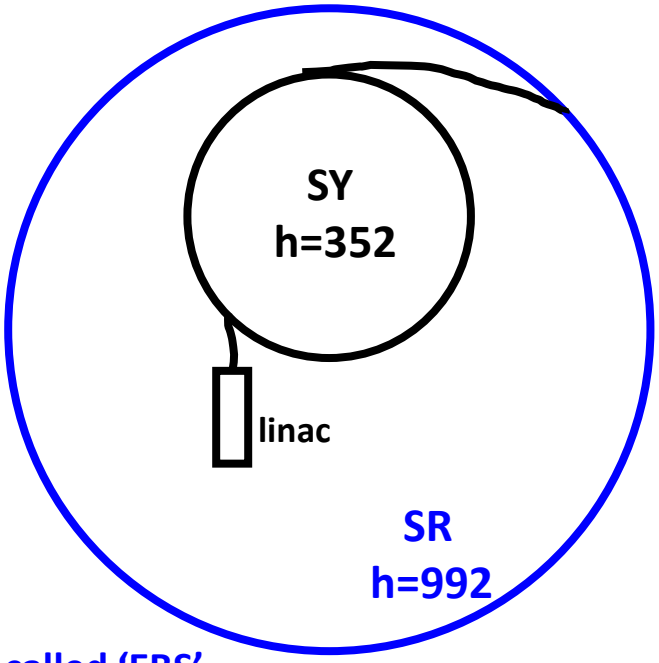
Elettra
Sincrotrone
Trieste

DEELS
May 2025

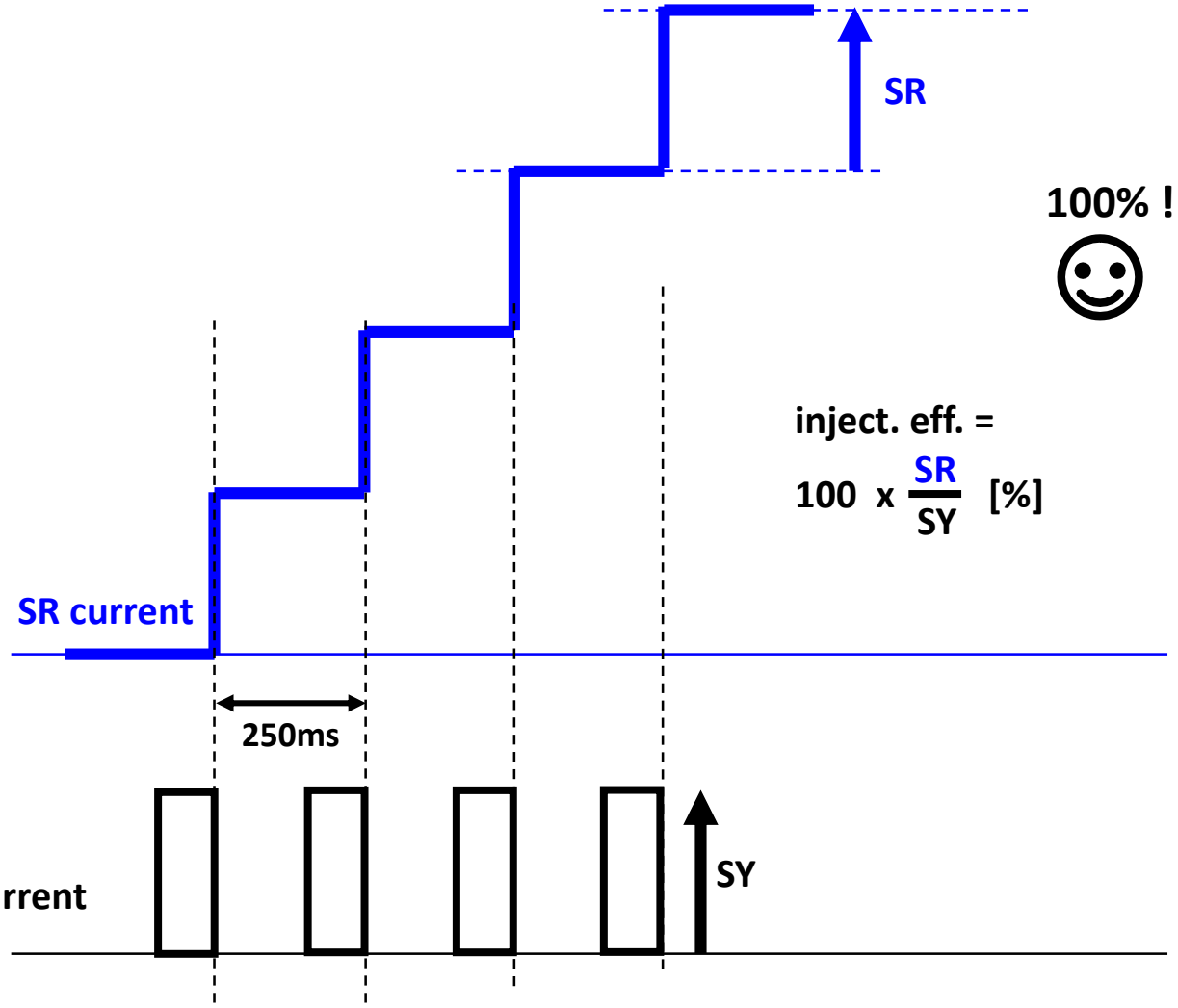
measurement at the ESRF of :

a) injection efficiency and

b) the time-resolved losses of these injections



called 'EBS'
since 2020



a) the precise measurement of this inject. eff. =

$$100 \times \frac{SR}{SY} = \ldots 70\ \%\ (typ.)$$

b) time-resolved losses of these injections

real life at the ESRF …

??

it happens that
we only add 20uA
on top of the 200mA

a weak 1E-4 step-increase
that we still measure with
a few % precision

the measurement of the injection efficiency is done by :

SY : **2 BPM blocks (2 x 4 buttons) + 2 Spark-BPM-electronics**

SR : **idem** **idem**

also for both :

- **the T-b-T-decimated (64) SUM buffers are read-out (Σ=A+B+C+D)**
- **at 4Hz**
- **fixed attenuation for all range of currents (i.e. no AGC.)**
- **calibration (between this SUM and the real current) is easily done using the (SY and SR) Current-Monitors (Bergoz), it is verified / redone only once a year (→ quite stable)**

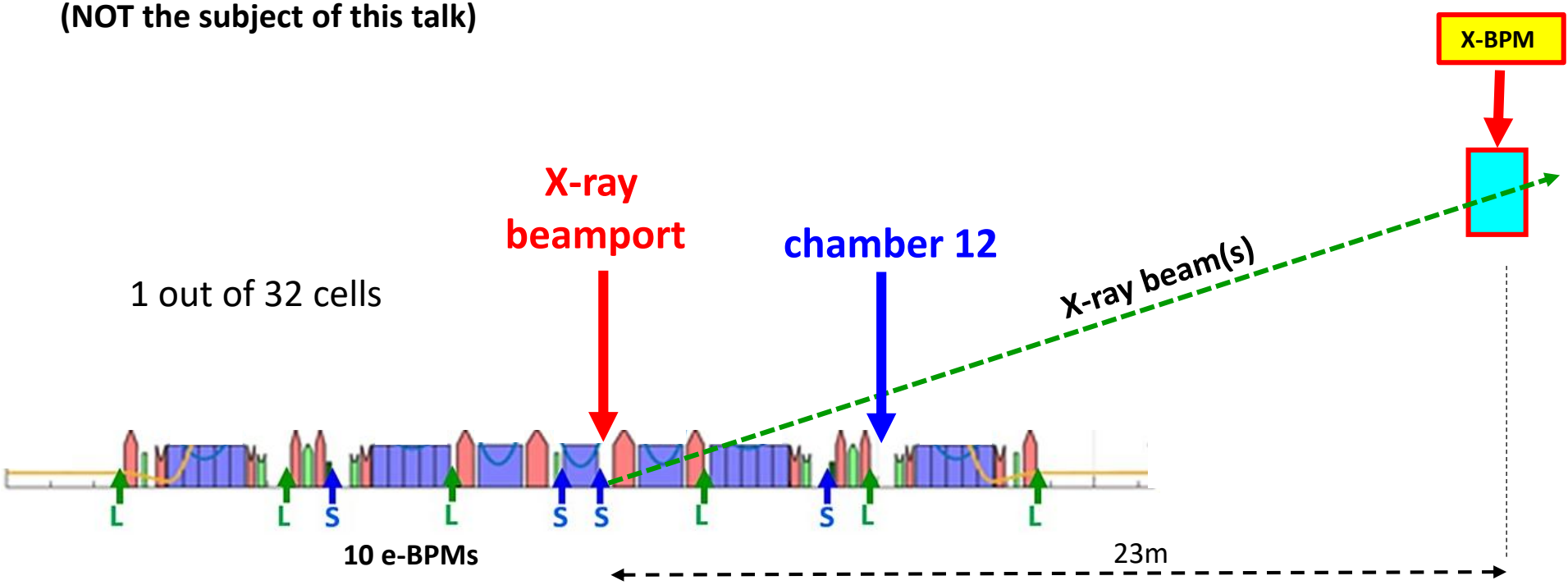
we use **2** x **2** BPMs to calculate **2** independent values of SY-current
and **2** independent values of SR-current
and then **4** values of Inj. Eff.
and then the **mean** & **rms** of these **4** values

inj.eff. [%] **error [%]**

we are privileged to have (much) space in our Rings to get numerous additional diagnostics devices : in almost each cell (32 in total) a straight-section (called chamber 12) is available, and thus we have

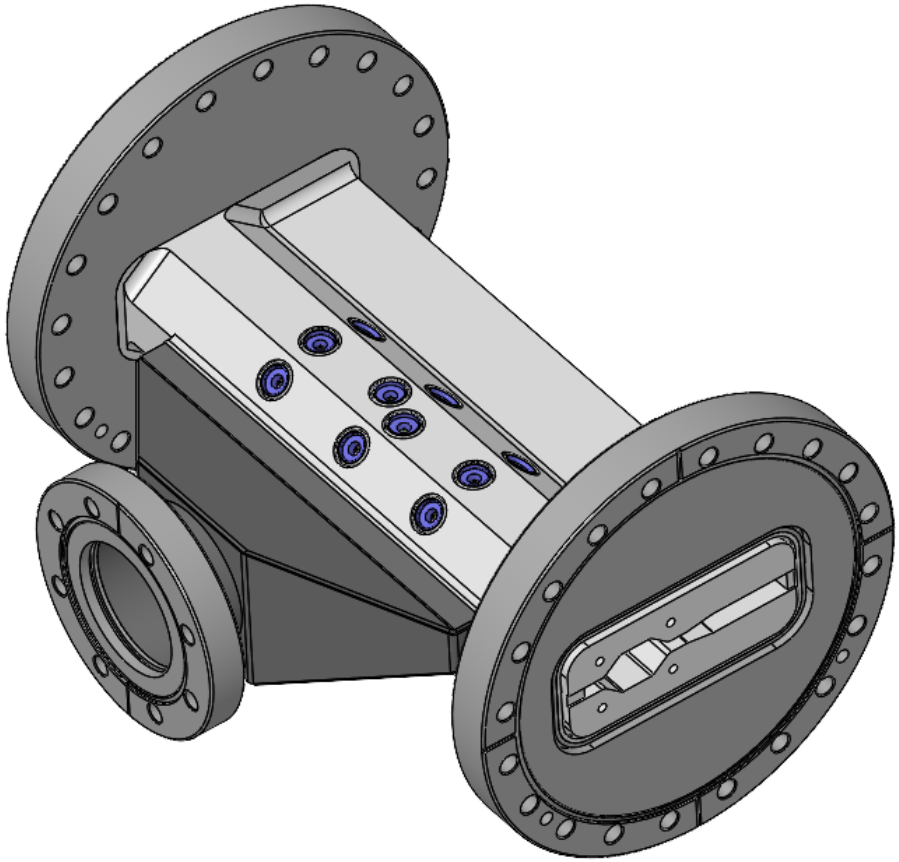
- **3 PCTs (current monitor, lifetime)**
- **3 chambers with each 20 BPM-buttons (60 buttons, 8 for this Inj.Eff.)**
- **3 strip-lines**
- **2 scrapers**
- **2 tune-monitors**
- **2 collimators**

in addition to that we have also many X-ray beamports available (>18) for other diagnostics : 5 emittance-monitors (pinhole type), 10 X-BPMs, 2 Halo-monitors, Energy-monitor (NOT the subject of this talk)



