Beam Loss Measurements at the ESRF with different Beam-Loss-Detectors and the new 4 channel Libera-BLM acquisition system

Libera WORKSHOP 2016

-1- the principle of electron beam loss detection

-2- test bench for various BLDs in the ESRF injection zone

-3- results on various BLDs, pros & cons, final design

-4- applications, perspectives at the ESRF

Road-map for an optimized Beam Loss Monitoring system :

- optimized for Light Sources (2 to 6GeV)

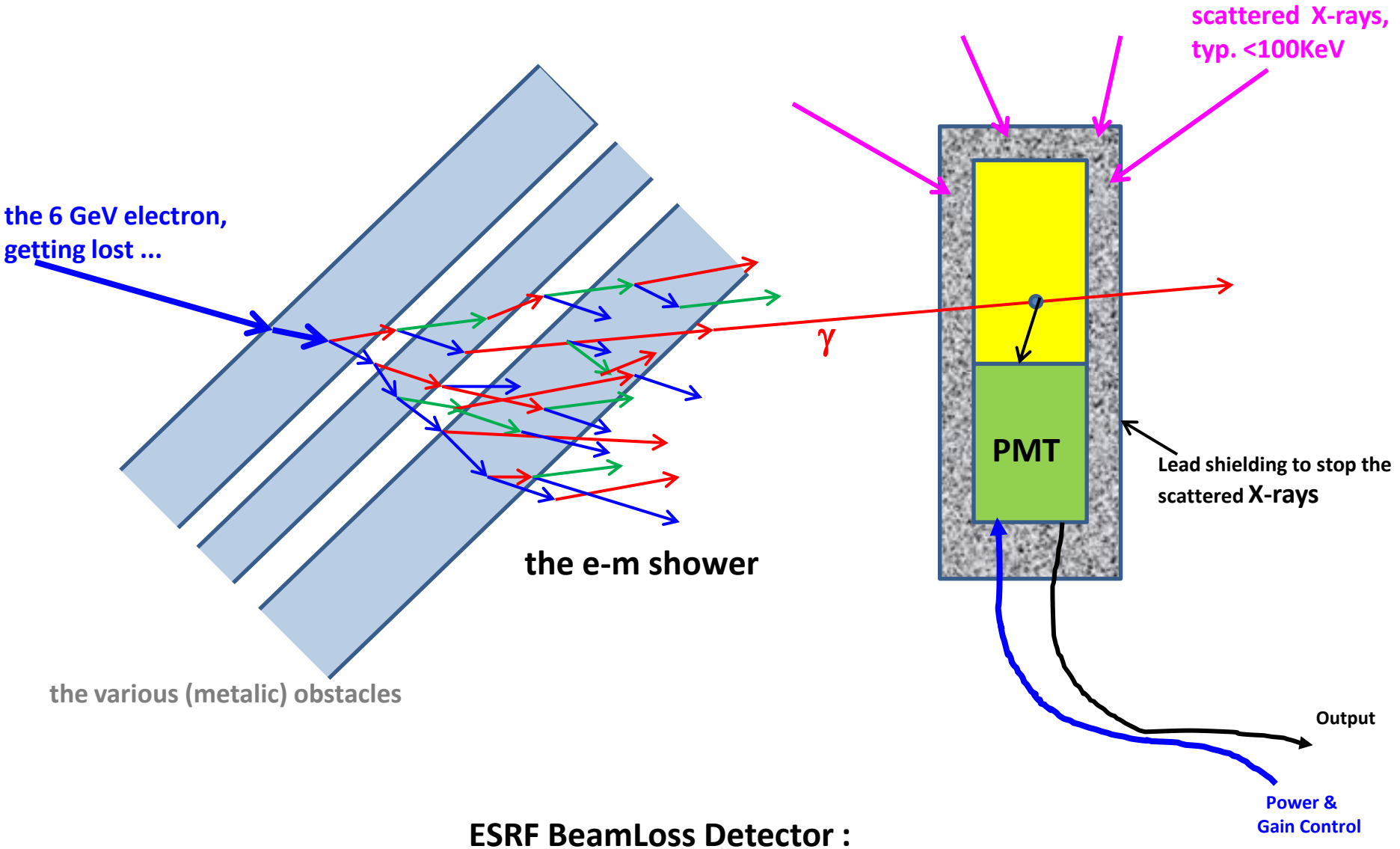
- covering (extreme) different applications → strong & fast losses
                                           → weak & slow losses

- commercially available at reasonable or low costs :
  → install many, at regular points

- the BeamLoss-Detector BLD and
- the Acquisition Electronics BLM should be fully compatible with each other

- so a choice needed to be made on the type of BLD :
  ionization-chamber ? semi-conductor ? CVD-sensors ?
  scintillator/radiator ←

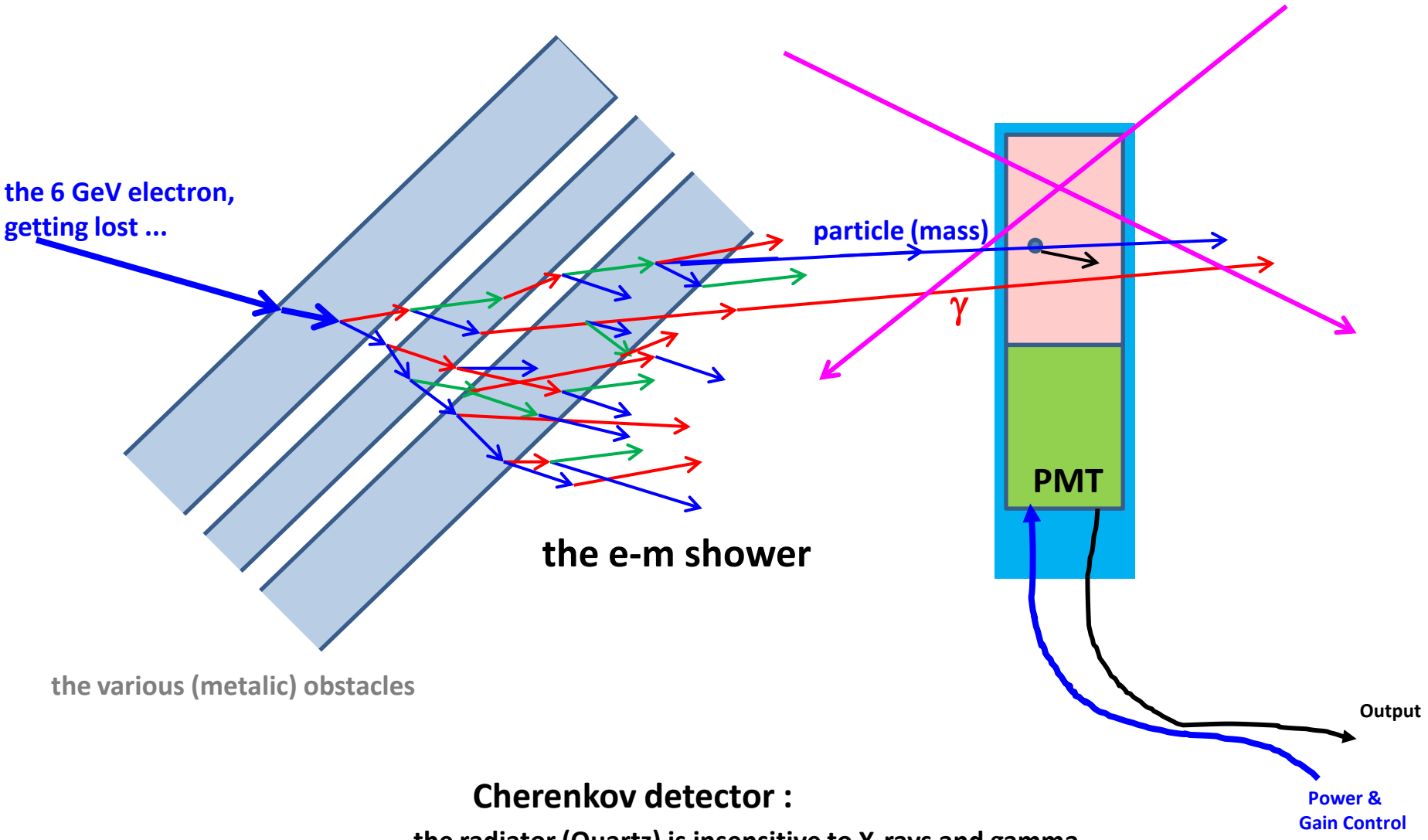
- and the component that produces the electric signal output :
  photo-diode, MPPC, other ...
  PMT ←



ESRF BeamLoss Detector :

the scintillator is (very) sensitive to both X-rays and gammas

so a Lead shielding is needed to stop the X-rays

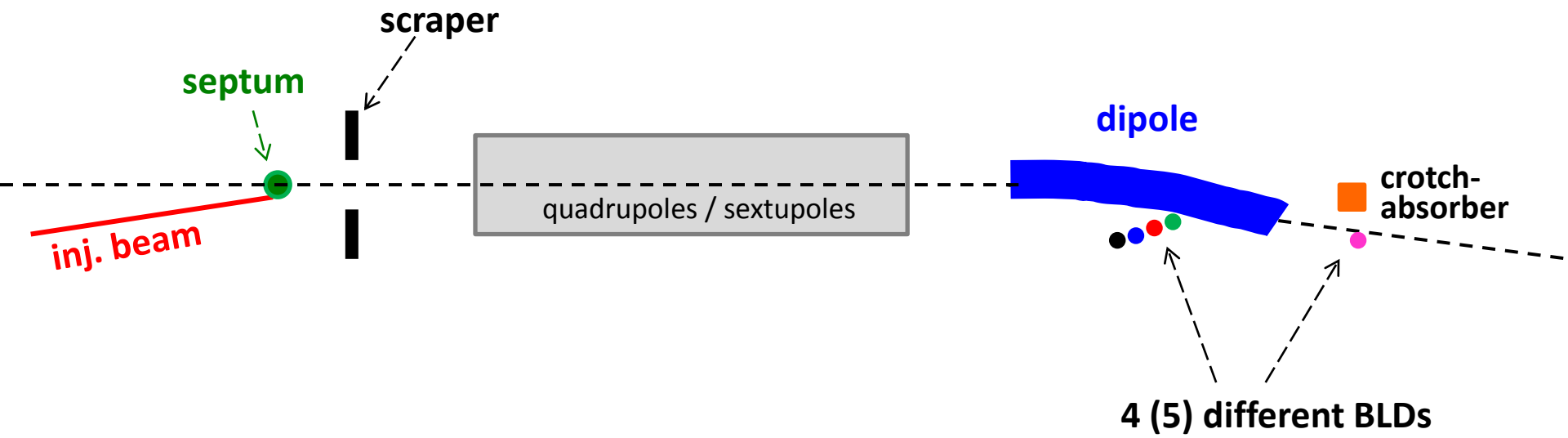


Cherenkov detector :

the radiator (Quartz) is insensitive to X-rays and gamma

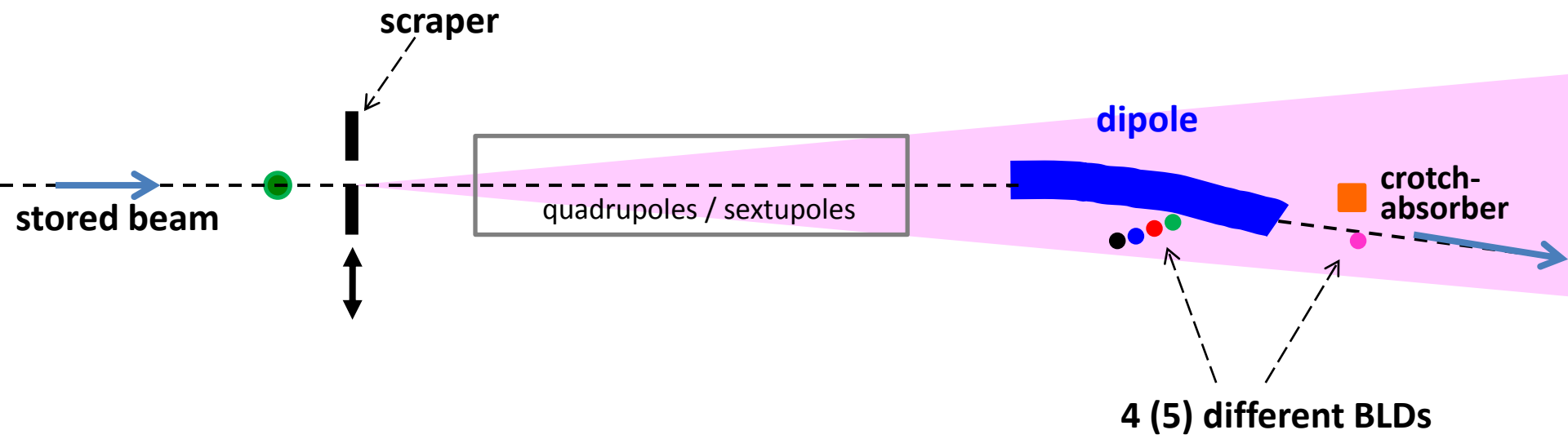
only particles with mass and sufficient energy will create visible (blue) light ('Cherenkov')

