國家同步輻射研究中心
National Synchrotron Radiation Research Center

Post-mortem diagnostics for the Taiwan Light Source

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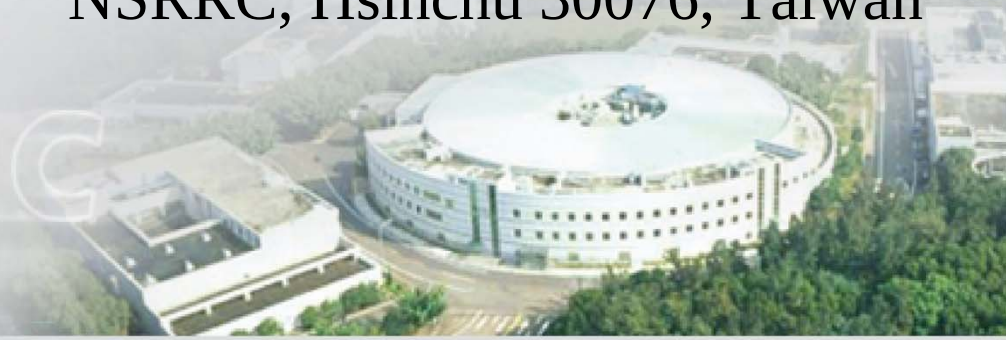
NSRRC, Hsinchu 30076, Taiwan



EPAC 2008, Genoa, Italy, June 23-27, 2008

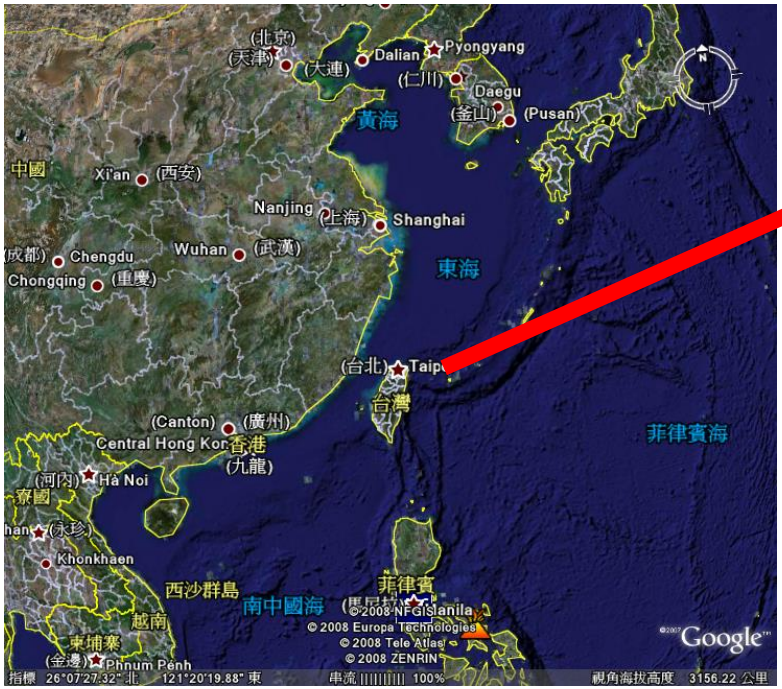
Outline

- NSRRC accelerator facility

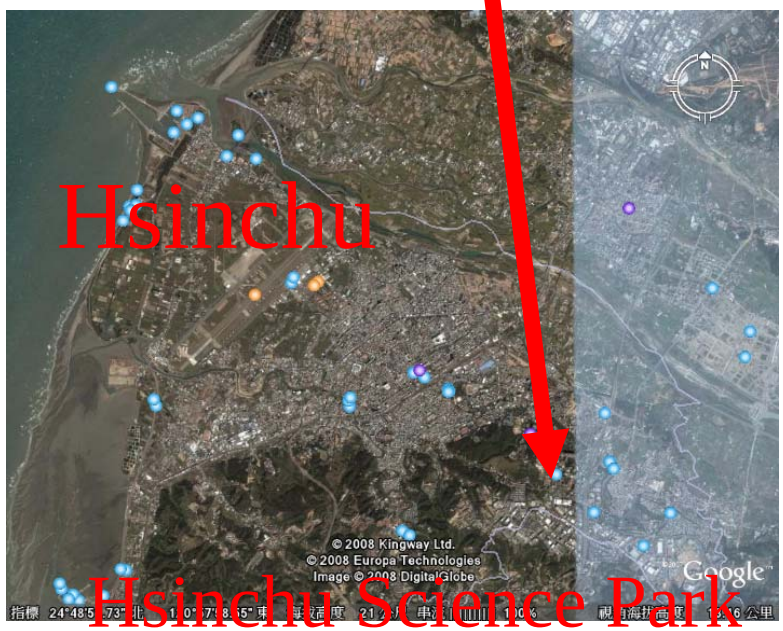
  Taiwan Light Source (TLS) and Taiwan Photon Source (TPS)

- Operation status of the TLS (poster WEPC058)
- Tools to capture data for post-mortem analysis
- Some trip scenarios analysis
- Summary

NSRRC accelerator facility



(Courtesy of Google Earth)



Hsinchu Science Park

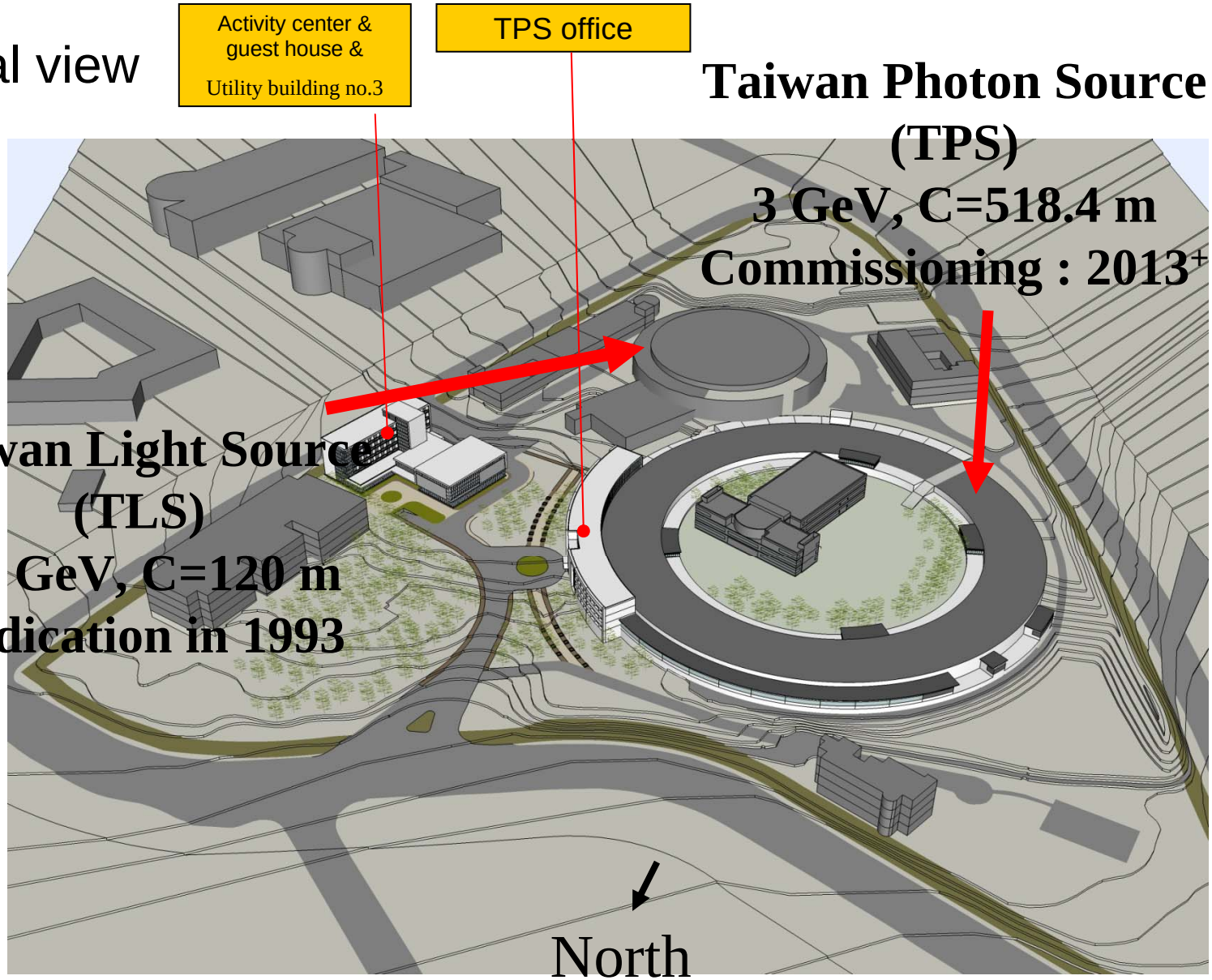
NSRRC accelerator facility - cont.

中心設施 1 大門 2 行政大樓 3 研光大樓 4 儀光大樓 5 增能環館 6 儲存環館 7 機電館 8 招待所

鄰近單位 9 國家高速網路與計算中心 10 交通大學

Taiwan Photon Source project

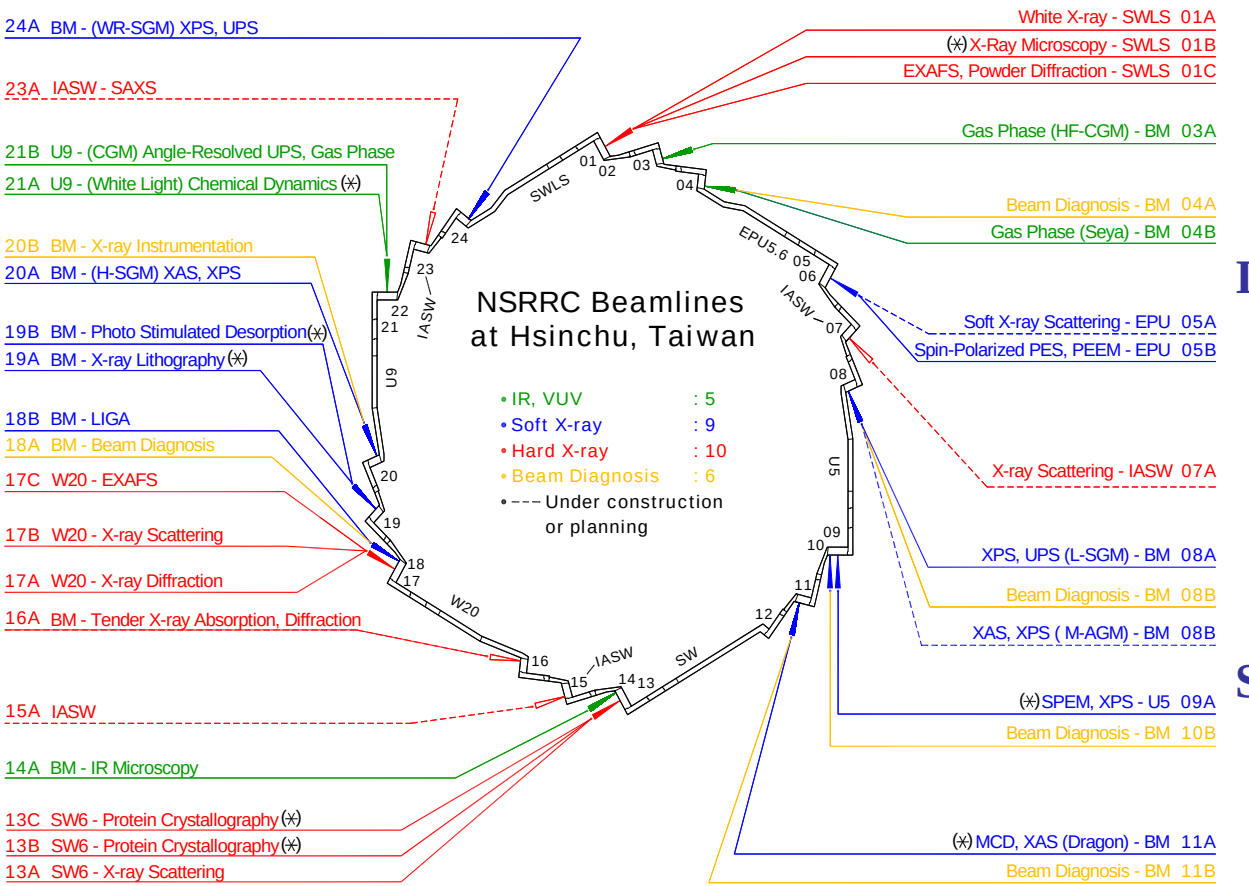
Aerial view



TPS related poster:

TUPC054
TUPC120
TUPC127
TUPD007
TUPP025
WEPC004
WEPC005
WEPC006
WEPC017
WEPC082
WEPC104
WEPC113
WEPC114
WEPC142
THPC005
THPC041
THPC120
THPP118
THPP143

TLS beamline status



ID Status

IDs:

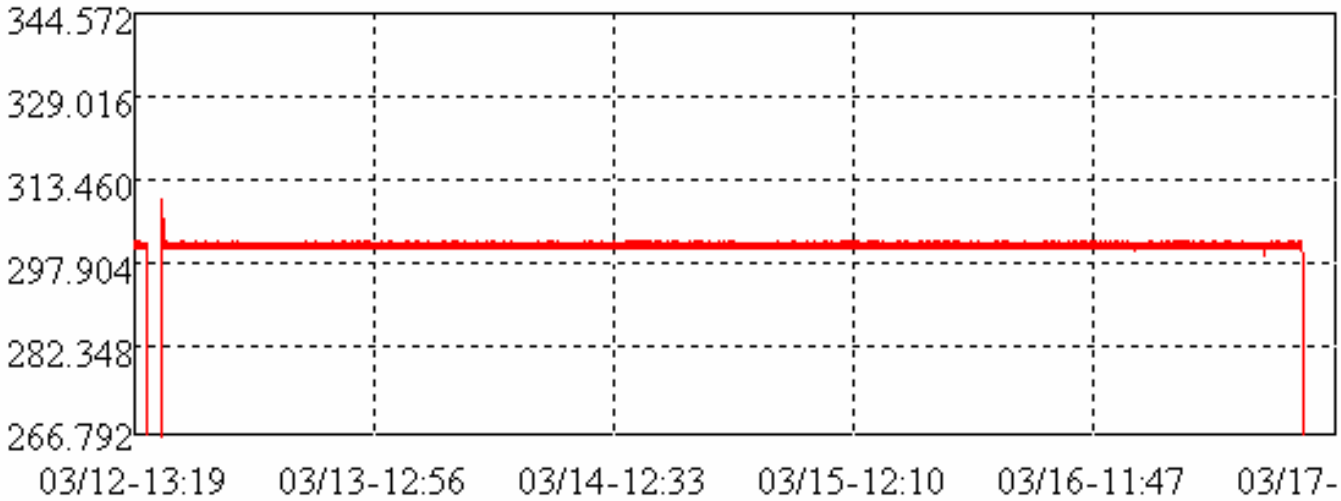
- W20
- U5
- U9
- EPU5.6
- EPU4.6 (2009)

Superconducting IDs:

- SWLS
- SW6
- IASW6-R6
- IASW6-R2 (2009)
- IASW6-R4 (2009)

TLS operation status

- 301 mA Top-Up operation
- ~ 0.05% photon flux constancy were achieved routinely
- > 98 % availability achieved



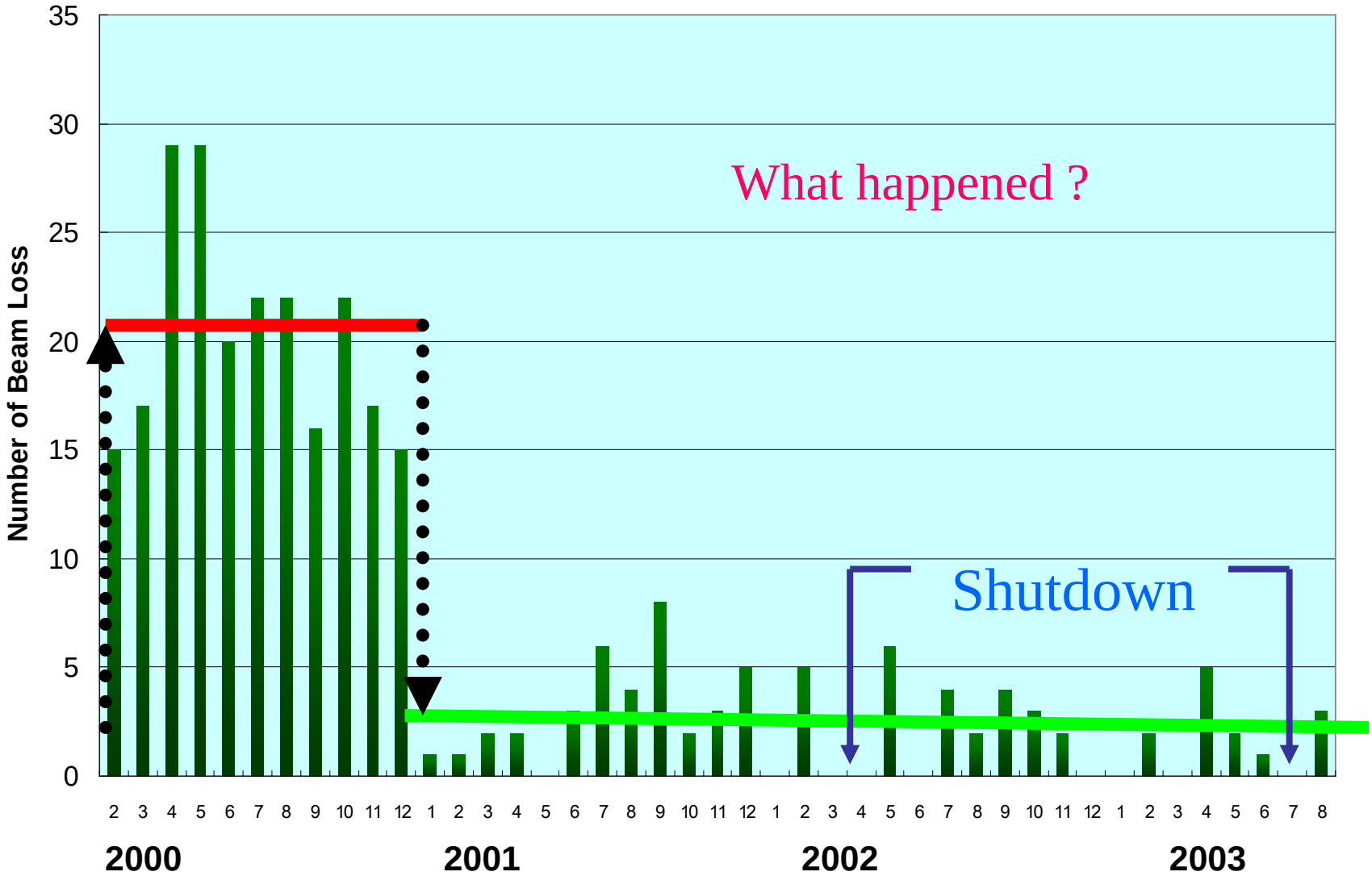
@ 2008

Signal Name	Max	Min	Dif	Avg	Sum
r3dccti (mA)	310.155	-0.686	310.841	289.330	12300844.321

- Keeping high stability and high availability is our commitment to the users
- How to achieve this?

Bad experience – one of an example

Problem of master oscillator related problem



Bad experience – one of an example - cont.

Trilogy of the abnormal high trip rate in (February - December, 2000)

Power distribution panel, bad contact (Voltage drop to about 70 ~80 V in a few power line cycle)

Control board malfunction , (always in by-pass mode, no indication)

Output coaxial switch was open when line voltage dropped to less than 90 V

Circuit Breaker

UPS

115 V
60 Hz

Master Oscillator

If some trip diagnostic tools existed, it might be solved soon!

LLRF
RF Low Level Electronics

RF Transmitter

RF Loss
(< 0.1 sec)

Beam Trip

Rule of Thumb : Don't Trust "Common Sense"

Proverb

久病成良醫 (三折肱成良醫)
Failure is the Mother of Success (失敗是成功之母)
Experience is the Mother of Wisdom (經驗是智慧之母)
Fall into a moat and you will gain wisdom from the experience (吃一塹長一智)
Fall Down Seven Times, Get Up Eight (七転八起)
Success comes from experience; but experience comes from failure (Mark Twain)

Strategies to improve or to keep high availability

Preventative maintenance
Identify weaknesses of the system and remove them
Operation automation
Analyze each trip event to identify where is the problem
=> **Fault diagnostic**
Capture data before and after specific event happened
=> **Post-mortem analysis**
Many measures were done after identify the real reasons for further improvement!

Various tools for beam trip data acquisition

Control system archiver

- Beam current
- Beam position
- Beam loss distribution
- Superconducting insertion device related signals

…….

Vision XP, High density cPCI digitizer

- Beam current
- Beam trip trigger
- SRF interlock
- Superconducting insertion device related signals

…….

BPM electronics

- Turn-by-turn beam position beam phase beam intensity

…….

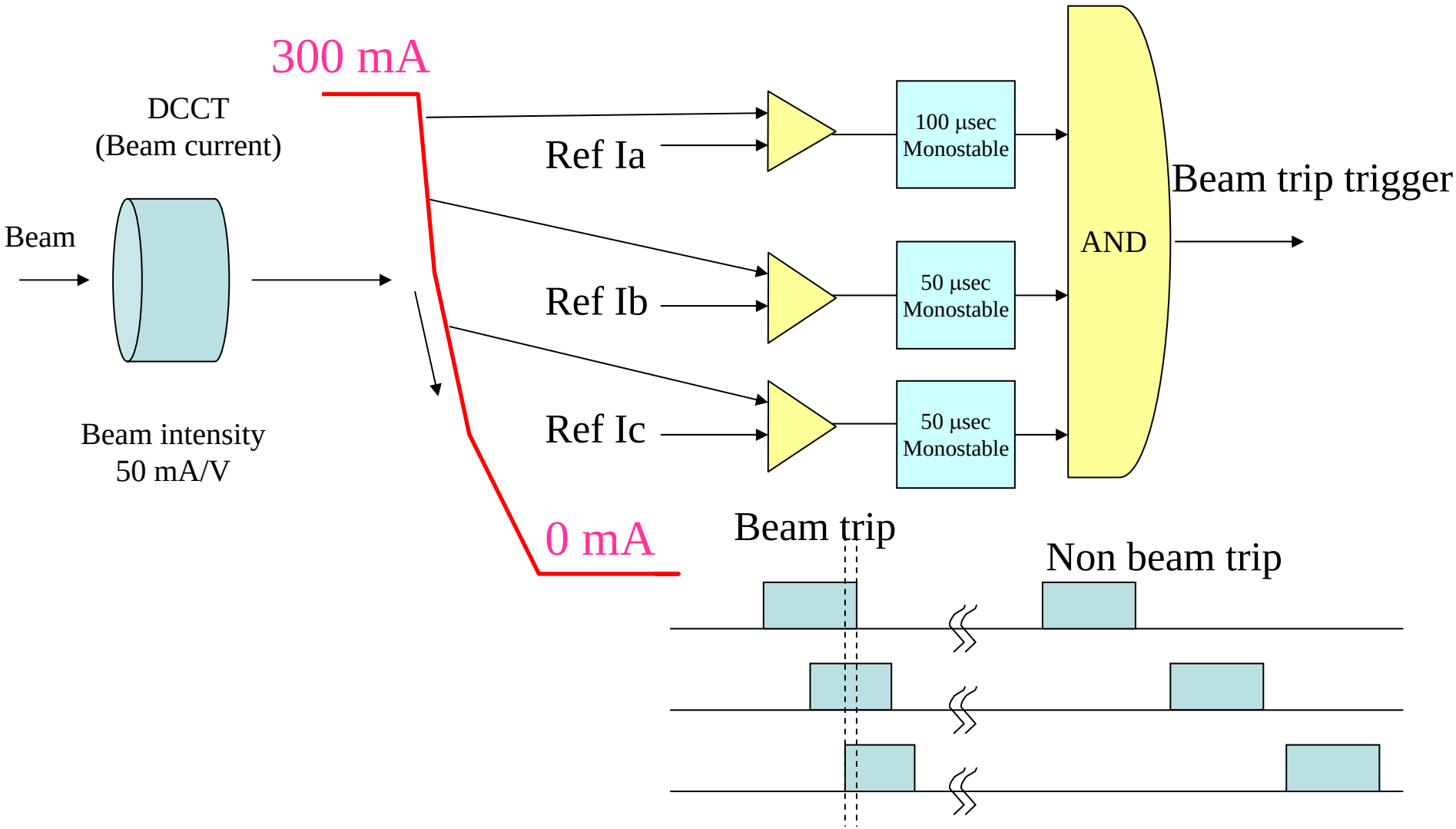
Oscilloscope, Fast digitizer

- Beam intensity
- Beam position
- Beam instability
- Beam trip trigger
- Kicker waveform

