U.S. DEPARTMENT OF ENERGY | Office of Science | JSA

OPS 2015 StayTreat

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Accelerator Div.
Jefferson Lab

Operations Session

Jefferson Lab
Thomas Jefferson National Accelerator Facility

OPS StayTreat Goals

The purpose of this two day workshop is to provide a forum for presentations and discussions on CEBAF operations during the recent commissioning operations. The presentations should present a balance of successes and shortcomings, with the ultimate goal of improving CEBAF operations, prepare for the challenges of 12GeV operations and establishing routine multi-user operations at the 12GeV design energy.

Additional items to be addressed during the workshop include, improving user<->OPS<->Eng communications, reducing the duration for CEBAF restoration and configuration change, reducing the duration for Hall setup, improving CEBAF reliability, and regaining the confidence of the user community that CEBAF and OPS can support the experimental program.

Outline

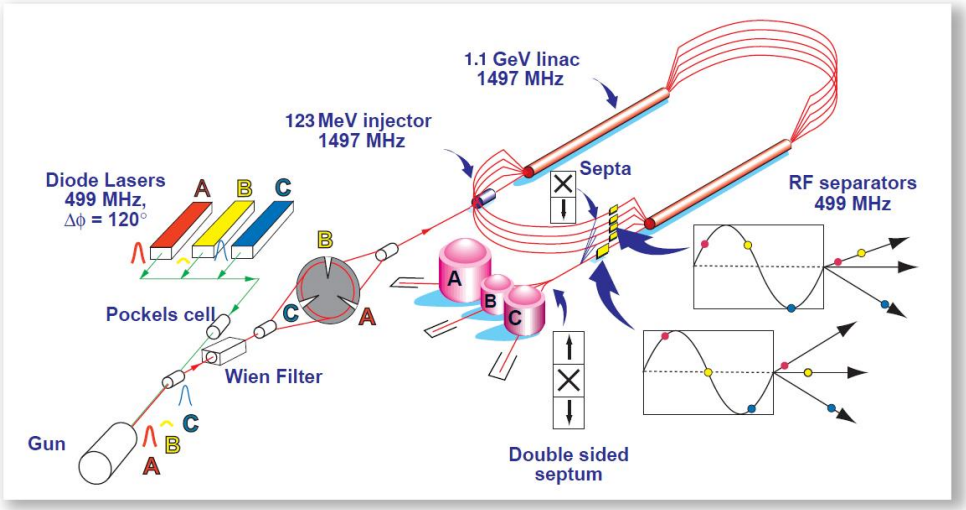
- Accelerator Operations Overview
- 12GeV Upgrade
  - Overview
  - Beam Commissioning to date
- Plans for Beam Operations at Design Energy
  - Summer 2015 Shutdown Tasks
  - Gradient Maintenance and Helium Processing
  - Fall 2015 Beam Plan
- Summary/Agenda

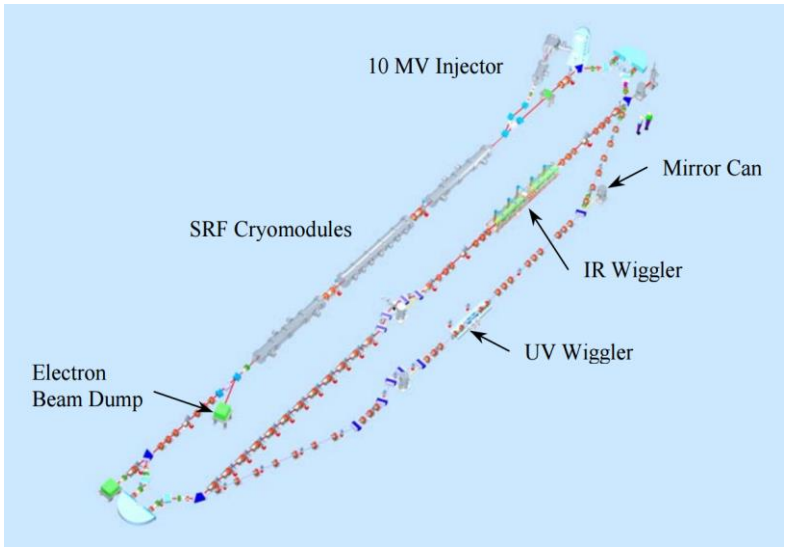
Accelerator Mission

Operate and upgrade the JLab accelerator facilities

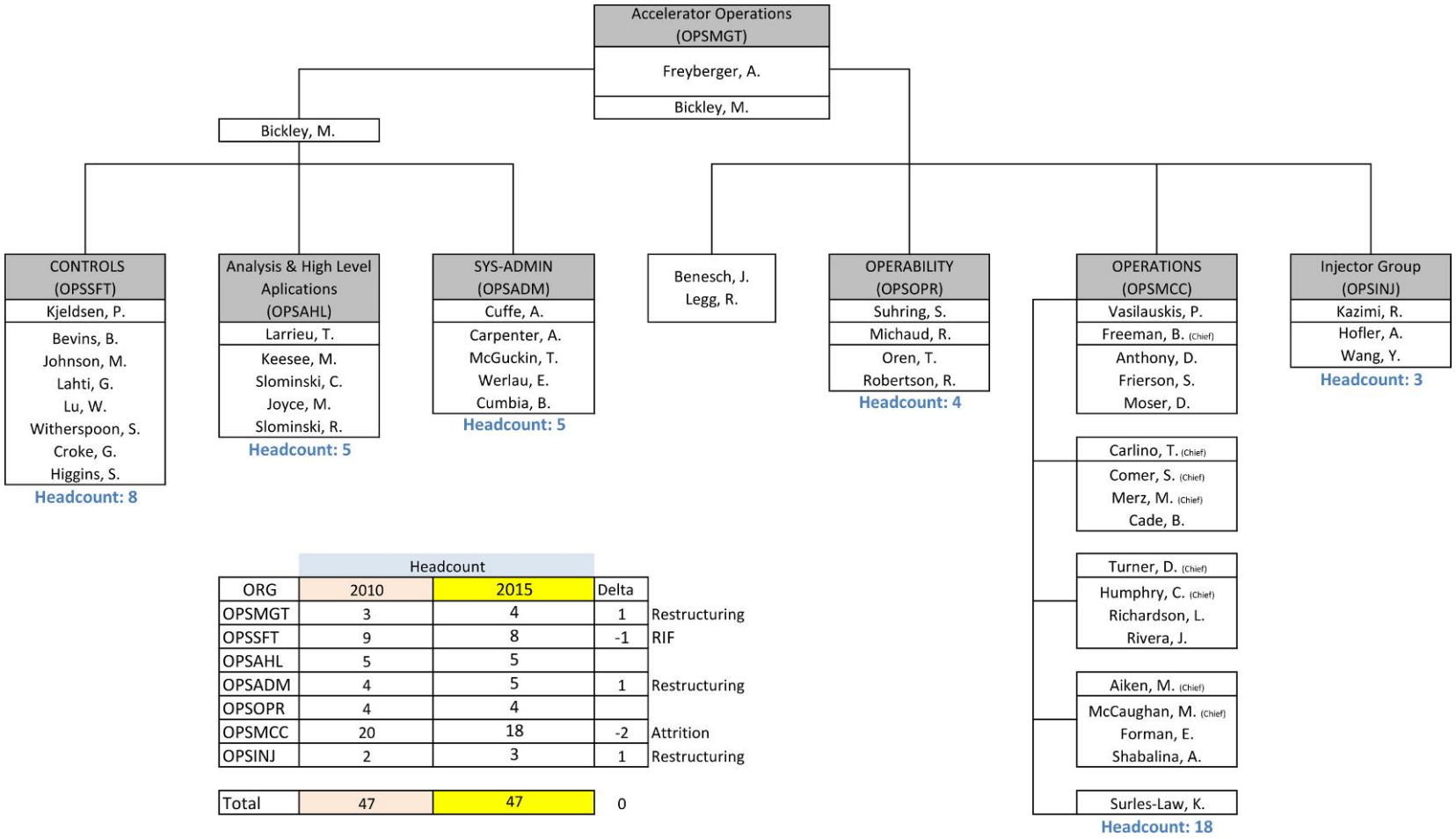
JLab accelerator facilities:

1. CEBAF, Continuous Electron Beam Accelerator Facility
2. LERF, Low Energy Recirculator Facility (formerly called the FEL).





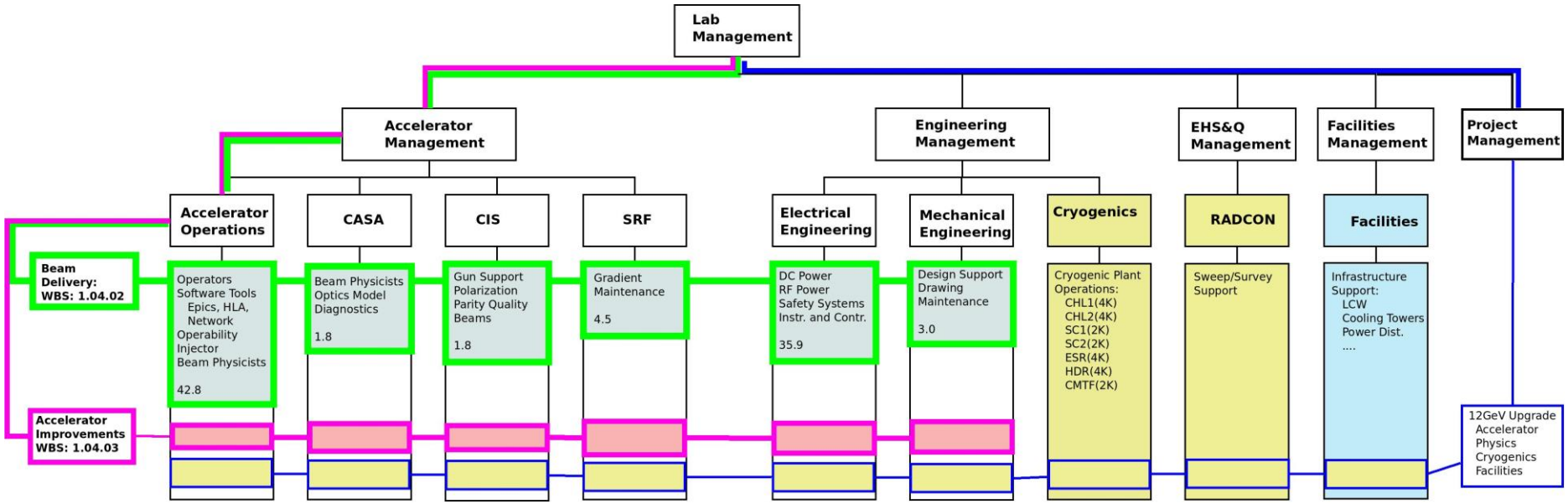
Operations Department



	Headcount			
ORG	2010	2015	Delta	
OPSMGT	3	4	1	Restructuring
OPSSFT	9	8	-1	RIF
OPSAHL	5	5		
OPSADM	4	5	1	Restructuring
OPSOPR	4	4		
OPSMCC	20	18	-2	Attrition
OPSINJ	2	3	1	Restructuring
Total	47	47	0	

