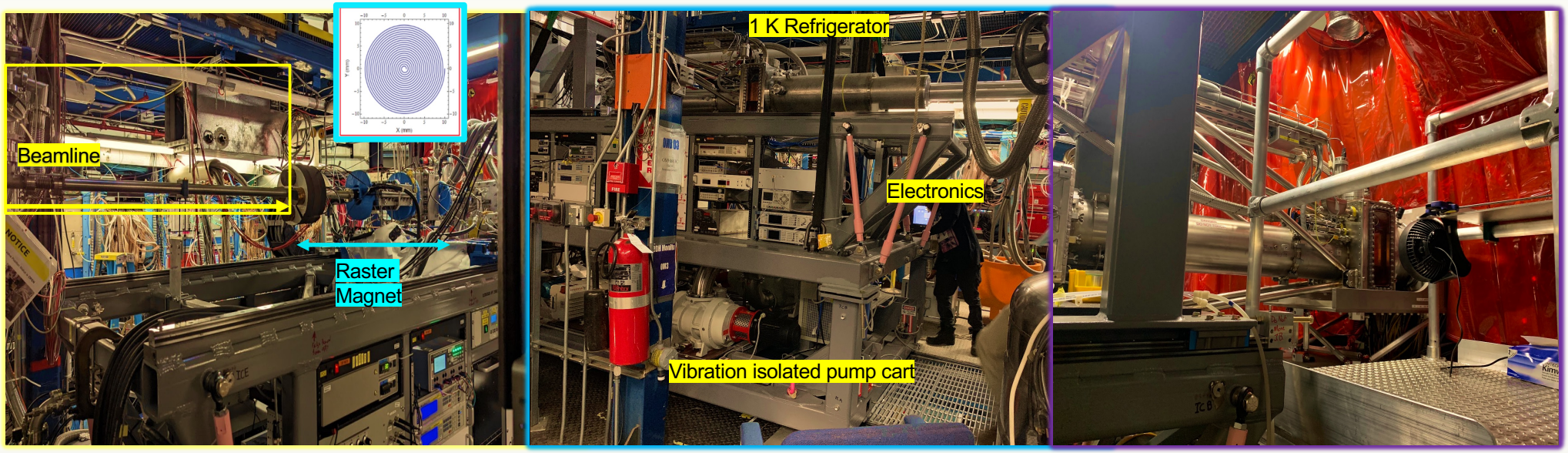
CLAS12 Run Group C

Jeopardy Review PAC 52

July 10, 2024



Sebastian Kuhn, *Old Dominion University*

for the Run Group and the CLAS collaboration

Overview

- Science goals of RG-C
  - Inclusive DIS (double spin asymmetries)
  - Semi-inclusive DIS
    - TMDs
    - Fracture Functions
    - Two-hadron production
  - DVCS
- Present Status, First Results, and Expected Data
- Status of Polarized Target
- Request

RG C Goals:

- Measure inclusive spin structure functions (A_1, g_1) of the proton and deuteron for PDF fits and sum rules
- Combine with flavor tagging ($\pi^{\pm}$, $K^{\pm}$) to extract Δq in the valence and moderate-x sea regions, constrain ΔG
- Measure spin- and transverse momentum-dependent (TMD) PDFs (SIDIS)
- Study novel fracture functions and two-hadron production
- Measure target single and beam/target double spin asymmetries in proton and neutron DVCS (and TCS)

Approved Experiments in RG C

Experiment number	Title	Contact person	PAC days (rating)
E12-06-109	Longitudinal Spin Structure of the Nucleon	S. Kuhn	80 (A)
E12-06-109A	DVCS on the neutron with polarized deuterium target	S. Niccolai	RG Addition
E12-06-119(b)	DVCS on longitudinally polarized proton target	M. Defurne	120 (A)
E12-07-107	Spin-Orbit Correlations with longitudinally polarized target	H. Avakian	103 (A-)
E12-09-007(b)	Study of partonic distributions using SIDIS K production	W. Armstrong	80 (A-)
E12-09-009	Spin-Orbit Correlations in K production with polarized targets	H. Avakian	103 (B+)
E12-09-007A	Dihadron Electroproduction in DIS with Long. Polarized Targets	C. Dilks	RG Addition
E12-07-107A	Baryon Production in the Target Fragmentation Region with Pol. Targets	T. Hayward	RG Addition

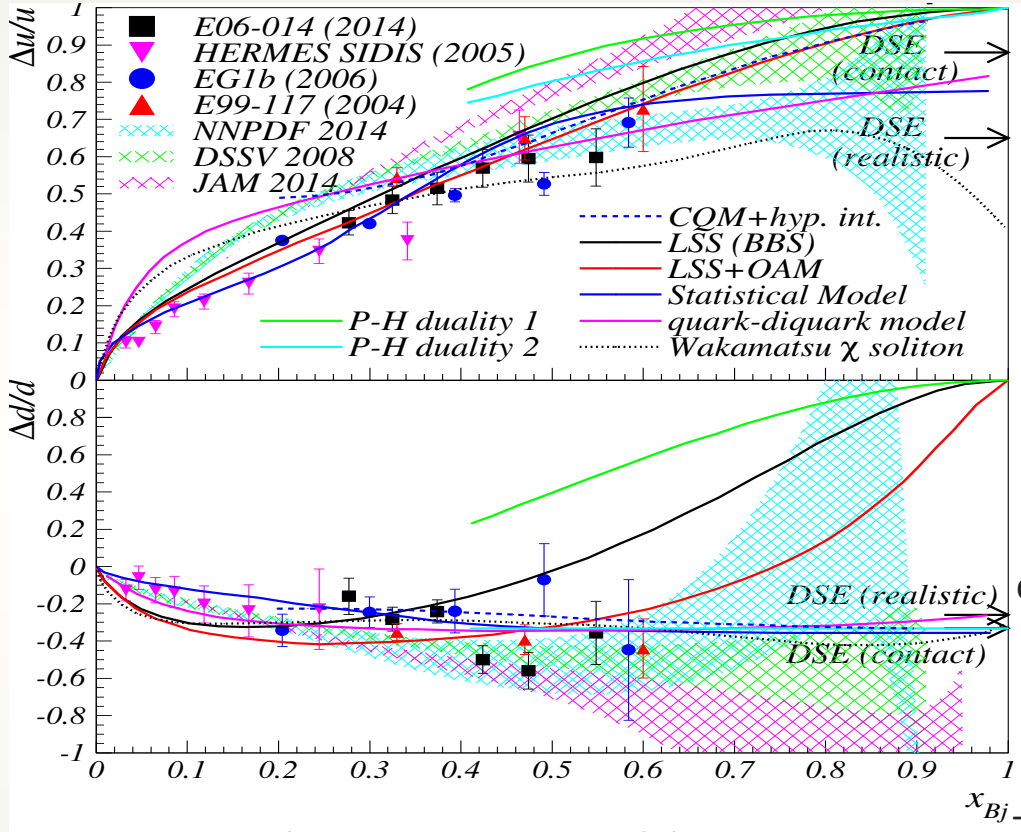
Additional channel under analysis: Time-like Compton Scattering

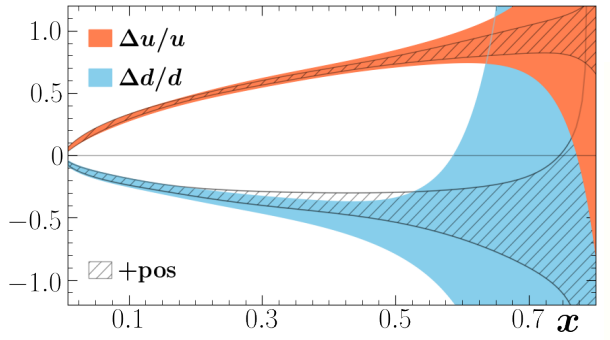
- 8 experiments with a total of 916 PAC days worth of new data
- Due to simultaneous data collection for all channels with CLAS12, actual requirement only 185 PAC days
  - Including 120 PAC days on NH_3 just for pDVCS
  - Plus 60 more PAC days on ND_3 just for nDVCS

A short history of RG-C

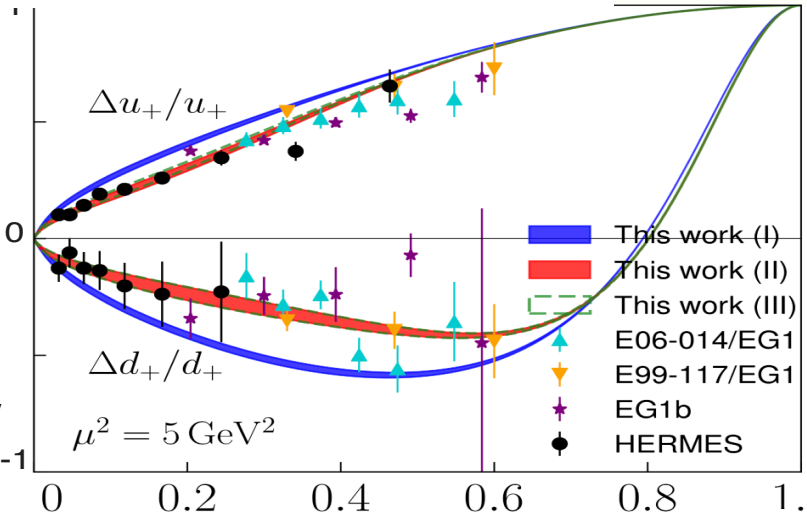
- Originally approved for 185 PAC days
- Reduced to 120 PAC days by Jeopardy PAC48 in 2020 (“with focus on the DVCS part”)
- Scheduled for 244 calendar days in June 2022 – March 2023
  - Roughly 2+2 months with “FTOn” configuration (small angle photons)
  - Roughly 2 months with “FTOut” configuration (higher luminosity)
- Due to extensive accelerator downtimes and major equipment failure (solenoid magnet power supply) only 80 PAC days of data collected.
- First 2 months FTOn fully calibrated, data processed. (Preliminary results will be shown)
- 2 month FTOut nearly calibrated, ready for processing
- Last 2 months FTOn calibration has started.
- Expect first results in 2025-6

DIS: Valence quark polarization at high *x*





C. Cocuzza, W. Melnitchouk, A. Metz, and N. Sato, Phys. Rev. D 106, 1.L031502 (2022).



From AdS/QCD determination of GPDs.
No free parameters.
Predicts Δd/d changes sign near x=0.8.
Reproduces QCD counting rules used for BBS/LSS.

