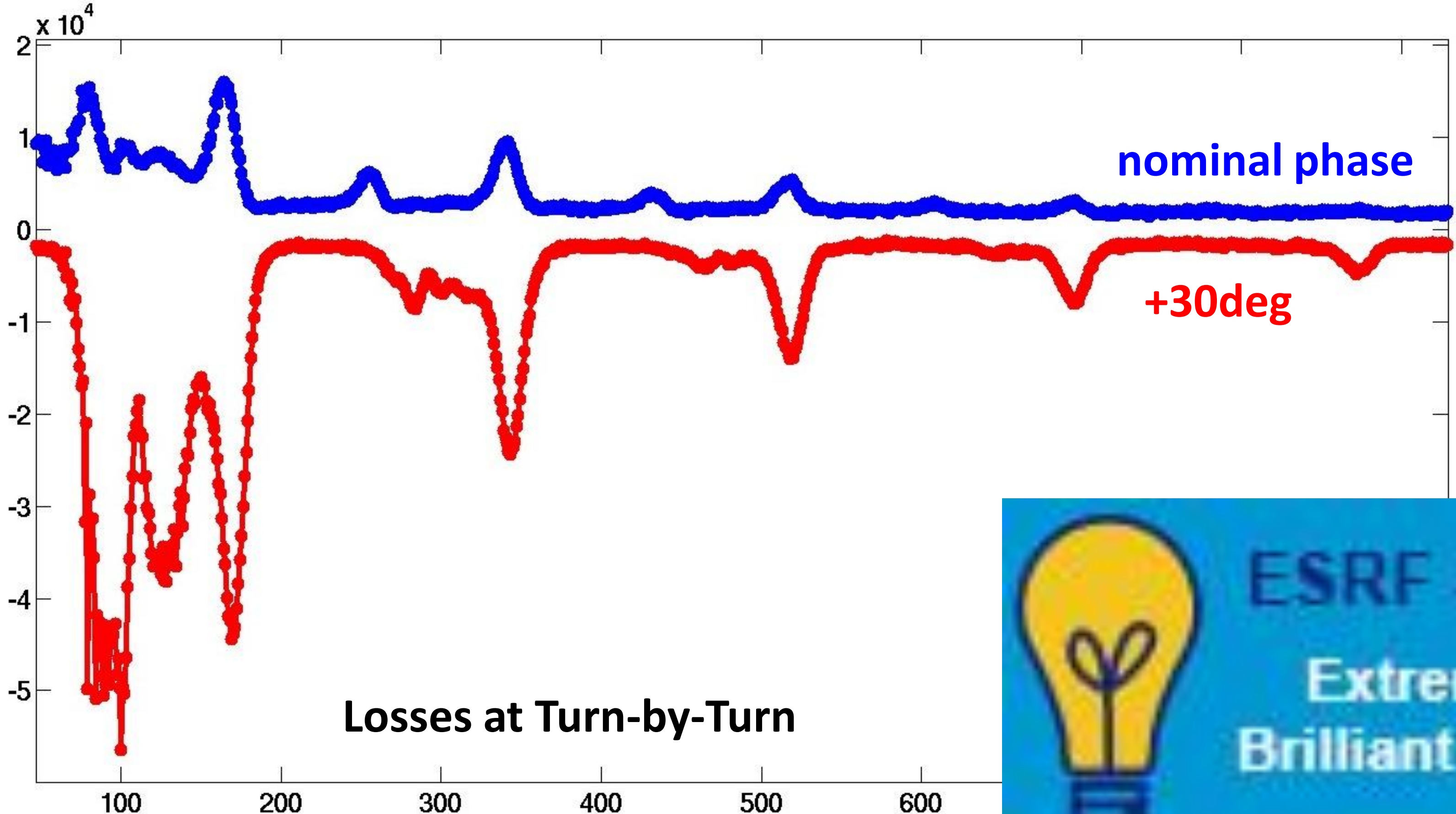
Beam Loss Measurements at the ESRF with different Beam-Loss-Detectors and the new 4 channel Libera-BLM acquisition system



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

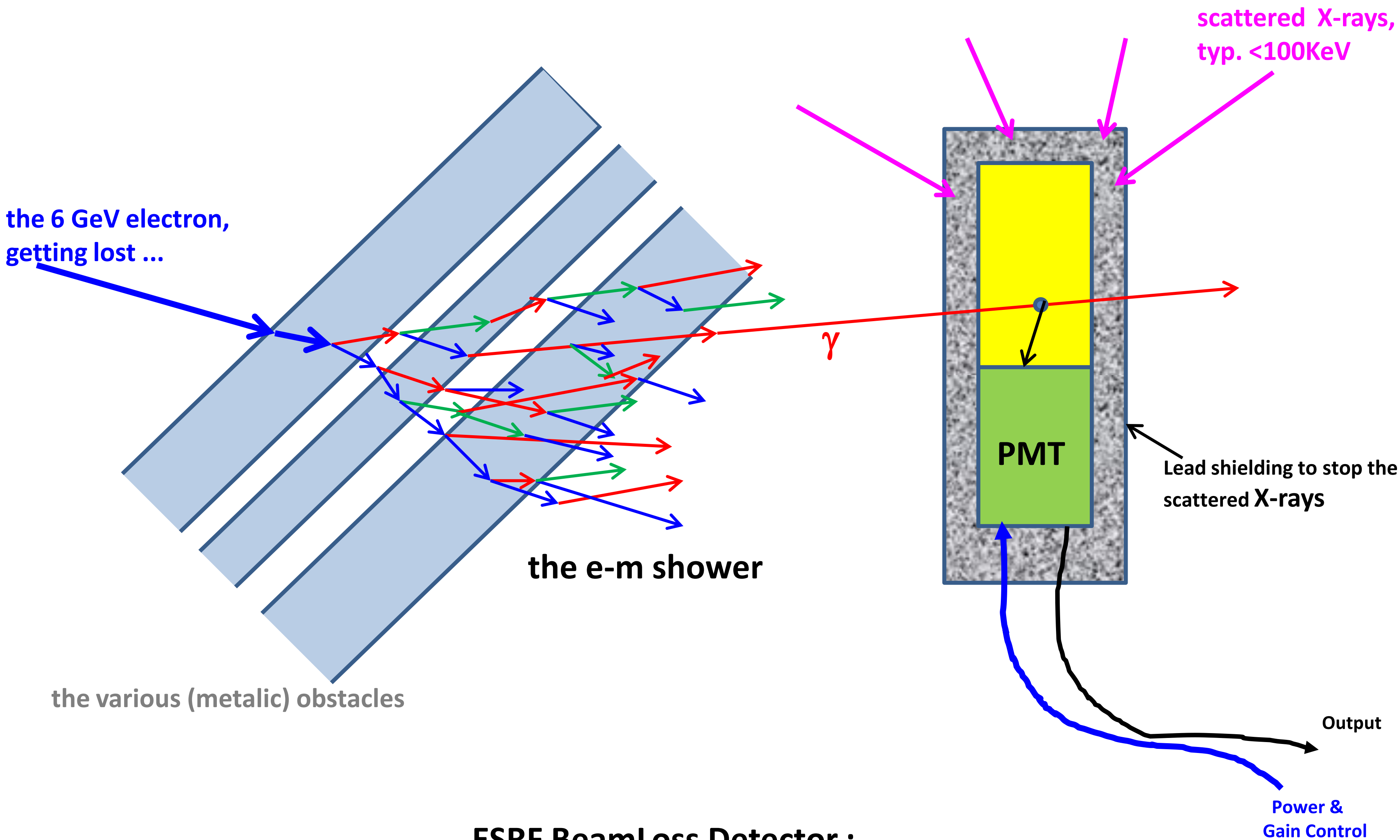
- (short-cut) choices needed to be made on the BLD :

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

→ scintillator/radiator ←

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

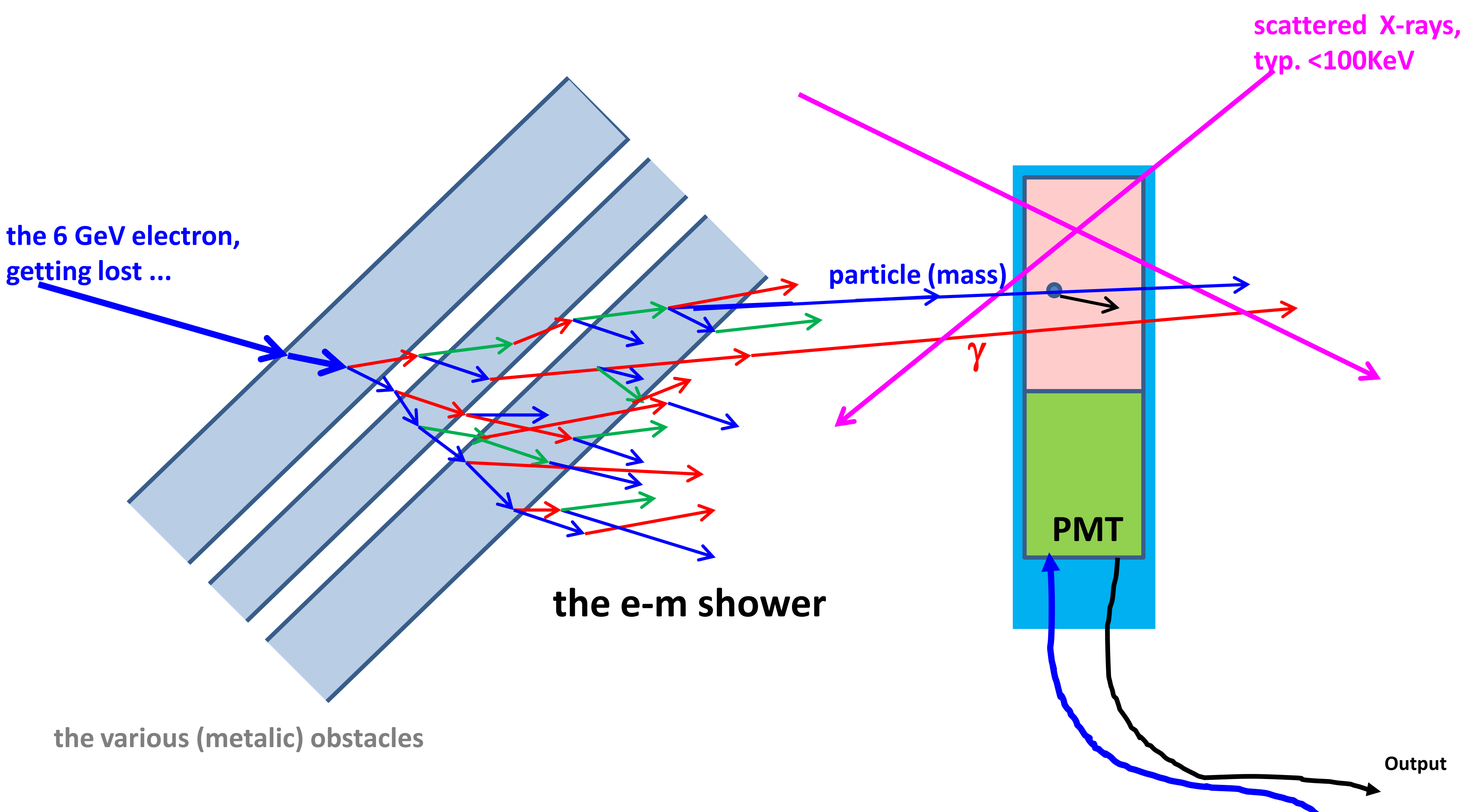
→ PMT ←



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



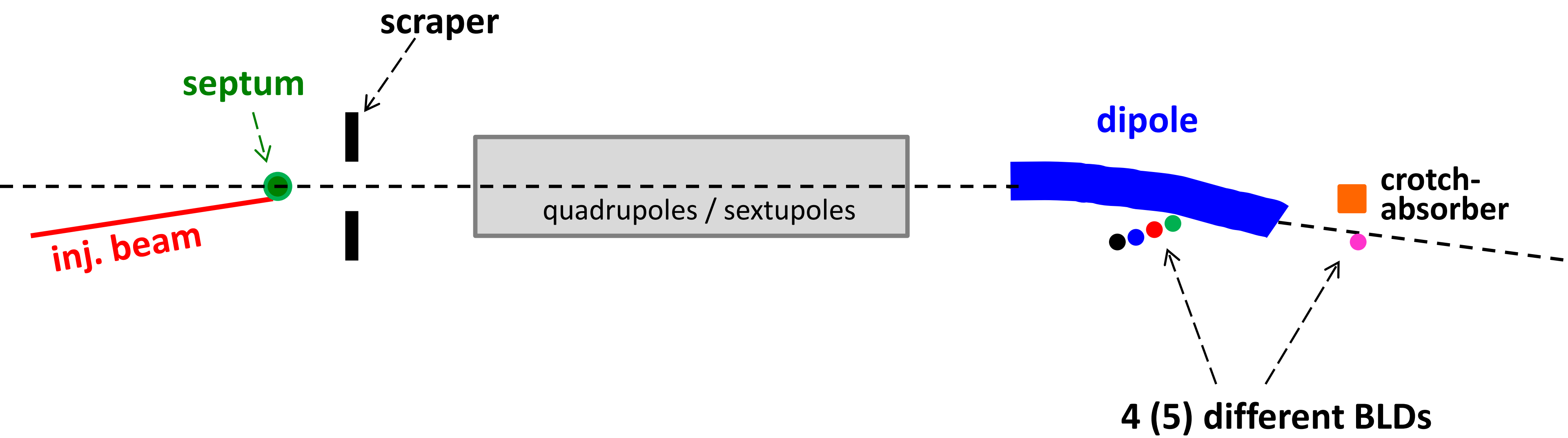
Cherenkov detector :

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')

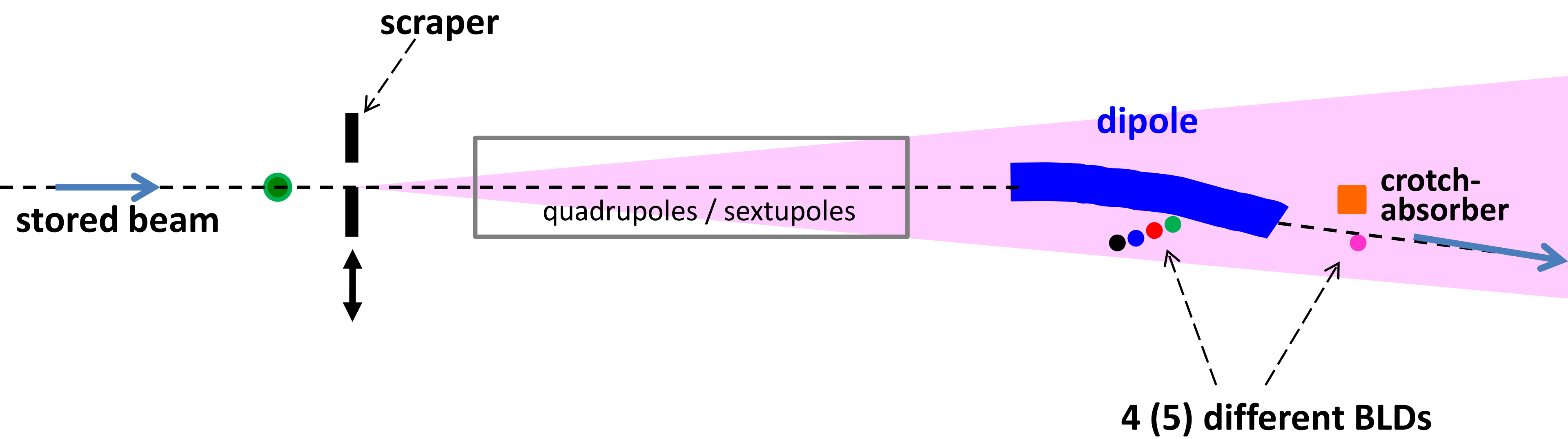
→ no need for Lead shielding

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

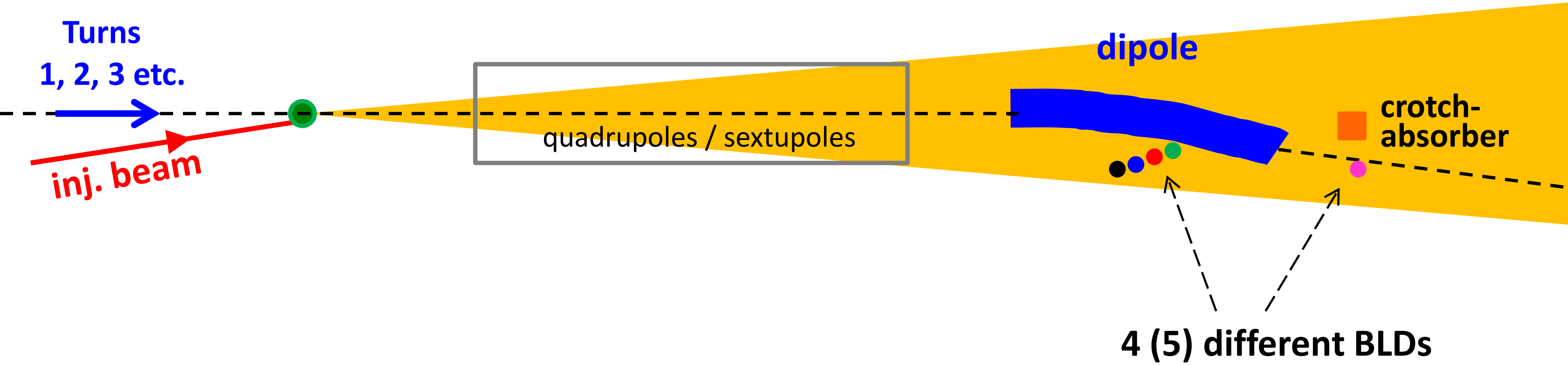


1) can be done during USM

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)



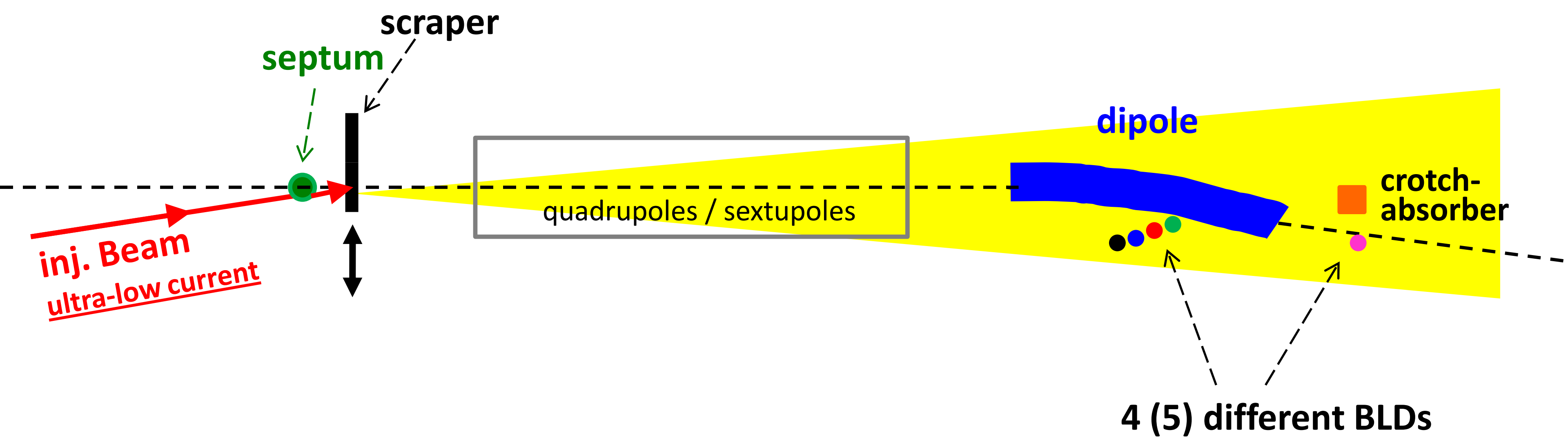
1) done at each top-up (20min for 16 bunch … but 12 hours for other fills !)

