Accelerator Status

Presenter
Eduard Pozdeyev, Director of Accelerator Operations

Presented To:
JLUO

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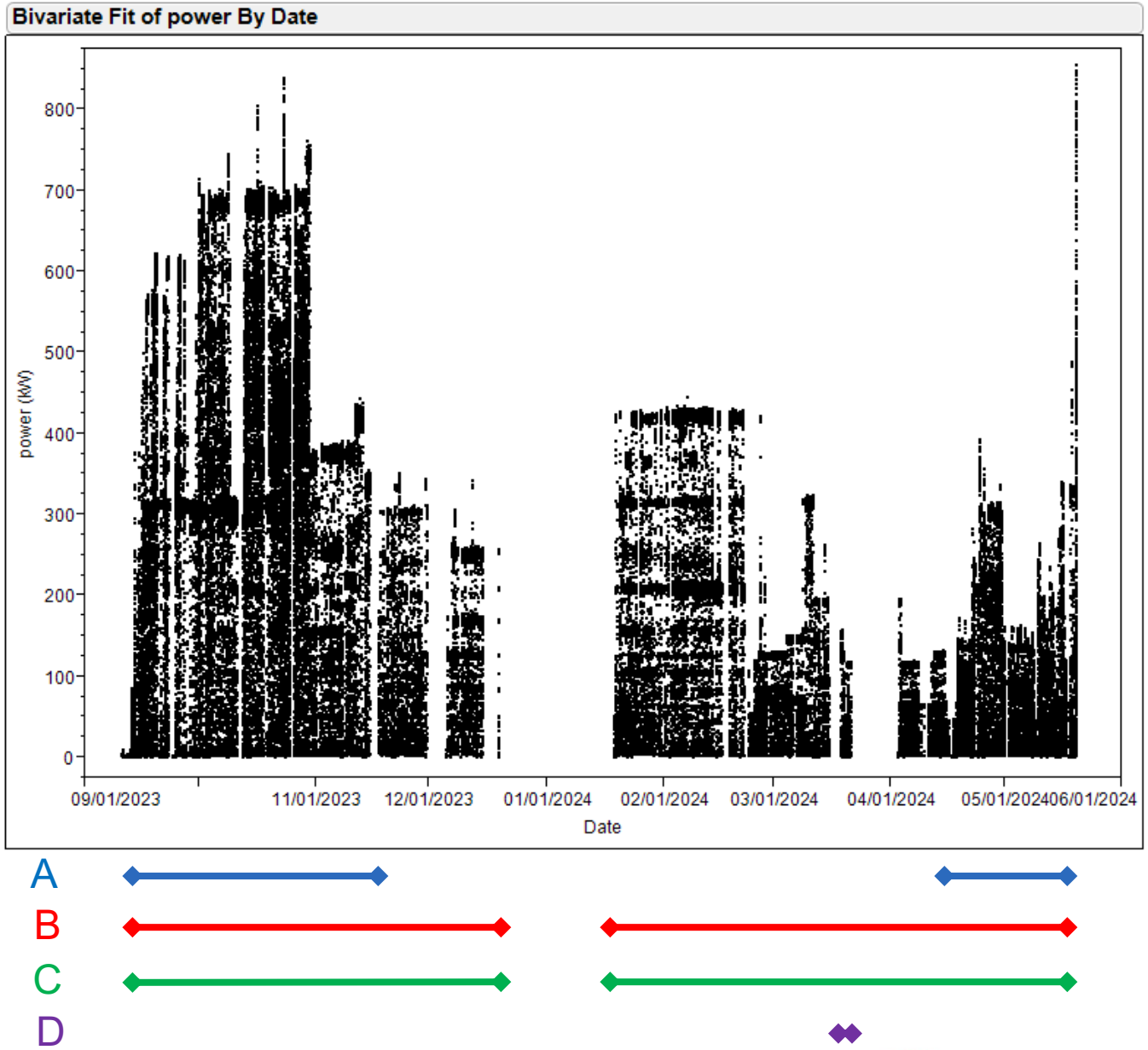
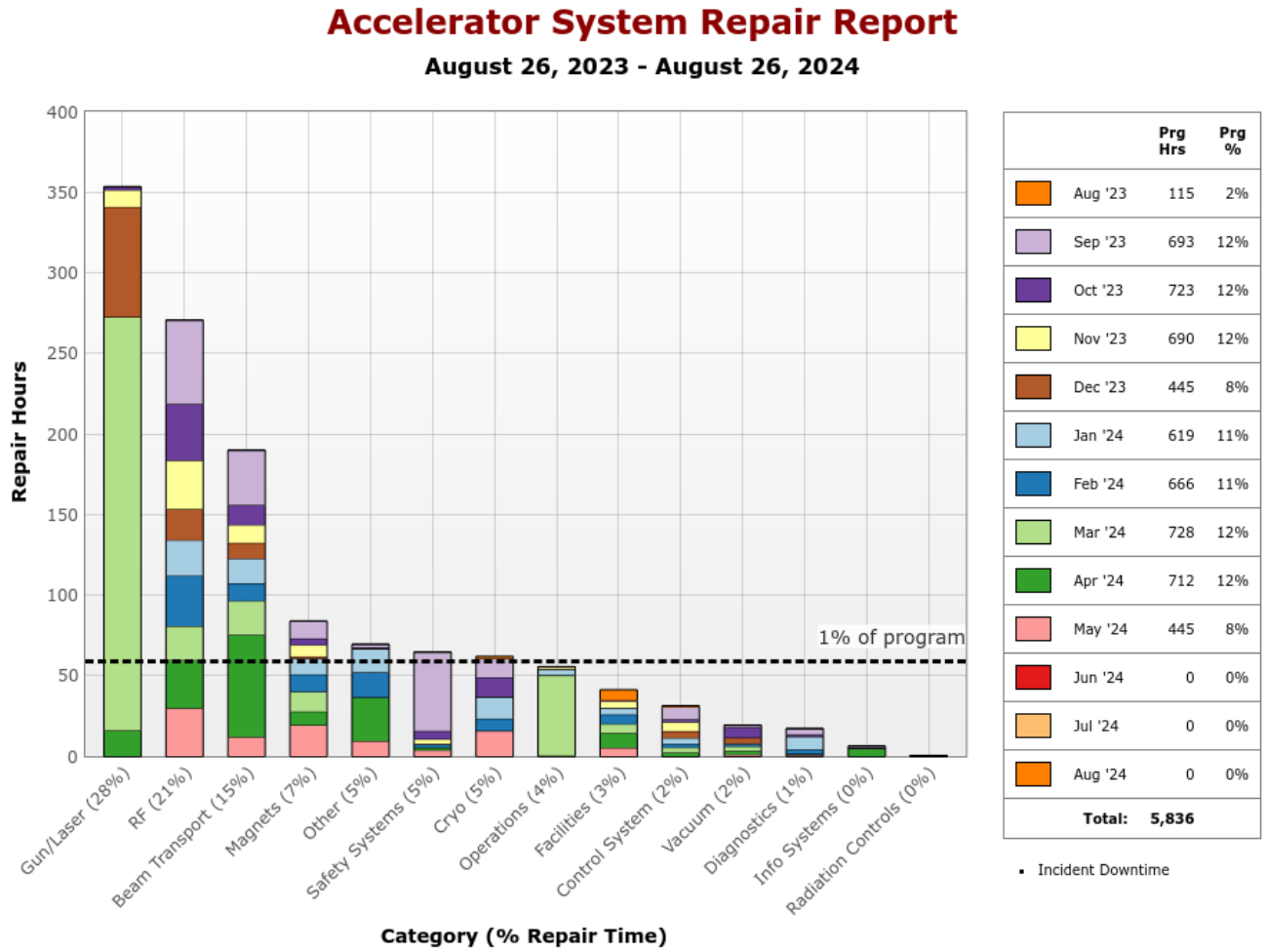
CEBAF Performance Last Run

