Fast Timing Consideration for Forward Calorimetry

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CMS Forward Calorimetry Task Force mtg, Nov. 8, 2012

this talk is meant to be a brief outline and update of work we have been doing for past 5 years on 10 picosec timing for calorimetry and tracking at high rates

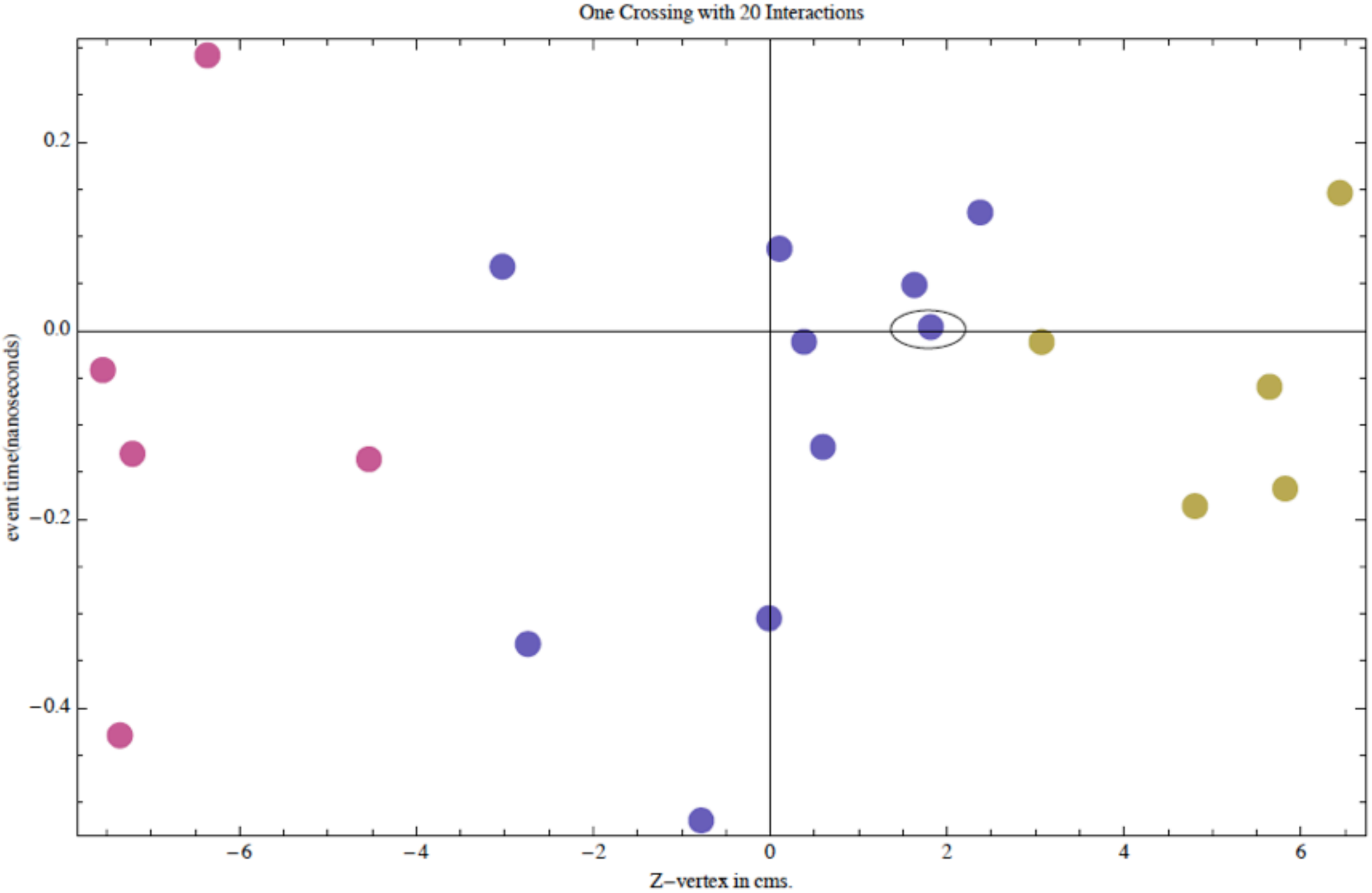
Earlier talks at Crakow picosec conference, Pisa, Saclay, NA62, and papers can be found on the web, my CERN CDS area or Kirk McDonald's web pages at Princeton

