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STAR Project

TITLE

Forward Time Projection Chamber
Final Design Review
Committee Report

Introduction

A Final Design Review (FDR) of the STAR Forward Time Projection Chambers (FTPCs) was held on May 28-29, 1998. A committee, consisting of R. Brown, D. Jared, R. Wells and B. Edwards (chair) participated in this review which took place at the Max-Planck-Institute (MPI) for Physics in Munich, Germany.

The review covered design requirements, analyses, prototyping results, further test plans, hardware design, production tooling and methods, assembly techniques, transportation plans and overall schedule. An additional purpose of the review was to communicate RHIC/STAR's standards and requirements for drawing and analysis documentation, procedures, safety analysis documents and safety and operational readiness reviews. This was covered in a general discussion on the last day.

The review agenda, presentation materials and action items can be found in the FTPC FDR binder in the STAR Project Office. The action items are considered an appendix to this report.

Another FDR will be necessary to review the final plans for water, gas and laser calibration systems. Preliminary schematics were all that were available at the time of this review, making it impossible to do a final, detailed review.

Executive Summary

Technical progress to date has been impressive and no "show stoppers" or significant issues were discovered during the course of the review. The MPI Facilities and the people involved are a good match to the needs of the FTPC construction project. The management that Volker Eckardt provides the project is highly effective and the institutional commitment by MPI is high.

The committee agrees with the plan to build a "short ring" (1/5th the length of a production FTPC) to use in prototype evaluation and production testing of readout chambers.

It is the opinion of the committee that the probability of even one of the two FTPC's being ready for installation into STAR by the summer of 1999 is very low (<20%). However, the committee feels that it is highly likely (80% probability) that the two FTPCs will be ready by the summer of 2000.

There are a few issues that need attention by the FTPC group in the coming months if they are to be successful in producing a detector that will integrate well into STAR. These issues will be discussed in some detail in the body of this report, however a summary is presented here:

1) Integration issues:

- water hose, field cage HV and laser beam transport pipe routing
- increased communication with the SVT (B. Leonhardt), electronics integration (H. Matis) and the safety coordinator (B. Miller)
- 3-D solid modeling of FTPC and integration interfaces

2) Electrical isolation and noise issues:

- electrically isolate the utility lines (for detector grounding)
- no pump or rotating equipment "noise" allowed on detector south platform
- electrically isolate the FTPC from the TPC in mounting system

3) Develop common hardware and consistent plans with the SVT group

4) RHIC/STAR standards, requirements, reviews and documentation issues:

- a "necessary evil"
- no way to avoid, so figure out the best way to fit in (utilize lessons learned by TPC for example)

5) Complete a few remaining relevant analyses and tests to ensure success:

- water cooling, temperature of IC's (effects on IC performance?)
- eddy current induced forces
- seismic analysis (~0.25g in any direction)

Design Overview and Schedule/Budget

The design of the FTPC is proceeding well. The Mechanical and Electronic parts are well thought out, only minor issues remain. Currently the group is completing the detailed design, constructing prototypes and testing. Several items will need to be addressed as the design is completed:

- Purging of air from the aluminum high voltage tubes needs to be addressed.
- Cooling of the front-end electronics was deemed marginal. An analysis of cooling the electronics needs to be performed.
- The ground plane between the pads must have a low impedance path to ground.

The schedule has not been developed in detail at this time and the material presented was minimal. It was felt that one FTPC has a <20% chance of being ready for installation by 1999 and an 80% chance of being ready with both chambers by 2000. Clearly the schedule needs to be actively addressed if there is a strong desire to make the 1999 installation window.

The budget was not presented. This is an internal concern of Munich, but could have an impact on the schedule. This is not considered a problem because Munich has a history of delivering the system they agree to build with no outside funds.

Engineering Analysis

Results from computer aided analysis of the electrostatic field and mechanical structure of the FTPC were presented. The electrostatic analysis employed the MAFIA 3-D code. Results from modeling the field cage with concentric cylindrical (Aluminum tube ring-type) electrodes at either end showed that radial field uniformity of better than 1 part in 10000 was achieved over the drift region independent of exterior boundary conditions over the full radius of the field cage. Similarly, the axial field was less than 1.5 V/m at 20 kV operating potential in the drift region. No presentation was made of the affect of imperfect geometry or of errors in the bias voltages of the end electrodes on the path of drift electrons. What the analysis did show was that the compression of the field near the end electrodes was localized to the vicinity of the electrodes and did not extend into the drift region.

