

CEBAF Accelerator Update

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Accelerator Division Leadership

- On April 30 **Andrew Hutton** stepped down as the head Accelerator Division
 - ~10 years as Associate Director
 - Prior to his appointment as Associate Director, Andrew was Director of Accelerator Operations for ~15 years.
 - Commissioning of 4 GeV CEBAF
 - Ramp up to 6 GeV
 - Recovery post-Hurricane Isabel
- **Fulvia Pilat** has assumed the role of *Acting Division leader* until the completion of the search for the new Division leader
 - Fulvia has also accepted the Director of the Research Accelerator Division at SNS and will assume this position in Fall 2017.

The View from ~~Inside~~ Your Side

"What area(s) do you most want covered in the Accelerator Update?"

- Beam availability (“reliability” vs. funding)
- Beam energy (immediate and near-term)
- Trip rate (beam interruptions)
- Other parameters
 - Stability
 - Momentum spread
 - Envelope (RMS and 10^{-3} halo)

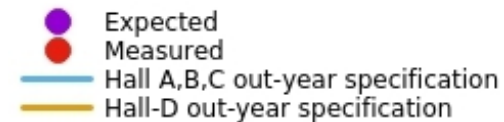
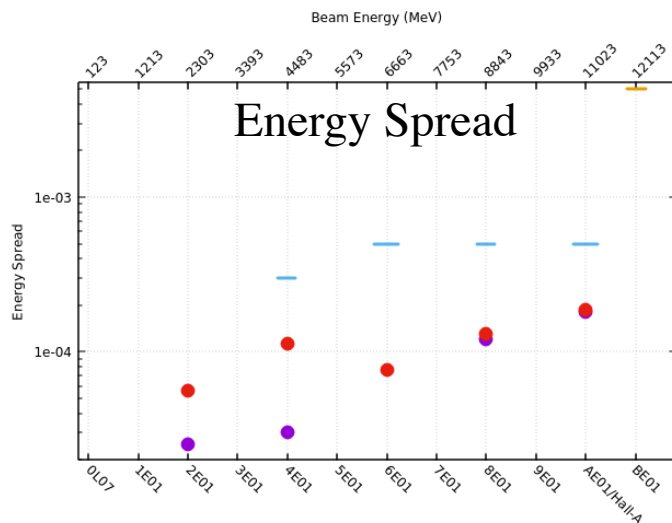
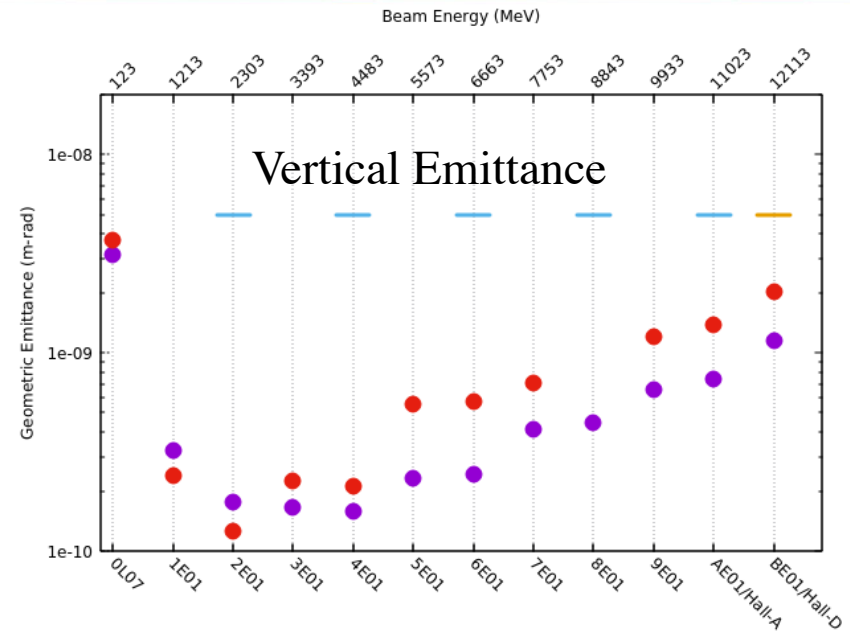
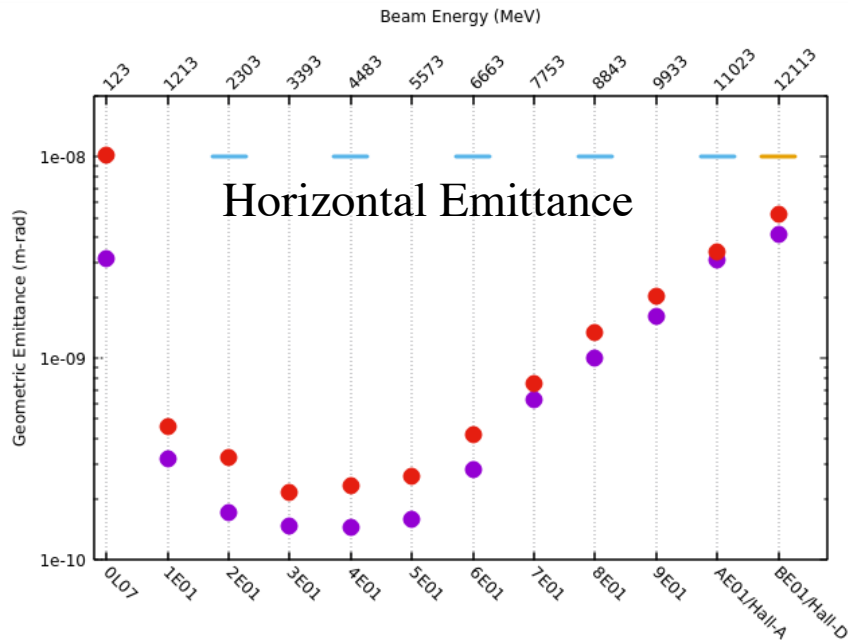
12 GeV Out-year Beam Requirements

Hall	Emittance (nm-rad)	Energy Spread σ (%)	Spot Size σ (μm)	Halo
A	$\varepsilon_x < 10$ $\varepsilon_y < 5$	< 0.05 (12 GeV) < 0.003 (2-4 GeV)	$\sigma_x < 400$ $\sigma_y < 200$ ($\sigma_y < 100$) (2-4 GeV)	$< 1 \times 10^{-4}\dagger$
B	$\varepsilon_x < 10$ $\varepsilon_y < 10$	< 0.1	$\sigma_x < 400$ $\sigma_y < 400$	$< 2 \times 10^{-4}\dagger$
C	$\varepsilon_x < 10$ $\varepsilon_y < 10$	< 0.05	$\sigma_x < 500$ $\sigma_y < 500$	$< 2 \times 10^{-4}\dagger$
D	$\varepsilon_x < 50$ $\varepsilon_y < 10$	< 0.5	At Radiator: $\sigma_x < 1550, \sigma_y < 550$ At Collimator $\sigma_x < 540, \sigma_y < 520$	$< 1\%\ddagger$

\dagger Ratio of the integrated non-Gaussian tail to Gaussian core.

