



Accelerator Status & Experiment Schedule

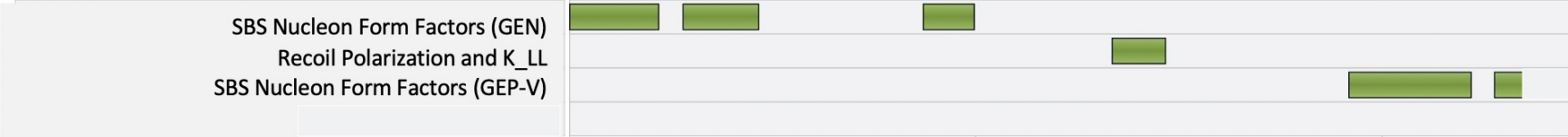
Douglas Higinbotham
Physics Division

TJNAF is managed by Jefferson Science
Associates for the US Department of Energy

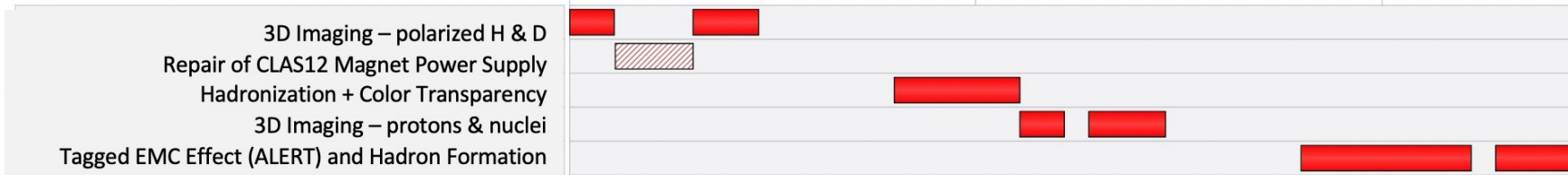
CEBAF Improvement Plan Is Proceeding

- Last run period, we pushed the CEBAF accelerator to 1047 MeV/linac
 - A good energy for delivering high polarization to Halls A, B and C
 - This equates to 10.5 GeV for A, B, C and 11.6 GeV for Hall D
- We ran at that energy the entire 32 weeks of physics beam!
 - Down side was limited beam current and high trip rates
- During this SAD (scheduling accelerator down) we have added a C100 to the north linac and replaced one in the south linac.
 - We are planning to continue with the 1047 MeV/linac with what should be more stable beam.
 - We have had a series of safety pauses which have caused a short term delay, but hopefully will mean smoother & safer long term running.
- Looking ahead the goal is to get CEBAF well into the operational energy range needed for the MOLLER experiment (10.6 to 11 GeV for Hall A)

Experimental Hall A



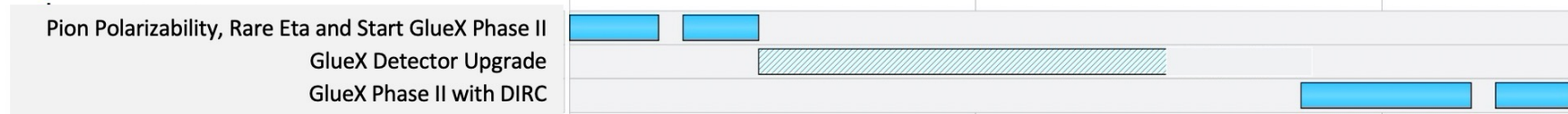
Experimental Hall B



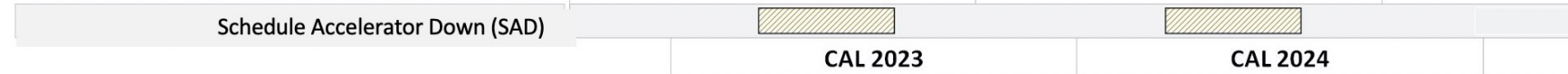
Experimental Hall C



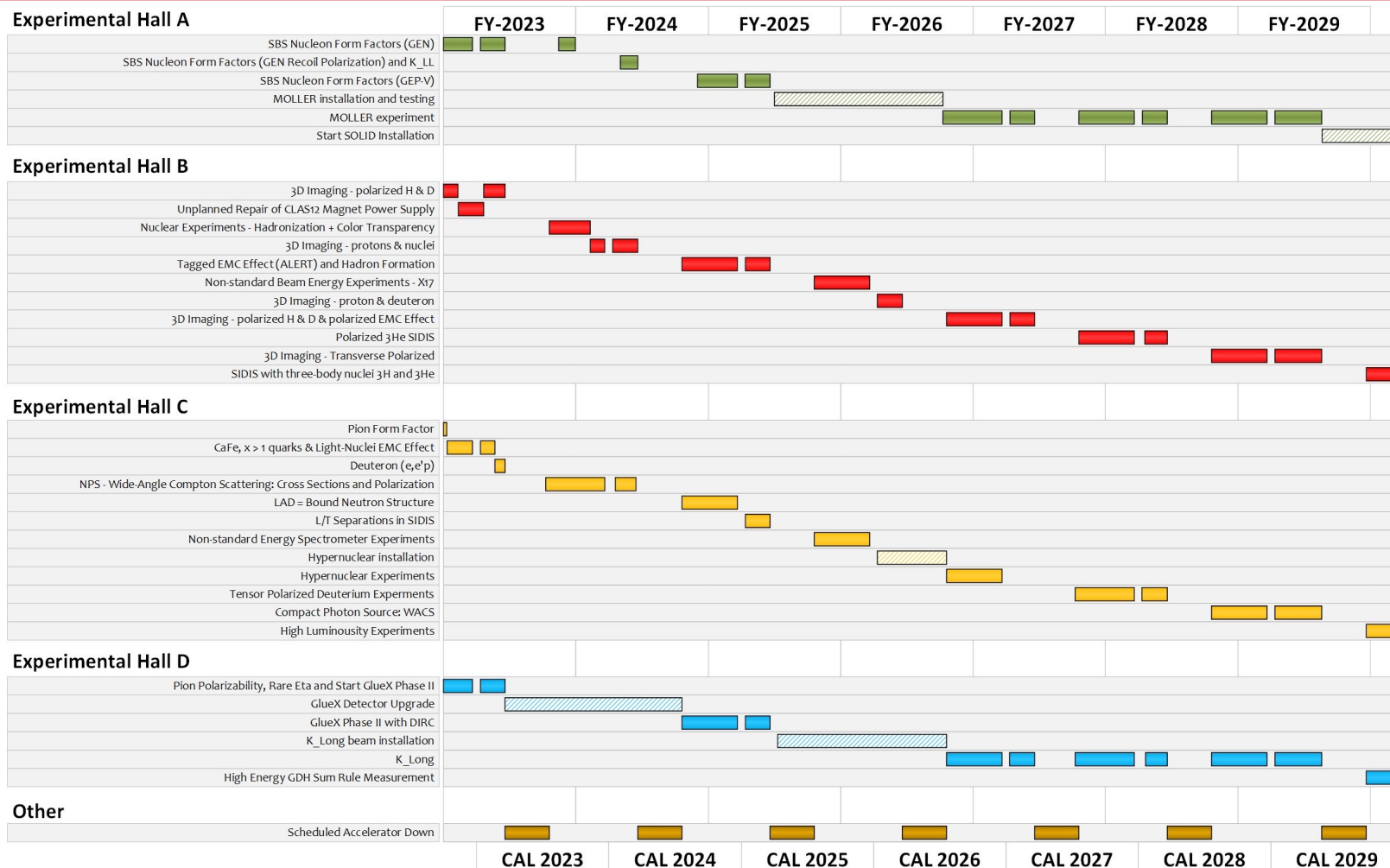
Experimental Hall D



Other



EXTENDED EXPERIMENTAL SCHEDULE



205 completed experiments to-date (28 full; 28 partial in 12 GeV era)

51 experiments remaining

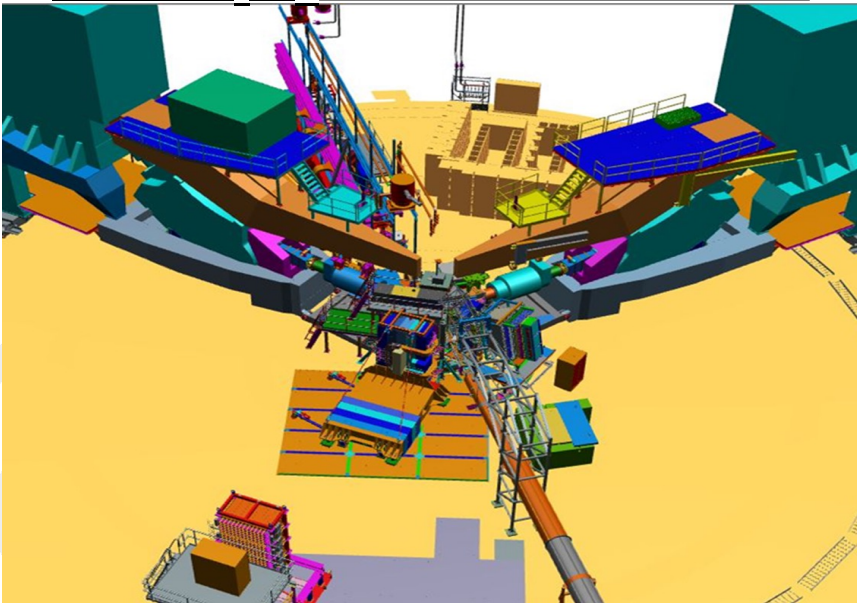
~7 years at ~30 weeks/year

...not including SoLID

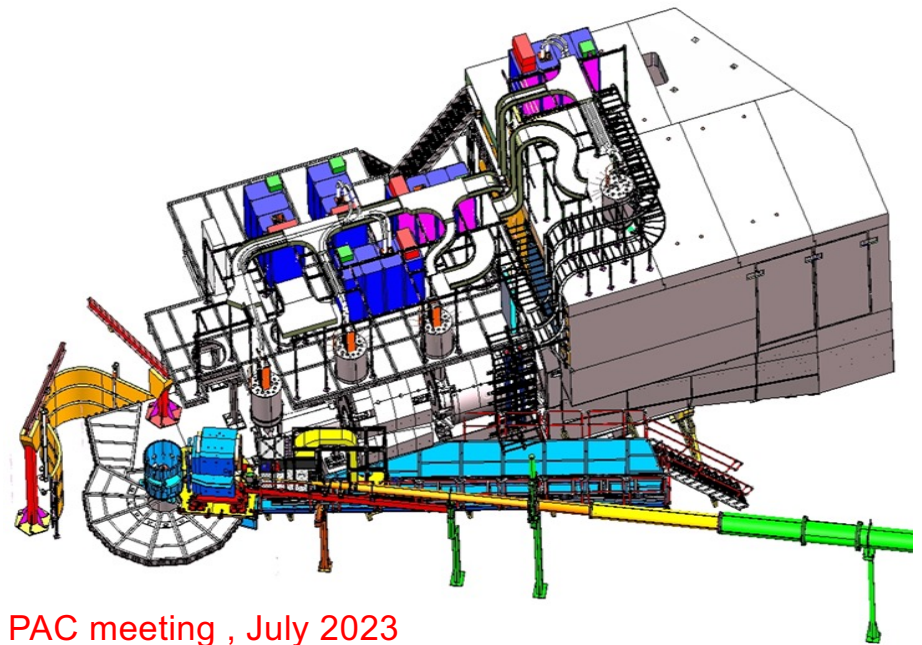
...not including new proposals

Hall A/C Status

Hall A:
Neutron G_E/G_M by Beam-target Asymmetry



Hall C:
Neutral Particle Spectrometer

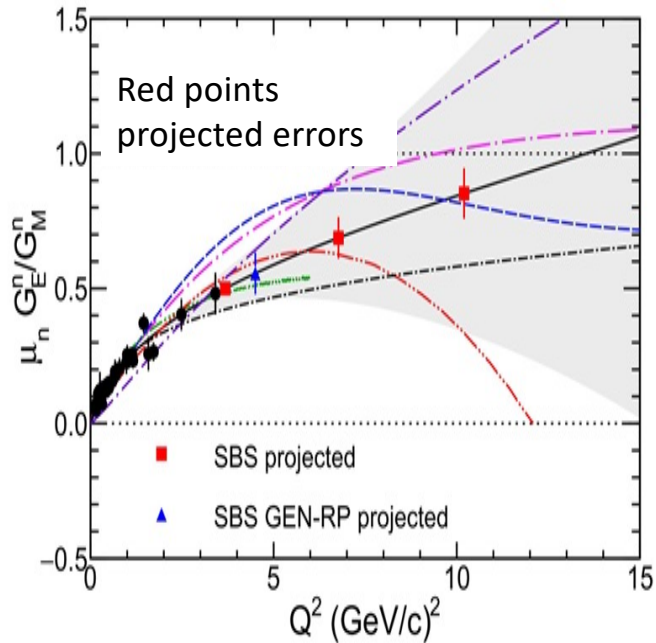


Mark Jones, Hall A/C Group Leader, PAC meeting , July 2023
Bob Michaels, Hall A/C Deputy Group Leader

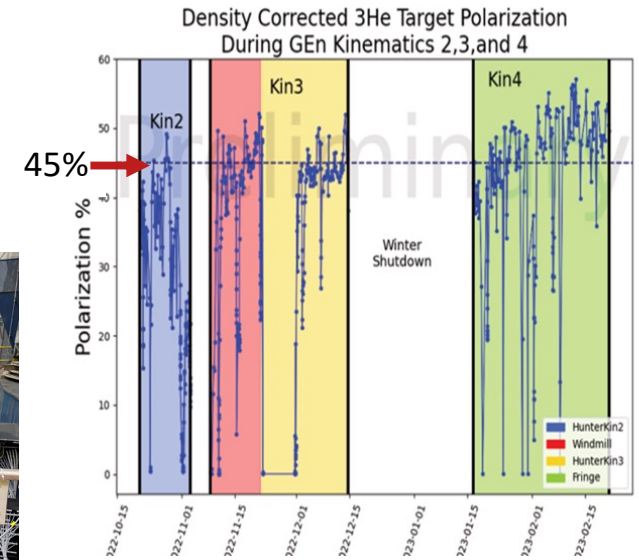
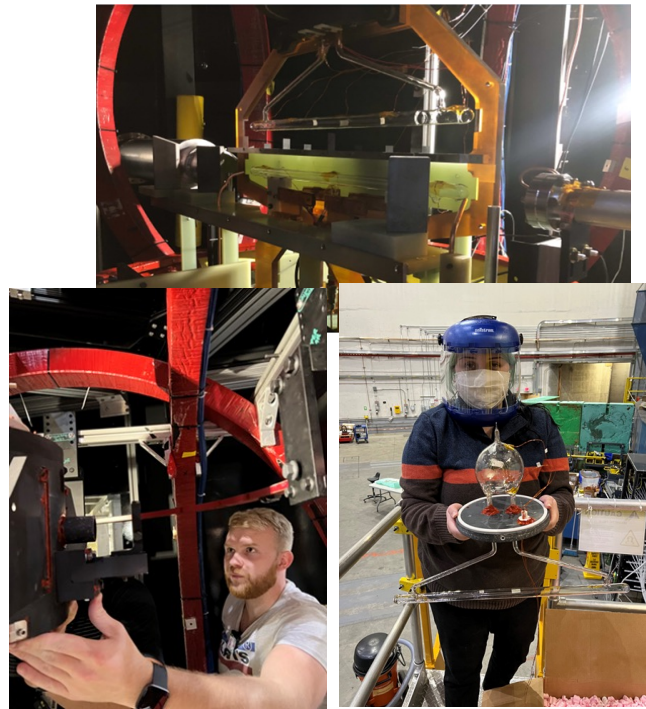
Hall A: Past Year's Experiments (July 2022- March 2023)

Neutron G_E/G_M by Beam-target Asymmetry on polarized ^3He

- Started in Oct 2022
 - Completed $Q^2 = 2.9$ and 6.6 GeV^2
 - $Q^2 = 9.9 \text{ GeV}^2$ is partially done.
 - Complete final 6 weeks running from Sept 2023-Nov 2023



- Polarized ^3He target
 - First time running with 60cm long ^3He cell
 - 50-55% polarization in beam!



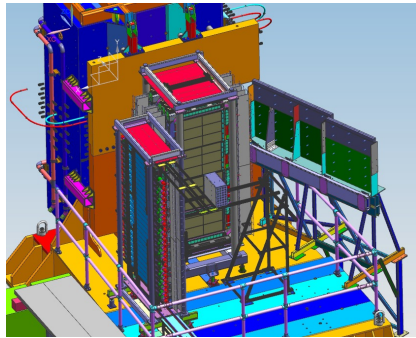
Hall A : Plan for coming years (Jan 2024 – July 2025)

Neutron G_E/G_M by recoil polarization

- Switch from 3He to LH2/LD2
- Plan to start in Spring 2024, $Q^2 = 4.5$



Test of SBS GEMs during 3He GEN.

