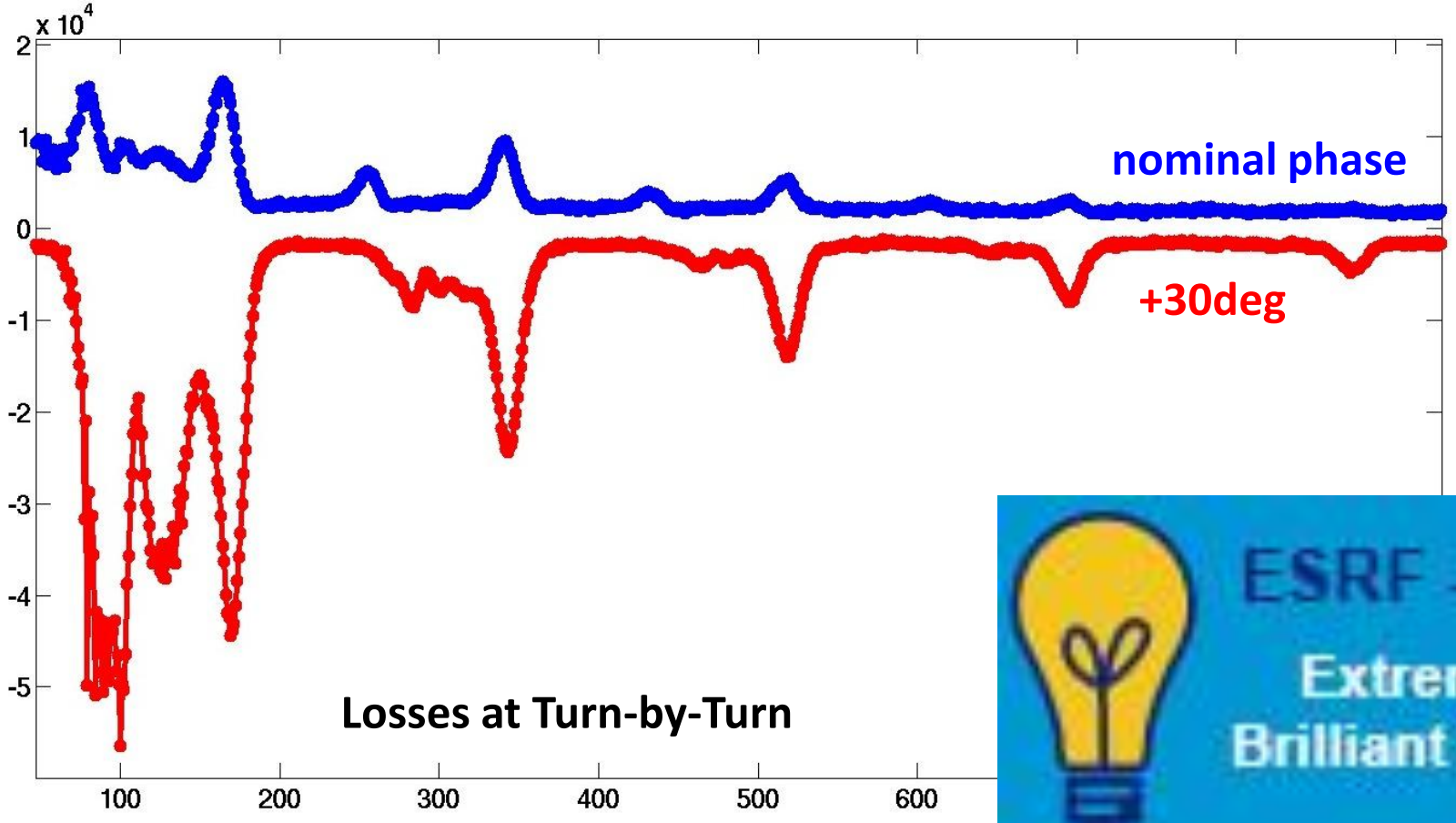
# Beam Loss Measurements at the ESRF with different Beam-Loss-Detectors and the new 4 channel Libera-BLM acquisition system




ESRF - EBS
Extremely Brilliant Source

DESY

DEELS-2016
June 27-28
Hamburg

-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

and (hopefully) lots of questions & discussion !!

# 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 / low costs :
  → install **many**, at regular points

- the BeamLoss-Detector BLD and
- the Acquisition Electronics BLM

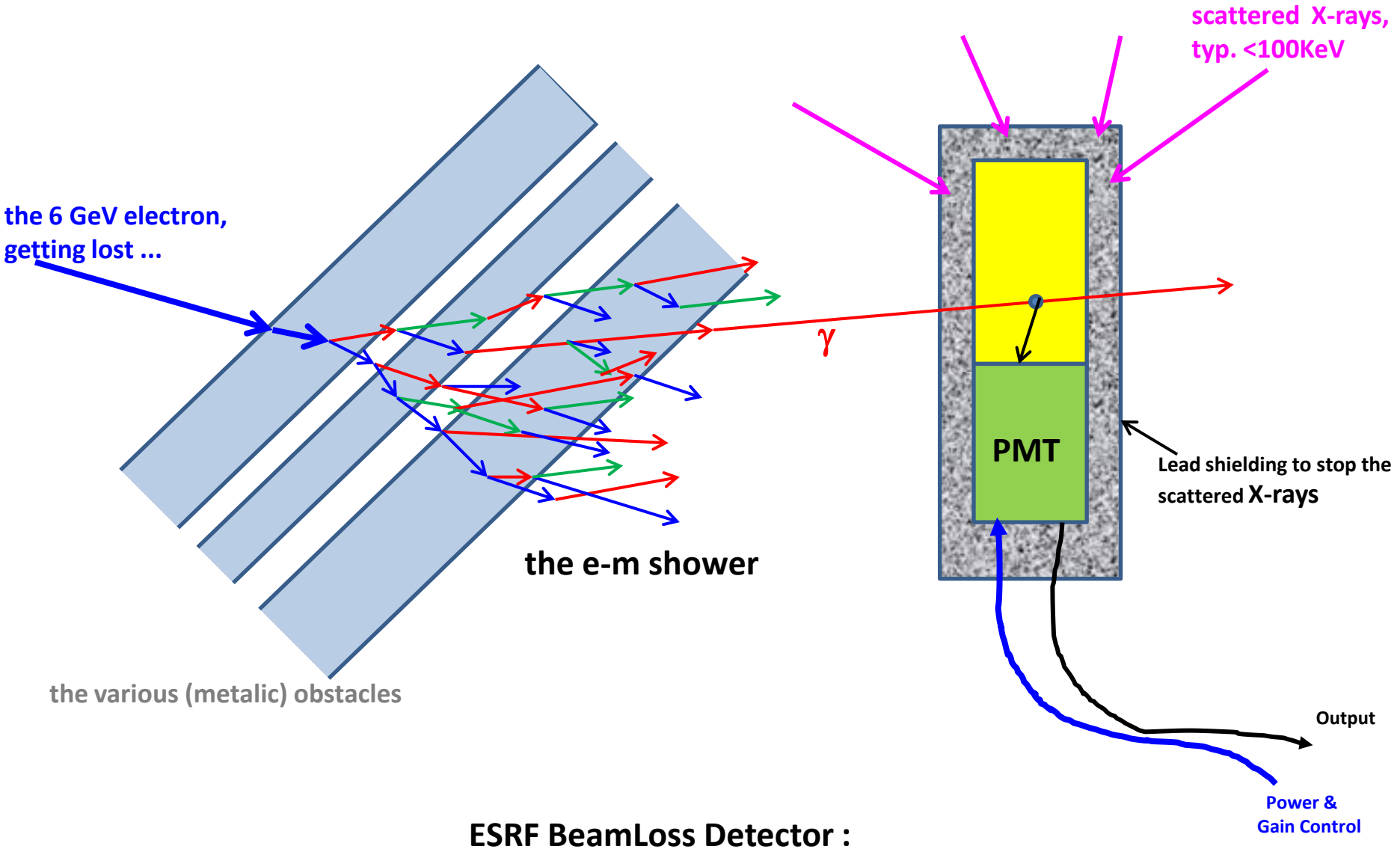
- (short-cut) choices needed to be made on the BLD :

on the type : ionization-chamber ? semi-conductor ? CVD-sensors ?

→ scintillator/radiator ←

- on the component that produces the electric signal output :
photo-diode ? , MPPC ?, other ?...

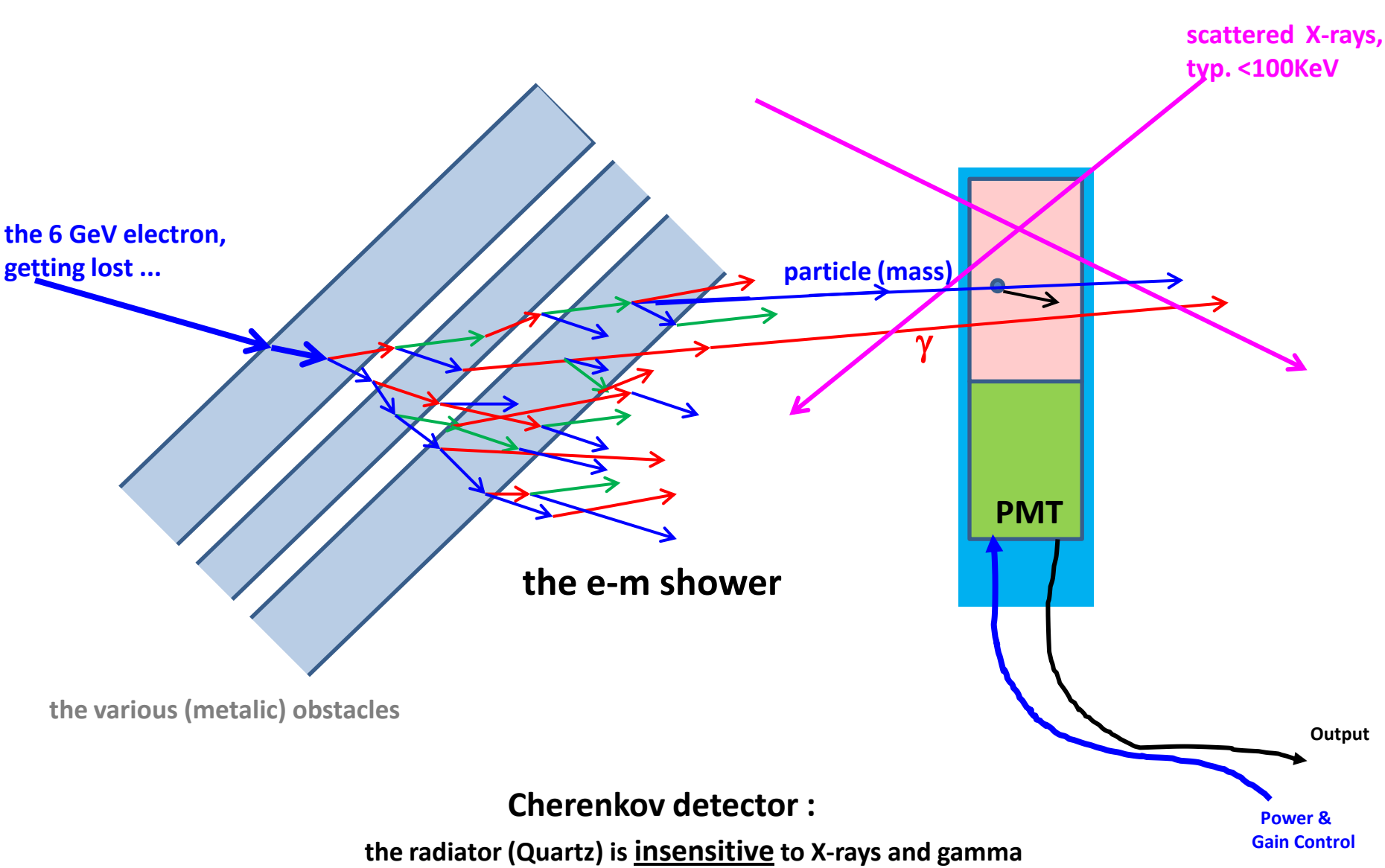
→ PMT ←




## 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



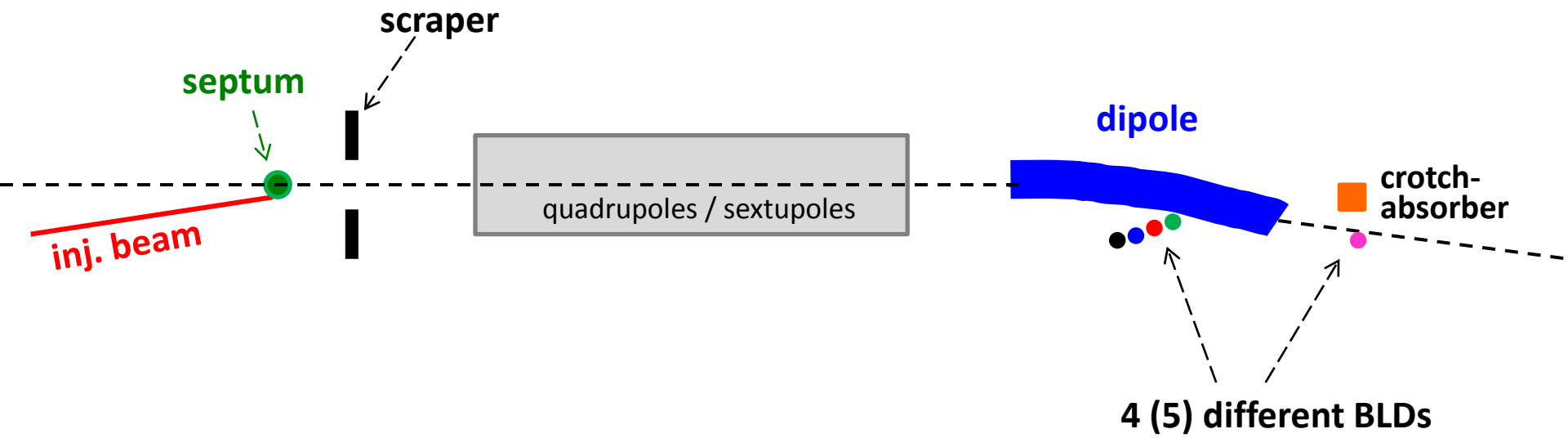

## Cherenkov detector :

the radiator (Quartz) is <u>insensitive</u> to X-rays and gamma

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

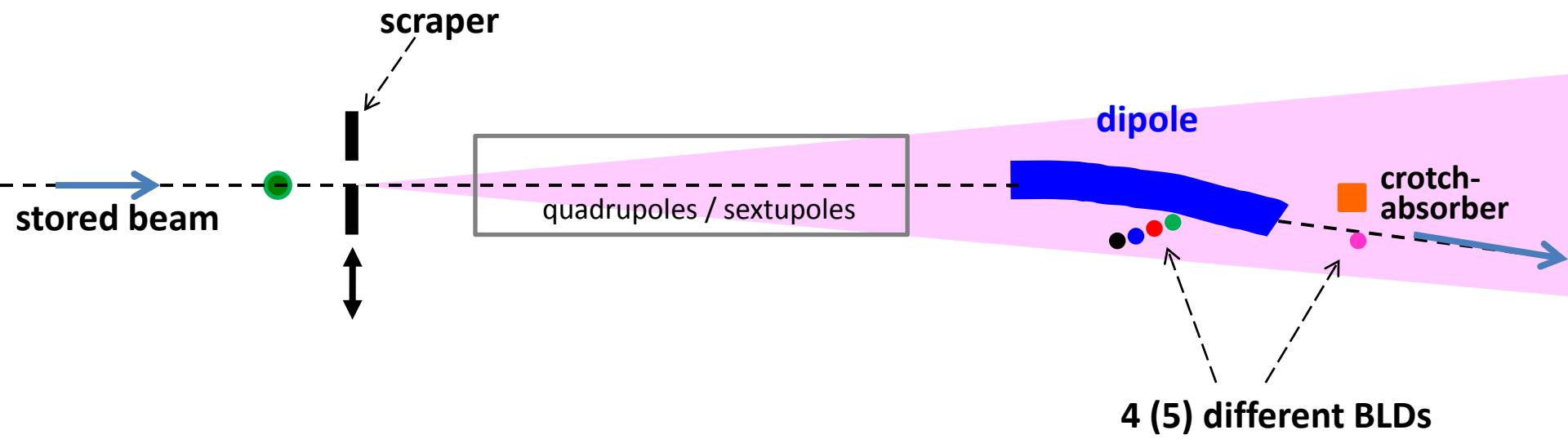
→ no need for Lead shielding

**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

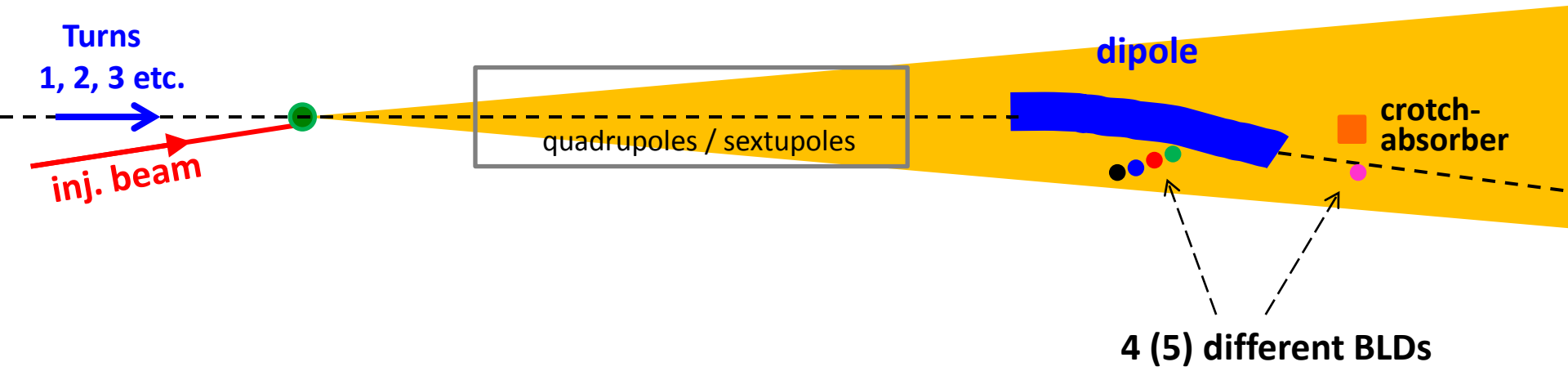



1) can be done during USM

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)



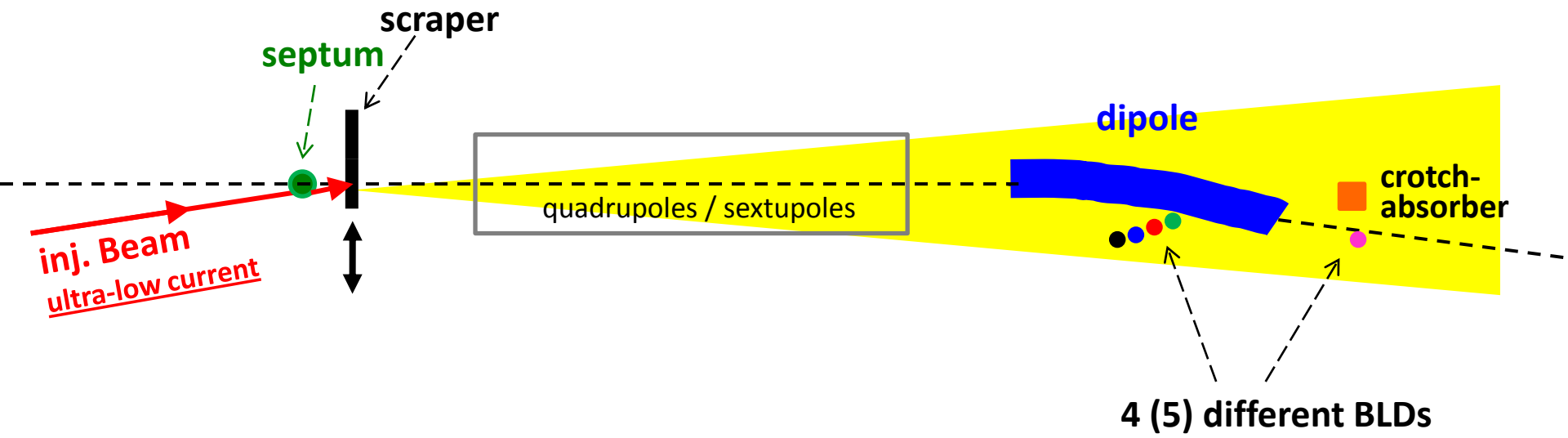

1) done at each top-up (20min for 16 bunch … but 12 hours for other fills !)

