Ultra-sensitive dark current measurements in the Injector

1) The ESRF has always provided filling-modes that suit Single Bunch users, i.e. with satisfactory purity (-> undesired RF buckets at zero electron level)

2) This purity is (so far) obtained by a cleaning method in the Storage Ring

3) That cleaning method uses a transverse resonant excitation of the undesired buckets and scraping them down to zero

4) It is done after each injection, takes roughly 1 minute

But : in future we will operate in Top-Up mode,
Cleaning in the Storage Ring no longer possible,
and so our Injector needs to provide a clean single bunch

The raises 2 challenging requirements :

1) Do the cleaning in the Injector (again transverse resonance + gating)

   or use an ultra fast injection kicker after the Linac (pick only the Single Bunch)

2) Measure that the above method provides indeed that pure Single Bunch

Bunch Cleaning in the .... Booster !

This is absolutely imperative, not only for the new Ring,
but as soon as Top-Up operation is implemented :

few questions & answers :

What is meant with "Bunch Cleaning" ?

removing (completely) the electrons in un-desired buckets :
e.g. in 16 bunch mode only 16 buckets out of 992 are filled
and the other 976 buckets should contain Zero electrons

How is it done now ?

in the Storage Ring, by exciting undesired buckets at a resonance frequency,
and loosing their electrons on a (temporarily "closed") scraper

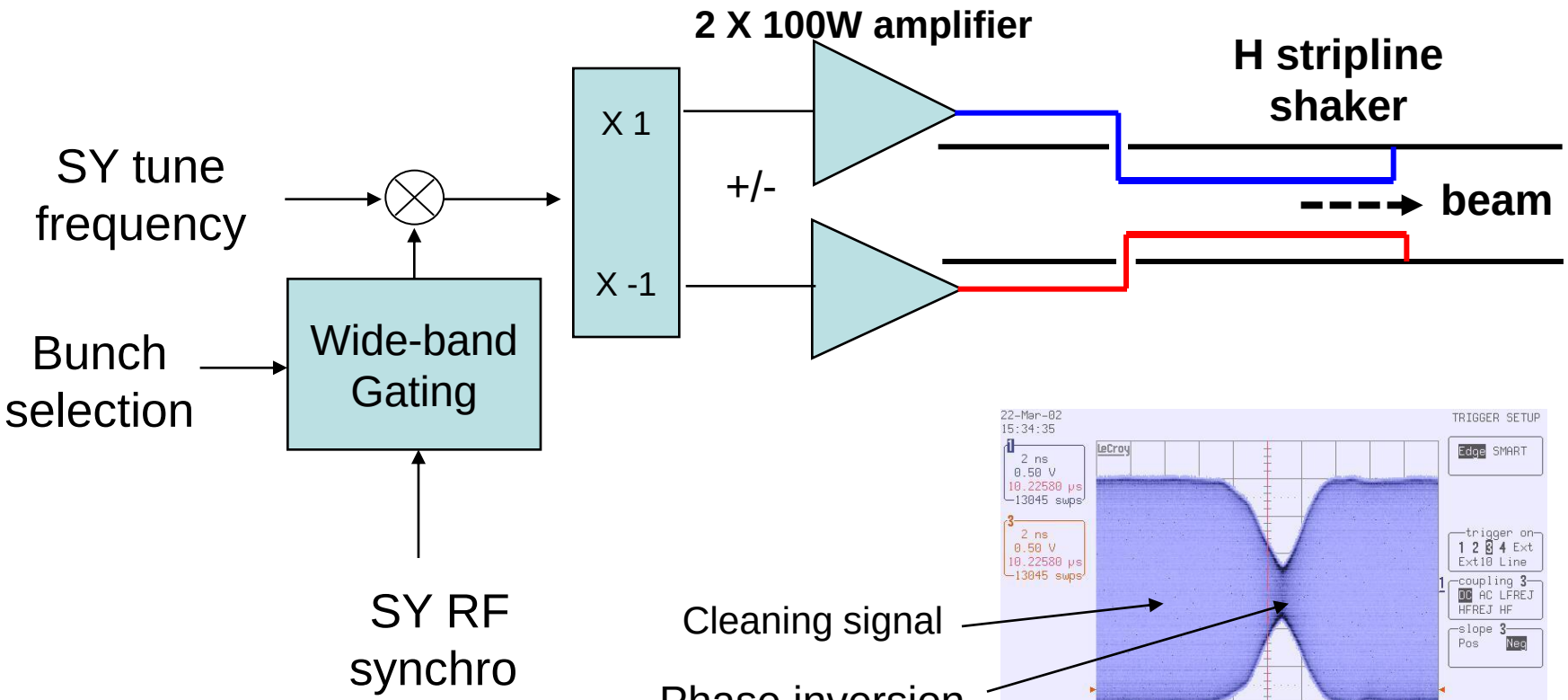
What is the problem then with Top-Up ?

the process (incl. "closing" this scraper) takes too much time,
compared to the periods between Top-Ups,
also : not completely transparent to beam stability

Cleaning in the booster by resonant RF knock out :

The Booster Beam is excited horizontally by a shaker at the Hor. Tune frequency.

