Summary of 4K Running

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DOE's Office of Science Selects 49 Scientists to Receive Early Career Research Program Funding

Program provides support to exceptional researchers.

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WASHINGTON, DC – The Department of Energy's (DOE's) Office of Science has selected 49 scientists from across the nation – including 22 from DOE's national laboratories and 27 from U.S. universities – to receive significant funding for research as

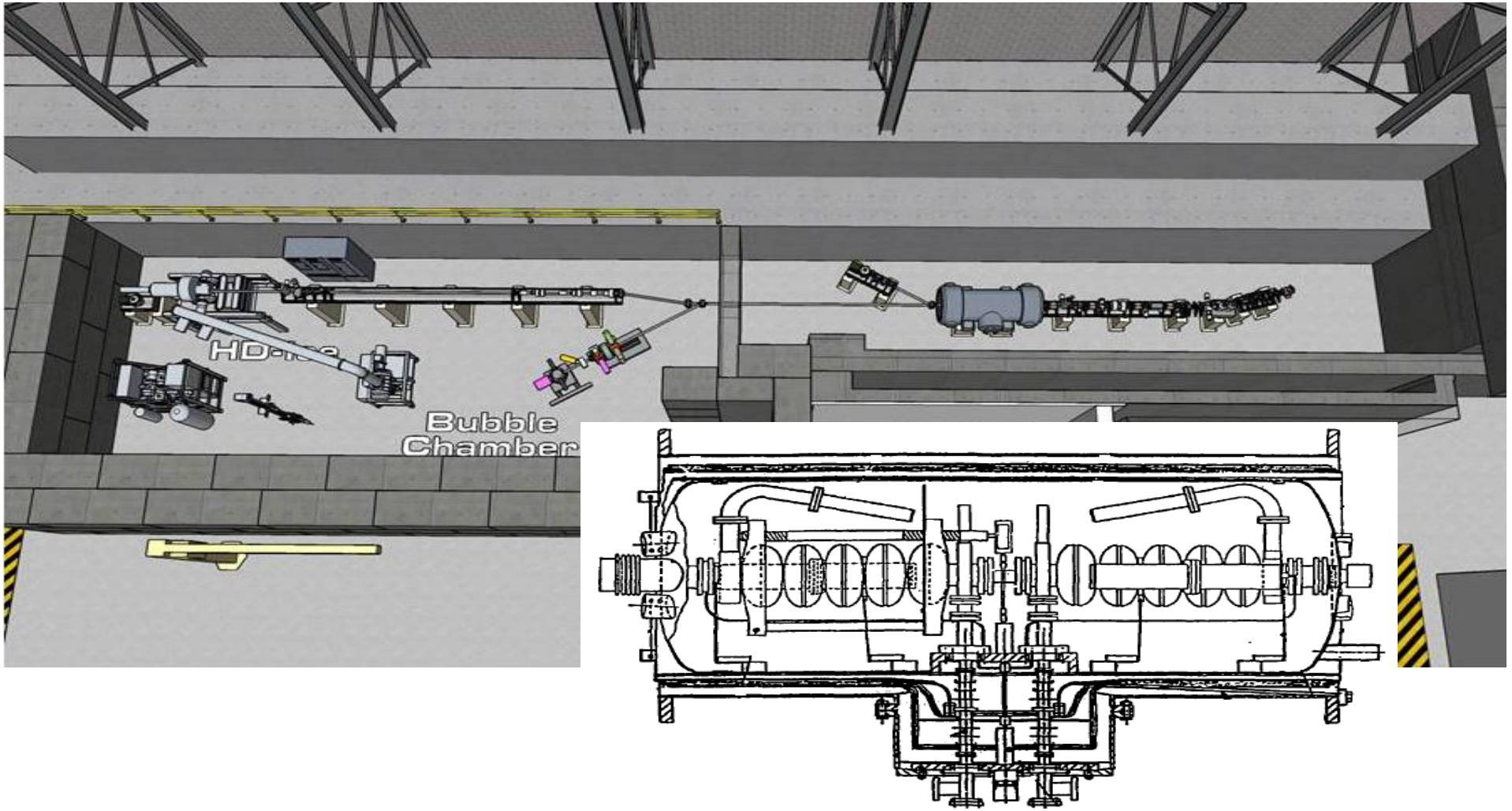
Exciting topic: 2 DOE Early Career research grants this year on Nb_3Sn SRF cavities!

Under the program, university-based researchers will receive at least $150,000 per year to cover summer salary and research expenses. For researchers based at DOE national laboratories, where DOE typically covers full salary and expenses of laboratory employees, grants will be at least $500,000 per year to cover year-round salary plus research expenses. The research grants are planned for five years.