- Energy per linac: 1047 MeV
- Hall A
  - 10 – 45 uA, pass: 2-4
- Hall B
  - 50 – 200 nA, pass: 3-5
- Hall C
  - 5 - 80 uA, pass: 3-5
- Hall D, successful short test run
  - Added to the schedule
  - 4 days, 200 nA, pass 5.5



Downtime and Beam Availability (08/26/2023 – 05/20/2024)



	Prg Hrs	Prg %
Aug '23	115	2%
Sep '23	693	12%
Oct '23	723	12%
Nov '23	690	12%
Dec '23	445	8%
Jan '24	619	11%
Feb '24	666	11%
Mar '24	728	12%
Apr '24	712	12%
May '24	445	8%
Jun '24	0	0%
Jul '24	0	0%
Aug '24	0	0%
Total:	5,836	

▪ Incident Downtime

August 26, 2023 - August 26, 2024

Delivered Research (Hours)*:	3,700.1
Delivered Beam Studies (Hours)*:	200.2
Delivered Tuning & Restore (Hours)*:	490.4
Total Delivered (Hours)*:	4,390.6
Budgeted Operations (Hours)*:	5,976.0
Total Delivered / Budgeted (%)*:	73.5%
Unscheduled Failures (Hours)*:	1,445.7
Total Scheduled (Hours)*:	5,836.3
Research / Scheduled (%)*:	63.4%
Reliability (%)*:	75.2%

- Two significant incidents caused by CEBAF gun: 1) field emission in Nov/Dec 2023 and 2) beam strike event in Mar/Apr 2024 caused by laser shutter failure.

