hKLM for the 2nd Detector (a compact combined HCAL, muID, ToF) based on 2511.08432 [physics.ins-det]

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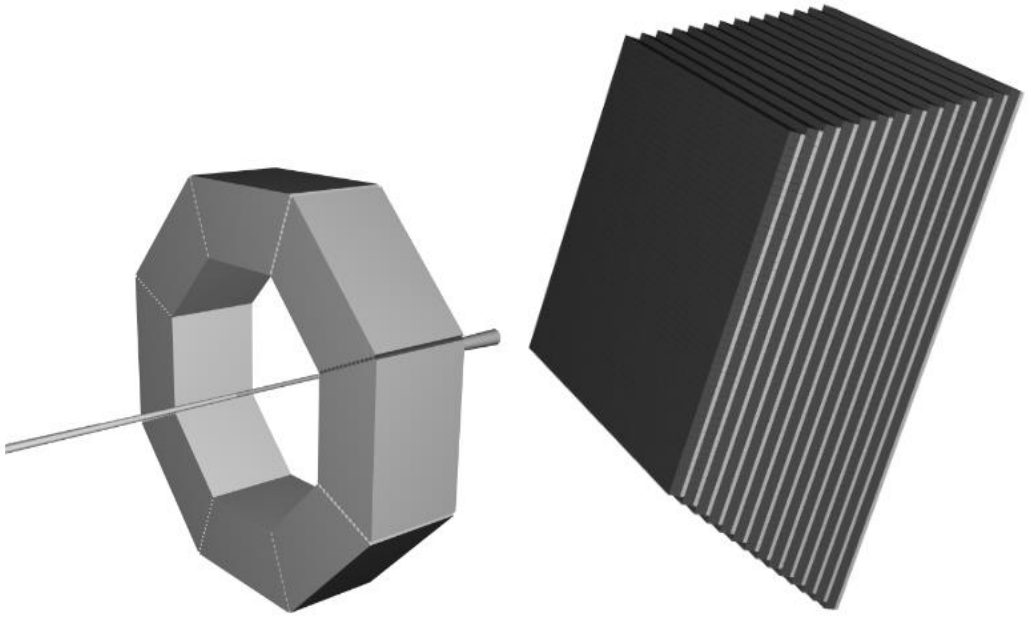
Overall Concept

- Scintillator/Iron Sandwich integrated in flux return

→similar to KLM at Belle II →Also upgrade unterway

- Modest thickness ($\approx 1\ m$)
  - →With e.g. 70% steel $\approx 4.2\ \lambda_{had}$
- Scintillator bars with direct readout
  - ➔Timing resolution $O(100ps)$
  - ➔Only one layer of scintillators needed (orthogonal direction from timing)
  - →ToF
  - →neutral Hadron momentum from ToF (given PID)
- Excellent performance from granularity +ML

