Beam loss monitor development at the ESRF

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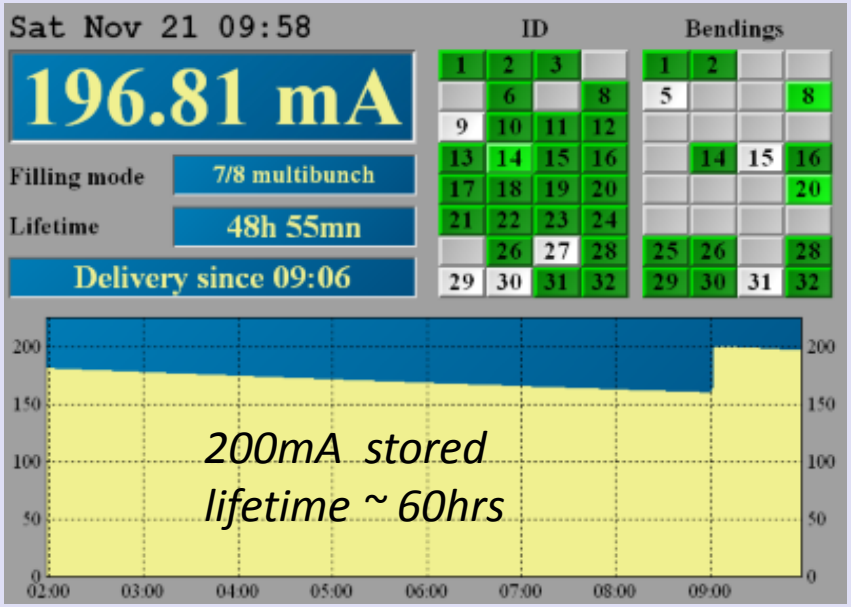
ESRF

- *ESRF – European Synchroton Light Source / Grenoble / France*

- *6 GeV electron energy*
- *200 mA stored current*
- *844 m circumference*
- *32 cells*
- *28 insertion device beamlines*
- *16 bending magnet beamlines*



⇒ *~ 16 million 6 GeV electrons/s* ***LOST***

Reasons for beam loss:

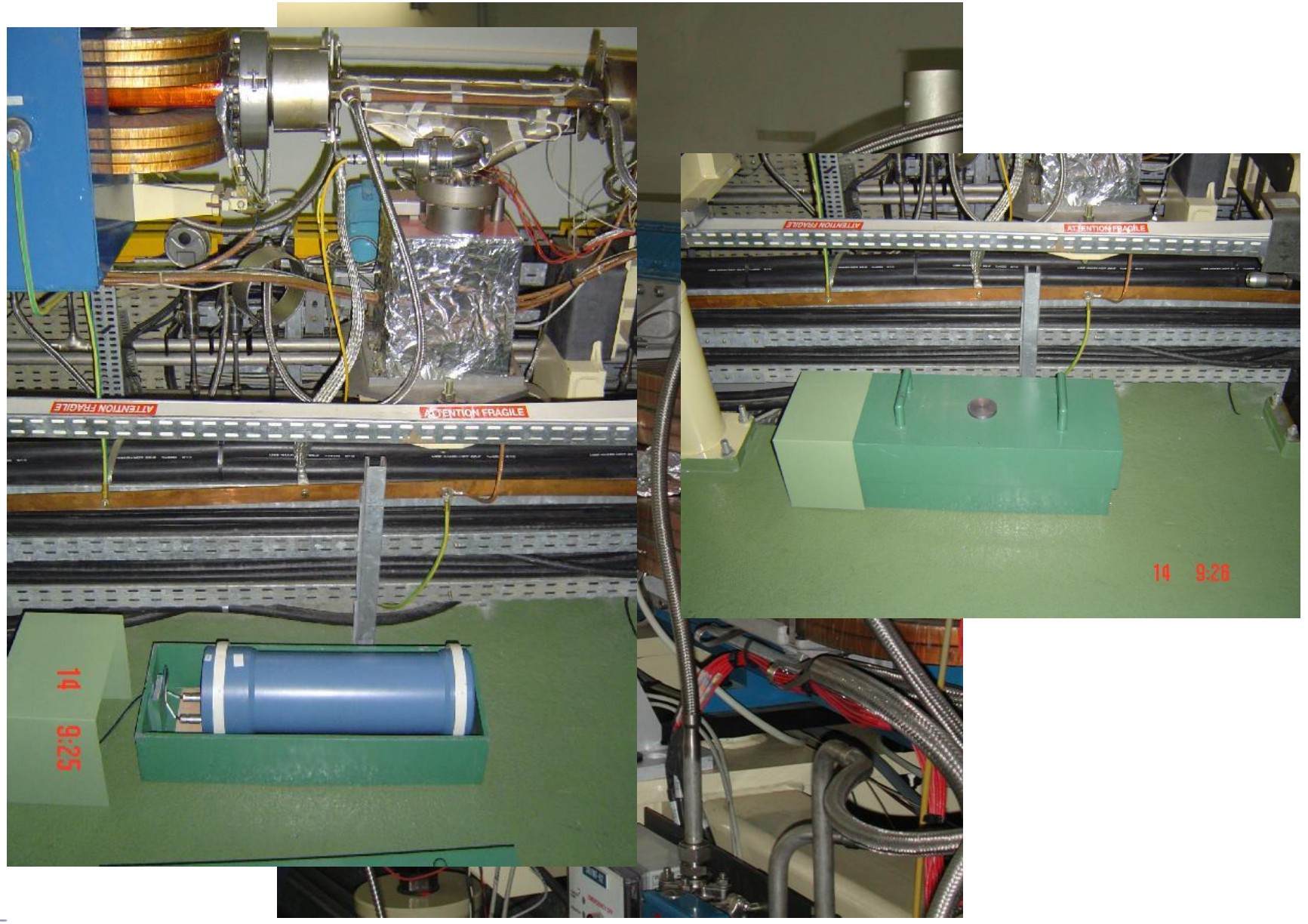
Touschek scattering

Vacuum quality
(overal vacuum level, leaks, ...)

Limited apertures
(small undulator gaps, misaligned vacuum pipes,...)

Beam missteering

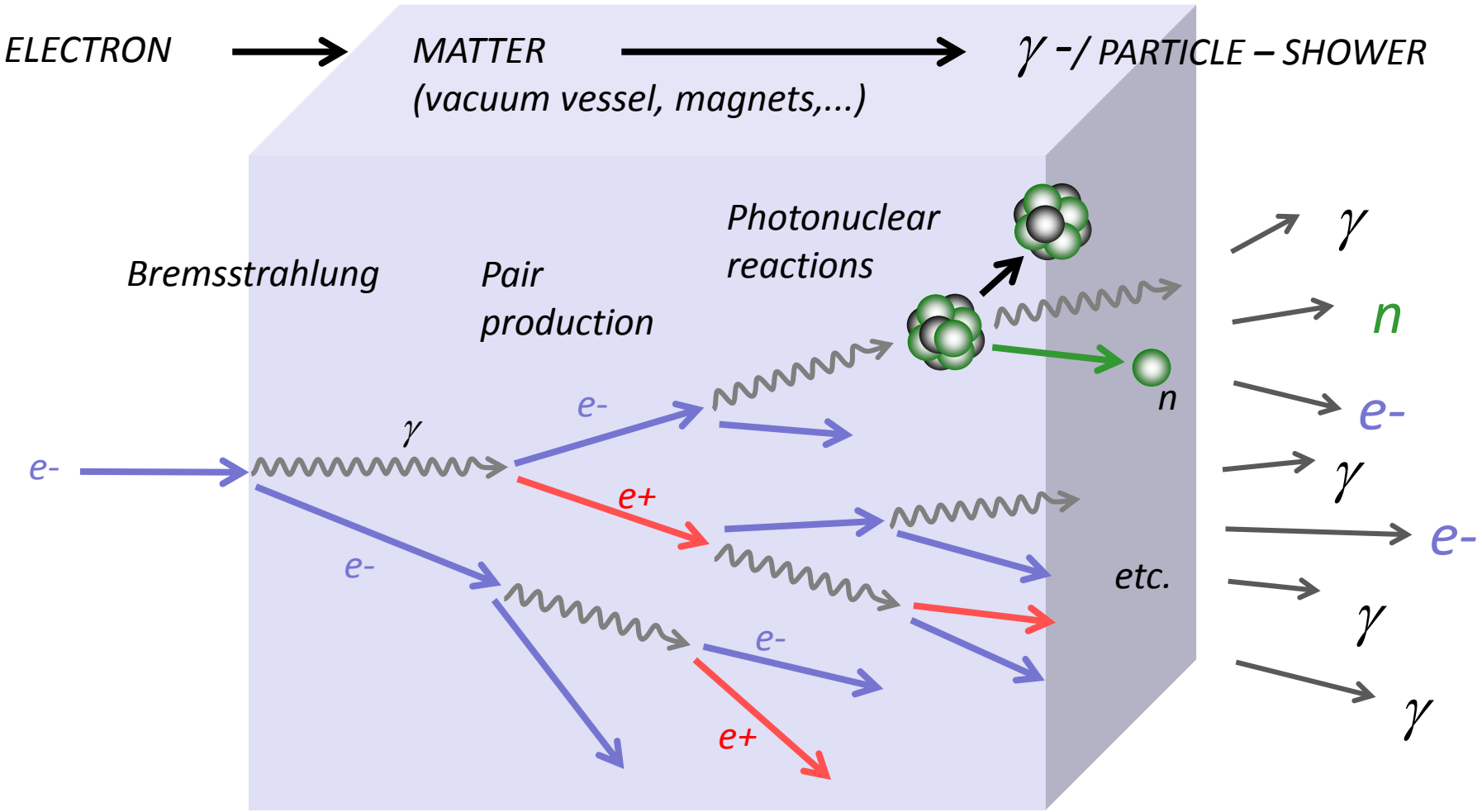
Loss monitors in one ESRF storage ring cell



