Level-3 Trigger for CLAS12 with Artificial Intelligence

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CLAS
CEBAF Large Acceptance Spectrometer
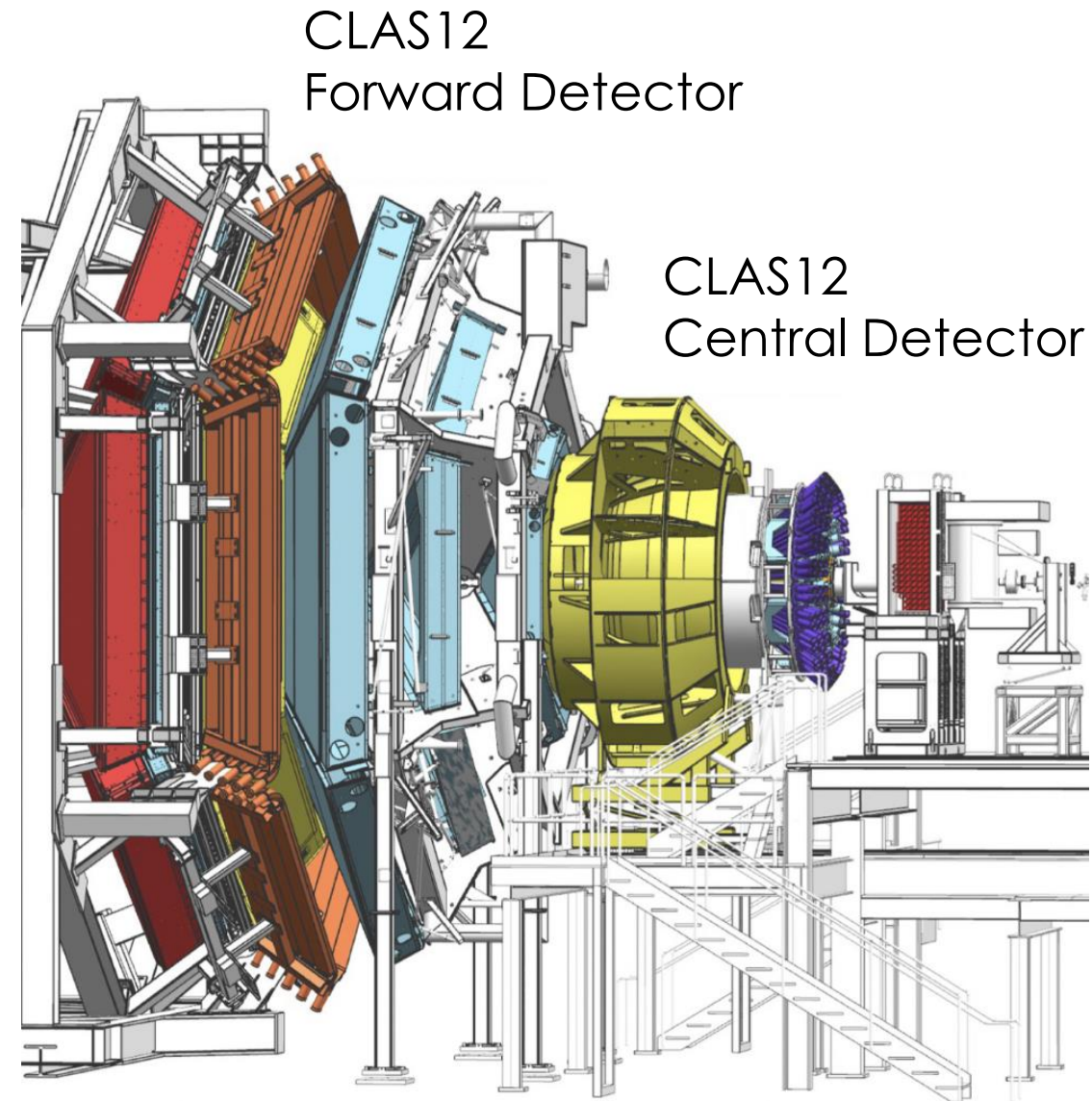
University of Glasgow
VIA VERITAS VITA

JLab

- The Thomas Jefferson National Accelerator Facility (JLab) is located in Newport News, Virginia.

- The Continuous Electron Beam Accelerator Facility (CEBAF) produces a 12 GeV electron beam will beam energies up to 11 GeV delivered to Hall B.

- The CEBAF Large Acceptance Spectrometer (CLAS12) is located in Hall B.

The CLAS12 Detector

- Large acceptance spectrometer with >100k readout channels.

- In 2018, data rates of 500 MB/s with a live time of 95% were achieved: a total of 2 pB of data was accumulated in 2018.

- An electron trigger is used to flag events relevant to the CLAS12 experimental program.

CLAS12
Forward Detector

CLAS12
Central Detector

Electron Trigger Purity and Efficiency

Confusion Matrix	Electron in Sector	No Electron in Sector
Selected by Trigger	True Positive (TP)	False Positive (FP)
Rejected by Trigger	False Negative (FN)	True Negative (TN)

Table 1: The electron trigger confusion matrix.

▸ The conventional CLAS12 level-1 trigger efficiency is above 99.5%.

▸ At higher luminosities, higher occupancy means the level-1 trigger purity decreases.

