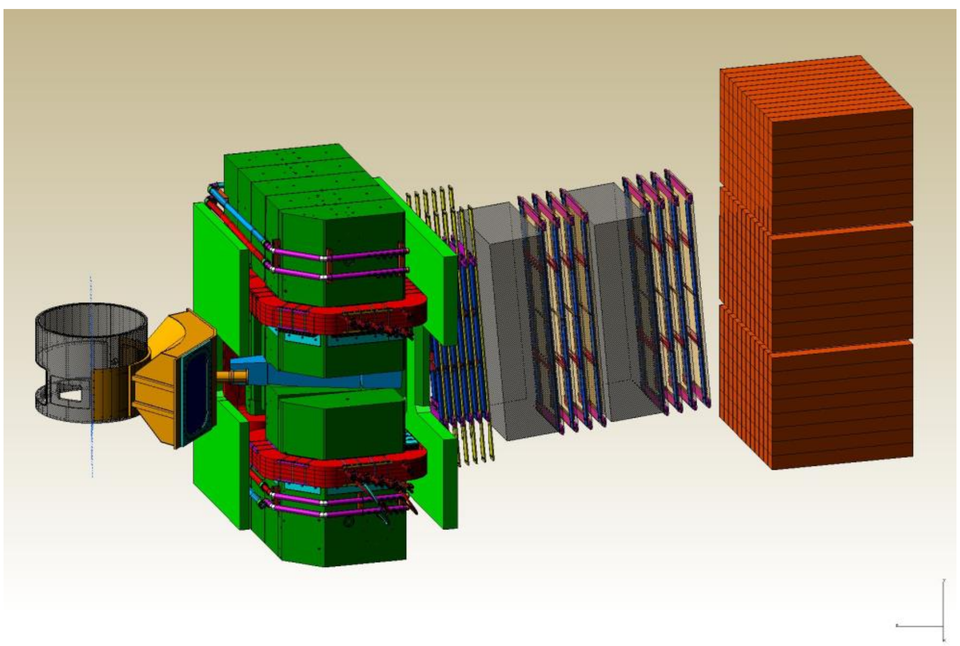
Super-Bigbite-Spectrometer (SBS)

Monthly Progress Report

May 15, 2015



Introduction:

The SBS Program consists of three separate, but interrelated Projects.

- The first Project, **SBS Basic (WBS 1)**, involves the acquisition of an existing magnet and the associated work of preparing it for use during the SBS research program. The effort includes modifications to the magnet, including machining a slot in the yoke for beam passage, field clamps, and a solenoid to reduce the transverse magnetic field on the beam line, the design and development of the infrastructure needed to run the magnet, and the construction of the platform on which it will stand.

- The second Project, **Neutron Form Factor (WBS 2)**, involves the construction of The PMT-based Coordinate Detector (CDet), trigger electronics for the Hadron Calorimeter (HCal) to meet the requirements of the approved neutron form factor measurements.

- The third and final Project, **Proton Form Factor (WBS 3)**, involves the construction of forty GEM detector modules with associated front-end and DAQ modules to meet the requirements of the approved proton form factor measurement.

Project Management Highlights:

This is the 32nd Monthly Progress Report for the SBS Program.
The SBS Basic (WBS 1) project started in FY13. The SBS Neutron Form Factor (WBS 2) started at the beginning of FY14. The SBS Proton Form Factor (WBS 3) started on October 1, 2012.

- The scintillator bars for the Coordinate Detector have been completed by Fermilab and shipped to Eljen for machining. This completes a WBS 2 Level 3 milestone.

- Prototype 4x4 block ECAL with heating oven was tested in Hall A at end of April. This test is one of the recommendations of the Nov 2014 DOE review. A short report is attached in Appendix II.

WBS 1: SBS Basic

WBS 1	**SBS Basic: (Hall A Infrastructure)**	**WBS 1.01**	Milestones
		WBS 1.02	Project Oversight
		WBS 1.1	Magnet, power and construction
		WBS 1.2	Magnet/detector platforms
		WBS 1.3	Beam line

WBS 1.02 Project Oversight:

- SBS weekly meetings, via tele and video conference were held on March 4, 11, 18 and 25th. Participants included Jefferson Lab, University of Virginia, Carnegie-Mellon University, William and Mary, Norfolk State University, University of Connecticut, University of Glasgow, Saint Mary's University, Idaho State University, and INFN Rome.
- Project is staffed appropriately for this stage, and includes a Jefferson Lab manager, scientist, and magnet engineer.

WBS 1.1 Magnet, Power and Construction:

- The SBS magnet was picked by the local vendor on April 1st. The modifications were completed and it is ready for delivery to JLab in May.
- Coils:
  - Racetrack coils: All coils are at JLab.
  - Saddle coil**:** Vendor was contacted. They are in the process of winding the coil and expect to meet the delivery date of July 31, 2015.
- Detailed design work on the corrector magnets is expected to be completed by May 15th. Expect to have order placed by mid June 2015.

