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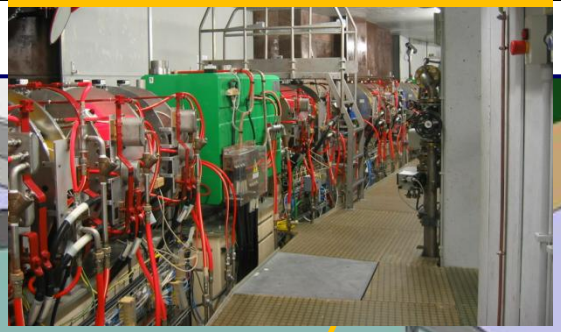
Beam Loss Monitoring System Inside ELETTRA Storage Ring

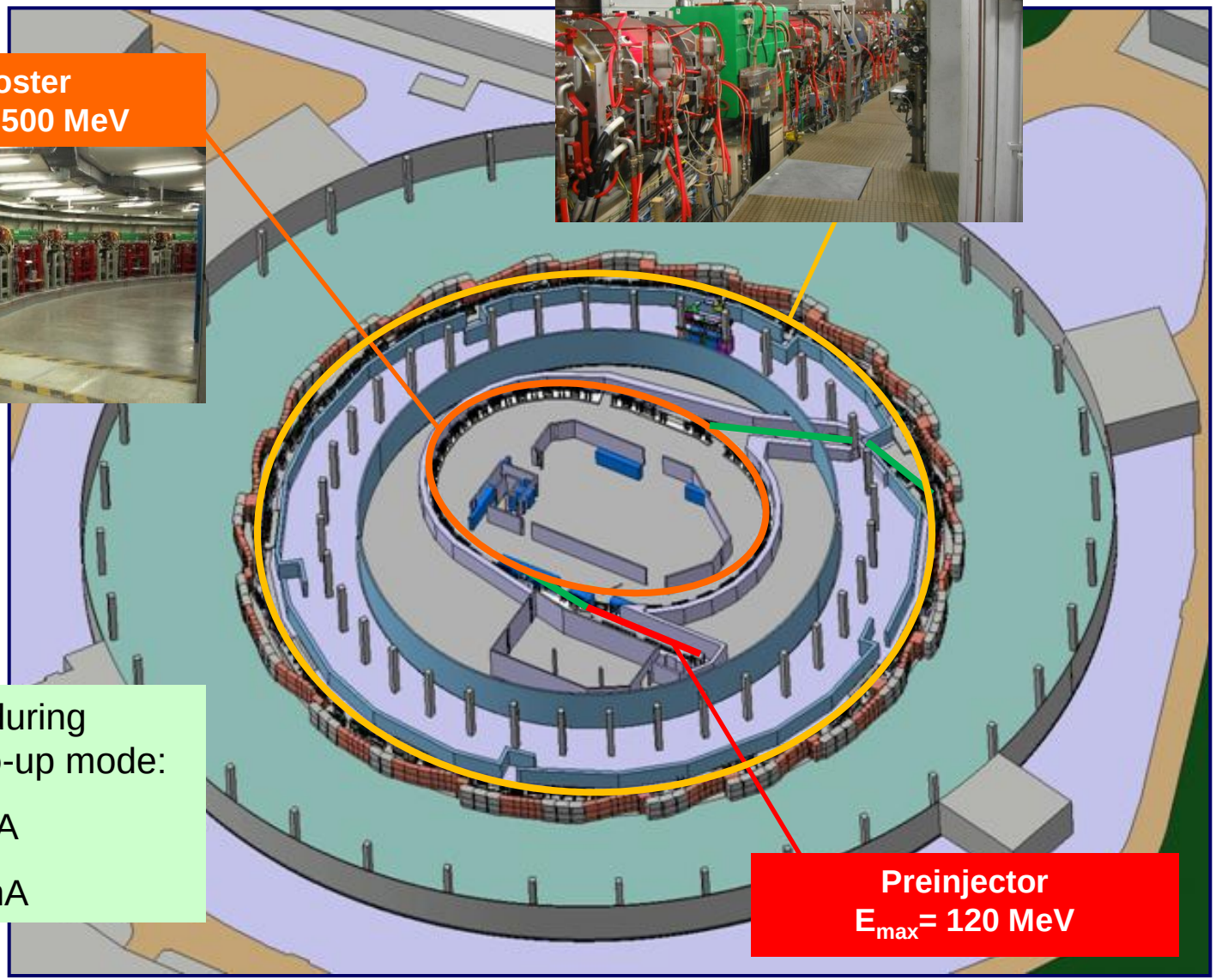
Seventh Internation Workshop on "Radiation Safety at Synchrotron Radiation Sources"
at the National Synchrotron Light Source – Brookhaven National Laboratory

ELETTRA machine

Ring
E_{max}= 2500 MeV



Booster
E_{max}= 2500 MeV

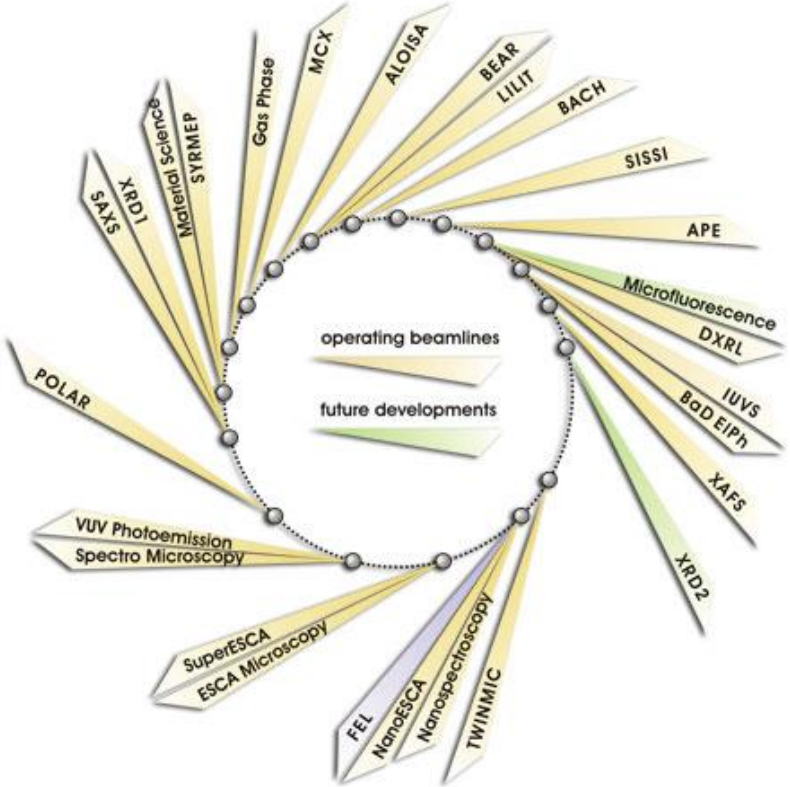


Preinjector
E_{max}= 120 MeV

SR parameters during users' shift in top-up mode:

- 2.0GeV, 310 mA
- 2.4 GeV, 140 mA

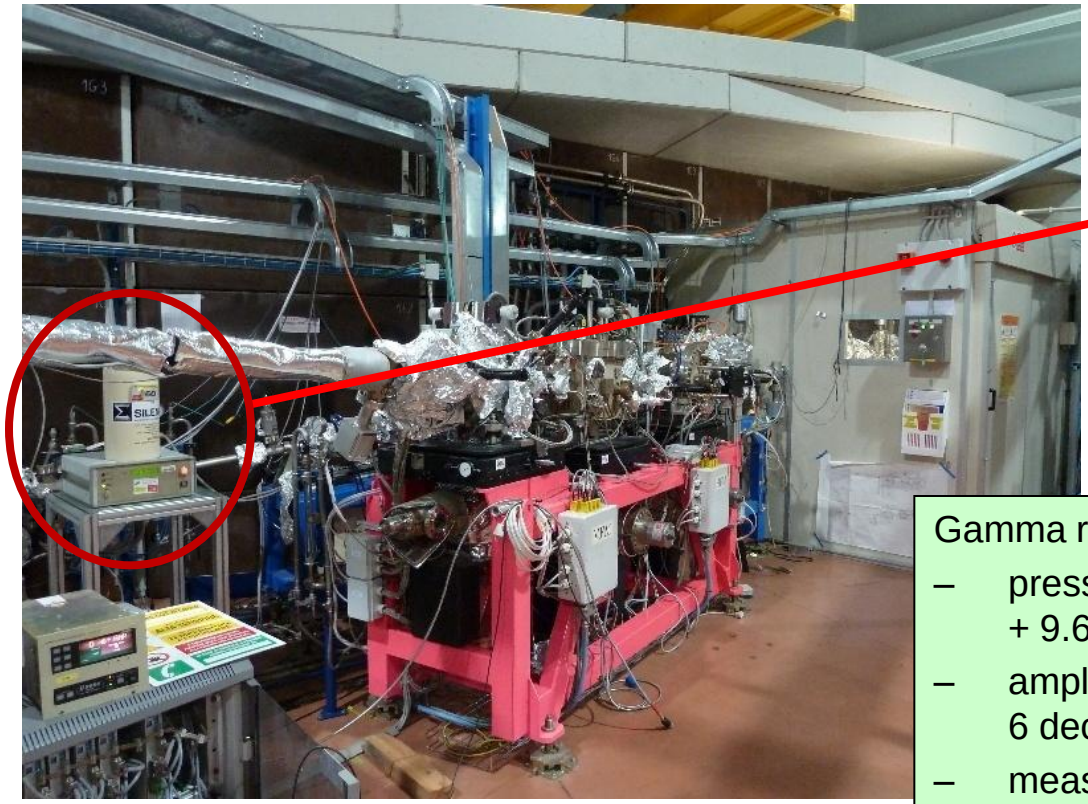
ELETTRA beamlines

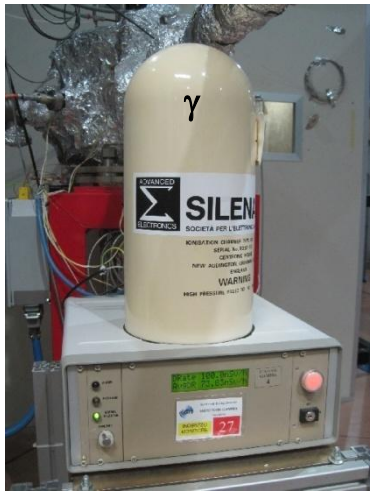


- Top-up operative since June 2010:
  - booster project started in 2005 and lasted about 3 years
  - in Dec. 2007 the booster was connected to the ring
  - in Feb. 2008 the first full-energy injection was carried out
  - in March 2008 the users' shifts re-started
  - from June 2010, top-up has become normal operation.

Experimental Hall radiation monitoring

- The radiation monitoring around the beamlines is performed through a network of gamma radiation monitors (about 30) connected to the beamlines' Personnel Safety System: if the <u>dose rate</u> or the <u>integrated dose</u> exceed pre-fixed thresholds, the beamline's stoppers are forced closed.





Gamma radiation monitors:

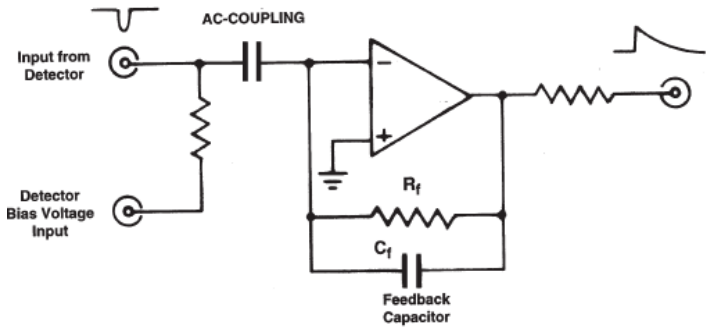
– pressurized ionization chambers (6.4 atm Ar + 9.6 atm N_2)
– amplifier/analog to digit converter linear over 6 decades with automatic scale range
– measurement accuracy at environmental background level is ±5%

Beam loss monitoring inside the SR (1)

What we had

- In 2008 the beam loss monitoring inside the storage ring was based on a network of 24 PIN photodiode detectors (BPW34).

- The front-end electronics was based on a charge amplifier, synchronized with the injection trigger → originally designed to detect beam losses in Linac during injection.



$$V_o = \frac{Q_D}{C_f} \text{ and } \tau_f = R_f C_f$$

- On-line measurements from PIN photodiodes were plotted on a bar graph, at disposal of the control room operator.

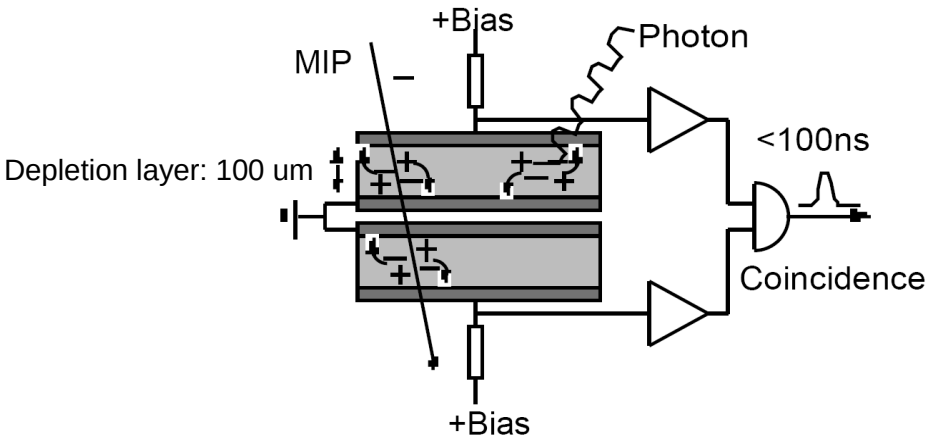
Beam loss monitoring inside the SR (2)

What we needed

- A monitoring system suitable to detect beam losses not only during injection, but also with accumulated beam:
  → high sensitivity.
- Normally beam losses are higher during injection and very small when machine operates in top-up mode or decay mode:
  → large dynamic range.
- Radiation produced by beam losses should not be confused with synchrotron radiation:
  → need to reject synchrotron radiation.
- In principle beam losses may occur at any point of the storage ring:
  → widespread monitoring system.
- Information coming from the monitoring system must be easy to understand, to manage and to recover:
  → need of a graphical user interface for on-line measurements
  → need of an archive.

A possible answer: Bergoz BLMs

Operating principle



Specifications

Single particle detection efficiency:	>30%
Size:	69x34x18 mm
PIN-photodiode surface:	7.34 mm^2
dE/dx in Si:	3.7 MeV/cm
Spurious count rate	<0.1 Hz
Maximum count rate:	>10 MHz
Fast:	~ 5ns
Sensitivity:	~ 50nC/rad/cm^2
Output:	positive TTL 50Ω

Two photodiodes are mounted face-to-face to detect charged particles.

