BSList 110120: Test beam power limits Executed 10/23/2023

report by Jay Benesch 11/1/2023

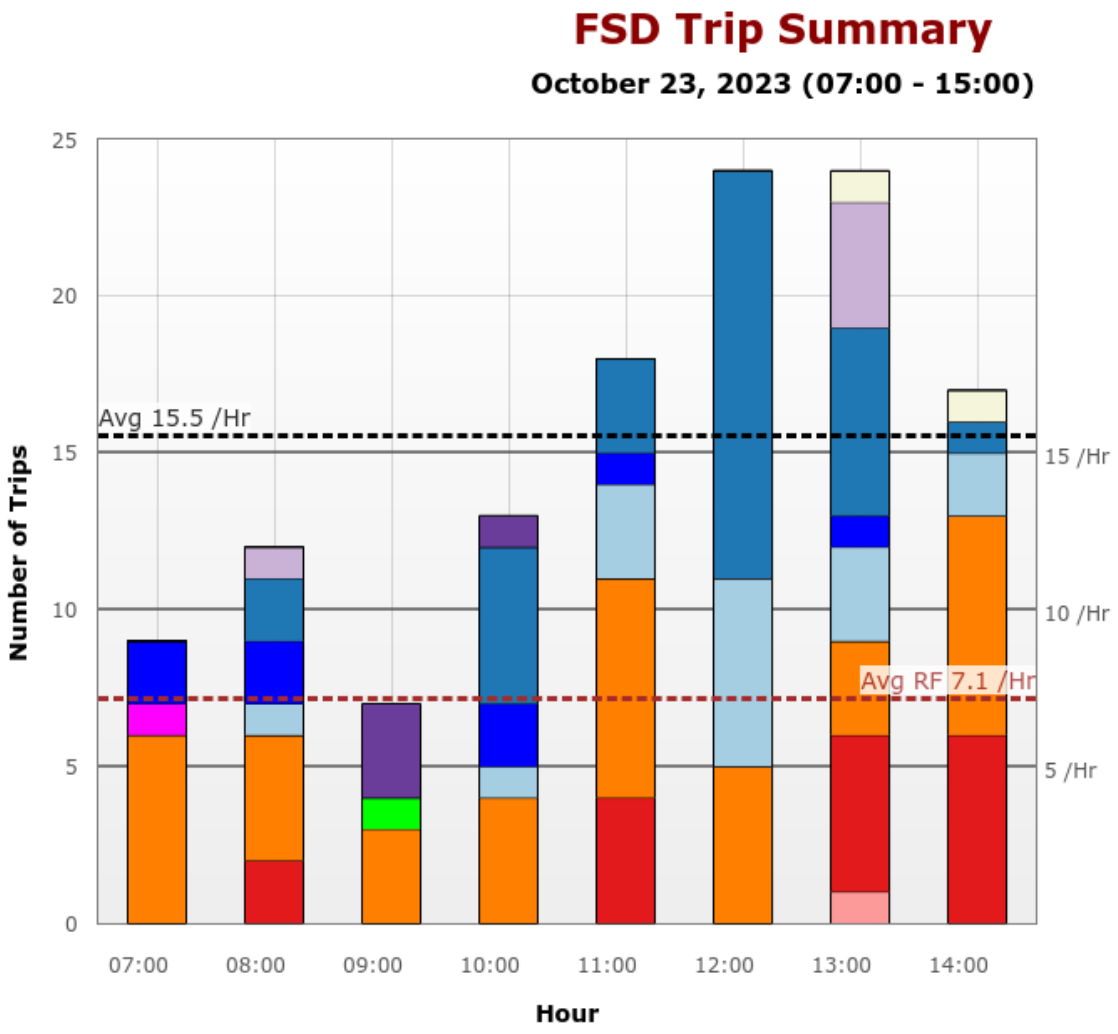
Purpose

The CY25 Physics program requires 1100 kW at 1090 MeV/linac. This is the first in a series of tests to find weak points in CEBAF so they may be remedied in 2024.