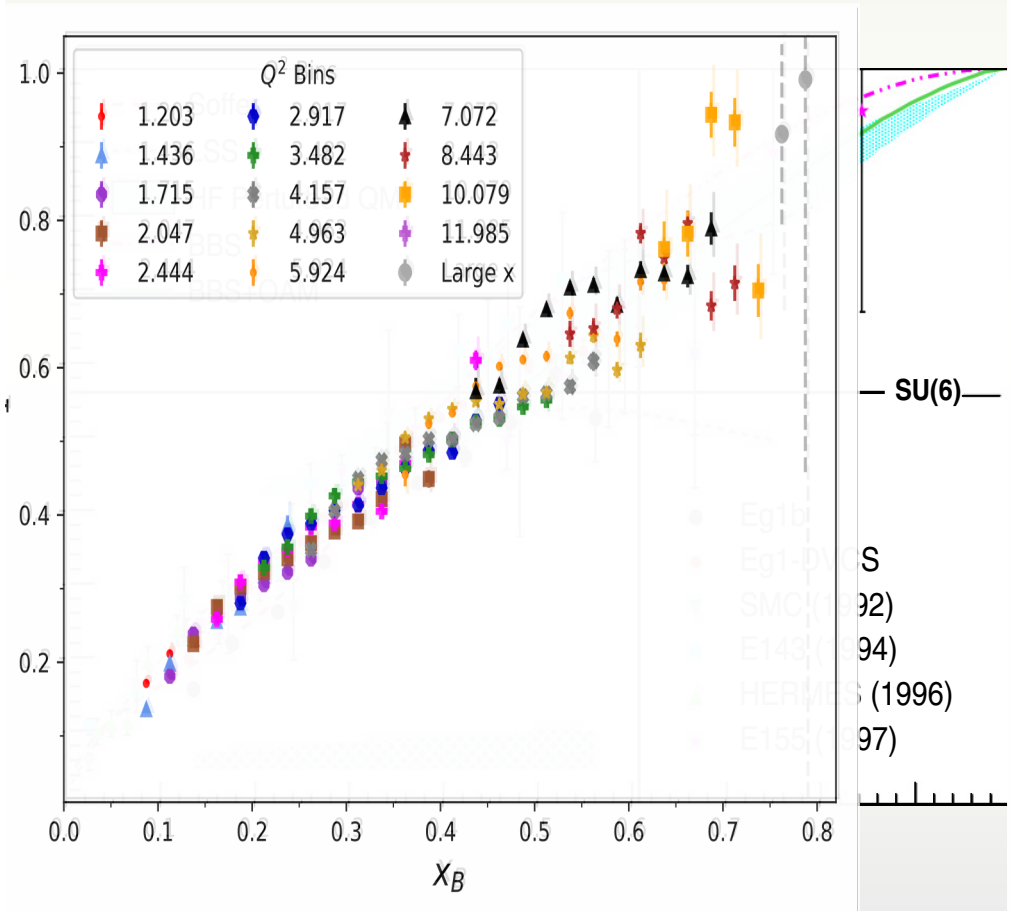
Full Data set (combined with Hall C ^{3}He data already in hand) will significantly constrain valence + sea quark and gluon PDF fits, higher twist effects and sum rules

