

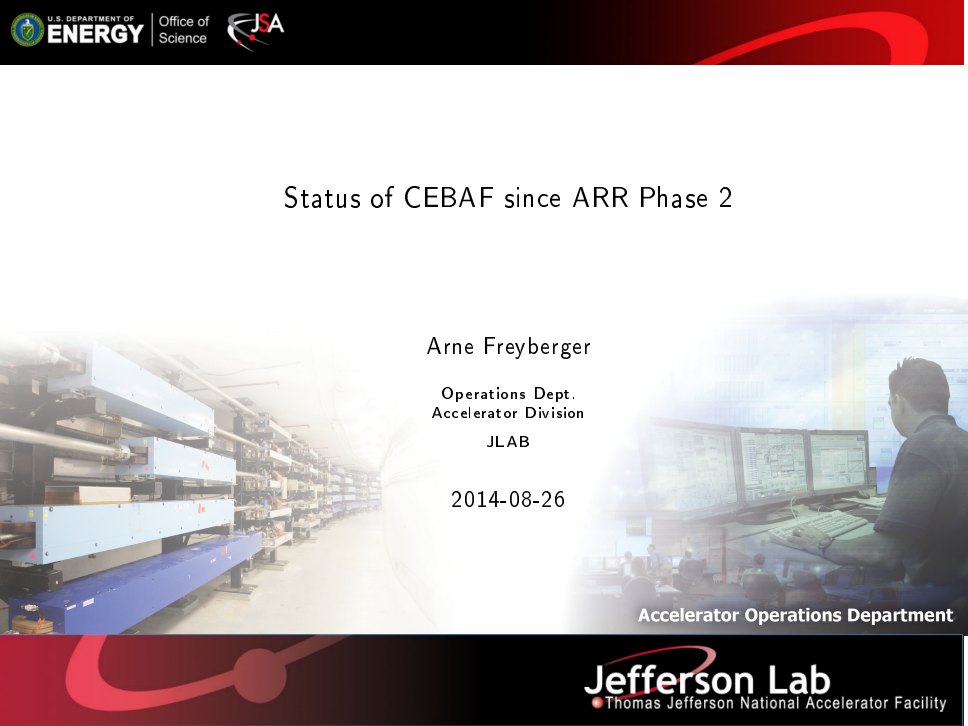
Status of CEBAF since ARR Phase 2

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2014-08-26



Accelerator Operations Department

1 CEBAF 12GeV Beam Commissioning Progress (to date)

- Timeline
- ARR Process
- Establishing CEBAF at 2.2GeV/pass
- Establishing Multipass Operations
- Establishing 5.5pass beam to the Tagger Dump
- FY14: ACC-I & ACC-II Plan, Goals and Accomplishments

2 Lessons Learned

3 Summary

12GeV CEBAF Timeline: To Date

- 2009 12GeV Upgrade construction starts in **May** with ground breaking ceremony at the Hall-D site.
 - 2011 First C100 installed in the 2L23 slot in CEBAF, **July**.
 - 2012 C100 module successfully operated at design specifications: 108MeV of energy gain with 465 μ A of beam loading on **May-18**. (End of 6GeV Operations.)
 - 2013 North and South Linac 2K LHe operations established, **Dec-09** for the first time with two CHL plants connected to a "split CEBAF".
 - 2013 12GeV CEBAF Beam Commissioning begins **Dec-13**.
-

Since ARR Phase-2:

- 2014 Beam successfully transported to the 2R dumplet with 2.2GeV/pass energy gain on **Feb-05**. Establishing RF capability to support 12GeV 5.5pass operation with greater than 50% availability.
- 2014 Injector achieves 12GeV design energy of 123MeV on **Mar-10**
- 2014 3-pass beam established to Hall-A **Mar-20**. Multi-pass capability established in the 12GeV era.
- 2014 **3-pass** CW beam with $E > 6\text{GeV}$ established to Hall-A on **Apr-01** and beam-target interactions recorded. First time beam transported to an end-station with energy that exceeds maximum energy set during the 6GeV CEBAF era.
- 2014 10.5GeV **5.5 pass** beam established to Hall-D Tagger dump on **May-07**.
- 2014 12GeV Project DOE CD-4A approval **July-30**.