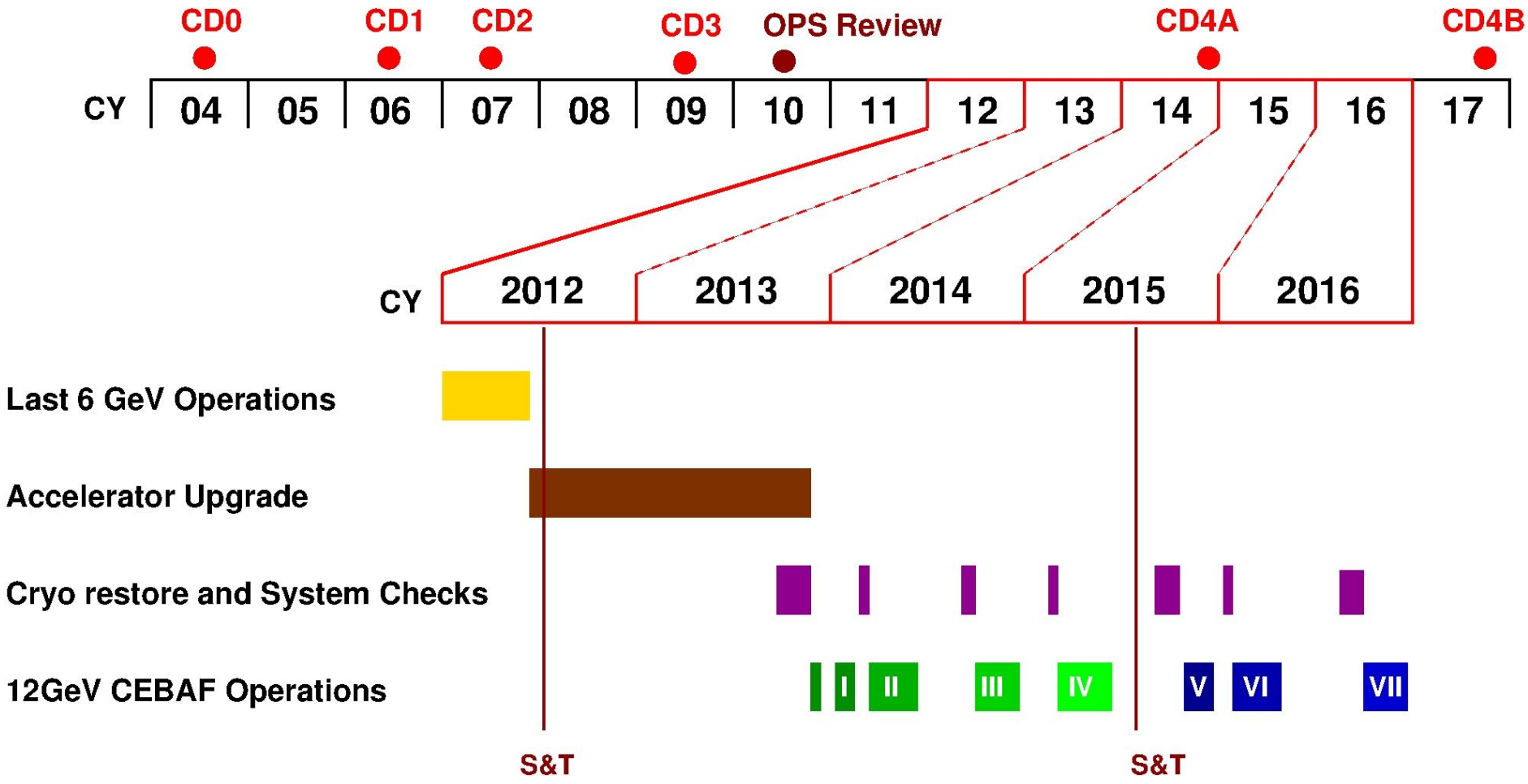
Presently have one open operator position

CEBAF Beam Delivery(WBS)



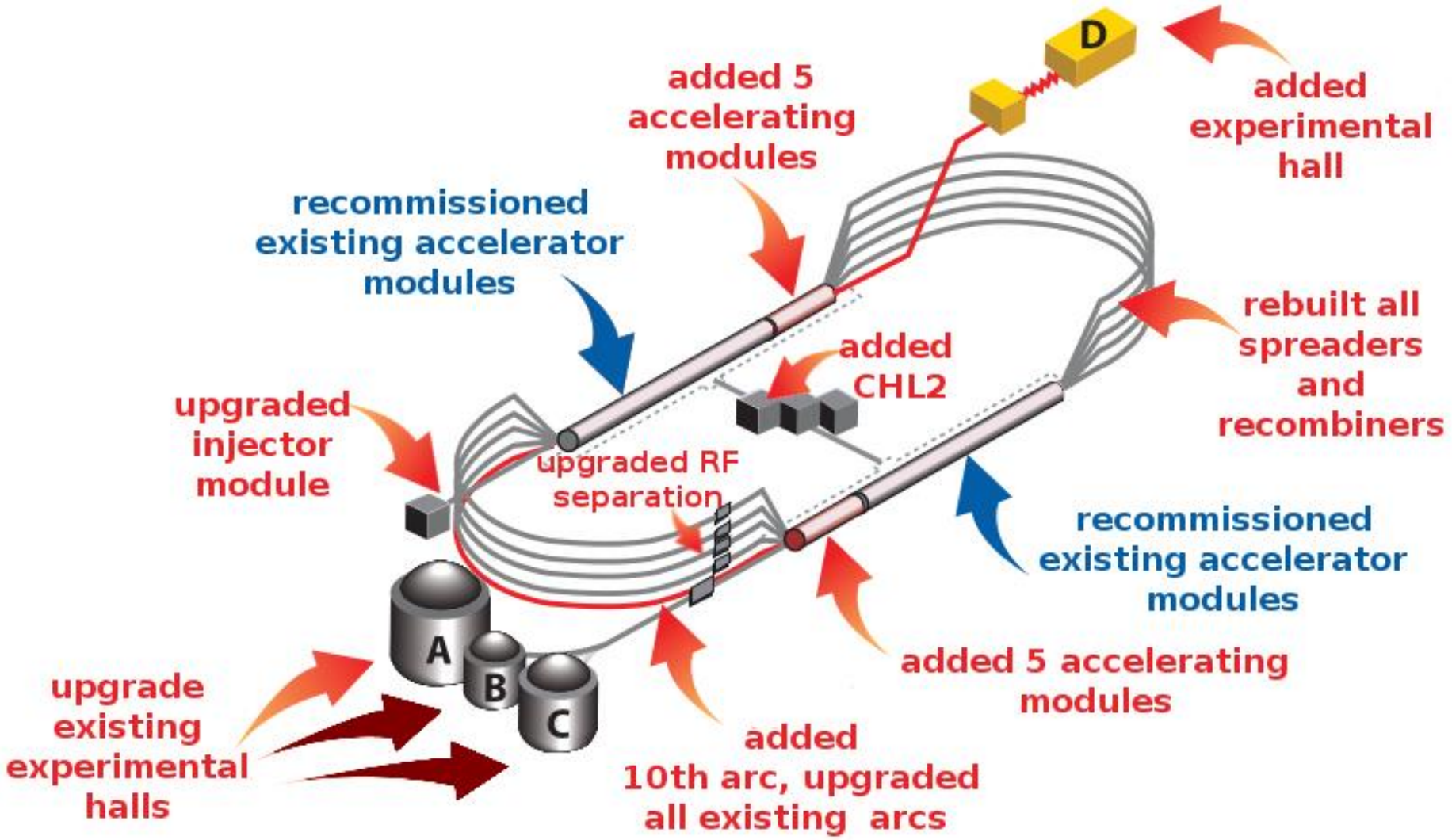
- 90 FTE (Beam Delivery 1.04.02) for FY15
- Work plans are developed each year to account for:
  - Operating weeks
  - Expected machine performance
  - Preventative maintenance tasks

12GeV Timeline



First extensive S&T review in the 12GeV era, mini-S&T reviews held in 2013 & 2014

12GeV Upgrade Overview



First Beam Operations

Run I (E_{pass} = 2.2GeV)

- 2013-Dec-13 to 2014-Feb-06
- Establish 1-pass beam
- **12GeV Project KPP**: 2.2 GeV/pass of energy gain

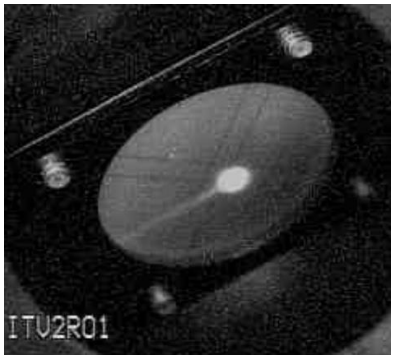
Run II (E_{pass} = 2.0GeV)

