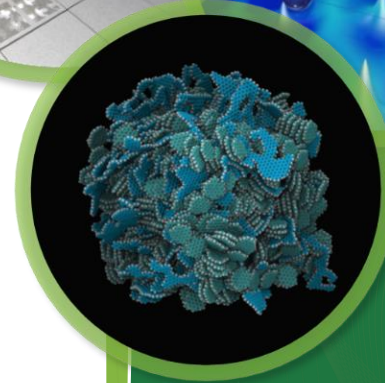
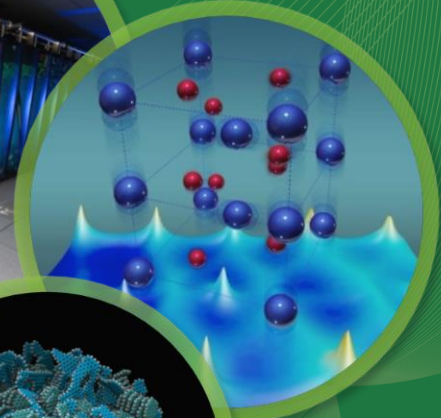


Machine Protection and Operation

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.

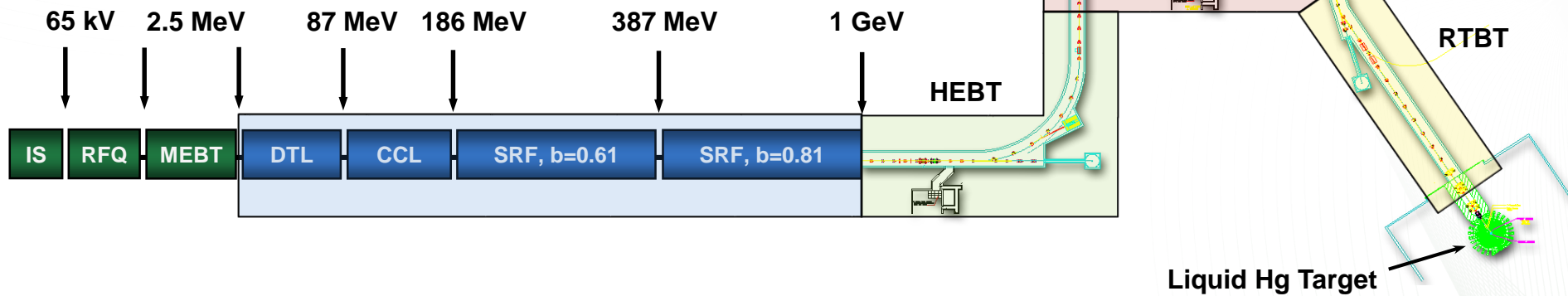
Priority #1 - Safety

- 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

Personal Protection System (PPS) tunnel segments

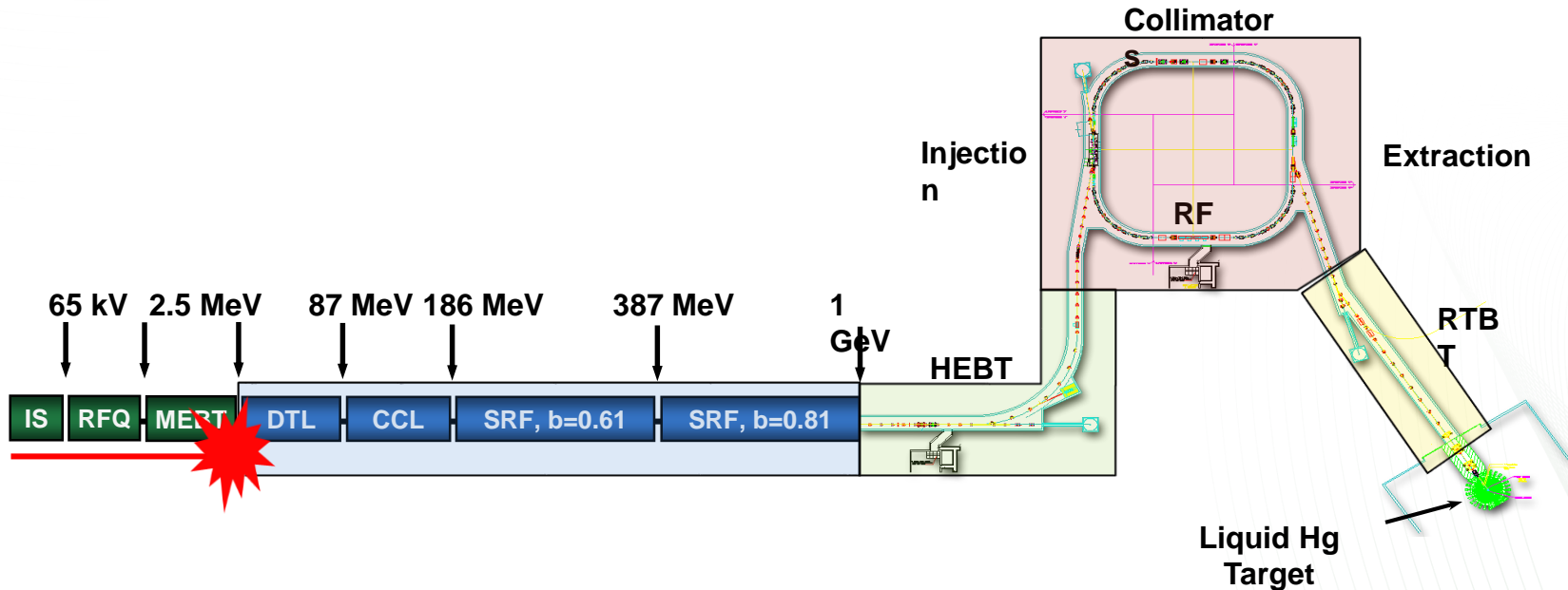


PPS Access Modes

- **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.

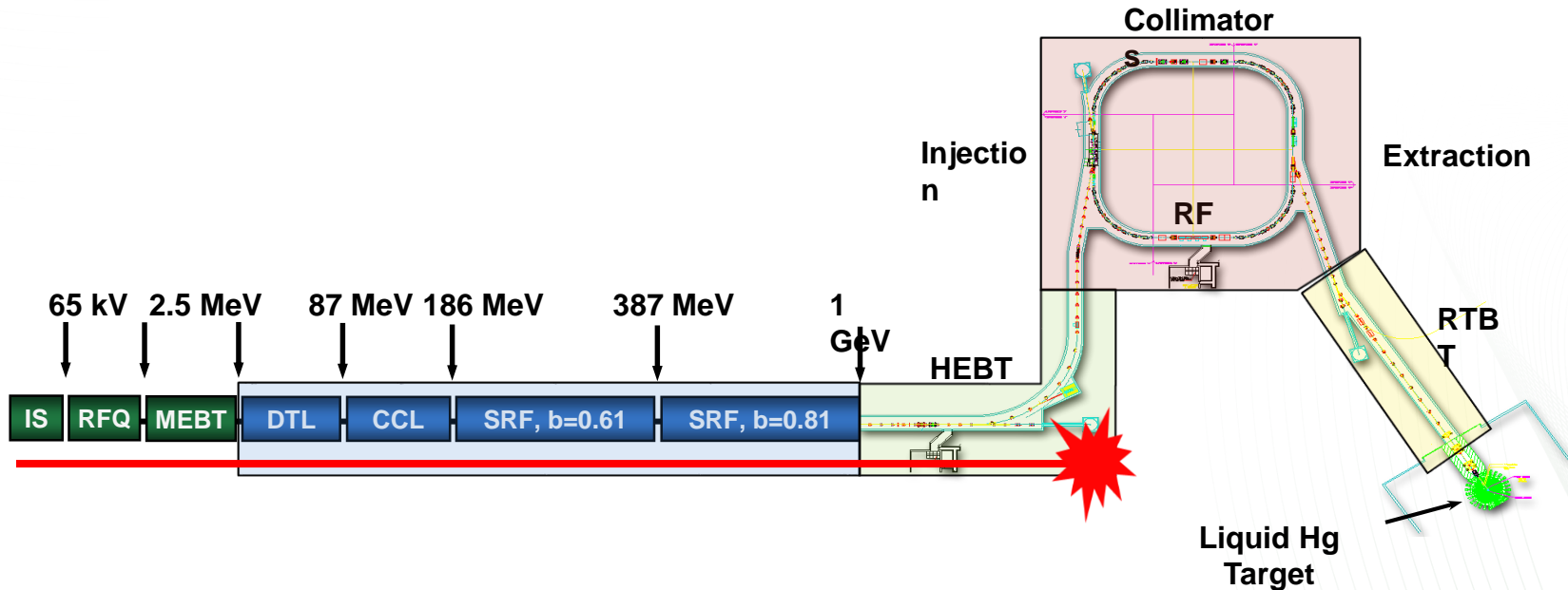
PPS Allowed Beam Modes

- 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



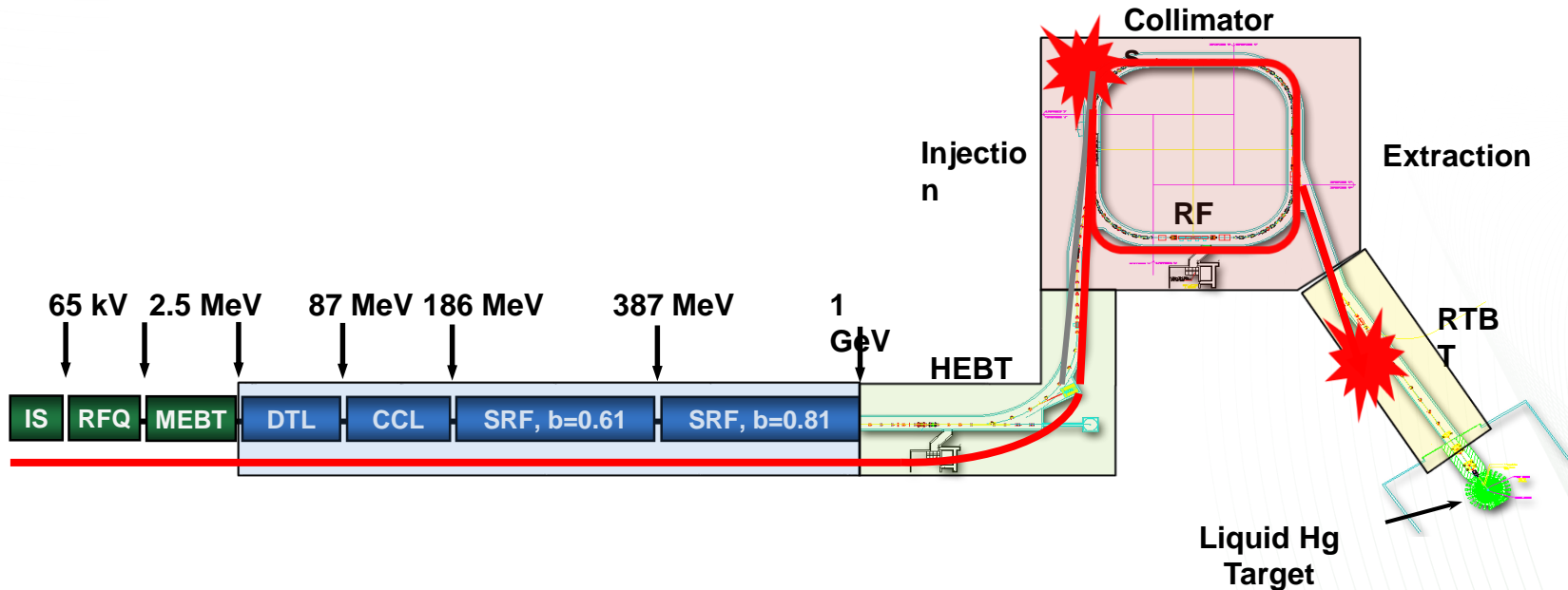
PPS Allowed Beam Modes

- 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



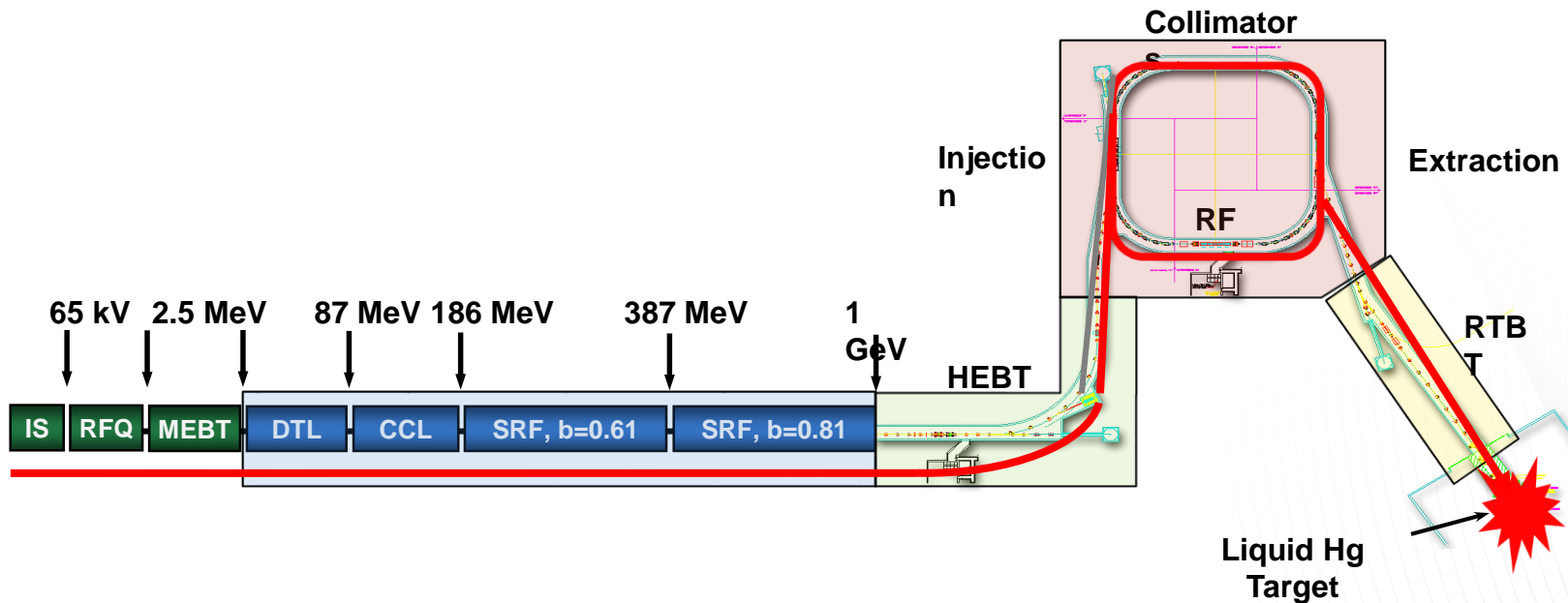
PPS Allowed Beam Modes

- 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



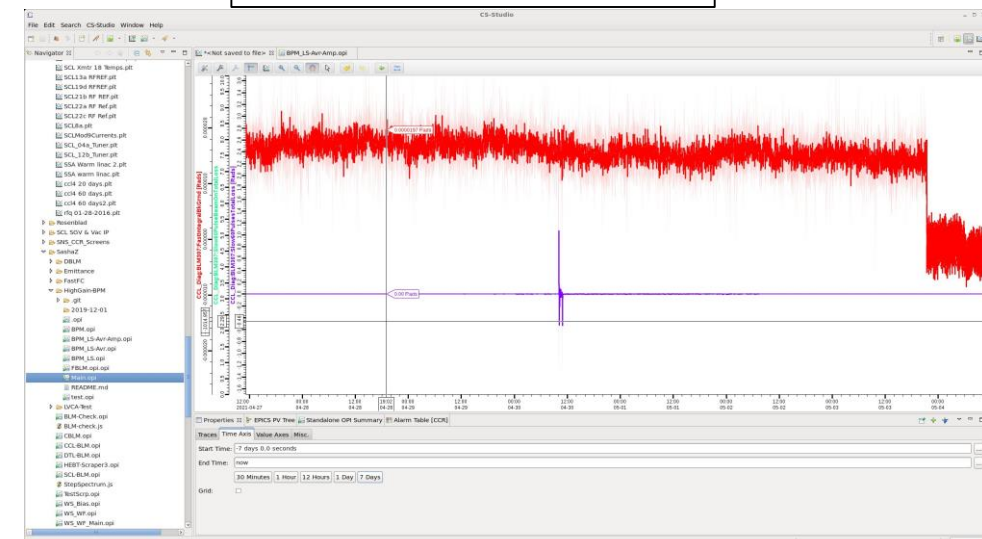
Equipment Control

- ≈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

Browser address: /ade/epics/iocTop/R3.14.8.2/snsMachine/opi/navwogif.edl

Navigation tabs: **MPS** | **IOC Status** | **Cooling Overview** | Diagnostics | ODH | PPS | MagPS | Timing | Vacuum | RF | Misc Tools | Web Links | OpenXAL | BLMs | Help

Left sidebar controls:

- RFQ 65KV Lens2 (Reset)
- PLC (MPS to PPS)
- EKicker (Reset All) | InjKicker (Reset All)
- CCR Controls
- Site Map
- CHuMPS
- Spark Counter
- Chopper Status: Connected (Connect/Disconnect)
- Current Rep-Rate: 59.9 @ 1.413 MW (PW On: 50, Max Turns: 1051)
- Continuous | Trigger | Chief Unlock | Errant Beam
- Beam Enabled | Goto 1 Hz | Ramp Up Seq | NP Beam Setup
- Goal | Down Time Rec

Smoke Alarms Section:

- Main Smoke Page
- RFQ Mod1-4, DTL Mod3-5, CCL Mod1-4 (all DISCHARGE)
- SCL Mod01, 05, 09, 12, 14, 15, 18, 21 (all DISCHARGE)
- Note: The CO2 "DISCHARGE" button remains below the associated modulator. When the smoke detector indication is present, discharge requires confirmation.

