**Review of CLAS12 Run Group H Proposal**

**1. Overview and Scientific Objectives**
The CLAS12 Run Group H (RGH) proposal presents an ambitious and timely effort to deepen our understanding of nucleon structure through three interconnected experiments utilizing a transversally polarized NH3 target:

* **C12-11-111**: SIDIS measurements with single hadrons to extract transversity and tensor charge, and the Sivers and Collins functions.
* **C12-12-009**: SIDIS measurements with dihadrons for transversity and tensor charge in the collinear framework.
* **C12-12-010**: DVCS measurements to access GPD E and study the nucleon's orbital angular momentum (via Ji’s sum rule).

The CLAS12 detector has a demonstrated ability to handle high luminosity and has already run with similar targets (e.g., NH3, ND3). The planned recoil detector configuration and the use of a dynamically polarized NH3 target build on established technologies, reducing technical risk. Full GEANT simulations are conducted and discussed, including beamline, background, and systematic studies.
The scientific goals are well aligned with the 2023 NSAC Long Range Plan and are intended to precede and complement the Electron-Ion Collider (EIC) program. The proposal focuses on accessing transversity PDF, related tensor charge, the Sivers function, and the elusive GPD E-each of which provides insight into the 3D spin and momentum structure of the nucleon. The results are expected to fill a critical gap in the data landscape *before* the EIC comes online, providing validation benchmarks for theoretical models and lattice QCD. High-*x* measurements of transversity and tensor charge are crucial to resolve tensions between phenomenological fits and lattice results. The DVCS measurement is uniquely positioned to constrain the elusive GPD E, key to understanding the orbital angular momentum of quarks in the proton.
*The proposal is logically organized, with detailed subsections for physics motivation, equipment, simulations, and systematic studies. The document is well-cited, showing awareness of current literature, competing efforts, and theoretical frameworks.*

**2. Importance of Transverse Spin Effects in SIDIS**
The transverse spin structure of the nucleon remains one of the most intriguing frontiers in QCD. The extraction of the transversity distribution and its first moment, the tensor charge, through SIDIS processes at high Bjorken-*x* is especially crucial. The Run Group H experiments offer a rare opportunity to study these effects in a multi-dimensional framework, allowing unprecedented access to parton dynamics in the valence region. Such measurements will serve as essential benchmarks for lattice QCD, and provide crucial constraints on global fits of transverse momentum dependent parton distribution functions (TMD PDFs), particularly through comparison between single-hadron (Collins/Sivers) and dihadron channels (collinear IFF-based extractions).

**3. Connections between different QCD regimes**

In several places in the document (e.g. p.13), it is said that the RGH experiment will study "the connections before different QCD regimes" (i.e. hard and soft regimes). It would be nice to illustrate this by showing what is the reach in terms of hard and soft regimes for example for a given probe and observable with the pseudo-data (e.g. extracted Sivers function or AUT of single hadron as a function of pT).

**4. Experimental Setup and Instrumentation**
The experimental configuration requires substantial modifications to CLAS12: removal of the central solenoid, installation of a 5-T split-coil magnet, integration of a new recoil detector (including a tracker and time-of-flight system), and the introduction of a three-magnet beam chicane. These changes are necessary to accommodate the transversely polarized target and allow full kinematic reconstruction, especially for DVCS. While technically challenging, these innovations build on proven systems from Halls A and C. However, the proposal must ensure that magnetic field mapping, calibration procedures, and mechanical integration (including vibration management) are well-understood and documented before the experimental campaign begins.

**5.Asymmetry Extraction and Background Control**
Backgrounds, especially from exclusive ρ⁰ mesons in SIDIS and π⁰ contamination in DVCS are acknowledged, yet the mitigation strategies could be more robust, including empirical control samples, sideband subtraction, and a quantitative estimate of the residual contamination effect on extracted asymmetries could be elaborated. In the case of DVCS, the use of the recoil detector is a major strength, but data-driven validation remains essential.

**6**. **CLAS12 acceptance effect, role of unpolarized cross section, luminosity variation**

An important concern that remains insufficiently addressed in the proposal is the impact of acceptance and luminosity variations on the extraction of transverse spin asymmetries in SIDIS. These asymmetries are expressed as ratios between polarized and unpolarized cross-section components. Since the unpolarized cross-section, *σ*U, typically dominates and varies steeply across kinematic variables such as *x*, *z*, and *P*T, it plays a critical role in shaping the observed asymmetries.
In practice, the measured asymmetries are convoluted with the detector acceptance A(k), which may be non-uniform and spin-dependent. As a result, even purely sinusoidal modulations in the true asymmetry (e.g., sin(φh+φS)) can be distorted or diluted:

If the acceptance is not uniform across spin states or kinematic bins, this convolution can introduce artificial asymmetries or obscure genuine signals. Furthermore, small inaccuracies in luminosity normalization between spin states can similarly bias the asymmetry extraction.

Did you study if there is any acceptance bias of the analysis method on the extraction of the single-hadron, dihadron and DVCS AUT and ALT asymmetries? In particular, did you compare with the help of the full RGH simulations reconstructed vs generated asymmetries? In section 4 and 5, details of the analysis are given but not on possible acceptance bias on asymmetry extractions. Also PhiS defined in Fig.2 and 11 is a new variable wrt previous CLAS12 analyses with longitudinally polarized target, and it would be nice to show that no acceptance bias is expected with a transversally polarized target. In particular, one could expect some acceptance bias due to the non-homogeneous acceptance of the detector or due to the removal of critical DC layers (by swiching them off) in sector 4, as proposed as a default setting in the proposal.
The proposal does not provide a quantitative assessment of these possible acceptance effects. There is no discussion of correction strategies, such as the use of acceptance-weighted Monte Carlo simulations or control samples from unpolarized data.

