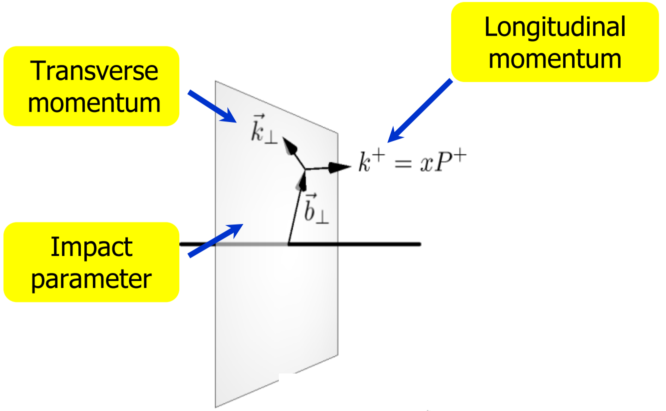
CLAS12 Run Group B

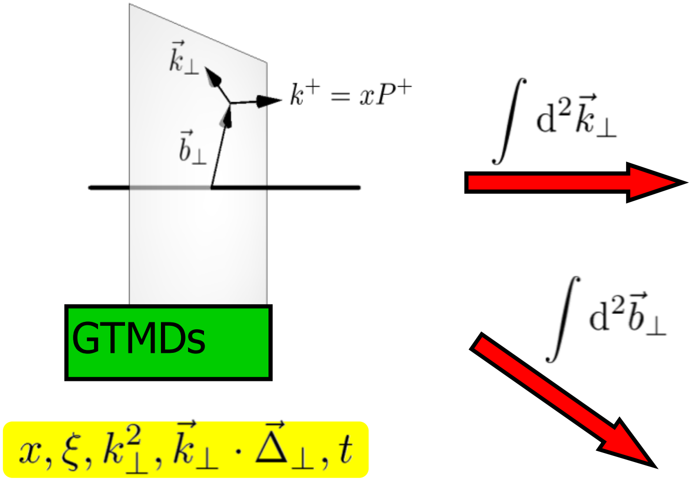
Electroproduction on deuterium with CLAS12

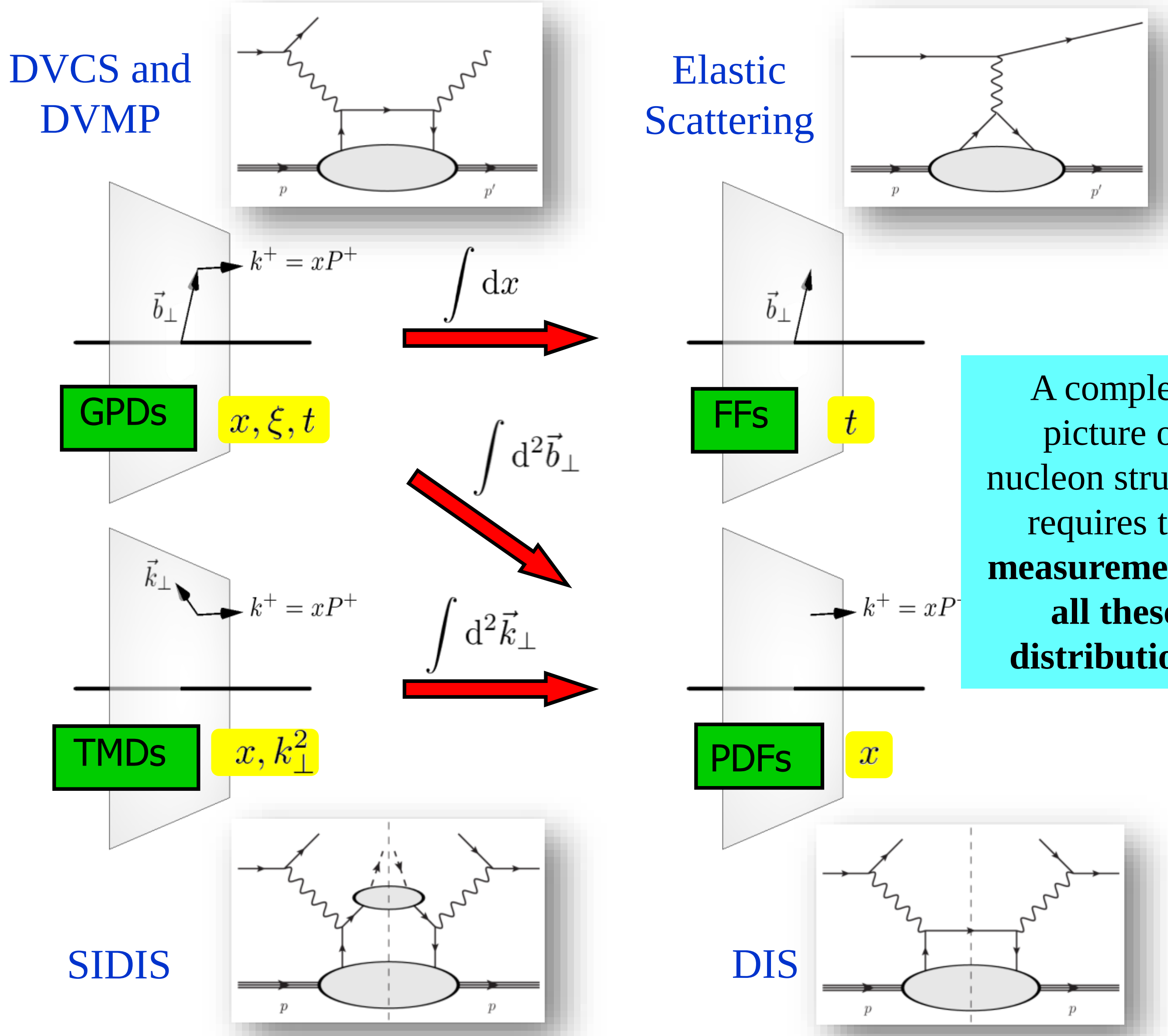
- Physics goals
- Run Group B experiments
- Overview of the data taking
- Results and analysis updates
- Beam time request

Silvia Niccolai, IJCLab Orsay (France)
PAC52, 7/10/2024

Multi-dimensional mapping of the nucleon





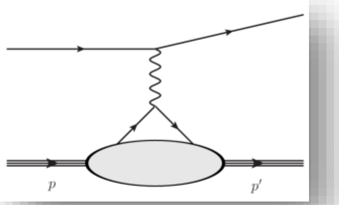


A complete picture of nucleon structure requires the **measurement of all these distributions**.

CLAS12 Run Group B aims to measure all these distributions, using **deuteron** as a **neutron target** → **Quark-flavor separation, combining with proton results**

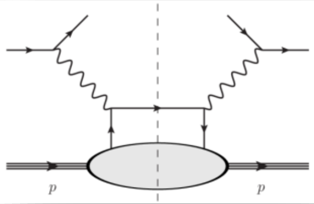
+ EMC effect, SRC
+ J/ψ photoproduction on deuteron

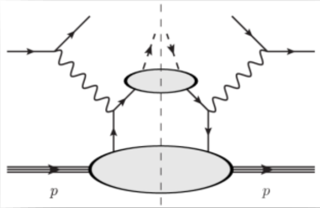
CLAS12 Run Group B: experiments



Elastic Scattering (G^n_M)

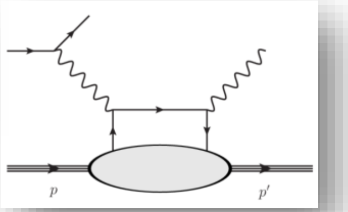
DIS (for SRC and EMC effect)

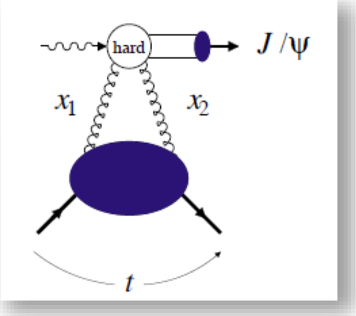




SIDIS (for PDFs and TMDs

nDVCS





J/ψ photoproduction

Experiment number	Title	Contact person	PAC days (rating)
E12-07-104	Neutron magnetic form factor	G. Gilfoyle	30 (A-)
E12-09-007a	Study of parton distributions in K SIDIS	W. Armstrong	56 (A-)
E12-09-008	Boer-Mulders asymmetry in K SIDIS	M. Contalbrigo	56 (A-)
E12-11-003	Deeply virtual Compton scattering on the neutron	S. Niccolai	90 (A High Impact)
E12-09-008b	Collinear nucleon structure at twist-3 in dihadron SIDIS	M. Mirazita	RG
E12-11-003a	In medium structure functions, SRC, and the EMC effect	O. Hen	RG
E12-11-003b	Study of J/ψ photoproduction off the deuteron	Y. Ilieva	RG
E12-11-003c/E12-07-104a	Quasi-real photoproduction on deuterium	F. Hauenstein	RG

Common features to all experiments of Run Group B:

- **Liquid deuterium target**
- **Beam energy: « 11 » GeV**

CLAS12 Run Group B: setup and run summary

Scheduled beam time:
Spring19: February 6th - March 25th 2019
Fall19: December 3rd –20th 2019
Spring20: January 6th – 30th 2020

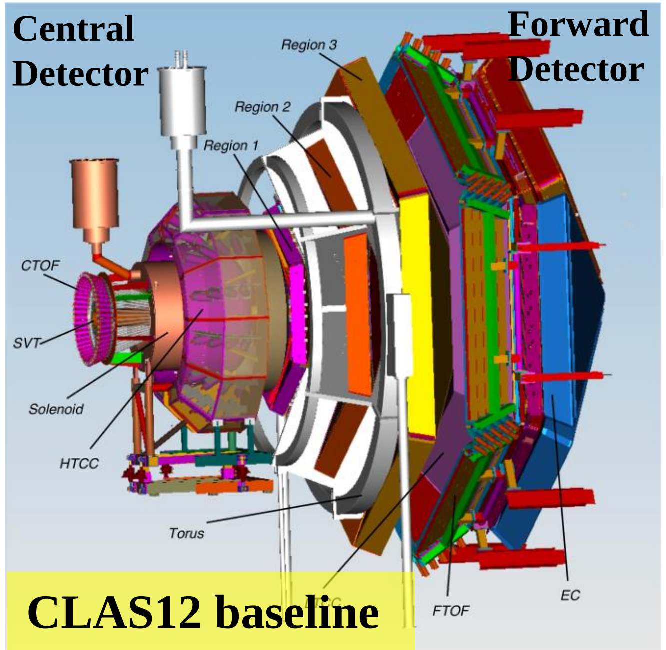
43.3 B triggers collected at 3 different beam energies and two torus polarities:

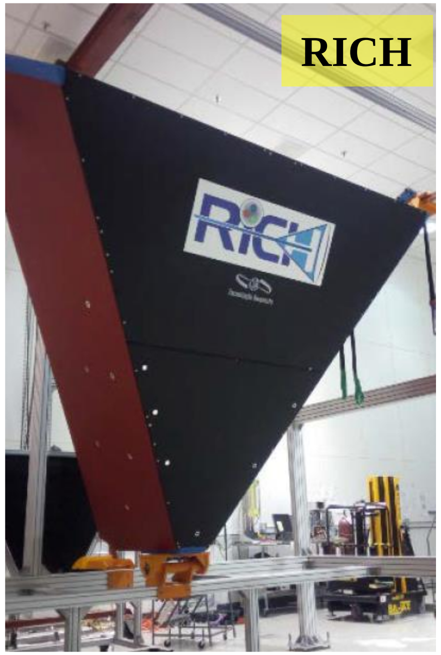
- 10.6 GeV (9.7 B inbending e^-) Spring19
- 10.2 GeV (11.7 B inbending e^-) Spring19
- 10.4 GeV (9 B outbending e^-) Fall19, **(**12.9 B inbending e^-) Spring20

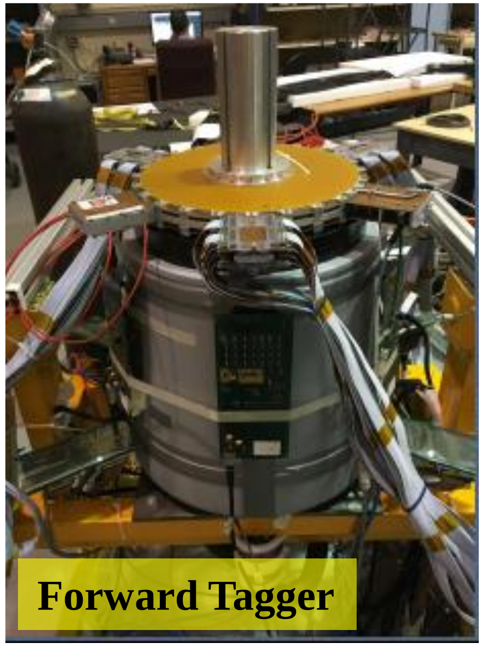
- Average beam polarization ~86%
- Liquid deuterium target, 5 cm long
- **L = ~0.65 10^{35} $cm^{-2}s^{-1}$** on neutron or proton (proposals had **10^{35} $cm^{-2}s^{-1}$**)

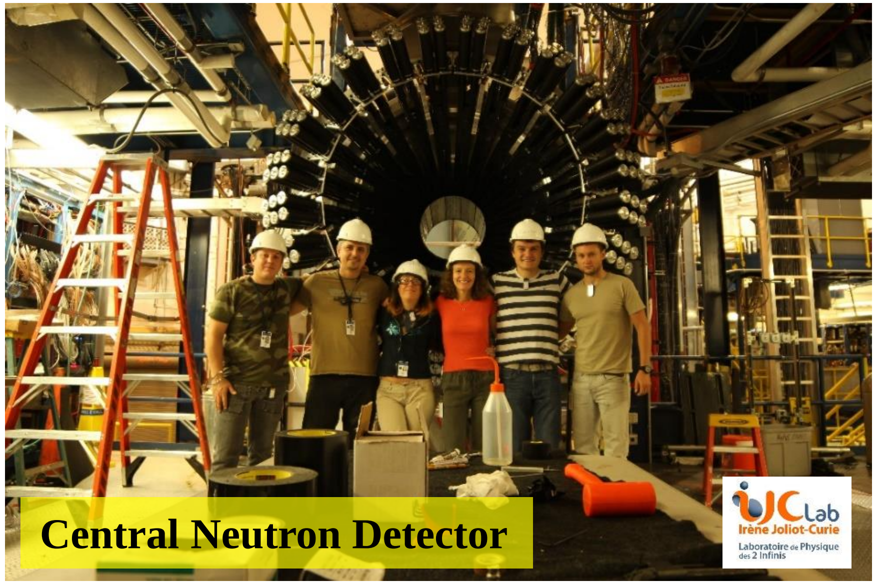
38.9 total PAC days according to ABUs
→ **43.2% of the approved 90 PAC days**
51 PAC days left to run

The data have been calibrated and reconstructed in 2 passes. The results shown in the following come mainly from Pass1. Pass2 has higher yields and better resolutions. **The improved CLAS12 tracking will allow us to run at higher luminosity.**









