

Early Commissioning Experience and Future Plans for 12 GeV CEBAF

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Center for The Advanced Studies of Accelerators



- Introduction
 - Jefferson Lab Overview
 - Scope of the 12 GeV Upgrade
 - Accelerator Overview
- Commissioning
 - Preparation
 - Execution
- Future Plans
 - Meeting Beam Requirements
 - Optimizing the LINAC Performance
 - Out-year Run Plans
- Acknowledgements

Jefferson Lab Overview

Department of Energy National Laboratories



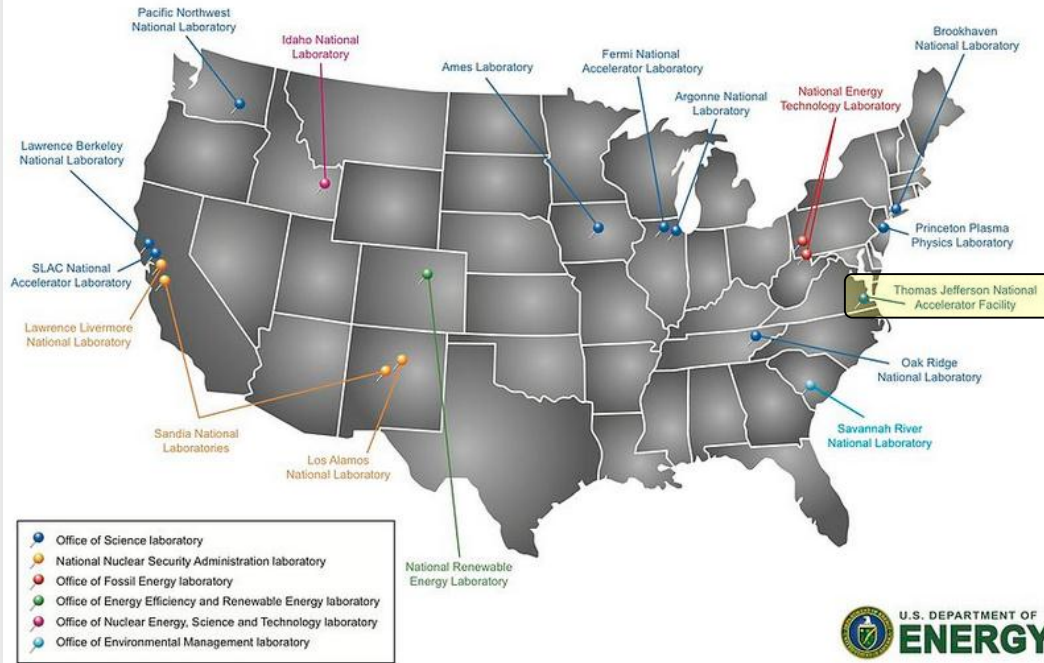
Core Competencies

- Nuclear Physics Research
- SRF Technology Leadership
- Polarized Electron Sources
- Cryogenics Research and Development
- Accelerator Physics and Diagnostics Development



Jefferson Lab Overview

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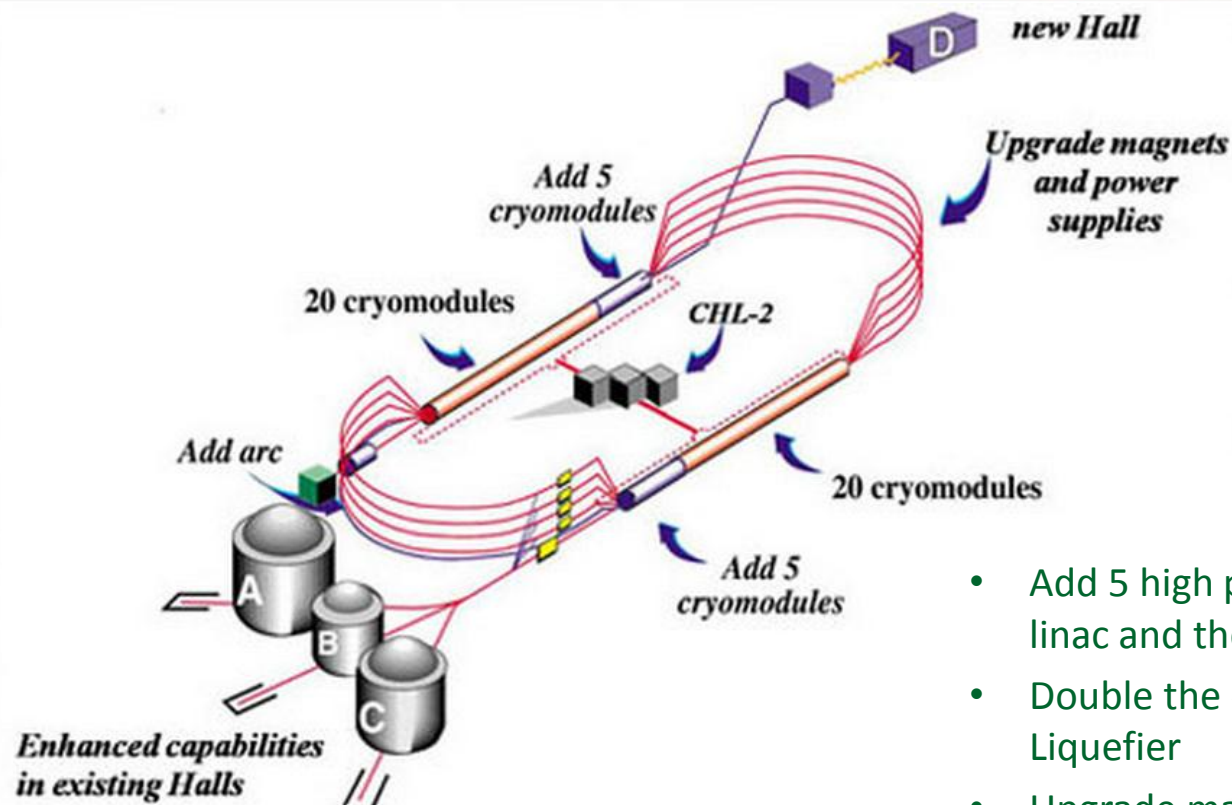


Quick Facts

- 180 M\$ annual operating budget
- 759 Full Time Employees
- 1,385 Active Users
- Produces ~1/3 of US PhDs in Nuclear Physics
- 169 acres and 83 buildings and trailers



