Machine-Learning PID For SoLID Detector Electromagnetic Calorimeter Beam Test

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SoLID — Solenoidal Large Intensity Device

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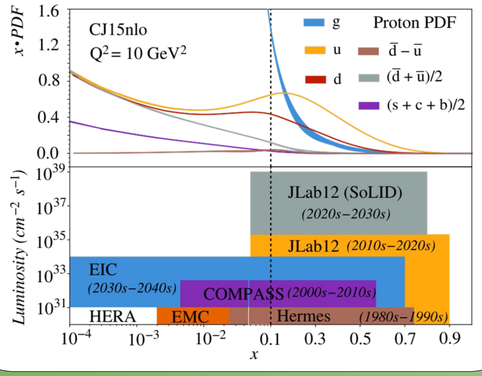
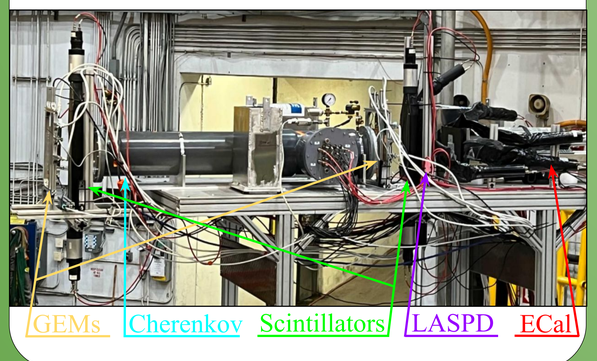
Introduction

The Solenoidal Large Intensity Device *SoLID* is a proposed high-luminosity, large-acceptance spectrometer for Hall A with plans to study Parity-Violating DIS, Semi-Inclusive DIS, J/Ψ photo-production, and more. Given the high-rate, high-radiation nature of SoLID, a beam test focusing on the electromagnetic calorimeter was conducted in Hall C. We worked to match the GEANT-based simulation and data with emphasis on particle identification *PID*. Through this study, we intend to develop foundational methods for use by the fully-realized SoLID.



SoLID Beam Test

- **Time**: July 2022 - March 2023
- **Locations**: 82°, 7°, 18°
- **Radiation Dose:** ~100-200 krad
- **Detectors**: Shown in figure below
  - **Scintillators & LASPD**: Used for triggering
  - **GEMs**: 4 used for tracking
  - **Threshold Cherenkov**: Used for PID (CO_2 gas)
  - **ECal**: 3 Preshower & 3 Shower Shashlik modules

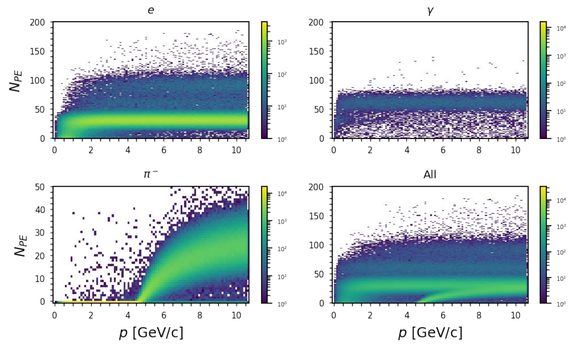


Pencil Simulation

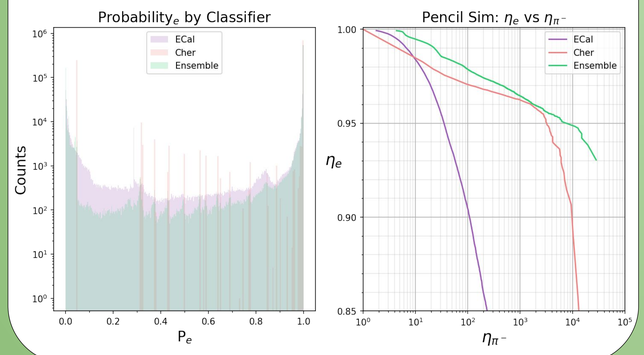
Using the pencil beam test simulation:

- Obtained results for charged-particle PID
- Explored various ML architectures & algorithms
- Investigated momentum-binning for the ECal
- Compared ECal PID results against desired SoLID specs

