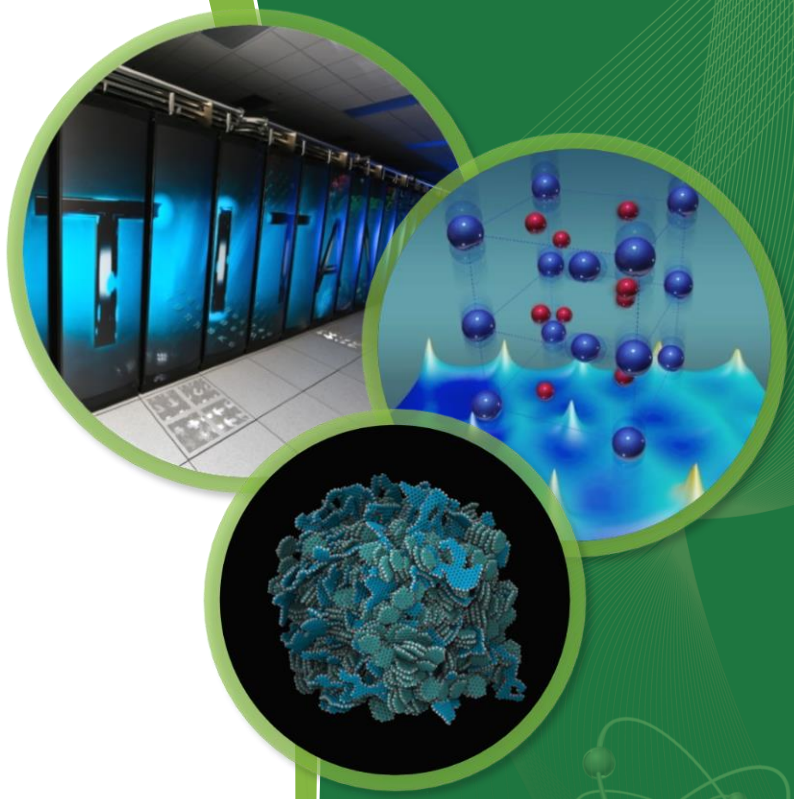
Machine Protection and Operation

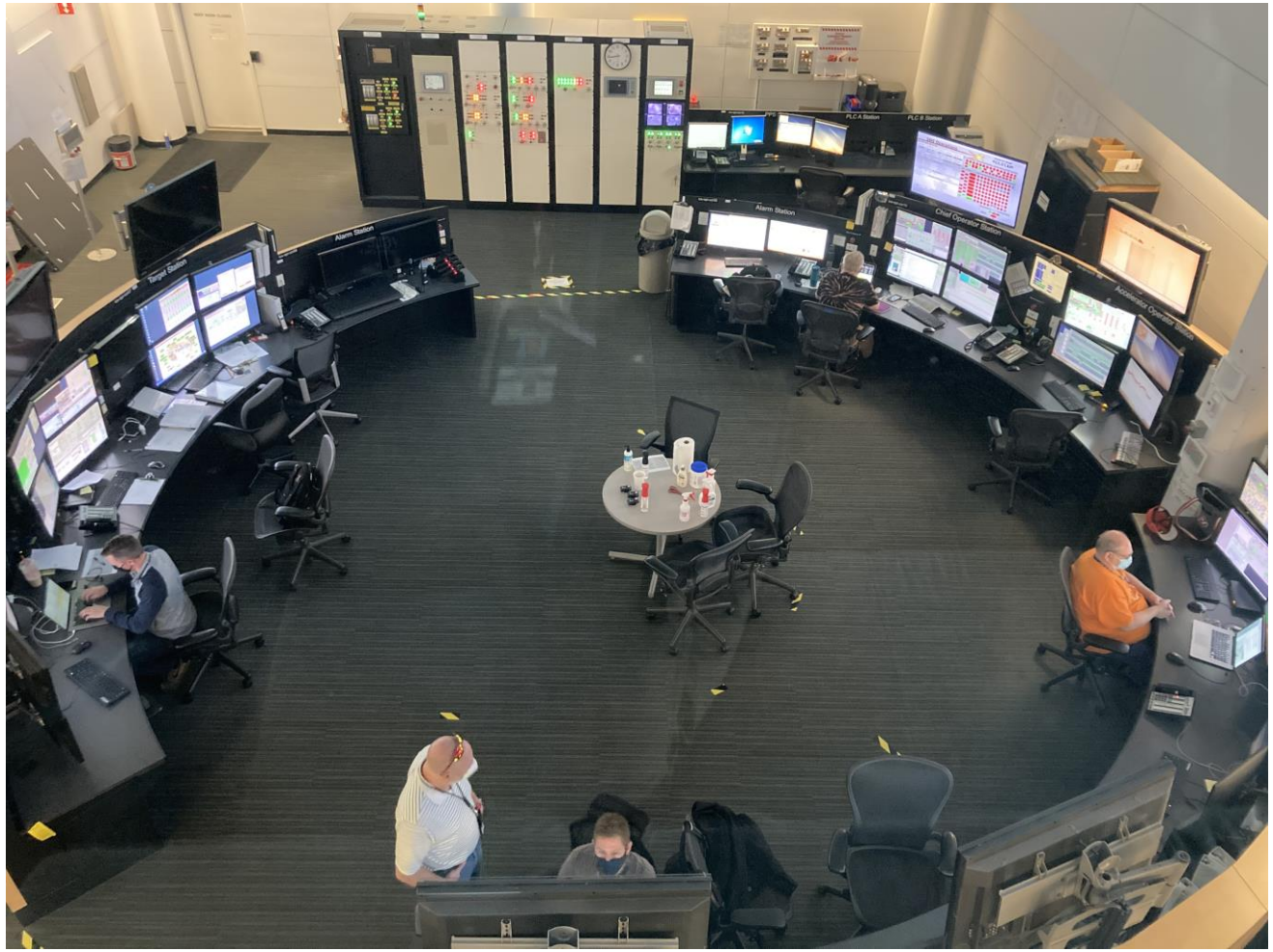
Charles Peters

USPAS, February 2, 2023



Main Roles for Operators

- Keep people safe
- Turn on and check out equipment
- Tune up the beam and make sure we stay below safety limits
- Keep the beam on



SNS Central Control Room

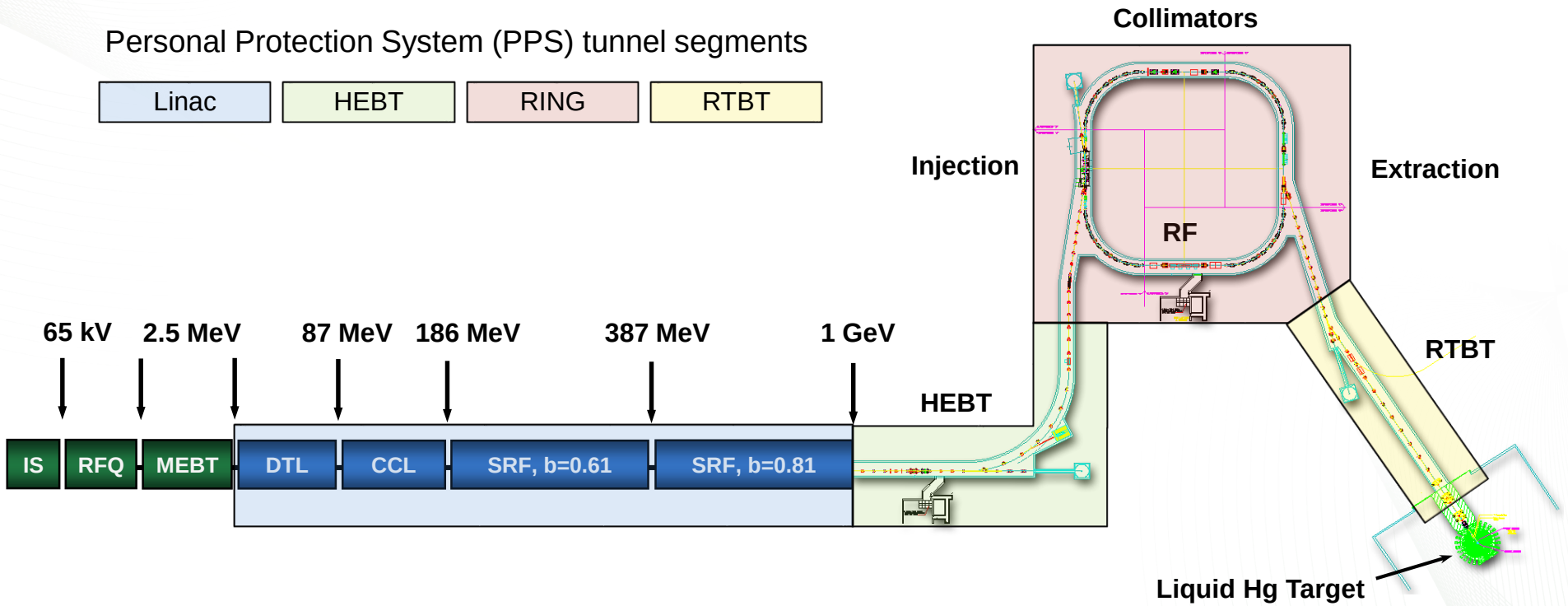
Operator Life

- 12 hour shifts, 5 week rotation, 2 weeks of days, 2 weeks of nights, 1 normal work week for training
- Someone is always in the control room (nights, weekends, holidays)
- Operators must know about everything
  - Safety, emergency, and operating procedures
  - Technical systems
    - Ion source, klystrons, cavities, modulators, magnet power supplies, cooling (pumps, valves, gauges), vacuum (pumps, valves, gauges), timing, alarms, software, etc.

Priority #1 - Safety

- Make sure no one will be harmed by turning on the RF, magnets, or beam
- Operations personnel work with the Personnel Protection System (PPS) to clear the tunnel of workers
  - Operators control physical keys to prevent RF or beam equipment from turning on while people could be in the tunnels

SNS Personnel Protection System (PPS) Layout

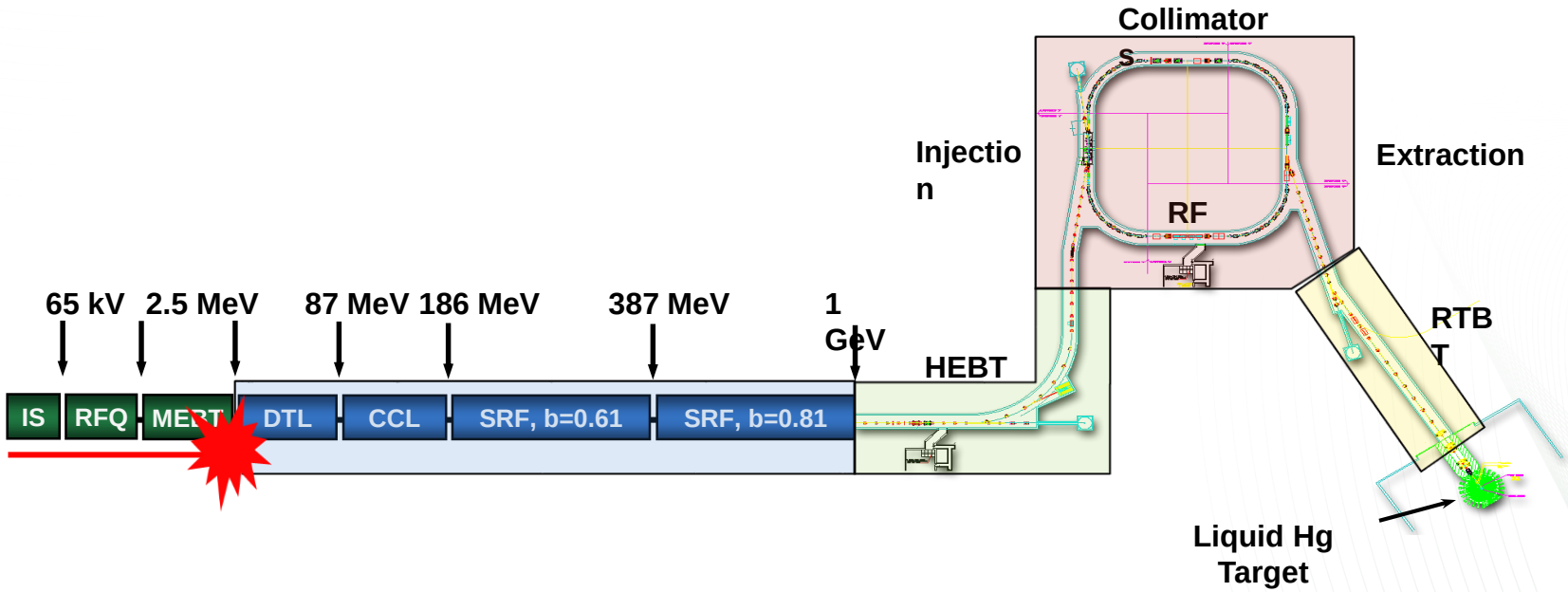


PPS Access Modes

- Restricted Access allows badge only access without Central Control Room (CCR) interaction. Tunnel must be swept for personnel after access.
- Controlled Access allows access but requires taking a key along with badge access and CCR interaction. Tunnel does not need to be swept for personnel after access.
- Power Permit does not allow access. Hazardous equipment can be energized but beam acceleration is disabled (ion source high voltage, RFQ, MEBT, DTL 1 and 2 cavities RF are disabled)
- Beam Permit does not allow access. Beam enabled.

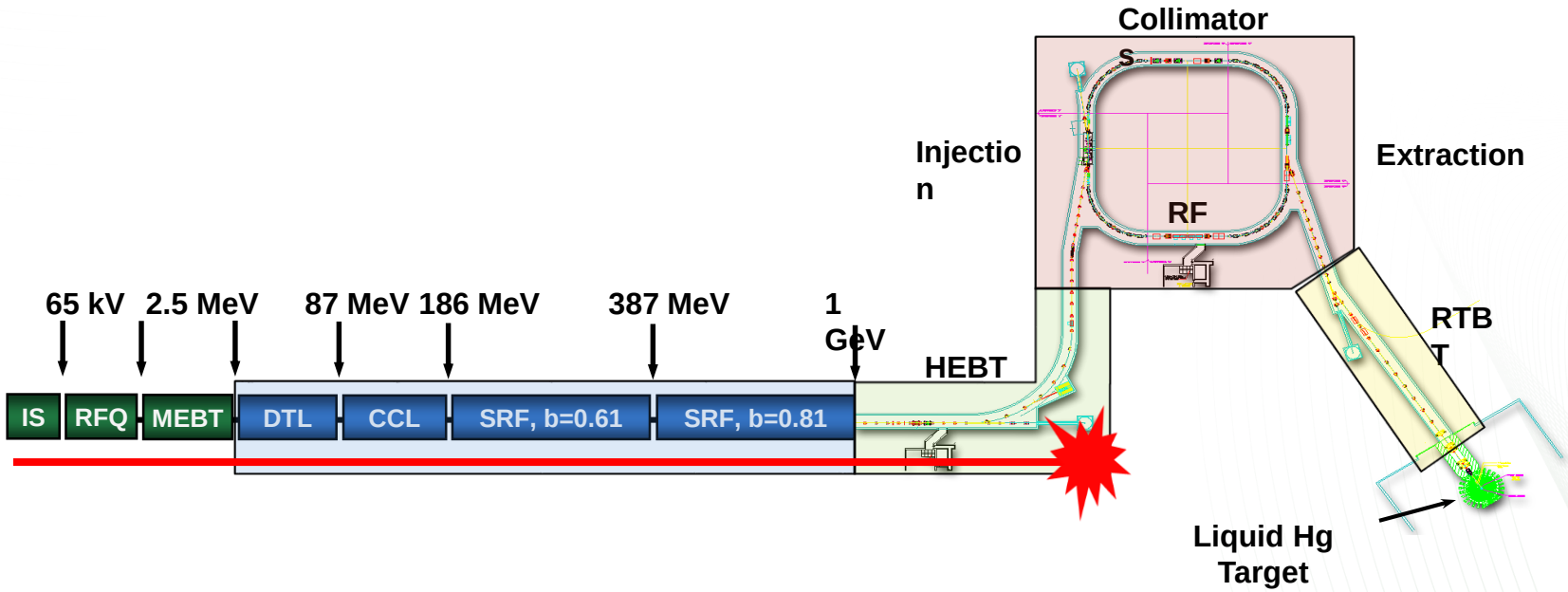
PPS Allowed Beam Modes

- Front End Only
  - Beam to MEBT beamstop, all tunnels may be accessed
    - Allows us to run the ion source and RFQ
    - Is actually only about 5 meters of distance



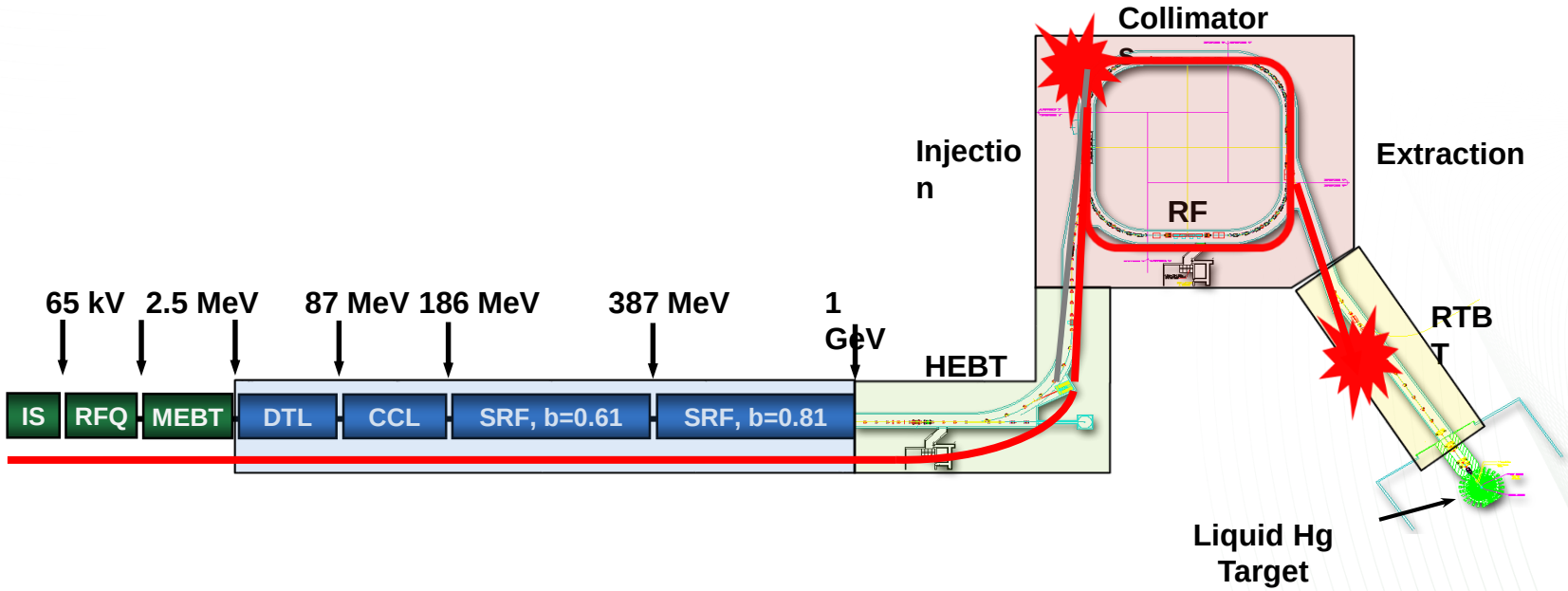
PPS Allowed Beam Modes

- Linac dump
  - No access to Linac and HEBT tunnels, Ring and RTBT may be accessed
    - Allows us to run linac RF and magnets, check beam parameters through linac



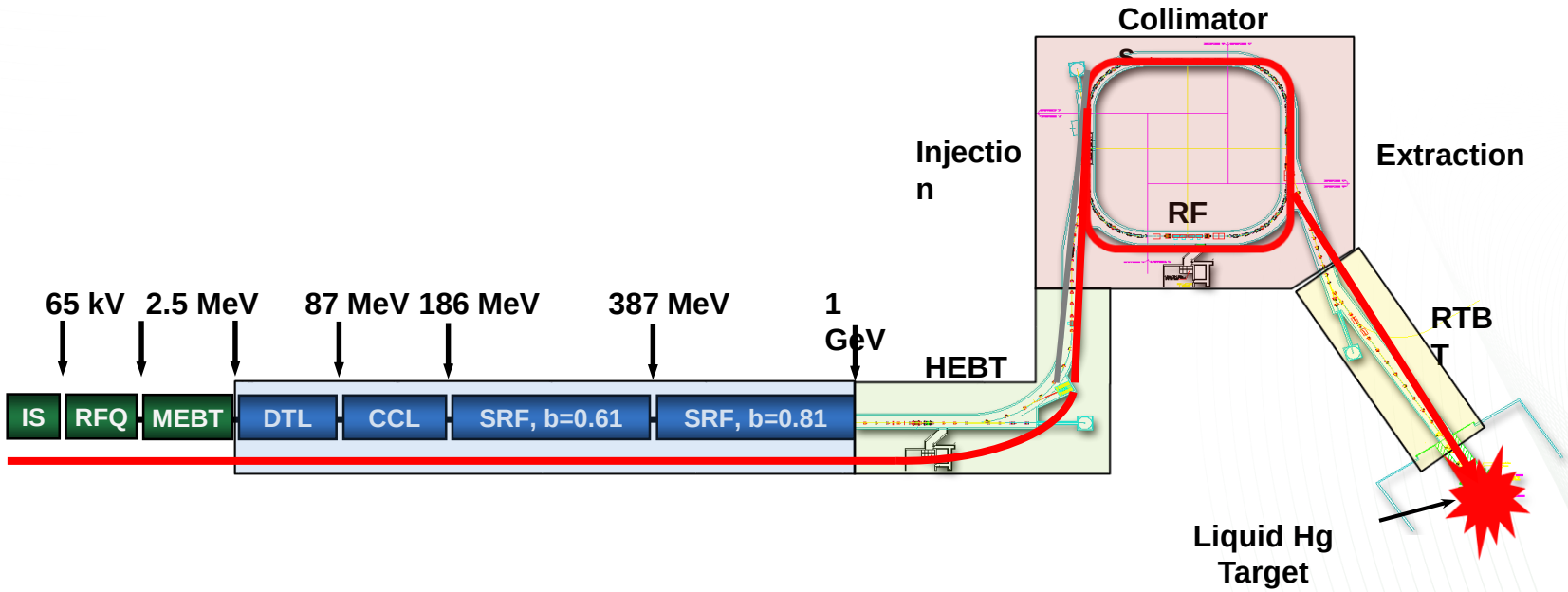
PPS Allowed Beam Modes

- Injection or Extraction dump
  - No access to accelerator tunnels, target must be inserted for extraction dump
    - Allows us to run ring RF and magnets, check beam parameters through ring



PPS Allowed Beam Modes

- Target
  - Make neutrons!



