Common Issues for Fast Timing Measurements

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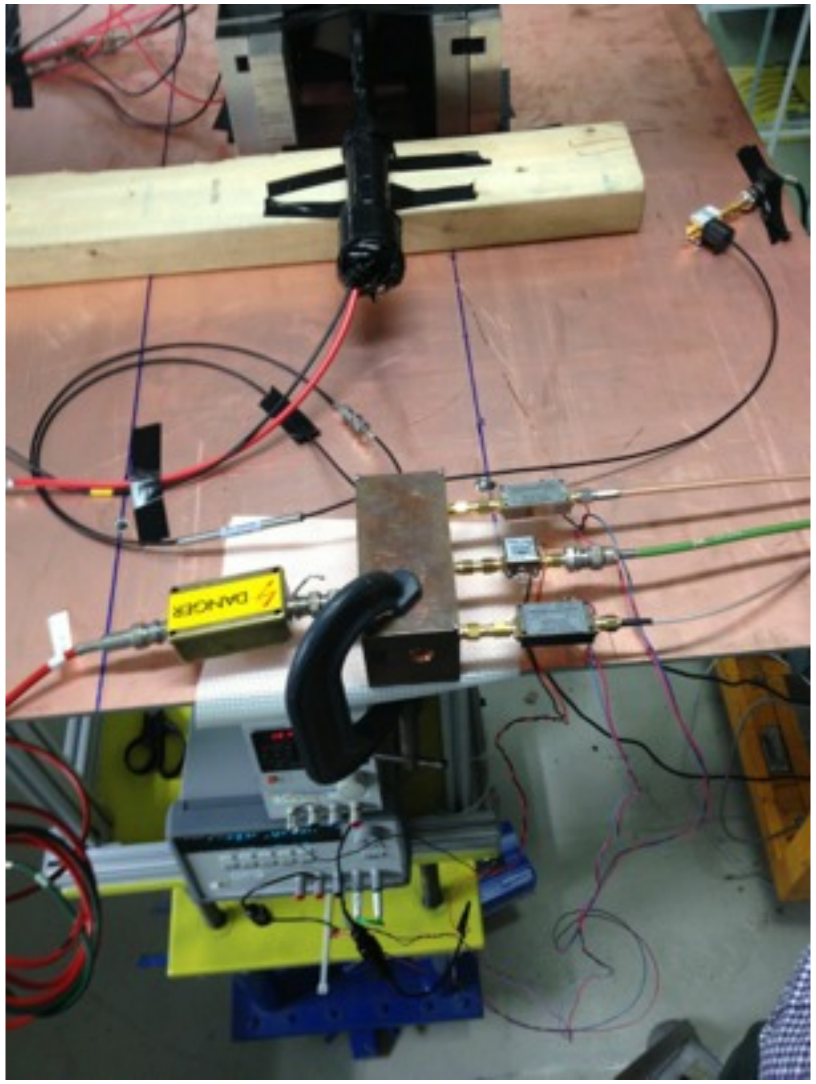
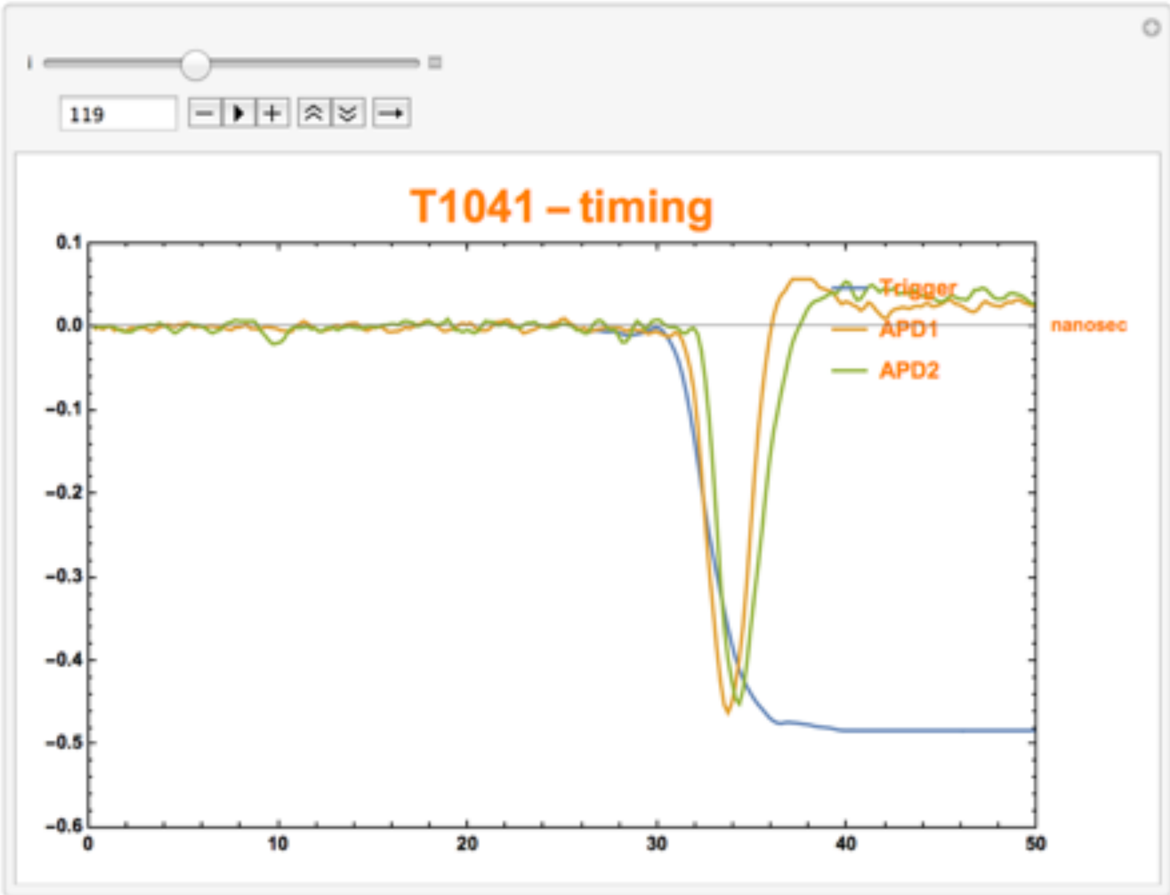
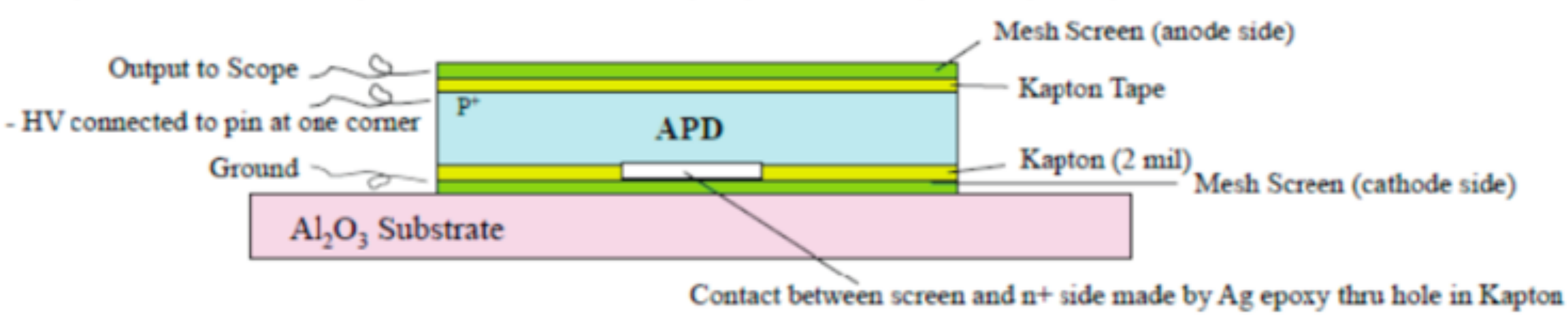
Much in common with our ongoing work on Si APD charged particle timing