DVCS on the neutron: motivation

A combined analysis of DVCS observables for proton and neutron targets is necessary for the flavor separation of GPDs

$$(H,E)_u(x,\xi,t) = {}^9/_{15}\left[4(H,E)_p(x,\xi,t) - (H,E)_n(x,\xi,t)\right]$$
$$(H,E)_d(x,\xi,t) = {}^9/_{15}\left[4(H,E)_n(x,\xi,t) - (H,E)_p(x,\xi,t)\right]$$

Moreover, the beam-spin asymmetry for nDVCS is the most sensitive observable to the GPD E
→ Ji's sum rule for Quarks' Angular Momentum

$$\frac{1}{2}\int_{-1}^{1} x dx (H(x,\xi,t=0) + E(x,\xi,t=0)) = J$$

Polarized beam, **unpolarized neutron target**:

$$\Delta\sigma_{LU} \sim \sin\phi \,\mathrm{Im}\{F_1\mathcal{H} + \xi(F_1+F_2)\tilde{\mathcal{H}} + kF_2\mathcal{E}\}d\phi$$

Unpolarized beam, **transversely polarized proton target**:

$$\Delta\sigma_{UT} \sim \cos\phi \,\mathrm{Im}\{k(F_2\mathcal{H} - F_1\mathcal{E}) + \ldots\}d\phi$$

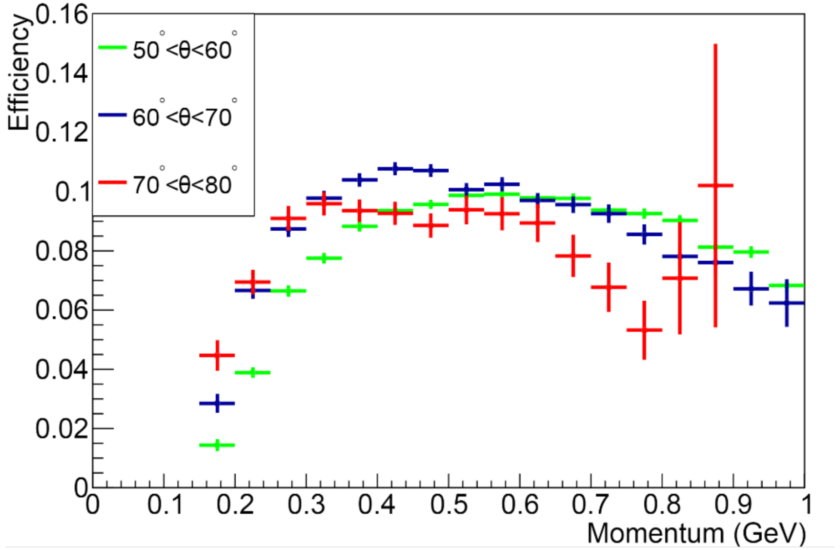
Similar sensitivity to E
Different quark combinations

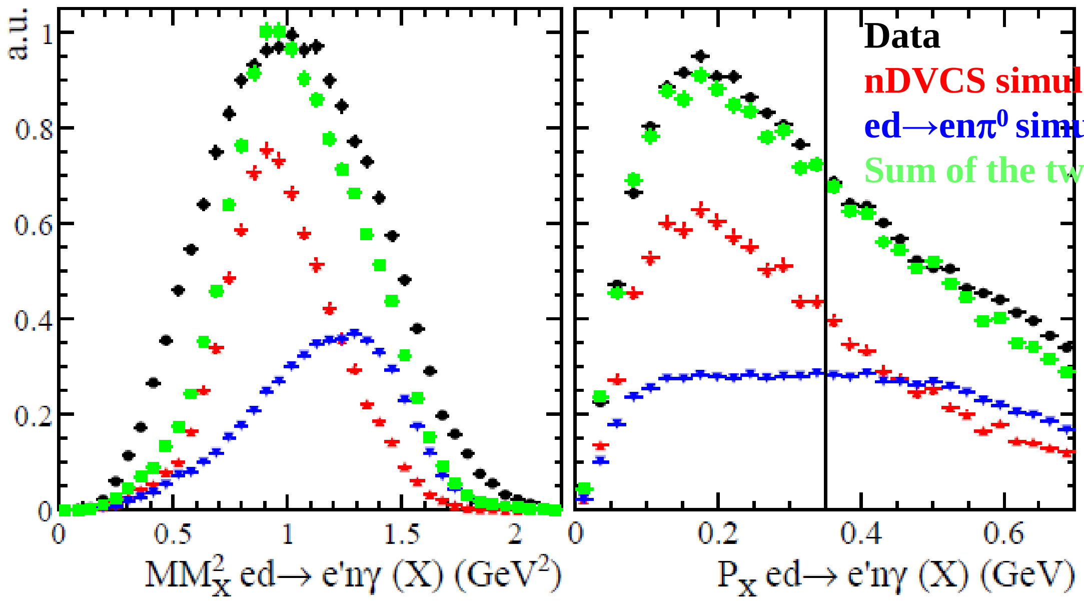
The BSA for nDVCS is expected to be smaller than for pDVCS
→ more beam time needed to achieve reasonable statistics

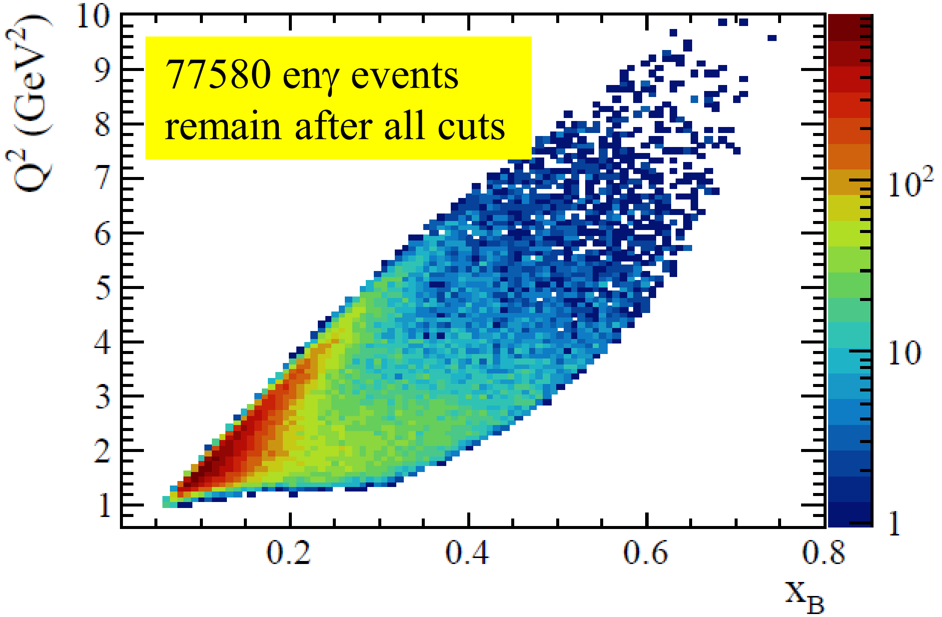
CLAS12-RGB: first-time measurement of BSA for nDVCS with detection of the active neutron

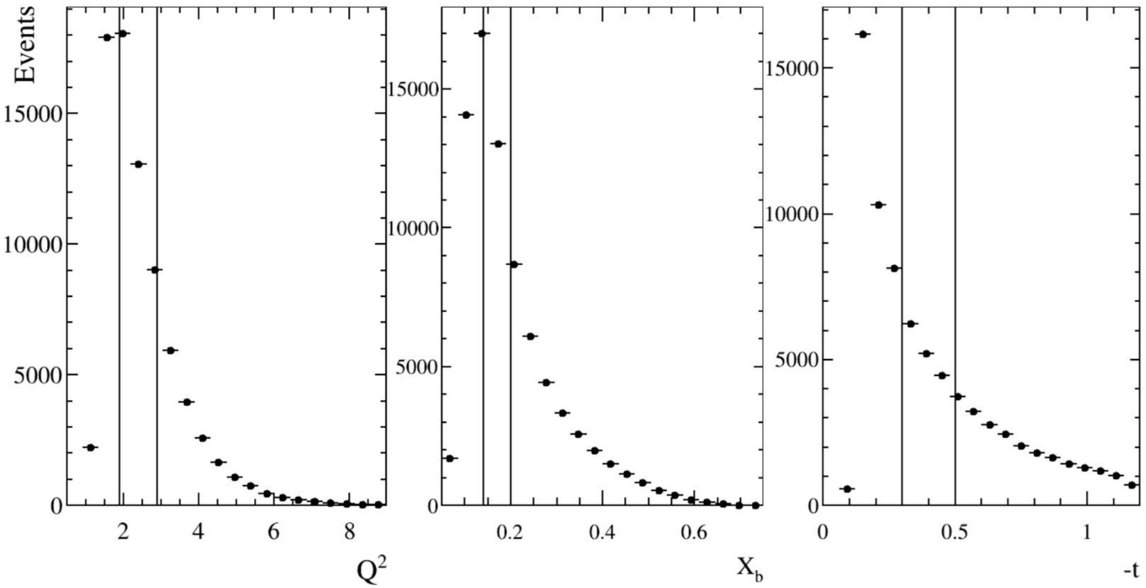
$\vec{e}d \rightarrow en\gamma(p)$

Neutron efficiency (CND) from $ep \rightarrow e'n\pi^+$ (RGA data)







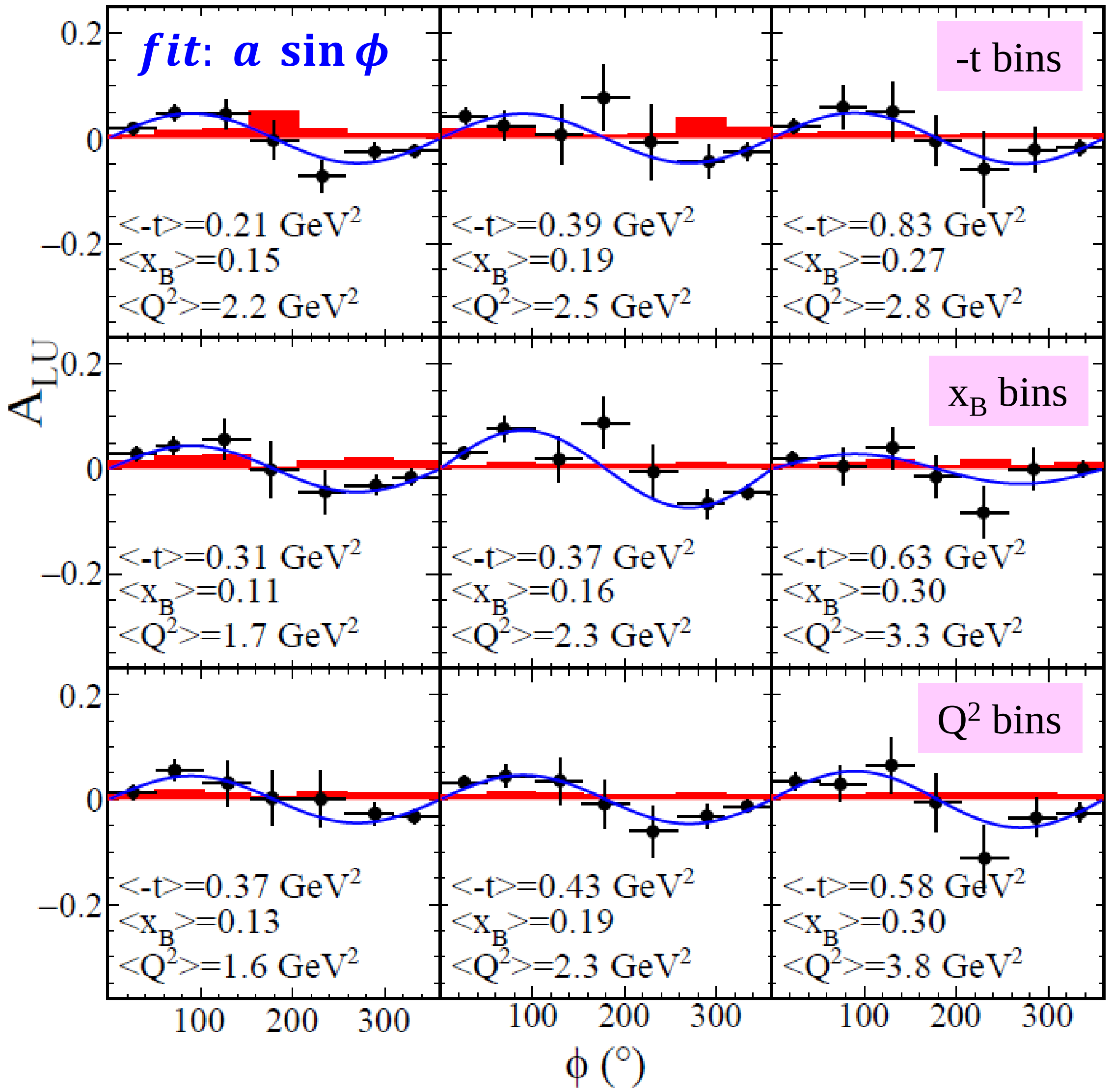


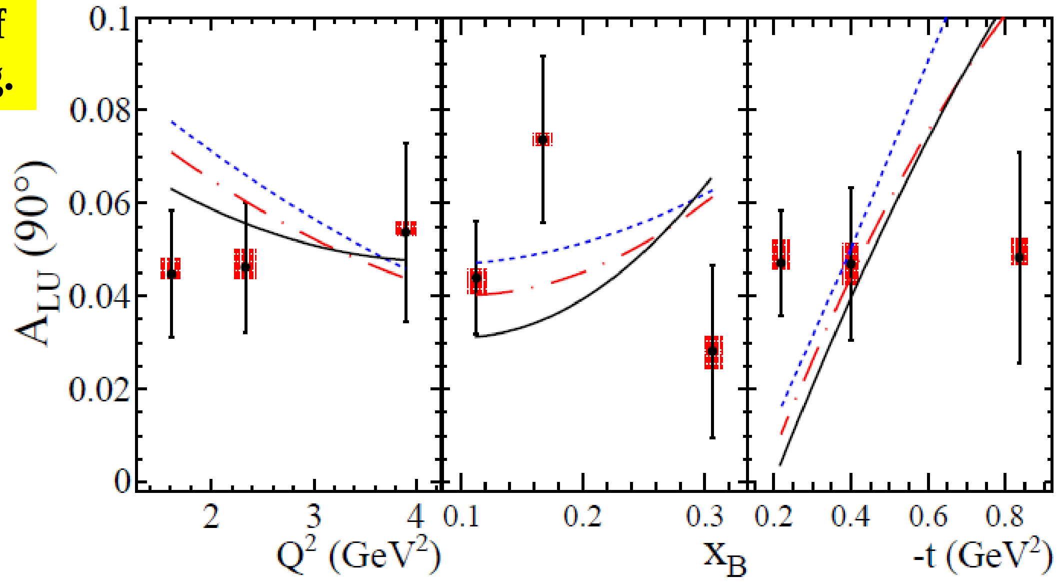
Binning in one variable at a time, 3 bins per variable

