AI for Experimental Controls at Jefferson Lab

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AI4EIC

Thursday, September 2, 2021

Jefferson Lab

EPSCI Experimental Physics Software and Computing Infrastructure

Carnegie Mellon University

U.S. Department of Energy | Office of Science

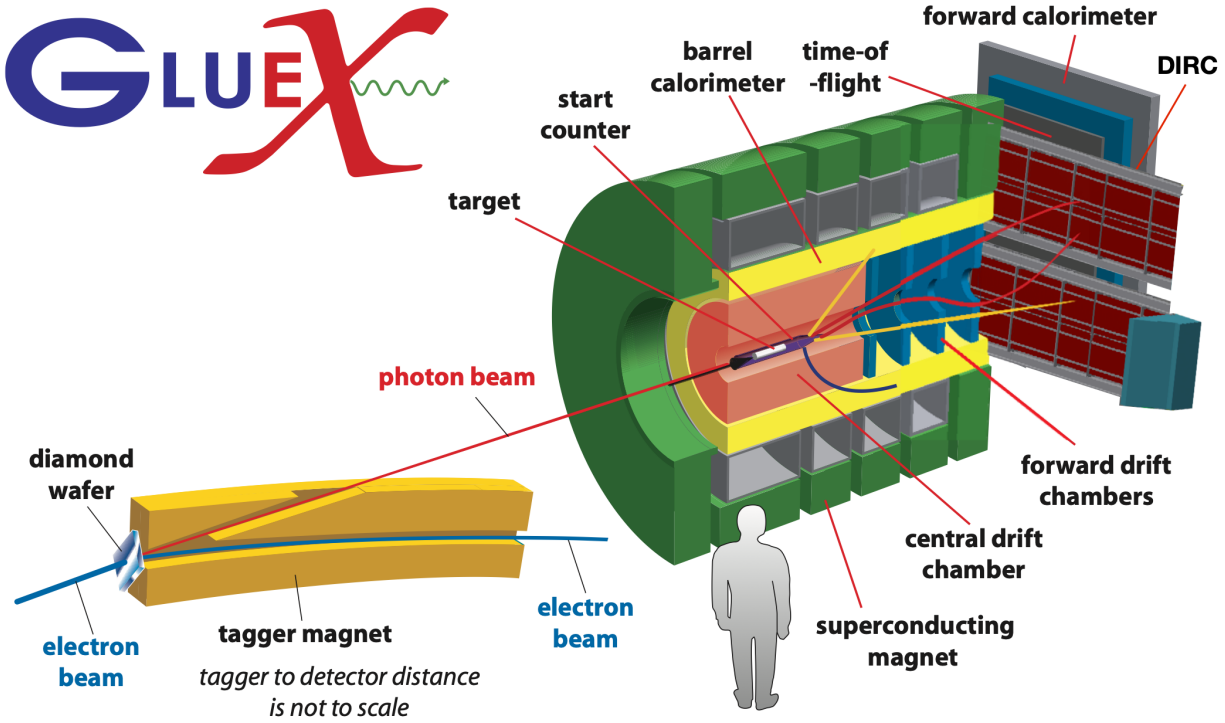
JSA

Gluonic Excitations Experiment in Hall D

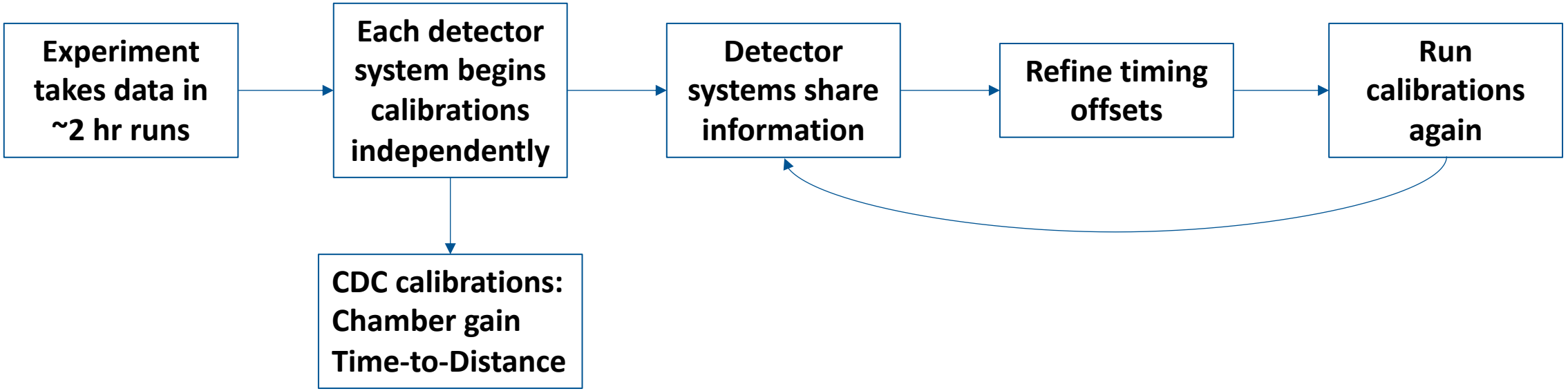
- Designed to reconstruct exclusive final states from photoproduction reactions on proton targets