- 2014-Mar-07 to 2014-May-11
- **12GeV Project KPP**: 5.5 pass beam to the Hall-D dumplet
- **Operations Goal**: Demonstrate full injection energy (123 MeV)
- **Operations Goal**: First multi-pass beams in the 12 GeV era
- **Operations Goal**: CW operations to Hall-A, 3-pass beam with E>6 GeV

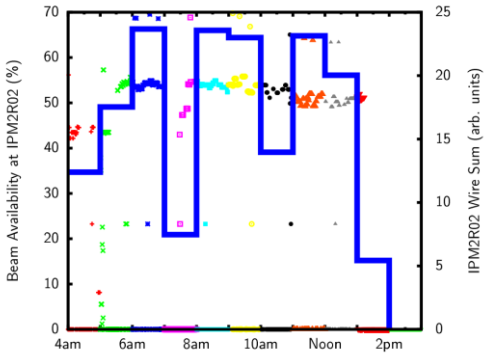
Run I

2.2 GeV/pass
2014-02-05

Beam Arc2 viewer



Availability > 50%, 8h run



12GeV Project KPP Achieved

Linac	Type	<E_{maxOPS}> (MV)	2014-Feb <GMES> (MV)	$\frac{<GMES>}{E_{maxOPS}}$ (%)
NL	C20	8.61	7.19	84
NL	C50	11.71	11.03	94
NL	C100	20.86	17.59	84
SL	C20	9.09	7.05	78
SL	C50	11.55	10.06	87
SL	C100	19.77	16.66	84

- E_{maxOPS}: maximum gradient during commissioning
- GMES: Operational gradient
- Majority of downtime due to C20 trips

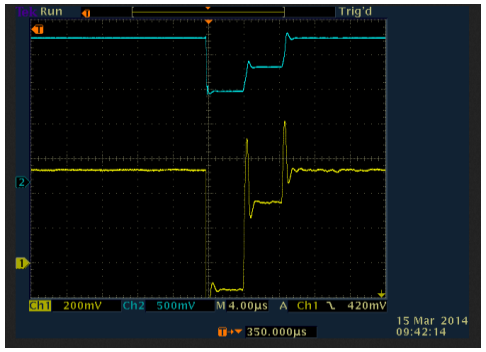
Based on this and other data from Spring2014 operations, the estimated maximum 5.5pass energy with less than 10 trips per hour is:

- 11.25 GeV, or 6% below design, or 2.05GeV/pass.

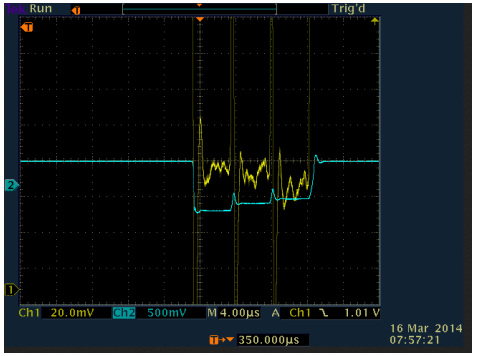
Run II: Milestones

Multi-pass (3-passes)
2014-03-15

Initial 1st to 2nd pathlength difference

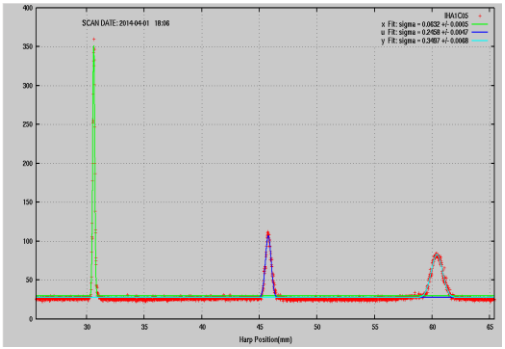


1st,2nd,3rd pass pathlength difference after MO adjustment + arc offsets

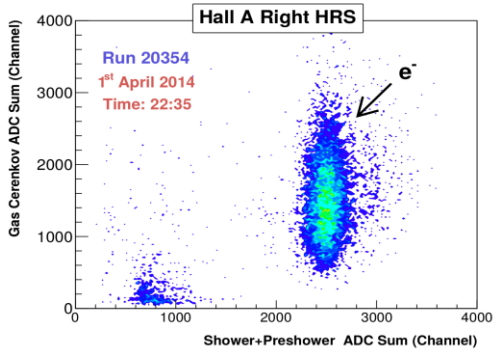


>6 GeV to Hall A
2014-04-01

Beam profile in A line

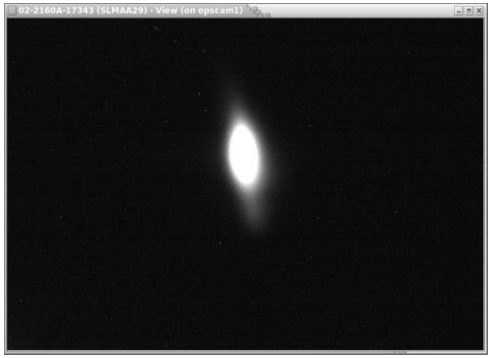


Elastic events in A Spectrometer

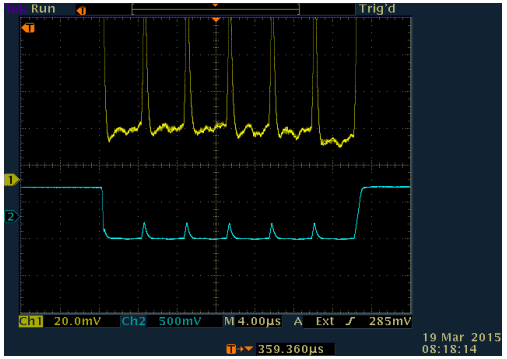


5.5 Pass Beam
2014-05-09

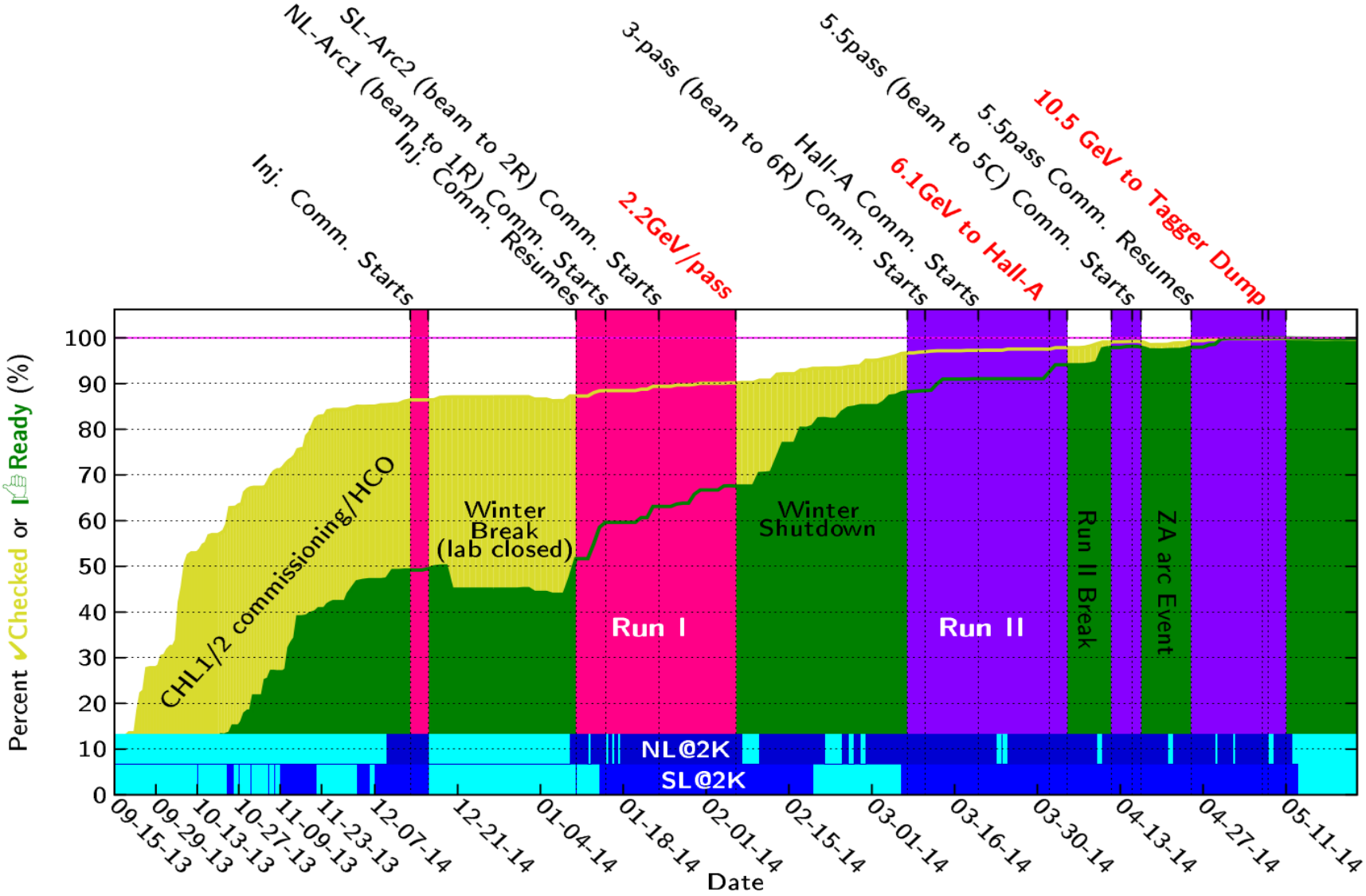
Synchrotron Light in Arc10



6-beams in North Linac



Run I and II Progression

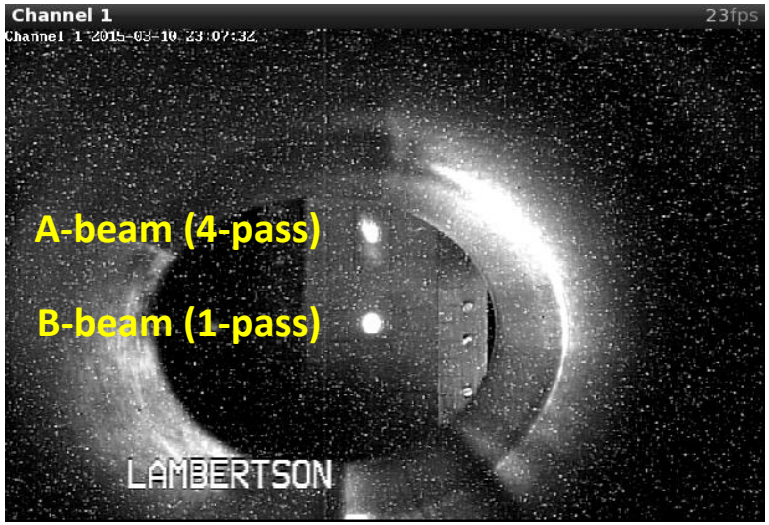


Run III (E_{pass} = 1.8GeV)