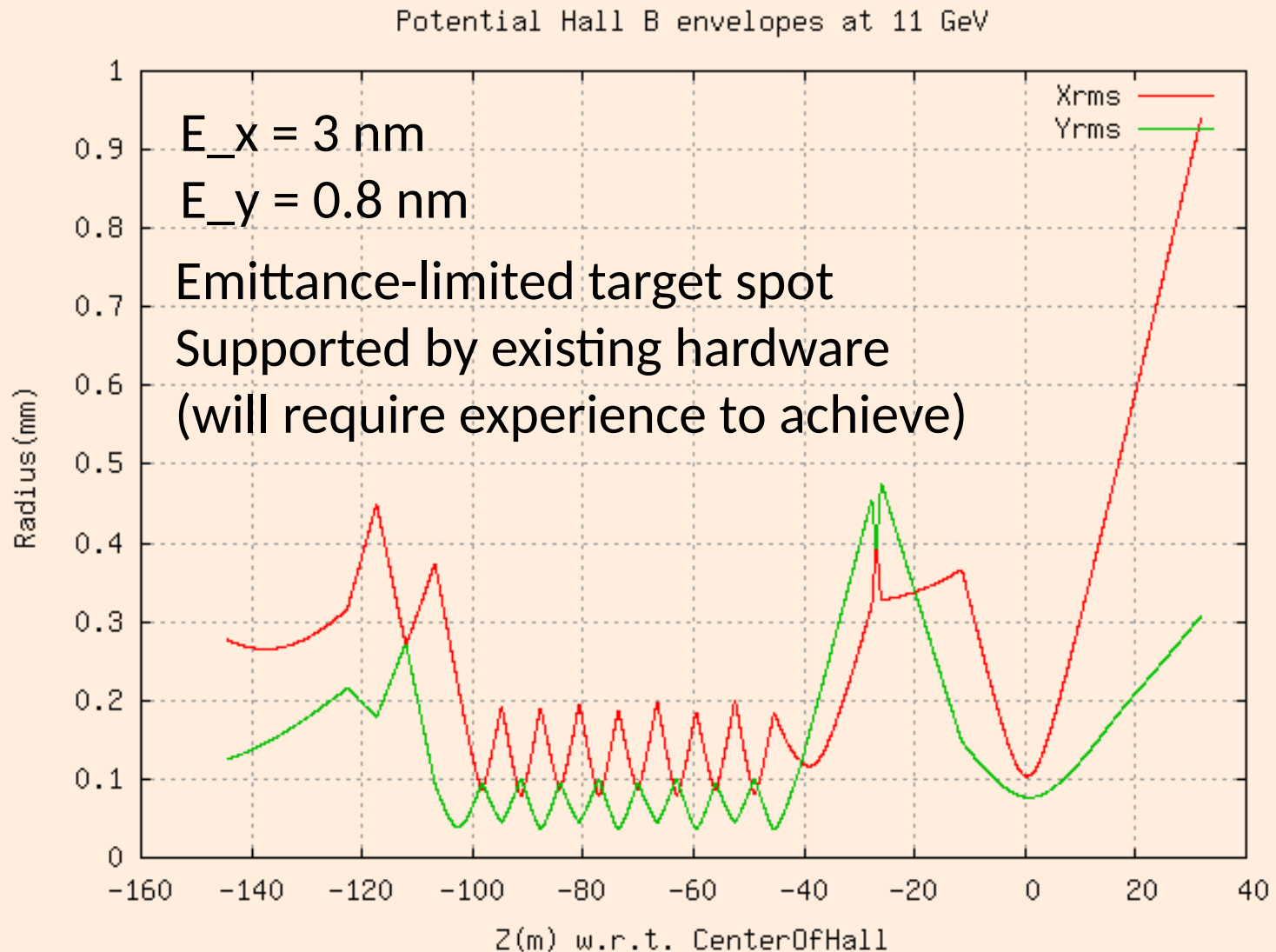
\ddagger Ratio of Halo background event rate to physics event rate.

Beam Parameters at 12 GeV (2.2 GeV/pass)



- Beam parameters at 12 GeV meet **out-year** specification.
- Growth in emittance/energy spread due to synchrotron radiation effects agrees well with expectations.

Potential Hall B 11 GeV Beam Envelope



CEBAF 4-Hall Operations Begins Fall 2017

4 Hall Operations (also called D+3) begins this Fall

Condition	(D+2)	(D+3)
• Maximum number of halls receiving beam	3 halls	4 halls
• ABC Beam @ 5 th pass (Hall D on)	499 MHz	249.5 MHz
• ABC Beam @ 5 th pass (Hall D off)	499 MHz	499 MHz
• ABC Beam @ lower passes	499 MHz	499 MHz

4 Hall Preparations Completedso far

- ✓ Rebuild laser table w/ 4th laser and 4-beam combination
- ✓ Two beams @ 249.5 MHz share one 499 MHz “RF Chopping Bucket”
- ✓ 750 MHz separators for 5th pass ABC / D separation

12 GeV Peak(best) Performance (to date)

Accelerator Incident Downtime (Hours) from April 7 - 25, 2016

Summary

Total Downtime (Hours):	27.0
MTTR (Hours):	0.8
Total Suspend (Hours):	22.8
Total Restore (Hours):	4.2
Period Duration (Hours):	422.0

**94% CEBAF
System Reliability**

Tight configuration control during this period; not one quadrupole magnet was manually adjusted. No tweaking, just monitoring.

