Hades Progress Report on MIPS traversing Single crystal diamonds

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for the Hades collaboration
with the help of the Electronics Department at GSI
and -of course- E.Berdermann + crew

Menu:

- Concept for optimizing signal-to-noise for fast signals
- Experimental results (efficiency, time resolution)
- Current development of a fast start detector for Mips and a simple readout scheme

- All beam measurements done at a rate of about 4.5 * 10^6 protons / s (1.25 GeV, MIPS)
- Detector thickness: 300 μm, size 3.5 mm * 3.5 mm (metallization: 2.8 mm * 2.8 mm)
  Metallisation: Ti/Pt/Au, 2nd Device: 500μm thickness, Al
- 4 segments, 0.1 mm gap
- 800-850 V bias (E = 2700 V/mm)
- Sr source measurement: 300 V bias

MIPS: energy loss in 300 μm Diamond app. 100 keV

Summary of previously discussed results (2006) for MIPS:

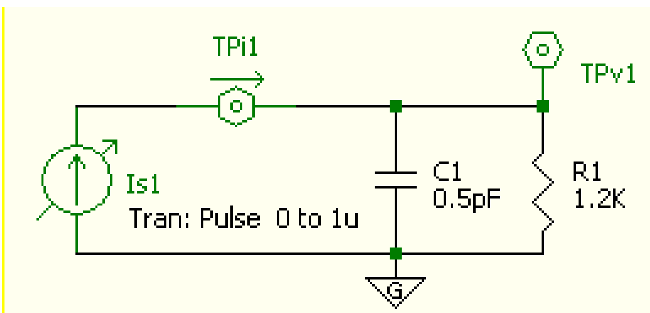
- Fast current sensitive amplifiers (50 Ohm impedance, frequency range 1-2GHz) do not allow to get the diamond signal out of the electronic noise.
- Signal-to-RMS Noise about 1.8-2.5 depending on rise time.
  (Peak noise = 5-6 * RMS noise)
- Amplifier noise close to the theoretical limit (25%-40%). No hope to improve by factor 2.

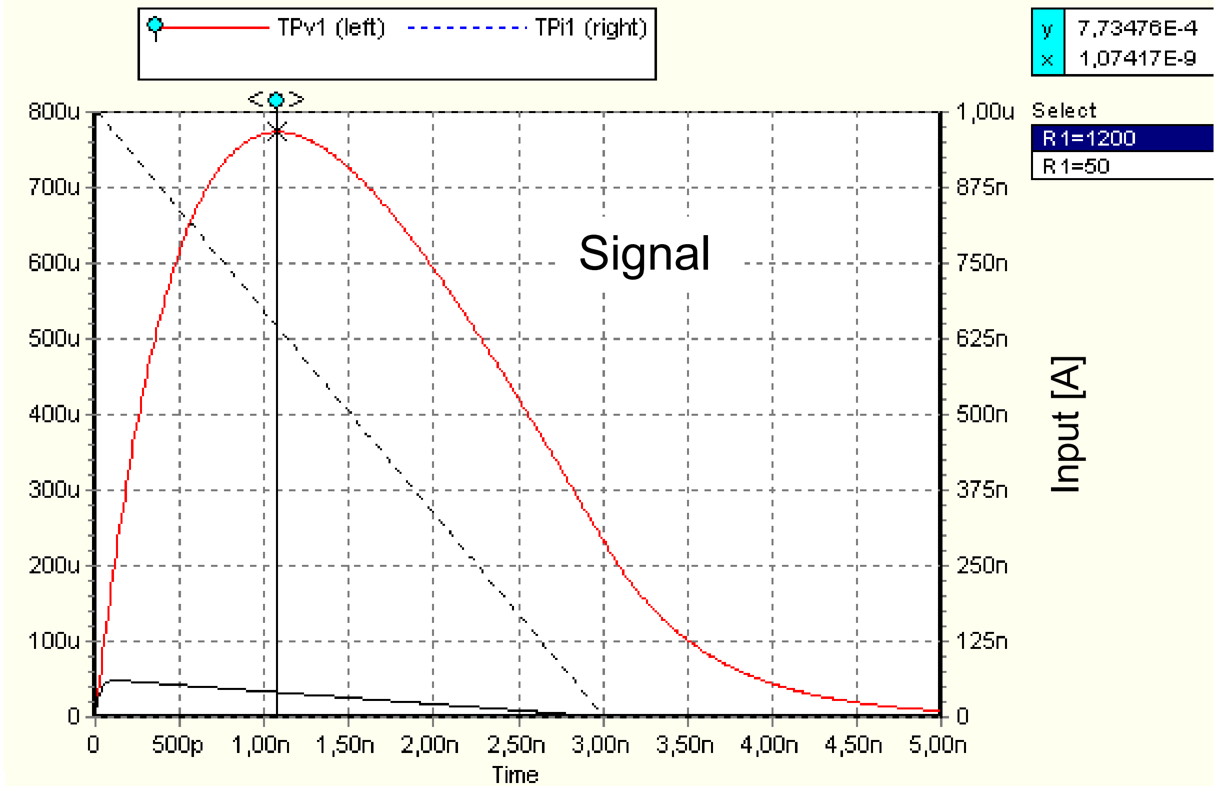
Way out:
Integrate signal by going to 'kind of' charge sensitive amplifier