these additional and independent buttons <u>are very useful</u>

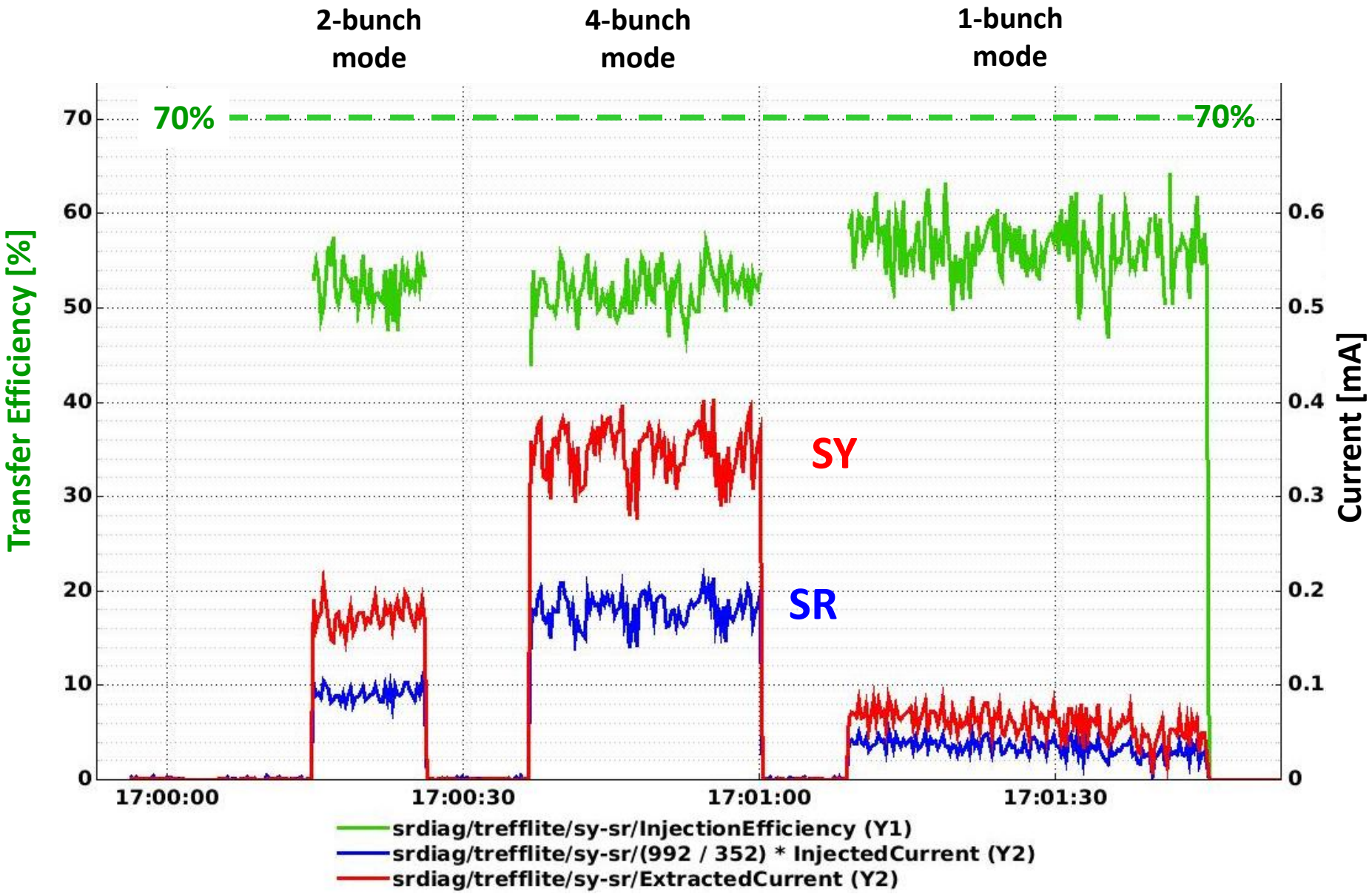
we do NOT share /mix signals & applications between
the regular 320 e-BPMs and other purposes (like this Inj.Eff. Monitor)



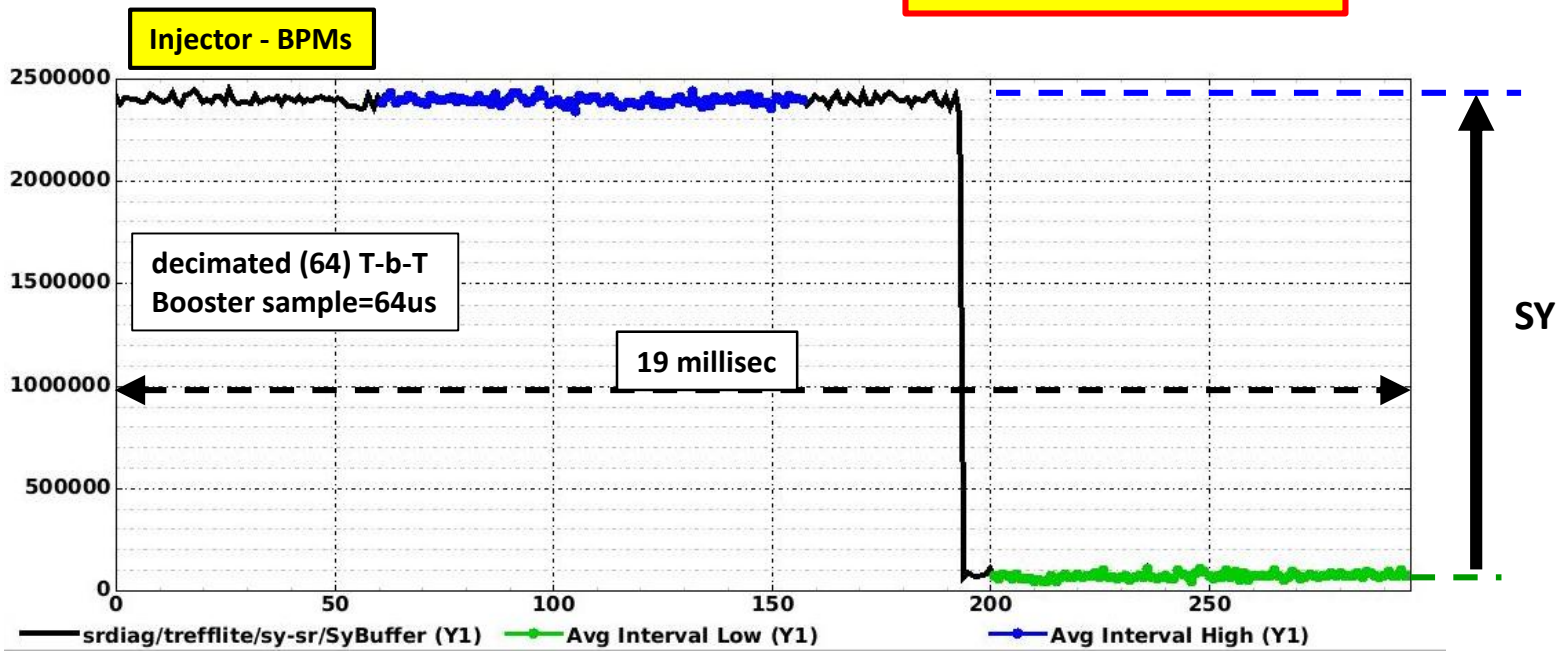
3 installed in the Storage Ring

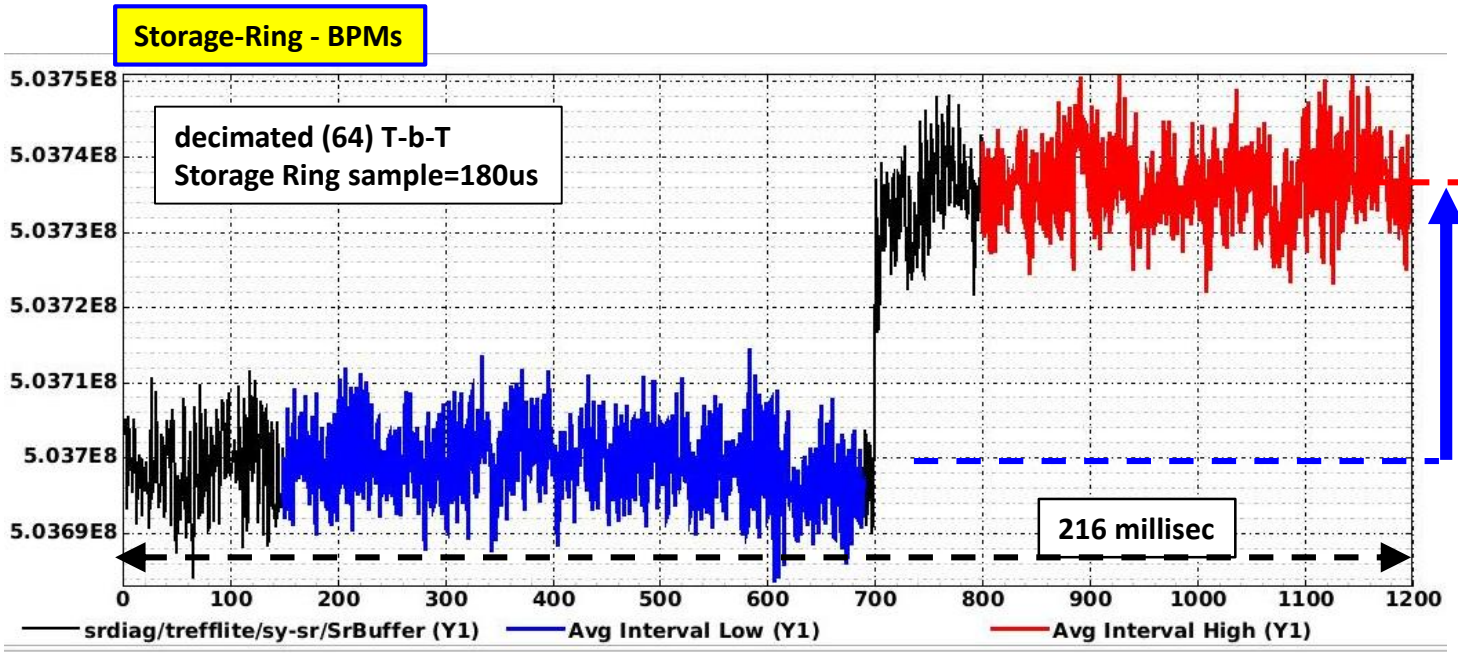
the 20-buttons chamber = Ch.12

results of Inj. Eff. :



results of Inj. Eff. :





$$\frac{0.00038\ E8}{5.03700\ E8}$$

= 7.5 E-5

= 15uA !!

time-resolved losses at injection

since we loose about a third it would be good to know MORE about these losses so to possibly remedy this

→ localization

→ time-resolution

① **128 BeamLoss Detectors (BLDs)**

localization and **time-resolution**

measure in slow-mode during decay, and also

measure in fast-mode at each injection, with T-b-T resolution (2.8us sample)

doubt : are the results linear ?

② **320 e-BPMs,** **Sum from the T-b-T buffer (2.8us sample)**

time-resolution

weakness : the bunch-length of the injected beam oscillates strongly

→ affects the amplitude of the button-signal

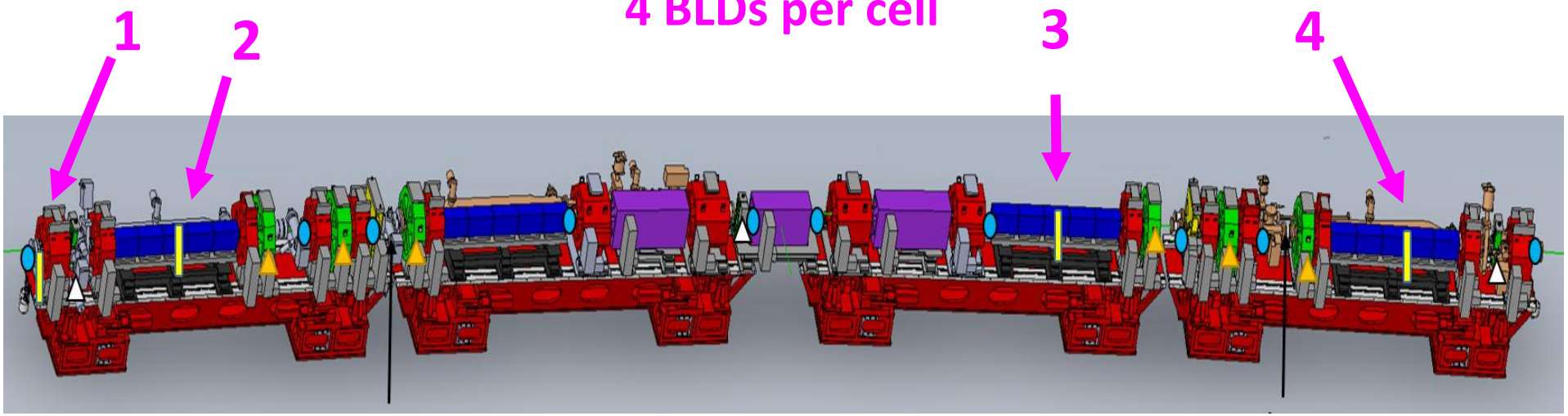
③ **visible light acquisition of (all) the injected beam**

time-resolution

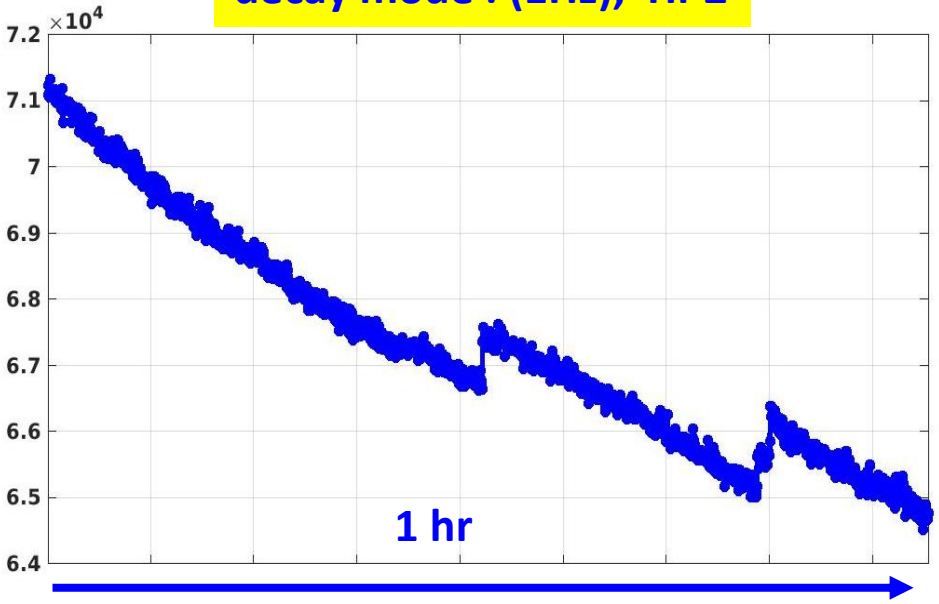
first attempts 2 years ago, some problems, aborted, but to be retried (?)