Scope of the 12 GeV Upgrade

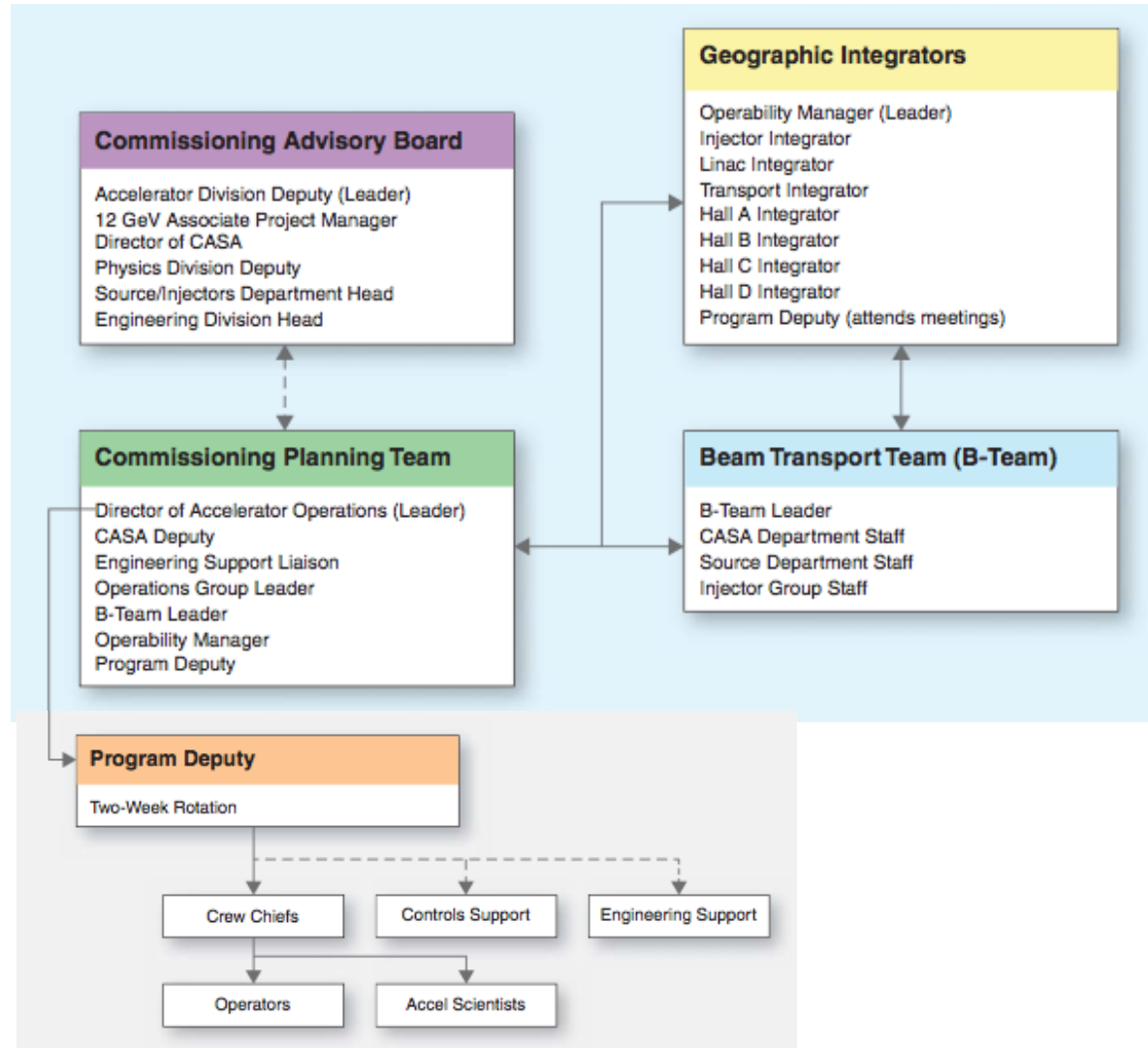


- Add 5 high performance cryomodules in each linac and their associated LLRF Systems
- Double the capacity of the Central Helium Liquefier
- Upgrade magnets and power supplies for recirculation arcs
- Upgrade Extraction, Instrumentation and Diagnostics, and Safety Systems
- Add new beamlines for Arc 10 and Hall D
- Add new experimental Hall D and upgrade existing Halls



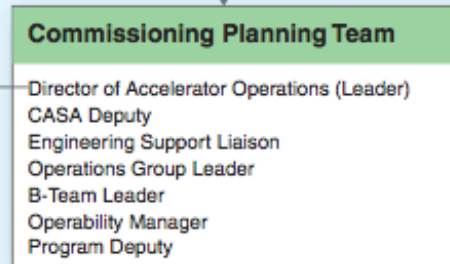
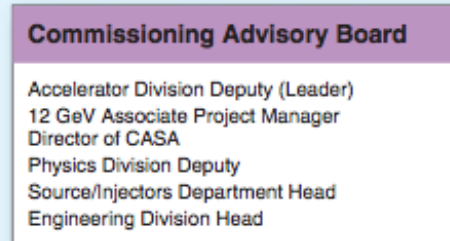
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Organizational Structure



Organizational Structure

Reviews plan and provides feedback.



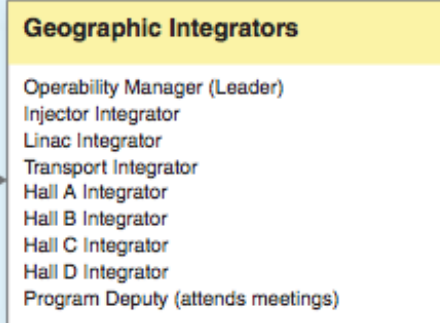
Crew Chiefs

Operators

Controls Support

Accel Scientists

Engineering Support



Ensures that the beam line segments are ready for beam.

Develops the detailed plan.

Executes the plan.

Hot Checkout Tool

- A tool to capture the readiness of all hardware for beam operations.
- Over 15000 components in system for 5.5 pass to Hall D
- Red** – component not yet checked.
- Yellow** – component checked by technician.
- Green** – component verified ready by system expert.

Hot Checkout

Readiness Signoff Checklists Links Reports Help

Login

Reports

Overall Status

Group Status

Activity Summary

Activity Detail

Signoff

Ready Signoff Turn

Component

Group Responsibility

Group Leader

Masked

Overall Status

Filter

Beam Destination: Beam to Hall D (5.5 pass)

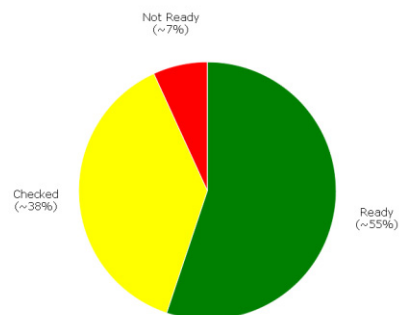
Subsystem:

Region:

Group:

Apply

Found 15,162 Signoffs in Beam Destination "Beam to Hall D (5.5 pass)" (3 Masked Components)