$$\vec{\gamma}p \rightarrow Xp$$

- Primary objective is to search for and measure exotic mesons



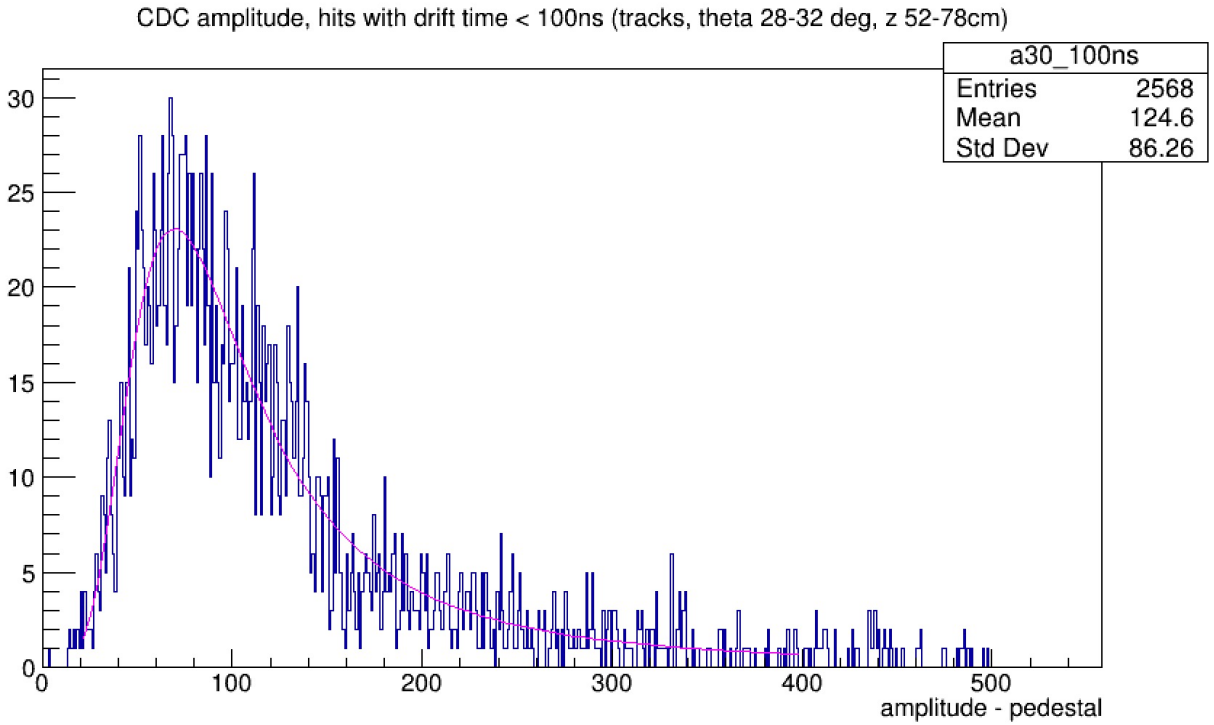
Calibrating Detectors is Time Consuming



Time scale for calibrations is on the order of months

Chamber gain calibration

- Calibration uses one raw data file (19GB) per run
  - ~450 production runs in 2018
  - ~950 production runs in 2020
- Gain Correction Factors are calculated based on most probable value of Landau fit to CDC pulse height



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Time To Distance Calibration

- Current calibration method produces 6 unique calibration constants from fit to data

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

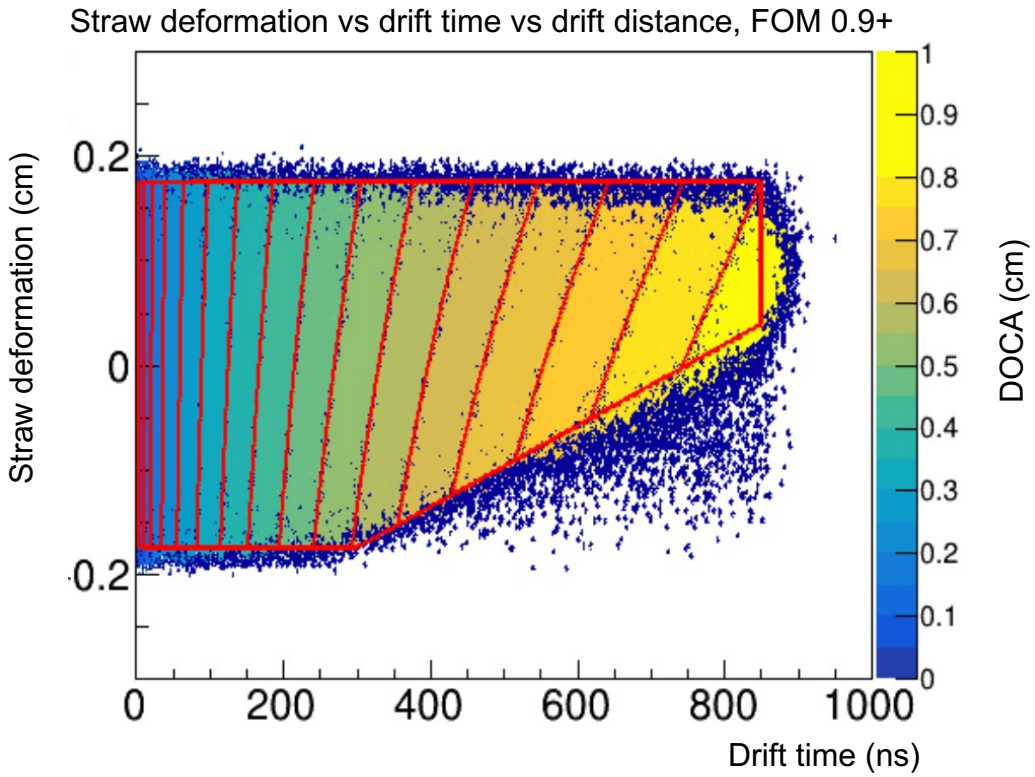
$$f_\delta = a\sqrt{t} + bt + ct^3$$

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

$$a = a_1 + a_2 |\delta|$$

$$b = b_1 + b_2 |\delta|$$

$$c = c_1 + c_2 |\delta|$$



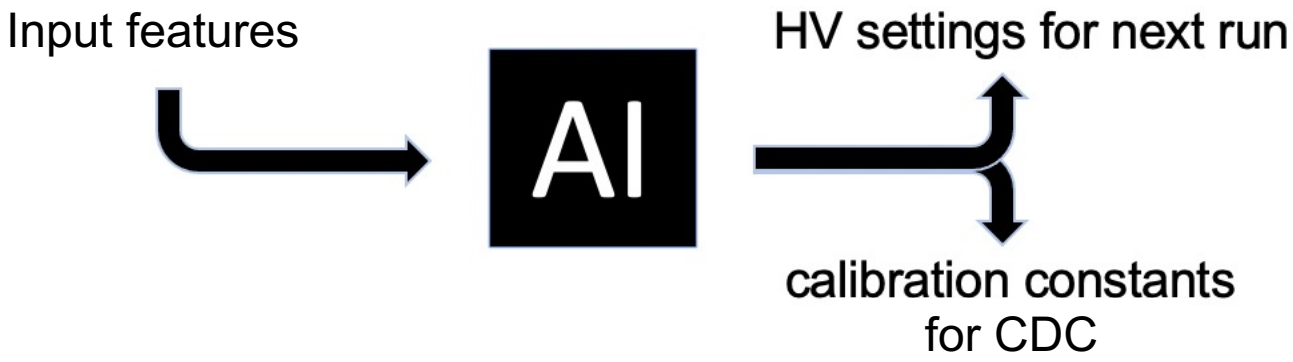
Model development for ttod calibration constants is in very early stages

Can we utilize AI to perform near real time calibrations?