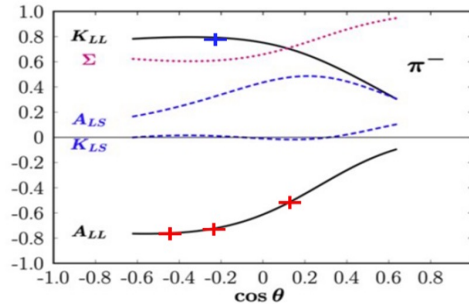


Polarimeter layout

Pion photo-production on neutron

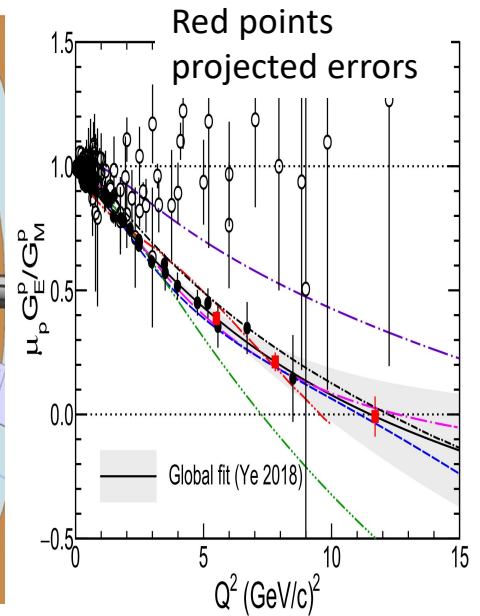
Short experiments

- Beam-target asymmetry, A_{LL}
- Recoil polarization, K_{LL}



Proton G_E/G_M by recoil polarization

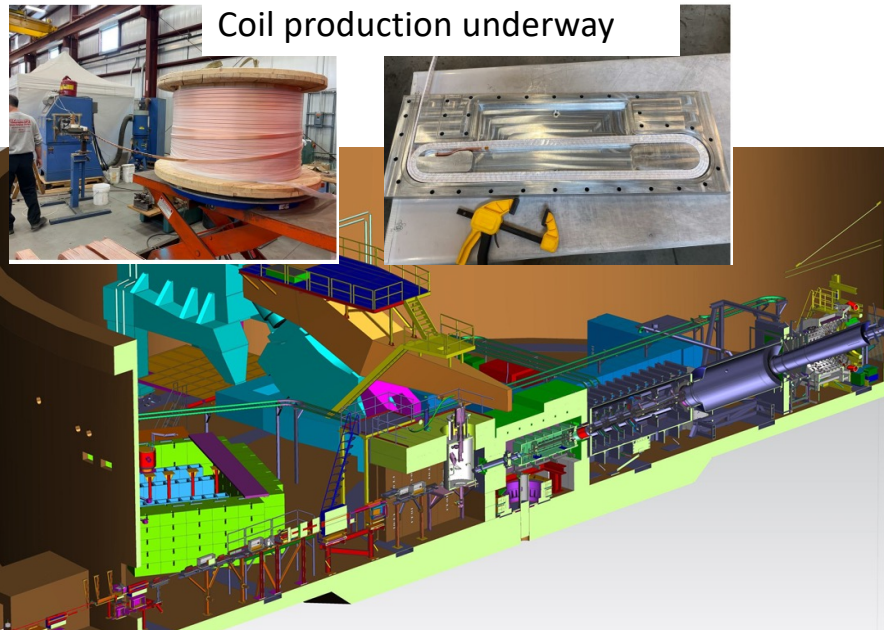
- ECAL platform is in Hall A and plan to start stacking in August.
- After Neutron Recoil Polarization is completed
 - Need about 6 months for installation
- Experiment will run in late 2024 to spring 2025.



Hall A : Plans beyond July 2025

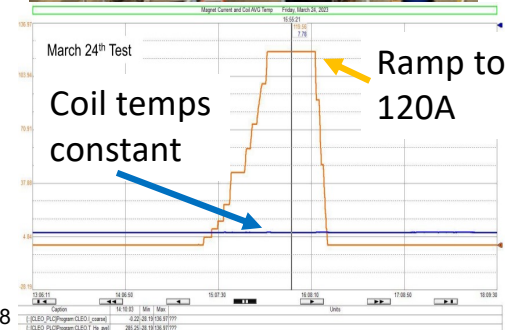
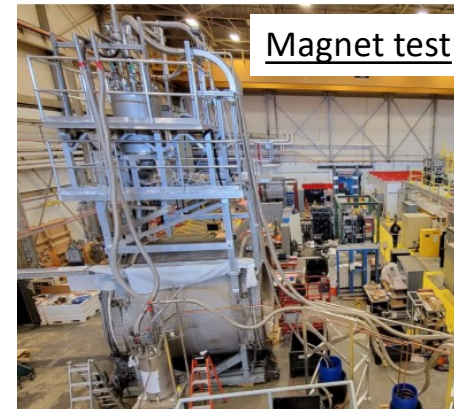
MOLLER

- Inflation Reduction Act provided full funding.
- In Jan 2023, passed CD-3A review and spending CD-3A funds.
- CD2 /CD3 review in October 2023.
- Aggressive installation schedule of 18 months after GEp run ends
- 3 years of running. Starting in Fall 2026
- Reuben Fair is new PM, Klaus Dehmelt is new DPM (Sept 1).

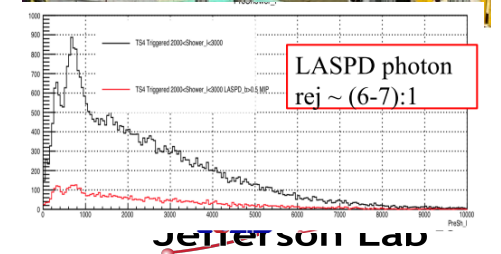
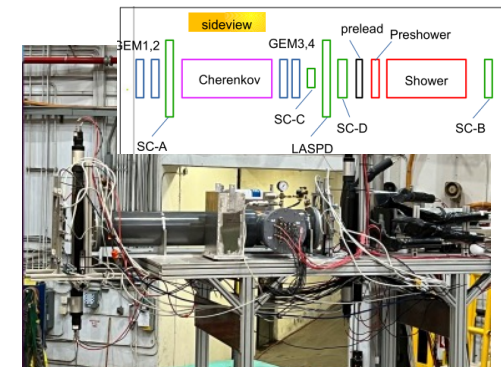


SoLID

- CLEO magnet cold test at 120A completed.
- High rate test of SoLID detector. Set at 8° and 17° in Hall C.
- SoLID mentioned in Recommendation 1 in the Hot/Cold QCD and the recommendations of FSNN LRP town meetings

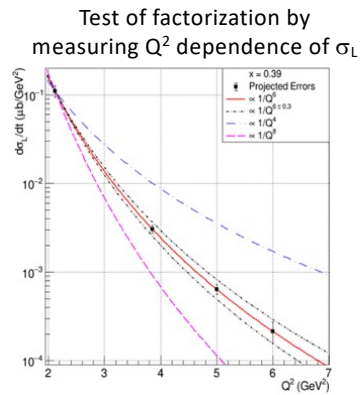
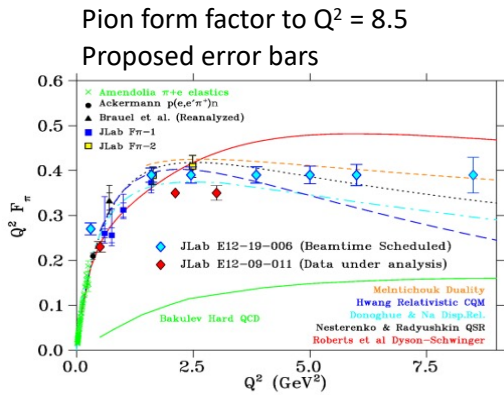


High rate test



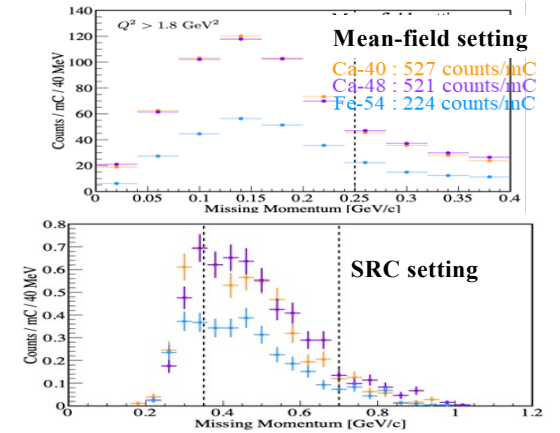
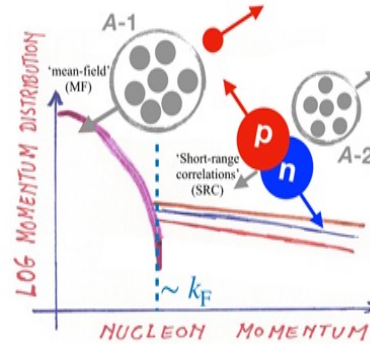
Hall C: Past Year's Running (July 2022-March 2023)

E12-19-006 : Ran from June to mid Sept to complete high ε points to match low ε points taken the previous run cycle.



• **E12-17-005** : Ran at the end of Sept 2022 for two weeks

Compare 40Ca, 48Ca, 54Fe

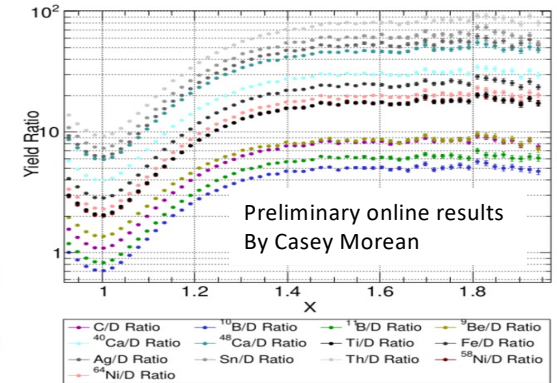
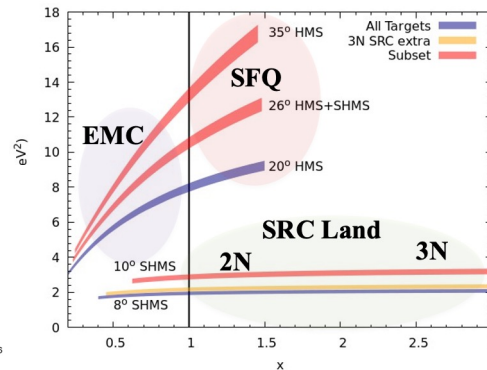
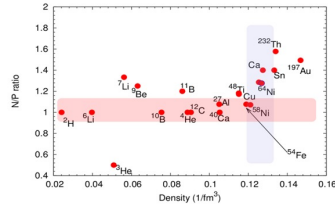


E12-10-008 Study EMC effect over range of nuclei

- 6Li and 7Li added to light nuclei already measured
- Flavor dependence with 40Ca and 48Ca

E12-06-105 Inclusive Scattering from Nuclei at $x > 1$

- Precision measurement of 2N SRC
 - A-dependence in light nuclei
 - Variation with neutron excess
 - Connect EMC effect and SRC
- First observations of 3N SRC
- Nuclear PDFs at $x > 1$ and look for superfa



E12-10-003 Deuteron Electro-Disintegration at Very High Missing Momentum

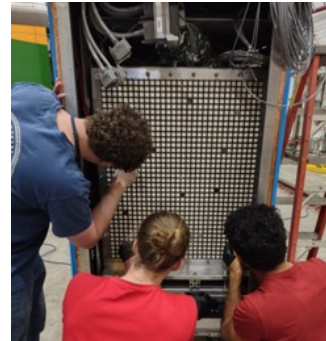
Hall C : Plan for next year (July 2023- July 2024)

Neutral Particle Spectrometer

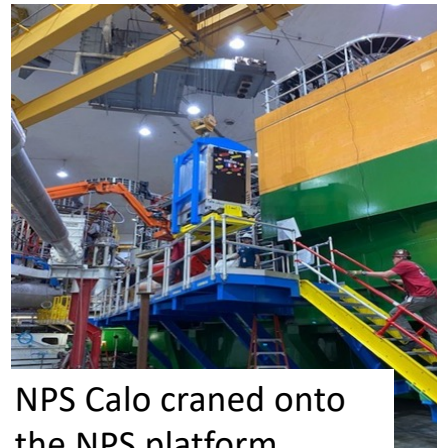
- Sweeping Magnet with calorimeter.
 - Magnet and power supply have been tested.
- NPS attached to SHMS carriage to allow easy angle change.
 - The calorimeter is on rails, cabled and taking cosmics.
- 1080 Lead-Tungstate blocks in calorimeter to detect γ and π^0

Two experiments using the NPS

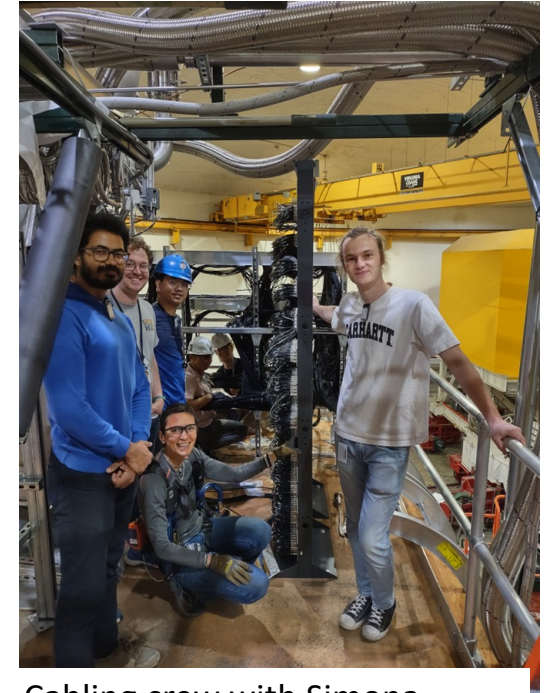
- [E12-13-010](#) is two concurrent experiments
 - Exclusive Deeply Virtual Compton on proton
 - SIDIS (e, e', π^0) cross section.
 - Map the transverse momentum dependence.
- [E12-22-006](#)
 - Exclusive Deeply Virtual Compton on deuteron
 - Subtract the proton data from deuteron data to get neutron.
- Proposal PR12-23-014 would be a new run group that measures $R = \sigma_L / \sigma_T$ in SIDIS (e, e', π^0) cross section.



Students putting fiducial marks on Calo



NPS Calo craned onto the NPS platform

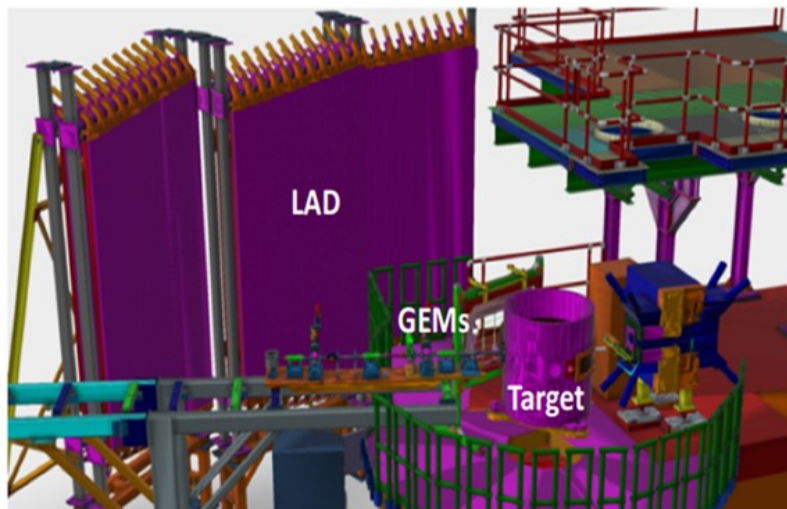


Cabling crew with Simona Malace who has led the installation of NPS Calo

Hall C: Plans beyond July 2024

Experiments to run in Fall 2024- Spring 2025

- Standard SHMS/HMS
 - [E12-06-104](#) $R=\sigma_L/\sigma_T$ in SIDIS on 1H and 2H
 - [E12-06-107](#) Complete CT experiment
 - [E12-11-107](#) Spectator tagged DIS $d(e,e'p_s)$
Install Large Angle Detector
HMS/SHMS detect electron



Fall 2025 and beyond

- **Depends on PAC recommendations**
- Starting in Fall 2025
 - Standard SHMS/HMS experiments.
 - Experiments with non-standard beam energies
 - New proposals
- Running during MOLLER and after:
- During MOLLER, limits on total target power and beam current in the two halls
 - Hypernuclear experiments in 2026
 - Polarized deuteron experiments
 - WACS and other experiments using the NPS
 - Experiments using the Compact Photon Source
 - Capital project is ongoing
 - SBS/BB experiments that did not run in Hall A
 - Exciting new letters of intent
- Future plans will incorporate needs of the other halls and target group resources.