Beamline Diagram:

- Front End | DTL | CCL | Medium Beta SCL | High Beta SCL | Linac Dump
- HEBT | Vacuum | Ring | Momentum Dump | RTBT | Target
- CHL | RFTF | CUB | Ext. Air Temp. 76.0 F

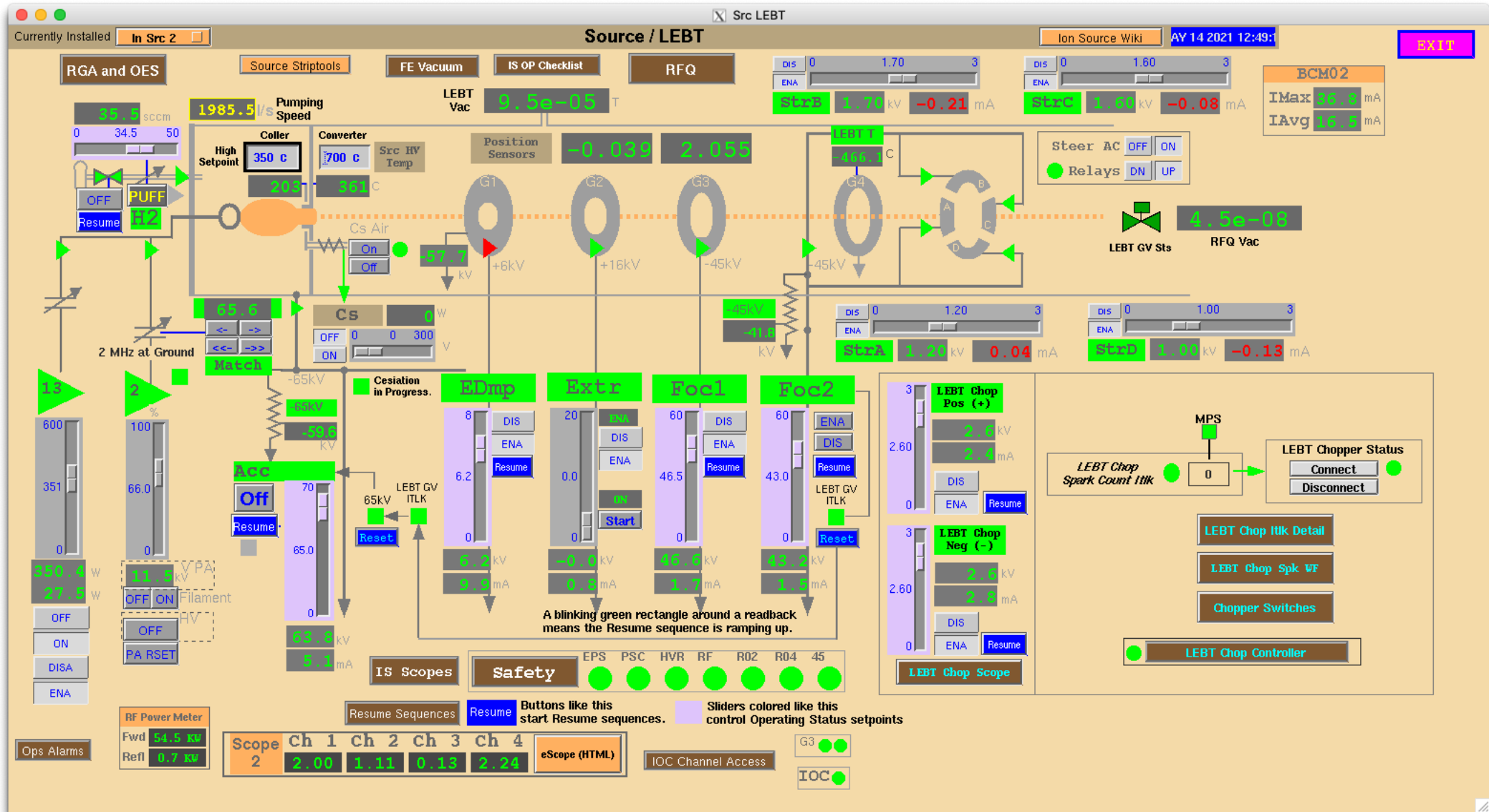
Target Temperature Data:

Beam Halo One Minute Avg Temps on Target		TPS Status	
185.9 F	343.1 F	187.0 F	65 KV OK
	352.6 F		RFQ OK

System Status:

- IDump Charge: 1.1e-06
- The last recognized trip was
- LEBT_Chop_MPS1_fault
- Time: 20210518_172133

Screens – Ion Source



Screens - RF

LLRF HPM
05/14/21 11:33:21
Main

LLRF HPM, SCL_LLRF 06c

Main

SCL 0

Status	RF Permit Inp. <input type="checkbox"/> 0 <input type="button" value="C"/>	MPS Permit Out <input type="checkbox"/> 250 <input type="button" value="C"/> (output to MPS)	<input type="button" value="Ctr.Reset"/> <input type="button" value="Hardware"/>							
	S/W RF Permit <input type="checkbox"/> Interlocks	Beam Permit <input type="checkbox"/> 101 <input type="button" value="C"/>	(all of them) <input type="button" value="Plot"/>							
Faults	<input type="checkbox"/> Chatter Faults <input type="button" value="Reset"/>	RF Permit <input type="checkbox"/>	<input type="button" value="ADC Cfg."/>							
	LLRF Permit Left <input type="checkbox"/> 0 <input type="button" value="C"/>	Hardware Error <input type="checkbox"/>								
	Center <input type="checkbox"/> 0 <input type="button" value="C"/>	ADC Error <input type="checkbox"/>								
	Right <input type="checkbox"/> 291 <input type="button" value="C"/>	Fiber Optic Arc <input type="checkbox"/>								
RF Channels	CavFld <input type="checkbox"/>	CavFwd <input type="checkbox"/>	CavRfl <input type="checkbox"/>	HOM_A <input type="checkbox"/>	HOM_B <input type="checkbox"/>	KlyFwd <input type="checkbox"/>	KlyRfl <input type="checkbox"/>	EProbe <input type="checkbox"/>	F.O.Arc Detectors <input type="checkbox"/>	Counter
Fault Count	258 <input type="button" value="C"/>	0 <input type="button" value="C"/>	1 <input type="button" value="C"/>	0 <input type="button" value="C"/>	0 <input type="button" value="C"/>	0 <input type="button" value="C"/>	0 <input type="button" value="C"/>	0 <input type="button" value="C"/>	Ch5 <input type="checkbox"/> <input type="button" value="Ignore"/> 0 <input type="button" value="C"/>	Ch6 <input type="checkbox"/> <input type="button" value="Ignore"/> 0 <input type="button" value="C"/>
ADC Test/Ovrlw.	<input type="checkbox"/> enabled	<input type="checkbox"/> enabled	<input type="checkbox"/> enabled	<input type="checkbox"/> enabled	<input type="checkbox"/> enabled	<input type="checkbox"/> enabled	<input type="checkbox"/> enabled	<input type="checkbox"/> ignored	Ch7 <input type="checkbox"/> <input type="button" value="Ignore"/> 0 <input type="button" value="C"/>	Ch8 <input type="checkbox"/> <input type="button" value="Ignore"/> 0 <input type="button" value="C"/>
ADC Data	0.000 W	0.005 kW	0.005 kW	0.000 W	0.000 W	0.002 kW	0.002 kW	-0.1 uA	Ch9 <input type="checkbox"/> <input type="button" value="Ignore"/> 0 <input type="button" value="C"/>	Ch10 <input type="checkbox"/> <input type="button" value="Ignore"/> 0 <input type="button" value="C"/>
Snapshot	0.150 W	106.362 kW	98.510 kW	0.000 W	0.000 W	99.373 kW	0.294 kW	-0.0 uA	Ch11 <input type="checkbox"/> <input type="button" value="Ignore"/> 0 <input type="button" value="C"/>	Ch12 <input type="checkbox"/> <input type="button" value="Ignore"/> 0 <input type="button" value="C"/>
Self Test Thresh.	<input type="button" value="1 counts"/>	<input type="button" value="1 counts"/>	<input type="button" value="1 counts"/>	<input type="button" value="1 counts"/>	<input type="button" value="1 counts"/>	<input type="button" value="1 counts"/>	<input type="button" value="1 counts"/>	<input type="button" value="1 counts"/>	Ch13 <input type="checkbox"/> <input type="button" value="Ignore"/> 0 <input type="button" value="C"/>	F.O. Arc Chassis <input type="button" value="Lamp Off"/>
HIGH Fault Thresh.	<input type="button" value="0.650 W"/>	<input type="button" value="600.000 kV"/>	<input type="button" value="600.000 kV"/>	<input type="button" value="2.000 W"/>	<input type="button" value="5.000 W"/>	<input type="button" value="600.000 kV"/>	<input type="button" value="9.000 kW"/>	<input type="button" value="60.000 uA"/>	Double/Triple LEDs: Left : Fault in last minute Middle: Fault in last seconds Right : Hardware register.	
HIGH Fit Trip Del.	<input type="button" value="3 us"/>	<input type="button" value="3 us"/>	<input type="button" value="12 us"/>	<input type="button" value="3 us"/>	<input type="button" value="3 us"/>	<input type="button" value="3 us"/>	<input type="button" value="12 us"/>	<input type="button" value="3 us"/>		
Cavity OK Min	0.103 W	<input type="button" value="Clear"/>	Fill Time Delay	<input type="button" value="250 us"/>	SRF Tune Delay:	<input type="button" value="0 us"/>			Peak	Limit
Cavity OK Min	<input type="button" value="80 %"/>	NCL: Power, SCL: % of amplitude setpoint	Refer to FCM operations screen for auto-setting of HPM delays.				...on error...	<input type="button" value="1.06 %"/>	<input type="button" value="6.25 %"/>	<input type="button" value="Ignore"/>

Kill RF

RF Power Width

Phase

Cryo

Liquid Level

Beam Pipe Coupl.

Loop Opened

Limit Fwd Pwr to for

05/13/21 12:33:29 Output clipped 1 times

05/13/21 12:33:35 Wrote 06c snapshot

05/13/21 12:34:02 Wrote 06c snapshot

05/13/21 12:34:22 Wrote 06c snapshot

05/13/21 18:36:48 Output clipped 1 times

Screens – SCL Magnet Power Supplies

POWER SUPPLY STATUS

Itlk	PS Name	Mode Select	Channel Status	Control Status	PS Status	Set I	Set B	I	V	ISET	IERR	B	B of QH	B of QV	B Book
1	SCL_Mag_PS_QH00	ON OFF STANDBY	Enabled	Remote	OK	426.421	18.370	426.434	10.396	427.065	3.125	18.371			18.530
1	SCL_Mag_PS_QV00	ON OFF STANDBY	Enabled	Remote	OK	411.722	17.768	414.200	9.690	412.131	2.905	17.874			17.340
1	SCL_Mag_PS_QD01	ON OFF STANDBY	Enabled	Remote	OK	282.000	4.374	280.061	9.911	281.261	3.145	4.344	4.344	4.343	4.470
1	SCL_Mag_PS_QD02	ON OFF STANDBY	Enabled	Remote	OK	284.500	4.412	283.062	10.110	282.501	2.932	4.389	4.378	4.379	4.340
1	SCL_Mag_PS_QD03	ON OFF STANDBY	Enabled	Remote	OK	299.000	4.635	307.432	11.024	299.671	3.170	4.765	4.768	4.772	4.540
1	SCL_Mag_PS_QD04	ON OFF STANDBY	Enabled	Remote	OK	241.000	3.743	241.569	8.717	241.130	3.032	3.756	3.754	3.755	3.800

SETPOINTS

READBACKS

SCL_Mag:PS_QD18 PS Detail (op)

Control

ON OFF STANDBY

RESET RECAL

Setpoints

Current: 248.000

Tolerance: 2.000

Average Count: 1

Readbacks

Current: 426.434

Setpoint: 426.421

Voltage: 10.396

Error: 3.098

Diff: 1.361

Time Stamp: 11:34:18

Glbl Time: 11:34:18

PSI DAC: 181254.00

PSC Status

- SWITCH ERROR
- CURRENT TOL
- MEMORY STOPPED
- MEMORY EMPTY
- TRIGGER LOST
- CHANNEL DISABLED
- CRC ERROR
- TRANS TIMEOUT
- CARRIER LOST
- TRIGGER OVERLAP
- BUFFER AVAILABLE
- COMMAND AVAILABLE
- SETPOINT AVAILABLE
- MEMORY BUFFER FULL

Common Power Supply Status Bits

- ON
- OFF
- STANDBY
- REMOTE MODE
- FAULT SUMMARY

Detailed Fault Status by Manufacturer

Alpha

- Output Fault (Over Current/Voltage/Ripple)
- Not Used
- Out of Regulation
- DGND
- Cooling Fault (Flow/Temp/Water)
- External Interlock
- Load Fault (Klixon Magnet Temp)
- DGND
- Ground Fault
- Current Limit Status
- Phase Loss

