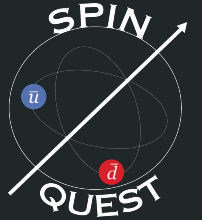
Online Q-Tracket reconstruction

Speaker: Jay on behalf of UVA OROM Team



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Fermilab

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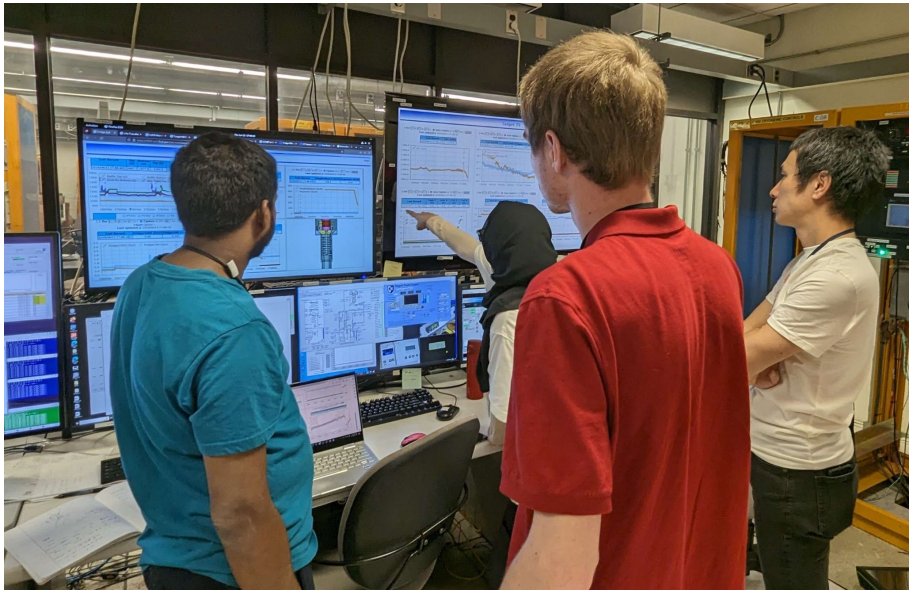
Online Monitoring Purpose

- Visualize information in real time
  - GPU acceleration is vital.
  - Visualization of the detector data, vertex information, Asymmetries, Weather.
- Detect anomalies and issues
  - AI models trained on past spills.
  - Trained to find patterns or detect known patterns.
- Alert/Alarm shift worker
  - Sound or alarm handler paired with anomalie AI.

