

Hall B Status and Future



[V.D. Burkert, L. Elouadrhiri, et al., Nuclear Inst. and Methods in Physics Research, A 959 (2020) 163419]

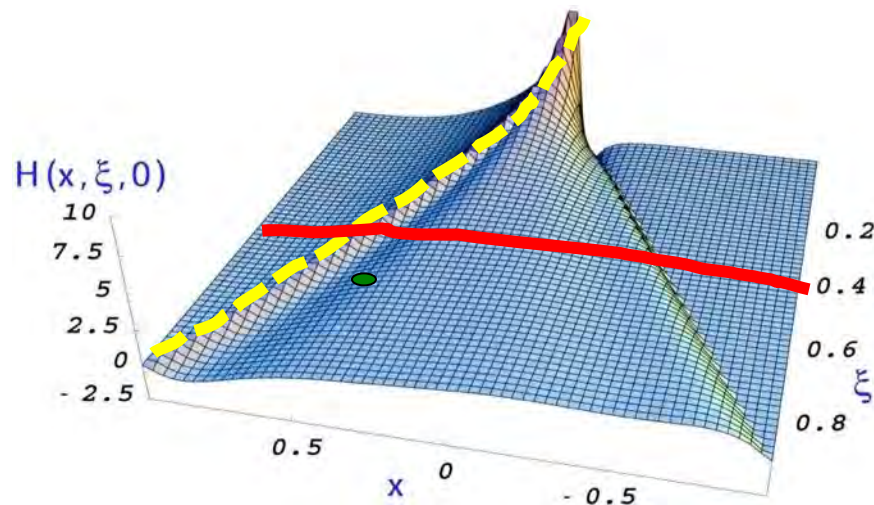
The Current Run



Run Group C Physics Goals

Proton and Neutron Spin Structure

- DIS inclusive and flavor-tagged spin structure functions
- Semi-inclusive DIS (SIDIS) to access Transverse Momentum Distributions (TMDs), dihadron production and backward baryon production
- Deeply Virtual Compton Scattering (DVCS) to access Generalized Parton Distributions (GPDs); Target single and beam/target double spin asymmetries in proton and neutron DVCS



Current Run-Group Experiments

Run Group C: 10.5 GeV highly polarized beam with 4/8 nA current in Hall B using the longitudinally-polarized frozen (deuterated) ammonia target

E12-06-109: Longitudinal spin structure of the nucleon

(Contact: S. Kuhn)

E12-06-109A: DVCS on the neutron with a polarized deuterium target

(Contact: S. Niccolai)

E12-06-119(b): DVCS on a longitudinally polarized proton target

(Contact: F. Sabatie)

E12-07-107: Spin-orbit correlations with a longitudinally polarized target

(Contact: H. Avakian)

E12-07-107A: Studies of single baryon production in the target fragmentation region with a Longitudinally polarized target (Contact: T. Hayward)

E12-09-007(b): Study of partonic distributions using SIDIS kaon production

(Contact: K. Hafidi)

E12-09-007A: Studies of dihadron electroproduction in DIS with longitudinally polarized hydrogen and deuterium targets

(Contact: C. Dilks)

E12-09-009: Spin-orbit correlations in kaon electroproduction in DIS

(Contact: H. Avakian)

Run Group C Schedule

- Eight month run in June 2022 – March 2023

Originally 185 PAC days, reduced to 120 PAC days in Jeopardy

→ 240 Calendar days scheduled + 4 days of commissioning

Proton (NH₃) and Deuteron (ND₃), auxiliary C, CH₂, CD₂, ⁴He/foil targets

- Outlook: return to “FTon” running over the Winter break
- Collect more data in “FTon” configuration from 1/16/2023 to 3/20/2023.

[Sebastian Kuhn]

Experimental Setup

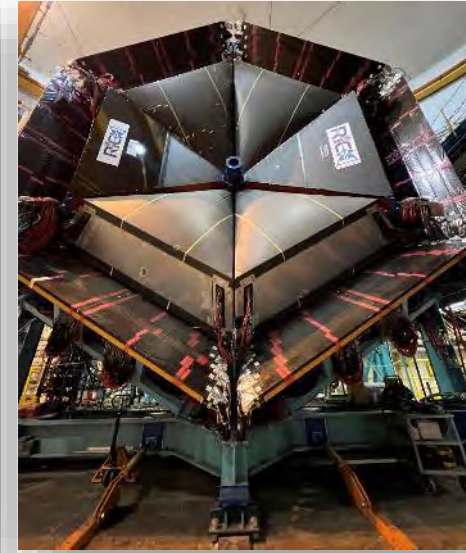
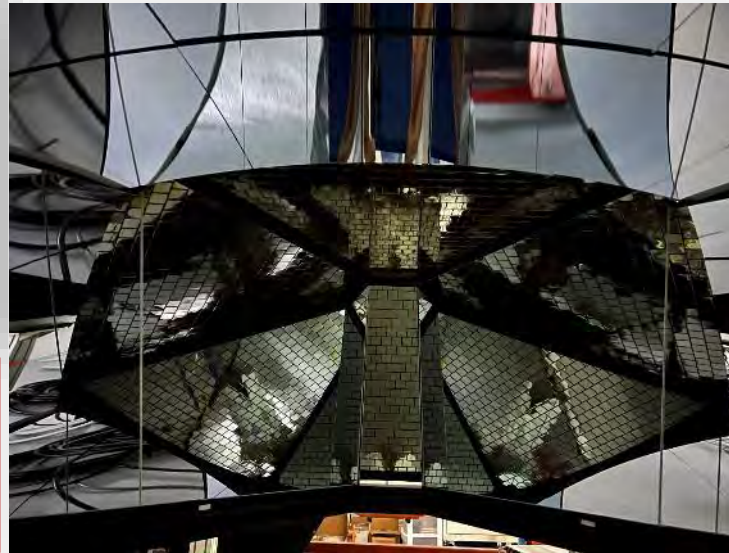


2nd RICH Installed and Operating

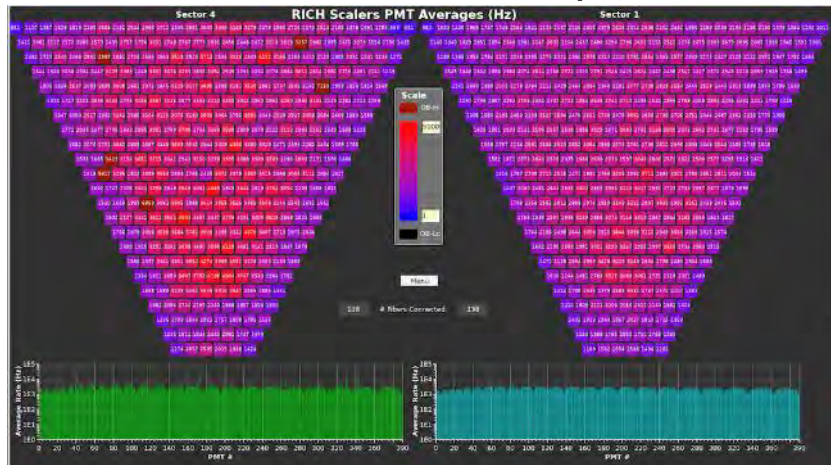
[Valery Kubarovsky]



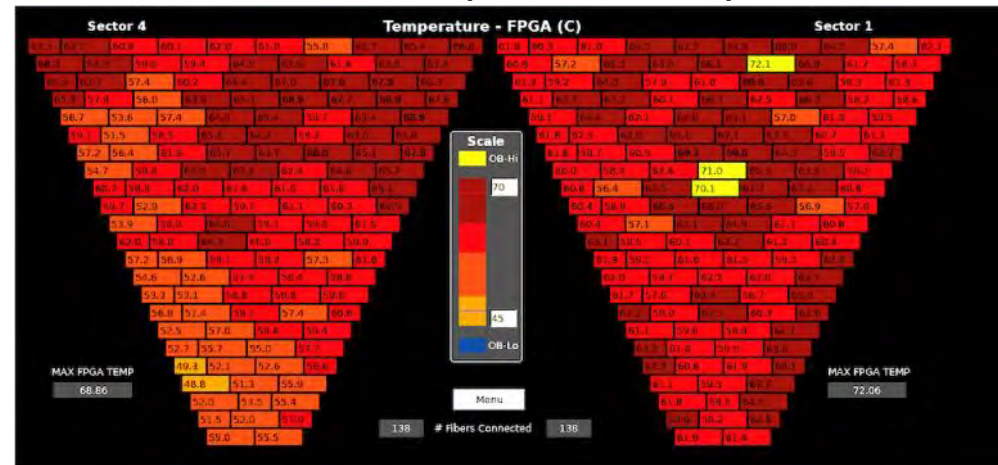
- Two sectors of FD with RICH, four with LTCCs
- 50,048 channels in total



RICH Scalers Map



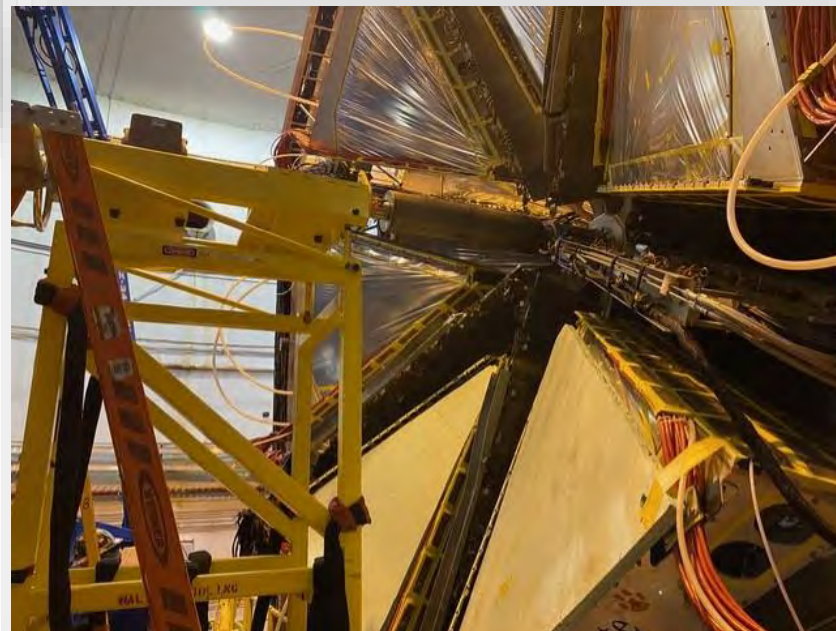
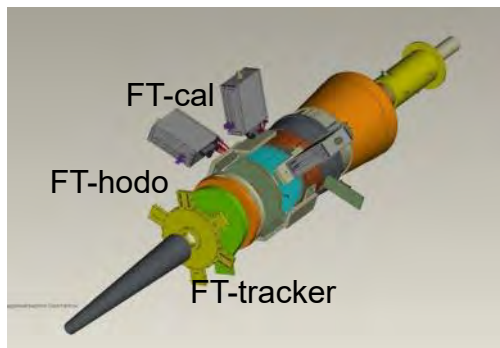
RICH Temperature Map



Setup Change in Aug 2022



- “FTon”: forward tagger calorimeter, reduced raster size and beam current
- “FToff”: no forward tagger calorimeter, full raster size, full beam current



[Bob Miller]

Manual Work in Hall B

HTCC was moved to the floor

[Stepan Stepanyan]



