Hall D: Progress & Status

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Control Account Manager

DOE SC OPA Review of
12 GeV Upgrade Project
Jefferson Lab
November 18-20, 2014

Outline

- Introduction to Technical Scope
- Status: Progress since IPR Apr 2014
  - Construction/installation 99% complete
  - Beam commissioning ongoing
- Cost and Schedule
- Check-out / Commissioning
- Recommendations: Optimization of the Solenoid Current
- Summary

Hall D Introduction

- **Mission:**
  - **Search for gluonic excitations in the spectra of light mesons (predicted in QCD) produced by photons**
  - **Provide a facility for other photoproduction experiments**

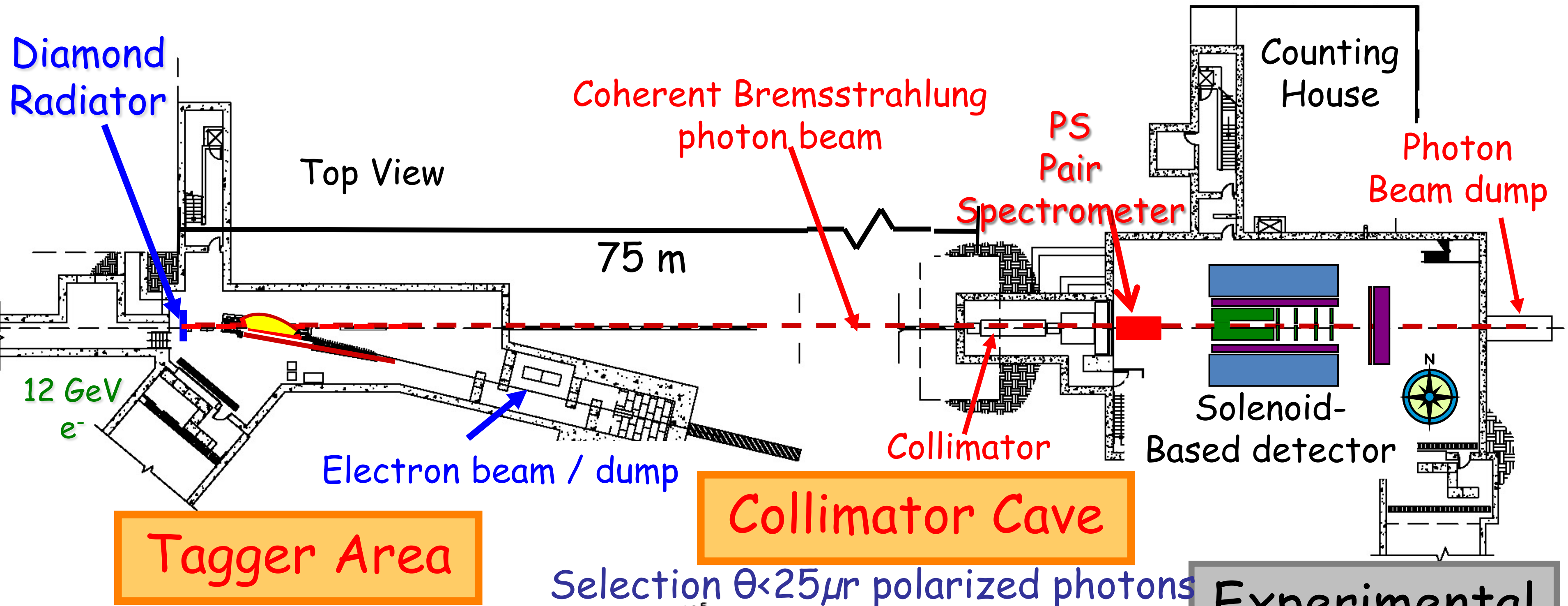
- **Scope – new beamline and new experimental hall and equipment**

An Experiment for Spectroscopy

- Photon beam with an endpoint of 12 GeV
  - coherent Bremsstrahlung → linear polarization ~40% at 8.4-9 GeV
  - sensitivity to masses < 2.5 GeV/c^2
  - linear polarization helps to identify the J^{PC} of the final states

- Detector requirements:
  - nearly hermetic detector for charged particles and photons
  - medium resolution: momentum (~ 1-4%), energy (2-20%)
  - identification of charged particles and π^o
  - high luminosity, soft trigger → high rate DAQ

Photon beam and experimental area

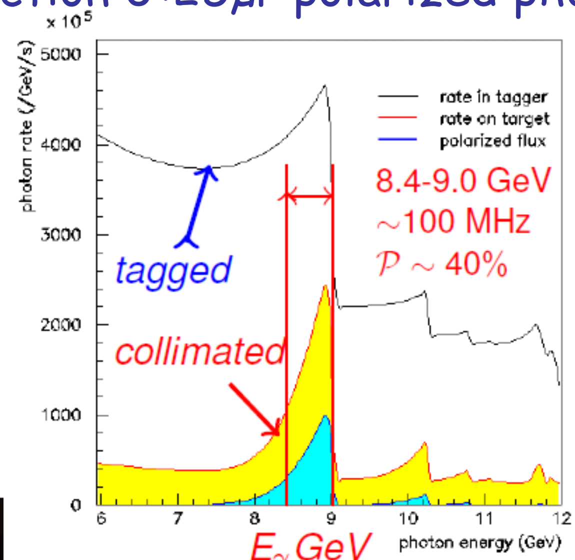


Selection θ<25μr polarized photons

Radiation $e^- Z \rightarrow \gamma\ e^-\ Z$

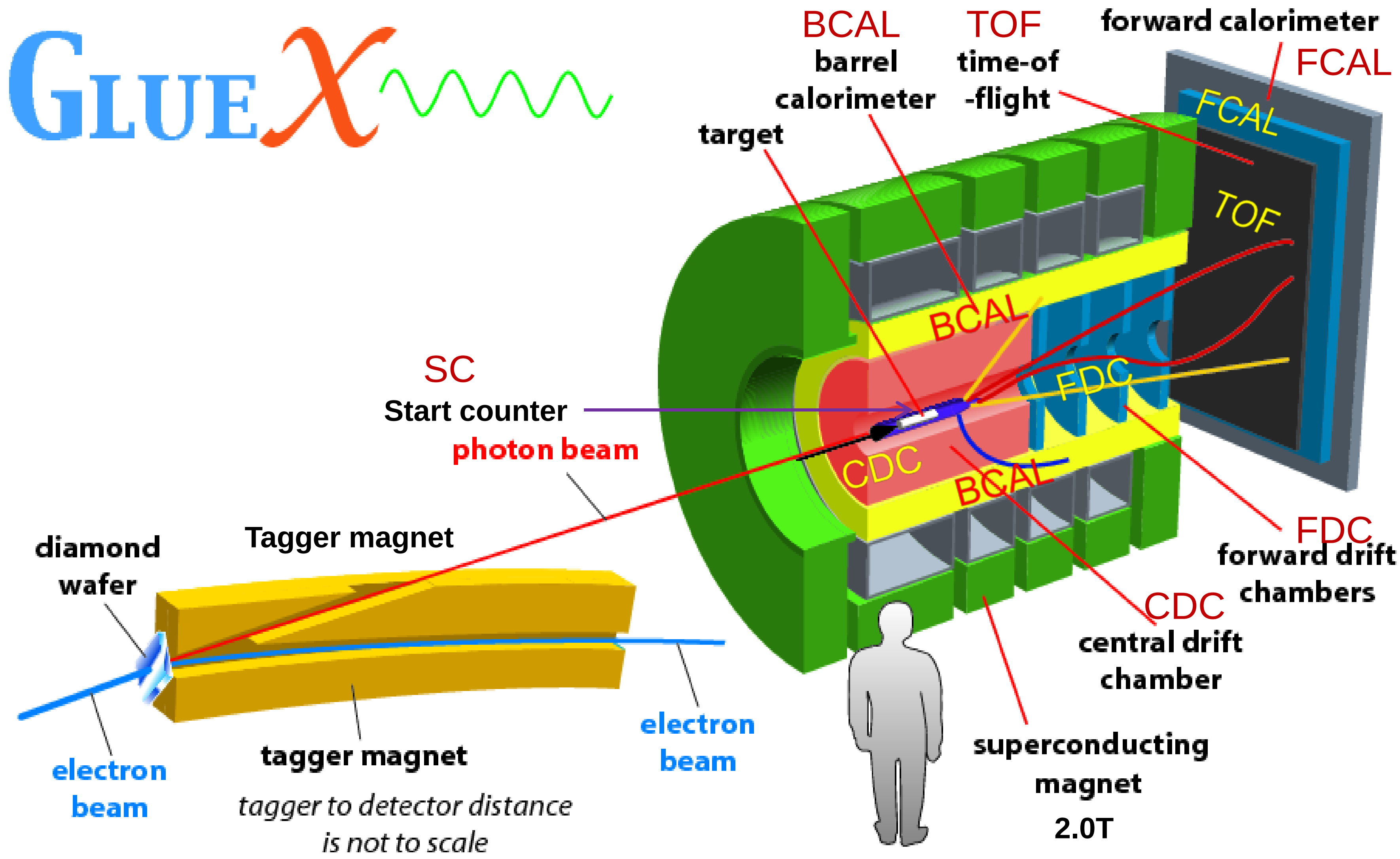
energy measured
(tagging)

Amorphous radiators
for beam tuning

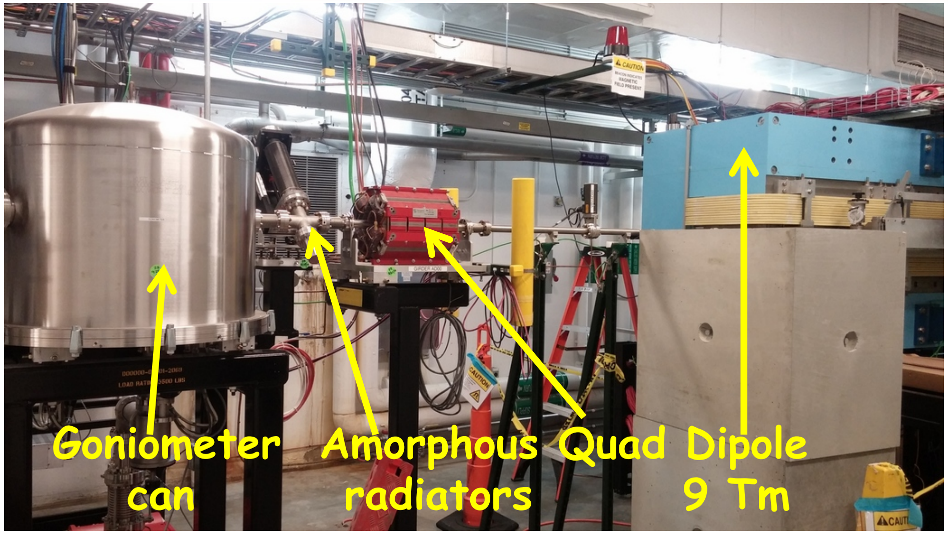


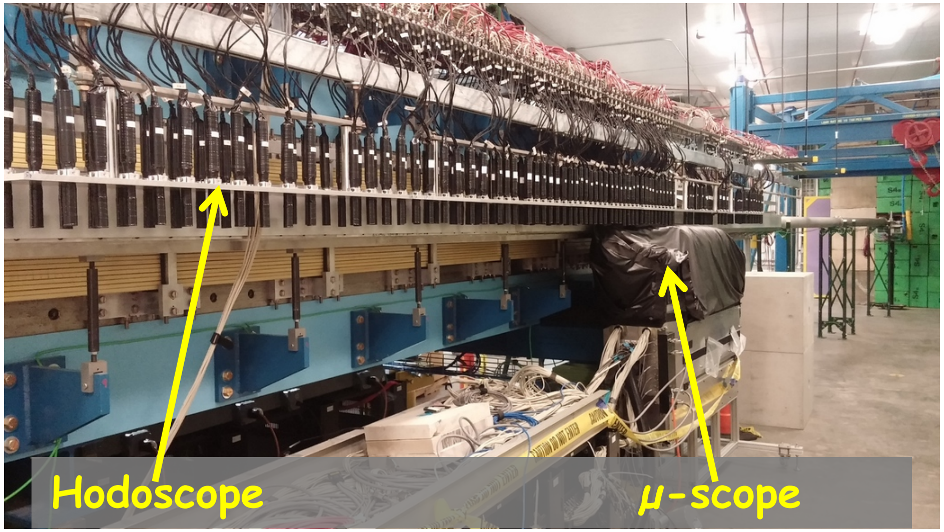
Target,
Spectrometer

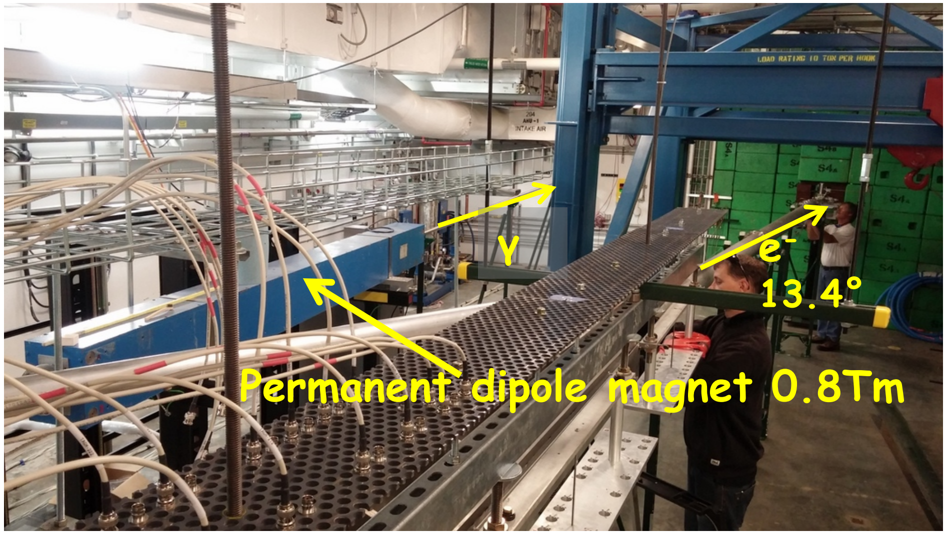
GlueX/Hall D Equipment



Tagger Hall


Goniometer can
Amorphous radiators
Quad
Dipole 9 Tm

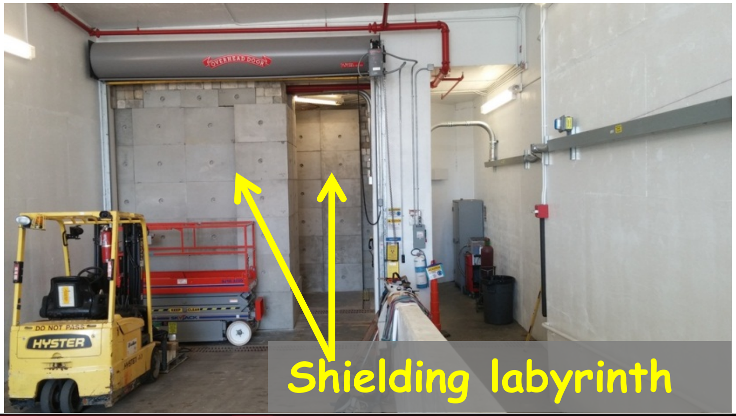

Hodoscope
μ-scope


γ
e⁻
13.4°
Permanent dipole magnet 0.8Tm

Tagger Hall Equipment

Optics and Beam Transport:

- Tagger magnet mapped at 0.6-1.7T (1.5T is nominal field for 12 GeV)
- Beamline/instrumentation installed
- First beam test in May 2014 at 10.5 GeV
  Beam scraping – radiation levels higher than expected
  - Ionization chambers) installed
- Shielding installed at the door
- **Beam commissioning in progress**
- **No excessive radiation observed**



Instrumentation and Detectors:

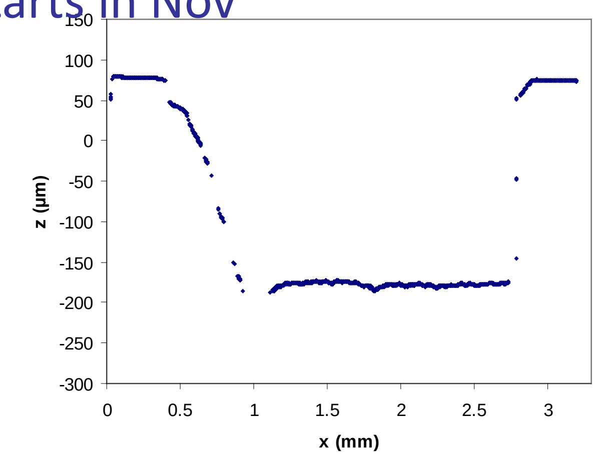
- Amorphous radiators/harp
- Tagger hodoscope (TAGH)
  - 218 scint. counters PMTs - FADC/TDC
  - Installed and tested
- Tagger µ-scope (TAGM) E_γ in coherent peak
  - 100x5 scint. fibers $2x2mm^2$
    SiPM readout
    100+20 readout channels FADC/TDC
  - Installed and tested

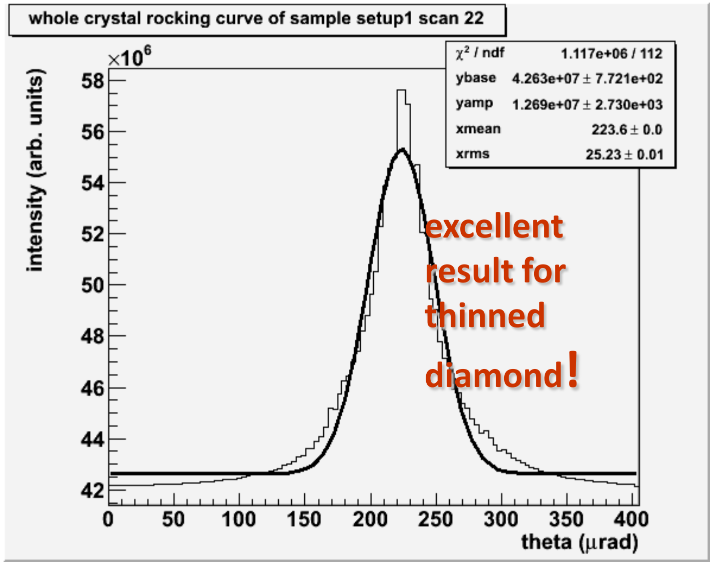
- **Beam commissioning in progress**
- Diamond radiators: delivery scheduled for March 2015

Diamond Radiators

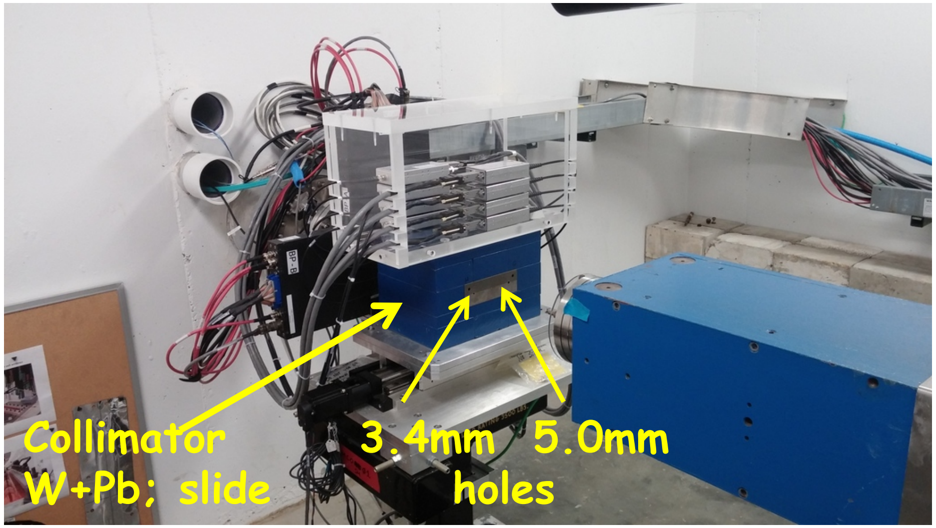
UConn

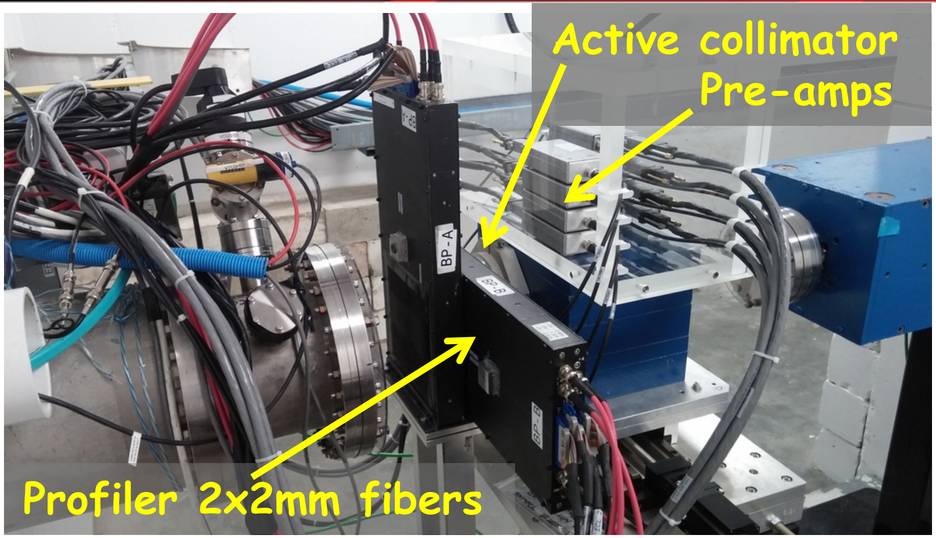
- Requirements: 20µm thick, >4x4mm², rocking curve width <25µrad
- Issues: a flat 20µm thick crystals warps
- Uconn developed technology for diamond thinning:
  - Start with 7x7mm² CVD (E6: 1mm thick, good lattice, measured at CHESS, procured)
  - Use industrial technology to thin it to 0.3mm
  - Use laser ablation to carve a central pit 4x4mm² down to 20µm thickness
  - Trained on 10 smaller crystals: alignment of the holder was improved
  - First 7x7mm² crystal thinned to 0.3mm
    Laser ablation starts in Nov

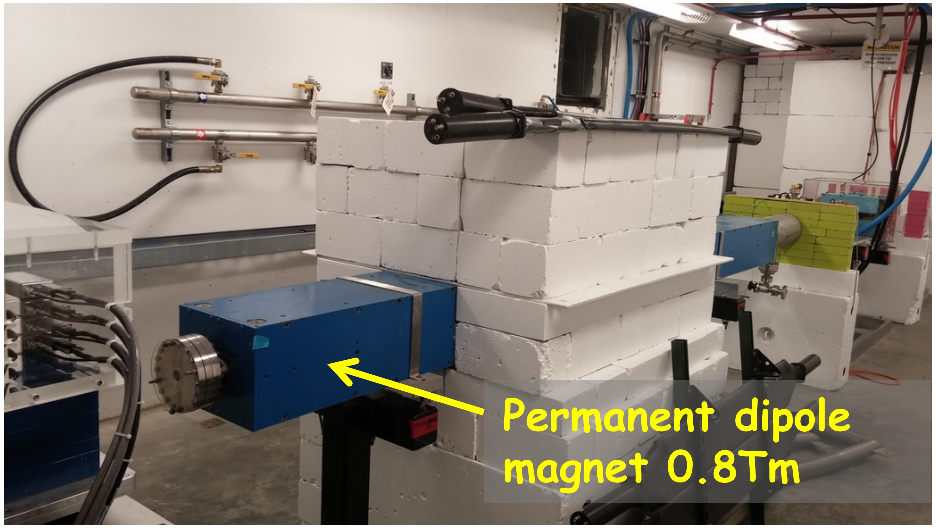




Collimator Cave



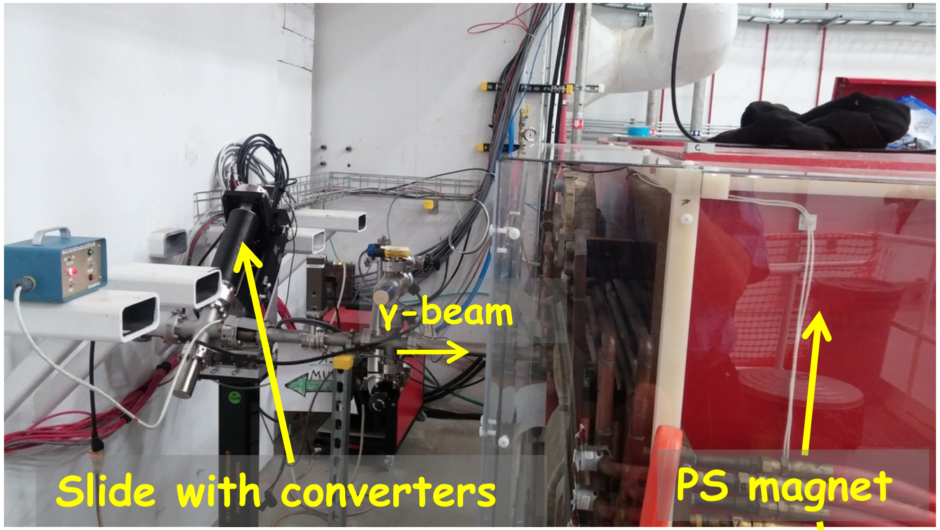


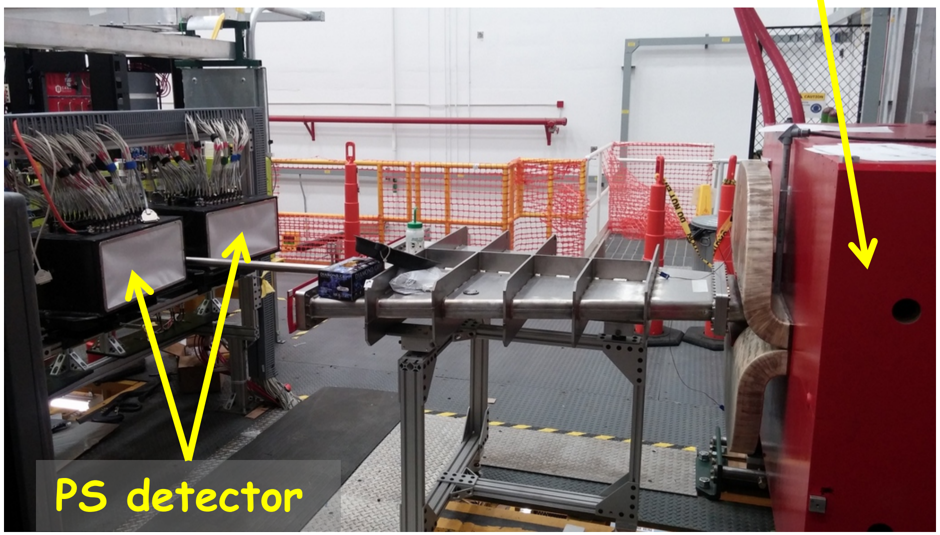


Instrumentation:

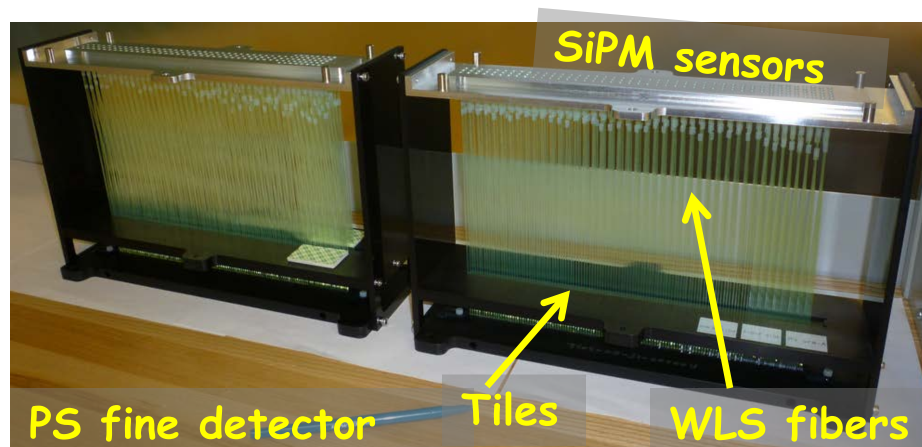
- Active collimator: photon beam position measurement
  - Secondary emission: 4 sectors (x2)
  - Aligned with a collimator hole
- Profiler: for the initial beam position measurements
  - 2x2mm^2 scint. fiber hodoscope
  - 64-ch PMTs, scaler readout
- **Beam commissioning: working well**