WBS 1.2 Magnet/Detector Platforms:

- Will order the small parts for the magnet/detector platform such as jacks and roller hardware in the next few months.

WBS 1.3 Beam Line:

- The vacuum snout is finished and arrangements are being made for delivery in May.
- Front clamp drawings are complete and will be sent to procurement in May.

WBS 1 Costs:

- The budget for this WBS for FY15 is $212K.
- The incremental budget (FY13+FY14+FY15) is $1,694K.
- Costed and obligated as of 5/1/2015: $1,232K (73%).

WBS 1.01 Milestones: (see Appendix 1 for graphic view of milestones)

Level (ID#)	Milestone	Scheduled Date	Expected Date 4/1/2015	Expected Date 5/1/2015	Comment
1 (1.1-01M)	Project start	10/1/2012			**Completed 10/1/2012**
2 (2-01M)	Magnet delivered to JLab	4/30/2013			**Completed 8/21/2013**
3	Power supply received	1/4/2014			**Completed 10/17/2014**
3	Magnet yoke modifications Completed	4/1/2014			**Completed 5/22/2014**
2 (1.2-10M)	Platform parts received	6/27/2014			**Completed 3/24/2015**
3	Assemble magnet in Testlab	7/1/2014			**Completed 9/4/2014**
3	Commissioning test of magnet in Testlab completed	10/1/2014			**Completed 10/29/2014**
3	Beampipe solenoid correctors received	1/5/2015	9/28/2015	9/28/2015	4 months of float until project completion.
3	Detector supports completed	4/1/2015			**Completed 3/24/2015**
2 (1.2-30M)	Beam-line parts received	9/24/2015	10/16/2015	10/16/2015	3 1/2 months of float until project completion.
1 (1.1-10M)	Project completion	1/29/2016	1/29/2016	1/29/2016	

WBS 2: Neutron Form Factor

WBS 2	**Neutron Form Factor**	**WBS 2.01**	Milestones
		WBS 2.02	Project oversight
		WBS 2.1	Coordinate Detector (ISU)
		WBS 2.2	Electronics Hut, Lead Shielding, Lead platform, and Detector Frames (JLab)
		WBS 2.3	Pole Shims and field clamp (JLab)
		WBS 2.4	Trigger (RU)

WBS 2.02 Project Oversight:

- SBS weekly meetings, via tele and video conference were held on March 4, 11, 18 and 25th. Participants included Jefferson Lab, University of Virginia, Carnegie-Mellon University, William and Mary, Norfolk State University, University of Connecticut, University of Glasgow, Saint Mary's University, Idaho State University, and INFN Rome.
- Project is staffed appropriately for this stage, and includes Jefferson Lab (manager, scientist) and Idaho State University (one scientist).

WBS 2.1 Coordinate Detector (ISU):.

- Production of all the extruded scintillators for CDet by Fermilab has been completed on April 7. Approximately 1,100 220-cm long. 100 170-cm long, and 130 120-cm long strips were produced.
- 1,100 220-cm long scintillator strips have been shipped to Eljen Technology for precision machining of the top and bottom surfaces. This completes a Level 3 milestone. Eljen will machine 700 of the best strips that will be used to build the detector. As of May 1, Eljen has completed the machining of 200+ strips. The rest 500 strips will be completed within the next three weeks.

- All wavelength shifting fibers (WLS) for the CDet (a total length of 2,860 m) have been produced by Saint Gobain Crystals and delivered to JLab.
- All engineering drawings for the CDet construction including support structures have been checked and finalized by the CDet sub-group and detailed documentations for the design have been produced. The final design drawings await approval from the JLab Engineering Group.
- The design of the equalizer boards for adjusting gain variation of the PMTs has been completed. Fabrication of the boards will start by the end of May and appropriate manpower for doing this work has been identified.
- The design of the NINO cards for CDet frontend electronics has been finalized and 2 cards are currently under production. Once these cards are verified, large scale production of all 168 cards will begin.
- Quotations for the individual modules frames and the overall frame have been received and they are within budget.

WBS 2.2 Electronics Hut, Lead Shielding & platform, and Detector Frames:

- Drawings of the electronic hut were sent for radiation calculation in beginning of April. New calculations were done and modifications of the electronic hut layout are underway. The updated layout will be ready in mid May for radiation calculations.
- A solution to the GEM noise problem from the longer HDMI cables has been found. A paper was found which had a solution to a similar problem for the Belle II Silicon Vertex Detector which used the APV25 chip connected to a FPGA readout by 12m twisted pair cables. This paper implemented a finite impulse response (FIR) filter programmed into the FPGA that reads out the signal from the APV25 to eliminate the noise for signal distortion and reflections. The INFN group has implemented the programming solution of the Belle paper into the FPGA of the MPD and with a 23m cable the noise reduction was a factor of two. The FIR filter coefficients need to be fine tuned for the specific GEM setup and then the noise should be eliminated as in the Belle paper.
- The plastic to be used as the analyzer for the Focal Plane Polarimeter was ordered. An overall frame that holds the detectors and analyzer has been designed and is being detailed.