Planned sequence

- Re-lem to gain headroom for gradient reduction. This proved unnecessary (hindsight) and took one hour. Altered ~120 GSETs.
- Starting currents: 45 μA to A, 30 μA to C
- Increase current to C in 3 μA steps every 30-45 minutes, adjusting gradients as necessary
- RF and SRF personnel provided support to Operations
- Halls A/B/C took data parasitically during the test

High power test shift (slide by K. Price)

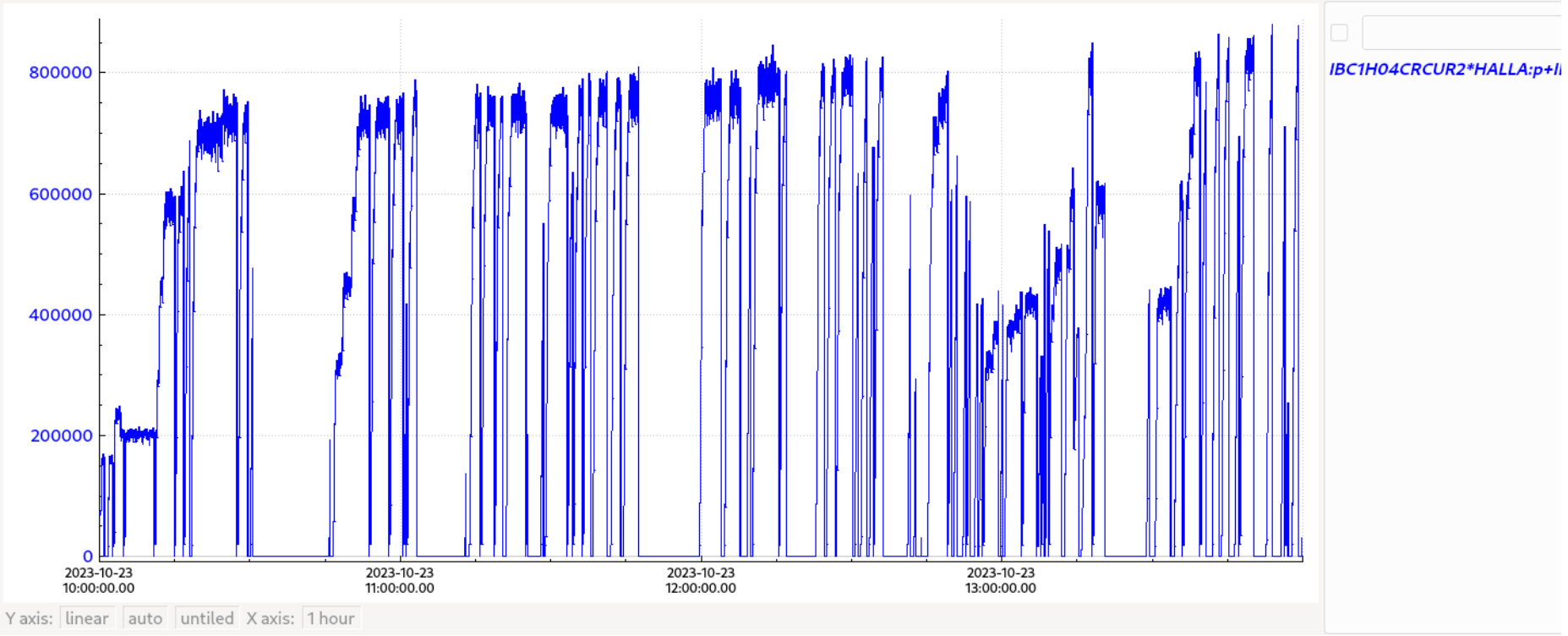


	Trips	Lost Hrs	Mins /Trip
Dump (Insert.)	4	0.0	0.1
Hall	2	0.1	2.6
MPS (BCM/BLA)	5	0.0	0.3
MPS (BLM)	30	0.2	0.3
MPS (IC)	8	0.0	0.3
MPS (Multi/Other)	16	0.1	0.3
Multiple/Other	1	0.0	0.3
Vacuum	1	0.0	0.3
RF (C25/50)	39	0.2	0.4
RF (C75/100)	17	0.3	1.0
RF (Multi/Other)	1	0.0	1.0
Total:	**124**	**0.9**	**0.5**