Pair Spectrometer

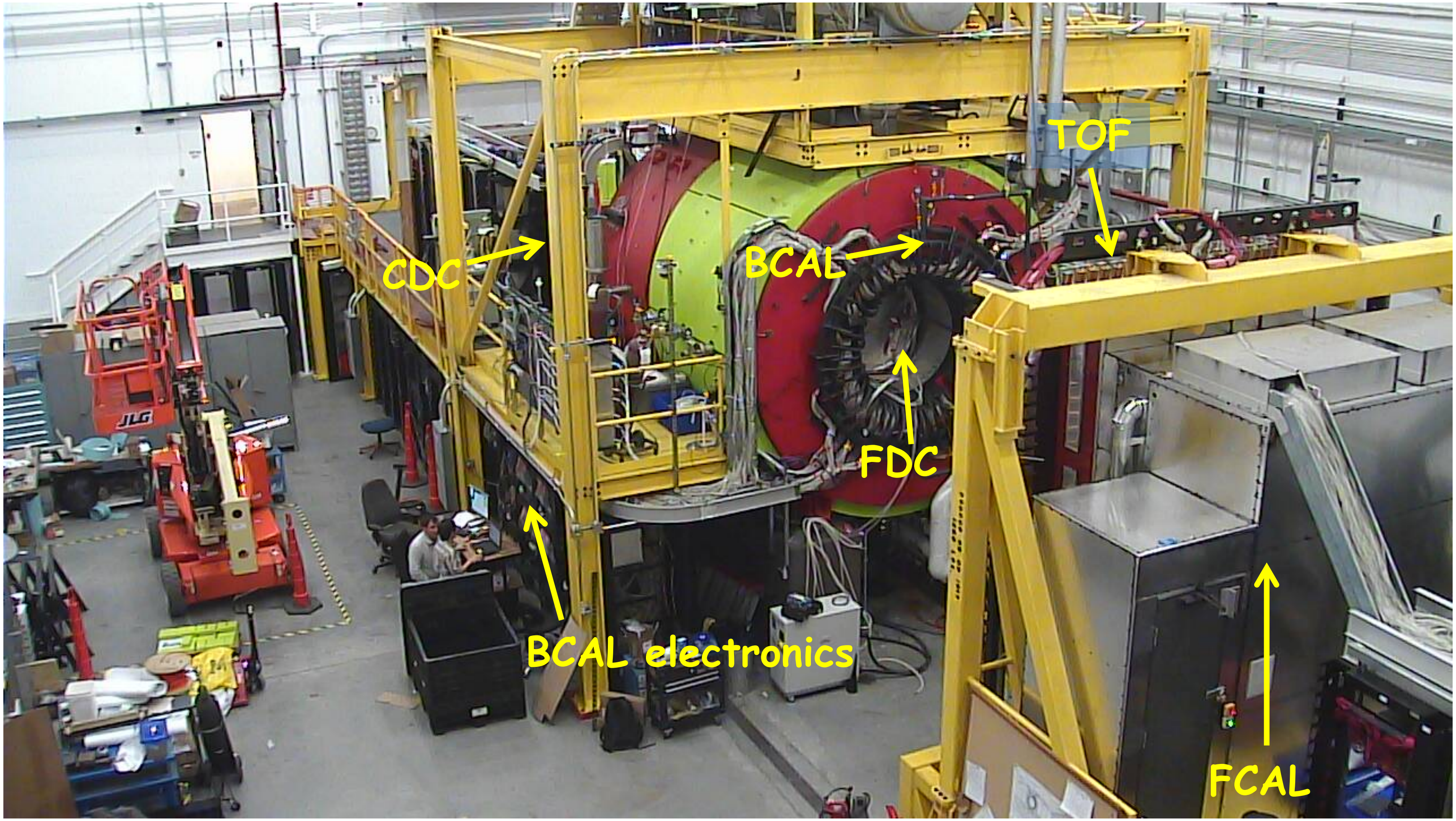




- $\gamma \to e^+ + e^-$
- Converter: 0.001 RL Al, Cu wire 0.25mm
- Magnet 18D36 ~1.6 Tm, mapped
- Detector: 2 arms; One arm covers $E_0/4<E<E_0/2+\Delta$ and includes:
  - Coarse: 8 scint+PMT- FADC, TDC
  - Fine: 145 tiles 1 and 2 mm WLS fibers readout SiPM -> FADC
- **Beam commissioning: working well**



Hall D (*July 2014*)



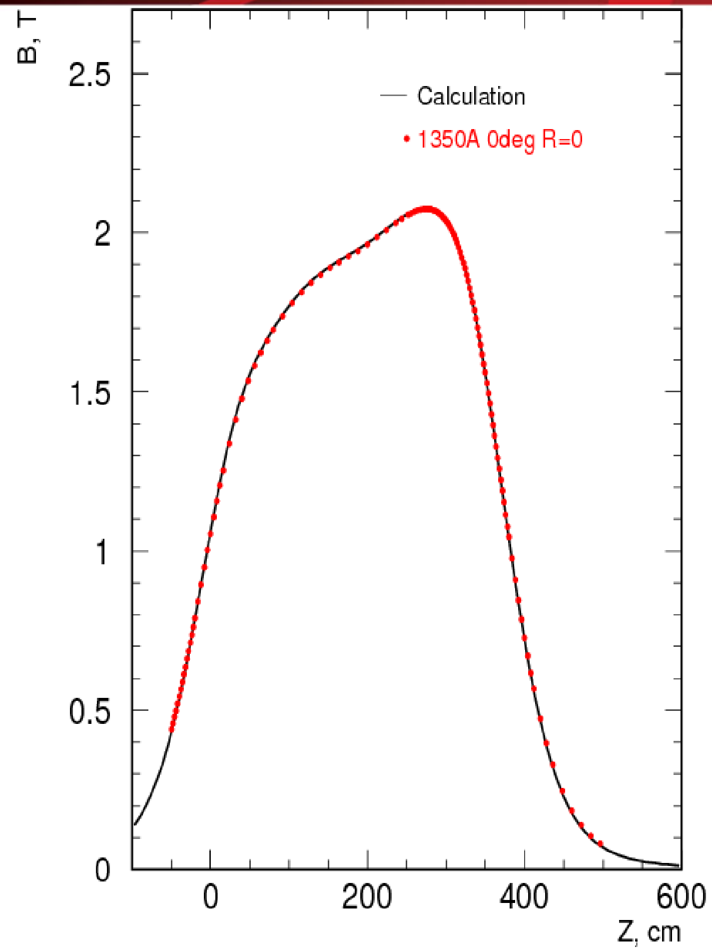
- *Detectors*: all detectors have been tested.

Hall D *(October 2014)*

- October: FCAL moved to the proper position closer to the magnet.
- **Commissioning with beam: all subsystems are functional, working as expected**

Hall D Solenoid

- Bore 4m long, 2m diameter
- Field at the axis ~ 2T at 1350A
- Full energy ~ 23 MJ at 1350A
- 4 coils in 4 separate He baths
- Built at SLAC in 1970-s, refurbished at IUCF and JLab



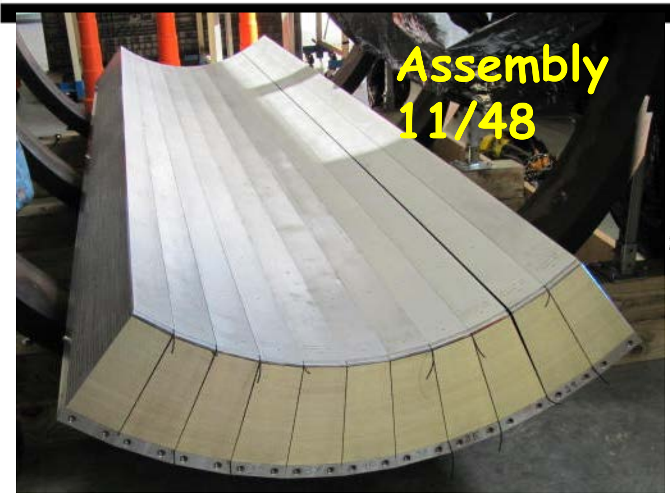
- July 2013: tested and mapped at 1350 A and 1300 A
- June 2014: refrigerator repaired (cryo-group)
- Aug 2014: stayed about a week at 1200 A
  - All the detectors and subsystems worked in the field and during the fast dump from 1200 A

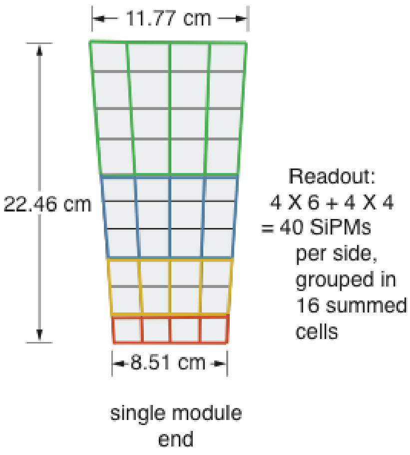
Tested in summer 2013
Measurements at 1350A
2-D calculations

Hall D Solenoid: maximum current issue

- Initial plan for GlueX: 1500 A (based on SLAC experience)
- April-May 2013 tests:
  - Reached 1500 A once
  - Next attempt two days later: quench at 1460 A at a 0.05K higher temperature
- A board of experts considered the cause of the quench:
  - No definite answer found
  - Recommended currents: 1350 A max and 1300 A for long-term operations
  - More details in the parallel presentation by Jonathan Creel
- The optimal current is being currently re-evaluated by GlueX collaboration (see the “Recommendation” section of this talk)

Barrel Calorimeter (BCAL)





U Regina, Santa-Maria U, JLab

390 cm long, 65 cm ID

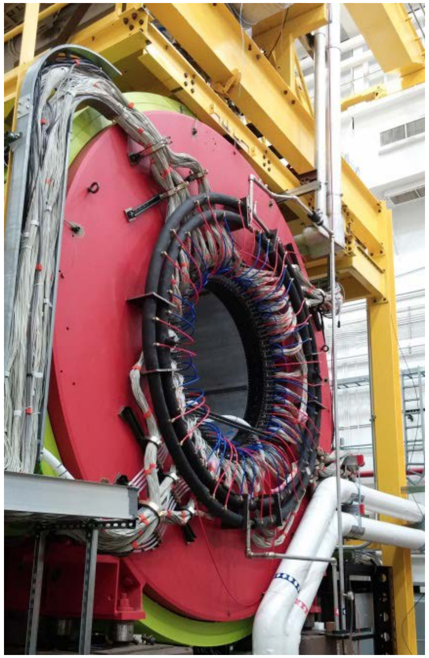
- Lead, 1mm diam. Scintillating fibers
- 191 layers Pb/Sc/Glue 37/49/14
- 48 modules, both-side readout

One side of a module:

- 40 light guides → 40 SiPM
- 40 SiPM → 16 readout channels
- 16 fADC-250MHz, 12 F1TDC

Auxiliary systems

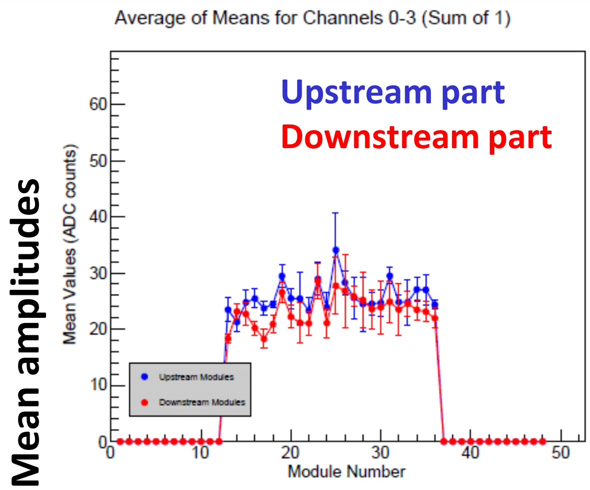
- SiPM liquid cooling to 5°C
- Readout modules: Nitrogen flushing
- LED signals for monitoring
- Bias voltage supply for the SiPM

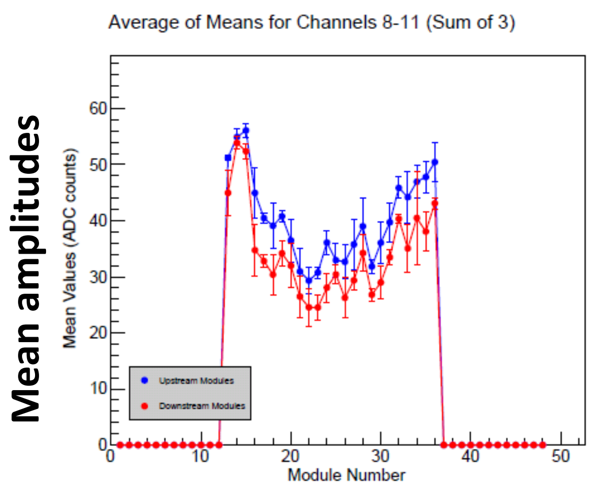


Status:

- Tested with LEDs and cosmics
- **Commissioning with beam: in progress**

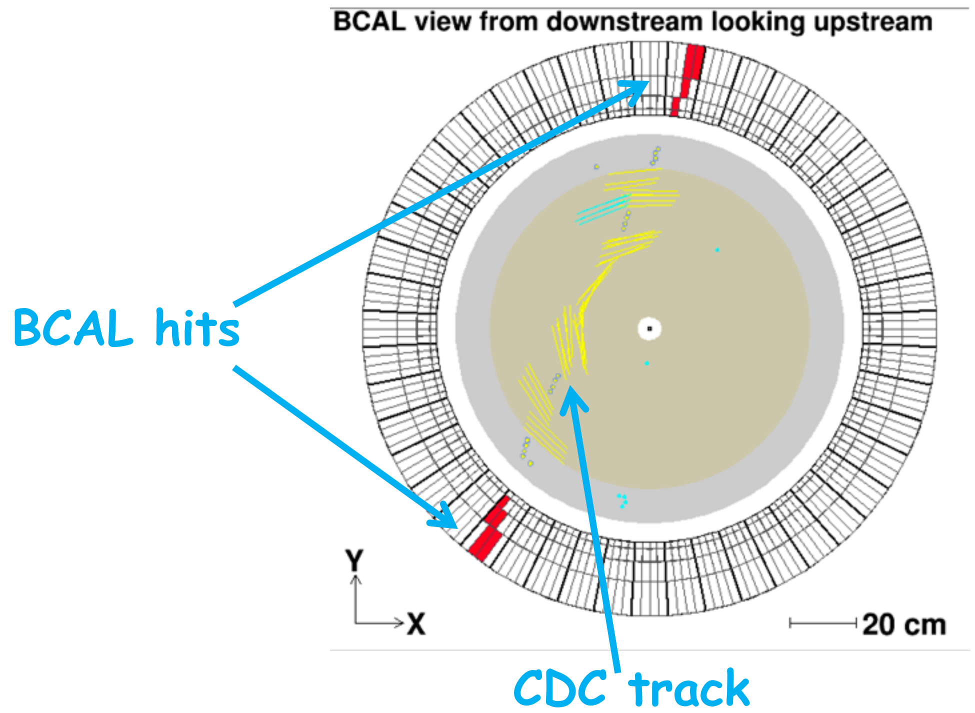
Barrel Calorimeter (BCAL)





Module number

Average amplitudes from cosmic particles



Track of a cosmic particle

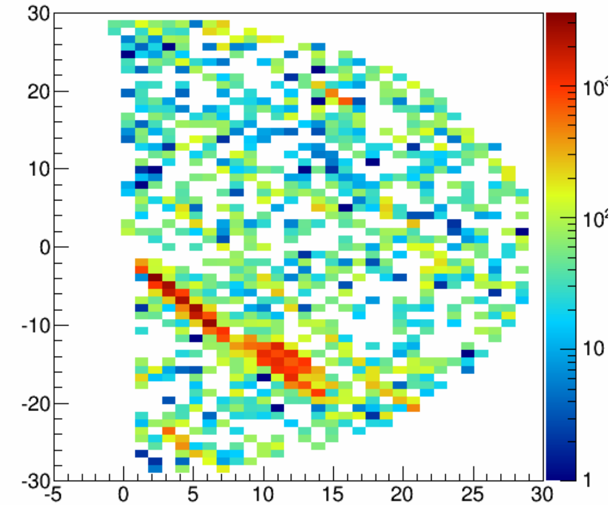
Forward Calorimeter (FCAL)

Indiana University

2800 lead glass blocks 4x4x45cm^3

FEU-84, Cockcroft-Walton bases,
readout FADC-250MHz

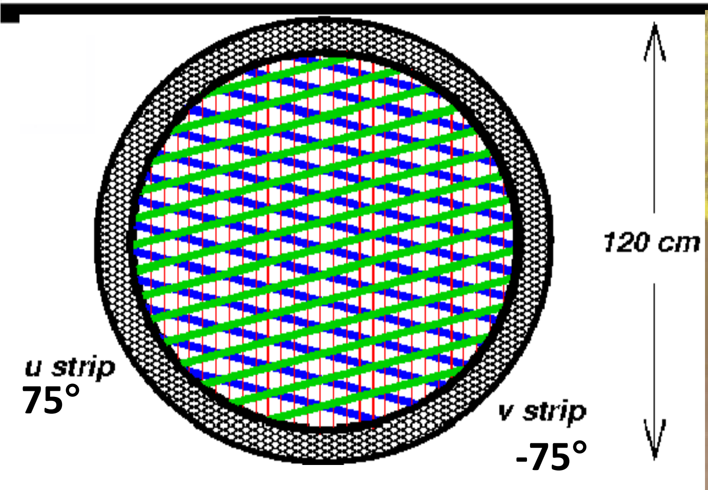
Cosmic event

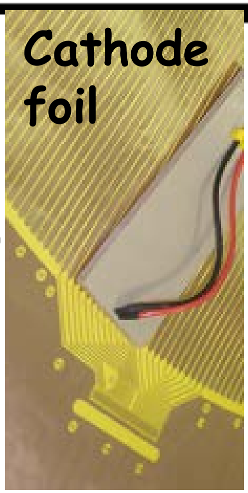


Status:

- Tested with LEDs and cosmics
- **Commissioning with beam: in progress**

Forward Drift Chambers (FDC)





JLab

Angular Coverage: $1^o – 30^o$ Ar/CO_2 40/60%

Pitch: 10mm wires, 5mm cathode strips

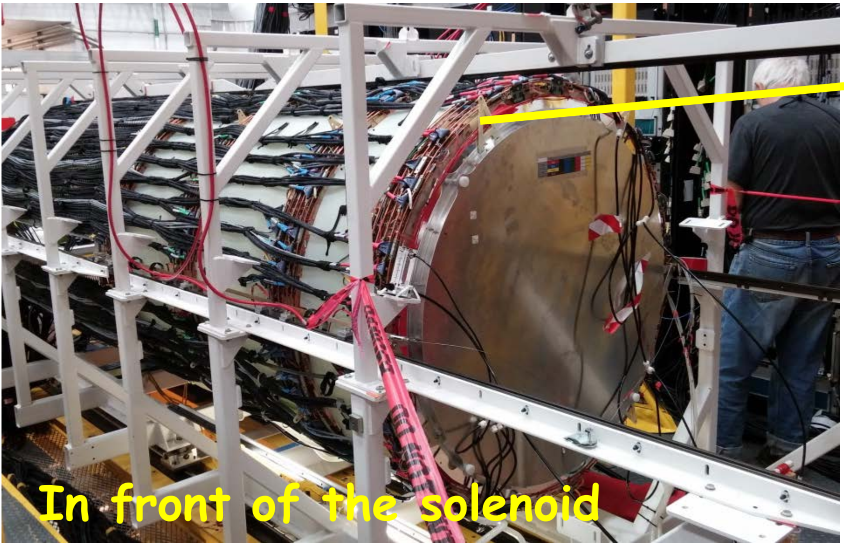
4 packages x 6 planes at 120°

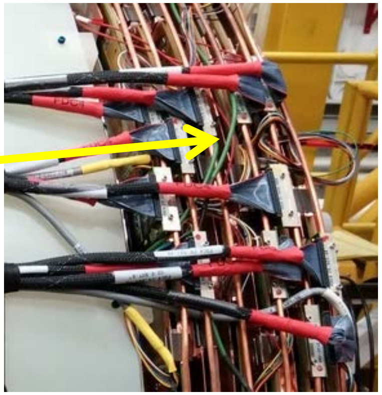
- 2300 anode wires → F1TDC
- 10200 cathode strips → FADC-125MHz

  3 measured projections per plane

Resolution: 200μm wires, 280μm strips

Preamps: liquid cooling

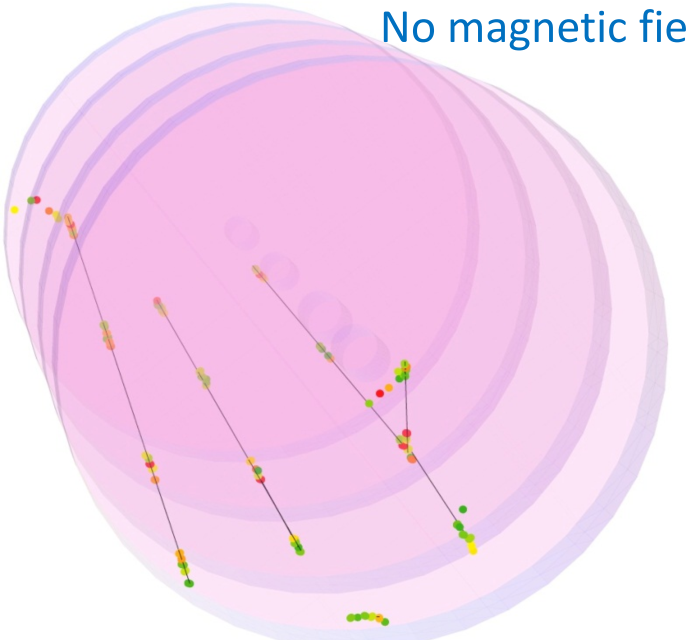




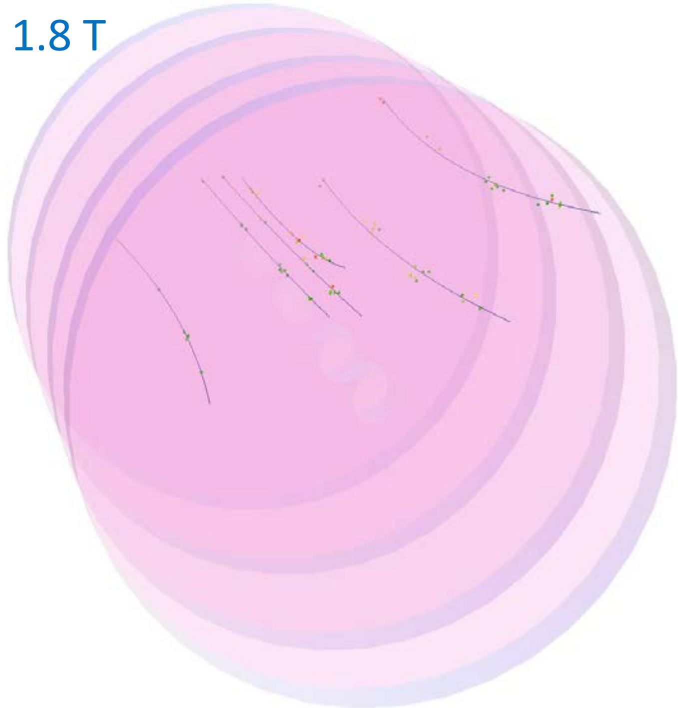
- Thoroughly tested before installation
- One package: cosmics→ resolution/efficiency
- All channels tested in situ
- **Commissioning with beam: in progress**

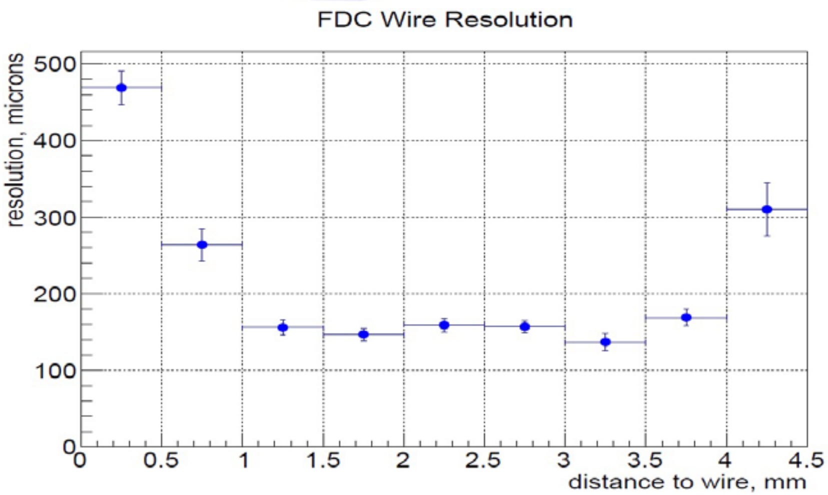
FDC - tests with cosmics

No magnetic field



Solenoid field ~ 1.8 T





Low energy (<20 MeV) particles follow field lines

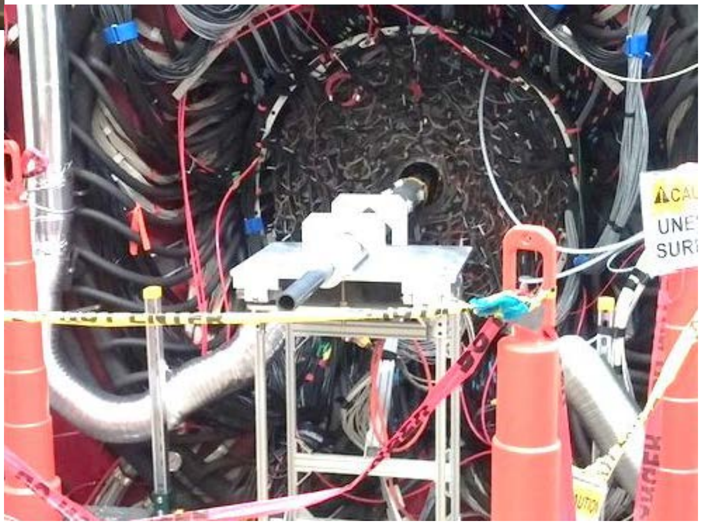
Resolutions:

- Wires: ~150µm (450µm close to wires)
- Cathode strips: ~150µm

Central Drift Chamber (CDC)

Carnegie Mellon U & JLab

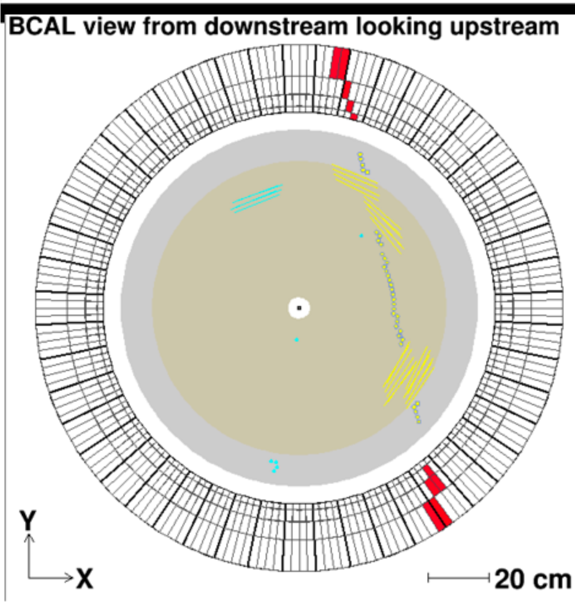
Angular Coverage: 6^o-155^o
3500 straw tubes r=8mm
dE/dx for p < 450 MeV/c
Gas mixture: ~60/40 Ar/CO_2
Readout: FADC-125MHz
Resolution: $\sigma_{r\phi}$ ~ 150 μm, σ_z~1.5 mm