FT tracker,
hodoscope,
and the
calorimeter
were removed



A new large Moller cone was installed

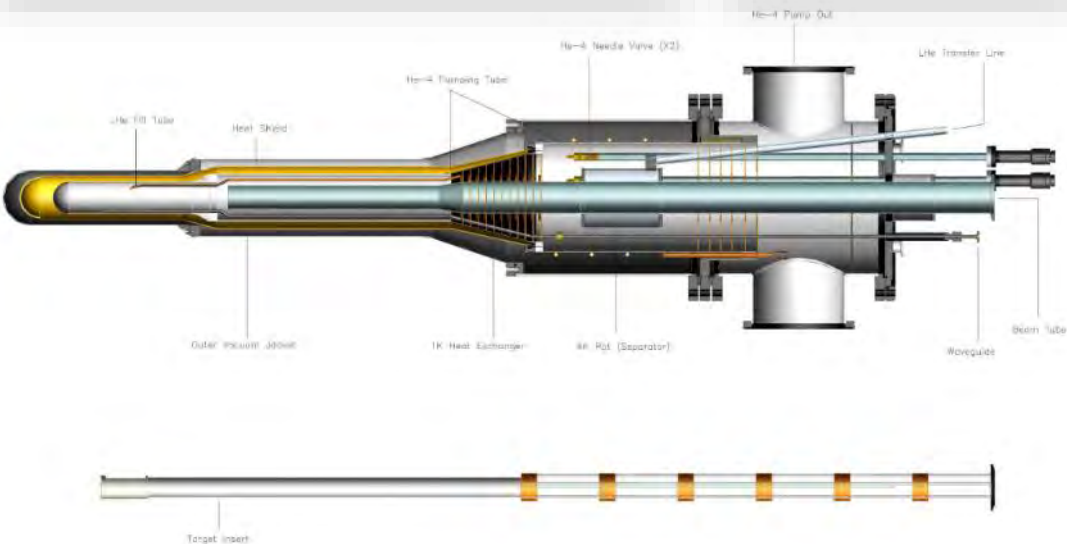


Changeover done by technicians and others within one week (Aug 26 – Sep 3)

Cryo-Target System



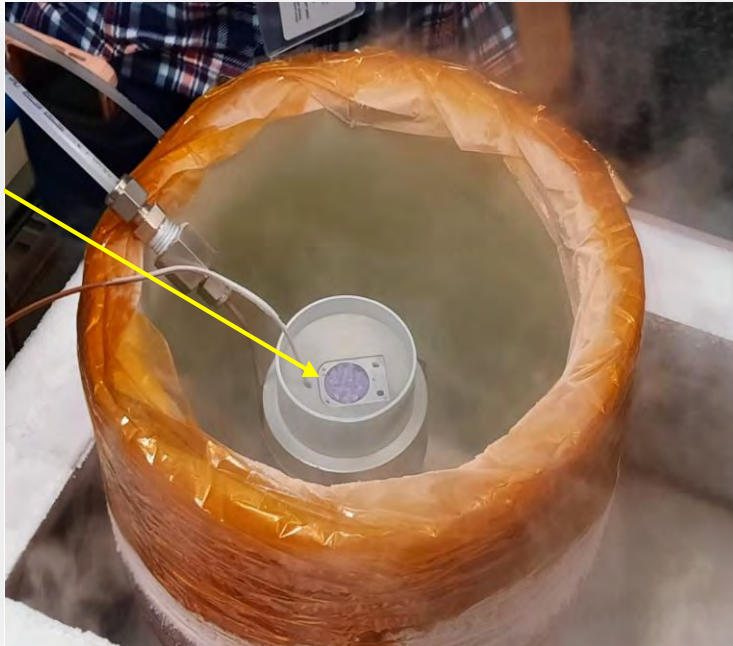
Complex high-maintenance device for long
(June 2022 – March 2023) data-taking period



All components work as expected and high polarization achieved

Polarized Frozen Ammonia

Fresh target sample
(ammonia beads in cell)



- DNP through 140 GHz μ wave irradiation
- Cooled to 1 K with 4 He evaporation refrigerator

Target cell after exposure to beam
(about to be unloaded)



Samples 5 cm long

Annealing performed once or twice per week for recovering the initial degree of polarization after radiation-induced depolarization

[Sebastian Kuhn]

Nov 2022

Patrick Achenbach

Changing Target Samples



Target inside
cell:



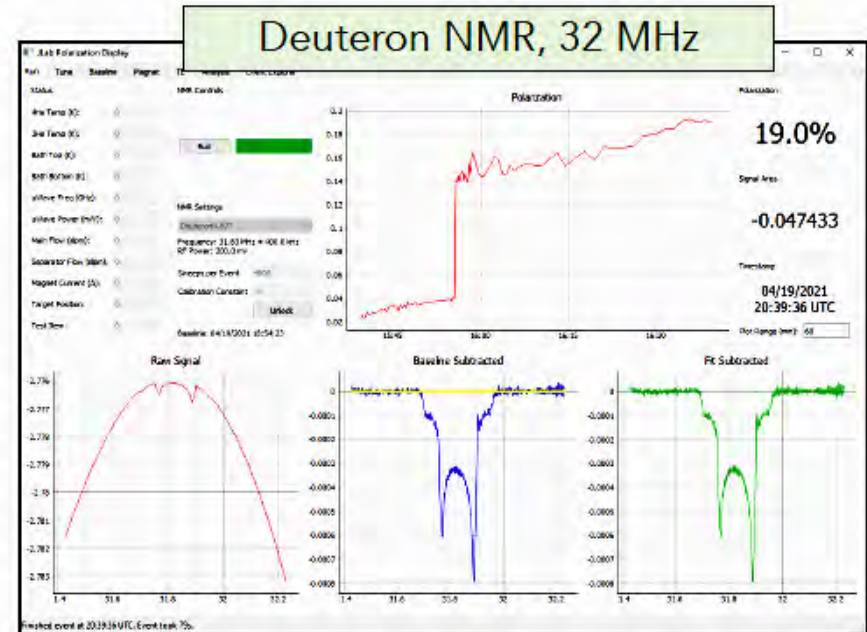
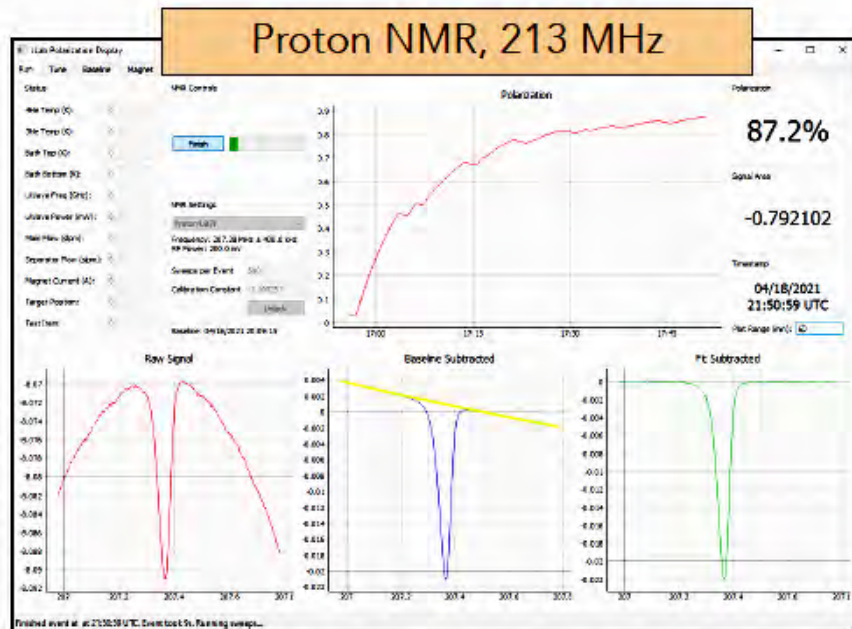
Cell inside
bath:



Target change on Oct 27
[Chris Keith]

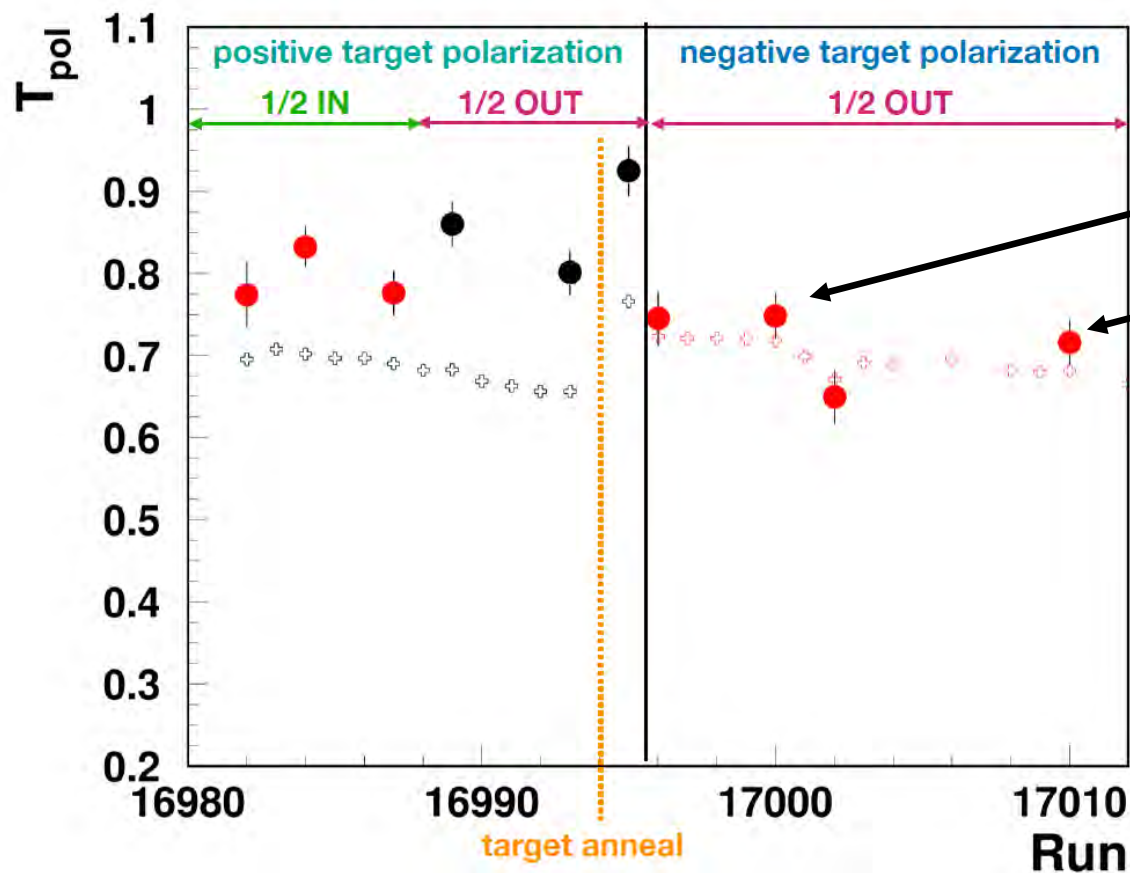
Polarization Read-out by NMR

- Ammonia used because of high radiation hardness as a proton target (and deuterated ammonia as neutron target)
- Read-out of relative polarization from NMR pick-up circuit (susceptible also to non-irradiated target volume)



Control of polarization is key to optimize annealing and target change procedures

