Jefferson Lab

FY25 LDRD presentations
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Parton structure from electroweak processes with positrons

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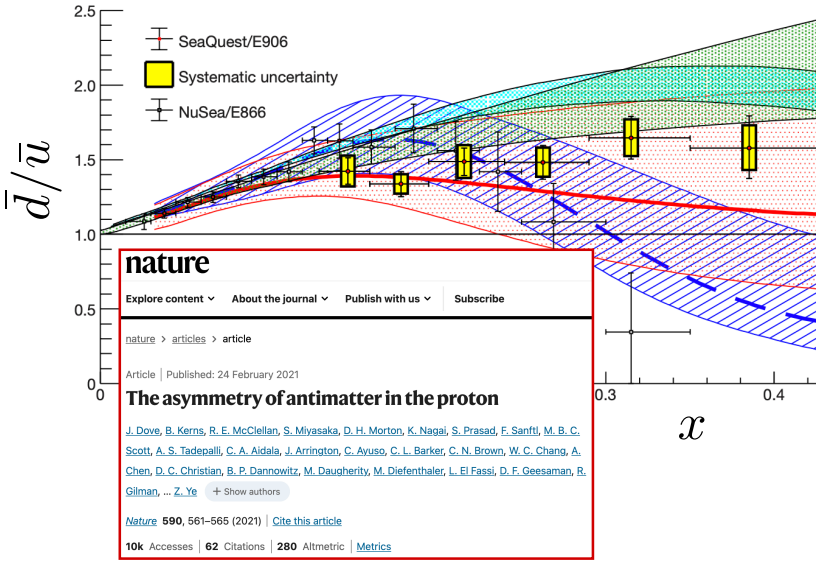
Impact and strategic value to JLab's mission

Unique opportunity to explore matter – antimatter asymmetry

Antiquark matter asymmetry established at Fermilab



→ $\bar{d} > \bar{u}$

Strange matter-antimatter asymmetry predicted but not yet established

→ important for other fields, *e.g.* W mass determinations, supernova explosions, …

→ most direct way to access asymmetry is through V-A interference $F_3^{\gamma Z}$ via $e^+ - e^-$ charge asymmetry

→ JLab is only facility where this is feasible … although signal is small and challenging to isolate with inclusive DIS

→ new ideas to enhance γZ interference signal beyond that possible with observed single-lepton final state

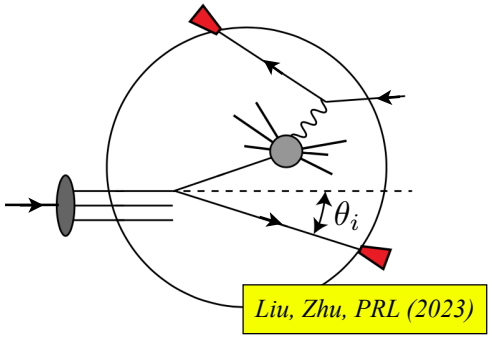
→ potential for discovery of fundamental but elusive physics effect, with development of new research directions in theory & ML, with wider applications for JLab and EIC

Level of innovation

New physics analysis strategy based on recent developments in pQCD and ML

energy-energy correlators

- new observables, complementary to DIS and SIDIS programs

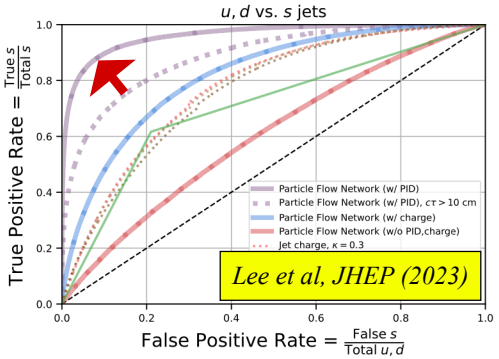


- measure scattered lepton, and energy of produced hadrons in final state
- related to "moments" of PDFs & TMDs (integrals over x at fixed angles)

cannot be carried out through existing programs

event-based ML analysis

- use event-level based observables (*energy flow polynomials*) to enhance γZ interference signal
- construct ML classifiers to discriminate between signal (s) and bkgd (no s)



cannot be carried out through existing programs

traditional observables

- simulations for standard inclusive DIS with e^+ and e^-

could be carried out through existing programs

outcomes

- feasibility for discovering strange — antistrange asymmetry at JLab
- development of ML tools for hadron structure studies