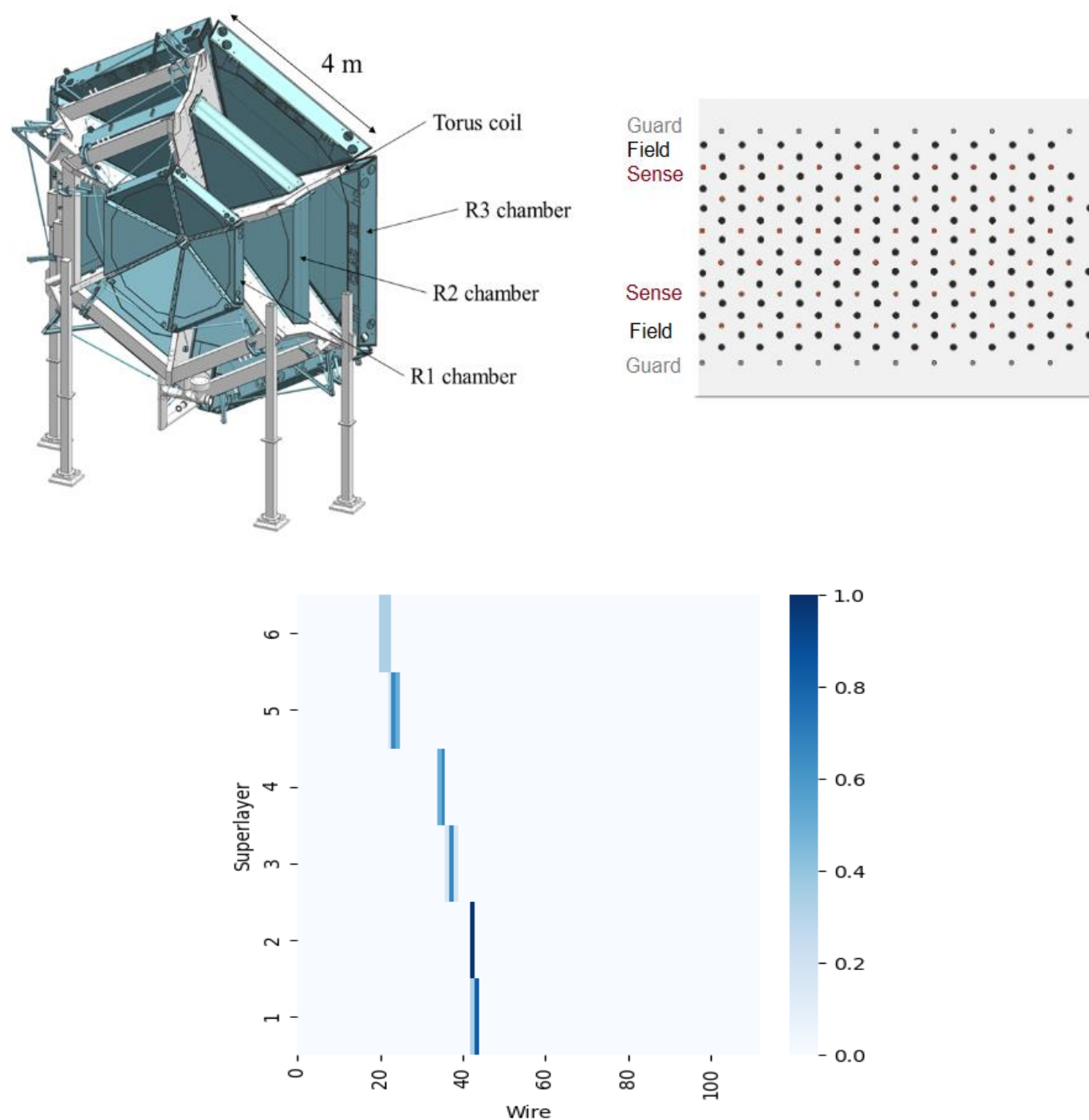▸ The aim of the level-3 trigger is to improve the purity especially at high luminosity.

