Accelerator status overview

Past performance, near to mid-term plans

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On behalf of Accelerator Operations

2022 Hall C Winter Collaboration Meeting

Introduction - Outline

I. 2021 In Review, past performance

II. Improving reliability, reducing tune time
   I. Operational improvements/procedural developments
   II. CPP program

III. Energy reach plan

IV. Winter SAD schedule

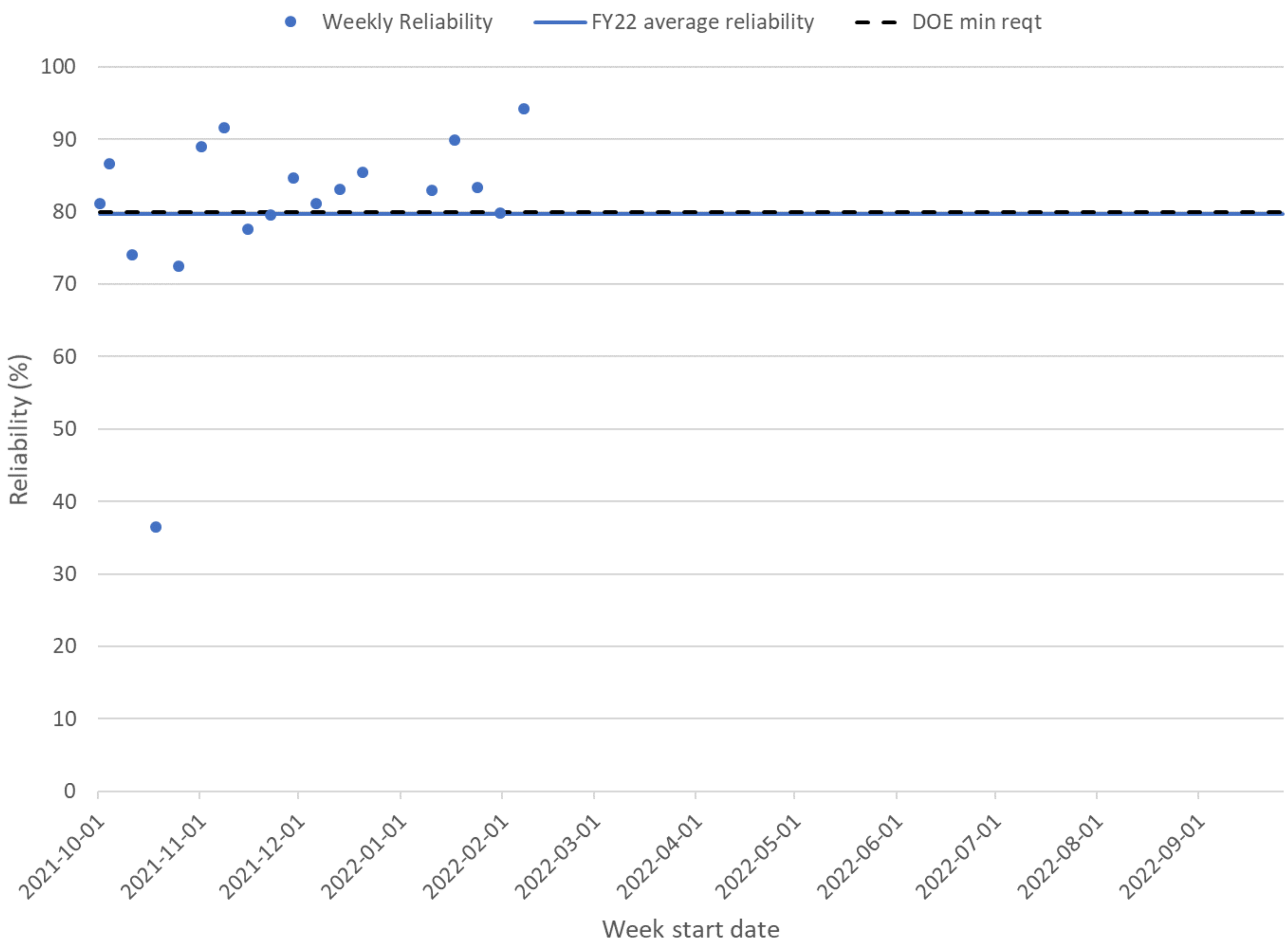
V. Upcoming physics run

VI. Moving towards the near future: Injector upgrade

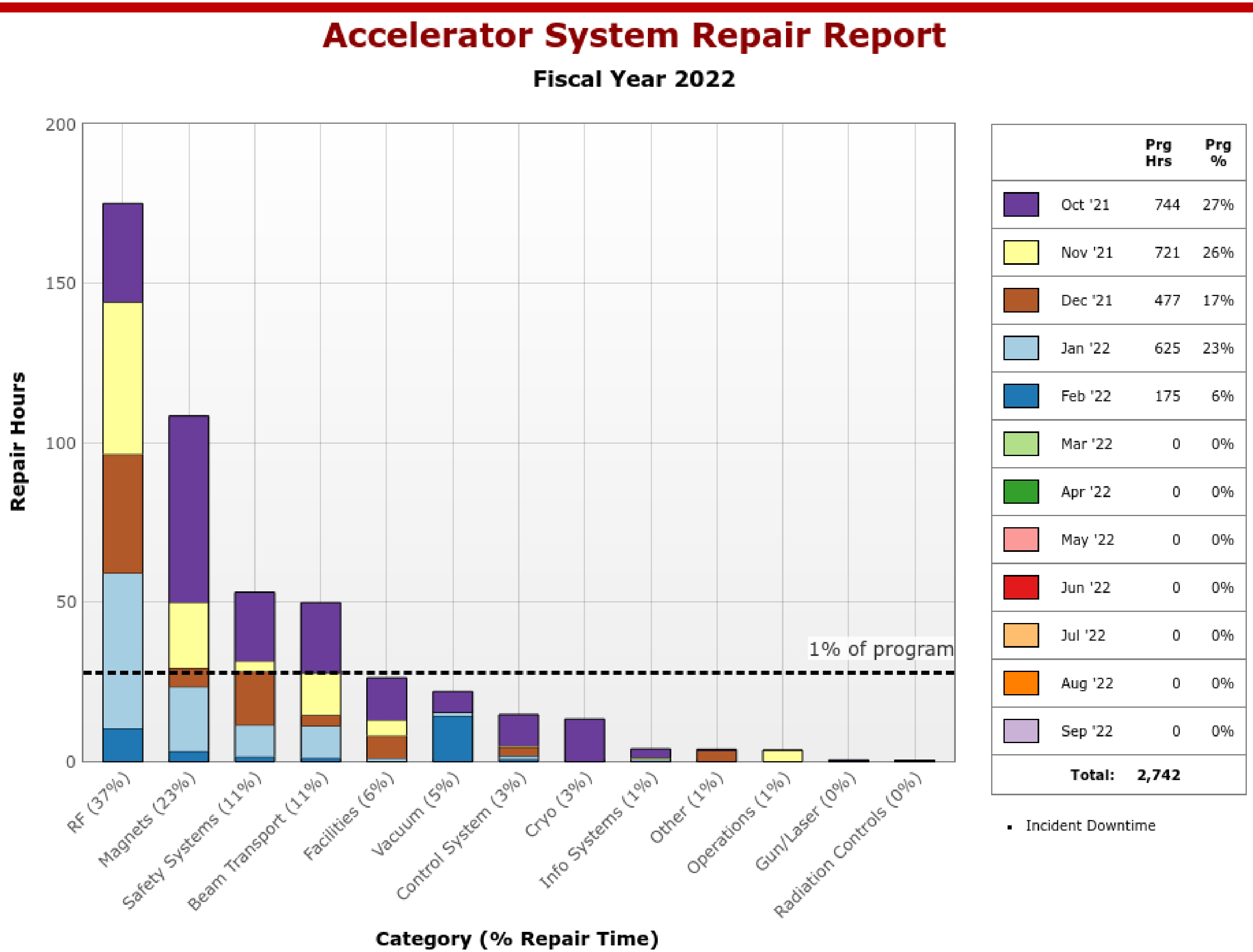
VII. Medium and far future: beam power, FFA