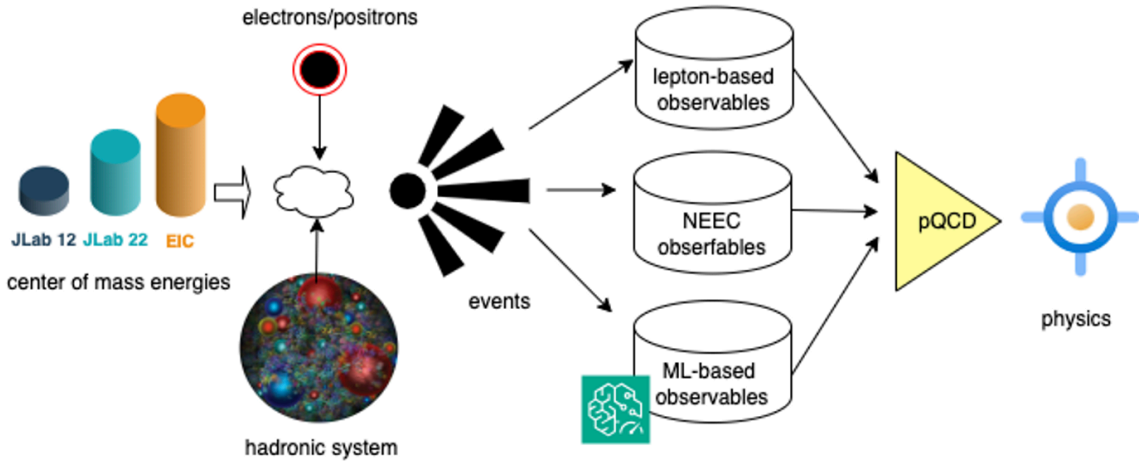
Deliverables: timeline and milestones

Aim 1: R&D for nucleon *energy-energy correlator* observables for electroweak probes

Aim 2: R&D for *ML-based event-level* observables for electroweak physics

Aim 3: Development of baseline analysis with *classical* observables

Aim 4: *Comparative* studies of newly developed observables



Aims	Objective Number	Milestone	FY25 Q1	FY25 Q2	FY25 Q3	FY25 Q4	FY26 Q1	FY26 Q2	FY26 Q3	FY26 Q4	
1	1	Develop a theory framework to access γZ interference effects using NEECs	■	■							
	2	Implement a computational framework to study NEECs		■							
	3	Simulate the reconstruction of NEECs at Jefferson Lab and the EIC		■	■						
	4	Perform impact studies for reconstructing the targeted physics using NEECs			■	■	*				
2	5	Develop an event-based theory framework to access γZ interference effects					■	■			
	6	Train ML models that maximize the γZ interference signal						■			
	7	Simulate event-level observables, such as energy flow polynomials and N-jettines basis						■	■		
	8	Perform impact studies for reconstructing the γZ interference physics using ML-assisted observables							■	■	*
3	9	Simulate reconstruction of classical observables (charge asymmetries) at JLab and EIC							■		
	10	Perform impact studies for reconstructing the targeted physics								■	
4	11	Perform comparative analysis among the various impact studies (A1-A3) across all simulations from JLab12, JLab22, and EIC								■	*

* expected publications

Budget and budget justification

- Staff salary 25% Melnitchouk
  Staff salary 5% Dalton
  Staff salary 5% Sato
  Postdoc salary 100%
  Ph.D. Student 50%
  Ph.D. Student 50%

Requested Budget for Effort by Investigator					
Name of Investigator	**Role (PI, Co-I, etc.)**	**FY25 Budget ($K)**	**FY25 Effort (% FTE)**	**FY26 Budget ($K)**	**FY26 Effort (% FTE)**
Melnitchouk	PI	73.3	25	75	25
Dalton	Co-I	10	5	10	5
Sato	Co-I	10	5	10	5
TBD	PD/Contributor	124.5	100	126.6	100
Subtotal for effort					
Equipment	Non-capital				
	Capital				
Subcontracts	TBD	48.4	100	48.4	100
Materials/ Supplies		3.5			
Travel		7.5		7	

Budget ($K)	**Total**	**FY25**	**FY26**
	555.0	**277.7**	**277.3**

Wally Melnitchouk (PI, JLab Theory) [25%]
— oversee project, develop theory framework for EECs

Nobuo Sato (co-I, JLab Theory) [5%]
— develop computational ML-based event-level framework, train ML models

Mark Dalton (co-I, JLab Physics) [5%]
— simulate reconstruction of EECs, classical observables at JLab/EIC

Xiaochao Zheng (co-I, U.Virginia) [collaborator]
— simulate reconstruction of EECs, classical observables at JLab/EIC

Postdoc (TBD) [100%]
— knowledgeable in EECs, energy-flow polynomials, AI/ML-trained
— simulate event-level observables, train ML models, perform impact & comparative studies

Richard Whitehill (ODU, PhD) [50%]
— develop theory framework for EECs, simulate reconstruction of EECs, perform impact & comparative studies

Experimental PhD student (UVa/JLab) [50%]
— simulate reconstruction of EECs, classical observables at JLab/EIC

Potential future funding (beyond LDRD)

- Anticipate future FOAs for AI applications in nuclear physics

  → upcoming FOA expected fall 2024

  → extend research scope of event-level ML-based analysis for hadron structure studies

- Strategic planning for new research directions

  → nucleon EECs for hadron structure studies, broaden research scope of the Theory Center, attract new talent

  → use of event-level analysis for future SCIDAC FOAs (QuanTom — unify theory & experiment analysis)

  → maintain leadership for JLab and future EIC in 3D hadron structure studies