CLAS12-RGB: first-time measurement of BSA for nDVCS with detection of the active neutron

$\vec{e}d \rightarrow en\gamma(p)$

Only **2-D binning** (ϕ+another variable), due to **low statistics** and **small size of the BSA.** Adding **the rest of the approved beam time** will allow **4-D binning.**



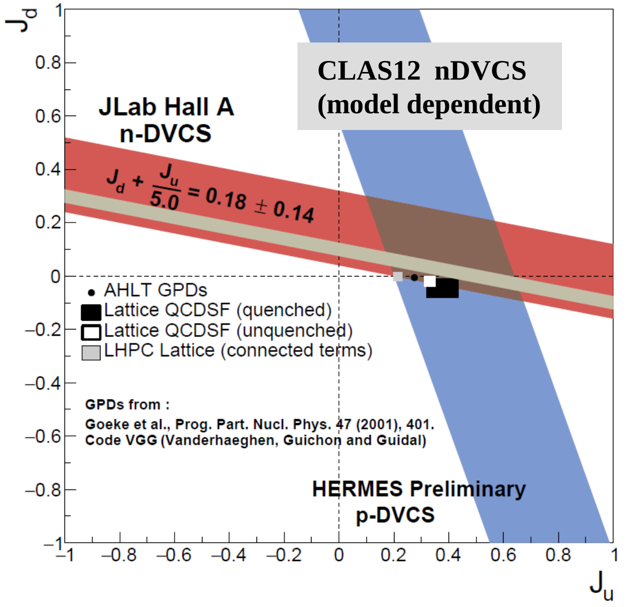


J_u = 0.35 J_d = 0.05

J_u = −0.2 J_d = 0.15

J_u = −0.45 J_d = 0.2

VGG model predictions giving the smallest χ^2



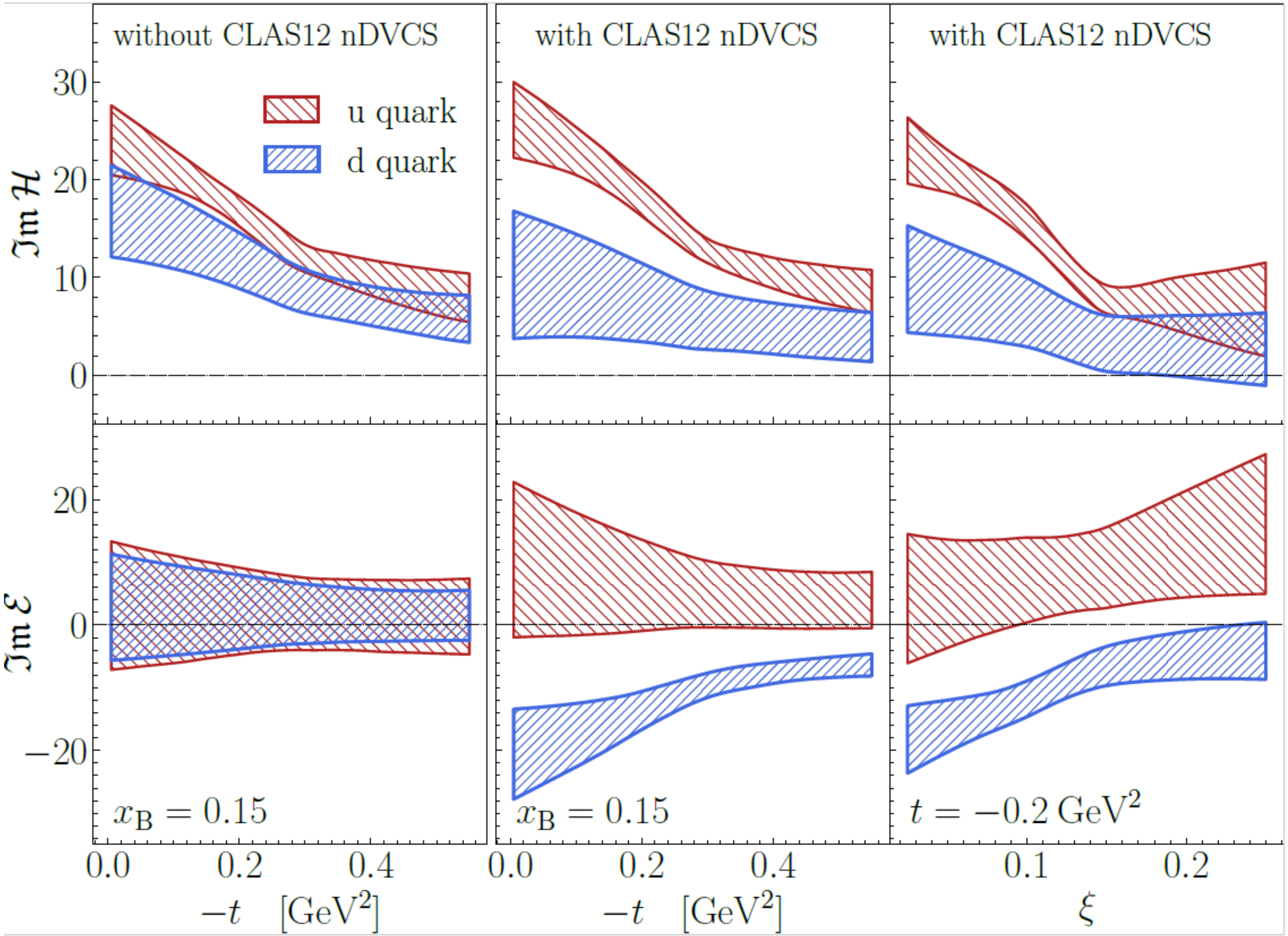
A. Hobart, S.N, et al. (CLAS) [arXiv:2406.15539](https://arxiv.org/abs/2406.15539) [hep-ex] - Submitted to PRL

Impact on flavor separation of CFFs of RGB nDVCS data

$\vec{e}d \rightarrow en\gamma(p)$

- **Global fits of CFF** using **neural networks** (**K. Kumericki et al., JHEP 07, 073531 (2011); M. Cuic, K. Kumericki, et al., Phys. Rev. Lett. 533 125, 232005 (2020)**).
- Data used: CLAS6 and HERMES pDVCS observables, CLAS12 pDVCS BSA and nDVCS BSA
- Same extraction method was applied to nDVCS Hall-A data at 6 GeV, but only separation for Im$\mathcal{H}$ was obtained

The CLAS12 nDVCS data allow the quark-flavor separation of both Im$\mathcal{H}$ and Im$\mathcal{E}$
The 4-D binning and higher statistics coming from the completion of the approved RGB beam time will increase the precision and coverage of these quark CFFs



A. Hobart, S.N, et al. (CLAS) arXiv:2406.15539 [hep-ex] - Submitted to PRL

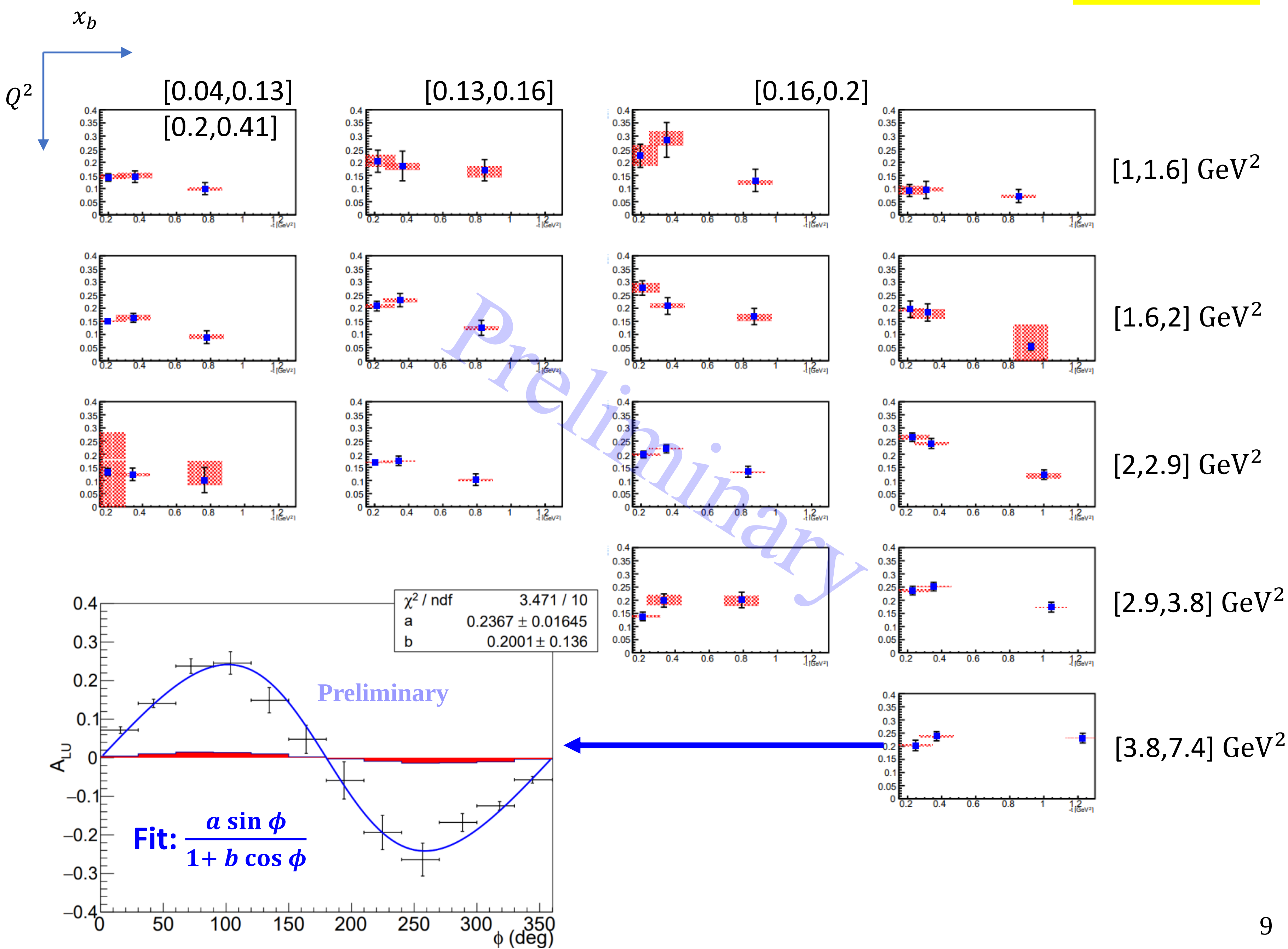
Incoherent pDVCS on a deuterium target

First-time measurement of incoherent pDVCS on deuteron

- Useful for the nDVCS measurement
  - Estimate the **free-neutron DVCS** from comparison of free/bound pDVCS
- Complementary to existing measurements of incoherent DVCS in light nuclei
  - Quantify **medium effects on GPDs**

The statistics are expected to **triple** with the **remaining approved beam time** and improvements to the reconstruction **→ finer binning will be possible**

- Systematic uncertainties (red bands)
- Results will be compared to free-proton DVCS BSA measured by CLAS12
- More statistics needed to match the RGA binning



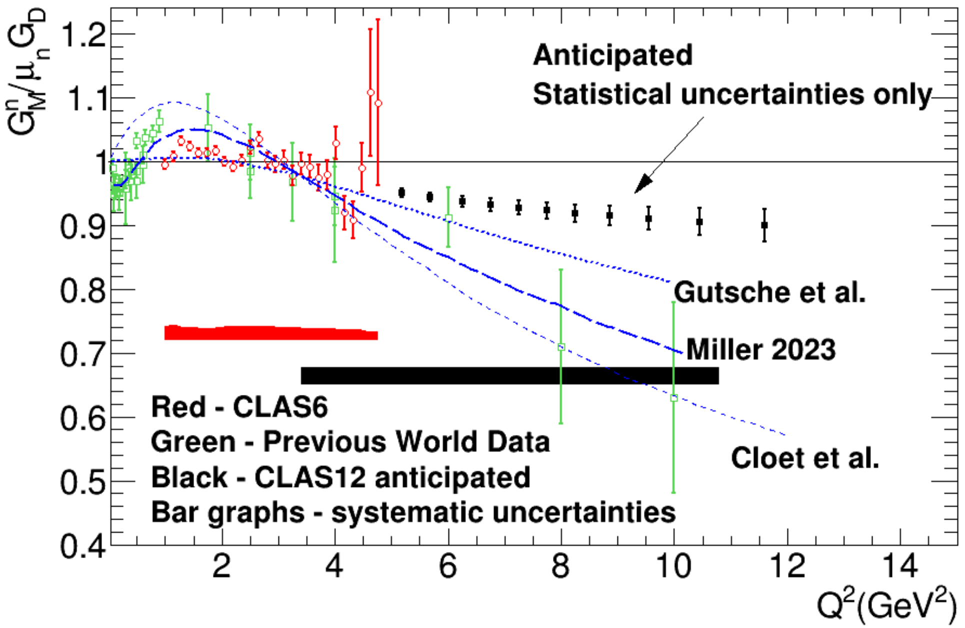
Measurement of the Neutron Magnetic Form Factor G_M^n at High Q^2 Using the Ratio Method on Deuterium

ed→en(p)

ed→ep(n)

L.Baashen (KSU), B.A.Raue (FIU), G.P.Gilfoyle (Richmond)

Goal: Extract G_M^n at high Q^2 using the ratio of quasi-elastic e-n and quasi-elastic e-p events on deuterium: $R = \frac{d(e,e'n)p}{d(e,e'p)n}$



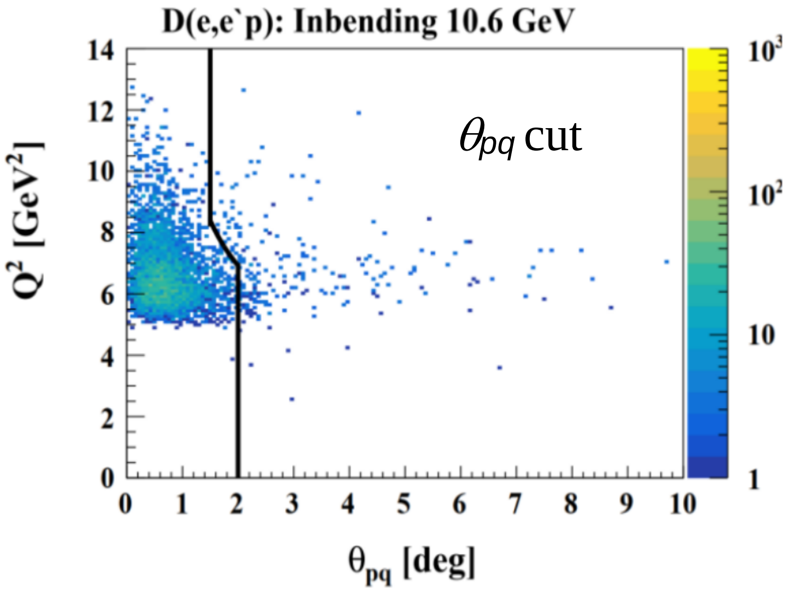
- $G_M{}^n$ is related to the **distribution of magnetization** in the neutron.
- World's data for G_M^n are **mainly at low Q^2**, and have **low precision**.
- Recent theoretical calculations: Gutsche et al. (PRD 97, 054011, 2018)) and Miller et al. (arXiv 1912.07797 [nucl-th], 2020).
- The Pass1 extraction of G_M^n is complete (L.Baashen's PhD thesis at FIU).
- Pass2 analysis ongoing, with increased statistics and improved resolution.
- **Completing RGB will extend the reach in Q^2 and improve statistical precision.**

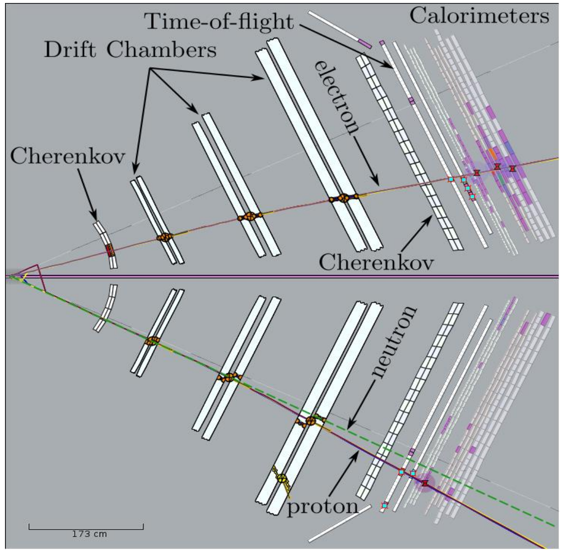
Quasi-Elastic e-n and e-p Event Selection

- Detection of electron and the active nucleons (**neutrons in ECAL**) allows to apply exclusivity cuts and obtain clean quasi-elastic final state selection.

