Hyperfast Si in CT-PPS

a look back

Sebastian White, CERN/Princeton CT-PPS timing meeting

Oct. 14, 2015

- we have been working on fast sensors for Generic HL-LHC pileup mitigation- partly in RD50&RD51 groups
- but in Jan 2009 posted the following paper which may still be relevant to CT-PPS today

Design of a 10 picosecond Time of Flight Detector using Avalanche Photodiodes

http://arxiv.org/pdf/0901.2530v1.pdf

Sebastian White[a,*], Mickey Chiu[a], Milind Diwan[a], Grigor Atoyan[b] and Vladimir Issakov[b]

Current Status of Generic R&D

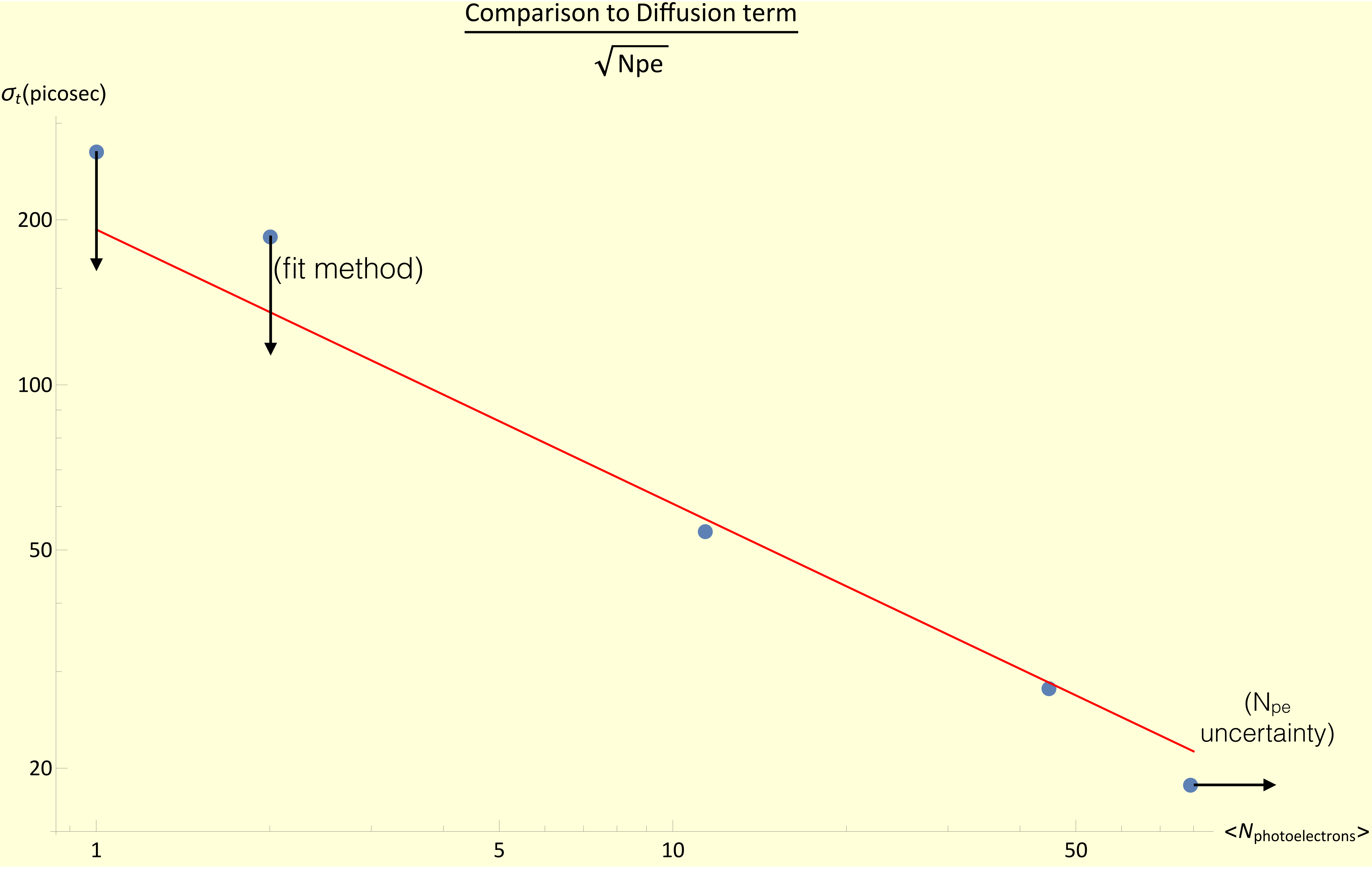
- (see my Sept. 25 CERN det. seminar here