Additionally, the role of the unpolarized SIDIS component in shaping the final asymmetry signal is not sufficiently explored. The reliability of transverse spin observables depends not only on statistical precision but also on the careful handling of systematic biases introduced through such convolutions. A more detailed treatment of these effects would enhance confidence in the physics reach of the proposed measurements.

**7. Radiative Effects and Polarization Contamination**
A more detailed treatment of radiative corrections is needed. While simulations demonstrate the presence of radiative tails in kinematic distributions, there is no formal plan for implementing corrections or unfolding procedures, particularly important for spin-dependent observables. Moreover, the small longitudinal component of the target polarization (relative to the virtual photon direction) may introduce mixing with longitudinal spin asymmetries (higher twist terms get mixed with ALL, which is rather large). The proposal currently does not assess or quantify this potential source of systematic uncertainty. The PAC may wish to request that the collaboration evaluate this contamination and explore correction methods, especially for asymmetries sensitive to transverse spin dynamics.

**8. DVCS without the recoil detector**

It seems possible for DVCS to perform an analysis without detecting the recoil proton. As mentioned in the document, this is quite useful to assess systematics and also to extend the kinematic reach. Can you provide a quantitative comparison of the Q2, x and t coverage with and without recoil proton detection?

**9. Recoil proton resolution**

Fig.46 right shows a quite poor resolution for the recoil proton momentum at low momenta. How does that compare to RGA recoil proton resolution and does that imply an issue for signing the exclusive process? We suppose t and phi are not defined by the recoil proton but rather by the produced photon, right? Are those simulations of Fig.46 (i.e. with background) used to define the projections shown in section 5?

**10. Sheet-of-flame**

The sheet-of-flame arises from beam particles that do not interact with the target. In Fig. 52 left, it shows that sector 4 of the DC detector has a large occupancy. However, when the magnetic field is reverse, is the opposite sector 1 expected to have a large occupancy? Is this statement correct and if so, how do you handle possible acceptance effect in your analysis when determining AUT?

**11. Impact of systematic uncertainties on result interpretation**

For the projections in Section 5, only statistical uncertainties are considered. Can you discuss for all the observables discussed, what is the impact of the systematic uncertainties estimated in Table 5-7 on the result interpretation? Indeed, these uncertainties are not negligible.

Also, there is no studies performed on A\_LT in Section 5. Are studies on A\_LT ongoing?

**12. JAMDIFF fit**

Are shown uncertainties only statistical on Fig. 69? Is it the dihadron asymmetries? Why does the curve JAMDIFF+CLAS12 have lower uncertainties than the data themselves? Indeed, one would expect the CLAS12 pseudo-data to constrain the JAMDIFF parametrization at the level of the data uncertainties.

**13. Technical and Operational Considerations**
Several engineering and operational factors merit attention. Asymmetric spacing of the chicane magnets complicates beamline tuning and may affect magnetic optics. Beam position monitoring at the proposed low currents (~1 nA) is challenging; however, the use of stripline BPMs at currents above 25 nA is being considered. Mechanical vibrations from the cryogenic systems and magnet infrastructure could influence detector stability. Additionally, systematic uncertainties related to the target packing factor, dilution factor, and both beam and target polarization appear somewhat underdeveloped or underestimated. It would be appreciated to provide more precise estimates, including worst-case bounds and cross-validation with prior polarized target data from Halls A/C.

Target ladder removal (p.30): after a displacement of the target ladder and cryostat, what is the precision of the repositioning of the target ladder? What precision do you aim at in order to be able to combine various data taking periods? Do you foresee specific alignment runs for that?

**14. Cross section and hadron multiplicity measurements**
While the proposal focuses on spin asymmetries, it does not include projections for cross sections or hadron multiplicities, which are essential for validating acceptance corrections, benchmarking with global fits, and enabling broader physics applications. The absence of these fundamental observables limits the interpretability and reusability of the data, and reduces the experiment’s complementarity with existing SIDIS and DVCS programs. It is said p.8 that "CLAS12 program will start with asymmetry measurements, but may be eventually extended to cross-section measurements". Why "may be"? Is there anything missing experimentally (luminometer, PAC days, ....) to extract absolute cross sections?

**Minor questions/comments or request for details:**

- p.6: z and Pt are not variables for DVCS process (should be "t")

- p.6: one cannot be competitive with calculations

- Fig.8 caption: please explain what means "favored" and "unfavored" cases.

- p.20: it is stated that RGH can bring significant constraint on J\_u (as RGA did on J\_d as shown on Fig.13). Can you show this is the case with pseudo-data?

- p.25: "BMK" is not defined

- Fig.42: units on y-axis are missing

- Fig.49: this is not understandable for a non expert. Can you show the z axis with an arrow for the electron beam and additionally more details for the figure description for the important part?

- p.59: rotation of the target by 90 degrees: if the sheet-of-flame is oriented towards the torus coil shadow, there might be secondaries or scattered particles. How would that affect the background in CLAS12?

- Fig.55: can you explain the structure (cut at theta > 40 degres for -150 < phi < -100 and 100 < phi < 150)?

- Fig.56: can you describe the subpanels: where is z and pt? It is not visible from the plot.

- Fig.67: what are the criteria for a CLAS12 RGH pseudo-data point to appear in this (x, Q2) plot? Do you consider a maximum statistical uncertainty in 4D?

- p.78: can you describe the alternative method to estimate the pi0 background on DVCS results?

- Fig.77: unit is missing for the right plot