CEBAF Accelerator Update:
News from the Eastern Front

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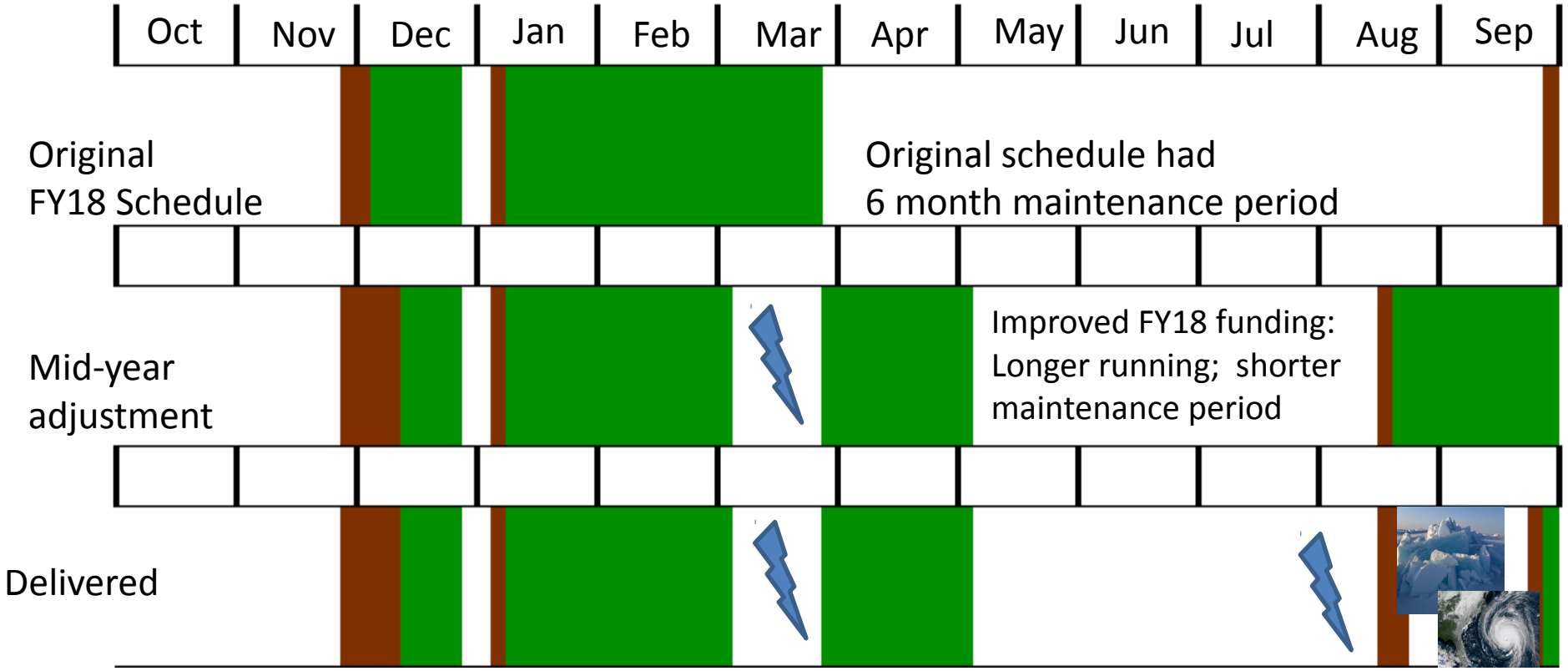
For Hall B
November 12-13, 2018
With grateful thanks
for input from many others

Topics of Interest

- Vacuum and other matters of substance
- Schedule updates
- CEBAF Performance Plan progress
- Other upgrades in progress
- A view from the Control Room
- APex/CRex specific issues upcoming

FY18 Plan vs Delivered



- CHL 4160 V transformer failure, 3 week interruption to the Spring run. Second transformer failed in August interrupting the "hot check out" period.
- Frozen N2 blockage in North linac cryomodule (1L21) prevented clean transport of beam. Beam restoration halted, 2 week delay to thermal cycle module.
- Hurricane Florence forecast to impact Hampton roads, evacuation order impacts restoration