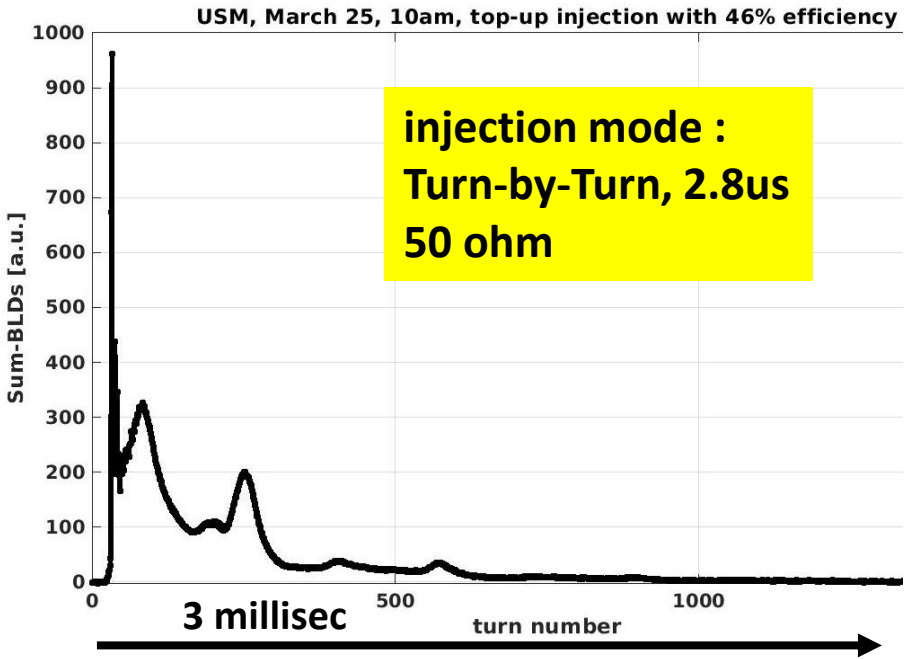
① → Beam Loss Detectors , 128 units

4 BLDs per cell



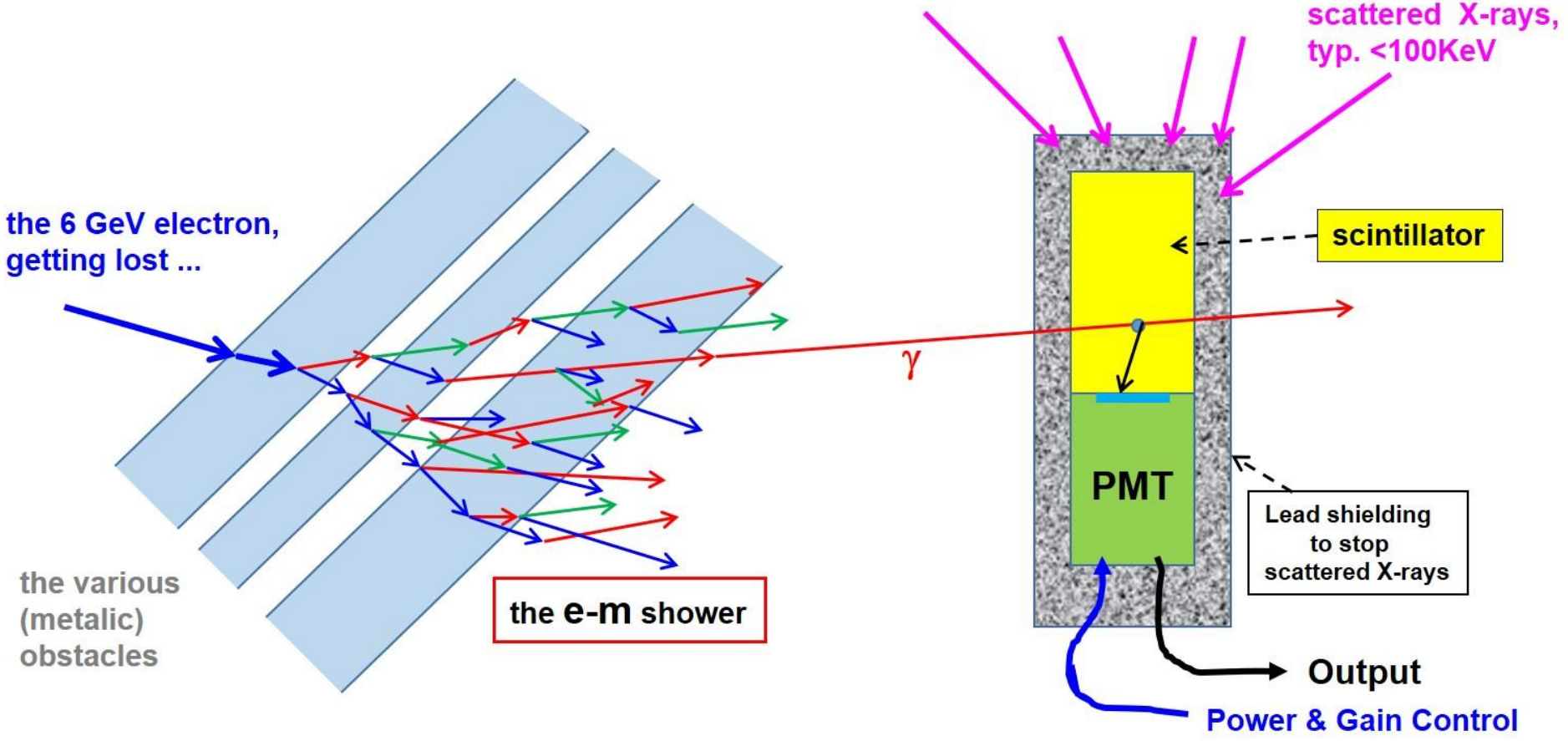
decay mode : (1Hz), Hi-Z





injection mode :
Turn-by-Turn, 2.8us
50 ohm

Beam Loss Detectors , 128 units

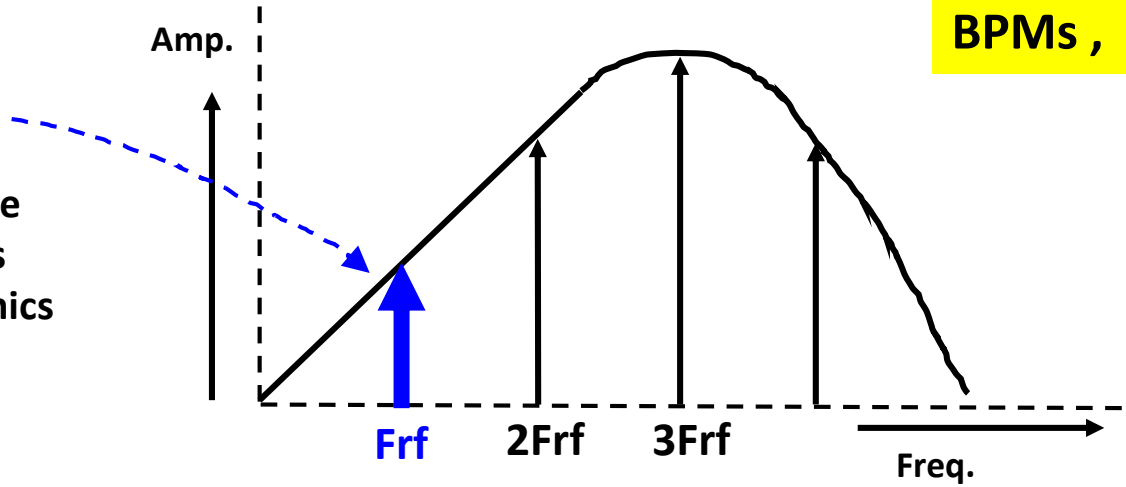


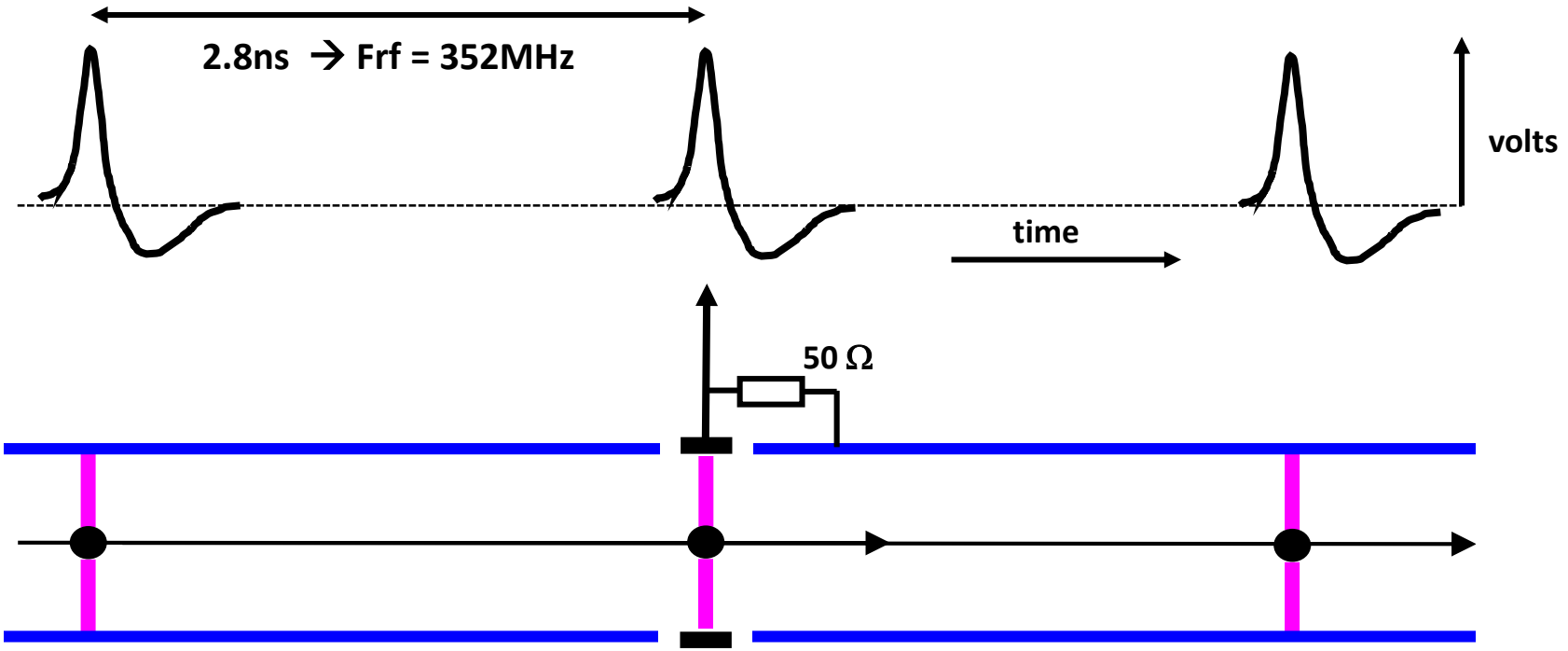
the input signal to the photo-multiplier-tube (PMT) is a pulse of about **30 picosec**, for **high amplitude** of that **short pulse** the **PMT** may **no longer be linear …..**

BPMs , 1280 buttons !

this amplitude

is all the time available
from 320 x 4 buttons
all through HQ-electronics
i.e. the Liberas





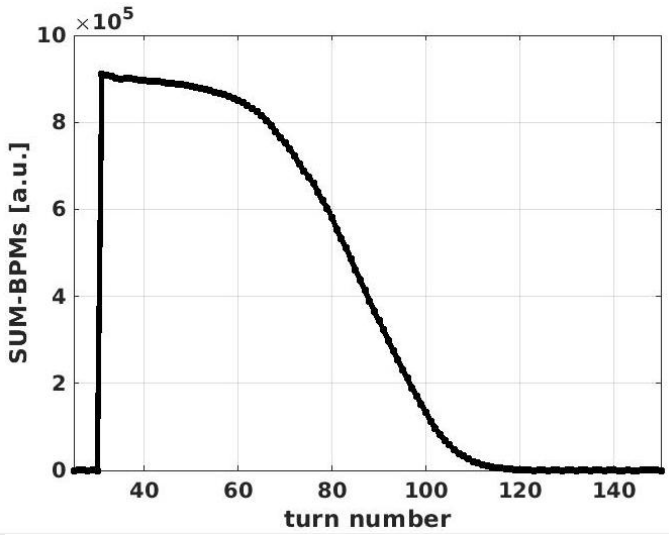
RF = OFF

→ 100% of beam is lost after 120 turns

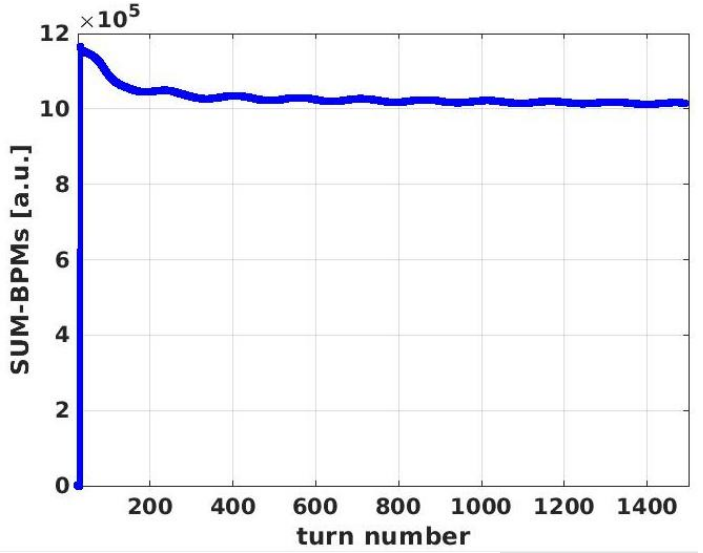
RF = normal

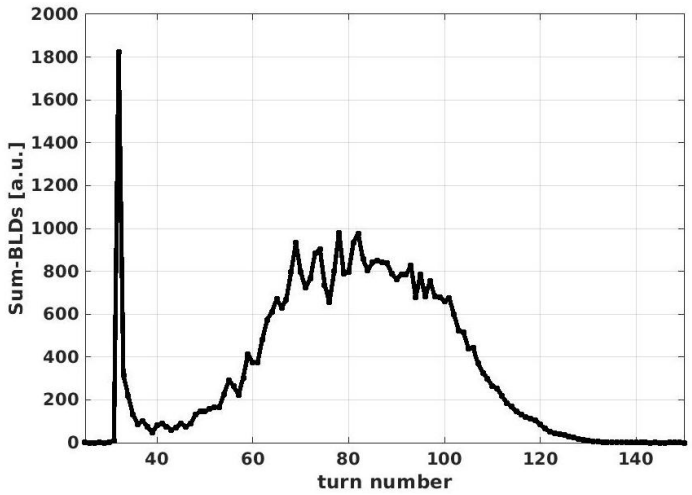
→ 40% of beam is lost ,

→ 60% is stored (i.e. Inject. Efficiency)