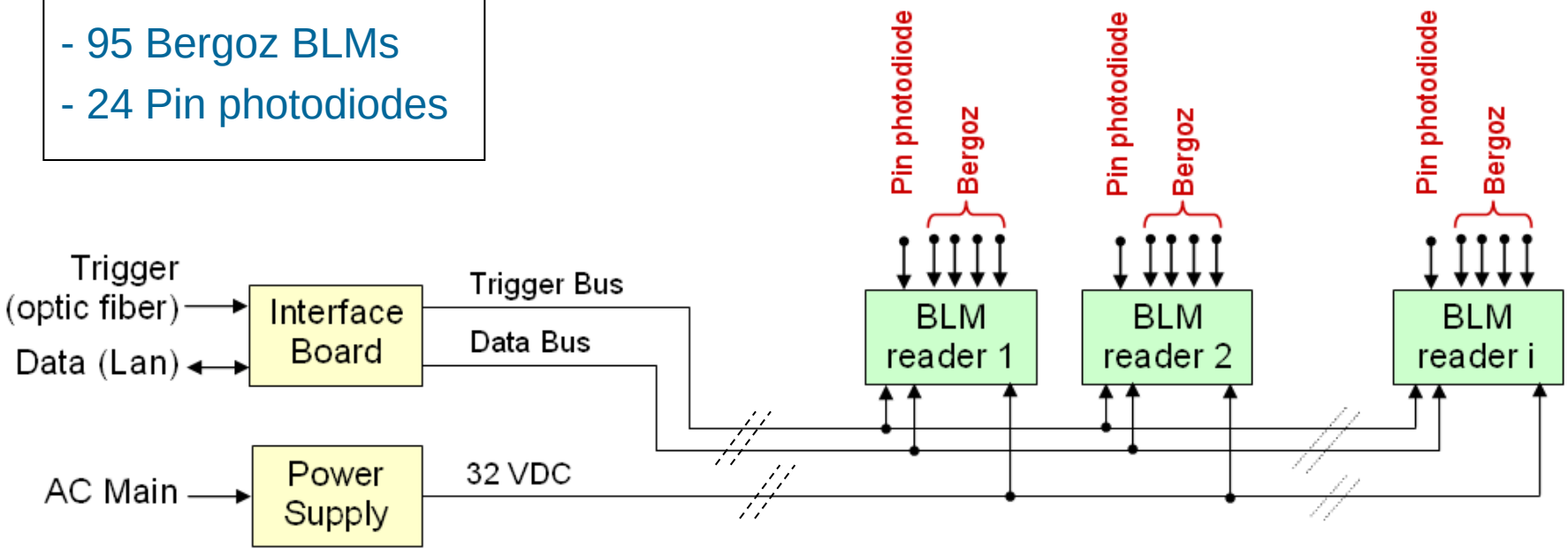
Charged particle crosses both PIN-photodiodes, causing a coincidence. Synchrotron radiation photons, if stopped by either PIN-diode, do not cause a coincidence.

Beam loss monitoring upgrade

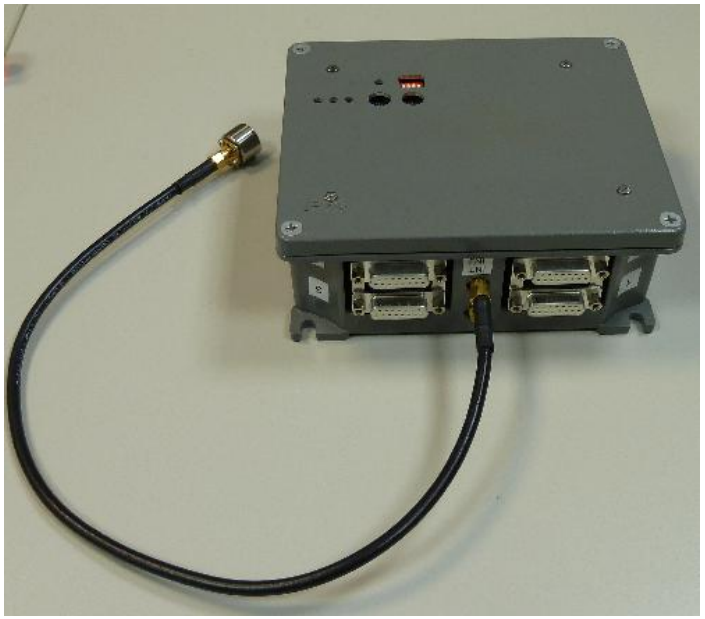
- To guarantee the possibility of acquiring with the same reader both the “old” synchronized Pin photodiodes and the “new” Bergoz BLMs, an acquisition electronics was developed in-house.

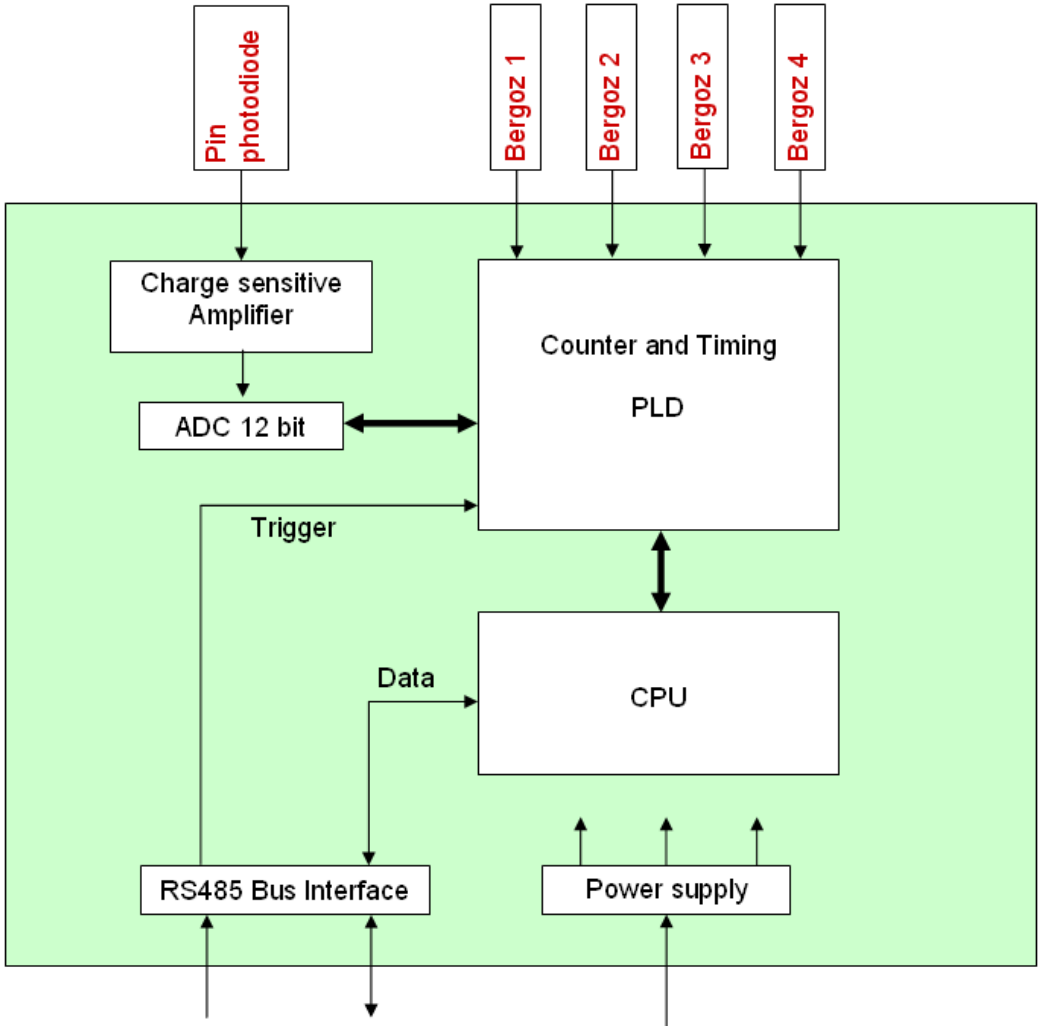
- The network of PIN photodiodes was initially integrated with a network of 16 Bergoz BLMs (that became then 48 and finally 95 in 2012).

- 24 readers
- 95 Bergoz BLMs
- 24 Pin photodiodes

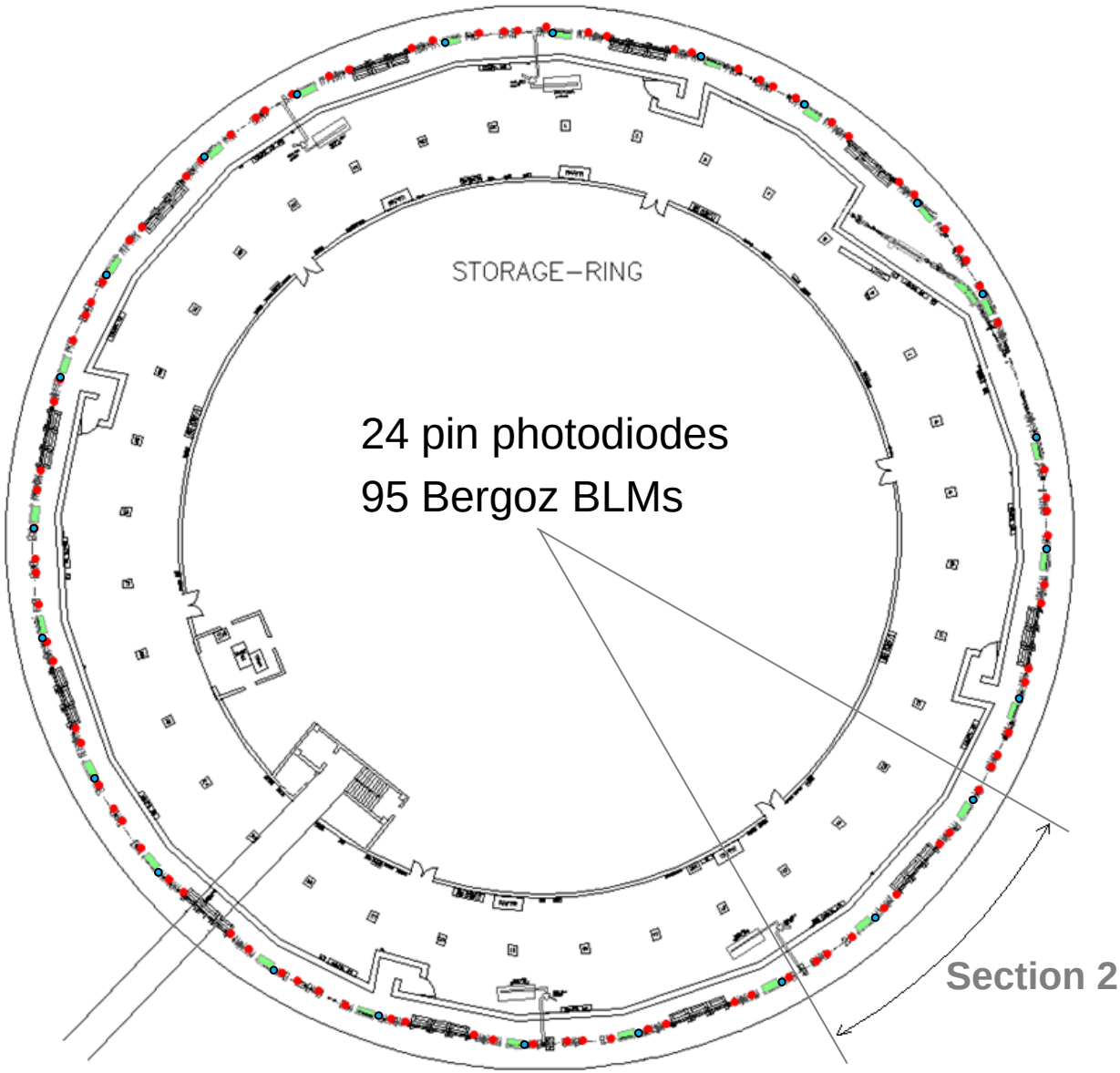


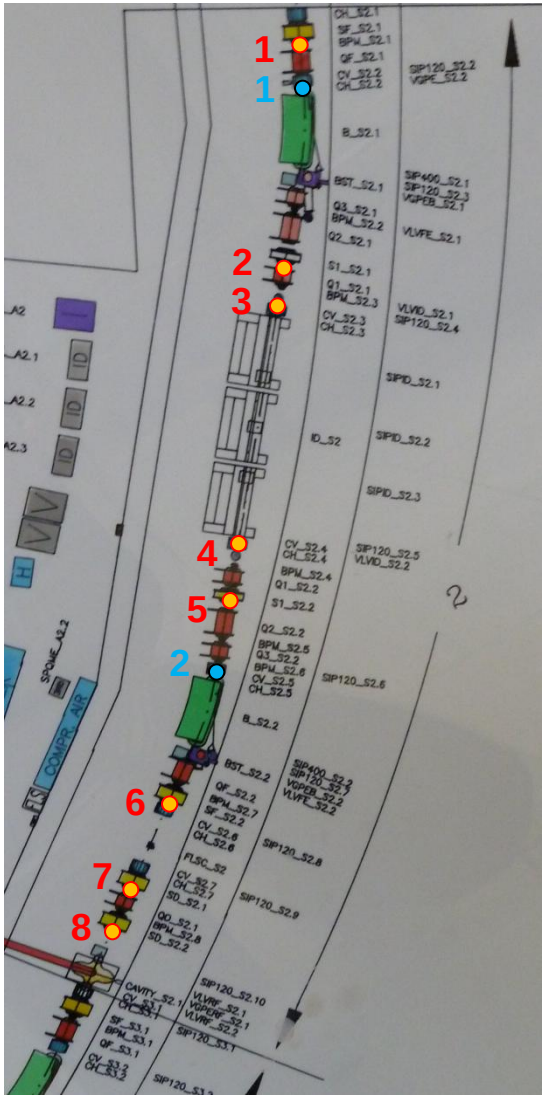
BLM reader




Pin photodiode
Bergoz 1
Bergoz 2
Bergoz 3
Bergoz 4
Charge sensitive Amplifier
ADC 12 bit
Counter and Timing
PLD
Trigger
Data
CPU
RS485 Bus Interface
Power supply

BLMs layout


STORAGE–RING
24 pin photodiodes
95 Bergoz BLMs
Section 2


1
1
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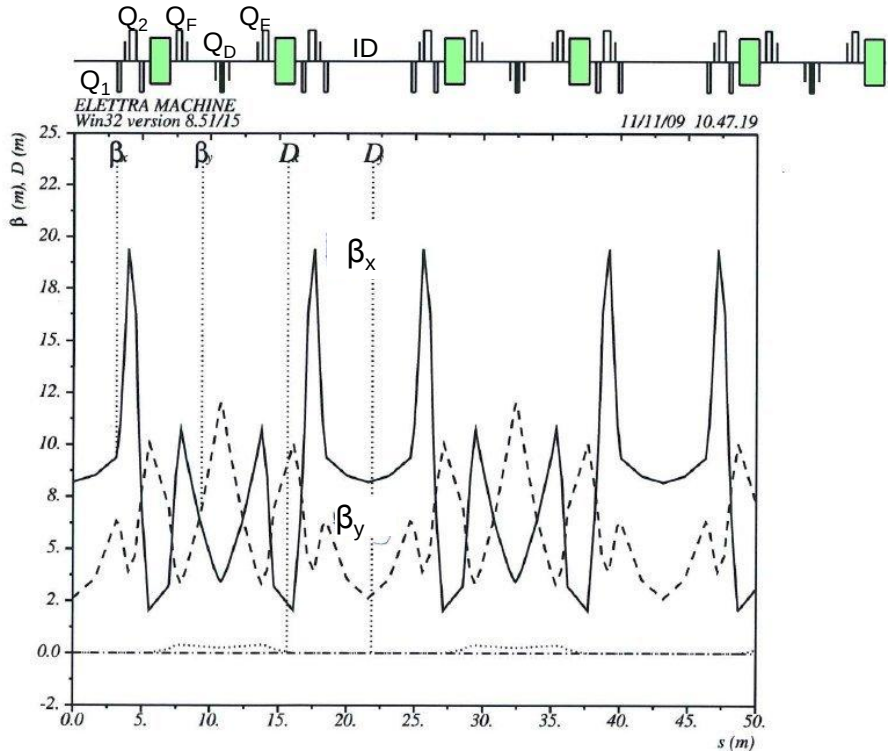
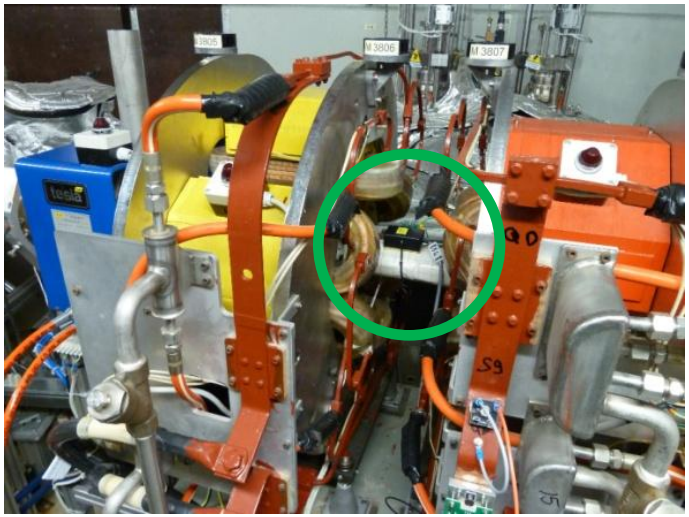
8