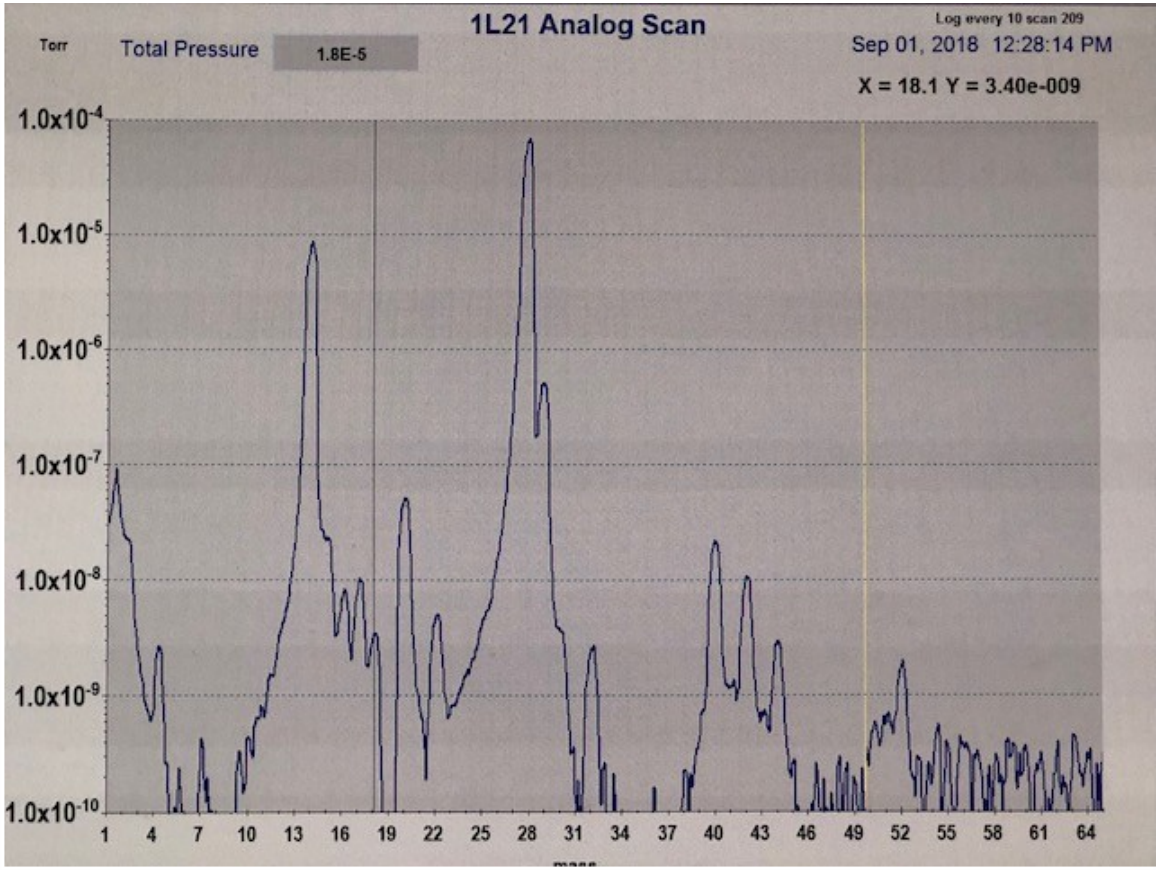
Development of vacuum problems

- Beam restoration started on Aug. 15th, finds lack of aperture near 1L21.
- Vacuum near 1L21 degraded Aug 29th closing beamline valves.
- Beam restoration halted to investigate/fix the problem.
  - No mechanical mis-alignments found
  - No leaks found in the warm girder regions
- Warmed 1L21 to investigate the lack of aperture in the 1L21 region.
- Thermal cycle shows presence of N2 in beam line vacuum.
  - Collateral damage from 1L23 cryomodule swap (leaky beamline valve).
  - 1L22, 1L23, 1L24 valves closed, brought to room temperature, beamline to 1ATM of N2
  - N2 leaked into 1L21 cold beamline vacuum, freezing out as N2 frost/ice.
  - Frozen N2 in 1L21 cryomodule prevented CW beam transport.
- As repairs concluded, Hurricane Florence interrupted, delaying return to 2K and beam operations
- All cryogenic systems brought to 4 K (2 K cold-boxes turned off) to establish stable, low risk cryogenic conditions at the projected impact time of Florence.

(Courtesy A. Freyberger)

RGA measurement

Released gases from 1L21 during warm-up: N2 (28) dominant, little O2.



