AI for Experimental Controls

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Project Objectives

Consistent CDC Response

Maintain consistent detector response in reaction to changing environmental and experimental variables

Stabilize gain to within 5% over a 2 week period with minimal degradation of the timing resolution

Data Acquisition→ Analysis

Reduce time it takes from data acquisition to analysis

Reduce the number of iterations required to calibrate the CDC or the number of runs that must be calibrated

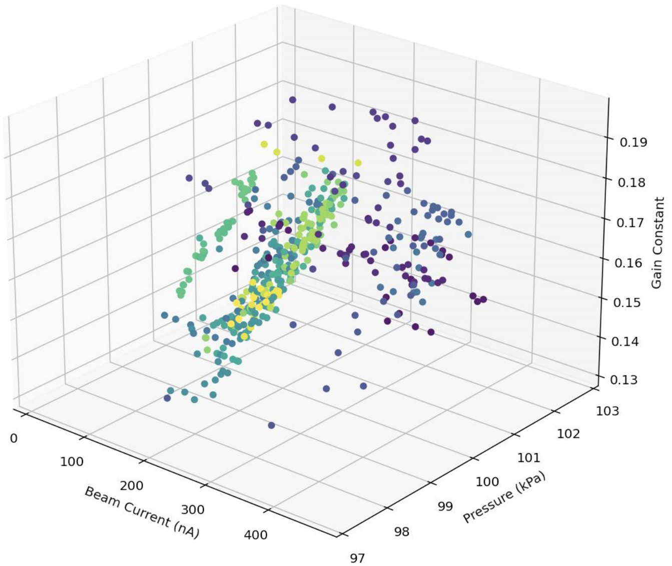
Apply to other detectors

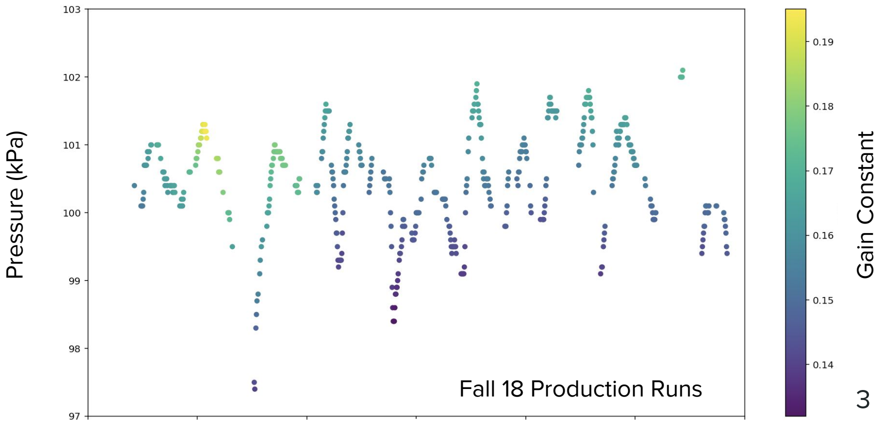
Apply same approach to CLAS12 drift chambers in Hall B

Develop open source software that can be easily applied to different detector systems

Consistent CDC Response

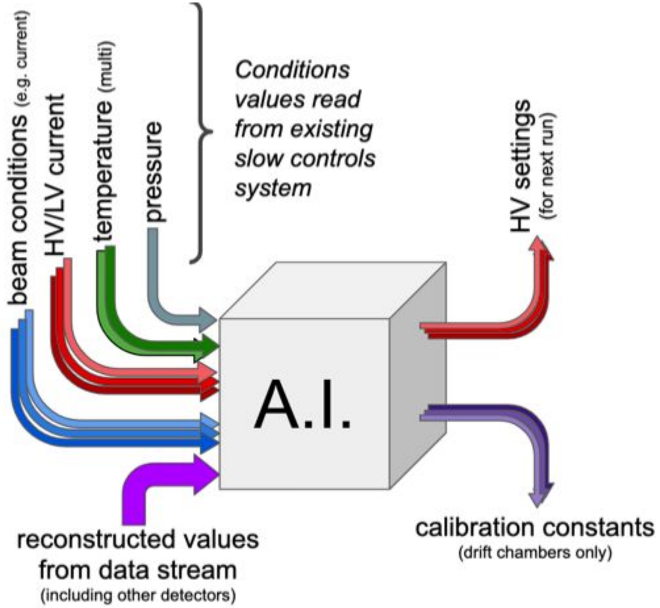
- Why is the gain important?
  - Chamber gain determines the size of the avalanche ➜ height of the pulse recorded
    - dE/dx ➜ particle ID
    - drift time ➜ particle momentum
- Factors that affect gain constant:
  - Environmental variables: Pressure, temperature
  - Experiment variables: beam current, anode voltage, pre-amp currents, event rate
- Use AI to determine relationships between gain constant and other more complicated variables
  - Currents drawn by high voltage boards