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

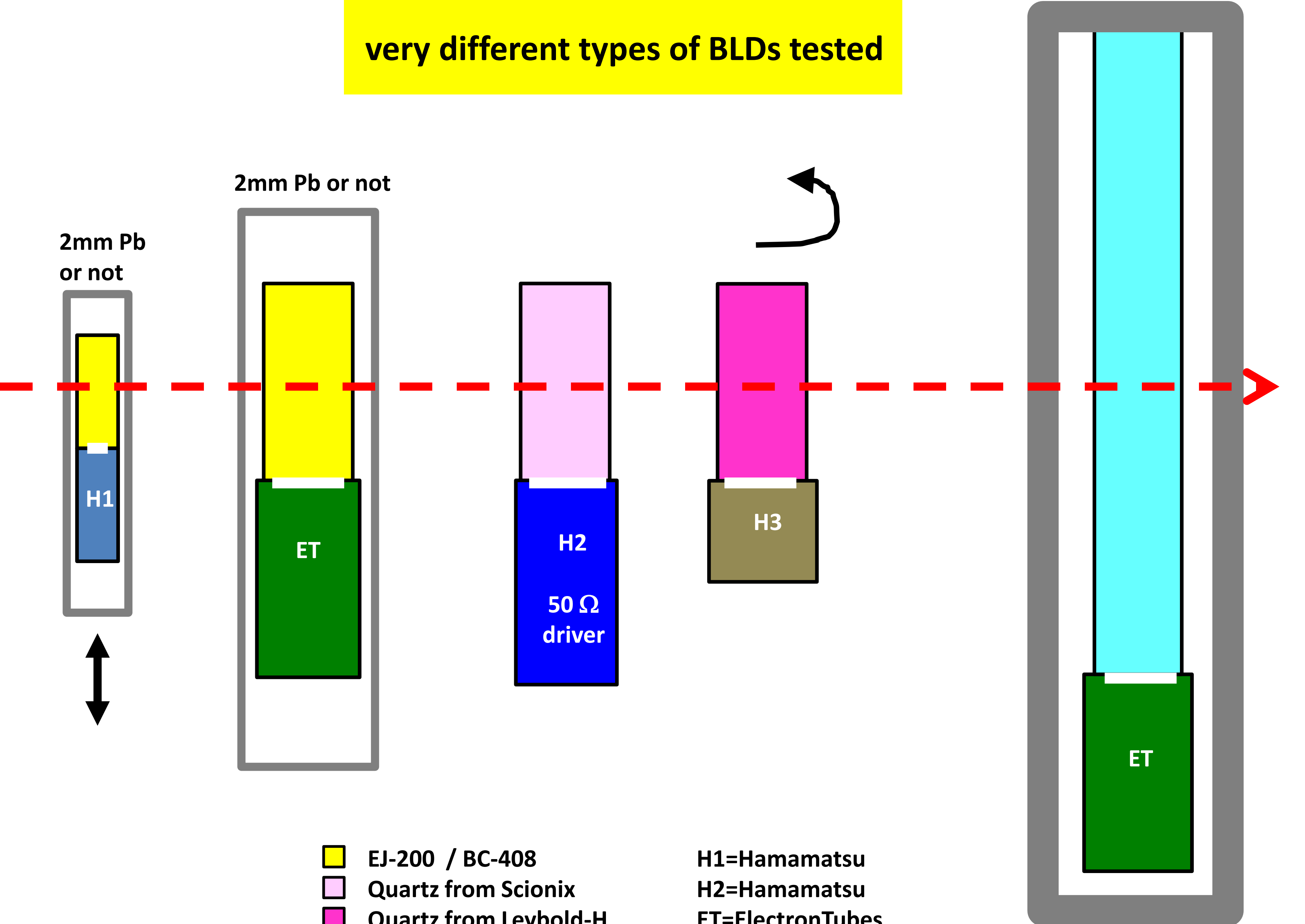
4) purpose : asses the BLD system on coping with (extreme) strong levels of losses

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



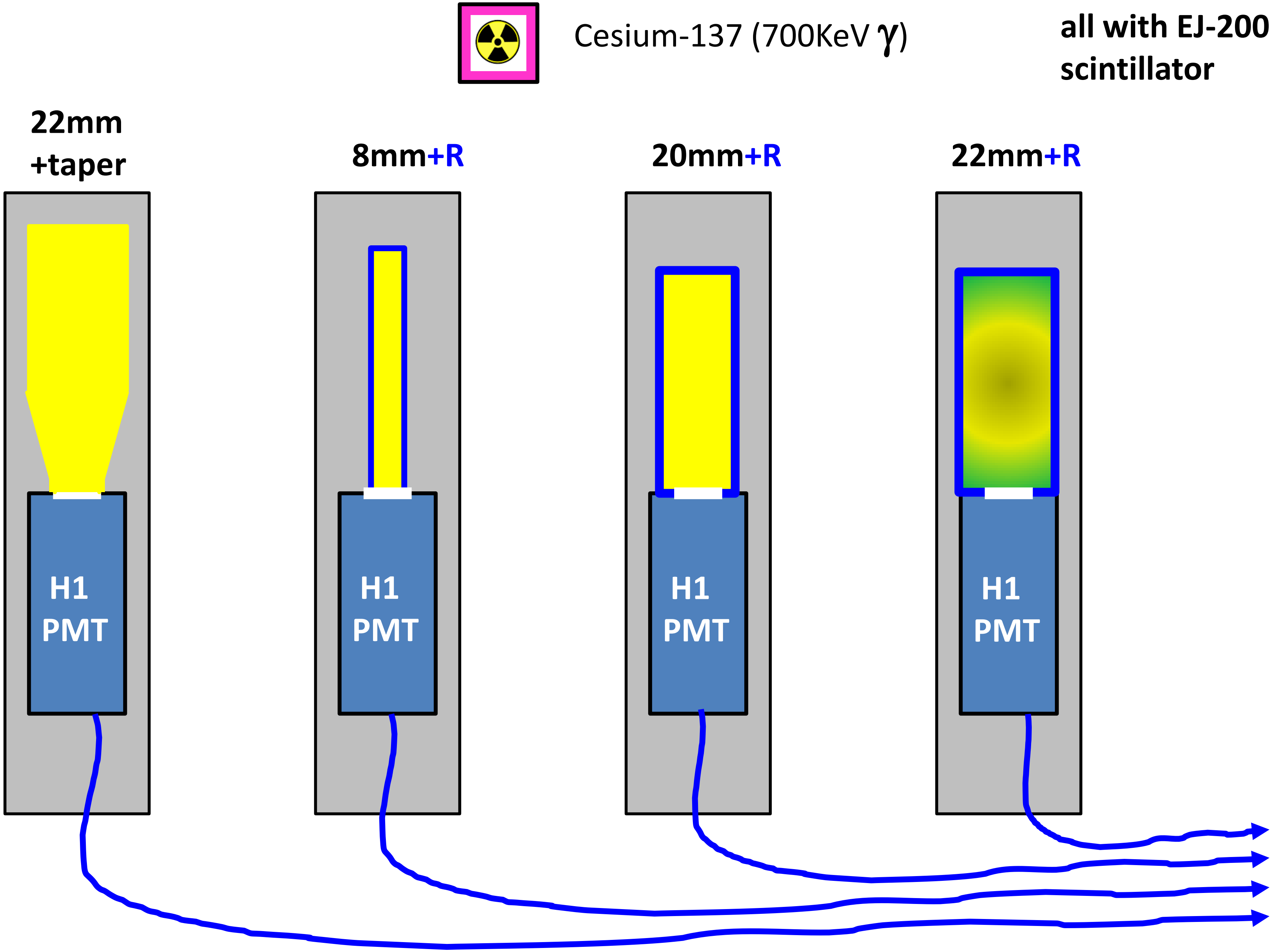
1) only possible during MDTs
2) LINAC gun OFF → "dark-current" = typically a handfull of electrons per shot
3) weak Single-Bunch + attenuating screens in the TL-1 and TL-2 → 0 to 1 electron
4) purpose : asses the BLD system on detecting (extreme) low-levels of losses

very different types of BLDs tested

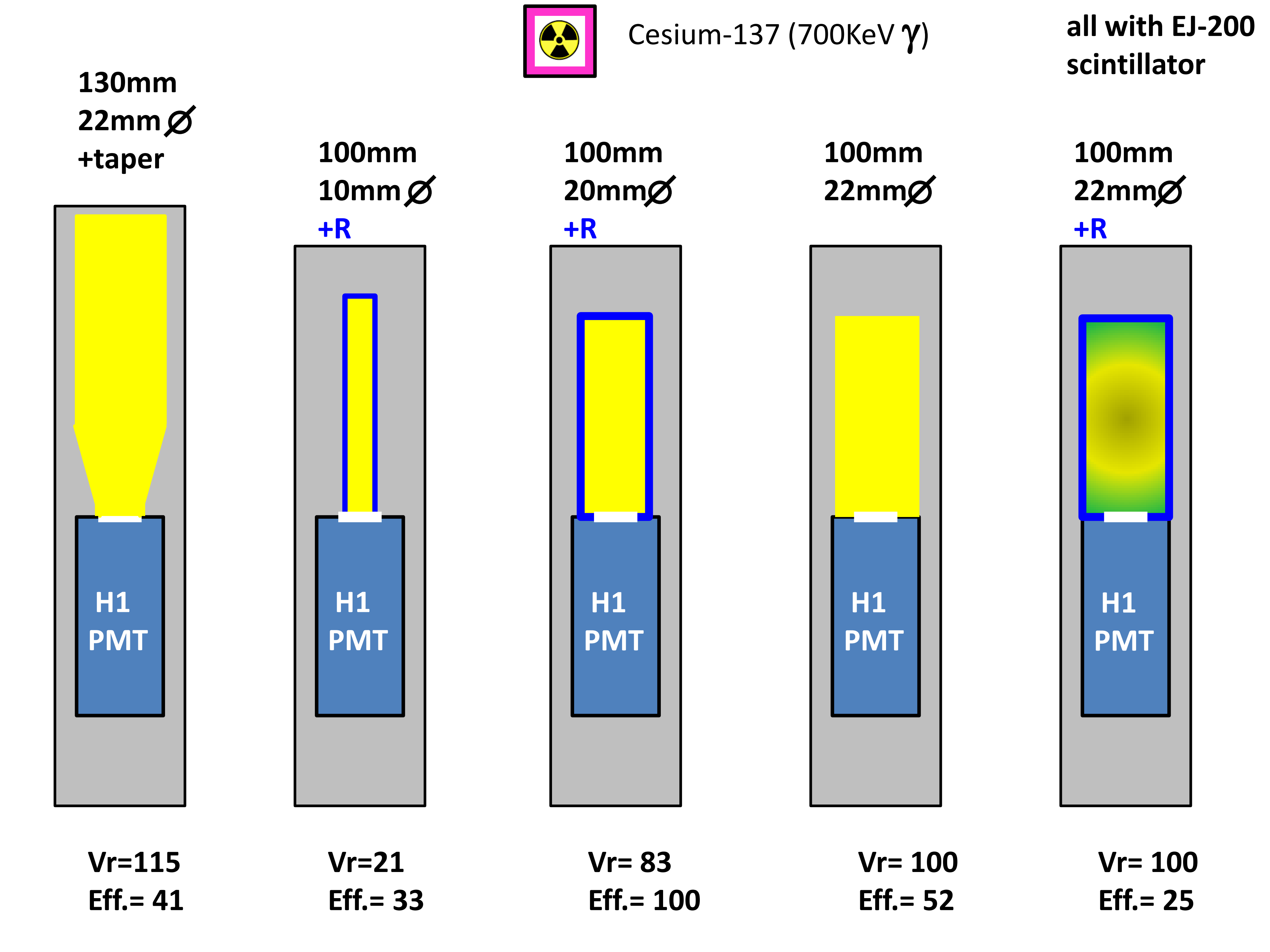


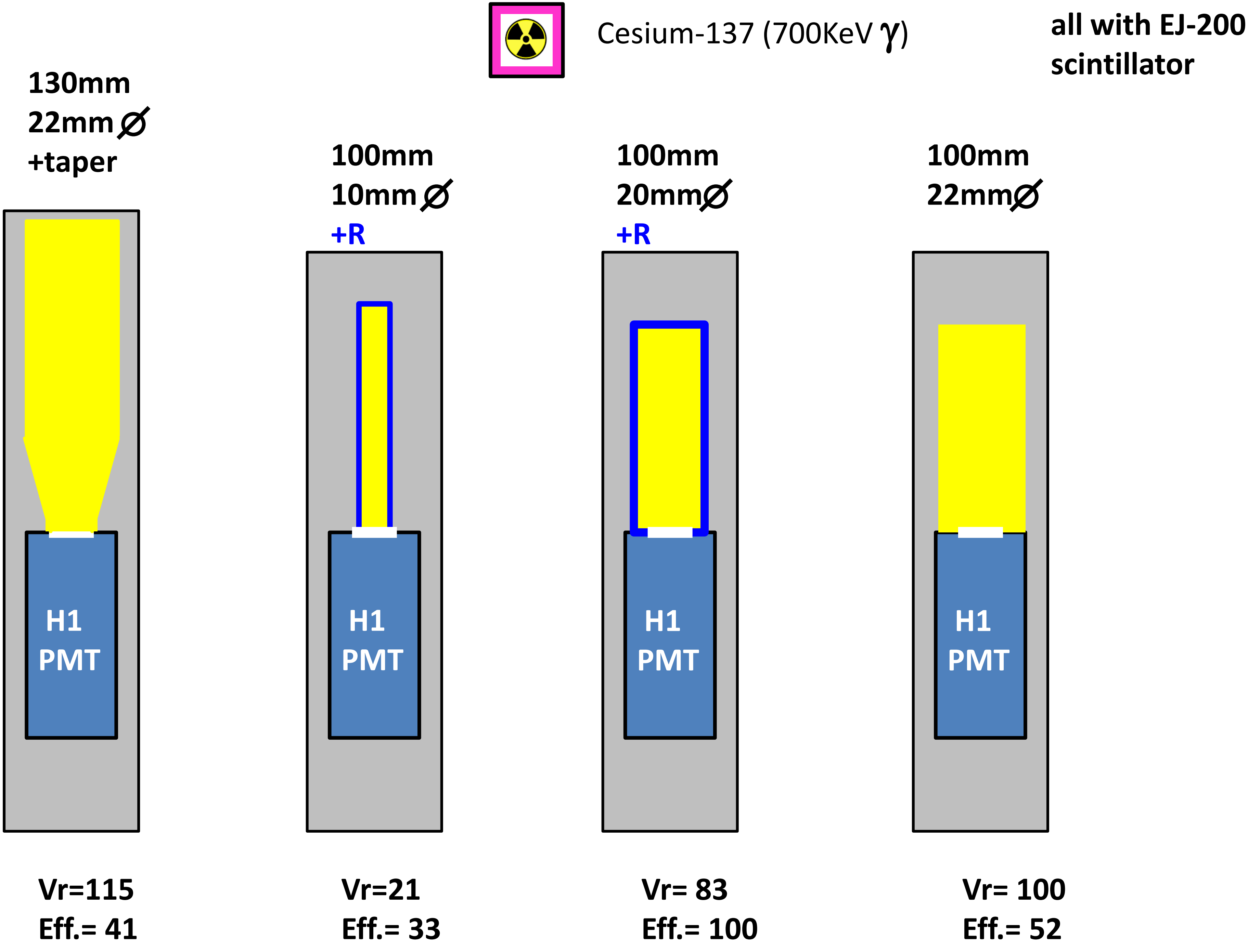
EJ-200 / BC-408
Quartz from Scionix
Quartz from Leybold-H
Perspex