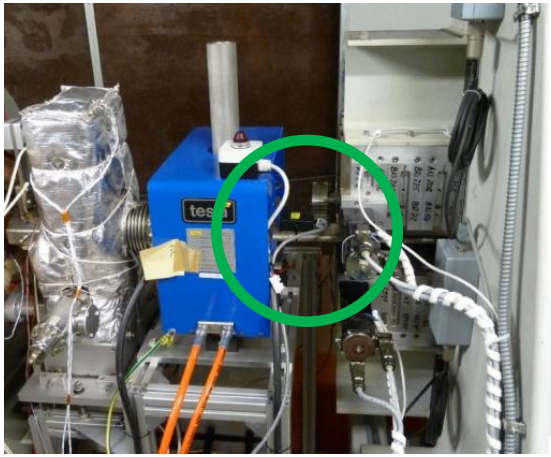
BLMs positioning

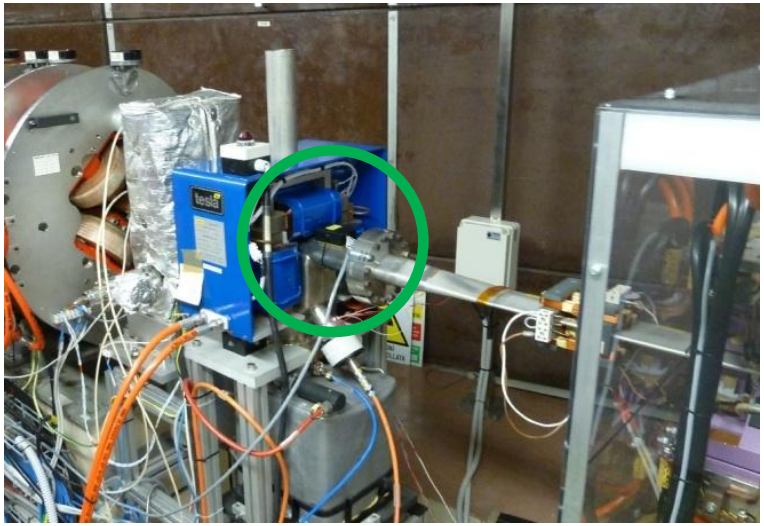
- The parameters taken in account for BLMs positioning were: space, vertical aperture of the vacuum chamber, machine parameters (e.g. dispersion), points of induced radioactivity measured during shutdown inspection.
- To maximize detectors'sensitivity, the BLMs were positioned directly on the vacuum chamber (as close as possible to the beam axis), with the active area perpendicular to the beam direction.

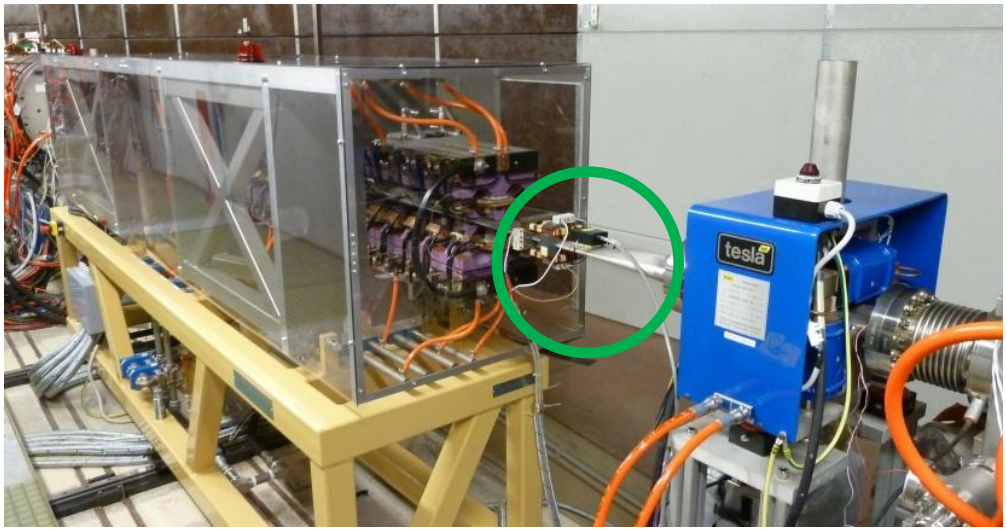


Some photos (1)

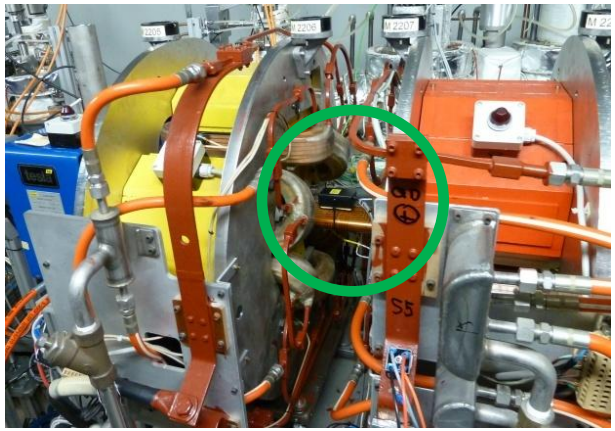


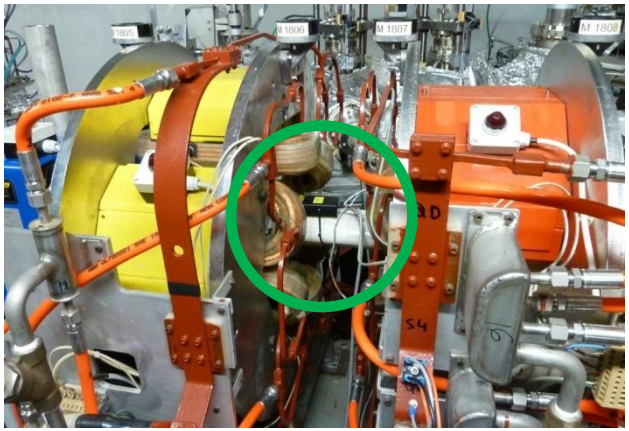


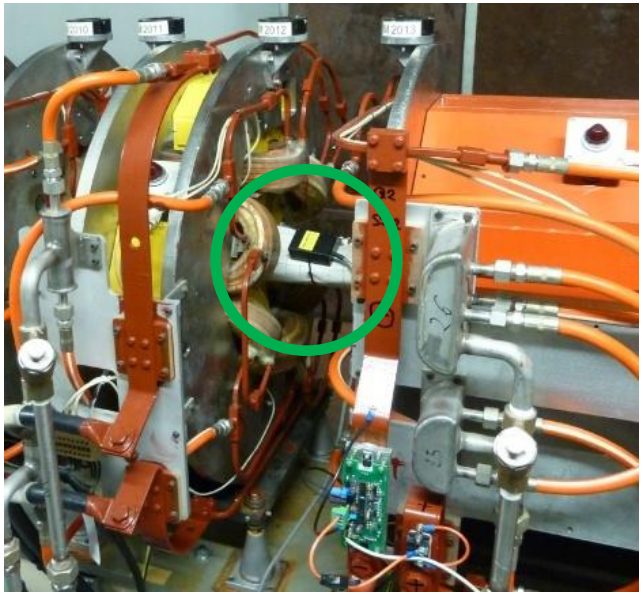




Some photos (2)



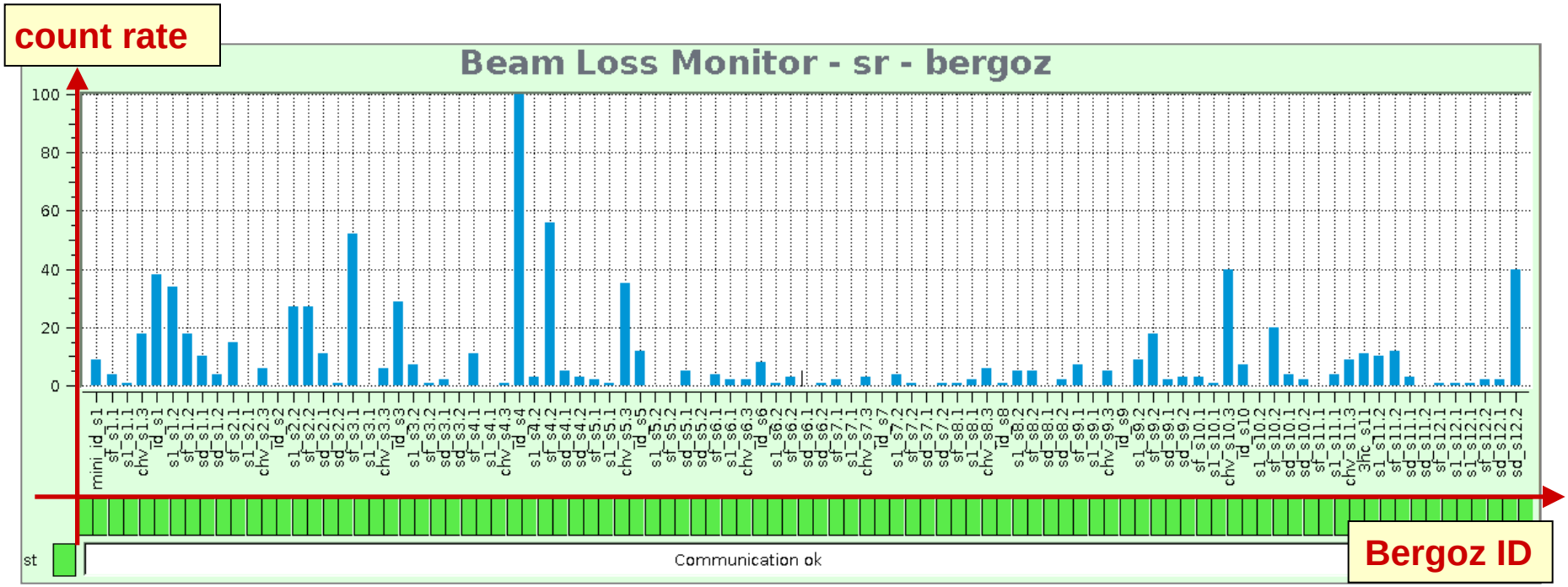




Graphical user interface (GUI)

- A graphical user interface was developed in-house for plotting data on-line, using Qtango libraries. A Tango historical database (HDB) permits data retrieval for further offline analysis.

- The GUI was fully integrated with the machine control system (Tango Control System), to provide a handy tool both for machine trouble shooting diagnosis and for routine operation.



Bergoz ID refers to the machine component installed just upstream of the detector

Measurements

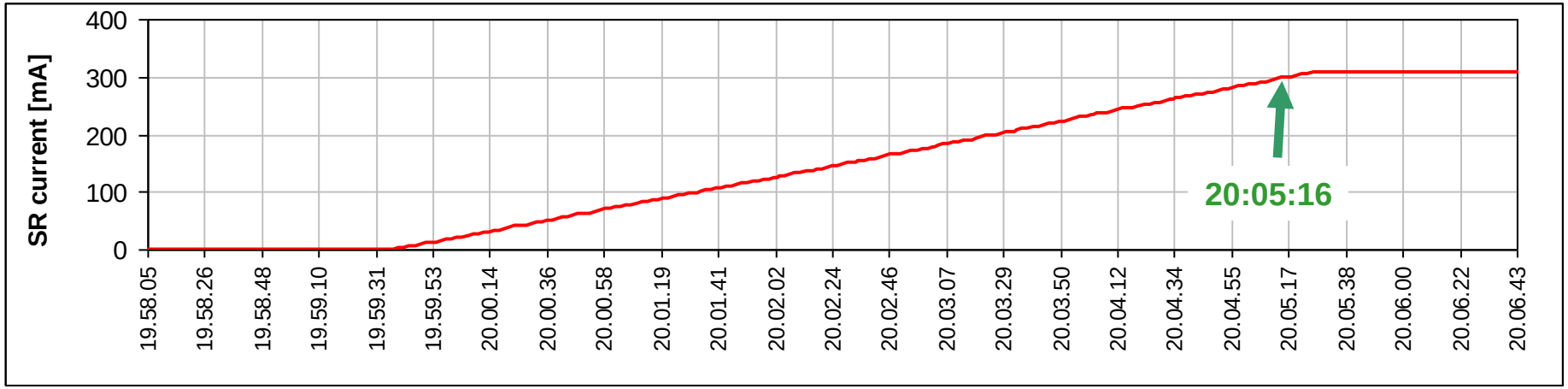
- A beam loss monitoring system inside the storage ring can be used for lots of application e.g. monitoring of vacuum chamber conditioning, detection of beam losses due to orbit mismatching, etc.

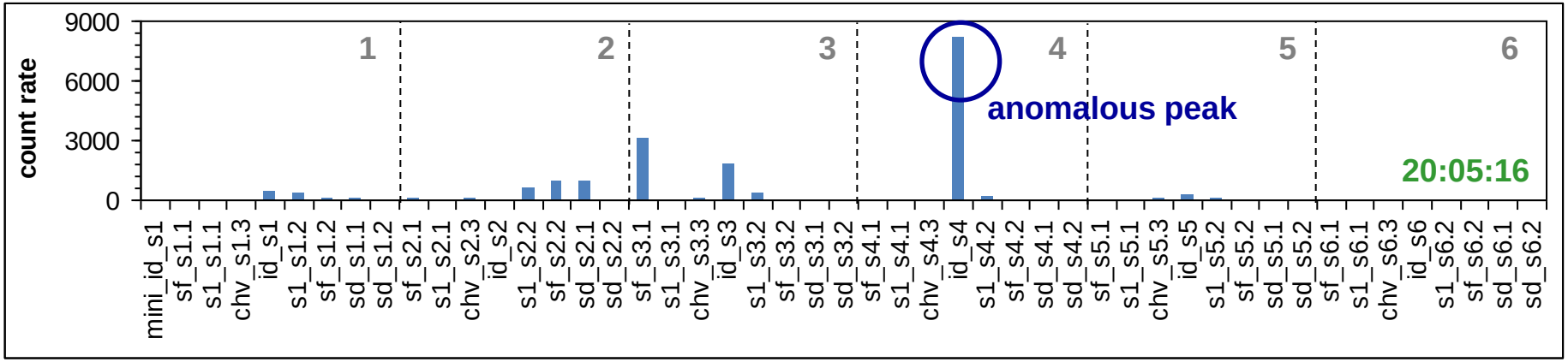
- Sometimes, if there is a “problem” causing beam loss, the diagnosis becomes clear just at the end of a complex debug: this is what is called “experience”.