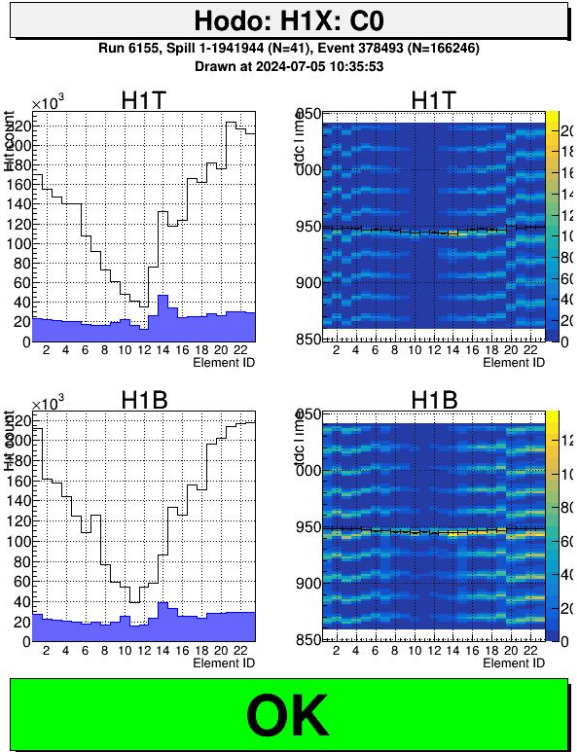


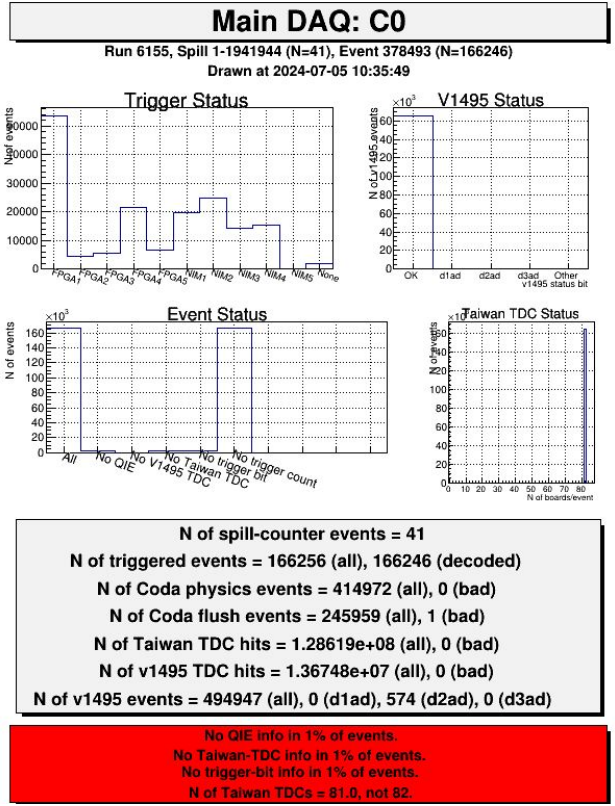
Online Monitoring Goals

- Display critical information in a efficient way, Use AI for detection of anomalies, Quickly Alert personal of the issue.
- Visualize direct information:
  - Hodoscope in-time window and record drifts in real time with respects to trigger TDC.
  - Hit Display: occupancy plots organized geometrically for intuitive feel of what's happening (DC, HODO, PROP).
  - Beam profile monitor with inferred positions in X, Y of the beam also showing profile.
- Visualize Processed information:
  - Dimuon mass spectrum per spill and integrated over all spills in that run.
  - Set of kinematic variable with momentum distributions per spill.
  - Vertex position of selected dimuons and single muons.
  - Qtracker track selection path and event display showing selected tracks and quality of tracks for good Dimuons.
  - ktracker displays: mass spectrum and kinematic variables.
  - Real time J/psi and DY Sivers Asymmetries.

Data Summary & Spectrometer Online Monitor

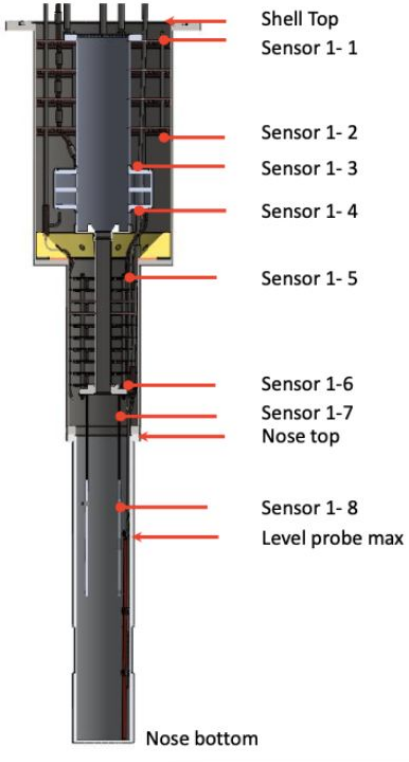
- Displays raw data from spectrometer on editable ROOT canvas.
- Later browserable on Data Summary.
- Data Summary displays:
  - Temperatures of the target, fridge, and lcw.
  - Liquid Levels of the magnet, dewars, and nose.
  - Positioning of the target insert.
- Goal: Integrate for anomaly detection.



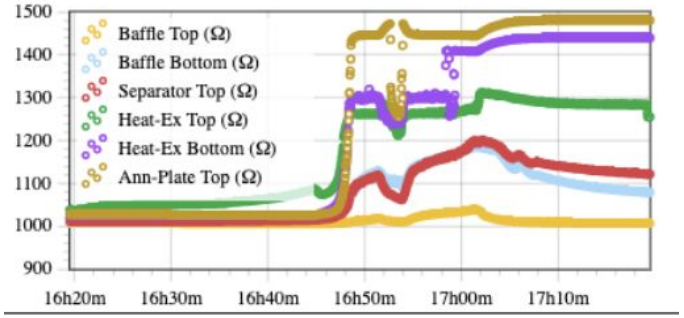


Cryogenic system Data

- Display data from sensors on the fridge, dewars, magnet, etc
- Allow for strip charts for monitoring on different time scales.
- Goal: Integrate for anomaly detection..



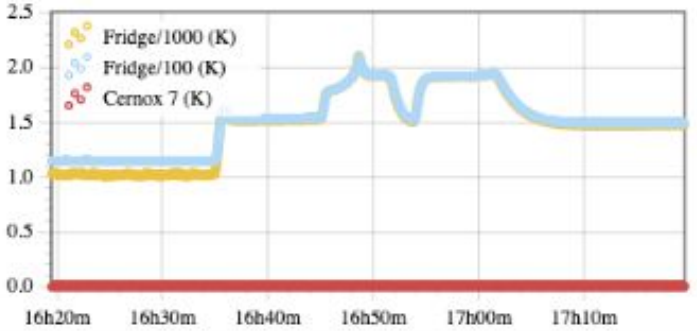
Last Record		Baffle Top (Ω)	Baffle Bottom (Ω)	Separator Top (Ω)	Heat-Ex Top (Ω)	Heat-Ex Bottom (Ω)	Ann-Plate Top (Ω)
2024/05/27 17:19:30	1	1006.8	1078.3	1121.2	1256.1	1439.4	1480.3



