Hall-B report

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PAC50 meeting

July 11, 2022

Outline of the talk:

- ❑ Physics highlights

- ❑ Ongoing run – RG-C

- ❑ Run schedule and plans for future

- ❑ Software news

- ❑ Summary

Overview

- Continue production of physics results and publications. Since the last PAC meeting, thirteen papers have been published (4-PRL and 1-Nature), and two more are waiting for journal acceptance.

  - Out of thirteen published, three are from CLAS12 (a total of four from CLAS12). More results are in the last stages of reviews, either in WGs, Ad Hoc, or collaboration, including the DVCS BSA on the neutron and the proton from deuterium data.

- Successfully completed the 2nd physics run for HPS and the 90% of RG-M (NN-correlations and $e4\nu$ experiments).

- Install and now running RG-C – longitudinally polarized targets (NH_3 and ND_3). A long run, aiming to run the approved beam time (120 days). Before the run starts, complete assembly and install the second RICH module!

- Planning for the next round of experiments. Three RGs are scheduled, several others are ready to follow.

- Other Hall-B collaborations:
  - HPS is preparing the second publication (in Ad Hoc review) and moving alone with calibrations of recent data;
  - PRad is preparing for new high precision measurements. Collaboration applied for the NSF grant for detector upgrades.

- Making progress with the software, a new release this week with AI-assisted and significantly improved tracking. The software group is working on various implementations of ML algorithms in the CLAS12 CVT and FD tracking.

- Advancing with a high luminosity upgrade of the CLAS12 forward tracker – fabrication of the µRWELL prototype started at CERN.

- Hall-B submitted four proposals to PAC50. One run group (CLAS12 RG-C), two returning C2s, A=3 proposal, and the PRad dark matter search, and one new proposal for π^0 transition form factor (from PRad/Primex).
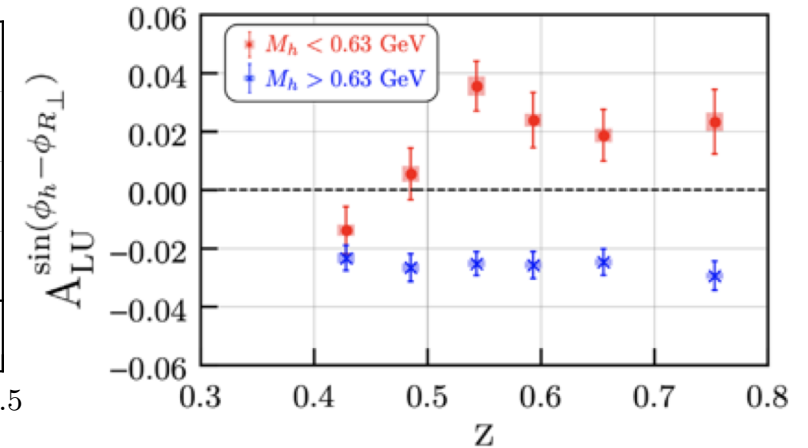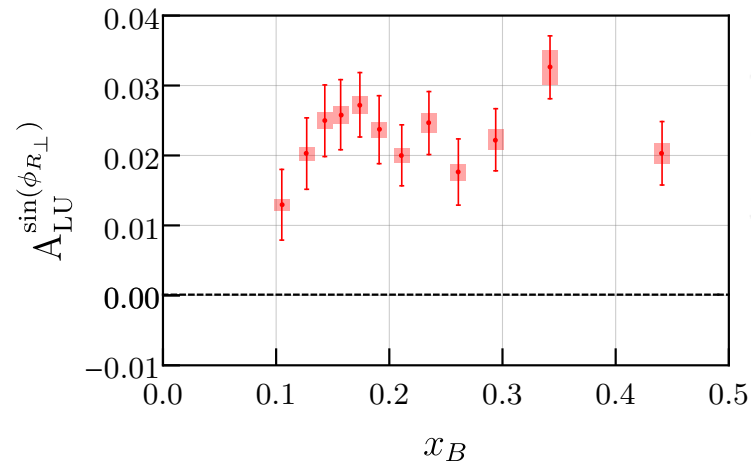
Hall-B Physics Highlights – CLAS12

T.B. Hayward et al. (CLAS Collaboration), "Observation of Beam Spin Asymmetries in the Process $ep \rightarrow e\pi^+\pi^- X$ with CLAS12", Phys. Rev. Lett. 126, 152501 (2021).

