Funding Call

Executive Summary

The DOE SC program in Nuclear Physics (NP) hereby announces its interest in receiving applications for research and development (R&D) efforts directed at artificial intelligence (AI) and machine learning (ML) for autonomous optimization and control of accelerators and detectors of relevance to current or next generation NP accelerator facilities and scientific instrumentation, as well as applications applying AI/ML to advance nuclear physics computations.

Major areas of research may include, for example:

- Efficient extraction of critical and strategic information from large complex data sets:
- Development and implementation of digital twins for future colliders;
- Efforts to address the challenges of autonomous control and experimentation,
- Efficient operation of accelerators and scientific instruments,
- Deployment of AI for reduction of large and/or complex experimental data,
- Development of software to enable data-driven discovery of new physics

Department of Energy (DOE)
Office of Science (SC)
Nuclear Physics (NP)

Artificial Intelligence and Machine Learning Applied to Nuclear Science and Technology

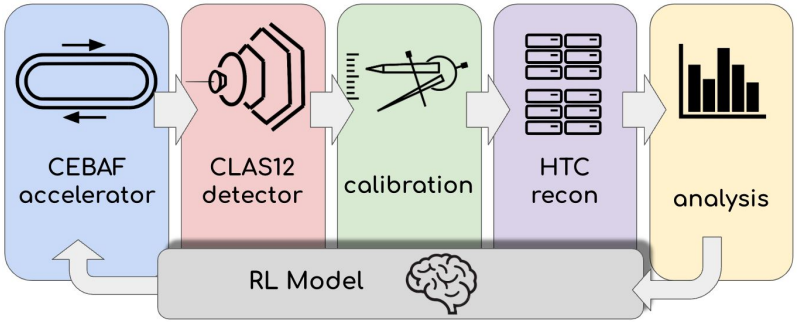
Notice of Funding Opportunity (NOFO) Number:
DE-FOA-0003458

NOFO Type: INITIAL
CFDA Number: 81.049

NOFO Issue Date:	Date: October 15, 2024
Submission Deadline for Letters of Intent:	Date:November 14, 2024 at 5:00 PM ET A Letter of Intent is required. Letters of Intent must be submitted by an authorized institutional representative.
Letter of Intent Response Date	Date: December 5, 2024 at 11:59 PM ET
Submission Deadline for Applications:	Date: January 14, 2025 at 11:59 PM ET

What is Being Proposed

- Process data in real-time from a large detector
- Estimate uncertainty of a physics measurement (cross-section) on timescale of <1hr
- Feedback to CEBAF Accelerator to adjust beam



Conditions during run will be intentionally changed to force the automated system to react

Key Objectives

- Demonstrate Automation of one or more Accelerator parameters via direct feedback from a large detector system based on a physics goal
  - Fast calibration of detector data
  - Fast event selection
  - Fast reconstruction
  - Process full detector data in real-time using HTC farm

Some work has been done using AI/ML independently in each of these areas. This project will need to advance that to the next stage of AI/ML for key detector subsystems

NOT Objectives

- Improve beam quality
- Improve detector resolution
- Make the best possible measurement the detector is capable of
- Make a new physics measurement that has never been made
- Advance Data Science through AI/ML research