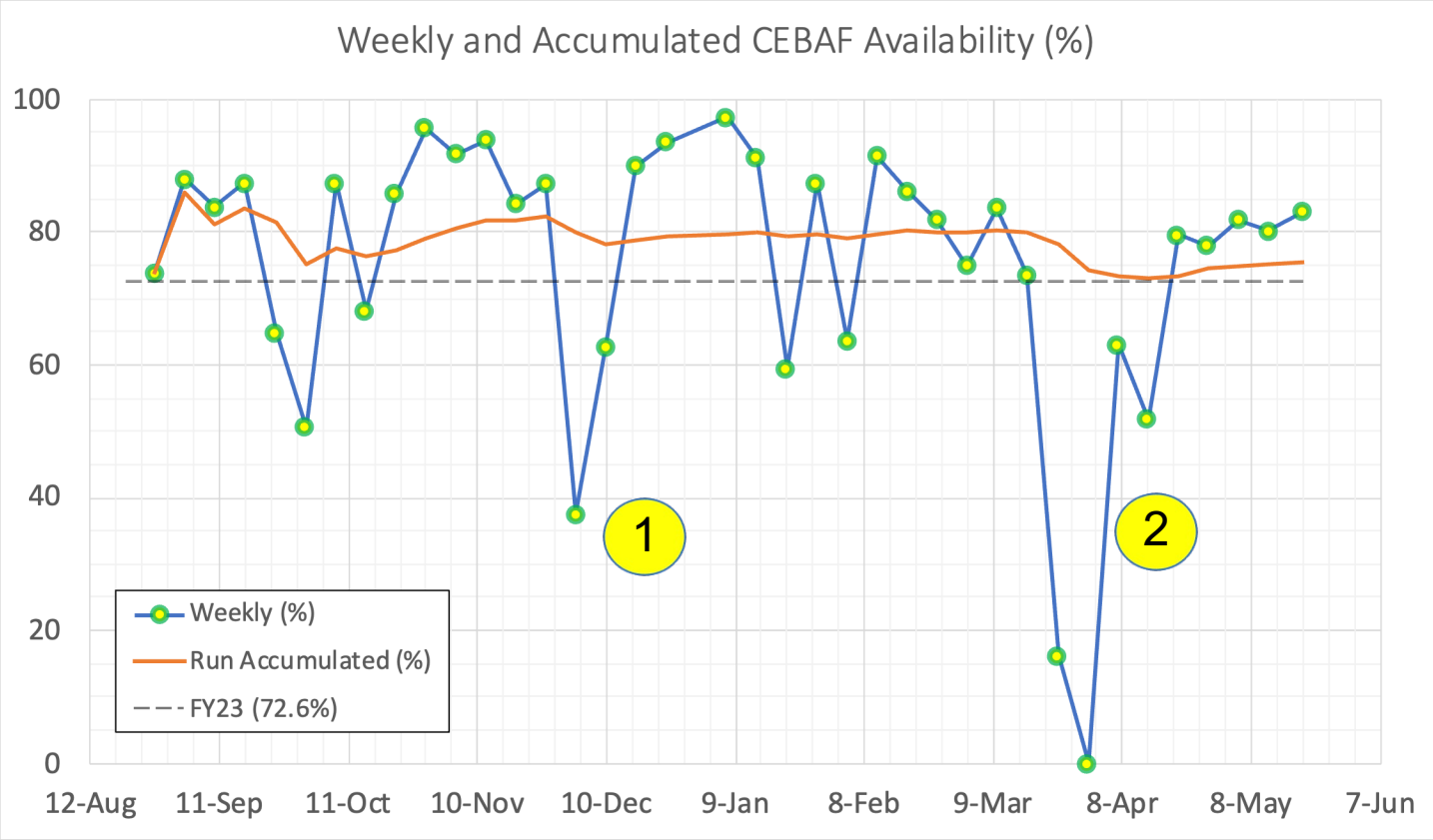
Reliability Comparison FY24 to FY23

- Significant improvement in RF, Beam Transport, and Magnet reliability
  - Improvement due to focus on maintenance, beam tuning, and their optimization
  - Added accelerator gradient to CEBAF during last SAD
  - Lower beam intensity this run
- Without gun failures, reliability would be at 83.5% in FY24

Category	FY23 Downtime, h (/%)	FY24 Downtime (h/%)	Progress (in relative terms)
RF	300 (7%)	222 (4%)	-37% ↓
Beam Transport	244 (6%)	156 (3%)	-45% ↓
Magnets/DC	229 (5%)	72 (1%)	-73% ↓
Gun	2 (0%)	353 (7%)	+16717% ↑
Scheduled hours	**4307**	**5027**	

Weekly CEBAF Reliability Last Run (08/26/2023 – 05/20/2024)

- Two significant downtime events that impacted reliability
  - Gun field emission, Nov/Dec 2023, and
  - Gun laser shutter failure, Mar/Apr 2024



1 Gun field emission required reducing gun HV and injector energy.
Root cause:
Design and test processes for the new gun did not follow best engineering practices.