PSC Control

Channel: ENABLED

Time: RESET

Sample Mode

STOP CONT BURST

Do not use quickset Off or Stdby WHEN Beam is ON

MAY 14, 2021 11:34:18

SCL Quad Power Supply Controls

Machine Status

Machine Mode: STANDBY

Beam Mode: ON

Set Magnetic Field(Tesla): 18.370

Field Rdbk(Tesla): 18.371 T

Set Current(Amps): 426.421

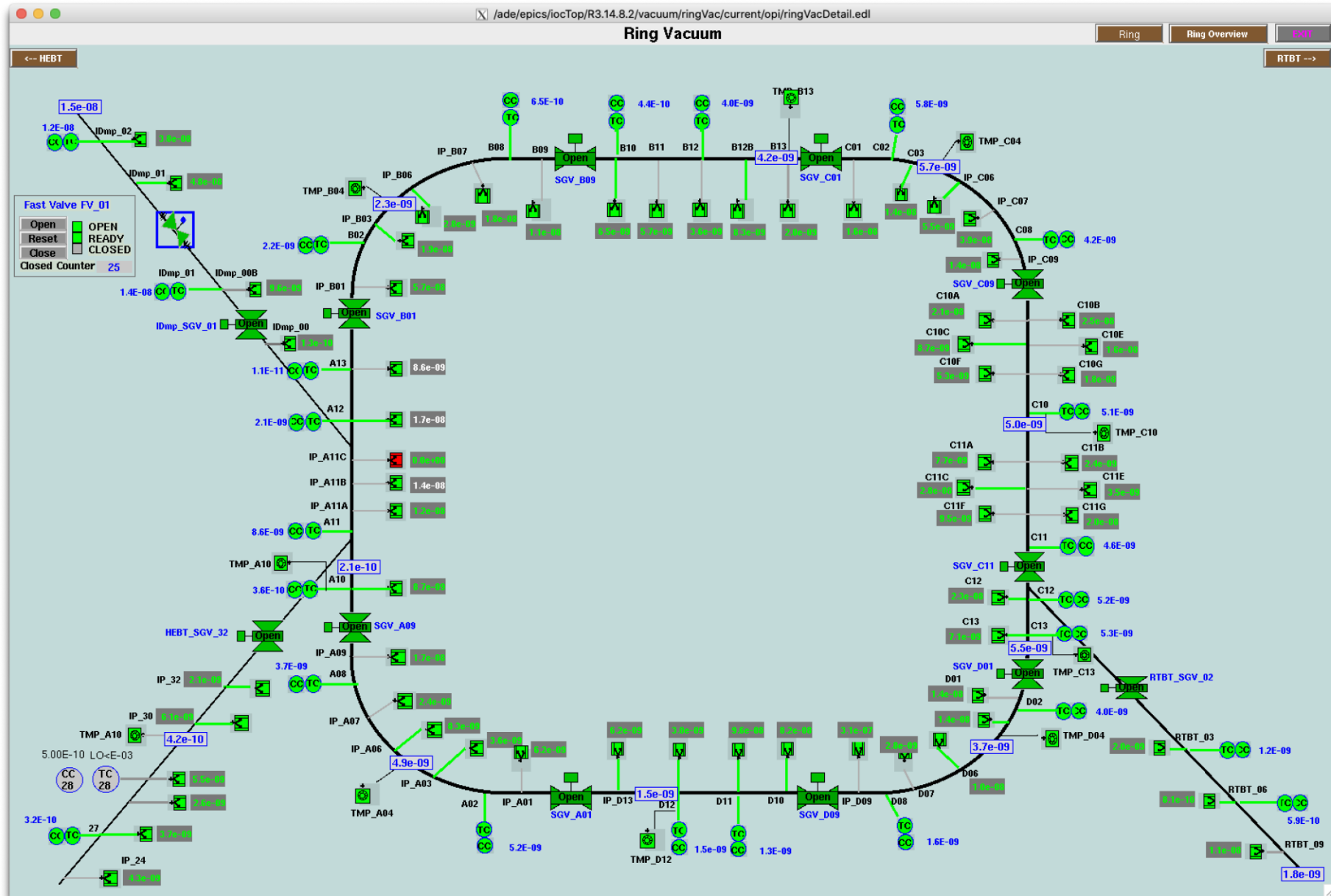
Current Rdbk(Amps): 426.434 Amps

B->MPS Int'l: 20.207 T

HH: 20.207 T

LL: 16.533 T

Screens – Ring Vacuum



SCORE – Save, Compare, Restore Variables

[SNS Production XAL] - Score

File Edit View Special Window Help

Snap n save Restore Selected Red Threshold

Select Systems:

- CCL
- CF
- DTL
- EDmp
- HEBT
- ICS
- IDmp
- LDmp
- LEBT
- MEBT
- RFQ
- RTBT
- Ring
- SCL
- Src

Select Subsystems:

- BLM
- Chop
- Foil
- HPRF
- Mag
- RF
- Scrp
- Src
- Steer
- Tim
- TP
- Tim

Select All

Open Score

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

Snapshot taken: 2021-05-02 00:51:08.0, 6.N-1 Doc - MB, bk

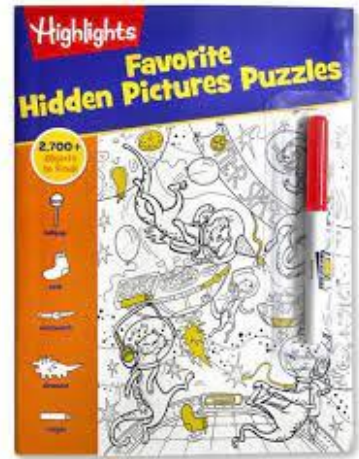
Some channels are not connected - see console output

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

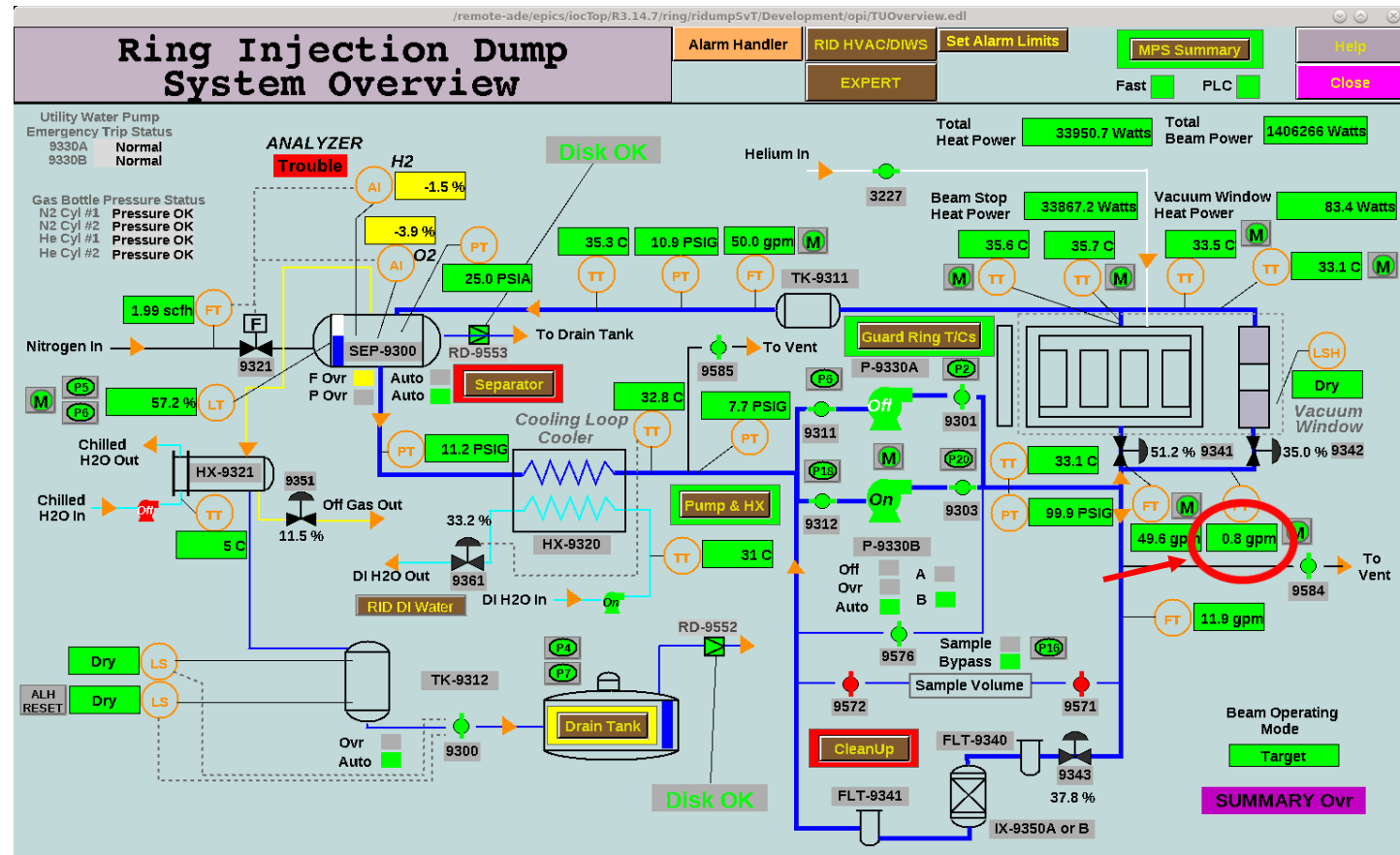
Don't know which input is faulting

Don't know which signal is which on the screen

Don't know interlock levels

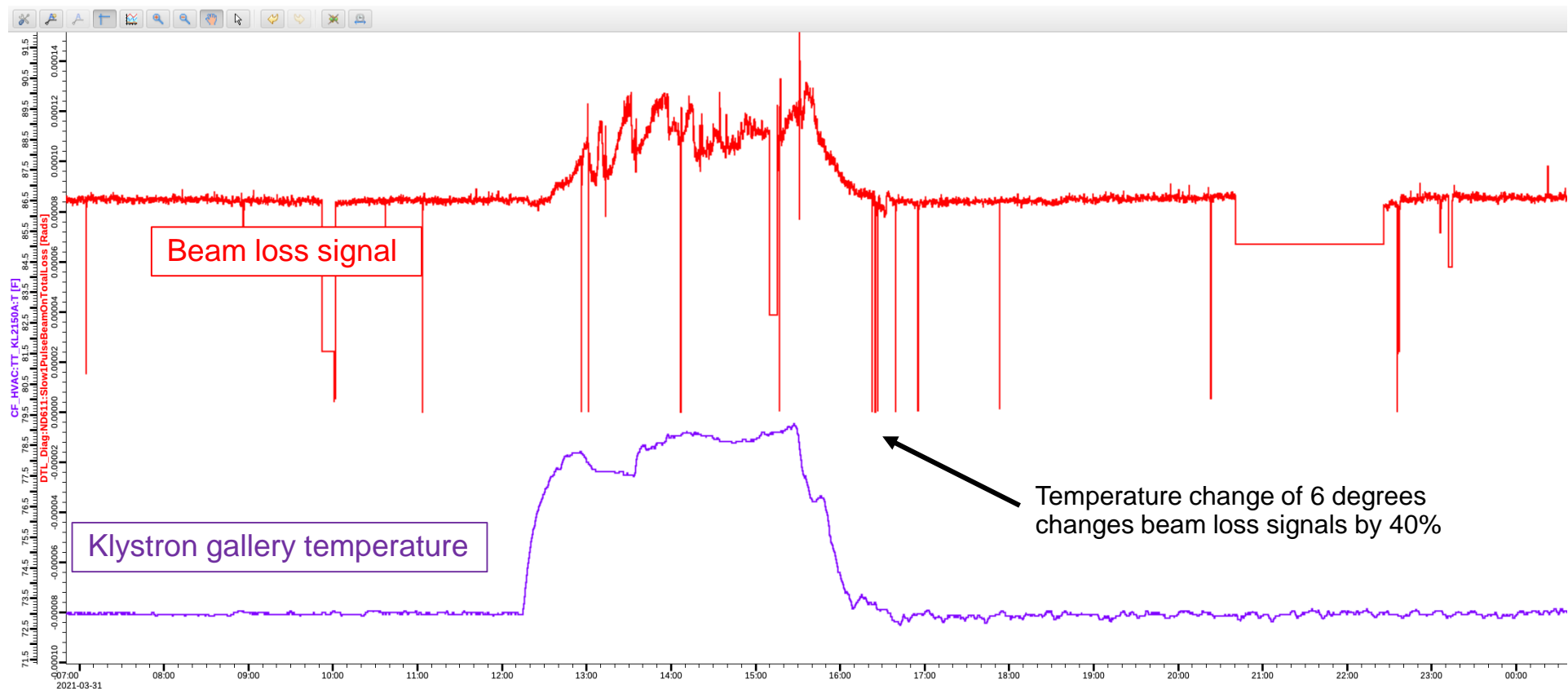
Alarm Indication

- 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



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
- Operators 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

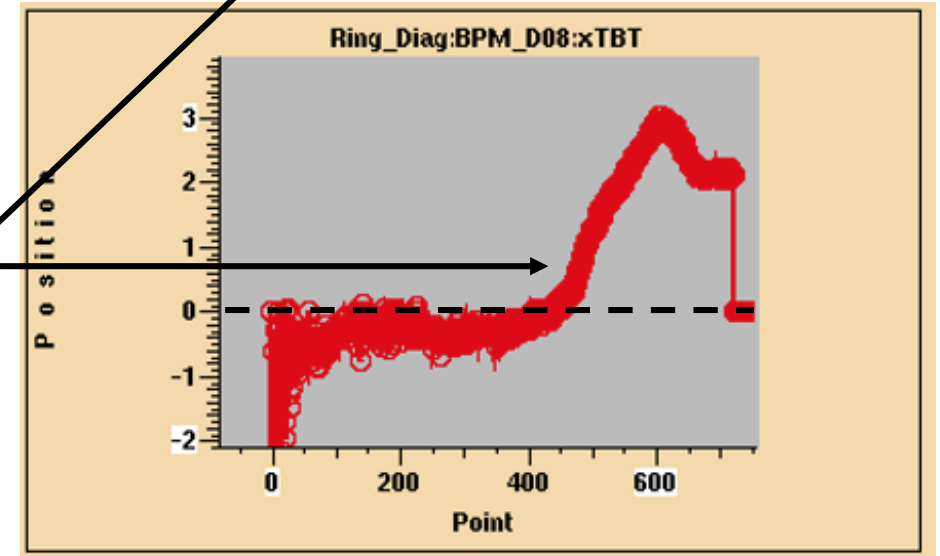
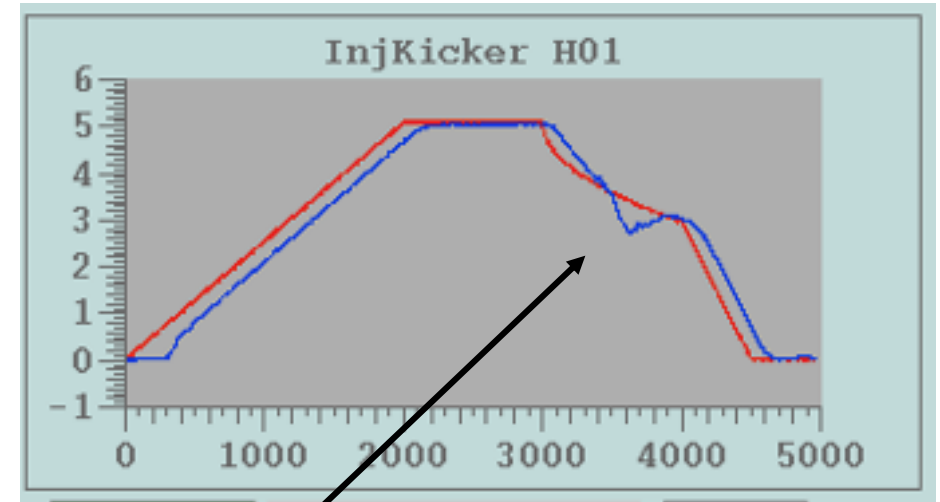


Beam Moves the.....Beam?