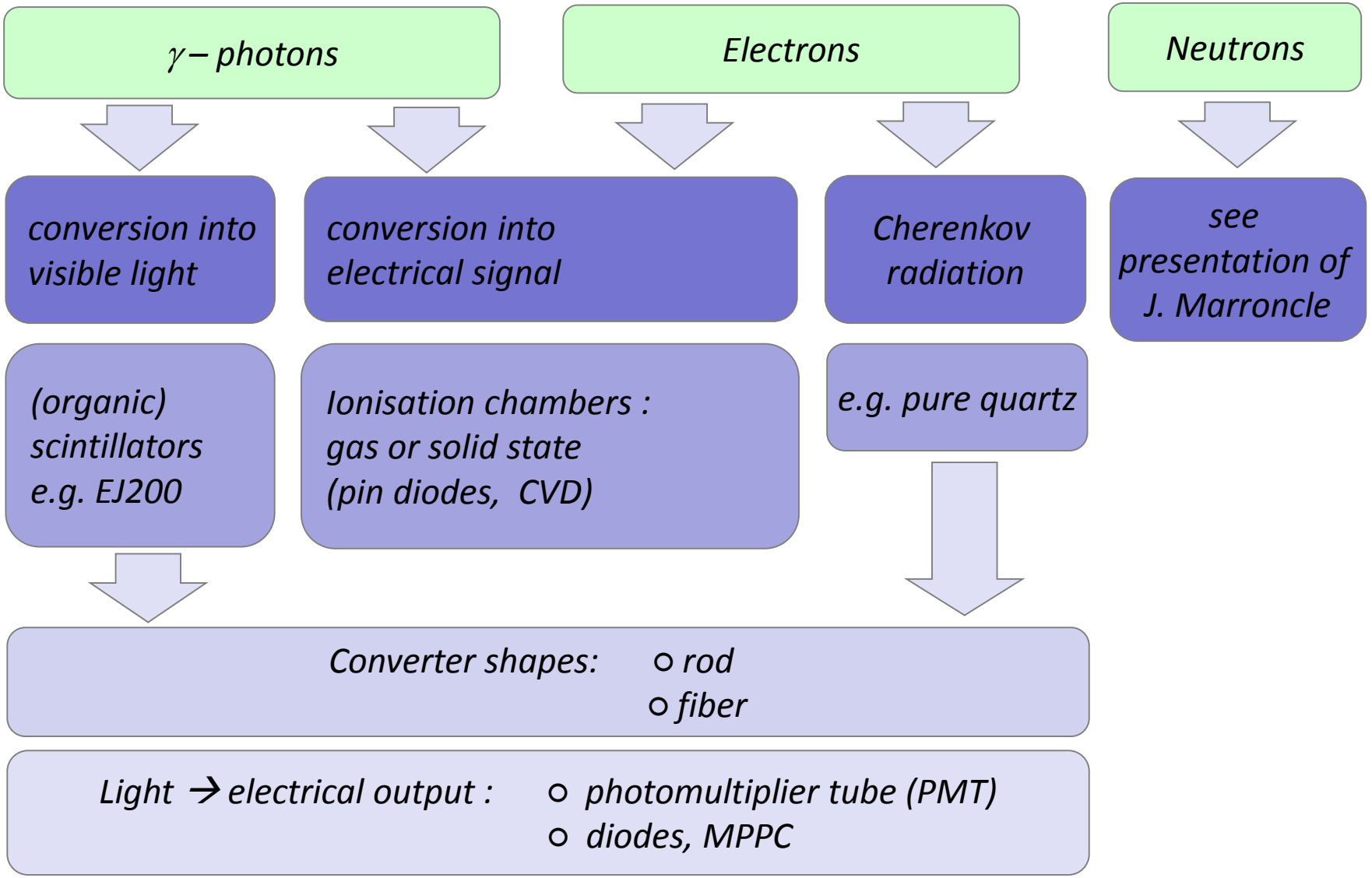
Outline

- *What happens when a 6 GeV electron is lost?*
- *How can we detect such losses?*
- *The new generation of beam loss detectors chosen for the ESRF*
- *Results obtained with prototypes installed in the storage ring*

Beam loss ? What happens when we loose a GeV electron?



Available particles and (some) detection methods



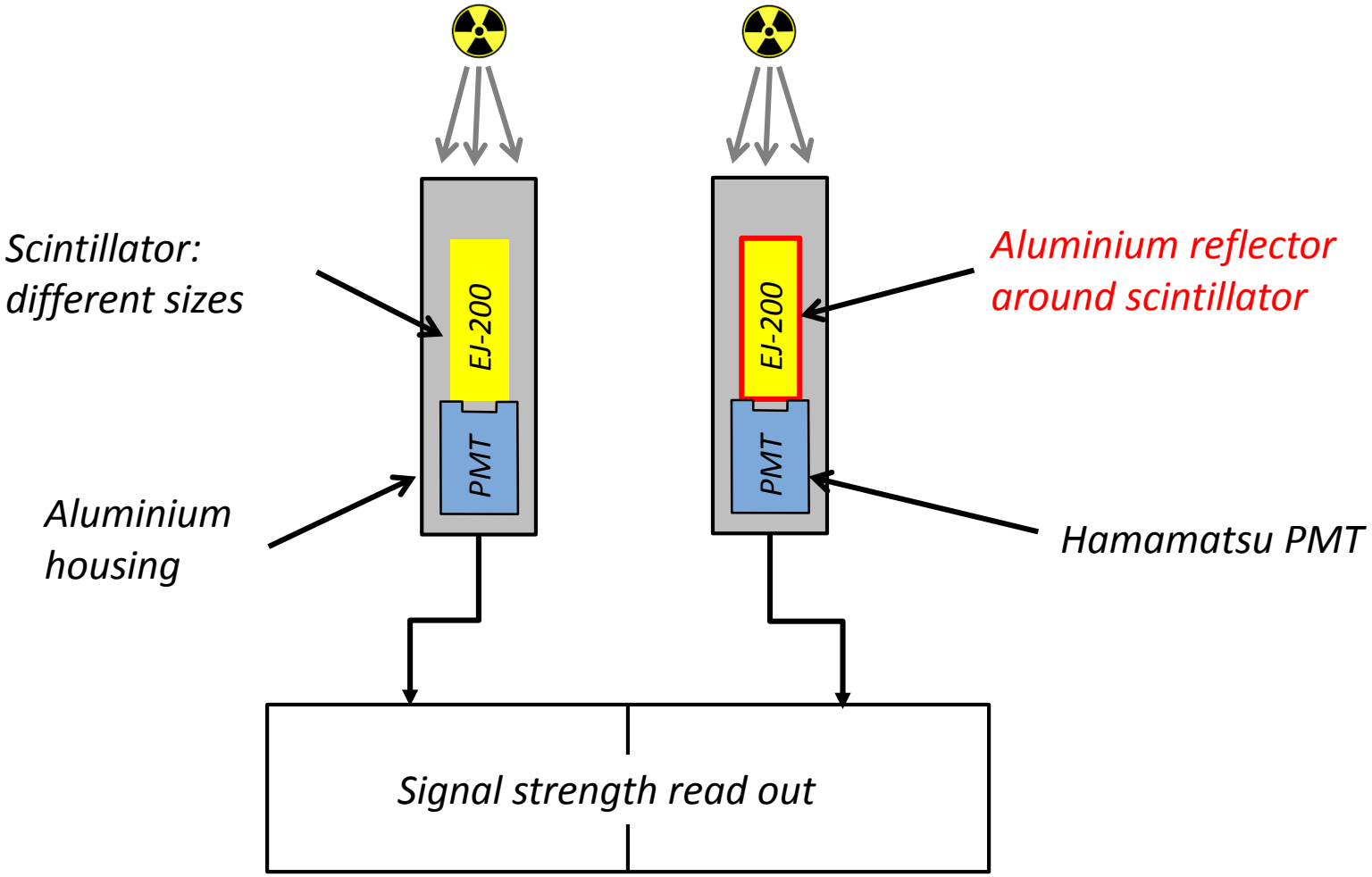
Scintillator versus Cherenkov radiation

	Cherenkov-radiator Quartz-glass	versus	Gamma-scintillator EJ-200 or BC-408
PRO :	no need for Pb shielding since immune to X-rays (?) therefore : - less volume - less weight - compact		- high light yield - cheap material
CONTRA:	- low light yield - more expensive		needs Pb shielding - bulky & heavy (?)