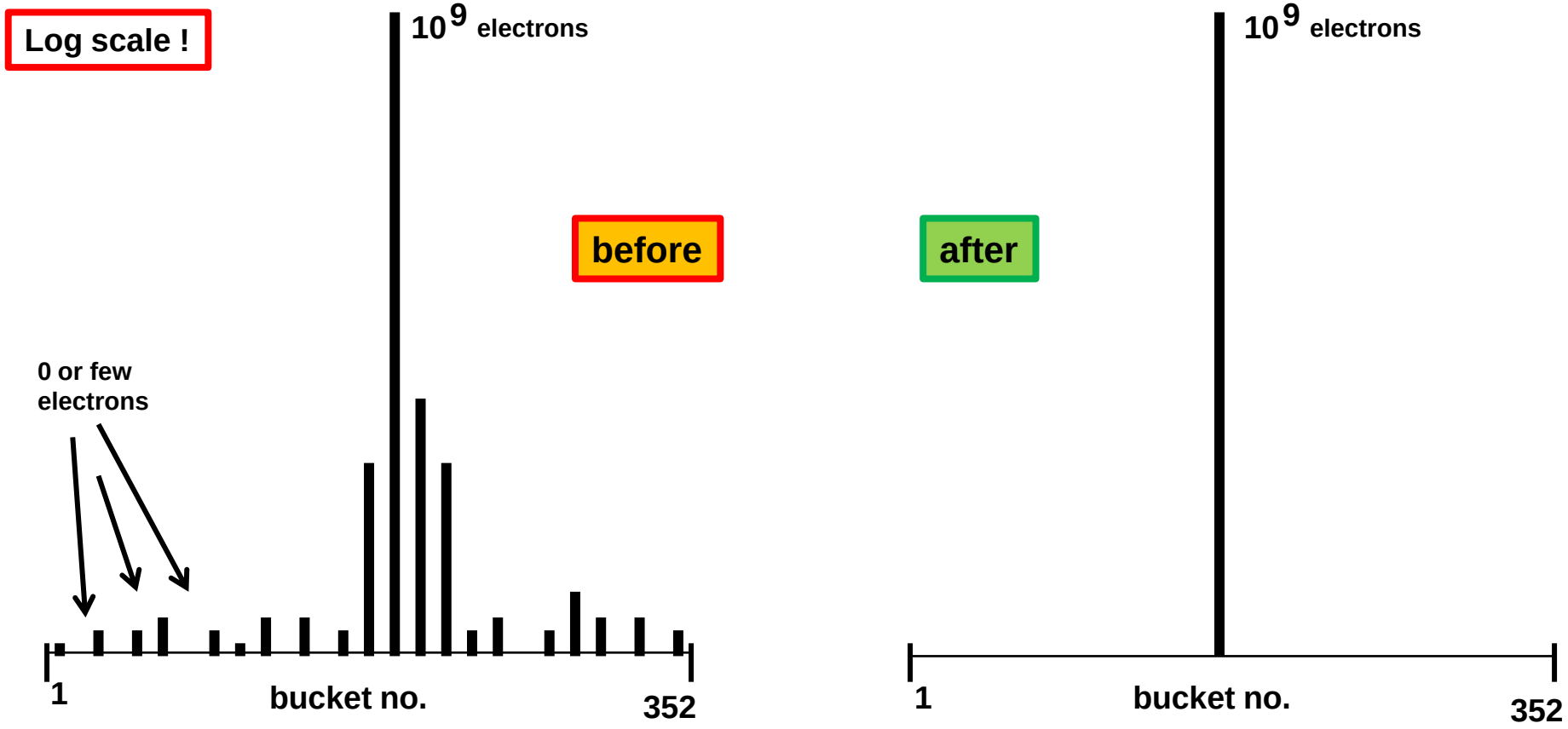
The Main Bunches are protected from this excitation : a synchronized phase inversion at their passage in the shaker.