- Direct extraction of twist-3 collinear PDF
  $$A_{LU}^{\sin(\phi_{R_\perp})} \sim e(x)$$
- The first ever signal sensitive to the helicity-dependent two-pion fragmentation function
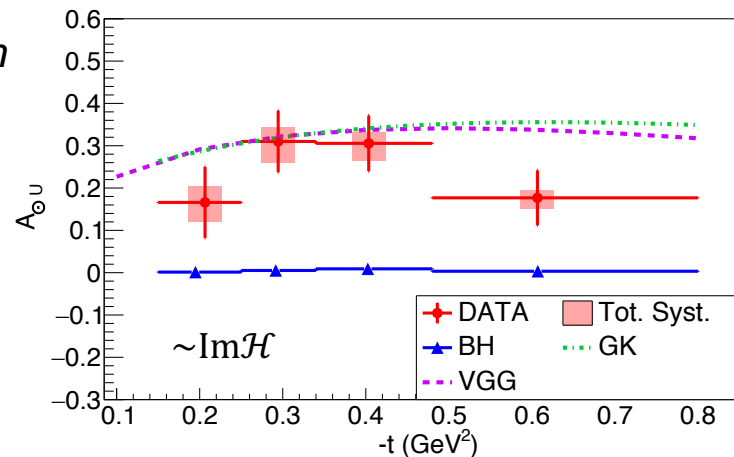 $$A_{LU}^{\sin(\phi_h - \phi_{R_\perp})} \sim G_1^\perp$$

P. Chatagnon et al. (CLAS Collaboration), "First-time Measurement of Timelike Compton Scattering", Phys. Rev. Lett. 127, 262501 (2021). First ever measurement of the TCS process.

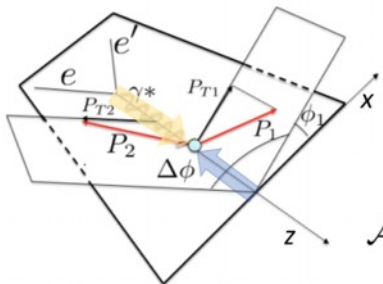- The beam helicity asymmetry, $A_{\odot U} \sim \sin\varphi \, ImM^{--}$, probes universality of GPDs

- The forward-backward asymmetry, $A_{FB} \sim \cos\varphi \, ReM^{--}$, direct access to the EM FF $D^Q(t)$ (D-term).
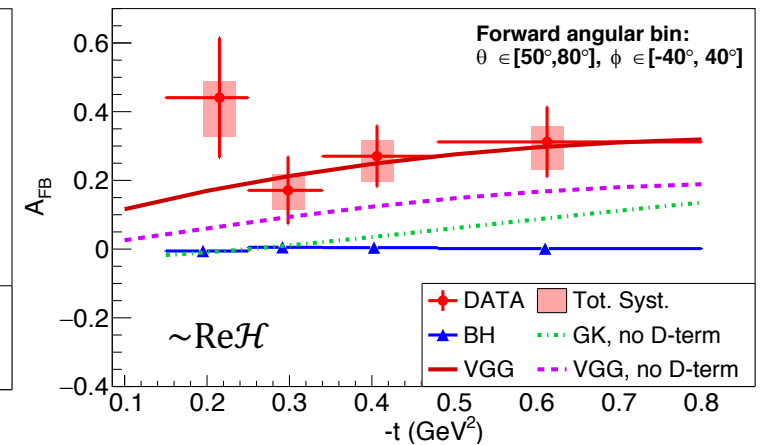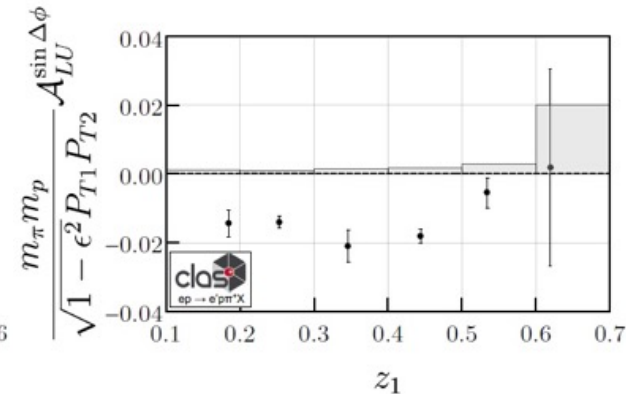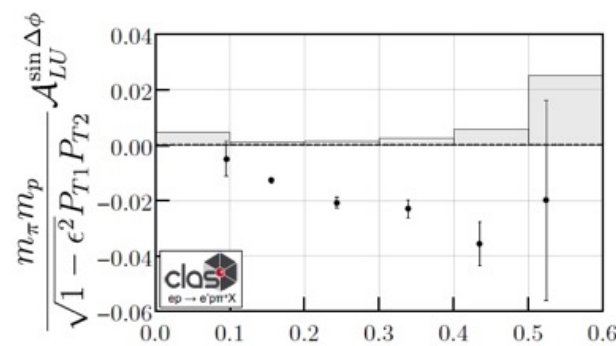
Hall-B Physics Highlights – CLAS12 (cont.)