We choose: BLD based on a small EJ-200 rod,
a small PMT (8mm window),
2mm of Pb shielding

Test of sensitivity of different geometrical configurations

γ – source : Cesium-137 (700 keV γ)



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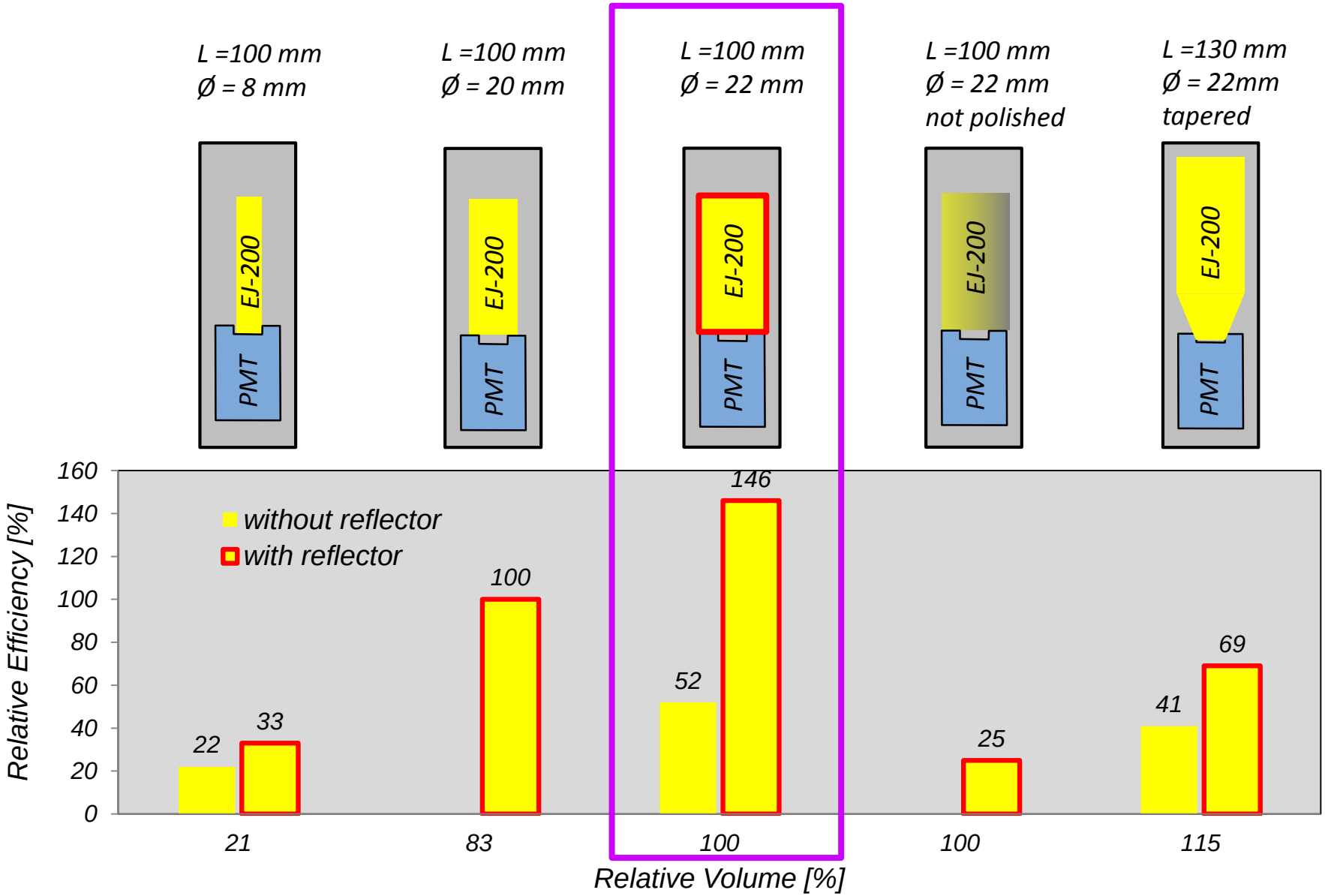
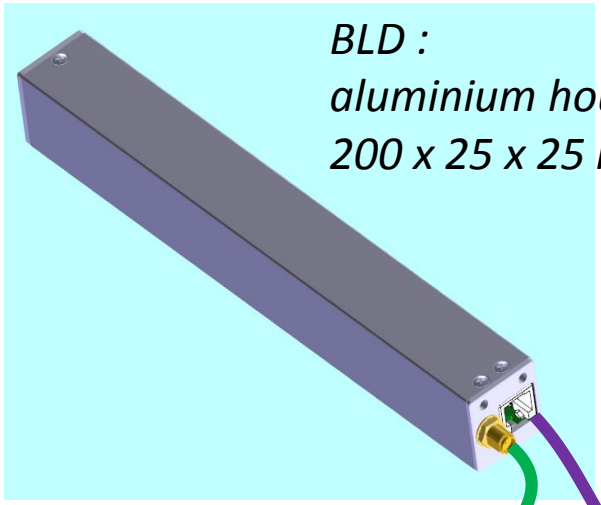
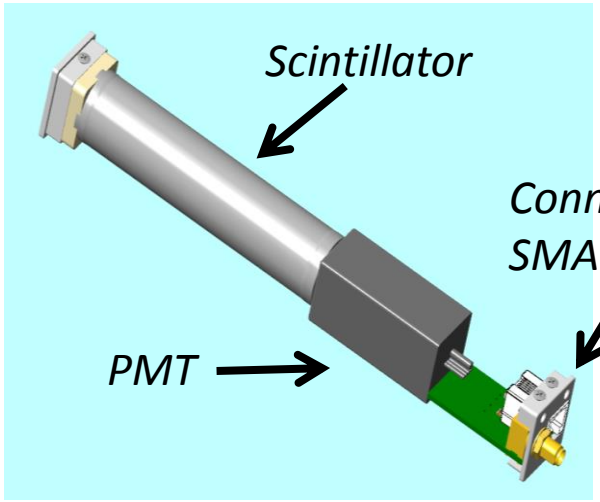


New ESRF beam loss monitors



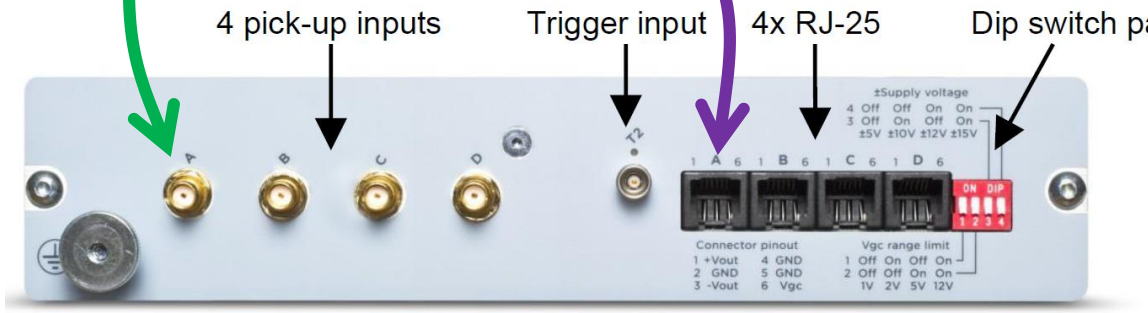
BLD :
aluminium housing
200 x 25 x 25 mm



Power-supply &
gain-control

BLD-signal

BLM
(Libera-BLM)



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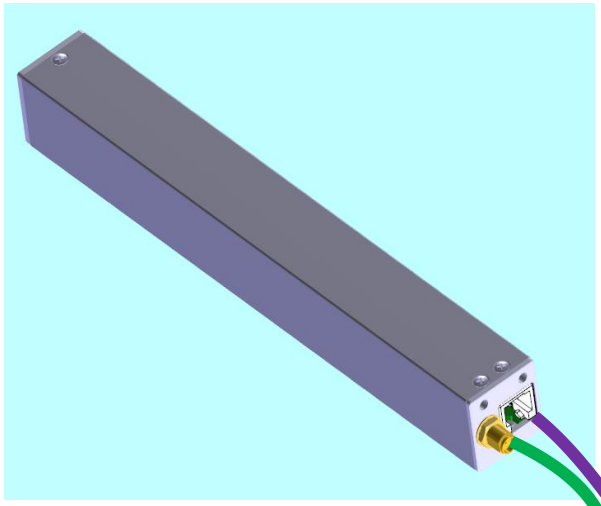


Scintillator :

EJ-200, 100 x 22 mm rod
wrapped in reflective Al-foil

PMT:

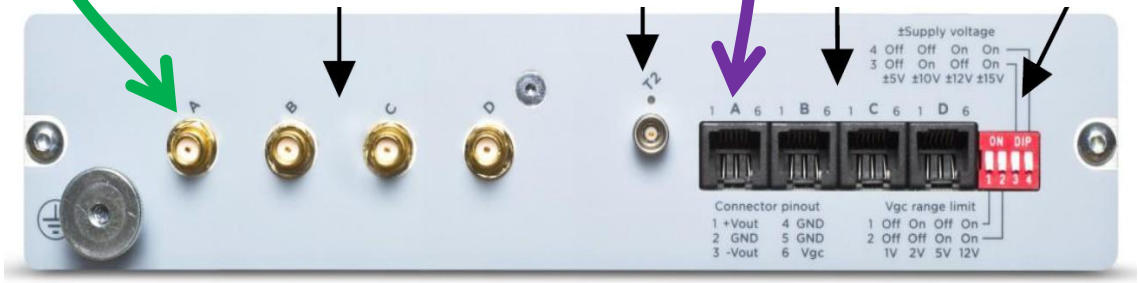
- *Hamamatsu H10721-110*
- *8mm active photo-cathode*
- *powered (+5 V) & gain-controlled from BLM*
- *3 orders of magnitude with 0-1V gain-control*
- *can drive 50 Ω load*