Hall B Status Report

1. Status of Hall B Group
2. Status of CLAS12 Detector and Experimental Hall
3. Status of Run Groups, Data Processing & Analyses
4. Status of Experiment Schedule

With Backup Slides for more Details

Patrick Achenbach
July 2023

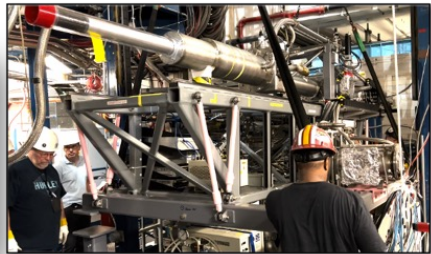


Hall B Experimental Setup 2022–23

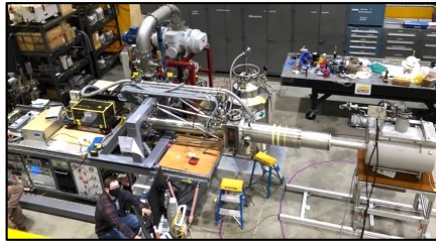
Longitudinally polarized cryo-target inside solenoid
 Multiple configurations: NH_3 , ND_3 , C, CH_2 , CD_2 , ...



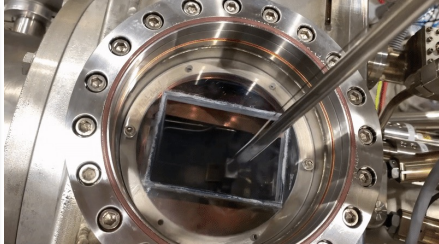
Thermoluminescence of target material



Installation in Hall B, June 2022



Testing in Target Lab, March 2022



Rapid exchange of target samples

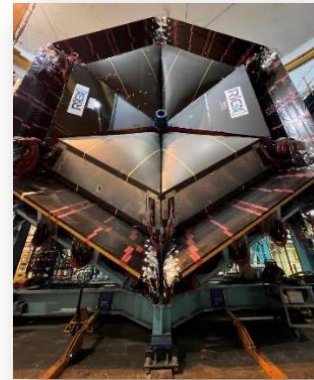
Proton		Deuteron	
Polarization	78.87%	Polarization	47.17%
Signal Area	-0.485024	Signal Area	-0.300473

< ~ 80% H polarization
 < ~ 45% D polarization
 DNP by 140 GHz μ waves
 1 K with ^4He refrigerator

Forward Tagger
 Replaced with ...
 ... Møller shield

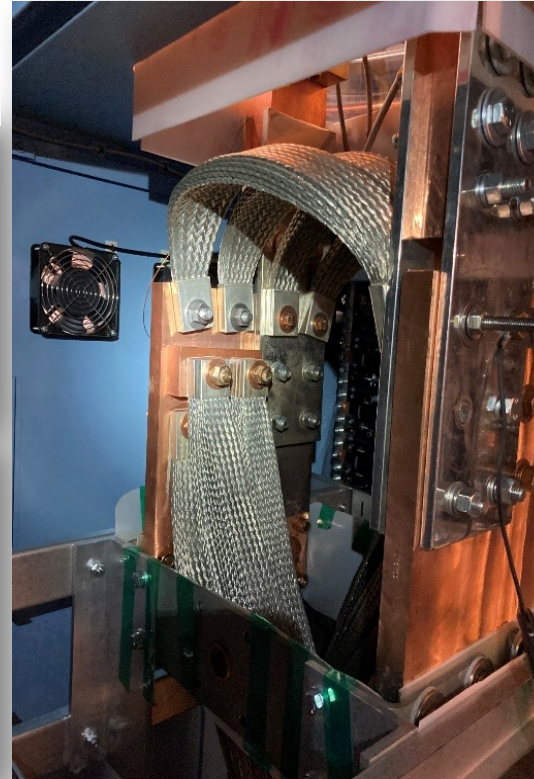


Additional 2nd sector **RICH**
 coverage with 50,048 channels



Solenoid Power Supply Failure in Fall 2022

**Polarity reversal at $I > 1$ kA
sparked, melted copper links
and contacts on 11 Nov 22**



Team from Danfysik, DC
Power, Hall B, DSG



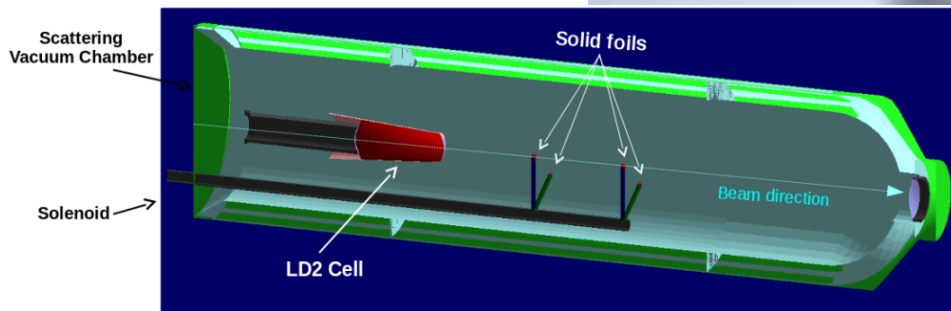
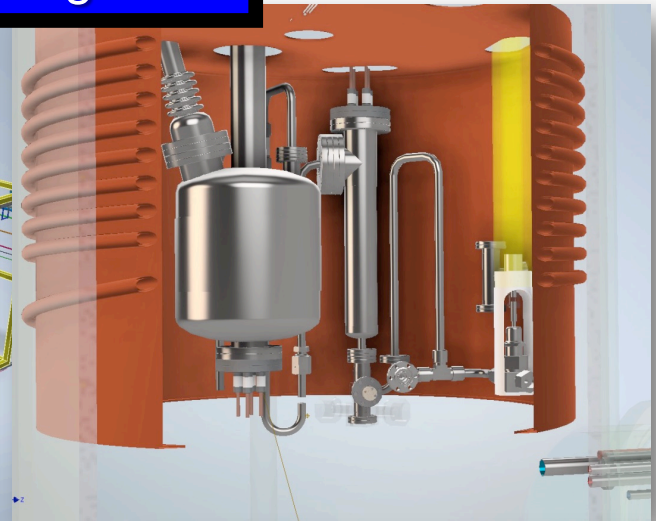
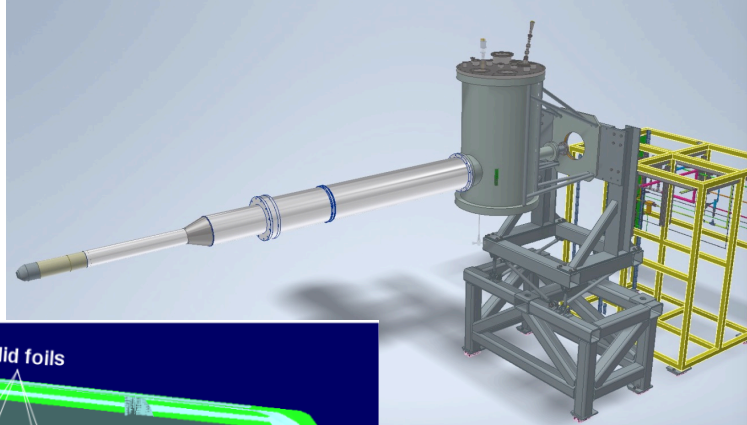
Repair completed 30 Jan 23

Hall B was down for 80 days from Nov 22 to Feb 23 →
Scheduled run for RG-C (240 cal. days) could not get completed

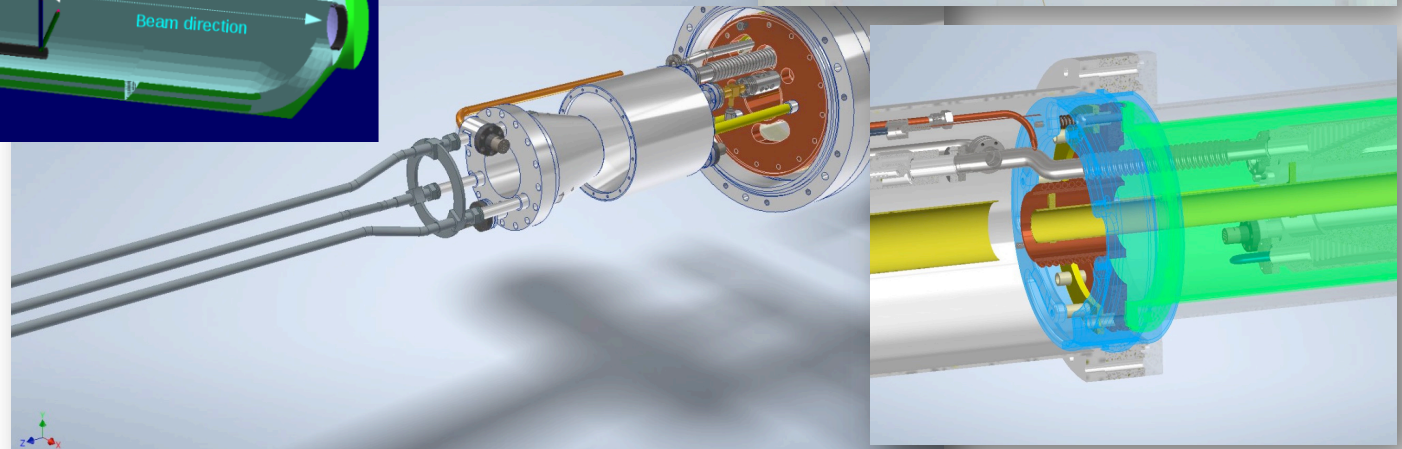
Unpolarized Cryo-Target for Runs Starting 2023

New Modular Design

- Conventional 1 K refrigerator
- Compatibility with existing cells and RG-D/E foil targets
- Solid targets cooling decoupled from cryo-target and cooled by heat shield



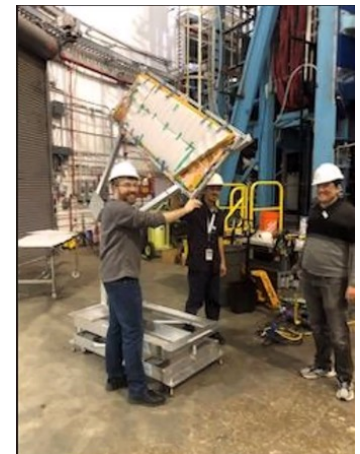
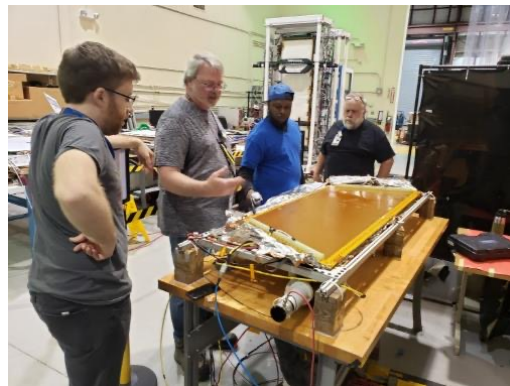
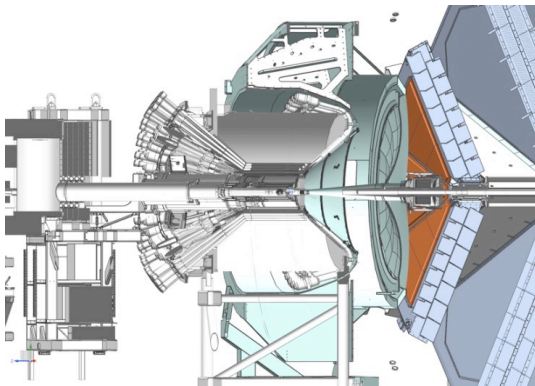
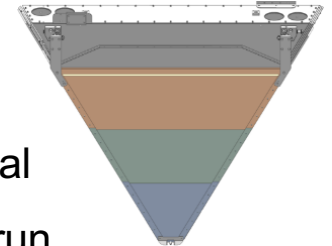
- Nesting conical mount of condenser to He coolant evaporator: Target cell easily removable



μRWELL Development for Luminosity Upgrade

- **μRWELL** with capacitive sharing readout will provide 2D points in front of DC for luminosity upgrade to $L = 2 \times 10^{35} \text{ cm}^{-2} \text{ sec}^{-1}$
- **Simulation** studies with background merging and μRWELL + DC + AI result in improved inefficiency of better than 0.1 % per nA, better than upgrade design goal
- Inconclusive **beam-tests** of a large-area μRWELL during the last days of RG-C run
- **Largest-ever prototype** now at CERN for repairs

μRWELL module



CLAS12 readiness for higher luminosities is key for future success

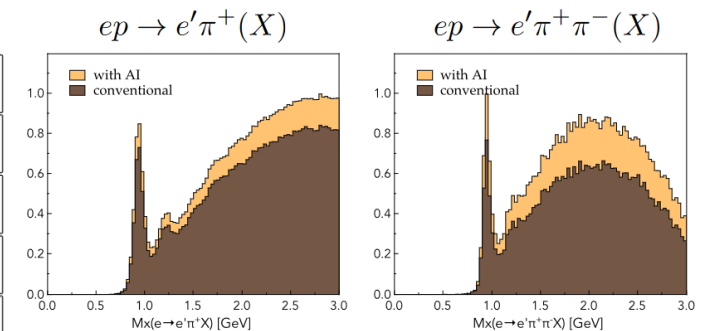
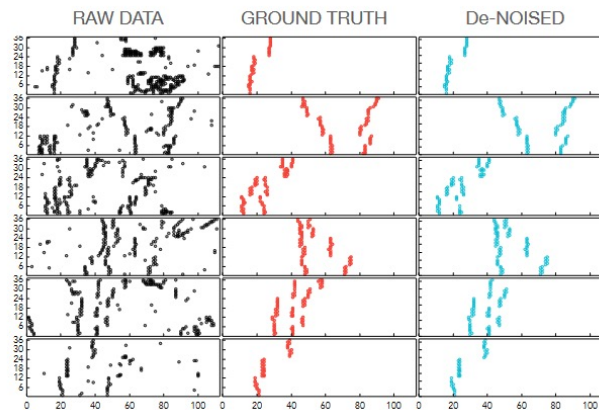
Data Processing Status

With use of latest software including improvements in tracking and reconstruction:

- RG-A: Spr19 **pass-2 cooking completed** (23 June – 13 July)
- RG-B: Spr19 **pass-2 cooking completed** (26 May – 27 June)
- RG-M: pass-1 (with pass-2 software) **cooking in progress** (at 85% since 27 June)
- RG-K pass-2 cooking will come next
- RG-A F18 pass-2 cooking following

Machine Learning Implementations

- Track identification in Drift Chambers
- Drift Chamber Data De-Noising
- RICH Particle Identification



- Up to ~35% gain in physics
- Moving to higher Luminosities

Hall B High-Impact Publications 2022–23

- > 10 CLAS papers published
- 1 HPS paper published
- Several other papers published

PHYSICAL REVIEW D **108**, 012015 (2023)

Searching for prompt and long-lived dark photons in electroproduced e^+e^- pairs with the heavy photon search experiment at JLab

P. H. Adrian,¹ N. A. Baltzell,² M. Battaglieri,³ M. Bondi,⁴ S. Boyarinov,² C. Bravo,^{5,1} S. Bueltmann,³ P. Butti,¹

PHYSICAL REVIEW LETTERS **131**, 021901 (2023)

First Measurement of Hard Exclusive $\pi^-\Delta^{++}$ Electroproduction Beam-Spin Asymmetries off the Proton

S. Diehl,^{14,6} N. Trotta,⁵ K. Joo,⁶ P. Achenbach,¹⁰ Z. Akbar,^{16,12} W. R. Armstrong,¹ H. Atac,¹⁰ H. Avakian,¹⁰ L. Baashen,¹¹

PHYSICAL REVIEW C **105**, 065201 (2022)

Beam-recoil transferred polarization in K^+Y electroproduction in the nucleon resonance region with CLAS12

D. S. Carman,^{20,*} A. D'Angelo,^{19,34} L. Lanza,¹⁹ V. I. Mokeev,⁴⁰ K. P. Adhikari,¹⁴ M. J. Amarian,³¹ W. R. Armstrong,¹