- Detector Area/channel ~64 mm^2 (suited for HL-LHC occupancy in Endcap)
- ->C_D~50-60 pF
- ->current limit on t_R with 50 Ohm preamp (~2nsec-- about 3 times slower than our low C_D APDs)

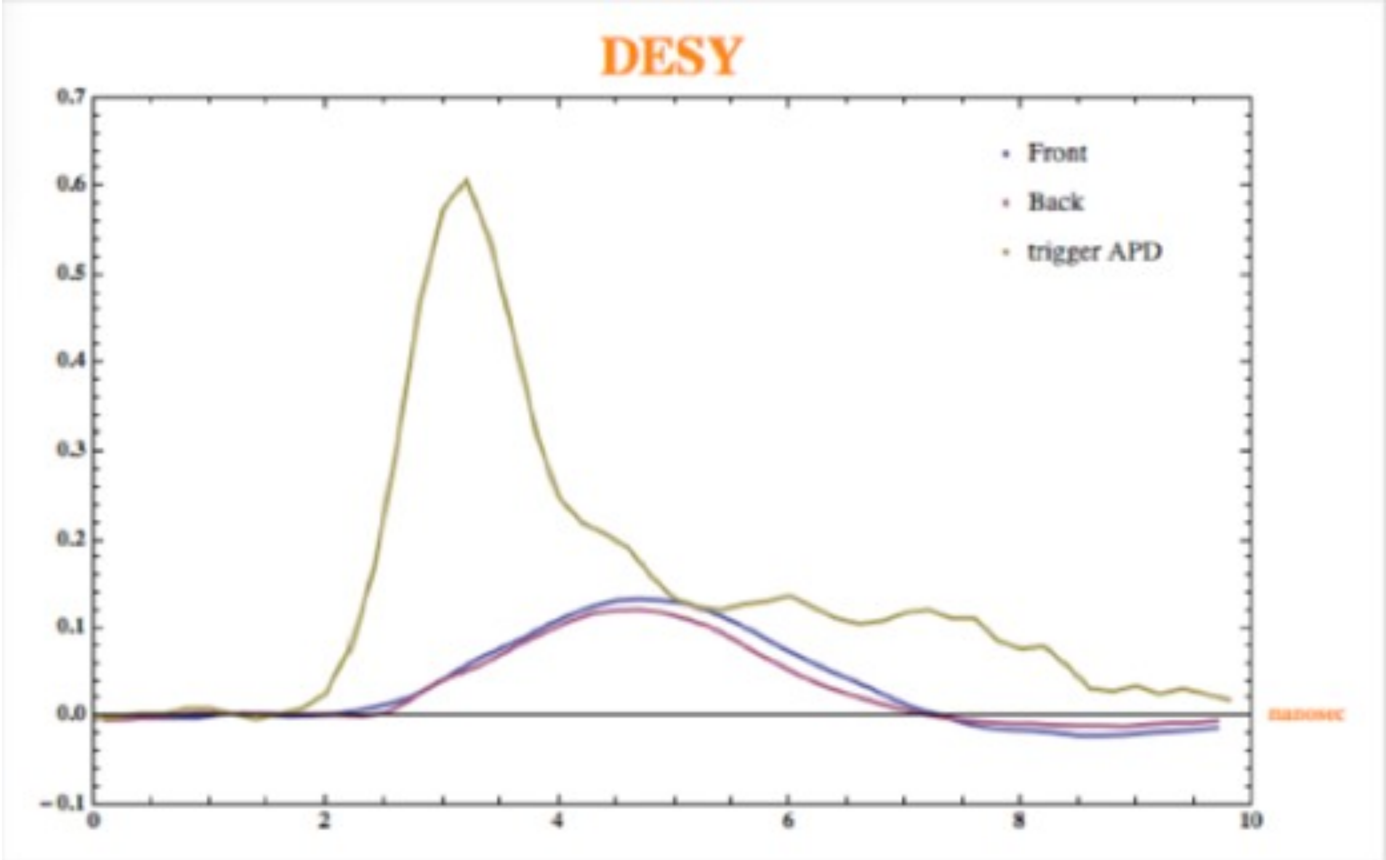




- Much of collaborative development over last 5 years w. RMD/Dynasil on metallization to reduce weighting field non-uniformity and improve high frequency performance=>MicroMegas/APD hybrid structure (eliminate effect of R_S)



- Main tool for this development was a ~1000 nm femtosecond laser with 20 micron spot size