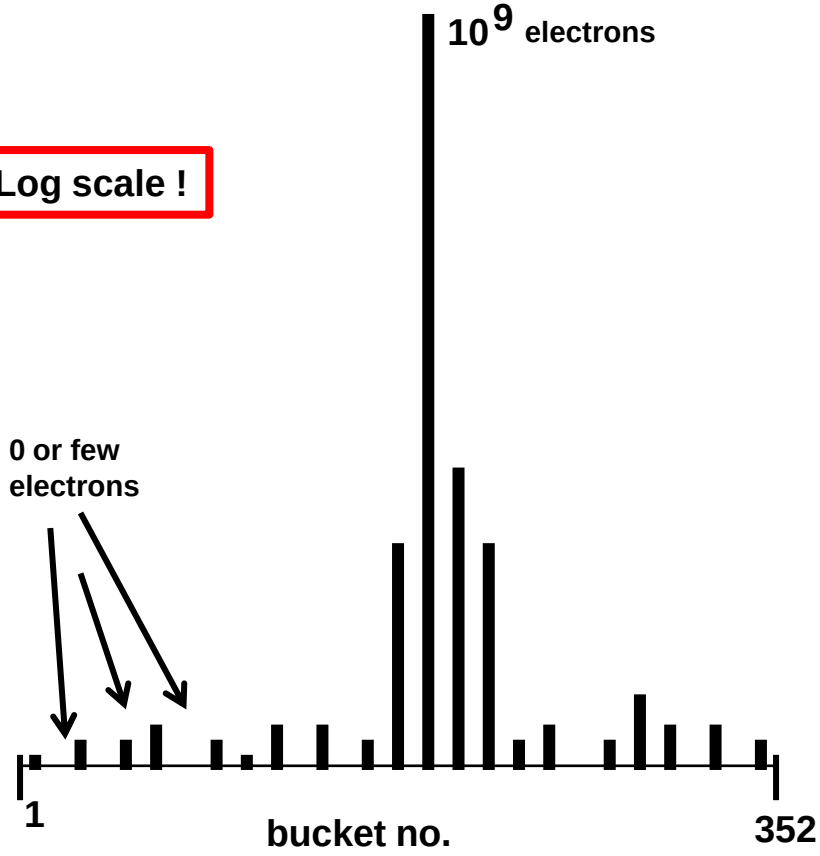


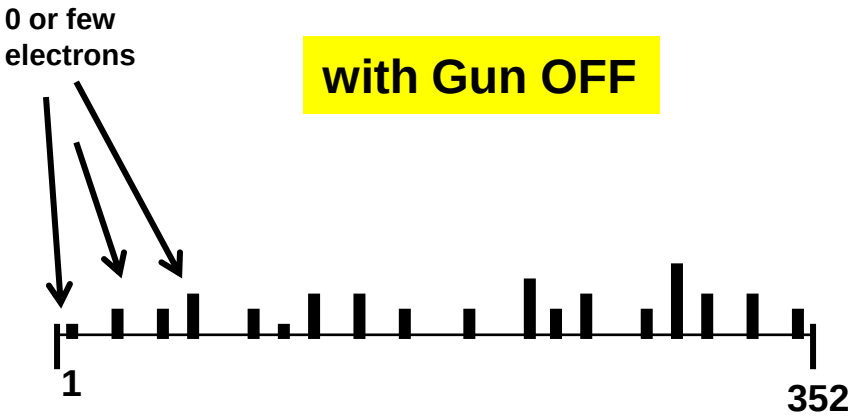
Bunch Purity Cleaning in the Booster is imperative for the Phase-2 upgrade

MDT of 23/7/2013

a sensitive (single electron) Booster dark-current measurement diagnostic







this is “dark current”

produced in the 1rst cell of Linac buncher :

thermal electrons, pulled-out & accelerated by the fields, they fall (by coincendence) in the good RF phase of the SYRF, finally end-up as 6 GeV electrons at the extraction

with Gun OFF

this “dark current”

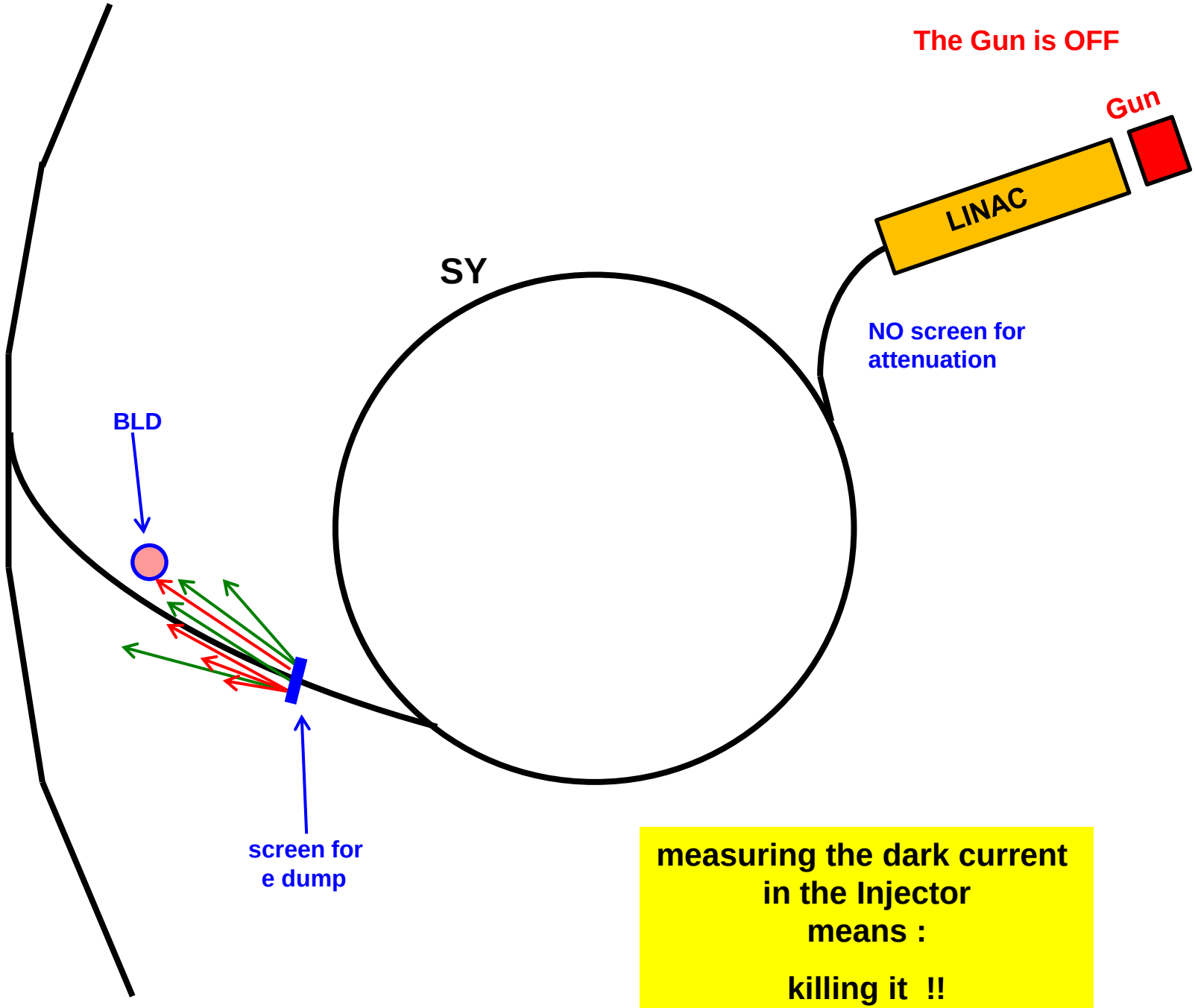
How much is it ??

very rough estimation done at MDT in February :
injecting 40 (dark) shots into SR and counting several minutes
with the photon counter of ID-25 in sensitive mode

The Booster dark current per shot is roughly 2 electrons per bucket, (roughly) distributed equally over all 352 buckets.