The SNS Control Room

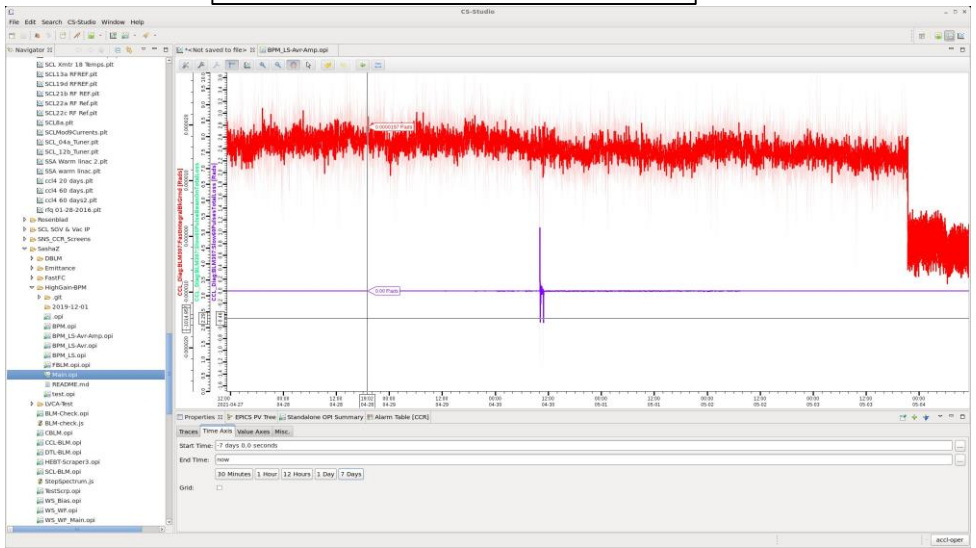
- First all digital control room for an accelerator
- ~ 500000 signals sent over private ethernet
- Able to control everything we need from one location

Equipment Control

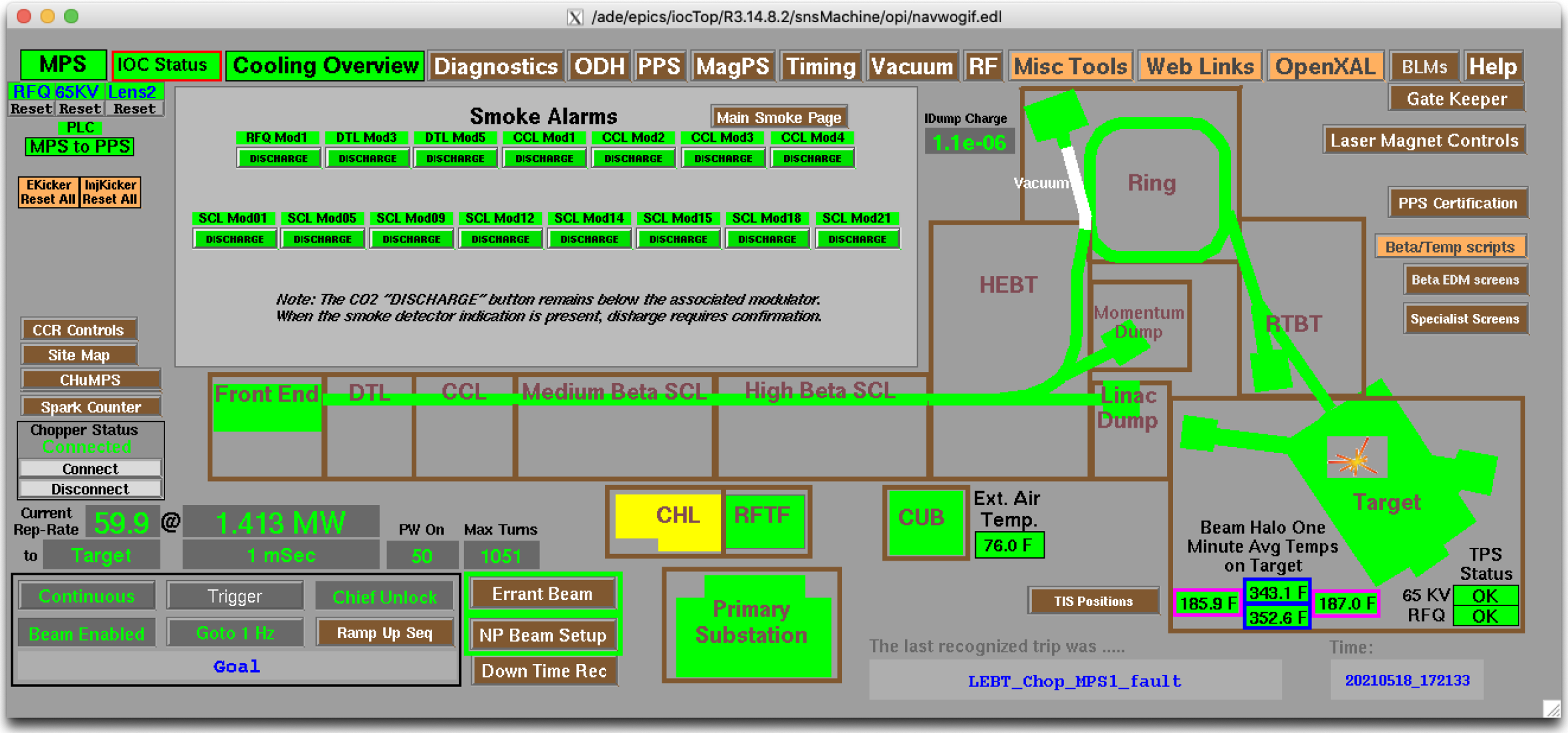
- ≈4000 screens to control equipment
  - Our magic bullets for turning things on
    - SCORE (Save, Compare, Restore), which saves the values of ~4000 variables. We can restore known good settings to all critical equipment
  - Start-up Checklists – 28 pages of system checks
- Control System Studio for looking at data trends and alarming
  - ≈90000 variables are stored in an Oracle database to be able to view their history
  - Useful for any variables not stored in SCORE
  - 12 GB/day of data.

Screen for Controlling Linac Equipment

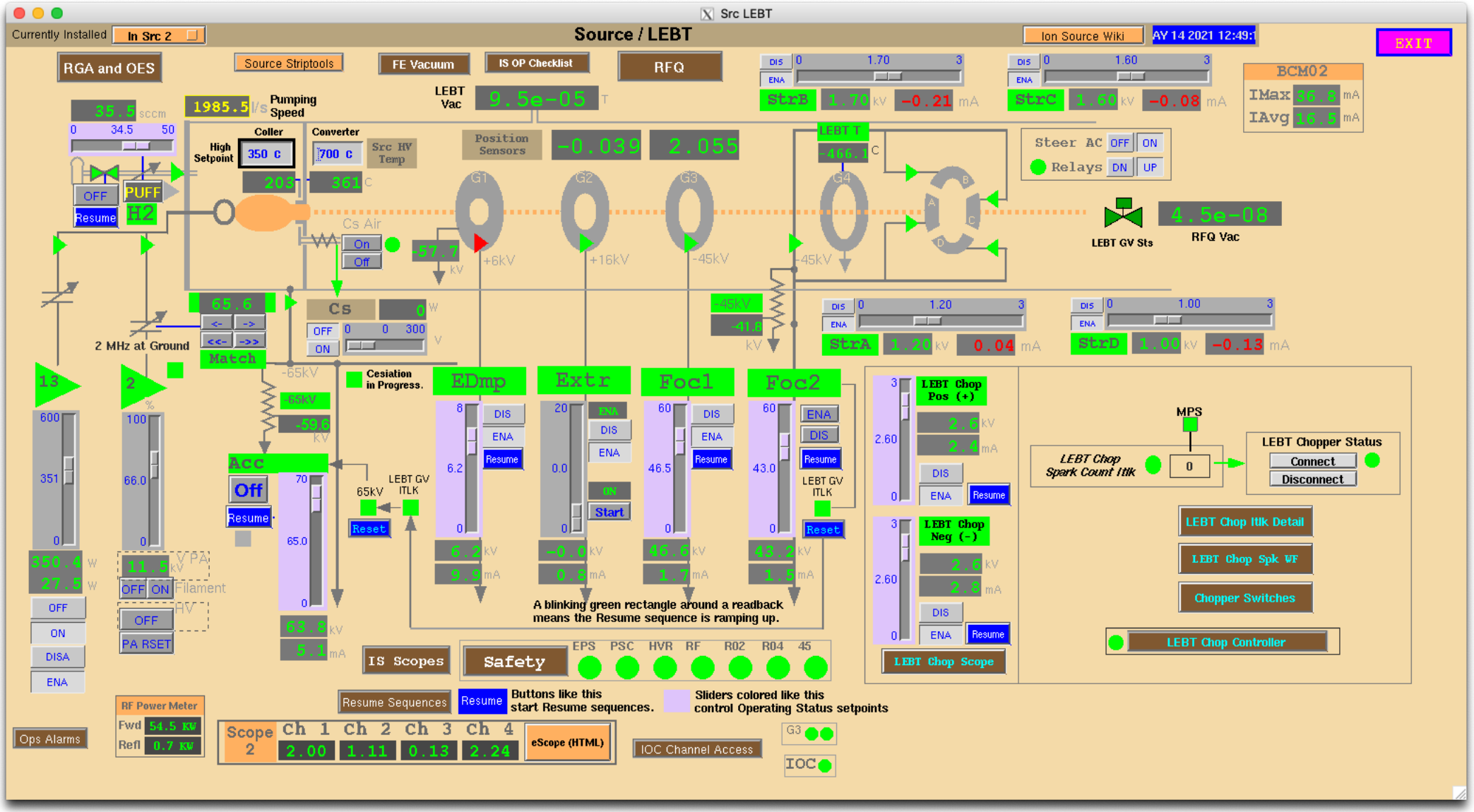
Archived data trends



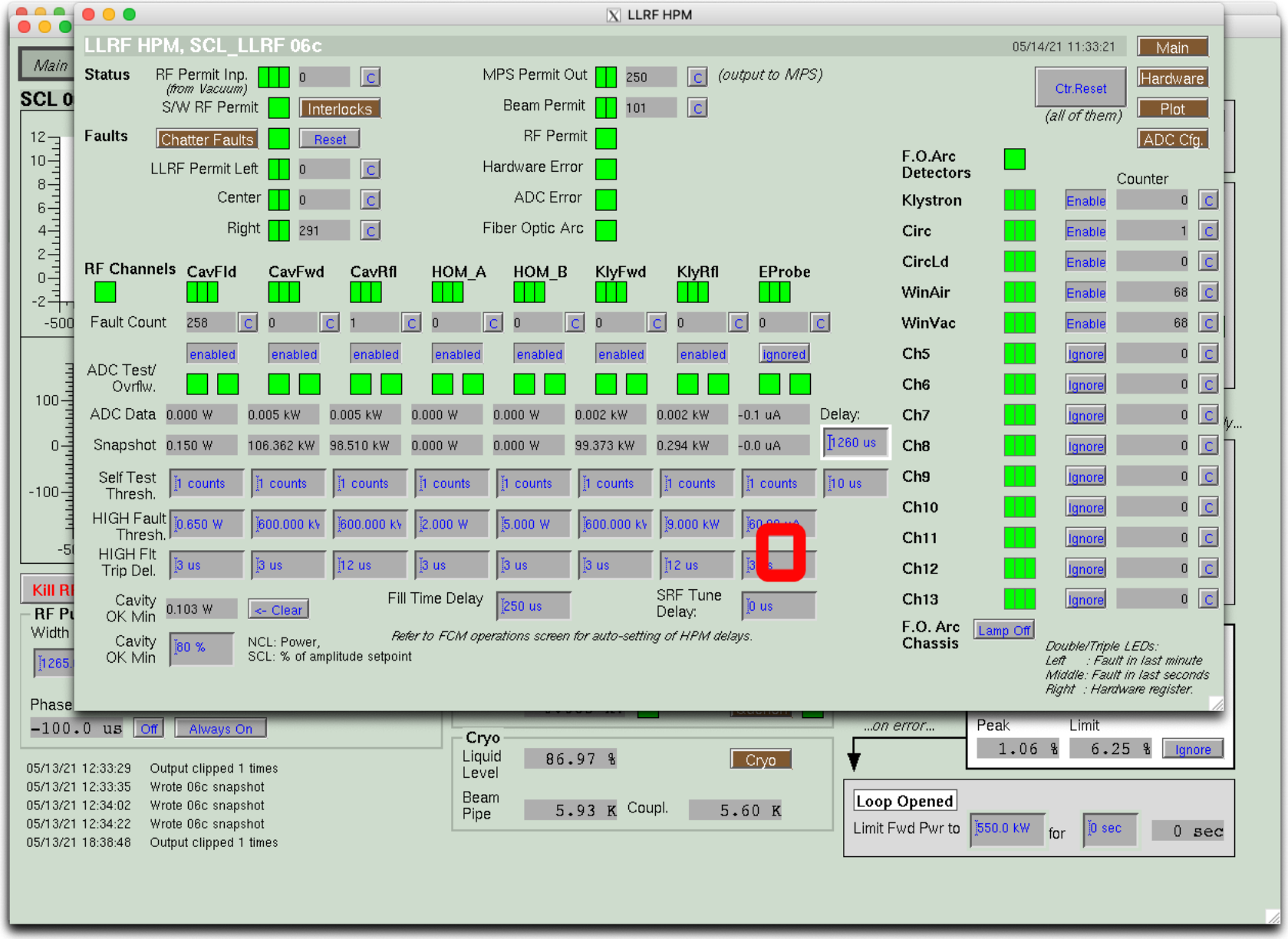
Screens - Overview



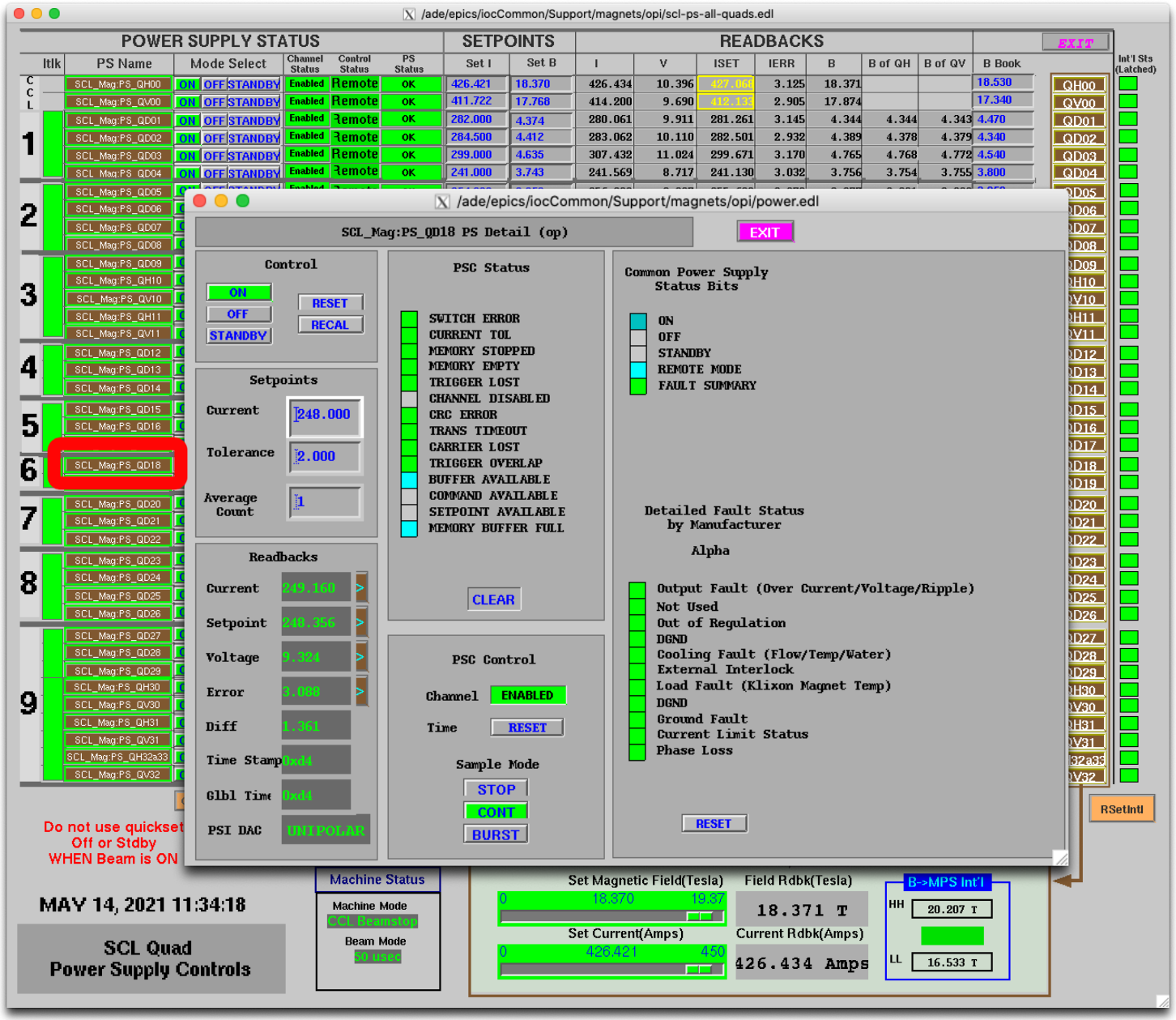
Screens – Ion Source



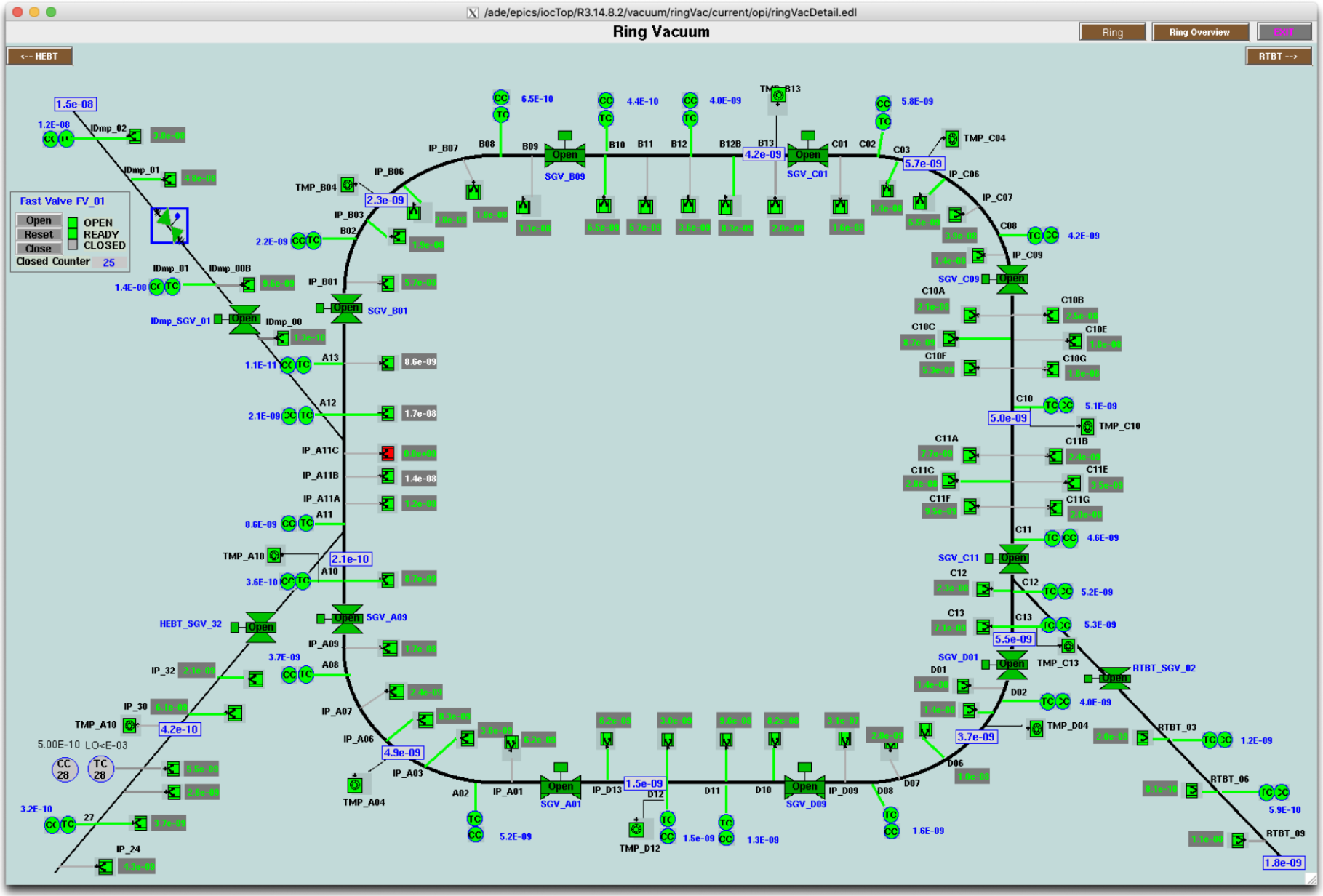
Screens - RF



Screens – SCL Magnet Power Supplies



Screens – Ring Vacuum



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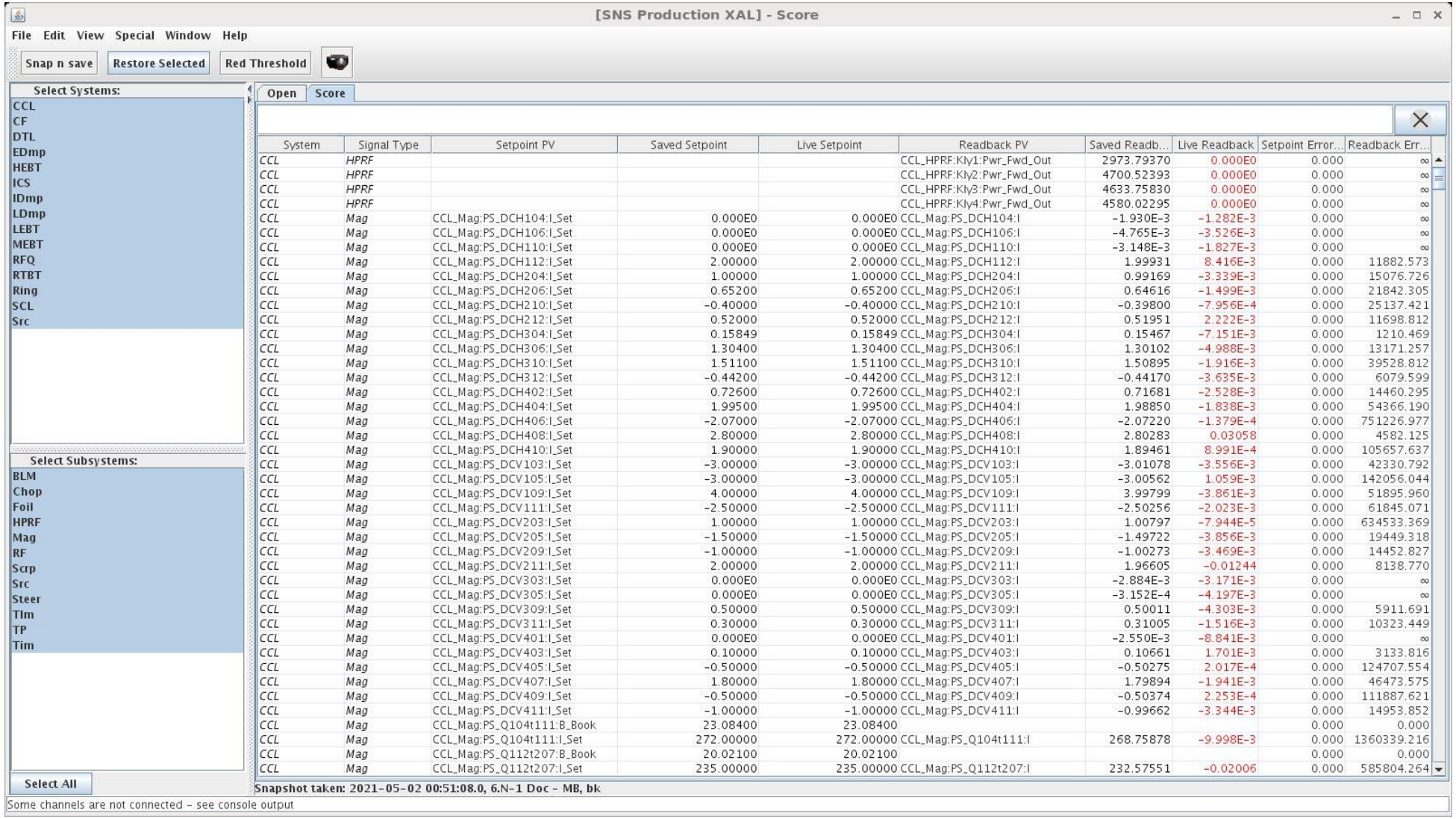
SCORE – Save, Compare, Restore Variables