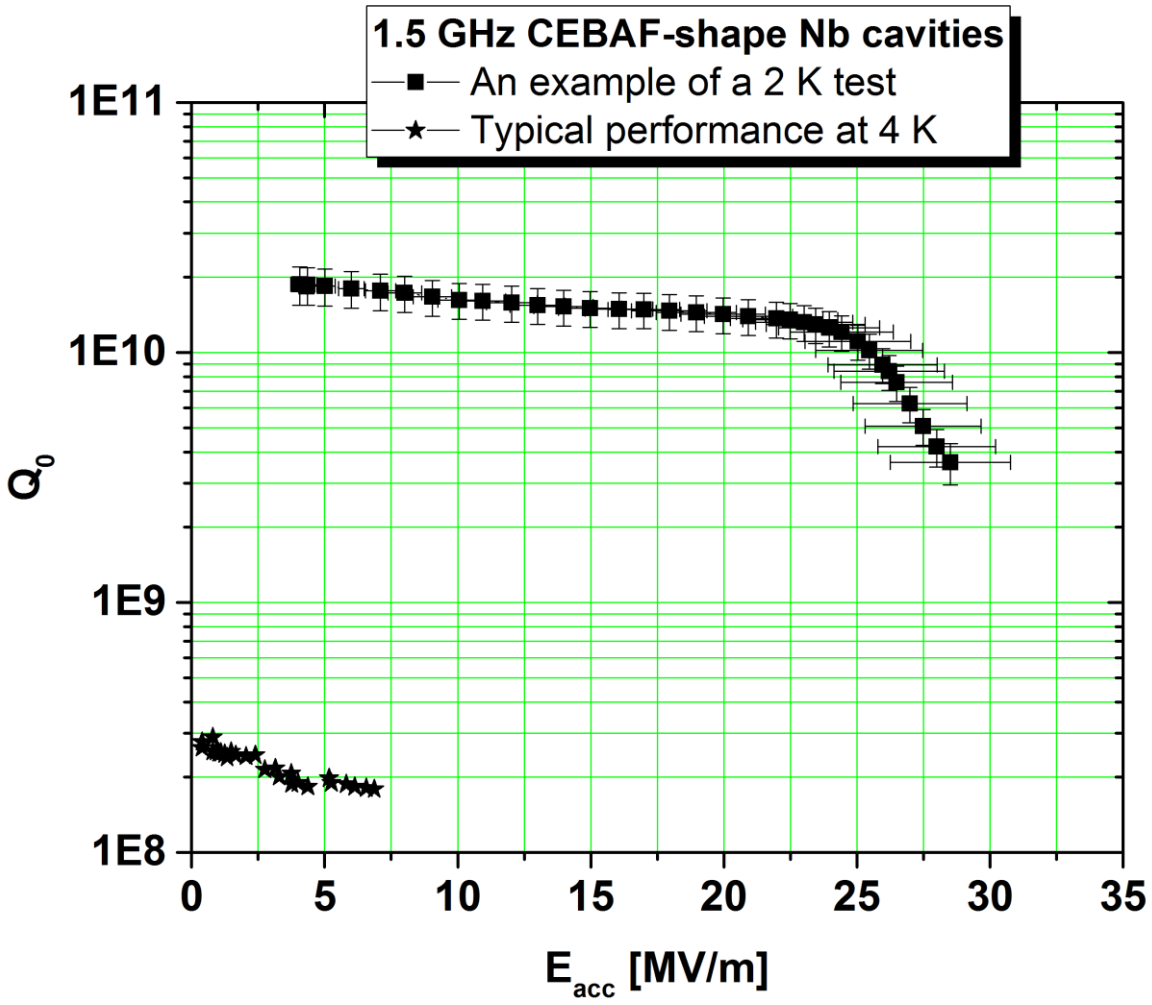
Posen, Sam, Fermi National Accelerator Laboratory, Batavia, IL, "Developing the Next Generation of Superconducting RF Cavities with Nb_3Sn," selected by the Office of High Energy Physics.

Eremeev, Grigory V., Thomas Jefferson National Accelerator Facility, Newport News, VA, "Formation of Superconducting Nb_3Sn Phase for Superconducting Radio Frequency (SRF) Cavities," selected by the Office of Nuclear Physics.

JLAB Upgraded Injector Test Facility



2K vs 4K cavity performance



4K quarter-cryomodule test

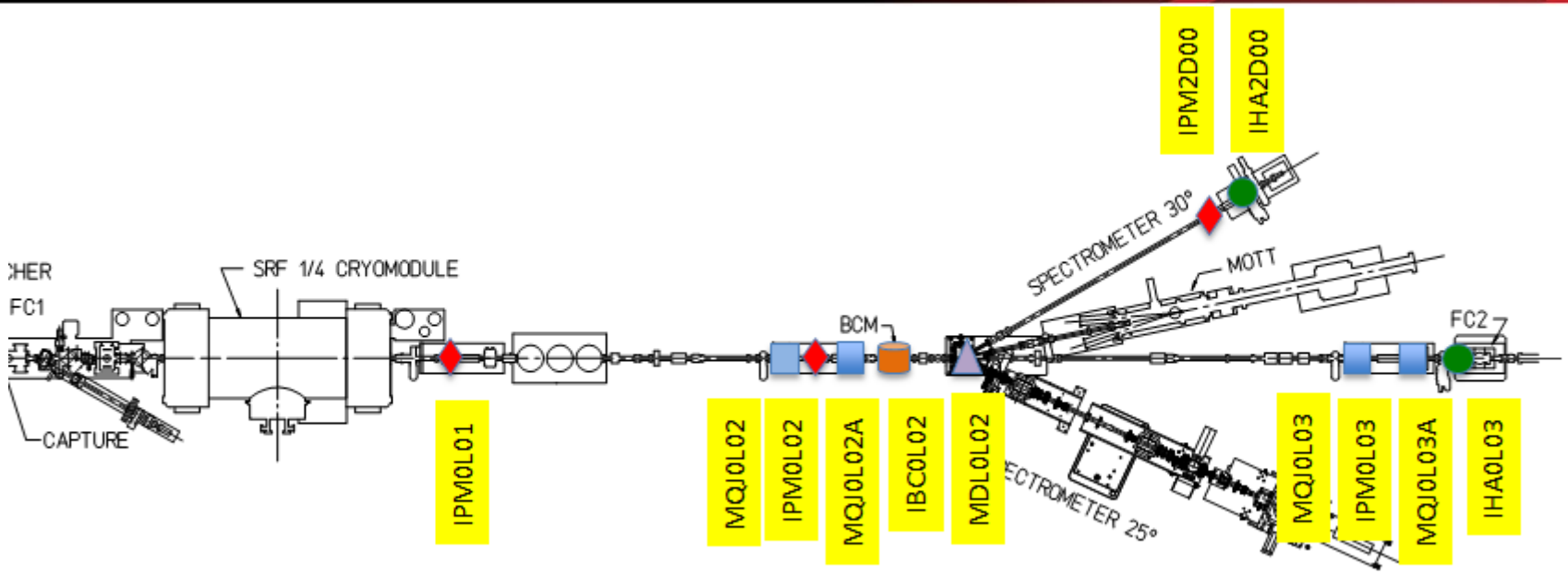
- The cavities, designated as #7 and #8 due to their position with respect to RF couplers in the tunnel, were tested at 4 K to determine stable operating gradients.