H1=Hamamatsu
H2=Hamamatsu
ET=ElectronTubes
H3=Hamamatsu/DESY



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


Cesium-137 (700KeV γ)
all with EJ-200 scintillator
130mm
22mm Ø
+taper
100mm
10mm Ø
+R
100mm
20mm Ø
+R
100mm
22mm Ø
100mm
22mm Ø
+R
H1 PMT
H1 PMT
H1 PMT
H1 PMT
H1 PMT
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 Ø
+taper
100mm
10mm Ø
+R
100mm
20mm Ø
+R
100mm
22mm Ø
H1 PMT
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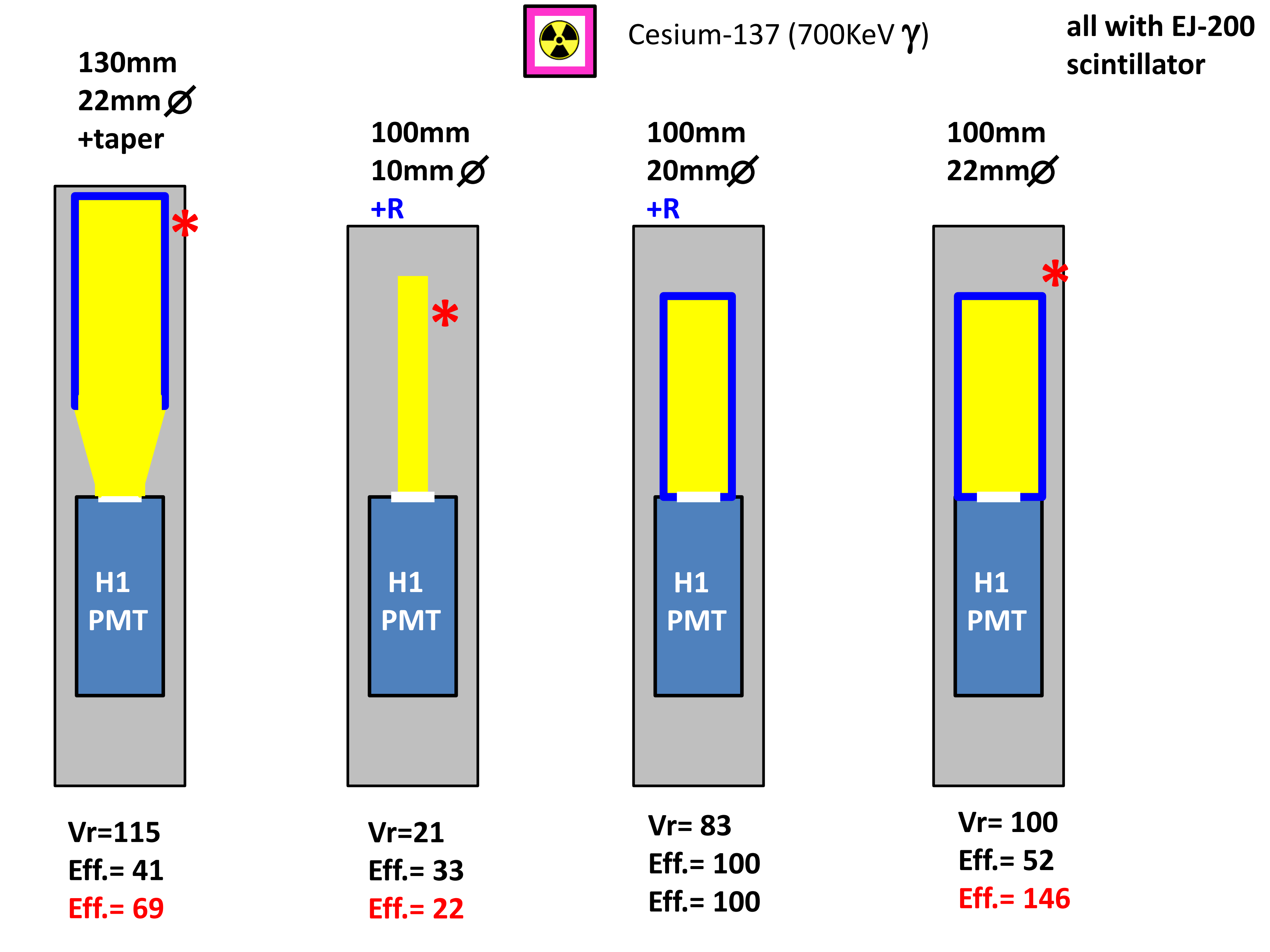
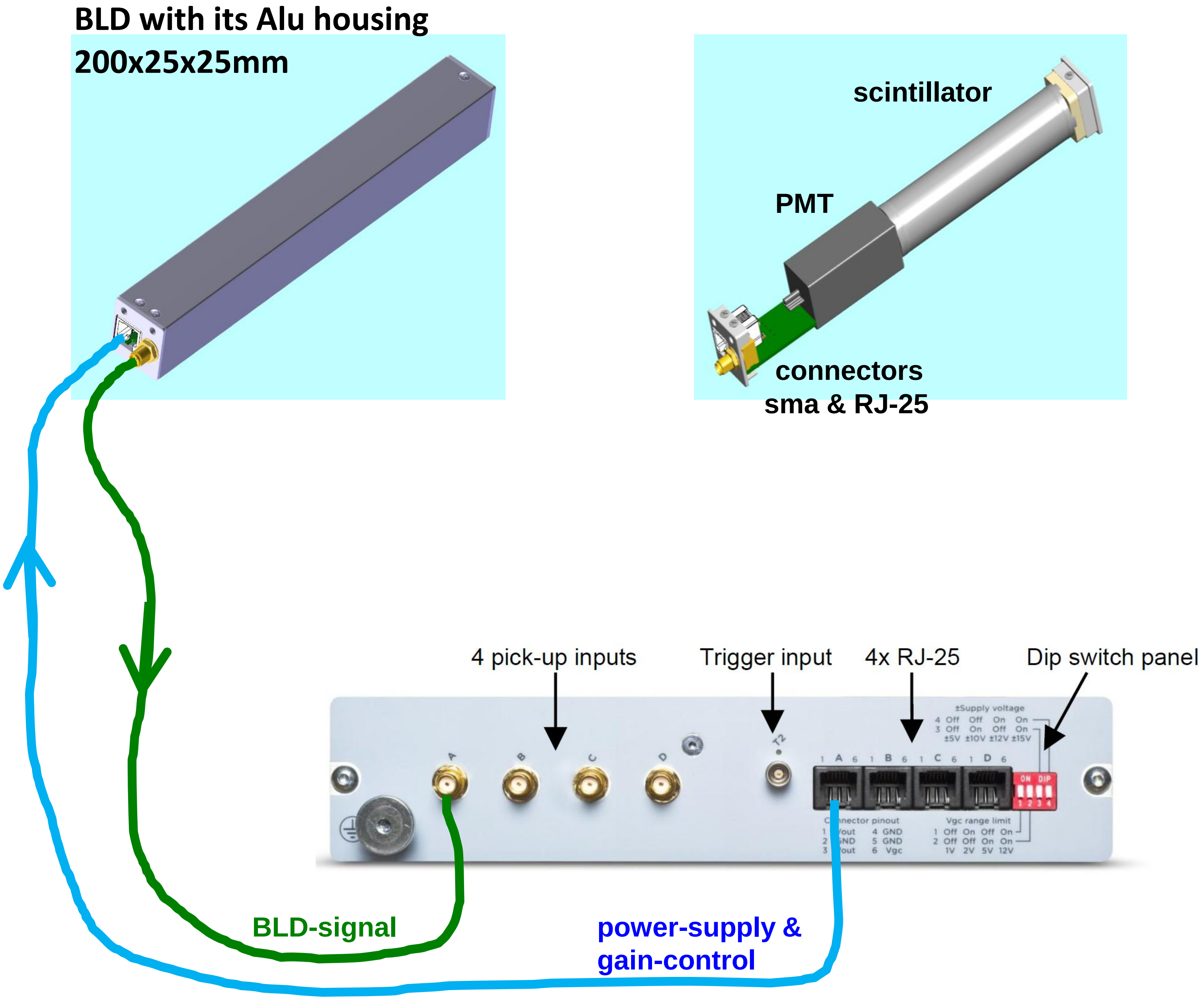
Eff.= 52

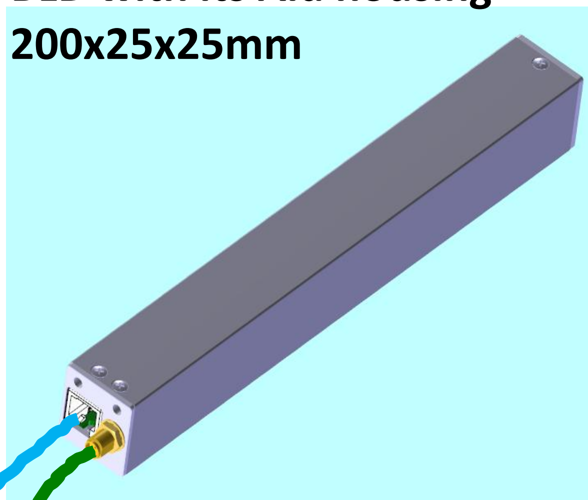


Cesium-137 (700KeV γ)
all with EJ-200
scintillator
130mm
22mm ∅
+taper
100mm
10mm ∅
+R
100mm
20mm∅
+R
100mm
22mm∅
H1
PMT
H1
PMT
H1
PMT
H1
PMT
*
*
*
Vr=115
Eff.= 41
Eff.= 69
Vr=21
Eff.= 33
Eff.= 22
Vr= 83
Eff.= 100
Eff.= 100
Vr= 100
Eff.= 52
Eff.= 146



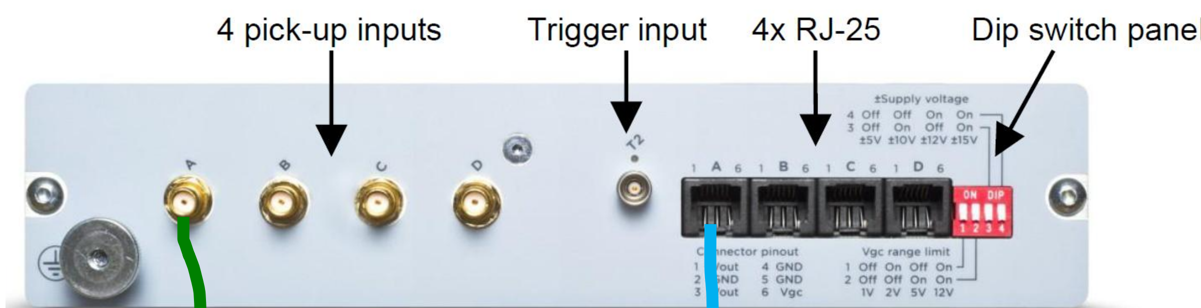
BLD with its Alu housing
200x25x25mm
scintillator
PMT
connectors
sma & RJ-25
4 pick-up inputs
Trigger input
4x RJ-25
Dip switch panel
±Supply voltage
4 Off Off On On
3 Off On Off On
±5V ±10V ±12V ±15V
1 A 6 1 B 6 1 C 6 1 D 6
ON DIP
1 2 3 4
4 GND
5 GND
6 Vgc
Vgc range limit
1 Off On Off On
2 Off Off On On
1V 2V 5V 12V
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



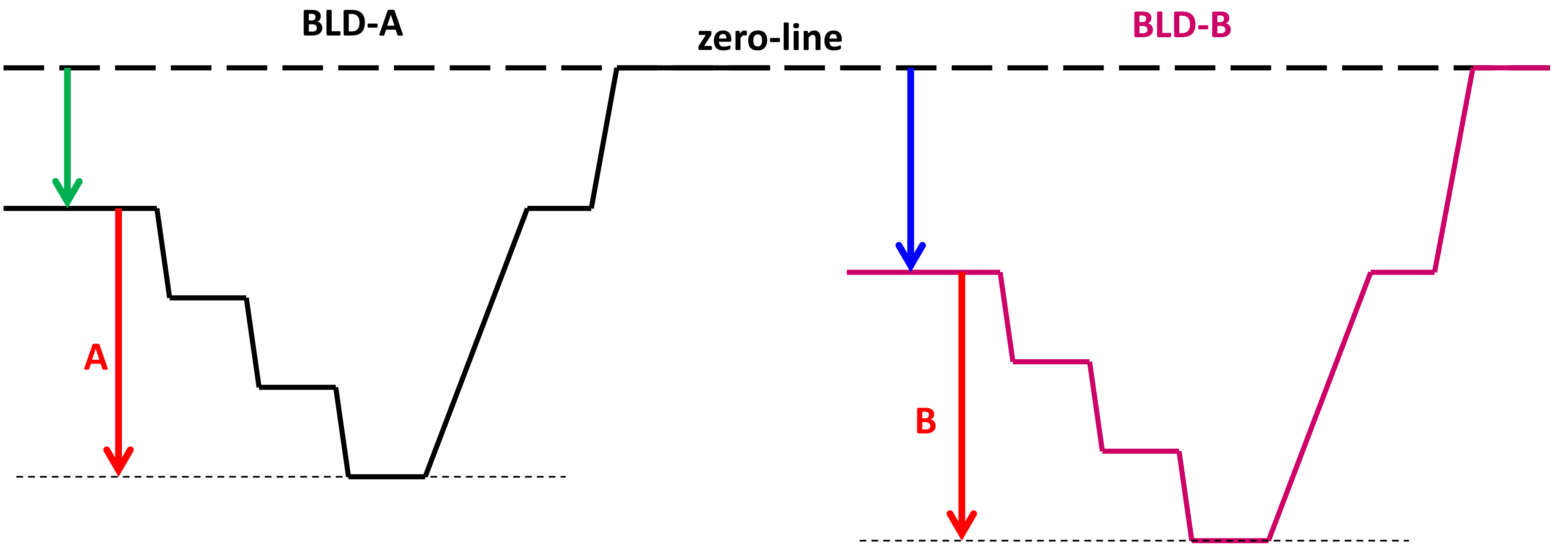
BLD-signal

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 ?

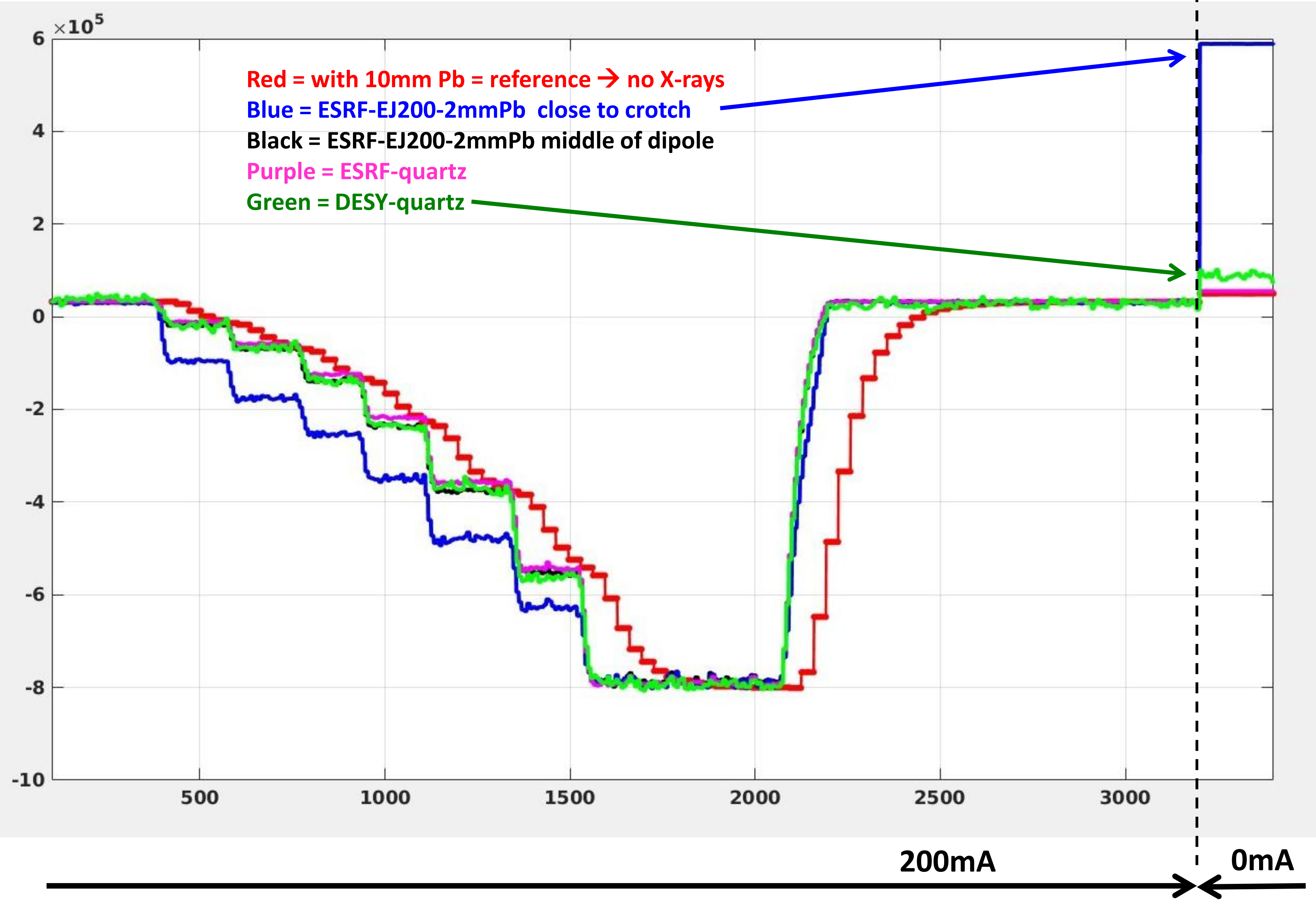


= e-losses (only)

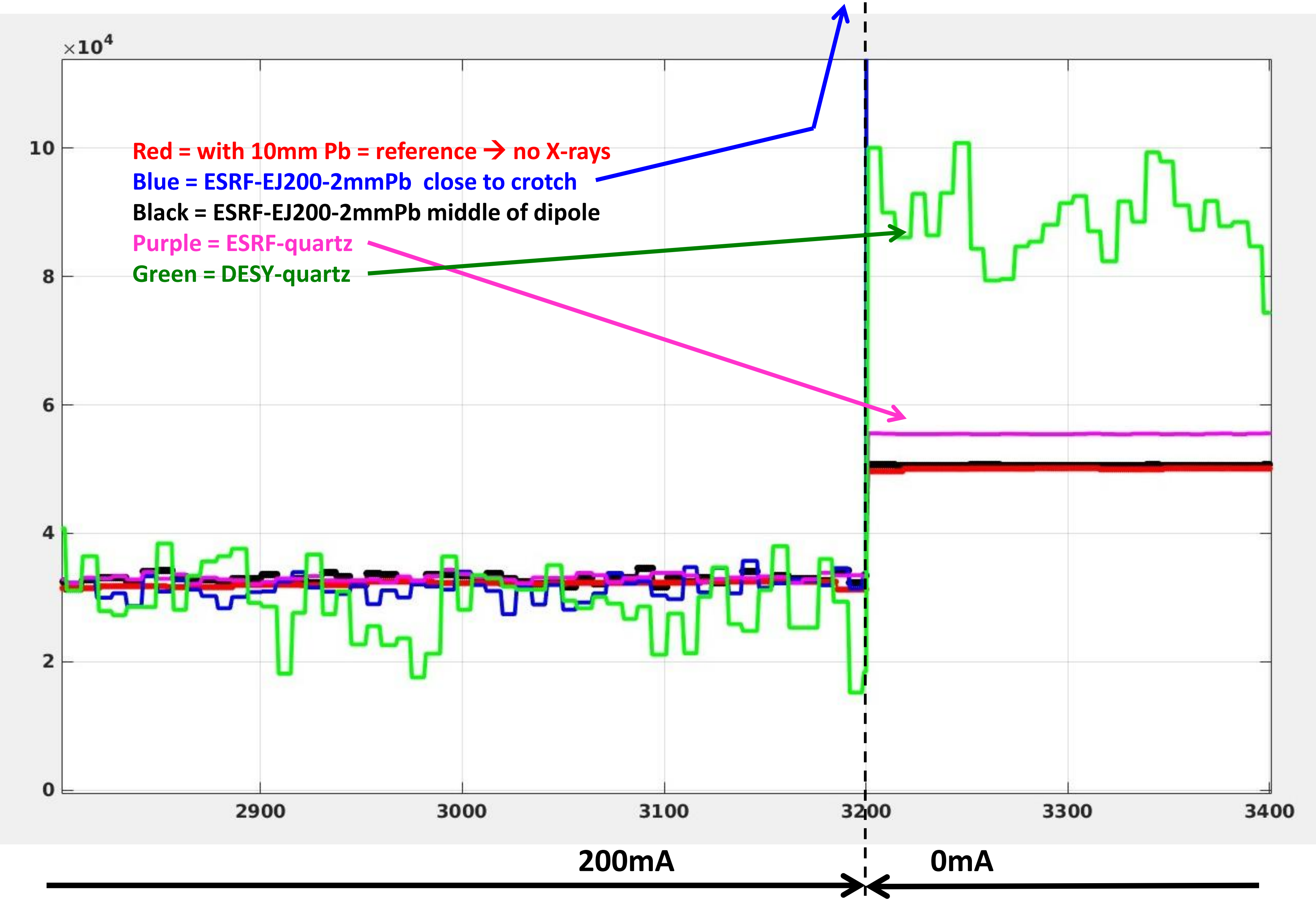
= e-losses + X-rays (?)