- => detailed response maps over detector area (Amplitude, delay, jitter)
- similar calibration methodology used in all testbeam work
- Thorlabs 980 nm Vcsels driven by fast pulser. Fiber optic splitter/distribution to APDs



most features reproduced in charged particle beams at PSI, CERN, DESY, FNAL

Modelling effect of large C_D

(with J. Kaplon)

Preamp in voltage mode

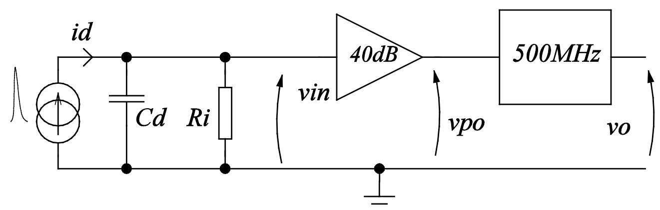
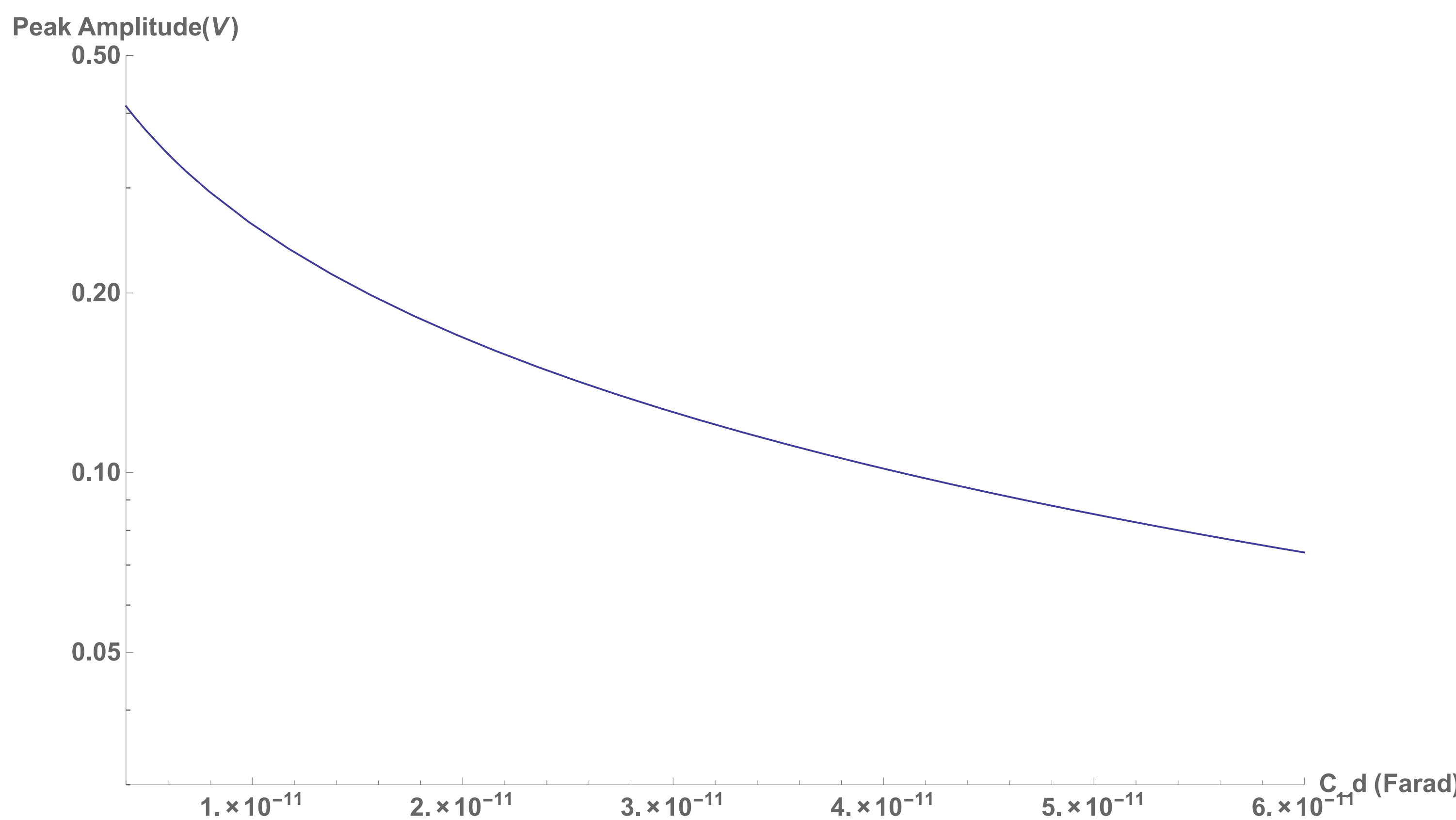


Fig1. Preamplifier working in voltage mode.