Physics Letters B **927** (2022) 136985

Beam-spin asymmetry Σ for Σ^- hyperon photoproduction off the neutron

CLAS Collaboration

N. Zachariou,^{16,*} E. Munevar,¹⁰, B.L. Berman,^{9,1} P. Bydžovský,³⁶ A. Cieplý,³⁶ G. Feldman,⁹,

Physics Letters B **839** (2023) 137761

A multidimensional study of the structure function ratio σ_{LT}/σ_0 from hard exclusive π^+ electro-production off protons in the GPD regime

S. Diehl,^{14,4} A. Kim,¹ K. Joo,¹ P. Achenbach,¹⁰ Z. Akbar,^{16,1} M.J. Amarian,³⁶ H. Atac,¹⁰,

PHYSICAL REVIEW LETTERS **130**, 142301 (2023)

First Measurement of Λ Electroproduction off Nuclei in the Current and Target Fragmentation Regions

T. Chetry,^{20,13} L. El Fassi,^{20,*} W. K. Brooks,^{41,43,46,43} R. Dupré,²³ A. El Alaoui,⁴⁴ K. Hafidi,¹ P. Achenbach,⁴³

PHYSICAL REVIEW LETTERS **130**, 211902 (2023)

First CLAS12 Measurement of Deeply Virtual Compton Scattering Beam-Spin Asymmetries in the Extended Valence Region

G. Christiaens,^{1,2} M. Defurne,^{1,7} D. Sokhan,^{1,2} P. Achenbach,³ Z. Akbar,⁴ M. J. Amarian,⁵ H. Atac,⁶ H. Avakian,³

PHYSICAL REVIEW C **107**, L061301 (2023)

Letter

Observation of large missing-momentum ($e, e'p$) cross-section scaling and the onset of correlated-pair dominance in nuclei

I. Korover,^{1,7} A. W. Denniston,^{1,7} A. Kiral,¹ A. Schmidt,³ A. Lovato,⁶ N. Rocco,⁷ A. Nikolakopoulos,⁷ L. B. Weinstein,⁴

PHYSICAL REVIEW C **105**, 015201 (2022)

Measurement of charged-pion production in deep-inelastic scattering off nuclei with the CLAS detector

S. Morán,^{1,3} R. Dupré,² H. Hakobyan,^{1,5,2} M. Arratia,³ W. K. Brooks,¹ A. Bórquez,¹ A. El Alaoui,¹ L. El Fassi,^{4,5} K. Hafidi,⁵

PHYSICAL REVIEW LETTERS **128**, 062005 (2022)

Multidimensional, High Precision Measurements of Beam Single Spin Asymmetries in Semi-inclusive π^+ Electroproduction off Protons in the Valence Region

S. Diehl,^{35,6} A. Kim,⁶ G. Angelini,¹³ K. Joo,⁶ S. Adhikari,¹¹ M. Amarian,³³ M. Arratia,⁵ H. Atac,⁴⁴ H. Avakian,⁴⁵

PHYSICAL REVIEW C **105**, L022201 (2022)

Letter

Polarized structure function σ_{LT} from π^0p electroproduction data in the resonance region at $0.4 \text{ GeV}^2 < Q^2 < 1.0 \text{ GeV}^2$

E. L. Isupov,^{36,7} V. D. Burkert,³⁰ A. A. Golubenko,³⁶ K. Joo,⁷ N. S. Markov,^{30,7} V. I. Mokeev,³⁰ L. C. Smith,⁴⁶

PHYSICAL REVIEW LETTERS **129**, 182501 (2022)

Observation of Azimuth-Dependent Suppression of Hadron Pairs in Electron Scattering off Nuclei

S. J. Paul,⁴⁶ S. Morán,⁴⁶ M. Arratia,^{46,42} A. El Alaoui,⁴³ H. Hakobyan,⁴³ W. Brooks,⁴³ M. J. Amarian,³⁴ W. R. Armstrong,¹

PHYSICAL REVIEW C **107**, 015201 (2023)

Exclusive π^- electroproduction off the neutron in deuterium in the resonance region

Y. Tian,^{1,2,7} R. W. Gothe,¹ V. I. Mokeev,³ G. Hollis,¹ M. J. Amarian,⁴ W. R. Armstrong,⁵ H. Atac,⁶ H. Avakian,³ L. Barion,⁷

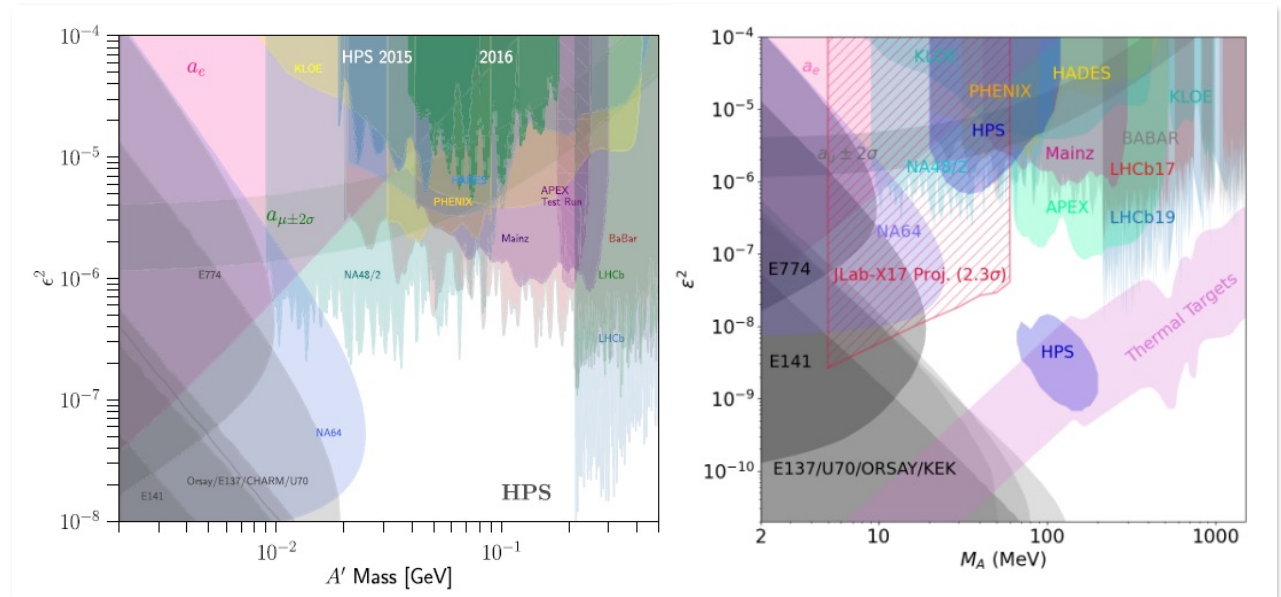
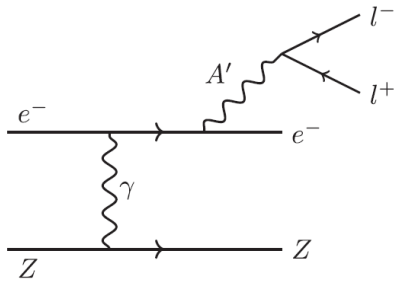
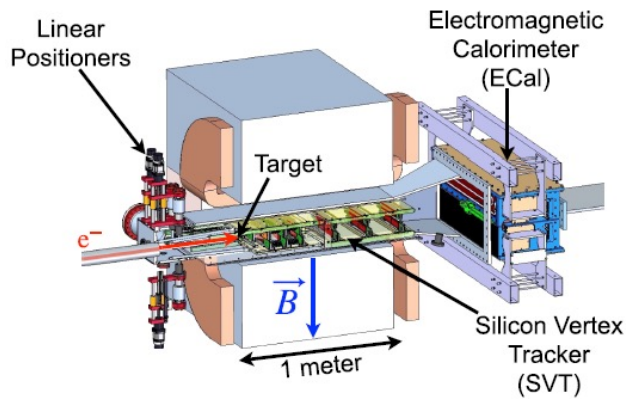
PHYSICAL REVIEW LETTERS **130**, 022501 (2023)

Observation of Correlations between Spin and Transverse Momenta in Back-to-Back Dihadron Production at CLAS12

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A few recent research highlights ...

First Displaced Vertex Analysis in Heavy Photon Search



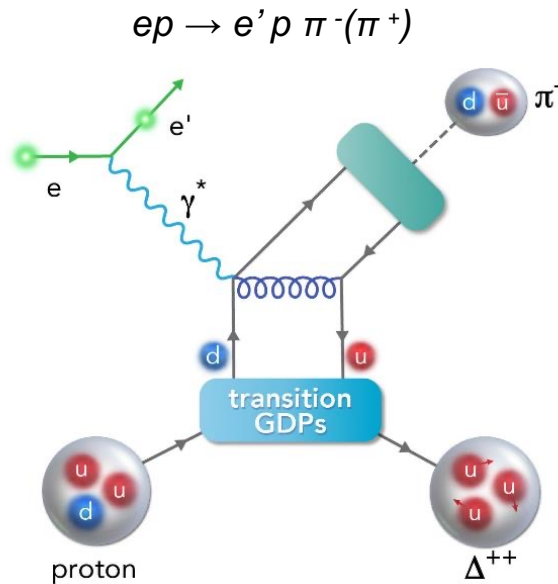
- Including both, bump hunt and displaced vertex search
- Results from 2.3 GeV 2016 engineering run
- Excludes A' production over mass range 40 – 180 MeV down to $\epsilon^2 = 10^{-5}$

[P. H. Adrian et al. (HPS Collab.), Phys. Rev. D 108, 012015, 21 July 2023]

Hard Exclusive $\pi\Delta^{++}$ Electro-Production off Protons

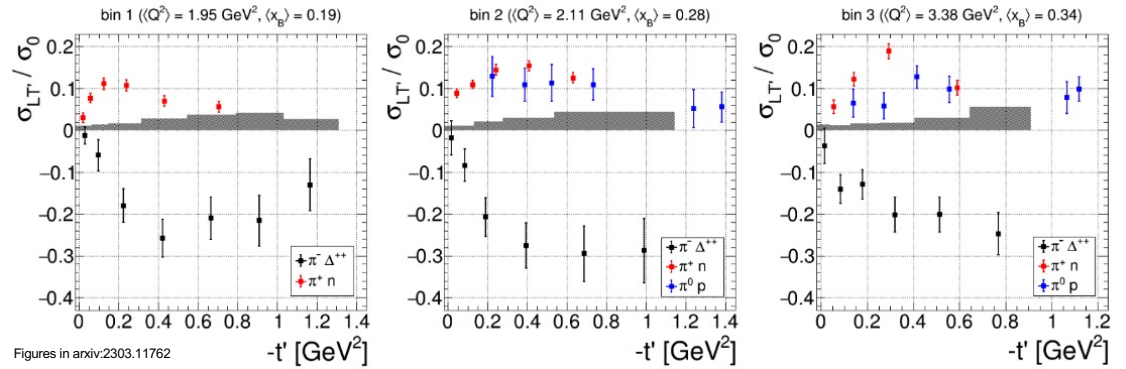
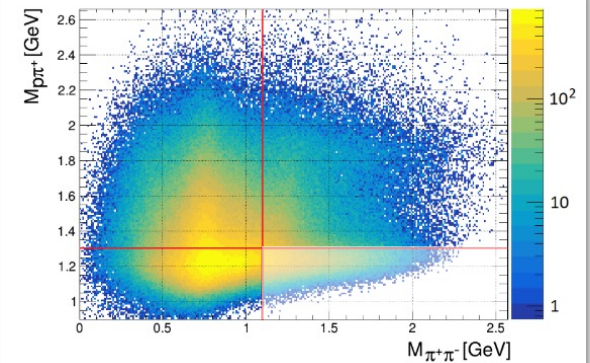
Transition GPDs

Generalizing GPDs to $N \rightarrow \Delta$ processes



$$BSA = \frac{\sqrt{2\epsilon(1-\epsilon)} \frac{\sigma_{LT'}}{\sigma_0} \sin \phi}{1 + \sqrt{2\epsilon(1+\epsilon)} \frac{\sigma_{LT}}{\sigma_0} \cos \phi + \epsilon \frac{\sigma_{TT}}{\sigma_0} \cos 2\phi}$$

- Exploratory measurement
- No other world data
- Access to transversity transition GPDs: 3D structure on resonances
- Access to d -quark content of the nucleon



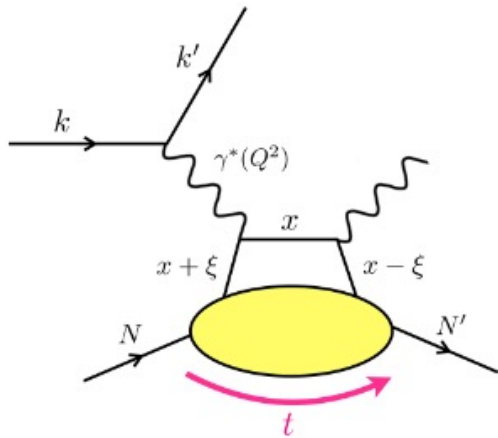
[S. Diehl et al. (CLAS Collab.), Phys. Rev. Lett. 131, 021901, 11 July 2023]

DVCS Beam-Spin Asymmetries

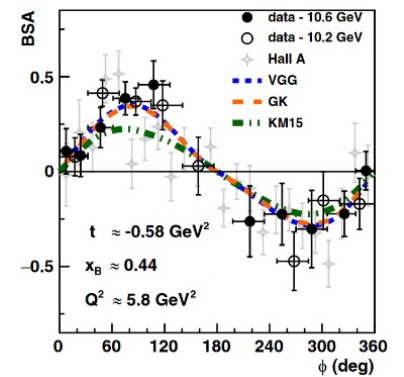
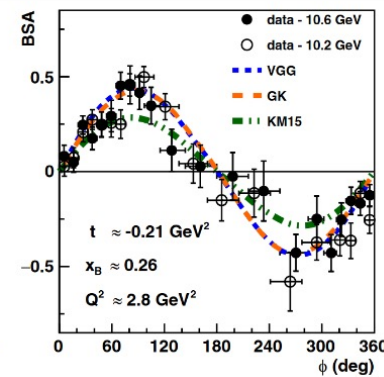
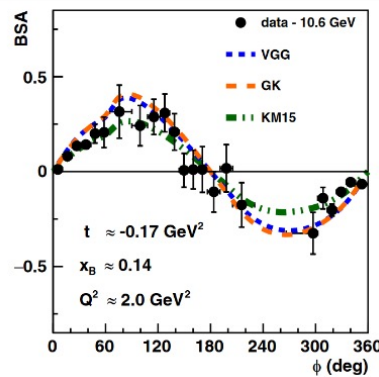
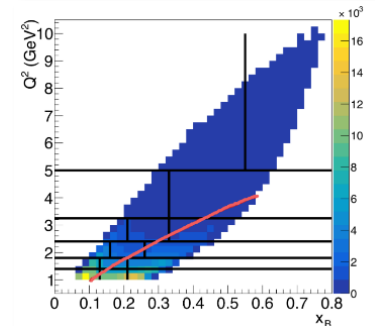
DVCS

Addressing Compton Form Factors, constraints on GPDs, and mechanical properties of the proton such as pressure and force distributions

$$ep \rightarrow e'p'\gamma$$



- 1600 new BSA data points
- 25% of total beam time for CLAS12 DVCS experiment on unpolarized proton
- First measurement of the DVCS beam-spin asymmetry using CLAS12
- Extending Q^2 and Bjorken- x phase space

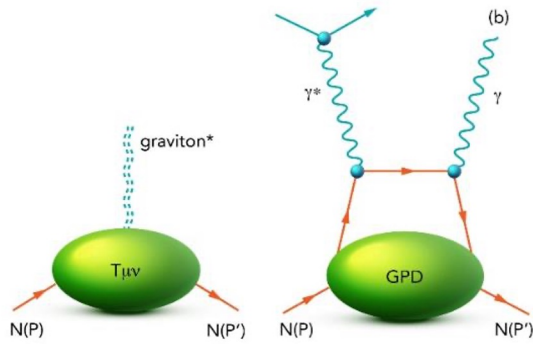


$$A_{LU} \propto \text{Im} \left[F_1 \mathcal{H} + \xi (F_1 + F_2) \tilde{\mathcal{H}} - \frac{t}{4M^2} F_2 \mathcal{E} \right]$$

[G. Christiaens et al. (CLAS Collab.), Phys. Rev. Lett. 130, 211902, 25 May 2023]