development & tests on new, optimized, Beam Loss Detectors



top-view of the ESRF Cell-4 (the injection zone)

creating "weak / slow" losses with the scraper

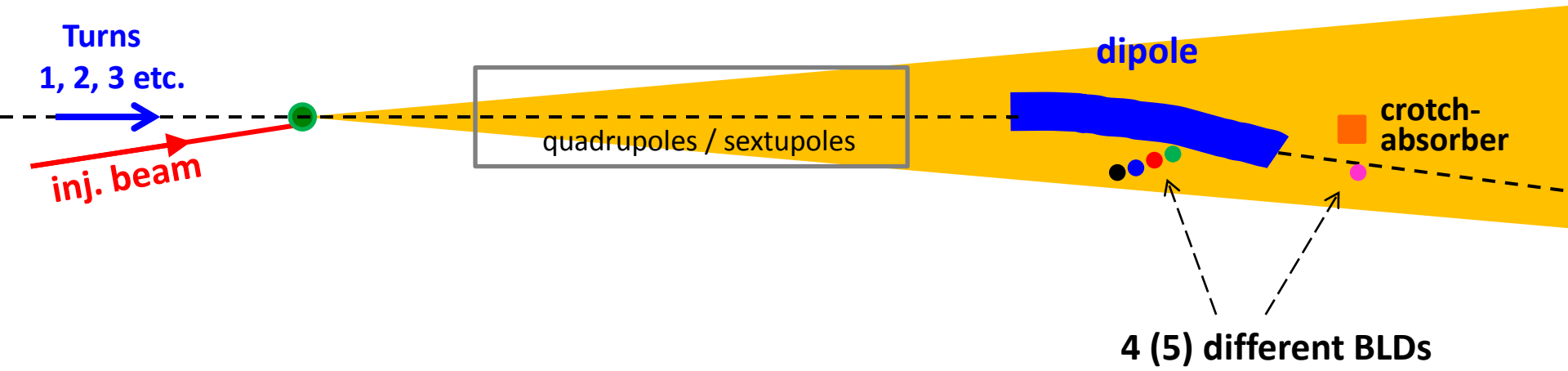


1) can be done during USM

2) do these different BLDs <u>only see e^- losses</u> or <u>also X-rays</u> ?

3) quantify the BLD sensitivity with (HQ) Life-Time measurements in parallel

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



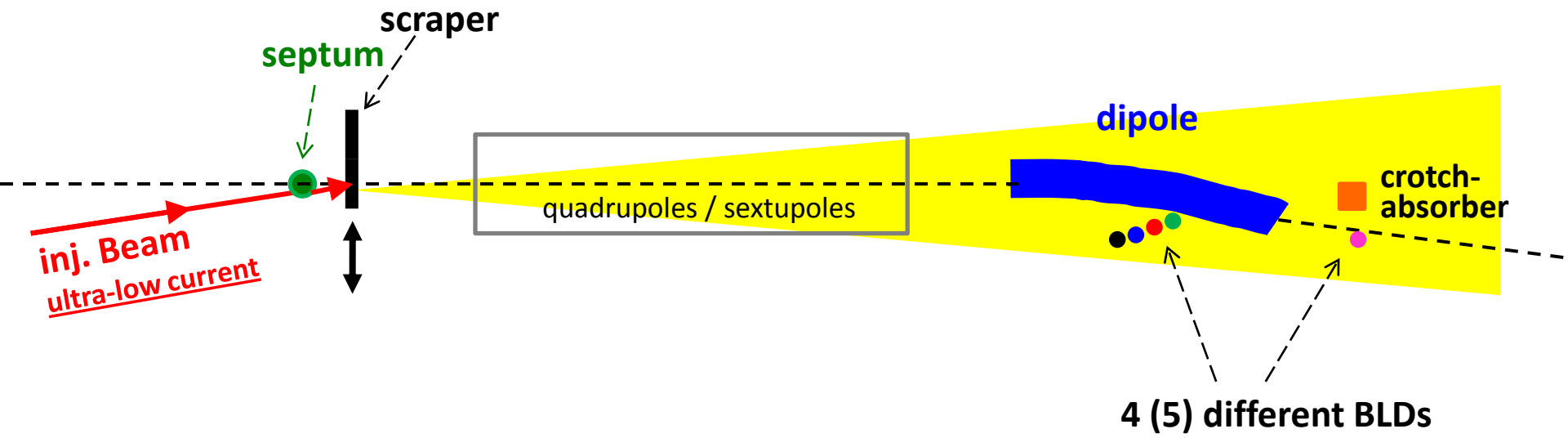
1) done at each top-up (20min for 16 bunch … but 12 hours for other fills !)

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

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



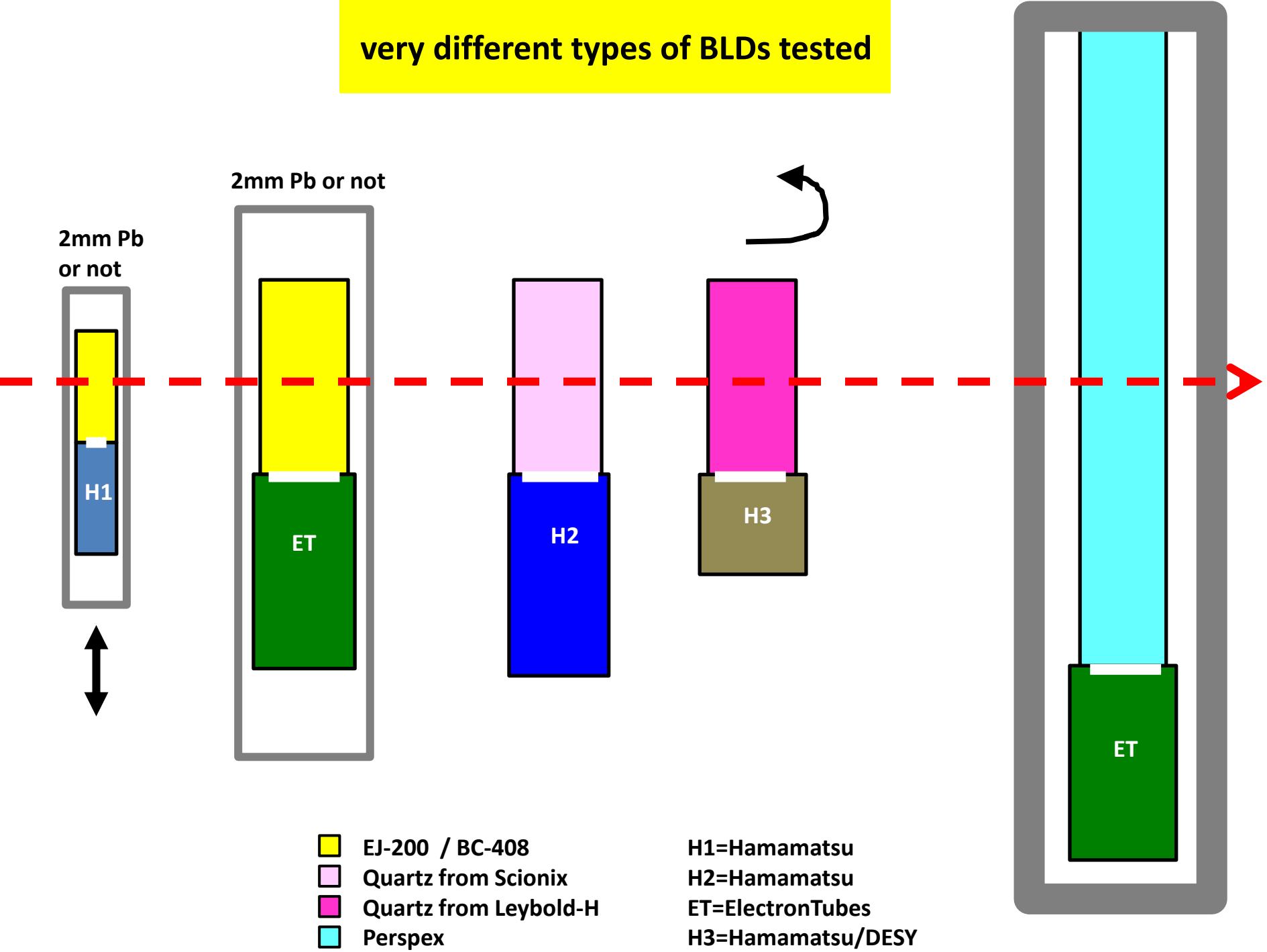
1) only possible during MDTs

2) LINAC gun OFF → "dark-current" = typically a handfull of electrons per shot

3) weak Single-Bunch + attenuating screens in the TL-1 and TL-2 → 0 to 1 electron

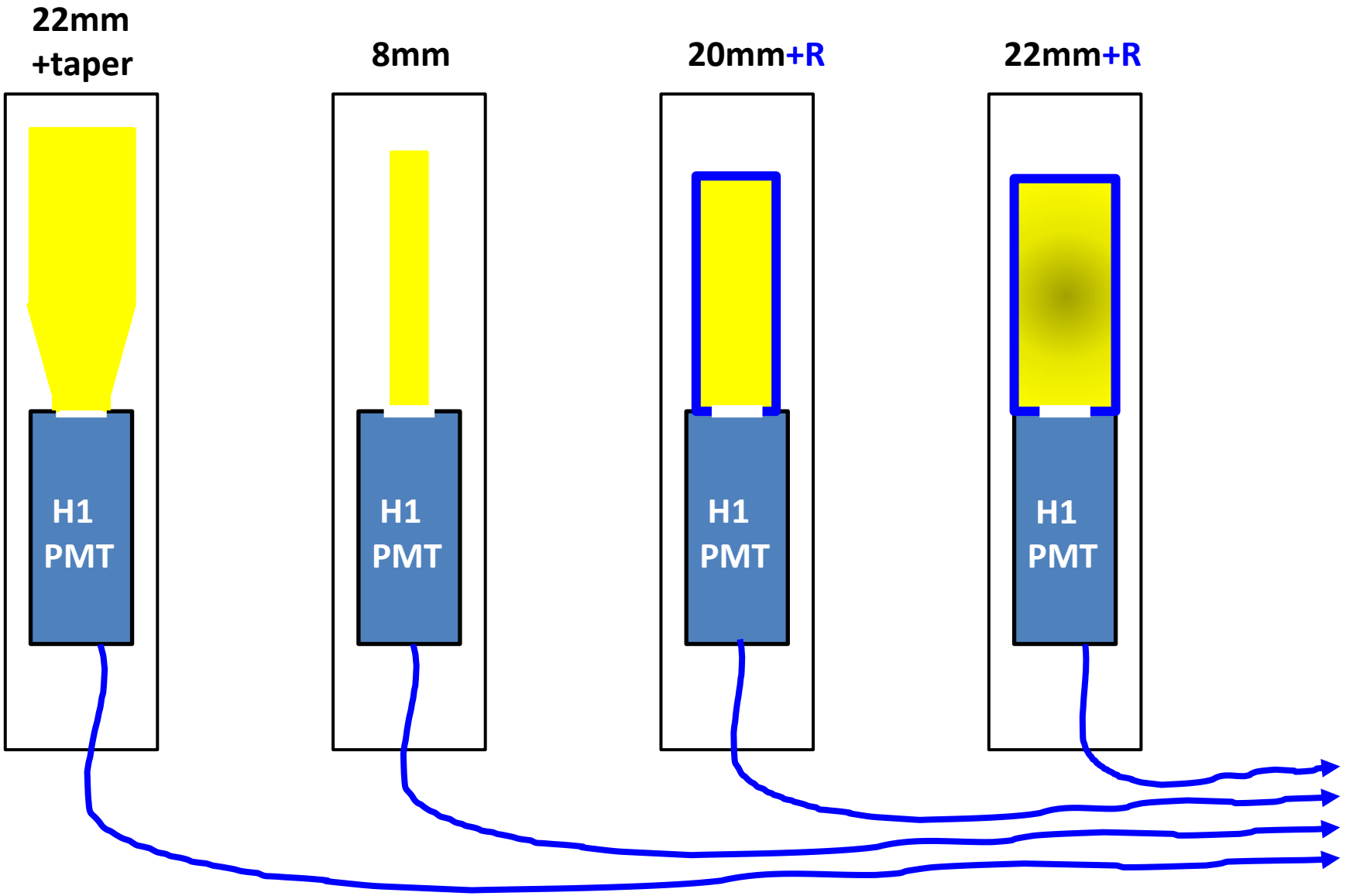
4) purpose : asses the BLD system on detecting (extreme) low-levels of losses

very different types of BLDs tested



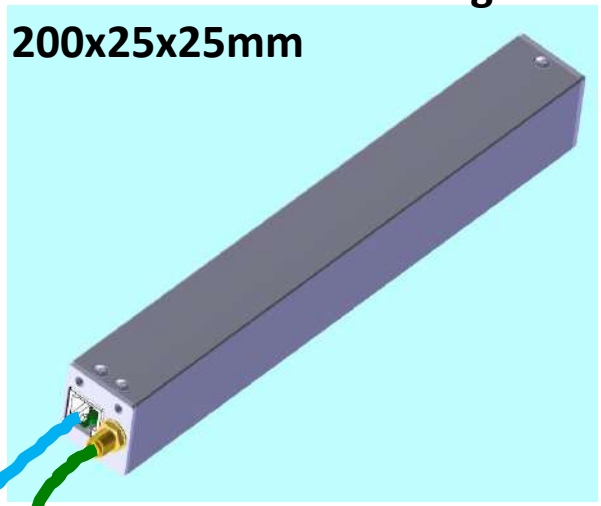
Cesium-137 (700KeV γ)