WBS 2.3 Pole Shims and field clamp:

- The pole shim is being readied for procurement. Need to determine whether material at JLab can be reused. Procurement of device to insert pole shim will be in May.
- Drawing of the rear clamp is finished and will be sent to procurement in May. The final detailing of clamp support is underway.

WBS 2.4 Trigger:

- Work was done by the JLab DAQ group to modify the firmware on the Trigger Supervisor module. The modification will allow that Trigger Supervisor to support a trigger scheme to allow better and simpler integration of the FASTBUS and pipelined VME DAQ systems.

WBS 2 Costs:

- Budget for this WBS for FY15 is $710K.
- The incremental budget for FY14+FY15 is $1,309K.
- Costed and obligated as of 5/1/2015: $818K (62%).

WBS 2.01 Milestones: See Appendix 1 for a graphic view of the milestones .

Level	Milestone	Scheduled Date	Expected date 4/1/2015	Expected date 5/1/2015	Comment
1	Project start	10/1/2013			**Completed 10/1/2013**
3	Finish testing of module prototype	8/30/2014			**Completed 8/30/2014**
3	Scintillator ordered	9/30/2014			**Completed 9/15/2014**
2	CDET module design completed	11/30/2014			**Completed 11/30/2014**
3	Wavelength Shifting Fibers ordered	1/15/2015			**Completed 1/20/2015**
3	Scintillator shipped for machining	4/30/2015	4/30/2015		**Completed 4/10/2015**
2	JLab receives exit field clamp	6/2/2015	7/31/2015	7/31/2015	
3	Begin preparation of WLS fibers	6/15/2015	6/15/2015	6/15/2015	
3	Begin construction of CDET modules	9/1/2015	9/1/2015	9/1/2015	
3	Assembled one CDET module	10/1/2015	10/1/2015	10/1/2015	
2	Electronics hut assembled	10/2/2015	12/18/2015	12/18/2015	
2	Trigger completed	10/4/2015	10/4/2015	10/4/2015	
3	Assembled one CDET plane	12/1/2015	12/1/2015	12/1/2015	
2	Coordinate Detector assembled	6/30/2016	6/30/2016	6/30/2016	
1	Project completion	1/29/2017	1/29/2017	1/29/2017	

WBS 3: Proton Form Factor

WBS 3	**Proton Form Factor**	**WBS 3.01**	Milestones
		WBS 3.02	Project Oversight
		WBS 3.1	GEM's (UVa)
		WBS 3.2	GEM electronics (UVa)

WBS 3.02 Project Oversight:

- SBS weekly meetings, via tele and video conference were held on March 4, 11, 18 and 25th. Participants included Jefferson Lab, University of Virginia, Carnegie-Mellon University, William and Mary, Norfolk State University, University of Connecticut, University of Glasgow, Saint Mary's University, Idaho State University, and INFN Rome.
- Project is staffed appropriately and includes Jefferson Lab (manager, scientist) and UVa (two scientists).

WBS 3.1 GEMs

- Module # 9 cosmic tests completed; all sectors fully operational.
- Module #10 cosmic tests completed; all sectors fully operational.
- Module #11 construction was completed. Module currently being prepared for HV testing.
- Module #12 construction is complete; Module currently being prepared for gas flow testing.
- A large set of x-ray data collected for module #8; data analysis is underway.
- Two possible issues are currently being investigated:
    1. Other groups have reported that Kapton Gas window may be porous to humidity. However, we have not observed any measurable degradation of chamber performance due to humidity mixing in with chamber gas; this may be due to the fact that at the operational gas flow rate of ~ 20 l/hour any humidity seeping in through the gas window is flushed out sufficiency quickly so that no significant accumulation occurs within the chamber. However, as a precaution all future chambers will have gas windows made out of aluminized Kapton (the aluminum layer is 0.1 μm thick and is on the outer surface of Kapton). The aluminum layer seals the Kapton foil and the possibility of humidity contamination is reduced by about an order of magnitude.
    2. During extensive x-ray testing of chamber #2, it was observed that the gas window attaches itself on to the surface of the Cathode; this could be due to very high levels of electrostatic

charge build up on the top side of the Cathode and the bottom side of the gas window; both these surfaces are made of highly insulating Kapton foil. This effect is reversible and even with the gas window attached to the Cathode, the chamber operates with proper gain, but with some degradation in signal timing. All chambers constructed after module #4 have a spacer grid between the gas window and the Cathode to reduce the possibility of Gas window attaching to the Cathode. X-ray testing of module #8 has indicated that the spacer grid is highly effective in this and the possibility of gas window attachment is significantly less. We are currently investigating the possibility of leaving a thin metal layer on the top side of the Cathode window as a further improvement.