First Determination of Distribution of Forces in the Proton

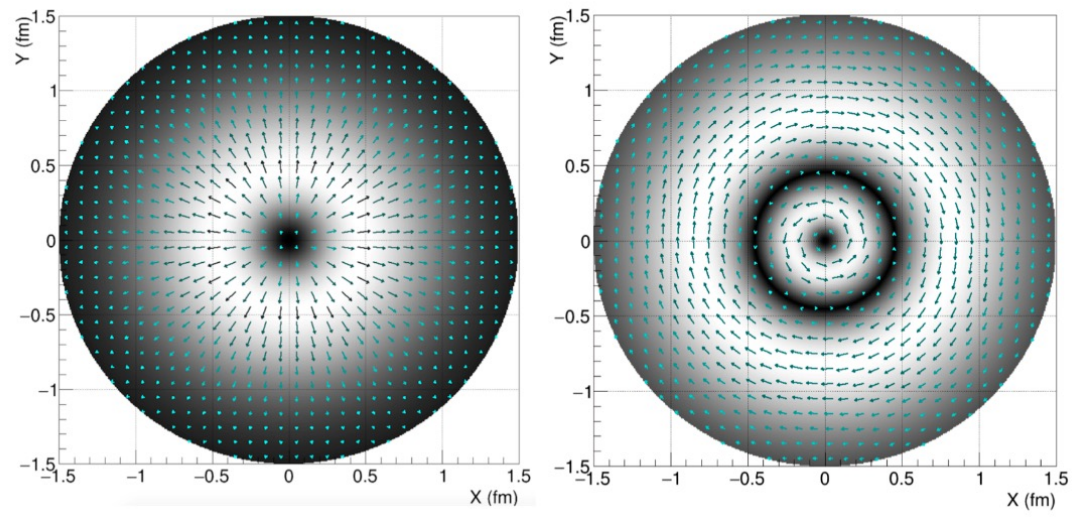
$$\langle p_2 | \hat{T}_{\mu\nu}^q | p_1 \rangle = \bar{U}(p_2) \left[M_2^q(t) \frac{P_\mu P_\nu}{M} + J^q(t) \frac{i(P_\mu \sigma_{\nu\rho} + P_\nu \sigma_{\mu\rho}) \Delta^\rho}{2M} + d_1^q(t) \frac{\Delta_\mu \Delta_\nu - g_{\mu\nu} \Delta^2}{5M} \right] U(p_1)$$



Graviton coupling to the proton

Deeply Virtual Compton Scattering (DVCS)

Distribution of forces as function of distance from proton center



Normal forces

Tangential forces

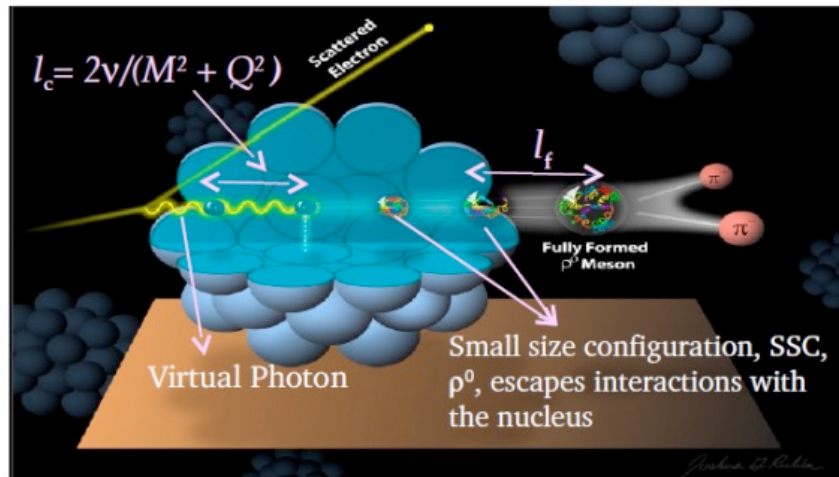
$$\int dx x [H(x, \xi, t) + E(x, \xi, t)] = 2J(t)$$

$$\int dx x H(x, \xi, t) = M_2(t) + \frac{4}{5} \xi^2 d_1(t),$$

[V. D. Burkert et al., submitted to Rev. Mod. Phys. (2023)]

Updated Tentative Run Group Scheduling

Disentangling Color Transparency Effects and Hadronization in the Nuclear Medium



- Data-taking **2023**: Experiments with CLAS12 probing incoherent ρ meson electroproduction off nuclei
- Data-taking **2024**: Study of quark propagation and hadron formation in the nuclear medium

- **RG-D**: Sep to Nov 2023, ~30 PAC days to **complete**
- **RG-K**: Nov to Dec 2023, and Jan to Mar 2024 to reach ~50% PAC days
- **RG-E**: Mar to May 2024, to reach ~ 50% PAC days
- 2024 SAD for installation of ALERT
- **RG-L**: Sep to Dec 2024, ~55 PAC days to **complete**
- Spring 2025 to be discussed
- 2025 SAD for setup/target change

Remaining PAC days for run groups

- RG-A: >70 PAC days
- RG-B: +/- 40 PAC days
- RG-C: +/- 25 PAC days
- RG-E: 30 PAC days
- RG-M: 10 PAC days

Not scheduled

- Non-CLAS12 expts: PRad-II, π^0 TFF, X17
- CLAS12 expts: Polarized He-3, H-3 and He-3, transverse polarized H/D, long. polarized LiH/LiD

Final Remarks

- First polarized target experiment with CLAS12 was successfully performed in Run Group C
- Run Group D to start in September with a completely refurbished unpolarized cryo-target
- Pass-2 cooking started with AI-assisted software upgrades and is progressing well
- CLAS and HPS published several papers in high-impact journals
- Four Hall B proposals to PAC51:

Two proposals for CLAS12 setup:

- RG-K addition and RG-L extension

One proposal for PRad setup:

- Deuteron radius and form factor

Two proposals for CLAS12+ setup:

- 2γ -exchange and pDVCS

One proposal for PRad+ setup:

- Dark photon search

Hall D Report

- 1 Experiments in Hall D, accelerator Schedule for 2023-2025 and outlook
- 2 Publications
- 3 Results close to publication
- 4 Preparations for future experiments

Physics Program in Hall D

Experiment	name	Title	PAC rating	PAC days	data taken
E12-06-102	GlueX-I	Mapping the Spectrum of Light Quark Mesons and Gluonic Excitations with Linearly Polarized Photons	A	120	100%
E12-12-002 A	GlueX-II	A study of meson and baryon decays to strange final states with GlueX in Hall D	A	220	46%
	JEF	Eta Decays with Emphasis on Rare Neutral Modes: The JLab Eta Factory(JEF) Experiment	Grp	100	0%
E12-10-011	PrimeX- η	A Precision Measurement of the eta Radiative Decay Width via the Primakoff Effect	A-	79	100%
E12-13-008	CPP/NPP	Measuring the Pion Polarizability in the $\gamma\gamma \rightarrow \pi\pi$ Reaction	A-	25	100%
E12-19-003	SRC/CT	Studying Short-Range Correlations with Real Photon Beams at GlueX	B+	15	100%
<i>Not yet scheduled</i>					
E12-19-001	KLF	Strange Hadron Spectroscopy with Secondary KL Beam in Hall D	A-	200	
E12-20-011	REGGE	Measurement of the high-energy contribution to the Gerasimov-Drell-Hearn sum rule	A-	33	

- considerable installation / new equipment required

- data taking complete

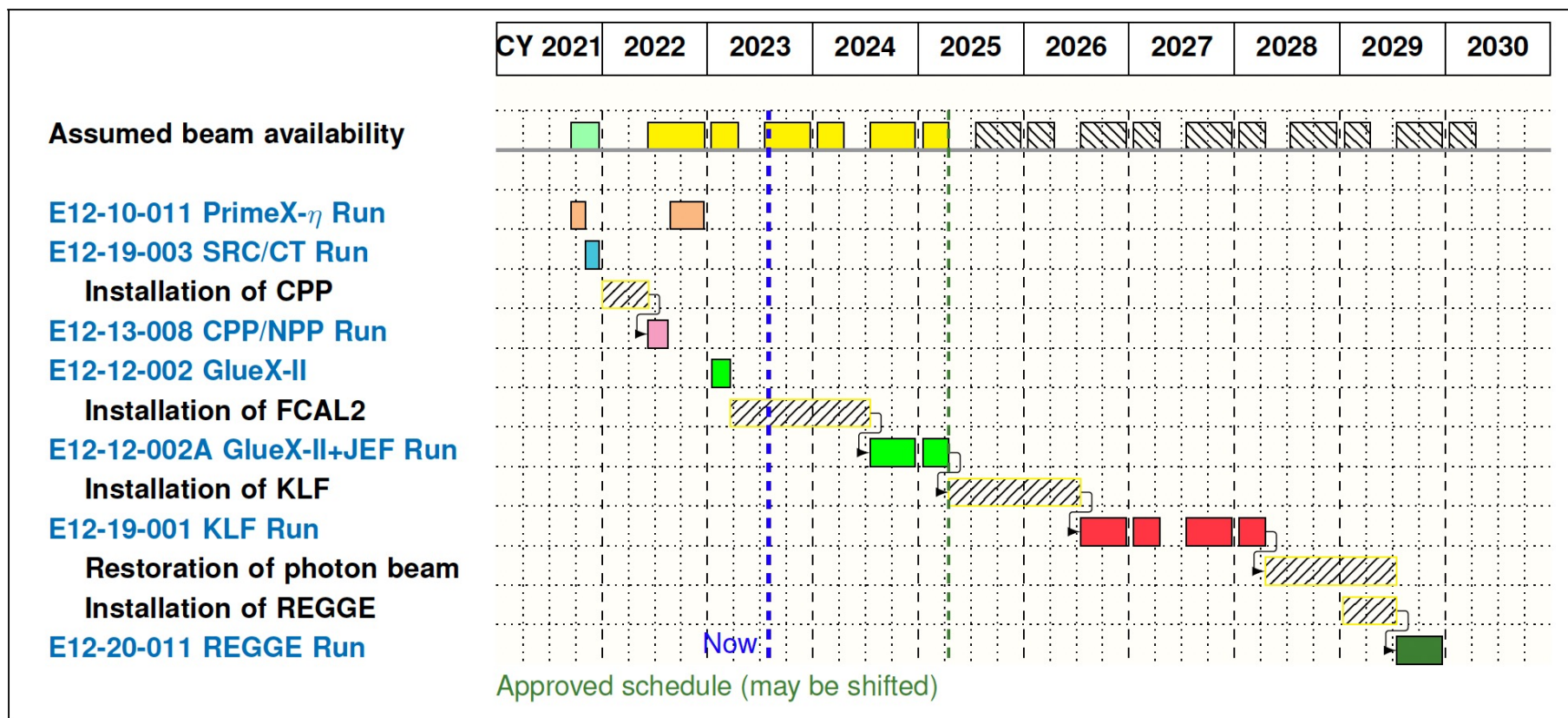
Physics Program in Hall D

Experiment	LOI/proposals to PAC51			PAC days	data taken
E12-06-102				120	100%
E12-12-002				220	46%
A		Eta Factory(JEF) Experiment		100	0%
E12-10-011	PrimeX- η	A Precision Measurement of the eta Radiative Decay Width via the Primakoff Effect	A-	79	100%
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E12-19-003	SRC/CT	Studying Short-Range Correlations with Real Photon Beams at GlueX	B+	15	100%
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- Proposal: SRC/CT
- LOI: GlueX at luminosity frontier
- LOI: GlueX+TRD Spectroscopy + charmonia
- LOI: GlueX GDH on nuclei

■ - considerable installation / new equipment required ■ - data taking complete

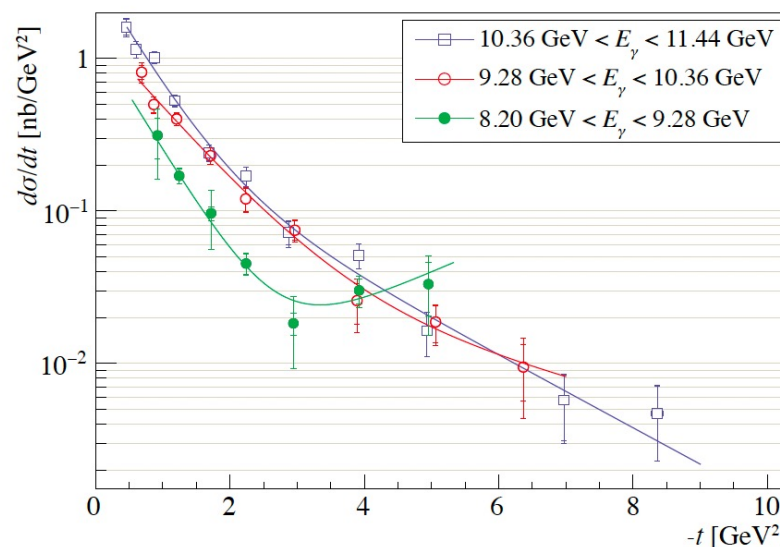
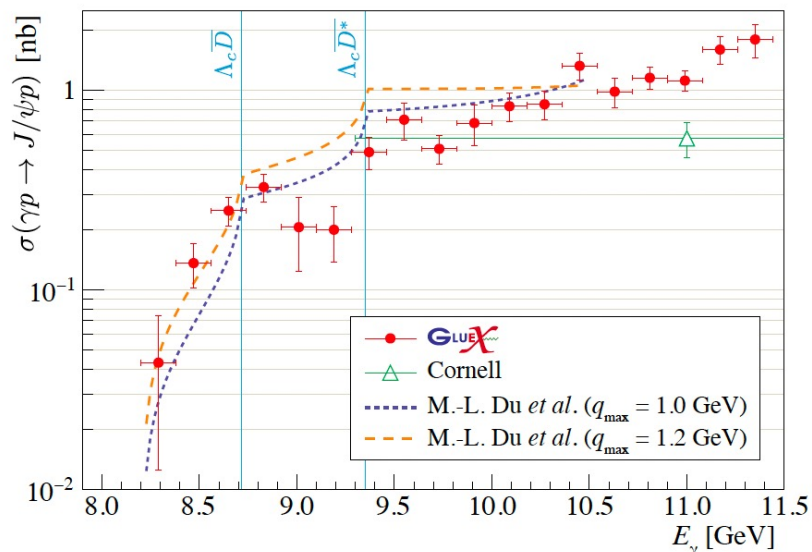
Hall D running schedule: outlook



- Assuming 31 weeks/year for Hall D running in 2024/07-2025/03 and 30 weeks afterwards
- Assuming KLF compatibility with MOLLER, and timing budgeting for KLF and REGGE
- Assuming timely construction of JEF,KLF,REGGE

GlueX E12-06-102: J/ψ production $\gamma p \rightarrow J/\psi p$ ($J/\psi \rightarrow e^+ e^-$)

PRL 123 (2019) 7, 072001 25% of data, >160 citations; new [arXiv 2304.04924 \(2023\) accepted at PRC](https://arxiv.org/abs/2304.04924) full GlueX-I data

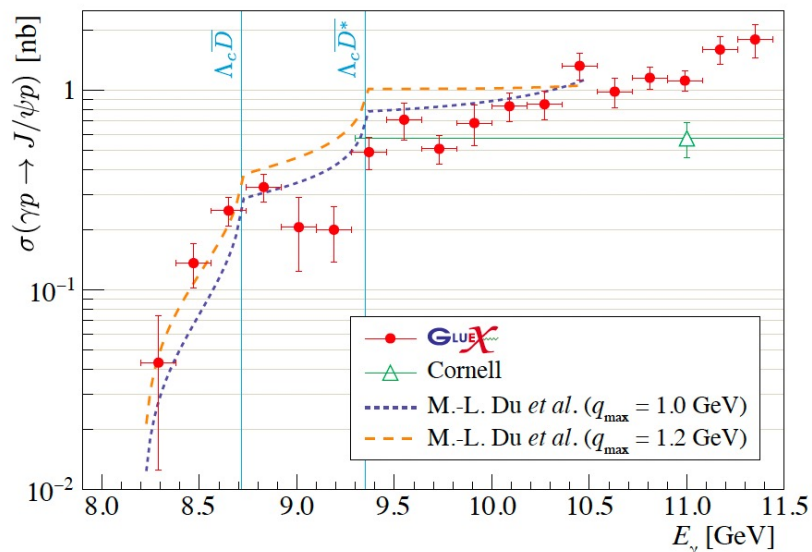


Interpretation is based on the production mechanism

- 2-gluon exchange, factorization
 - ▶ Relation to *gravitational formfactors*, *EMT trace anomaly* - nucleon mass
 - ▶ Relation to nucleon mass radius
- Other possible mechanisms: open charm exchange