For 1 h 0 m 0 s | Auto-Update in 3 / 5 sec | Update

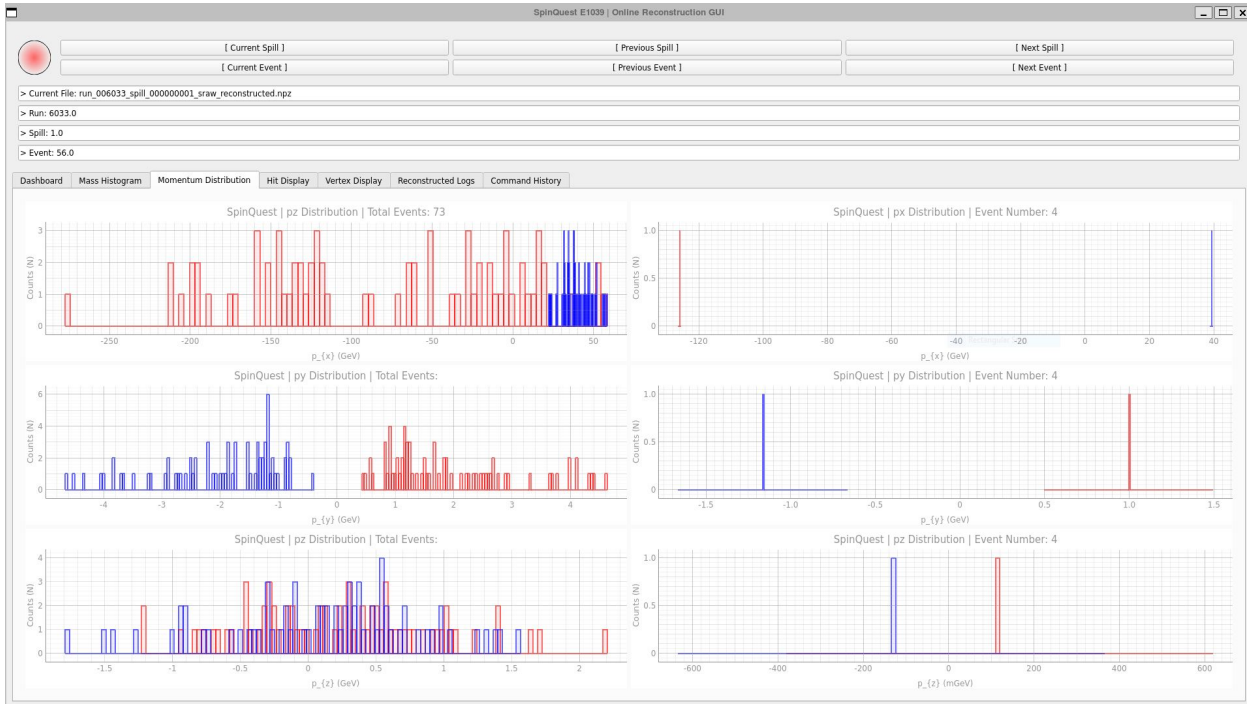
Last updated @ 2024/05/27 17:19:31

Last Record		Fridge/1000 (K)	Fridge/100 (K)	Cernox 7 (K)
2024/05/27 17:19:29	3	1.473	1.489	0.000