BLD-signal

Power-supply & gain-control

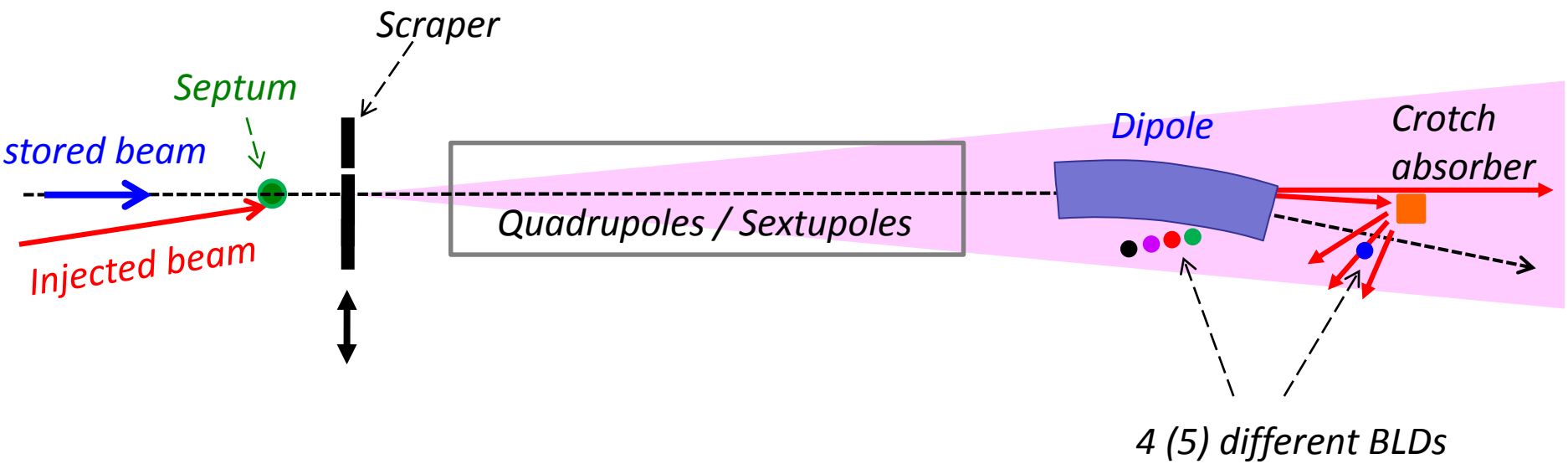
BLM :

- *4 independent channels*
- *14 bit ADCs, +/- 5 V to +/- 150 mV full-scale (adjustable)*
- *>10 MHz bandwidth*
- *50 Ω or HiZ input*
- *PoE*
- *Embedded Tango-DS*



BLD "test bench" in the ESRF injection zone

Do the BLDs only see e- losses or also bending magnet radiation ?



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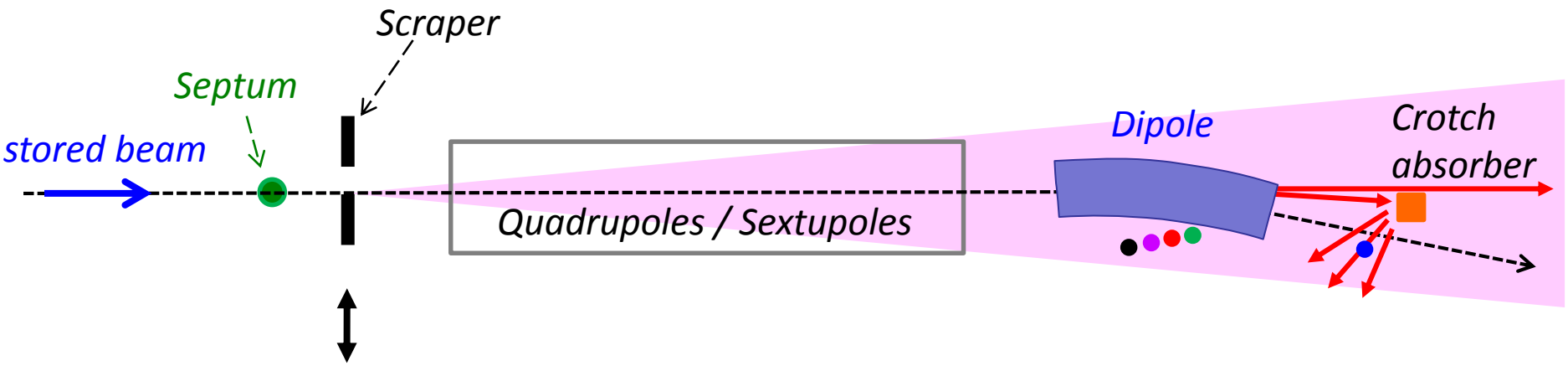


Stored current = 200 mA :

60 hours lifetime

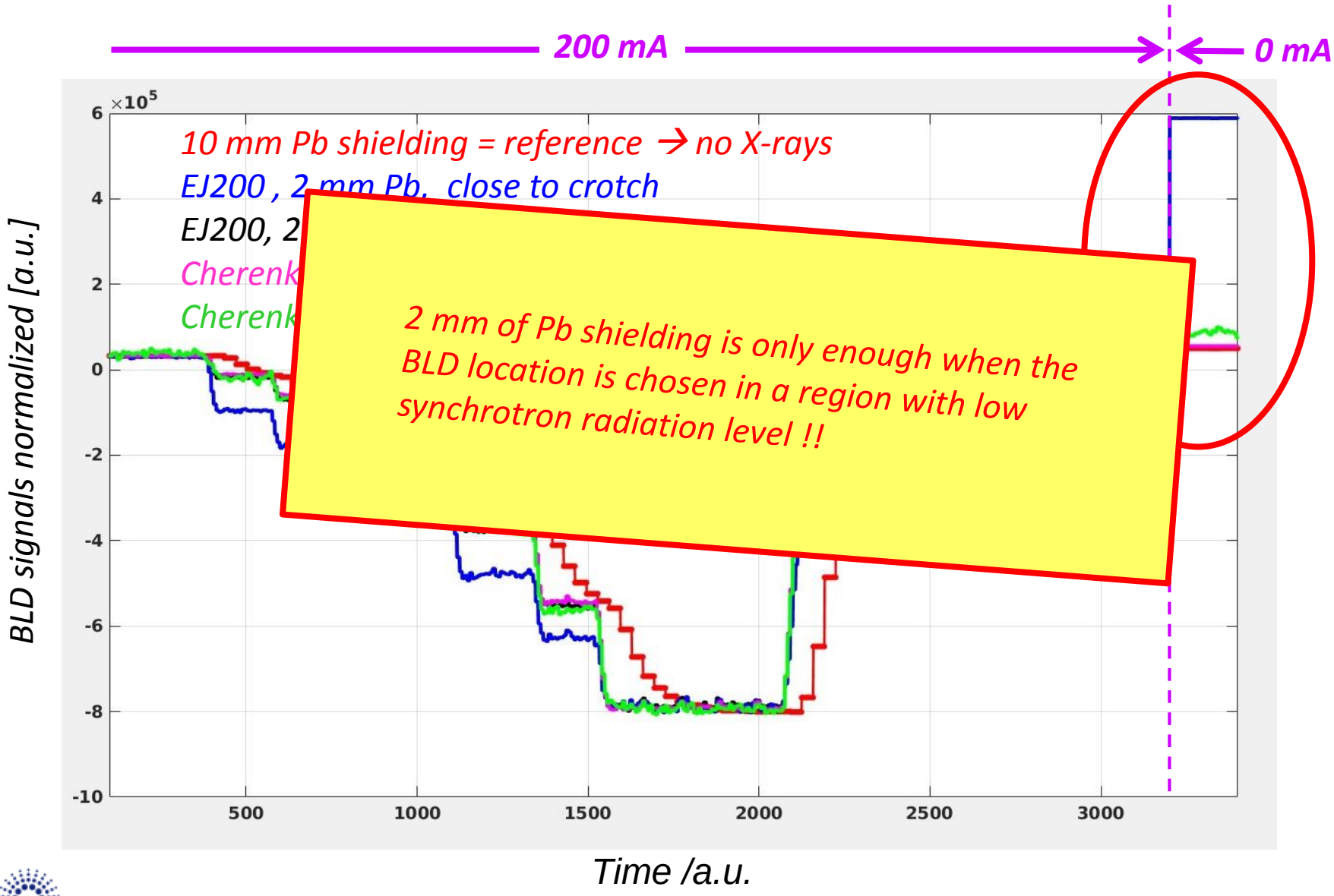
→ *16 million 6 GeV electrons/sec lost = ~ 2·10 $^{-11}$ Watt/meter (with 844 m of circumference)*

Crotch absorber takes many kW from synchrotron light, (E_{crit} ~ 20 keV)

→ *a tiny fraction of that power converted into back-scattered photons can create a dominant signal in the BLD*