Cross-Check of NMR Read-Out



NMR reading

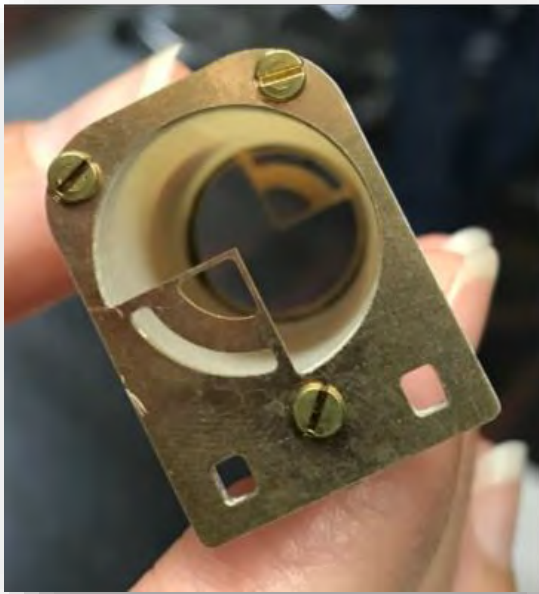
From physical asymmetries

More details:
Nathan Baltzell today

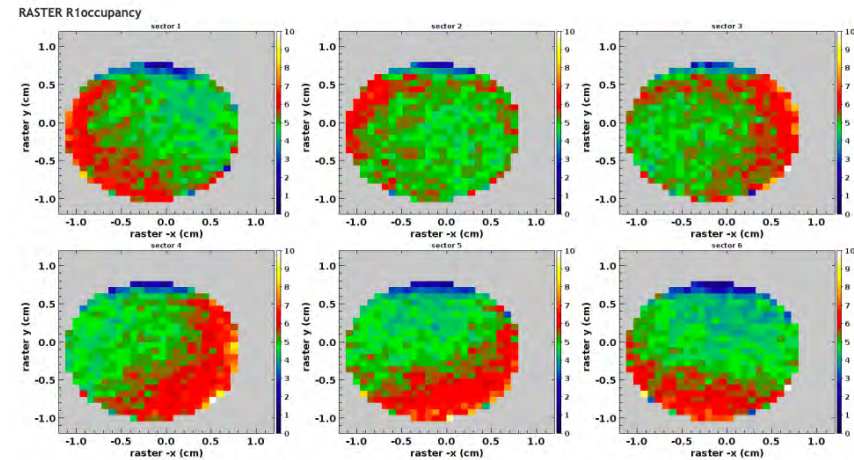
- Physical asymmetries support NMR readings
- New *online* tool to track polarization

Beam Rastering

Calibration target

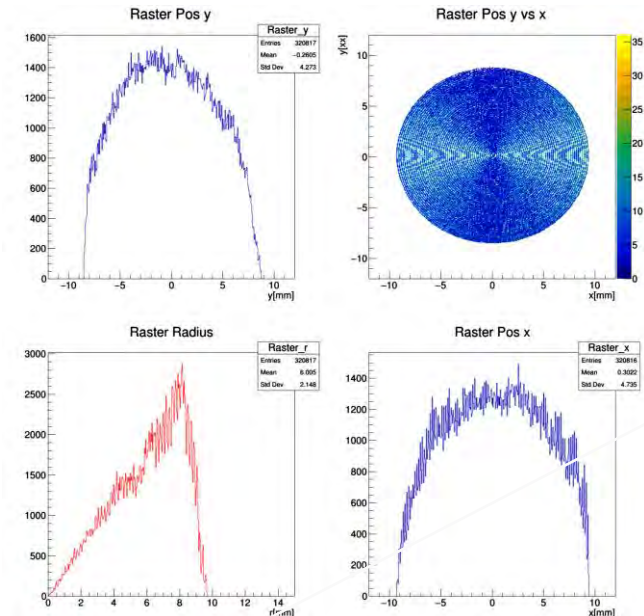


Drift chamber
occupancy vs.
raster position

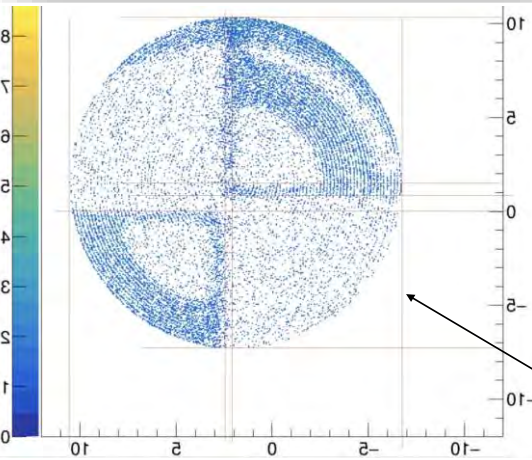


Raster
pattern

Raster is key to optimize
irradiation of target



Reconstructed count
rate vs. raster position

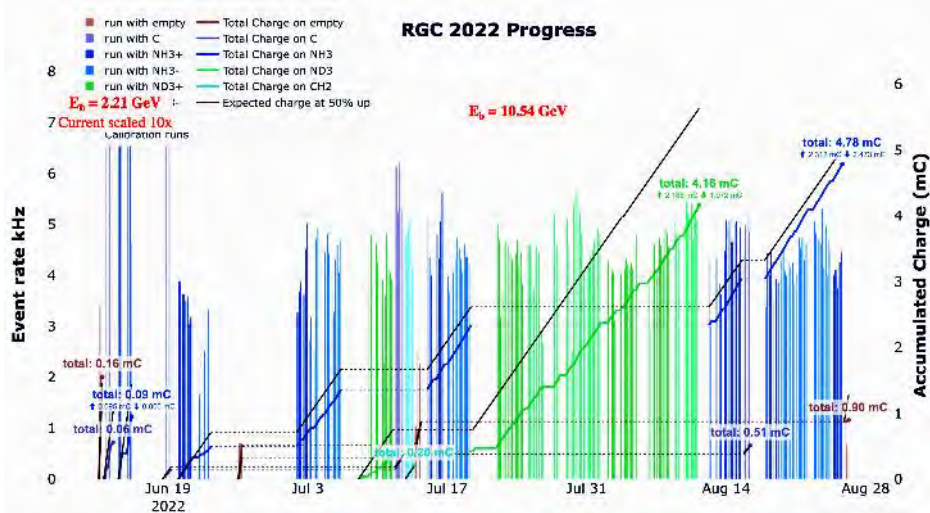


[Sebastian Kuhn]

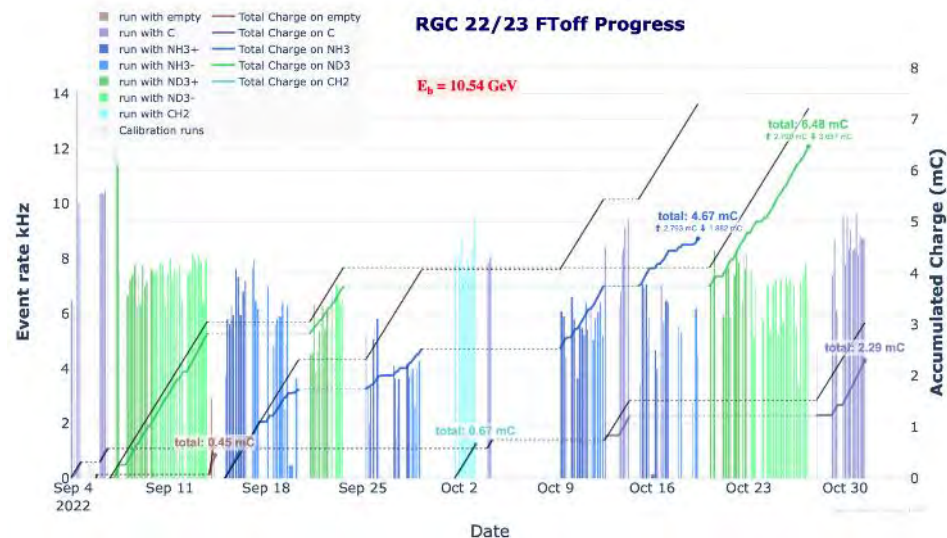
Run Group C Data Taking



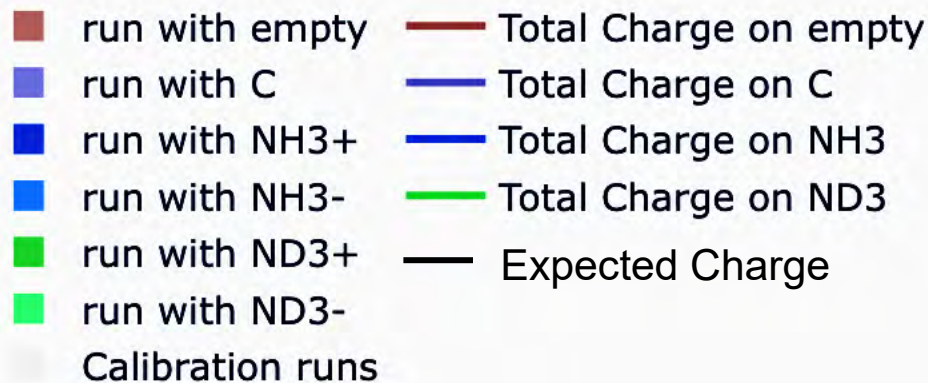
Progress on Data Collection



1st period: June – Aug 2022



2nd period: Aug – Dec 2022



[Sebastian Kuhn]

Nov 2022

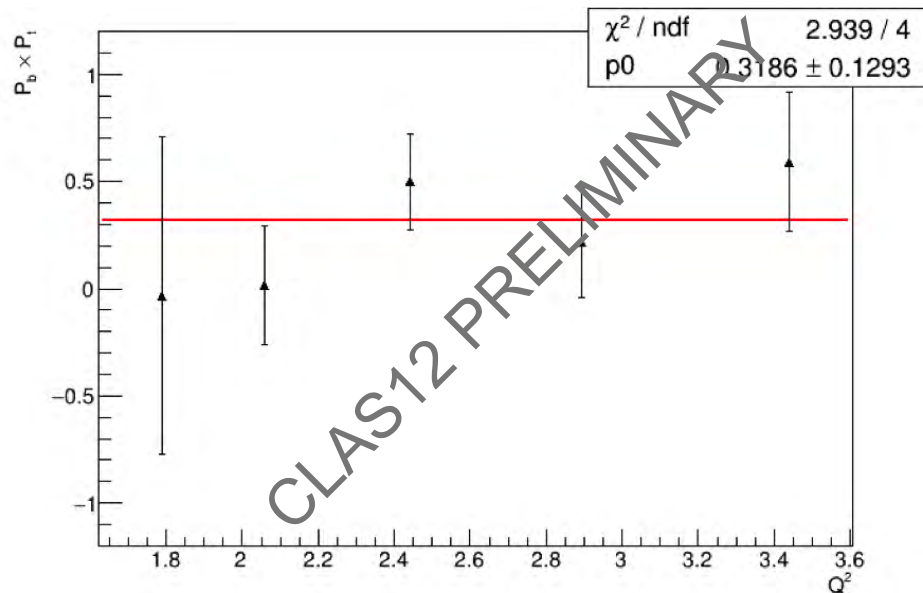
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Preliminary Data Analysis from ND₃