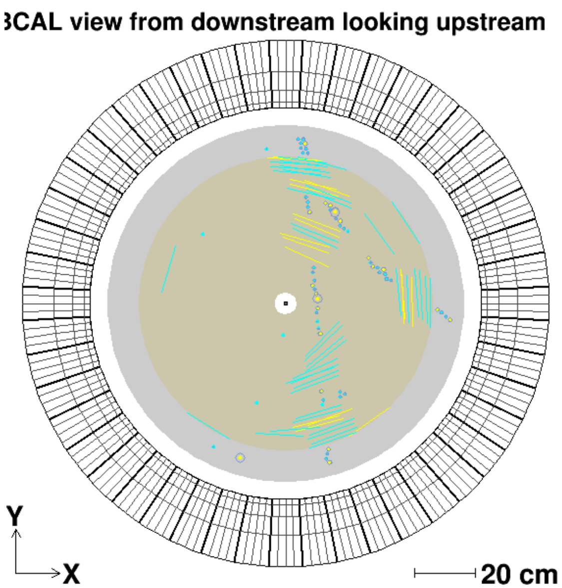


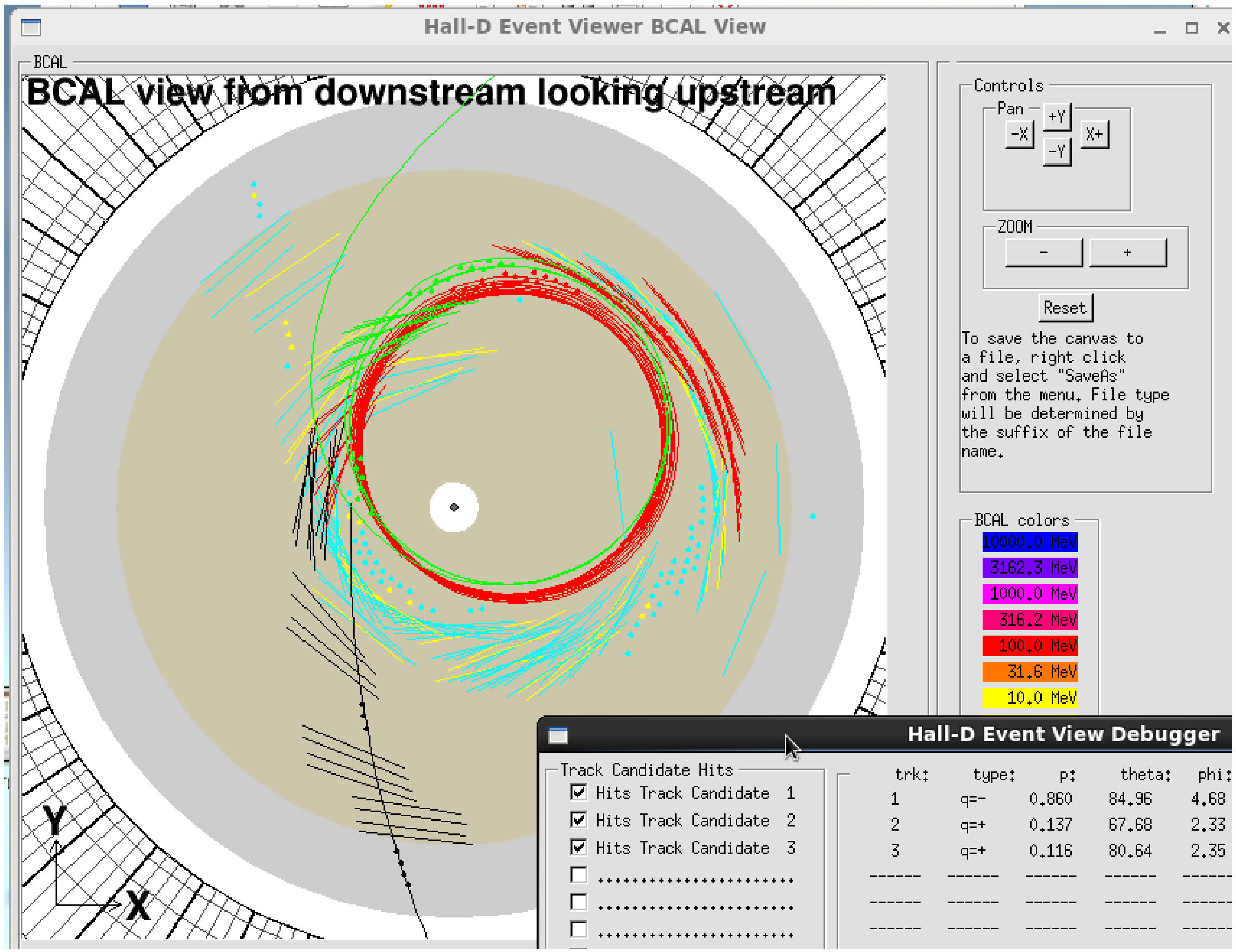
Status:

- Tested with cosmics in situ
- **Commissioning with beam: in progress**

CDC – tests with cosmics







CDC: Tracks of cosmic particles

Scintillator Hodoscopes

TOF – *Florida State U*

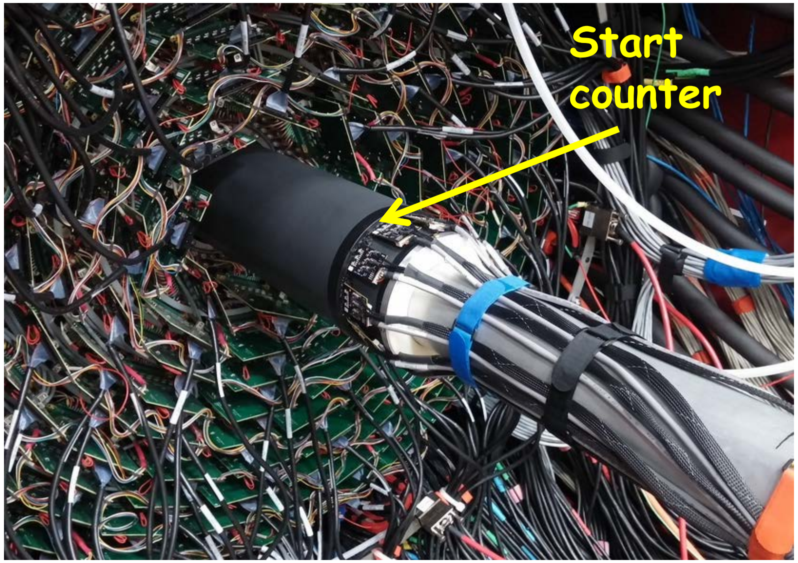
88 scintillator paddles, 2 PMT/paddle

Commissioning with beam: in progress

Start counter - *Florida International U*

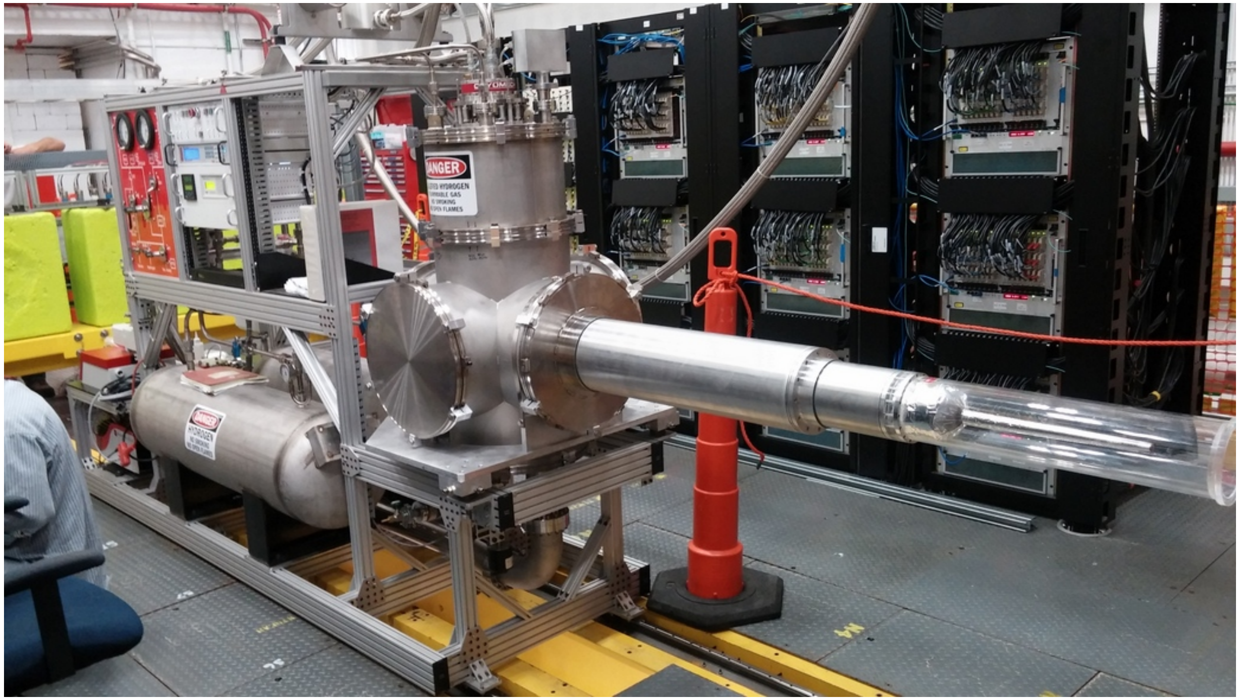
30 bent scintillator counters around the target, SiPM readout

Commissioning with beam: in progress



WBS HIGHLIGHTS: Major Systems

- *LH2 target* Has been commissioned in Hall D: cooled and filled with LH2, then removed and stored in Hall D
- *Solid targets* are used for the initial commissioning

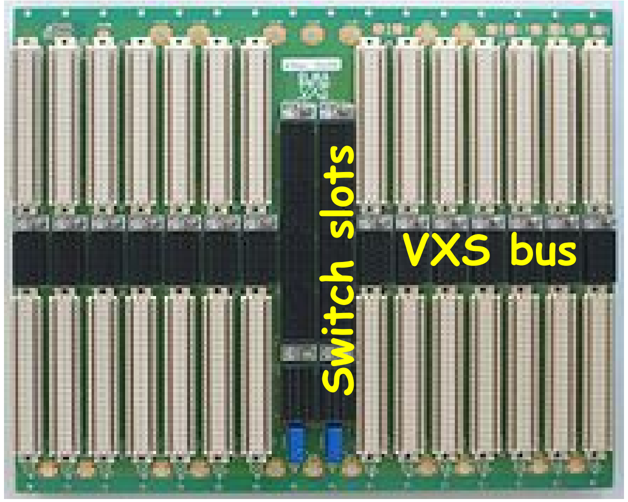


Electronics

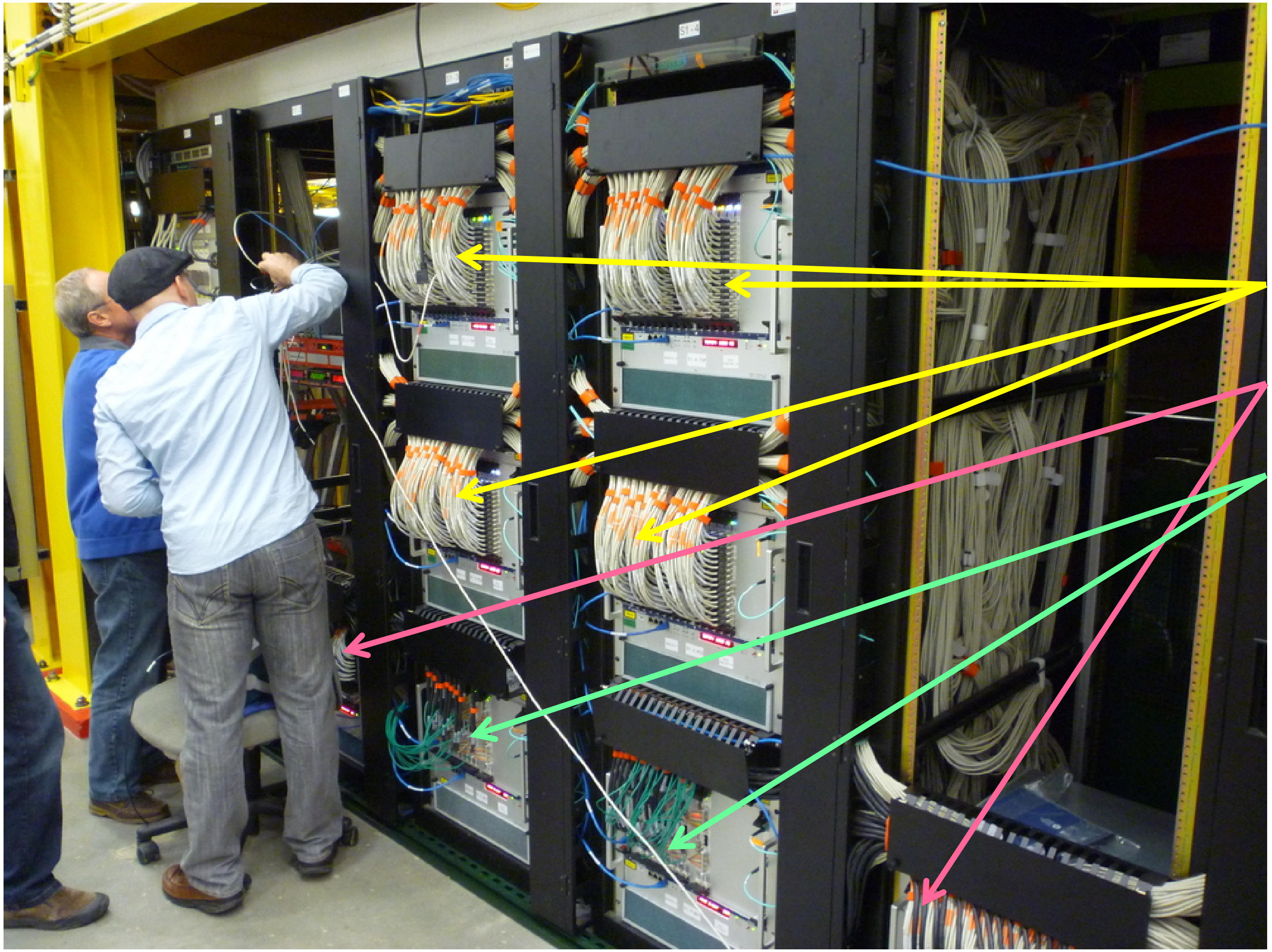
Function	Quantities
ASIC	2034
Preamp Card	678
FADC125	193
SiPM	4216
FADC250	321
F1TDC	102
CAEN1290AE/Distribution	6/1
Discriminator (LE)	106
Splitter (Chs.)	304 Passive
Trigger Interface – TI/TD	56
Signal Distribution -SD	56
Crate Trigger Processor - CTP	26
Sub-System Processor - SSP	8
Global Trigger Processor - GTP	2
Trigger Supervisor - TS	1
Trigger Distribution – TI/TD	7
VME Crates	12
VXS Crates	57
Cockcroft- Walton Bases	2800
HV Modules	39
HV Chassis	7
LV Modules	46
LV Chassis	8
LV Distribution (FDC,CDC,BCAL)	6 + 4
Racks	52