$$Purity = \frac{TP}{TP + FP}$$

$$Efficiency = \frac{TP}{TP + FN}$$

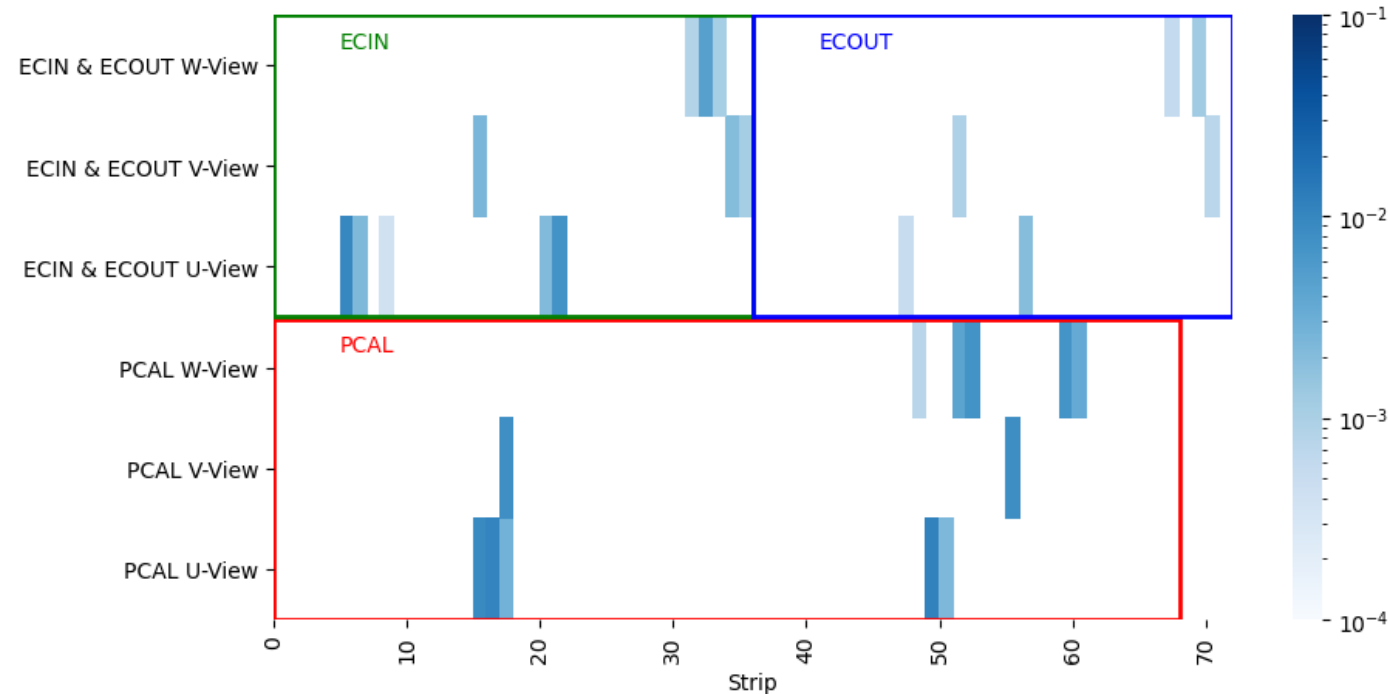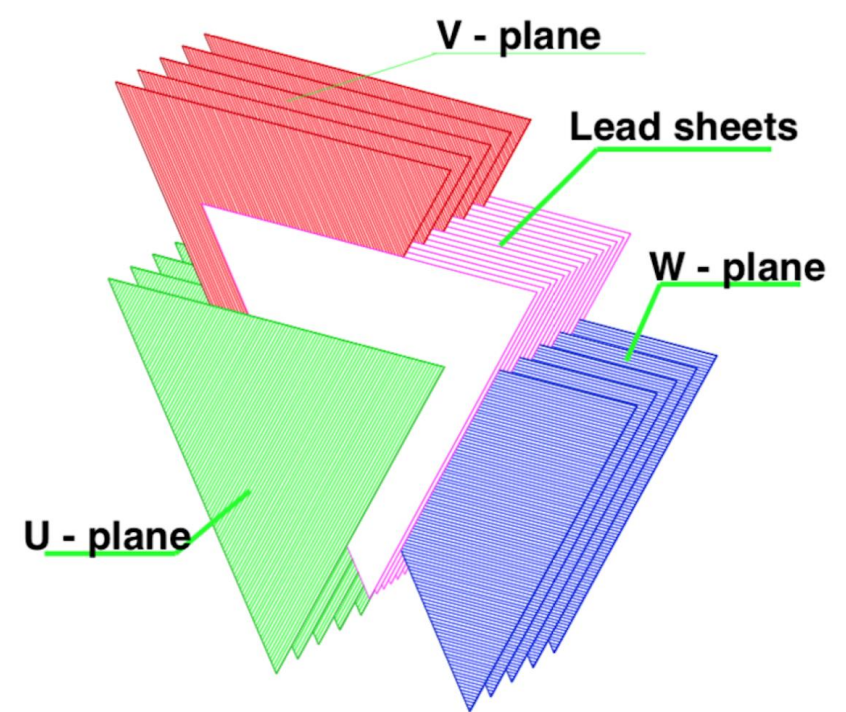$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

Drift Chamber (DC) Tracking

- The DC is composed of 6 superlayers with 6 layers and 112 wires per layer.