- Max Trip Duration: 5 Minutes
- Rate from Program (8.0 hrs)
- SAD Trips excluded

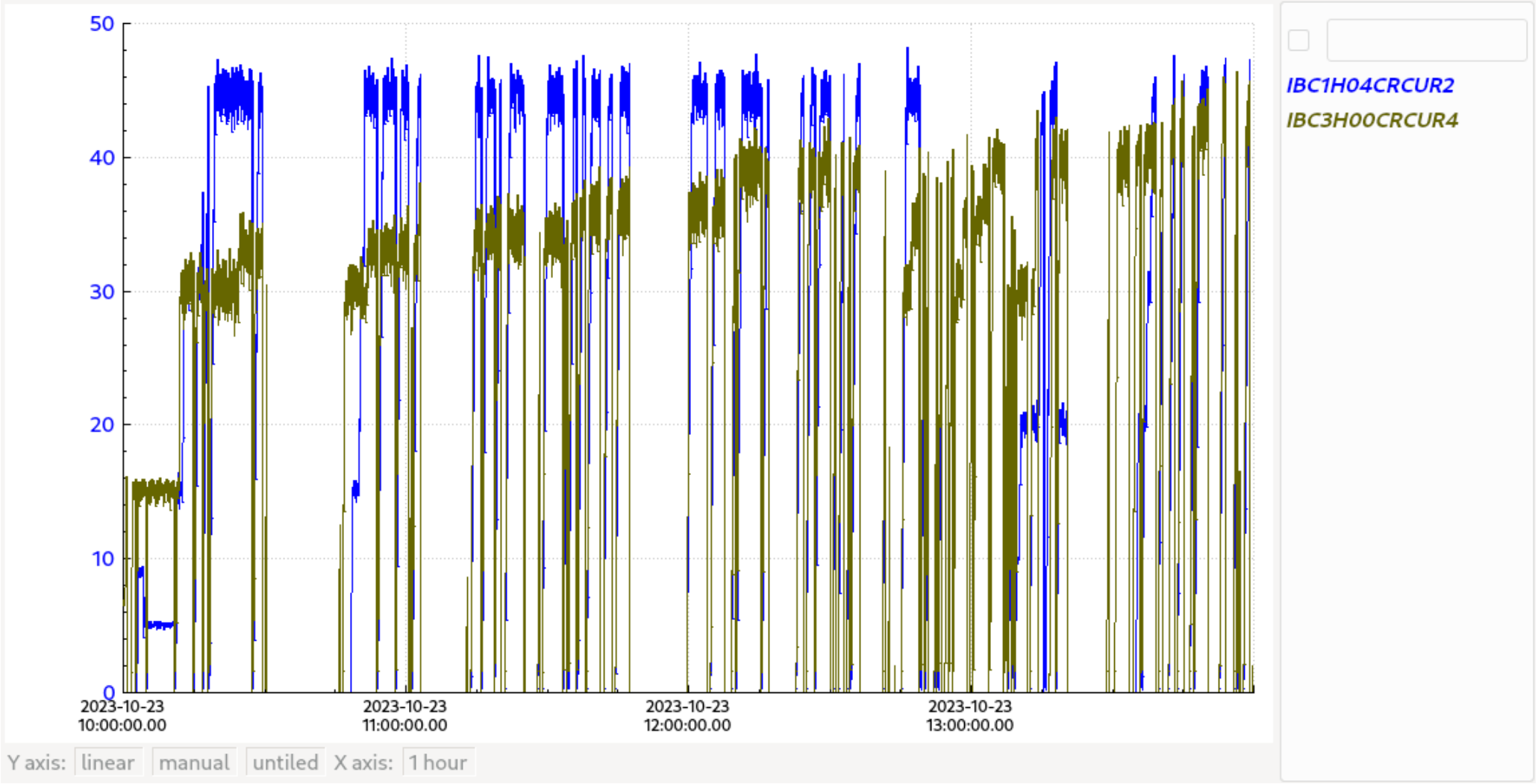
BLM	no. trips
ILM0L02	12
ILM1C10A	3
ILM1C12C	1
ILM3C00	4
ILM3C03	1
ILM4D00	4
ILM7S01	17
ILM8E02	18