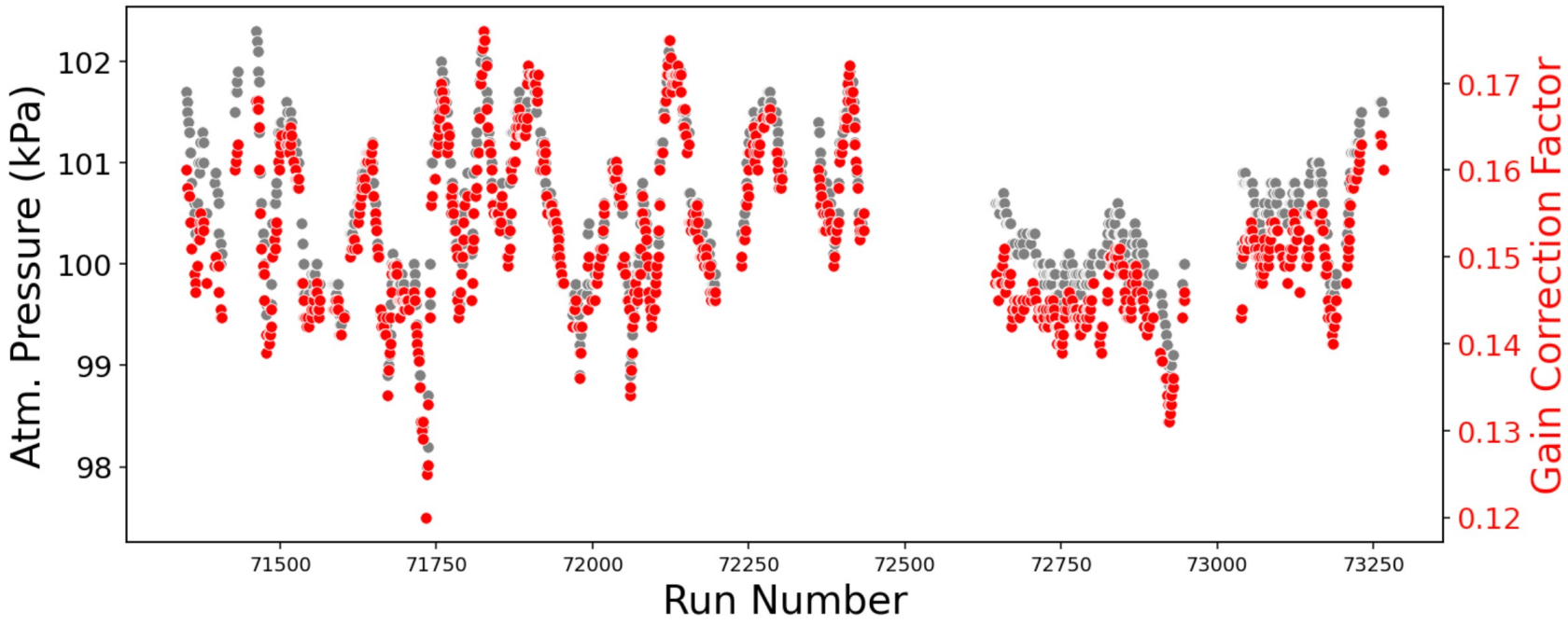
Maintain consistent detector response to changing conditions via *recommending* HV settings for next run

Reduce time needed for calibrations

Make it adaptable to other detector systems

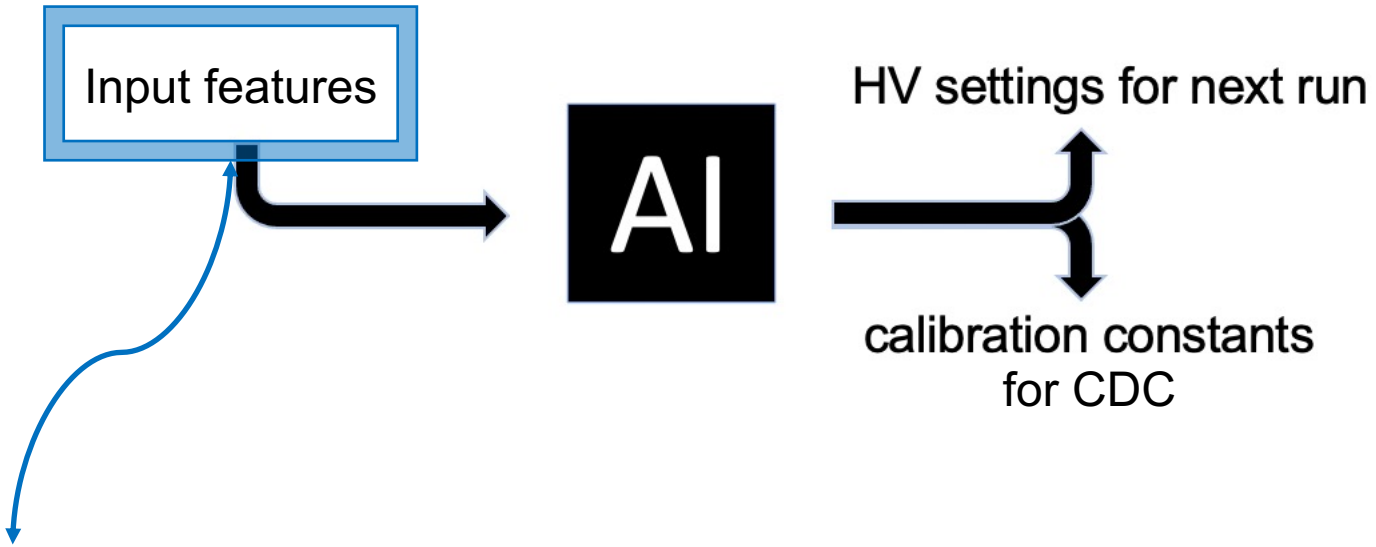


GCF fluctuations with pressure



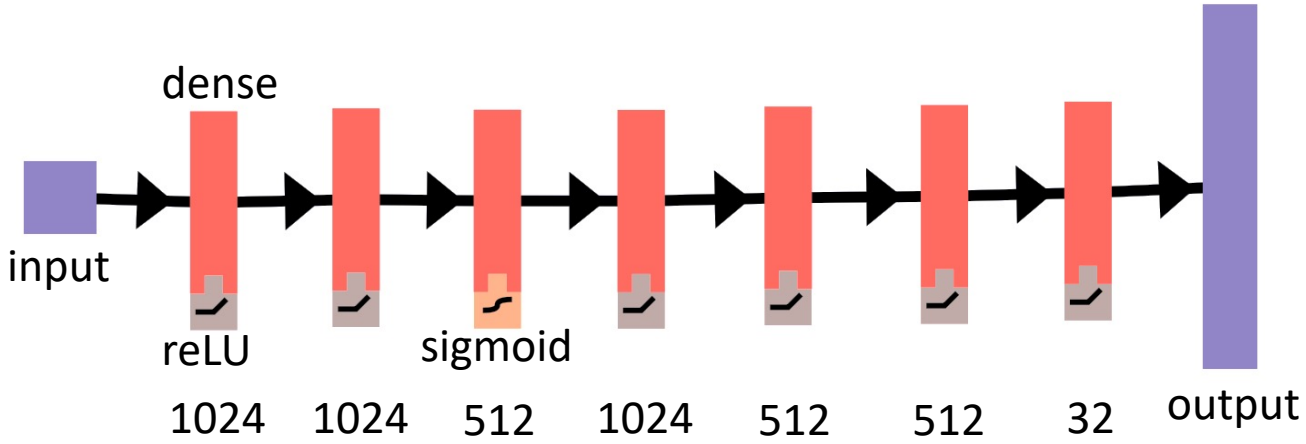
- GCFs are dependent on atmospheric pressure, temperature, current drawn by the high voltage boards, beam intensity, etc