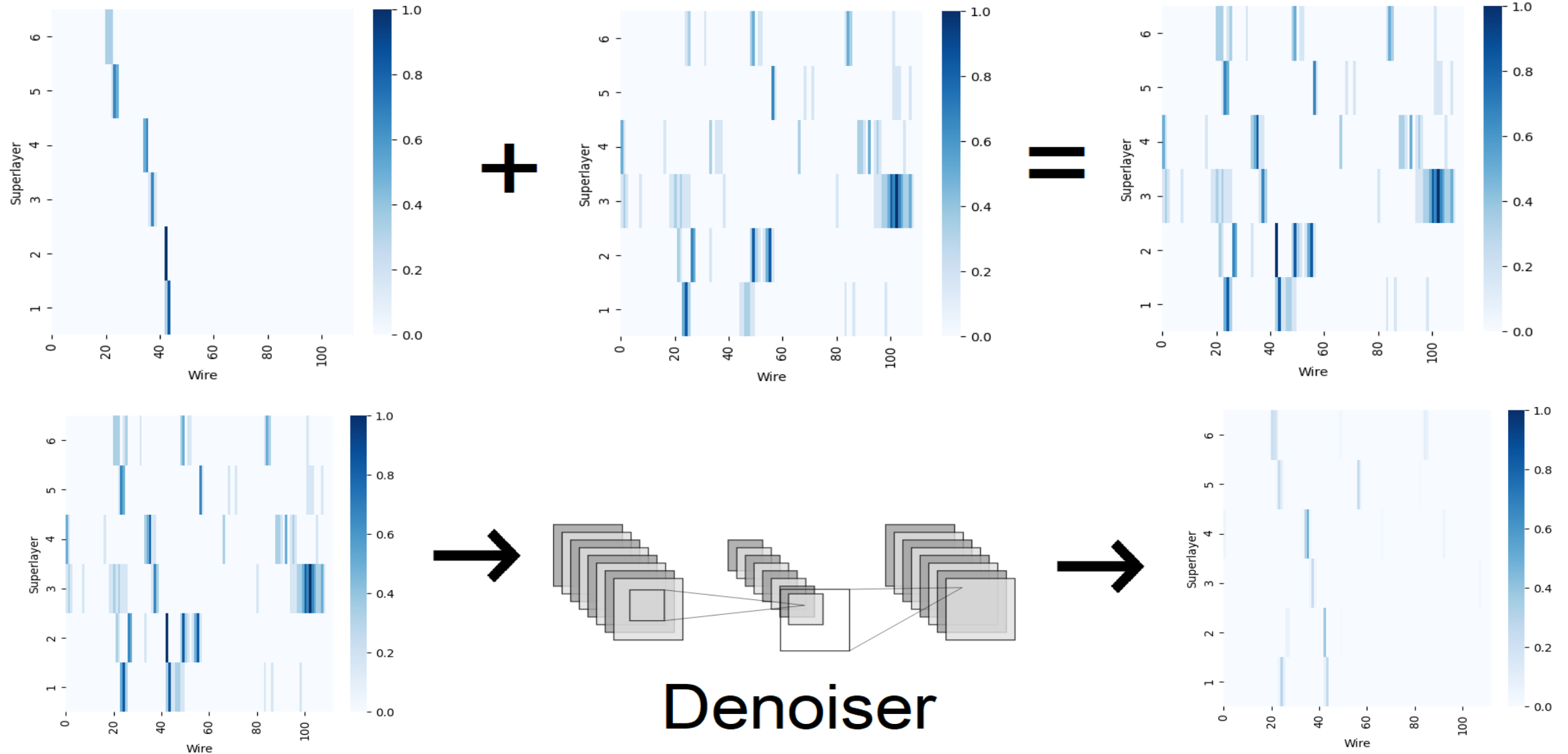- We can have multiple tracks for each element of our training or testing samples.
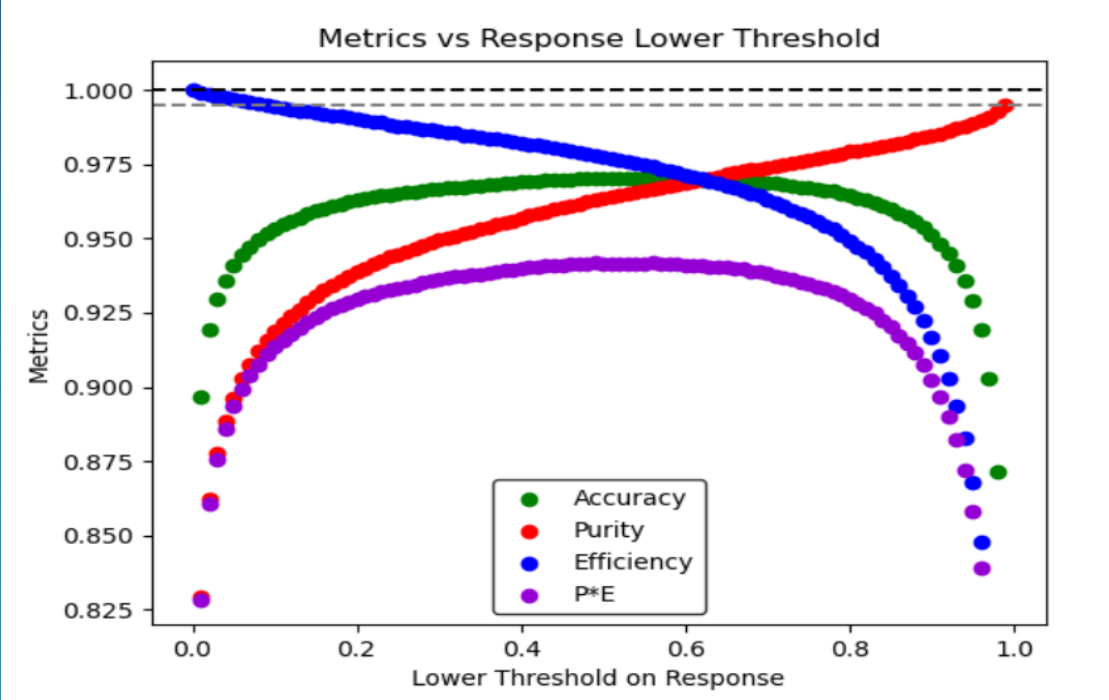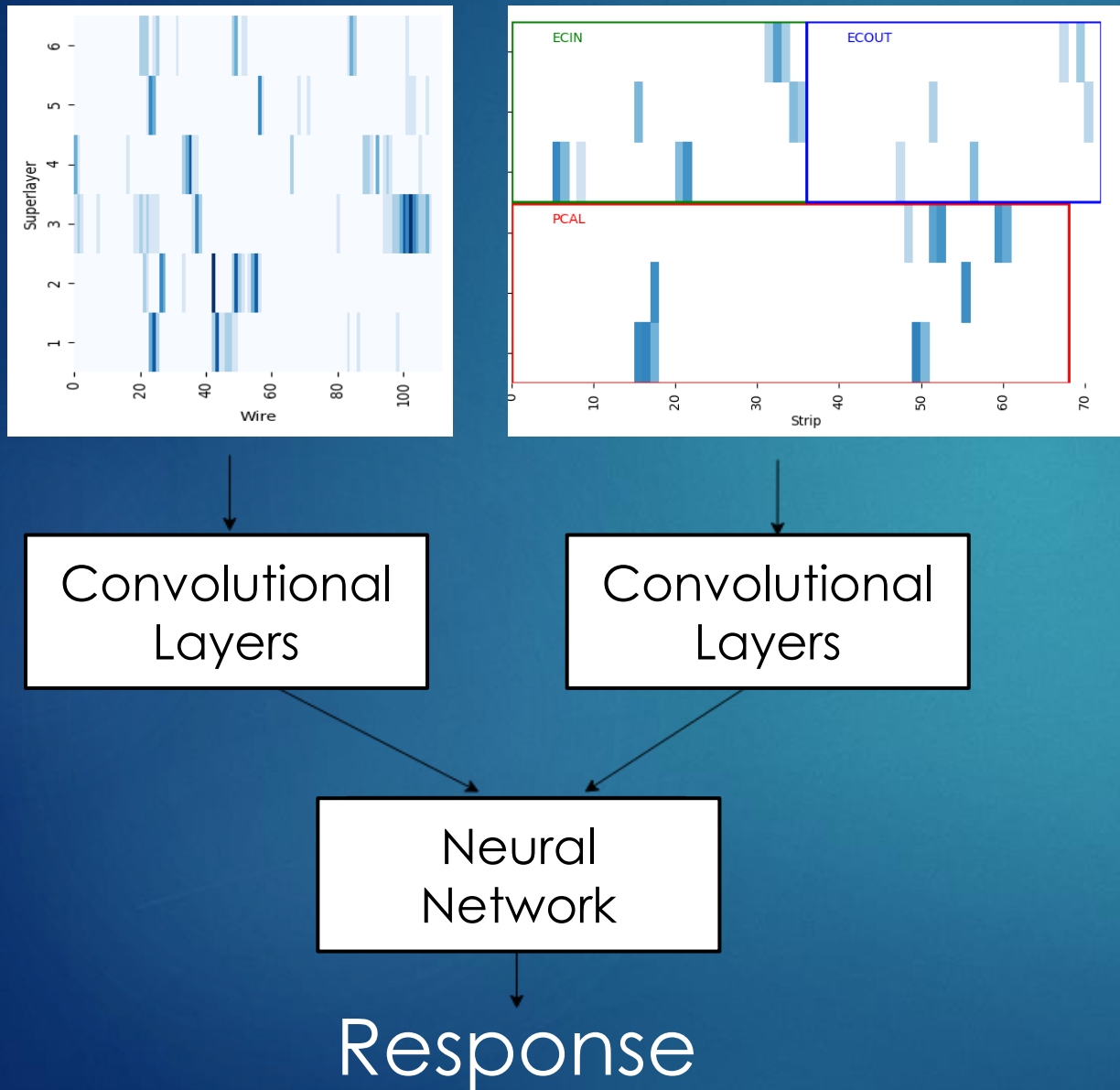
Calorimetry (ECAL)

