Bunch-by-bunch diagnostics at DAFNE for studies to increase the luminosity

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"What's next at LNF"

Topics

- Introduction
- Multiple scientific cases: luminosity in e+/e- collision, parasitic e-cloud in storage rings, bunch-by-bunch and turn-by-turn diagnostics, IR detectors (uncooled, multi-pixel, time resolved)
- Bunch-by-bunch diagnostics can have a key role
- 3L_2D project description and present status
- Measurements
- New proposal (bunch-by-bunch luminometer)
- Comments & conclusions
- Reference

Introduction

- The existing luminosity diagnostics at DAΦNE cannot explain the 30% discrepancy between the extrapolated 10 bunches peak luminosity and the standard fill pattern made by colliding 100 bunches.
- In my opinion, to understand the terms of the problem, many bunch-by-bunch diagnostic tools can be useful.
- They are based not only on the b-b-b feedback systems, but also on 3L_2D, a new infrared time resolved multi-pixel detector (funded by CSN V) and also by new proposals, as for example a bunch-by-bunch luminosity monitor.

Scientific Case N.ro 1: luminosity

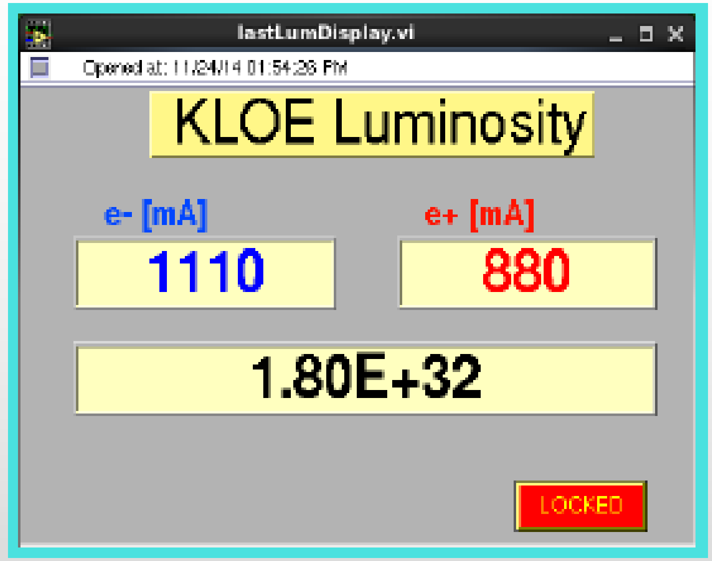
1) Why the DAΦNE luminosity is so different from Siddartha experiment and KLOE detector (about a factor 2) ?

2) How to explain the 30% discrepancy between the extrapolated 10 bunches peak luminosity and the standard fill pattern made by colliding 100 bunches ?

Peak Luminosity

Courtesy of
C.Milardi

24 Nov 2014



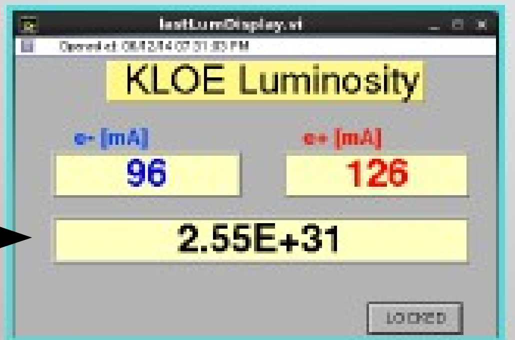
95 bunches

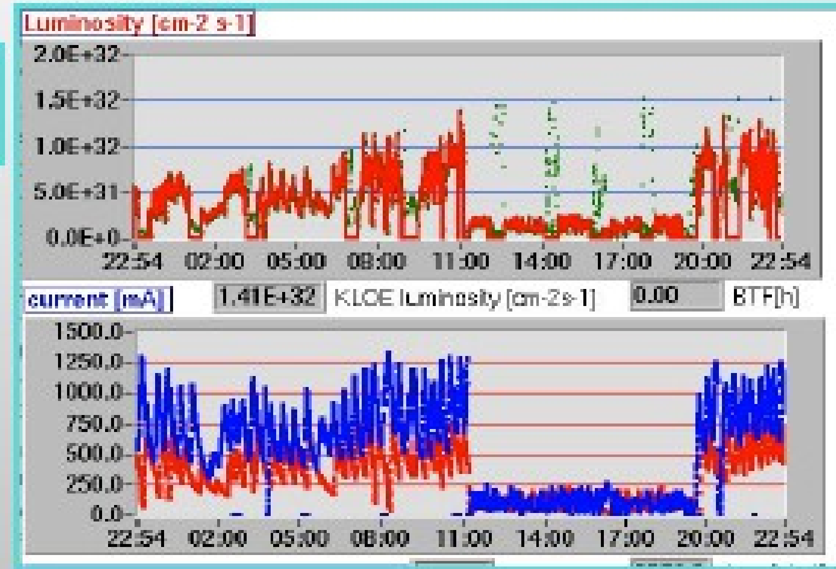
	DAΦNE CW upgrade SIDDHARTA (2009)	DAΦNE KLOE (2005)	DAΦNE (CW) KLOE (2012)	DAΦNE (CW) KLOE-2 (2014)
L_{peak} [$cm^{-2}s^{-1}$]	$4.53 \cdot 10^{32}$	$1.50 \cdot 10^{32}$	$1.52 \cdot 10^{32}$	$1.80 \cdot 10^{32}$
I^- [A]	1.52	1.4	0.93	1.11
I^+ [A]	1.0	1.2	0.72	0.88
$N_{bunches}$	105	111	100	95

10 Bunches Luminosity

Courtesy of C.Milardi

Aiming at minimizing the impact of collective effects on *L*





***L_{peak} ~ 2.5 10^{32} cm^{-2} s^{-1}** might be achieved by using 100 bunches*

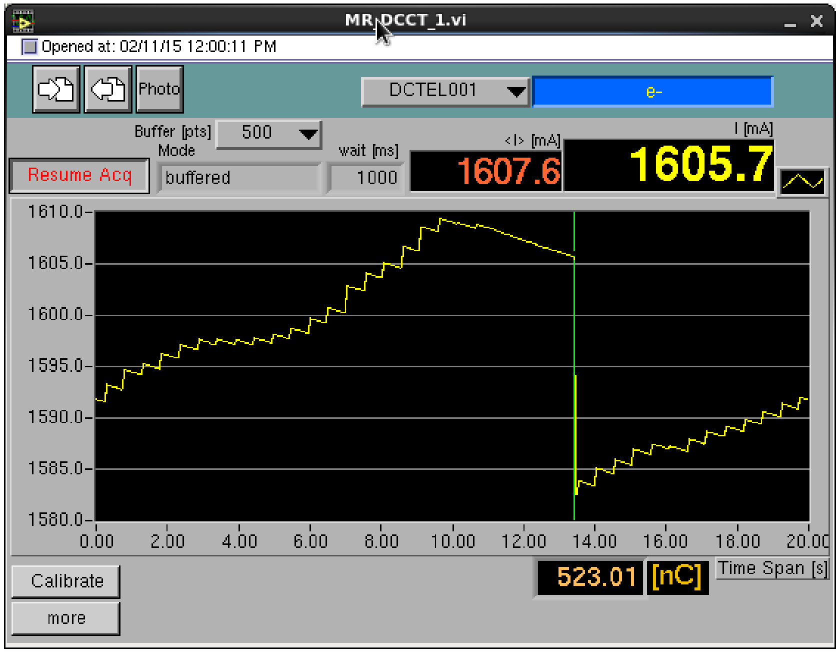
- *Beam-beam is not a limiting factor*
- *Crab-Waist Sextupoles work (even at lower strength)*