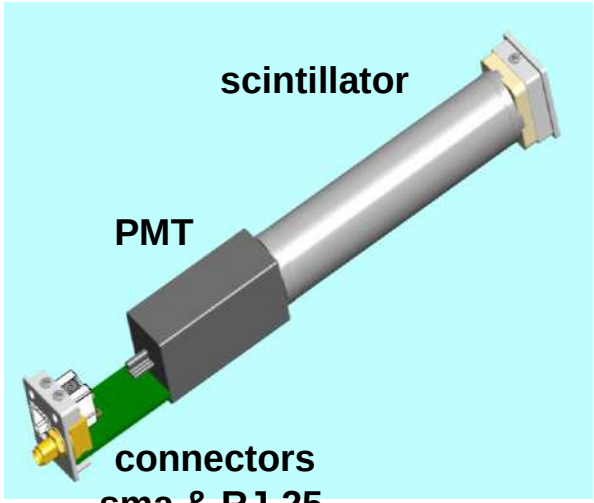
all with EJ-200 scintillator

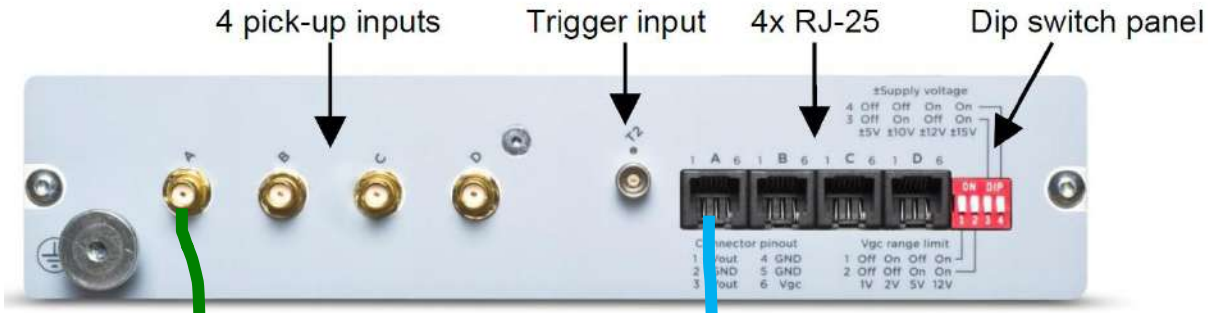


Lab tests with small gamma-source → optimizing **geometric aspects** of the scintillator

BLD with its Alu housing
200x25x25mm



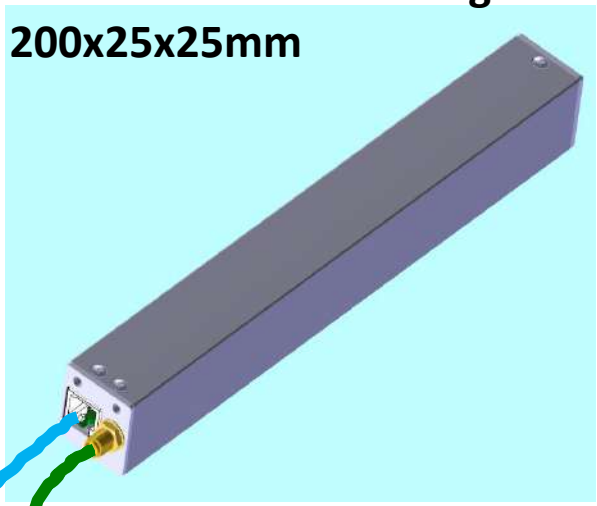




BLD-signal

power-supply &
gain-control

BLD with its Alu housing
200x25x25mm

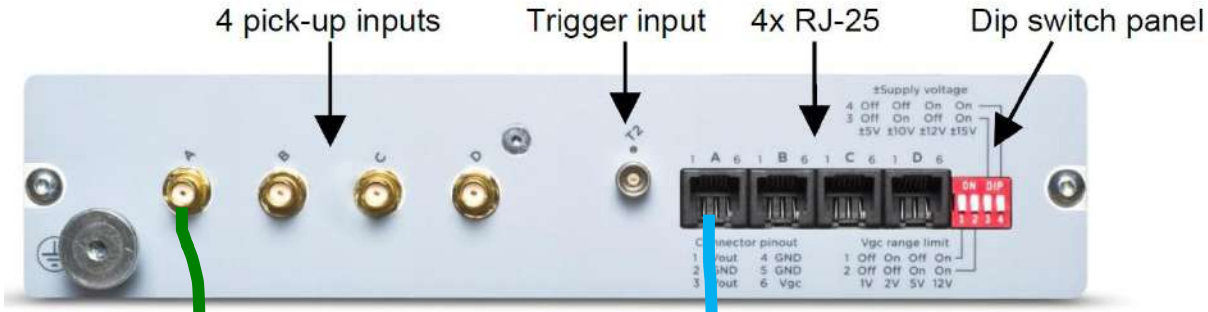


BLD :

- entirely powered (+5V) & gain-controlled from the BLM
- several orders of magnitude with 0-1V gain-control
- can drive 50ohm load

BLM :

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



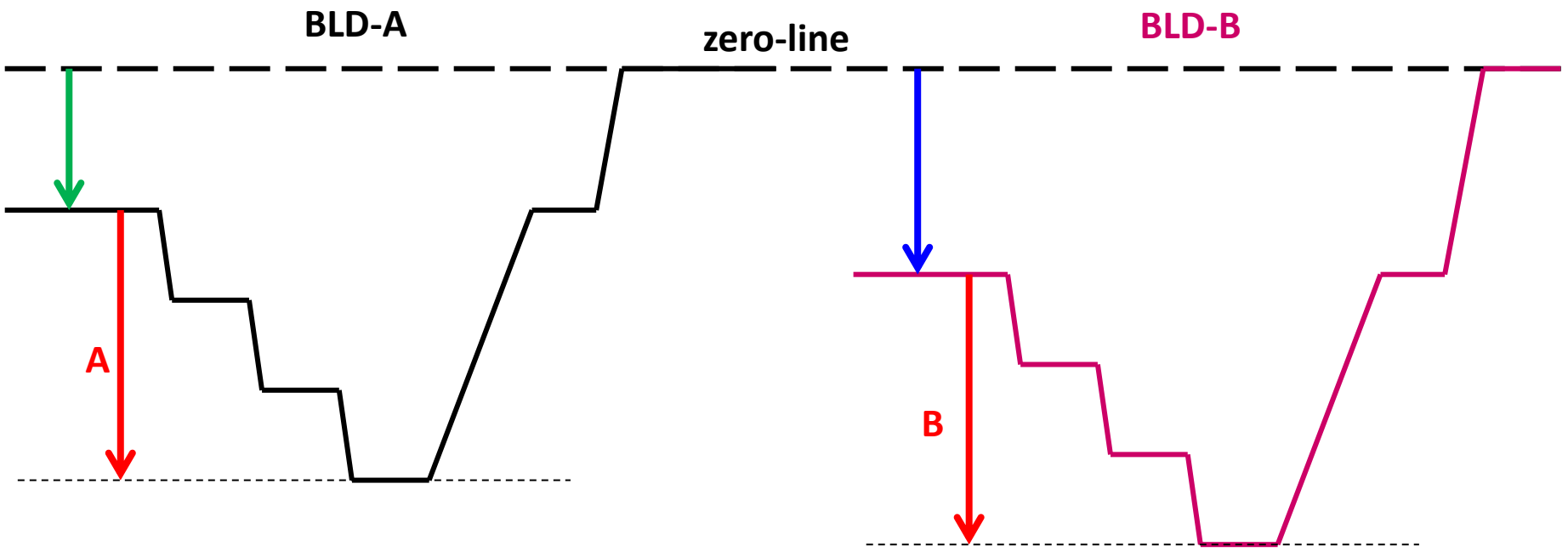
BLD-signal

power-supply &
gain-control

BLM (Libera-BLM)

although it looks like a “Spark”

how to asses the immunity of the BLD to scattered X-rays ?

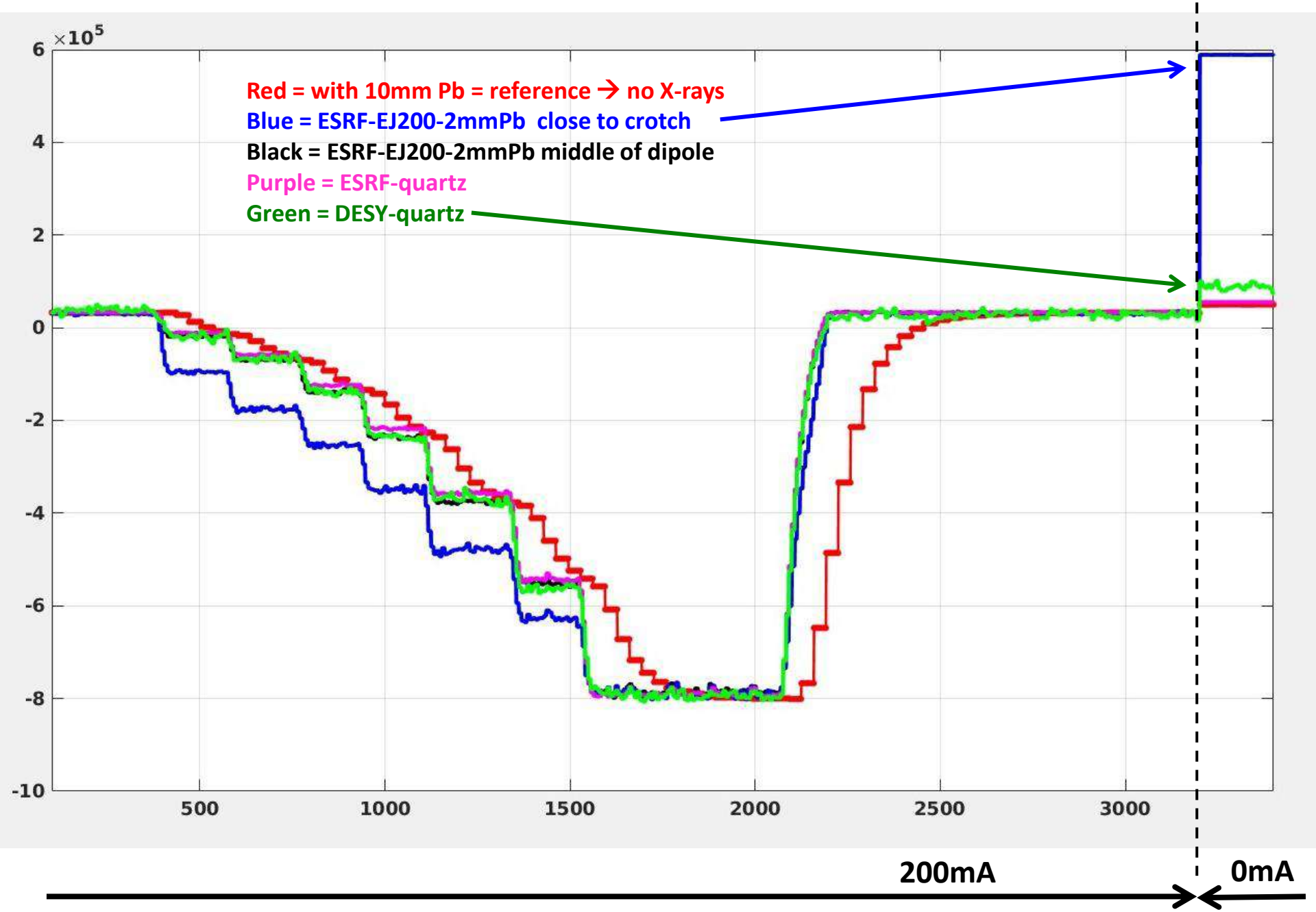


= e-losses (only)

= e-losses + X-rays (?)