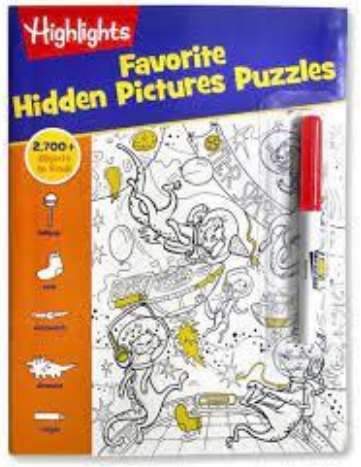
System	Signal Type	Setpoint PV	Saved Setpoint	Live Setpoint	Readback PV	Saved Readb...	Live Readback	Setpoint Error...	Readback Err...
CCL	HPRF				CCL_HPRF:Kly1:Pwr_Fwd_Out	2973.79370	0.000E0	0.000	∞
CCL	HPRF				CCL_HPRF:Kly2:Pwr_Fwd_Out	4700.52393	0.000E0	0.000	∞
CCL	HPRF				CCL_HPRF:Kly3:Pwr_Fwd_Out	4633.75830	0.000E0	0.000	∞
CCL	HPRF				CCL_HPRF:Kly4:Pwr_Fwd_Out	4580.02295	0.000E0	0.000	∞
CCL	Mag	CCL_Mag:PS_DCH104:I_Set	0.000E0	0.000E0	CCL_Mag:PS_DCH104:I	-1.930E-3	-1.282E-3	0.000	∞
CCL	Mag	CCL_Mag:PS_DCH106:I_Set	0.000E0	0.000E0	CCL_Mag:PS_DCH106:I	-4.765E-3	-3.526E-3	0.000	∞
CCL	Mag	CCL_Mag:PS_DCH110:I_Set	0.000E0	0.000E0	CCL_Mag:PS_DCH110:I	-3.148E-3	-1.827E-3	0.000	∞
CCL	Mag	CCL_Mag:PS_DCH112:I_Set	2.00000	2.00000	CCL_Mag:PS_DCH112:I	1.99931	8.416E-3	0.000	11882.573
CCL	Mag	CCL_Mag:PS_DCH204:I_Set	1.00000	1.00000	CCL_Mag:PS_DCH204:I	0.99169	-3.339E-3	0.000	15076.726
CCL	Mag	CCL_Mag:PS_DCH206:I_Set	0.65200	0.65200	CCL_Mag:PS_DCH206:I	0.64616	-1.499E-3	0.000	21842.305
CCL	Mag	CCL_Mag:PS_DCH210:I_Set	-0.40000	-0.40000	CCL_Mag:PS_DCH210:I	-0.39800	-7.956E-4	0.000	25137.421
CCL	Mag	CCL_Mag:PS_DCH212:I_Set	0.52000	0.52000	CCL_Mag:PS_DCH212:I	0.51951	2.222E-3	0.000	11698.812
CCL	Mag	CCL_Mag:PS_DCH304:I_Set	0.15849	0.15849	CCL_Mag:PS_DCH304:I	0.15467	-7.151E-3	0.000	1210.469
CCL	Mag	CCL_Mag:PS_DCH306:I_Set	1.30400	1.30400	CCL_Mag:PS_DCH306:I	1.30102	-4.988E-3	0.000	13171.257
CCL	Mag	CCL_Mag:PS_DCH310:I_Set	1.51100	1.51100	CCL_Mag:PS_DCH310:I	1.50895	-1.916E-3	0.000	39528.812
CCL	Mag	CCL_Mag:PS_DCH312:I_Set	-0.44200	-0.44200	CCL_Mag:PS_DCH312:I	-0.44170	-3.635E-3	0.000	6079.599
CCL	Mag	CCL_Mag:PS_DCH402:I_Set	0.72600	0.72600	CCL_Mag:PS_DCH402:I	0.71681	-2.528E-3	0.000	14460.295
CCL	Mag	CCL_Mag:PS_DCH404:I_Set	1.99500	1.99500	CCL_Mag:PS_DCH404:I	1.98850	-1.838E-3	0.000	54366.190
CCL	Mag	CCL_Mag:PS_DCH406:I_Set	-2.07000	-2.07000	CCL_Mag:PS_DCH406:I	-2.07220	-1.379E-4	0.000	751226.977
CCL	Mag	CCL_Mag:PS_DCH408:I_Set	2.80000	2.80000	CCL_Mag:PS_DCH408:I	2.80283	0.03058	0.000	4582.125
CCL	Mag	CCL_Mag:PS_DCH410:I_Set	1.90000	1.90000	CCL_Mag:PS_DCH410:I	1.89461	8.991E-4	0.000	105657.637
CCL	Mag	CCL_Mag:PS_DCV103:I_Set	-3.00000	-3.00000	CCL_Mag:PS_DCV103:I	-3.01078	-3.556E-3	0.000	42330.792
CCL	Mag	CCL_Mag:PS_DCV105:I_Set	-3.00000	-3.00000	CCL_Mag:PS_DCV105:I	-3.00562	1.059E-3	0.000	142056.044
CCL	Mag	CCL_Mag:PS_DCV109:I_Set	4.00000	4.00000	CCL_Mag:PS_DCV109:I	3.99799	-3.861E-3	0.000	51895.960
CCL	Mag	CCL_Mag:PS_DCV111:I_Set	-2.50000	-2.50000	CCL_Mag:PS_DCV111:I	-2.50256	-2.023E-3	0.000	61845.071
CCL	Mag	CCL_Mag:PS_DCV203:I_Set	1.00000	1.00000	CCL_Mag:PS_DCV203:I	1.00797	-7.944E-5	0.000	634533.369
CCL	Mag	CCL_Mag:PS_DCV205:I_Set	-1.50000	-1.50000	CCL_Mag:PS_DCV205:I	-1.49722	-3.856E-3	0.000	19449.318
CCL	Mag	CCL_Mag:PS_DCV209:I_Set	-1.00000	-1.00000	CCL_Mag:PS_DCV209:I	-1.00273	-3.469E-3	0.000	14452.827
CCL	Mag	CCL_Mag:PS_DCV211:I_Set	2.00000	2.00000	CCL_Mag:PS_DCV211:I	1.96605	-0.01244	0.000	8138.770
CCL	Mag	CCL_Mag:PS_DCV303:I_Set	0.000E0	0.000E0	CCL_Mag:PS_DCV303:I	-2.884E-3	-3.171E-3	0.000	∞
CCL	Mag	CCL_Mag:PS_DCV305:I_Set	0.000E0	0.000E0	CCL_Mag:PS_DCV305:I	-3.152E-4	-4.197E-3	0.000	∞
CCL	Mag	CCL_Mag:PS_DCV309:I_Set	0.50000	0.50000	CCL_Mag:PS_DCV309:I	0.50011	-4.303E-3	0.000	5911.691
CCL	Mag	CCL_Mag:PS_DCV311:I_Set	0.30000	0.30000	CCL_Mag:PS_DCV311:I	0.31005	-1.516E-3	0.000	10323.449
CCL	Mag	CCL_Mag:PS_DCV401:I_Set	0.000E0	0.000E0	CCL_Mag:PS_DCV401:I	-2.550E-3	-8.841E-3	0.000	∞
CCL	Mag	CCL_Mag:PS_DCV403:I_Set	0.10000	0.10000	CCL_Mag:PS_DCV403:I	0.10661	1.701E-3	0.000	3133.816
CCL	Mag	CCL_Mag:PS_DCV405:I_Set	-0.50000	-0.50000	CCL_Mag:PS_DCV405:I	-0.50275	2.017E-4	0.000	124707.554
CCL	Mag	CCL_Mag:PS_DCV407:I_Set	1.80000	1.80000	CCL_Mag:PS_DCV407:I	1.79894	-1.941E-3	0.000	46473.575
CCL	Mag	CCL_Mag:PS_DCV409:I_Set	-0.50000	-0.50000	CCL_Mag:PS_DCV409:I	-0.50374	2.253E-4	0.000	111887.621
CCL	Mag	CCL_Mag:PS_DCV411:I_Set	-1.00000	-1.00000	CCL_Mag:PS_DCV411:I	-0.99662	-3.344E-3	0.000	14953.852
CCL	Mag	CCL_Mag:PS_Q104t111:B_Book	23.08400	23.08400				0.000	0.000
CCL	Mag	CCL_Mag:PS_Q104t111:I_Set	272.00000	272.00000	CCL_Mag:PS_Q104t111:I	268.75878	-9.998E-3	0.000	1360339.216
CCL	Mag	CCL_Mag:PS_Q112t207:B_Book	20.02100	20.02100				0.000	0.000
CCL	Mag	CCL_Mag:PS_Q112t207:I_Set	235.00000	235.00000	CCL_Mag:PS_Q112t207:I	232.57551	-0.02006	0.000	585804.264

Good Operators are Logic Masters

- There are half a million signals so how do you know which fault sequence means try to reset, call an expert, or call Fulvia ☹?
  - Experience, documentation, and constant development of our tools
- What makes a good operator?
  - Be a vampire (kidding!)
  - Ability to know just about everything
    - Our trigger word to know if someone is going to end up tripping off the beam
      - Totally transparent to beam operations
  - Good memory and good with logic and pattern recognition

Find the Mismatch

Thanks mom!



- Beam trip with no warning and no alarms and only indication is a fault from an interlock summation

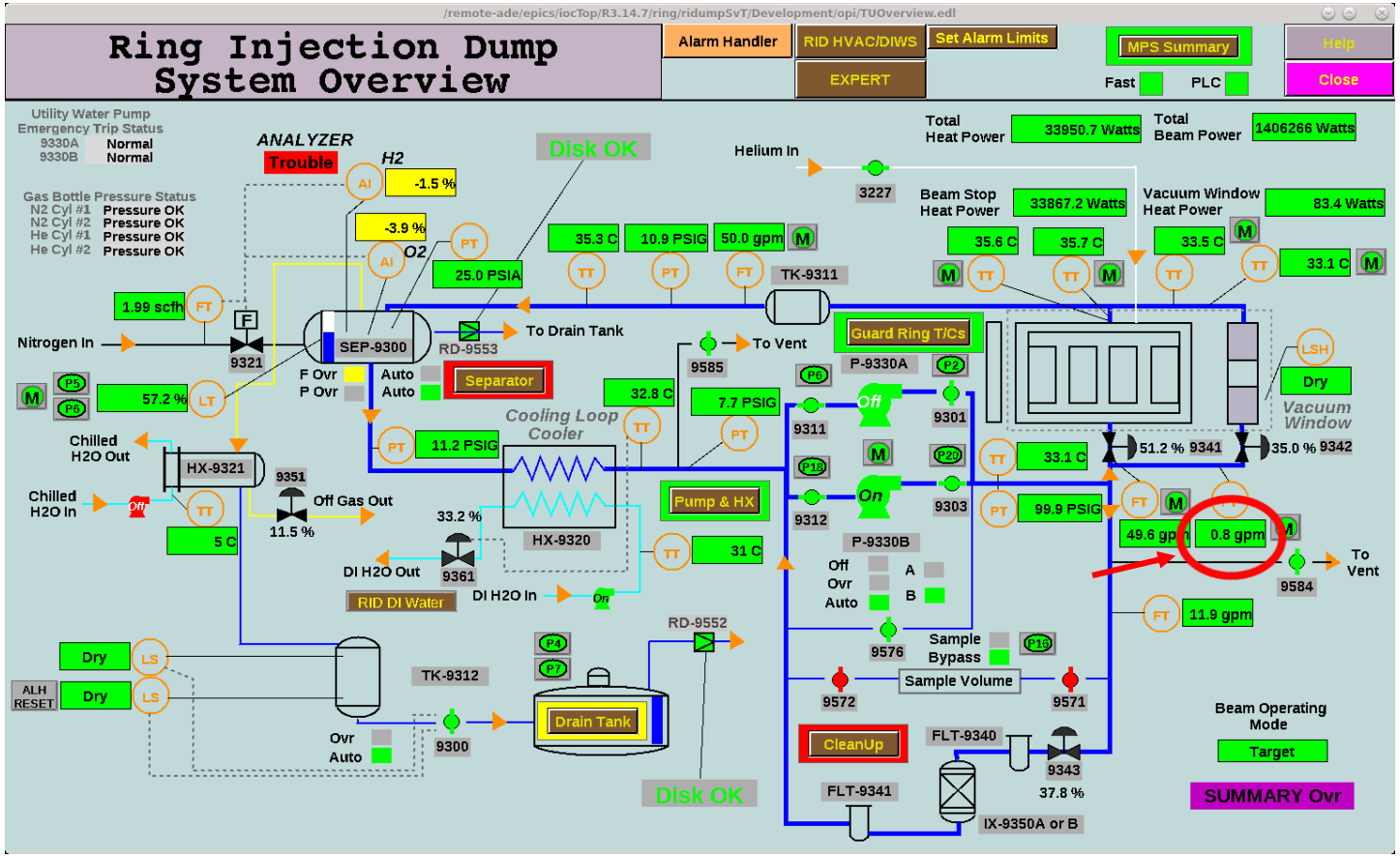
Don't know which input is faulting

Don't know which signal is which on the screen

Don't know interlock levels

Alarm Indication

- Beam Stop Flow Low-Low
- Vacuum Window Flow Low-Low
- Beam Stop Temp A High-High
- Beam Stop Temp B High-High
- Delay Tank Flow Low-Low
- Vac Window Temp A High-High
- Vac Window Temp B High-High
- GLS Level Low-Low
- Pump A and Pump B Failed



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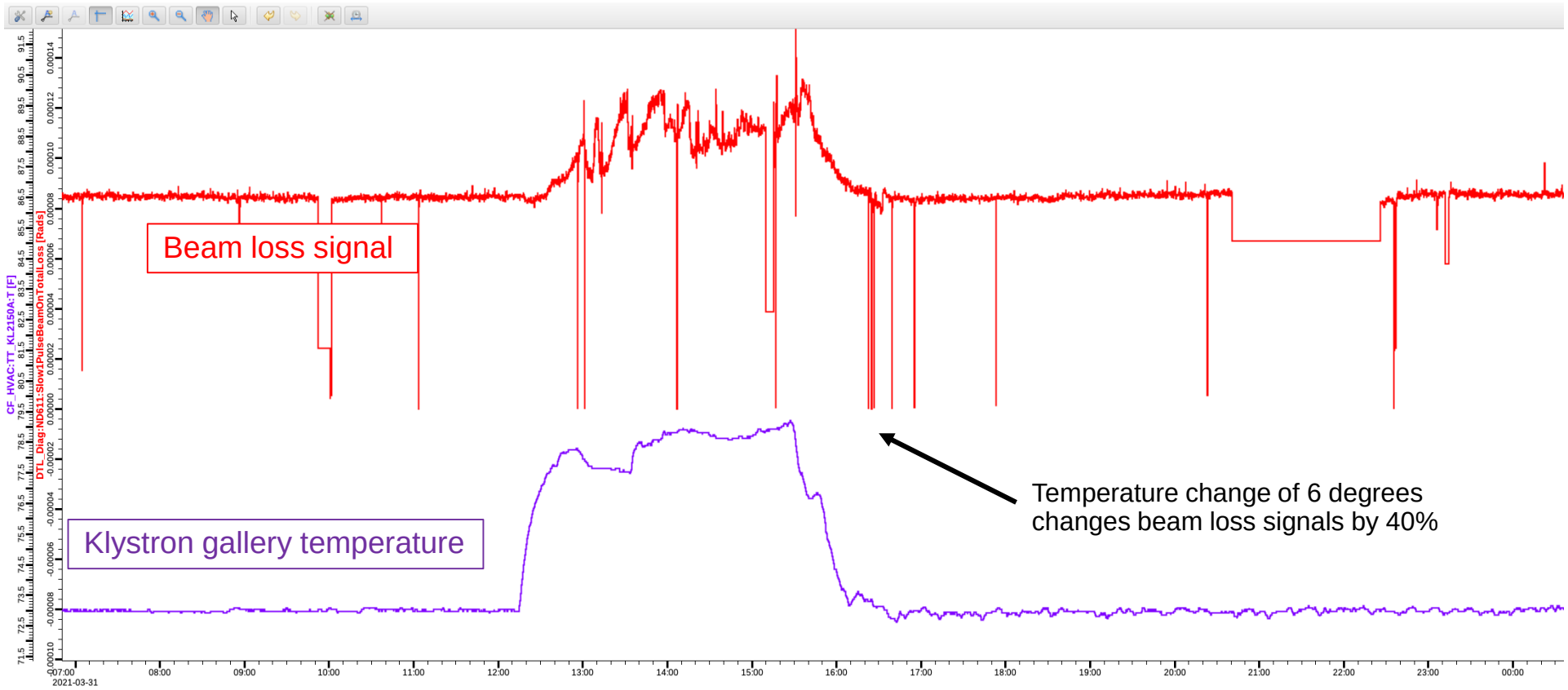
Temperature and Humidity Move the Beam

- The temperature and humidity in the klystron gallery cause the beam to move
  - Operators want stable (hot or cold doesn't matter just stay the same)



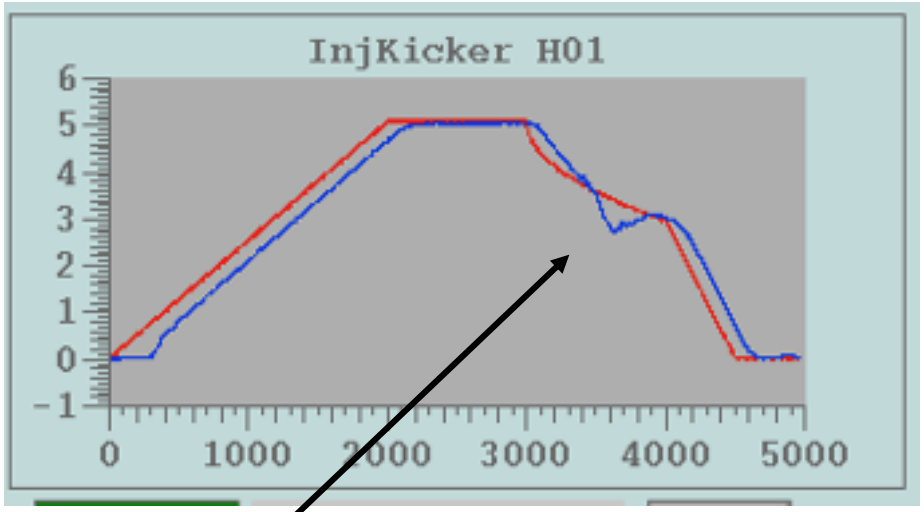
Stripper Foils Flutter in Vacuum?

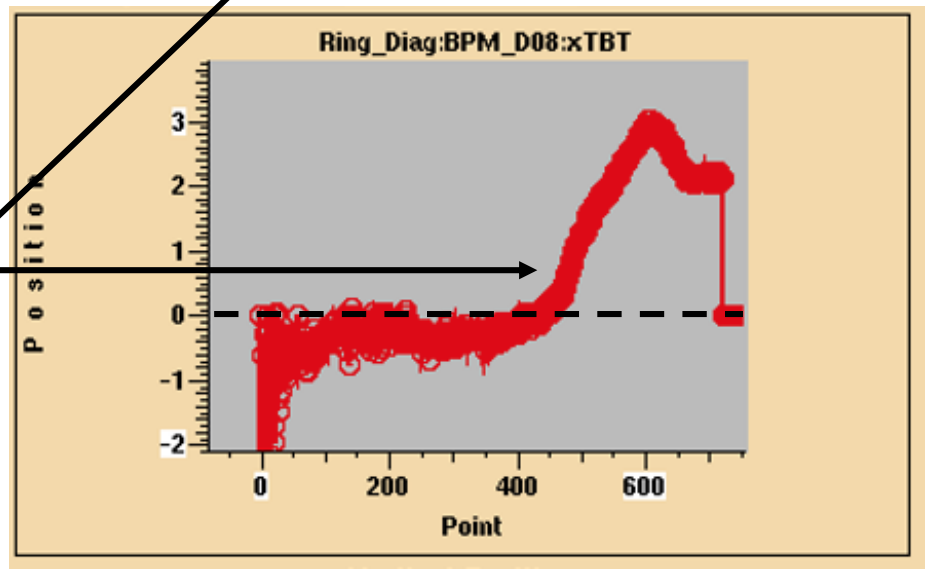
- Very early into beam operations we noticed that the beam was moving on the stripper foil
  - No beam movement was seen on beam position monitors
  - No magnet movement was seen on magnetic field readbacks
- Operaors had the same eureka moment and both said move the foil
  - We moved the foil and it stopped fluttering!
- Lots of speculation but no definitive cause found for the flutter

Beam Moves the……Beam?

- The beam is so intense it moves itself!
  - Beam induced electrical signals move up cables from the tunnel into service buildings which then couple back into equipment upstairs
  - The signals then go back down into the tunnel and move the beam!
    - Engineers have become “electronic noise” experts

Red is waveform to follow
Blue is the readback



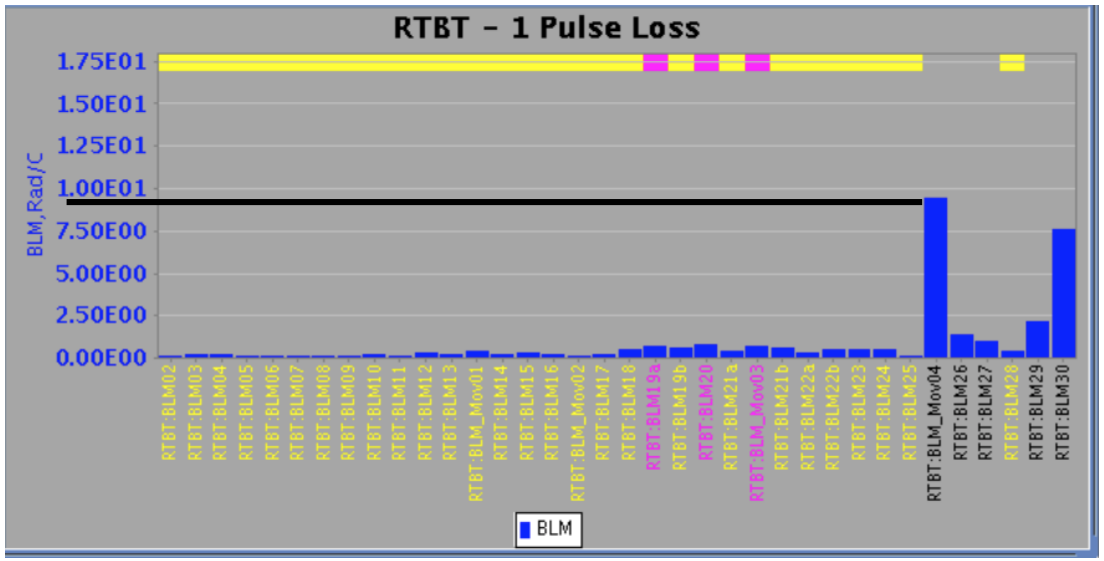


As the beam grows it begins to affect itself and starts shifting it’s own position

Things That Can Go Wrong After Maintenance

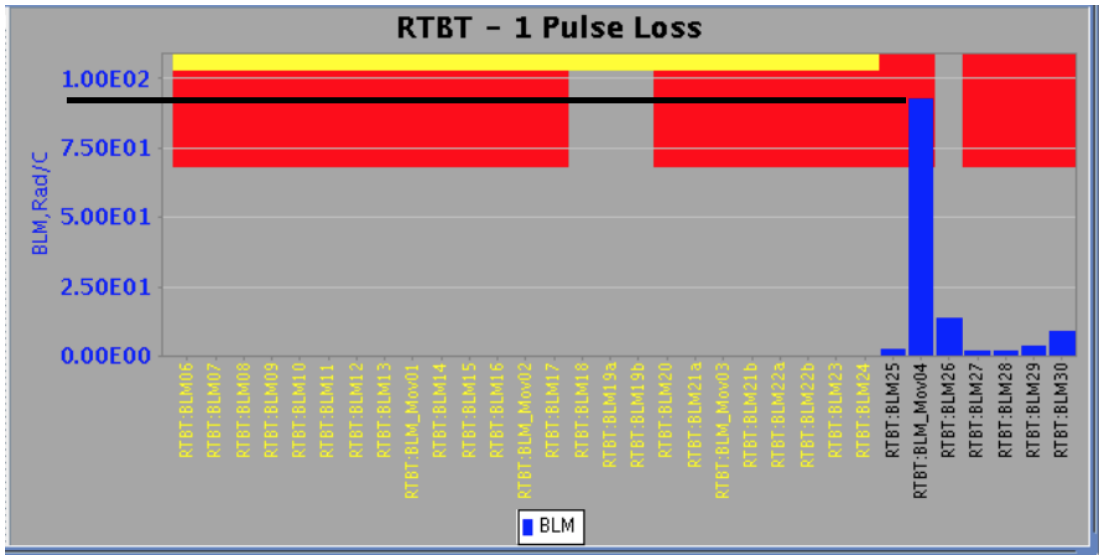
- Turn on the beam after a maintenance outage and we find increased beam losses (order of magnitude higher)