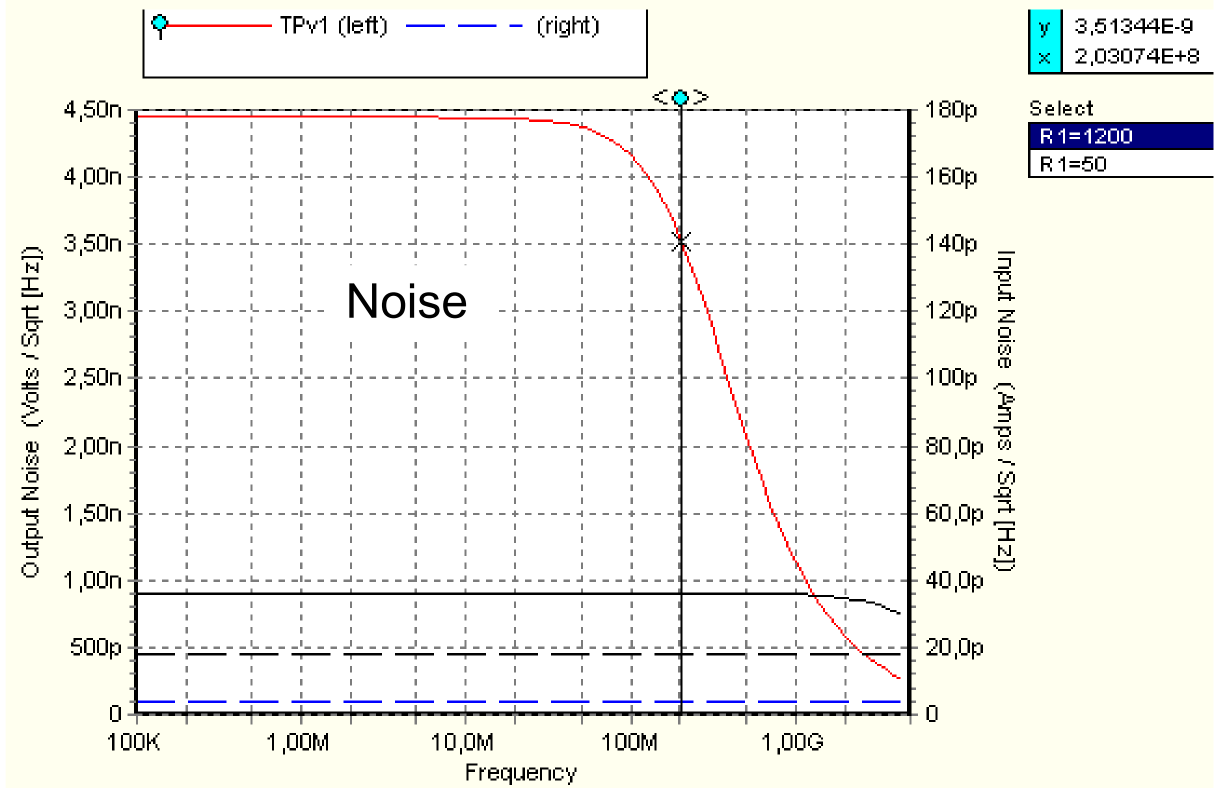
Signal-to-Noise and time resolution for Mips traversing diamonds

- 300 um thick single crystal diamond
- segmented, small capacitance (0.5pF)

Current readout (50 Ohm, **black**) versus charge sensitive amplifier: a hybrid solution (1.2k Ohm, **red**)







Signal / RMS-Noise:

- 1.2k Ohm: **8.7**
- 50 Ohm:**0.88**

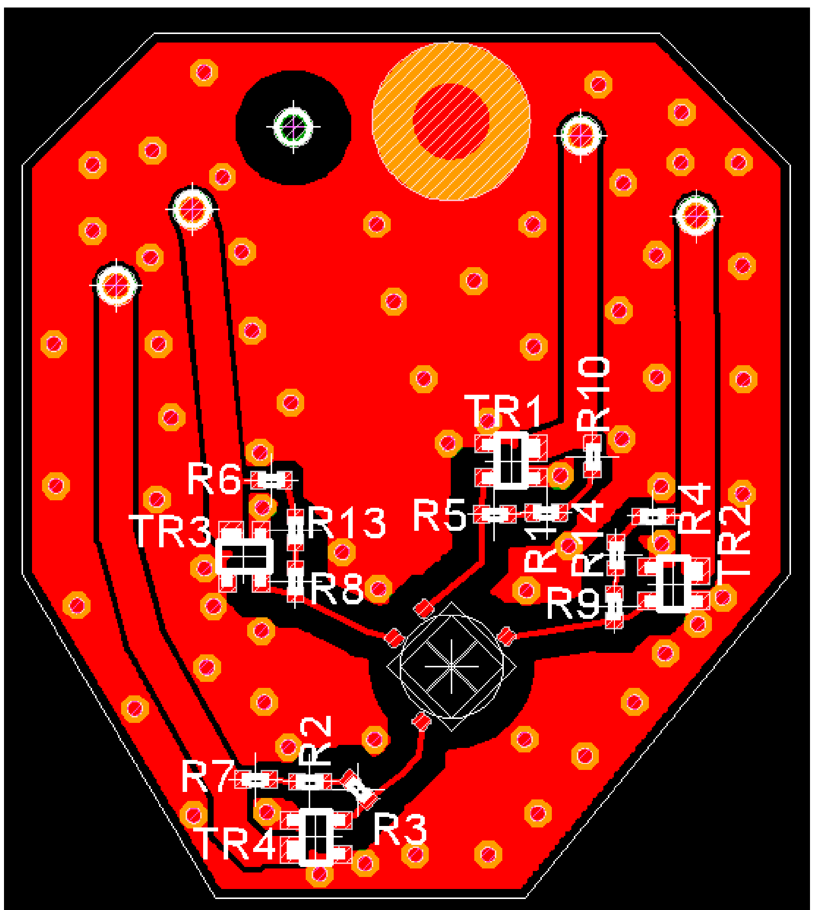
Time Resolution:

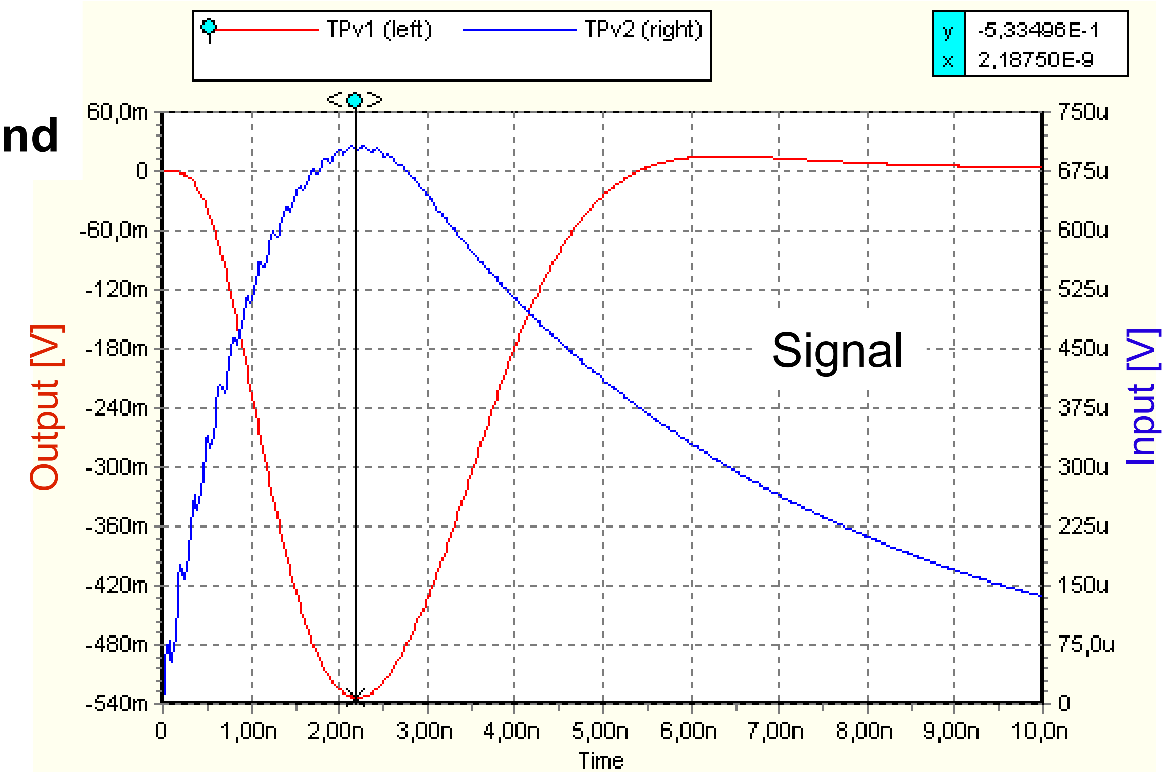
ΔT = Risetime * Noise / S

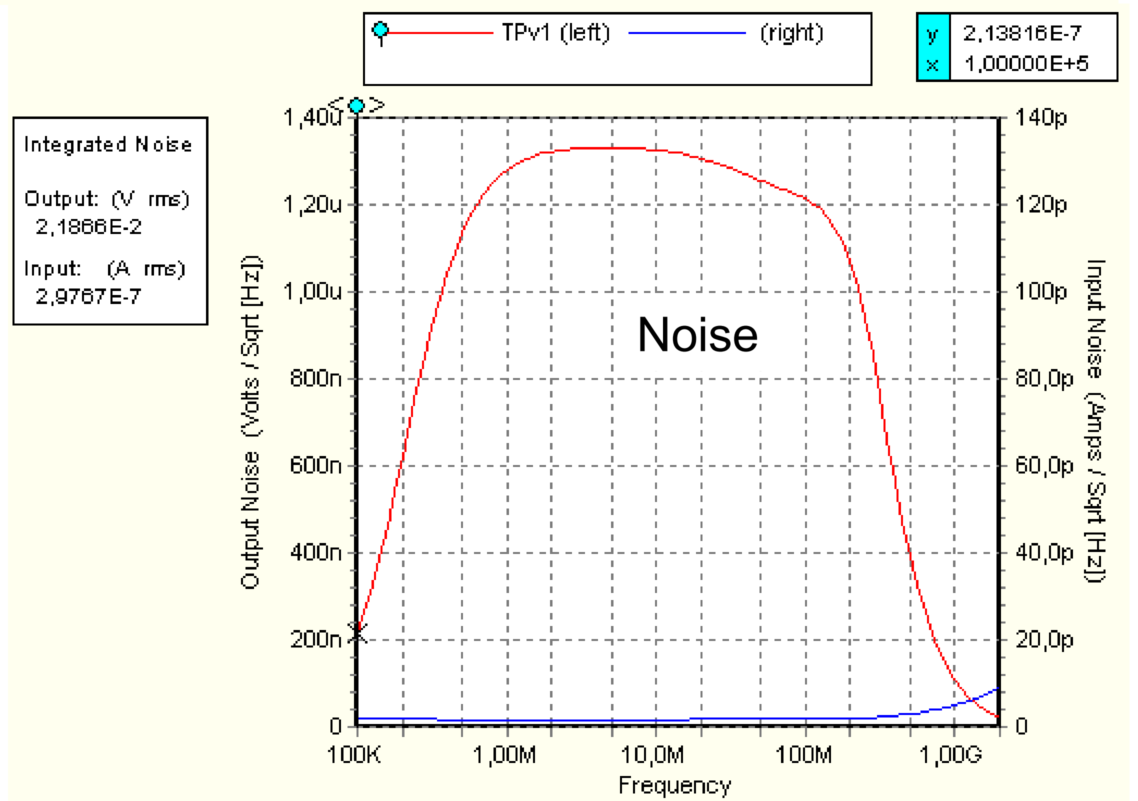
55 ps both cases

Simulation Result for a real amplifier (BFG310) directly attached to the diamond

- Detector segment C= 0.25pF
- Signal to RMS-Noise = 24.4
- Rise Time 1.2 ns
- Pulse Height for MIPS = 0.5 V (after Booster amplifier)





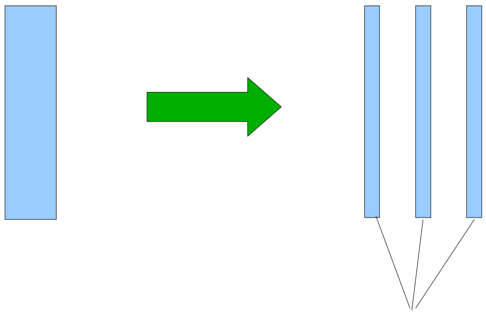


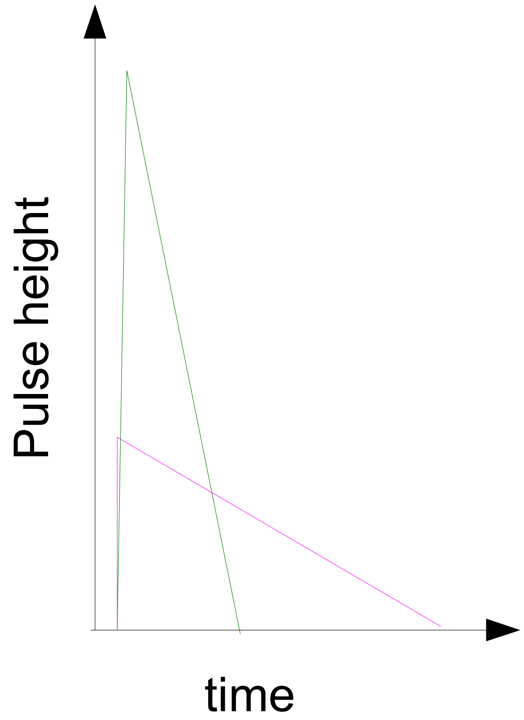
FET based solution (standard charge sensitive amplifier)

- Theory much more complicated (violating my KISS principle)
- Best signal to noise, if FET capacitance = detector capacitance
- FET's with 0.25pF capacitance are not available (2 pF typically)