WBS 3.2 GEM electronics

WBS 3 Costs:

- Budget for this WBS for FY15 is $371K.
- The incremental budget of FY13+FY14+FY15 is $1,440K.
- With the addition of the moving the $209K plus contingency forward from FY16 makes an incremental budget of $1,687K.
- Costed and obligated as of 5/1/2015: $1,428K (85%).

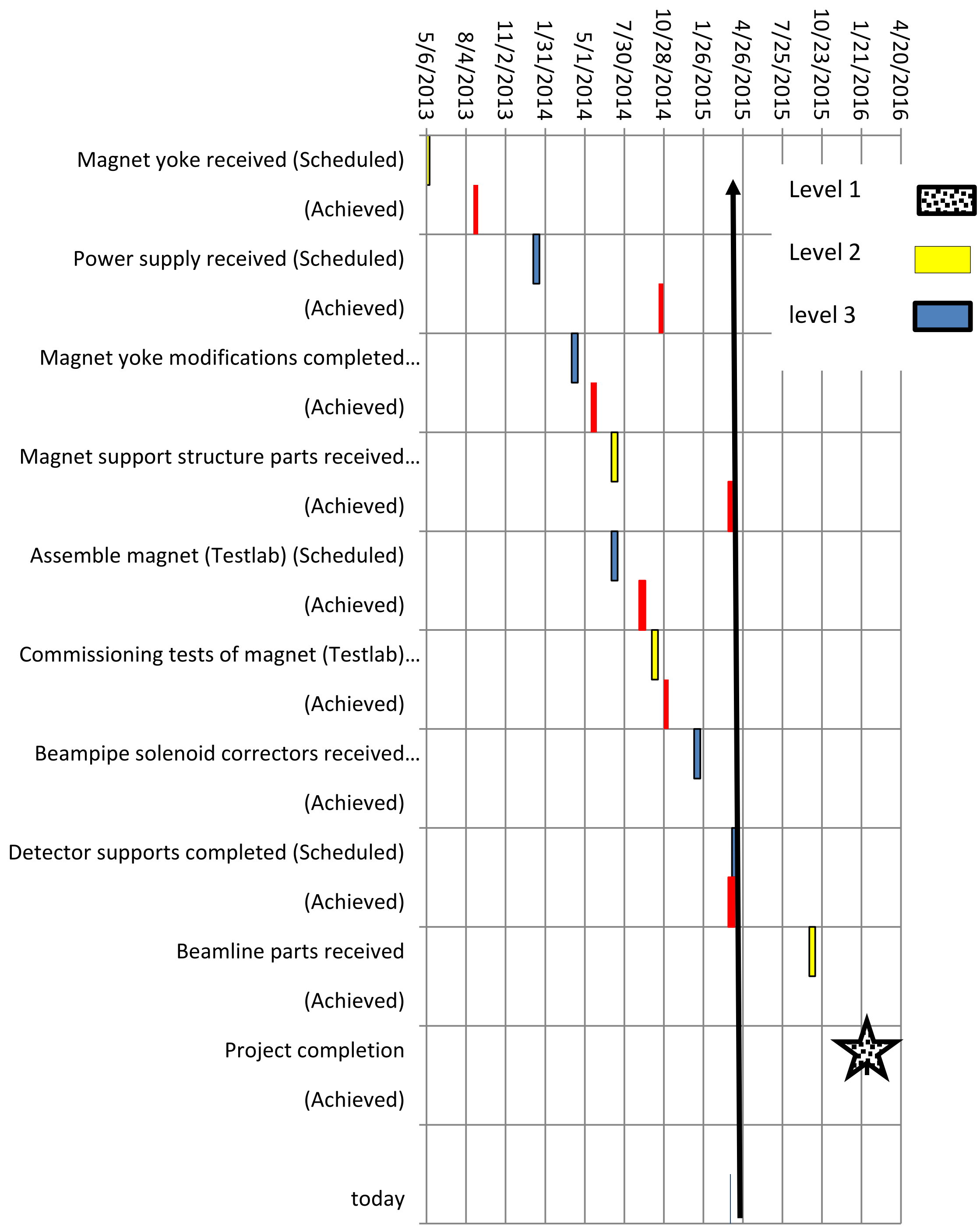
WBS 3.01 Milestones: (see Appendix 1 for a graphic view of the milestones)