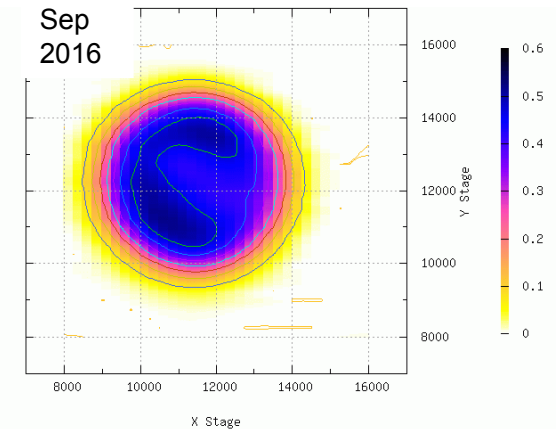
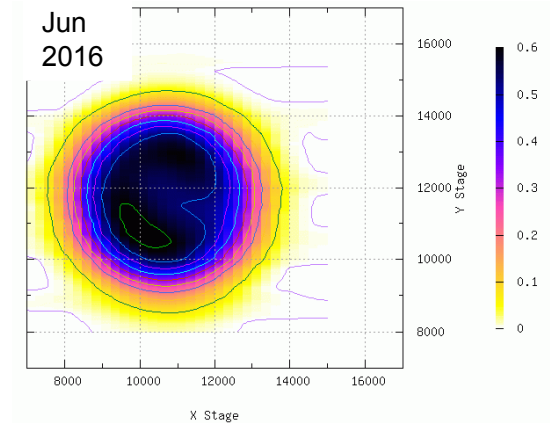
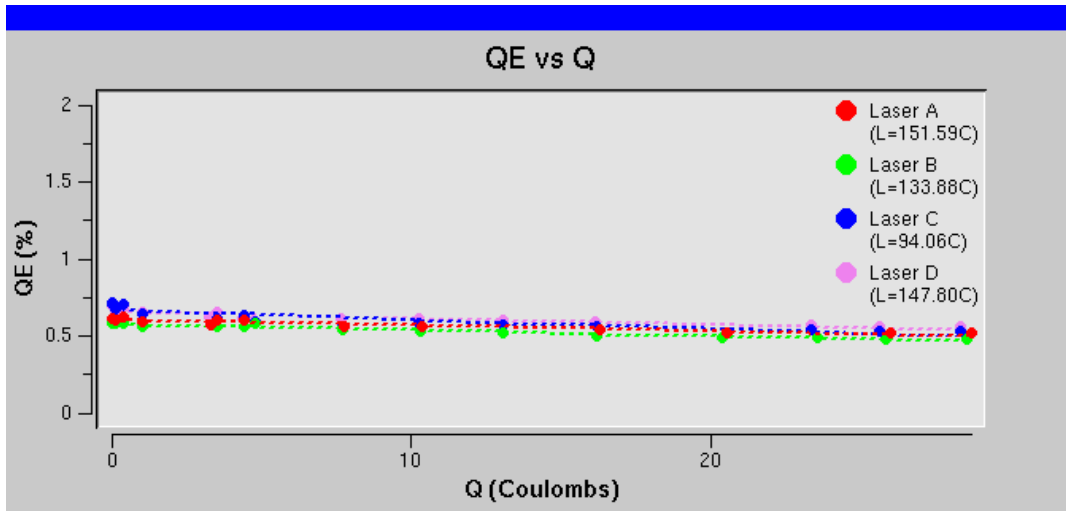
Source Operation

Spring/Fall 2016

- SSL GaAs/GaAsP SVT #5756-4 (Polarization $\sim 87\%$)
- No heat/activation over Summer 2016 / Winter 2017 SADS

Fall 2016

- Gun2 operating at -130 kV without any problems
- Charge lifetime $>100\text{C}$ with average current $70\text{-}80\text{ }\mu\text{A}$



Spring 2017

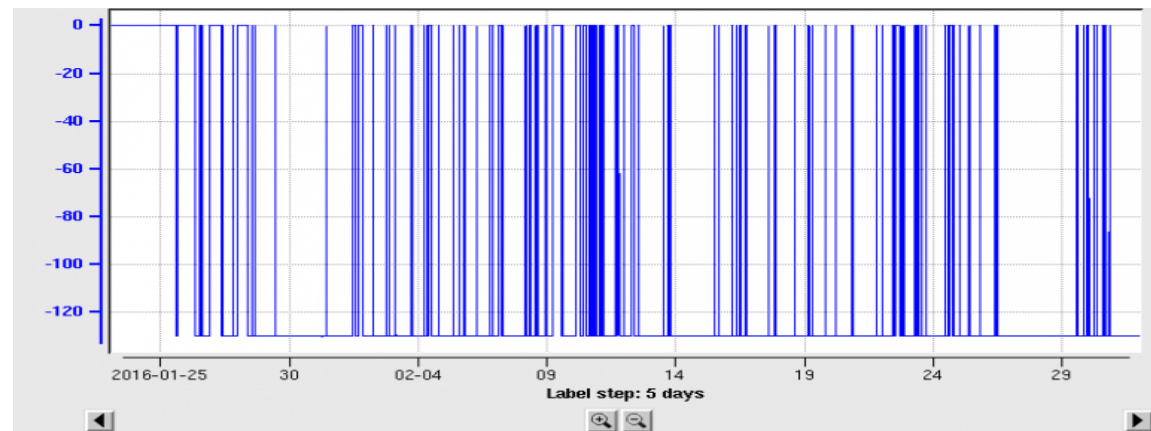
- Delivering up to 3 halls at a time (either 249.5 or 499 MHz)
- Hall A (Physics), Hall B (KPP), Hall C (KPP), Hall D (Physics)

PSS High Voltage Interface Upgrade

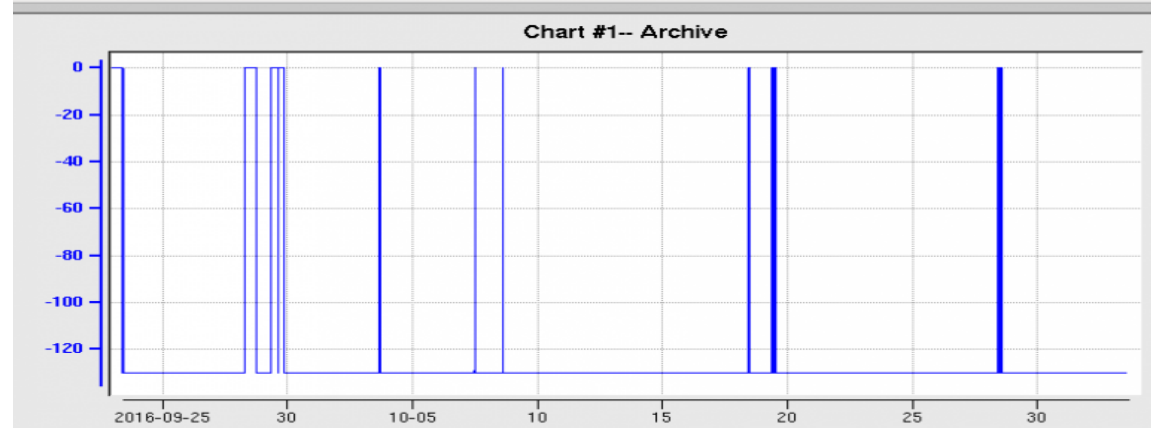
Fall 2016

- Historically Gun HV commensurate with PSS Beam Permit state => Off often!
- Gun HV power supply now remains ON when PSS = Power Permit
- Anticipate improved injector reliability and possibly increased charge lifetime

First 5 weeks of
Spring 2016 Run
(before upgrade)



First 5 weeks of
Fall 2016 Run
(after upgrade)



Injector Summary

CEBAF Operations

- Source is operating well, providing high polarization at 11 GeV
- On track for 4-Beam operations in Fall 2017, time will tell how easy this is.