- Back-to-back di-hadron production (T. Hayward et al.) – will be submitted to PRL anytime now. First time measurement, with a sizable asymmetry.

One of hadrons in CFR another in TFR, provides access to *leading twist* fracture functions, $\hat{l}_1^{\perp h}$ and $\hat{u}_1$.

$$\mathcal{A}_{LU} = -\sqrt{1-\epsilon^2}\frac{|\vec{P}_{T1}||\vec{P}_{T2}|}{m_N\,m_2}\frac{\mathcal{C}[w_5\,\hat{l}_1^{\perp h}D_1]}{\mathcal{C}[\hat{u}_1 D_1]}\sin\Delta\phi.$$
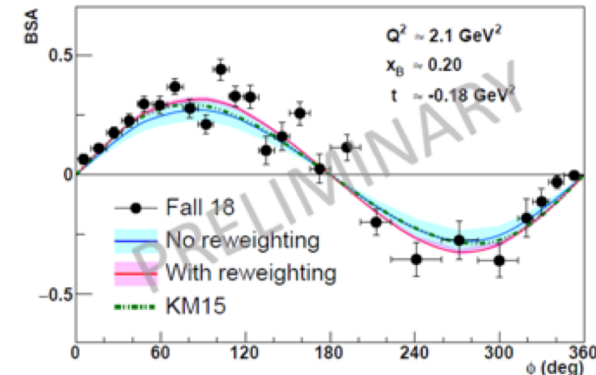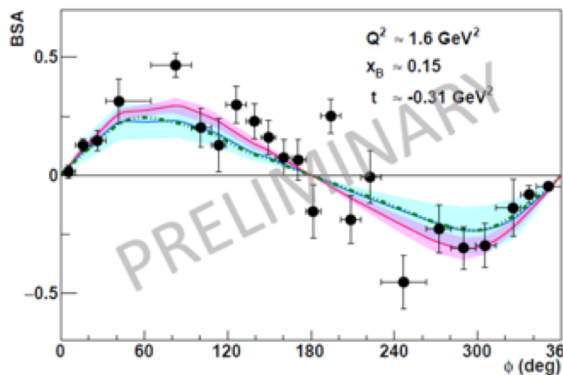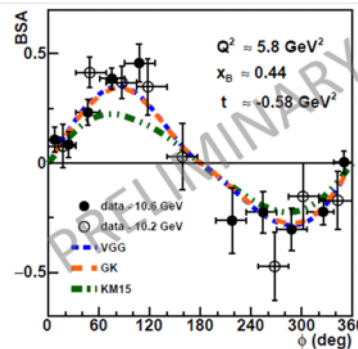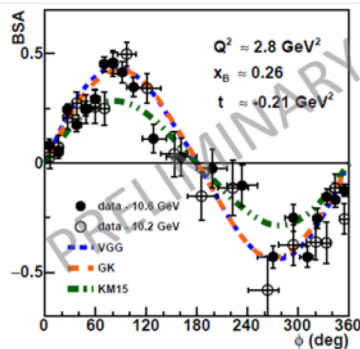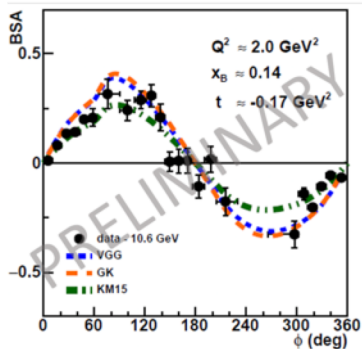