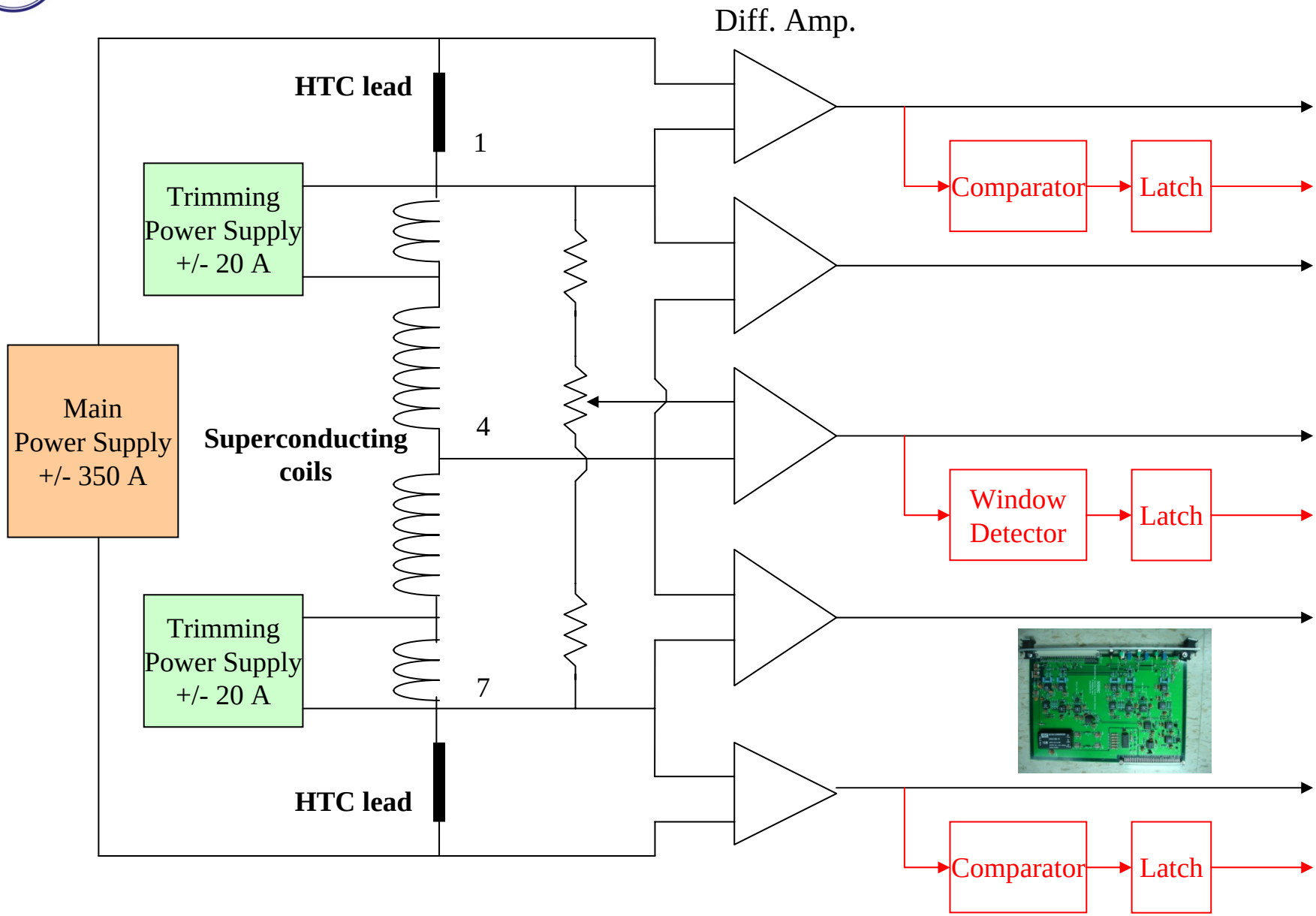
…….

- All tools are trigged by the sum signal:
  beam trip + superconducting IDs quench + SRF trip + predefined trigger conditions

How to detect beam loss?



Superconducting insertion device quench detection



Recorder, oscilloscope, and b-by-b feedback processor, t-by-t BPM

Recorder

Oscilloscope

Data memory in bunch-by-bunch feedback processor

Post-mortem buffer of BPM electronics

cPCI based high density digitizer

Beam trip trigger

SRF related signals

SWLS related signals

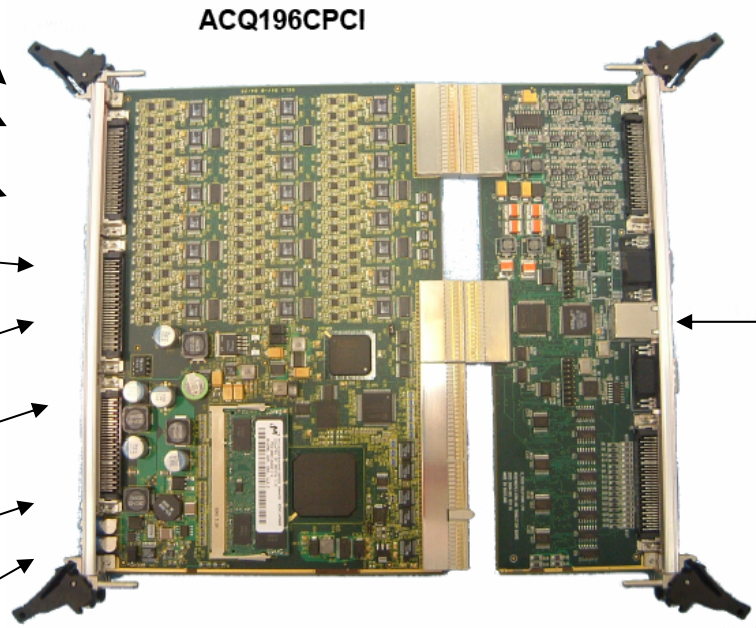
SW6 related signals

IASW-R6 related signals

IASW-R2 related signals

IASW-R4 related signals

Power Lines



Control Ethernet

PC/Linux File Server

Sampling rate: up to 500 kS/sec

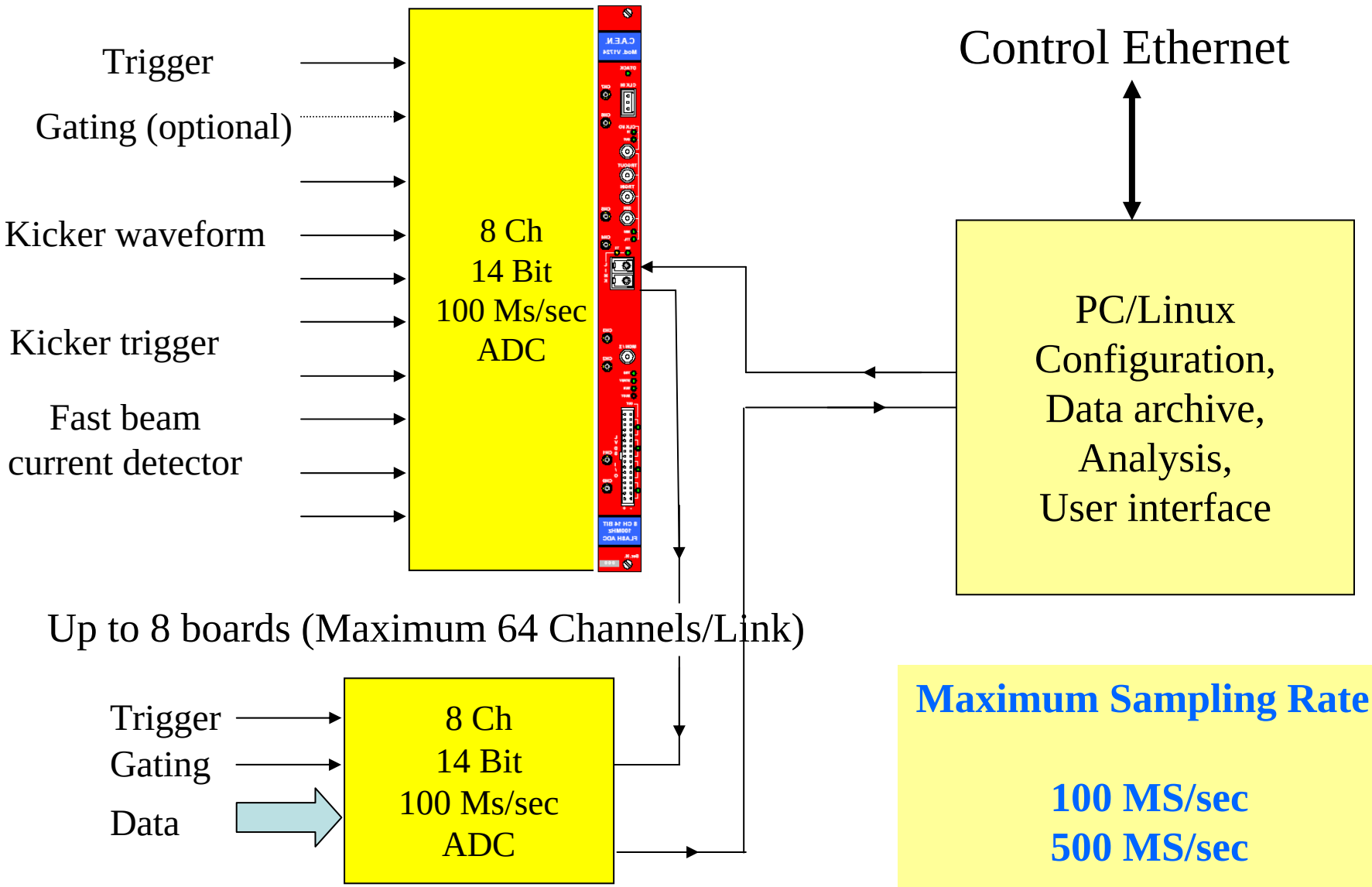
Record length: msec to 10 sec (depending on sampling rate)

Embedded EPICS IOC

96 channels/board

1. Record data before and after the trigger event for several seconds
2. The server saves all data for further analysis
3. Automatically identify faulty signals

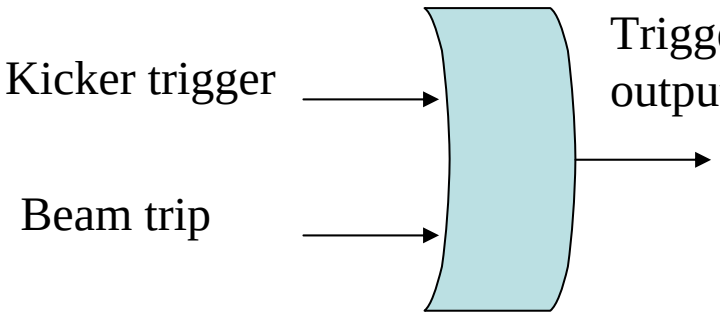
VME based fast digitizer



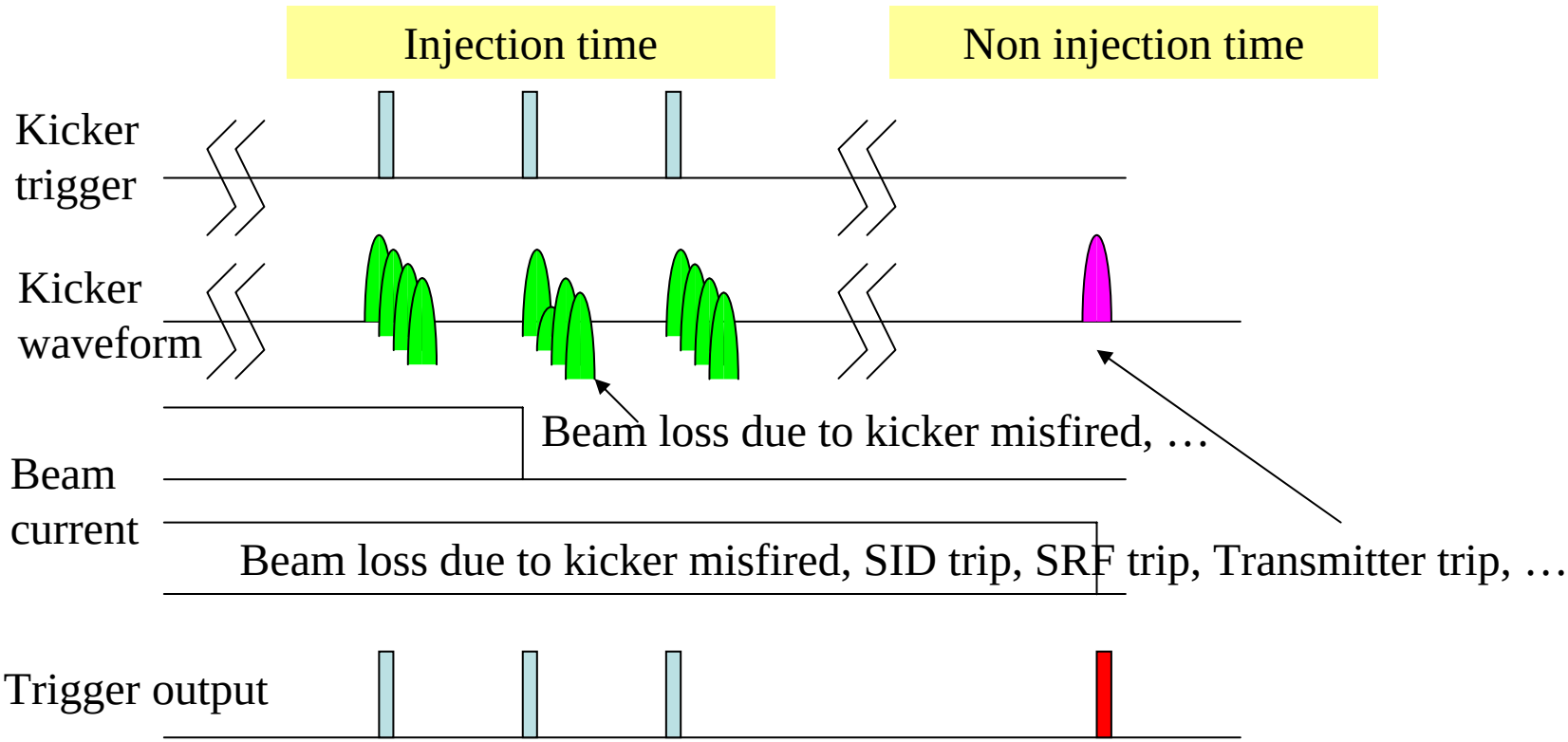
Maximum Sampling Rate:

100 MS/sec
500 MS/sec
…

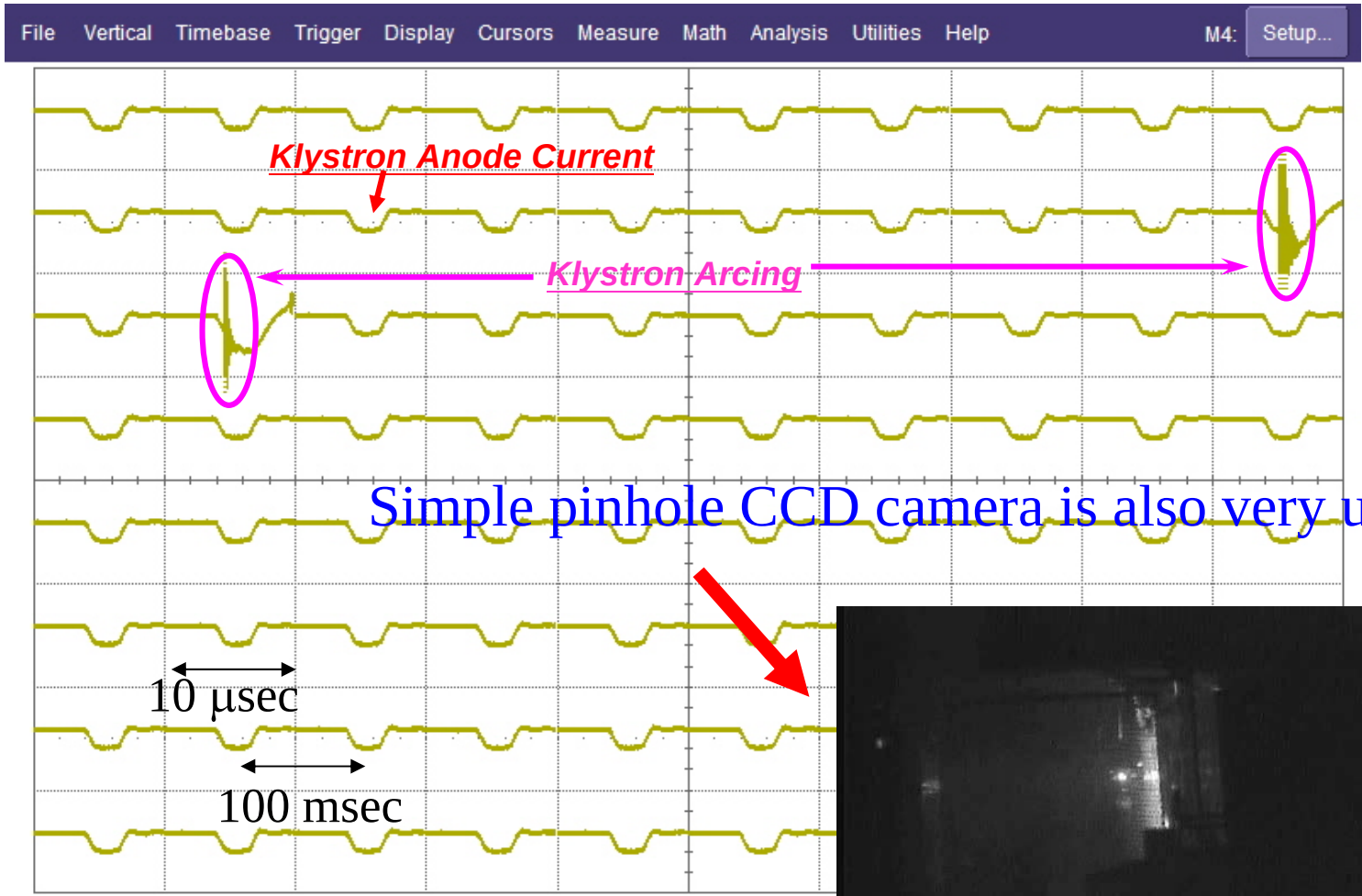
VME based fast digitizer – cont.



- Live display for every top-up injection cycle
- Store data if beam loss occurred



Linac klystron stand arcing diagnostics



Simple pinhole CCD camera is also very useful!

This symptom is just the precursor of isolation breakdown!

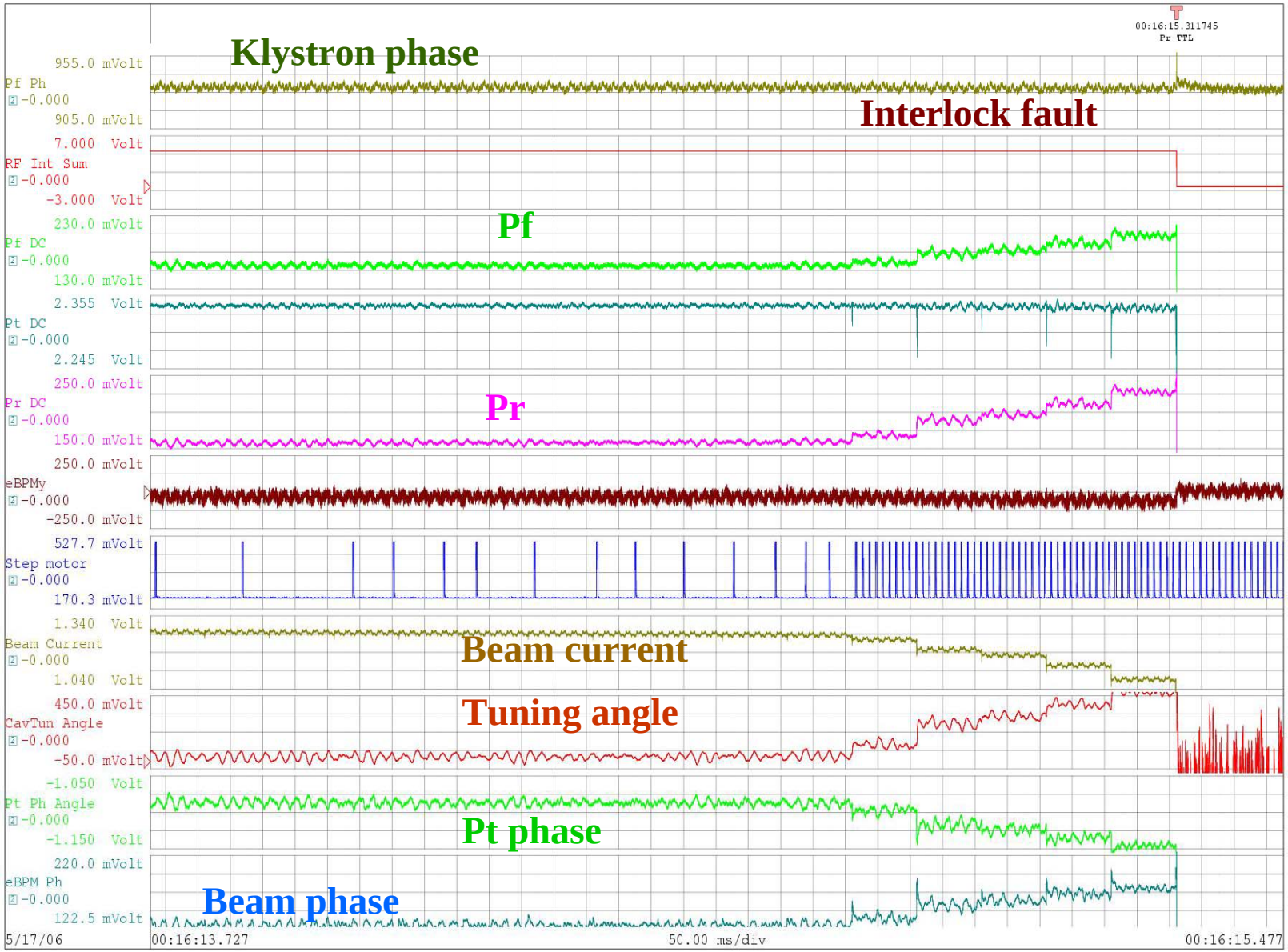
Diagnostic tools for the SRF system

- Try to understand the reasons of every RF/SRF fault

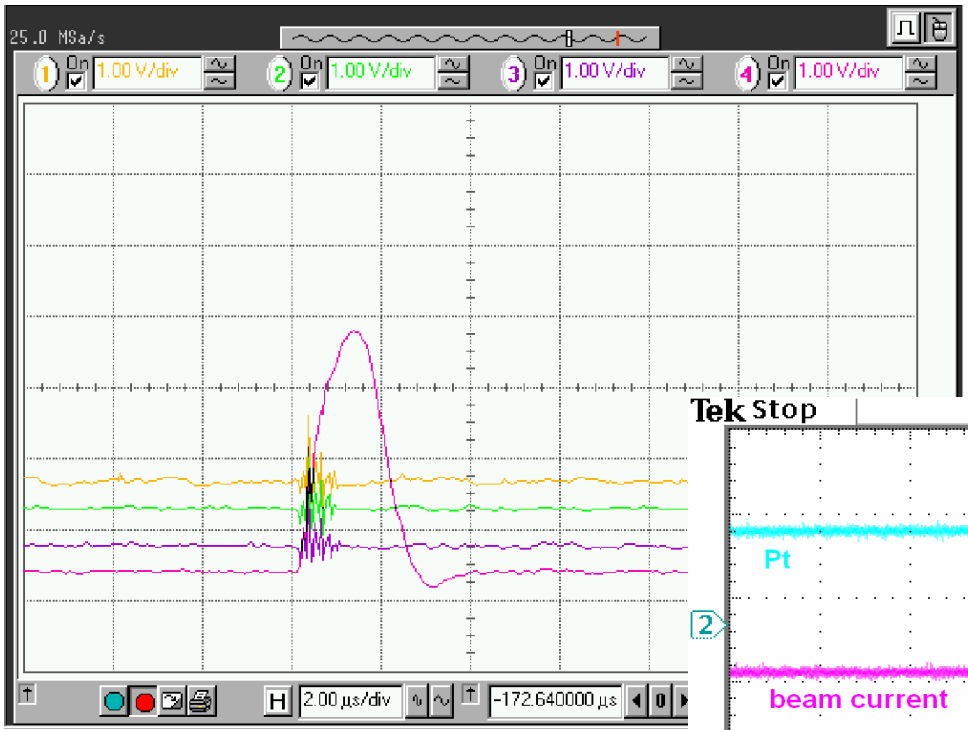
- **What we experience a lot…**
  - SRF "quench" due to fast change of beam behaviors…
    - Fast beam dump or partial beam loss due to various reasons;
    - Fast beam dump due to kicker misfired;
    - Orbit change;
    - …
  - LLRF's feedback loop becomes unstable due to heavy beam loading…
  - False alarm by window arcing…
  - We experience with a "new" kind of trip event every few months and usually solve it by reducing various feedback loop gains.
  - Modified many LLRF electronics to avoid false alarm.

- **What we never or seldom experience…**
  - Multipacting in the cold surface waveguide (Pf < 70 kW);
  - Real quench or field emission (rf gap voltage < 1.6 MV);
  - Vacuum burst due to hydrogen desorption (vacuum better than 0.7 nTorr);

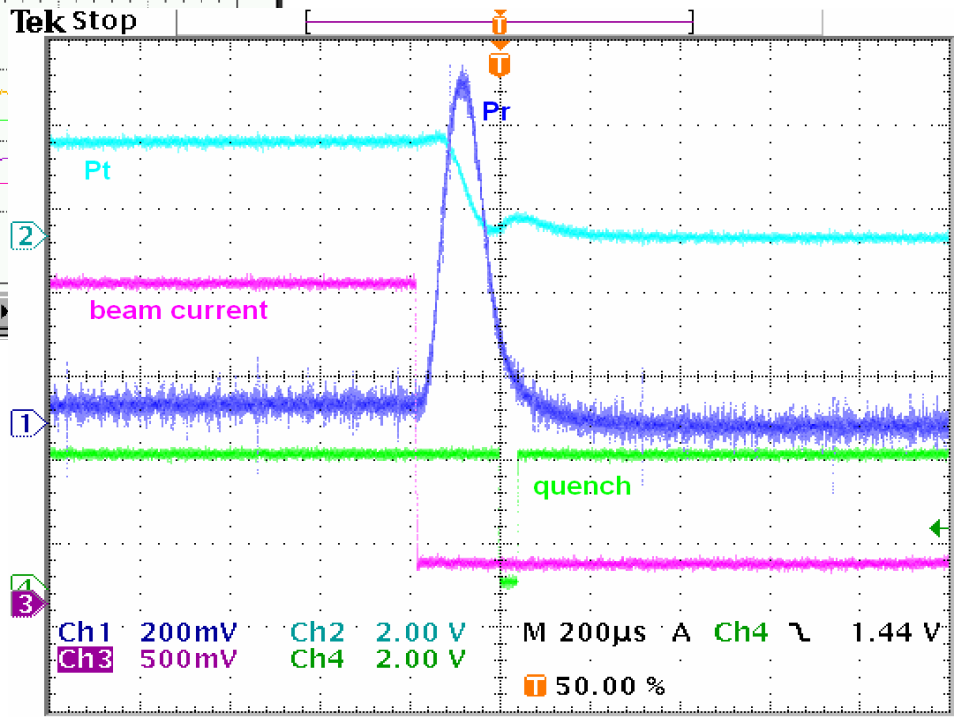
SRF trip due to mismatch of beam loaded cavity



