# SPS Bunch intensity interlock using the FBCT in BA3

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- OP notice the new PS to SPS vistar shows 4e11 ppb for the last two injections (from TT2/TT10 FBCTs)
- Total intensity from the DC-BCT on Page1 is as expected
- Three cycles were injected like this and circulate on flat-bottom
  - 07:10:54 – dumped at 14.2s (3B+7s)
  - 07:00:32 – dumped at 8.5s (3B+1.3s)
  - 06:59:48 – OK
  - 06:59:03 – dumped at 7.5s (3B+0.3s)
  - 06:58:19 – OK

- Leads to vacuum spikes on MKE
  - 1 hour of conditioning needed
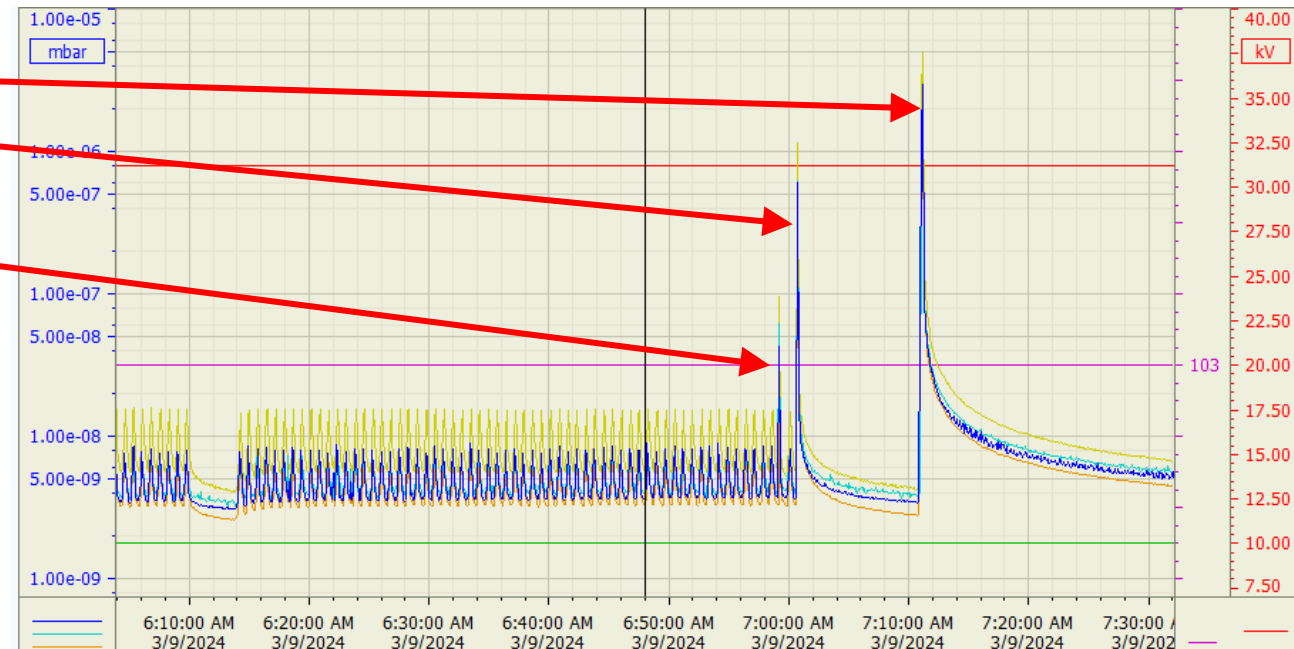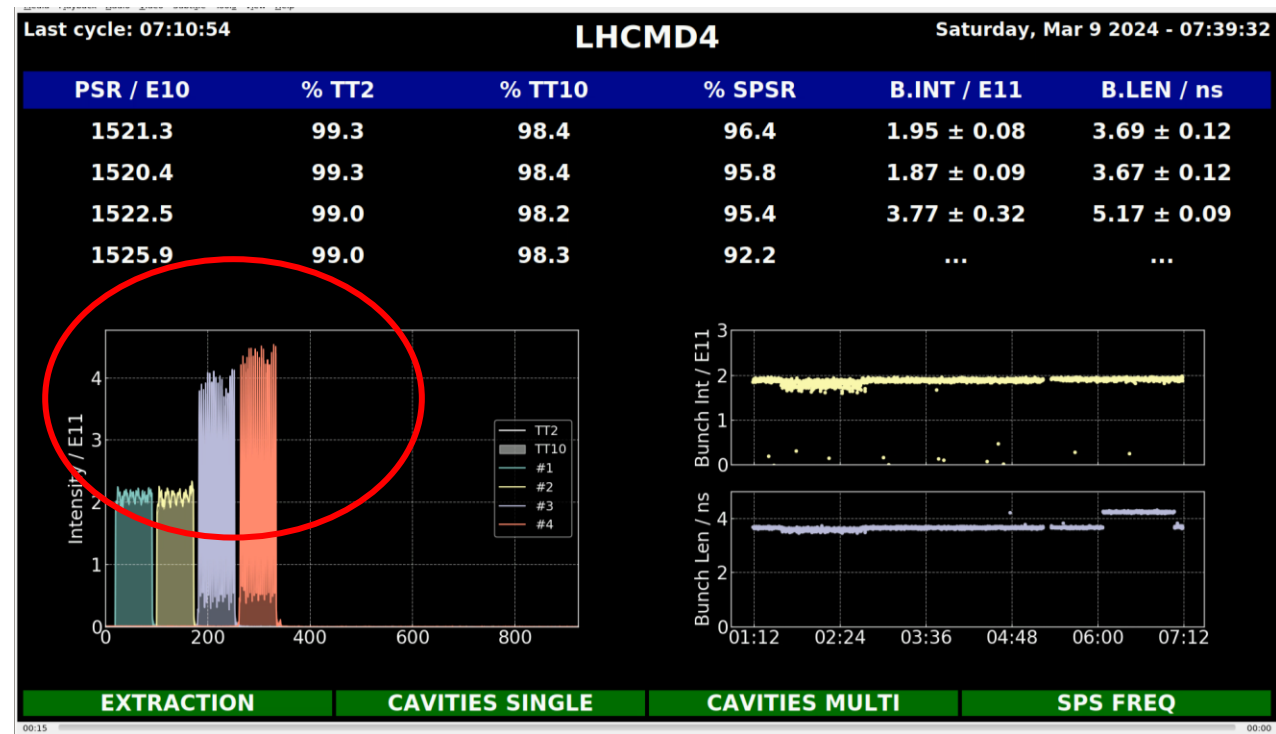
SPS Analysis
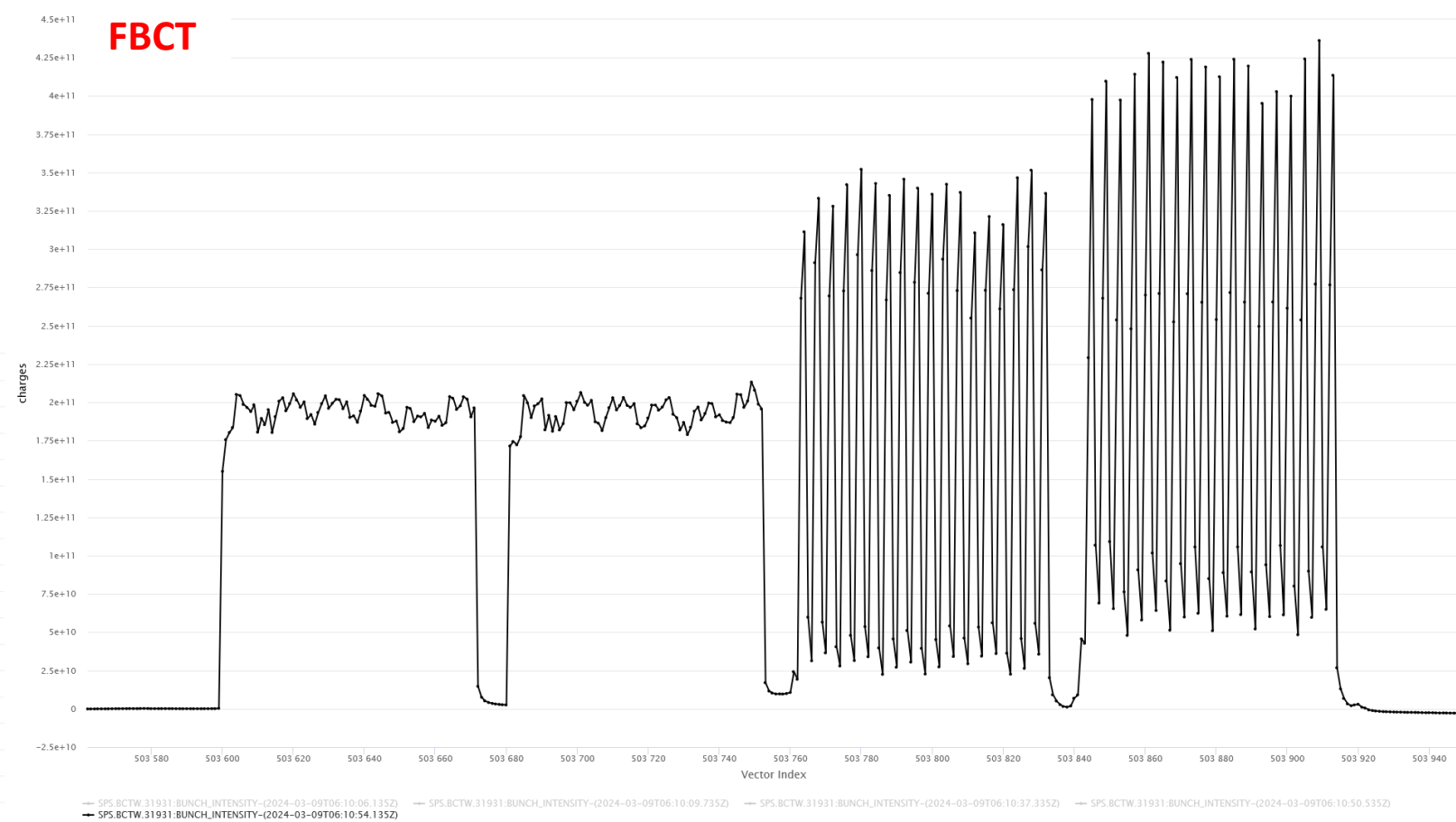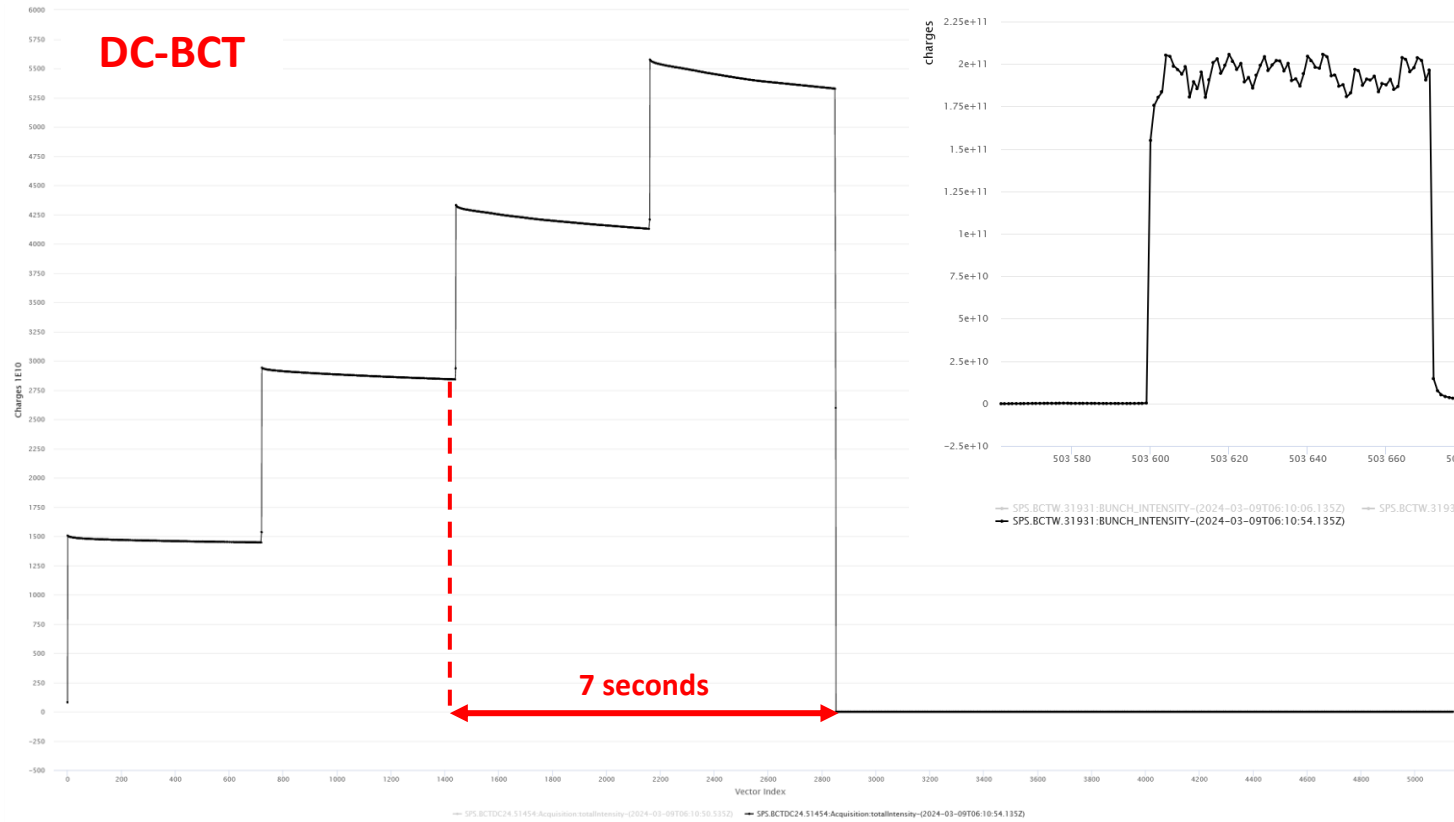
2b+2e beam with 36b of >4e11 was injected for last two injections
and circulated for ~7 seconds until beam was dumped

