picosecond timing at the LHC -a silicon based solution

Sebastian White, Center for Studies in Physics and Biology, Rockefeller University

Saclay seminar , April 27, 2012

In this talk: General LHC relevance, HAPD and APD development, single electron project

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*."

2012

- In 2012 the LHC is trading cms. energy for Intensity

- Although many initial goals have been realized (in HI program, LHCb, TOTEM σ_{tot}, LHCf..)the mainstream objectives of ATLAS and CMS are now entering a difficult phase- beyond "rediscovering the standard model"

- The Push for intensity highlights issues of radiation damage(extensively studied-ie in Si devices) and pileup(where issues are less well understood)

- Heuer's presentation of 3 possible 2012 running scenarios(25 ns, 50 ns and mixed) highlights the uncertainties in detector performance, which are not well modeled

“Data Driven”

- many aspects of the 2012 run depart from the past 20 years, where analysis tools developed in a virtual world of detector and physics modeling. One example is the effort to reduce CMS ECAL constant term-crucial for low mass Higgs.
- Signal timing is starting to be seen as a useful tool for dealing with pileup. Initially little interest because <100 picosec needed(everything happens in σ_t~170 picosec)
- Clear opportunities for new, high rate detectors(this work) and parallel developments in electronics and more rigorous analysis of limits to performance

Up to now rate/lifetime has been a limitation

- C.Williams, ALICE TOF. Rates limited by glass resistivity. <20 picosec achieved in testbeam.
- Chicago/Saclay/Orsay "Picosecond timing club":Electronics for timing, reduce cost of large area MCP-PMT, incremental lifetime improvement.
- TOFPET
- Super-B R&D at SLAC and Nagoya
- PHENIX (15.5k channel hybrid/Shashlik EMCAL/charged particle TOF) ~90 psec@Eγ=1GeV
- measuring faster-than-light neutrinos from CERN

but signs of progress-ie:

- ATLAS LAr timing ~100 picosec and timing in upgraded CMS HCAL

FP420 R&D Project

- work completed ~2 years ago

- negative response to proposed changes in LHC@420m. Many Issues-including cryogenic collimators

- retreated to 220-240m stations only. This limits coverage to larger diffractive mass

- Today the flagship measurement-”Central Exclusive Higgs Production” -is no longer relevant
  - Higgs mass too low to be accessed at ~240m
  - Larger production cross sections (possible in certain MSSM scenarios) excluded.
  - difficult topic of absorptive corrections (a la Khoze-Martin-Rhyskin) reaching consensus of larger suppression

nevertheless a strong case for instrumenting forward protons at full luminosity

- generally useful to add this important aspect of full coverage to CMS
- other physics topics mentioned by FP420 in CEP and 2 gamma physics(anomalous couplings, exclusive dijets, etc)
- and some overlooked (ie "Large t Diffractive processes in QCD" Frankfurt/Strikman, PRL 1989)

also renewed interest by the collaborations in instrumenting 240m

- ATLAS upgrade LOI submitted to LHCC
- CMS High Performance Spectrometer(HPS)

my opinion:

- since almost all expertise in forward proton measurement at ~240m is concentrated in TOTEM, a TOTEM/CMS collaboration has the highest chance of success

-significant experience studying actual rates in the bend plane (not measured in ALFA)

Outline

- topics with leading baryons/protons
- 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
- experience with a fast forward detector suitable for $L<10^{33}$ in PHENIX and ATLAS.

relevant papers from my CDS at CERN

Swhite_cds
13 items, no notes yet
last update: 15 Dec 2011, 08:10

Add item · Edit basket · Delete basket

1. **Diffraction at the LHC: a non-technical Introduction** / White, Sebastian
   In diffractive interactions of protons or nuclei a violent collision can occur that leaves the forward going particle completely intact -with probability determined by the structure of the proton or nucleus. [...]
   arXiv:1003.4252. - 2010.
   Preprint
   Detailed record - Add a note... Copy item Remove item

2. **On the Correlation of Subevents in the ATLAS and CMS/Totem Experiments** / White, Sebastian N
   We analyze the problem of correlating pp interaction data from the central detectors with a subevent measured in an independent system of leading proton detectors using FP420 as an example. [...]
   arXiv:0707.1500. - 2007. - 19 p.
   Full text
   Detailed record - Add a note... Copy item Remove item

3. **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.
   Preprint
   Detailed record - Add a note... Copy item Remove item

4. **ATLAS Results from the first Pb-Pb Collisions** / White, Sebastian N (Rockefeller U.)
   The ATLAS detector is capable of resolving the highest energy pp collisions at luminosities sufficient to yield 10's of simultaneous interactions within a bunch collision lasting <0.5 nsec. [...]
   arXiv:1111.2789. - 2011. - 9 p.
   Preprint
   Detailed record - Add a note... Copy item Remove item

5. **The FP420 R&D Project: Higgs and New Physics with forward protons at the LHC** /
   arXiv:0806.0302.- 2009 - 176 p. - Published in : *J. Instrum.* 4 (2009) T10001 **SISSA/IOP Open Access article :** PDF; **External link:** Fulltext
   Detailed record - Add a note... Copy item Remove item

6. **Inelastic Diffraction at Heavy Ion Colliders** / White, Sebastian N (Brookhaven Nat. Lab.)
The heavy ion physics approach to global event characterization has led us to instrument the forward region in the PHENIX experiment at RHIC. In heavy ion collisions this coverage yields a measurement of the "spectator" energy and its distribution about the beam direction. [...]
nucl-ex/0501004.- 2005 - Published in : *Nucl. Phys. B, Proc. Suppl. 146 (2005) 48-52* nucl-ex/0501004 PDF
Presented at : International Workshop on Diffraction in High-Energy Physics, Cala Gonone, Italy, 18 - 23 Sep 2004, pp.48-52
Detailed record - Add a note... Copy item Remove item

7. **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 water cerenkov or Liquid Argon neutrino detectors. [...]
arXiv:1004.3068. - 2010.
Preprint
Detailed record - Add a note... Copy item Remove item

8. **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.
Preprint
Detailed record - Add a note... Copy item Remove item

9. **The role of Spectator Fragments at an electron Ion collider** / White, Sebastian ; Strikman, Mark
Efficient detection of spectator fragments is key to the main topics at an electron-ion collider (eIC). [...]
arXiv:1003.2196. - 2010.
Preprint
Detailed record - Add a note... Copy item Remove item

10. **Beam Fragmentation in Heavy Ion Collisions and its implication for RHIC triggers at low s** / White, Sebastian ; Strikman, Mark
We show that with a realistic treatment of spectator momentum distributions the RHIC detector trigger sensitivity is high even when RHIC is run below injection energies. [...]
arXiv:0910.3205. - 2009.
Preprint
Detailed record - Add a note... Copy item Remove item

indirectly relevant......

11. **Mathematica with ROOT** / Hsieh, Ken ; Throwe, Thomas G ; White, Sebastian
We present an open-source Mathematica importer for CERN ROOT files [...]
arXiv:1102.5068. - 2011.
Preprint

Detailed record - Add a note... Copy item Remove item

12. 

Tesla Sparked the Era of Particle Accelerators (presented at Tesla Conference 2011) / White, Sebastian (speaker) (Rockefeller/Pisa)
2011 - Streaming video. Commemorations **External link**: Event details *In* : Tesla Sparked the Era of Particle Accelerators (presented at Tesla Conference 2011)

Detailed record - Add a note... Copy item Remove item

13. 

"Do you think Evolution should be taught in schools?" Interview with Sebastian White

Produced by: CERN video productions
Director: CERN video productions
04:47 min. / 25 August 2011 / © **2011 CERN**
Keywords: evolution, america, school, teach, interview, Sebastian White, 2011, science, scientist
Reference: CERN-VIDEORUSH-2011-090
Language: English

Detailed record - Add a note... Copy item Remove item

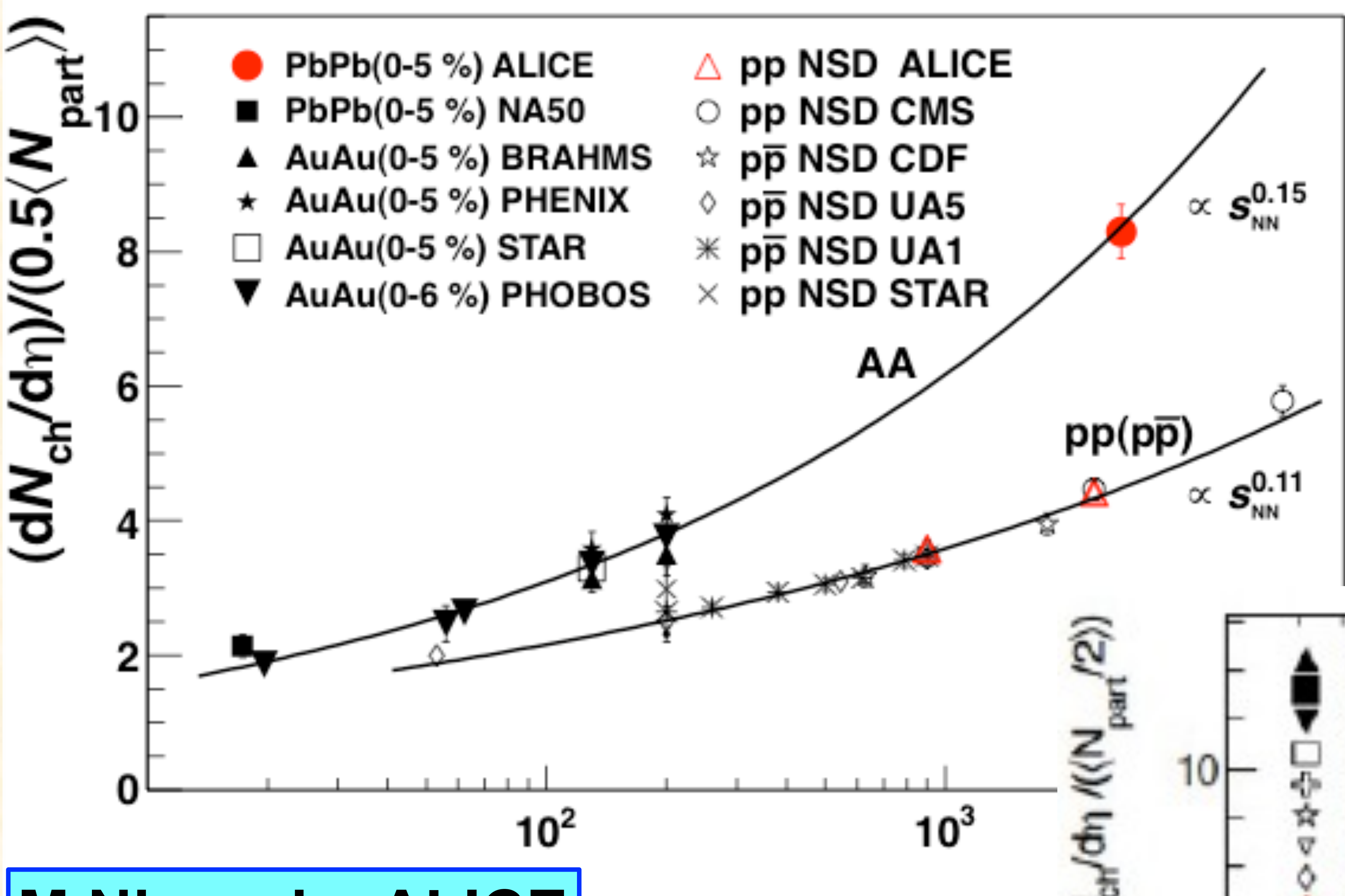
leading Baryons

- 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



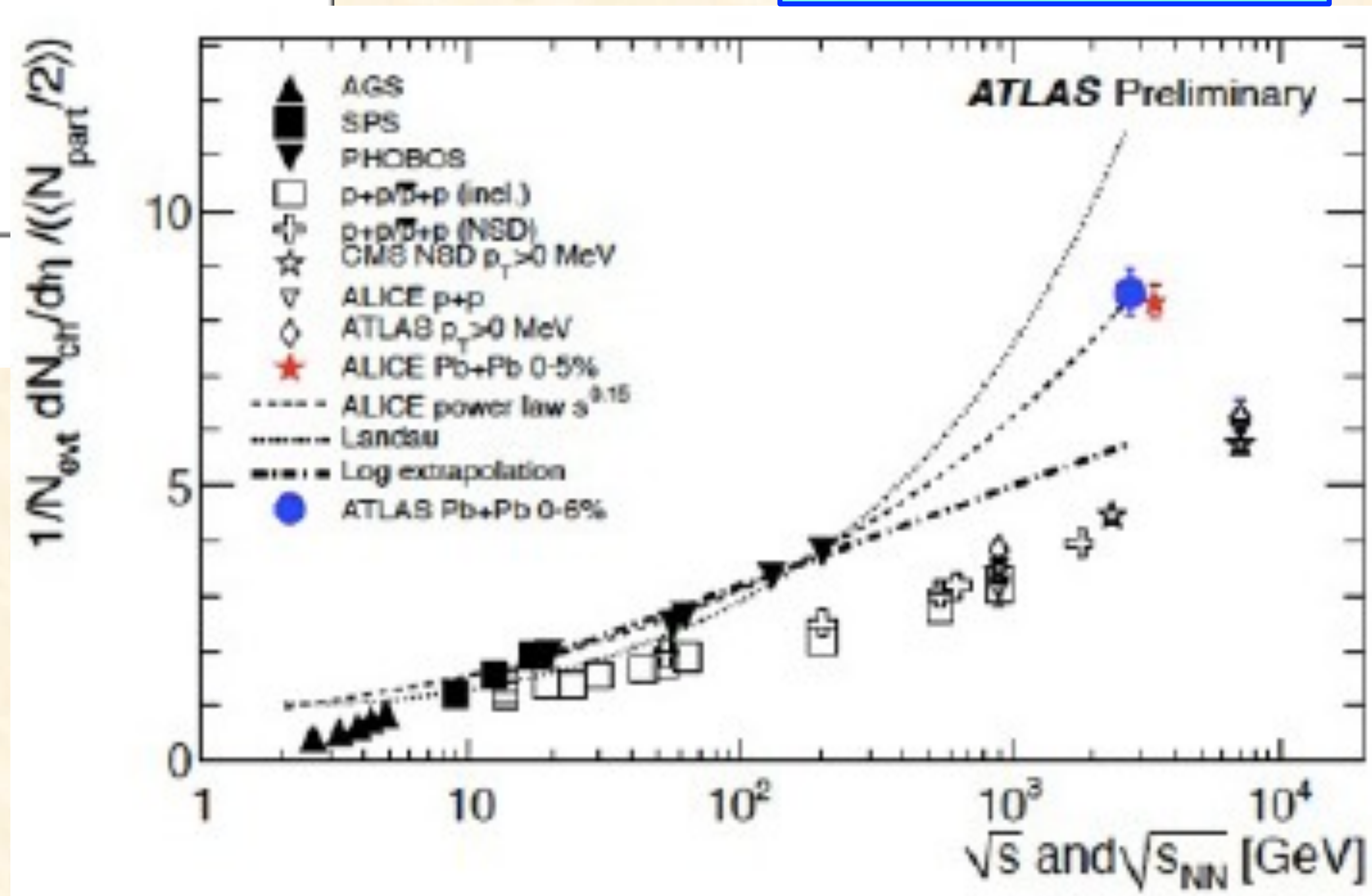
M.Nicassio, ALICE

- growing faster then pp
- increase by factor

-2.2 compared to RHIC

-1.9 compared to pp

S.White, ATLAS



agreement among experiments

Rockefeller U. ①
14 May 2010

THE PARTON MODEL: 2010

J. BJORKEN

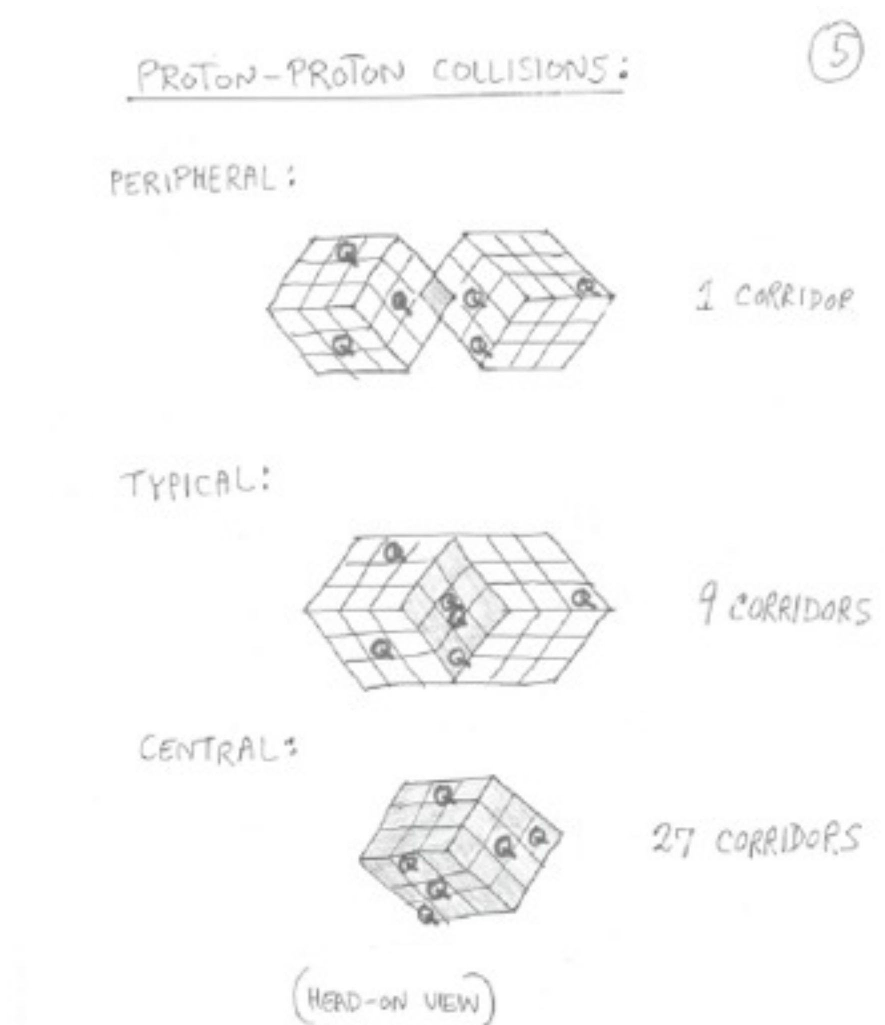
I. PARTON CONFIGURATIONS

II. PROTON - PROTON COLLISIONS

III. ELECTRON - PROTON COLLISIONS

IV. IONS

V. COMMENTS

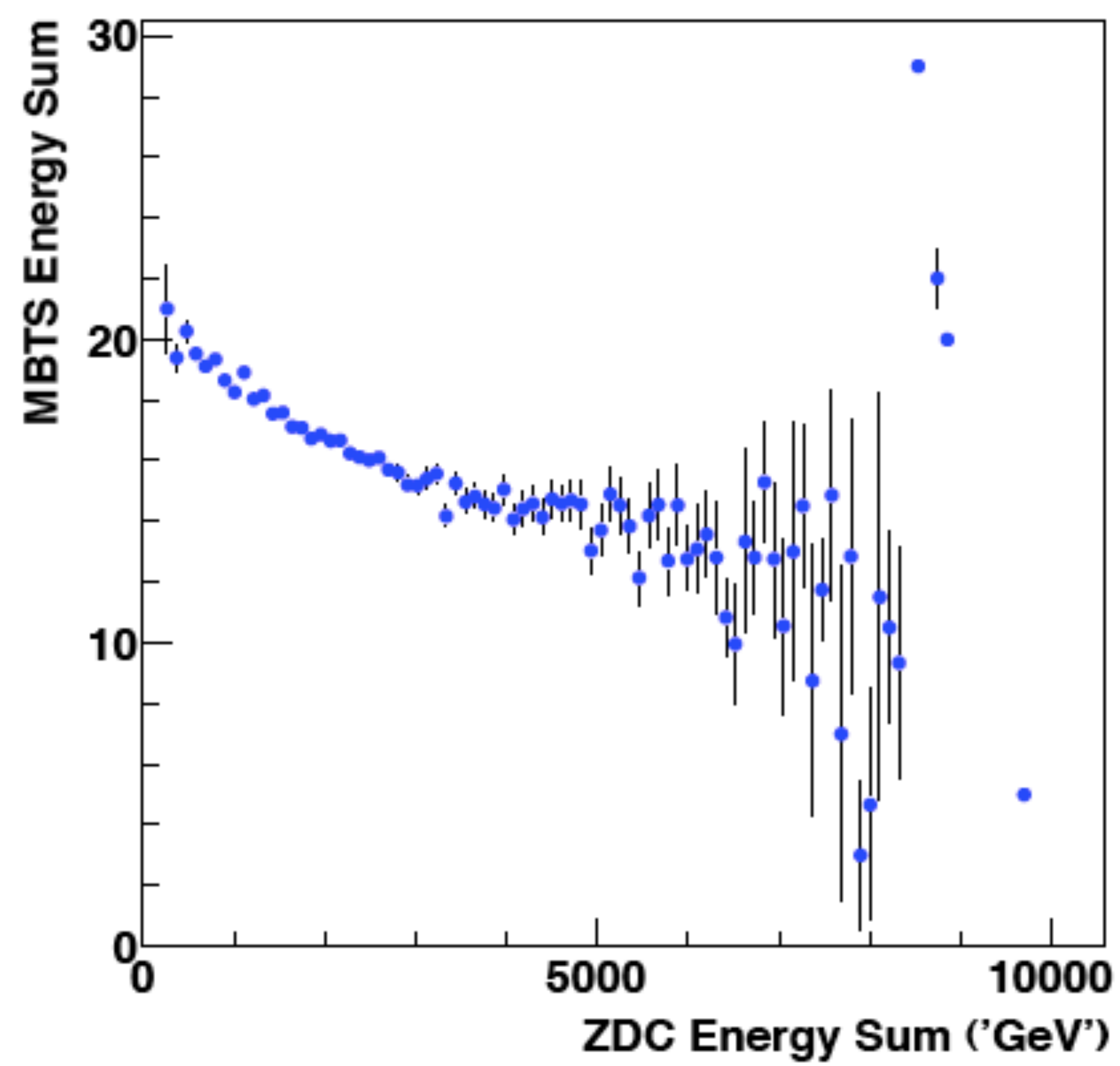


Bj slides from a workshop I organized with Marciano and Strikman
-usefulness of thinking of proton as an extended object

An example: charged particle multiplicity vs. ATLAS Zero Degree Calorimeter(ZDC) energy data in 7 TeV pp collision

many aspects of this measurement interesting:ie dependence of multiplicity fluctuations on ZDC energy

currently analyzing charged multiplicity in inner tracker vs. calibrated neutron energy



Issues at full Luminosity

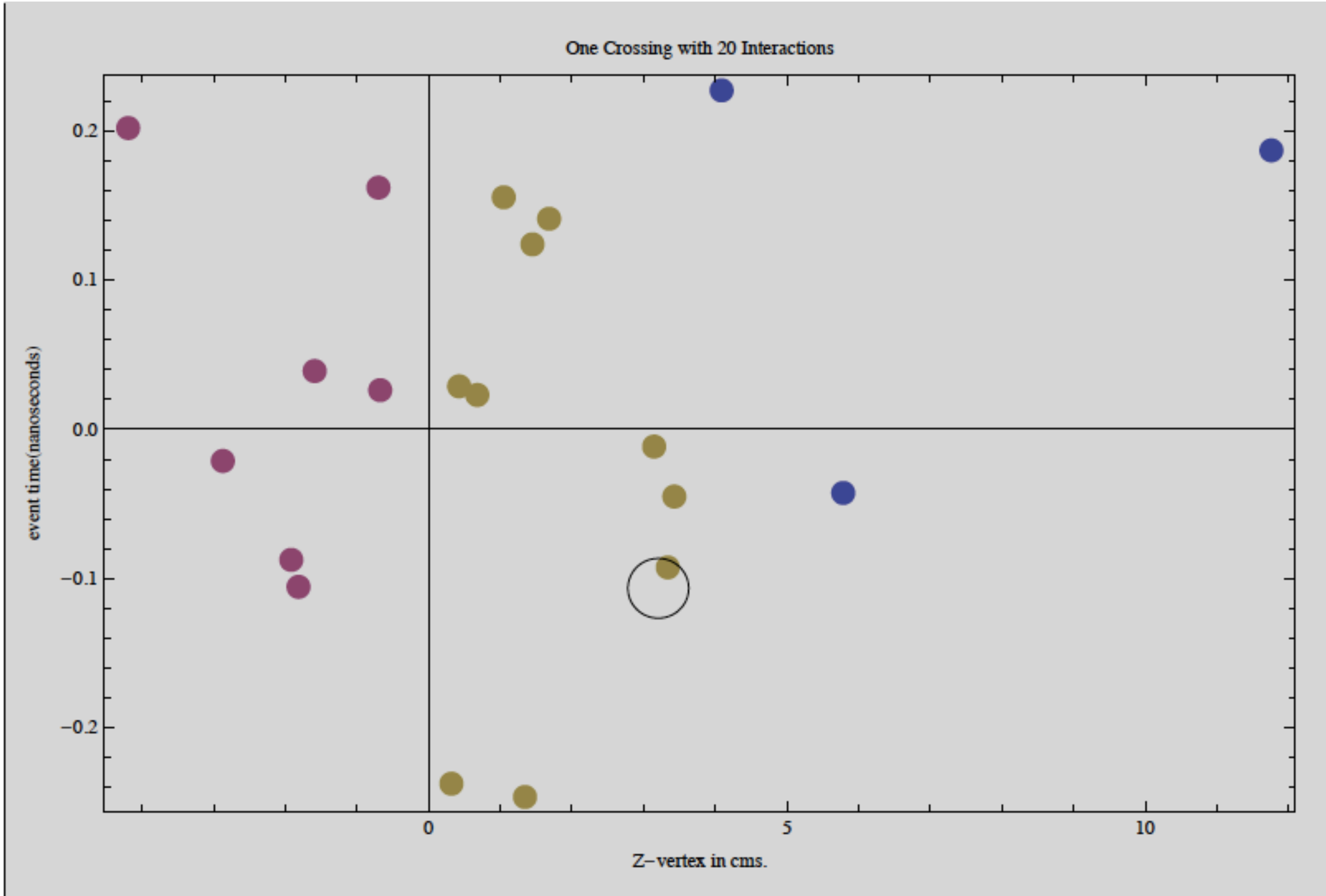
- at Design luminosity the rate in the forward proton tracking is several 10's of MHz/cm^2. Integrated over a year of running, displacement damage in silicon devices is a significant issue. In an MCP-PMT, normal operation (a la Super-B) leads to severe photocathode damage in much less than a year. see:

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.