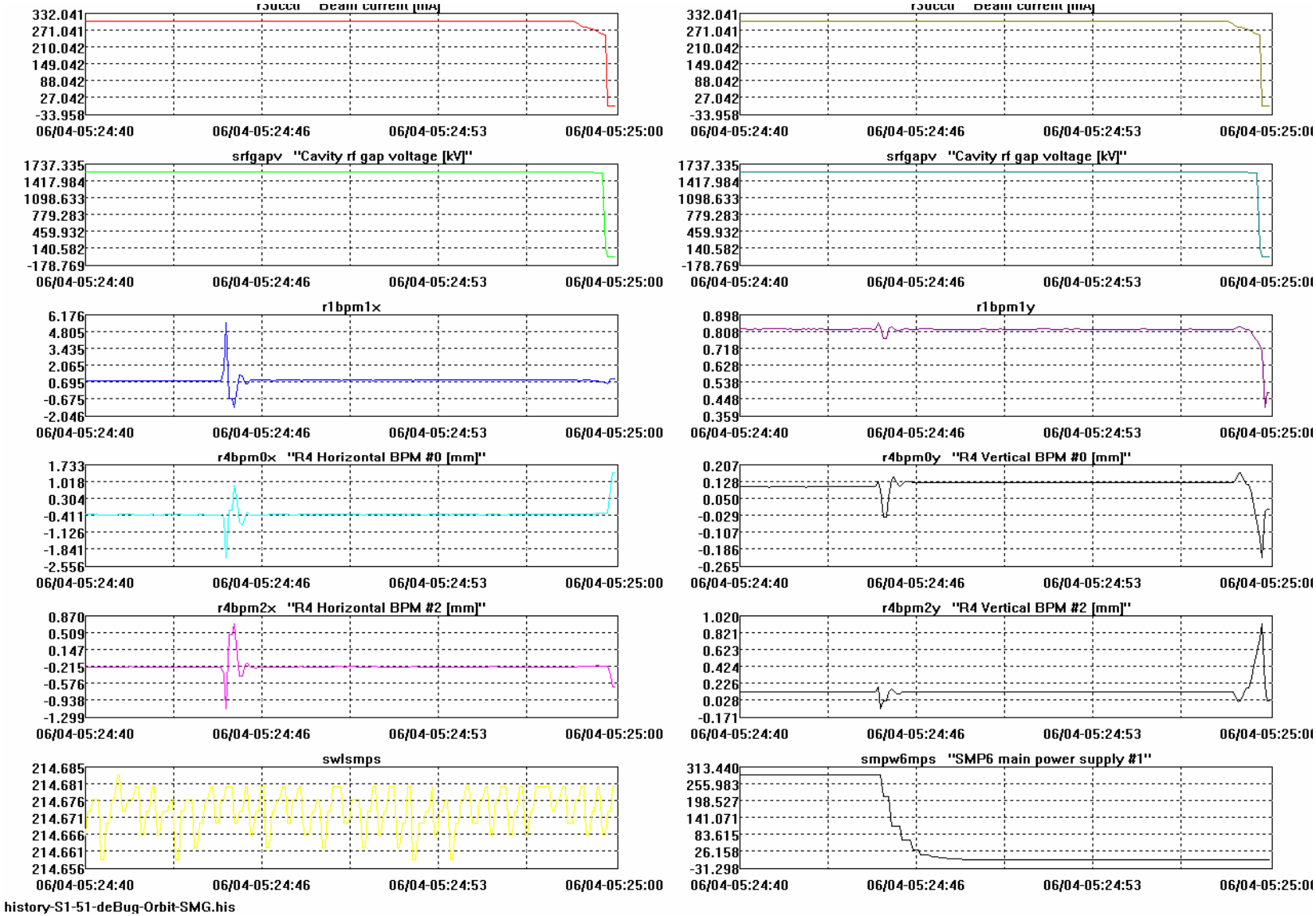
SRF trip due to mismatch of beam loaded cavity – kicker misfired



Spontaneous kicker fired
(bad grounding contact)