Accelerator Readiness Reviews: Highlights

2013-Jun Director's Review of the 12GeV commissioning plan

External review of the beam commissioning plan in preparation for the upcoming ARR reviews.

2013-Aug ARR Phase IA

CEBAF beam commissioning up to 5.5 passes. Focus on process, planning and documentation.

2013-Oct ARR Phase IB

Complete Phase I review with a focus on hardware and staff readiness for operations. Pre-start findings defined and local team formed to verify resolution of **pre-start** findings (**green team**).

2013-Jan ARR Phase II

Reviewed beam commissioning (including CW beam) to Hall-A, Hall-A experimental readiness and beam commissioning to the Tagger Vault.

All **pre-start** findings from these reviews have been closed.

Remaining ARR:

2014-Aug ARR Phase III

Readiness to begin commissioning and operations in Hall-D. Readiness to support beam operations to Hall-B, for non-CLAS12 experiments.

2016-??? ARR Phase IV

Readiness to begin beam commissioning and operations in Hall-B (CLAS12) and Hall-C.

ARR pre-start sign-offs

aka "The Green Team"

Green Team Composition

Mike Epps DOE Site-office, 12GeV Federal Project Director (FPD).

Harry Fanning ARR committee representative, Accelerator Division Safety Officer.

Steve Smith EHS&Q Quality Assurance Continuous Improvement Manager.

Scope

Completeness of Hot CheckOut (peak readiness, 2014-May-05: 6533 elements, 15059 signoffs), status of interlock by-passes and completeness of work plans.

Pre-start sign-offs

2013-Dec-10 Beam to end of the injector (inline dump).

2014-Jan-14 Beam to 1R dumplette (half-pass).

2014-Jan-24 Beam to 2R dumplette (one-pass).

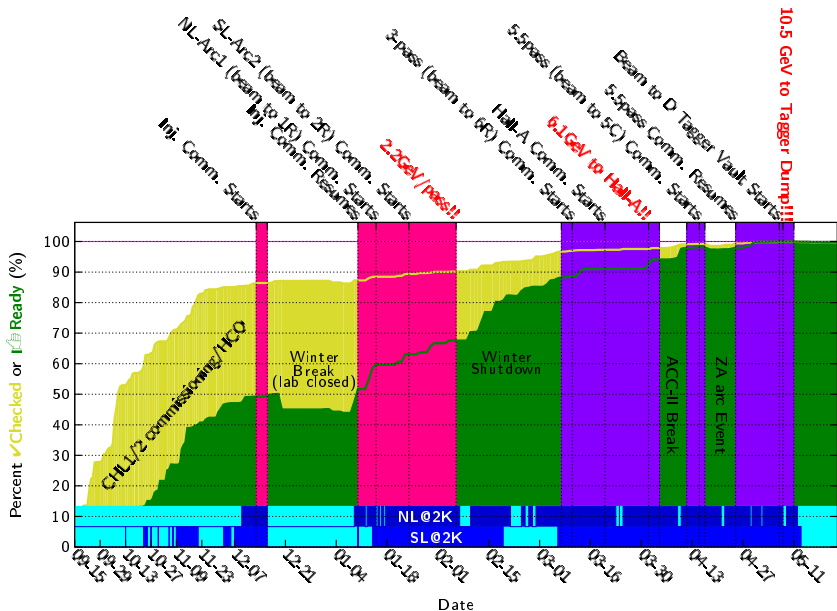
2014-Mar-11 Beam to 6R dumplette (three-pass).

2014-Mar-20 Beam to Hall-A, ready to start commissioning with beam in Hall-A.