- Cavity #7 reached E_{acc} = 9.5 MV/m and cavity #8 reached E_{acc} = 10 MV/m, before being limited by window arcing above E_{acc} = 10.5 MV/m. In both cases the helium liquid level remained stable with the JT valve opened to 70 %, which we considered a heat load limit not to exceed

- Both cavities were simultaneously powered to E_{acc} = 8 MV/m, again with the JT valve open to 70 %

- Assuming a typical $Q_0 = 3 \cdot 10^8$ at 4.3 K, we estimate about 200 Watts were dissipated into the helium bath during 4 K testing

4K tests with the beam



Parameter	Unit	March 23, 2016	June 17, 2016
CHL Condition	K	4K	2K
Cavities	#	0L02-7,8	0L02-7,8
Gradient	MV/m	5.00, 5.32	5.00, 5.32
PSET (Crest)	deg	164.8, 83.2	-168.4, 123.6
Momentum	MeV/c	6.34	6.47
Laser Used	Hall	A	A
Max Intensity (IBC0L02)	µA	80	60
Horizontal Normalized Emittance (MQJ0L02)	mm-mrad	0.38 ± 0.01	0.44 ± 0.01
Horizontal Beta (MQJ0L02)	m	5.21 ± 0.08	9.55 ± 0.12
Horizontal Alpha (MQJ0L02)	rad	-1.01 ± 0.01	-3.03 ± 0.04
Vertical Normalized Emittance (MQJ0L02)	mm-mrad	0.34 ± 0.01	0.54 ± 0.01
Vertical Beta (MQJ0L02)	m	2.53 ± 0.06	15.8 ± 0.1
Vertical Alpha (MQJ0L02)	rad	-0.42 ± 0.01	-4.39 ± 0.02
Horizontal Profile Scan (IHA2D00)	mm	2.35 ± 0.02	1.46 ± 0.02
Momentum Spread (dp/p)	%	0.22%	0.14%
Energy Spread (dE/E)	keV	14	9

Me are happy

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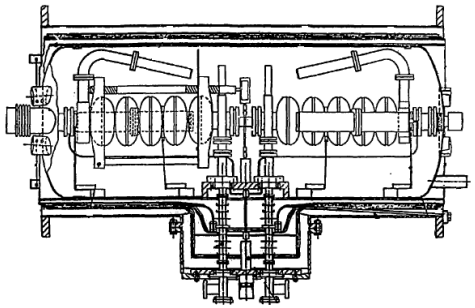
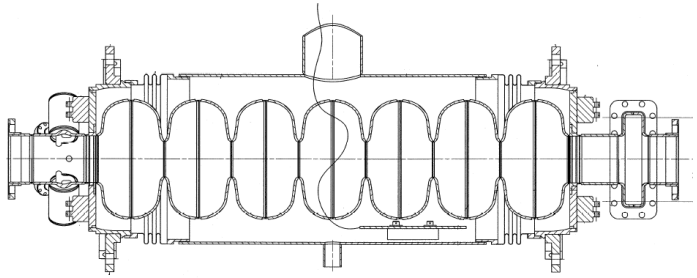
0L03 & 0L04 @ 4K

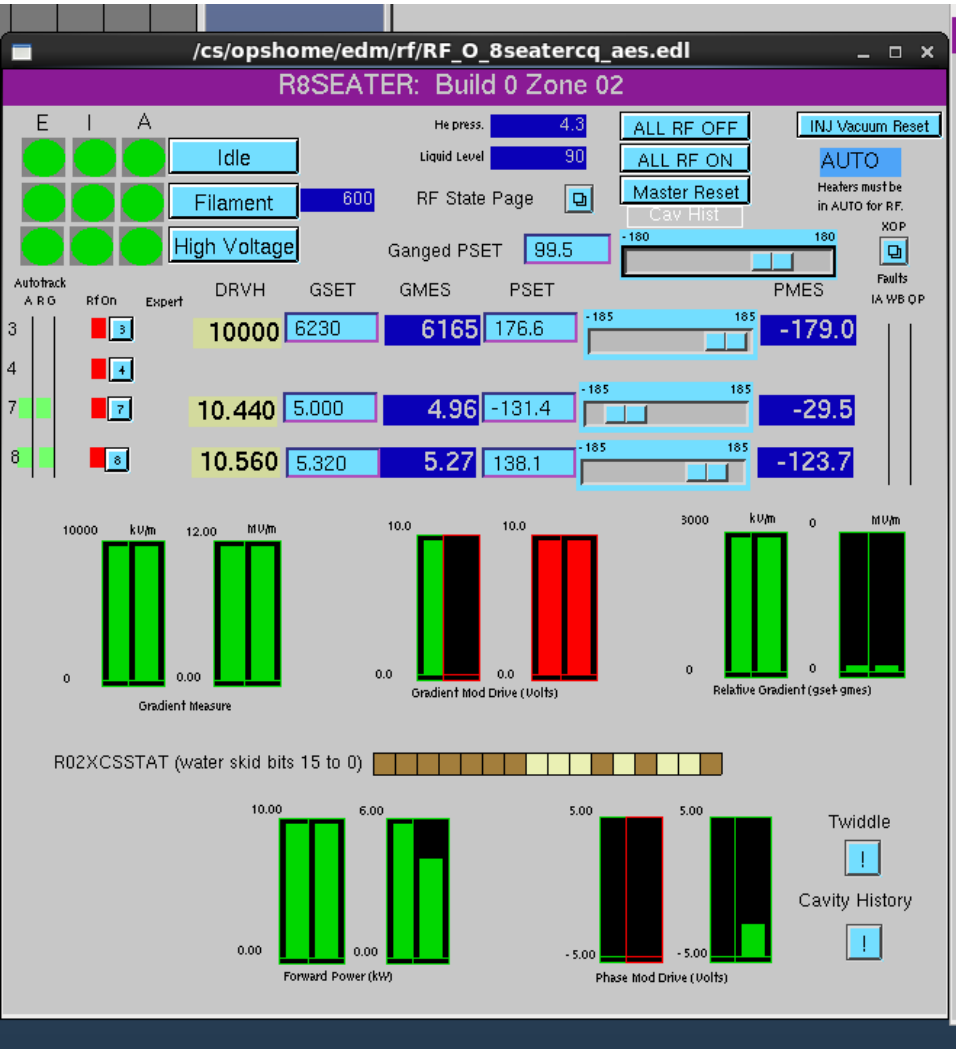
Cavity #	E_{max} [MV/m]	JT @ E_{max}
1	8.7	75%
2	(6.0)	59%
3	9.9	75%
4	8.4	70%
5	3.5	54%
6	3.4	53%
7	10.0	71%
8	6.9	72%