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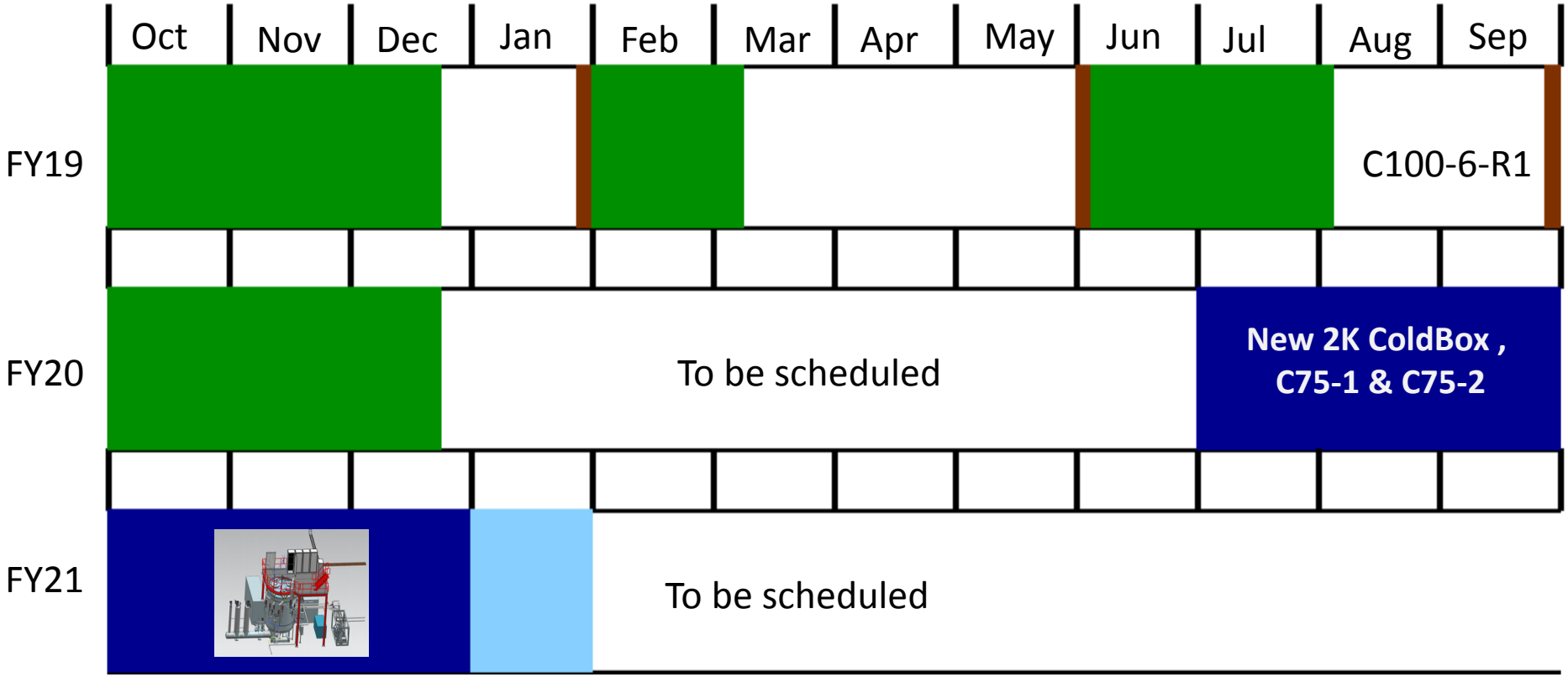
Lessons (Being) Learned

Group leaders are reviewing system downtime data, identifying trends and developing lessons learned. Examples:

- SRF-OPS has identified the following *tentative* lessons learned:
  - CEBAF SRF beamline vacuum work procedure will be updated and reviewed prior to new work on CEBAF
  - Improvements identified at this point include:
    - Use Helium gas instead of dry N2 to bleed up vacuum spaces.
    - Improved configuration control of beamline valves and vacuum monitoring of adjacent zones.
- Task stack-up at the end of a maintenance periods can be challenging
  - Additional daily 3pm coordination meetings during the last 2 weeks of the maintenance period were helpful and should be extended to 4 weeks prior and 1-2 weeks post restoration.

(courtesy A. Freyberger)

FY19, FY20 & FY21 Plans: Circa Sept. 2018



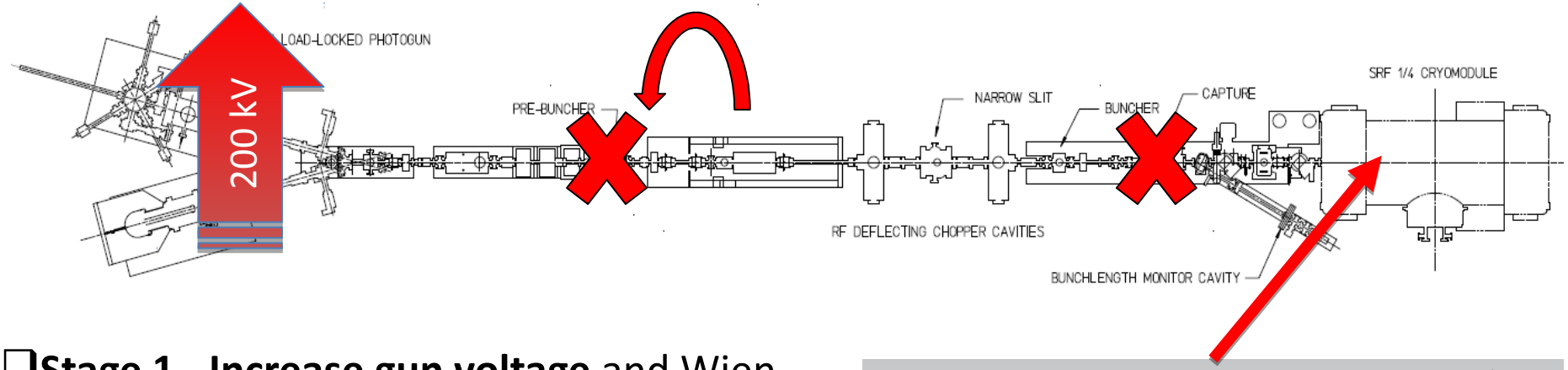
- FY19/FY20 Schedule adjustment under consideration to recover lost weeks from Aug/Sep 2018 startup and improve alignment with C100-6-R1 delivery