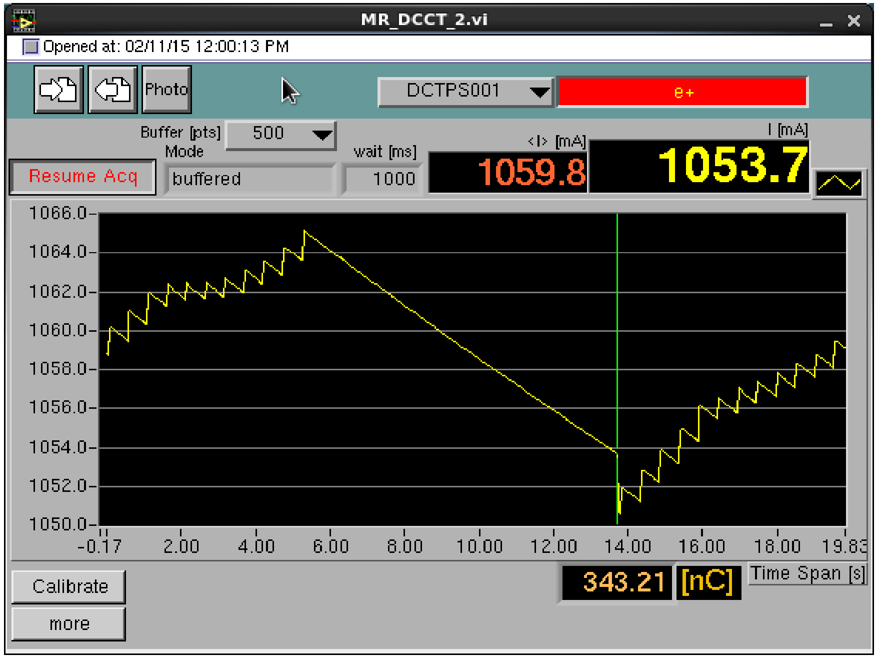
This result can be improved by:

- *optimizing dynamical vacuum*
- *perfecting colliding beams parameters*
- *tuning multi-bunch and high current operations*

NOTE: I partially disagree with the last points: of course these are standard operations that we do routinely. But in my opinion the situation is much more complicated and we need to understand better.

Indeed the feedback are already tuned for high current operation! (see for example the MD of 12/2/2015)





- Stored 1.6 A of e- beam current in 90 bunches without instabilities
- Current limited by saturation in injection

- Positron beam: injected 33mA in just one bunch.
- Stored 1064mA in 50 bunches: 20b. +10b. gap+ 10bunch +20b. gap+10bunch+ 50b.gap
- Current limited by e- cloud!

Comments on Scientific Case N.ro 1: luminosity

- There is an evident deep disagreement between the luminosity results that is difficult to explain (apart difference introduced by the KLOE and compensator solenoids).
- First of all I would be not so sure about calibration and linearity of the luminometer used during Siddartha experiment: 4.53x10^32 is a very high value in comparison to KLOE luminosity values.
- But...at least the two measurements done for KLOE (by using KLOE as luminometer) with 10 and ~100 bunches should agree!
- The first trivial and simple explanation to this 30% discrepancy could be in the reason that, with 100 bunch colliding, KLOE could go in saturation so the true max luminosity achieved by DAFNE would be in effect 2.5 x 10^32 and not 1.8 x 10^32.
- Otherwise, if it is not the case, we need a much more powerful beam diagnostics to see if different (along the bunch train) vertical bunch sizes and positions as well as hor/ver tunes give different luminosity in connection to the bunch number.