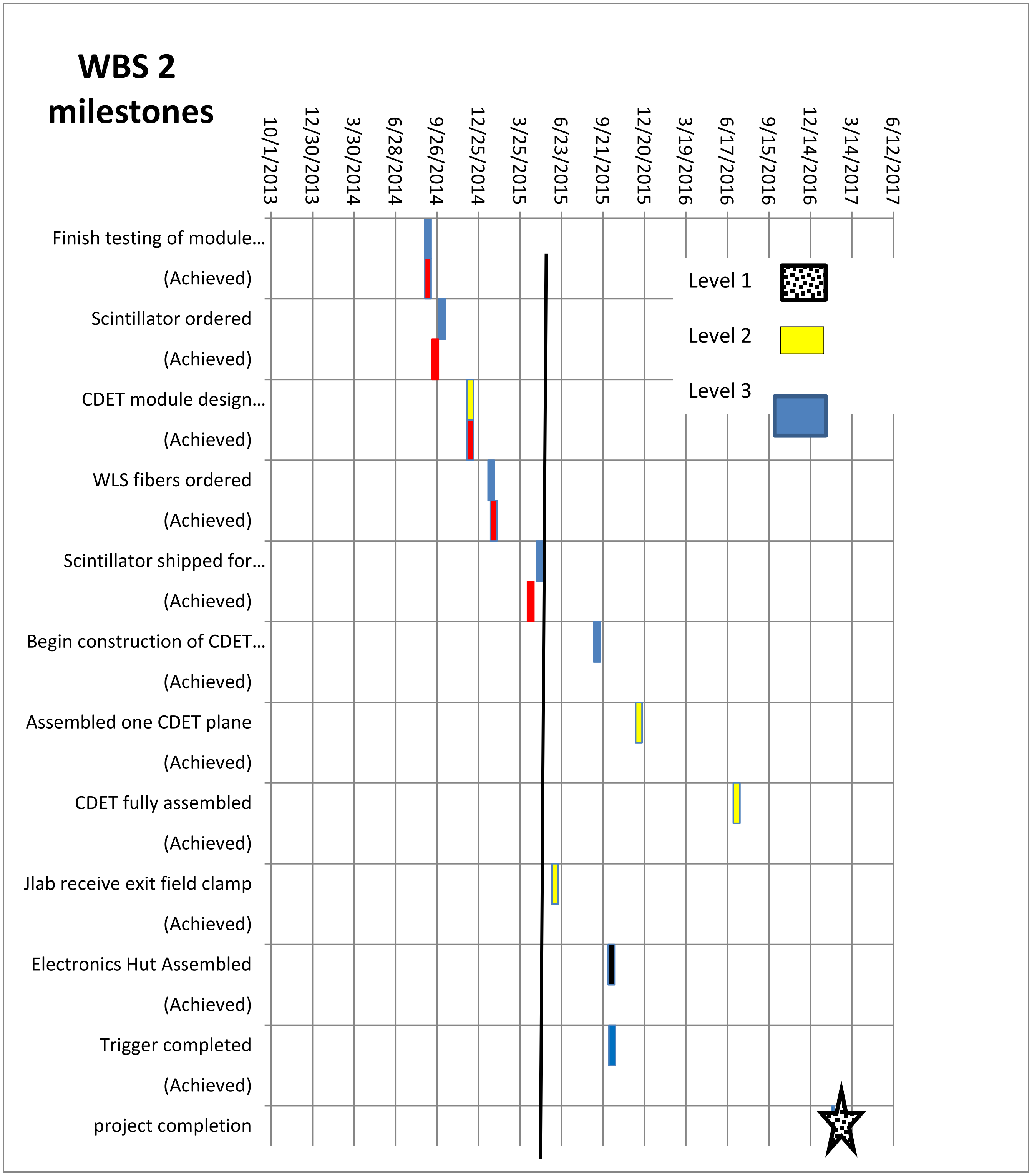
Level (ID#)	Milestone	Scheduled Date	Expected date 4/1/2015	Expected date 5/1/2015	Comment
1 (3.1-01M)	Project start	10/1/2012			**Completed 10/1/2012**
3	Order GEM Parts	10/1/2013			**Completed 10/18/2013**
3	UVa receives GEM parts	2/3/2014			**Completed 4/23/2014**
2 (3.2-01M)	First module assembled and tested	3/3/2014			**Completed 5/15/2014**
2 (3.2-10M)	UVa 5 GEM modules assembled and tested	6/2/2014			**Completed 12/23/2014**
2 (3.2-20M)	UVa 6-16 GEM modules assembled and tested	9/30/2014	6/15/2015	6/15/2015	
2 (3.2-30M)	UVa 17-29 GEM modules assembled and tested	3/2/2015	1/1/2016	1/1/2016	
2 (3.2-40M)	UVa 30-40 GEM modules assembled and tested	7/15/2015	6/15/2016	6/15/2016	
2 (3.2-50M)	1st order of Front End Electronics	10/1/2014	3/15/2015		**Completed 3/5/2015**
2 (3.2-60M)	2nd order of Front End Electronics	10/1/2015	3/15/2015		**Completed 3/5/2015**
1 (3.1-10M)	Project completion	7/31/2017	7/31/2017	7/31/2017	