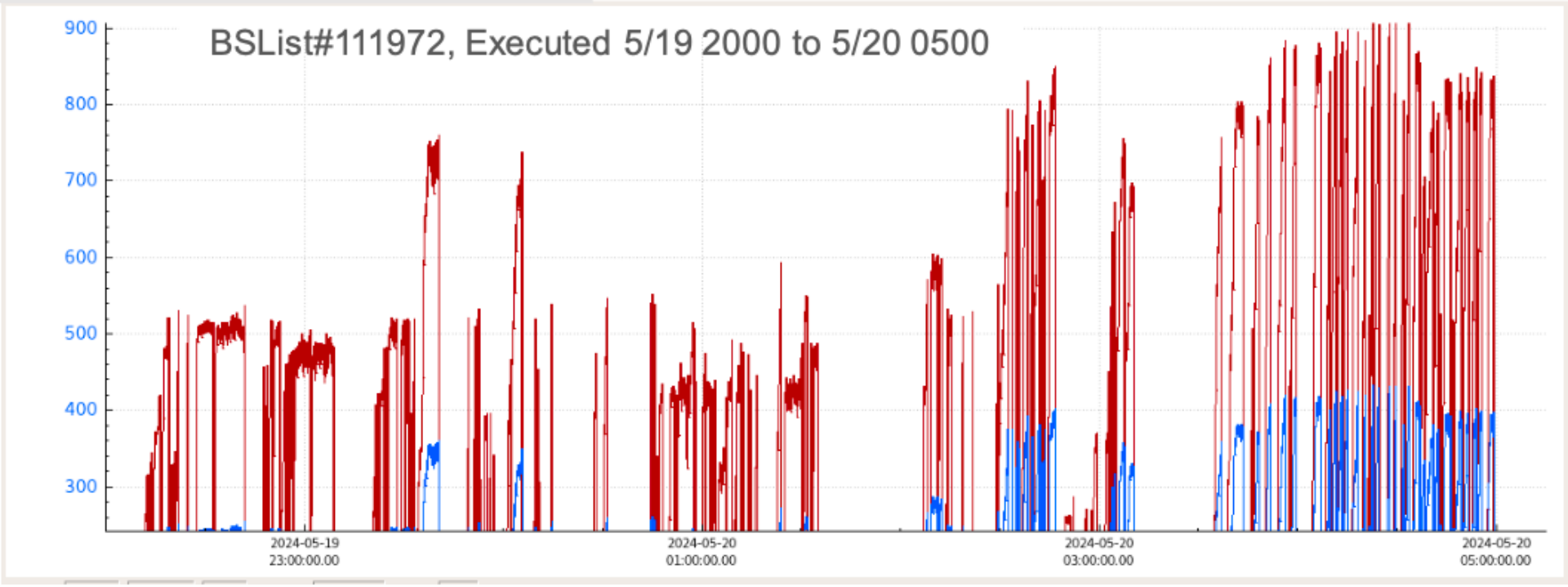
2 Gun laser shutter was not in the right position after maintenance and failed to stop the laser beam, causing beam strike event.
Root causes:
1) Inadequate configuration control
2) Gun laser system can fail and send full beam for tens of milliseconds without ability to stop it.

Various Improvements Over SAD 2023 and Last Run

- Refurbished two C100 CMs, 1L26 and 2L26 (SAD 23)
- Successful plasma processing of four CMs in SL (SAD 23)
  - Operational energy gain of 44 MeV. The gradient gain seems to stick.
- Optimization of C100 Q_L to reduce required RF power and improve cavity stability under high beam loading (SAD 23)
- C100 klystron power increased
  - C100 klystron cathode voltage and power were increased
  - Klystrons were operated with reduced cathode voltage, not meeting power requirements
- Beam-based linac cavity field calibration
  - Optimal voltage and power settings matching model
- LLRF, multiple improvements to the control algorithm
- Optimized voltage of (some) BLMs to reduce false MPS trips

High Power Beam Test, 5/20/2024

- 85 uA beam current to Hall C @ 5 pass => 900 kW
- 860 kW for 2 min (1L22 RF trip), 800 kW for 3 min (1L23 RF trip)
- Maximum beam power was limited by available RF power
- We need a few days of sustained effort to push power beyond this level after SAD

