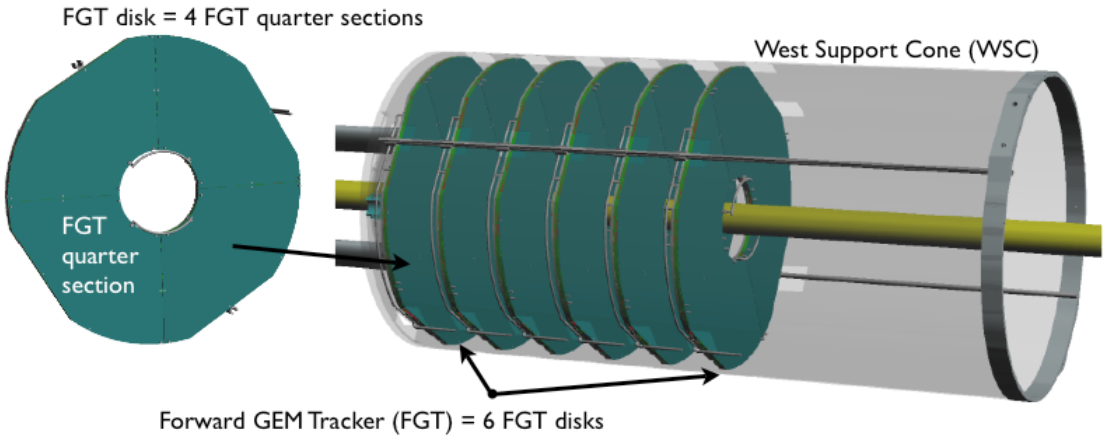
Project Name: STAR-FGT Date: January, 2009
Federal Project Director:
Contract Project Manager: Bernd Surrow, MIT

Reminder of some nomenclature:



The above sketch is taken from the FGT implementation into SolidWorks design and is meant to clarify the basic FGT nomenclature.

Narrative of project highlights:

Milestone: WBS1.1.1.1
Description
Quarter section design complete
Projected completion date: FY08 4th Quarter

Comments: All aspects of the quarter section design are completed. The final layout requires fixing the outer radius of the WSC, which is expected to occur by summer 2009 as part of the STAR integration effort. More details on the quarter section design are provided below in the section on 'Triple-GEM detectors'. The WSC design status is discussed in the section on 'Integration.'

Milestone: WBS1.1.1.7
Description:
Full-size GEM foils tested and meet specifications
Projected completion date: FY09 1st Quarter

Comments: Tech-Etch Inc. has delivered at the end of the FY09 1st Quarter eight full-sized GEM foils according to our design of a full FGT quarter section. Simple quality assurance tests (HV and optical inspection of some regions) were performed by Tech-Etch. We will perform HV tests and measure inner and outer hole diameters (related to

gain uniformity) on a large number of GEM holes. This should be done by the end of February. All necessary equipment is in place to perform those tests profiting from the R&D work that has been done on small GEM foil samples that were successfully tested as part of three triple-GEM detectors in a test-beam experiment at FNAL.

Brief summary of project status, issues, concerns, successes:

The following summary is separated according to the main WBS categories:

1 Triple-GEM detectors:

The design for the Forward GEM Tracking Detector (FGT) is essentially finished. The detector will consist of six disks at Z = 70-120cm inside a new West Support Cylinder (WSC). Each disk will be made of four quadrants of triple GEM detectors mounted to a NOMEX support plate. The active area of each detector will cover approximately R = 11.5-38cm. The final dimensions will be finalized once the WSC dimensions are fixed.

In order to study the proposed design we are producing a 'full-size' prototype based on our best estimate for the final dimensions. This prototype will use large GEM foils delivered by Tech-Etch. The frames for the full-size prototype have been produced and delivered. The gluing and assembly fixtures have been designed and are in production. Initial tests will be performed with plain Kapton foils to verify that flatness is maintained on the assembled foils. These tests should be completed by the end of February after which the assembly of a real full-size prototype could begin.

In order to produce a 2D-readout layer the charge-sharing between the top and bottom layers of a laser etched 2D readout board must be thoroughly understood. To accomplish this, a charge-sharing test board with sixteen combinations of line width and pitch for the top layer has been produced. This will be assembled into one of the 10X10cm^2 prototype triple GEM detectors already produced and tested using a ^{55}Fe radioactive source. This will also test the front-end electronics APV module which is in production. With the results from this test we can design and order the 2D-readout layer for the full-size prototype.