SOME RECENT EXPERIENCES…

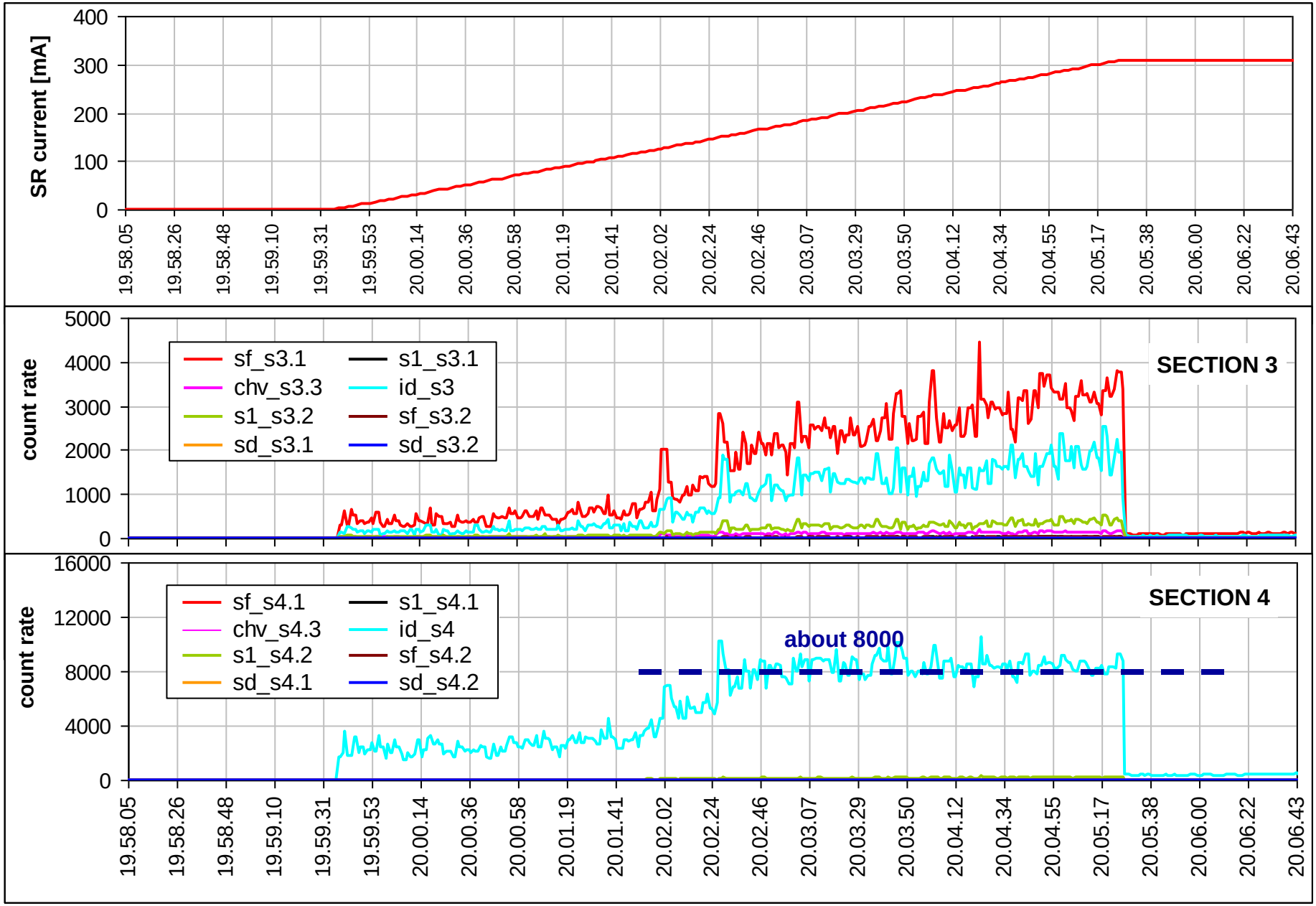
Case 1: anomalous beam loss

- 18 March, 2013: an anomalous beam loss was detected during injection in section 4 of the storage ring.



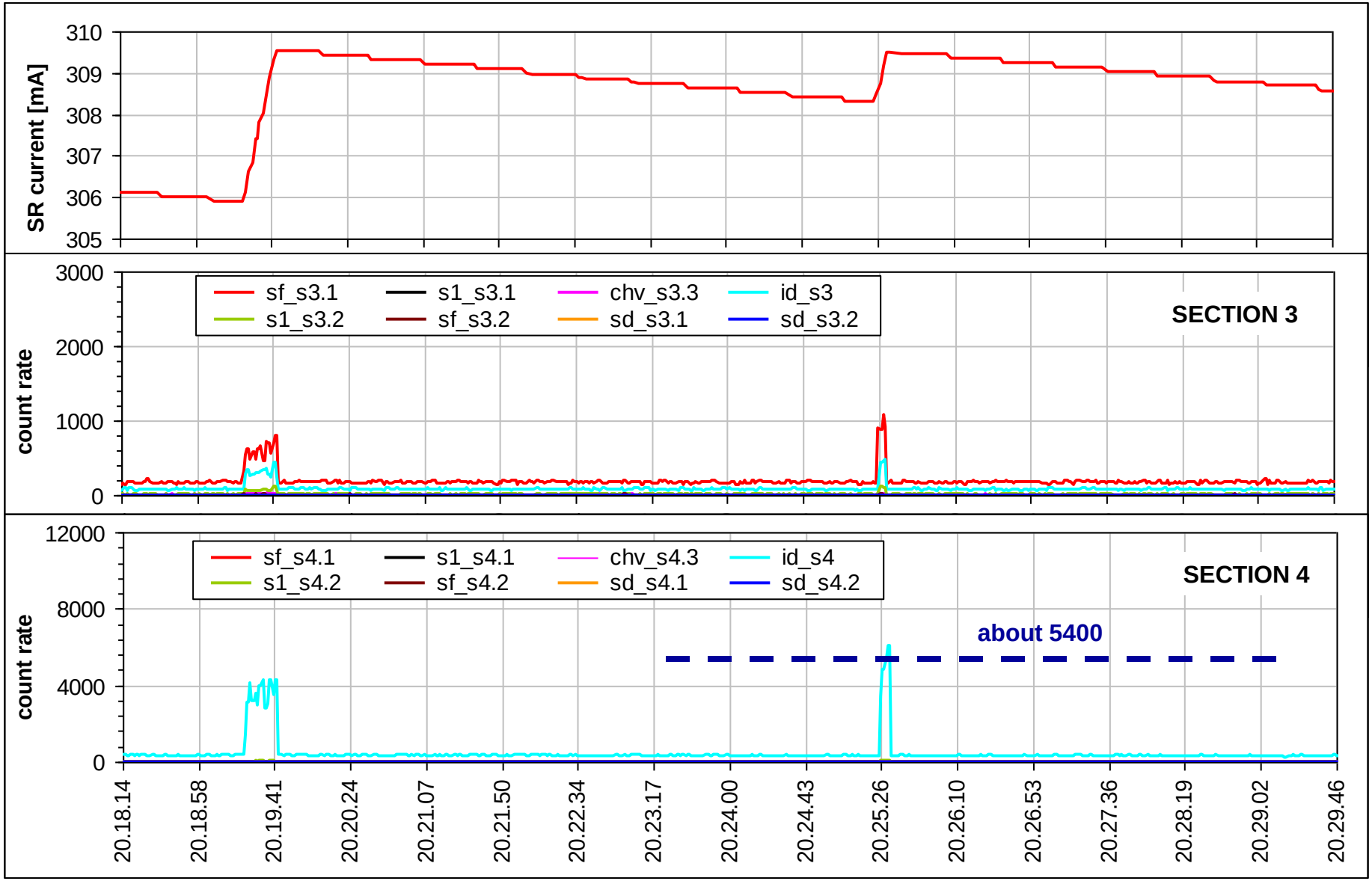


Data from archive (injection)



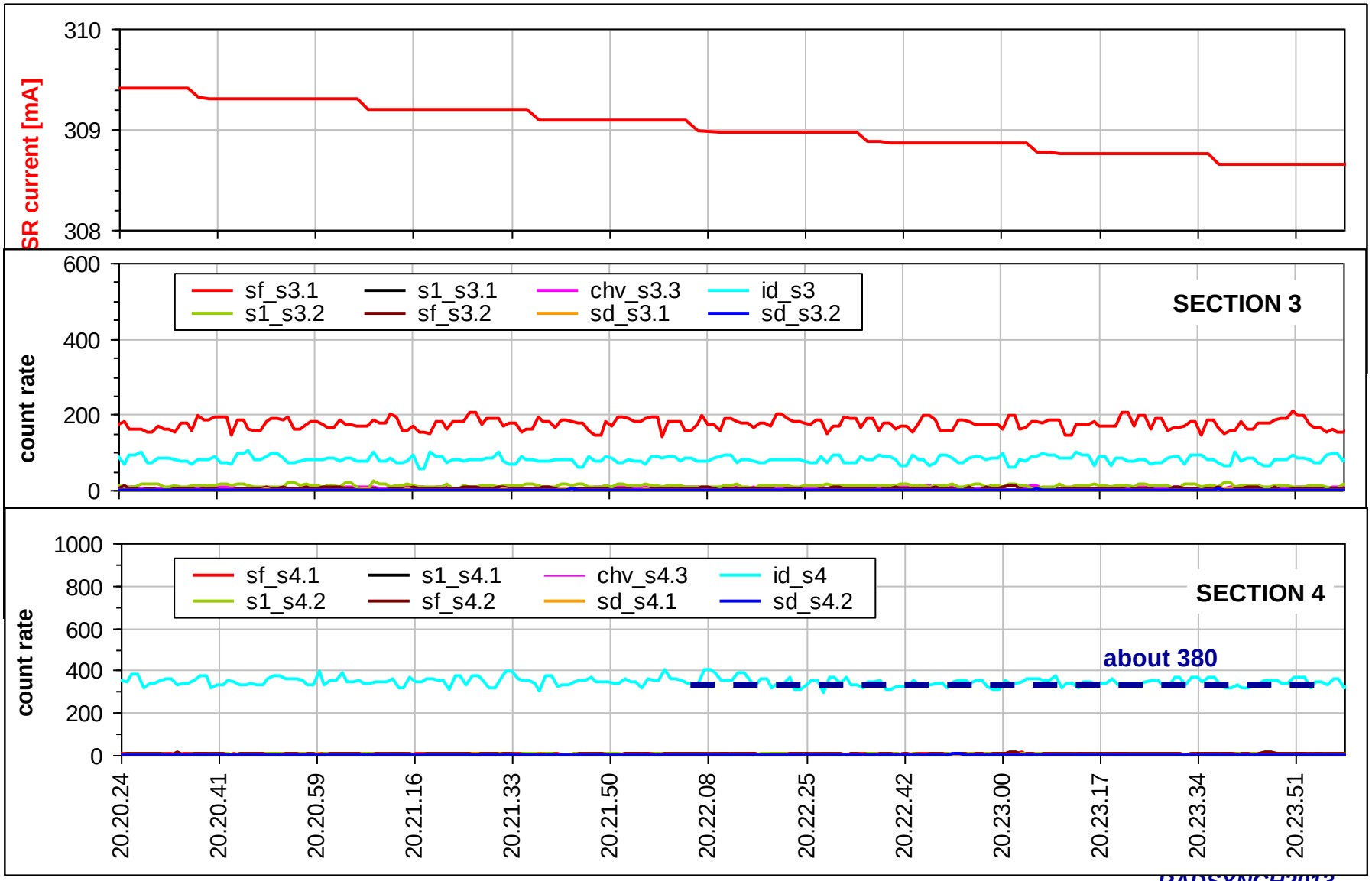
Data from archive (top-up)

- The loss was present also when top-up mode was activated...



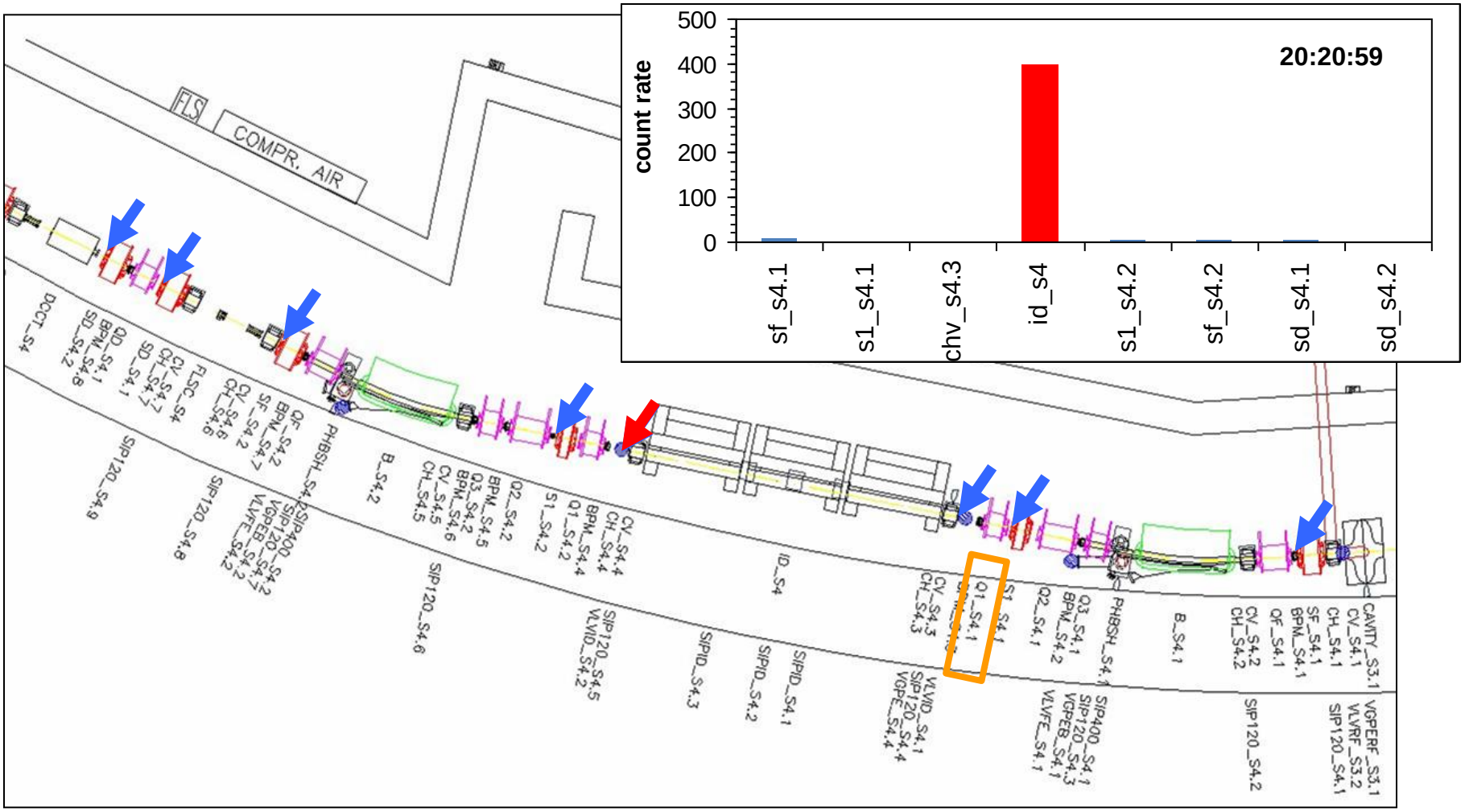
Data from archive (decay)

- ... and also between a two top-up inj. and the other, with stored beam.



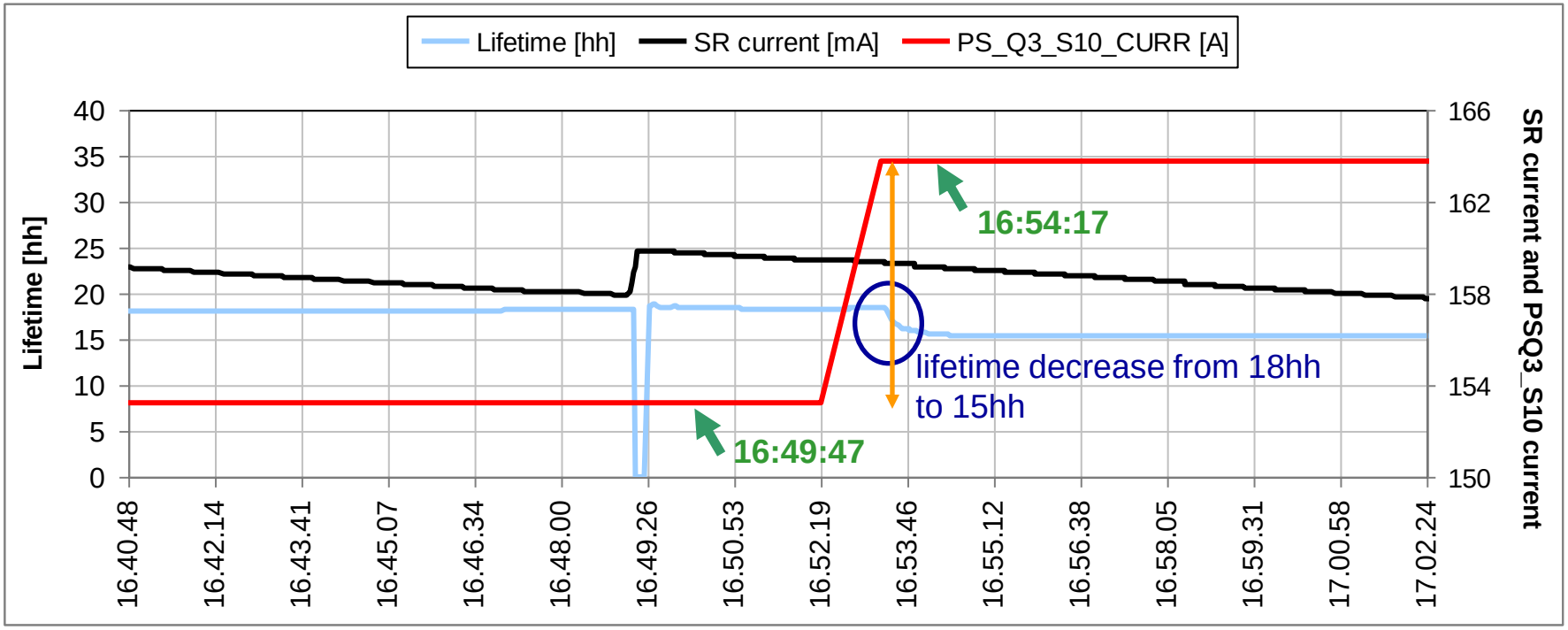
Problem debug

- Finally a focalization problem was found: increasing the strength of the quadrupole upstream the ID, a beam loss decrease was observed in sect.4 (together with a lifetime increase, from about 25 to about 27 hh).