- The ECAL has three views (U/V/W) for each of the PCAL, EC Inner, EC Outer.

- We can have hits from multiple particles for each element of our training or testing samples.
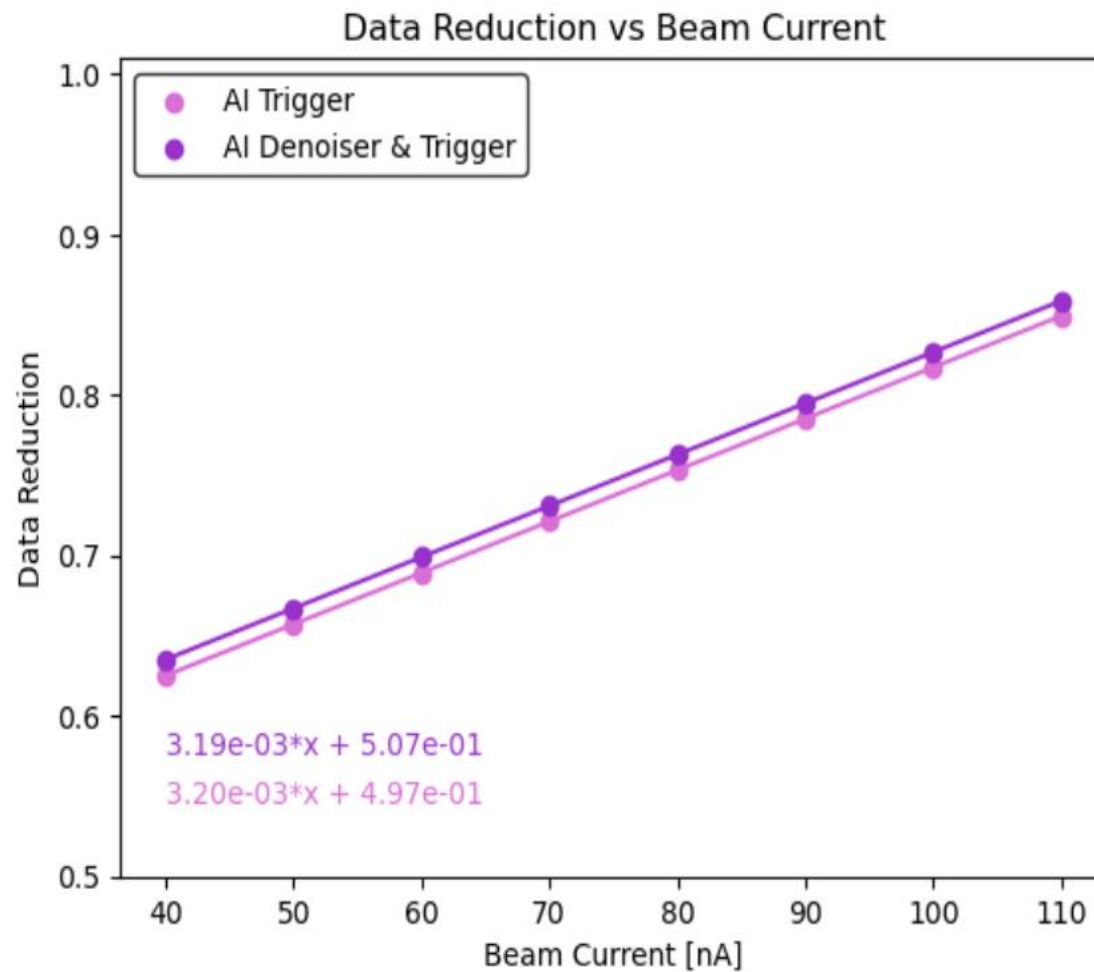
Noising and Denoising