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



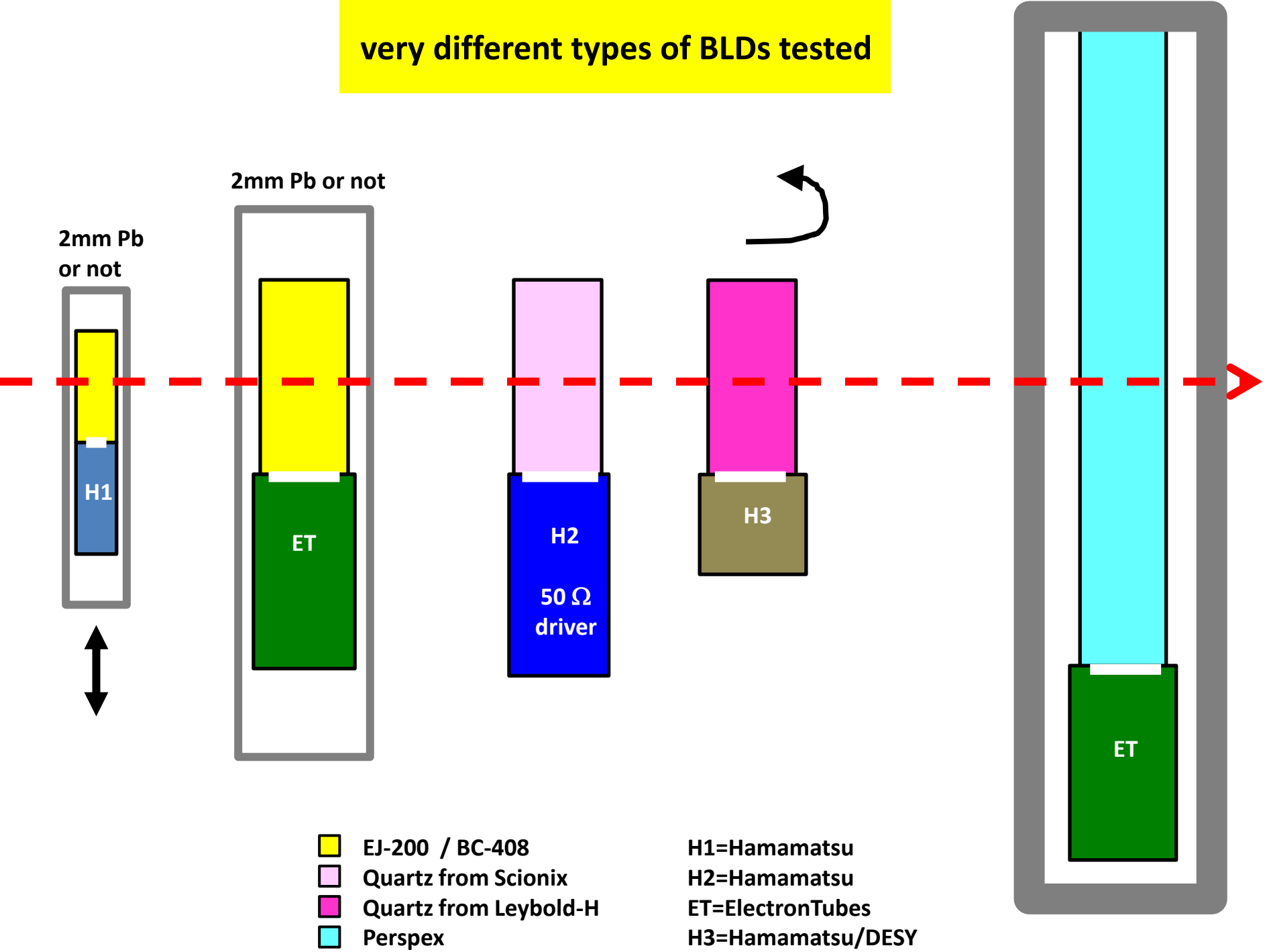

1) only possible during MDTs

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

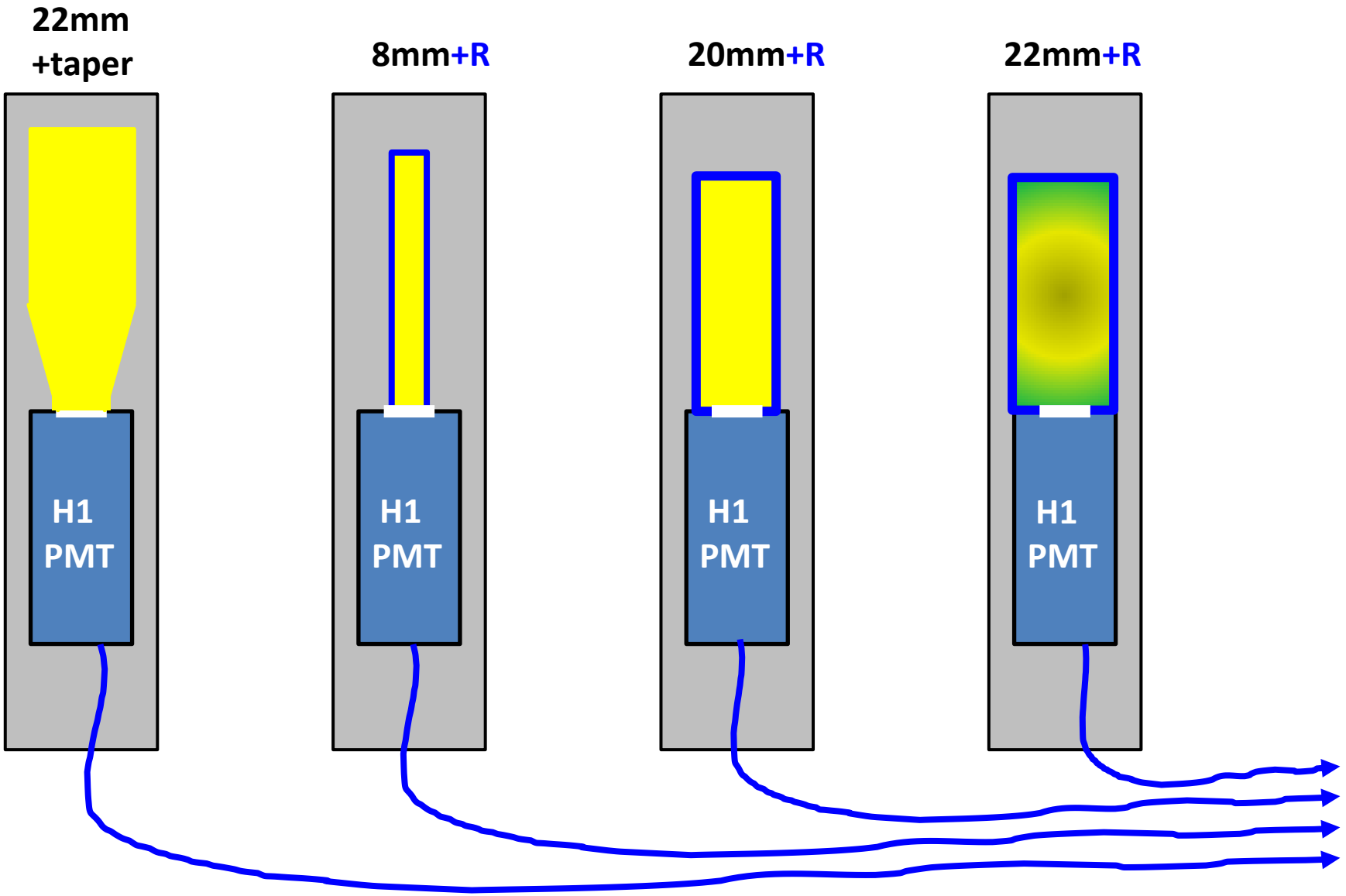
4) purpose : asses the BLD system on detecting (extreme) low-levels of losses

# 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

Cesium-137 (700KeV γ)

all with EJ-200 scintillator

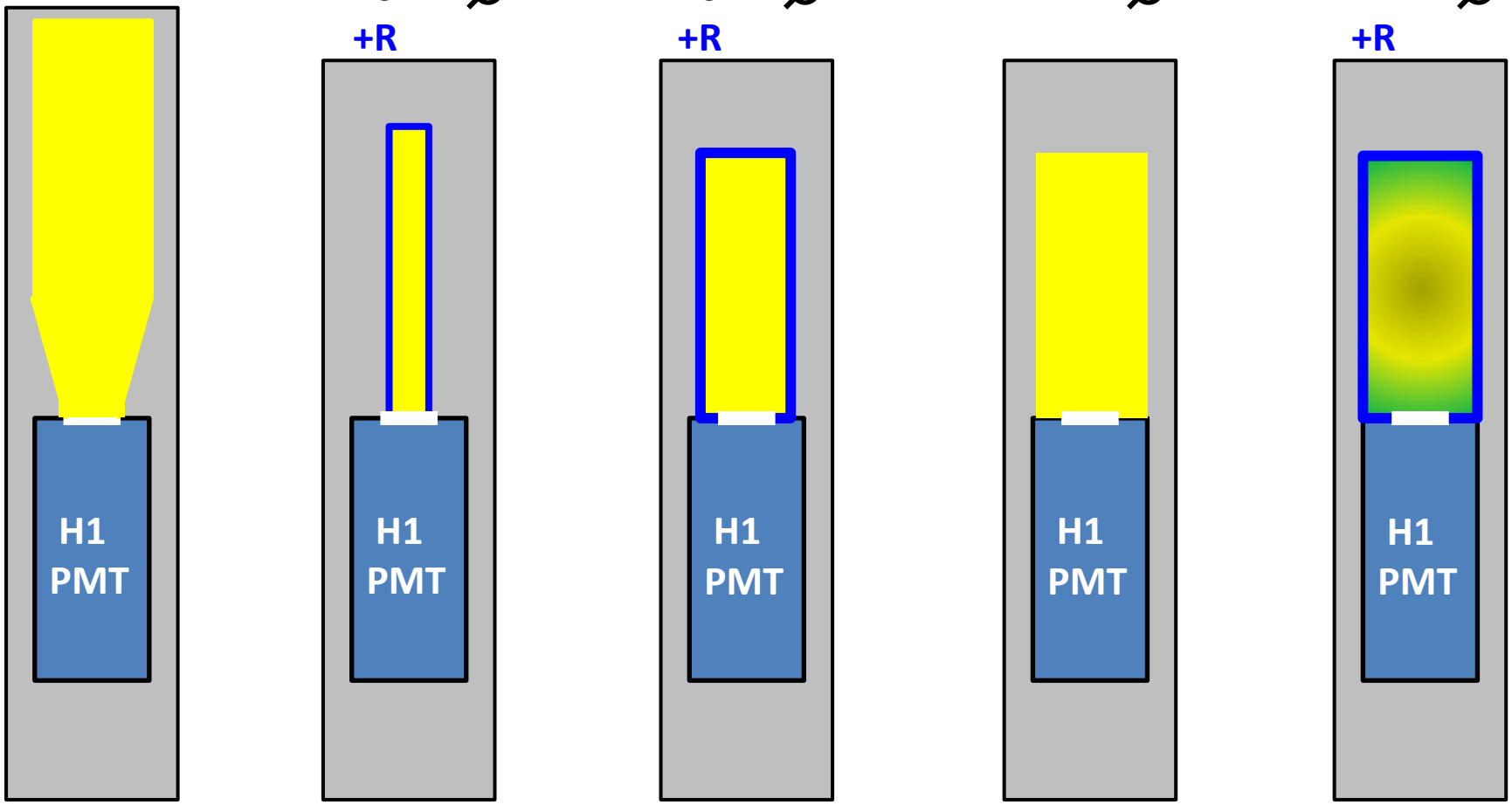
130mm
22mm ⌀
+taper

100mm
10mm ⌀
+R

100mm
20mm ⌀
+R

100mm
22mm ⌀

100mm
22mm ⌀
+R




Vr=115
Eff.= 41

Vr=21
Eff.= 33

Vr= 83
Eff.= 100

Vr= 100
Eff.= 52

Vr= 100
Eff.= 25

Cesium-137 (700KeV γ)

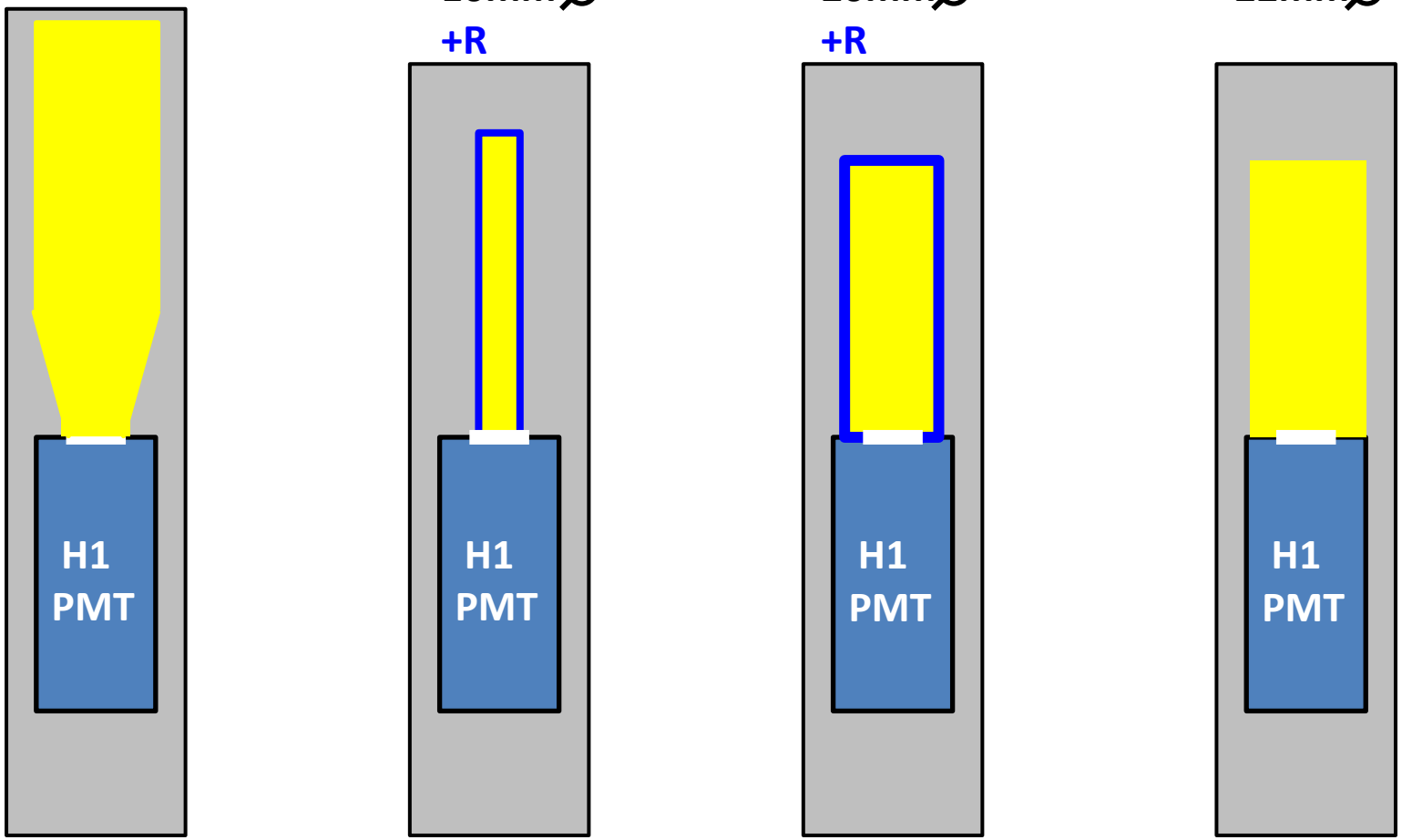
all with EJ-200 scintillator

130mm
22mm ∅
+taper

100mm
10mm ∅
+R

100mm
20mm ∅
+R

100mm
22mm ∅

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Cesium-137 (700KeV γ)

all with EJ-200 scintillator

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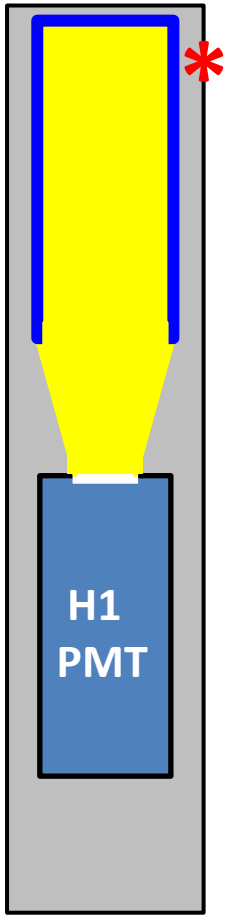
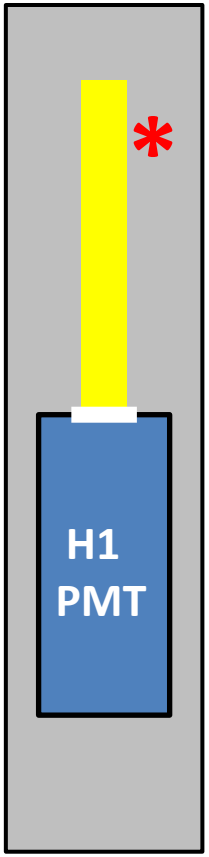
22mm ∅
+taper