Outline

- Background on this work
- General Principle of Pileup Mitigation with Fast Timing in the "Forward Region"(we initially focus on the T1 region).
- Results on Technologies for photodetectors and direct charged particle timing
- Plans: What readout technologies are in the pipeline suitable for CMS future?-40 MHz, Latency, post-processing, additional uses of fast timing for EM/Had discrimination from waveform

- assumption is that critical role for timing at 10 picosecond level is in pileup mitigation when trying to deal with "the rest of the event" at high luminosity
- we call this "correlation of sub-events"
- examples are VBF in Higgs production or WW scattering. Others lower are exclusive production and potentially interesting and more practical non-exclusive diffractive production
- At the 100's of picosec level, potential interest, ie in calorimeter virtual segmentation through timing as shown by Wigmans et al.

Principle of pileup mitigation



In forward region vertex measurement becomes increasingly difficult. In simple case of 2 leading objects

TIME DIFFERENCE

is equivalent to another vertex measurement. Much of what we are interested in is a combination.

- generic fast timing R&D grew out of our work on ATLAS ZDC which we built, primarily at BNL and Yale. ATLAS ZDC is fastest calorimeter (or detector?) at the LHC. <100 picosecond resolution. Subject for a future talk.

- team changed in 2010. Mike Zeller retired, Volodja Issakov passed away , I left BNL and the rest of the group are no longer on ATLAS

- In the current Princeton/Rockefeller R&D only Thomas Tsang and I remain from the original team

much detail in the original draft for a proposal. Never submitted in original form but ATLAS forward proton (AFP) posted it on their website 3 or 4 years ago.

