A novel Silicon device incorporating MicroMegas technology for picosecond Charged particle measurement at high rates

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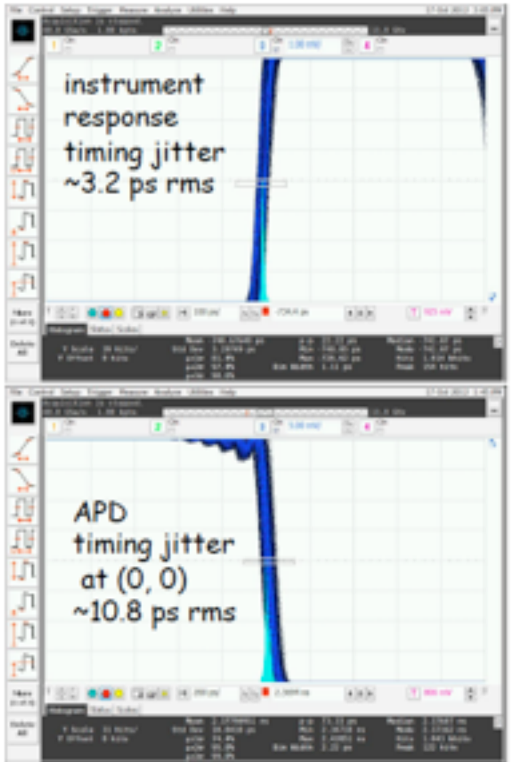
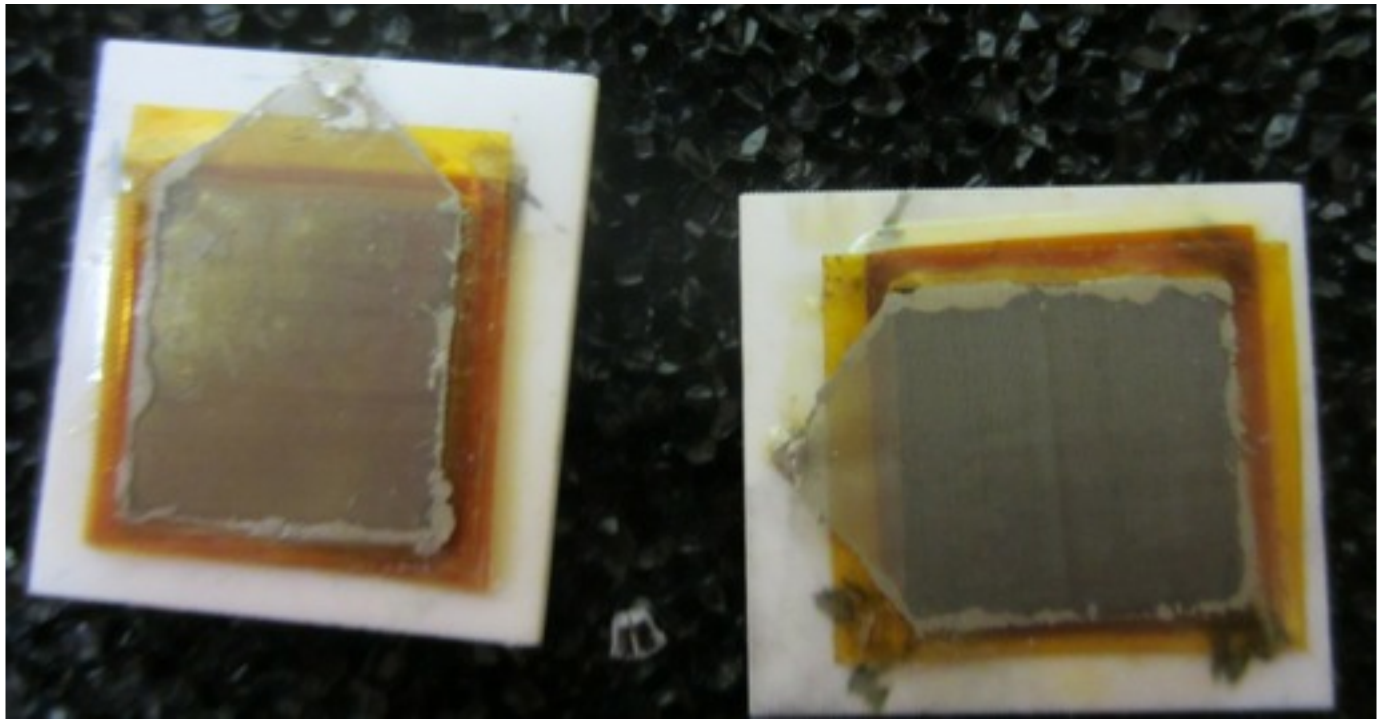
RD 51 Collaboration meeting

Dec. 3,2012

we report on DOE AD R&D funded generic R&D, Kirk McDonald & SNW -coPIs

**also refer to work done in CMS Forward Calorimeter Task Force context over past 5 months. However this is not a CMS talk. Simply my personal assessment of possible CMS impact.*





Outline

- Phase II post discovery studies of Higgs production and related phenomena
- beyond inclusive measurements-the challenges of associating tags in high pileup(PU)
- the role of jet and charged particle/photon timing
- prior calorimetry timing experience
- a high rate 11 picosec SPTR photodetector
- a novel silicon structure incorporating Micromegas mesh for direct charged particle timing (~12 picosec) at high rates

Phase II unique LHC capabilities

- CMS will study Higgs couplings through decay modes and may eventually hand off to ILC for ultimate precision measurements
- exploration of different production modes is unique territory of CMS
- similarly, study in WW scattering up to sqrt(s)~ 2 TeV
- most interesting production modes involve detection (and correct association) of a tag
- challenging to do this in an era of PU~200 !

Tags

- put aside PYTHIA, VECBOS, etc. and calculate particle production by composite objects like proton or Pb nucleus
- seminal 1924 paper by Fermi: "**On the Theory of Collisions between Atoms and Electrically Charged Particles**" **http://arxiv.org/abs/hep-th/0205086**
- Fermi's Equivalent Photon Approximation has been applied to Higgs production in Heavy Ion Collisions-eg: http://cdsweb.cern.ch/record/325236/files/9705220.pdf
- and Extended to Equivalent W approximation-ie S. Dawson, "The Effective W Approximation", Nucl.Phys. B249 (1985) 42.

Tags (continued)

- in 1980's conceptually similar "equivalent Pomeron approximation" made popular by Ingleman and Schlein
- however this concept proved apocryphal by data of HERA and CDF-"Pomeron flux" is not an attribute of the proton. It depends on probe.
- much has been learned but qcd is simply more complex in pp case
- Nevertheless, if, in future, there is an opportunity for leading proton acceptance for 126 GeV Higgs (@420m or IP3(Eggert)) CEP could be useful
- my take is that opportunities not requiring coherence or exclusive production far more likely

Tags(continued)-Hard Photoproduction

Higgs Photoproduction calculated (eg in Baltz and Strikman) using equivalent photon approximation (aka Weiszacker-Williams method)

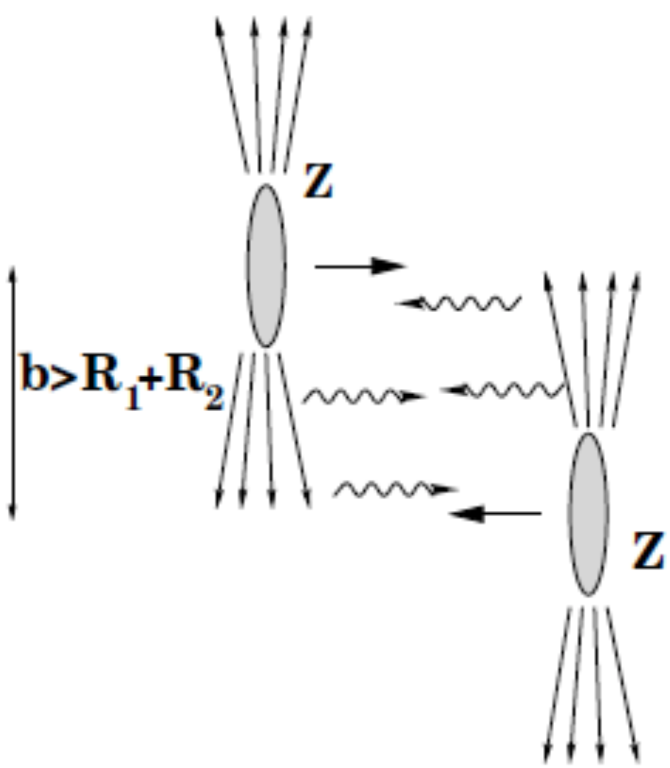
"photon flux"-->

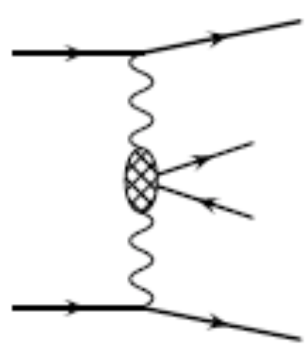
$$N(\omega, b_i) = \frac{Z^2 \alpha \omega^2}{\pi^2 \gamma^2} K_1^2(\frac{b_i\, \omega}{\gamma})$$

$$L_{\gamma\gamma}(W) = 2\pi \int \frac{d\omega_1}{\omega_1} \int_{R_1}^{\infty} b_1\, db_1 \int_{R_2}^{\infty} b_2\, db_2 \int_0^{2\pi} d\phi\, N_1(\omega_1, b_1)\, N_2(\frac{W^2}{4\omega_1}, b_2)\, \theta(b - R_1 - R_2)$$

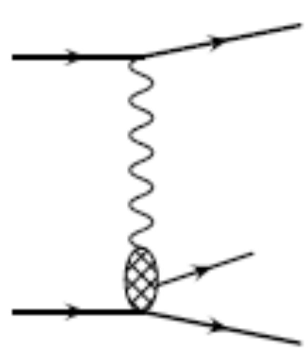
production cross section-->

$$\sigma(W) = \frac{8\pi^2}{W^3} \Gamma_{H\rightarrow\gamma\gamma}(W)\, L_{\gamma\gamma}(W)$$





2 photon- eg. Higgs @LHC



hard photoproduction
-eg PHENIX J/Psi

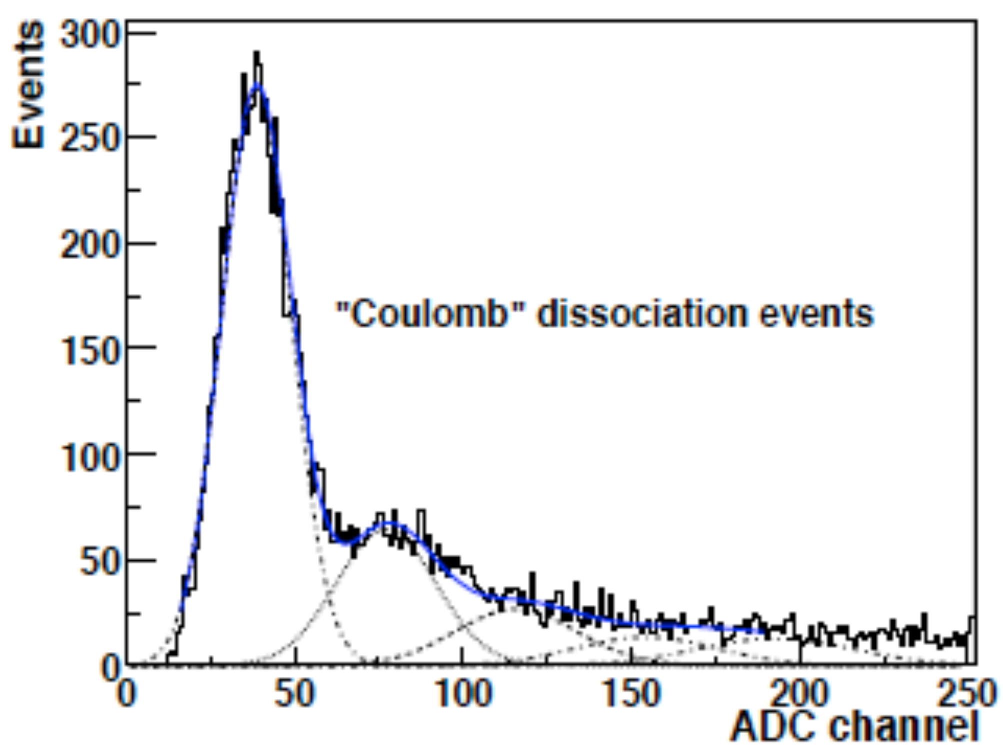
tags-Hard Photoproduction

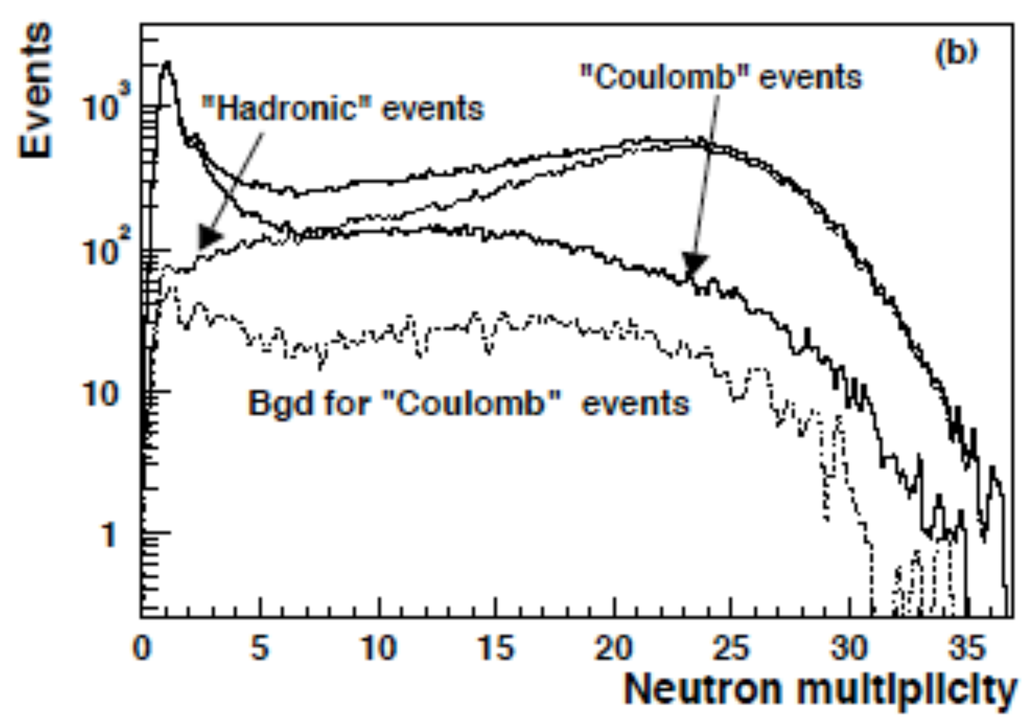
- the Z^4 factor in the cross section makes Heavy Ion processes more favorable than in pp case
- also significant advantage in signal-to-noise since hadronic diffraction backgrounds~$A^{1/3}*B^{1/3}$
- naively the tag for these processes would be beam particles deflected through small angle from the beam
- however:
  - -there is currently no opportunity at the LHC to access forward protons corresponding to 126 GeV Higgs mass
  - -there is never an opportunity to access the beam Pb ions since rigidity larger and <t> smaller

Tags-Hard Photoproduction

- for these reasons "tags" in photoproduction at the LHC refer to dissociation neutrons @~beam energy
- soft neutron emmission doesn't break coherence because Coulomb breakup primarily due to independent opportunistic excitation by other gammas in Weizsacker-Williams cloud

this was the primary motivation for building ATLAS ZDC





Tags-Hard Photoproduction

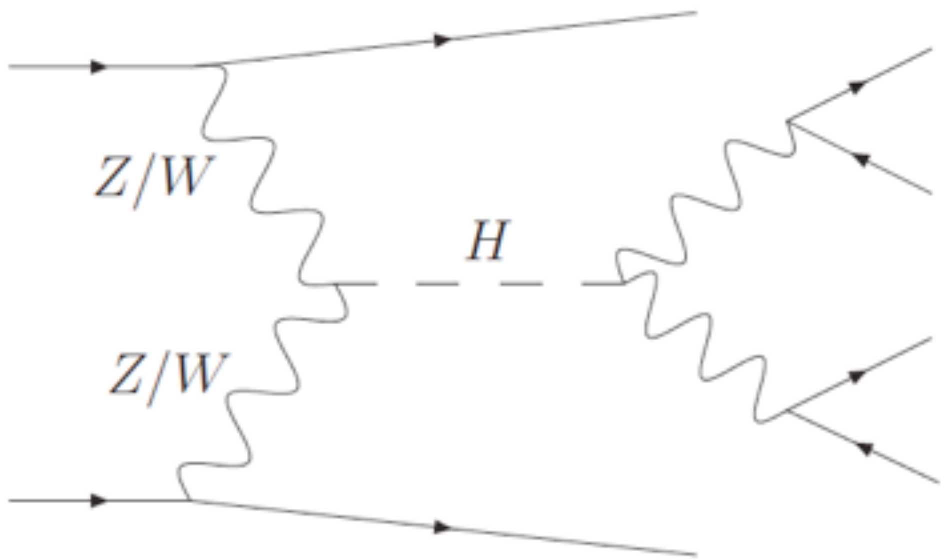
However:

- the Higgs photoproduction cross section in Pb-Pb is too small to be practical at LHC
- multiple event pileup unlikely to become a major issue in PbPb@LHC

Nevertheless:

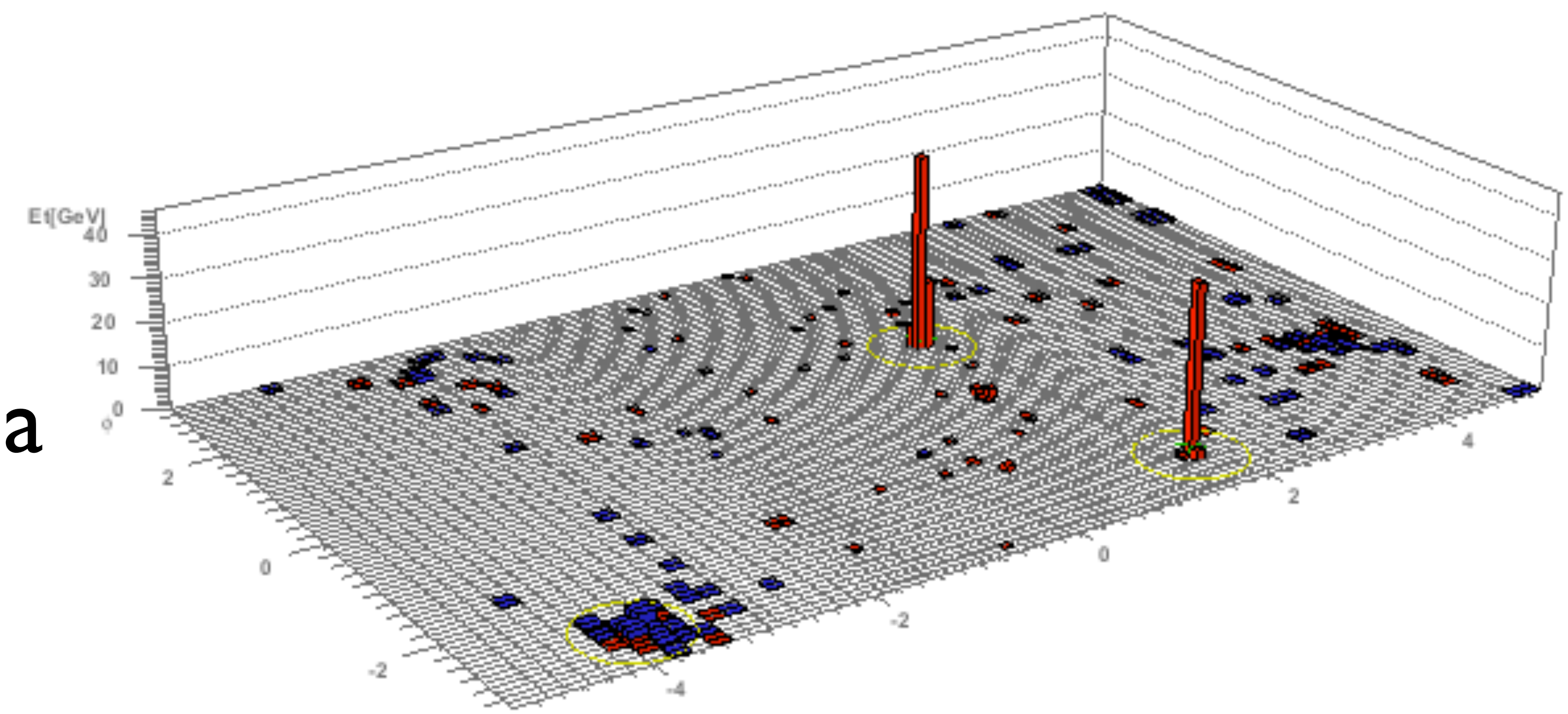
- useful to discuss ZDC forward neutron tags as an illustrative example
- but primary topic of this talk is pp->Jet-Higgs-Jet rather than PbPb->neutrons-Higgs-neutrons

Tags-VBF

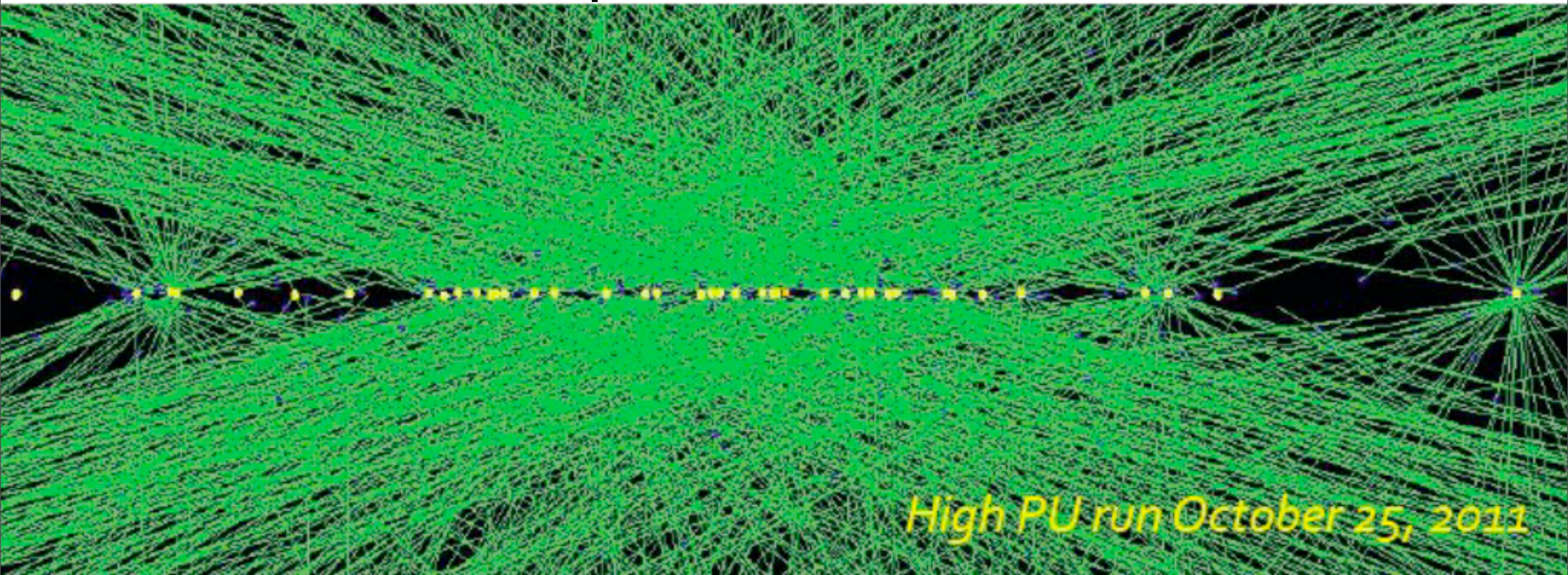


- analogous to 2 photon production
- in W fusion leading baryon->neutron
- but pay a huge price in form factor

instead we will tag with "forward" jets (central H->gamma-gamma + "tag" jets)



this work is about associating tag to Higgs, in case of previous slide



- CMS has been successful in retaining key Higgs signatures in era of PU~25 (with vertexing as primary tool)
- unlikely to be sustainable in era of HiLum-LHC
- "We are going to run out of bullets. It's time to look for another gun."-Joel Butler

Model LHC bunch crossing at IP5 as in
2007 paper:**"On the Correlation of Subevents in the ATLAS and CMS/Totem Experiments", S.White, http://arxiv.org/abs/0707.1500**

To analyze the problem we study the population within an individual beam crossing in both the spatial domain (z-vertex) and the time domain (t-absolute). We first remind ourselves that, in the traversal of two gaussian beam distributions, the spatial distribution of the Luminosity function, L(z), is an invariant with respect to time. Therefore the measurements by the central detector, of the interaction distribution within a crossing are uncorrelated in space and time.

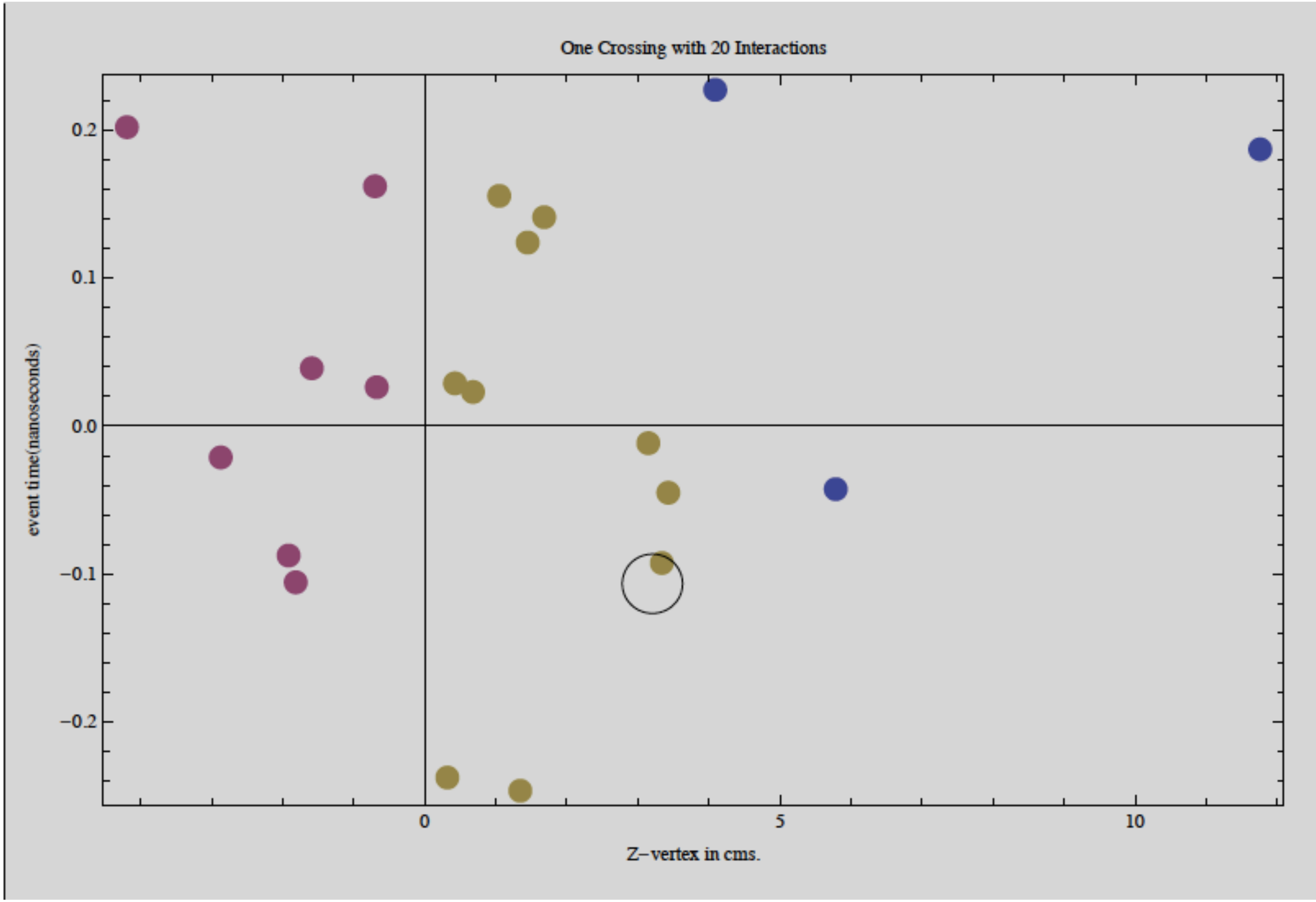
ie $$L(z,t)=I(z,t)*I(z,-t)=\frac{e^{-\frac{(-ct+z)^2}{2\sigma_1^2}-\frac{(ct+z)^2}{2\sigma_1^2}}}{2\pi\sigma_1^2}=\frac{e^{-\frac{c^2t^2+z^2}{\sigma_1^2}}}{2\pi\sigma_1^2}=L(z)*L(t)$$

which manifestly factors into the product of 2 Gaussian distributions- one in space with a variance of $\frac{\sigma_1}{\sqrt{2}}$ and one in time with a variance of $\frac{\sigma_1}{c\sqrt{2}}$.

computer animations at:
http://library.wolfram.com/infocenter/Articles/7716/

as move to larger pseudorapidity, vertexing becomes increasingly difficult. Only timing available for forward neutrons, for example

simulation of bunch crossing with mu=20



how effectively is PU resolved with n(or Jet) ideal time resolution of 10 picosec? Illustrated by error elipse

Fast timing has many potential benefits, aside from pileup rejection

Wigmans et al.