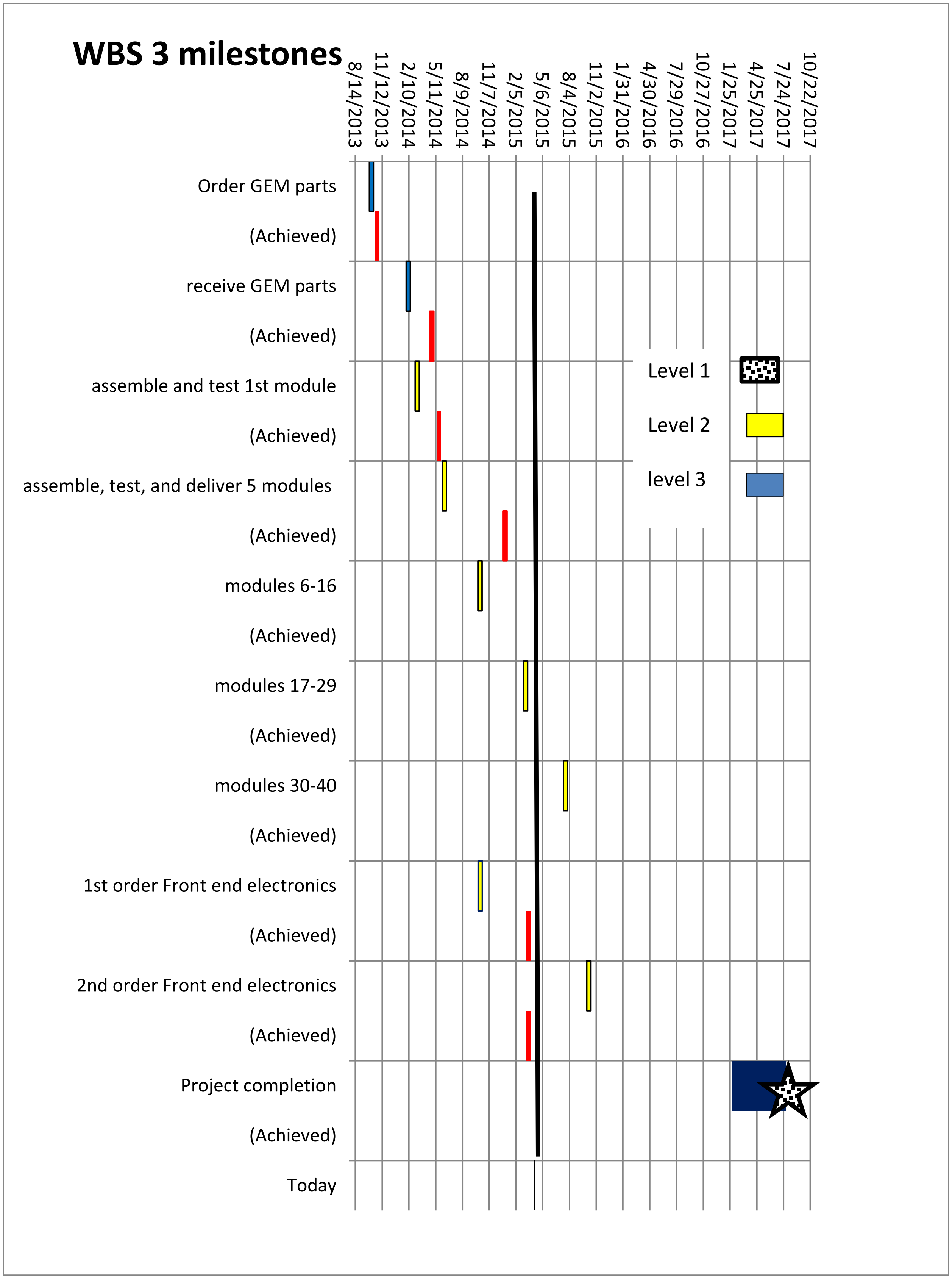
Appendix I

The following are graphical representations of the milestones for SBS Basic (WBS 1), Neutron Form Factor (WBS 2,) and Proton Form Factor (WBS 3), updated on December 1, 2013. Black represents level 1 milestones as specified in the PMP. Yellow represents level 2 milestones from the PMP. Blue represents the new level 3 milestones to allow better quarterly tracking. The black vertical line indicates the day the chart was made. The red bar indicates when the milestone was achieved (e.g. Magnet yoke received.

WBS 1 Milestones




WBS 2 milestones
10/1/2013
12/30/2013
3/30/2014
6/28/2014
9/26/2014
12/25/2014
3/25/2015
6/23/2015
9/21/2015
12/20/2015
3/19/2016
6/17/2016
9/15/2016
12/14/2016
3/14/2017
6/12/2017
Finish testing of module...
(Achieved)
Scintillator ordered
(Achieved)
CDET module design...
(Achieved)
WLS fibers ordered
(Achieved)
Scintillator shipped for...
(Achieved)
Begin construction of CDET...
(Achieved)
Assembled one CDET plane
(Achieved)
CDET fully assembled
(Achieved)
Jlab receive exit field clamp
(Achieved)
Electronics Hut Assembled
(Achieved)
Trigger completed
(Achieved)
project completion
Level 1
Level 2
Level 3