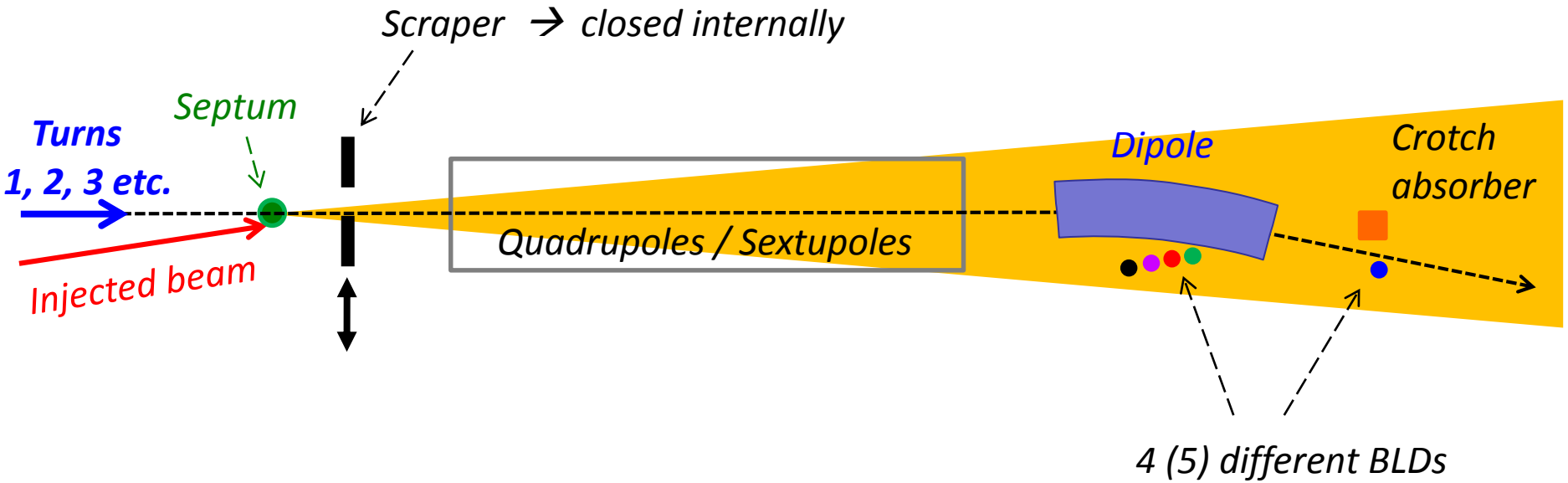
→ ***Pb-shielding necessary to suppress up to 200 keV X-rays***

5 different BLDs tested for immunity against X-rays



BLD "test bench" in the ESRF injection zone

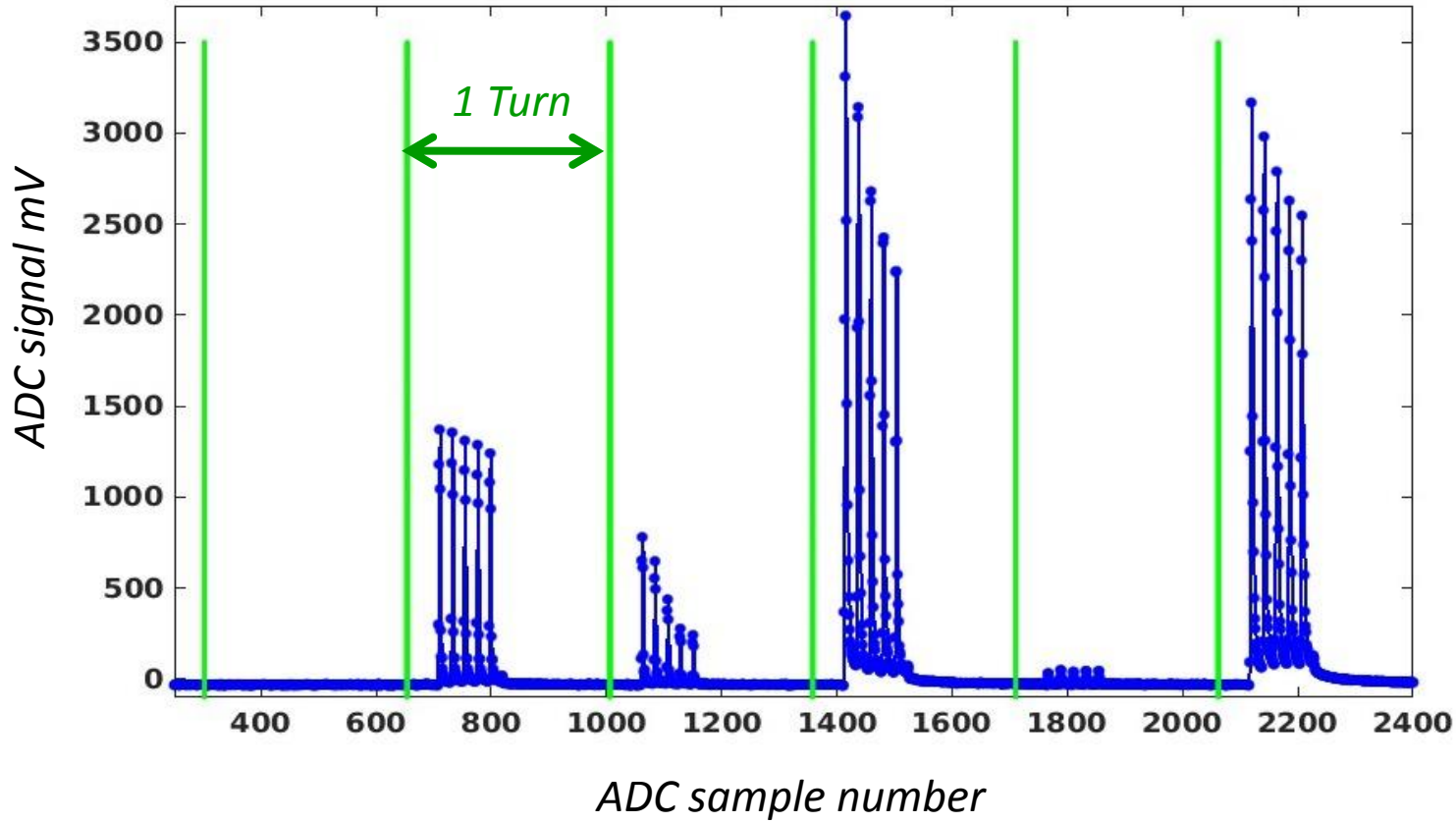
" Strong & Fast " losses at injection (top-up)



1) done at each top-up
2) obtain time-resolved loss-patterns, at ADC-rate or T-b-T-rate (or slower)
3) vary numerous injection parameters, and see the effects on these loss-patterns
4) purpose : asses the BLD system on coping with (extreme) strong levels of losses

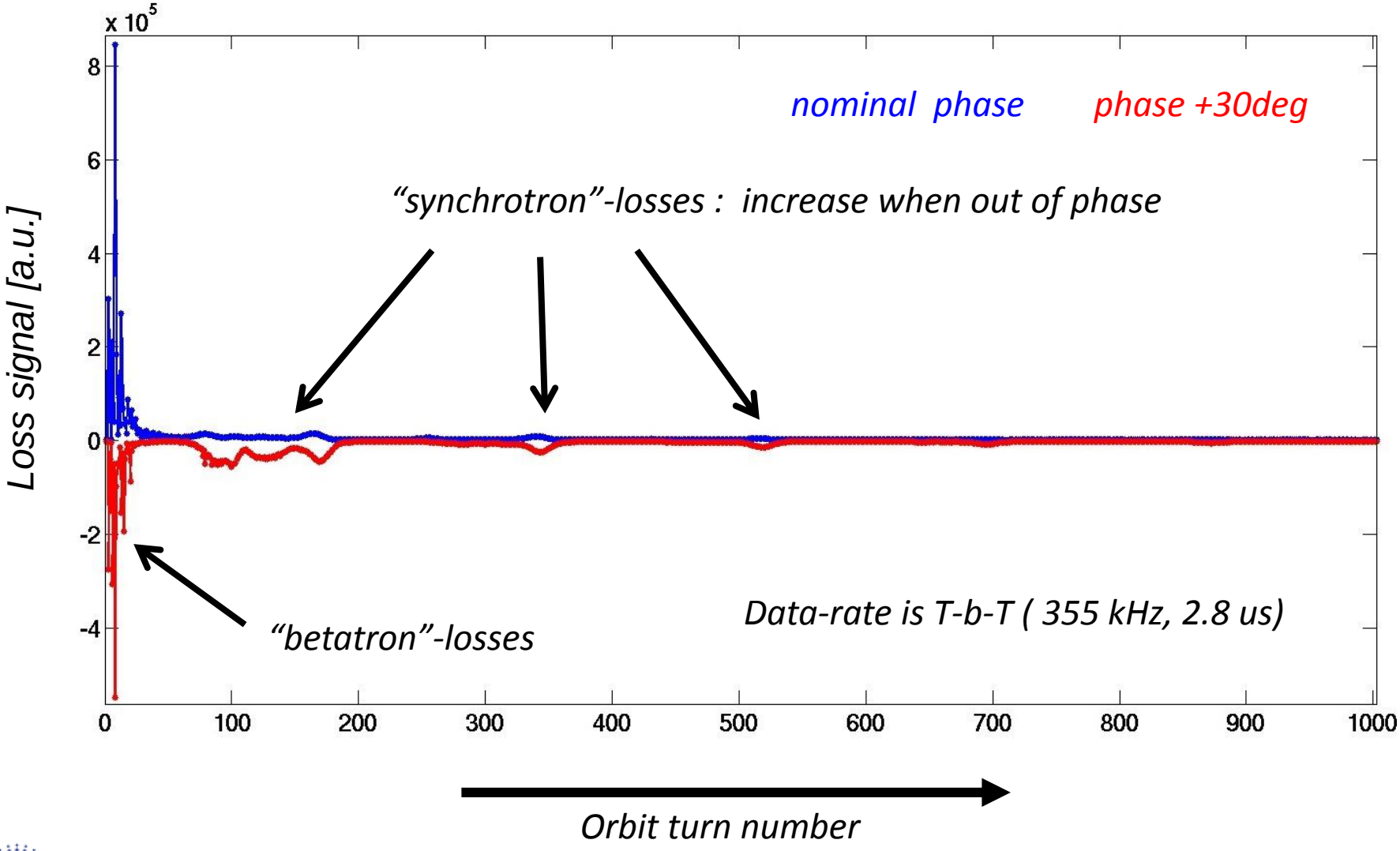
ADC buffer at injection of 5 bunches into the storage ring