Summer 2019: 9 weeks of low linac gradient Physics

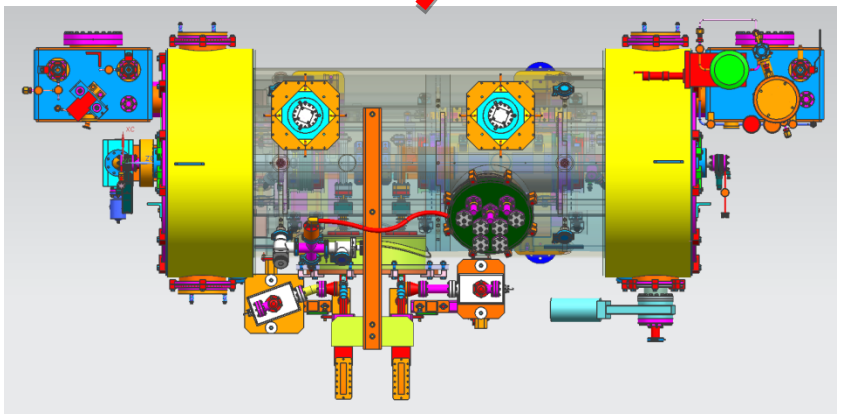
- Hall A: E12-11-101
  - 1-pass, 70 microAmpere
  - Parity Violation Asymmetry measurement on a Pb target.
  - Expect significant injector optimization to maintain parity quality beam.
- Hall B: HPS
  - 5-pass beam
- Hall C: Various experiments
  - 3/4/5 pass beam, up to 90 microAmpere
  - High beam current simultaneously with Parity Quality Beam will stress the injector setup and RF due to beam loading.
  - 3 pass changes in the eight days of the run
- No Hall D operations
  - B&C may receive 499 MHz beam on 5-pass if useful.

(A. Freyberger; JLAAC 10/11/18)

Injector Upgrade Project



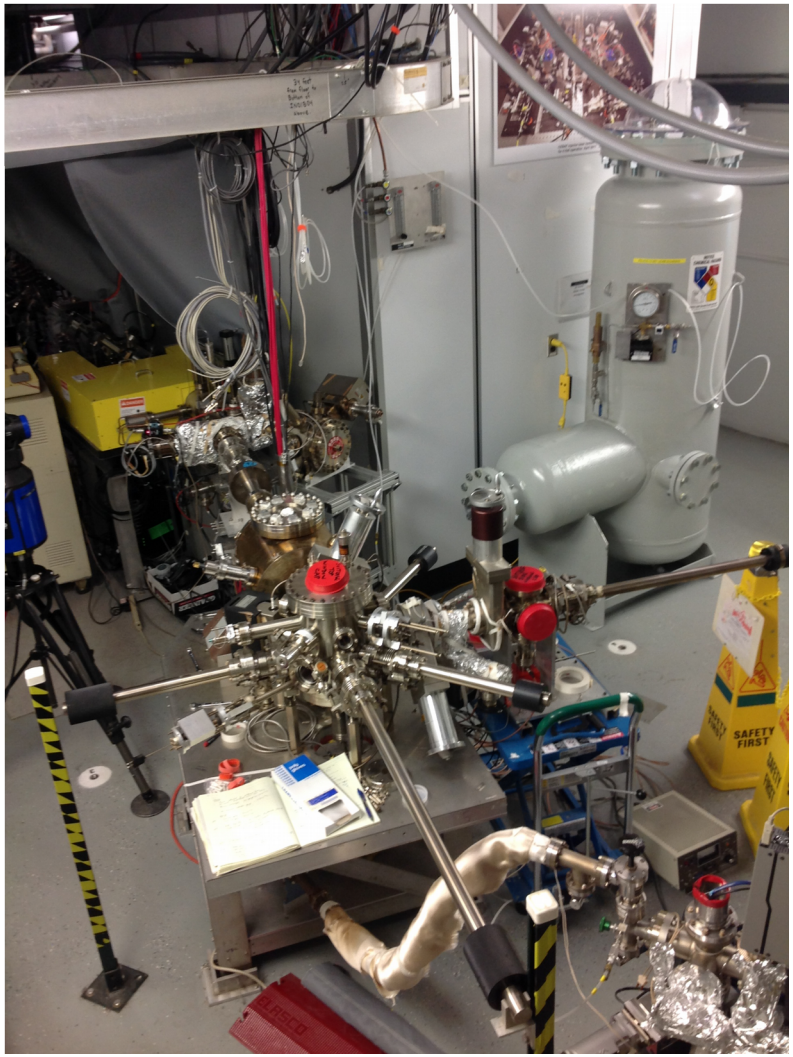
- **Stage 1 - Increase gun voltage** and Wien filters for **200kV operation**
- Stage 2 - Locate Wien filters (spin rotator) upstream of pre-buncher cavity
- Stage 3 - New SRF booster eliminates warm capture, RF deflection and x/y coupling