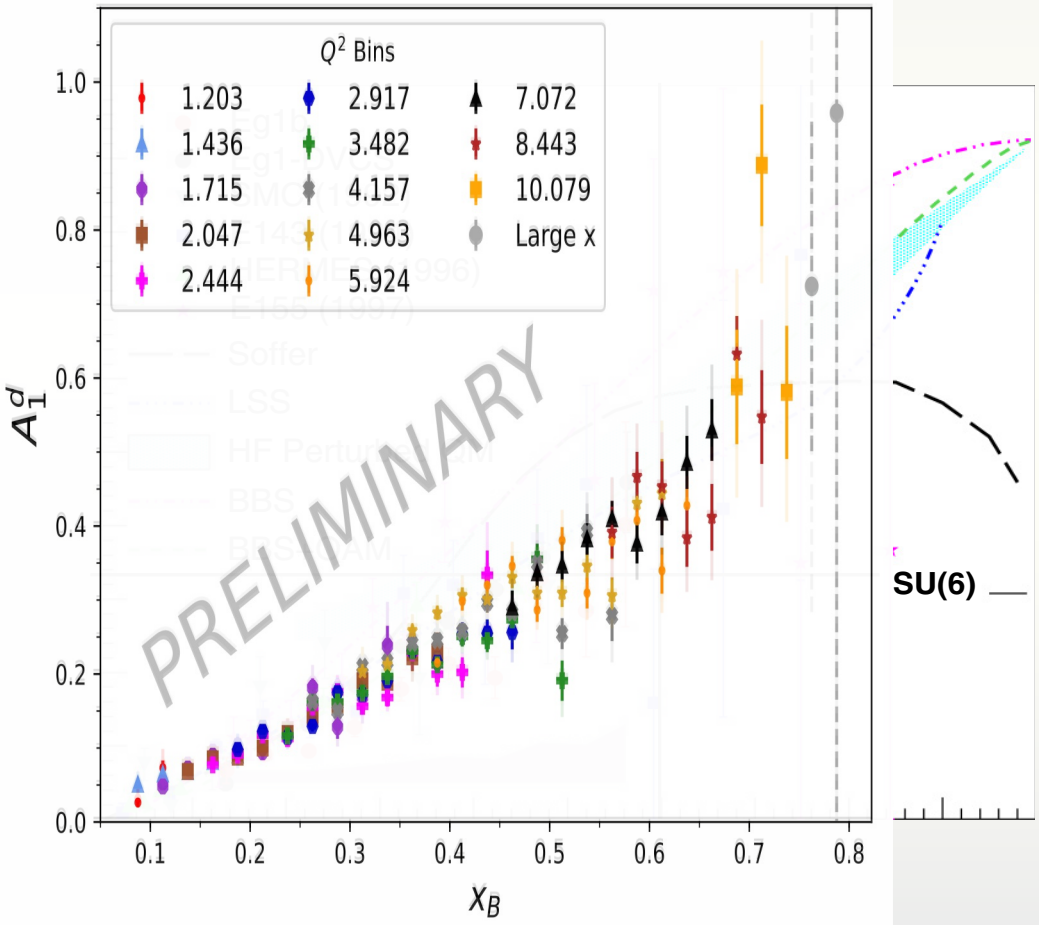
Preliminary Data from CLAS12 RG-C - DIS

Proton

$W > 2$; $Q^2 > 1$

Deuteron





Preliminary Data from CLAS12 RG-C - DIS

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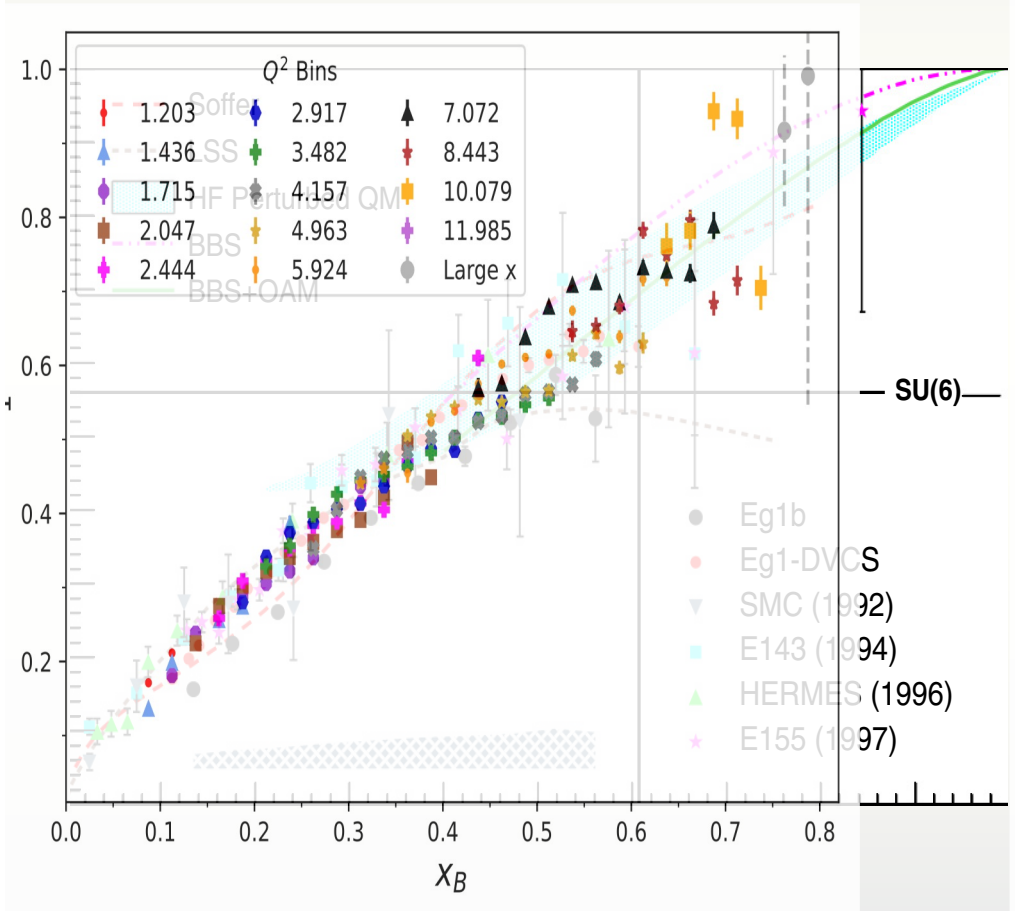
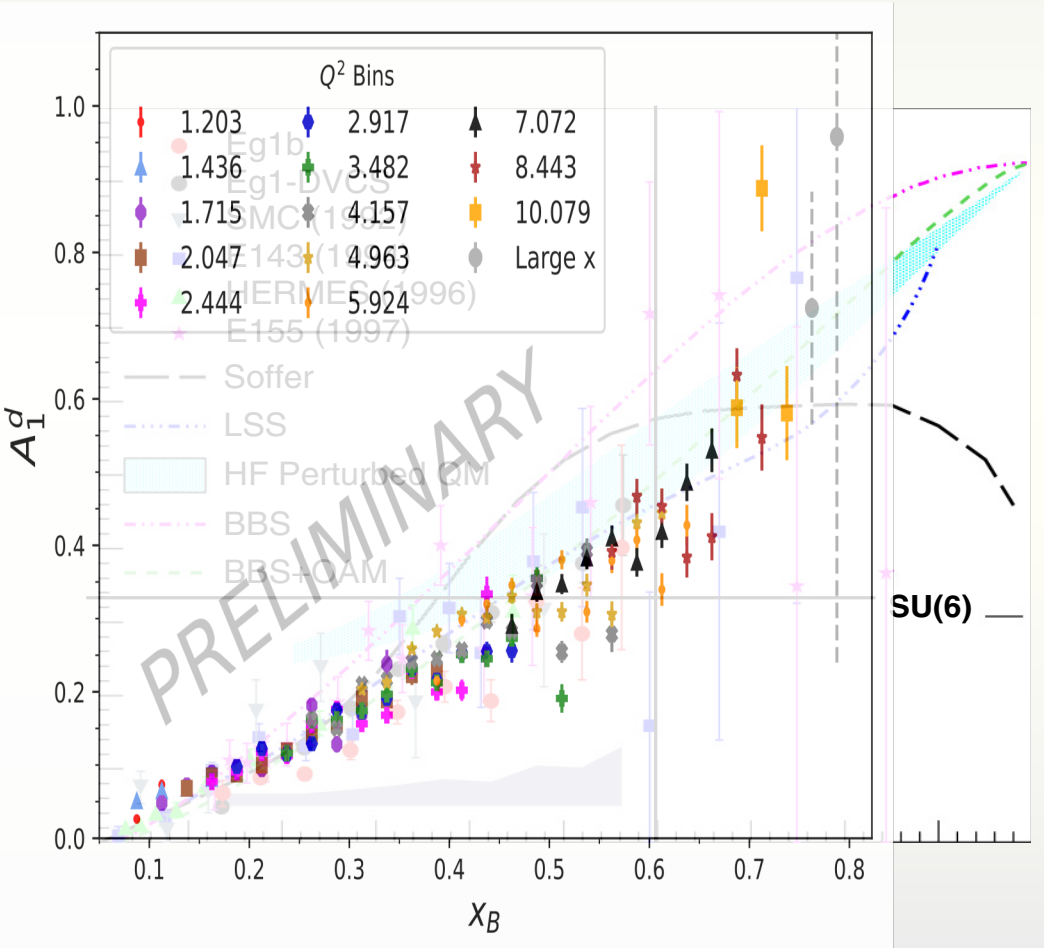
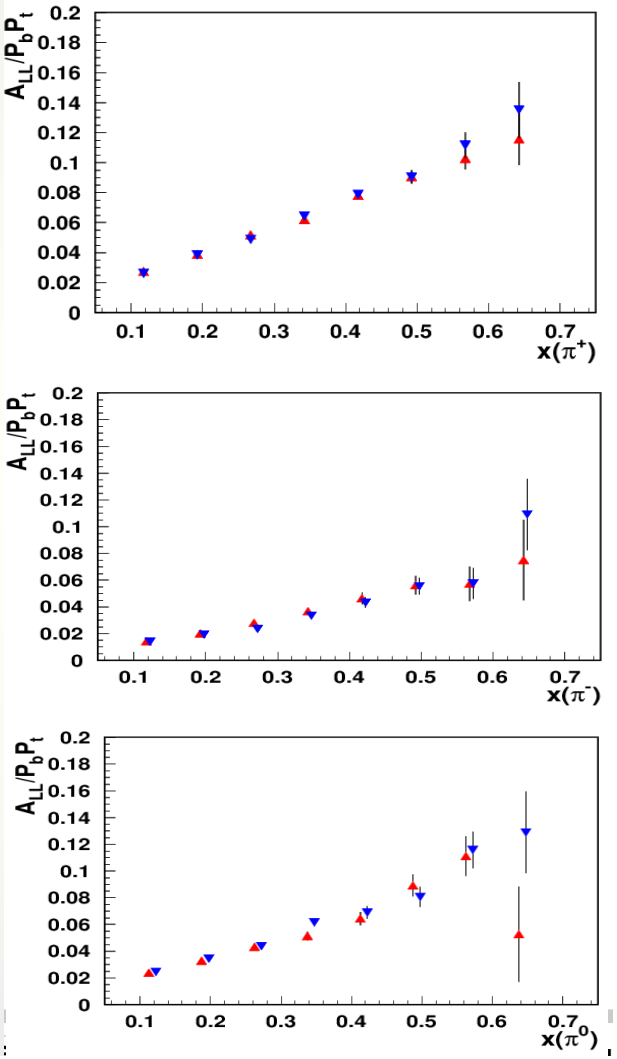


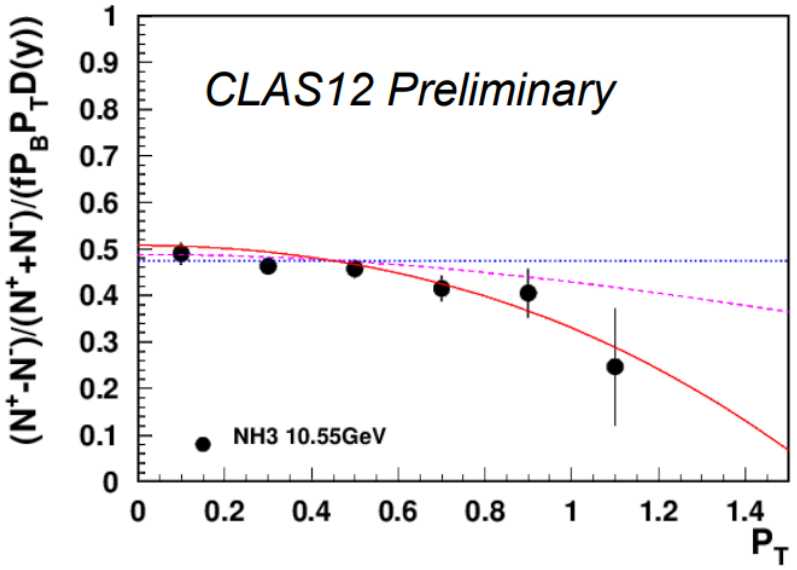


SIDIS: Single pions



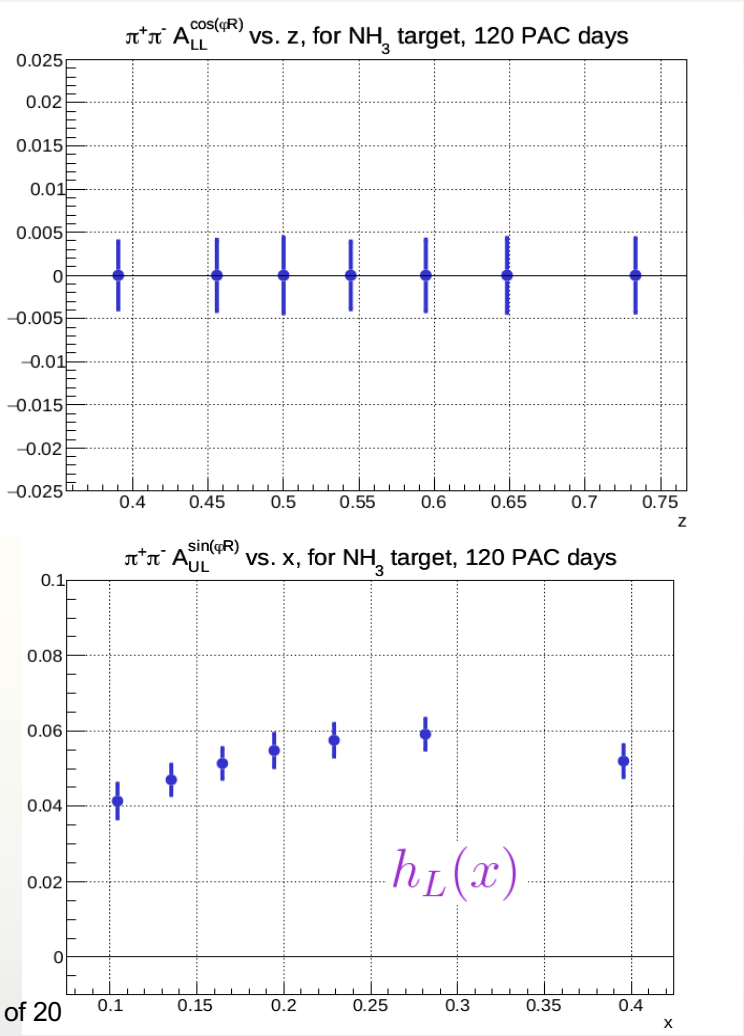
P_BP_T +=0.75+/-0.03
P_BP_T-=0.66+/-0.03

Kaon SIDIS is also crucial but requires the highest possible statistics (only 2 sectors of RICH)