- DVCS BSA with CLAS12 (G. Christiaens, M. Defurne, D. Sokhan et al.) – finishing the Ad-Hoc review, intended for PRL.

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

Comparisons with KM15 and VGG/GK models.   Fit with ANNs, constrained on 6 GeV data.
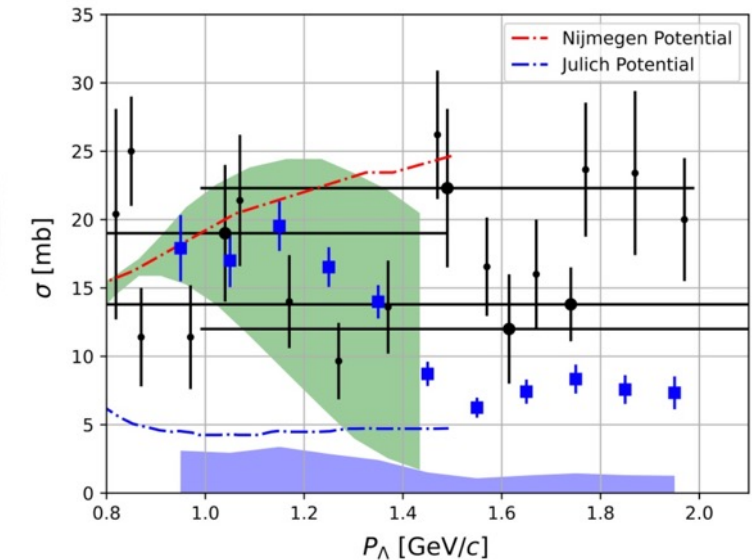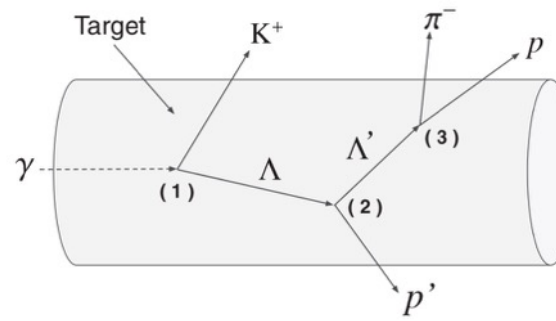
Hall-B Physics Highlights – CLAS Data Mining

J. Rowley et al., PRL **127**, 272303 (2021)

- Λp elastic scattering cross section for Λ-momentum range form 0.9 GeV/c to 2 GeV/c from analysis of CLAS *g12* data set;

- Highest statistical precision measurement over 40 years (old bubble chamber data dates to 1960's and 70's;

- Important input to the theoretical models for EOS of neutron stars.