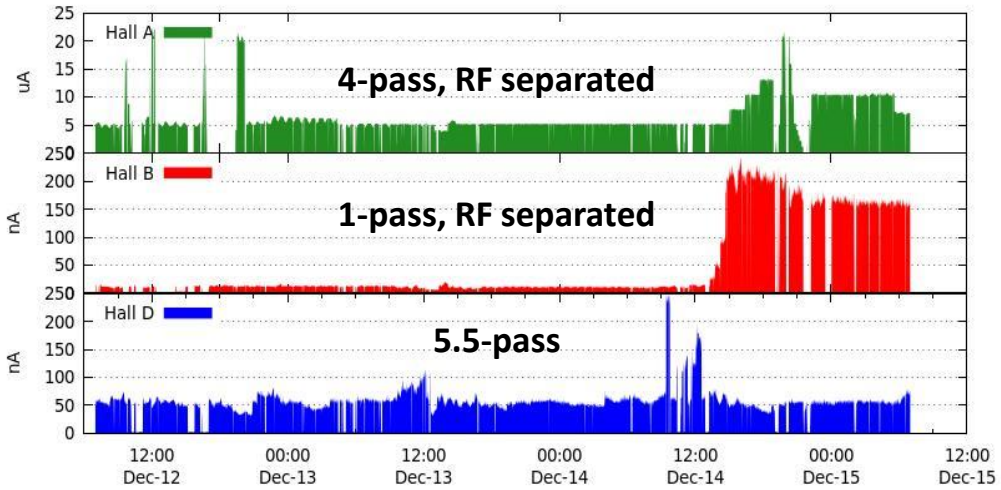
2014-Oct-08 to 2014-Dec-21

- CW beam, E>10 GeV, 5.5pass beam to Hall-D
- First photons into the new experimental hall
- **12GeV Project KPP**: Hall-D detector commissioning
- **Operations Goal**: RF separation (1-4 pass), first simultaneous multiple users in the 12GeV era
- **Operations Goal**: Establish 2-hall operation

Separated beams on beam viewer



Sustained 3-Hall operations



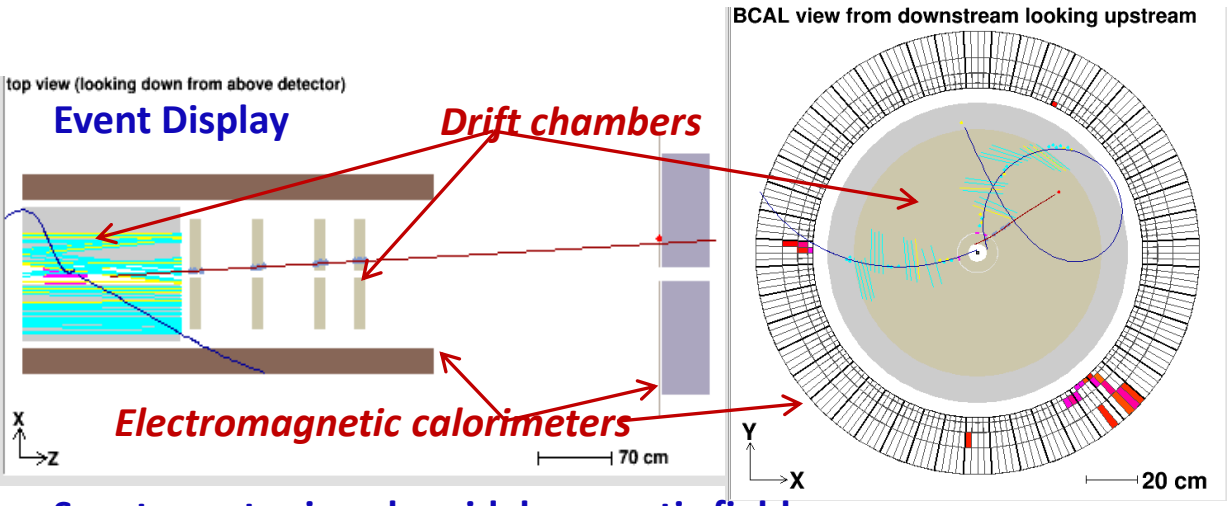
Hall D Commissioning

- Hall D: facility for experiments using linearly polarized photon beam
- Main goal: search for gluonic excitations in light meson spectra (GlueX experiment)
- Photon beam line + large acceptance spectrometer for charged particles & photons
- Commissioning with beam Nov. & Dec. 2014
  - **Program Goals** demonstrated

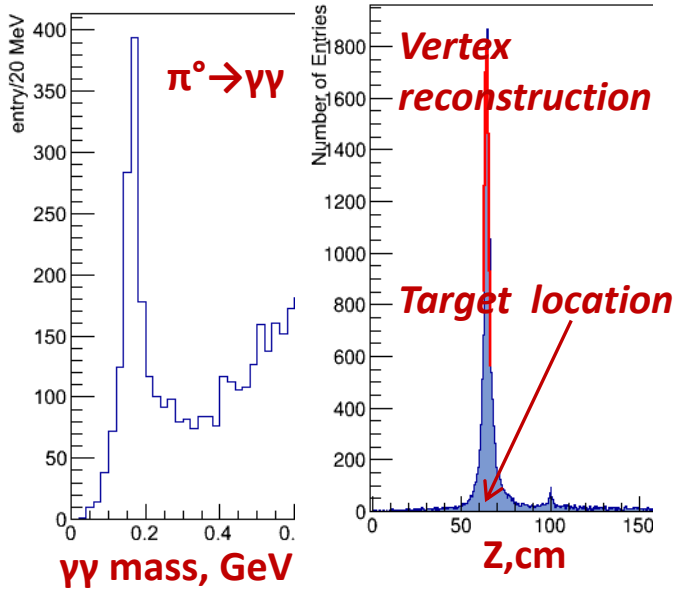
Results with preliminary detector calibration and alignment

Neutral particles reconstruction

Charged particles tracking



Spectrometer in solenoidal magnetic field

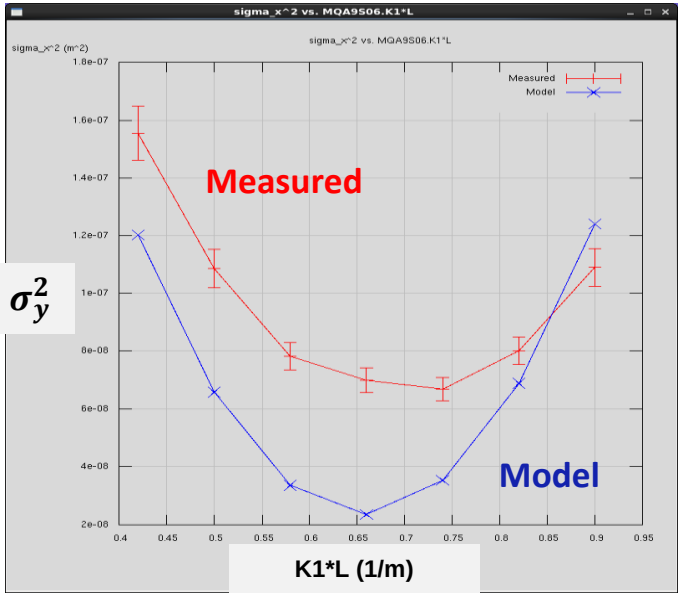


Run IV (E_{pass} = 1.9GeV)

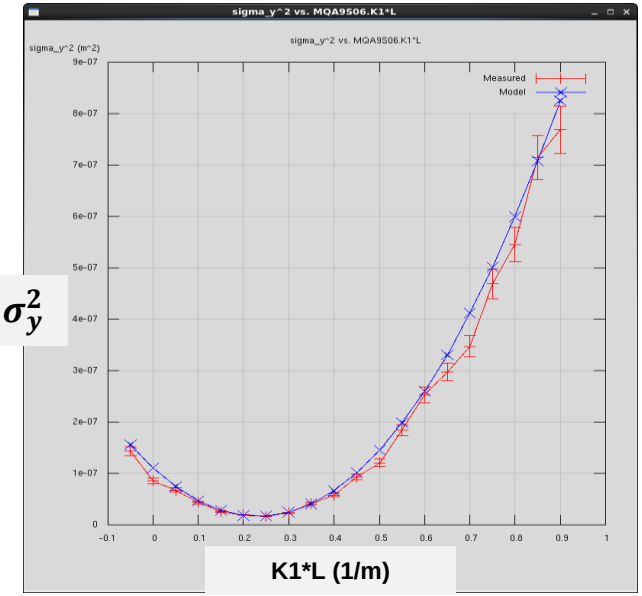
2015-Feb-13 to 2015-May-18

- Commission new 249.5 MHz laser/injector configuration
- Commission new 750 MHz 5-pass separators
- Exercise new setup process and associated tools: New beam matching process
- Establish baseline emittance and bunch length evolution
- Support ~5wk “early Physics” Operation