Injector Upgrade

- Deliver and test 200 kV beam at CEBAF injector Summer 2017 SAD
- Test of 200 kV Wien filter, new QCM and higher voltage polarized gun at UITF
- Rebuild baked beamline with 2-Wien spin flipper Summer 2018 SAD

Parity Quality Beam Readiness

- Required specifications have been demonstrated
- We are ready to return to setting up and delivering PQB beams

Linacs and Accelerator Systems

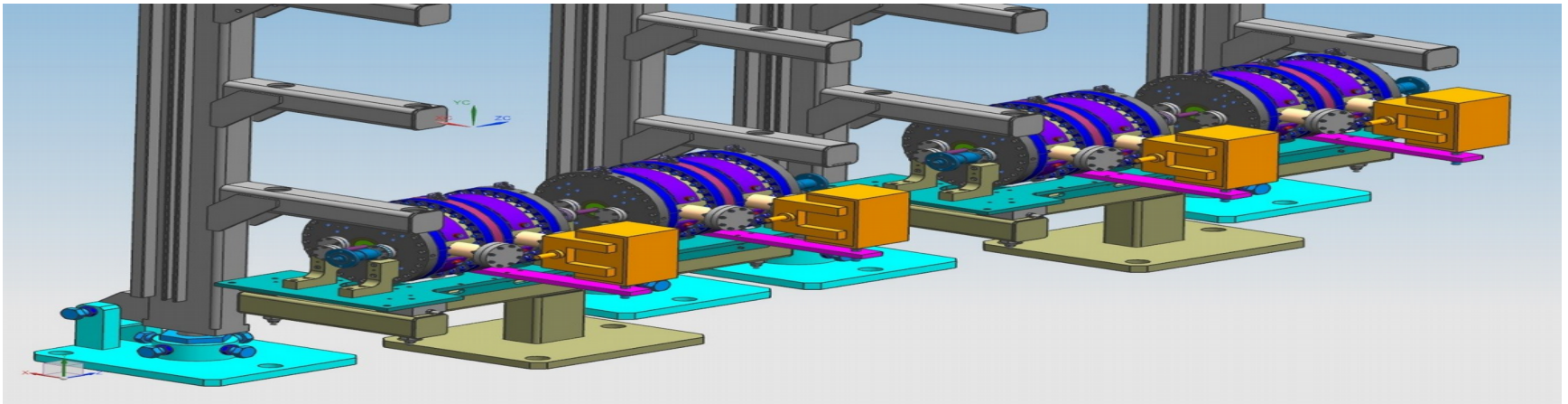
- Energy set to 4% below 12 GeV nominal value
 - Expect to hold at this energy (A. Freyberger 3/28/17)
- Trip rate is “acceptable”
- 750 MHz separators are operational
- We are learning how to operate the hardware
- We are learning where the limits are
 - Some things have broken
 - Some are being fixed
 - Some are being worked around
- Development of the accelerator continues
- Working at hardware limits eats “clock time”
 - a Bad Idea

Fall 2016 RF Performance

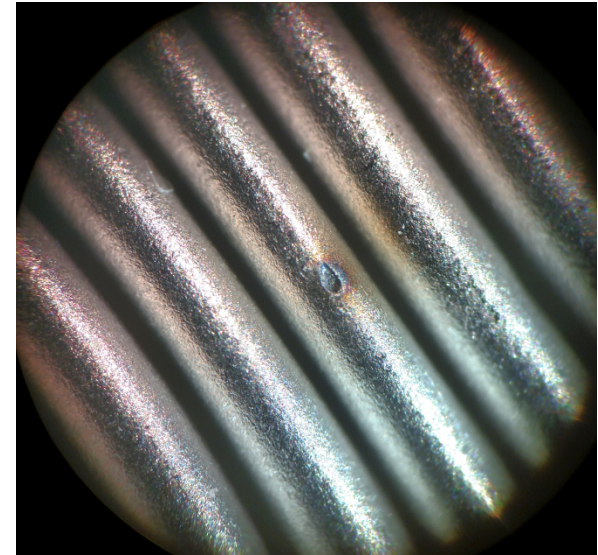
- One pass energy gain set to 2.1 GeV/pass
 - 100 MeV/pass lower than 12 GeV design (-5%)
 - Availability during Spring 2016 Operations at 2.2 GeV/pass suffered due to lack of gradient margin.
- ~50 MeV/linac of gradient margin in Oct. 2016 (at 2.1 GeV/pass)
 - Program flexibility: by-passed troubled cavities in a few minutes and resume beam operations.
 - By Dec. margin was reduced to 25 MeV/linac due to by-passed cavities and other gradient reductions.
 - Most of this reduction was recovered during Jan. 2017 SAD

Fall 2016 Accelerator Operations

- Hall A (1,3,4,5 passes, 70 μ A) & Hall-D 5.5 passes
- Linac Energy: 1050 MeV/linac
- Commission 5th pass separator
 - Validate improvements made over the Summer 2016
 - Compact Geometry (+9%)
 - Increase RF power (+10%)
 - Vacuum leak in one of the cavities immediately following commissioning rained on the parade



750 MHz Separator Leak



- Leak in tuner bellows associated with some discoloration
- Root cause of the leak still not identified
 - Bellows and near-by wall surface nominally at ground potential
 - No associated discoloration found on cavity wall