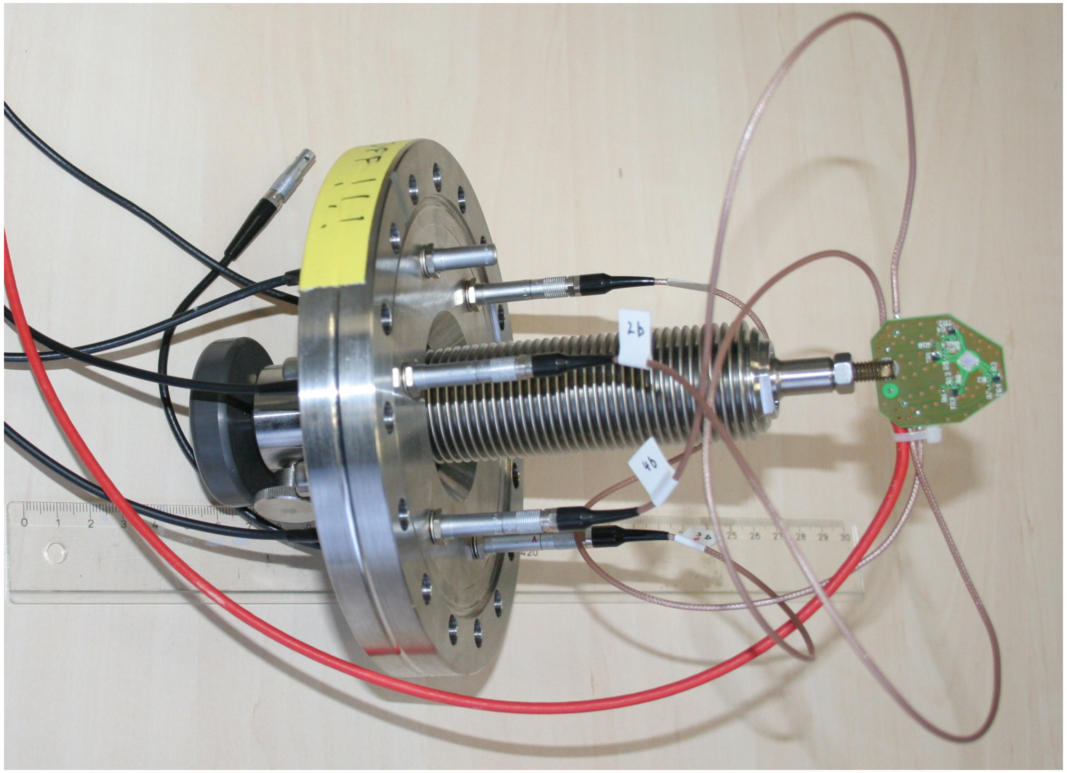
Way Out:

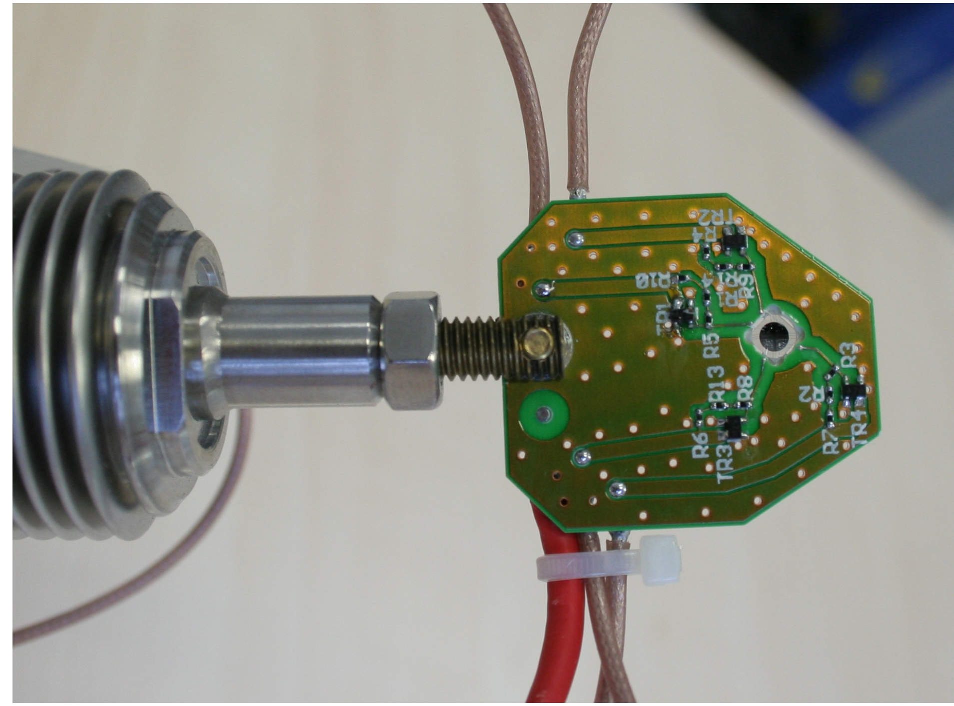
- take 3 diamonds with 1/3 thickness.
- primary pulse width reduced by factor 3.
- primary pulse height increased by factor 3.
- capacitance increased by factor 9.
- **cost increased by by factor 3.**
- **Nearly as good as my solution**