VIII. Summary

Reliability FY22 aka Availability per DOE requirement



Reliability FY22

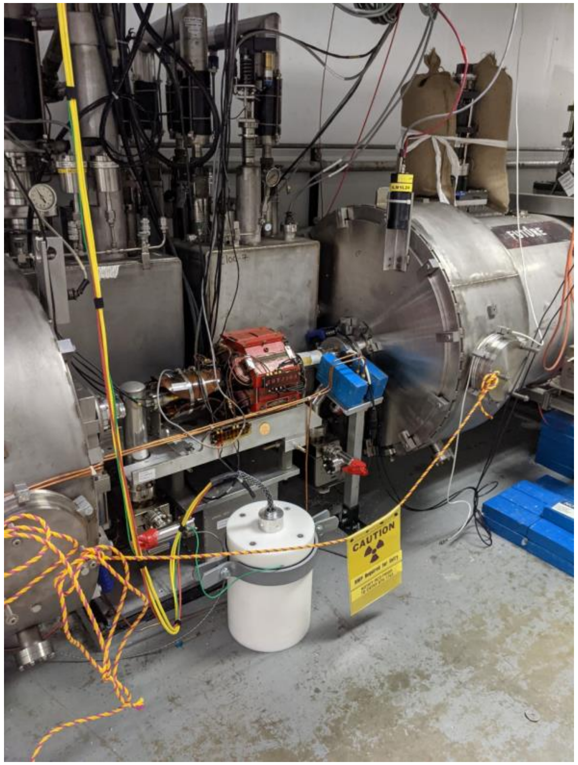


Improving reliability, reducing tune time

- Operational procedures are being reviewed/rewritten.
- Optics Restoration and Finalization Procedure (ORFP)
  - Systematic task driven method to restore the machine
- Energy scaling
  - New process reduces tune time from five to one calendar day
- Pass change setup improved
- Beam envelope match into the halls

In FY2022 The lab is investing $2.5M in upgrading obsolete systems and procuring spares. *Email R. Michaud for a copy of his JLACC talk on the CEBAF performance plan (rmichaud@jlab.org)*

Improving reliability: Optimizing for reduced radiation

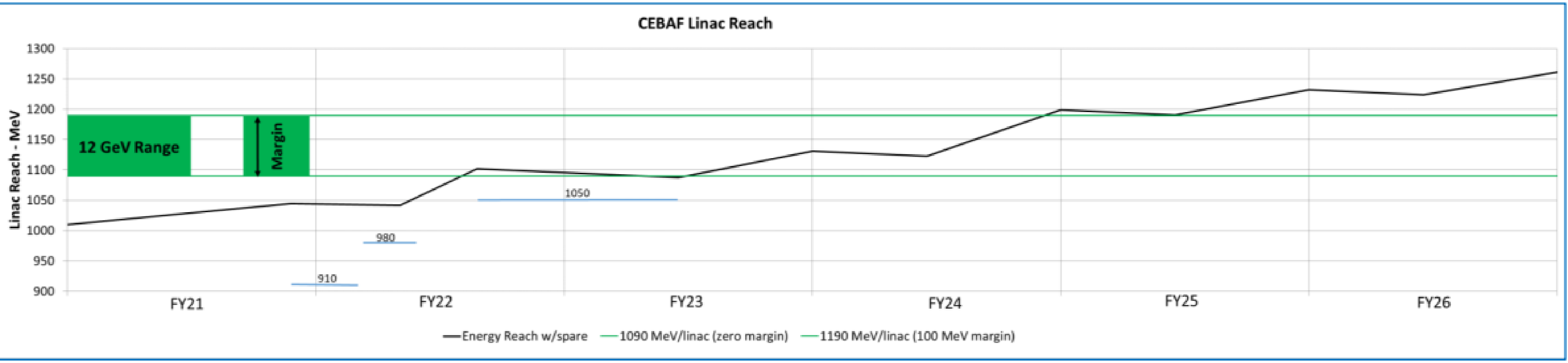


- NDX (neutron) detectors were installed in the accelerator enclosure.
- They inform gradient redistribution with the aim of reducing the radiation induced field emission.
- Designed and build by the Rad. Control group.
- Gradient / radiation reduction moving toward AI optimization.
  - Currently the focus of efforts from the Radiation control group, Operations and CASA.
  - TN-21-036 discusses initial manual effort.