Physics Signal: Cross-Section $\gamma^* p \rightarrow p\rho^o$

Eur. Phys. J. A 39, 5–31 (2009) DOI 10.1140/epja/i2008-10683-5

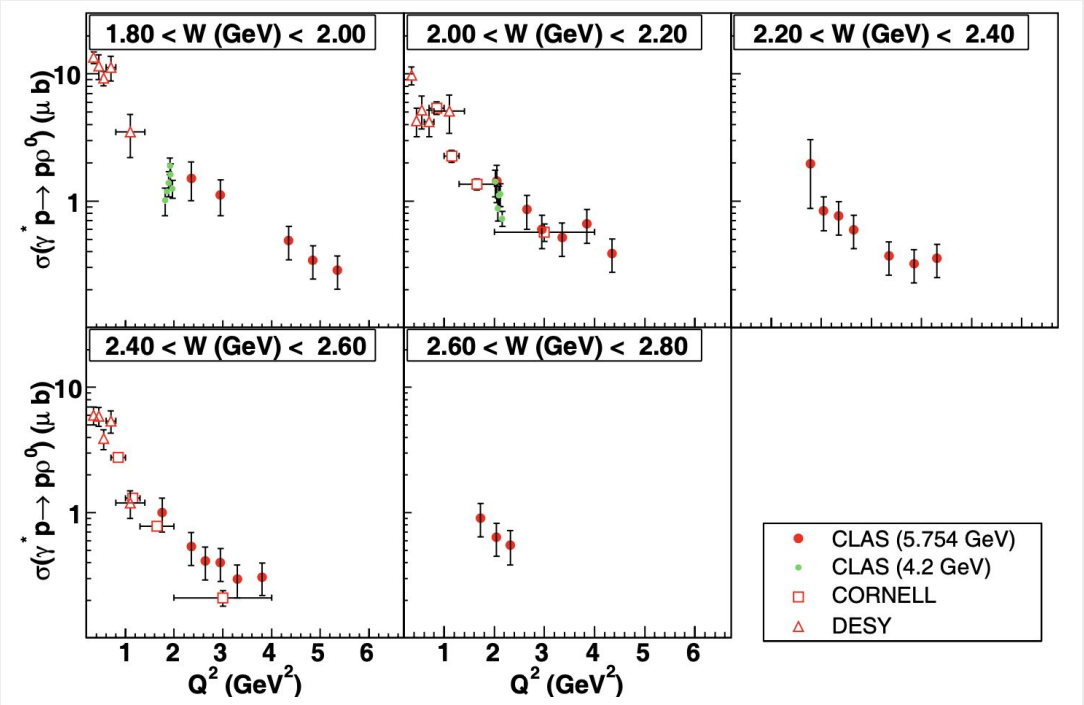
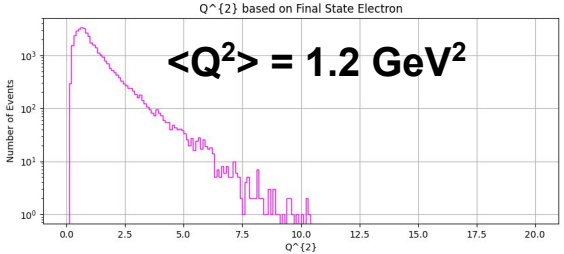
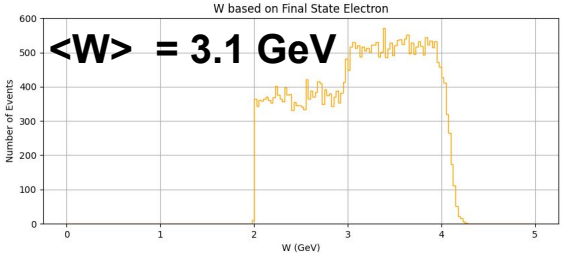


Fig. 13. Reduced cross-sections $\gamma^* p \rightarrow p\rho^0$ as a function of Q^2 for constant W bins, in units of μbarn. The 4.2 GeV CLAS, Cornell and DESY data are, respectively, from refs. [21], [19] and [18].

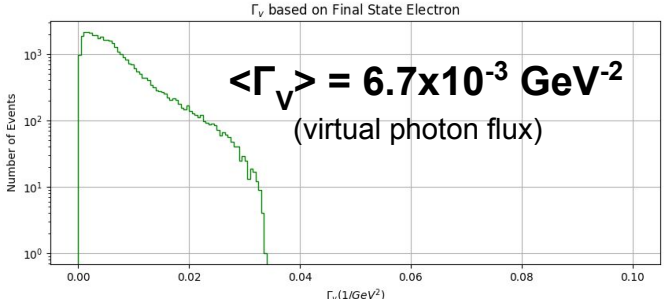
Generated pi+pi- events with CLAS12 geometric acceptance cuts and momentum-dependent* tracking efficiencies at 10.6GeV





**Momentum dependence taken from fig. 20 of Nuclear Inst. and Methods in Physics Research, A 959 (2020) 163472*

Estimating Signal Event Rate

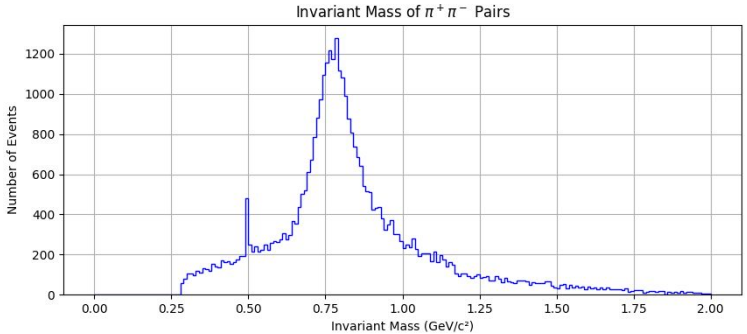


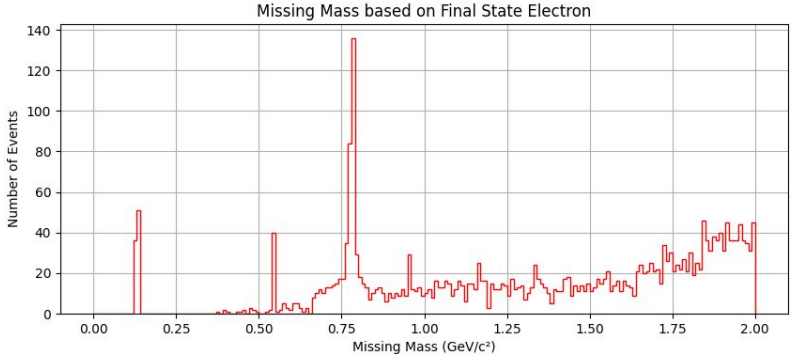
luminosity: $\mathcal{L} = 10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$

x-sect: $\sigma(\gamma^* p \to p\rho^o) \approx 1\mu b$

ρ^o production rate: $\mathcal{L} \cdot \sigma \cdot \langle\Gamma_v\rangle \cdot (3600s/hr) \approx 240k$/hr