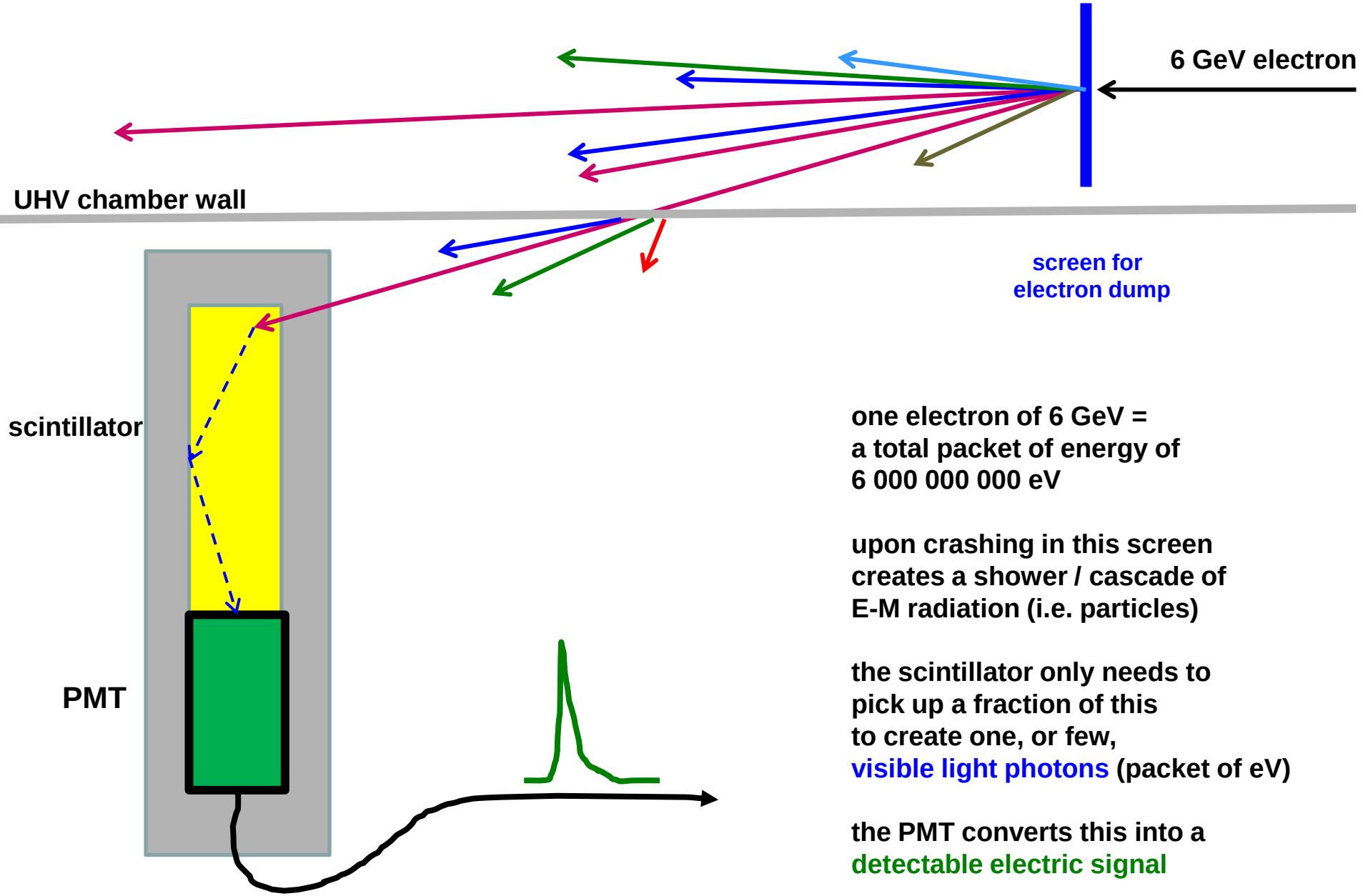
can we measure it quickly & precisely in the Injector ?

i.e. independent of Storage Ring, i.e. during USM



measuring the dark current in the Injector means :

killing it !!