Beam →



Normal

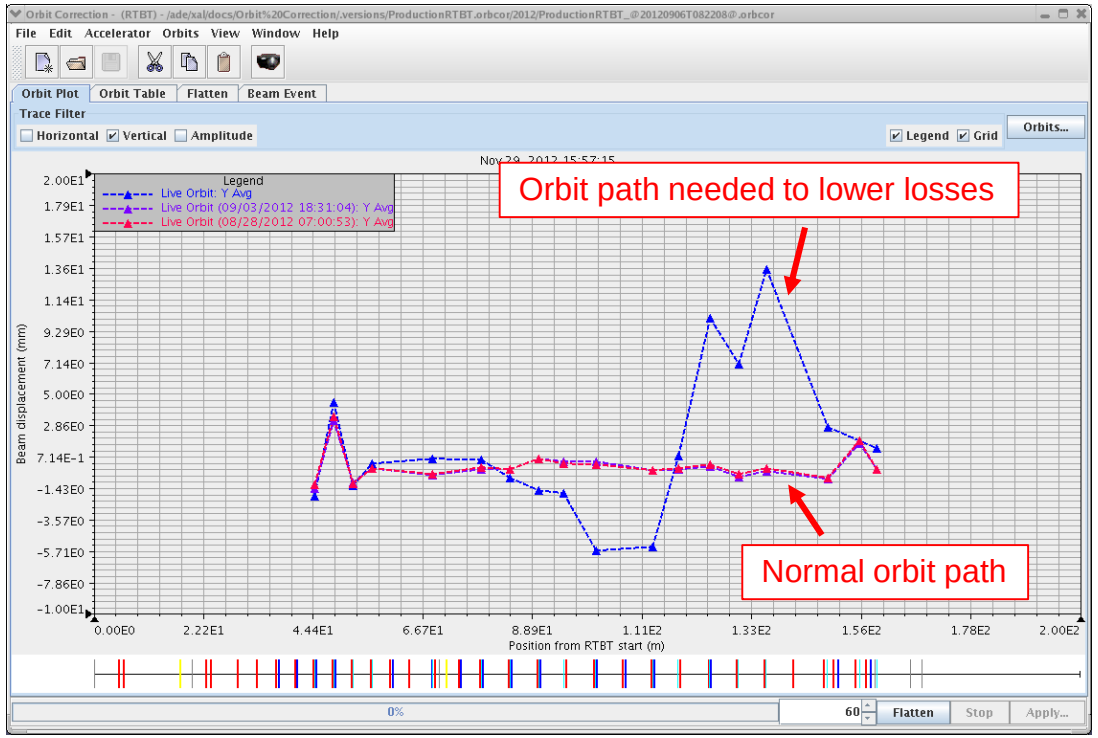
Beam →



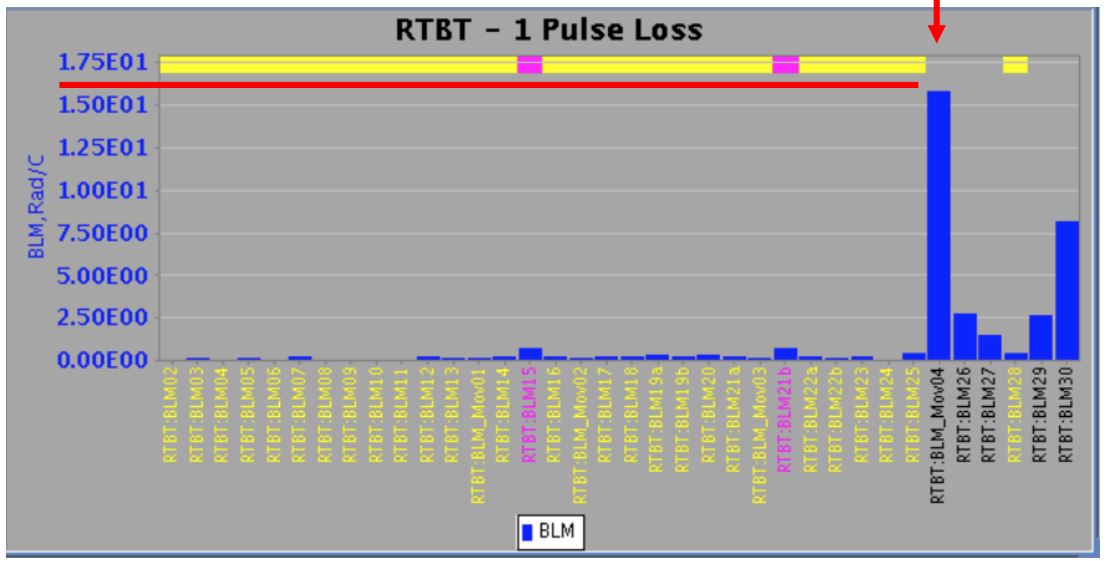
Abormal

Get the Beam On and then Interact with Different Groups

- First try to adjust to keep the beam on



Beam losses close to nominal



- Next contact experts to help figure out possible causes and solutions
  - Physicists, Beam Instrumentation, Vacuum, Target (borescope)

Beam measurements and setup

MPS checkout helps get equipment working

- The MPS is one of the core systems needed for safe beam operations
- Following extended outage periods each MPS signal is verified to fault the beam off
  - The MPS quickly informs operations personnel the needed systems to run beam
- MPS personnel work with system experts to turn on equipment to clear MPS and turn off equipment to verify the MPS faults and beam cannot be recovered
  - A great way to figure out which core equipment is not working

Operations Envelope (OE) sets beam limits for equipment

Average power limit = Beam energy x Current x Pulse width x Rep rate

Energy per pulse limit = Beam energy x Current x Pulse width

- The Operations Envelope (OE) works with the MPS to try to limit damage to equipment
  - The OE is the administrative limits
  - The MPS provides the active protection

- **Wire Scanners (* Longer pulse lengths are acceptable at lower peak currents, such that the product of current and pulse length is maintained within the OE)**

System	Typical Beam Parameters **	Maximum Beam Current (OE)	Maximum Repetition Rate (OE) limit
MEBT Wire Scanners	50 mA x 50 µs = 2500 mA-µs	4000 mA -µs	5 Hz
DTL Wire Scanners	40 mA x 50 µs = 2000 mA-µs	3000 mA -µs	5 Hz
CCL Wire Scanners	40 mA x 50 µs = 2000 mA -µs	3000 mA -µs	5 Hz
Linac Dump Wire Scanners	40 mA x 50 µs = 2000 mA -µs	3000 mA -µs	5 Hz
HEBT Wire Scanners	40 mA x 50 µs = 2000 mA -µs	3000 mA -µs	5 Hz
RTBT Wire Scanners	38 mA x 1000 µs = 38,000 mA -µs ***	38,000 mA -µs	60 Hz

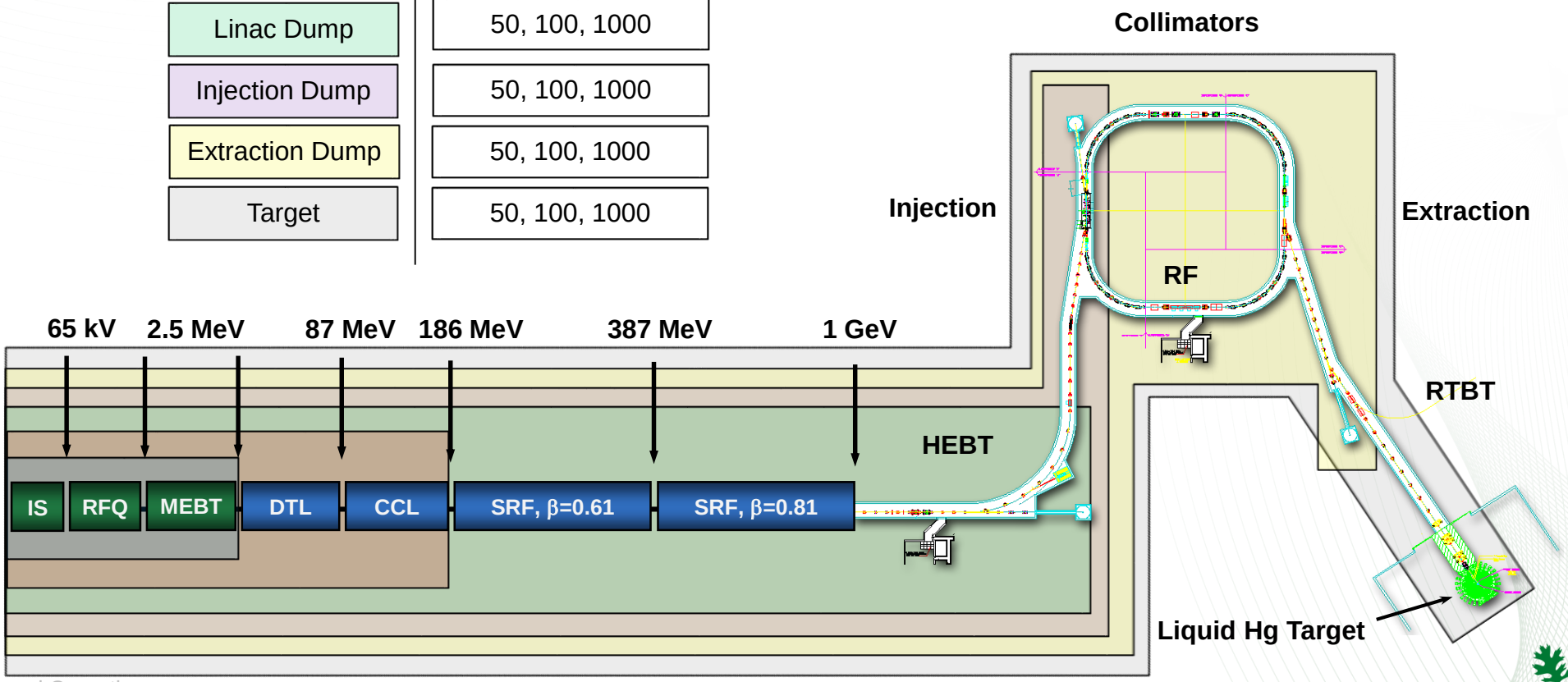
** The MPS typically limits the pulse width to 50 µs.
***The RTBT current and pulse length given in the table corresponds to the beam entering the ring. The beam exiting is of course much shorter and higher intensity.

- **Target, Beam Dumps, Apertures, Faraday Cups and Beam Stops**

System	Typical Energy (MeV)	Typical beam parameters	Typical: Single pulse Energy (J) / Average Beam power (W)	Maximum (OE): Single pulse Energy (J) / Average Beam power (W) limit
MEBT Aperture	2.5	40 mA, 50 µs, 1 Hz (MPS limit 50 µs)	5 J / 5 W	8 J / 250 W
MEBT Emittance	2.5	40 mA, 50 µs, 6 Hz (MPS limit 50 µs)	5 J / 30 W	8 J / 50 W
MEBT Beam Stop	2.5	for beam current ≤ 60 mA 60 mA, 50 µs, 1 Hz for beam current > 60 mA 70 mA, 35 µs, 1 Hz (MPS limit 50 µs)	7 J / 7 W 6 J / 6 W	10 J / 10 W
DTL 1 Energy Degrader / Faraday Cup	7.5	40 mA, 50 µs at 2 Hz (MPS limit 50 µs)	15 J / 30 W	22 J / 45 W
DTL 2 Energy Degrader / Faraday Cup	23	20 mA, 50 µs at **1 Hz** (MPS limit 50 µs)	23 J / 23 W	40 J / 40 W
DTL 3 Energy Degrader / Faraday Cup	40	20 mA, 50 µs at 2 Hz (MPS limit 50 µs)	40 J / 80 W	60 J / 120 W
DTL 4 Energy Degrader / Faraday Cup	57	**18** mA, 50 µs at 2 Hz (MPS limit 50 µs)	50 J / 100 W	75 J / 150 W
DTL 5 Energy Degrader / Faraday Cup	73	**18** mA, 50 µs at 2 Hz (MPS limit 50 µs)	65 J / 130 W	100 J / 200 W
DTL 6 Energy Degrader / Faraday Cup	87	30 mA, 50 µs at **1 Hz** (MPS limit 50 µs)	130 J / 130 W	200 J / 200 W
CCL Tuning Beam Stop	160	30 mA, 50 µs at **1 Hz** (MPS limit 50 µs)	240 J / 240 W	500 J / 500 W
Linac Beam Dump	1100	30 mA, 100 µs / 30 mA, 1000 µs at 0.1 Hz	3,300 J / 3,300 W	33,000 J / 7,000 W
Ring Injection Dump	1100	30 mA, 500 µs / 30 mA, 750 µs at 2 Hz	16,500 J / 49,500 W	33,000 J / 140,000 W
Extraction Dump	1100	30 mA, 100 µs / 30 mA, 1000 µs at 0.1 Hz	3,300 J / 3,300 W	33,000 J / 7,000 W
Collimators – HEBT, Ring and RTBT	1100	30 mA, 50 µs / 30 mA, 500 µs at 0.1 Hz	1,650 J / 1,650 W	33,000 J / 2,000 W
Foil Video Screens (primary and secondary)	1100	33 mA, 300 µs one shot	11,000 J	11,000 J
Foil Video Screens (primary and secondary)	1100	1 mini-pulse (~ 38mA, 0.65µs) at 1 Hz for 300 seconds maximum	25W for 300 seconds (maximum)	25W for 300 seconds (maximum)
Target Systems	1100	23.5 mA (Chopped), 1000 µs at 60 Hz	25,833 J / 1,550,000 W	35,000 J / 2,100,000 W

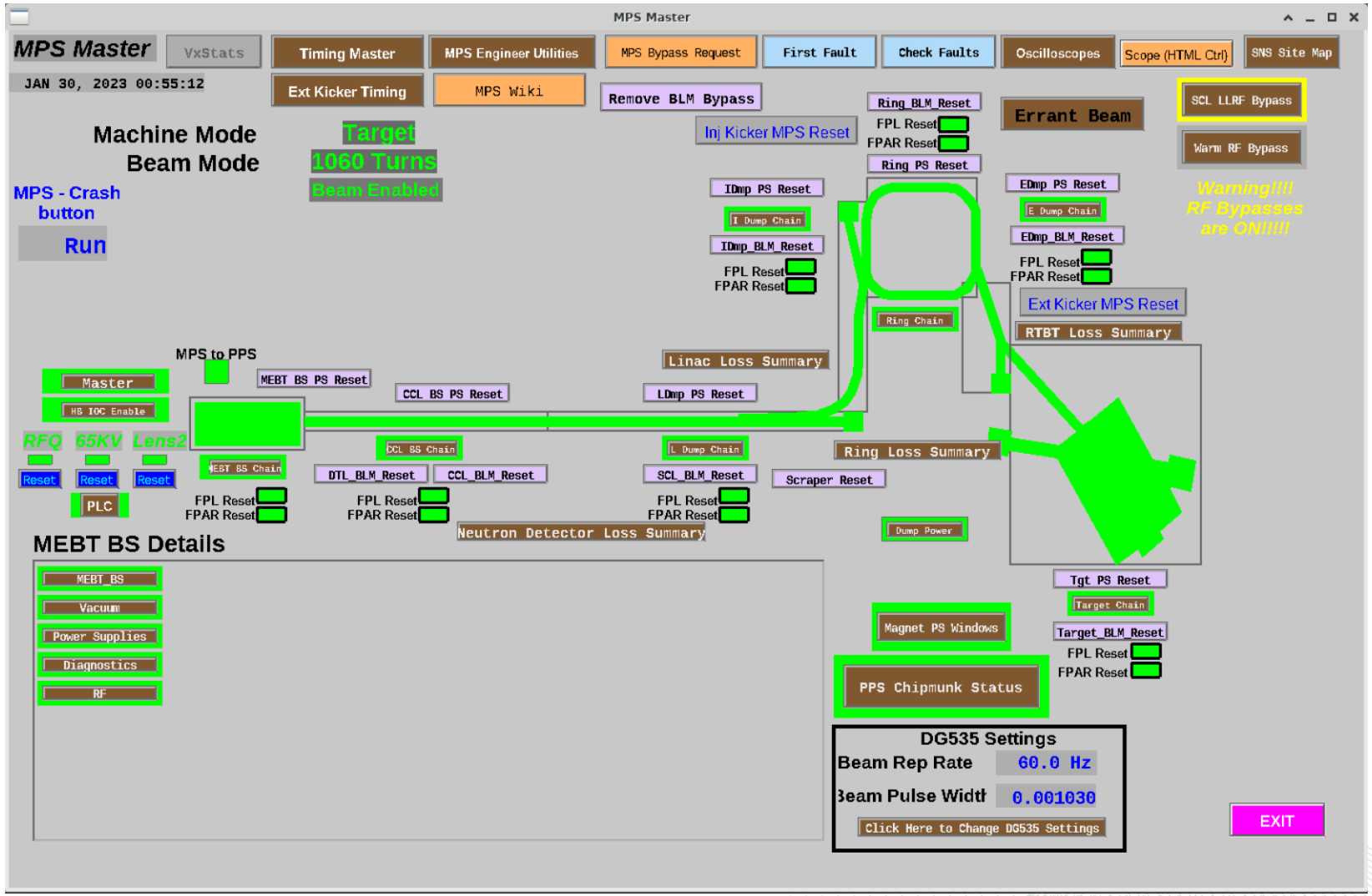
The MPS actively protects equipment based on beam pulse width and possible beam destinations

Destination	Allowed beam timing (microseconds)
MEBT Beamstop	50
CCL Beamstop	50
Linac Dump	50, 100, 1000
Injection Dump	50, 100, 1000
Extraction Dump	50, 100, 1000
Target	50, 100, 1000

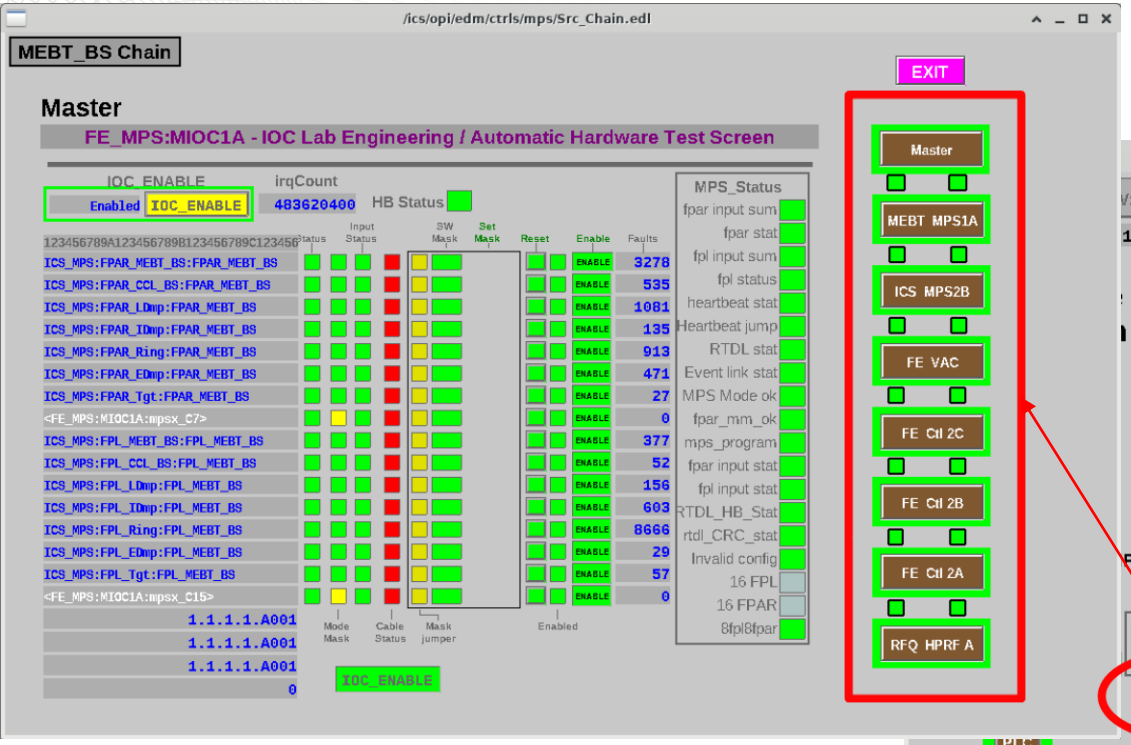


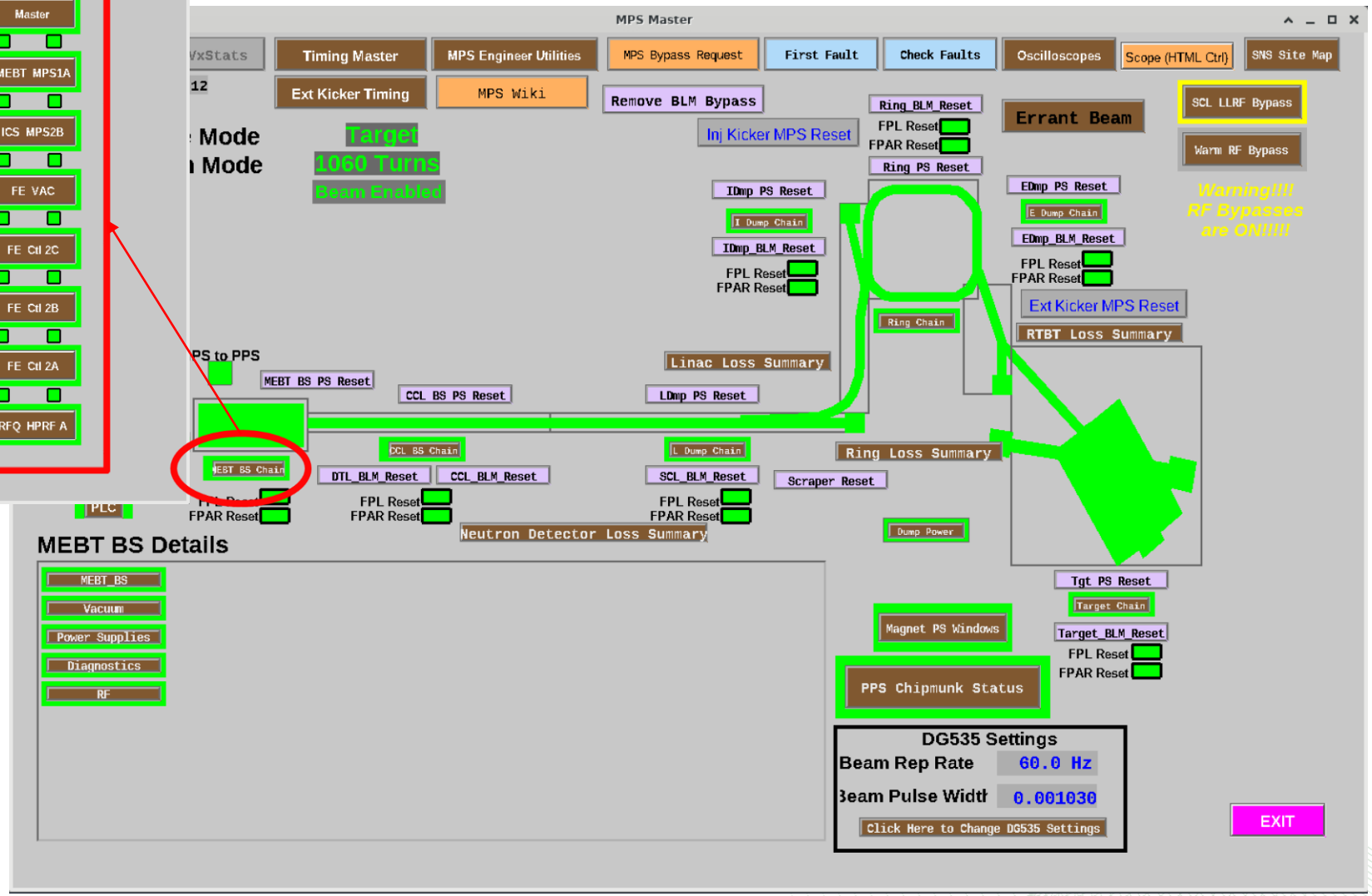
Control screens visualize the MPS segmentation

- MPS master is broken up into chains
  - Individual chains show the equipment connections to the MPS