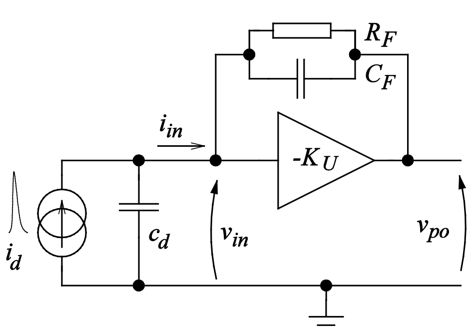
Response (vo(t)) can be found solving following equations.

Voltages:

$vin = id \frac{1}{s\,Cd+\frac{1}{Ri}} = id \frac{Ri}{1+s\,Cd\,Ri}$ $\qquad vo = vin\,Ku(s) = vin \frac{Ku}{1+s\,\tau_{P0}}$

Where τ_{P0} defines bandwidth of the amplifier (for 500MHz 3dB bandwidth τ_{P0} =0.32ns)

Preamp in charge/transimpedance mode



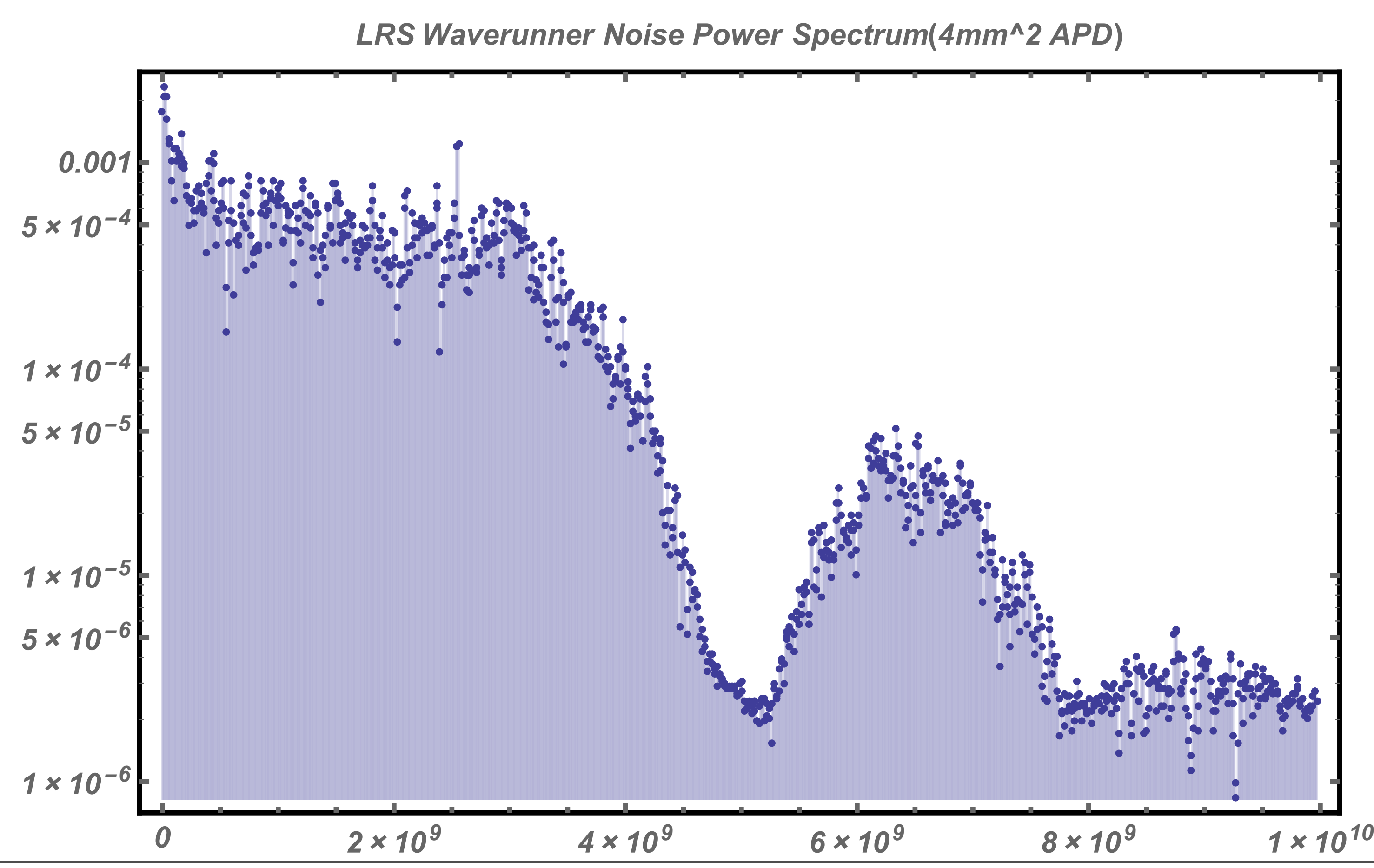
Assuming high Ku the amplitude response does not depends in first order on c_d.

Performance Specs

- for pileup mitigation need 10-20psec timing (from "bunch crossing time"~170psec)
- what do we expect with present commercial 50 Ohm amps->t_R~2nsec ?
- roughly given by $d_T=t_R/SNR$
- is SNR ~100:1 reasonable?
  - signal (40micron, 80e-h micron,APDGain=520, 50dB preamp)->75mV
  - noise (~Sqrt[4kT(BW)(50Ohm)]*50dB)~4 mV
- ->need another factor of ~5 (new preamps should deliver ~15)

Meanwhile: Are there tricks to beat time jitter from noise?