CEBAF performance Plan: Energy reach FY2021-2026

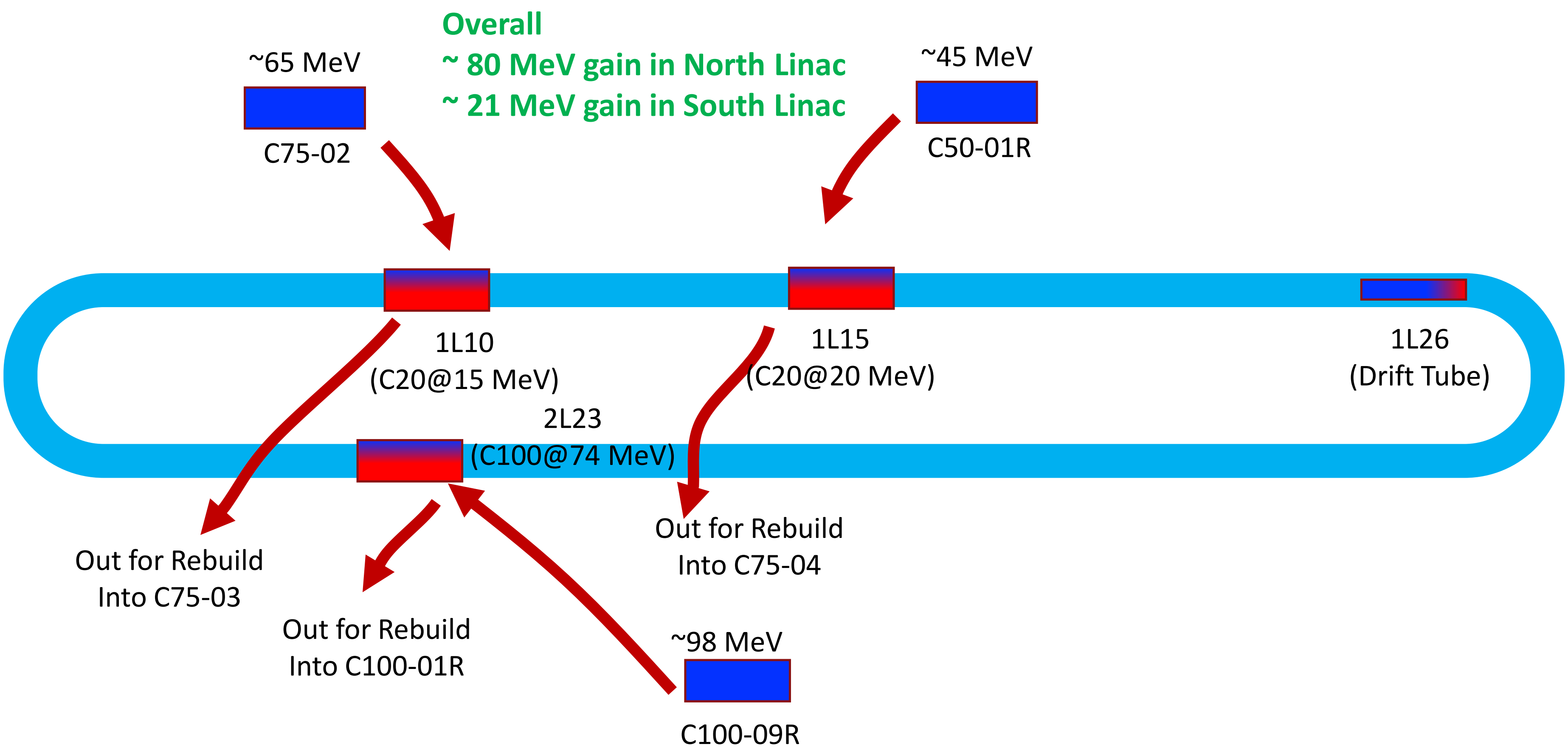
	#CM assembled (previous year)	CM serial number	NL energy reach (MeV)	SL energy reach (MeV)	
FY21	2	P1 (NL), C75-01 (NL)	1038.5	1047.8	
FY22	3	C75-02(SL), C50 (SL), C100-09R(NL)	1096	1100	
FY23	3	C75-03(SL), C100-10R (SL), C100-X1R (SL), []	1124	1123	remove C75-04 (SL)
FY24	4	C75-04 (SL), C75-05 (NL), [], C100-X2R (SL), spare C100	1191	1196	add C75-04 (SL), remove C75-06 (SL)
FY25	4	C75-06 (SL), C75-07 (NL), [], C100-X3R (NL)	1227	1223.9	add C75-06 (SL), remove C75-08 (SL)
FY26	2	C75-08 (SL), C75-09 (NL), []	1253	1301.7	add C75-08 (SL), remove C100-XR4 (SL)

Changes from Oct 2020 plan marked in red



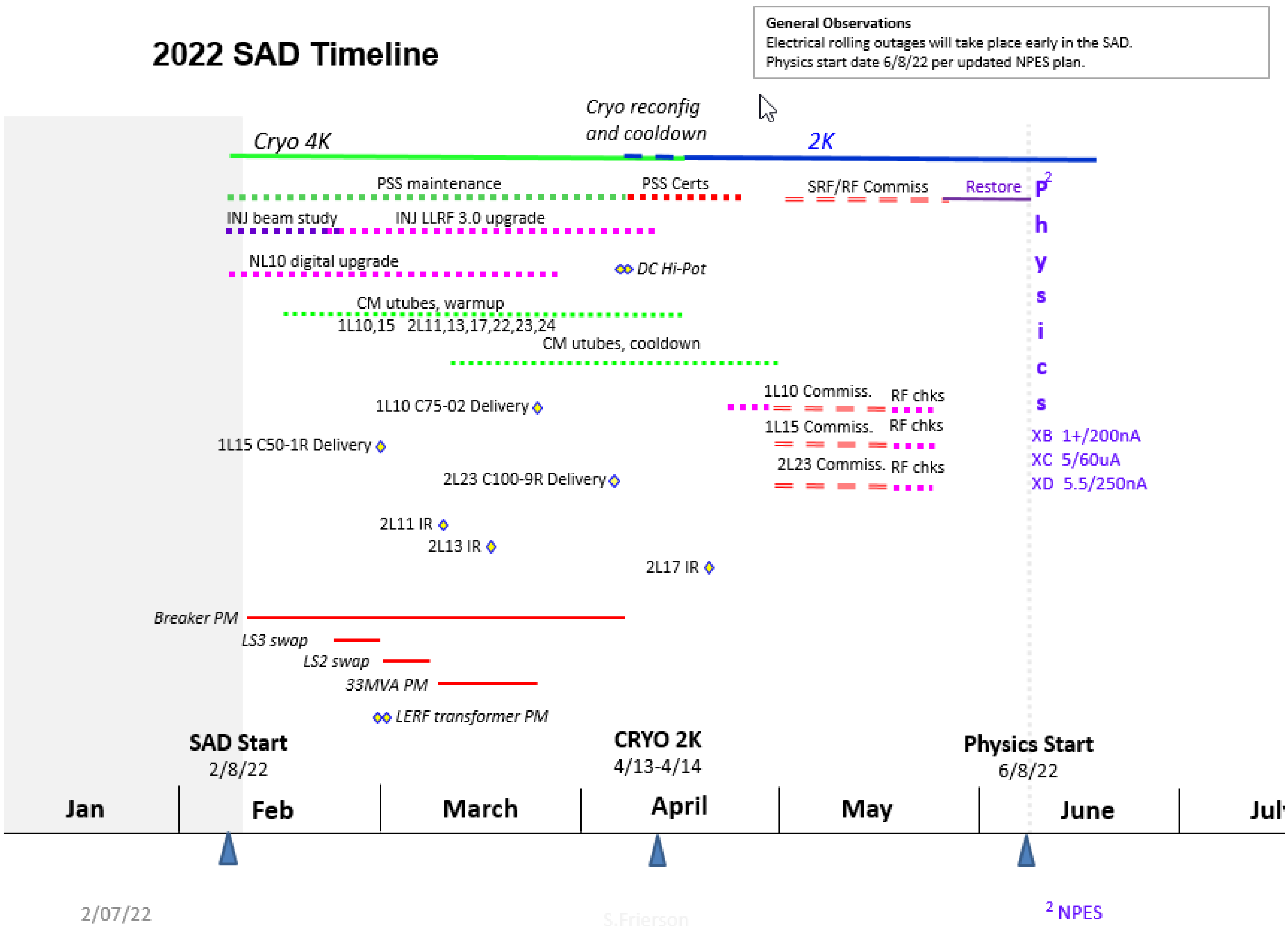
Update: NL lost 33MeV due to 300K cryo-cycling, another 5 MeV to C50 performance, assuming we can only recover 75% of the known bad cavities, we are left with 1053.