New "1/4 cryomodule":
2 cell capture section + 7 cell cavity, should provide 10 MeV beam with minimal x/y coupling: better matching, more-adiabatic acceleration

Courtesy Joseph Grames

Summer 2018 SAD Status



Courtesy Joseph Grames

May – June

- ✓ Replaced Gun2 with an electrode optimized to reach 200 kV
- ✓ Replaced 150kV PS with a 350 kV PS that now sits beside Gun2 in SF6 tank
- ✓ Added two new BPM's to the NEG tube just downstream of Gun2

June – July

- ✓ Conditioned Gun2 electrode for beam tests to 180 kV (limited time this SAD)
- ✓ Tested magnets, PSS kicker and chopper w/ 180 keV beam for higher voltage operation
- ✓ Restored Gun2 operation for 130 kV and delivered beam to FC2 at 6.3 MeV
- High polarization photocathode used during Spring run activated and ready in Gun2

CEBAF Performance Plan (CPP)

- Long term strategy: improve and maintain CEBAF performance:
- Identify/purchase Critical Spares to mitigate single point failures
- Replenish consumed hardware spares (I.e. Klystrons)
- Increase Energy Reach to support design energy with margin:
- **C75 –** Refurbish 8 original C20 modules; new cavities, digital controls.
- **C100** – Develop and execute C100 refurbishment plan.
- **Particulate Control –** Clean warm girder regions, upgrade vacuum systems.
- Upgrade obsolescent original CEBAF systems to maintain reliability
- Procurements enabling more efficient maintenance to support up to 34 weeks-per-year of CEBAF operation.