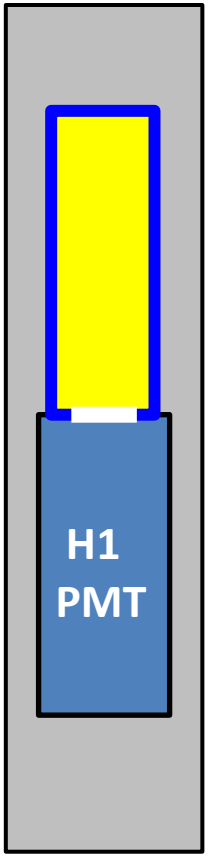

Vr=115
Eff.= 41
Eff.= 69

100mm
10mm ∅
+R



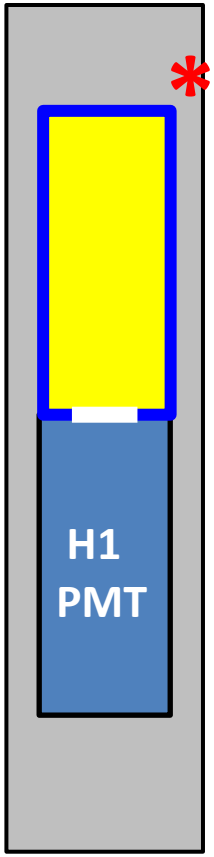

Vr=21
Eff.= 33
Eff.= 22

100mm
20mm ∅
+R



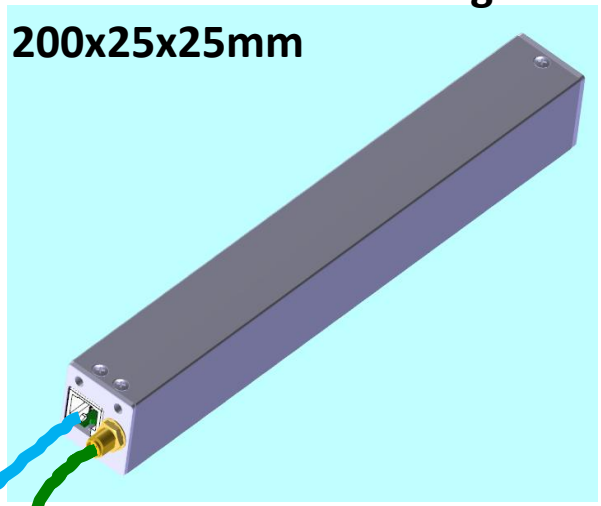

Vr= 83
Eff.= 100
Eff.= 100

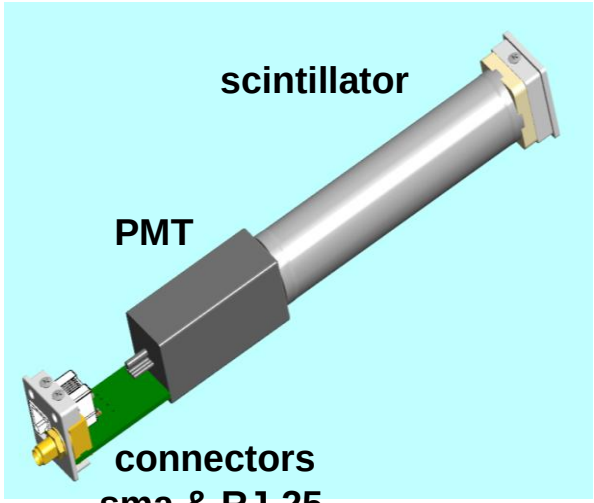
100mm
22mm ∅

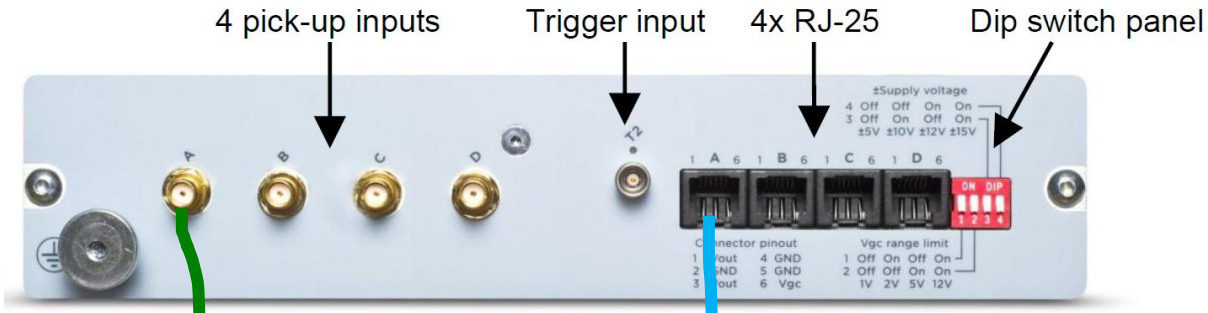



Vr= 100
Eff.= 52
Eff.= 146

**BLD with its Alu housing**
**200x25x25mm**



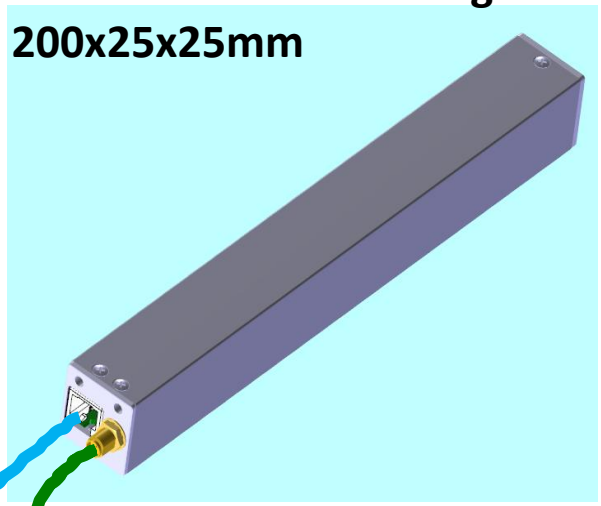



**BLD-signal**

**power-supply &**
**gain-control**

BLD with its Alu housing
200x25x25mm

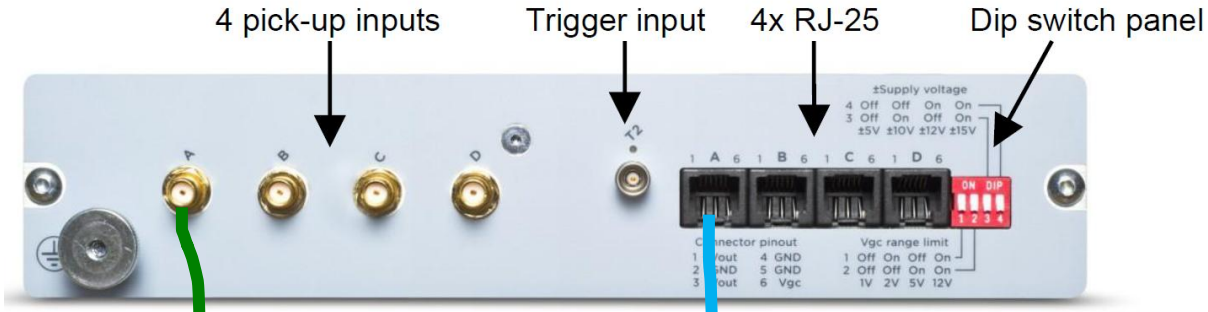


## BLD :

- 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



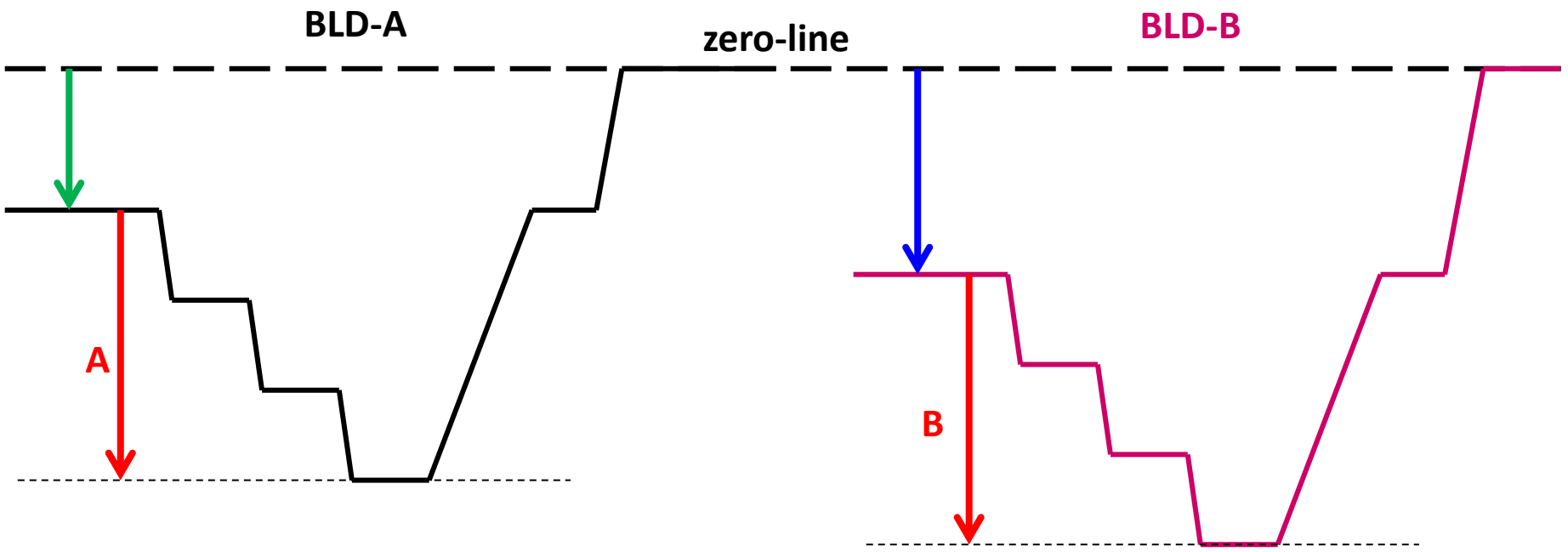

BLD-signal

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 ?**

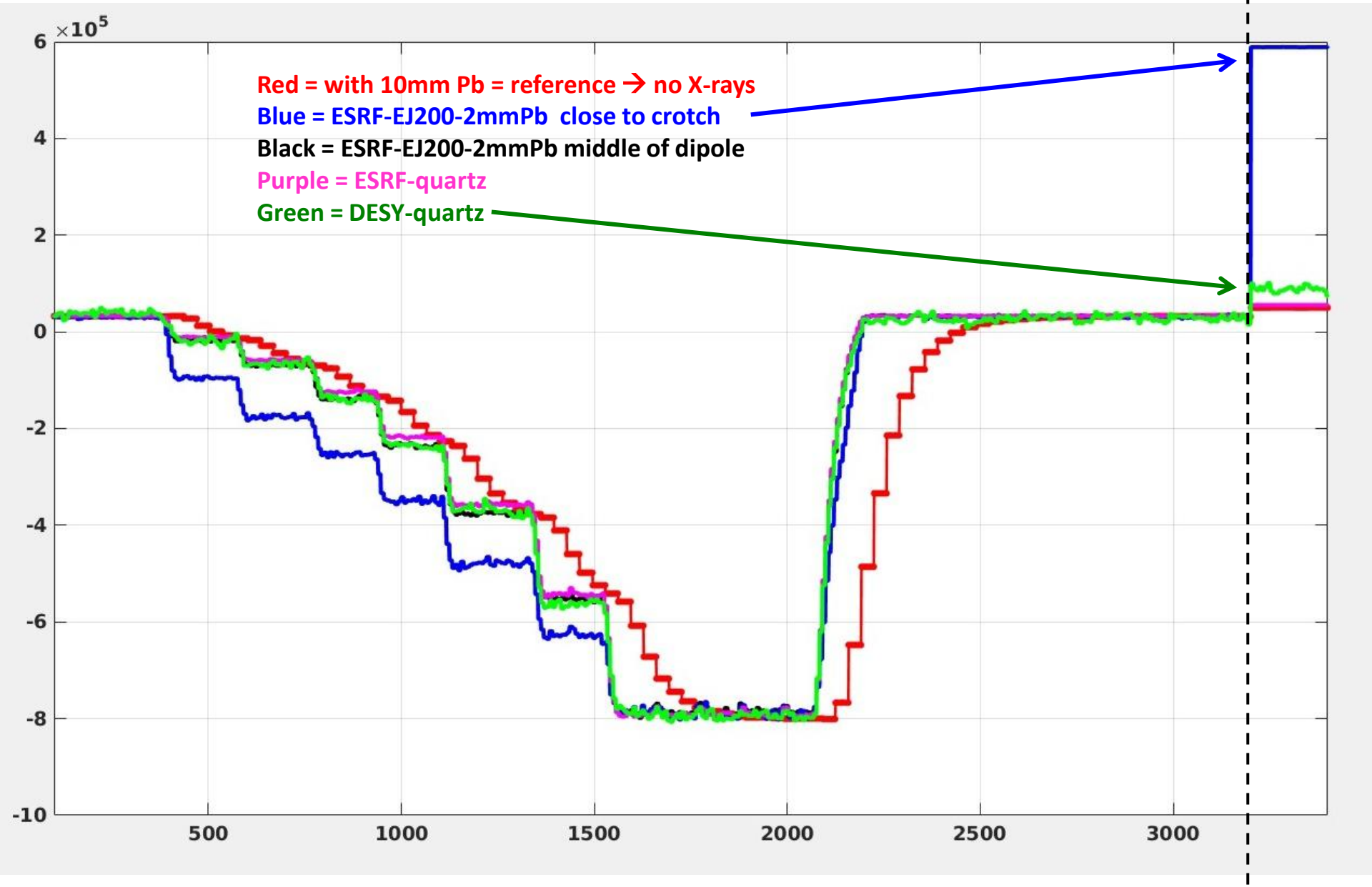



= e-losses (only)

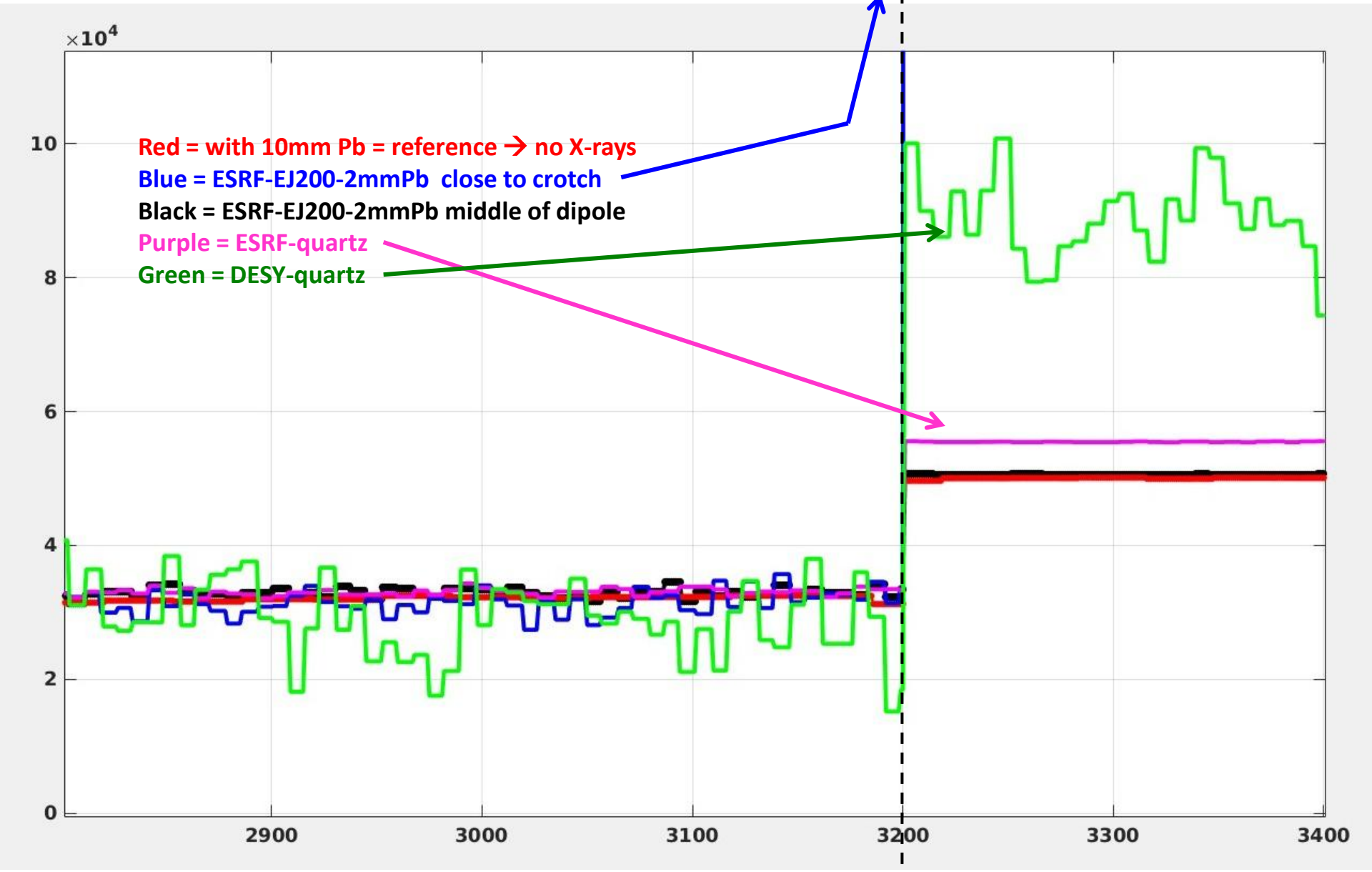
= e-losses + X-rays (?)

