UChicago Smartpix at a Muon Collider Update

May 13, 2026

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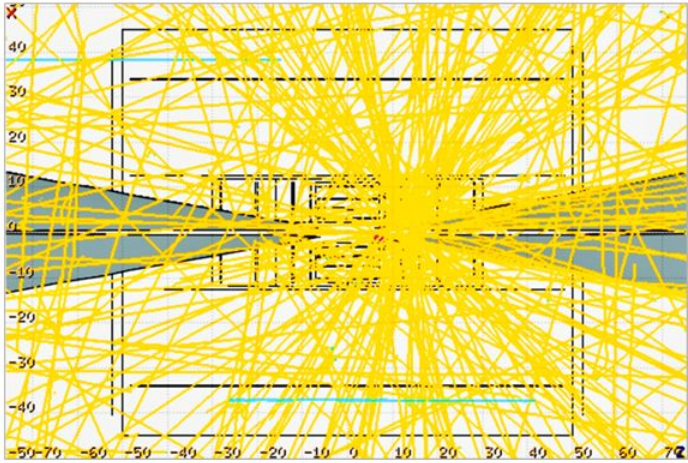
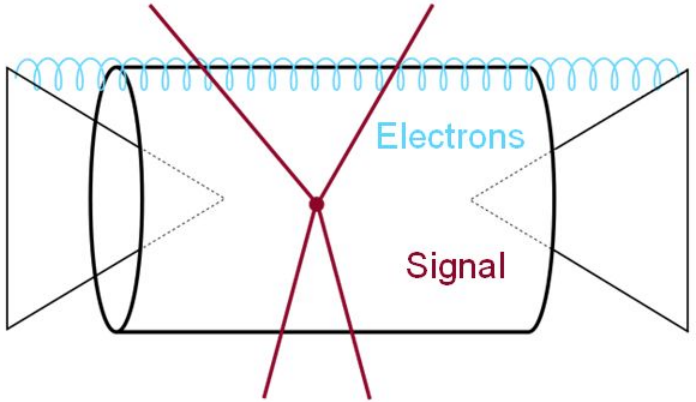
BIB REJECTION AT A MUON COLLIDER

- We want to read out the pixel detector **<u>for every event</u>**
  - Muon Collider: 30 μs
  - LHC: 25 ns
- We anticipate this exceeding read-out constraints ~10 Gbps/FE
- Need on-detector intelligence to reduce data volume per event
  - E.g. regression variables
  - **E.g. differentiate low energy electrons from particles originating from the interaction point in the pixel detector**