Beam Power vs Time



Hall A current * Hall A Momentum + Hall C current * Hall C Momentum (Watts) Broad band at top of trace is due to current variations which are always present.

Current vs Time



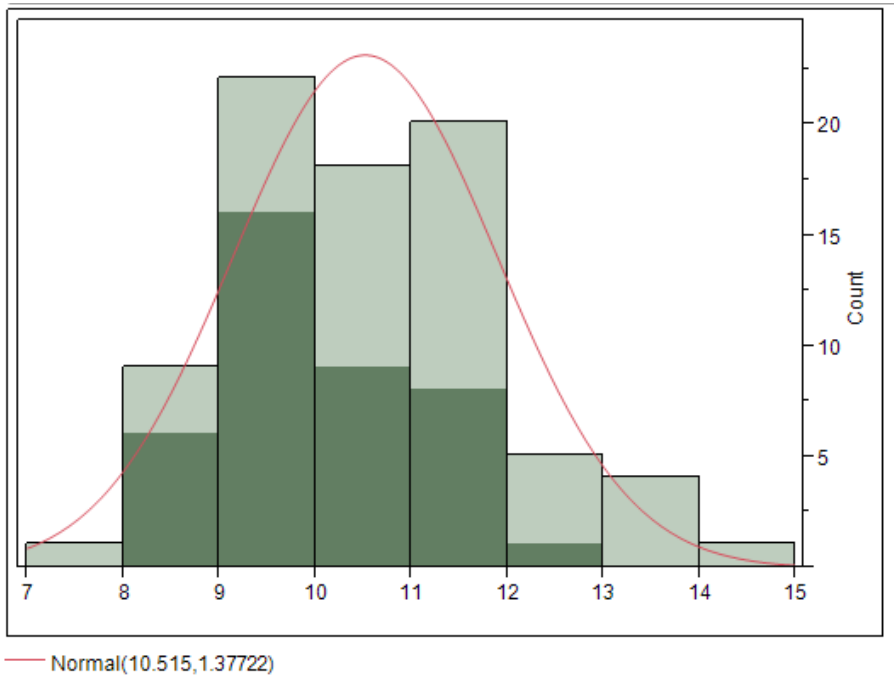
Fourteen cavities adjusted

- Two in 1L03 turned off due to microphonics from scroll pump, one recovered after SRF work to anchor hose to floor 10/25.
- Three C25 cavities had GSET reduced manually due to beam loading
  - 1L06-2, 2L06-6, 2L21-5
- Three C100 cavities had GSET reduced manually due to beam loading
  - 1L24-5, 1L25-7, 2L24-4
- Six other cavities were tuned (TDOFF changed)
  - 1L06-2, 1L11-8, 2L7-2, 2L12-3, 2L21-2 and 2L21-5
- Longest period without a trip about three minutes.
- Forty RF trips during the four hour test
- Three NL changes backed out to restore headroom, three SL changes left in.