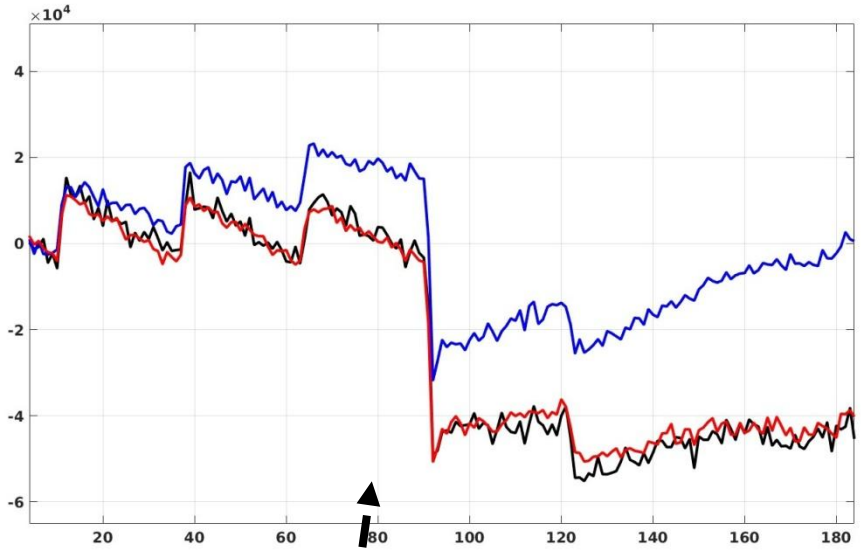
= pure e-losses from scraping = A = B

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



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





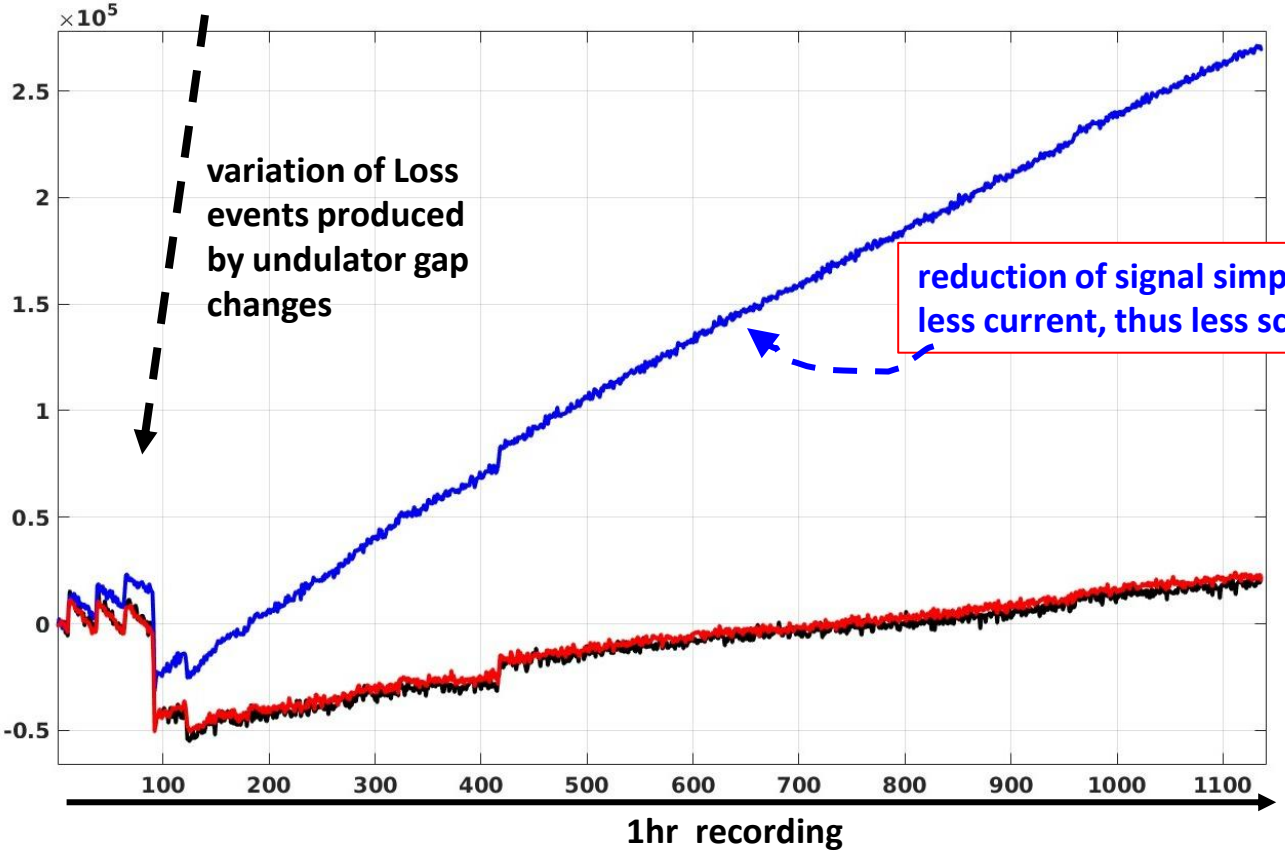

3 different BLDs , during beam decay (1hr):

**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**

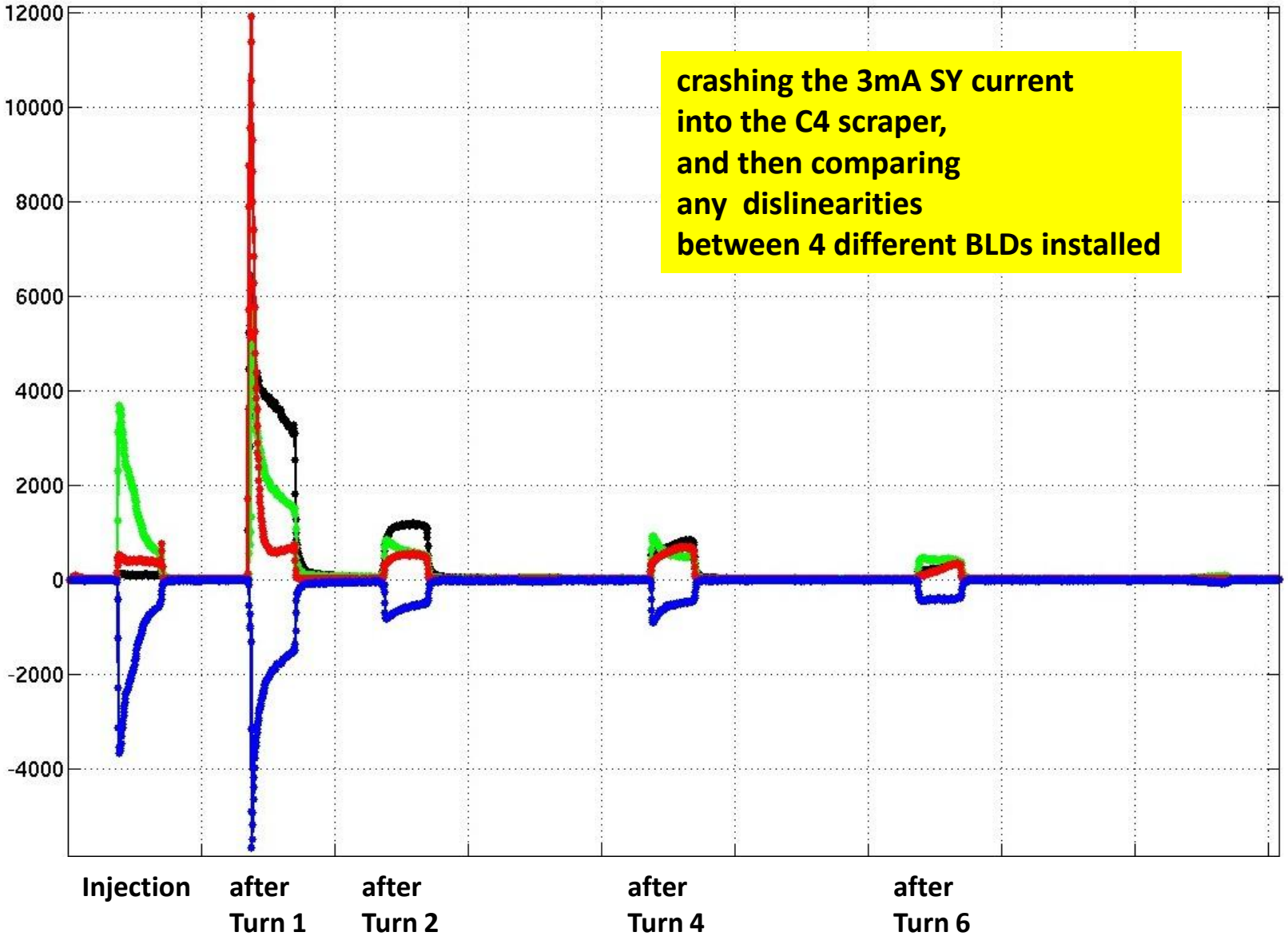
**reduction of signal simply due to less current, thus less scattered X-rays**

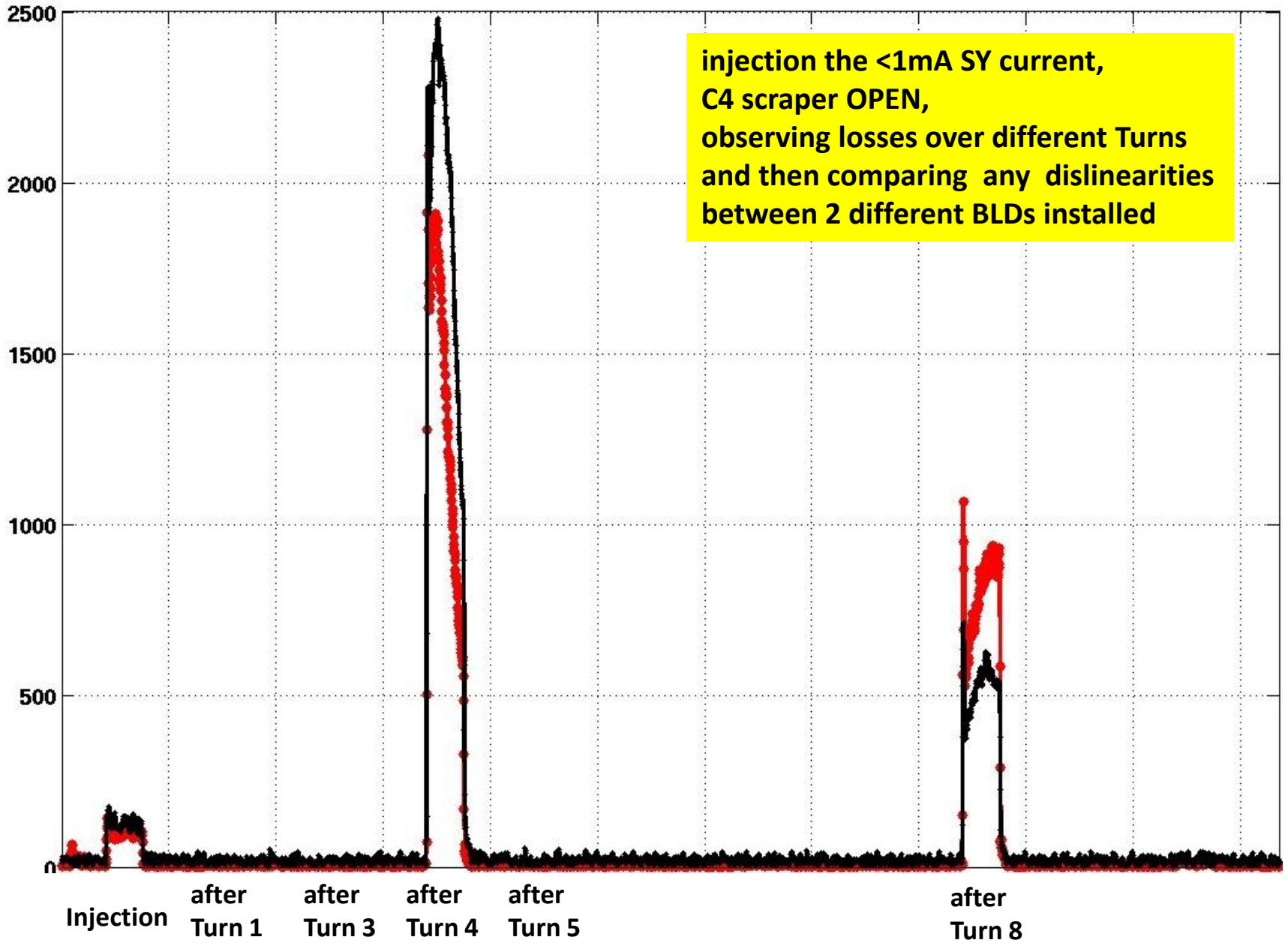
| | Cherenkov-radiator<br><br>Quartz-glass | versus | Gamma-scintillator<br><br>EJ-200 or BC-408 |
|---|---|---|---|
| PROS : | no need for Pb shielding<br>since immune to X-rays (?)<br>therefore : - less volume<br>- less weight<br>- compact | | - high light yield<br>- cheap material |
| CONS : | - low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

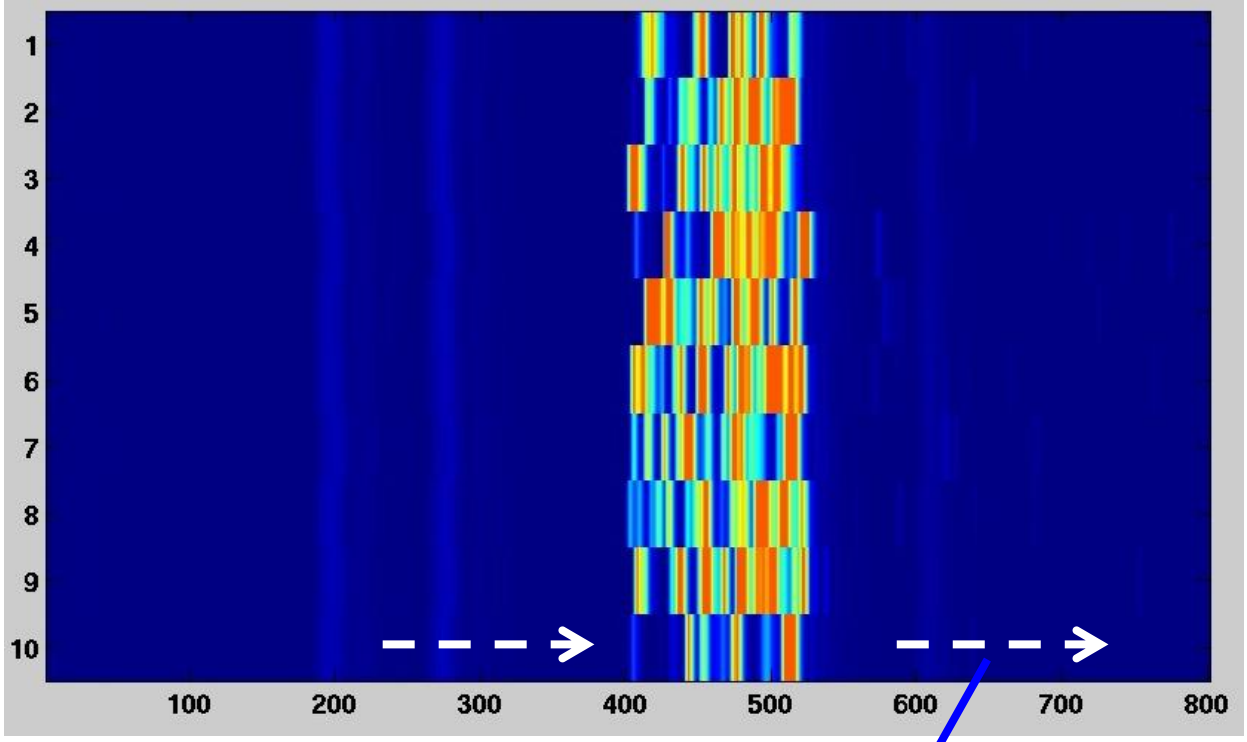
in the end : BLD based on a small EJ-200 rod with a small PMT (8mm window)
with only 2mm of Pb shielding , is :
- more compact
- cheaper
- more sensitive
- fully immune to X-rays (….)