https://indico.cern.ch/event/439571/)

- our RD51 common fund proposal awarded in March and currently achieving 27 picosecond resolution proof of principle. We expect a further factor of 2-3 improvement by optimizing gas/field. see current CERN Courier and today's RD51 conference presentation of T.P.:

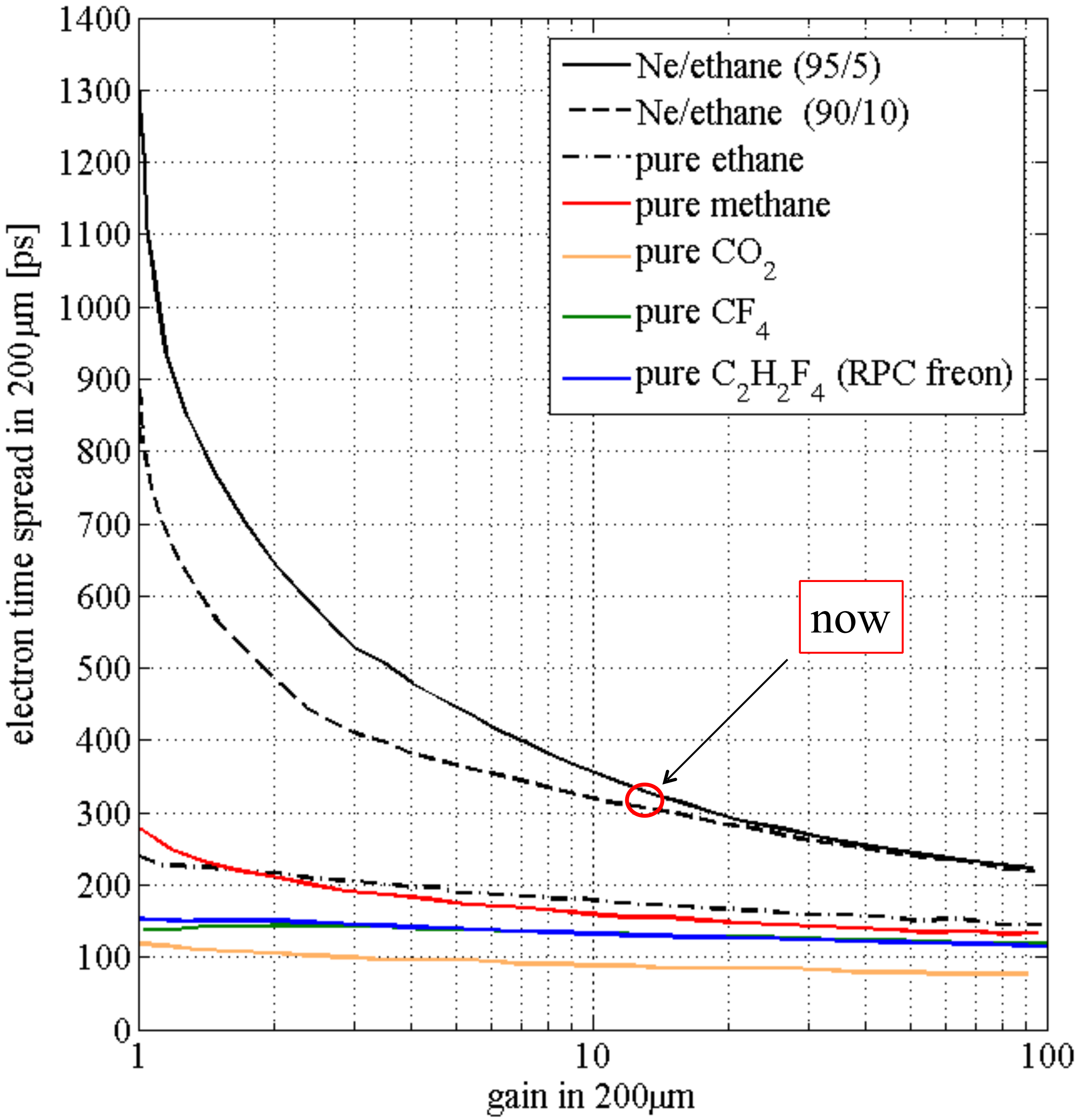
https://agenda.infn.it/conferenceTimeTable.py?confId=8839#all.detailed