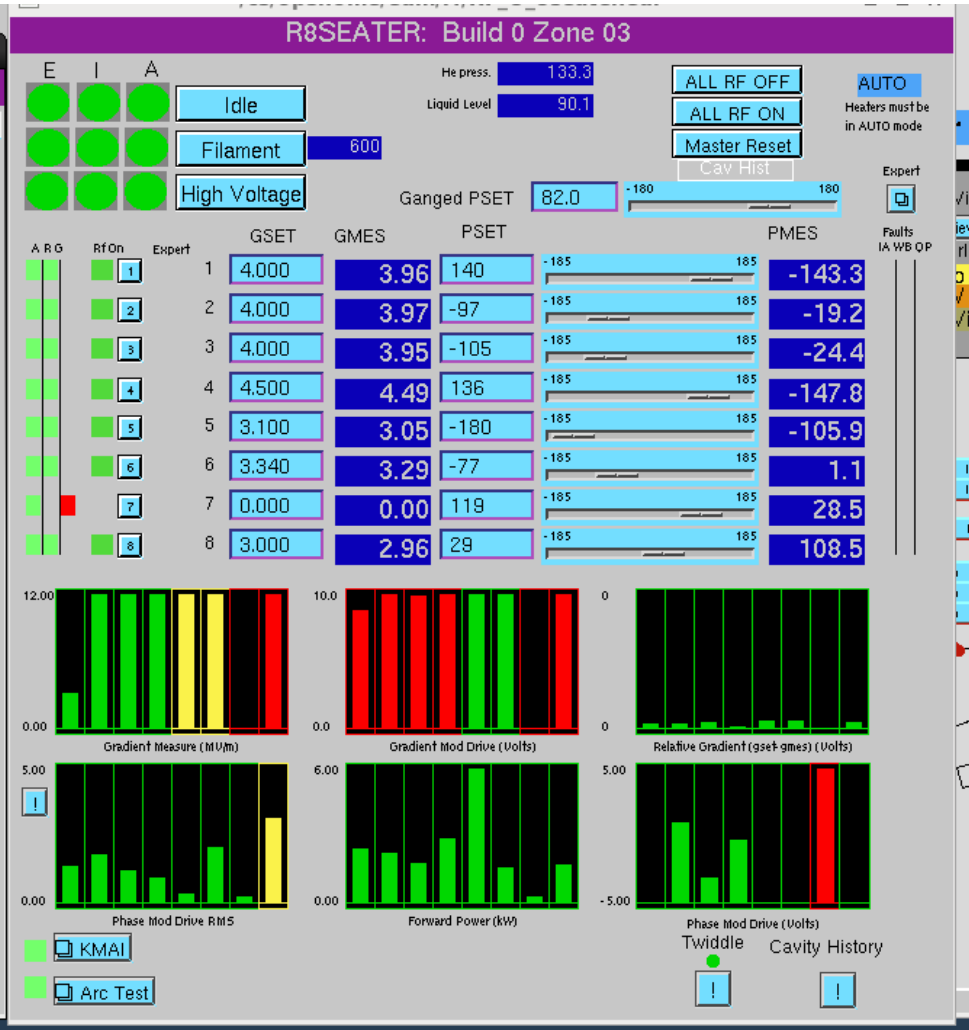


Cavity #	E_{max} [MV/m]	JT @ E_{max}
1	3	85%
2		
3		
4		
5		
6		
7		
8		



Beam run @ 18.5 MeV





Beam quality and cost comparison between 4K and 2K for electron linac operation

- How is the beam quality different between 4K and 2K?
- How are the quality factor and the maximum gradient different?
- How are the microphonic and the cost of RF different?
- How is the cryogenic cost different?
- How does the beam quality change with the current and accelerating voltage at 4K and 2K?
- What can be recommended for 4K operation?
- What energy can be expected from CEBAF at 4K? (CEBAF commissioning prior to 1996 was done at 4K.)