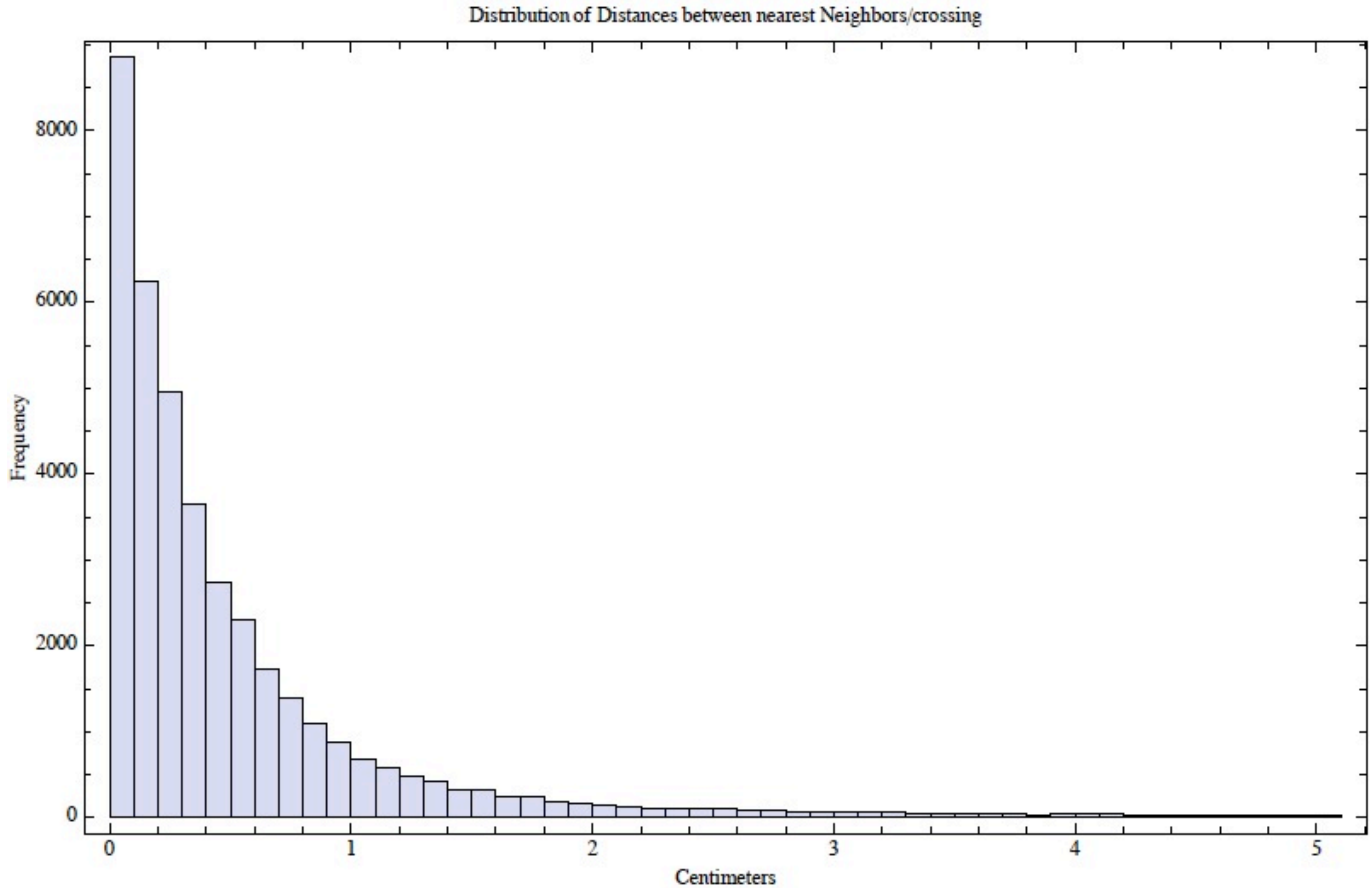
- depending on the choice of event generator the mean # of protons in the tracker/timing detector is ~1 due to physics at mu=25. Indications from TOTEM that non-physics contribution also significant.-> important to have a technology with completely scalable segmentation in timing detector.

resolving association with leading protons:

SNW, http://adsabs.harvard.edu/abs/2007arXiv0707.1500W



assume a true 2 p coincidence, match to vertex. Similar analysis for accidental SD (dominant physics bkg)



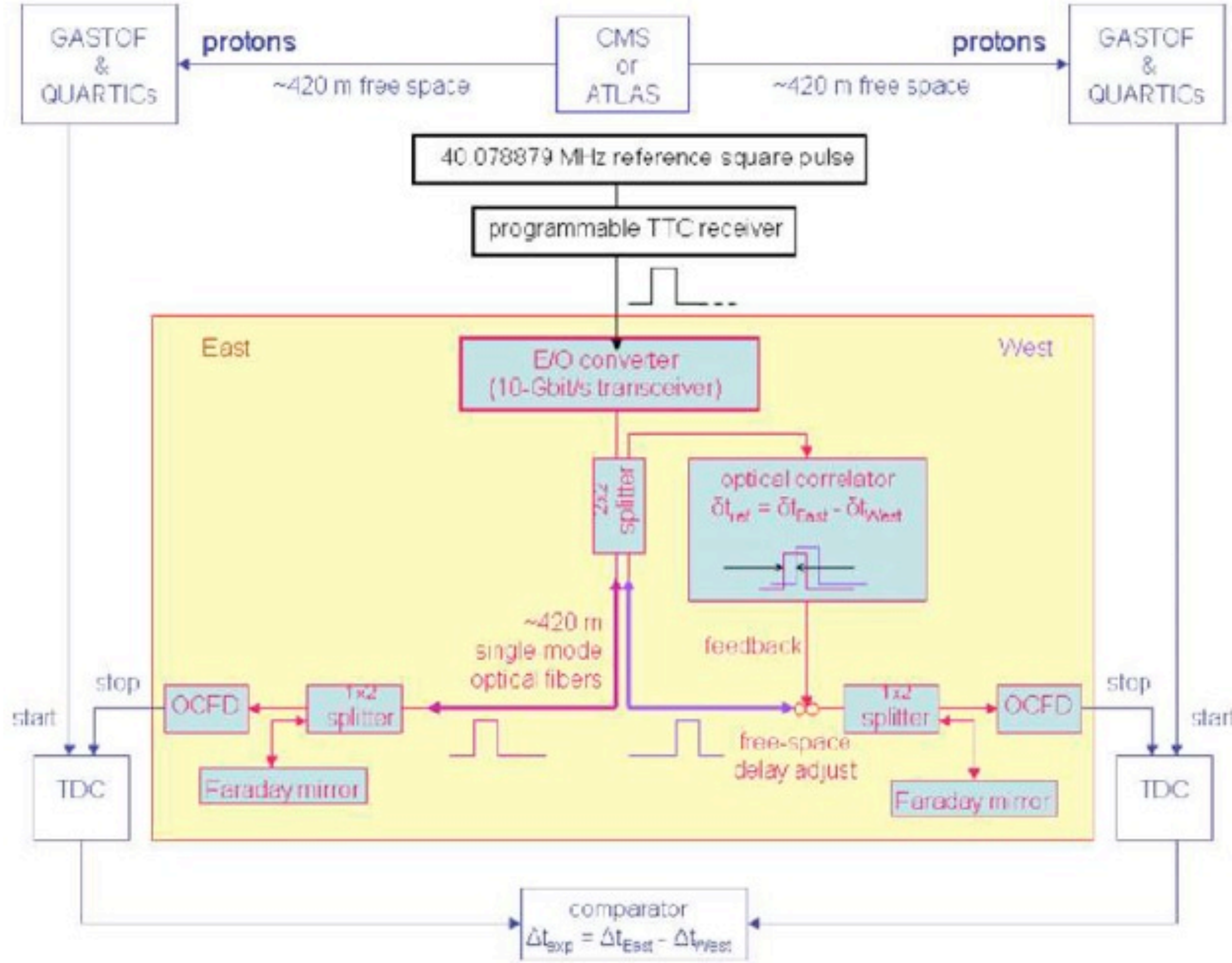
Exponential due to Poisson distributed population

see eg. p 362 Papoulis: Probability, random variables and stochastic processes (1991 ed)

Synchronization of detectors 1km apart to <5 psec is not expensive.

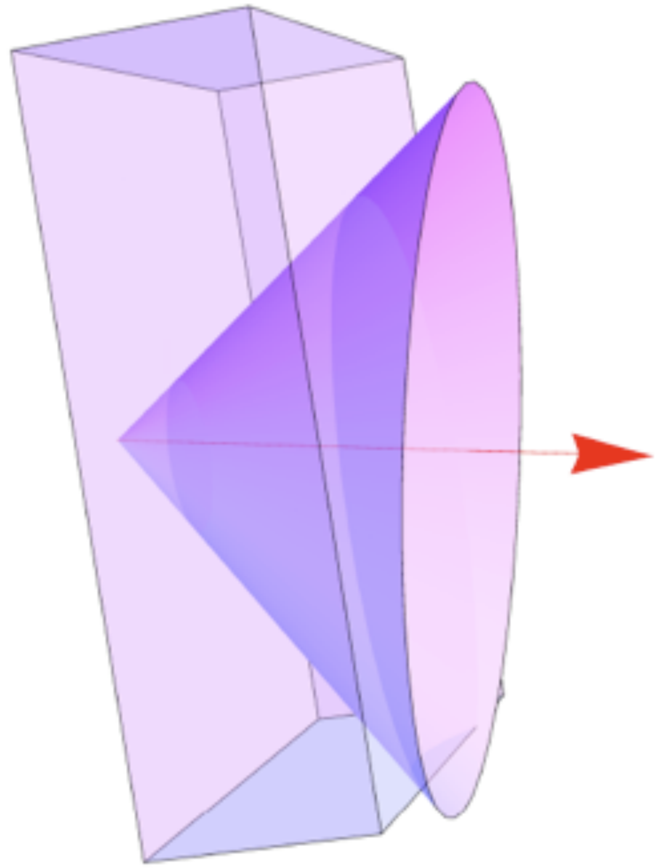
T.Tsang and SNW:
design for FP420
(cost ~$60k)

State of the art is
~10 femtoseconds
using interferometrically
stabilized optical fiber
-see ILC design or
National Ignition Facility



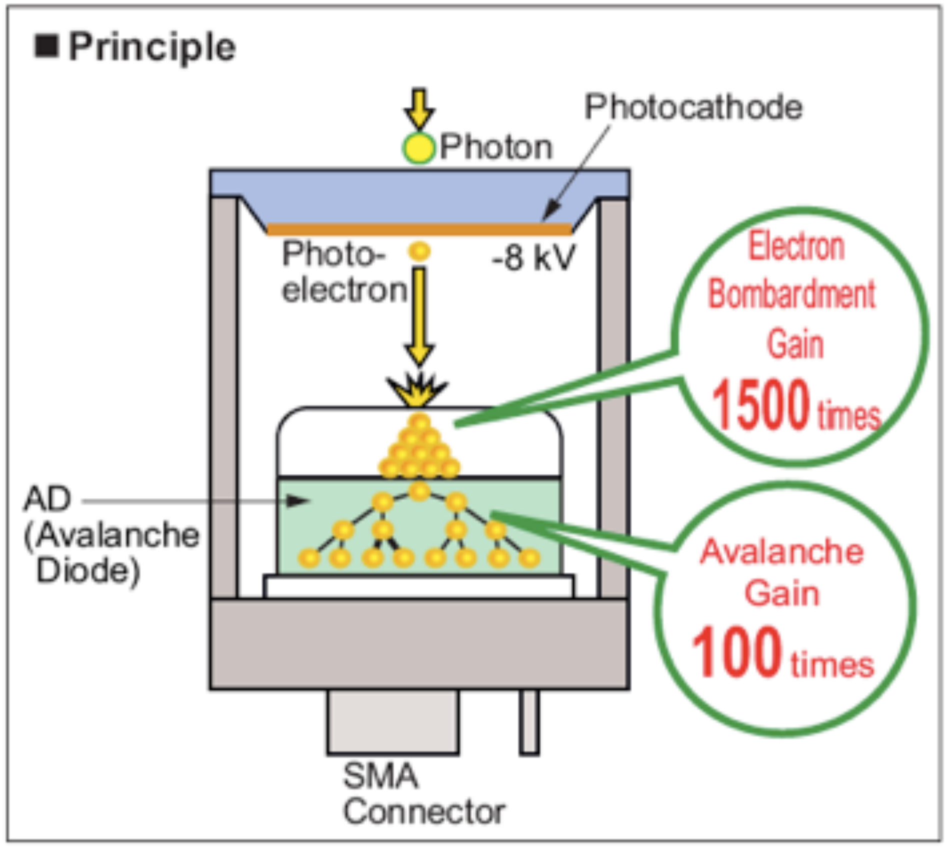
an alternative photosensor for high rates (HAPD)

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



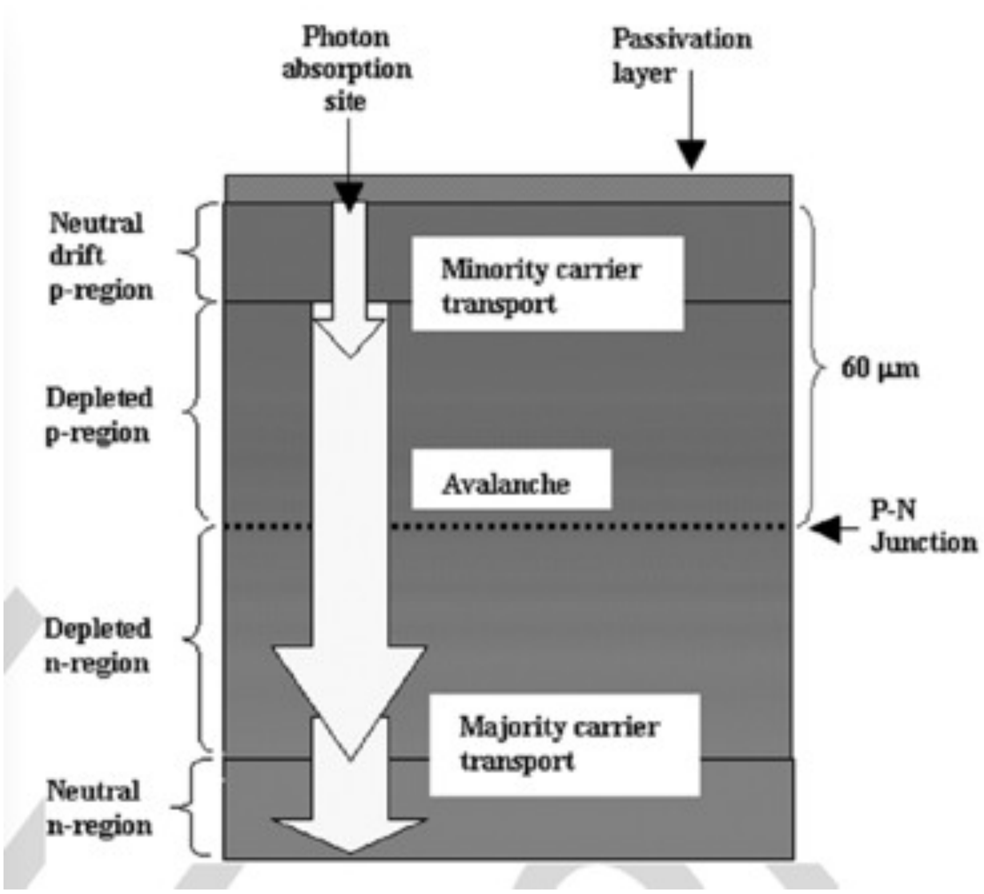
Cerenkov Radiation cone

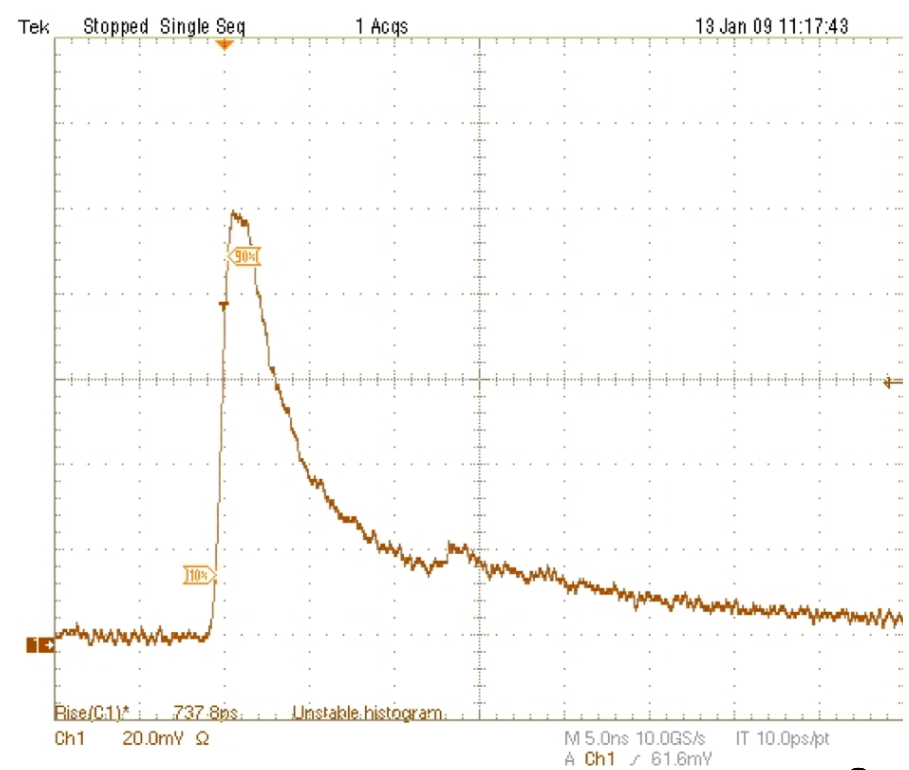
Cerenkov
or
APD
option



Pre-production Hybrid photodetector

“A 10 picosecond time of flight detector using APD’s”, SNW et al.

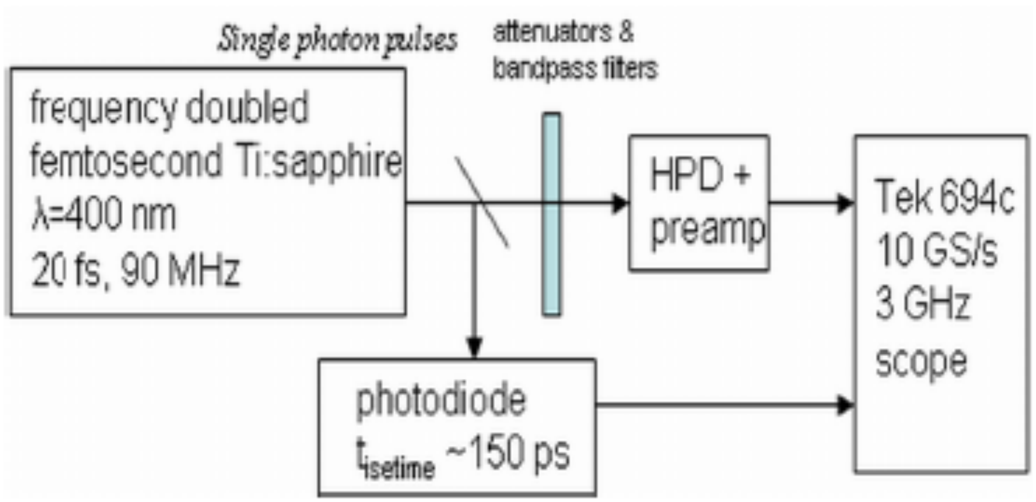




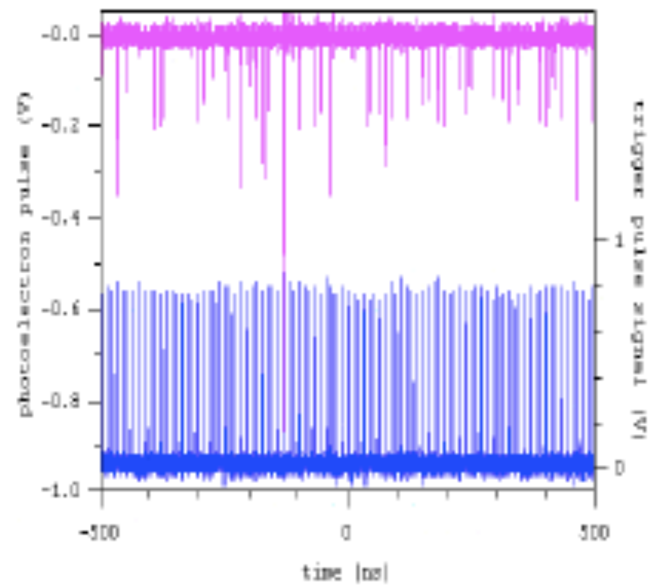
650 picosecond risetime (β’s)

Deep diffused avalanche photodiode

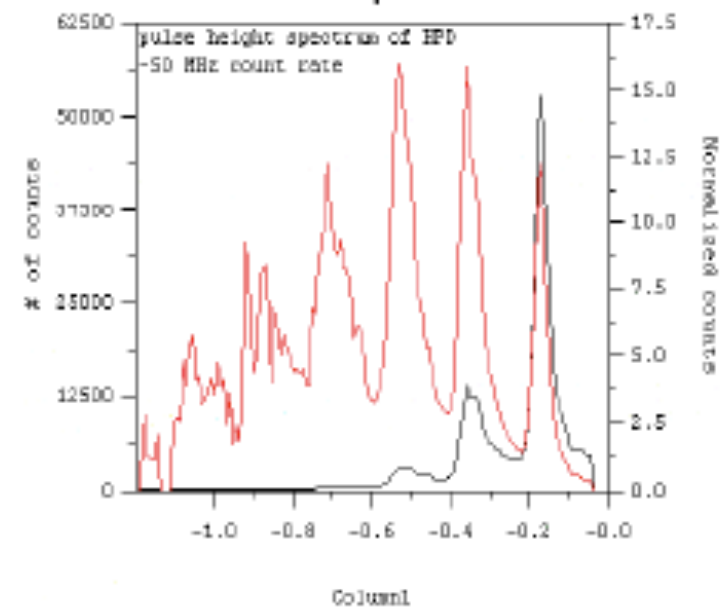
Applications in eg fluorescence spectroscopy
T.Tsang, S.White



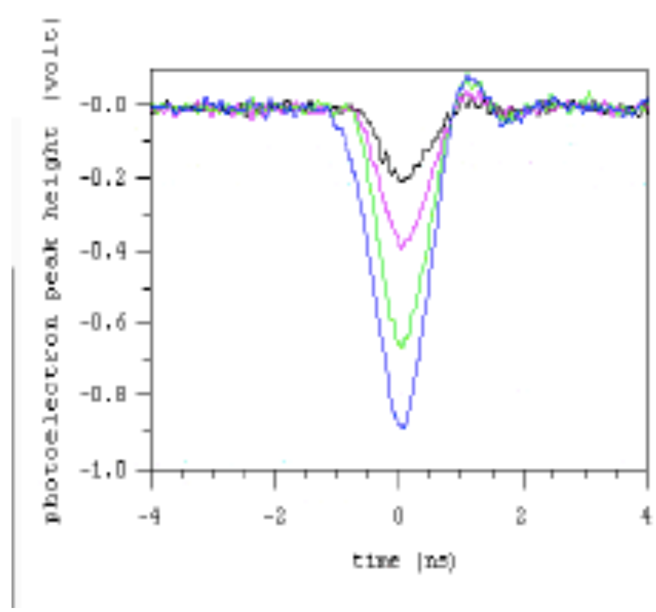
Temporal response



N_{pe}

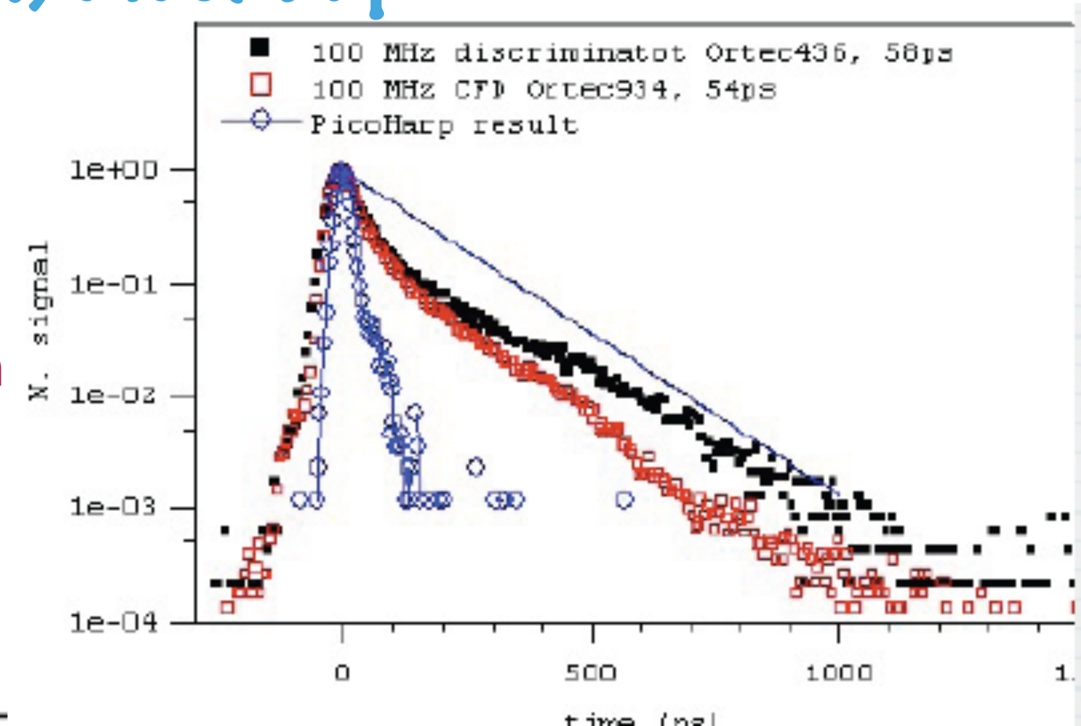


risetime=300 psec

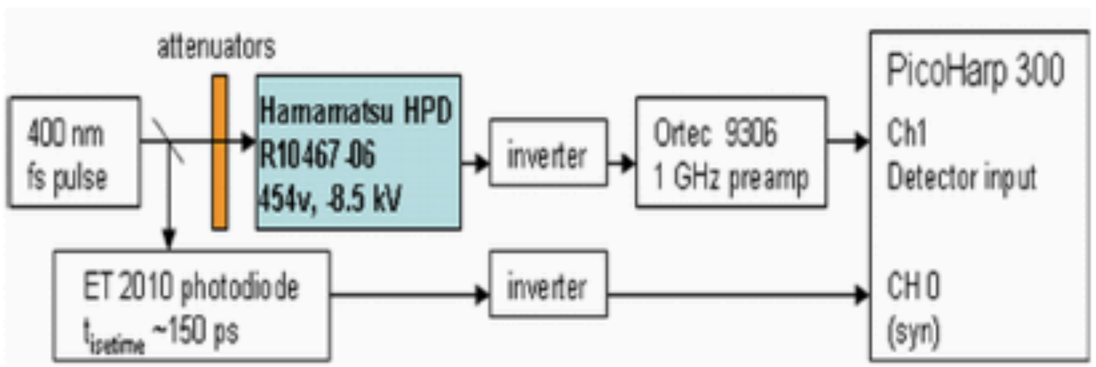


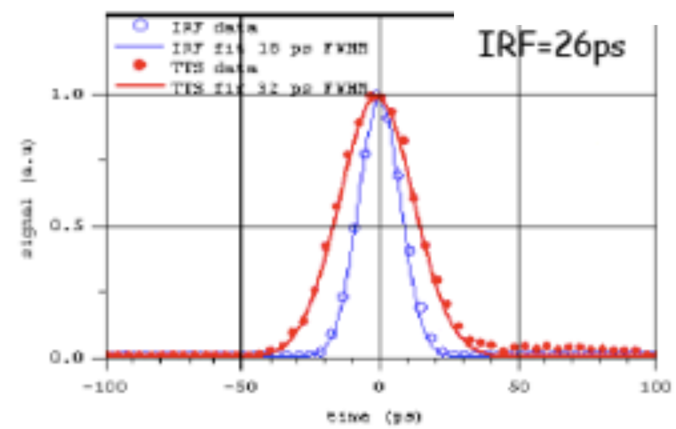
N_{pe}	pulse height after preamp (Volt)	pulse height before preamp (mV)	normalized count rate
1	0.176	2.2	1
2	0.36	4.5	0.26
3	0.528	6.6	0.061
4	0.71	8.9	0.009
5			~0.0014
6			~0.0002

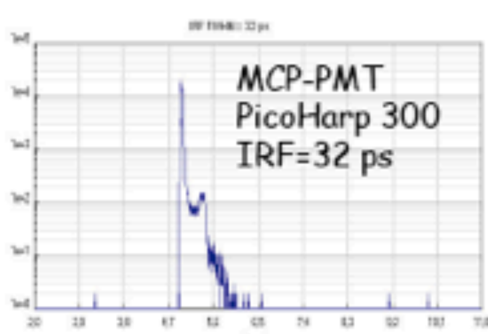
11 psec single photon response is not common! Below studies comparing LE, CFD, PicoHarp

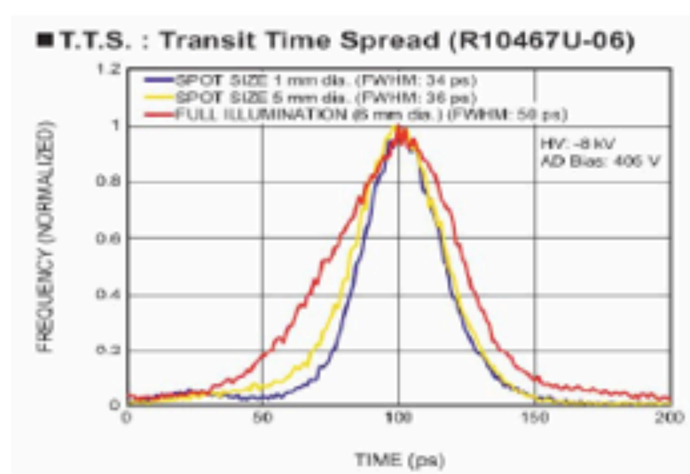


similar exercises in literature comparing methods
(see eg. Breton, Delanges, Va'vra, et al.)
now developing formalism for calculating expected resolution
-potentially useful for electronics development









Clearly a great substitute
for MCP-PMT
with 10^2-10^3 times
the lifetime!