Typical ADC data, 6 turns with 5 bunches injected:
Strongly varying loss level from turn to turn



Data-rate is ADC : 125 MHz = 352 samples/turn
= 22 samples between bunches

Time-resolved losses of injected beam at different RF phases :



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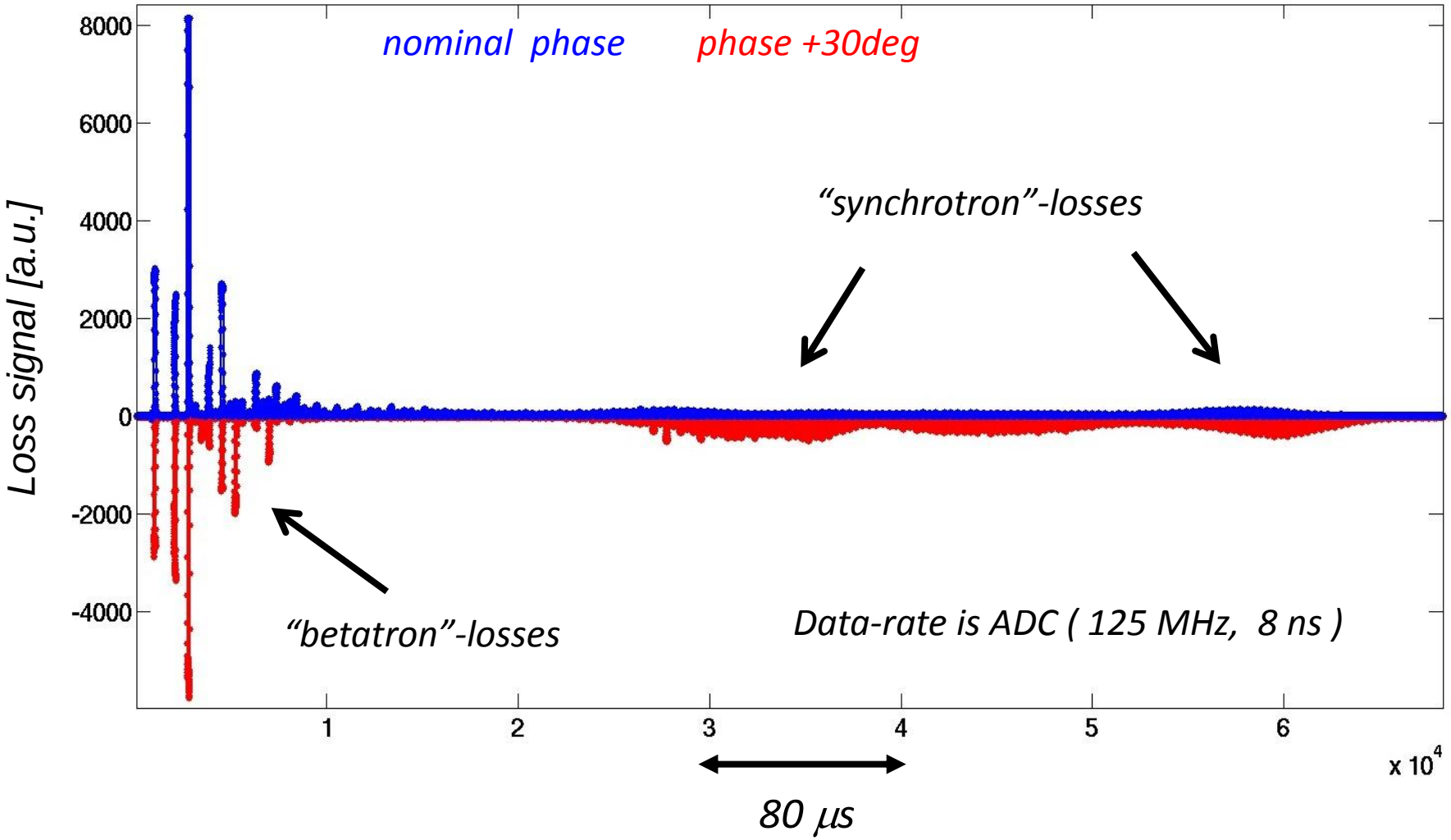

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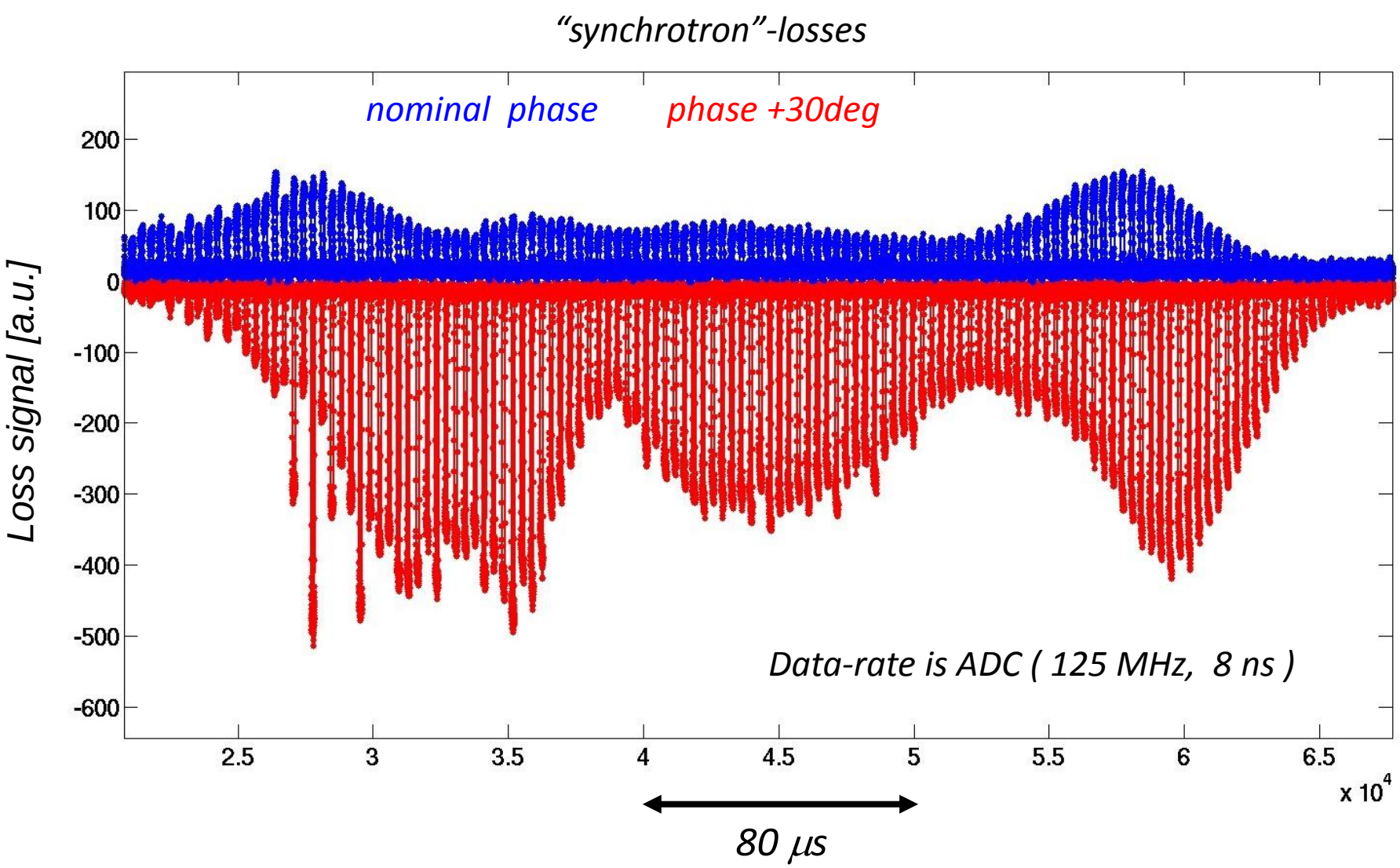
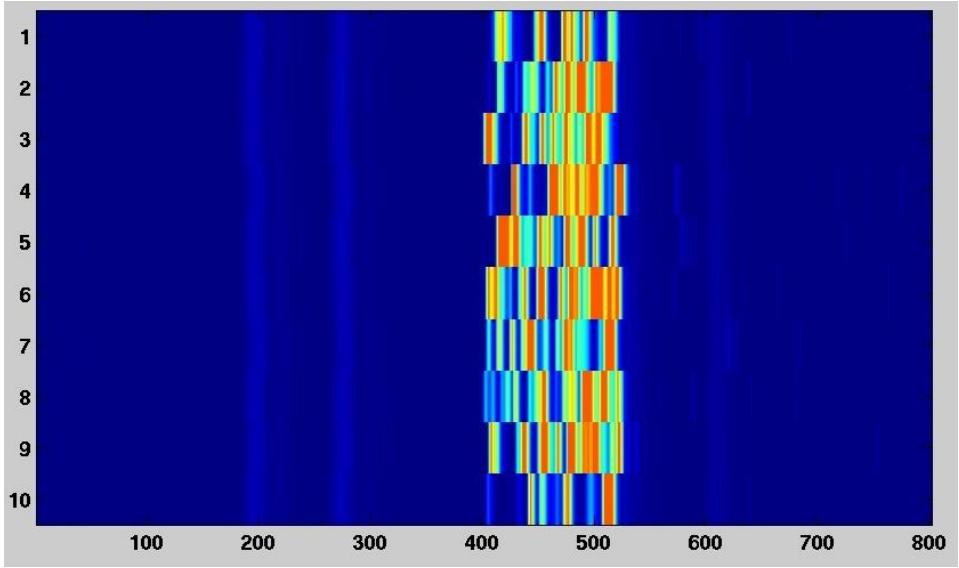
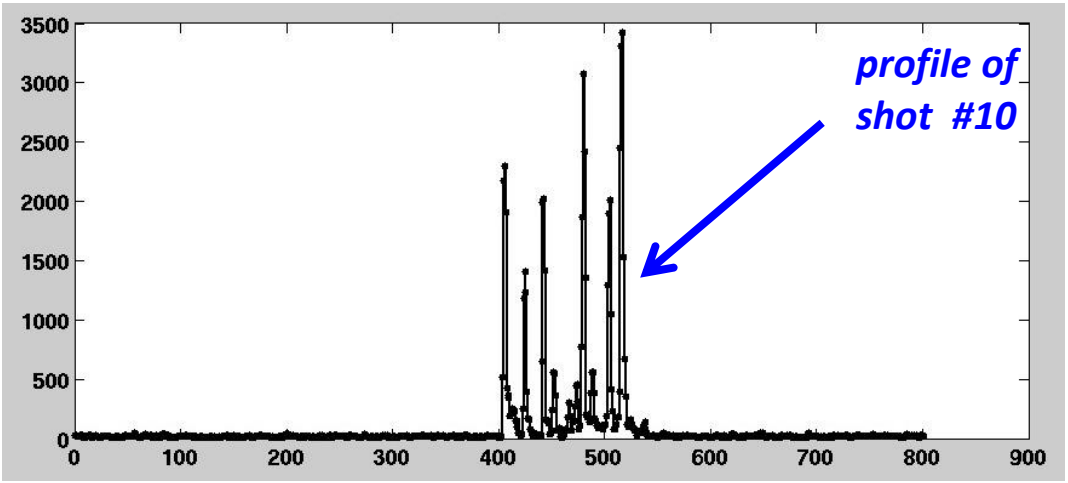