Input features



- EPICS: Experimental Physics and Industrial Controls System
- Beam current, atmospheric pressure, thermocouple temperatures, pair spectrometer rates, high voltage board current, existing calibration constants
- Currently take data from one of multiple raw data files per *production* run

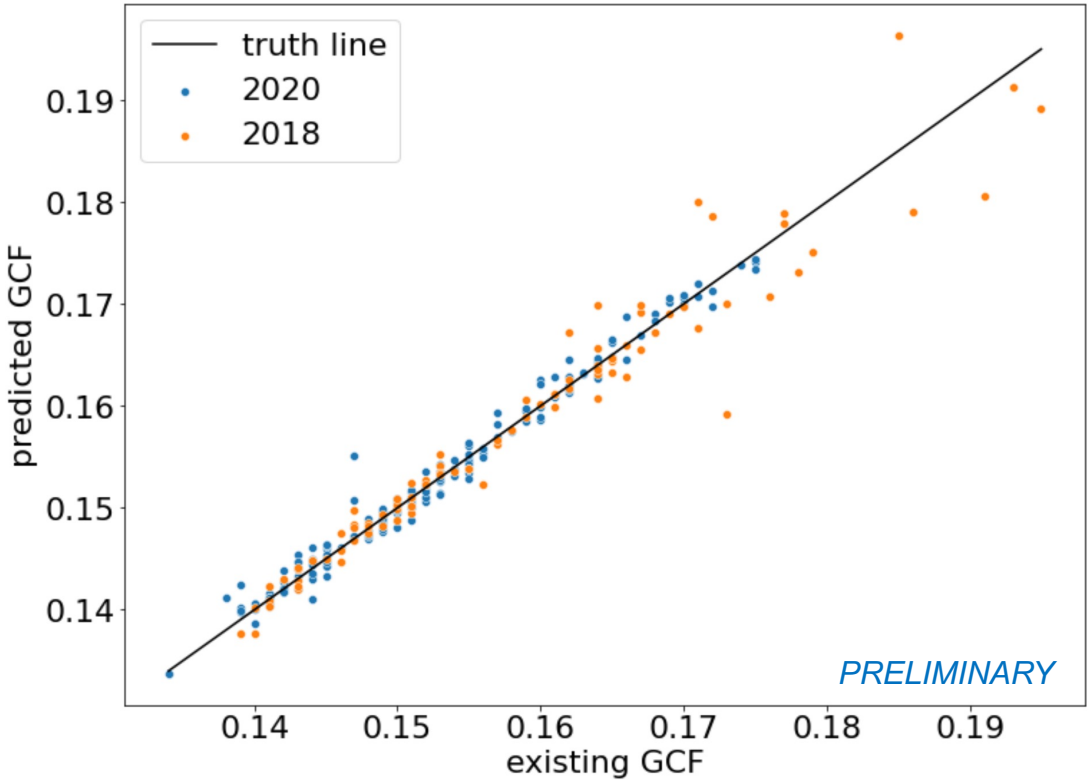
Gain calibration model architecture

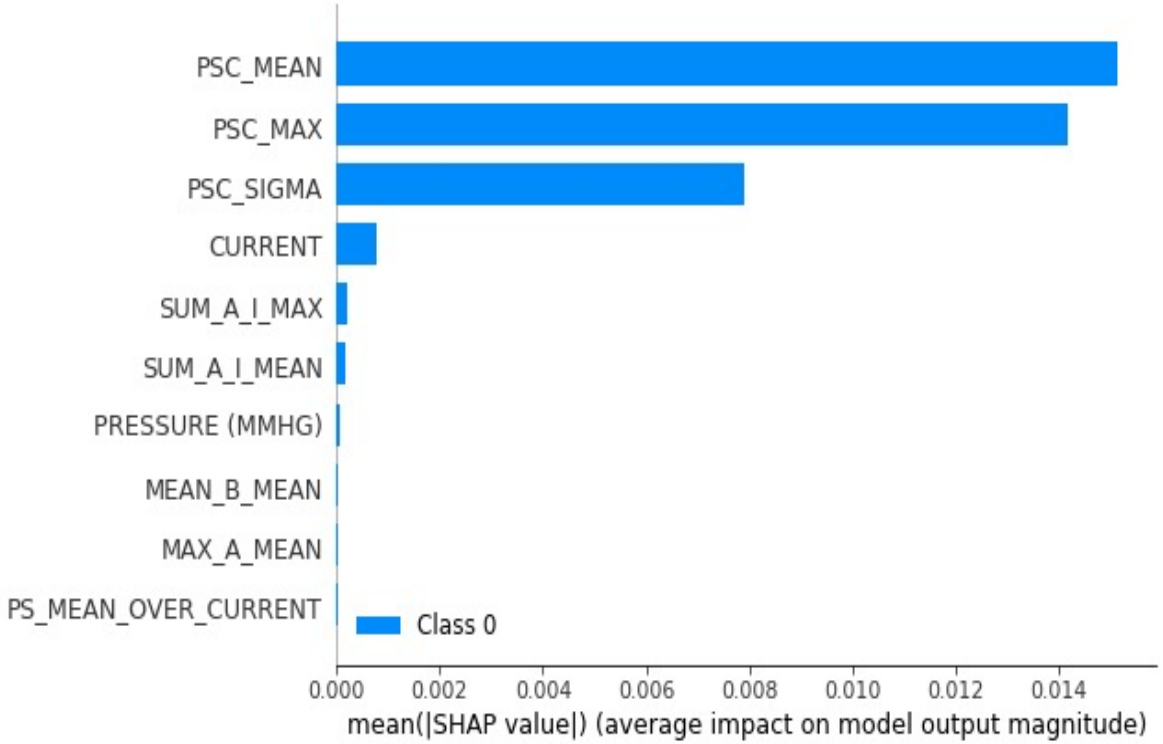


Sequential Neural Network

- 122 total features
- Each feature is min-max scaled
- Loss function: % error between predicted GCF and existing GCF
- Optimizer: Adam, learning rate: 0.0002, with decrease learning rate on plateau used during training
- Early stopping if learning stopped for 50 epochs