PS Analysis

- Issue traced to failure of the 1st double splitting at flat top due to a bad phase of the 20MHz RF cavities

- In this case the majority of the macro-bunch intensity ends up in the first pair of 25ns bunches

- A card was replaced by RF experts

- **BUT:** issue has reoccurred over the weekend of 16th March (5e11 injected)

- It seems that it also happened in 2023

- Started a discussion with PS/SPS OP to find a way to protect against this…
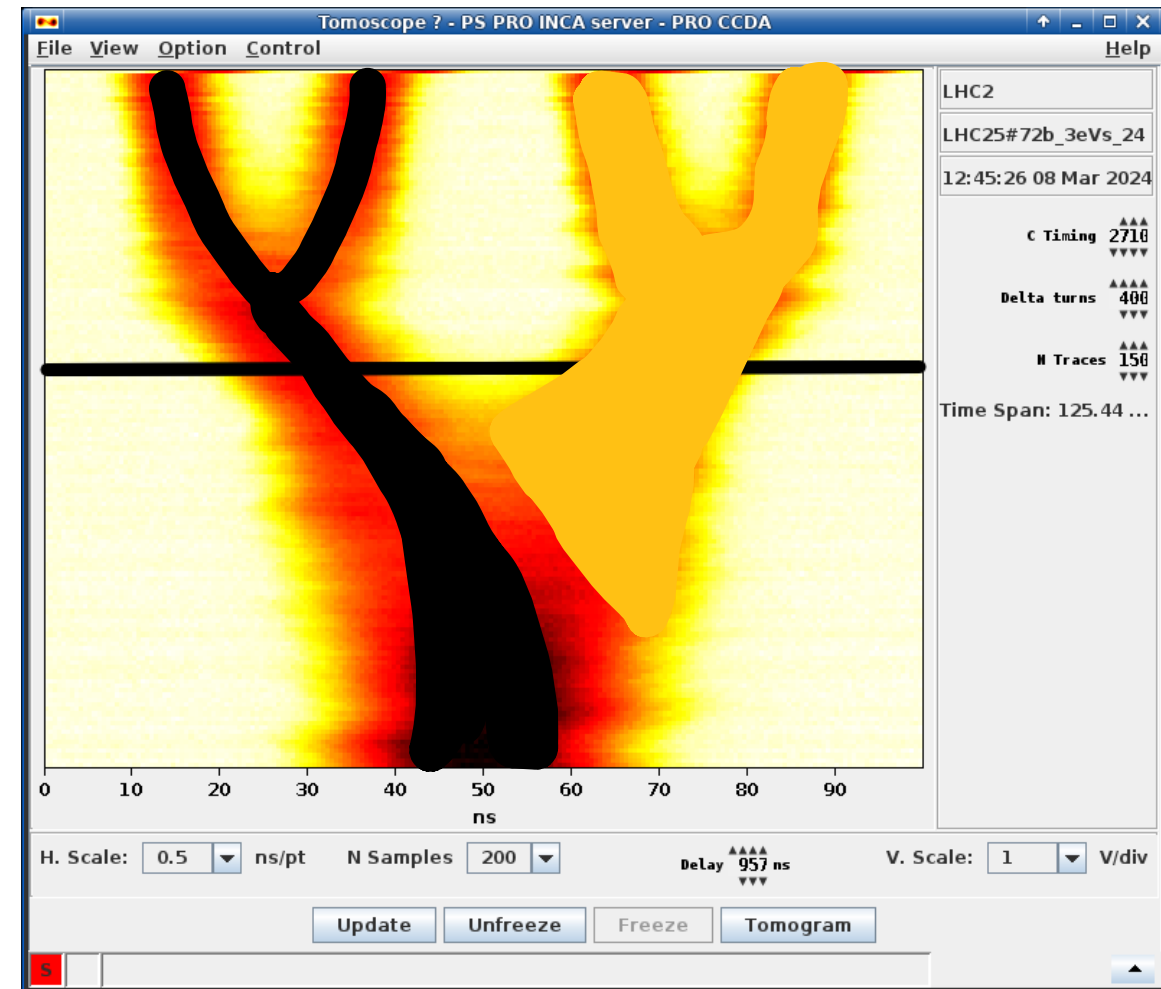
Options for protection: PS

- **Ideal world: do not inject the beam into the SPS**
- This is difficult as:
  - The 1st double splitting happens **only 60ms** before extraction
  - To send the beam to the D2 dump requires inhibiting the BHZ ramp **350ms** before extraction
    - So, if extracted, it is not possible to avoid sending it down TT10
  - To make matters worse: the PS doesn't (currently) have an operational ring FBCT
- Option:
  - Observe the 1st double splitting using the WCM OASIS acquisition (TBC: processing delay?)
  - Inhibit the extraction kicker (TBC: possible ~50ms before extraction?)
  - Trigger the internal dump using the existing DC-BCT intensity comparator mechanism (TBC?)
  - Would need a longer flat top in the PS to dump the beam (+100ms possible)
- But… what happens if the 2nd double splitting fails instead?
  - Same issue for SPS, but we wouldn't be protected by this interlock
- Doesn't seem to be a simple option to implement