Energy reach plan for FY2022, cryomodule dance



December forecast. The situation is in flux and plan will be adjusted as one becomes aware of the SRF reach (affected by component failures,etc..)

Winter Scheduled Accelerator Down



Upcoming 2022/2023 physics run

- We are restarting in June and running for 260 days, not including a 26 day interruption for winter break and recovery, almost ten months.
- Choice of linac energy will be determined by consulting with physics and considering:
  - Energy reach with anticipated SRF inventory
  - Impact on physics program
  - Optimization for polarized beam delivery
  - Possibility of doing more frequent RF recovery during run period.

- Currently, we are planning to go with 1047 MeV/linac . We are preparing a backup plan with 1028 MeV/linac in the event that the SRF performance is inadequate.
- We have a new procedure to quickly scale the machine to a different energy. It took us 6 hours on Nov 5th to go from 910 to 980 MeV/linac and get 70 uamps CW back to Hall C.

- The energy target might change as we learn more about our gradient reach during the SAD. See J. Benesch TN-22-002 for discussion and expected polarizations

Expected polarization for various scenarios

Table 1 Polarization figures of merit for eight other scenarios

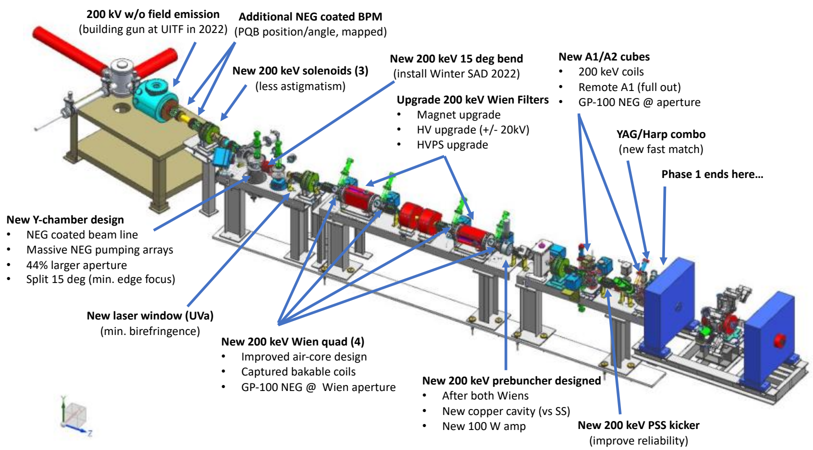
Inj MeV	NL MeV	SL MeV	P^2 A1 B5	P^2 A2 B5	P^2 A3 B5	P^2 A4 B5	P^2 sum	Hall C MeV	Hall D MeV
112.8	1000	1000	0.866	0.996	0.981	0.932	3.78	10076	11064
114	1010	1010	0.871	0.935	0.848	0.527	3.18	10175	11174
115.1	1020	1020	0.874	0.807	0.652	0.956	3.29	10275	11283
115.7	1025	1025	0.830	0.947	0.831	0.996	3.60	10325	11337
116.0	*1028*	*1028*	*0.611*	*0.640*	*0.987*	*0.949*	*3.19*	*10355*	*11370*
116.2	1030	1030	0.876	0.631	0.992	0.891	3.39	10374	11392
116.8	1035	1035	0.826	0.999	0.674	0.670	3.17	10424	11446
117.4	1040	1040	0.881	0.562	0.812	0.600	2.86	10474	11501
117.9	1045	1045	0.824	0.974	0.995	0.839	3.63	10524	11555
118.15	*1047*	*1047*	*0.536*	*0.987*	*0.927*	*0.911*	*3.36*	*10544*	*11577*
118.5	1050	1050	0.883	0.748	0.697	0.981	3.31	10573	11610

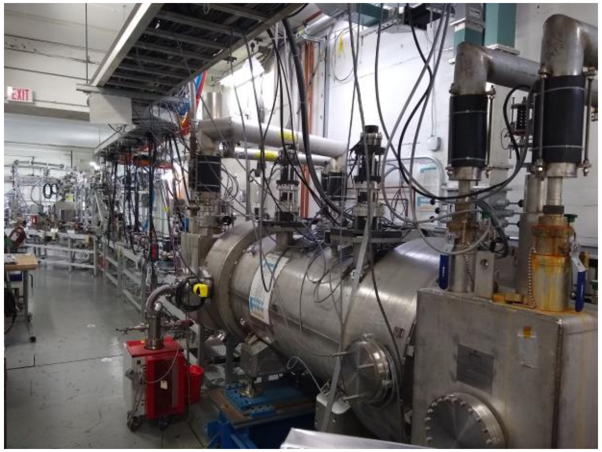
Lines in italics prepared in response to a discussion with Doug Higinbotham and others on 1 February.