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

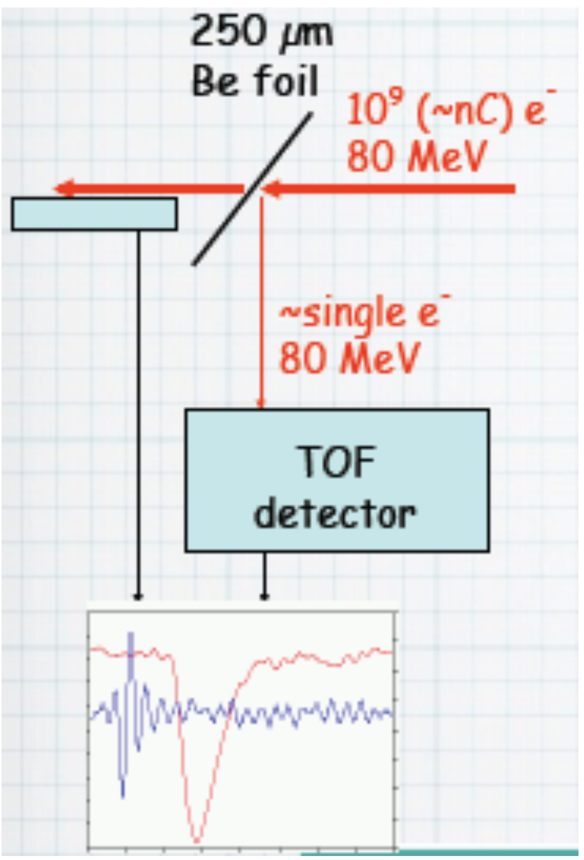
$$\sigma_{HPD} = \frac{\sigma_{TTS}}{\sqrt{N_{pe^-}}} = \frac{11\,ps}{\sqrt{N_{pe^-}}}$$

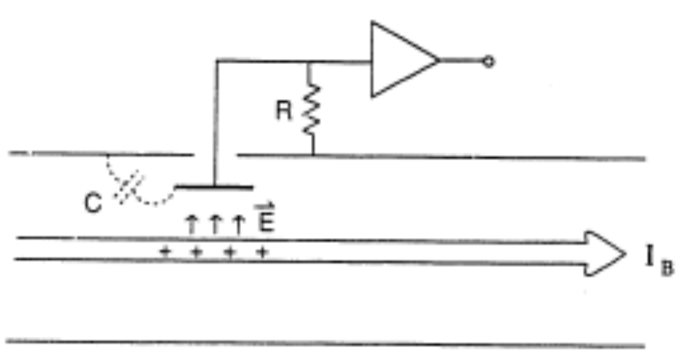
Testbeams used to characterize APD based timing detector

1. Single electron project at ATF
2. PSI (~200 MeV muons and electrons)
3. Frascati BTF <500 MeV electrons, tertiary beam from DAFNE Linac

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.

rates calculated based on Hofstadter's data



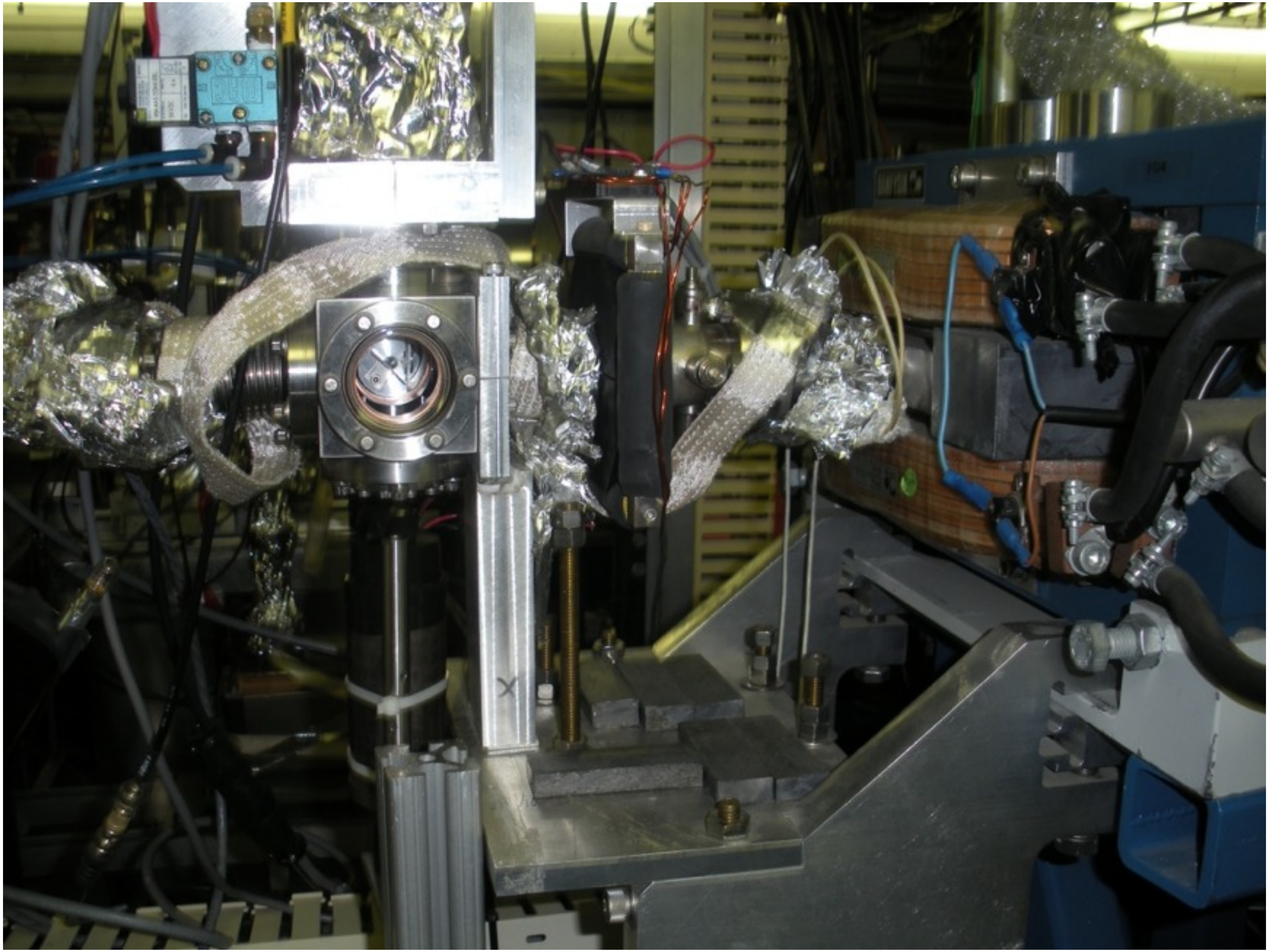


- a unique feature of ATF beam is 3 picosec bunch length(streak camera)
- could this be exploited to evaluate fast timing detectors?
- common technique for secondary beam design is successive dispersion and collimation
- this requires real estate

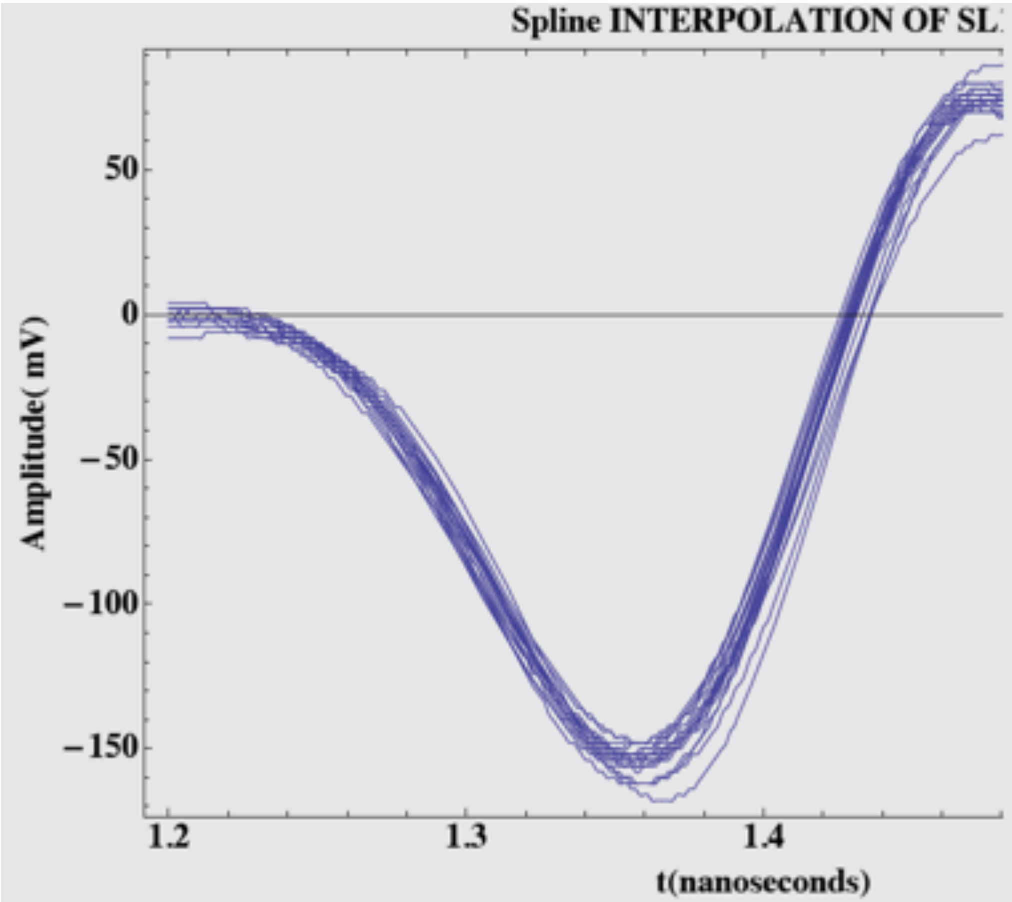
Kirk, Thomas, Misha

Vitaly

the beamline

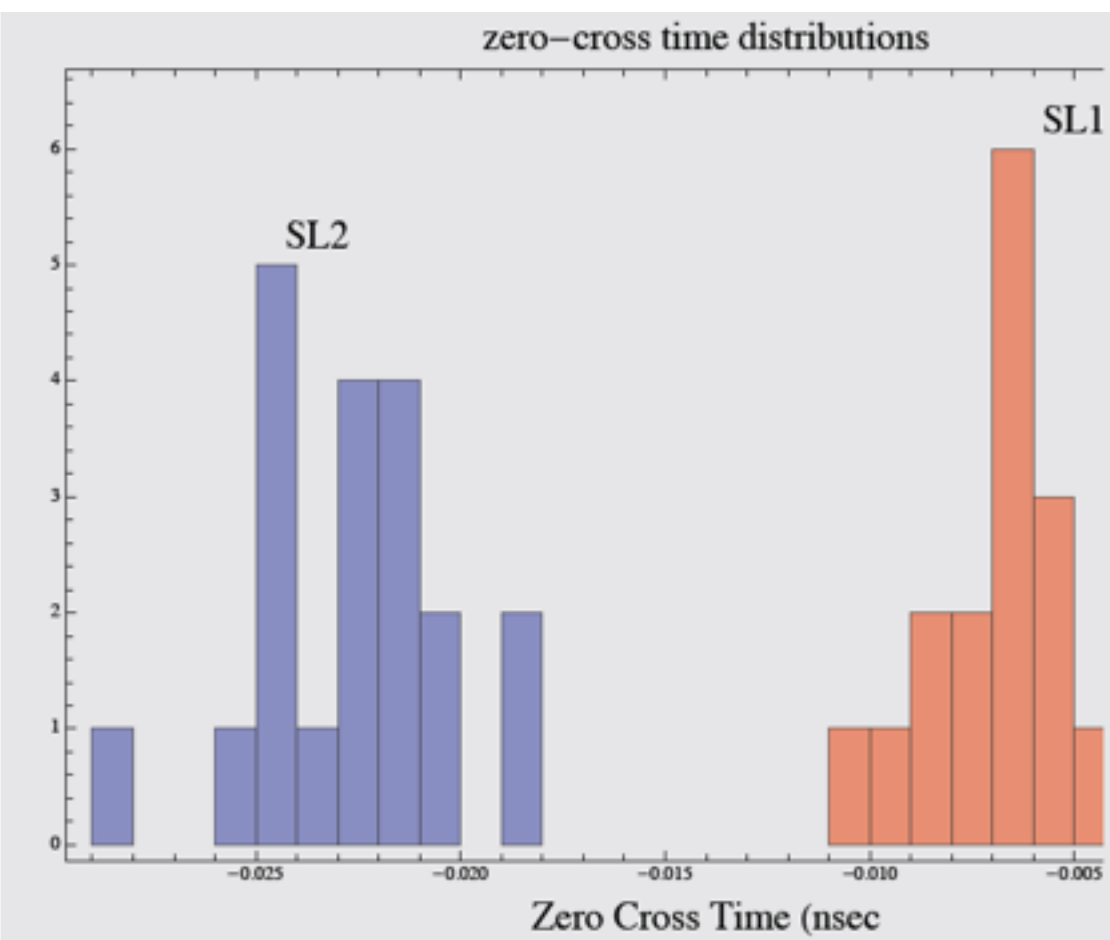


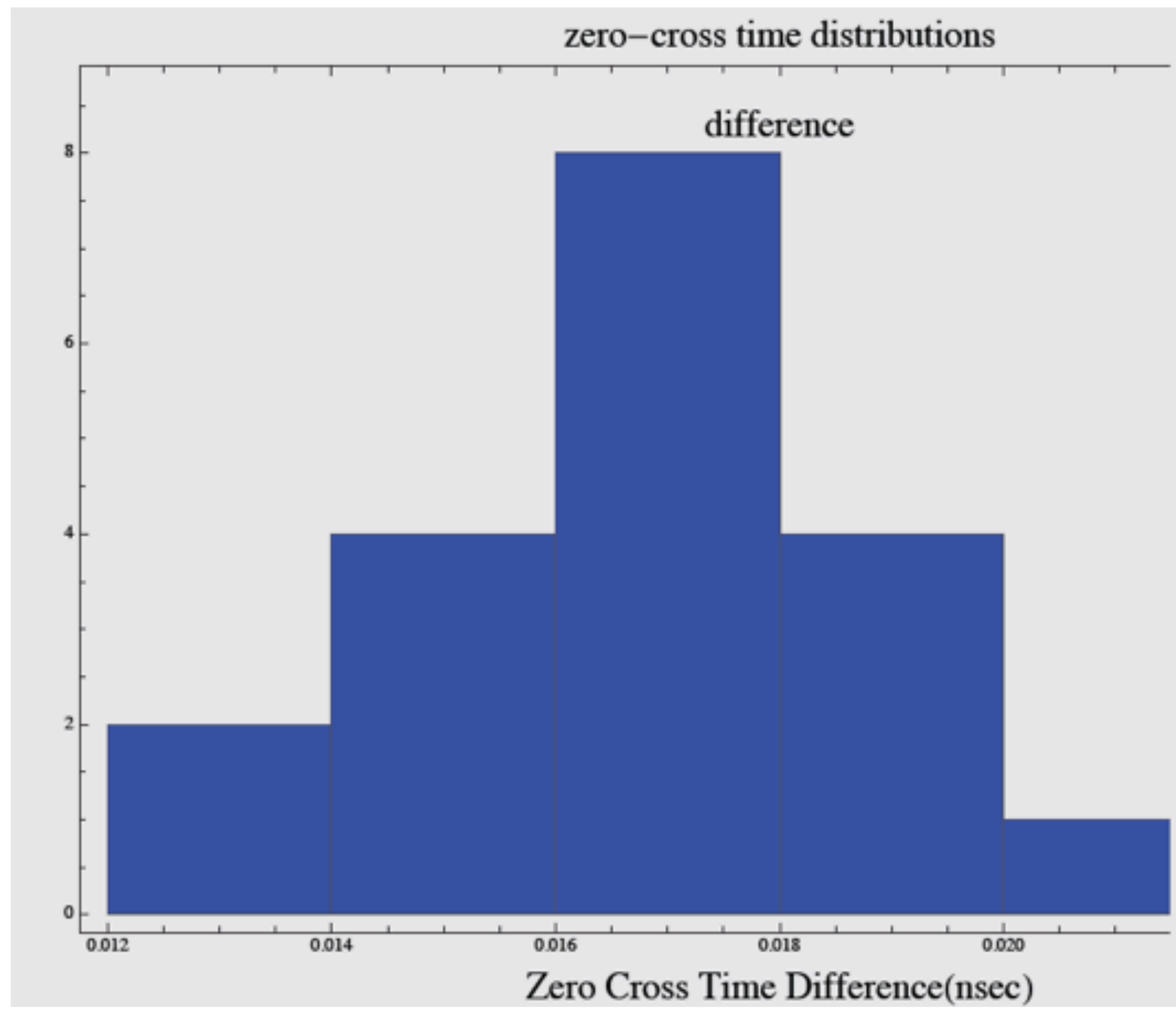
Initial study of "start time" resolution from ATF stripline

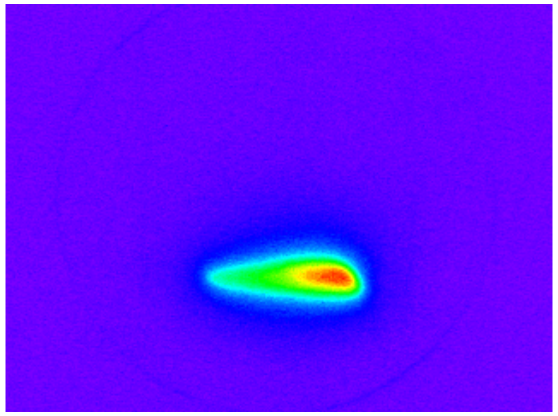


stripline waveforms w.
on-chip Sin[x]/x interpolation+spline

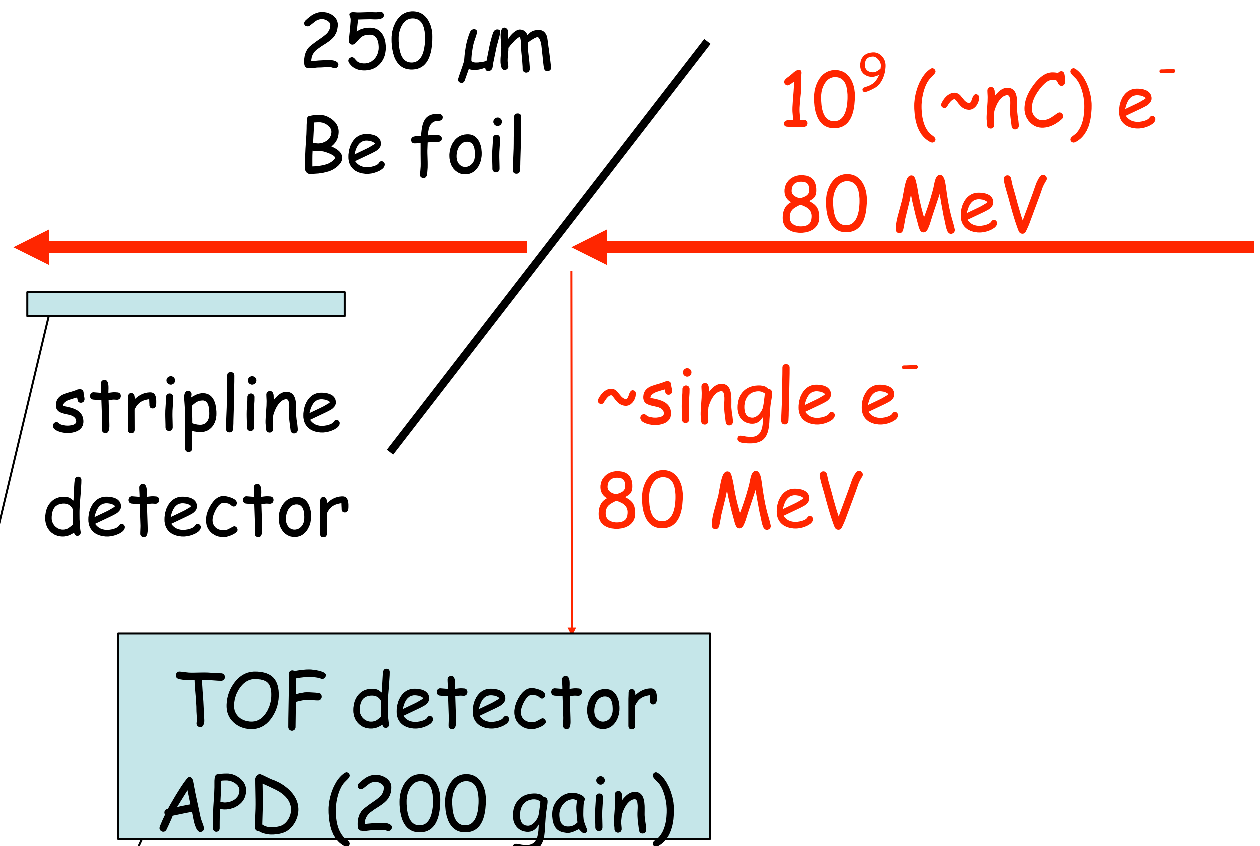
rms on time diff
between detectors <2.5 psec

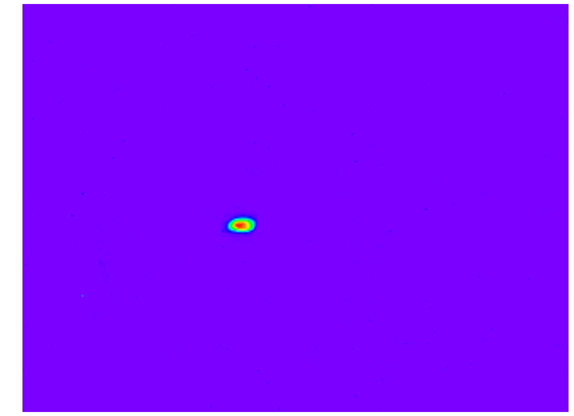




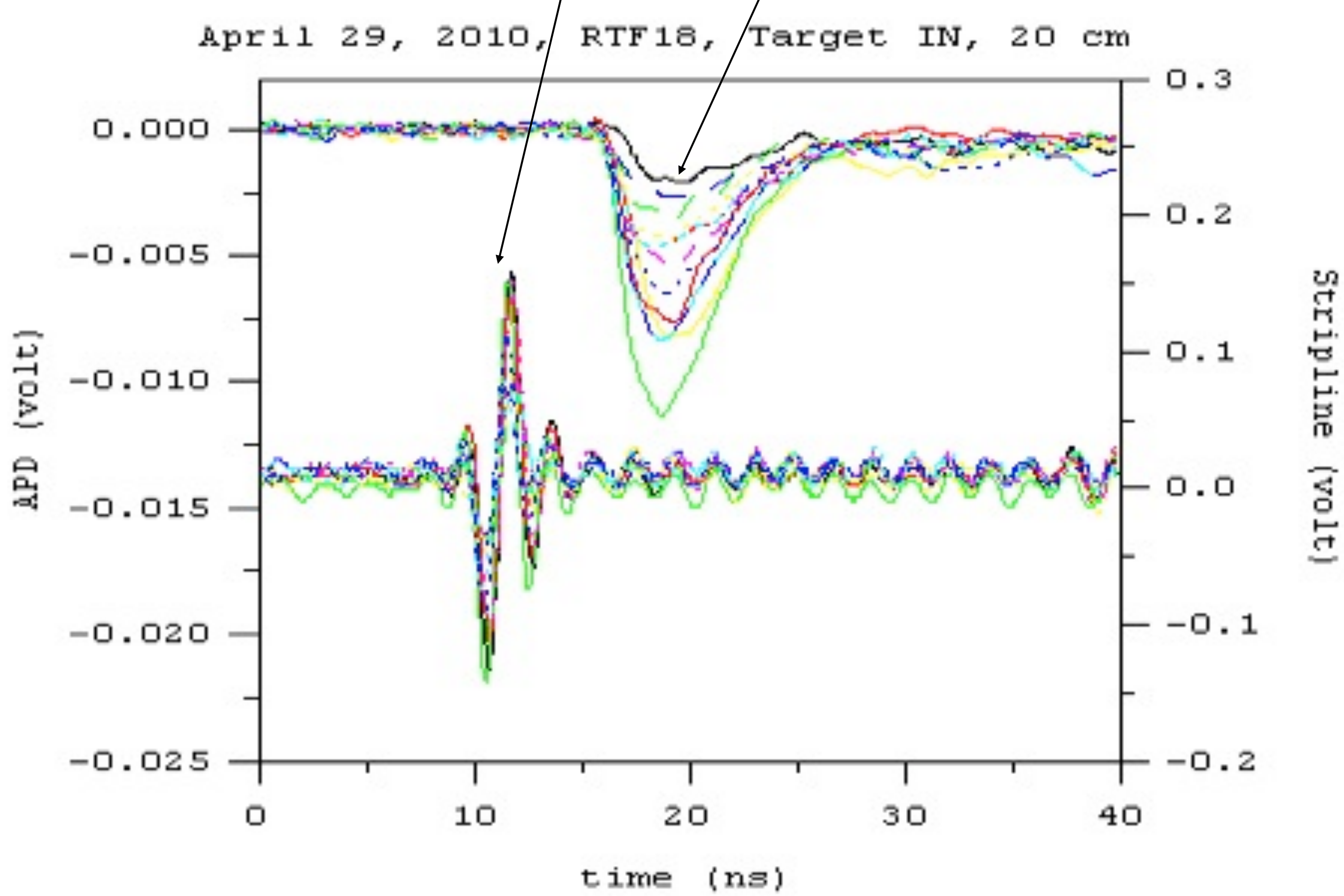


e- beam size @ Pop #8
640x480 pixels
20 μm/pixel

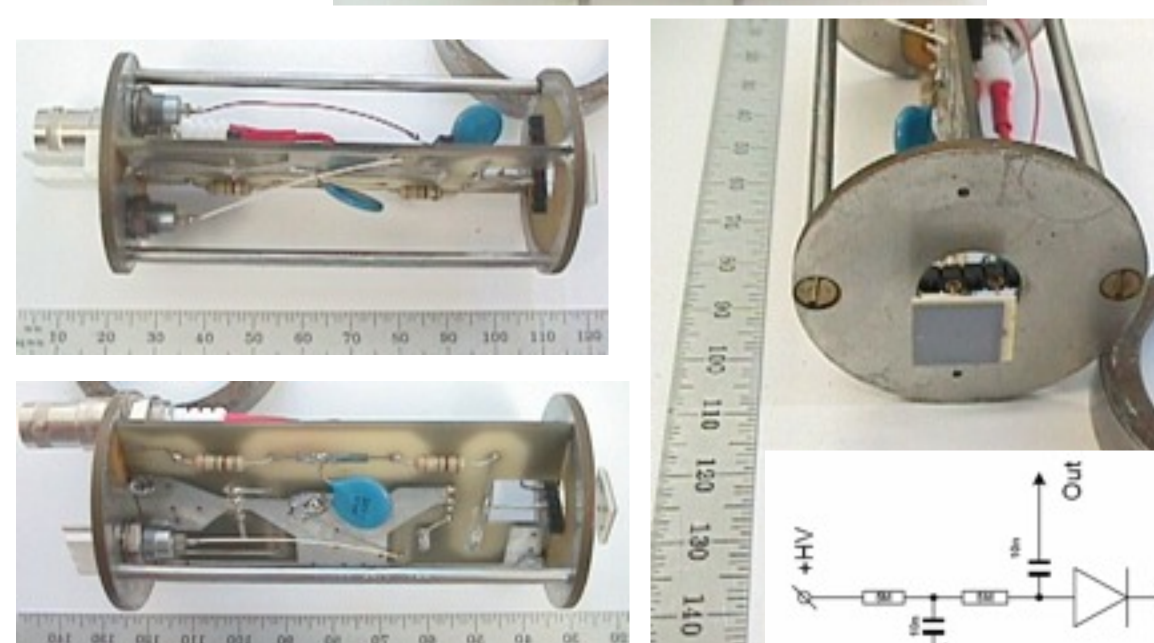




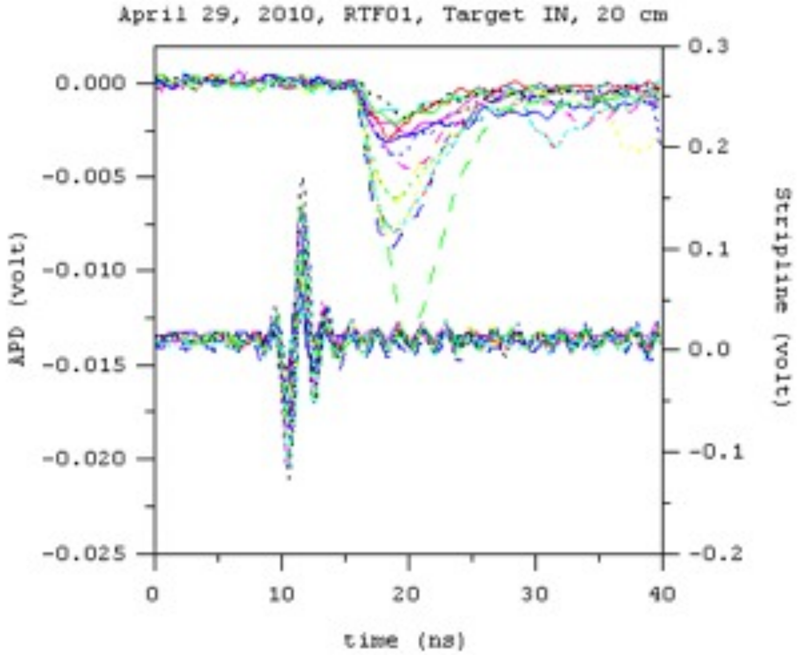
e^- beam size @ Pop #7
640x480 pixels
20 μm/pixel
V: 13 pixels FWHM
H: 25 pixels FWHM