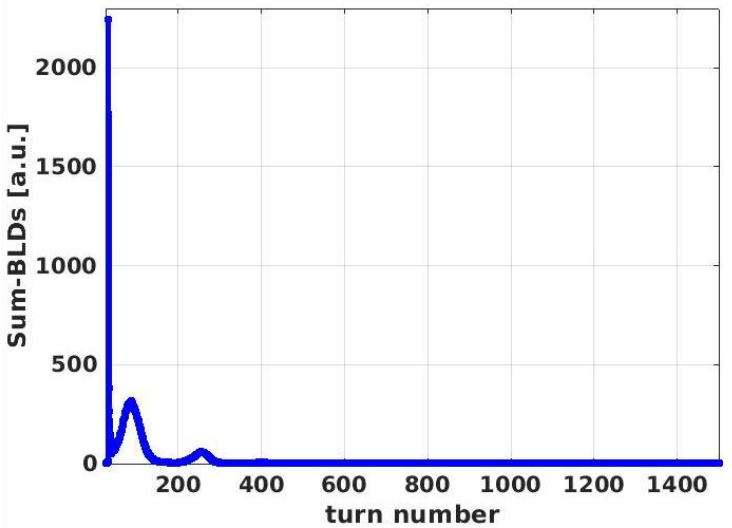


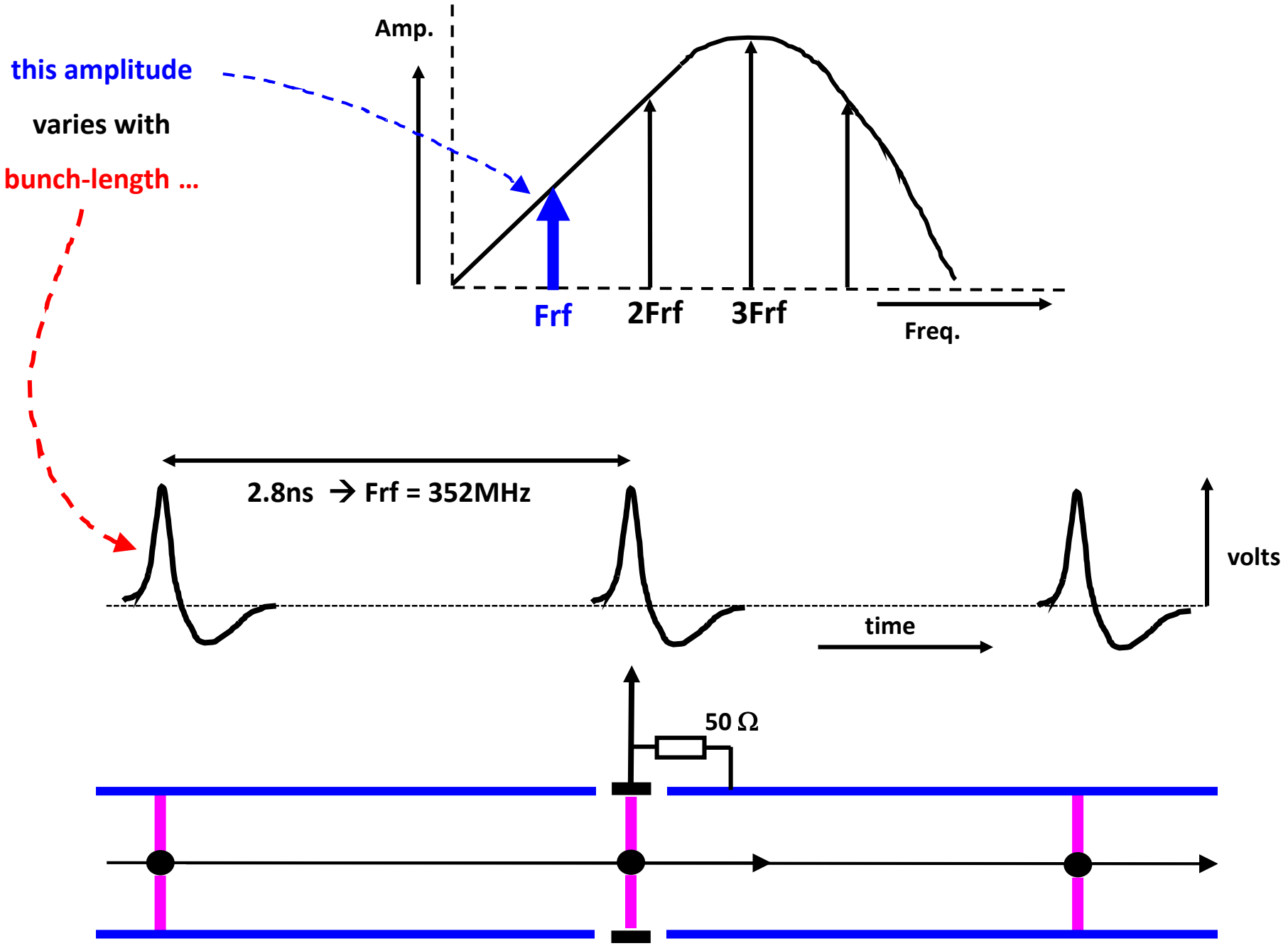
BPMs





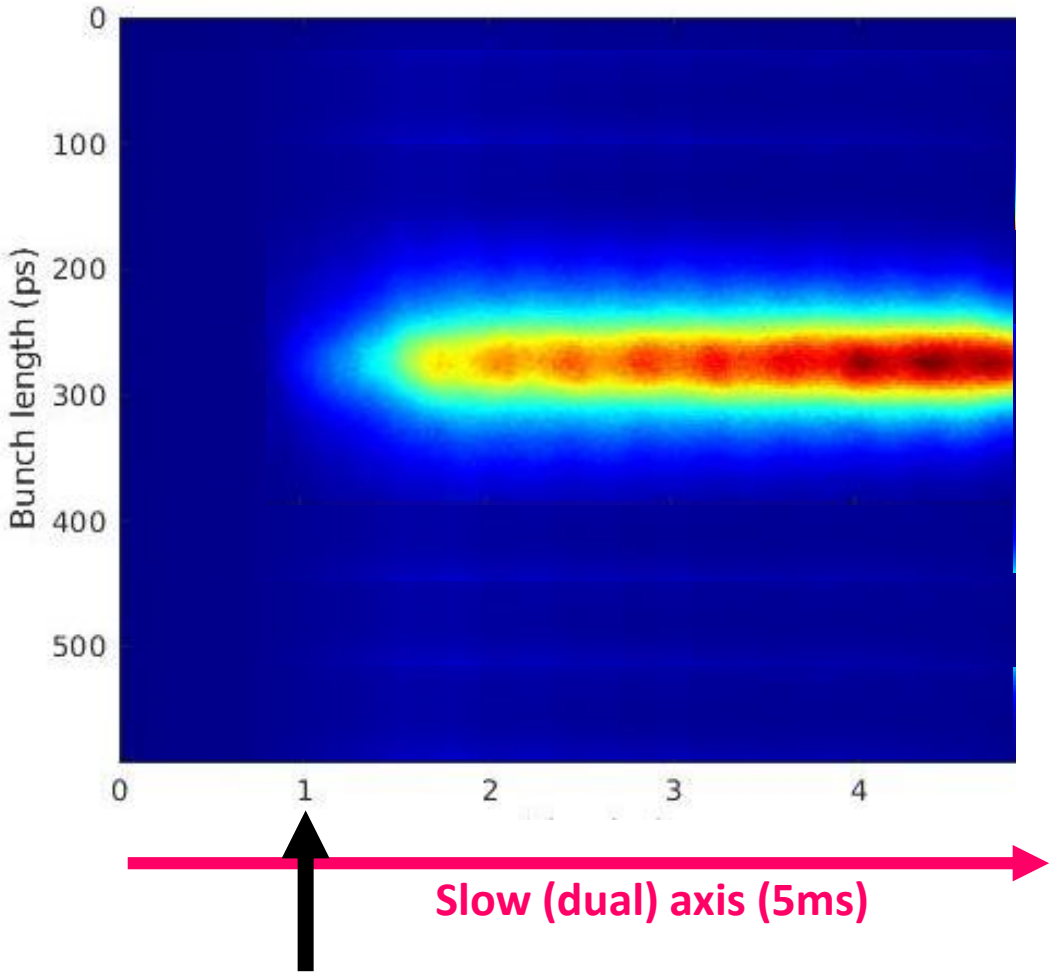
BLDs




this amplitude
varies with
bunch-length …
Amp.
Frf
2Frf
3Frf
Freq.
2.8ns → Frf = 352MHz
volts
time
50 Ω