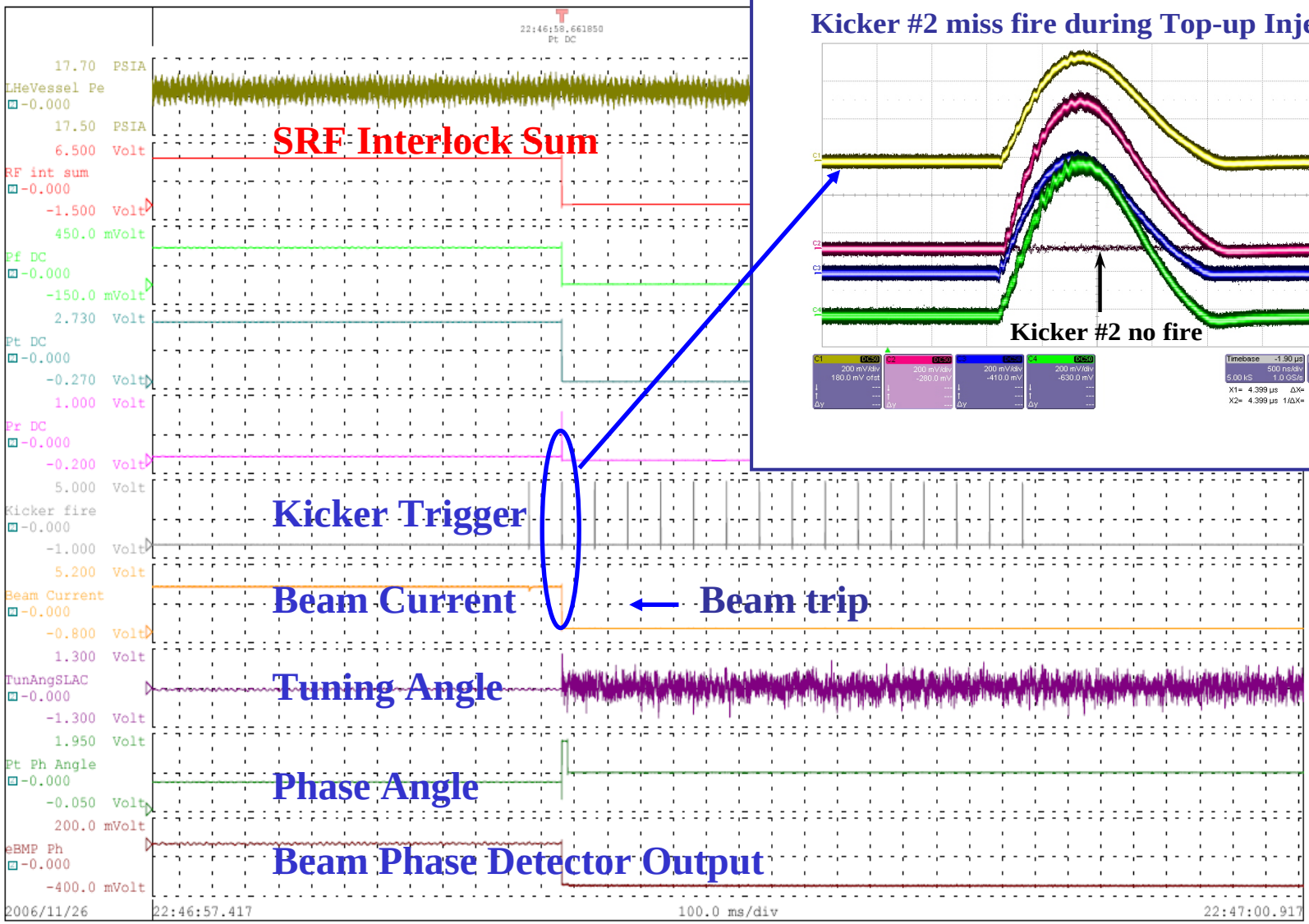


SRF Trip due to mismatch of beam loaded cavity – SW6 fault



Feedback loop oscillations due to heavy beam loading

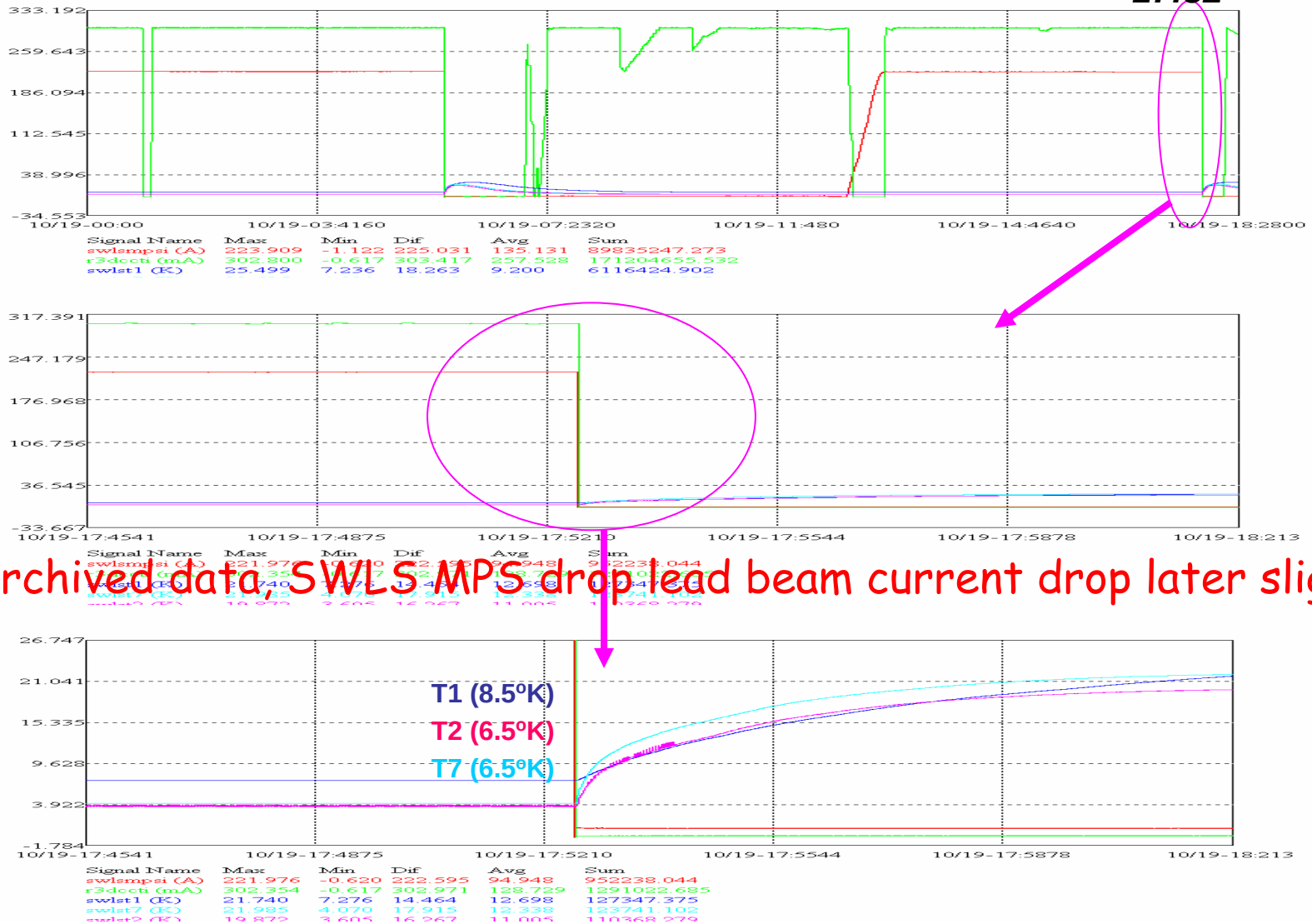
The beam trip caused by kicker misfired



Trip caused by the SWLS main power supply failed

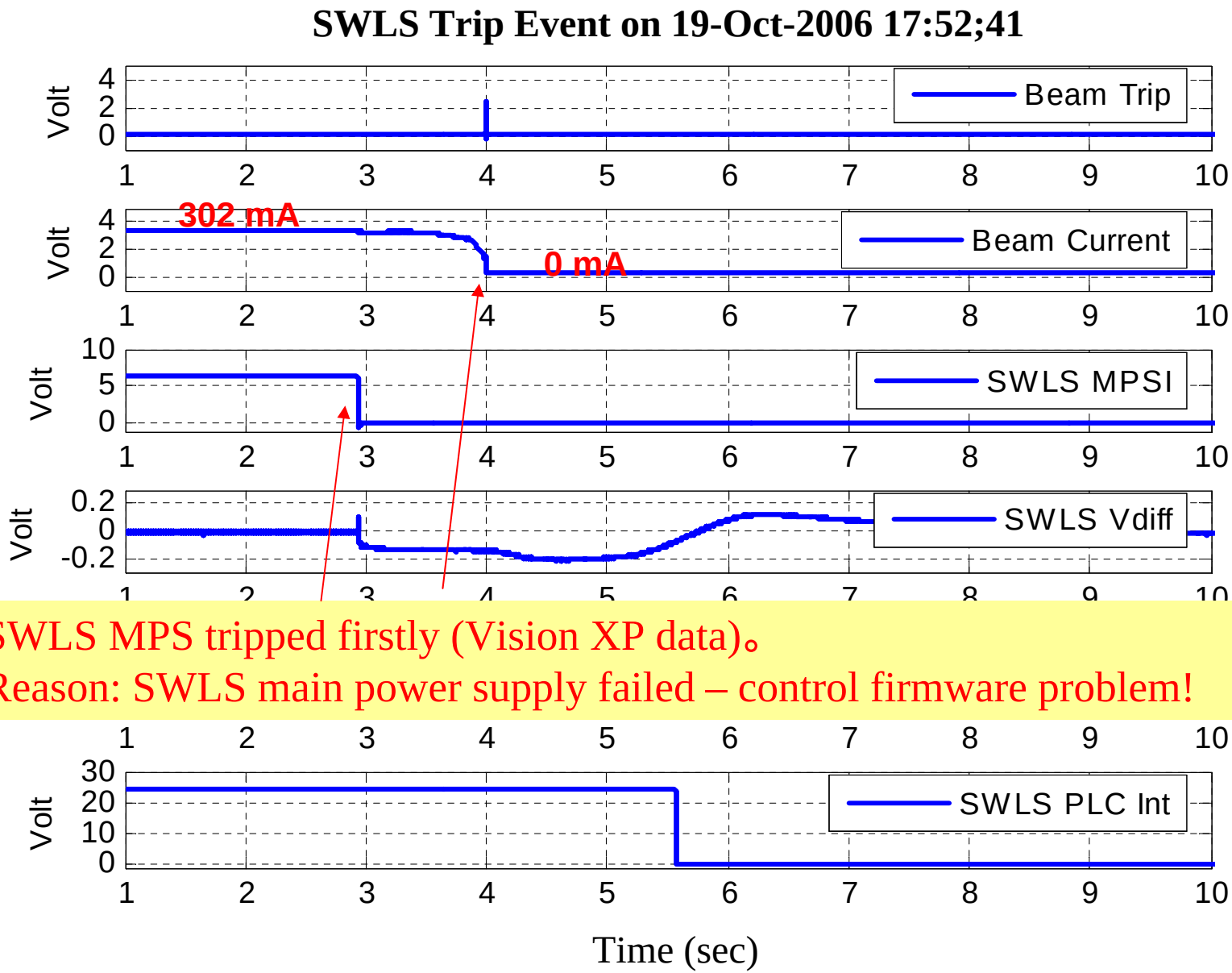
SWLS main coil PS failed

030 10/19/2006 17:52



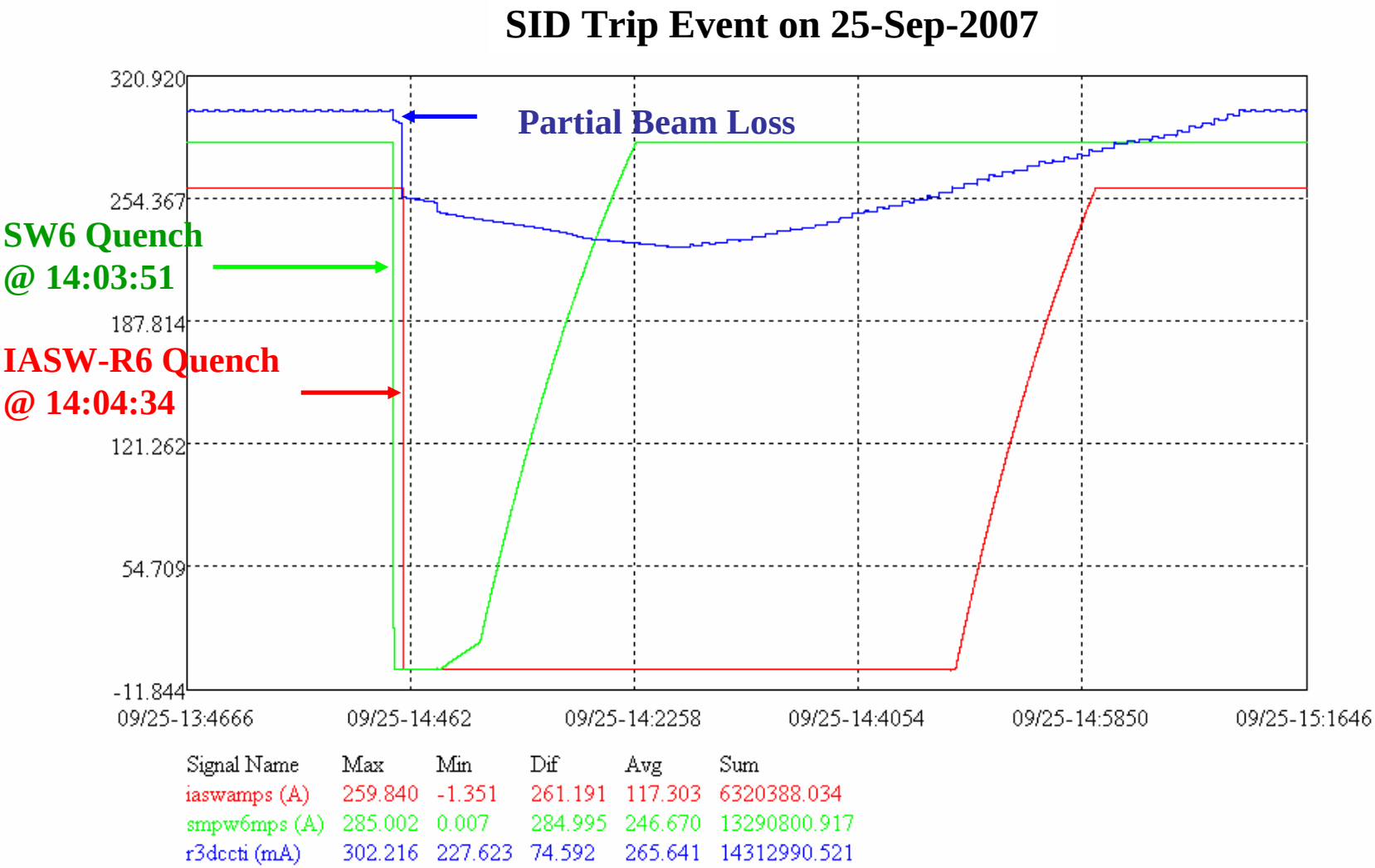
10 Hz archived data, SWLS MPS drop lead beam current drop later slightly!

Trip caused by the SWLS main power supply failed – cont.

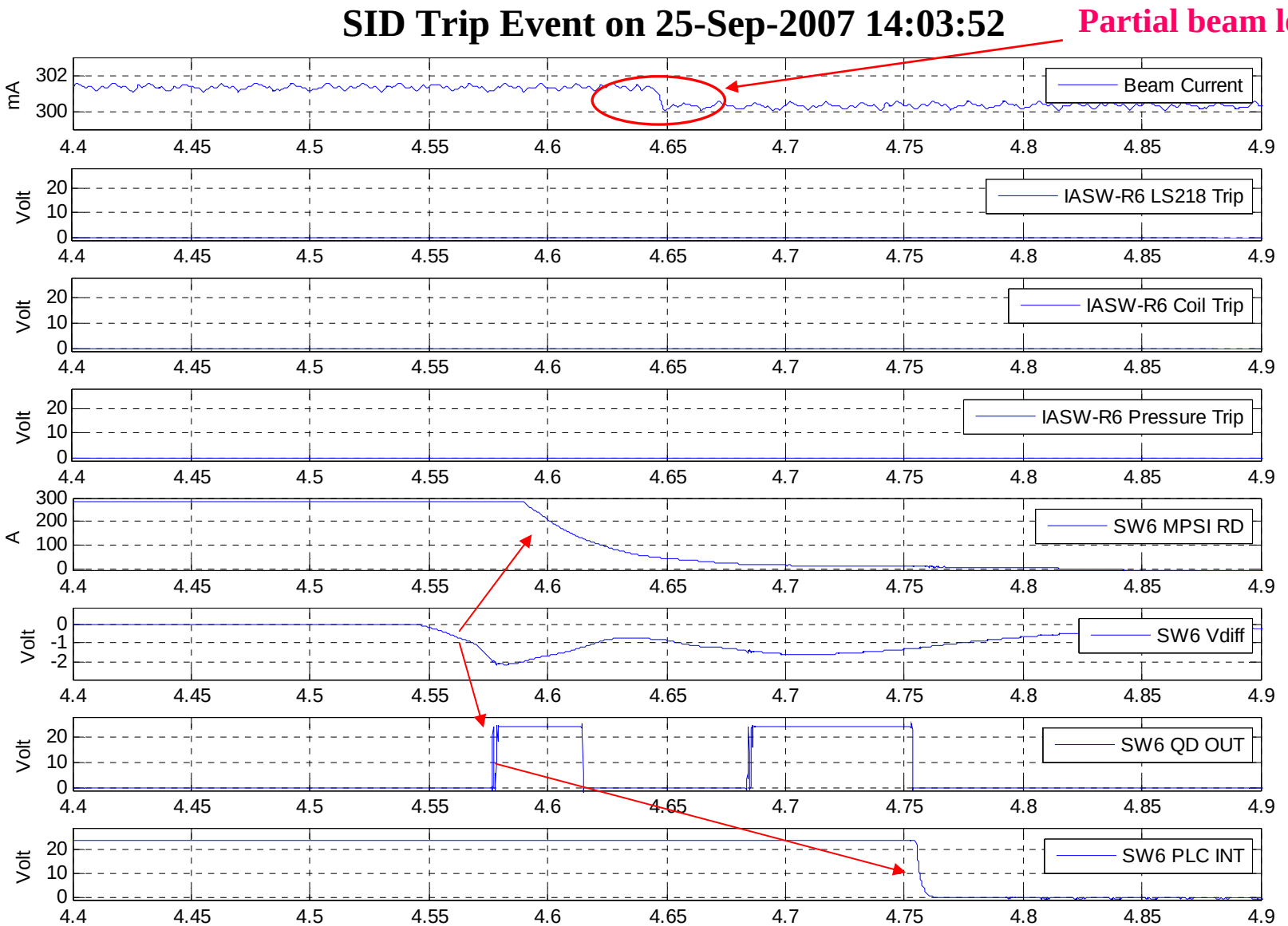


SWLS MPS tripped firstly (Vision XP data)。
Reason: SWLS main power supply failed – control firmware problem!

SW6 and IASW-R6 quench - I

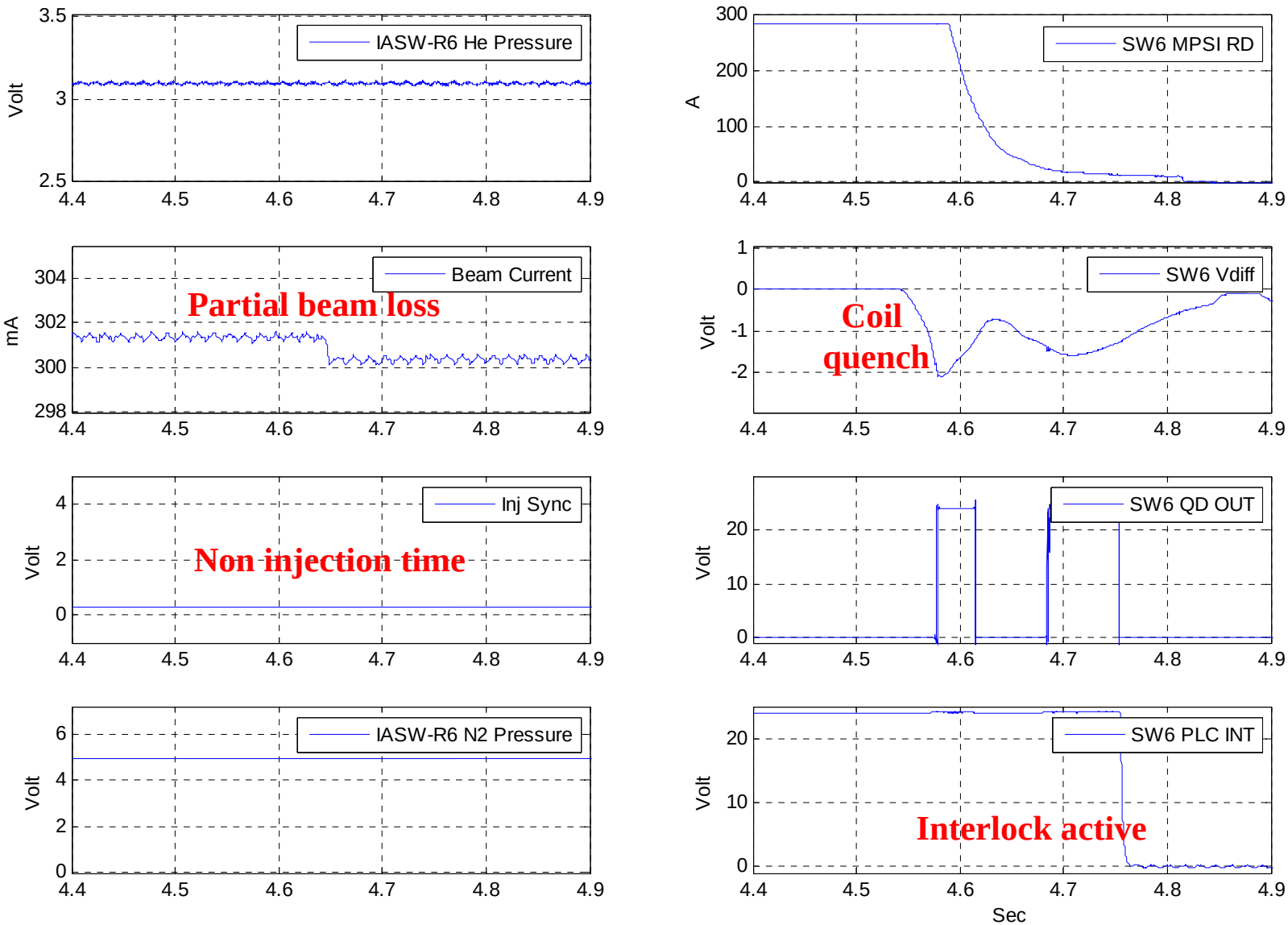


SW6 and IASW-R6 quench – II (SW6 quench)