N_{PE} vs p: By PID



Ensemble Classifier for Pencil Sim

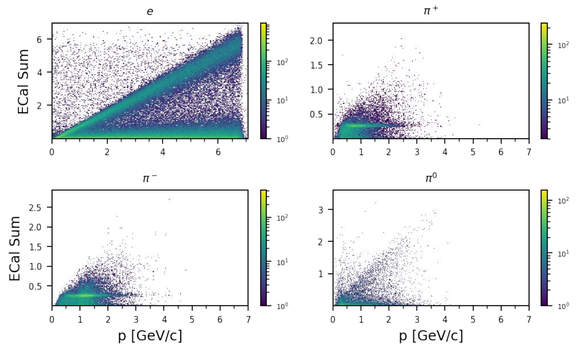


Full Simulation

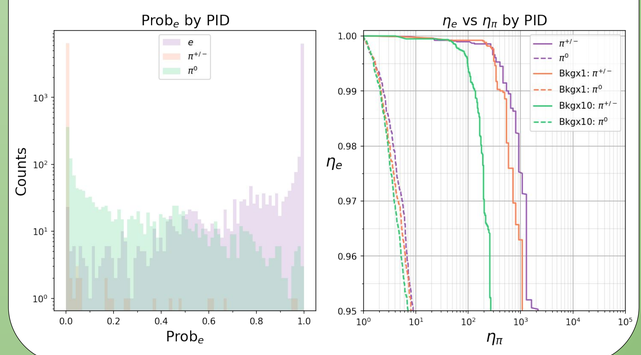
Using the full beam test simulation:

- Applied charged-particle trigger (TS3) cuts to simulation
- Explored effects of background on classification
- Included smearing effects in classification
- Obtained classifiers for use on beam test data

ECal Sum vs p: By PID



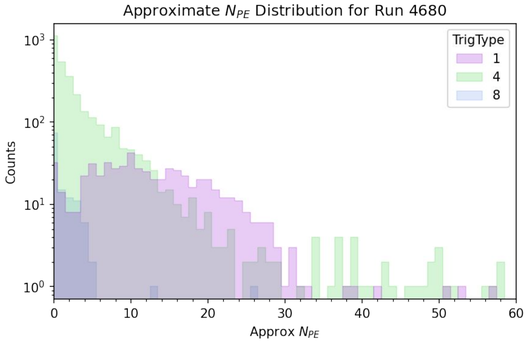
Classification for Beam Test Sim - TS3



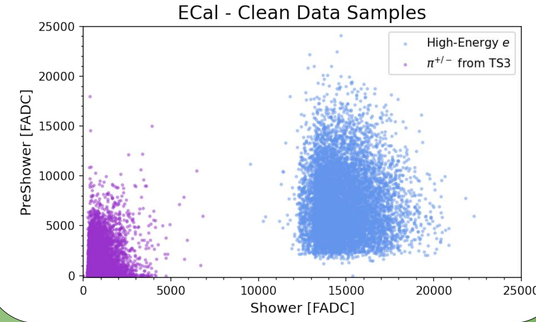
Classifying Data

After following the analysis from the pencil sim then full beam test simulation, we plan to use the trained MLP to classify events for the charged-particle and electron trigger for the data. This requires selection of clean samples and preparing the data for classification.

Approximate N_{PE} Distribution for Run 4680

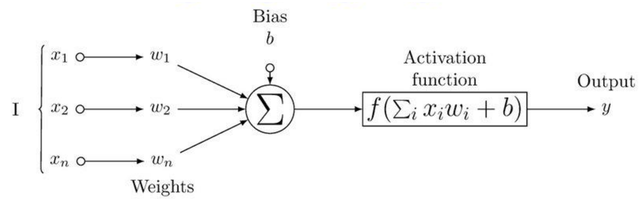


ECal - Clean Data Samples

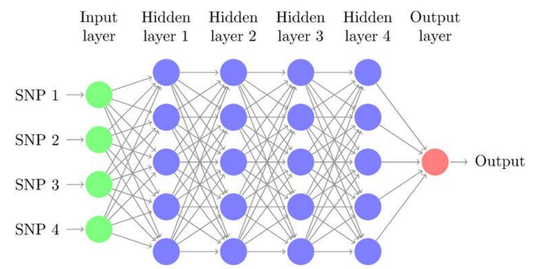


Machine Learning For PID

While "traditional" PID approaches emphasizes placing cuts to select triggered events, ML models output a probability value for given events. For the SoLID ECal beam test, we started with traditional methods, then used ML methods comparing the results set by step.



MLP Architecture



Future Applications

With preliminary results for ML-assisted PID using the beam test SoLID, we hope that these results will:

- Apply classifiers first to full beam test data
- Provide a baseline for full-scale ML-based PID
- Complement ML-assisted background rejection
- Encourage the development of ML-assisted tracking

Acknowledgements

UVA Group: Mike Nycz, Spencer Opatrny, Jixie Zhang

SoLID Group: JP Chen, Ye Tian, Zhiwen Zhao, and others

JLab Staff: Harut Avagyan, Kishan Rajput, and many more

JLab Sci-Ed: Jalyn Dio, Steve Gagnon, Lisa Surles-Law