WBS 3 milestones
8/14/2013
11/12/2013
2/10/2014
5/11/2014
8/9/2014
11/7/2014
2/5/2015
5/6/2015
8/4/2015
11/2/2015
1/31/2016
4/30/2016
7/29/2016
10/27/2016
1/25/2017
4/25/2017
7/24/2017
10/22/2017
Order GEM parts
(Achieved)
receive GEM parts
(Achieved)
assemble and test 1st module
(Achieved)
assemble, test, and deliver 5 modules
(Achieved)
modules 6-16
(Achieved)
modules 17-29
(Achieved)
modules 30-40
(Achieved)
1st order Front end electronics
(Achieved)
2nd order Front end electronics
(Achieved)
Project completion
(Achieved)
Today
Level 1
Level 2
level 3

Appendix II

List of integration milestones for all equipment off-project, as well as key JLab readiness and safety reviews. For each milestone the additional float is indicated.

The Gas Cherenkov detector(GRINCH) from W&M (for GMN and GEN)

Milestone	Completion date	Comment
Design and drawings for vessel are complete	Feb 1, 2015	**Completed Feb 2015**
Photon Detector Array assembled and tested	Aug 1 , 2015	
NINO chip front end cards system shipped to JLab	Jul 1, 2015	
Purchase order issued for vessel	Oct 15, 2015	
Full DAQ system ready	Dec 1, 2015	
Vessel completely assembled	Mar 15, 2016	
GRINCH ready for installation	Jun 15, 2016	
Final analysis software complete	Jun 15, 2016	

HCal-J from CMU (for GMN, GEN and GEP)

Milestone	Completion date	Comment
Detailed design completed	June 2014	**Completed July 2014**
Design review	Sept 2014	**Completed Dec 2014**
Module construction initiated	Mar 2015	**Completed Mar 2015**
Module assembly 25% complete	Sept 2015	
Module assembly 50% complete	Mar 2016	
Module assembly completed	Sept 2016	

Status update:

- Module production is ongoing. Have produced 16 modules of the total of 288 modules in HCAL and expect to complete 30 modules per month.
- Have build custom transport dollies for holding 6 modules at a time.
- Expect to ship 60 modules to JLab in mid June.

Front Tracker from INFN (for GMN, GEN and GEP)

Milestone	**Completion date**	**Comment**
Electronics in production	Sept 2014	**Completed Sept 2014**
GEM chambers 1 and 2 completed	Sept 2015	
Initial Electronics QA completed	Dec 2015	
GEM chambers 3 and 4 completed	May 2016	
GEM chambers 5 and 6 completed	Dec 2016	

Status update:

- The first GEM chamber (3 modules) is assembled and will be shipped to JLab with arrival expected on May 15^{th}.
- Three GEM modules (which will form the 2^{nd} Gem chamber) are being shipped from Catania to Rome. At Rome they will be given a final Q&A test.

ECal from JLab (for GEP)

Milestone	**Completion date**	**Comment**
Develop concept of annealing	July 2014	**Completed July 2014**
Design review	Nov 2015	
Electronics are ready	Nov 2016	
ECAL is ready	July 2017	

Status update:

- Prototype 4x4 block ECAL with heating oven was tested in Hall A at end of April. A short report is given after the tables.

Polarized ^{3}He target from UVa (for GEN)

Milestone	**Completion date**	**Comment**
Selection of target-cell design for high luminosity	Nov 2014	**Completed Oct 2014**
Simulated-beam test (bench test) of selected design	Dec 2016	
Design for target hardware and instrumentation complete	July 2017	
GEn Polarized ^{3}He target is ready	Jan 2018	

Short report on prototype ECAL test

At the end of April, a test of a prototype ECAL, C16, was performed in Hall A. The C16 was a 4x4 array of lead glass block inside an oven as shown in Fig. 1. The oven provides continuous thermal annealing of the lead glass to repair the radiation damaged induced by low energy photons during an experiment. The heating elements of the oven were arranged around the sides, the top and bottom of the blocks. The heating elements are surrounded by glass foam brick insulator. Lead glass blocks and PMTs were enclosed in a thin aluminum box for light tightness. The total thickness of insulator material in front of the lead glass was about 0.15 radiation lengths. A 15 cm long light guide is between each lead glass block and its phototube. Cool air was blown into the