A High Rate, Picosecond Timing Solution

for

PET Imaging

and

High Luminosity Forward Physics at the LHC

Mickey Chiu, Sergio Rescia, Thomas Tsang and Sebastian White**

Brookhaven National Lab

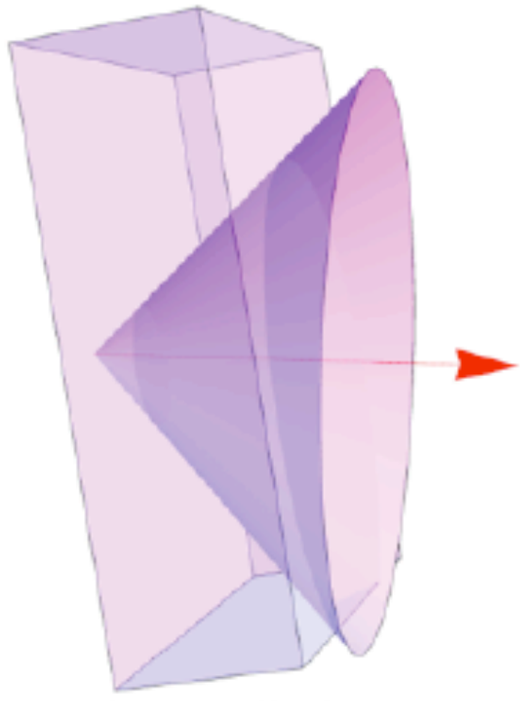
Karsten Eggert

CERN and Penn State University

Grigor Atoyan, Vladimir Issakov, Andrei Poblaguev and Mike Zeller

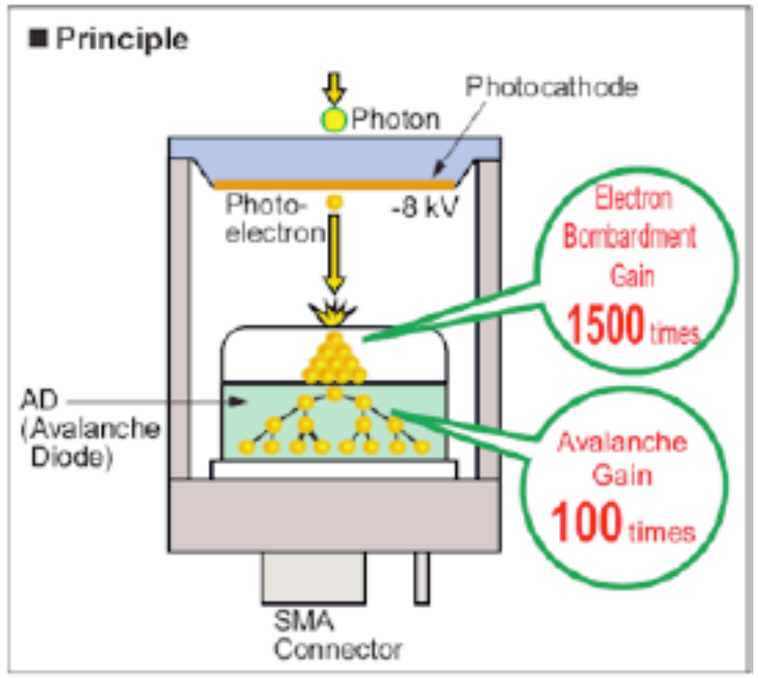
Yale University

**-Contact Person: 631-344-5488 swhite@bnl.gov



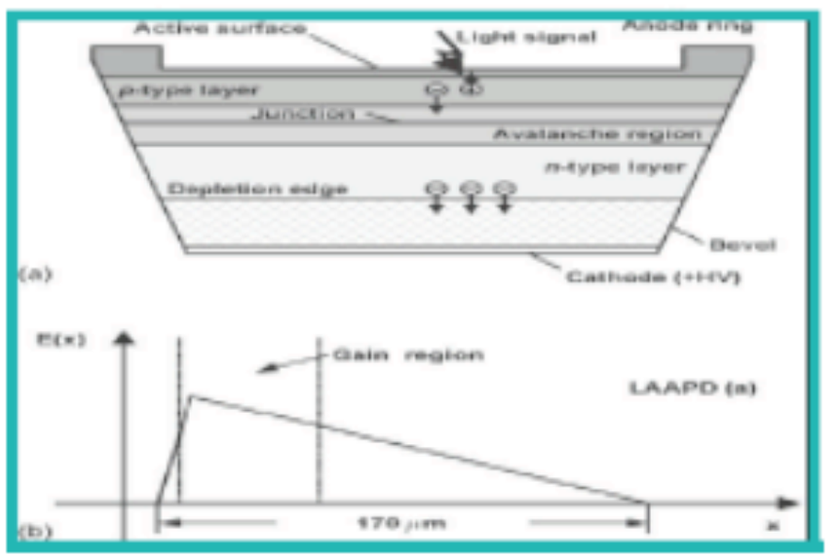