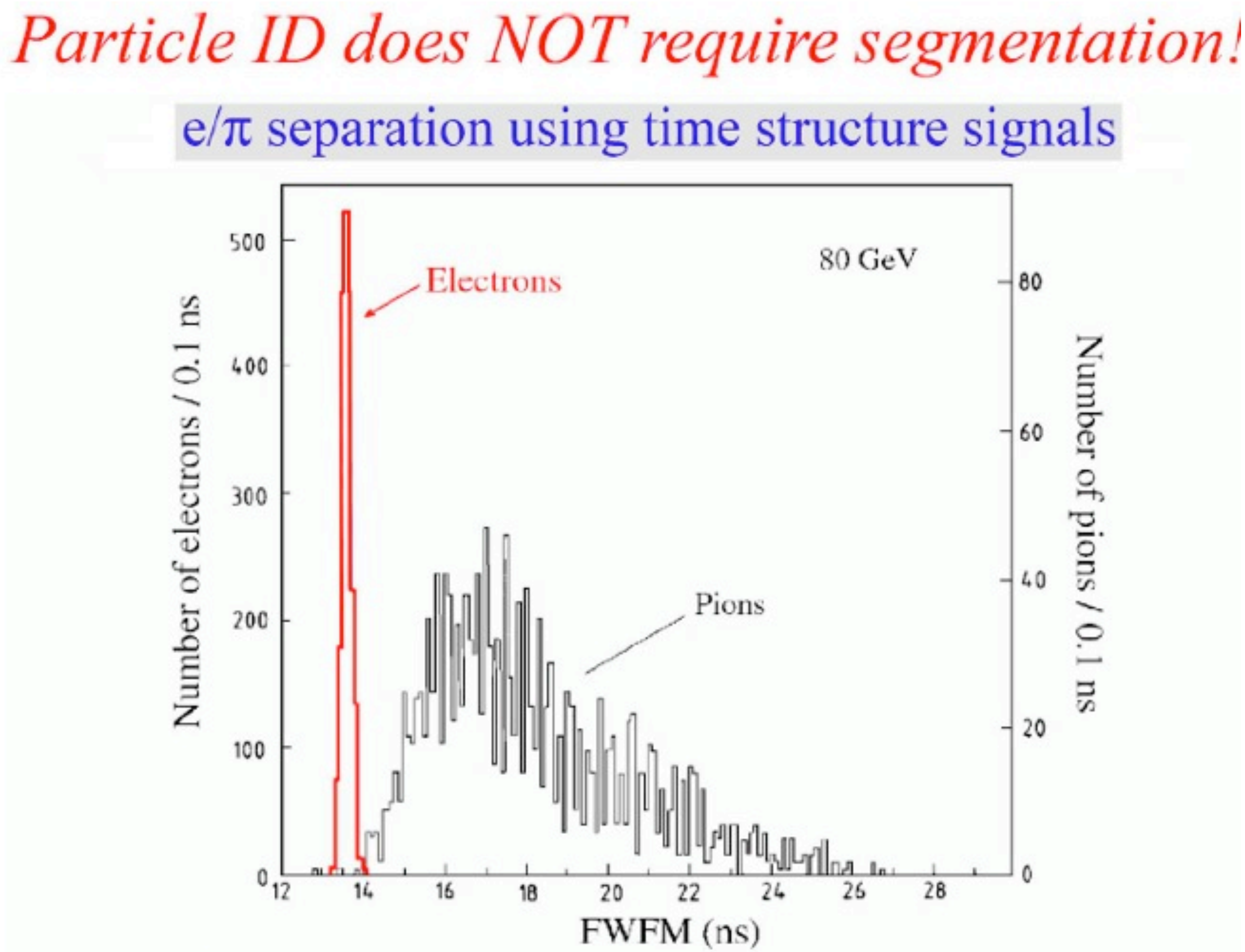


FIG. 7.33. The distribution of the full width at one-fifth maximum (FWFM) for 80 GeV electron and pion signals in SPACAL [Aco 91a].

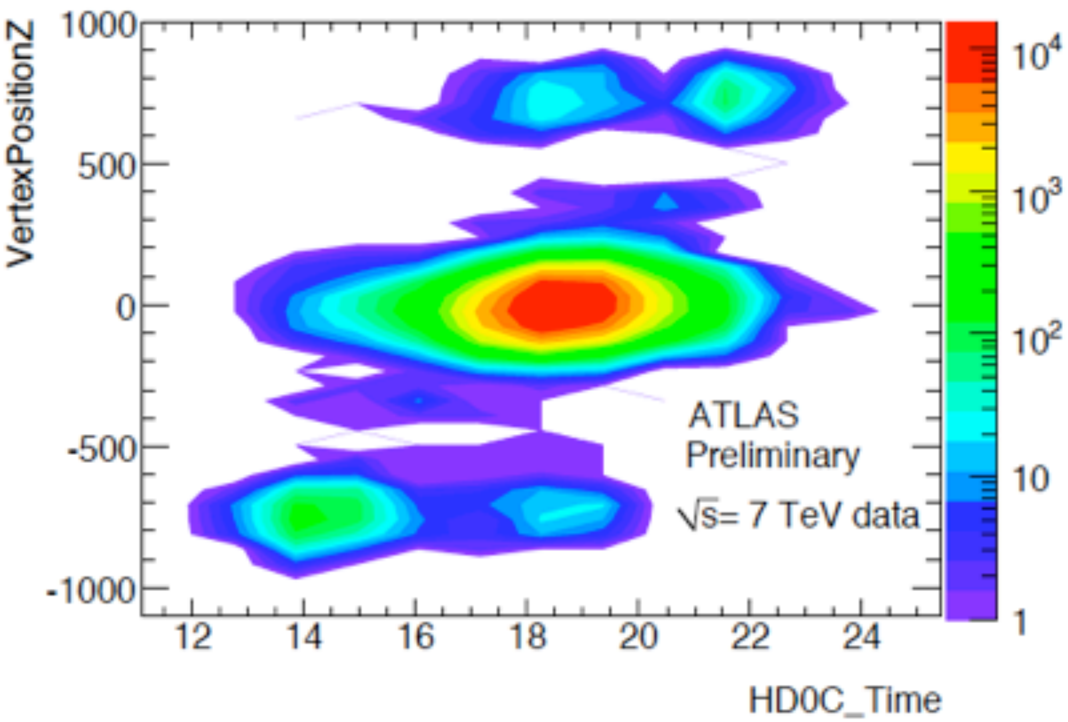
Event timing has a long history in Physics

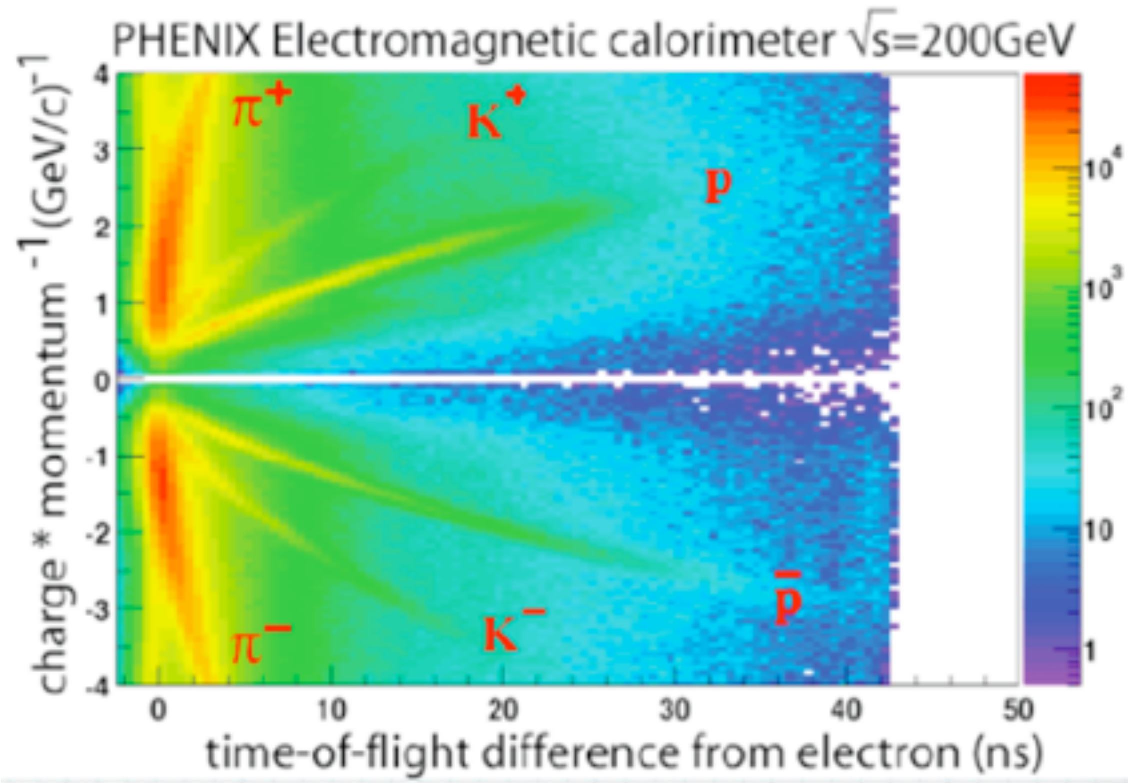
- Galilei's last invention was a more precise clock to time Astronomical observations
- CTR Wilson insisted on putting a clock in cloud chamber photos
- in spite of events in 2011, it was a good thing to add timing to OPERA
- there are many interesting fundamental problems in physics involving fast timing -eg "Measuring Propagation Speed of Coulomb Fields",http://arxiv.org/pdf/1211.2913.pdf

Previous experience with calorimeter timing measurements

BNL-Yale built ATLAS ZDC timing(Quartz-Tungsten Shashlik) resolves 400 MHz micro-bunch structure in LHC (only LHC detector to achieve this?)
despite reduced bandwidth from low quality cable runs & 40 MSa/s sampling

15,552 tower PHENIX shashlik also used for hadron id via TOF
despite low energy deposit of ~0.5 GeV hadrons and TTS in un(longitudinally)-segmented calorimeter



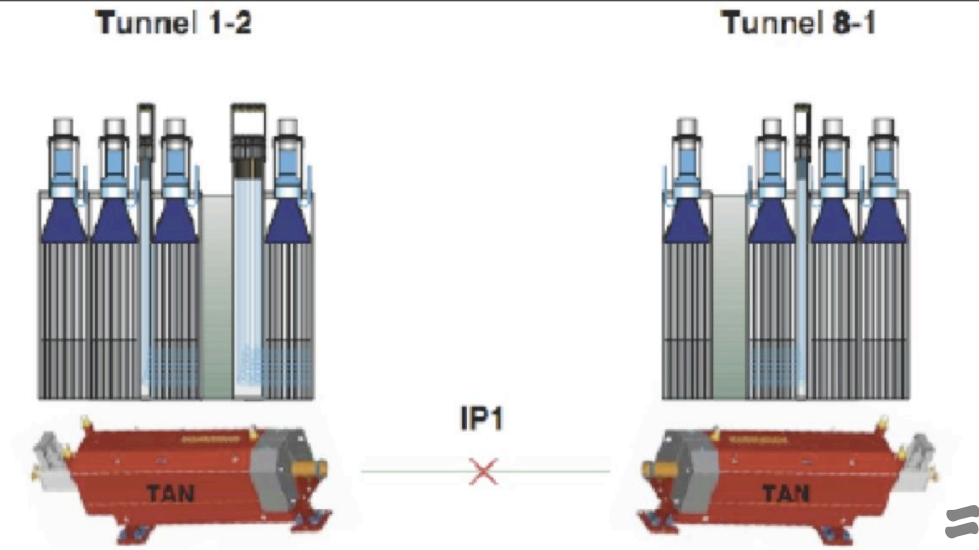


The Z vertex distribution from inner tracker vs. the time of arrival of showers in ZDC-C relative to the ATLAS clock calculated from waveform reconstruction using Shannon interpolation of 40 MegaSample/sec ATLAS data (readout via the ATLAS L1calo Pre-processor modules). Typical time resolution is ~200 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.

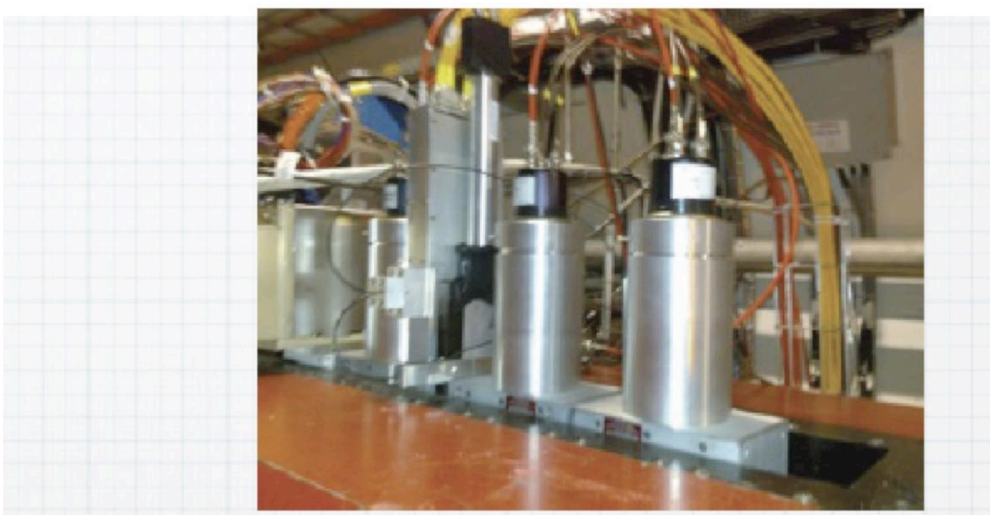
What is optimal signal processing?

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

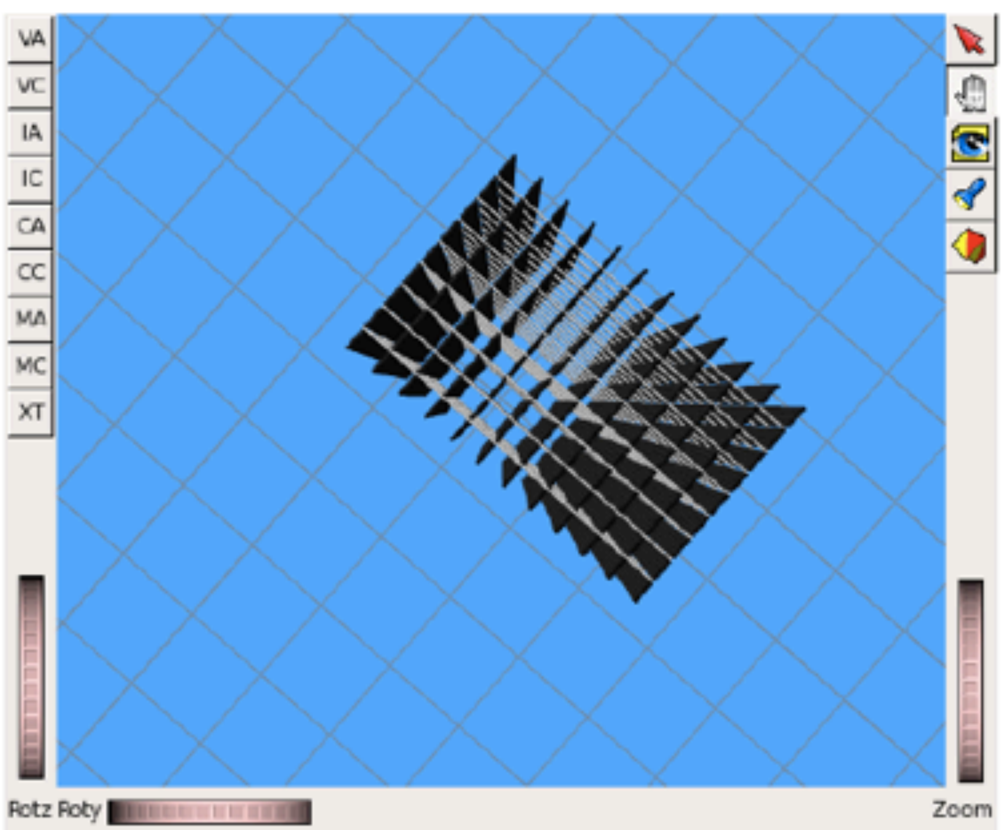
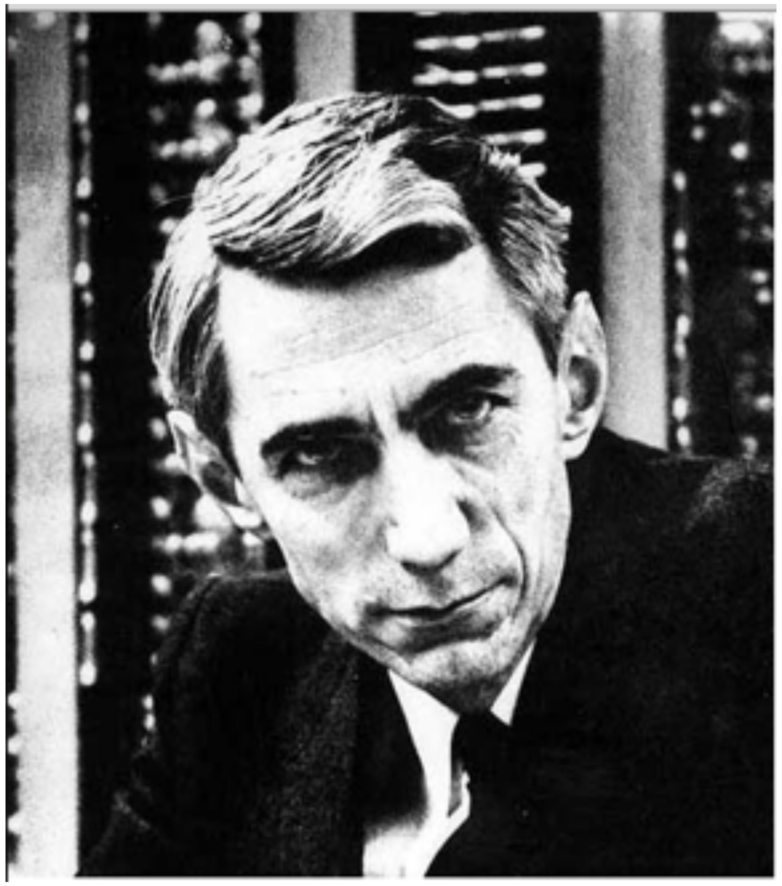


Figure 4: ZDC Drawn with VP1. Plot shows the grid of Strips and Pixels within the EMXY Module



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.

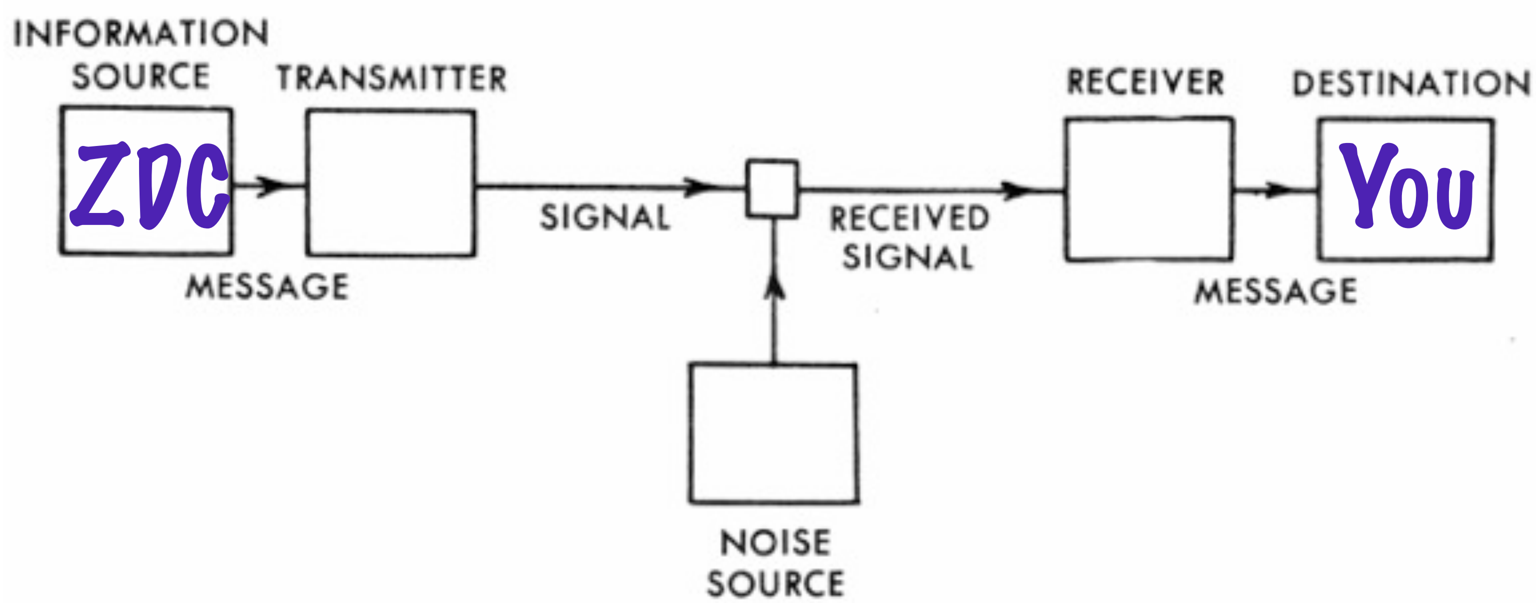
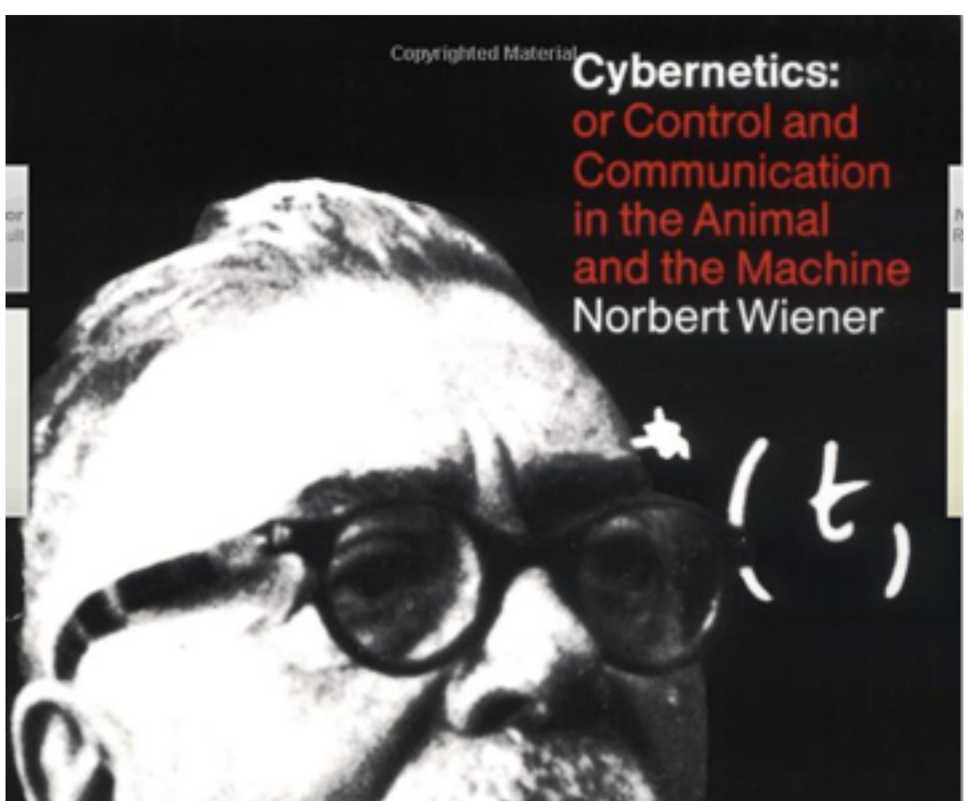
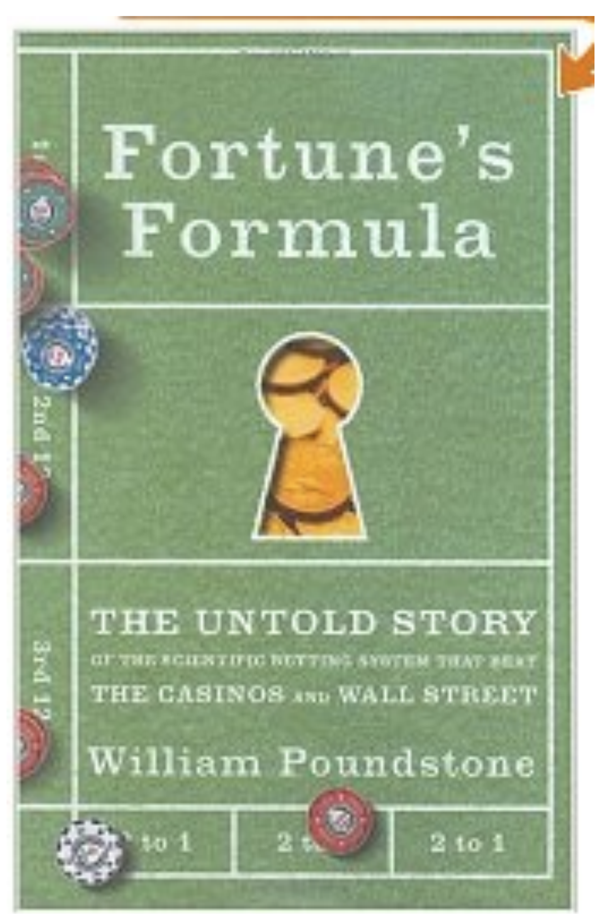


Fig. 1. — Schematic diagram of a general communication system.