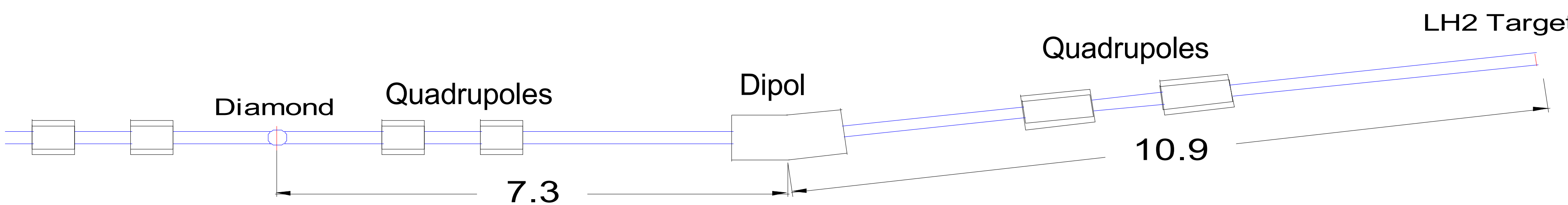




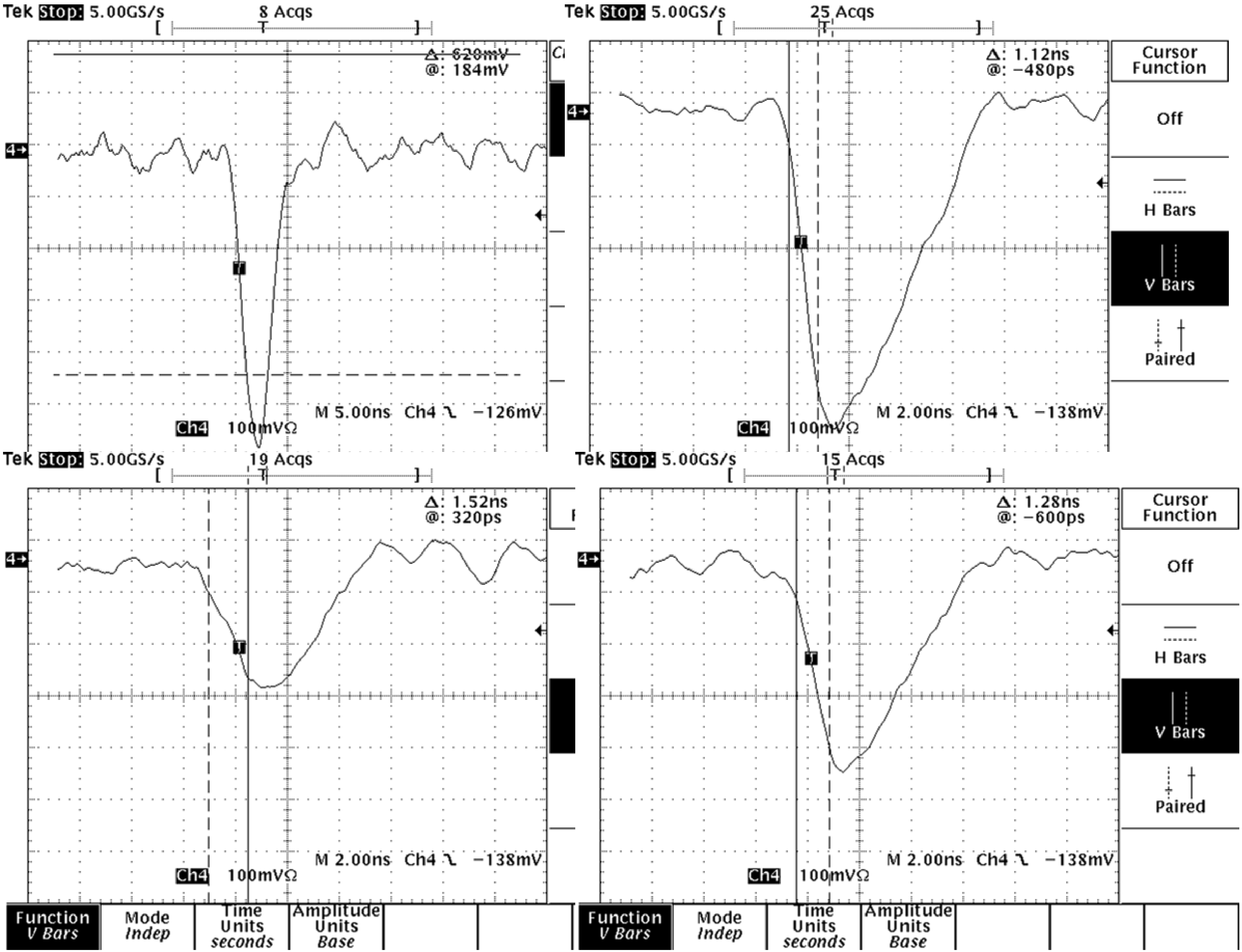
Diamond located at an intermediate focus 18 m downstream of the experiment