" Single-electron " losses by dumping injector's dark current into scraper



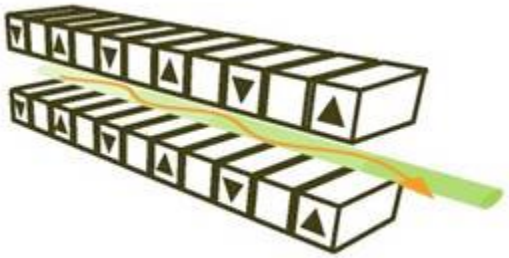
Any lost electron will create a different shower, and thus signal strength.



other extreme : high sensitivity
→ Single electron detectivity

Beam loss measurements in the vicinity of in-vacuum undulators

*Magnet arrays of in-vacuum undulators are **very close** to the electron beam :*



*The 'gap' can be as small as **5mm***
→ Gain in flux

but: scattered electrons now get lost on these magnets
→ Degradation of the magnets over less than a few years

This can be a real problem in rings with smaller beam-sizes (like ESRF-EBS …!)
→ more scattering = less lifetime = more losses . . .

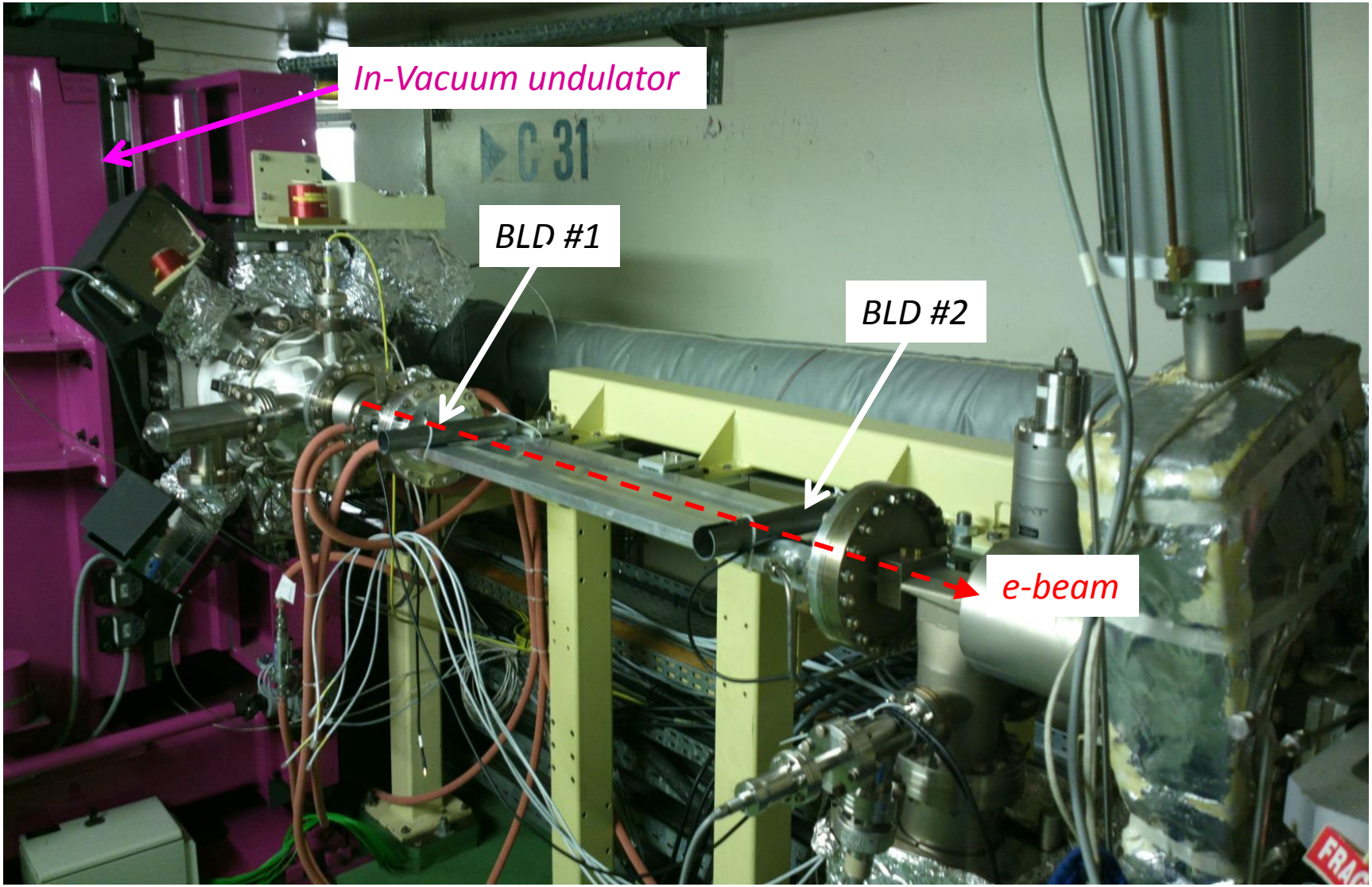
less lifetime** is compensated with more frequent refills → **top-up
But any damage to In-Vacs is only felt after it is done

Solutions :

Add special & dedicated scrapers-collimators in that ring
→ the scattered electrons get lost there

