CEBAF Status and Beam Transport to Hall B

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Many materials generously provided by Arne Freyberger

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Talk Outline

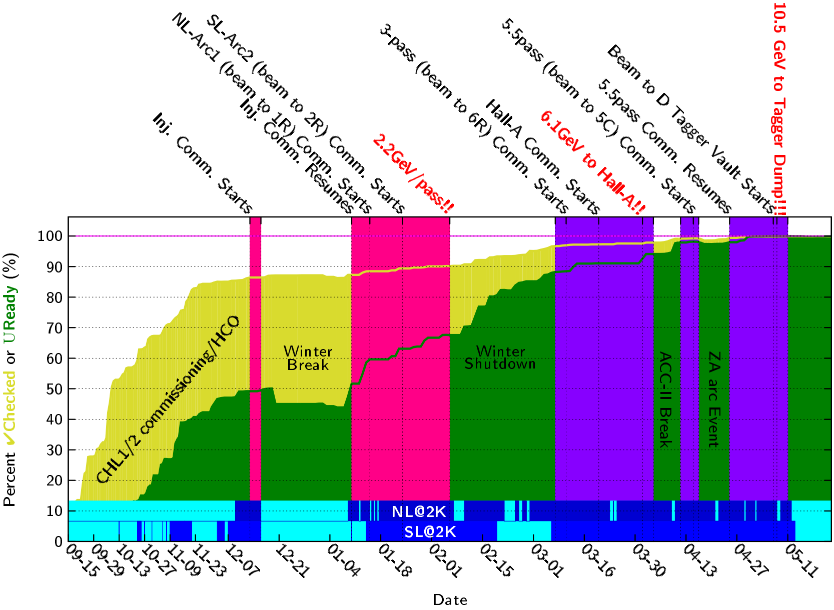
1. CEBAF Status
    - Timeline
    - Hot Check Out
    - CEBAF Status for lower passes
    - Hall B Line Status
2. Summer Activities and Fall Commissioning
3. HPS Beam Requirements
4. Summary

12GeV CEBAF Timeline: To Date

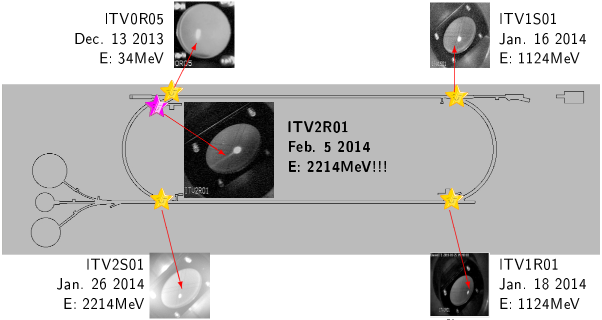
- 2009 12GeV Upgrade construction starts in **May** with ground breaking ceremony at the Hall-D site.
- 2011 First C100 installed in the 2L23 slot in CEBAF, **July**.
- 2012 C100 module successfully operated at design specifications: 108MeV of energy gain with 465μA of beam loading on **May-18**. (End 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**.
- 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$>$ 6GeV 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**.

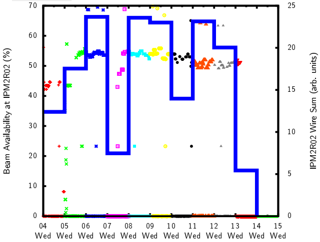
Hot Check Out and Commissioning Progress



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



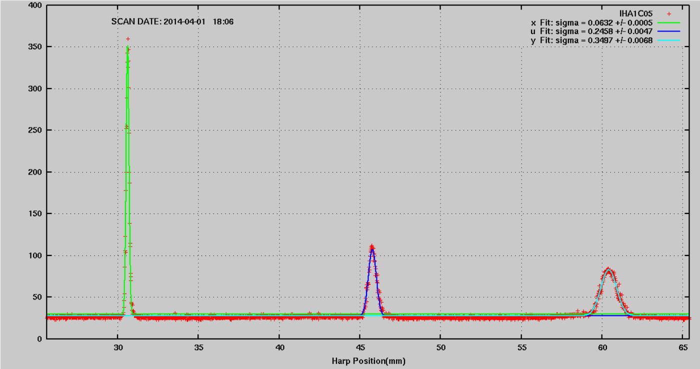
- Tune-mode beam, 8h dwell
- Availability measured by presence of beam at BPM just upstream of 2R dumplet.
- Peak availability ≈ 65%, average for 8h period availability >50%.



CEBAF: 3-pass CW established

- Some data collected at a few energies, analysis in progress.
- Dipole focusing terms (body gradients) need to be well understood to achieve deterministic energy scaling.
- Relied on the nominal 6GeV era process to work through the energy changes.