MEBT Beam Stop



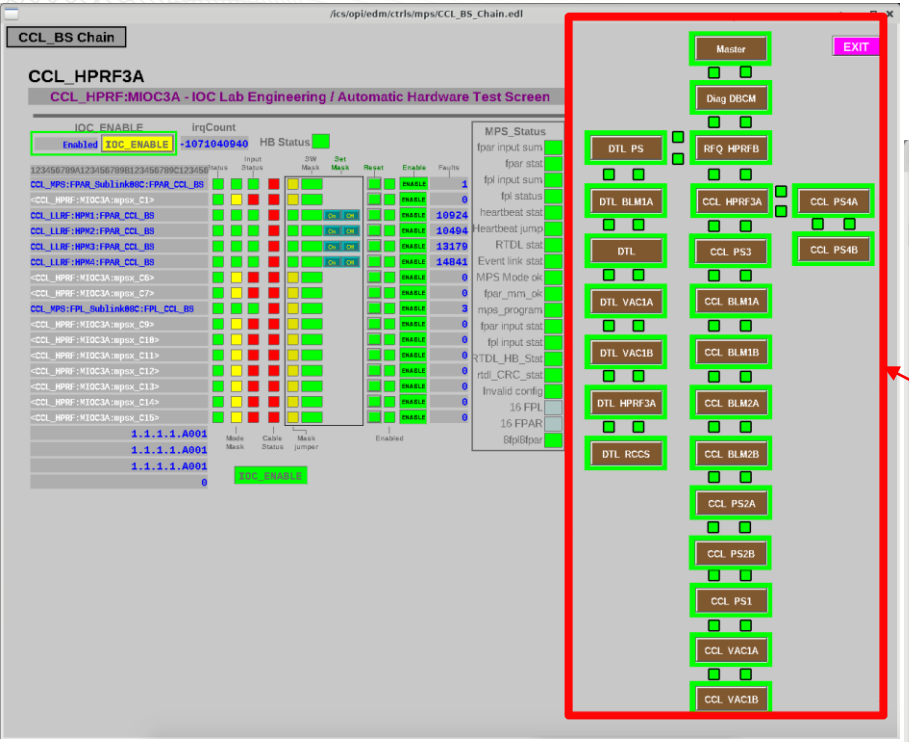


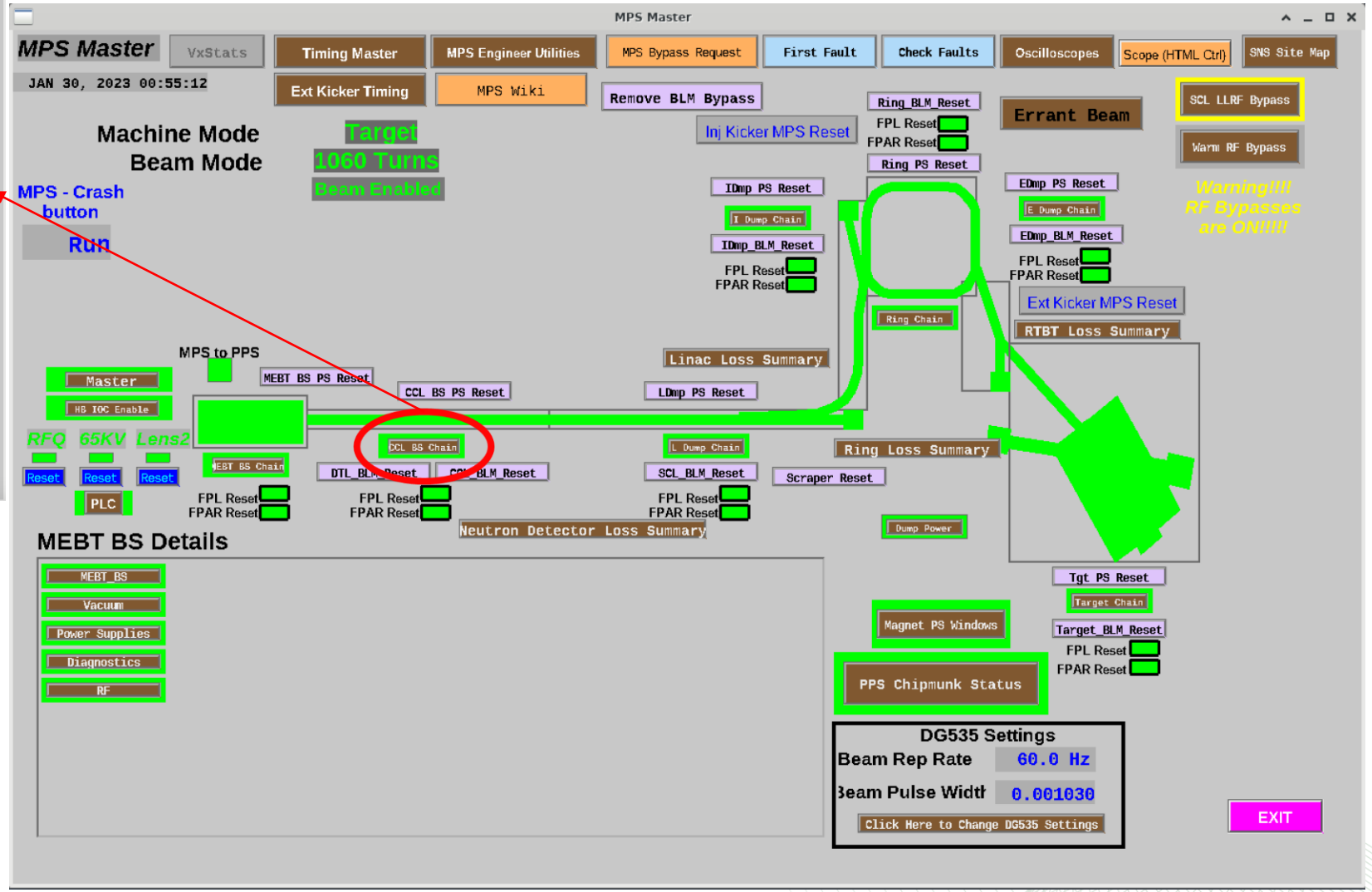
Chain to Chassis to Equipment Signal

Chassis feed into each to pass fault state

Each chassis has 16 inputs

CCL Beam Stop



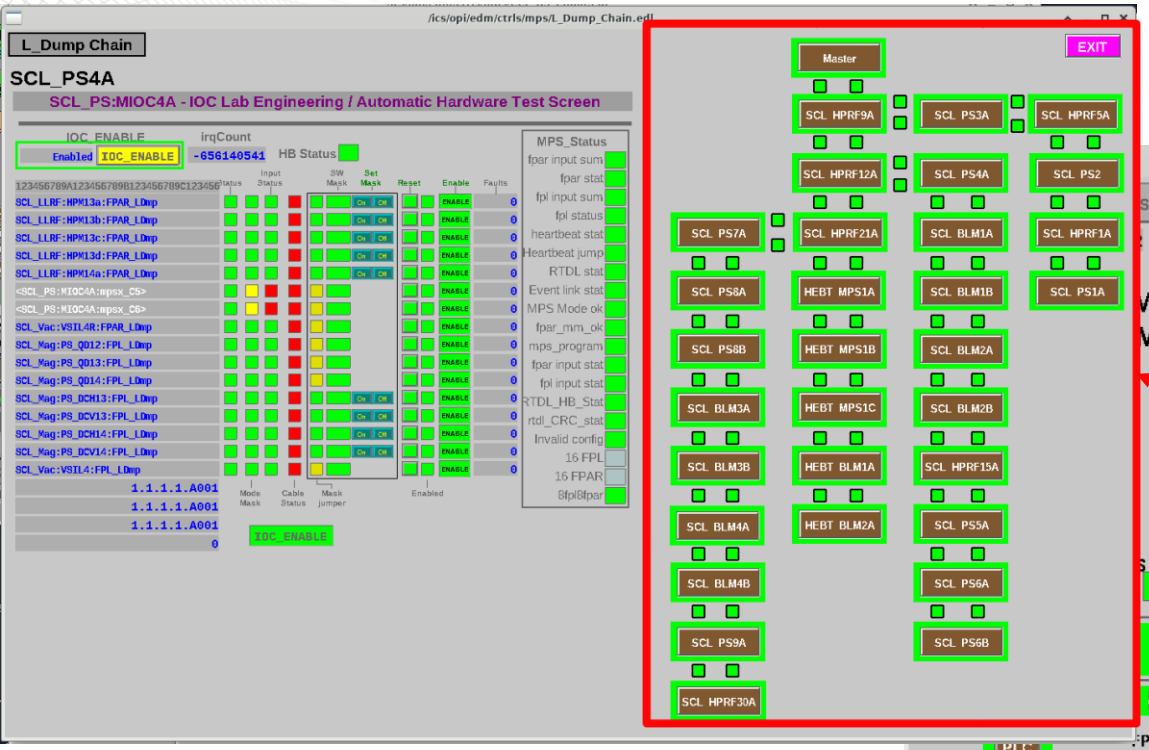


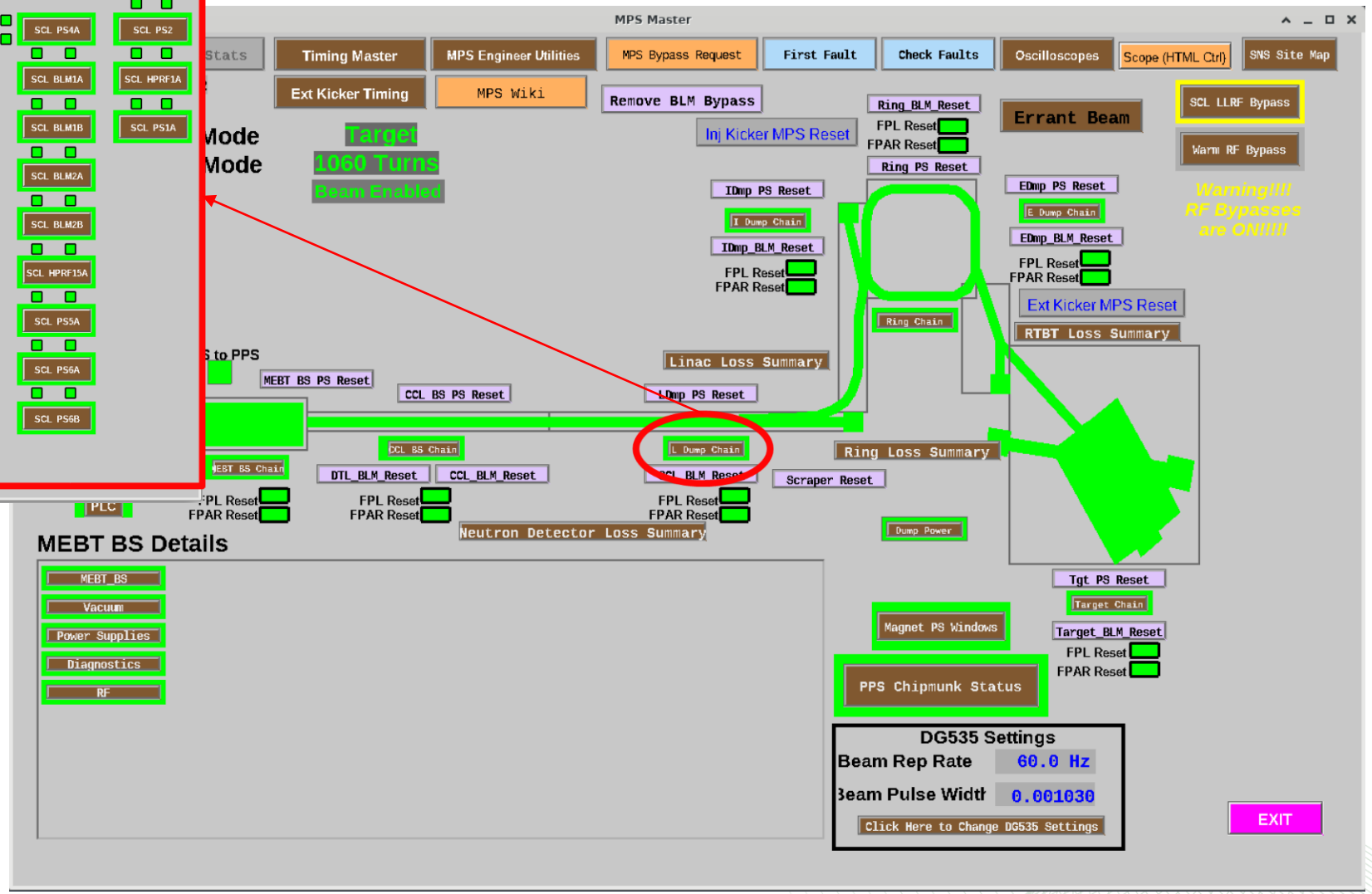
Chain to Chassis to Equipment Signal

Chassis feed into each to pass fault state

Each chassis has 16 inputs

Linac Dump



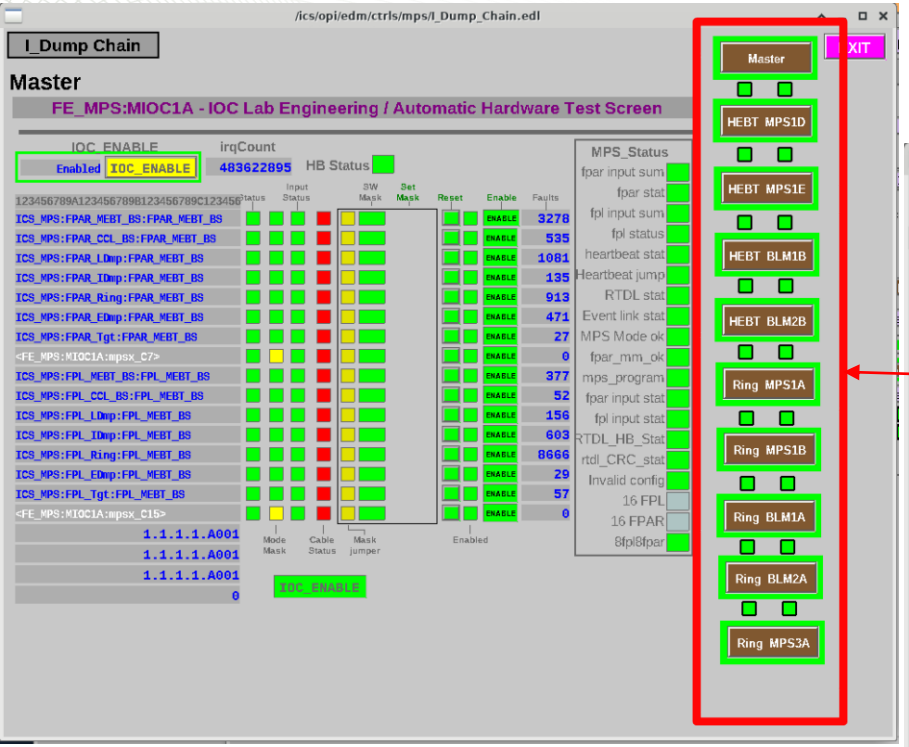


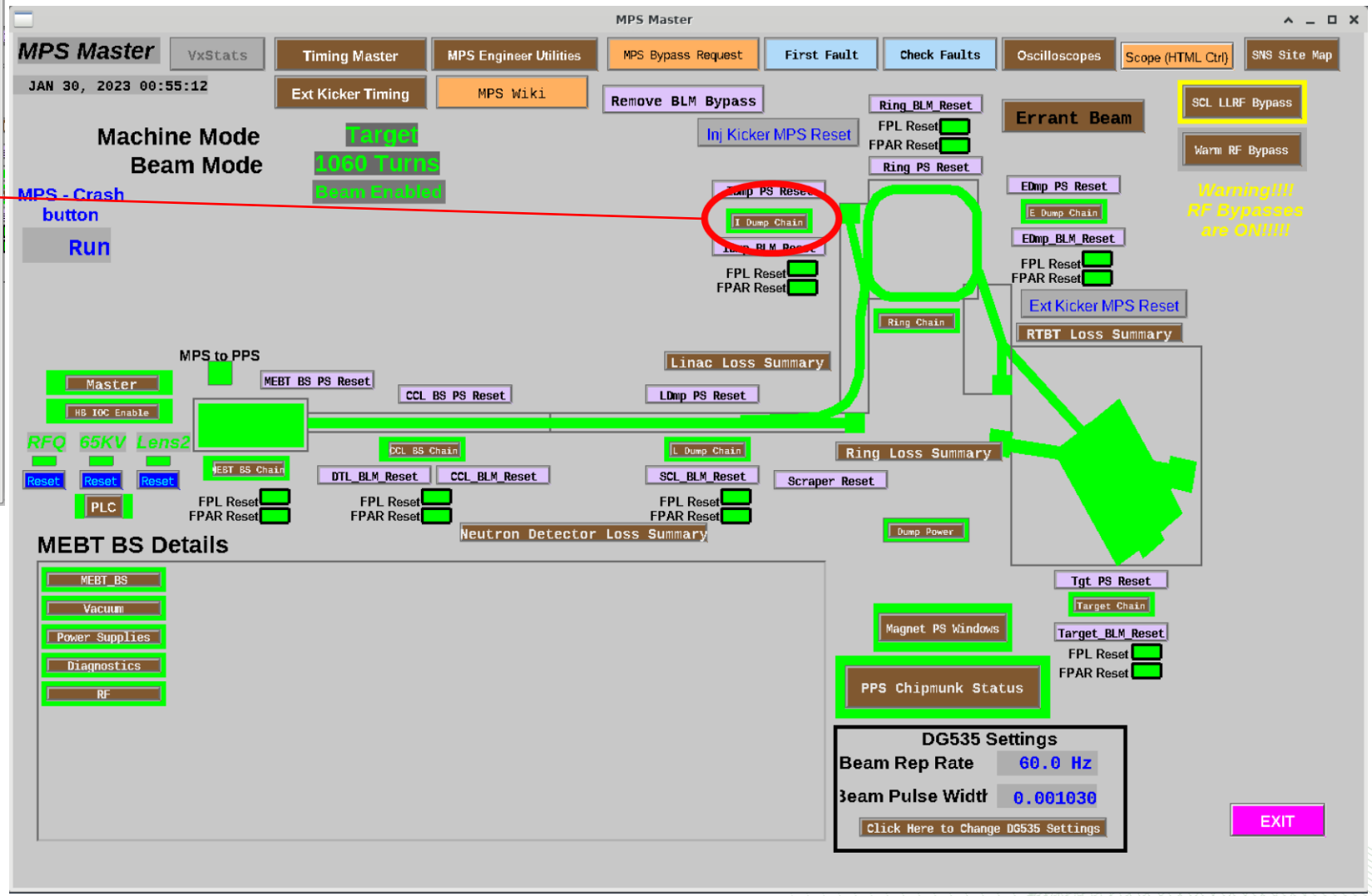
Chain to Chassis to Equipment Signal

Chassis feed into each to pass fault state

Each chassis has 16 inputs

Injection Dump



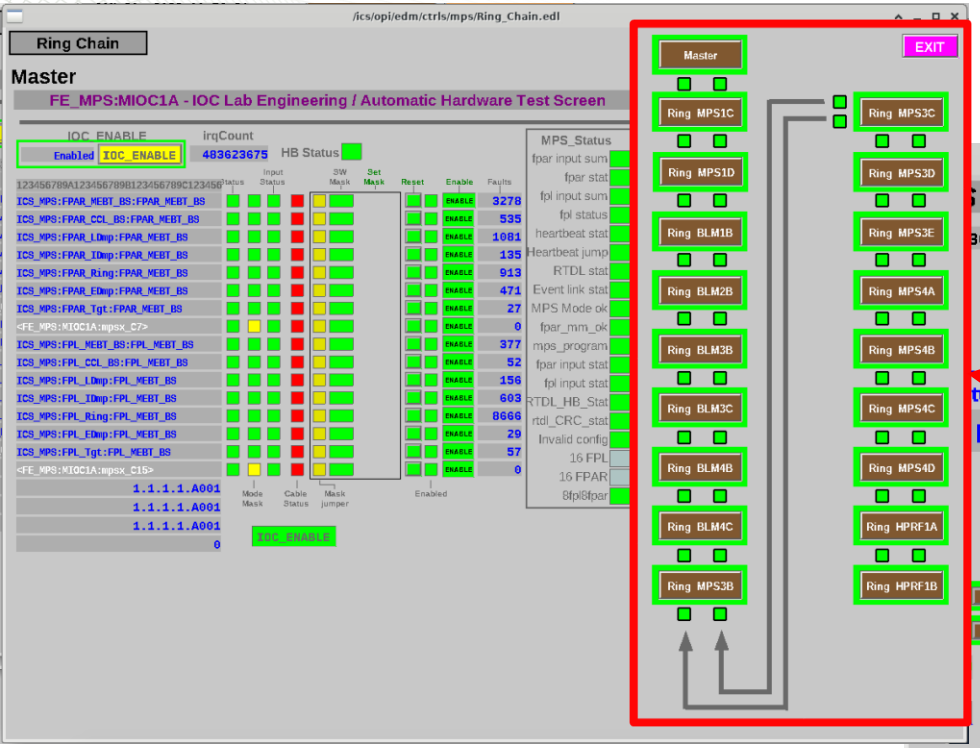


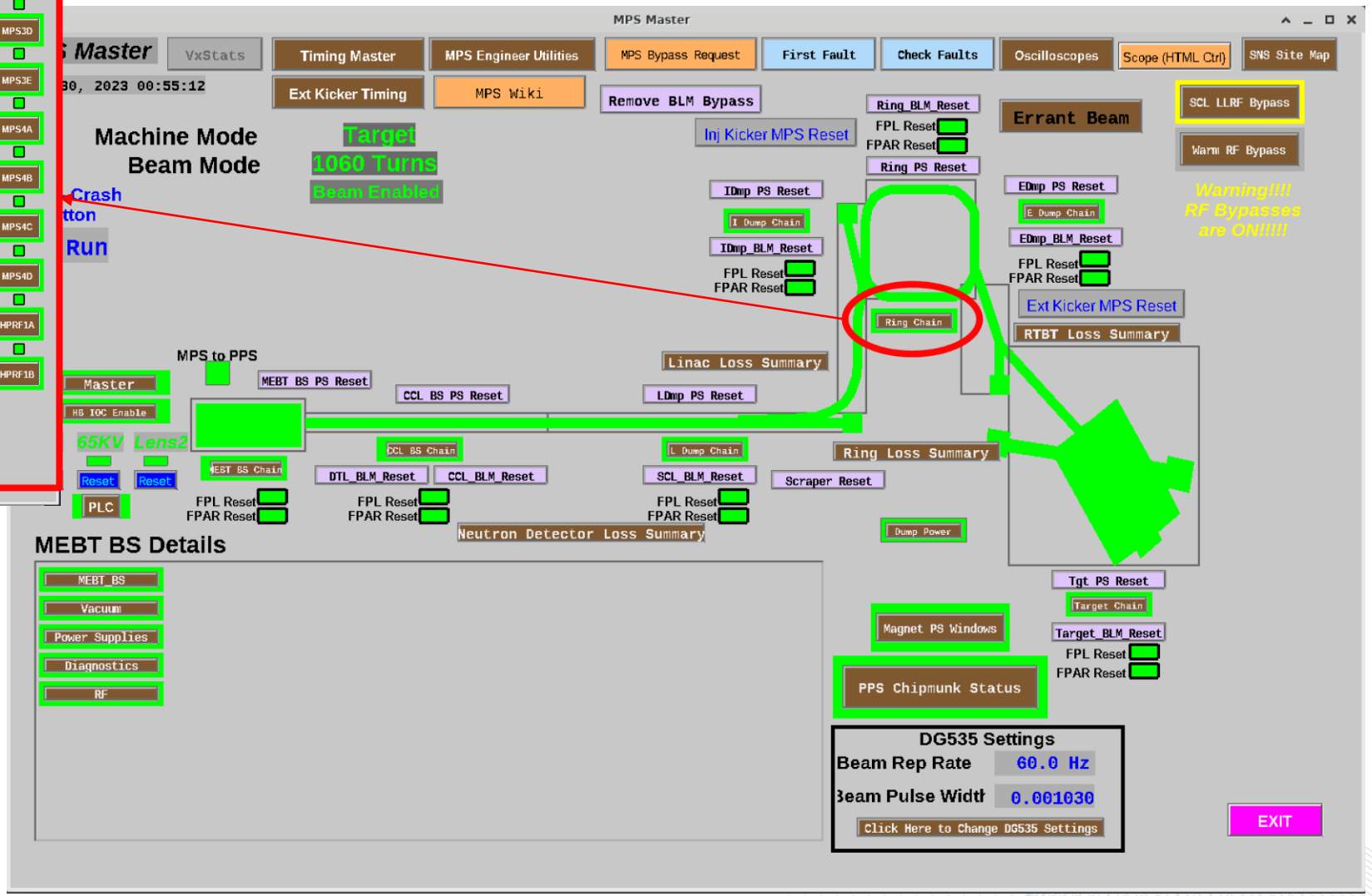
Chain to Chassis to Equipment Signal

Chassis feed into each to pass fault state

Each chassis has 16 inputs

Ring



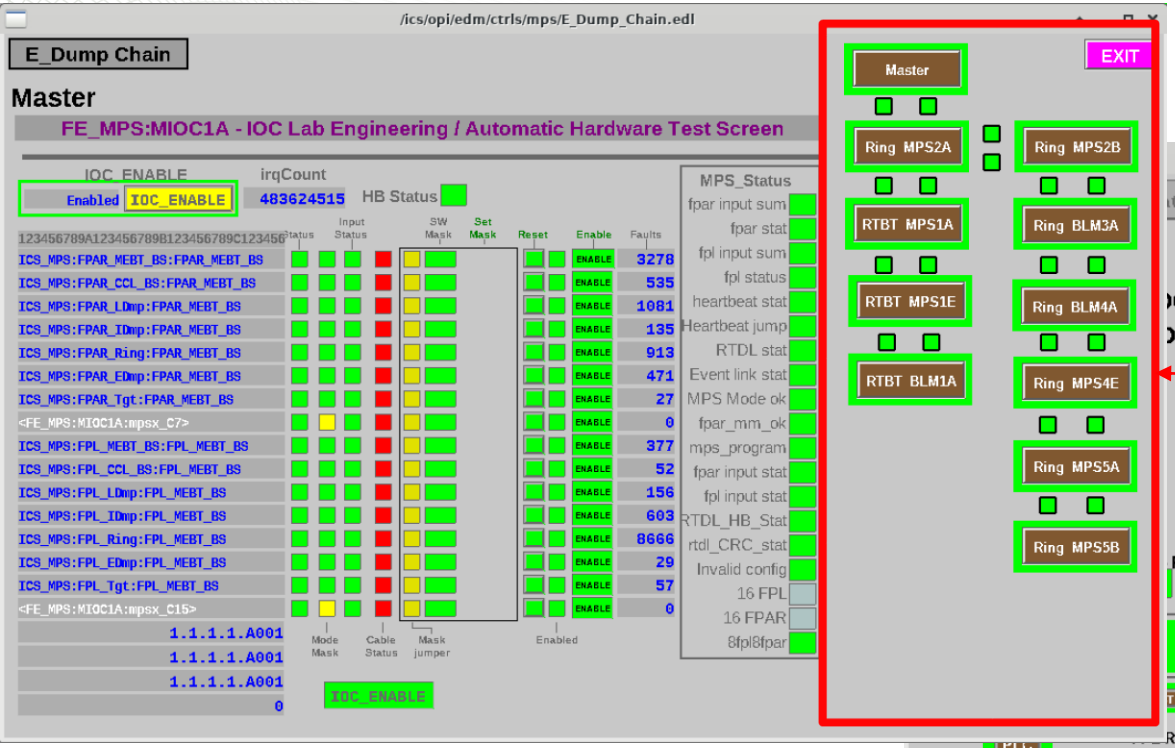


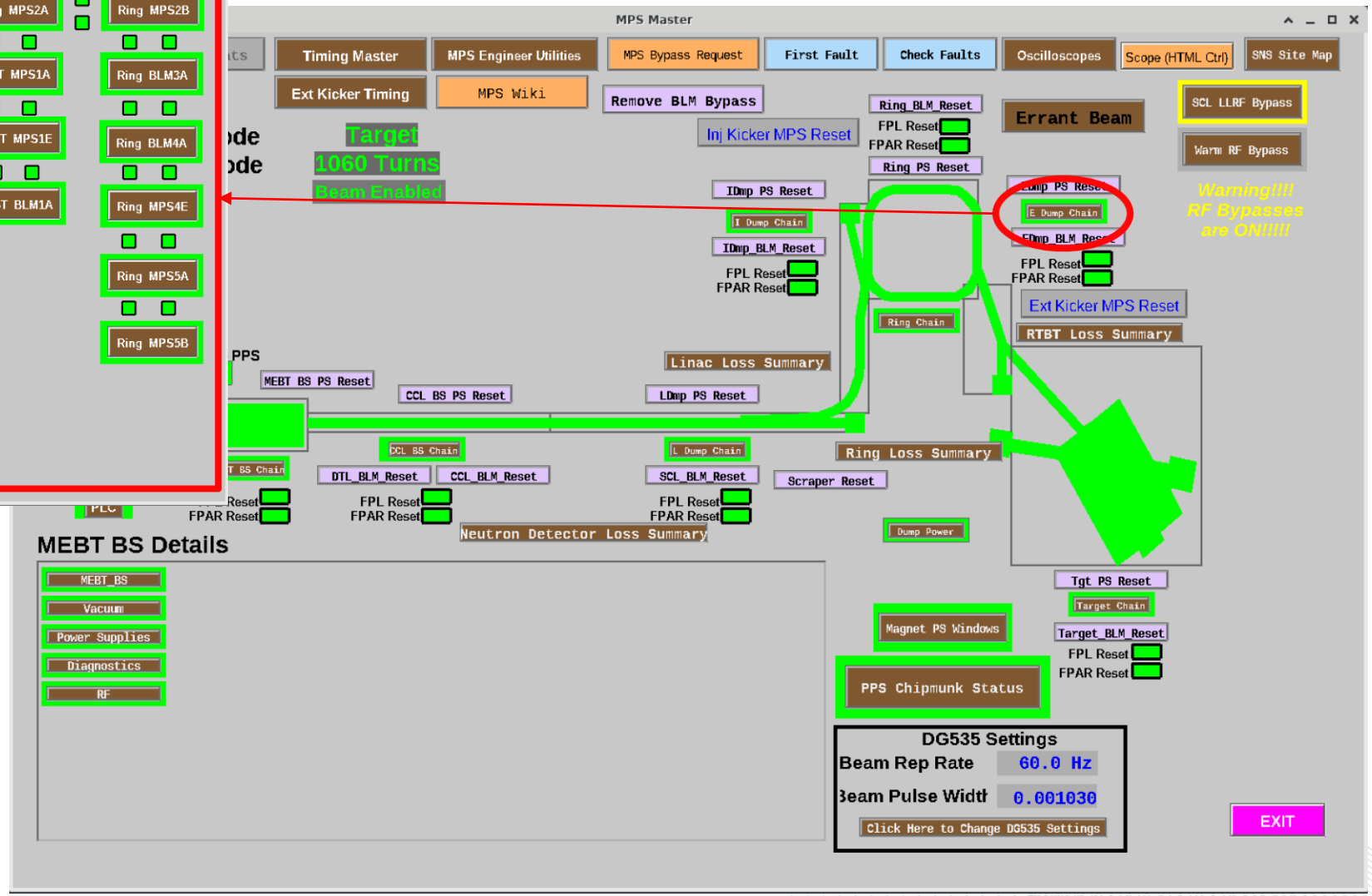
Chain to Chassis to Equipment Signal

Chassis feed into each to pass fault state

Each chassis has 16 inputs

Extraction Dump



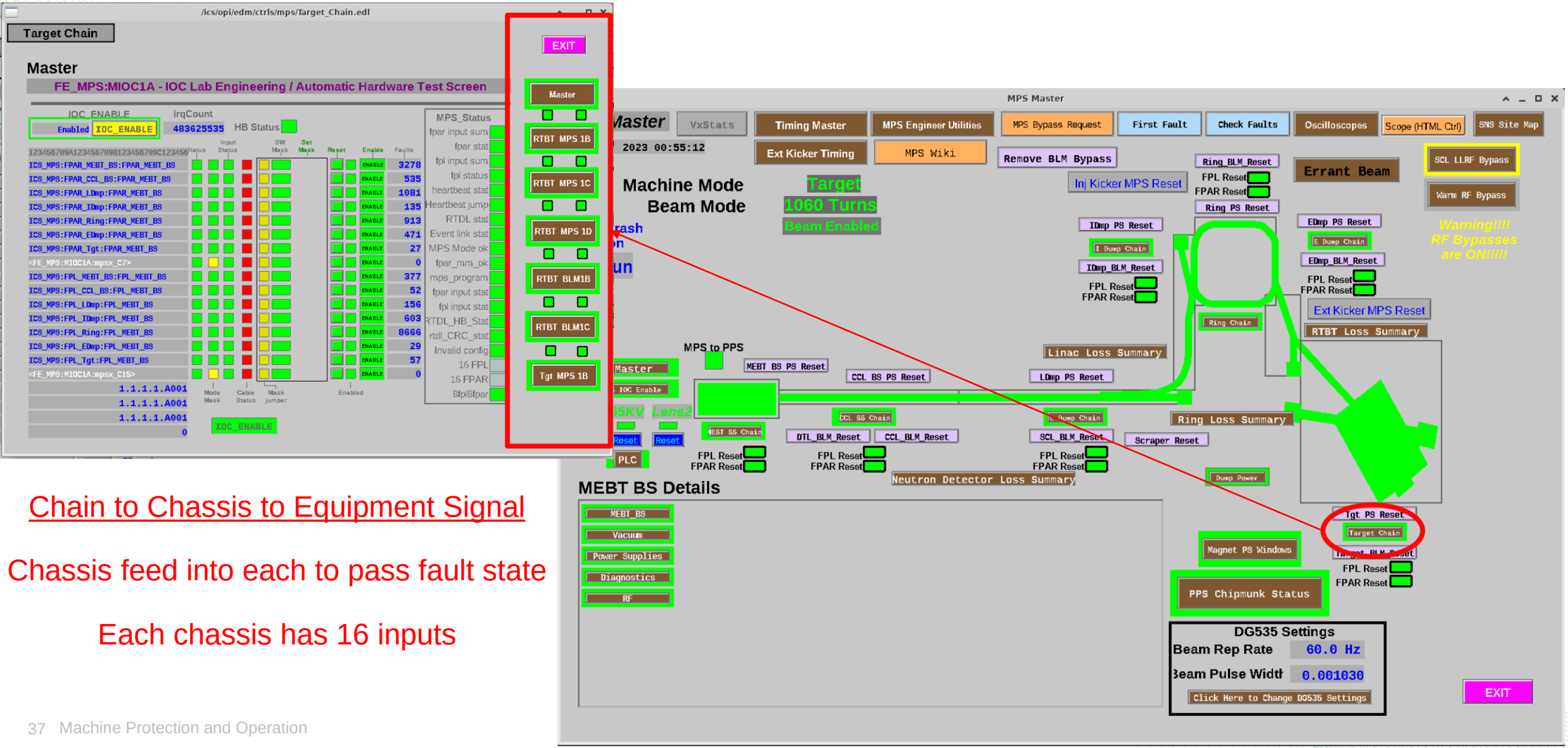


Chain to Chassis to Equipment Signal

Chassis feed into each to pass fault state

Each chassis has 16 inputs

Target



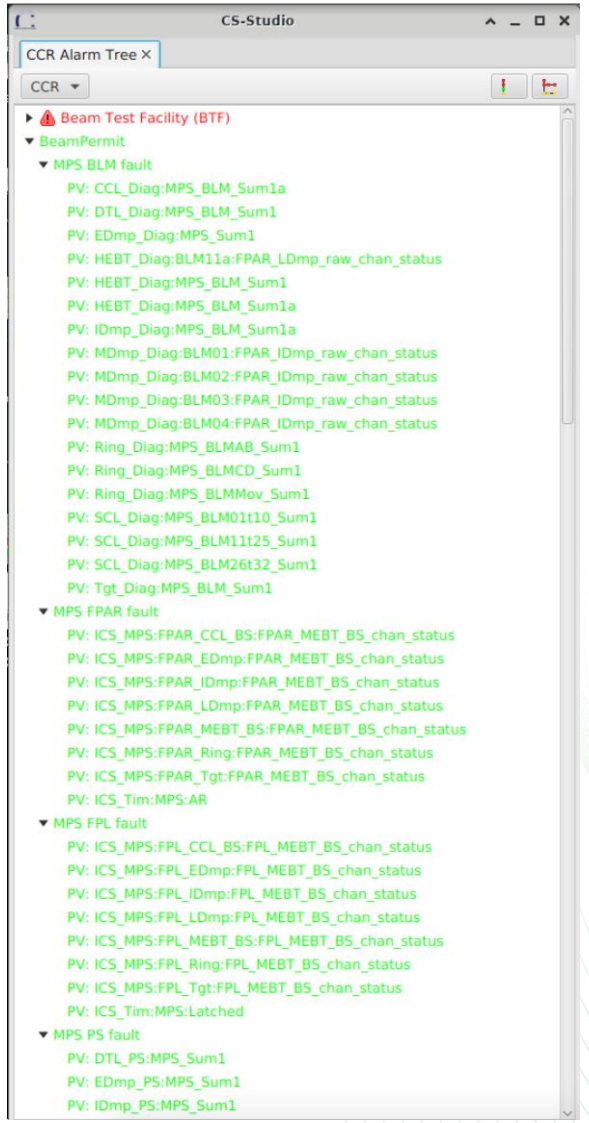
Chain to Chassis to Equipment Signal

Chassis feed into each to pass fault state

Each chassis has 16 inputs

MPS alarms in the BEAST focus operator attention

- SNS alarm handler is the Beast Ever Alarm System Toolkit (BEAST)
- General rule is to not set alarm level at the interlock setting
  - Equipment alarm levels should be set to indicate an impending issue before an interlock occurs
- MPS alarms are utilized to indicate the area and the system that caused the interlock



Bypass request system documents bypassing of MPS signals

1 - 15

	ByPass Num.	Status	System	SubSystem	Device	Date Added	ByPass Comment	Added By	Bypass Approved By RAD Operations Group Leader	Bypass Approved by Area Manager	Bypass Approved by System Expert	Date Removed	Removal Comment	Removed By	RA
	1522	Installed	SCL	HPRF	SCL_HPRF:Cpl09c	22-DEC-22	T_Out.HIGH and .HIHI raised due to erroneous detector read back interlocking beam	Jonathan Rye	Milanovich, Geoffrey	Howell, Matthew	Geng, Rong-Li	-	-	-	-
	1521	Installed	SCL	HPRF	SCL_HPRF:Cpl09b	22-DEC-22	T_Out.HIGH and .HIHI raised due to erroneous detector read back interlocking beam	Jonathan Rye	Milanovich, Geoffrey	Howell, Matthew	Geng, Rong-Li	-	-	-	-
	1520	Installed	SCL	LLRF	SCL_LLRF:HPM32d	20-DEC-22	SCL 32d removed from service.	John Moss	Milanovich, Geoffrey	Cardinal, Mark	Crofford, Mark	-	-	-	-
	1519	Installed	-	-	TGT_Hg:Tnk_ESX5011BA	07-DEC-22	TGT_HG:Tnk_ESX5011BA, Interstitial B HG Leak detector locked in.	Michael Boone	Milanovich, Geoffrey	Denison, John	Moore, Jody	-	-	-	-
	1518	Installed	PPS	RTBT	PPS_RTBT:BPLS_MPS_B	28-NOV-22	BPLS not in service.	Geoffrey Milanovich	Milanovich, Geoffrey	Evans, Nicholas	Bong, Patrick	-	-	-	-
	1517	Installed	PPS	RTBT	PPS_RTBT:BPLS_MPS_A	28-NOV-22	BPLS not in service.	Geoffrey Milanovich	Milanovich, Geoffrey	Evans, Nicholas	Bong, Patrick	-	-	-	-
	1516	Installed	SCL	LLRF	SCL_LLRF:HPM31d	28-NOV-22	Klystron removed from service.	Victoria Cordina	Milanovich, Geoffrey	Cardinal, Mark	Moss, John	-	-	-	-
	1515	Installed	SCL	HPRF	SCL_HPRF:Cpl03a	12-NOV-22	T_Out.HIGH and HIHI raised due to erroneous detector behavior	Jonathan Rye	Milanovich, Geoffrey	Howell, Matthew	Kim, Sang-Ho	-	-	-	-