= 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):

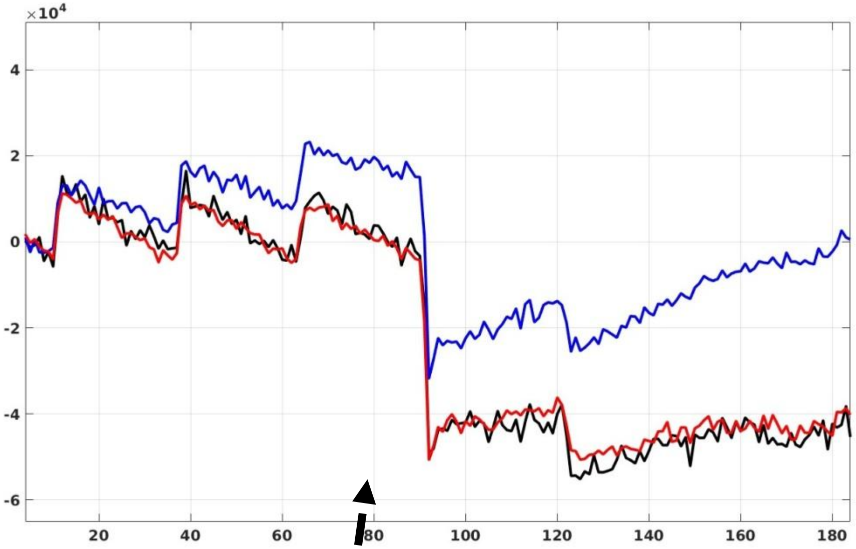
Red= DESY=Cherenkov

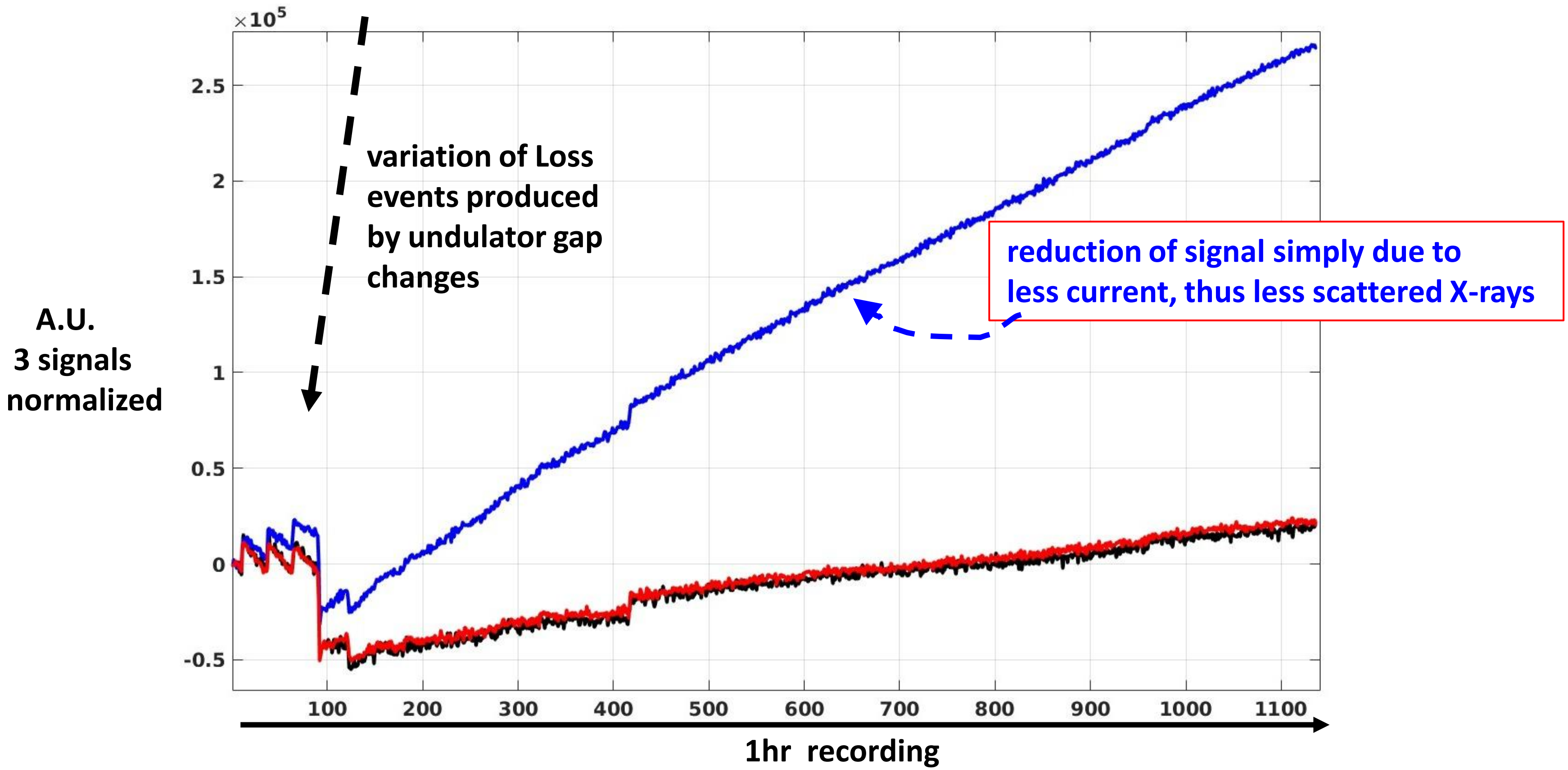
Black= ESRF-2mmPb -mi-Dipole

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

conclusion :

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



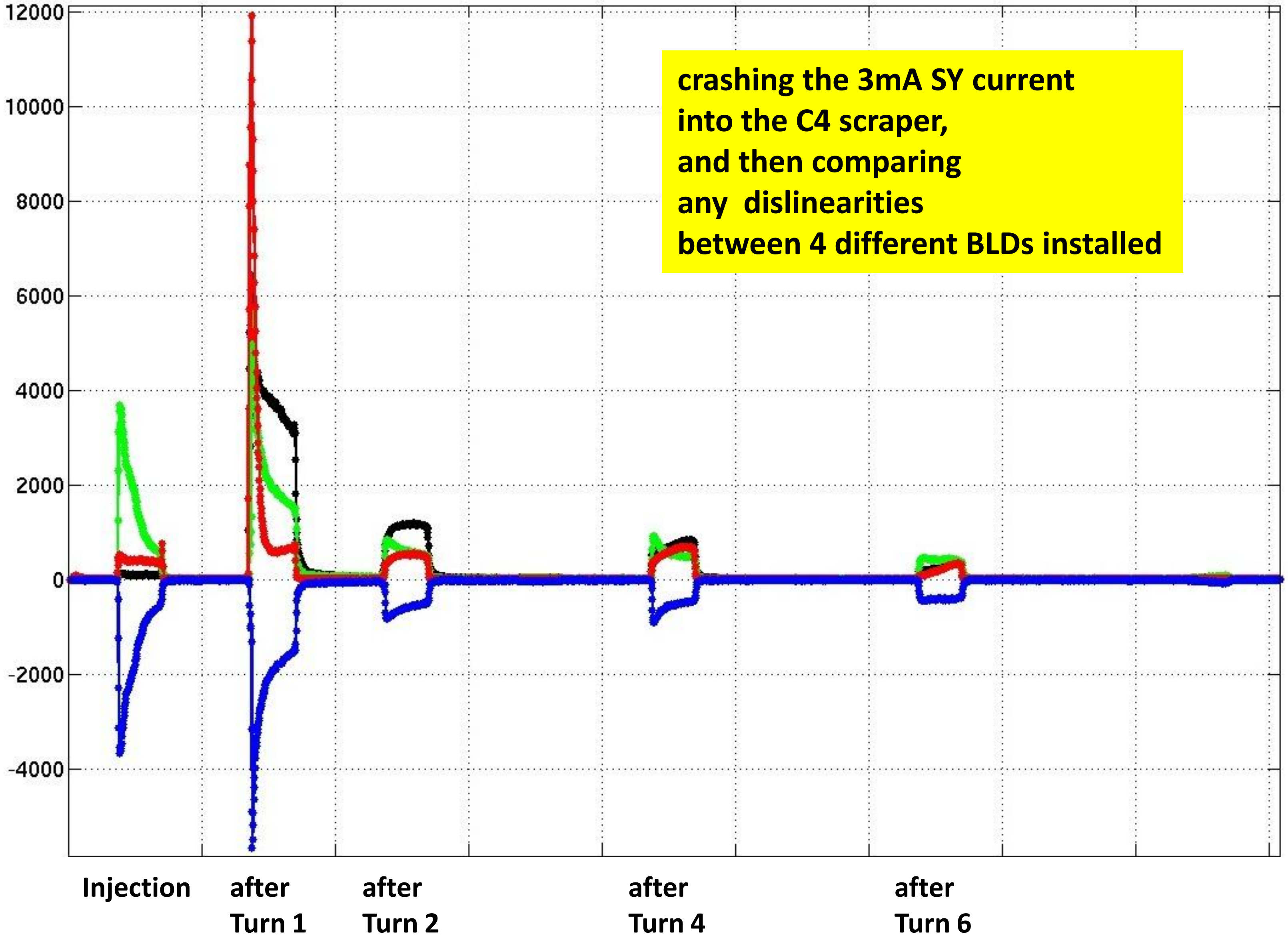


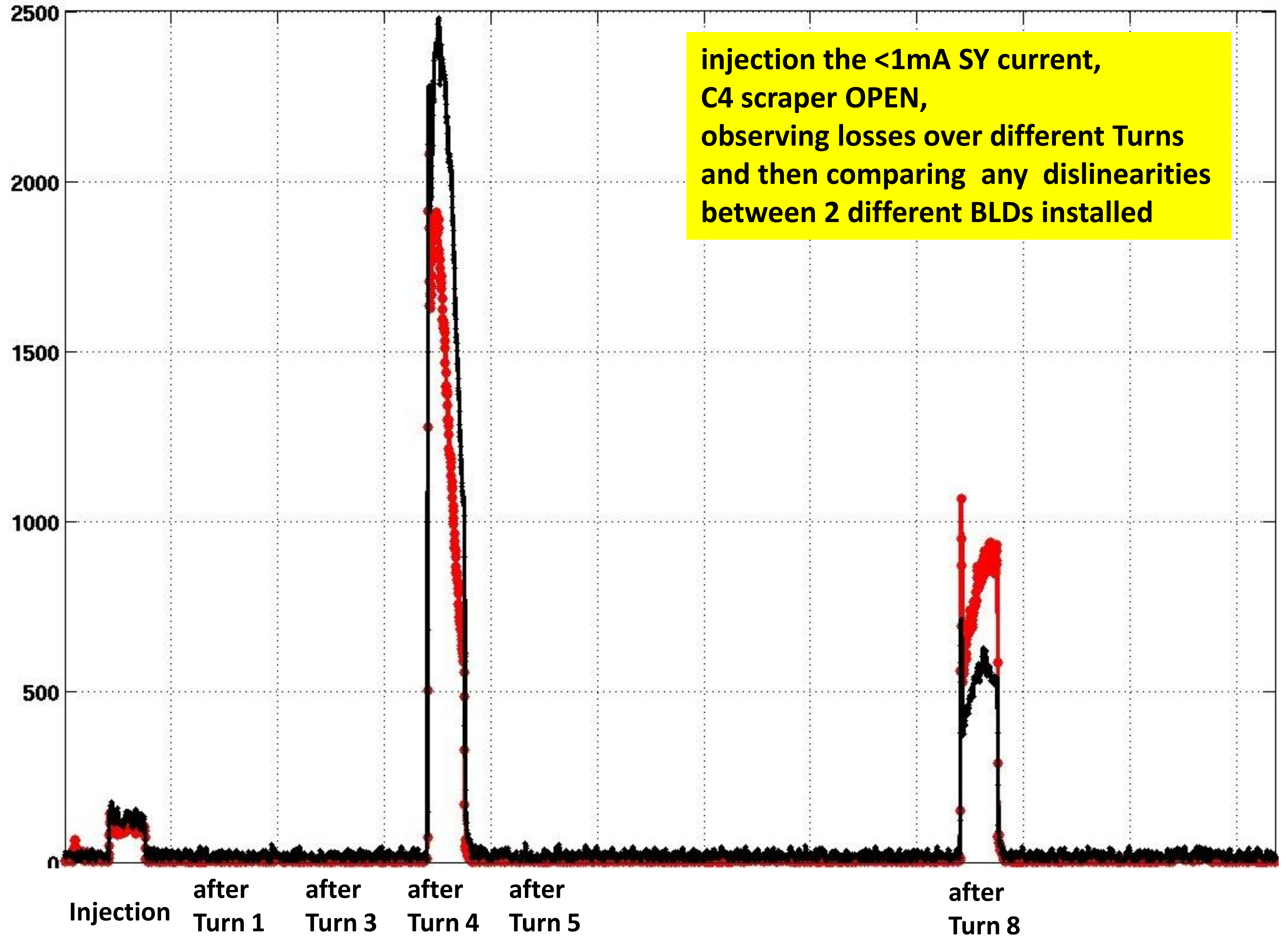
	Cherenkov-radiator	versus	Gamma-scintillator
	Quartz-glass		EJ-200 or BC-408
PROS :	no need for Pb shielding since immune to X-rays (?) therefore : - less volume - less weight - compact		- high light yield - cheap material
CONS :	- low light yield - more expensive		needs Pb shielding - bulky & heavy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

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 (....)

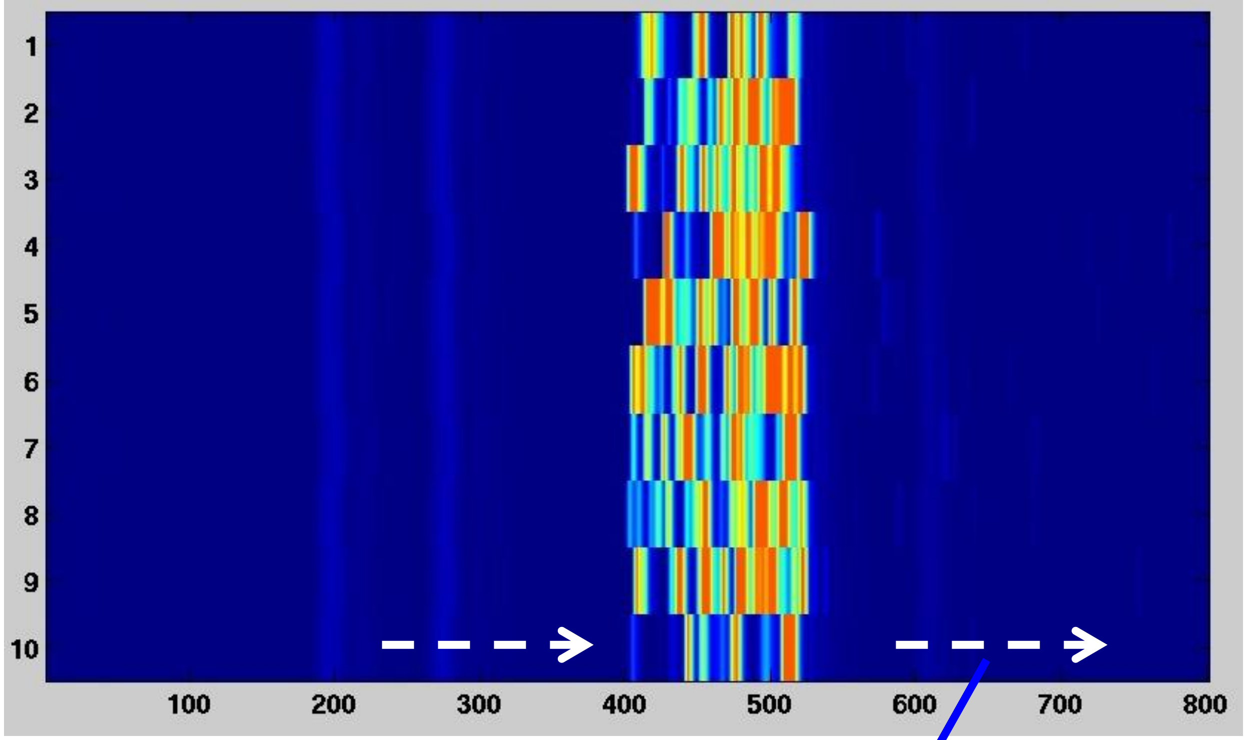
then the BLD based on Cherenkov-radiator

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



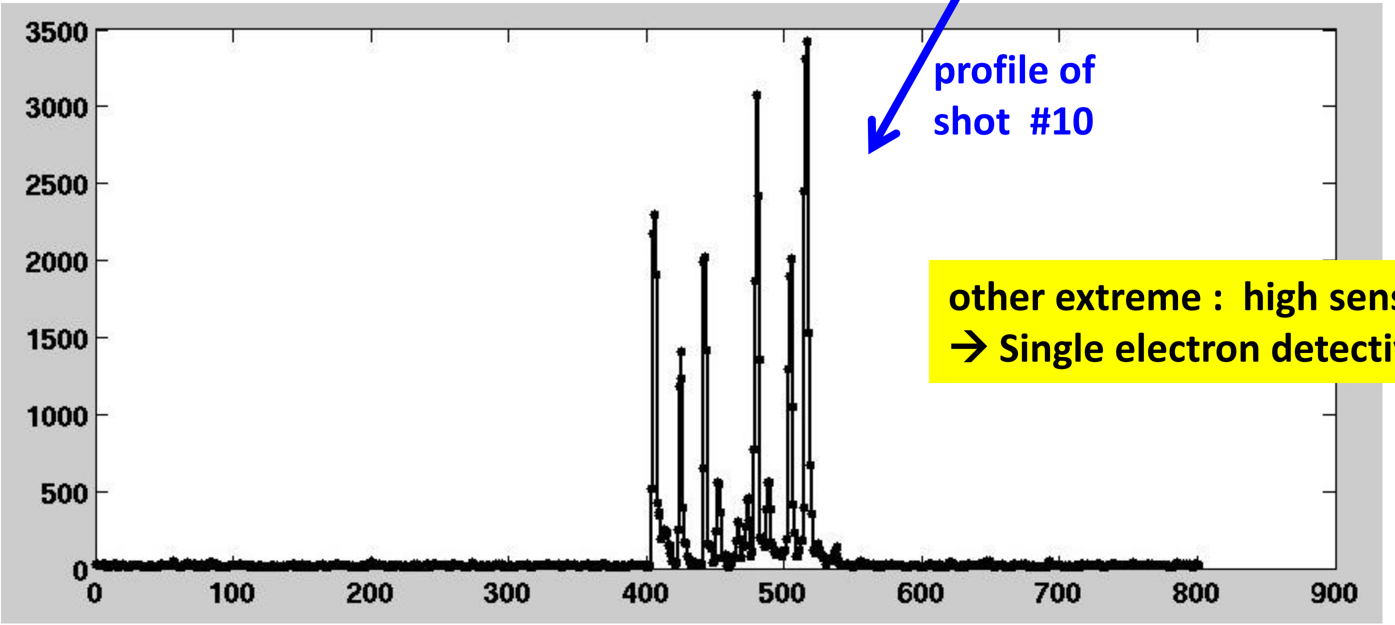


injection the <1mA SY current,
C4 scraper OPEN,
observing losses over different Turns
and then comparing any dislinearities
between 2 different BLDs installed
2500
2000
1500
1000
500
0
Injection
after Turn 1
after Turn 3
after Turn 4
after Turn 5
after Turn 8