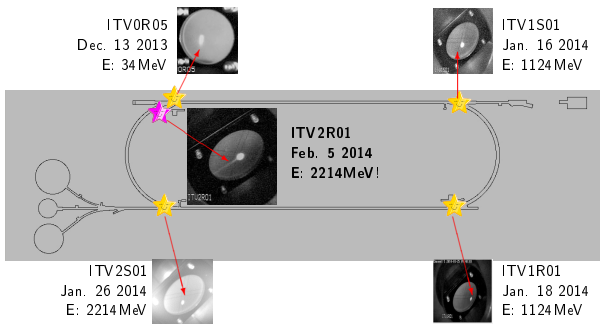
2014-Apr-11 Beam to 7R dumplette (3.5-pass) and beyond.

2014-May-05 Beam to Hall-D tagger vault (5.5pass), the last 120m of beamline.

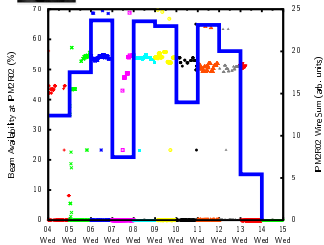
Hot Check Out and Commissioning Progress



Energy Reach: One-pass beam 2.2GeV/pass!



- Tune-mode beam, 8h dwell
- Availability measured by presence of beam at BPM just upstream of 2R dumplet.
- Peak availability $\approx 65\%$, average for 8h period availability $>50\%$.



RF and ARC1:p/ARC2:p status at: 2014-02-05 09:05

Linac	Type	Ncav	<GMES> (MV)	GMES _{RMS} (MV)	Min-Max (MV)	Egain (MeV)
Inj	C20	10	6.72	0.81	5.86-8.63	33.6
NL	C20	119	7.19	1.64	2.97-11.71	427.6
NL	C50	40	11.03	1.49	6.34-13.45	220.7
NL	C100	38	17.59	2.40	9.80-20.77	467.9
SL	C20	108	7.05	1.40	4.78-10.56	380.7
SL	C50	47	10.06	1.90	6.41-12.36	236.4
SL	C100	40	16.66	2.75	9.70-20.00	466.4

Linac	Egain (MeV)	Σ_E (MeV)	Spectrometer	Momentum (MeV/c)
Injector	33.58	33.58	INJ:p	33.41
North	1116.15	1149.73	Arc1:p	1124.03
South	1083.44	2233.17	Arc2:p	2214.51

Injector Beam Current(IBC0R08): 8.88

3-pass, 6.1GeV, polarized, CW beam to Hall-A!

Start_Run_20354, Run_type=Commission, target_type=Carbon, comment_text=Run type: Comm., Carbon tgt, I=1 micro A, ps1=1, no raster, sieves out

Lognumber 3279524. Submitted by adaq on Tue, 04/01/2014 - 22:35.

Last updated on Tue, 04/01/2014 - 22:35

Logbooks: HALOG
Tags: StartOfRun

User name adaq

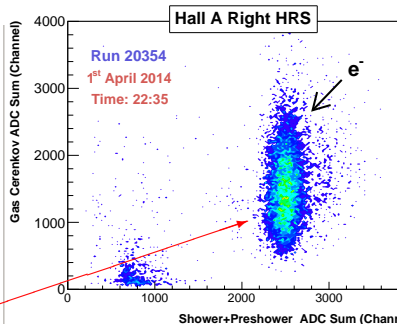
Log entry time 22:35:56 on April 1, 2014

Entry number 388530

keyword=Start_Run_20354, Run_type=Commission, target_type=Carbon, comment_text=Run type: Comm., Carbon tgt, I=1 micro A, ps1=1, no raster, sieves out