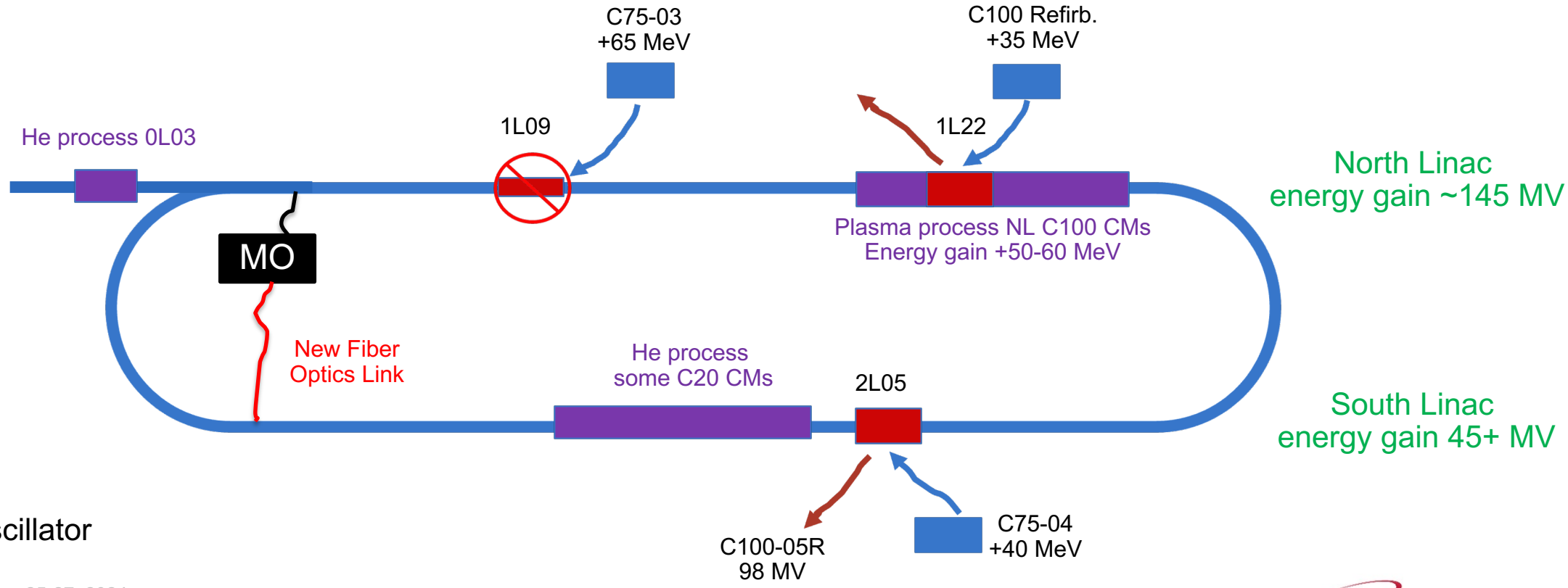


Accelerator Performance Limitations

- SRF
  - C100 cavity gradient degradation due to field emission and linac contamination
  - Loss of cryomodules and cavities to vacuum leaks and other events
  - Cavity faults caused by microphonics and other effects.
- RF
  - Performance of C100 RF stations lags relatively to the requirement
  - Loss of RF stations during run
  - C20, C50, C75 Klystron degradation needs attention
- Outdated and inadequate accelerator systems, limit understanding of the machine, post-mortem capabilities, and application of advanced techniques such as AI/ML
  - LLRF, earlier, analog versions are still prevalent at CEBAF
  - BPMs, slow DAQ (most), no buffering for postmortem processing
  - BLMs, slow DAQ
  - (No) Global timing system to synchronize CEBAF systems
  - Mitigation: AIP projects

SAD 2024 Work: SRF, RF, LLRF

- SRF
  - Two new C75 CMs: 1L09 and 2L05
  - Refurbished C100 in 1L22
  - Plasma process North Linac CMs and possibly some in South Linac
  - Helium process some South Linac CMs and injector 0L03
  - Additional work to address degradation issues in some cavities
- RF
  - New HP/LLRF systems for 1L09 and 2L05 C75 CM
  - 8 kW circulators for C75 CMs to utilize full power of 8 kW klystrons
  - Change houses in some zones, start systematic RF refurbishment
- LLRF – fiber optics link for MO
  - Reduces sensitivity of South Linac to lightning