Options for protection: TT2/TT10

- The SPS FBCTs in TT2/TT10 measure the bunch-by-bunch intensity

- We have an FPGA available to implement a hardware interlock

- BUT the propagation time of the beam from the TT2 FBCT to SPS injection kickers is **only 2.5us**

- Even via the BIS, it is unlikely that the SPS injection kickers could be interlocked in time

- If we found a way, we would still dump high intensity beams on the SPS injection dump

- Doesn't seem to be a viable option

Options for protection: SPS ring

- We accept that we inject this beam into the SPS and can dump it on the SBDS
- We can therefore add an interlock on the SPS ring FBCT in BA3
  - Using the 20ms averaged data we can interlock 20ms after injection
  - Use of raw data would allow faster response but would make analysis more difficult as nothing would be visible on FBCT acquisition
- Option of SIS interlock discussed:
  - Currently SIS is evaluated at end of cycle, would not inhibit further injections
  - SIS could be adapted, but would add some operational complexity
- Input to BIS preferred by OP → FPGA implementation
- Luckily: we have a cable from the BCT3 CIBU which was <u>removed during YETS</u>!
- Pragmatic solution with possibility of a quick implementation
  - Minor firmware/software work for BI, HW for connection to BIS existing, cable existing

Implementation

- KISS approach:
  - Single non-PPM threshold (at 3.5e11 to cover AWAKE)
  - If any bunch is above this threshold the beam will be dumped 20ms after injection
  - Further injections of the same SPS cycle will be inhibited
- FPGA and FESA done and tested in lab on 19th March
  - It works as expected!
- Deployed during morning access on 20th March
  - FPGA/FESA updated, interface RTM installed
  - CIBU installed and commissioned with TE/MPE
- Initial tests with beam early afternoon on 20th March!

Initial test with beam

- Circulating INDIV with intensity ~1.1-1.2e11
- Threshold lowered to 1.05e11…

LSA Applications Suite (v 16.5.25)