Run Timestamp: Tue Apr 1 22:32:46 EDT 2014

Beginning-of-run EPICS data for Run Number 20354 at Tue Apr 1 22:35:36 EDT 2014

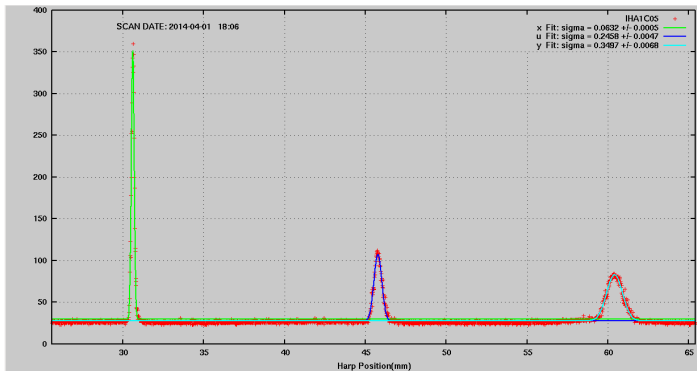


Beam on Carbon Target
Apr. 1 2014
E: 6112MeV

		Beam Energy Monitor				01 April 19:20:49	
		dp/p bpm	dp/p corr	dp/p total	MeV	Target	Valid
INJ	off on	3.59e-04	-1.11e-02	-1.07e-02	111.16	112.85	●●
ARC1	off on	-2.36e-05	4.58e-04	4.35e-04	1113.29	1112.85	●●
ARC2	off on	9.24e-06	-1.21e-04	-1.11e-04	2112.56	2112.85	●●
ARC3	off on	1.85e-04	1.36e-03	1.55e-03	3117.58	3112.85	●●
ARC4	off on	9.87e-05	7.58e-04	8.57e-04	4128.67	4112.85	●●
ARC5	off on	-1.86e-04	1.44e-03	1.25e-03	5128.50	5112.85	●●
HALLA	off on	-5.92e-05	6.75e-05	8.28e-06	6051.77	6112.85	●●

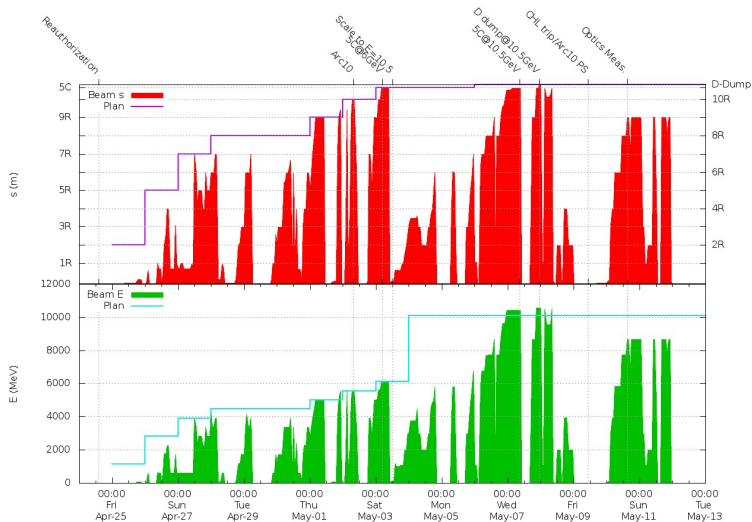
Beam Optics through 3-pass

Beam profile of Hall-A beam during **6.11GeV** setup (Apr-01):



- > 2 GeV/pass Energy Gain
- CW beam.
- Polarized beam, Hall-A commissioned new Møller polarimeter with this beam.
- $E_{beam} > 6$ GeV with only 60% of CEBAF, 3-pass.

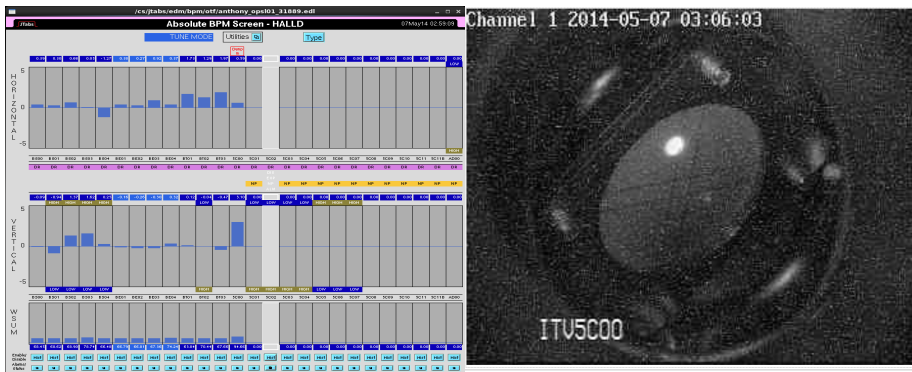
Establishing 5.5pass, 10.5GeV beam to the Tagger Dump