The mechanical analysis was performed using the ANSYS finite element code. One half of the aluminum supporting structure was modeled, which by symmetry accurately represents the complete structure. The model included all known loads from both external sources and the weight of the structure itself. The calculated peak stresses were 25.8 MPa (3740 psi) and are well within the allowable limits for common aluminum alloys. The deflected shape of the field cage exhibited an overall vertical "sag" of nearly 0.4 mm at the end of the FTPC toward the I.P. This displacement has two components. The larger part, approximately 0.25 mm, is the global sagging along the z-direction due to the asymmetric fixation which can be corrected by hardware and/or software. The other component, in the order of 0.15 mm, is the deviation of the diameter from the ideal circle in the vertical direction. While this presents no hazard to adjacent detectors, and from a global standpoint is negligible, according to the FTPC team this level of non-uniformity in the field cage and the concomitant distortion of the electric field may introduce a measurement error. The desired limit on distortion was stated to be 0.1 mm. However, the affect of this distortion on physics parameters was not presented.

In conjunction to computational analysis, high voltage testing of the ring electrode structure was performed to determine the breakdown voltage. The ring type structure was developed to address the voltage holding limitations of the conventional Kapton insulated copper strip electrodes. At the inner radius of the FTPC the electric field approaches 1400 V/cm. The ring electrodes fabricated from readily available aluminum tube and ceramic spokes successfully held voltage differences that equate to a 4 kV/cm uniform field. The absence of plastic insulating material between electrodes also argues for good long-term voltage holding since degradation of the insulating medium is not an issue.

In addition to the analysis already done, an analysis of eddy current induced forces (and the resulting stresses) should be completed. Further, because there is a seismic design requirement at RHIC, an additional 0.25g should be applied to the existing structural model in all directions and the resulting stresses checked.

Gas, Cooling and Calibration Subsystems

One-line schematics were presented for the Gas and Cooling Subsystems along with the general system requirements. Both of these systems will be designed and fabricated at CERN in the near future. No detailed schematics or component lists were available at the time of this review. The FTPC will use Argon/CO2 (50/50) mixture with a constant flow rate as low as 1 liter/min in a single pass configuration; there will be no re-circulation of gas. The gas pressure will be very close to the ambient atmospheric pressure. FTPC cooling will be provided by a “leak-less” water system mounted in a rack on the second level of the instrumentation platform. Total heat dissipation from both east and west FTPCs is not expected to exceed 600 W. A total combined water flow for both FTPC units will be of the order of 10 liters/minute.

The Laser Calibration system is a collaborative effort with UC Davis, MEPhI and presumably the main TPC. The design, as presented, incorporates 15 beamlets, segregated into three sets of 5, spaced evenly in azimuth. A single beam at east and west ends of the detector will be diverted from the main TPC’s calibration system and impinge on a single three-way splitter that sends the beam to three mirrors mounted at the outside edge of the FTPC end flange. The mirror passes the beam through a window in the radial edge of the end flange and strikes a series of 1 mm mirrors arranged to divert a portion of this beam into three paths parallel to the FTPC axis and two paths crossing at mid length. The use of these mirrors, supplied by MEPhI, and the concept in general has been successfully demonstrated in the main TPC.

While the general concept for the Laser Calibration system appears to be sound, many details need further development. As presently drawn, the beam diameter at the FTPC is specified to be 8 mm which is too large for the FTPC end flange opening, yet only one-half the 16 mm diameter of the beam supplied by the main TPC. The design of the FTPC end flange must be changed to accommodate the larger opening and it may be necessary to add an optical element between the TPC and FTPC to reduce the beam diameter. While space has been added to the main TPC splitter enclosure for a diverting mirror on the face of STAR Magnet’s outer end ring, no viable path from this point to the FTPC was defined. The route from outside the Magnet to the FTPC will require considerable thought and coordination with other subsystems within STAR. A companion problem to passing a beam from TPC to FTPC is keeping the beam aimed as the magnet expands due to temperature changes and settles due to floor movement. This may require an active steering element at the FTPC coupled to a beam position sensor and computer controlled feedback loop. This type of system is in development for the main TPC and may be applicable to the FTPC provided there is room from these elements within the FTPC envelope.

