Tools for Studies in Diffraction at Full LHC Luminosity

Sebastian White, Rockefeller/Pisa

HPS mtg, Dec. 12, 2011

this work began within the context of FP420 R&D collaboration. Charged by Brian Cox with exploring new technologies appropriate for rate/lifetime/segmentation challenges of $L=10^{34}$.

from FP420 R&D summary:

"At maximum luminosity the proposed detectors will have rates in the 10 MHz range and see an integrated charge of a few to tens of coulombs per year depending on the exact details of the detectors and the gain at which the phototubes are operated. *The current commercially available MCP-PMT's will not sustain such high rates and will not have an adequate lifetime*."

Outline

- topics with leading baryons/protons
- experience with a fast forward detector suitable for $L<10^{33}$ in PHENIX and ATLAS.
- Development of an alternative (to MCP) photosensor suitable for high rates.
- A silicon sensor for direct charged particle detection with few picosecond timing.
- Beam tests and possible implementation

leading Baryons

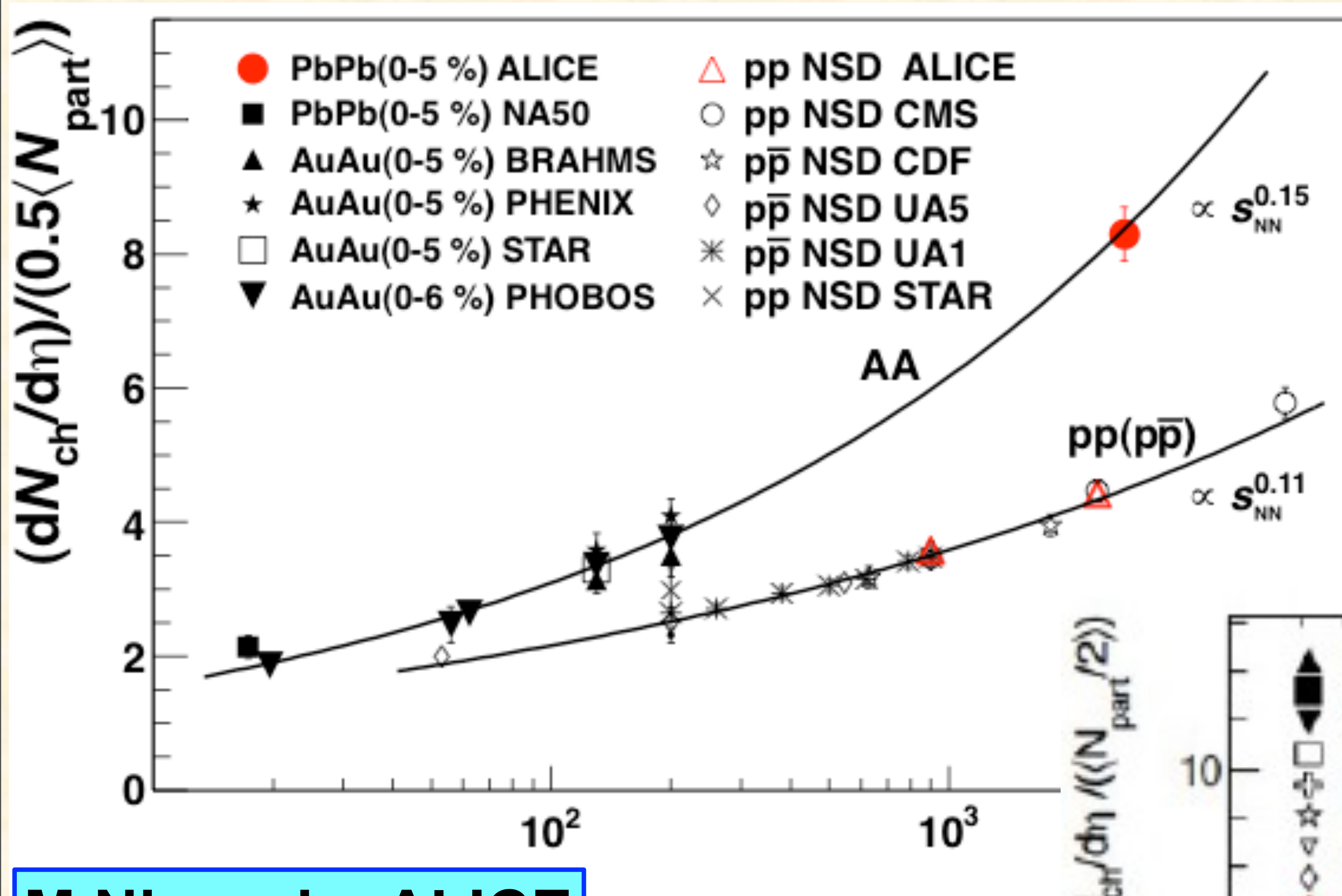
- leading Baryon in pp breaks universality in charged multiplicity distributions. Alternatively can be used to measure centrality of pp collisions(Bjorken).

- a leading baryon(or intact nucleus) tags coherent exchange- as in hard photoproduction or CEP (latter via 2 gluon exchange). This is a broad topic of general interest. see eg:

M. **Strikman**, R. **Vogt** and S. **White**, Phys. Rev. Lett. 96 (2006) 082001

and, of course, FP420 R&D report

Energy dependence of multiplicity



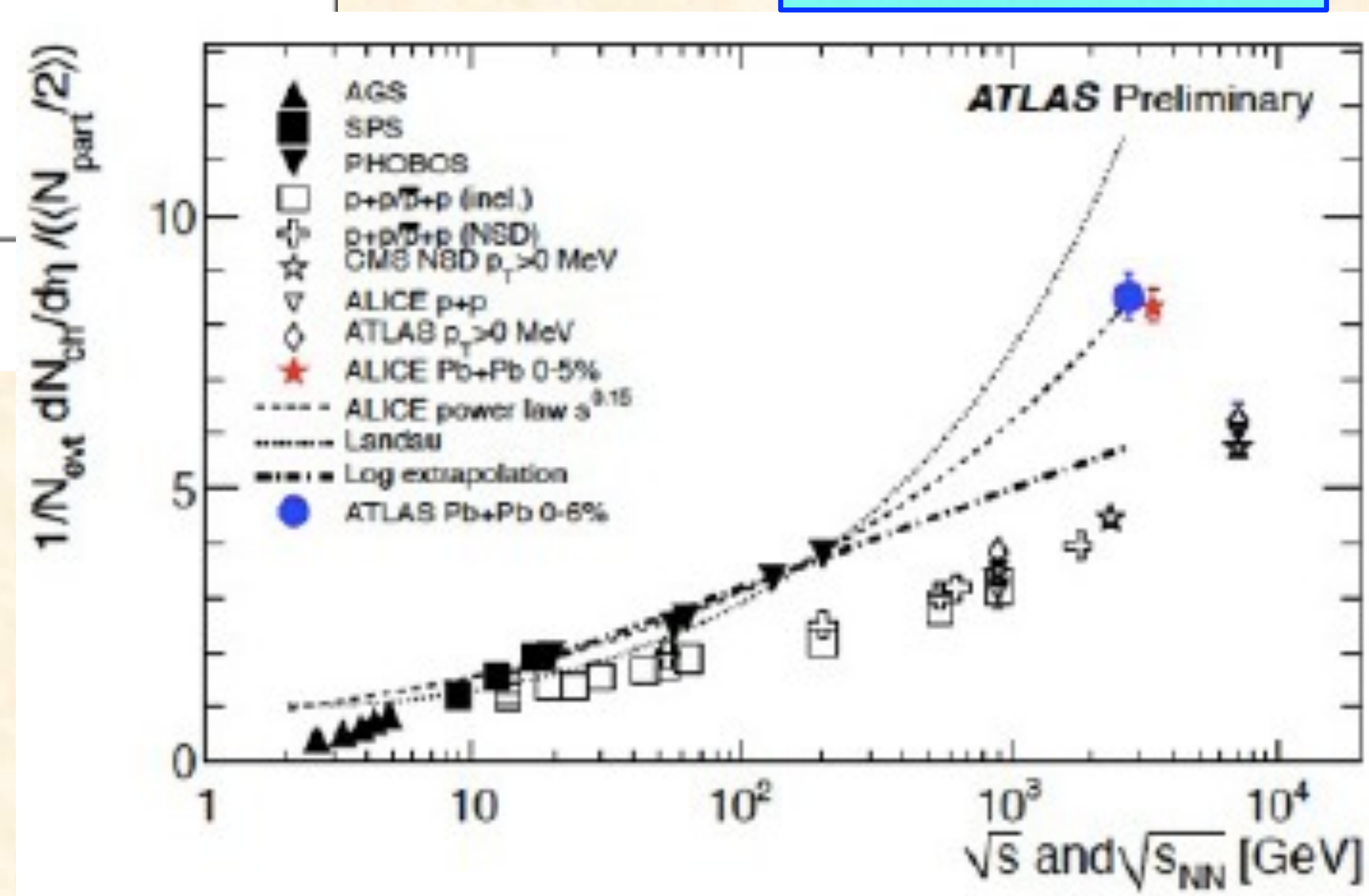
M.Nicassio, ALICE

- growing faster then pp
- increase by factor

-2.2 compared to RHIC

-1.9 compared to pp

S.White, ATLAS



agreement among experiments

Issues at full Luminosity

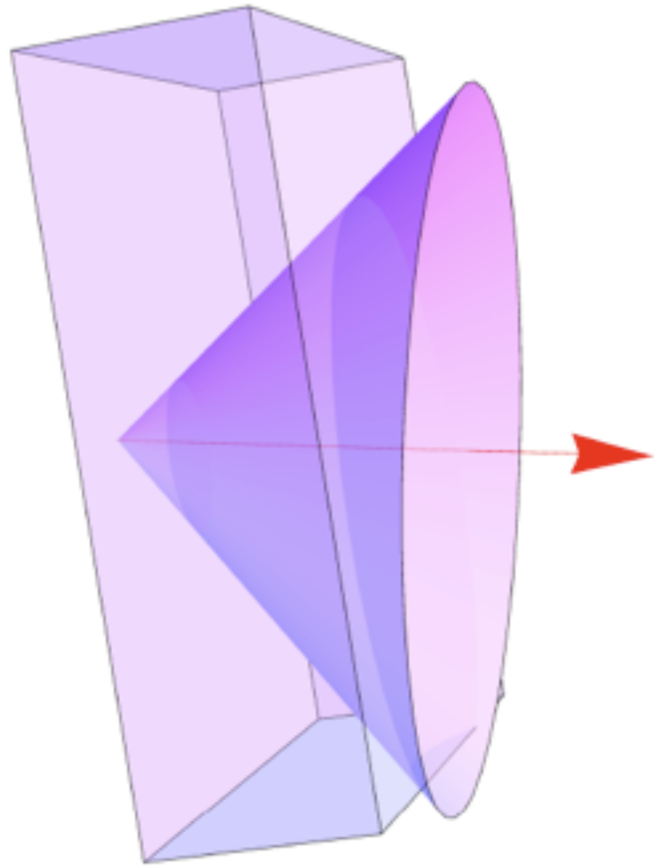
- at Design luminosity the rate in the forward proton tracking is several 10's of MHz/cm^2. Integrated over a year of running, displacement damage in silicon devices is a significant issue. In an MCP-PMT, normal operation (a la Super-B) leads to severe photocathode damage in much less than a year. see:

  Design of a 10 picosecond Time of Flight Detector using Avalanche Photodiodes / White, Sebastian ; Chiu, Mickey ; Diwan, Milind ; Atoian, Grigor ; Issakov, Vladimir We describe a detector for measuring the time of flight of forward protons at the Large Hadron Collider (LHC) up to and beyond the full instantaneous design luminosity of 1034 cm-2 s-1. [...] arXiv:0901.2530. - 2009.

- depending on the choice of event generator the mean # of protons in the tracker/timing detector is ~1 due to physics at mu=25. Indications from TOTEM that non-physics contribution also significant.-> important to have a technology with completely scalable segmentation in timing detector.