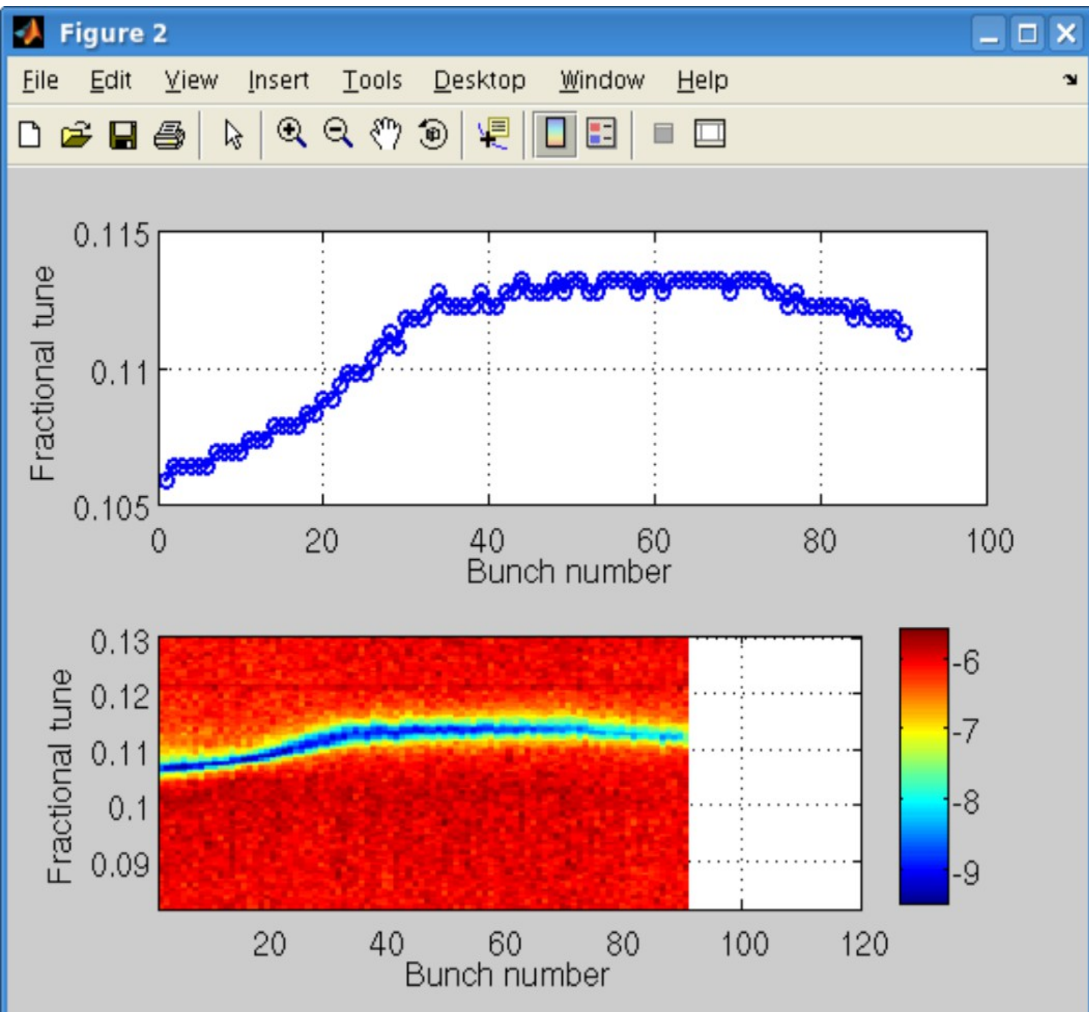
Scientific Case N.ro 2: e- cloud

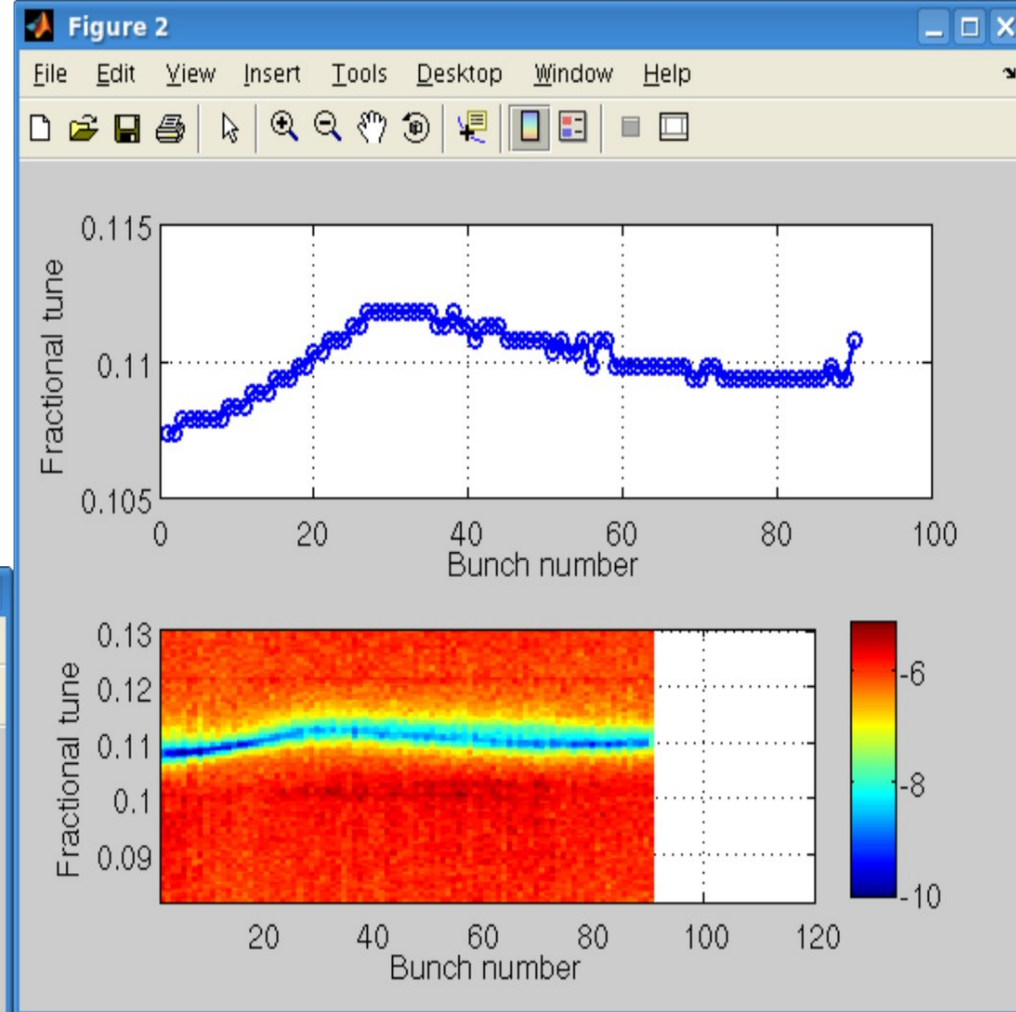
1) Parasitic e- clouds in DAΦNE positron ring **cause** strong horizontal instabilities and vertical bunch enlargements (it's a fact).
2) Not all the mitigation techniques can be applied to DAΦNE: solenoids in the straight sections and clearing electrodes in the 8 bending magnets and in the 4 wiggler magnets has been installed.
3) Special coating is not more possible and large part of the vacuum chamber is done by aluminium, the worst material respect to the e-clouds.
4) Furthermore 3 of 4 clearing electrodes in the wigglers are out of work!
5) The powerful bunch-by-bunch feedback systems can damp the extremely fast horizontal instability but also they can be used to perform some types of bunch-by-bunch diagnostics
6) An important b-b-b diagnostic tool is the measure of the modal grow rate in each oscillation planes versus clearing electrodes power supplies.

Scientific Case N.ro 3: bunch-by-bunch & turn-by-turn diagnostics

- We are in presence of a 30% discrepancy between the luminosity values for the case ~100 bunches and the case 10 bunches extrapolated to 100 and it is possible to analyze the problem while we cannot do anything now for the Siddartha vs. Kloe luminosity discrepancy
- The bunch-by-bunch diagnostics can identify which colliding bunches of the train make more collisions and which less
- This can be done acquiring and storing bunch-by-bunch luminometer signals together with beam currents in real time
- Another important factor is the betatron tune of each bunch of e+ and e- trains: the simulation programs (see M. Zobov work) and the control room experience show clearly that the luminosity is a function of the betatron tunes
- Bunch-by-bunch tune data can be acquired by using the DAFNE feedback systems that can store contiguous tracks up to 32 ms of data on disks
- From the analysis of these tracks it is evident the e-cloud effect indeed the electron beam does not show substantial betratron tune spread

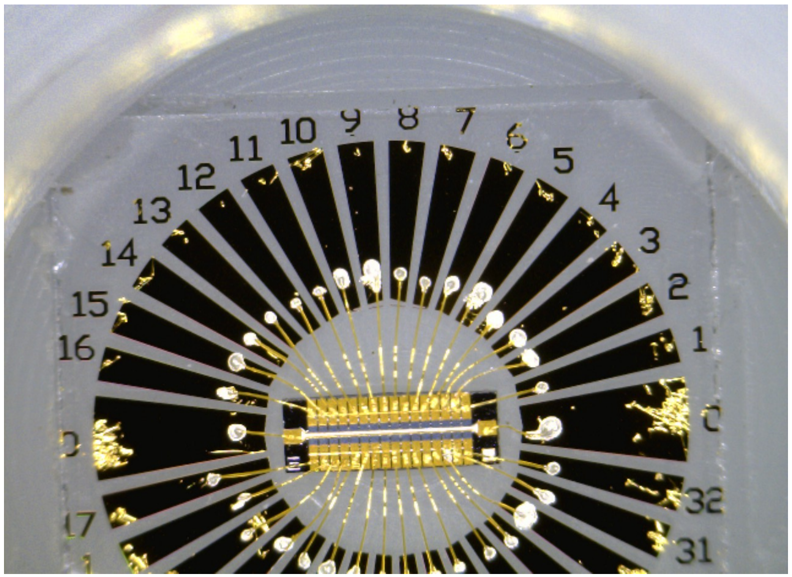
Horizontal e$^+$ fractional tune spread vs. bunch number (1-90) with clearing electrodes turned off and 600 mA beam current. The spread is 0.008 (from 0.106 to 0.114).