- 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

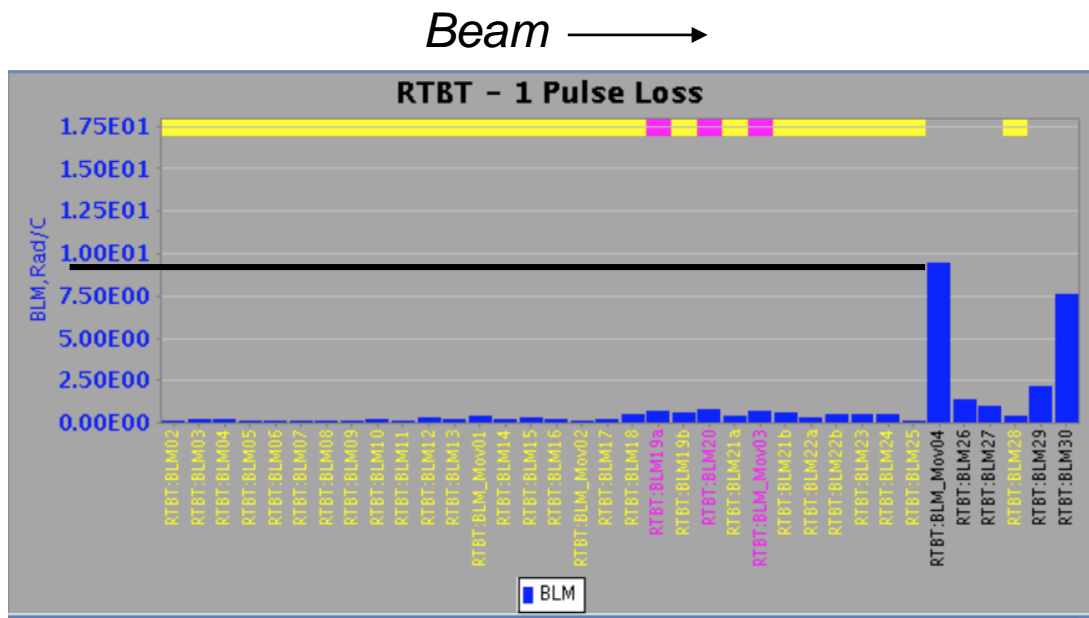
As the beam grows it begins to affect itself and starts shifting it's own position

Red is waveform to follow
Blue is the readback

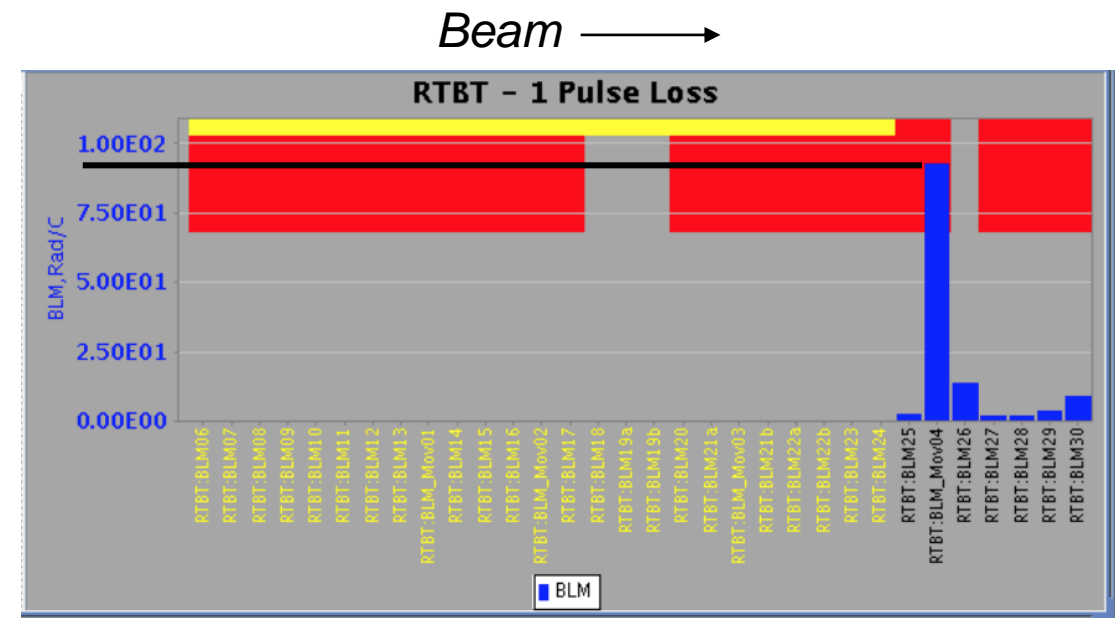


Things That Can Go Wrong After Maintenance

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



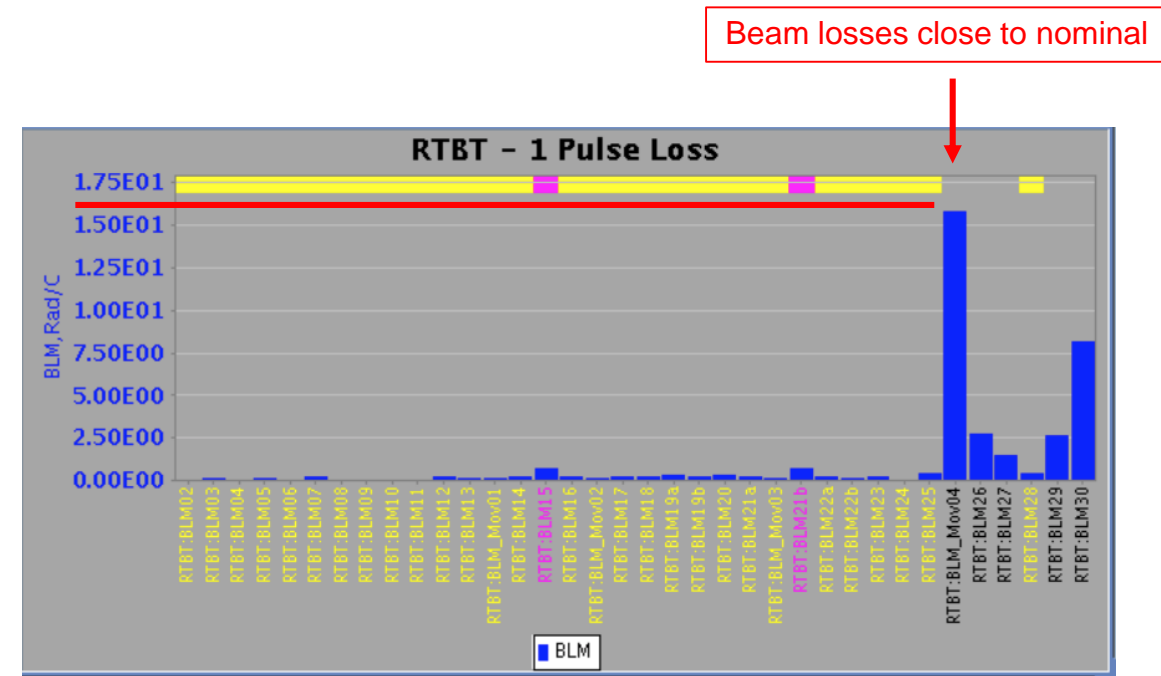
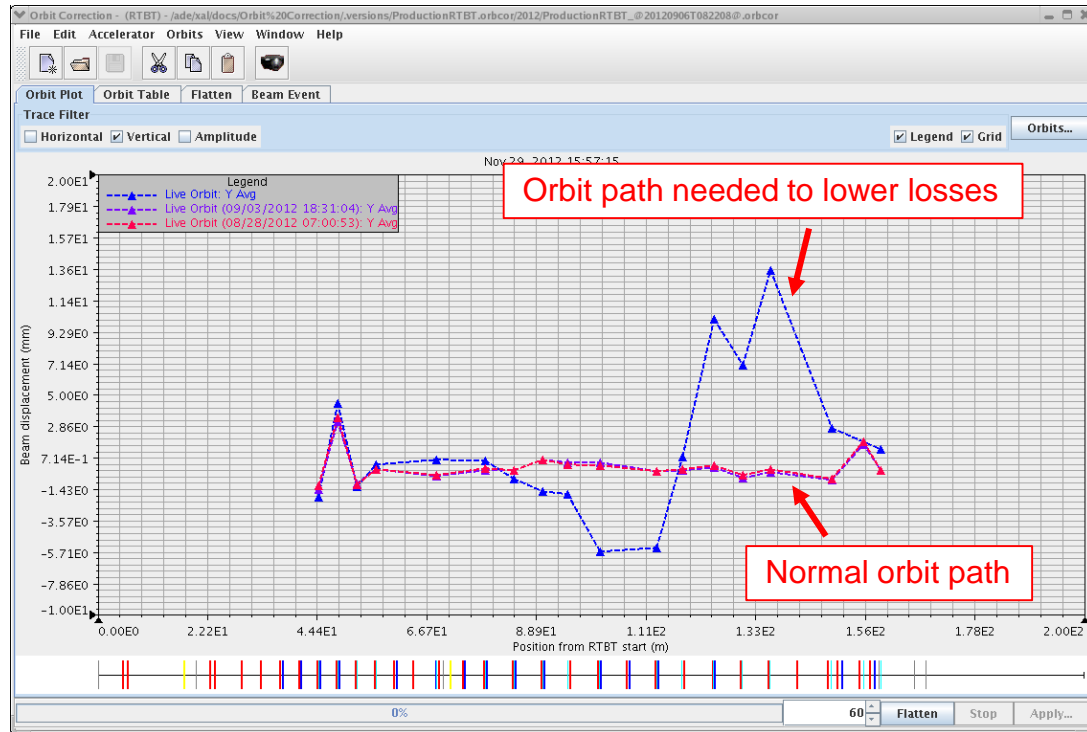
Normal



Abnormal

Get the Beam On and then Interact with Different Groups

- First try to adjust to keep the beam on



- 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

$$\text{Average power limit} = \text{Beam energy} \times \text{Current} \times \text{Pulse width} \times \text{Rep rate}$$

$$\text{Energy per pulse limit} = \text{Beam energy} \times \text{Current} \times \text{Pulse width}$$

- 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.

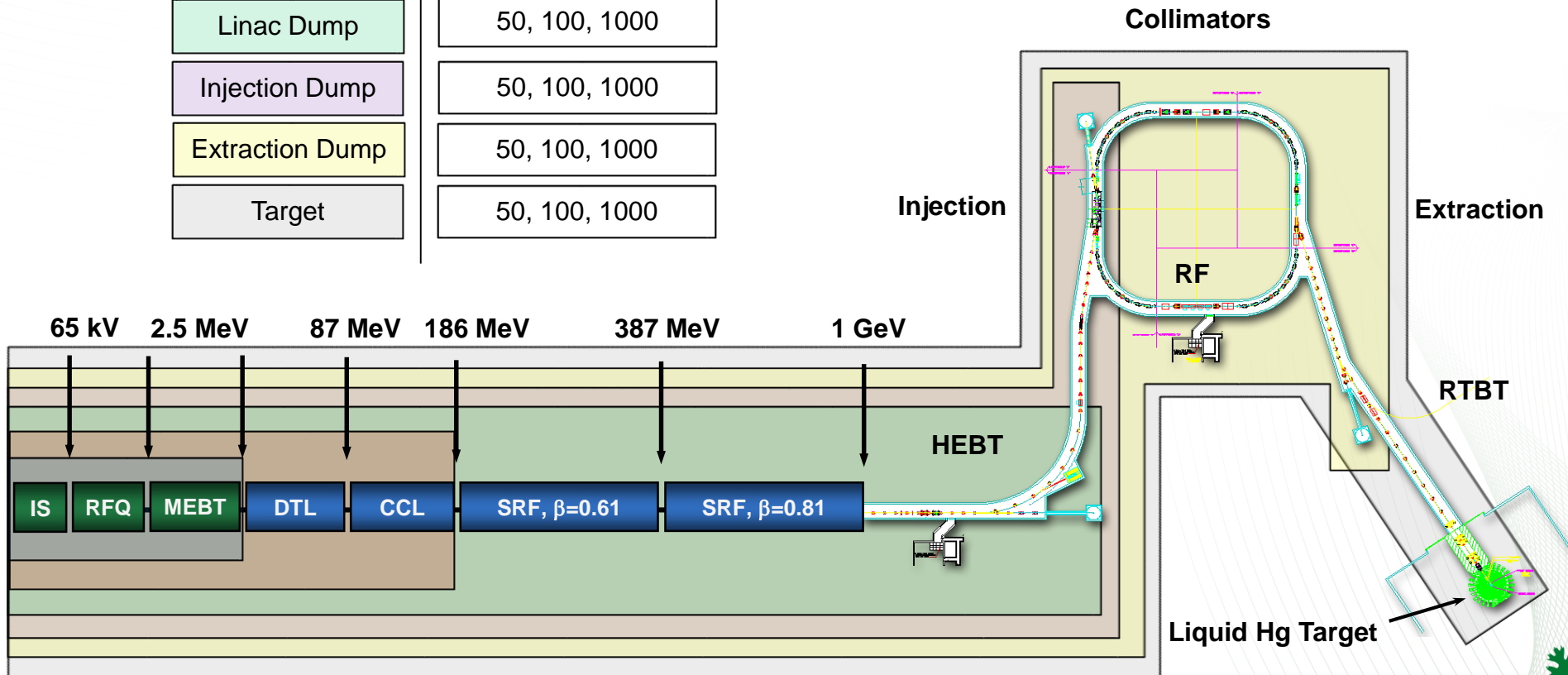
***The RTBT current and pulse length given in the table corresponds to the beam entering the ring. The beam exiting is of course much shorter and higher intensity.

- 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 Degradator / 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 Degradator / 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 Degradator / 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 Degradator / 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 Degradator / 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 Degradator / 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

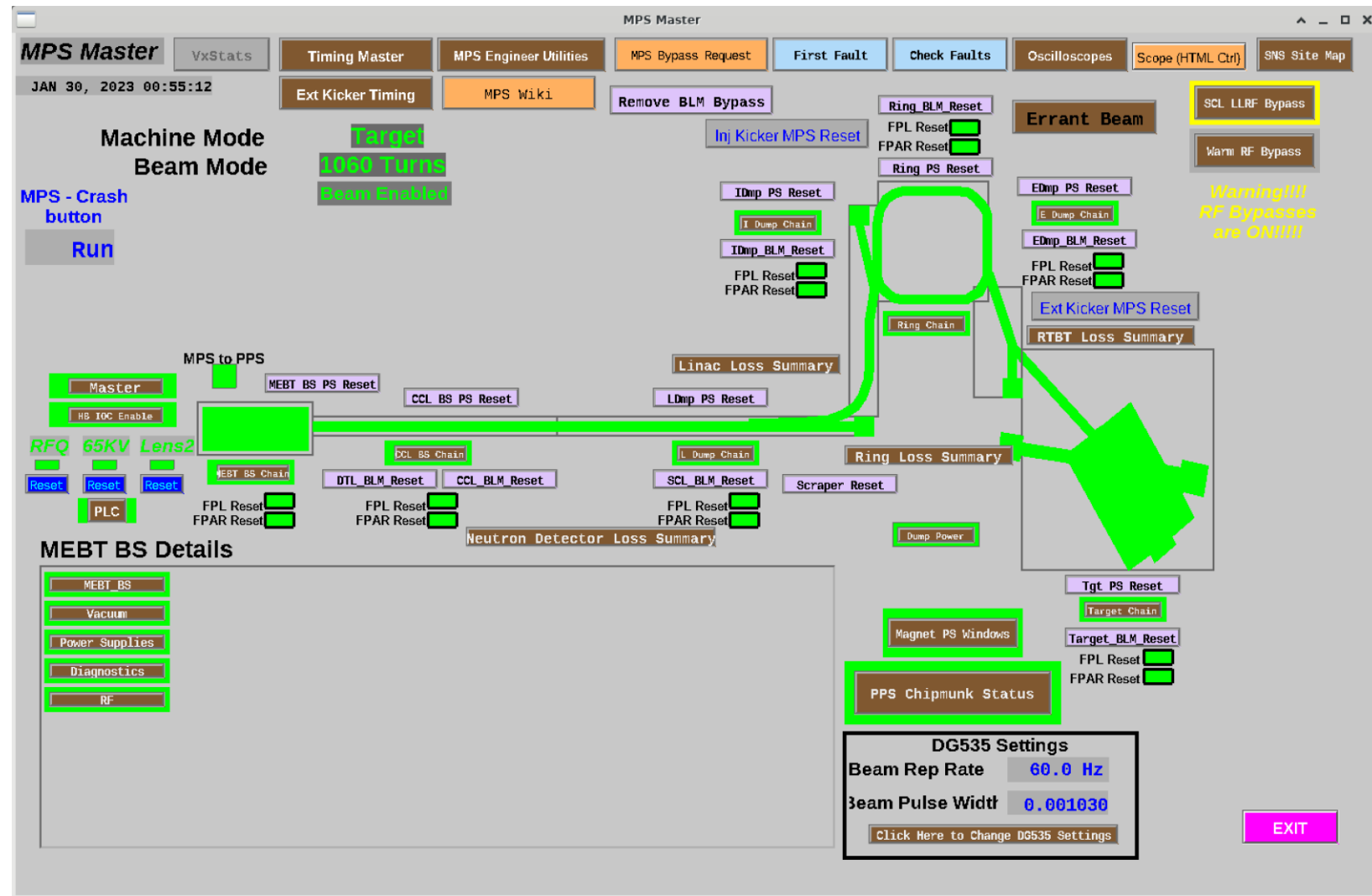
The MPS actively protects equipment based on beam pulse width and possible beam destinations