Status	Count	Percent
Ready	8,359	~55%
Checked	5,767	~38%
Not Ready	1,036	~7%

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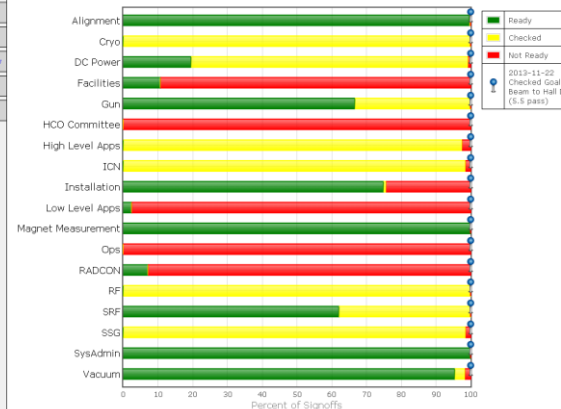
Beam Destination: Beam to Hall D (5.5 pass)

Subsystem:

Region:

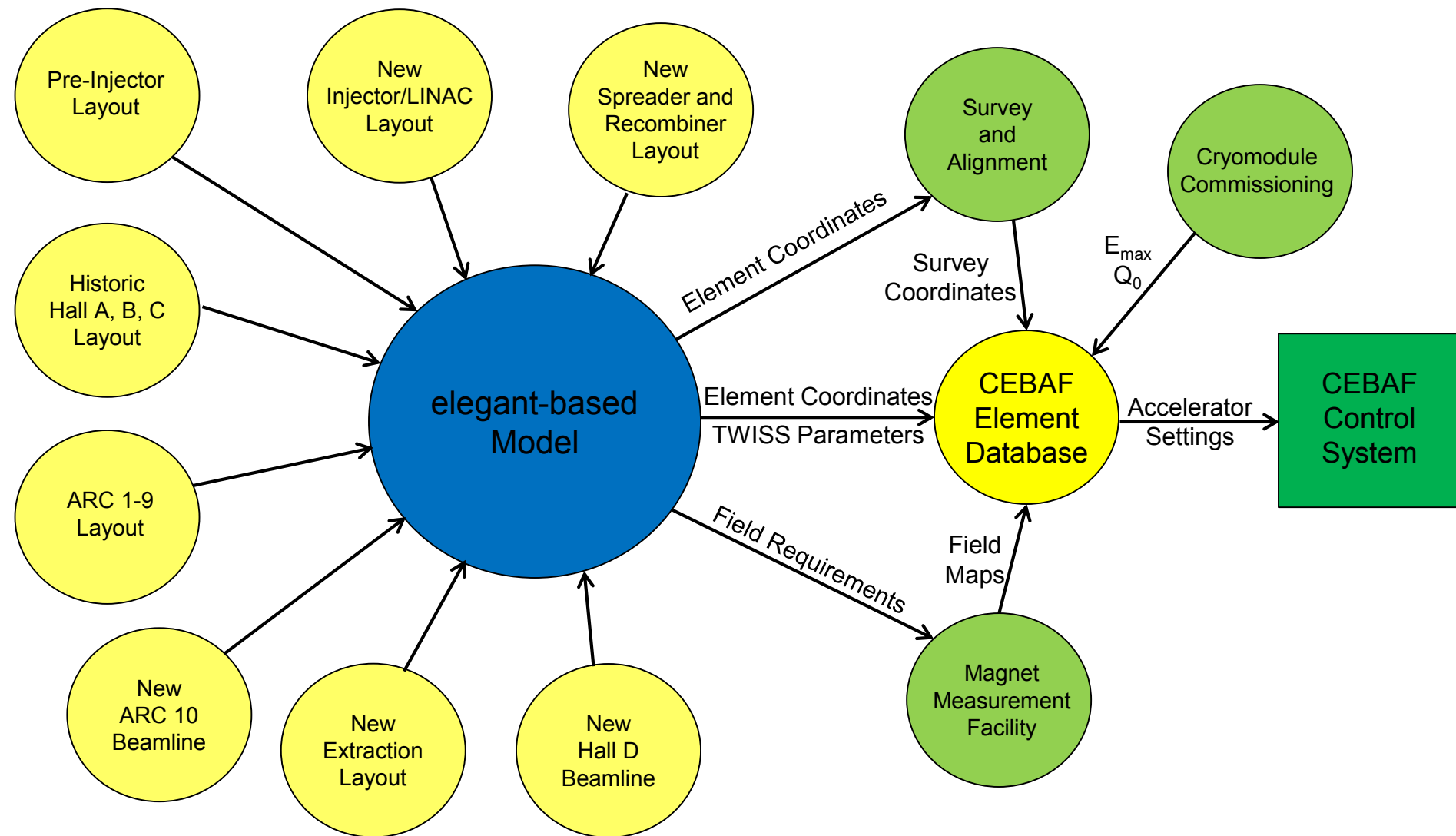
Apply

Found 15,162 Signoffs in Beam Destination "Beam to Hall D (5.5 pass)" (3 Masked Components)



Group	Signoff Total	Signoff Count			Signoff Percent			2013-11-22 Checked Goal Beam to Hall D (5.5 pass)	
		Ready	Checked	Not Ready	Ready	Checked	Not Ready		
Alignment	2,007	1,999	5	3	~99%	~0%	~0%	100%	
Cryo	71	0	71	0	~0%	~100%	~0%	100%	
DC Power	1,993	389	1,589	15	~19%	~79%	~0%	100%	
Facilities	56	6	0	50	~10%	~0%	~89%	100%	
Gun	30	20	10	0	~66%	~33%	~0%	100%	
HCO Committee	1	0	0	1	~0%	~0%	~100%	100%	
High Level Apps	40	0	39	1	~0%	~97%	~2%	100%	
IGN	2,810	0	2,768	42	~0%	~98%	~1%	100%	
Installation	2,416	1,810	17	589	~74%	~0%	~24%	100%	
Low Level Apps	285	7	0	278	~2%	~0%	~97%	100%	
Magnet Measurement	1,884	1,884	0	0	~100%	~0%	~0%	100%	
Ops	3	0	0	3	~0%	~0%	~100%	100%	
RADCON	28	2	0	26	~7%	~0%	~92%	100%	
RF	479	0	479	0	~0%	~100%	~0%	100%	
SRF	1,250	776	474	0	~62%	~37%	~0%	100%	
SSG	275	0	271	4	~0%	~98%	~1%	100%	
SysAdmin	53	53	0	0	~100%	~0%	~0%	100%	
Vacuum	1,481	1,413	44	24	~95%	~2%	~1%	100%	