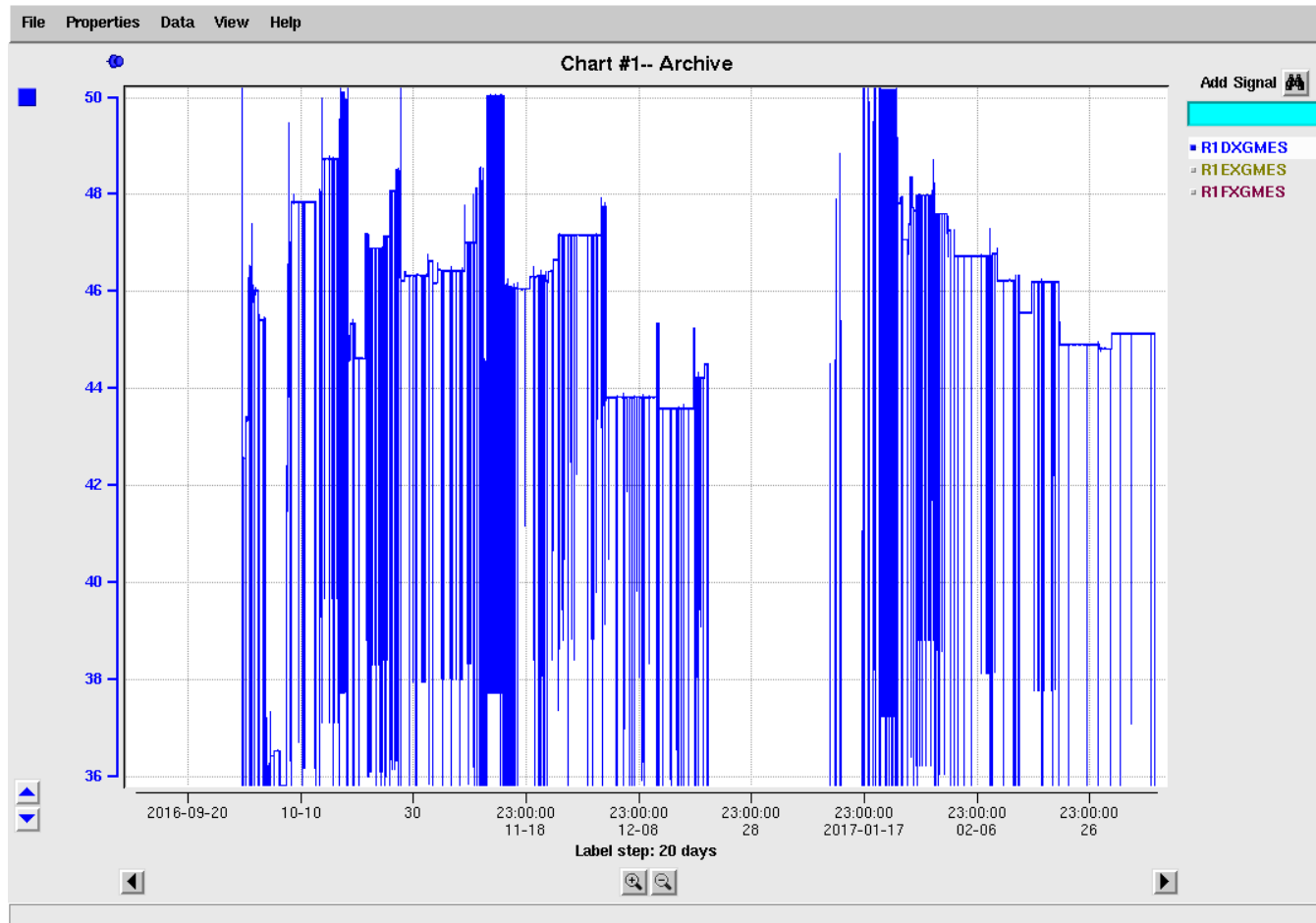
750 MHz Separators

- Vacuum issue repaired (bellows punch-through)
- Arc mark in thin bellows (multipacting?)
- Separator system re-commissioned
- Improved system layout adds power margin
- Thermal control issues identified
- System is capable of continuous operation

This fault was not anticipated. While not fully understood, it is not considered likely to recur.

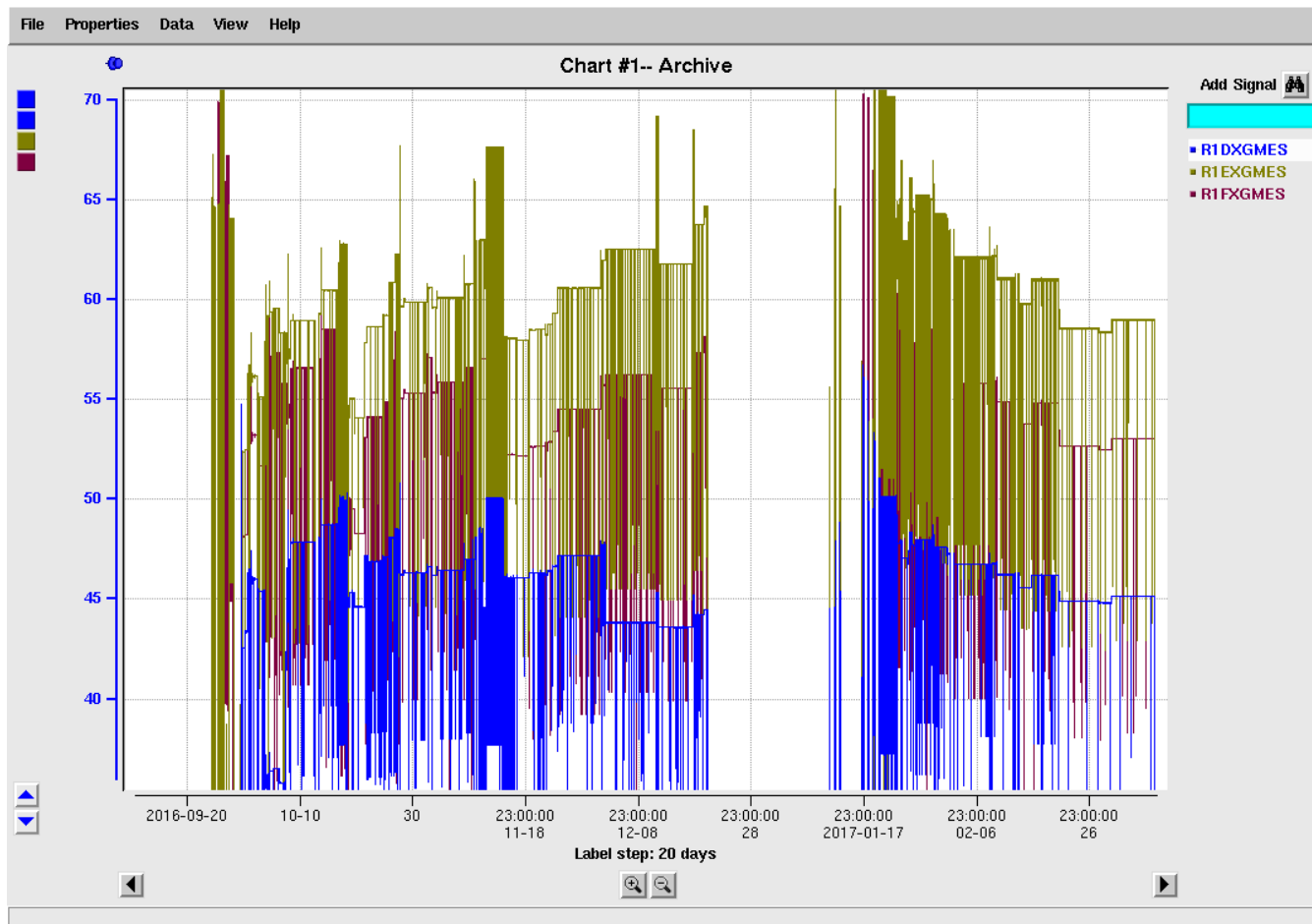
Replace Cryomodule 1L13 with a C50

C25 replacement boosts 22 MeV to ~50 MeV
(Note improvement over time through Spring 2017)



Ops RF trip rate management works

Adjacent C25 zones 1L14/1L15 more capable than 1L13
(Again note improvement over time through Spring 2017)