Cerenkov Radiation cone

Cerenkov
or
APD
option

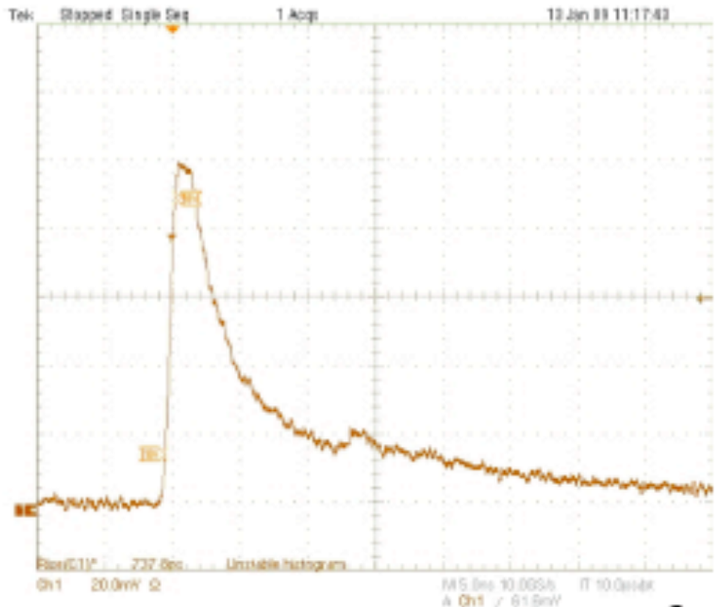


Pre-production Hybrid photodetector

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



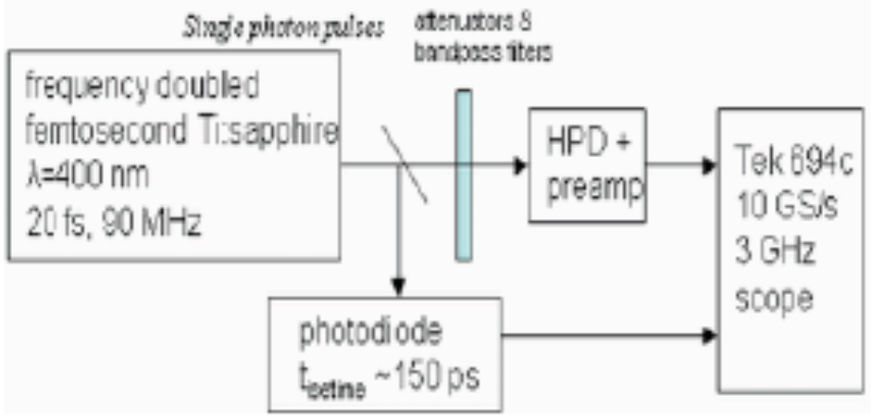
Deep diffused avalanche photodiode



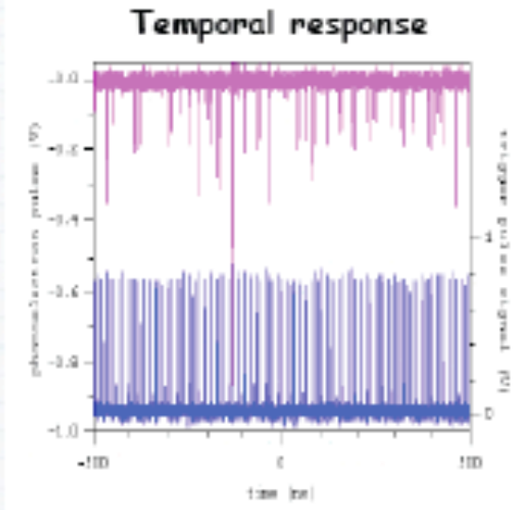
650 picosecond risetime (β's)

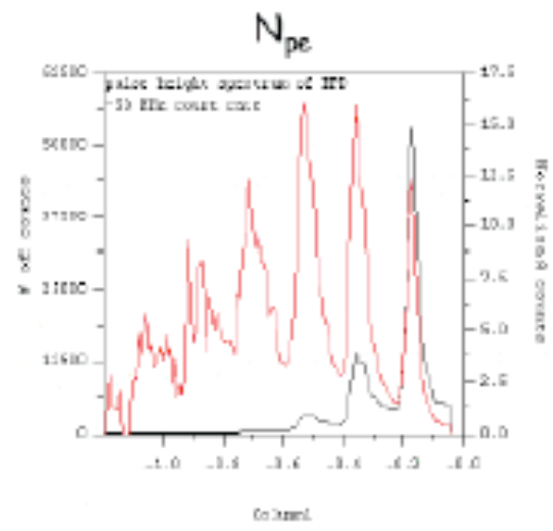
Applications in eg fluorescence spectroscopy