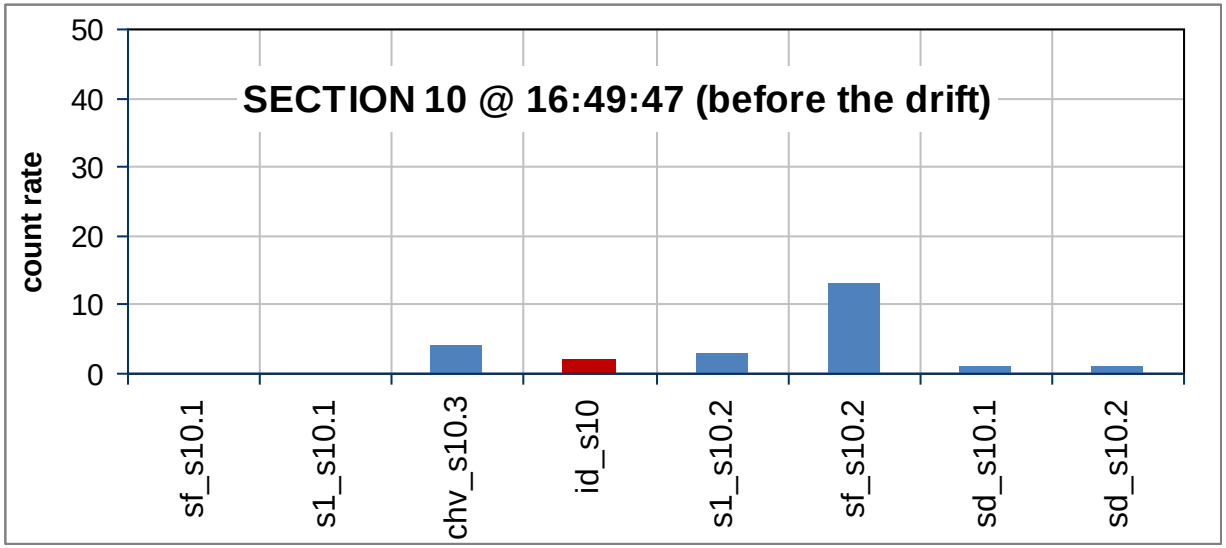


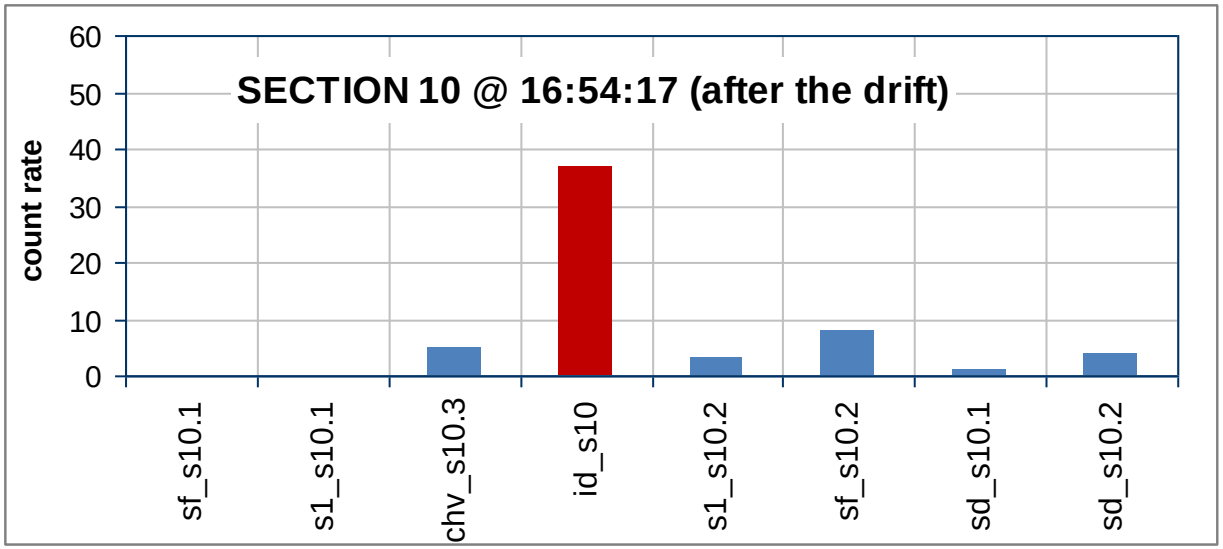
Case 2: quadrupole current drift

- 12 April 2013, in the afternoon: an anomalous current drift of a quadrupole (Q3_S10) occurred in section 10 of the ring, during a users' shift in top-up mode.

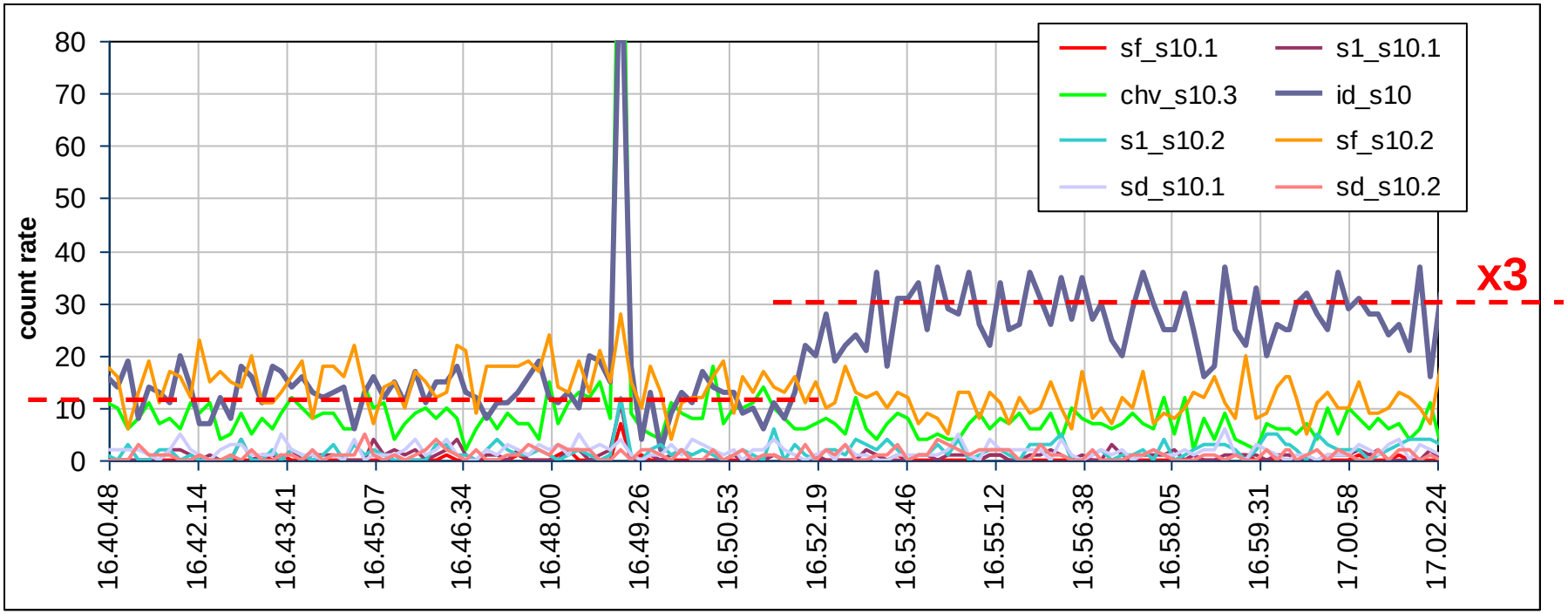


Bergoz BLMs response



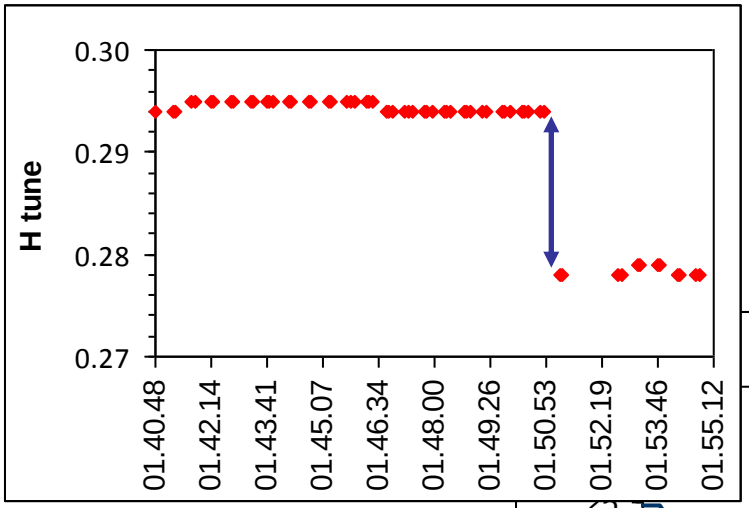


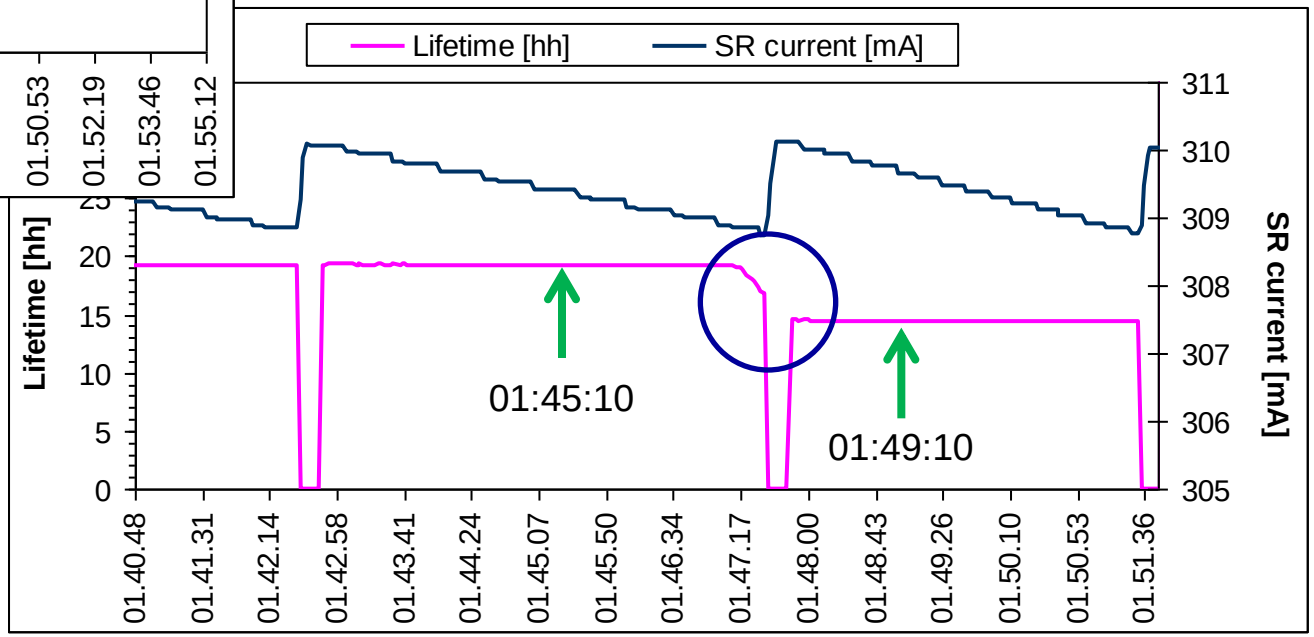
Data from archive



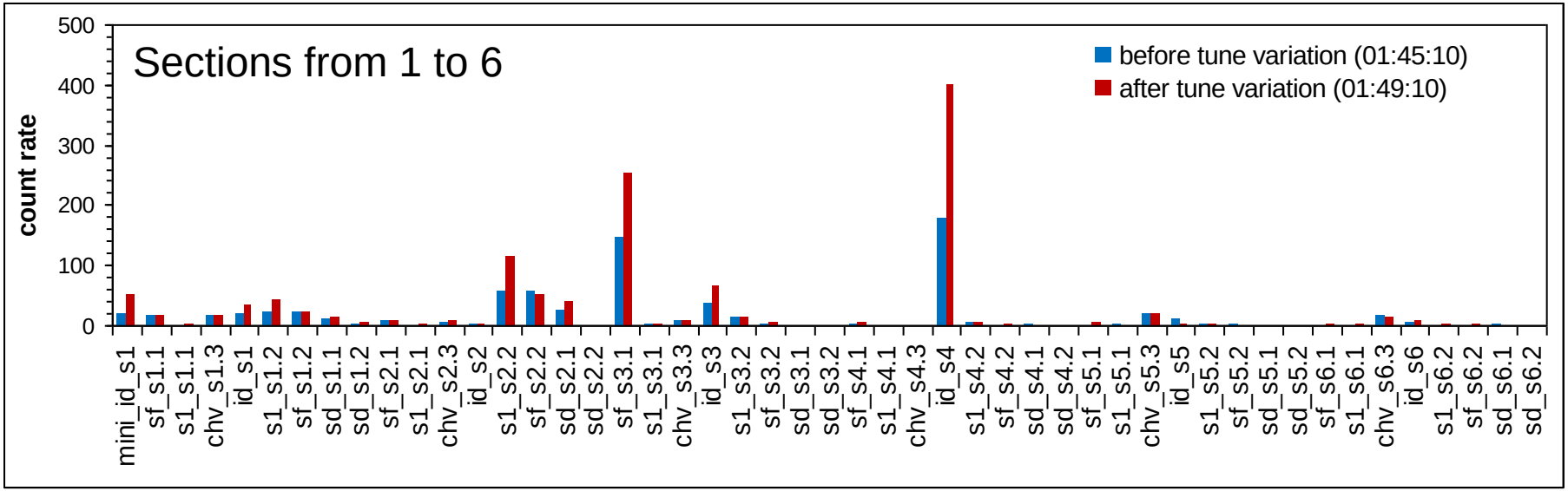
Case 3: tune variation

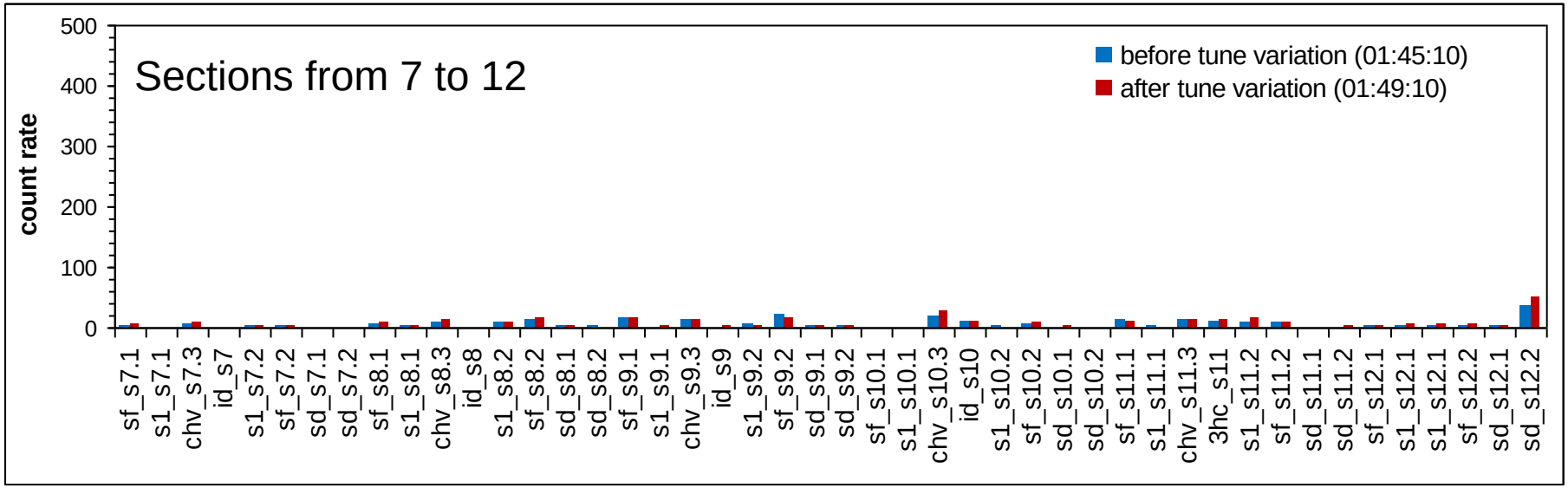
- A strong variation of the horizontal tune was registered on 28 April 2013, during a users' shift in top-up mode.
- Effect: decrease of lifetime: 19.2 hh → 14.5 hh