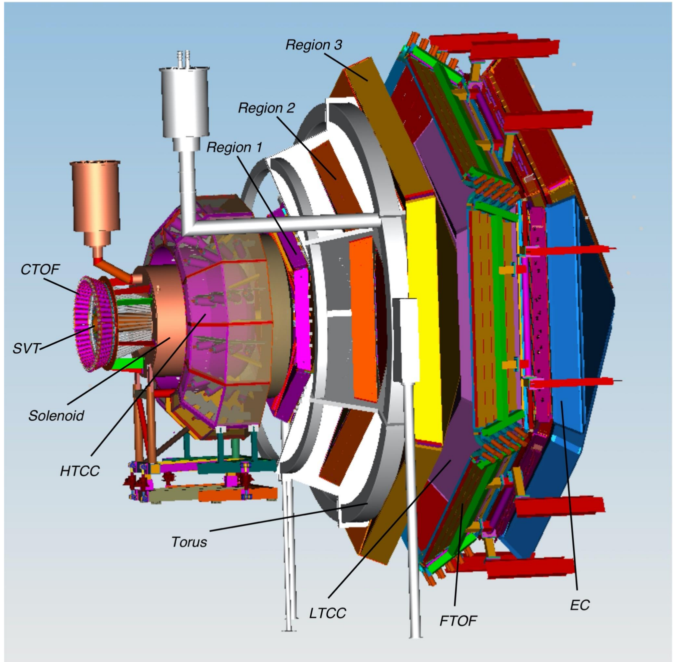
Speeding up Data Acquisition→Analysis

- Gain Calibration
    - Gain calibration constant(s) for individual wires and overall chamber obtained via Landau fit to amplitude-pedestal
- Time-to-Distance calibration constants obtained via functional fit to data
    - Fall 18 data set used 18 parameters
- Overall detector calibration undergoes multiple rounds:
    - 1st: detectors calibrated individually
    - Subsequent: detectors share information to update timing offsets, vertex track positions, etc



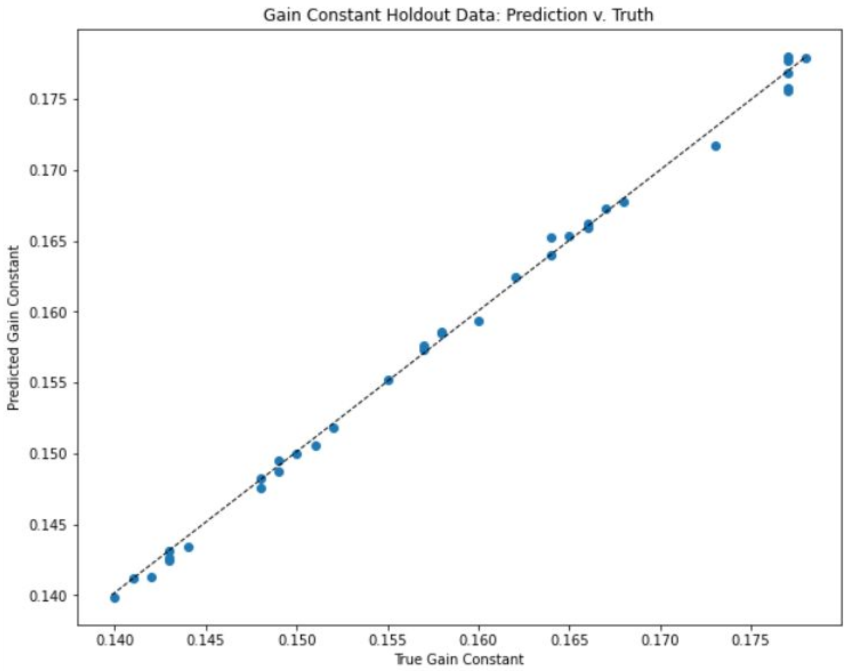
Application to Hall B Drift Chamber System

