Charged Particle Tracking in CLAS12

Report of the CLAS internal review committee

L.B. Weinstein (chair), G.P.Gilfoyle, F.J. Klein

1 Introduction

The committee was charged with evaluating the design of the CLAS12 tracking system presented at the Hall B 12 GeV Upgrade Workshop held at JLab February 2-3, 2007. We also set some priorities in preparation for an external review of the tracking system scheduled for March 2-4 and the CD2 review later in the year. The committee wishes to express its appreciation for the amount of work that has been done so far, from design of drift chambers (DC), silicon vertex tracker (SVT) and possible micro mesh (Micromega) chambers. Cost estimates were not discussed nor evaluated at this point.

Simulations for these devices have begun though most results were based on overall parameterization in a fast Monte Carlo. The preliminary design is largely based on experience with the current CLAS detector systems, with most thoughts on improvements to overcome shortcoming in the current detector systems. We expect that many incremental improvements will occur over the next few months. However, we'd like to consider non-incremental improvements as well in preparation for CD2.

1. central tracker made of micro mesh and microstrip detectors.
2. large stereo angle superlayer.
3. more drift chambers or chambers with more than 2 superlayers.

2 Questions and concerns

2.1 Physics requirements and detector design

Despite several general statements the physics requirements for the tracking devices have to be clearly and consistently specified and described. Most important questions to be addressed:

- Why lower the minimum polar angle to 5°? Increased electromagnetic background is expected, which might not be accounted for in the drift chamber and forward SVT design. A detailed technical design (esp. concerning support material) and simulation is required for CD2. At 5° the detector coverage is merely 50% (assuming no additional shadow from an inner calorimeter).

- What are the resolution requirements for the forward and central tracker? Since the azimuth of the tagged particle is measured with respect to the direction of the virtual photon, small areas are swept out by a full circle in ϕ.

- Presentations on the workshop contained differing statements on resolution and acceptance. This has to converge for the upcoming DC review in March and CD2.

2.2 Vertex tracker design

The current detailed design for the central tracker is based on 4 double-layers of silicon microstrip detectors, oriented at stereo angles of $\pm 1.5°$ providing a very good resolution in (x, y) or ϕ, i.e. perpendicular to the beam line. However, the theta resolution is moderate. This can be greatly improved by replacing part of the MSD layers with Micromega layers oriented at 90°. Micromega additionally decreases the material (with about 1/3 of the density of silicon). However, it is unclear how these layers can be made sufficiently stiff to ensure stable construction. Detailed simulations, technical design, and prototyping have to be performed to find optimal solutions.

The current design spaces the forward MSD layers by 1 cm instead of 5 cm. In case of severe space limitations we recommend to investigate the effect of 2 instead of 3 double-layers. There is also a possibility of measuring track segments (tracklets) between the SVT layers. We need to investigate the effect of such a method on the overall tracking and if significant improvements can be made, then how we can optimized the SVT design. Additionally, combinations of Micromega and MSDs should be considered.

The question of background (luminosity limitations) is more severe for the forward SVT and has to be studied in more detail with respect to occupancy and background separation in track reconstruction. Optimal ways of matching between forward SVT and drift chambers have to be investigated in preparation for CD2.

The innermost layers of the central and possibly the forward vertex tracker have to be removable or the inner diameter increased to prevent interference between the SVT and a polarized target. The effect of different torus field setting and polarities and beam rastering on the performance of the forward SVT needs to be studied more deeply.

2.3 Drift chamber design

The drift chamber design accommodates the current system to higher luminosity requirements. Individual effects contributing to improved resolution for the chosen cell size have been calculated, though detailed simulations are recommended to show the feasibility. Stereo angles of $\pm 6°$ are chosen (based on current CLAS drift chambers). However, a $\pm 3°$ design together with a large stereo angle (60°) superlayer in one chamber seems to result in better resolution. Simulations of this effect are necessary to assess any possible benefits.

Other options to be considered: (i) chambers with 3 instead of 2 superlayers, (ii) superlayers with less than 6 layers of drift cells, (iii) additional chambers – this might, however, increase difficulties with positioning and alignment and ultimately cost. Simulations are again needed here and/or documentation of past studies.

One considered factor to reduce the costs is the reuse of Fastbus multi-hit TDCs (LCR 1877). This would be the only Fastbus component in the upgraded DAQ preventing a systematic pipeline readout mode for CLAS12. Enough spares would be available for the aging technology, but only if multiplexing will still be performed, i.e. reuse of ADBs and MUX boards. The ADBs should be at least refurbished to decrease the voltage dependent signal length, the DC voltage should be monitored by ADCs (not simply binary information). We consider this proposal one of the riskiest parts of the current design. We should consider alternatives to this plan in the event that the TDCs begin to fail.