Summary of Ne-Ethane(10%): Efield=10kV/cm; Drift Gap =0.2 mm
1,2 pe data points consistent with 40% worse template method
fitted curve->~2xbetter than Sigma(diffusion)



Optimum gas mixtures in timing Micromegas? (D. Gonzalez&R. Veenhof)

Look for the minimum time spread ('fastest mixture') at any given gain



Simulations from Rob Veenhof ($C_2H_2F_4$ from data)

There's still room at the bottom!

Notes:

- Working fields in the MM for pure quenchers need to be about x2 higher. May limit the gain in case of defects.
- Drift fields for pure quenchers need to be about x3 higher.
- Dissociative attachment for CO_2 and freons expected to be compensated by gain. Needs to be verified.

Could we eliminate need for radiator?
->Secondary emission
->Proposals by Princeton, Saclay

Silicon fast timing

we have also reported recently on progress in several areas:

1. development of a new transimpedence amplifier for state-of-the-art timing (w. U. Penn.)
2. further rad dammage measurements->10^14 p/cm^2
3. productive collaboration betw. Princeton/RMD/Penn-> packaging , electronics solution for LHC
4. I work in the CERN RD50 group which has oversight in several related projects (GTK, UFSD…)
5. It is unlikely that another solid state device will have as good time performance (ie see Abe Seiden, which reports UFSD similar to GTK (170 psec):

https://indico.cern.ch/event/368528/session/19/#20150603)

6. Gain instability of Si devices with gain under irradiation is becoming an issue.
7. Since we already are using heavier dopants than Boron none will do better

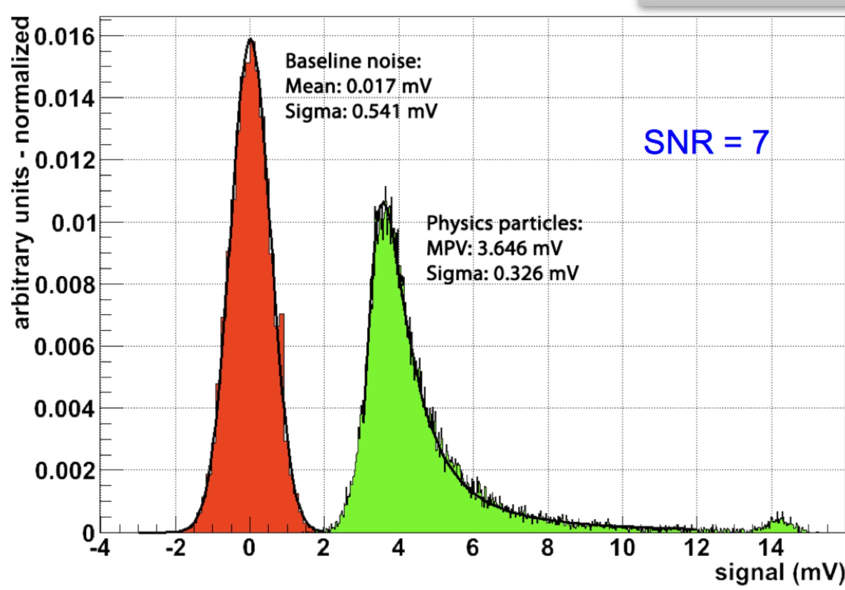
signals:

Hyperfast Si(waveforms)

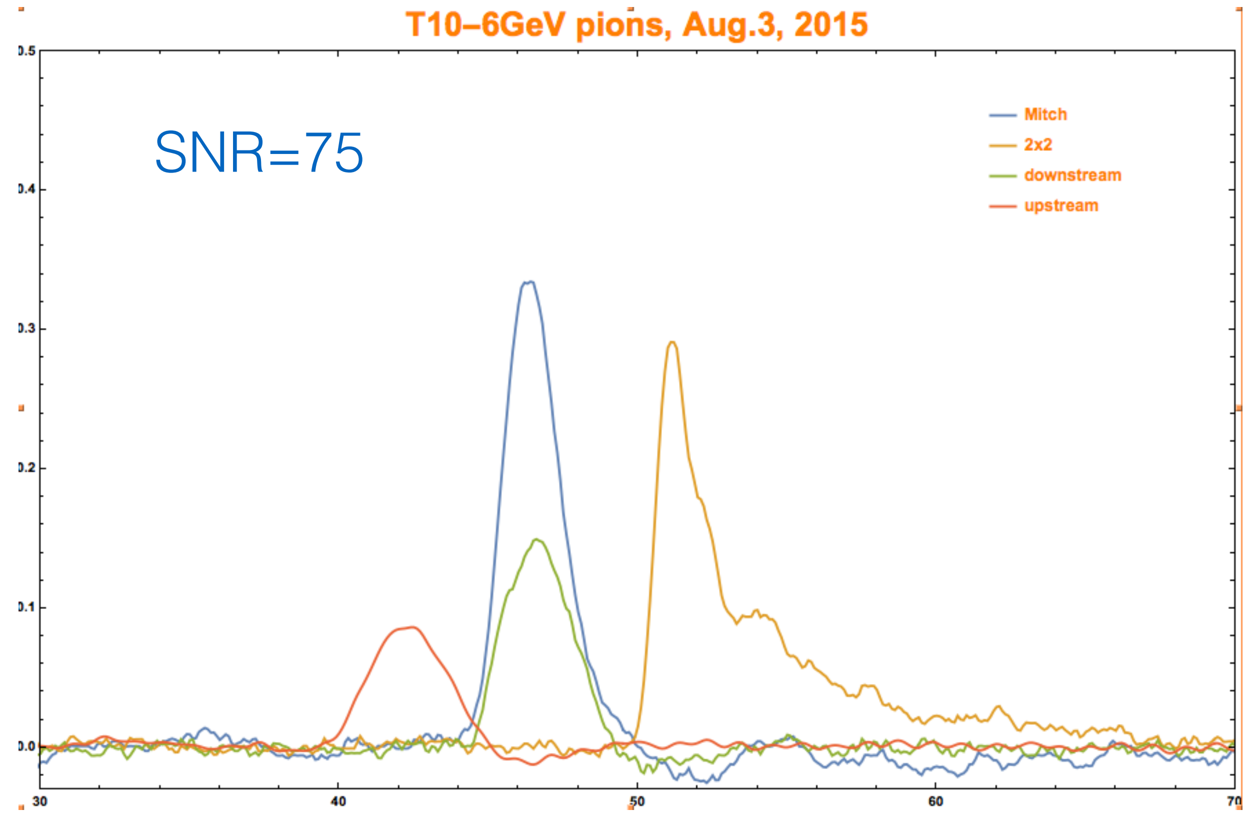
-significant SNR and speed advantage

Signal & Noise

diamond



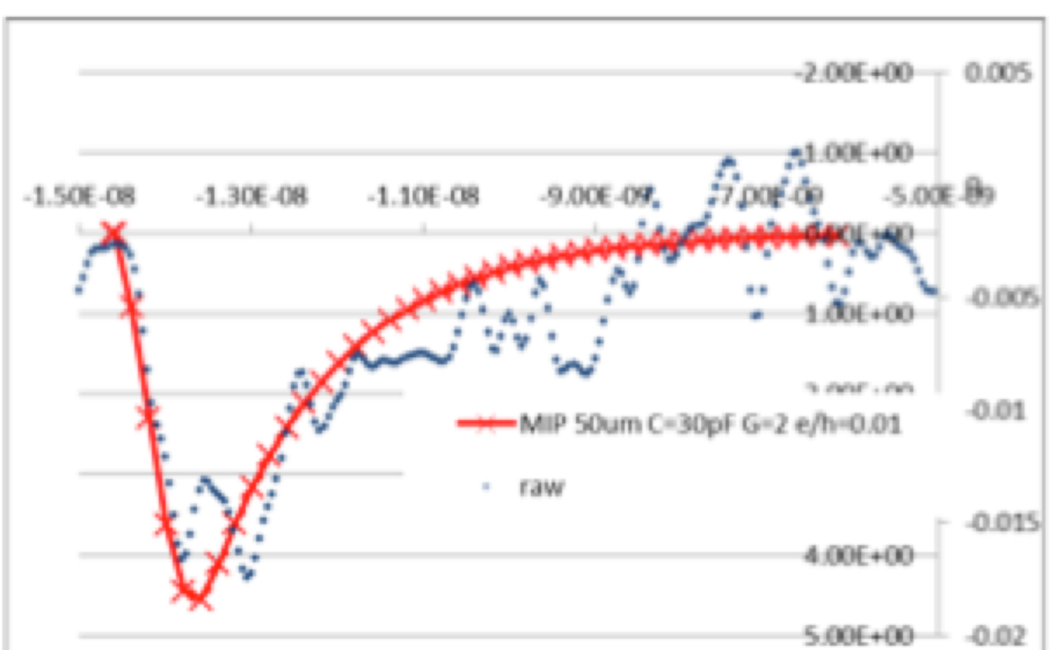
V



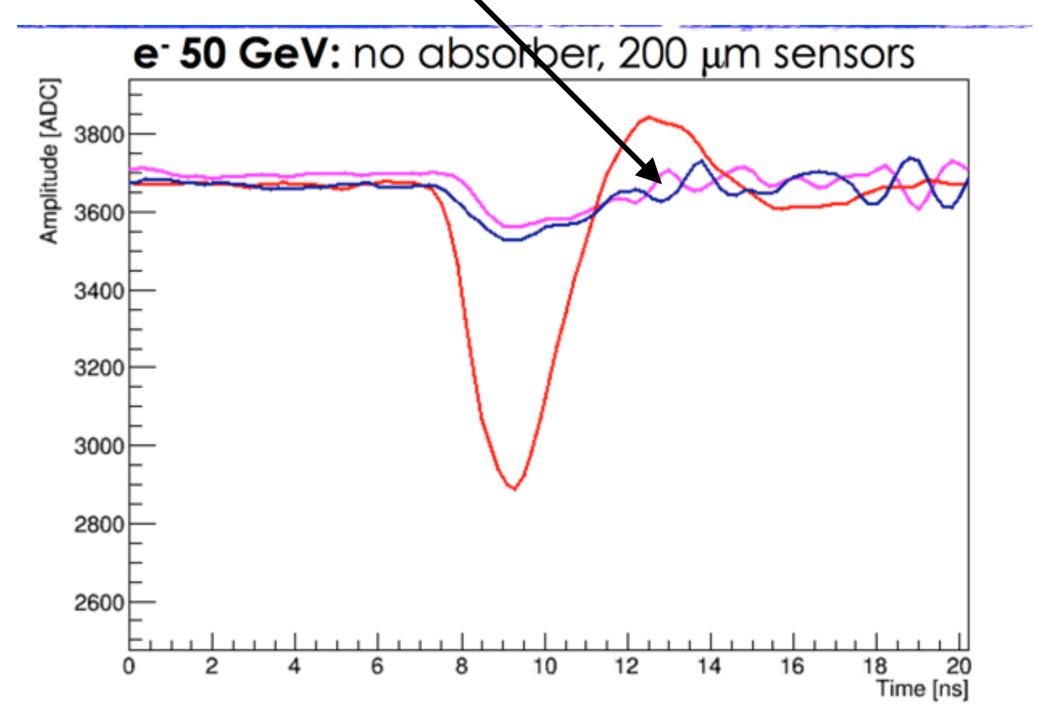
t(nanosec)->

UFSD

MIP's Pulse shape C = 34 pF, Gain = 3



HGC Si



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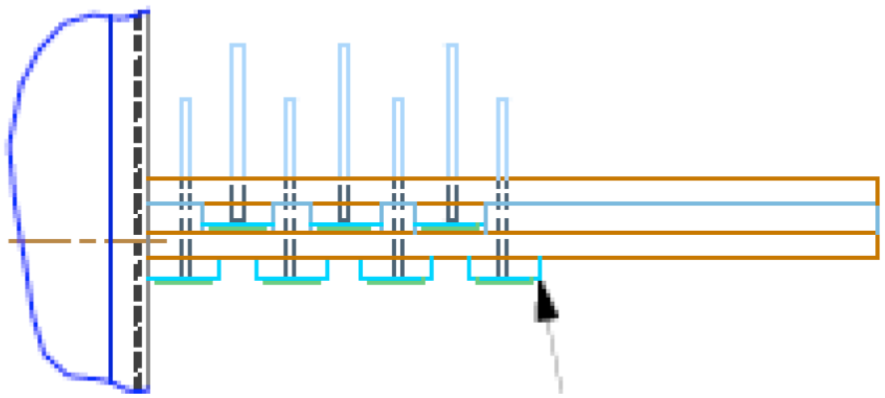

Figure 1. Top view of the 7 detectors starting at the left from the beam pipe. The detectors are staggered and overlap to eliminate the dead region.

The high rates (0.5 tracks/bunch) require segmentation of the TOF since an event of interest is lost if either proton hits the same segment as another particle. For 7 segments the one arm efficiency is:

$$\varepsilon ff(1) = \frac{\sum_{n=1}^{\infty} P_m(n)\left(\frac{7-1}{7}\right)^{n-1}}{1 - P_m(0)}$$

where $P_m(n)$ is the Poisson distribution and the mean, m is =0.5.
Then the efficiency for exclusive events is $Eff^2 = 92\%$.
At 220 m, due to the higher rates, it is 55%.

Design based on 7 identical sensors with active area 3x10 mm^2 sensitive to 0.5mm from wall

7.4. Time Resolution:

With leading edge timing the noise jitter is [1]

$\delta t = \sigma(e)/(d(\text{Amplitude})/dt)$

where $d(\text{Amplitude})/dt = N_{e\text{-}h}/\tau_R$

and τ_R is the signal risetime. In our case the dominant noise contribution is from leakage current:

$\sigma_{leakage}^2(e) = (I_{surface}/G^2 + I_{bulk}*f) * \tau_{shaping}/q_e$

so the noise limit to the time jitter at –30°C and after 10 years of irradiation is

$\delta t = 48e/6000e* \ \tau_R = 5.2$ psec

As mentioned before, the amplitude jitter, which has contributions from gain nonuniformity(<3%), excess noise factor (<2%) and the Landau distributed fluctuation of energy loss (18%) totals 18%. We therefore need to correct for walk to a level of 0.18*650 psec/10 psec or ~11. This is roughly what was achieved in ref. [3].

Update w. RMD

- I recently reviewed this design with RMD
- they confirm that plenty of flexibility to produce rectangular devices as above but also smaller pixels down to 0.9mm on a side
- sensitivity from edge @0.5 mm is, more or less,standard
- since we are now packaging at Princeton will become more familiar with these issues.