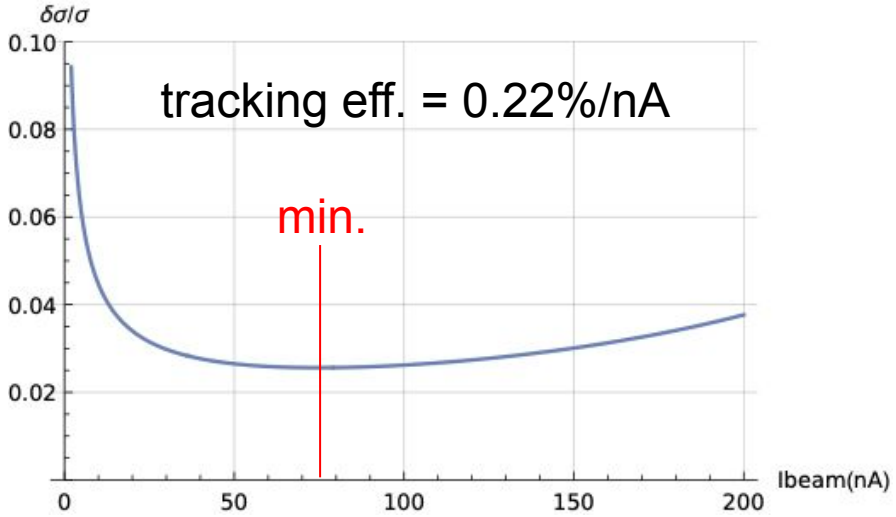
$\pi^+\pi^-$ acceptance rate: $240 \times 4.4\% \approx 10k$/hr

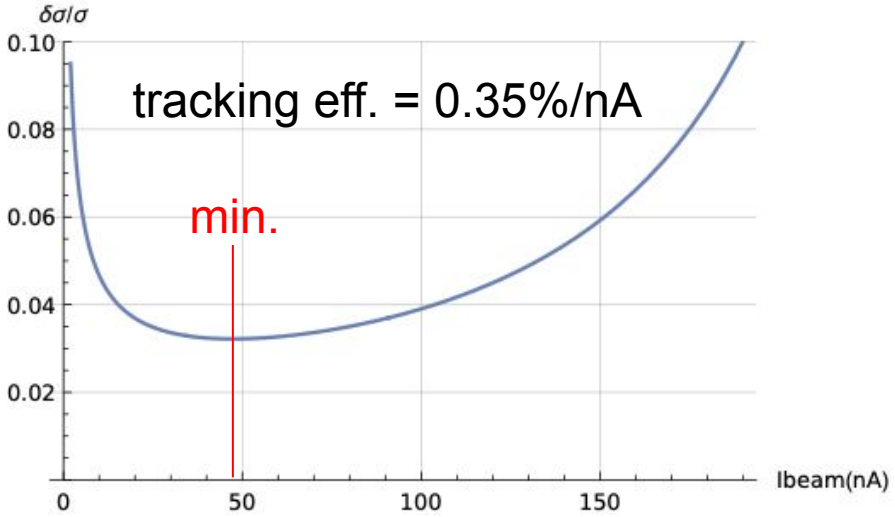




Statistical Uncertainty vs. Beam Current

Tracking efficiency is linearly dependent on beam current due to increased occupancies in the tracking detectors.





Estimates Based on 1hr of $ep \rightarrow e'p\rho^o$ *data*

Spoiling the Experiment

Stable beam and detector operation will not be interesting. Some intentional changes will need to be made to force the system to respond.

1. Change the physics channel (e.g. switch to $ep \rightarrow e'p\eta \rightarrow e'p\pi^o\pi^o\pi^o$)
2. Spoil the beam (e.g. tweak quad to increase halo?)
3. Lower the HV on the tracking chambers?

Backups

$$Q^2 = 4E_{\text{beam}}E_e \sin^2\left(\frac{\theta_e}{2}\right)$$

$$W^2 = m_p^2 + 2m_p(E_{\text{beam}} - E_e) - Q^2$$

$$\Gamma_{\gamma^*} = \frac{\alpha}{2\pi^2}\frac{E_e}{E_{\text{beam}}}\frac{K}{Q^2}\frac{1}{1-\epsilon}$$