Beam at start of Hall-A line during 6.11GeV setup (Apr-01):



1^{st} and 2^{nd} passes commissioned, ready for extraction into the 2C line!

2C line (Hall-B transport) status

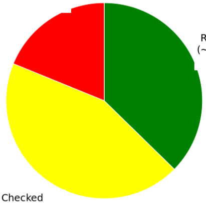
- 12GeV project (Accelerator scope) modifications complete
  - Dipole magnets modified and mapped through 12GeV beam energy
  - Seventeen quadrupole magnets changed out for stronger magnets
  - Five additional quadrupole power supplies beefed up for higher current
- 2C line aligned, vertical shift to correct for tunnel/hall sinking.
- HPS modifications, new elements in the Hall proper, incorporated in CED→HCO.

CEBAF HCO Status: Hall-B Destination

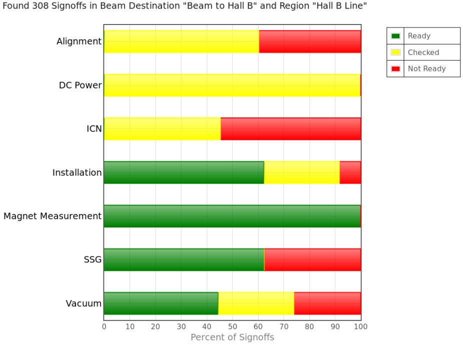
Accelerator Hot CheckOut (HCO) tool populated with Hall-B elements.

- 135 items are in the Checked state
- 58 items are Not Ready.
  - These 193 "Checked" or "Not Ready" elements are in the Bline. HCO in progress, with expectations for completion by mid-Sept 2014.

Found 308 Signoffs in Beam Destination "Beam to Hall B" and Region "Hall B Line"



	Status	Count	Percent
	Ready	115	~37%
	Checked	135	~44%
	Not Ready	58	~19%



Hall-B Beam Delivery

- Hall B transport line essentially unchanged from 6 GeV
- Identical footprint for transport dipoles and lattice
- HPS chicane masquerades as a drift between CLAS12 and dump
- Supplementary BPMs added for HPS beam control/monitoring
- Standard Hall B beam delivery procedure currently being revised

1. CEBAF Status
2. Summer Activities and Fall Commissioning
   - Remaining Installation
   - Remaining Beam Commissioning Activities
3. HPS Beam Requirements
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Remaining Installation: Summer2014

RF Separation: 1-4pass

Summer2014 Complete the upgrade of the RF power & controls for 12GeV era beam energies.

Fall2014 Commission 4,1,3,2 pass separators (priority ordering).

Winter2015 5-pass separator cavities late2014/early2015, no 5-pass separation until Spring2015.

Beam Commissioning Activities: Fall2014

- 5.5 pass setup with detailed accommodation of the synchrotron radiation effects, emittance growth and beam matching.
- 5.5 pass CW beam transport.
- Beam Switch Yard (BSY) Dump line and BSY dump
  - Provides a CW dump for establishing quality CW beam independent of the Halls.
- Transport Lines:2T,4T,8T,AT
  - 6T line (3-pass) has already been commissioned.
- RF Separation:1-4 pass
  - Multi-beam capability, improved CEBAF efficiency with simultaneous users/programs.
- Hall-D Detector Commissioning
- 2C (Hall-B) Beamline (HPS)
- Energy Scaling, beam model, operational procedures

Talk Outline

1. CEBAF Status
2. Summer Activities and Fall Commissioning
3. HPS Beam Requirements
   - HPS Beam Requirements Table
   - HPS Beamline Design
   - Beam Halo
   - Beam properties 12GeV versus 6GeV CEBAF
   - Slow Wire Scan Results
   - TAC Comments
4. Summary

HPS Beam Requirements

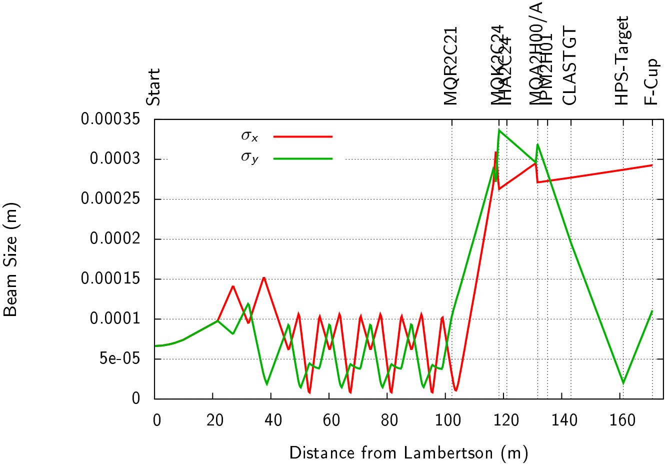
Parameter	Requirement	Unit
E	1100, 2220, 6600	MeV
$\delta E/E$	$< 10^{-4}$	
Current	< 200, < 400, < 500	nA
Current Instability	< 5	%
σ_x	< 300	μm
σ_y	< 50	μm
Position Stability	< 30	μm
Divergence	< 100	μrad
Beam Halo ($> 5\sigma_y$)	$< 10^{-5}$	