= pure e-losses from scraping = A = B

5 different BLDs tested for **immunity against X-rays**



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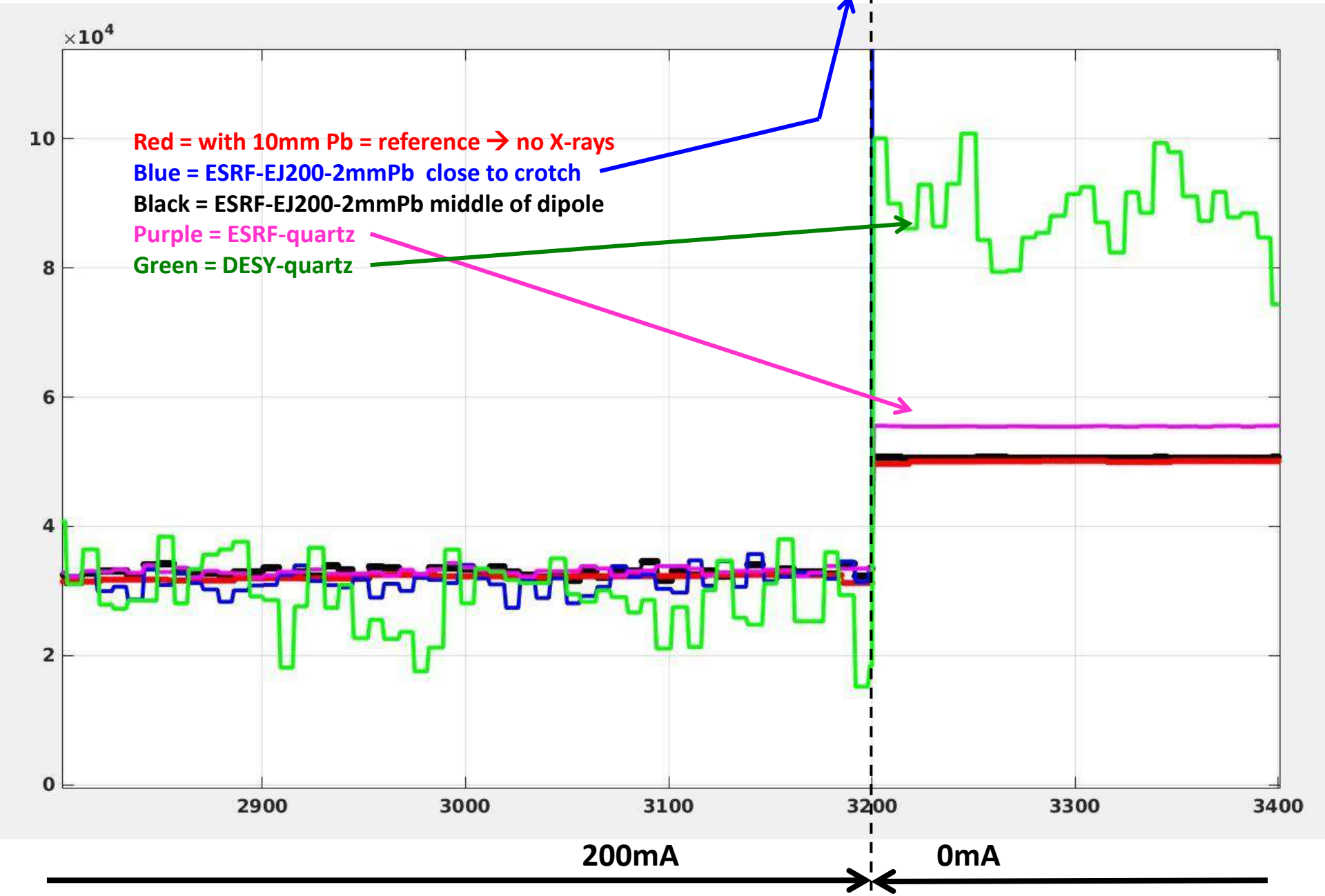
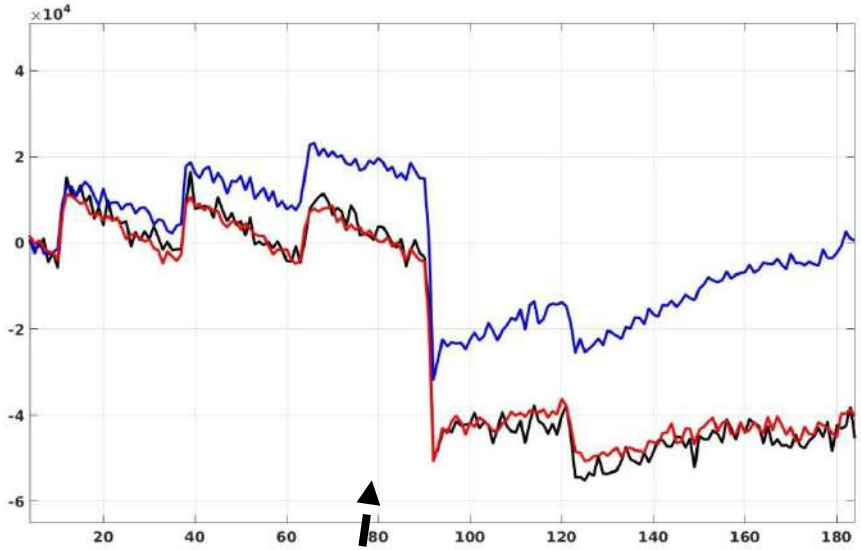




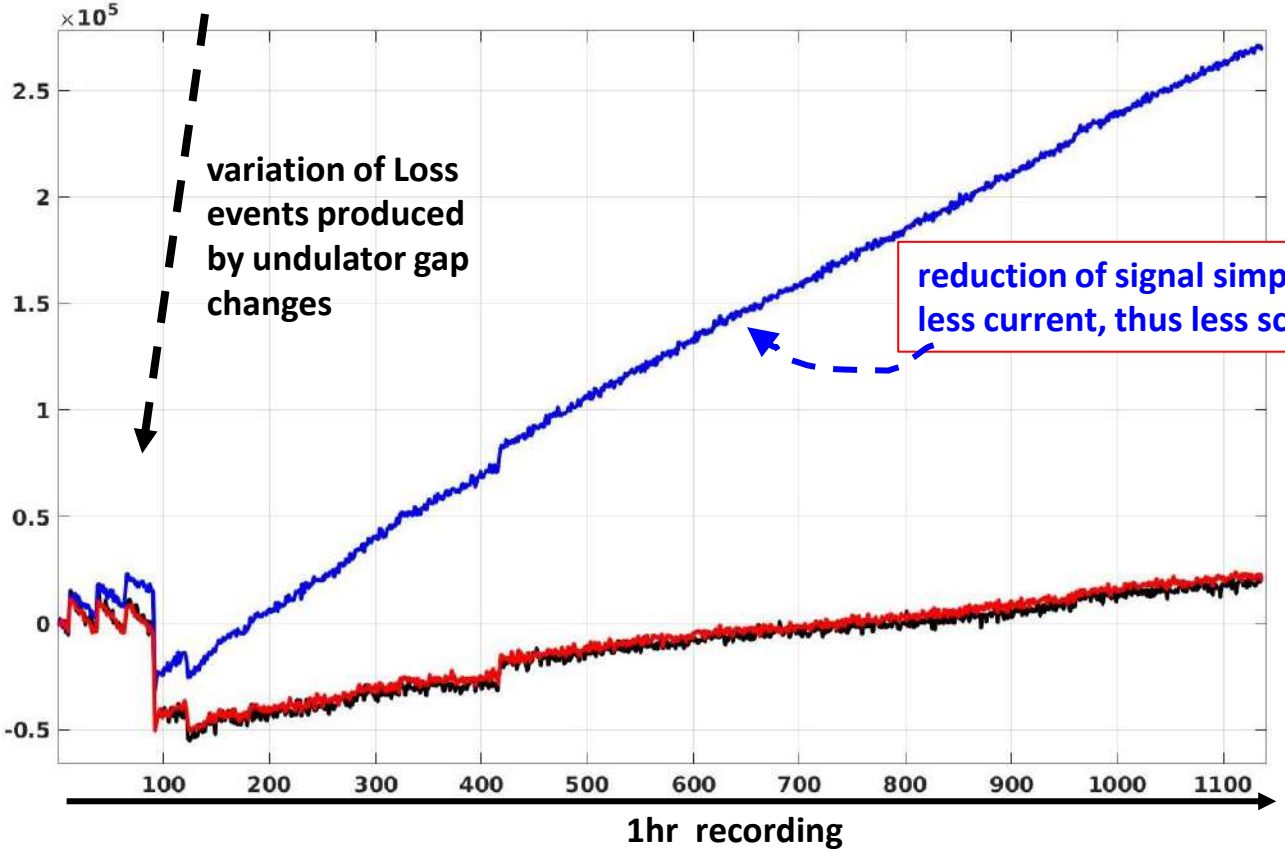
3 different BLDs , during beam decay (1hr):

Red= DESY=Cherenkov

Black= ESRF-2mmPb -mi-Dipole

Blue = ESRF-2mmPb -close-to-crotch

conclusion :
- 2mm Pb is not enough, and/or
- position is not suitable



A.U.
3 signals normalized

variation of Loss events produced by undulator gap changes

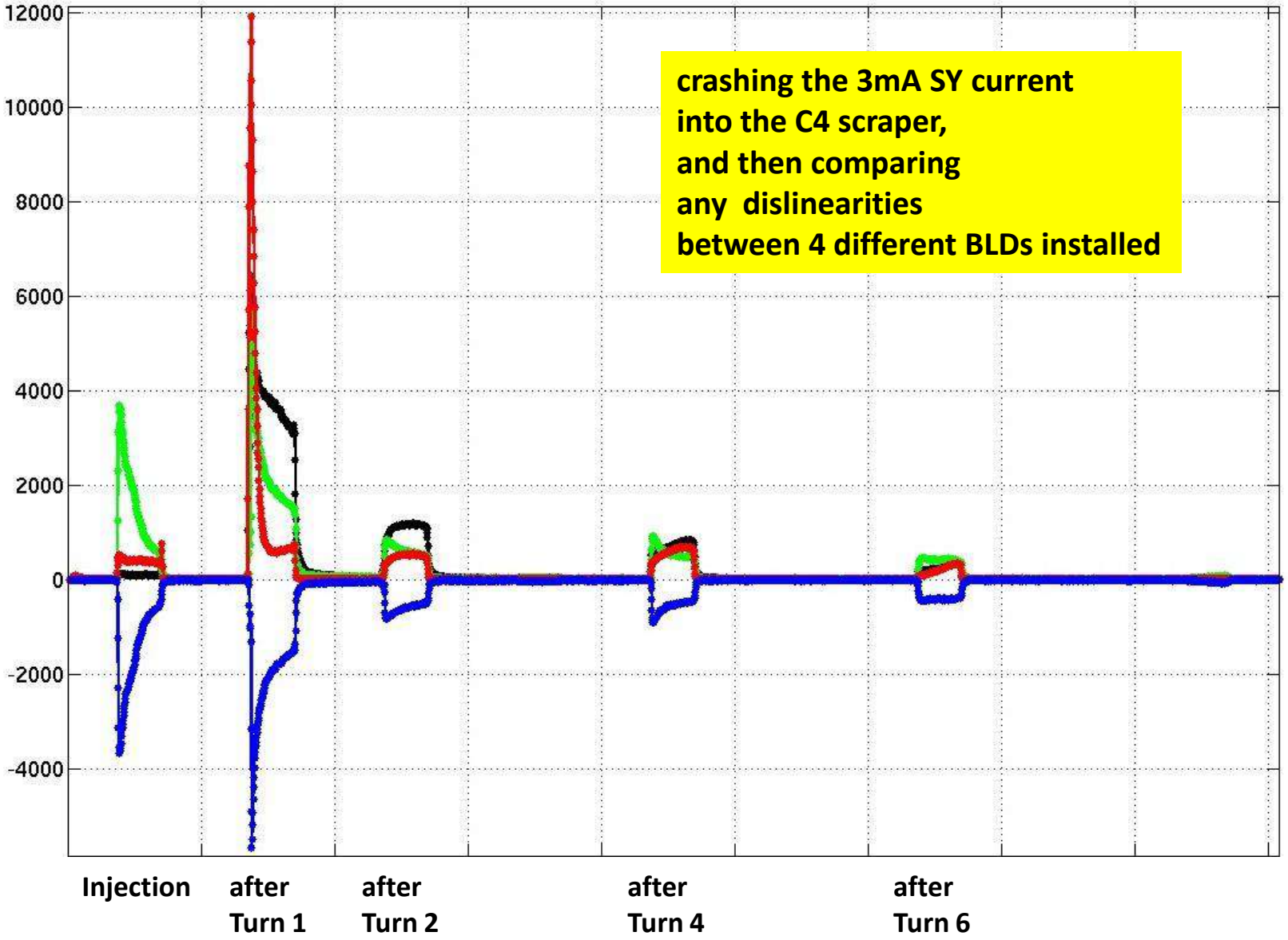
reduction of signal simply due to less current, thus less scattered X-rays