SPS ▾ | G C ▾ | spsop ▾
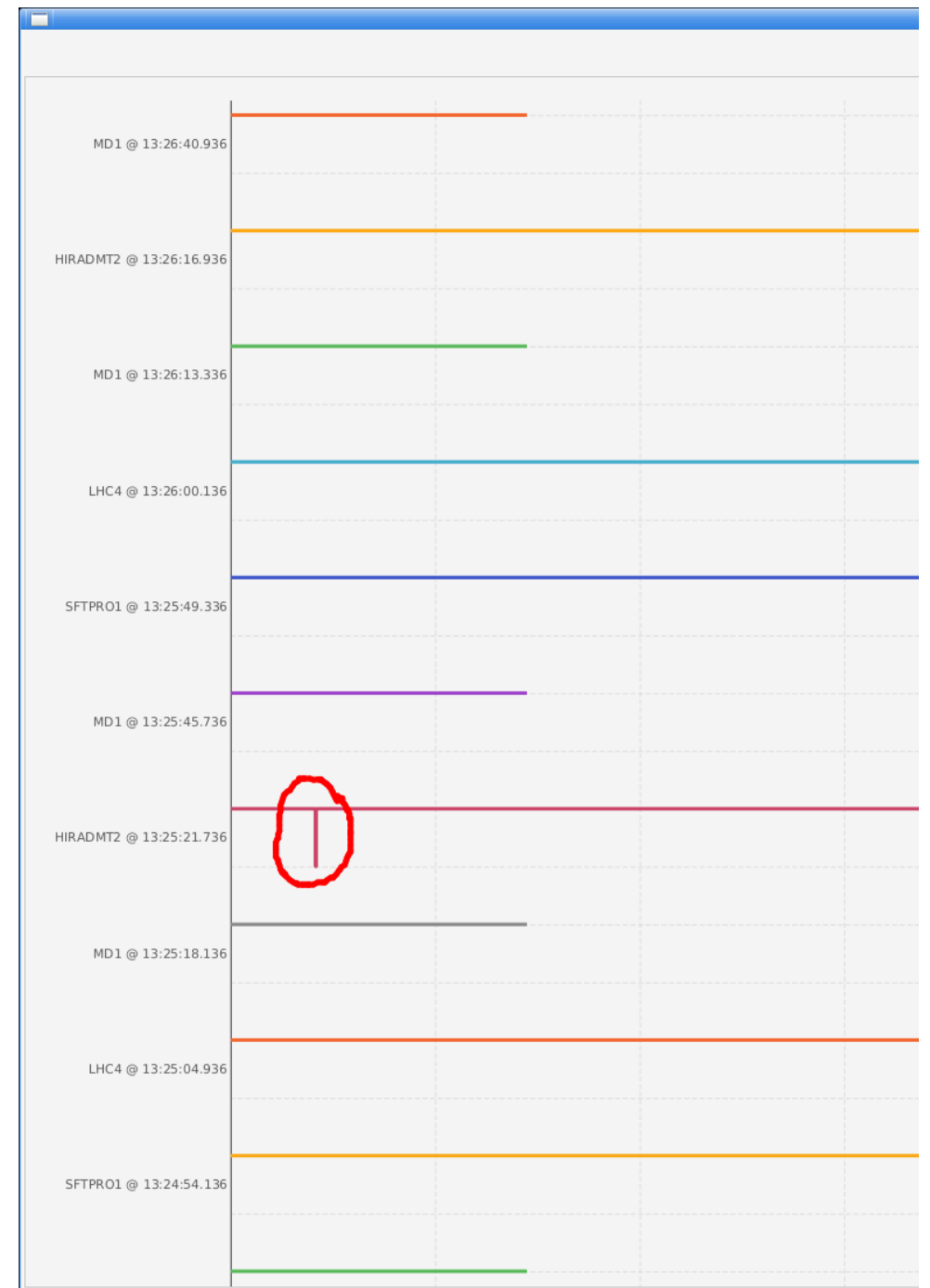