then the BLD based on Cherenkov-radiator

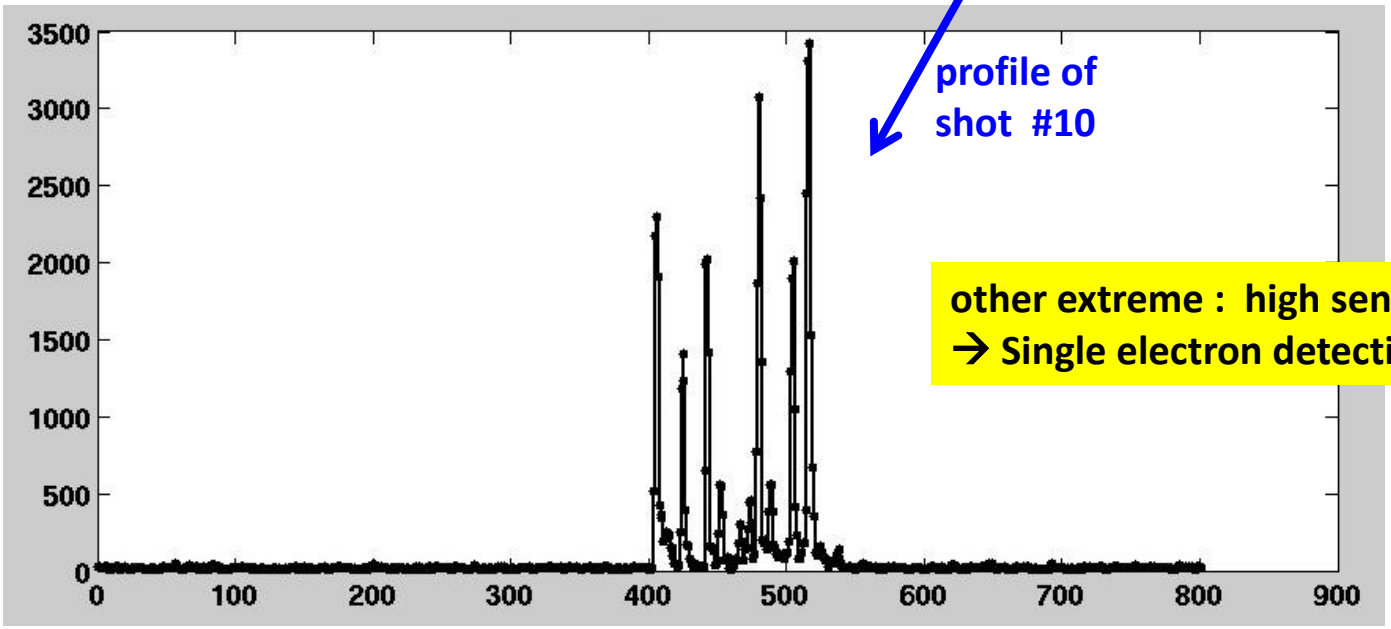
## 4) MDT : Specific tests on the new BLDs to assess both any saturation issues and sensitivity aspects




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

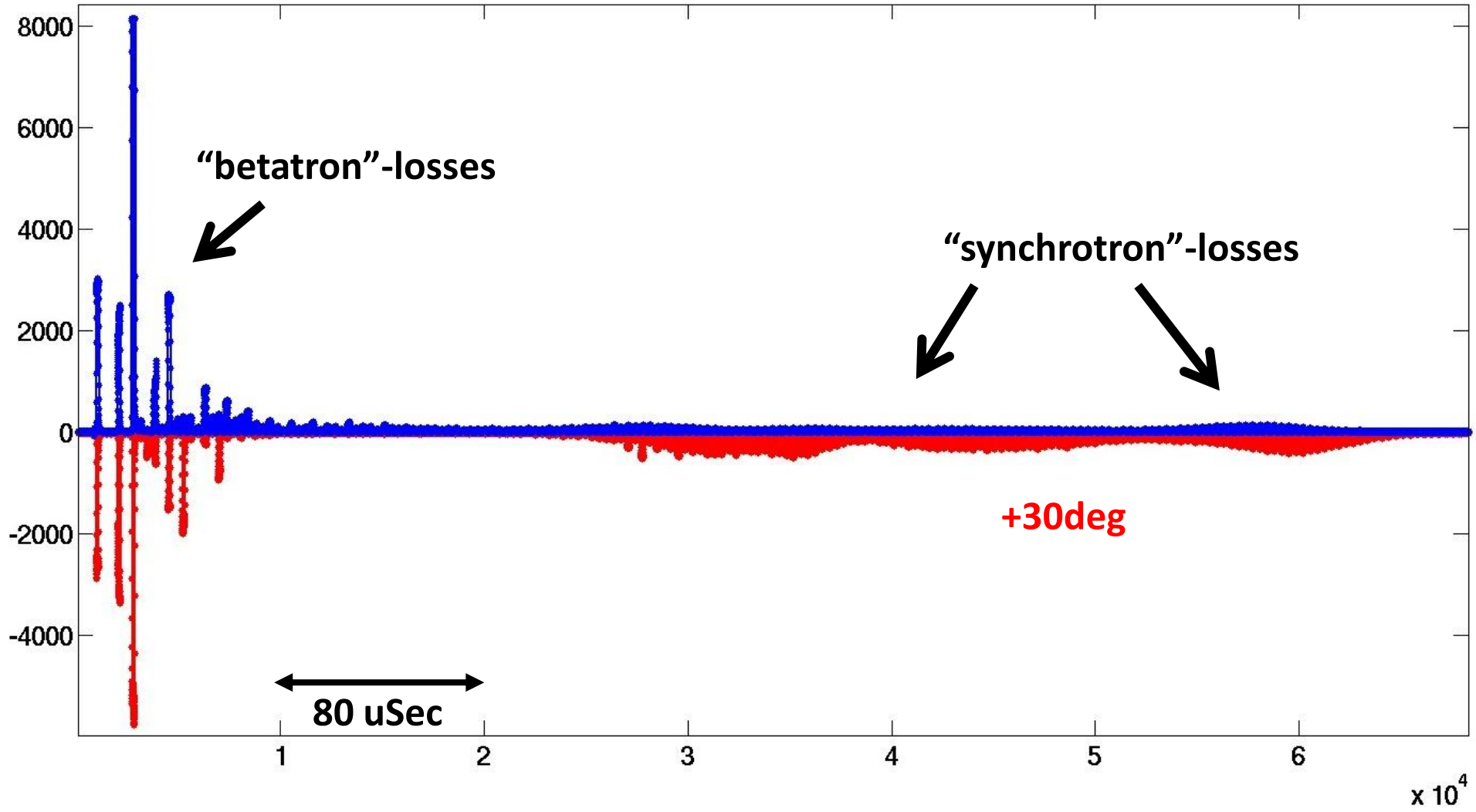



profile of
shot #10

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 )



**time-resolved losses of injected beam at different RF phases :**
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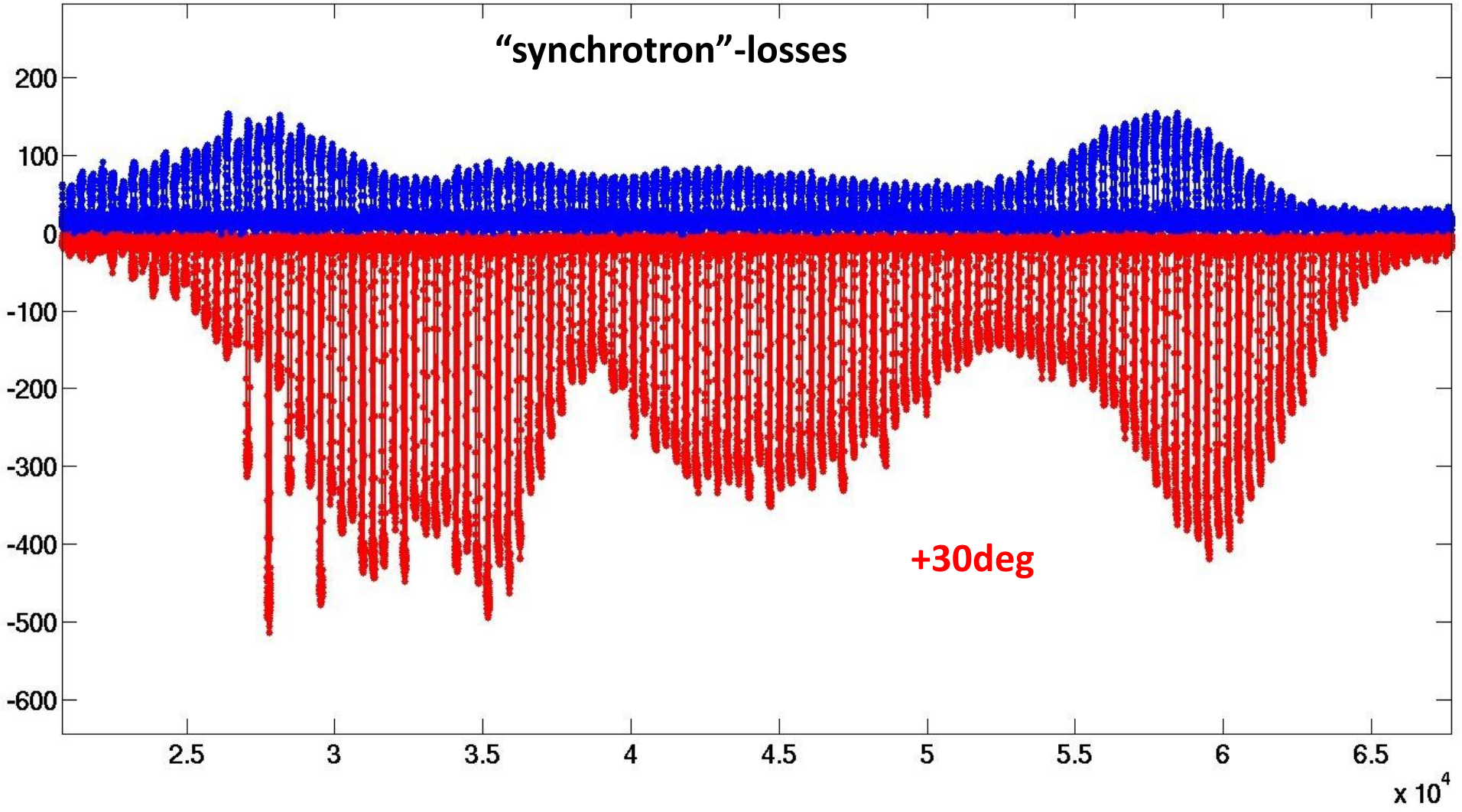

time-resolved losses of injected beam at different RF phases :
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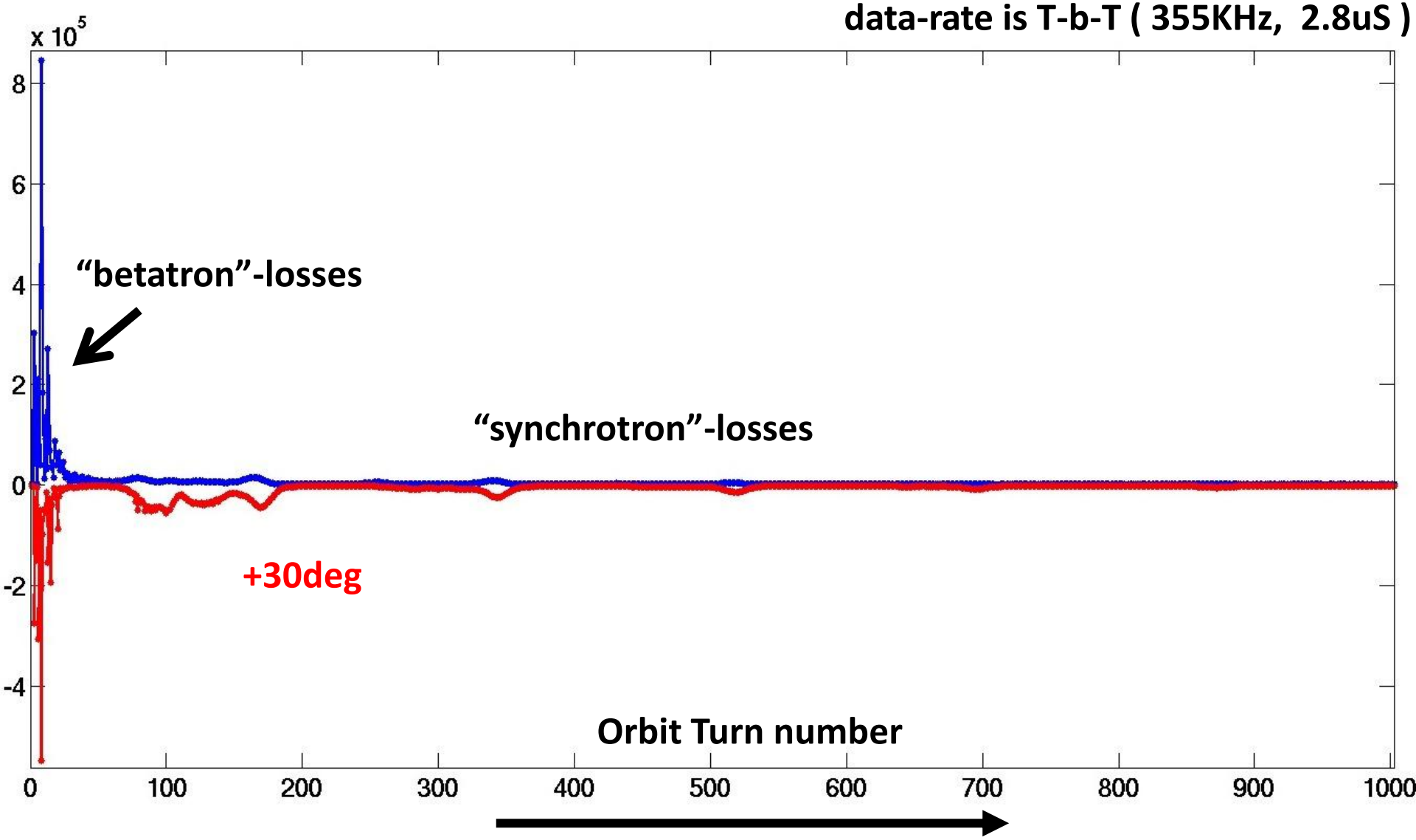
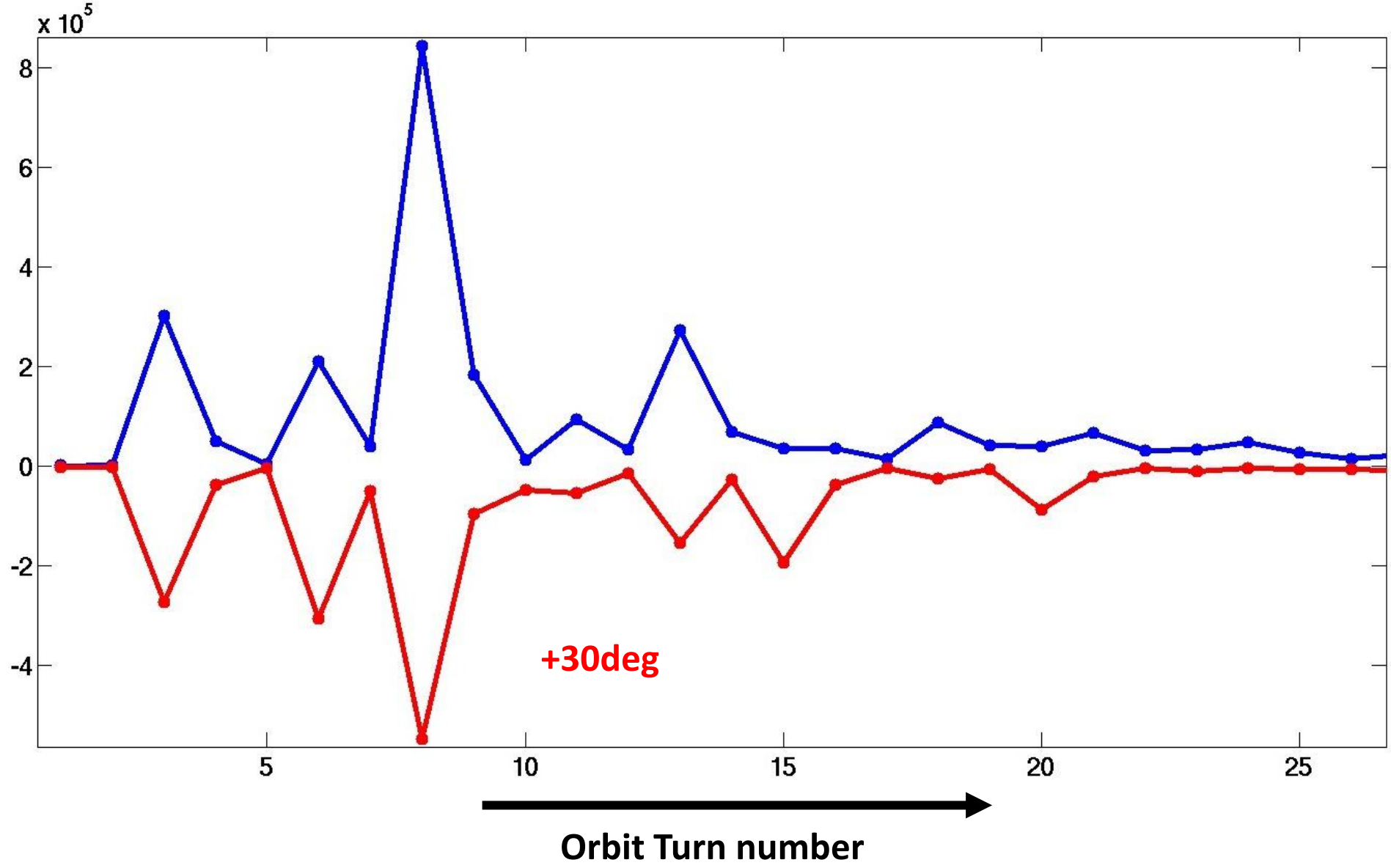
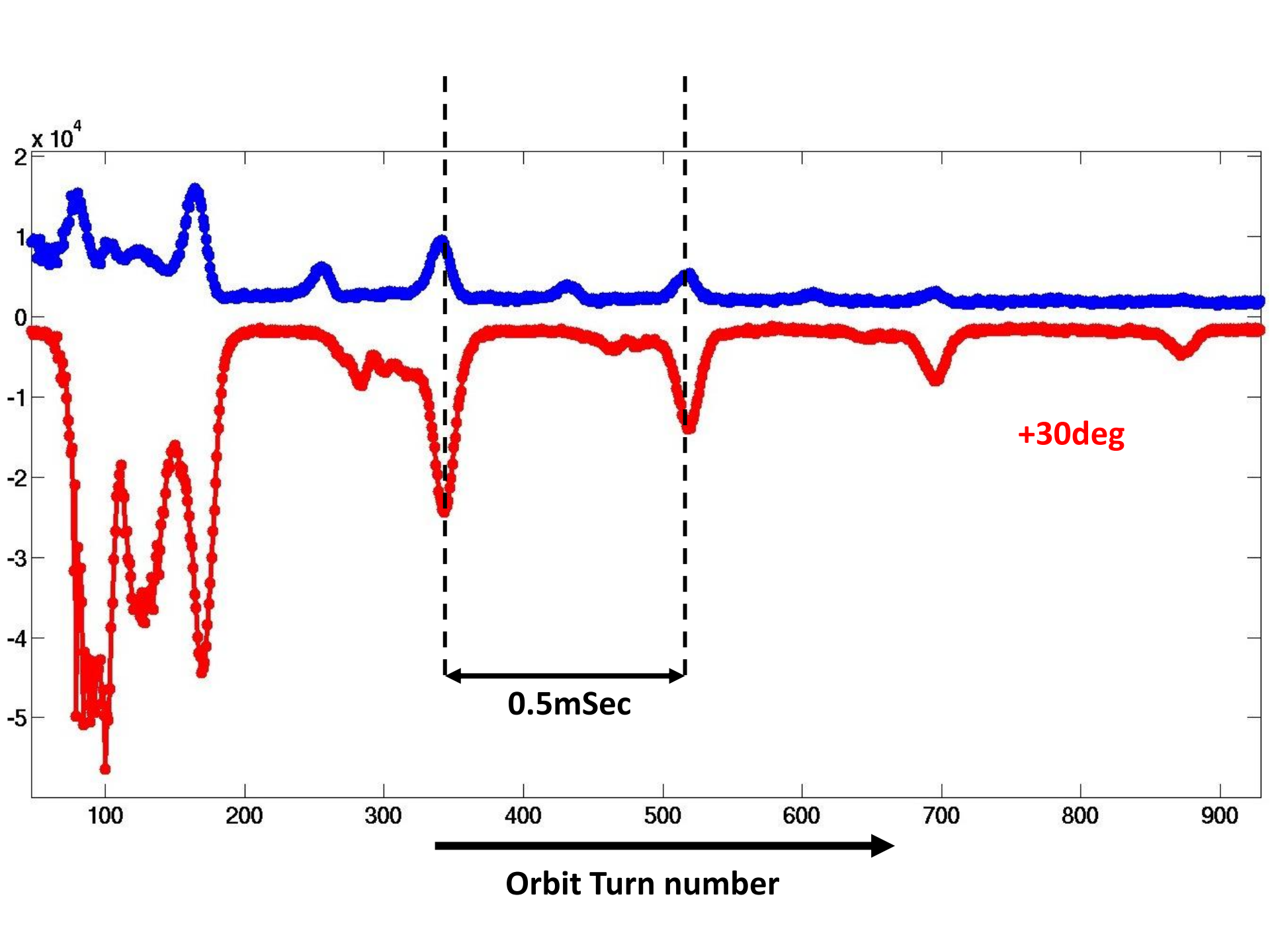