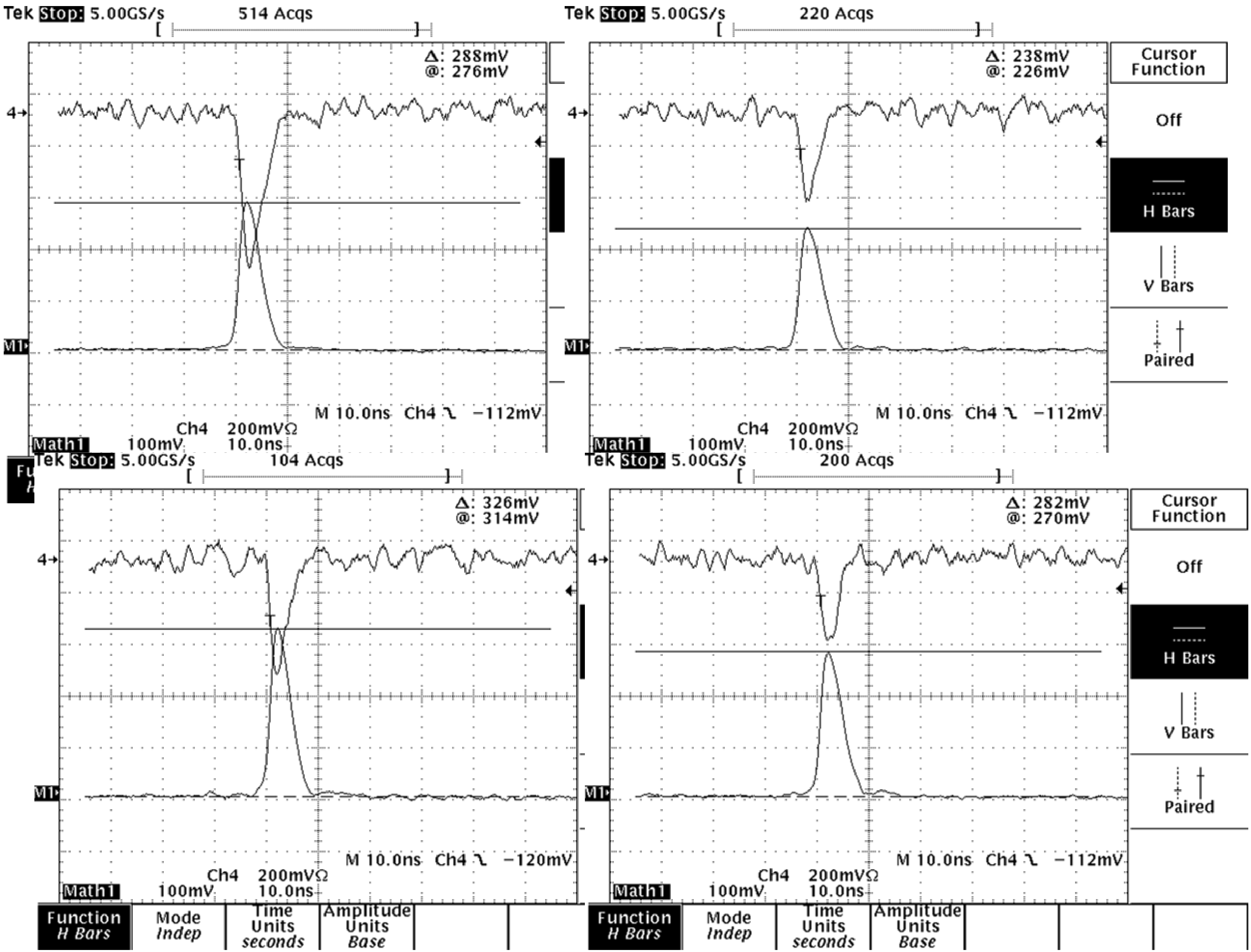




Sr^{90} source results: some snapshots of signals   Risetime: 1.3 ns @ 300V bias

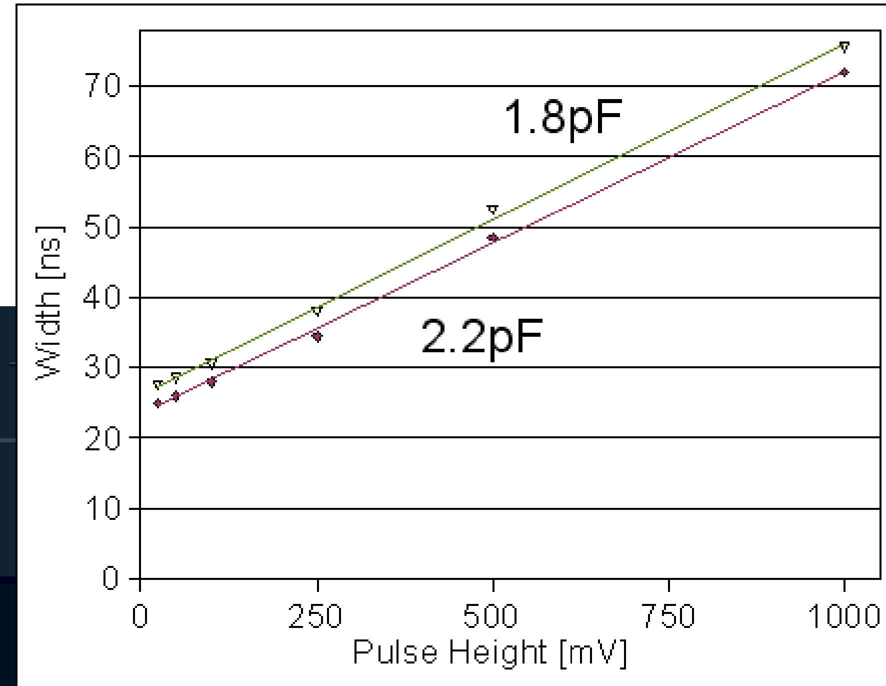


