Hall D Forward Drift Chambers Incremental Technical Review

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Executive Summary:

We reviewed plans for construction of the Hall D Forward Drift Chambers (FDC). The plans have advanced significantly since the March 2007 Drift Chamber Review. Significant work has been done in designing and prototyping the wire-cathode chambers and in simulating both wire-only and wire-cathode FDCs. The wire-cathode design appears to be superior to the wire-only design, although more studies can be done to finalize this determination. We are satisfied with the progress to date in design, prototyping, simulation and ES&H and have no specific comments or recommendations. Suggestions and concerns are described in the body of the report.

Direct Responses to the Charge:

1. *Are the technical performance requirements adequate, appropriate, and complete?*

Based upon the latest results of simulations, the Committee concludes that the performance requirements presented for the FDC system will provide the forward tracking function necessary to perform the Glue-X experiment. The proposed system is appropriate in that it completely meets but does not significantly exceed the Glue-X requirements.

2. *Do the current designs and plans appear likely to achieve the performance specifications with a low risk of cost increases, schedule delays, and performance problems?*

   Are there opportunities for improvements in cost or performance that the design team should consider?

Current plans and designs are very likely to achieve the stated specifications within cost and on schedule. Specific suggestions for improvements (such as continuation of the ongoing development effort and consideration of slightly modified design options) appear in the discussion below.

3. *Have ES&H considerations been adequately incorporated into the designs at their present stage?*

For this stage of the design, ES&H planning is quite complete. Nonflammable, environmentally benign gases have been chosen, for example. Hazards such as high-voltages have been identified and mitigation measures are planned.

Introduction:

We were impressed with the quality of the work presented and with the quality of the documentation and the presentation. The FDC Technical Design Report was clear, thorough, and very well written. The presentations were also clear and thorough.

The prototyping performed so far has addressed many of the important design questions. They have shown that wire-cathode chambers can be operated as horizontal drift chambers with good resolution and excellent track-point identification. They have started prototyping cathode manufacturing techniques. They have shown that the proposed composite frame is stiff enough and significantly reduces the mass of the frames. Suggestions for further prototyping are discussed later.

We were presented with the results of several different simulations: 1) a parametric Monte Carlo (track point resolution σ=150 μm, x/X_0=1.7%); 2) studies of the momentum resolution to be expected for a selection of reasonable detector design options (each with σ=200 μm point resolution but differing readout options, plane multiplicities, and geometric layouts); and 3) a simulation using a preliminary hit-based Monte Carlo, pattern recognition, and reconstruction software. Study #1 confirmed that the simulated system would not generate a false exotic (1^{-+}) signal in a sample of pure non-exotic (1^{++}) events, a typical fundamental requirement for Glue-X physics signals. Study #2 showed that σ_{Pt}/P_t is largely driven by the amount of material in the tracking system, as is the loss of photons due to conversions in the same material. The first two simulations assumed perfect hit assignments for track-finding, but did take detector acceptance into account. Simulation #3 was used to demonstrate the ability of the reconstruction software to disentangle detector signals and form space points, assign the points to tracks, and reconstruct the tracks. These results are very encouraging, and the preliminary conclusions are that tracks definitely can be recognized and reconstructed by each of two very different algorithms, and that the combinatoric background for track recognition with the cathode-wire-cathode detector design appears to be significantly lower than with the wire-only design (although the analysis package for the latter may benefit from some parameter optimization).

The Glue-X FDC team has incorporated design features which will lead to a reliable detector with minimum maintenance needs, and in which any required maintenance will be relatively straightforward. Both calculations and laboratory measurements have been used to determine the rigidity of the detector frames. This and the field-proven technique of using epoxy to hold the wire tension will minimize wire breakage and tension loss. High voltage circuits have been subdivided in an attempt to minimize the impact of any wires that do break after the detector is in operation. On-chamber electronic components will be on removable modules to simplify replacement in case of failures. A scheme for routing signal, power, and high voltage cables has already been outlined and a system ground scheme is under development. The early decision to avoid the use of any flammable gasses will simplify the design of the gas system and remove the need for expensive and high-maintenance leak detection systems. It is foreseen that any repairs to the FDC system will begin with the removal of the whole package from the solenoid, eliminating the need for extraordinary access procedures.