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

The screenshot displays the 'MEBT_BS Chain' control interface. On the left, a 'Master' panel shows 'FE_MPS:MIOC1A - IOC Lab Engineering / Automatic Hardware Test Screen' with various status indicators and a table of inputs. A red box highlights a vertical stack of control buttons: 'EXIT', 'Master', 'MEBT MPS1A', 'ICS MPS2B', 'FE VAC', 'FE Ctl 2C', 'FE Ctl 2B', 'FE Ctl 2A', and 'RFQ HPRF A'. A red arrow points from this stack to a 'MEBT BS Chain' button in the main interface. The main interface includes a 'MPS Master' section with buttons for 'Timing Master', 'MPS Engineer Utilities', 'MPS Bypass Request', 'First Fault', 'Check Faults', 'Oscilloscopes', 'Scope (HTML Ctrl)', and 'SNS Site Map'. A central display shows 'Target 1000 Turns Beam Enabled'. Other sections include 'Errant Beam', 'Ring Loss Summary', 'Linac Loss Summary', 'Neutron Detector Loss Summary', 'Magnet PS Windows', and 'DG535 Settings' (Beam Rep Rate: 60.0 Hz, Beam Pulse Width: 0.001030). A 'Warning!!! RF Bypasses are ON!!!' message is visible on the right. An 'EXIT' button is located at the bottom right.

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

The screenshot displays the 'L Dump Chain' control interface. On the left, a table shows the status of various SCL PS4A units, including their I/OC status, input status, and various control buttons like 'FPL Reset' and 'FPAR Reset'. A red box highlights a grid of these units. The main interface contains numerous control buttons for different components, such as 'Timing Master', 'MPS Engineer Utilities', 'MPS Bypass Request', and 'First Fault'. A green box highlights a 'Dump Chain' button, which is circled in red. A red arrow points from this button to the highlighted grid of units. Other elements include 'MPS Master' controls, 'Errant Beam' warnings, and 'DG535 Settings' for beam parameters.

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

The screenshot displays the 'Ring Chain' control interface. On the left, a 'Master' panel shows a table of IOCs with columns for 'IOC_ENABLE', 'IrqCount', and 'HB Status'. Below this is a 'MPS_Status' section with various diagnostic indicators. The central part of the interface features a 'Machine Mode Beam Mode' section with a 'Target 1000 Turns Beam Enabled' indicator. To the right, there are numerous control buttons for different components, including 'Ring MPS1C' through 'Ring MPS4D', 'Ring BLM1B' through 'Ring BLM4C', and 'Ring HPRF1A' through 'Ring HPRF1B'. A red box highlights a vertical column of these ring control buttons. A red arrow points from the text 'Crash to Run' to a 'Ring Chain' button in the 'Ring Loss Summary' section. The bottom right corner shows 'DG535 Settings' with 'Beam Rep Rate' at 60.0 Hz and 'Beam Pulse Width' at 0.001030. An 'EXIT' button is located in the bottom right corner.

Chain to Chassis to Equipment Signal

Chassis feed into each to pass fault state

Each chassis has 16 inputs

Extraction Dump

The screenshot displays the 'E_Dump Chain' control interface. On the left, a 'Master' panel shows system status including 'IOC_ENABLE' (Enabled), 'irqCount' (483624515), and 'HB Status'. Below this is a table of ICS and FPAR status for various components like MEBT_BS, CCL_BS, and FPL. A red box highlights a vertical signal chain of components: Master, Ring MPS2A, RTBT MPS1A, RTBT MPS1E, RTBT BLM1A, Ring MPS2B, Ring BLM3A, Ring BLM4A, Ring MPS4E, Ring MPS5A, and Ring MPS5B. A red arrow points from this chain to a 'Dump Chain' component circled in red in the main interface. The main interface contains numerous control buttons for 'MPS Master', 'Timing Master', 'MPS Engineer Utilities', and various reset functions. A green box highlights the 'Dump Chain' and 'Ring Chain' components. A green text overlay reads 'Target 1000 Turns Beam Enabled'. At the bottom, a 'MEBT BS Details' panel lists 'MEBT BS', 'Vacuum', 'Power Supplies', 'Diagnostics', and 'RF'. A 'DG535 Settings' panel shows 'Beam Rep Rate' at 60.0 Hz and 'Beam Pulse Width' at 0.001030. An 'EXIT' button is visible in the bottom right corner.

Chain to Chassis to Equipment Signal
 Chassis feed into each to pass fault state
 Each chassis has 16 inputs

Target

The screenshot displays a complex control interface for a Target Chain. On the left, a 'Master' panel shows 'FE_MPS:MIOC1A - IOC Lab Engineering / Automatic Hardware Test Screen' with various status indicators like 'IOC_ENABLE' (Enabled), 'irqCount' (483625535), and 'HB Status'. Below this is a table of ICS_MPS and FPAR status for various beam sections. A central 'Machine Mode Beam Mode' panel shows 'Target 1000 Turns Beam Enabled'. The right side features a 'MPS Master' panel with numerous control buttons such as 'Timing Master', 'MPS Engineer Utilities', 'MPS Bypass Request', 'First Fault', 'Check Faults', 'Oscilloscopes', 'Scope (HTML Ctrl)', 'SNS Site Map', 'Remove BLM Bypass', 'Inj Kicker MPS Reset', 'Ring BLM Reset', 'FPL Reset', 'FPAR Reset', 'Ring PS Reset', 'Errant Beam', 'SCL LLRF Bypass', 'Warm RF Bypass', 'Warning!!! RF Bypasses are ON!!!', 'EDmp PS Reset', 'EDmp BLM Reset', 'FPL Reset', 'FPAR Reset', 'Ext Kicker MPS Reset', 'RTBT Loss Summary', 'Linac Loss Summary', 'LDmp PS Reset', 'Ring Loss Summary', 'DTL BLM Reset', 'CCL BLM Reset', 'SCL BLM Reset', 'Scrapper Reset', 'Neutron Detector Loss Summary', 'Dump Power', 'Magnet PS Windows', 'PPS Chipmunk Status', 'DG535 Settings' (Beam Rep Rate: 60.0 Hz, Beam Pulse Width: 0.001030), and 'EXIT' buttons. A red box highlights a vertical column of buttons: 'EXIT', 'Master', 'RTBT MPS 1B', 'RTBT MPS 1C', 'RTBT MPS 1D', 'RTBT BLM1B', 'RTBT BLM1C', and 'Tgt MPS 1B'. A red arrow points from this box to a 'Target Chain' button in the 'Tgt PS Reset' section. A green box highlights a 'Ring Chain' button in the 'Ring PS Reset' section. A green line connects the 'Ring Chain' to the 'Target Chain' button. A 'MEBT BS Details' panel at the bottom left shows 'MEBT BS', 'Vacuum', 'Power Supplies', 'Diagnostics', and 'RF' sections.

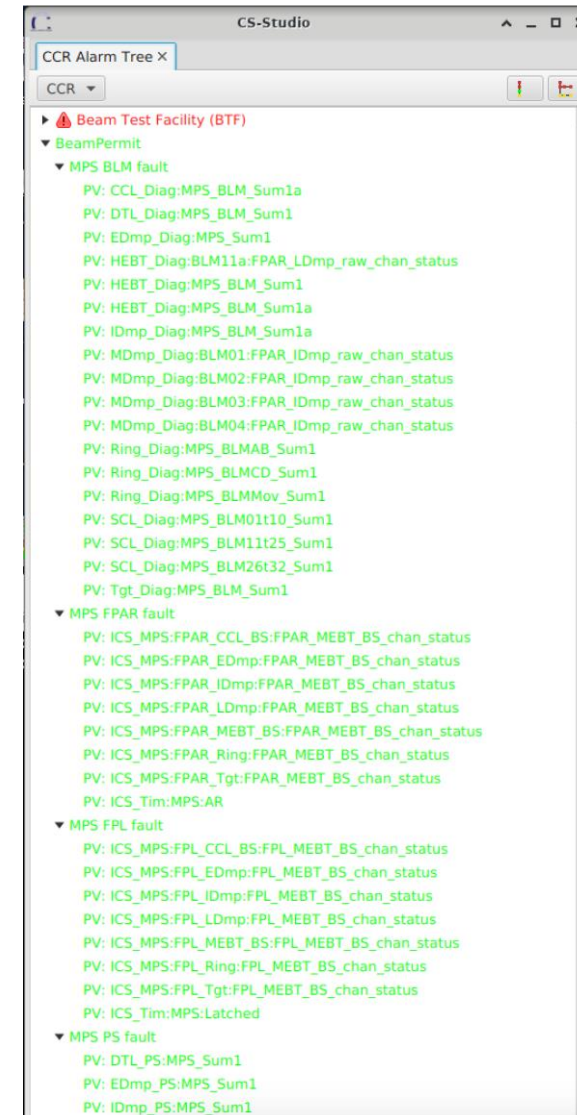
Chain to Chassis to Equipment Signal

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 X

Machine Mode: State: Requested:

Counts
 Total: Bypassed: Bypassable: Not Bypassable: Disconnected: Error:

Operating State

RTDL Switch

Beam Mode

Machine Mode

Legend

Bypassed Bypassable NotBypassable Disconnected InError

#	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

Top 10 hitters in last 200 MPS faults

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

MPS last fault

JAN 30 2023 00:29:17 Latest MPS Fault MPS Master

Time	Chain	Chassis	(Col , Row)	Channel
Jan 30 2023 00:29:16	LDmp	SCL HPRF30A	{ 1 , 12 }	SCL LLRF:HPM31c:FPA LDmp
Jan 30 2023 00:29:16	LDmp	SCL HPRF21A	{ 2 , 4 }	LDmp MPS:FPA SublinkCR5:FPA LDmp
Jan 30 2023 00:28:49	LDmp	SCL HPRF30A	{ 1 , 12 }	SCL LLRF:HPM31c:FPA LDmp
Jan 30 2023 00:28:49	LDmp	SCL HPRF21A	{ 2 , 4 }	LDmp MPS:FPA SublinkCR5:FPA LDmp
Jan 30 2023 00:28:15	LDmp	SCL HPRF30A	{ 1 , 12 }	SCL LLRF:HPM31c:FPA LDmp
Jan 30 2023 00:28:15	LDmp	SCL HPRF21A	{ 2 , 4 }	LDmp MPS:FPA SublinkCR5:FPA LDmp
Jan 30 2023 00:28:14	LDmp	SCL HPRF30A	{ 1 , 12 }	SCL LLRF:HPM31c:FPA LDmp
Jan 30 2023 00:28:14	LDmp	SCL HPRF21A	{ 2 , 4 }	LDmp MPS:FPA SublinkCR5:FPA LDmp
Jan 30 2023 00:28:13	LDmp	SCL HPRF30A	{ 1 , 12 }	SCL LLRF:HPM31c:FPA LDmp

MPS Chassis
location on EDM
screen
(Column, Row)

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

The screenshot displays the SCL_Diag:MIOC_BLM4B - IOC Lab Engineering / Automatic Hardware Test Screen. The main table lists diagnostic signals with the following columns: Status, Input Status, SW Mask, Set Mask, Reset, Enabled, and Faults. The signal 'SCL_Diag:BLM31c:FPAR_LDmp' is highlighted with a red circle. To the right, the MPS Status section shows a grid of components arranged in 11 rows and 4 columns. The component 'SCL_BLM4B' is located at row 10, column 1, and is also highlighted with a red circle. Red arrows connect the highlighted signal in the table to its location on the MPS Status grid.

Column	1	2	3	4
1	Master			EXIT
2	SCL_HPRF9A	SCL_PS3A	SCL_HPRF5A	
3	SCL_HPRF12A	SCL_PS4A	SCL_PS2	
4	SCL_PS7A	SCL_HPRF21A	SCL_BLM1A	SCL_HPRF1A
5	SCL_PS8A	HEBT_MPS1A	SCL_BLM1B	SCL_PS1A
6	SCL_PS8B	HEBT_MPS1B	SCL_BLM2A	
7	SCL_BLM3A	HEBT_MPS1C	SCL_BLM2B	
8	SCL_BLM3B	HEBT_BLM1A	SCL_HPRF15A	
9	SCL_BLM4A	HEBT_BLM2A	SCL_PS5A	
10	SCL_BLM4B		SCL_PS6A	
11	SCL_PS9A		SCL_PS6B	

The Sublink fault is an effect and not the cause

L_Dump Chain
SCL_HPRF:MIOC21A - IOC Lab Engineering

IOC ENABLE	irqCount	HB Status
Enabled	197102673	IOG_ENABLE
123456789A123456789B123456789C123456	status	Input Status
SCL_LLRF:HPM20a:FPAR_LDmp	On	Off
SCL_LLRF:HPM20b:FPAR_LDmp	On	Off
SCL_LLRF:HPM20c:FPAR_LDmp	On	Off
SCL_LLRF:HPM20d:FPAR_LDmp	On	Off
SCL_LLRF:HPM21a:FPAR_LDmp	On	Off
SCL_LLRF:HPM21b:FPAR_LDmp	On	Off
SCL_LLRF:HPM21c:FPAR_LDmp	On	Off
LDmp_MPS:FPAR_SublinkCR5:FPAR_LDmp	On	Off
SCL_HPRF:Mod21:FPL_LDmp	On	Off
SCL_HPRF:Xmtr20:FPL_LDmp	On	Off
SCL_HPRF:Xmtr21:FPL_LDmp	On	Off
SCL_HPRF:Xmtr22:FPL_LDmp	On	Off
<SCL_HPRF:MIOC21A:mpsx_C12>	On	Off
<SCL_HPRF:MIOC21A:mpsx_C13>	On	Off
<SCL_HPRF:MIOC21A:mpsx_C14>	On	Off
LDmp_MPS:FPL_SublinkCR5:FPL_LDmp	On	Off

2 The fault signal goes into the "SCL_HPRF21A" chassis as an input
This means that the counter for that input will update and Last MPS fault will update indicating a Sublink fault
It just means that an MPS fault occurred in one of the chassis in the Sublink line

1 Fault begins here and travels up the Sublink

TRUNK
Master
EXIT

SUBLINK
SCL_HPRF9A
SCL_PS3A
SCL_HPRF5A
SCL_HPRF12A
SCL_PS4A
SCL_PS2
SCL_PS7A
SCL_HPRF21A
SCL_BLM1A
SCL_HPRF1A
SCL_PS8A
HEBT_MPS1A
SCL_BLM1B
SCL_PS1A
SCL_PS8B
HEBT_MPS1B
SCL_BLM2A
SCL_BLM3A
HEBT_MPS1C
SCL_BLM2B
SCL_BLM3B
HEBT_BLM1A
SCL_HPRF15A
SCL_BLM4A
HEBT_BLM2A
SCL_PS5A
SCL_PS6A
SCL_PS9A
SCL_PS6B