2 Front-End Electronics:

All APV25 readout chips on 8 large wafers including a significant number of spares have been purchased and are now located inside the silicon clean room at the Laboratory for Nuclear Science at MIT. The chips will be diced around summer 2009. Contacts to a company have been made.

A unified front-end board, APV module, has been designed and is in production. This APV module has 5 APV25-S1 readout chips, which can read out 640 channels and can be plugged into the actual FGT quarter section using standard (SAMTEC MEC6) edge connectors. In an effort to reduce the overall cost, the preference was to use industrial printed circuit board techniques (FR4). However, the small bonding-pad pitch of the

readout chip and the minimum trace width on FR4 (2mil/2mil) made it necessary to go to a multi-level board design. All passive components were moved into depressions on the backside of the board in order to avoid soldering contamination of the bonding pads on the front side of the board. The board design can be considered challenging, but does not seem to pose any fabrication problems.

The APV module will be used for both the FGT prototypes and a charge sharing test board. The charge sharing board has already been produced and is awaiting arrival of the finished APV module boards. The read-out system of the APV modules is realized using existing electronics, which was designed for the FGT test beam experiment at FNAL.

The APV module is the prototype of the final front-end board of which two will be used on each FGT quarter section. The design and production of the final FGT front-end module will start, once the functionality tests of the APV module have been completed. This is expected to happen before or during the summer of 2009.

3 Data-Acquisition System:

The scope of FGT "DAQ" portion includes all off-detector electronics in the readout chain as well as the power-supplies for the detector and on-detector electronics and the cables connecting these elements. In addition, elements of software design required to support the testing and integration of this hardware, though not to duplicate or preclude the efforts of FGT Slow Controls group or STAR DAQ group. A modular, crate-based architecture for the FGT DAQ has been described in the proposal, and has been developed in more detail over the past half year. Preliminary indications from measurements of an APV chip analog output driving a 62 foot twisted pair cable are that we can locate ADC's and all readout electronics on the platform instead of on the STAR magnet structure. We are presently working to confirm this by developing a complete test setup that will fully power, control, and read APV chips over a single long cable. With only platform-mounted electronics, operational considerations at STAR become significantly simpler, magnetics-based power supplies are feasible, and potential cost savings may be realized. Discussions have been started with one possible vendor, Wiener, for the crate and power supplies to base this readout system on. They offer a semi-custom crate from their standard components that will integrate 3 eight-channel ISEG HV modules and two 7-slot 6Ux220mm card cages with "VME" backplane, in a single rack-mount package with integrated power supply and Ethernet controls. With this and two custom modules, the ARM (APV Readout Module, to be developed at IUCF) and the ARC (APV Readout Controller, to be developed at ANL), and the standard CERN DDL link hardware and a linux PC, the DAQ hardware is completed. These modules will communicate via a custom protocol on the standard VME backplane hardware – a custom backplane in such small quantities would be expensive. The other major item is the cable, which is critical for all the usual integration reasons but additionally here for the high demands we place on its signal quality and on low mass of the inner cabling near the detector. We expect a solution involving off-the-shelf copper cables to the inner diameter of the TPC, transitioning to custom copper-plated or copper-

clad aluminum cables for the final 1.5 m to the detector, and have initiated discussions with vendors for the latter. On the firmware/software side, we have been prototyping the required controls interfaces with the DDL data link and the APV chips (I^2C).
Items that we expect to address within the coming ½ year include, principally:

- Complete the test board set to fully operate APV's on a long cable, determine tolerable cable length. Make final go/no-go decision for platform mounted readout electronics.
- Enter into final agreement with STAR operations on FGT rack location (tentatively 3A9 to be installed) and cable routing.
- Evaluate ISEG HV module, and investigate alternatives. Procure crate and HV modules.
- Complete the evaluation of copper-plated versus (thicker) copper-clad aluminum cable; procure custom cable for inner region.
- Complete the requirements and interface document for the ARC module and the definition of the crate backplane signals and protocol. We plan a meeting at ANL dedicated to this issue.
- Begin selection of final line receiver, ADC, and isolated power supply components for the ARM module (IUCF).
- Preliminary design of ARC module and definition of slow controls interface scheme.