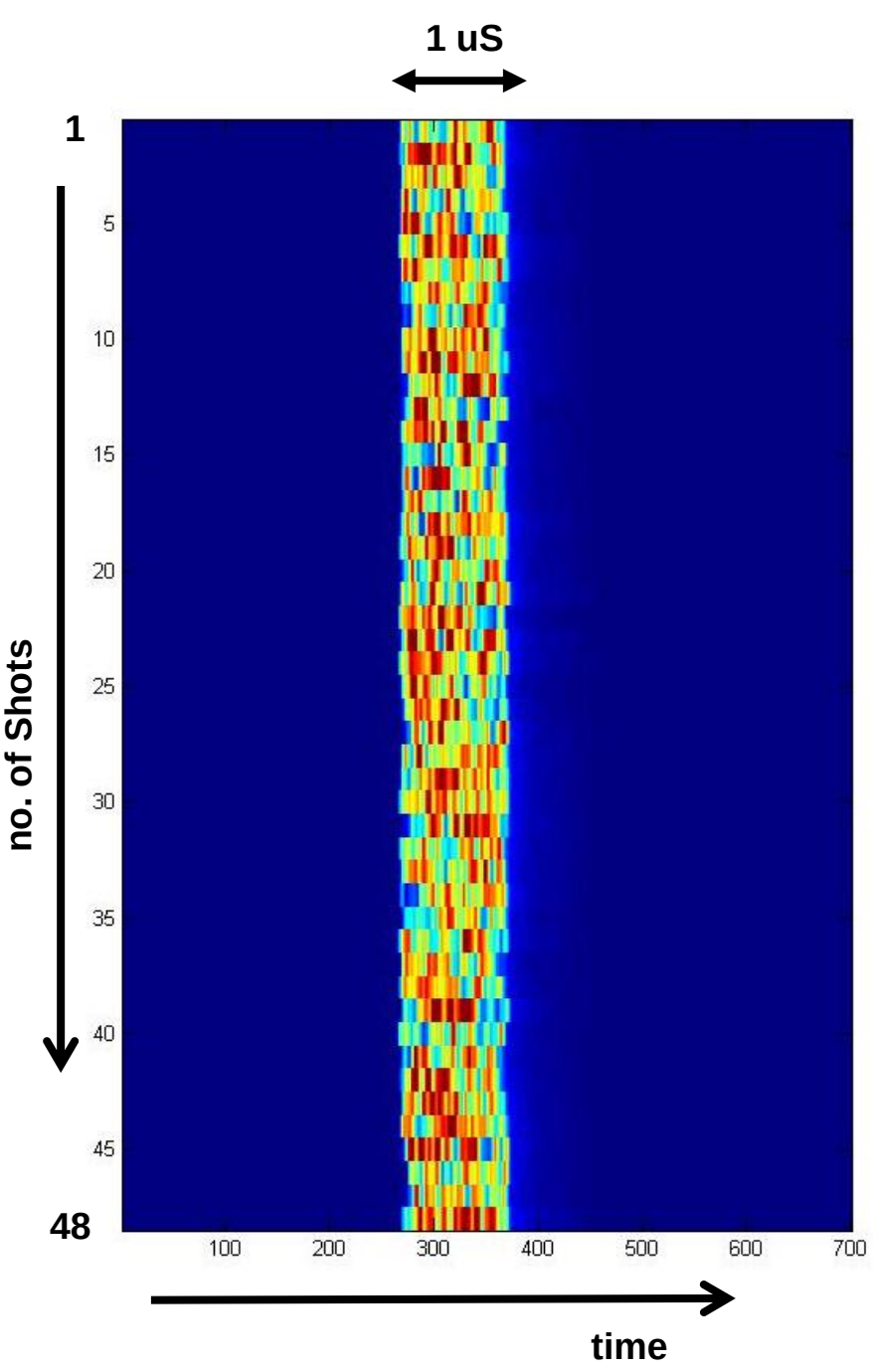
one electron of 6 GeV =
a total packet of energy of
6 000 000 000 eV

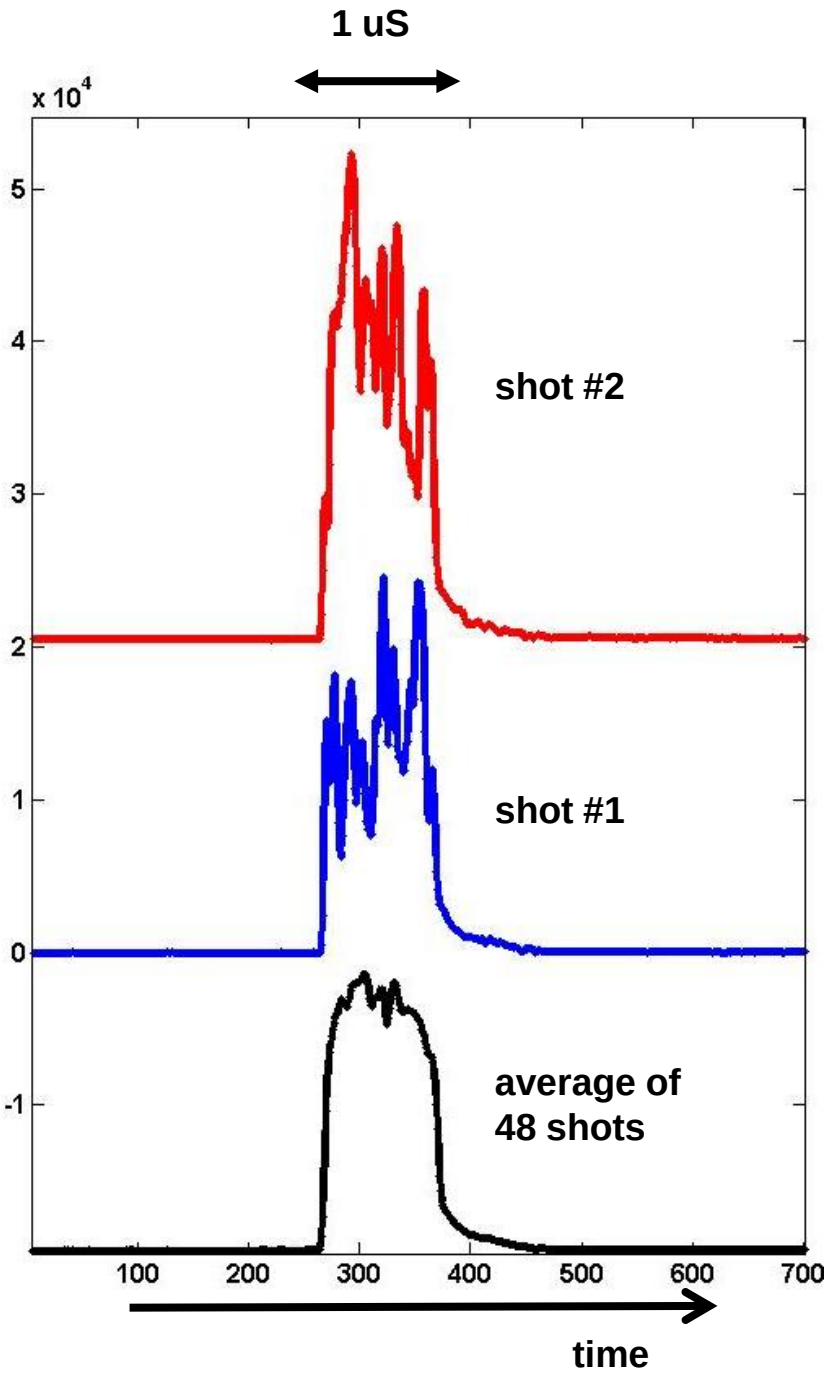
upon crashing in this screen
creates a shower / cascade of
E-M radiation (i.e. particles)