M. Khachatryan et al., Nature **599**, 565-570 (2021)

- Use electron–nucleus scattering data with known incident energies to models for neutrino energy reconstruction in the neutrino oscillation experiments;

- Data from CLAS *e2* experiment, electron beams of 1.1 GeV to 4.4 GeV incident on nuclear targets ^{4}He, ^{12}C, and ^{56}Fe;

- Methods used: (a) cross section of the inclusive electron scattering , relevant for T2K and Hyper-Kamiokanda, (b) "calorimetric" method, a total energy of the final state particles, important for DUNE.
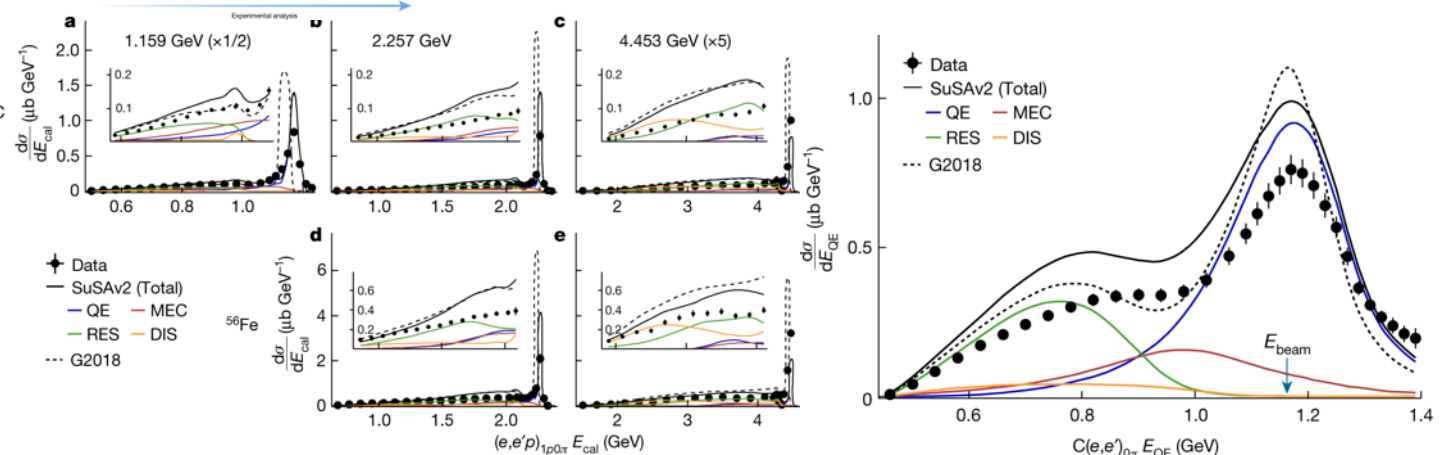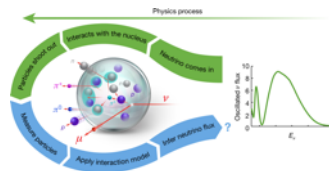
RG-C run

- Good start, CLAS12 came up reasonably well (~140000 channels).
- Few new systems, RICH-II, raster, and polarized target.