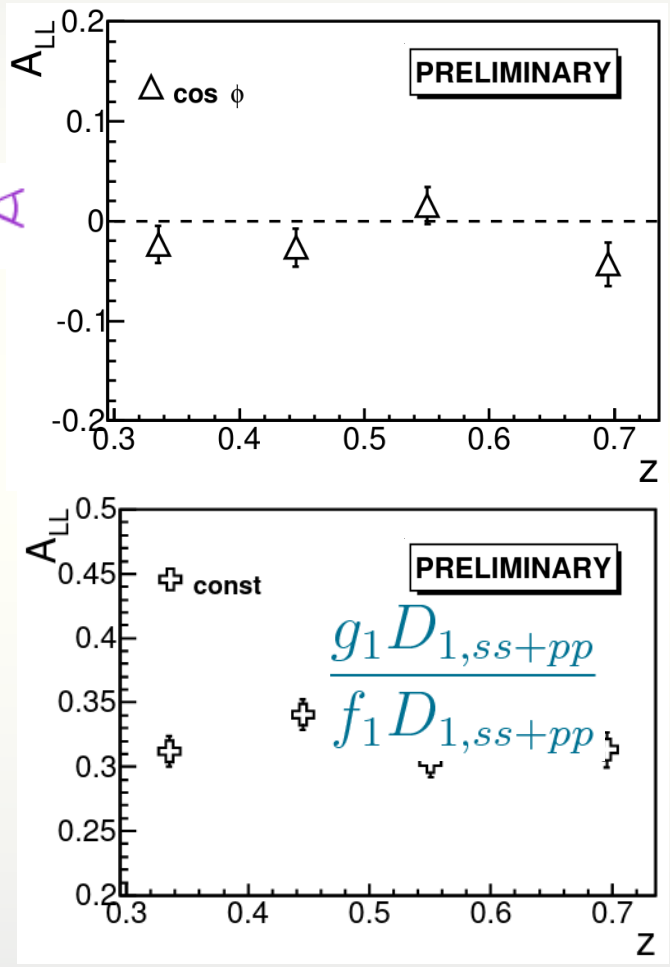
Double spin asymmetries consistent for 2 target polarizations, and with world data
25% of total RGC

SIDIS Dihadron Production: $e^- p \rightarrow e^- h_1 h_2 X$



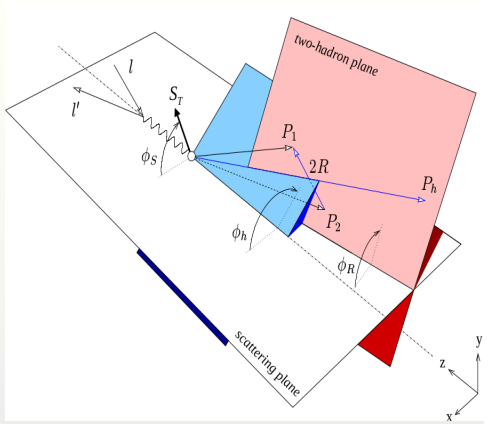
$\tilde{D}^{\sphericalangle}$

Compare to CLAS6 Measurement

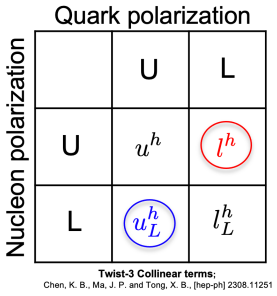


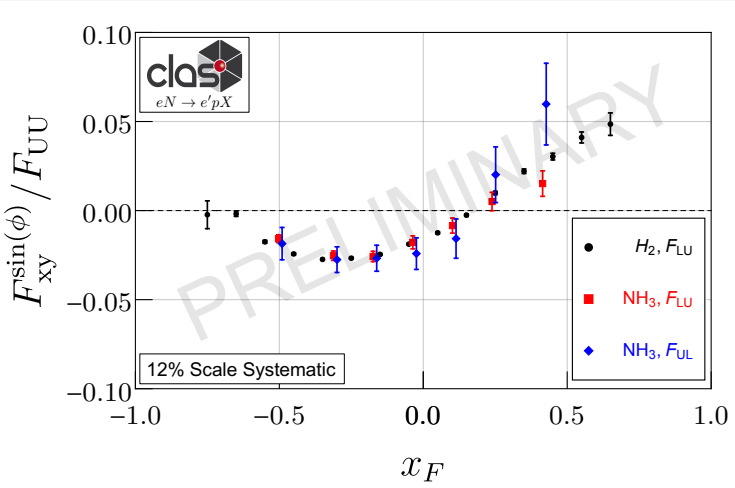
Collinear PDFs
- Twist-2
- Twist-3

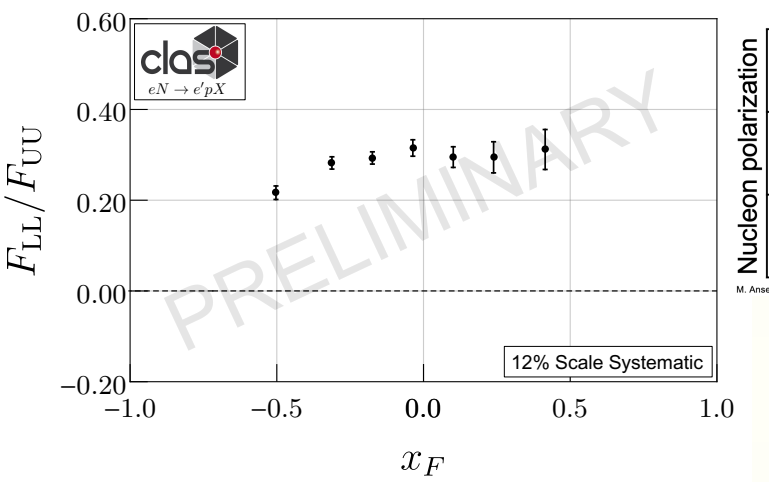
	U	L	T
U	f_1		e
L		g_1	h_L
T		g_T	h_1

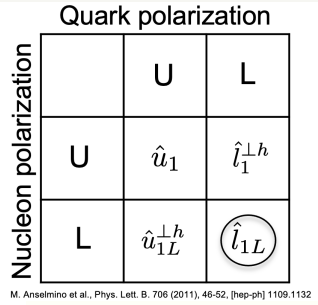


Current and Target Separation – Fracture Functions

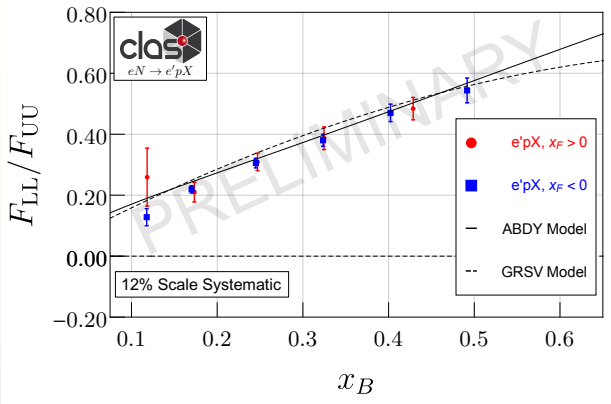


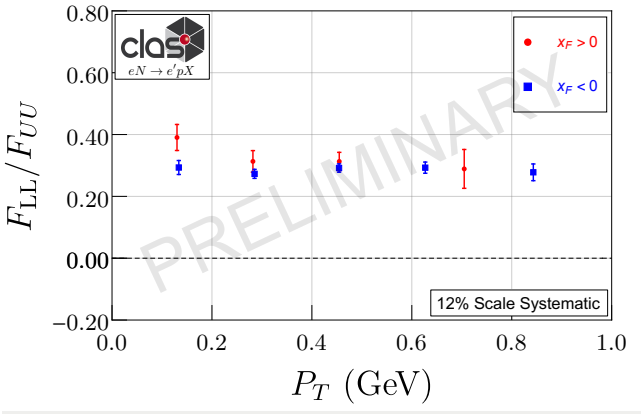




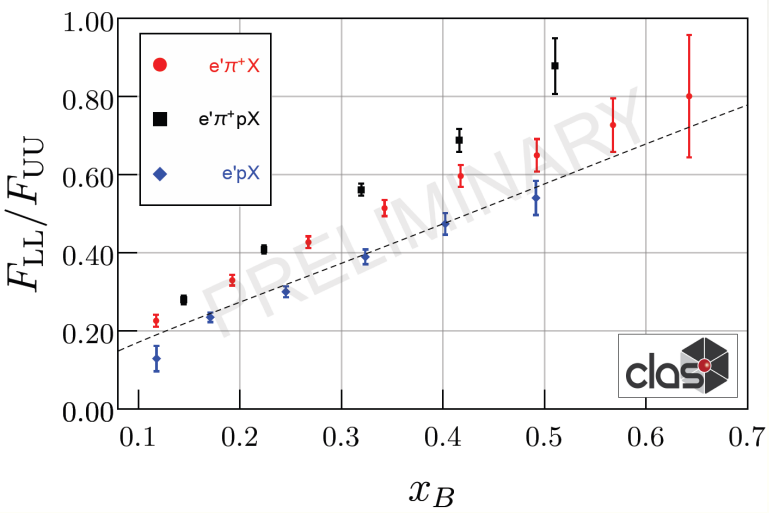


- Odd-function (sine) modulations exhibit a sign flip around the transition from target to current fragmentation. Interestingly, we observe $F_{LU} \sim F_{UL}$.
- Even-function (cosine) behavior of double-spin asymmetry does not show a sign flip; possible signs decreasing F_{LL} as $x_F \to \pm 1$ (x_B decreasing but likely not the only cause).
- Consistent beam-spin asymmetries in unpolarized H_2 and polarized NH_3 indicates minimal nuclear medium modification.