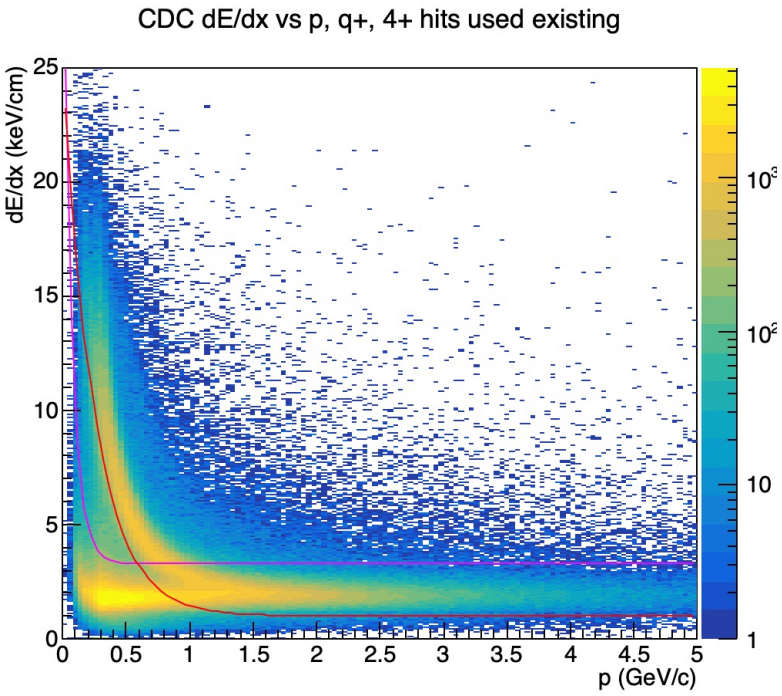
Model predictions and feature evaluation

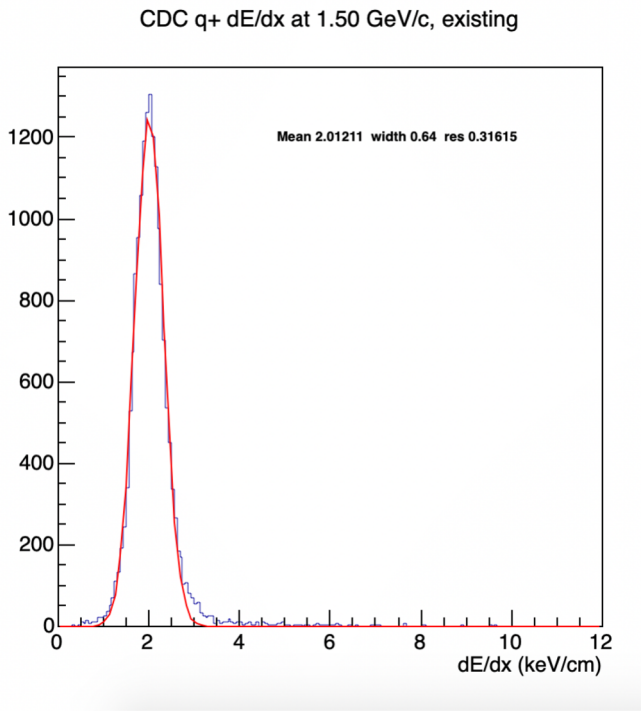


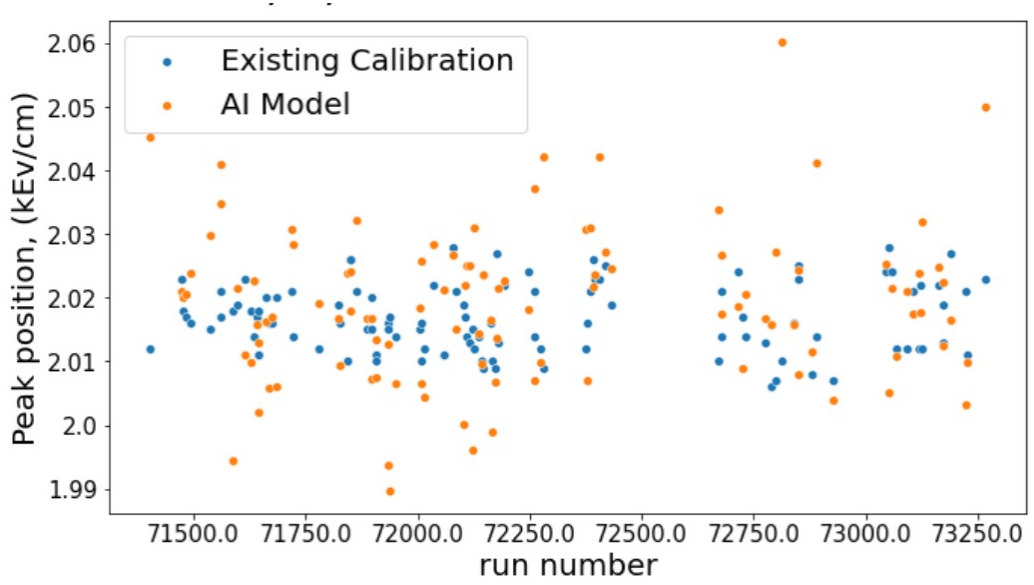


Very preliminary physics validation studies

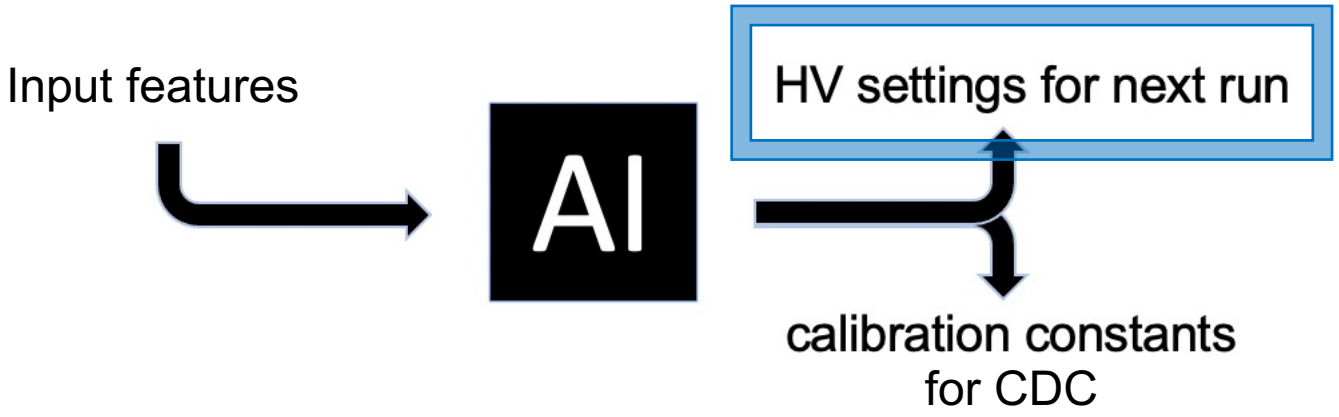
- Existing calibration constants might not be the best truth to compare to
- Evaluate CDC resolution using predicted constants