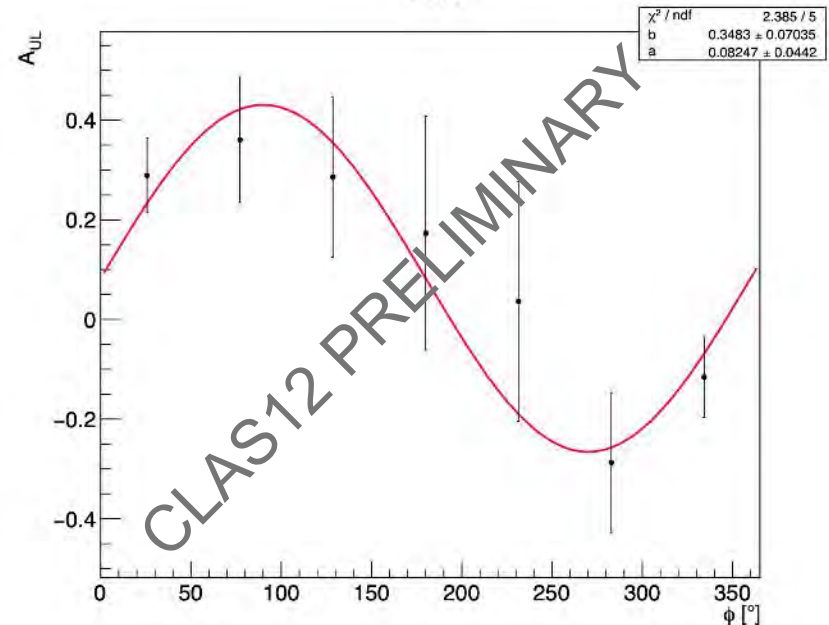
Using proton DVCS from “FTon” period

$$\langle Q^2 \rangle = 2.231, \langle x_B \rangle = 0.1801, \langle -t \rangle = 0.4061$$

Polarization from quasi-elastic scattering:



TSA



[Maxime Defurne, Noémie Pilleux and Silvia Niccolai]

Extraction of neutron longitudinal target spin asymmetries
associated to neutron DVCS

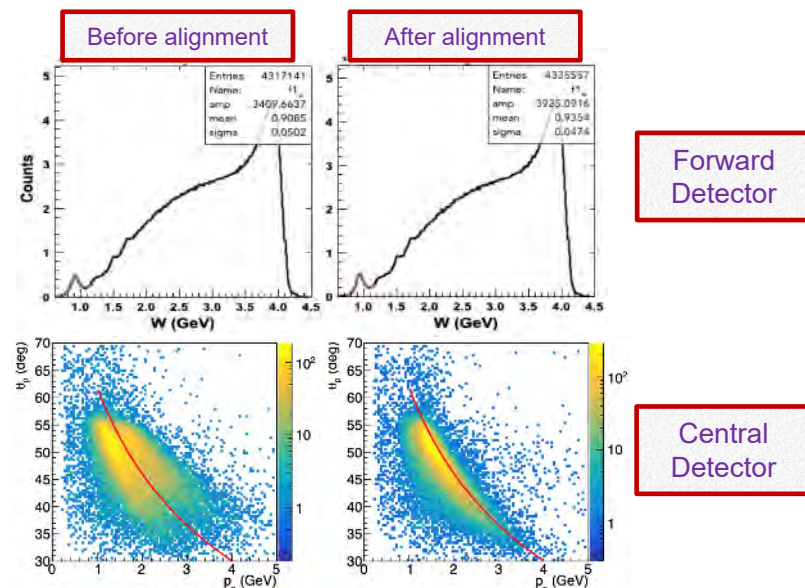
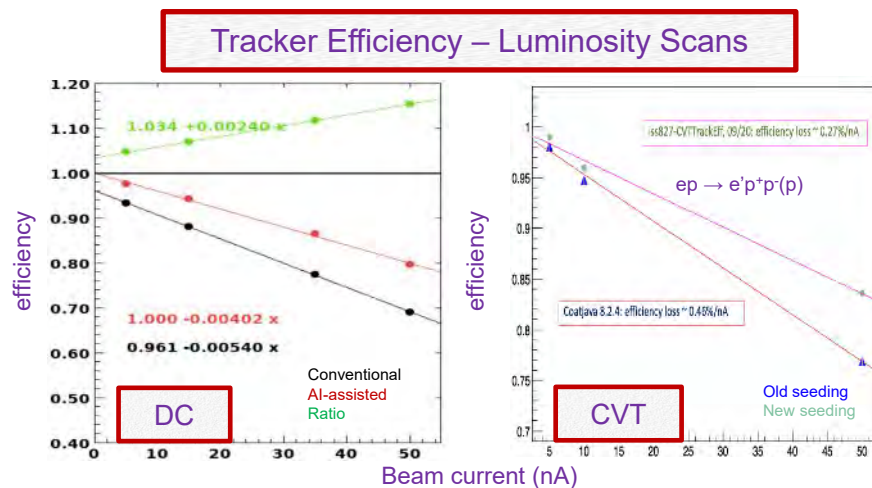
Alignments, Calibrations and Cooking



CLAS12 CALCOM Status

Pass-2 re-calibration status:

- [RG-B Spr19 \(LD2\)](#) – calibrations completed for all subsystems; ready for cooking review held on Oct. 28 (chair Marco Battaglieri) – cooking to begin by end of Nov. after addressing items raised during the review.
- [RG-A Spr19 \(LH2\)](#) – calibrations completed for all subsystems; detailed pass-2 vs. pass-1 reconstruction studies in progress; ready for cooking review to be scheduled in the first half of November.
- [RG-K Win18 \(LH2\)](#) – tracker alignment work nearly complete; initial pass-0 for assessment to be launched shortly; two-month-long calibration sequence to begin before the end of Nov.
- [Next steps](#) – “ready for calibration” reviews for RG-B (F19/Win20) and RG-A (F18) datasets later this month.
- [Status](#) – Work proceeding efficiently with good interactions with Run Groups, Software Group, and CALCOM.



Polar angle vs. momentum for elastic protons

[Daniel Carman]

Nov 2022

Patrick Achenbach

Reconstruction Software Status

Reconstruction software:

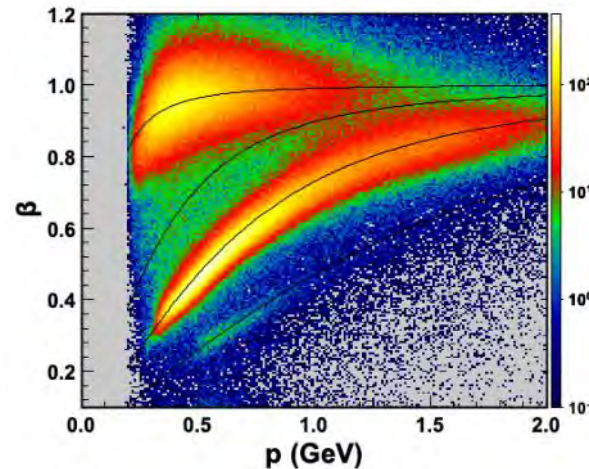
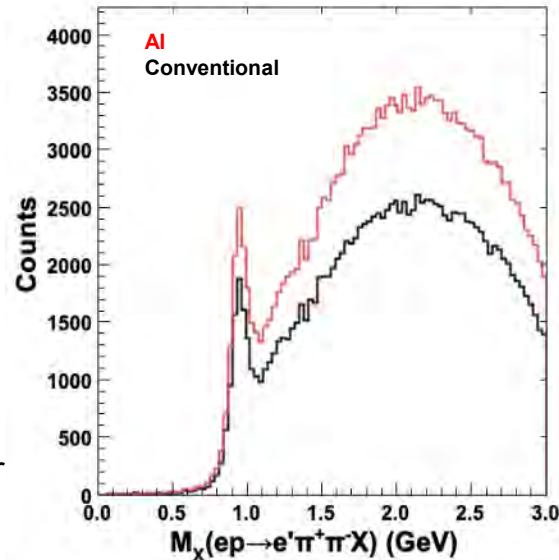
- All major software development completed, or in the final stage (open pull requests)
- Extensive validation from RG-A and RG-B

Pass2 vs. Pass1:

- Large increase in charged particle reconstruction efficiency (10% per track or more)
- Resolution improvements due to alignment (both FD and CD) and removal of tracking biases and energy loss correction (CD)
- Improvements to neutral reconstruction in ECAL (handling of overlapping clusters) and FT (improved calibrations)
- Several updates to EB to improve track-hit matching and provide more information for analyses

[Raffaella De Vita]

RG-B Spring 2019



CD PID after energy loss, showing pion, proton and deuteron bands

Alignment of trackers:

- CVT alignment based on Kalman Filter Alignment algorithm (see S. Paul *et al.* (CLAS), arXiv:2208.05054, submitted to NIM)
- New implementation of DC alignment
- DC-CVT alignment based on beam spot method

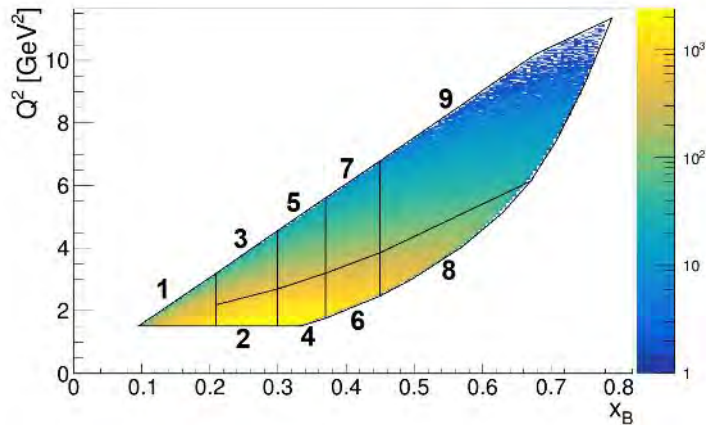
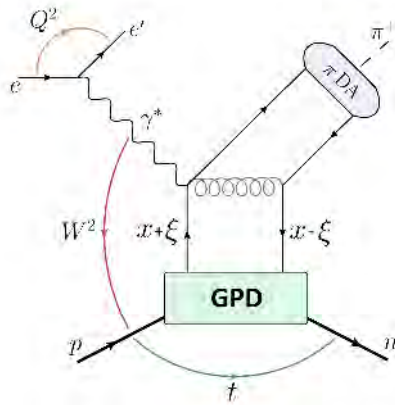
RGA Data Analysis and Publications