# “betatron”-losses in the first 20 turns

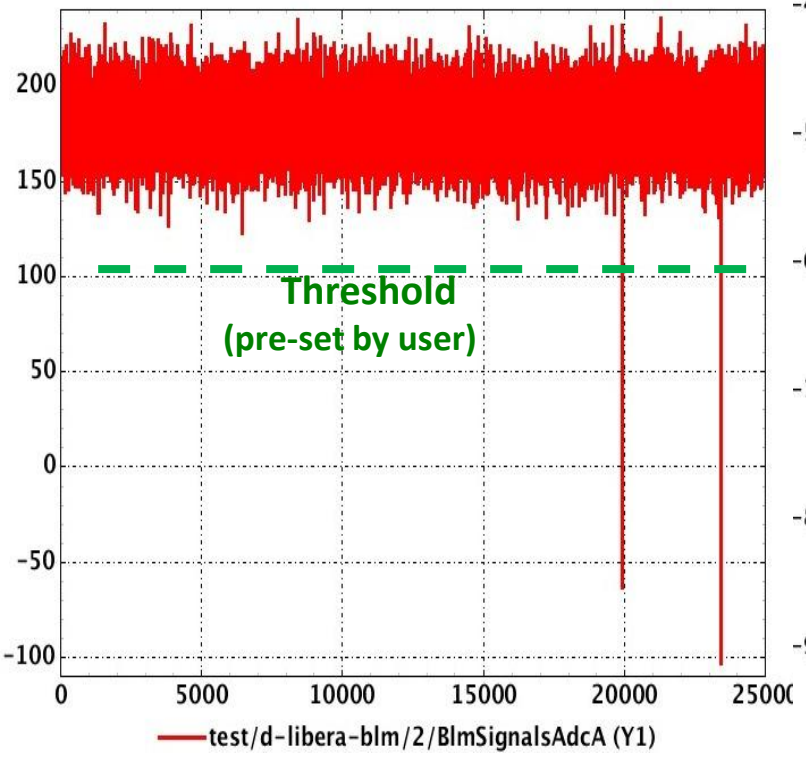



x 10^4
2
1
0
-1
-2
-3
-4
-5
100
200
300
400
500
600
700
800
900
+30deg
0.5mSec
Orbit Turn number

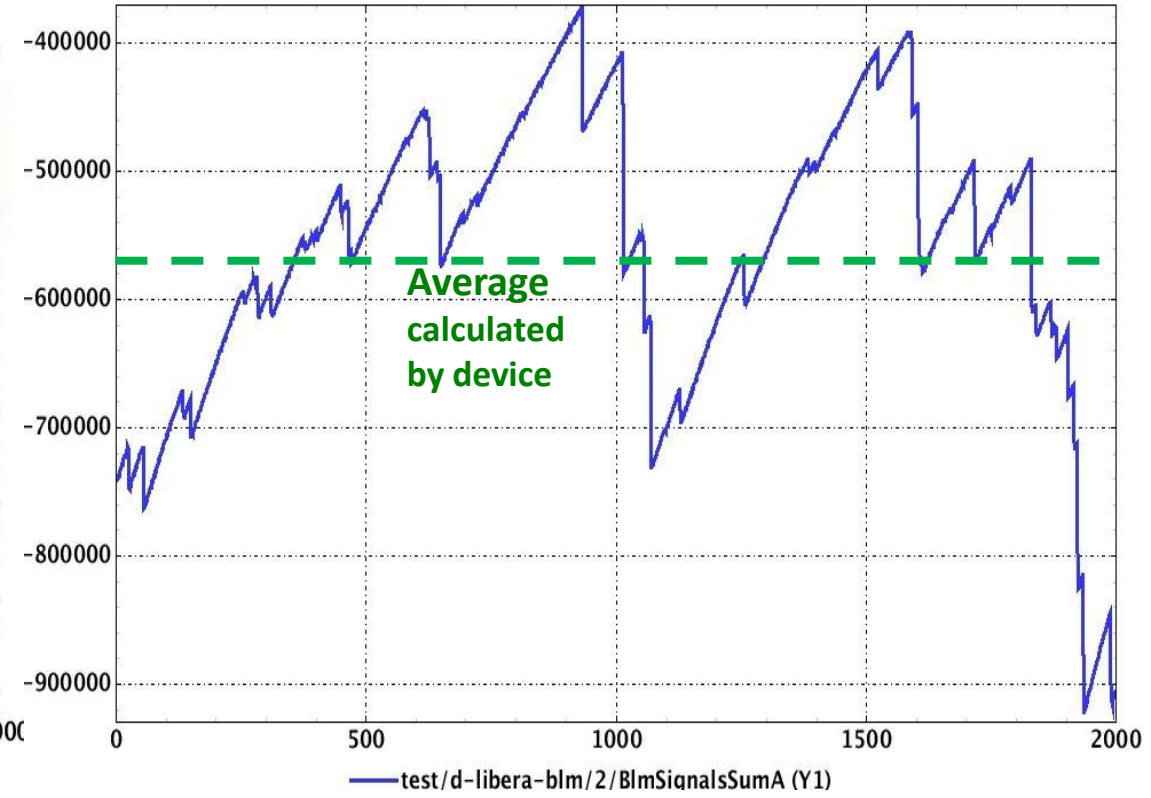
**Counting-mode**
**50 Ω**

**versus**

**Integrating-mode**
**Hi-Z**

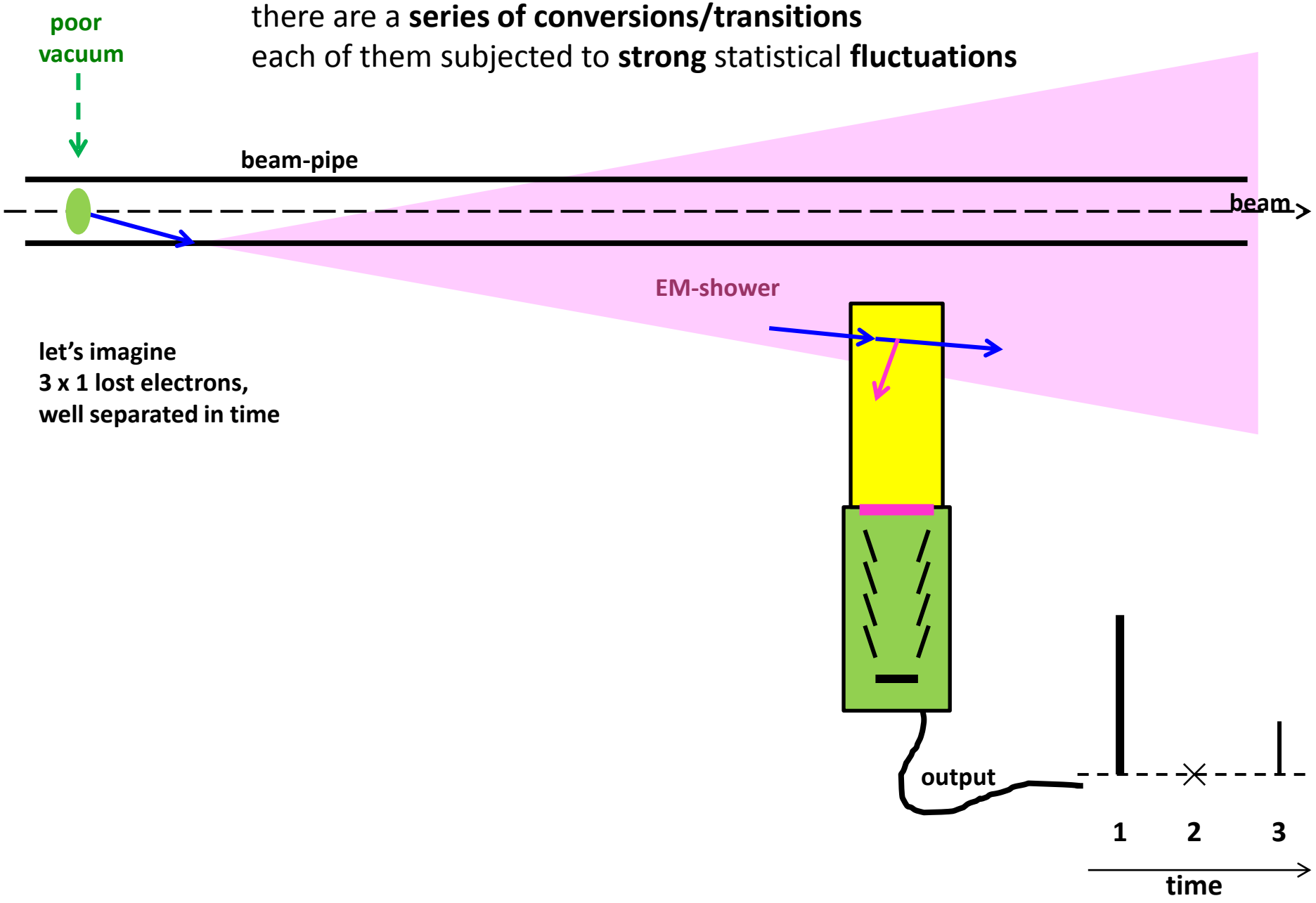



**20 µs**




**6 ms**

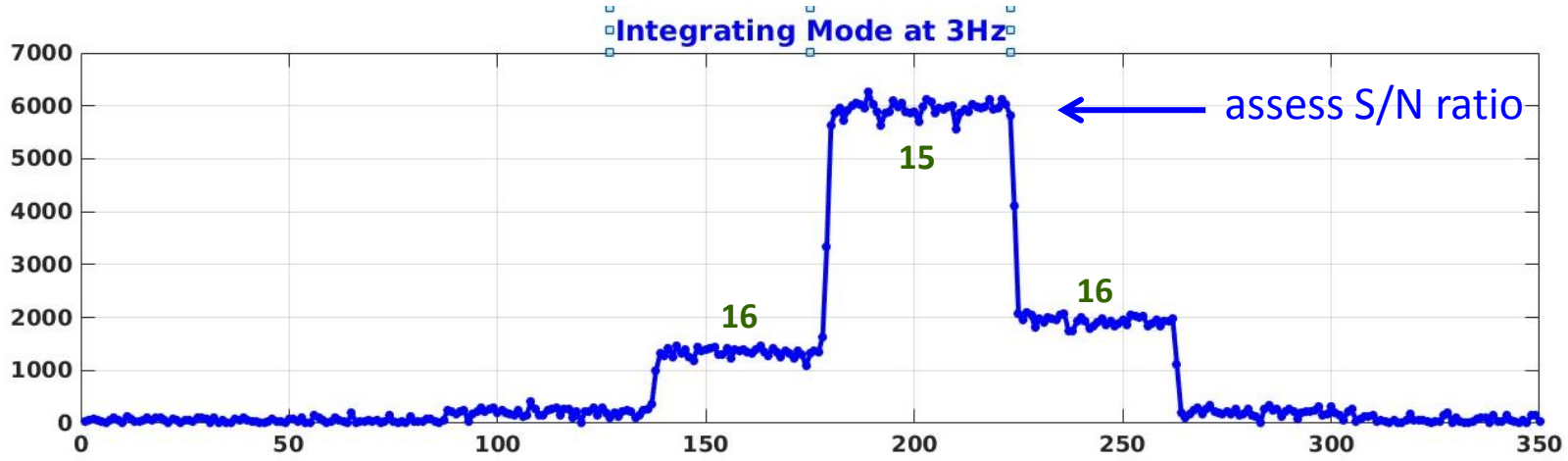
between the event of a lost electron
and the final recording of that event in the detector
there are a **series of conversions/transitions**
each of them subjected to **strong** statistical **fluctuations**

