Chapter 1

OVERVIEW AND STATUS OF THE STAR DETECTOR AT RHIC *

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Abstract Presented here is the current status of the STAR Detector. STAR is one of the four detectors being constructed at the RHIC collider facility. The STAR detector is scheduled to have its first engineering run with the RHIC beams about six months from the date of this conference. The STAR project is on schedule and expects to be complete on time.

Keywords: RHIC, quarks, gluons, hadrons, STAR, QGP

1. INTRODUCTION

The STAR (Solenoidal Tracker At RHIC) detector is one of the four detectors presently under construction at the RHIC (Relativistic Heavy Ion Collider) Facility. In this document the current status of all of the major subsystems of the STAR detector is presented. The baseline STAR detector systems are the Time Projection Chamber (TPC) and its readout electronics, the Central Trigger Barrel (CTB) and the associated trigger electronics, the Solenoid magnet, and the Data Acquisition System (DAQ). Also included in the STAR baseline systems are the Slow Control system, the Online computing system, and the offline event reconstruction and analysis software.

STAR also has a number of additional detectors in its future. These detectors include the Barrel Electromagnetic Calorimeter (BEMC), the Endcap Electromagnetic Calorimeter (EEMC), the Silicon Vertex Tracker (SVT), the Forward Time Projection Chambers (FTPCs), a Time of Flight System (TOF), and a Ring Imaging Cherenkov Detector (RICH).

In what follows I will give a brief overview of the various STAR detector subsystems and give the current status of each system.

2. THE TIME PROJECTION CHAMBER

The TPC is a large acceptance charged particle tracking detector. It has an inner radius of 50 cm, an outer radius of 200 cm, and extends 210 cm in each direction from the central cathode membrane. The acceptance of the TPC covers 2π in azimuth, and $|\eta| < 1$ in pseudorapidity for tracks that traverse to the outer radius of the device before reaching the anode planes at ± 210 cm. With decreasing momentum resolution the acceptance of the device extends out to $|\eta| < 2$. Tracks that traverse the entire radius of the TPC leave hits on up to 45 padrows. Using the energy loss in the gas (P-10) for the reconstructed charged particle tracks one can extract particle identification for pions and kaons out to transverse momenta (p_T) of about 600 MeV/c, and identify protons out to p_T of about 1.3 GeV/c.

The TPC was designed and constructed at Lawrence Berkeley National Lab (LBNL). It was tested with cosmic rays while still at LBNL in the Fall of 1997. In November of 1998 the TPC was flown out to Brookhaven National Lab (BNL) on a large (C5) military transport plane. The device was then setup in the STAR assembly building (AB). After installing and commissioning the TPC gas system and various temporary support systems (e.g. power supplies, cooling water, high voltage, cosmic ray trigger system, etc.) the TPC was again used to collect cosmic ray data. Only one sector of the TPC was outfitted with electronics at a time for this testing. By moving the electronics around, data was collected for three of the twelve sectors on each end of the TPC. By analyzing the residuals for the reconstructed tracks, a study was done to look for distortions in the drift of the ionization electrons in the TPC. Using information gathered through the analysis of the cosmic ray tracks a few shorts were located in the field cage and some tuning of the voltage potentials at the ends of the field cage was performed. Some additional testing that has taken place for the TPC includes:

- Anode, Cathode, and Ground planes have all passed integration tests.
- DC testing of the gating grids have been completed on all sectors.
- The automatic drift velocity control system has been tested.
- A proof of principal of the laser calibration system has been performed, generating "real" calibration data from the TPC.

3. TPC FRONT END ELECTRONICS

The Front End Electronics (FEE) for the TPC consist of what are known as FEE boards and Readout boards. There are 4,344 Front End Electronics (FEE) boards used for the TPC readout. The present status is that all of the FEE boards are in hand. More than 4,500 FEE boards have been produced and tested. The readout of the TPC is subdivided into twenty-four sectors. Twenty-two of the twenty-four sectors have all of their front end boards installed. There are a total of 144 readout boards required to read out the TPC. 160 of these readout boards have been produced and are currently being tested. Six pre-production prototype readout boards were used in the cosmic ray tests.

The FEE are powered by low voltage power supplies which reside on the three story platform that is attached to the South side of the STAR magnet. All of these low voltage supplies have been designed, procured, and installed. Approximately 80% of the cabling for the TPC has been installed.

4. STAR SOLENOID MAGNET

The STAR solenoid magnet has an inner diameter of 5.26 m, a length of 6.2 m, and a nominal operating field of 0.5 T. The construction of the STAR magnet has been completed. All of the power supplies (five in total) used to power the STAR magnet have been designed, procured, and installed. The water cooling system for the magnet, which supplies 1100 gpm of water to take away the 3.5 MW of heat generated when the magnet is in operation, has been installed and brought online.