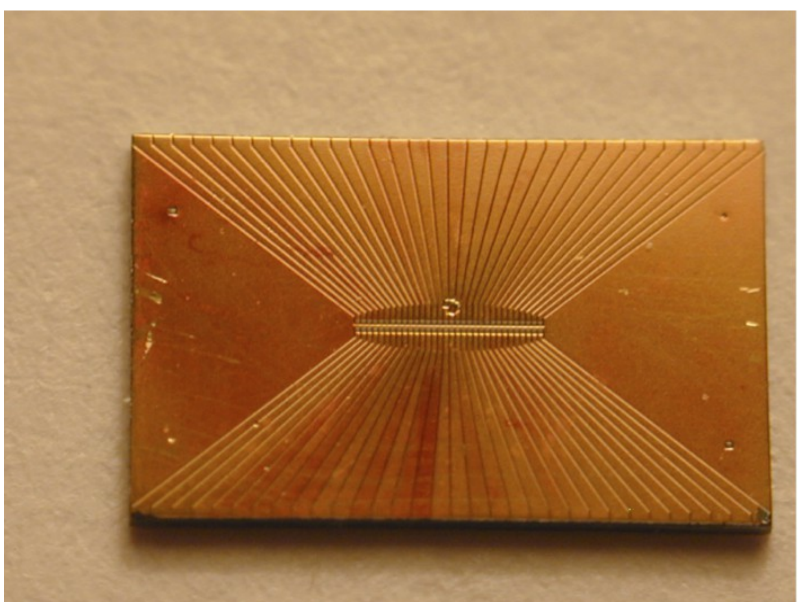


Horizontal e$^+$ fractional tune spread vs. bunch number (1-90) with clearing electrodes turned on and 600 mA beam current. The spread is 0.004 (from 0.108 to 0.112).

Scientific Case N.ro 4: IR detectors



- In collaboration with the VIGO System SA (Poland) many standard and custom IR detectors have been tested at LNF
- They are uncooled, time resolved, working in mid-IR, single pixel and multi-pixels
- So they can be used for b-b-b diagnostics as in the 3L_2D experiment funded by CSNV for 2013-2014



•Bunch-by-bunch diagnostics can have a key role

Diagnostics systems are necessary to verify and evaluate the setup and the correct operation of solenoids and electrodes, for example checking the best voltage value to apply to the electrodes and with which polarity. The voltage has been progressively increased up to 500 V while the polarity, at the begin with attractive sign, is now changed to the repulsive one. This is to avoid to have too large parasitic currents towards the electrode power supplies causing faults.

At DAFNE, up to now, the diagnostics used to monitor solenoids and electrodes basically are:

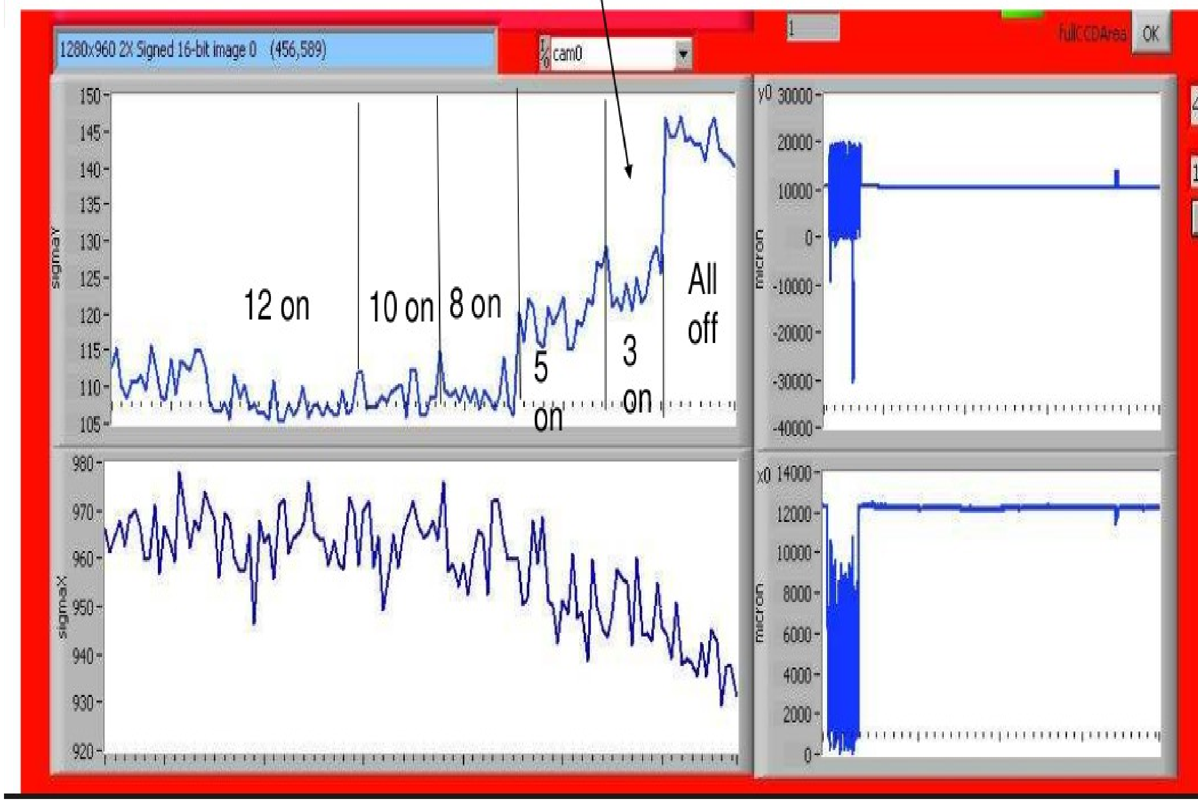
a) standard SLM (synchrotron light monitor),

b) modal grow rate measurements,

c) bunch by bunch betatron tune spread along the pattern train.

For the first diagnostics the SLM gives only beam transverse sizes, enveloping all the bunch train, while the last two measurements are bunch-by-bunch techniques made by using the feedback capabilities.

Turning off the electrodes,
a vertical enlargement is evident on the SLM



The importance of these measurements is in the fact that a vertical enlargement can be also produced for the positron beam by the e-cloud effect (observed by the SLM turning off the clearing electrodes, see Fig. above.). A beam vertical enlargement of course decreases the peak luminosity as intuitively and analytically it can be argued.