The arrangement of mirrors within the FTPC has some advantages over the implementation of this same technique in the main TPC. Firstly, the mirrors are screened electrically from the drift volume by the ring electrodes and thus do not require special shields. Secondly, there is an order of magnitude fewer elements to position and support; although, how the mirrors are aimed and mounted may have a large impact on their utility. Specifically, if the groups of 5 mirrors are to be pre-aligned to a common carrier before installation, the deflection of this support must be evaluated.

Design Detail, Production Methods, Assembly Tooling, and Plans

The design details and production methods for the construction of the two FTPCs were presented. The majority of what was presented was at the preliminary stage, but it was clear from the discussion and sketches that it was well thought out. The aluminum structure support frame is a cylindrical fabrication with exterior cord surfaces to support the pad readouts and FEE cards. It is a difficult fabrication due to its compact physical size and close tolerance requirements. Plans are to have this fabricated by an outside vendor from a local area shop. It is recommended that due to the complexity of the geometry and tolerance constraints, the detailed drawings should be completed and discussions with vendors begin so as to converge on an acceptable fabrication process.

The field cage design concept is quite mature and fabrication techniques for the series of ring electrode tubes are being developed at MPI. The assembly technique for pinning each of the rings to the ceramic support rods and the associated tooling required to control the assembly tolerance needs to be prototyped as soon as possible. This will prove whether the ring fabrication along with the assembly technique is viable.

The Pad Plane design concept, although mature, has not been prototyped completely to insure that the design and production methods are sound. Some initial prototyping using Bendflex pad material was shown to maintain the required radial curved geometry. Further prototyping of a completed Pad Plane is required to insure a viable technique. Wire bonding of the Pad Plane via Kapton cable is a technique that MPI has a great deal of experience with. It was demonstrated in their labs that their methods are sound and their technique well developed.

Installation Tooling and Plans

Plans for the installation of the FTPCs into the STAR Detector have not been completely developed to date. Open discussion with the committee with regard to installation issues, integration with neighboring subsystems, detector utilities, tooling, and rigging procedures took place. The committee believes there to be an 80% probability that the FTPCs will be ready for installation in an FY2000 shutdown. Since it's likely they will be installed after Baseline and AEE Detectors, it is recommended that the group closely coordinate their installation plans now with SVT, TPC, and Installation Groups to insure their successful installation into STAR.

Interface and Utilities

The outside interfaces and utilities needs are understood by the FTPC group. However, there is a need to clearly communicate these interfaces and utilities to STAR. A document should exist that clearly shows the interfaces and utilities. The document should contain:

- A listing of the utilities needed (gas, water, AC power, etc.) and the expected flow rates or quantities needed.
- A listing of the location of items (rack layouts, pumps, lasers, etc.).
- A listing of water pipes, gas lines and cables, including their sizes and routing.
- Details showing the electronic isolation of the pipes and the chamber.
- A description of the installation of the chamber at RHIC with a clear indication of the items STAR is to provide.

The STAR Integration Group (Howard Matis) should be the keeper of this updated information.

Shipping

The FTPC group is clearly aware of the need to protect the FTPC from shock and vibration during shipment but no details were presented.

Documentation & Safety Review Requirements

During the review, there was a broad discussion of documentation standards and requirements for STAR as well as discussion of the Safety & Operational Readiness Review process.

Among the documentation requirements, drawing format and title block standards were discussed with reference made to STAR Note 106. It was decided that the European DIN standard for drawings would be acceptable to STAR since ANSI standards are not the norm in Europe and there are many parallels between the two systems. The title block used by MPI appeared to have space available for the information required by STAR & RHIC which was not already present on their drawings. The missing items included (but was not limited to) STAR & RHIC drawing numbers, revision letter and STAR WBS number.

Other required documents that were discussed at the review were STAR Notes summarizing structural and thermal analyses, and rigging and operating procedures.

With the completion of this design review, the only remaining STAR design review will cover the final design of the water, laser & gas systems. This will likely occur in the winter or spring of 1999. The RHIC Experimental Safety Committee (ESC) will hold one or two safety reviews of the STAR FTPC as well. For these reviews, STAR Note(s) summarizing the structural & thermal analyses will be necessary; and a completed Safety Analysis Document (SAD) will also be helpful. When this process is completed, the ESC will wish to review the FTPC's rigging & operating procedures. Following this, there will be a BNL Operational Readiness Review (ORR) of the procedures and then a "walk-through," where the committee will view the hardware and have an opportunity to ask detailed questions. The documentation and review requirements were discussed so that the FTPC group would be aware of the significant effort involved.