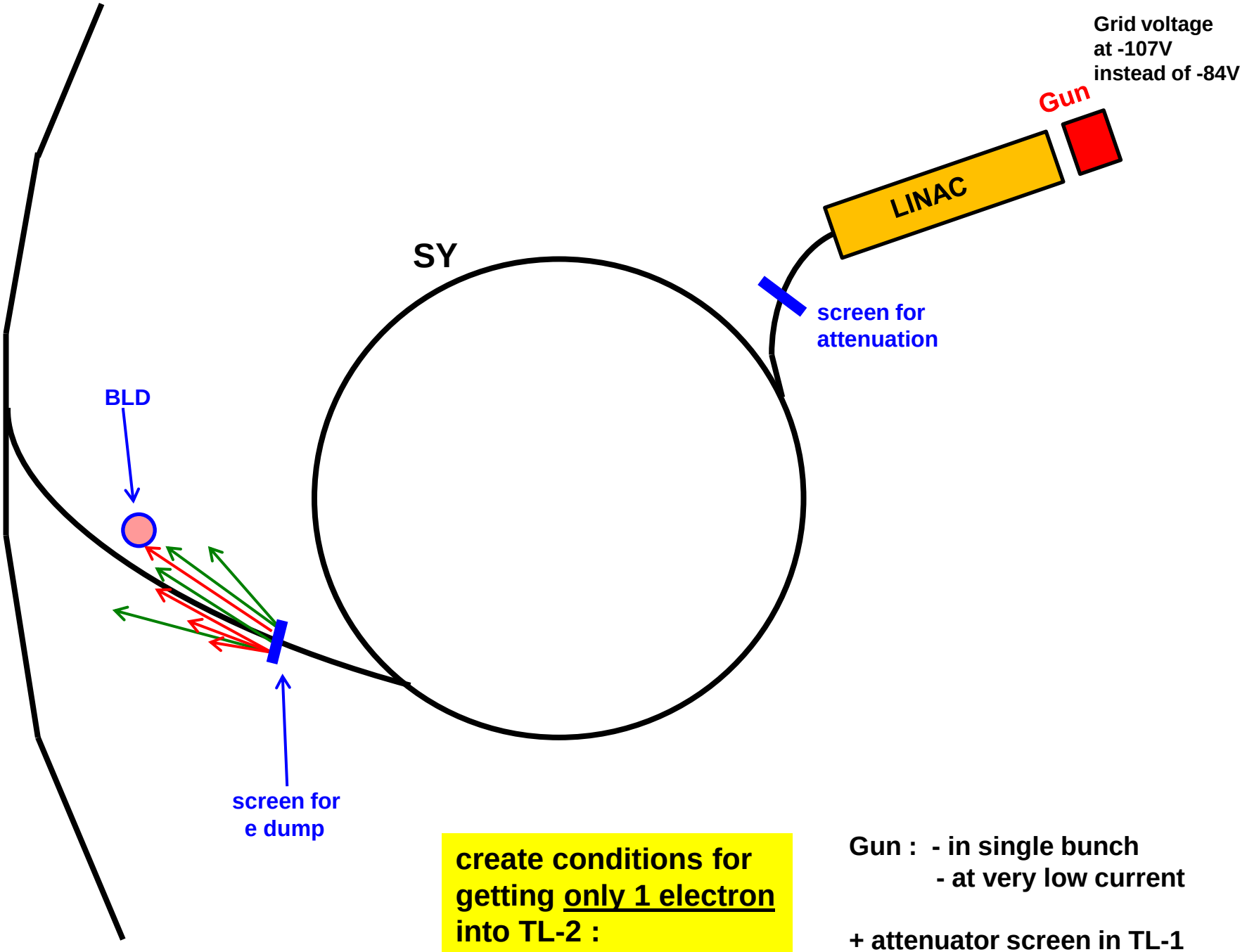
the scintillator only needs to
pick up a fraction of this
to create one, or few,
visible light photons (packet of eV)

the PMT converts this into a
detectable electric signal

digitized by a Libera-BLM


1 uS
1
5
10
15
20
25
30
35
40
45
48
no. of Shots
100
200
300
400
500
600
700
time