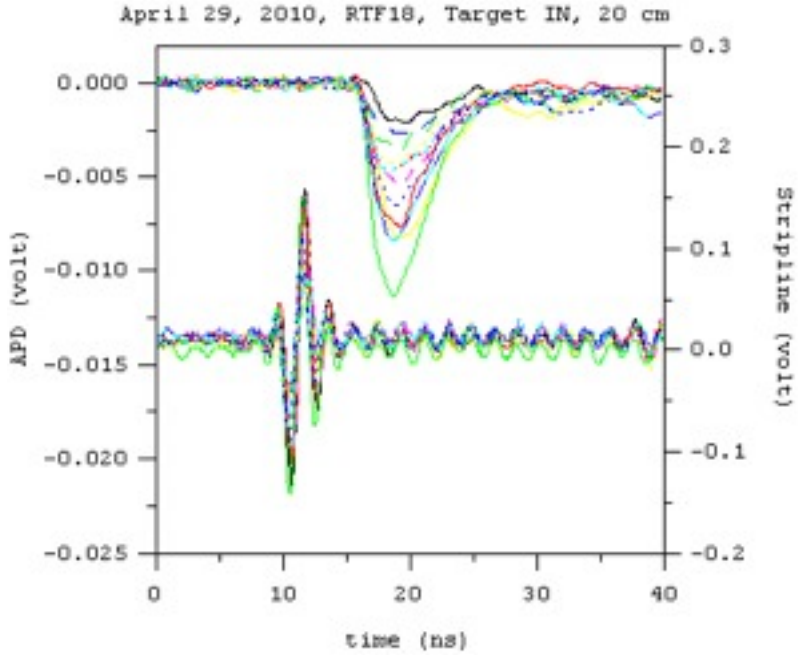


APD
+1750 volt bias

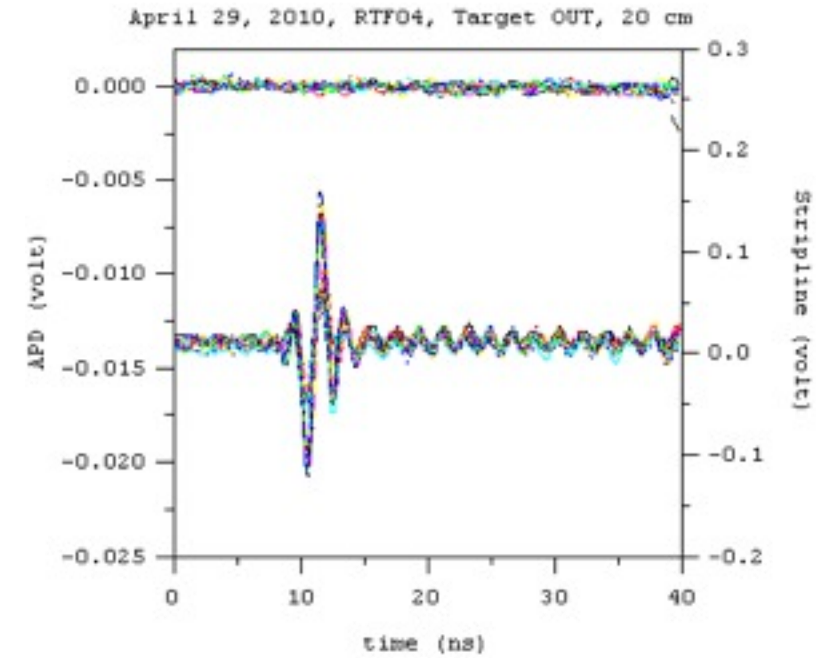


Target IN 20 cm

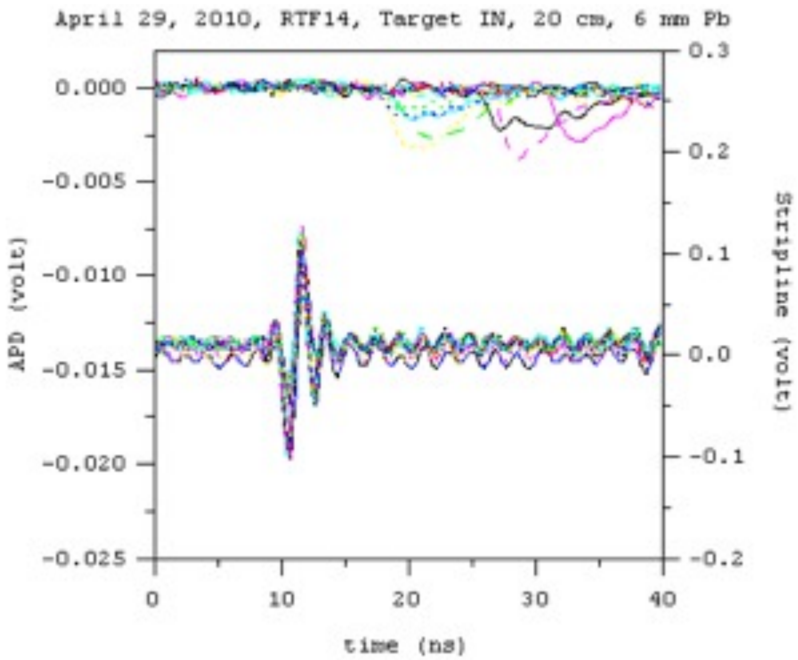


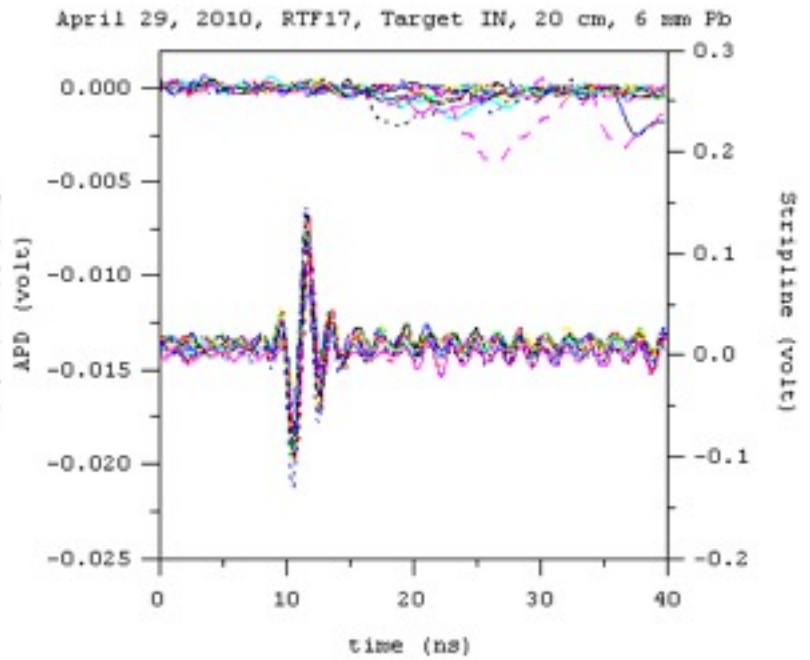


Target OUT 20 cm

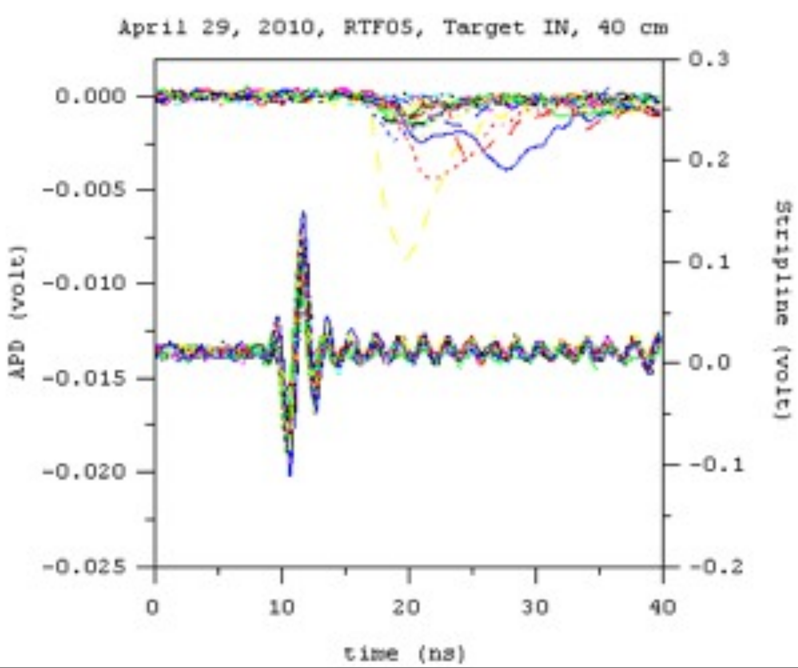


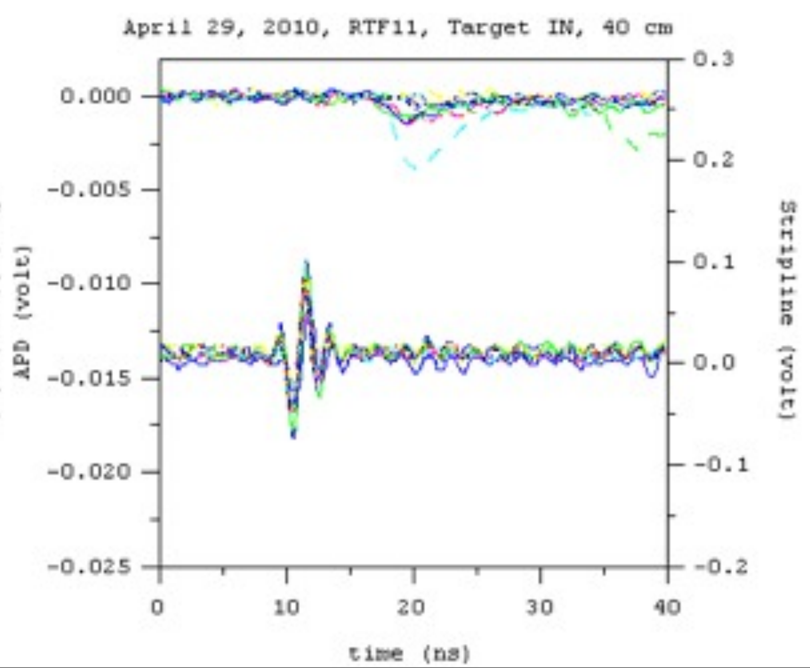
Target IN 20 cm, 6 mm Pb



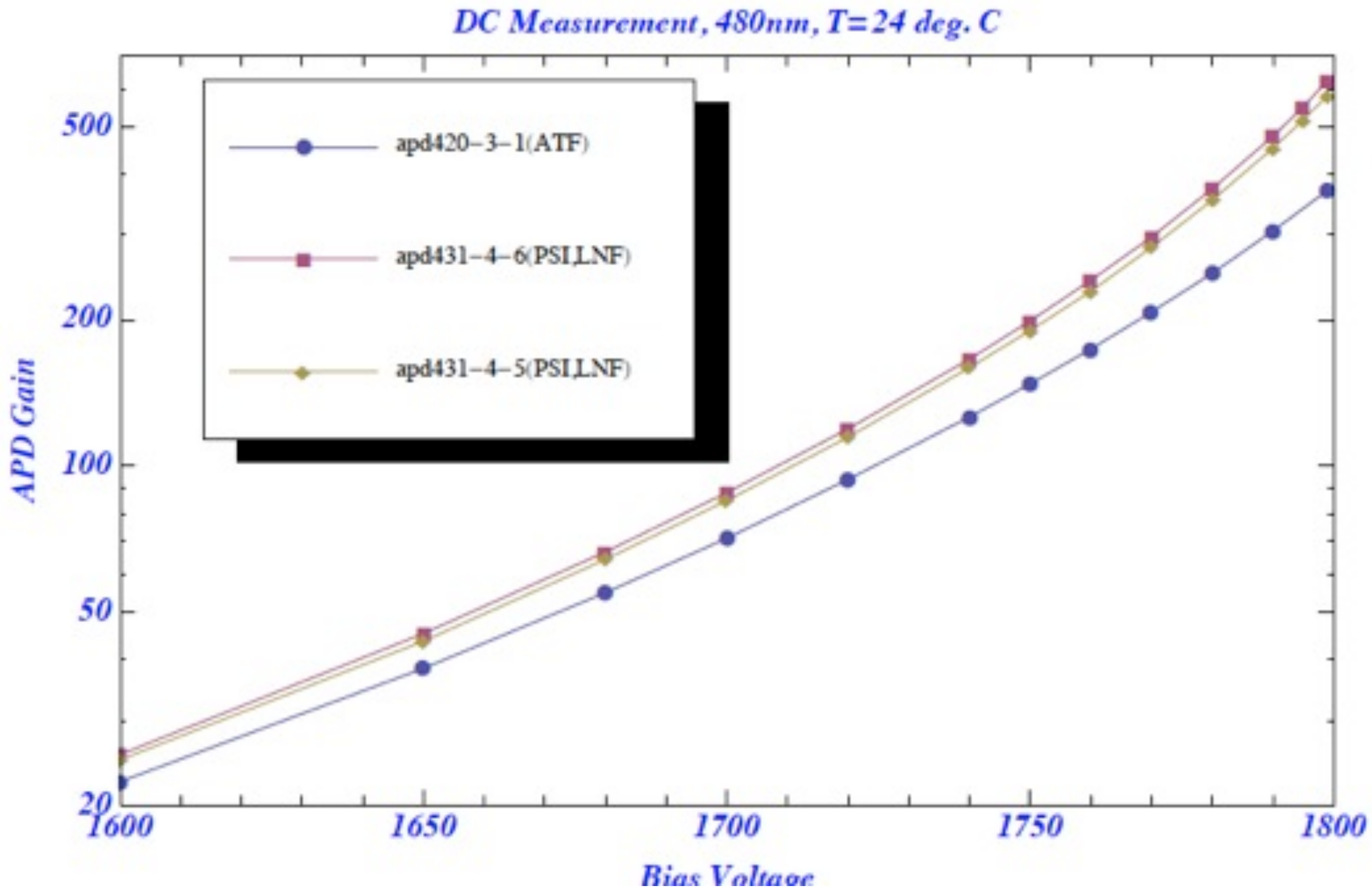


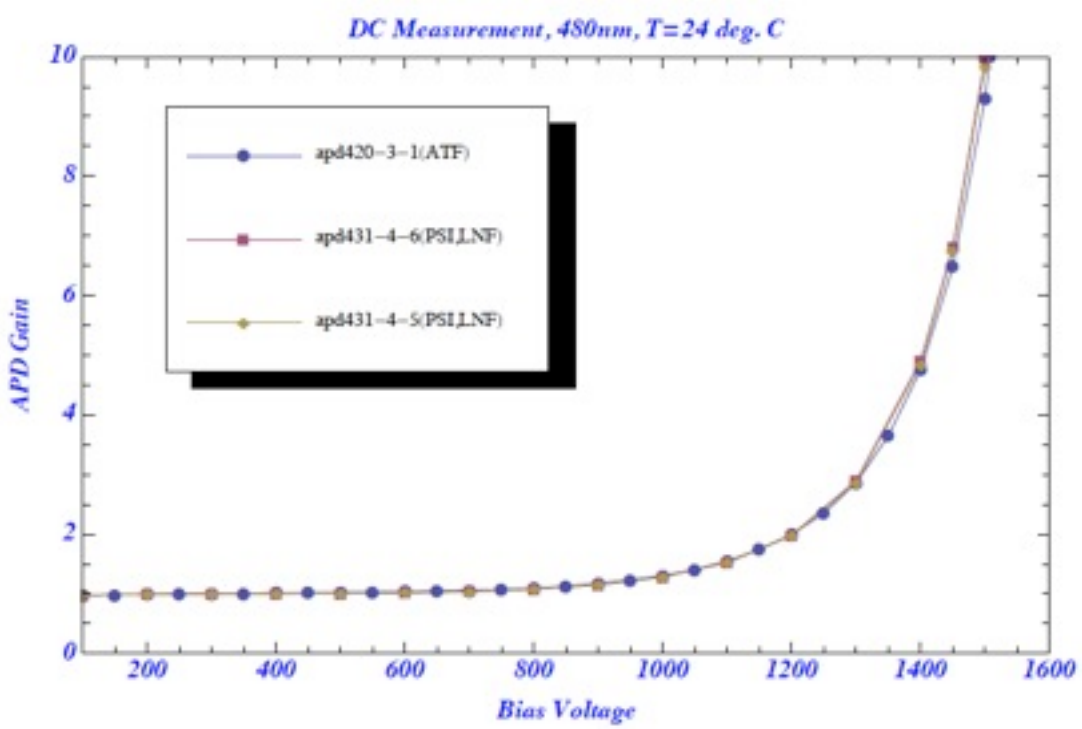
Target IN 40 cm





Gain Curve for APDs used in Frascati/PSI





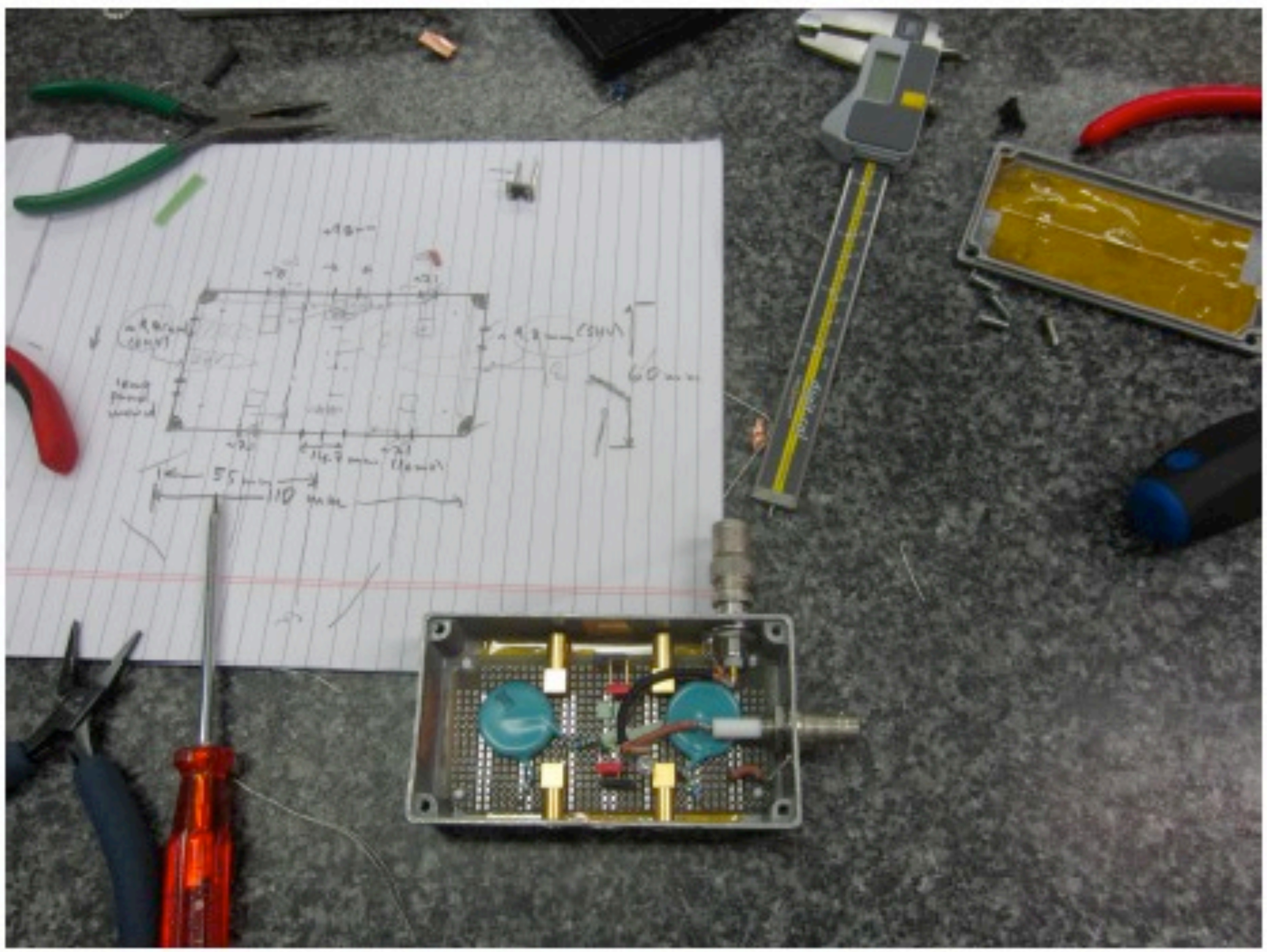
Expected APD mip signal

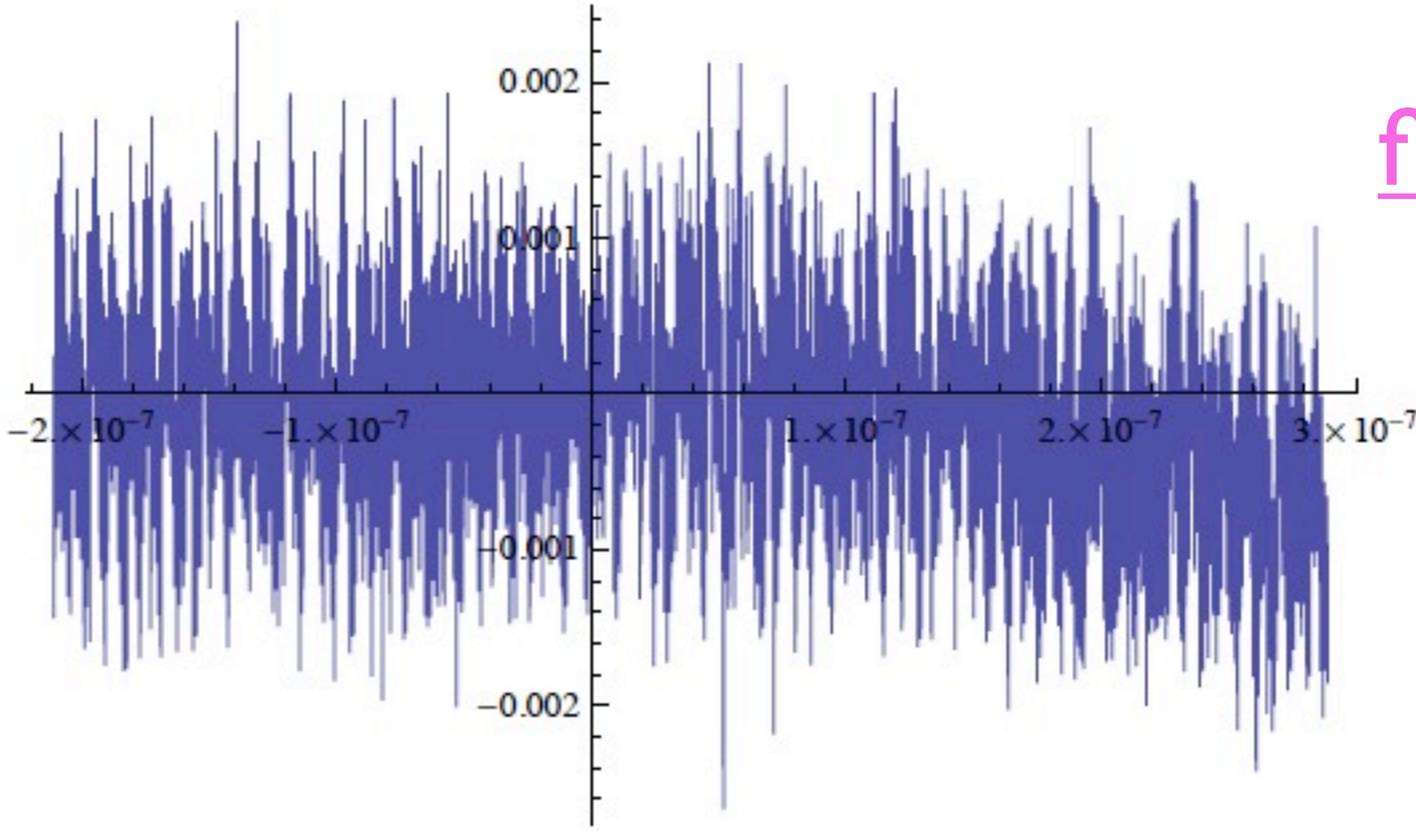
```
In[130]:=
q = 6000 * 200 * 1.6 * 10^-19;
ampgain = 8;
t = 5 * 10^-9;
i = 2 * q / t;
mV = 1000;
e = i * 50 * mV * ampgain

Out[135]= 30.72
```

In Nov/Dec. '11 at CERN focused on getting fastest possible signal from apd. Low noise, fast amplifiers, LRS 6 GHz, 40 GSa/s scope, etc.

help from Crispin Williams, Fritz Caspers,Christian Joram, Iouri Musienko, Philippe Farthouat, Xavier Boissier...