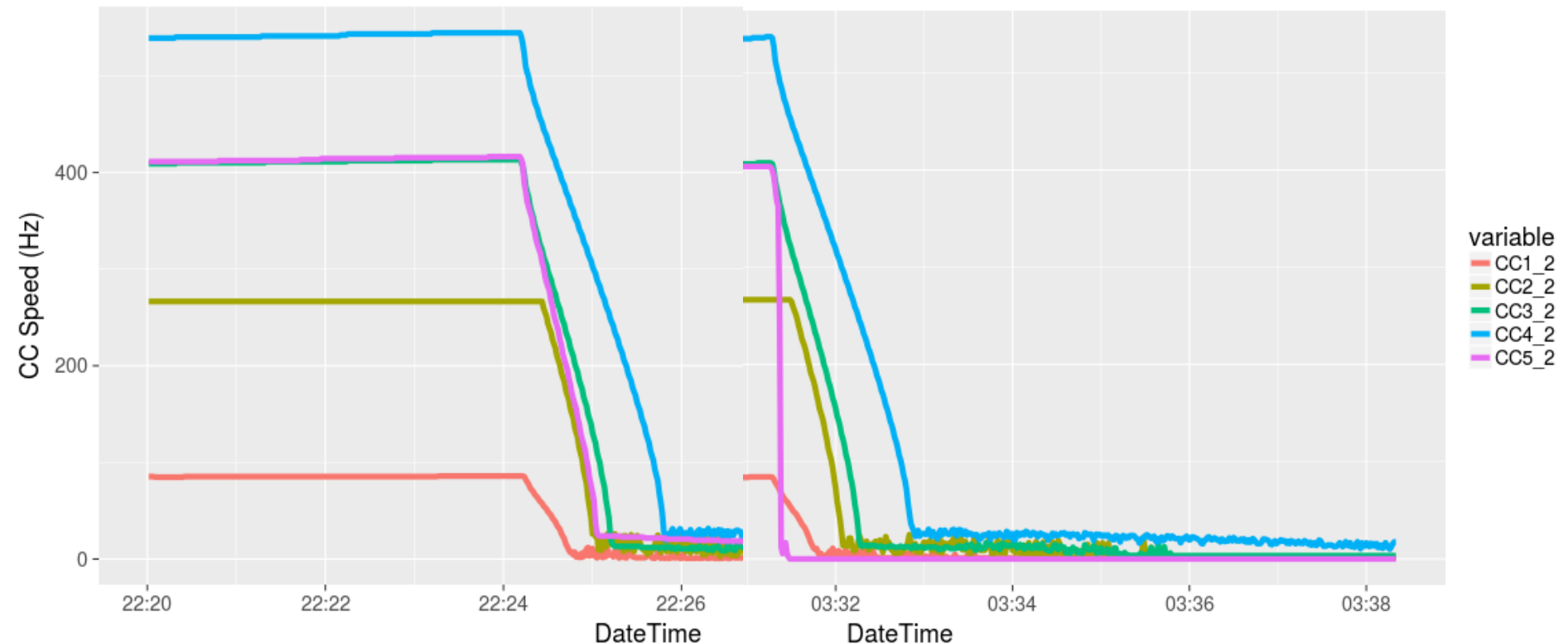


Linac Systems Issues Summary

- RF Performance in Fall 2016 was very good
 - RF trips < 5 trips/h
 - C100 trips factor two less than Spring 2016
- Up 80 μ A, 700kW delivered to Hall-A on 4th pass.
- Support two-hall operations on the last week.
- Month of Dec. had 80% overall availability
- 750 MHz separation improvement demonstrated (vacuum leak prevented further operation).
 - Root cause not as yet known
 - Repairs successfully accomplished
- 750 MHz separators fully functional
 - Unanticipated LCW pressure vulnerability to be fixed

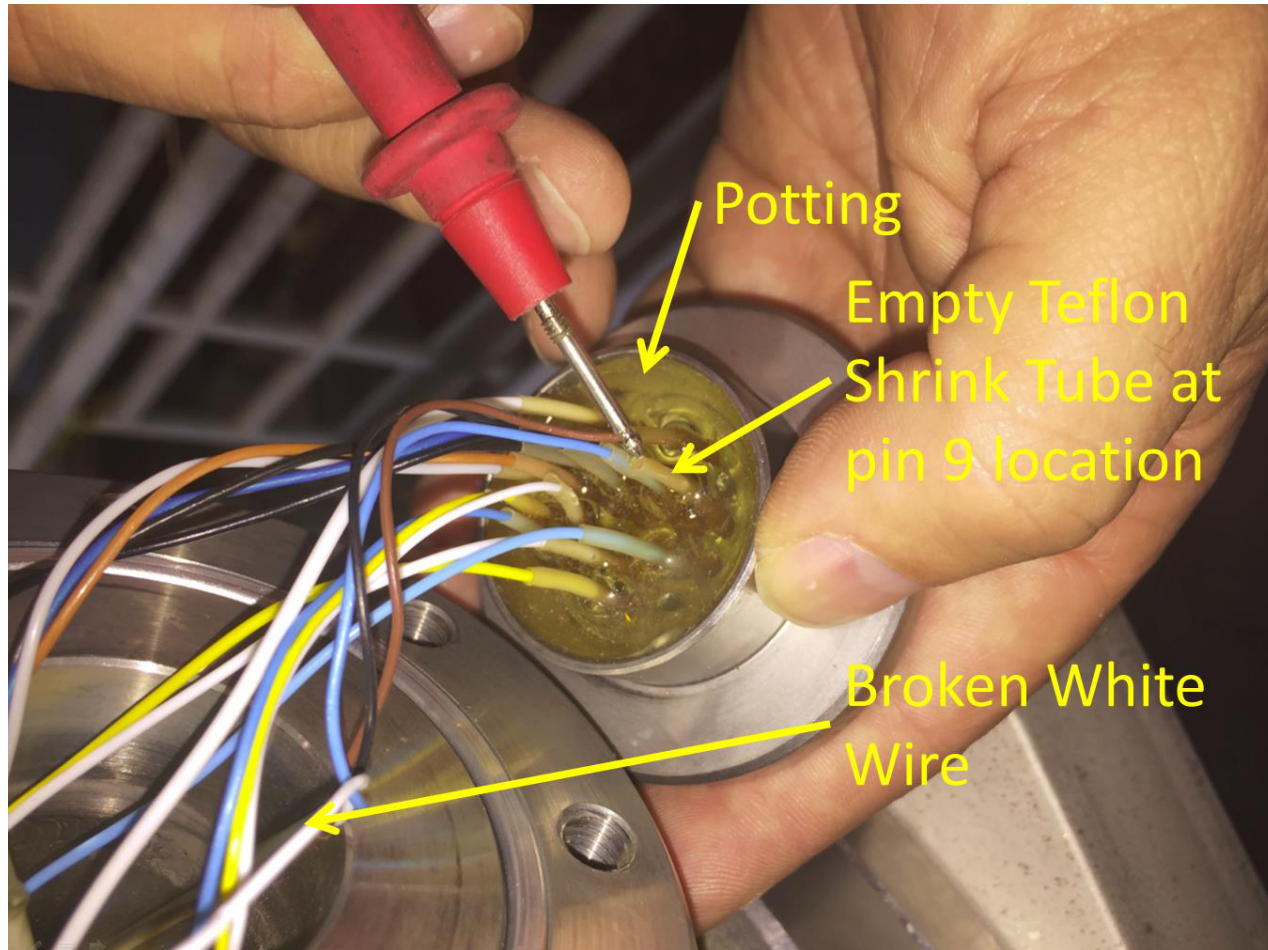
Cold Compressor Trip, fast spin-down

- Spring 2017 run was going well up to March 9th 2017
 - CHL1->SC1 tripped off in the evening
 - Recovered and tripped in the early morning of March 10th
 - Cold Compressor 5 (CC5) inoperable post 2nd trip.
 - Not initiated by power failure as earlier event



Cryo: CHL1->SC1->CC5 Update

2017-05-02: Broken wire on magnetic bearing connector was found.



CHL Status Now

- Failed CC4 from 2 years ago
 - rebuilt and returned a week ago
 - preparing for reinstallation
 - Warm spin testing expected week of June 19
- identified new CC5 wiring issue
 - "infant mortality" in low-time system
 - Repaired; warm spin testing this week
- spare oil-based compressor (2500 hp)
 - deleted from 12 GeV project to cut costs
 - equivalent item purchased (UIM)
 - available for use now

Unscheduled Tuning: what is it?