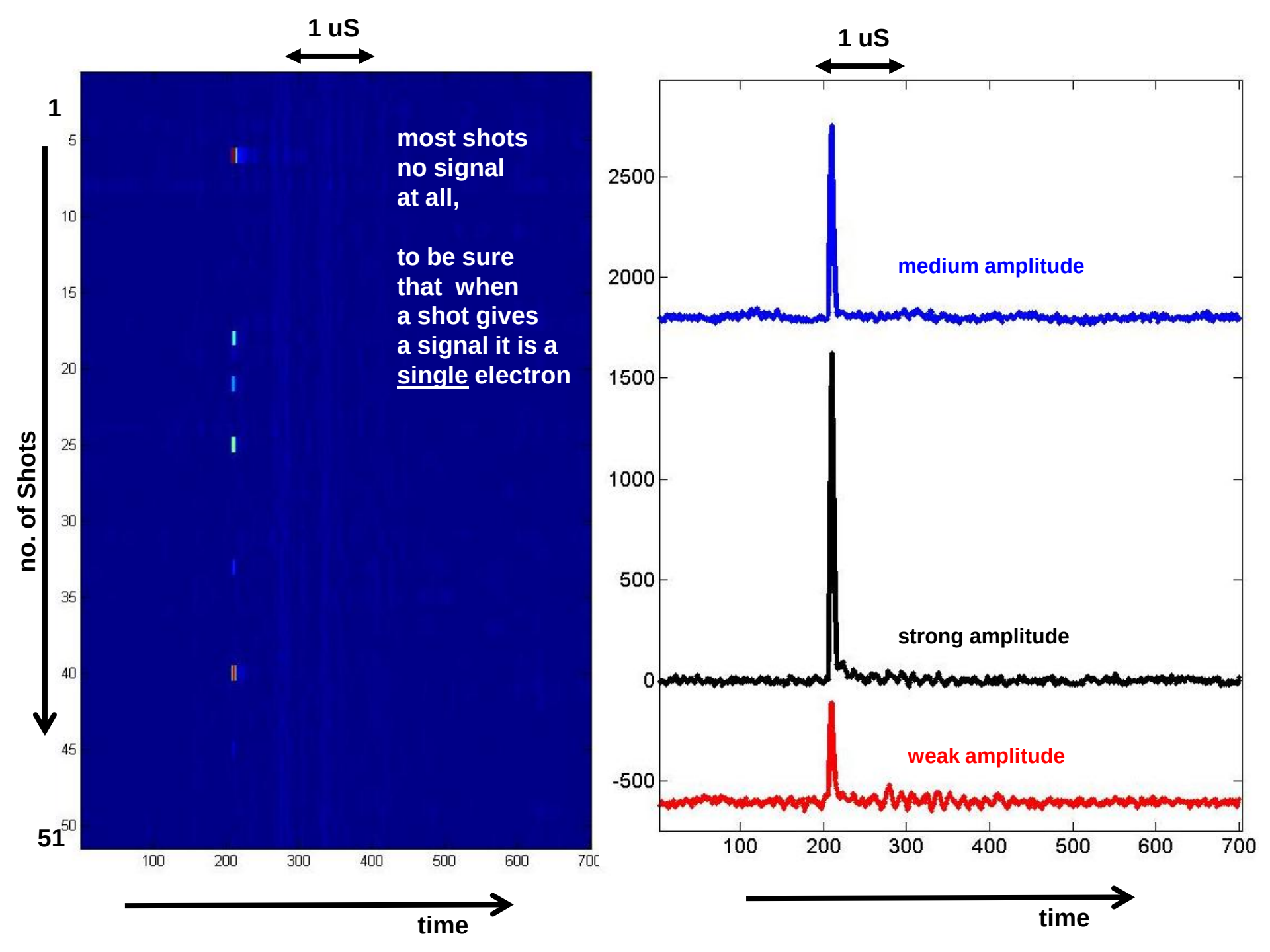

1 uS
x 10^4
5
4
3
2
1
0
-1
shot #2
shot #1
average of
48 shots
100
200
300
400
500
600
700
time