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





first demonstrate need for doing it carefully!

```
slice = ConstantArray[0, npts - 2]; tfit = ConstantArray[0, npts - 2];
{tfit, slice} = Transpose[gain];
dt = tfit[[2]] - tfit[[1]]
```

$5. \times 10^{-11}$

Interpolation. Takes Days.

```
shannon[t_] := -Sum[slice[[j]]*Sinc[Pi*(t - tfit[[j]])/dt], {j, 1, npts - 2}];
FourierTransform[shannon[t], t, ω]
```

- **Discrete Fourier Transform. Quicker.**

```
Timing[ fftslice = Fourier[slice]; ]
```

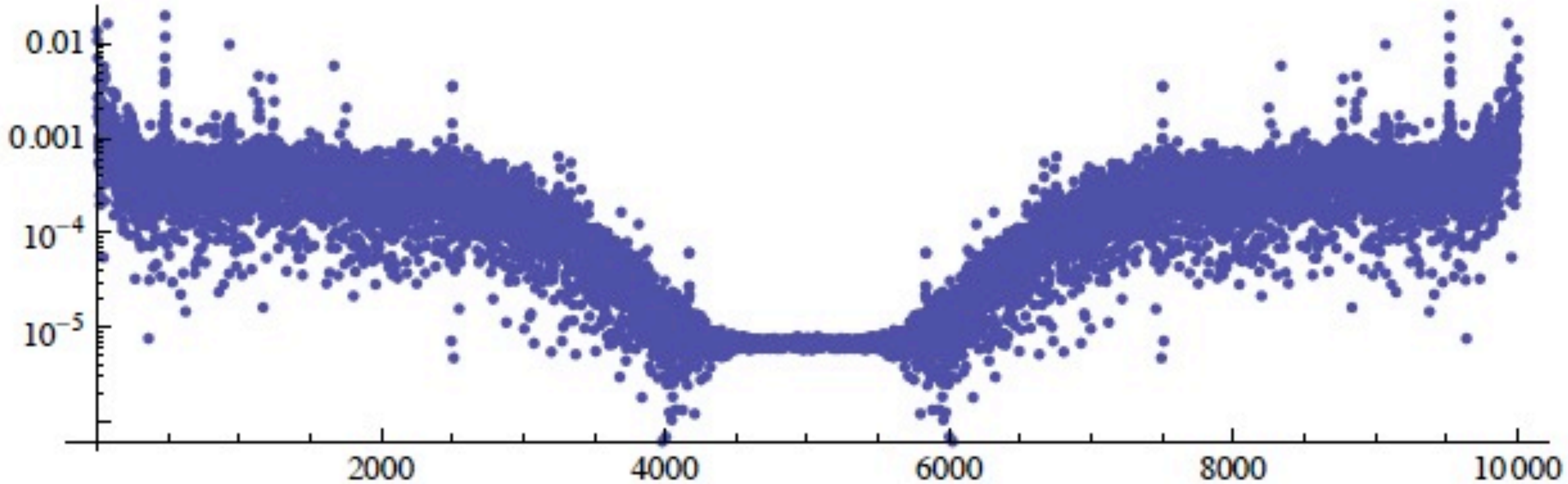
{0.012667, Null}

```
Dimensions[fftslice]
```

{10 002}

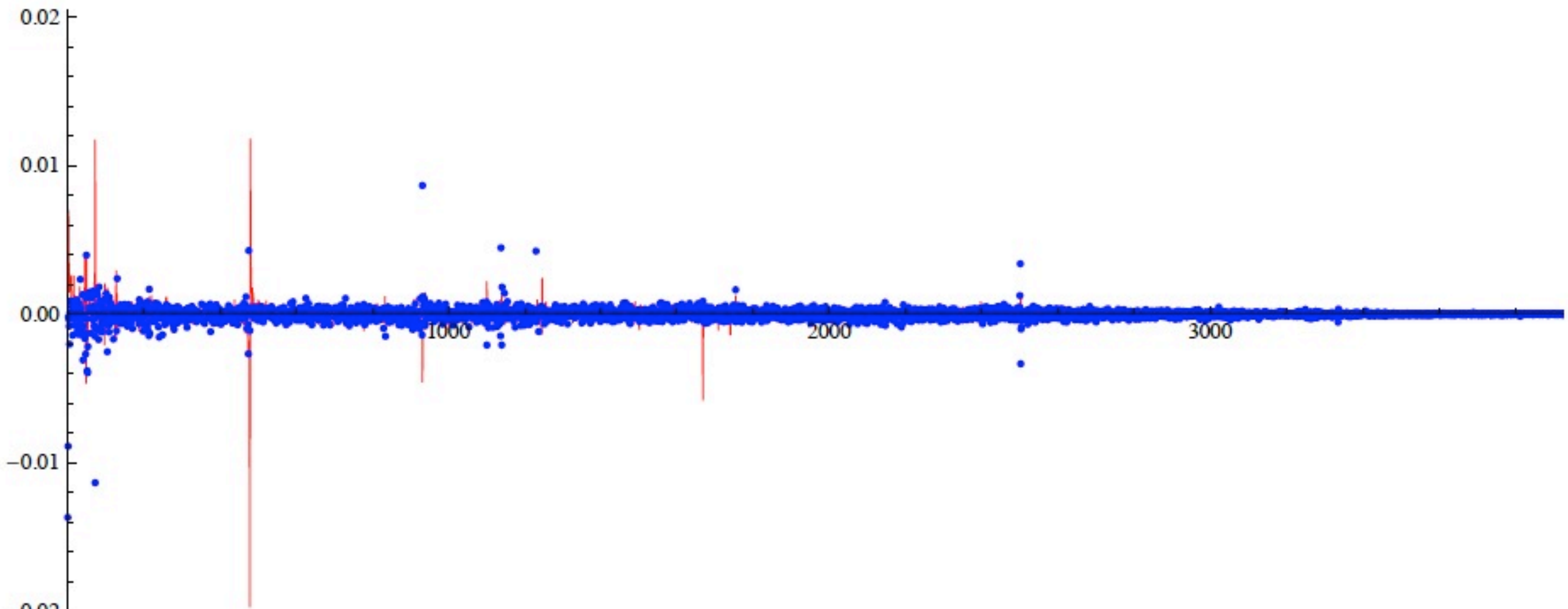
This has zero frequency in element 1. The 5002-th element corresponds to 1/2 the sampling frequency. After that aliassing takes over and the frequency heads back to zero.

```
ListLogPlot[Abs[fftslice], AspectRatio → 0.3, PlotRange → All]
```

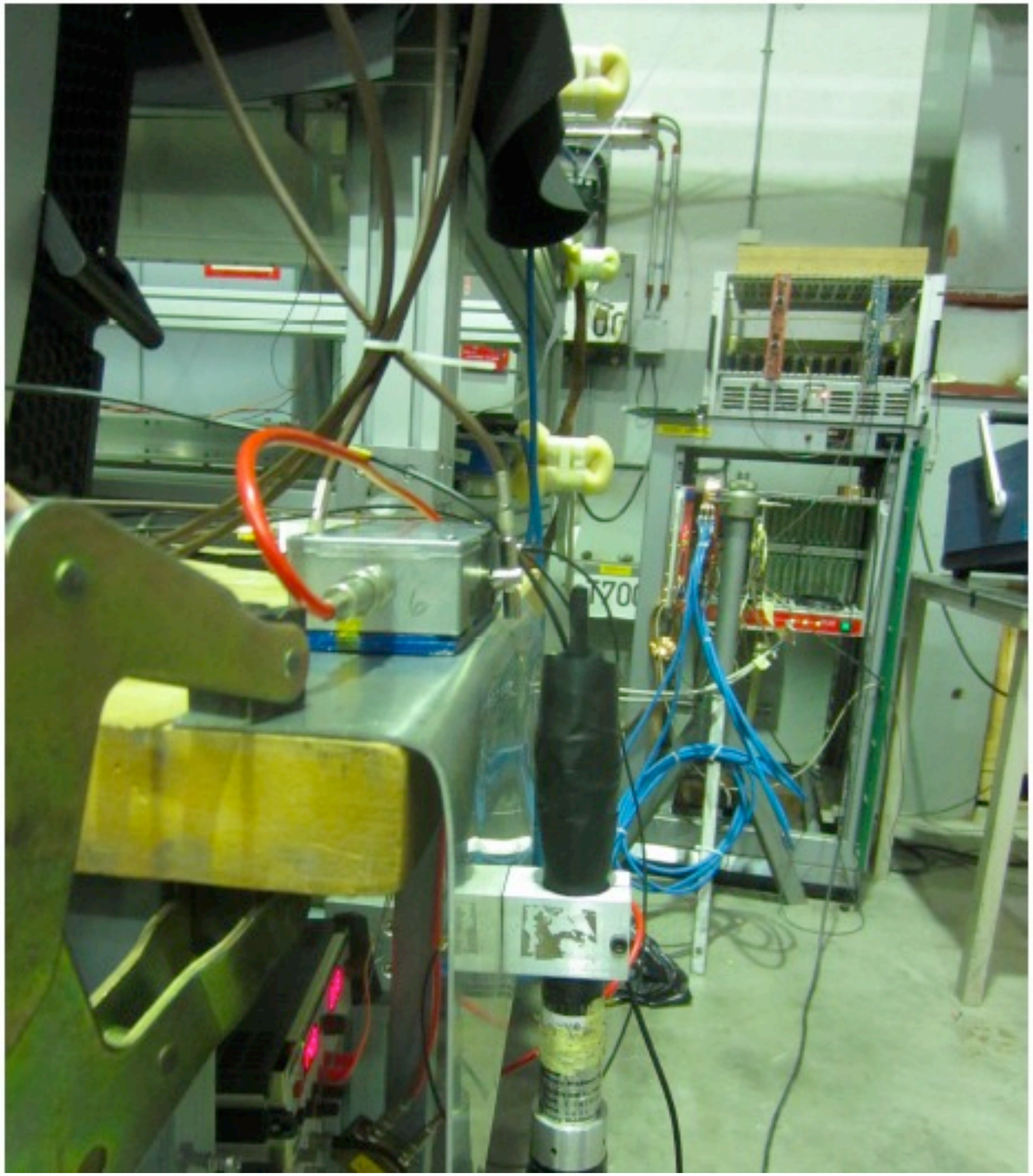


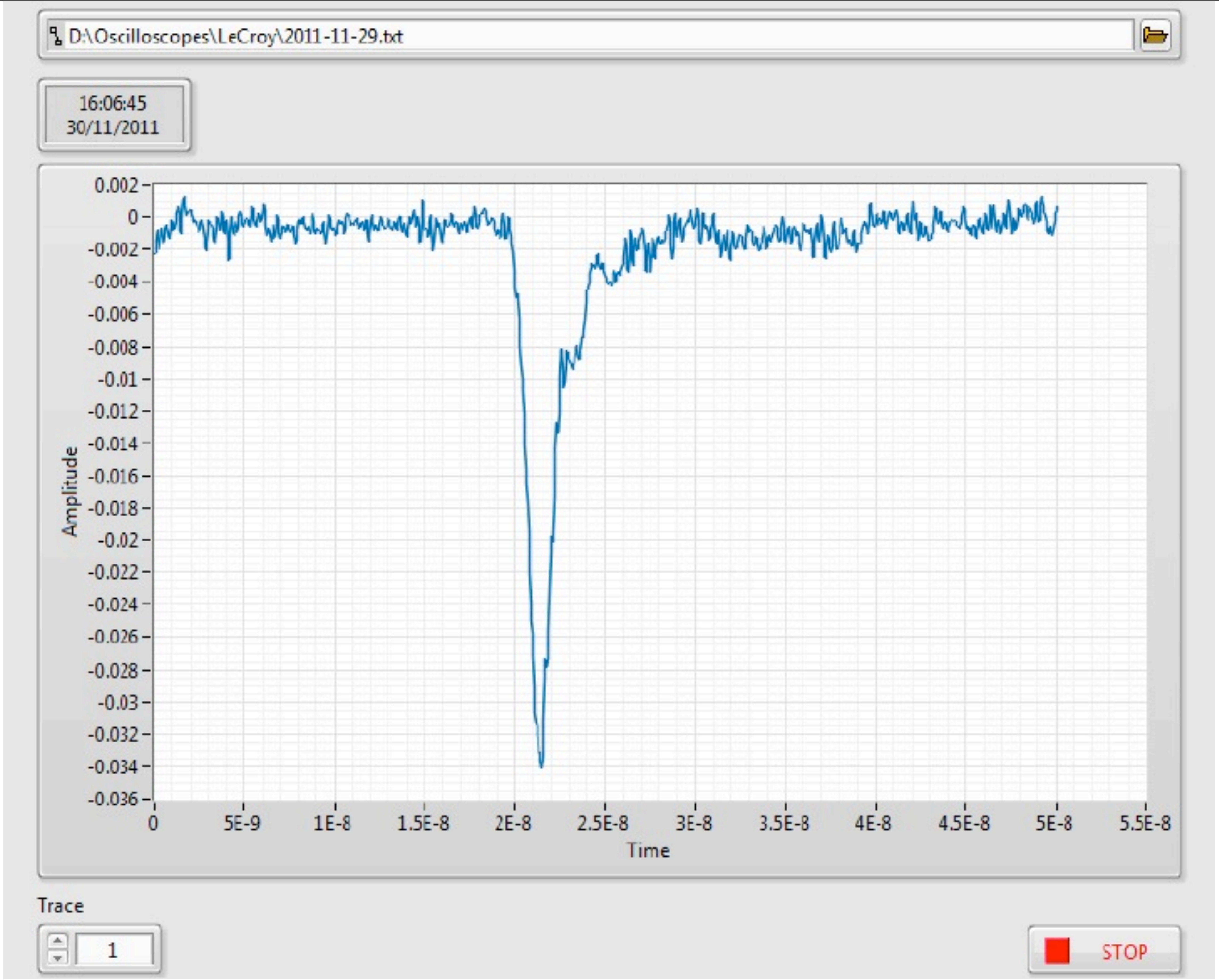
Separate Real and Imaginary components.

```
ListPlot[{Re[fftslice], Im[fftslice]}, AspectRatio → 0.4, PlotRange → {{0, 4000}, All},
  PlotStyle → {Blue, Red}, Joined → {False, True}]
```

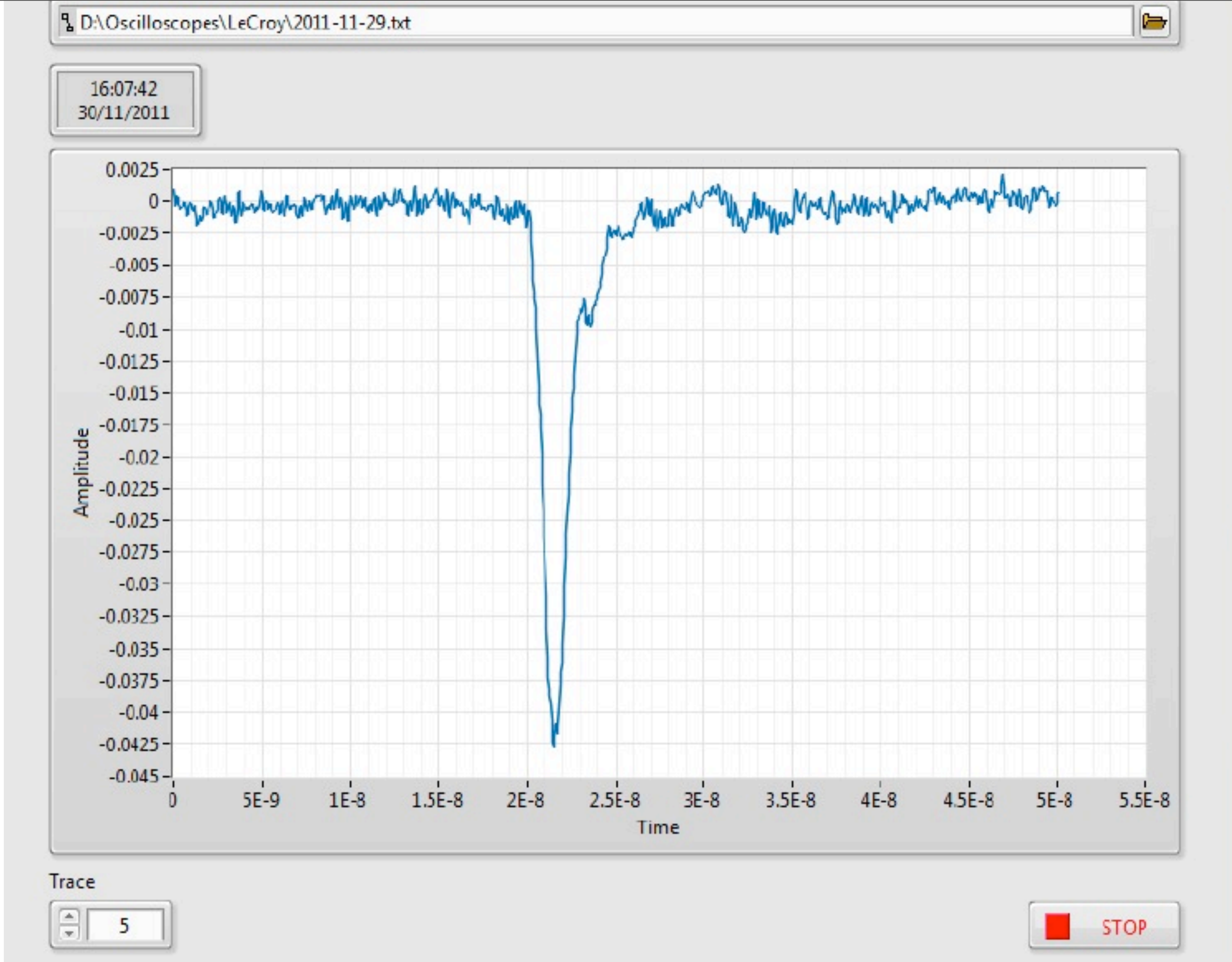


Telescope for PSI test (only the components on the aluminium bracket will be placed in the beam).





D:\Oscilloscopes\LeCroy\2011-11-29.txt
16:06:45
30/11/2011
Amplitude
Time
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
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
Trace
1
STOP

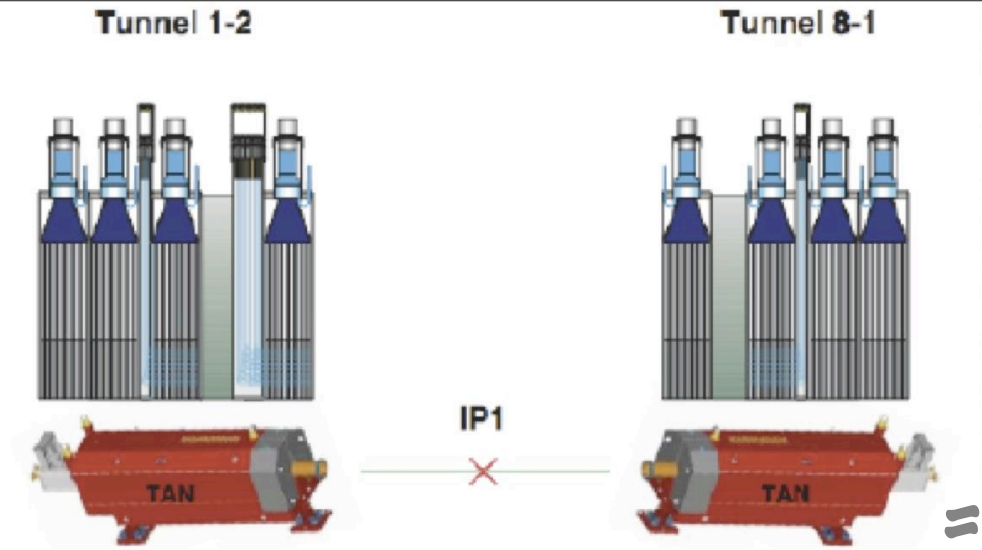


More Amplifiers with higher bandwidth just arrived from Princeton=>this will improve both risetime and SNR.

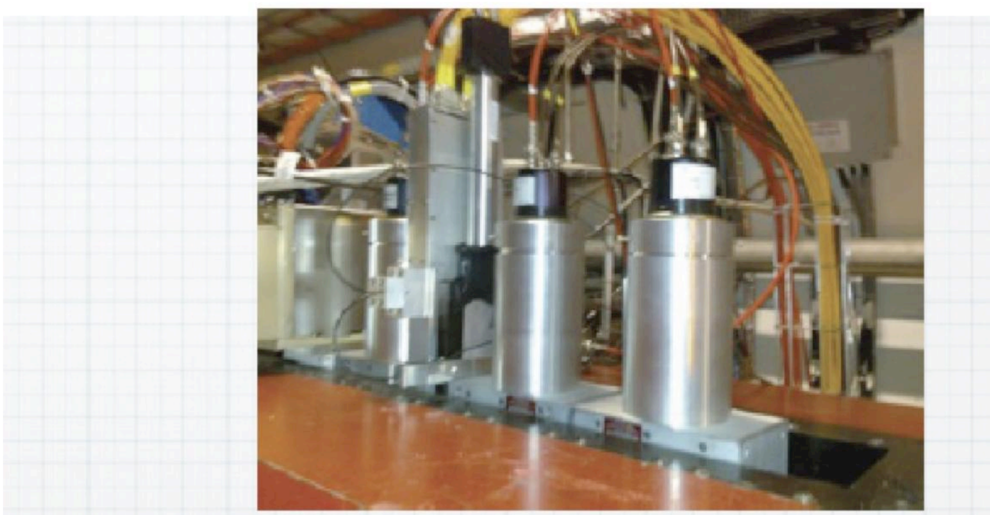
What is optimal signal processing?

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...



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

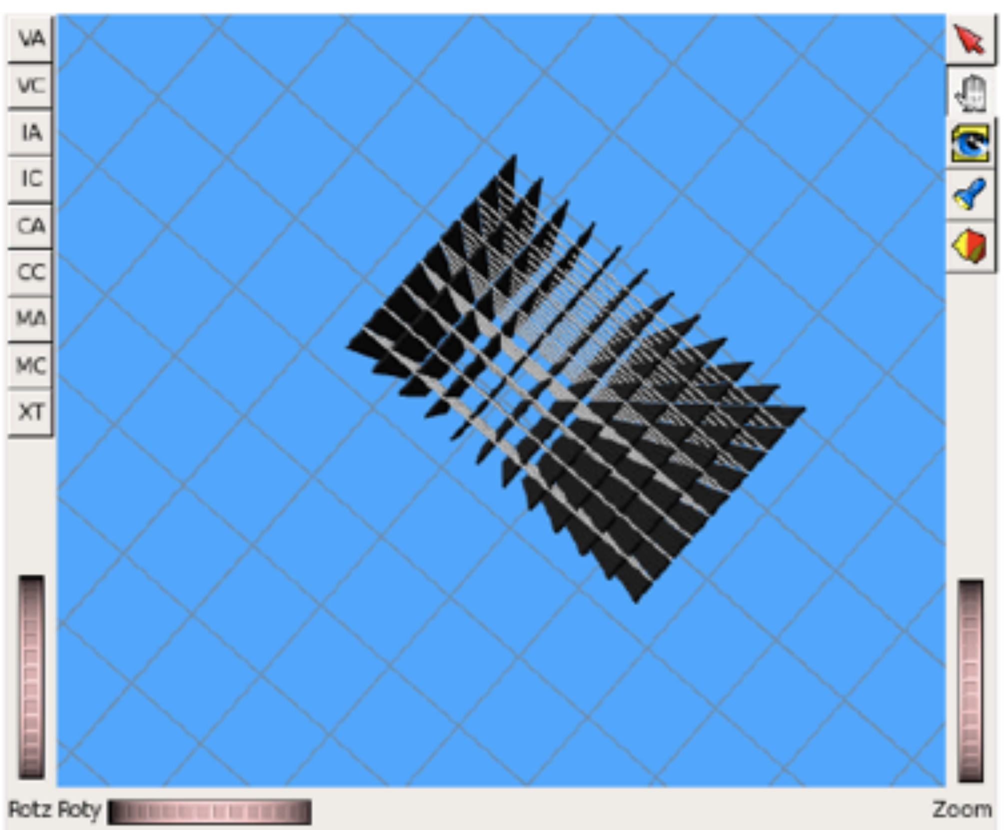
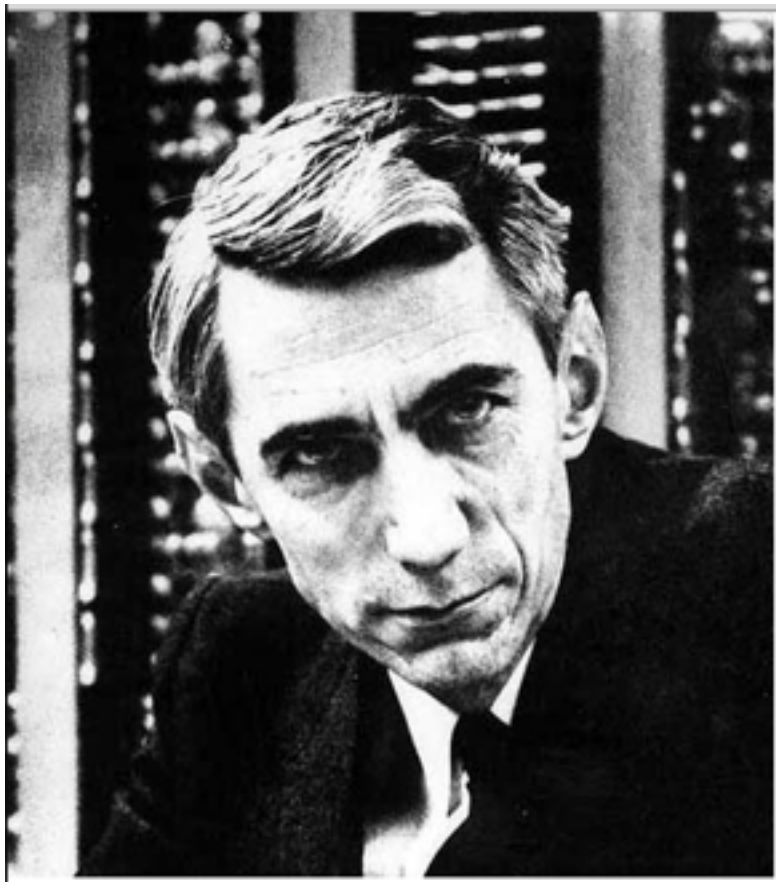


Figure 4: ZDC Drawn with VP1. Plot shows the grid of Strips and Pixels within the EMXY Module



Optimal reconstruction of sparsely sampled ZDC waveforms

- resulted in Shannon's 1940 PhD thesis at MIT, *An Algebra for Theoretical Genetics*[6]
- Victor Shestakov, at Moscow State University, had proposed a theory of electric switches based on Boolean logic a little bit earlier than Shannon, in 1935, but the first publication of Shestakov's result took place in 1941, after the publication of Shannon's thesis.
- The theorem is commonly called the **Nyquist sampling theorem**, and is also known as **Nyquist–Shannon–Kotelnikov**, **Whittaker–Shannon–Kotelnikov**, **Whittaker–Nyquist–Kotelnikov–Shannon**, **WKS**, etc., sampling theorem, as well as the **Cardinal Theorem of Interpolation Theory**. It is often referred to as simply ***the sampling theorem***.
- The theoretical rigor of Shannon's work completely replaced the *ad hoc* methods that had previously prevailed.
- Shannon and Turing met every day at teatime in the cafeteria.[8] Turing showed Shannon his seminal 1936 paper that defined what is now known as the "Universal Turing machine"[9][10] which impressed him, as many of its ideas were complementary to his own.
- He is also considered the co-inventor of the first wearable computer along with Edward O. Thorp.[16] The device was used to improve the odds when playing roulette.