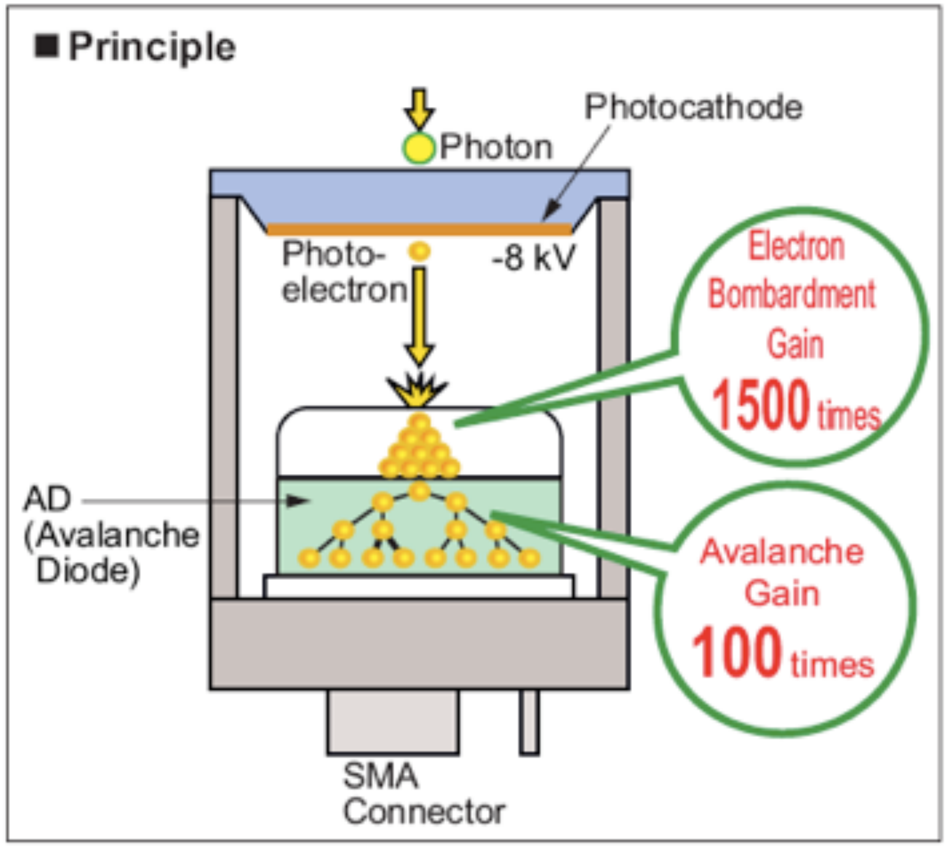
an alternative photosensor for high rates (HAPD)

- we found one (see below) but my personal opinion is that this is a non-starter because hard to deal with pileup in a Cernekov based timing detector. Also, design of isochronous photon collection with high photostatistics difficult.
- achieved 11 psec single photon response with 300 psec risetime



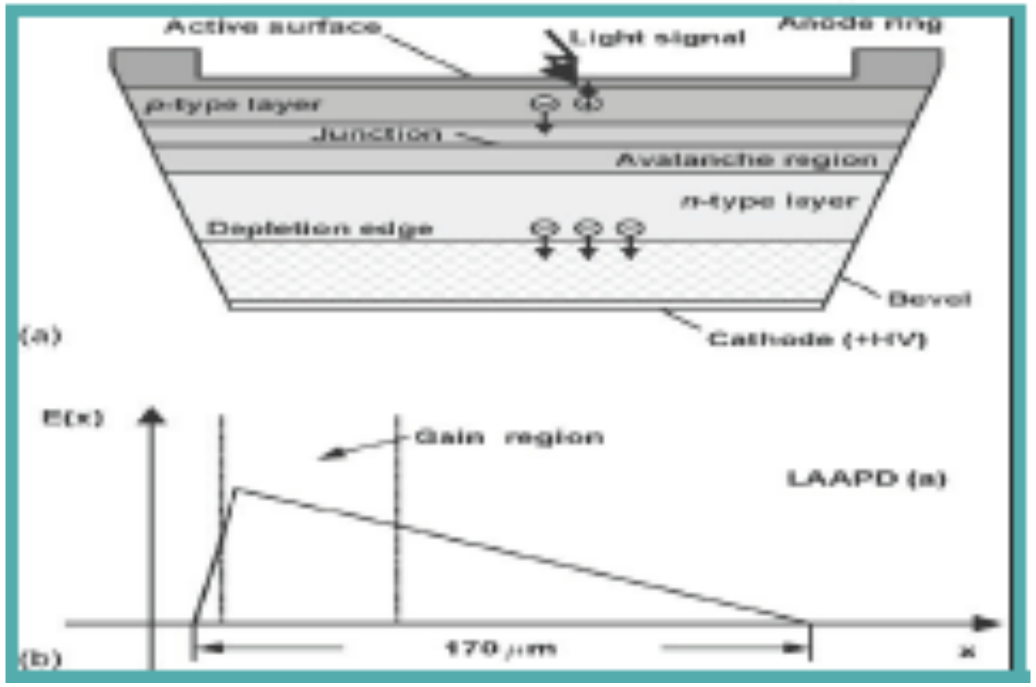
Cerenkov Radiation cone

Cerenkov
or
APD
option

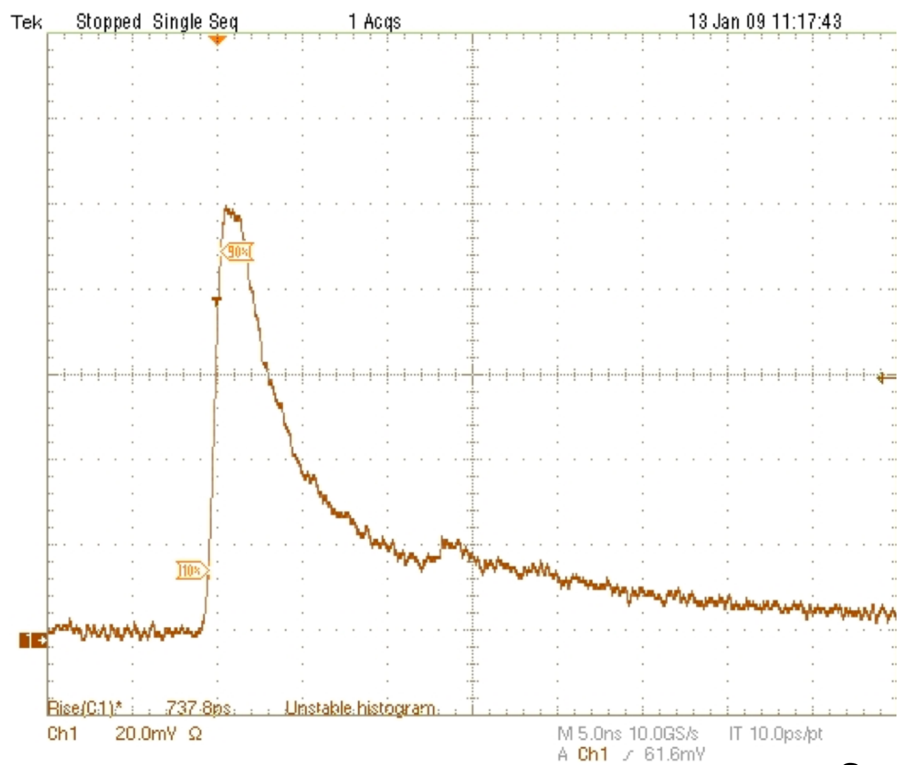


Pre-production Hybrid photodetector

"A 10 picosecond time of flight detector using APD's", SNW et al.

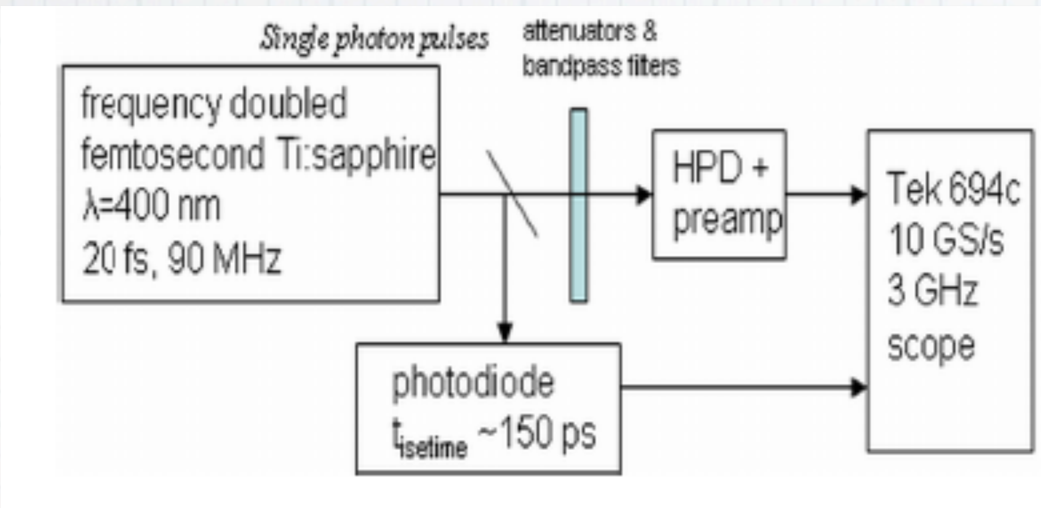


Deep diffused avalanche photodiode

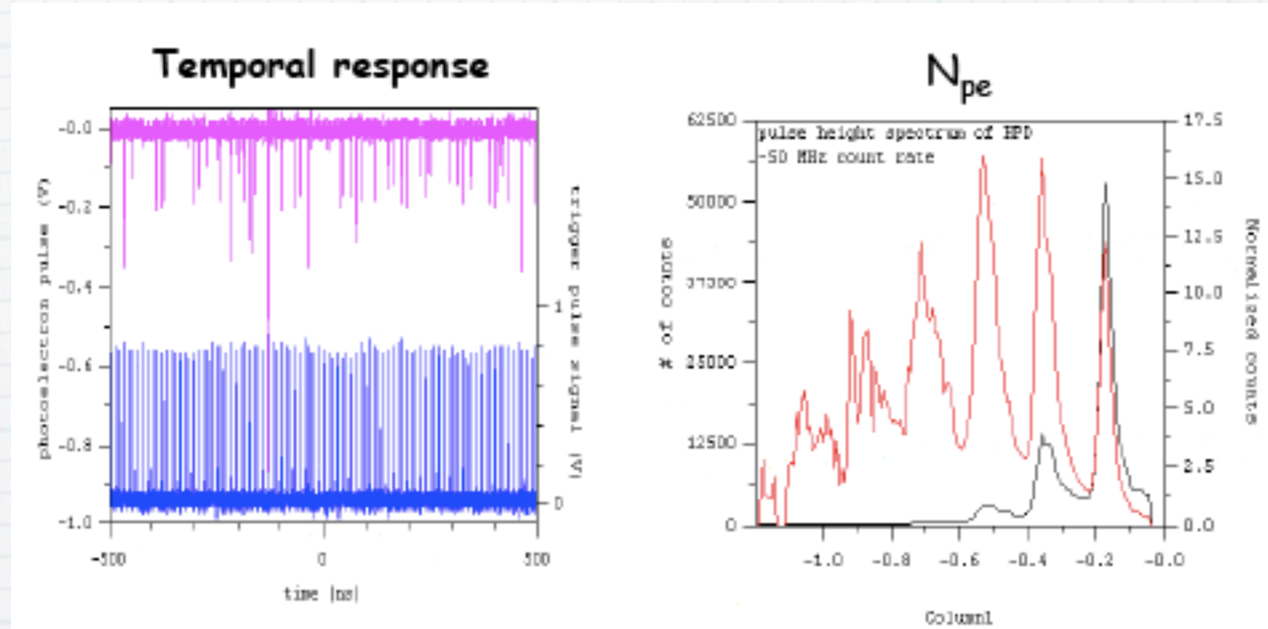


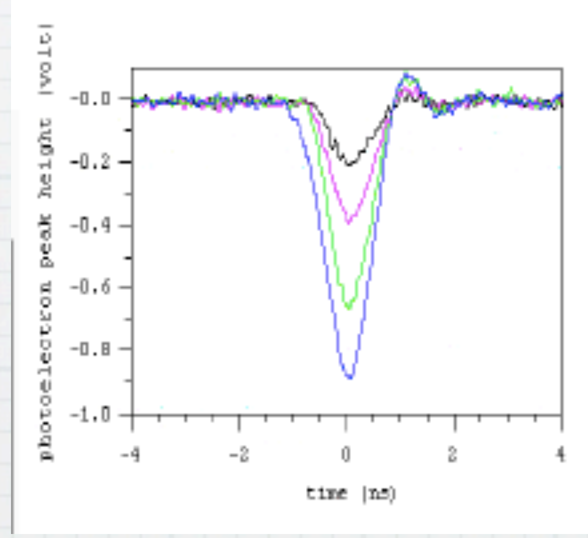
650 picosecond risetime (β's)