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

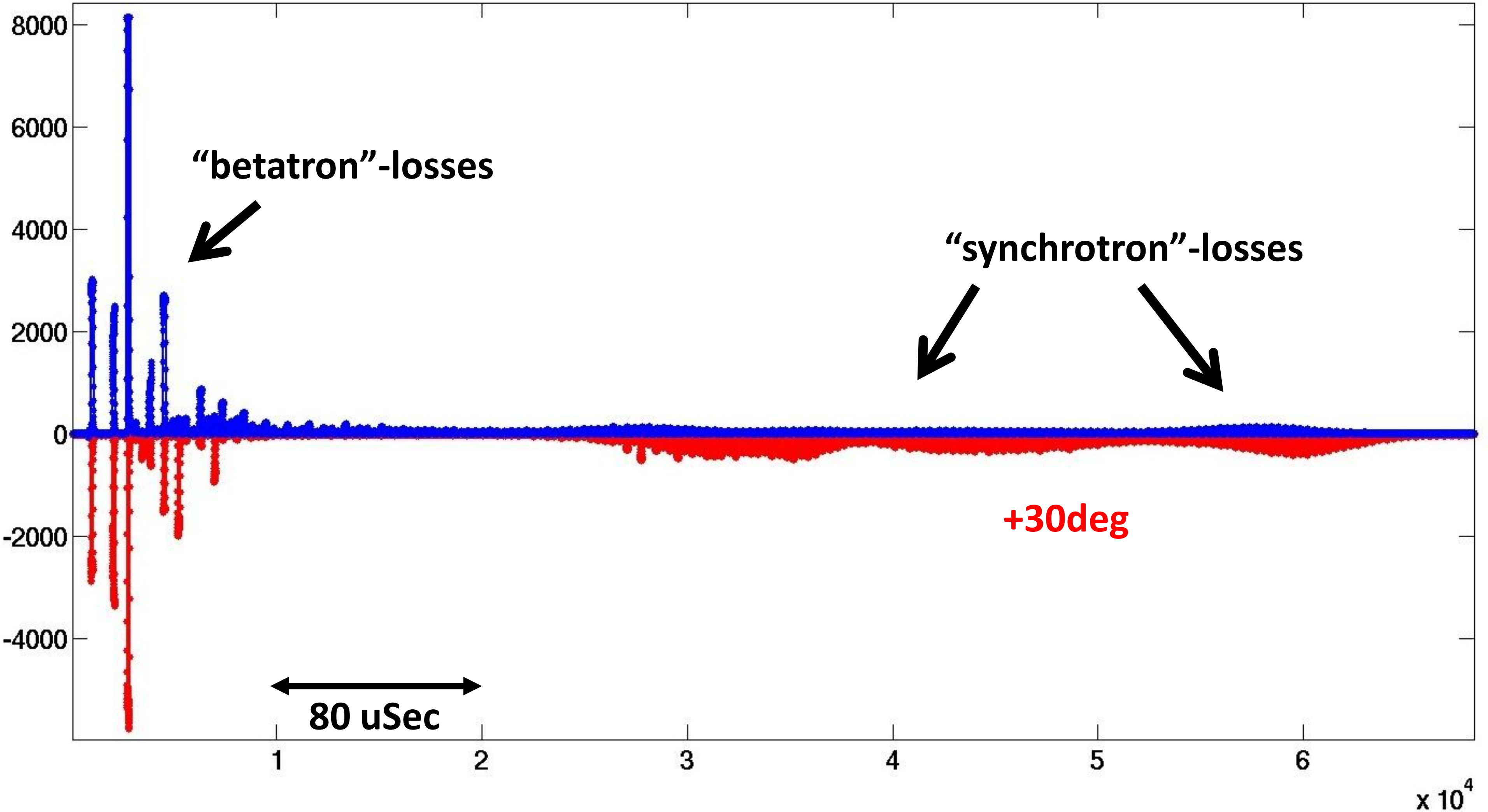
profile of shot #10



other extreme : high sensitivity
→ Single electron detectivity

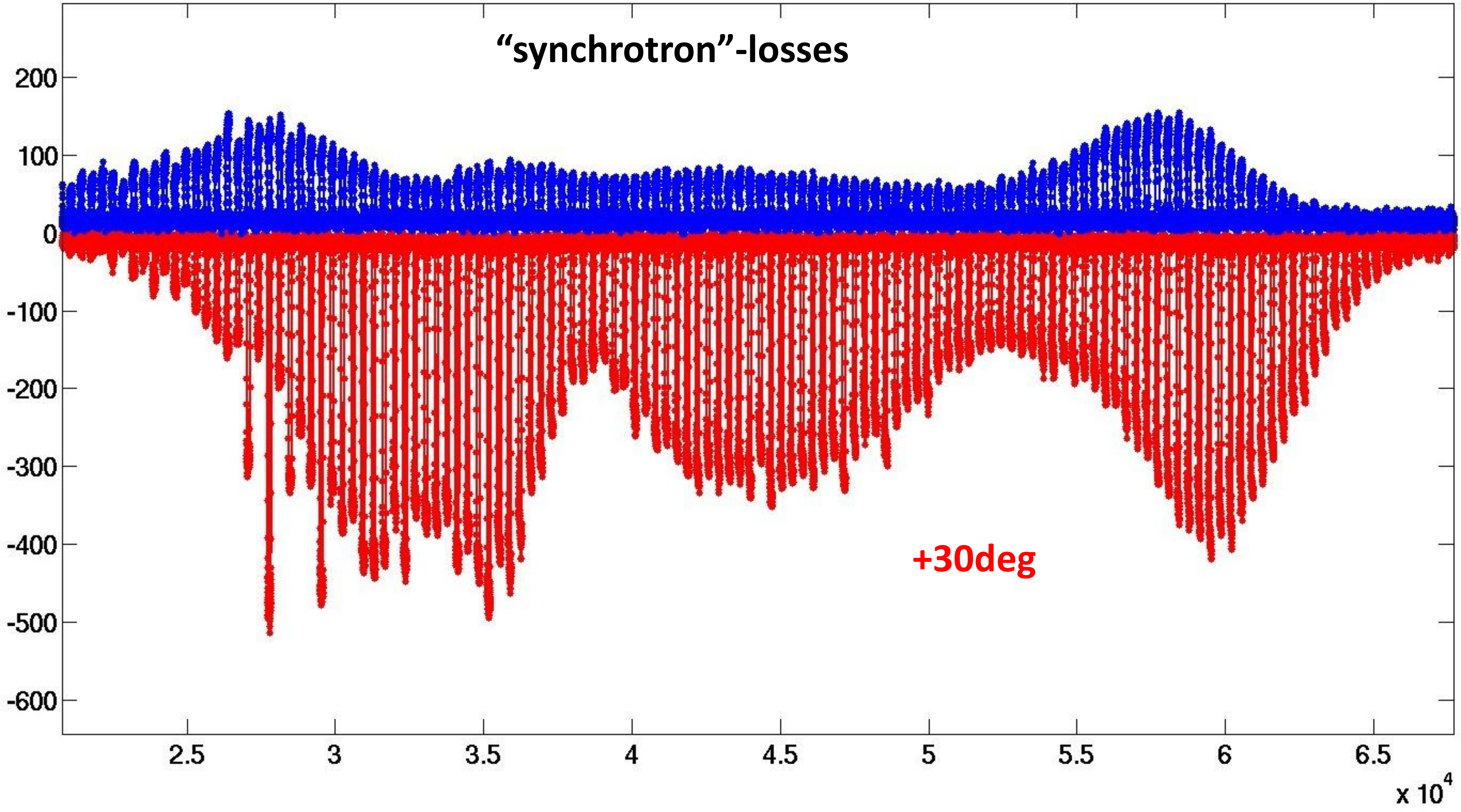
time-resolved losses of injected beam at different RF phases :
nominal (blue) and +30deg (red)

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

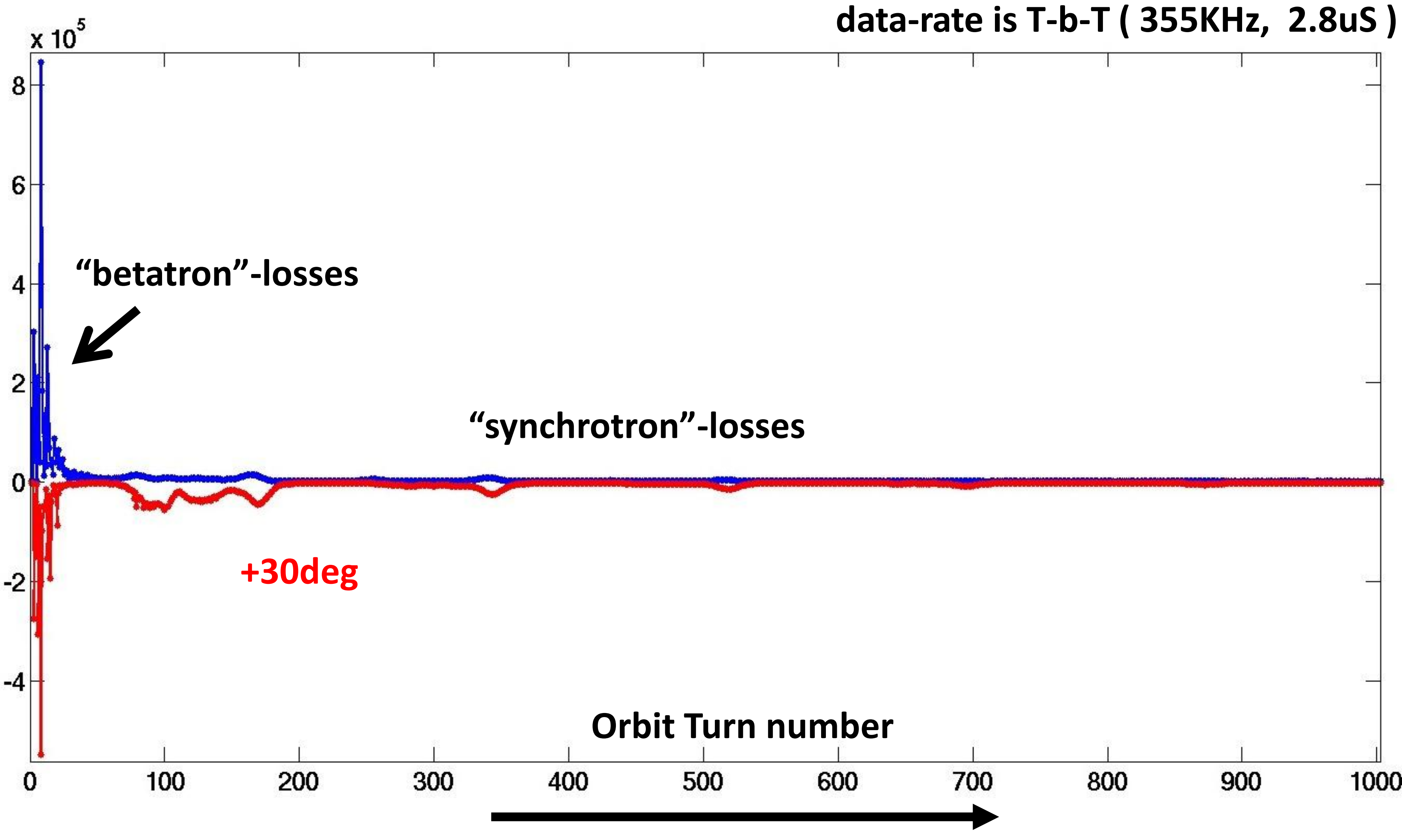


time-resolved losses of injected beam at different RF phases :
nominal (blue) and +30deg (red)

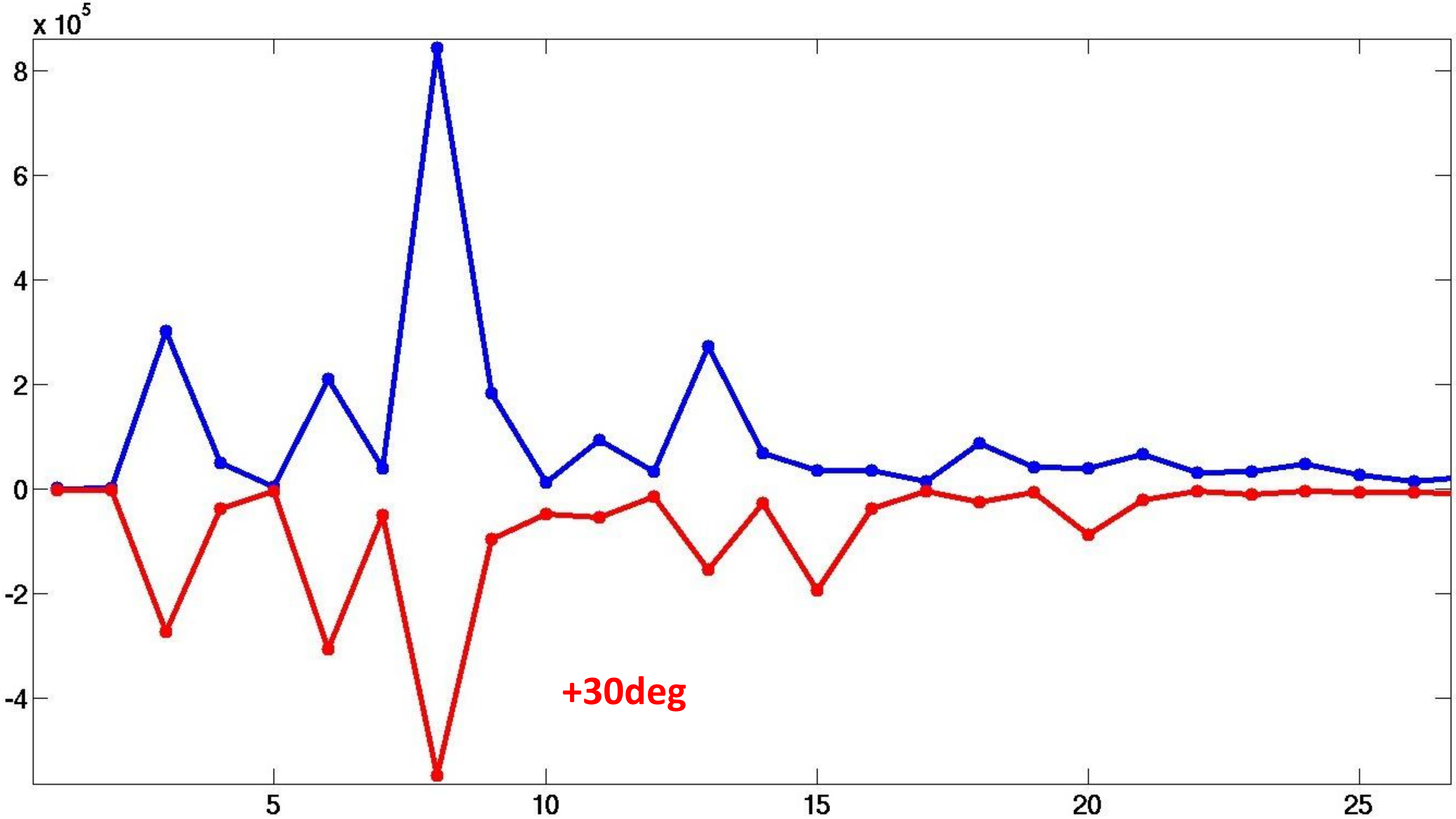
data-rate is ADC (125MHz, 8nS)



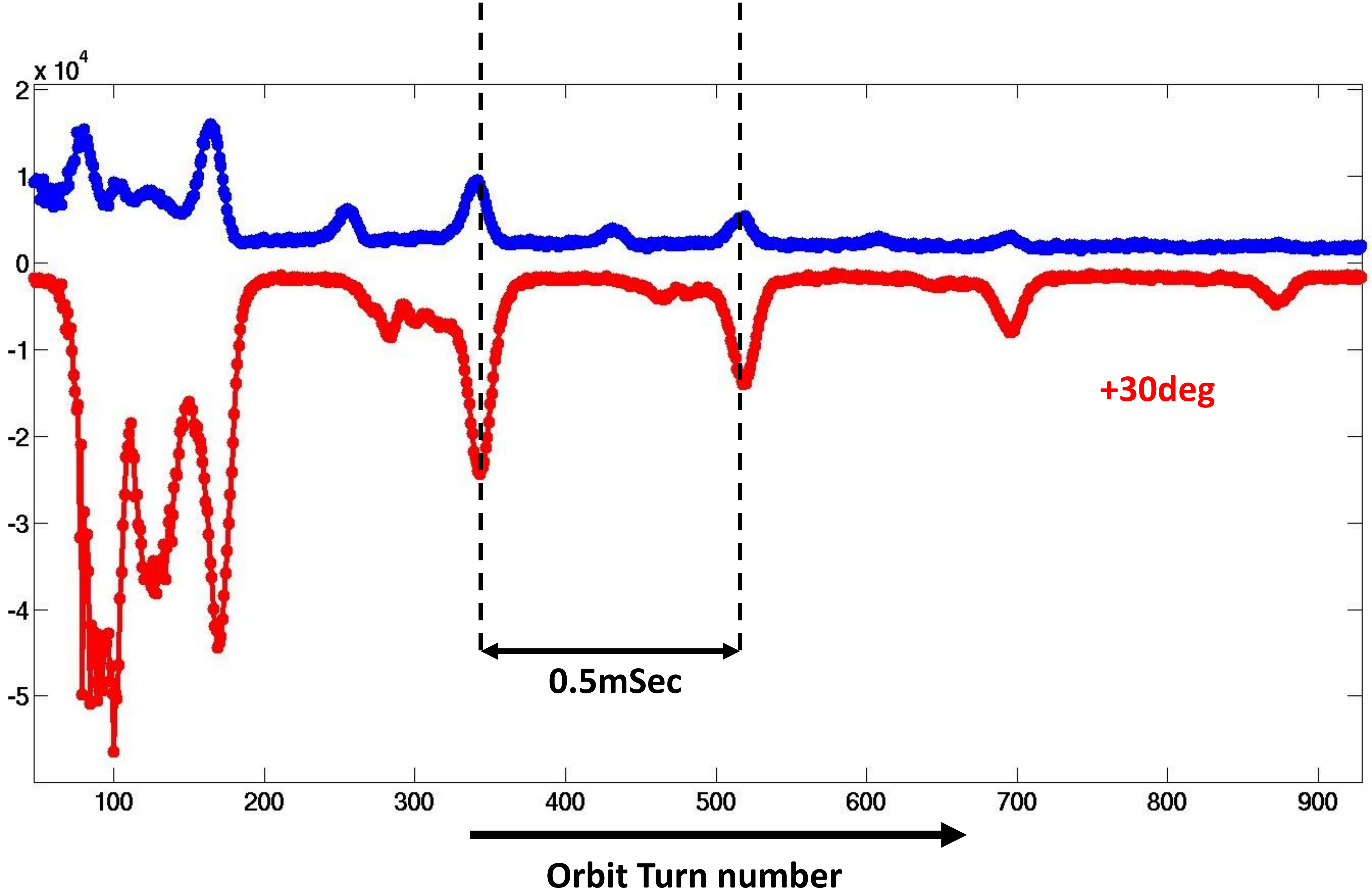
time-resolved losses of injected beam at different RF phases :
nominal (blue) and +30deg (red)