Two sectors of RICH

~1 Hz full cycle

Longitudinally polarized NH3 and ND3 target system in the hall
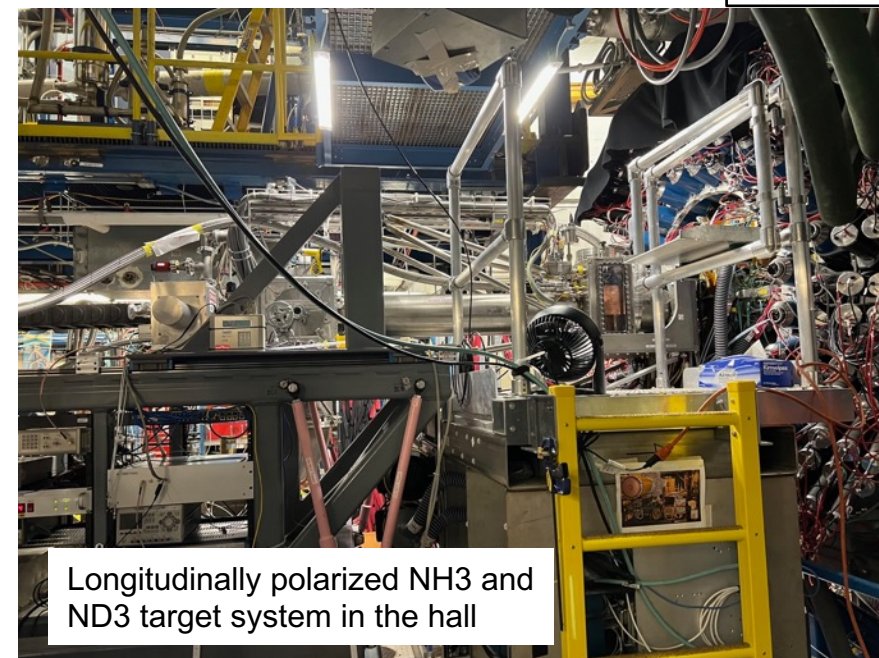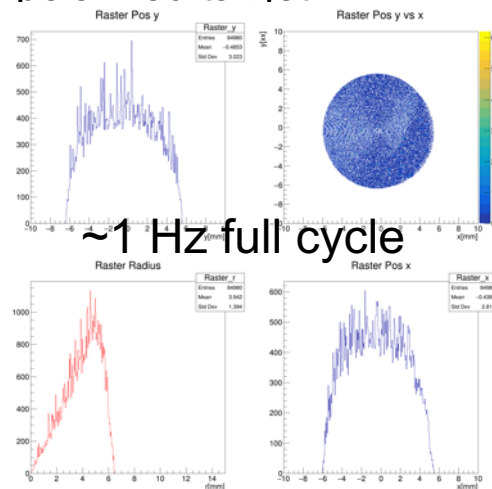
- This is the first time target has been polarized in the CLAS12 solenoid field.
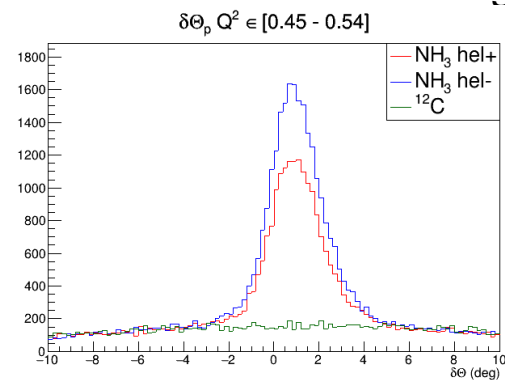
Measured high polarization for NH_3 from the elastic scattering data:

$$ep \to e'p'$$

$E_b = 2.2 \; GeV$

NH_3

$P_t \approx P_b \approx 0.85$

$E_b = 10.55 \; GeV$

NH_3

PRELIMINARY

$P_t \approx 0.8$

Hall-B runs

Schedule through March 2024 -

- RG-C: will run till March 20, 2023. Will use all the approved beam time (120 PAC days).
- RG-D: July 17 to September 17, 2023. Must have 30 PAC days to compete.
- RG-K: September 20 to December 17. Should be able to complete ~50% of the approved beam time.
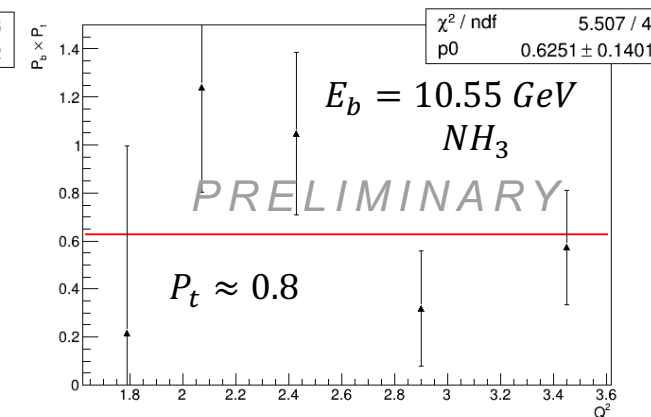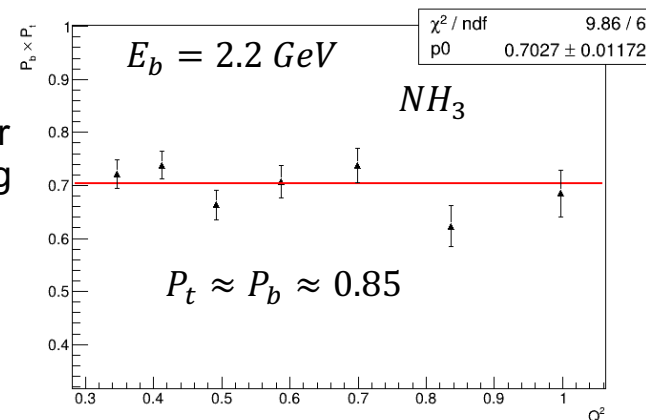- RG-E: January 15 to March 17, 2024. Scheduled for 50% of the approved beam time.