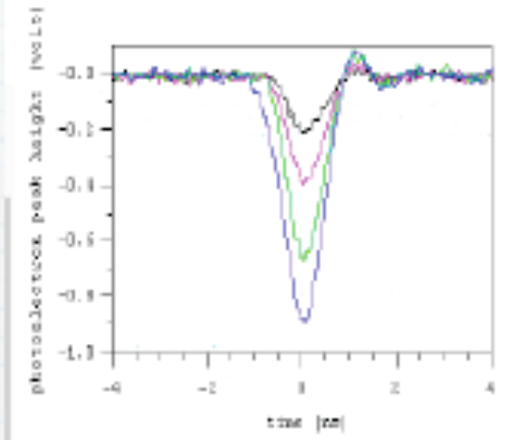
T.Tsang, S.White



risetime=300 psec

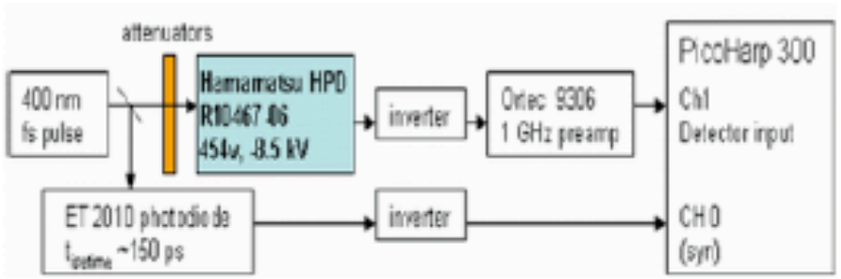


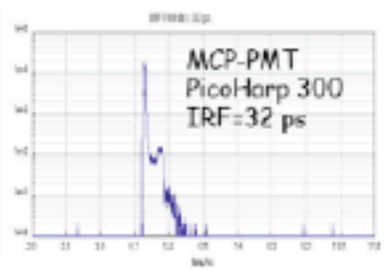




N_{pe}	pulse height after preamp (Volt)	pulse height before preamp (mV)	normalized count rate
1	0.176	2.2	1
2	0.36	4.5	0.26
3	0.528	6.6	0.061
4	0.71	8.9	0.009
5			~0.0014
6			~0.0002

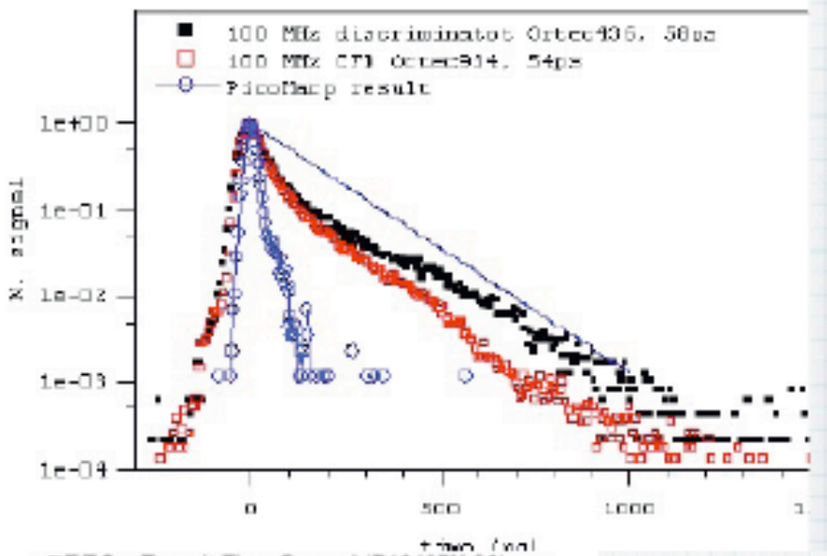
11 psec single photon response is not common. Below studies comparing LE, CFD, PicoHarp