4 Integration:

During the last STAR integration meeting at MIT in December 2008, it was shown and agreed that the field on the proposed West Support Cylinder could be kept safely below the 4kV/cm limit with an outer radius up to 40.63cm provided a 4cm radii on the flat and at the east end of the WSC and biasing to 3kV was incorporated into the design. However, this larger diameter for the WSC may be in conflict with the mounting flange and the insertion tooling. The insertion tooling is used to install the entire inner detector so this should not be changed. Similarly it would be easier to use the existing mounting flange. These last issues are being studied and a decision on the WSC outer diameter is expected within two months. Once the final dimensions are fixed the detailed design can proceed. A carbon fiber structure is envisaged minimizing the material wherever possible to reduce multi-scattering in the tracking region. The detailed design phase is expected to take approximately 6 months. The dimensions of the WSC of course dictate the maximum outer radii for the FGT disks so the final design for the FGT is also waiting on this decision.

The heat load of the FGT is not large (~180W inside the WSC). A design for flowing ambient air through the WSC has been proposed and a realistic, full-size model of the WSC and FGT disks simulating the heating of the front-end electronics is being built to determine the air-flow required.

Similarly the SSD cooling problem must be solved. The proposed FGT cooling scheme would allow the SSD to be cooled using air from the west end, between the TPC inner field cage (IFC) and WSC, and exhausted out the east end. This of course must be approved by the SSD group.

To minimize material in the tracking region copper-clad aluminum cables are being tested for the FGT control and signal cables. In addition to the FGT cables, gas lines, and other services; the SSD detector also needs to route cables through the inside of the WSC. At present the number and size of these cables is not fixed but is being studied. Providing space for SSD cabling and services and solving the SSD cooling must be done before the design of the FGT can be finalized. The full-size model being build for the thermal studies can also be used to study how to route the SSD and FGT cables.

5 Infrastructure:

The design of a slow-control system for the FGT has been started based on the existing type that the STAR experiment is already using. The cooling system design is the focus of a full thermal model, which has to be finalized in connection with the cooling needs of the STAR SSD detector system as part of the STAR HFT project. The gas system is rather simple for the FGT and the current plan is to have an independent implementation and not use the existing FTPC gas system, since this system might be re-installed at a later stage as part of a dedicated low-energy running request.

Summary of total expenditures:

WBS	Item	Baseline Total Cost (AY$)	Costed & Committed (AY$)	Estimate To Complete (AY$)	Estimated Total Cost (AY$)	Baseline Contingency (AY$)	Remaining Contingency (AY$)
1.1.1	Design and Prototyping	167.4	28.4	139.0	167.4	33.4	33.4
1.1.2	Procurement	270.1	-	270.1	270.1	56.7	56.7
1.1.4	Tooling	2.0	-	2.0	2.0	0.4	0.4
1.1.5	Machining	4.1	-	4.1	4.1	0.8	0.8
1.1.6	Assembly	19.3	-	19.3	19.3	3.9	3.9
1.1 Total	**Triple-GEM Detector**	**462.9**	**28.4**	**434.5**	**462.9**	**95.2**	**95.2**
1.2.1	Design and Prototyping	90.4	24.8	65.6	90.5	18.1	18.1

1.2.2	Procurement	134.2	45.2	84.2	129.4	36.8	41.6
1.2.4	Assembly	62.8	-	62.8	62.8	12.5	12.5
1.2.5	Testing	62.8	-	62.8	62.8	12.6	12.6
1.2 Total	**Front-End Electronics**	**350.2**	**70.0**	**275.4**	**345.4**	**80.0**	**84.8**
1.3	**Data Acquisition**	**299.3**	**-**	**299.3**	**299.3**	**60.3**	**60.3**
1.4	**Infrastructure**	**81.7**	**-**	**81.7**	**81.7**	**20.3**	**20.3**
1.5	**Integration**	**297.2**	**-**	**297.2**	**297.2**	**155.5**	**155.5**
1.6	**Software**	**0**	**-**	**0**	**0**	**0**	**0**
1.7	**BNL overhead**	**119.0**	**119.0**	**0**	**119.0**	**0**	**0**
1.8	**Non-DOE contribution**	**(193.9)**	**-**	**(193.9)**	**(193.9)**		
Totals:		**1,416.4**	**217.4**	**1,194.2**	**1,411.6**	**411.3**	**416.1**

Summary of expenditures by FY:

	FY 2008	FY 2009	FY 2010
a) Funds allocated	$167 k		
b) Costs accrued	$50.9 k		
c) Uncosted commitments	$47.4 k		
d) Uncommitted funds (d=a-b-c)	$68.7 k		
e) Remaining total contingency			

Summary of schedule:

	Baseline Start Date mo/year	Baseline Completion Date mo/year	Forecast Start Date mo/year	Forecast Completion mo/year	% Complete Baseline	% Complete Actual
Design						
1.1.1 Triple-GEM	5/08	3/09	8/08	3/09	100%	80%
1.2.1 FEE	9/08	4/09	9/08	4/09	100%	100%
1.3.1 DAQ	10/08	7/09	10/08	7/09	0%	0%
1.4.1.1 Gas syst	7/08	4/09	2/09	4/09	0%	0%
1.4.2.1 Air flow	7/08	4/09	7/08	4/09	0%	0%
1.4.3.1 Slow contr	7/09	10/09	7/09	10/09	0%	0%

1.5.1 WSC	10/08	5/09	10/08	5/09	0%	0%
Procurement						
1.1.2 Triple-GEM	1/09	7/09	1/09	7/09	0%	0%
1.2.2 FEE	9/08	5/09	11/08	5/09	35%	35%
1.3.2 DAQ	5/08	10/09	?/09	10/09	0%	0%
1.4.1.2 Gas syst	9/09	11/09	9/09	11/09	0%	0%
1.4.2.2 Air flow	9/09	11/09	9/09	11/09	0%	0%
1.4.3.2 Slow contr	4/10	6/10	4/10	6/10	0%	0%
1.5.2 WSC	5/09	8/09	5/09	8/09	0%	0%
Component test						
1.1.3 Triple-GEM	2/09	7/09	2/09	7/09	0%	0%
1.2.3.1 FEE chips	10/08	12/08	5/09	8/09	0%	0%
Fabrication						
1.1.5 Triple-GEM	4/09	5/09	4/09	5/09	0%	0%
Assembly						
1.1.6 Triple-GEM	5/09	8/09	5/09	8/09	0%	0%
1.2.4 FEE	5/09	8/09	5/09	8/09	0%	0%
1.3.3 DAQ	2/09	10/09	2/09	10/09	0%	0%
1.4.1.3 Gas syst	2/10	3/10	2/10	3/10	0%	0%
1.4.2.3 Air flow	2/10	3/10	2/10	3/10	0%	0%
1.4.3.3 Slow contr	8/10	9/10	8/10	9/10	0%	0%
1.5.3 WSC	8/09	12/09	8/09	12/09	0%	0%
Testing						
1.1.7 Triple-GEM	6/09	9/09	6/09	9/09	0%	0%
1.2.5 FEE	5/09	9/09	5/09	9/09	0%	0%
1.3.4 DAQ	4/09	12/09	4/09	12/09	0%	0%
1.5.4 WSC	11/09	1/10	11/09	1/10	0%	0%
1.5.7 System	7/10	8/10	7/10	8/10	0%	0%

Summary of control milestones:

WBS Number	Control Milestone Name	Baseline Date	Actual/ Forecast Date
WBS 1.1.1.1	Quarter section design complete	Q4 FY08	Q1 FY09
WBS 1.1.1.4	2D readout board design complete	Q2 FY09	Q2 FY09
WBS 1.1.1.7	Full-size GEM foils tested and meet specifications	Q1 FY09	Q2 FY09
WBS 1.1.1.9	Successful full quarter section test	Q2 FY09	Q2 FY09
WBS 1.1.2.1	All GEM foils delivered by TechEtch that meet specification	Q3 FY09	Q3 FY09
WBS 1.1.6	All detector frames assembled and tested	Q1 FY10	Q1 FY10
WBS 1.2.1	Successful testing of first prototype of front-end electronic readout board	Q3 FY09	Q3 FY09

WBS 1.2.5	All FEE readout boards assembled and tested	Q1 FY10	Q1 FY10
WBS 1.3.1.2	DAQ readout board prototype complete	Q4 FY09	Q4 FY09
WBS 1.3.2.3	DAQ crate master board design complete	Q2 FY09	Q2 FY09
WBS 1.3.4.4	Successful DAQ readout test	Q1 FY10	Q1 FY10
WBS 1. 4.1.1	STAR airflow design and prototype complete	Q3 FY09	Q3 FY09
WBS 1.4.2.4	STAR airflow system installed	Q3 FY10	Q3 FY10
WBS 1.4.3.4	Slow controls installed	Q1 FY10	Q1 FY10
WBS 1.5.1	Design of West Support Cone complete	Q3 FY09	Q3 FY09
WBS 1.5.3	Assembly of West Support Cone complete	Q1 FY10	Q1 FY10
WBS 1.5.7	System test	Q4 FY10	Q4 FY10