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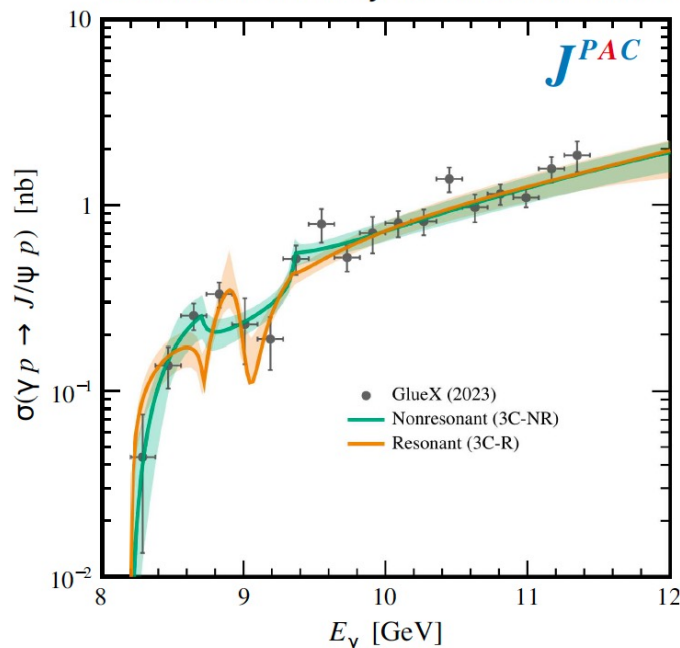


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New GlueX results are used:

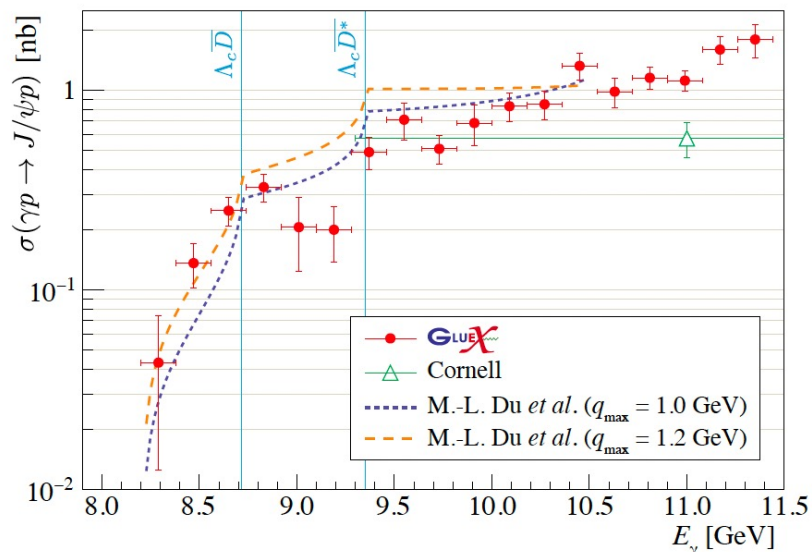
JPAC: D. Winney et al arXiv 2305.01449 (2023)



More data are needed, in particular around the “cusps” at ~ 9 GeV in order to disentangle different production mechanisms

GlueX E12-06-102: J/ψ production $\gamma p \rightarrow J/\psi p$ ($J/\psi \rightarrow e^+ e^-$)

PRL 123 (2019) 7, 072001 25% of data, >160 citations; new arXiv 2304.04924 (2023) accepted at PRC full GlueX-I data

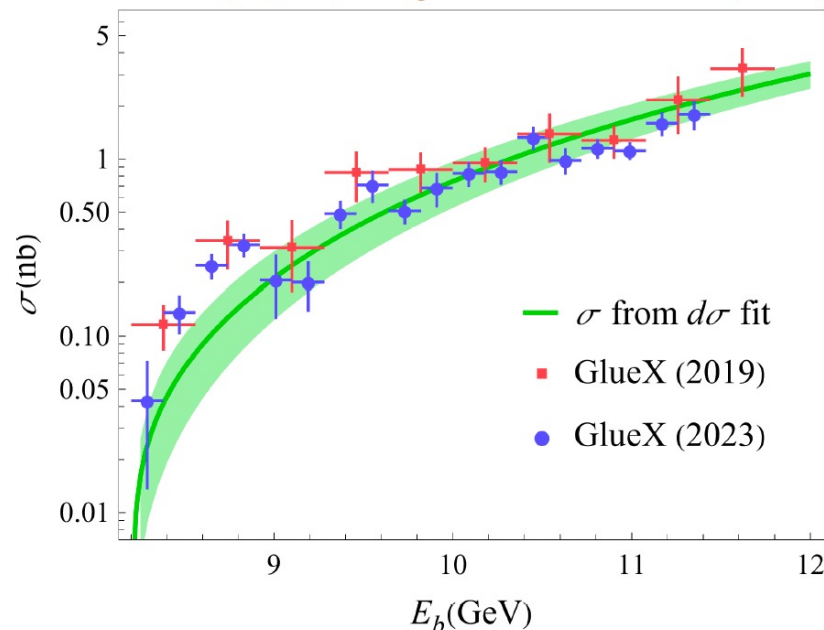


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New GlueX results are used:

Guo, Ji, Liu, Yang arXiv 2305.06992 (2023)

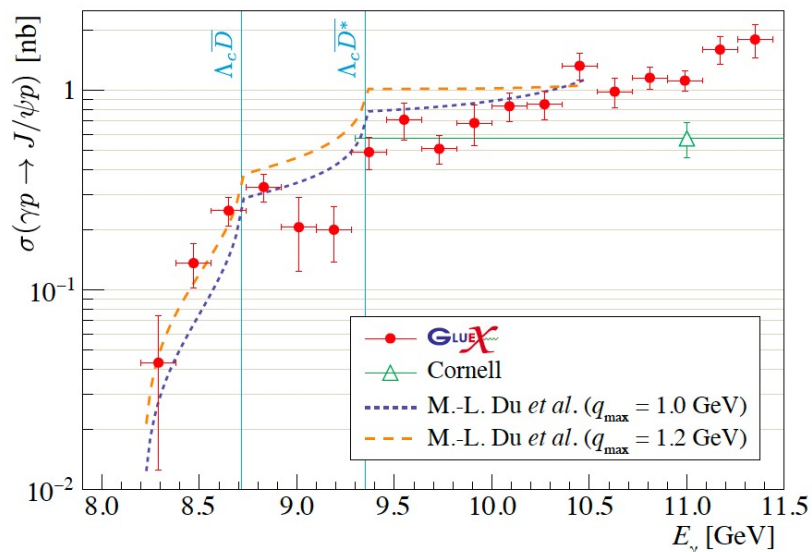


Gravitation formfactors were calculated using $d\sigma/dt$
More quality data at high $|t|$ and high “skewness” are needed

GlueX E12-06-102: J/ψ production $\gamma p \rightarrow J/\psi p$ ($J/\psi \rightarrow e^+ e^-$)

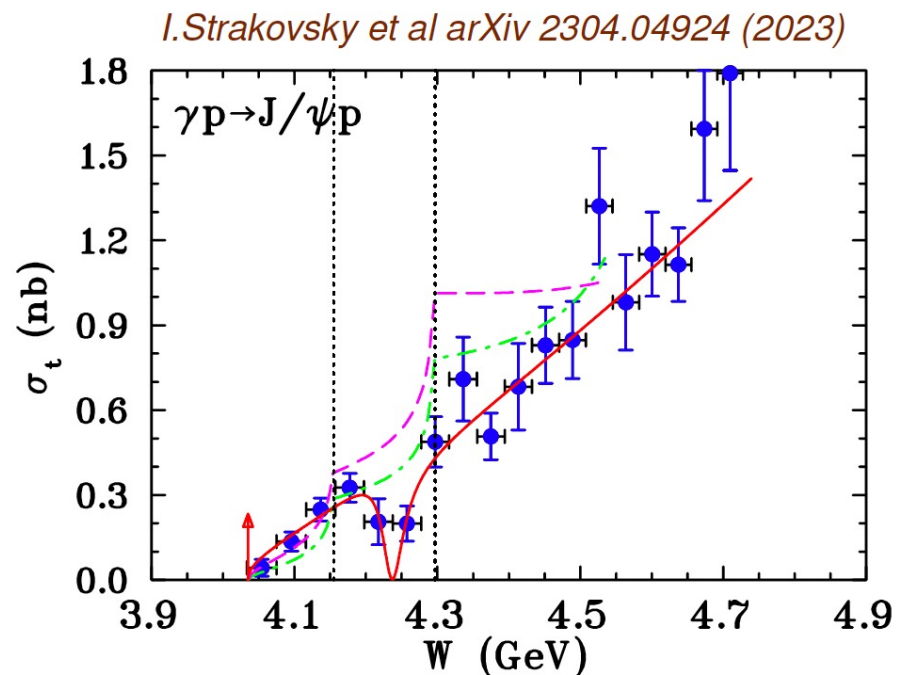
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New GlueX results are used:



Interpretation is based on the production mechanism

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The structure can be caused by destructive interference between the continuum and a LHCb P_C pentaquark. More statistics is needed!

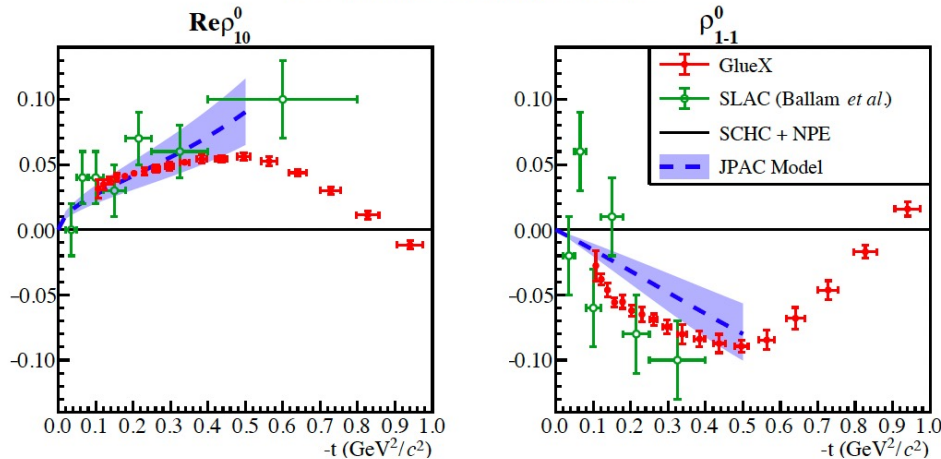
GlueX E12-06-102: Recent results on SDMEs

arXiv 2505.09047 (2023), submitted to PRC

Measurement of SDME in $\rho(770)$ production by linearly polarized photons at 8.2-8.8 GeV

$$\gamma p \rightarrow \rho^0 p, \rho^0 \rightarrow \pi^+ \pi^-$$

2 SDMEs shown, out of 9



- Greatly supersedes the old data in this energy range
- Good matching of the SDME analysis results and amplitude analysis results: foundation for hybrid meson search
- Enables modeling of production of known resonances

E.Chudakov

PAC51, Jul 2023

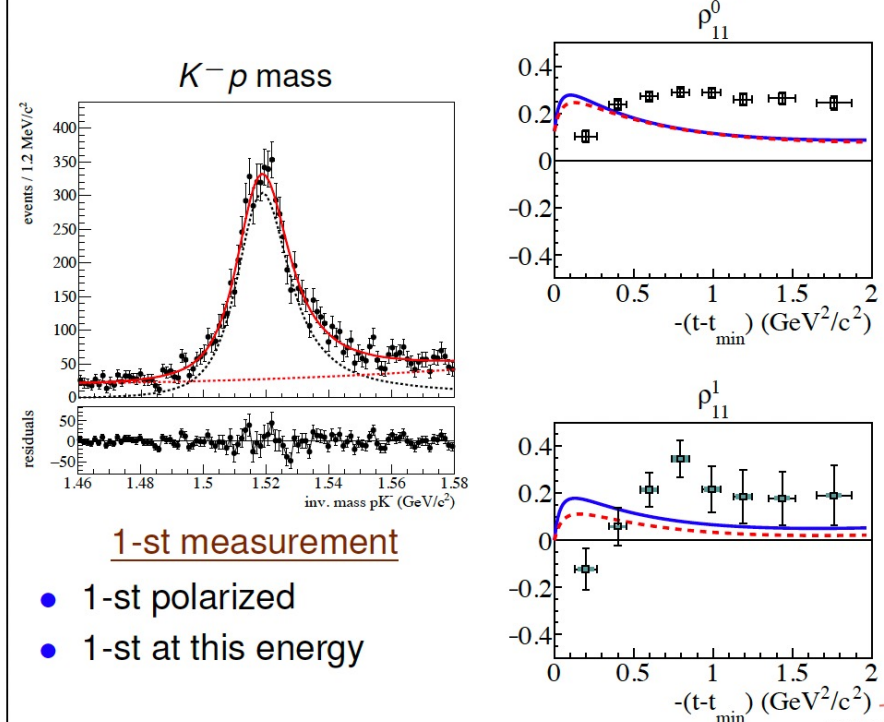
Hall D Report

PRC 105, 035201 (2022)

Measurement of SDME in $\Lambda(1520)$ Photoproduction at 8.2-8.8 GeV

$$\gamma p \rightarrow \Lambda(1520) K^+, \Lambda(1520) \rightarrow K^- p$$

2 SDMEs, out of 9



1-st measurement

- 1-st polarized
- 1-st at this energy

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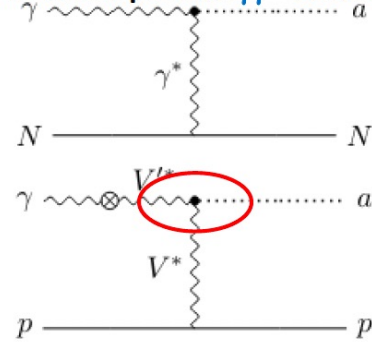
Jefferson Lab

GlueX E12-06-102: Results of exotics

PRD 105, 052007 (2022)

Search for photoproduction of axion-like particles at GlueX

Primakoff process $\gamma\gamma \rightarrow a$ coupling

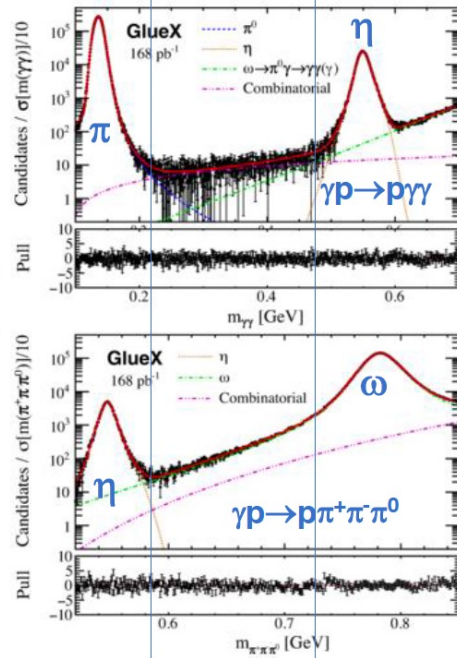


Photopr. process $gg \rightarrow a$ coupling

Search for peaks in the mass spectra of the final states:

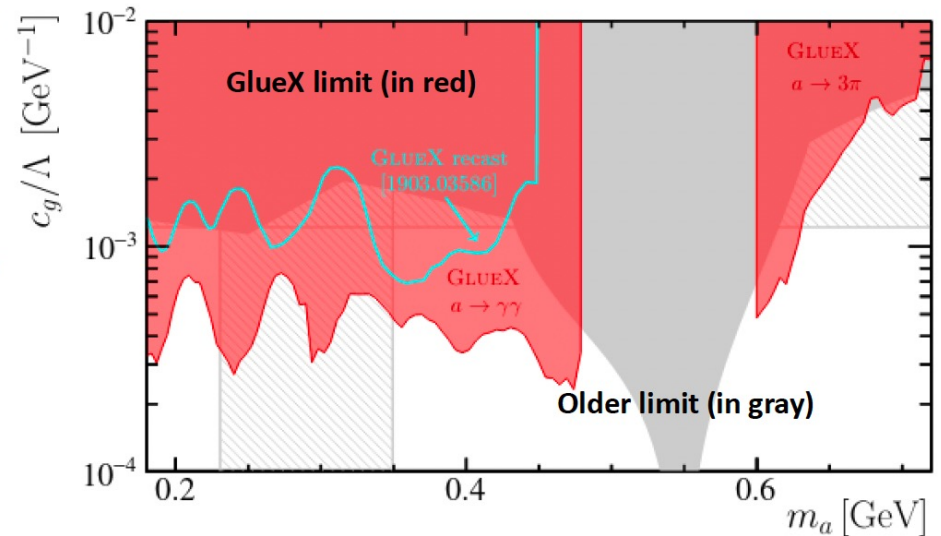
$\gamma\gamma$ and $\pi^+\pi^-\pi^0$

Search range



Search for Axion-like particles

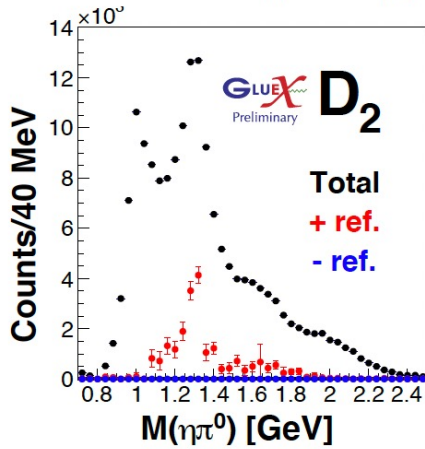
- Recent interest to ALP at Λ_{QCD} mass scale
- Such ALP would solve the CP problem in QCD
- $m_a > \Lambda_{\text{QCD}}$ is robust against UV contributions
- Measured limit on the ALP coupling with gluons c_g/Λ