	1514	Installed	-	-	TGT_HG:Tnk_ESX5011D	11-NOV-22	MTX-29 does not have a burst disk. Burst disk indicator input bypassed in PLC.	John Miller	Milanovich, Geoffrey	Denison, John	Dial, Leonard	-	-	-	-
	1513	Installed	Ring	Mag	Ring_Mag:PS_QSC_D08	08-NOV-22	Power supply being shuttered.	David Brown	Milanovich, Geoffrey	Evans, Nicholas	Tan, Yugang	-	-	-	-
	1512	Installed	Ring	Mag	Ring_Mag:PS_QSC_D07	08-NOV-22	Power supply being shuttered.	David Brown	Milanovich, Geoffrey	Evans, Nicholas	Tan, Yugang	-	-	-	-
	1511	Installed	Ring	Mag	Ring_Mag:PS_QSC_D05	08-NOV-22	Power supply being shuttered.	David Brown	Milanovich, Geoffrey	Evans, Nicholas	Tan, Yugang	-	-	-	-
	1510	Installed	Ring	Mag	Ring_Mag:PS_QSC_D03	08-NOV-22	Power supply being shuttered.	David Brown	Milanovich, Geoffrey	Evans, Nicholas	Tan, Yugang	-	-	-	-
	1509	Installed	Ring	Mag	Ring_Mag:PS_QSC_D02	08-NOV-22	Power supply being	David	Milanovich, Geoffrey	Evans, Nicholas	Tan, Yugang	-	-	-	-

MPS bypass tool verifies a bypass request has been created

MPS Bypasses ×

Machine Mode: Site | State: Bypassed | Requested: All | Reload

Counts

Total: 1126 | Bypassed: 103 | Bypassable: 689 | Not Bypassable: 326 | Disconnected: 8 | Error: 0

Operating State

	RTDL	Switch
Beam Mode	Standby	Standby
Machine Mode	Target	Target

Legend

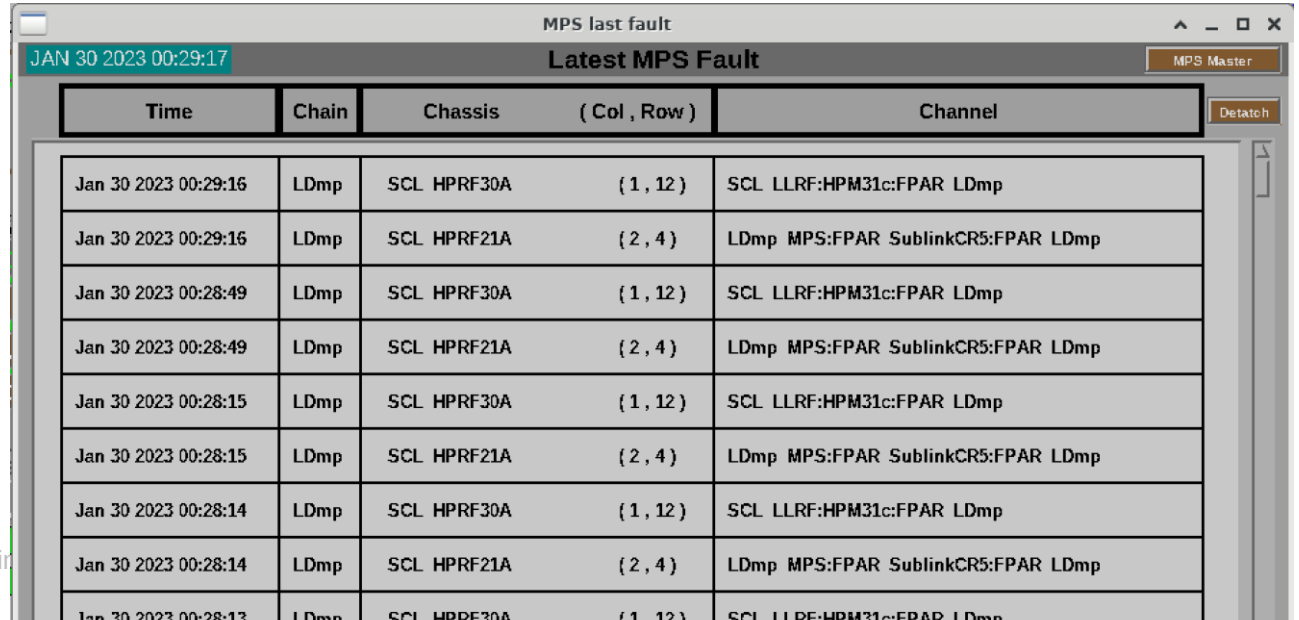
Bypassed	Bypassable	NotBypassable	Disconnected	InError
Requested	Requested	Requested	Requested	Requested
Not Requested	Not Requested	Not Requested	Not Requested	Not Requested

#	Bypass	State	Requestor	Request Date
1	DTL_Mag:PS_DCH242 (FPL CCL BS)	Bypassed	David Dunthorn (00034651)	2020-10-20
2	HEBT_Diag:BLM_Mov01 (FPAR IDmp)	Bypassed	Charles Peters (00935958)	2010-02-17
3	HEBT_Diag:BLM_Mov02 (FPAR IDmp)	Bypassed	Charles Peters (00935958)	2008-08-21
4	HEBT_Diag:BLM_Mov03 (FPAR IDmp)	Bypassed	Charles Peters (00935958)	2008-08-21
5	HEBT_Diag:BLM_Mov05 (FPAR IDmp)	Bypassed	Charles Peters (00935958)	2008-08-21
6	HEBT_Diag:BLM_Mov06 (FPAR IDmp)	Bypassed	Charles Peters (00935958)	2008-08-21
7	HEBT_Diag:BLM_Mov07 (FPAR IDmp)	Bypassed	Charles Peters (00935958)	2008-08-21
8	HEBT_Diag:BLM_Mov08 (FPAR IDmp)	Bypassed	Charles Peters (00935958)	2008-08-21
9	HEBT_Diag:Scrp02_Right (FPAR LDmp)	Bypassed	Victoria Cordina (03096374)	2022-06-17
10	HEBT_Diag:Scrp03_Left (FPL IDmp)	Bypassed	Michael Boone (03048074)	2017-11-08
11	HEBT_Diag:Scrp03_Right (FPL IDmp)	Bypassed	Michael Boone (03048074)	2017-11-08
12	IDmp_Diag:BLM_Mov01 (FPAR IDmp)	Bypassed	Charles Peters (00935958)	2008-08-21
13	PPS_RTBT:BPLS_MPS_A (FPL Tgt)	Bypassed	Geoffrey Milanovich (00956111)	2022-11-28
14	PPS_RTBT:BPLS_MPS_B (FPL Tgt)	Bypassed	Geoffrey Milanovich (00956111)	2022-11-28
15	RTBT_Diag:BLM_Mov01 (FPAR Tgt)	Bypassed	Vaughn Patania (00029392)	2011-10-27
16	RTBT_Diag:BLM_Mov02 (FPAR Tgt)	Bypassed	Charles Peters (00935958)	2011-10-27
17	RTBT_Diag:BLM_Mov03 (FPAR Tgt)	Bypassed	Charles Peters (00935958)	2008-08-21
18	RTBT_Diag:BLM_Mov04 (FPAR Tgt)	Bypassed	Charles Peters (00935958)	2010-02-17
19	Ring_Diag:BLM_AMov01 (FPAR Ring)	Bypassed	Charles Peters (00935958)	2010-02-17
20	Ring_Diag:BLM_BMov01 (FPAR Ring)	Bypassed	Charles Peters (00935958)	2008-08-21
21	Ring_Diag:BLM_BMov02 (FPAR Ring)	Bypassed	Charles Peters (00935958)	2008-08-21
22	Ring_Diag:BLM_CMov01 (FPAR Ring)	Bypassed	Charles Peters (00935958)	2008-08-21

c2y

Machine Protection System is the accelerator nerve center for operations

- For SNS there are approximately 1100 pieces of equipment connected to the system
- The MPS shows the health of the accelerator utilizing signal fault count rates