books about Shannon:

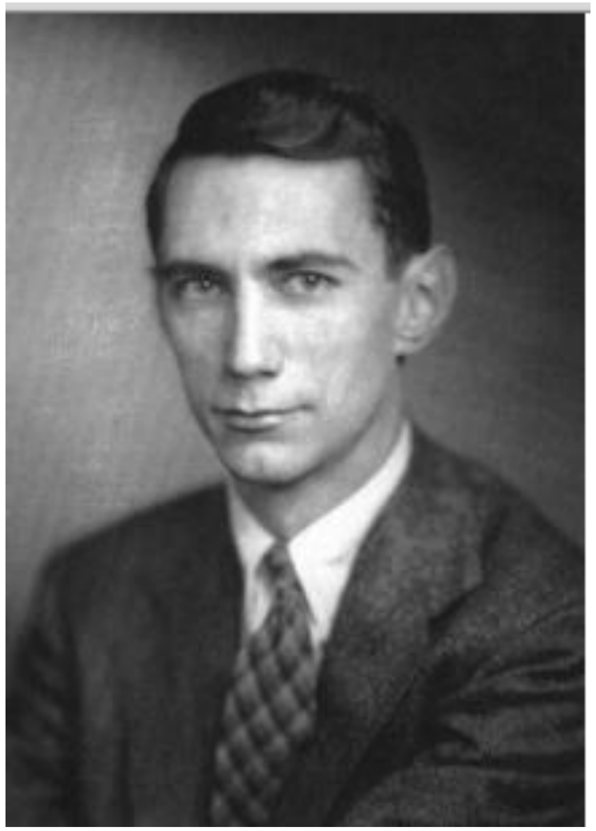




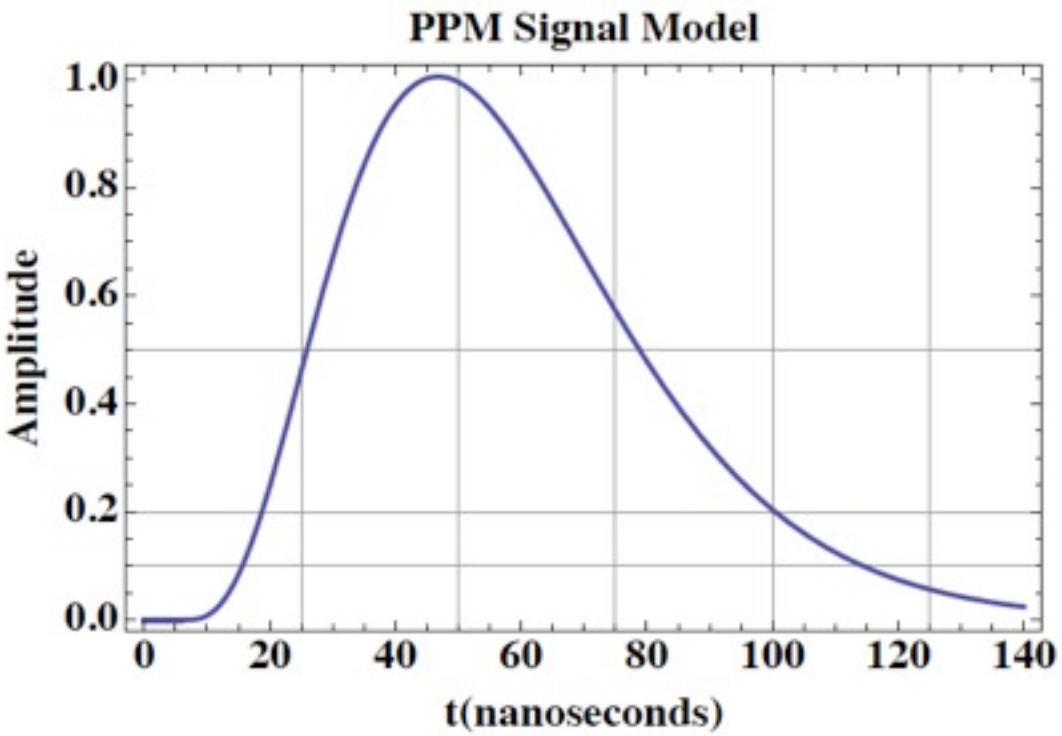
In 1956 two Bell Labs scientists discovered the scientific formula for getting rich. One was the mathematician Claude Shannon, neurotic father of our digital age, whose genius is ranked with Einstein's. The other was John L. Kelly, Jr., a gun-toting Texas-born physicist. Together they applied the science 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

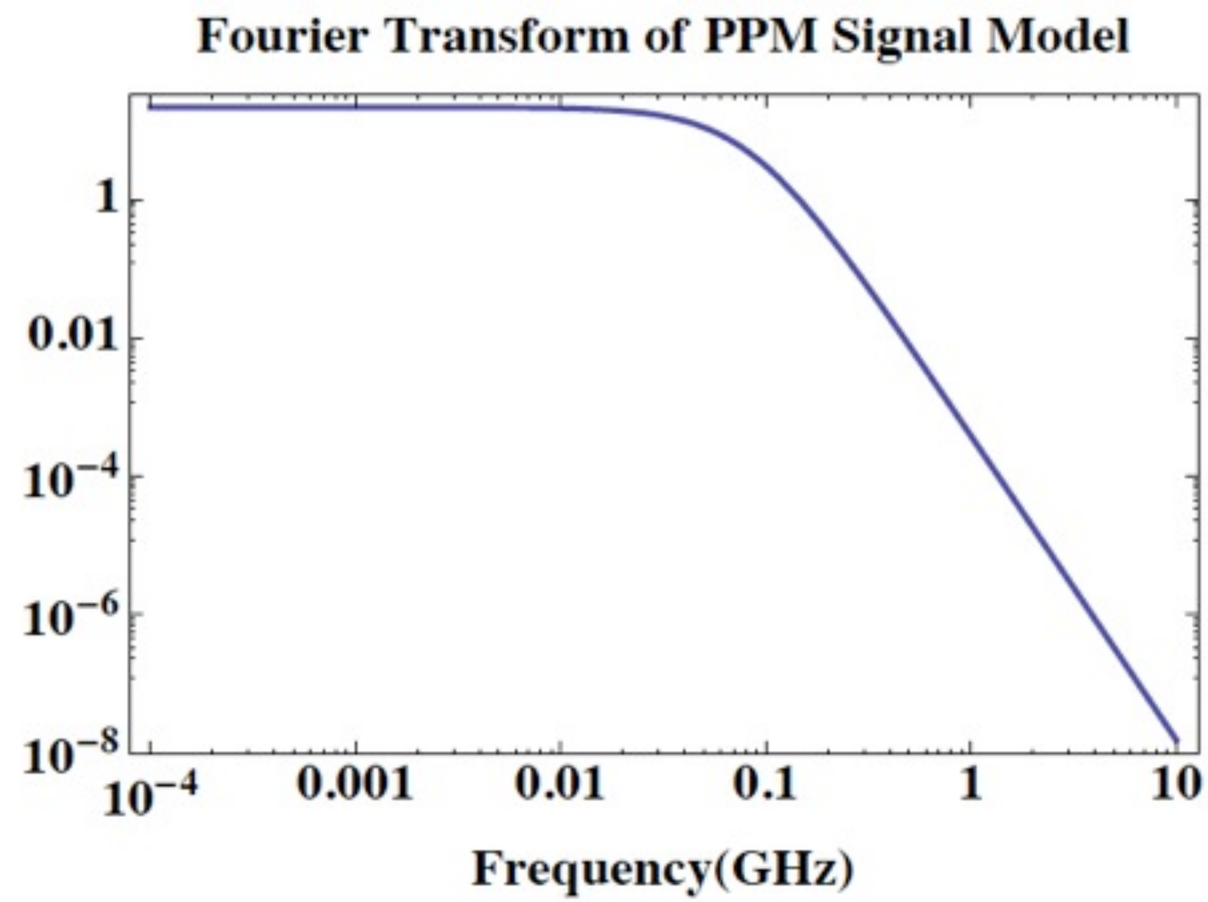
no time to discuss Shannon's method for getting rich