Quad Scan: Before match



Quad Scan: **After** match



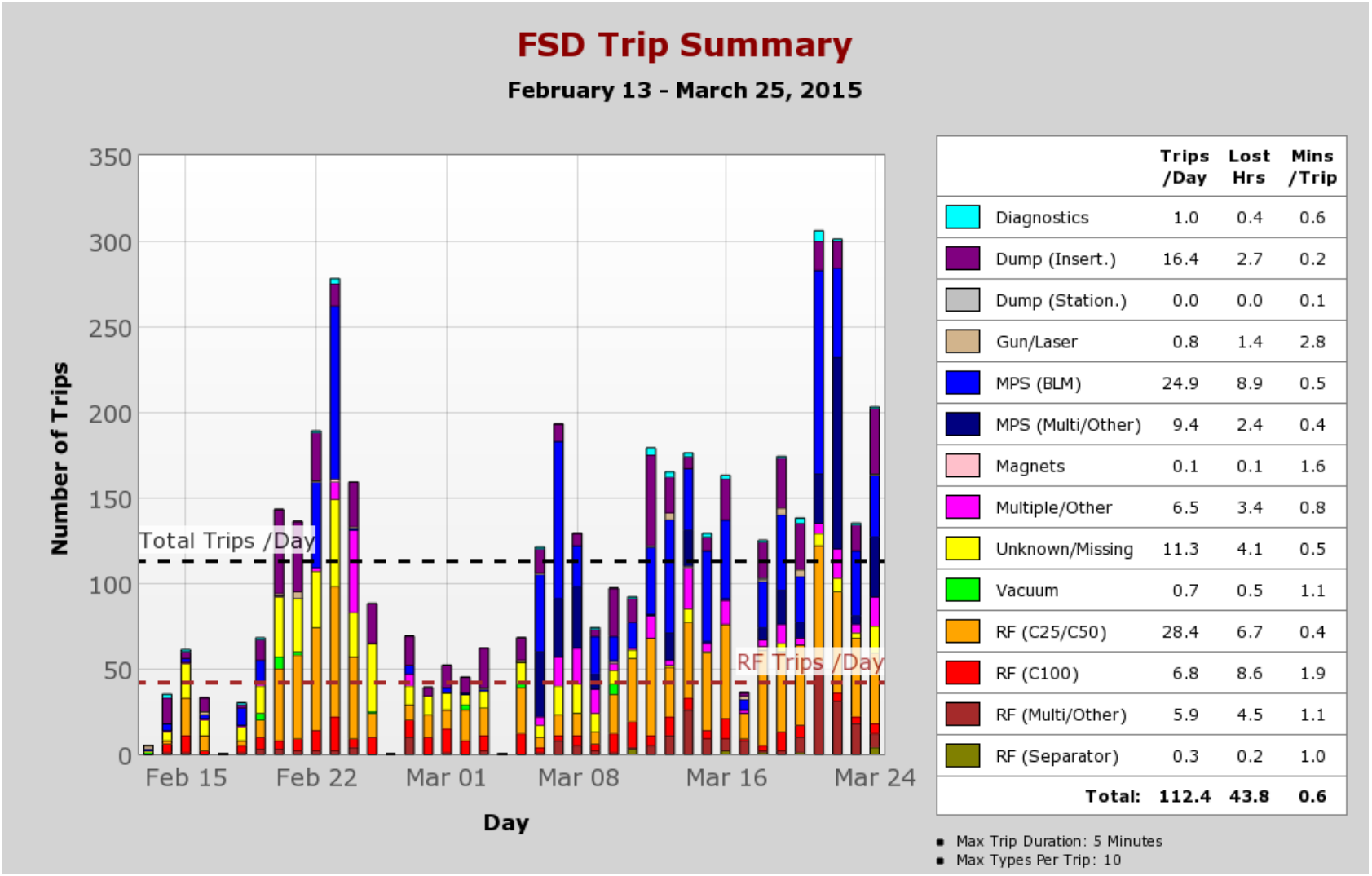
Beam Emittance Evolution at 1.9GeV/pass

Table 3: Model and Measured Emittances (11 GeV)

Region	Model $\varepsilon_x, \varepsilon_y$ [nm-rad]	Measured $\varepsilon_x, \varepsilon_y$ [nm-rad]
Chicane	4.00 4.00	2.5±0.9 1.9±0.6
Arc 1	0.41 0.41	0.43±0.04 0.32±0.05
Arc 2	0.26 0.23	0.50±0.10 0.31±0.10
Arc 3	0.22 0.21	0.63±0.05 0.72±0.07
Arc 4	0.21 0.24	0.81±0.07 0.65±0.10
Arc 5	0.33 0.25	--- ---
Arc 6	0.58 0.31	0.48±0.05 0.66±0.04
Arc 7	0.79 0.44	--- ---
Arc 8	1.21 0.57	1.1±0.1 1.0±0.1
Arc 9	2.09 0.64	3.1±0.2 1.9±0.3
Arc 10	2.97 0.95	2.4±0.3 1.7±0.4

Presented at IPAC15: Satogata (WEBD1), more beam physics later today.

Tracking Performance: Beam Trips



	Trips /Day	Lost Hrs	Mins /Trip
Diagnostics	1.0	0.4	0.6
Dump (Insert.)	16.4	2.7	0.2
Dump (Station.)	0.0	0.0	0.1
Gun/Laser	0.8	1.4	2.8
MPS (BLM)	24.9	8.9	0.5
MPS (Multi/Other)	9.4	2.4	0.4
Magnets	0.1	0.1	1.6
Multiple/Other	6.5	3.4	0.8
Unknown/Missing	11.3	4.1	0.5
Vacuum	0.7	0.5	1.1
RF (C25/C50)	28.4	6.7	0.4
RF (C100)	6.8	8.6	1.9
RF (Multi/Other)	5.9	4.5	1.1
RF (Separator)	0.3	0.2	1.0
Total:	**112.4**	**43.8**	**0.6**

- Max Trip Duration: 5 Minutes
- Max Types Per Trip: 10

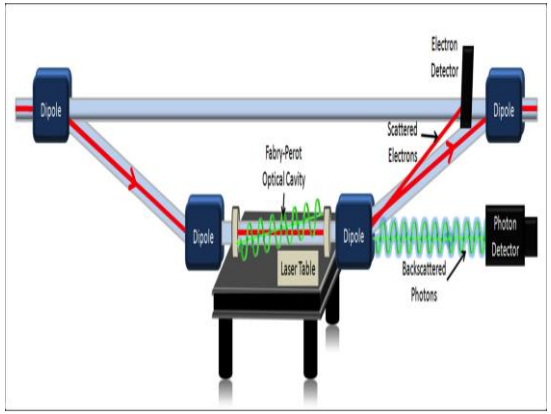
CEBAF Reliability

	Scheduled Weeks	Operated Weeks	Reliability Target	Reliability Achieved	
FY14	13	10.3	50	48	
FY15	18	19.7	58	68	Received additional funds for more operating weeks
FY16	16		66		
FY17	27		70		
FY18	27		74		
FY19	28		78		
FY20	28		82		
FY21	28		85		

- Long term schedule is based on “Cost of Living” scenario.
- Additional funding will generally add more operating weeks and may also result in an increase to the reliability target.
- Reliability session this afternoon
- Metrics presentation on Friday

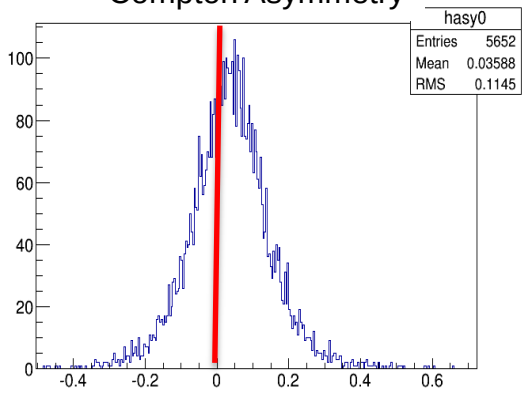
Three Hall Program: (E_{pass}= 1.0 GeV)

Hall-A: Commissioning e- polarimeters

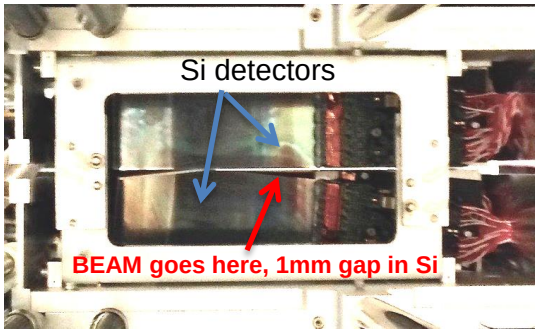


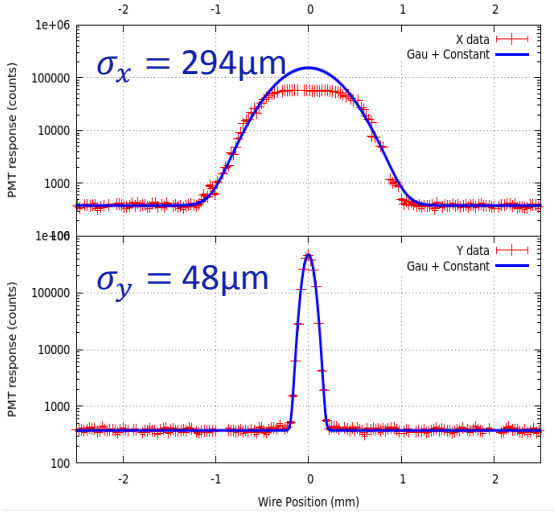
$$A_{Raw} = \frac{N_+ - N_-}{N_+ + N_-}$$