NL 4K run

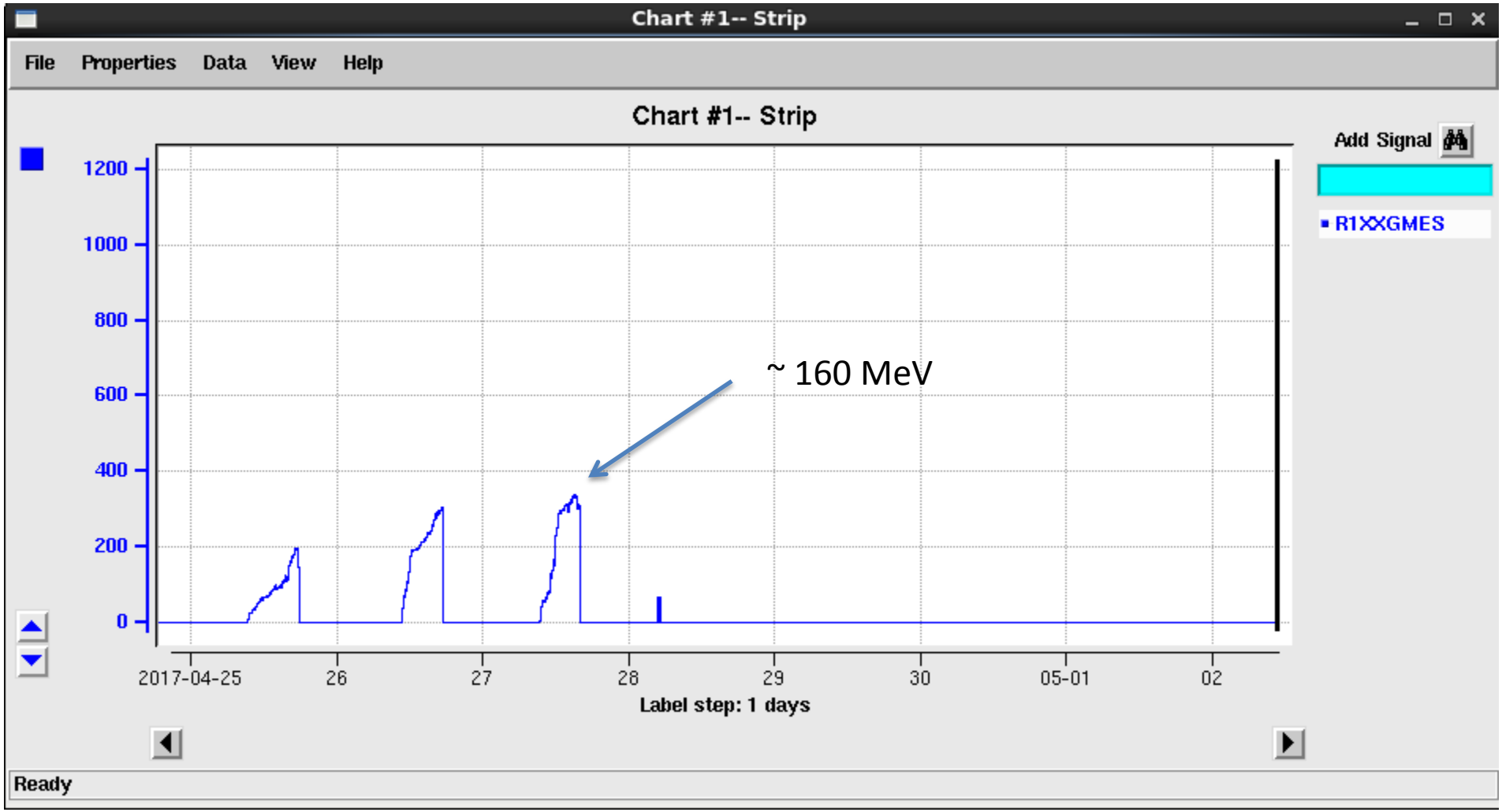
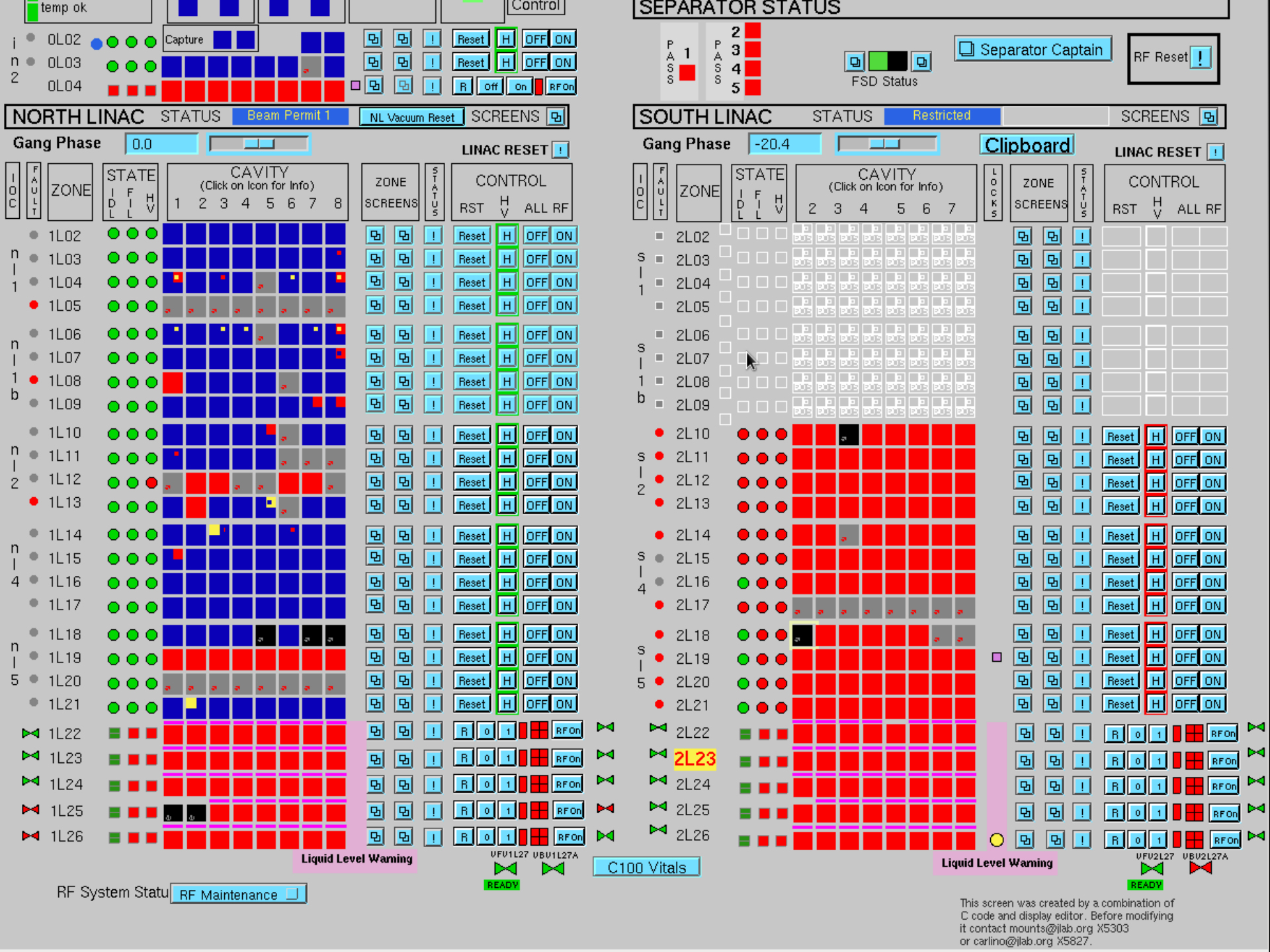