- Something goes wrong during beam delivery
- No system shows a fault
- Beam doesn't go where/how we want
 - Vacuum
 - Focusing magnets
 - Bending/Steering magnets
 - Accelerating RF
 - Bunch formation RF in injector
 - Cathode drive laser
 - Unrecognized drifts in other systems
- Use the beam for sub-system diagnosis
 - Time-consuming, inefficient

Example: MQA2R09 wiring error

- Resistance (barely) within range
- Use rayTrace differential orbit data to diagnose
- Identified long-standing 15% focusing strength error

Fig. 1 [04/21/2017 16:21:56]

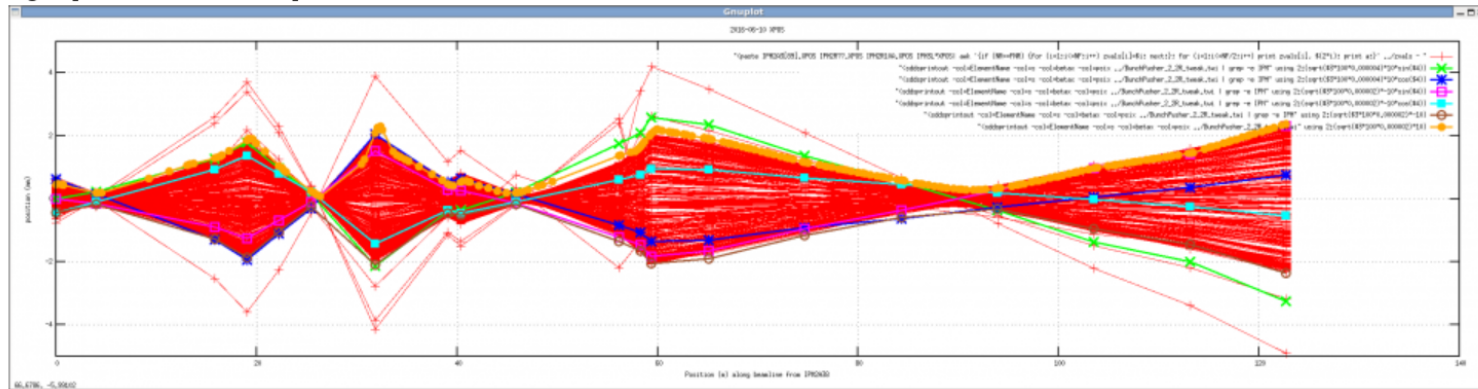
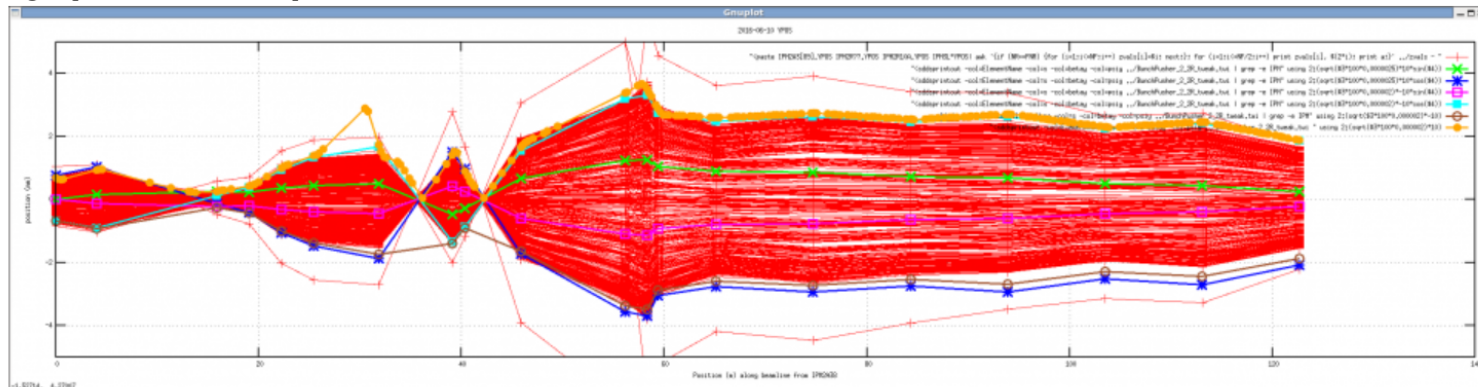
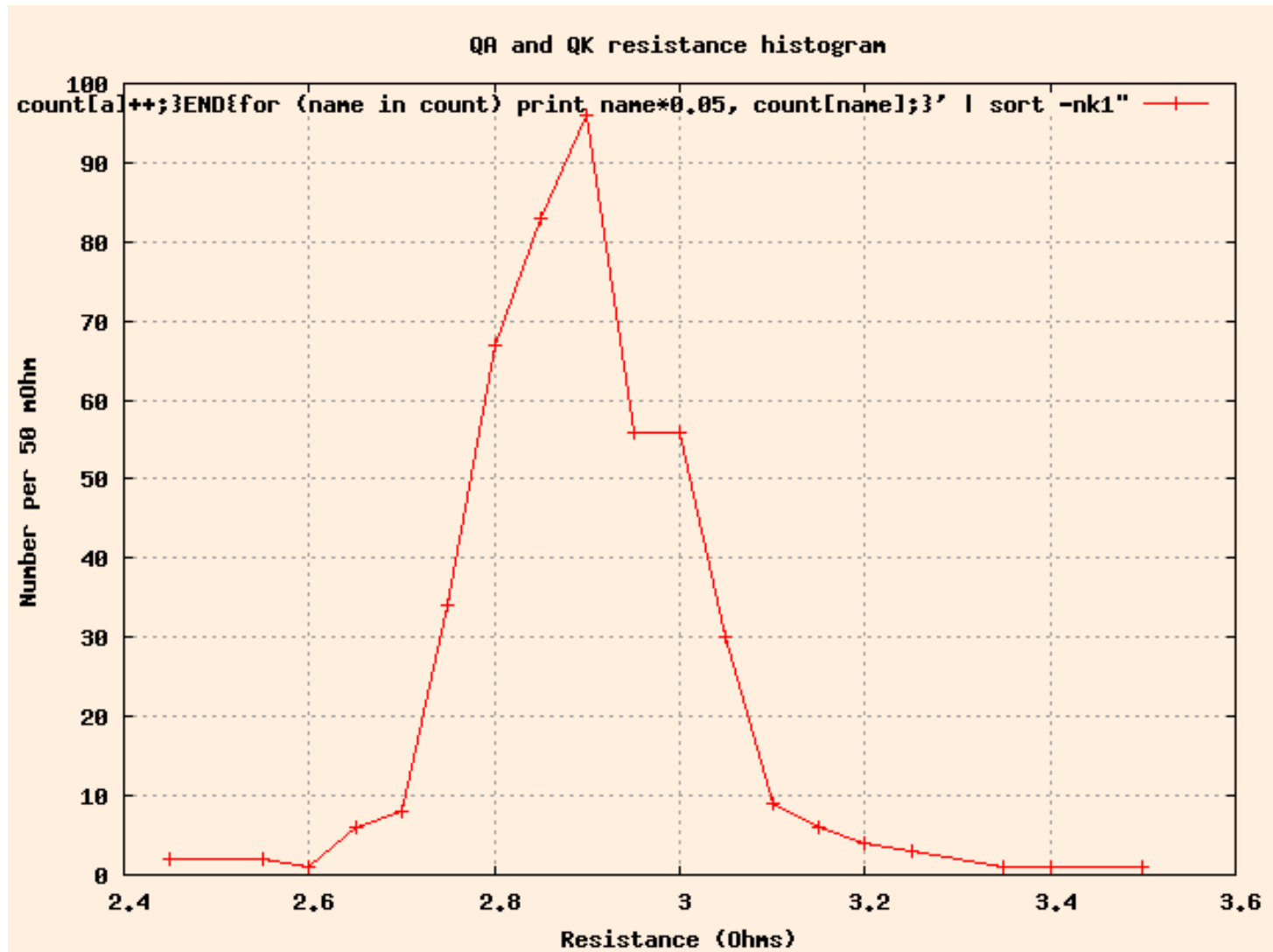