Level-3 Electron Trigger

Threshold	Purity	Efficiency	Accuracy
0.01	83.0 %	99.9 %	89.7 %
0.04	88.8 %	99.7 %	93.6 %
0.08	91.2 %	99.5 %	95.0 %

R. Tyson, G. Gavalian, D. Ireland, B. McKinnon,
Deep Learning Level-3 Electron Trigger
for CLAS12 (2023), arXiv:2302.07635
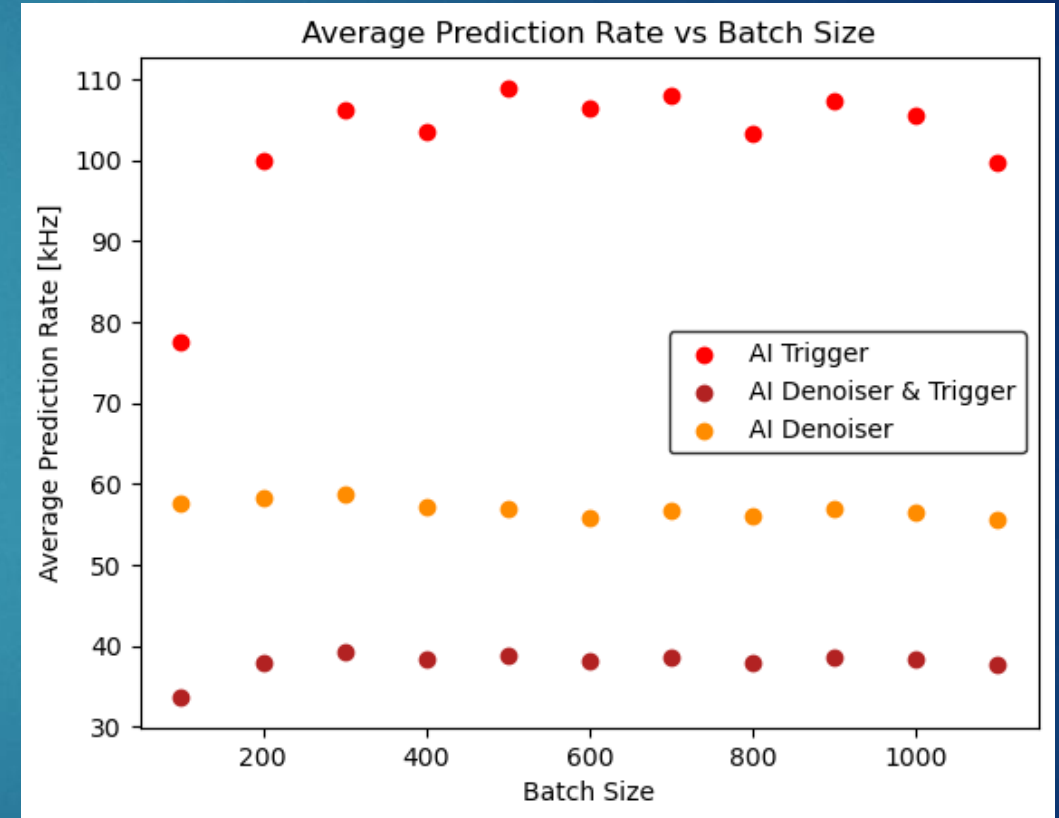
Level-3 Trigger Performance
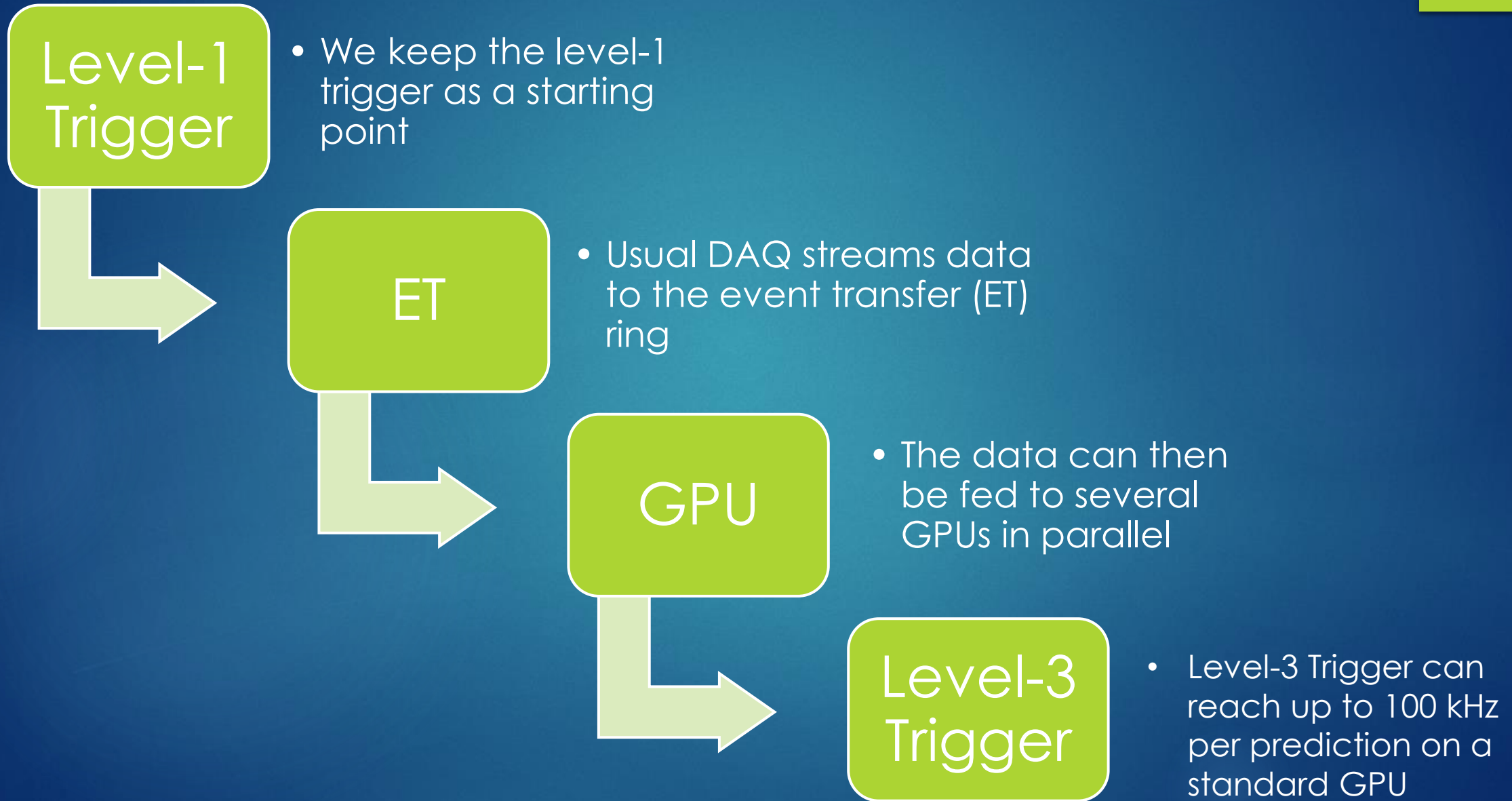
Prediction Rate