- s The maximum s-value (m) for a contiguous set of BPM readings per hour of operations.
- E Energy (MeV) at the determined maximum s-value.

North Linac→5C Dumplet: May-07-2014

- New magnetic extraction line at the end of the North Linac
- New Beam Position Monitors, Signal pick-up→front-end electronics→EPICS software.

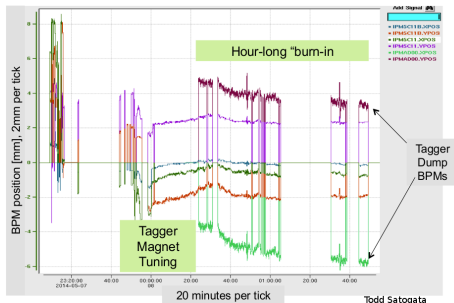


The new Hall-D beam position monitors worked *out of the box*. Technical staff dead reckoned the electronics/software timing with respect to the tune-mode beam structure, and got it right.

5C Dumplet → Tagger Dump: May-07-2014

The last 120m

- New 5C transport line, leading into the Tagger Magnet.
- New Tagger Magnet, Hall-D ownership, accelerator-physics compatibility.



QuickPic - BEAM ON HALL D Tagger DUMP!

Lognumber 3285622. Submitted by eforman on Wed, 05/07/2014 - 23:41.

Last updated on Wed, 05/07/2014 - 23:42

Logbooks: [ELOG](#)
Tags: [Readme](#)
Entry Makers: [eforman](#)

Fig. 2 [05/07/2014 23:41:27]

Channel 4 2014-05-07 23:41:24



- Tagger magnet integrated field error understood.
- Evaluation of Tagger hall radiation levels for the design of shielding wall completed.

No show stoppers identified during this brief period of beam operation to the Tagger dump.

Beam Operations

- Plan: 19 weeks of operations, divided into two run periods.
 - ▶ Achieved 13weeks of beam operations
- Plan: Beam commissioning to start first week in 2013-Nov. and end first week of 2014-May.
 - ▶ Achieved: Beam Commissioning started in earnest 2014-Jan. and ended May-11

ACC-I & ACC-II Goals

- 100% Establish 1-pass 2.2GeV tune-mode beam to 2R dumper. CD4A Accelerator Project deliverable. (6wks)
- 100% Establish 3-pass tune-mode beam to Hall-A. Level II 12GeV Project Milestone. (2wks)
- 100% Hall-A detector checkout. (1wk)
 - 25% Characterize all new magnetic elements up to 3rd pass for 50% to 100% of nominal 12GeV energy. Needed to establish operational procedures required for efficient out-years CEBAF operations. (4wks)
- 100% Establish 5.5 pass beam in CEBAF, preparing for beam into Hall-D in Fall2015 (CD4B Deliverable, Level-II milestone). (3wks)
 - 20% 4/5/5.5 pass Magnet/Optics characterization. (2wks)
- 100% Establish first beam to Hall-D tagger vault, Level III 12GeV Project Milestone (originally planned for Fall2014). (1wk)