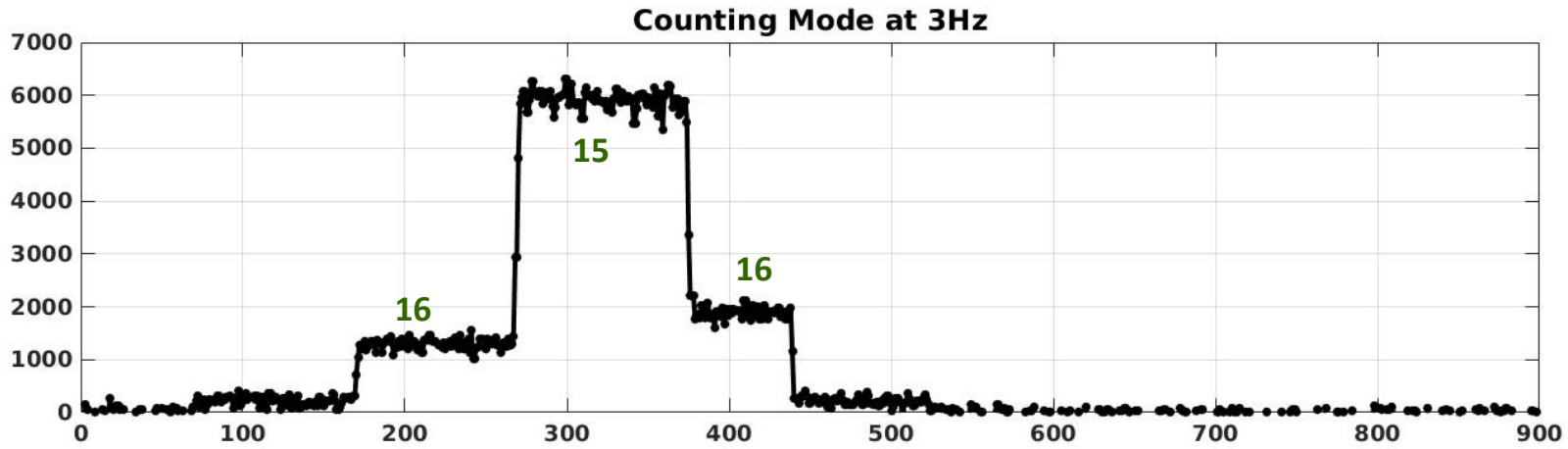


BLM-attenuator=4dB, PMT-GCV=0.55V, **scraper at 18-17-16-15-16-17-18 mm**

Integrating period = 0.37sec

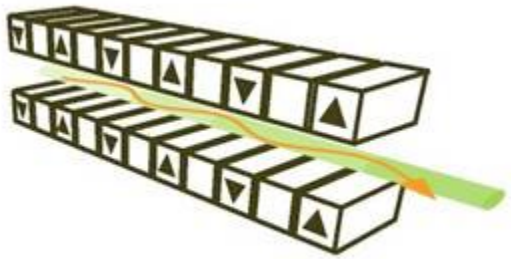
Counting period = 0.25sec



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

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

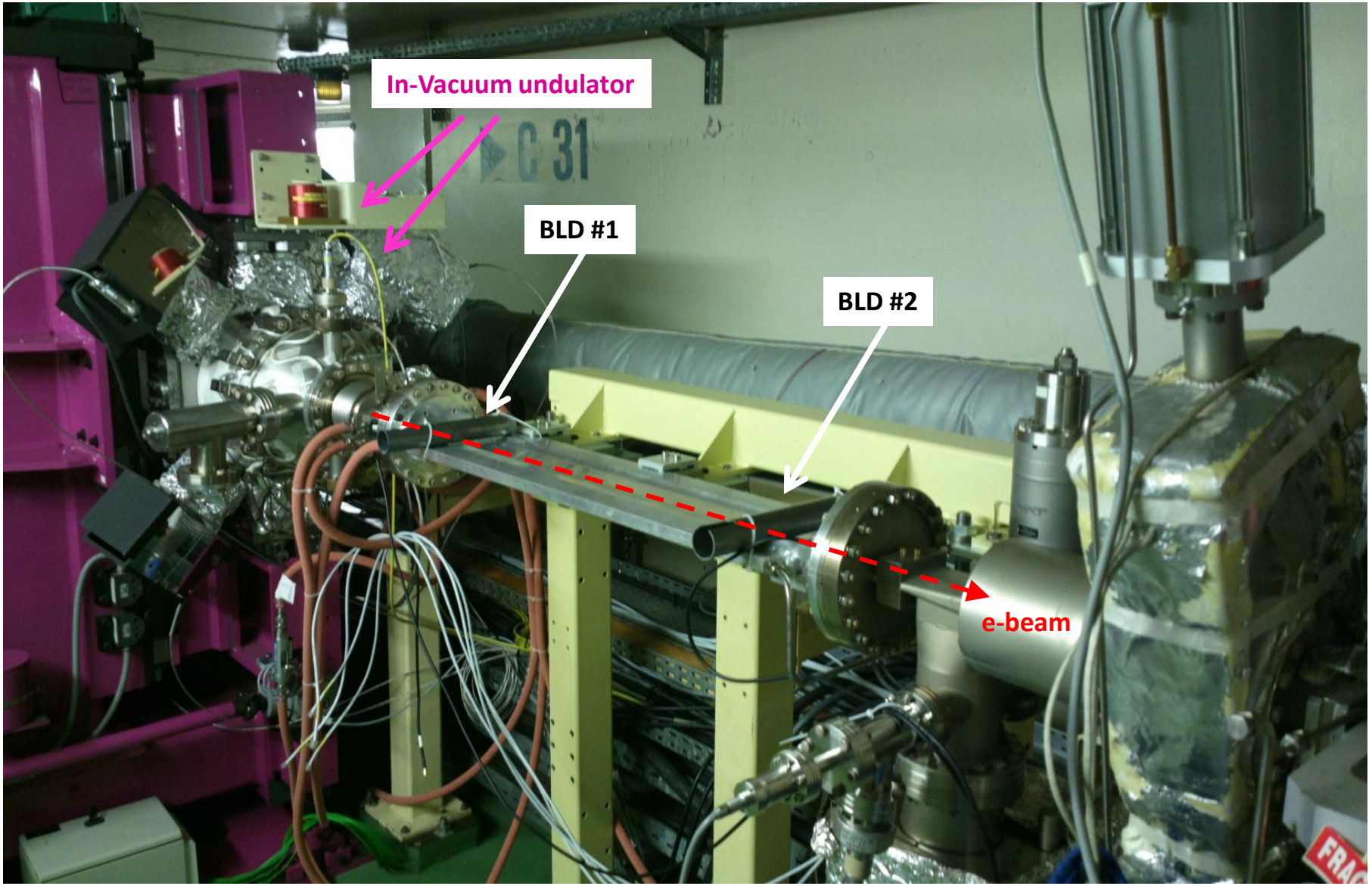
this can be a real problem in rings with smaller beam-sizes (EBS …!)
→ more scattering, less lifetime, more losses . . .

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

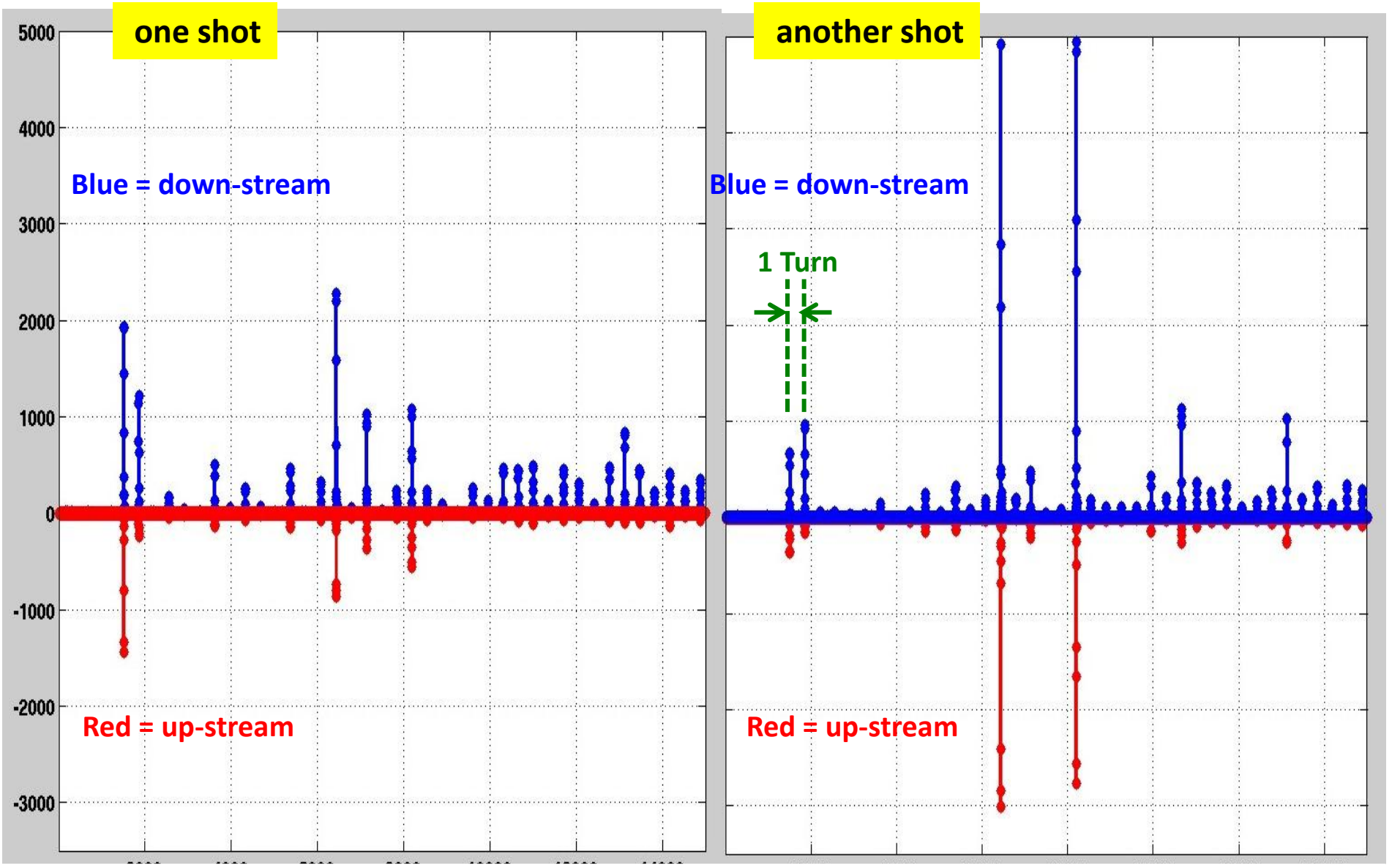
## Solutions :

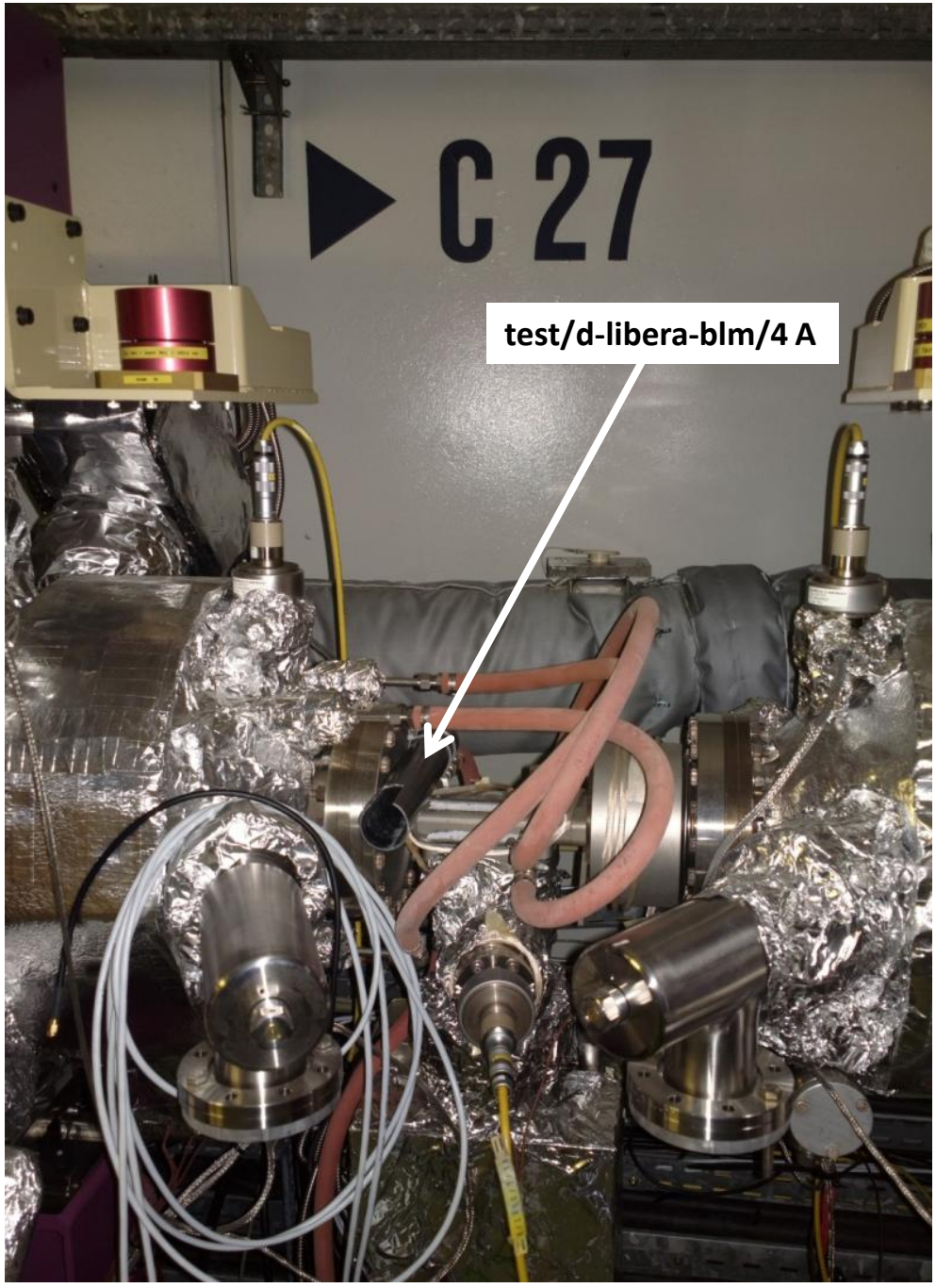
- add **special & dedicated scrapers-collimators** in that ring
→ the scattered electrons get lost there

- **improved monitoring of losses** to verify that these **In-Vacs** are indeed protected, under various conditions

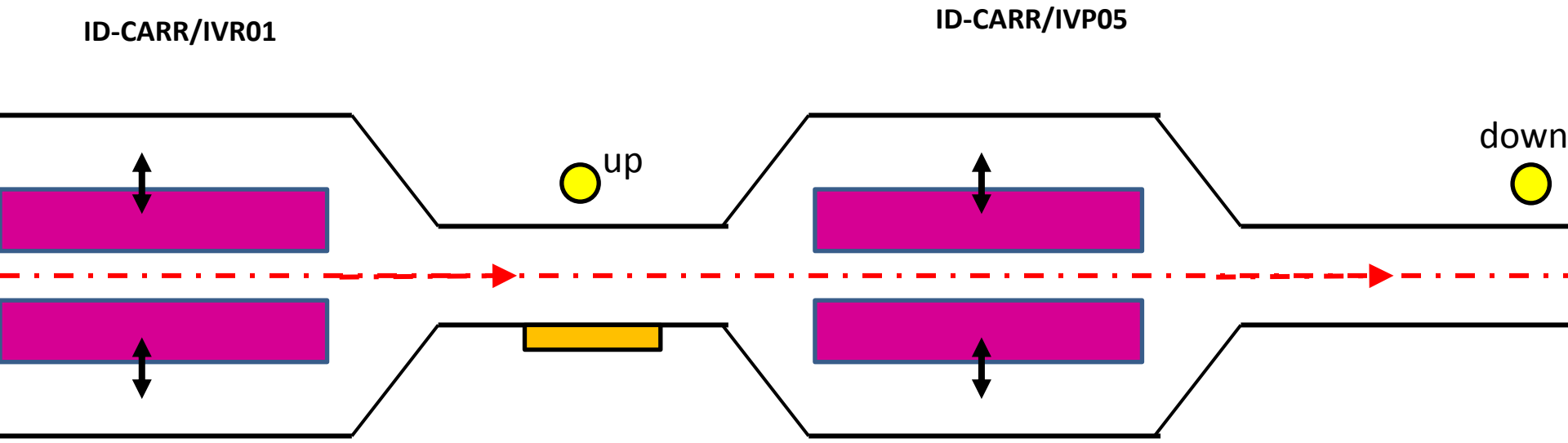

In-Vacuum undulator
BLD #1
BLD #2
e-beam

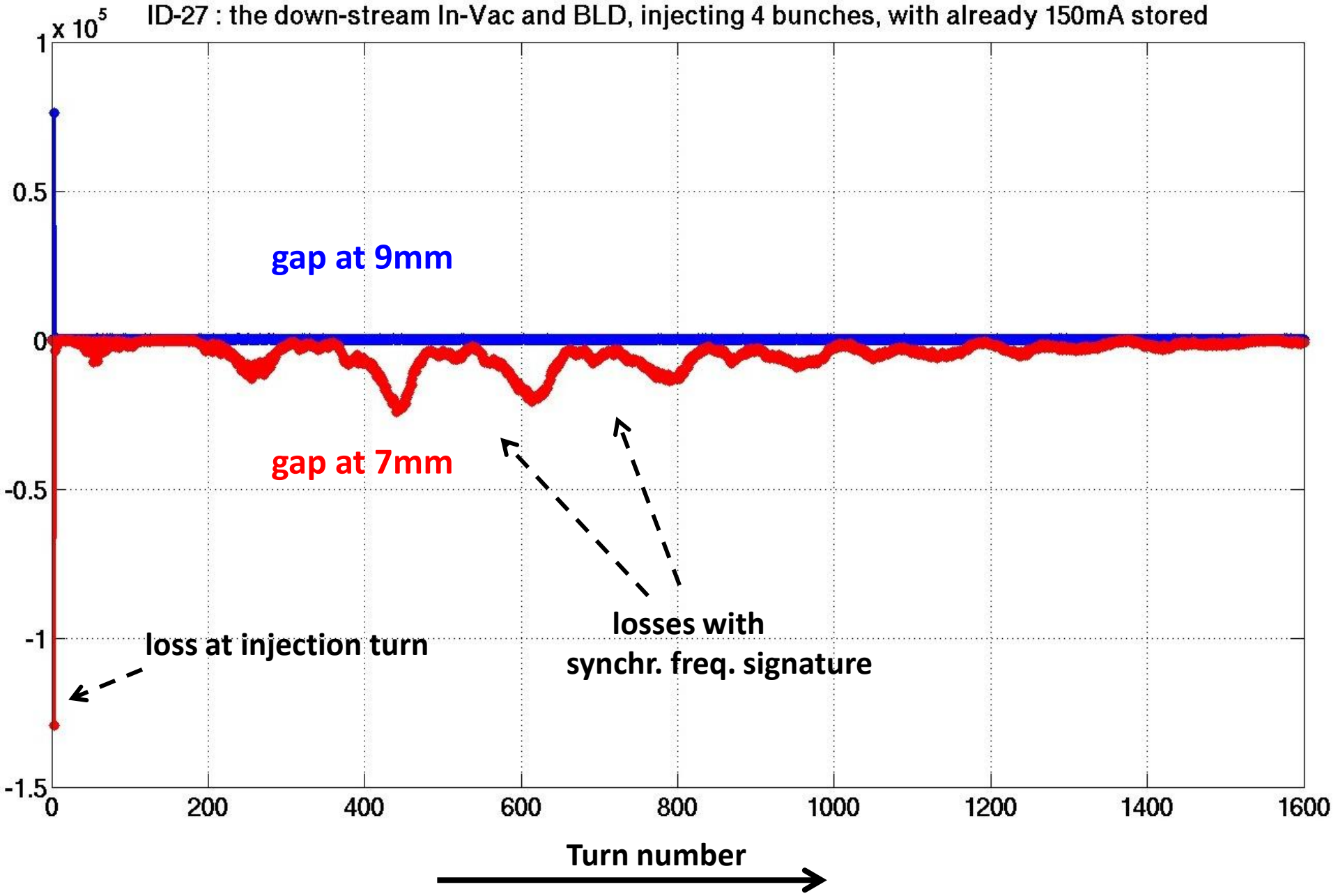
# ADC data from 2 BLDs (red & blue) near In-Vac, at 2 different injections