J. Benesch TN22-002

CEBAF Injector Upgrade

- **<u>Phase 1</u>**
  - CEBAF beamline rebuilt with improved vacuum and 200 KV magnets and Wien filters
  - A 200 kV polarized gun is being assembled now for commissioning at the UITF this summer
- **<u>Phase 2</u>**
  - A 10 MeV SRF Booster has been commissioned at UITF, used for HDIce and Wastewater LDRD
  - ME design of remaining beam line nearly complete, for 2023 installation.





It may be necessary to reach the parity quality beam specifications needed by future experiments such as MOLLER.

Medium future – beam power increase

- Safety Control Management Board has agreed to alter documentation to allow 1.1 MW beginning October 1 and 2 MW by end of calendar 2022. Environmental Assessment of 2007 allows 2 MW.
- Beam dump cooling system intermediate heat exchanger limit is 1.1 MW. Request for 2 MW upgrade submitted to FLM planning group.
- C100 and C75 cavity input resistances were optimized for gradient, not current. Five-stub tuners may allow the C100 input resistances to be altered to increase current capacity at expense of gradient. Eight are on order for installation this SAD. Testing with beam after Hall A ready.
- A test plan has been submitted to determine actual beam power capability of SRF/RF system. https://opsweb.acc.jlab.org/CSUEApps/atlis/task/23550
- See TN-21-016 https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-242263/21-016.pdf for my view of details

Far Future: FFA to double energy again

- Remove one or two of the higher pass electromagnetic arcs and replace them with combined function magnets which are designed to allow a range of energies in the same magnet. Typically ~2:1 range.
- CBETA at Cornell was a successful demonstration at 150 MeV
- Permanent magnet development lead at BNL, Stephen Brooks, has an LDRD for design and development of magnets suitable for use here
- Ryan Bodenstein, CASA, has an LDRD for end to end simulation of FFA at CEBAF. LDRD funds are being applied for learning of BMAD, the chosen code, by Ryan and students. Definition of the beam line **not** included.
- The biggest optics problem in CEBAF is the ratio of injection energy to sixth pass through North Linac: 90:1. Beam envelope is large on fifth and sixth passes. Particle loss has been observed via NDX detectors.
- The working group proposes to solve this by building a two-pass recirculating linac with three new cryomodules in a new vault adjacent to the existing tunnel in lieu of the 55 m injector chicane. Final energy 650 MeV. Ratio at start of NL on way to Halls A/B/C 34:1. SL 19:1

Energy steps

linac energy=	925	1000	1100
extraction energy			
first	2400	2590	2850
second	4250	4590	5050
third	6090	6590	7250
fourth	7930	8580	9440
fifth	9770	10570	11620
sixth	11600	12540	13790
seventh	13370	14450	15900
eighth	15090	16310	17940
ninth	16820	18180	20000
tenth	18490	19990	21990

- Stephen Brooks uses 925-1100 MeV as the linac energy range in his permanent magnet design efforts to keep peak field down.
- First three passes are electromagnetic so 2.0-7.25 GeV continuously available if FFAs are not used. 2 GeV minimum chosen to limit span of Hall dipoles to 11:1.
- The working group does not yet have a concept for extracting the energies shown in red.

Input Requested for White Paper and IPAC

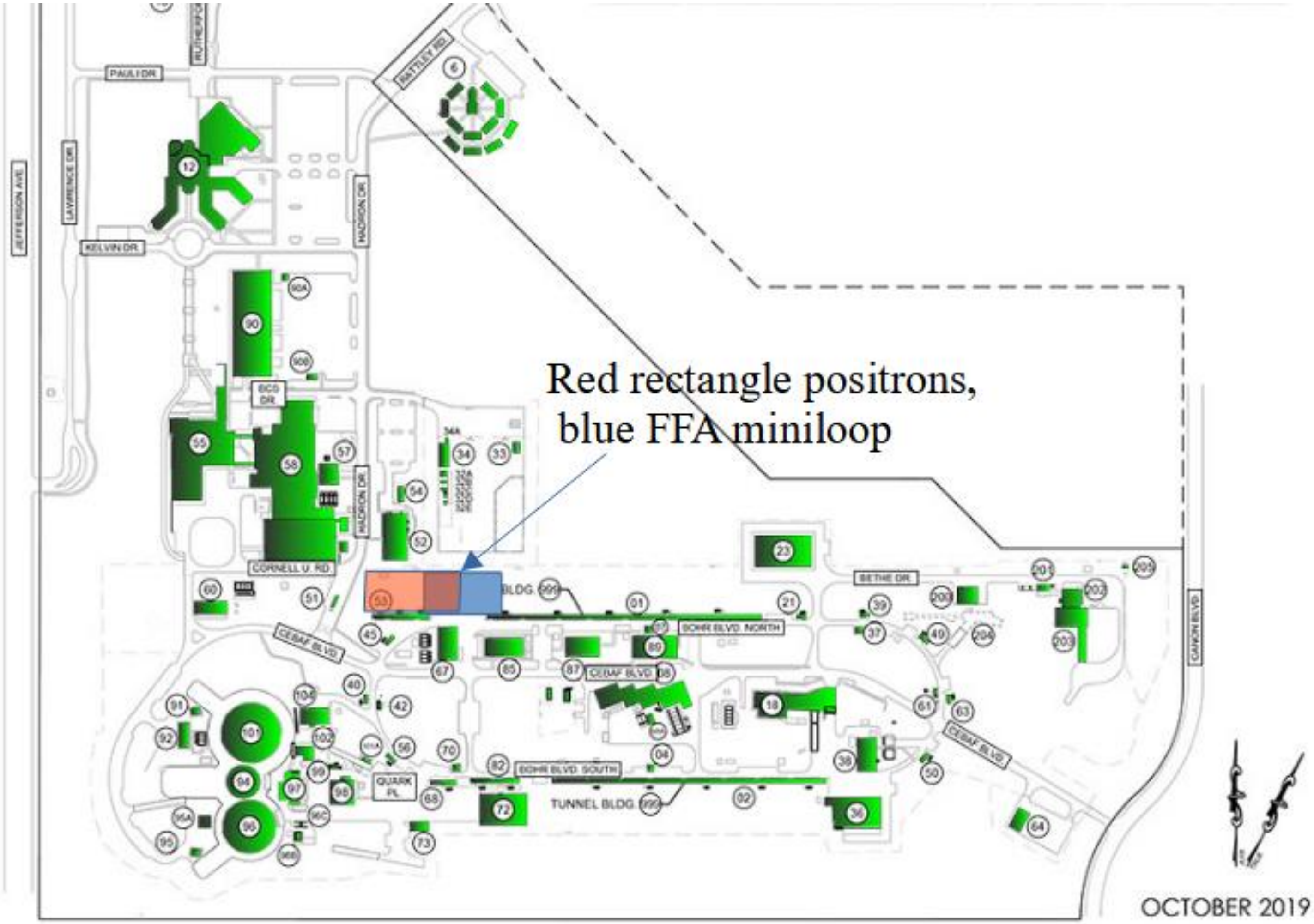
- What physics drives the higher energy?
- What physics drives the needed energy spacing?
- Which is more important, physics with positrons or higher energy? (Vault for intermediate injector may preclude positron source.)
- What questions do you have that I might answer now?
- What modifications do you want the FFA collaboration to work on? Priority?
- The J-Future workshop, March 28-30, will discuss physics with positrons and higher CEBAF energy. See https://indico.jlab.org/event/520/overview