Chart #1-- Strip
File
Properties
Data
View
Help
Chart #1-- Strip
Add Signal
R1XXGMES
1200
1000
800
600
400
200
0
~ 160 MeV
2017-04-25
26
27
28
29
30
05-01
02
Label step: 1 days
Ready


temp ok
Control
SEPARATOR STATUS
Capture
Reset
H
OFF
ON
R
Off
On
RFOn
PASS 1
PASS 2 3 4 5
FSD Status
Separator Captain
RF Reset
NORTH LINAC STATUS
Beam Permit 1
NL Vacuum Reset
SCREENS
Gang Phase
0.0
LINAC RESET
SOUTH LINAC STATUS
Restricted
-20.4
Clipboard
IOC
FAULT
ZONE
STATE
IDL FIL HV
CAVITY
(Click on Icon for Info)
1 2 3 4 5 6 7 8
2 3 4 5 6 7
LOCKS
ZONE SCREENS
STATUS
CONTROL
RST HV ALL RF
1L02
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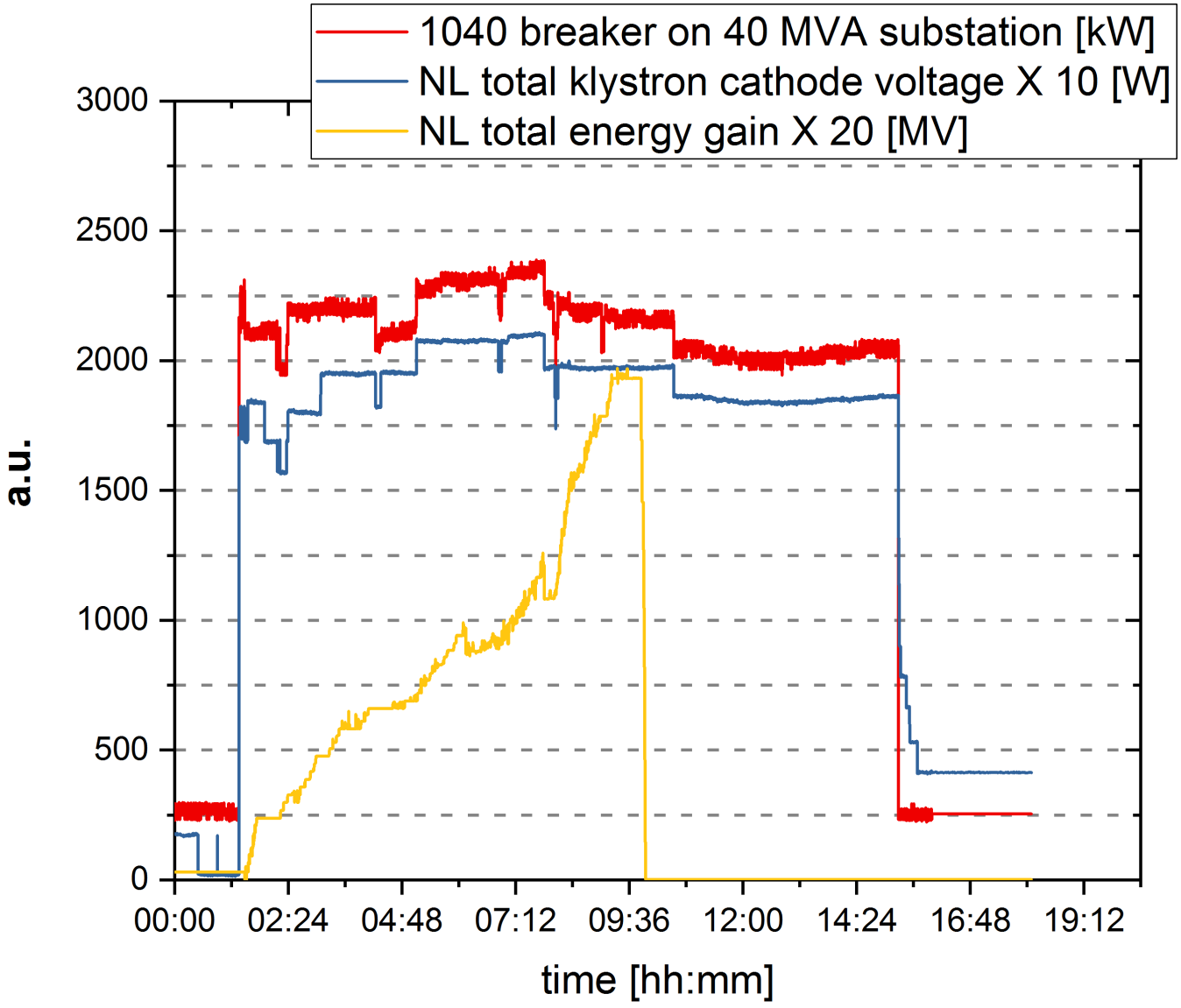
2L21
2L22
2L23
2L24
2L25
2L26
Liquid Level Warning
VFV1L27 VBV1L27A
READY
C100 Vitals
VFV2L27 VBV2L27A
RF System Statu
RF Maintenance
This screen was created by a combination of
C code and display editor. Before modifying
it contact mounts@jlab.org X5303
or carlino@jlab.org X5827.