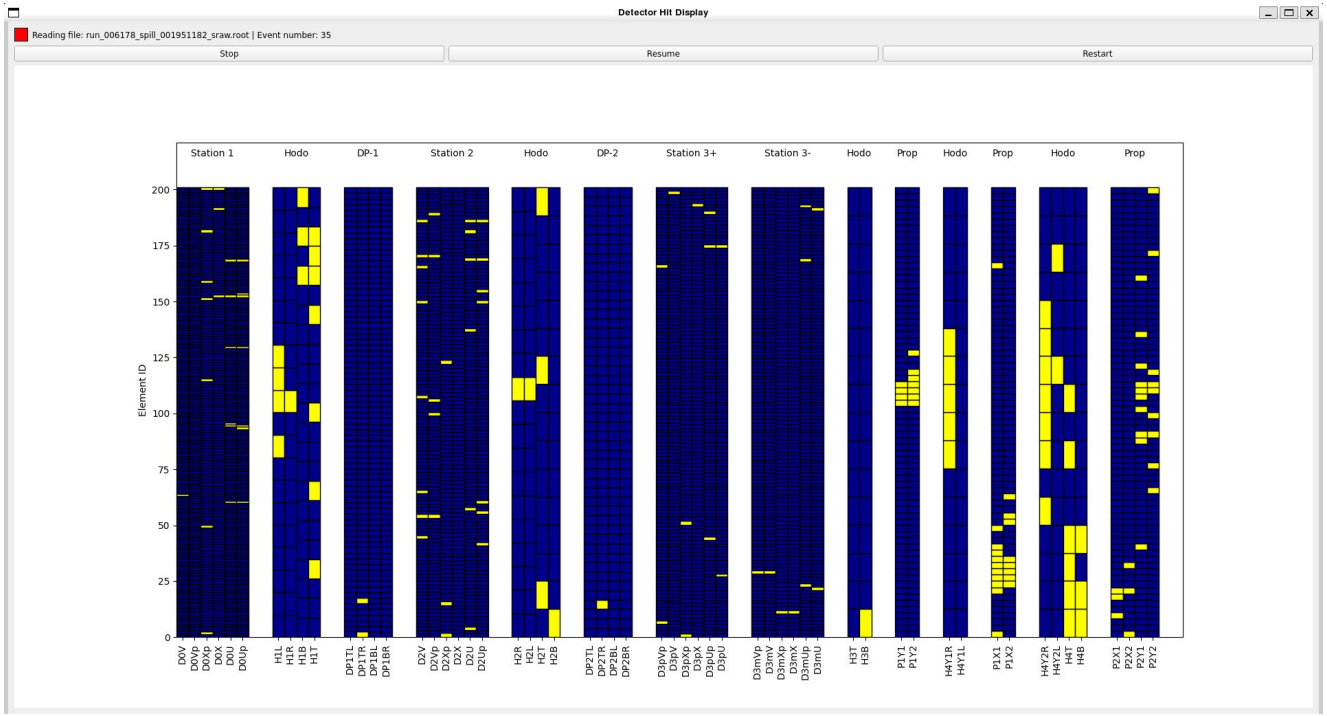
Gui setup

- Allows for viewing events as they occur.
- Layout needs refinement: Most critical plots on one page.
- Space is limited!
- Can be ran on a different gpu than the reconstruction.



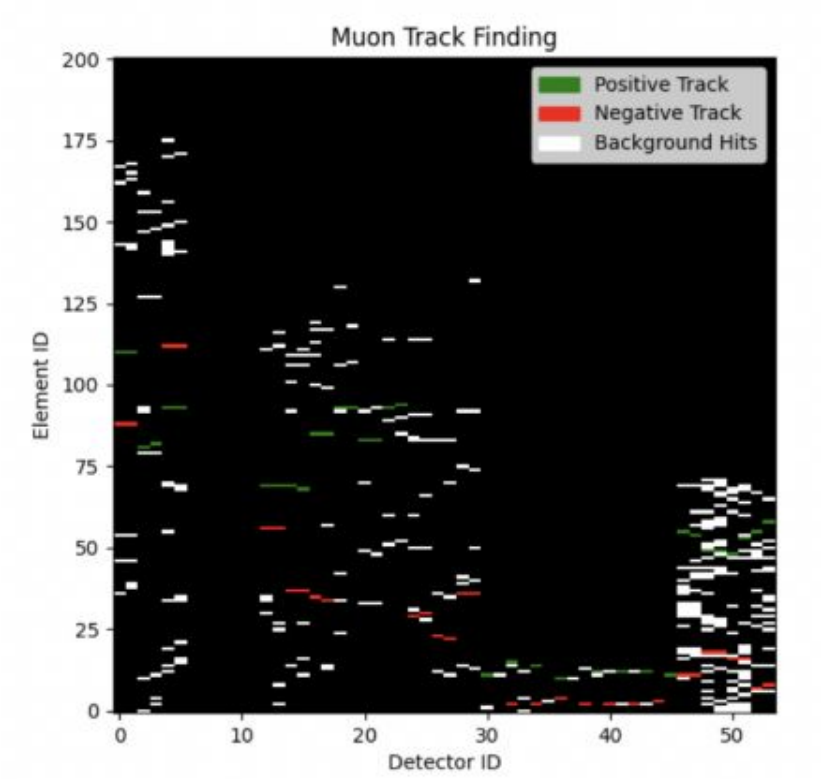
Hit Display

- Order by geometry of the detectors.
- Only shows raw hits. Need to add reconstructed tracks.
- Shows the entire detector in one display.
- Only shows one event at a time.



Fast Reconstruction

- Using AI models accelerated with GPU’s.
- Input is a hit matrix of shape (event_number,detector,element).
- Can preform reconstruction in seconds to give as close to real time results.
- Output directed towards a universal file structure.