Model-Based Operations



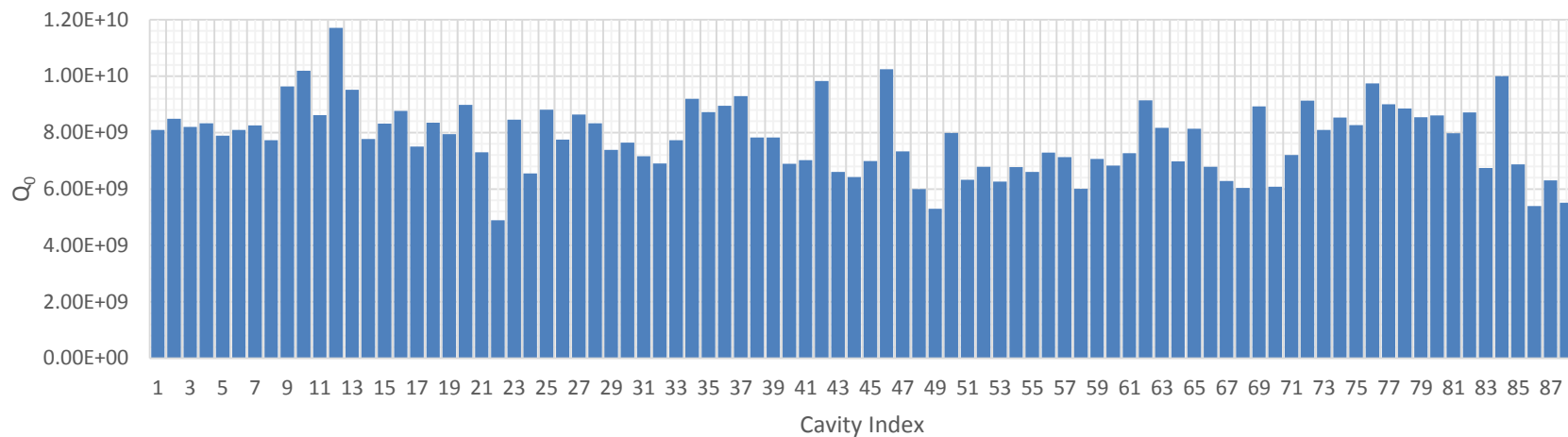
Cryomodule Commissioning

- Between May and November of last year 415 cavities were recommissioned in advance of beam operations.
 - Measured:
 - ✓ Maximum accelerating gradient
 - ✓ Cavity Q_0 s
 - ✓ Field emission survey

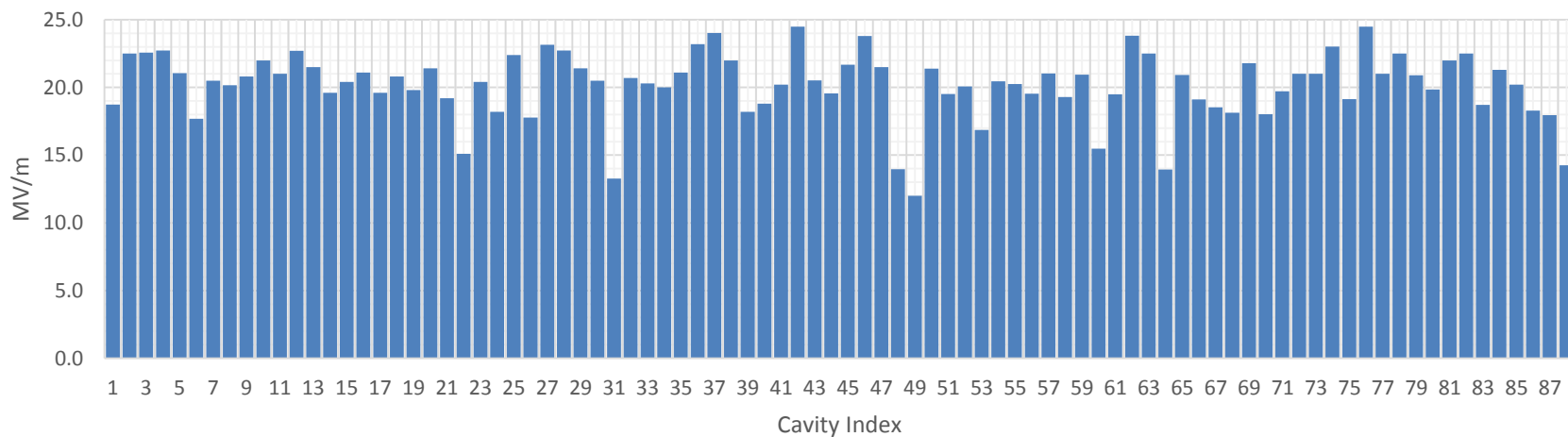
Linac	Type	Neav	<Gmax> (MV/m)	<Q ₀ @Gmax >
NL	C20	120	8.61	3.91x10 ⁹
NL	C50	40	11.72	3.74x10 ⁹
NL	C100	40	20.86	8.11x10 ⁹
SL	C20	110	9.09	4.33x10 ⁹
SL	C50	47	11.55	3.81x10 ⁹
SL	C100	40	19.77	7.44x10 ⁹

C100 Cavity Performance

C100 Q_0 at $E_{\max}$



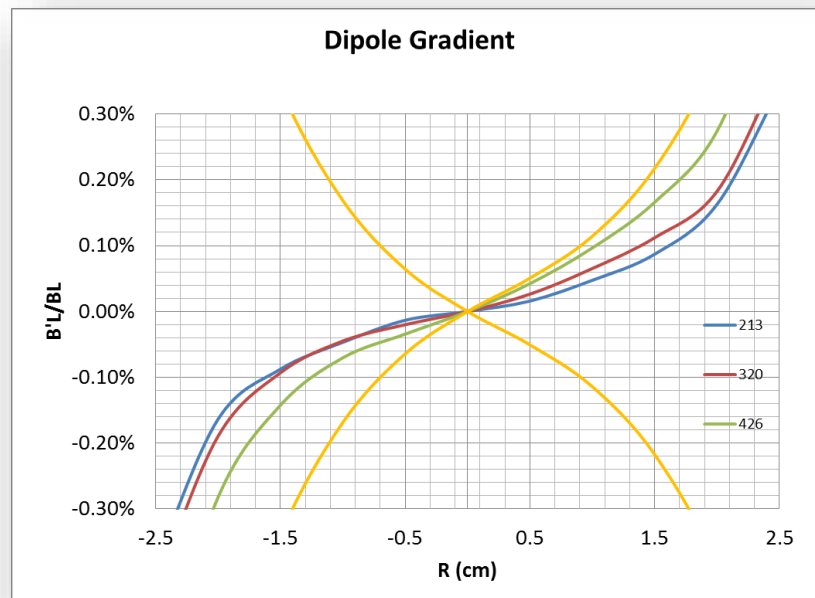
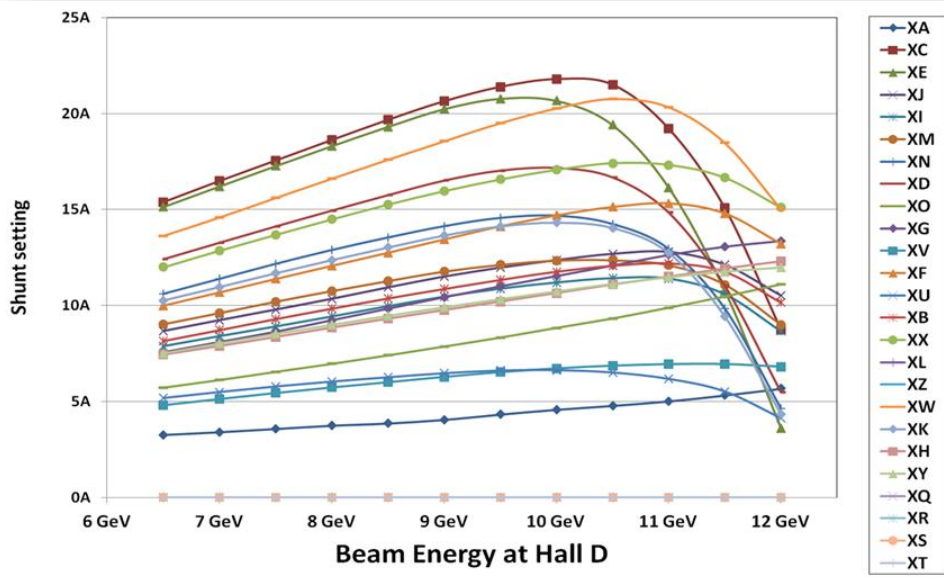
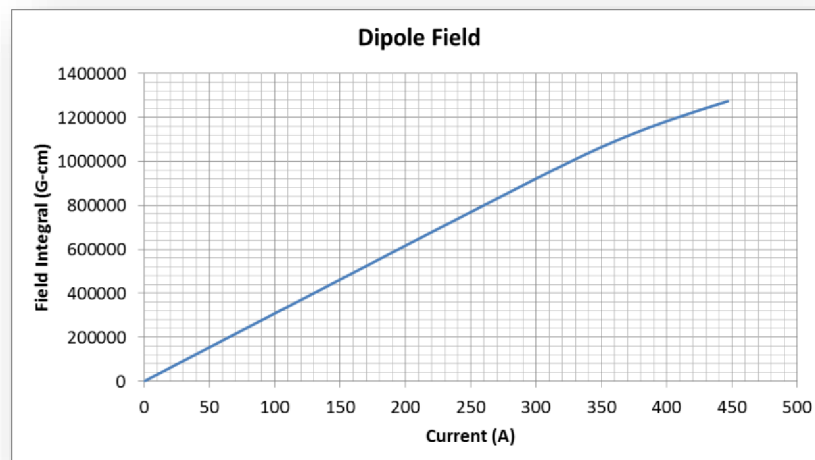
C100 $E_{\max}$