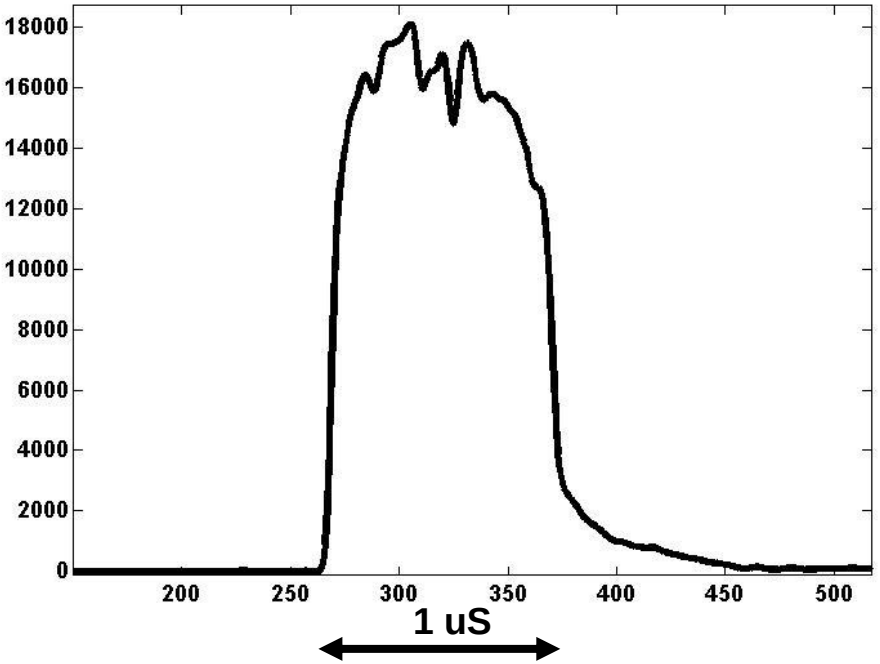


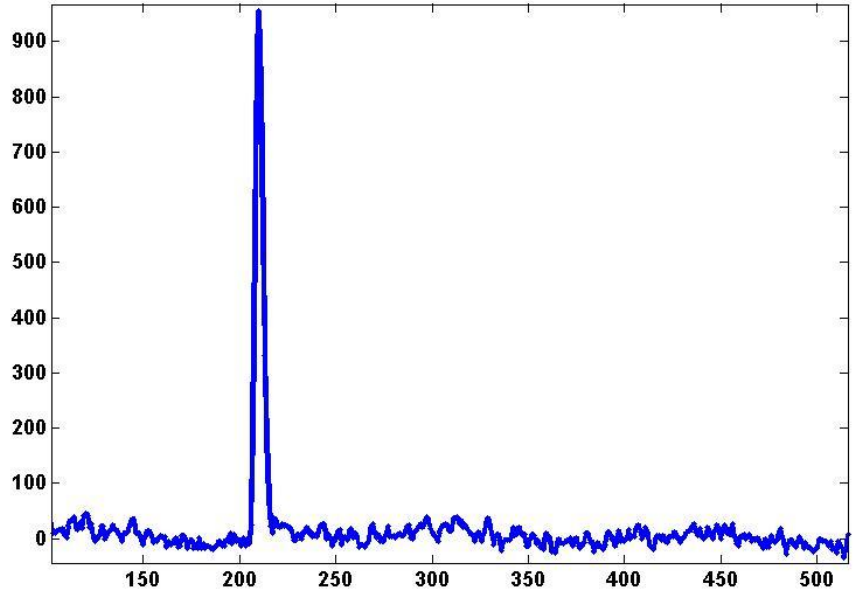
create conditions for getting <u>only 1 electron</u> into TL-2 :

Gun : - in single bunch
- at very low current

+ attenuator screen in TL-1


1 uS
1
5
10
15
20
25
30
35
40
45
50
51
no. of Shots
most shots
no signal
at all,
to be sure
that when
a shot gives
a signal it is a
single electron
100
200
300
400
500
600
700
time
1 uS
2500
2000
1500
1000
500
0
-500
medium amplitude
strong amplitude
weak amplitude
100
200
300
400
500
600
700
time





the integrated value of the pulse from the "dark current"

divided by

the integrated value of the average strength pulse from the single electron

yields the number of electrons in that "dark current"

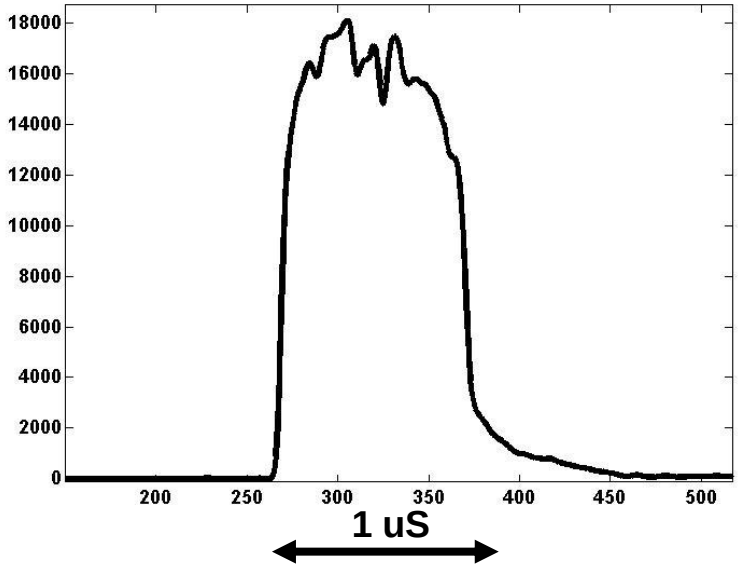
Result :

roughly 150 electrons per shot

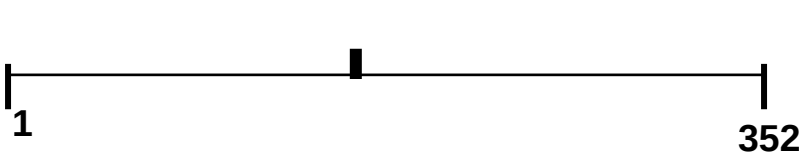
i.e. 0.5 electron per bucket

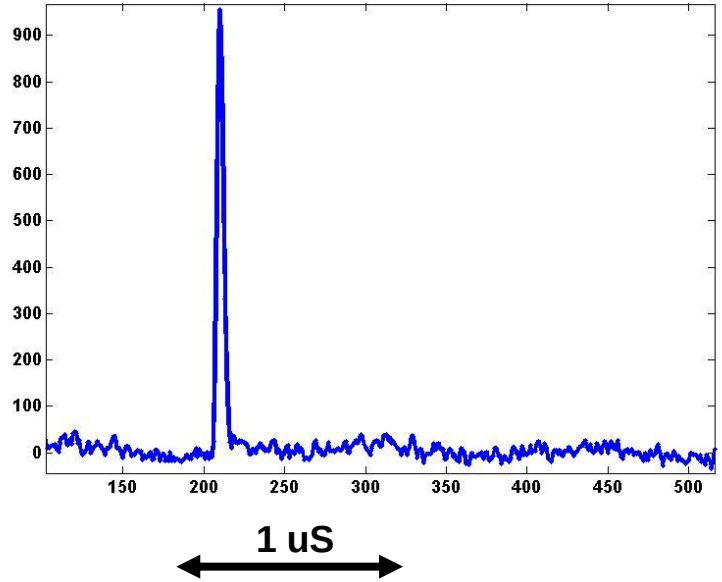
compared to 2 electrons/bucket found (very roughly) in February

with Gun OFF
& NO cleaning



with Gun OFF
& cleaning (successful)





this diagnostic should be helpful for the commissioning of the Booster cleaning during USM

Ultra-sensitive dark current measurements in the Injector

This is a destructive and an indirect measurement technique

But in the absence of other techniques still (hopefully) useful during the commissioning of Booster Bunch Cleaning

any other (ideas of) measurement techniques much welcome … !