Acceptance Matching

- Need to have the same solid angle W for e-n and e-p events.





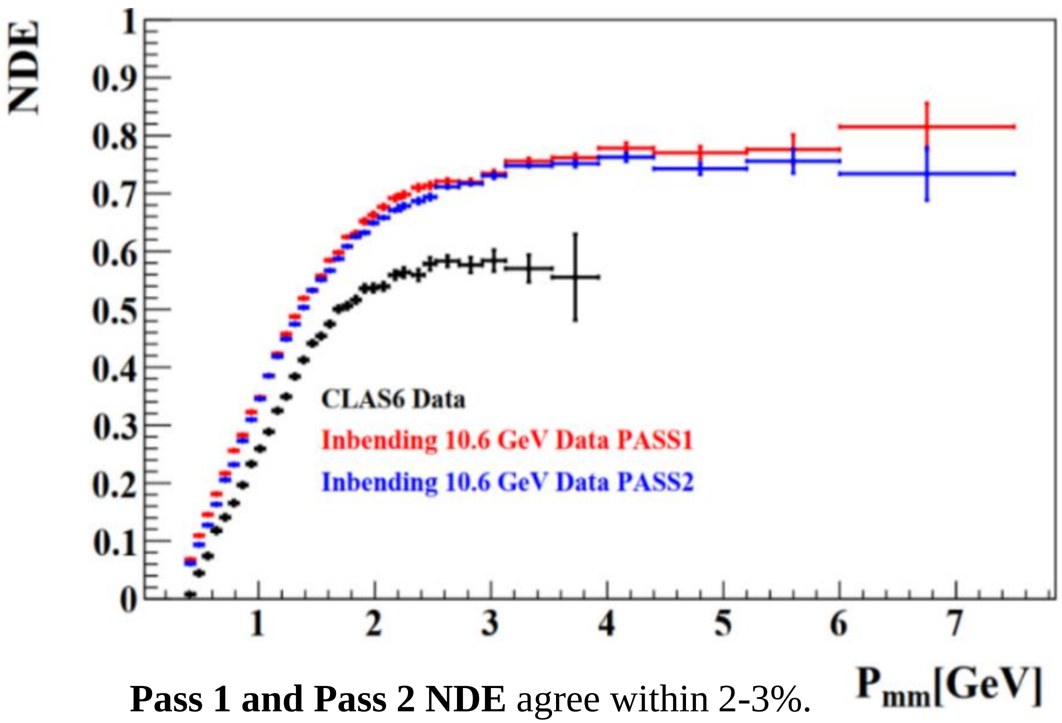
Corrections to the e-n/e-p ratio and preliminary result

ed→en(p)

ed→ep(n)

Measuring the neutron detection efficiency (NDE) for quasi-elastic e-n

- Use ep→e'π^+(n) from Run Group A on LH_2 target.
- Require a good electron and π^+ and then predict the neutron trajectory.
- If the trajectory intersects the PCAL/ECAL this is an expected event.
- Search for a neutral hit near the intersection. If found, this is a detected event.
- The NDE is the ratio of detected events to expected ones.

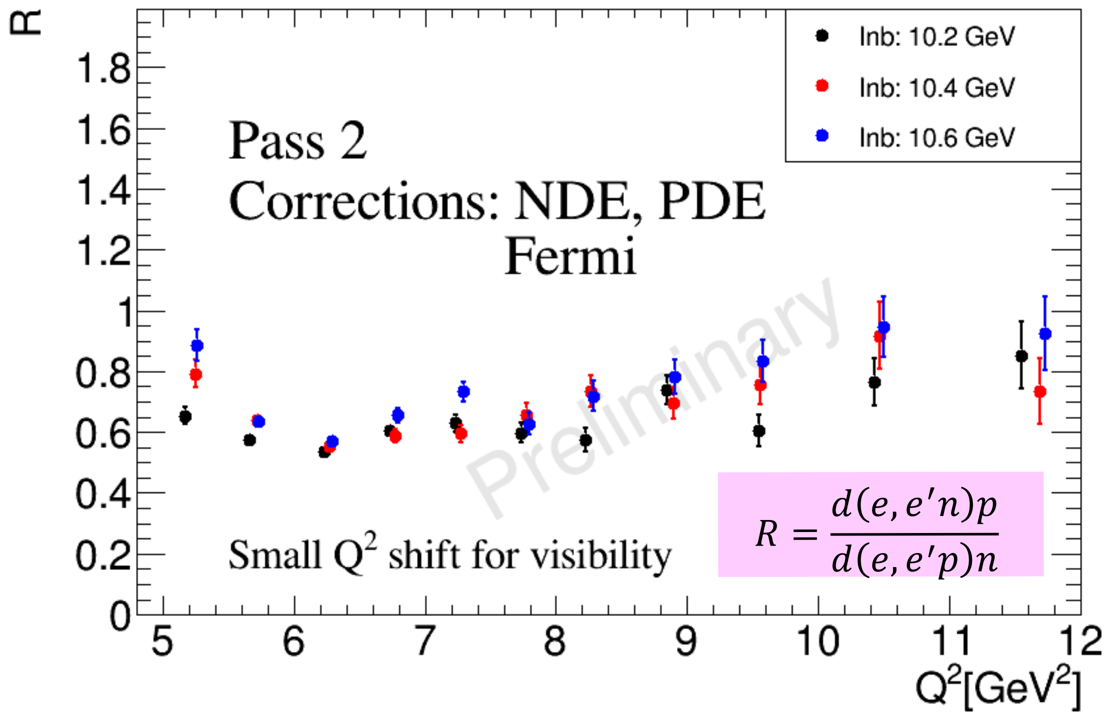


Pass 1 and Pass 2 NDE agree within 2-3%.
CLAS12 NDE overall higher than CLAS's.

Other Corrections

1) Proton Detection Efficiency (PDE)
2) Fermi Correction
3) Radiative Correction
4) Nuclear Correction

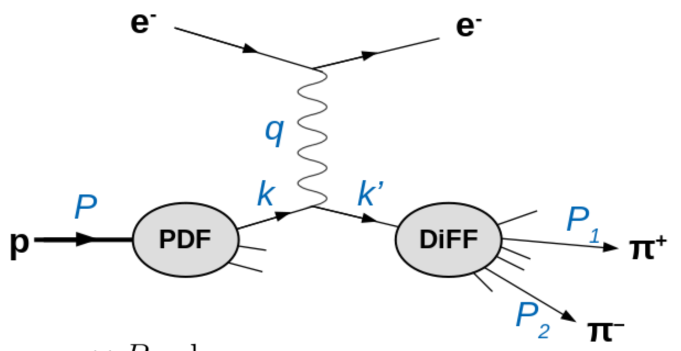
Corrections 1-3 were completed for Pass1 and are ongoing for Pass2. Radiative corrections are very close to one. Work ongoing on the nuclear correction.



C. Dilks (JLab)
T. Hayward (UConn)

SIDIS: Current Fragmentation Dihadron Production

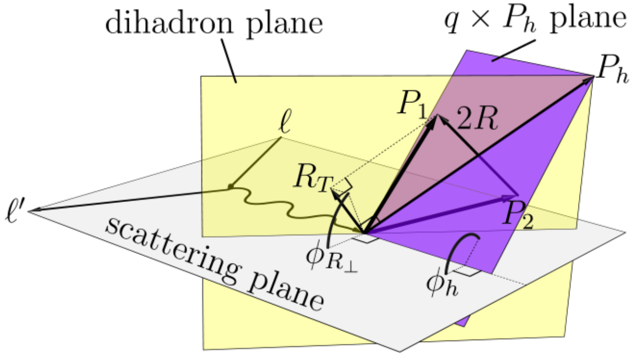
$\vec{e}d \rightarrow e\pi^+\pi^- X$



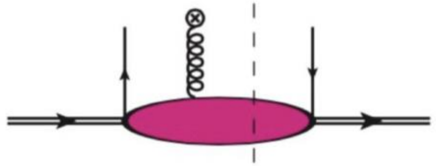
$$eN \rightarrow e + \pi^+(P_1) + \pi^-(P_2) + X$$

Beam spin asymmetry → collinear twist-3 PDF *e(x)* *(and more)*

$$A_{LU} = \frac{d\sigma_+ - d\sigma_-}{d\sigma_+ + d\sigma_-} = A_{LU}^{\sin\phi_R} \sin\phi_R + A_{LU}^{\sin\phi_h} \sin\phi_h + \dots$$

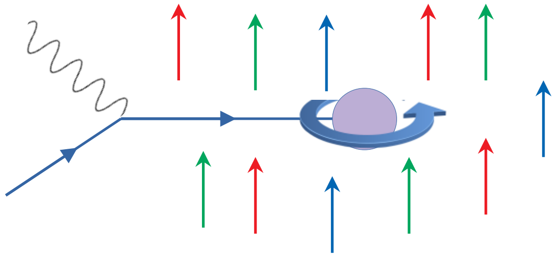


- Twist-3 PDFs: quark-gluon interactions



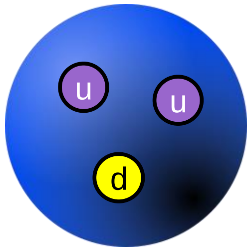
- **e(x) physical interpretation via *x* moments:**
  - 1st: Contribution of finite quark masses to nucleon mass: $m_q \rightarrow m_N$
  - 3rd: "Boer-Mulders Force": Transverse force exerted by color field on q↑ after scattering, in an unpolarized nucleon

Phys.Rev.D 88 (2013) 114502



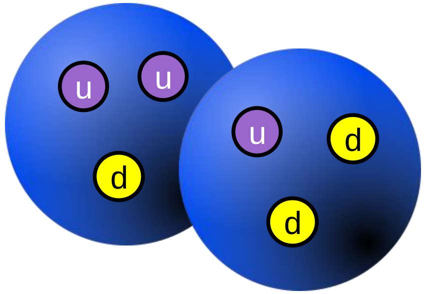
Different targets → e(x) flavor dependence

RG-A



vs.

RG-B



→ access decoupled valence distributions:

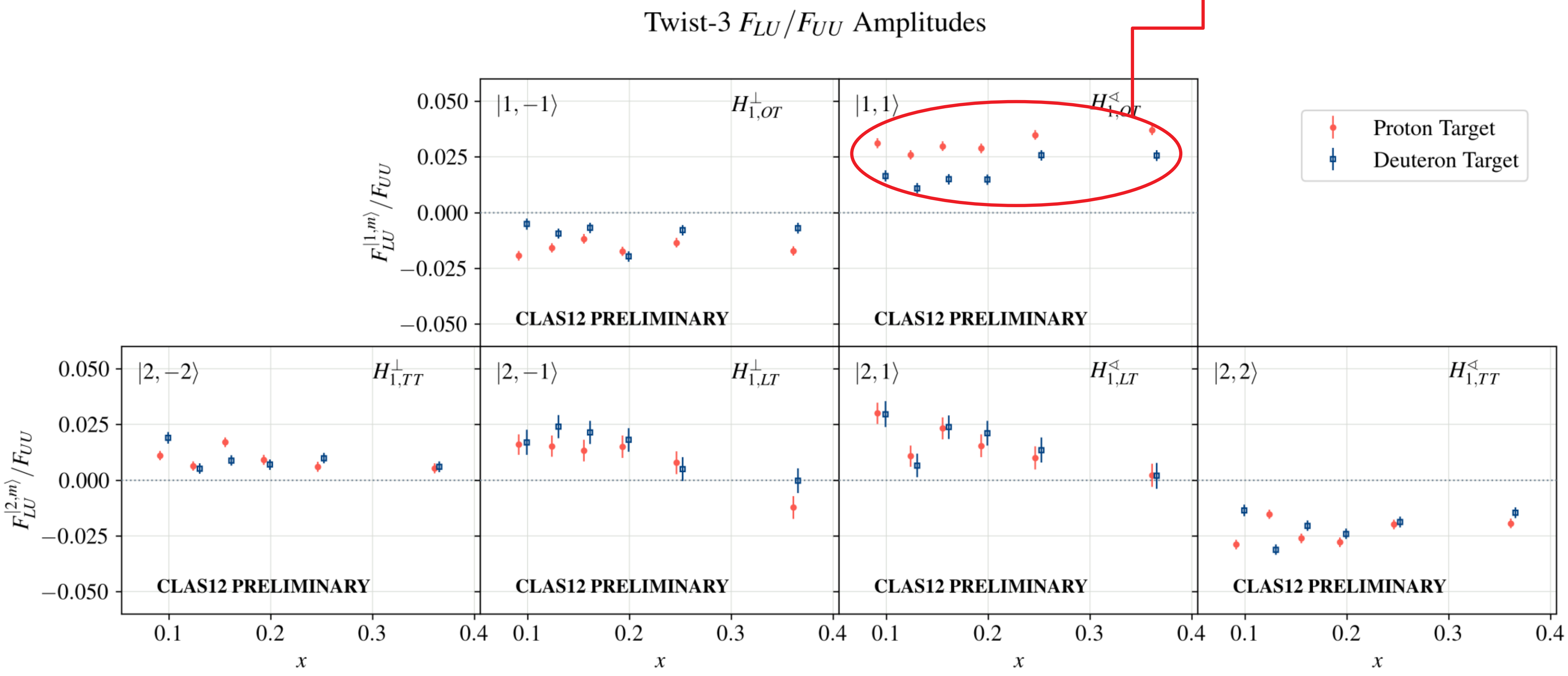
$$e^{u_V}(x) \text{ and } e^{d_V}(x)$$

SIDIS: Current Fragmentation Dihadron Production

$\vec{e}d \rightarrow e\pi^+\pi^- X$

- Significant difference between targets' $A_{LU}^{\sin\phi_R}$ → provides a path for flavor-dependent e(x) extraction
- Partial waves provide more insight into dihadron fragmentation angular momentum dependence
- **The completion of the data taking will allow finer multi-dimensional binning for the flavor decomposition of *e(x)***