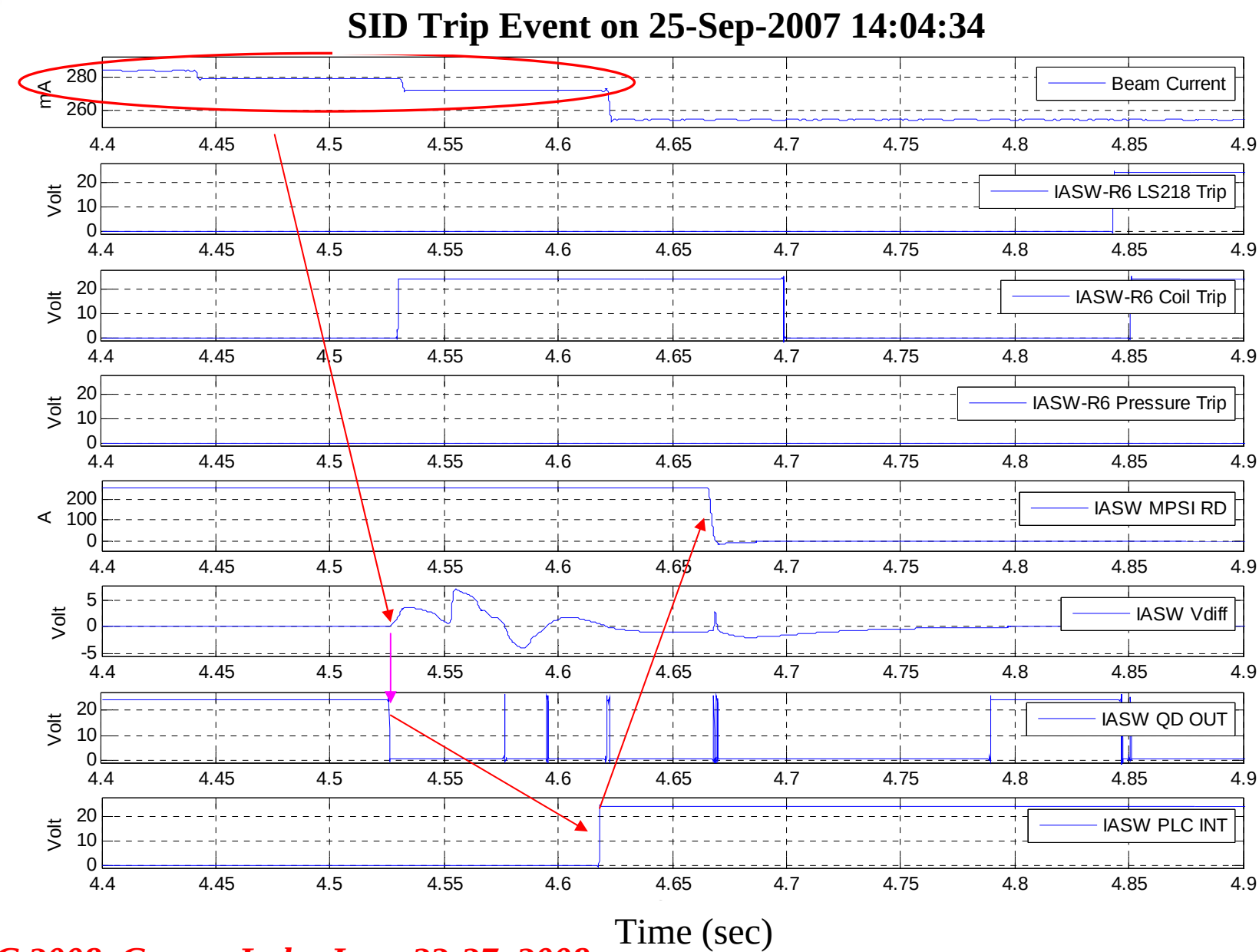


SW6 and IASW-R6 quench – III (SW6 quench)

SID Trip Event on 25-Sep-2007 14:03:52

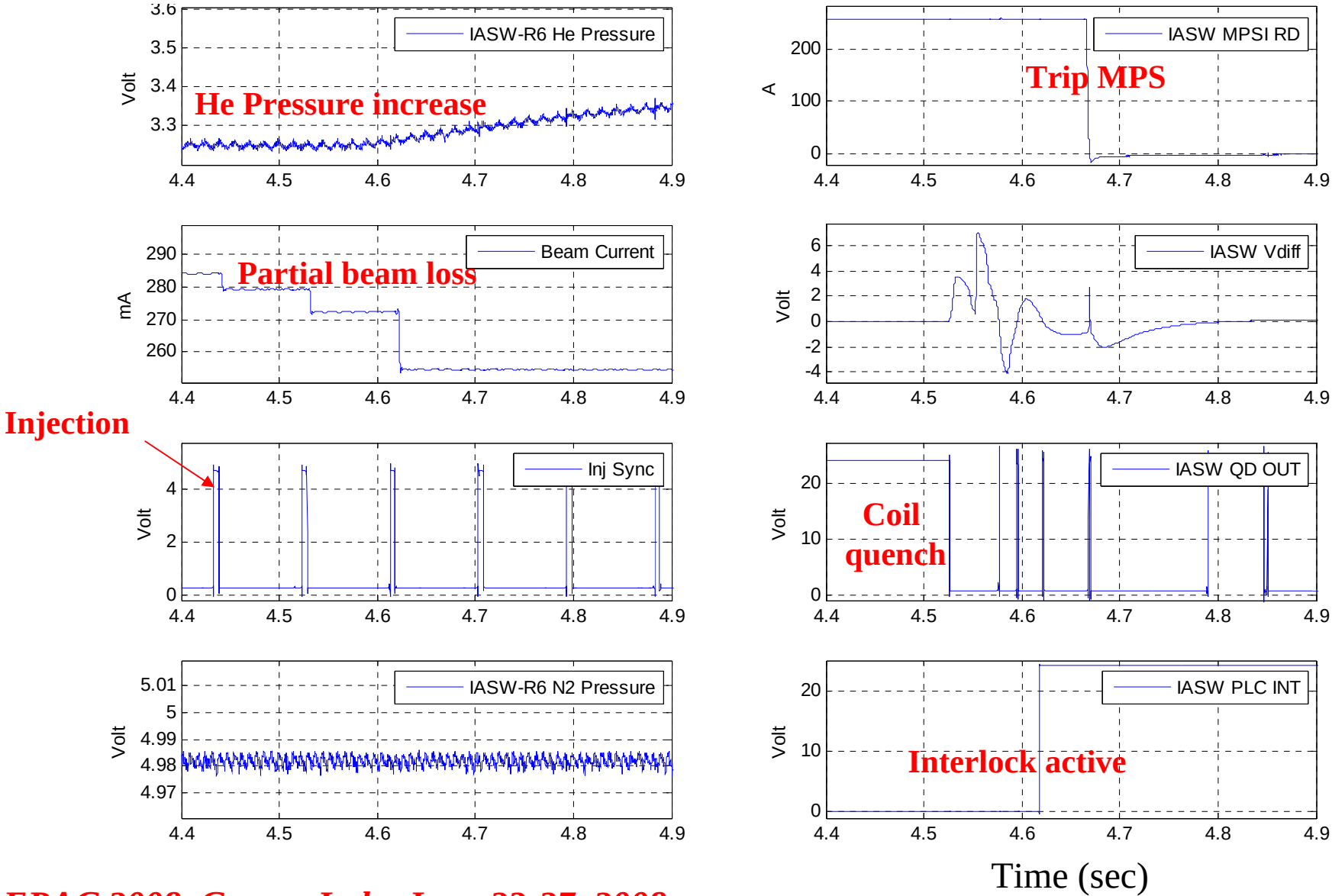


SW6 and IASW-R6 quench – IV (IASW-R6 quench)



SW6 and IASW-R6 quench – V (IASW-R6 quench)

SID Trip Event on 25-Sep-2007 14:04:34



SW6 and IASW-R6 quench – VI

- 25-Sep-2007 14:03:51 SW6 quench.
  * SW6 quench happened.
  * MPS output dropped to 0 (before PLC interlock tripped MPS).

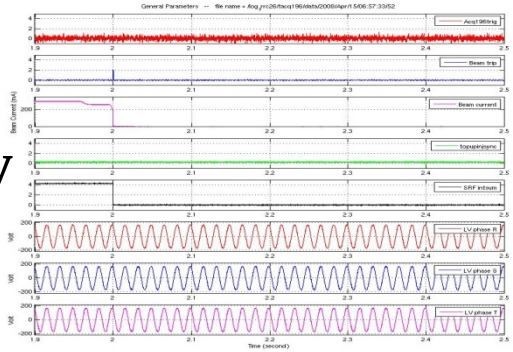
- 25-Sep-2007 14:04:34 IASW-R6 quench.
  * Partial beam loss happened during injection instance.
  * IASW-R6 quench.
  * PLC interlock tripped MPS.

- Unknown reason caused SW6 quench, then partial beam loss at every injection instance, then IASW-R6 quench.

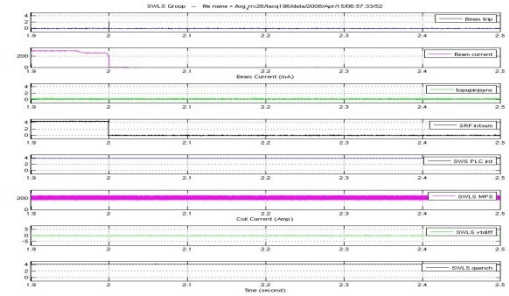
- Many improvements were done: coil winding (poster WEPC114), liquid He filling procedure, interlock logic modification…

Beam loss induced IASW-R6 trip (2008/04/15 06:57)