HPS Beamline Design

- Use the **unmodified** 2C line (started from 12GeV design layout).
- Begin with 12GeV design values for initial beam parameters entering 2C line ($\varepsilon, \frac{\delta p}{p}, \beta, \alpha$).
- Alter settings for 2C quadrupole magnets at end of line (MQR2C20, MQR2C21, MQA2C21A, MQK2C22, MQK2C23, MQK2C24) to satisfy HPS requirements.
- **Add** two additional quadrupoles downstream of tagger magnet to provide additional focusing strength.
- **Add** correctors and BPMs between tagger and HPS experiment to monitor and enable control of beam trajectory.

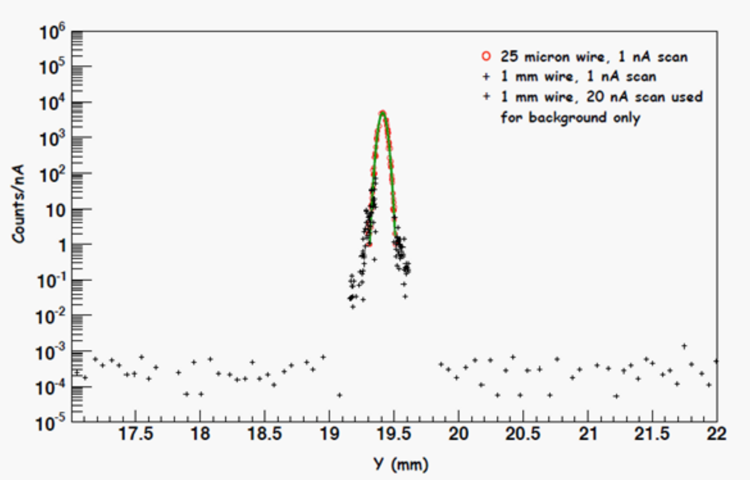
	Unit	1.1GeV	2.2GeV	6.6GeV
σ_x at target	(mm)	0.275	0.287	0.289
σ_y at target	(mm)	0.020	0.020	0.021
MQR2C20.K1	(1/m)	1.5636	1.7226	1.7213
MQR2C21.K1	(1/m)	-1.3080	-0.2544	-0.2566
MQA2C21A.K1	(1/m)	-0.0010	-0.0009	-0.0010
MQK2C22.K1	(1/m)	-0.4168	-0.4984	-0.4951
MQK2C23.K1	(1/m)	1.3485	1.3454	1.3550
MQK2C24.K1	(1/m)	-0.8219	-0.8327	-0.8605
MQA2H00.K1 NEW	(1/m)	1.8614	0.9666	0.9934
MQA2H00A.K1 NEW	(1/m)	-1.8723	-0.9985	-0.9995

HPS 2C line transport – 2.2 GeV



Beam Halo: PRad measurement

PRad experiment in Hall-B has a stringent requirement on halo (10^{-7}).
Measurements were made during the 6GeV era to gauge CEBAF's ability to meet the requirement.
The experiment was approved.



Comparison of emittance and energy spread for 6 GeV and 12 GeV CEBAF

$\sigma_x = \sqrt{\varepsilon_x \beta_x}$

Expected 6 GeV CEBAF beam emittance and energy spread

Linear model with no synchrotron radiation effects. Emittance and energy spread for 6-pass beam probably underestimated.

Where	E (GeV)	$\frac{dp}{p}$ (%)	ε_x (nm)	ε_y (nm)
Pass-1(ABC)	1.3	0.005	0.39	0.39
Pass-2(ABC)	2.5	0.002	0.20	0.20
Pass-3(ABC)	3.7	0.002	0.14	0.14
Pass-4(ABC)	4.9	0.001	0.10	0.10
Pass-5(ABC)	6.0	0.001	0.09	0.09

Expected 12 GeV CEBAF beam emittance and energy spread

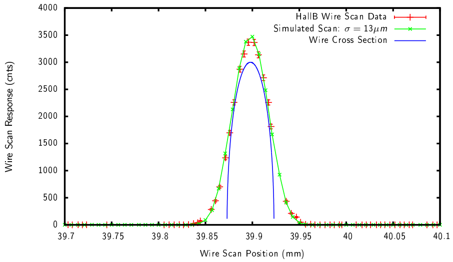
12GeV beam transport calculations include synchrotron radiation and magnetic multipole contributions.

