Hall D Tagger Magnet Engineering Design Review

Committee Report

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The scope of review presentations included the spectrometer requirements, magnet requirements, engineering requirements, design, schedule, installation and procurements plans of the Hall D Tagger Magnet system. The cost estimate for the major Tagger system devices was also presented and there are some reviewer comments added to the procurement plans section.

Tagger Magnet Design Review Close out Report

For the Hall D Tagger Magnet Engineering Design review, we were asked to address the following questions:

1. Are the magnetic, mechanical and electrical requirements for the tagger magnet adequately defined?

Findings/Comments

Spectrometer resolution requirements are well stated

Global field uniformity specification is ambiguous and potentially in error

Magnetic field specifications are incomplete

Magnetic, Mechanical and Electrical requirements are stated, but not justified…rational behind them is unclear

Recommendations

Conduct a full resolution error analysis

Use these results to improve the magnetic field specifications

Use improved magnetic field specifications to update mechanical requirements

Consider spectrometer calibration technique to verify performance

2. Is the reference design adequately defined at this point in time to address all requirements?

    Findings/Comments

        The design has addressed the requirements as stated

        The design seems to have adequately anticipated a variety of problems

    Recommendations

        Update as needed after completing the recommendations from Charge #1

3. Is the reference design adequately developed to justify completing the design in house or should the final design be sub-contracted to an external source?

    Findings/Comments

        The reference design is well advanced and adequately developed to justify completing the design in-house

    Recommendations

        Complete the design in-house

4. Is the procurement schedule and plan reasonable? Is it reasonable to assume that the complete package can be sub-contracted to one company? Should the procurements be broken up?

    Findings/Comments

        Plans for Design-Build as well as Build-to-Print were presented

        Procurement schedules and plans are reasonable

        Concurrent design and fabrication appear to be a way to gain float in the schedule and helps with resource leveling

        There are companies that have the capabilities to do the complete scope (design and build)

        Engineering resources for contract award and management appear low

    Recommendations

        The costs presented need to be updated to reflect the current market condition and design completeness

        Recommend multiple Build-to-Print procurements

5. Have ES&H considerations been adequately incorporated into the in-hall installation plans and the design at their present stage?

Findings/Comments

ES&H considerations have been adequately addressed to the design level at their present stage

Pressure safety for the vacuum chamber design has been thoroughly addressed by using ASME BPV

Installation plans at the current design level have been done with prudence regarding ES&H guidance

Recent addition of an experienced hall coordinator will greatly enhance the work planning and scheduling

Recommendations

Continue with the development of the procedures, lift plans, pertinent OSPs and TOSPs, etc.

Commentary on the Charge

1. Are the magnetic, mechanical and electrical requirements for the tagger magnet adequately defined?

Findings

- Bend requirement was stated to be 13.4° right-hand deflection for 12GeV electrons so as to put the electrons on the beam dump.
- Spectrometer resolution requirements was presented as 0.5%.
- Spectrometer resolution performance was presented as <0.1%. Calculations that led to that result were not described.
- Requirements were given for Magnet Type, Nominal magnetic field, Maximum magnetic field, Magnet Gap , Effective Length @1.5T, Distance to -x effective field boundary @1.5T, Uniformity from simulations not including machining tolerances, and Global uniformity (volume). Rational behind them was not presented other than for field integral ($B * L_{effective}$)
- Field uniformity was stated to be 0.03% over +/- 180mm on a slice 77mm inside the effective field boundary. Field characteristics elsewhere were not presented.
- Beam trajectory was stated to be 1cm inside the uniform field region. The definition of “uniform field” was not given.
- Physical constraints on the magnet design resulting from building shape/size and material handling were presented.
- Mechanical requirements were presented but not justified.
- Requirements for the coil were presented but not justified.
- Global field uniformity specification is ambiguous and potentially in error
- Magnetic field specifications are incomplete
- Magnetic, Mechanical and Electrical requirements are stated, but not justified…rational behind them is unclear

Comments

- Physical constraints on the magnet design (resulting from building shape/size and material handling were presented) seemed appropriate.
- The team appears to be using a “classical” design approach for the system in which specifications are individually pushed to near-perfection. A more cost effective approach uses tracking of real particles through the already-constructed spectrometer to calibrate it. The goal of the design process is then to ensure that the system is sufficiently good for that process to work. Cost savings are typically realized with this approach versus the “classical” one.
- It was not possible to connect the mechanical specifications for the magnet back to the spectrometer performance requirement.