Applications in eg fluorescence spectroscopy
T.Tsang, S.White



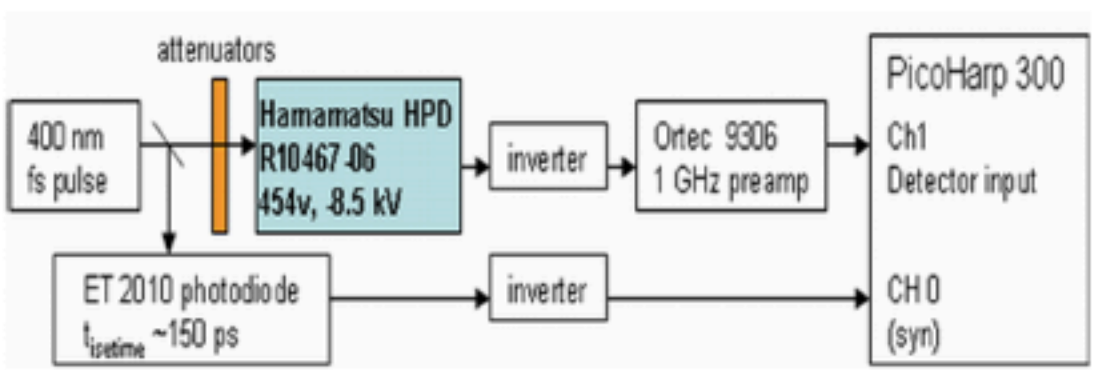
risetime=300 psec

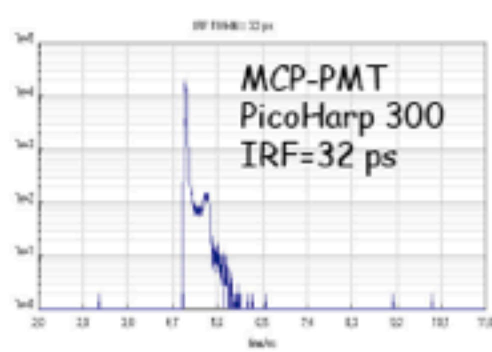


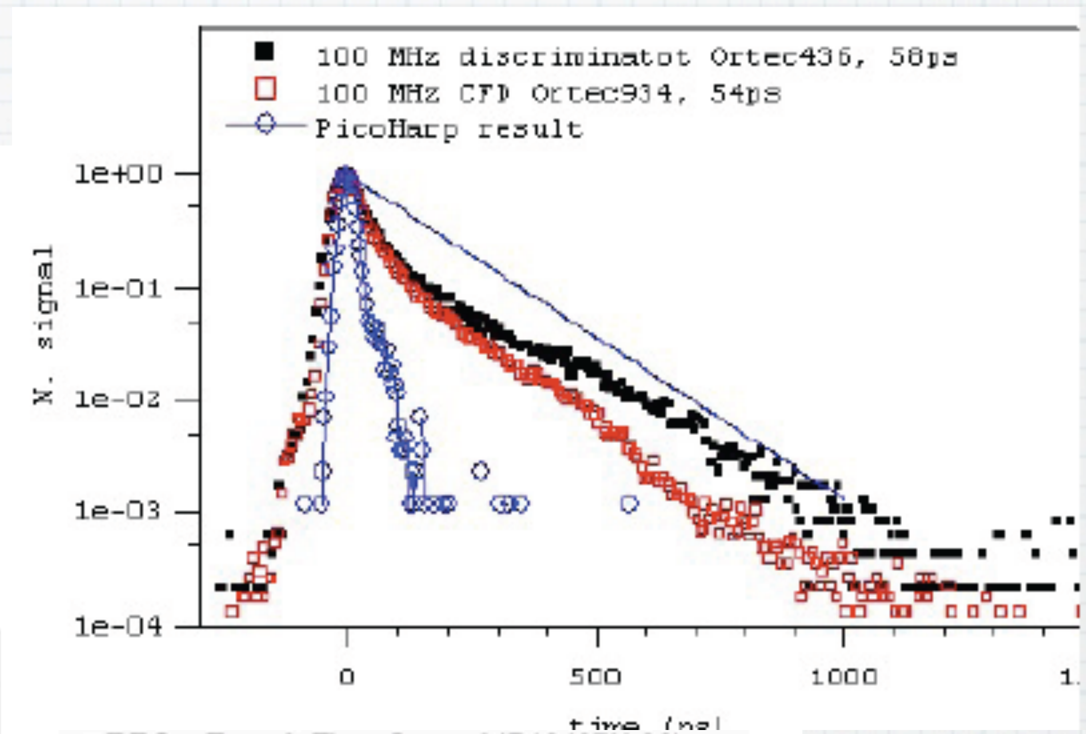


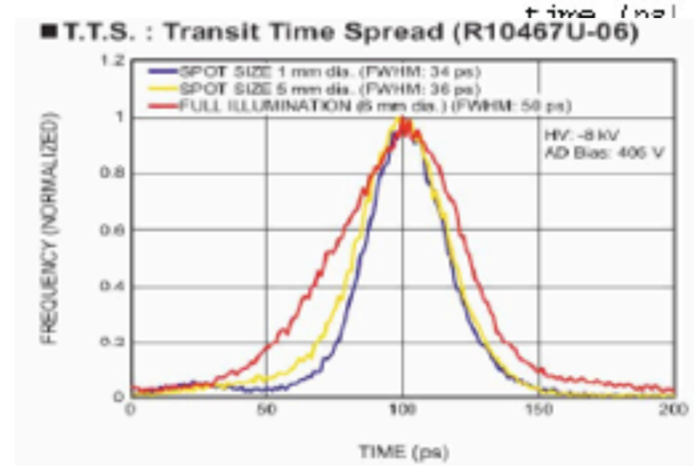
N_{pe}	pulse height after preamp (Volt)	pulse height before preamp (mV)	normalized count rate
1	0.176	2.2	1
2	0.36	4.5	0.26
3	0.528	6.6	0.061
4	0.71	8.9	0.009
5			~0.0014
6			~0.0002

11 psec single photon response is not common. Below studies comparing LE, CFD, PicoHarp









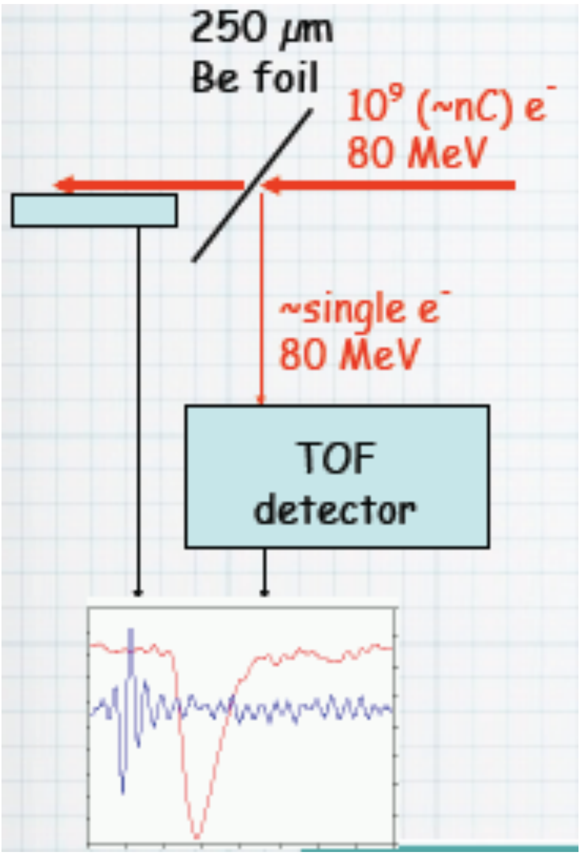
$$\sigma_{TOF} = \sqrt{\sigma^2_{HPD} + \sigma^2_{radiator} + \sigma^2_{electronics}}$$

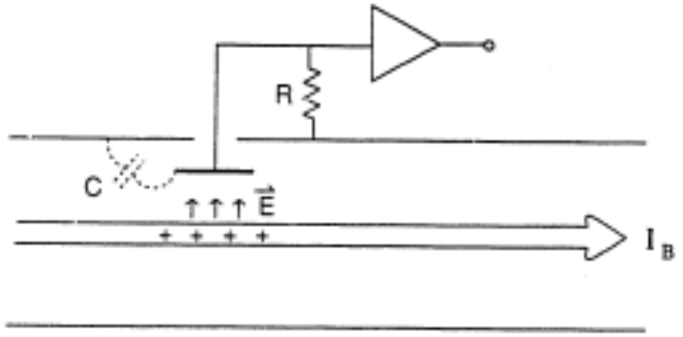
$$\sigma_{HPD} = \frac{\sigma_{TTS}}{\sqrt{N_{pe^-}}} = \frac{11\ ps}{\sqrt{N_{pe^-}}}$$

Testbeams used to characterize APD based timing detector

1. Single electron project at ATF
2. PSI (~200 MeV muons and electrons)
3. Frascati BTF <500 MeV electrons

5. **Energy Calibration of Underground Neutrino Detectors using a 100 MeV electron accelerator** / White, Sebastian ; Yakimenko, Vitaly
An electron accelerator in the 100 MeV range, similar to the one used at BNL's Accelerator test Facility, for example, would have some advantages as a calibration tool for
Argon neutrino detectors. [...]
arXiv:1004.3068. - 2010.



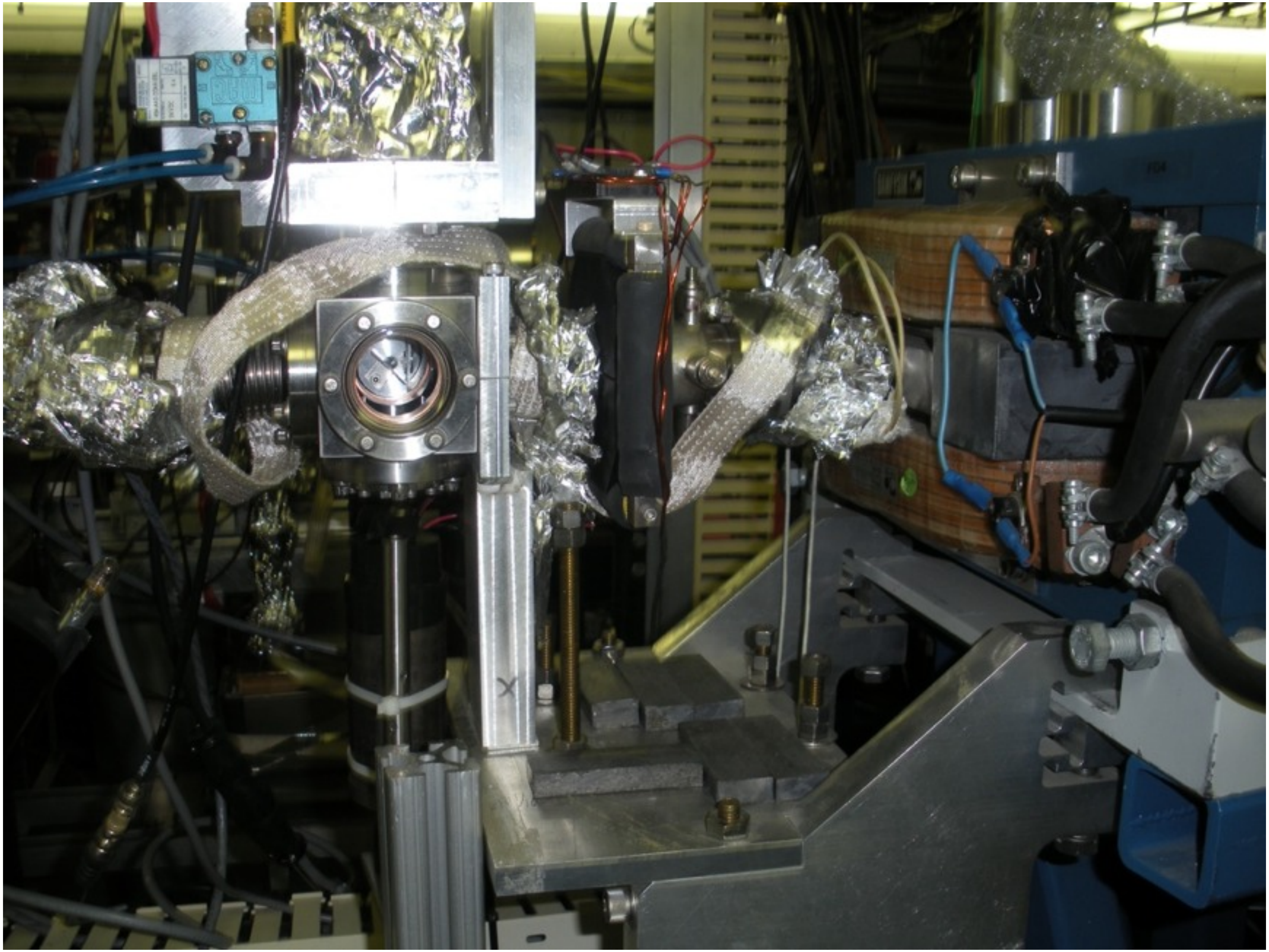


- a unique feature of ATF beam is 3 picosec bunch length(streak camera)
- could this be exploited to evaluate fast timing detectors?
- common technique for secondary beam design is successive dispersion and collimation
- this requires real estate