“betatron”-losses in the first 20 turns



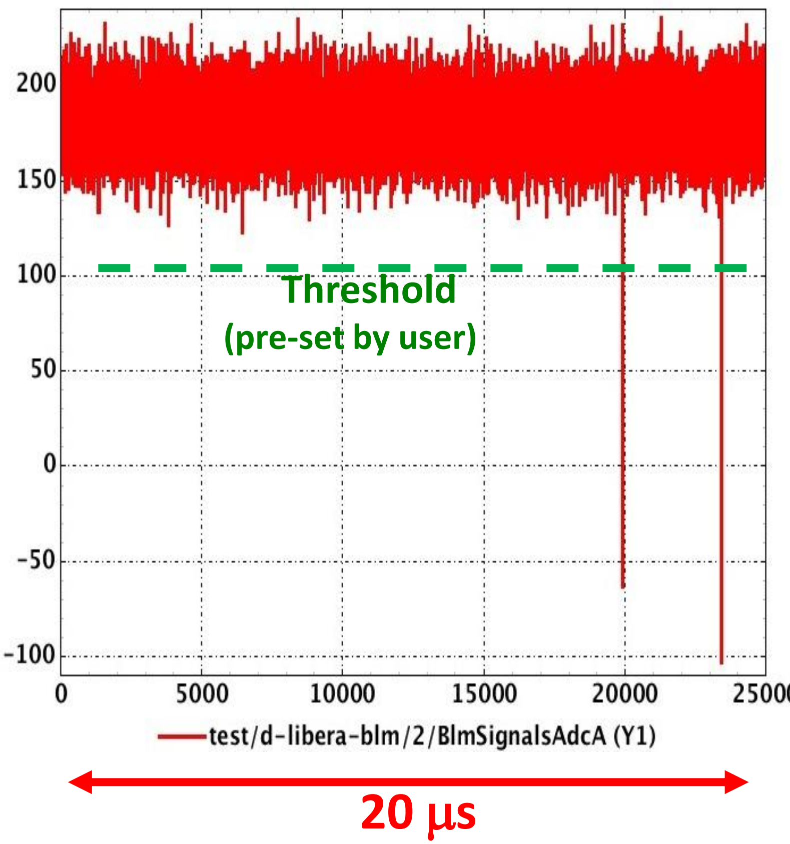
Orbit Turn number

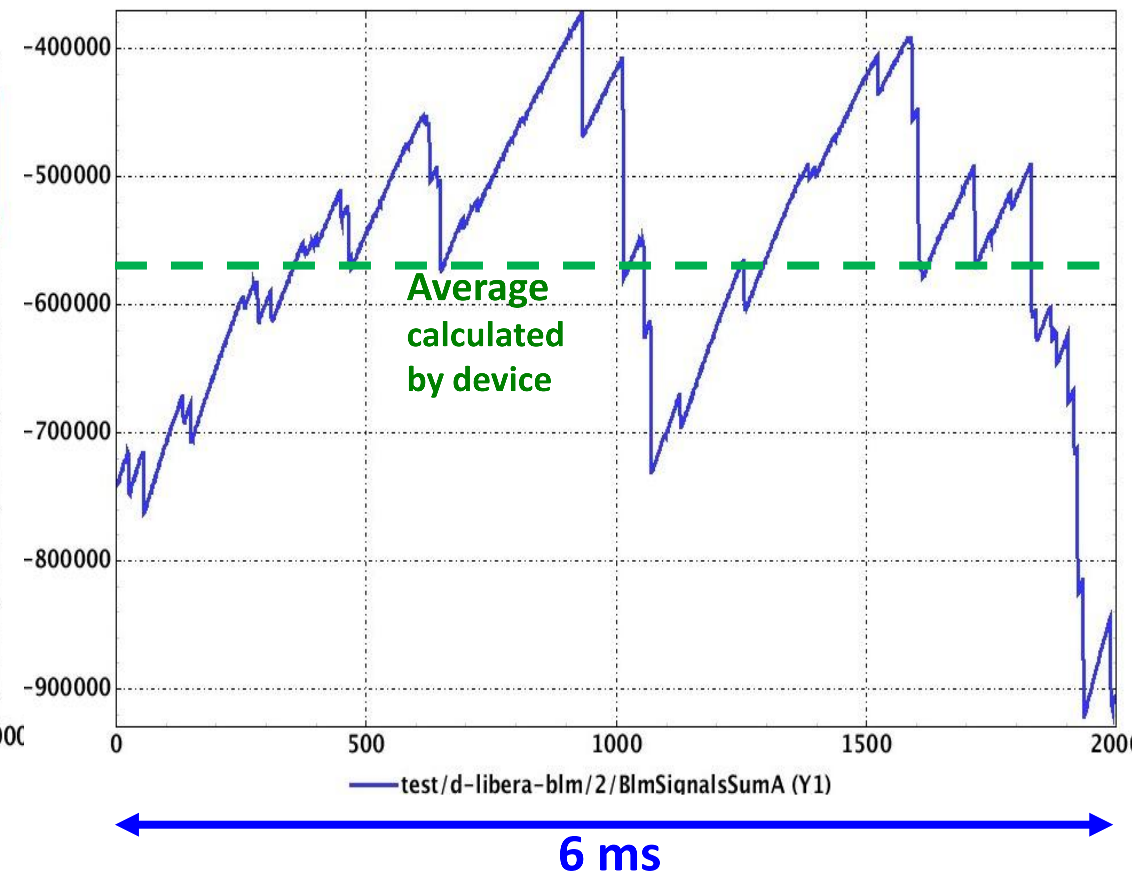


x 10^4
2
1
0
-1
-2
-3
-4
-5
100
200
300
400
500
600
700
800
900
+30deg
0.5mSec
Orbit Turn number

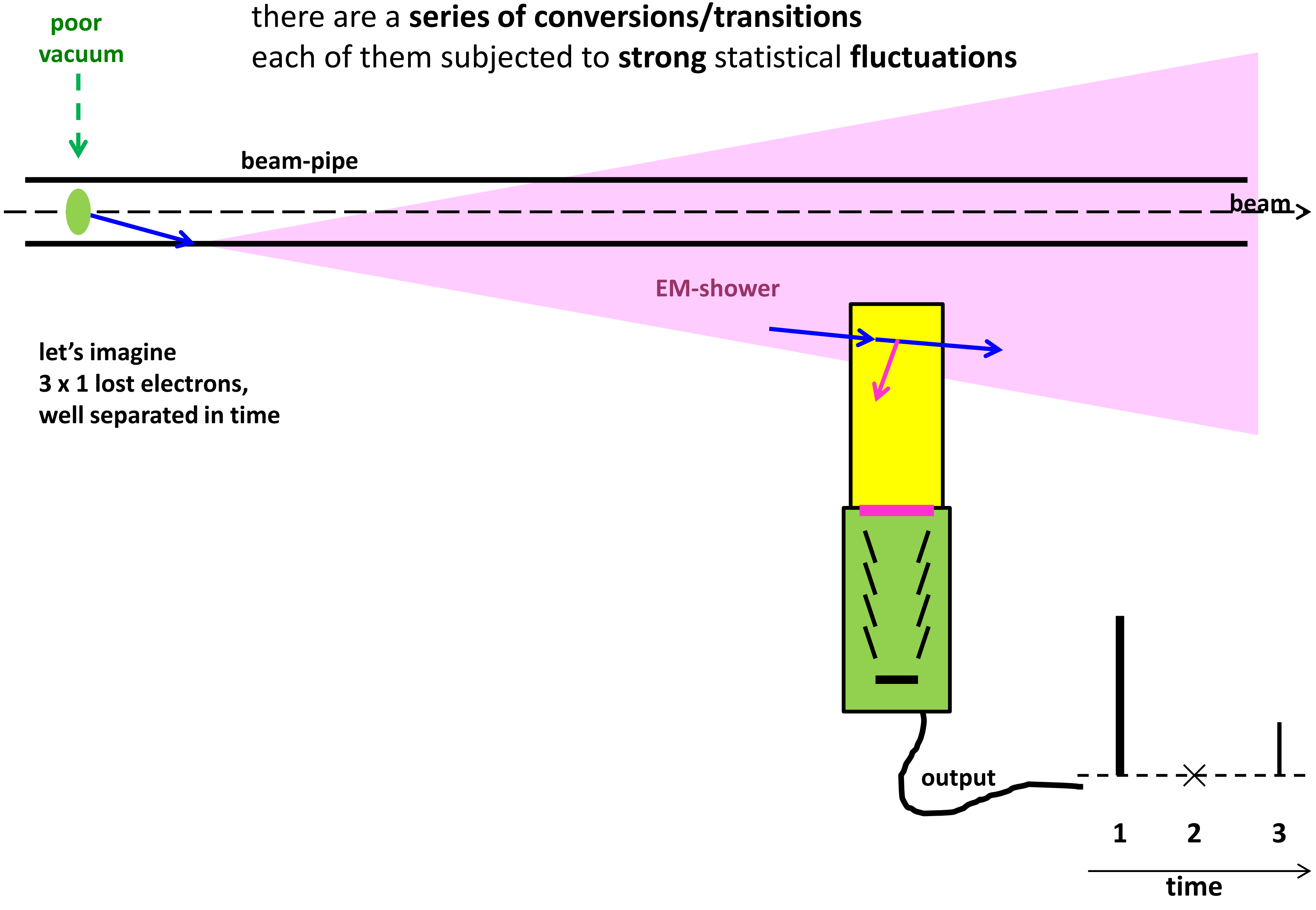
Counting-mode versus **Integrating-mode**

50 Ω — **Hi-Z**





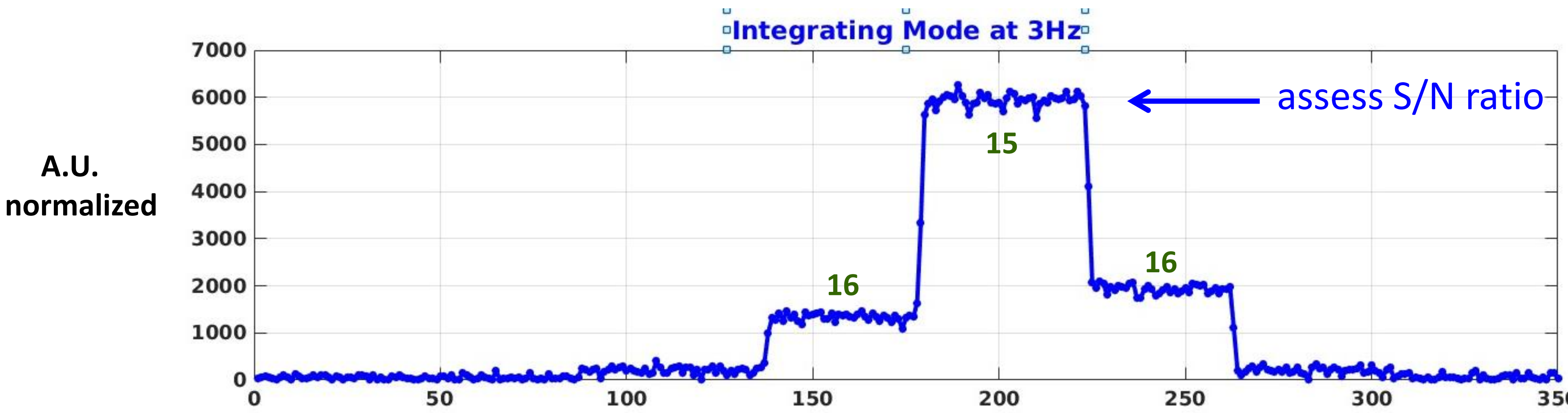
between the event of a lost electron
and the final recording of that event in the detector
there are a **series of conversions/transitions**
each of them subjected to **strong** statistical **fluctuations**

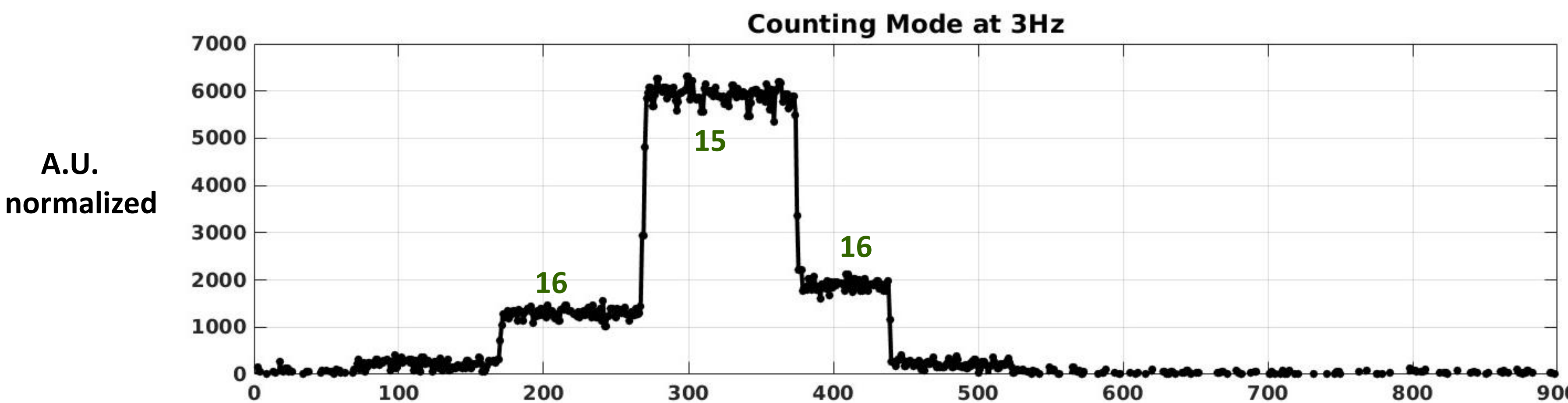


BLM-attenuator=4dB, PMT-GCV=0.55V, **scraper at 18-17-16-15-16-17-18 mm**

Integrating period = 0.37sec

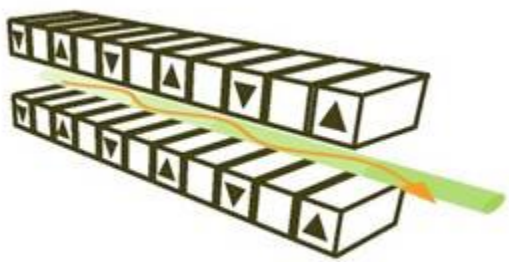
Counting period = 0.25sec





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 

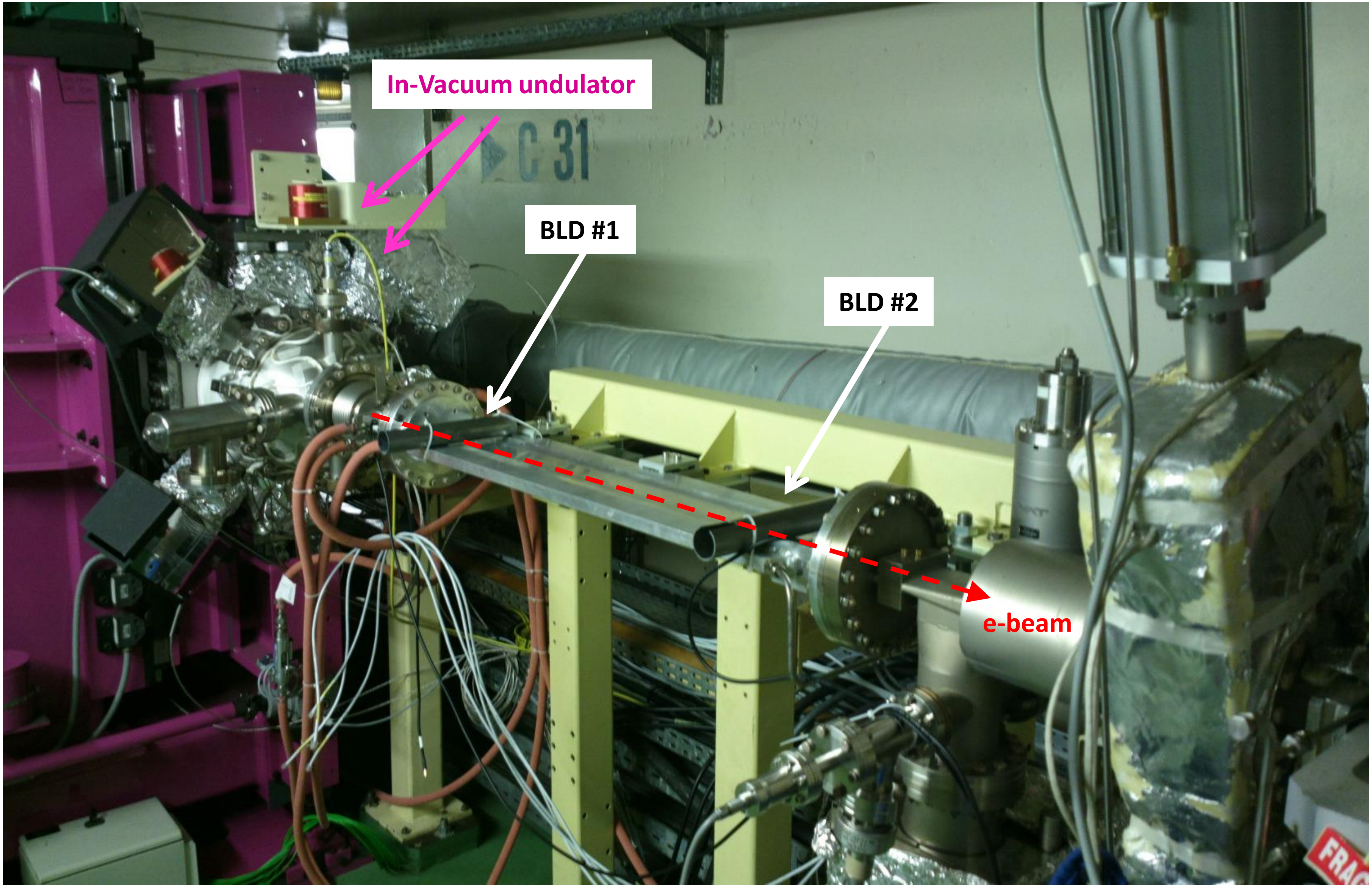
this can be a real problem in rings with smaller beam-sizes (EBS …!)
→ more scattering, less lifetime, more losses . . .