MO – master oscillator

SAD 2024 Work: Other Systems

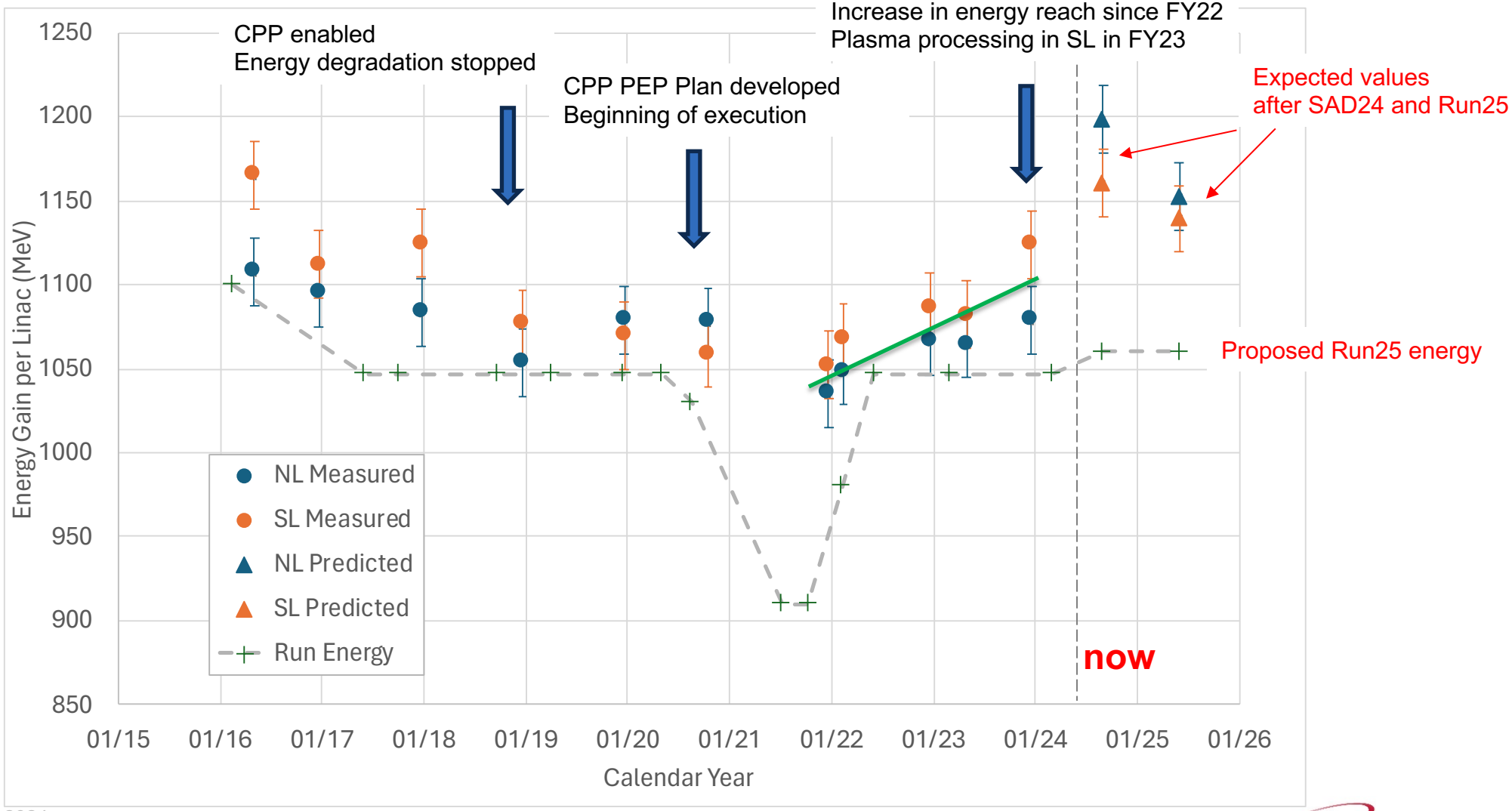
- Injector Fix
  - Modify, install, and test the new spherical gun (again)
  - Fix injector solenoids
- Synchrotron light interferometer will be installed for Hyper Nuclear Experiments
- Personnel Safety System
  - BSY PSS system upgrade to new system
- Irradiation line in the injector
  - To irradiate LiD and ammonia polarized cryogenic targets
- Beam degrader installation to simulate and study transport of e+ beam
- Facilities:
  - Hall D-line LCW deOx system to address D-line magnet clogging
  - Tunnel and injector ventilation to reduce impact of outside temperature fluctuations

Plan For Beam Studies Next Year

- MOLLER
  - Continue Hall A Fast Feedback / Feedforward tests
  - Parity quality injector tests
- K-Long beam transport and impact on MOLLER beam
  - Postponed to coming run (FY25) due to issues with the injector solenoids.
- Hyper-Nuclear/MOLLER
  - Revive and test CREST procedure to keep beam on-crest and reduce and control energy spread/drift
  - Revive and test MoMod - similar to CREST
  - Test of synchrotron light interferometer for energy spread measurement
- BLM and Ion Chamber settings optimization to reduce false MPS trips
  - At the beginning of the run
- RF calibration test at the beginning of the run
- High power runs to identify intensity limitations (>1 MW)
- Irradiation Beam line test
- Beam degrader test (e+ effort)