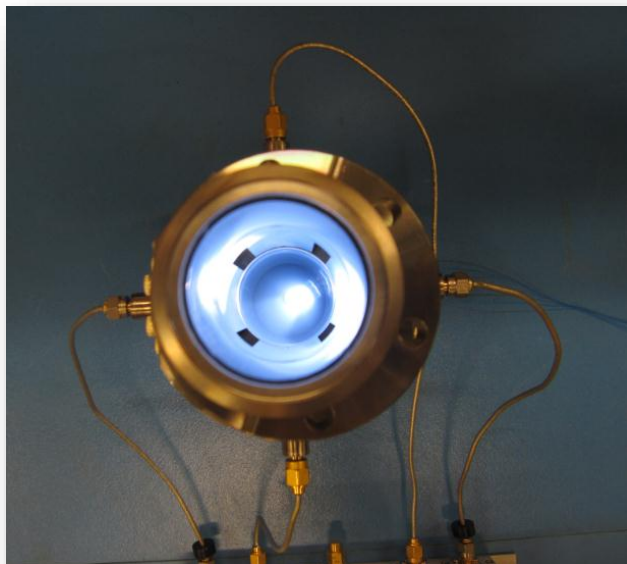
Magnet Field Quality

Magnet Measurement Facility Data

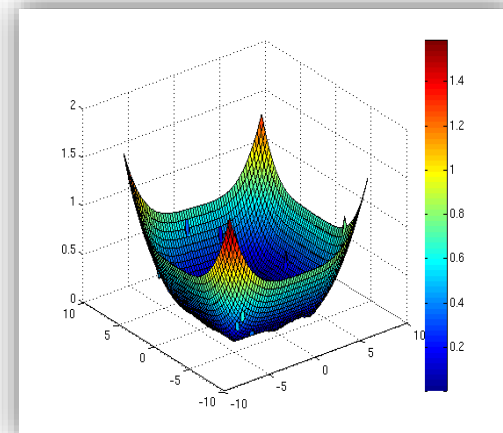
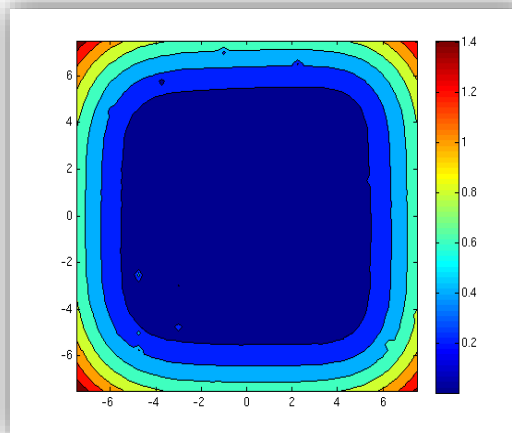
- All dipole and septa magnets measured for field quality.
- All quad families measured for field quality.
- Integrated field and dipole gradient data entered into the CEBAF Element Database.
- Control system gets information from the CEBAF Element Database.