Compton Asymmetry

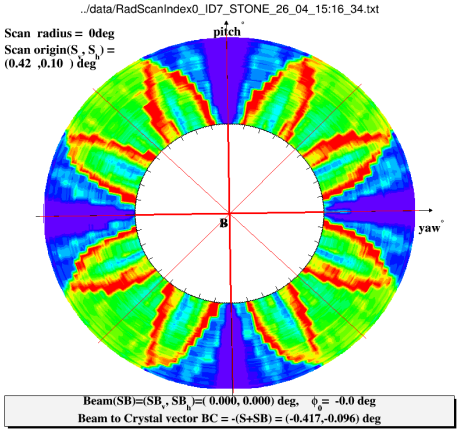


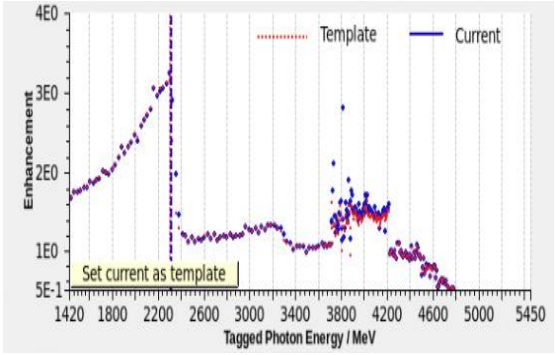
Hall-B: Ribbon beam for dark matter search





Hall-D: First coherent bremsstrahlung spectrum





Summer 2015 Shutdown Tasks

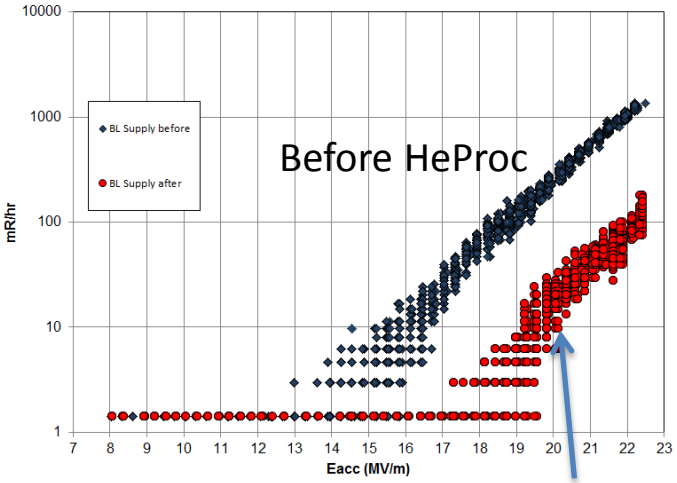
Preparing for 12GeV Operations:

- Utilities Infrastructure Modernization upgrade
  - Power grid, cooling towers, communications
- Helium Processing
  - Energy Reach
- 750MHz Separator Cavities
  - Modifications to achieve design, enable RF separation at 11GeV.
- Cryogenic plant repair and maintenance
- Pathlength chicane upgrade
  - Restoring the range of the pathlength chicane to the 6GeV equivalent.
- Tunnel Air Conditioning
  - Control temperature rise in tunnel. Temperature should not rise above 35 C.
- Vacuum system hardening
  - Preparing for synchrotron radiation induced vacuum loads
- Operations StayTreat

Helium Processing

- Utilized during 6GeV era to improve maximum operating gradient of SRF cavities (to reach 6GeV).
- Insert small amount of gaseous He into the cavity.
- Process cavity with RF power, watch for the radiation signature to drop (field emitters extinguished).
- Cryo-cycle the cavity to remove the He.
- Determine the new maximum operating gradient

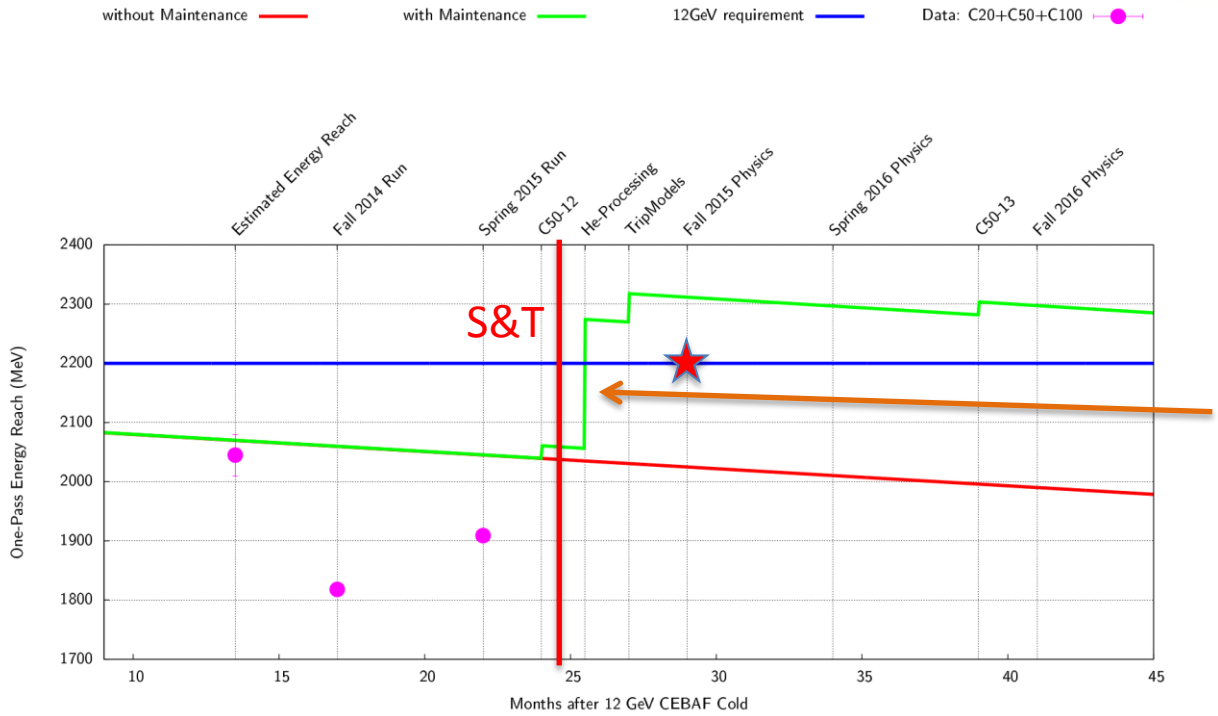
Representative gain (~4MV/m) on one C100 cavity recently Helium processed.



Application	C20 Gain (MV/m)	C50 Gain (MV/m)	C100 Gain (MV/m)
First	**1.2**	1.9	**3.8**
Second	**0.9**	1.4	2.9
Third	**0.7**	1.0	2.2

Table 12: Estimated gains from initial and subsequent applications of Helium processing on the three CEBAF cavity types. **Bold** values are derived from the references, plain text values are a best guess.

Energy Reach: Past and Future



Helium processing of all cavities planned for Summer 2015

- C20/C50 performance degradation:
  - 0.21 MV/m – year (~34 MeV/pass - year).
  - Cause of degradation is unknown, actively being investigated.
- C100 insufficient data to date to reliably estimate degradation, if any.

- Commissioning vs. Operations cavity performance:
  - $78\% < \frac{Operational\ Gradient}{Commissioning\ Gradient} < 94\%$

12GeV Operations: Future

- Complete the Summer 2015 shutdown tasks.
- Operate RF systems 24/7 for two weeks prior beam operations.
  - Optimize C100 LLRF to achieve design gradients (or beyond).
  - Collect data on C20 trip rates, used to optimize gradient distribution with minimal trip rate.
  - Decrease the gap between E_{maxOPS} and GMES for all cavity types.

Fall2015 (E_{pass} = 2.2 GeV):

2015-Oct-26 to 2015-Dec-21

- Emittance/energy spread growth studies.
- SRF performance optimization at full energy.
  - Minimize trip rate
  - Minimize recovery time
  - Maximize gradient
- Detector commissioning at full energy.
- Opportunistic beams for Physics.

Spring2016 (E_{pass} = 2.2 GeV):

2016-Jan-28 to 2016-Mar-31

- **First Physics runs with CEBAF at 12 GeV energy: Halls A&D**

Non-Beam Accomplishments

- Successfully completed the Accelerator Readiness Review process (several staged reviews) for 12GeV CEBAF.
- Commissioned the cryo plants and established 2K operations in North and South linacs.
- Established the CEBAF Element Database (CED) as the definitive source for CEBAF configuration.
  - CED used to drive many other new developments, Hot Check Out tool, control screen generation, beam matching tool, etc.
- Installed and checked every CEBAF element (over 8000) before beam transport.
  - Accelerator 12GeV KPP demonstrated
- Fully characterized (E_{max}, Q_0, Field Emission) every SRF cavity before the start of 12GeV operations.
  - Provides a baseline for gauging SRF performance in the future.

Beam Commissioning Accomplishments

- 2.2GeV/pass one-pass beam transport with greater than 50% availability.
  - Accelerator 12GeV Project KPP demonstrated
  - Evidence that the RF gradient is insufficient for Physics operations (high availability).
- Multi-pass capability established.
  - First use of small (kHz) change of the Master Oscillator to deal with large (2cm'ish) changes in CEBAF circumference.
- 5.5pass beam transported to the Hall-D dump.
  - Shielding issues identified and addressed.
  - CW beam successfully transported to Hall-D dump.
  - First photons generated and sent into Hall-D.
  - Hall-D detector 12GeV Project KPP demonstrated.

Beam Commissioning Accomplishments (cont.)

- Multi-user capability established.
- CW beam, up to 50μA delivered to Hall-A (2-pass).
- Extraction system 499MHz and 750MHz commissioned.
  - New 750MHz cavity power limitation identified.
  - New 249.5MHz laser drive system issues identified.
- Physics quality beams delivered to Hall-A and Hall-B.
  - Hall-A DVCS exp. one Q^2 point measured.
  - Hall-B HPS exp. ~1/3 of the 1GeV data collected (additional runs at 2.2,4.4 and 6.6 GeV).

What We've Learned

- Gradient not quite enough for Physics operations
  - Helium Processing required to achieve design energy
  - C100 controls optimization/operations training -> increase C100 operational gradients.
- CEBAF Circumference can change significantly during long down periods.
  - Master Oscillator $\Delta\lambda$ crucial in dealing with large change.
  - Some diagnostics (a few special BPMs) not happy with large (10kHz) changes.
- Beam matching at the Arc entrance is a valid approach for CEBAF setup.
  - Non-zero M_{56} in the upper arcs has presented some challenges.
  - Plan to revert back to M_{56}=0 (6GeV CEBAF Optics) for the Fall program.
- Four hall separation system, 750MHz cavities & 249.5MHz laser drive, not 11GeV capable.
  - New 249.5MHz drive system under design, in the meantime analog system in place.
  - 750MHz cavity power issues identified and being addressed.