The magnetic field for the STAR magnet was mapped in November of 1998. The mapping device that was used was borrowed from CERN. High precision, complete field maps were made at half field (0.25 T) and full field (0.5 T). The maps confirmed that the magnetic field uniformity that had been specified for the design of the magnet, necessary to constrain the azimuthal displacement of the drifting electrons throughout the volume of the TPC, had been achieved.

5. DATA ACQUISITION SYSTEM

The data acquisition system (DAQ) is the only electronic system for STAR that does not reside either directly on the detector itself, or on the three story platforms attached to either side of the detector. The DAQ system for the TPC consists of 144 "receiver" boards, one board for each of the 144 readout boards in the TPC FEE system. The data from the TPC, digitized and multiplexed, is carried from each readout board to

a receiver board through 144 optical fibers. Each of the receiver boards has three daughter or mezzanine boards attached to it. In the baseline configuration for STAR these 144 receiver boards reside in twelve VME crates in our DAQ room. Each of these twelve VME crates also contain "sector brokers" and networking hardware. Finally, there is an "event builder" which collects all of the data from the TPC crates, as well as data from the other STAR detectors, and builds the whole event.

The present status of the DAQ system is that 10 of the eventual 177 receiver boards are at BNL and being tested. Twenty out of the 530 mezzanine boards are in house at BNL. All of the receiver boards should be at BNL by May of this year. All twelve of the sector brokers have been procured and tested at BNL. The software for these devices has been developed and tested. The event builder, which utilizes a commercial CPU, has been procured. The alpha version of the software for the device has been written and is currently being tested. Events have been run through parts of the DAQ system and delivered to tape and to disk. The writing to disk is a placeholder for the eventual readout scheme that has the STAR DAQ writing out its events to what's known as a buffer box, which then passes the data to the RHIC computer facility via a dedicated optical fiber link.

6. TRIGGER

The baseline trigger system for STAR consists of the Central Trigger Barrel (CTB), and an electronics system that provides for multiple stage trigger decisions. The Central trigger barrel consists of 120 "trays" that attach to the outer field cage of the TPC. Each tray covers 6 degrees in azimuth and one unit of pseudorapidity (0 to +1 or 0 to -1). Inside of each tray are two scintillator slats, covering one half a unit of pseudorapidity, and their readout photomultiplier tubes.

The present status of this system is that all of the trays have been produced. Tray installation has begun onto the TPC, and will be completed in February. The software interface between the trigger and the STAR online computing system has been defined and is being tested. A production prototype of the "Trigger control unit" (a component of the trigger electronics) has been produced and tested. A prototype Data Storage and Manipulation board (another piece of the electronics) has also been built and tested. Work is ongoing on the design of electronics which will enable the anode wires on the TPC readout to be readout and used in the trigger. This will extend the pseudorapidity coverage of the trigger detectors to four units ($|\eta| < 2$).

7. ONLINE SOFTWARE

The online computing system for STAR ties together the DAQ, trigger, and slow controls systems and provides the user interface for STAR run control. The requirements for this system have been written and have passed their review within STAR. A resource loaded schedule for the online system is complete. The essential architecture for the system has been defined, and the interfaces to the trigger and slow controls systems have been worked out. The interface to the DAQ system is in progress. A prototype of the online system will be ready for testing with the DAQ and trigger systems soon.

8. OFFLINE SOFTWARE AND EVENT RECONSTRUCTION

All areas of the STAR software effort are accelerating rapidly. STAF executables and KUIP macros for TPC analysis have been developed, documented, and made available to users within the collaboration. The software that processes the raw TPC pixel data has been significantly improved (more than an order of magnitude in speed). This includes the raw data reformater, the TPC cluster finder, and the space point reconstruction software.

Software packages exist and are being tuned for fast TPC space point simulation as well as slow TPC raw pixel (raw data) simulation, for tracking, for extracting energy loss for the tracks (dE/dx), and for evaluation of the Monte Carlo data. The data structure definitions for the software have been drafted and are being iterated and refined.

Silicon drift detectors of the same design as will be used in the STAR Silicon Vertex Tracker were used in a heavy ion experiment at the AGS (E896). The data that was collected is being analyzed using STAR SVT software. The data that has been collected during electronics system tests, and cosmic ray and laser calibration tests of the TPC is being analyzed and provides the valuable ability to run the developing software on real data well before the STAR detector sees its first beam-beam collisions at RHIC. There has been one Mock Data Challenge, which is an effort to exercise the detector software and RHIC computing center hardware on simulated data, completed. It proved to be a very useful exercise, pointing out the areas that needed more effort. A second Mock Data challenge is planned for March.