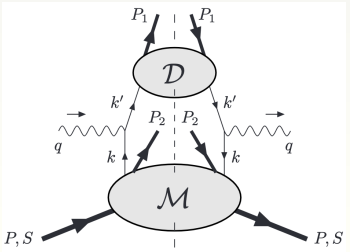




Longitudinally polarized quarks in B2B SIDIS



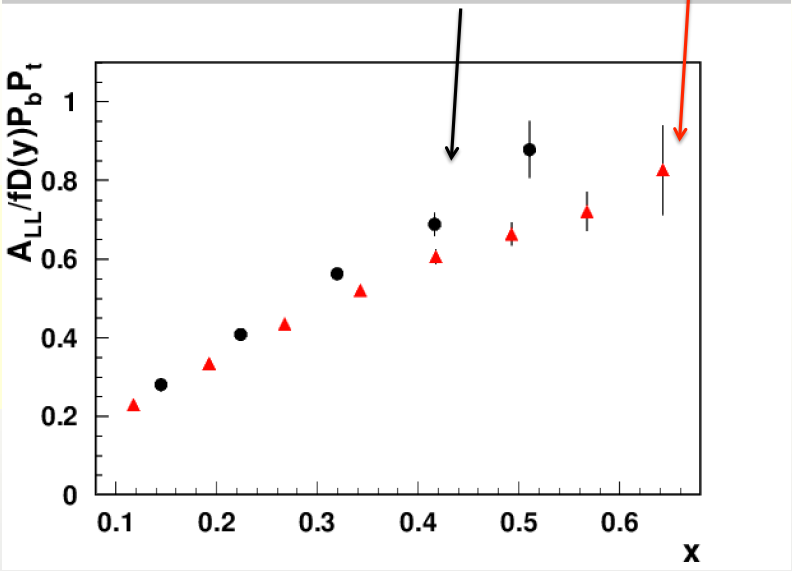
ep→e'pπX



N/q	U	L	T
U	$\hat{u}_1$	$\hat{l}_1^{\perp h}$	$\hat{t}_1^h, \hat{t}_1^\perp$
L	$\hat{u}_{1L}^{\perp h}$	$\hat{l}_{1L}$	$\hat{t}_{1L}^h, \hat{t}_{1L}^\perp$
T	$\hat{u}_{1T}^h, \hat{u}_{1T}^\perp$	$\hat{l}_{1T}^h, \hat{l}_{1T}^\perp$	$\hat{t}_{1T}, \hat{t}_{1T}^{hh}, \hat{t}_{1T}^{\perp\perp}, \hat{t}_{1T}^{\perp h}$

- **Formalism based on fracture functions (Anselmino, Barone, Kotzinian (back-to-back, b2b, hadron production, DSIDIS)**
- **Semi-exclusive processes, involving GPDs/GTMDs on proton side (TFR) and FFs on pion side (CFR) Yuan and Guo**

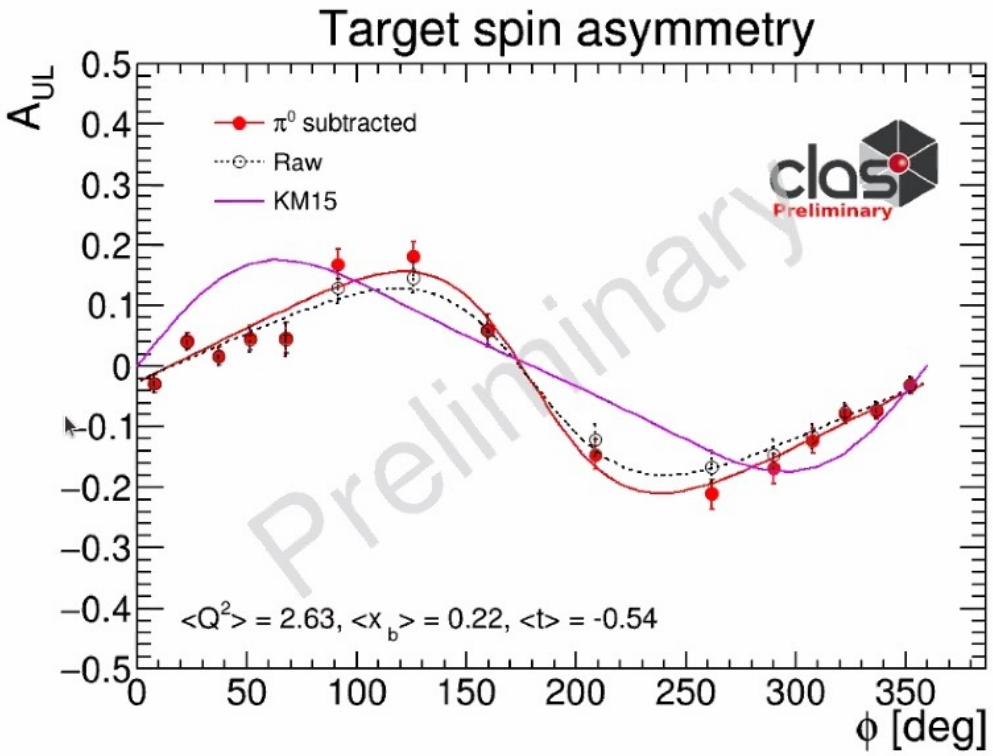
Comparing e'pπ+X with e'π+X

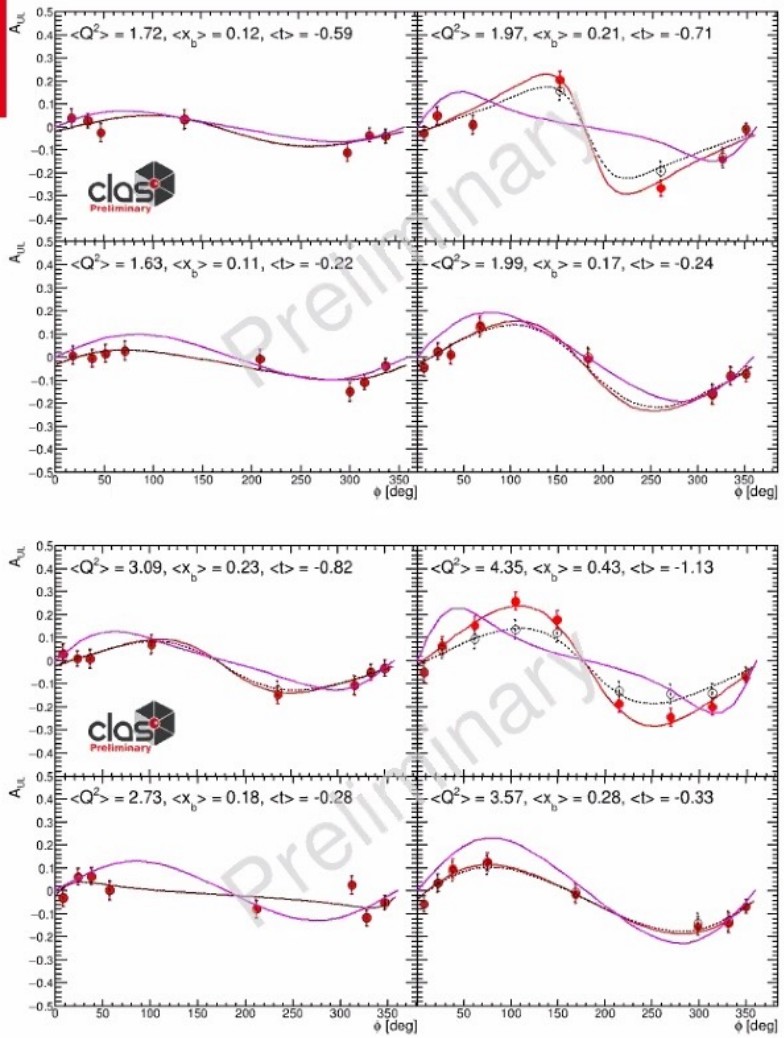


- Differences in A_{LL}, due to different weights on PDFs can provide additional info on impact of possible ingredients
- Measurements of A_{LL} for ρ^0 indicate very small values, and can be one of the reasons for higher A_{LL} with protons with a M_X cuts above 1.5 GeV (excluding exclusive ρ^0)