- Similarly, the specifications for the coil looked ad hoc. There may be room for improvement.
- The requirement for Global Uniformity volume   was listed as 1%. This seemed to be in conflict with the desire to have a 0.5% spectrometer.
- The electrons reaching the detector will have transited both the entrance and exit fringe fields. The resolution cannot be quoted w/o analysis of the effects of those fields.
- Overall, it was not possible to trace any of the mechanical or electrical requirements back to the spectrometer resolution specification (or any other specification).

Recommendations

- Conduct a complete and detailed error analysis for the spectrometer resolution.
- Use these results to improve the magnetic field specifications of the dipole
- Use improved magnetic field specifications to update mechanical requirements
- Identify and utilize a set of criterion for the coil design.

2 Mechanical Design

When considering the overall mechanical design of the magnet core, coils and vacuum chamber, the design was thoroughly detailed and met the magnetic and mechanical requirements of the assembly at this stage in the design process. A thorough Finite Element Analysis, conducted in ANSYS, was presented for the pole plates and vacuum chamber as well as the vacuum chamber tie rods and associated basketry.

Core assembly analysis was conducted to predict the maximum deflection of the pole plate. This analysis was done considering all of the known forces including magnetic load, vacuum load and magnet weight. Core assembly analysis predicted the total pole plate deflection to be 0.004 inches. This prediction is less than the specification requirement of 0.006 inches and the manufacturing tolerance of 0.005 inches. This calculation was compared with similar analysis conducted by Glasgow University and deemed reasonable. Analysis was also conducted to appropriately size threaded holes in the core pieces and determine the length of screw engagement that would prevent thread stripping. It was found that the 1.125-7 screws used to secure the top plate to the upper pole plate (and similarly for the bottom) would require threaded inserts. The screws securing the vacuum chamber bracket to the plates will be preloaded to 6500 lbs and thread inserts are not required, but will be used as a conservative element. There is some optimization to be completed to confirm the need for eleven 1.25 inch grade 8 bolts that are used to supplement the compression of the O-ring and keep the upper pole plate from tipping during assembly.

Vacuum chamber analysis was conducted to quantify vacuum chamber and support-skeleton stresses, minimize the motion of the O-ring seal in contact with the poles and minimize the change in the opening width of the 11.2 meter thin window flange. Allowable stress values from the ASME B&PV code were used as the limiting stress for this design. O-ring motion was reduced to 0.008 inches by the addition of 0.5-13 UNC tie rods supporting the edge of the flange. The tie rods are a well anticipated addition that should save time during the commissioning phase of this project. Such a low O-ring deflection may allow a resizing of the O-ring from 0.375 inches to 0.250 inches. 'C-ribs' were used to limit the change in the opening width of the thin window flange to 0.069 inches. Vacuum plate deflections maxed out in their worst case to 0.096 inches. Both of these deflections were stated to meet the deflection requirements of the design. A lifting plan for the vacuum chamber, thin window analysis, coil attachments and weldment supports has not yet been developed at this stage of the design.

The coil design was comprehensive and consisted of a 12x7 bundle of 11 mm square tubing. The coils have been designed to run up to 366 amps at 200 volts producing a 1.8 T gap field, though the nominal operating conditions will be 220 amps at 105 volts producing a 1.5 T gap field. The coils will be cooled using 28 parallel circuits designed for 34 gpm with a net temperature rise of 8 C. All of these parameters meet the design requirements specified in the presentation. Though this design is adequate for this stage of the design process, further refinement may reduce costs associated with the coil procurement. Possible areas of improvement are implementing a two-in-hand coil winding technique and reworking the LCW-to-terminal end connections.