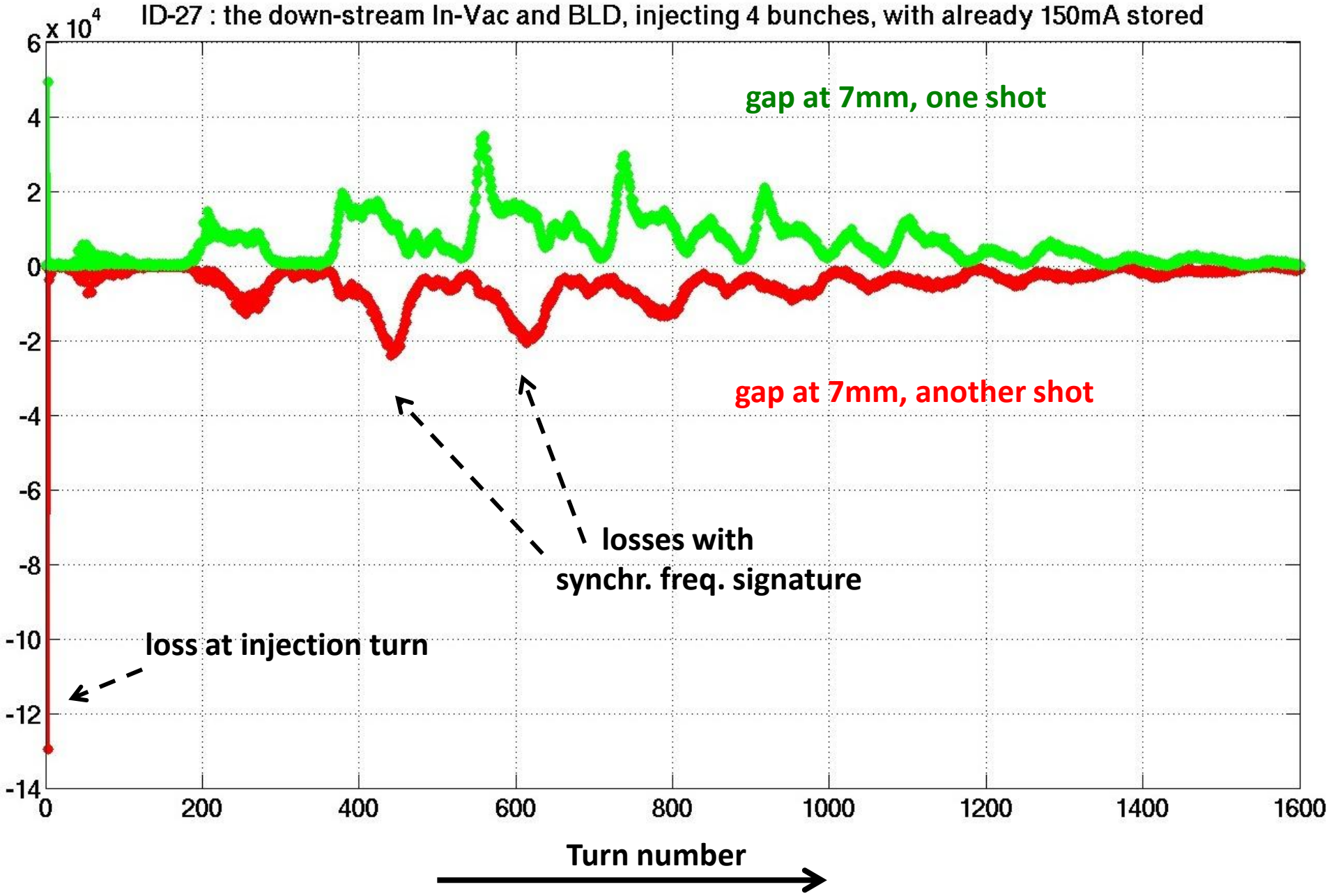



C 27
test/d-libera-blm/4 A

# ID-27 *side-view*

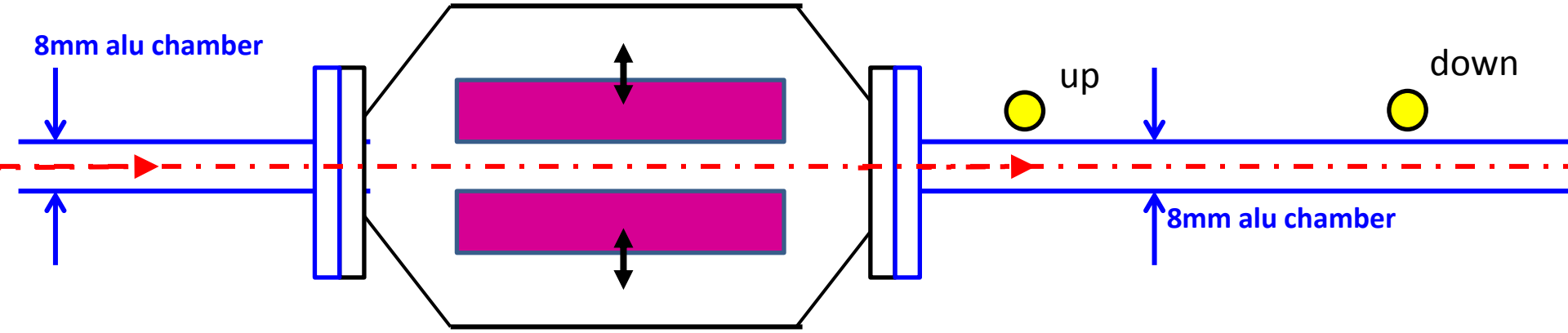


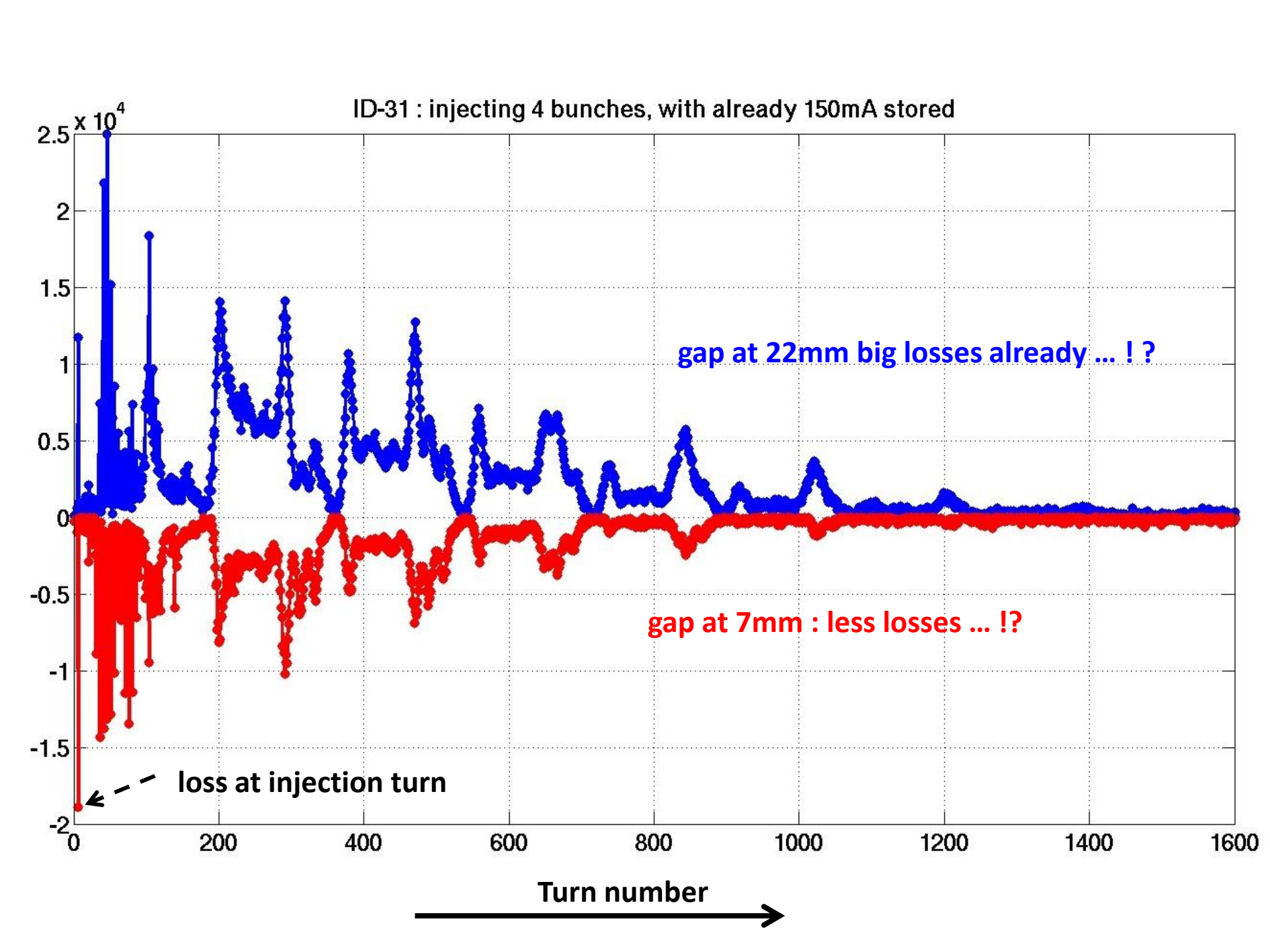

ID-27 : the down-stream In-Vac and BLD, injecting 4 bunches, with already 150mA stored
x 10^5
1
0.5
0
-0.5
-1
-1.5
0
200
400
600
800
1000
1200
1400
1600
gap at 9mm
gap at 7mm
loss at injection turn
losses with
synchr. freq. signature
Turn number

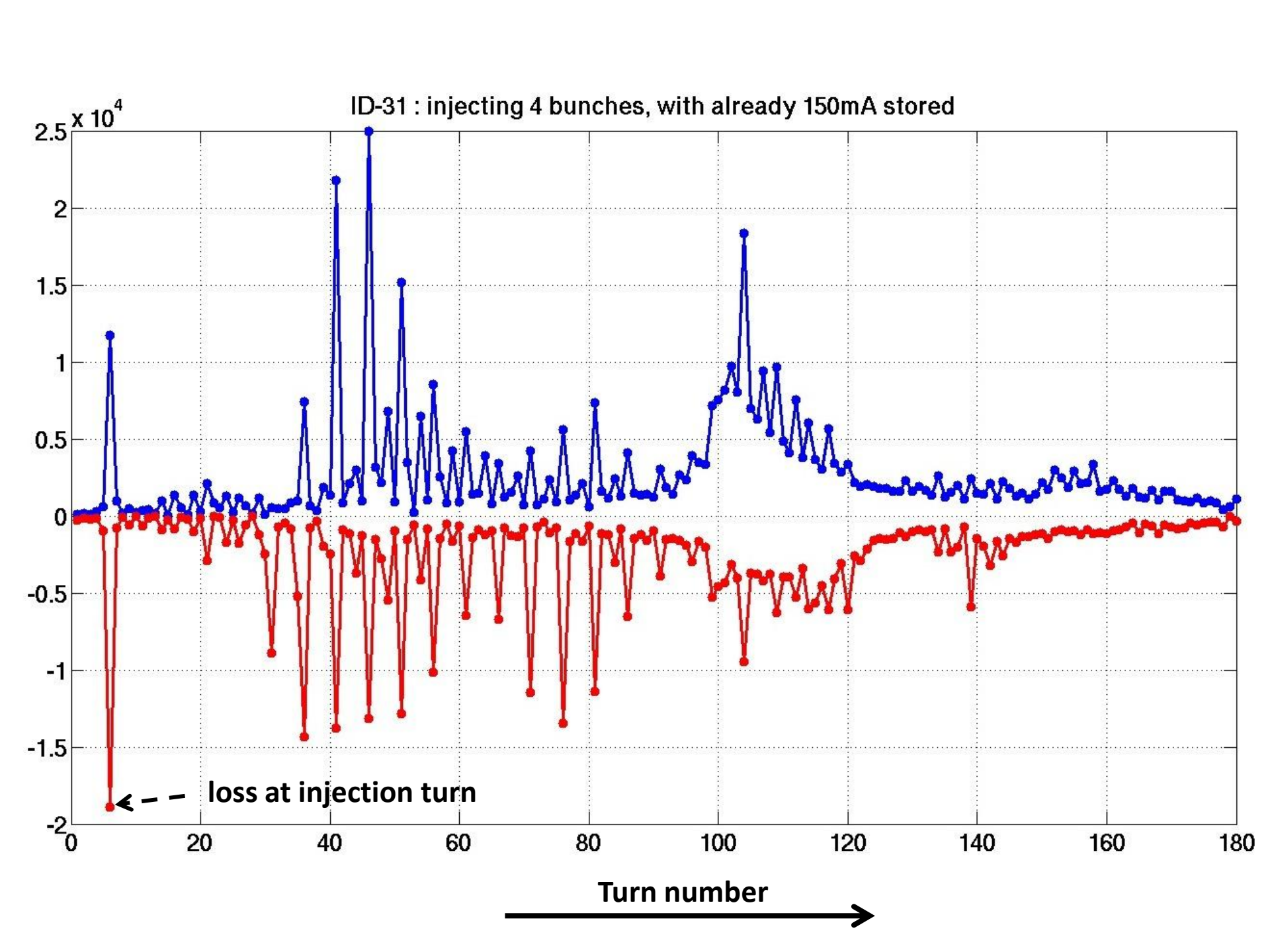

ID-27 : the down-stream In-Vac and BLD, injecting 4 bunches, with already 150mA stored
x 10^4
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
0
200
400
600
800
1000
1200
1400
1600
gap at 7mm, one shot
gap at 7mm, another shot
losses with
synchr. freq. signature
loss at injection turn
Turn number

# ID-31

id-carr/IVW1/carriage

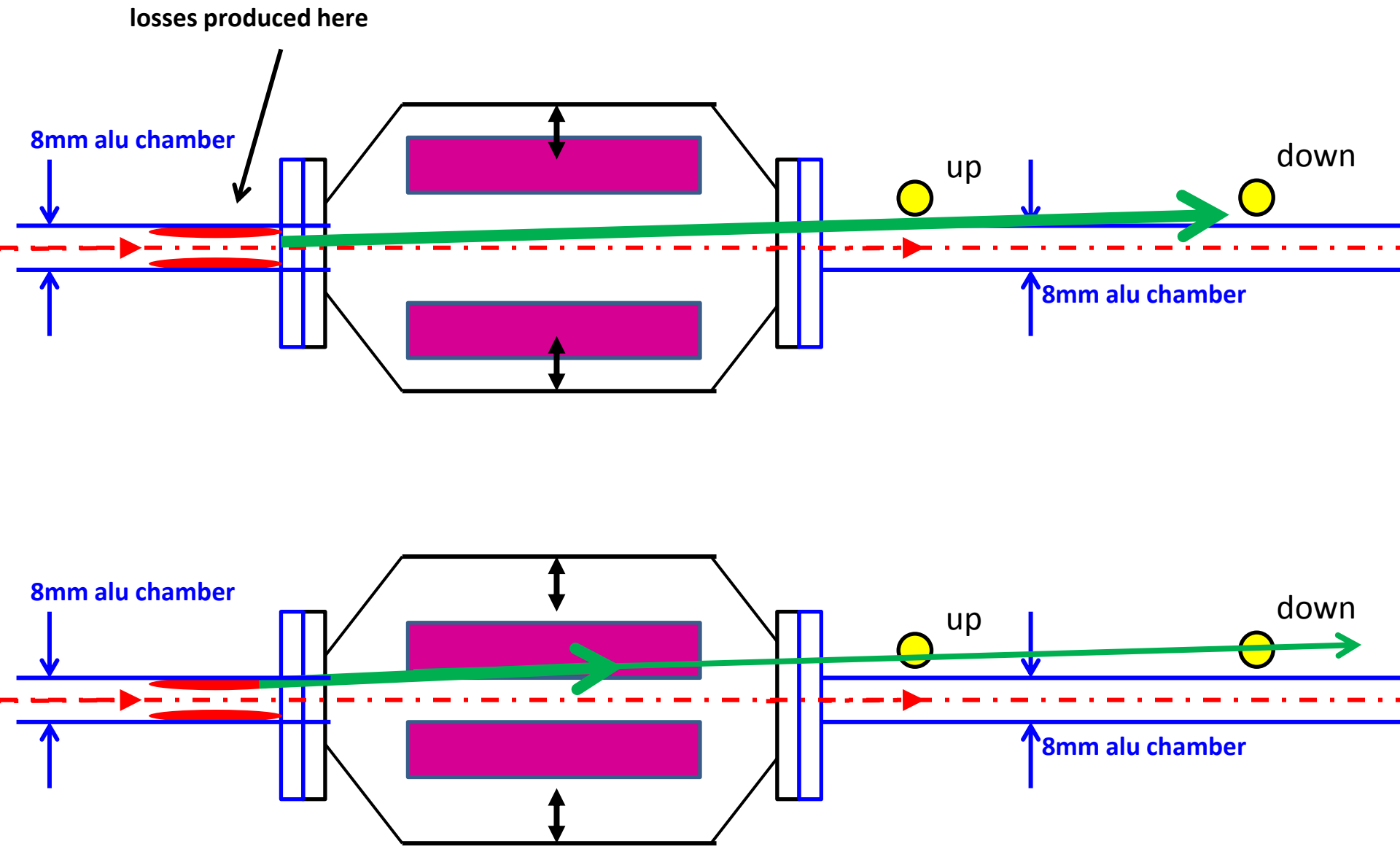



ID-31 : injecting 4 bunches, with already 150mA stored
x 10^4
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
200
400
600
800
1000
1200
1400
1600
gap at 22mm big losses already … ! ?
gap at 7mm : less losses … !?
loss at injection turn
Turn number


ID-31 : injecting 4 bunches, with already 150mA stored
x 10^4
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
20
40
60
80
100
120
140
160
180
loss at injection turn
Turn number

# ID-31

id-carr/IVW1/carriage



# plans at the ESRF for adding a new BLM system now

**Presently we have already :**

**64 old BLDs (scintillator + PMT) that are heavy & huge with only slow read-out electronics (<1Hz)**

**64 Ionization chambers : even heavier, extreme sizes (!) and even slower read-out systems**

**we now envisage (nearly decided) to procure 160 BLDs (and 40 BLMs) , and to install 128 units at strictly regular positions (4/cell)**

**and to install the others (32) at points of interests like some In-Vac IDs, injection_zone, near scrapers etc.**

**this new BLM system should be commissioned in early 2017 and then be used extensively in 2017 & 2018 (2019 is the installation of EBS)**
**the old & heavy system would NOT be re-installed in 2019**
**comparison of BLM data taken in 2017/18 (old ring) with that from EBS (from 2020) should be useful**

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

# thank you for your attention


**DEELS-2016**
**June 27-28**
**Hamburg**