CEBAF Energy Reach Evolution and Next Year Projection

- CPP stopped and turned around energy degradation and reliability decrease



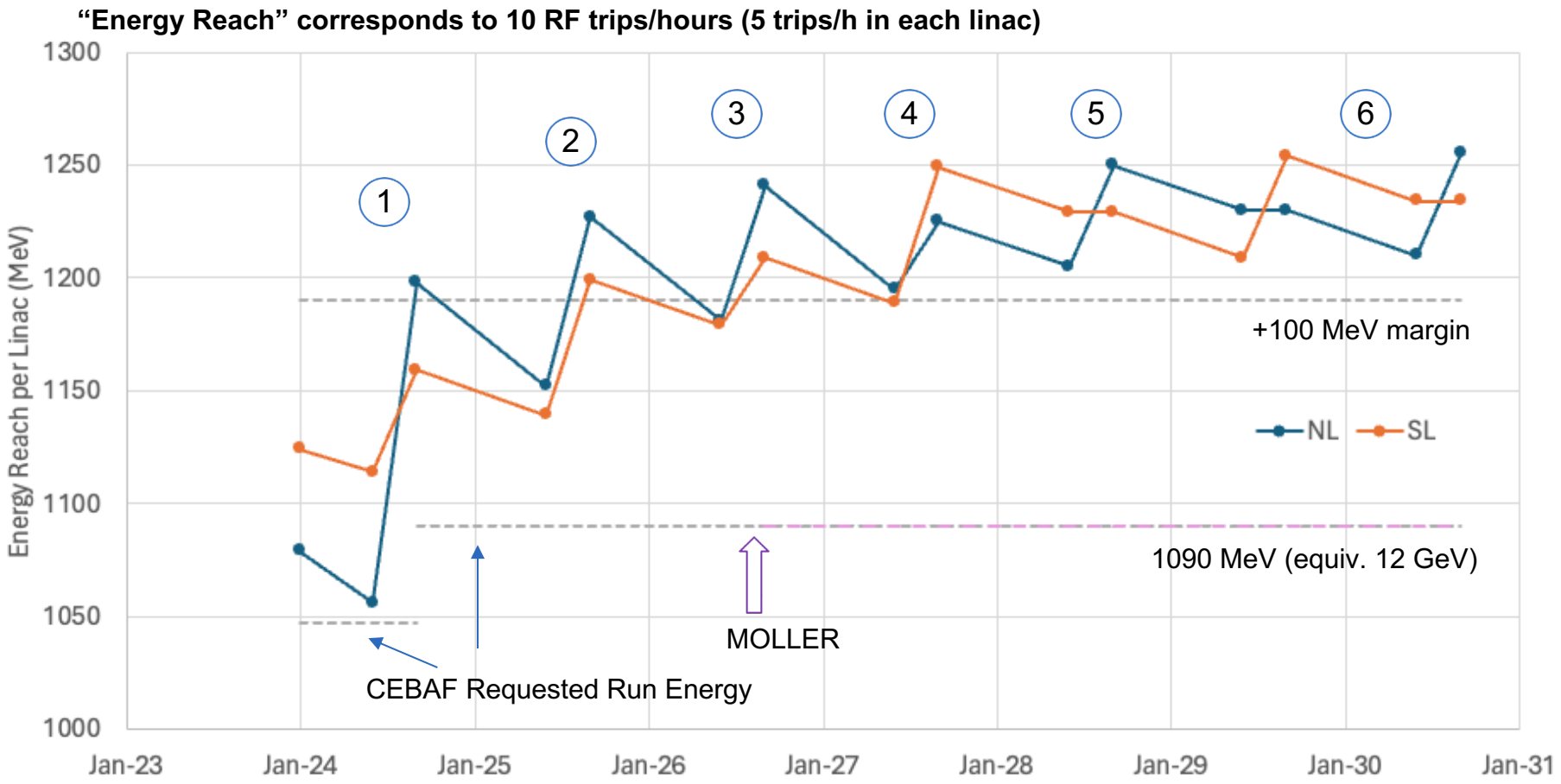
Energy reach corresponds to 10 RF trips/h for zero beam current.

Maximum beam energy Is lower for a high beam current because of insufficient RF power.

Beam Parameters For Next Run

- Proposed Beam Energy 1060 MeV/linac
  - 10.7 GeV after 5 passes; 11.8 GeV after 5.5 passes
  - Meets minimum MOLLER requirements
  - Next option 1100 MeV can be problematic towards the end of the run, needs improvements in RF.
- Total beam power goal >900 kW
- Polarization to all Halls
- RF trip rate at these parameters ~5 trip/h

CPP Energy Reach Project Is Critical For Success



1. C75-03, C75-04, C100R + 44 MeV Plasma Processing
2. C75-05, C75-06, C100R + 15 MeV PP SL
3. C75-07, C100R + 15 MeV PP NL
4. C75-08, C100R + 15 MeV PP SL
5. C75-09 (+ Booster)
6. Steady State: C100R + 15 MeV PP Each linac alternating years

Required CEBAF Energy Reach with margin can be nearly achieved in FY 26 and exceeded in FY27 with the proposed profile.

Challenges And Risks

- Impact of delayed and reduced budget in FY24
  - Unable to procure and install all-metal gate valves this SAD due to late arrival of funding and procurement freeze. This delays effort to mitigate gradient degradation in CEBAF by a year.
  - Delay in refurbishment of klystrons (CPP). Risk of losing potential vendor for klystron refurbishment.
  - 50% reduction in funding of the CPP Obsolescence program. Risk of catastrophic failures increases.
- Safety issues have negative impact on operations
  - Take focus and effort away from operations and reliability
  - Make SAD and maintenance work planning and execution difficult
- Risk: insufficient CPP funding
  - Insufficient funds for CPP can further affect our ability to address energy reach and reliability gaps
- Risk: Insufficient funding of AIPs, favorable Scenario 2 does not materialize
  - Upgrade of LLRF, BPM, BLM, Timing System can be significantly delayed limiting our ability to improve CEBAF performance

