LPROT Experiment

TE/MPE/PE

EN/STI

EN/MME

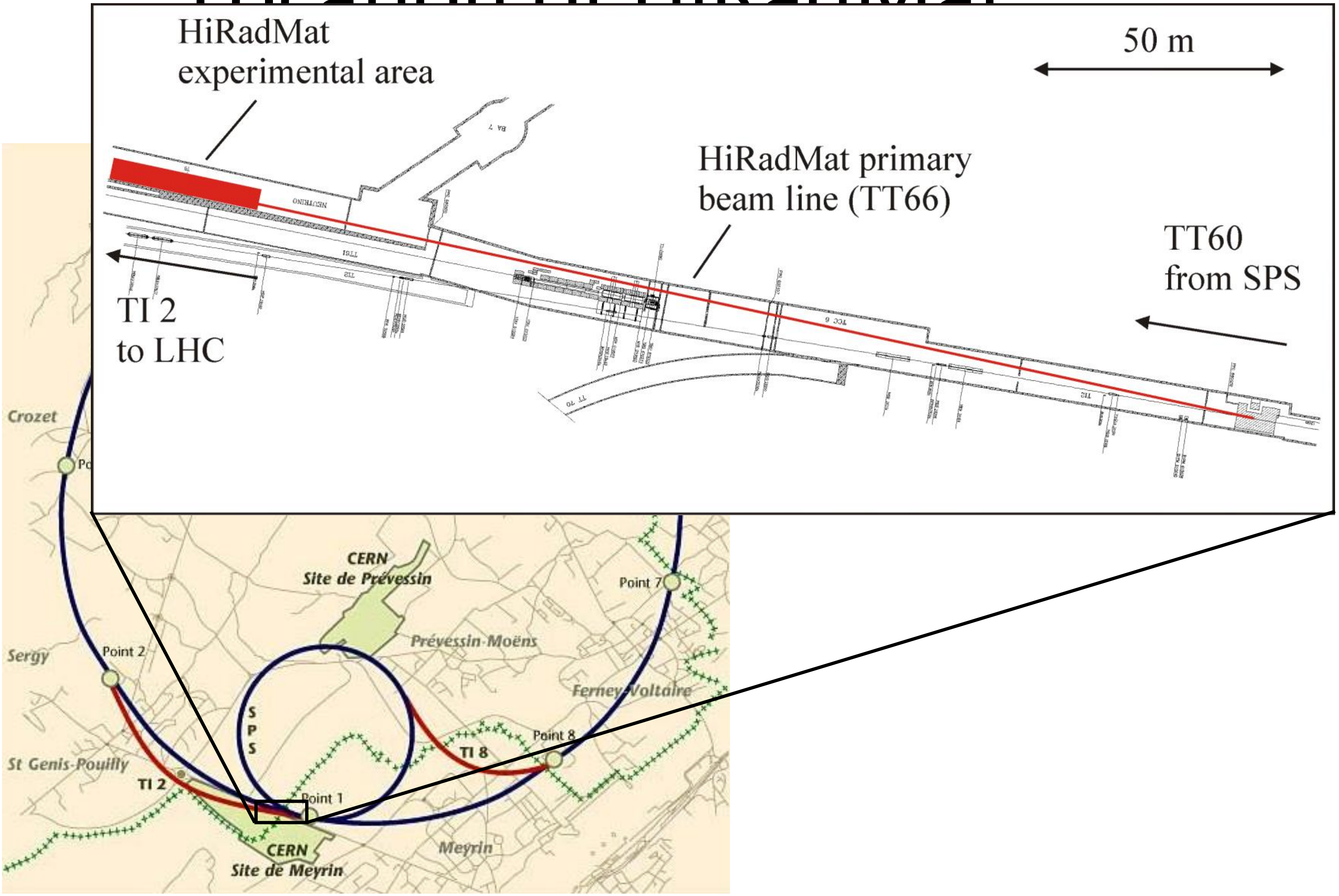
J. Blanco

Objectives

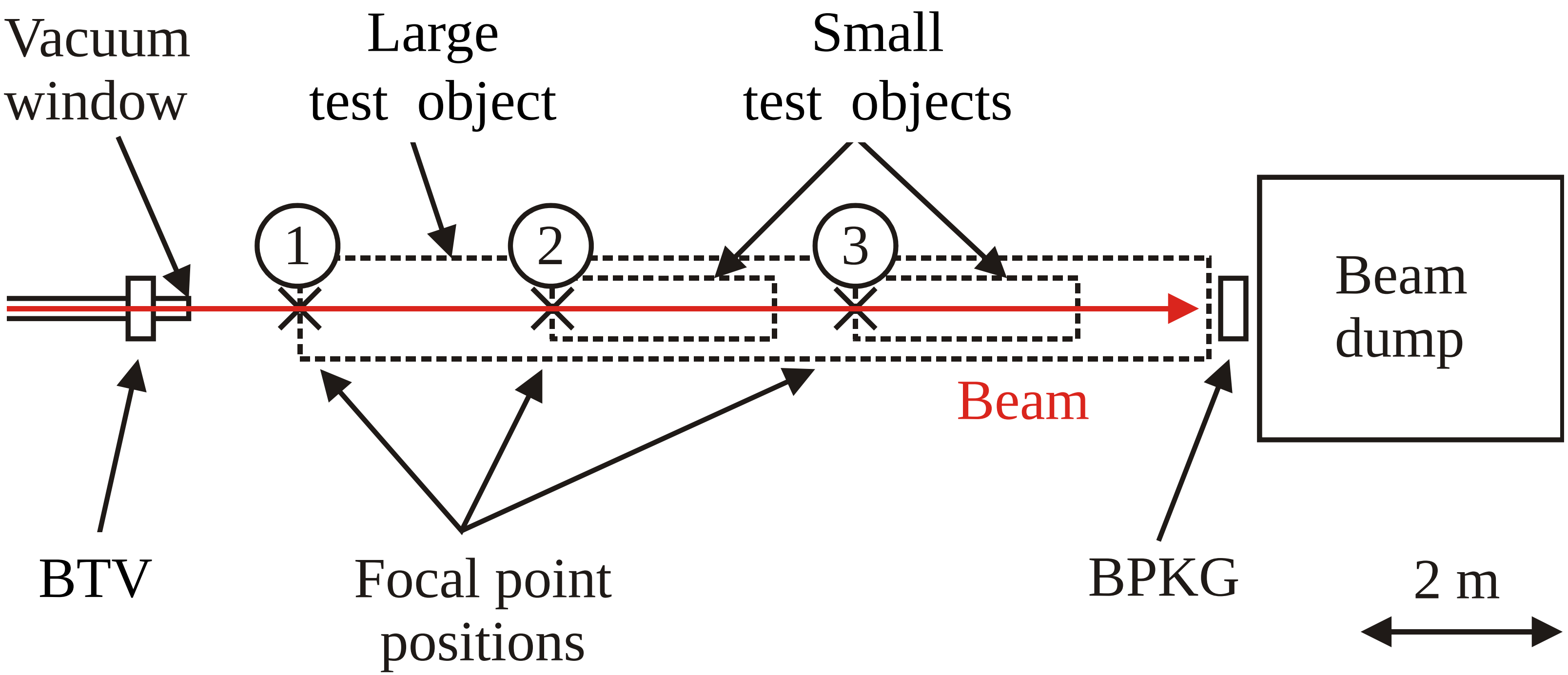
- Understand the damage potential of high intensity beams.
- Create the conditions to produce hydrodynamic tunneling predicted by simulations.
- Irradiate a High-Z material with a high intensity high dense beam and then visually inspect.
- Benchmark complex simulation programs (FLUKA-BIG2).
- In addition to the visual inspection, detectors could be added to follow the dynamic evolution of the hydrodynamic tunneling.

Hydrodynamic tunneling

Location of HiRadMat

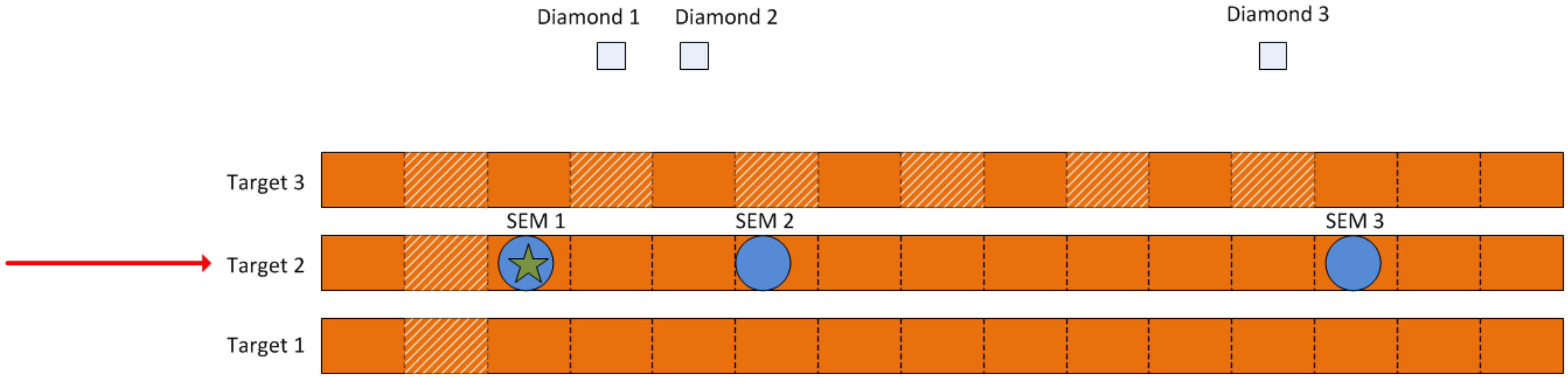


Layout of Experimental Area

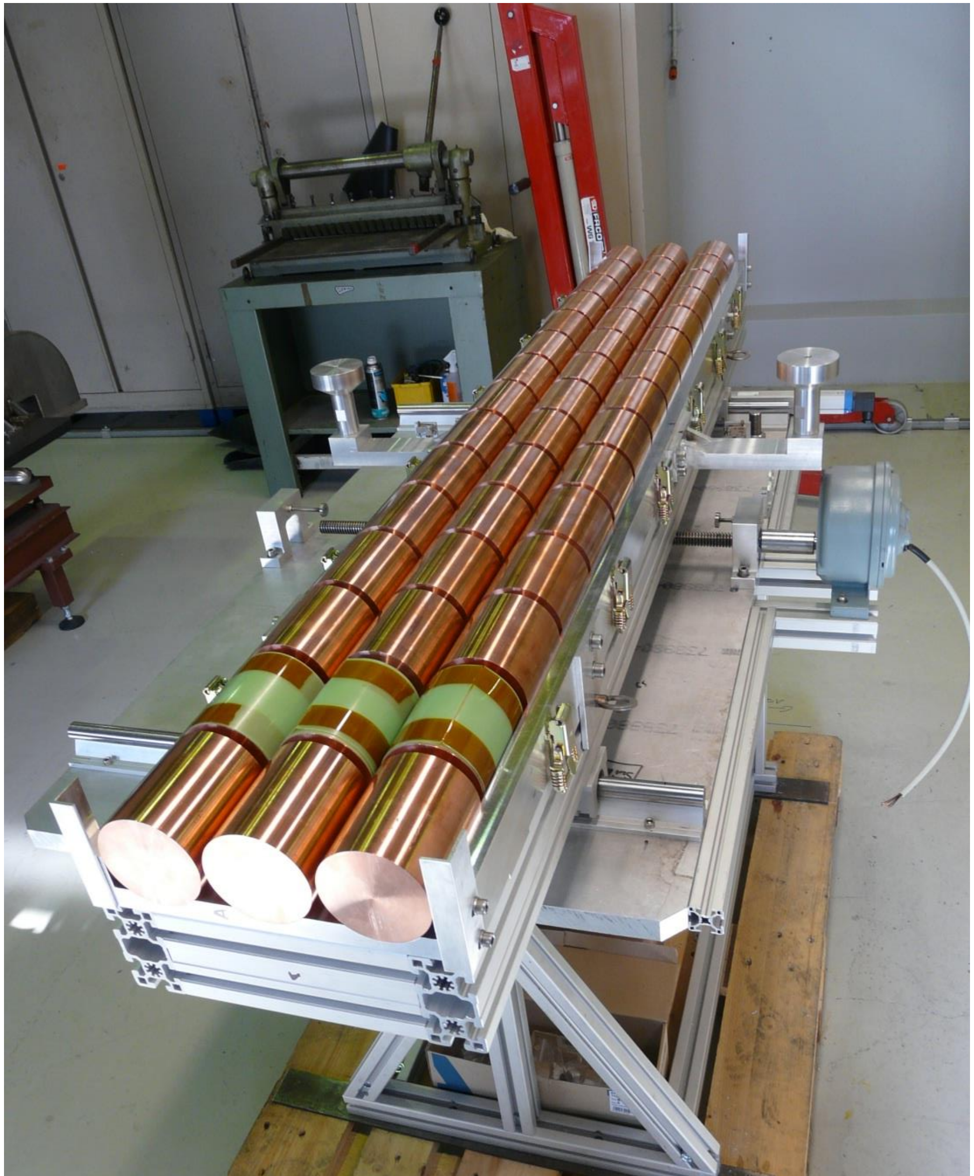


- Flexible optics to provide beam radii of σ = 0.1 to 2.0 mm at the focal points.
- Focal point longitudinal location continuously variable between positions 1 and 3.
- Predefined optics for 3 focal points and 6 beam sizes.

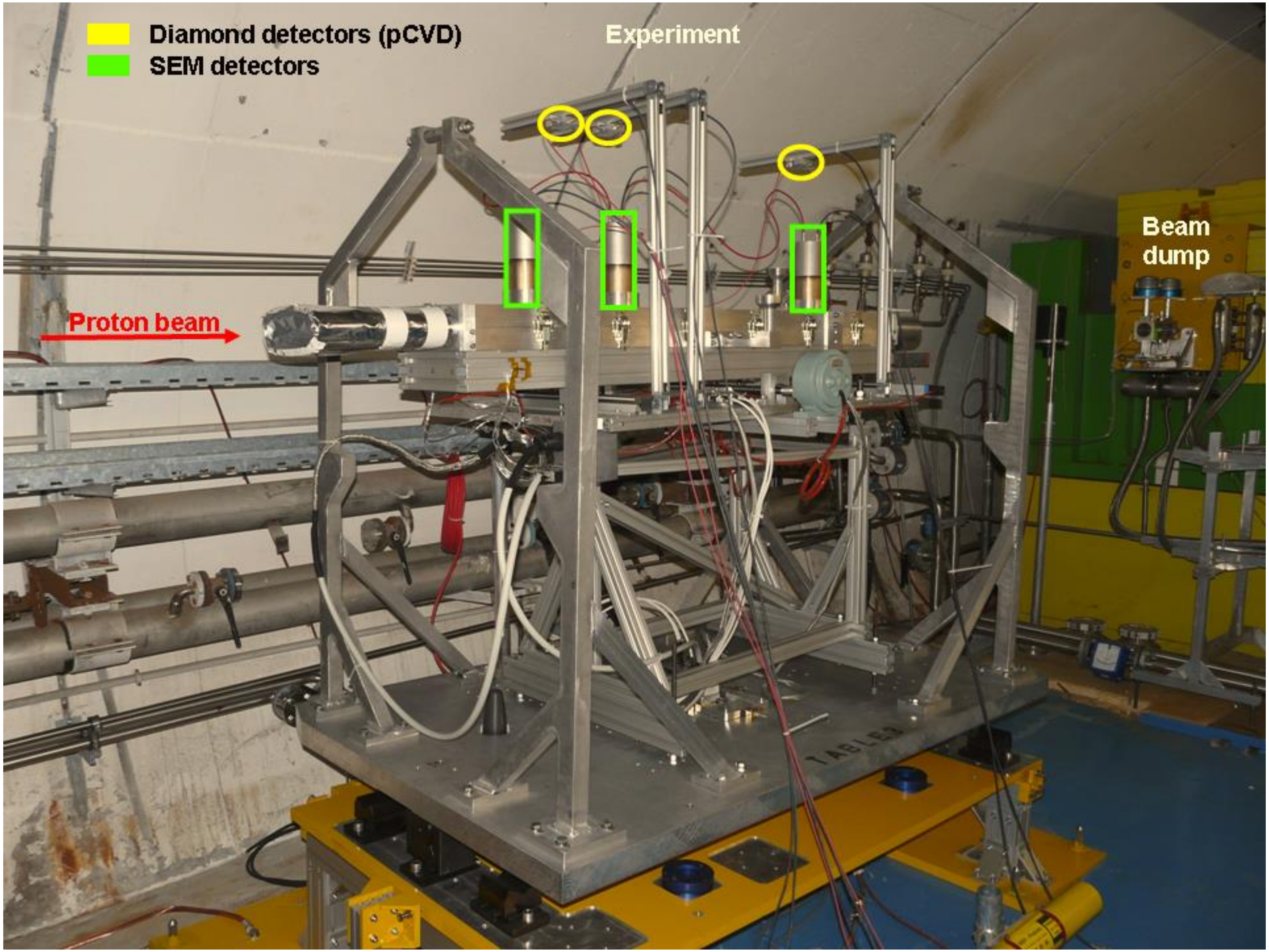
target


Diamond 1
Diamond 2
Diamond 3
Target 3
SEM 1
SEM 2
SEM 3
Target 2
Target 1

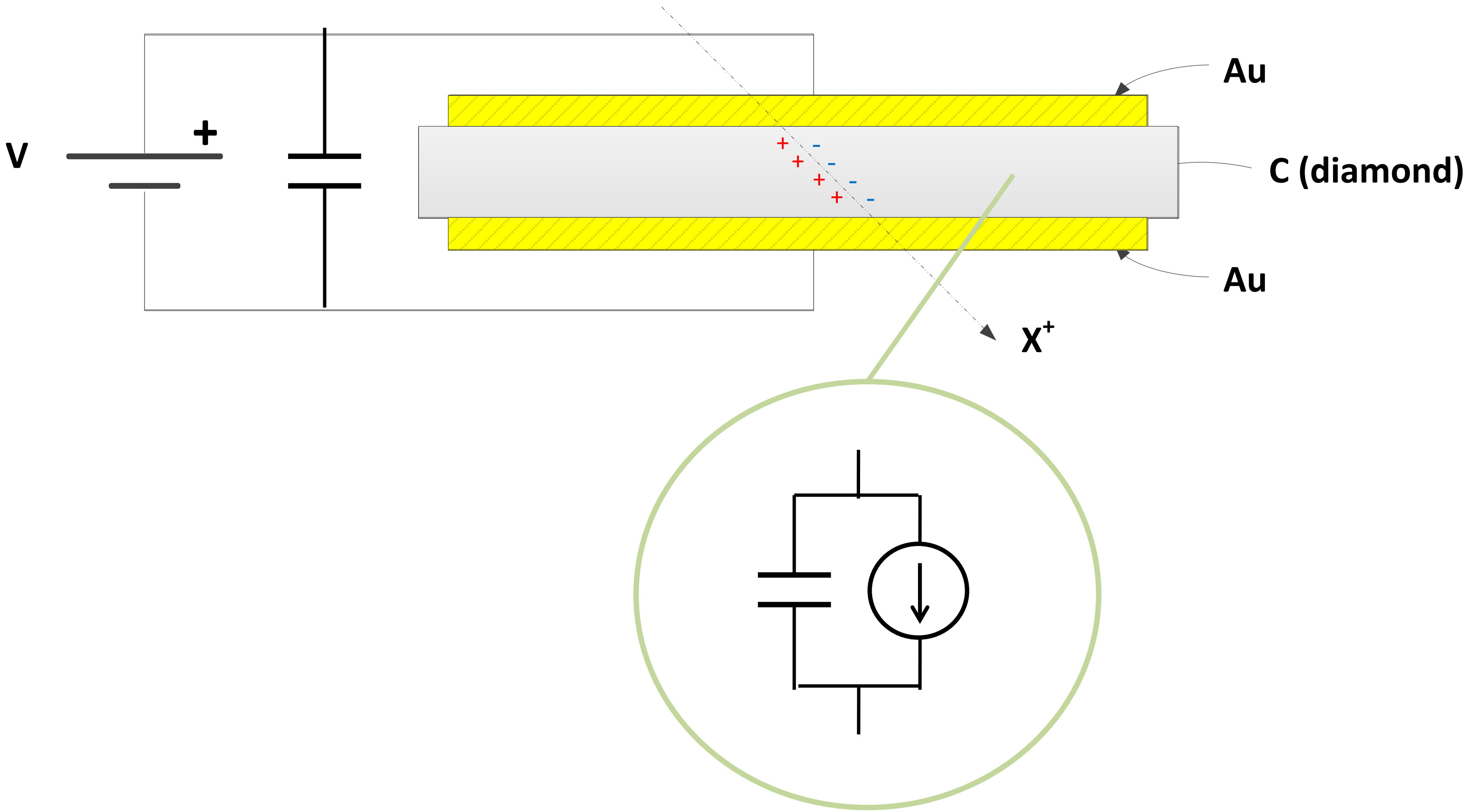
target



Installation

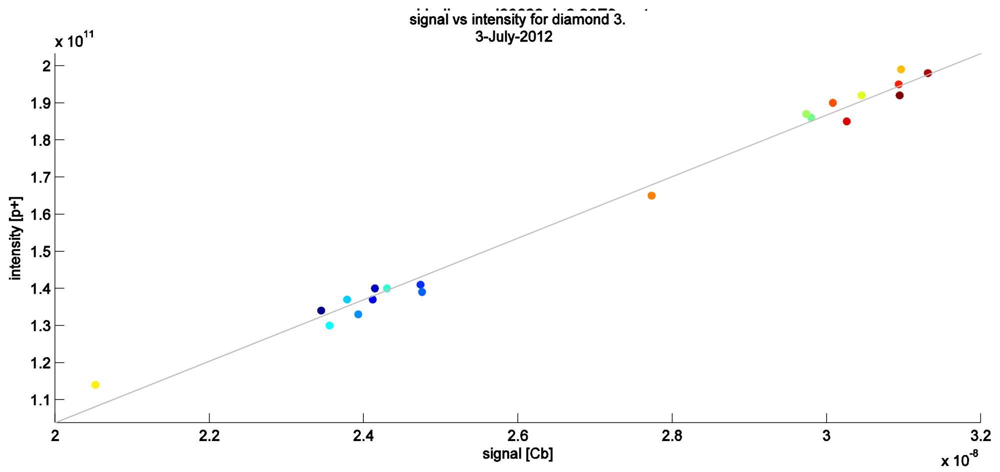


Diamond Detectors



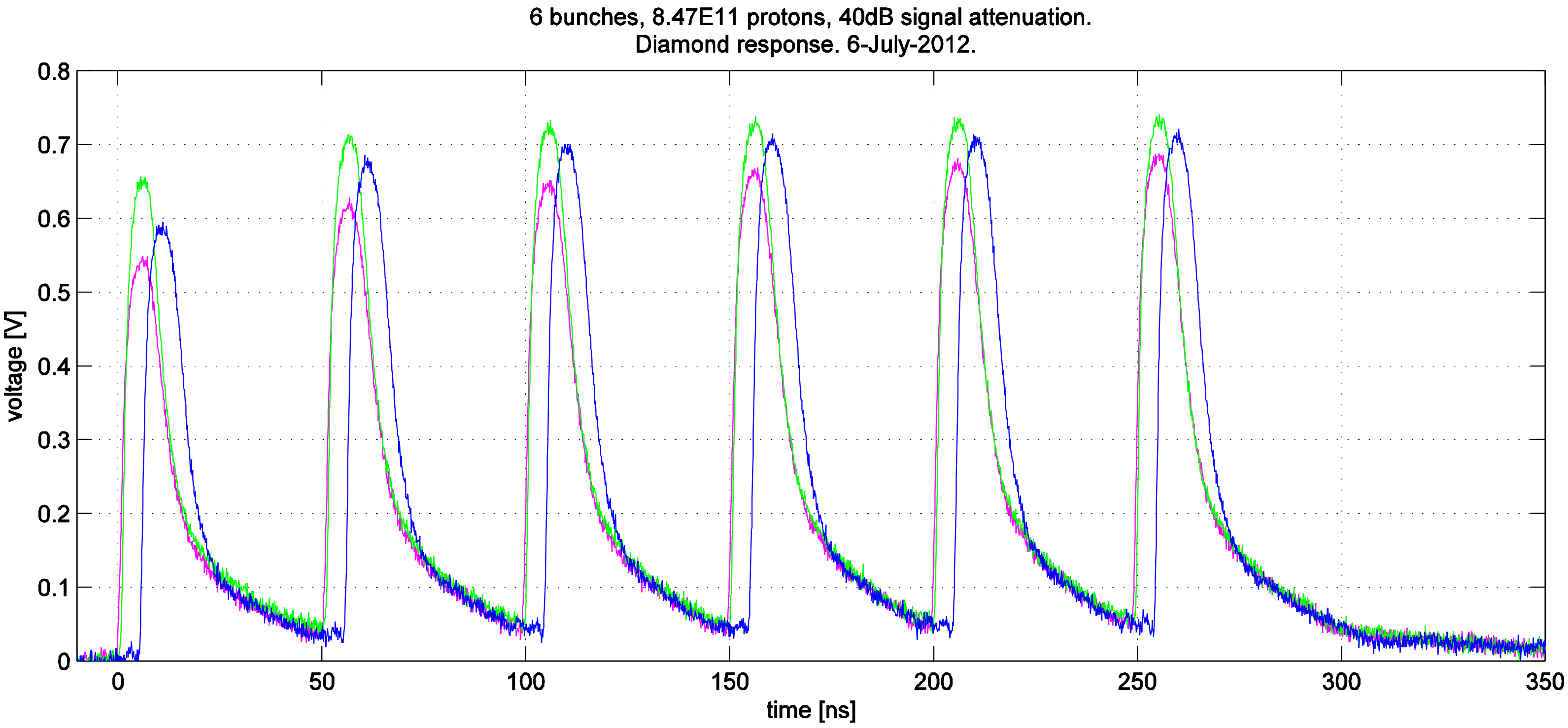
Phase I.a. (22nd June, 2nd,3rd July), Beam summary

- 71 low intensity single bunch shots (2E9-1E10 p+)
- 85 high intensity single bunch shots (1E11-2E11 p+)



Phase I.b. (6th July), Beam summary

- 8 high intensity multi-bunch shots (1.5E11 p+)

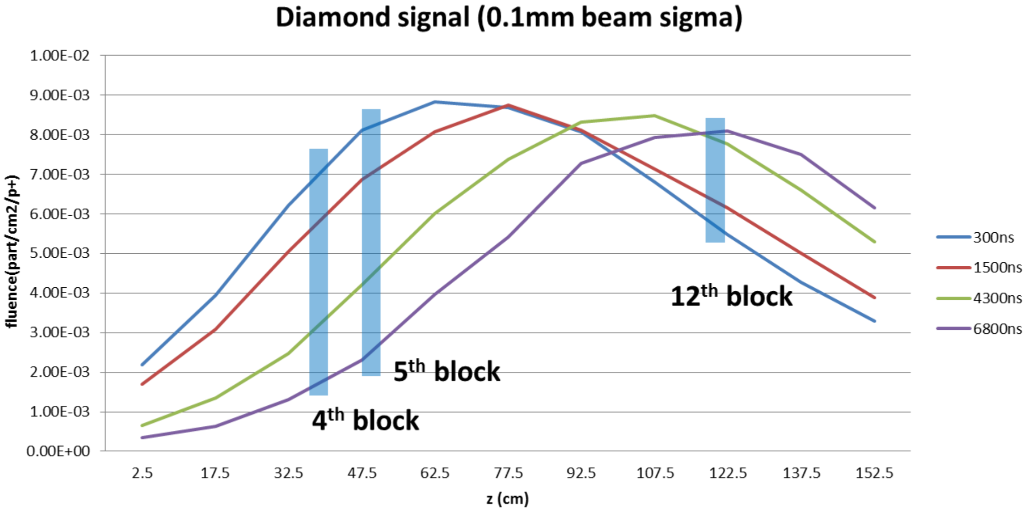


Phase II (12-July-2012)

- Target 1: 144 bunches ~1.9E11 @ 50ns, 2mm sigma beam (no tunneling expected) -> reference shot
- Target 2: 108 bunches ~1.9E11 @ 50ns, 0.2mm sigma beam -> tunneling expected
- Target 3: 144 bunches ~1.9E11 @ 50ns, 0.2mm sigma beam -> tunneling expected

Expected signal

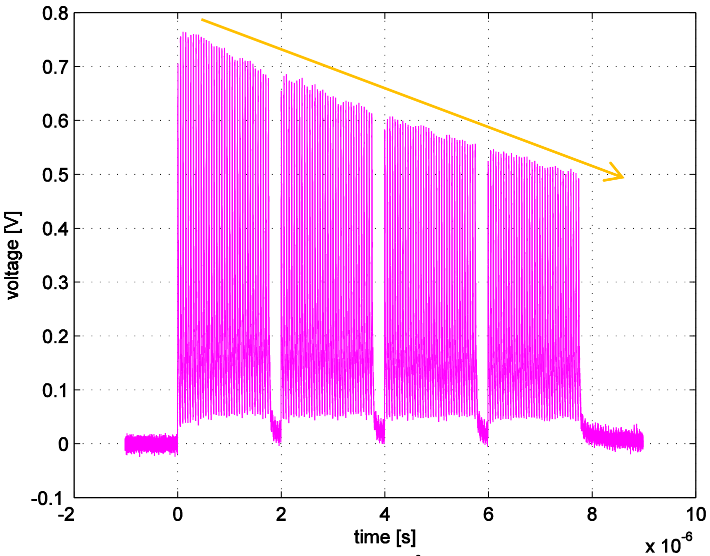
- For target 1, large beam size, no tunnelling
  - **Constant** signal with time on all diamond
- For target 2 and 3, small beam size, tunnelling
  - Diamond 1 signal: **decreases**
  - Diamond 2 signal: **decreases**
  - Diamond 3 signal: **increases**



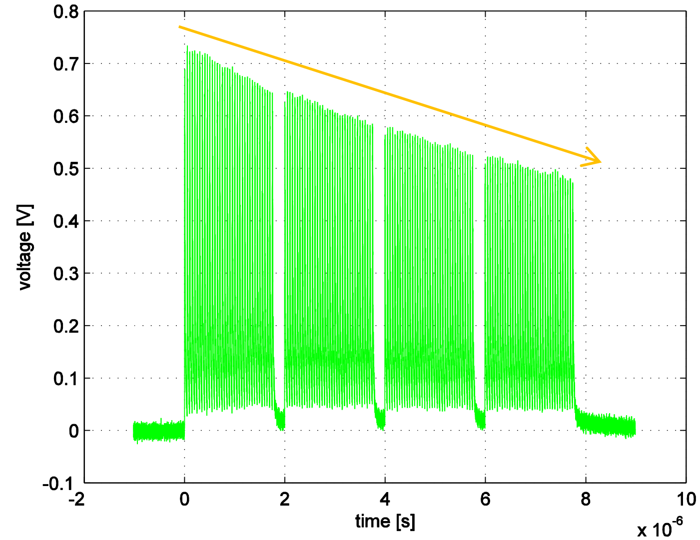
Diamond detectors raw signals

Target 1

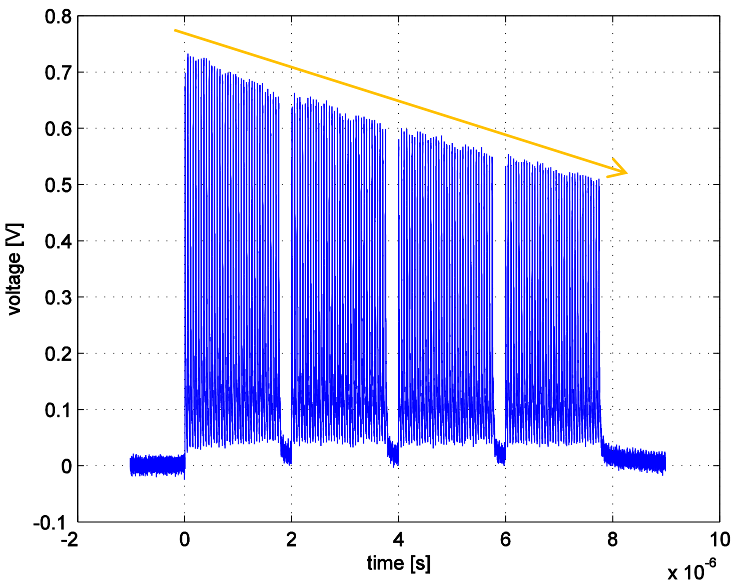
Diamond 1



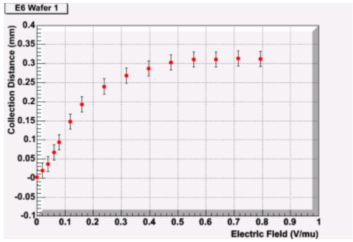
Diamond 2



Diamond 3



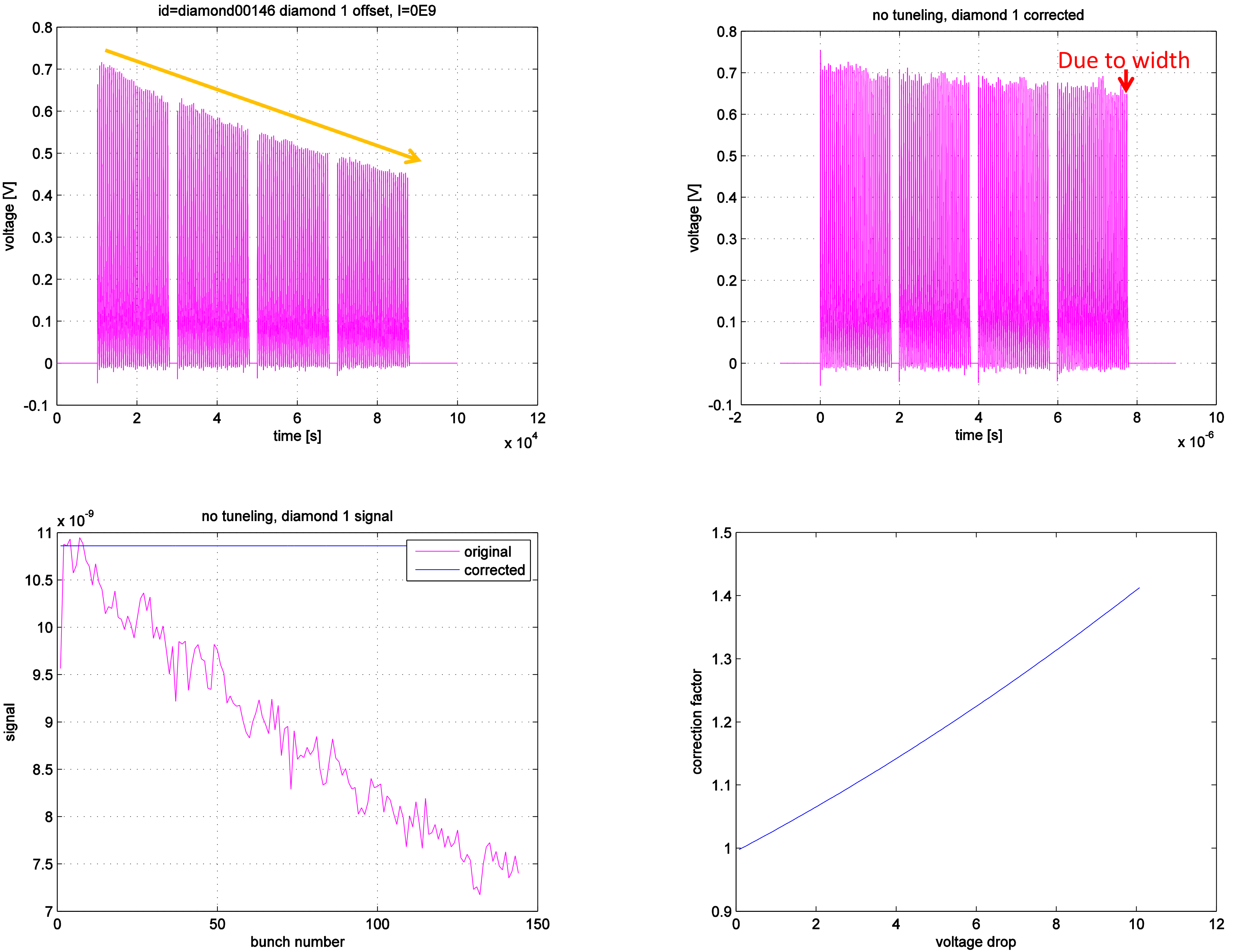
- **Expected constant signal** -> no tunneling
- Signal drops due to a decrease in the bias voltage.
- The voltage decrease is caused by the discharge of the HV capacitors.



Data correction

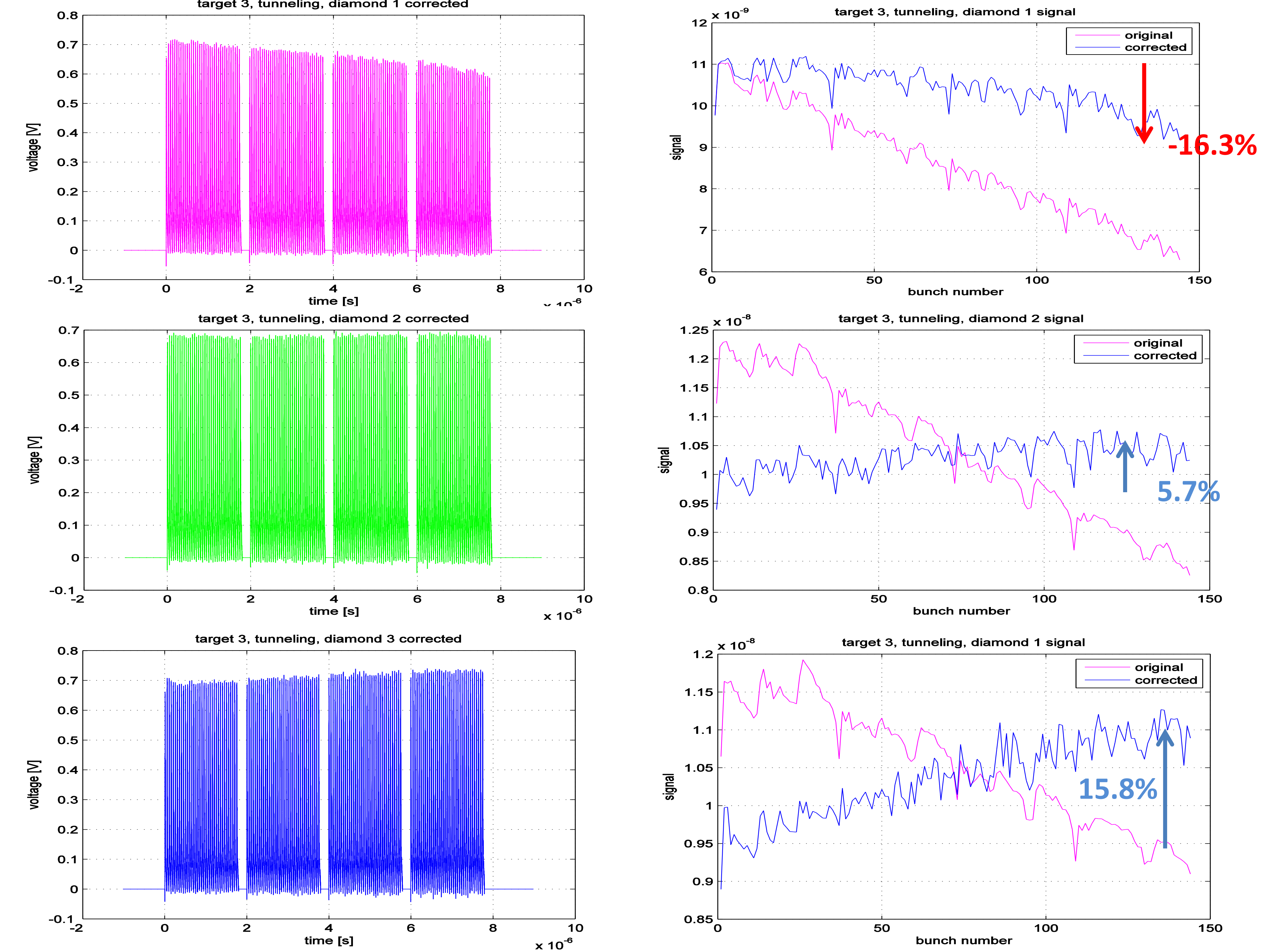
- For target 1:
  1. Calculate the ΔV for each bunch.
  2. Ratio between signal bunch(x)/bunch(3)
  3. Ration between FWHM bunch(x)/bunch(3)

- For target 2 and 3:
  1. Calculate the ΔV for each bunch.
  2. Look the correction coefficient from calibration in target 1.
  3. Look for the FWHM correction from calibration in target 1.


id=diamond00146 diamond 1 offset, I=0E9
voltage [V]
time [s]
x 10^4
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
2
4
6
8
10
12
no tuneling, diamond 1 corrected
Due to width
voltage [V]
time [s]
x 10^-6
-2
0
2
4
6
8
10
no tuneling, diamond 1 signal
x 10^-9
signal
bunch number
11
10.5
10
9.5
9
8.5
8
7.5
7
0
50
100
150
original
corrected
correction factor
voltage drop
1.5
1.4
1.3
1.2
1.1
1
0.9
0
2
4
6
8
10
12

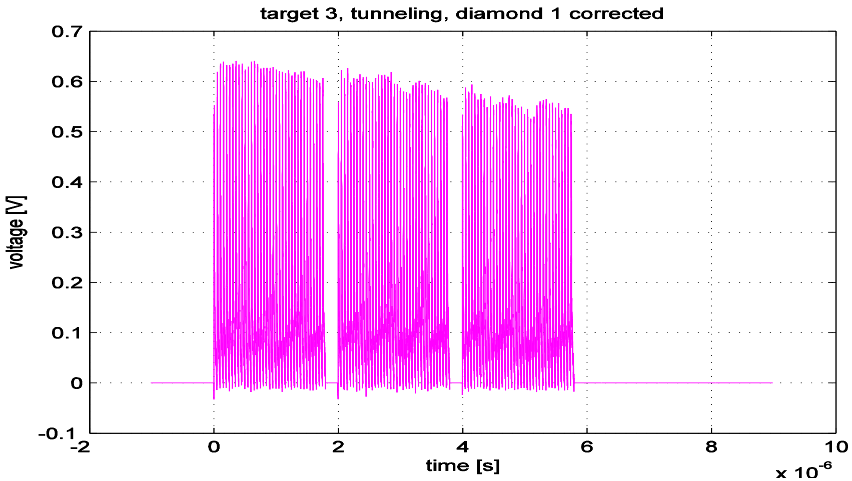
Corrected signals for target 3

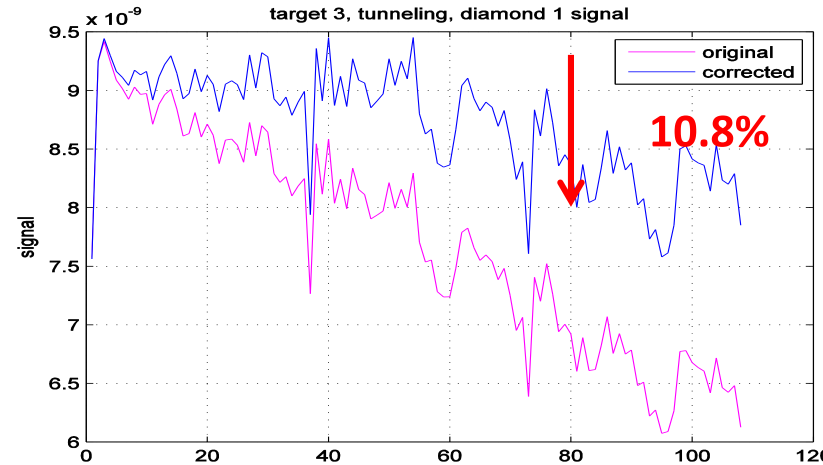
(144 bunches, 50ns, 0.2 mm sigma)

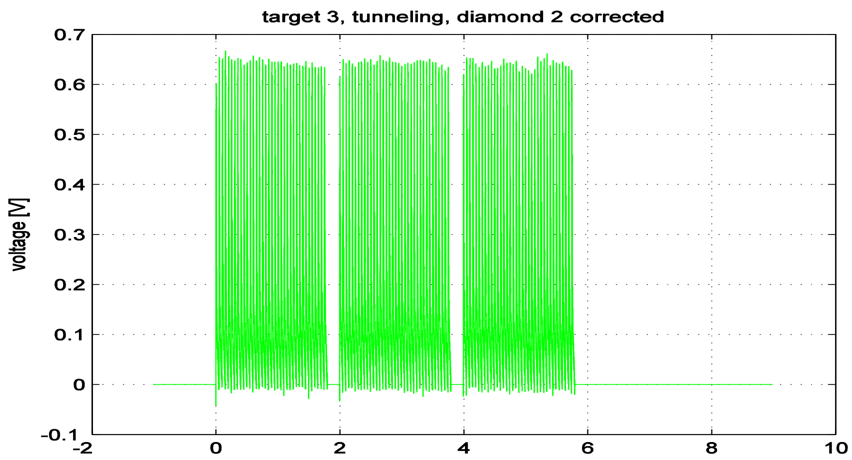

target 3, tunneling, diamond 1 corrected
voltage [V]
time [s]
x 10^-6
target 3, tunneling, diamond 1 signal
x 10^-9
original
corrected
signal
bunch number
-16.3%
target 3, tunneling, diamond 2 corrected
voltage [V]
time [s]
x 10^-6
target 3, tunneling, diamond 2 signal
x 10^-8
original
corrected
signal
bunch number
5.7%
target 3, tunneling, diamond 3 corrected
voltage [V]
time [s]
x 10^-6
target 3, tunneling, diamond 1 signal
x 10^-8
original
corrected
signal
bunch number
15.8%

Corrected signals target 2

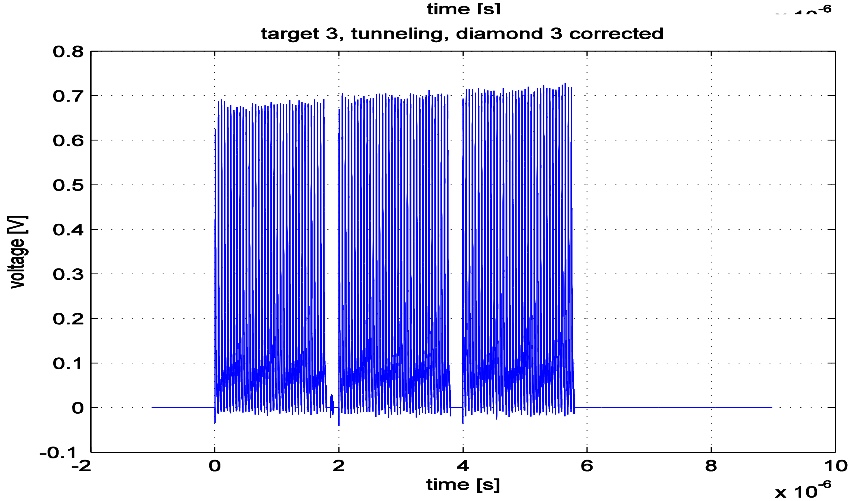
(108 bunches, 50ns, 0.2 mm sigma)

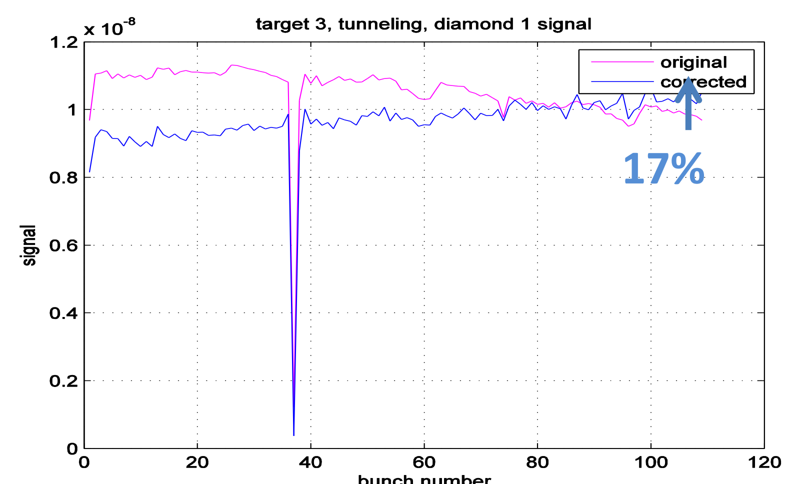

target 3, tunneling, diamond 1 corrected
voltage [V]
time [s]
x 10^-6


target 3, tunneling, diamond 1 signal
x 10^-9
signal
original
corrected
10.8%


target 3, tunneling, diamond 2 corrected
voltage [V]
time [s]

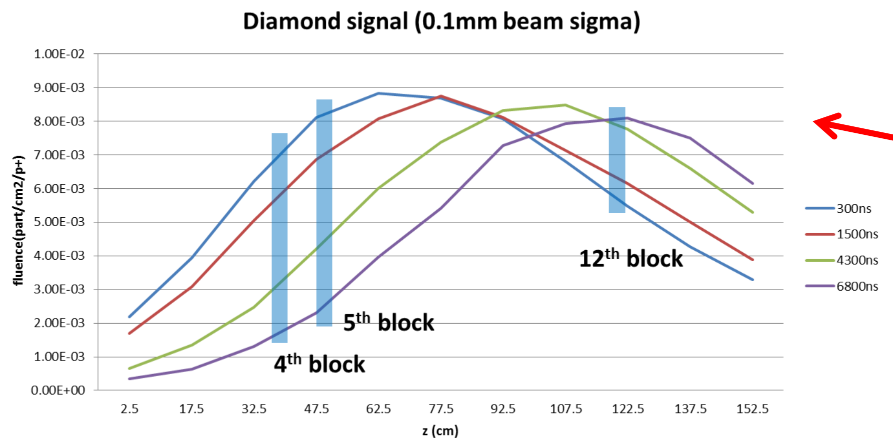

target 3, tunneling, diamond 2 signal
x 10^-9
signal
original
corrected
2.7%
bunch number


target 3, tunneling, diamond 3 corrected
voltage [V]
time [s]
x 10^-6


target 3, tunneling, diamond 1 signal
x 10^-8
signal
original
corrected
17%
bunch number

Results

- Diamond 1 and 3 signal **move in the expected direction**
- Diamond 2 signal slight **increase** however expected to decrease (from simulation for 0.1mm)
  - Under-correcting: unconsidered effects
  - Large difference from simulations



Different parameters:
-sigma
-Nb
-Ib
-bunch spaceing

Results

- Compare target 3 and target 2
  - Different geometry -> affects d2 & d3
  - Target 2 should have less difference in % from T1

	Diamond 1	Diamond 2	Diamond 3
Target 3 (144b)	-16.3%	5.7%	15.8%
Target 2 (108b)*	-10.8%	2.7%	17.0%

**Ok,
less affected by geometry
(assuming 0.1mm sim)**

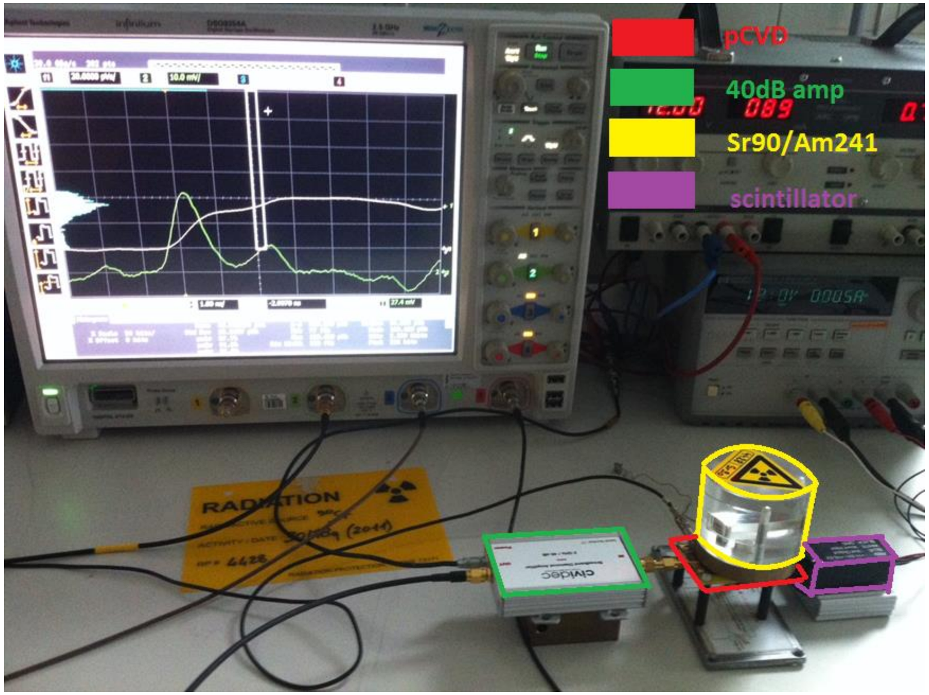
**Not OK
(assuming 0.1mm sim)**

Results

- For the moment, a direct comparison of absolute values from diamonds to simulation data is risky.
- Some effects are still not understood.
- Although the ration between diamonds from target 1 to target 3 could be used
- and the ration between diamonds from target 3: d2/d1, d3/d1

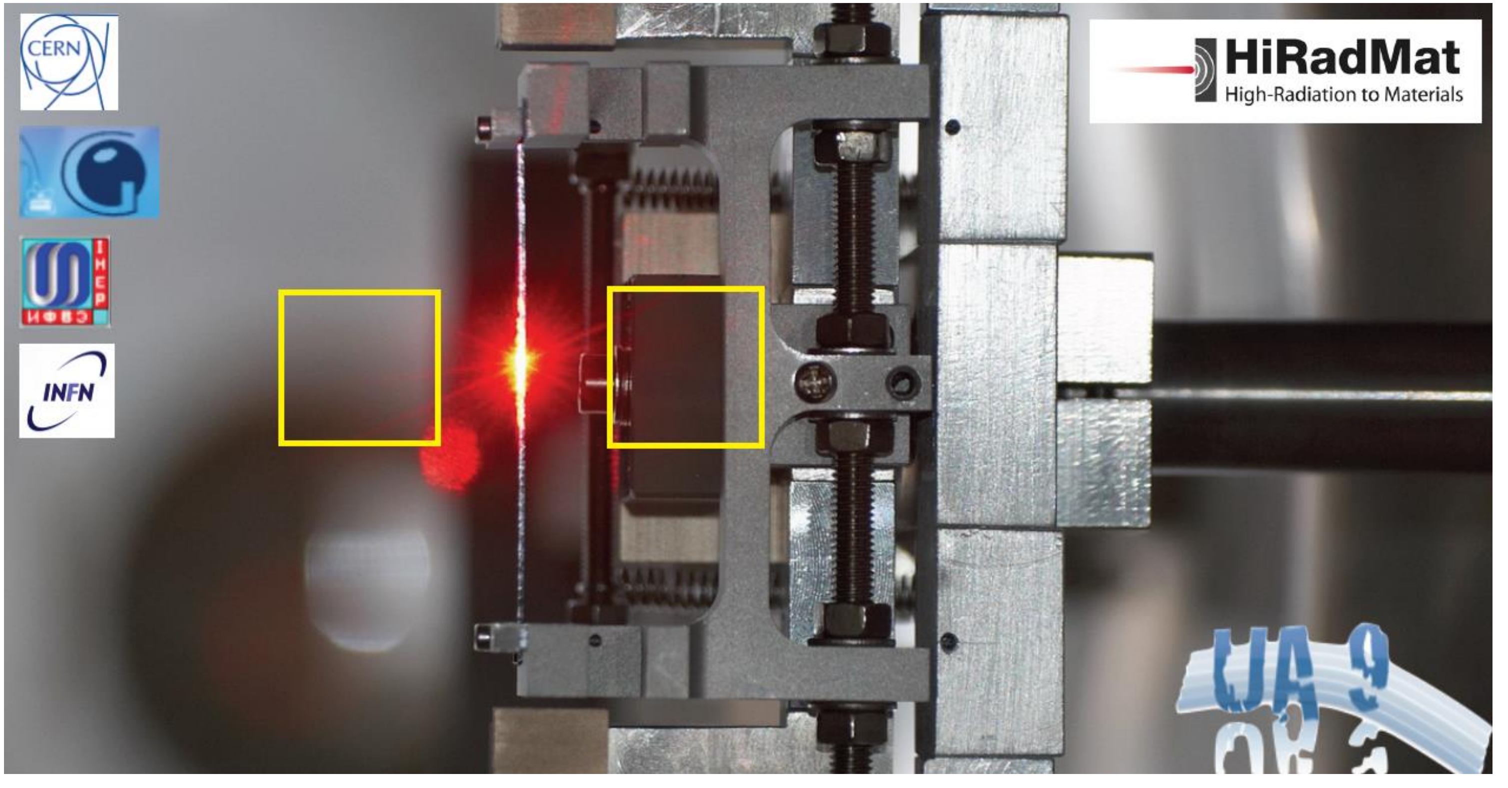
Better correction

- Calibration experiment:
  1. Calculate the diamond signal (Q) vs bias voltage
- For target 2 and 3:
  1. Calculate the ΔV for each bunch.
  2. Look the correction coefficient from calibration experiment (Q/Q_0).



Another calibration experiment

- Alignment for HiRadMat crystal collimator experiment
- Profit from experiment -> calibrate diamond detector signal against simulations
- Symmetrical geometry provides a ratio between diamond signals



Upcoming (january)

- Open the target and visually inspect it.
- Measure activation profile on the targets
- If activation is acceptable, take some samples to a lab and perform: Xrays or Ultrasounds.

- **Compare diamond signal with simulations and with samples**

Conclusions

- **First** hydrodynamic experiment with a high-intense high-dense beam
- Experiment was a **success** -> evidence of tunneling
- In detail analysis of the samples needed to precisely evaluate penetration length
- **Successful** Diamond design and implementation. Although, design could be improved.

end

Microphones

Target 3
Single bunch 4.5E10 protons
Beam sound

Target 3
Single bunch 144 bunches
1.5E11 protons/bunch
Beam sound

Source: Daniel Deboy

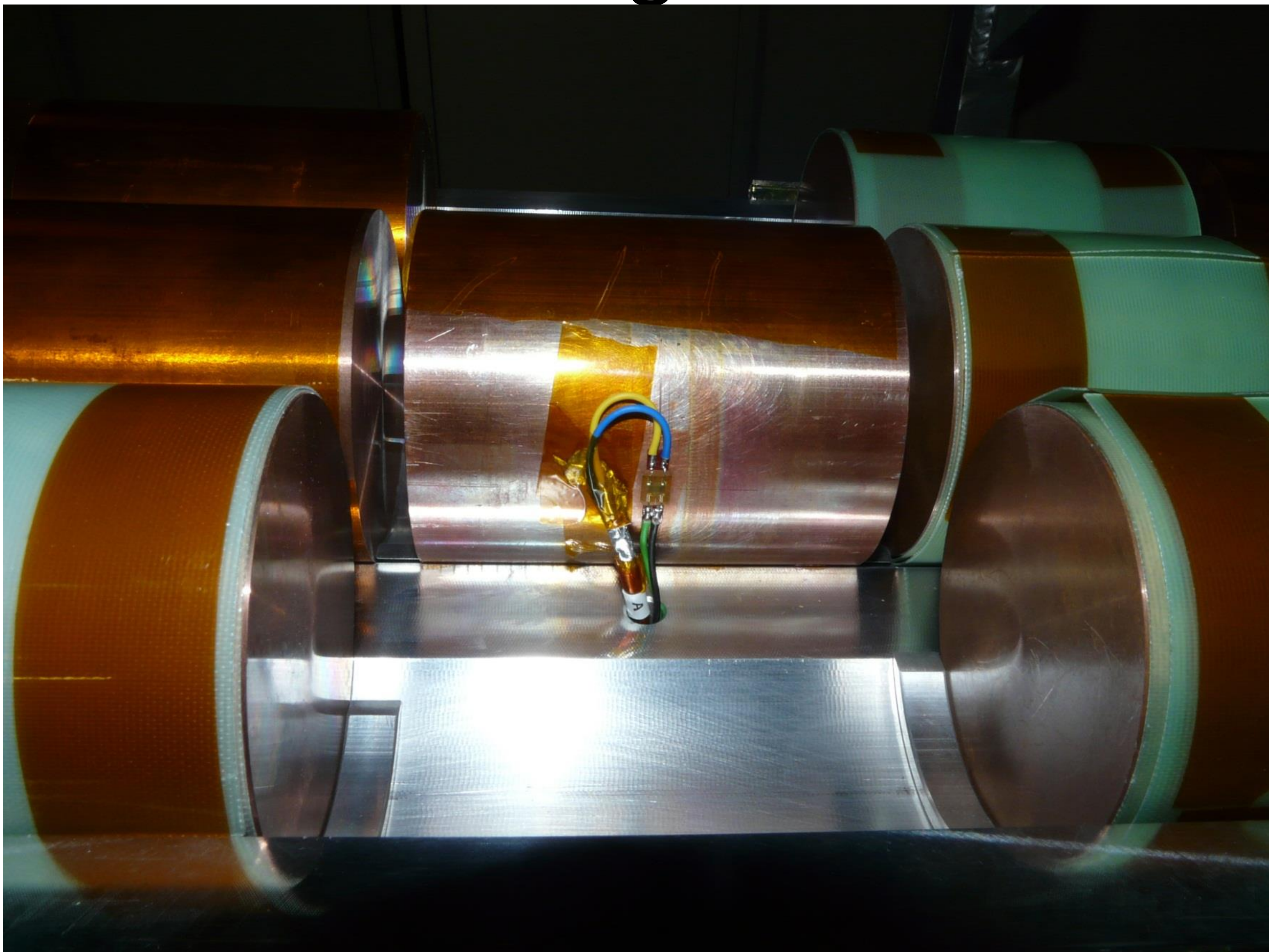
Experiment

- Target assembly done in collaboration with EN/STI
- Diamond detectors + associated electronics, designed specifically for this experiment in collaboration with EG (Erich Griesmayer)
- Strain gauges in collaboration with EN/MME

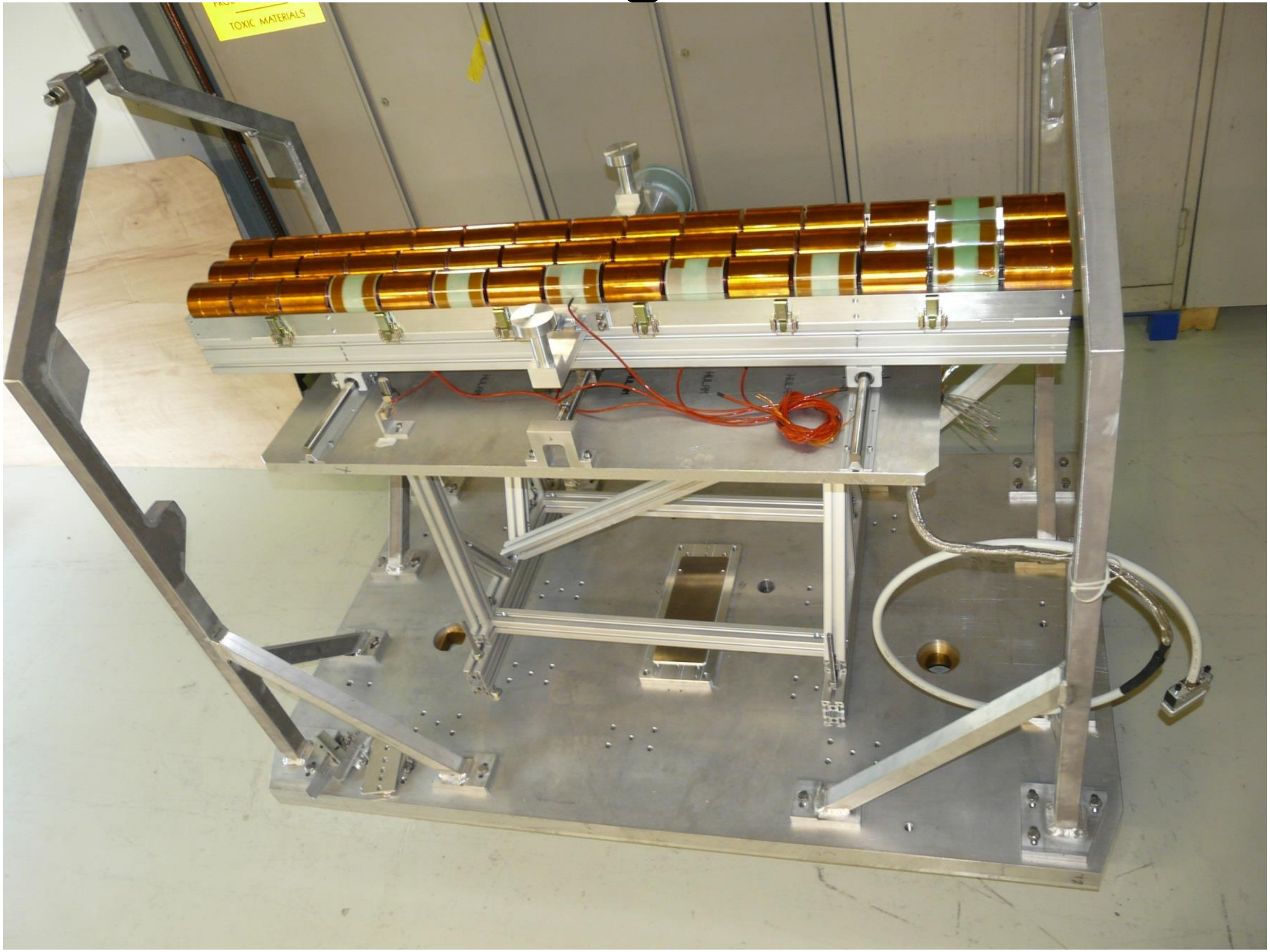
Detectors

- Diamond detectors
  - pCVD, 100um, 3mm diameter
- SEM detectors
  - LHC type with capacitors at the HV side
- Strain Gauges
  - Resistive
- Temperature sensors
  - PT100

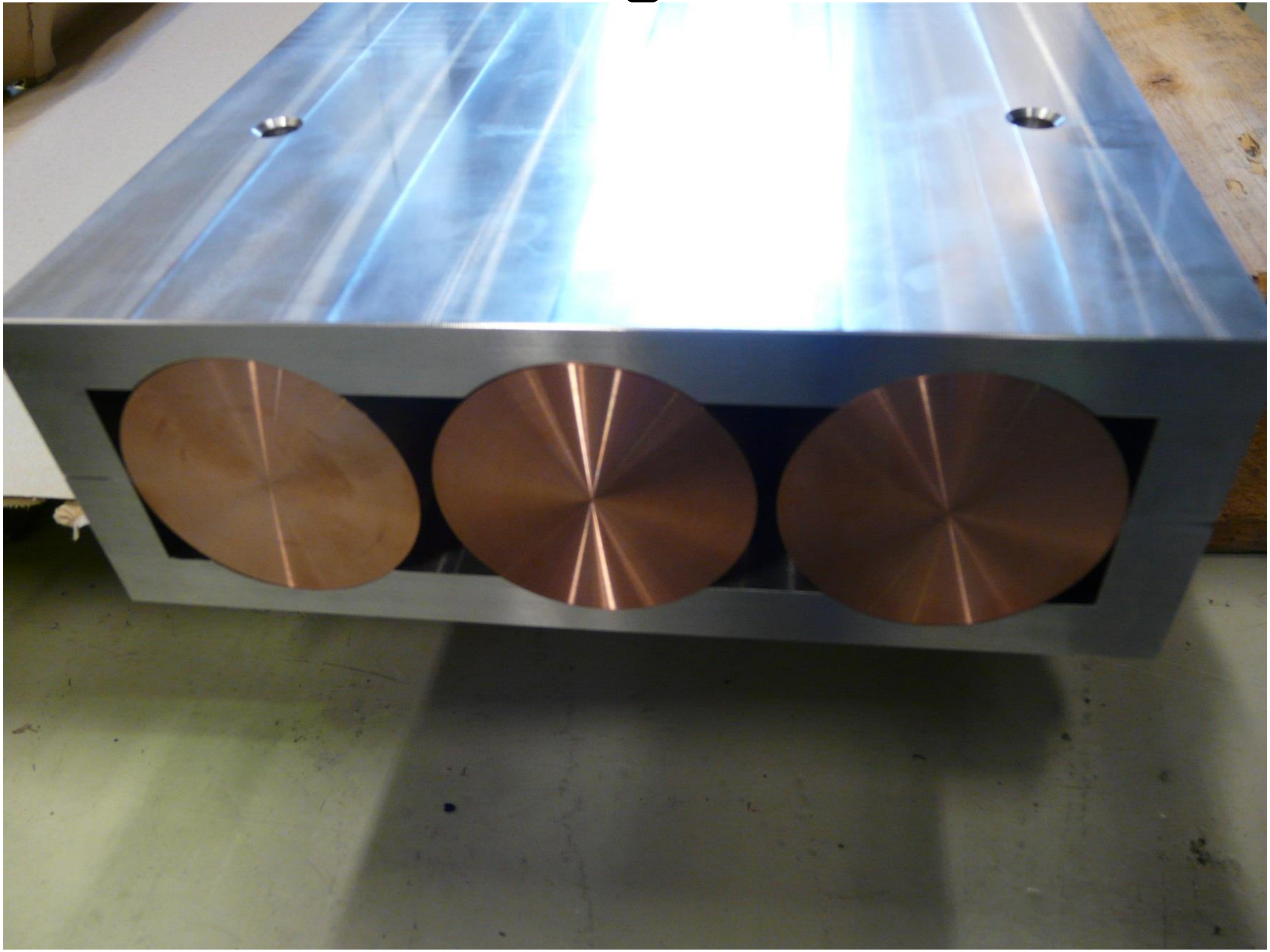
target



target



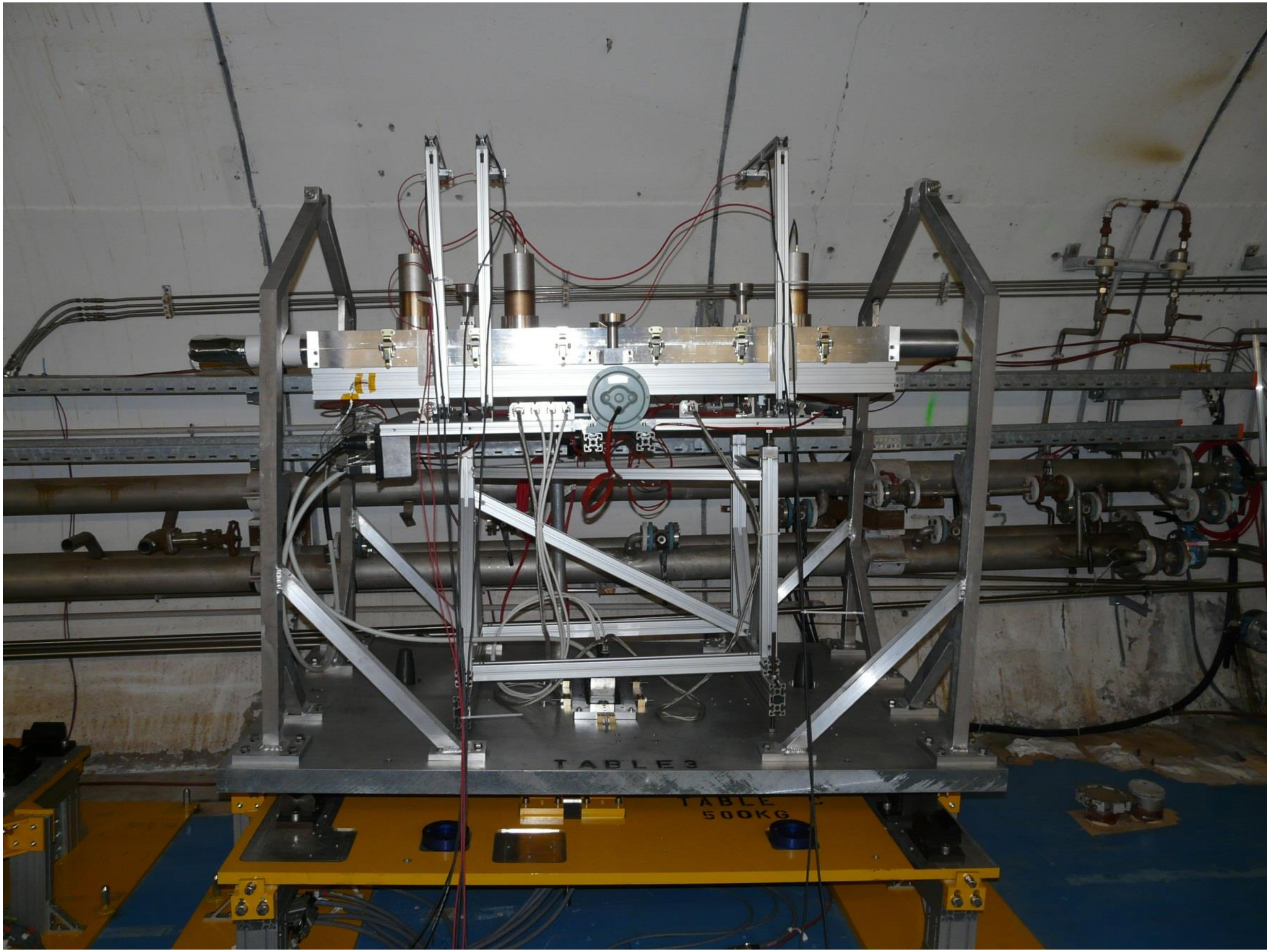
target



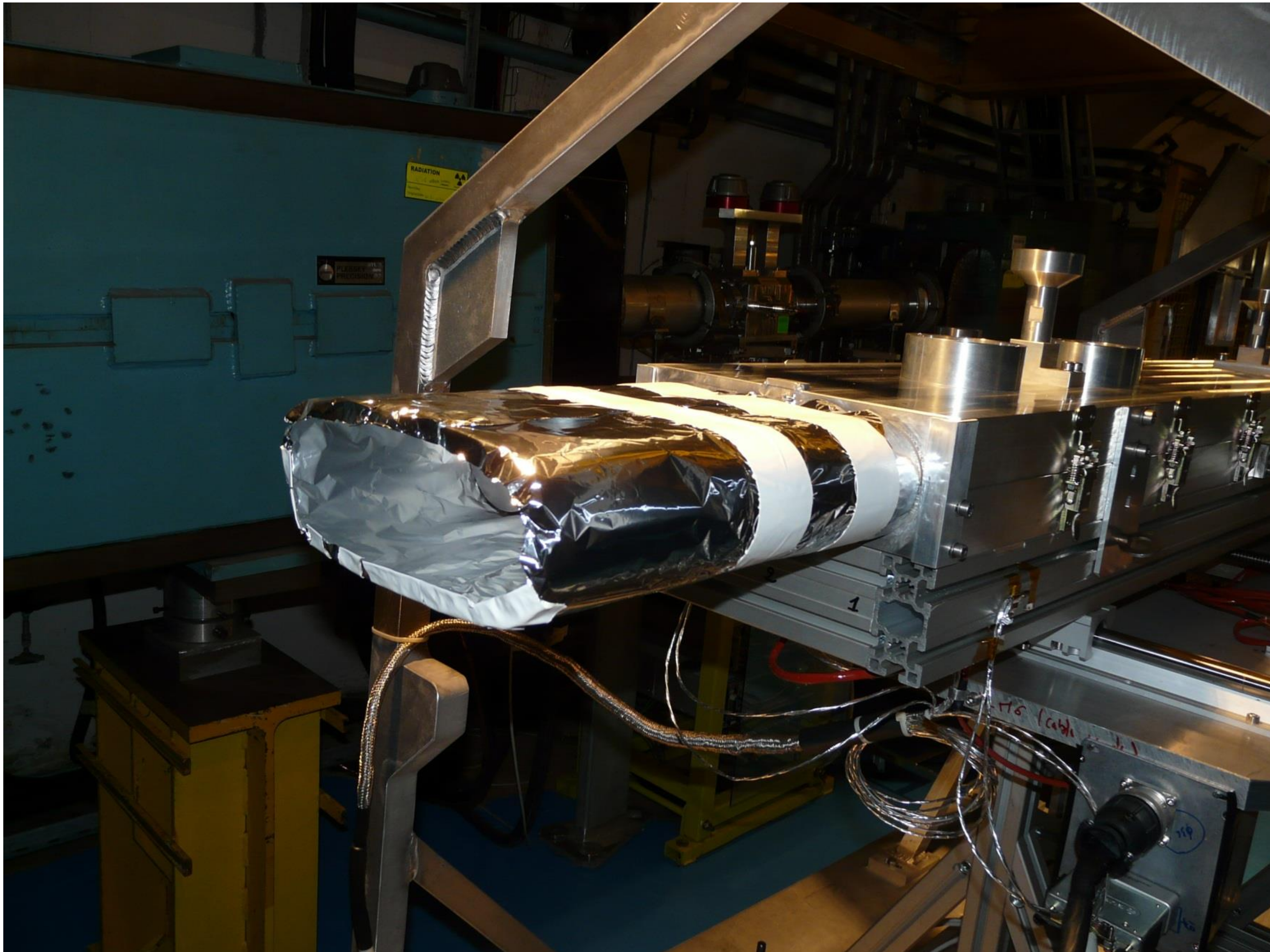
target

table

Installation



Installation



- Continue to experiment and understand diamond detectors -> new little experiments
- Further analyze experiment data
- Expand the application of diamond detectors
- Possibly prepare more complete/complex experiments

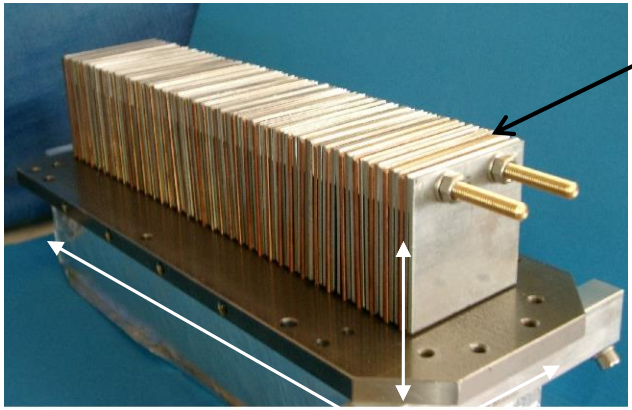
History

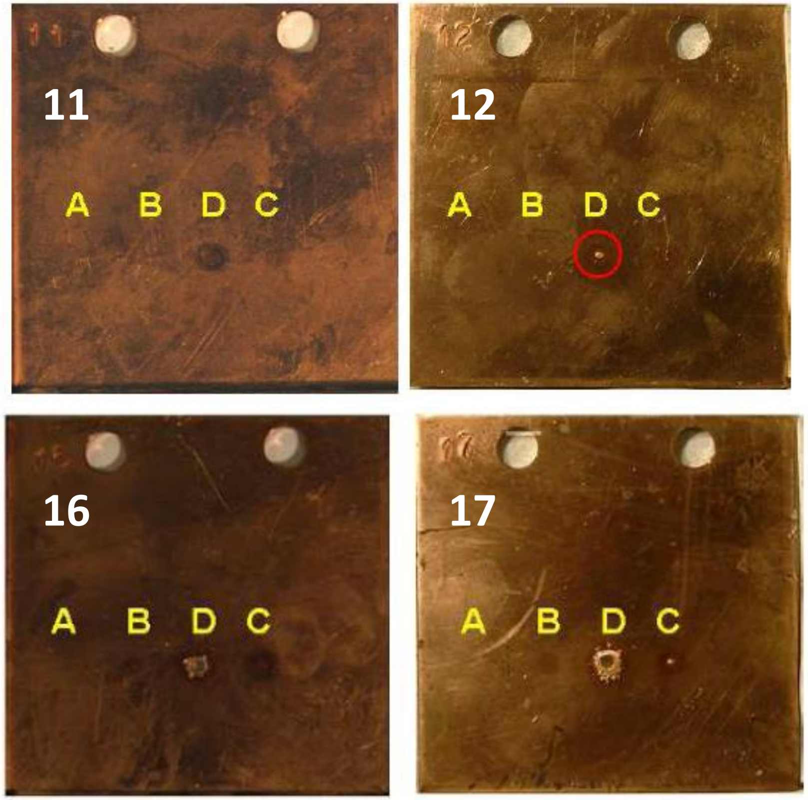
- >8 yr ago. Simulations from N. Tahir and CERN pointed that a tunneling process happens when a high-intense high-dense beam interacts with matter.
- Verena & Rüdiger experiment at SPS.
- Couple of years ago, SPS experiment idea.
- Last year, HiRadMat facility experiment request.

SPS material test

Verena Kain (2005)

Zinc, stainless steel, copper and INCONEL





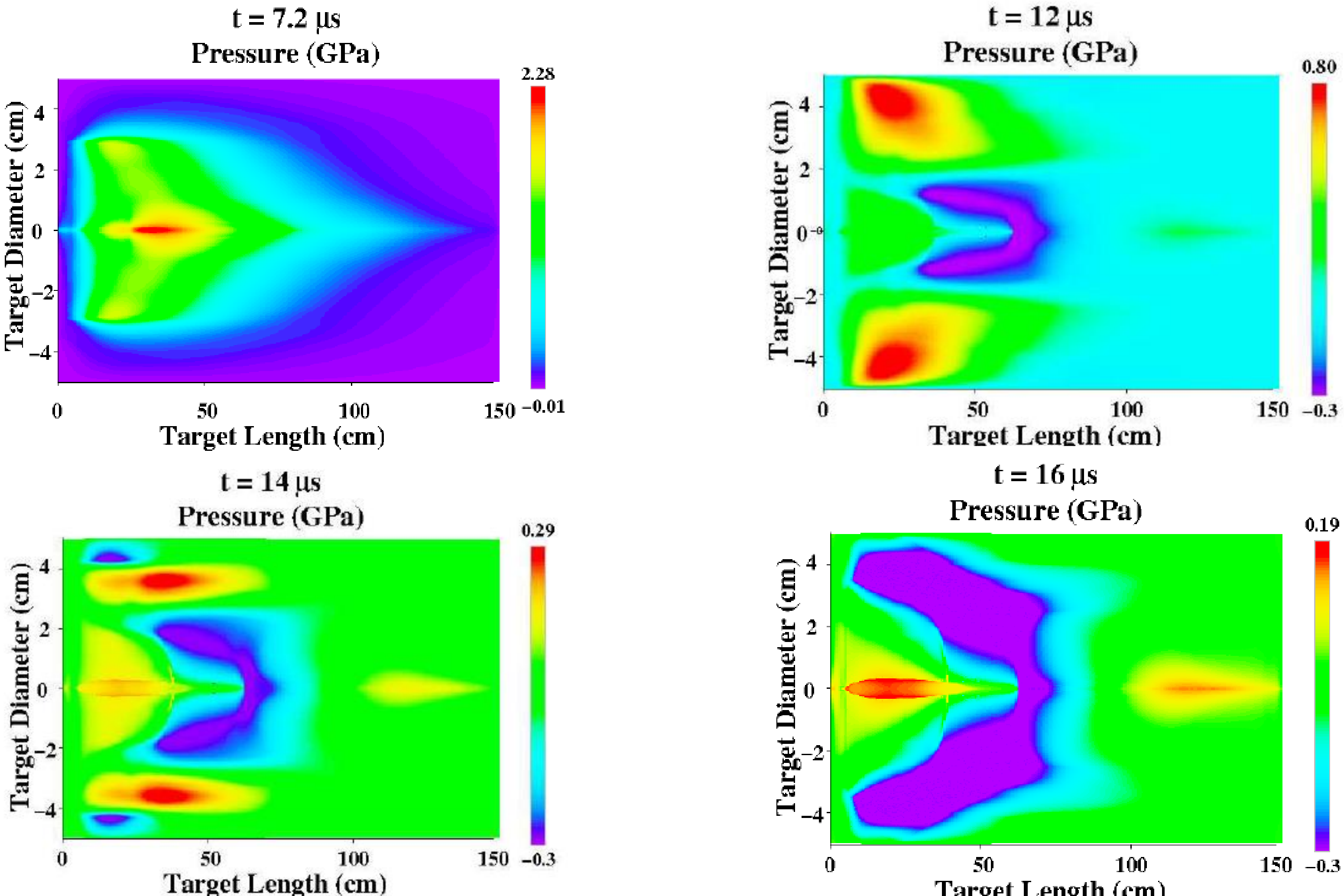
Four intensities [SPS-beam type @ 450 GeV 1.1x0.6mm sigma]:

$A=1.3\times10^{12}$, $B=2.6\times10^{12}$,
$C=5.3\times10^{12}$, $D=7.9\times10^{12}$

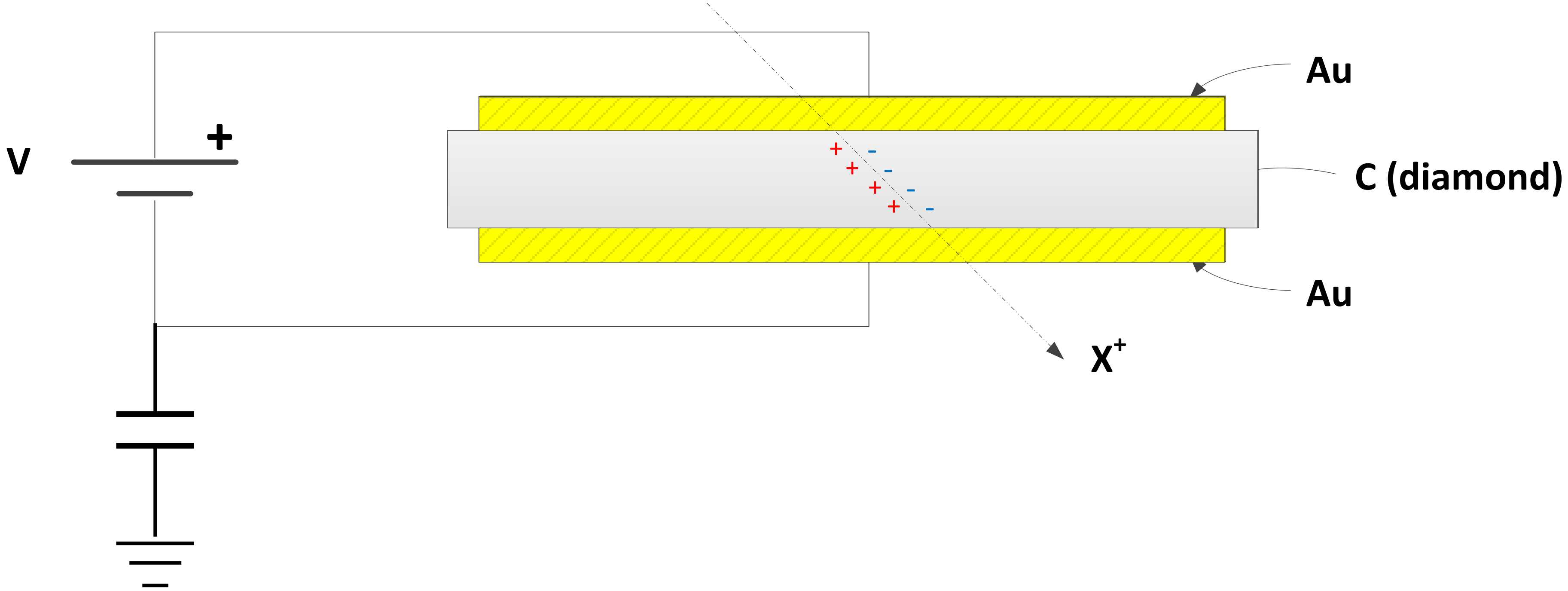
The experiment confirms the 5% (2.3e12 p) equipment damage level @ 450GeV

Cu plates (simulations predicts plate 18th 1st to melt)

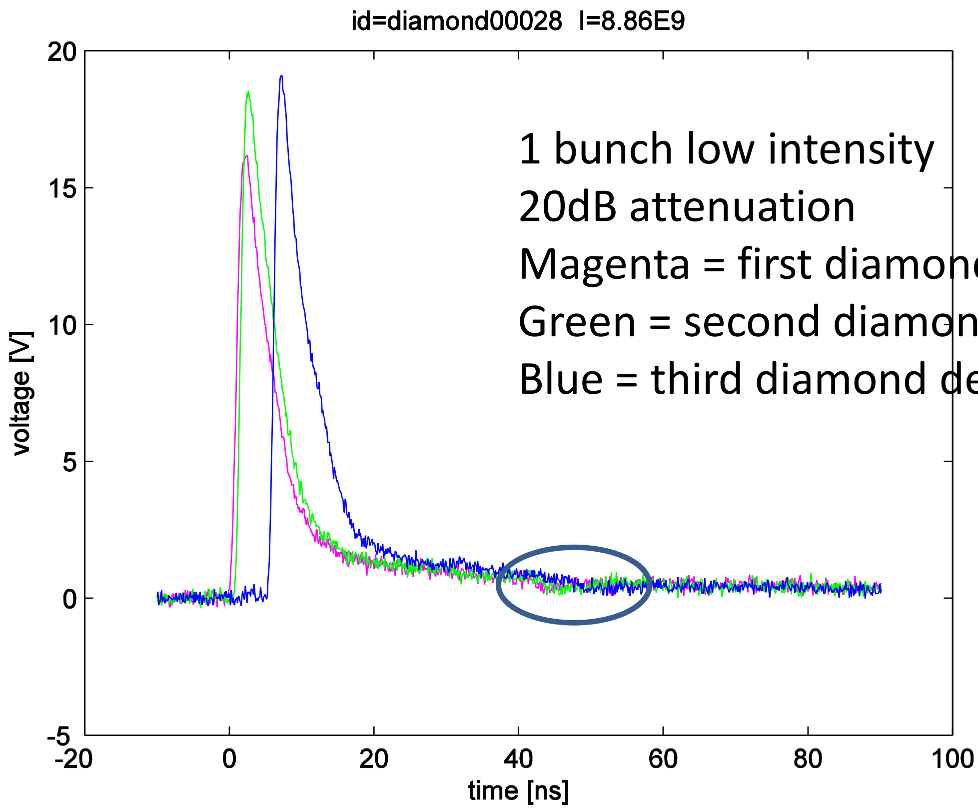
Pressure evolution (0.5mm)



Diamond Detectors Background



Diamond detector signal



1 bunch low intensity

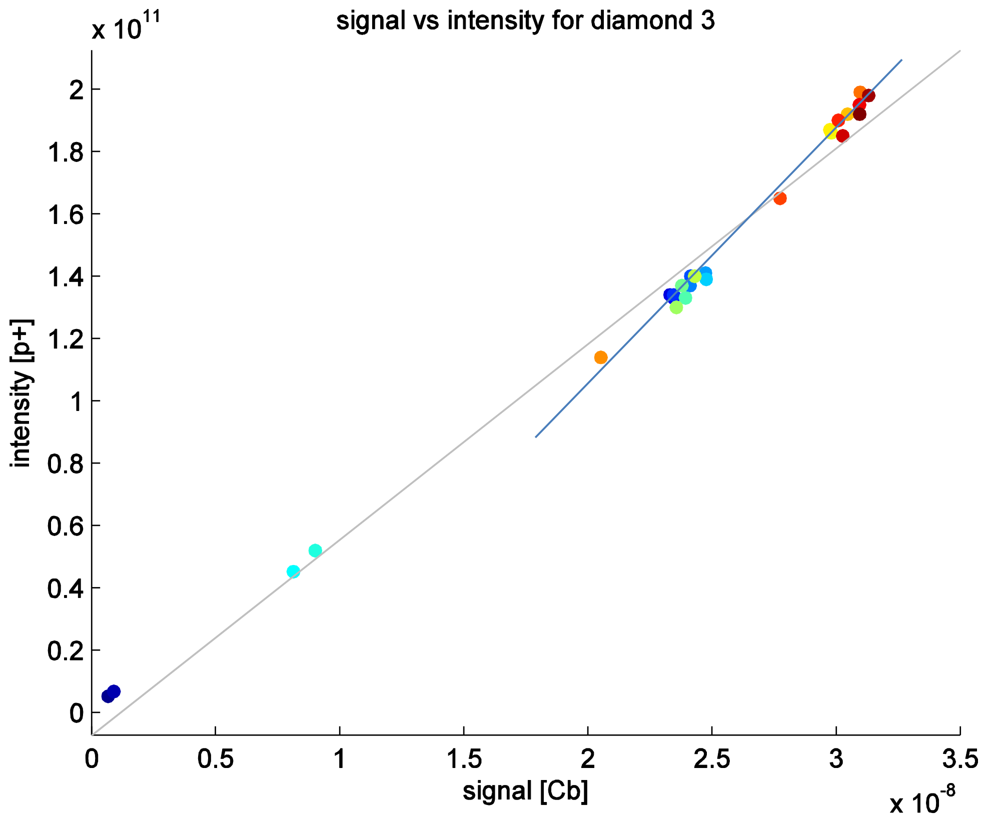
20dB attenuation

Magenta = first diamond detector (z=40cm)

Green = second diamond detector (z=50cm)

Blue = third diamond detector (z=120cm)

Diamond detector linearity

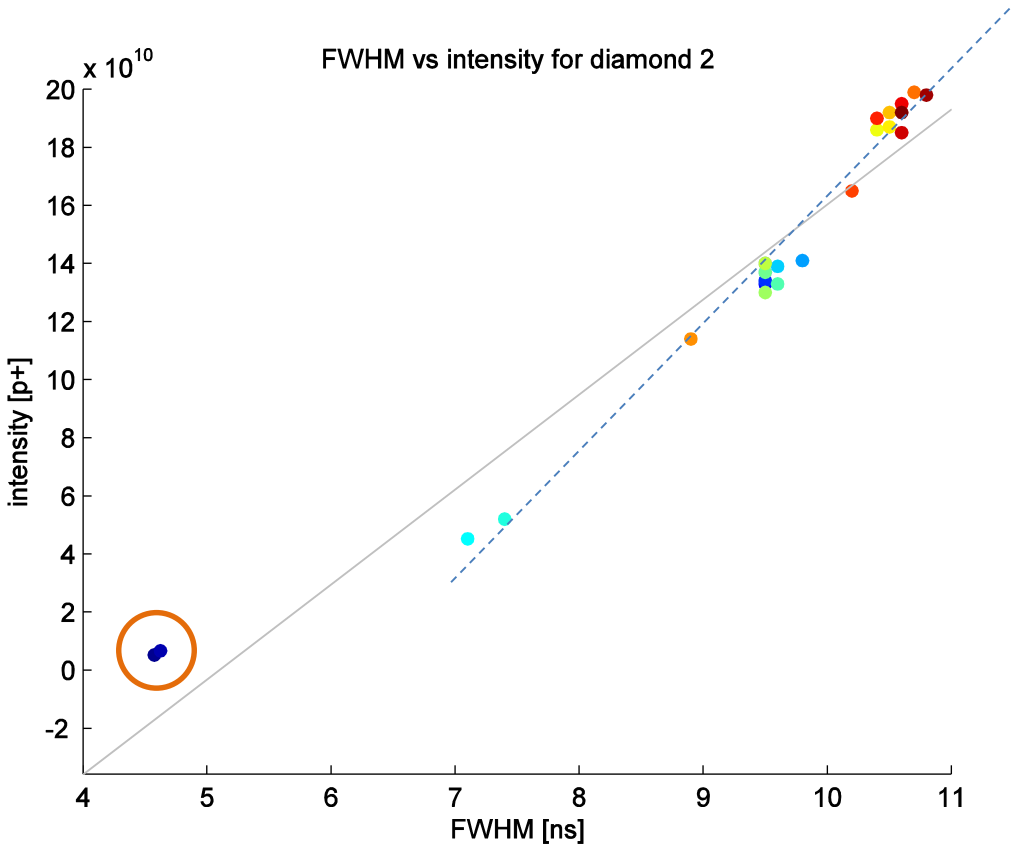


Detector signal versus beam intensity

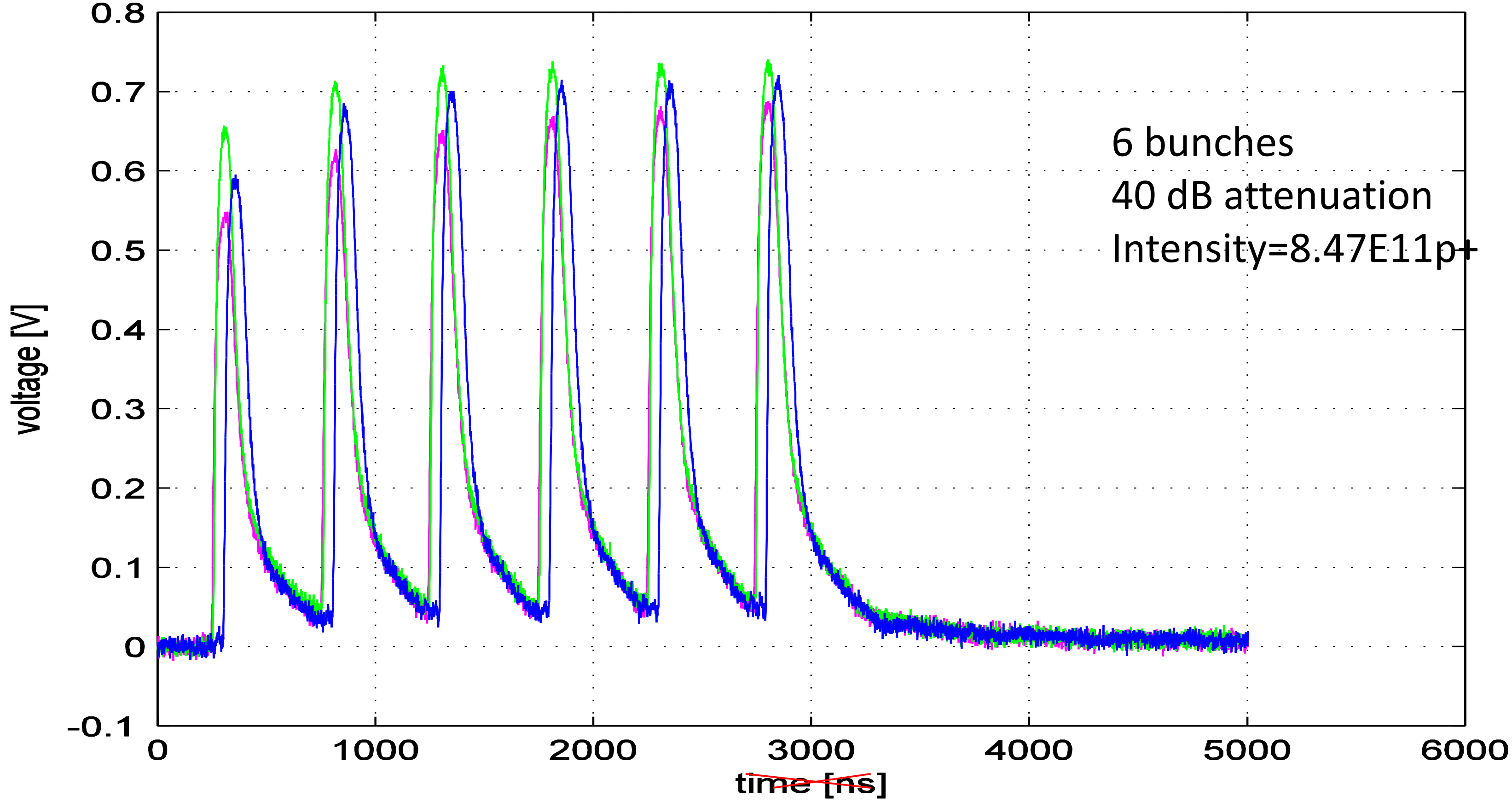
Diamond detector linearity

- Diamond detectors have a good linearity for a wide intensity range.
- Tested different bias voltage across the detectors and its influence on the signal.
- Other characteristics also understood and in process of understanding.

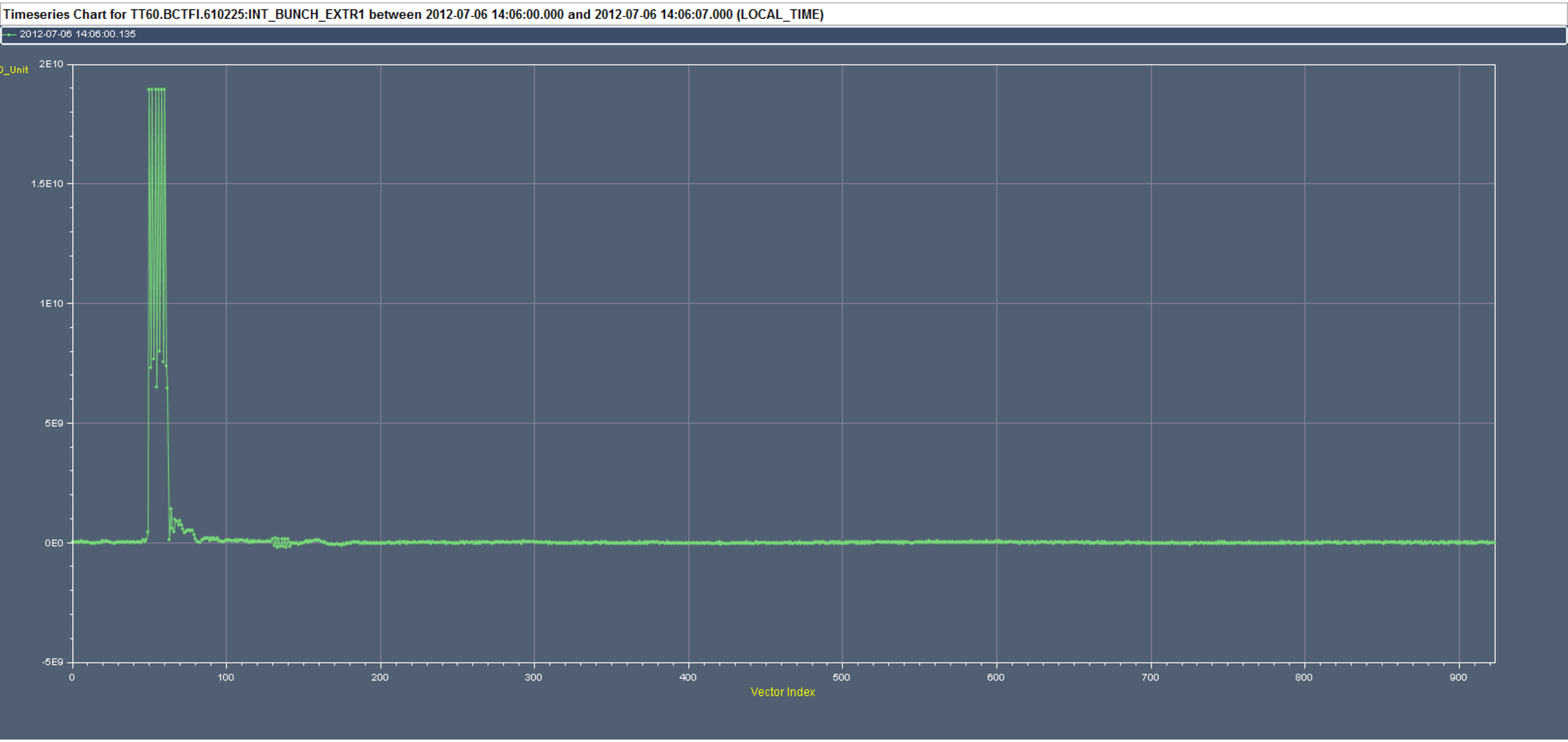
Diamond FWHM



Multi-bunch

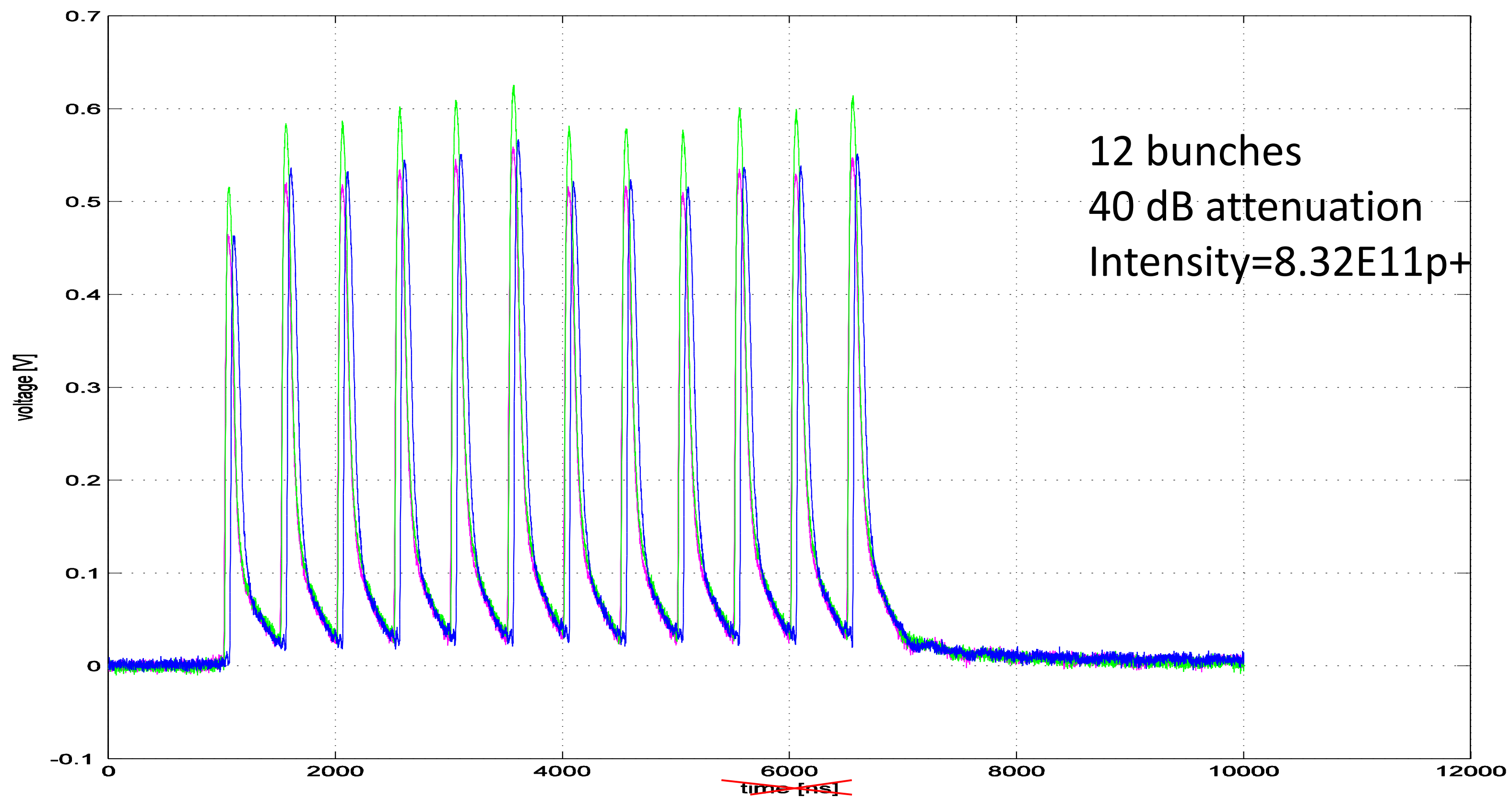

6 bunches
40 dB attenuation
Intensity=8.47E11p+
voltage [V]
time [ns]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
1000
2000
3000
4000
5000
6000

Multi-bunch



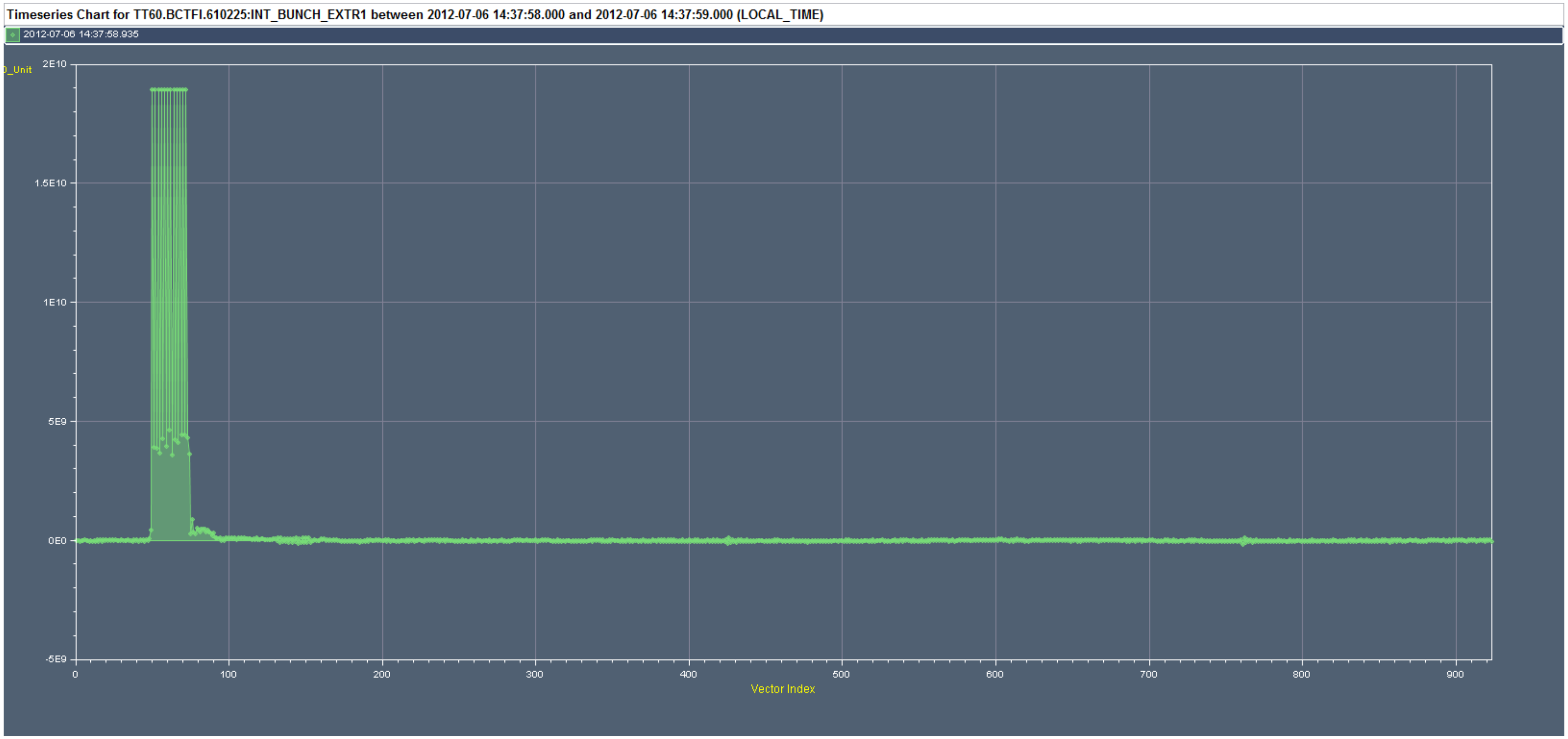
1.9E11p+ per bunch, 6 bunches.

Multi-bunch



0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
voltage [V]
0
2000
4000
6000
8000
10000
12000
time [ns]
12 bunches
40 dB attenuation
Intensity=8.32E11p+

Multi-bunch

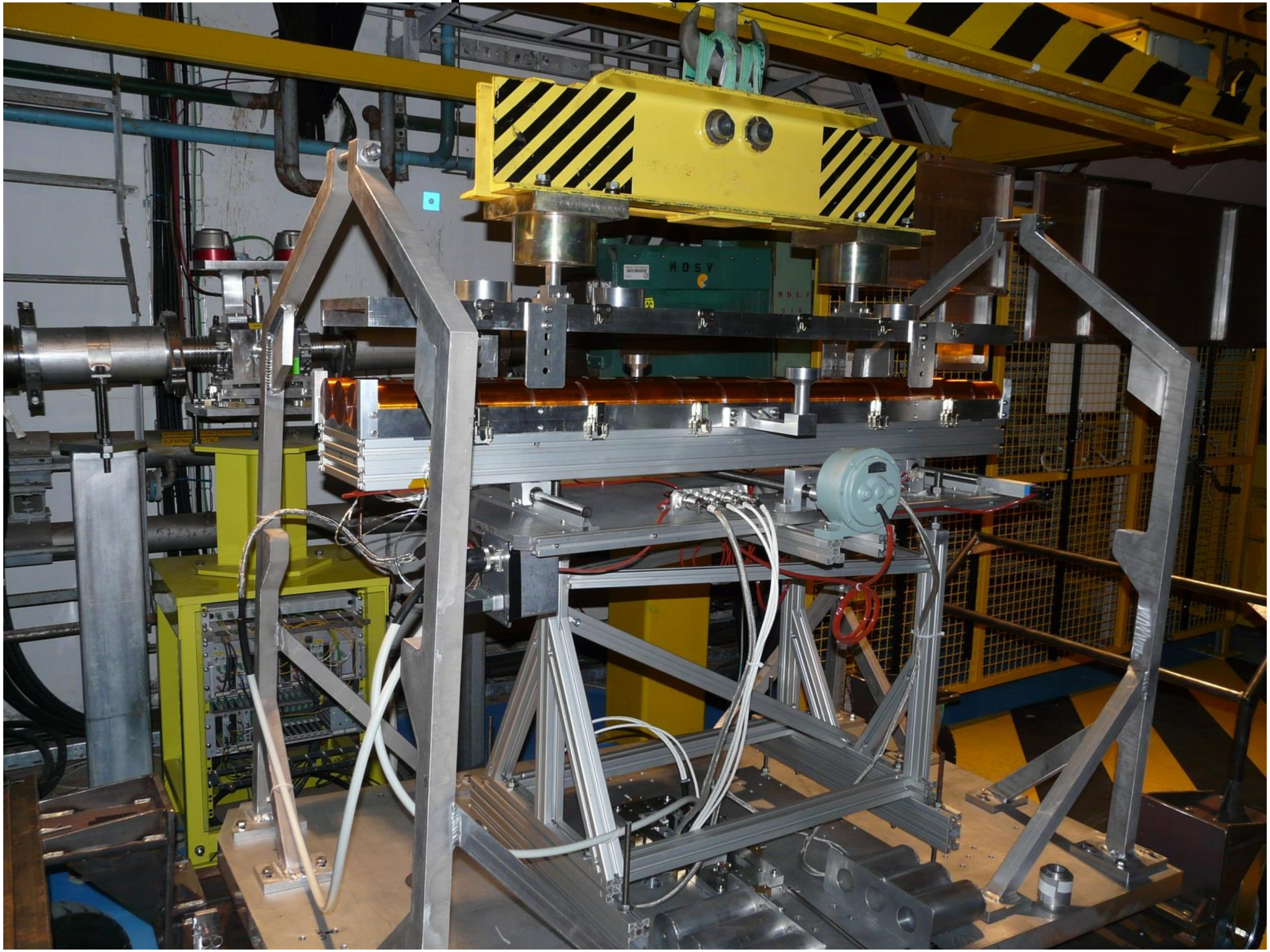


~1.9E11p+ per bunch, 12 bunches.

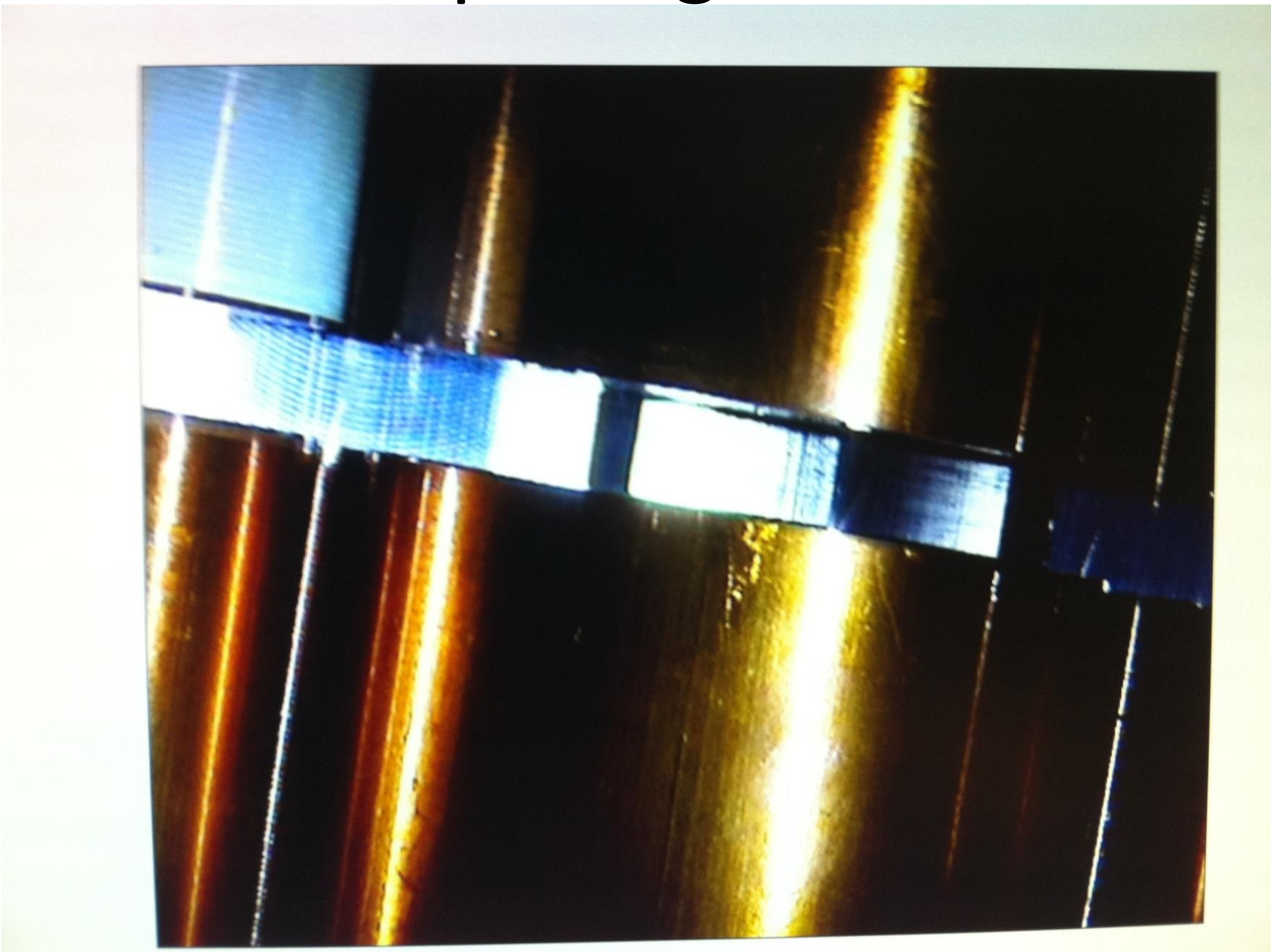
Multi-bunch

- Offset after second bunch of 50mV. Coming from electronics.
- No signal pile-up.
- No offset pile-up.
- Diamond signal linear for every bunch.

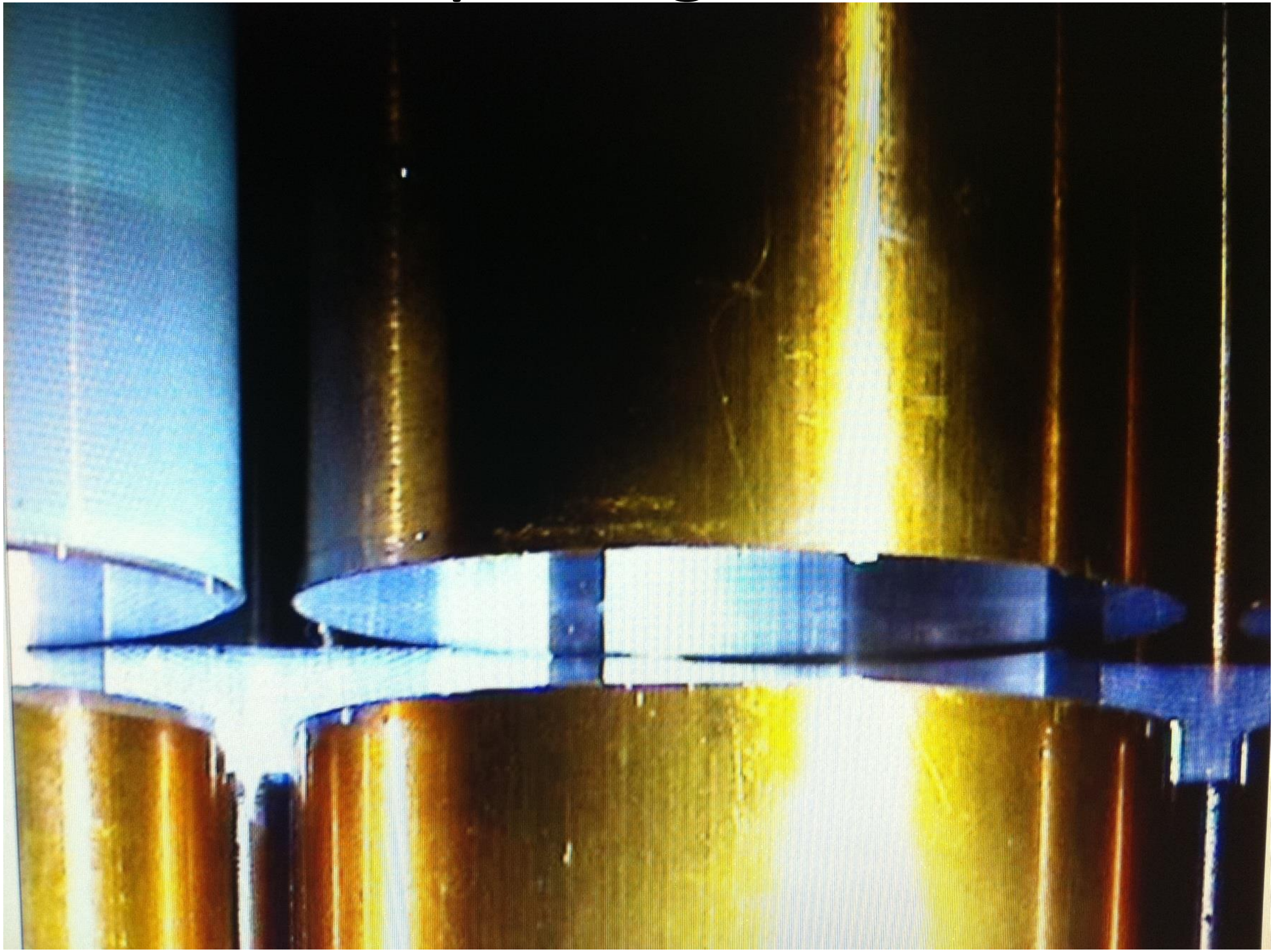
Opening test



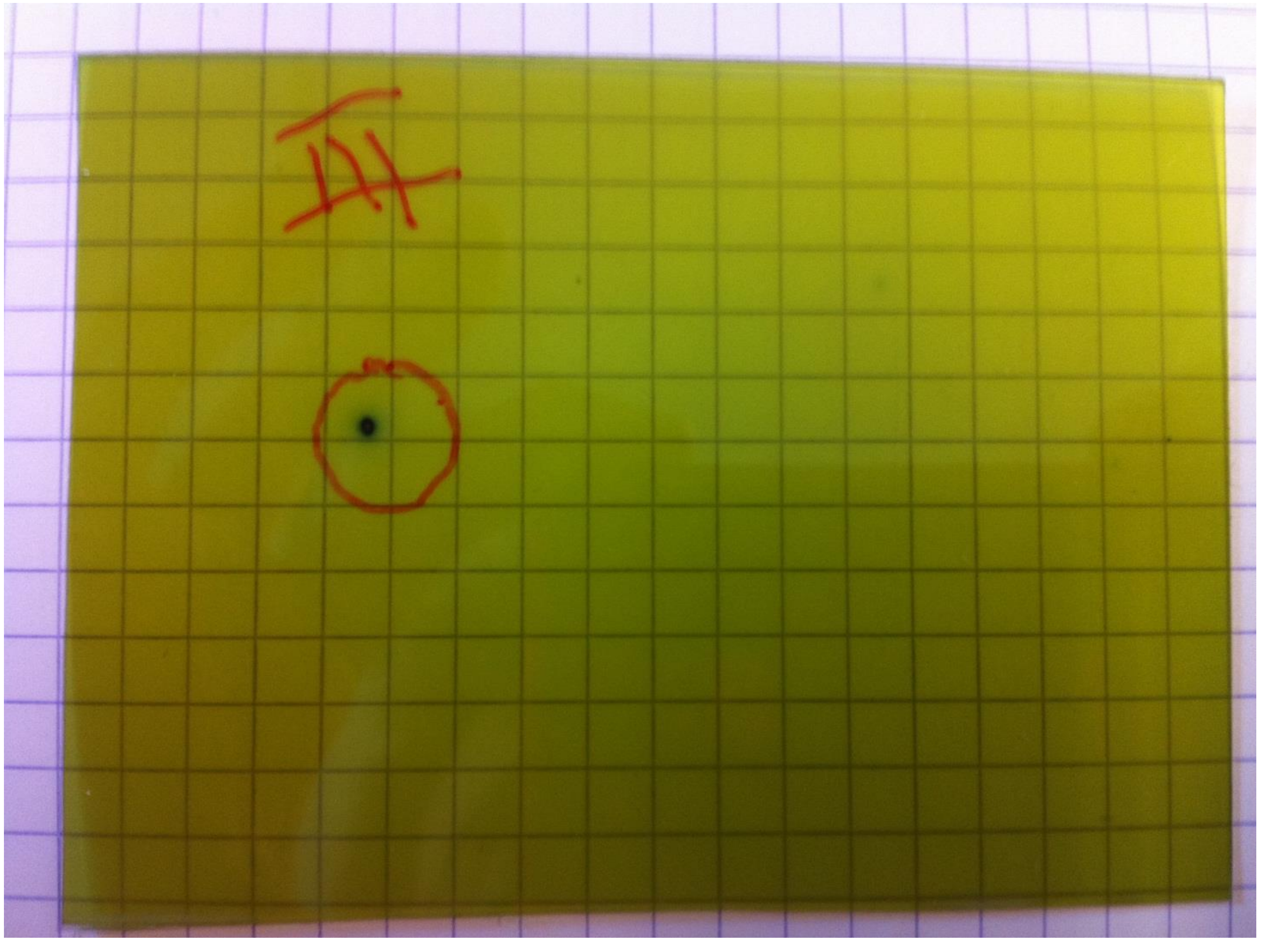
Opening test



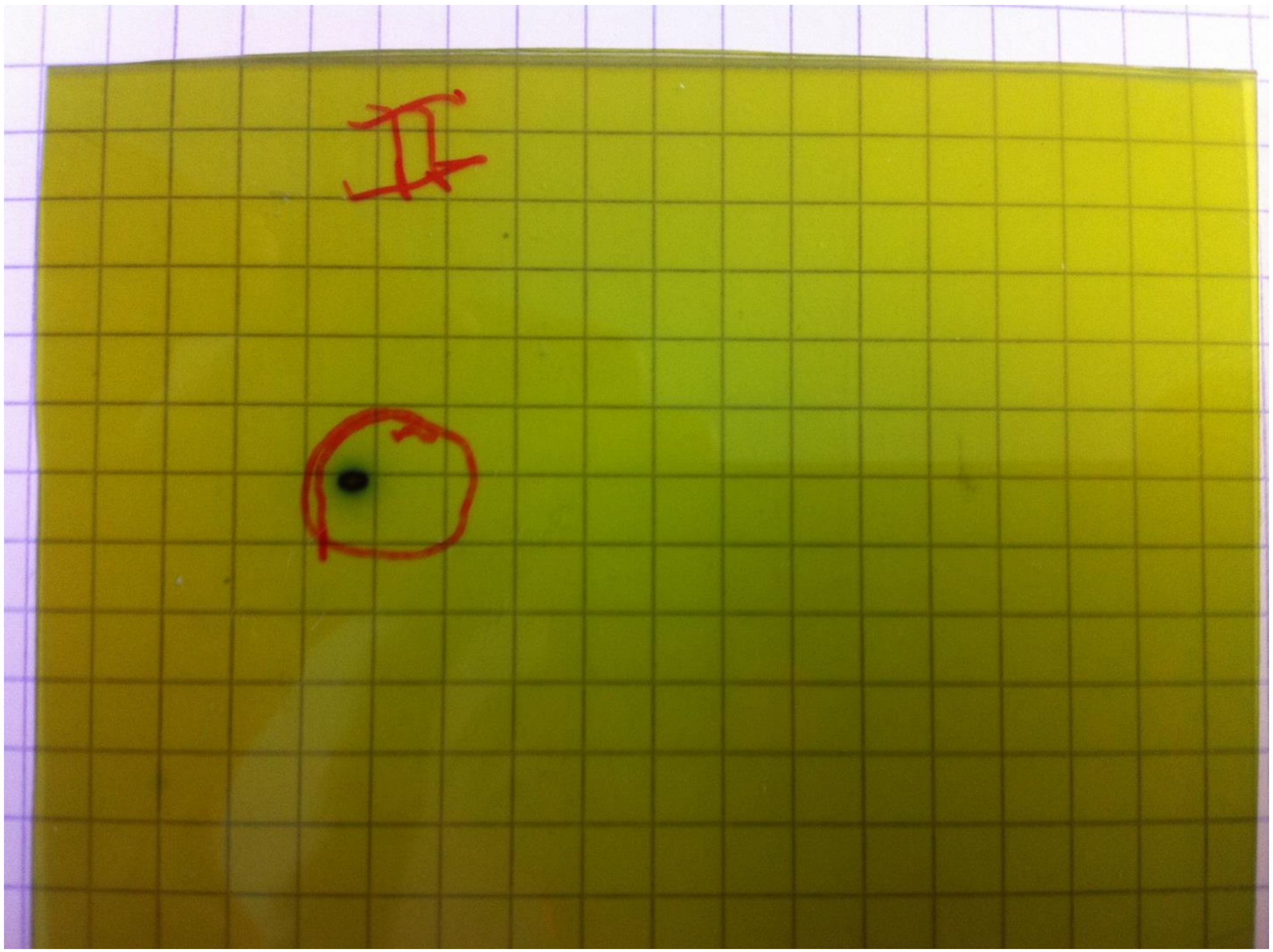
Opening test



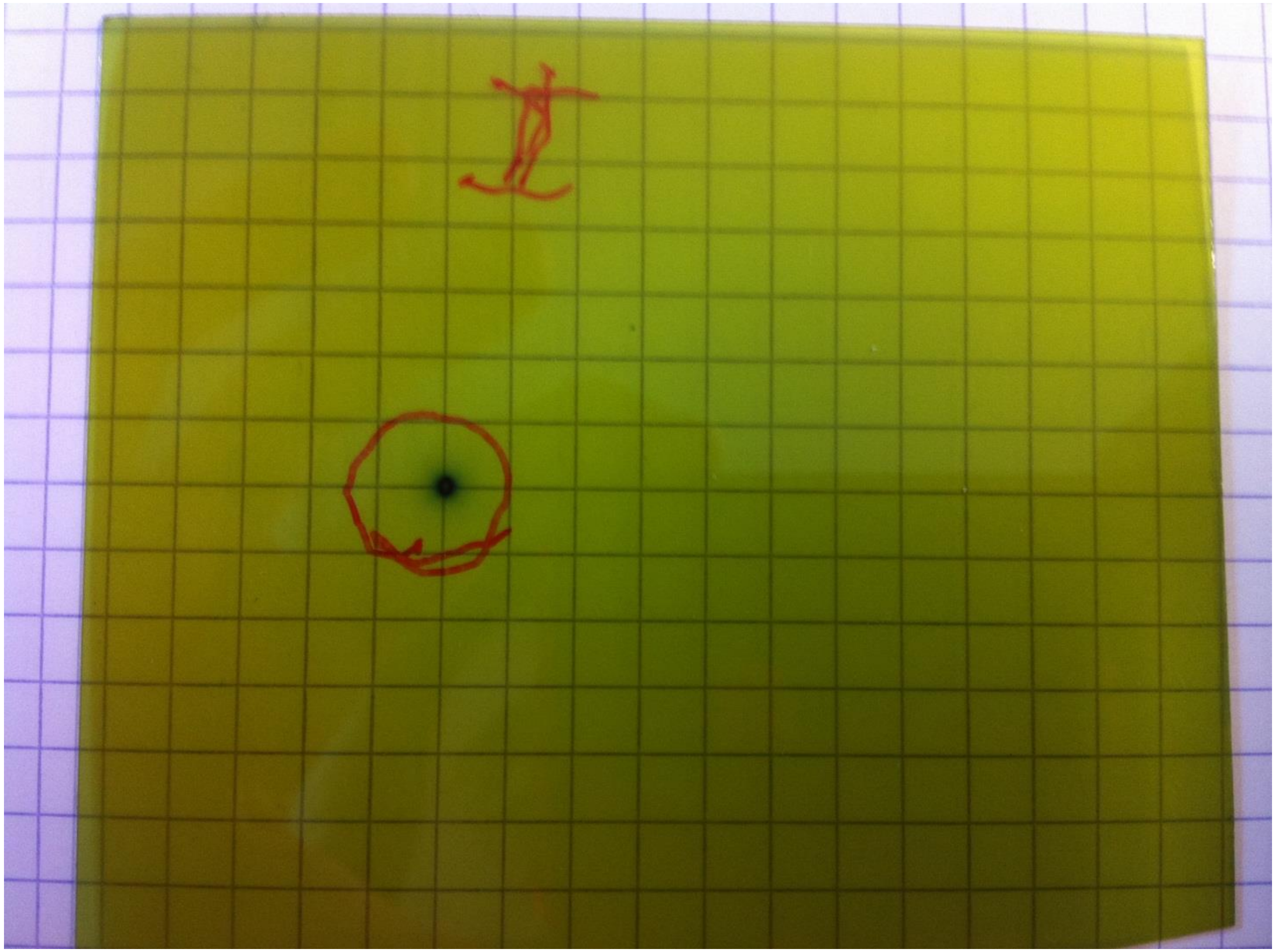
Photographic paper



Photographic paper



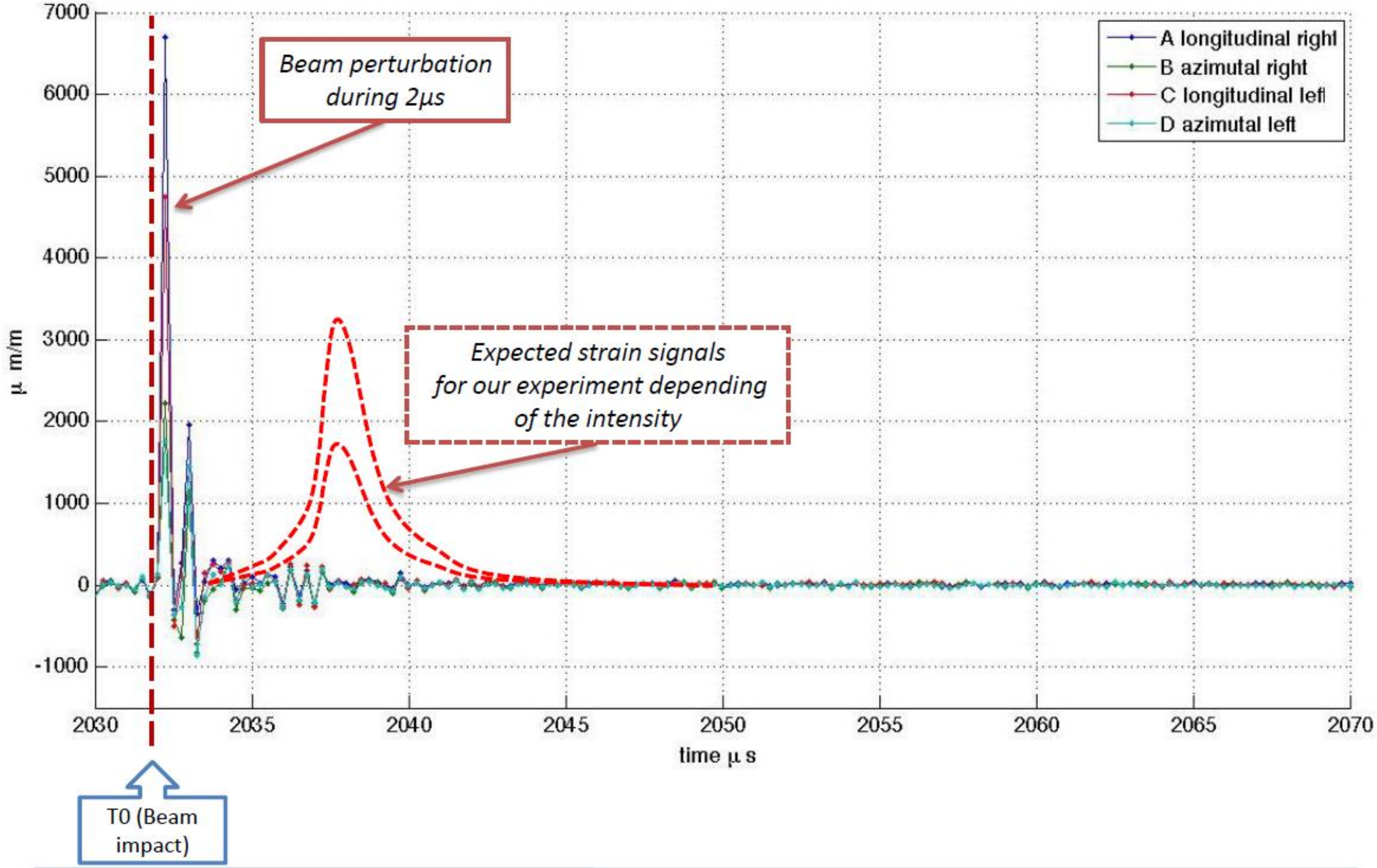
Photographic paper



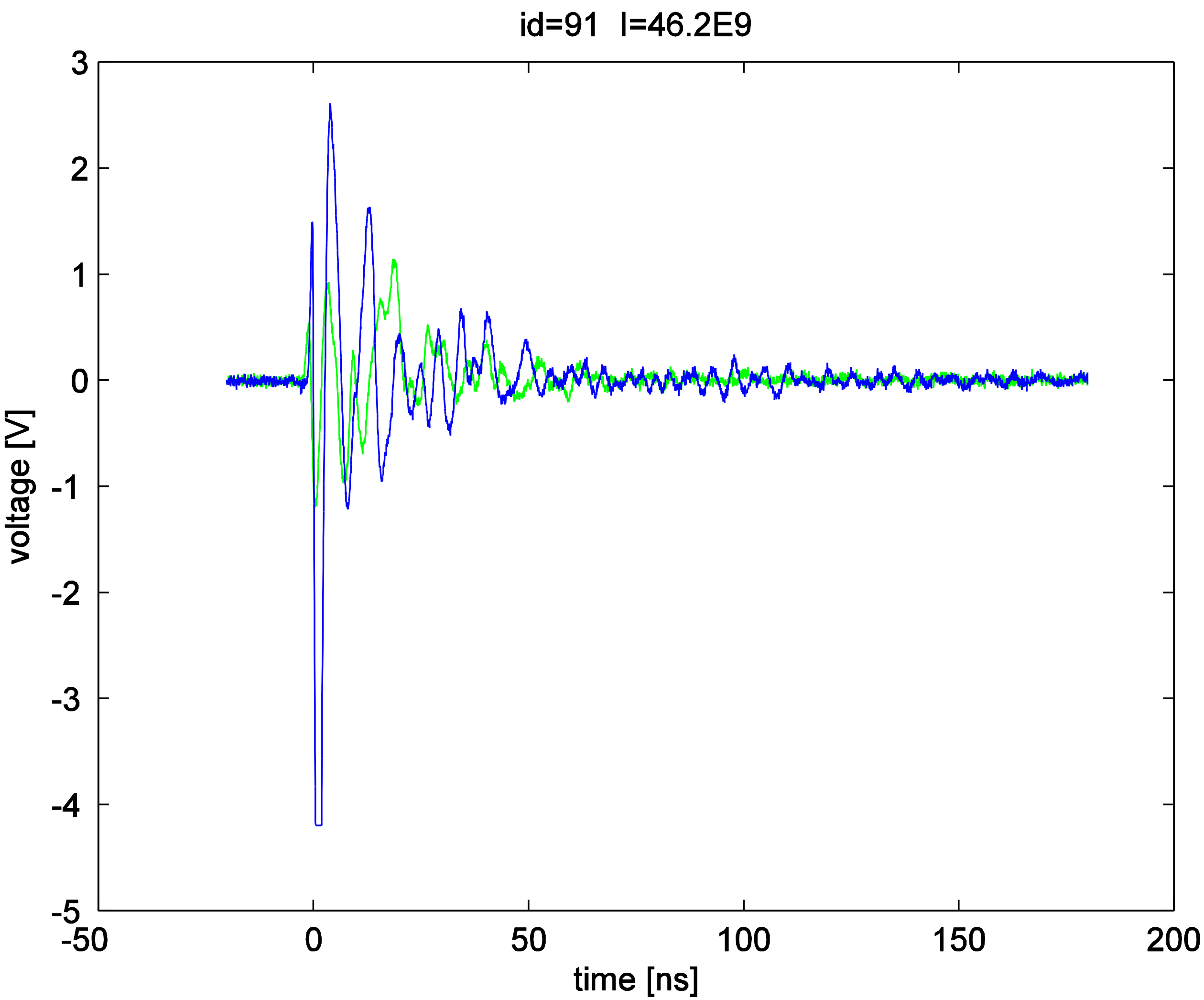
Photographic paper

Strain Gauges

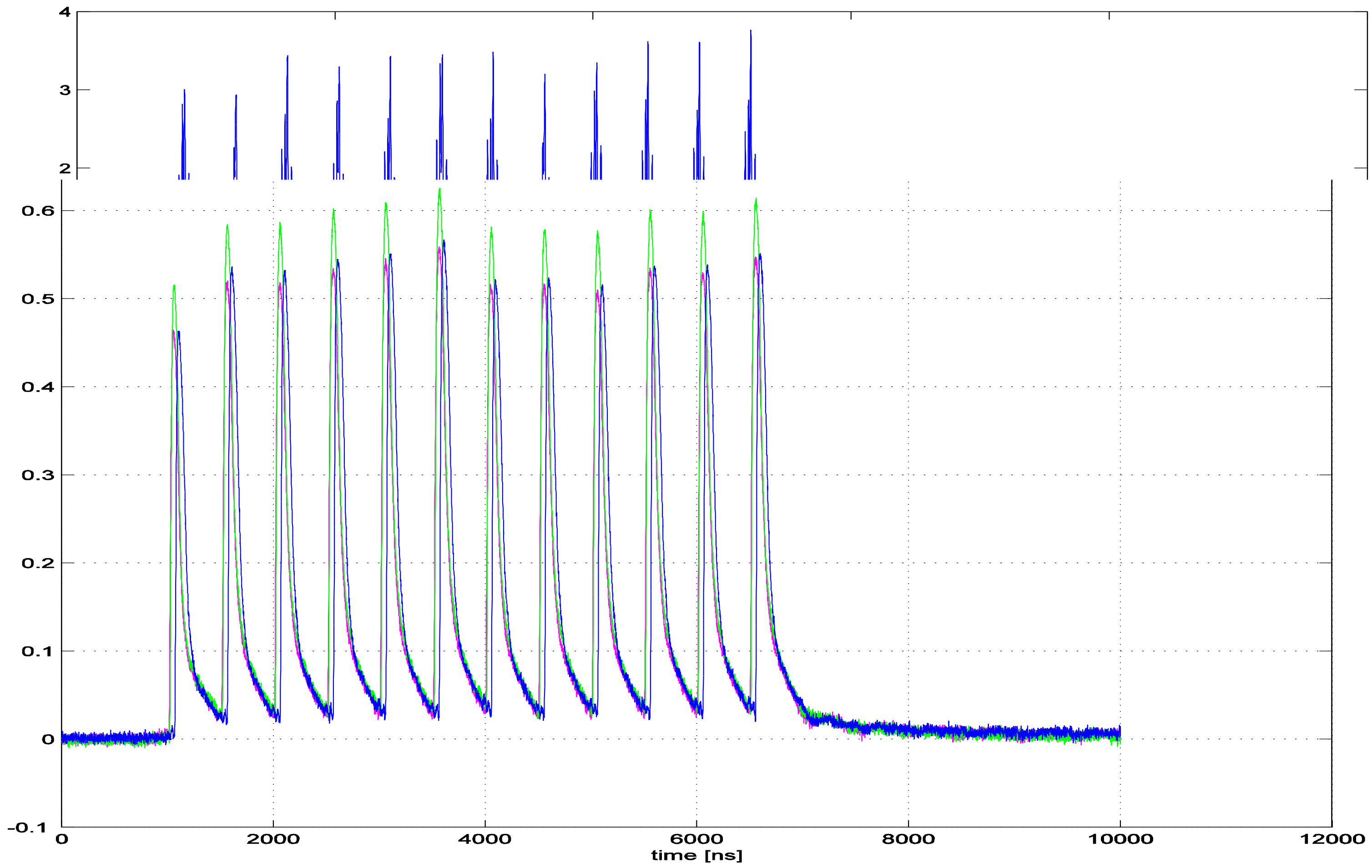
First Shot with pilot beam in a copper cylinder



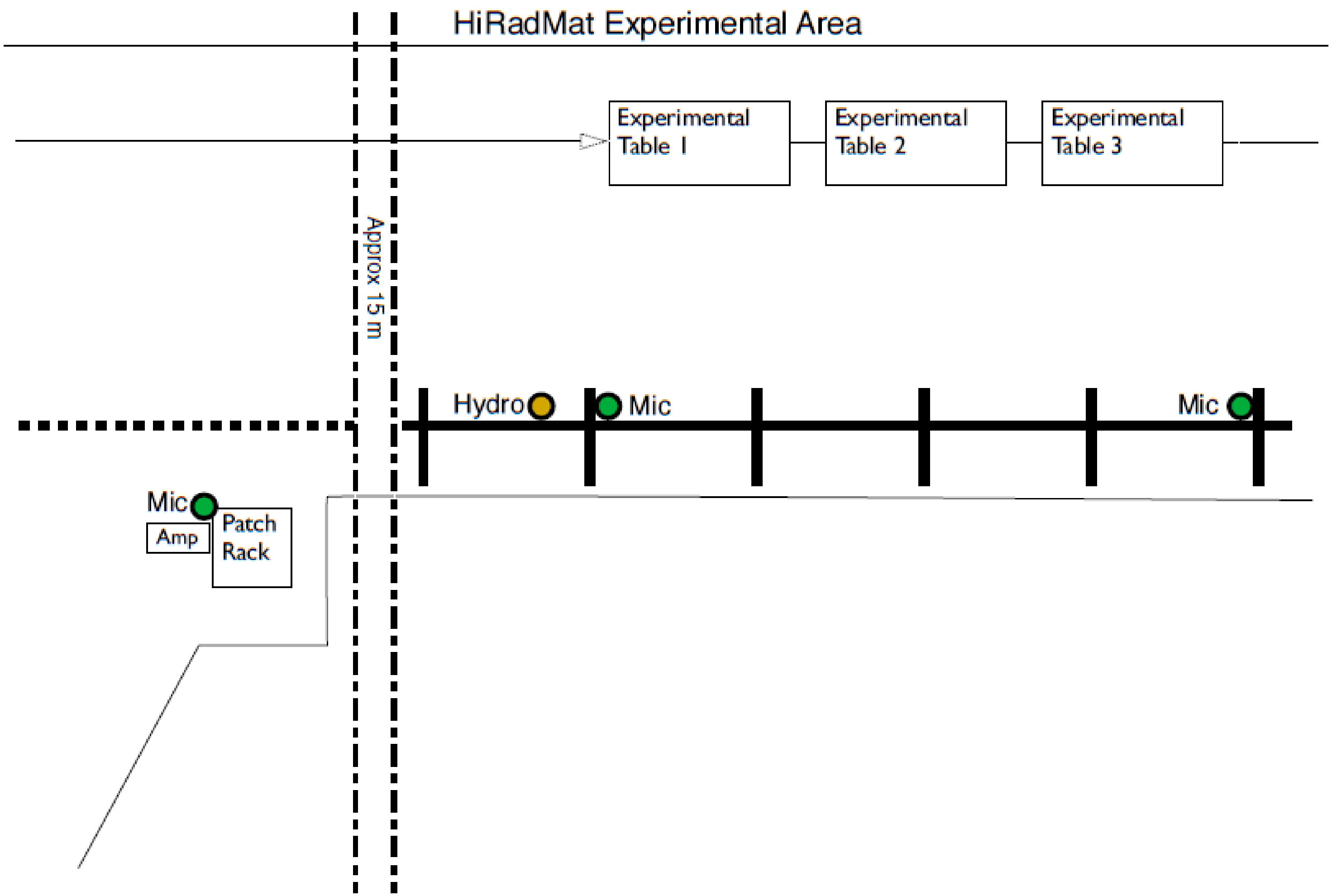
SEM detectors



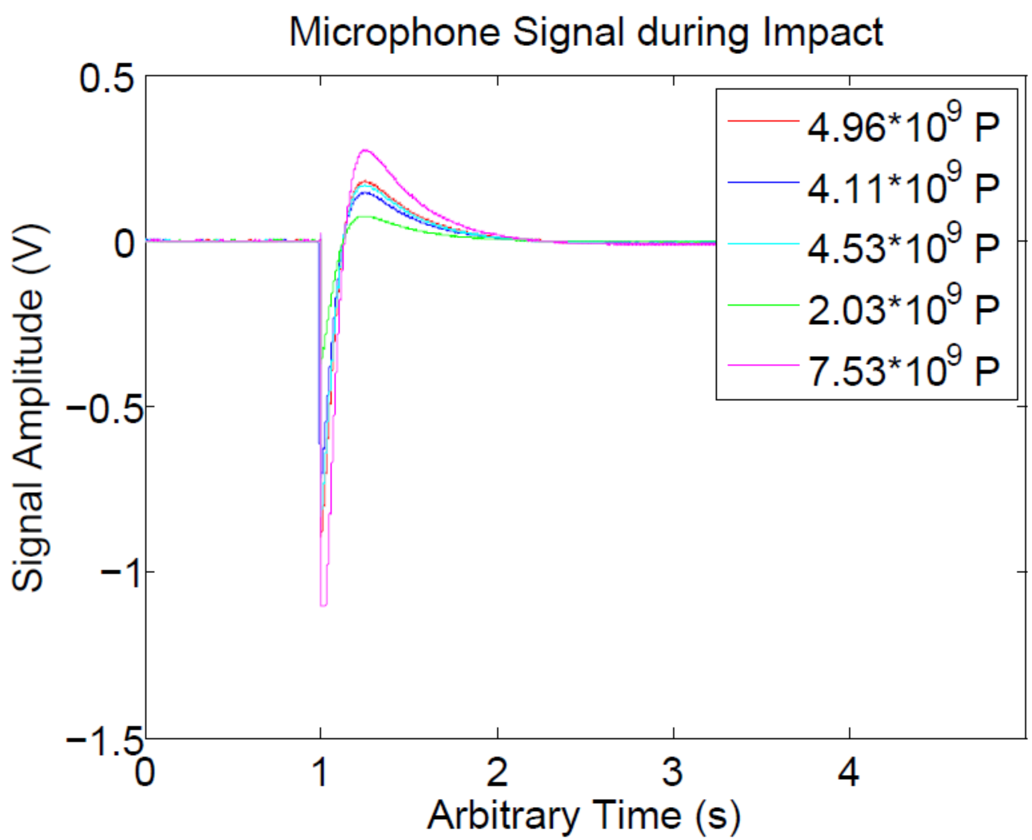
SEM detectors



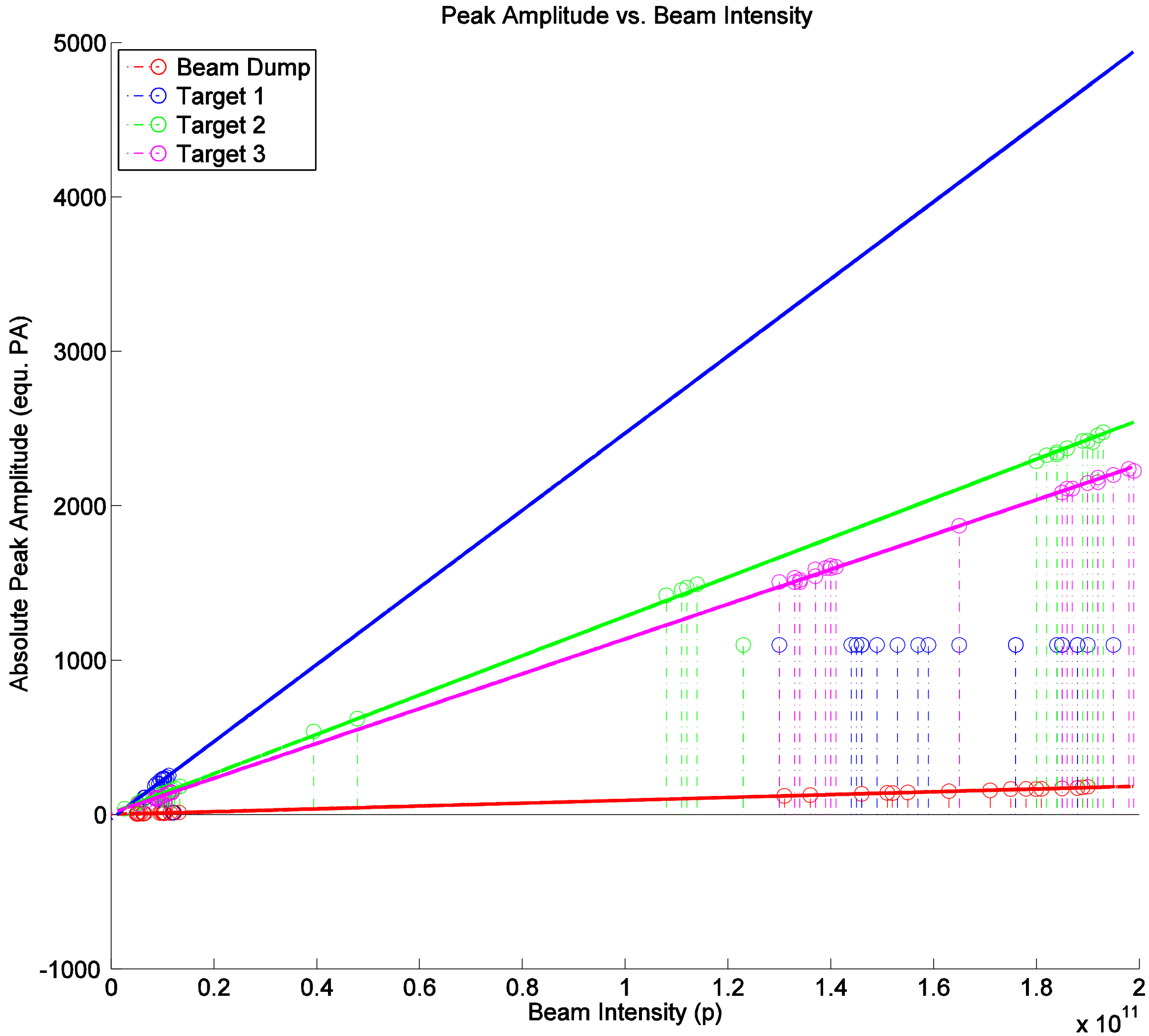
Microphones



Microphones



Microphones

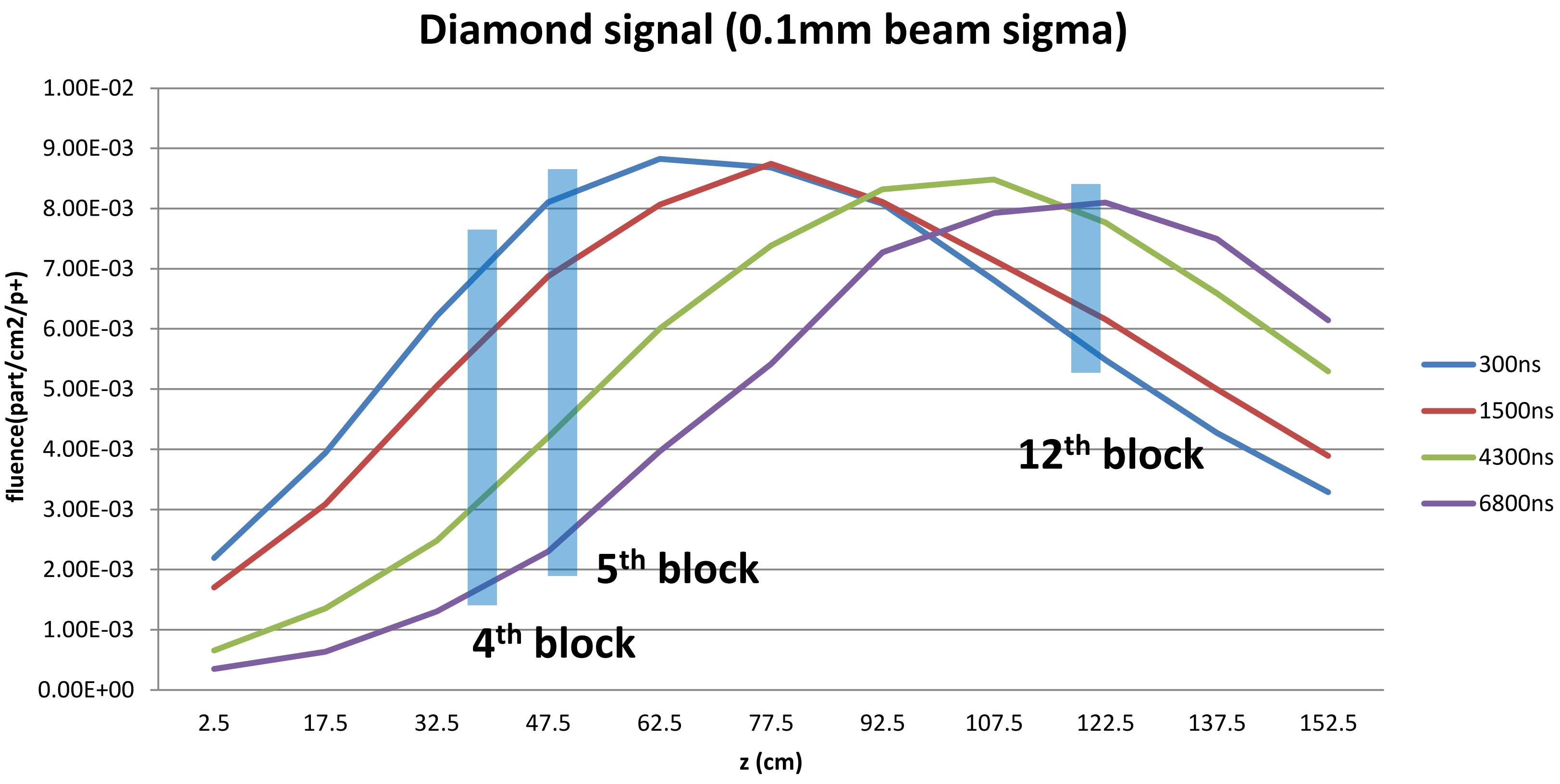


Microphones

Target 3
Single bunch 4.5E10 protons
Beam sound

Source: Daniel Deboy

Simulations



Simulations: different beam size, beam intensity, Nbunches, bunch spacing.