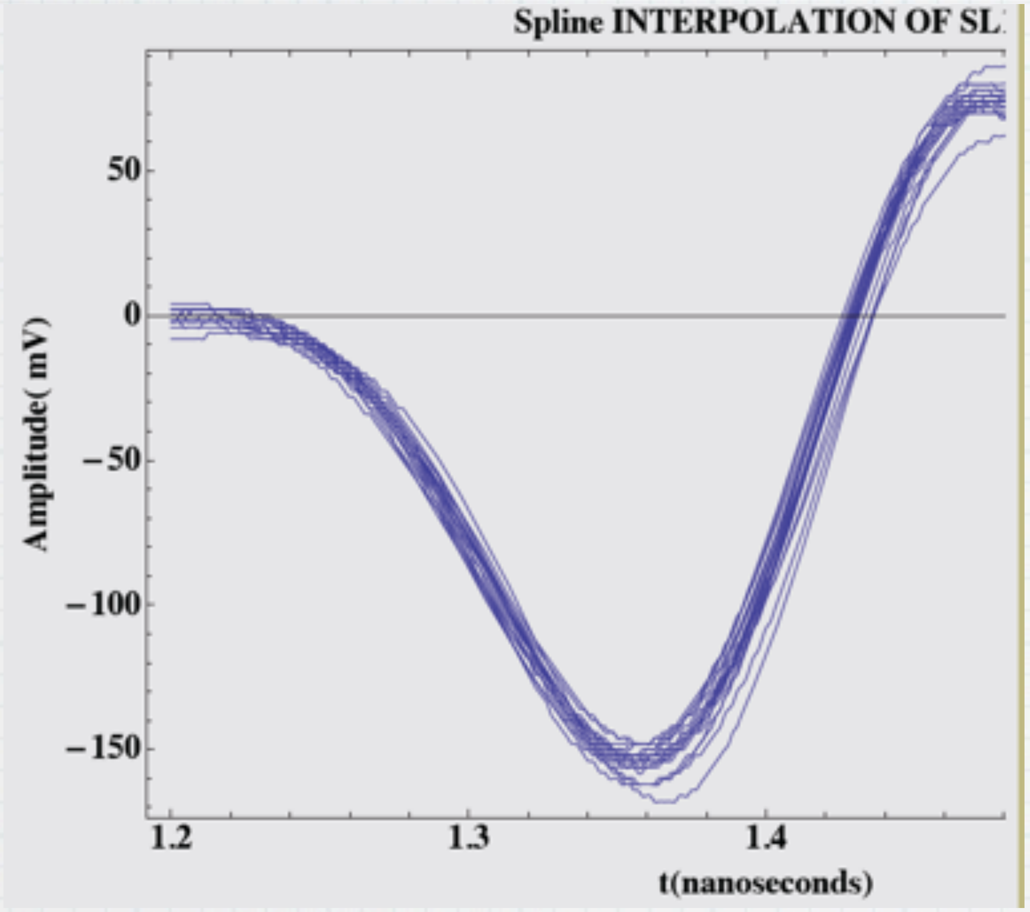
Kirk, Thomas, Misha

Vitaly

the beamline

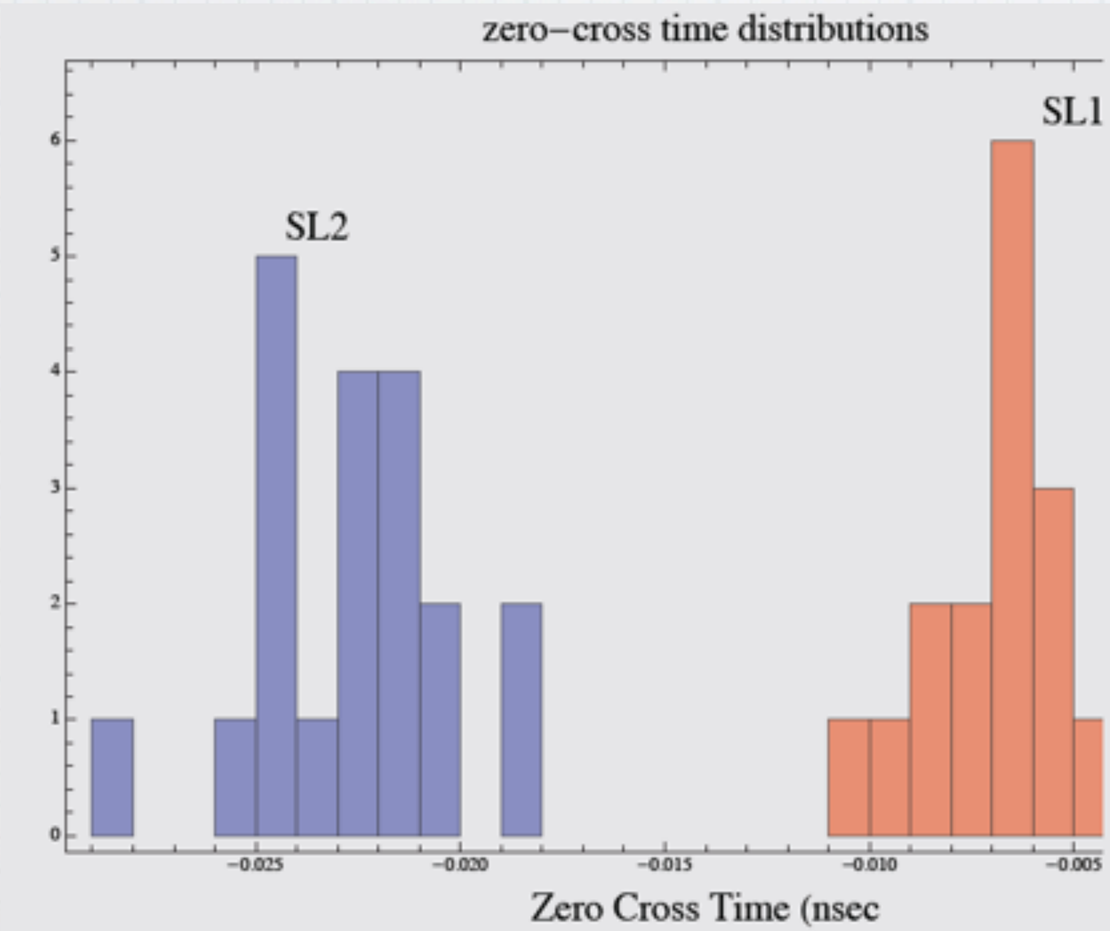


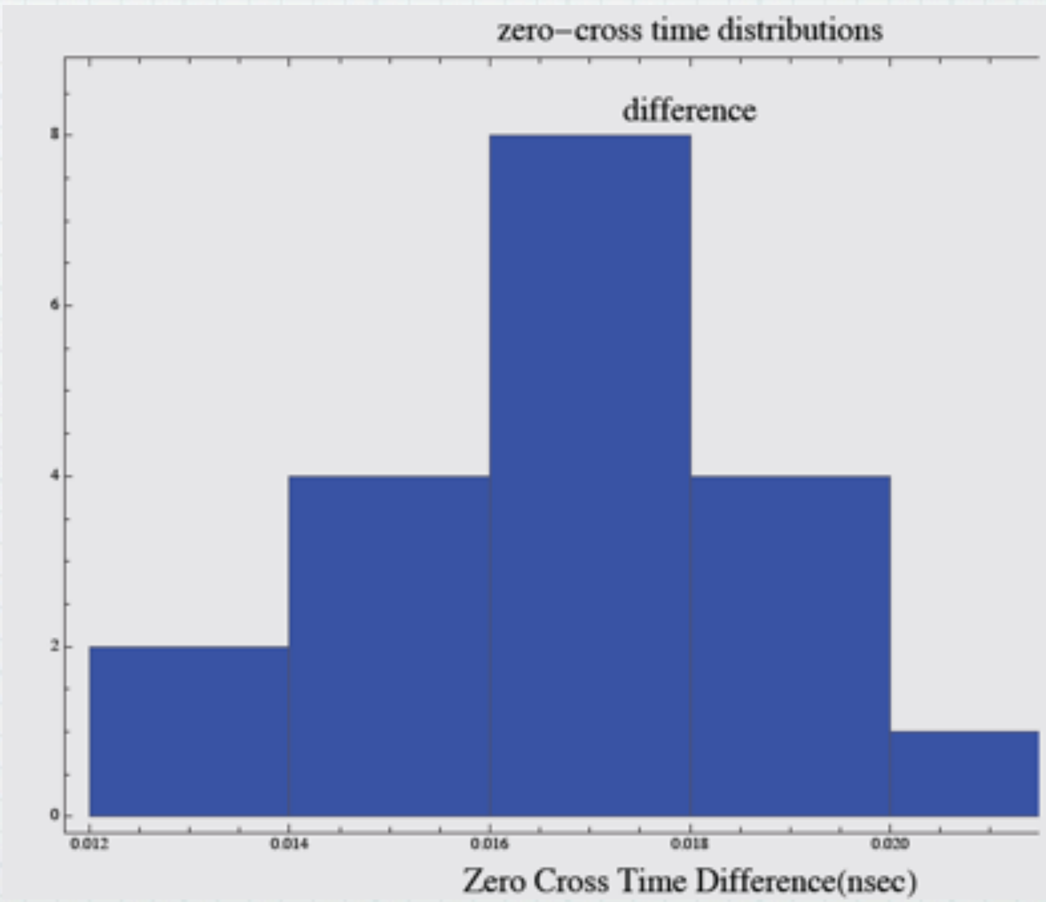
Initial study of "start time" resolution from ATF stripline



stripline waveforms w.
on-chip Sin[x]/x interpolation+spline

rms on time diff
between detectors <2.5 psec





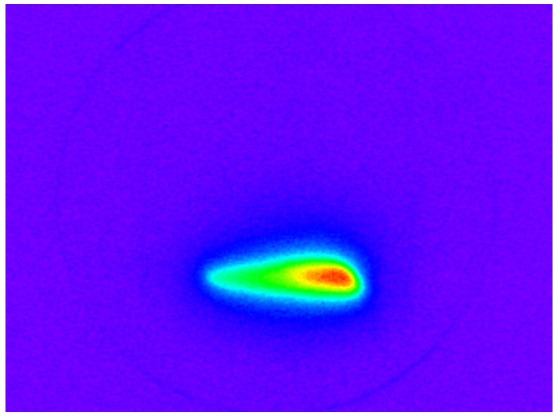
250 μm
Be foil

10^9 (~nC) e^-
80 MeV

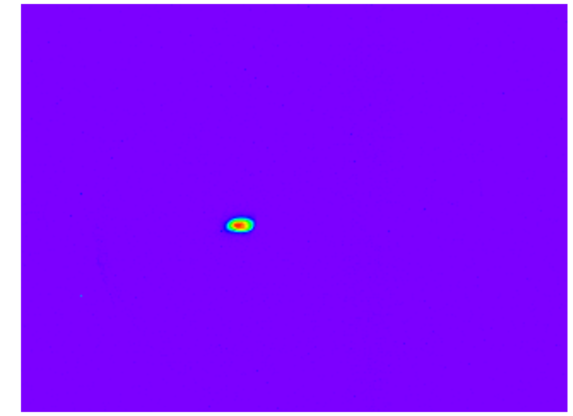
stripline
detector

~single e^-
80 MeV

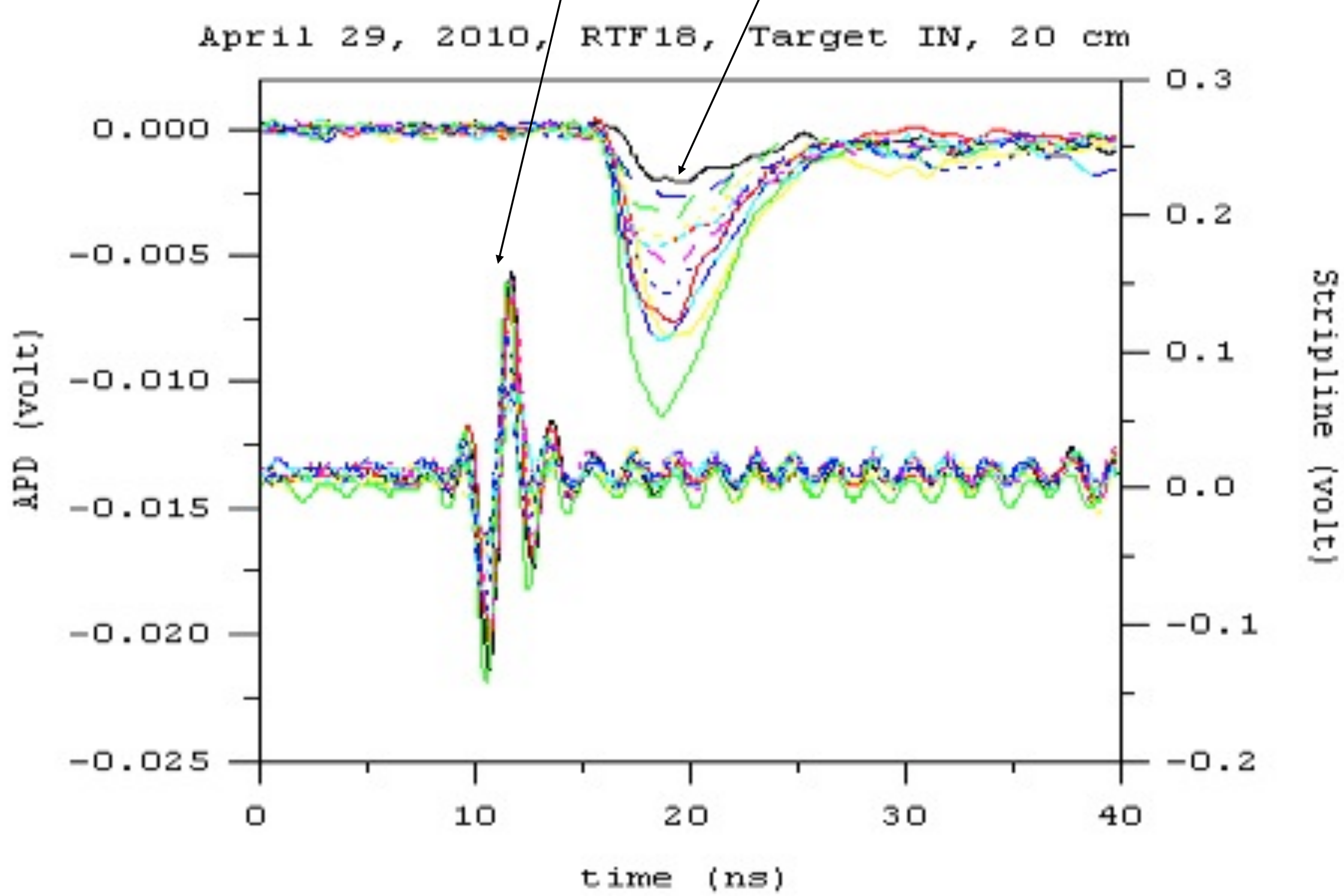
TOF detector
APD (200 gain)