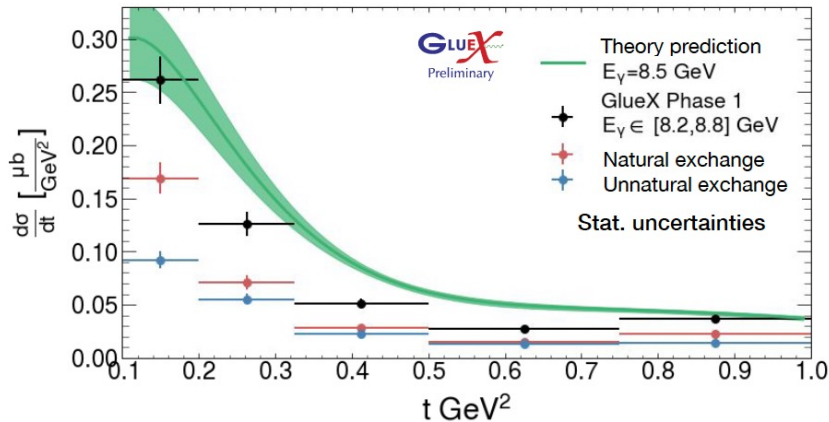
GlueX E12-06-102: Results close to publication

Photoproduction of $a_2(1320)$ at 8.2-8.8 GeV

$$\gamma p \rightarrow a_2(1320)p, a_2 \rightarrow \eta\pi$$



- Full amplitude analysis
- The dominant D-waves for 2 reflectivities
- A milestone for hybrid search



E.Chudakov

PAC51, Jul 2023

Hall D Report

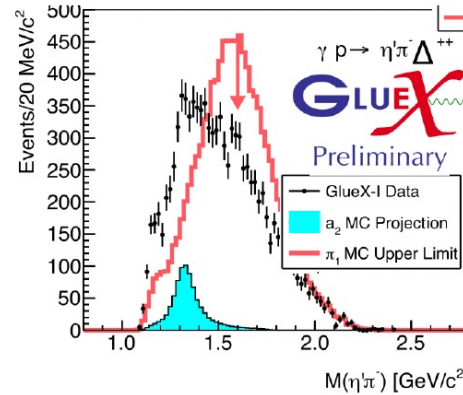
Search for $1^{-+} \pi_1(1600)$ Photoproduction at 8.2-8.8 GeV

$$\gamma p \rightarrow \omega \pi^- \pi^0 \Delta^{++}$$

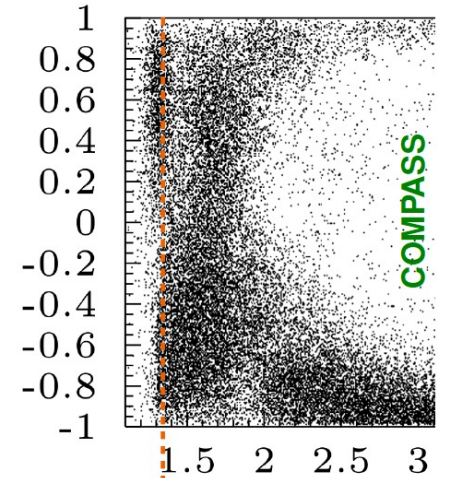
- LQCD-dominant decay
- Upper limit on $\sigma(\pi_1)$

$$\gamma p \rightarrow \eta' \pi^- \Delta^{++}$$

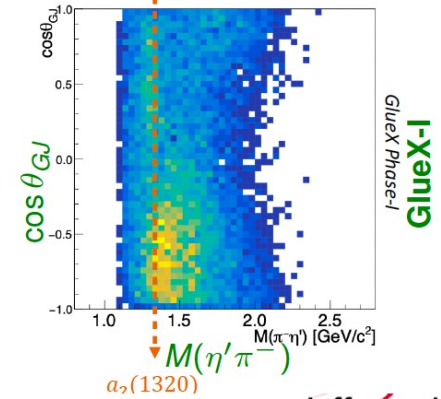
- $\cos \theta_{GJ}$ large asymmetry similar to COMPASS: odd wave interference
- Next step: amplitude analysis



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COMPASS Collab., PLB 740, 303 (2015)

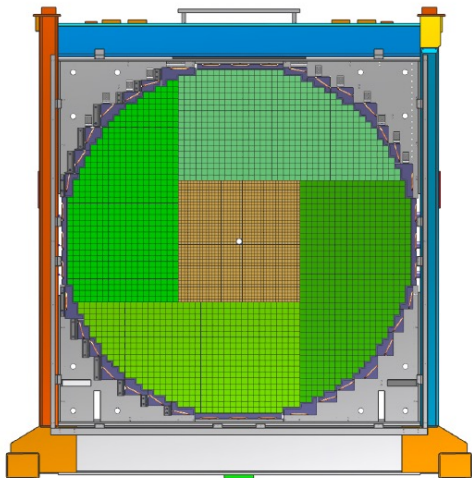


Jefferson Lab

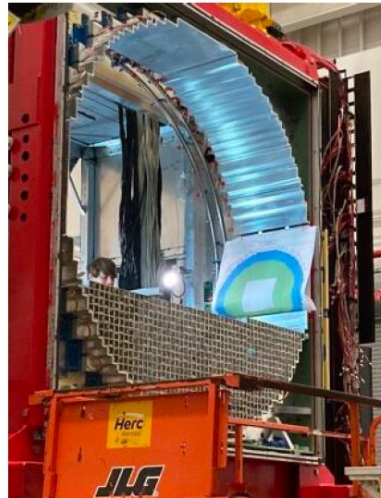
Ongoing projects for future experiments

FCAL2 PbWO₄ insert: Installation

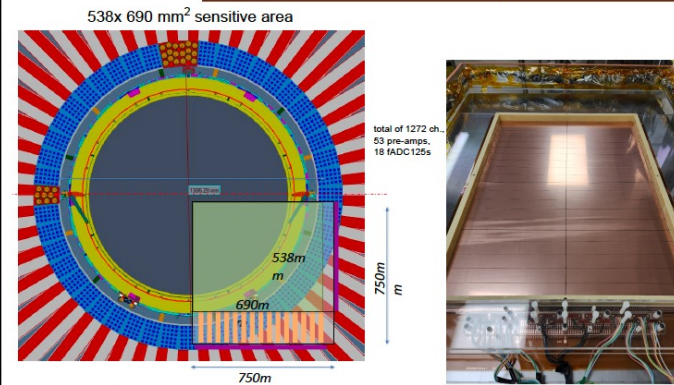
- Replacement of 400 lead glass blocks (out of 2800) with 1600 PbWO₄ crystals
- Twice better energy and spacial resolution, much better radiation hardness
- Required for the JEF experiment (to run with GlueX-II in 2024-2025)
- Installation in progress



Re-stacking LG blocks into a new frame



GEM TRD: prototyping and testing



- Goal: additional PID for electrons and positrons, pion suppression ~ 10 at $\sim 90\%$ electron efficiency
- Prototype of 25% of area has been built
- Prototypes tested in test beams (JLab and FNAL)

KLF: designing the components

- Be target and the “collimator cave” - design is complete
- Conceptual design of the Compact Photon Source (CPS) in progress
- A pre-readiness review by ENP (ERR-1) on Aug 2, 2023

An aerial photograph of the Jefferson Lab facility, showing various buildings, parking lots, and surrounding greenery. A large red title is overlaid on the center of the image.

JLab Positrons & 22 GeV

Patrizia Rossi

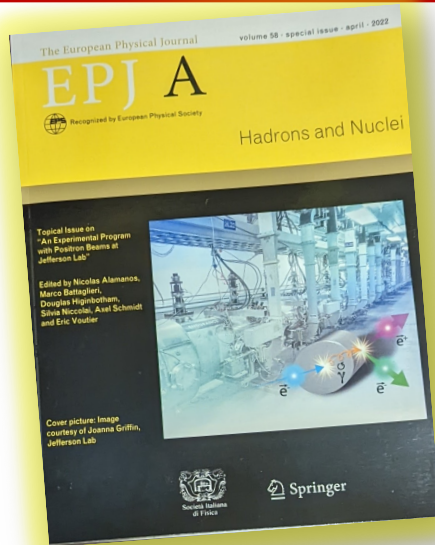
PAC51

Jefferson Lab, July 24-28, 2023

TJNAF is managed by Jefferson Science
Associates for the US Department of Energy

The logo for Jefferson Lab, featuring the text "Jefferson Lab" in a bold, sans-serif font, with "Thomas Jefferson National Accelerator Facility" in a smaller font below it. A red swoosh underline is positioned above the text.

Science at the Luminosity Frontier: JLab Upgrade Development



- **Topical issue on An Experimental Program with Positron Beams at Jefferson Lab**
Eur. Phys. J. A 58 (2022) 3, 45
JLab PWG = ~250 Physicists

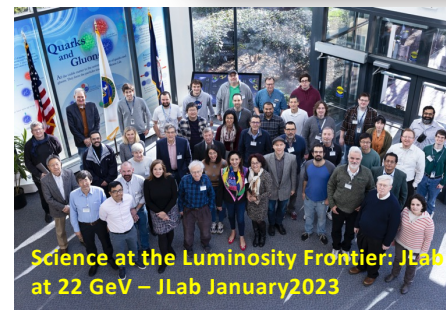


- J-Future - Messina (Italy)
28–30 Mar 2022

- **Strong Interaction Physics at the Luminosity Frontier with 22 GeV Electrons**
2306.09360 [nucl-ex] 435+ authors



- International Workshop on Physics with Positrons at Jefferson Lab, JPos09, March 2009
- International Workshop on Physics with Positrons at Jefferson Lab, JPos17, September 2017
- XVIIIth International Conference on Positron Annihilation, Orlando (USA), August 2018
- Positron Working Group Workshop –UVA (USA), Mar 2023



- High Energy workshop series 2022 - Jefferson Lab, June - August 2022
- Hadron Physics Opportunities with JLab Energy Upgrade – Pohang (S. Korea), July 2022
- Opportunity with JLab Energy and Luminosity Upgrade- ECT* Trento (Italy), September 2022
- Science at the Luminosity Frontier: JLab at 22 GeV – Jefferson Lab, January 2023

Broad community interest in this science



What a Positron Beam will bring?

- Positron beams, both polarized and unpolarized, open the door to understanding a range of physics that can't be accessed with electrons alone

- **E.M. processes (BCA)**

- Two-photon exchange
- DVCS

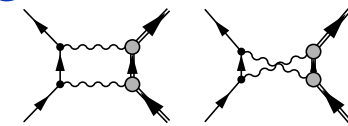
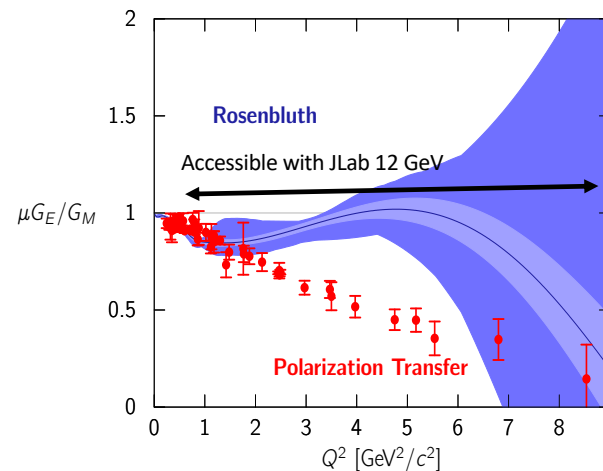
- **Annihilation processes**

- Light dark matter searches

- **Charged-current processes**

- Inverse beta-decay
- Strangeness with charm-tagging
- Charged lepton flavor violation
- Axial Form Factor

6 Proposals and 5 LOI
submitted to this PAC



Two-photon exchange

- A challenge to calculate
- Leading contribution has opposite effect for e^+
- Measurements of $\sigma_{e^+}/\sigma_{e^-}$ isolate TPE

$$R_{2\gamma} \equiv \frac{\sigma_{e^+p}}{\sigma_{e^-p}} = 1 + 4 \frac{\text{Re}[\mathcal{M}_{1\gamma}\mathcal{M}_{2\gamma}]}{|\mathcal{M}_{1\gamma}|^2} + \dots$$

Short Name	Experiment		Measurement Configuration			Beam Parameters			Time (d)	
	Label	Contact	Hall	Detector	Target	Polarity	P_p (GeV/c)	P (%)		I (μ A)
<i>Two Photon Exchange Physics</i>										
Coulomb Distorsion	PR12+23-003	D. Gaskell	C	HMS	LD ₂ Au	+	4.4/11.	0	1.0	10
TPE@CLAS12	PR12+23-008	A. Schmidt	B	CLAS12	LH ₂	+/-s	2.2/4.4/6.6	0	0.075/0.075	55
Super-Rosenbluth	PR12+23-012	M. Nycz	C	HMS	LH ₂	+/-	0.65-11.	0	1.0/20.	56
Polarization Transfert	LOI12+23-008	A. Puckett	A	SBS+BigCal	LH ₂	+	2.2/4.4	60	0.200	120
Dispersive Effects	LOI12+23-015	P. Gueye	A,C	HRS or HMS	C,Al,Cu,Ca,Fe,Pb	+	0.6-4.4	0		
<i>Nuclear Structure Physics</i>										
DVCS BCAs	PR12+23-002	E. Voutier	B	CLAS12	LH ₂	+/-s	2.2/11.	60/60	0.050/0.050	100
DVCS XSection	PR12+23-006	C. Muñoz Camacho	C	SHMS+NPS	LH ₂	+	6.6/8.8/11.	0	1.0	135
Polarizabilities	LOI12+23-001	N. Sparveris	C	SHMS+HMS	LH ₂	+/-	2.2	0	5.0/50.	77
Axial Form Factor	LOI12+23-002	D. Dutta	A,C	mTPC+SBS	² H	+	2.0-6.0	60	0.200	60
<i>Beyond the Standard Model Physics</i>										
Dark Photon Search	PR12+23-005	B. Wojtsekhowski	B	PRad	LH ₂	+	2.2/4.4/11.	0	0.050	60
Dark Bhabha	LOI12+23-005	D. Mack	C	Pair Spec.	e ⁻	+	0.50-11.			

What a 22 GeV Upgrade will bring?