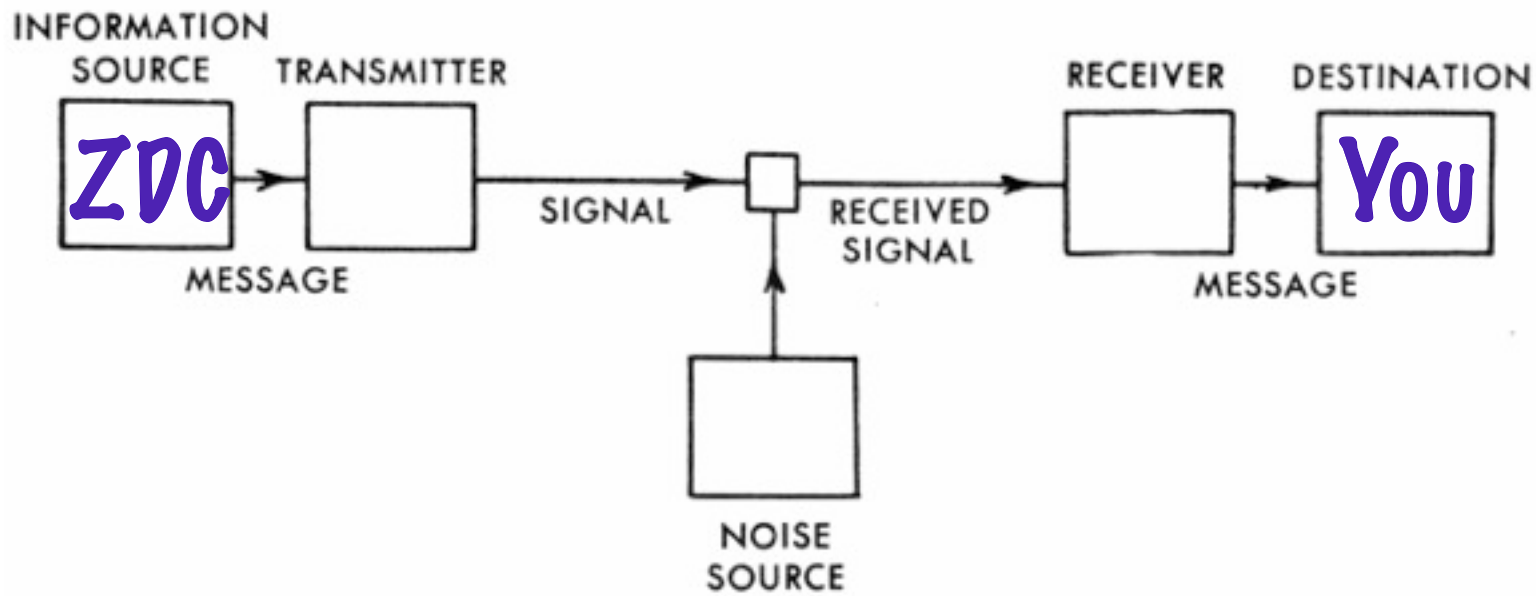
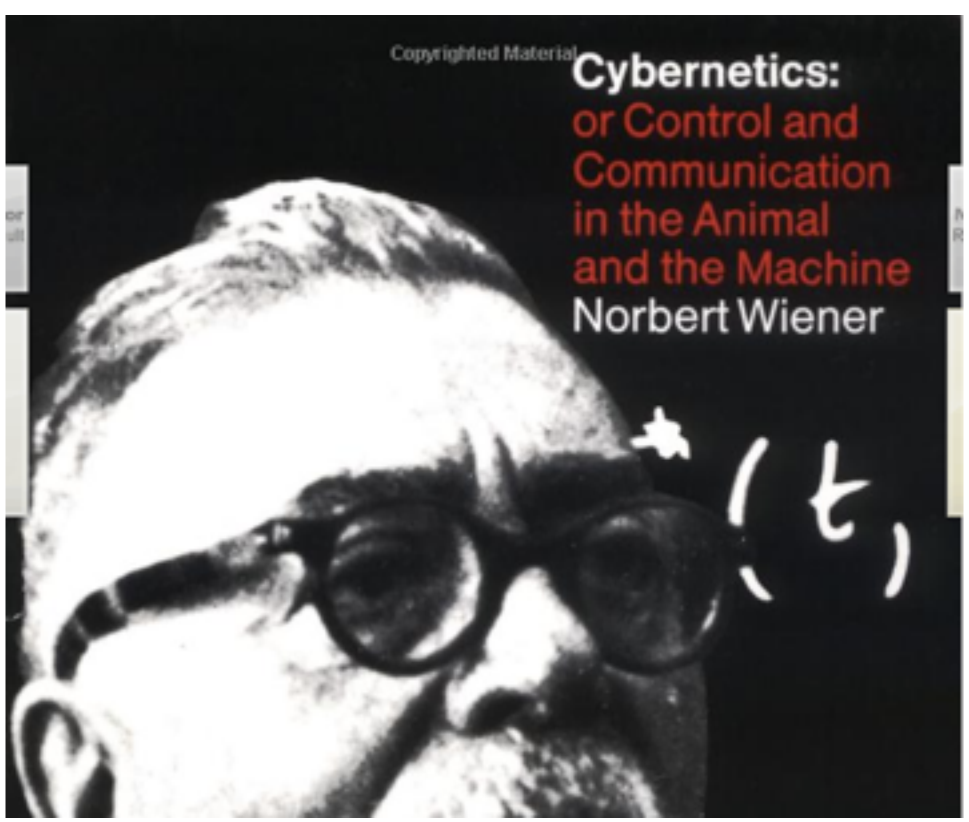
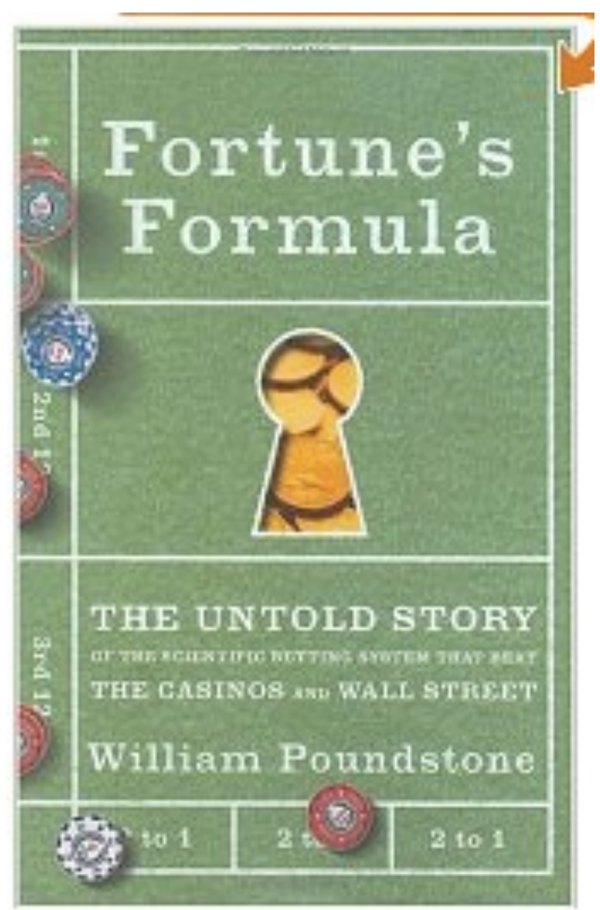


Fig. 1. — Schematic diagram of a general communication system.

books about Shannon:

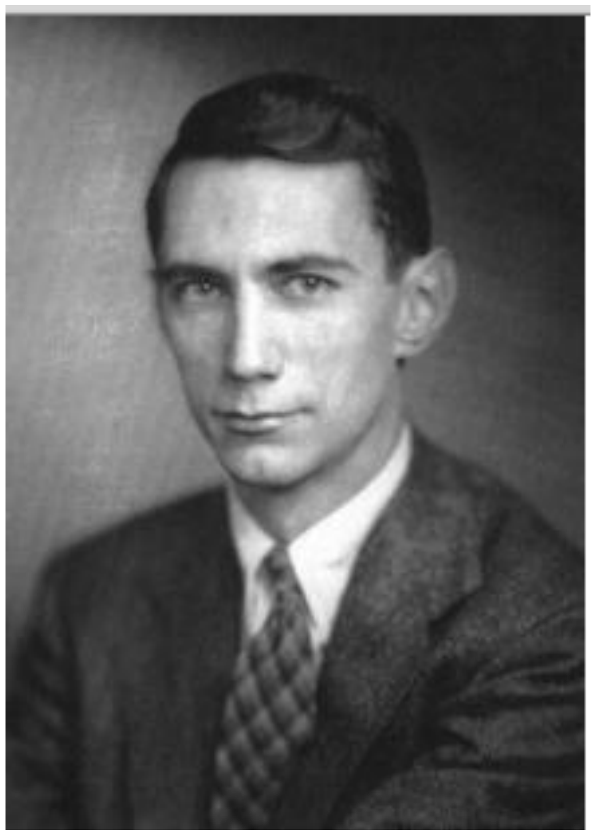




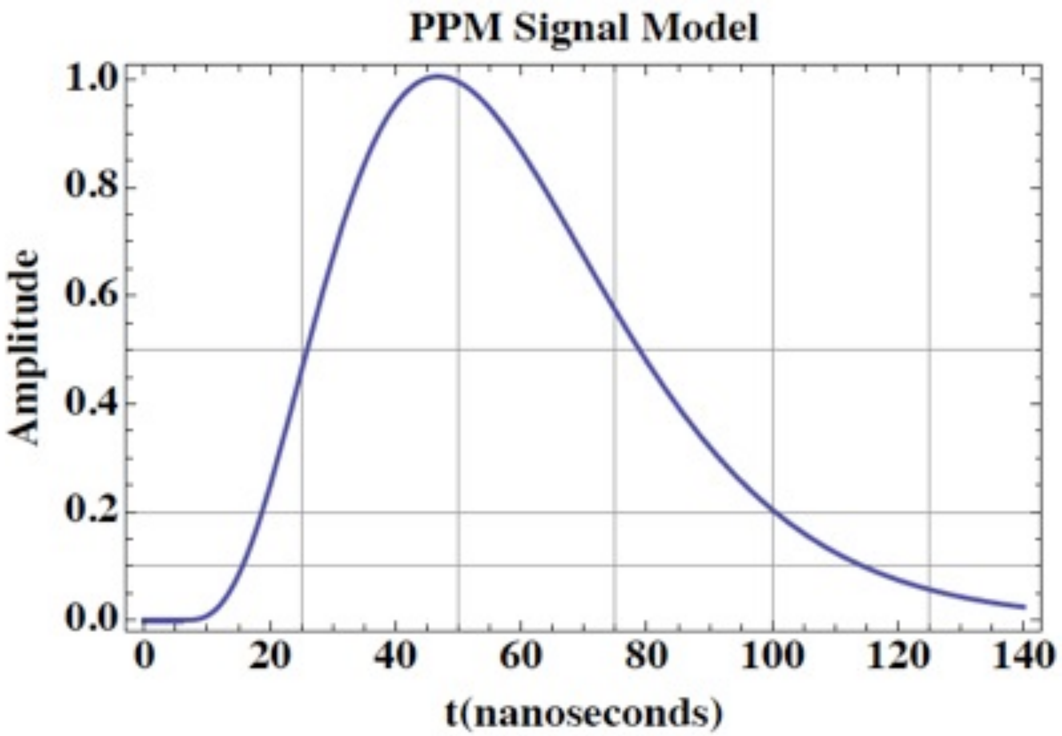
In 1956 two Bell Labs scientists discovered the scientific formula for getting rich. One was the mathematician Claude Shannon, neurotic father of our digital age, whose genius is ranked with Einstein's. The other was John L. Kelly, Jr., a gun-toting Texas-born physicist. Together they applied the science of information theory—the basis of computers and the Internet—to the problem of making as much money as possible, as fast as possible. Shannon and MIT mathematician Edward O. Thorp took the "Kelly formula" to the roulette and blackjack tables of Las Vegas. It worked. They realized that there was even more money to be made in the stock market, specifically in the risky trading known as arbitrage. Thorp used the Kelly system with his phenomenally successful hedge fund Princeton-Newport Partners. Shannon became a successful investor, too, topping even Warren Buffett's rate of return and

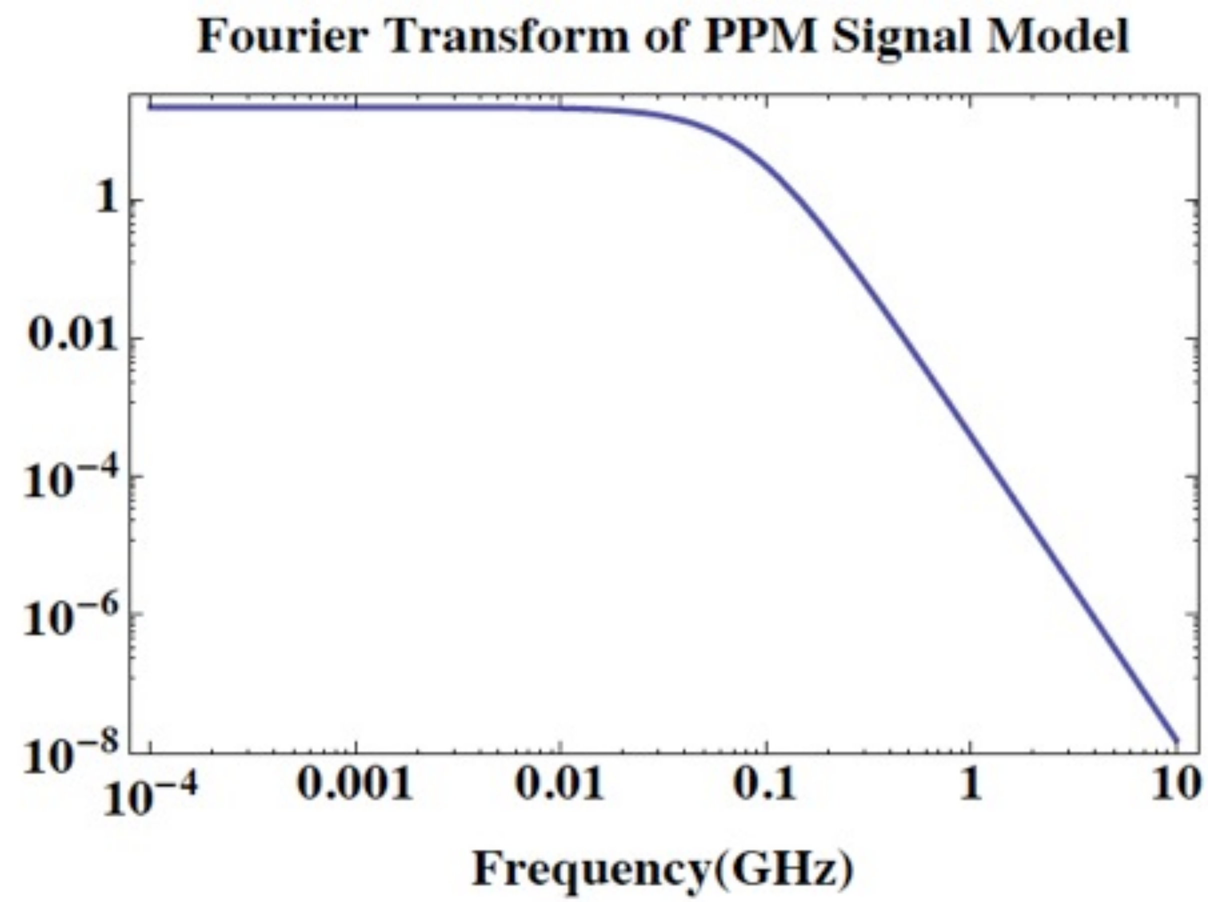
no time to discuss Shannon's method for getting rich

will discuss Shannon's method for reconstructing digitized waveforms



ZDC waveform: bandwidth limited by low quality cable






```
FourierTransform[(((t - toff) / tdecay) ^trise) * .47 * Exp[- (t - toff) / tdecay], t, ω]
```

$$0.0000662123\left(\frac{6.14786\, e^{6 i \omega}}{\left(\frac{1}{12} - i\omega\right)^{4.4}} + \frac{0.\, e^{-6 i \omega}}{\left(\frac{1}{12} + i\omega\right)^{4.4}} + (0. + 0.\, i)\,\text{Hypergeometric1F1}\left[1, 5.4, -\frac{1}{2} - 6 i \omega\right] - \left(4.26326\times10^{-13} + 1.25056\times10^{-12}\, i\right)\text{Hypergeometric1F1}\left[1, 5.4, -\frac{1}{2} + 6 i \omega\right] + \frac{(0. + 0.\, i)\,\text{HypergeometricPFQ}\left[\{-3.4, -3.9\}, \{-3.4, -3.9\}, -\frac{1}{2} - 6 i \omega\right]}{\left(\frac{1}{12} + i\omega\right)^{4.4}} - \frac{(0.967912 + 2.97893\, i)\,\text{HypergeometricPFQ}\left[\{-3.4, -3.9\}, \{-3.4, -3.9\}, -\frac{1}{2} + 6 i \omega\right]}{\left(\frac{1}{12} - i\omega\right)^{4.4}}\right)$$

<u>=>a sampling frequency of 40 or 80 Mz is below Shannon-Nyquist frequency (=2*B)</u>

$$shannon[t] = \sum_{i=1}^{nslice} slice[i] \times Sinc[\pi \times (t - time(i))/25] \qquad (6)$$

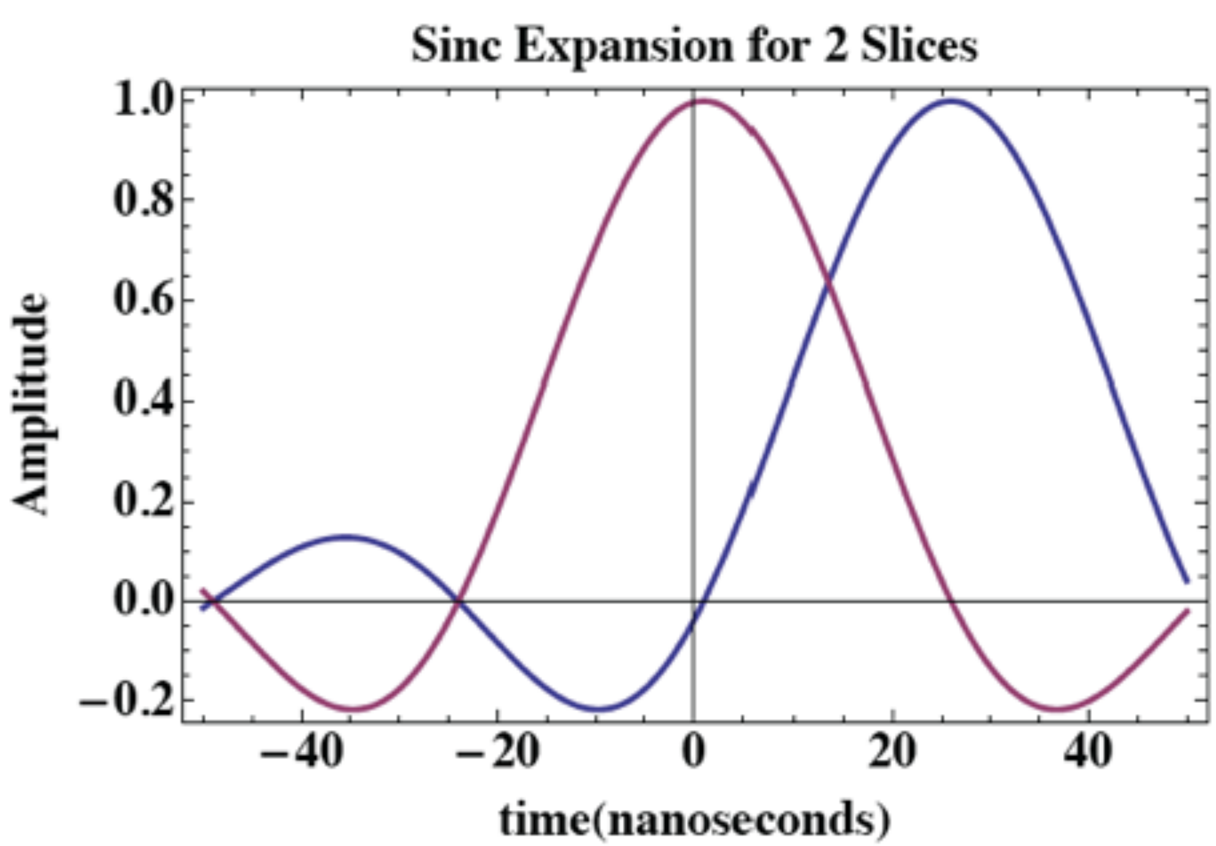
An animated gif can be found at:
http://www.phenix.bnl.gov/phenix/WWW/publish/swhite/ShannonFilm.gif

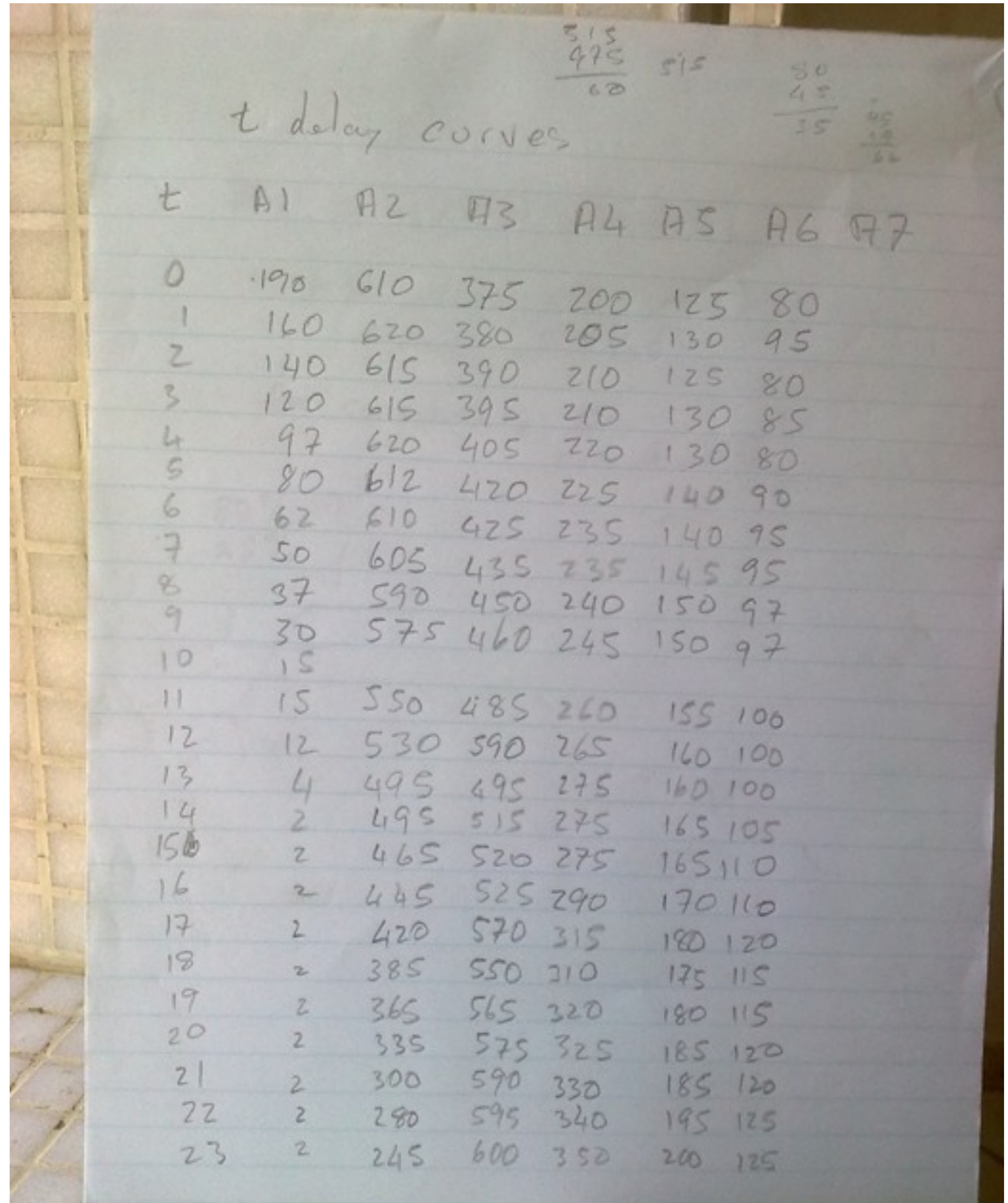
ATLAS data set used to develop ZDC reconstruction and do L1calo calibration (in Mathematica 7.0)