Wire-only vs. wire-cathode design considerations:

The cathode-wire-cathode readout scheme appears to us to be the most promising choice, even though it requires more material than the wire-only solution. The significantly improved ability to correctly assign multiple hit signals, especially taken in context with the improved geometric arrangement, appears to be well worth the relatively small loss of photon detection efficiency caused by the increased material. We encourage the collaboration to devote their primary effort to demonstrating the feasibility of this approach. In particular, the hit-based Monte Carlo and reconstruction software should be developed well enough to allow investigation of how reliably high multiplicity events can be reconstructed, given that several cathode strips will see signals from each of the tracks. Should it be found that this solution is incapable of providing the necessary performance for the physics goals of Glue-X, it will be straightforward to re-tool the existing detector design and simulations to use the alternative wire-only option. We note that the cost estimates indicate that the cathode-wire-cathode design would be slightly less expensive than the wire-only design, although the difference may not be significant.

Concerns:

Cathode frame construction costs: The plan to prototype the production method for the cathode planes should be completed, using a 'typical' production team, in order to provide a firm cost estimate, to be sure that the method works reliably, and to certify that it can be used for mass production

Software: The Glue-X FDC collaboration is making progress towards turning physics requirements into specifications for detector performance. However, so far the collaboration has continued to push on the wire-only and wire-with-cathodes technologies to see what is the ultimate performance that can be achieved, with the goal of 200 um resolution and minimum achievable material budget taken as targets. Parametric Monte Carlo studies, qualified by comparison with preliminary hit-based studies, are presently at the level of sophistication that physics signals can be searched for. This is a work in progress and is not yet complete. We feel that the collaborators know how to proceed with this study and we encourage them to continue. An extension of the parametric studies that generates non-gaussian tails in the residual distributions (to be expected in the case of mis-assigned hits, for example) may be illuminating. Should they find that the above-mentioned resolution and material budget targets are consistent with the physics goals, the parametric simulation efforts can be considered to be complete.

Resolution and Physics Goals: A better understanding of these effects will be gained from mature hit-based studies which will include even better optimized pattern-recognition and event reconstruction software. This study should include the effects of electronic noise and crosstalk, as well as physics backgrounds. This study could conclusively determine the relative merits of wire-only and wire-cathode designs. A successful demonstration that the proposed detector system and analysis software can extract the relevant physics signals would be a compelling component of the upcoming CD-3 review.

Magnetic Field Performance: However the detector is constructed, it will need to operate in a high magnetic field. The Lorentz forces acting on drifting electrons will displace and distribute the charges which initiate each avalanche, complicating the determination of the positions at which particles traversed the detector plane. In a drift cell this effect requires a field-dependent correction for the time-to-distance relation. For cathode-strip readout, an additional left-right ambiguity results and an increase in the best possible resolution may be introduced that cannot be mitigated by any correction applied during analysis. Minimizing the integrated Lorentz angle appears to be the only solution to this problem. The Committee applauds the research done to date and urges the collaborators to continue investigating gas mixtures and field configurations that minimize the uncertainty. Available software tools such as MAGBOLTZ and GARFIELD should be applied to this problem.

Prototyping with the Small Detector: The tests done with the small strip chamber prototype so far have used cathode strips placed at ±45° with respect to the anode wires. The prototype has since been re-built using strips placed at the angles defined in the CD-3 design (±75°). We feel that it is important that reconstruction and resolution studies using this new configuration be carried out as planned. We note that such studies will require a high-resolution external tracking system as the self-calibration techniques applied previously will not be as incisive for the smaller strip-to-strip stereo angle. An important part of this investigation will be the study of different gas mixtures with the prototype immersed in a magnetic field. Ideally, the external tracking system will reside within the same field volume in order to avoid multiple scattering of incident particles in the material of the magnet.

Electronic noise and neighboring-channel crosstalk will limit the resolution that can be achieved in any cathode-strip chamber. We urge the FDC collaborators to gain experience with their small prototype to solidify their understanding of these effects and appropriate mitigation techniques. Additionally, while the inclusion of isolating ground planes between the detection layers within a six-layer module may appear to be "best practice", the added material in these ground planes might actually degrade the overall system performance because of the increased multiple scattering and photon conversion probability. Crosstalk between neighboring cathode strip layers may not be an issue because the voltage swing on the strips is small (capacitive crosstalk should be minimal) and strips on the two planes will be oriented at different angles (reducing inductive coupling). We suggest that the collaborators use the small prototype as well as engineering calculations to quantify any inter-plane crosstalk resulting from omitting the ground planes.

Prototyping the full scale detector: Full scale prototyping is important to optimize the design and the construction techniques and to determine the time and resources needed for construction. The largest construction uncertainty is the effort needed to construct the cathode planes. However, everything possible should be prototyped to avoid potentially nasty surprises. The full-scale functioning prototype detector will particularly allow more precise determination of the resolution and investigation of any efficiency effects caused by the rounded edge of the active area.

Schedule: We are concerned about the potential loss of institutional memory and expertise between the end of the PED and the beginning of construction.