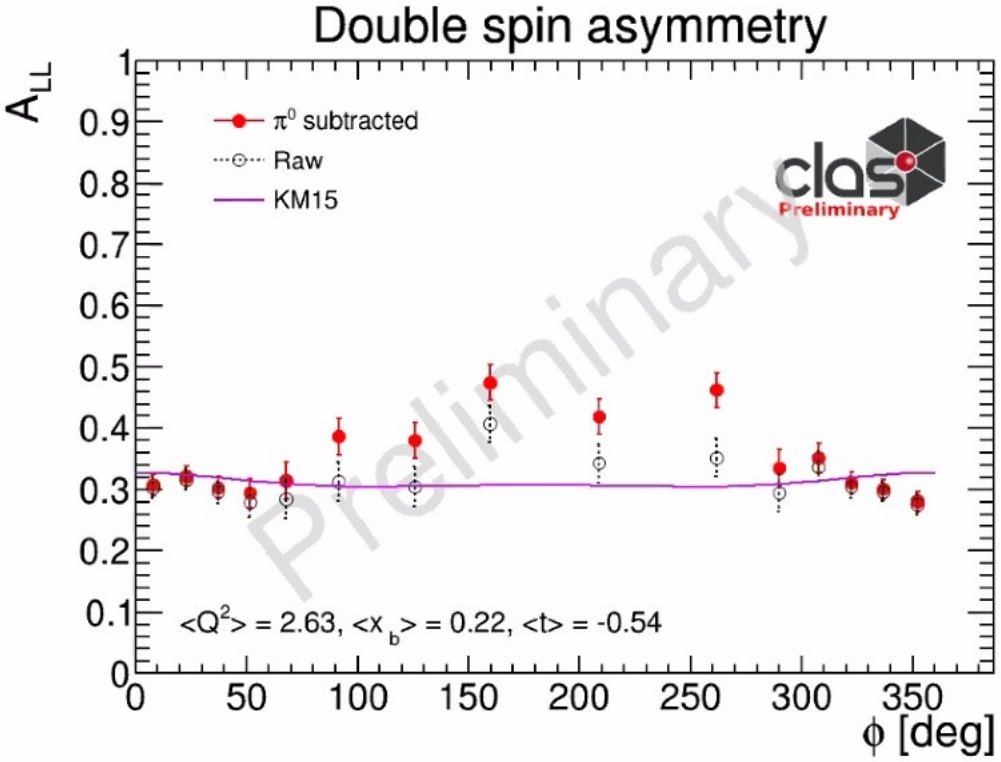
H. Avakian, CNU, June 26

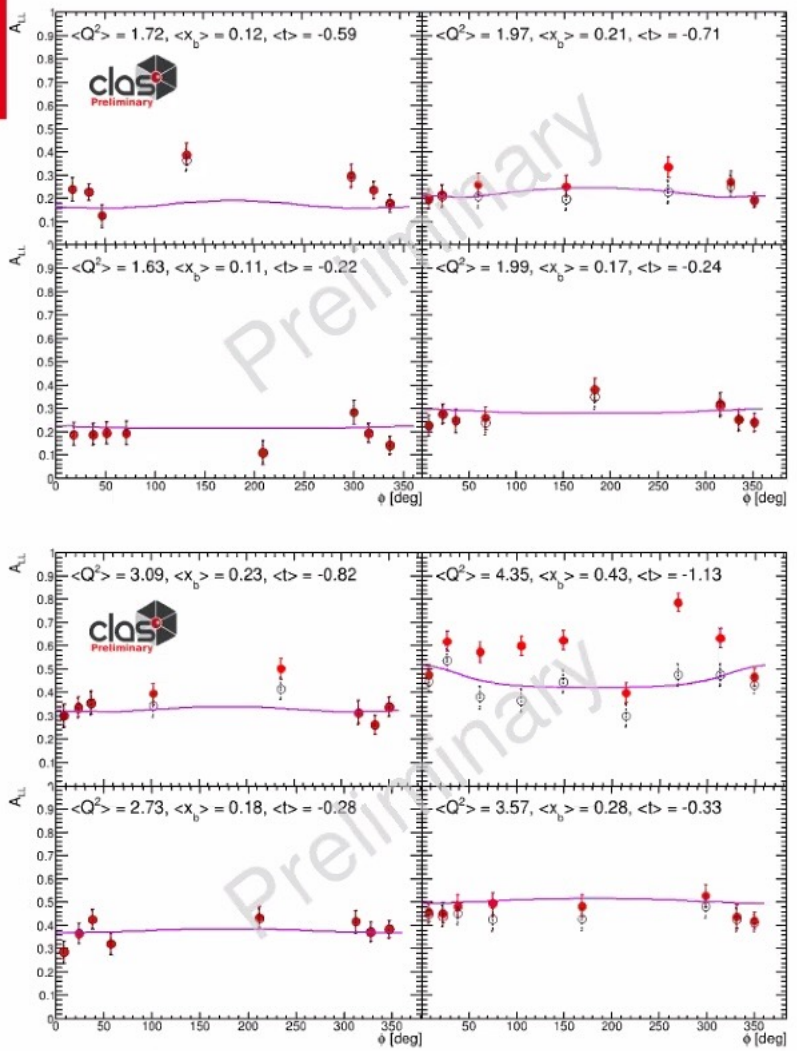
Target spin asymmetry pDVCS



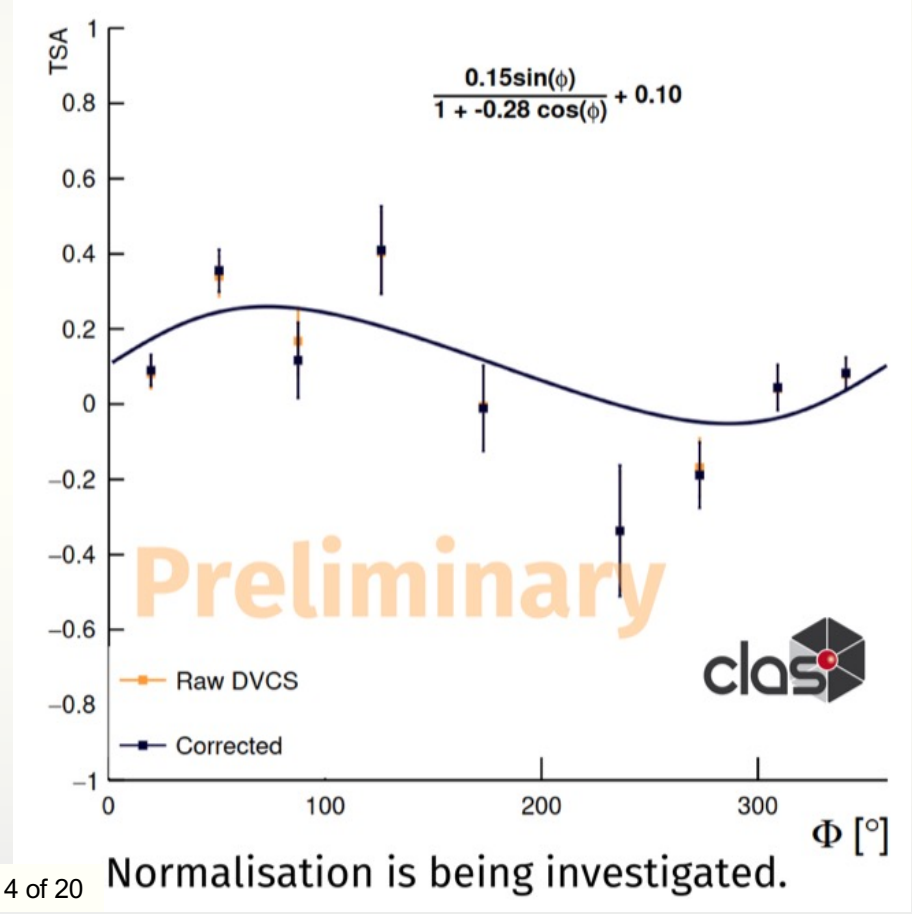


Double spin asymmetry pDVCS

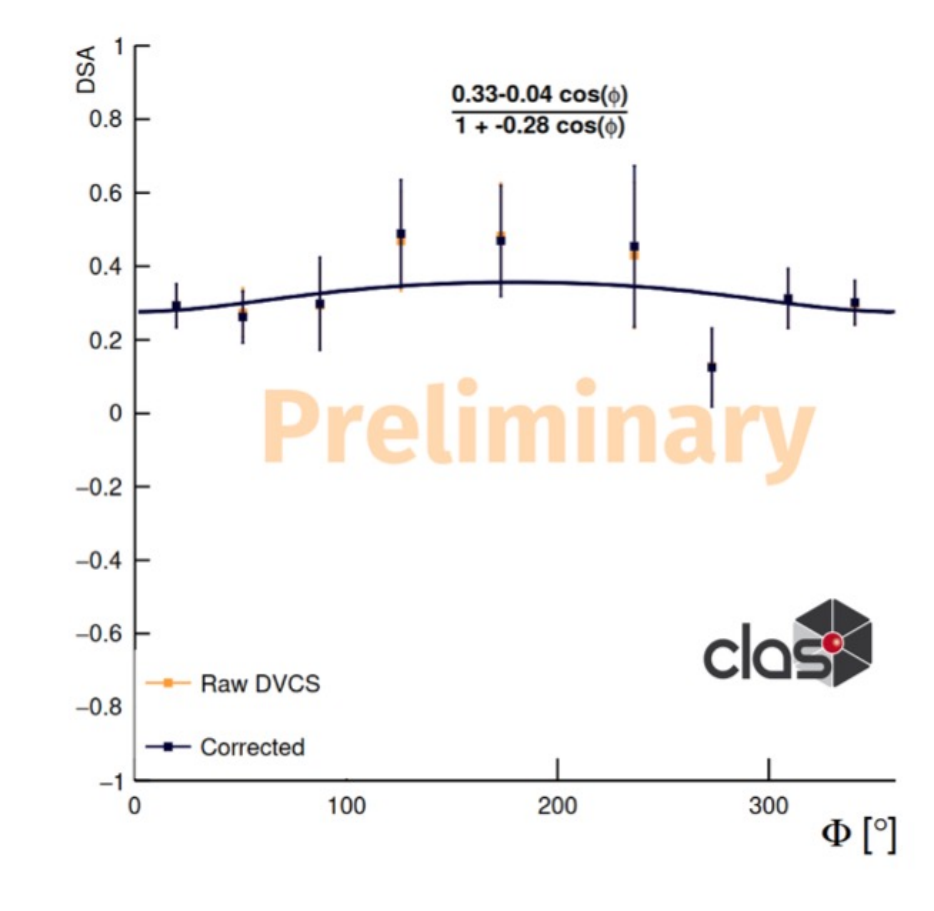




pDVCS on D



Normalisation is being investigated.