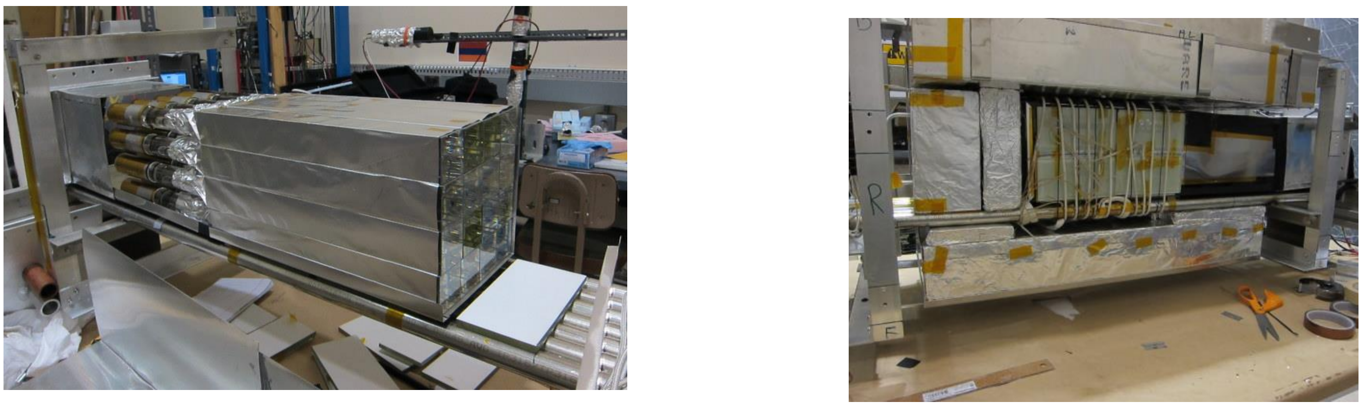


Figure 1: The left picture shows the 4x4 lead glass blocks with light guide and PMT. The right picture shows the heating element wrapped around the lead glass surrounded by glass foam bricks (enclosed in aluminum foil).

light tight box enclosing the PMTs and the temperature was kept at 38^{o} C at the PMTs. Temperature probes were placed to monitor at various places inside the oven. Previous tests had shown that the desired oven setting would heat the front end of the glass at 225^{o} C and have the temperature gradually dropped to 185^{o} C at the rear end of the lead glass.

The test experiment was done with an electron beam energy of 2.056 GeV/c hitting a 15cm LH2 target. The beam current was varied between 6 and 20 uA during the test. The beam right HRS was set at 48.74^{o} and in positive polarity to accept 1.0 GeV/c protons. The C16 was placed on a movable platform and at beam left. First it was placed at roughly 31^{o} and 6.9m from the target to detect elastic electrons in coincidence with the RHRS. The coincidence electron has an energy of 1.570 GeV and the energy resolution of the lead glass is expected to be 6 to 7%. The DAQ used FADC250 to store the calorimeter ADC signals and the trigger was the good scintillator trigger in the RHRS. Data was first taken with the oven off and a low radiation dose. The energy resolution, $\Delta E/E$, was 8.8 +/- 0.3 % for a run taken before the oven was turned on. An access was made to turn on the oven and to place 5 lead glass blocks at different locations to monitor the radiation damage. One lead glass block was placed in front of the C16 and perpendicular to the front. Another along lead glass block was placed along the small angle side of the C16. The other three bars were placed on the LHRS platform at a height lower than the C16. After intermittent beam was taken for 8 hours, an access was made to monitor the temperatures . Data was taken at 6uA and an energy resolution of 9.6 +/- 0.3% was measured. After another 4 hours of 20uA beam, data was taken at 6uA and an energy resolution of 9.1 +/- 0.3% was measured. An access was made to move the C16 to smaller angle to increase the radiation dose rate. The temperatures at the front end of blocks, rear end of blocks and PMTs were 250^{o}, 190^{o} and 38^{o} C. The lead glass blocks set near the C16 to monitor showed no visible signs of radiation damage. The C16 platform was moved to 10^{o} and 6.1m from the target which increased the radiation dose by a factor of 100. The beam was resumed for an 8 hour period during which a 20 uA beam was incident on the 15cm LH2 target for a total of 0.7 C of beam. An access to the hall was made. The lead glass blocks near the C16 had become dark brown as shown by the blocks labelled 1 and 2 in Figure 2. This level of rate of irradiation is much higher than what is expected for the SBS GEp experiment. The other three blocks are labelled 3,4,5 in Fig. 2 and show moderate signs of radiation damage. The temperatures at the front end of blocks, rear end of blocks and PMTs were 270^{o}, 190^{o} and 38^{o} C. The C16 platform was moved back to 31^{o} and 6.9m. Data was taken with 6uA beam for about one hour and the energy resolution of 9.7 +/- 0.3% was measured. The energy resolution became slightly larger, but, given the significant amount of radiation, the increase is relatively small. The test successfully demonstrates that the technique of constant thermal annealing the lead glass blocks in an oven can keep the energy resolution of the lead glass blocks constant under a large radiation dose. The large radiation dose completely darkened the lead glass blocks near the C16 used as monitors to a level which the transmission of light would be near zero.

Figure 2: Lead glass blocks placed at various locations in the hall as a radiation monitor. The blocks labelled 1 and 2 were near the C16 and show significant darkening after the C16 was moved to 10^{o}. The blocks labelled 3,4 and 5 were located at larger angles and show no darkening.