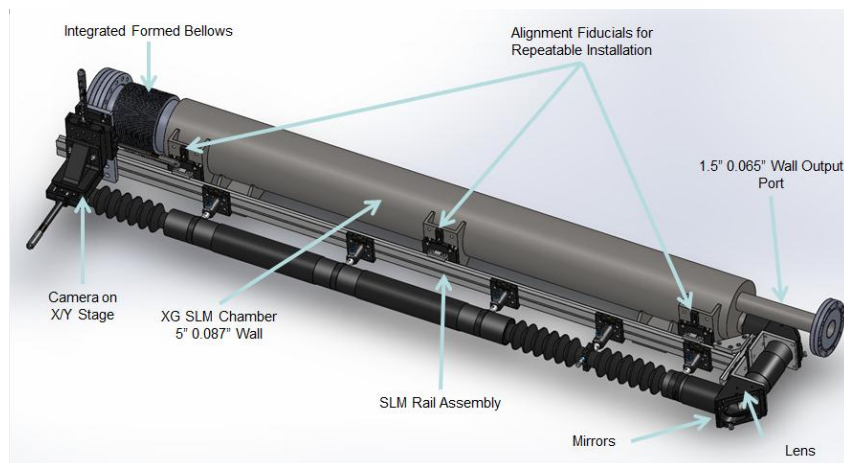
Diagnostics for New Beamlines



Stripline Beam Position Monitor



Map of BPM Response from Stretched-Wire Test Stand

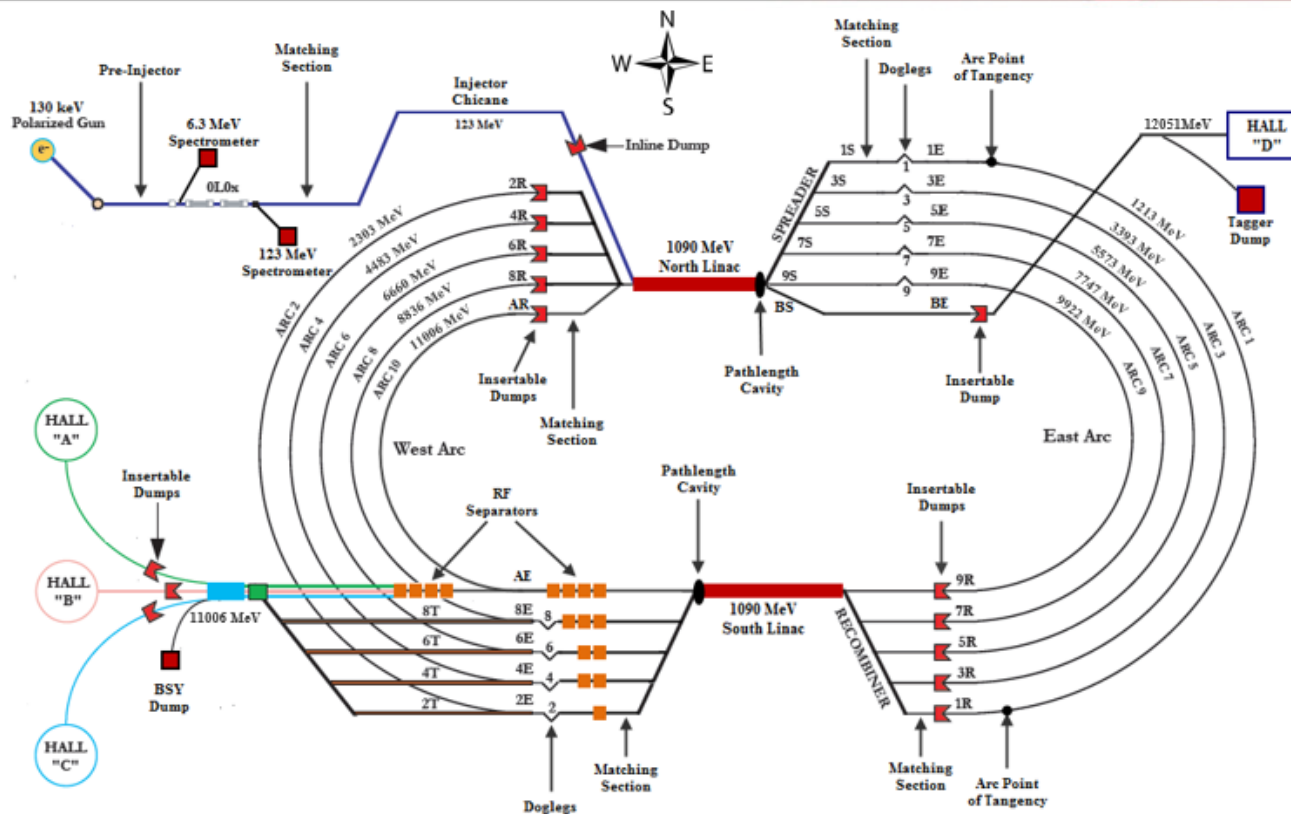


Synchrotron Light Monitor

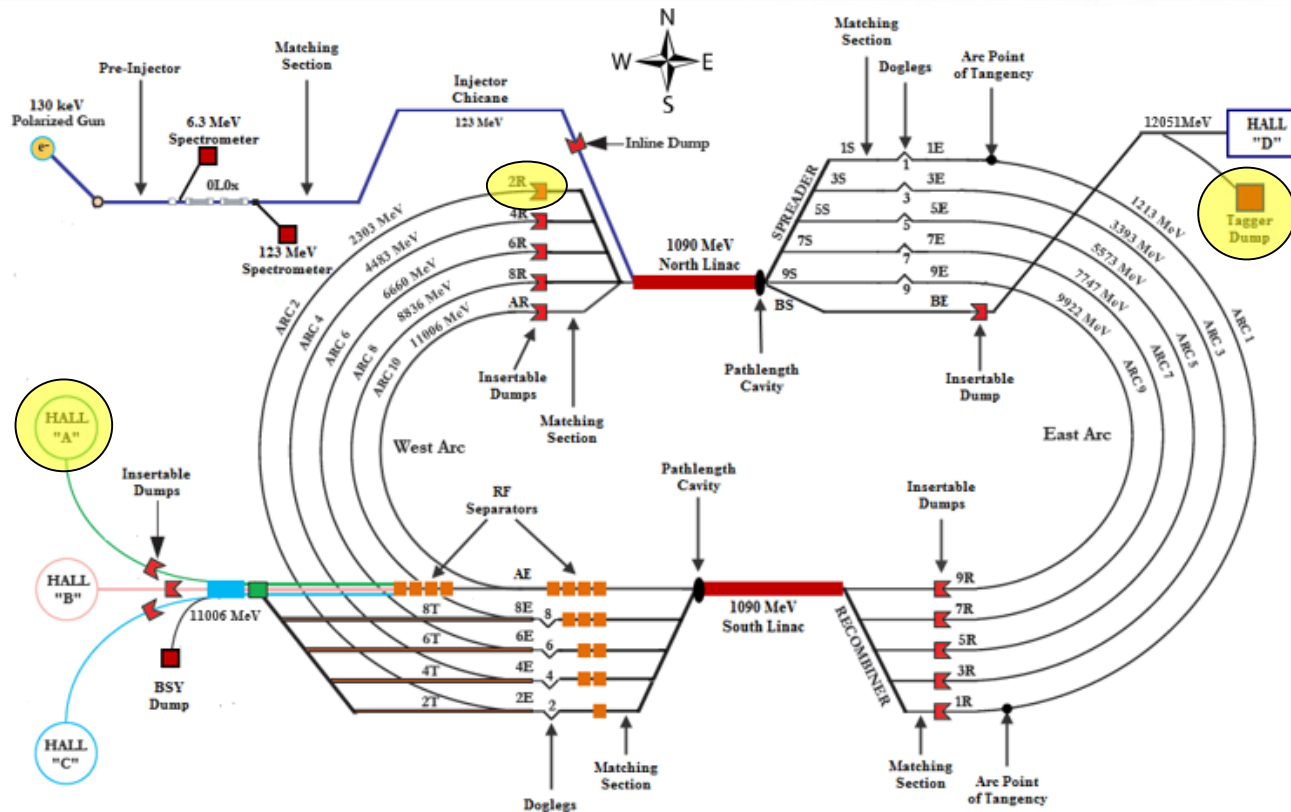


Synchrotron Light from 9 GeV Beam in Arc10

Commissioning Milestones

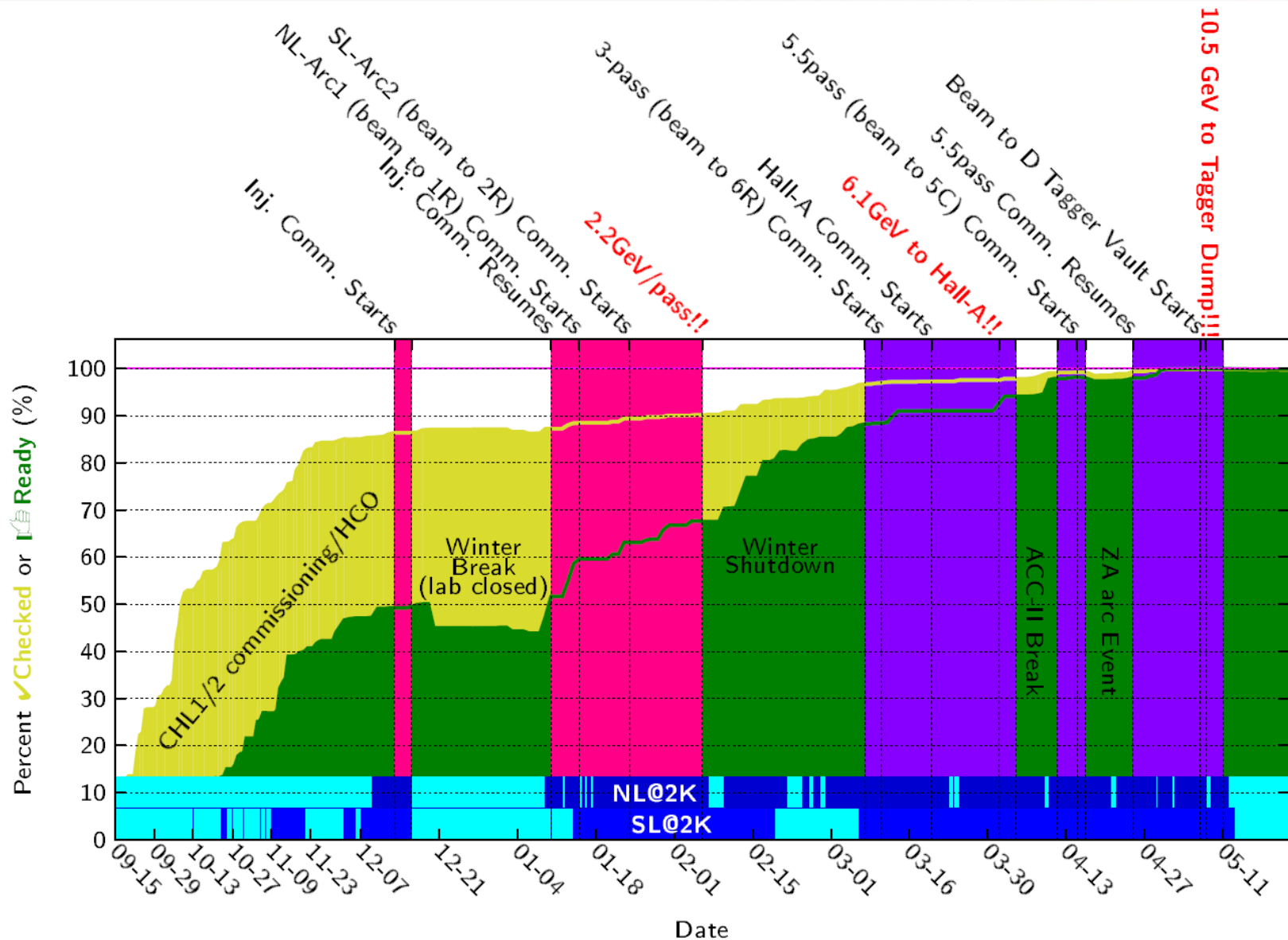


Commissioning Milestones



- Three main goals for the November 2013 – May 2014 run period:
 - Deliver 2.2 GeV Beam to the 2R dump.
 - Deliver greater than 6 GeV beam to Hall A and run first CW beam of the 12 GeV era to an experimental Hall.
 - Deliver greater than 10 GeV in 5.5 passes to Hall D.

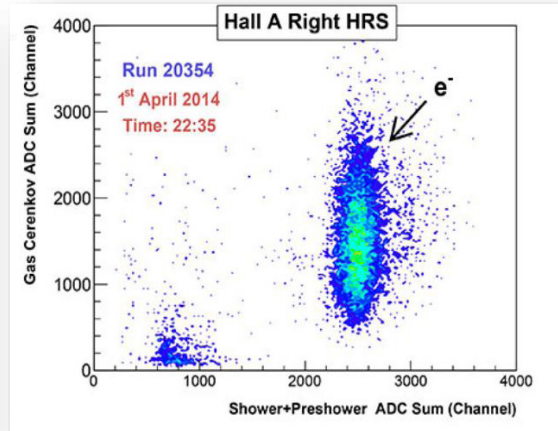
Timeline of Commissioning Progress



Commissioning Milestones



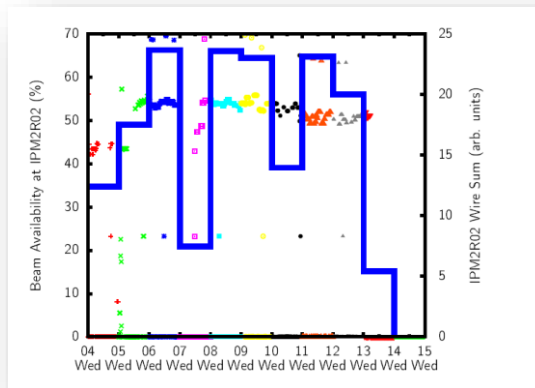
2.2 GeV Beam on ARC 2 Viewer



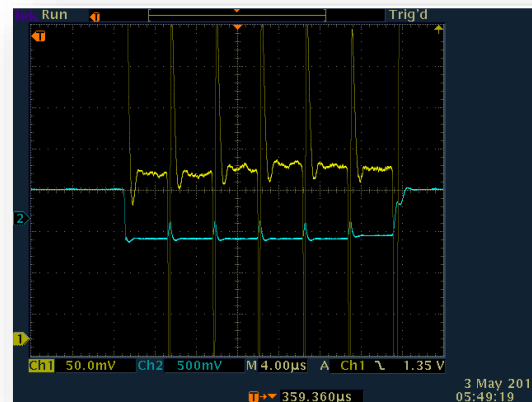
First data from Scattered Electrons in Hall A



10.5 GeV Beam to Hall D Ramp



8 Hour Availability for 2.2 GeV Run



Six Beams in the NL for the First Time



10.5 GeV Beam to Hall D Tagger Dump

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Meeting Beam Requirements

- Some of the challenges to refine CEBAF Operations:
 - Optimizing the performance of the SRF Systems.
 - Understanding Synchrotron Radiation Effects.
 - ✓ Synchrotron Radiation Compensation Coils.
 - ✓ Minimizing emittance growth due to synchrotron radiation losses.
 - Model Development - Reduce amplitude of tuning quads.
 - ✓ Linear Optics from Closed Orbit (LOCO) – measure body gradients of Spreader, Arc and Recombiner dipoles.
 - ✓ RayTrace – measure phase-space pseudo-ellipse using coordinated corrector kicks in x-plane and y-plane. Compare to model of phase-space evolution to look for point sources of model errors.
 - Ramp energy to 12 GeV to Hall D.
 - ✓ Dogleg Upgrade.
 - ✓ Tunnel Air Conditioning.