2.4 Tracking considerations

The survey of all detector components has to be considered in great detail. Additionally, other procedures to measure the alignment should be in place. Compared to the current CLAS drift chambers, the common cell size per superlayer simplifies this effort.

The most important parameters to ensure a symmetrical electric field, and a more linear drift time to distance relation, are position and wire uniformity. Some procedures should be in place to estimate their uncertainties, despite the fact that these are less critical for the thicker wires (30μm instead of the current 20μm).

Another issue that prevents accurate tracking is the limited knowledge of the B-fields (torus and target magnets). Procedures should be in place for reliable measurement and mapping as well as monitoring, e.g. Hall probes mounted on chambers.

Finally, various aspects of satisfactory detector maintenance should be considered: HV and LV controls and monitoring, prevention of malfunctioning HV or readout electronics turning off large numbers of cells, check for gas mixtures including pressure and temperature, (cable swaps,)...

2.5 Simulations

Questions to be addressed:

1. What are the physics goals? Can we achieve them with the current design – or what has to be improved? This step requires considerable coordination with the user community.

2. Simulation and tracking should include SVT and DC.

3. Luminosity studies are needed to estimate background in SVT and DC.

4. We have to study acceptance and dead areas. What would be the advantage of having tracklets in the shadow of the torus coils? What is the effect of overlapping layers for the SVT?

3 Future Plans

We discuss in this section short and long term priorities related to the development of the tracking system for CLAS12.

3.1 Software

The highest priority in the short term is to prepare for the external review of the CLAS12 tracking scheduled for March 1-3. With that in mind we present the list below of projects that should be addressed in the next few weeks before that external review.

1. The latest geometry for CLAS12 should be verified for all components (beamline, Moeller shield, ...) and incorporated in the code MOMRES. This simulation program should be used to recalculate the resolutions in θ, ϕ, and momentum p for CLAS12. The occupancies in the drift chambers should also be recalculated along with calculations of the CLAS12 backgrounds from Moeller scattering and noise hits.

2. Using the results for updated resolutions from the previous item on this last, physics calculations using FASTMC should be redone to see if there are significant effects on the physics goals of the project. The sensitivity of these calculations to variations in the resolutions should also be explored by increasing the resolutions by 50% to observe effects on the physics requirements.

3. Using updated geometry, drift chamber occupancies, and background studies, the simulation GSIM12 should be run again, the events reconstructed with the package RECSIS12, and compared with the FASTMC results. This will build confidence that the current tracking system can meet the physics requirements and that FASTMC is accurate.

Once the goals above have been met, the next priority is to prepare for the CD2 review. The following projects should be performed in preparation for that review.

1. The silicon geometry for the central and forward parts of the Silicon Vertex Tracker (SVT) should be incorporated into the GEANT4 simulation package.

2. One the previous item in this list is complete, then the tracking group should update their estimates of occupancies and background in the drift chambers and pass those results onto the physics groups to update their simulations and investigate the impact on the physics requirements.

Beyond the CD2 review the CLAS12 tracking group should continue to incorporate more of the geometry of CLAS12 into the GEANT4 simulation. A subgroup within the tracking group should be formed to organize and coordinate the development of reconstruction software. One of the interesting, new technologies being considered for the SVT is the use of micromegas detectors. That technology should be pursued to determine if it can be a cost-effective alternative to the current SVT design.

3.2 Design and Construction

The CLAS12 project is still in the design and prototyping phase. There are many prototyping projects underway and Table 1 shows a list of those efforts. The Region 1 prototype

CLAS12 Component	Group
Region 1	JLab and ODU
Multiplexing boards	JLab
SVT assembly frame	JLab
Micromegas	Saclay
forward SVT assembly frame	JLab
DC wire feedthroughs	Idaho State

Table 1: CLAS12 tracking prototyping projects currently underway

will be an essential tool to evaluate many of the new features of the CLAS12 drift chambers (effect of sense wire size, higher fields, different feedthroughs, ...) and it should be given a high priority. Two areas that need more attention are the method for surveying the drift chambers, making the magnetic field map, and monitoring (*e.g.* installing Hall probes). Cost estimates for all these components need to be updated with the latest information from the different parts of the collaboration.