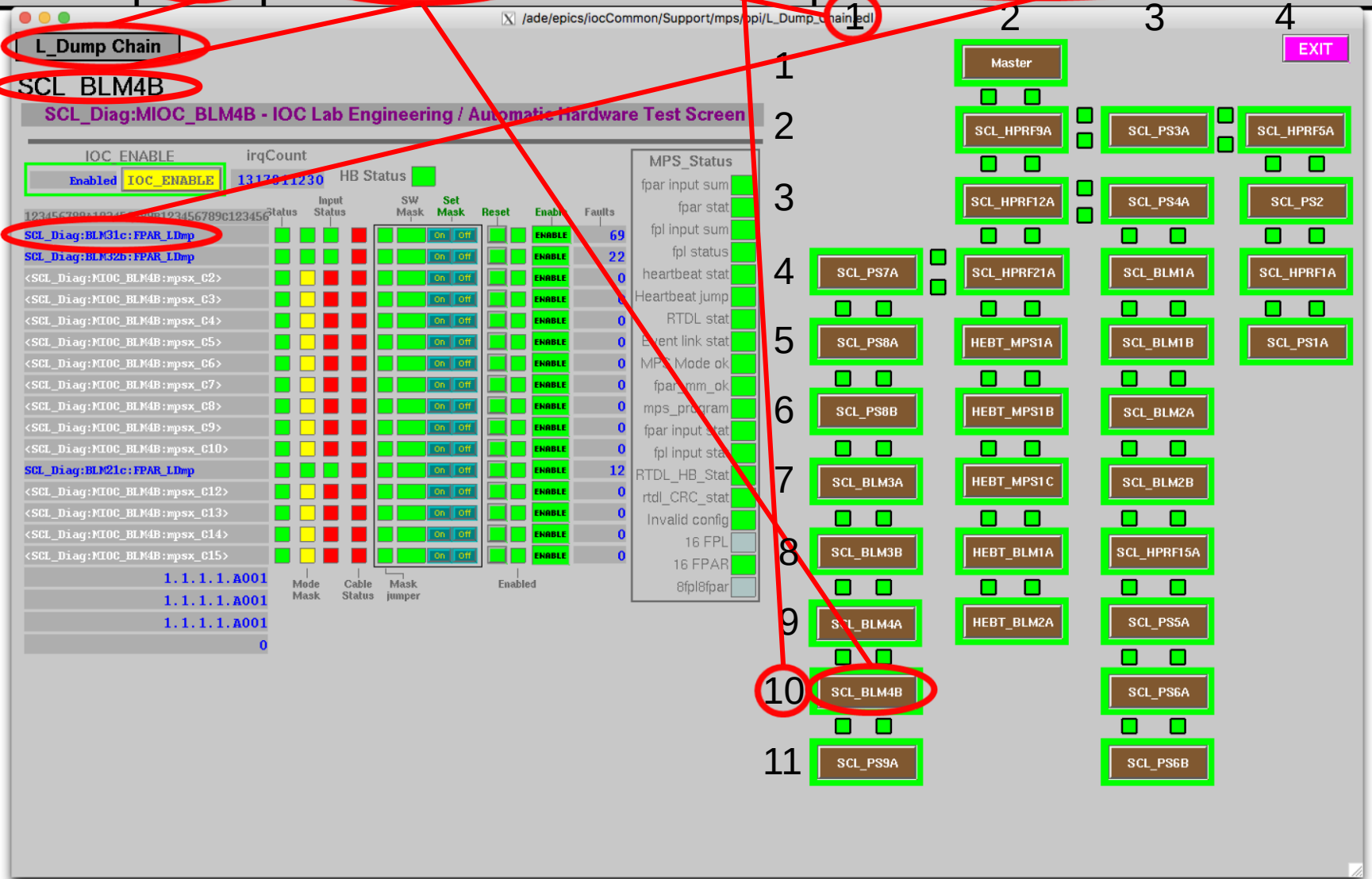


Time	Chain	Chassis	(Col , Row)	Channel
Jan 30 2023 00:29:16	LDmp	SCL HPRF30A	(1 , 12)	SCL LLRF:HPM31c:FPAR LDmp
Jan 30 2023 00:29:16	LDmp	SCL HPRF21A	(2 , 4)	LDmp MPS:FPAR SublinkCR5:FPAR LDmp
Jan 30 2023 00:28:49	LDmp	SCL HPRF30A	(1 , 12)	SCL LLRF:HPM31c:FPAR LDmp
Jan 30 2023 00:28:49	LDmp	SCL HPRF21A	(2 , 4)	LDmp MPS:FPAR SublinkCR5:FPAR LDmp
Jan 30 2023 00:28:15	LDmp	SCL HPRF30A	(1 , 12)	SCL LLRF:HPM31c:FPAR LDmp
Jan 30 2023 00:28:15	LDmp	SCL HPRF21A	(2 , 4)	LDmp MPS:FPAR SublinkCR5:FPAR LDmp
Jan 30 2023 00:28:14	LDmp	SCL HPRF30A	(1 , 12)	SCL LLRF:HPM31c:FPAR LDmp
Jan 30 2023 00:28:14	LDmp	SCL HPRF21A	(2 , 4)	LDmp MPS:FPAR SublinkCR5:FPAR LDmp

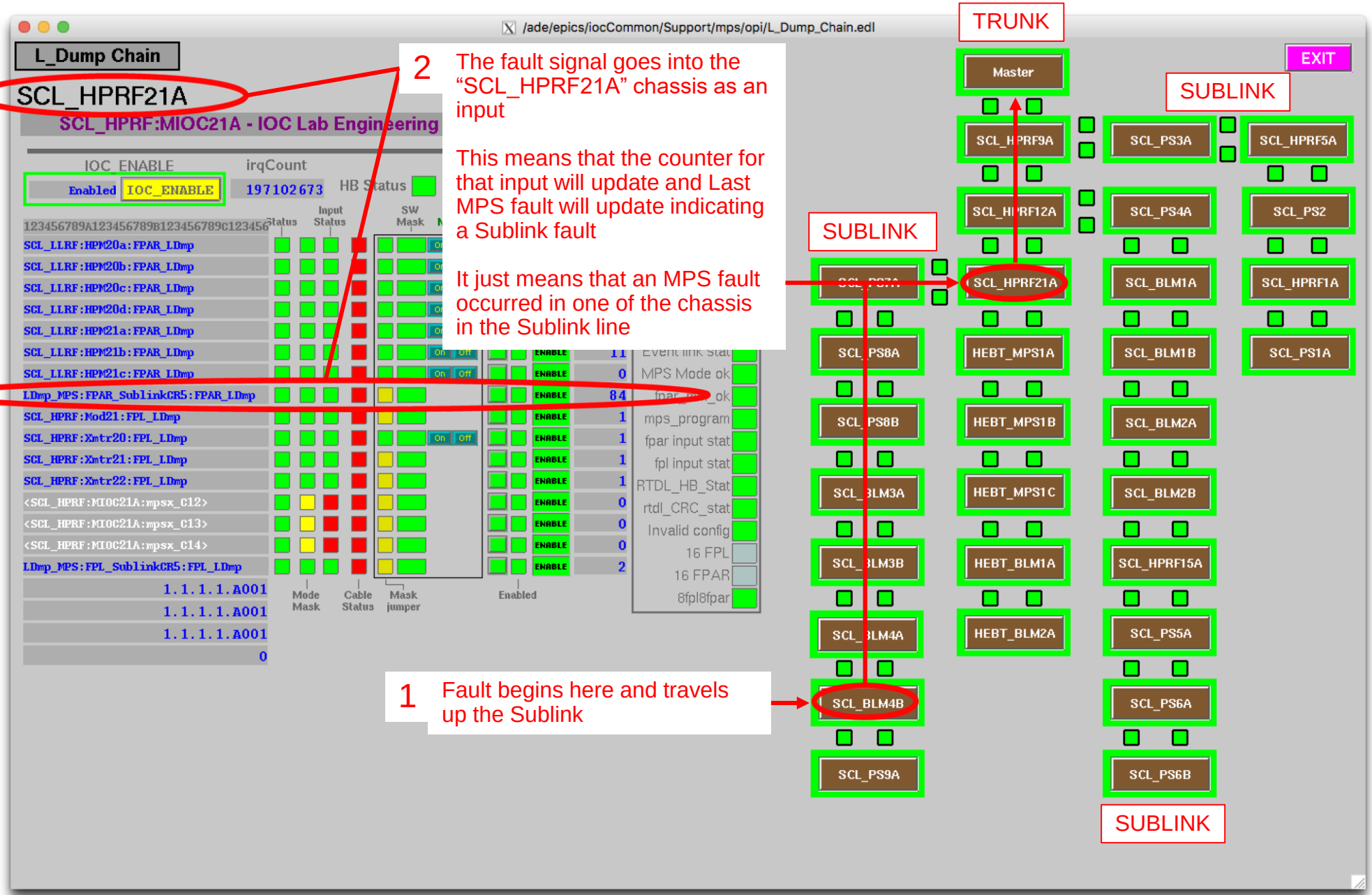
Top 10 hitters in last 200 MPS faults

Counts per Hour	Total Counts	Channel
18	43	LEBT Chop:DBCM01:FPAR MEBT BS
12	29	IDmp Diag:NCD01:FPAR IDmp
5	13	RFQ LLRF:HPM1:FPAR MEBT BS
2	5	LDmp MPS:FPAR SublinkCR5:FPAR LDmp
1	3	HEBT Mag:PS DH12t18:FPL IDmp
1	3	SCL LLRF:HPM31c:FPAR LDmp
1	3	EDmp MPS:FPL Sublink1:FPL EDmp
1	2	Ring Mag:PS QV11a12:FPL Ring
1	2	Ring Mag:PS DH A11:FPL Ring
1	2	Ring Mag:PS DH A13:FPL Ring

Timestamp	MPS Chain	MPS Chassis	MPS Chassis location on EDM screen (Column, Row)	Signal that counted
Sep 21 2018 01:51:58	LDmp	SCL_Diag_BLM4B	(1 , 10)	SCL_Diag:BLM31c:FPAR_LDmp



The Sublink fault is an effect and not the cause



EPICS first fault

- The MPS lists all faults but not the first fault or the logical cause
- Different software written to find the most logical cause for the trip using equipment information and timestamp data
- Only utilizes MPS signals so cannot find the actual root cause of the equipment failure

TRIP INFORMATION

The last recognized trip was .....

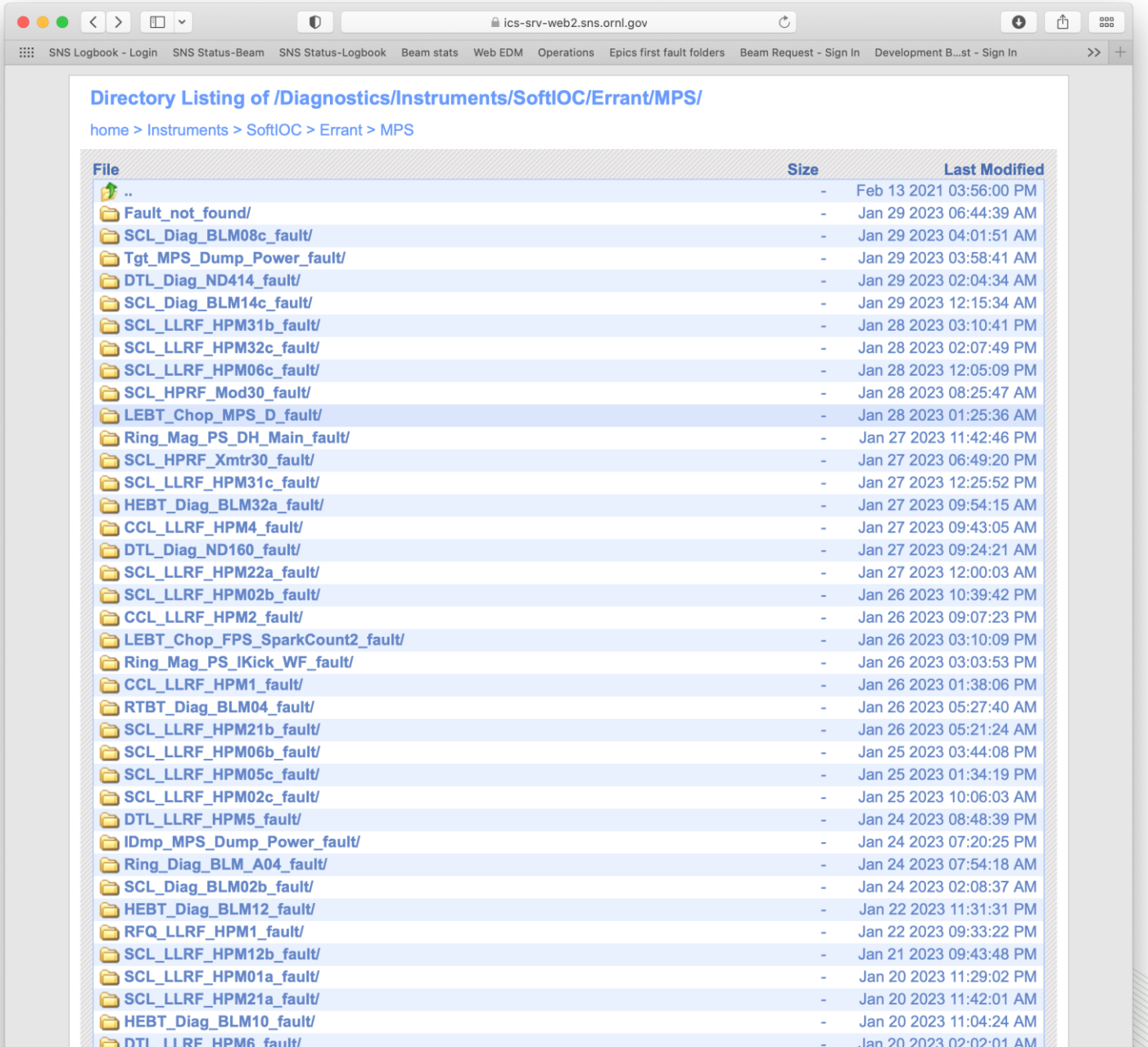
SCL_LLRF_HPM31a_fault	20230130_141537	Downtime Start Time
	20230130_142309	Repair Time End
	20230130_142309	Recovery Time End

DOWNTIME
0 = NO
1 = YES
2 = WAITING

BLM			
SCL_Diag_BLM08c_fault	20230130_135914.767459	AP Mode	2
PS			
RTBT_Mag_PS_DCH06_fault	20230130_002741.917535	AP Mode	2
LLRF			
SCL_LLRF_HPM31a_fault	20230130_141537.511209	AP Mode	2
HPRF			
Ring_HPRF_RF14b_fault	20230129_233429.731883	AP Mode	2
MOD			
SCL_HPRF_Mod01_fault	20230129_131240.57241	AP Mode	2
ION SOURCE			
Ion source plasma outage	20230106_140326.717842	AP Mode	2
VACUUM			
SCL_Vac_VSIL6_fault	20230120_114201.703856	AP Mode	2
DIAG			
HEBT_Diag_Scrp02_Up_fault	20230124_172105.152545	AP Mode	2
MISC			
Tgt_MPS_Dump_Power_fault	20230130_140709.348185	AP Mode	2

Data organized based on cause

- Data are saved into folders for postmortem analysis
  - Data trending for predictive maintenance
  - Machine learning classification



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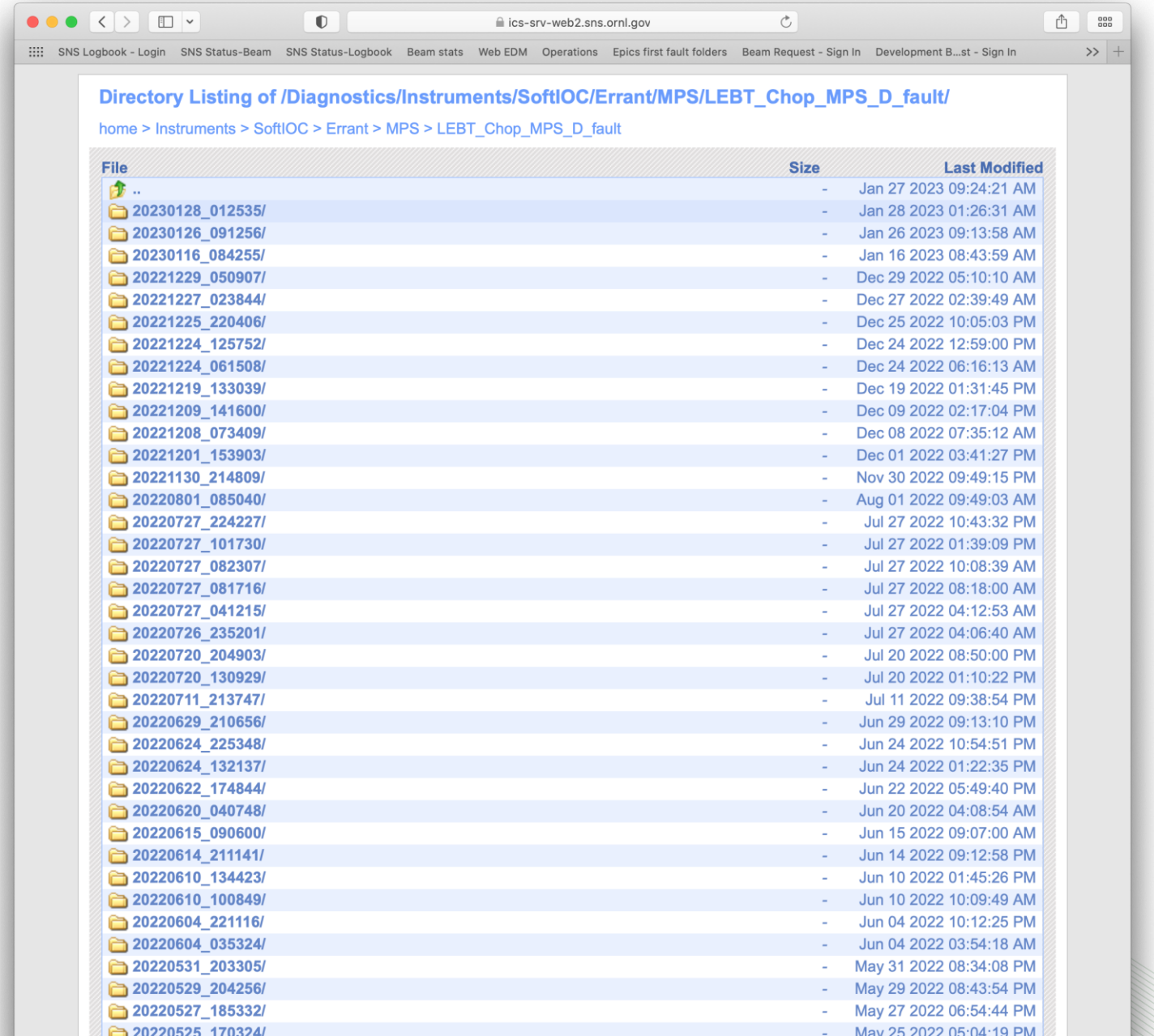

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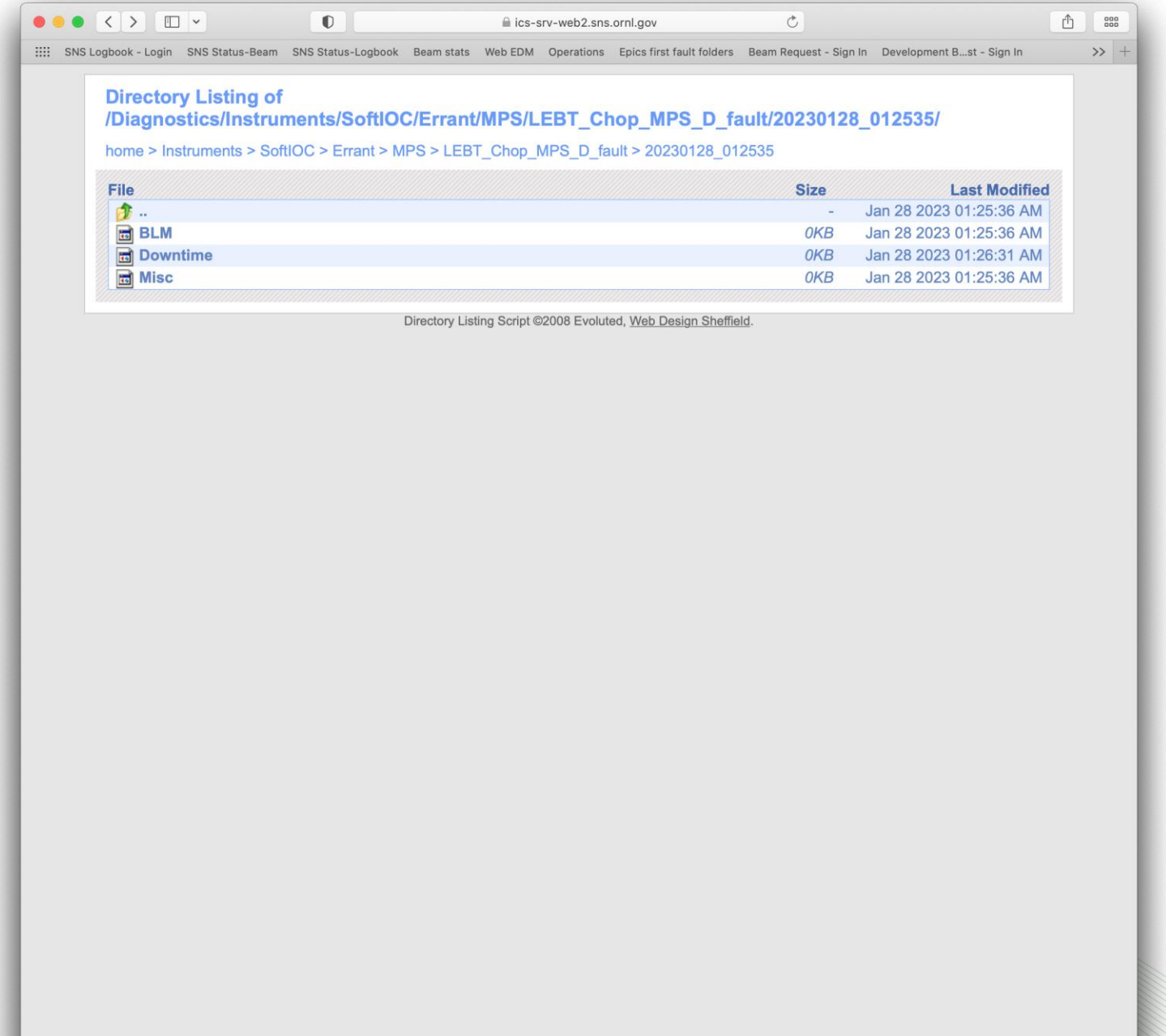

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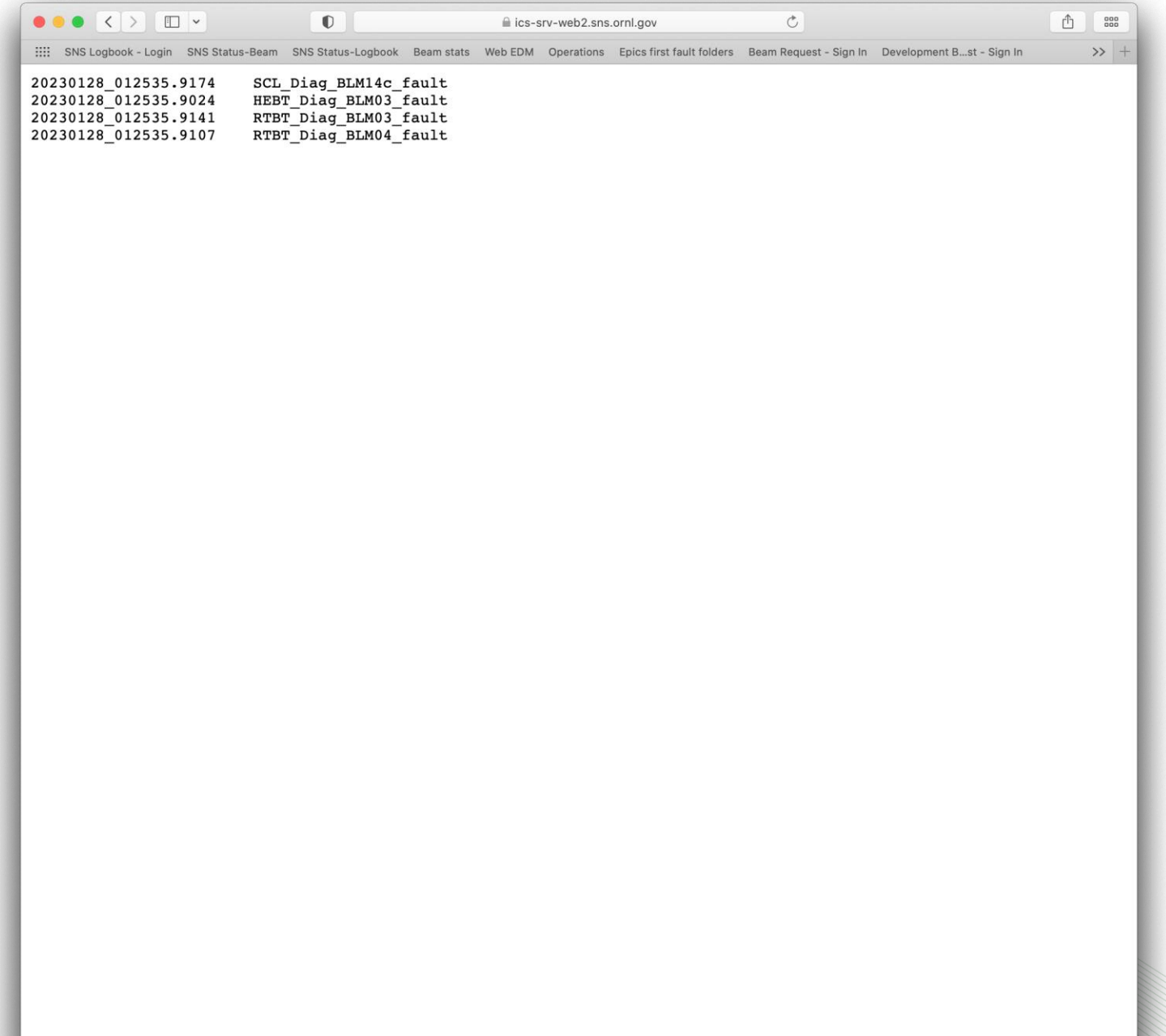