Hard Exclusive π^+ Electro-Production off Protons

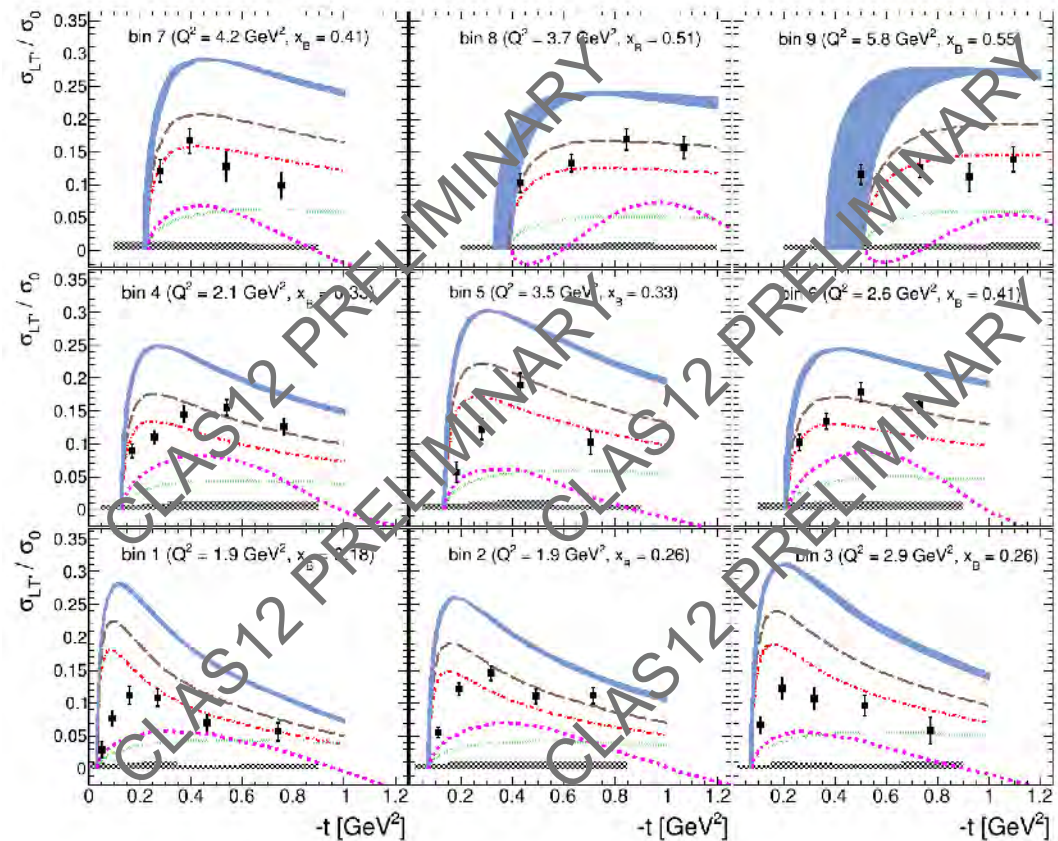
Stefan Diehl (JLU Gießen and UCONN)
arXiv: 2210.14557 submitted to PLB

Access to chiral-odd GPDs



A multidimensional study of the structure function ratio $\sigma_{LT'}/\sigma_0$ from hard exclusive π^+ electro-production off protons in the GPD regime

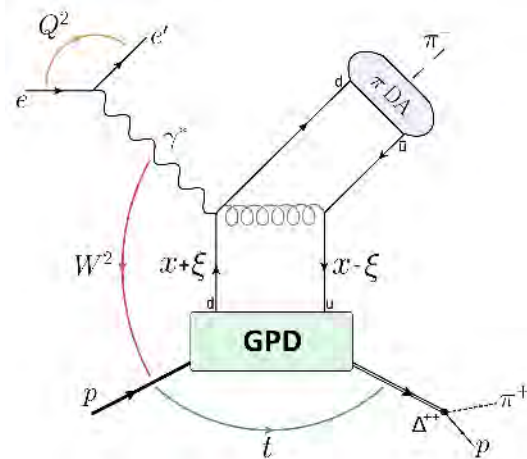
S. Diehl^{ah,f}, A. Kim^f, K. Joo^f, P. Achenbach^{uv}, Z. Akbar^{uu,l},
M.J. Amarian^{ag}, H. Atac^{am}, H. Avagyan^{en}, C. Ayerbe Gayoso^{av},



blue: GK GPD model magenta: Laget Regge model

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

Stefan Diehl (JLU Gießen and UCONN)
Analysis review



First measurement of hard exclusive $\pi^- (\Delta^{++})$ electro-production beam spin asymmetries off the proton

S. Diehl,^{1,2} N. Trotta,² and K. Joo²

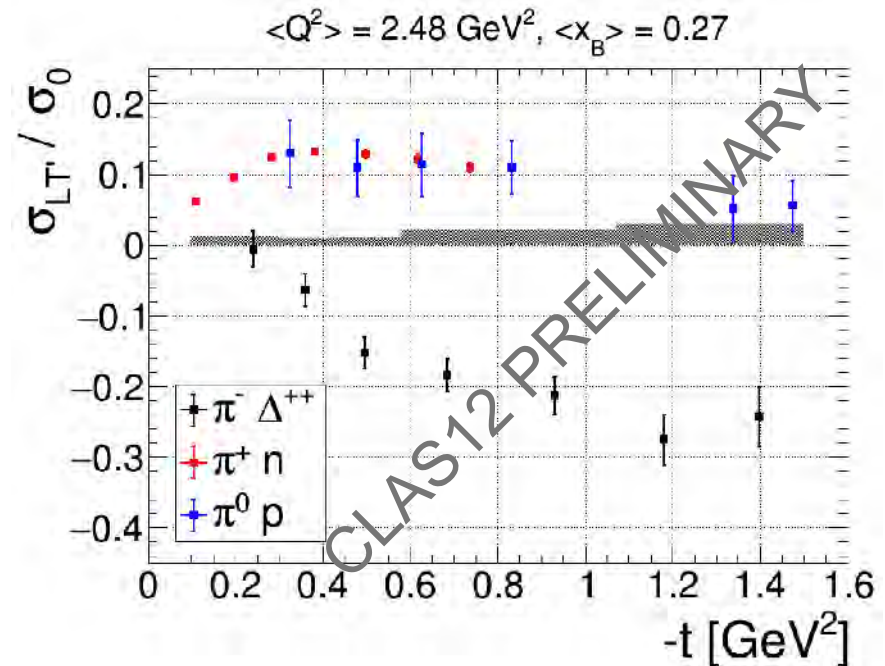
(The CLAS Collaboration)

¹H. Physikalisches Institut der Universität Gießen, 35392 Gießen, Germany

²University of Connecticut, Storrs, Connecticut 06269

The polarized cross section ratio σ_{LT}/σ_0 from hard exclusive $\pi^- (\Delta^{++})$ electro-production off an unpolarized hydrogen target has been extracted based on beam spin asymmetry measurements using a 10.2 GeV / 10.6 GeV incident electron beam and the CLAS12 spectrometer at Jefferson Lab. The study, which provides the first observation of this channel in the deep-inelastic regime, focuses on very forward kinematics ($t/Q^2 \ll 1$) with a wide kinematic range of x_B in the valence regime, and virtualities Q^2 ranging from 1.5 GeV² up to 6 GeV². The reaction provides a first direct, clean access to the d-quark content of the nucleon and to $p \rightarrow \Delta^{++}$ transition generalized parton distributions. A comparison to existing results for the hard exclusive $\pi^+(n)$ and $\pi^0(p)$ electro-production is provided.

PACS numbers: 13.60.Lc, 14.20.Dh, 14.40.Bc, 24.85.+p



- Access to transition GPDs
- 3D structure of resonances

Multidimensional Study of SIDIS Single π^- and π^0 BSA

$$\frac{d\sigma}{dx_B dQ^2 dz d\vec{P}_T d\phi} = K(x, y, Q^2) \{ F_{UU,T} + \epsilon F_{UU,L} + \epsilon F_{UU}^{\cos 2\phi} \cos(2\phi) + \sqrt{2\epsilon(1+\epsilon)} F_{UU}^{\cos\phi} \cos(\phi) + \lambda_e \sqrt{2\epsilon(1-\epsilon)} F_{LU}^{\sin\phi} \sin(\phi) \}$$

$$F_{LU}^{\sin\phi} = \frac{2M}{Q} \zeta \left(\frac{-\hat{h} \cdot k_T}{M_h} \left(x e H_1^\perp + \frac{M_h}{M} f_1 \frac{\vec{G}^\perp}{z} \right) + \frac{\hat{h} \cdot P_T}{M} \left(x g^\perp D_1 + \frac{M_h}{M} h_1^\perp \frac{\vec{E}}{z} \right) \right)$$

A multidimensional study of SIDIS π^- and π^0 beam spin asymmetry over a wide range of kinematics

Stefan Diehl^{1,2}, Andrey Kim², Kyungseon Joo³

¹Justus Liebig University Gießen

²University of Connecticut

version 1 - September 28 2022

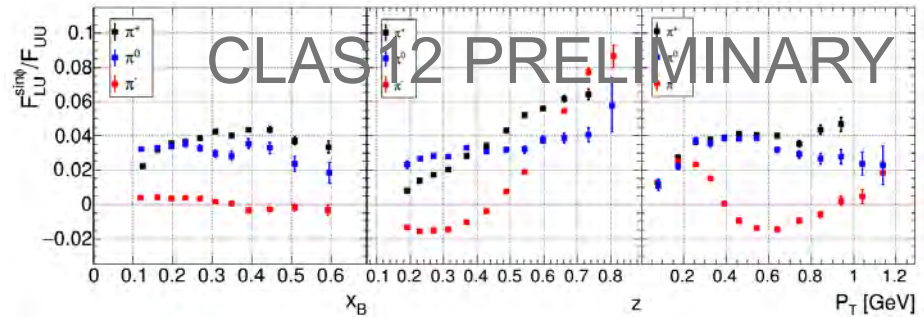
Abstract

A high precision study of the structure function ratio $F_{LU}^{\sin\phi}/F_{UU}$ corresponding to the polarized electron beam spin asymmetry in semi-inclusive deep inelastic scattering has been performed over a wide range of kinematics. $F_{LU}^{\sin\phi}$ is a twist-3 quantity which provides information about the quark-gluon correlations in the nucleus. The contribution will present for the first time a multidimensional study of single π^- and π^0 SIDIS over a large kinematic range of x , x_B , P_T and Q^2 with virtualities Q^2 ranging from 1 GeV² up to 8 GeV².

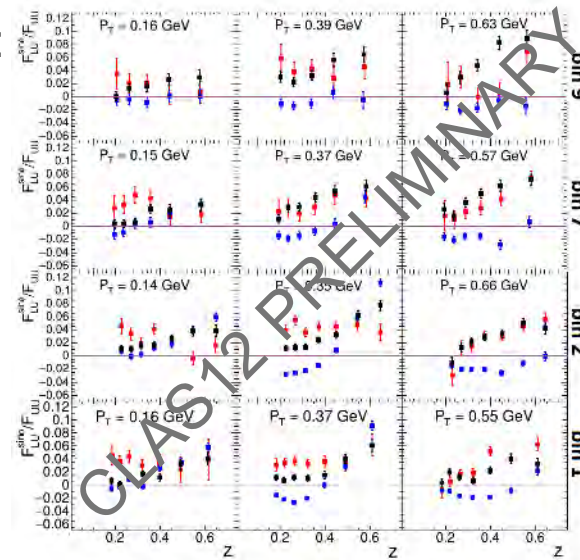
- Extension of published π^+ SIDIS
- Flavor decomposition of TMDs

Stefan Diehl (JLU Gießen and UCONN)
Analysis note

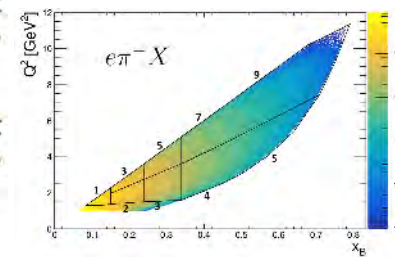
1D:



4D:



black: π^+
red: π^0
blue: π^-



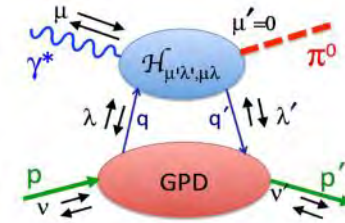
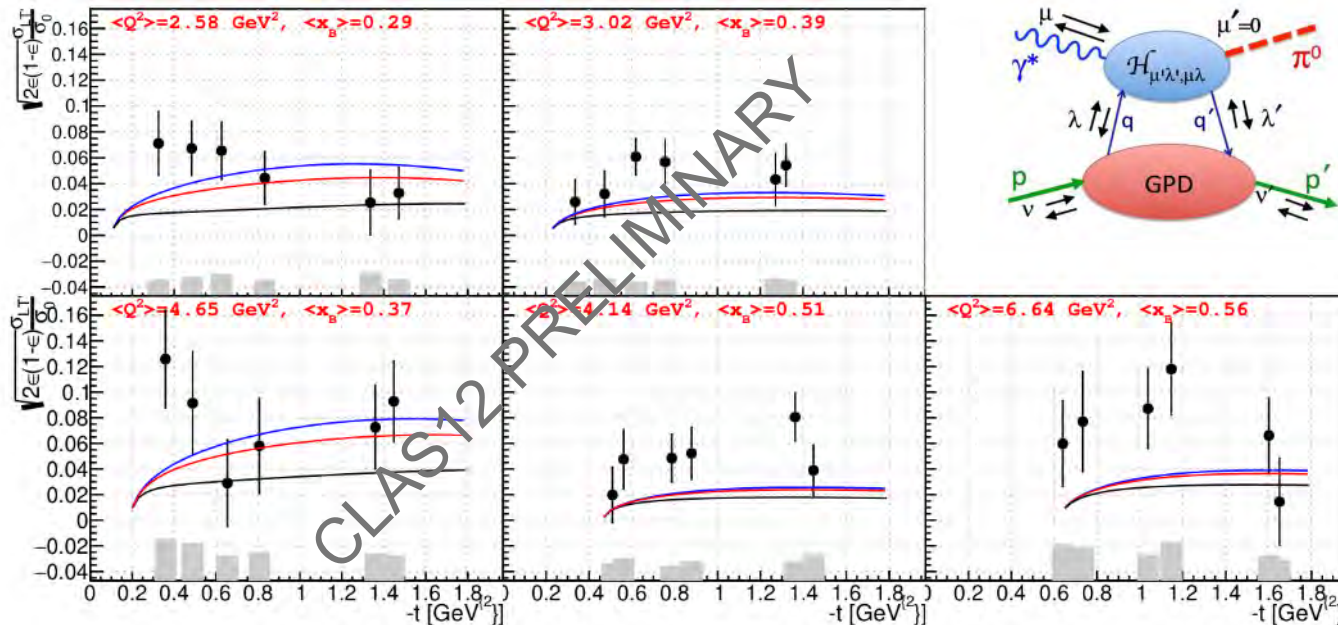
Nov 2022

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Beam Spin Asymmetries in Deeply Virtual π^0 Production

$$\sigma_{LT'} \sim \xi \sqrt{1 - \xi^2} \frac{\sqrt{-t'}}{2m} \text{Im}[\langle \bar{E}_T \rangle^* \langle \tilde{H} \rangle + \langle H_T \rangle^* \langle \tilde{E} \rangle]$$

Andrey Kim (UCONN)
Analysis note approved

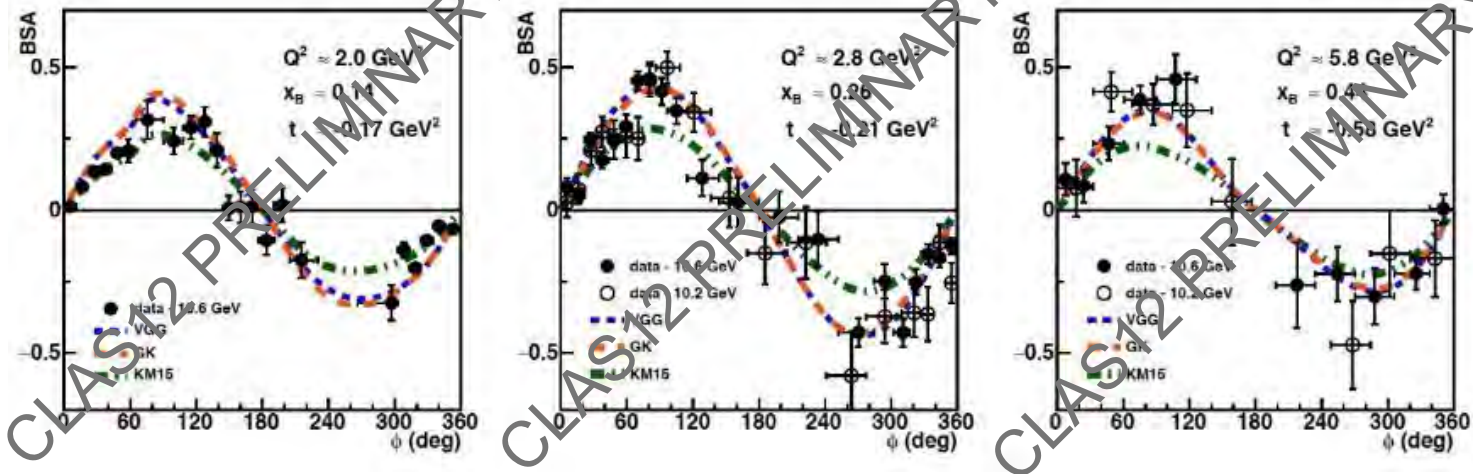


Access to the chiral-odd GPDs from beam spin asymmetries in exclusive pion electroproduction

DVCS Beam-Spin Asymmetries in Extended Valence Region

G. Christiaens
to be submitted to PRL

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

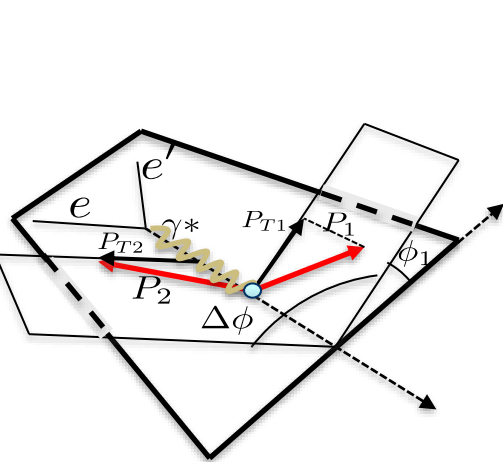


Greatly extend the Q^2 and Bjorken- x phase space in the valence region

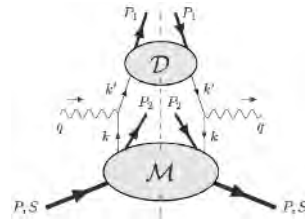
Correlations in Back-To-Back 2-Hadron Production

arXiv: 2208.05086

Submitted to PRL

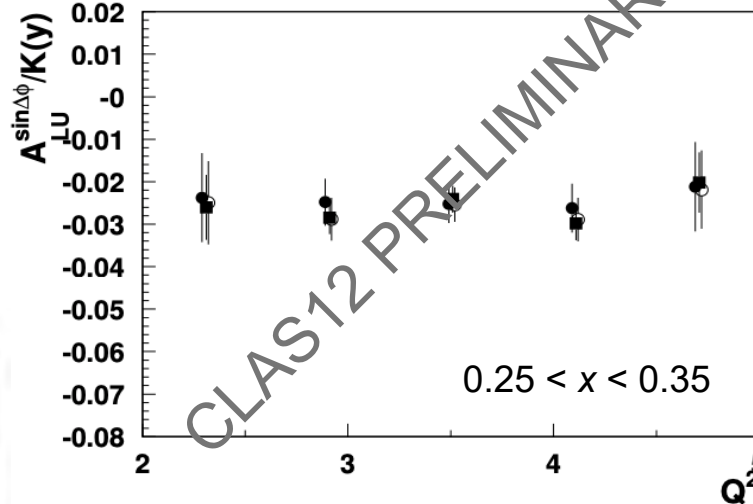


$ep \rightarrow e'p'\pi^+X$



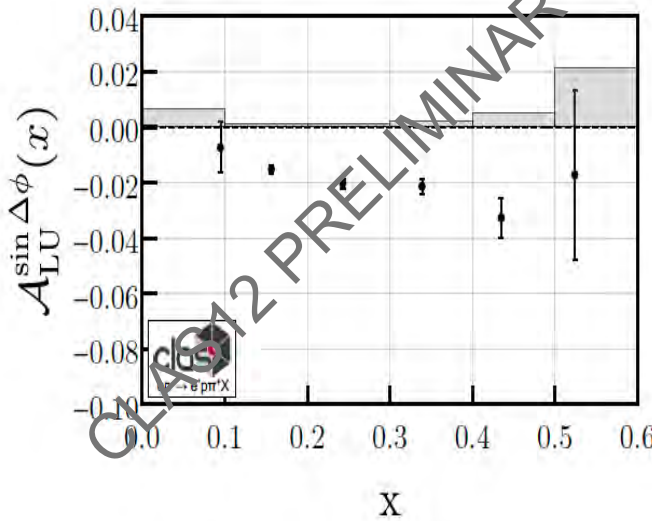
$$A_{LU} \propto \frac{C[w_5 \hat{l}_1^{\perp h} D_1]}{C[\hat{u}_1 D_1]} \sin \Delta\phi$$

3 independent methods used



Twist-2 table

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



- SSA significant at large x in valence quarks region
- Access to Leading Twist (LT) spin- and transverse-momentum-dependent fracture functions of **longitudinally polarized quarks**
- Multidimensionality crucial for evolution studies

[Harut Avakian]

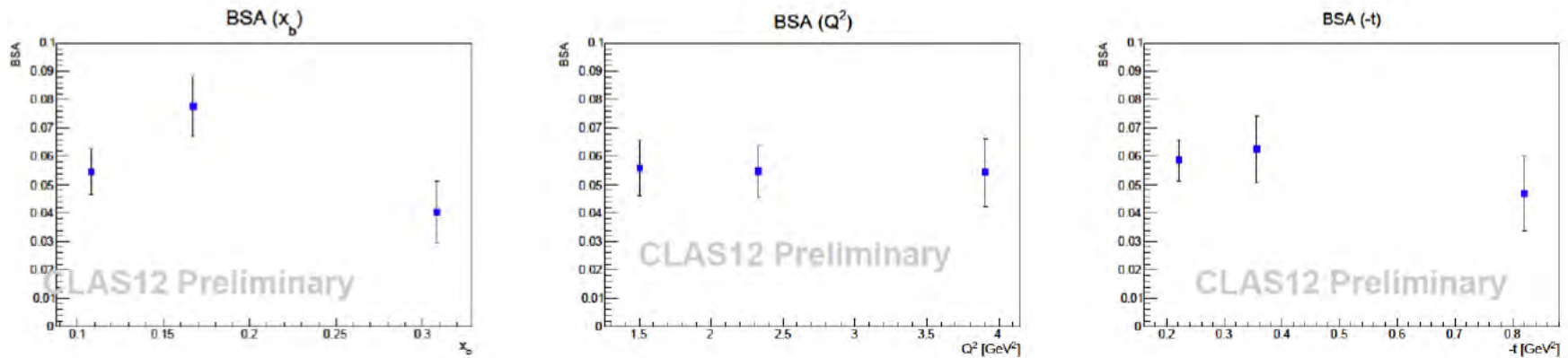
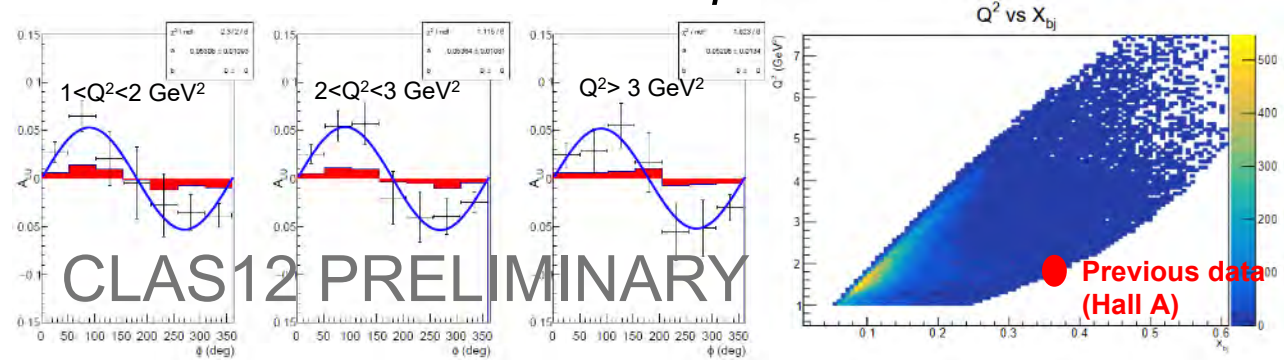
RGB Data Analysis and Publications