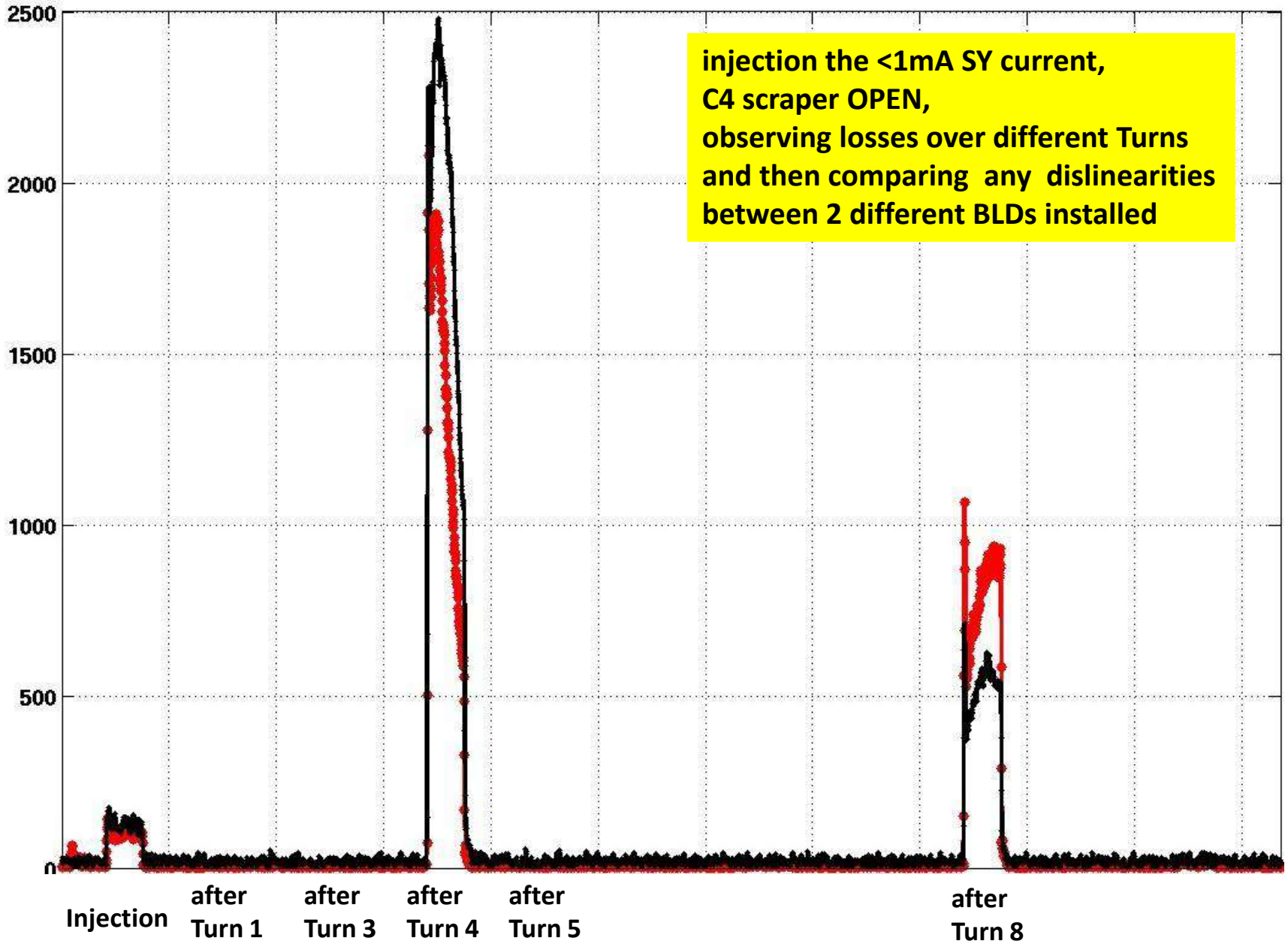
	Cherenkov-radiator Quartz-glass	versus	Gamma-scintillator EJ-200 or BC-408
PROS :	no need for Pb shielding since immune to X-rays (?) therefore : - less volume - less weight - compact		- high light yield - cheap material
CONS :	- low light yield - more expensive		needs Pb shielding - bulky & heavy (?)

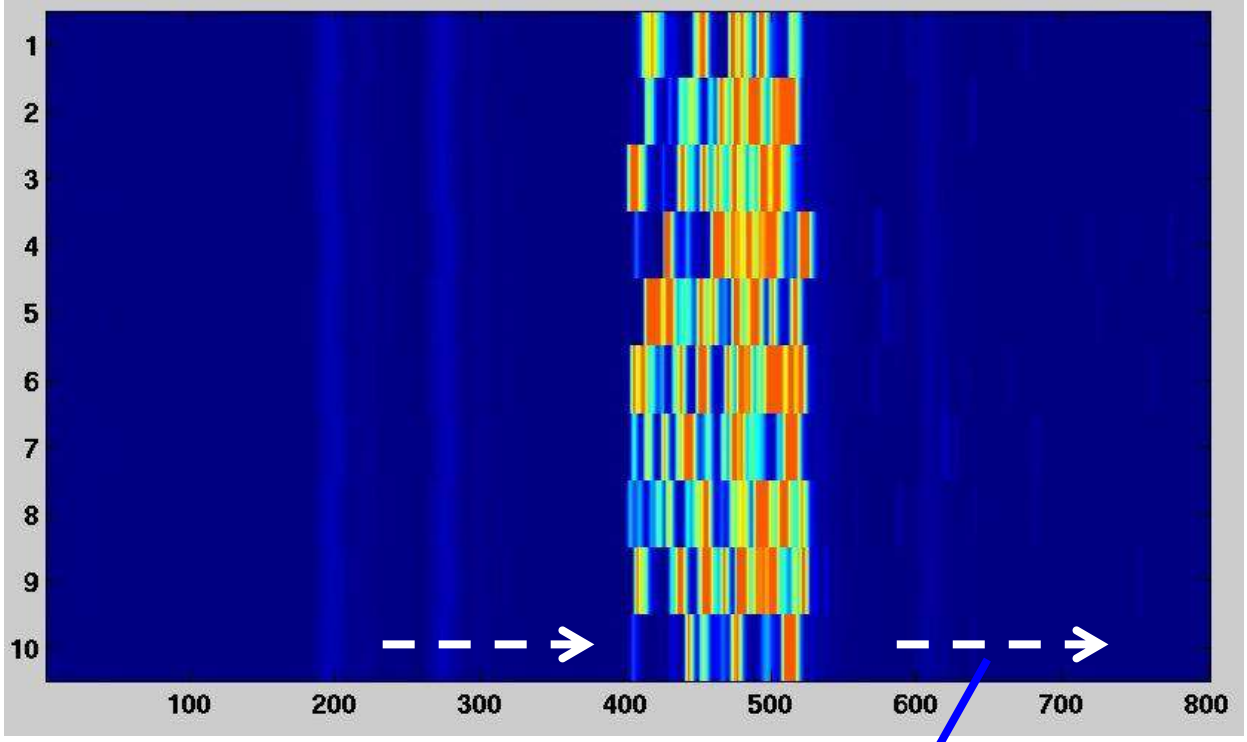
in the end : BLD based on a small EJ-200 rod with a small PMT (8mm window)
with only 2mm of Pb shielding , is :
- more compact
- cheaper
- more sensitive
- fully immune to X-rays (….)

then the BLD based on Cherenkov-radiator

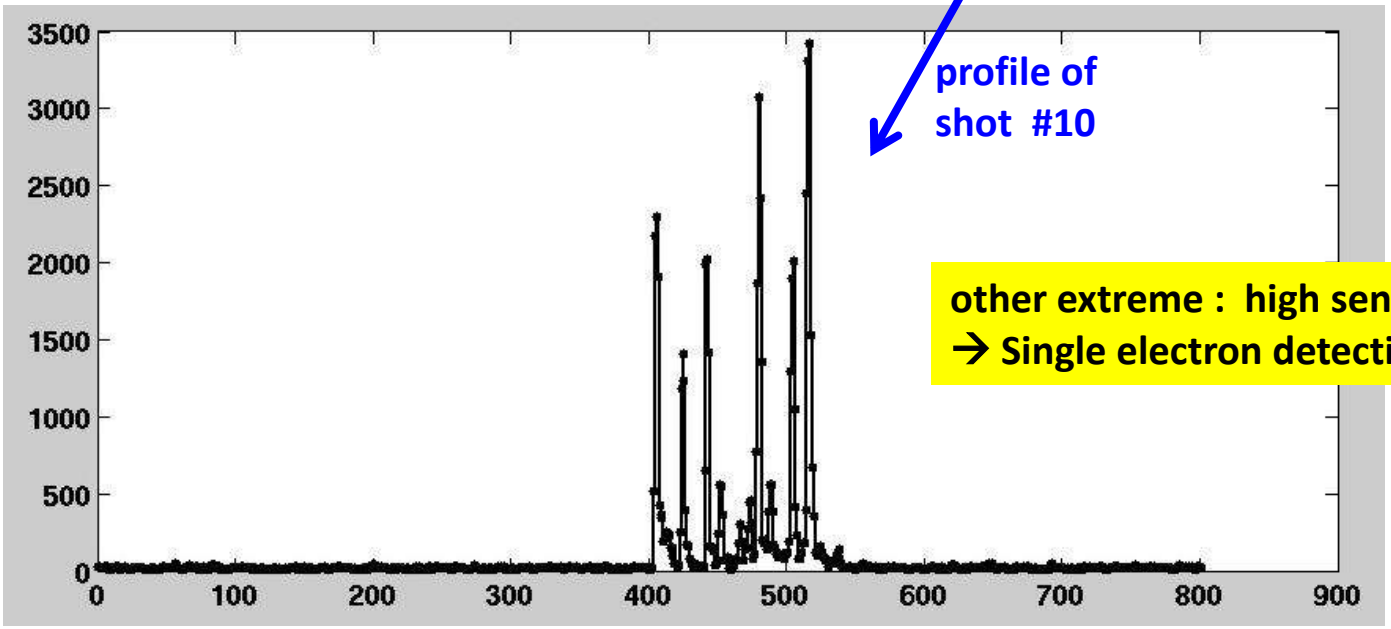
4) MDT : Specific tests on the new BLDs to assess both any saturation issues and sensitivity aspects




injection the <1mA SY current,
C4 scraper OPEN,
observing losses over different Turns
and then comparing any dislinearities
between 2 different BLDs installed
2500
2000
1500
1000
500
0
Injection
after Turn 1
after Turn 3
after Turn 4
after Turn 5
after Turn 8



crashing the so-called
dark-current of the injector
i.e. Linac Gun OFF,
into the C4 scraper

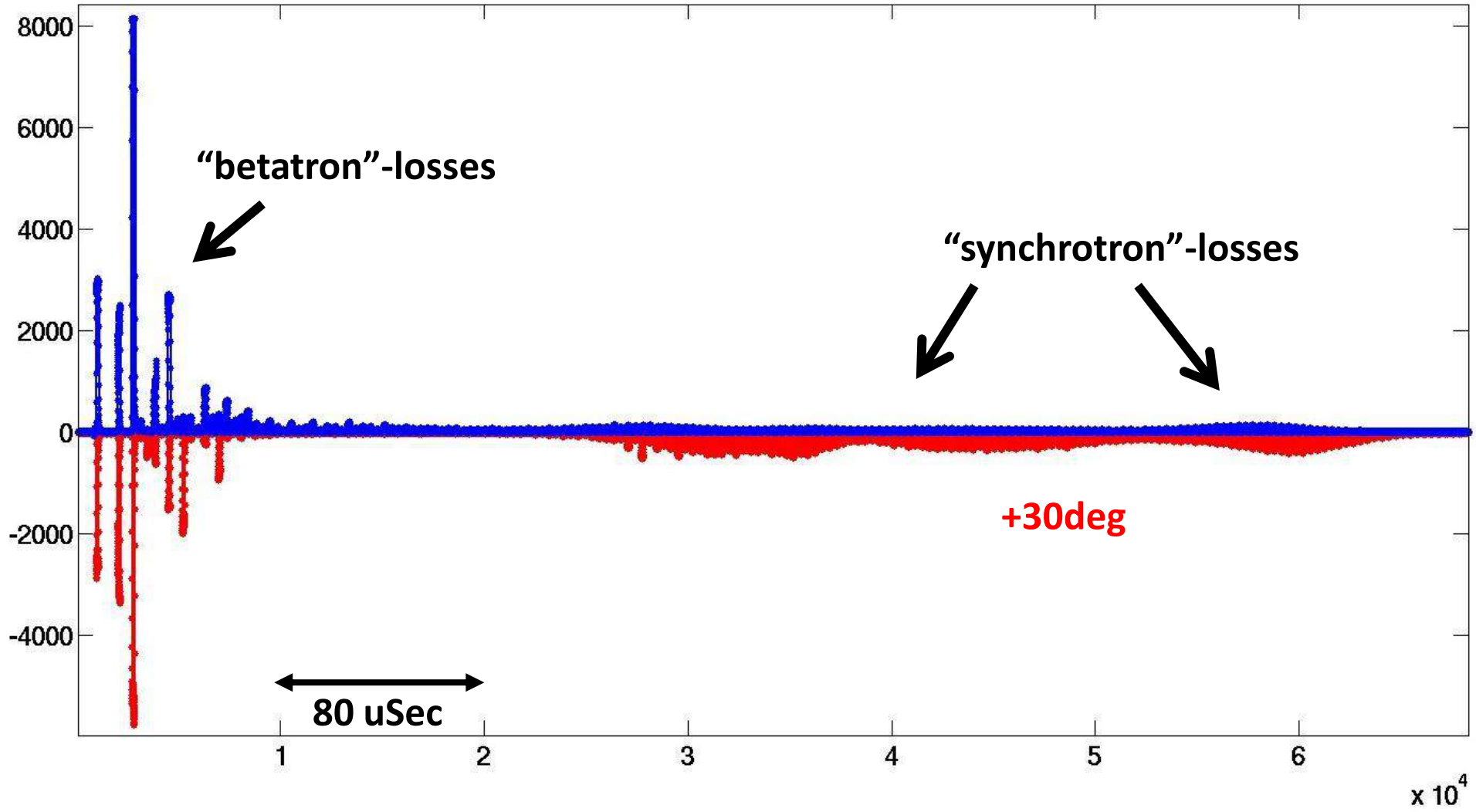


profile of
shot #10

other extreme : high sensitivity
→ Single electron detectivity

time-resolved losses of injected beam at different RF phases :
nominal (blue) and +30deg (red)

data-rate is ADC (125MHz, 8nS)