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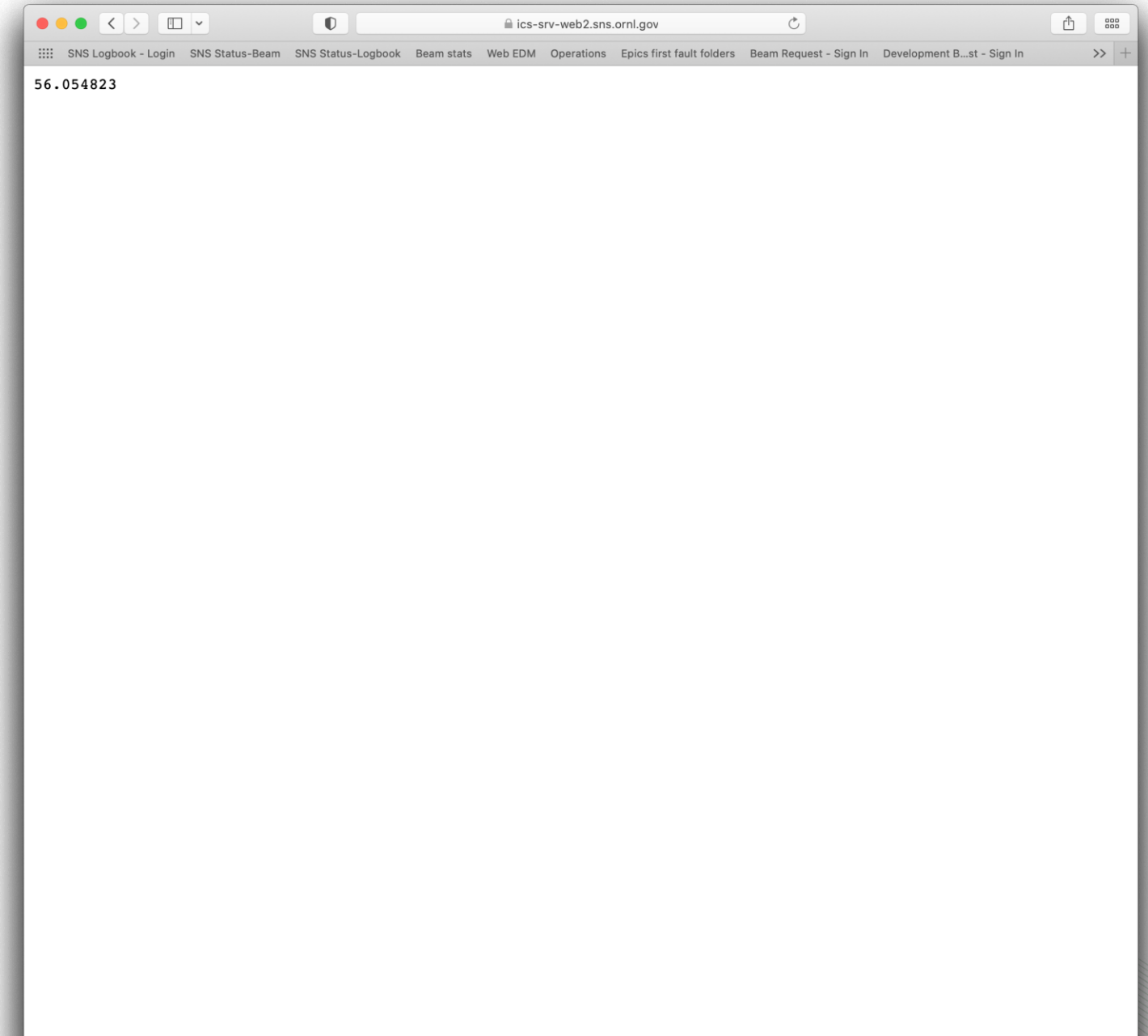

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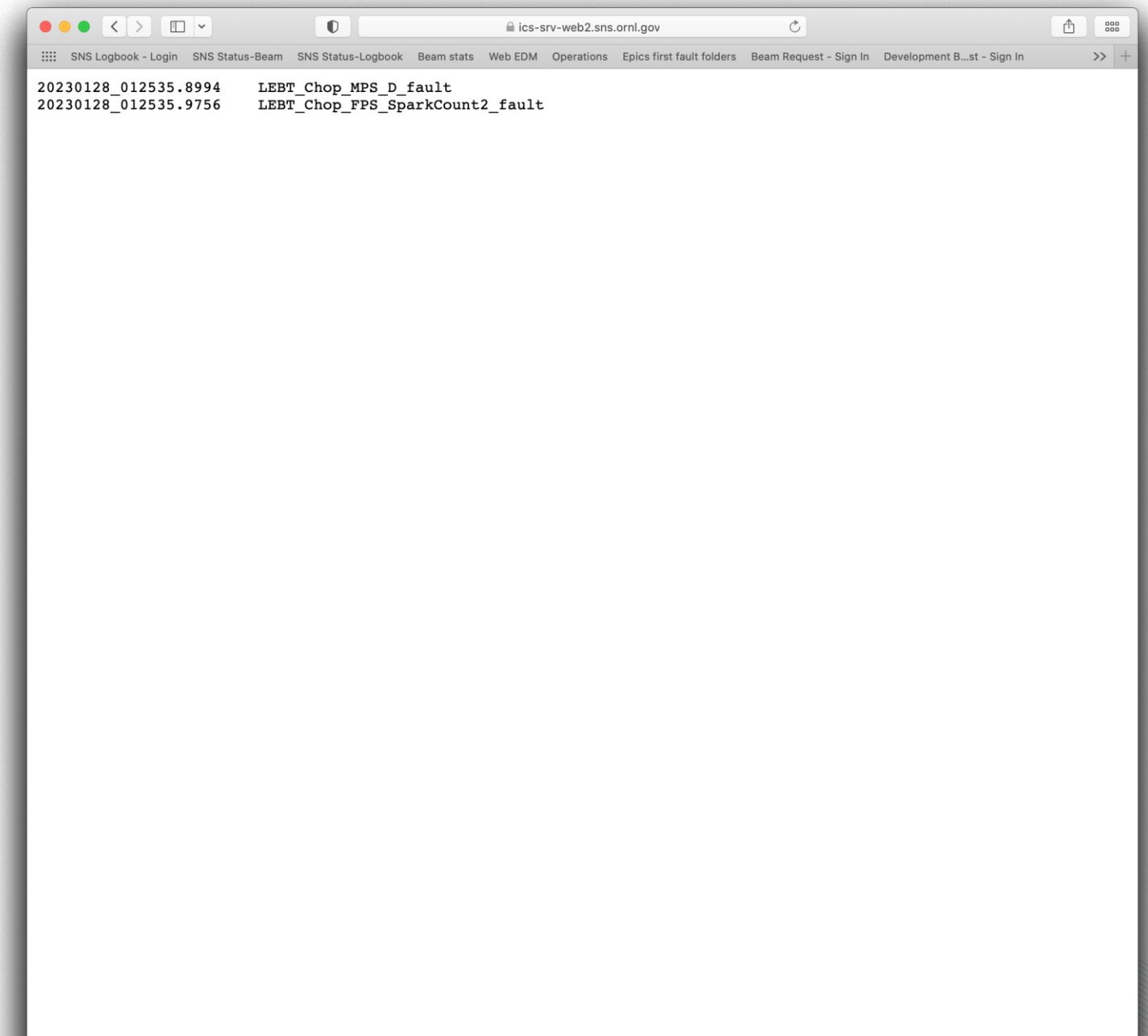

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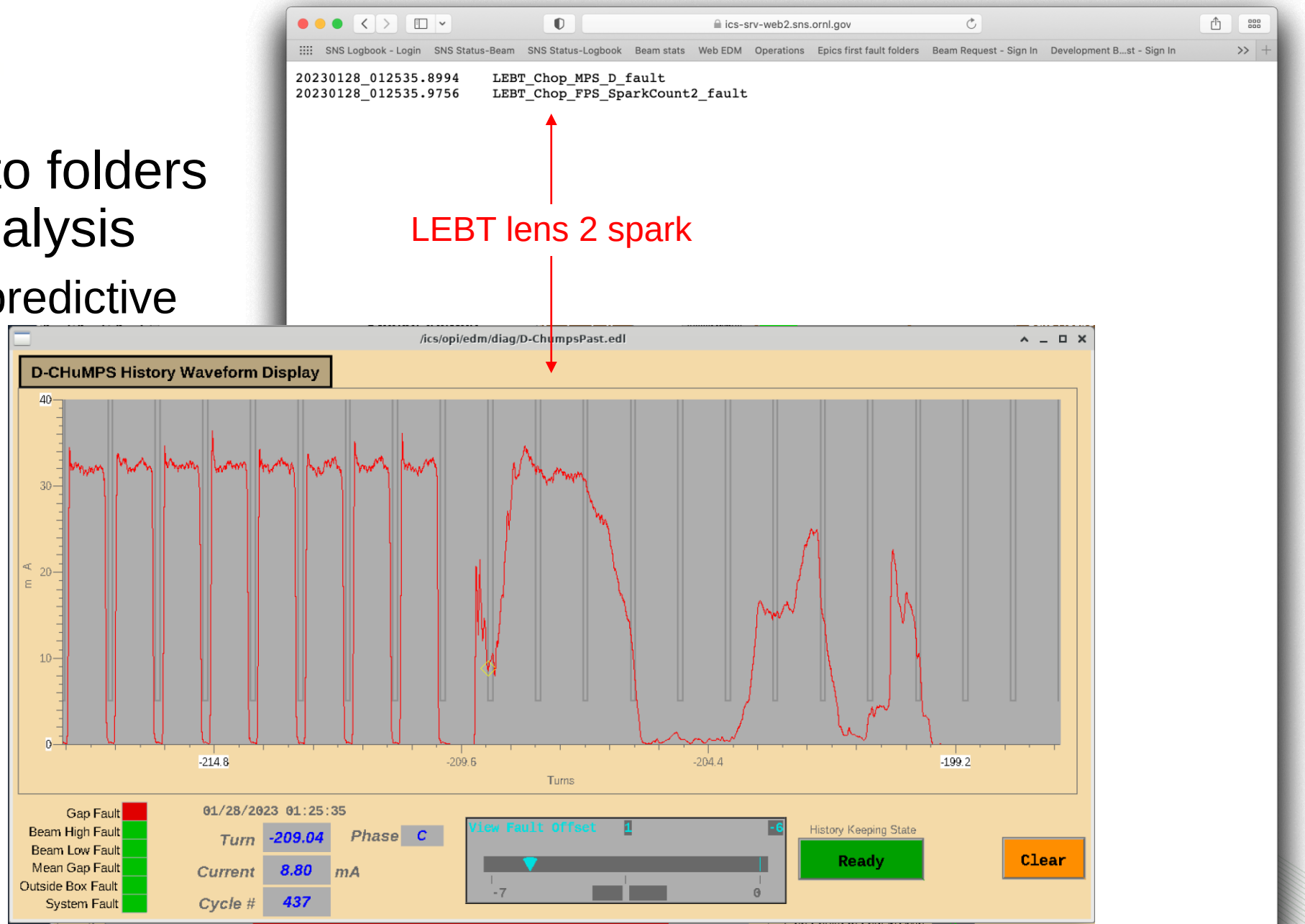


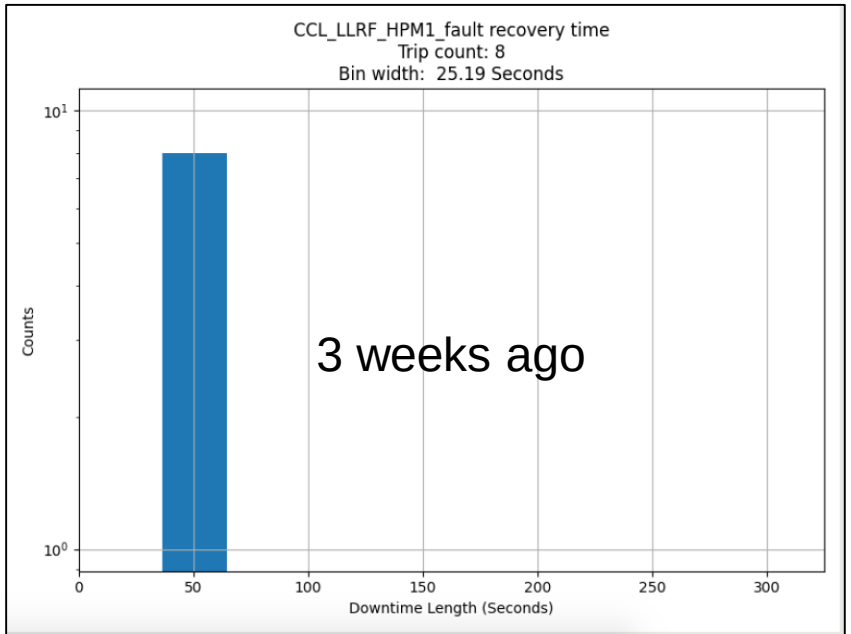
MPS data trends displayed during weekly metrics meeting

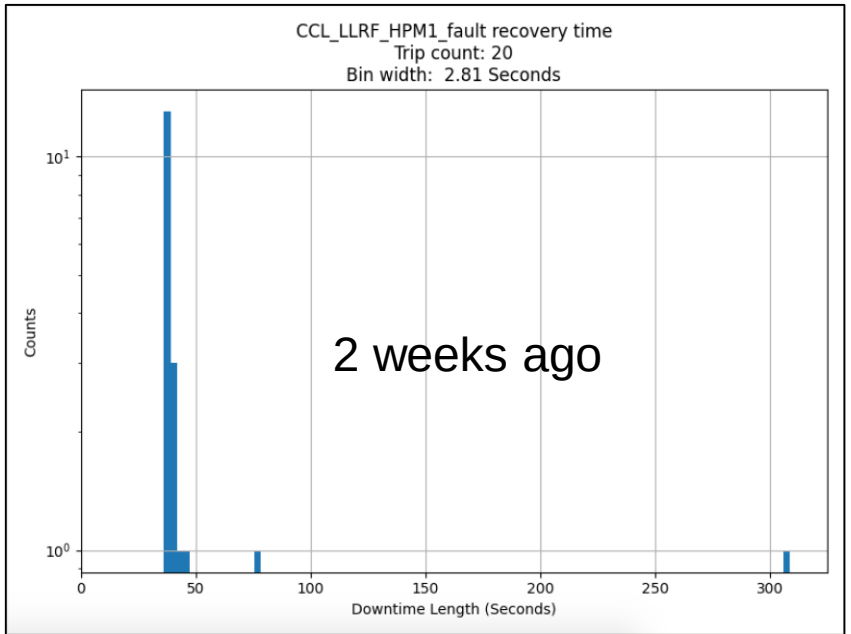
- Examine MPS fault causes and totals from the last 3 weeks
- Provide histograms of downtimes for each fault per week and last 3 weeks combined

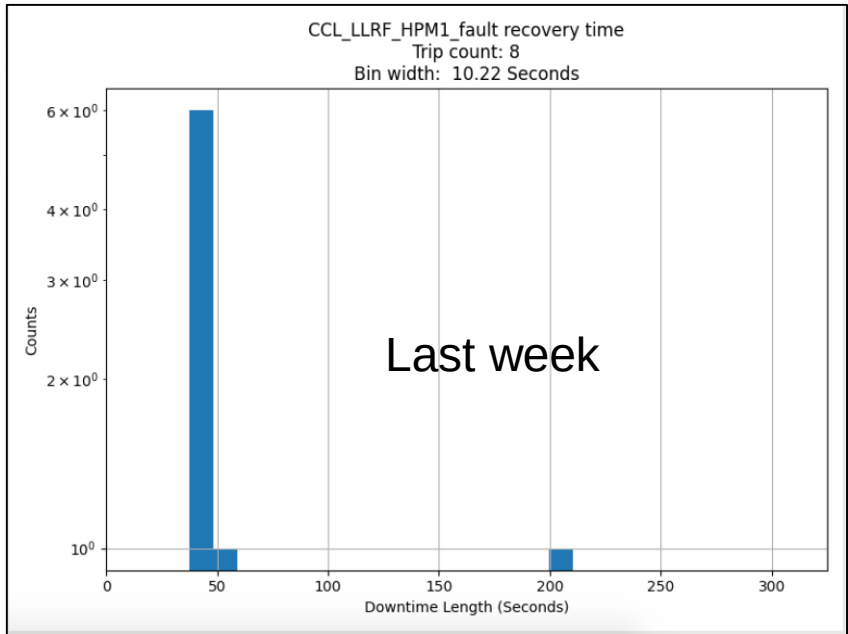
	Total Hits		
System	Last week	2 wks. ago	3 wks. ago
BLM	529	400	919
LLRF	40	50	309
PS	9	0	60
Misc	6	14	9
Vac	4	2	13
Mod	0	3	38
HPRF	0	3	23
Diag	0	0	1
Source *	0	0	0

*Source power supplies are not in the MPS so homemade PVs may be too slow to react to a source glitch

LLRF 3 wk. trends			First Hits		
System	Subsys.	Device	Last week	2 wks. ago	3 wks. ago
LLRF	HPM	CCL 1	8	20	8
LLRF	HPM	DTL 6	3	0	0
LLRF	HPM	SCL 12b	2	0	0
LLRF	HPM	CCL 2	2	1	1
HPRF 3 wk. trends					
PS 3 wk. trends					
Mag	PS	HEBT QV07	3	0	0
Mag	PS	RTBT DCV15	1	0	2
Mag	PS	RTBT DCV19	1	0	2
Mag	PS	RTBT DCV23	1	0	2





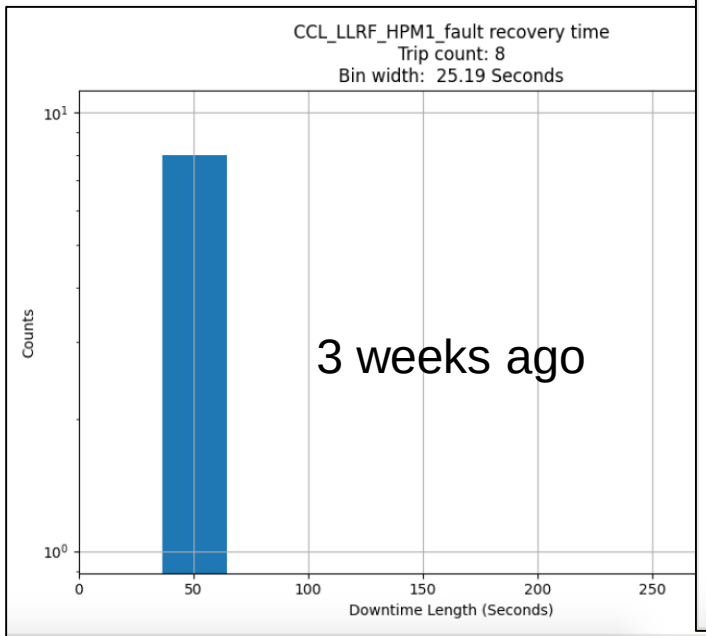


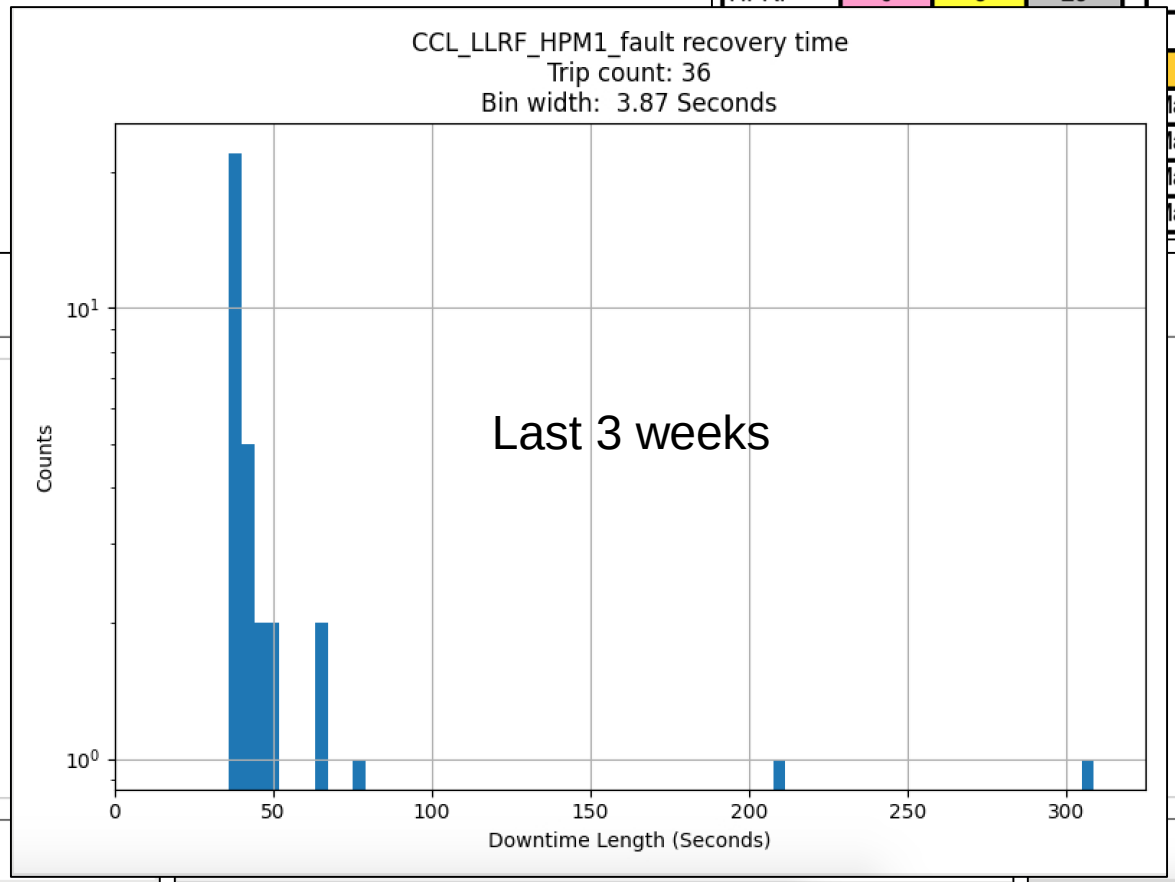
MPS data trends displayed during weekly metrics meeting

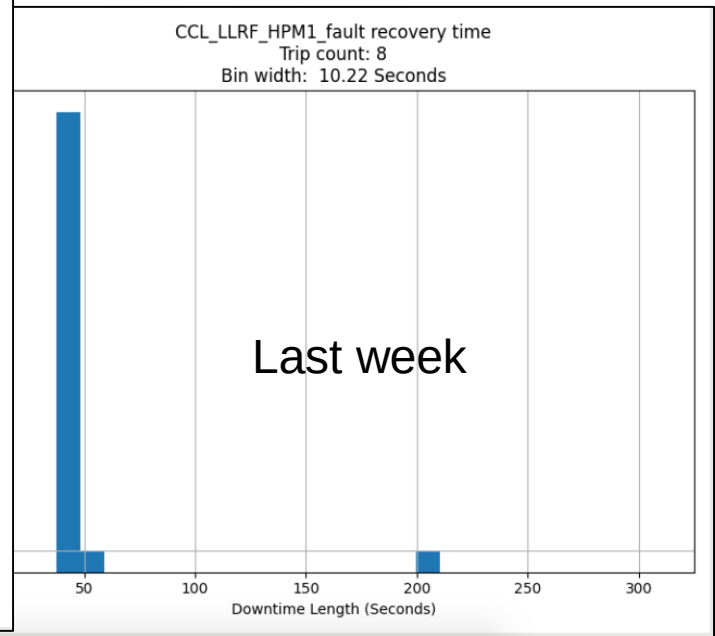
- Examine MPS fault causes and totals from the last 3 weeks
- Provide histograms of downtimes for each fault per week and last 3 weeks combined

	Total Hits		
System	Last week	2 wks. ago	3 wks. ago
BLM	529	400	919
LLRF	40	50	309
PS	9	0	60
Misc	6	14	9
Vac	4	2	13
Mod	0	3	38
HPRF	0	3	23

LLRF 3 wk. trends			First Hits		
System	Subsys.	Device	Last week	2 wks. ago	3 wks. ago
LLRF	HPM	CCL 1	8	20	8
LLRF	HPM	DTL 6	3	0	0
LLRF	HPM	SCL 12b	2	0	0
LLRF	HPM	CCL 2	2	1	1
HPRF 3 wk. trends					
PS 3 wk. trends					
lag	PS	HEBT QV07	3	0	0
lag	PS	RTBT DCV15	1	0	2
lag	PS	RTBT DCV19	1	0	2
lag	PS	RTBT DCV23	1	0	2







Summary

- The MPS is the first system operators check to figure out what is wrong
- Administrative documentation and verification safely manages the need to bypass MPS signals when needed
- Machine health can be determined using MPS data and we’re just scratching the surface