1 CEBAF 12GeV Beam Commissioning Progress (to date)

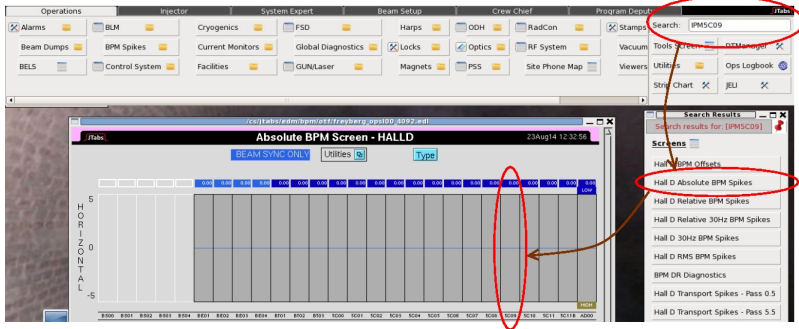
2 Lessons Learned

- The Successes
 - CED and its offspring
 - New hardware
 - Tunnel Temperature and Power Usage
- The Surprises
 - Initial Pathlength 2cm short
 - ZA Event

3 Summary

Software Tools: database driven control system

- CEBAF Element Database (CED) defines the CEBAF configuration.
- Used as the starting point for many new tools:
 - ▶ Hot Check Out Tool
 - ▶ EPICS Control screens are now generated on-the-fly. Change CEBAF configuration → update CED → screens automatically updated.
 - ▶ Optics model and tools that rely on the model.
 - ▶ More to come, goal is for the entire control system from IOC/EPICS configuration to control screens and High Level applications to be driven by CED.



New Beam Position Monitors (BPM) for Hall-D

- New stripline design, robust construction technique (no electron beam welding as per the old design).
- New electronics, old design deemed obsolete.
- Worked “out of the box”! All timing issues had been roughed in correctly.



New Synchrotron Light Monitors (SLM) in ArcA and 5C line

- Copious amount of synchrotron light generated in the upper passes at these high energies
- SLM used to continuously monitor beam size, optics match, energy jitter and energy spread.
- New digital imaging and network will allow for improved real-time image analysis.



Surprise!! The Accelerator Circumference is 2cm short!!

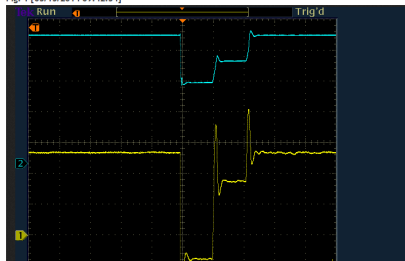
- Immediately evident when multi-pass operations was attempted on Mar. 15th.
- Required pathlength adjustment beyond the capability of the *dog-leg* system.
- Utilize orbit offsets to investigate the pass dependence. Found all passes roughly 2cm short, a global shrinkage.
- Reach for the new (for the 12GeV era) pathlength knob, adjust the Master Oscillator (MO) frequency (wavelength) to adjust CEBAF into an integral number of wavelengths.
 - ▶ Adjustment was 7.5kHz on the 499MHz MO.

References: 3272007 - M55/M56 Hot Checkout
Backlinks: Follow-up Re: Pathlength

Reacquainting myself with pathlength scope and controls. Quoted precision is 10mV/deg. Present difference between pass-2 and pass-1 is over 400mV or 40degrees!!! Or 2.2cm!!!

We need a rubber band!

Fig. 1 [03/15/2014 09:42:54]

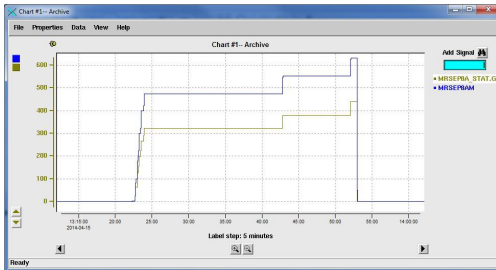


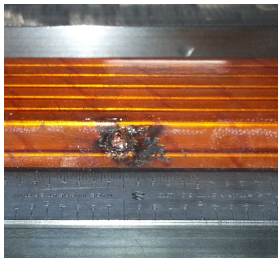
The source of the 2cm short-fall was investigated in depth via the Repair Assessment Process.