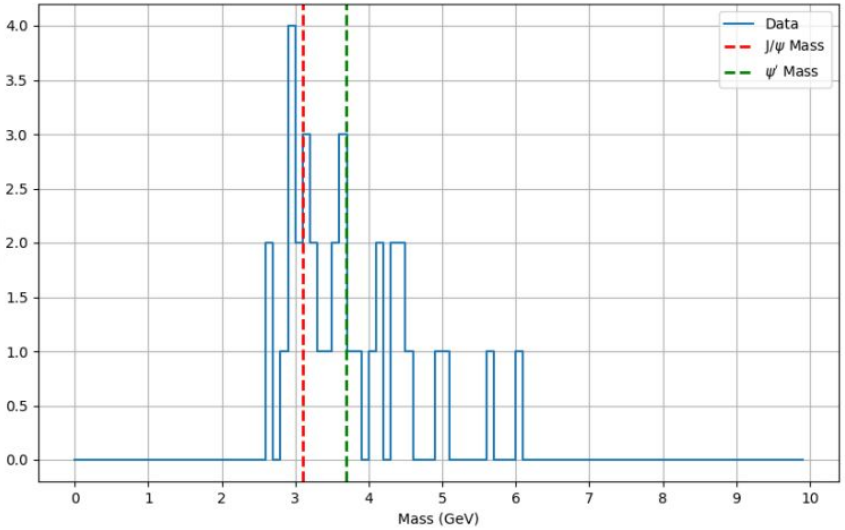


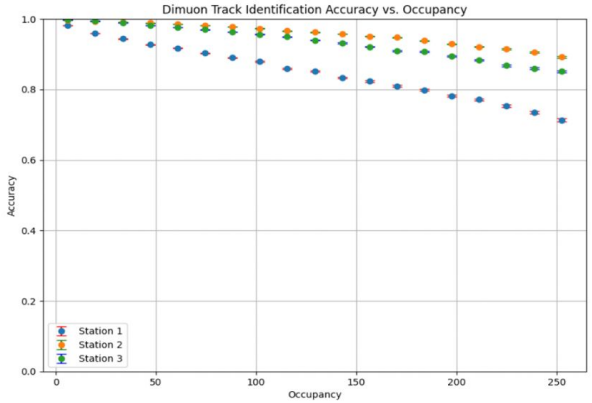
Q-Tracker

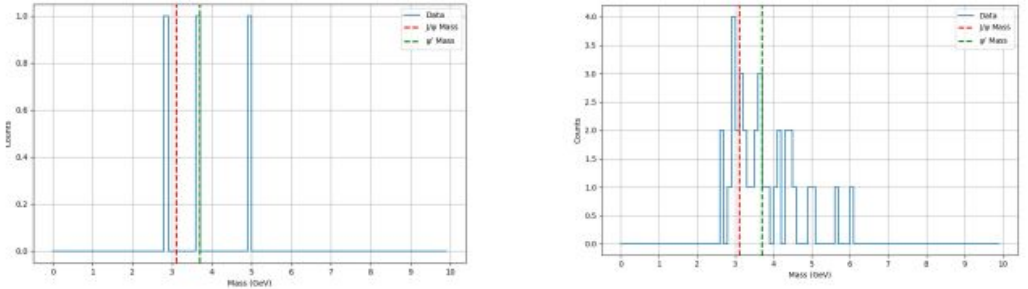
- A large network of Deep Neural Networks and Convolutional Networks.
- Filters out events only keeping high probabilistic events with 2 complete muon tracks.
- Can tuned this probability to filter more or less events.
- See Dustin's talk for more!

Q-Tracker Current State

- Allows for Quick reconstruction of spills for mass displays.
- Limited to events with only 1 dimuon track.





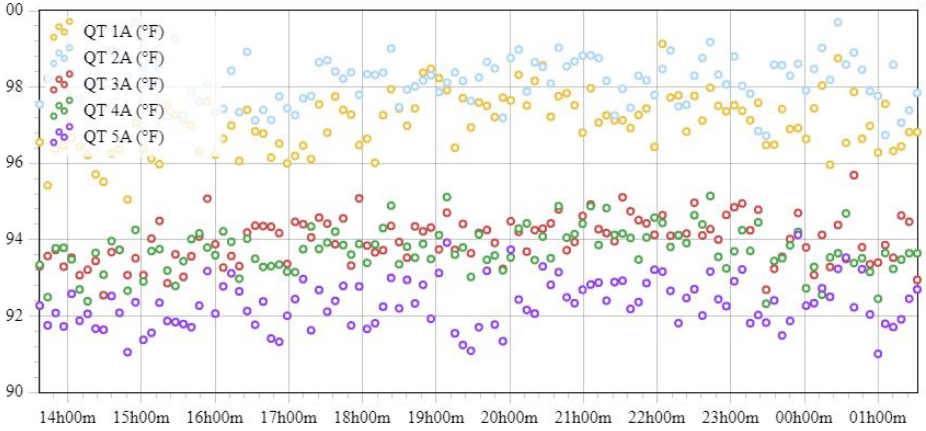


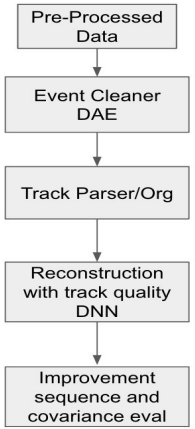
Realtime online monitoring with and without KMag using QTracker

What we have learned

- First build of the Gui
- System Monitoring
  - IVC
  - Full Cyrogenic System
  - LCW temperature
  - Detectors Health Monitoring
- Q-Tracker
  - Separate GPUs
  - Train for more than 2 muons tracks.
  - Future improvements on training MC.