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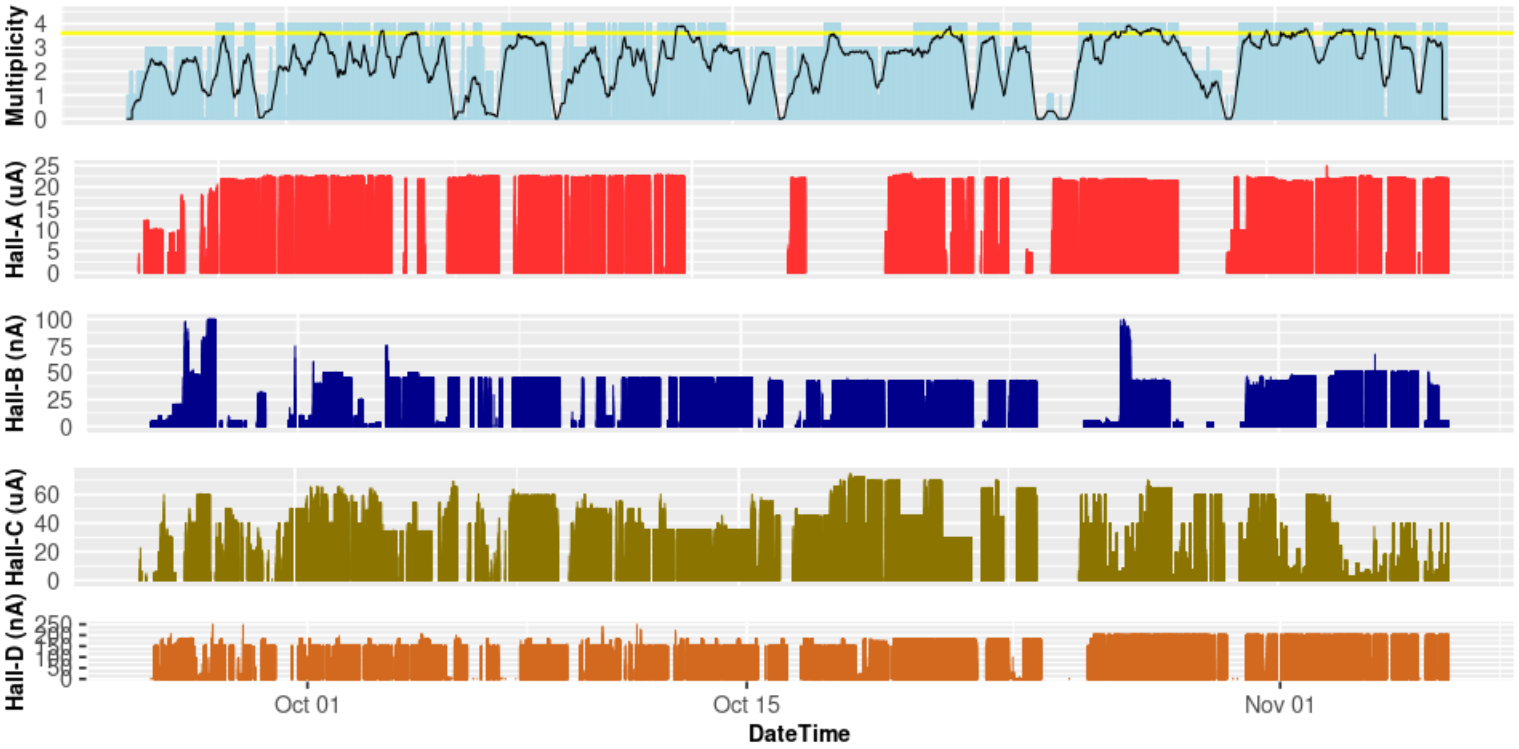
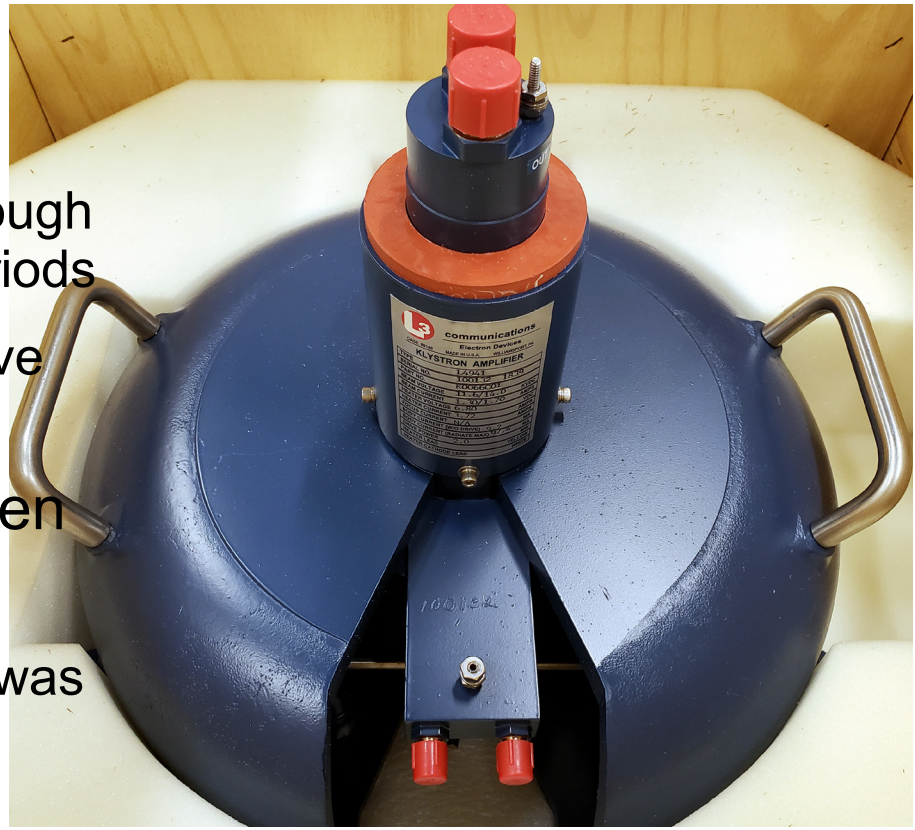
Present Status: Steady Improvement in 2018-Oct.



- Experiment multiplicity is often near 4
- Approximately weekly interruptions for RF recovery
- Injector and CHL upgrades are on track

Accelerator Ops: running with the machine

- CEBAF Operations peak performance has reached the expected level
  - Must preserve this performance through runs and spanning maintenance periods
  - Plans are being developed to improve turn-on performance
- CEBAF Performance Plan has been actively worked in FY18
  - First new 8 kW klystron in 10 years was just delivered
  - Several items purchased with CPP funds in FY17 are deployed and in service



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Recent Achievements: dp/p < 5e-5 beam for Hall-A