3L_2D project description and present status / 1

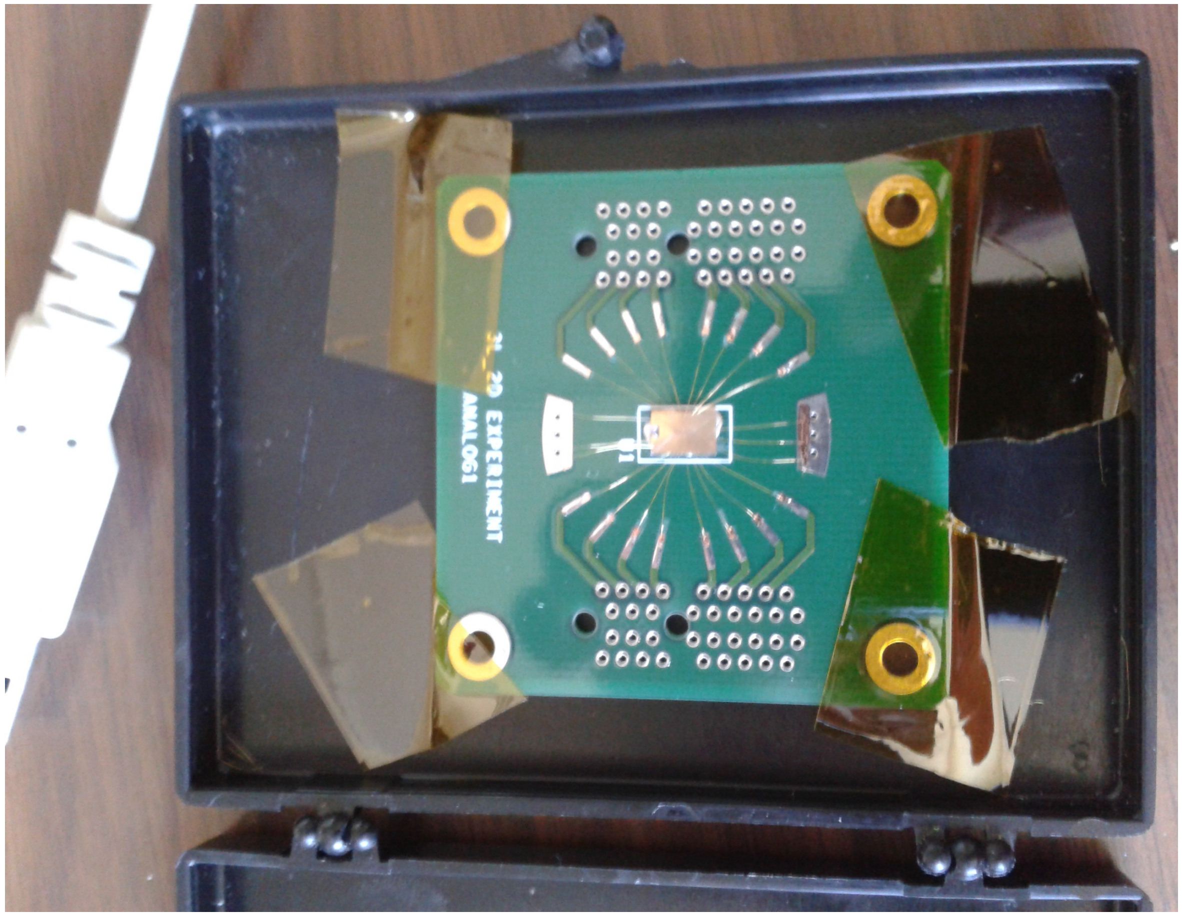
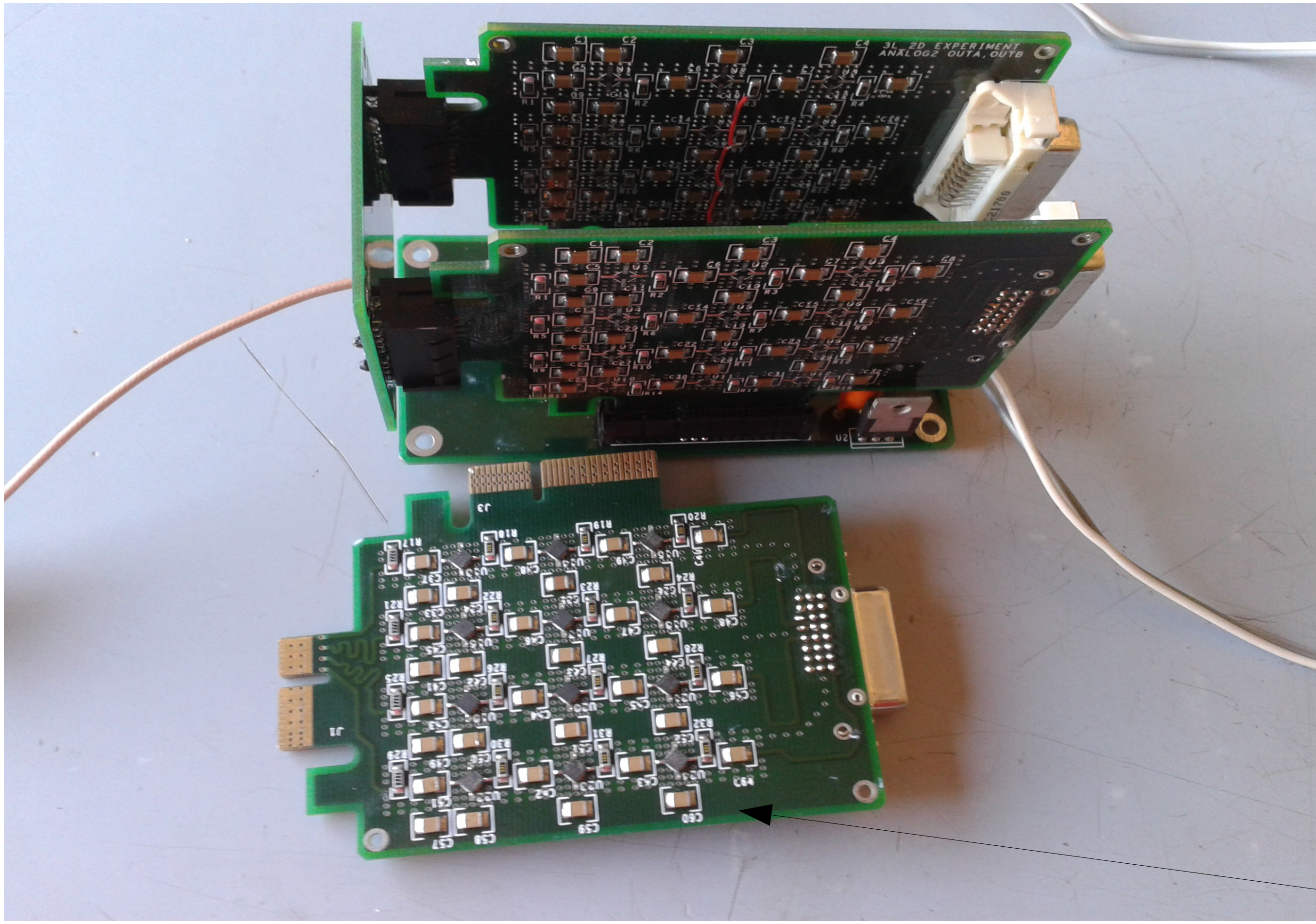


Photo of the 2×32 pixels HgCdTe array detector placed on a small custom printed circuit board and bonded by using gold wires.