9. ADDITIONAL STAR DETECTORS

The strength of a collaboration and a detector effort can be seen not only by its current status, but also by its plans and prospects for the future.

The Silicon Vertex Tracker, a high precision charged particle tracking device that resides between the beam pipe and the inner radius of the TPC, is funded and well along in its construction. Approximately half of the total number of silicon drift detector wafers necessary for the complete SVT have been produced. The integrated circuit that contains the preamplifier and shaping amplifier (PASA) for the SVT have completed the design stage and are in production. The switched capacitor array (SCA) chip has also been designed and is in production. The Hybrid board that holds the various FEE chips has been designed and is in production, and final prototypes for the Readout components (similar to TPC readout boards) have been produced. Mechanically, the Beryllium support structures that hold the Silicon Drift Detectors (SDD) have been machined, and our French collaborators have delivered the support cone, that holds the SVT in place at the center of STAR, to BNL. The present schedule calls for the SVT to be installed during the summer shutdown of 2000. A fifteen layer array of STAR SDDs was used in E896 at the AGS. Please see the contribution to these proceedings from Rene Bellweid for more details.

The design of the Barrel Electromagnetic Calorimeter (BEMC) for STAR is essentially complete and funding for the construction of the detector has started. A full scale prototype of one of the 120 modules that comprise the BEMC was built and successfully tested this Fall in a test beam at the AGS. The schedule calls for somewhere between 6 to 12 of the BEMC modules to be produced and installed into the STAR detector this summer, so that they are available for use in the first physics run, which starts in November. The remainder of the BEMC modules will be produced and installed over the next three years. Please see the contribution to these proceeding from Gary Westfall for more details about this device.

The Forward Time Projection Chambers (FTPCs) have completed the design stage and are well along in their production. The FTPCs will provide the STAR detector with tracking for the pseudorapidity range of 2.4 to 4.0 on each side of the interaction. The schedule calls for the FTPCs to be installed during the summer 2000 shutdown.

A French group has recently joined the STAR collaboration and are building a layer of silicon strip detectors that will reside in the region between the outer radius of the SVT and the inner radius of the TPC.

This device will enhance the ability to reconstruct short lived particles which decay before they reach the TPC.

There is a funded effort by the STAR collaborators at Frankfurt Germany to supply hardware (primarily CPUs), and software manpower to advance the third level trigger for STAR. The primary feature of this third level trigger is that it quickly reconstructs the tracks in the TPC and allows one to use the tracking information in trigger decisions before the data is written out for archival storage.

There is an approved proposal to install an existing RICH detector into STAR from a group comprised primarily of STAR collaborators from Yale University, CERN personnel, and personnel from Bari(Italy). This device will significantly extend the STAR particle identification information as a function of p_T for a limited solid angle. The schedule calls for this device to be installed this summer. Please see the contribution to these proceedings from Gerd Kunde for more details about this device.

There is a proposal that has been submitted to the NSF, led by a recent addition to the STAR collaboration from Indiana University, to procure funding to build an Endcap Electromagnetic Calorimeter for STAR. The addition of this device will extend the pseudorapidity coverage for electromagnetic calorimetry in STAR from the $+1$ that we achieve with the BEMC to -1 to 2 . The addition of this detector will significantly extend the ability of the STAR detector to measure both the polarized gluon distributions in pp running and the perhaps modified gluon distribution in nucleons bound in nuclei. The proposed schedule for the EEMC has it being installed into STAR in the summer 2002 shutdown.

Finally, there is a proposal to add a patch of Time of Flight (TOF) coverage to STAR, and an effort to put together a proposal to add Photon Multiplicity Detectors (PMDs) to measure very forward electromagnetic energy.

10. SUMMARY

The facility work for the STAR detector is largely finished, with the remaining work on schedule. The magnet is finished and mapped. Some further power supply tests are planned for this March. The TPC structure is finished and has been well tested outside of the STAR magnet. Cosmic ray data is being analyzed, and approximately 90% of the FEE has been installed. The TPC was installed into the magnet in early December and the final electronics installation and cabling is expected to be complete by mid-March. The water and gas hookups are progressing

and should also be completed in March. The DAQ system is in production. A portion of the complete system is up and running and all hardware is scheduled to be on site by May. The trigger electronics is in preproduction testing. The CTB trays are complete and will be fully installed by late February. The STAR software is up and running. MDC2 is the next milestone for the software effort, and then the final polish of the system and the code will take place in preparation for data taking in June. We are actively into planning and working on the upcoming transition in the STAR effort from the construction phase to operations.

The STAR project has every expectation of being ready to take data when the first collisions take place at RHIC this Spring, starting an exciting new era in Heavy Ion physics.