Path Forward

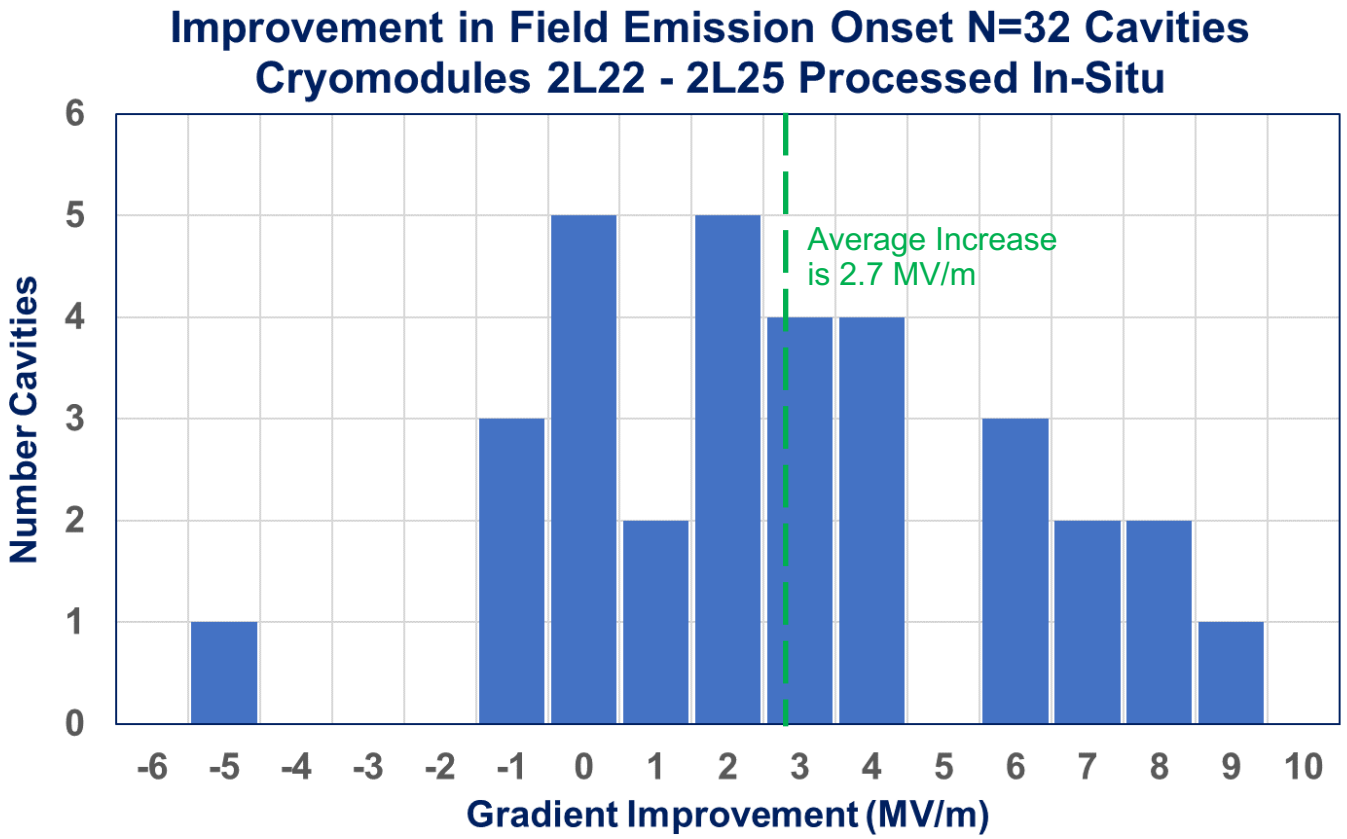
- Continue critical CPP effort to close energy and reliability performance gaps
- Reestablish CEBAF SRF cleanness effort, implement it as part of CPP, and include plasma processing into operations
- Review and improve CEBAF RF performance
- Improve beam transport and tuning procedures and ensure continuity of experience with machine tuning within AD
- Focus on improving reliability, restore reliability team, and continue effort to turn maintenance from reactive to proactive
- Upgrade CEBAF accelerator system through AIPs and expedite upgrades if possible
- Develop Accelerator Management Plan that will summarize CEBAF path forward for next five years (by end of CY24)

Thank You

Main Recurring Sources of Downtime

- RF failures are consistently large contribution to downtime, ~30%
  - Klystron HV and high-power electronics
  - High power components (transformers, breakers, etc.)
  - Hose failure
- Beam transport consistently is a high contribution, ~15%-25%
  - Beam losses due to optics and orbit drifts
  - Injector tuning was difficult this year because of solenoids
  - Suboptimal HV settings and location of BLMs causing false trips
- Rare catastrophic failures significantly and systematically contribute to downtime
  - Example, Gun failure this run
- Outdated and inadequate accelerator systems (see slide 8)

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

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