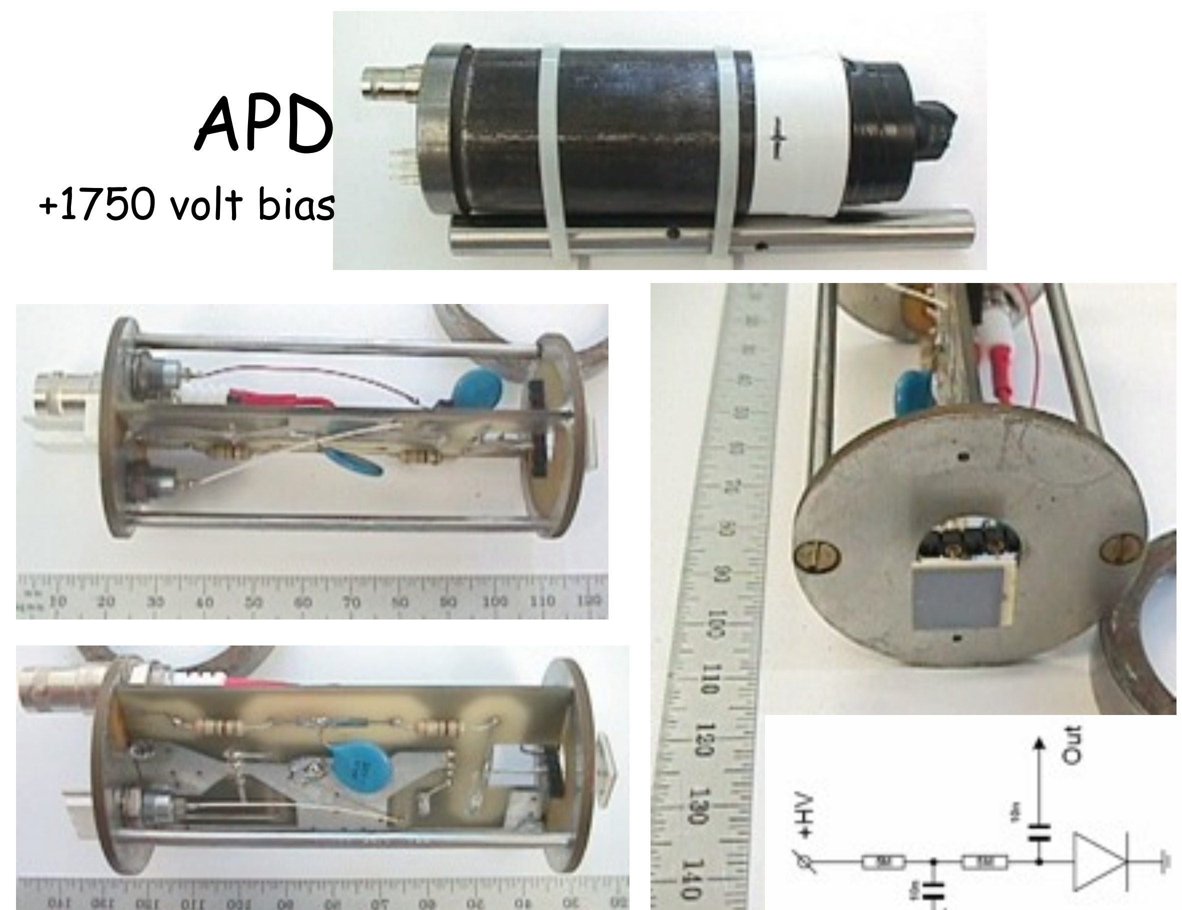
e- beam size @ Pop #8
640x480 pixels
20 μm/pixel



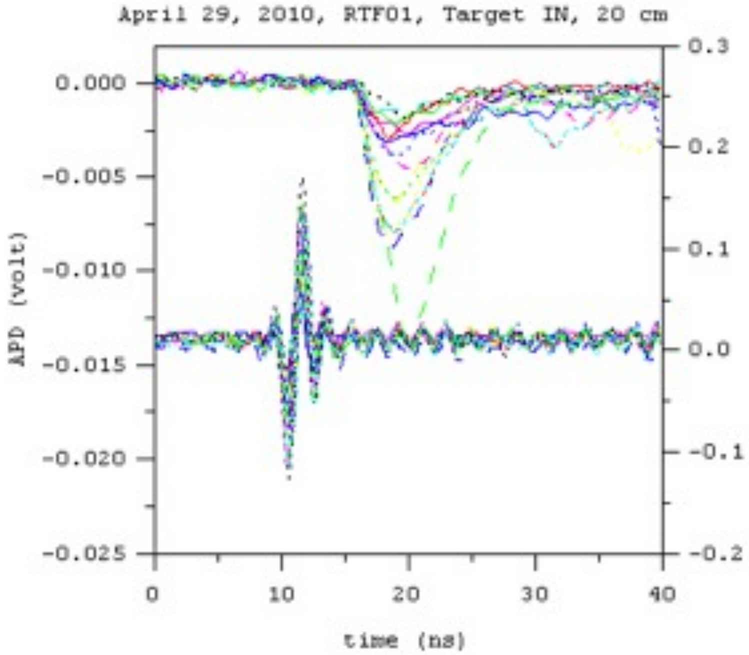
e^- beam size @ Pop #7
640x480 pixels
20 μm/pixel
V: 13 pixels FWHM
H: 25 pixels FWHM

