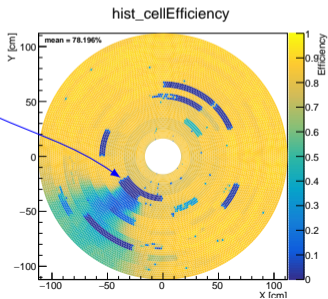
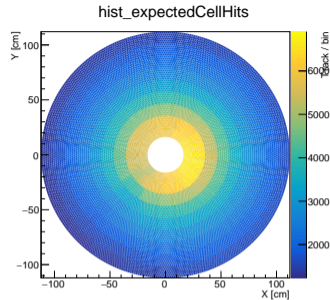
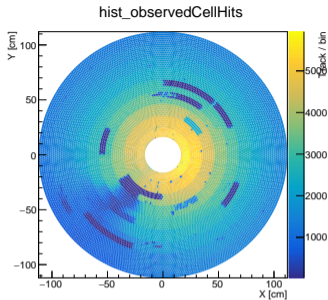
- CDC is the main tracking detector of Belle II
 - supplemented by inner Silicon Vertex Detector.
- CDC wire health is traditionally monitored using:
 - drift time information,
 - collected charge,
 - wire hit map.
- Even seen fine, these fail to indicate faults in tracking.
- SVD finds tracks not found by CDC [backup]
 - false confidence.



Data Quality Plots for Belle II

So we asked the same question routinely asked in RPC - but wire by wire.

- Here tracking provides helices, \rightarrow wire efficiency = $\frac{\text{Observed}}{\text{Expected}}$.
- The efficiency plot provides a reconstruction-level *geometric* view of CDC.
- As a result, a tracking failure at -130° becomes visible, \rightarrow caused by two disabled boards creating a gap in an axial layer.
- Wires with *good* and *bad* efficiency are tracked over runs, \rightarrow enabling informed run selection for analysis.



Summary

- Channel-level and electronics-level monitoring is necessary,
 - but insufficient to assess tracking performance.
- In multi-detector systems, detector inefficiencies can be compensated,
 - creating false confidence in overall performance.
- Extrapolation-based efficiency is a standard diagnostic in tracking detectors,
 - and is directly applicable wire by wire in the CDC;
 - exposing localized failures that are invisible to channel-level plots.
- The method is implemented in DQM,
 - providing actionable feedback for operations and analysis,
 - and supporting long-term performance and ageing studies.

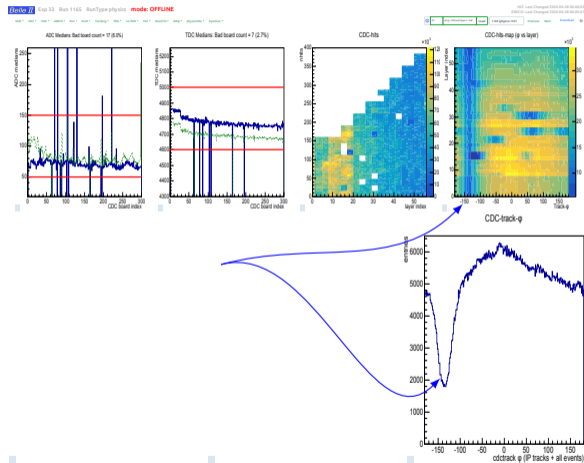
Diagnostic plots should answer a well-defined question,
or raise a well-defined question for further investigation.

Thank you

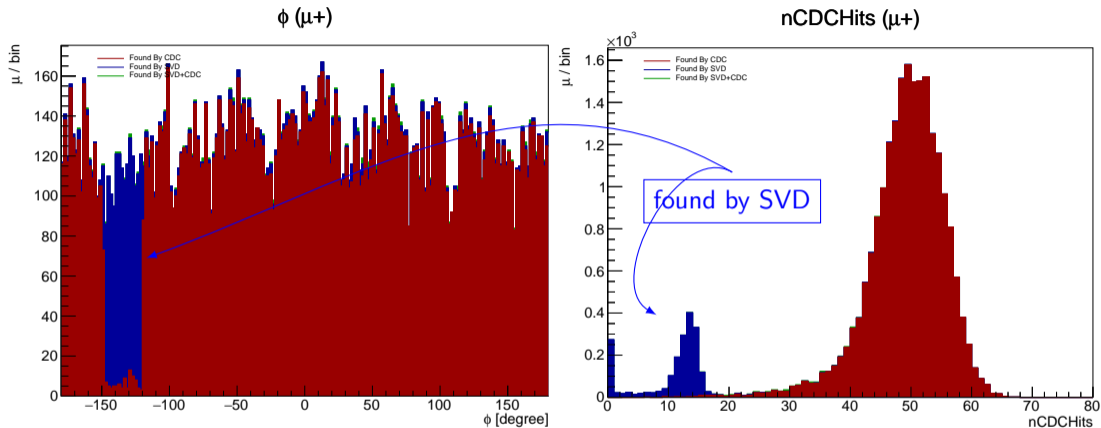
Backup

Drop of ϕ efficiency in CDC-DQM histogram

- Track ϕ in CDC DQM plot shows a large drop of efficiency at around certain ϕ around mid 2024
 - in this data, near $\phi = -130^\circ$
- Existing DQM and offline plots by CDC experts did not provide explanation.
- To investigate it, reproduced the issue using $ee \rightarrow \mu\mu$ sample which has long and clean tracks.
 - Tracks are marked based on which detector find them.



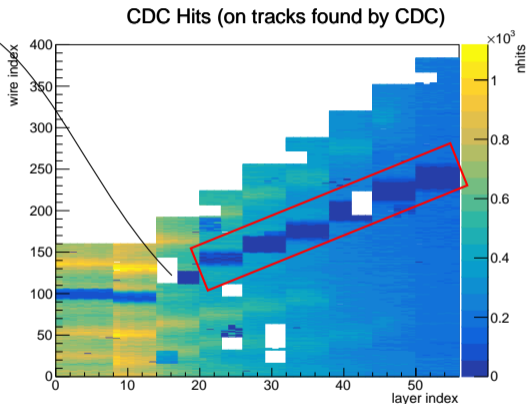
Distributions in $ee \rightarrow \mu\mu$ events



- In standard reconstruction, we do not see any drop in efficiency in ϕ distribution
- Tracks not found by CDC in $\phi[-150, -120]$, are reconstructed by SVD.
- Moreover SVDtoCDCCKF fails to attach all the CDC hits to the track.

TrackQualityEstimator deletes 'bad' tracks

- The issue is a missing axial layer in a track.
- The CDC track quality estimate that deleting the track which failed quality estimation.
- **The MVA based quality-estimator was not trained to face this scenario.**
- Should this issue arise again, an immediate detection is necessary to avoid confusion.
- So created few histograms, which are now in CDC DQM.



$ee \rightarrow \mu\mu$ events

New plots for Belle II DQM

Detector's tracking efficiency monitoring is very crucial, which was common in INO.

Expected: intersection of a track (helix) with a layer

Observed: the same, but if hit(s) attached to the track in that layer

$$\text{Efficiency} = \frac{\text{Observed Hits}}{\text{Expected Hits}}$$