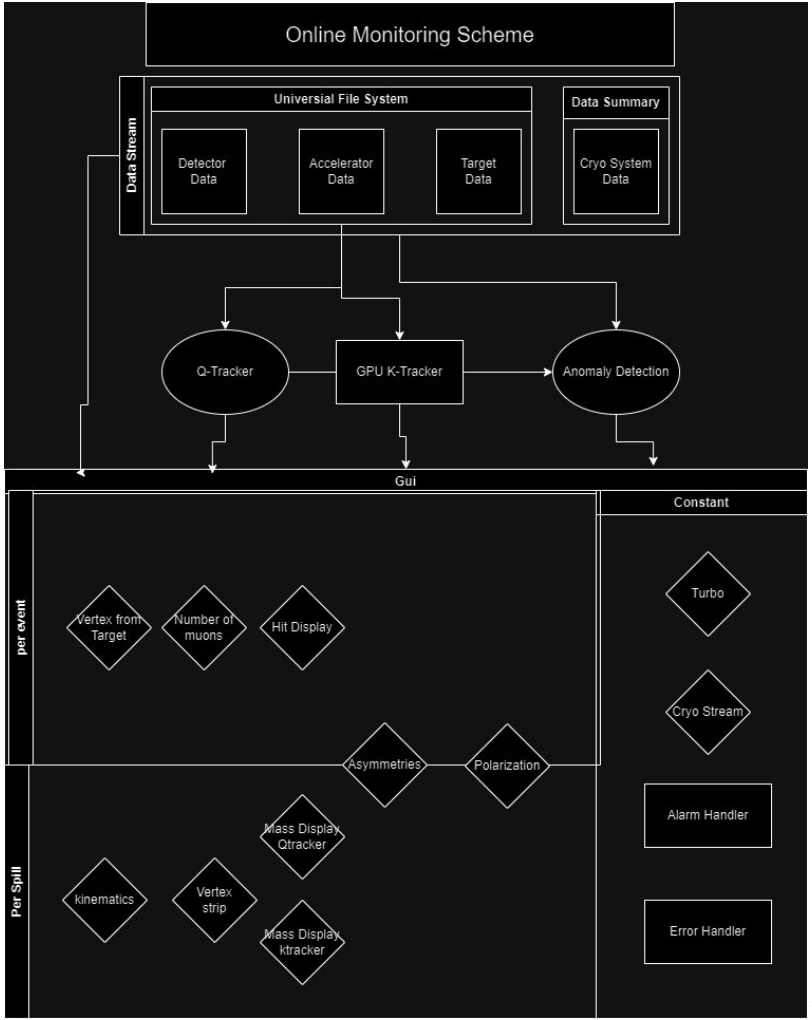
Last Record		QT 1A (°F)	QT 2A (°F)	QT 3A (°F)	QT 4A (°F)	QT 5A (°F)
2024/08/08 01:31:50	25	96.816177	97.844915	92.943861	93.644675	92.696461





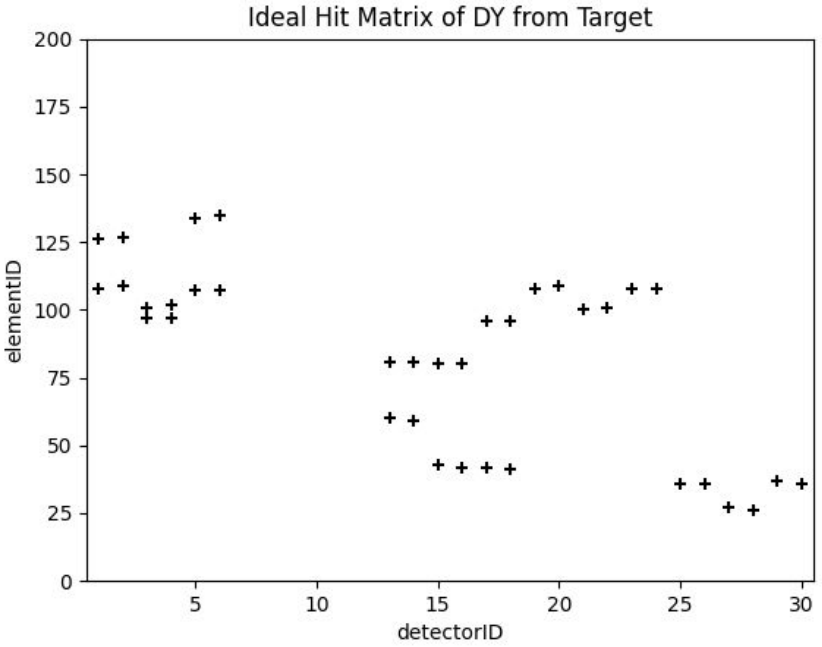
Online monitoring Plan

- Focus on refining models.
- Monitor IVC and Cooling systems.
- Include Track Display into current Hit Display.
- Monitor muons coming from target.
- Plot Accumulated Asymmetries and Polarization.
- Monitor false asymmetries.
- Create a robust Alarm system.