- **A NEW territory to explore** → cross the critical threshold into the region where $c\bar{c}$ states can be produced in large quantities, and with additional light quark degrees of freedom.
- **A BETTER (and needed) insight into our current program** → enhancement of the phase space
- **A BRIDGE between JLab @ 12 GeV and EIC** → test and validation of our theory from lower to higher energy and with high precision

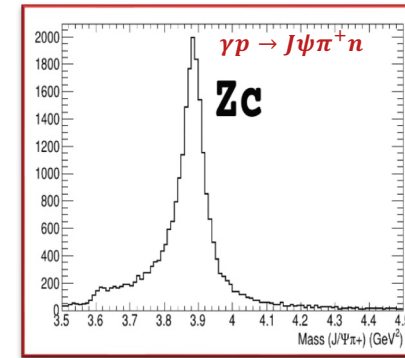
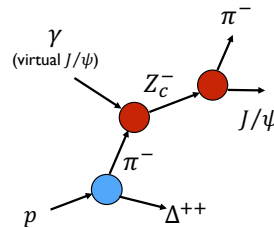
The physics program will:

- **Leverage on the uniqueness of CEBAF HIGH LUMINOSITY**
- **Utilize largely existing or already-planned Hall equipment**
- **Take advantage of recent novel advances in accelerator technology**

Photoproduction of Hadrons with Charm Quarks

- **Potentially decisive information about the nature of some 5-quark and XYZ candidates**

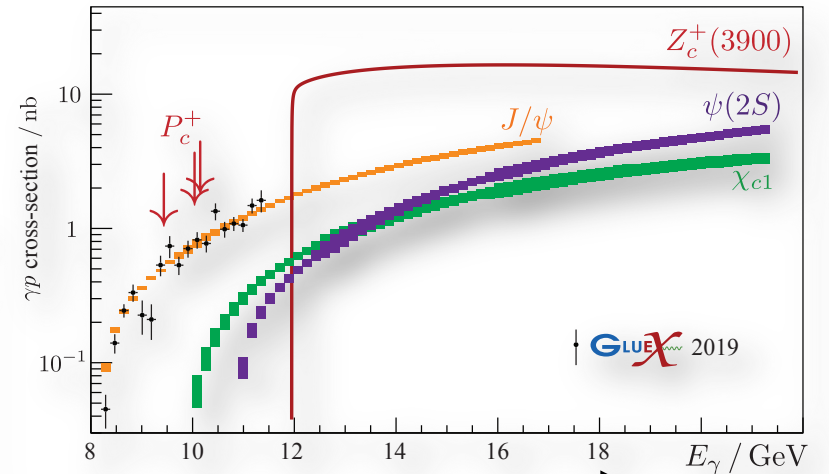
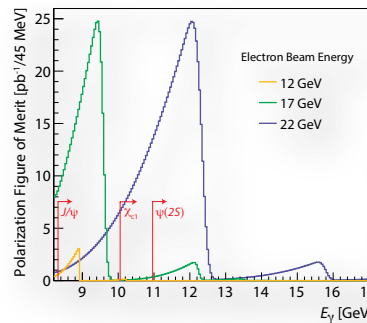
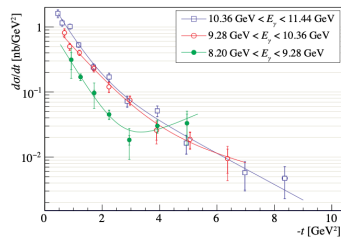
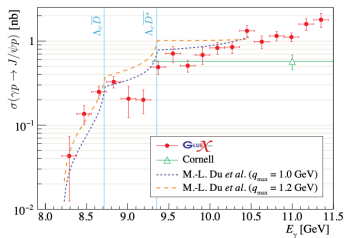
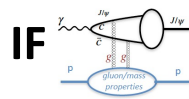
- Many “XYZ” states observed in B decays, e^+e^- but scarce consistency between various production mech. → internal structure not understood yet
- Never directly produced using γ /lepton beam → possibility to study the reaction mechanism without re-scattering effects



Full CLAS12 signal MC simulation with EXISTING detector → capabilities of the existing detectors to measure these reactions

- **Near-threshold J/ψ photoproduction: a unique method to probe the proton’s gluonic structure**

- gluon GPD
- mass radius of the proton
- anomalous contr. to p mass

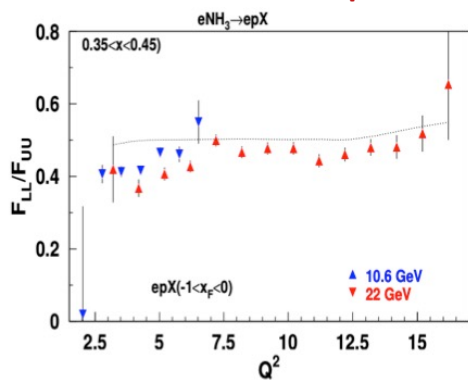


Thresholds crossed and t range opens up at higher energy

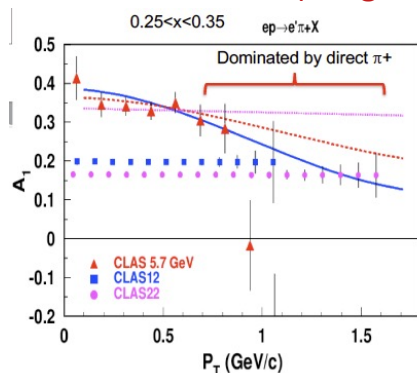
Nucleon 3D Structure

SIDIS - TMD

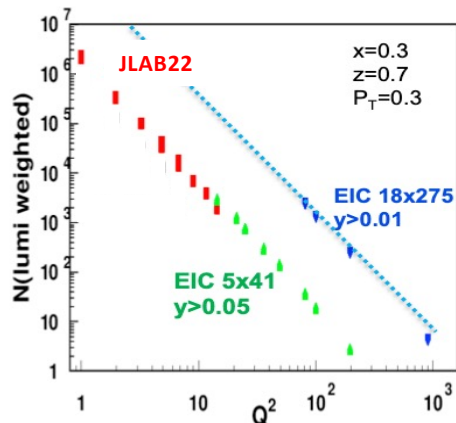
- Q² evolution studies possible



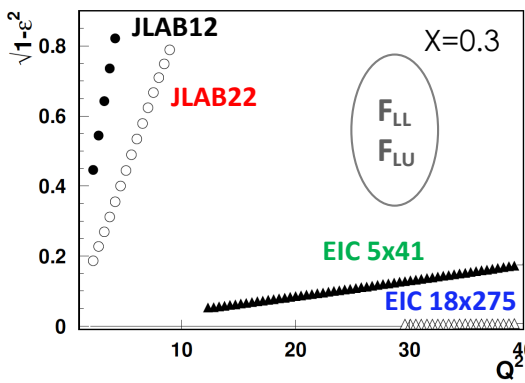
- Enhancement of P_T range



- Complementarity with EIC

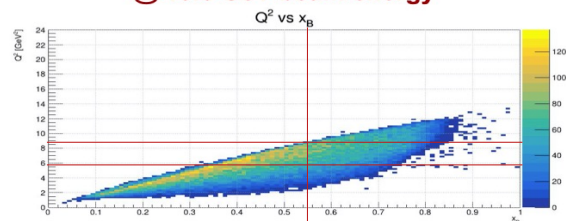


- ALL SF measurement possible

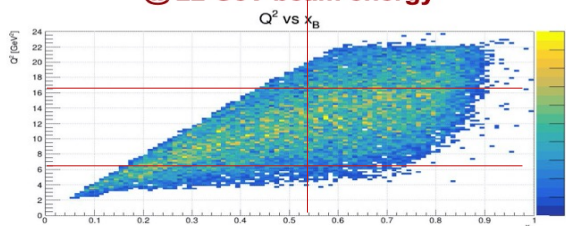


Exclusive Process

@ 10.6 GeV beam energy



@ 22 GeV beam energy



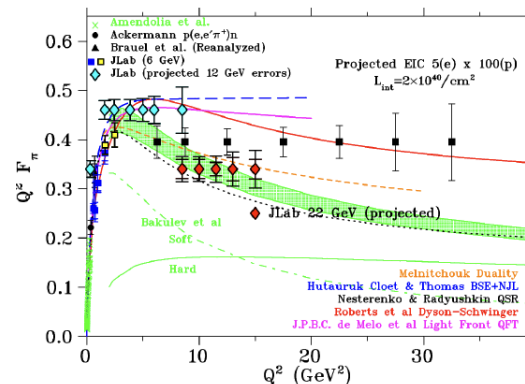
GPDs

One of the most stringent tests of factorization : x-section Q² dependence

- σ_L scales to LO as Q⁻⁶
- σ_T expectation as Q⁻⁸
- As Q² becomes large: σ_L >> σ_T

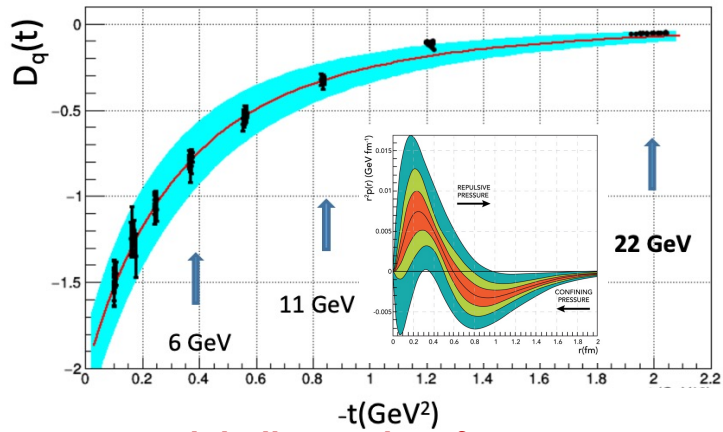
Pion FF

σ_L/σ_T separation only possible at Jlab

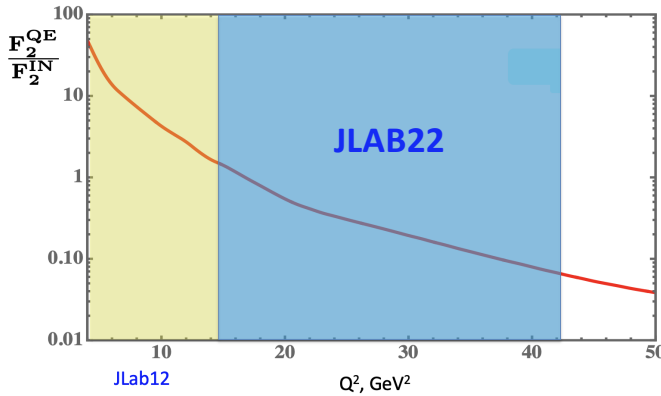


...and More

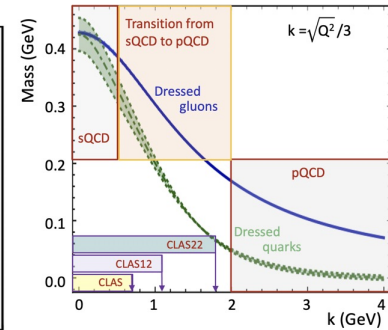
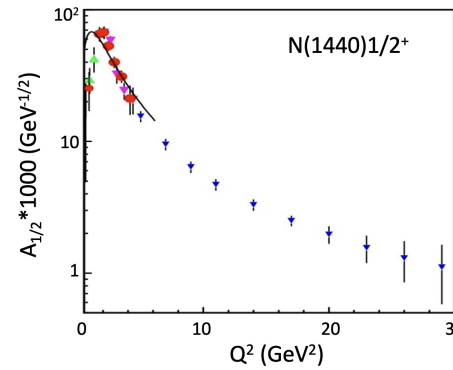
- $D(t)$ term and the determination of the pressure distribution inside the proton



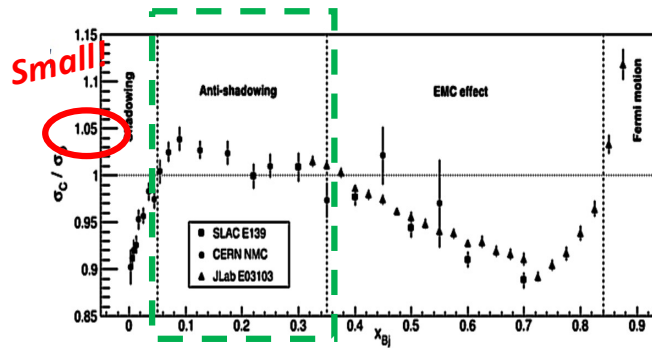
- Reach to the nuclear forces dominated by nuclear repulsion



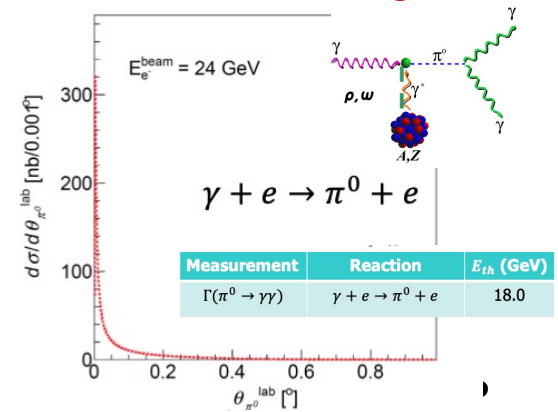
- insight into hadron mass generation & the emergence of the N^* structure through the Q^2 evolution of the $\gamma_V p N^*$ electrocouplings (CSM approach)



- Access the anti-shadowing region (small effect!) ($x \sim 0.1-0.3$) at moderate Q^2 using multiples exp. techniques

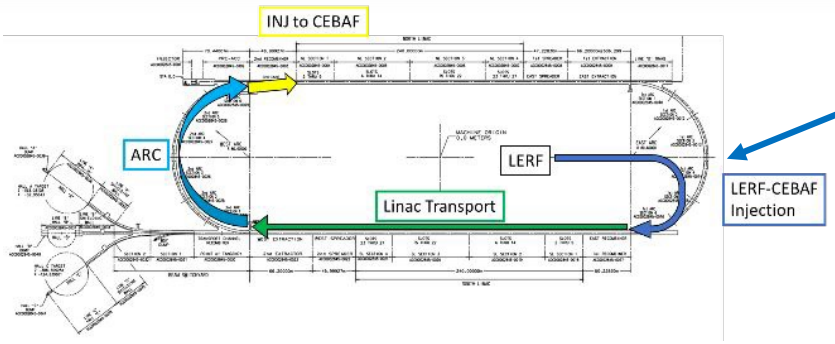


- π^0 Primakoff production off an electron target



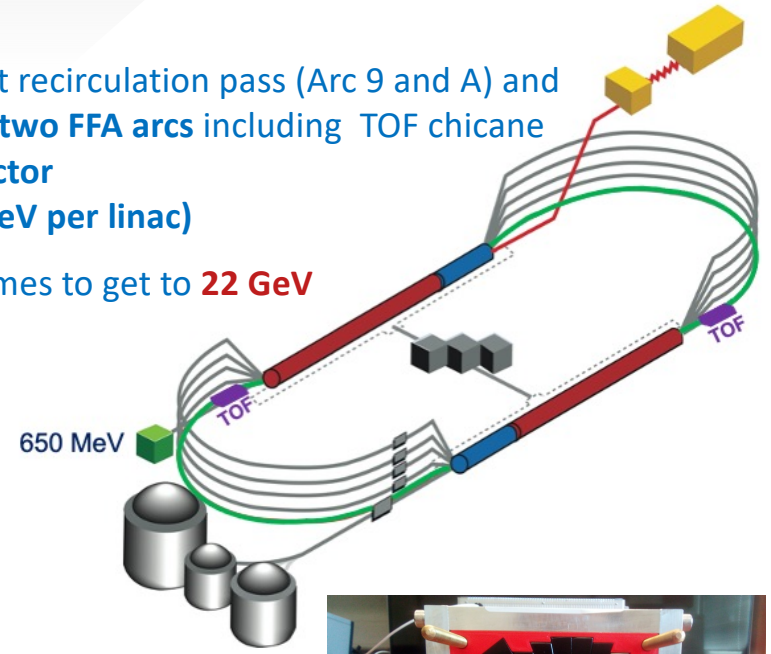
Feasible, Cost effective, Innovative Path from e⁺ to 22 GeV

Capitalize on recent science insights and US-led accelerator science and technology innovations to develop a **staged program at the luminosity frontier**

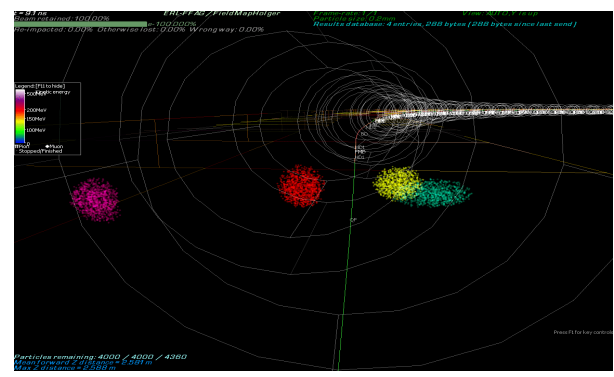


- Remove the highest recirculation pass (Arc 9 and A) and replace them with two FFA arcs including TOF chicane
- New 650 MeV injector
- NO new SRF (1.1 GeV per linac)
- Recirculate 4.5+6times to get to **22 GeV**

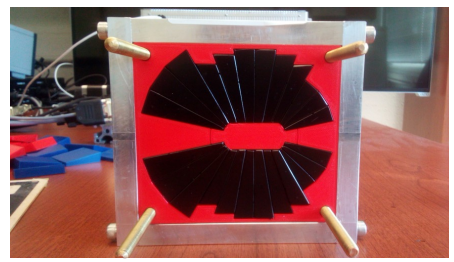
- Positrons (e⁺) in the LERF with transport to CEBAF



• R&D developments on-going supported by Laboratory Directed (LDRD) funds



- A prototype magnet built and evaluated for mechanical integrity



Summary

- Understanding the different facets of the dynamics of non-pQCD that manifest in hadron/nuclei structures is a complex problem which requires multiple observables using different approaches and measurements
 - Positron beams, both polarized and unpolarized, are essential tools for a precise understanding of the electromagnetic structure of the nucleon and nuclei, in both the elastic and the deep-inelastic regimes (form factors, PDFs, GPDs,...), but also for search for physics beyond the standard model.
 - With CEBAF at higher energy: a) some important thresholds will be crossed providing new territories to explore, b) a better insight into our current program will be possible, and c) a bridge between JLab @ 12 GeV and EIC will be established. This will be critical to elucidate the properties of QCD in the valence regime.
- **A rich scientific program to leverage existing infrastructure and the uniqueness of CEBAF HIGH LUMINOSITY is being developed and it has been presented at the Long Range Plan of NP**