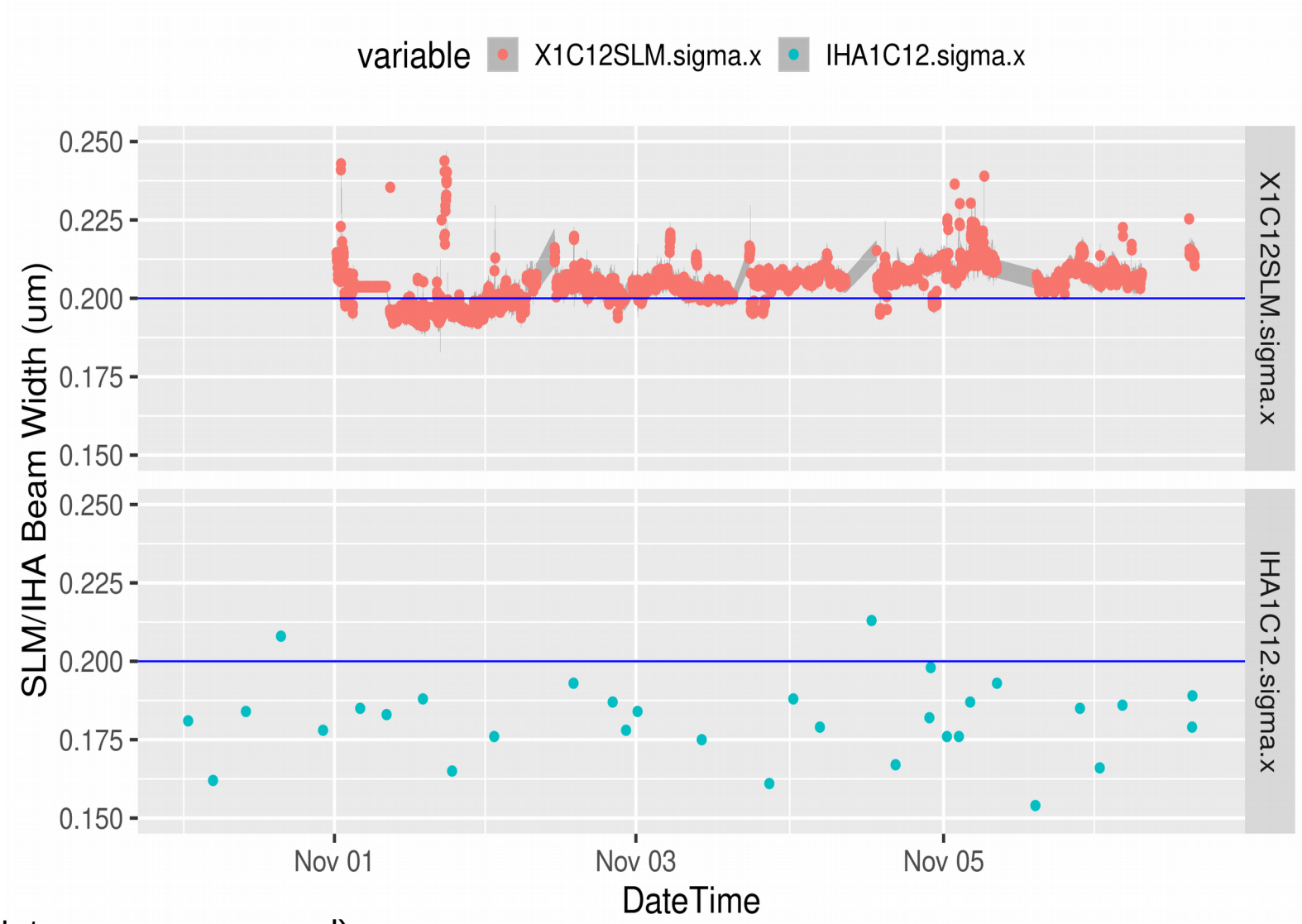
Hyper-nuclear program requires CEBAF to deliver low energy spread beam

- Specification is RMS dp/p < 5e-5
- Requires all RF cavities to be well phase regulated (~¼ degree) and well-crested
- Requires low RMS bunch length (sub 500 fs; 150 micron)

Momentum spread is monitored via beam size at 1C12, dispersion= 4m

- Wire scanner IHA1C12
  - Invasive, but calibration is well understood
  - Measured width consistently less than 200μm (dp/p < 5e-5)
- Synchrotron light monitor SLM1C12
  - Non-invasive
  - Focal properties and calibration are improving
  - SLM provides a good continuous monitor

RMS beam widths at 1C12 SLM and harp



(Note: zero suppressed)