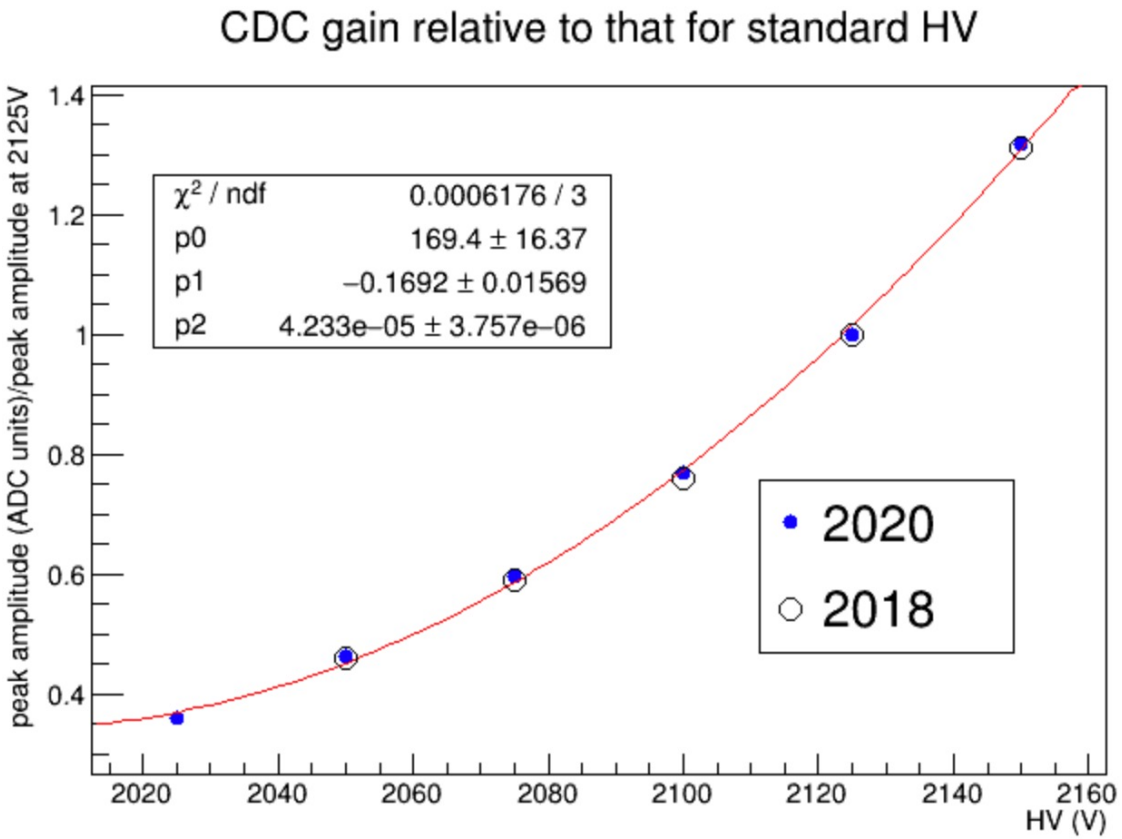
Altered HV running conditions



- HV settings for the next run may not be the same as the standard operating voltage!
- We don’t want to recommend a HV setting that could trip the CDC or cause other problems

Adjusting CDC operating voltage

- Current CDC operating voltage is 2125 V
  - This does not really change
  - Limited data obtained from HV scans
- For high and low gain scenarios, what is the associated high voltage?



*figures from Naomi Jarvis, CMU

Estimating new HV running values

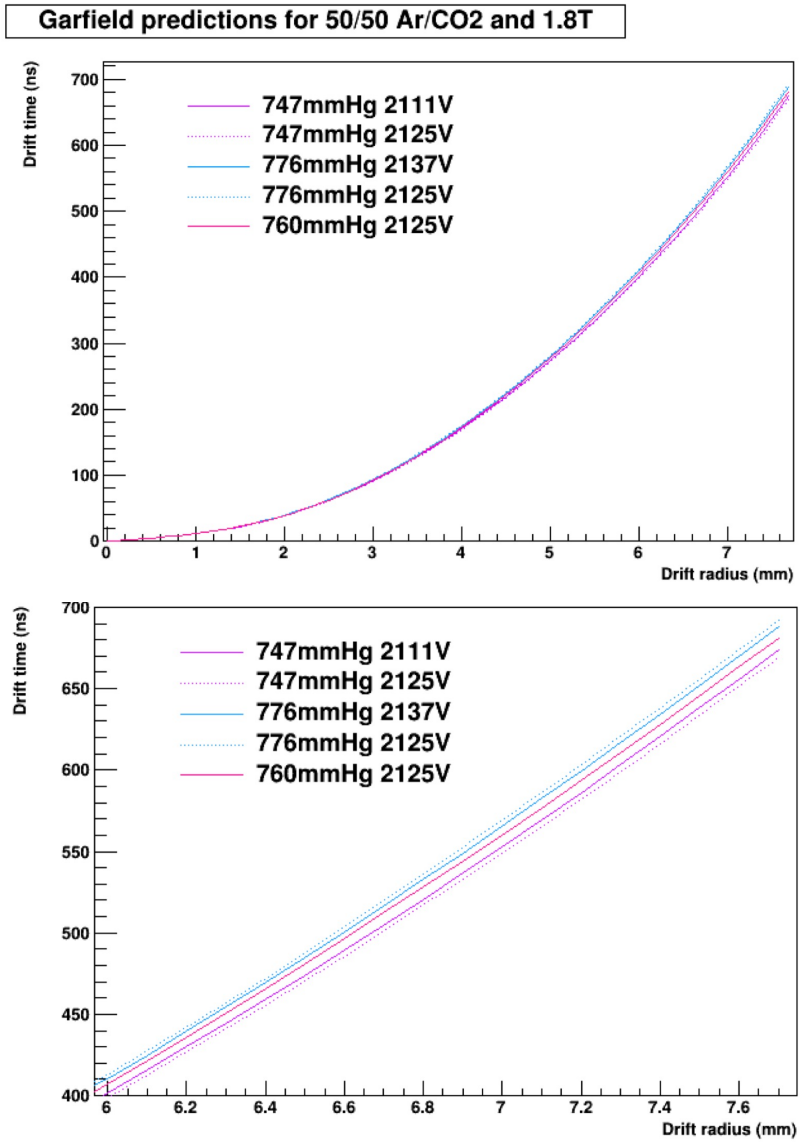
- Obtain new HV values associated with various GCFs at high/low pressure