- this is key to limits from rad damage effects. Otherwise jitter from leakage current->10^{14} n lifetime
- mostly trial and error. Use bandpass filtering, Wiener filter, centroid,.. on digitized waveforms. Not yet much better than simple CF algorithm.



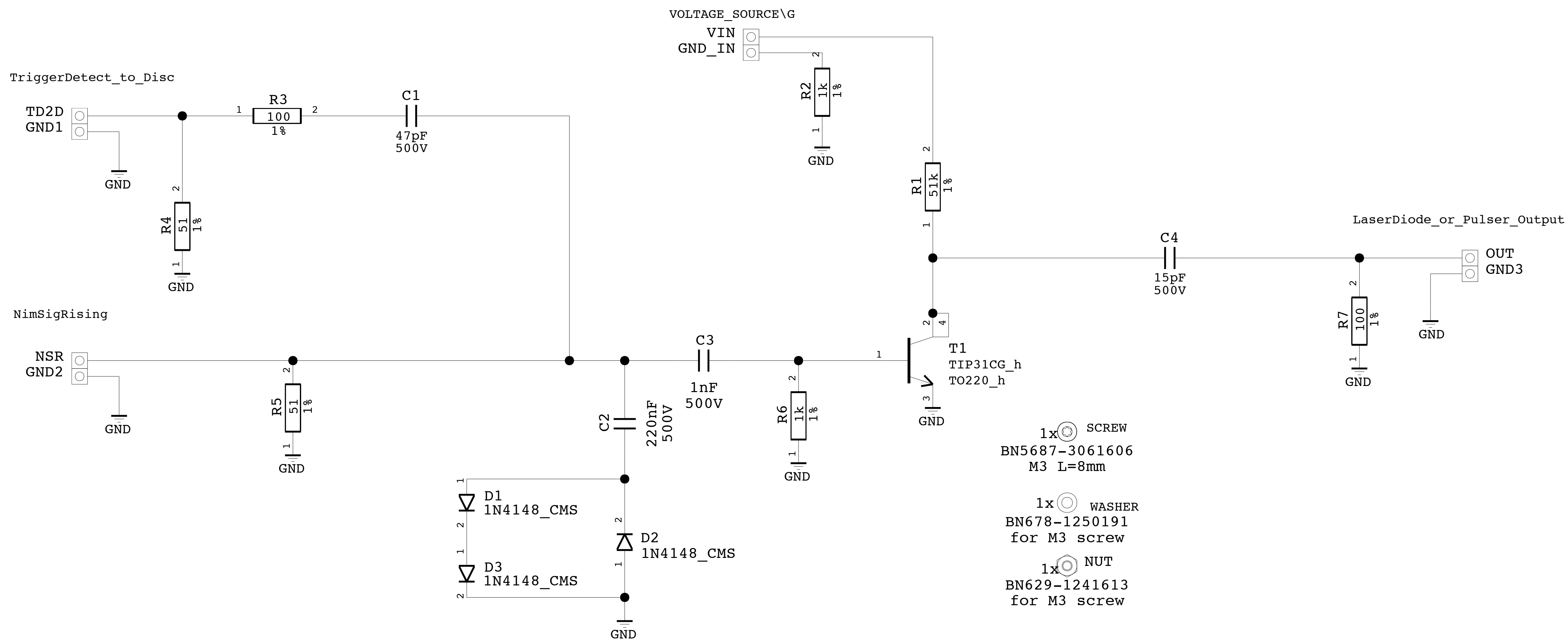
typical noise power spectrum

DAQ/digitizer considerations

- mostly using Waverunner series digital scopes (eg 1GHz carried by CERN pool), SAMPIC and DRS4v5
- in recent bidding exercise we compared Tektronix, Lecroy, Agilent
- in some respects R&S avoids compromises made by other manufacturers. "digital zoom", BW limiting on low scales and "interleaving" have sometimes caused problems in the past.
- there's a nice Labview DAQ tool that runs on all these scopes written by Roman Z.
- wrt Shannon-Nyquist theorem (ie $f_{Sample} > 2BW_{signal}$) we are always oversampling. This can help w. 8bit limit.

Test Equipment:Pulsers

- best we could do with CERN e-pool eqpt. was 3 nsec t_R, 6nsec width
- <1nsec pulsers often pricey
- so we developed a cheap one "Instapulser-CMS". PC boards made at CERN paid by A. Ball
- based on driving a transistor close to breakdown, triggered by a ~1V rising edge at base.
- very fast, large amplitude. I normally add a 10pF series capacitor(which limits a bit tR), an inverting transformer and a x20 attenuator --> to get a ~+1.5 V pulse.