$e(x)\square H_{1,OT}^{\sphericalangle}$



SIDIS: Correlating with the Target Fragmentation Region (TFR)

$\vec{e}d \rightarrow e\pi^{\pm}pX$

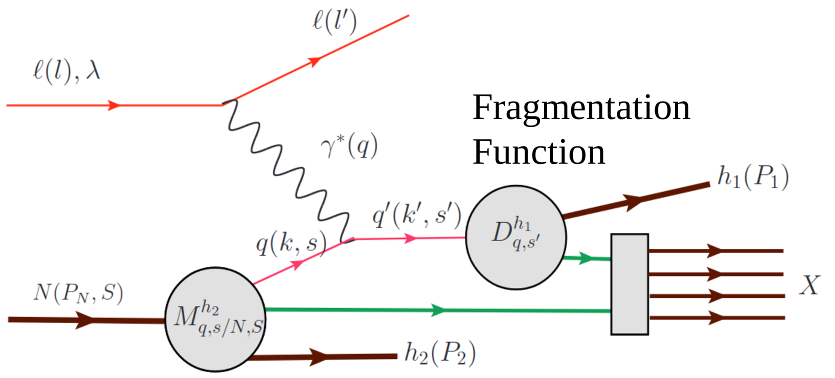
C. Dilks (JLab)
T. Hayward (UConn)

Current **F**ragmentation **R**egion

Target **F**ragmentation **R**egion

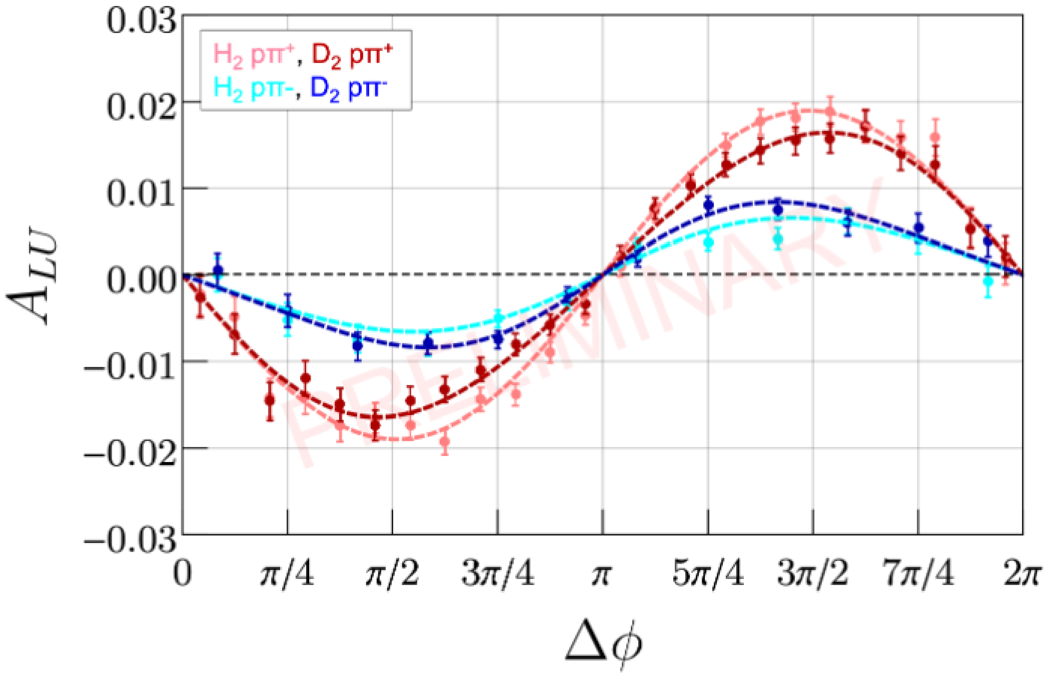
$$eN \rightarrow e + \pi^{\pm}(P_1) + p(P_2) + X$$

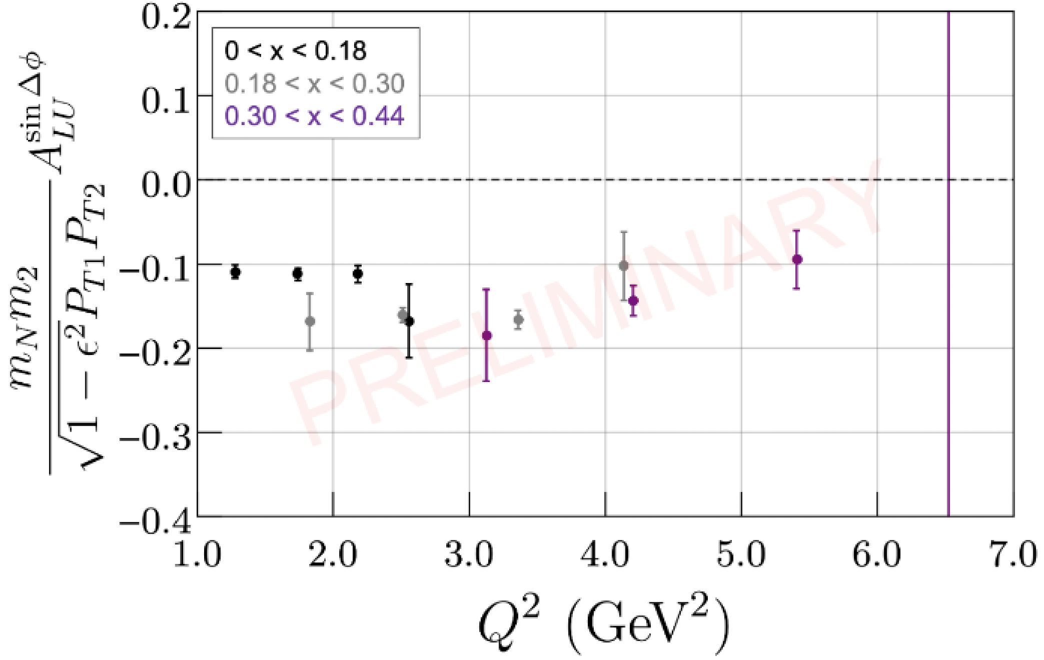
- **Fracture Function:** conditional probability to produce a TFR hadron
- Largely unexplored → Accessible in beam spin asymmetries in Back-to-Back proton-pion production
- Different targets → flavor-dependent fracture functions



Fracture Function

A. Kotzinian, M. Anselmino, and V. Barone, Nuovo Cim. C 036, 127 (2013)





The completion of RGB will allow a **finely binned multi-dimensional study** of the asymmetry to confirm (or not) the predictions of its **twist-2** nature

E. Segarra (MIT)
T. Kurtz (MIT)

BAND/CLAS12 tagged DIS analysis

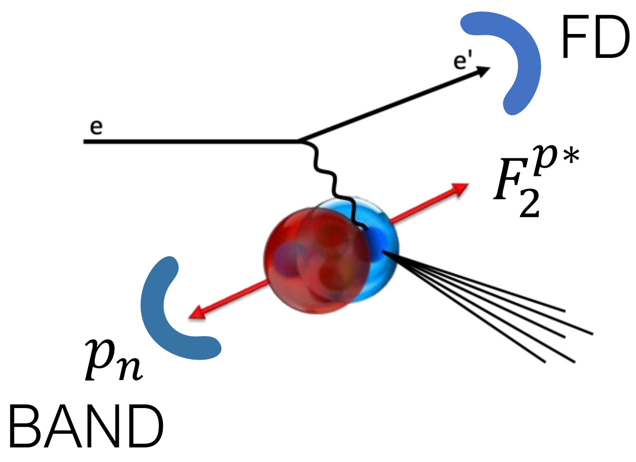
ed→enX

Observable (double ratio): $$\mathcal{R}(\alpha_{S,i}, x') = \frac{Y_{exp}(\alpha_{S,i}, x')/Y_{exp}(\alpha_{S,i}, x'_0)}{Y_{sim}(\alpha_{S,i}, x')/Y_{sim}(\alpha_{S,i}, x'_0)}$$

α_S: spectator neutron light-cone momentum fraction

x': Bjorken scaling variable for a moving nucleon

$x'_0=0.3$

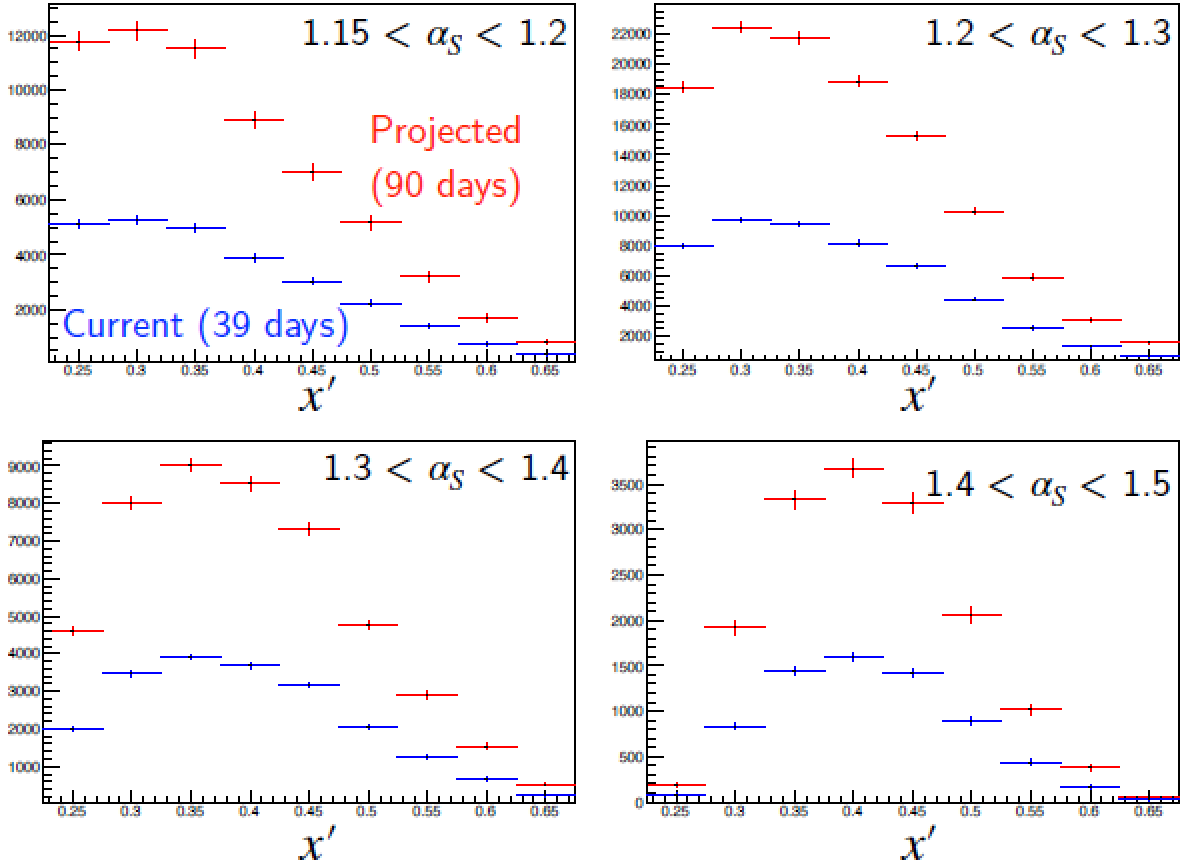


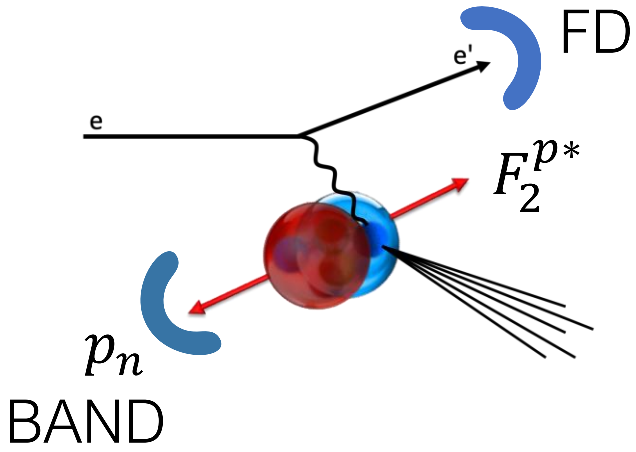
- Neutron-tagged DIS from deuterium, tagged by the detection of a **high-momentum spectator neutron**, allows the study of the **bound proton structure function** $\mathbf{F_2^{*p}}$ when the proton is in a high-momentum, highly-virtual state
- The experimental yield is proportional to the bound proton structure
- The simulated yield is proportional to the free proton structure (free used in event generator)
- The double ratio is sensitive to bound/free proton cross section
- Comparing the ratio with theoretical predictions allows one to disentangle the various effects (nucleon motion, short-range correlations, binding) contributing to the modification of the structure function.
- An analysis note based upon RGB data is in the final stages of internal review in the CLAS Collaboration

BAND/CLAS12 tagged DIS analysis

ed→enX

Observable (double ratio): $$\mathcal{R}(\alpha_{S,i}, x') = \frac{Y_{exp}(\alpha_{S,i}, x')/Y_{exp}(\alpha_{S,i}, x'_0)}{Y_{sim}(\alpha_{S,i}, x')/Y_{sim}(\alpha_{S,i}, x'_0)}$$