Summary

Turbulent Spring 2015:

- Beam matching at entrance to each Arc demonstrated as a valid approach.
- 4-hall separation system commissioned.
- Cryogenics remains a single point of failure.

Plan for 12GeV Operations:

- Helium processing of all cavities will provide the gradient reach needed for 12GeV operations.
- Tunnel AC, Dogleg upgrade, 750MHz cavity, vacuum system hardening, etc. will ease some of the challenges of 12GeV operation.

Majority of the Summer 2015 shutdown work is in support of operating CEBAF at the 12GeV design energy this Fall, Spring 2016 and beyond.

Operations 3-day StayTreat

Thursday, July 16, 2015		
OPS		
Assemble: Coffee and Pastries provided		
OPS and the Users		
Chair: Arne Freyberger		
8:30	Welcome and Meeting Goals	Arne Freyberger
9:00	Hall-A User feedback	Thia Keppel
9:15	Hall-B User feedback	F-X Girod
9:30	Hall-D User feedback	Hovanes Egiyan
9:45	Hall-C Status and plans	Thia Keppel
10:00	OPS & the users	Mike McCaughan
Break: Cold coffee and stale pastries		
Beam Transport		
Chair: Mike Spata		
10:30	Status of the injector process-driven setu	Alicia Hofler
10:50	ORFP Status	Todd Satogata
11:15	Pathlength/MO Setup	Michael Tiefenback
11:30	Extraction/Separator Setup	Mike Spata
11:45	Discussion	All
Lunch: On your own		
Reliability		
Chair: Steve Suhring		
13:30	RAR Summary	Randy Michaud
13:50	Bellows: RAR report summary	Brian Freeman
14:05	Vacuum: 12GeV hardening	Anthony Dipette
14:20	Harps: Reliability improvement plans	Omar Garza
14:35	Downtime: Global analysis	Randy Michaud
Break: Cookies, H2O, Ice Tea? Cold soda? Warm soda?		
Beam Physics		
Chair: Todd Satogata		
15:30	Transverse Emittance	Todd Satogata
15:50	Model Developments/Status	Yves Roblin
16:05	qsUtility / eDT Update	Dennis Turner
16:20	Bunch Length Measurements and Plans	Mahmoud Ahmad
16:40	Discussion	All
END		

Friday, July 17, 2015		
OPS		
Assemble: Coffee and Pastries provided		
Tools and Software		
Chair: Matt Bickley		
8:30	CED status: new features and data maintenance	Theo Larrieu
9:00	Lock configuration and mangement	Brian Bevins
9:20	FSD Fault Categorization	Ryan Slominski
9:40	Getting the most from your requests for help with software	Michele Joyce
10:00	Content of a good log entry	Ron Lauze
Break: Cold coffee and stale pastries		
Safety and Metrics		
Chair: Bill Merz		
10:30	PSS status and plans	Henry Robertson
10:50	OPS and PSS	Paul Vasilauskis
11:10	Service Buildings, B&D rapid access plans	Vashek Vylet
11:30	DOE Metrics Reliability	Arne Freyberger
Lunch: On your own		
Projects		
Chair: Ken Baggett		
13:30	Dogleg upgrade	Andrew Kimber
13:45	Hall-D feedback	Trent Allison
14:00	High Power Dumps	Dipette/Michalski
14:20	Laser/Inj. Upgrades to support 4-hall ops	Joe Grames
14:40	AIP Plans	Arne Freyberger
Break: Cookies, H2O, Ice Tea? Cold soda? Warm soda?		
Long Range Plans and Close Out		
Chair: Joe Grames		
15:30	SRF Long Range PIT	Geoff Krafft
15:50	Partity Quality Beam Working group report	Riad Suleiman
16:10	LERF Plans	Steve Benson
16:30	UITF Status and Plans	Matt Poelker
16:50	Wrap Up	Arne Freyberger
END?		

- Chairs please keep the speakers on schedule and the discussion focused.
- Speakers please respect the schedule.
- Audience please keep the discussion relevant, respectful, crisp and invigorating.
- Actions items will be distilled from the presentations and discussion. No need to solve the problem during the meeting.

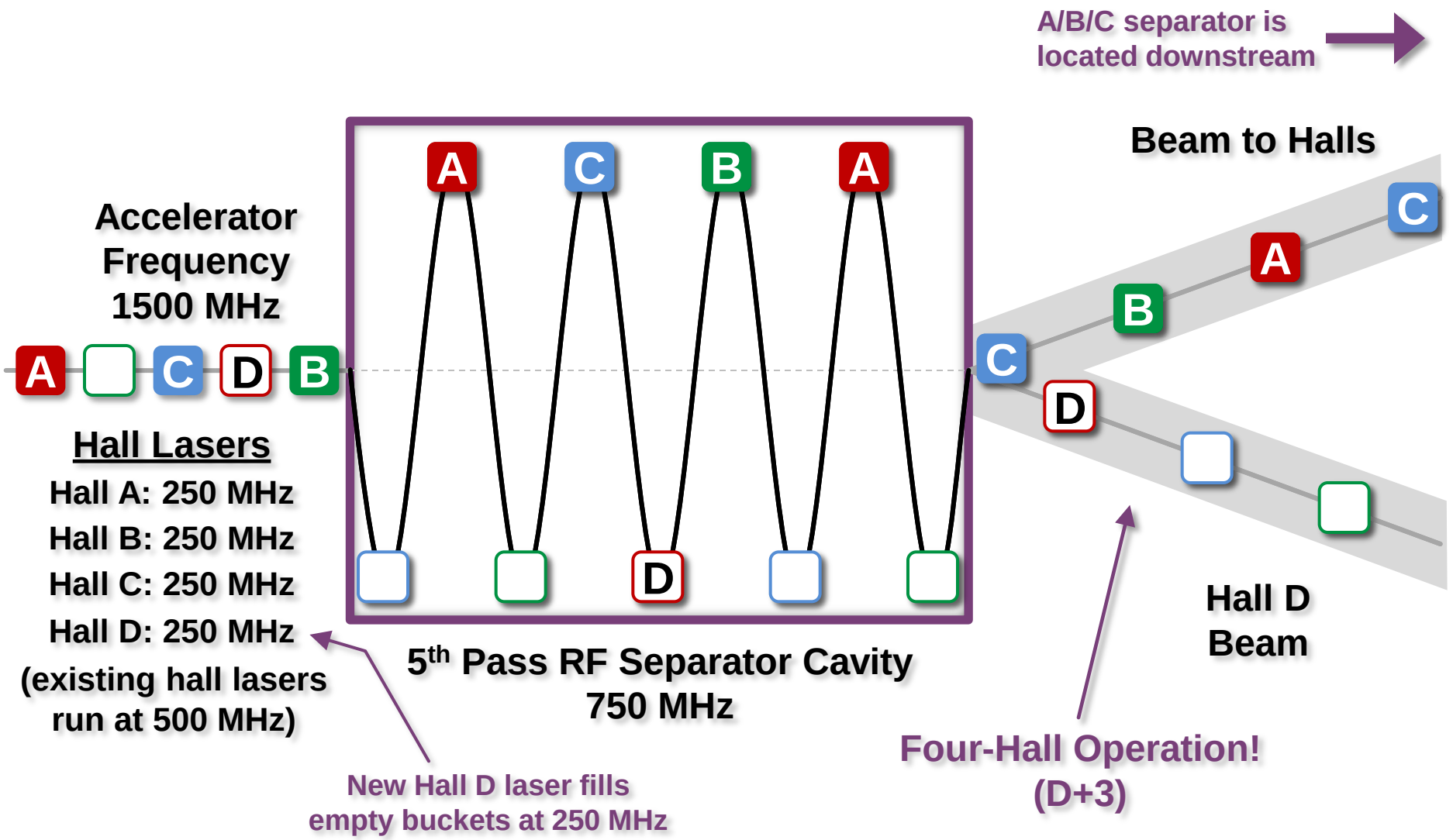
Back Ups

Accelerator Mission

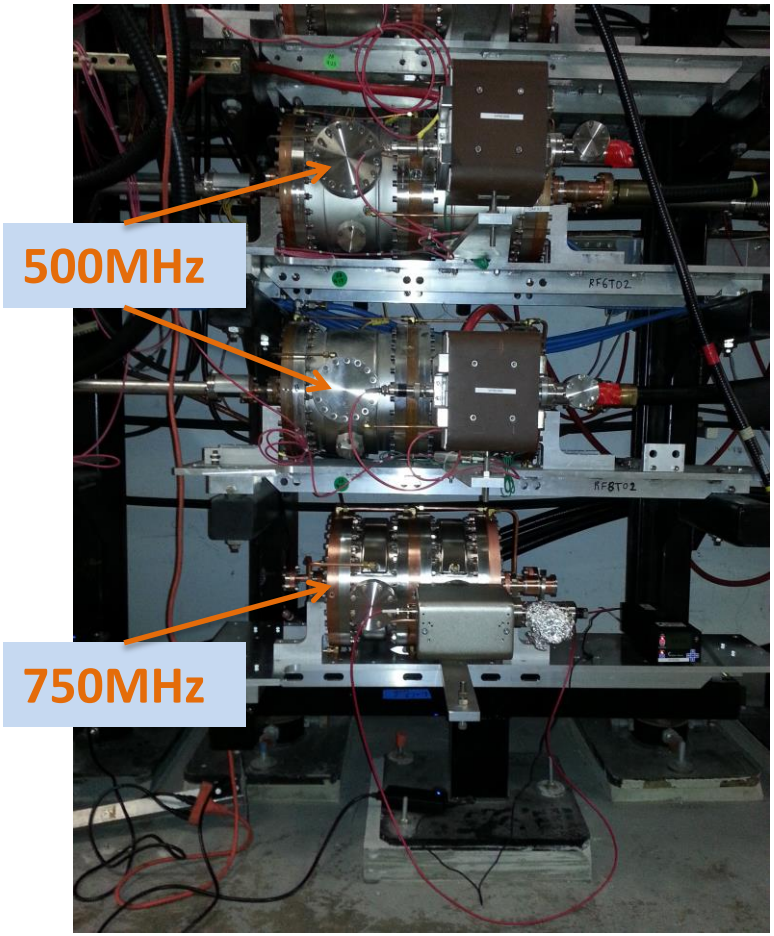
- The Accelerator Mission is to advance the capability of Jefferson Lab to carry out world-class nuclear science and, more broadly, to develop Jefferson Lab's expertise in technologies associated with high-power superconducting linacs