3L_2D project description and present status / 2



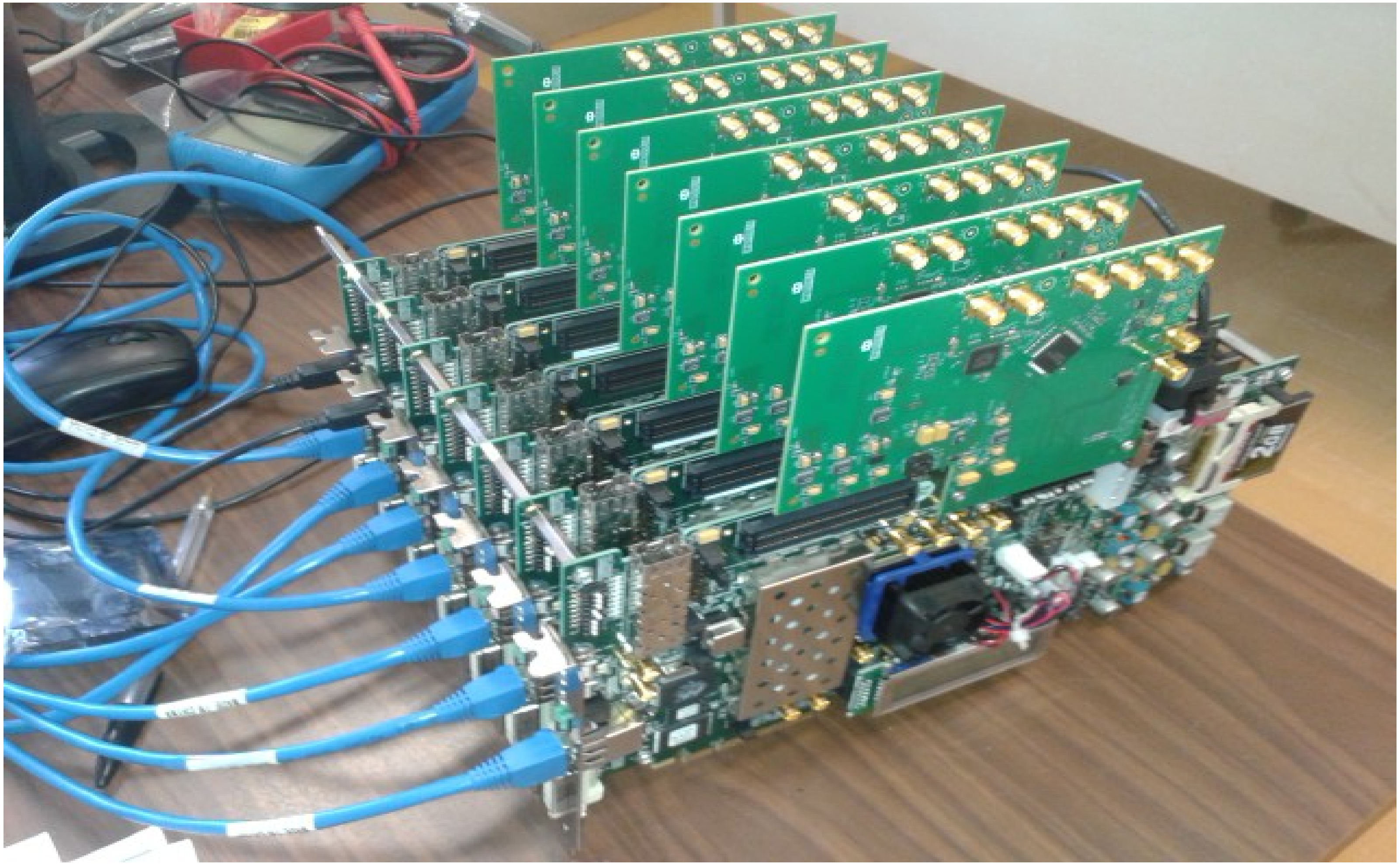
The four analogue modules containing the array and the 16 channels of the 3-stage amplification outside their box case.

These modules have been designed in LNF Div Acc with external supports for loading the very small amplifiers (in black)

3L_2D project description and present status / 3

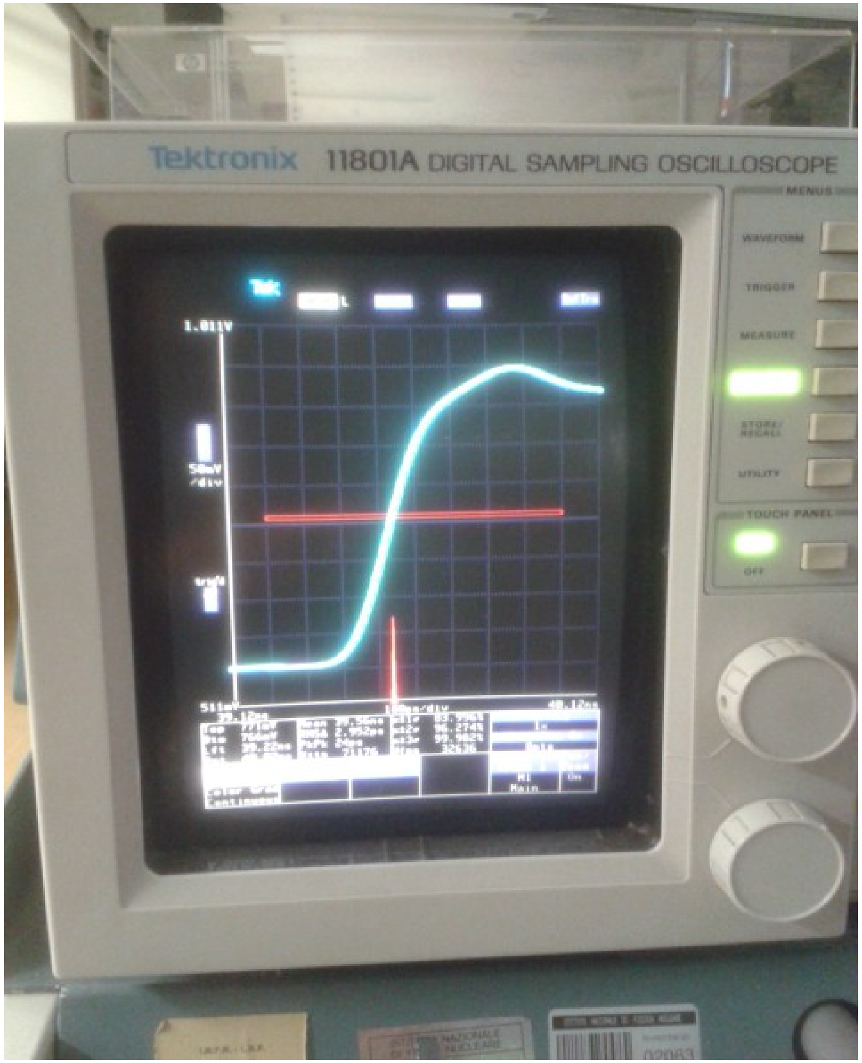
- Timing module with Arduino interface
- The timing module, assembled at SELCED can deskew up to 8 acquisition channels with a rms jitter of 1-2 ps
- The programmability of the channel skew is given by the arduino module connected via USB to a pc