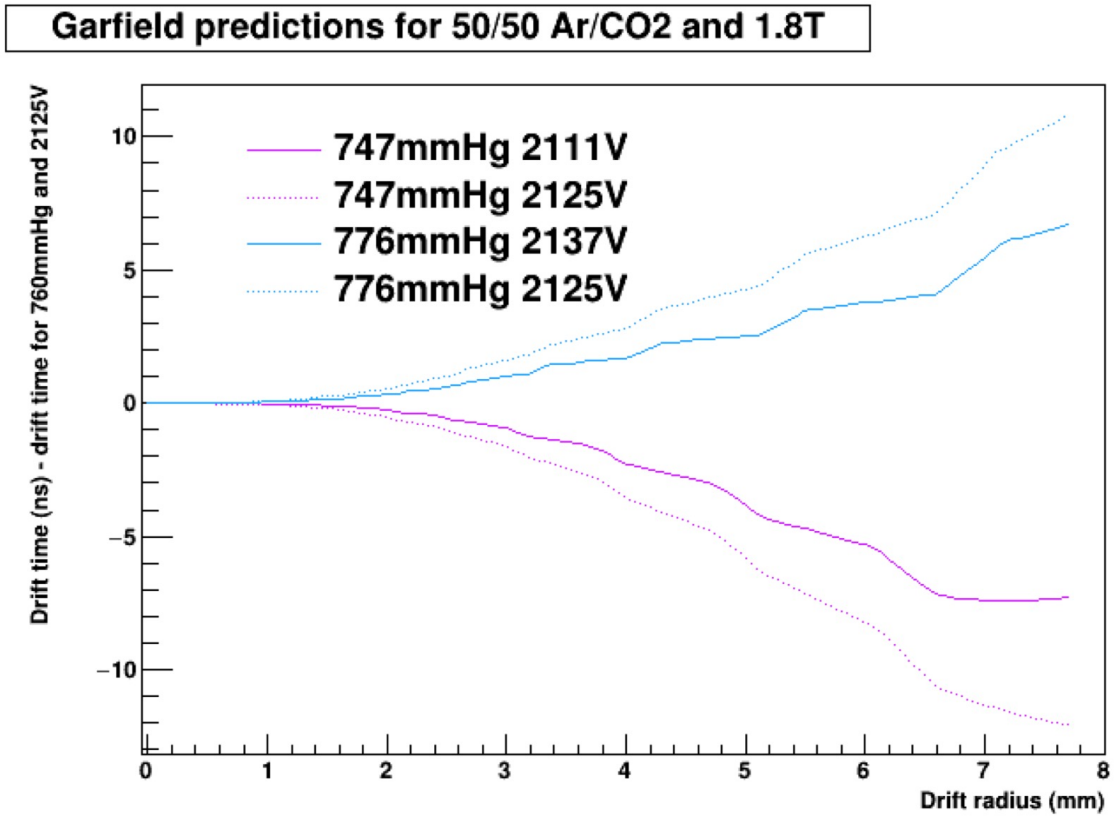
Run	GCF	Pressure from EPICS (kPa)	Calibrated Pressure (mmHg)	GCF/GCF at std Pressure	New HV
51687	0.173	102.067	776	1.146	2137
51570	0.160	101.042	768	1.060	2129
51762	**0.151**	**100.016**	**760**	**1.000**	**2125**
51287	0.139	99.1262	753	0.921	2116
51160	0.132	98.4129	747	0.874	2111

New HV from fit to relative GCF as function of HV. Runs selected reflect the highest and lowest values of pressure seen during the 2018 run period.

*figures from Naomi Jarvis, CMU

Drift times with altered high voltage





*figures from Naomi Jarvis, CMU
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Recap + Ongoing work

Recap:

- Predict existing gain calibration constants with changing experimental conditions (2018 vs 2020 data)
- Established boundary for operating voltage of CDC based on previous run periods

Ongoing work:

- Evaluating CDC resolution with predicted calibration constants
- Time to Distance model development in progress
- Incorporating physics information into model
- Application to CLAS12 Drift Chambers located in Hall B