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]
```

$$0.0000662123 \left(\frac{6.14786\, e^{6 i \omega}}{\left(\frac{1}{12} - i\omega\right)^{4.4}} + \frac{0.\, e^{-6 i \omega}}{\left(\frac{1}{12} + i\omega\right)^{4.4}} + (0. + 0.\, i)\, \text{Hypergeometric1F1}\left[1, 5.4, -\frac{1}{2} - 6 i \omega\right] - \left(4.26326 \times 10^{-13} + 1.25056 \times 10^{-12} i\right) \text{Hypergeometric1F1}\left[1, 5.4, -\frac{1}{2} + 6 i \omega\right] + \frac{(0. + 0.\, i)\, \text{HypergeometricPFQ}\left[\{-3.4, -3.9\}, \{-3.4, -3.9\}, -\frac{1}{2} - 6 i \omega\right]}{\left(\frac{1}{12} + i\omega\right)^{4.4}} - \frac{(0.967912 + 2.97893\, i)\, \text{HypergeometricPFQ}\left[\{-3.4, -3.9\}, \{-3.4, -3.9\}, -\frac{1}{2} + 6 i \omega\right]}{\left(\frac{1}{12} - i\omega\right)^{4.4}} \right)$$

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

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

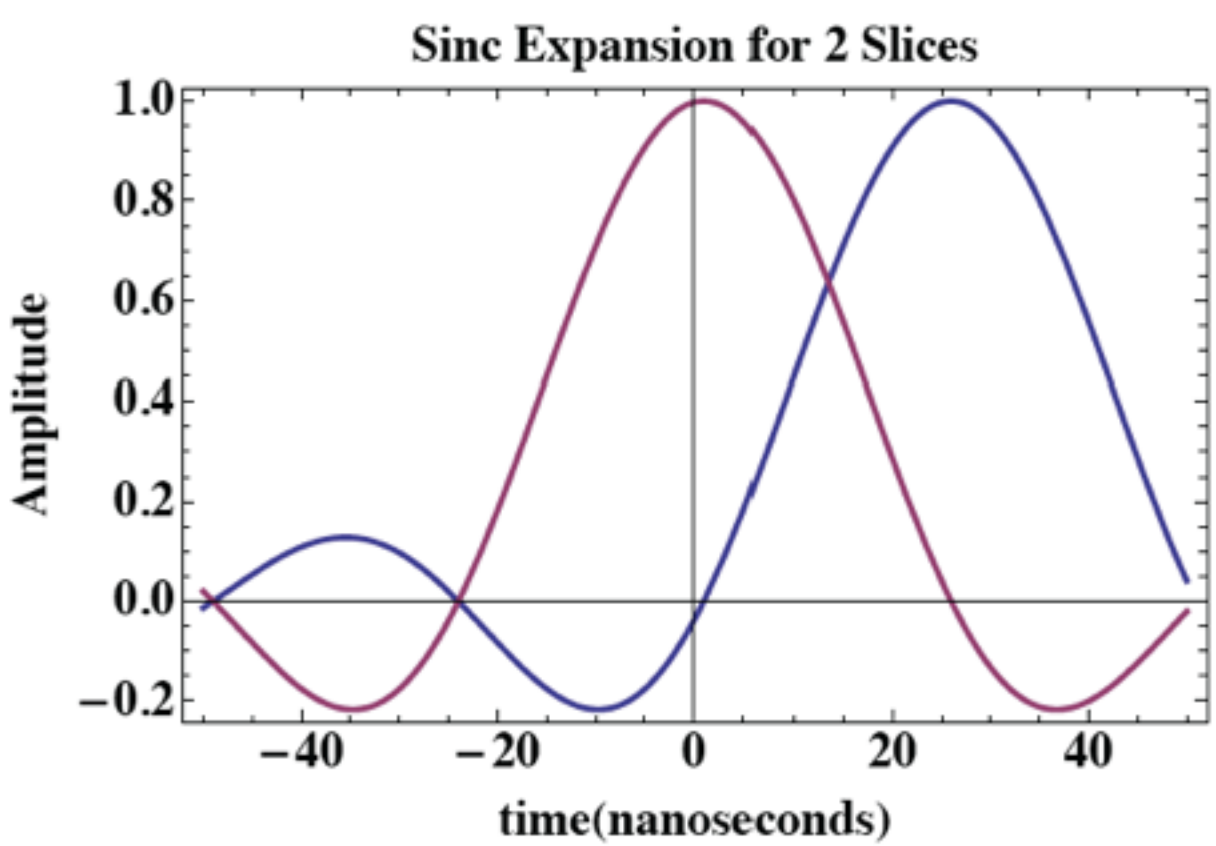
An animated gif can be found at:
http://www.phenix.bnl.gov/phenix/WWW/publish/swhite/ShannonFilm.gif

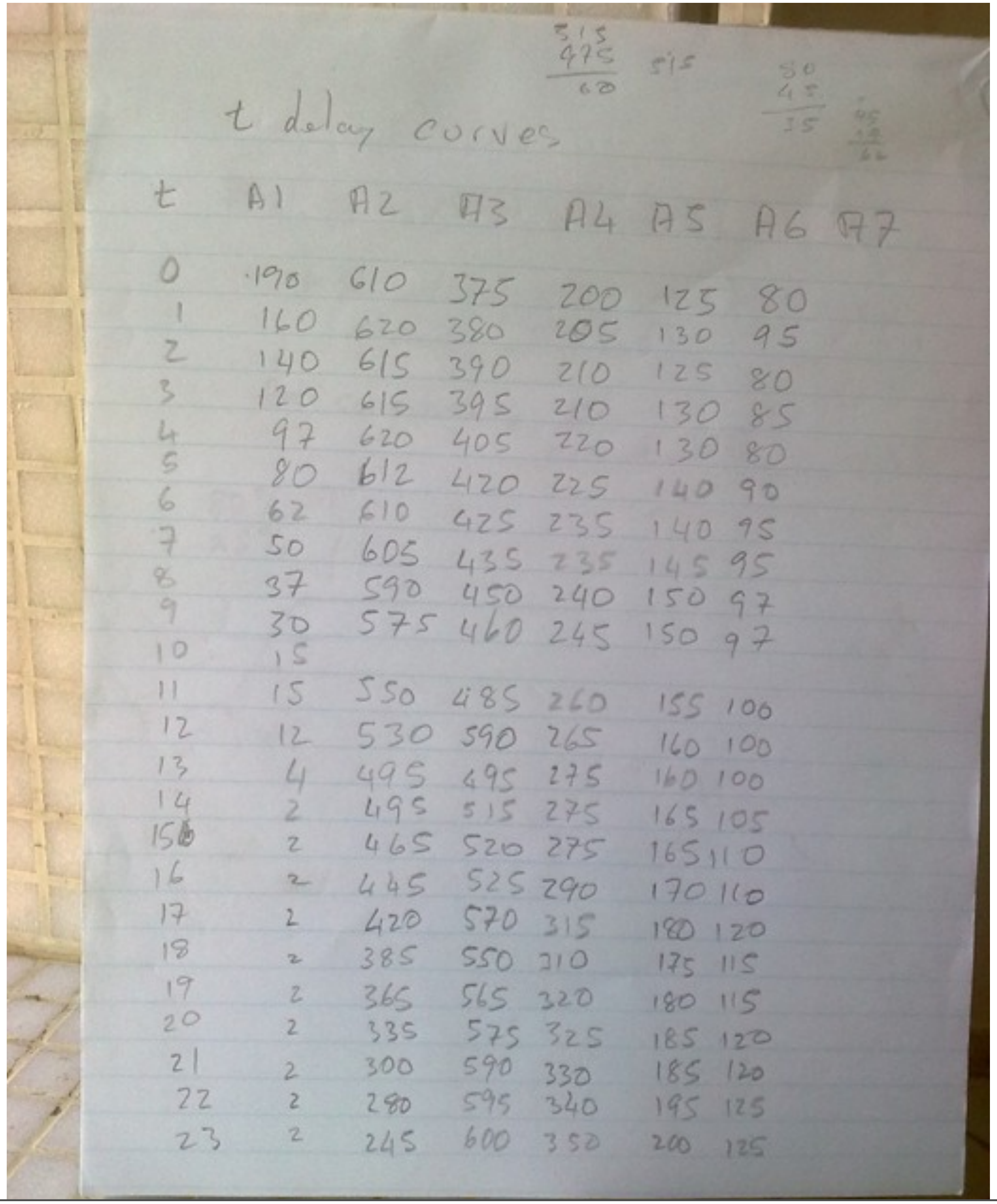
ATLAS data set used to develop ZDC reconstruction and do L1calo calibration (in Mathematica 7.0)

Reconstruction of ZDC Pre-Processor Data and its timing Calibration

Soumya Mohapatra, Andrei Poblaguev and Sebastian White

Aug.8,2010



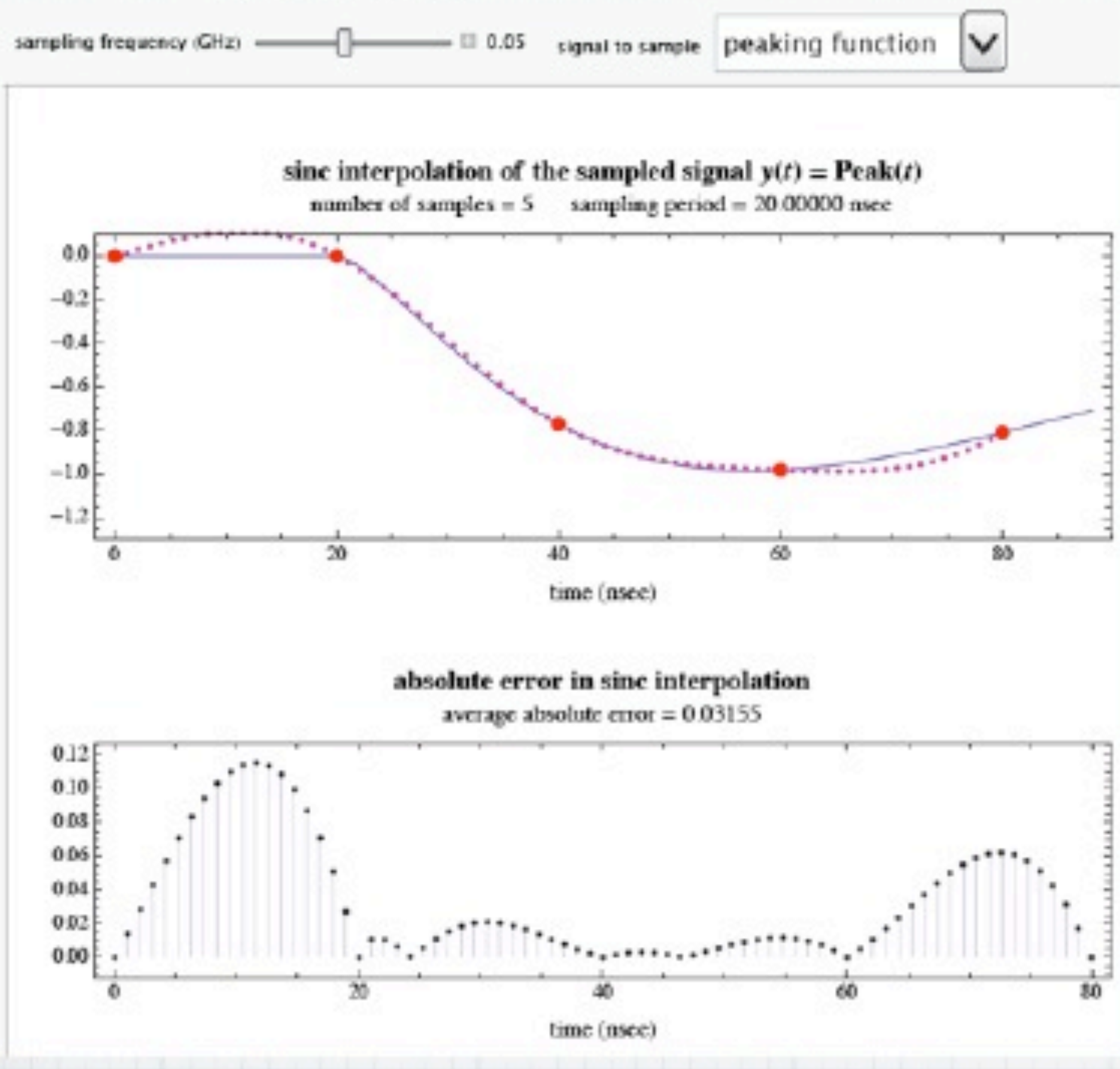


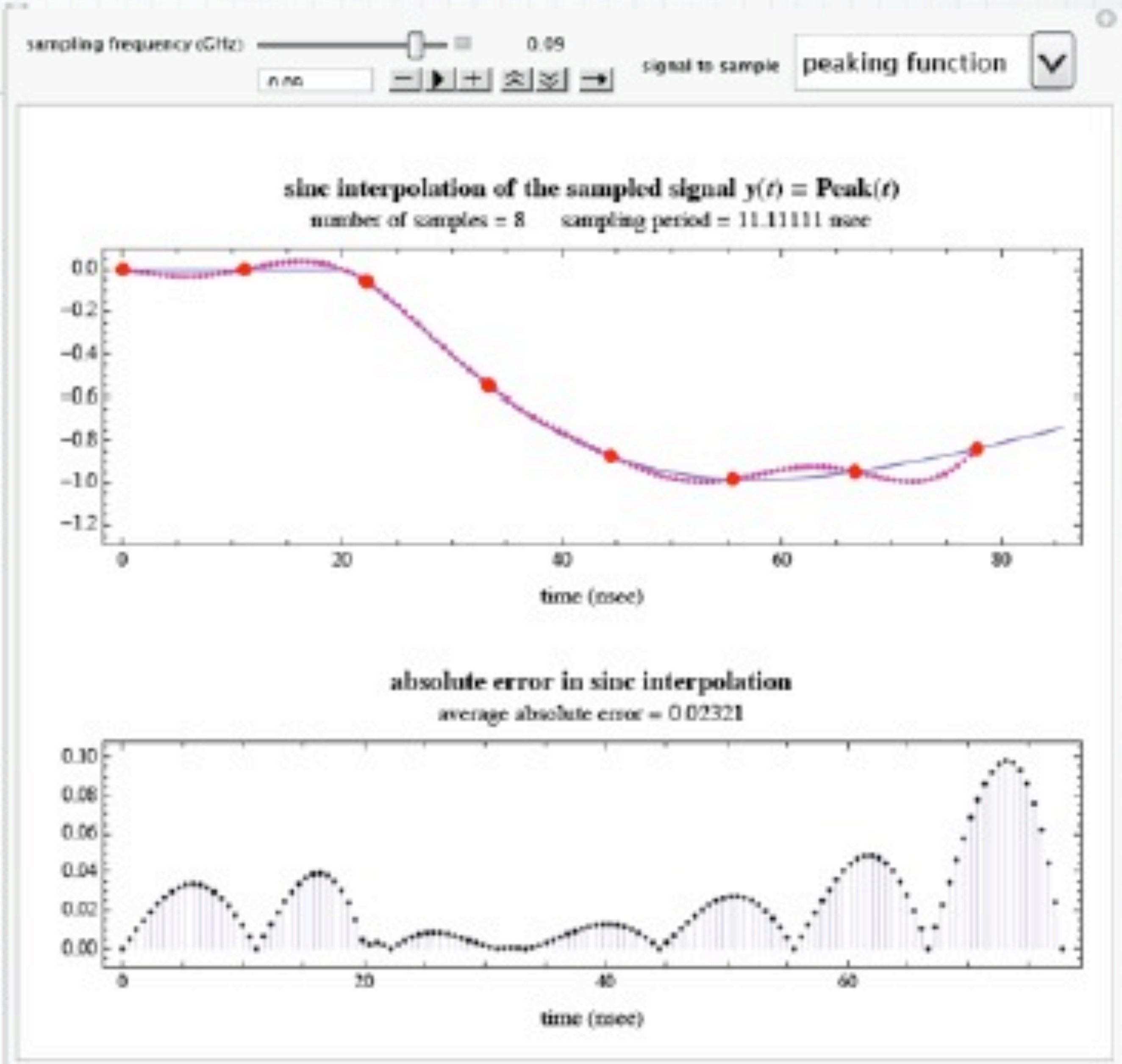
t delay curves

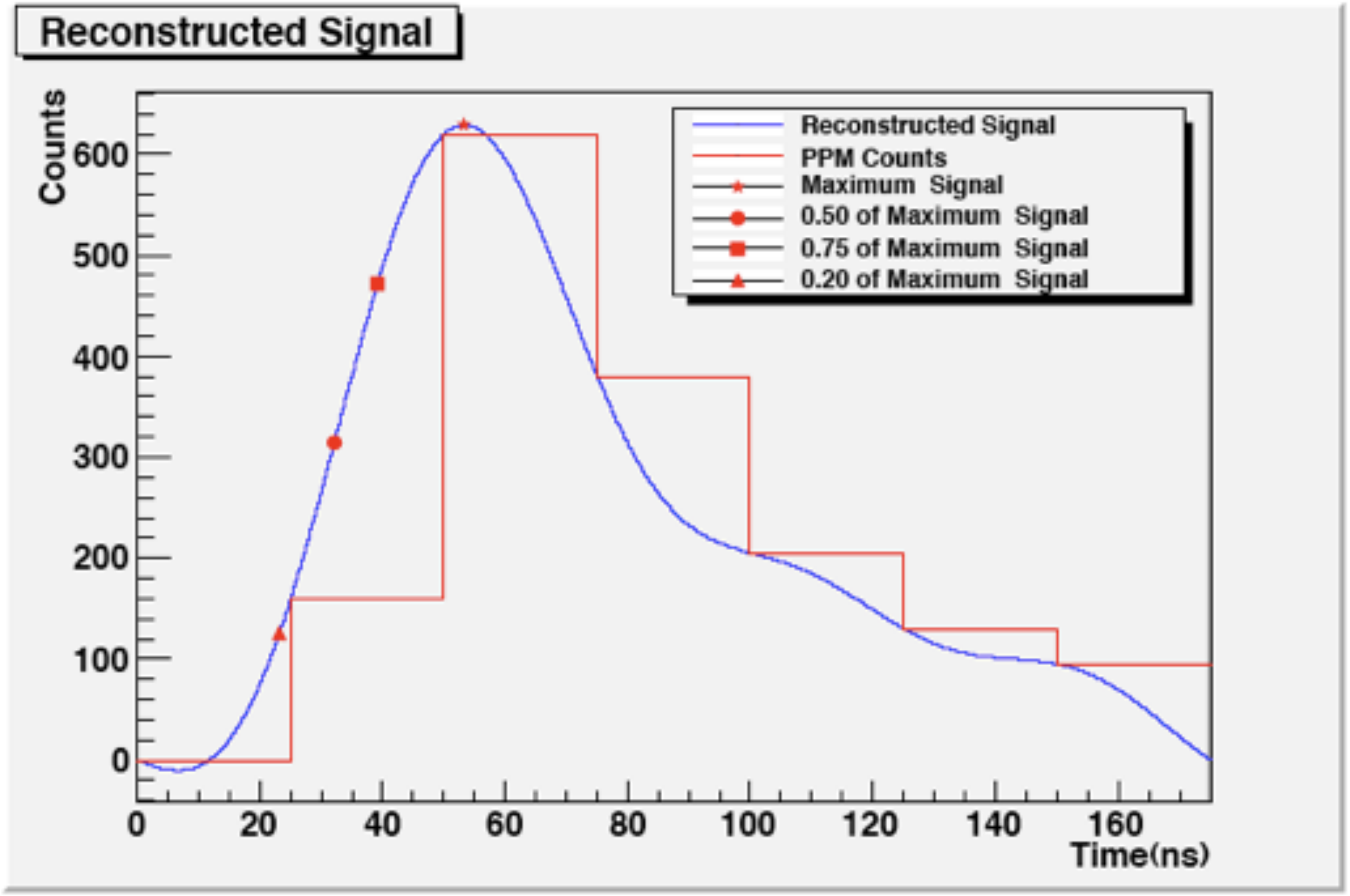
t	A1	A2	A3	A4	A5	A6	A7
0	190	610	375	200	125	80	
1	160	620	380	205	130	95	
2	140	615	390	210	125	80	
3	120	615	395	210	130	85	
4	97	620	405	220	130	80	
5	80	612	420	225	140	90	
6	62	610	425	235	140	95	
7	50	605	435	235	145	95	
8	37	590	450	240	150	97	
9	30	575	460	245	150	97	
10	15						
11	15	550	485	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	

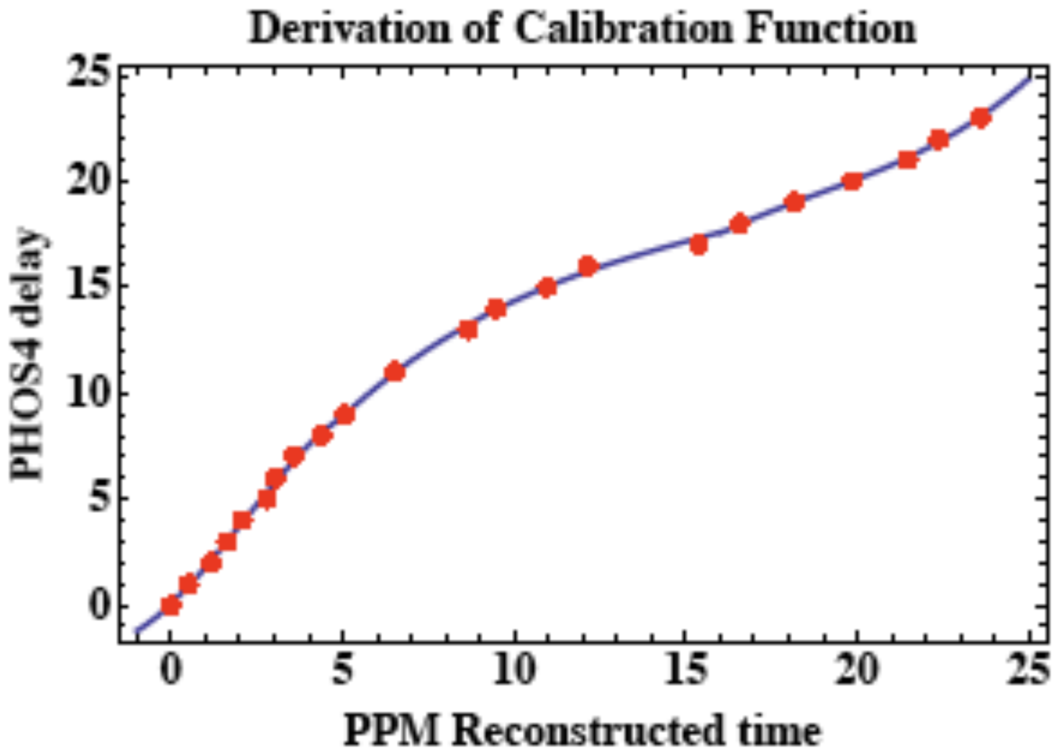
Signal Reconstruction

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

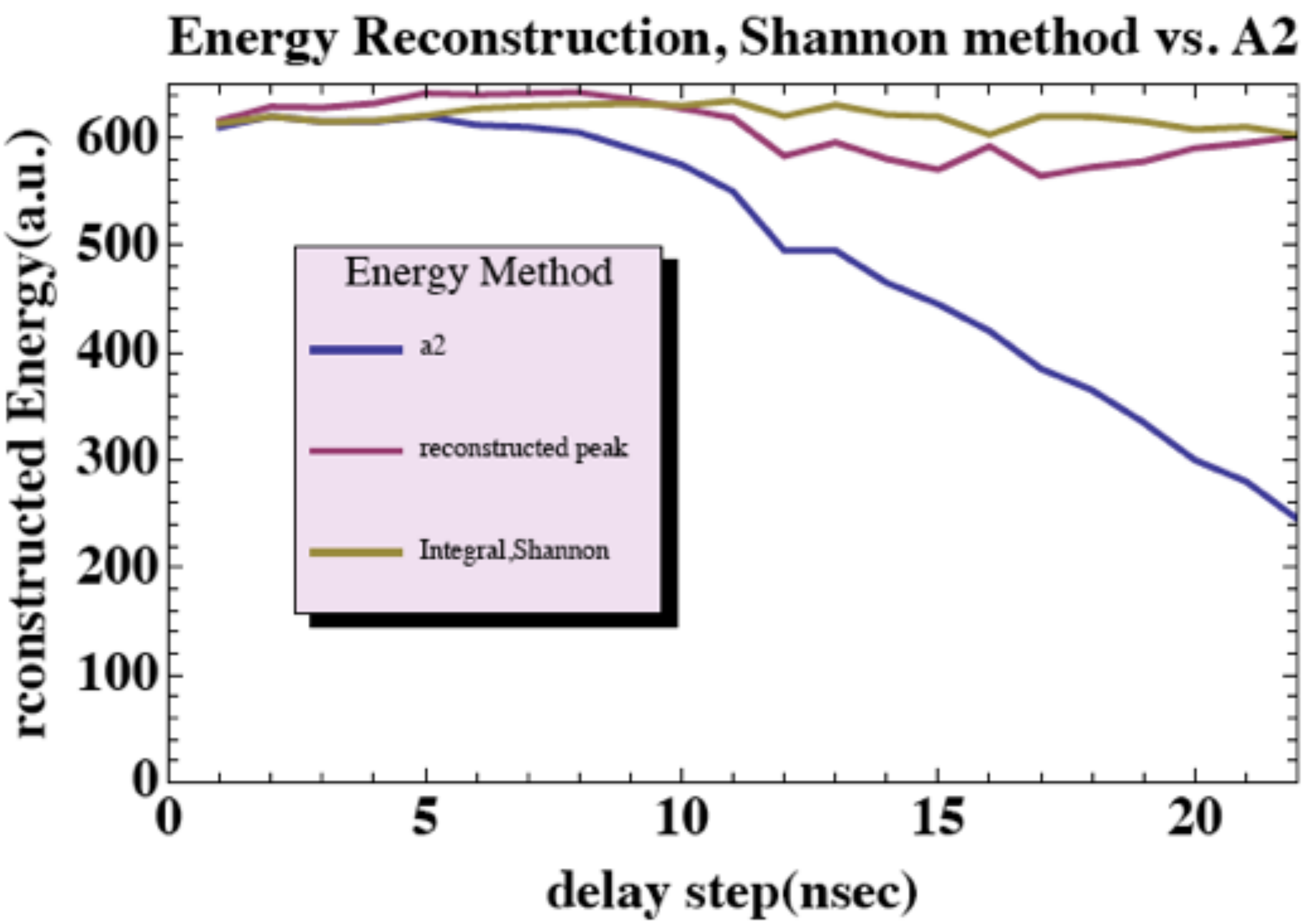




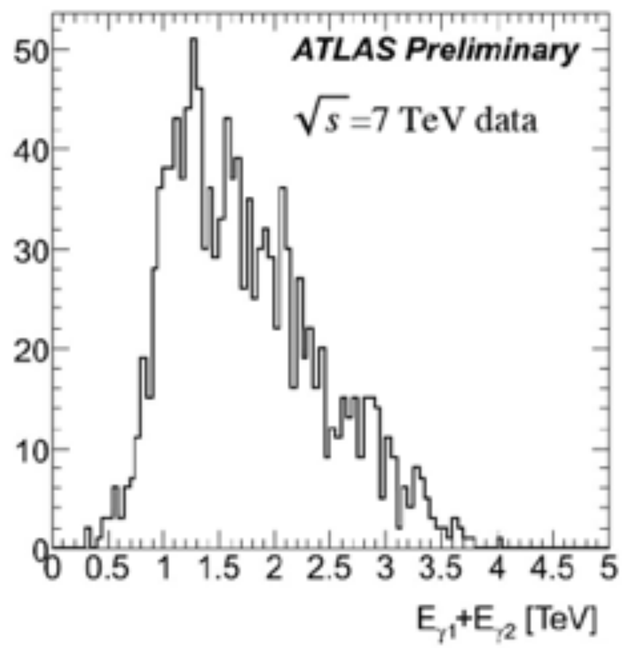




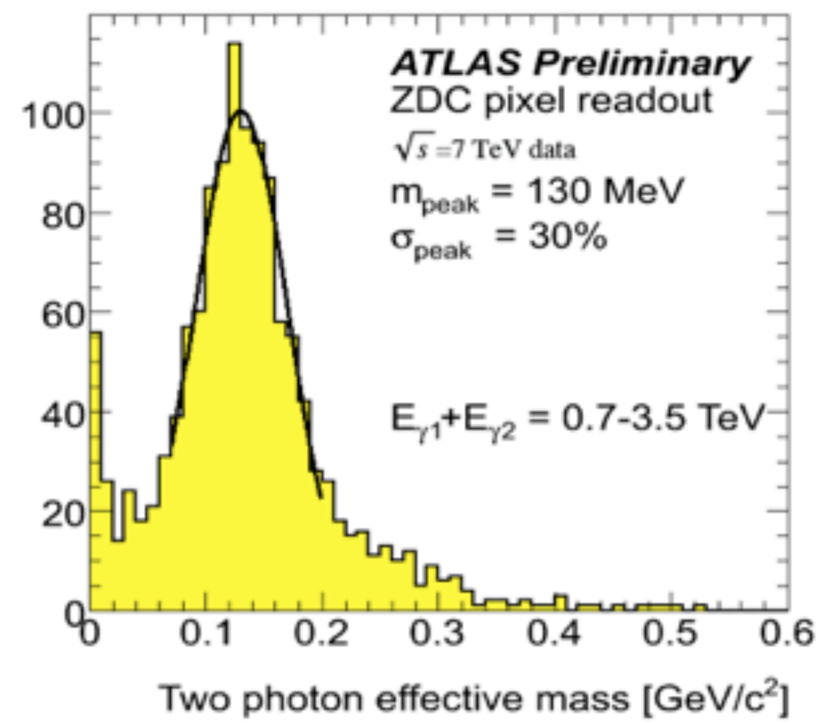
(d) Piecewise fit to the full range.



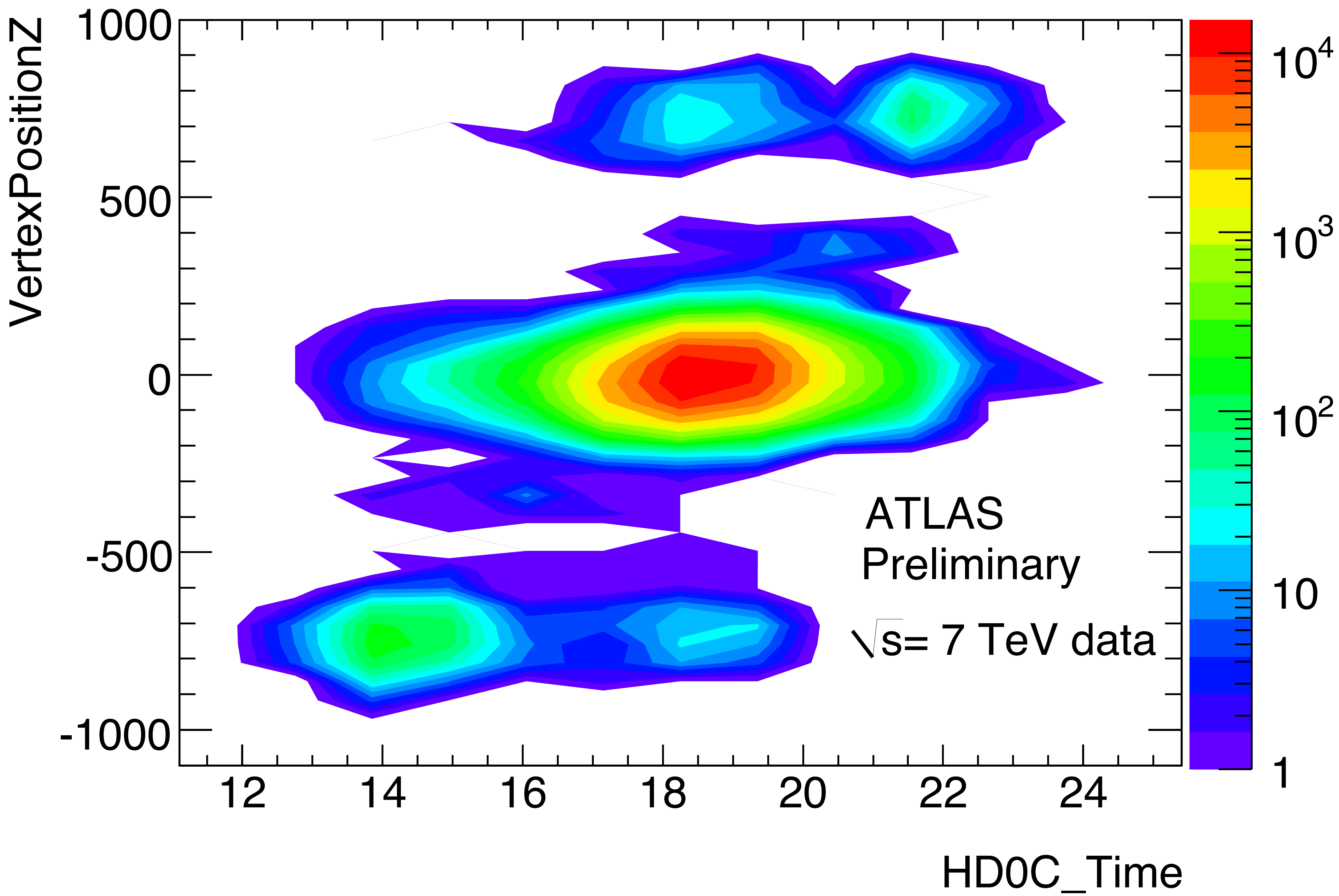
2- photon reconstruction



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 foun in ongoing simulation of pi0 reconstruction within the full ATLAS framework (see ZDC simulati 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.



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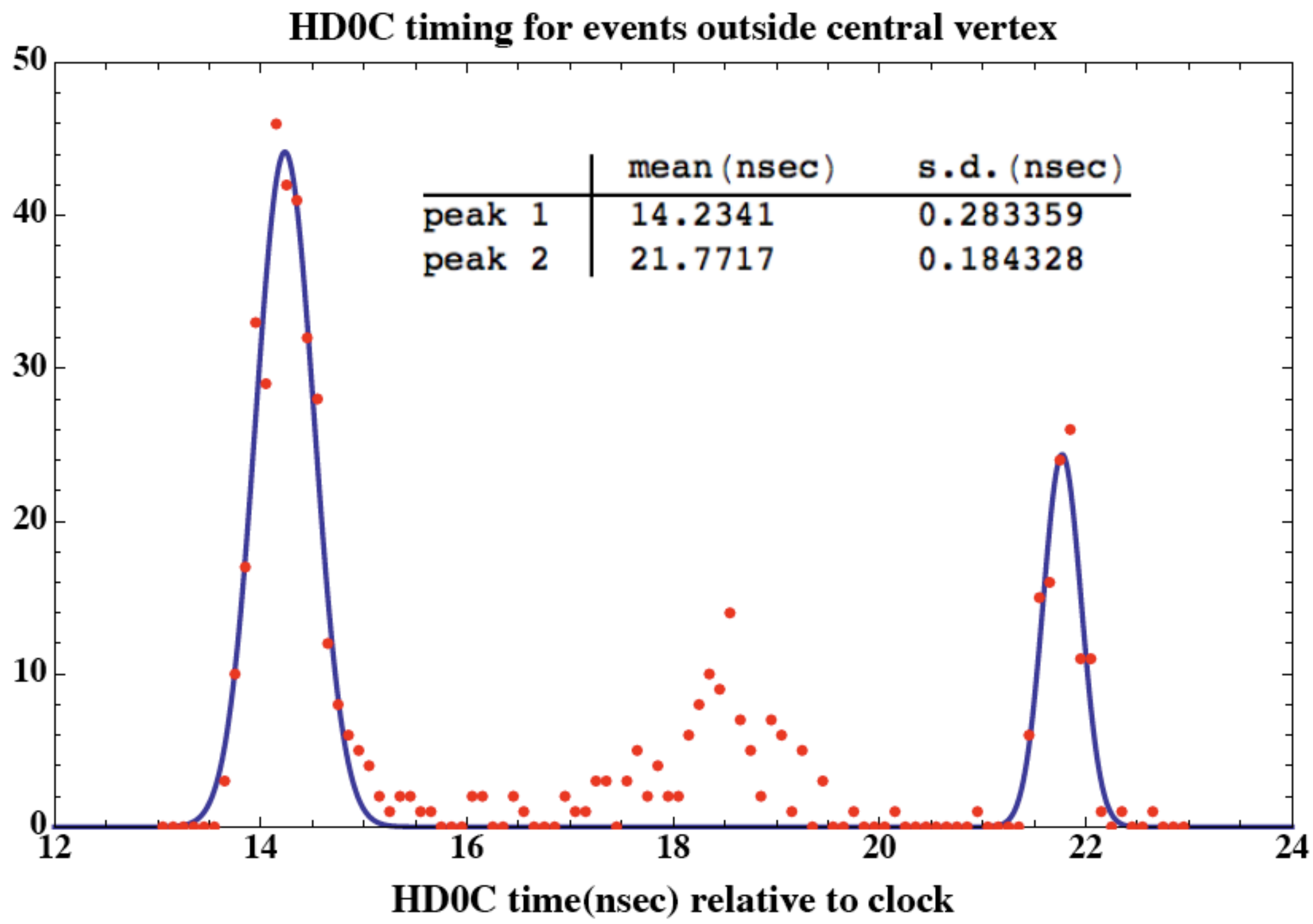
Support material for blessing:

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

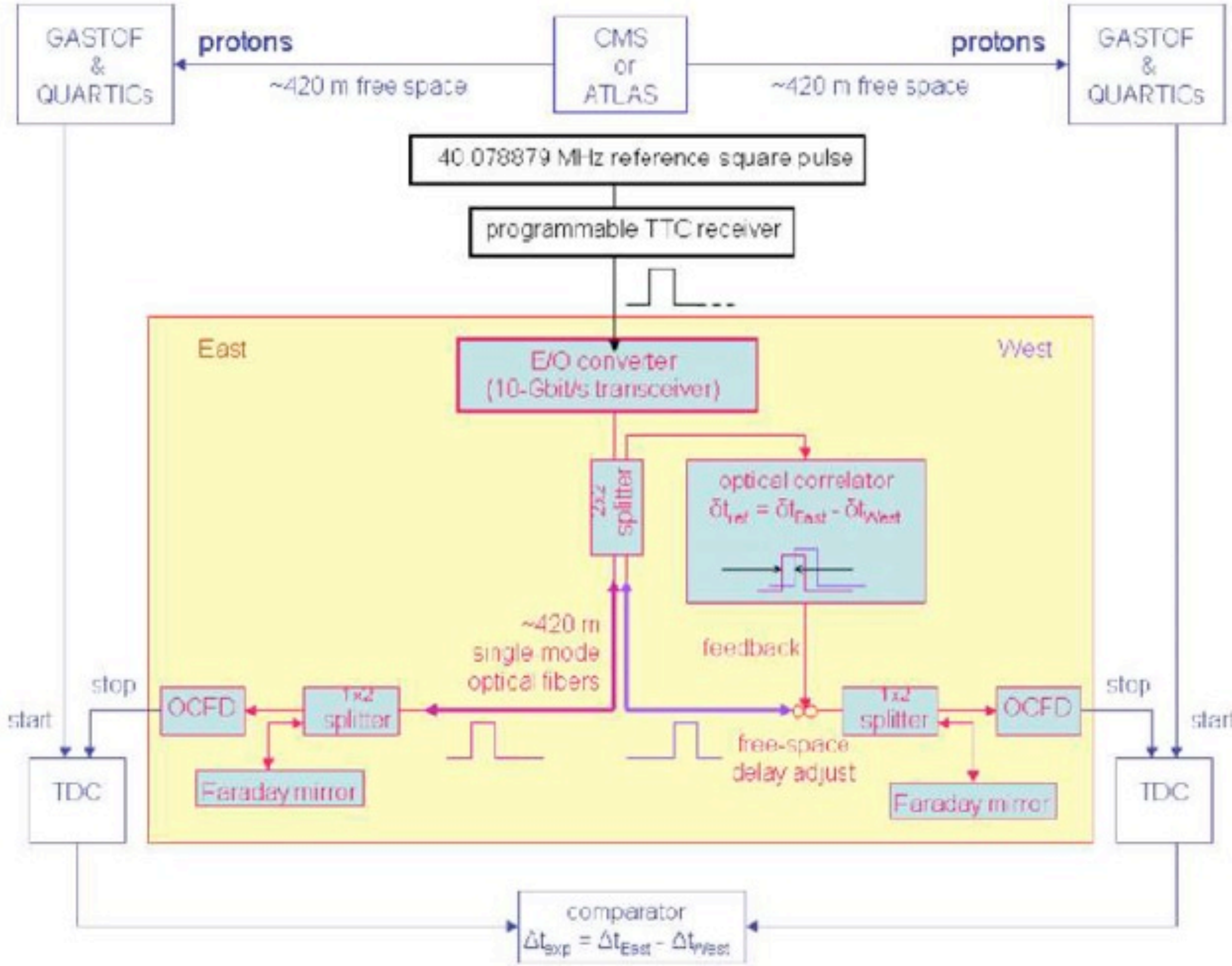


	mean(nsec)	s.d.(nsec)
peak 1	14.2341	0.283359
peak 2	21.7717	0.184328

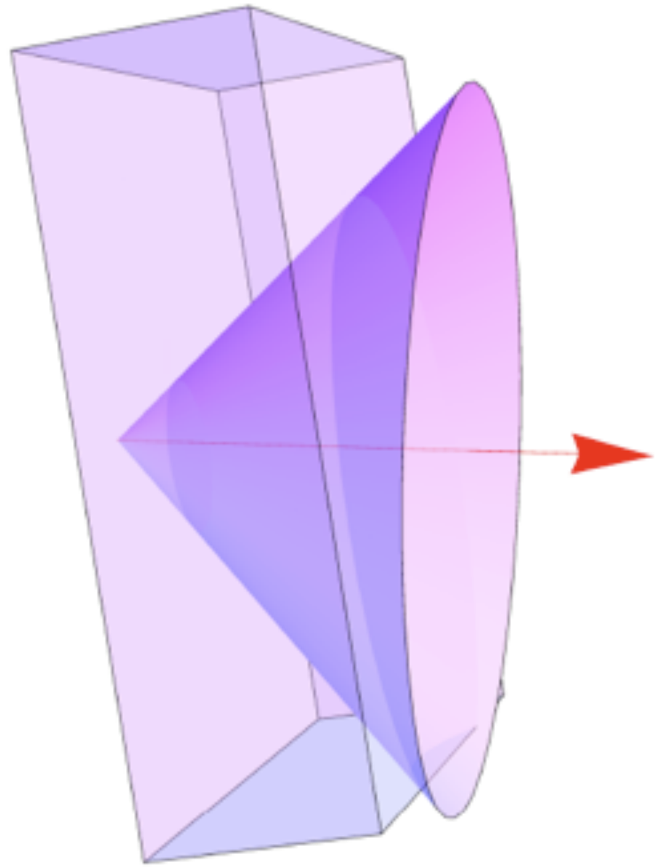
Synchronization of detectors 1km apart to <5 psec is not expensive.

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

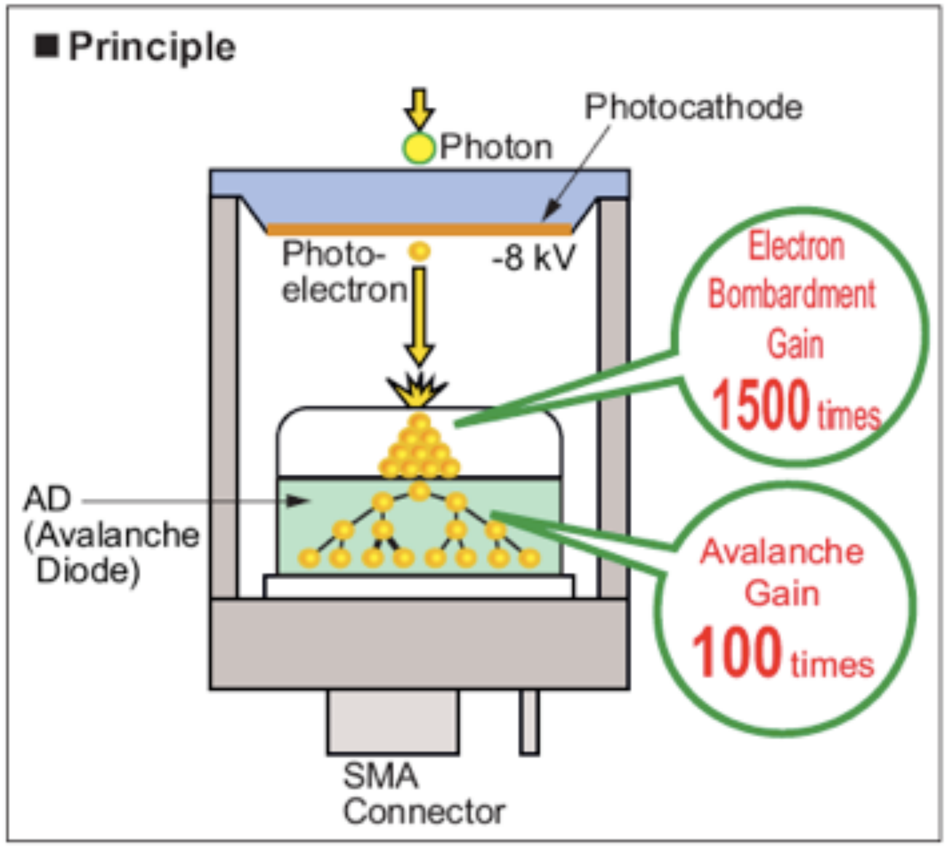
State of the art is ~10 femtoseconds using interferometrically stabilized optical fiber -see ILC design or National Ignition Facility



Sensor technology



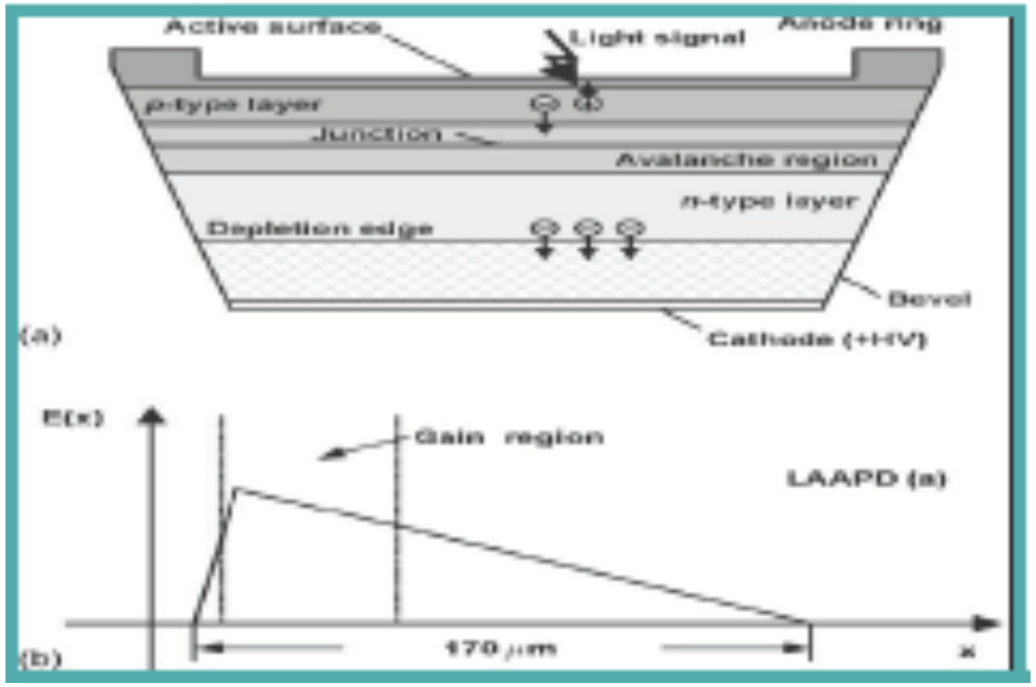
Cerenkov or APD option

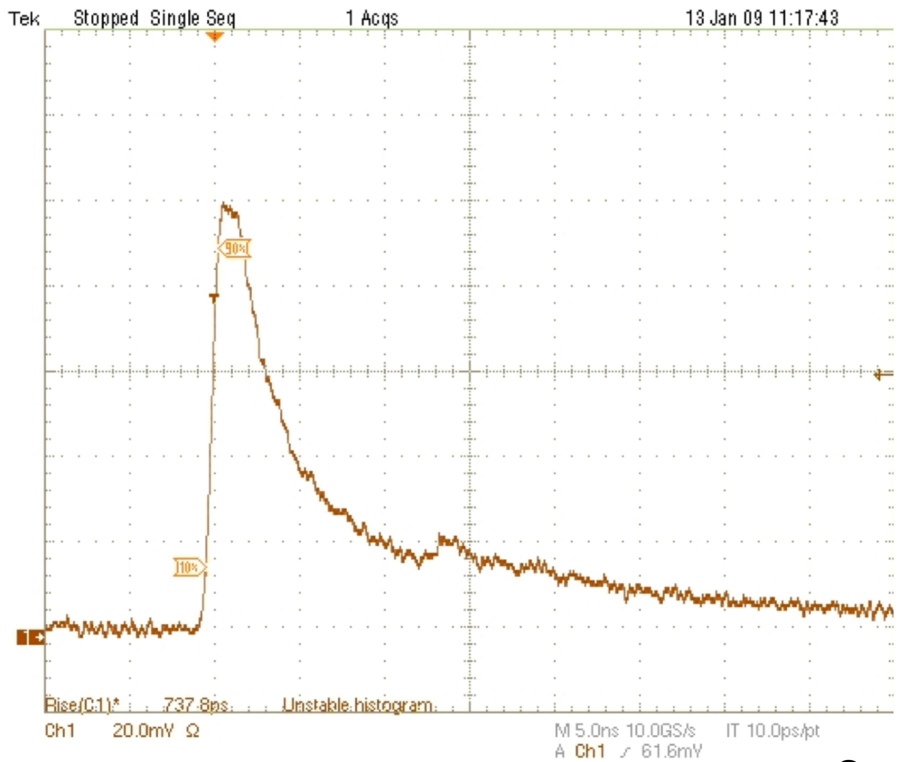


Cerenkov Radiation cone

Pre-production Hybrid photodetector

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

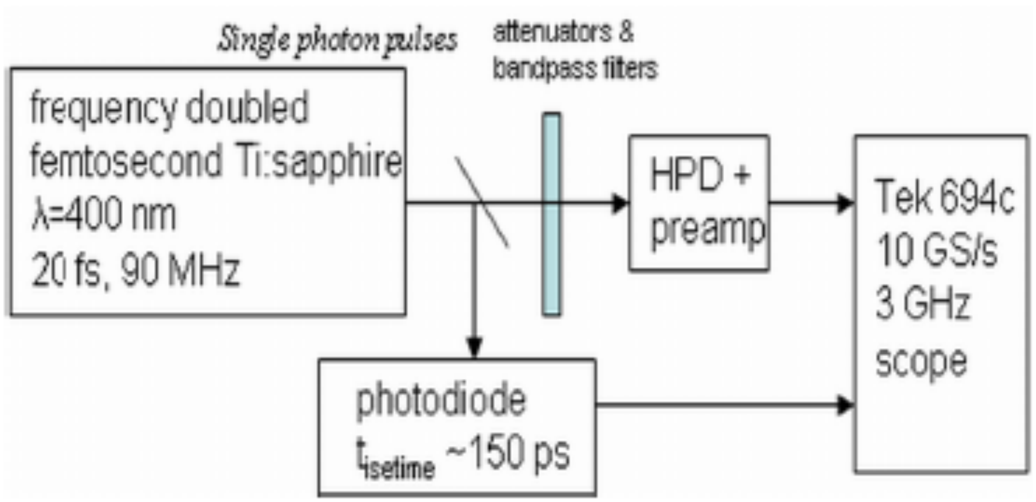




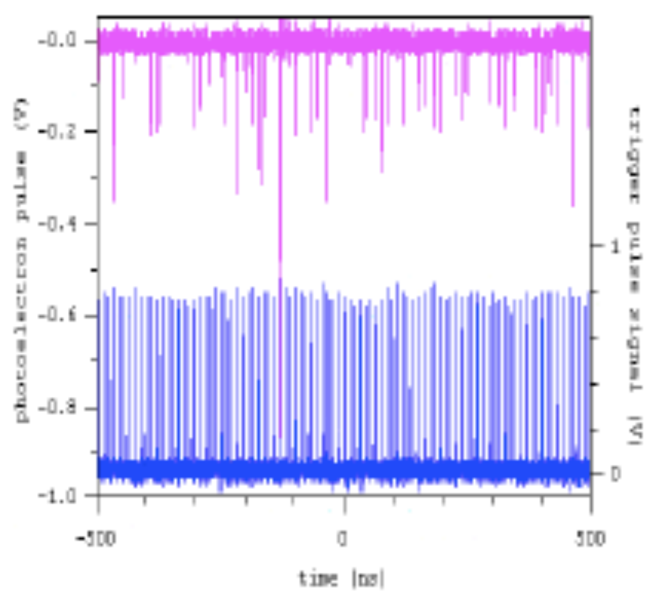
Deep diffused avalanche photodiode

650 picosecond risetime (β's)

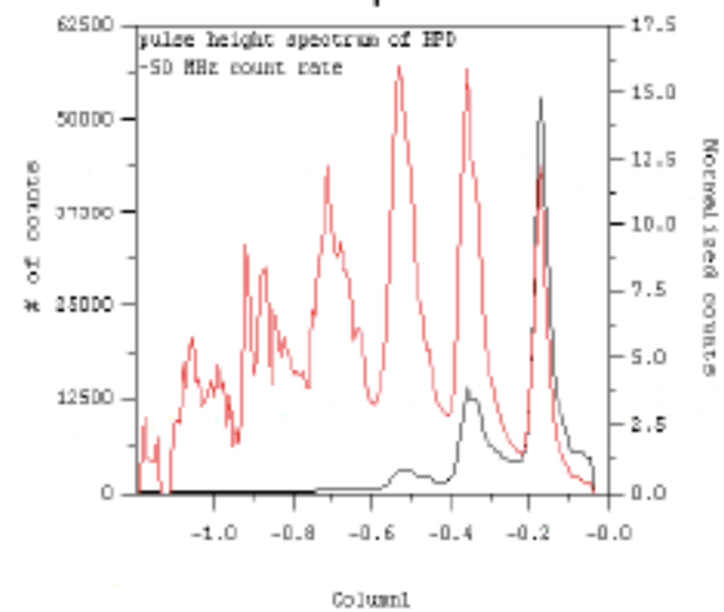
Applications in eg fluorescence spectroscopy
T.Tsang, S.White



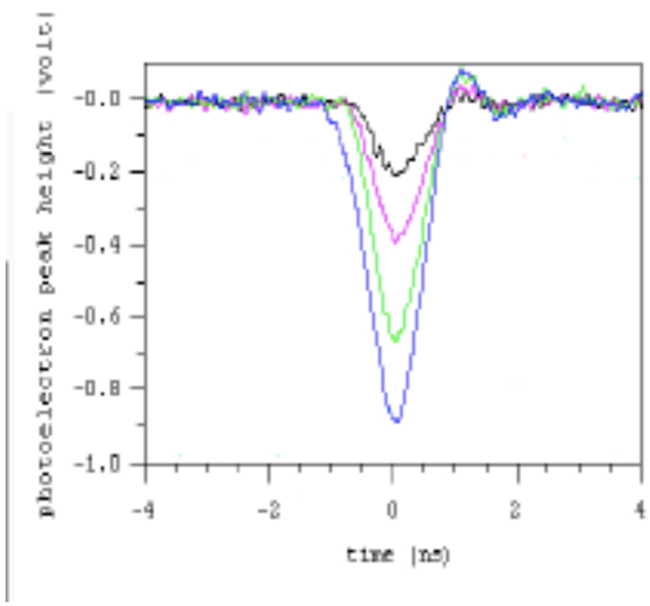
Temporal response



N_{pe}



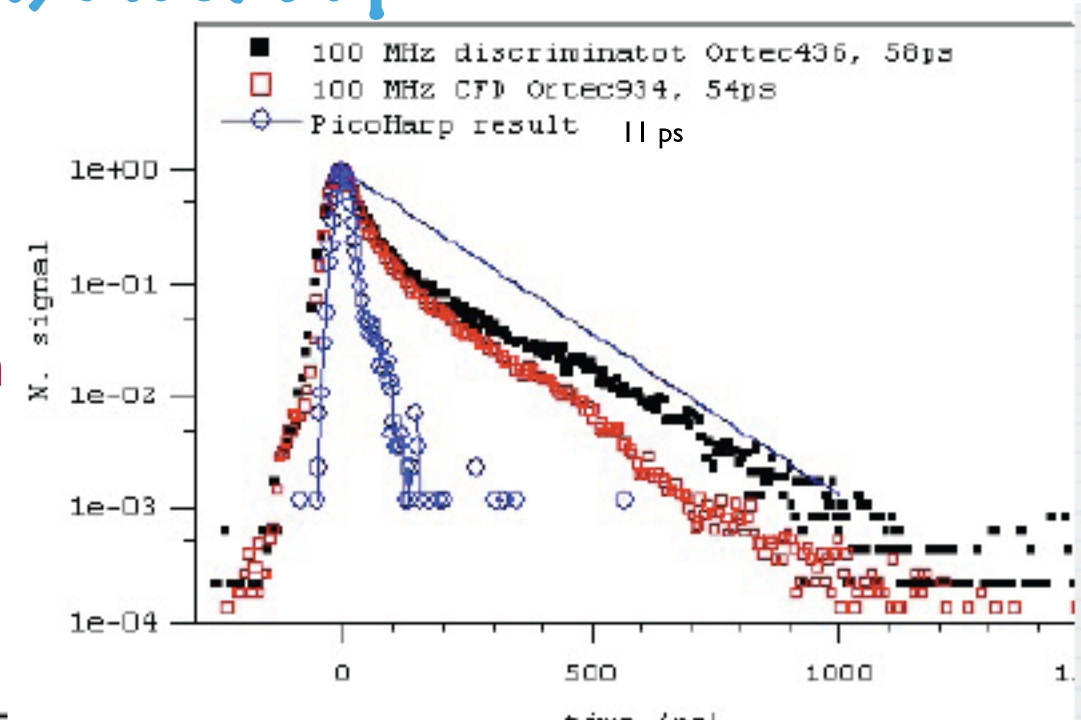
risetime=300 psec

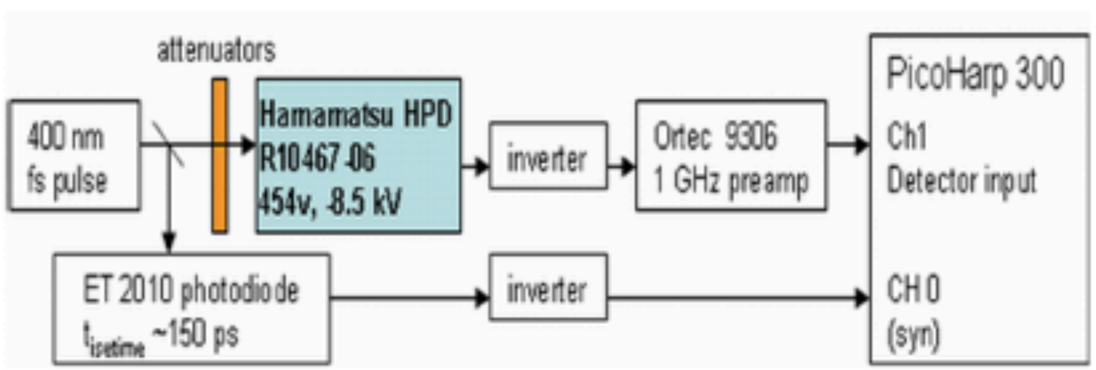


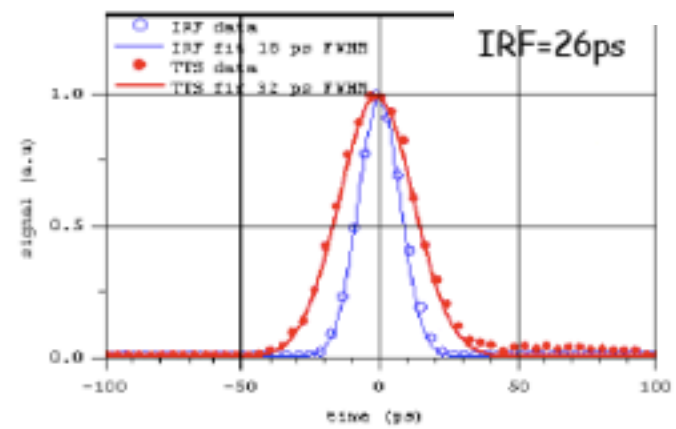
N_{pe}	pulse height after preamp (Volt)	pulse height before preamp (mV)	normalized count rate
1	0.176	2.2	1
2	0.36	4.5	0.26
3	0.528	6.6	0.061
4	0.71	8.9	0.009
5			~0.0014
6			~0.0002

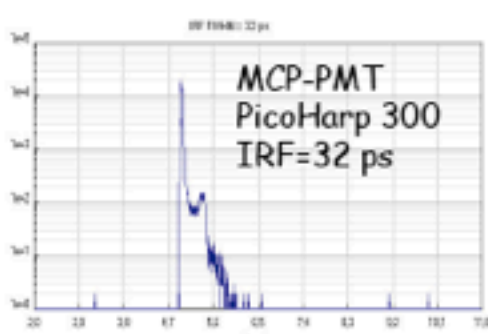
11 psec single photon response is not common!
Below studies comparing LE, CFD, PicoHarp

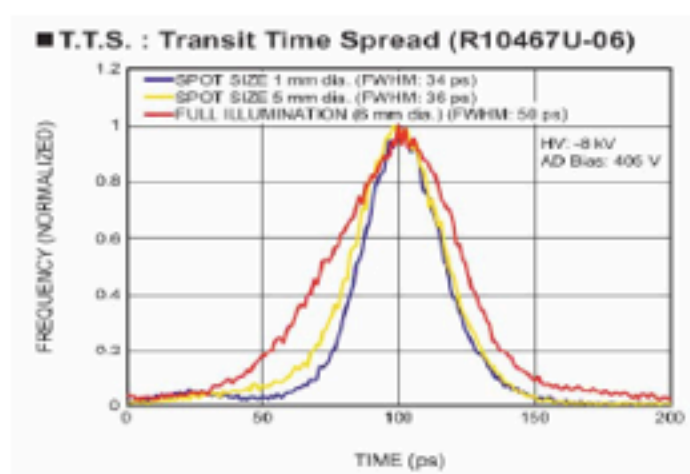
similar exercises in literature comparing methods
(see eg. Breton, Delanges, Va'vra, et al.)
now developing formalism for calculating expected resolution
-potentially useful for electronics development











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

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

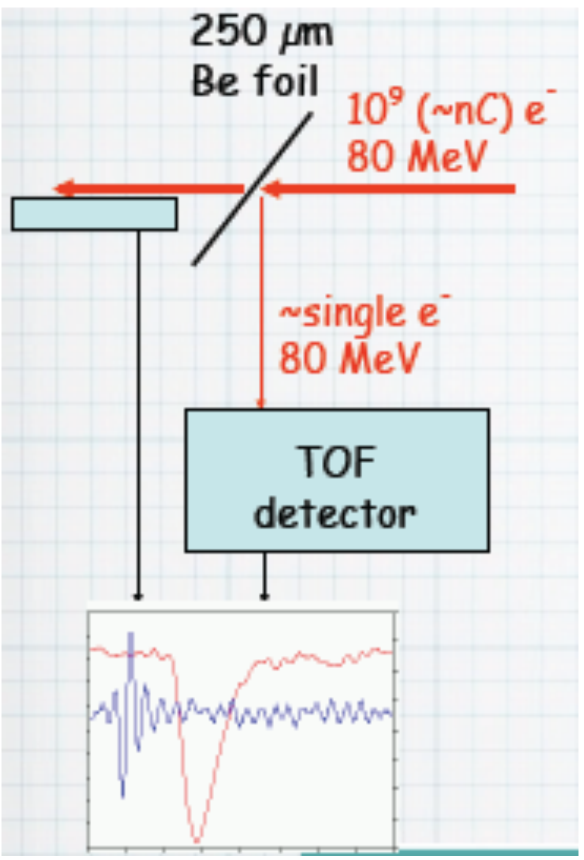
$$\sigma_{HPD} = \frac{\sigma_{TTS}}{\sqrt{N_{pe^-}}} = \frac{11\,ps}{\sqrt{N_{pe^-}}}$$

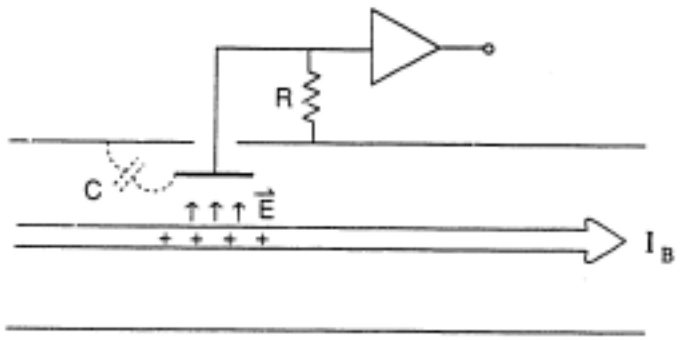
Testbeams used to characterize APD based timing detector

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 v
Argon neutrino detectors. [...]
arXiv:1004.3068. - 2010.

rates calculated based on Hofstadter's data



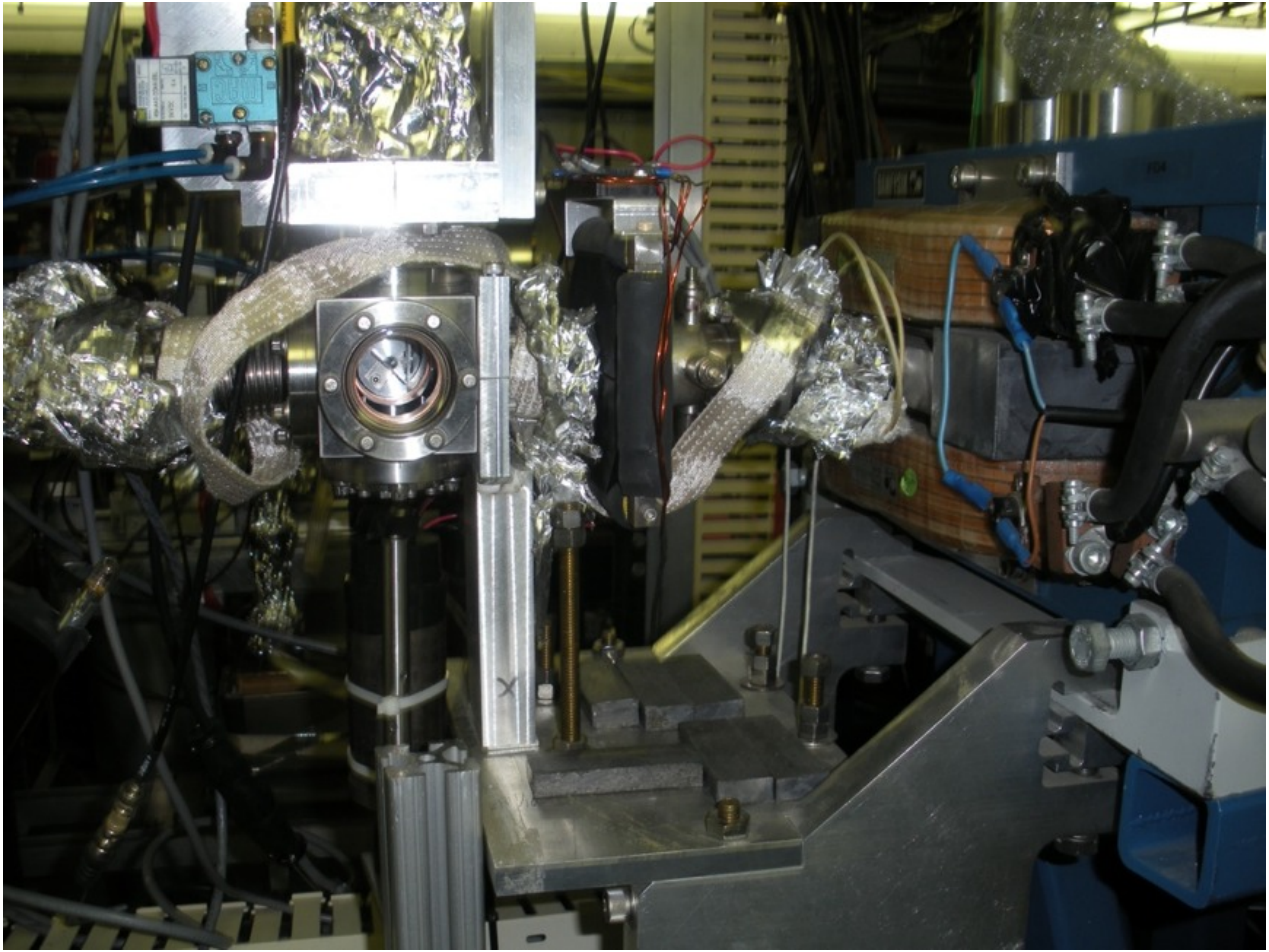


- a unique feature of ATF beam is 3 picosec bunch length(streak camera)
- could this be exploited to evaluate fast timing detectors?
- common technique for secondary beam design is successive dispersion and collimation