ROC (Readout Controller) ***60***

- Fully pipelined electronics latency ~ 3.5 μs
- VXS – *VMEBus Switched Serial* crates and electronics boards
- Trigger and clock: VXS
- Trigger logic: FADC→VXS→CTP
- ***Status:*** **Commissioning with beam: in progress**



Electronics for Calorimeters



JLab

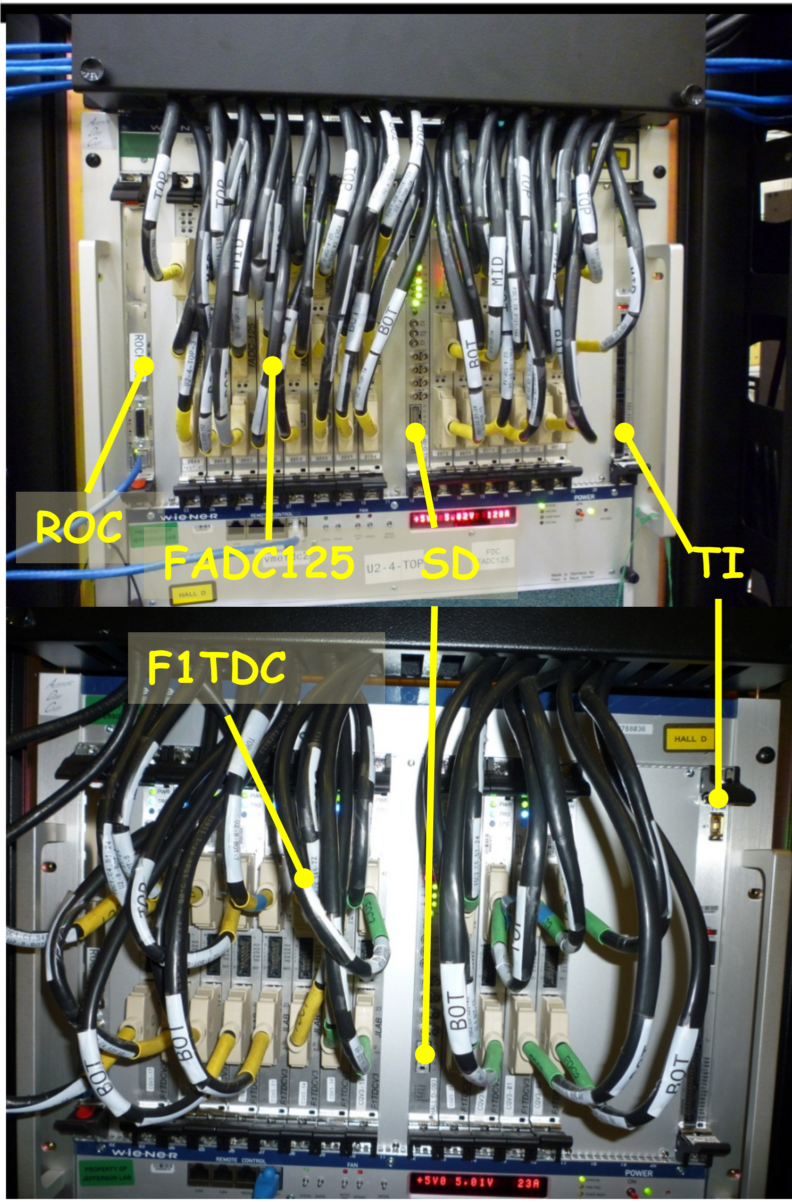
BCAL electronics (one half)

FADC-250 MHz VXS

Discriminators VME

TDC VXS

Electronics for Drift Chambers

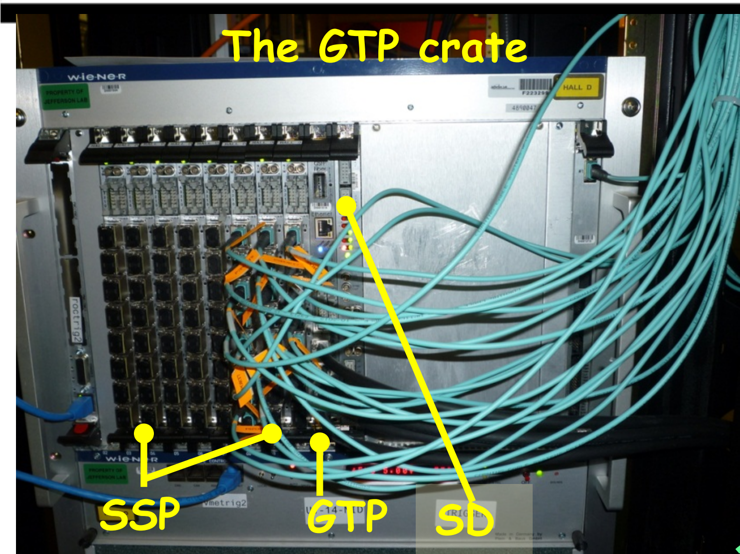


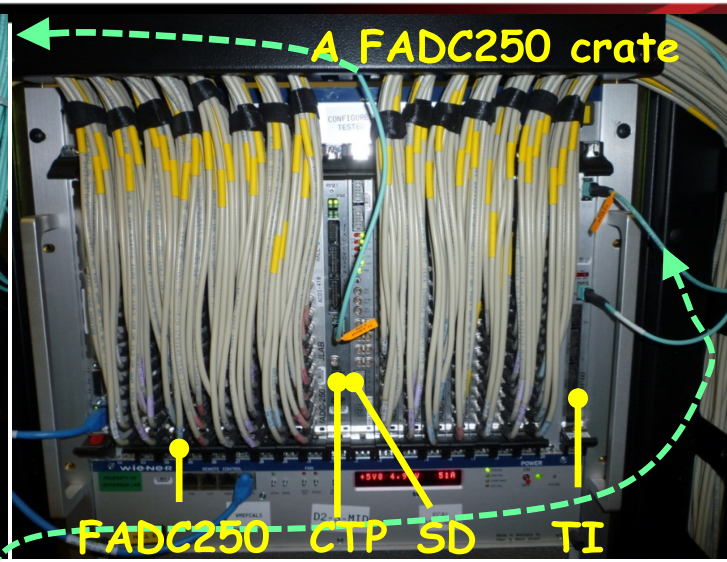
- FADC-125MHz 12bit 72 channels/module
- F1TDC 48 channels/module

Issues with FADC-125 MHz:

- Manufacturer: insufficient QA for soldering the FPGA chips
- FADC-125MHz 10% (40/400) of the boards were rejected → no spares (2 boards in one module)
- About 10 other modules are unstable (timeouts, depends on the firmware timing)
- Mitigation plan: 25 more modules ordered, ready by March 2015

Trigger

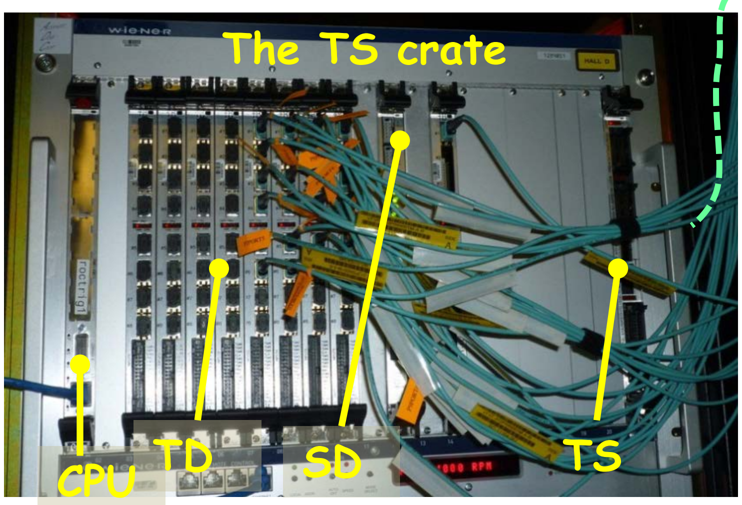




VME/VXS

All the modules designed at JLab

All installed



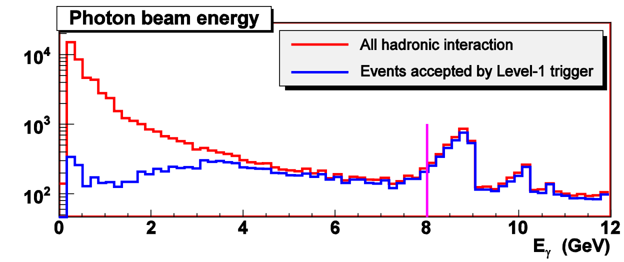
- FADC-250MHz 12bit 16 channels/module
- TI: Trigger Interface module
- SD: Signal Distribution module
- CTP: Crate Trigger Processor
- SSP: Sub-System Processor
- GTP: Global Trigger Processor
- TS: Trigger Supervisor
- TD: Trigger Distribution module

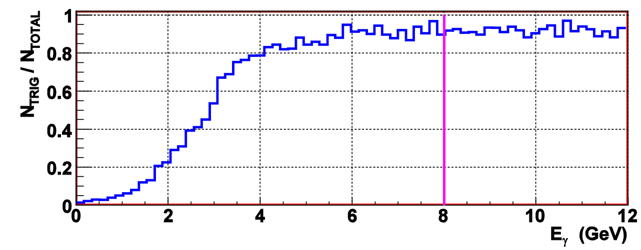
Trigger delay ~ 2.7μs – short enough to read out all crates including those in the tagger hall

Beam commissioning: in progress

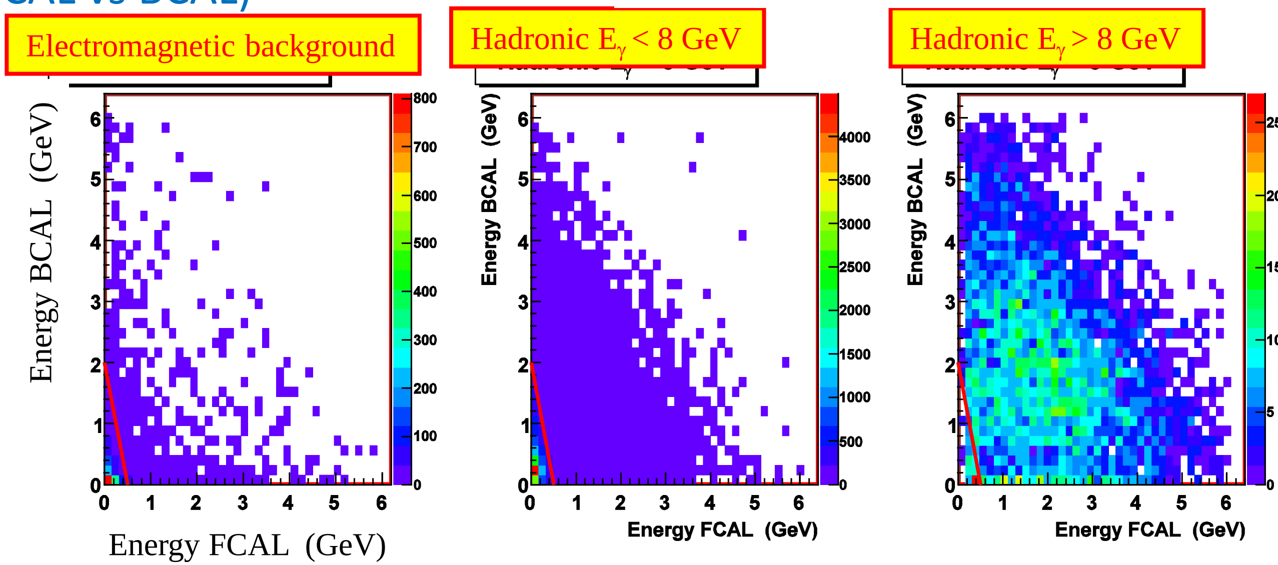
Trigger algorithm, DAQ

- Goal: accept all photoproduction at E_γ>8 GeV
- Main BG: electromagnetic interactions
- GlueX-I: beam 10MHz/GeV ≈ 2kHz photoproduction
  - Level-1 → 20 kHz → ROC → Tape (300 MB/s)
- GlueX-II: beam 100MHz/GeV ≈ 20kHz photoproduction
  - Level-1 → 200 kHz → ROC → Level-3 →20 kHz →Tape
- Trigger algorithm: Energy(FCAL vs BCAL)