4K run power consumption

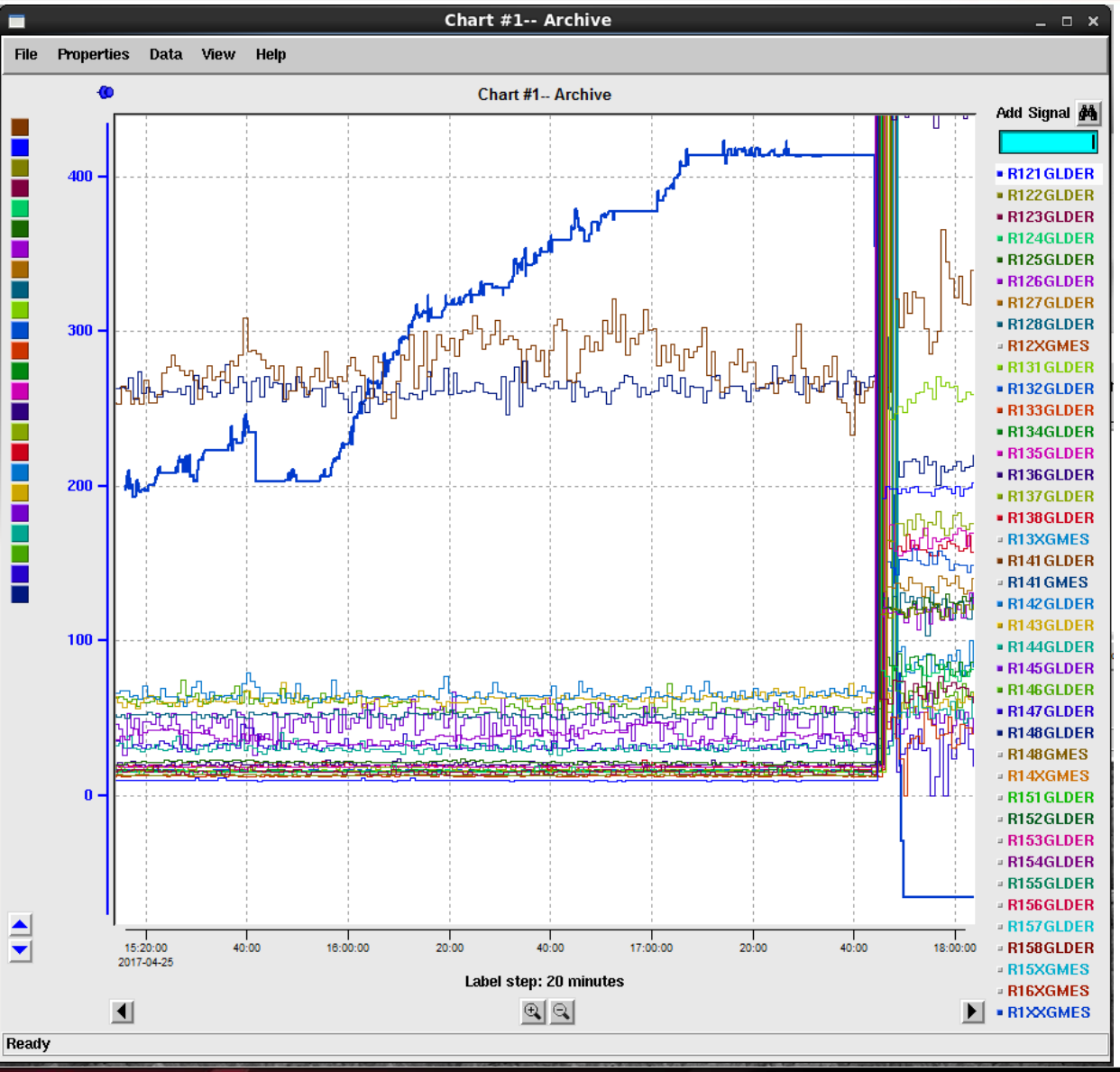


4K run power consumption

- The estimated power load was 2.4 MW at the highest energy gain.

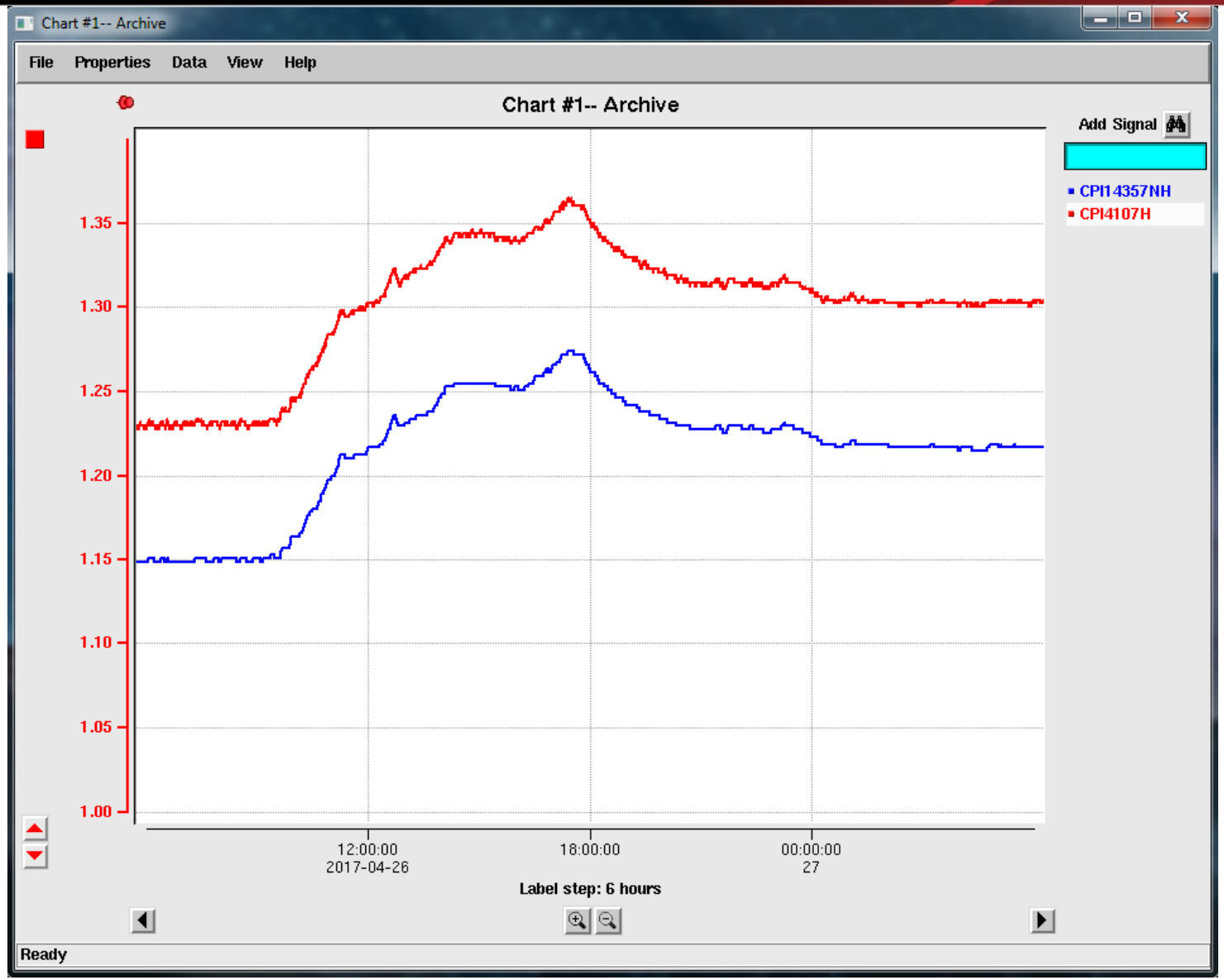
- Most of this consumption was due to HPA. Once the HPA is on, it draws AC power, whether RF field is generated or not in the cavities.