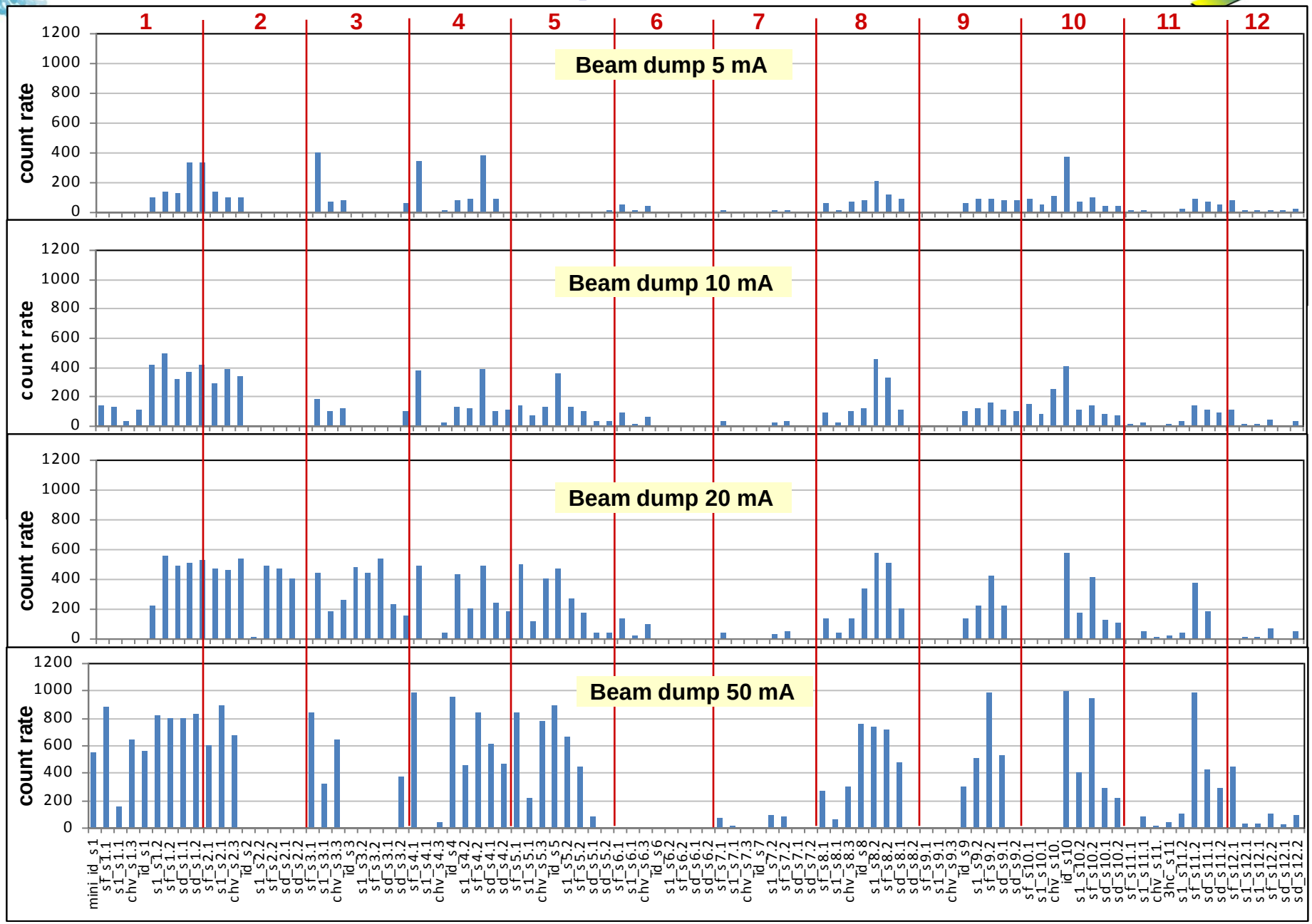


Bergoz BLMs response



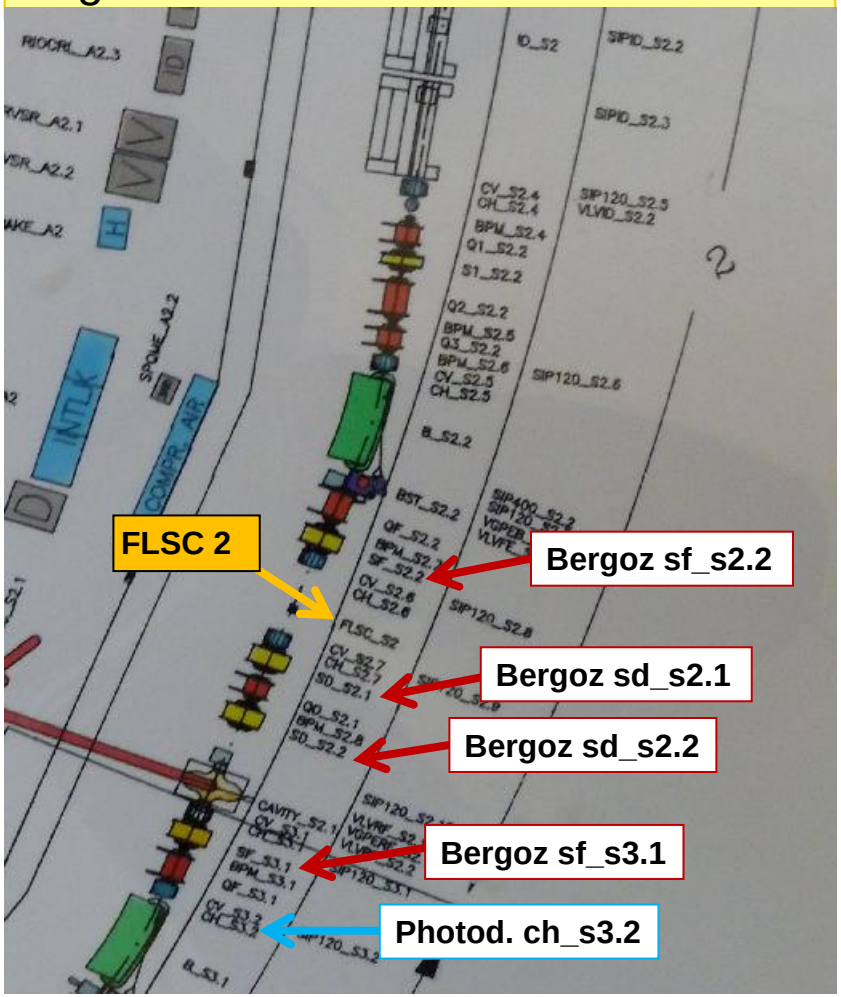


Case 4: beam dumps

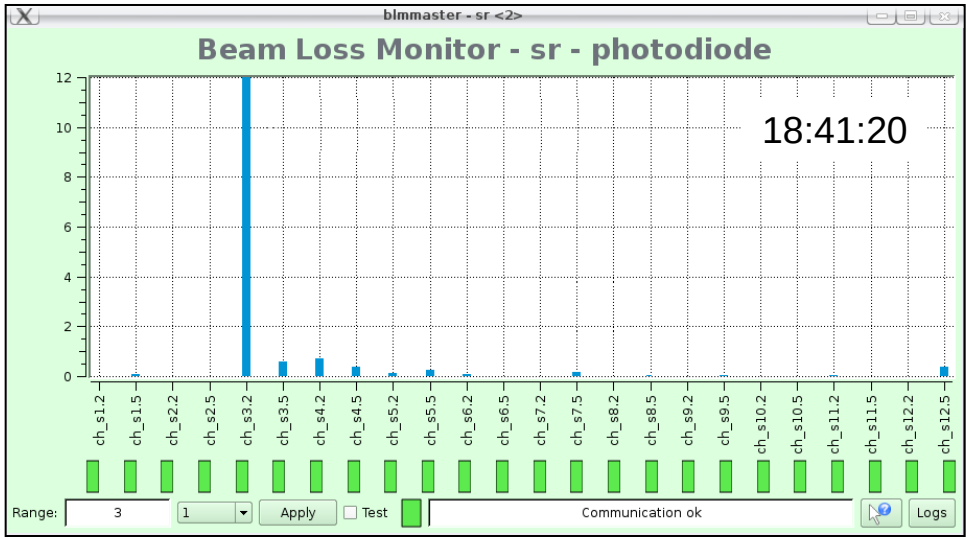


Case 5: a limit in beam loss detection?

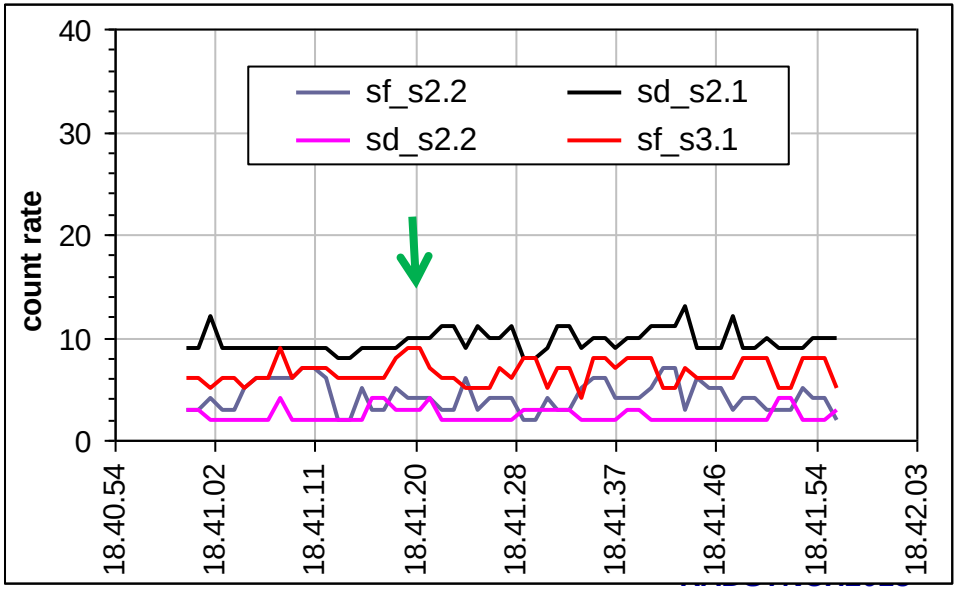
Beam losses produced when the electron beam hits the FLSC positioned in section 2 of the storage ring.