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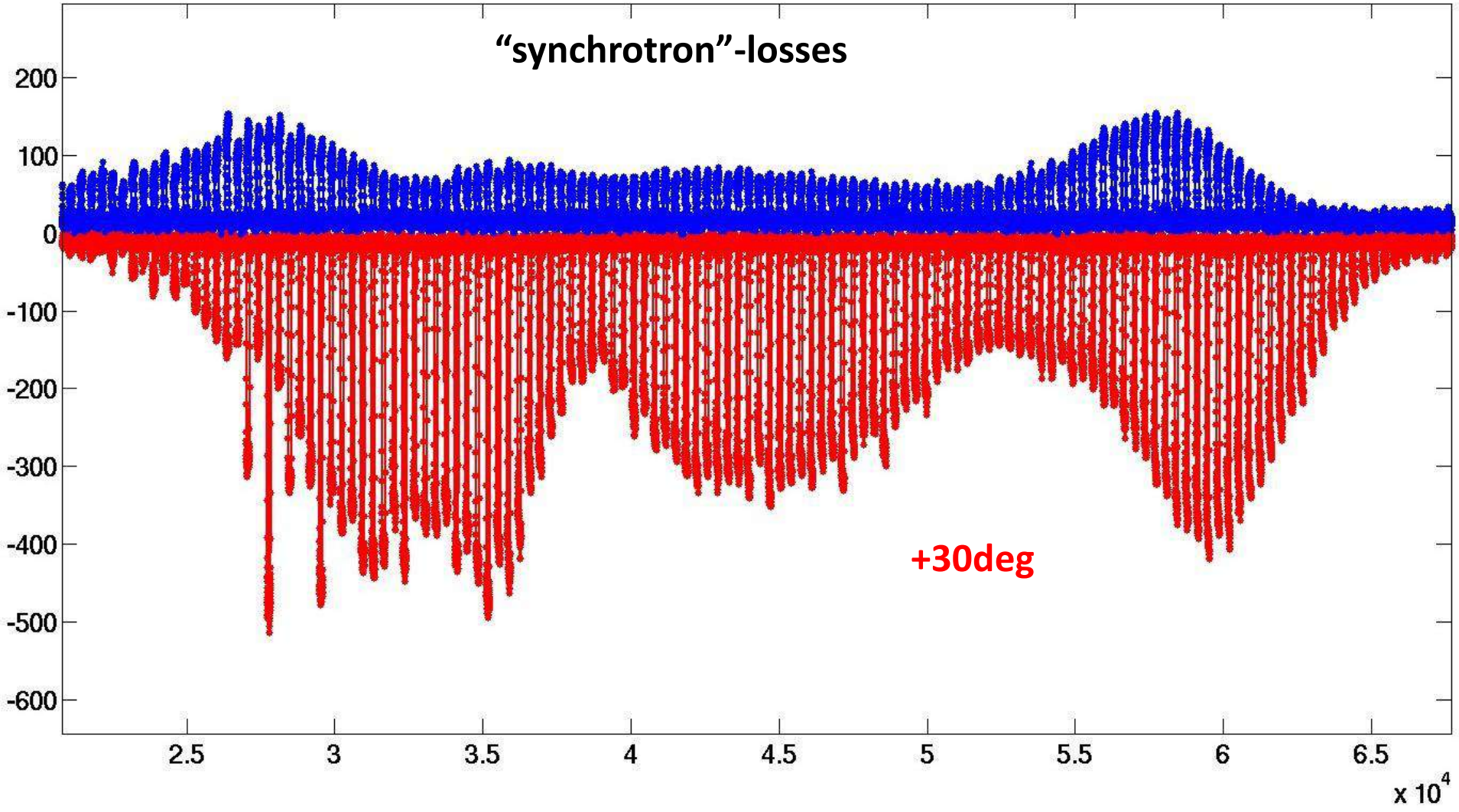

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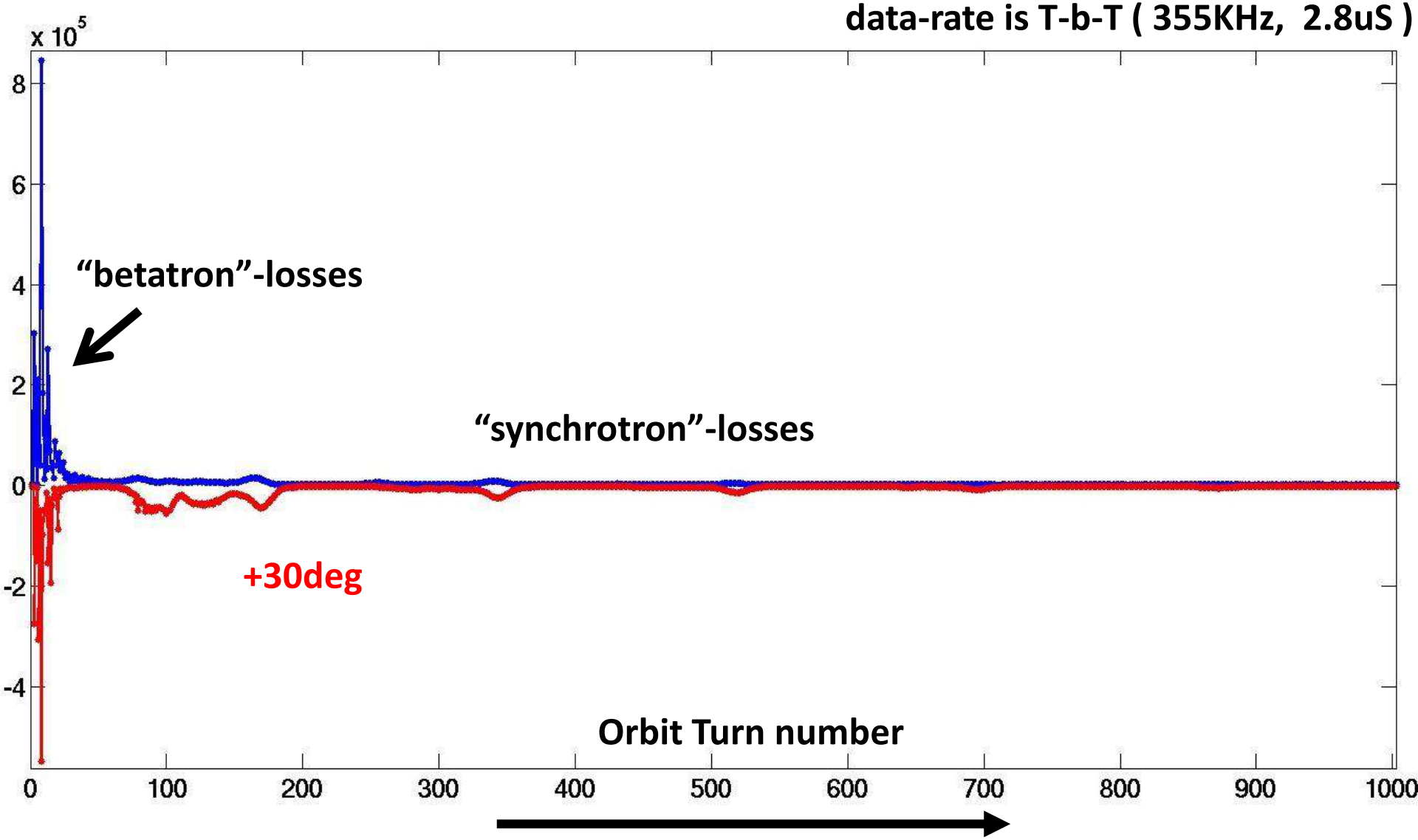
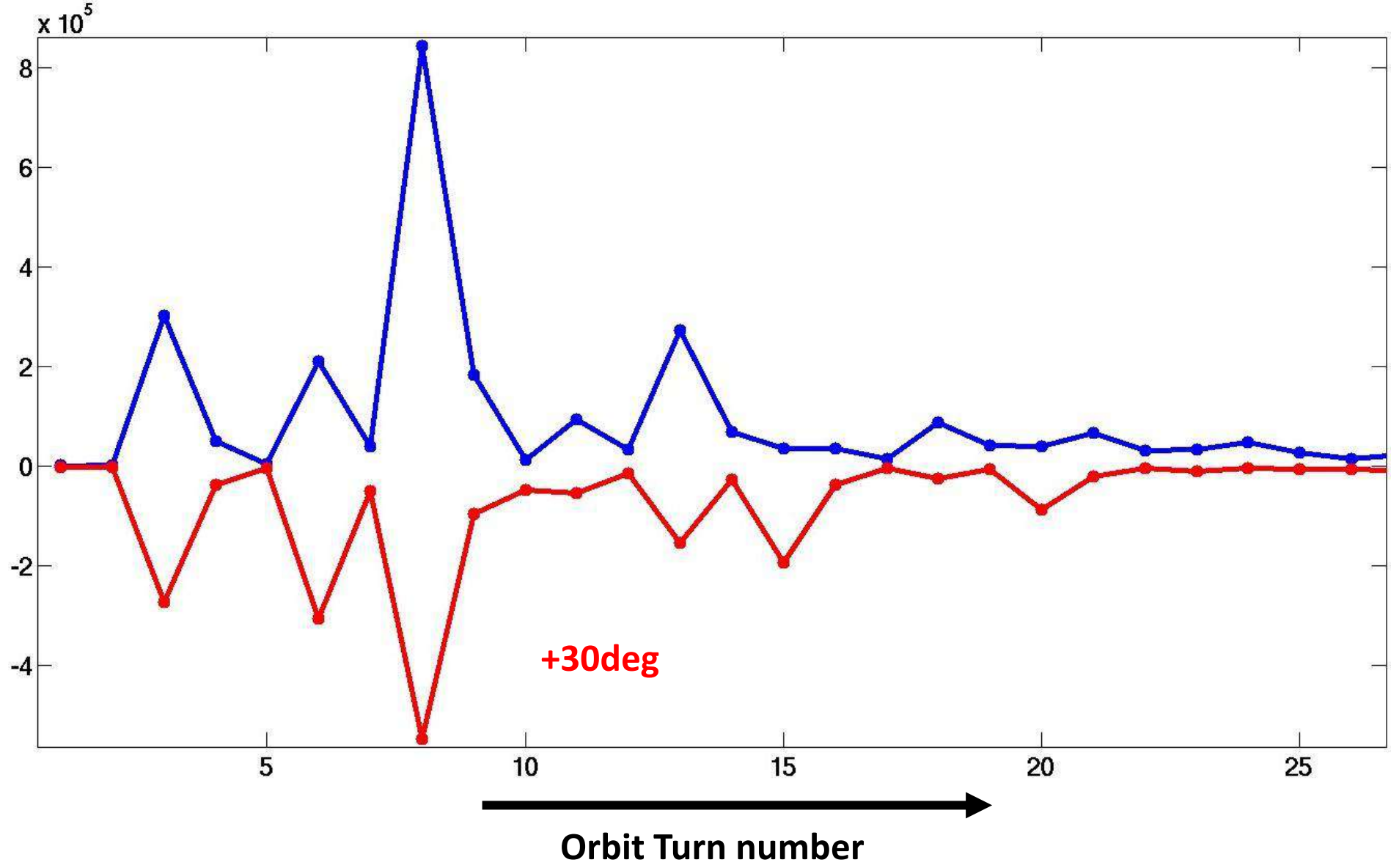
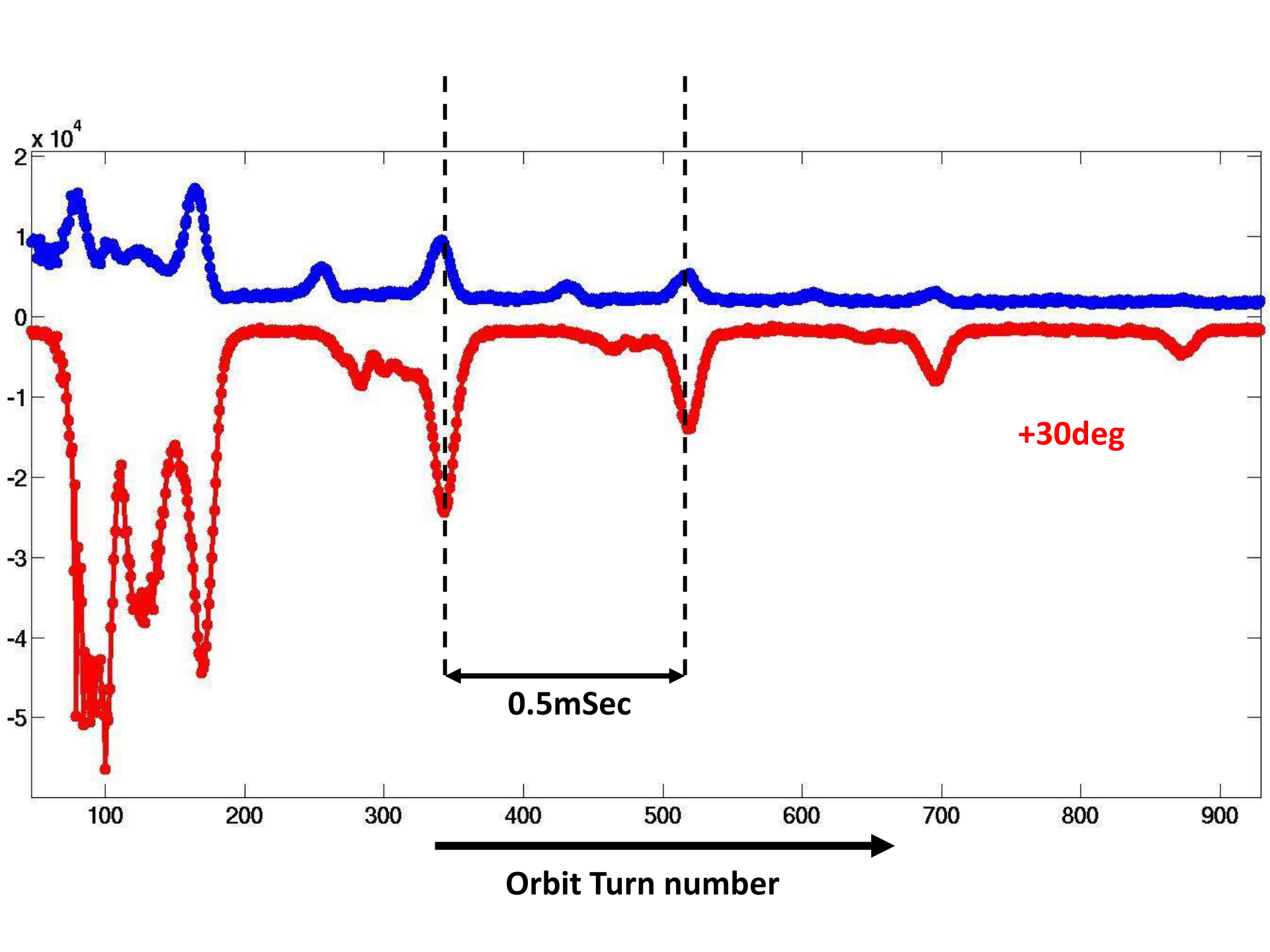