FORK1MM2

Project file:instapulser_cms.cpm

SYSTEM: SPB16.3

EDA-02888-V1-0

PROJECT:Instapulser CMS

European Organization
for Nuclear Research
1211 GENEVA 23
SWITZERLAND

TS/DEM

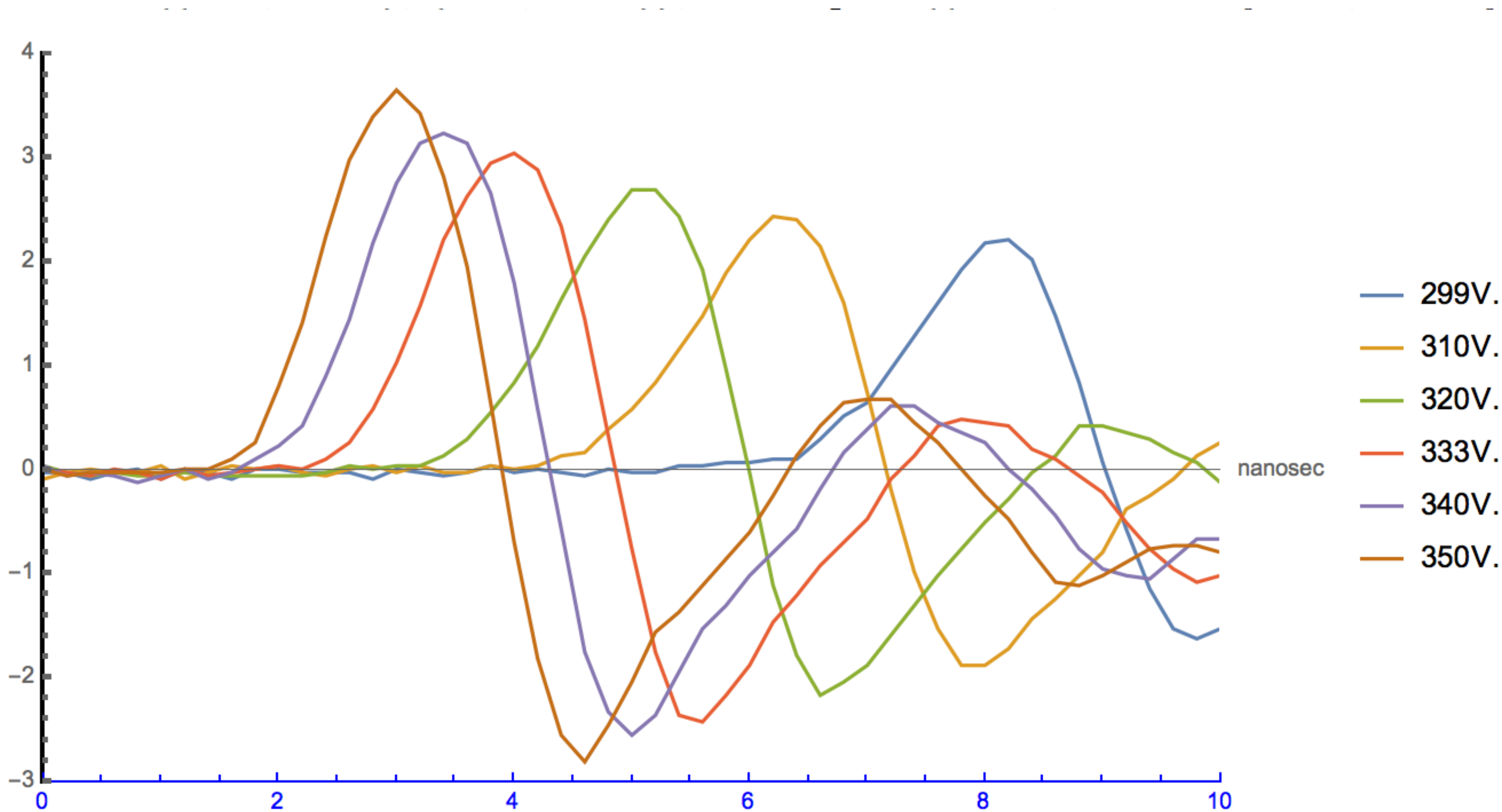
MODULE:instapulser_cms

Sheet: Module: 1/1 Project: 1/1

LAST_MODIFIED=Thu Dec 12 11:59:07 2013

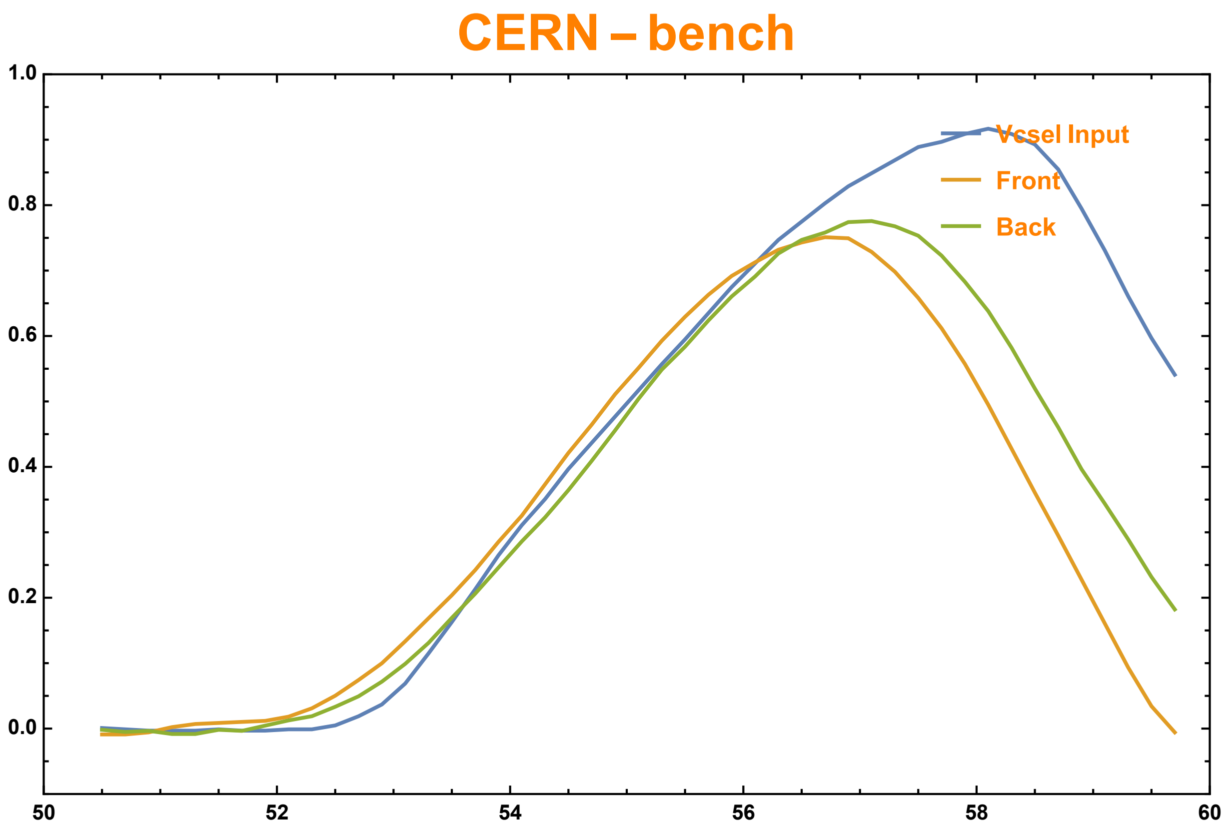
Design by: White/Newcomer | PCB by: WB | DATE: 10/12/2013