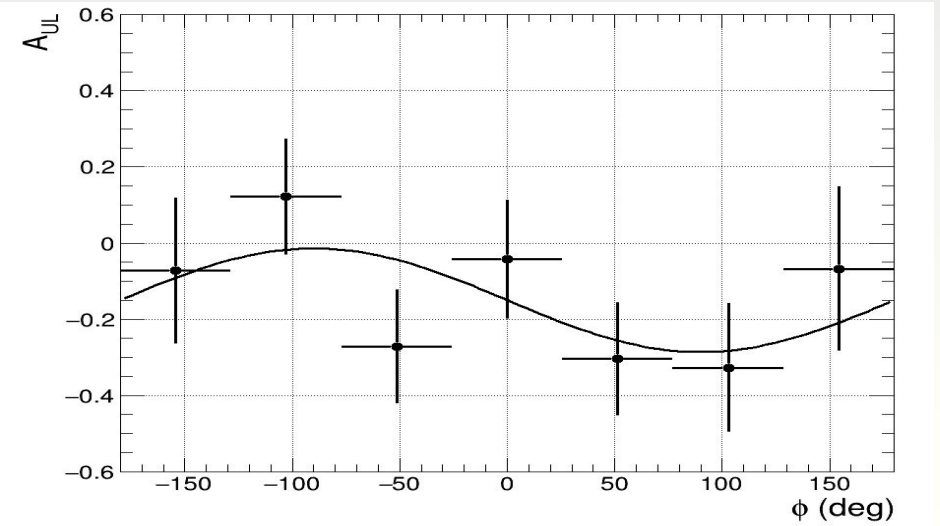
TSA in Timelike DVCS

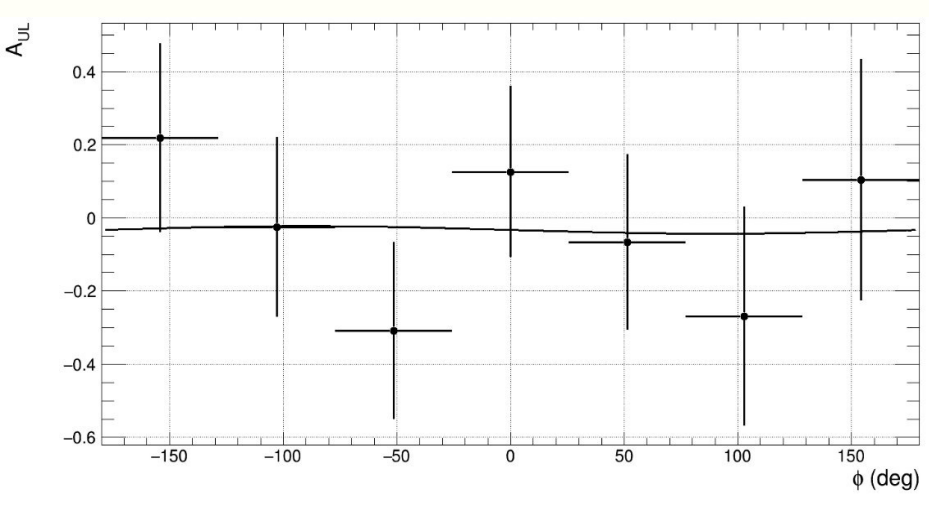
Top - No requirement on proton (allowing CD and FD simultaneously – potential contributions from meson resonances between 1.5 and 2GeV)

More runs with negative target polarization than positive hence the shift.

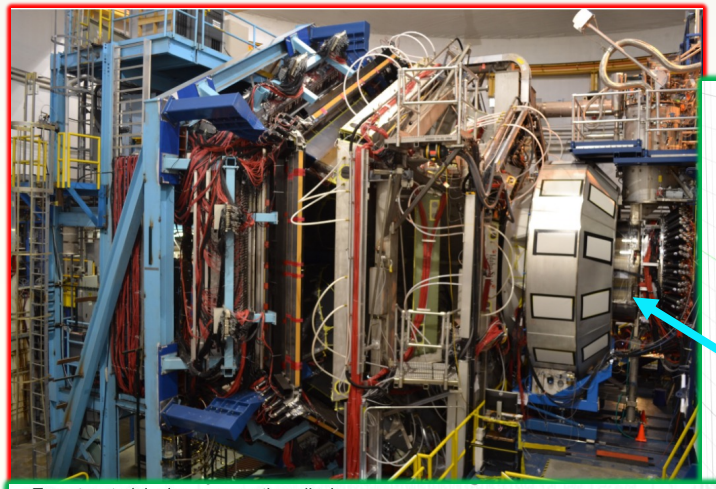
Bottom - Only FD protons – reduces statistics by approximately half

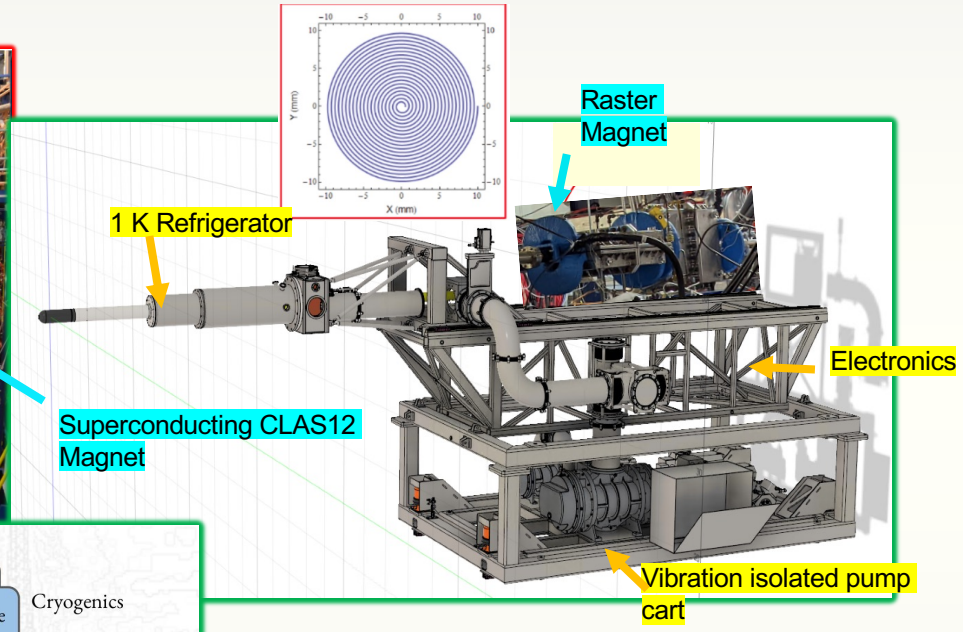
Variable	Min	Max
MM^2 (GeV^2)	-0.4	0.4
-t (GeV^2)	0.2	0.8
IM (GeV)	1.5	3
E_γ (GeV)	4	10.6
Pt/P (GeV)	< 0.05	



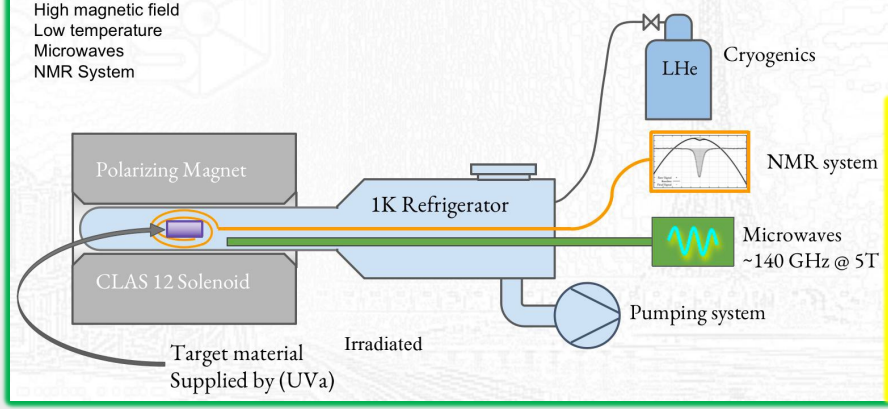


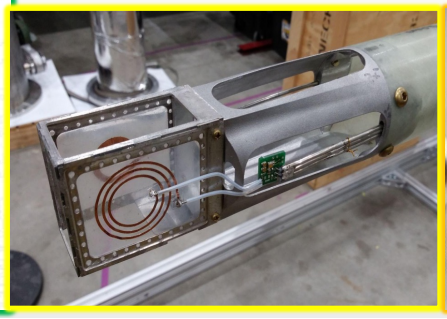
Polarized Target

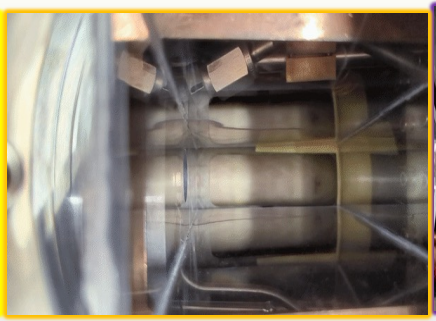




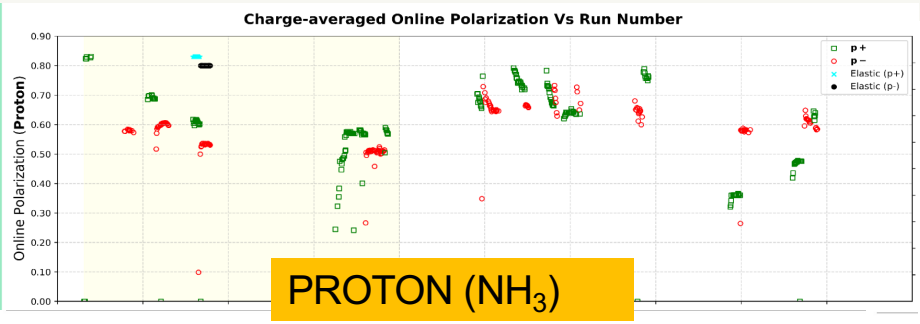
Target material w/ paramagnetic radicals
High magnetic field
Low temperature
Microwaves
NMR System