“betatron”-losses in the first 20 turns

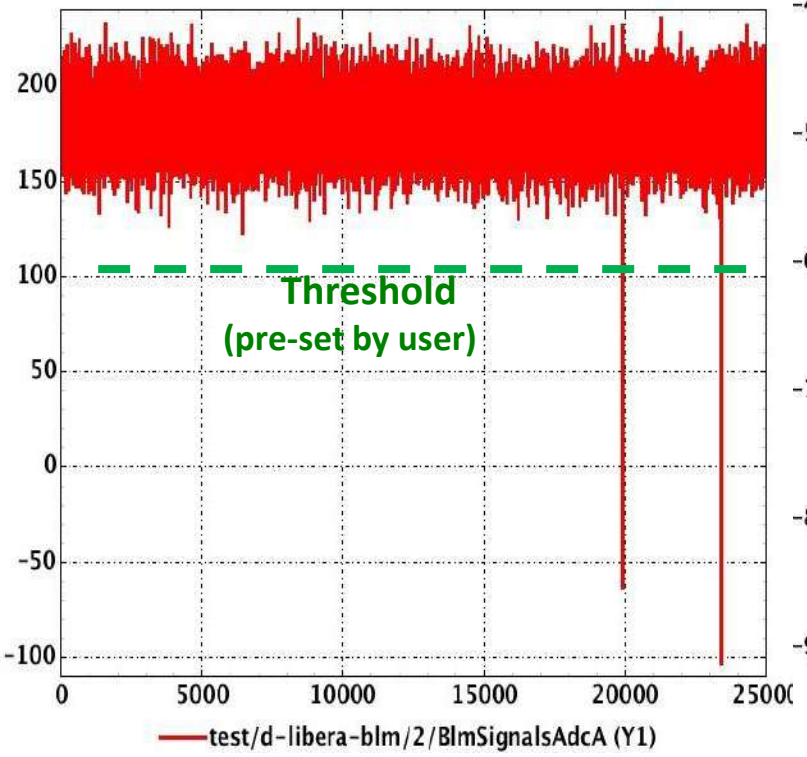



x 10^4
2
1
0
-1
-2
-3
-4
-5
100
200
300
400
500
600
700
800
900
+30deg
0.5mSec
Orbit Turn number