Reconstruction of ZDC Pre-Processor Data and its timing Calibration

Soumya Mohapatra, Andrei Poblaguev and Sebastian White

Aug.8,2010

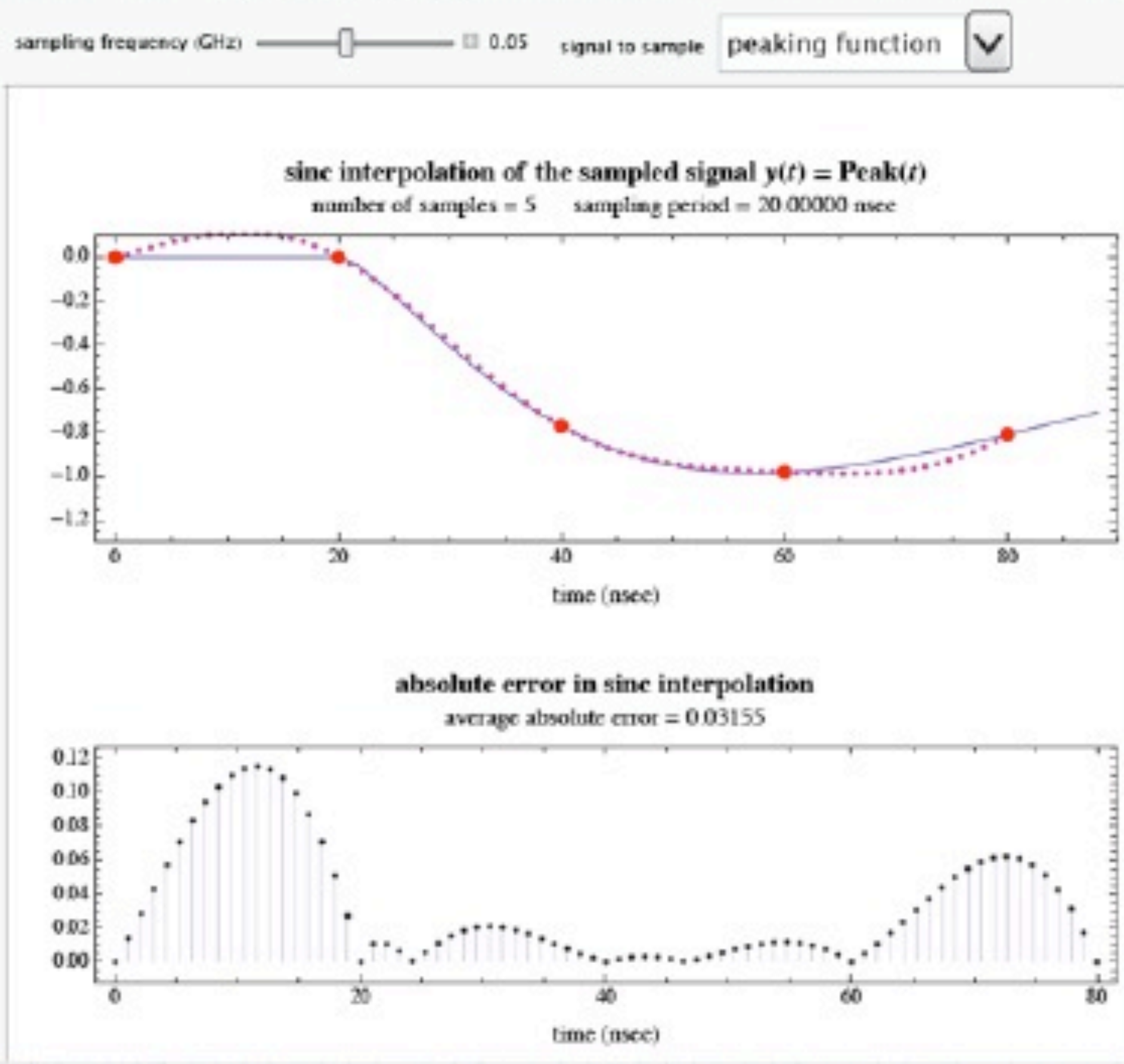


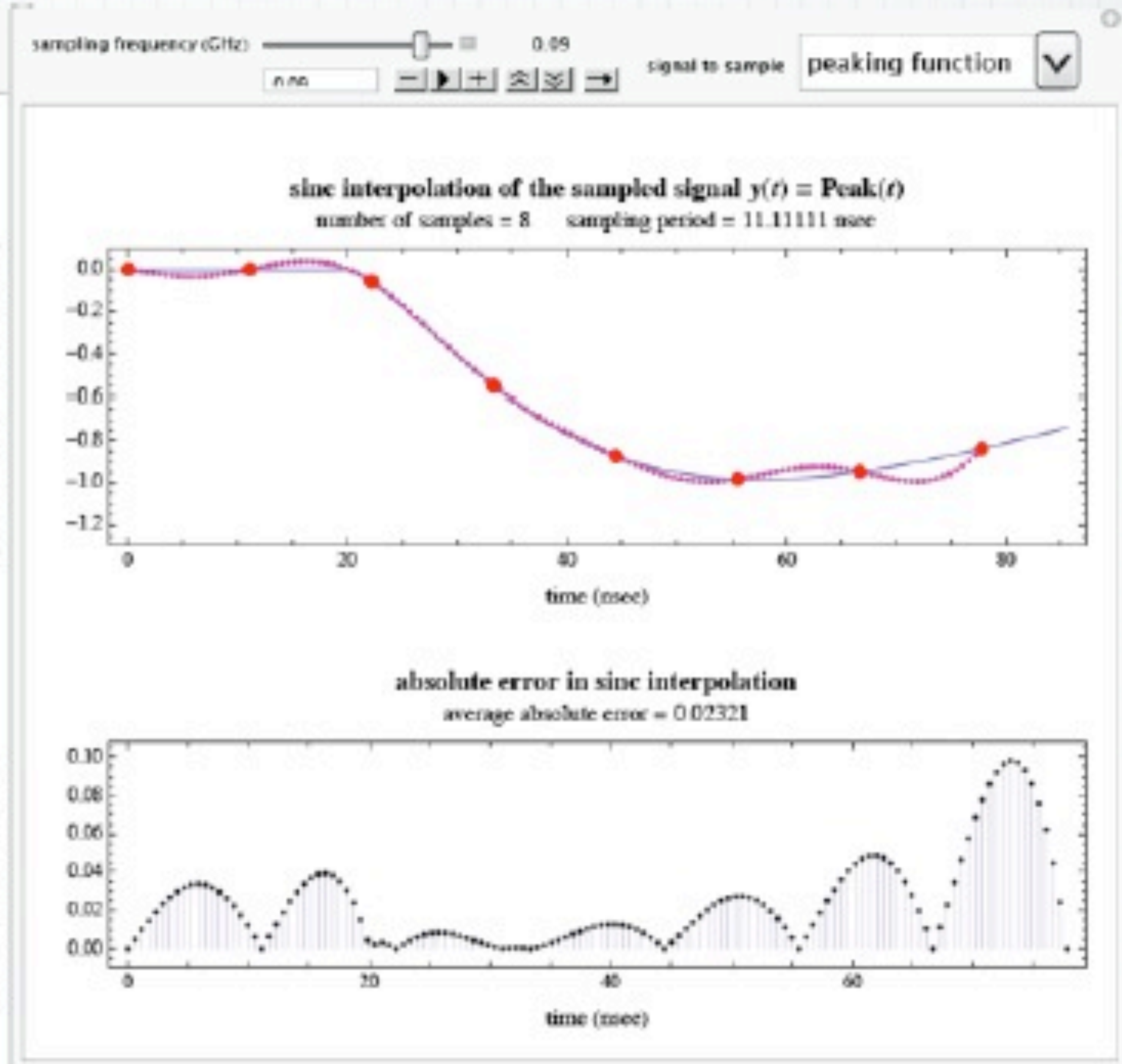


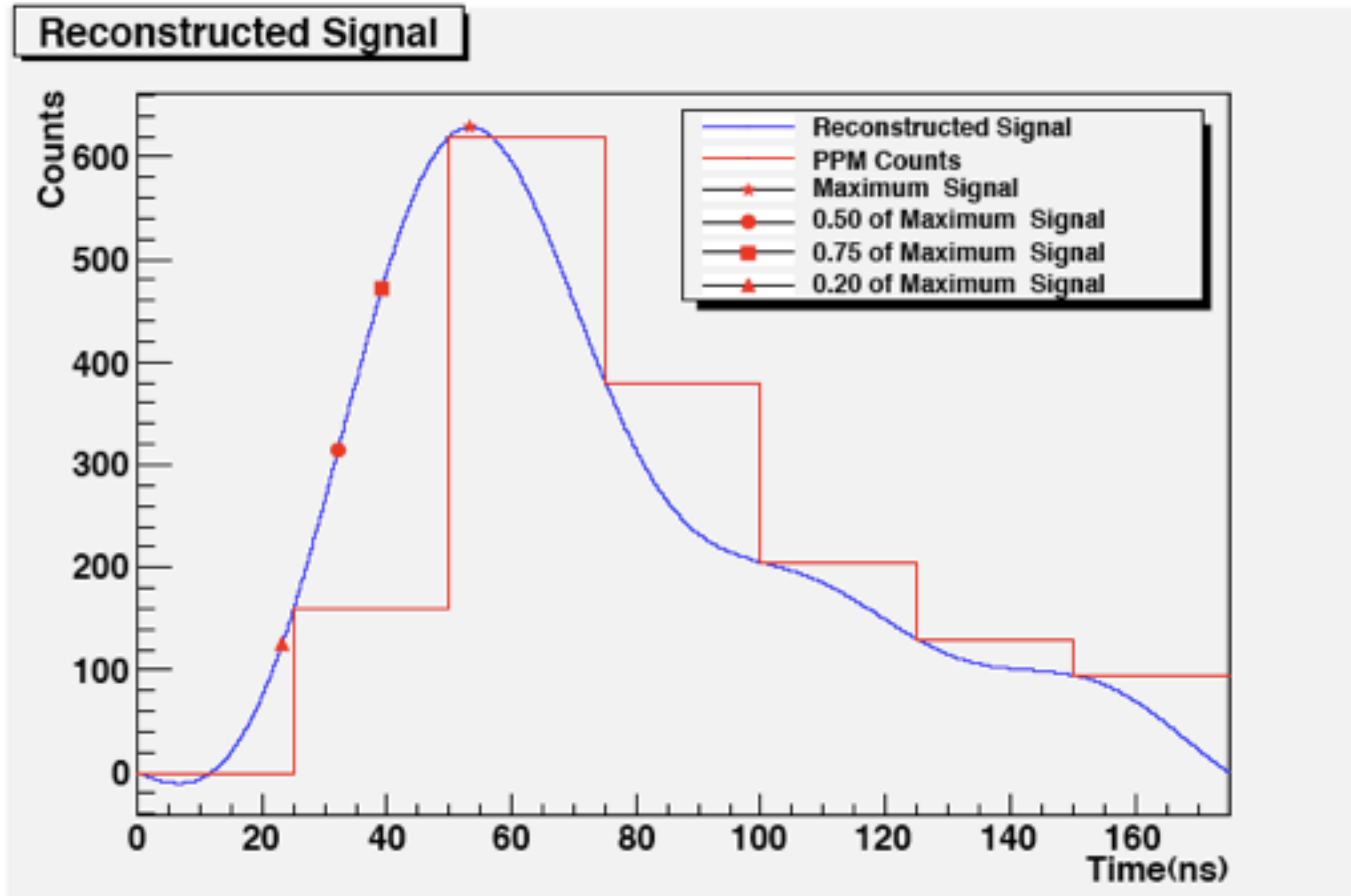
t	A1	A2	A3	A4	A5	A6	A7
0	190	610	375	200	125	80	
1	160	620	380	205	130	95	
2	140	615	390	210	125	80	
3	120	615	395	210	130	85	
4	97	620	405	220	130	80	
5	80	612	420	225	140	90	
6	62	610	425	235	140	95	
7	50	605	435	235	145	95	
8	37	590	450	240	150	97	
9	30	575	460	245	150	97	
10	15						
11	15	550	485	260	155	100	
12	12	530	590	265	160	100	
13	4	495	495	275	160	100	
14	2	495	515	275	165	105	
15	2	465	520	275	165	110	
16	2	445	525	290	170	110	
17	2	420	570	315	180	120	
18	2	385	550	310	175	115	
19	2	365	565	320	180	115	
20	2	335	575	325	185	120	
21	2	300	590	330	185	120	
22	2	280	595	340	195	125	
23	2	245	600	350	200	125	

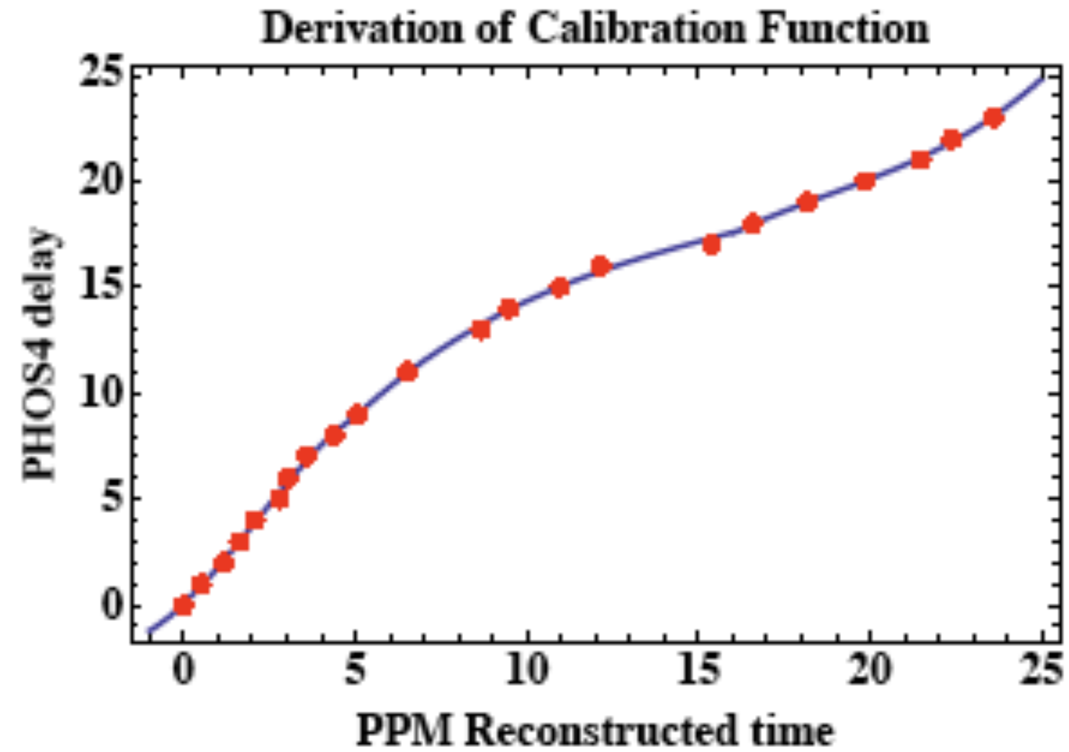
Signal Reconstruction

The document ATL-COM-LUM-2010-027
Title: Reconstruction of ZDC Pre-Processor Data and its timing Calibration
Author(s): Mohapatra, S :SUNYSB
Poblaguev, A :Yale:BNL
White, S :BNL

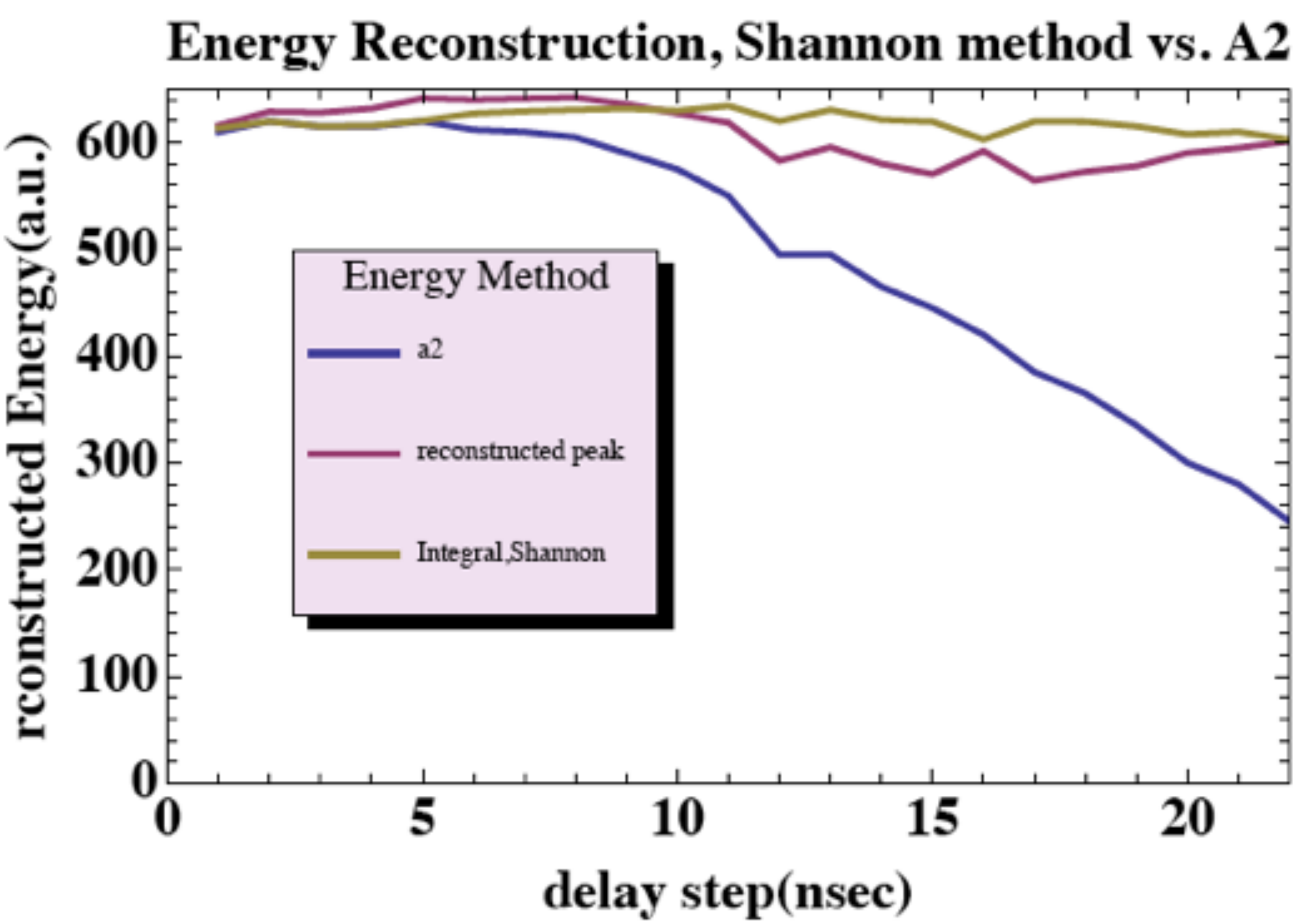




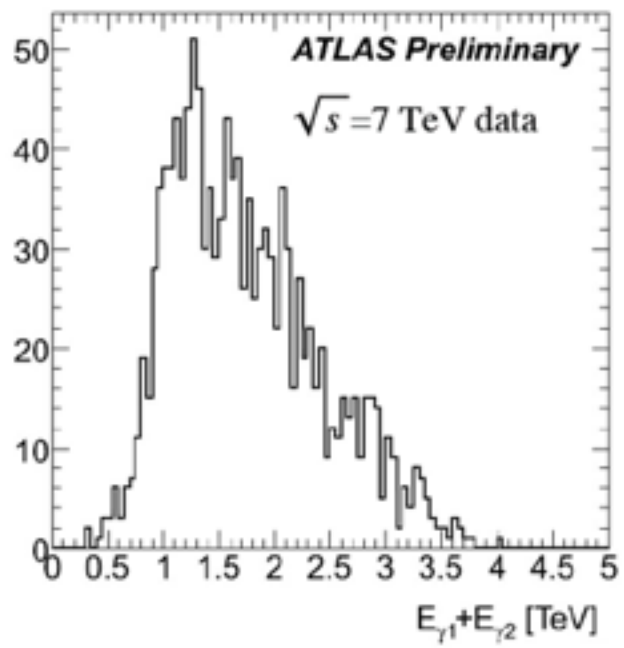




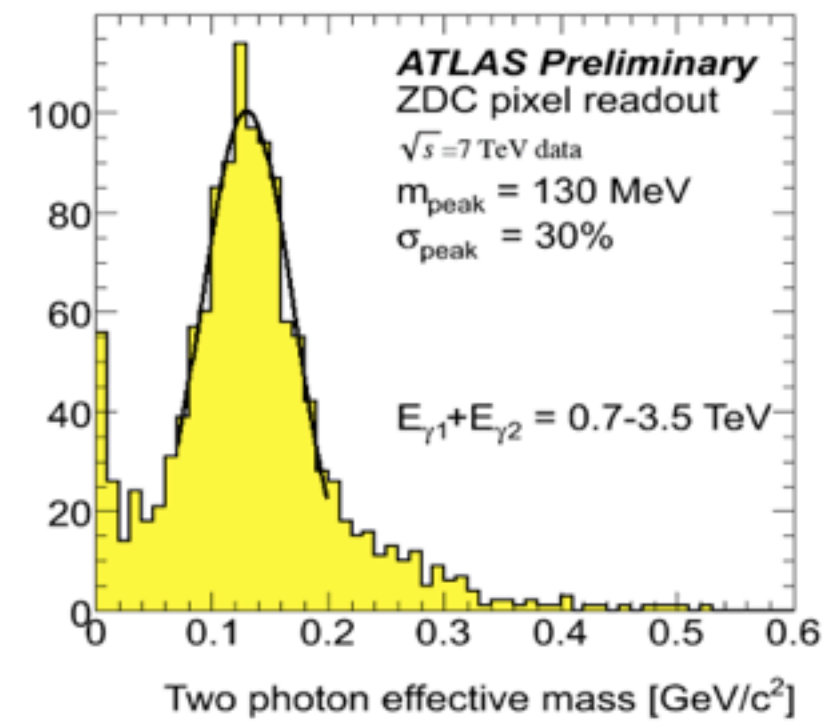
(d) Piecewise fit to the full range.



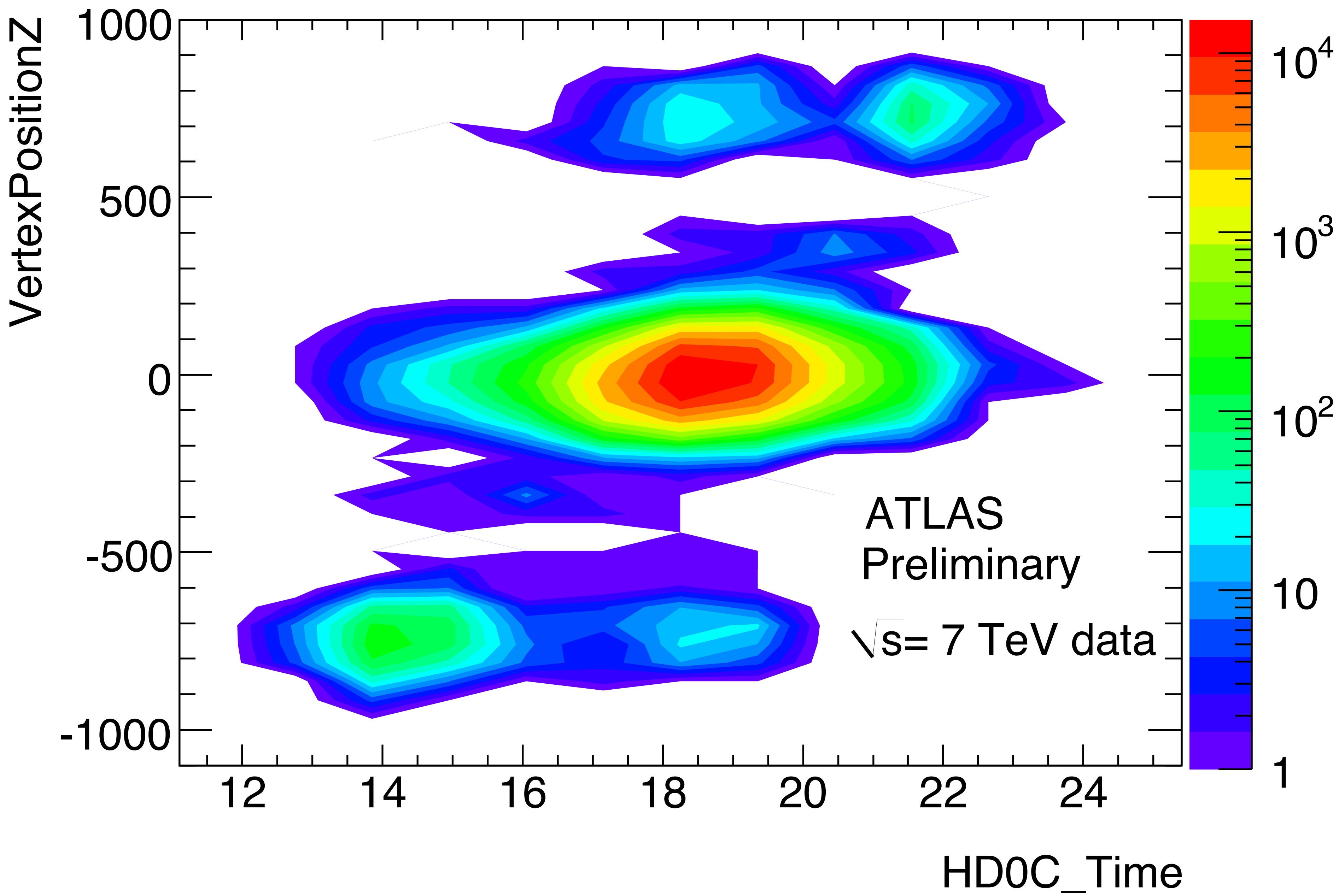
2- photon reconstruction



Energy distribution of 2 photon candidates in the ZDC, selected using the longitudin shower profile. The ZDC energy scale was established using the endpoint measured in 7 TeV collision data. Since the shower energy is concurrently measured in the "pixel" coordinate readout channels this allows energy calibration to be established for these channels also.



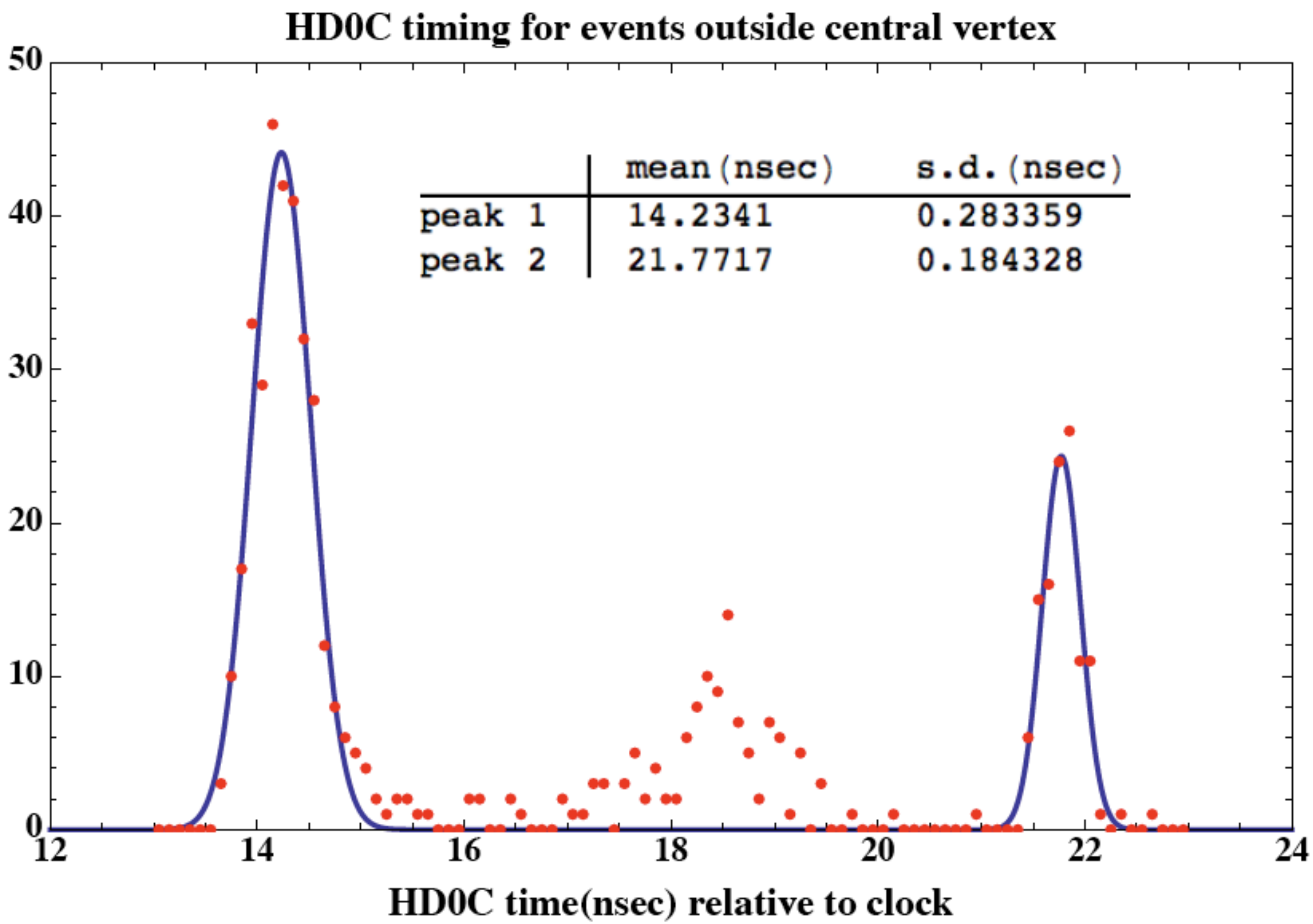
For 7 TeV collision data taken prior to LHCf removal the first ZDC module is the so-called "Hadronic x,y" which has identical energy resolution to all of the other ZDC modules. The coordinate resolution, however, is inferior to that of the high resolution EM, installed 7/20/10. Nevertheless, the reconstructed mass resolution is found to be 30% at m=130 MeV. As is found in ongoing simulation of pi0 reconstruction within the full ATLAS framework (see ZDC simulatic TWIKI), the pi0 width is completely dominated by the energy resolution. Therefore, the current state of ATLAS ZDC photon energy resolution can be inferred from this plot.