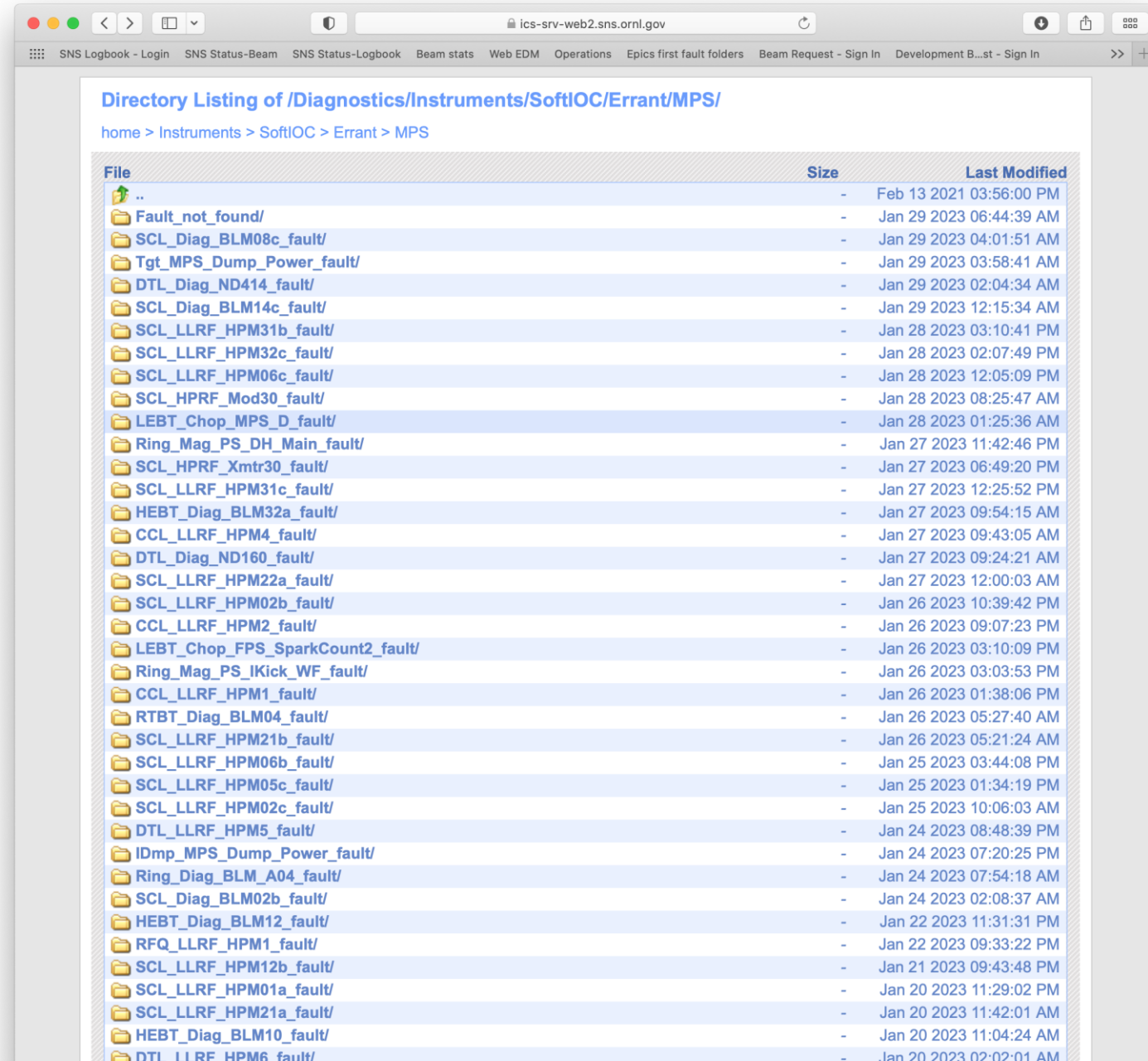
EPICS first fault

- 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_141537.511289	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_114201.703056	AP Mode	2
DIAG	HEBT_Diag_Scrp02_Up_fault	20230124_172105.152545	AP Mode	2
MISC	Tgt_MPS_Dump_Power_fault	20230130_140709.348105	AP Mode	2

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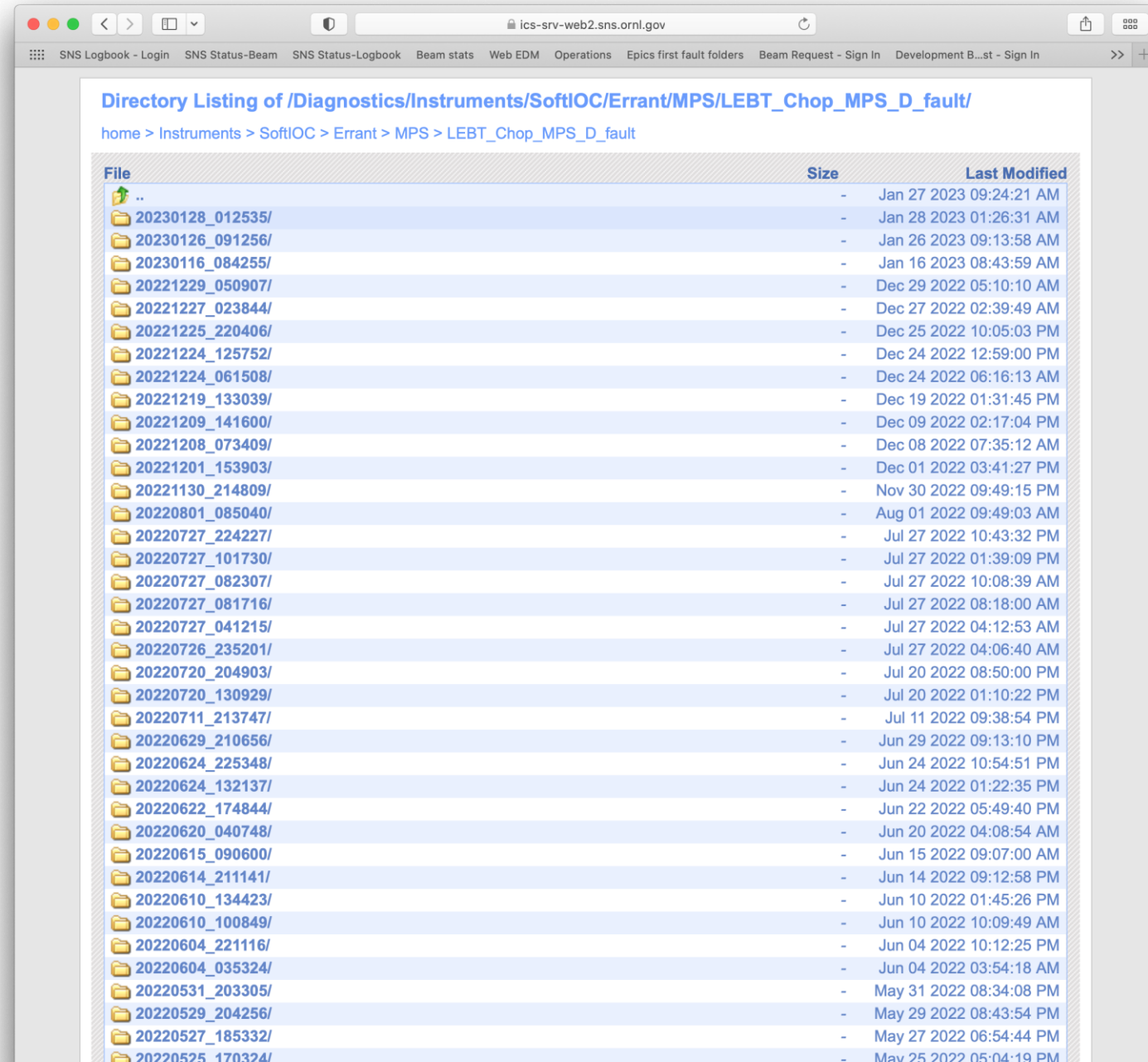


The screenshot shows a web browser window with the address bar at `ics-srv-web2.sns.ornl.gov`. The page title is "Directory Listing of /Diagnostics/Instruments/SoftIOC/Errant/MPS/". The breadcrumb path is `home > Instruments > SoftIOC > Errant > MPS`. The main content is a table listing folders with columns for "File", "Size", and "Last Modified".

File	Size	Last Modified
..	-	Feb 13 2021 03:56:00 PM
Fault_not_found/	-	Jan 29 2023 06:44:39 AM
SCL_Diag_BLM08c_fault/	-	Jan 29 2023 04:01:51 AM
Tgt_MPS_Dump_Power_fault/	-	Jan 29 2023 03:58:41 AM
DTL_Diag_ND414_fault/	-	Jan 29 2023 02:04:34 AM
SCL_Diag_BLM14c_fault/	-	Jan 29 2023 12:15:34 AM
SCL_LLRf_HPM31b_fault/	-	Jan 28 2023 03:10:41 PM
SCL_LLRf_HPM32c_fault/	-	Jan 28 2023 02:07:49 PM
SCL_LLRf_HPM06c_fault/	-	Jan 28 2023 12:05:09 PM
SCL_HPRF_Mod30_fault/	-	Jan 28 2023 08:25:47 AM
LEBT_Chop_MPS_D_fault/	-	Jan 28 2023 01:25:36 AM
Ring_Mag_PS_DH_Main_fault/	-	Jan 27 2023 11:42:46 PM
SCL_HPRF_Xmtr30_fault/	-	Jan 27 2023 06:49:20 PM
SCL_LLRf_HPM31c_fault/	-	Jan 27 2023 12:25:52 PM
HEBT_Diag_BLM32a_fault/	-	Jan 27 2023 09:54:15 AM
CCL_LLRf_HPM4_fault/	-	Jan 27 2023 09:43:05 AM
DTL_Diag_ND160_fault/	-	Jan 27 2023 09:24:21 AM
SCL_LLRf_HPM22a_fault/	-	Jan 27 2023 12:00:03 AM
SCL_LLRf_HPM02b_fault/	-	Jan 26 2023 10:39:42 PM
CCL_LLRf_HPM2_fault/	-	Jan 26 2023 09:07:23 PM
LEBT_Chop_FPS_SparkCount2_fault/	-	Jan 26 2023 03:10:09 PM
Ring_Mag_PS_IKick_WF_fault/	-	Jan 26 2023 03:03:53 PM
CCL_LLRf_HPM1_fault/	-	Jan 26 2023 01:38:06 PM
RTBT_Diag_BLM04_fault/	-	Jan 26 2023 05:27:40 AM
SCL_LLRf_HPM21b_fault/	-	Jan 26 2023 05:21:24 AM
SCL_LLRf_HPM06b_fault/	-	Jan 25 2023 03:44:08 PM
SCL_LLRf_HPM05c_fault/	-	Jan 25 2023 01:34:19 PM
SCL_LLRf_HPM02c_fault/	-	Jan 25 2023 10:06:03 AM
DTL_LLRf_HPM5_fault/	-	Jan 24 2023 08:48:39 PM
IDmp_MPS_Dump_Power_fault/	-	Jan 24 2023 07:20:25 PM
Ring_Diag_BLM_A04_fault/	-	Jan 24 2023 07:54:18 AM
SCL_Diag_BLM02b_fault/	-	Jan 24 2023 02:08:37 AM
HEBT_Diag_BLM12_fault/	-	Jan 22 2023 11:31:31 PM
RFQ_LLRf_HPM1_fault/	-	Jan 22 2023 09:33:22 PM
SCL_LLRf_HPM12b_fault/	-	Jan 21 2023 09:43:48 PM
SCL_LLRf_HPM01a_fault/	-	Jan 20 2023 11:29:02 PM
SCL_LLRf_HPM21a_fault/	-	Jan 20 2023 11:42:01 AM
HEBT_Diag_BLM10_fault/	-	Jan 20 2023 11:04:24 AM
DTL_LLRf_HPM6_fault/	-	Jan 20 2023 02:02:01 AM

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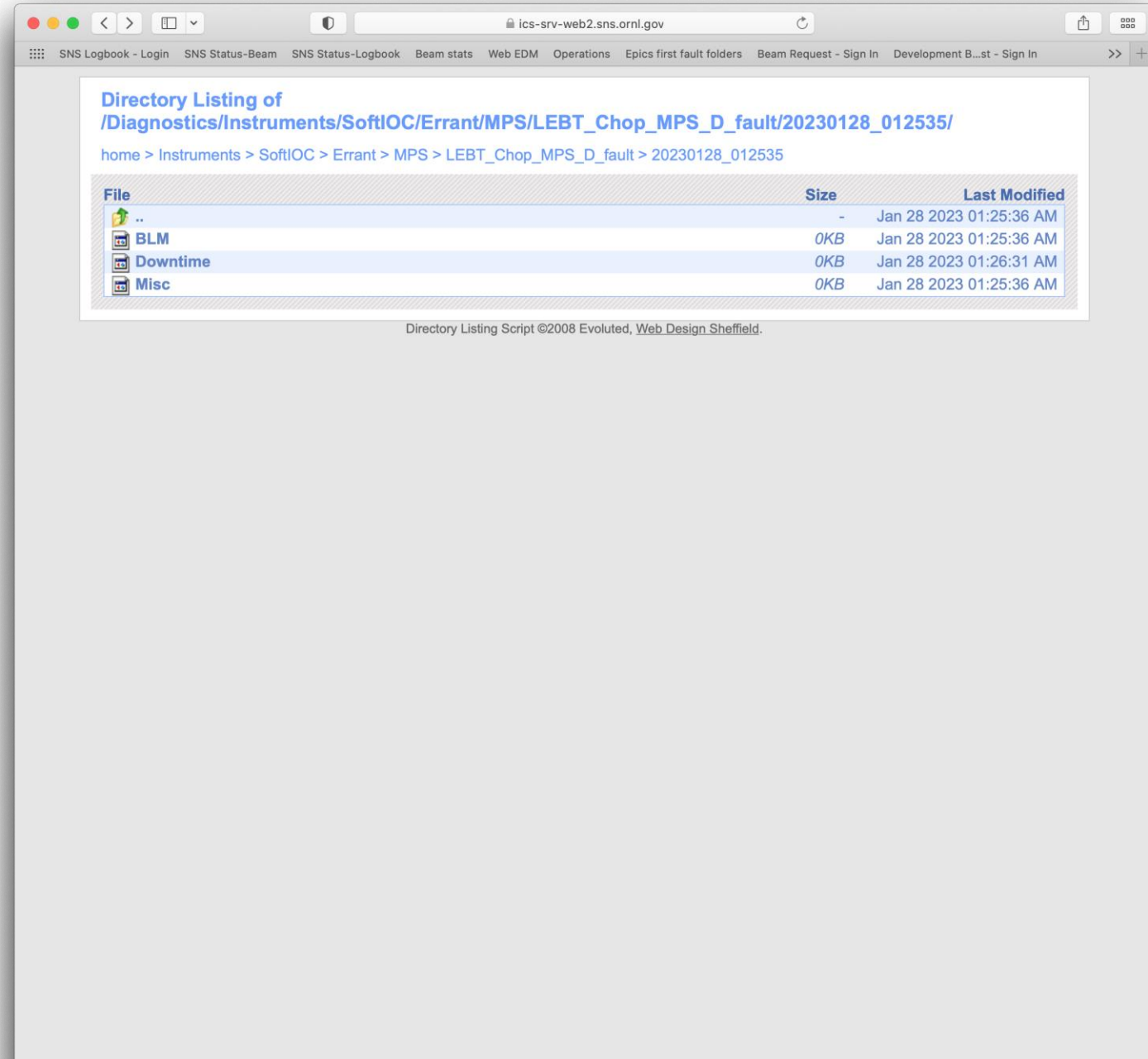


The screenshot shows a web browser window with the address bar at `ics-srv-web2.sns.ornl.gov`. The page title is "Directory Listing of /Diagnostics/Instruments/SoftIOC/Errant/MPS/LEBT_Chop_MPS_D_fault/". The breadcrumb path is "home > Instruments > SoftIOC > Errant > MPS > LEBT_Chop_MPS_D_fault". The main content is a table listing files and folders with columns for "File", "Size", and "Last Modified".