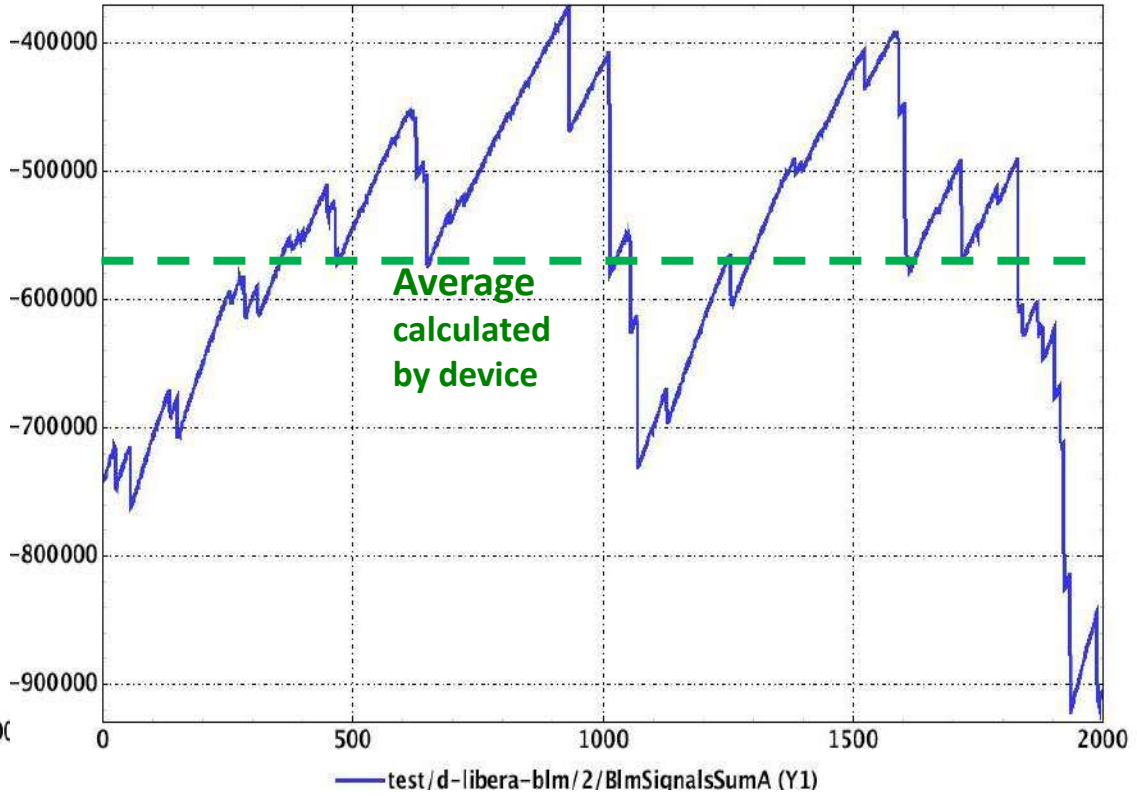
Counting-mode
50 Ω

versus

Integrating-mode
Hi-Z

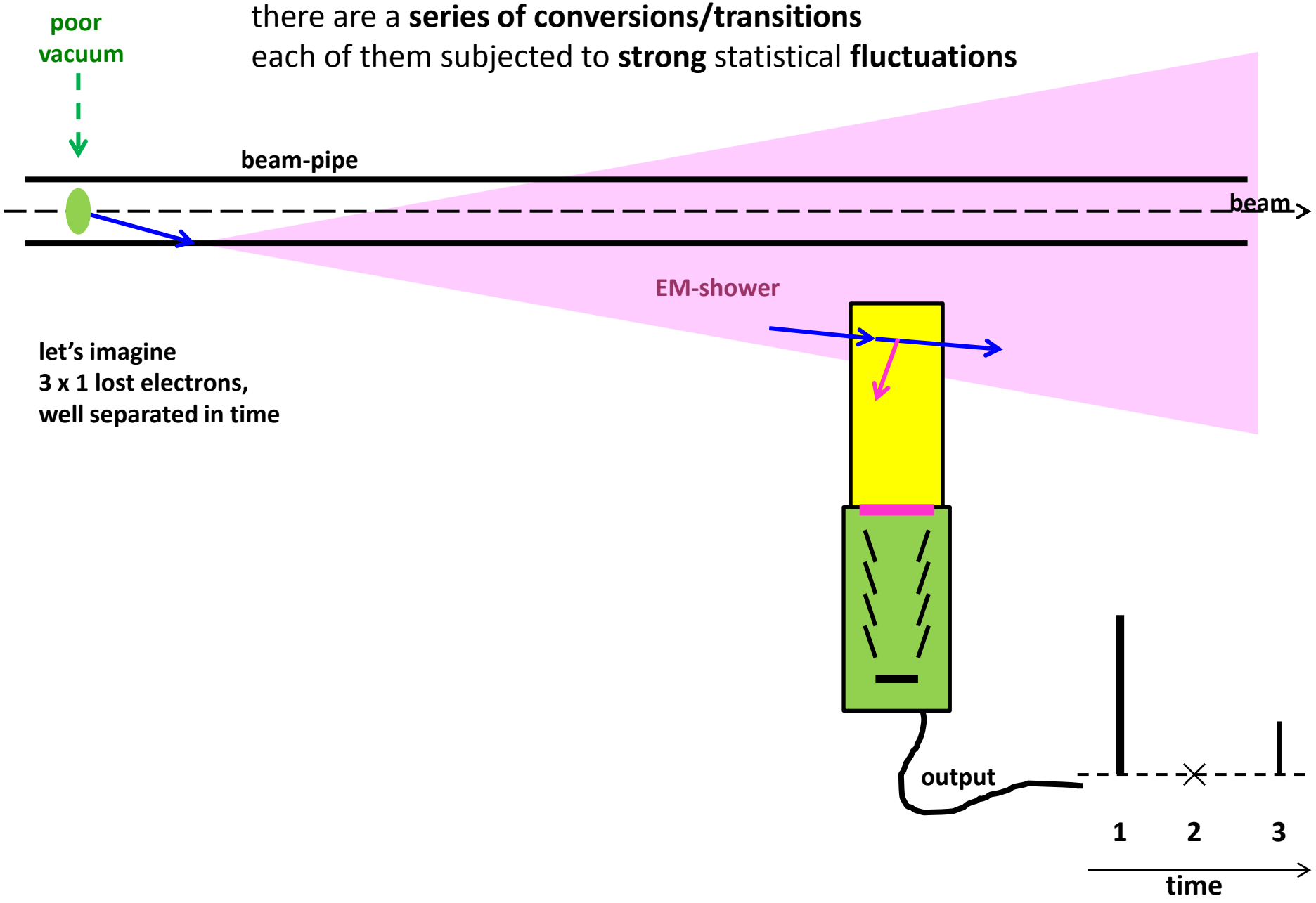


20 µs



6 ms

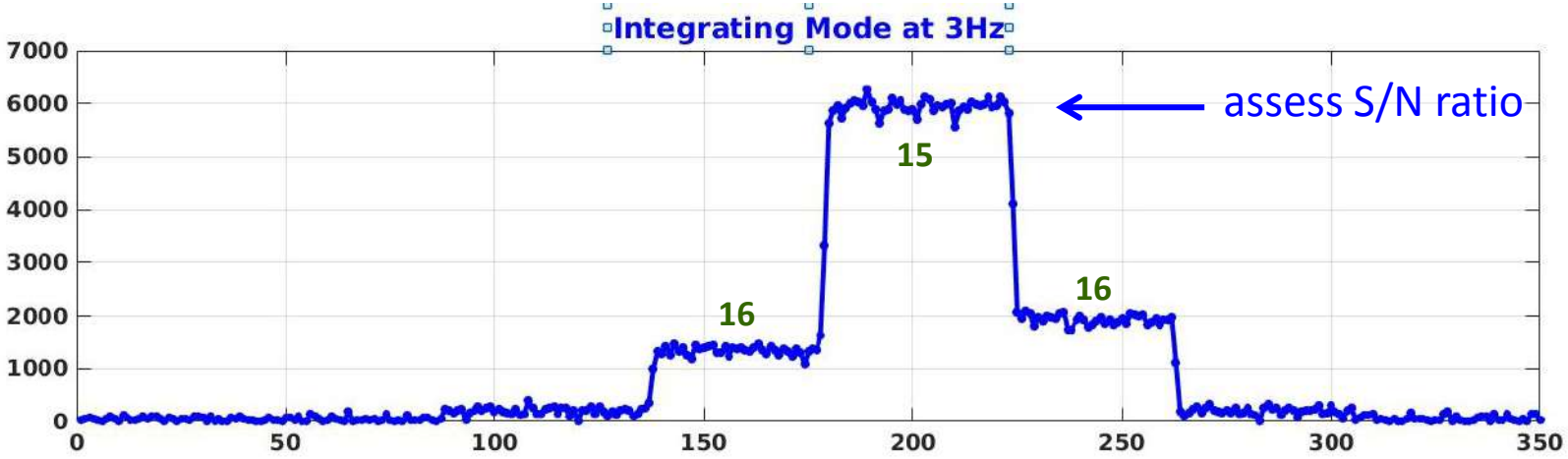
between the event of a lost electron
and the final recording of that event in the detector
there are a **series of conversions/transitions**
each of them subjected to **strong** statistical **fluctuations**

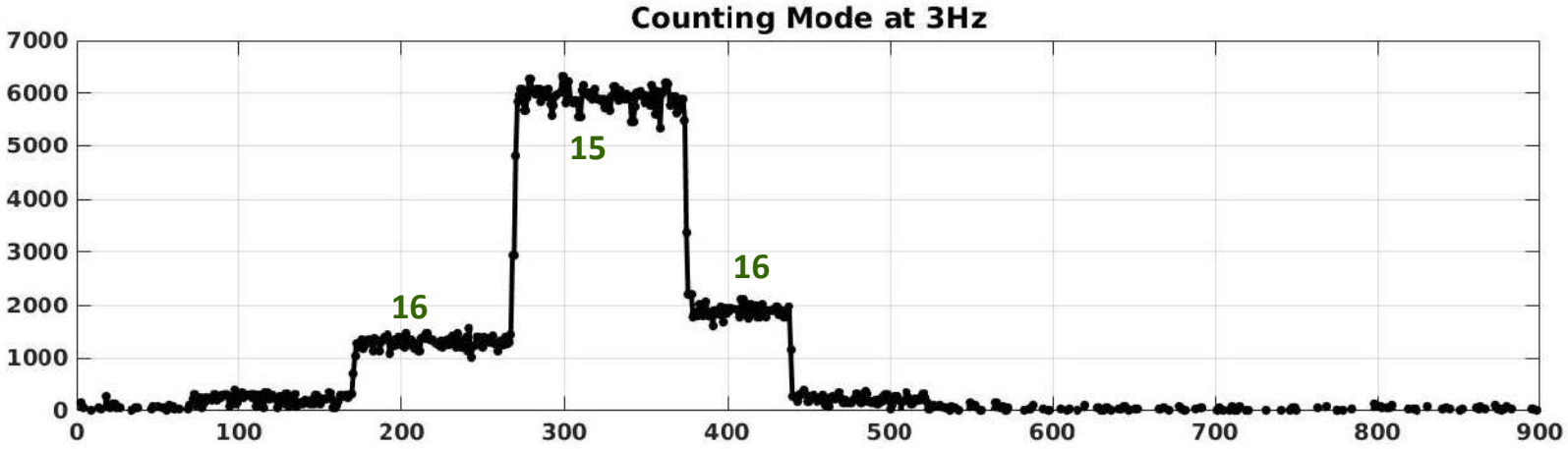


BLM-attenuator=4dB, PMT-GCV=0.55V, **scraper at 18-17-16-15-16-17-18 mm**

Integrating period = 0.37sec

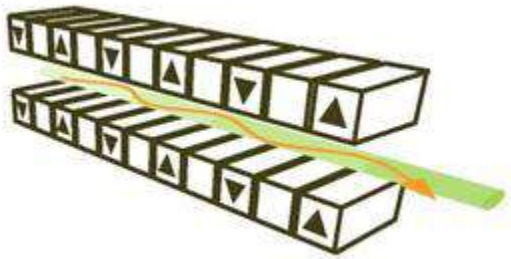
Counting period = 0.25sec





6 GeV electrons lost at **In-Vacuum undulators**

these devices have their magnet arrays **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 

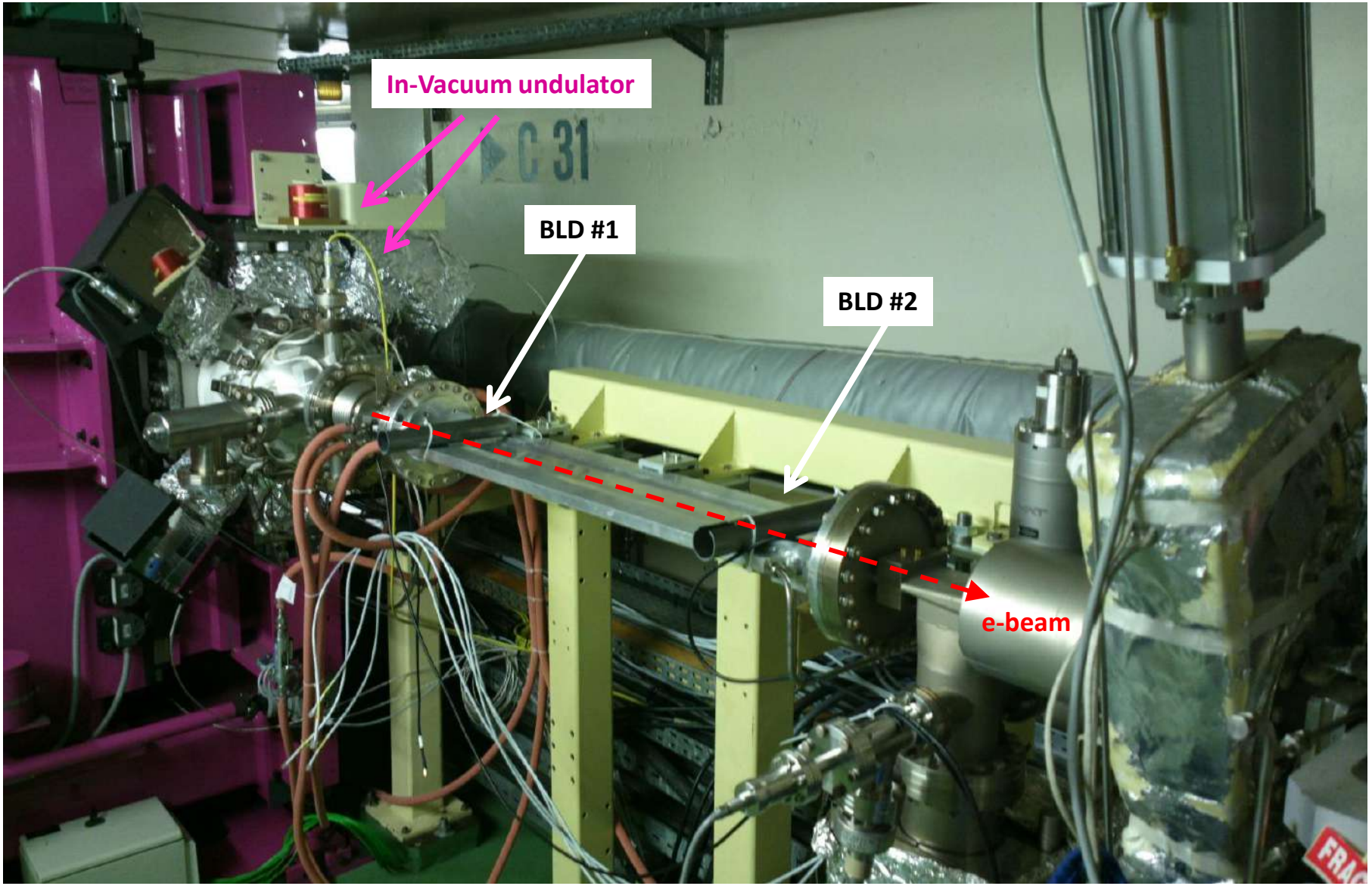
this can be a real problem in rings with smaller beam-sizes
→ more scattering, less lifetime, more losses . . .

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

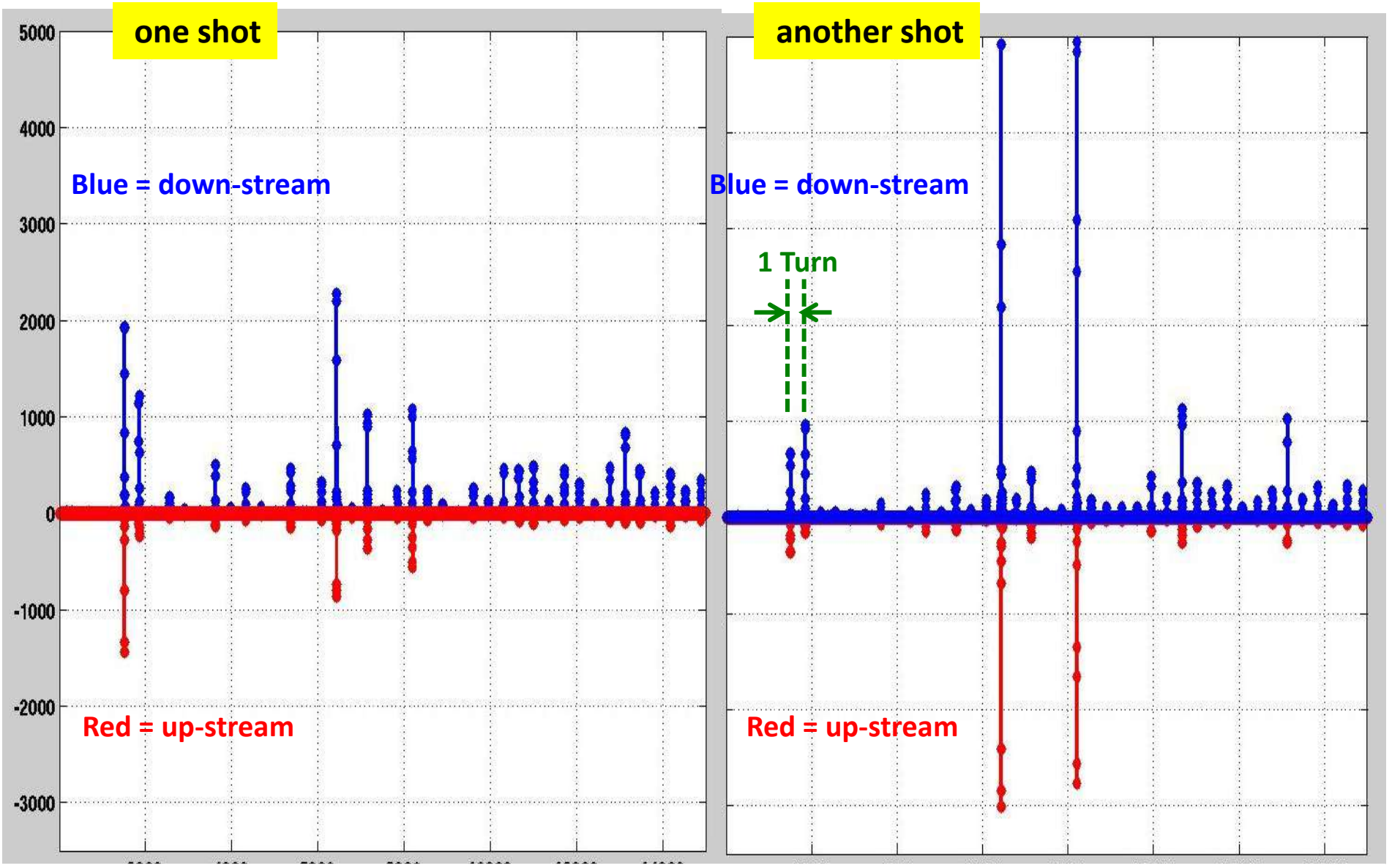
Solutions :

- 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, under various conditions


In-Vacuum undulator
BLD #1
BLD #2
e-beam

ADC data from 2 BLDs (red & blue) near In-Vac, at 2 different injections



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thank you for your attention