Summary

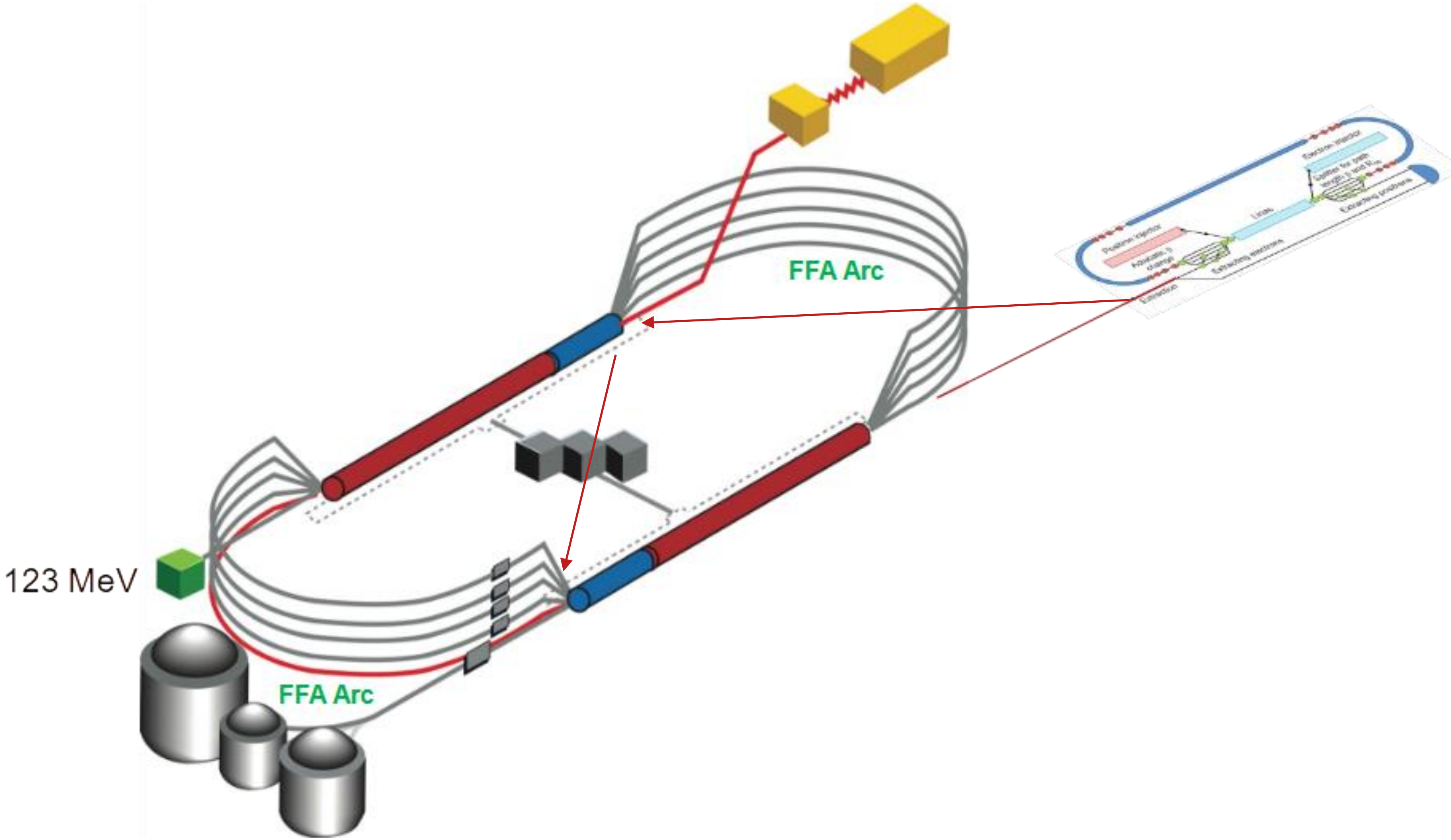
- Successfully ran at 910 and 980 MeV per linac with up to 70uamps CW at pass 5.
- Machine reliability is improving despite pandemic related issues in supply chain and labor.
- A robust CPP program is in place to address remaining vulnerabilities
- There is a long term plan for the gradient ramp-up and SRF inventory is being upgraded with new cryomodules
- Working groups are exploring positrons (Joe Grames, lead) and energy doubling (Alex Bogacz, lead)