Where	E (GeV)	$\frac{dp}{p}$ (%)	ε_x (nm)	ε_y (nm)
Pass-1(ABC)	2.3	0.003	0.22	0.22
Pass-2(ABC)	4.4	0.003	0.17	0.16
Pass-3(ABC)	6.6	0.005	0.28	0.21
Pass-4(ABC)	8.8	0.009	0.69	0.38
Pass-5(ABC)	11	0.015	1.88	0.86
Pass-5.5(D)	12	0.018	2.70	1.03

12 GeV CEBAF on 1^{st}, 2^{nd} and 3^{rd} pass comparable to 6 GeV CEBAF performance.

Slow Wire Scan Test: Feb-2011

- Special optics loaded to achieve a 10μm vertical beam size at the Tagger wire scanner.
- Wire Scanner speed: 0.1mm/sec
- PMT readout rate: 14Hz
- Wire diameter: 50μm
- Gaps in data are due to EPICS IOC deadtime.
- Raw measured beam size: 18.5μm
- Corrected measured beam size: 13μm (JLAB-TN-14-002)



Duration of scan shown in plot is 4s, complete scan took minutes. Beam stability not an issue during this scan and achieves the HPS requirement of $< 30\mu$m.

Beam Related TAC Comments generated during proposal process

4 It should be verified that the requested small beam spot size of $\sigma_{x,y} < 30\mu$m can also be achieved in the 12 GeV era. The same applies to the halo of $<10^{-05}$ beyond 1 mm.

- ✔ Beamline design used 12GeV 2C layout and 12GeV values for beam emittance, energy spread and initial TWISS values. With these values beam sizes a factor two smaller than required were achieved.
- ✔ Detailed Halo studies by CASA through 5.5 pass did not show any evidence of halo generation.
- ✔ Halo conditions (or the absence of halo) on lower passes (1-3) likely to be identical to the 6GeV era beam quality in the 12GeV era.

7 A modified FFB system may be needed to keep the vertex stable in x, y.

- ✔ Slow wire scan data shows beam stability at the tenth of a Hz level. Nominal EPICS based PID locks sufficient to maintain beam stability on this timeframe.
- ✔ Addition of two new stripline BPMs with new electronics may be used in feed back loops/

8 Mechanical vibration of the quads maybe an issue as they are mounted well above the floor. All quadrupole magnets may have to be mounted on the same aluminum extrusion.

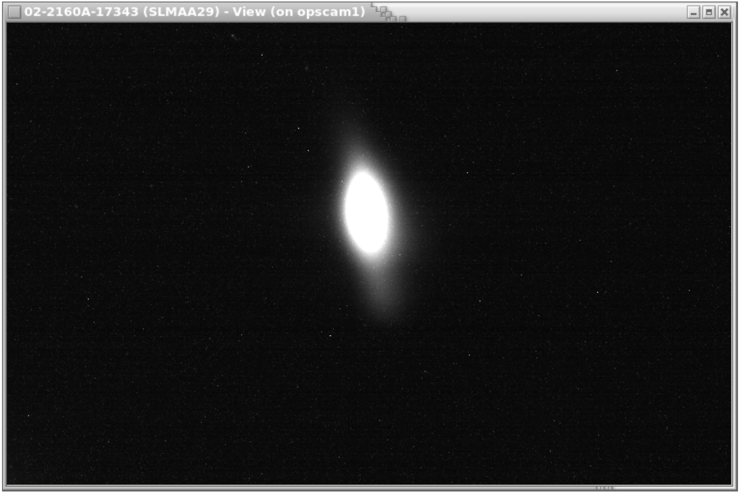
- ✔ The two new quads **are** mounted on the same aluminum extrusion.

Summary

4 Are the anticipated beam emittance, halo characteristics and general stability likely to be within the required specification to perform this measurement?

✔anticipated beam emittance	The 12GeV design emittances (anticipated) were used in the design of the beamline. Beam sizes half of the specification were achieved (safety factor).
✔anticipated halo characteristics	Measurements in the 6GeV era (PRad halo measurements) and the near equivalence of the CEBAF elements and beam properties at 1.1 and 2.2 GeV support meeting this requirement.
✔anticipated general stability	Measurements in the 6GeV era (slow wire scans) and the near equivalence of the CEBAF elements and beam properties at 1.1 and 2.2 GeV support meeting this requirement.
✔hardware availability	Hot Check-Out progress is on track to assure proper hardware function on schedule

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.