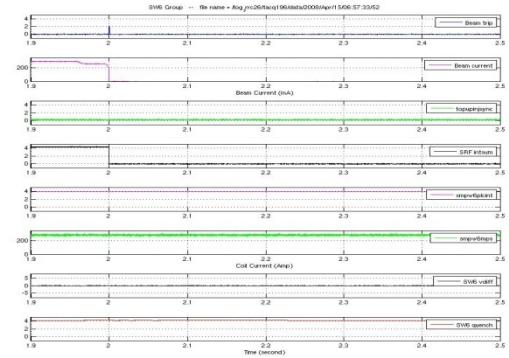
Summary



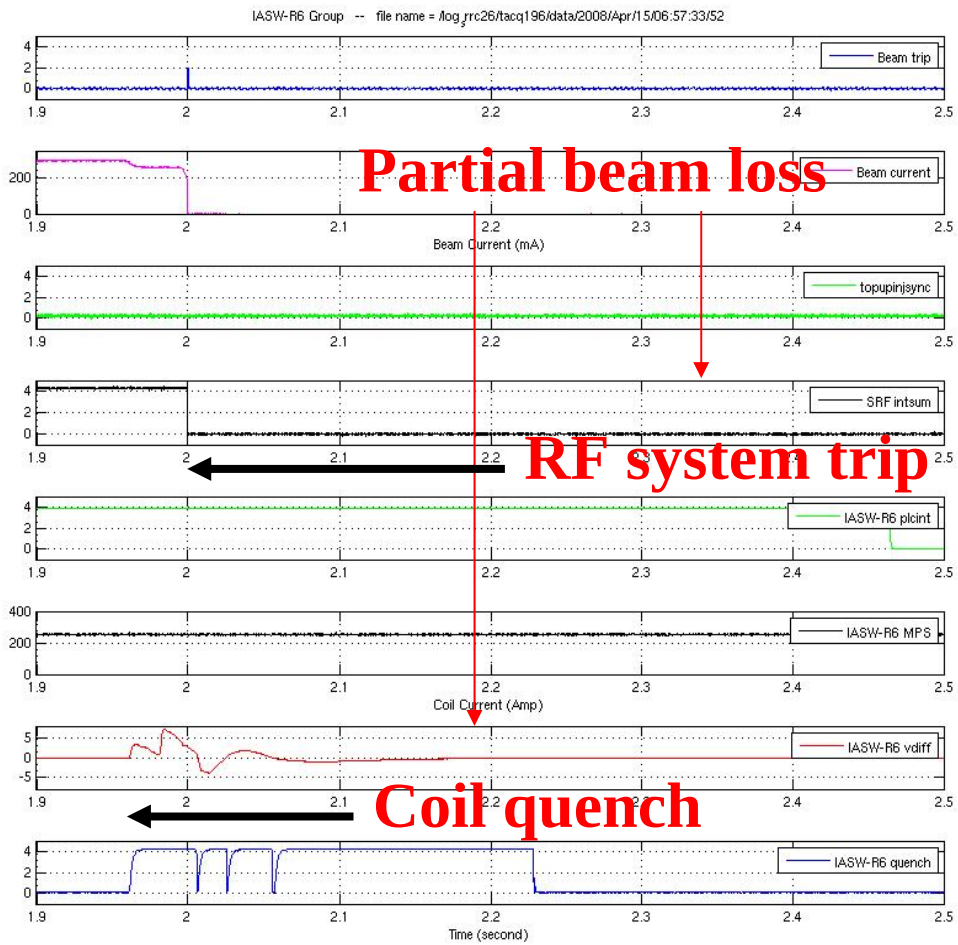
SWLS



SW6



IASW-R6

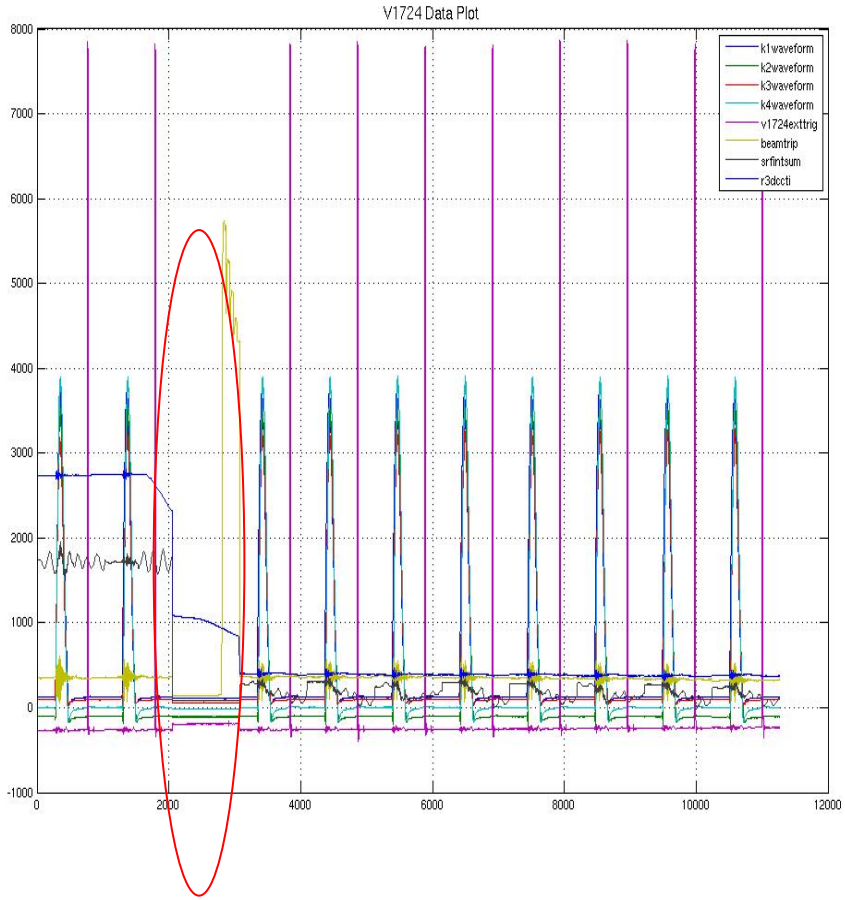


Reason: one vertical corrector PS failed

Kicker diagnostic

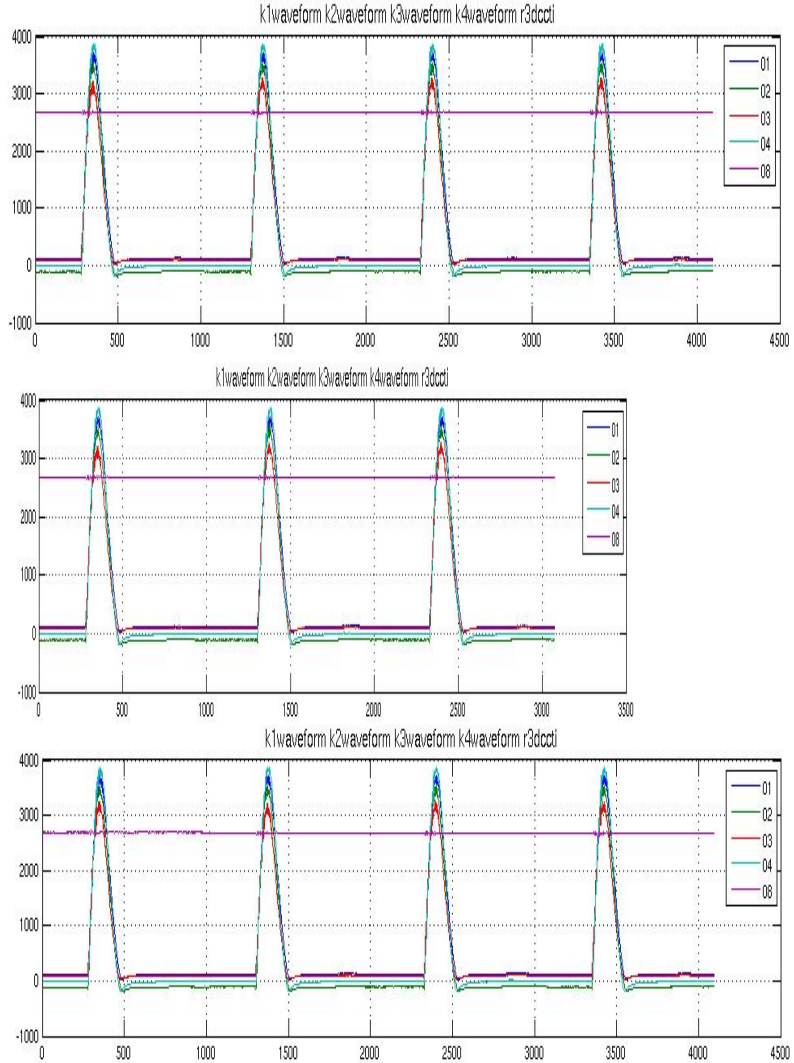
Kicker diagnostic (VME digitizer working in segmented capture mode)

Maintenance test



Beam Loss

Normal top-up injection



BPM post-mortem data for large kicker jitters

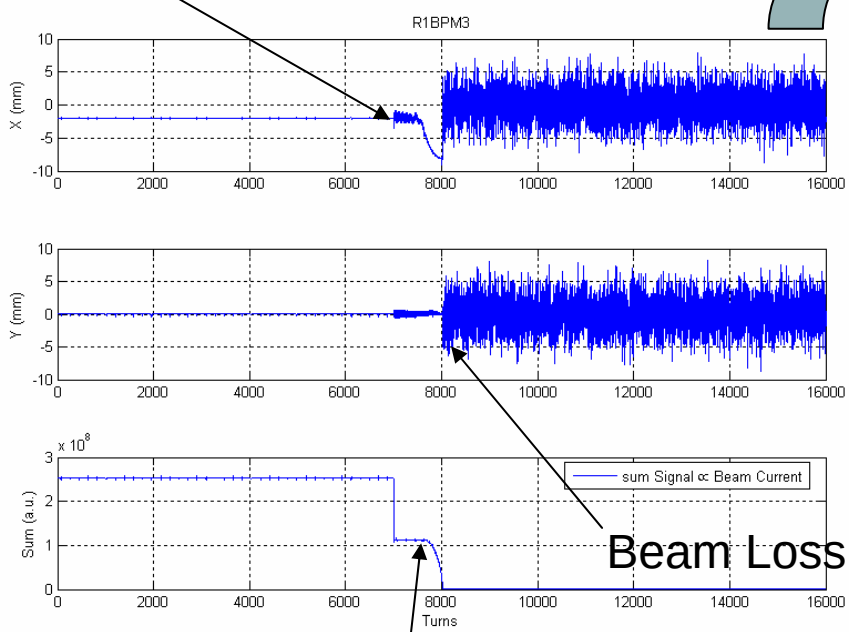
Libera Brilliance post-mortem data (turn-by-turn)
Diagnostics node (10 KHz rate for ~ 10 sec) is in implementation

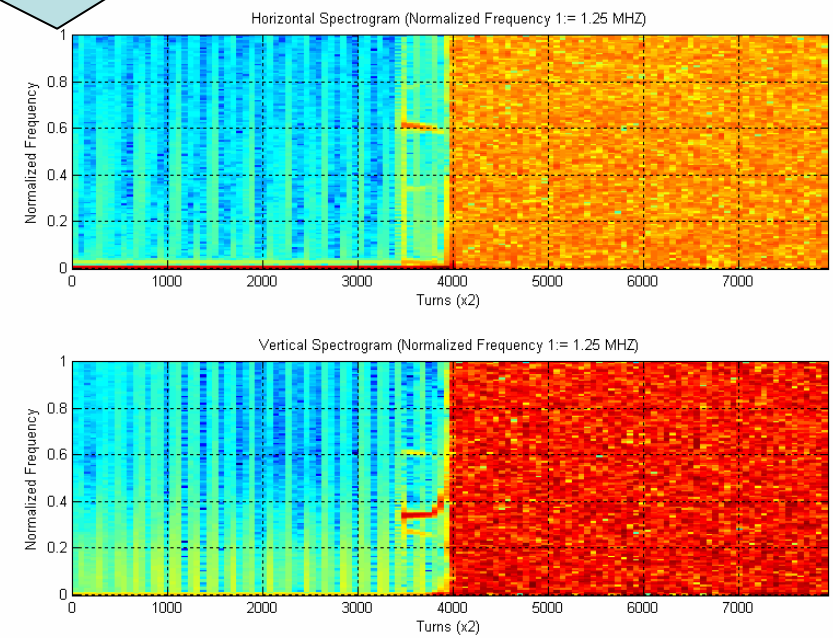
Short-time
Fourier Analysis

K1 trigger -150ns

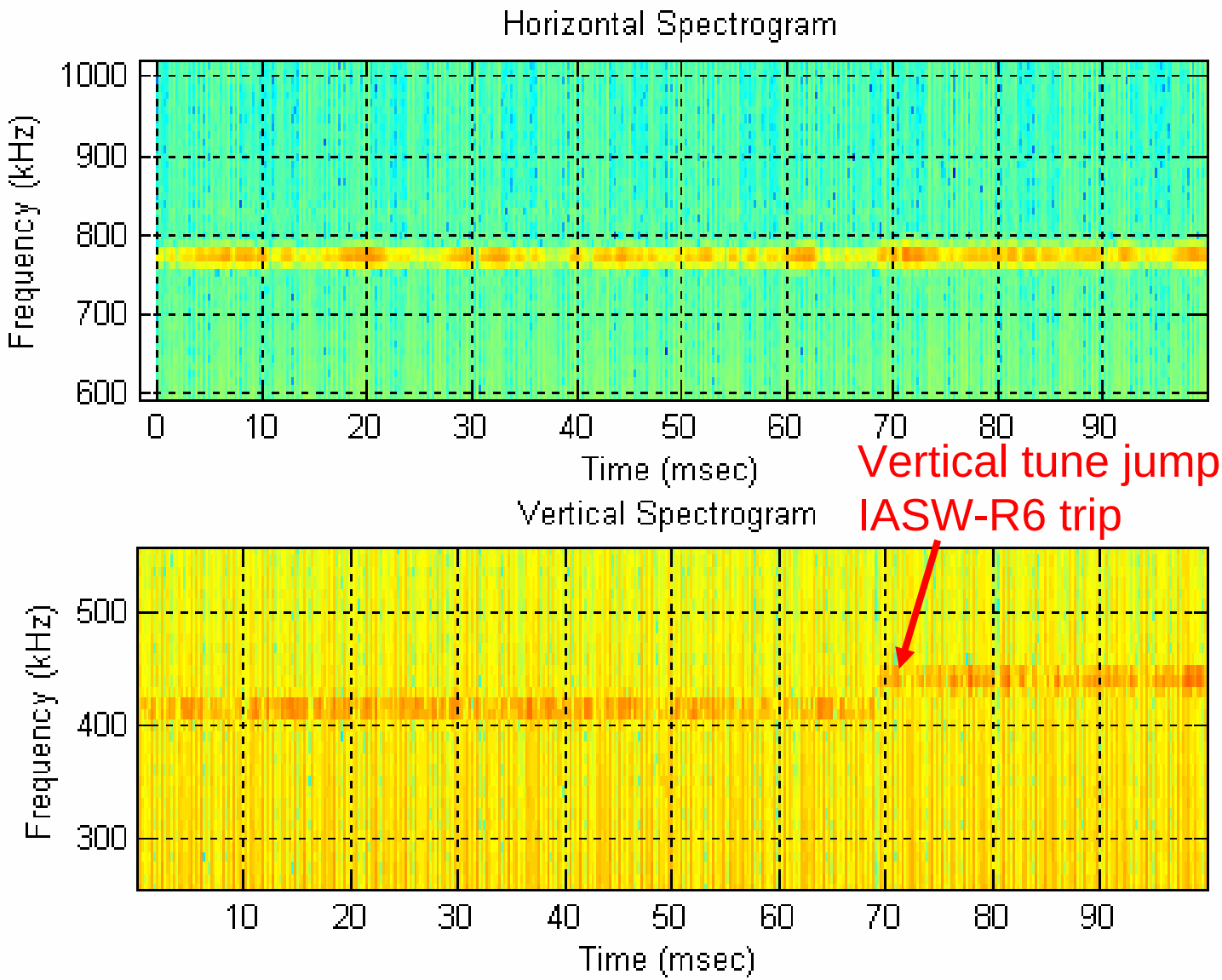
R1BPM3

Spectrogram





BPM post-mortem data for IASW-R6 trip



Vertical tune jumps due to IASW-R6 trip

What we have achieved?

- Several different tools are available.
- Some occasions have helped to identify some peculiar events.
- However no all events can explanation.
  => further efforts are essential !
- Simple automatic signal analysis are supported.

Our current efforts

- Better integration of various diagnostic tools with the control system.
- Archive the events.
- Develop automatic analysis tools to search various signals.
- Develop better user interface.
- Automatic report generation.

Summary

- Taiwan Light Source (TLS) is current operated at 301 mA top-up operation. Top-up operation at 360 mA was commissioning.
  => Poster WEPC043
  (stable beam up to 400 mA has been tested)

- Photon flux constancy can be kept around ~ 0.05%.

- Availability is achieved 97 ~ 99% routinely.

- To provide user better service, reduce trip rate is an important routine job.

- Improving reliability, availability and serviceability is still on going.

- All of the experiences will help the reliability and availability design for the newly proposed Taiwan Photon Source.

  => Reliability design for various subsystem.

  => Post-mortem buffer are expected embedded in BPM electronics, superconducting insertion devices' controller, LLRF system, power supply controller, FOFB diagnostic node, … etc.

We learn and get helps from accelerator community a lot.

Thank You

Hope we can contribute something!

Thank You for Your Attention!