- Typical level-1 trigger rates at CLAS12 are ~15 kHz.

- The level-3 trigger prediction rates were measured using tensorflow with a GPU with the following specs:

  - Nvidia GeForce RTX 2080 Ti graphics card with 11 GB GDDR6 RAM and 4352 CUDA cores.

Average Prediction Rate vs Batch Size

Suggested Deployment

Level-1 Trigger

- We keep the level-1 trigger as a starting point

ET

- Usual DAQ streams data to the event transfer (ET) ring

GPU

- The data can then be fed to several GPUs in parallel

Level-3 Trigger

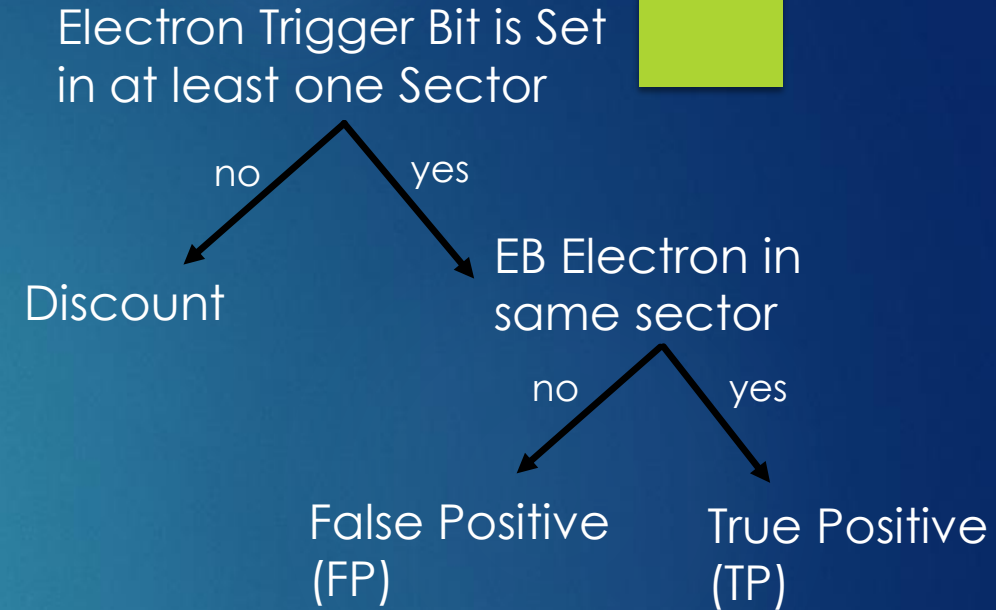- Level-3 Trigger can reach up to 100 kHz per prediction on a standard GPU

Conclusion

- CLAS12 is a large acceptance spectrometer with a high data output, requiring a trigger with a high purity to save on costs of storage and post processing times.

- A CNN based level-3 electron trigger can greatly improve the purity of the conventional level-1 trigger at CLAS12.

- With CLAS12 moving to higher luminosities, the level-3 trigger will be key to managing experimental data sizes and processing times.

- The level-3 trigger will be deployed on GPUs and is fast enough to keep up with the rate of data taking. First online tests expected for summer of 2023!

Backup Slides

CLAS12 Trigger Purity

Electron Trigger Bit is Set in at least one Sector

no   yes

Discount   EB Electron in same sector

no   yes

False Positive (FP)   True Positive (TP)

▶ The level-1 electron trigger requires geometrically matched:

- ▶ HTCC clusters with at least two photoelectrons
- ▶ PCAL clusters with >60 MeV energy deposition in all calorimeters
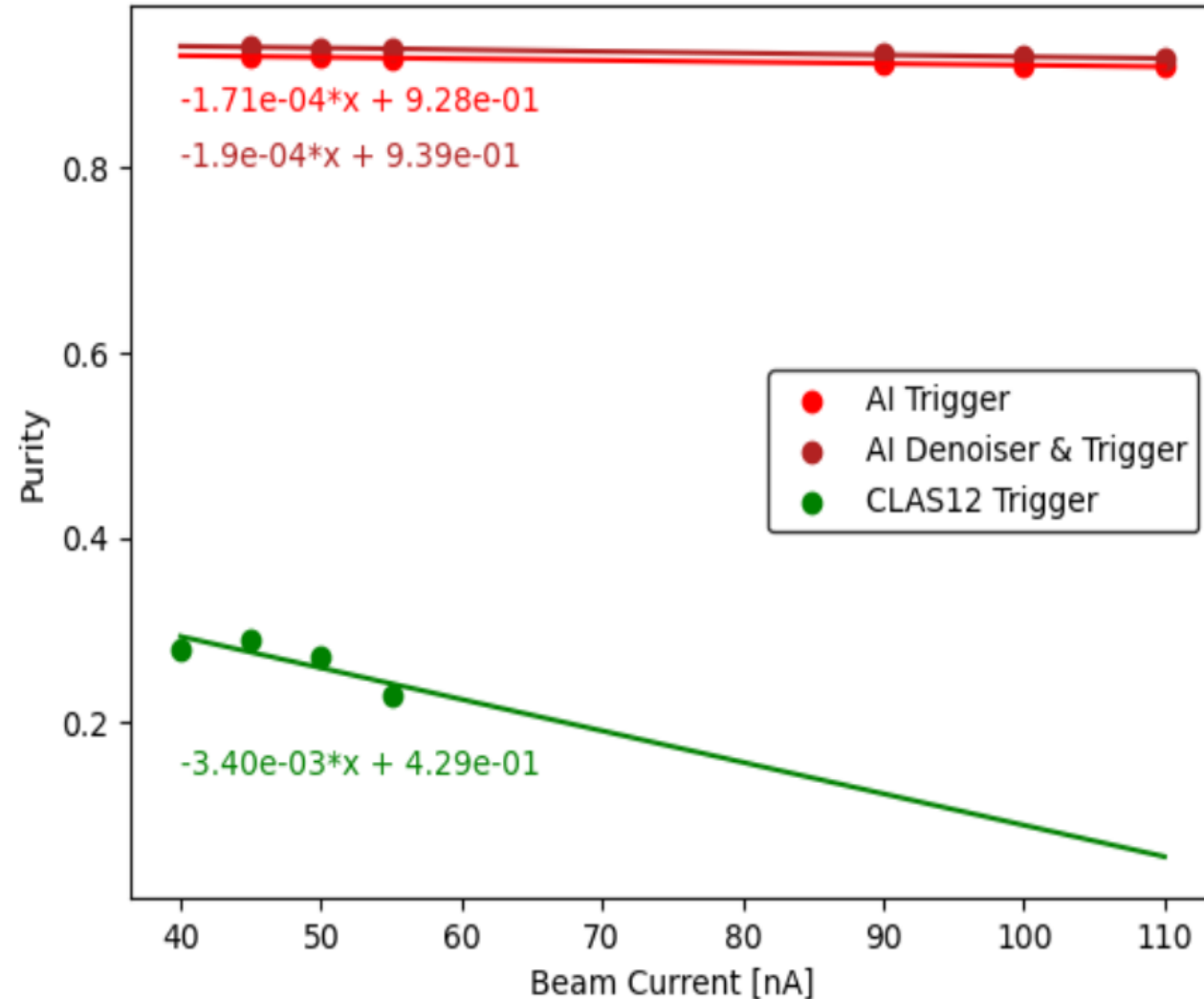- ▶ DC track with at least 5 superlayer segments (3 layers in each superlayer)

Beam Current	Purity TP/(TP+FP)
5 nA	0.43
40 nA	0.28
45 nA	0.29
50 nA	0.27
55 nA	0.23

Purity and Efficiency vs Beam Current