Fig. 2 [04/21/2017 16:22:02]



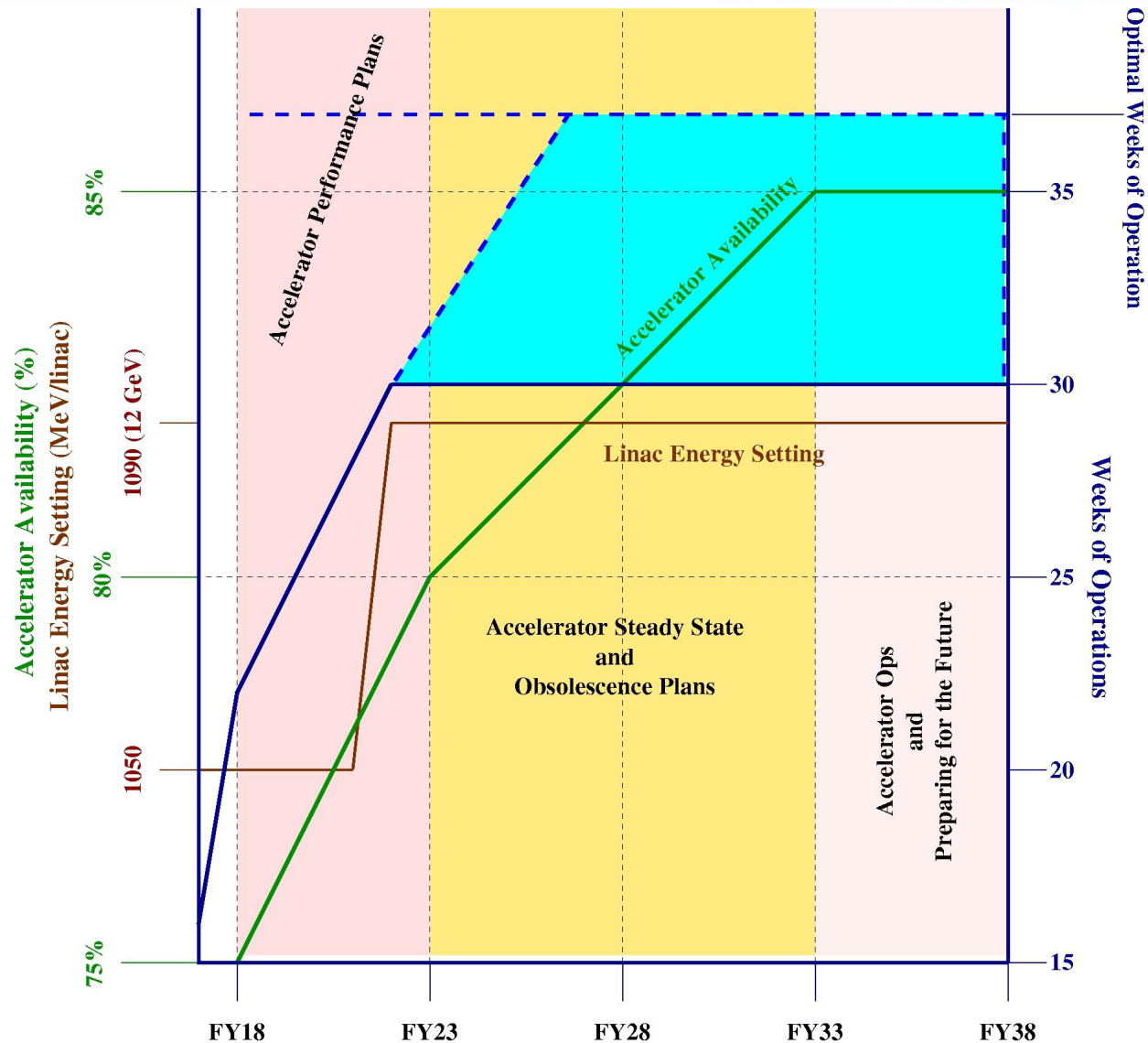
Reported Resistance of QA/QK Quads



Improved Calibration of DC Power

- Systematic measurement of magnet resistances
- Recalibration of voltage read-back in trim system
 - Voltage historically secondary to amperage
 - Improved resistance measurements
 - Identification of difficult-to-diagnose errors
- Follow-on to previous system improvements
 - Noise alarm (flicker in readback)
 - Voltage tracking after establishing set point
 - Target: detection of in-situ degradation
- Better system monitoring
- Early identification of installation errors

CEBAF Performance Plan (Under Development)



Performance Goals

What	Unit	Goal
Availability	%	> 80
Optimal Weeks	weeks-per-year	37
Beam Tuning Hours	h/week	< 8
Peak Hall Multiplicity	Number of halls	4
12 GeV Program Expected Duration	years	20
Performance Plan Duration	years	5
Linac Design Energy	MeV	1090
Required Linac Energy Margin at start of FY	MeV	> 110
Overall FSD Trip rate	trips/h	< 15
Overall FSD Trip Downtime	min/h	5
RF Trip rate	trips/h	< 10
Beam Loss Trip rate	trips/h	< 5

Short-term Outlook

- CHL configuration uncertain for a few more weeks
 - Overhauled cold compressor tests imminent
- Linac (SRF and other systems) performance improving
- 750 MHz separators back on-line
- Operational issues being solved
 - Energy gain per pass is improving
 - Improving operations procedures
 - Improving internal calibrations
- Budget and schedule?
 - We should all find out soon

Summary

- **12 GeV Experimental program established**
 - Hall-A: GMp **completed** (Hall-A), schedule portion of DVCS completed
 - Hall-B: PRad **completed**, HPS engineering run
 - Hall-D: First production run Spring 2017
- **12 GeV beam related activities completed**
 - Hall-B KPP
 - Hall-C KPP
- Accelerator Operations continues to dial in 12 GeV performance
 - Combined effort with CASA, SRF, Engineering, Facilities
- Availability Challenges Remain
 - New systems issues: Box supplies, magnet buses
 - End-of-life issues: SRF Window failures, SC1 2K cold-box
 - Performance Plan in development
 - Lack of critical spares
 - End-of-life issues and obsolescence