- CEBAF cooled and subsequently shrunk significantly during the upgrade impacting Survey and Alignment placement of objects.
- CEBAF appears to be on a *warming* trend and the circumference is increasing.

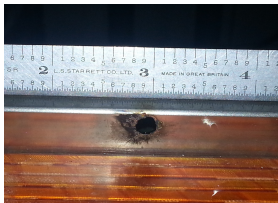
Link to the [Pathlength Assessment Report](#)

- @13:53 on April 15 during beam operations there was a loss of vacuum in the second recombiner.
- Loss of vacuum was coincident with a power supply ground fault in the MZAAR03 magnet. Beam was not being transport through MZAAR03 at the time of ground fault and vacuum loss.





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Coil arcing to adjacent vacuum chamber, punches hole in magnet coil, magnet coil spews LCW.

Arc drills hole in vacuum chamber, vacuum sucks up LCW.

LCW level on an optical viewport.

- What caused the ARC? Magnet had passed full tests in the magnet measurement facility.
- Why was the ARC so persistent? Why didn't the power supply shut off before the coil and vacuum chamber had been damaged?

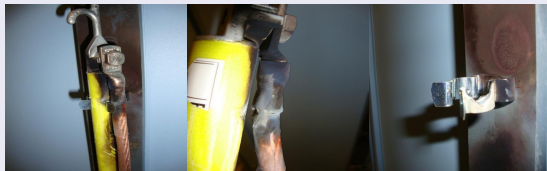
Shrapnel between coil and chamber, and coil motion when magnet energized

Well, there's one kind of favor I'll ask of you
Well, there's one kind of favor I'll ask of you
There's just one kind of favor I'll ask of you
You can see that my *tunnel* is kept clean



Power Supply discharge stick inappropriately configured

- Alternate ground path, compromised ground fault detector.
- All new box power supplies have been modified to correct this problem.



ZA Event: Timeline and Recovery Path

- ZA Event: 13:53 April 15th.
- Investigation and Repair teams formed within 24h of event, several meetings held by end of COB on April 16th.
- Had one spare coil on hand. No spare vacuum chamber.
- Considered using identical ZA in transport line as replacement, but opted for removal and repair.
- Magnet repair and beamline vacuum restoration in parallel, nine days.
- Vacuum chamber repaired by a well conceived and executed patch.
- Commission Advisory Board, with supplemental external subject matter experts, reviewed preliminary findings from the investigation team and recommended resumption of beam commissioning on Apr-24.

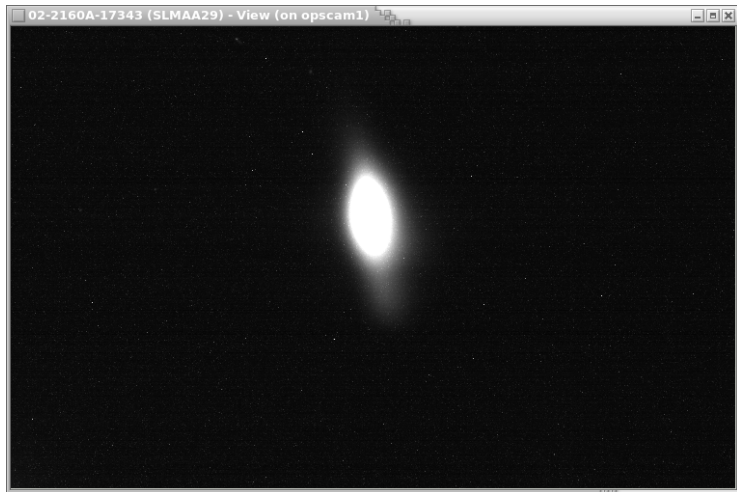
This event consumed the one spare ZA left coil. No spare vacuum chambers are on hand. Lack of spares is a concern going forward. Risk of a major downtime (months) have increased.