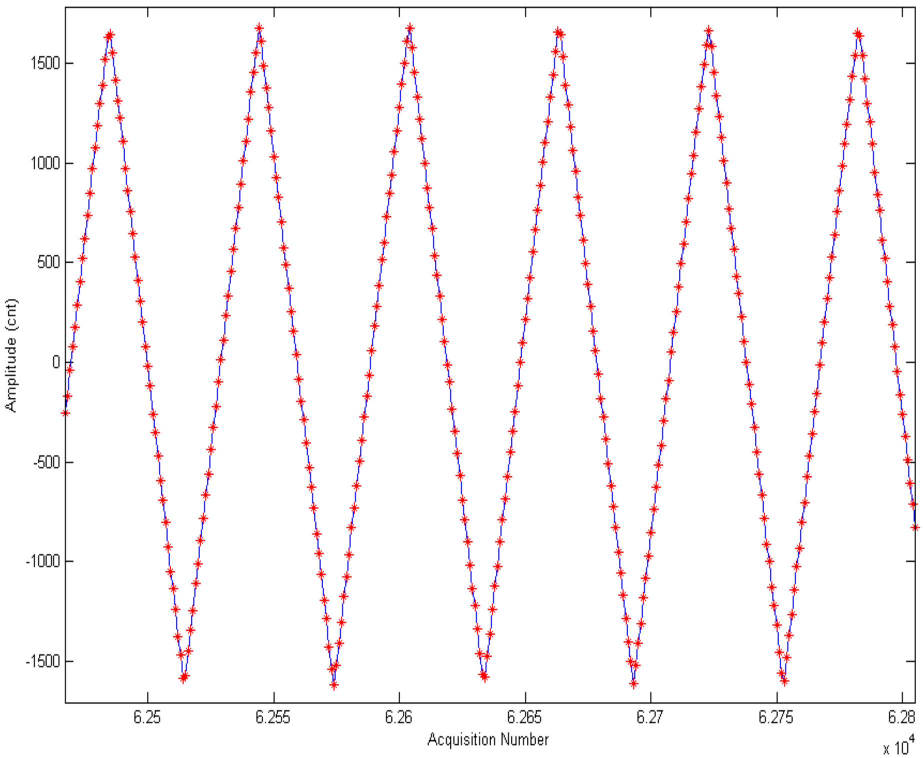
3L_2D project description and present status / 4



- These are 8 acquisition channels each composed by Xilinx FPGA commercial board and by AD (14 bits conversion) custom board