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

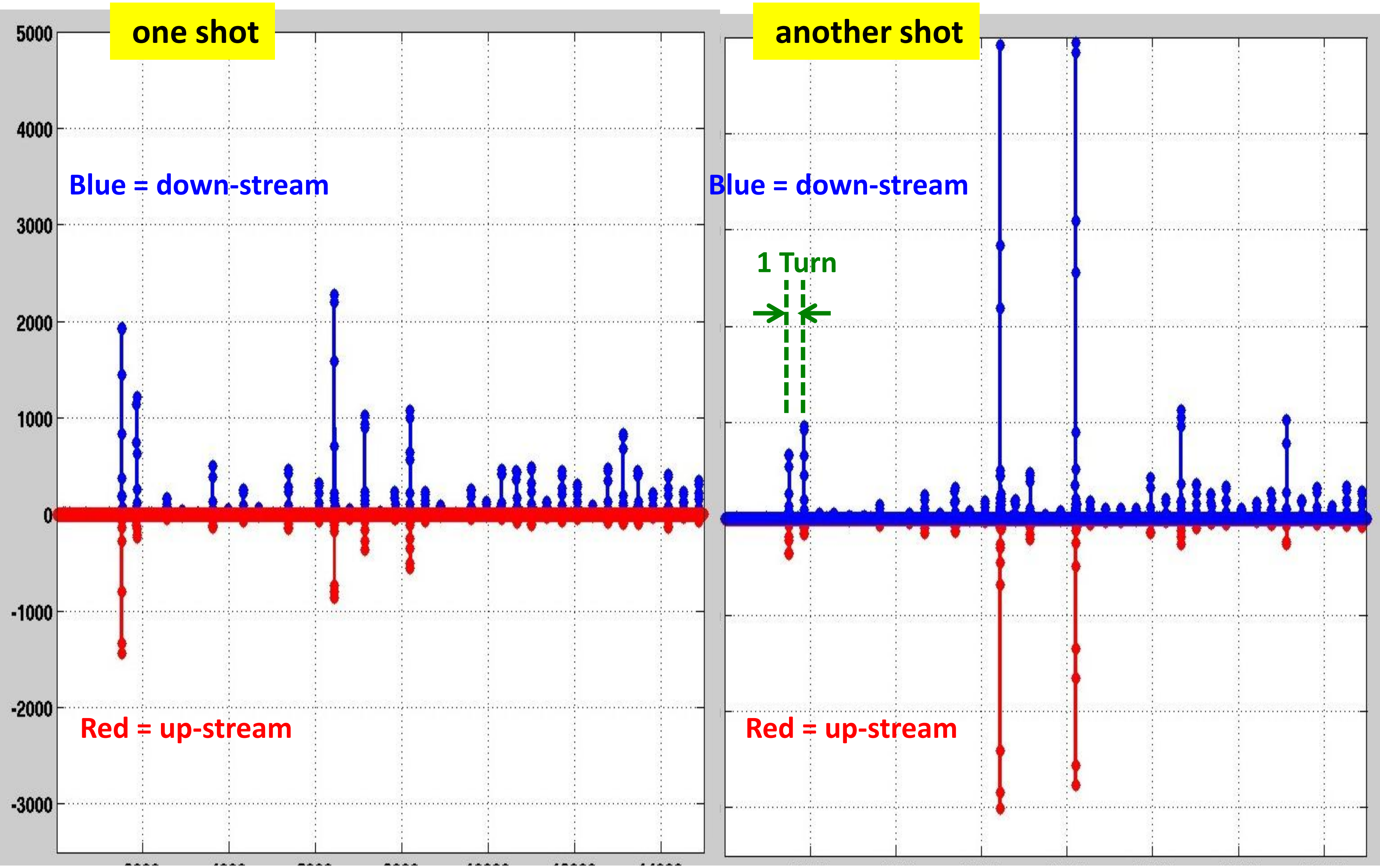
Solutions :

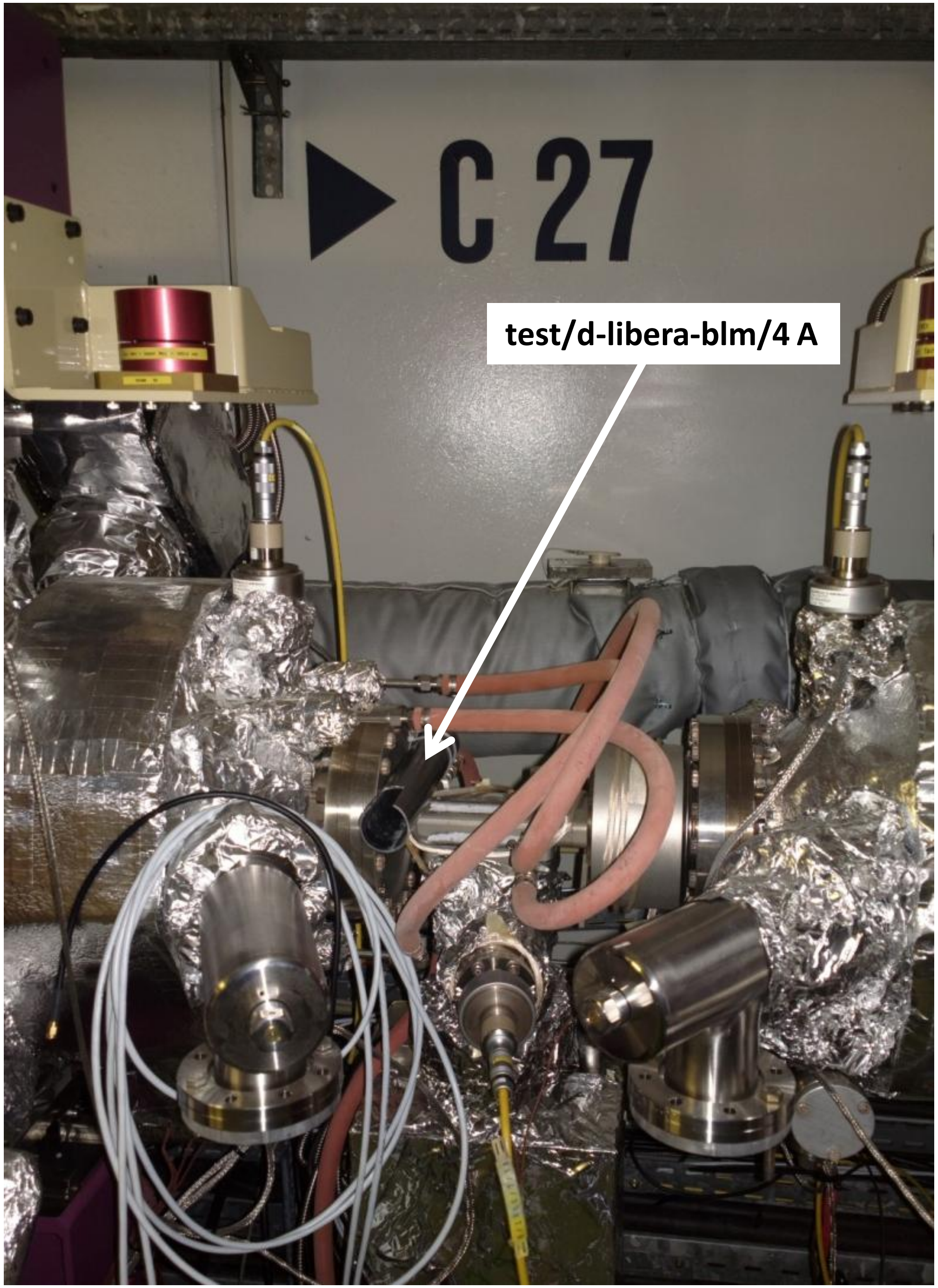
- add **special & dedicated scrapers-collimators** in that ring
→ the scattered electrons get lost there

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

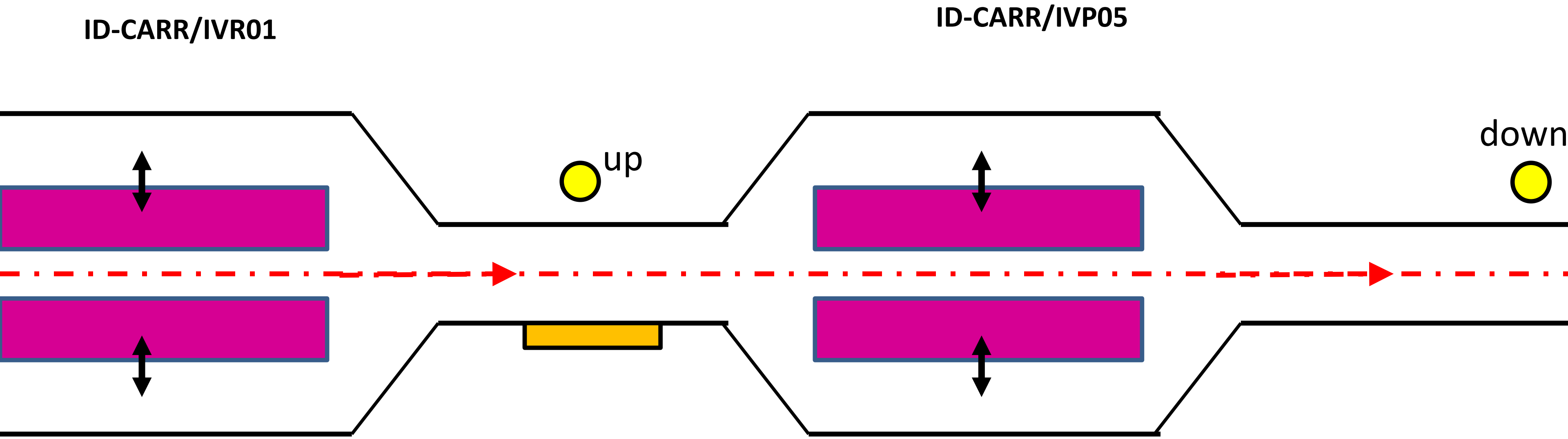

In-Vacuum undulator
BLD #1
BLD #2
e-beam
C 31

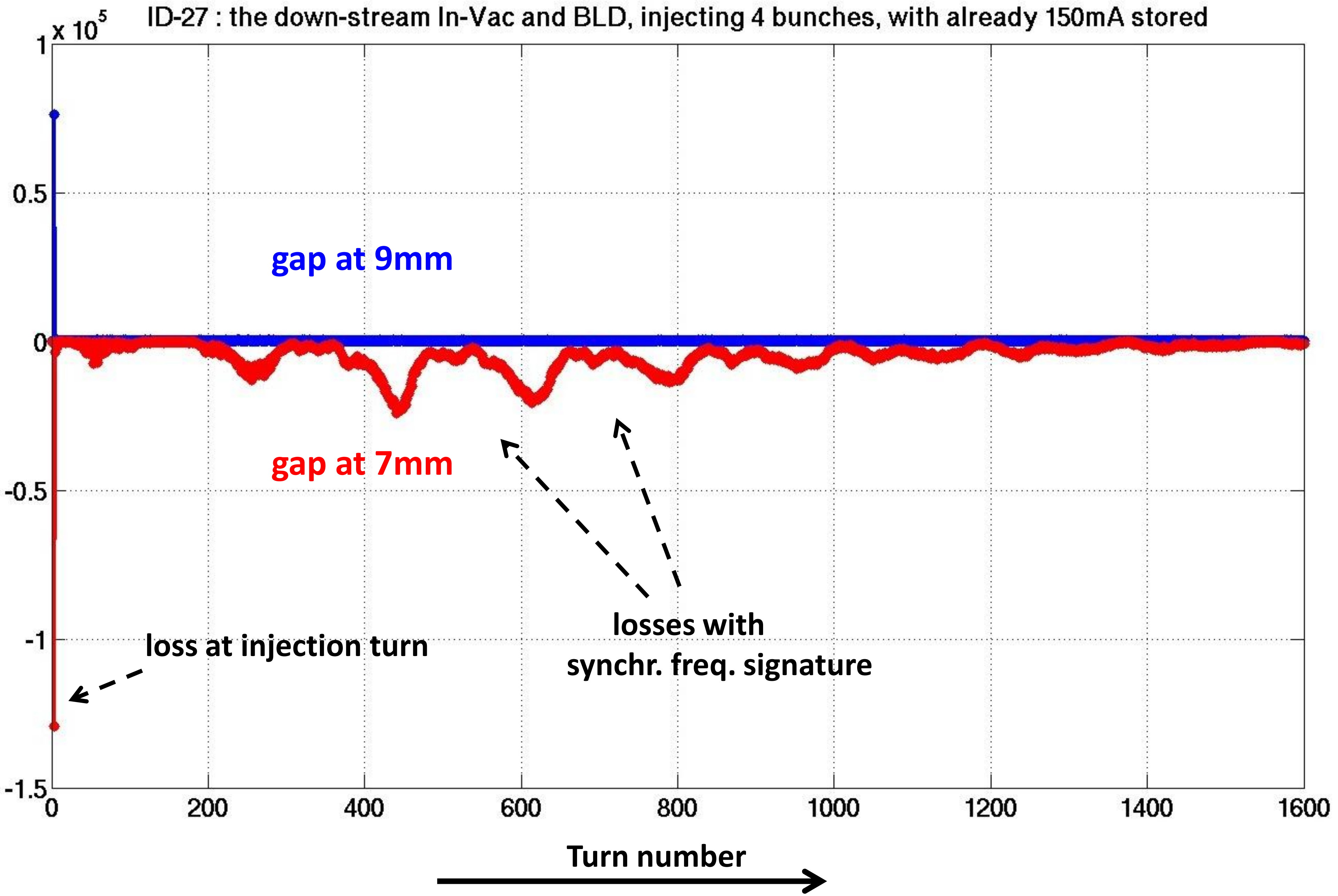
ADC data from 2 BLDs (red & blue) near In-Vac, at 2 different injections