evolution of the bunch-length
of the injected beam

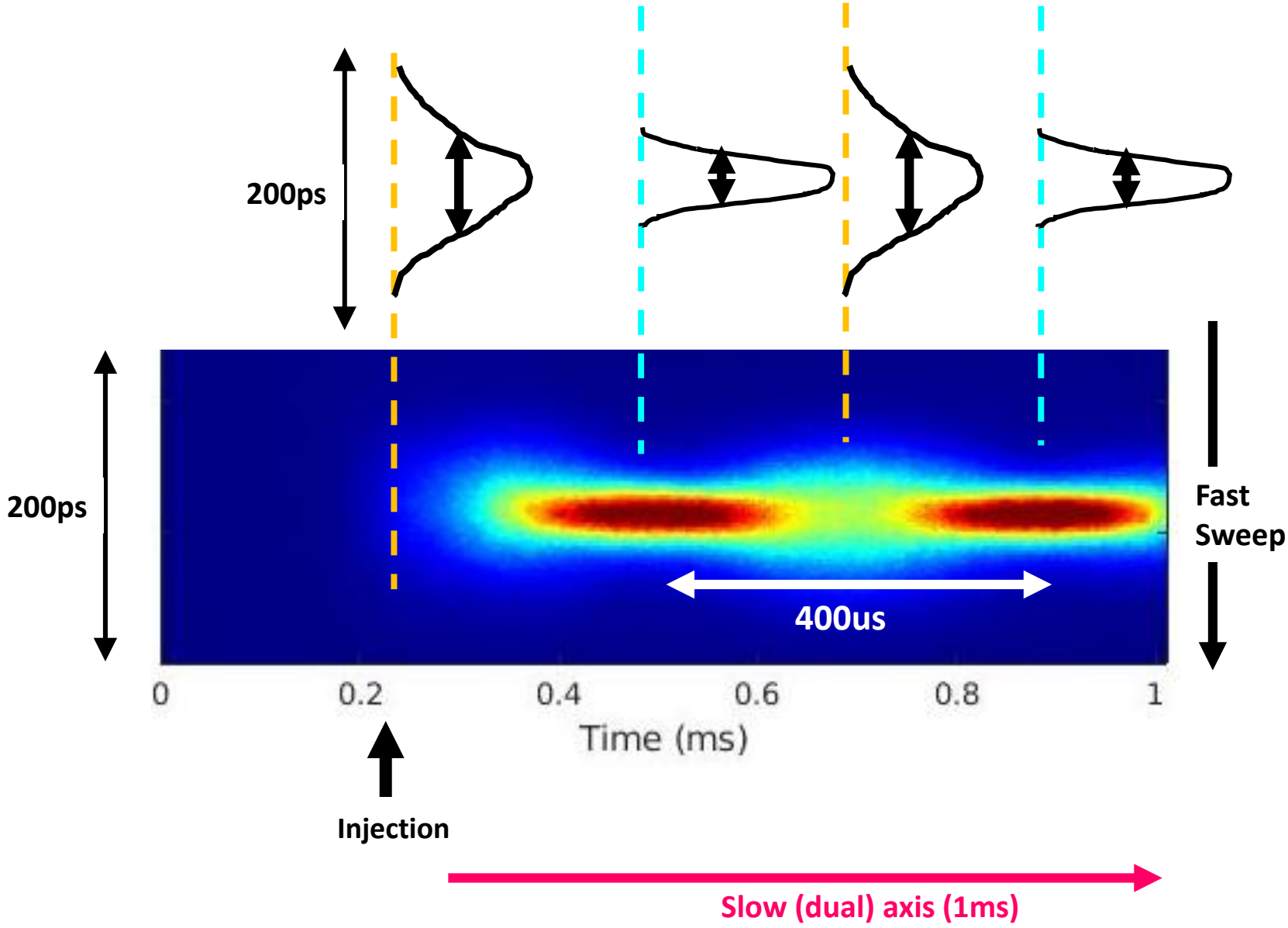
Streak camera



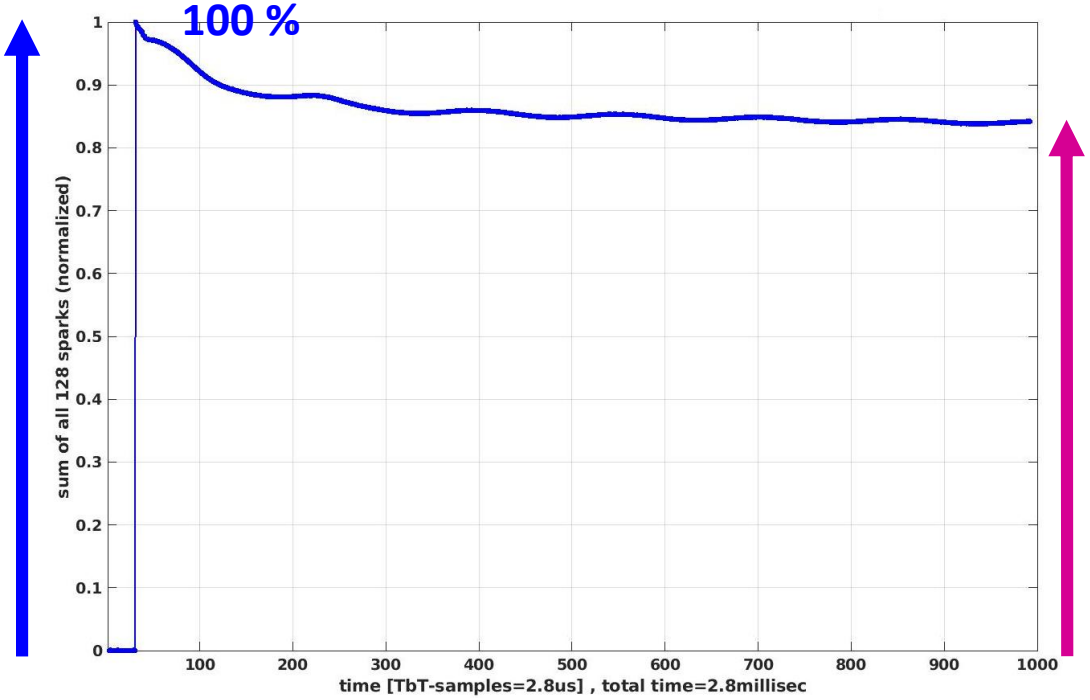
the beam is injected <u>into an empty SR</u>

the bunch length at injection is large
and then shrinks with time,
while oscillating for
a number of periods
and stabilizes after about 10ms

Evolution of the bunch-length of the injected beam



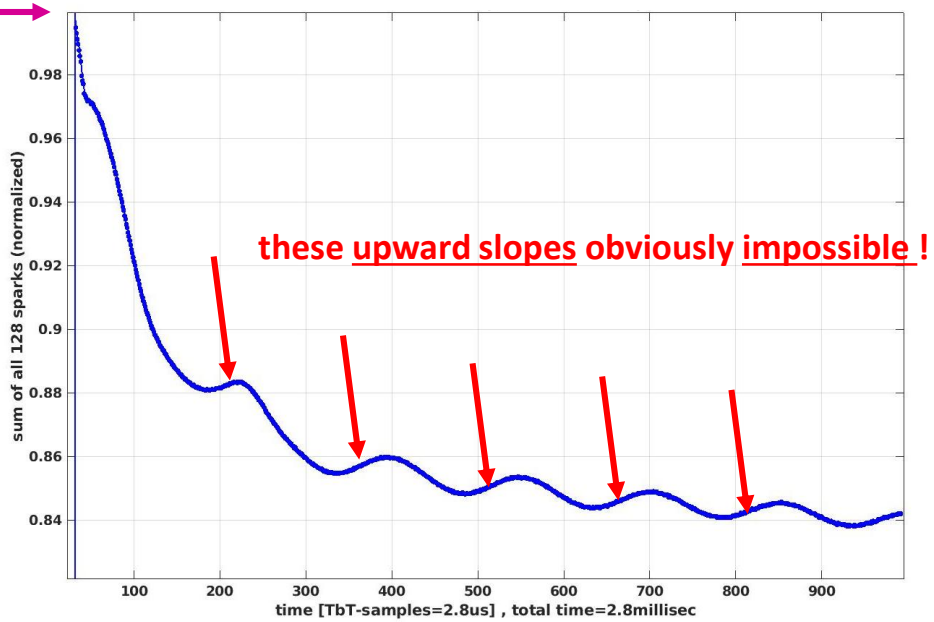
time resolved injection from BPM buttons



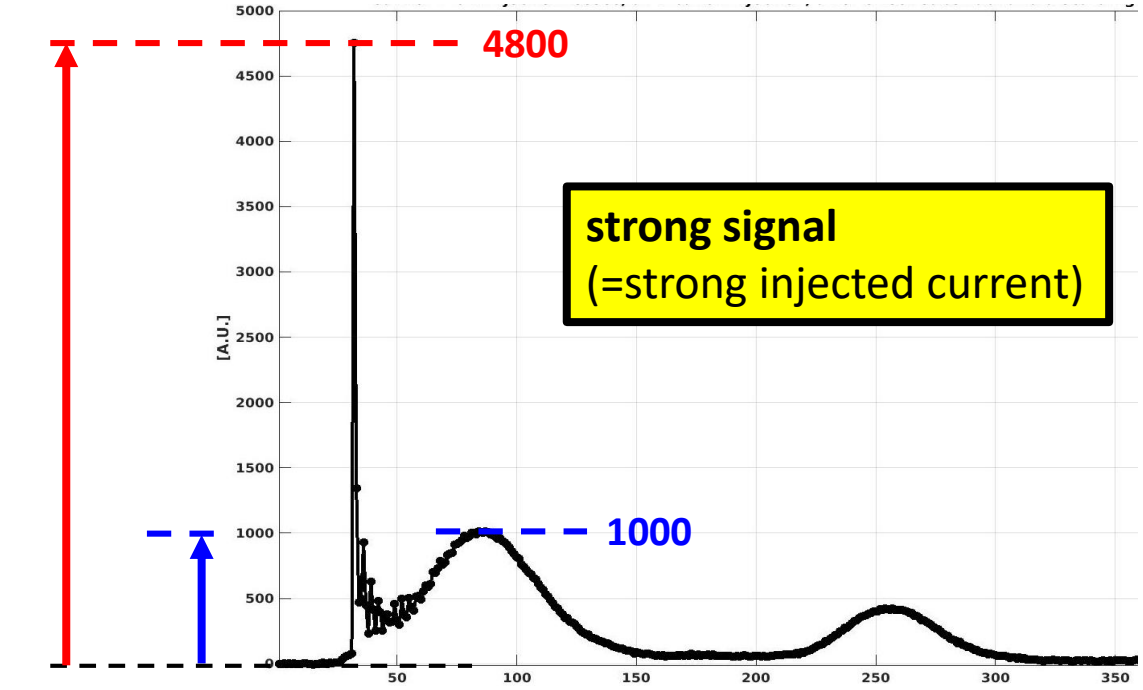
hey …
>85% !??

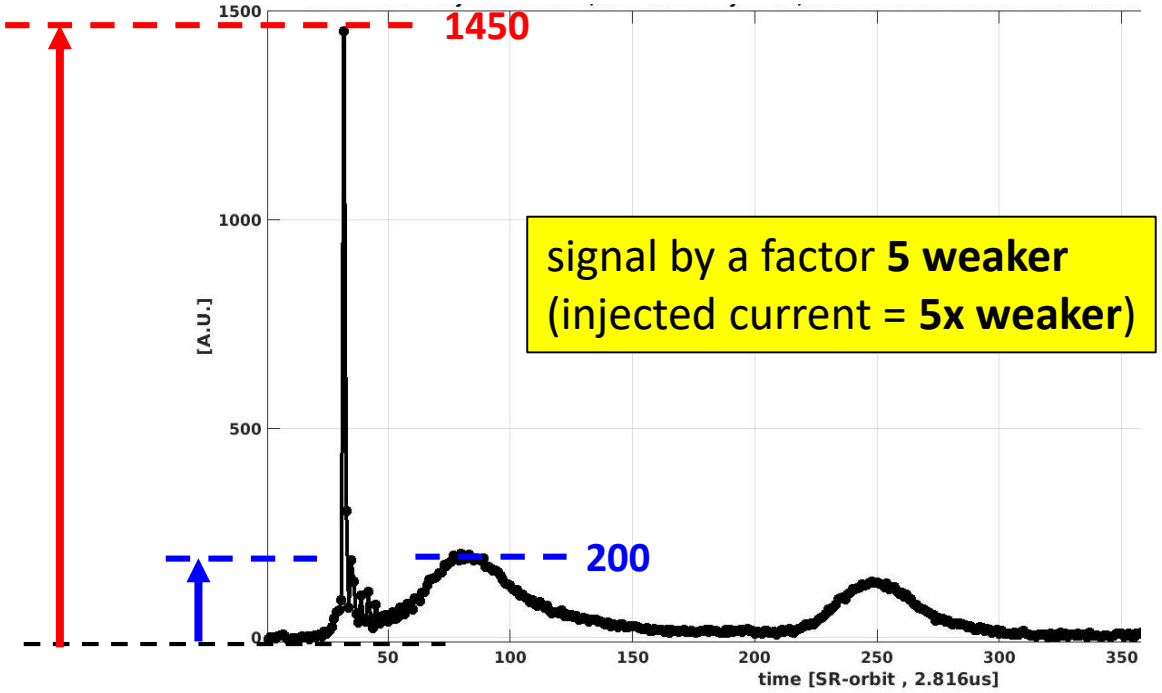
sadly, we never had 85% ….

the injected
beam-charge
is under-valued
→ large bunch-length



→ caused by bunch-length variations of the injected beam





two measurements
weak (1) and strong (5)
all other conditions identical

blue (weaker losses) is a factor 5 stronger (1000/200)

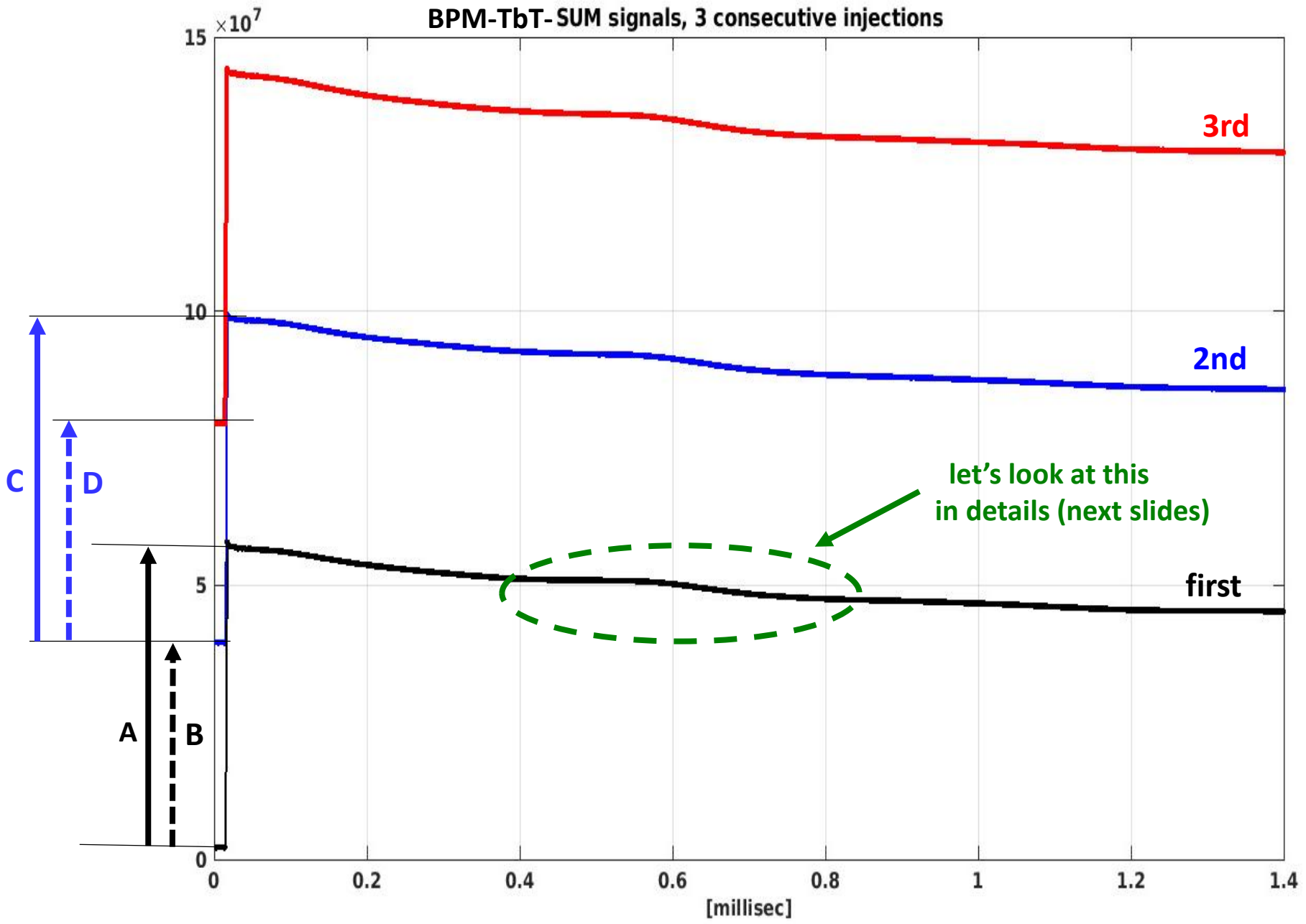
red (peaked losses) shows only a factor 3.3 …

some dis-linearity (30%) for high amplitudes ….