The next with the approved beamtime request is RG-L (ALERT). 2024 SAD is the right time to install it.

- RG-L, ALERT program with four experiments, will use a new low energy recoil detector, now in construction at Orsay and ANL, to replace CVT.
- Run group is approved for 55 PAC days and will run in one setting.

Run groups ready to run (With 30 weeks a year for physics, this will take ~3 years to complete):

- 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 (HPS), still has 102 PAC days remains at 2-4 GeV.

Other Hall-B run groups

- **Other CLAS12 experiments have non-trivial targets (in the order of group definitions):**
  - RG-G, longitudinally polarized ^{6}LiH and ^{7}LiD targets. It will be the RG-C target system, somewhat modified. The experiment is approved for 55 days.
  - RG-H, transversely polarized DNP NH$_3$ target (the original proposals were based on the HDIce target and are approved for 100 days). The installation requires major changes to the beamline (chicane magnets and a new shielding).
  - RG-P, ^{3}H/^{3}He targets with 2.2 and 6.6 GeV beams, approved for 60 days. Another experiment, with the same set of targets but at 11 GeV, was C2 approved and is coming back to PAC50.
  - RG-N, longitudinally polarized ^{3}He gas target. C1 approved for 30 days. Target is still in the development stage.
- **Non-CLAS12 experiment:**
  - RG-O, PRad-II, C1 approved for 40 days, non-trivial beam energies: 0.7, 1.4, and 2.1 GeV.
  - Two more proposals from PRad/PrimEx collaboration, C2 approved X17 (PAC49), and a new proposal for p0 TFF (submitted to PAC50).

  With 30 weeks a year for physics, to complete already approved beamtime will take 2.7+ years.
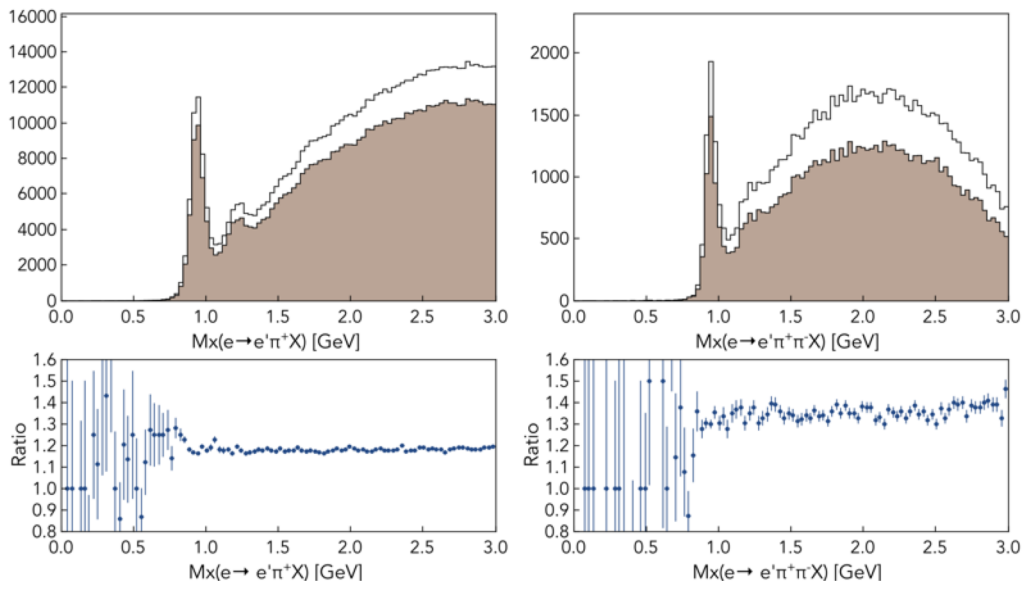
Software update

AI-assisted FD-tracking:

- A single-particle efficiency increase by 12%-15% after introduction of AI track candidate classification

- The increase in statistics for physics observables ranges from 20%-35% depending on the final state topology

- Forward detector tracking code speed up ~30%

Improved CVT tracking and alignment:

- KF-based alignment, with improved geometry representation for SVT and BMT

- Beamline constrained KF fit, 2nd pass for Eloss correction.