- The goals to achieve the mission deliver results in four strategic areas:
  - **Operate and upgrade the JLab accelerator facilities**
  - Prepare for a Medium-Energy Electron Ion Collider (MEIC) at Jefferson Lab
  - Sustain Jefferson Lab's core accelerator competencies to support DOE Office of Science projects and other partnerships
  - Attract and educate the next generation of accelerator scientists and engineers
- Goals are in priority order

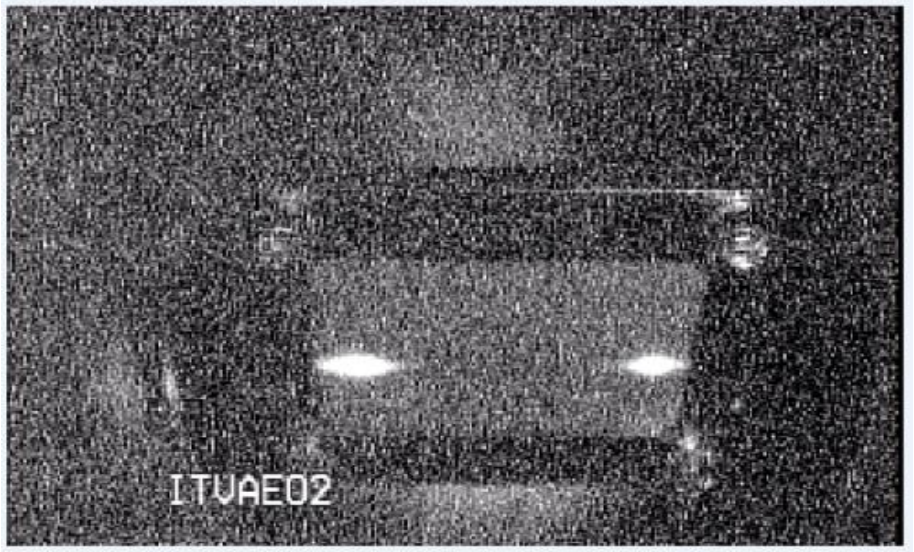
RF Separation – Four Halls



750MHz Separation



A & D beam separated on 5th pass at 9.6 GeV.



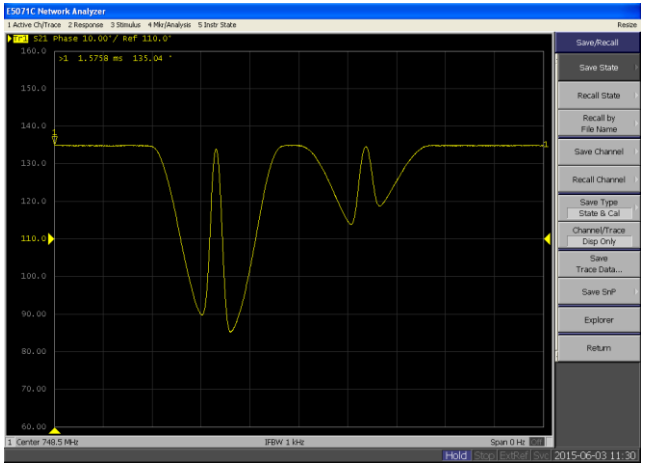
Commissioning effort identified improvements required to achieve full-energy separation

Design maximum beam energy is 11 GeV

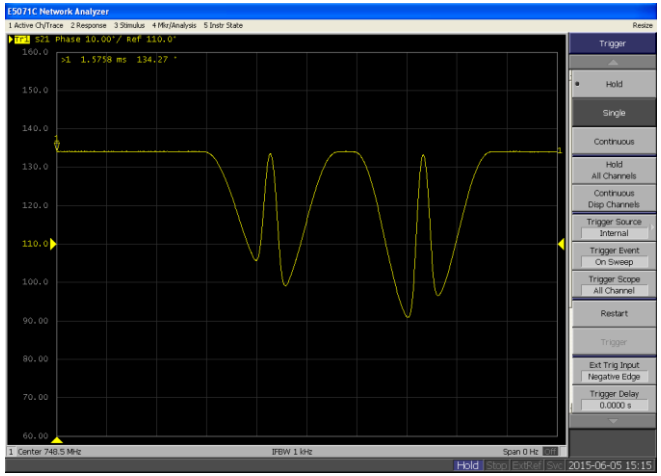
750MHz Separators: Path toward 11GeV capability

- Increase power input by operating Inductive Output Tubes (IOT) at full power (done)
- Improve resonance controls (Prototype done, production systems in progress):
  - Warm Cu cavities, tuning controlled via temperature
  - Improve temperature control hardware (better valves, sensors) and software (feedback loops).
- Improve coupling into the cavity (Prototype done, modifications in progress):
  - Improve alignment
  - Improve field monitoring

Example of poor field flatness, poor coupling into 2nd cell



Example of improved field flatness and coupling into 2nd cell



Cryogenic Plants

SC1 CC4 Repair

- SNS Spare CC shipped to JLab
- SNS Spare CC installation in SC1 on-going
- Expect SC1 ready for operation by end of August
- Still waiting for vendor quote on repair of damaged CC4

CHL2 Heat Exchanger

- CHL2 efficiency not meeting specifications
- New heat exchanger being installed by vendor
- Expect work to be completed by end of August.

Gradient Maintenance

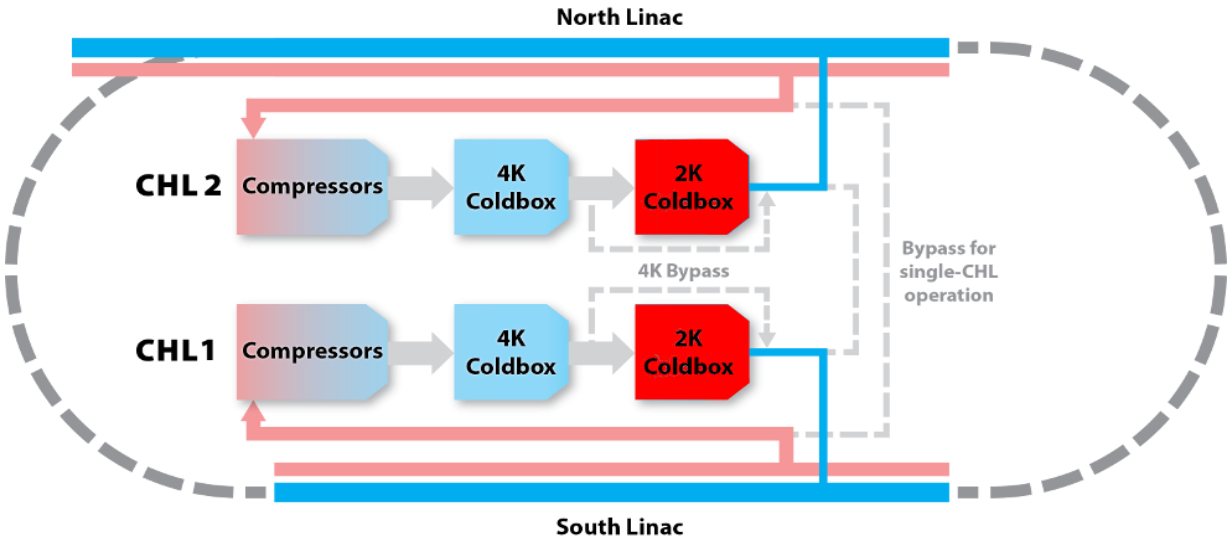
Repeated Helium processing in the near term after this years processing will have limited return.

- **C50 program**: Refurbish the weakest original CEBAF cryomodules (C20).
  - Refurbished energy gain is ~50MeV, for a delta of about 20MeV (depends on C20 being refurbished).
  - Plan is to refurbish one C20 every year.
  - Energy gain of one refurbishment per year is insufficient to maintain constant energy reach.
- **R&D on the source of the gradient loss**:
  - Examine C20 modules at start of refurbishment process for sources of gradient degradation.
    - Examination of the most recent C20 undergoing refurbishment, while preliminary, encouraging.
  - Monitor, track and document installed SRF performance.
- **C75 development**:
  - Develop an alternative to the C50 refurbishment program that results in a cryomodule with 75MeV of energy gain.
  - Competitive, in terms of k$/MV, if cost is less than $3.5M (C50 refurbishment is about $1.5M)

March 25th Power Event: Technical Stop

- Offsite power failure, CEBAF Site without power
  - ALL systems affected, including cryo plants
- Power restored in a couple of hours
  - 4K operations resumed immediately (Helium inventory management)
- Restoring 2K operations problematic:
  - **CHL2->SC2->NorthLinac** cannot achieve stable 2K operations due to contamination issues.
  - **CHL1->SC1->SouthLinac** cannot start due to issue with cold compressor 4 (CC4) in SC1.

12GeV cryogenic configuration



Power Event Impact

CEBAF Down hard: 2015-03-25 – 2015-04-15

- Warm up SC2 to remove contaminants, purge/pump cycles.
- SC1 CC4 Failure
  - Compressor wheel stuck, will not rotate, seized, not good.
  - CC4 safe shutdown system found not working.
  - Compressor wheel had a hard landing at full speed (>30000 rpm).
- Reconfigure cryo-plants/CEBAF with both linacs connected to CHL2->SC2.
  - Return to CEBAF Ops with one CHL plant
  - Limited cooling capacity
  - Limited beam energy
- Physics program continued with an alternative program at 1GeV/pass.

CC4 disassembled in June: