Accelerator Operations Update

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CLAS Collaboration Meeting
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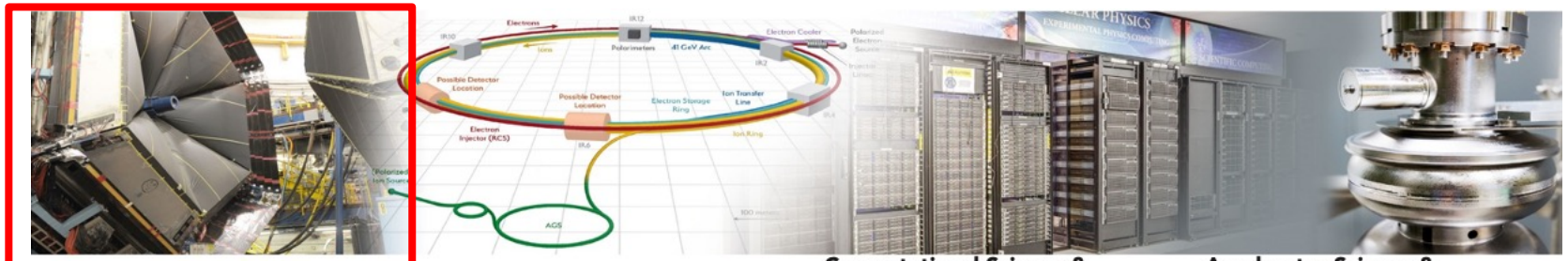
Outline

- Priorities of CEBAF Operations
- Status of Accelerator Operations
- Beam availability and downtime mitigation
- CEBAF Performance Plan (CPP)
- Accelerator Improvement Projects (AIPs) and R&D portfolio
- Accelerator Division reorganization
- Conclusions

Mission of Accelerator Operations



Nuclear Physics at CEBAF

Vibrant 12 GeV research program, operating >30 weeks/yr, supporting > 1,800 users

MOLLER Project & SoLID proposal

Future opportunities in fixed-target, high-luminosity complementary to EIC

Theory and computation supporting NP goals

Electron-Ion Collider

Partnering with BNL in the management, design, and construction of the Electron-Ion Collider Project

Leadership in EIC scientific program

Computational Science & Technology

Vision for world-leading computational program

Developing concept of a High Performance Data Facility focused on the unique challenges and opportunities for data-intensive applications and near real-time computing needs

Computational Nuclear Physics

Accelerator Science & Technology

Accelerator component production for DOE/SC projects, including LCLS-II and LCLS-II-HE at SLAC, and SNS-PPU at ORNL

R&D in accelerators, detectors, isotopes

Adapted from S. Henderson's all-hands presentation 07/2023

- Operate CEBAF for Nuclear Physics for >30 week/yr. for >1800 users
- Ensure CEBAF ready for upcoming 12 GeV experimental program (MOLLER, SoLID, K-Long)
- Support future upgrades providing new experimental capabilities (22 GeV and e+)

Priorities of CEBAF Operations

- Deliver beam (up) to four halls for nuclear physics program safely and reliably
- Increase beam availability, reduce unscheduled downtime and frequency of trips
- Improve CEBAF multi-hall performance with a high intensity beam.
- Prepare for upcoming experiments to meet users' requirements
- Execute CEBAF Performance Plan
  - Extend CEBAF energy reach up to 12 GeV after 5.5 passes with margin
  - Improve hardware reliability through acquisition of critical components and spares
  - Address hardware obsolescence
- Enhance CEBAF capabilities through AIPs, upgrades, and R&D
- Maintain strong operations team capable of meeting operational challenges

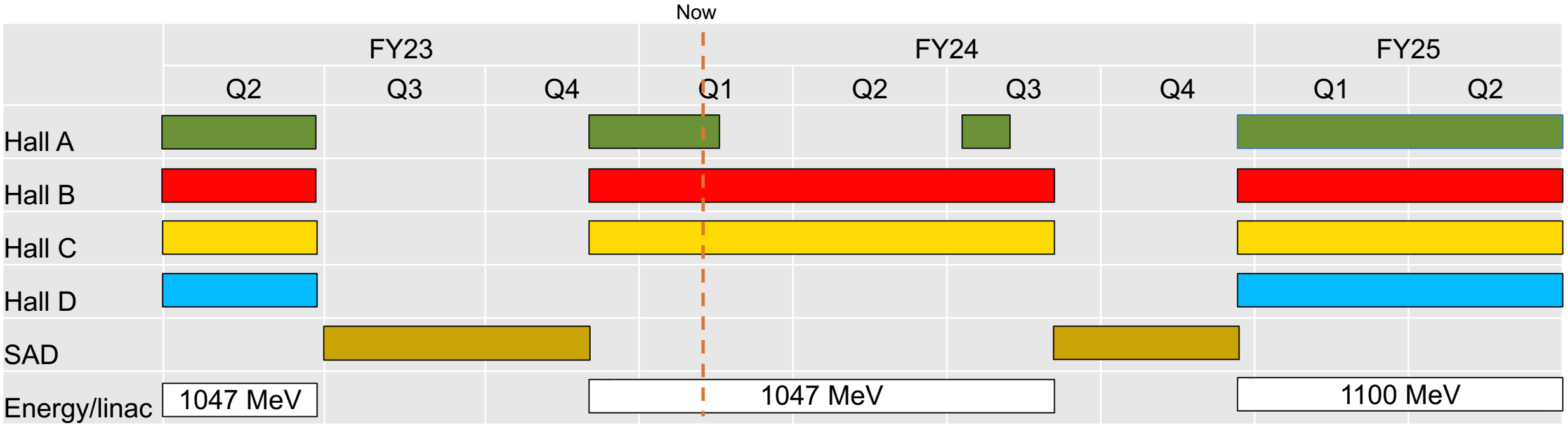
FY24 and FY25 Operations

FY24 Run

- 34 weeks of beam operations, ~31 weeks physics
- Expected challenges
  - Increasing reliability and beam availability
- Scheduled Accelerator Down starts on May 20th

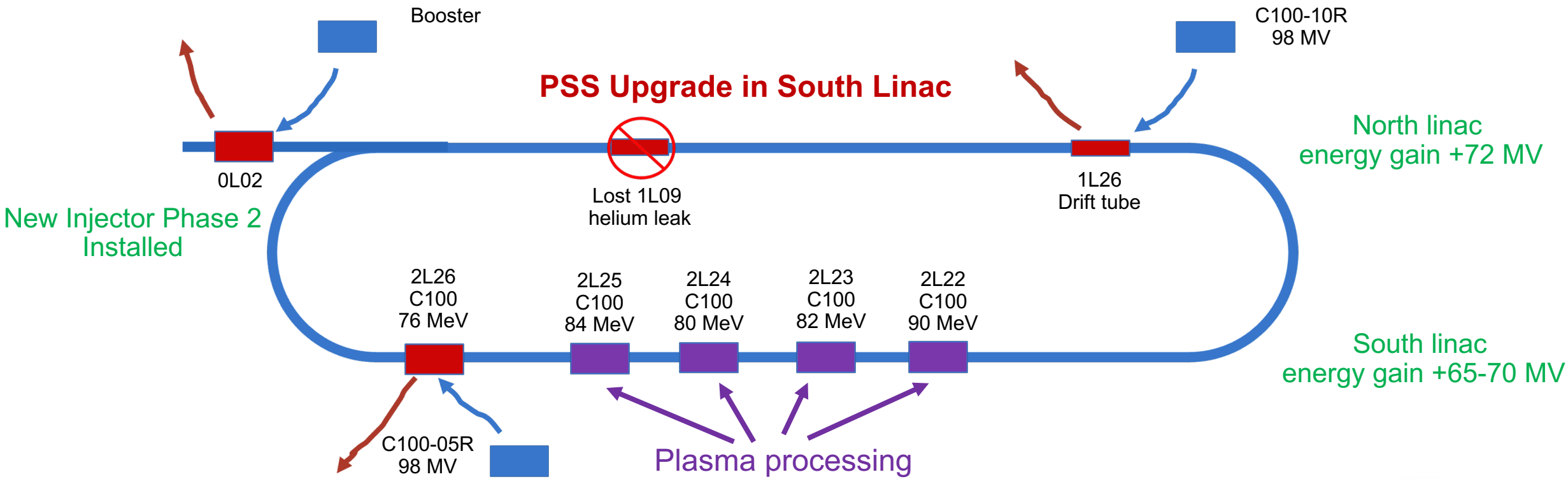
FY25 Run

- 33 weeks of beam operations, ~31 weeks physics
- Expected challenges
  - Physics requests CEBAF to operate at full design energy (12 GeV) and high beam power (1.1 MW)
- Increasing CEBAF energy reach will be critical



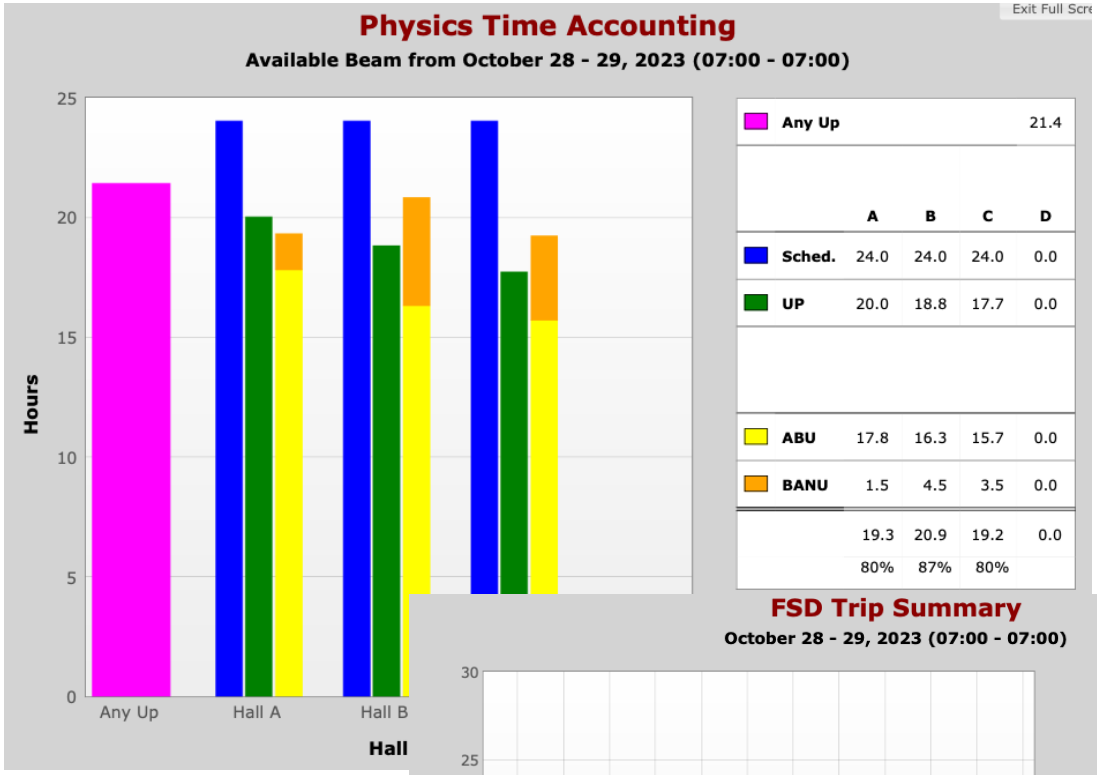
FY23 Scheduled Accelerator Downtime (SAD) Completed

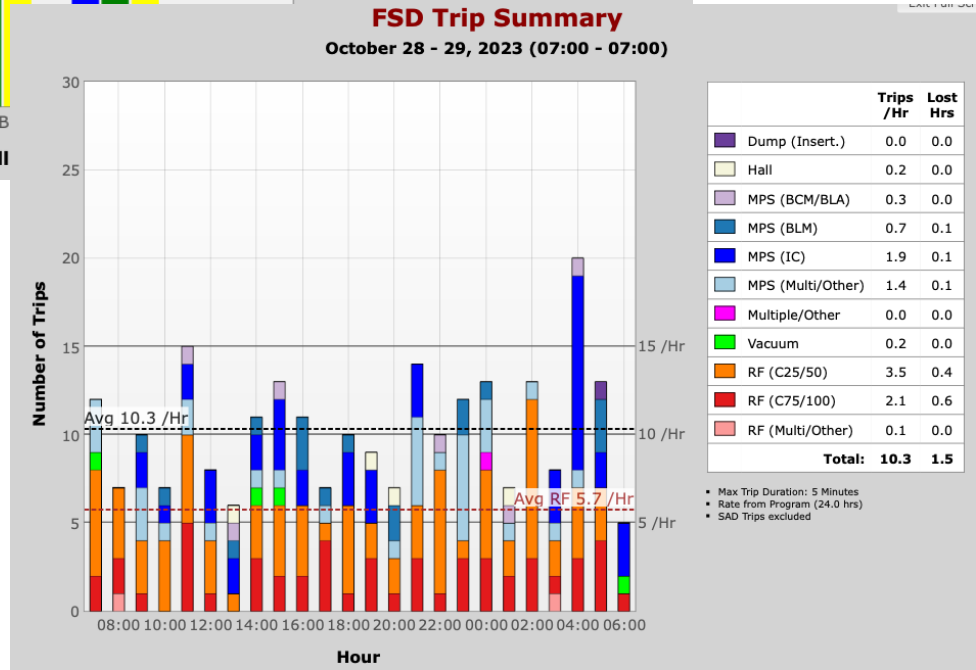
- New injector will reduce helicity correlated asymmetries for MOLLER.
- Installed cryomodules and plasma processing increased the energy reach.
- Upgrade of Personnel Safety System in South Linac. Certification once per year is considered.



Status of CEBAF Beam Operations

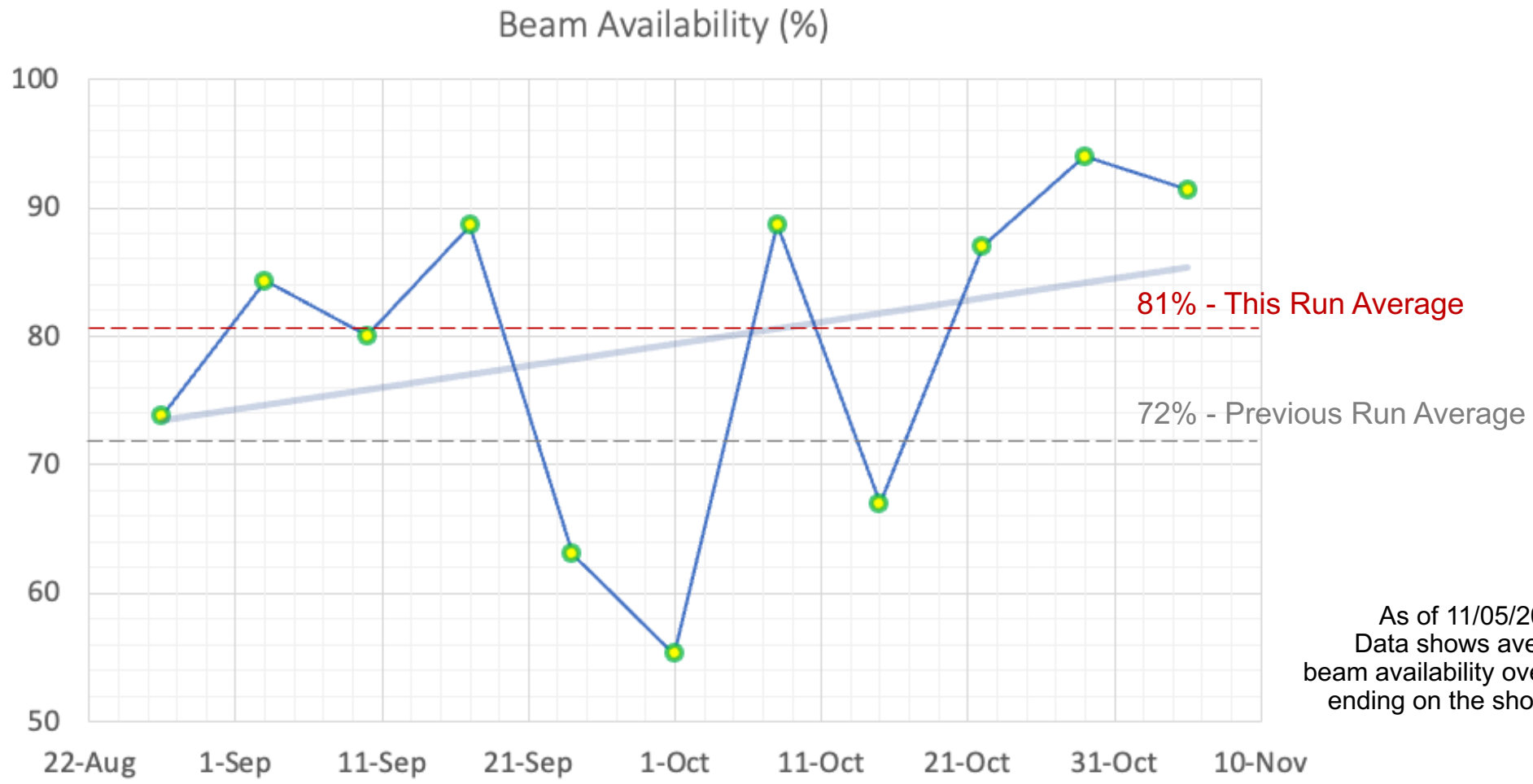
- Beam parameters on target
  - Hall A: ~40 uA, 4 pass
  - Hall B: 5 – 100 nA, 5 pass
  - Hall C: 10 – 30 uA, 5 pass
- More stable beam than last year
  - Reduced number of RF trips
  - Longer uninterrupted runs
  - Likely, due to increased energy reach, smaller number of Halls





Status of CEBAF Beam Operations: Beam Availability

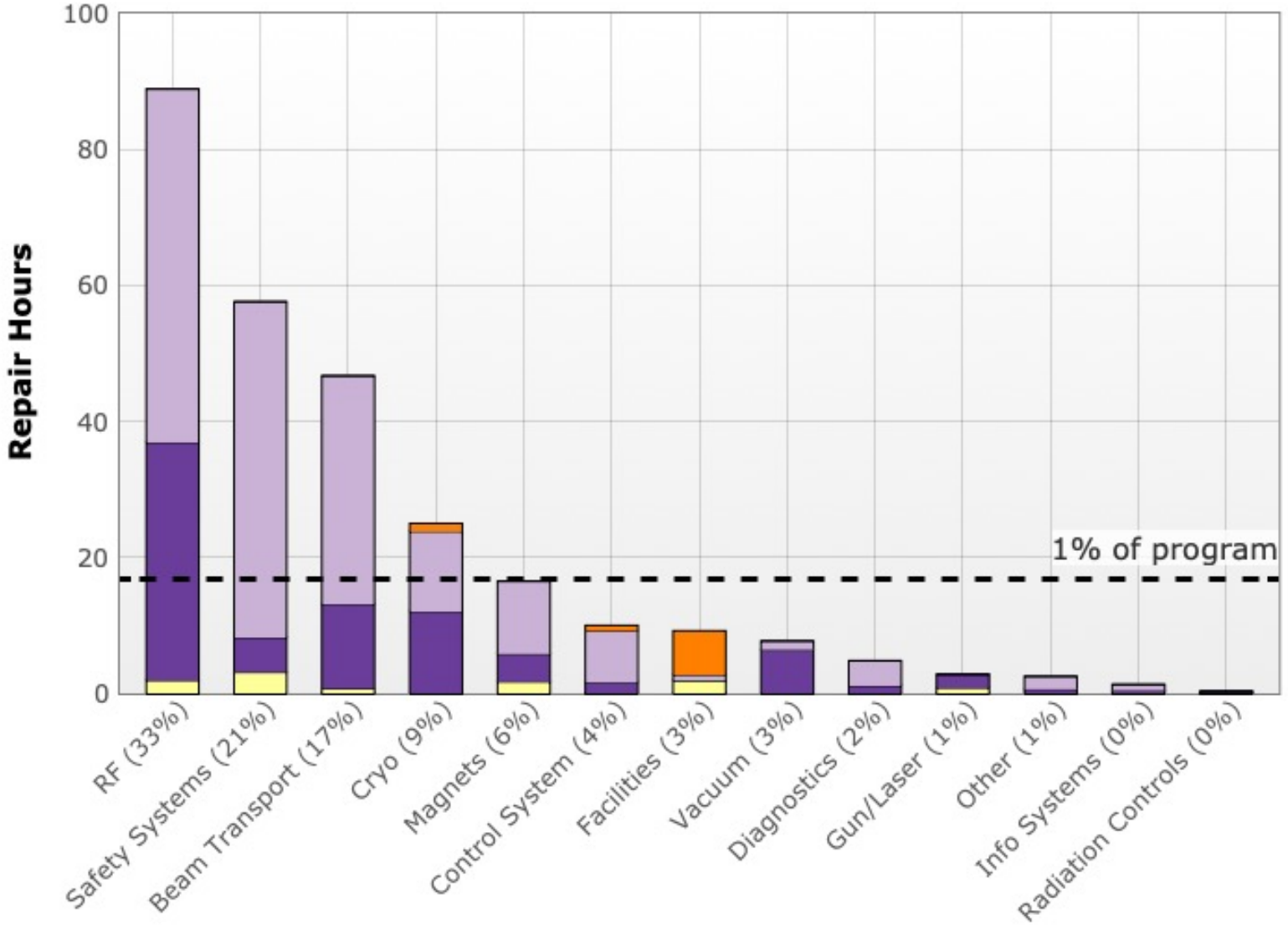
- Average beam availability for this run is 81%



As of 11/05/2023
Data shows average
beam availability over a week
ending on the shown date

Beam Availability and Reliability, This Run (08/26/2023 – now)

August 5, 2023 - August 5, 2024



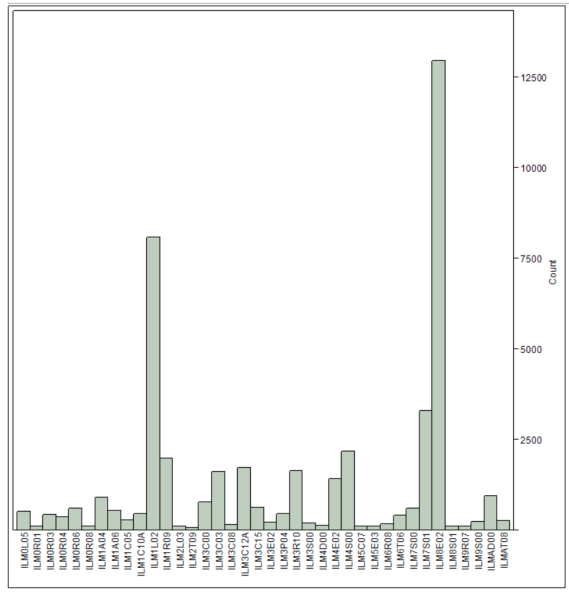
August 26 - December 18, 2023

Delivered Research (Hours)*:	996.1
Delivered Beam Studies (Hours)*:	30.1
Delivered Tuning & Restore (Hours)*:	295.7
Total Delivered (Hours)*:	1,321.9
Budgeted Operations (Hours)*:	2,664.0
Total Delivered / Budgeted (%)*:	49.6%
Unscheduled Failures (Hours)*:	321.5
Total Scheduled (Hours)*:	1,643.5
Research / Scheduled (%)*:	60.6%
Reliability (%)*:	80.4%

Main Sources of Downtime and Their Mitigation

- RF/SRF failures are the largest contribution to downtime
  - CEBAF Performance Plan (see following slides)
  - CEBAF Gradient Team formed to address immediate SRF/RF performance issues and identify opportunities for improvement
  - SRF/RF/Operations meeting to address to issues common for SRF/RF/Ops
  - Q_{ext} reduced 3e7 to 1.6e7 due to lower field and higher microphonics
- Beam losses and unscheduled tuning is a consistently high contribution
  - Improve and automate beam measurement and tuning procedures
  - Ongoing effort to Re-calibrate most offending beam loss monitors
  - Conduct a mini-workshop to develop path forward with BLM system upgrade

Number of MPS fast trips caused by BLMs
60% of all trips are caused by four BLMs



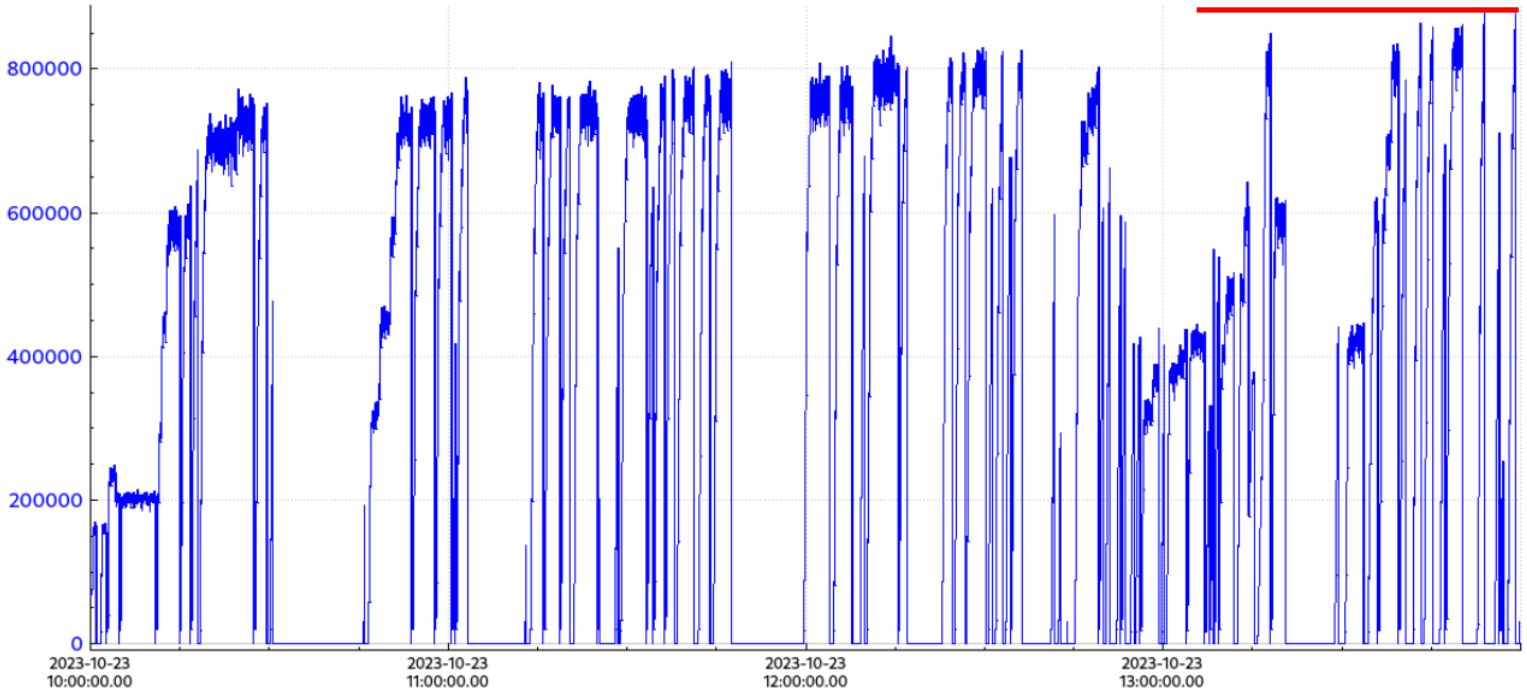
Improving Reliability Is High Priority

- Last run beam availability was 72%. DOE wants to see 80% at least.
- Accelerator Ops are hiring Operability Deputy with a focus on reliability.
- Need a cultural change to shift from reactive approach to proactive/preventive maintenance.
  - Identify immediate opportunities to improve reliability
  - Long term planning to address aging CEBAF systems
- SMEs must be fully engaged in the process, understand failure modes of their systems, proactively think how to improve reliability, and plan for upgrades
- CEBAF Performance Plan addresses critical spares and obsolescence
  - Procurement of critical spares and maintaining spares inventory
  - Replacement of obsolete systems

Probing CEBAF Performance Limits
Increased Intensity Run in 10/2023

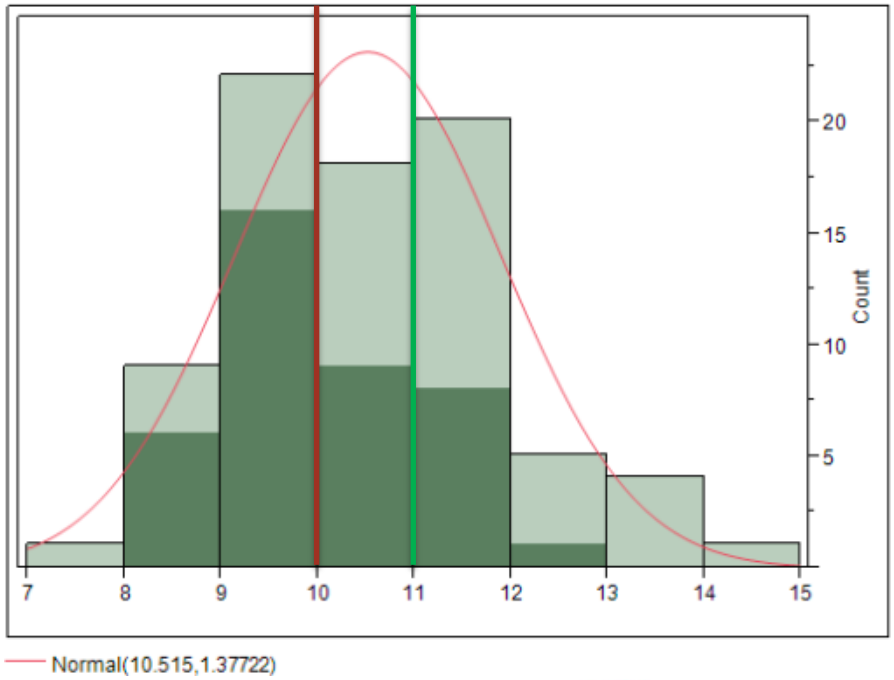
- High intensity run to identify CEBAF limitations in anticipation of the high-power run in FY 2025 (1.1 MW).

Beam power as function of time



RF Klystron Power Distribution

Absolutely needed 10 kW RF power output
Klystrons are specified at 11 kW linear regime.



CEBAF Performance Plan (CPP)

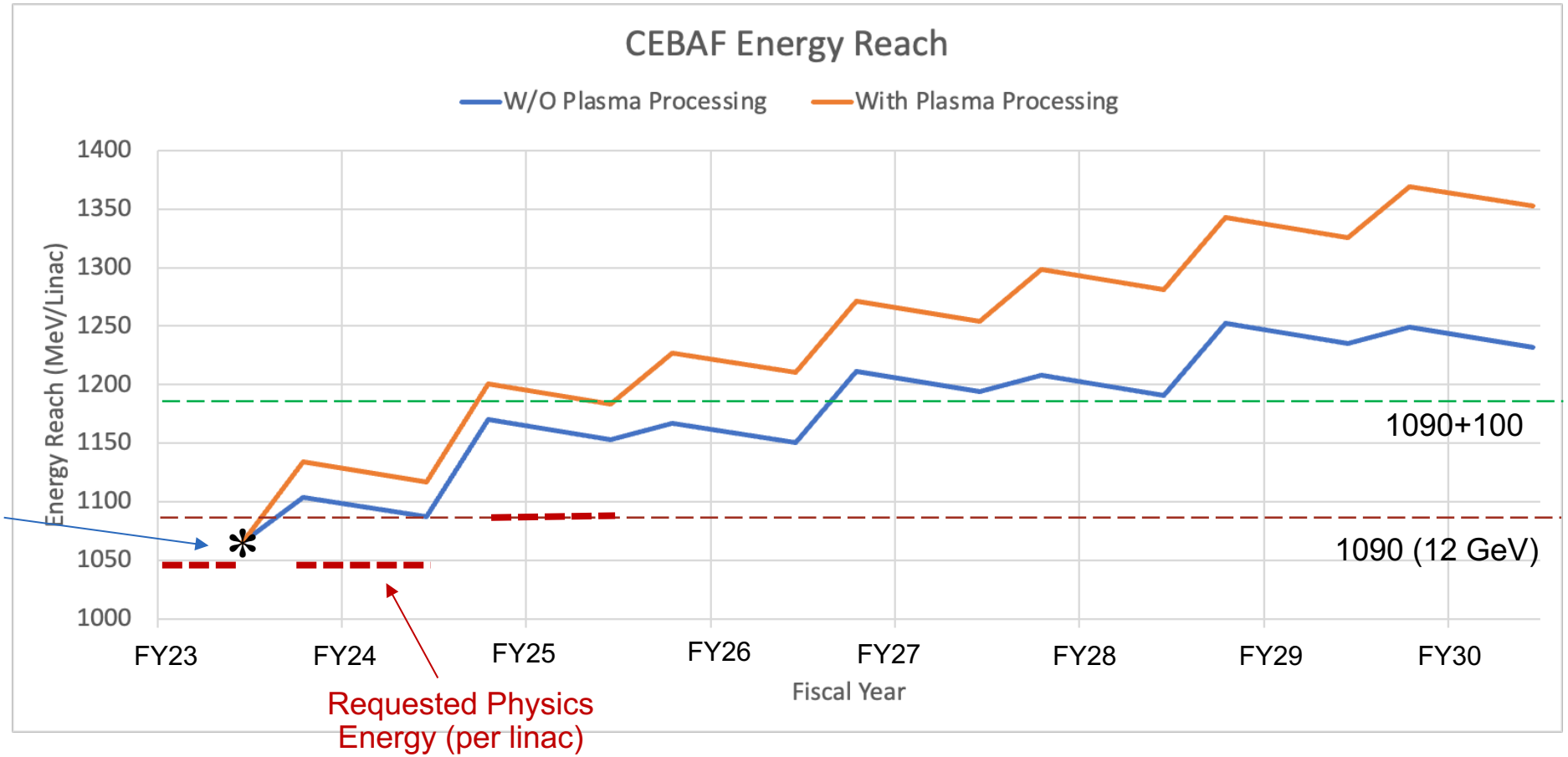
Goal: ensure CEBAF reaches 12 GeV in 5.5 passes and sustains reliable operations to meet physics program requirements

- Energy Reach Project, manager – Tony Reilly
- Reliability Project, manager – Randy Michaud

Cryomodule Installation Plan

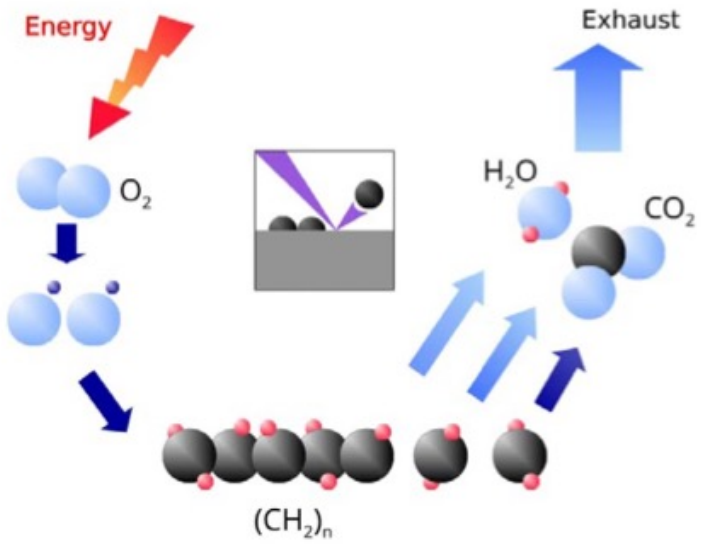
	Cryomodules Installed	Cryomodules Removed	Energy Gain (NL/SL), MV
FY23	C100, C100	C100	98 / 22
FY24	C100, C75, C75	F100, C20, C20	24 / 97
FY25	C100, C75	C100, C20	75 / 0
FY26	C100, C75	C100, C20	0 / 75
FY27	C100, C75	C100, C20	75 / 0
FY28	C100, C75	C100, C20	0 / 75
FY29	C100, C75	C100, C20	75 / 0
FY30	C100, C75	C100, C20	0 / 75

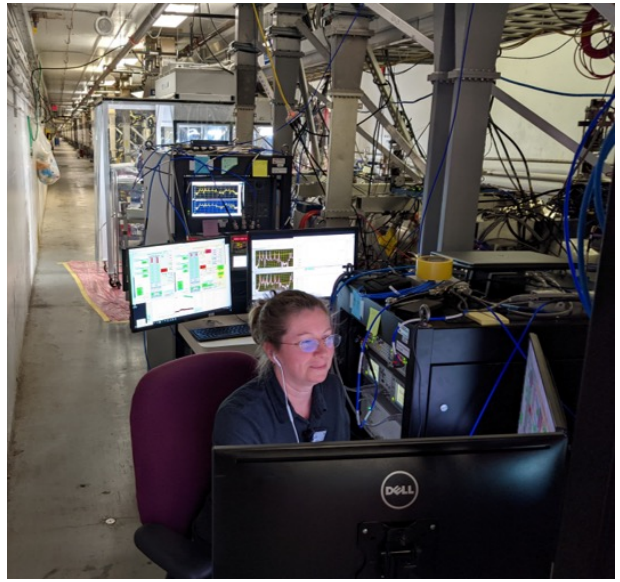
CPP: Energy Reach Projection



- Energy reach is the energy gain per linac corresponding to 10 RF trips/hour
- Available RF power and beam current can dictate linac voltage profile and frequency of RF trips

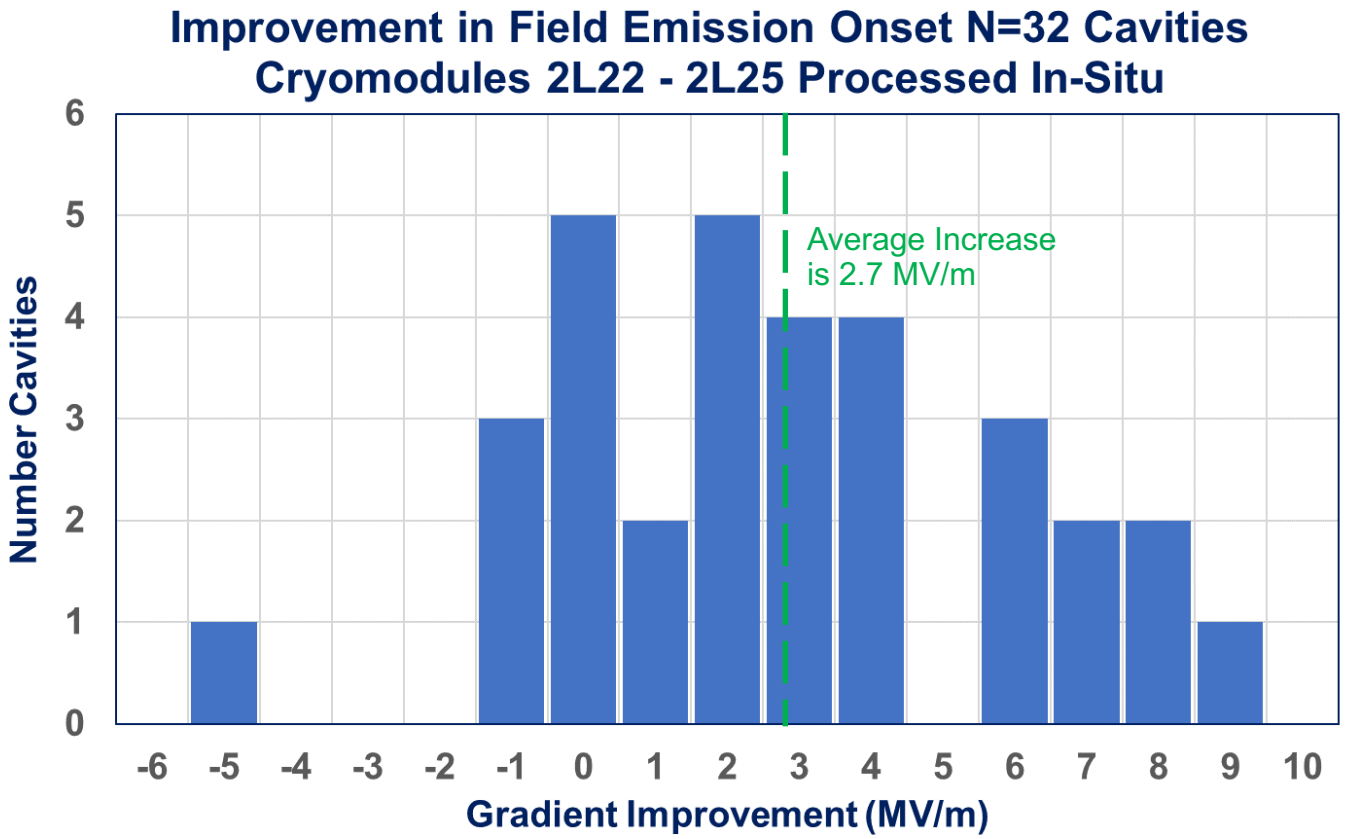
Successful In-Situ Plasma Processing Of CEBAF CMs





- Four cryomodules, 2L22 - 2L25 (all cavities), were plasma-processed in the tunnel during last SAD
- Path Forward
  - Process 3 to 4 C100 and C75 cryomodules during accelerator shutdowns.
  - Extend plasma processing to C75 cavities.

In-Situ Plasma Processing Increased Gradient by 2.7 MV/m



- Field emission free operation was improved by 59.1 MeV (24%).
- An average improvement of 2.7 MV/m.
- 5 cavities were field emission free after processing.

Success of plasma processing supports more aggressive curve for CEBAF energy reach

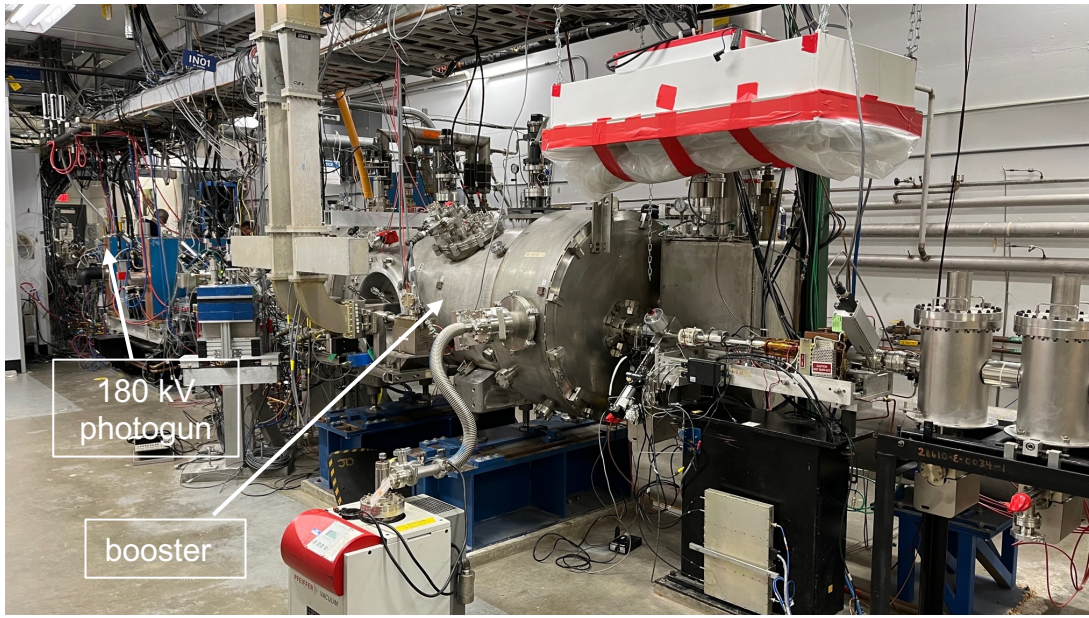
Accelerator Improvement Projects

- AIPs are used to upgrade existing system and bring new functionality

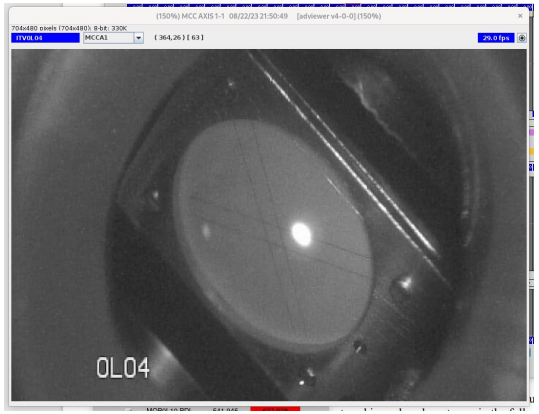
AIP	Status
Full Energy Injector - Integration	Completed
LLRF Digital Upgrades - C75 LLRF	On-going
Next Gen BPM Upgrade	Prototyping
Global Timing System	Not started
Spare CEBAF Booster	Not started
Waveguide Stub Tuners	Not started
BLM system upgrade (New)	Not started
RF one zone upgrade (New)	Not started

AIPs: Injector Upgrade Completed

- The injector upgrade reduces helicity correlated asymmetries for the Parity Quality program (MOLLER).
- Scope
  - Increased gun voltage from 130 to 180 keV.
  - Upgraded Wien filters.
  - Solenoids with a larger aperture.
  - New SRF Booster cryomodule with reduced deflection and coupling.
- *Injector is successfully used for this beam run*
- Beam tests to quantify beam Parity Quality and fully evaluate the injector are on-going



New injector and Booster CM
In the CEBAF tunnel

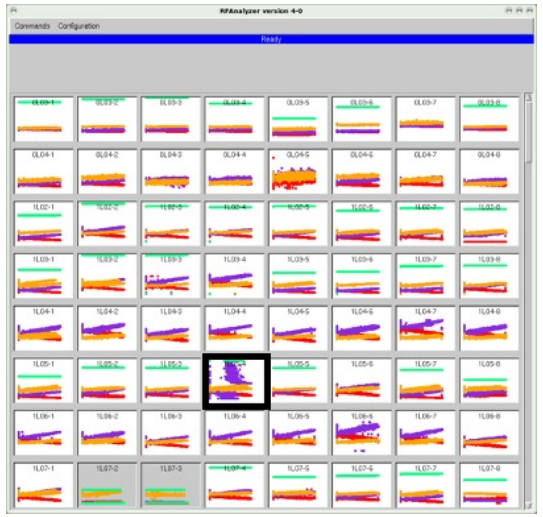


Beam in the injector

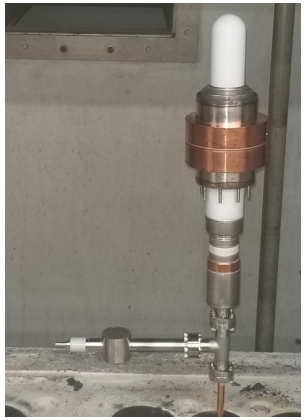
Portfolio of R&D and SBIR-Funded Projects

- Three AI/ML DOE funded projects (FOA-LAB-20-2261)
  - Automate identification of unstable SRF cavities.
  - C100 Cavity Fault Prediction.
  - CEBAF cavity field emission management using neutron detectors and surrogate models (ML)
    - Reduce field emission, increase lifetime of components
- He flowmeter (SBIR, Hyperboloid LLC)
  - Allows for fast and accurate measurement of cavity heat and Q_0
- 1497 MHz Magnetron RF source (SBIR, Muon Inc)
  - Demonstrate feasibility of magnetron as alternative, efficient RF source for CEBAF

Detection of anomalies in cavity field



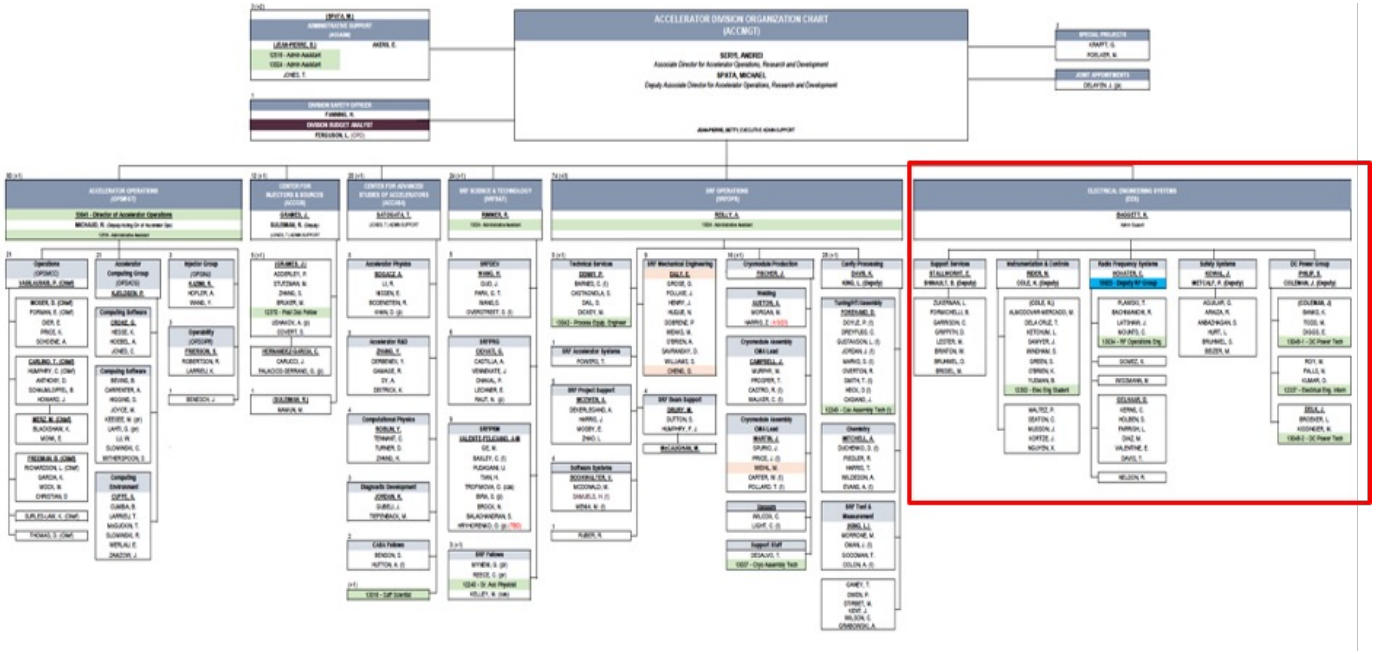
Helium Mass Flow Monitor



First L-Band tube at Richardson Electronics

Accelerator Division Reorganization

- Effective October 1, 2023, DC Power, RF, I&C, Safety Systems, Support Services, Vacuum Technicians, Specific Mechanical Engineering personnel moved from Engineering Division to Accelerator Division
- Goal: align resources, responsibility and accountability for CEBAF operations, maintenance and improvements within a single organization