- Write open-source software that is easily modified for different detector systems
- Hall B Drift Chambers have similar procedure for calibration
  - Different time-to-distance function compared to Hall D
- Process to extract gain constants and other relevant inputs has been started



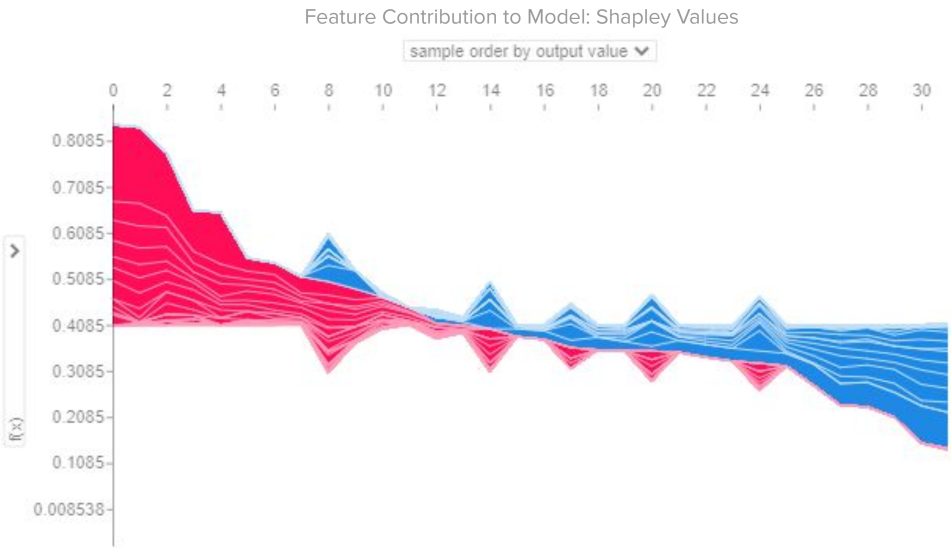
Development of AI model

- Can we reproduce known gain and TToD constants?
  - Use aggregate data set with environmental input, beam conditions, experimental inputs
  - Aggregate data: min, mean, max, quartile values, standard deviation, range, and CV
- Simple sequential neural network used to predict gain constants
- First results: **Gain Constant**
  - Able to predict gain constants to within 1% using 39 features engineered from seven aggregate variables: netamp, amplitude, theta, drift time, count of run events, beam current, and pressure.
  - MAE on Holdout data: 0.0008, a 0.5% error from average gain constant in holdout data.



Ongoing work

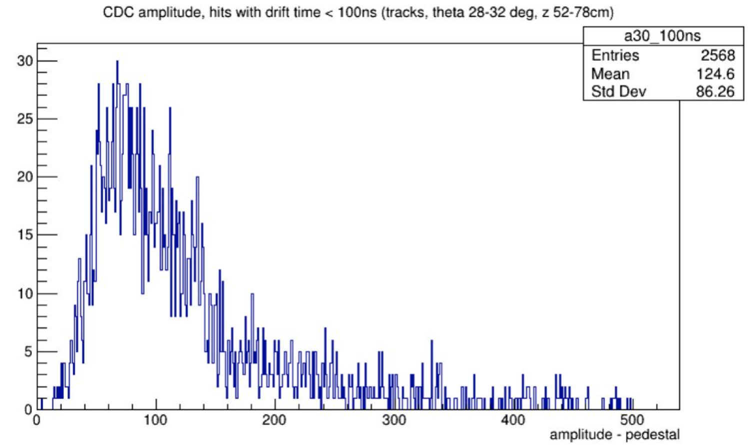
- TToD Constant
- Evaluating feature importance
- Evaluating feature range
    - Initial data is for Fall 2018. Wider variety of conditions needed.
- Developing prediction confidence based on beam conditions, environment conditions and event counts used.
- Testing model predictions with “raw” data: i.e. tracked and untracked hits.
- Investigating models using non-aggregate variables.