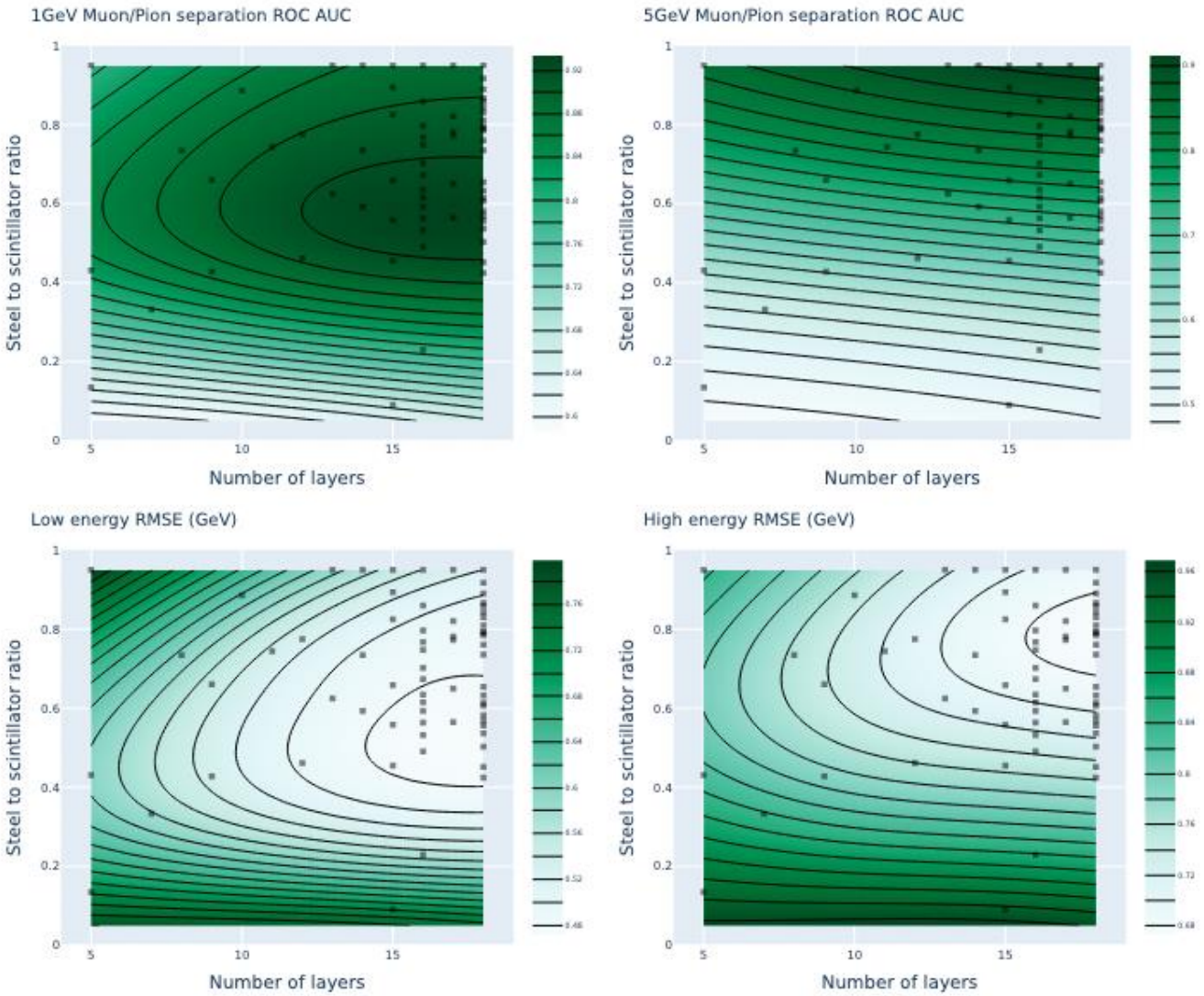


- Here: Simulation studies
- FEE+scintillators are currently being tested at USC
- Beamtest prototype planned

Design process

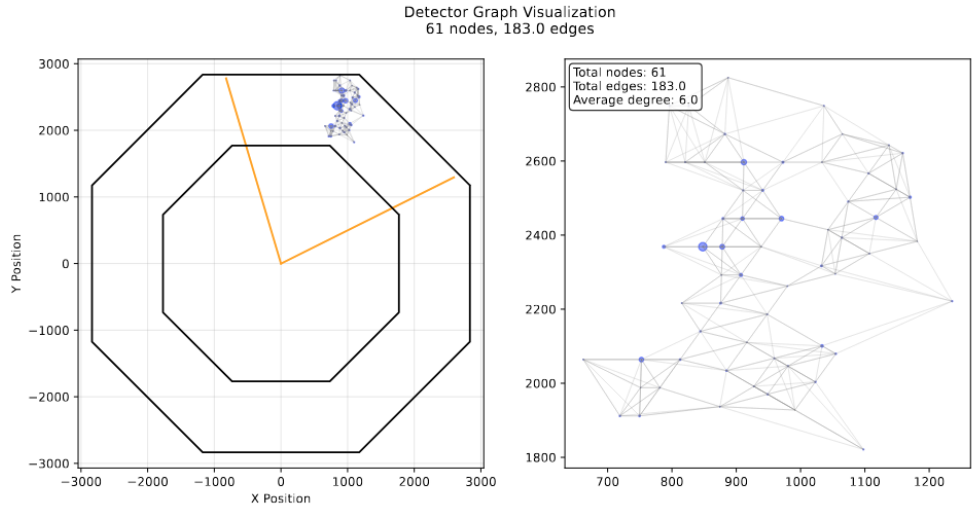
- Multi Objective ML/AI guided design using AID2E (*JINST* 19 (2024) 07, C07001)
- Generative AI for scintillator signal
- GNN for energy and muID
- Optimize Detector geometry and reconstruction algorithm (only HCAL at the moment) at the same time
- See 2511.08432 [physics.ins-det] for full pareto fronts