- this requires real estate

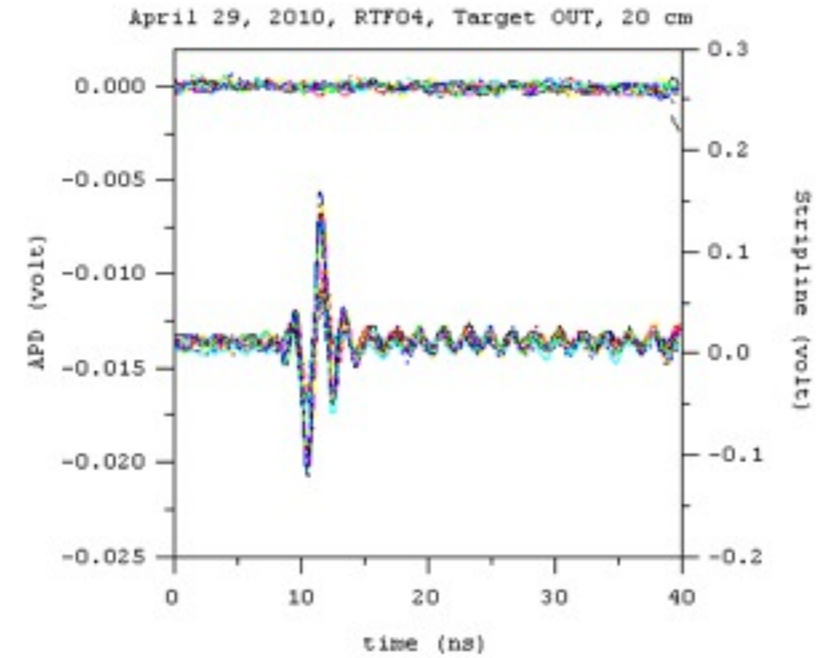
Kirk, Thomas, Misha

Vitaly

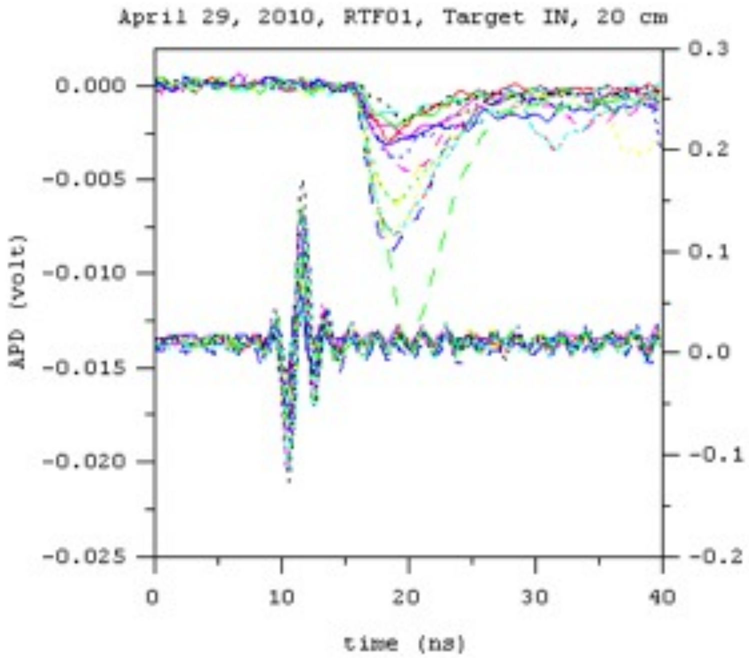
the beamline

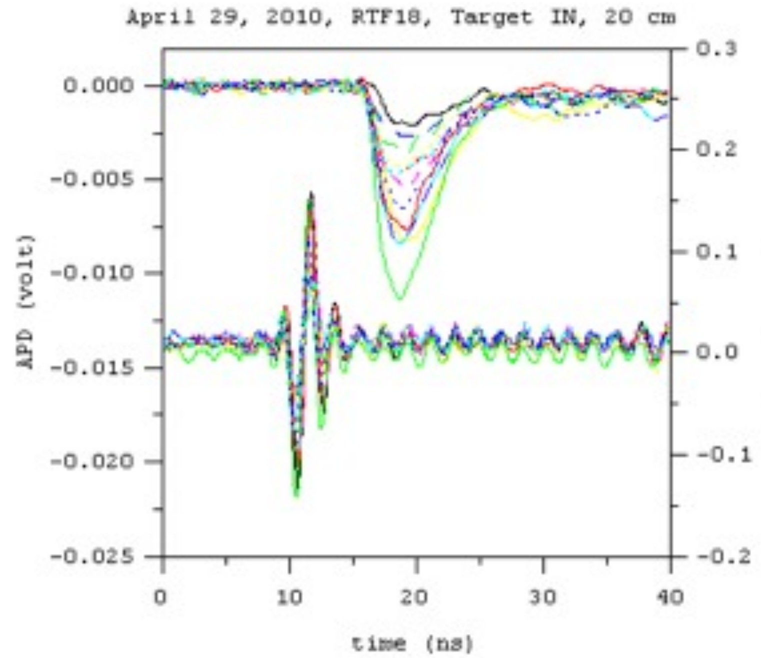


Target OUT 20 cm

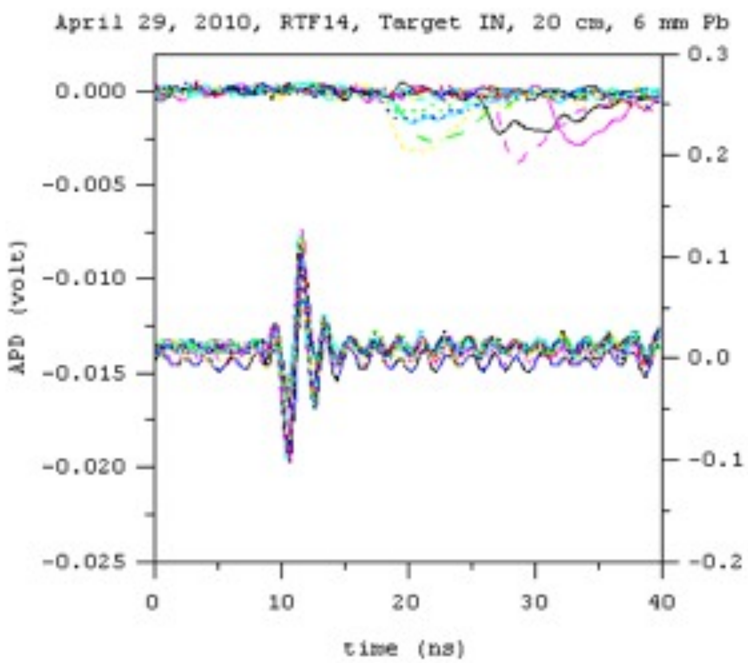


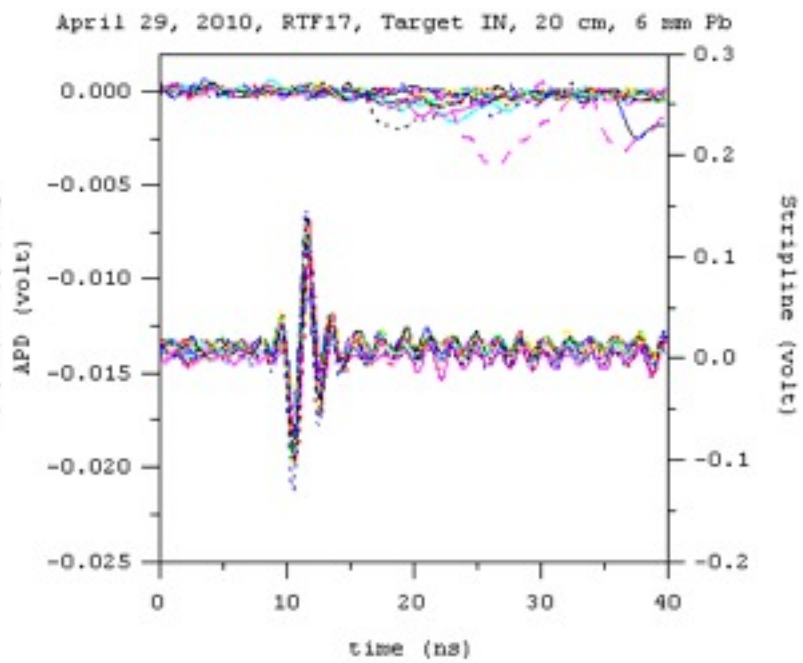
Target IN 20 cm



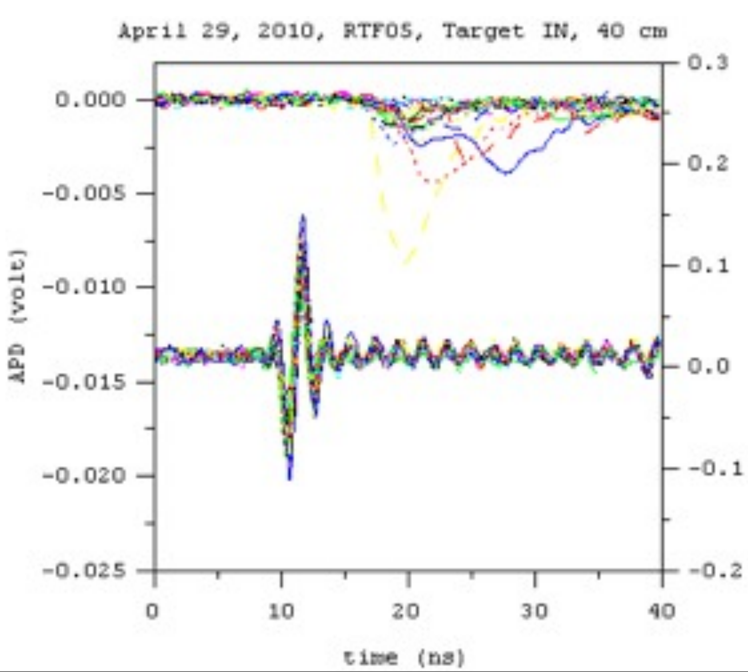


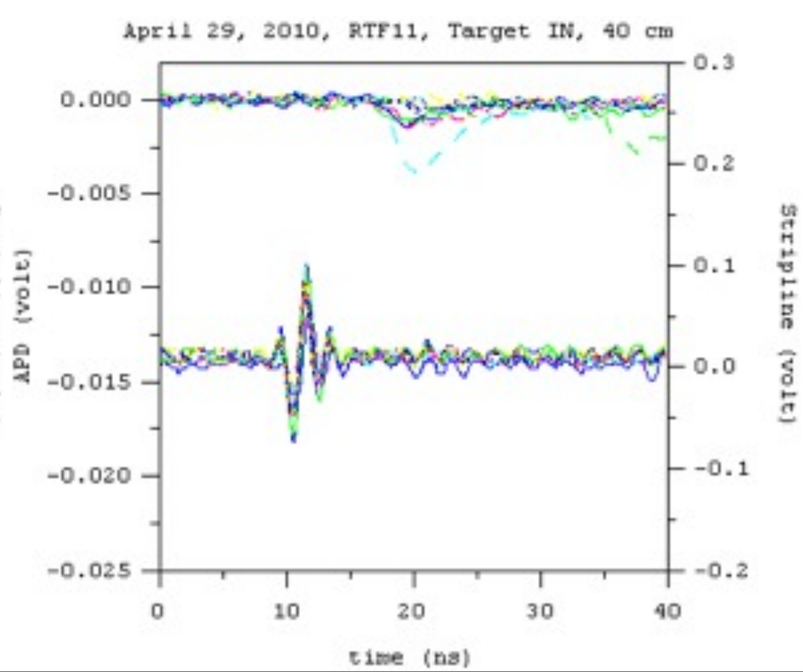
Target IN 20 cm, 6 mm Pb



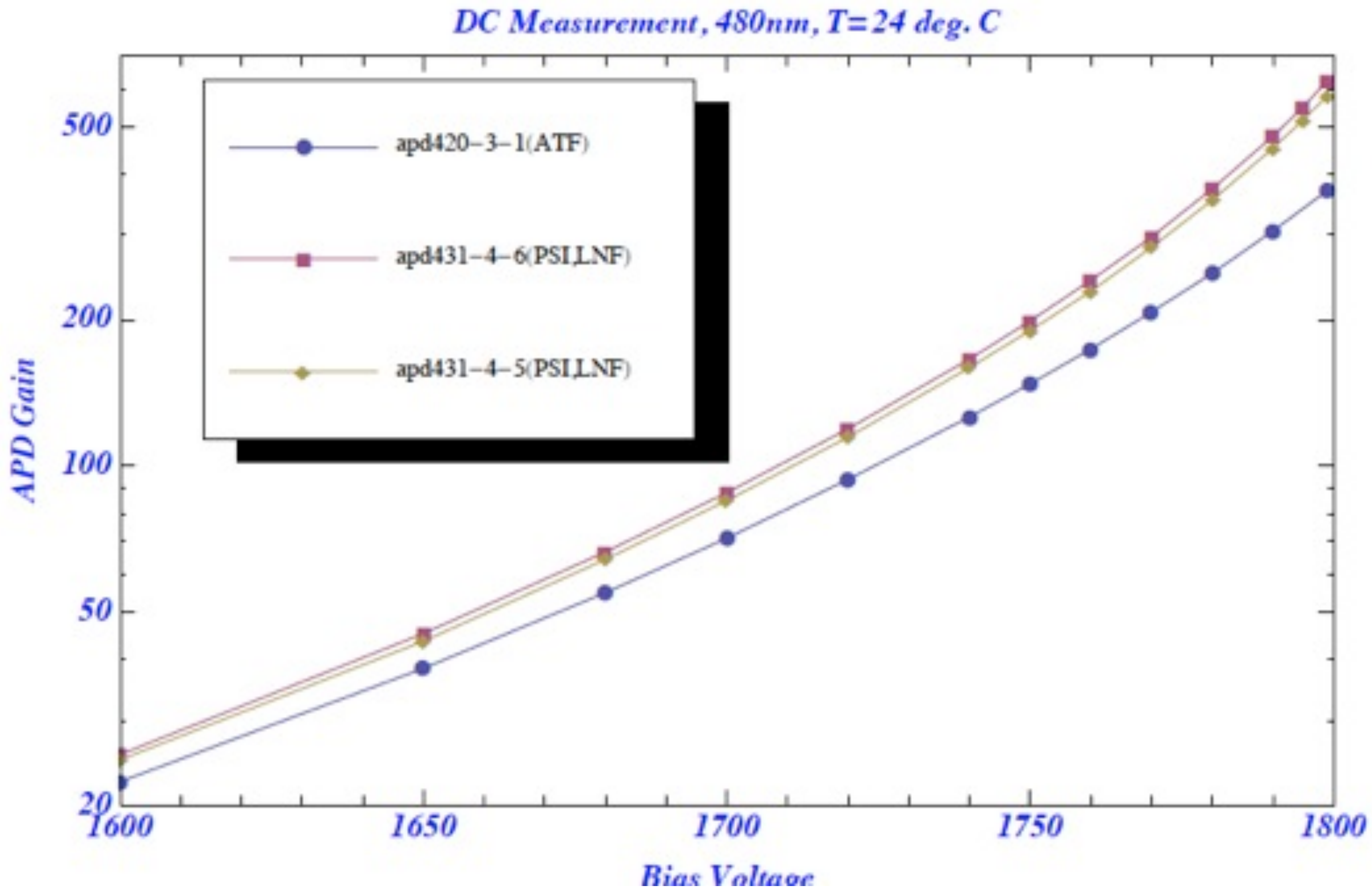


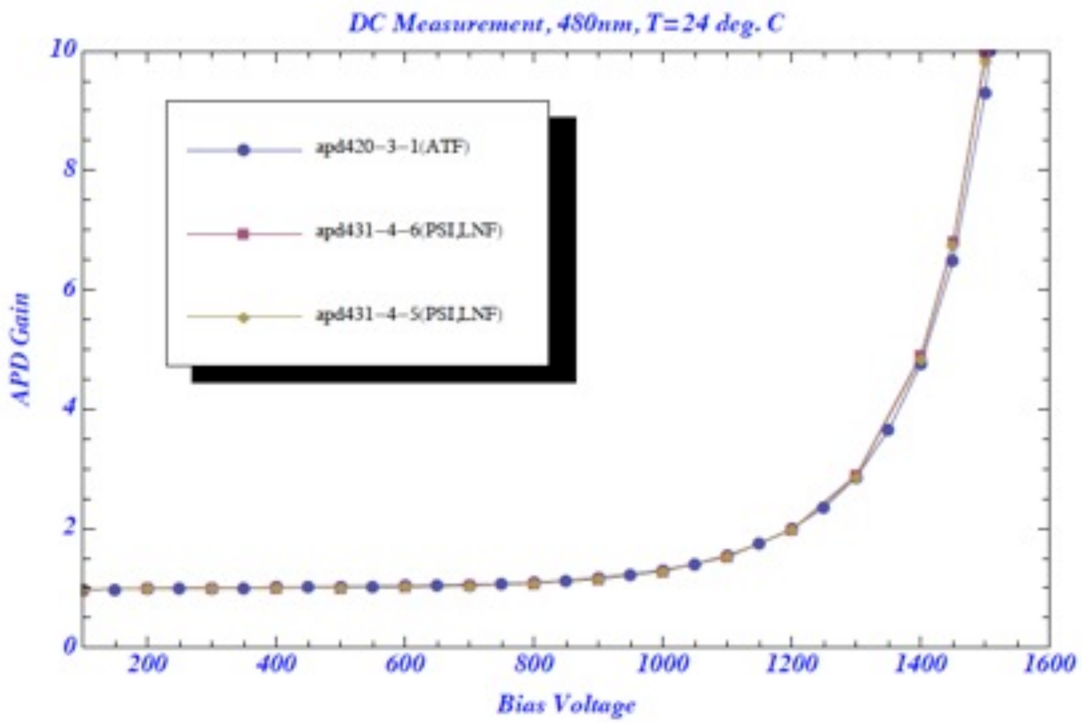
Target IN 40 cm





Gain Curve for APDs used in Frascati/PSI





Expected APD mip signal

In[130]:=

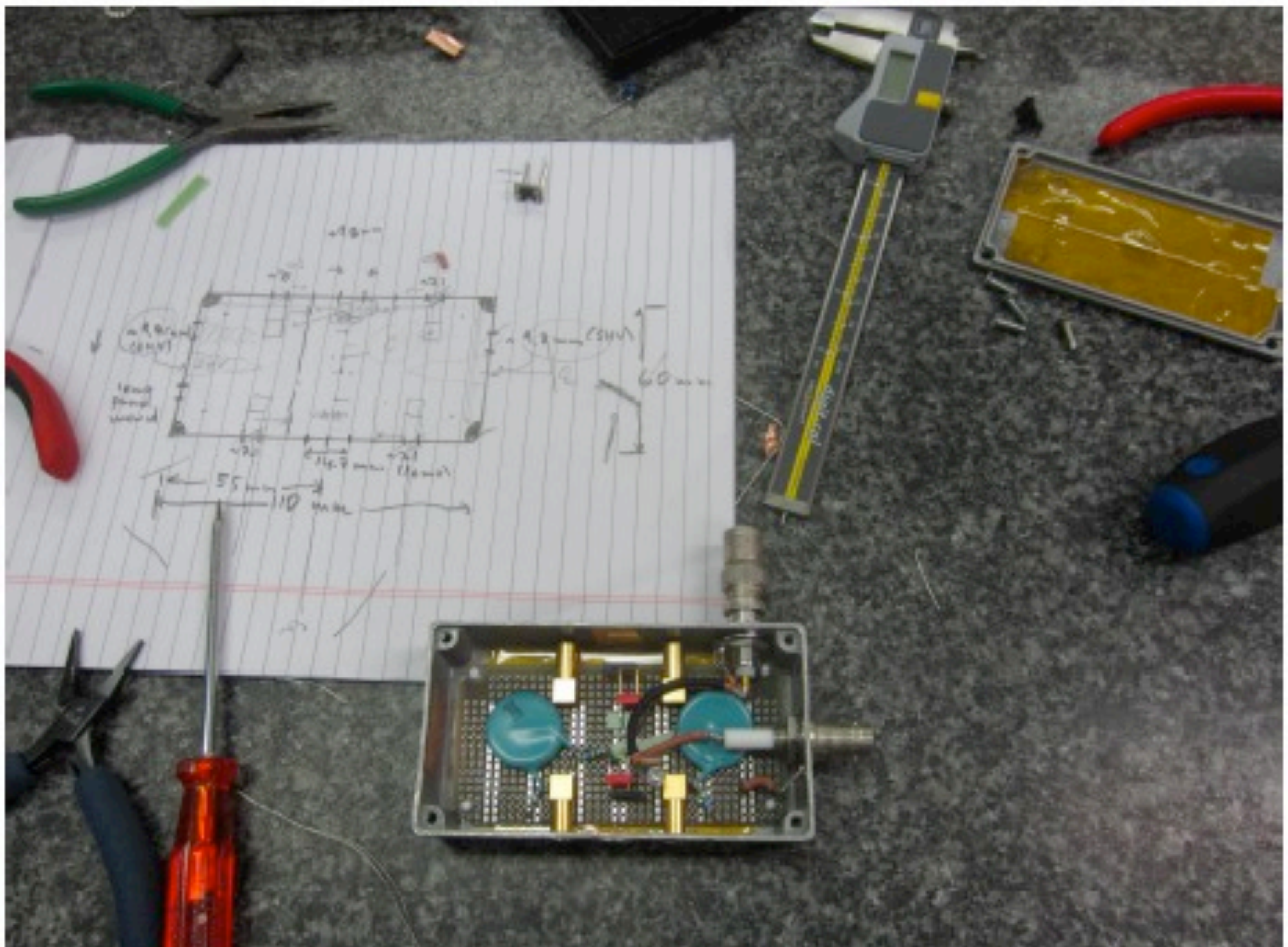
```
q = 6000 * 200 * 1.6 * 10^-19;
ampgain = 8;
t = 5 * 10^-9;
i = 2 * q / t;
mV = 1000;
e = i * 50 * mV * ampgain
```

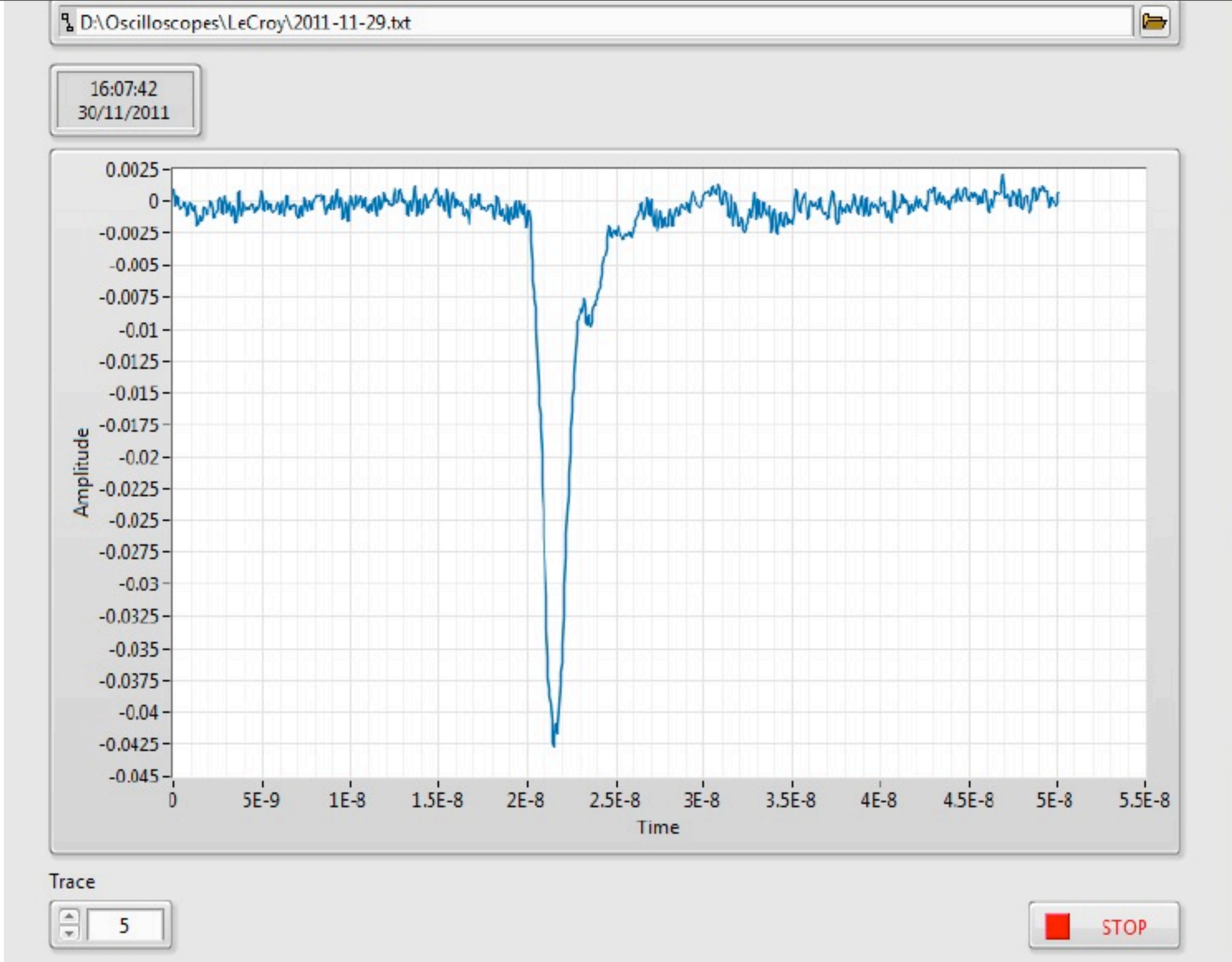
Out[135]= 30.72

In fall 2011 (in Crispin's lab) 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).



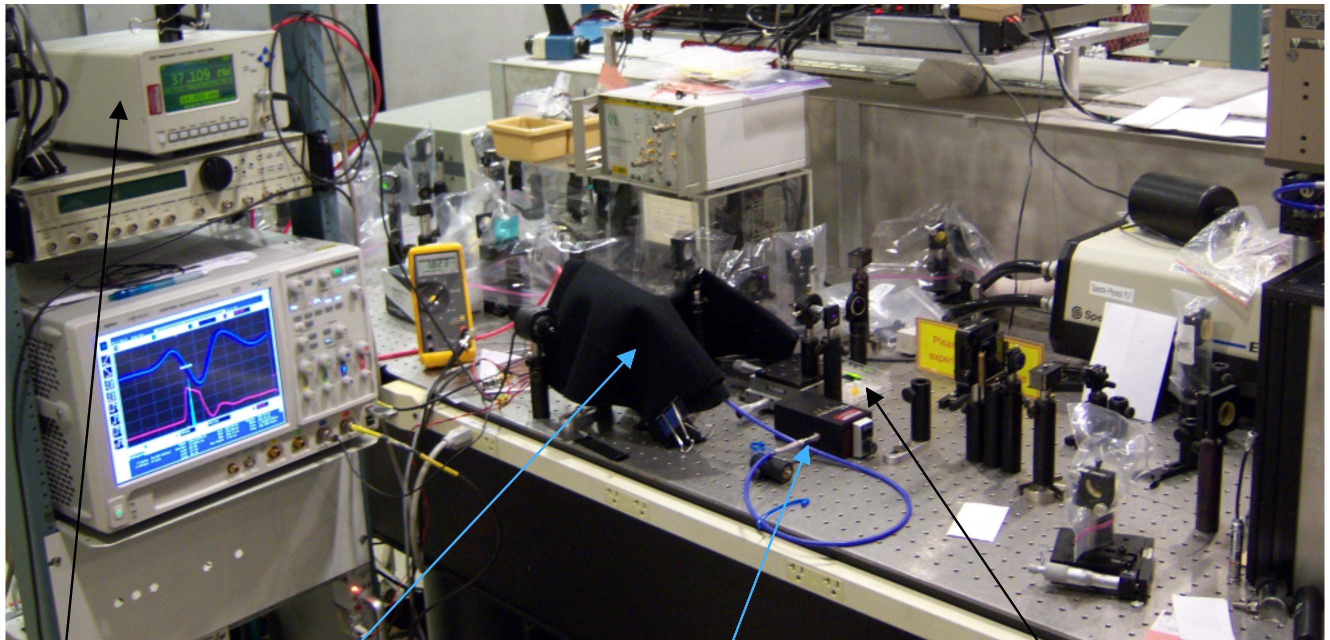


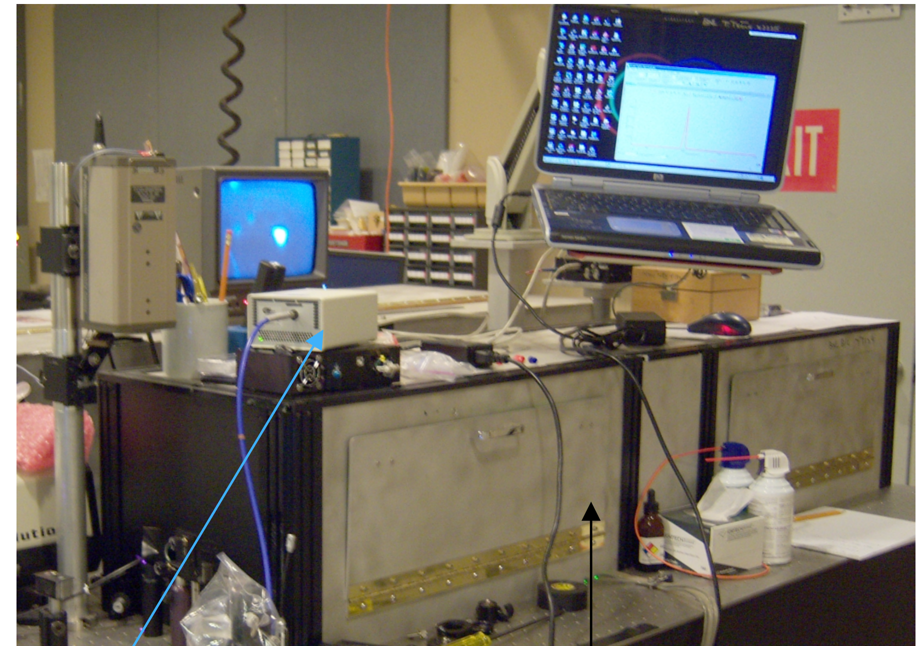
with higher BW amplifiers (ie 3GHz $70 ones from min-circuits) reduced risetime to 0.5nsec).Noise is DAQ limited (scope noise floor).

PSI testbeam team:

- testbeam results (all with 8x8mm APDs) and beta source tests (mostly using 2x2mm APDs) gave inconsistent results which we attributed to lack of tracking information and potential for position dependence of timing performance. This has held up publication of results- particularly under the DOE ADR&D project.
- In late August 2012 started tests with a femtosec laser. At ~1000nm and with proper intensity this is excellent model for MIP signal formation. Advantage of good localization (to <20 microm) and laser timing signal (to beter than 2 picosec).

Experimental set-up for femtosecond laser tests





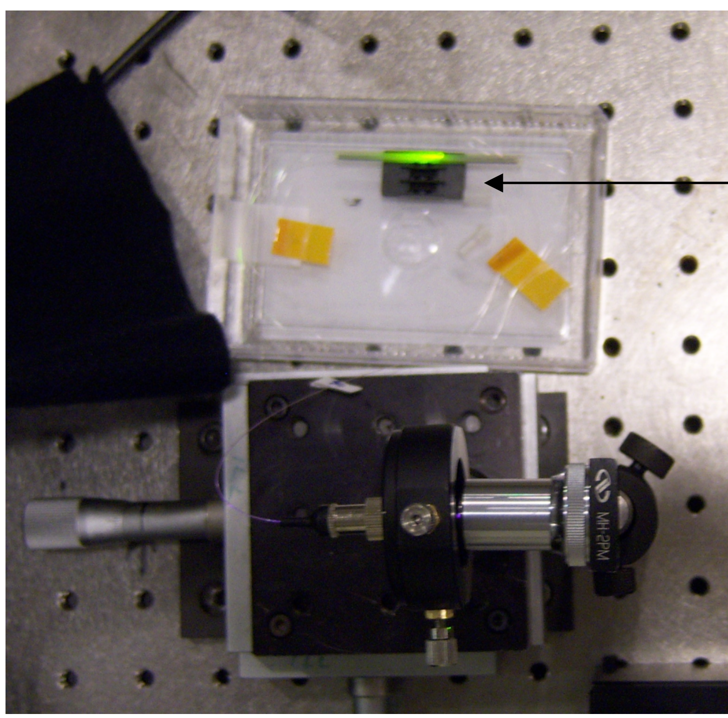
optical power meter

RMD APD

monochromator for IR wavelength selection

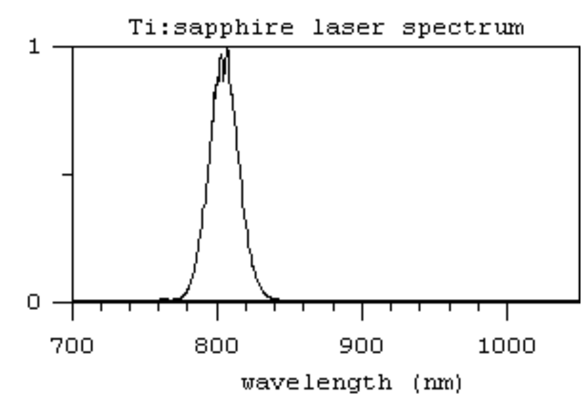
IR spectrometer

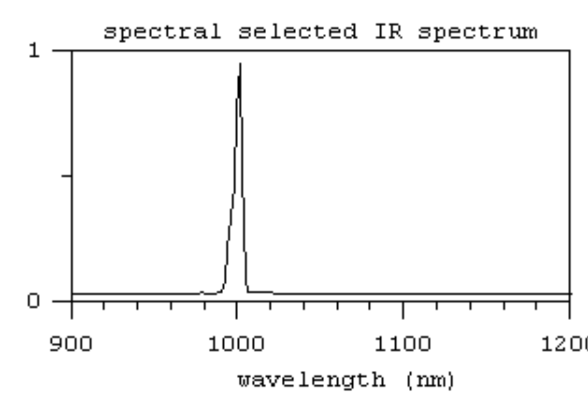
Femtosecond Ti:sapphire laser oscillator



white light supercontinuum generation from photonic crystal fiber

send IR beam directly from φ=0.6 mm optical fiber directly onto the APD both separated by <5 mm.





August 24, 2012   APD timimg jitter on Agilent DSO91304A 13 GHz oscilloscope

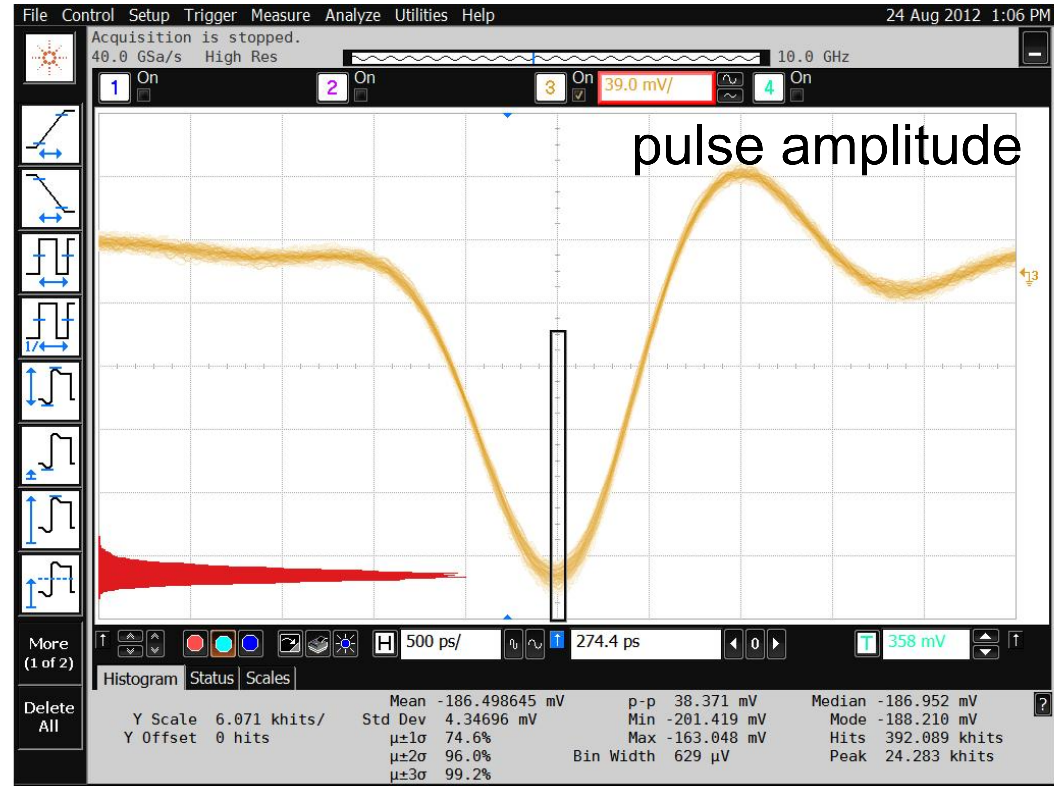
Laser wavelength: **1000 nm, ~ 2 μW**

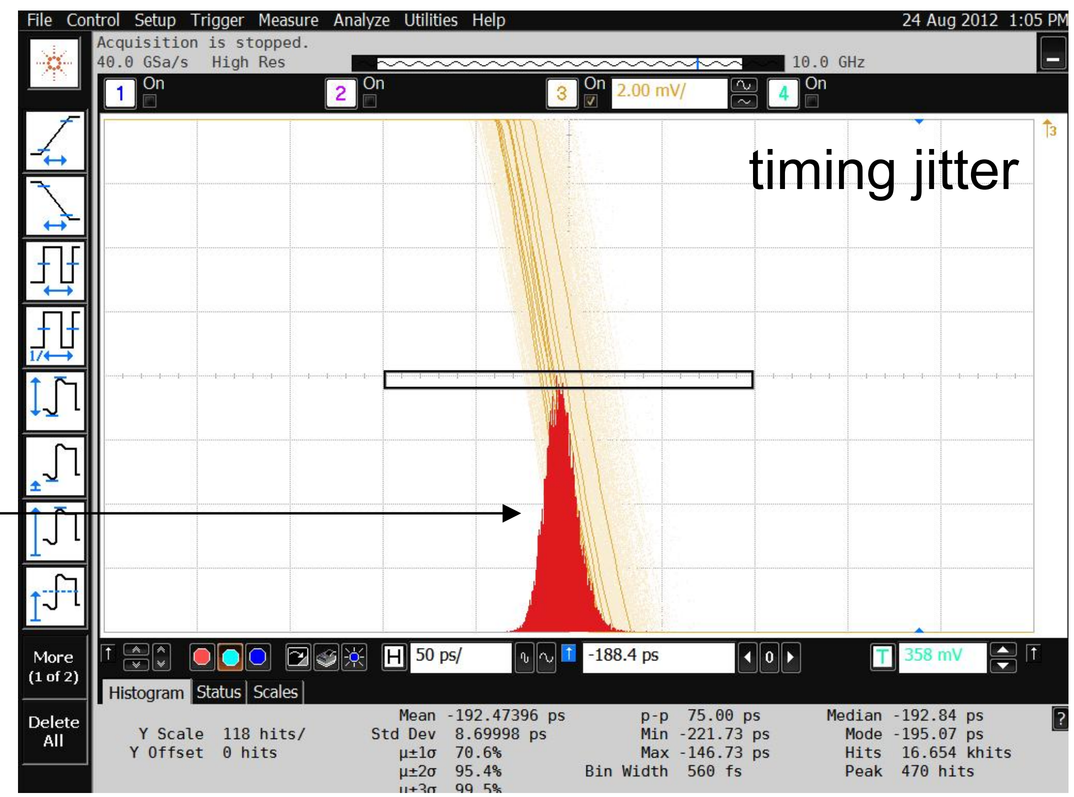
Trigger: ET2010 photodiode, t_r=120 ps

Signal: RMD APD + Ortec 9306 preamp

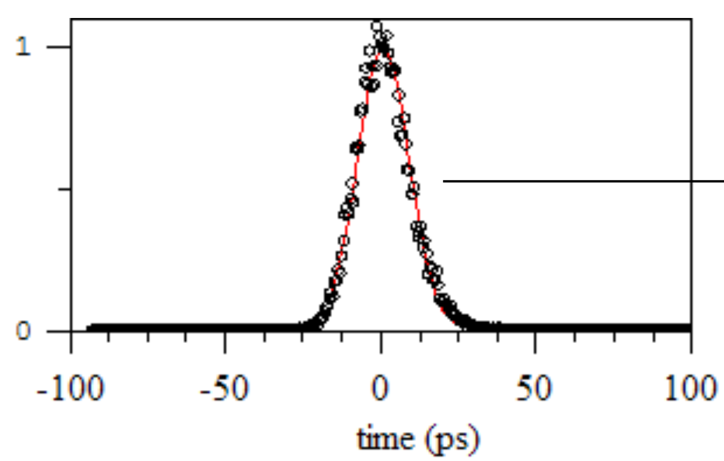
