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Hall B & D Drift Chamber Review

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Executive Summary:

We reviewed the plans for construction of the drift chambers for the Hall B upgrade (CLAS12) and for the drift chambers of the GlueX experiment in Hall D at Jefferson Laboratory. Both use well-established technologies with very low associated risk and predictable costs.

The Hall B preparations are in an advanced stage. The designs are based on operating experience from the existing CLAS experiment and are of sufficient quality to serve as a basis for a cost and schedule baseline.

The designs of the drift chambers for the GlueX spectrometer are less advanced but are also sufficient to establish a cost and schedule baseline.

Both collaborations presented designs that integrated safety considerations with the requirements of their scientific programs. Gas and electrical distribution systems include necessary and appropriate engineering controls for protection of personnel, the environment, and equipment during operation and maintenance.

We have a number of comments which we hope will be of value to the two collaborations. We only have two recommendations which we strongly feel should be acted upon, namely:

1. Priority should be given to studying design modifications that would significantly reduce the amount of material in the GlueX tracking chambers.

2. Additional resources and expertise should be applied to the development of track reconstruction software for GlueX, and to a complete and realistic hit-level simulation of the GlueX spectrometer.

The time between CD2 and CD3 reviews should be sufficient to complete all remaining studies and to prepare for construction.

Findings (Hall B)

The conceptual design of the Hall B drift chamber upgrade is well motivated by the group's summary of deep inelastic electron scattering physics.

The performance requirements for the drift chambers are derived from these physics requirements.

The design is a simplification (using planar instead of curved chambers) of the existing CLAS drift chamber system, which has performed well for many years.

Comments (Hall B)

We strongly support the Hall B group's plan to build full-scale prototype drift chambers as soon as possible. This will allow the group to reestablish and optimize their wire stringing procedure, to test new metal trumpets as well as integrated plastic feed-throughs, and to verify that the chambers can be operated at the design voltages. We urge the group to use the prototypes to explore cost-saving construction procedures and alternatives. We also urge the group to explore design modifications for the region 2 chambers that will maximize the active area near the CLAS beam line.

We believe that it will also be important to do detailed Monte Carlo simulations of the CLAS12 detector in the near future. These simulations should include estimates of the material in the silicon detectors and the high-threshold Cherenkov counter until detailed designs exist, and should include modifications of the detailed chamber geometry to include systematic variations of component and installation alignments. The detailed simulation will help the group understand how best to combine tracking information from the silicon strip detectors and the drift chambers. It will also impact the design of the wire chamber frames and enable studies of chamber misalignment and the effect of wire positioning errors on track reconstruction and resolutions. The latter will help verify the tolerances being specified for endplates, endplate defections, trumpets, etc. We recommend that the group also consider the possibility of installing helium bags between the drift chambers.

Findings (Hall D)

The GlueX group presented a design for a large-acceptance solenoid spectrometer with charged-particle tracking provided by a straw-tube cylindrical drift chamber and planar cathode-strip-readout drift chambers. This design provides uniform acceptance as a function of azimuthal angle, and coverage for large polar angles, including most of the relevant backward hemisphere. The effective coverage in the forward direction is limited by the lack of magnetic field transverse to the beam direction. Momentum and angular track resolutions are dominated by multiple scattering for essentially all of the phase space occupied by tracks of interest.

The group presented results of prototyping that has been done to date of the central and forward drift chambers. Significant progress has been made in the development of both systems.

The group has developed feed-through hardware for the central drift chamber (CDC) straws, and has demonstrated that the end connections can reliably be made leak tight and conductive. Plans for installation alignment and surveying were presented, and are consistent with procedures on existing experiments. Details of the assembly procedure and the alignment of components during construction of the chamber were not presented.

Full-sized prototypes of the forward drift chamber (FDC) cathode planes have been constructed, and demonstrate that the desired flatness can be achieved. Small prototypes of the FDCs have also been successfully tested.

The development of simulation and track reconstruction software is at an early state. The detector model includes complete and realistic material descriptions of both the CDC and FDC components, and a detailed magnetic field calculated using TOSCA. The effects of multiple scattering and energy loss in materials are included in the charged particle simulation. However, the simulation assumes 100% efficiency for hit production and track reconstruction.

Comments (Hall D)

In preparation for future reviews, the collaboration should better articulate how the performance requirements of the tracking detectors are derived from the goals of the experimental program.

The plan for chamber signal processing is conservative and is based on established designs.

The change from aluminized Mylar straws to aluminized Kapton straws is a significant improvement and will result in a more robust central drift chamber, as well as cost savings deriving from substantially higher fabrication yield.
Detailed specifications and requirements for alignment precision of the endplates (relative rotation and tilt, absolute tilt, and concentricity) should be developed and incorporated into the design. A detailed description of fabrication alignment methods (CMM, tooling holes, and reference marks) should be incorporated into the CDC design. Procedures to utilize these features in assembly should be developed.

Design and prototyping of CDC assembly fixtures should be undertaken, including mechanisms for setting, monitoring, and maintaining the relative and absolute alignments of the endplates to the required precision during straw installation.

Prototypes of the FDC chambers have been used to study performance of the cathode strips and anode wires. The prototypes have also being used to test the readout scheme. These studies are currently limited in rate because of the acceptance of the setup, which makes the process slower than necessary. Also, the tests are restricted to tracks perpendicular to the chambers. Actual tracks will cover a wide range of angles, and the magnetic field will vary in magnitude and direction across the chambers. It will be important to study these effects and to understand the reconstruction of tracks in all cases.

Technical and engineering support will be required for adequate design and development of mechanical components, assembly, electrical and electronic distribution, and gas plumbing systems. These issues must be integrated with the overall detector design in order to meet the physics goals of the experiment. The collaboration and Jefferson Laboratory should explore methods to obtain resources in these areas early in the design process, to facilitate such integration.

Tracking simulation should include realistic hit-level inefficiencies to determine the effect on fit results and resolutions. Realistic background estimates should be used to determine the effect of hit confusion on fit bias. The development of pattern recognition algorithms is important for realistic evaluation of tracking efficiencies, both without and with inclusion of event backgrounds.

Identification of small partial waves will be hampered by “leakage” from dominant channels via imperfections in the detector response. Examples of these imperfections are limited acceptance and hadronic interactions in the detector materials. The effects of limited particle acceptance on the partial-wave analysis have been taken into account extensively in the design of the detector. Particle interactions have not yet been included in the simulations.

We believe that the current design has too much material in the tracking volume. Reducing the amount of material would improve the momentum and angle resolution and reduce secondary interactions. This would facilitate pattern recognition and result in better isolation of exclusive final states, especially for non-dominant channels.

Relationships with tracking experts outside of the GlueX collaboration should be cultivated to help fill gaps in existing capabilities. There is strong overlap with CLAS in problems which need to be solved (B Field variations, pattern recognition, track finding and fitting); access to that expertise should be encouraged.

The original LASS solenoid magnetic field is well documented. However, the collaboration is modifying the solenoid and adding iron. TOSCA calculations will provide a good estimate of the resulting magnetic field, but it will be important to verify the calculations by direct measurements. This should be done at a sufficient number of points within the tracking volume to ensure that uncertainties in the magnetic field do not impact significantly on the detector momentum resolution. Probes to monitor the change in magnetic field before and after the detector is fully assembled should also be considered.

Recommendations (Hall D)

1. Priority should be given to studying design modifications that would significantly reduce the amount of material in the GlueX tracking chambers.

2. Additional resources and expertise should be applied to the development of track reconstruction software for GlueX, and to a complete and realistic hit-level simulation of the GlueX spectrometer.