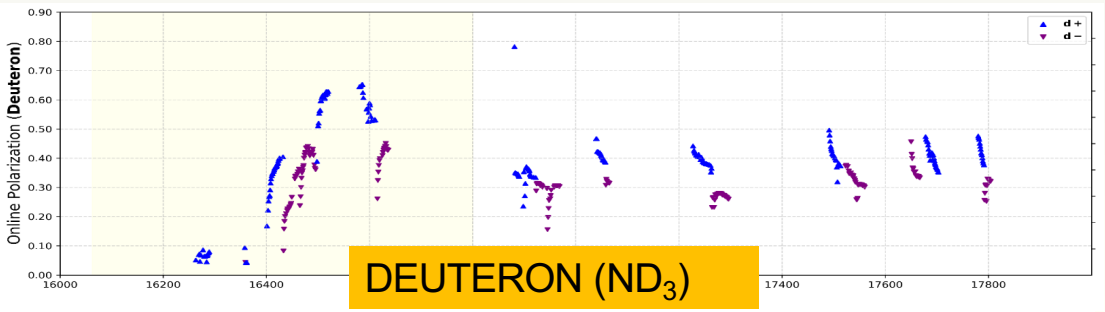




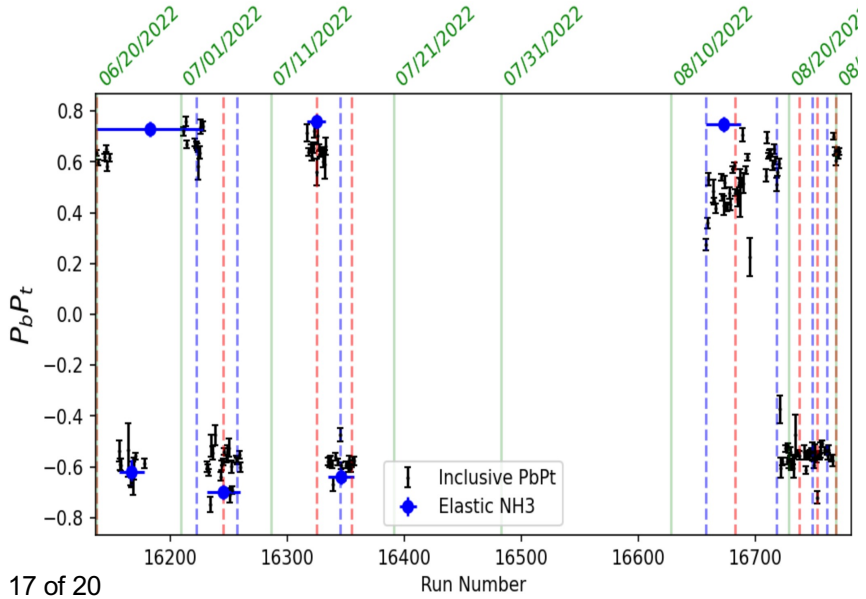
Target performance

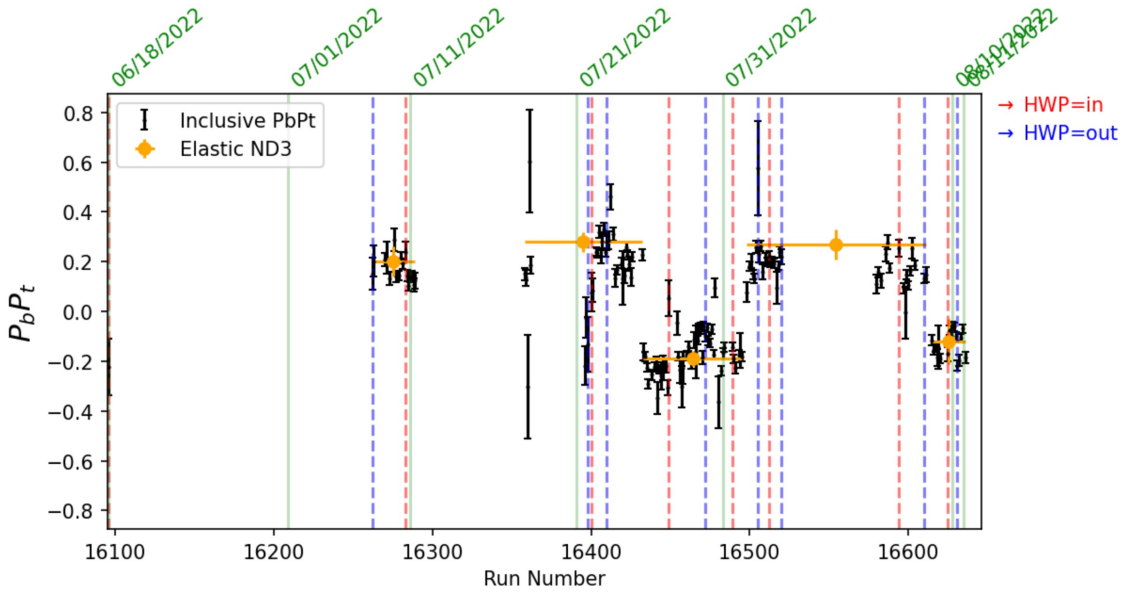


PROTON (NH_3)



DEUTERON (ND_3)





Target Status and Prospect for 2026

- Polarized target has performed well with a few exceptions:
  - Initial polarization of some material was very low
  - Some material was rather old and of unknown provenance

    => Need new material, better irradiation facility, ability to test polarizability on location

- Target is in storage and can be reused with few to no modifications (remove mothballs and test all components)
- Will work for both RG-C and RG-G (just replace NH_3/ND_3 cells with ^{7}LiD)
- TAC Report:

The longitudinal polarized target system has been developed, constructed, and installed for RG-C and has been operating with great success during the years 2022-23. The target performance was excellent. It is now stored and is ready for re-installation.

Comments:

There are no technical issues with these proposals.

Spin Polarized Nuclei Project

- Irradiation Cryostat:
  - Stand design complete
  - Injector area survey with Matt Poelker and Jennifer Williams complete
  - Cryogenic transfer lines and cryostat plumbing design in progress, new supply transfer line route determined from walkthrough
  - Heat load analysis at 2K in progress
  - In-flow radial heater calculation done, 6-in heat exchanger with a 1500 W heater will suffice
- Polarization Chamber:
  - Rough geometry established as well as basic functionality
  - 7.5T solenoid magnet either 76mm or 105mm bore diameter yet to be purchased
  - Potential dilution refrigerator/polarization device install location determined, must route cryogenics and magnetized cryogenic injection line
  - Using XLD1000sl dilution refrigerator as our starting point for engineering designs

(June 18, 2024)

Potential Run Plan

Conditional Schedule 2026-27

SAD or scheduled Run Group	Setup / Status	Target	Beam Energy	Start Date	End Date	Scheduled Calendar Days	Remaining PAC Days Before Run	Scheduled PAC Days	Actual PAC Days from ABUs	Remaining PAC Days After Run
Assuming ~ 100 PAC days in this period and successful Experiment Readiness Review in 2025										
RG-C		long. pol. NH3/ND3	11	2026-27		80	40	40		0
RG-G		long. pol. 7LiD	11	2026-27		110	55	55		0
SAD 2027	reconfigure	change					**sum:**	**95**		

- The centerpiece, the **longitudinal polarized target**, has been constructed and used
- **RG-C** will have **to return** for 40 days to complete its approved 120 PAC day program
- Consecutive execution of RG-C and RG-G would minimize substantial overhead
- RG-G no longer requests a double target but will alternate between NH_3 and ^7LiD, so **no modifications to the polarized target will be necessary**
- For producing paramagnetic radicals needed for DNP, **irradiation** using 8 MeV beam from injector and a variable temperature **cryostat**, commissioning expected 2024-25
- **Well aligned** with the **Spin-Polarized Fusion Project** (new engineer, technician, …)

Run Conditions As Before

- > 10.5 GeV electron beam, polarization > 0.85
- p and d (ammonia and deuterated ammonia) targets polarized (via DNP) along or opposite to the beam direction
- Standard CLAS12 Forward Tracker including 2 (or more) sectors of LTCC and **2** sectors of RICH; FT or new Møller Cone installed
- Standard CLAS12 Central Detector with all components (SVT, BMT, CTOF, CND); no BAND or FMT
- Beam raster over up to 2 cm diameter (demonstrated)
- Standard e^- inclusive trigger with ”roads”; data rate and data storage similar to previous run
- 40 PAC days on NH_3 and ND_3
  - In addition, higher average target polarization and luminosity will yield about 70% (FoM) more data
  - Improved systematics and extended kinematic reach by running BOTH solenoid and torus polarities & optimal complement of background measurements (interrupted by lost days)
- If run in conjunction with RG-G: Common auxiliary targets and systematic measurements shared (C, CH_2, CD_2, ^4He, Empty)

Summary

- RG-C combines several highly rated experiments that will make crucial contributions to the core 12 GeV program at Jefferson Lab
- The physics goals of RG-C continue to enjoy high interest in the community, with a steady stream of new publications (and new observables!)
- The longitudinally polarized target is ready (tremendous investment by Lab and collaborators, including NSF MRI).
- We request re-approval of the remaining runtime for Run Group C (40 additional PAC days).
- More statistics crucial for multi-dimensional binning, statistics-starved channels (DVCS, TCS, K-SIDIS), and all Deuteron asymmetries, plus for improved systematics.

J12-24-RunGroupC

CLAS12 Run Group C:
Jeopardy updated document

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Due to major downtimes of the accelerator and Hall B equipment issues, the Run Group C was only able to run 2/3 of the PAC48-approved days. In this Jeopardy proposal, the RGC requests beam time to finalize the additional missing PAC days, which are critical for the completion of the experiments and for achieving optimal accuracy in the measurements. There are several experiments in the RGC that all require a longitudinally polarized target to access a variety of fundamental quantities in hadron structure, including helicity-dependent PDFs, TMDs, and GPDs, all of which are highlighted in the 2023 NSAC Long Range Plan.

To illustrate the importance of completing these measurements, the new data on DIS and SIDIS will provide access to the longitudinally polarized structure function F_{LL}, which is extremely challenging to measure in the high-x region due to suppression induced by an ϵ-dependent kinematic factor. These measurements will provide a unique opportunity to reconstruct helicity PDFs/TMDs at high x, particularly the d-quark PDF. There is considerable interest in the polarized d-quark PDF, for example, whose possible sign change at high x is still elusive, according to the most recent analysis by the JAM Collaboration, which has recently included W-lepton and jet production data in polarized pp collisions at RHIC, and the available high-x data from Jefferson Lab.

This Run Group is one of the central pillars of the hadron structure component of the 12 GeV program, and it is vital for its successful completion to collect these data with sufficient precision to make the expected impact on our knowledge of the parton structure of the nucleon.