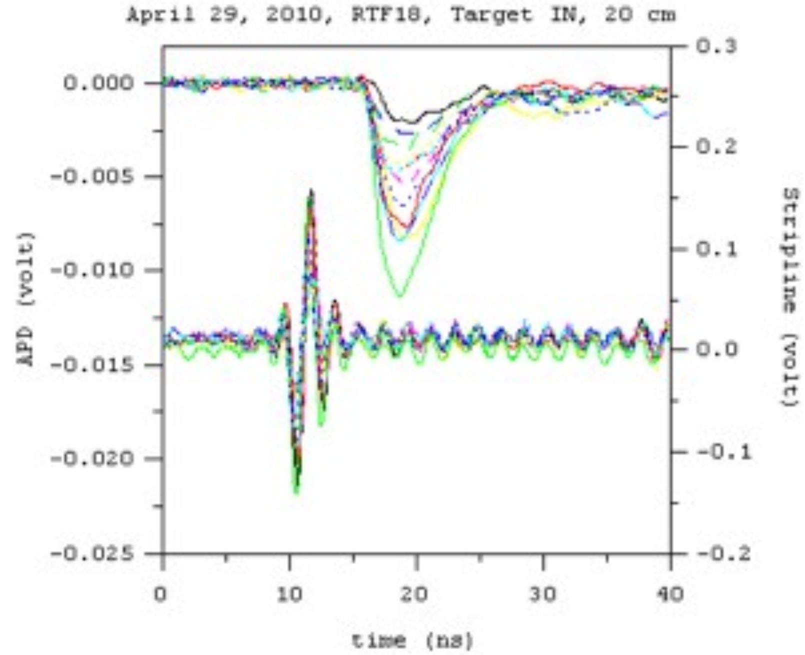


APD
+1750 volt bias

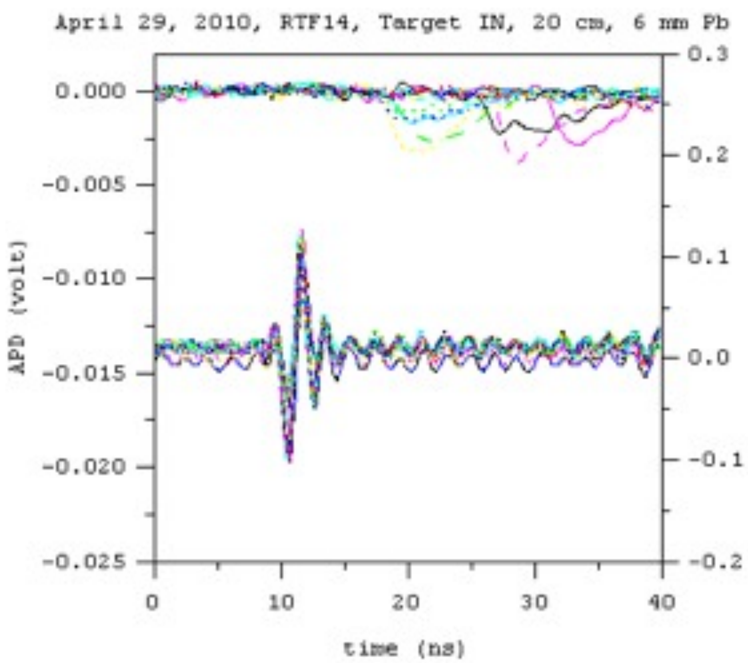


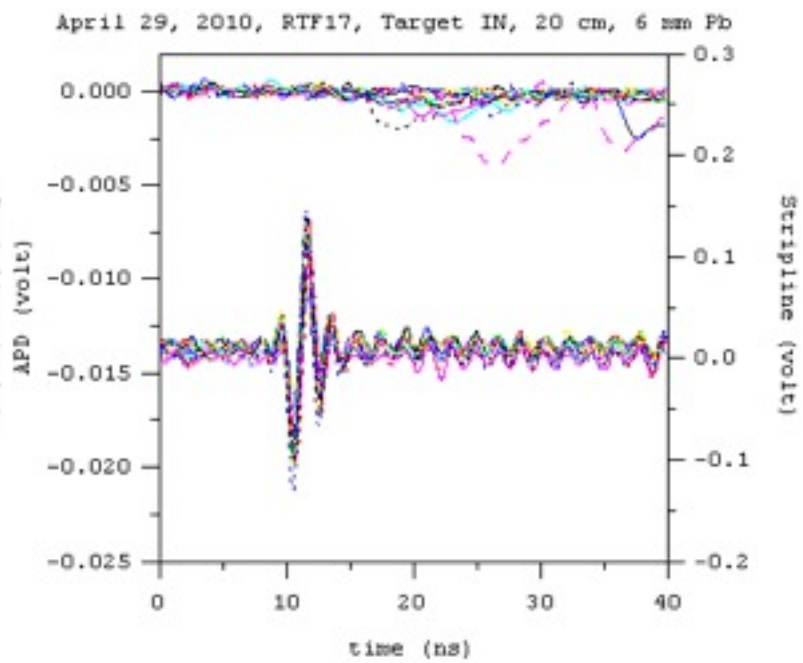
Target IN 20 cm



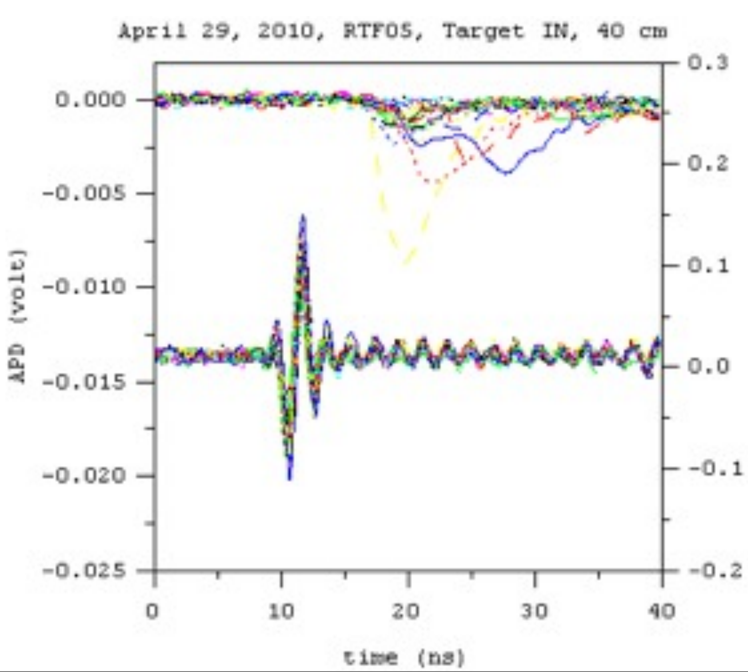


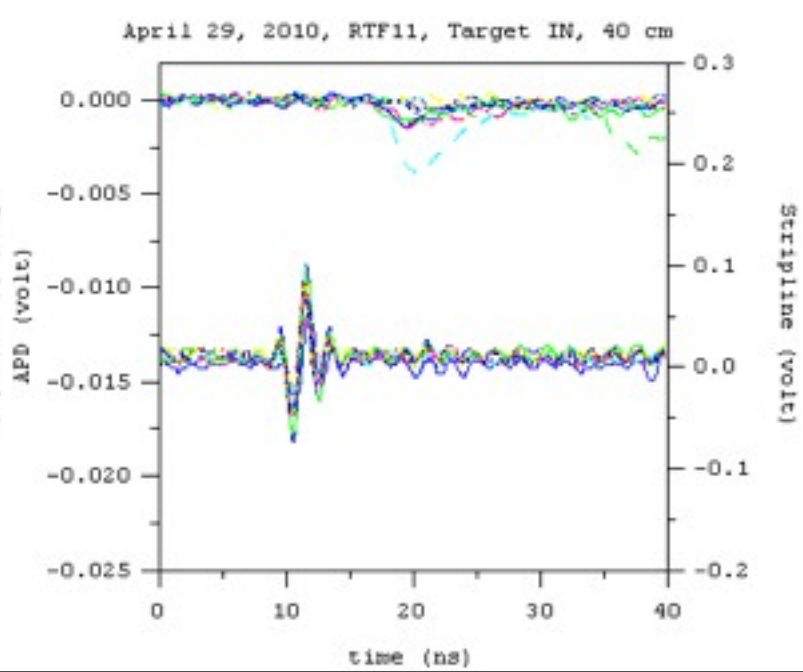
Target IN 20 cm, 6 mm Pb



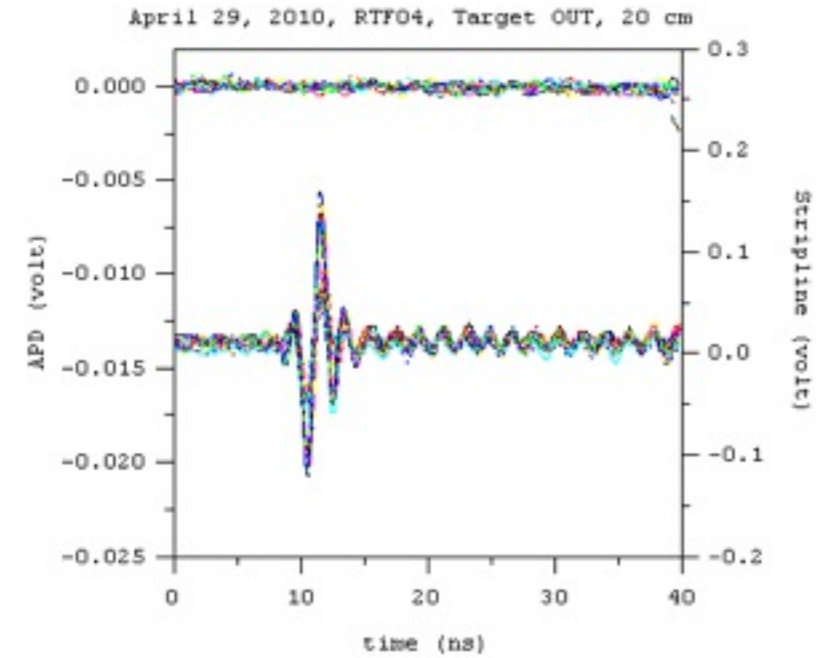


Target IN 40 cm



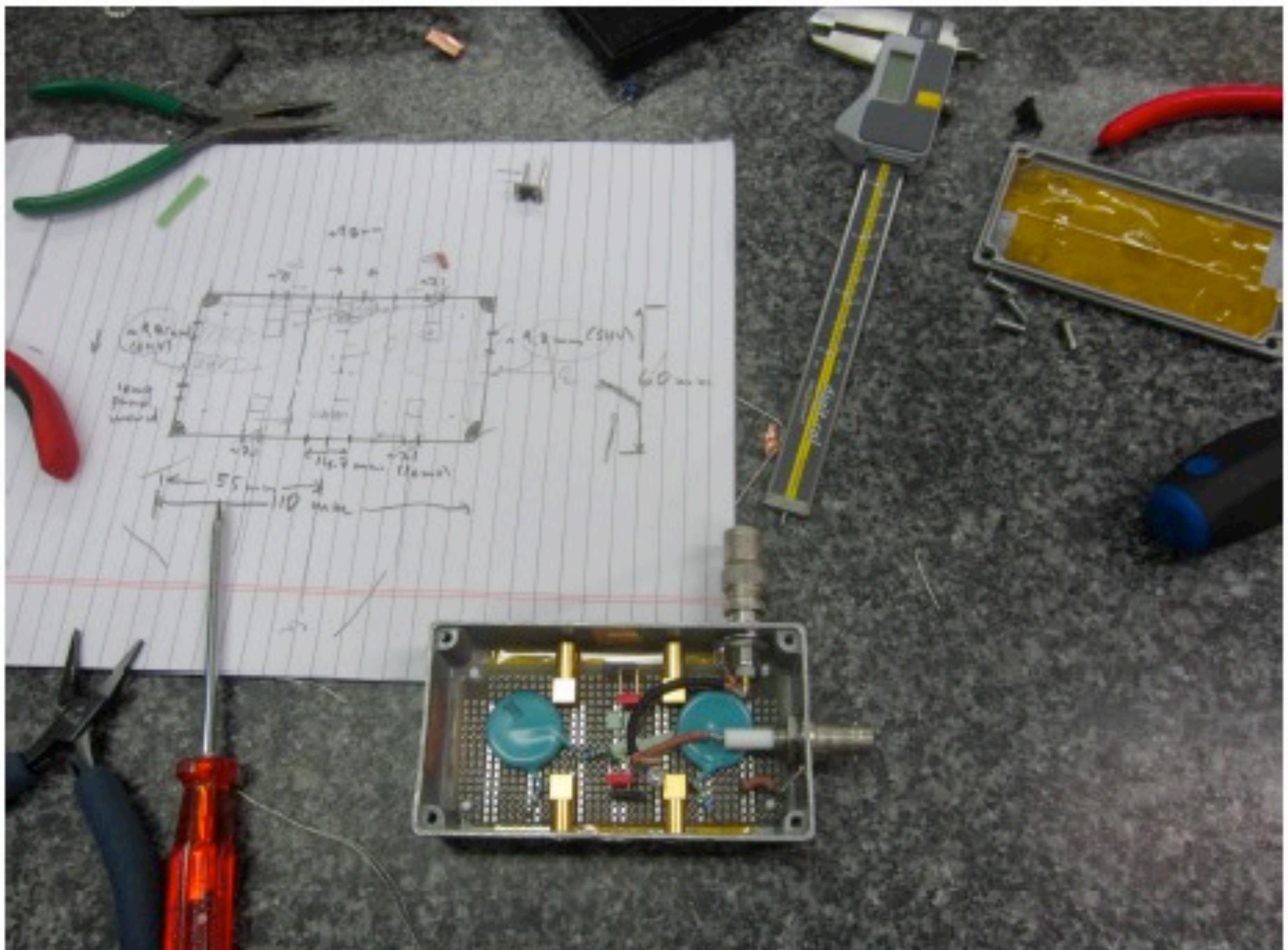


Target OUT 20 cm

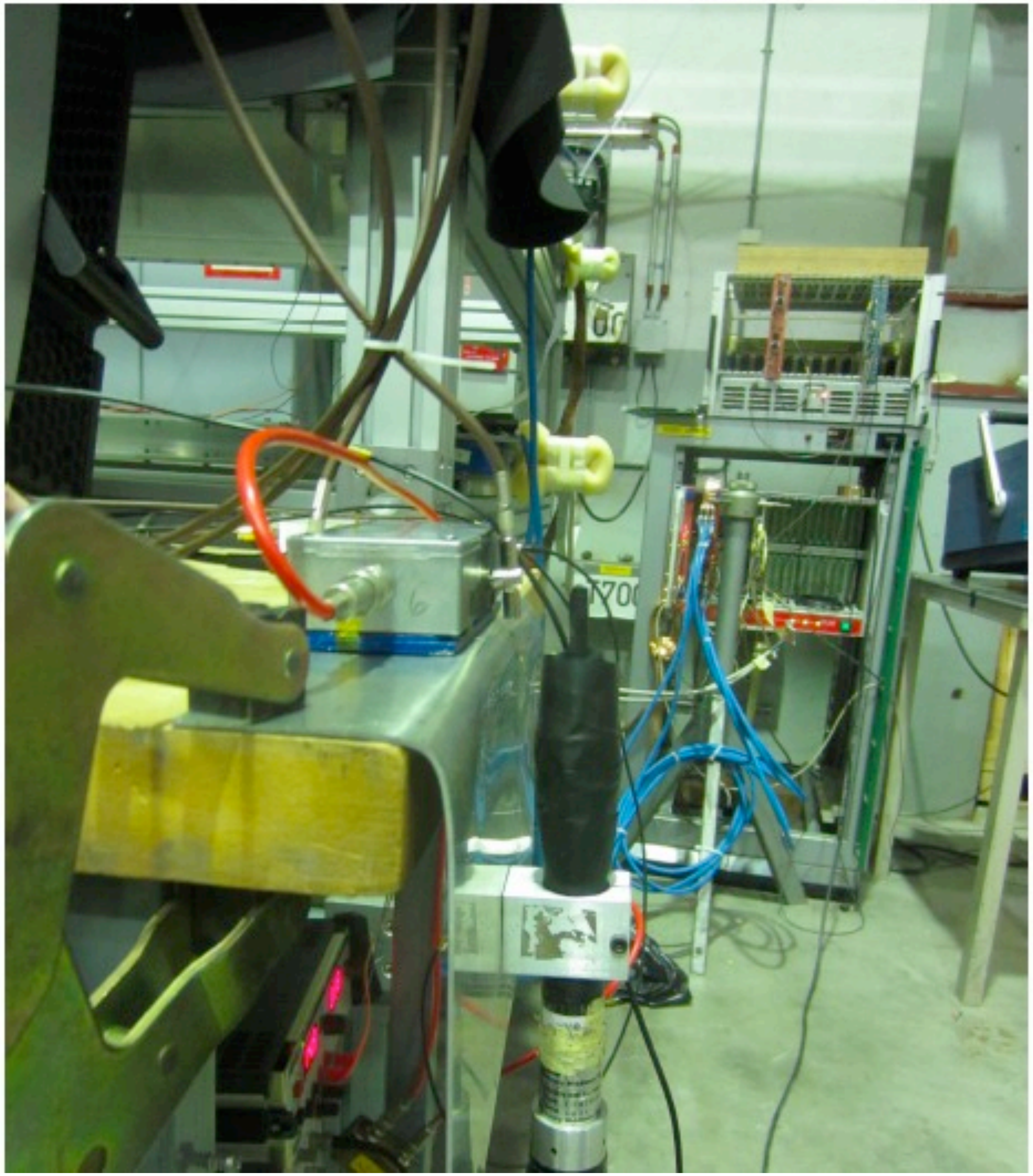


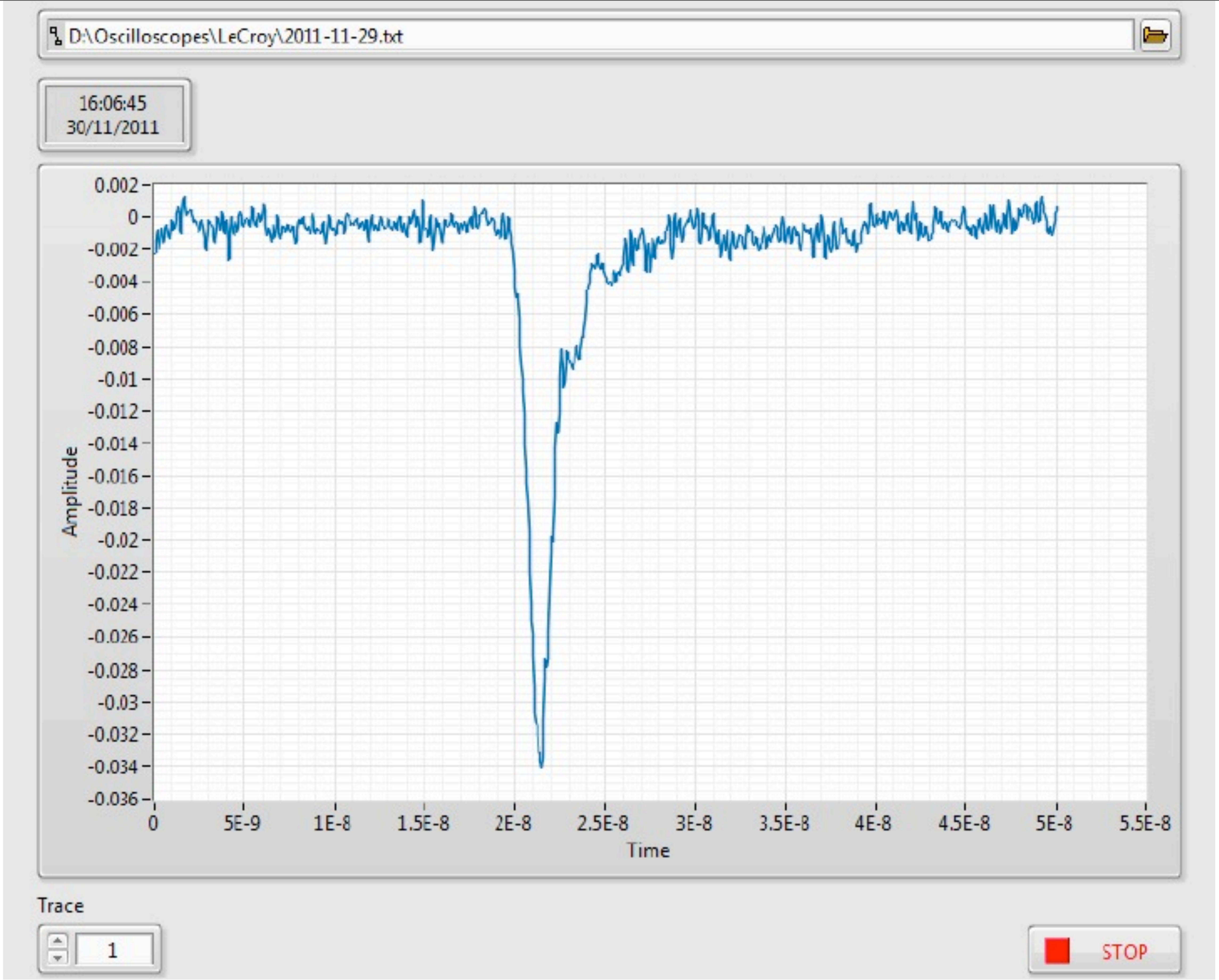
In last couple weeks at CERN focused on getting fastest possible signal from apd. Low noise, fast amplifiers, LRS 6 GHz, 40 GSa/s scope, etc.