HV bias on APD -1.85 kV

(this is a relatively high bias- near
Top of range. At lower bias (1.75 kV)
Jitter is 9.8 psec.)
Nb: these are raw distributions from
LE timing, no signal processing, baseline
Restoration or post-analysis.





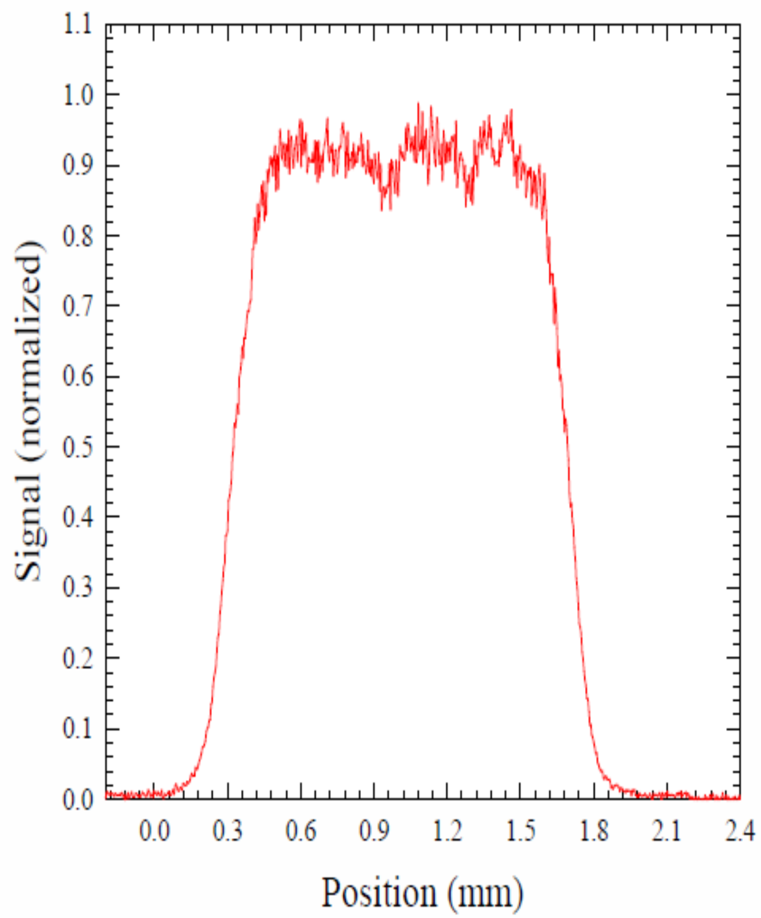
timing jitter
t_{rms}=8.28 ps



Spatial response map of RMD APD

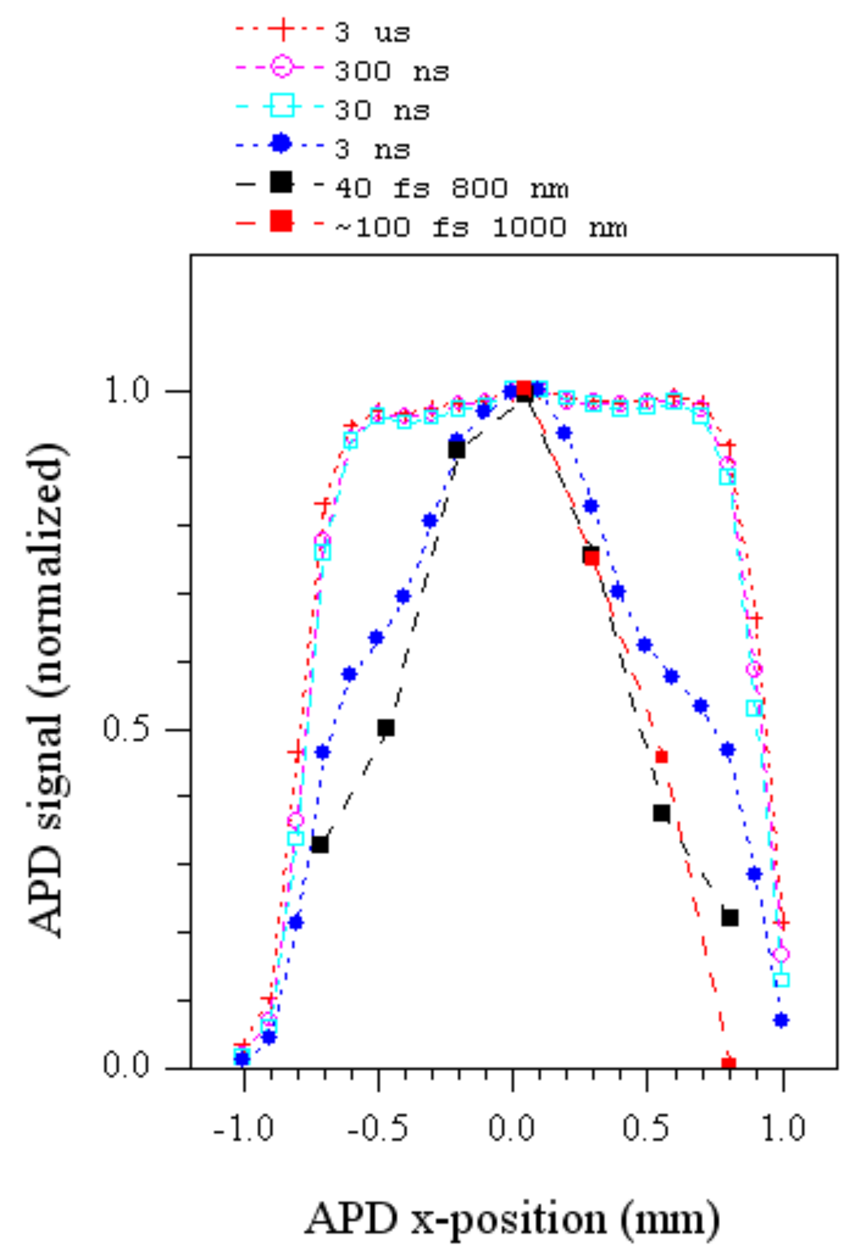
RMD data

Data from 1/12/10
Standard ~ 4 mm2
APD biased near breakdown (Gain > 500)
980 nm laser pulse, 2 µs, no averaging
laser focal spot size ~ 10 µm



T. Tsang data, Inst. Div.

Sept. 12, 2012
Laser pulse width 3 µs to ~fs

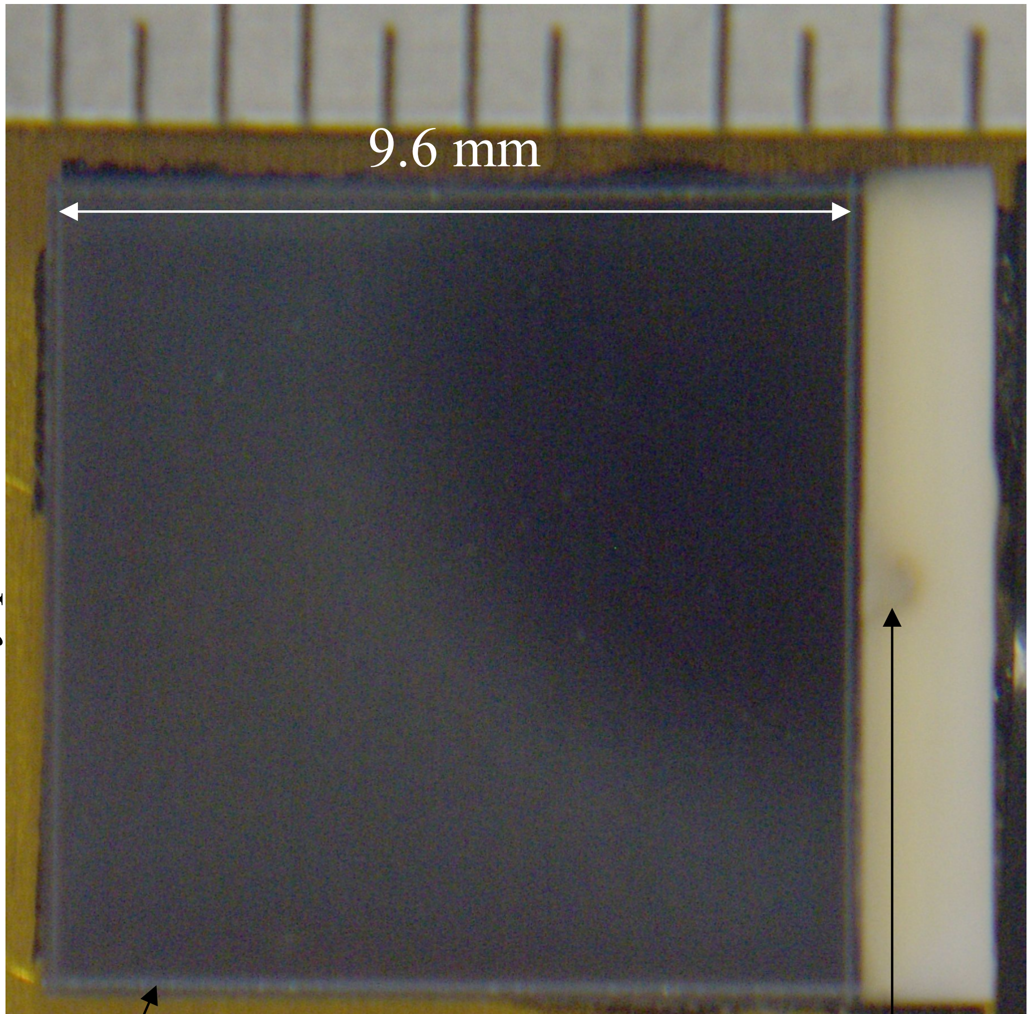


Sept 26, 2012 RMD APD 8x8 mm^2

Spatial response map

APD bias at -1750 volt, 850 nm laser
laser focus spot size <100 µm
~3 µs pulse, 1 kHz, 8.5×10^7 photons/pulse

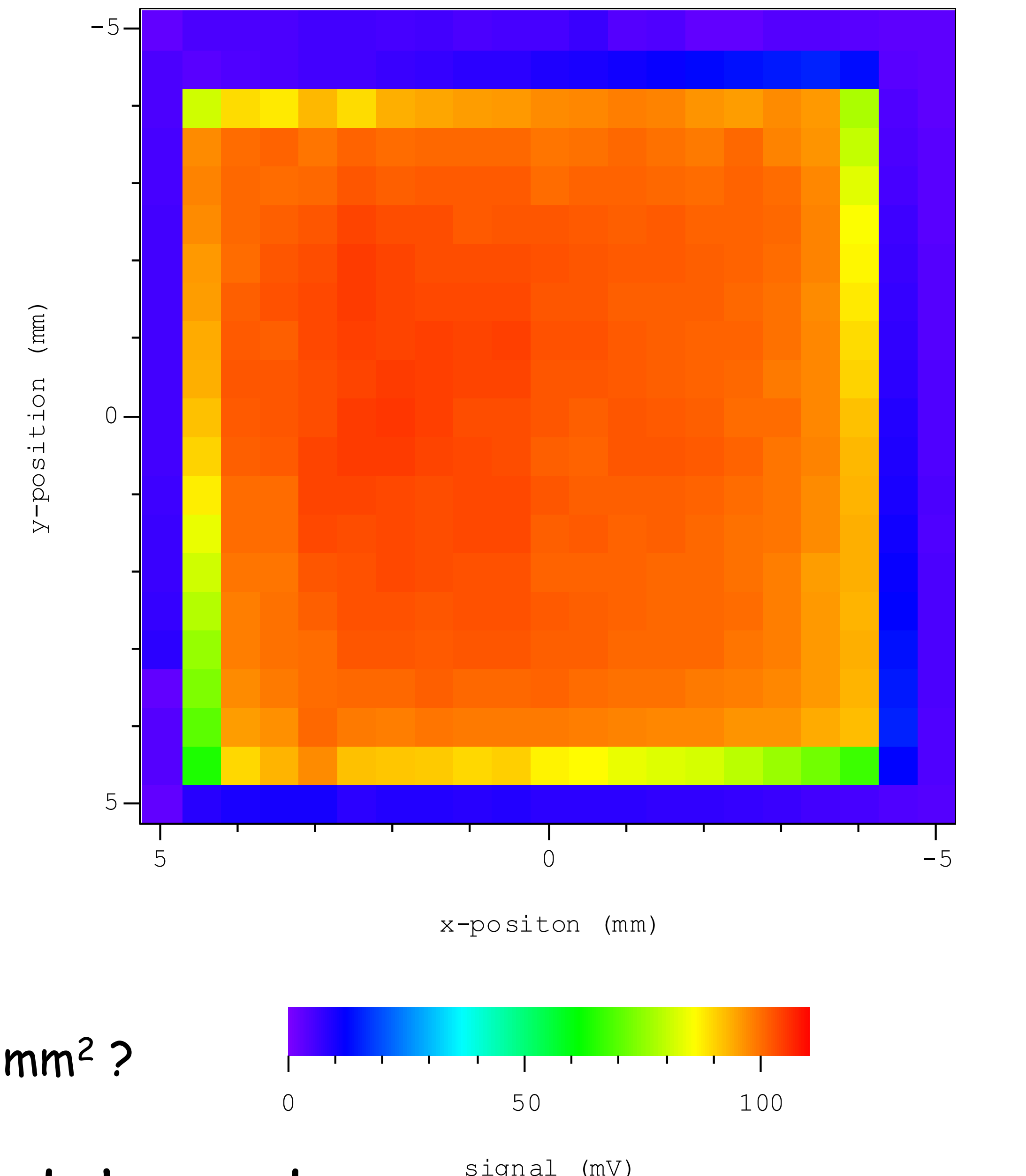
y-position



x-position

guard ring box

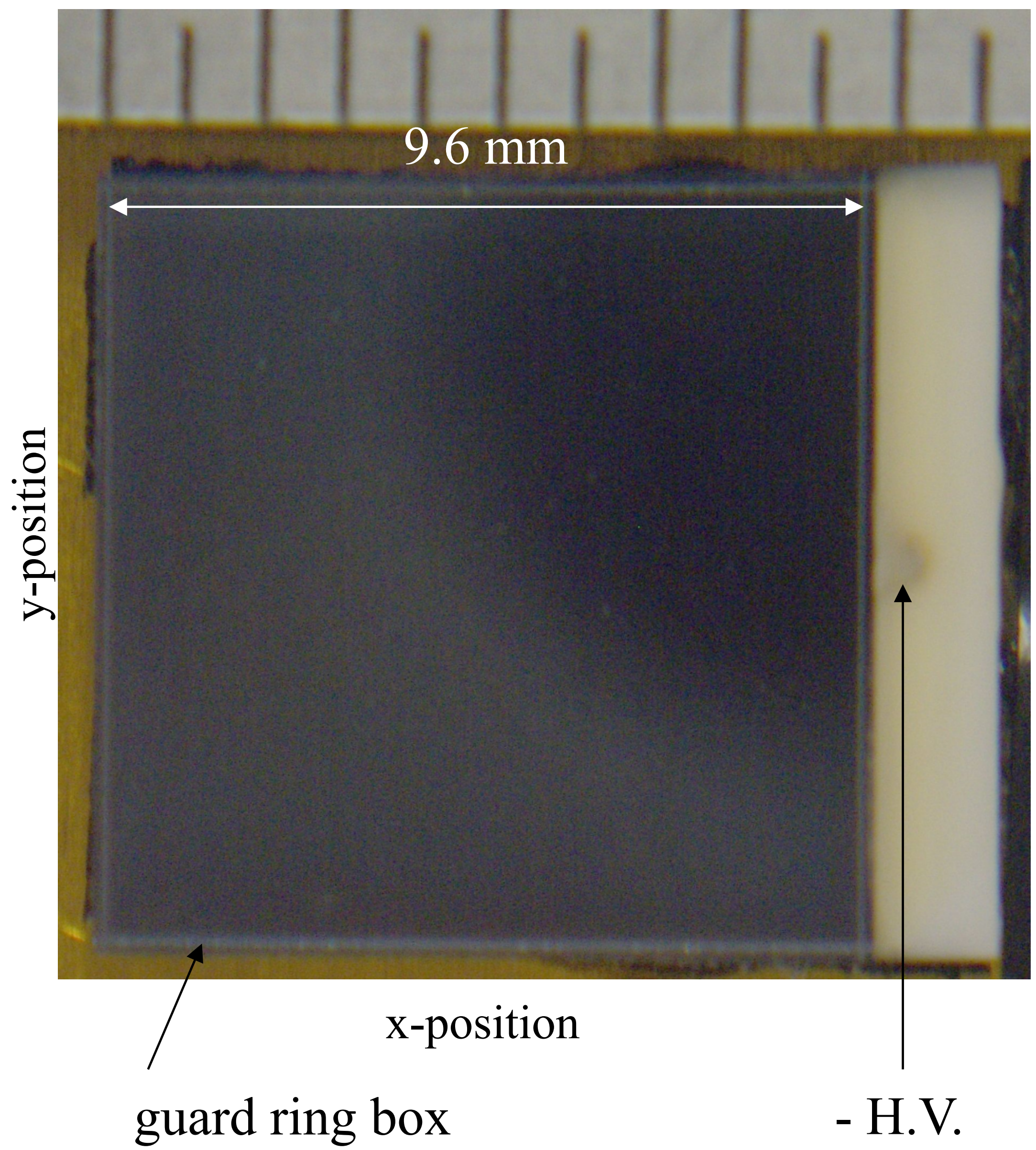
- H.V.



APD active area is larger than 8x8 mm^2 ?

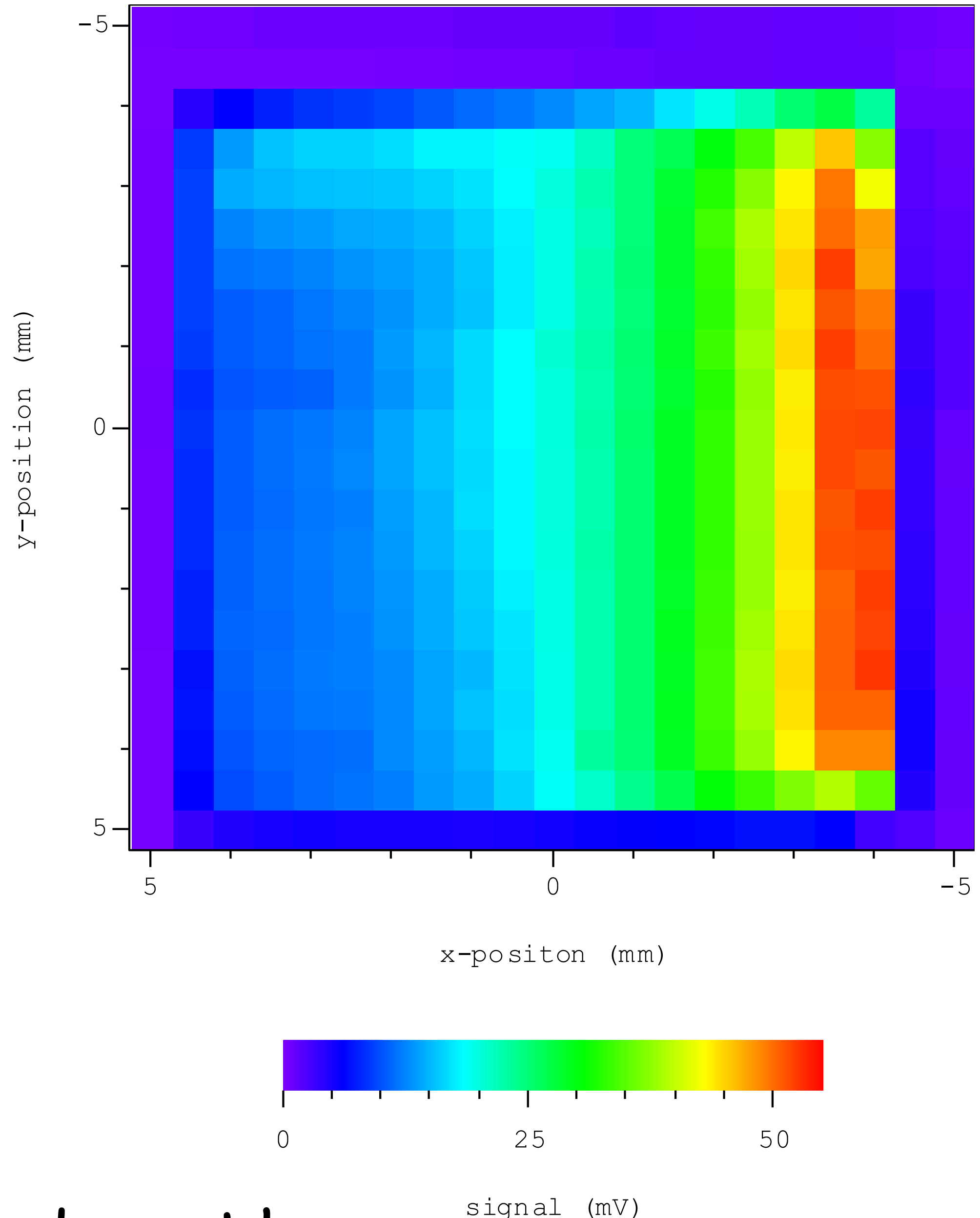
APD signal amplitude has good spatial uniformity with long duration light pulses

Sept 26, 2012 RMD APD 8x8 mm^2



Spatial response map

APD bias at -1750 volt, 850 nm laser
laser focus spot size <100 μm
~3 ns pulse, 1 kHz, 2.5x10^5 photons/pulse
(1-σ noise ~7.7x10^3 photons)



APD signal amplitude does not has good spatial uniformity with ns short light pulses

Here too there is clearly an issue with metalization!

Oct. 2nd message from Dick Farrell, Director of APD Research at RMD, Dynasil:

"Hello All,

I promised Sebastian that I would let him know if we saw anything interesting. We don't yet have the APD coated with 50 Angstrom Al , but yesterday I applied a band of Indium around the top edge of an '8X8mm' device. This device had previously had Indium applied to its 7X7mm n+ back contact, but when tested it showed the same nonuniform response to short laser pulses as had shown up in Thomas' data. When re-tested after the Indium band was applied around the top surface, however, there was a marked improvement in the uniformity of response across the exposed area using 2ns pulses from a 980nm laser. Looking at the scope, we could discern no variation in pulse amplitude across the APD area.
My best guess, based on this result, is that......."

=>Very realistic expectation that we will have in hand 8x8 mm APDs which do not show position variation and will be fully characterized with femtosecond laser tests.
=>This greatly simplifies upcoming beam tests at T10, since tracking will be unnecessary.