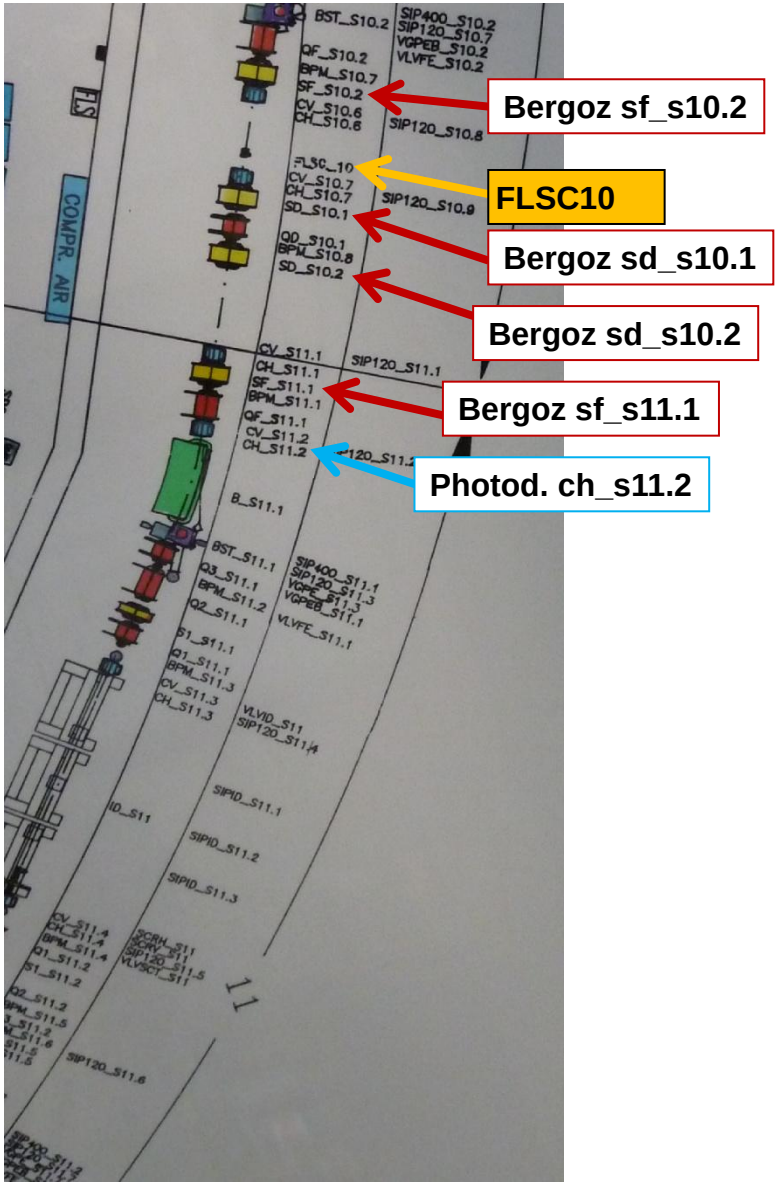
Pin photodiodes' response



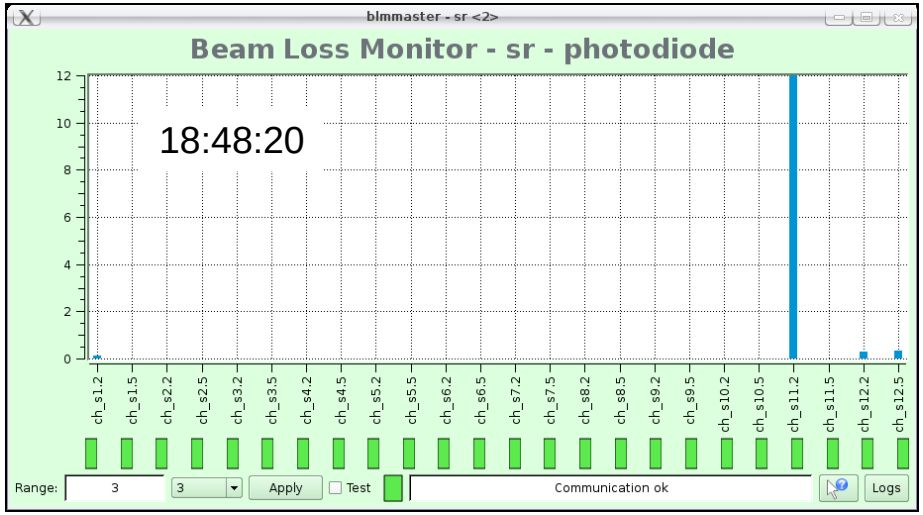
Bergoz BLMs' response



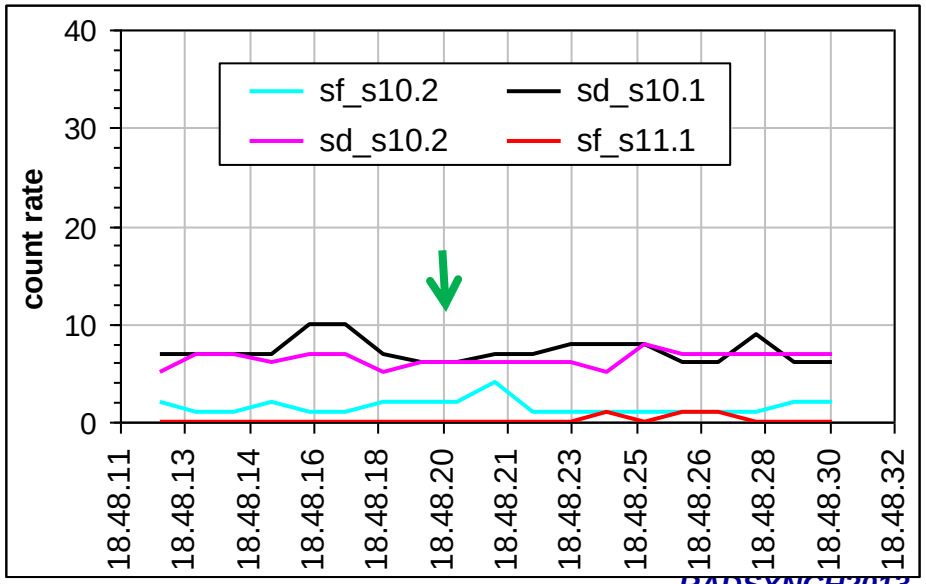
Similar experiment in section 10



Pin photodiodes' response



Bergoz BLMs' response



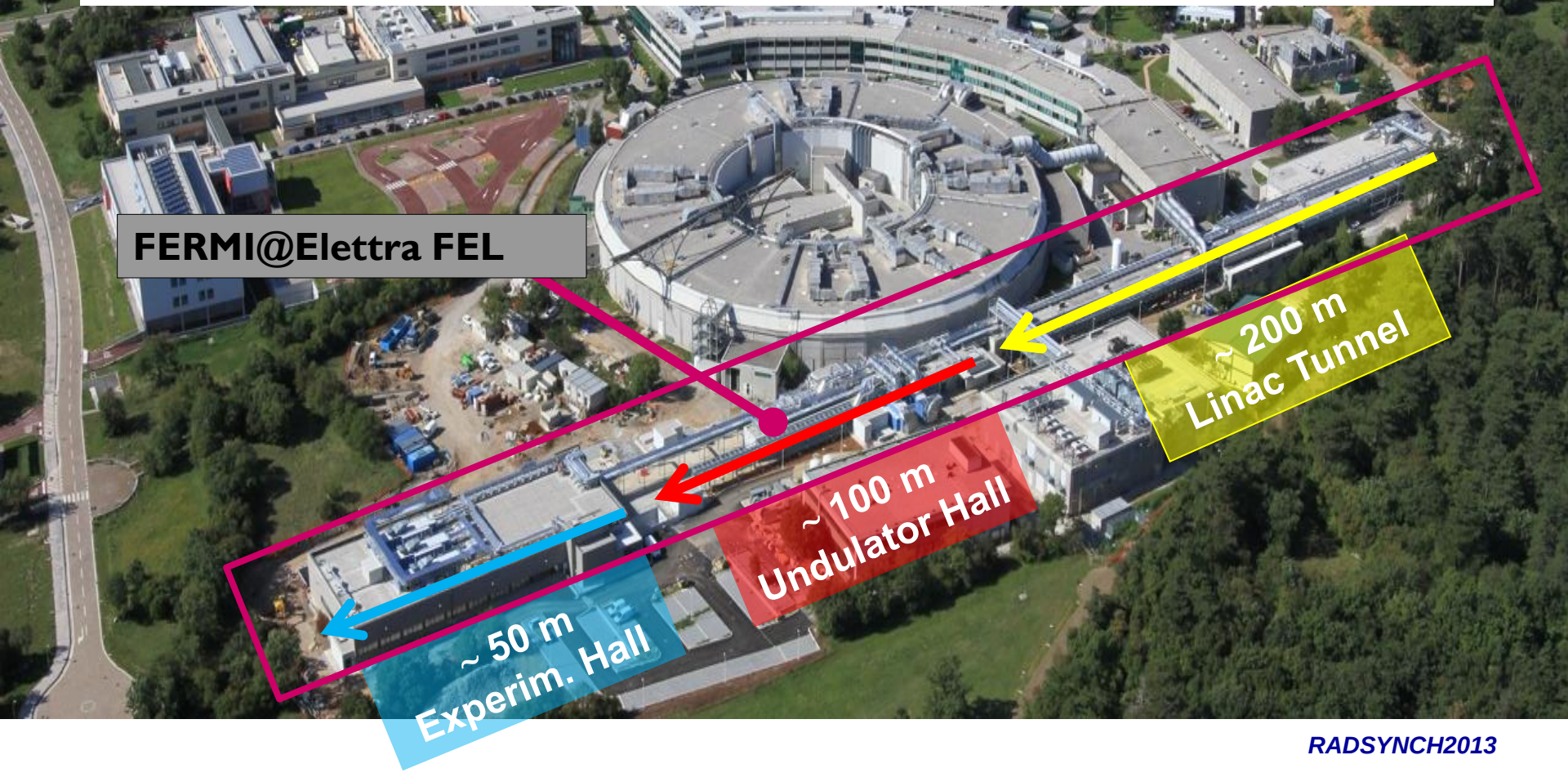
Conclusions

- The monitoring of machine parameters, including beam losses, provide a valuable tool for diagnostic purposes.
- A BLM system installed inside machine tunnel permits to easily locate beam losses, focusing attention on precise ring sections (→ if you know, you can try to minimize).
- If it is sensitive enough, it allows to locate even small beam losses (due to vacuum leakage, optics mismatching, etc.)
- This can facilitate machine physicists' work (e.g. optimization of optics and trajectory), providing a useful (additional) real-time feedback to their choices.
- Last (but not least): the detection of beam losses provides useful indications about which area of the storage ring can be affected by induced radioactivity issues (→ useful for the shutdown inspection).

End of the presentation?

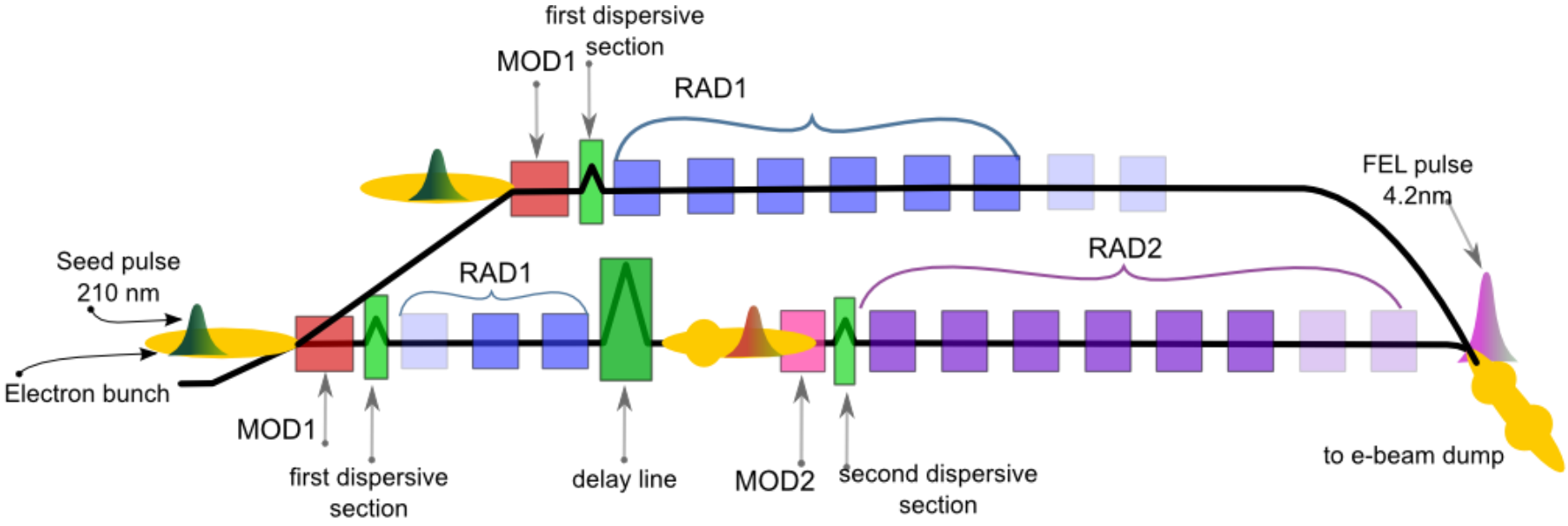
A further development…

- In parallel to the installation of the Bergoz BLMs along the Elettra SR, a revision of the “old” Pin photodiode electronics started, in order to increase their dynamic range and beam loss detection sensitivity.
- General idea: to develop a widespread, low cost, beam loss detection system for the new facility FERMI@elettra.



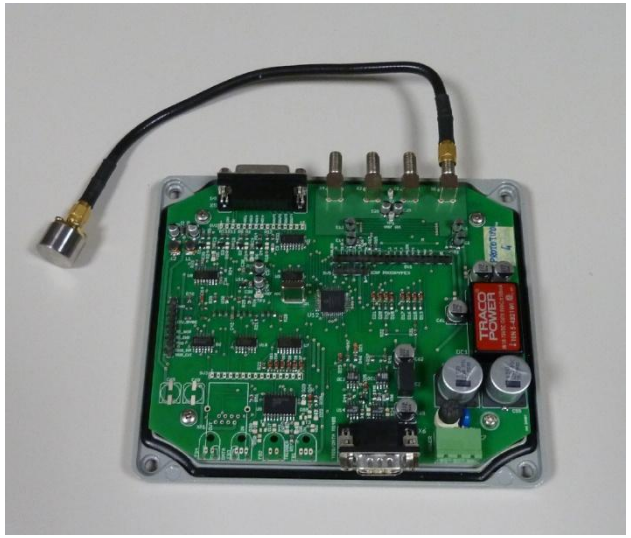
Machine main parameters

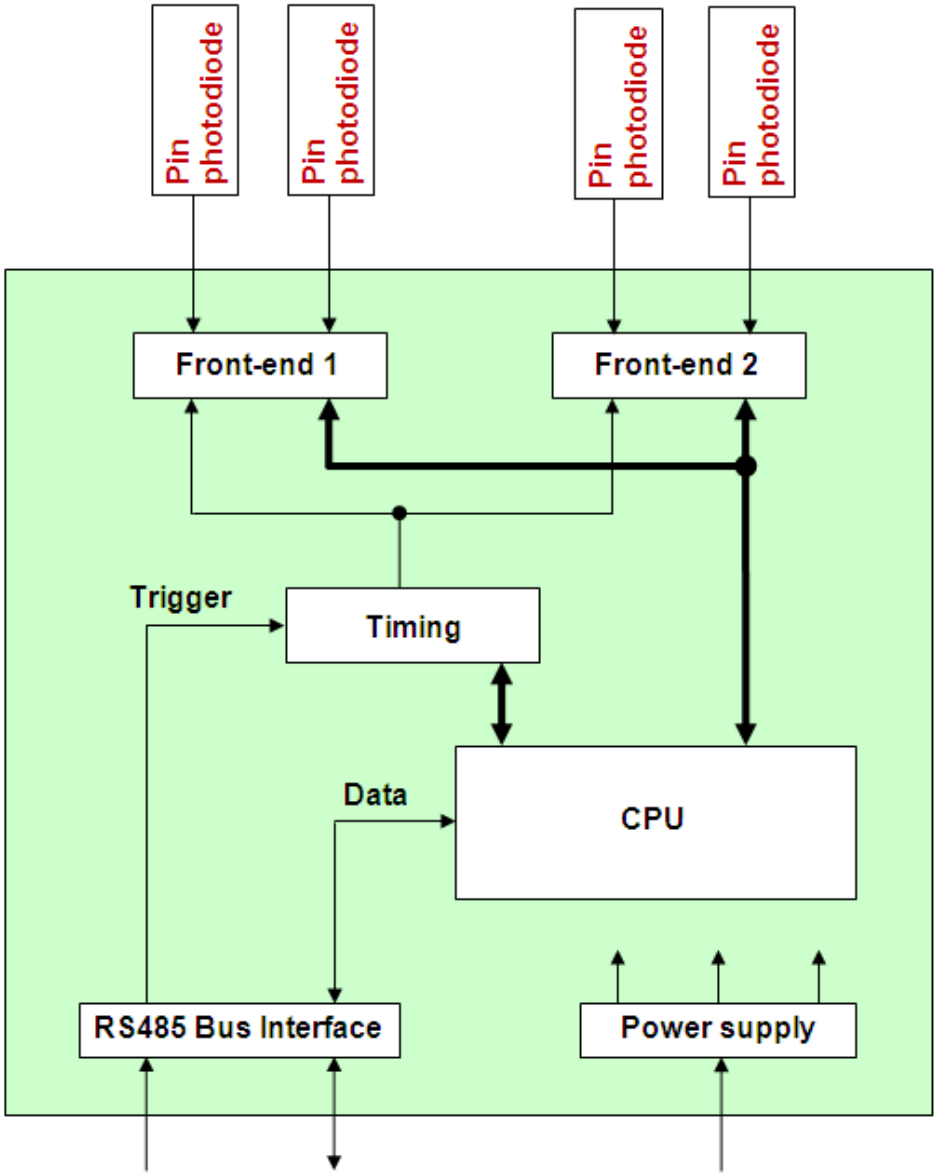
- FERMI is a free electron laser facility projected to produce two FEL beams, that cover different spectral regions: FEL1 covers the spectral range from ~100 nm down to 20nm, FEL2 from 20 to ~4 nm.