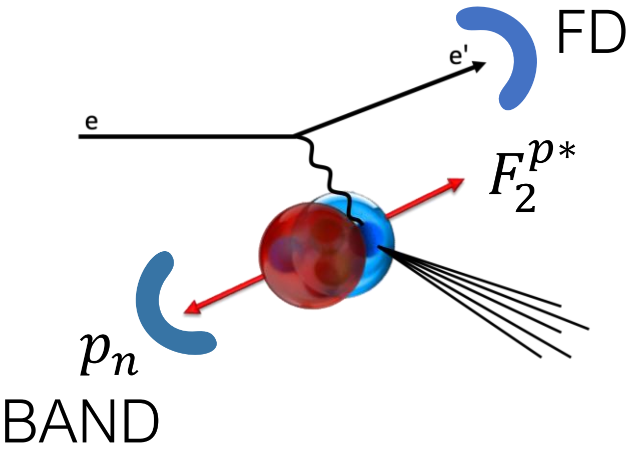


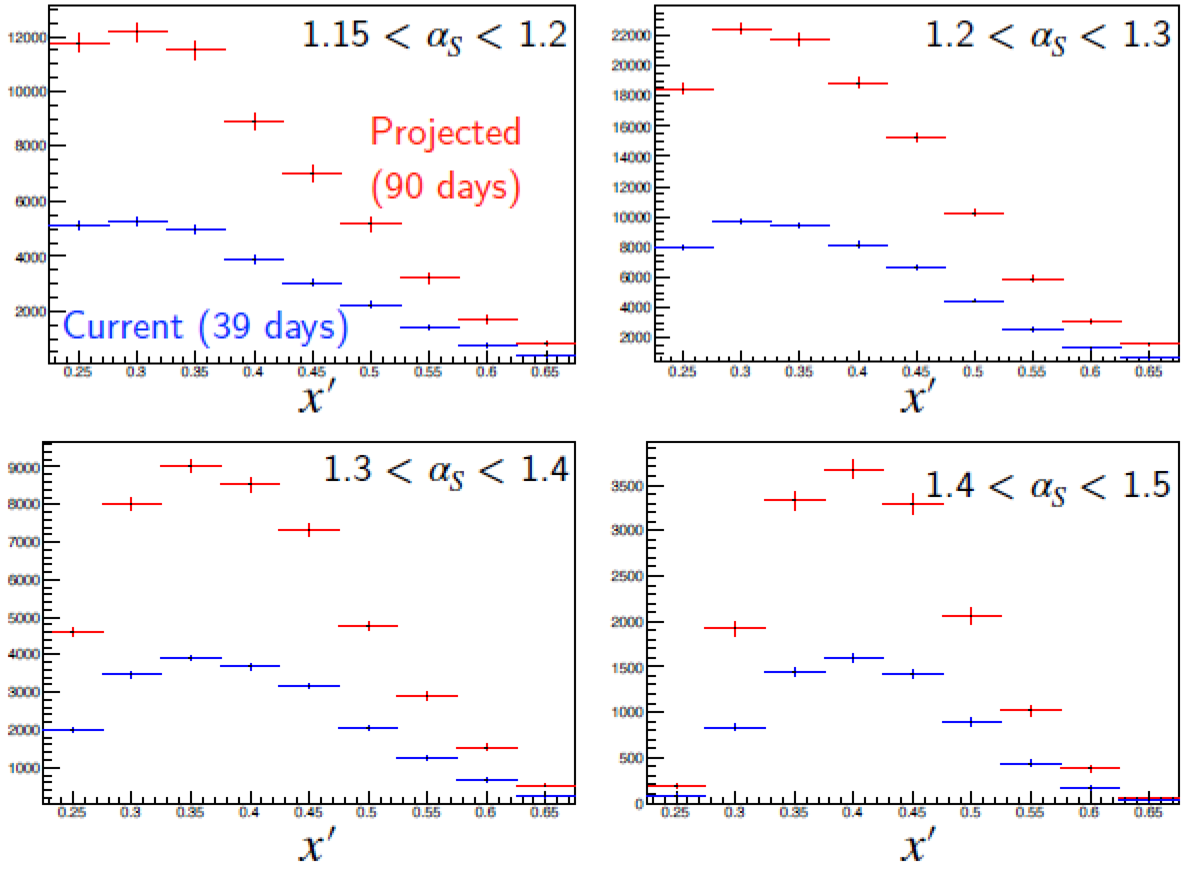


BAND/CLAS12 tagged DIS analysis

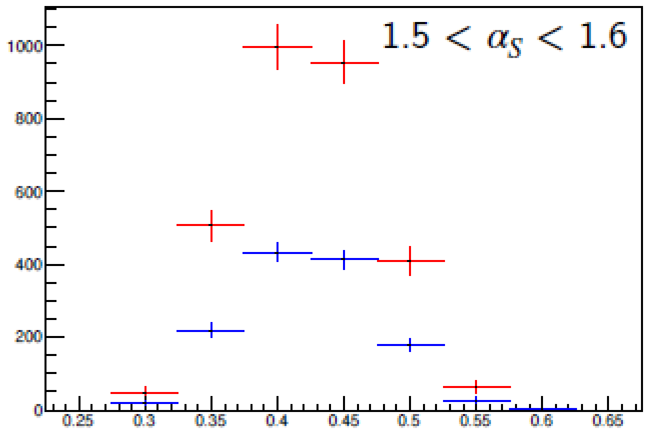
ed→enX

Observable (double ratio): $$\mathcal{R}(\alpha_{S,i}, x') = \frac{Y_{exp}(\alpha_{S,i}, x')/Y_{exp}(\alpha_{S,i}, x'_0)}{Y_{sim}(\alpha_{S,i}, x')/Y_{sim}(\alpha_{S,i}, x'_0)}$$





Could also extend analysis **to higher α_S bin** with approximately **same stats as current highest bin**

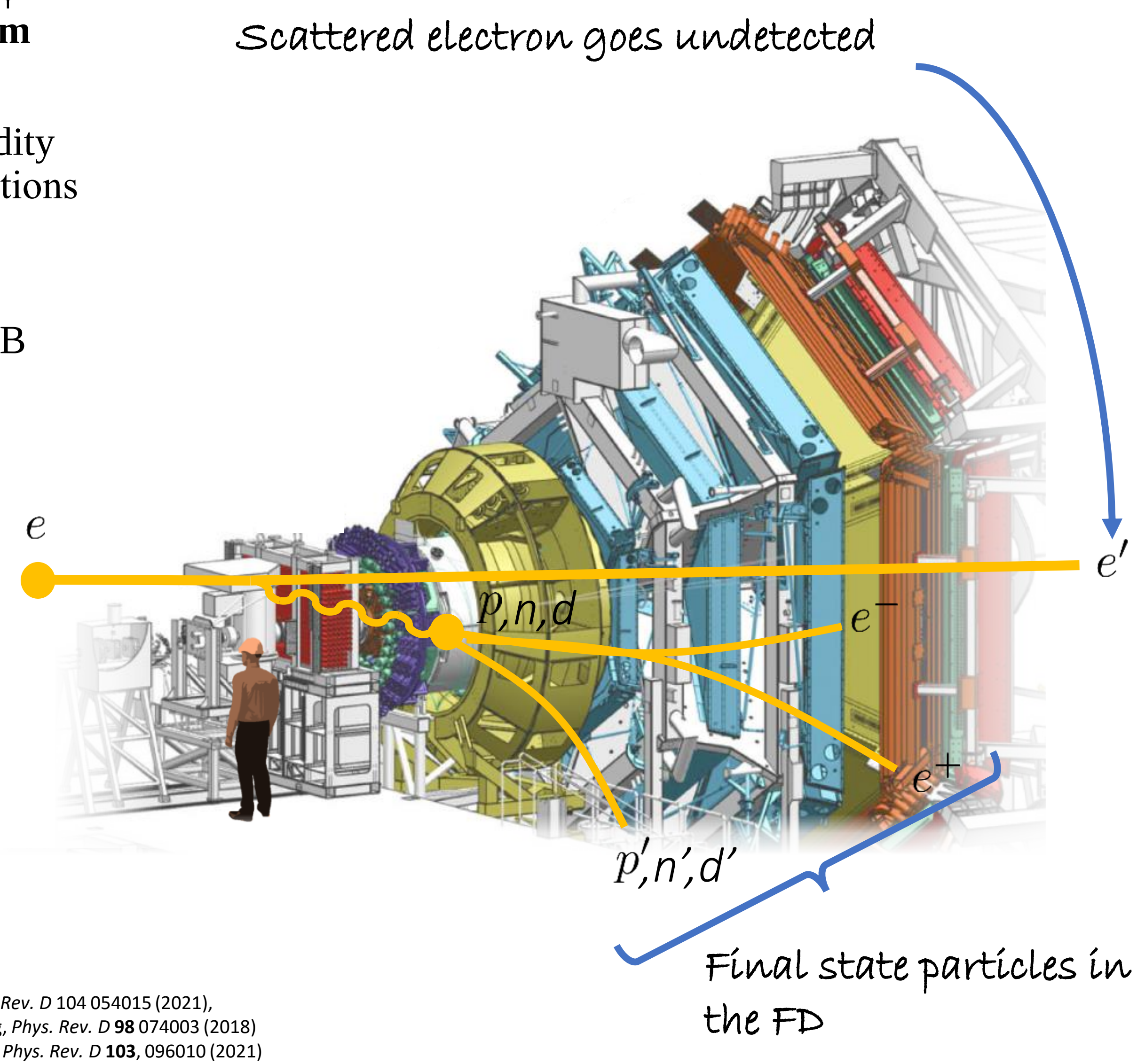


J/ψ Photoproduction (E12-11-003B)

$\gamma N \rightarrow (e')J/\psi \rightarrow (e)e^+e^-N$

- Models based on VMD, holographic QCD and GPD frameworks relate J/ψ near-threshold photoproduction to the **nucleon gluonic gravitational form factors** (gGFFs) [1-3].
- There is some disagreement within the theoretical community on the validity of estimating the gGFFs from J/ψ photoproduction. There are also suggestions in GlueX data that other production mechanisms may dominate the near-threshold region [4-6].
- A **first measurement of J/ψ photoproduction on the neutron** with RG-B data can help establish the **isospin invariance** of the near-threshold production mechanism. This could also lead to estimates of the **neutron gGFFs**.
- **High-precision data** is needed to clarify the validity of relating J/ψ photoproduction to the gGFFs [4-6].

- The aim is to study **coherent and incoherent J/ψ quasi-real photoproduction on the deuteron**:
  - $\gamma N \rightarrow J/\psi\, N'$ (N=p,n incoherent production on p & n)
  - $\gamma d \rightarrow J/\psi\, d'$ (coherent production on d)
  - for J/ψ decaying to $l^- l^+ = e^-e^+$ or $\mu^-\mu^+$

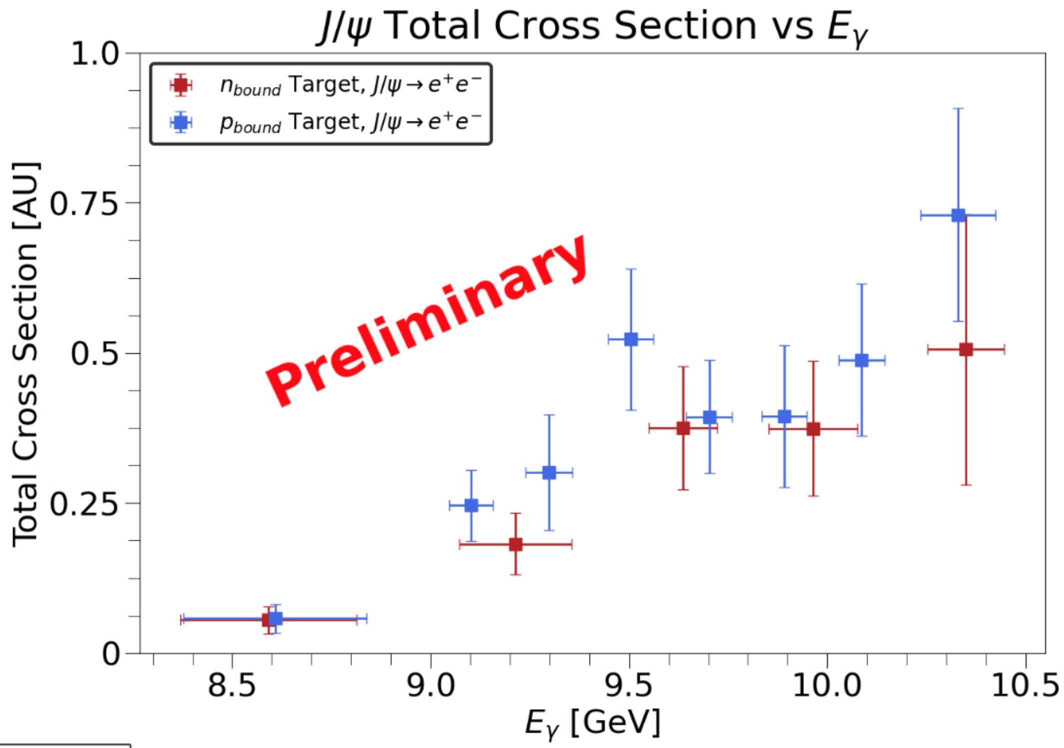


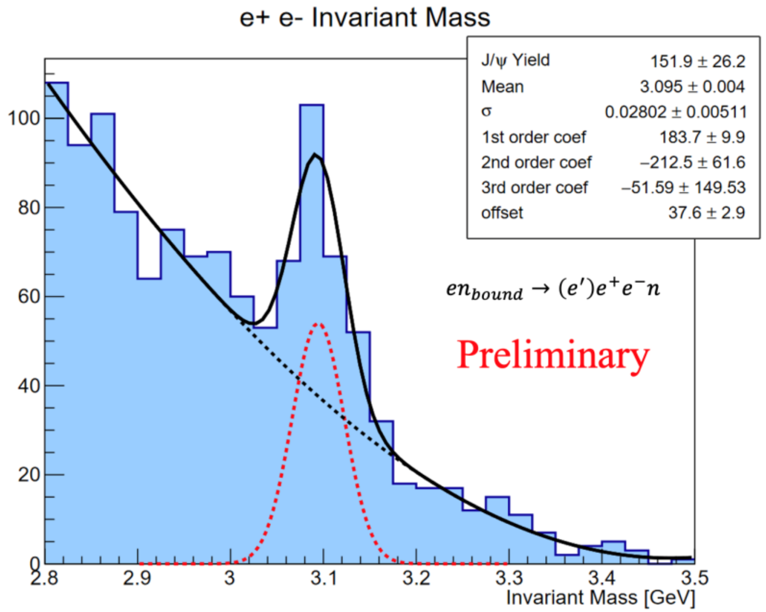
[1] D. Kharzeev, *Phys. Rev. D* 104 054015 (2021),
[2] Y. Hatta, D.-L. Yang, *Phys. Rev. D* **98** 074003 (2018)
[3] Y. Guo, X. Ji, Y. Liu, *Phys. Rev. D* **103**, 096010 (2021)
[4] L. Tang, Y.-X. Yang, Z.-F. Cui, C. D. Roberts *arXiv*:2405.17675
[5] M.-L. Du, *et. al.* , *Eur. Phys. J. C* 80 1053 (2020)
[6] D. Winney, *et. al.* (JPAC), *Phys. Rev. D* **108**, 054018 (2023)

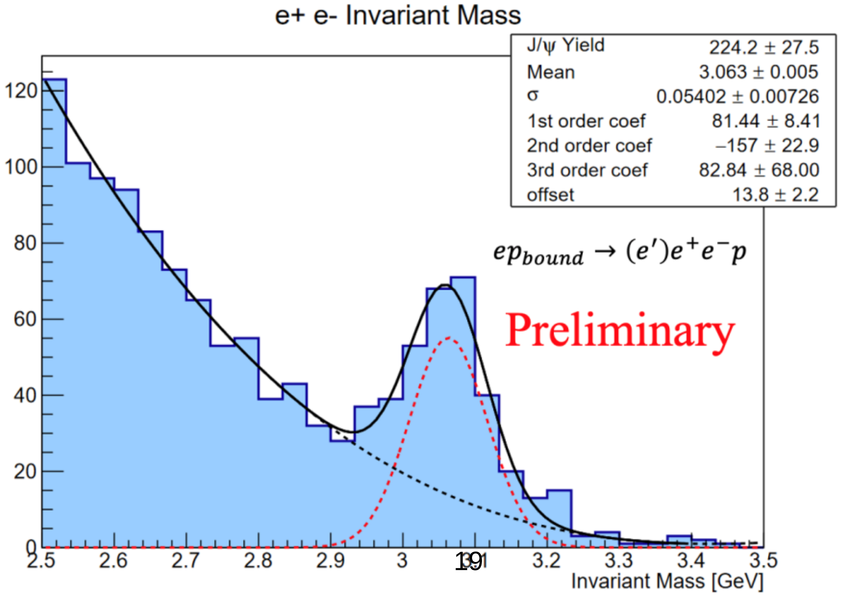
J/ψ Photoproduction (E12-11-003B)

$\gamma N \rightarrow (e') J/\psi \rightarrow (e) e^+ e^- N$

- Analysis based on **Pass2 data**
- Exclusivity is achieved through the analysis of the missing four momentum of the scattered electron.
- Analysis of J/ψ photoproduction on proton and neutron is well advanced.
- One PhD Thesis on J/ψ photoproduction on proton and neutron (R. Tyson, Uni. Of Glasgow).