Effort: Quality Metric

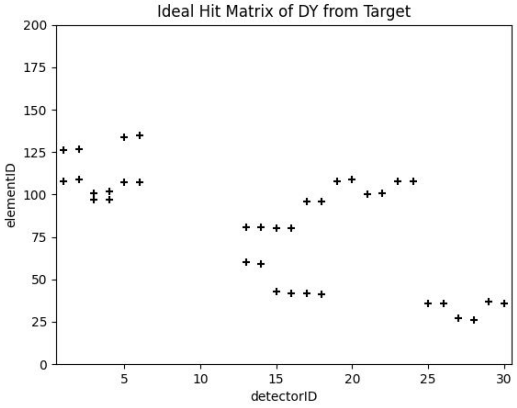
- Define the limits of a reconstructable track.
- Aims to improve the number of tracks kept during Q-Tracker Reconstruction.
- How many hits can we miss to still be a reconstructable track?



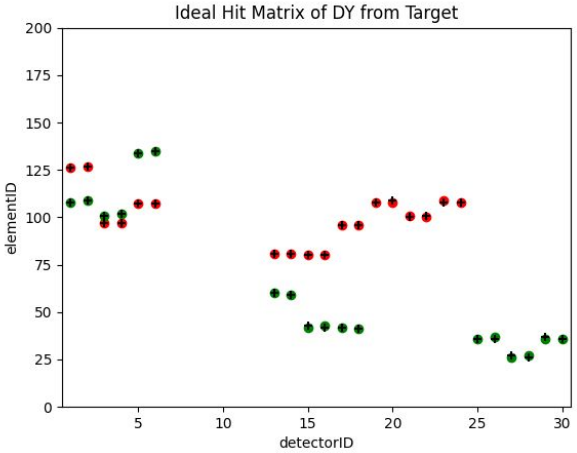
Quality Metric: Plan

- Need to generate a large set of MC from a wide range of vertices.
- Filter those events to contain “ideal” tracks.
  - The event needs 34 hits for each tracks.
  - The event needs 2 tracks or less per event.
- Organize those events into hit matrices to act as features in a DNN.
- DNN produce hit arrays that contain element ID from positive and negative tracks.
- 2nd DNN takes in those hit arrays and produce four momentum.
- Comparison between true values and model values.