File	Size	Last Modified
..	-	Jan 27 2023 09:24:21 AM
20230128_012535/	-	Jan 28 2023 01:26:31 AM
20230126_091256/	-	Jan 26 2023 09:13:58 AM
20230116_084255/	-	Jan 16 2023 08:43:59 AM
20221229_050907/	-	Dec 29 2022 05:10:10 AM
20221227_023844/	-	Dec 27 2022 02:39:49 AM
20221225_220406/	-	Dec 25 2022 10:05:03 PM
20221224_125752/	-	Dec 24 2022 12:59:00 PM
20221224_061508/	-	Dec 24 2022 06:16:13 AM
20221219_133039/	-	Dec 19 2022 01:31:45 PM
20221209_141600/	-	Dec 09 2022 02:17:04 PM
20221208_073409/	-	Dec 08 2022 07:35:12 AM
20221201_153903/	-	Dec 01 2022 03:41:27 PM
20221130_214809/	-	Nov 30 2022 09:49:15 PM
20220801_085040/	-	Aug 01 2022 09:49:03 AM
20220727_224227/	-	Jul 27 2022 10:43:32 PM
20220727_101730/	-	Jul 27 2022 01:39:09 PM
20220727_082307/	-	Jul 27 2022 10:08:39 AM
20220727_081716/	-	Jul 27 2022 08:18:00 AM
20220727_041215/	-	Jul 27 2022 04:12:53 AM
20220726_235201/	-	Jul 27 2022 04:06:40 AM
20220720_204903/	-	Jul 20 2022 08:50:00 PM
20220720_130929/	-	Jul 20 2022 01:10:22 PM
20220711_213747/	-	Jul 11 2022 09:38:54 PM
20220629_210656/	-	Jun 29 2022 09:13:10 PM
20220624_225348/	-	Jun 24 2022 10:54:51 PM
20220624_132137/	-	Jun 24 2022 01:22:35 PM
20220622_174844/	-	Jun 22 2022 05:49:40 PM
20220620_040748/	-	Jun 20 2022 04:08:54 AM
20220615_090600/	-	Jun 15 2022 09:07:00 AM
20220614_211141/	-	Jun 14 2022 09:12:58 PM
20220610_134423/	-	Jun 10 2022 01:45:26 PM
20220610_100849/	-	Jun 10 2022 10:09:49 AM
20220604_221116/	-	Jun 04 2022 10:12:25 PM
20220604_035324/	-	Jun 04 2022 03:54:18 AM
20220531_203305/	-	May 31 2022 08:34:08 PM
20220529_204256/	-	May 29 2022 08:43:54 PM
20220527_185332/	-	May 27 2022 06:54:44 PM
20220525_170324/	-	May 25 2022 05:04:19 PM

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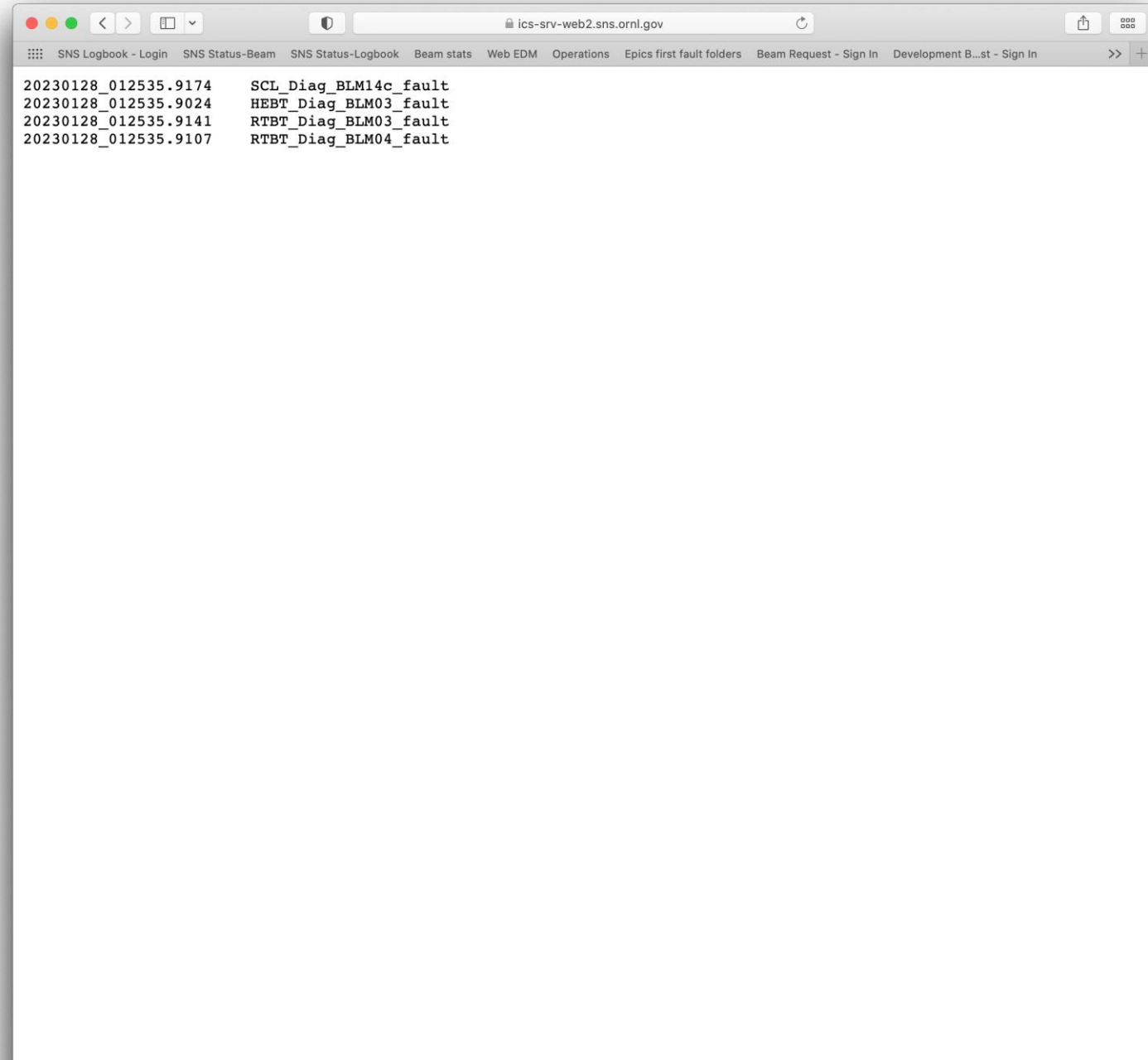
The screenshot shows a web browser window with the URL `ics-srv-web2.sns.ornl.gov`. The browser's address bar and tabs are visible. The main content area displays a directory listing for the path `/Diagnostics/Instruments/SoftIOC/Errant/MPS/LEBT_Chop_MPS_D_fault/20230128_012535/`. Below the path, there is a breadcrumb trail: `home > Instruments > SoftIOC > Errant > MPS > LEBT_Chop_MPS_D_fault > 20230128_012535`. A table lists the files in the directory:

File	Size	Last Modified
..	-	Jan 28 2023 01:25:36 AM
BLM	0KB	Jan 28 2023 01:25:36 AM
Downtime	0KB	Jan 28 2023 01:26:31 AM
Misc	0KB	Jan 28 2023 01:25:36 AM

At the bottom of the page, there is a footer: `Directory Listing Script ©2008 Evoluted, Web Design Sheffield.`

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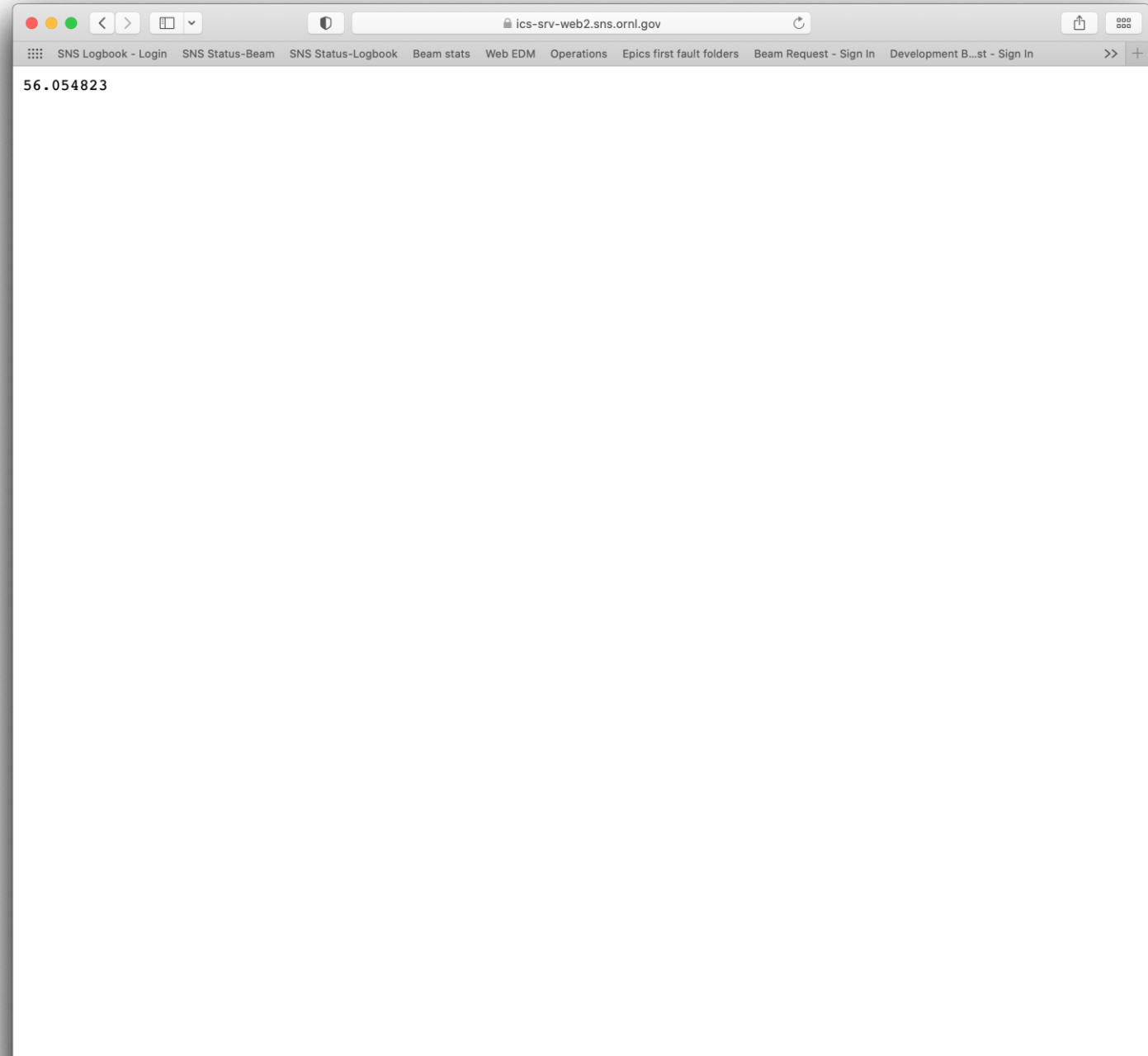


The screenshot shows a web browser window with the URL `ics-srv-web2.sns.ornl.gov`. The browser's address bar and navigation buttons are visible at the top. Below the address bar, there is a navigation menu with several items: `SNS Logbook - Login`, `SNS Status-Beam`, `SNS Status-Logbook`, `Beam stats`, `Web EDM`, `Operations`, `Epics first fault folders`, `Beam Request - Sign In`, and `Development B...st - Sign In`. The main content area of the browser displays a list of four data entries, each consisting of a timestamp and a fault description:

<code>20230128_012535.9174</code>	<code>SCL_Diag_BLM14c_fault</code>
<code>20230128_012535.9024</code>	<code>HEBT_Diag_BLM03_fault</code>
<code>20230128_012535.9141</code>	<code>RTBT_Diag_BLM03_fault</code>
<code>20230128_012535.9107</code>	<code>RTBT_Diag_BLM04_fault</code>