10/29 attempt to increase Hall C current

1306-1400: two BLM/IC, eleven C25/C50 and five C75/C100 faults

Klystron power limits



Moments

Mean	10.514986
Std Dev	1.3772167
Std Err Mean	0.1539775
Upper 95% Mean	10.82147
Lower 95% Mean	10.208501
N	80

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	10.514986	10.208501	10.82147
Dispersion	σ	1.3772167	1.1919161	1.6312754

-2log(Likelihood) = 277.24049608541

Goodness-of-Fit Test

Shapiro-Wilk W Test

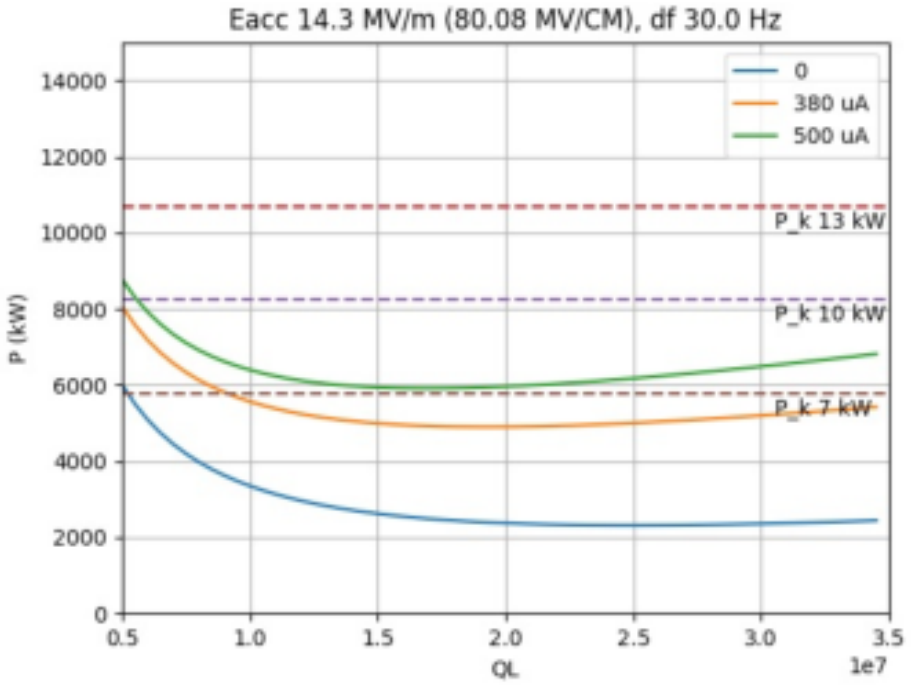
W	Prob<W
0.979148	0.2160

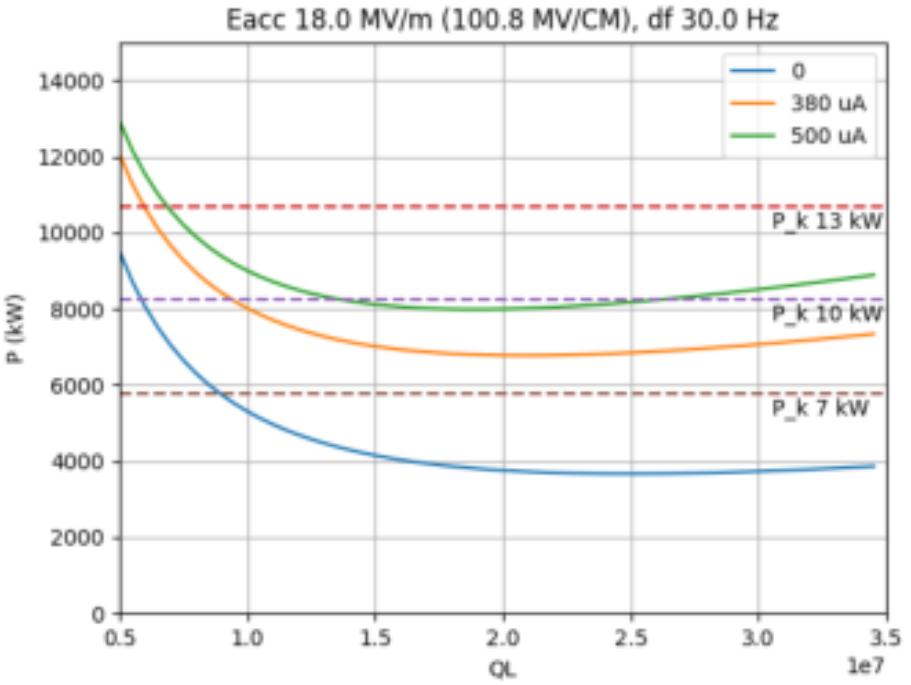
Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