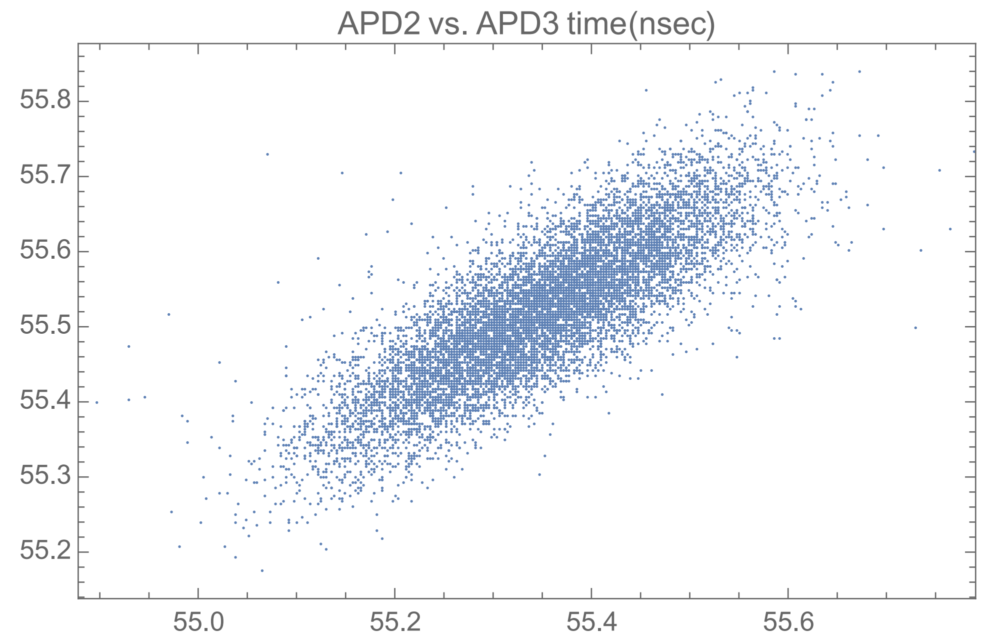
Instapulser Output pulse vs. V_{in}

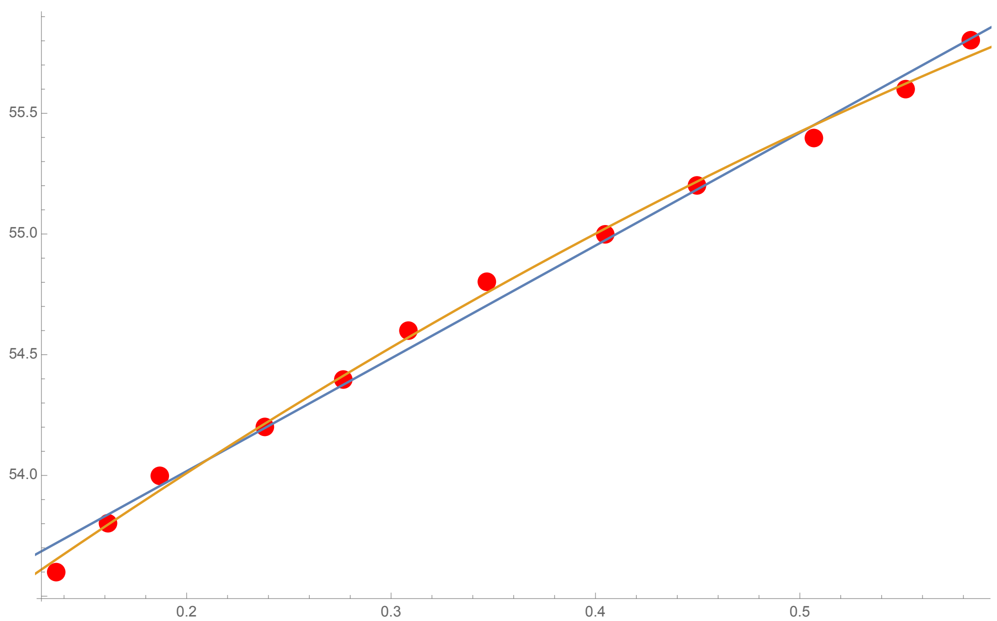


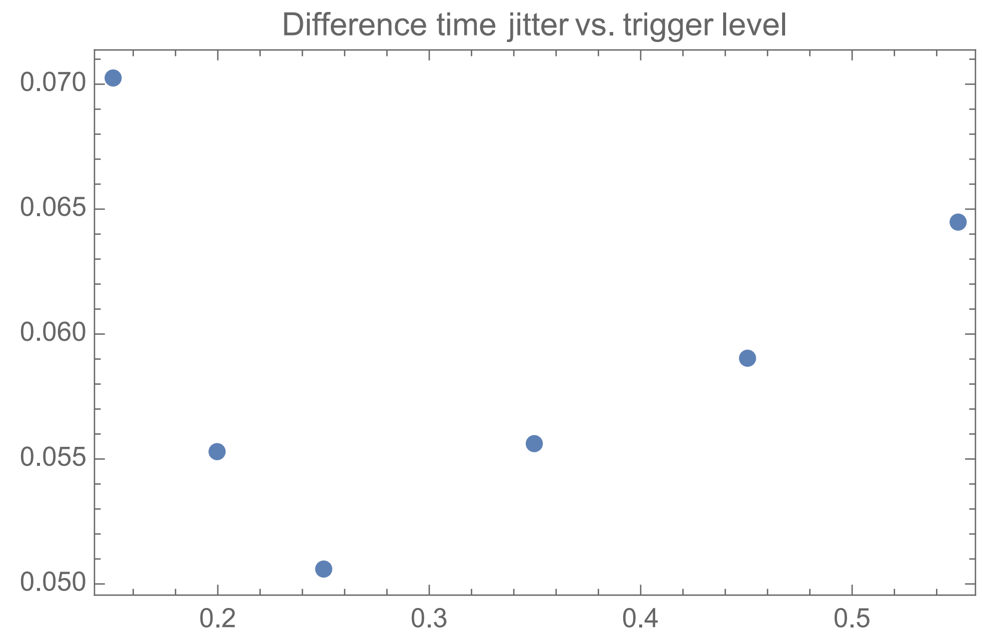
At 350V, peak=4V(with x10 attenuator!), t_R~0.8nsec, fine for our application. Could be tweaked w. C_{out} and V_{in}.

tests w. a poor t_R





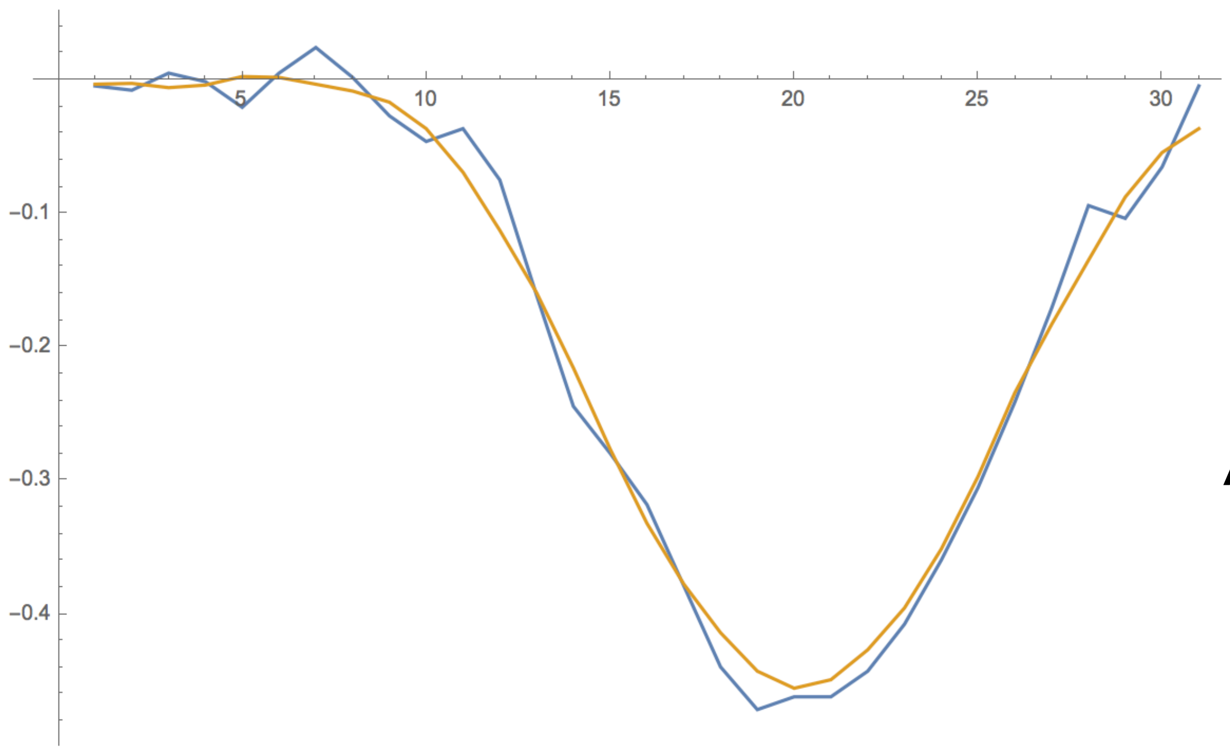




linear fit method and polynomial
give similar jitter->~35psec/detector
linear less sensitive to threshold.

return to filtering

```
ListPlot[{wave, WienerFilter[wave, 1.5, .1]}, Joined → True, ImageSize → Large]
```



unoptimized Wiener filter seems effective.

A signal with 2 nsec t_R contains no frequencies higher than 200 MHz.

Near term plans:

- a lot of opportunities for beam testing at CERN in next 2 months.
- Transimpedance amplifier has gone through 3 prototype stages in last month
- original plan to send a telescope to Mitch Newcomer to optimize interconnections
- prefer to do it here
    - meanwhile continue algorithm development using Vcsel and DESY data