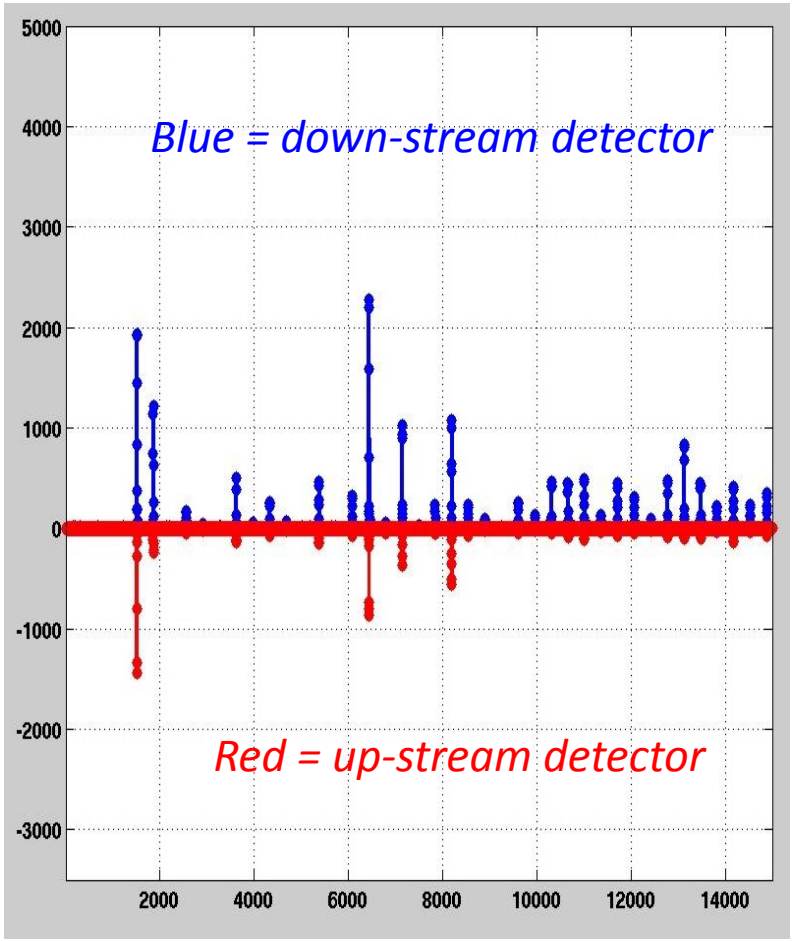
Improved monitoring of losses to verify that these in-vacs are indeed protected.

BLD installation at in-vacuum undulator

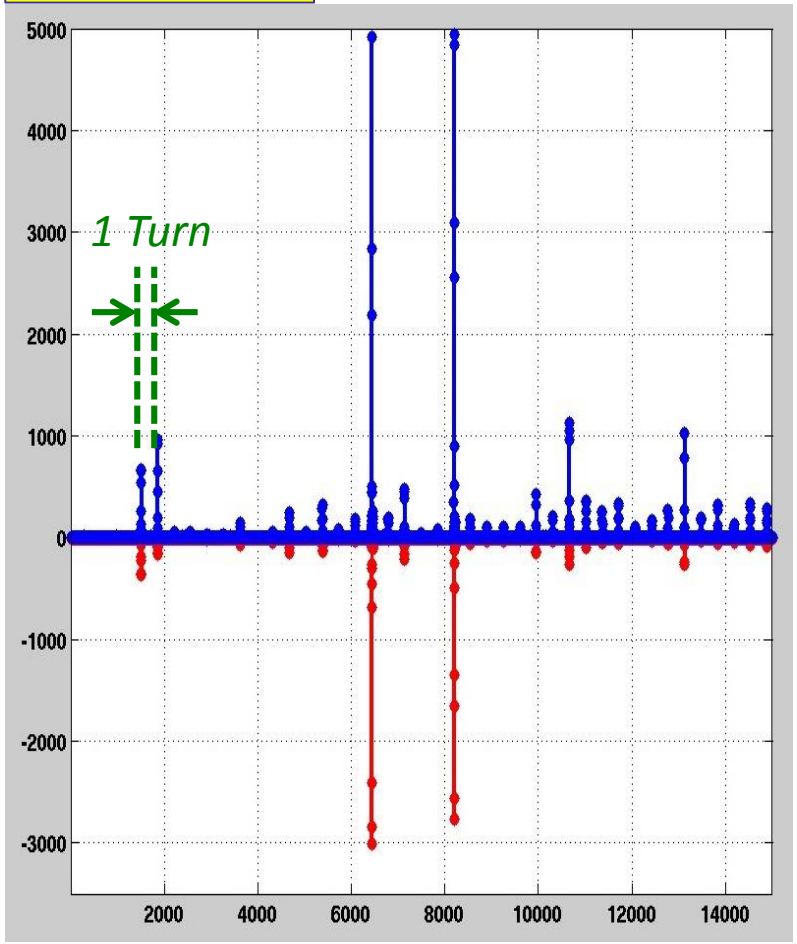


ADC data from 2 BLDs near in-vacuum undulator, at 2 different injections

one shot

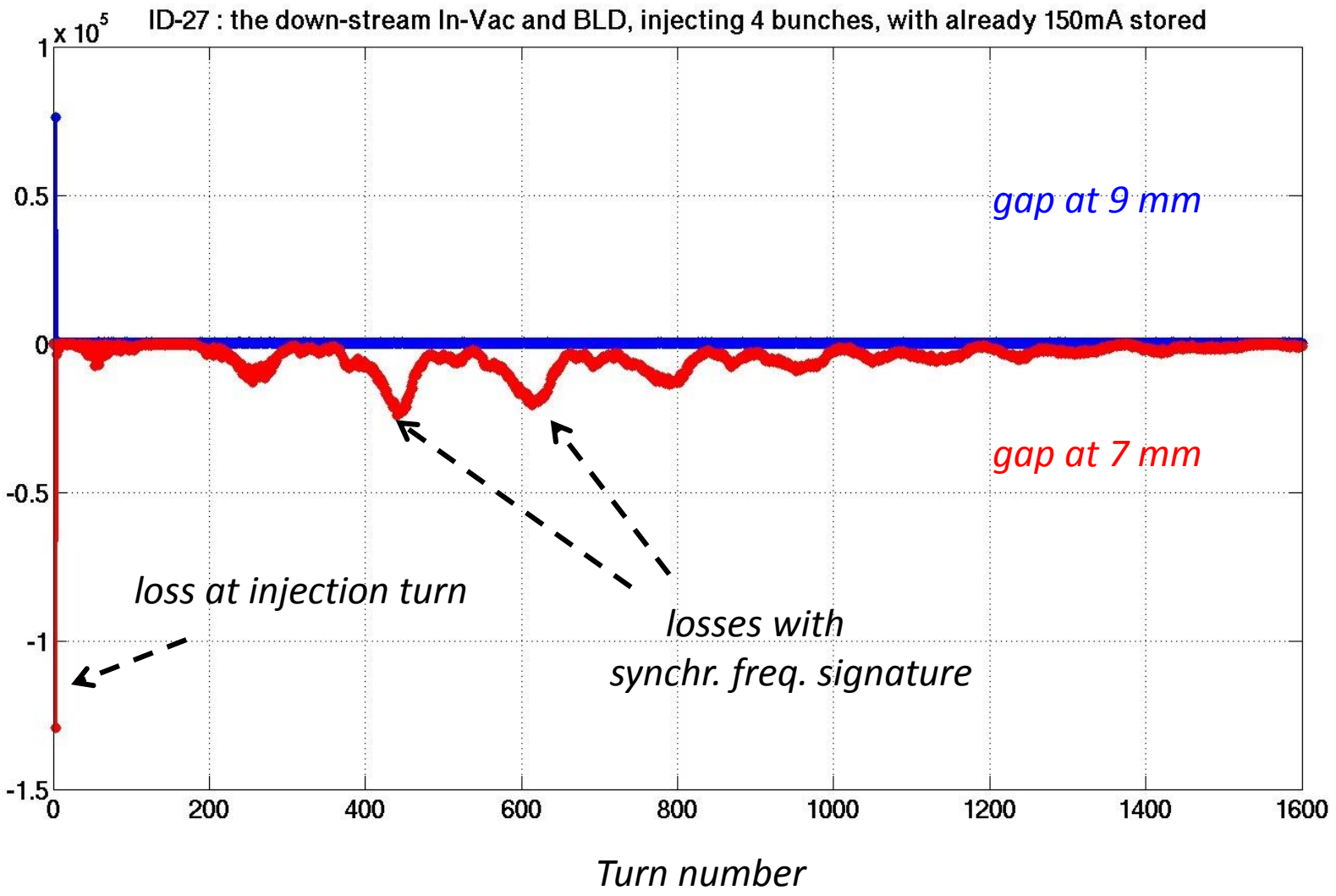


another shot



Registered losses depend on detector position.
Losses are not the same at each injection shot.

Beam loss at undulator with closed gap at injection



Plans at the ESRF for adding a new BLM system now

- *Presently we have already :*
  - *64 old BLDs (scintillator + PMT) that are heavy & big with slow read-out electronics (<1Hz)*
  - *64 Ionization chambers : even heavier, very big*

- ***128 BLDs of the new type** and 40 BLM electronics will be installed at strictly regular positions (4/cell)*

  32 more units will be installed at points of interest like some in-vacuum IDs, injection zone, close to scrapers etc.

- *Commissioning of the new BLD/BLM system will start in early 2017.*

- *In 2019/20 all of these devices will be transferred to the new storage ring. The experience acquired in the present ring will be valuable for judging data taken at the start-up of ESRF-EBS.*

Acknowledgements and References

The BLD/BLM development as presented here is a collaboration between the ESRF (Kees Scheidt, Nicolas Benoist, Fouhed Taoutaou, Francis Epaud) and Instrumentation Technologies.

For a more detailed description of the BLD/BLM system:

K. Scheidt, F. Ewald, P. Leban et al. "Optimized beam loss monitor system for the ESRF", IBIC2016 proceedings, MOPG20