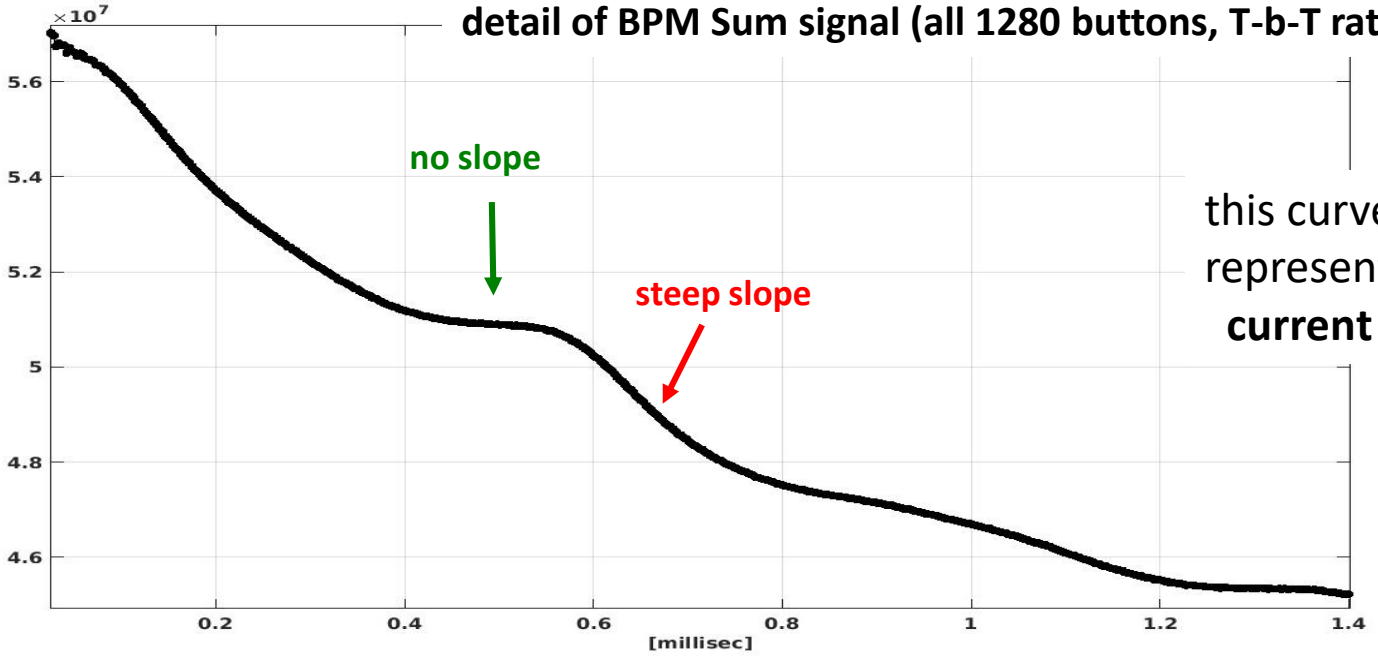
is NOT an issue for most BLD applications

but not allowing a precise and a certain measurement of time-resolved losses …

time resolved injection from BPM buttons

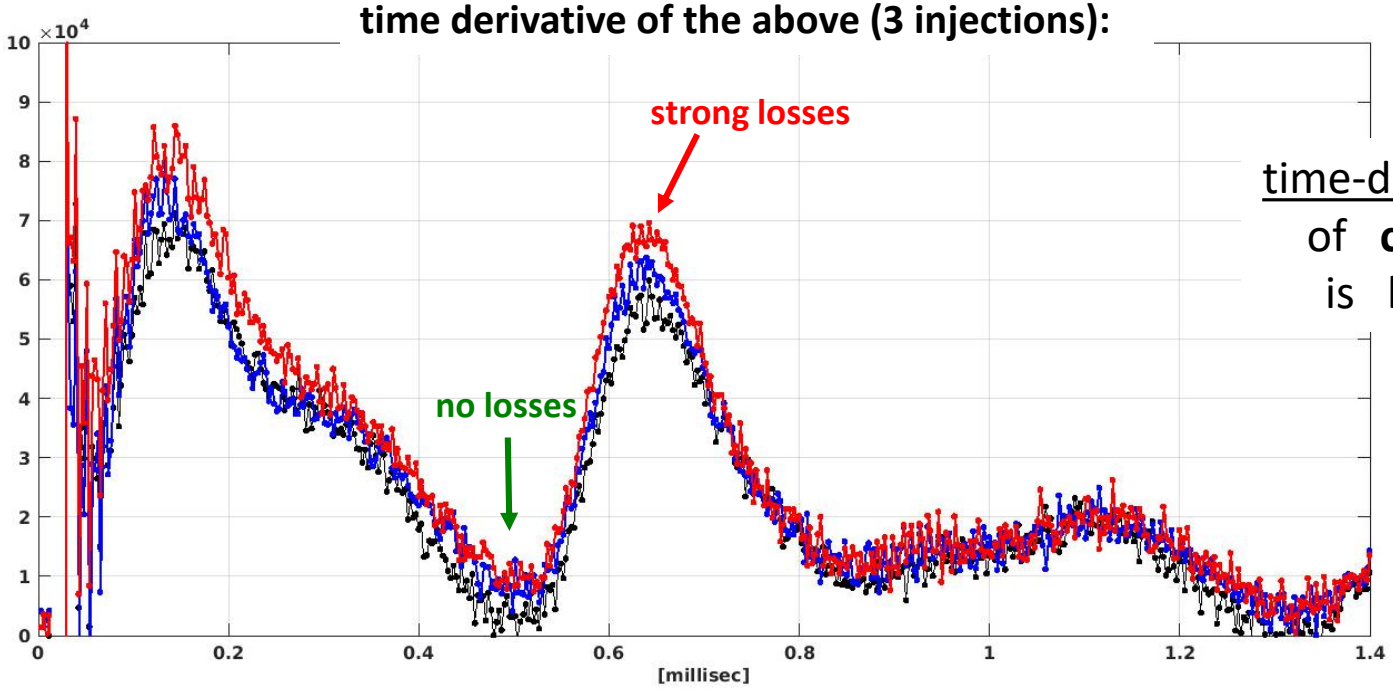


detail of BPM Sum signal (all 1280 buttons, T-b-T rate)



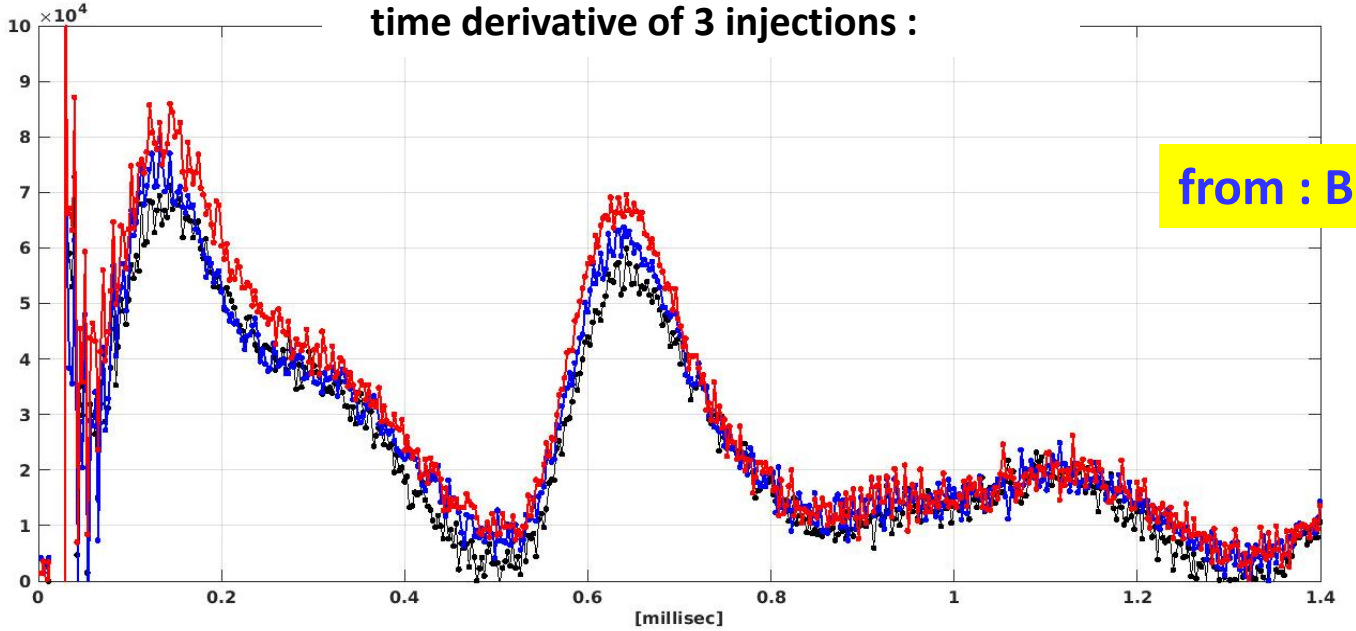
this curve represents **current**

time derivative of the above (3 injections):

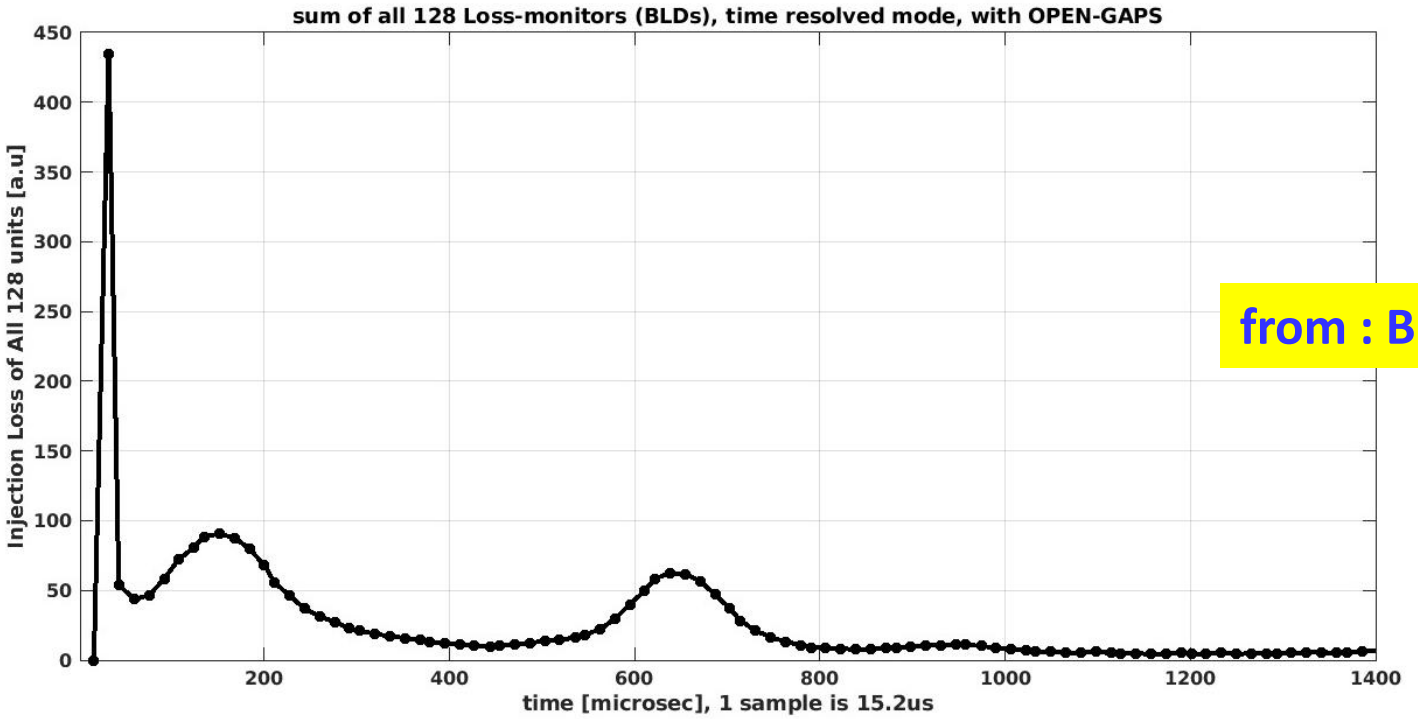


time-derivative of **current** is **losses**

time derivative of 3 injections :