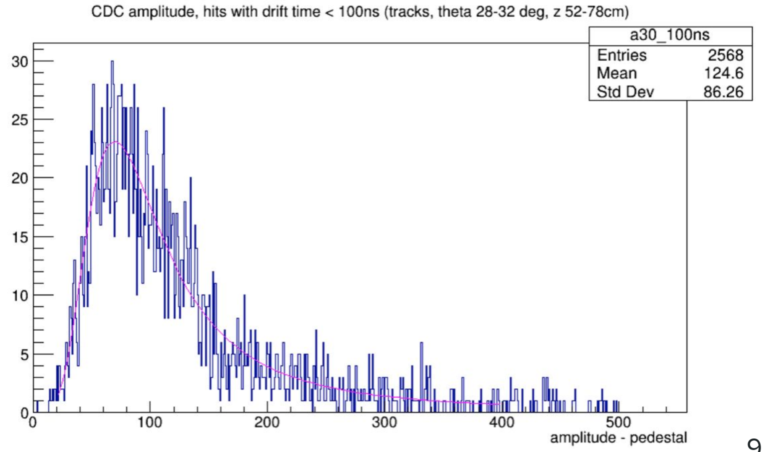


Back up slides

Wire/Chamber Gain Calibrations

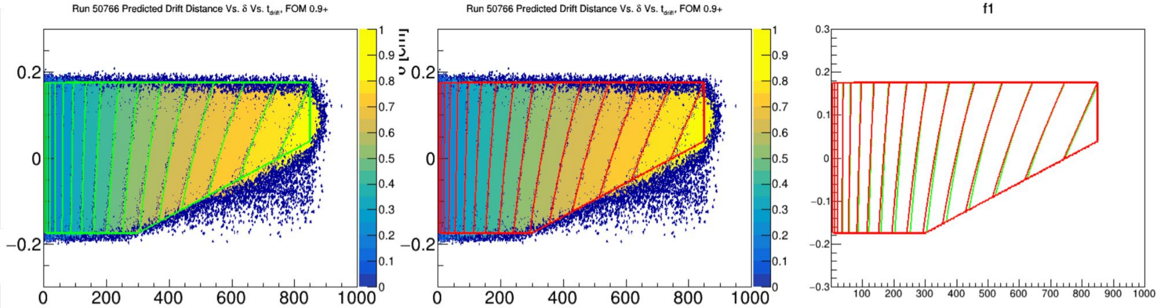
- Performed close to start of each run period
- Individual wire and overall chamber gain is calculated
- 3522 individual wires
- MPV from Landau fit is scaled by idealMPV and ASCALE
  - Ideal MPV is for hits in 0-100 ns with theta 28-32 deg, z 52-78 cm, low pressure run 11621, adjusted to put dE/dx (1.5GeV) at 2.02 keV/cm to match geant
  - ASCALE for tracked ztheta hits from 11621

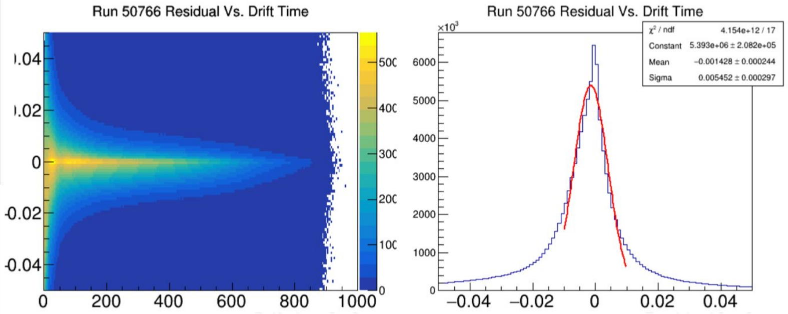




Time-to-Distance Calibrations

- Obtain calibration constants from Time-to-Distance function
- Calibration constants are produced for each run
  - 18 parameters for Fall 2018 run period





$$d(t) = f_\delta \left(\frac{d_0(t)}{f_0} P + 1 - P \right)$$

$$f_\delta = a\sqrt{t} + bt + ct^3$$

$$f_0 = a_1\sqrt{t} + b_1 t + c_1 t^3$$

- If $\delta(z, \phi_{LOCA}) \geq 0$,

$$a = a_1 + a_2|\delta|$$
$$b = b_1 + b_2|\delta|$$
$$c = c_1 + c_2|\delta| + c_3\delta^2$$

If $\delta(z, \phi_{LOCA}) \leq 0$, Using ttodfit.C:

a_2, b_2, c_2 are negative, a_3 and b_3 are not used

Parameters are obtained from fit to data using Garfield generated tables for ideal straws