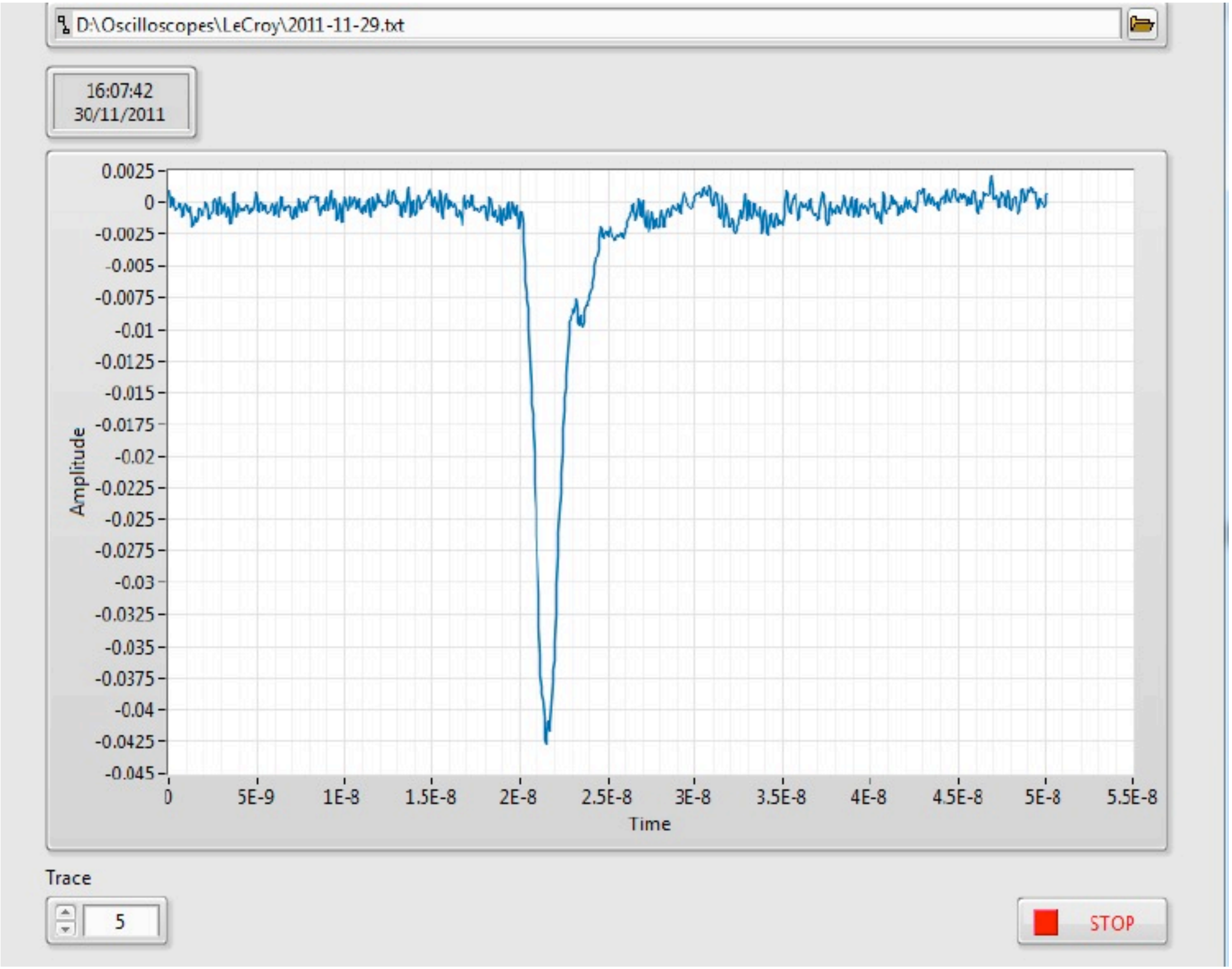
Partly assembled APD telescope(the kluge board is suited for high frequency work since it has a ground plane on the underside).



Telescope for PSI test (only the components on the aluminium bracket will be placed in the beam).



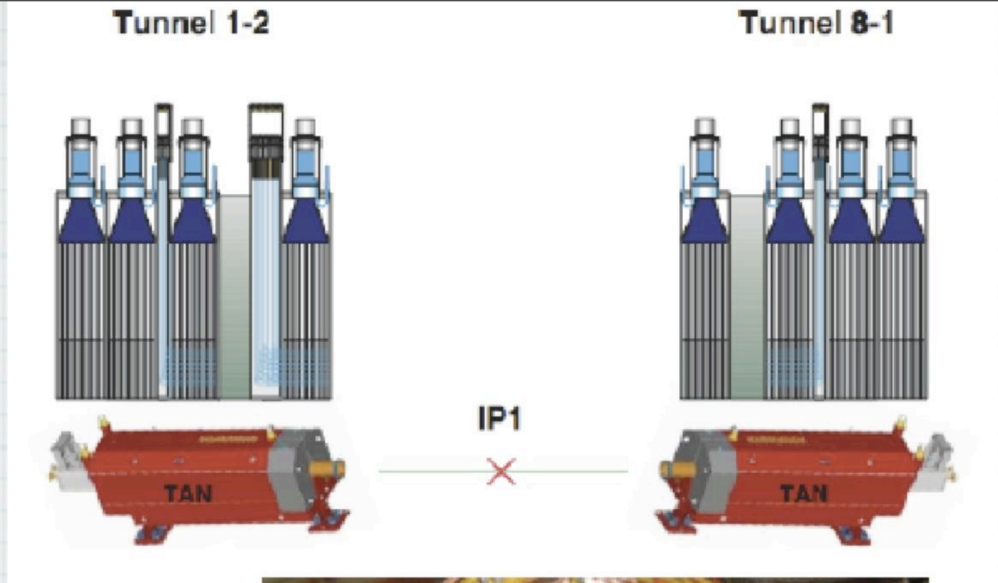

D:\Oscilloscopes\LeCroy\2011-11-29.txt
16:06:45
30/11/2011
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.016
-0.018
-0.02
-0.022
-0.024
-0.026
-0.028
-0.03
-0.032
-0.034
-0.036
Amplitude
0
5E-9
1E-8
1.5E-8
2E-8
2.5E-8
3E-8
3.5E-8
4E-8
4.5E-8
5E-8
5.5E-8
Time
Trace
1
STOP


D:\Oscilloscopes\LeCroy\2011-11-29.txt
16:07:42
30/11/2011
0.0025
0
-0.0025
-0.005
-0.0075
-0.01
-0.0125
-0.015
-0.0175
-0.02
-0.0225
-0.025
-0.0275
-0.03
-0.0325
-0.035
-0.0375
-0.04
-0.0425
-0.045
Amplitude
0
5E-9
1E-8
1.5E-8
2E-8
2.5E-8
3E-8
3.5E-8
4E-8
4.5E-8
5E-8
5.5E-8
Time
Trace
5
STOP

What is optimal signal processing?

In a related project (ATLAS ZDC) achieved ~100psec time resolution with 40 MSa/s sampling of a PMT signal:

Very Forward Calorimetry at the LHC - Recent results from ATLAS / White, Sebastian N (Brookhaven)
We present first results from the ATLAS Zero Degree Calorimeters (ZDC) based on 7~TeV pp collision data recorded in 2010. [...]
arXiv:1101.2889. - 2011. - 8 p.



ATLAS ZDC had severe constraints
compared to PHENIX
-5 Giga Rad/yr rad dose @ design lum
=200 Watt continuous beam deposition
LHC politics vis. LHCf, LUMI...

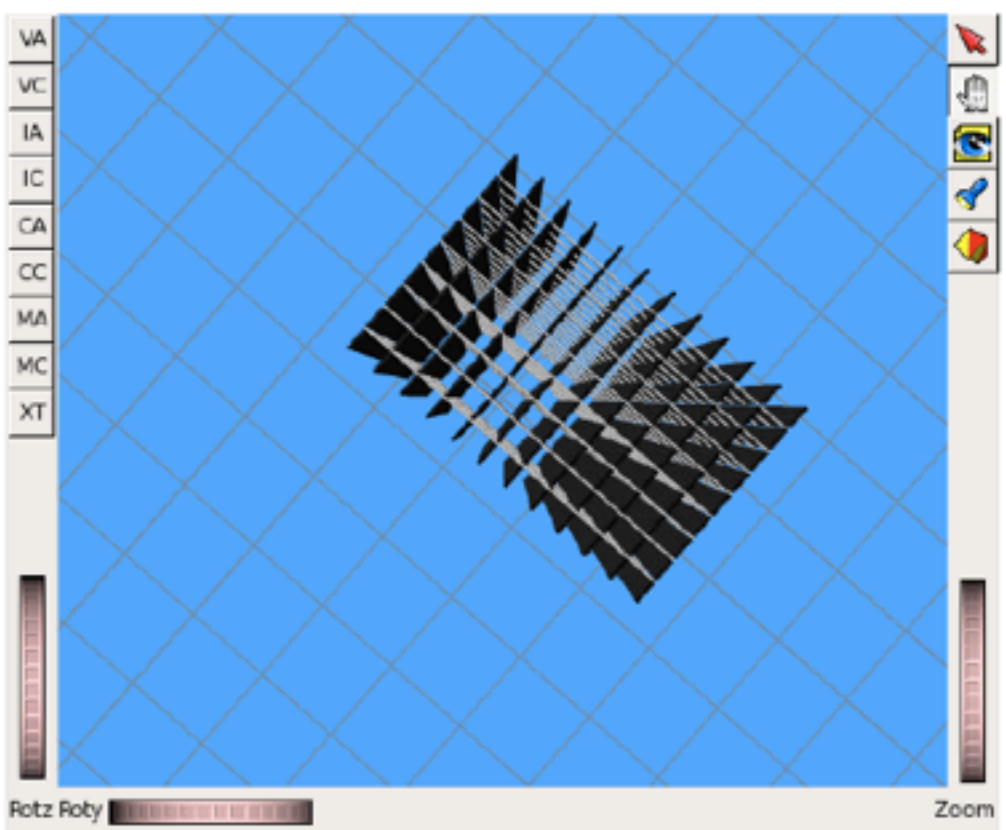
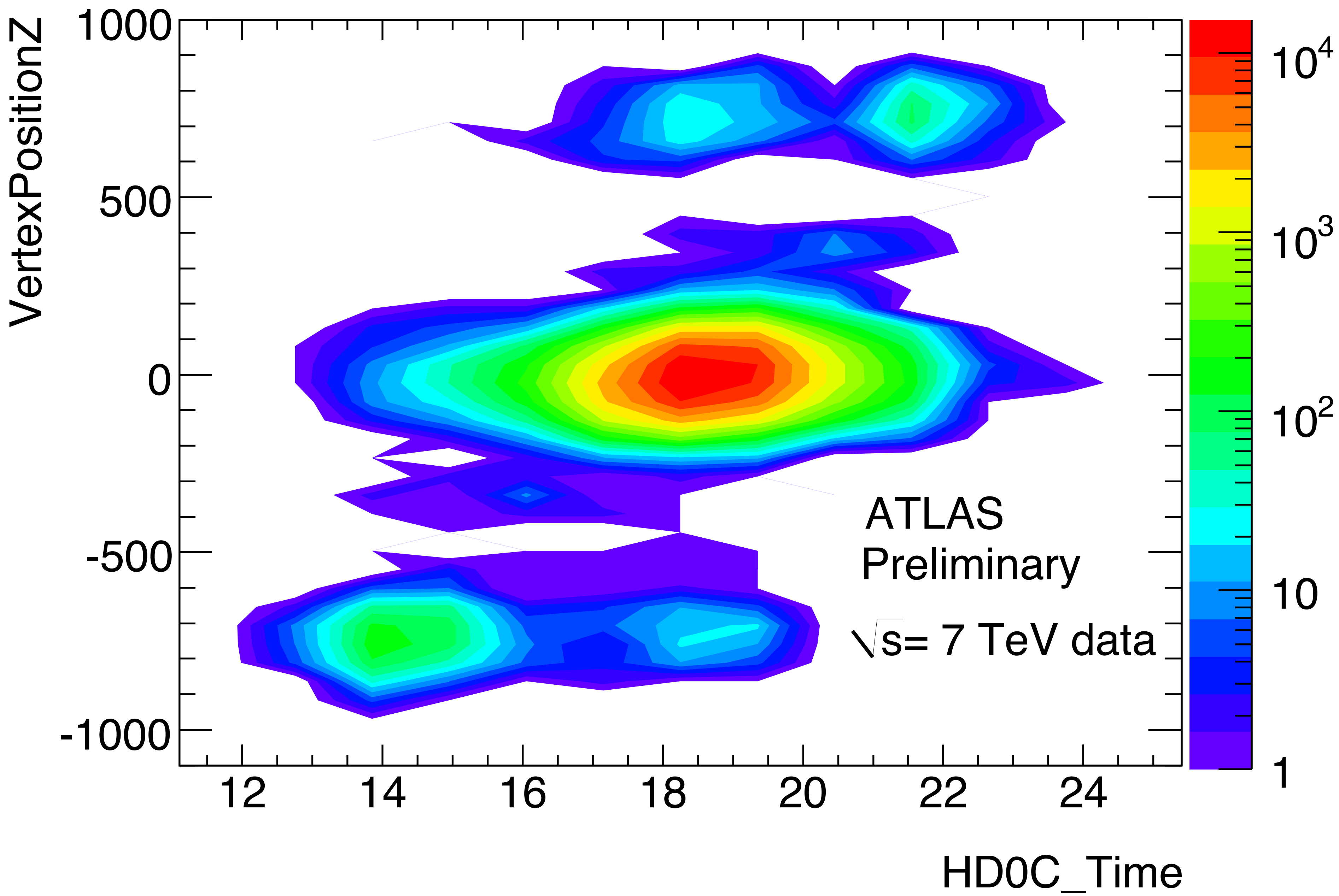