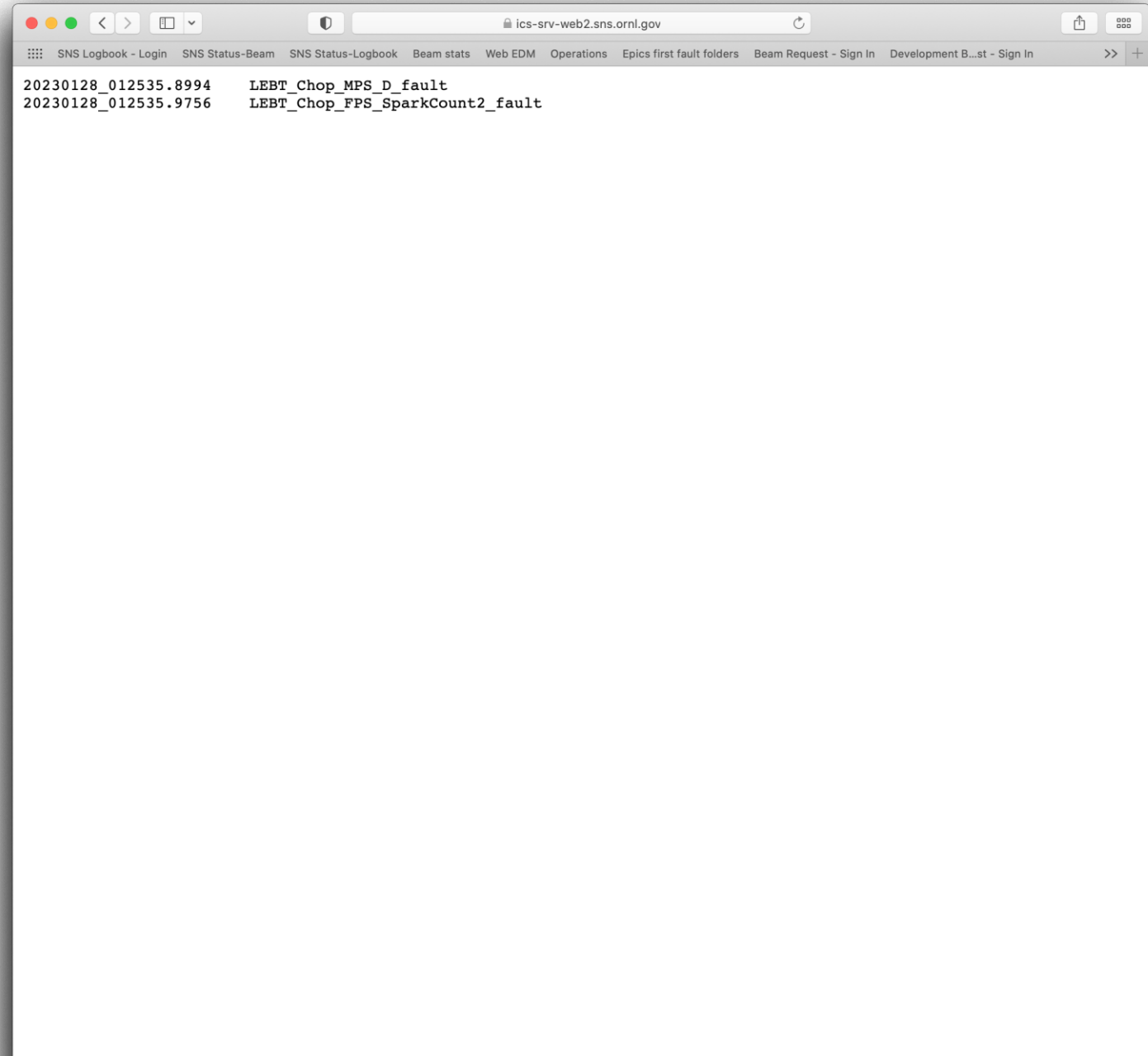
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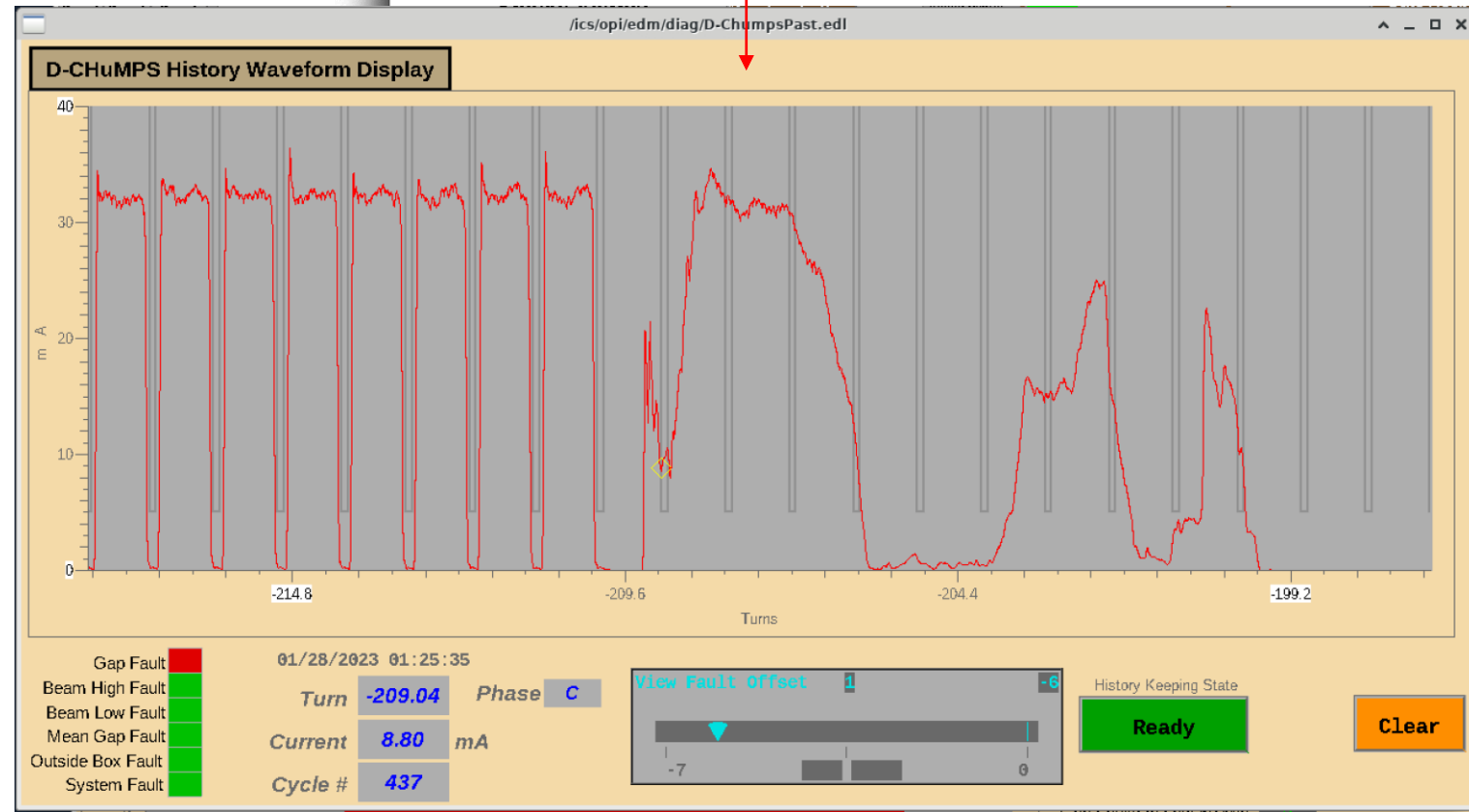
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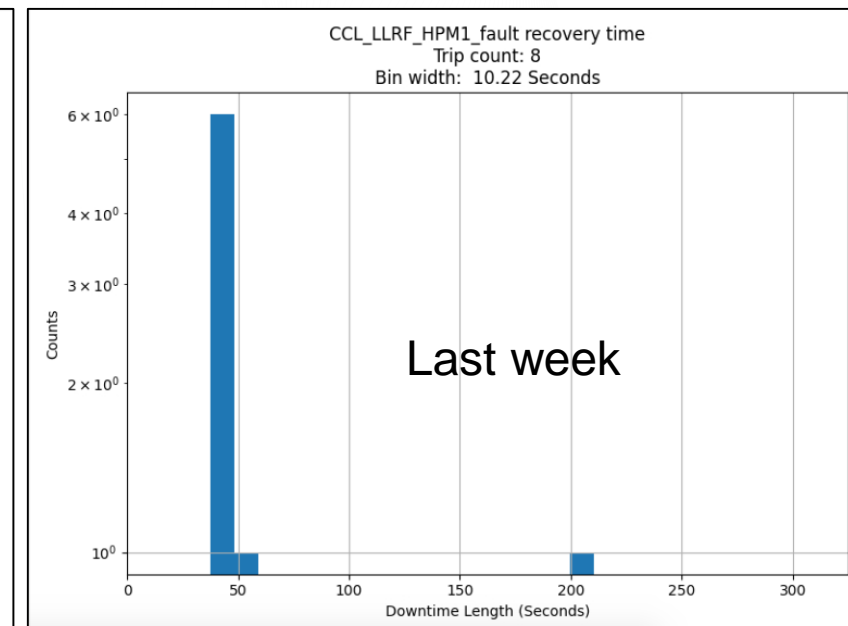
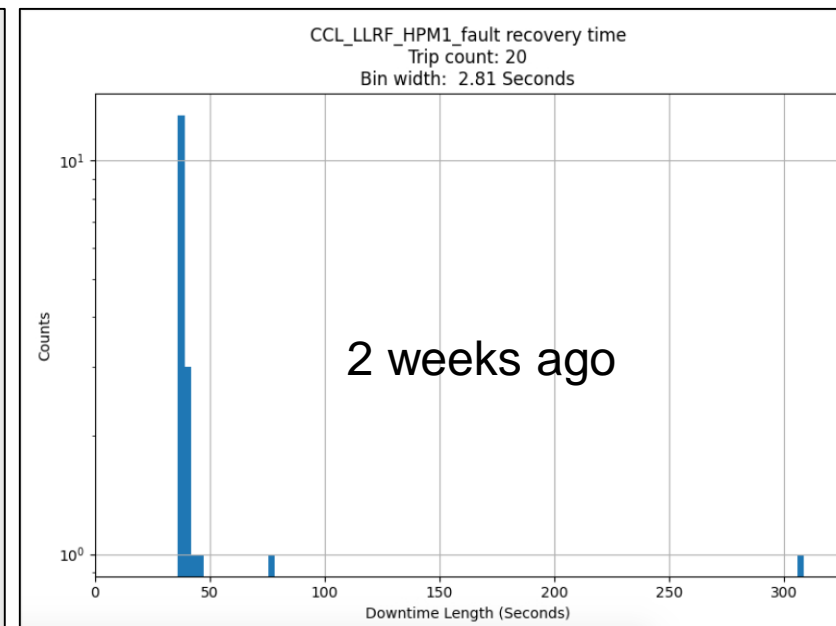
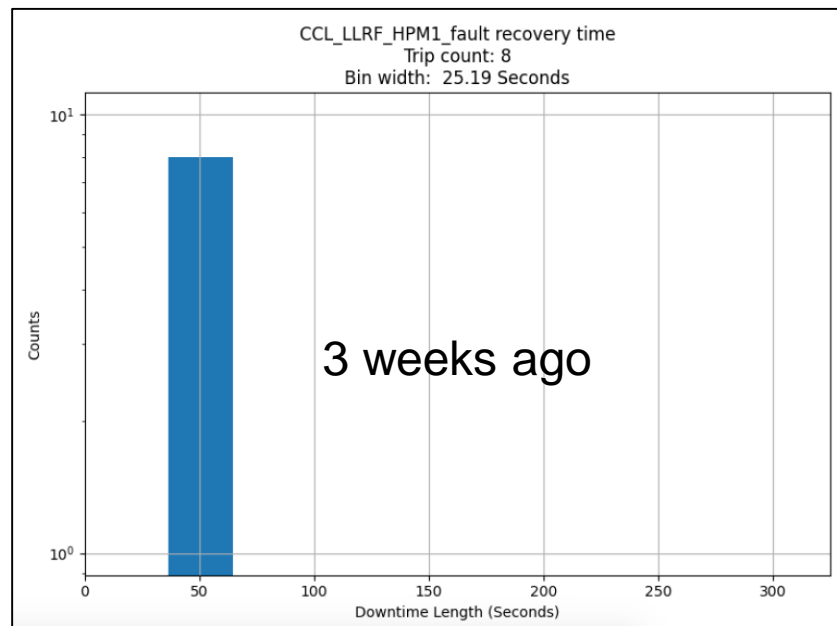
MPS data trends displayed during weekly metrics meeting

- 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

System	Total Hits		
	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

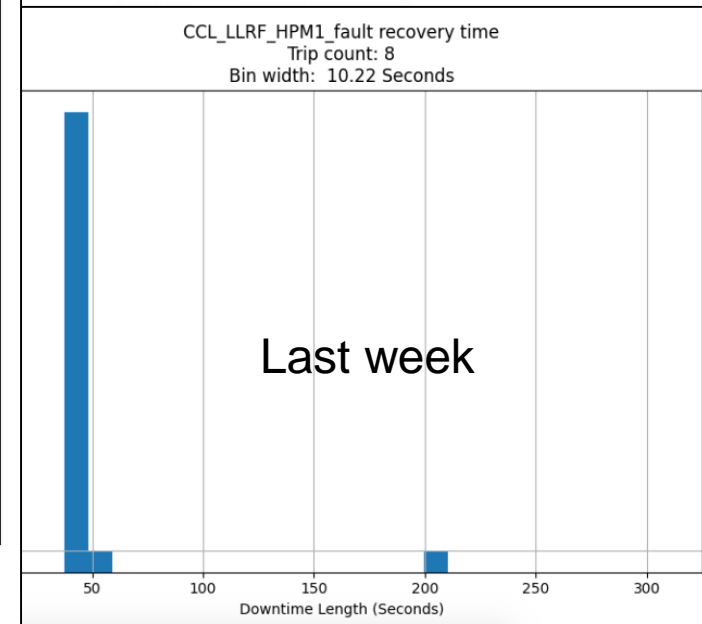
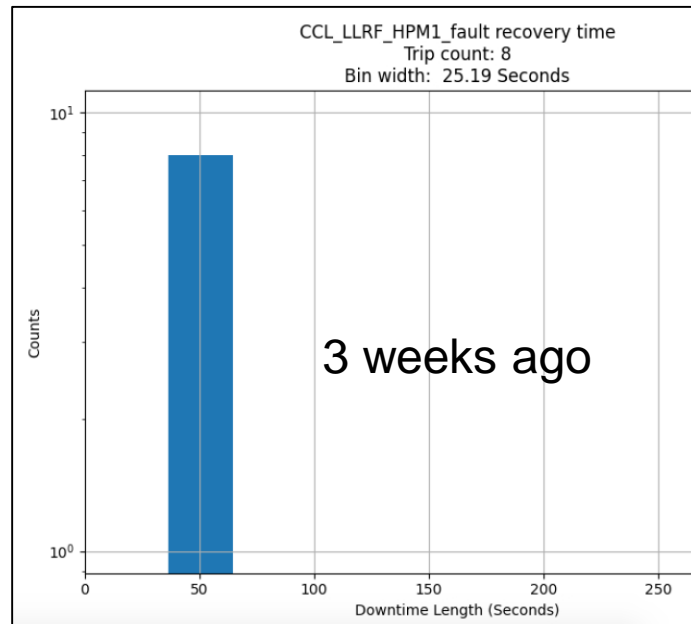
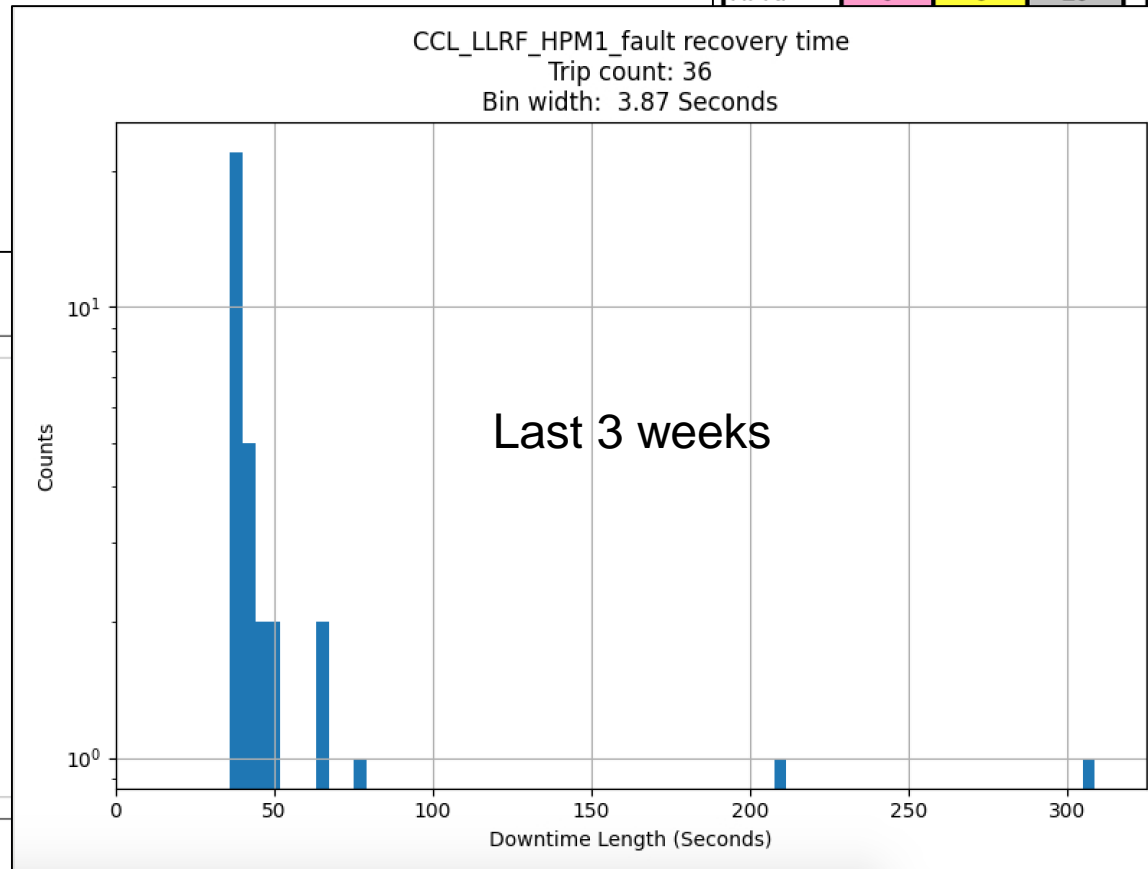


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LLRF 3 wk. trends			First Hits		
System	Subsys.	Device	Last week	2 wks. ago	3 wks. ago
LLRF	HPM	CCL 1	8	20	8
LLRF	HPM	DTL 6	3	0	0
LLRF	HPM	SCL 12b	2	0	0
LLRF	HPM	CCL 2	2	1	1
HPRF 3 wk. trends					
PS 3 wk. trends					
lag	PS	HEBT QV07	3	0	0
lag	PS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