Results in AU as normalization is in progress.

Only using spring 2019 data (21.7 PAC days):
- ~ 56 % of collected data
- ~ 24% of allocated beam time

The completion of the approved RGB beam time will yield a reduction by a factor of ~2 in the error bars and allow for binning in t

Theory and TAC reports

J12-24-RunGroupB

CLAS12 Run Group B:
Electroproduction on deuterium with CLAS12

A. Accardi, A. Rodas

CLAS12 Run Group B combines measurements using the deuterium target and the 11 GeV polarized electron beam. These measurements cover a range of physics objectives that are central to the study of 3D hadron structure in QCD and nuclear interactions at the nucleonic and partonic level, and were commented on in detail in the original theory review prepared for PAC 48 by C. Weiss and T. Rogers. The Run Group was approved by PAC 48 and ran in 2019, but only obtained 39 days out of the 90 awarded by the PAC, largely due to the beam not being available. The current proposal requests award of the remaining 51 days to complete the original scope of work.

Several of the originally proposed analyses have been finalized or are in advanced stages. However the limited statistics only partially allowed the multidimensional binning originally sought, and the additional beam time is needed to fully sample the multi-dimensional kinematic dependence of the measured observables. This is important for a satisfactory understanding of the underlying effects.

A new analysis of incoherent proton DVCS on the deuterium target has also been demonstrated, going beyond the original proposal and increasing its interest. Such analysis (of which little detail is, however, offered) is important to: (i) complement a similar measurement on 4He target published in 2019 and study the nuclear dependence of GPDs; and (ii) to extract the neutron PDF by comparison to measurements on proton targets.

Proposal: J12+24 Run Groups A, B, and C
Hall: B – CLAS12

The jeopardy proposals for CLAS12 Run Groups A, B, and C are covering many complementary high-precision experiments running with CLAS12 with a 5th pass electron beam. The three run groups have been reapproved before by PAC48.

Findings:

All of these experiments have received a significant amount of beam time in the past years, between around 40 to 70 %. The CLAS Collaboration has made significant progress in data calibration, noise suppression, and track reconstruction, and data analyses are underway by many groups with initial papers published and more in preparation.

There is no change of the detector, trigger, or beam requirements requested for the remaining beam time. The only reason these run groups have not been completed data taking is the high demand of beam time for Hall B with several other CLAS12 Run Groups (RG-D, RG-E, RG-F, RG-K, RG-M) and several non-CLAS experiments (HPS, PRAD) having received beam in the past.

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. The unpolarized target system used for RG-A (LH2) and RG-B (LD2), the so-called Saclay-target, has been decommissioned and was replaced by a new unpolarized target in Fall 2023. This new target was operated without any problems with LD2 for RG-D and RG-E and with LH2 for RG-K. It will now be stored during the ALERT run and is ready for re-installation. Before the next use of this target, some minor modifications are planned.

Comments:

There are no technical issues with these proposals.

Conclusions and beam-time request

- Run Group B aims at mapping the **3D structure of the neutron** via electroproduction on deuterium
- **Quark-flavor separation** of the measured structure functions combining with proton data
- The first « half » of RG-B running ended on January 30 2020
- **~38.9 PAC days collected out of the 90 PAC days approved for nDVCS**
- Three different beam energies for the 3 periods
- **Physics analyses finished or advanced**: n/p/(d)-DVCS, G^n_M, Di-hadron SIDIS, J/ψ, Tagged-DIS, (n/p-DVMP(π^0))

<u>We request the PAC to allow us to run the remainder 51 days of our approved beam time:</u>

- ✓ ***To measure the BSA for nDVCS in 4-D (Q^2, x_B, -t, ϕ), exploiting the full available phase-space, and possibly at a constant beam energy, thus delivering the originally proposed physics output and providing unprecedented constraints on the CFFs of the GPD E***
- ✓ ***To achieve high precision at high Q^2 for G^n_M, where no other data exist***
- ✓ ***To allow precise multi-dimensional extraction of dihadron beam-spin asymmetries for u and d quarks***
- ✓ ***To provide a first-time measurement of J/ψ photoproduction on deuterium***
- ✓ ***To perform a multi-dimensional study of SRC on a bound proton***
- ✓ ***To provide first-time pioneering measurements for new channels (incoherent pDVCS, d-DVCS, n-DVMP(π^0))***
- ✓ ***To provide higher statistics for reactions with kaons in the final state, as the 51 more days will run with 2 RICH sectors***

Back-up slides

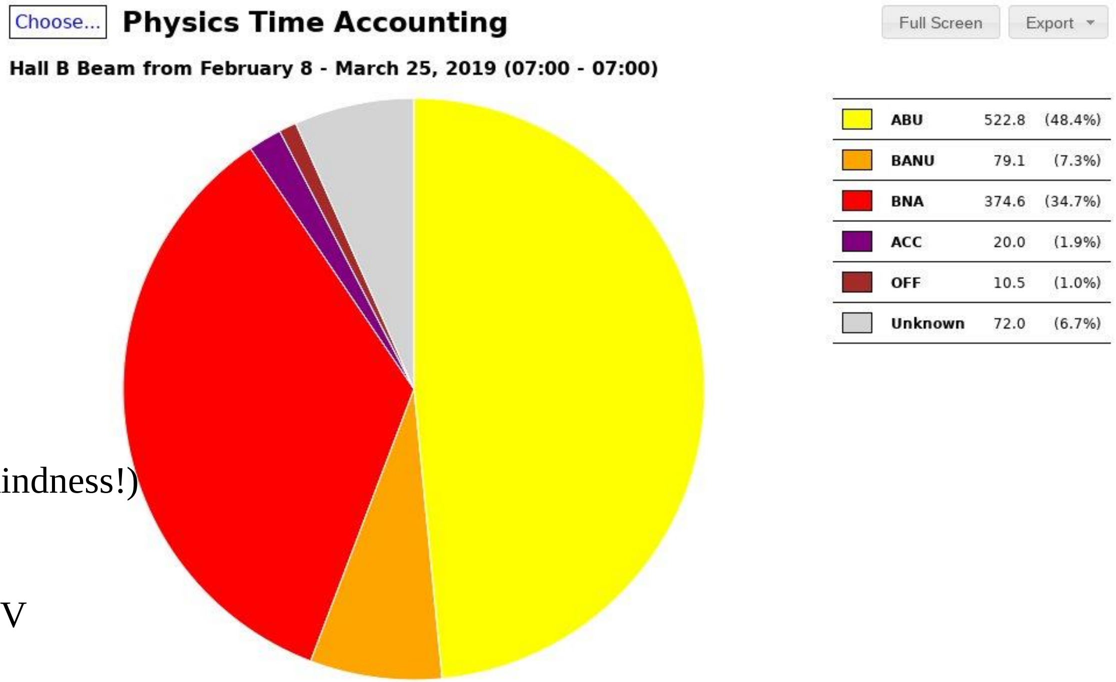
Run Group B spring 2019 run

Running conditions:

- **10.6** – **10.2** GeV beam energy
- Torus ***inbending***
- Production current: 35 nA → 50 nA
- Event-weighed average current: 47.9 nA
- DAQ rate: ~14 kHz

Outcome:

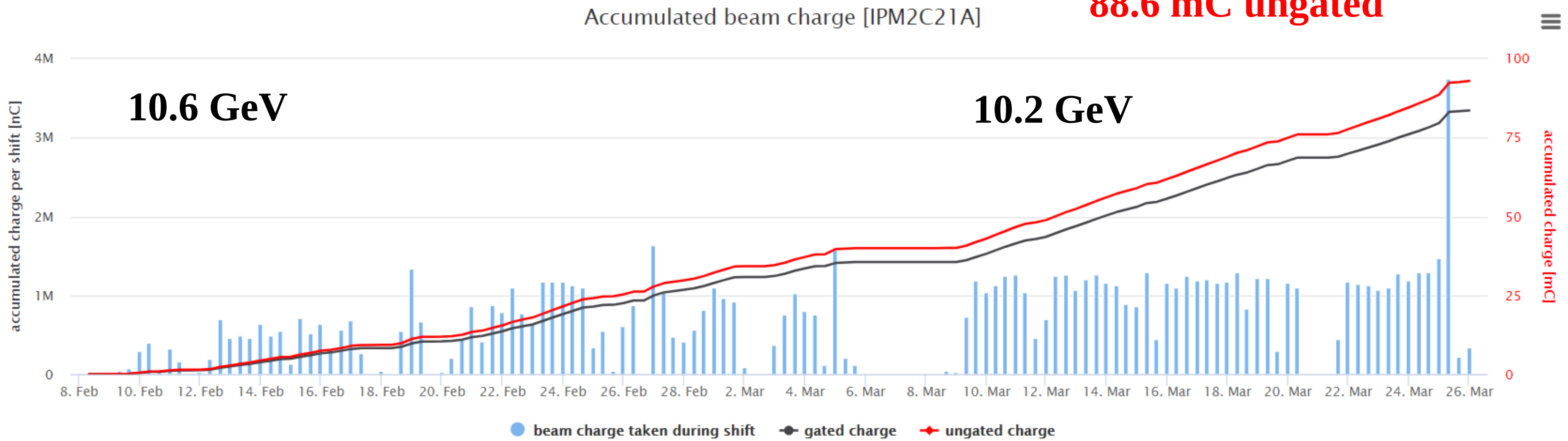
- Original schedule: 1/30 – 3/10
- Final accelerator schedule: 2/8 – 3/17
- Actual days ran: 2/8 – 3/25 (thanks to RG-A's kindness!)
- 21.7 PAC days according to ABUs (48.4%)
- 237 good production runs
- ~9.7 B triggers at 10.6 GeV, ~11.7 B at 10.2 GeV



start date: 02/08/2019 end date: 03/25/2019

79.6 mC gated

88.6 mC ungated



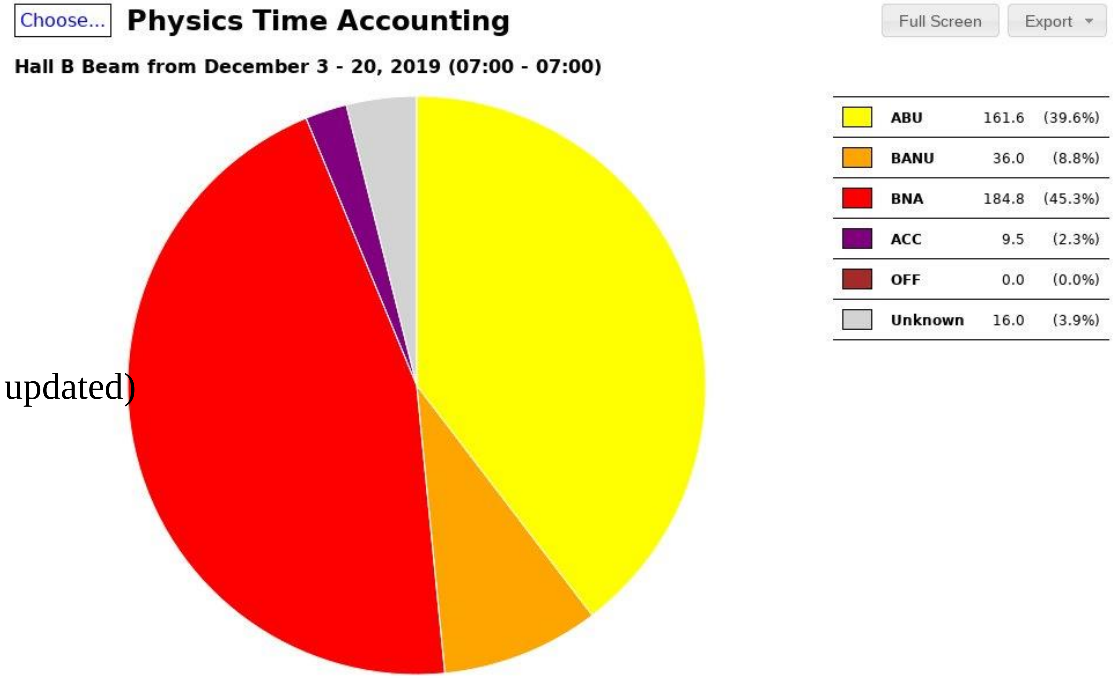
Run Group B fall 2019 run

Running conditions:

- **10.4** GeV beam energy
- Torus ***outbending***
- Production current: 40 nA
- Event-weighed average current: 38.8 nA
- DAQ rate: ~24 kHz
- ~1 day at 2-pass for BAND

Outcome:

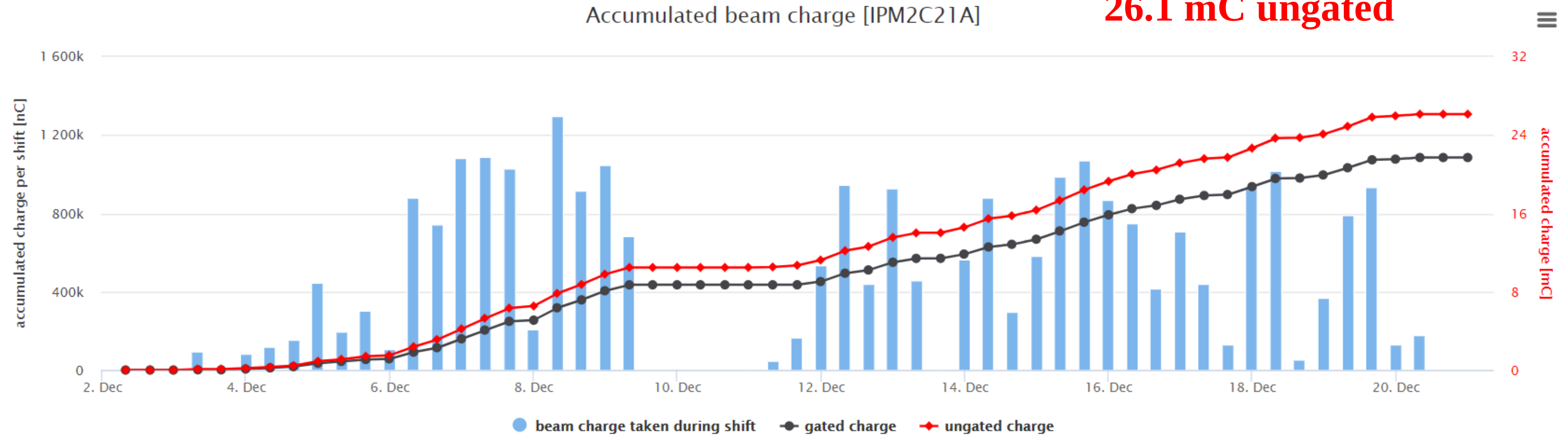
- Accelerator schedule: 11/25 – 12/19 (should be updated)
- Actual days ran: 12/3 – 12/20
- 6.7 PAC days according to ABUs (39.6%)
- 91 good production runs
- ~9. B triggers at 10.4 GeV



start date: 12/02/2019 end date: 12/20/2019

21.7 mC gated

26.1 mC ungated



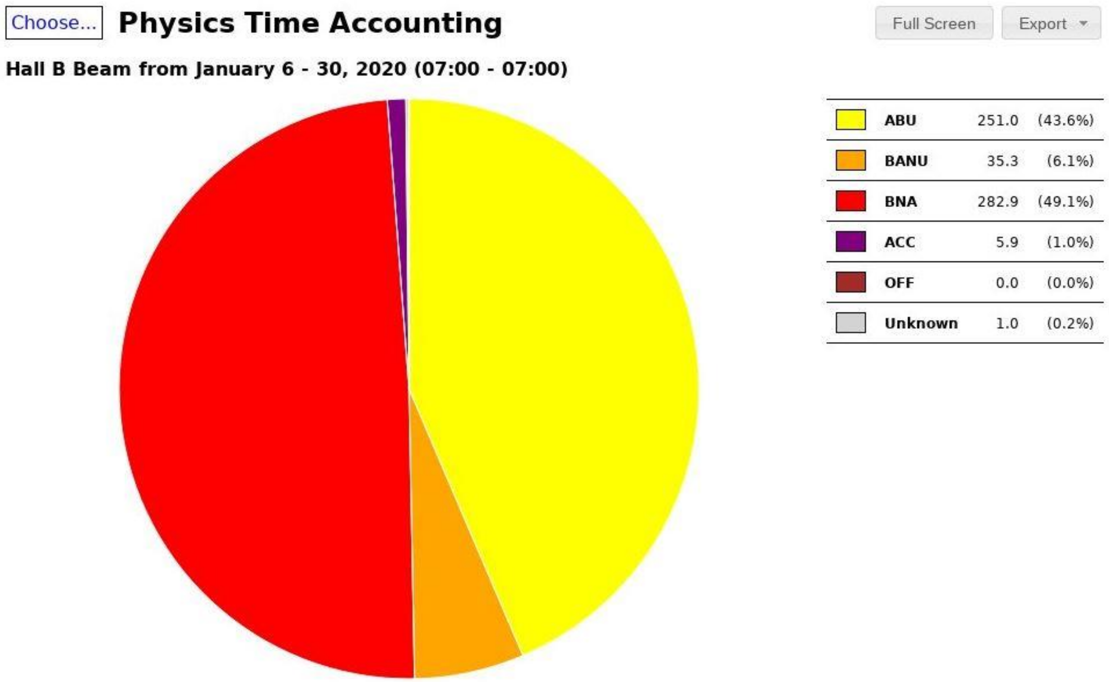
Run Group B winter 2020 run

Running conditions:

- **10.4** GeV beam energy
- Torus ***inbending***
- Production current: 40 → 50 nA
- Event-weighed average current: 45.1 nA
- DAQ rate: ~19 kHz

Outcome:

- Accelerator schedule: 1/10 – 1/29
- Actual days ran: 1/7 – 1/29
- 10.5 PAC days according to ABUs (43.6%)
- 181 good production runs
- 12.9 B triggers at 10.4 GeV

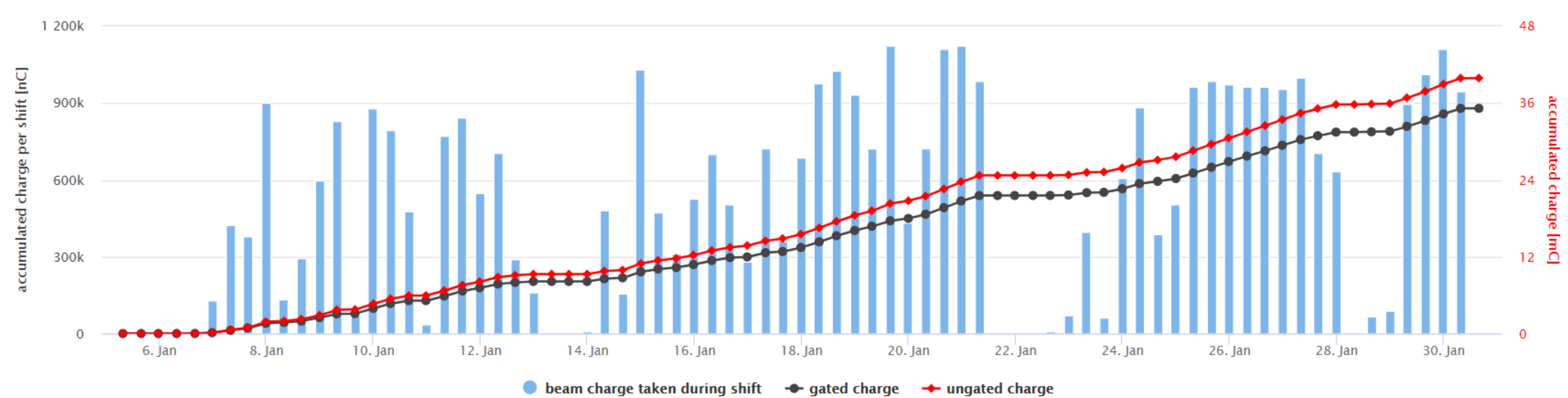


start date: 01/05/2020 end date: 01/30/2020

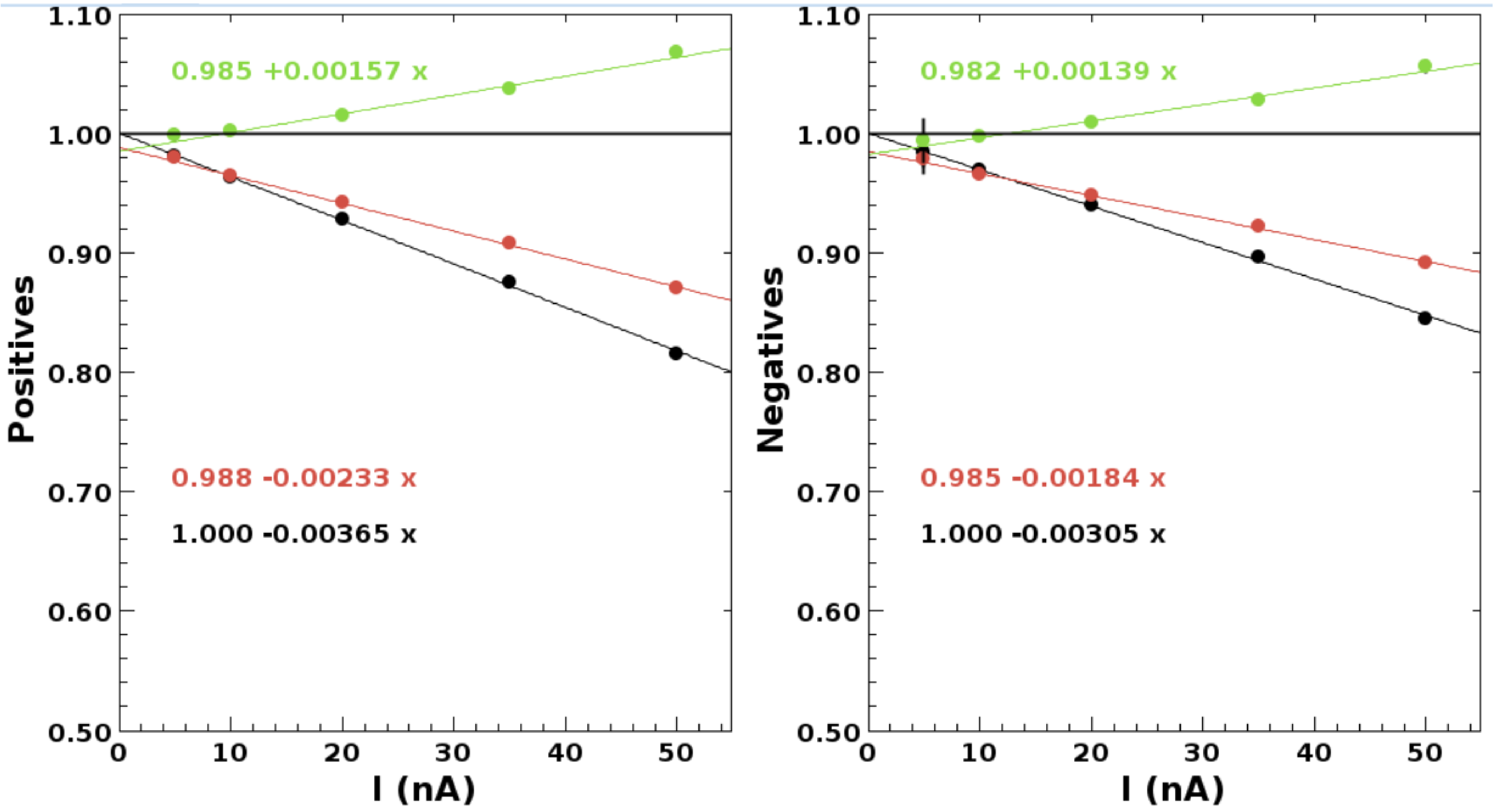
35.2 mC gated

39.9 mC ungated

Accumulated beam charge [IPM2C21A]



W20 data, including denoising, scale 0



DVCS on the neutron: motivation

A combined analysis of DVCS observables for proton and neutron targets is necessary for the flavor separation of GPDs

$$(H,E)_u(x,\xi,t) = {}^9/_{15}\left[4(H,E)_p(x,\xi,t) - (H,E)_n(x,\xi,t)\right]$$
$$(H,E)_d(x,\xi,t) = {}^9/_{15}\left[4(H,E)_n(x,\xi,t) - (H,E)_p(x,\xi,t)\right]$$

Moreover, the beam-spin asymmetry for nDVCS is the most sensitive observable to the GPD E → Ji's sum rule for Quarks Angular Momentum

$$\frac{1}{2}\int_{-1}^{1} x dx \left(H(x,\xi,t=0) + E(x,\xi,t=0)\right) = J$$

Polarized beam, **unpolarized neutron target**:

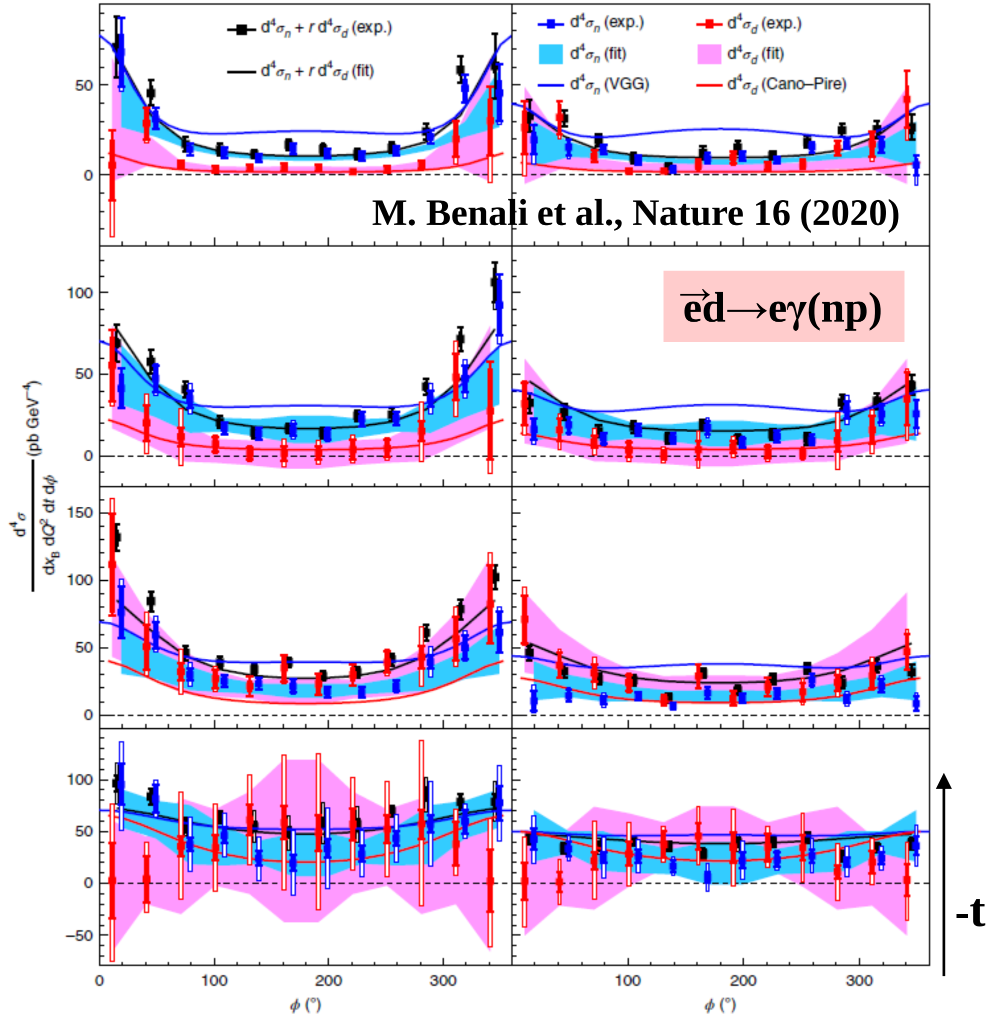
$$\Delta\sigma_{LU} \sim \sin\phi \,\mathrm{Im}\left\{F_1\mathcal{H} + \xi(F_1+F_2)\tilde{\mathcal{H}} + kF_2\mathcal{E}\right\}d\phi$$

Unpolarized beam, **transversely polarized proton target**:

$$\Delta\sigma_{UT} \sim \cos\phi \,\mathrm{Im}\left\{k(F_2\mathcal{H} - F_1\mathcal{E}) + \ldots\right\}d\phi$$

Similar sensitivity to E
Different quark combinations

The BSA for nDVCS is expected to be smaller than for pDVCS → more beam time needed to achieve reasonable statistics



Hall-A 6-GeV experiment E08-025 (2010)

- Beam-energy « Rosenbluth » separation of nDVCS CS using an LD2 target and two beam energies
- **Measured convolution of nDVCS and dDVCS**
- **Large correlations at low –t**

Current error bars on the double ratio (BAND experiment)