BACKUP SLIDES

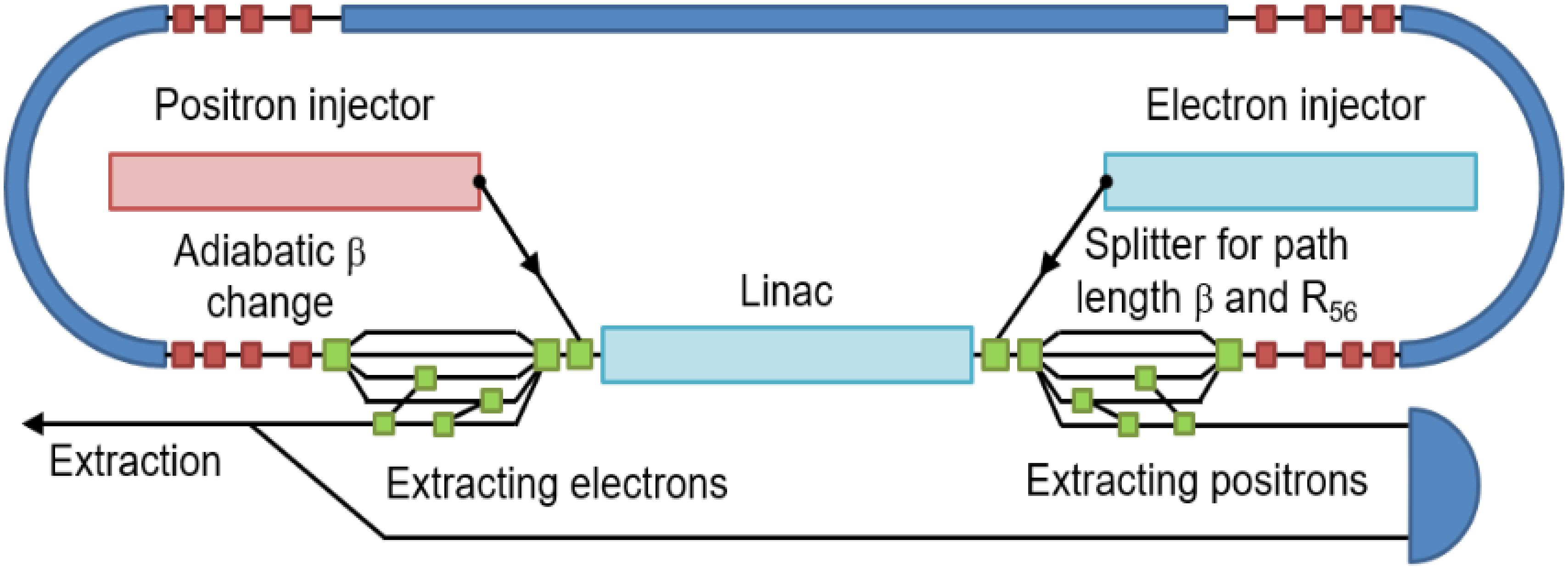
Cartoon of real estate issue



The expensive option

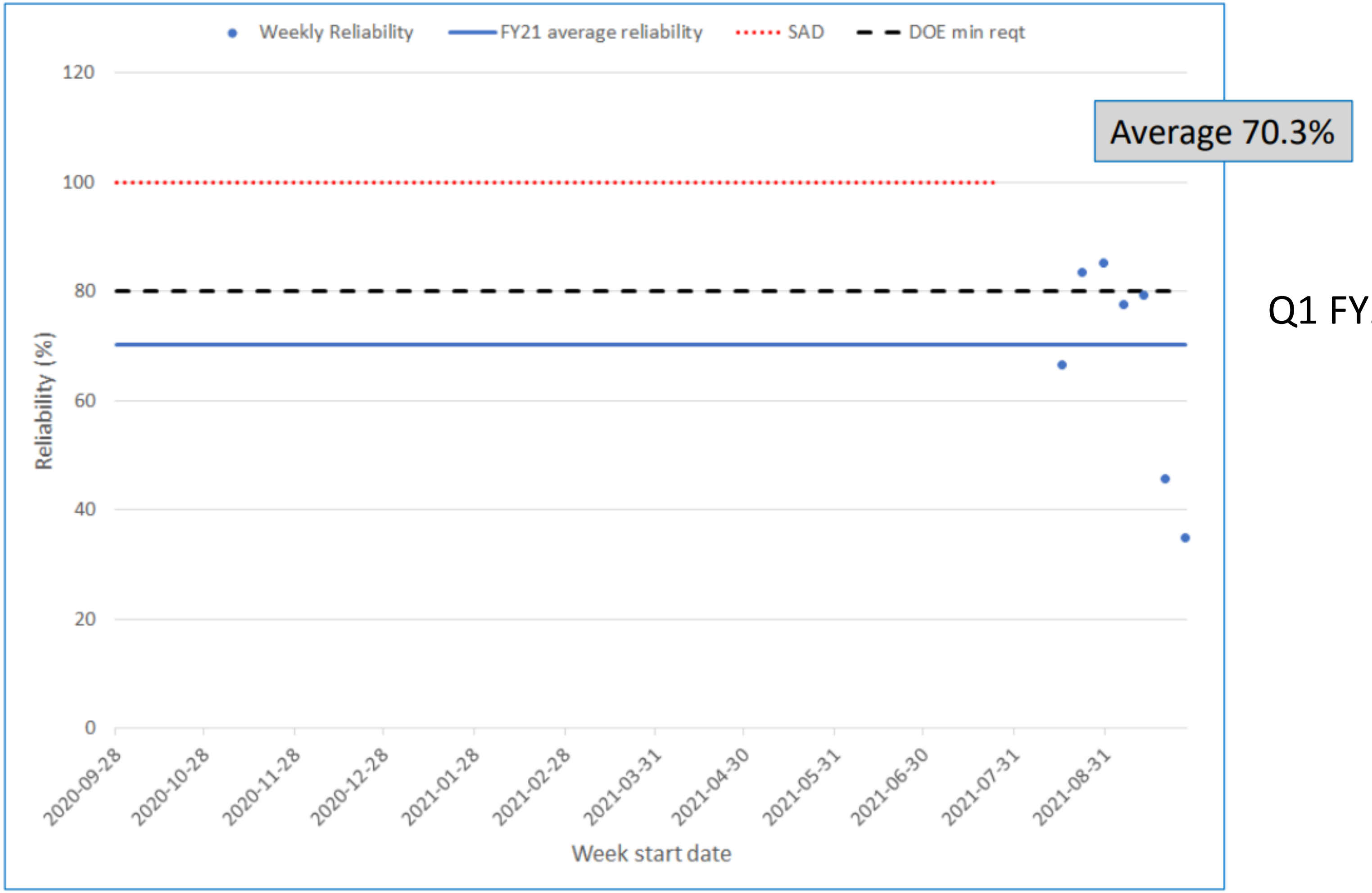


1.2 GeV FFA booster injector



Space for up to three positron injectors and one chopped electron injector inside ring. To reduce systematics, positron injectors might be configured to select either positrons or electrons from pair production