FY24 SAD Planning Started

- Dates (preliminary) 5/19/2024 – 9/5/2024
- SRF
  - Install 2xC75 CM and swap one C100 CM
  - Plasma-process 3-4 C100 and C75 CMs
  - Change gate valves around these CMs, girders?
- RF
  - Keep installing LLRF 3.0
  - Install fiber links for Master Oscillator to North and South Linacs to reduce EMI induced trips
- …

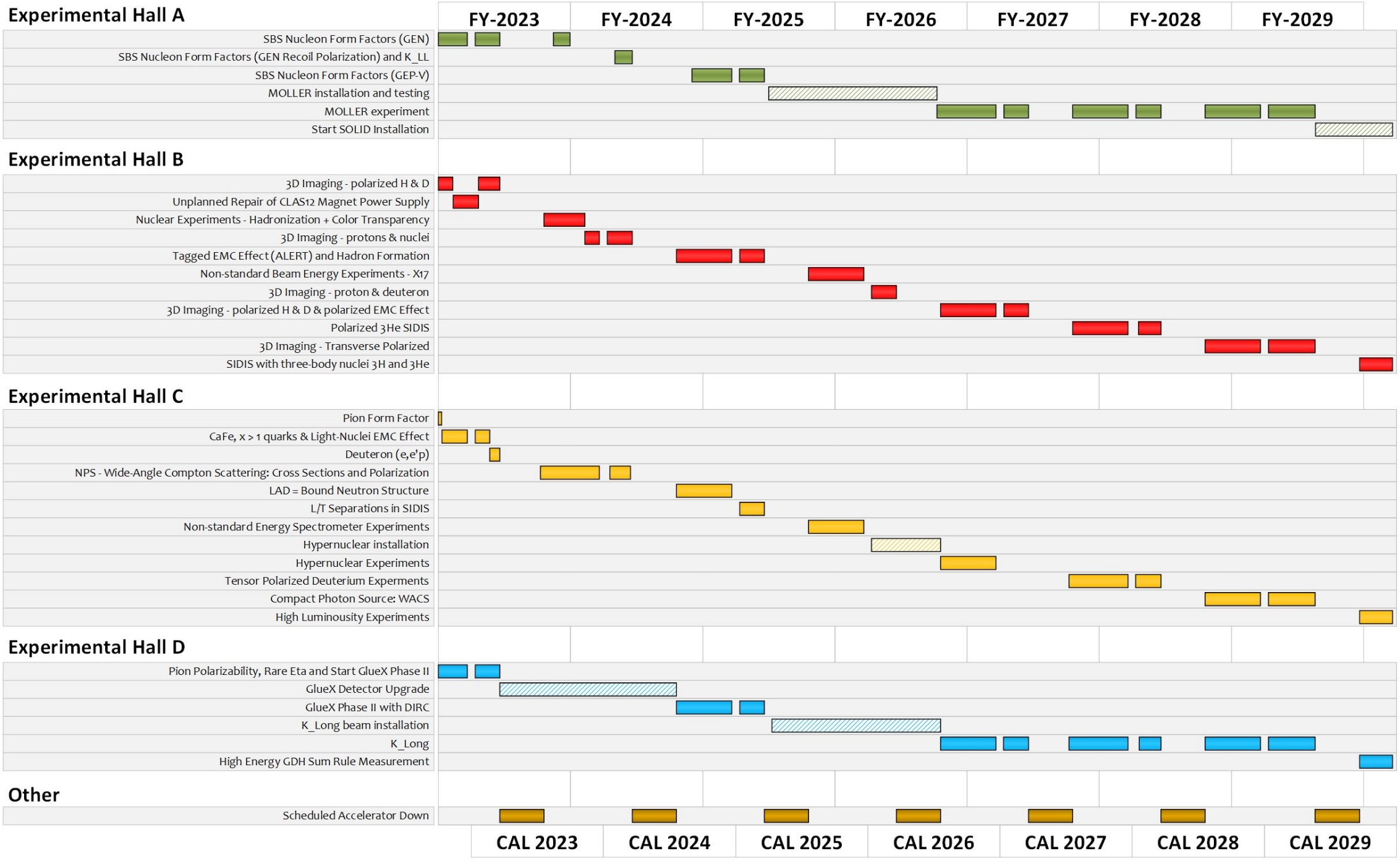
How Do CEBAF Operations Compare To Other Facilities

- The Good
  - Close interaction with experimental halls
  - Strong CEBAF operator group and training
  - Work release system (ATLis)
- The Bad
  - Culture of reactive approach to hardware maintenance results in low reliability
  - In-consistent use of best engineering practices and processes and lack of ownership
- And we really need to think about it…
  - How are we going to upgrade aging infrastructure under present funding and schedule boundary conditions
  - Succession planning

Conclusions

- Beam run in CEBAF is in full progress. Average reliability for the run is 81%.
- Focus on improvement of communication between Ops and SMEs and performance and reliability issues
- Energy reach will meet 12 GeV requirements with the required margin in FY 25-27. Successful demonstration of in-situ plasma processing will speed up growth of the CEBAF energy.
- Accelerator Division reorganization will align resources with CEBAF operations
- Looking forward to another successful year of delivering beam to NP users.

Thank you!


Experimental Hall A
FY-2023
FY-2024
FY-2025
FY-2026
FY-2027
FY-2028
FY-2029
SBS Nucleon Form Factors (GEN)
SBS Nucleon Form Factors (GEN Recoil Polarization) and K_LL
SBS Nucleon Form Factors (GEP-V)
MOLLER installation and testing
MOLLER experiment
Start SOLID Installation
Experimental Hall B
3D Imaging - polarized H & D
Unplanned Repair of CLAS12 Magnet Power Supply
Nuclear Experiments - Hadronization + Color Transparency
3D Imaging - protons & nuclei
Tagged EMC Effect (ALERT) and Hadron Formation
Non-standard Beam Energy Experiments - X17
3D Imaging - proton & deuteron
3D Imaging - polarized H & D & polarized EMC Effect
Polarized 3He SIDIS
3D Imaging - Transverse Polarized
SIDIS with three-body nuclei 3H and 3He
Experimental Hall C
Pion Form Factor
CaFe, x > 1 quarks & Light-Nuclei EMC Effect
Deuteron (e,e'p)
NPS - Wide-Angle Compton Scattering: Cross Sections and Polarization
LAD = Bound Neutron Structure
L/T Separations in SIDIS
Non-standard Energy Spectrometer Experiments
Hypernuclear installation
Hypernuclear Experiments
Tensor Polarized Deuterium Experments
Compact Photon Source: WACS
High Luminousity Experiments
Experimental Hall D
Pion Polarizability, Rare Eta and Start GlueX Phase II
GlueX Detector Upgrade
GlueX Phase II with DIRC
K_Long beam installation
K_Long
High Energy GDH Sum Rule Measurement
Other
Scheduled Accelerator Down
CAL 2023
CAL 2024
CAL 2025
CAL 2026
CAL 2027
CAL 2028
CAL 2029