3L_2D project description and present status / 5



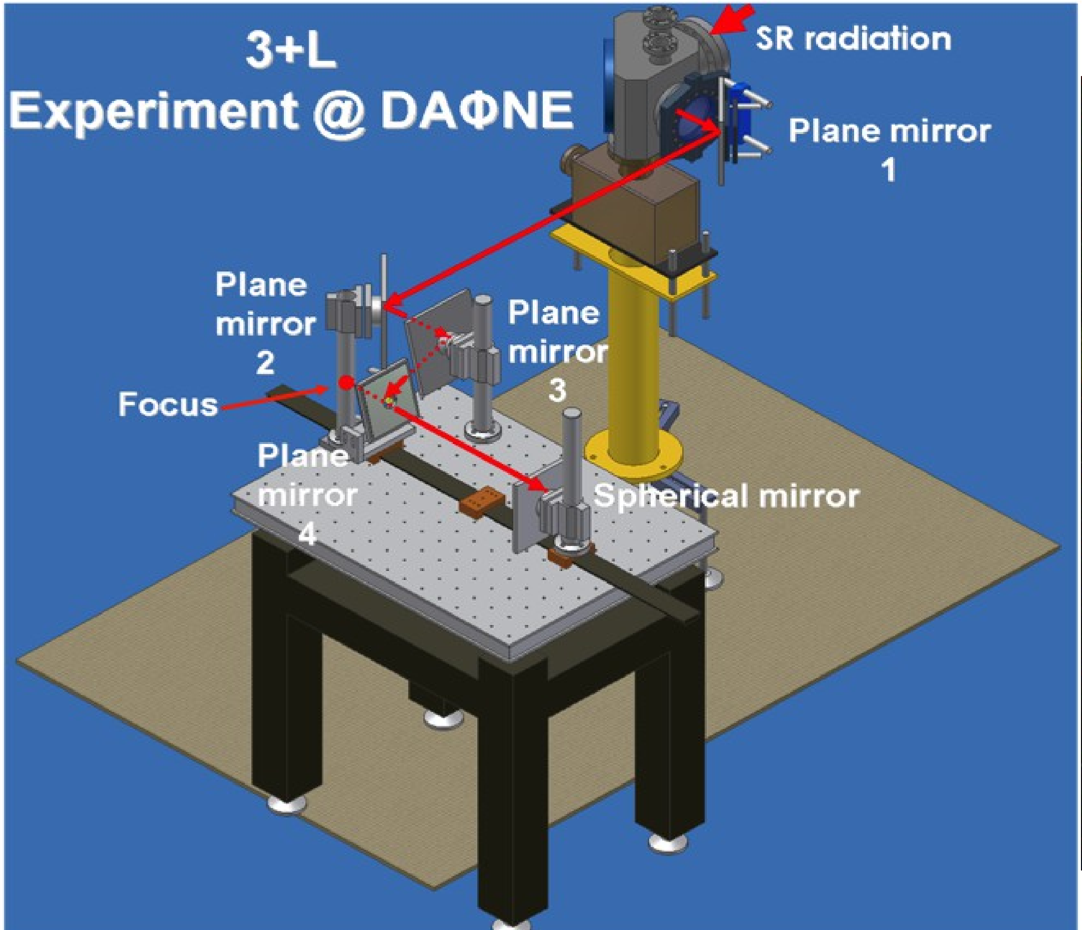


- Test of the timing board and of acquisition channel (HW+SW) completed

3L_2D project description and present status / 6

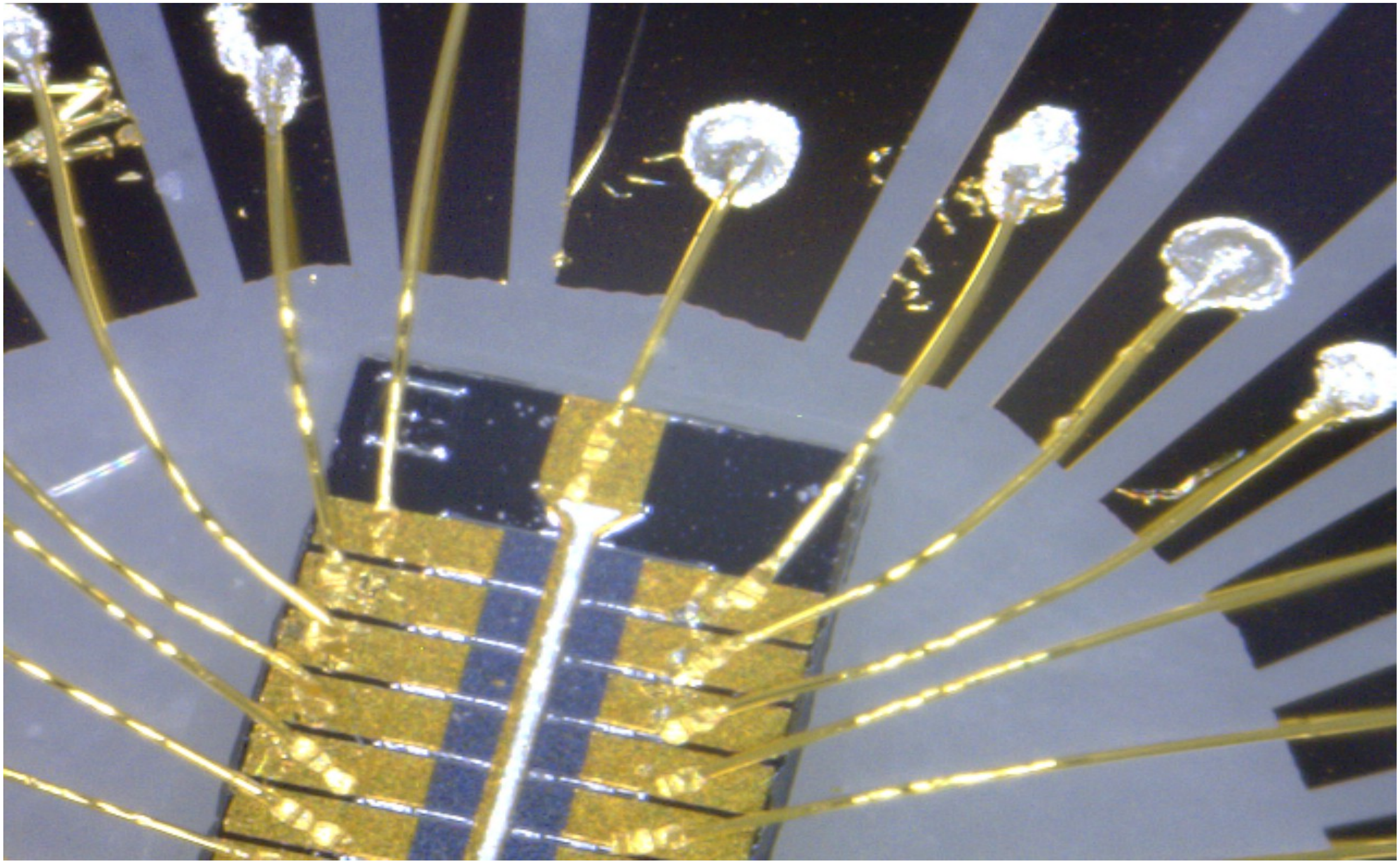
- All the module are installed and working at the 3+L bealine in DAFNE e+ ring from the first bending magnet after IP2
- Remote connection are used to make the data taking operation

3L_2D project description and present status / 7



- On the left picture, a layout of 3+L beamline with 4 plane mirrors and one spherical mirror (the last mirror has a hole)
- In the second picture the beam spot that still need to be perfectly aligned

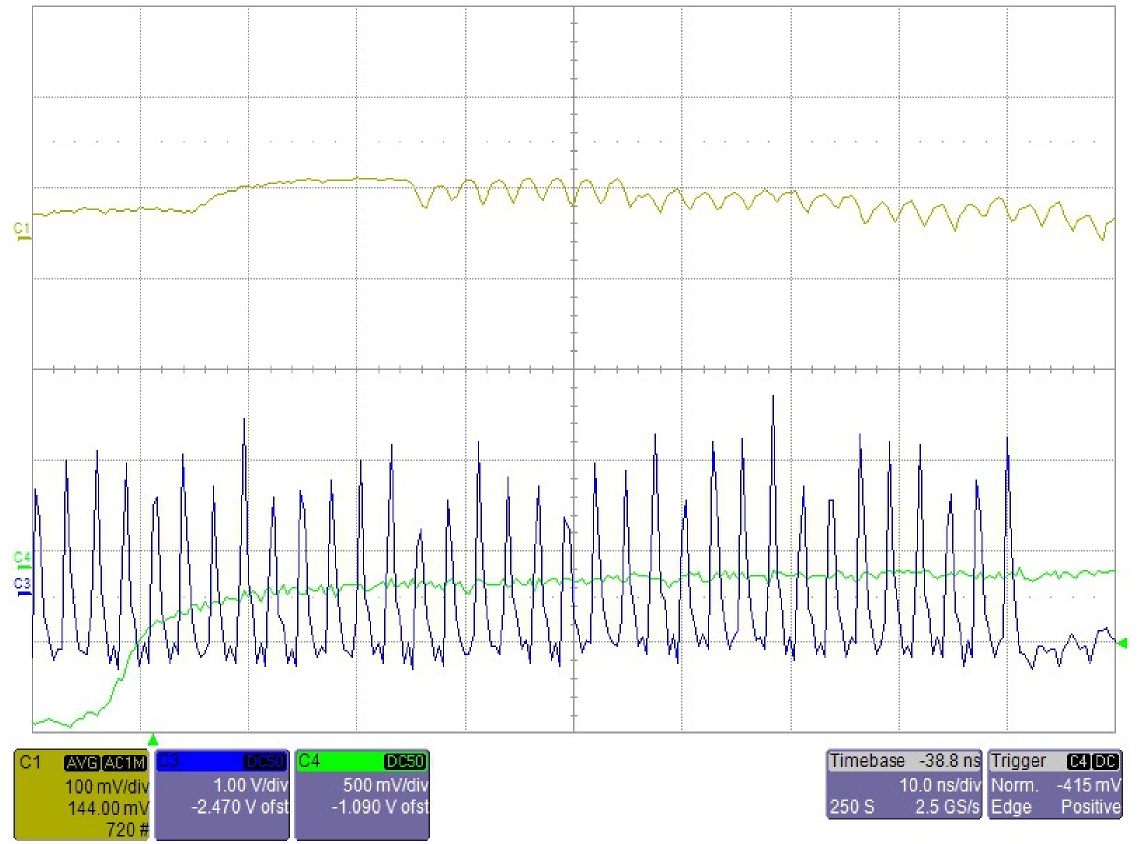
3L_2D project description and present status / 8



- Bonding of the new 2x16 array is in progress at Florence University by E. Pace

3L_2D Measurements
(as proof of correct work in single pixel)

DAΦNE data taking at SINBAD on June 13, 2014. The trace are: the ring revolution trigger (green), the beam signal from an electromagnetic pickup (blue) and from one HgCdTe pixel (yellow) amplified by 40 dB. The horizontal scale is 10 ns while the vertical scales is 0.5V/div for the trigger (green) and 1V/div for e.m. pickup signal (blue) and 0.1V/div for the IR signal (yellow). The blue signal shows the last bunches before the gap while the yellow one is the first part of the bunch train. Beam data have been collected in different ring locations.



New proposal: a bunch-by-bunch luminometer

- At present the 3L_2D system has installed 8 channels of acquisition but other 4 channel have been bought and what is missing should arrive in March.
- Soon we could use the remaining 4 channels to arrange a b-b-b luminometer at zero cost instead of being added to 3L_2D to acquire 12 pixels in place of 8 pixels. This can be just for a test
- The 4 channels can be devoted to acquire 2 luminosity signals from KLOE and e+ / e- beam currents with real time data storing (bunch-by-bunch and turn-by-turn)
- This could be done if the Accelerator Division gives the necessary support to mount two timing boards and to assembly all the part

Comments & conclusion

- DAFNE behaviour in terms of luminosity (but also in many other issues!) shows some not well cleared puzzles
- Innovative diagnostics systems can help to make a higher luminosity
- 3L_2D has completed the design steps and it is almost ready to take interesting data even if still missing few items ordered in last part of 2014
- A bunch-by-bunch and turn-by-turn luminometer can be easily implemented if the Accelerator Division gives the green light and the necessary support (at zero cost!)

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