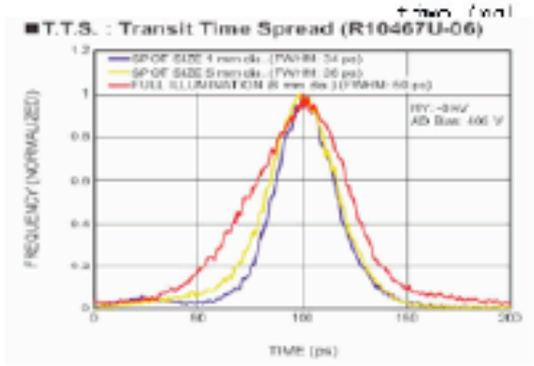




$$\sigma_{TOF} = \sqrt{\sigma^2_{HPD} + \sigma^2_{radiator} + \sigma^2_{electronics}}$$

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

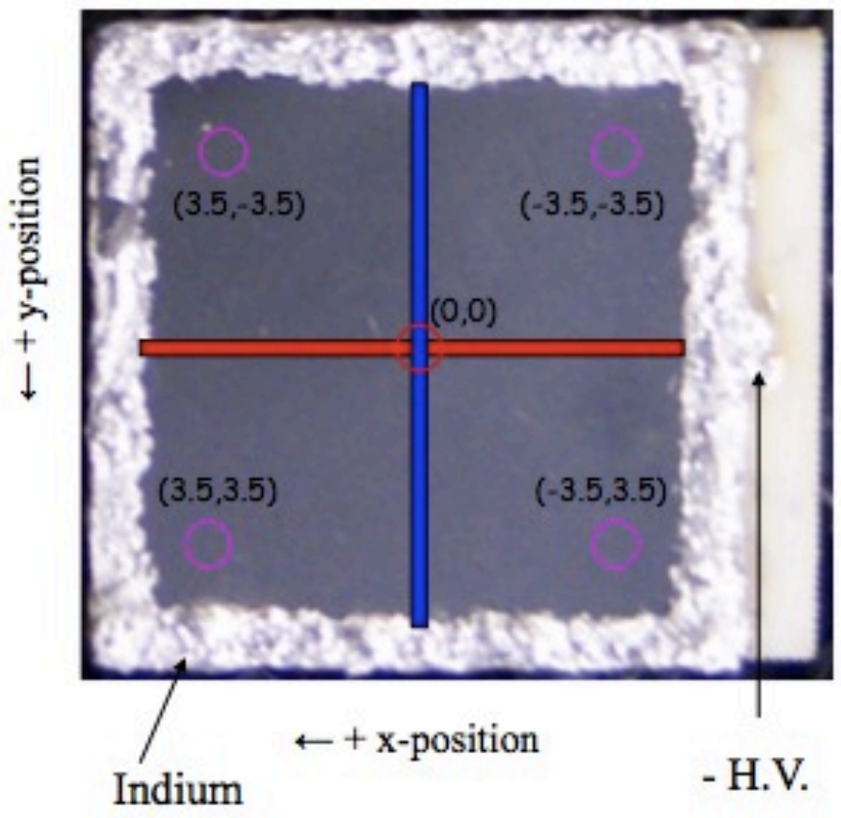




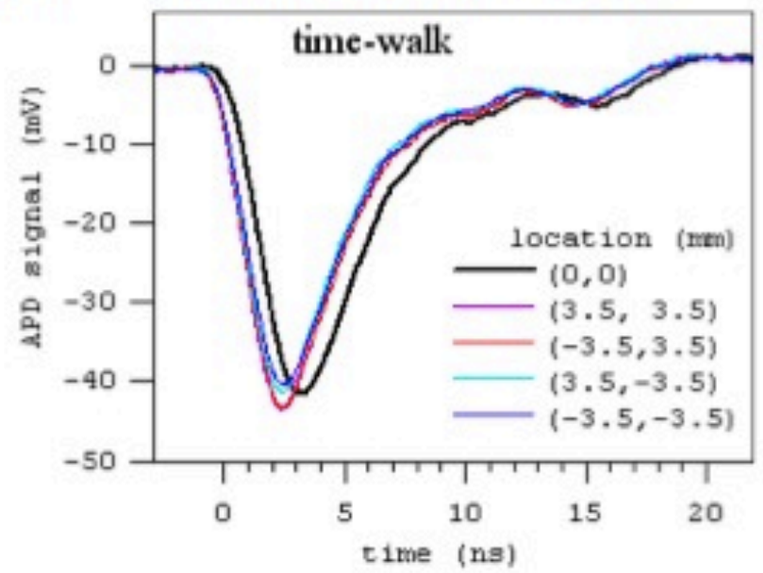
work done in close collaboration with Hamamatsu Photonics. Our conclusion: we have a viable photosensor. 10 picosec SPR and lifetime 2-3 orders of magnitude higher than MCP. What about direct charged particle detection? Obviously APD is a strong candidate

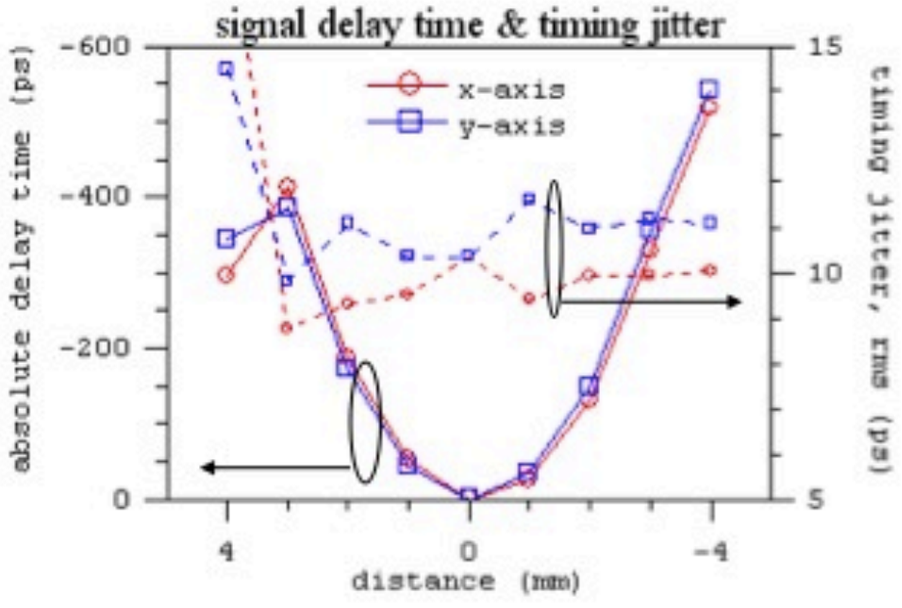
This has been a rapidly moving development over the last 2 months. Close collaboration with RMD, Inc./DYNASIL

Oct. 22, 2012 RMD APD 8x8 mm² – indium



Signal delay time on APD





APD time-walk translates to timing jitter in particle detection

- we have focused on improved metalization and this has eliminated position dependence of time jitter
- goal in the next few weeks is to eliminate position dependence of time of arrival.
- we know that radiation hardness is adequate form earlier work.
- Iouri Musienko is currently doing rad damage studies of our devices to confirm this
- plan on testbeam in collaboration with RD52/ DREAM this month.

- current discussion with Caltech/ Chicago/ Saclay on readout options and strawman detectors
- work with Giomataris, Veenhof on a gas chamber option
- all of this probably needs a generic RD collaboration, which has been discussed with Ball, Bertolucci, Bloch and others since limited current picosecond timing activity within CMS

there are potentially very interesting other benefits from thinking about timing!!!