Charge:	500 pC
Repetition rate:	max 50 Hz
Energy:	1.2-1.5 GeV

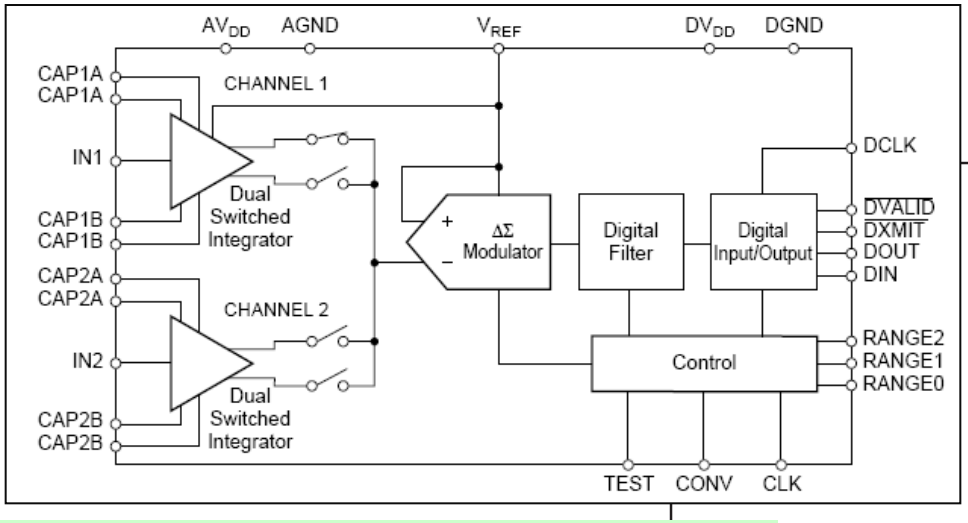
FERMI BLMs reader

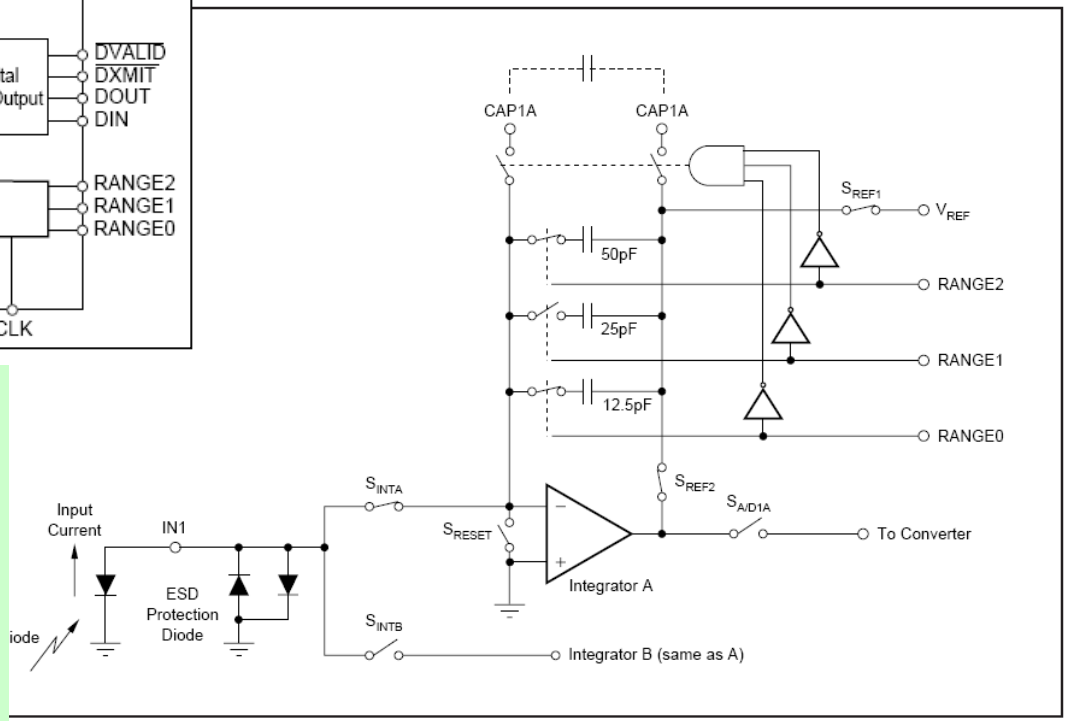




More in detail…

- The detector is always a BPW34 photodiode; the front-end stage has been substituted by a dual input, wide dynamic range, charge-digitizing Analog-to-Digital Converter with 20-bit resolution.



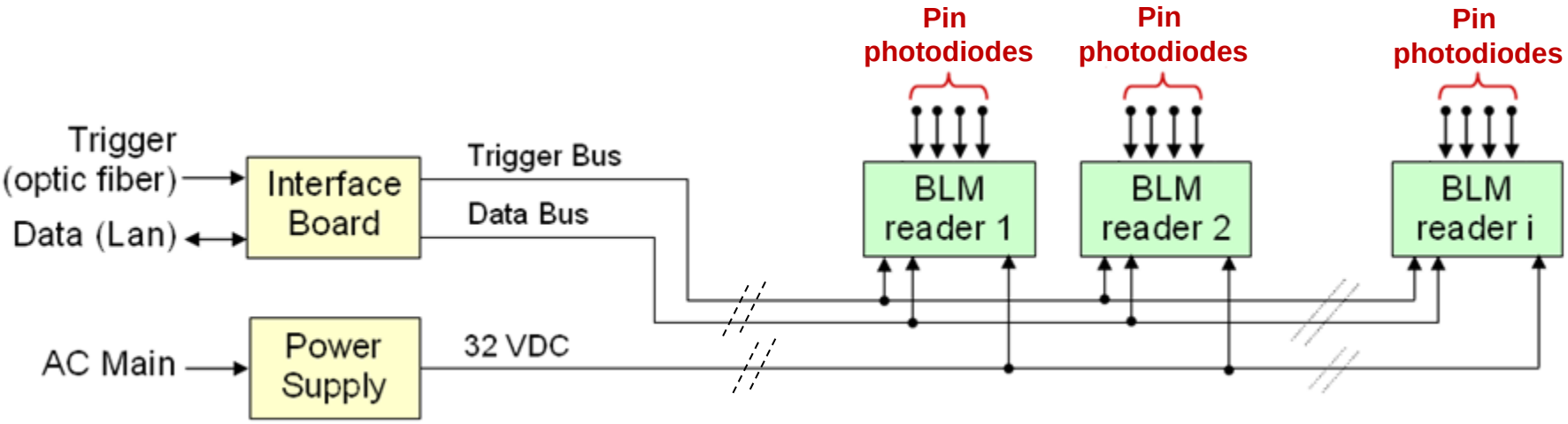


rator Configuration for Input 1 Shown with a 250pC (C_F = 62.5pF) Input Range.

- Possibility to select the integration capacitor of the front-end electronics (and therefore the input range, from about 0.02pC to 1nC).
- Use of a 20-bit resolution ADC, fully integrated in the electronic component.
- Possibility to test the device functionality through the “TEST” input.

FERMI BLMs' network configuration

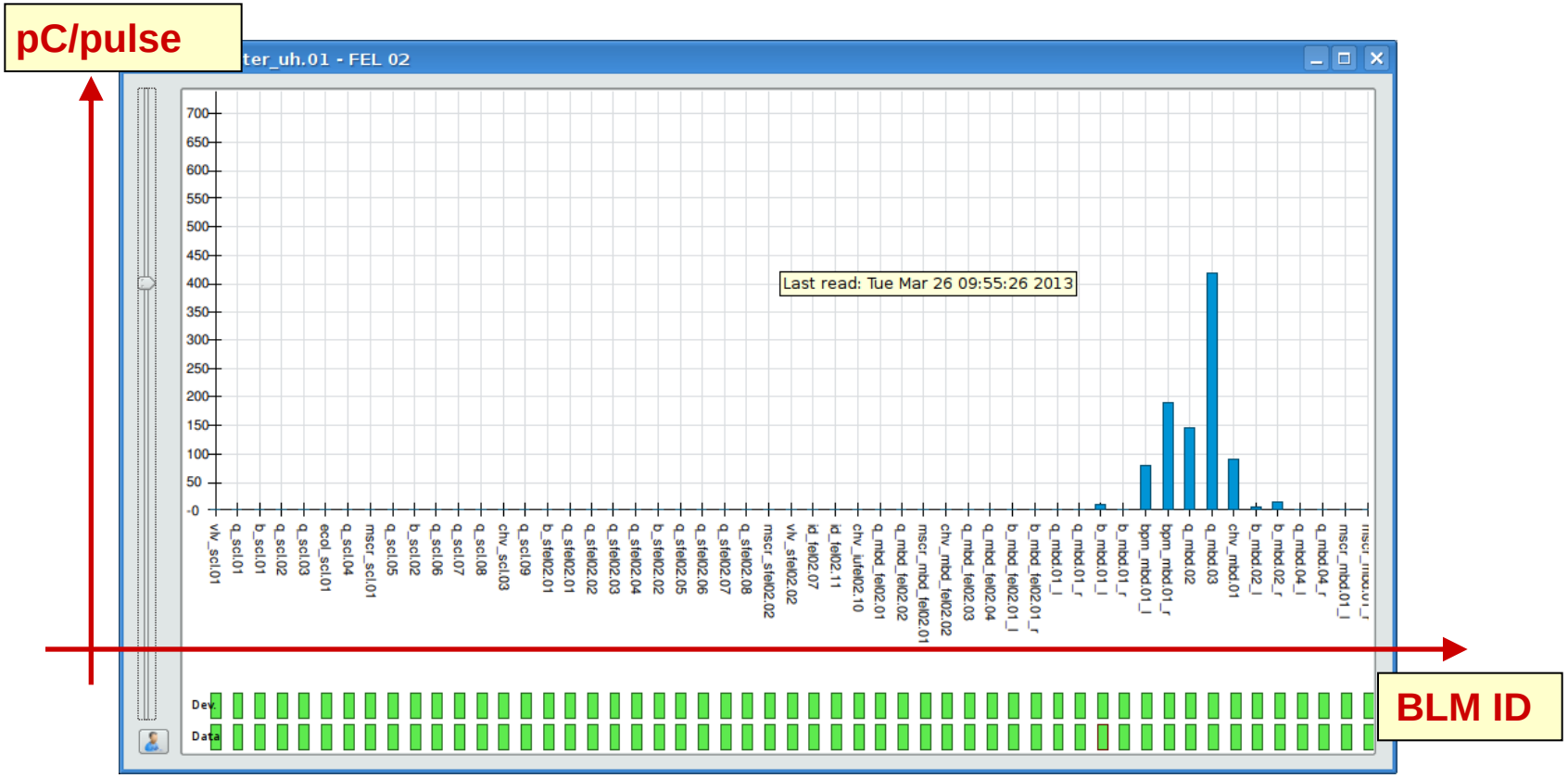
- Three networks have been installed inside the machine tunnel: two for the Linac and one for the Undulator Hall.

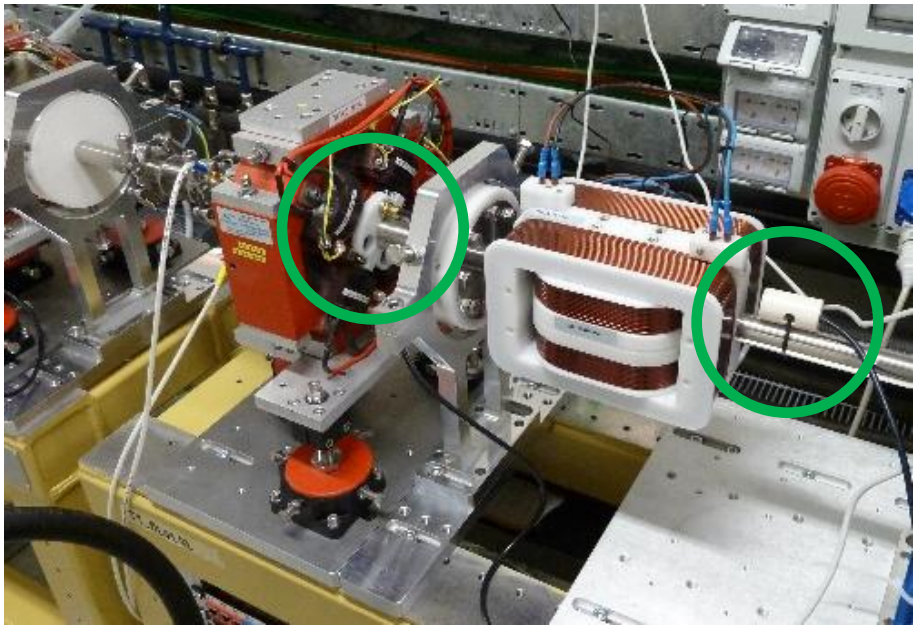
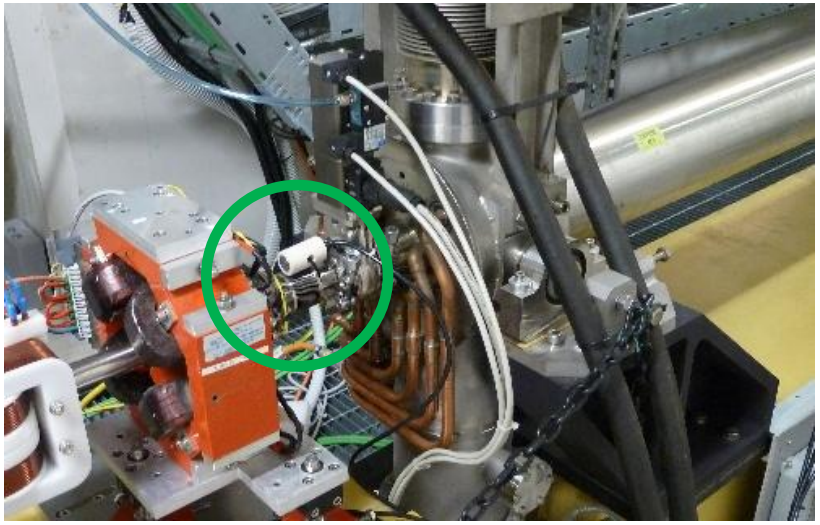
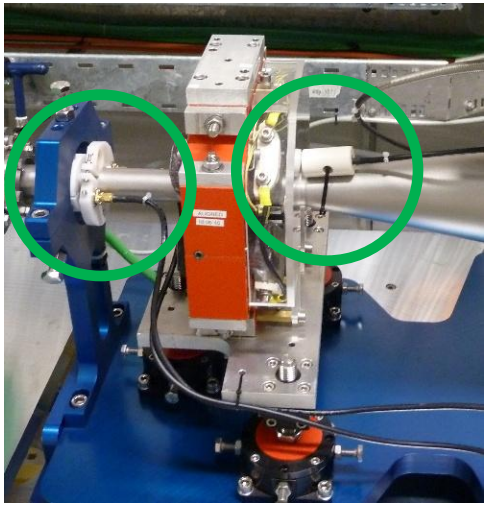
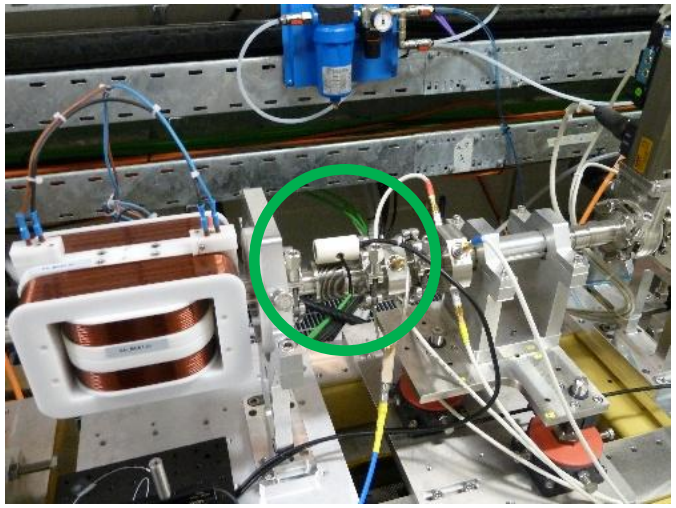
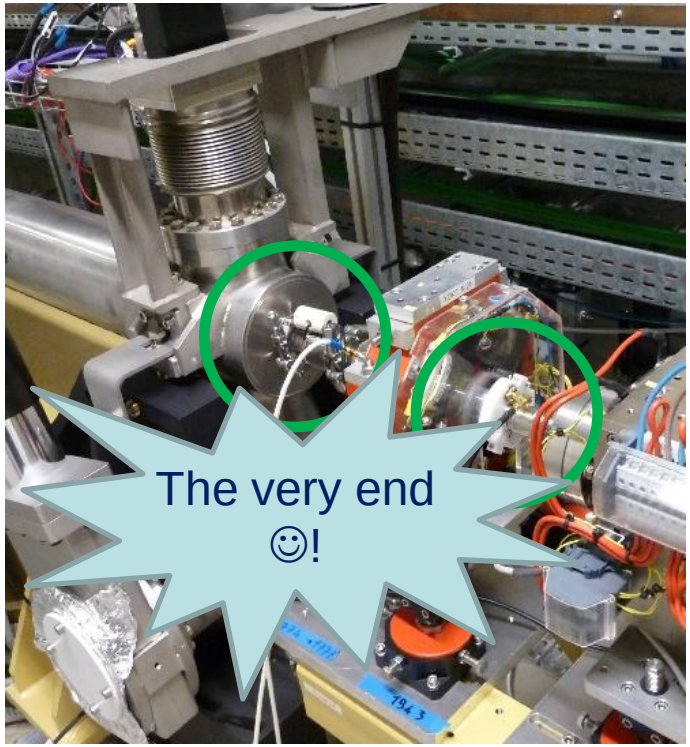


- 67 readers (45 in Linac and 22 in UH)
- each reader can acquire up to 4 detectors (BPW34)
- number of photodiodes installed:
  - 127 in Linac
  - 57 along FEL1
  - 52 along FEL2.

Graphical user interface

- The graphical users'interface was developed on the basys of the one already realized for the storage ring BLMs.



- The network of BLMs inside FERMI tunnel is very widespread: the beam loss detection system has proved to be very useful for optimizing e^- beam transport and represents a useful real-time feedback for machine physicists.

Some photos