- Various steps tested separately
- **Beam commissioning: in progress**



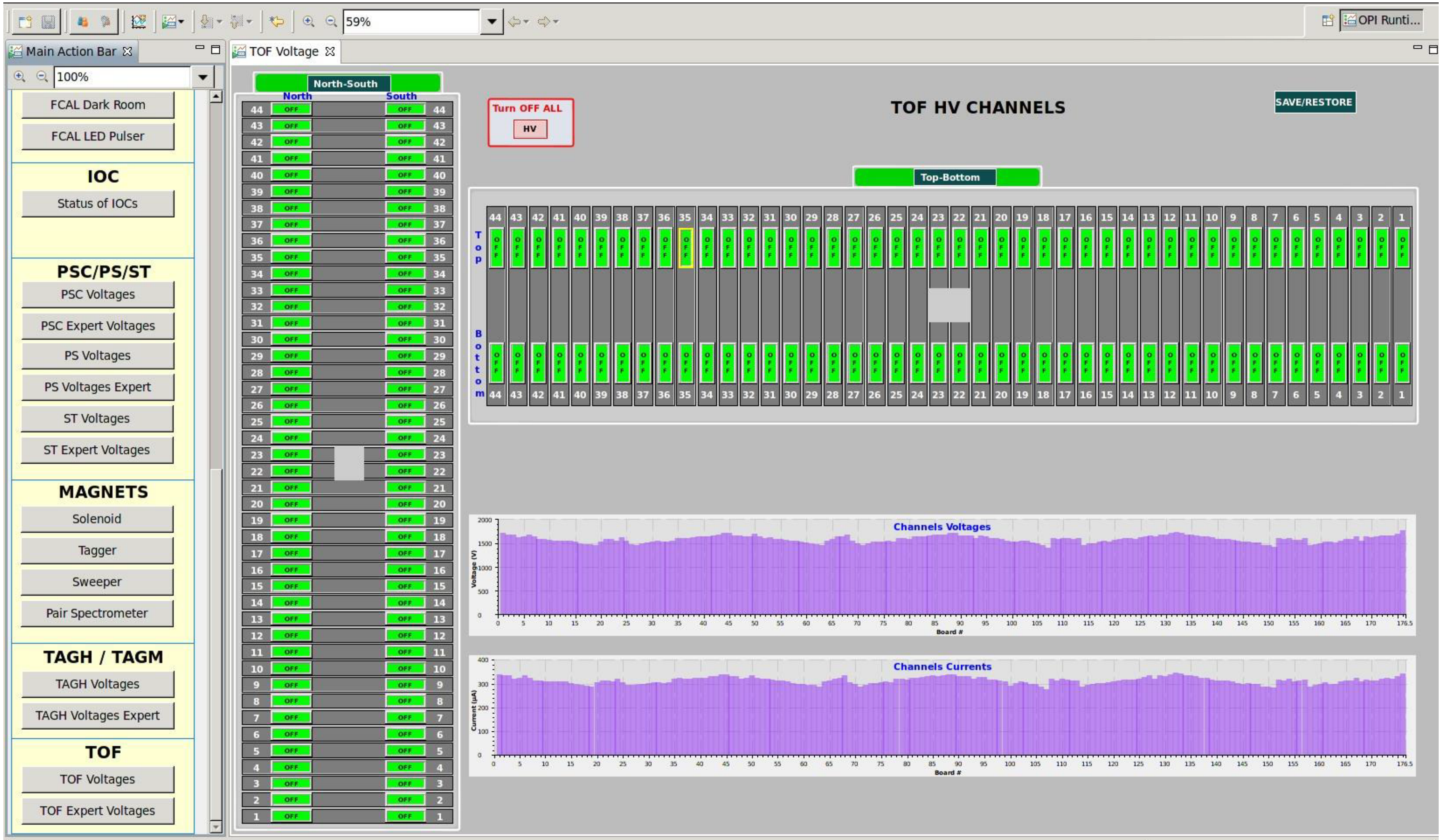
Online and Slow Control

- Counting house equipped
- Online computers running
- Slow control tasks (HV, magnets, slides, cooling, environmental control, etc.) ready

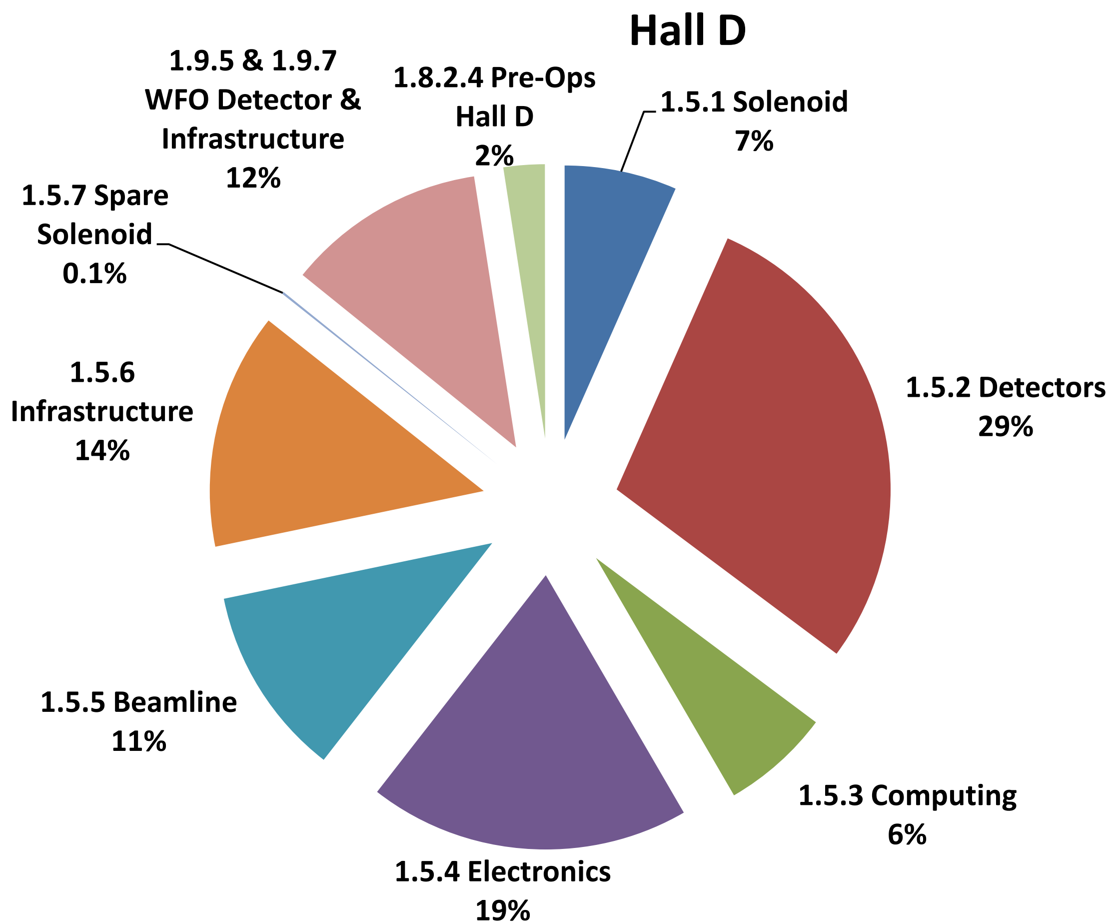
Commissioning with beam: in progress

Example of the Controls GUIs

- *Example:* HV control GUI for TOF



Hall D Construction & Pre-Ops Cost



* 1.9.5 & 1.9.7: WFO (Work for Others) - VA funding

Hall D Construction & Pre-Ops Cost

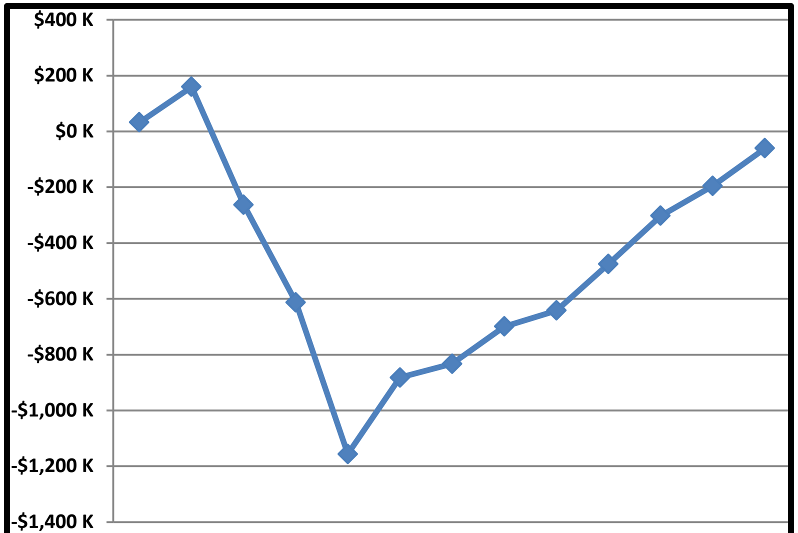
WBS	Hall D	BAC Burdened & Escalated ($K)	% Complete
1.5.1	Solenoid	3,094	100%
1.5.2	Detectors	13,321	100%
1.5.3	Computing	2,985	100%
1.5.4	Electronics	8,826	100%
1.5.5	Beamline	5,233	98%
1.5.6	Infrastructure	6,488	100%
1.5.7	Spare Solenoid	60	100%
1.5.	**Total**	**40,008**	**100%**
1.9.5 & 1.9.7	**WFO Detector & Infrastructure**	**5,484**	**100%**
1.8.2.4	**Pre-Ops Hall D**	**1,141**	**84%**

Hall D: Cost Methodology

Basis of Estimate (BOE)		
	IPR Apr 2014	IPR Nov 2014
Costed	93%	99%
Obligated (including phased)	1%	1%
Quotes from vendors	0%	0%
Catalog price	1%	0%
Estimates from vendors	1%	0%
Previous JLab experience*	3%	0%
Info from other labs, universities, etc.*	0%	0%
Engineering judgment*	1%	0%

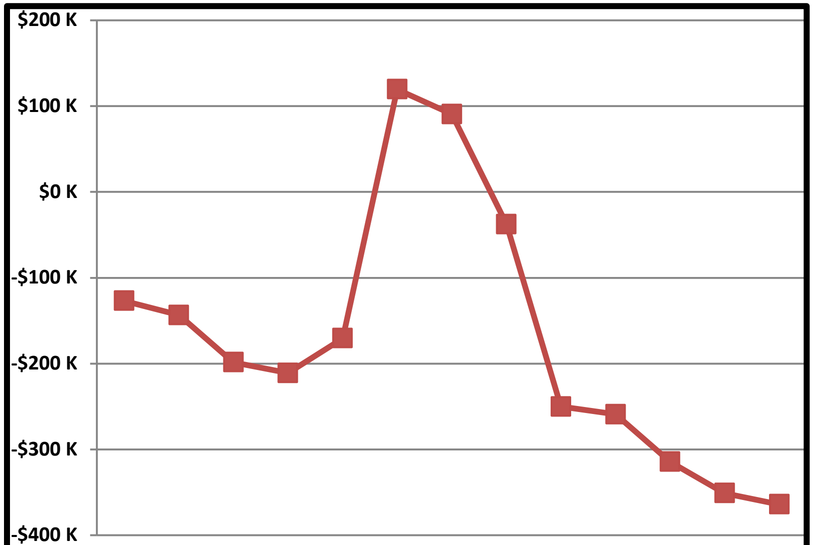
Hall D: CV and SV (Sep-13 to Sep-14)

Schedule Variance



	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14
SV	32	159	-263	-613	-1156	-882	-833	-700	-642	-475	-302	-195	-61

Cost Variance



	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14
CV	-127	-144	-198	-211	-171	120	91	-38	-250	-259	-315	-351	-364

- Jan-Sep 2014 – recovered from a substantial schedule variance

Hall D: Cost Variance (FY14$K)

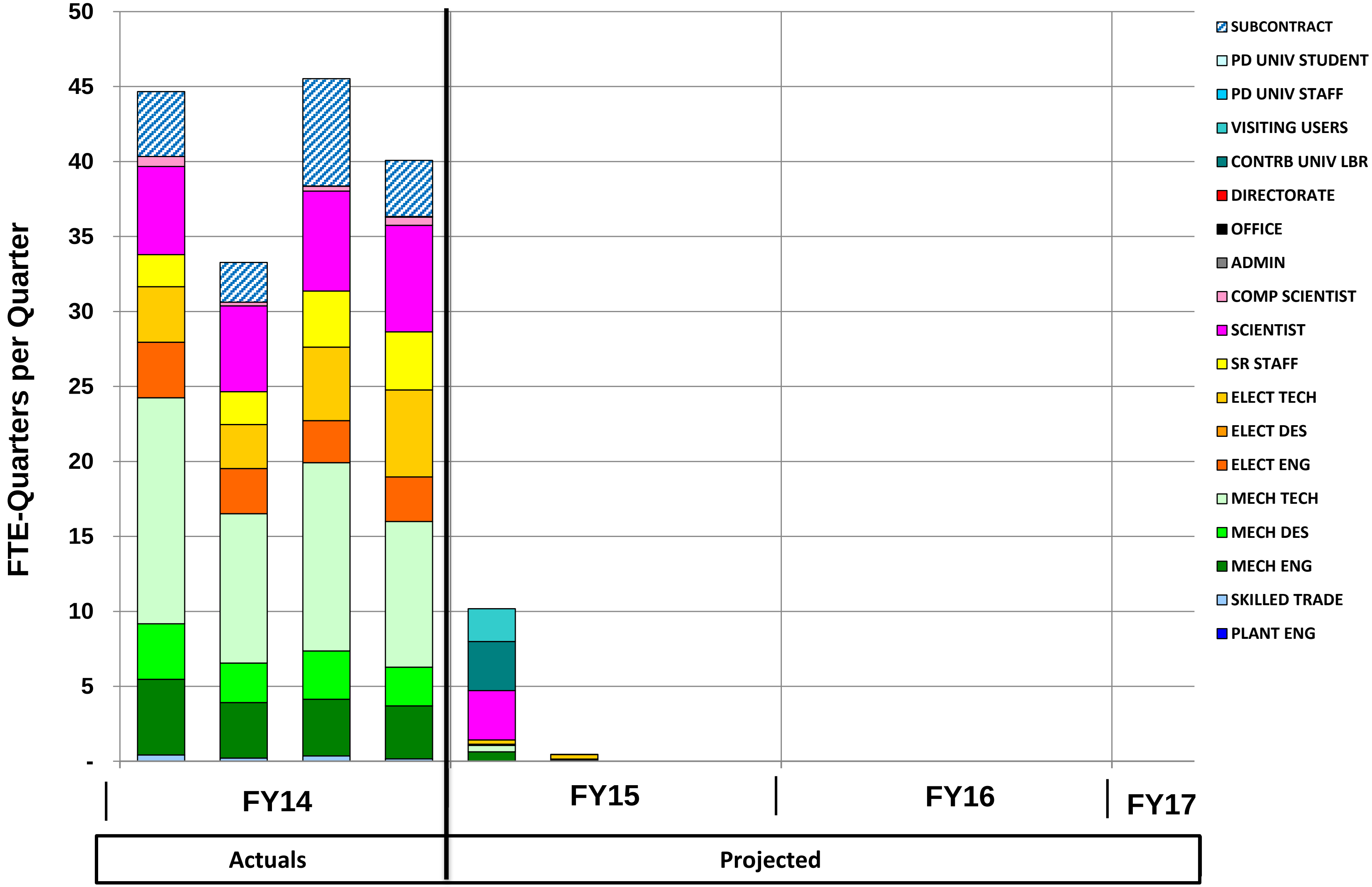
WBS	Hall D	1-Sep 2013	30-Sep 2014	Delta	Reason for Variances
1.5.1	Solenoid	0	6	6	
1.5.2.	Detectors	0	51	51	Lower cost of TOF (FSU contract)
1.5.3.	Computing	0	172	172	Optimization of the structure and code
1.5.4.	Electronics	0	-49	-49	Repairs
1.5.5.	Beamline	0	-300	-300	LH2 target (-200), detectors support/testing (-50)
1.5.6.	Infrastructure	0	-244	-244	Shielding, survey & alignment, AC power
1.5.7.	Spare Solenoid	0	0	0	
1.5.	**Total Construction**	**0**	**-364**	**-364**	
1.8.2.4	Hall D Checkout & Beam Commissioning	0	-70	-70	Solenoid testing
1.9.5 & 1.9.7	Non-DOE	0	-68	-68	Infrastructure (space, facilities, equipment rental)
	Total Hall D	**0**	**-503**	**-503**	