Figure 4: ZDC Drawn with VP1. Plot shows the grid of Strips and Pixels within the EMXY Module

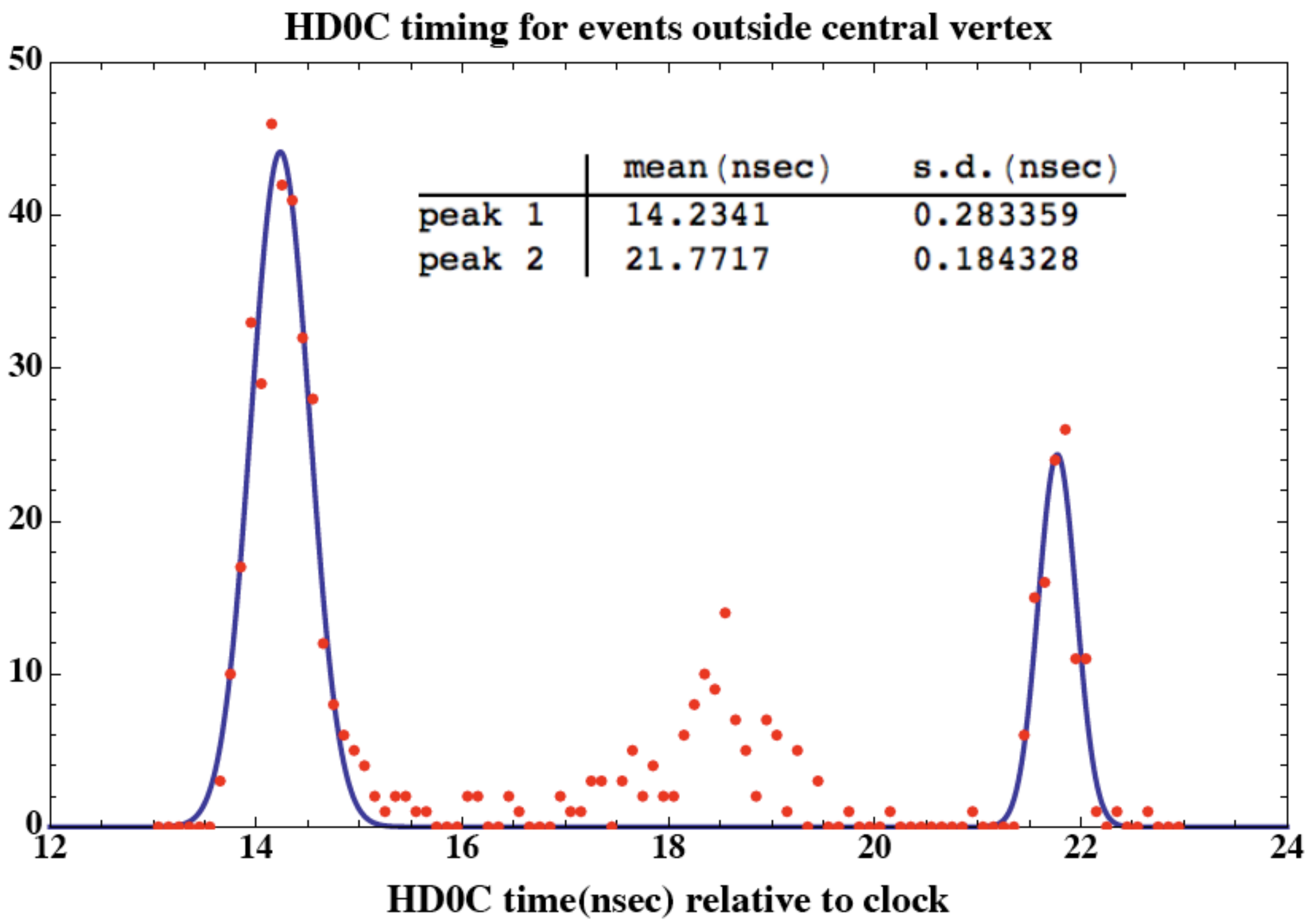
despite constraints
-> ATLAS is the only imaging
ZDC (x,y,z)
on the planet
"shashlik"/layer
sampling hybrid



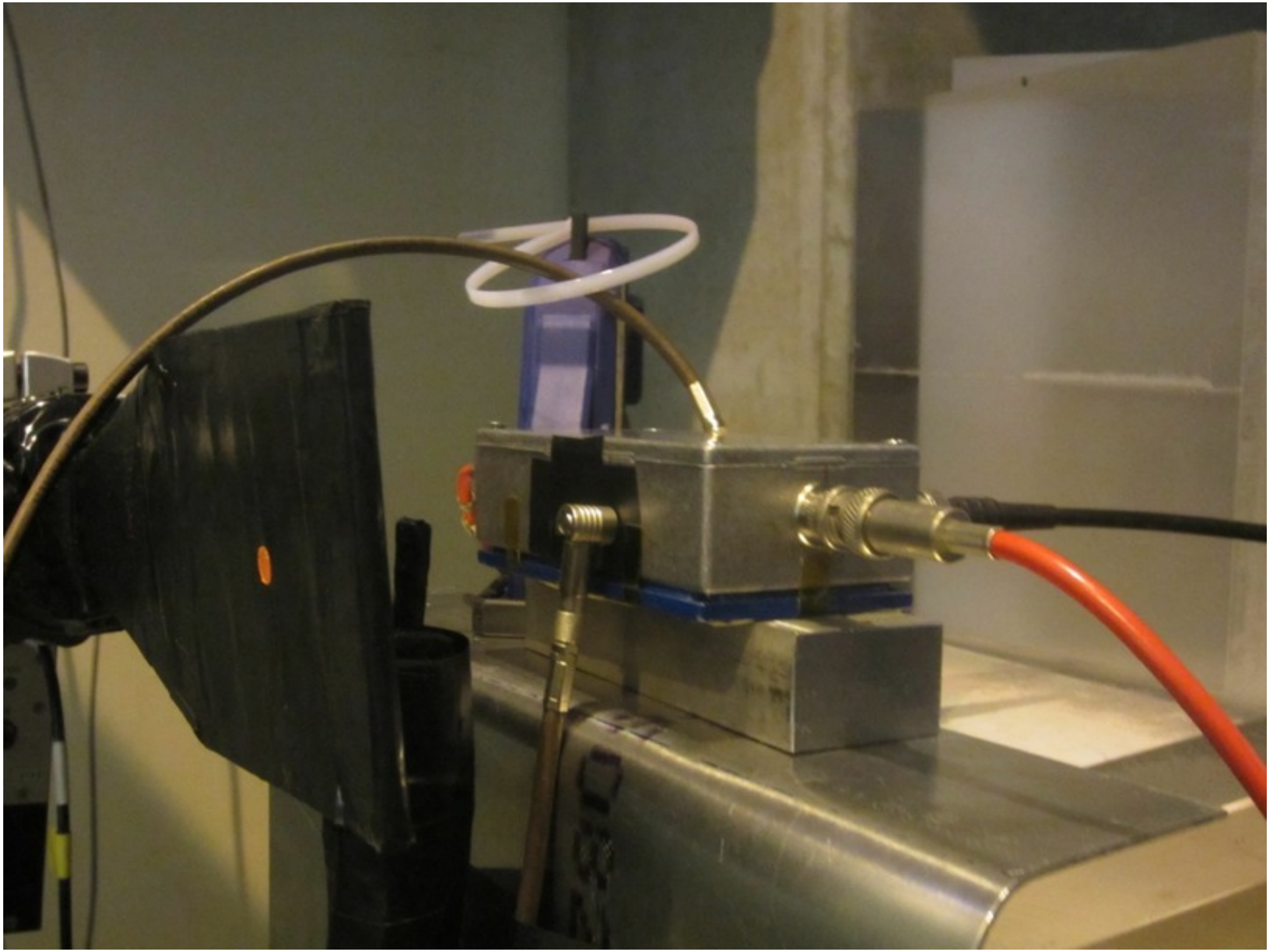
The Z vertex distribution from inner tracker vs. the time of arrival of showers in ZDC-C relative to the ATLAS clock calculated from waveform reconstruction using Shannon interpolation of 40 MegaSample/sec ATLAS data (readout via the ATLAS L1calo Pre-processor modules). Typical time resolution is ~200 psec per photomultiplier (see ATL-COM-LUM-2010-022). The two areas outside the main high intensity area are due to satellite bunches. Note that this plot also provides a more precise calibration of the ZDC timing (here shown using the ZDC timing algorithm not corrected for the digitizer non-linearity discussed in ATL-COM-LUM-2010-027). With the non-linearity correction the upper and lower satellite separations are equalized.

Support material for blessing:

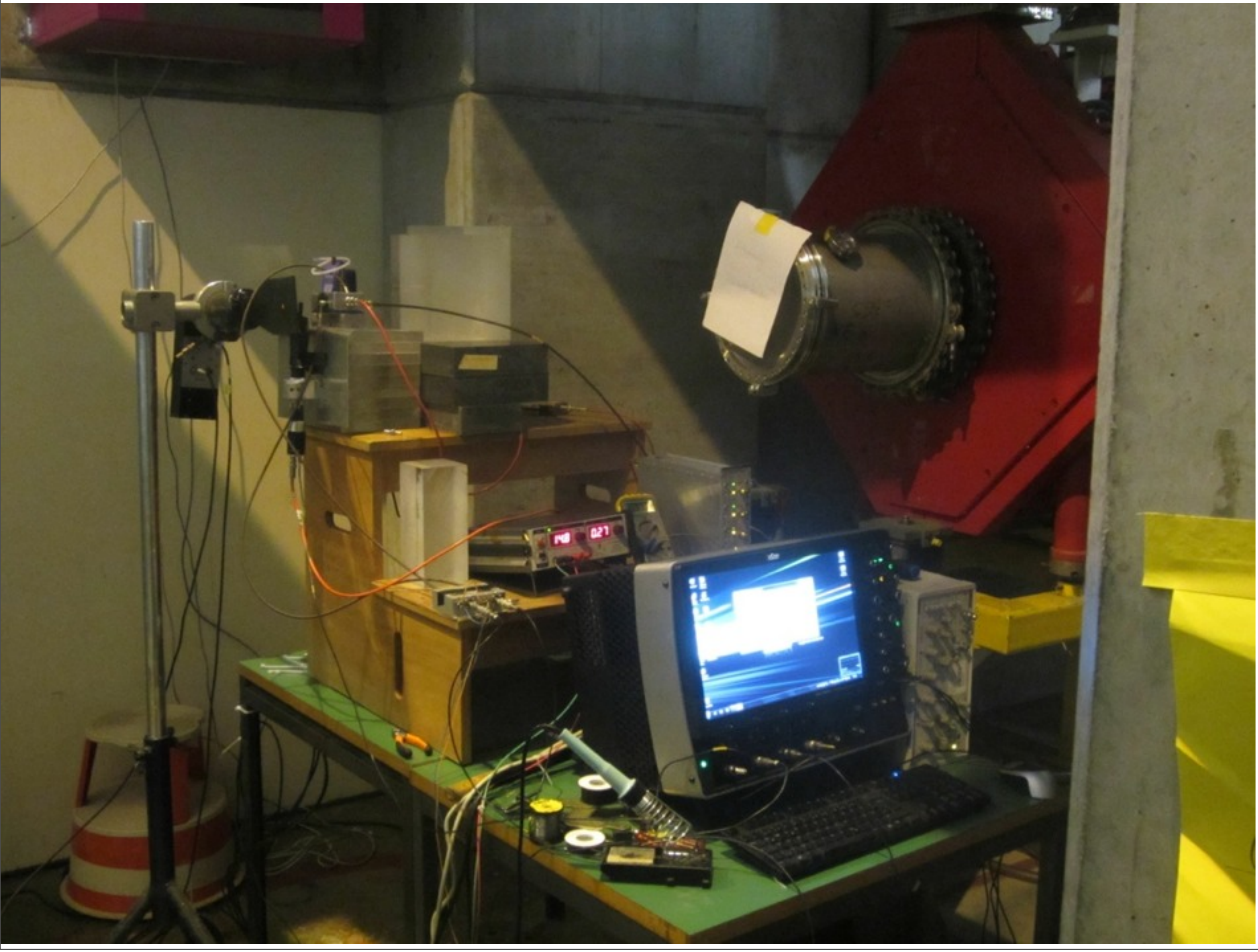
"anyone who abandons what is for what should be pursues his downfall rather than his preservation"
Niccolo Machiavelli



Picture show



PSI setup



Frascati beam