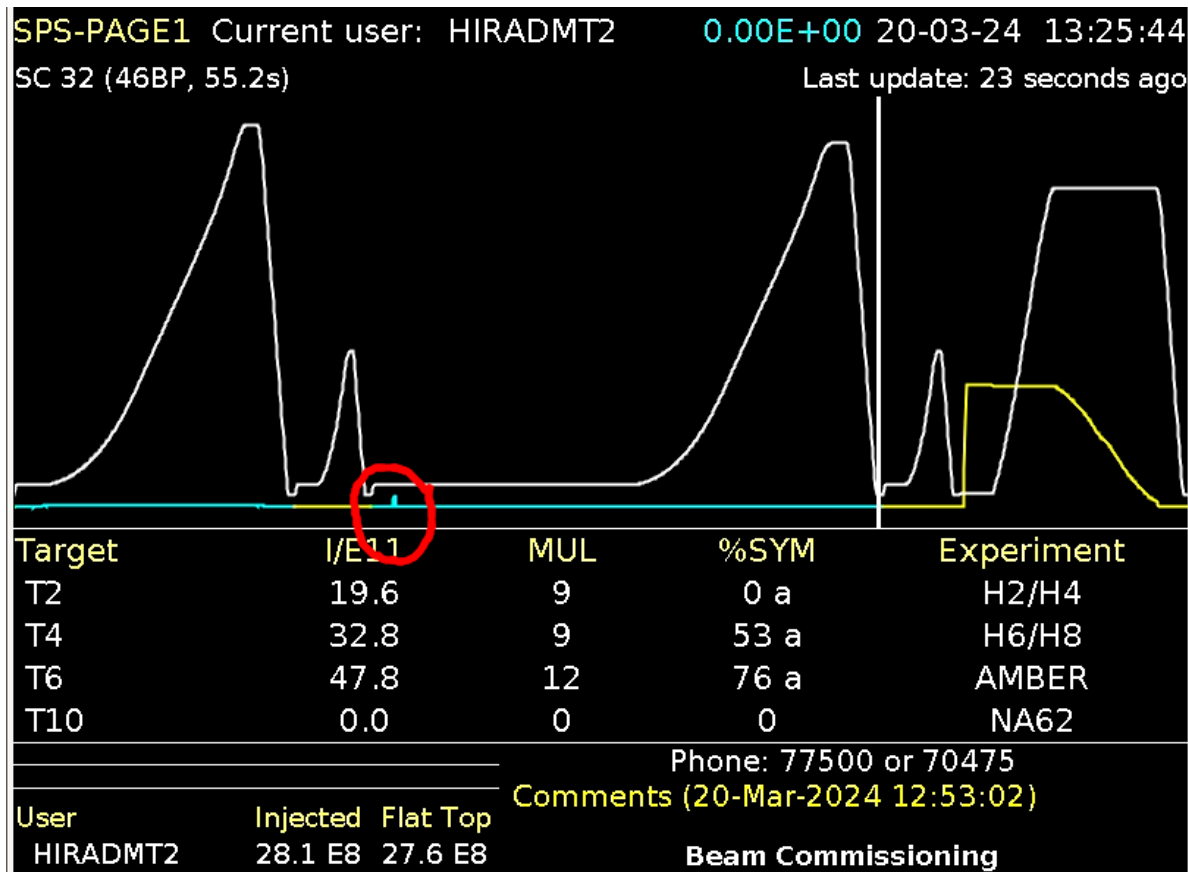
Settings Management ✕