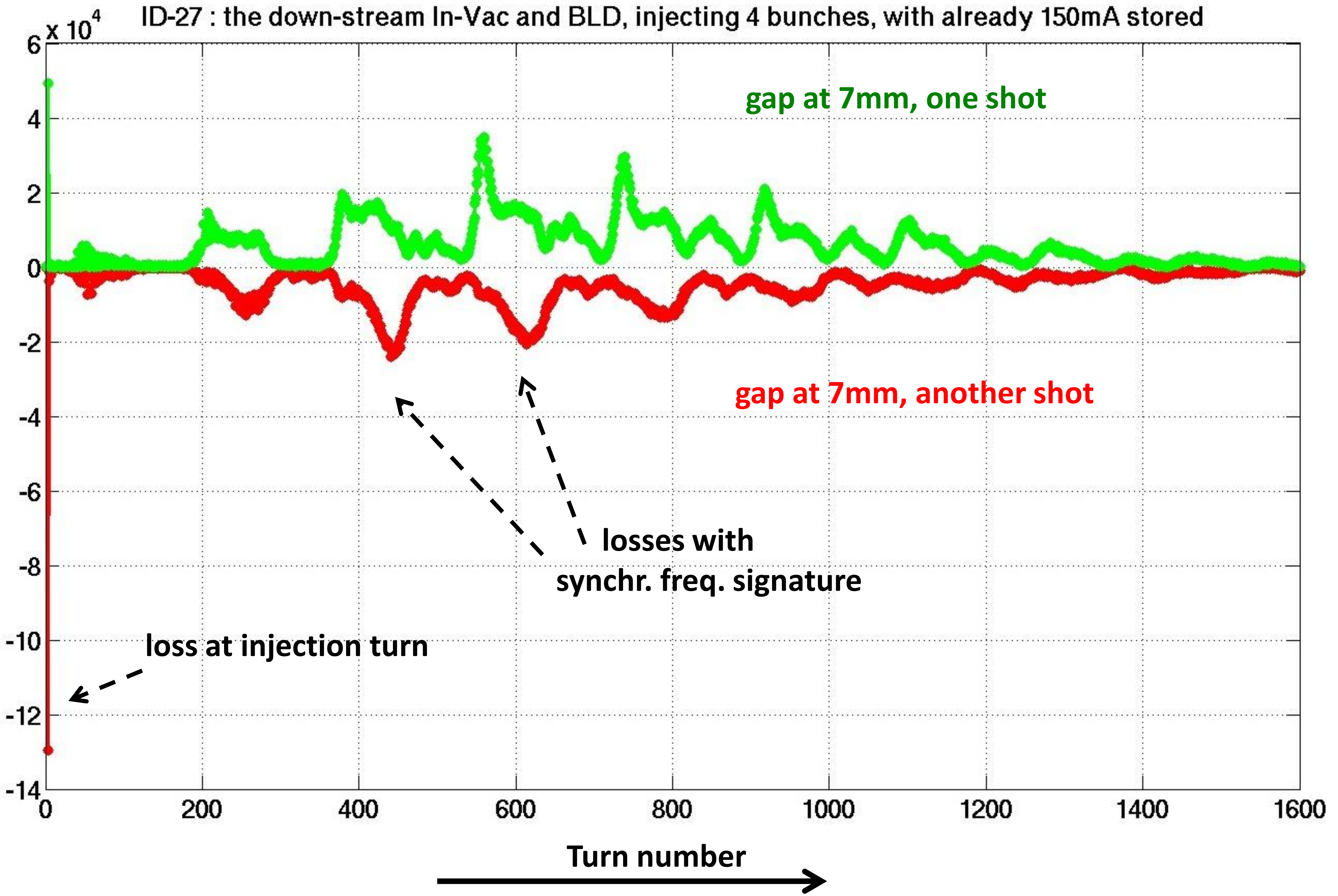



C 27
test/d-libera-blm/4 A

ID-27 *side-view*

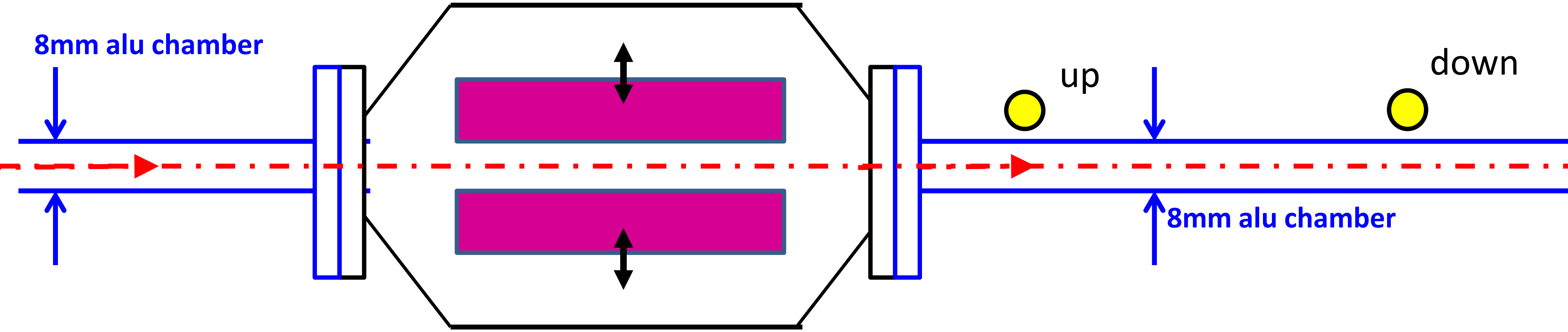


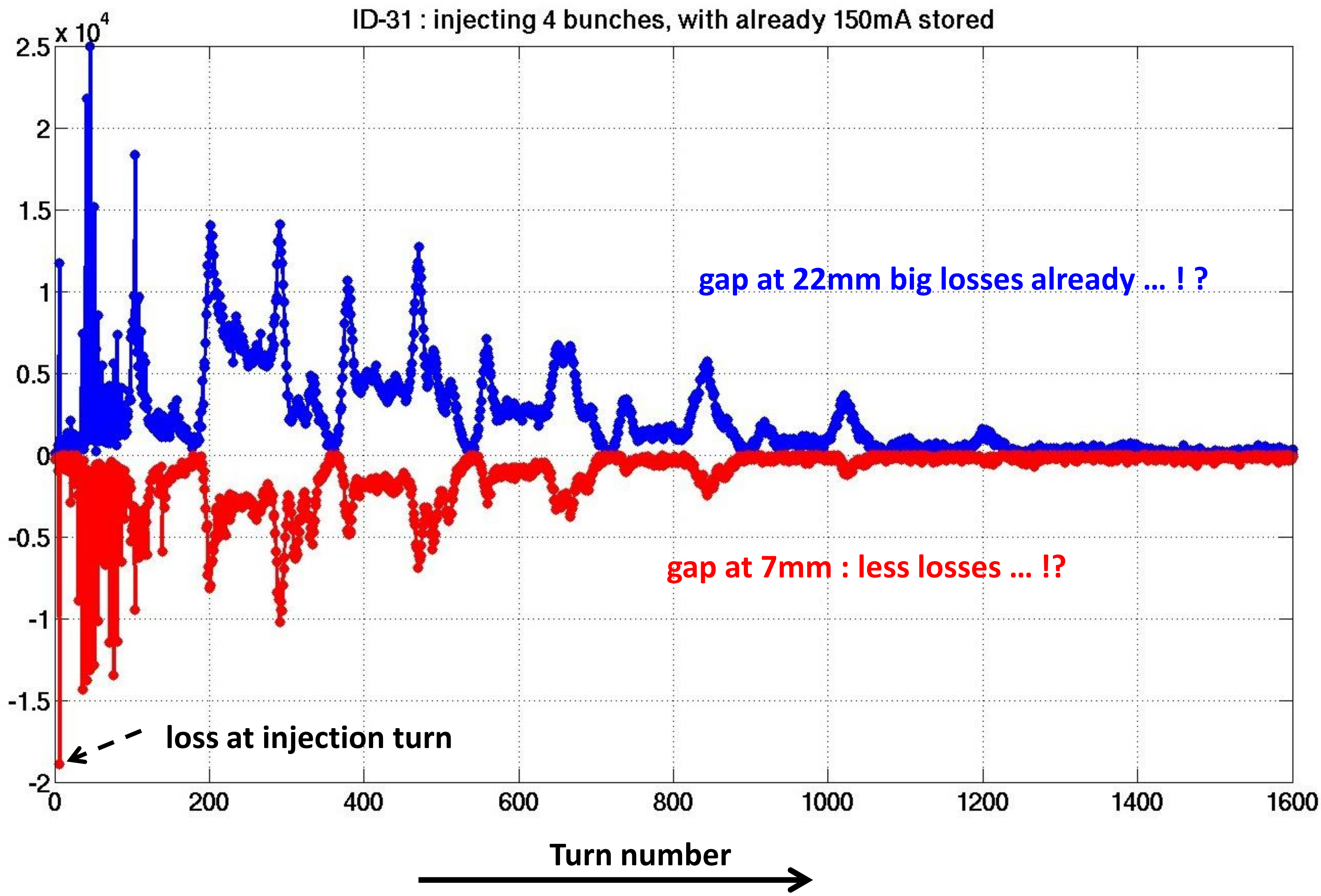

ID-27 : the down-stream In-Vac and BLD, injecting 4 bunches, with already 150mA stored
x 10^5
1
0.5
0
-0.5
-1
-1.5
0
200
400
600
800
1000
1200
1400
1600
gap at 9mm
gap at 7mm
loss at injection turn
losses with
synchr. freq. signature
Turn number


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

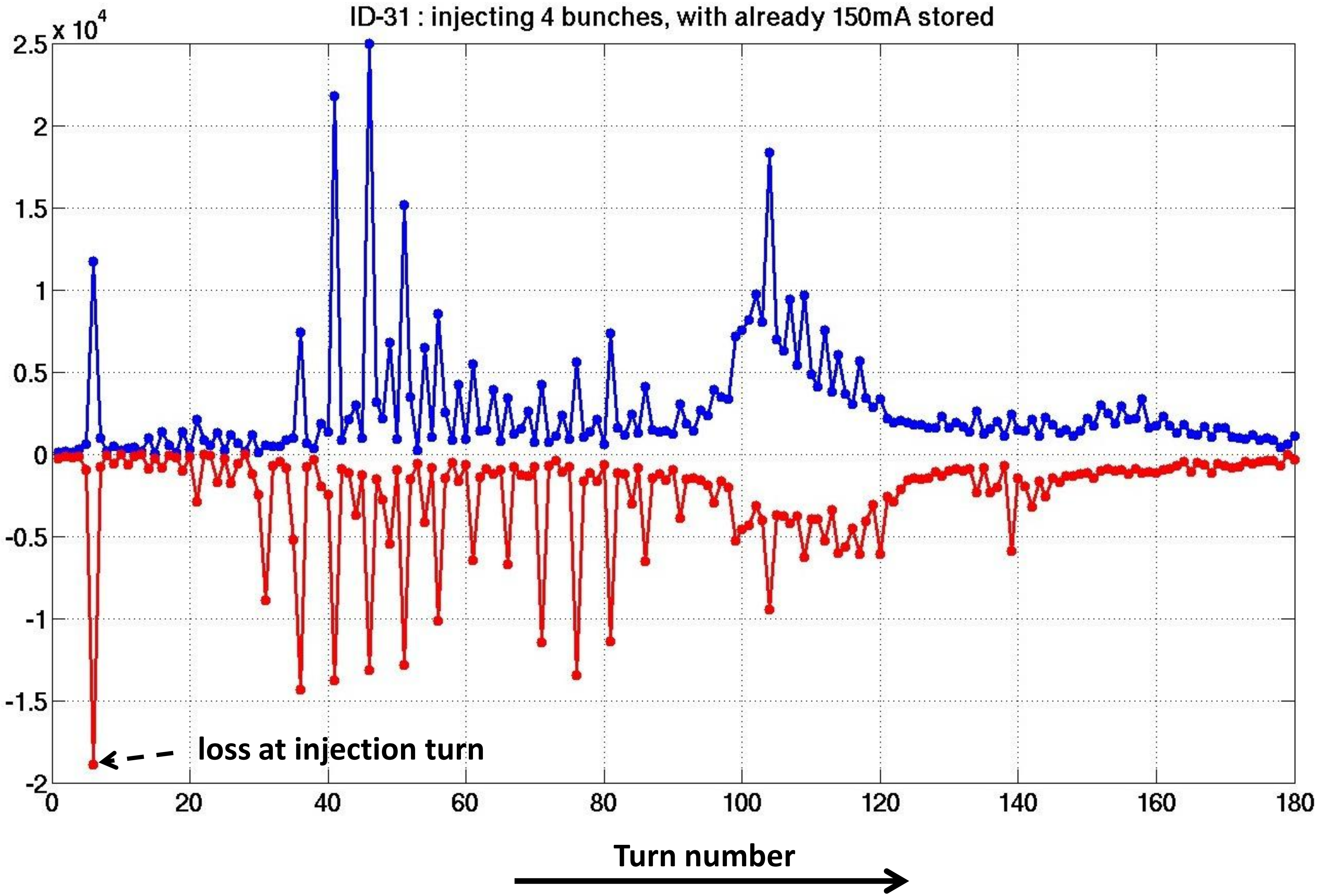
ID-31

id-carr/IVW1/carriage

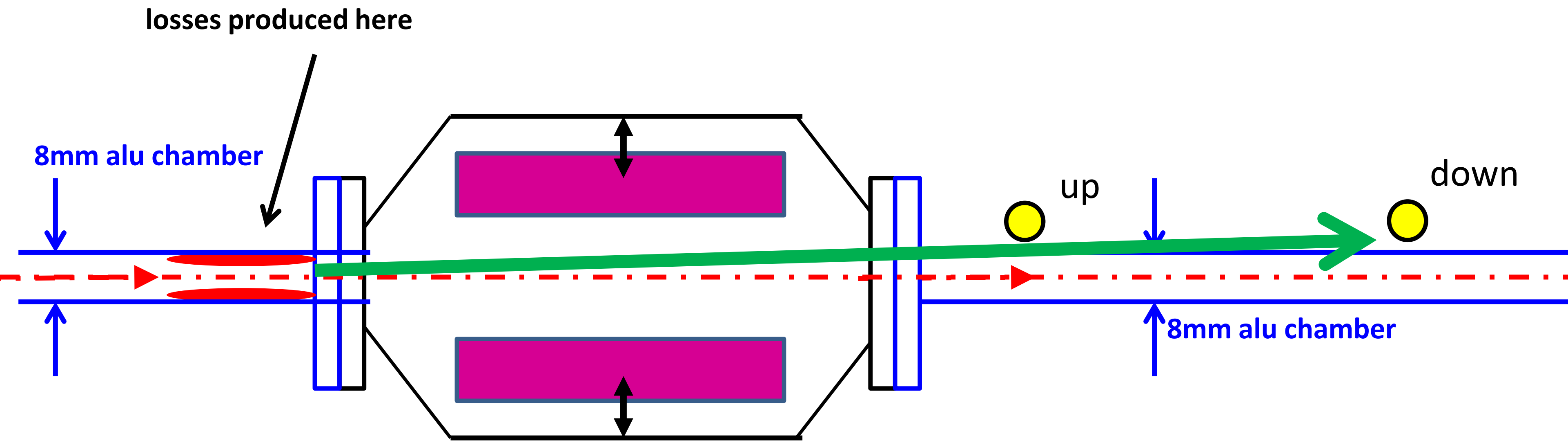


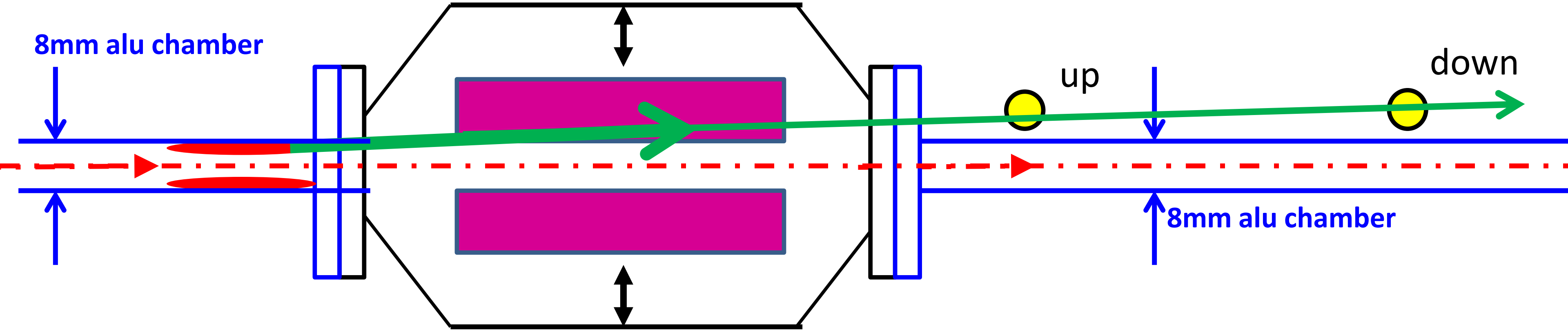


ID-31 : injecting 4 bunches, with already 150mA stored
x 10^4
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
200
400
600
800
1000
1200
1400
1600
gap at 22mm big losses already … ! ?
gap at 7mm : less losses … !?
loss at injection turn
Turn number

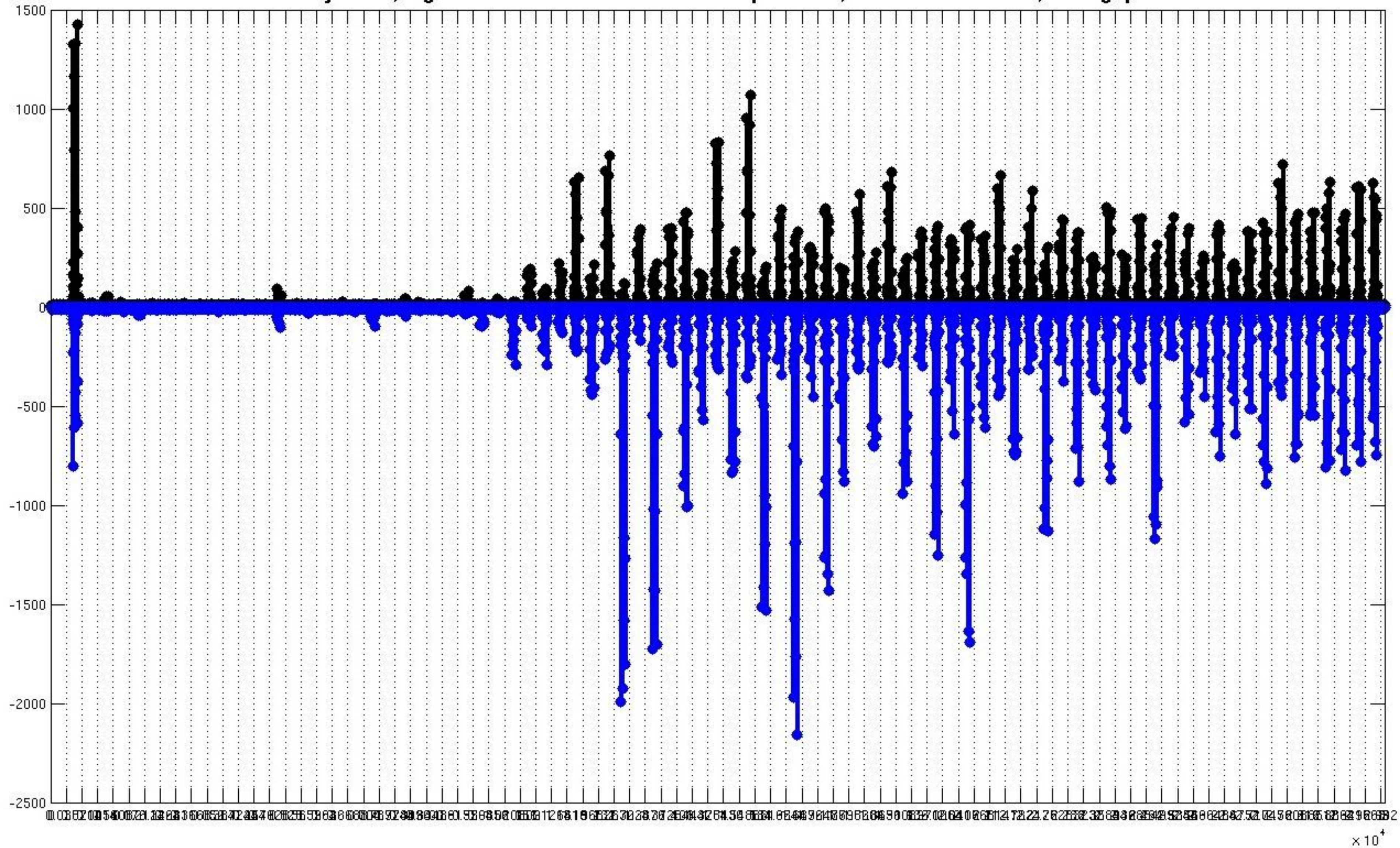

ID-31 : injecting 4 bunches, with already 150mA stored
x 10^4
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
20
40
60
80
100
120
140
160
180
loss at injection turn
Turn number

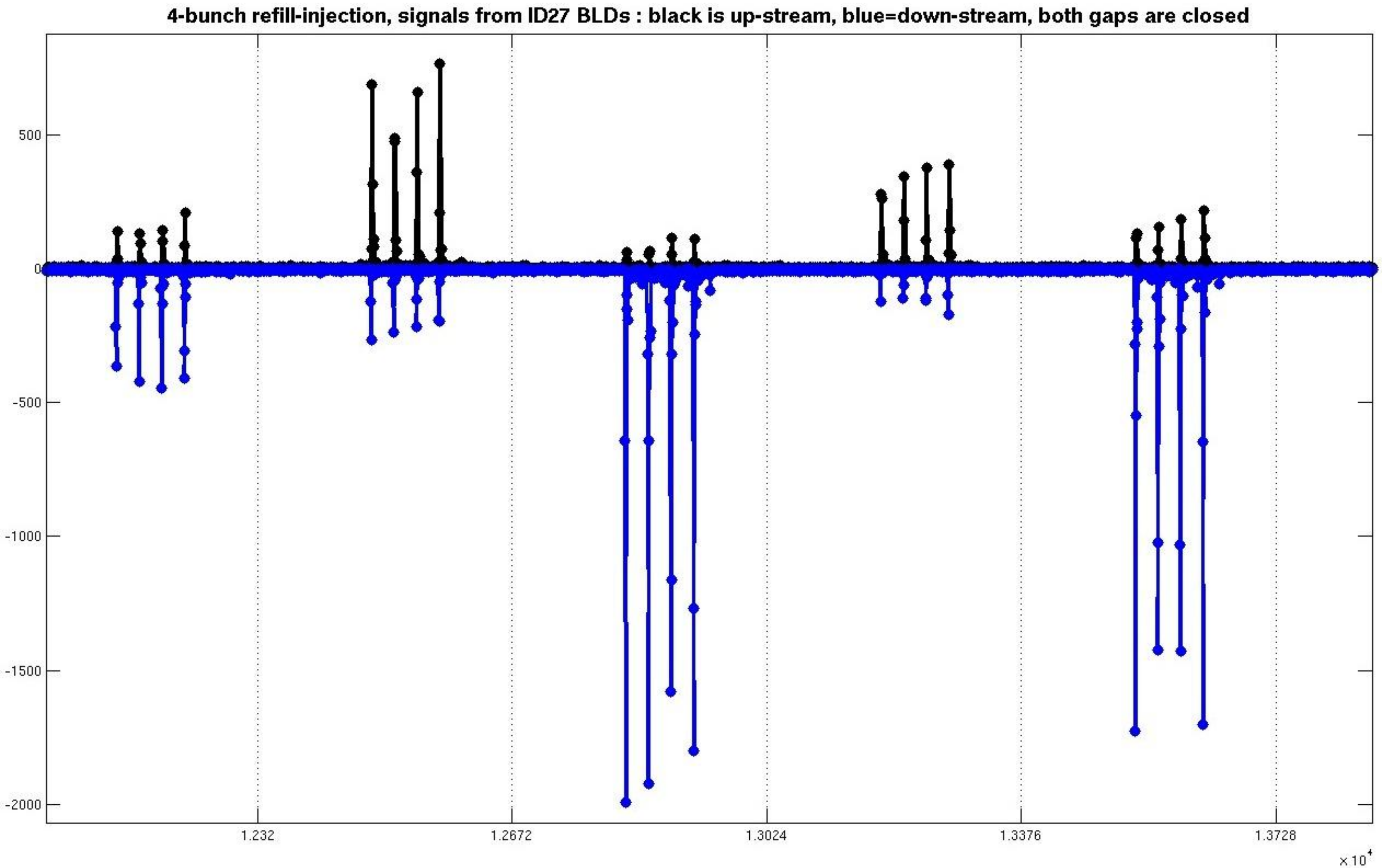
ID-31 id-carr/IVW1/carriage





4-bunch refill-injection, signals from ID27 BLDs : black is up-stream, blue=down-stream, both gaps are closed




4-bunch refill-injection, signals from ID27 BLDs : black is up-stream, blue=down-stream, both gaps are closed
500
0
-500
-1000
-1500
-2000
1.232
1.2672
1.3024
1.3376
1.3728
× 10⁴

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