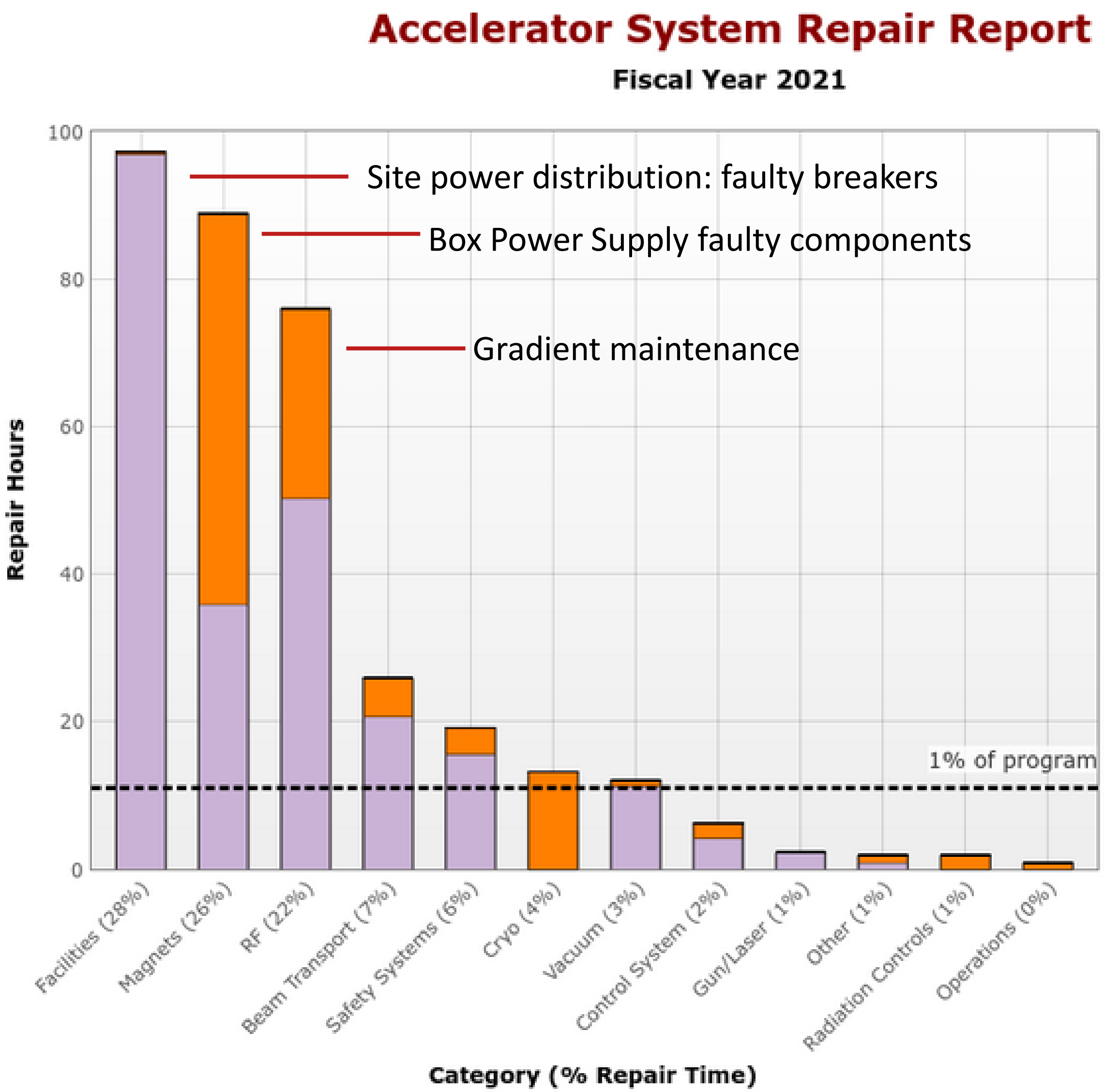
FY2021 performance



Q1 FY2022:78.1 %

FY2021 issues were mostly due to power supply failures compounded by the supply chain difficulties in getting reliable spare components.

Reliability at CEBAF



	Prg Hrs	Prg %
Oct '20	0	0%
Nov '20	0	0%
Dec '20	0	0%
Jan '21	0	0%
Feb '21	0	0%
Mar '21	0	0%
Apr '21	0	0%
May '21	0	0%
Jun '21	0	0%
Jul '21	0	0%
Aug '21	369	34%
Sep '21	706	66%
Total:	1,075	

- Incident Downtime

FY	% Reliability
FY21	70.30%
FY20	68.30%
FY19	81.30%
FY18	76.00%

Jefferson Lab

Reliability at CEBAF – Major Failures Journey

1. **Spring 2014**: ZA magnet coil and vacuum failure; **3 week interruption** to replace damaged coil and repair the vacuum chamber. This failure consumed the existing spare coil; **recovery from the next failure will take much longer**.
2. **Spring 2015**: Cold compressor 4 failure in 2 K cold-box, SC1; No spare at JLab, consumed the SNS cold compressor spare. **Program change required:** half design energy after 5 week down.
3. **Fall 2015:** YR coil on 3-pass extraction generated a spontaneous leak. No 3-pass program for FY16, repaired Summer 2016, consumed a YR coil spare. Required Hall-A DVCS experiment to re-arrange its run plan.
4. **Fall 2016**: Arc7 box supply failure, no spare. **Program change required:** to single hall operation until supply repaired.
5. **Fall 2016**: 5th pass separator vacuum leak. **Program change required**, could not support 5th pass beam to Hall-A simultaneously with 5.5 pass beam to Hall-D.
6. **Spring 2017**: Cold compressor 5 failure in 2 K cold-box, SC1; **Scheduled program terminated.**
7. **Fall 2017**: Magnet Power Supply XSEPT4T experiences contactor failure. **Program change required**, could not support 2nd pass program.
8. **Spring 2018**: CHL Transformer failure; **Major program interuption.**
9. **Summer 2018**: CHL Transformer failure (sister transformer); **Major startup interuption.**

Reliability at CEBAF – Major Failures Journey

10. **Fall 2018:** 1L21/1L22 Vacuum degradation, beam steering – **delayed restoration from SAD (~ 2 weeks).**

11. **Summer 2020:** Site Chiller failure resulting in elevated Service Building temperatures – **delayed restoration from SAD (~ 2 weeks).**

12. **Fall 2021:** Magnet Box Power Supply IGBT Failure and investigation – **delayed restoration from SAD (~ 1 week).**

13. **Fall 2021:** Accelerator Power Breaker failure for Magnet Box Power Supply – **interruption to program (~ 4 days).**

Major Failures Summary:

- We have seen a shift in the extent of “major failures” impacting accelerator operation and the physics programs:
  - **“Delays”** in days and weeks vs. **“Program Terminated”, “Program Change Required”.**

- CPP Critical Spares – specifically magnet box power supplies – has significantly contributed to reducing the impact of failures on our physics programs.