CVT-DC momentum residuals
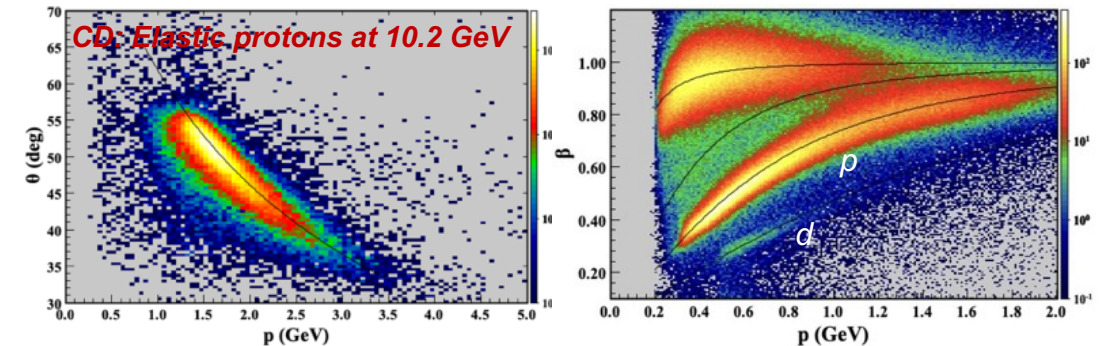
A difference of momenta measured by FD and CD tracking for a charged particle passing through both. FD/DC tracking resolution is ~1.5%, the CVT tracing resolution dominates the residuals.
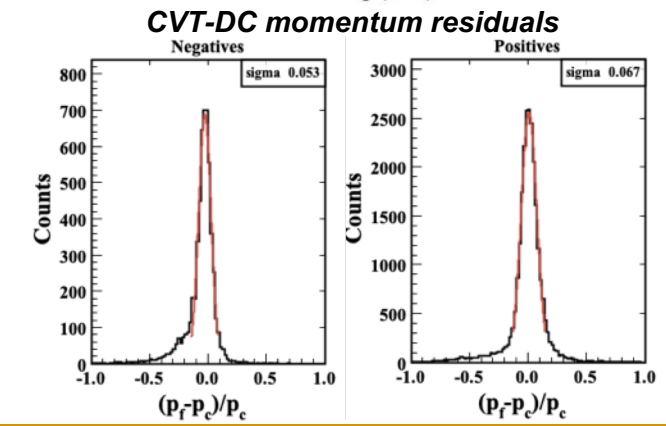
Summary

Hall-B continues data taking and producing high-quality physics results, publishing about 10 -13 papers yearly. A ~60% of publications are still from CLAS data-mining efforts, but the analysis of CLAS12 data is peaking up. Expect two or more publications by year's end.

Successfully installed and running RG-C – the first polarized target experiment with CLAS12. Preparing for the next round of experiments with new detectors and various polarized targets (transversely polarized NH_3, longitudinally polarized LiH/LiD, and gas ^{3}He).

Continue improving data reduction and analysis software, implementing ML algorithms into CLAS12 offline reconstruction software.

Progressing with detector upgrades –
- RICH-II is in service,
- a new dual-target for RG-E and the low-energy recoil detector for RG-L are in the works,
- the construction of the first μRWELL detector prototype for R1 tracking addition for the CLAS12 luminosity upgrade started at CERN.

Gradually upgrading the DAQ hardware to be ready for streaming-readout for very high luminosity operations. Working on the development of *L3*-trigger and online reconstruction software.