The specification for building the magnet core and coils is sufficiently detailed and contains various sections from other successful projects. Small improvements may be made to the specification and will be relayed to the design team in a private communication, as not to weary this report. The specifications for the vacuum chamber and the magnet support stands have not been completed at this stage of the design process.

3 Hall D Tagger Installation Schedule

With the addition of the new Hall D Work Coordinator to the staff of Hall D revisit the installation schedule. The following items should be addressed:

1. Break down of line items of the tasks for the installation

2. Prioritize tasks, Look for conflicts of the schedule with other tasks and resource allocation.
3. Compare Contract component delivery time to the schedule
4. Look at resource leveling for tasks occurring during the same time frame.
5. Interface with support groups, Alignment, Civil, Eng.
   Look for interferences within the project schedule with support groups.
6. Insure tasks are in order of installation by date as well as available resources.
7. Insure all Task Hazard Analysis, OSP's and TOSP's are in-place and reviewed.
8. Utilize Lab resources.

4 Tagger System Procurement Plans and Tagger Magnet cost

The Hall D staff presented two procurement strategies: the first was a Design-Build concept and the second a Build to Print plan. The Hall D staff also presented evidence of substantial design completion far beyond what would be required by a Design Build approach. The reviewers were impressed with the quality, thoroughness and completeness of the Tagger system mechanical design. We strongly recommend that the Hall D design staff continue and pursue a Build to Print strategy for Tagger system acquisition. This approach has little or no technical risk and will certainly achieve the Tagger system procurement at a lower cost to the project than a Design-Build approach especially at this advanced stage. The reviewers suggest that a review of the Tagger magnet performance specification together with the required Tagger spectrometer performance could result in an overall more cost effective Tagger magnet. (see comments to charge 1). At this stage the Hall D staff could use some magnetic expertise and someone familiar with the tagger spectrometer optics to quickly review the spectrometer requirements, magnetic performance and the realities of field quality due to the deformation of the "C" magnet yoke and consequent introduction of a ~ 3 % gradient in to the Tagger optics. The previous involvement of the Glasgow group with the Tagger design supplied this expertise but the relationship between Glasgow and Hall D seems to have practically ended leaving the Hall D staff without this valuable technical skill set. It does not seem productive to procure a magnet with 1 part in 1000 flatness or a local flatness of 1 part in 10,000 if there are gradients of almost 3 % coming from the yoke distortion and a required final resolution of ~ 1 %. A careful study of the resulting Tagger performance with these gradients will certainly lead to a more relaxed specification and possibly some cost savings and at the very least more qualified vendors.

We strongly recommend a Build to Print tagger acquisition after a thorough review of the Tagger magnet specification and requirements.

The Tagger magnet cost presented was not very detailed. It consisted of a single entry titled "Tagger Yoke" suggesting the perhaps over simplified question "Where's the coil?". The cost book entry was based on a very preliminary letter of interest inquiry conducted by the Glasgow group about five years ago. The letter of inquiry was based (this reviewer remembers) upon the previous two magnet tagger design. The reviewers strongly recommend that the present tagger design be carefully re-estimated with the hindsight gained from the recent 4 meter dipole procurement for the 12 GeV Upgrade. The unit costs derived from this recent procurement action and the overall size of the 4 meter dipole compared to the Tagger magnet makes this an especially valuable and accurate comparison. The reviewers feel that the Project will benefit from a Tagger magnet cost re-estimation at this stage to avoid any sticker shock while actually bidding. A review of the tagger magnet specifications, requirements and expected cost together will provide the management and Hall D staff with the confidence to proceed to procurement.

The reviewers feel that the costs of the other major Tagger system components are well documented for this stage of the project but that the Tagger magnet cost should be re-estimated taking into account the current Tagger Magnet design, possibly relaxed specifications following a review of required performance and the current economic reality of large similar scale magnets.