Quality Metric Process



DNN



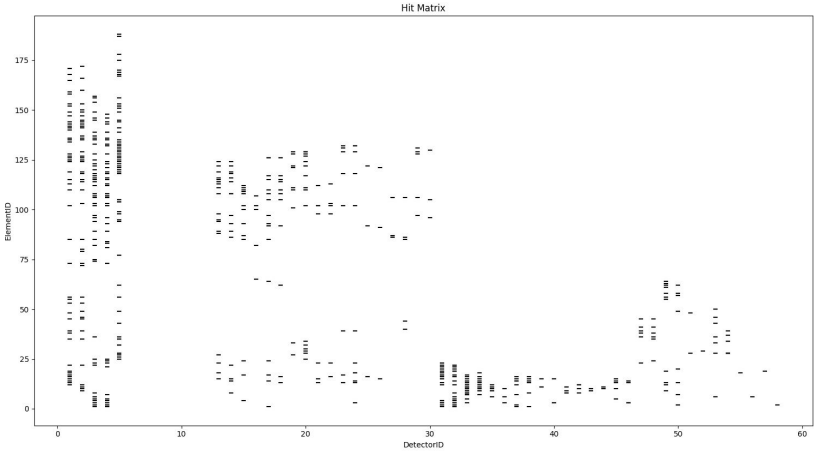
DNN

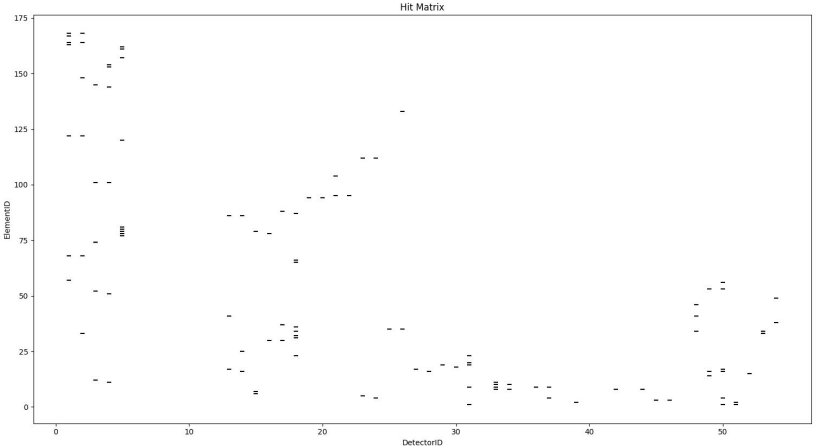
P_Truth - P_Reco

- Once successful reconstruction has been completed. Remove or add elementID's.
- Question: How partial or noisy can a track be to obtain accurate reconstruction?

Effort: Training MC

- Culurate background based on event studies. Origin of every hit is known and is produced via MC.
- Mimic track behaviour:
  - How much of the spectrometer does the track go through?
- Mimic detector behaviour:
  - Clustering
  - Electronic noise
  - Edge Hits of neighboring chamber cells



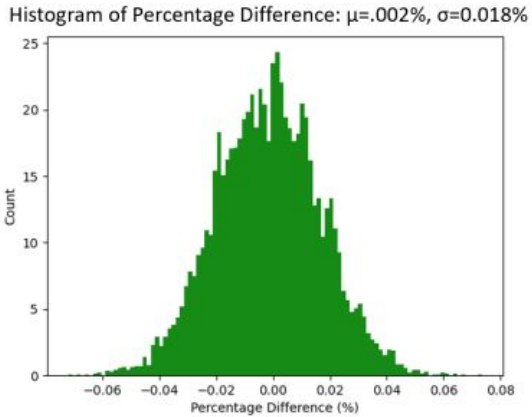


Training with MC Hit Matrices: Plan

- Do a full study of events that came out of production/commissioning runs.
- Generate muons with MC from a wide range of vertices.
- Organize hit information keeping track of:
  - Vertex
  - Truth values of four momentum
  - Hit position and drift distance
- Create simulated background events by sampling from events allowing the track to go through a percentage of the spectrometer.
  - Do this based on occupancy studies.
  - Apply noise around each track.
  - Keep track of each vertex.
- Inject complete dimu track.

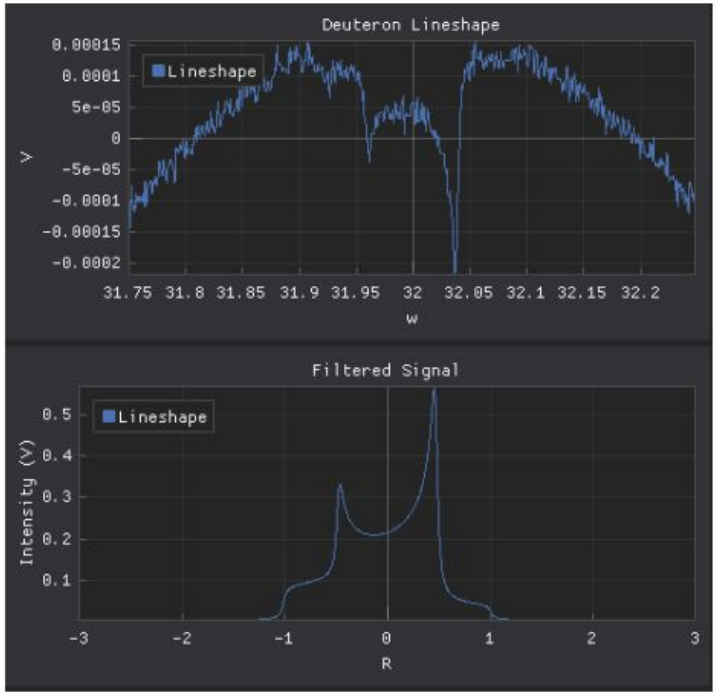
Incorporate polarization analysis

- Prediction of polarization from DNN.
- Reconstruction of lineshape
- See Nuwans talk



$$P_{Diff} = P_{True} - P_{Predicted}$$

$$P = \frac{r^2 - 1}{r^2 + 1 + r}$$



Prediction by NN model for 10K sample events between 0% – 100%.
Accuracy: 99.8% Precision 98.2%

Summary

- A effort is ongoing at UVA to provide a robust online monitoring system.
- Online monitoring is needed to catch issues as they occur and give confidence in the events being produced.
- A Gui has been established but needs refinement.
- A Hit Display has been established but need to include reconstructed tracks.
- A fast reconstruction software has been produced called Q-Tracker.
- There are 2 efforts ongoing to improve the performance further of Q-Tracker.
- An effort is ongoing to use AI to provide real time polarization analysis.

Thank you

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