-24-RunGroupH:

CLAS12 Run-Group H Experiments with a Transversely Polarized Target

The choice to move from the HD-Ice polarized target to an NH3 polarized target is a significant change to the original proposal that completely changes the entire technical scope of the proposal. Similar to the hypernuclear experiments proposed for Hall A but then moved to Hall C, these significant changes require a new proposal to address all the technical aspects of the experiment that were either different or not present in the original proposal. Neither the required 5T transverse magnet nor the required magnet chicane system exist and all need to be designed and built. In particular, the design of the transverse target magnet will impact the possible acceptance and design of the recoil detector.

We claim to have identified the most viable solution for the RGH target (consolidated NH_3 and detector technology, recently realized or commercial magnets) that favor physics outcome over endless R&D.

Note we do not request to remove the approval condition on the target figure-of-merit. We take it as a metric of the complete experimental configuration and plan to clear it working with the lab management and the formal readiness review process.

Comments:

1.The original proposals with HD-Ice targets (e.g. C12-12-009) assumed a target polarization of 60% and a luminosity of 5*10^33. These assumptions lead to a figure-of-merit ratio of NH3/HD=0.56 and not 2.4 as quoted in this report.

As stated in the jeopardy document, we refer to the running parameters stipulated by the PAC for approval. Because the luminosity and polarization assumed in the proposal were unproven for a charged beam, the PAC set minimum beam and polarization lifetime conditions which they felt would provide acceptable physics results. These are our reference values since then.

2.The geometry of the recoil detector is not defined nor are its requirements in terms of acceptance in physical space and momentum space.

It should be noted the recoil detector is based on ongoing developments and does not pose particular technological challenges. The geometry of the recoil is defined plain by the magnet structure openings.

The central one (up to 30 degrees) is covered by the CLAS forward detector. The recoil detector is required to instrument just the solid angle opened by the left an right apertures (from 30 to 60 degrees horizontally, from 0.3 GeV/c up to 1.2 GeV/c in proton momentum), within the clearance of the LTCC volume. A stack of 3 planar micro-Rwell chambers and a scintillating fiber timing layer is assumed for each aperture. The area to cover is limited, of the order of 0.3 m^2 per layer, and comparable with the current prototypes of the CLAS12 high-lumi project.

Such a recoil detector has been implemented in the CLAS12 simulations and its performance accounted for in the presented projections.

3.What are the expected modes of operations for the target magnet and chicane magnets? Are these magnets expected to be operational all the time during beam operation to reach the beam dump or are there modes of operation envisioned where the magnets are off and a straight beamline is required?

We expect the magnets to be operational all the time during the run. The magnets could anyway be mounted on a movable platform in case of need (i.e. for initial tuning or extraordinary maintenance).

4. Beam tuning may be difficult because any beam loss into the superconducting magnets cooled by pulse tube refrigeration will cause a quench and the recovery time will be of order 24 hr. A dedicated beam loss detection system and beam dump system may be needed.

Our conceptual design for the superconducting magnet is based on a 5 T superconducting magnet recently procured in 2022 for upcoming polarized target experiments in Hall C (E12-14-006, E12-13-011, E12-15-005). That magnet is cryogen-free and uses a single pulse-tube cryocooler for refrigeration. Cooling from room temperature to 4 K requires 60 hours. A 2nd pulse-tube will be added to reduce this time. With a single pulse-tube, the **measured** recovery time following a quench is 4 hours. We expect similar performance for the proposed Hall B magnet. In any case we agree a dedicated beam loss detection system and beam dump system would be worth.

5. The transversely polarized target has been developed through a conceptual design phase, but a detailed design still must be developed and fully costed. Considerations of R&D and system testing must be developed and a realistic cost and schedule prepared.

a. A decision must be made on the target magnet orientation to advance background and shielding studies.
b. Shielding of local electronics and control systems from expected background rates about the Space Frame needs to be considered for different target magnet field directions.

It should be noted that the choosen configuration is based on variations of already realized targets (e.g. Hall-A G^2_p-G^e_p) and magnets (Hall-C E12-15-005). As a consequence cost and time estimates are under control and R&D is not necessary.

It is not customary to provide detailed, fully-costed designs of new equipment at the proposal stage. Based on previous experience, an estimate for the cost of the target system is \$0.7 – 1M and will be dominated by the cost of the new magnet. Procurement of the new Hall C magnet (\$0.4M) required approximately 2 years. Design, fabrication, and testing of the target refrigerator and ancillary equipment will require 3-4 years, dependent upon labor availability, and can be performed, in part, parallel to the magnet construction. The cost of each chicane magnet is $0.2-0.3M depending on the required modifications.

The baseline solution presented in the RGH jeopardy document is a vertical field orientation. Background studies have been performed for this orientation with an optimized beamline shield, leading to the presented luminosity estimate.

6. Commercial magnets for the beam chicane system are being considered. Work with the Hall B engineer must be advanced to lay out the planned RG-H beamline, including power and utilities.

The compatibility of the RGH chicane with the Hall-B beam line and the CLAS12 solenoid parking position has been verified. The detailed study of power and utilities belongs to the activity in preparation of the experiment readiness review.

7. The beam raster system is not discussed in the jeopardy document. Has its effects on beam transport and beam-related backgrounds been considered in detail?

The beam current is not limited by the target polarization lifetime, but by the background occupancies in the CLAS12 drift chambers. The beam raster employed for RGC is more than adequate and will be re-used. We have verified that the there are not adverse effect in beam transport (within the choosen magnet acceptance) and background (with the studied shield).

8. Does the target system have adequate cooling due to beam heating effects from synchrotron radiation generated in beam transport?

The heating from synchrotron radiation is typically negligible compared to the power deposited by the direct electron beam (about 100 mW) or from the microwaves used to dynamically polarized the target (300 mW). Similar target systems have operated in Hall C with beam currents up 100 nA.

9. With an advanced design of the beamline and target, detailed background simulations need to be advanced to understand luminosity limitations in the drift chambers and recoil detectors.

We have presented a worse-case scenario in which tracking in one sector is off and the other sectors run at the present CLAS12 capability. We are confident that with the high-lumi upgrade, dedicated DC readout and reconstruction algorithm updates, and further shielding optimization, the performance can only improve.

10. The leptons subject to deceleration in the target by emitting synchrotron radiation will be bent in the “horizontal” plane away from the nominal beamline and entering sector 4 of the CLAS12 spectrometer. Sectors 1 and 4 are equipped with PID Cherenkov

detectors and such high radiation from these electrons (“sheet of flame”) may be detrimental to them.

RICH can be moved and operated on sector 3.