Source

Cycle	Parameter Group	Property	Device/Property
MD4 **SFT_PRO_MD_aperture_2024_V1**	FEI	**BCTFSPS/InterlockSetting**	**SPS.BCTW.31931/InterlockSetting**
SFTPRO2 **SFT_PRO_MTE_East_Extraction_L4780_**	INSTRUMENTATION	LTIM/OutEnable	
ZERO **SPS_TIMING_2021_V1**	**INSTRUMENTATION BCT**		
NON_MULTIPLEXED_SPS	INSTRUMENTATION BSRT		
AWAKE_1Inj_FB60_FT850_Q20_2022_V1	INSTRUMENTATION HEAD-TAIL		
AWAKE_1Inj_FB60_FT850_Q20_2023_V1	LATTICE MEASUREMENT		
AWAKE_1Inj_FB60_FT850_Q20_2023_V1_Clone	MOMENTUM		

Filter (1/131) | Select All | Select All | Select All | Hierarchy |

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Filter (1/49)   Filter (1/2)   Filter (1/1)

☐ Show Sub Contexts   Search Parameter(s)   Parameter filters: none ▾

Setting Part: ◉ Value   ○ Target   ○ Correction   Time Base: ◉ Cycle ○ Beamprocess ○ Injection   **Trim History**

☐ Transpose table | 0 | Add delta   Table/Function

PARAMETER	_NON_MULTIPLEXED_SPS_SPSRING	20-03-2024 13:25:11
SPS.BCTW.31931/InterlockSetting#dumpBunchIntensity	3.49999989E11	1.05000002E11

⚙   Zero Settings ▾   ⟲ Trim   ↩ Cancel last trim ▾   ✓ Apply Trim

ⓘ 13:25:30 Trim(s) reverted successfully: 1 Parameter(s) were updated, 1 Parameter(s) were sent to Hardware

Conclusion

- Due to a failure of the PS double splitting, multiple injections of >4e11 ppb injected into SPS leading to MKE vacuum spikes

- A new interlock on the SPS FBCT, observing the maximum bunch intensity, has been designed and commissioned to protect against this

- Thanks:
  - To PS & SPS OP colleagues for the fruitful discussion
  - To Athanasios for implementing the FESA changes
  - To MPP for their pre-approval of the installation
  - To MPE for installing a new CIBU channel
  - **… all at very short notice!**