RF perspective



Preliminary look at gradient and phase loop detector errors suggests that both the gradients and phases were within the specifications at the highest attained gradients.

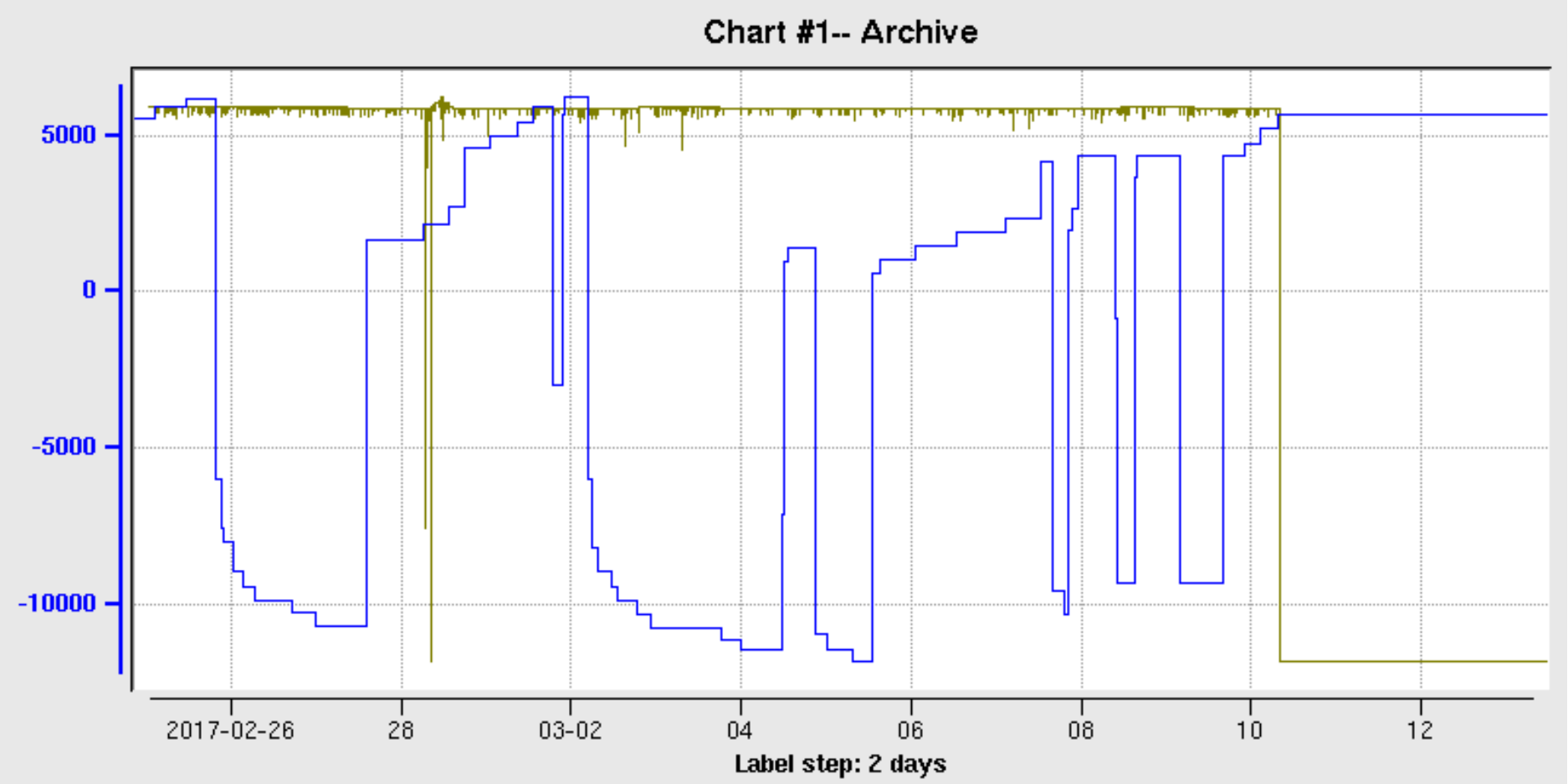
Cryogenic perspective



Cryogenic perspective

- There was approximately 1.3 kW of additional heat in the NL.
- During the test, CHL1 behaved normally. The C2 & C3 1st stage and C4 & C5 2nd stage compressors were running.
- The maximum refrigeration capacity of CHL1 is expected to be similar to that of CHL2, which is 11.6 kW. However, it is not clear whether the plant can be operated in a stable manner at such load.

Operational perspective



Operational perspective

- After a trip cavities detuned and required open loop (manual) tuning more often than they do at 2K;
- It was difficult to regulate below 3MeV, some cavities would only stabilize at 4-4.5MeV;
- The sensitivity to helium pressure was obvious. At higher linac energy gain and, hence, higher helium pressure in the linac, RF was detuned from the day before and almost all cryomodules required to be manually retuned.
- Overall, if one wants to run at 4K, it would require a lot of effort and attention to each trip and therefore more downtime, unless the recovery scripts are adapted.

Beam quality and cost comparison between 4K and 2K for electron linac operation

- How is the beam quality different between 4K and 2K?
  Unaffected to the extent tested.
- How are the quality factor and the maximum gradient different?
  Quality factor is lower by ~ 10, maximum gradient similar
- How are the microphonic and the cost of RF different?
  Unaffected to the extent tested.
- How is the cryogenic cost different?
  ~ 0.5 MW for 150 MeV. Need to be tested with CHL2.
- How does the beam quality change with the current and accelerating voltage at 4K and 2K? not tested

- What can be recommended for 4K operation?
  Patience
- What energy can be expected from CEBAF at 4K?
  100 MeV, feasible; 200 MeV, probable; >200 MeV, pulsed.

Acknowledgements

N. Hasan, C. Mounts, W. Oren, A. Solopova, M. Wright, M. Drury, J. Grames, R. Kazimi, M. Poelker, J. Preble, R. Suleiman, Y. Wang, M. Wright, A. Hutton, H. Areti et al.