from : BPMs



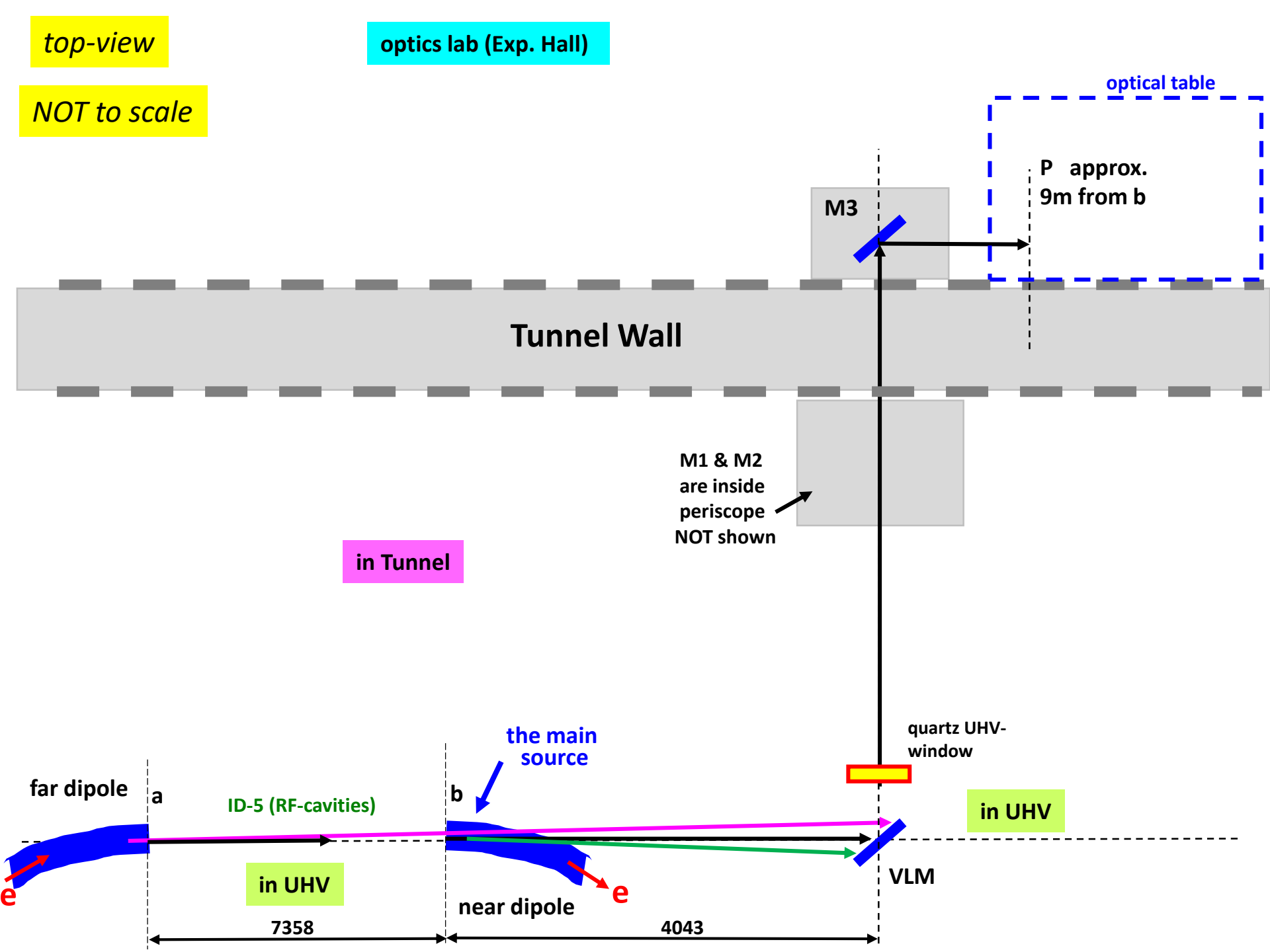
from : BLDs

the two methods (using BPMs and BLDs) have both different limitations,
but they nevertheless show also (partly) a good consistency between them

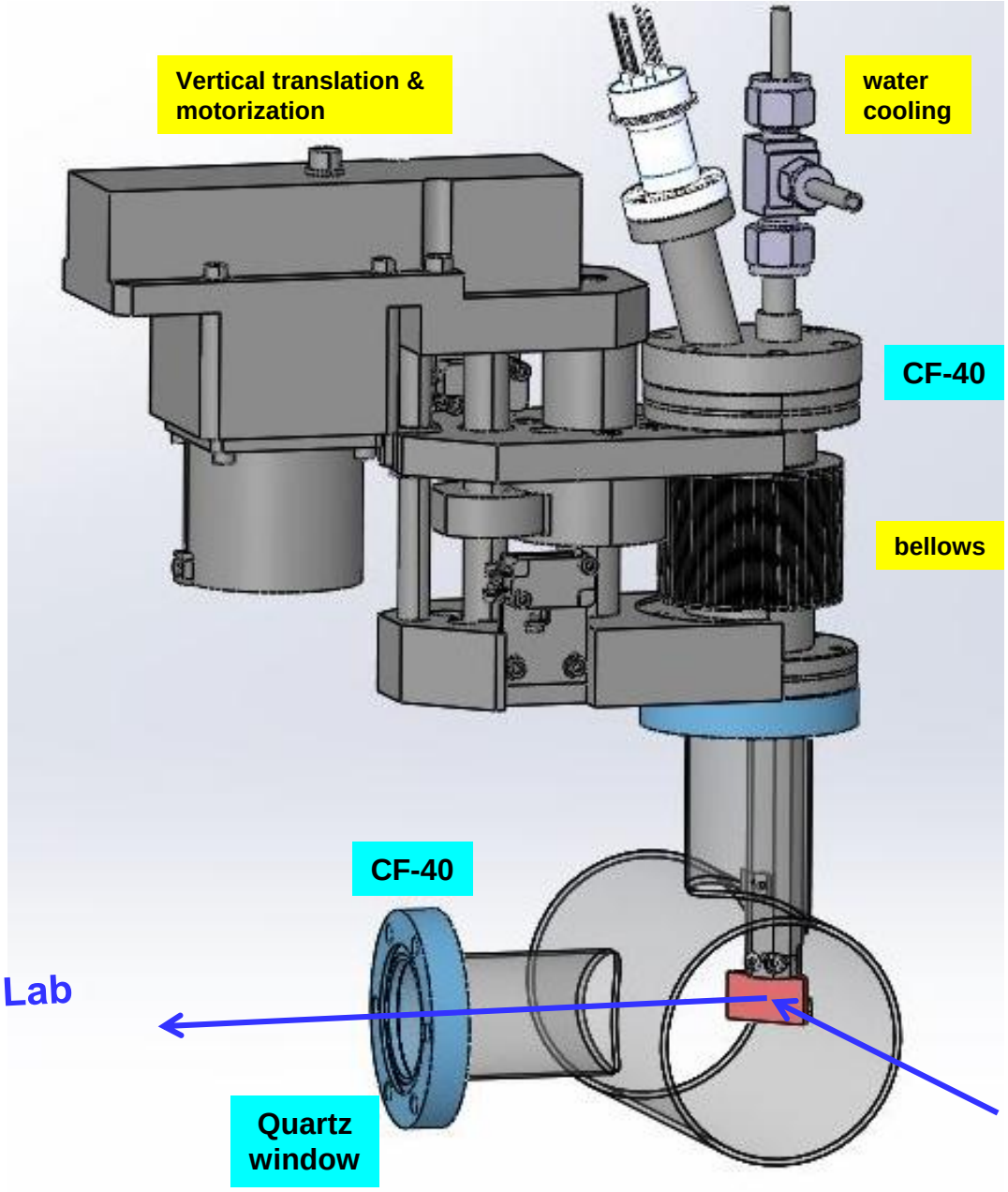
can we think of a new and independent method to even better measure
time-resolved injection losses (at T-b-T rate) ?

→ capture the full cone of **visible light**, at injection, into an empty storage ring,
and focus all that light onto a suitable detector → acquire at T-b-T rate

advantages : - the flux of visible light is not dependent of bunch-length
- this detector can handle strong peaked flux (no dislinearity)


top-view
NOT to scale
optics lab (Exp. Hall)
optical table
P approx.
9m from b
M3
Tunnel Wall
M1 & M2
are inside
periscope
NOT shown
in Tunnel
quartz UHV-
window
the main
source
far dipole
a
ID-5 (RF-cavities)
b
in UHV
in UHV
VLM
e
e
near dipole
7358
4043