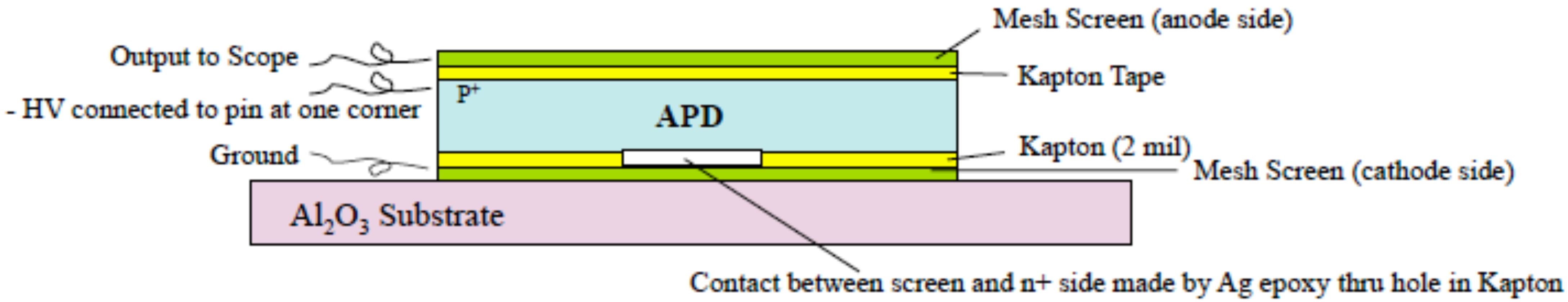
Plans for coming months concerning APD (charged particle)timing R&D

- we are in productive close contact with RMD APD development activities and are jointly submitting a related SBIR
- for completeness, also in close contact with Hamamatsu concerning limits of their (thin) APD technology
- have applied for testbeam scheduling in Oct-Nov at PS
- longstanding discussion with TOTEM technical coordination about an LHC exposure in Jan-Feb 2013

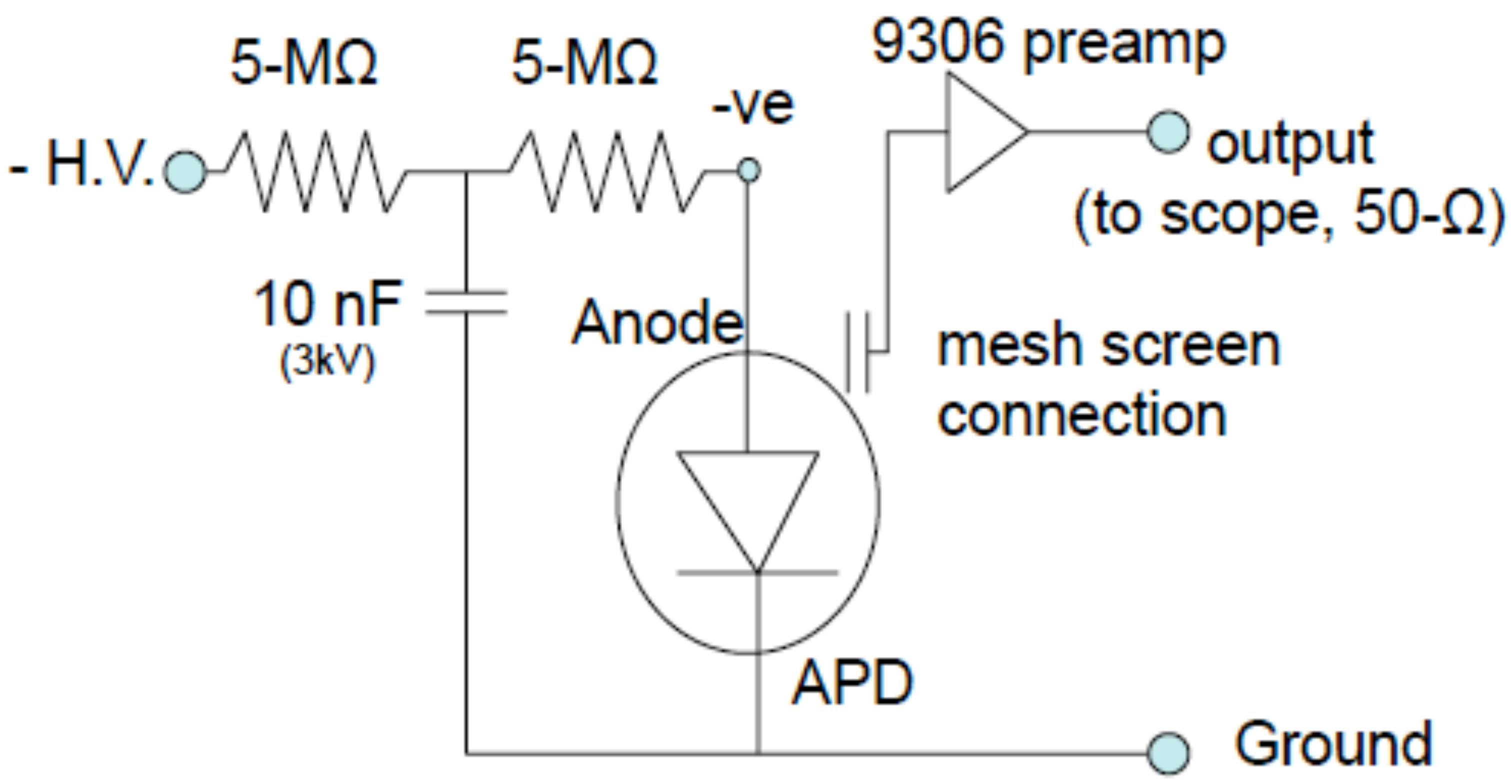
*partial list of collaborators can be found in Kirk's web area- ie: http://puhep1.princeton.edu/~mcdonald/LHC/White/ATF_proposal_final_k.pdf

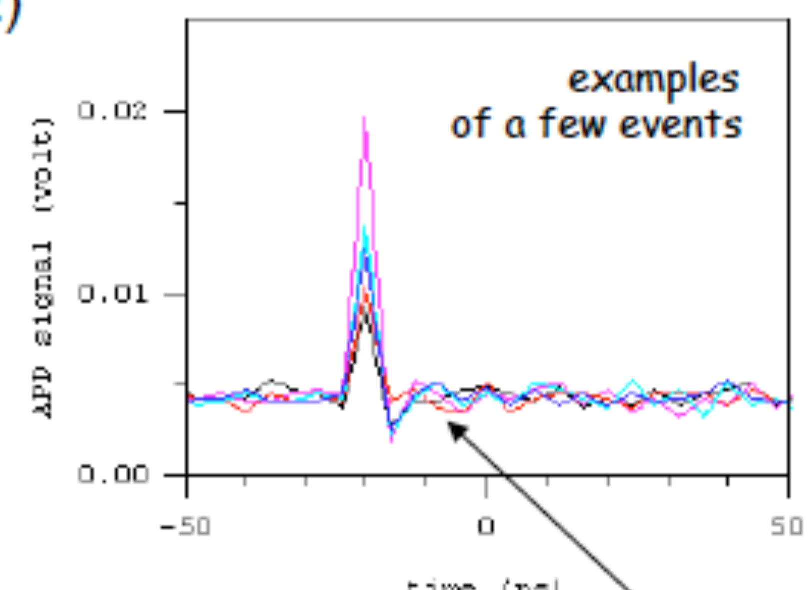
Nov. 15, 2012 RMD APD 8x8 mm2 - mesh screen

Top Screen Output Connection (capacitively coupled)



3-pin APD bias and readout circuit

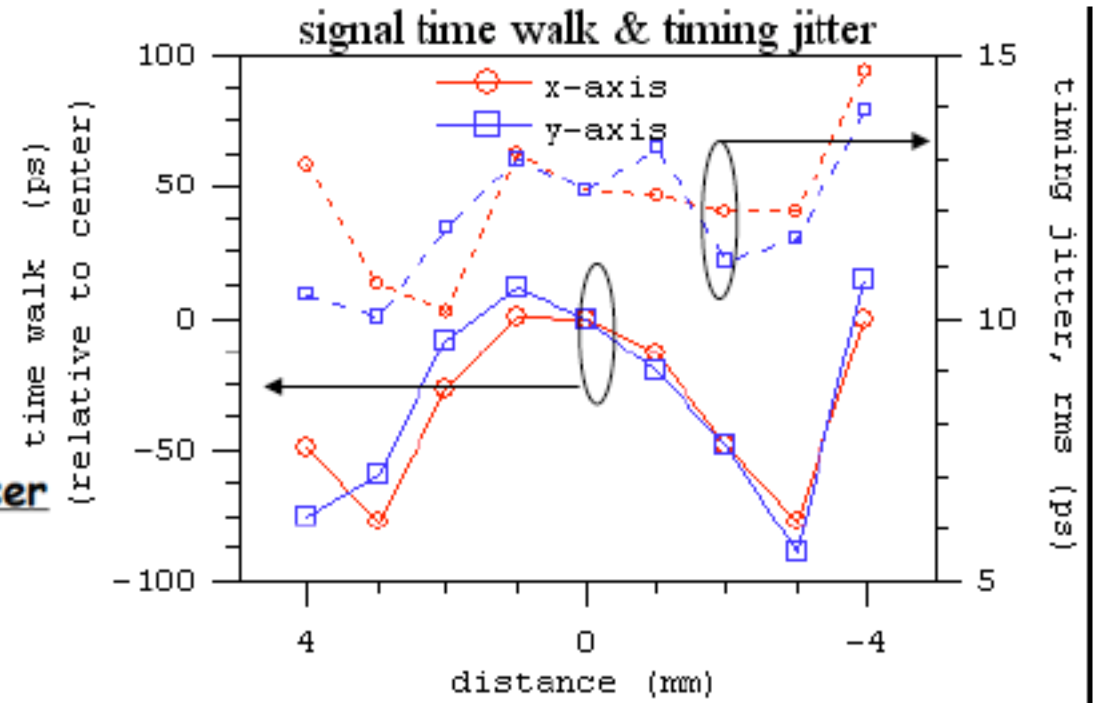




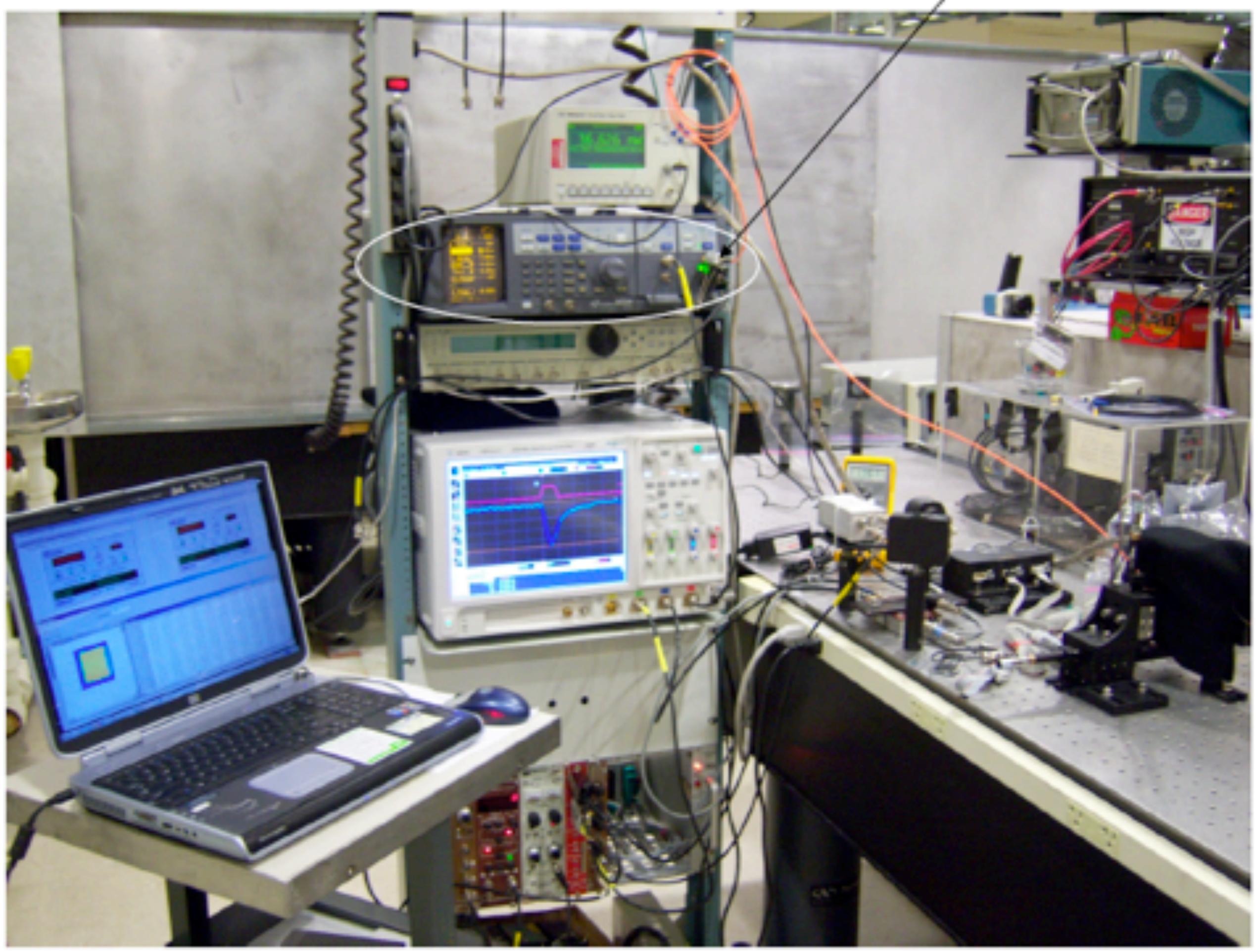
Has biased the APD at -1.75 kV overnight, stable, no HV trip (set at 1 μA)
Logged some cosmic events? over ~14 hours overnight (on a much lower BW scope!)

femtosecond laser and Vecsel used to characterize uniformity

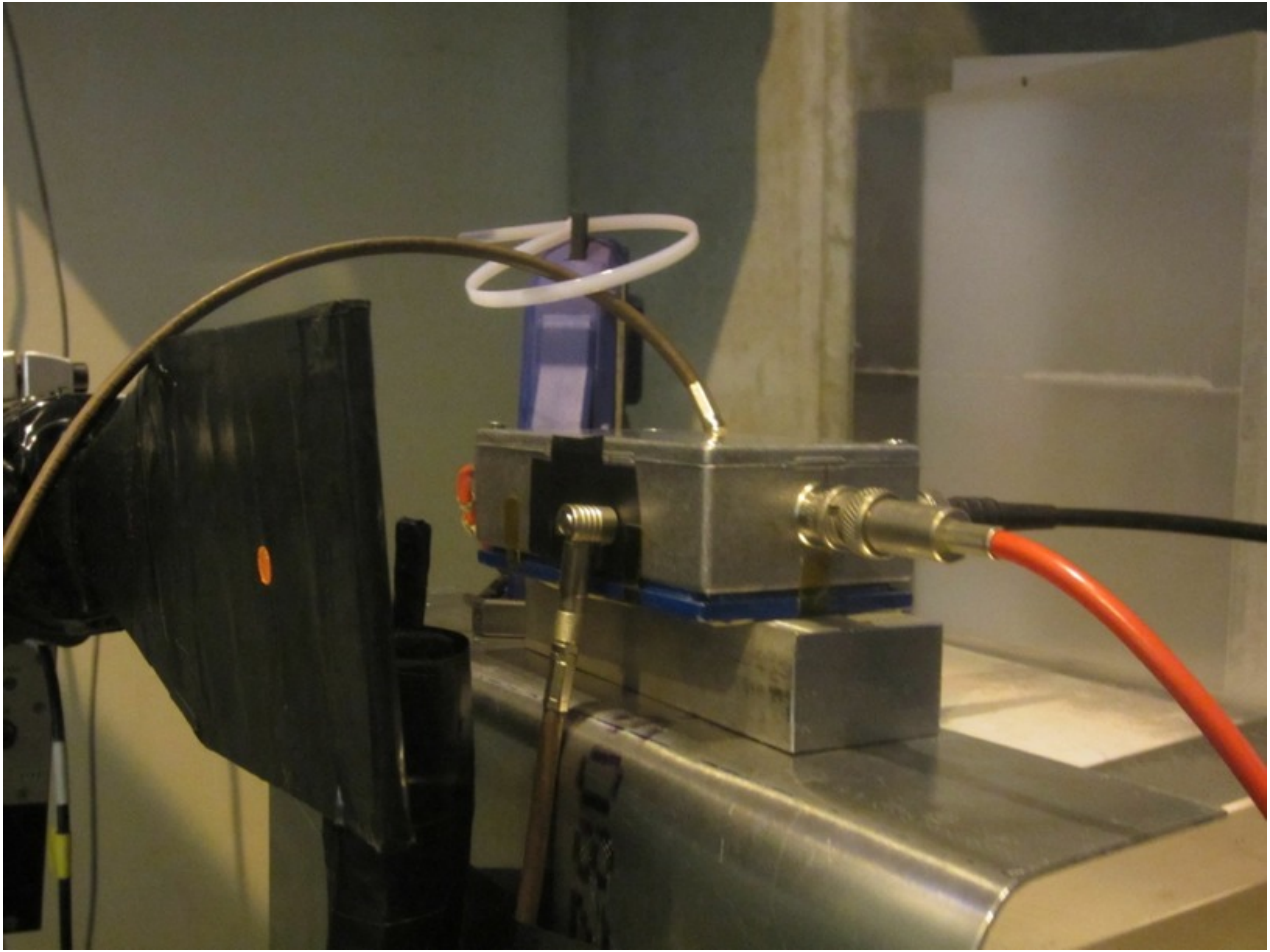
an earlier device w. mesh



All experimental results are now done by pulsing a 980 nm Vcsel laser
(no femtosecond laser is needed)

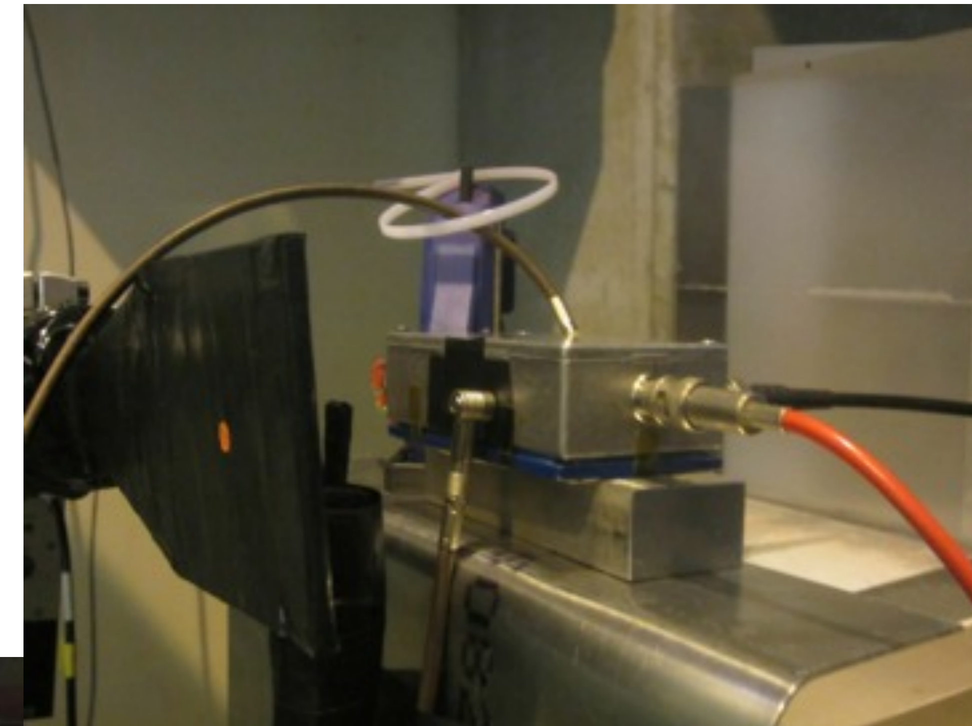


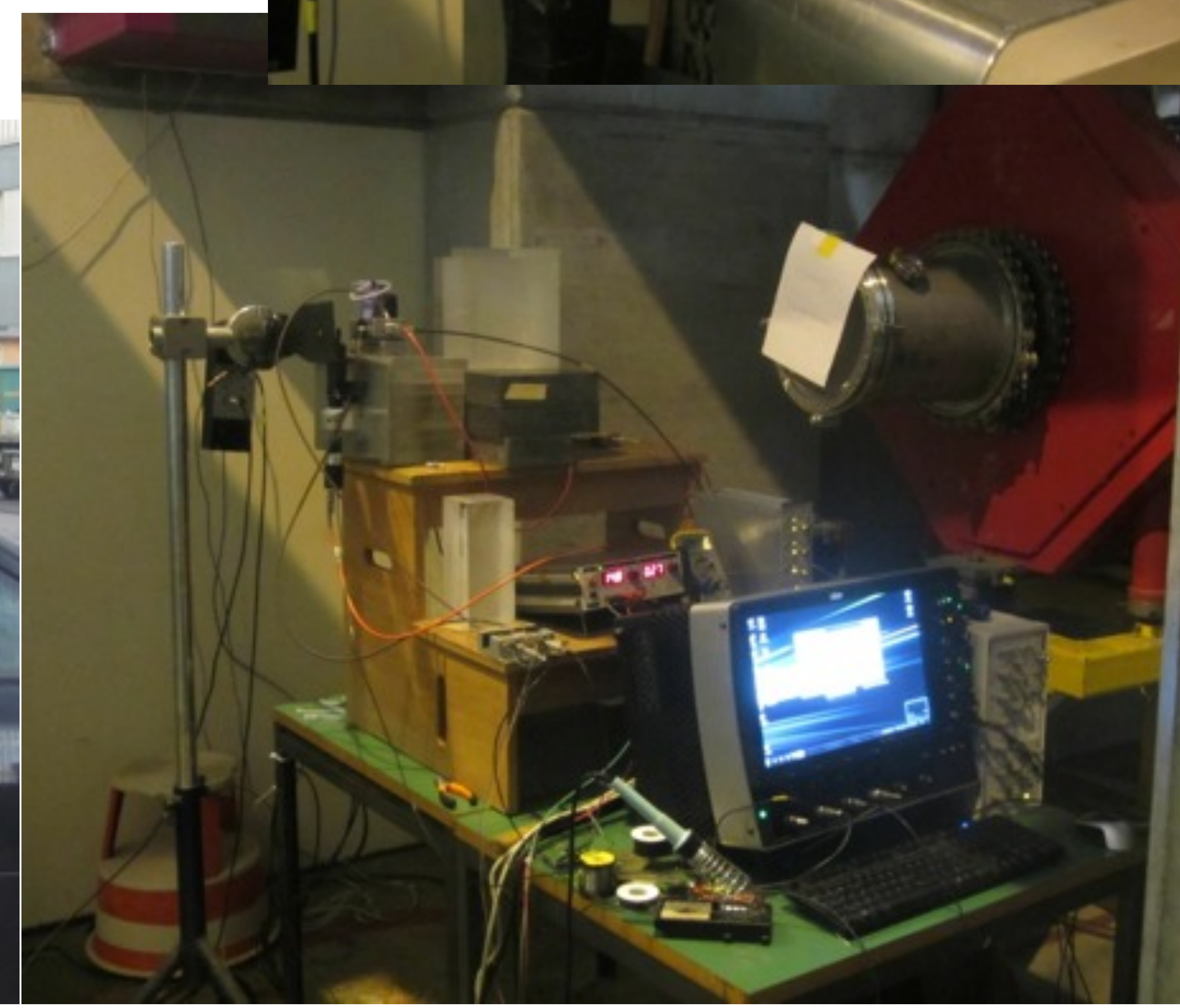
Picture show




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
1830V
1740 - 1870V
1890V
DANGER
DRS4 Evaluation Board
TELEMETER ELECTRONIC GMBH
TELEMETER ELECTRONIC GMBH
WolframAlpha
LeCroy

PSI beam test
10 PM, (2011)Dec. 1->7 AM, Dec. 2
170 MeV negative beam
hadrons suppressed with absorber





me, Konrad and Michele

setup in the beam

2012 TB in RD52 (ended this morning) and PS for next 2 weeks

Plans

- we are currently in CERN testbeams through end of season
- work continuing in context of CMS Forward Calorimeter Task Force
- CMS generic R&D committee considering proposal on sensor development
- discussions ongoing about merging with existing R&D collab at CERN -possibly RD52

Principal Authors

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Cc: Sebastian White <swhite@rockefeller.edu>, "Tsang, Thomas Y" <tsang@bnl.gov>, Kirk T McDonald <kirkmcd@Princeton.EDU>, Sebastian White <swhite@rockefeller.edu>,
Changguo Lu <changguo@Princeton.EDU>, Mickel McClish <MMcclish@rmdinc.com>, Rick Myers <RMyers@rmdinc.com>

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