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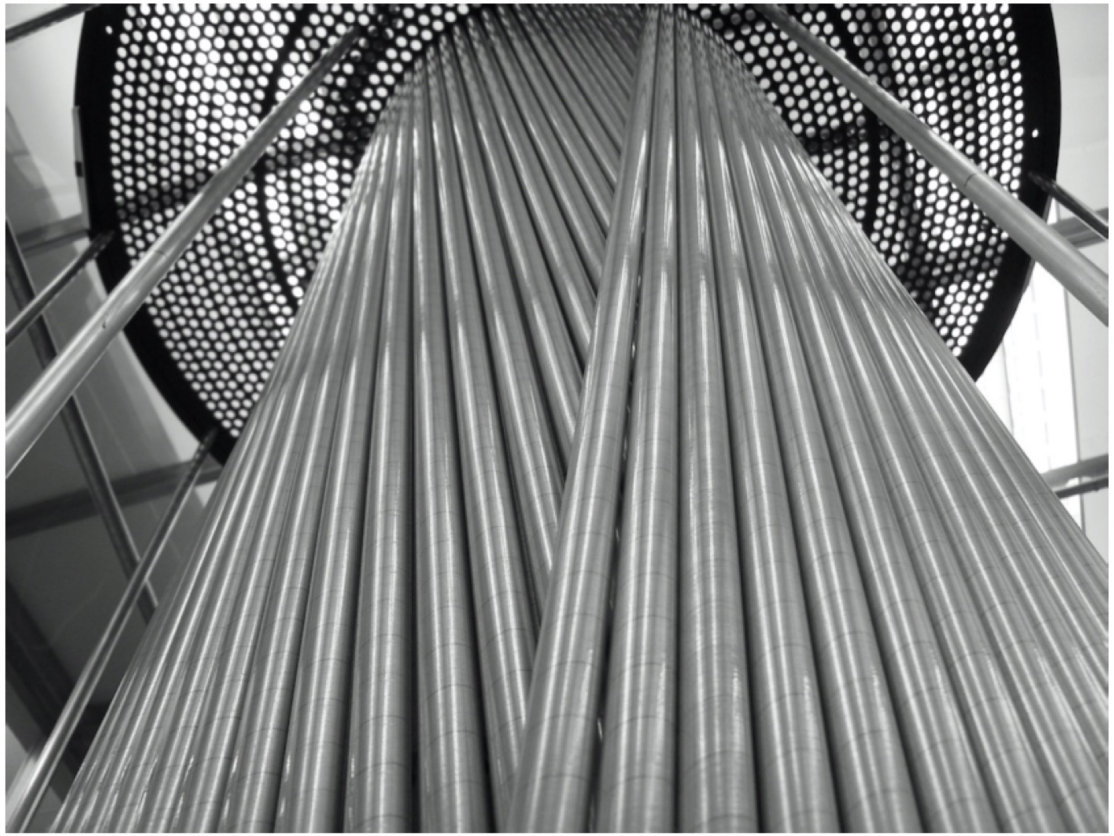
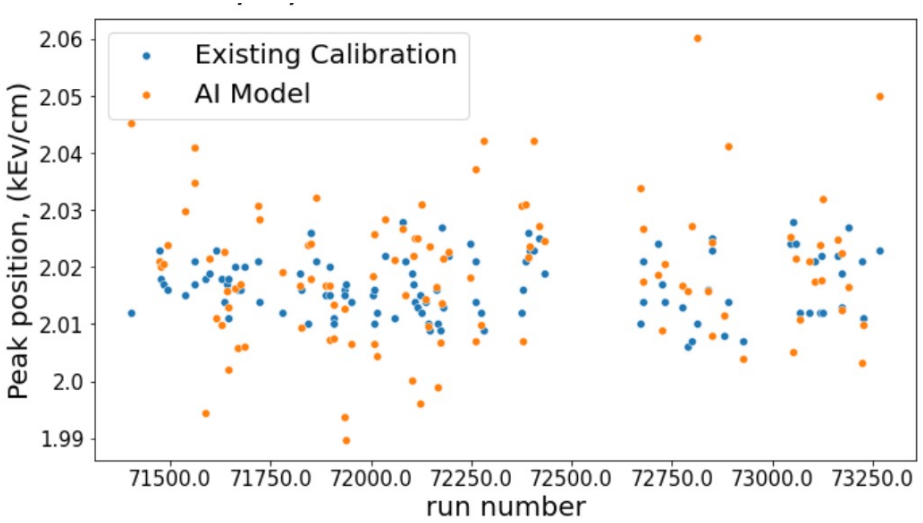
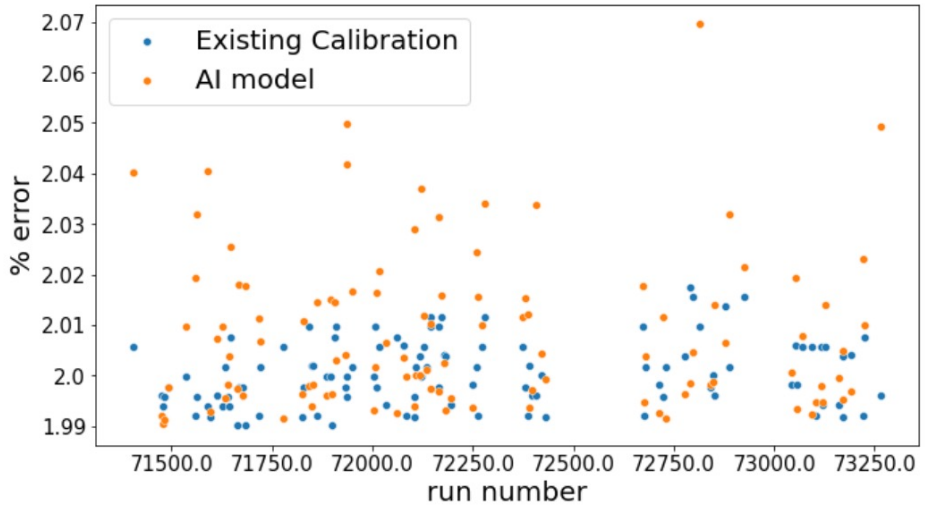
back ups

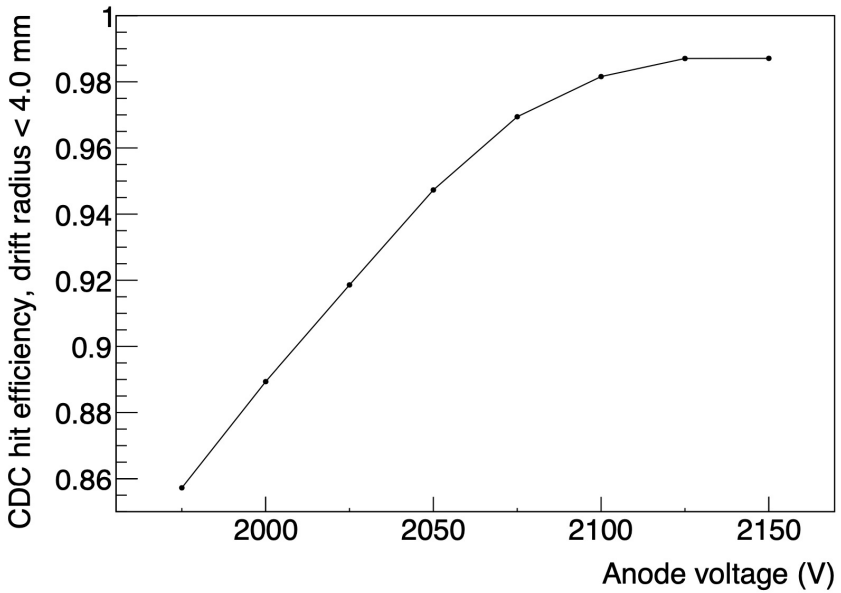
GlueX Central Drift Chamber

- Cylindrical, straw-tube wire chamber
  - 3522 straw tubes arranged in 28 layers: 12 axial and 16 at offset from axial
  - Straws are 1.5 m long with 1.6 cm diameter
  - Gold-plated tungsten wire as the anode
  - 50:50 mix of Ar: flows through straws
- Used to detect and track charged particles with momenta p > 0.25 GeV/c
- Can also be used for PID using dE/dx




Existing Calibration
AI Model
Peak position, (kEv/cm)
2.06
2.05
2.04
2.03
2.02
2.01
2.0
1.99
71500.0
71750.0
72000.0
72250.0
72500.0
72750.0
73000.0
73250.0
run number


Existing Calibration
AI model
% error
2.07
2.06
2.05
2.04
2.03
2.02
2.01
2.0
1.99
71500.0
71750.0
72000.0
72250.0
72500.0
72750.0
73000.0
73250.0
run number


CDC hit efficiency, drift radius < 4.0 mm
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
2000
2050
2100
2150
Anode voltage (V)