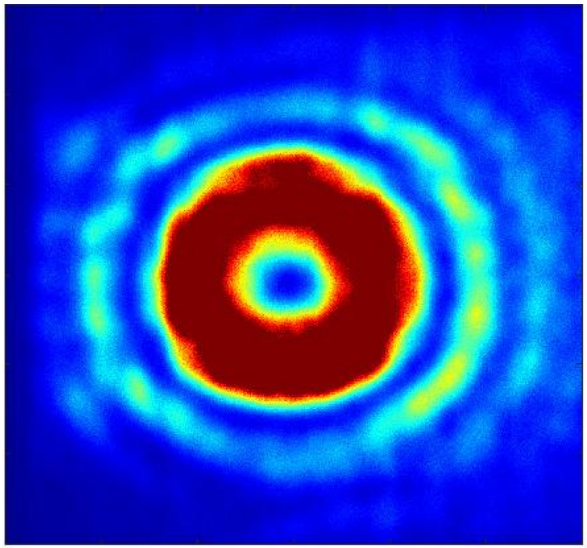
Visible Light Mirror : VLM

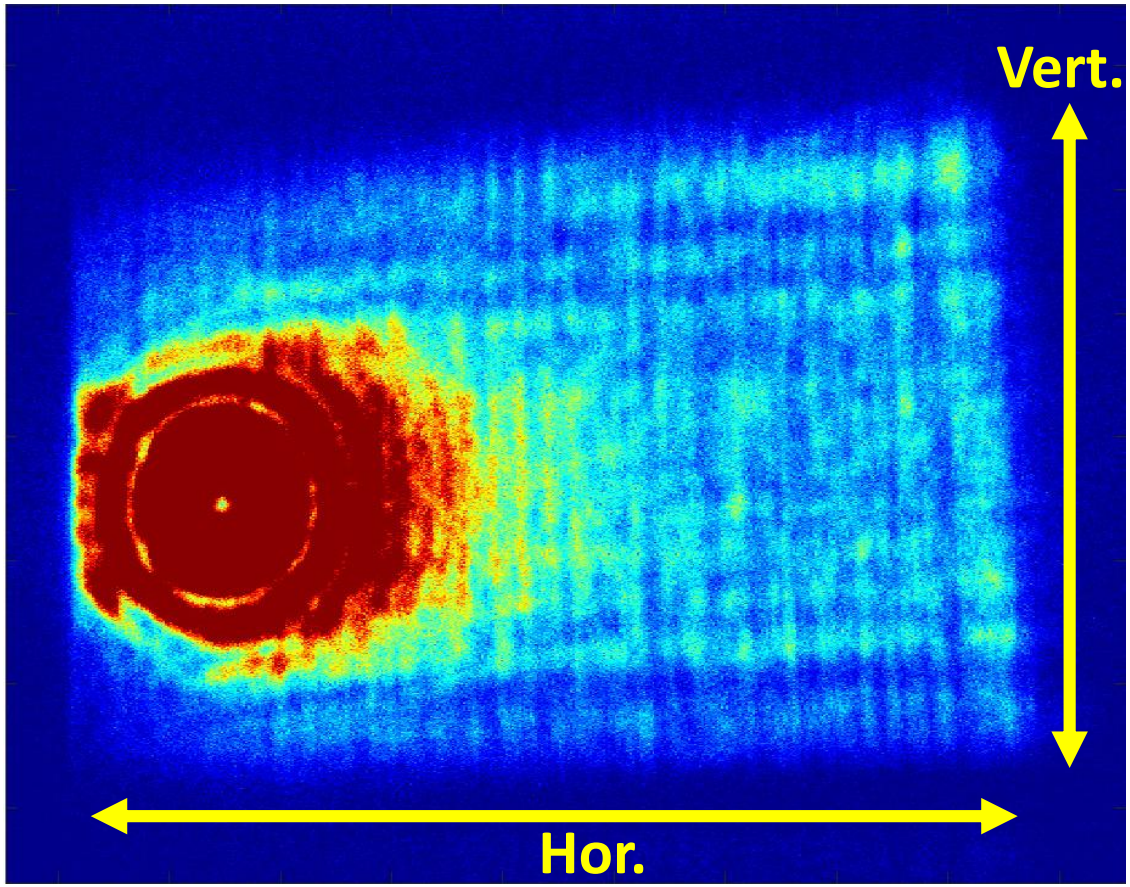


this mirror can be fully inserted into the beam-path

no heat-load issues since we inject <1mA into an empty ring

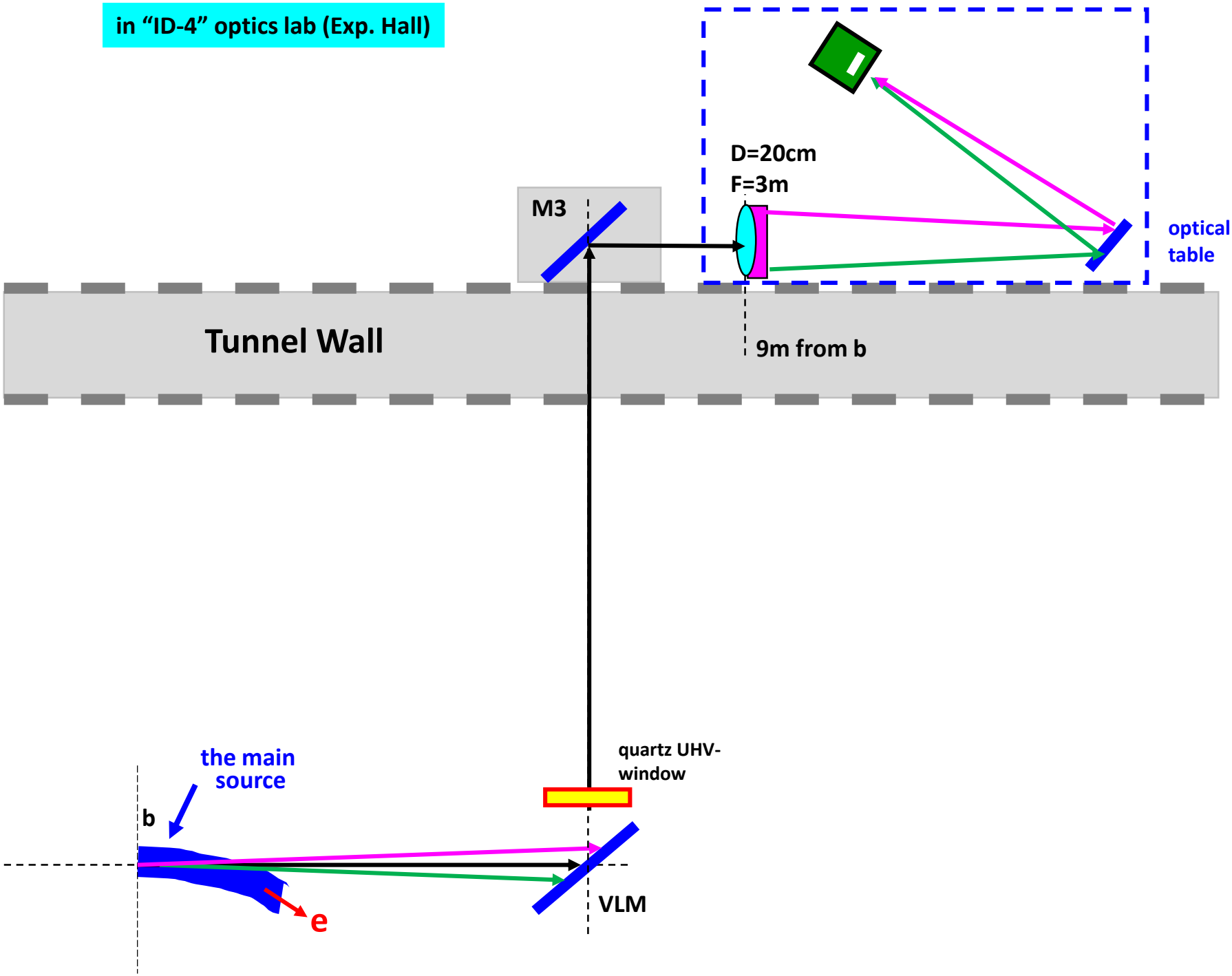
images taken with
stable stored beam



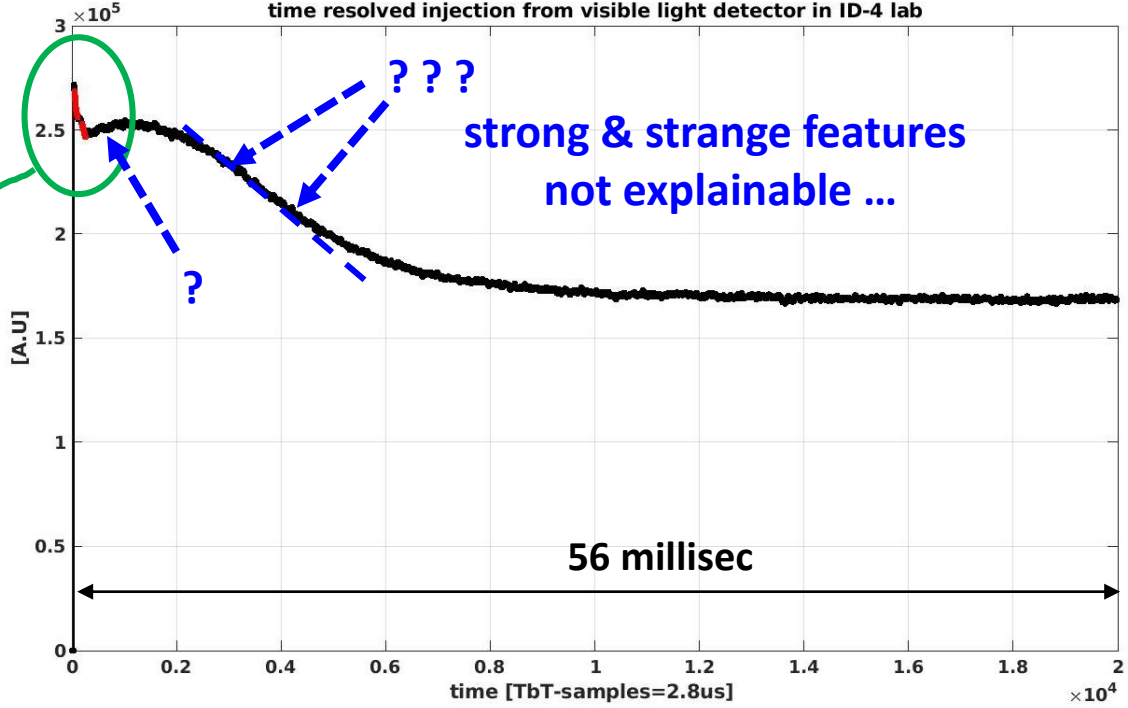


interference pattern of
Visible Light produced by
the fringe (slope) fields
of two Dipole magnets

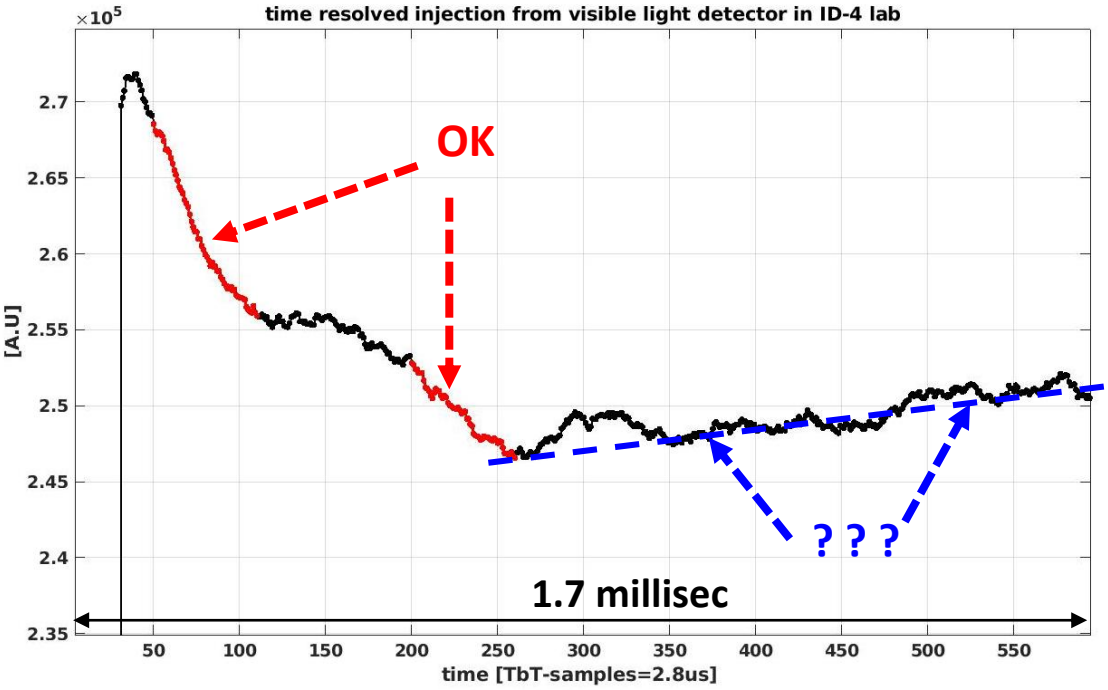
the full extracted light :
the dimensions correspond
well to what expected,


in “ID-4” optics lab (Exp. Hall)
D=20cm
F=3m
M3
optical table
Tunnel Wall
9m from b
the main source
b
quartz UHV-window
VLM
e

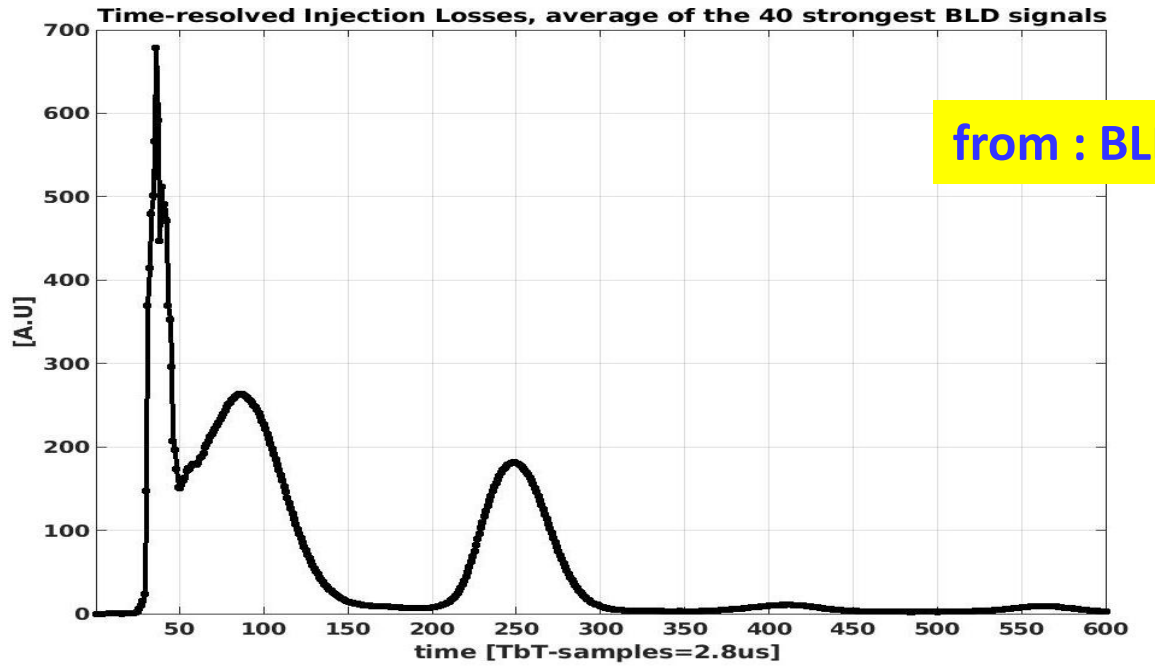
Visible Light Detector

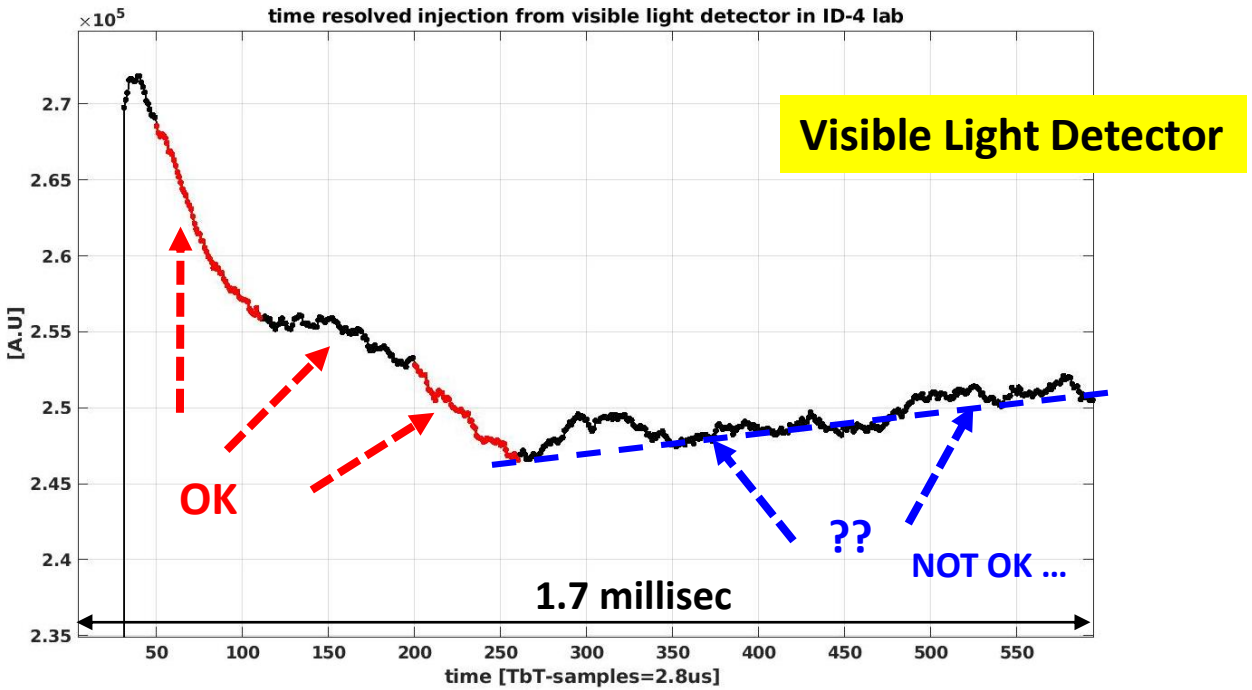


zoom



NOT OK …
upwards slope NOT possible


Time-resolved Injection Losses, average of the 40 strongest BLD signals
[A.U]
time [TbT-samples=2.8us]
from : BLDs


time resolved injection from visible light detector in ID-4 lab
×10^5
[A.U]
time [TbT-samples=2.8us]
Visible Light Detector
OK
??
NOT OK …
1.7 millisec

measurement at the ESRF of :

a) **injection efficiency and**
b) **the time-resolved losses of these injections**

conclusions :

we operate a good, reliable and precise and high-resolution injection-efficiency monitor based on simply (a few extra) BPM-buttons & Libera-Spark electronics

although we also get the fast T-b-T data from (all) BPM-buttons & Sparks there is distortion in that data, due to inevitable bunch-length fluctuations

the BLDs in fast/injection mode yield beautiful data of these fast losses, but a dislinearity exists (in the PMT) when handling strong & peaked signals (30ps)

tests on acquiring visible light for these fast injection losses were not fully satisfactory this method is anyway not compatible for measurements with a filled storage ring

Elettra
Sincrotrone
Trieste

DEELS
May 2025

measurement at the ESRF of :

a) injection efficiency and
b) the time-resolved losses of these injections

thank you for your attention !

is injection efficiency important for your light source ?

how do you measure injection efficiency ?

with what precision/resolution ? at what rate ?

can you resolve the time-structure of injection losses ?

can you localize these losses in your Storage Ring ?