Hall D: Estimate To Complete (AY$K)

WBS #	Name	Open Obligations	Remaining Obligations Including Cv	ETC Total		Remaining Scope/Rationale
1.5.1	Solenoid	0	0	0		Closed Account
1.5.2	Detectors	10	0	10		Closed Account
1.5.3	Computing	17	0	17		Closed Account
1.5.4	Electronics	170	0	170		**Replacement FADC125 (PO)**
1.5.5	Beamline	87	41	128		**Diamond thinning (UConn)**
1.5.6	Infrastructure	46	0	46		**Shielding blocks, polarimeter installation**
1.5.7	Spare Solenoid	0	0	0		Closed Account
1.5	**Hall D Construction Total**	**330**	**41**	**371**		
1.8.2.4	**Hall D Pre-Ops Total**	**7**	**180**	**187**		**Commissioning with beam**
	Total Hall D	**338**	**221**	**558**		
1.9.5	Non-DOE Hall D	0	0	0		Closed Account
1.9.7	Non-DOE Infrastructure	19	0	19		Closed Account

Closed to new charges

Hall D: Labor by Skills



Includes Pre-Ops labor

Hall D: Commissioning with beam

Commissioning with beam Oct 2014 – WBS 1.8.2.4.X

OBJECTIVES: Transport an electron beam with an energy of at least 10 GeV, average current of at least 2 nA, and emittance < 20 nm-rad at tagger radiator (CD4B-VIII).

- Transport photons from the tagger radiator through a collimator to a target within Hall D spectrometer
- checkout of individual detector components with photon beam
- checkout the trigger logic for real events
- checkout all slow-control and monitoring software
- write full events to tape

Reviews

Commissioning readiness was reviewed in 2014:

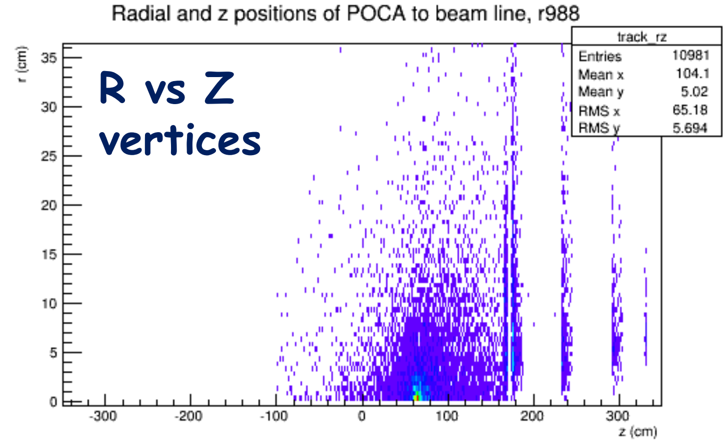
- Jul 2-3 ERR - Experimental Readiness Review (ENP)
- Aug 8-9 Review of the Commissioning Plan (Internal)
- Aug 26-28 ARR Phase 3 – Accelerator Readiness Review (DOE)

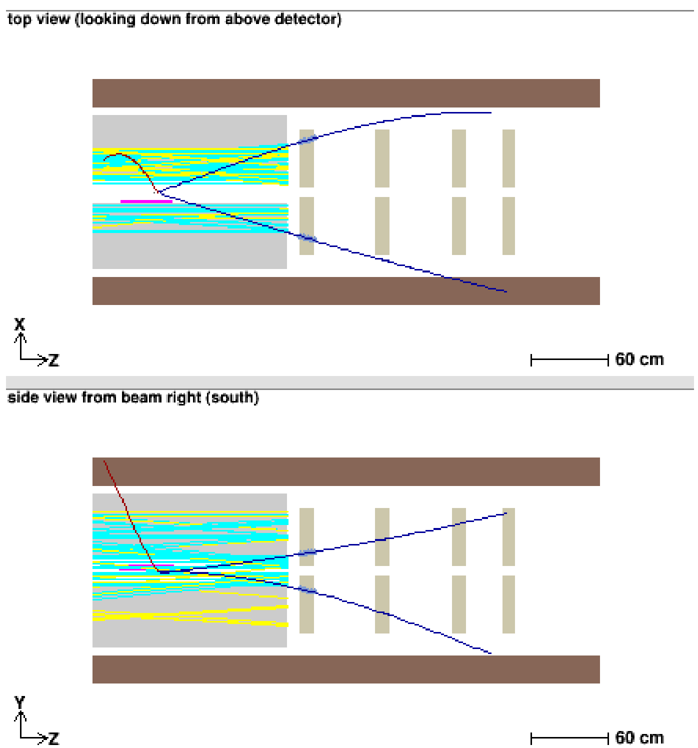
The recommendations have been addressed and implemented

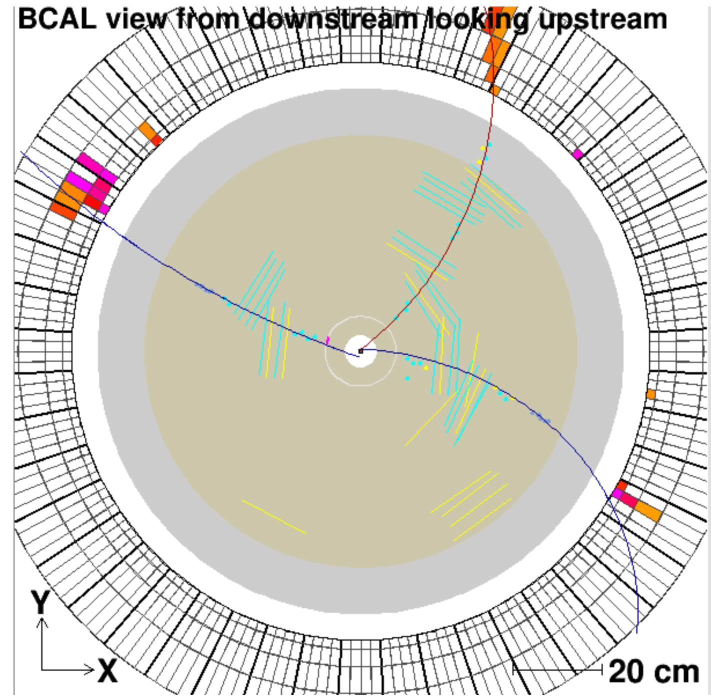
- Oct 16 – ENP Commissioning Readiness Certificate issued
- Oct 27 – Photon beam tune started

Commissioning: Early Data

- Beam through the collimator: tuned
- Trigger: FCAL
- Target: 1cm plastic + air
- Solenoid 1000 A







Recommendations

Recommendation # April 2014 IPR-08:

Carry out a study of the physics impact of running the Hall D solenoid at lower fields.

•“Results should be analyzed and summarized in a document made available to Hall D experimenters. The Monte Carlo study should focus on more than one physics measurement and should address not only reductions in physics sensitivity but also potential increases in running time required to obtain a significant measurement”.

Status:

Study performed for several channels as a function of solenoid current. Optimal current depends on reaction. No overall negative impact from running at 1350A vs 1500A is expected, at least at Stage I of GlueX running. Results were presented at recent GlueX collaboration meeting, and have been published as a collaboration Document (Gluex Doc #2595).

Closed

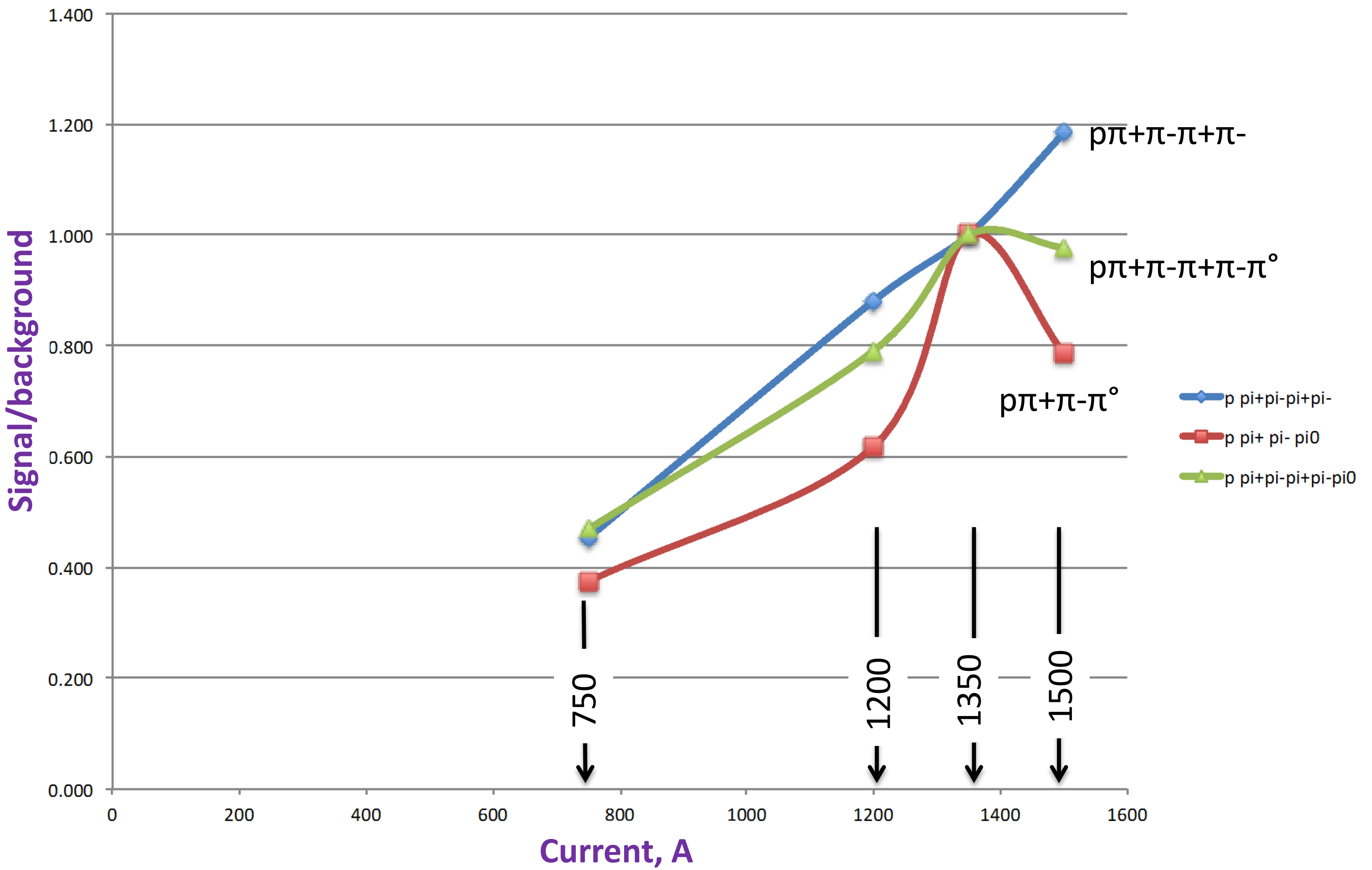
GlueX: Optimization of the solenoid field

A set of studies has been carried out by GlueX collaboration (Gluex Doc #2595).

Effects of a lower field:

- higher physics background (coming from different reactions),
- higher reconstruction efficiency,
- higher pileup in the detectors close to the beam.

Optimal magnetic field for GlueX



GlueX: Optimization of the solenoid field

Conclusions:

- Optimal current depends on reaction. The reactions considered seem equally promising for the GlueX program.
- No overall negative impact from running at 1350A vs 1500A is expected, at least at Stage I of GlueX (at lower intensity).
- At higher intensity (Stage II) the rates in the detectors close to the beam (primarily the FDC) may become too high at lower fields. In such a case the beam intensity has to be reduced. These effects will be studied during Stage I.

Summary

- WBS 1.5: 99.7% complete!
  - The remaining activities: contract with UConn – diamond thinning (by April 2015), polarimeter installation (February 2015), assembling and testing the replacement 25 modules of FADC125MHz

- WBS 1.8.2.4 (pre-ops): 84% complete
  - The remaining activities: Commissioning with beam (by mid-Dec 2015)

- CV expected at completion: -$570k (CPI=91%)

- Beam commissioning in progress. All the systems are functional.