Here: ‘classic’ muon id based on expectation value of range



- Use GNN to make use of granularity of detector

- GNN improves at high momentum where punch-through becomes an issue



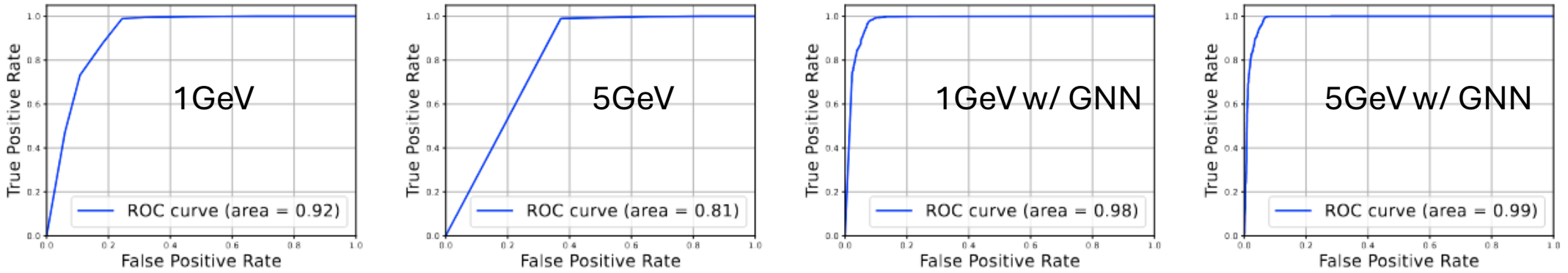


FIG. 3: ROC curves for MuID perfomance with baseline design using the conventional ID method for 1-GeV muons (left) and 5-GeV muons (second from left). The two plots on the right show the performance using a GNN for 1-GeV and 5-GeV muons, in that order.

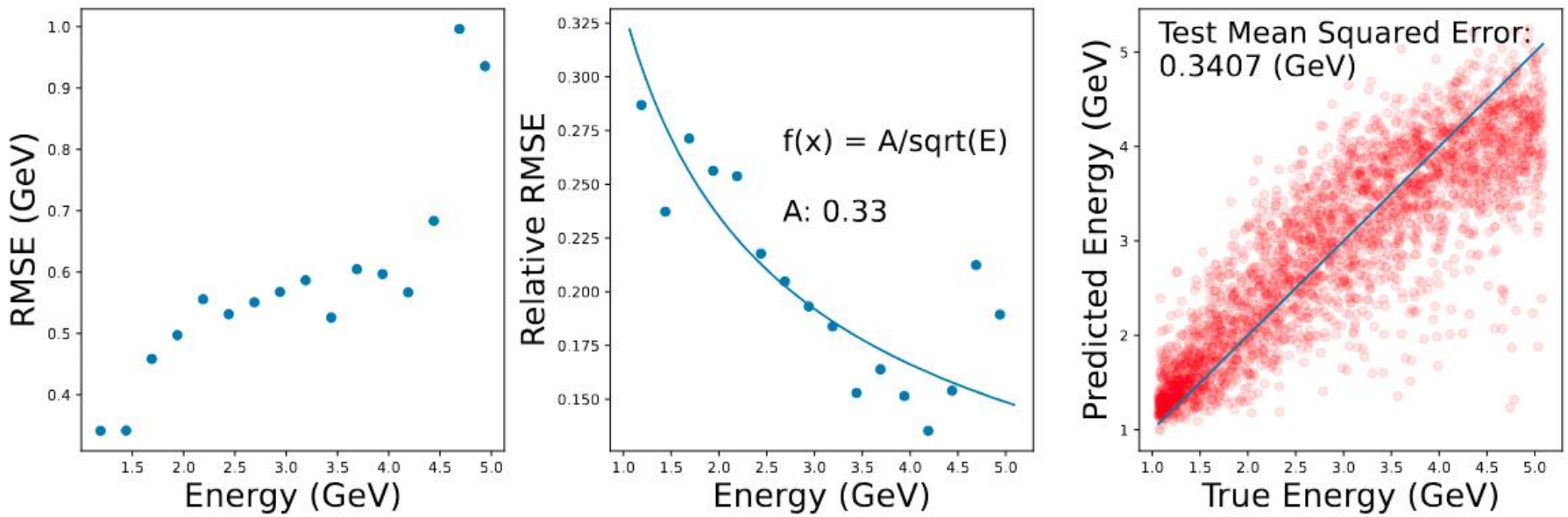


FIG. 5: Energy resolution for neutrons for the baseline design. Left: total error. Middle: relative error. A fit to the functional form $A/\sqrt{E}$ indicates a relative error of $33\%/\sqrt{E}$. Right: True and predicted energy deposit.

Summary

- Granularity + ML has excellent performance even in thinner detectors
- Could extend studies to full events
  - Full event input would also be helpful but requires more work

- SiPM: Hamamatsu S14160-4050HS
- Scintillator EJ-230, EJ-230