Beam Spin Asymmetries in Large Kinematic Range

$$\vec{e}n \rightarrow e'n'\gamma$$

A. Hobart and S. Niccolai,
in review process



$$\Delta\sigma_{LU} \sim \sin\phi \text{Im}\{ F_1\mathcal{H} + \xi(F_1+F_2)\mathcal{H} - kF_2\mathcal{E} \}$$

First-time measurement of neutron DVCS
with detection of the active neutron

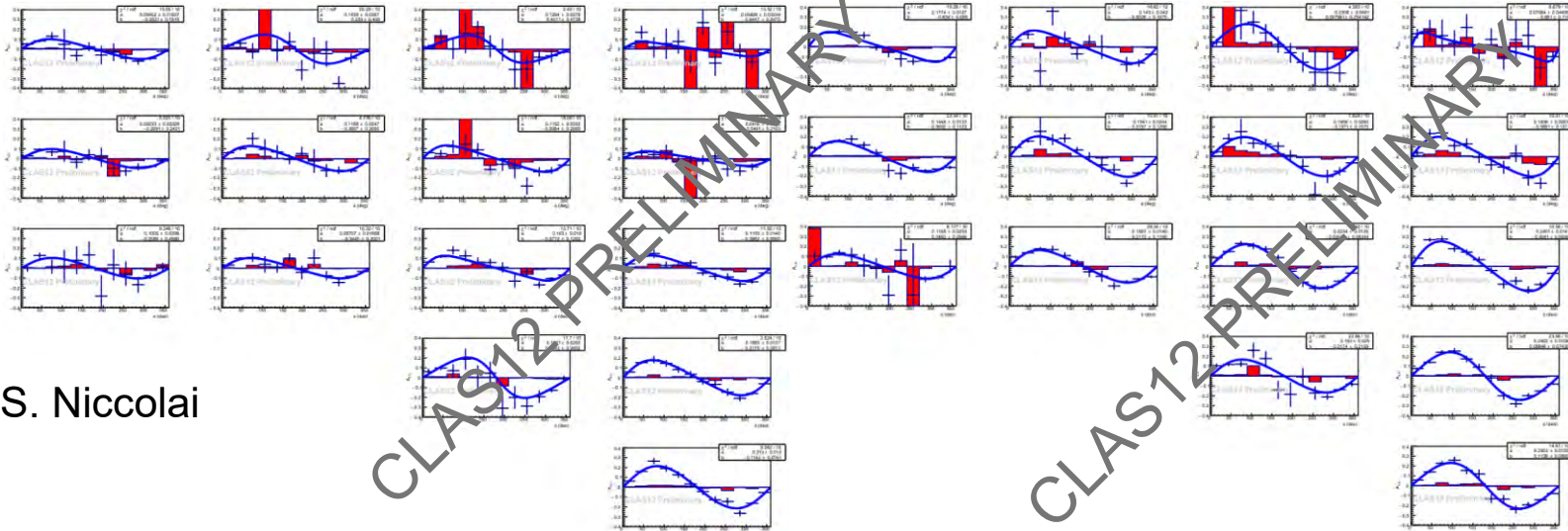
[Adam Hobart]

Nov 2022

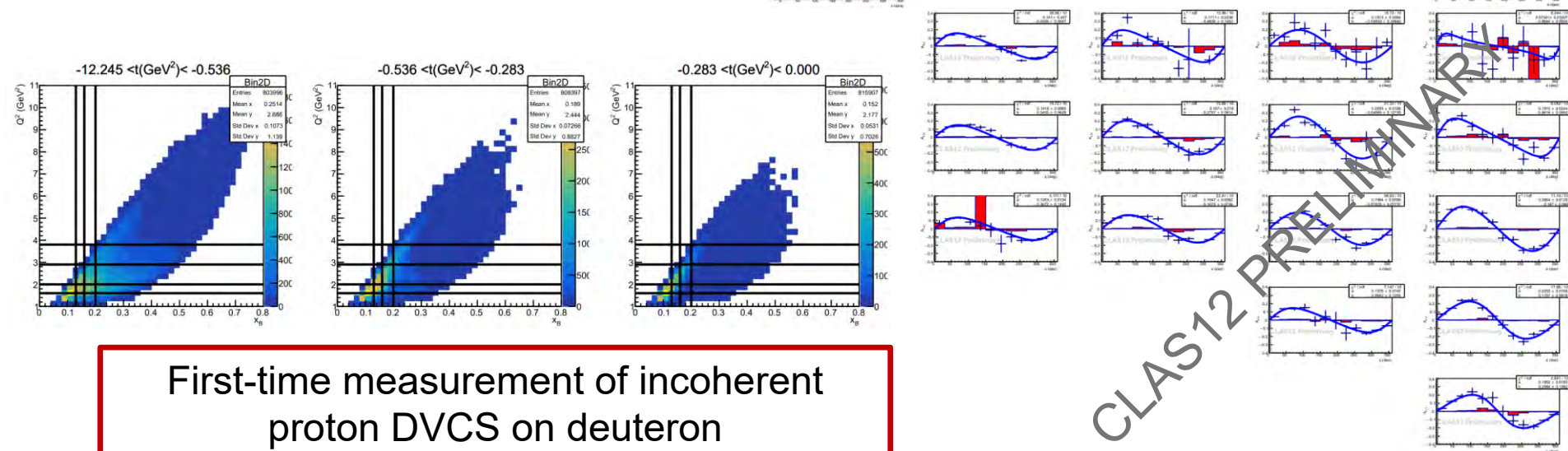
Patrick Achenbach

Beam Spin Asymmetries in Large Kinematic Range

$$\vec{e}d \rightarrow e'p\gamma$$



A. Hobart and S. Niccolai
Analysis note



First-time measurement of incoherent
proton DVCS on deuteron

PAC 50 Closeout 15 Jul 2022

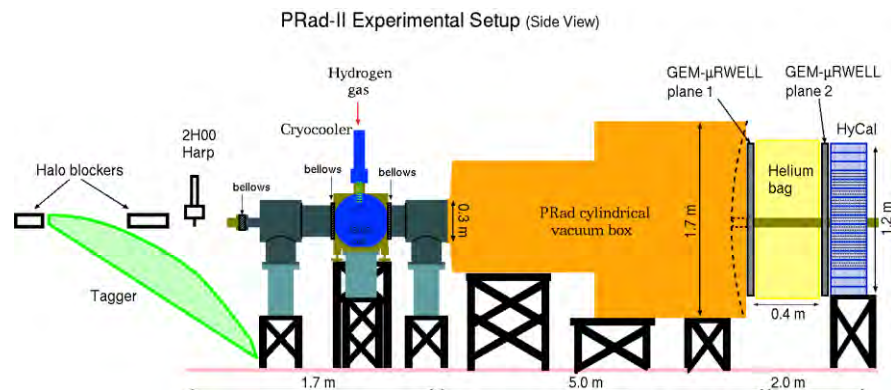
NUMBER	TITLE	CONTACT PERSON	HALL	DAYS REQUESTED	DAYS AWARDED	SCIENTIFIC RATING	PAC DECISION
New & Conditional Proposals							
C12-21-004	Semi-Inclusive Deep Inelastic Scattering Measurement of A=3 Nuclei with CLAS12 in Hall B	Larry Weinstein	B	58			C2
C12-21-003	A Direct Detection Search for Hidden Sector New Particles in the 3-60 MeV Mass Range	Ashot Gasparian	B	60	60	A	Approved
PR12-22-003	Precision Measurement of the Neutral Pion Transition Form Factor	Ilya Larin	B	67	67	A-	Approved

E12-07-107A Studies of Single Baryon Production in the Target Fragmentation Region with a Longitudinal Polarized Target Hall B

Endorsed

Two of the approved experiments require PRad-II exp. setup:

Hall-B did quite well



Outlook



Run Group Scheduling



- RG-D: July 17 to September 17, 2023, must have 30 PAC days to compete
- RG-K: September 20 to December 17 should complete ~50% of the approved beam time
- RG-E: January 15 to March 17, 2024, scheduled for 50% of the approved beam time
- Next with approved beamtime request is RG-L (ALERT), 2024 SAD right time to install ALERT program with four experiments will use a new low energy recoil detector, now in construction at Orsay and ANL, to replace CVT, 55 PAC days and will run in one setting

Run groups ready to run:

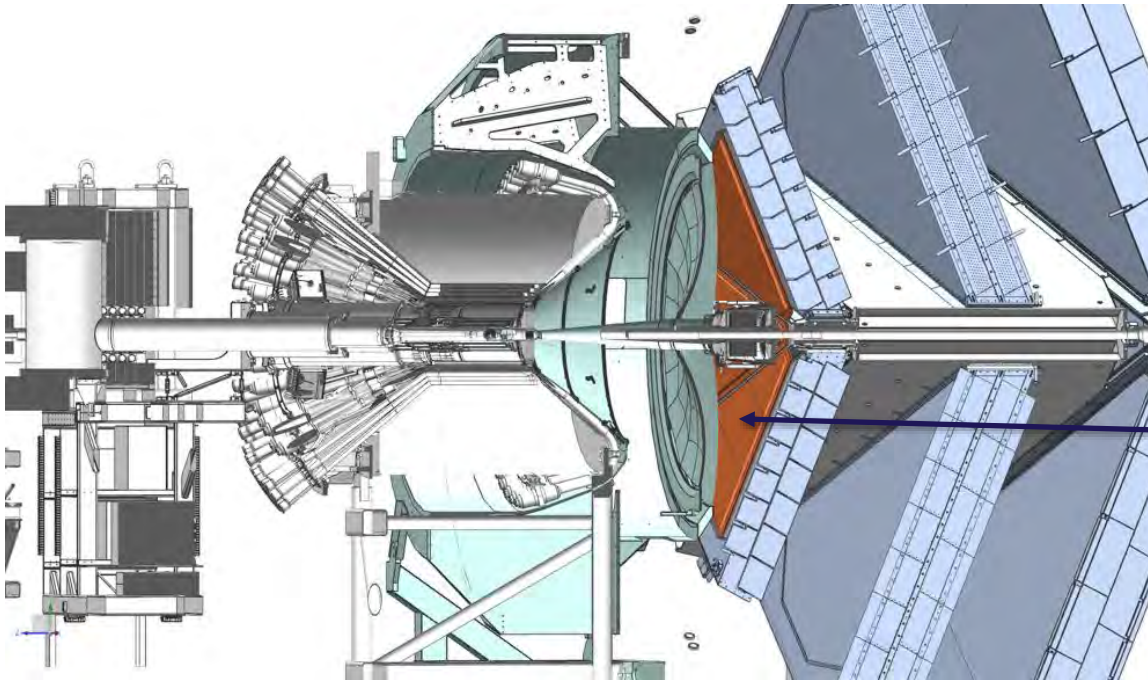
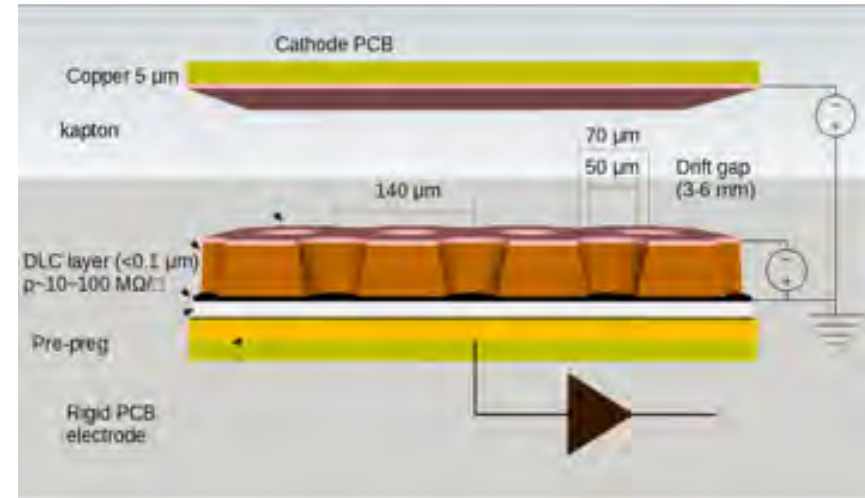
- RG-A, has >70 PAC days to run
- RG-B still have 40 PAC days
- RG-E remaining 30 PAC days
- RG-K remaining beamtime, about 50 PAC days, at 6.6 and 8.8 GeV
- RG-M has 10 days at 1.1 GeV, non-standard energy
- Non-CLAS12 experiment, RG-I, Heavy photon search, 102 PAC days remain at 2-4 GeV

Request for early scheduling:

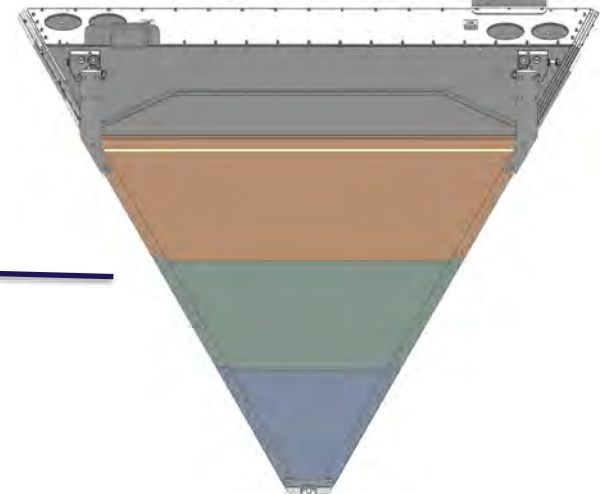
Non-CLAS12 experiment, RG-J, PRadII, π^0 TFF, X17

Luminosity (x2) Upgrade

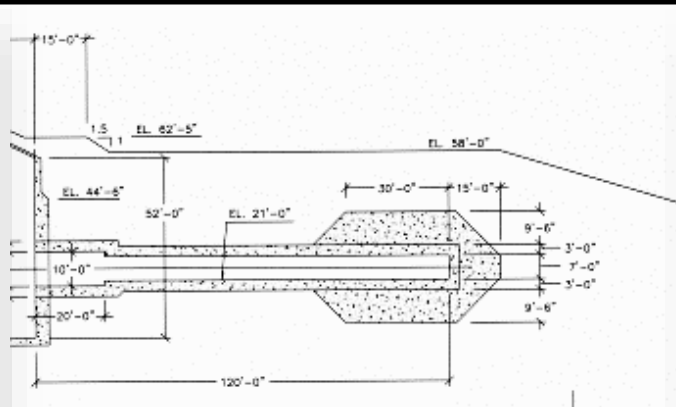
- Improvement by a factor of two to $L = 2 \times 10^{35} \text{cm}^{-2} \text{sec}^{-1}$: μ RWELL with capacitive sharing readout
- Time frame of 2 to 3 years



μ RWELL module mounted on R1 DC



Beam Dump (Phase 1) Upgrade



Hall-B needs:

- Alert: 500 – 900 nA
- He-3 expt: 2500 nA
- Lumi upgrade: 5000 nA



- No need for beam blocker anymore due to new safety evaluation
- Faraday cup will be moved down towards the end of the tunnel
- Work to be accomplished in upcoming scheduled accelerator down
- Funding for this phase of the upgrade secured (Phase 2 requires entirely new high-power dump)

Future of CLAS: 20+ GeV Upgrade



- Higher beam energy
- Positron beam
- Higher luminosity

OPPORTUNITIES WITH JLAB ENERGY AND LUMINOSITY UPGRADE



26 September 2022 — 30 September 2022

ECT* - Villa Tambosi

Strada delle Tabarelle, 286
Trento - Italy



Progress in Particle and Nuclear Physics

Volume 127, November 2022, 103985



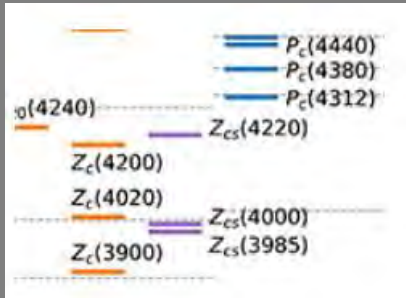
Review

Physics with CEBAF at 12 GeV and future opportunities

J. Arrington ^a, M. Battaglieri ^{b, o}, A. Boehnlein ^b, S.A. Bogacz ^b, W.K. Brooks ^j, E. Chudakov ^{b, l},
Cloët ^c, R. Ent ^b, H. Gao ^d, J. Grames ^b, L. Harwood ^b, X. Ji ^{e, f}, C. Keppel ^b, G. Krafft ^b, R.D.
McKeown ^{b, h, g} ✉, J. Napolitano ^g, J.W. Qiu ^{b, h}, P. Rossi ^{b, n} ... X. Zheng ^k

High Energy Workshop Series 2022

Hadron Spectroscopy with a CEBAF Energy Upgrade



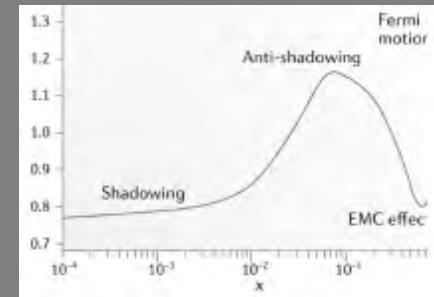
- 38 registered part.
- 8 talks

The Next Generation of 3D Imaging



- 55 registered part.
- 13 talks + summary talk

Science at Mid x: Anti-shadowing and the Role of the Sea



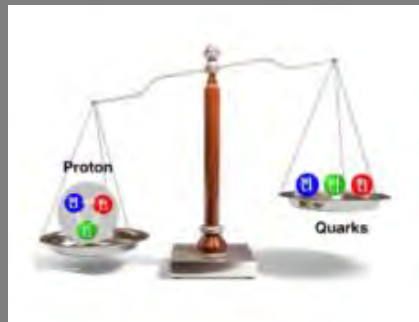
- 43 registered part.
- 14 talks

Physics Beyond the Standard Model



- 37 registered part.
- 6 talks

J/Psi and Beyond



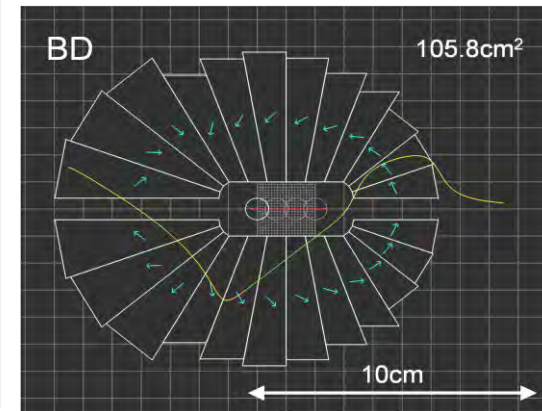
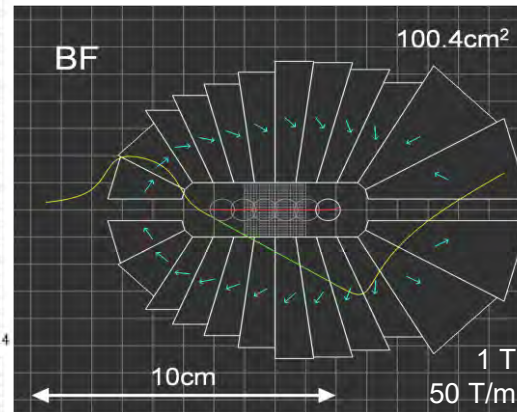
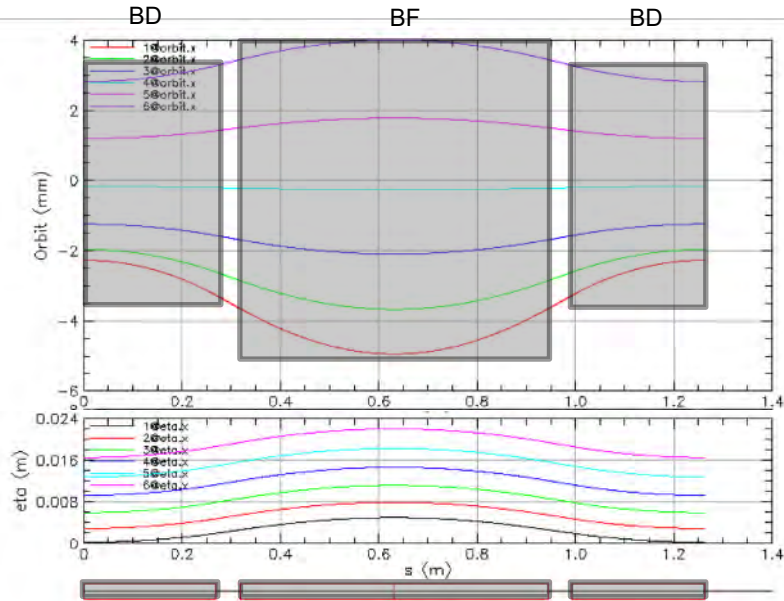
- 38 registered part.
- 7 talks + two 1-slide pres.

White paper in preparation:

- deeper access to quark-gluon dynamics
- opening new opportunities on studies of charm sector

Beam Energy Doubling in CEBAF

Large momentum acceptance fixed-field alternating-gradient cell, transporting six beams with energies spanning a factor of two through same string of permanent magnets



- FFAs combine relatively less expensive magnets with increased beam focus of strong focusing machines such as synchrotrons
- Closely spaced orbits for all six beams (~ 1 cm)
- CBETA demonstrated 42, 78, 114, and 150 MeV in common chamber

Summary

- Run Group C running successfully first polarized target experiment
- Reconstruction upgrades, partly AI assisted, improved performance
- Pass-2 cooking starting this month
- Several publications submitted and analyses in review
- Detector und beamdump upgrades progressing