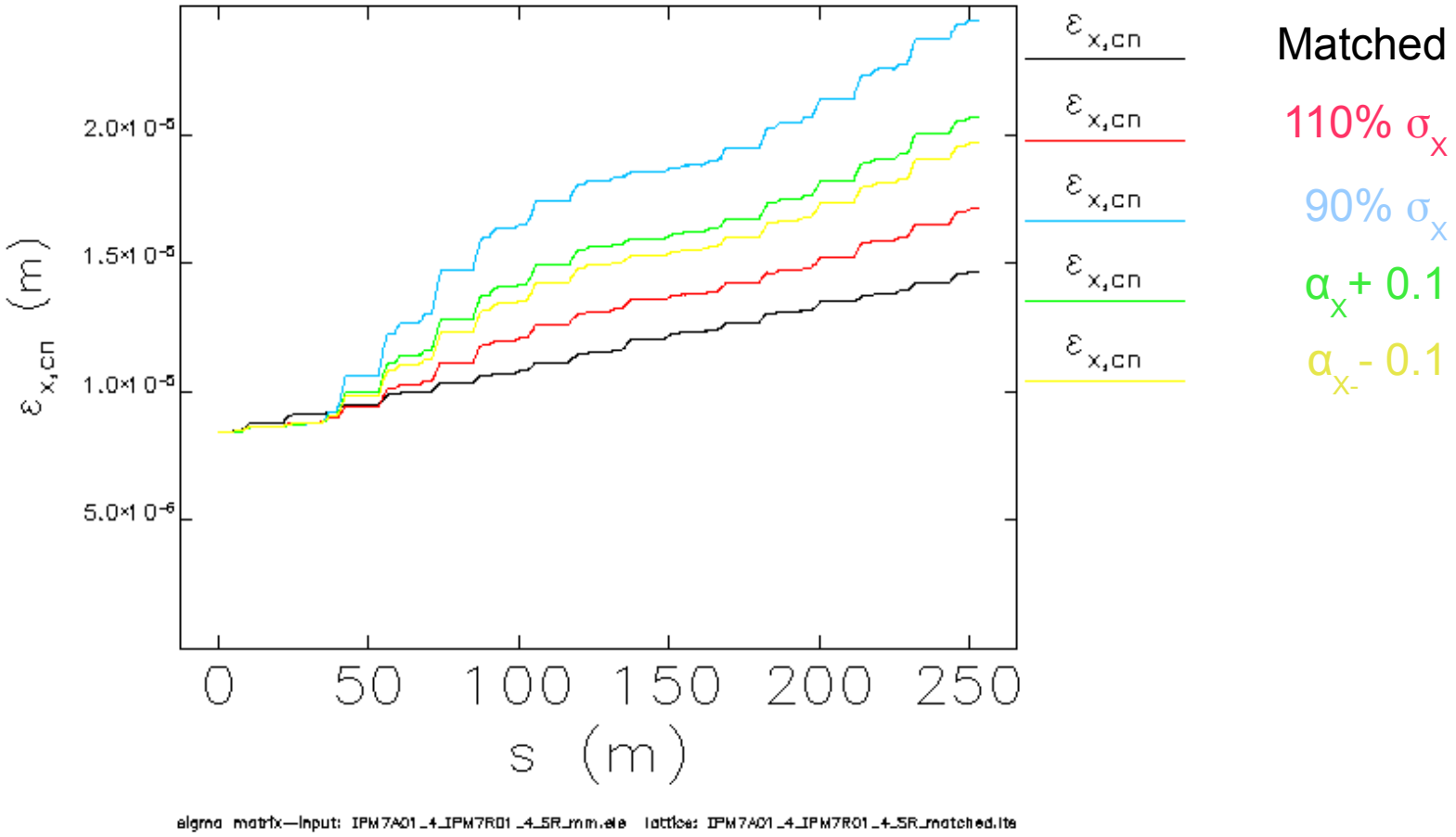
Absolute Energy Calibrations

- 12 GeV upgrade magnetic calibrations replaced all previous magnet calibration data ...
  - [Except for Hall A 9th dipole system (P. Vernin, et al.)]
- Systematically high beam momentum
  - Measured via spin rotation (spin dance)
  - Measured by 9th dipole system
  - (9th dipole system had been principal 6 GeV reference)
- Typical discrepancy: +0.25% above nominal
- Recent comparison drift beam through South Linac into Arc 2A and Hall A's 9th dipole
  - Momentum value from 9th diole is 0.22% to 0.24% higher than indicated in 1A and 2A, while 1A and 2A agree
- Expect to apply tentative correction for 2019

Other Beam Diagnostic Updates

- Hall A and C Fast FeedBack (FFB) now function, with energy lock for Hall C not yet fully tested
- MOMod beam-linac relative phase monitor partially recommissioned, but already useful
- Synchrotron Light monitors are becoming more useful with quantitative measurements being made available from image processing (B. Freeman)
  - Plan to compare image-based optical matching against wire-scanner based procedures in 2019
- With Hall A beam energy "locked" by FFB on 2nd pass, 5th pass momentum to Hall C varies at 1.e-4 level. Possibly due to imperfect understanding of MOMod interaction with C100s.

Emittance Growth from Mis-Match (computed)



Horizontal emittance illustrated; growth can be limited but not recovered

PREX and CREX specific issues

- Injector Upgrade targets parity quality issues, with simplification and improvement of optics across bunch formation and pre-acceleration region.
  - Reduced parity-correlated differences in beam properties
- Gun upgrades to higher potential also target improved parity quality parameters
- Polarization flipping at moderate frequency (240 Hz) in 2019, higher for later runs
- MOMod interaction with digital SRF (C100s) vs. 5-cell needs to be understood to support momentum centroid stability

Summary

- We are all stilll “working the bugs out” of the machine
- There are many improvements yet to be made
  - Procedures (e.g., controlling vertical emittance growth)
  - Diagnostic improvements (SLMs/etc)
  - Reintroduction of PTune to keep cavities on resonance and allow reliable detection of off-crest cavities at beam loading transients
- Specific C100 issues are being identified and corrected (radiation hardening, etc)
- Vacuum issues are being addressed (e.g., ion pump field emission, leaky valves)
- Forecast is good for 2022 full 12 GeV beam energy