Particle ID does NOT require segmentation!

e/π separation using time structure signals

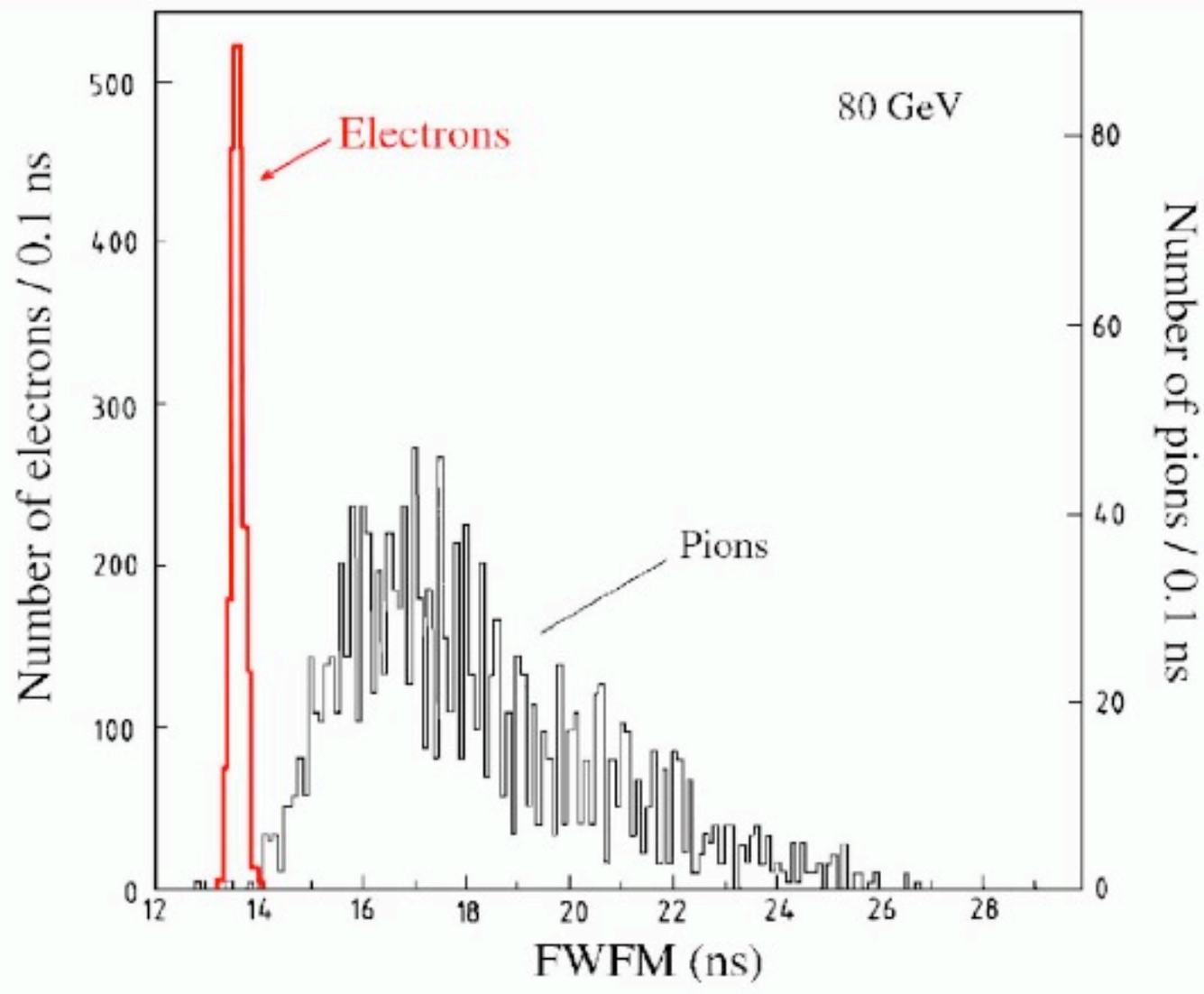


FIG. 7.33. The distribution of the full width at one-fifth maximum (FWFM) for 80 GeV electron and pion signals in SPACAL [Aco 91a].