NL Klystrons dark.

I was surprised the distribution is normal.
NL klystron mean 10 kW and SL 11 kW, both also normal.
See last slide for power of each klystron.

E. Pozdeyev: linac current, QL, klystron power





59 of C100s have QL ~1.5E7 using stub tuners, 21 have 2-3.5E7
30 Hz is representative of measured microphonics (but not max)
More than 10 kW is required of all tubes to use C100 cryomodules at specification (right figure)

My Conclusions

- CEBAF needs significant improvement to meet CY25 program requirements.
- Few of the 13 kW klystrons (C100) still meet specification. Out-coupler on one tube was found damaged; this may be a systematic problem.
- Additional RF/SRF headroom would help as seen in 10/29 slide.
- Current variation is present at the exit of the injector. Harmonics of 60 Hz are seen on Beam Loss Accounting system FFTs.
- Steering to reduce BLM trips prior to the test was assisted by the new IIX ion chambers. Little steering was done during the test; RF/SRF work was the emphasis. The next set of IIX ion chambers should be placed in the East Spreader given ILM7S01 trips.
- Beam loss monitor 1992 calibration procedure is not fit for purpose and should be revisited. See TNs 22-042, 23-002, 23-051 and 23-070.

Klystron power

Cavity	kW	Cavity	kW	Cavity	kW	Cavity	kW
R1M1	11.3	R1O5	8.4	R2M1	11.2	R2O5	11.2
R1M2	11.7	R1O6	8.9	R2M2	10.4	R2O6	11.7
R1M3	9.5	R1O7	9.5	R2M3	11.2	R2O7	12.6
R1M4	9.4	R1O8	9.9	R2M4	10.3	R2O8	10.2
R1M5	9.3	R1P1	9.3	R2M5	9.8	R2P1	14.2
R1M6	10.9	R1P2	8.9	R2M6	13.1	R2P2	11.7
R1M7	11.3	R1P3	10.8	R2M7	12.3	R2P3	10.0
R1M8	8.2	R1P4	8.2	R2M8	12.5	R2P4	9.9
R1N1	9.1	R1P5	9.1	R2N1	11.5	R2P5	10.1
R1N2	10.6	R1P6	9.6	R2N2	13.2	R2P6	8.8
R1N3	9.4	R1P7	9.1	R2N3	11.0	R2P7	13.7
R1N4	9.1	R1P8	10.3	R2N4	11.8	R2P8	11.4
R1N5	9.6	R1Q1	10.1	R2N5	11.0	R2Q1	11.1
R1N6	9.3	R1Q2	11.1	R2N6	10.9	R2Q2	13.5
R1N7	10.9	R1Q3	11.1	R2N7	12.0	R2Q3	10.0
R1N8	8.4	R1Q4	10.4	R2N8	9.5	R2Q4	12.3
R1O1	11.5	R1Q5	10.4	R2O1	9.7	R2Q5	10.0
R1O2	11.7	R1Q6	9.2	R2O2	11.1	R2Q6	11.2
R1O3	9.6	R1Q7	12.6	R2O3	10.6	R2Q7	7.9
R1O4	11.0	R1Q8	10.5	R2O4	8.9	R2Q8	8.6