Optimizing the SRF Performance

Run Period	Dates	Max. 5.5pass Energy	Trip Downtime Goal (% - min/hr)
ACC-III	Fall2014	11 GeV	<20% <12
ACC-IV	Spring2015	11 GeV	<17% <10
Phy-I	Fall2015	12 GeV	<20% <12
Phy-II	Spring2016	12 GeV	<17% <10
Phy-III	Fall2016	12 GeV	<13% <8
Phy-IV	Spring2017	12 GeV	<12% <7
Phy-V	Fall2017	12 GeV	<10% <6
Phy-VI	Spring2018	12 GeV	<10% <6
Ultimate		12 GeV	<5% <3

Multiple options for reaching the availability goals over time:

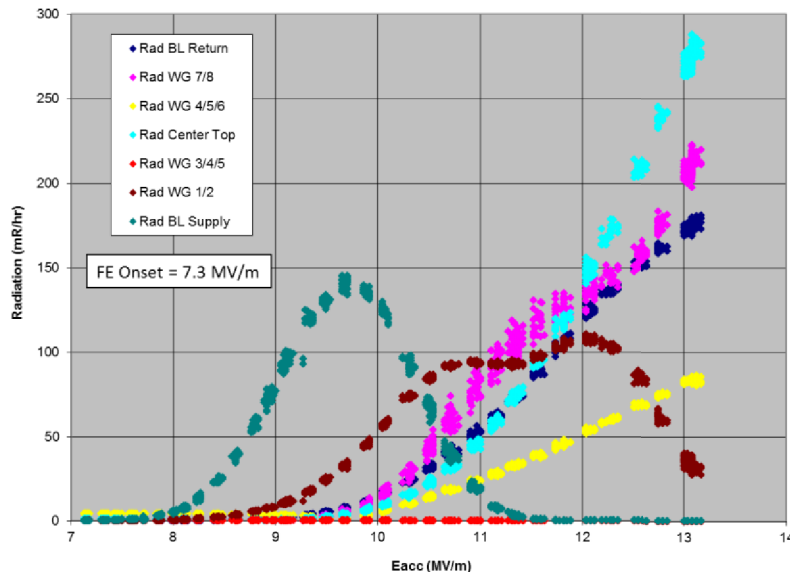
- Improve C20 trip models, maximize gradient/minimize trip rate.
- C50 program, one C50 refurbishment is in progress.
- Build more C100s.
- In-situ Helium Processing to reduce field emission.

Helium Processing

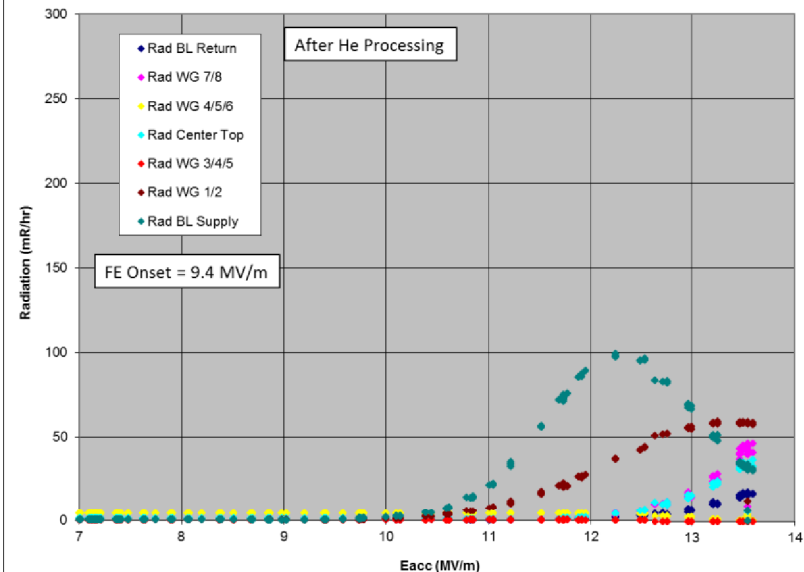
Helium Processing of a C100 Cryomodule:

- Introduce helium gas into cavity vacuum space.
- Run RF to clean cavity surfaces.
- Warm up and pump down to remove residual gas.
- Improves high-field Q, reduces x-ray production and greatly reduces incidence of arcing at the cold ceramic window.

Field Emission vs. Gradient C100-4-1 (C100-RI-037)
Acceptance 03/31/12



Field Emission vs. Gradient C100-4-1 (C100-RI-037)
Acceptance 05/03/12



Future Run Plans

Fall 2014 Run

- Restore 5.5 pass beam to the Hall D Tagger vault.
- Deliver CW electron beam to Hall D Tagger and first photon beam to Hall D for detector checkout.
- Commission the 499 MHz RF Separators and extraction beamlines.
- Refine beam tuning procedures.
- Study synchrotron radiation induced emittance growth in the upper passes.
- Parasitic support of an early Physics run in Hall A and Hall B.

Future Run Plans

Winter 2015 Shutdown

- Upgrade the Dogleg system to provide additional capacity to adjust the machine pathlength.
- Install the 5th pass 750 MHz RF Separator system.
- Install the 250 MHz drive lasers for the polarized source.

The last two bullets allow for simultaneous operation of Hall A and Hall D at the highest pass and for simultaneous 4-Hall operations.

Spring 2015 Run

- Commission the 750 MHz RF Separators.
- Commission the 250 MHz Drive Laser system.
- Deliver beam for Physics contingent on funding.

Summer 2015 Shutdown

Major installation work is planned for this shutdown that will enable us to make the push to 12 GeV for the first time. The highlights for the shutdown are:

- Installation of a C50 cryomodule.
- Installation of the tunnel air conditioning.
- Completion of a lab wide upgrade of the power distribution, cooling towers and network.
- Helium processing of SRF cryomodules to reduce field emission and increase the energy reach of the linacs.

Future Run Plans

Fall 2015 Run

- Demonstrate 12 GeV capability for the first time.
- Finalize optics setup, energy scaling and procedures.

Spring 2016 Run

- Establish beam to Halls B and C in preparation for detector checkout.
- Deliver beam in support of Hall B and C detector checkout.
- Support Engineering run in Hall D and Physics in Hall A.
- Deliver beam for Physics contingent on funding.

Acknowledgements

This work presented on behalf of the Laboratory staff in general and especially for the members of the Beam Transport Team.

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And finally....thanks to the organizing committee for giving me the opportunity to come and talk about our recent commissioning experience.