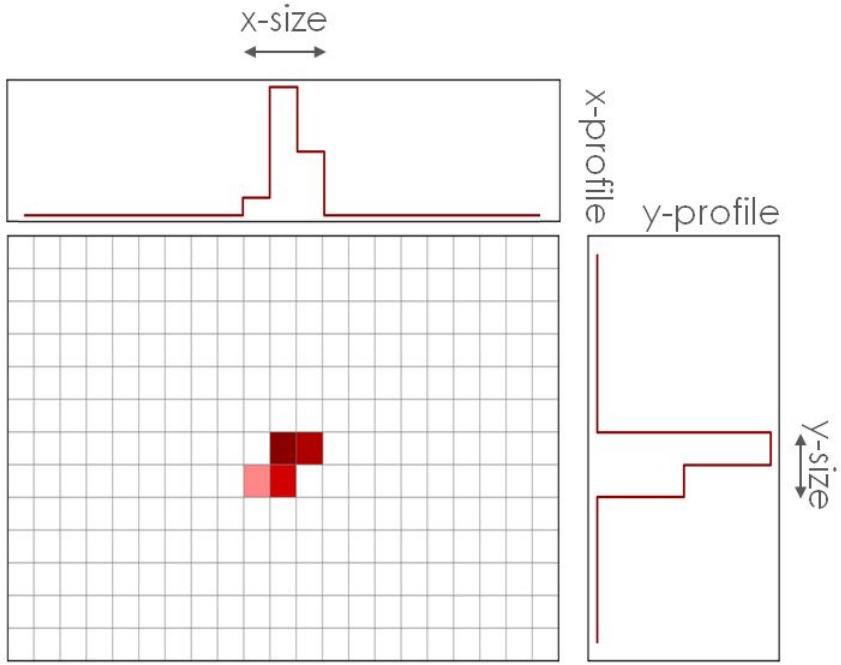


0.0003% of a BIB event



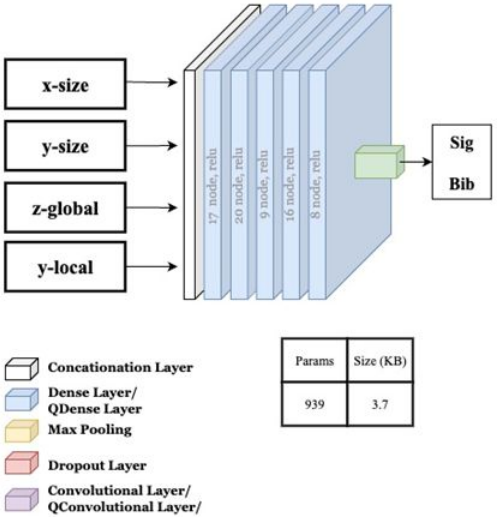
DATASET PARAMETERS

- PixelAV outputs a cluster shape in a region of interest
  - cluster "image" of deposited charge
  - x-profile, y-profile
  - x-size, y-size
- We shift the coordinates of the region of interest to center at the centroid of charge
  - y-local, z-global are charge centroid coordinates



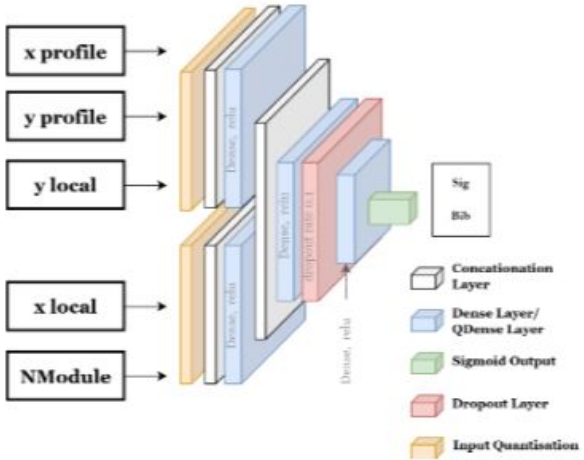
NEURAL NETWORK ARCHITECTURES

Model 1

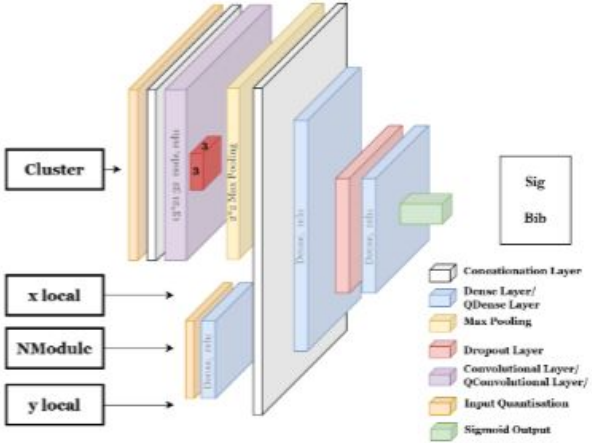


Params	Size (KB)
939	3.7

Model 2



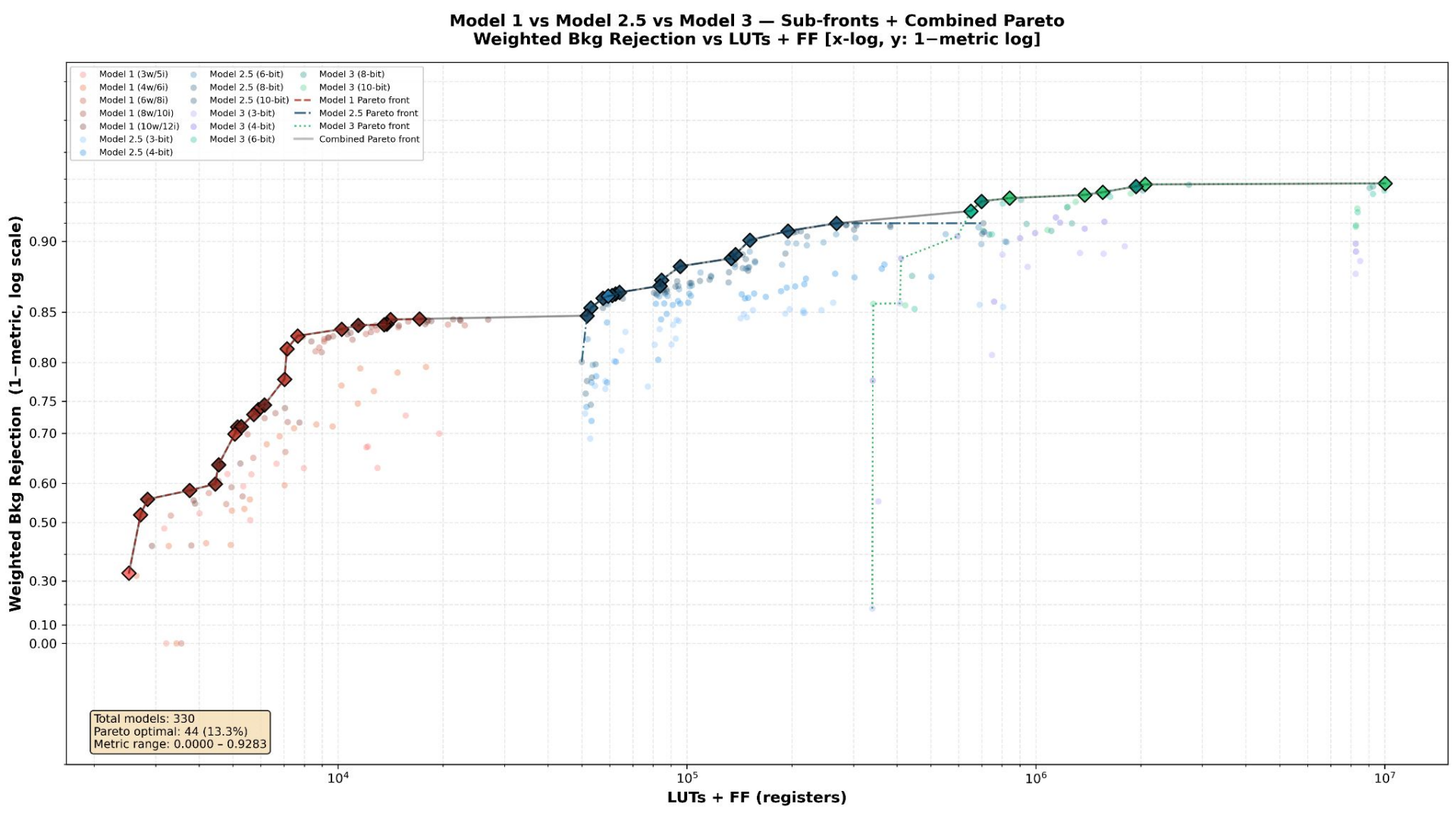
Model 3



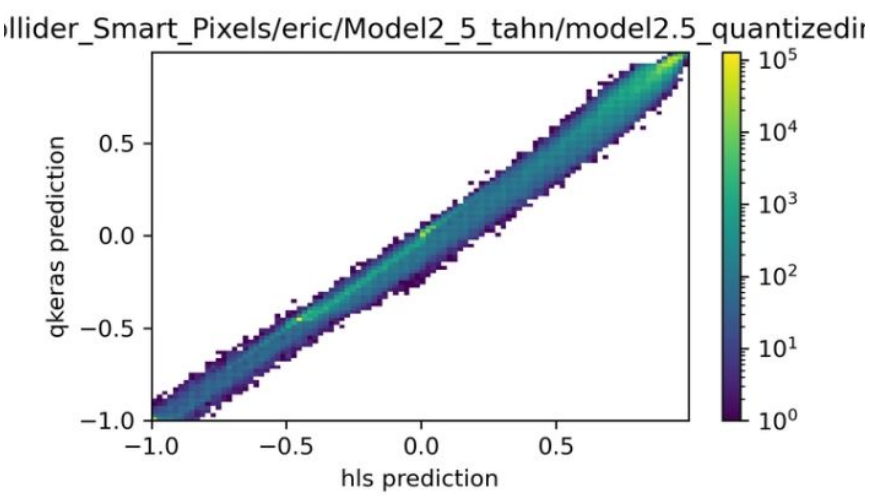
- Note: Exact architecture (number of nodes) will change as we experiment with model size based on synthesis with hls4ml

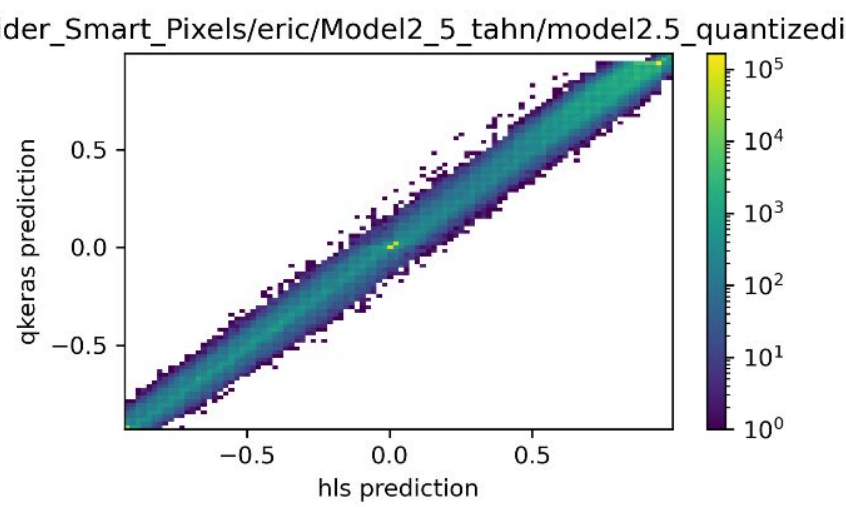
Current status

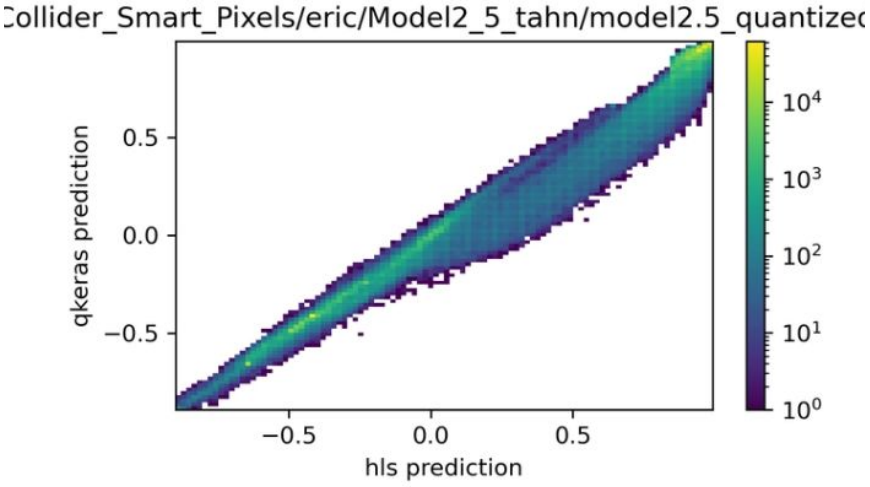
- We are considering 3 models which filter clusters of BIB from signal
- We have run extensive hyperparameter searches for 3 of the models
- Synthesized the models with hls4ml for FPGA, using LUTs+FFs as a metric of hardware usage **-> what is a “reasonable hardware usage”?**
- Have a pipeline to synthesize with Catapult HLS, but there seems to be a bug with catapult where concatenate layers are concatenated randomly in C++
- Have a pipeline to validate hls4ml C++ models match qkeras models **-> what is a “good enough match”?**

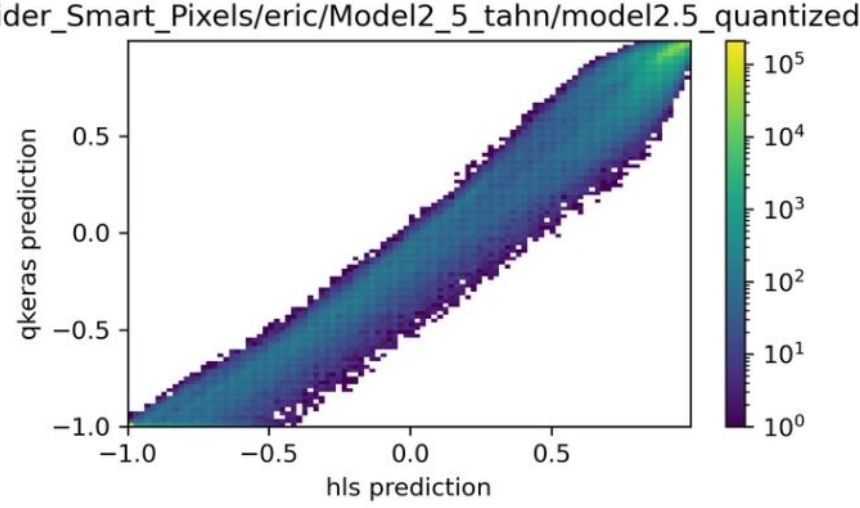

Model 1 vs Model 2.5 vs Model 3 — Sub-fronts + Combined Pareto
Weighted Bkg Rejection vs LUTs + FF [x-log, y: 1−metric log]
Model 1 (3w/5i)
Model 1 (4w/6i)
Model 1 (6w/8i)
Model 1 (8w/10i)
Model 1 (10w/12i)
Model 2.5 (3-bit)
Model 2.5 (4-bit)
Model 2.5 (6-bit)
Model 2.5 (8-bit)
Model 2.5 (10-bit)
Model 3 (3-bit)
Model 3 (4-bit)
Model 3 (6-bit)
Model 3 (8-bit)
Model 3 (10-bit)
Model 1 Pareto front
Model 2.5 Pareto front
Model 3 Pareto front
Combined Pareto front
Weighted Bkg Rejection (1−metric, log scale)
0.90
0.85
0.80
0.75
0.70
0.60
0.50
0.30
0.10
0.00
Total models: 330
Pareto optimal: 44 (13.3%)
Metric range: 0.0000 – 0.9283
10^4
10^5
10^6
10^7
LUTs + FF (registers)

Various model 2.5 files, 8 bit weight









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