Link to the [ZA Repair Assessment Report](#)

- 1 CEBAF 12GeV Beam Commissioning Progress (to date)
- 2 Lessons Learned
- 3 Summary
 - Summary Slide

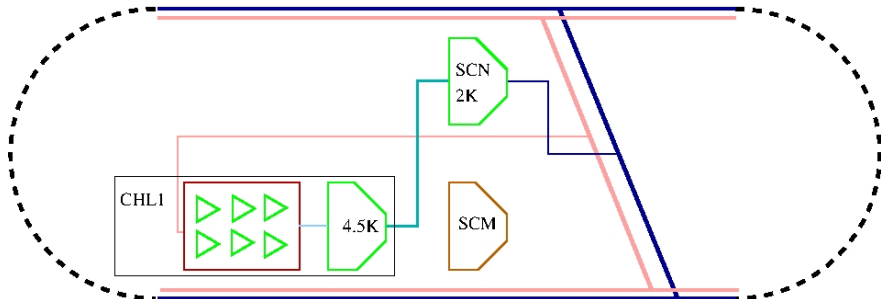
- **No show stoppers encountered.**
- Beam has traversed all 5.5 passes!! (**Bold** items below are new sections/elements):
 - ① The injector, including the **new R100 cryomodule and injection chicane.**
 - ② Every Arc including the new **ArcA (the 10th Arc)** and **all the spreaders and recombiners.**
 - ③ North Linac **6-times**, South Linac 5-times, all **ten C100 cryomodules commissioned and operating**
 - ④ **6T & Hall-A line, polarized CW beam to Hall-A dump.**
 - ⑤ **BS & 5C line, the Tagger Vault, tune-mode beam to the Hall-D dump**
- Beam transport issues are being identified and actively worked.
 - ▶ Beam model and energy scaling
 - ▶ Gradient Maintenance and high availability 12GeV operations.
- The process of bridging the gap between 12GeV Project beam requirements and Physics quality beam has been initiated.
 - ▶ Active use of beams for Physics will accelerate this process by re-establishing the strong feedback loop/relationship between Users and Operations.

Thank you for your time and attention



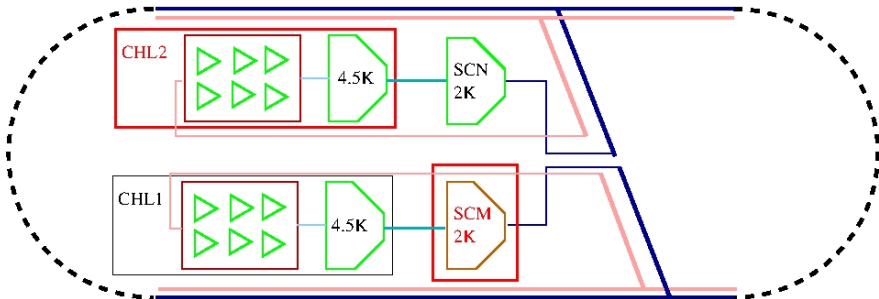
Beam image produced by the synchrotron light emitted in ArcA, $E_{beam} = 9.5$ GeV, tune-mode beam.

Cryogenic Configuration: 6 GeV era



- CHL1** Central Helium Liquifier, takes gaseous He and passes it through a series of compressors to make liquid He. Liquid accumulates in the 4.5K coldbox.
- SCN** 2K Coldbox. A series of compressors are used to lower the pressure and reduce the Helium temperature. **SCN** is the second 6GeV era coldbox, used since the early 2000s.
- SCM** original 4GeV CEBAF coldbox, decommissioned early on due to *issues*. Refurbished, but never commissioned or used as of Oct. 2013.

Cryogenic Configuration: 12 GeV era



CHL2 New Central Helium Liquifier

SCM Must be commissioned as if new.

Linacs Linacs are now separated with one CHL-SC pair tied to one Linac. Each Linac presents the equivalent cryogenic load as in the 6GeV era, but with half the Helium volume.

Both Linacs at 2K on separated CHL on Dec. 9th 2013