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.

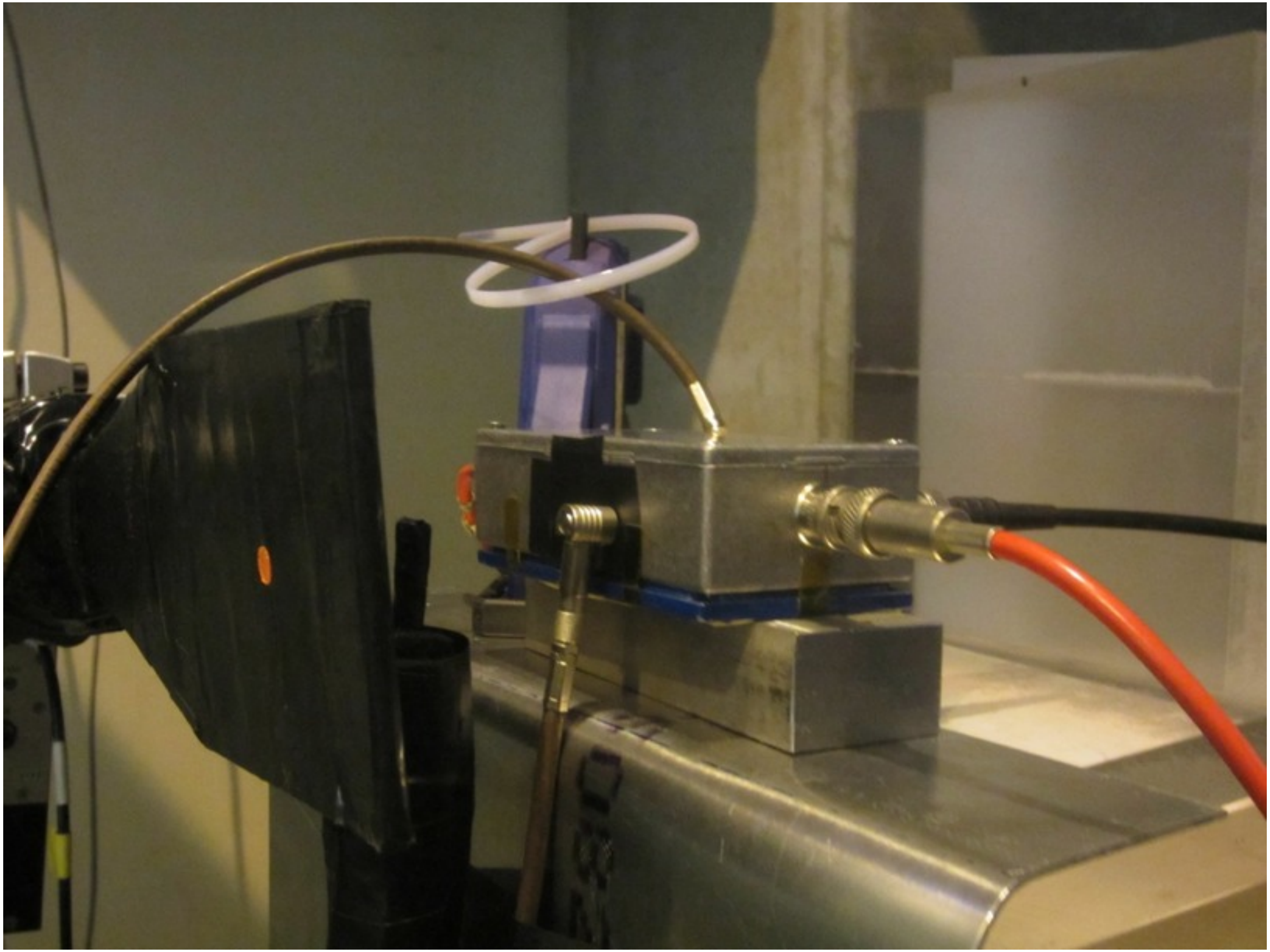
Support material for blessing:

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



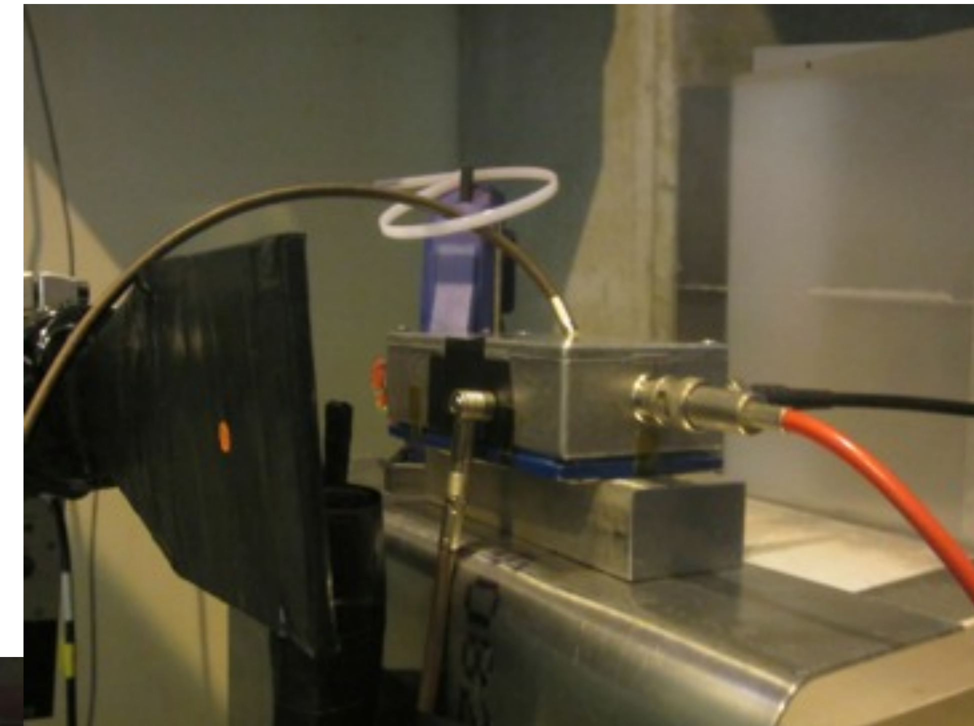
	mean (nsec)	s.d. (nsec)
peak 1	14.2341	0.283359
peak 2	21.7717	0.184328

Picture show

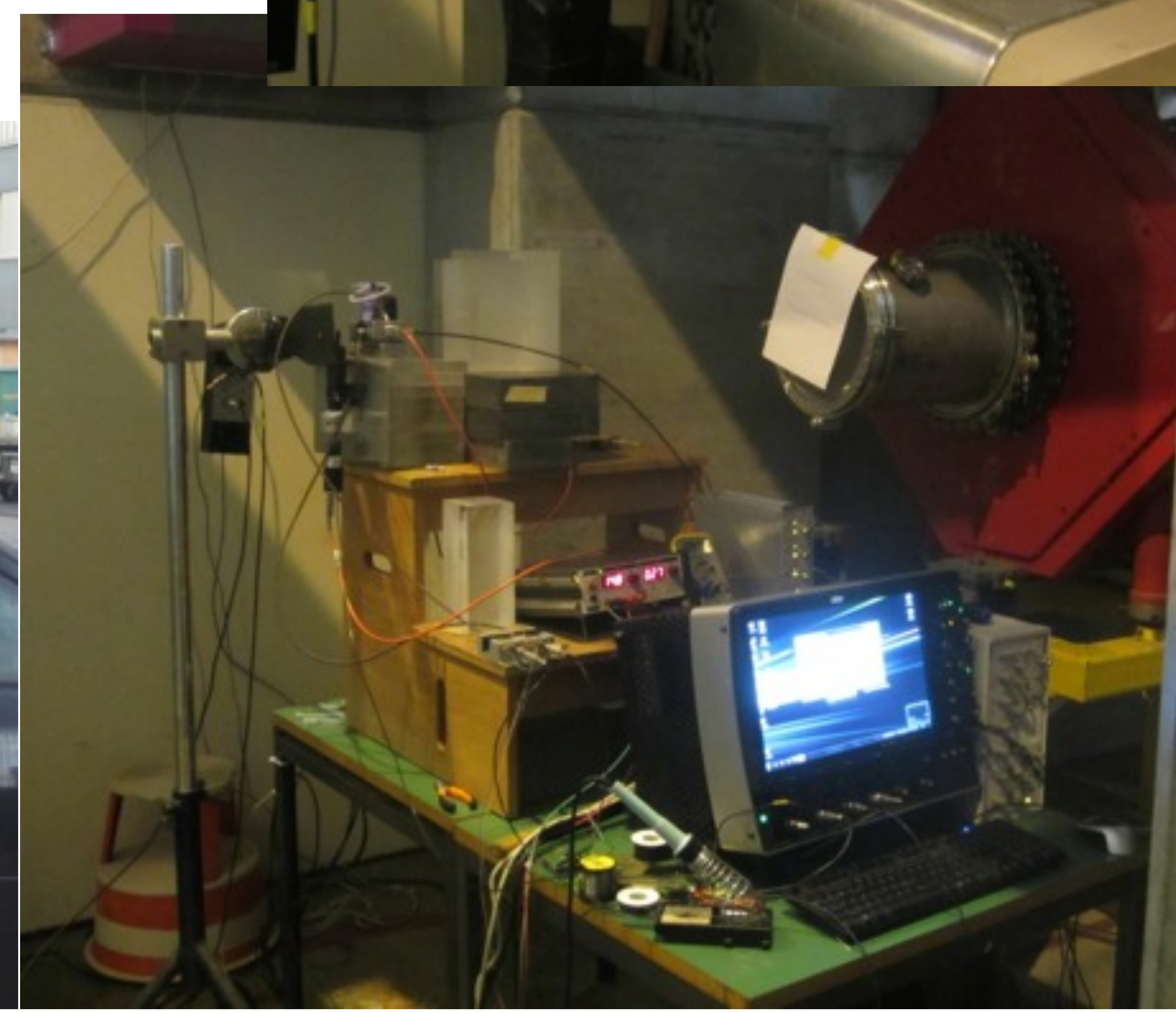



DANGER
DIS-1
RADOS
WHITE.S.N
RMD
Radiation Monitoring Devices, Inc.
R. Farrell
44 Hunt Street, Watertown, Massachusetts 02472
TO Sebastian White
Please return ASAP
Operating Range
Breakdown
1710 - 1810 V
1830 V
1740 - 1870 V
1890 V
DANGER
DRS4 Evaluation Board
TELEMETER ELECTRONIC GMBH
TELEMETER ELECTRONIC GMBH
WolframAlpha
LeCroy

PSI beam test
10 PM, Dec. 1->7 AM, Dec. 2
170 MeV negative beam
hadrons suppressed with absorber



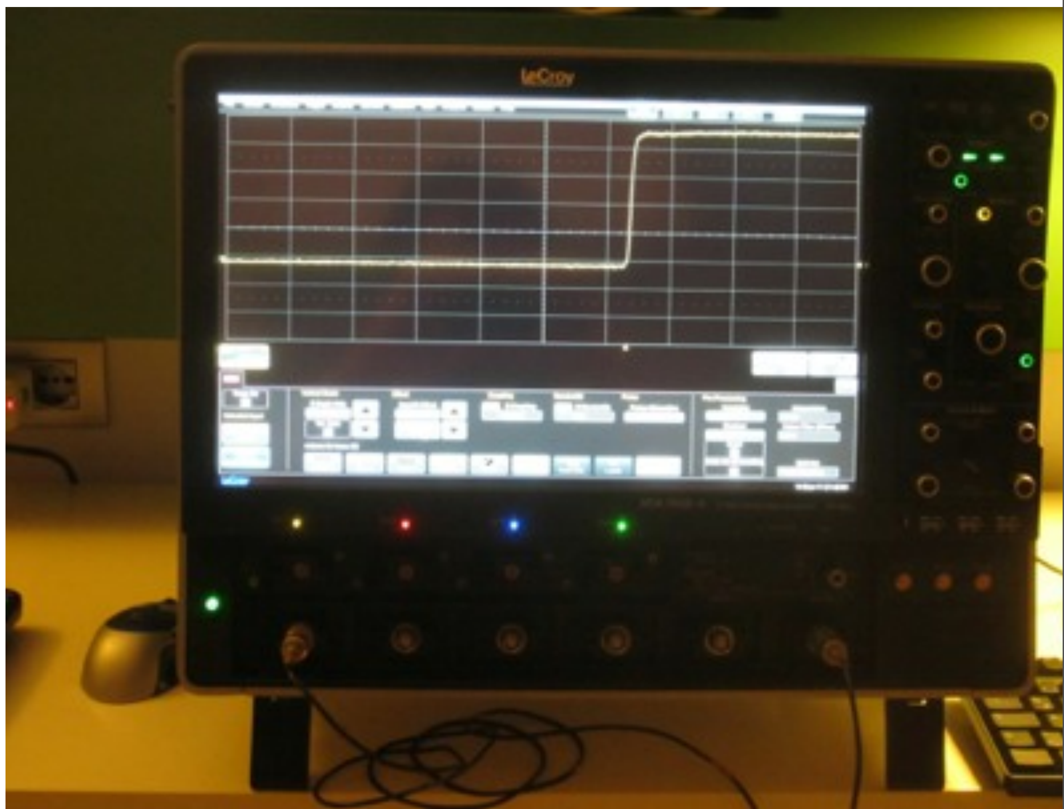
me, Konrad and Michele



setup in the beam

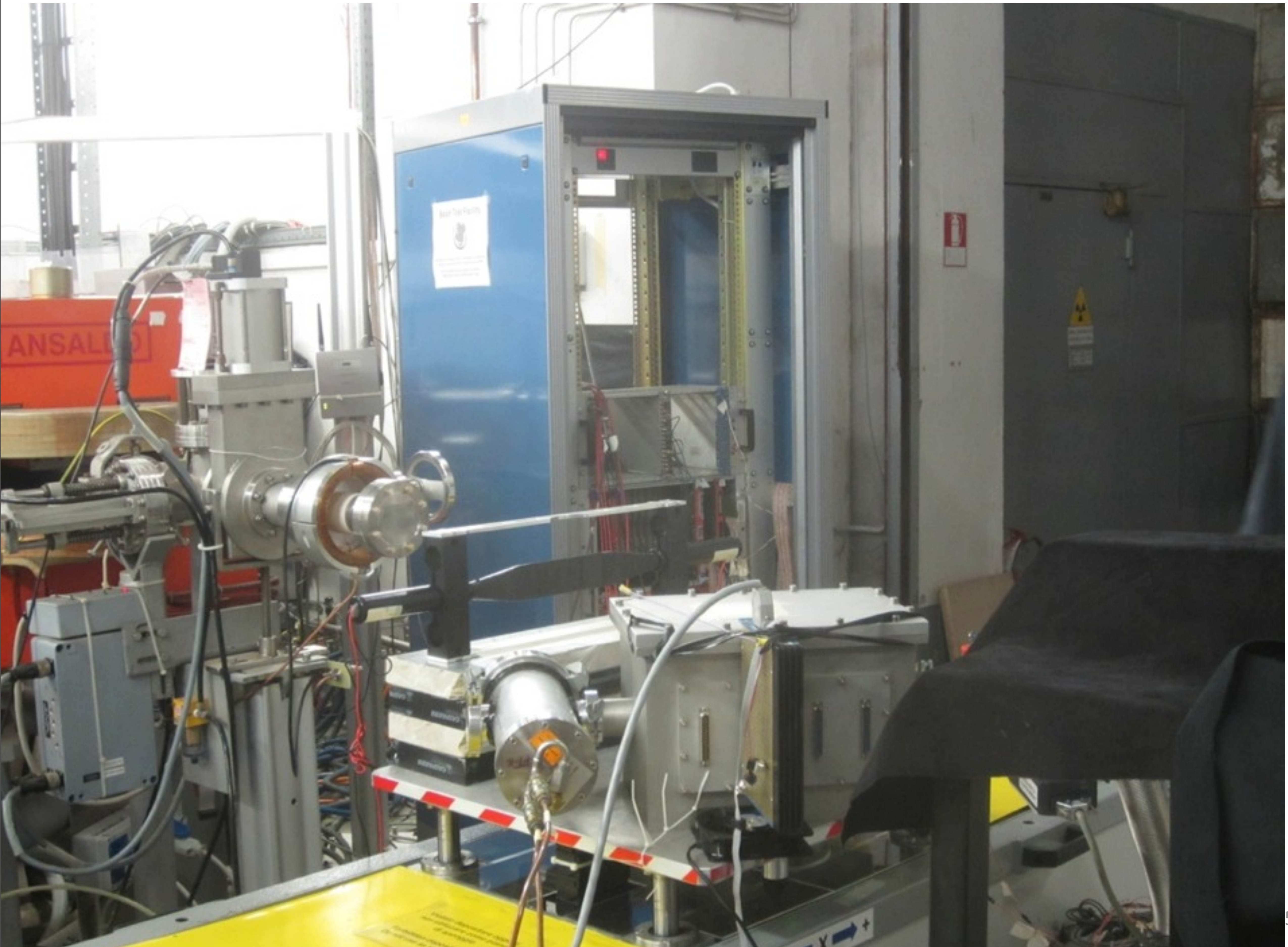
Source test (Ru,Sr^{90})

logistics



Frascati

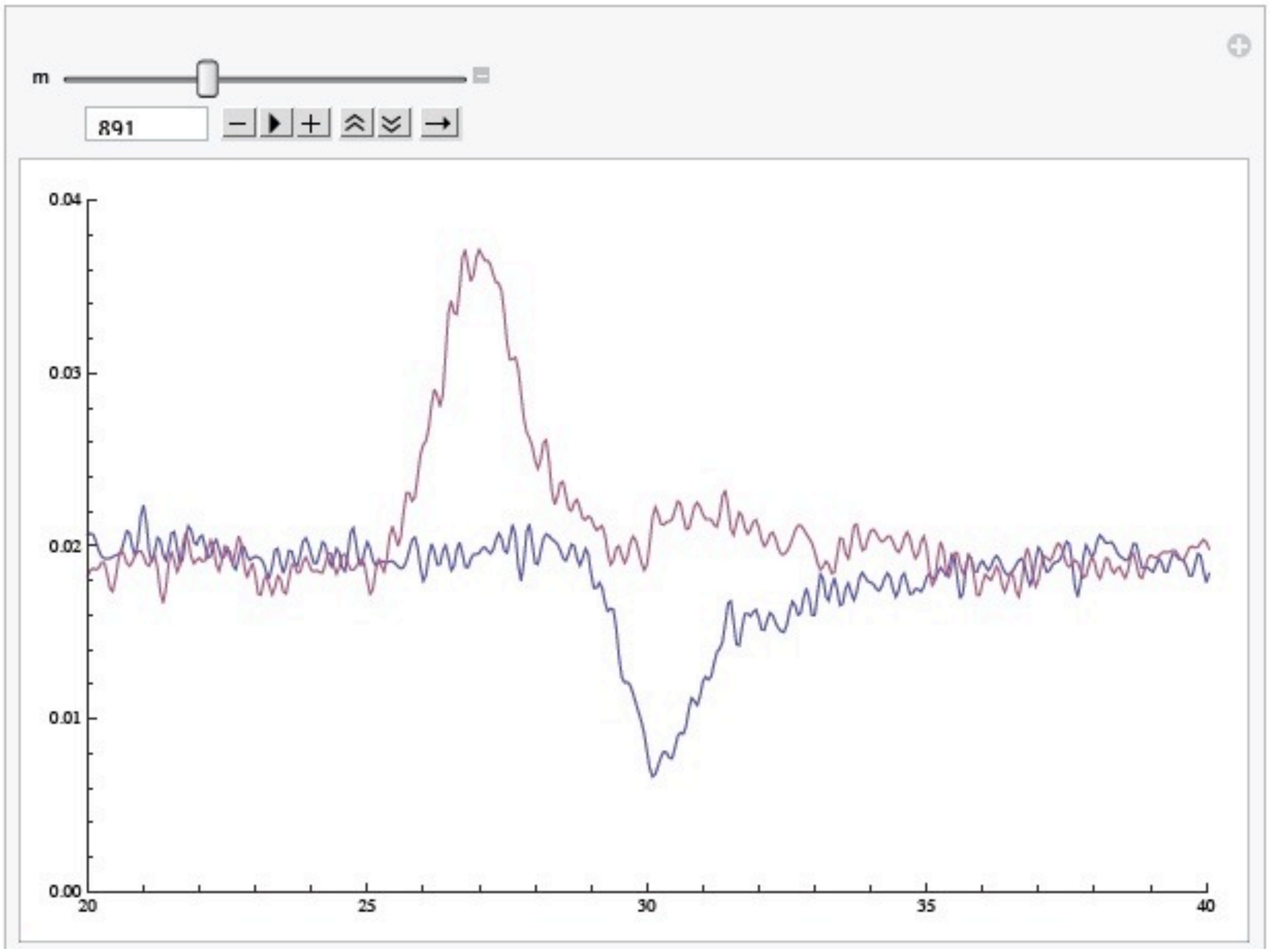
Frascati beam



2 detector coincidence from Frascati 500 MeV e

In[147]:=
```
time1 = 10^9 x Table[dt (n - 4), {n, 404, 805}];
Manipulate[ListPlot[{Transpose[{time1, Table[data[[m, n]], {n, 404, 805}] + .02}],
    Transpose[{time1, -Table[data[[m + 1, n]], {n, 404, 805}] + .02}]},
  PlotRange → {{20, 40}, {0, .04}}, Joined → True, ImageSize → Large], {m, 1, 2592, 2}]
```

Out[148]=



First Look at Charged Particle TOF resolution from β-source tests at Princeton

Changguo Lu, Kirk McDonald and

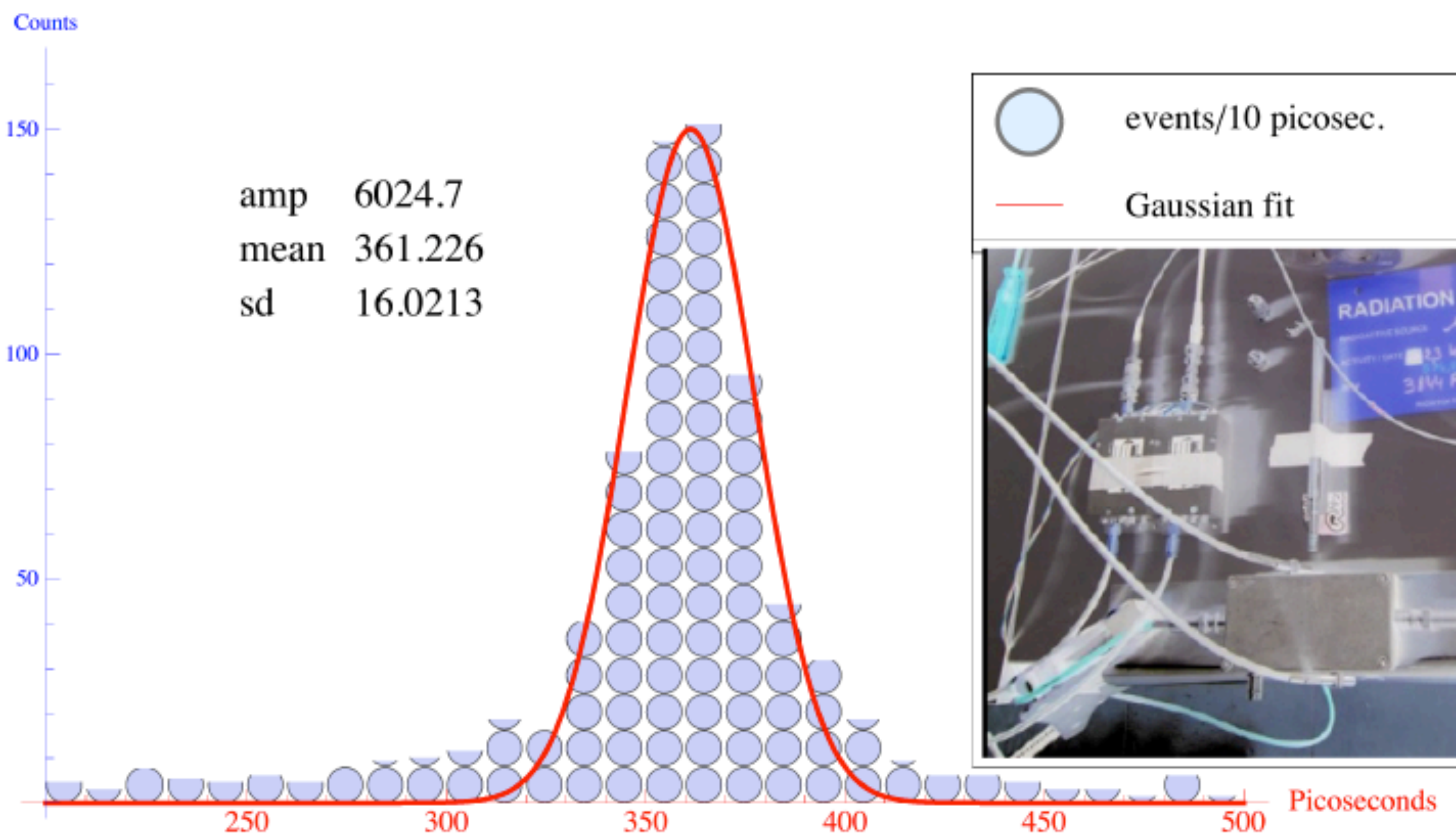
Sebastian White 4/18/2012

Plotted Quantity=t_{APD1}-t_{APD2}(raw distribution)

t_{APDi}=$t_{ZeroCross}$(from APD->Amplifier->Scope input)

```
In[744]:= Show[slshn, Graphics[Inset[photo, {0.7, -.15}]],
        Graphics[Inset[ tgff  , {-.5, 0.2}]]]
```

Out[744]=



return of WavePro to Boissier after a fruitful 2 months

Key Aspects of Work Plan

within context of DOE Advanced Detector R&D grant (SNW and Kirk McDonald, co-PI's)

- basic measurements on timing performance at testbeams (ATF, LNF, possibly also CERN and PSI)
- radiation damage tests of devices to verify extrapolations using CMS APD scaling laws(at Mass General or CERN)
- Extend calculations of neutron equivalent dose for 7 TeV protons (with N. Mokhov)

- device characterization measurements at Princeton-ie development with beta sources prior to beam testing
- telescopes for measurements w. various pixel arrays recently purchased from RMD

  targeted R&D to address application specific issues

  design with sensors integrated with new rad hard Si trackers
- parallel development of high rate readout electronics and tools for analyzing ultimate performance with different algorithms
- secondary issues-like cooling
- some of our APDs have 4 terminal readout and good spatial resolution-interesting to develop both capabilities (ie simultaneous tracking/timing in same device)
- given opportunities for in situ testing at LHC the electronics issues becoming urgent. Input from Saclay/Orsay could be very helpful.