Mean pulses for the 4 segments after averaging (lower trace).
Good agreement with simulation (20 mV RMS noise)

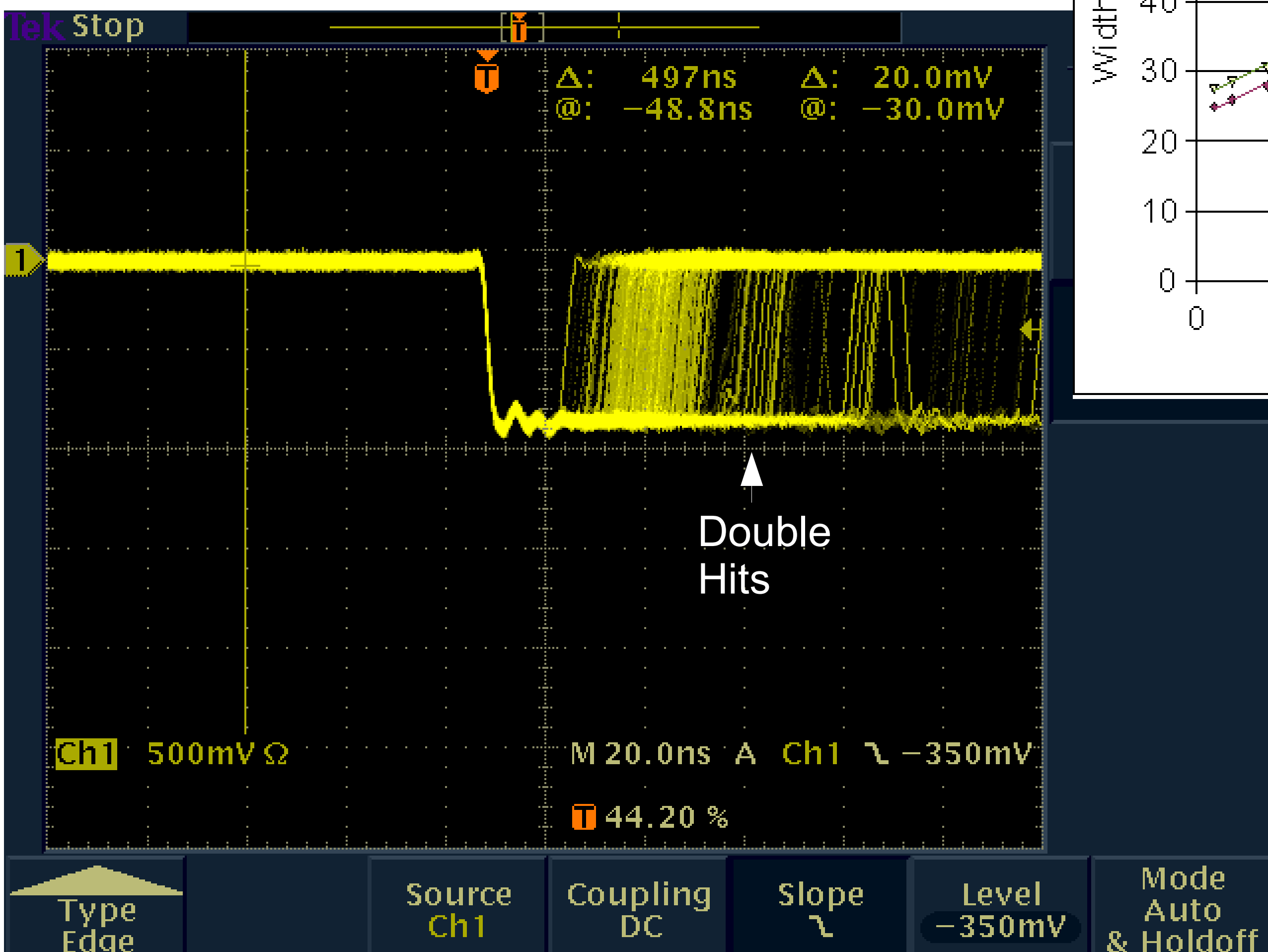


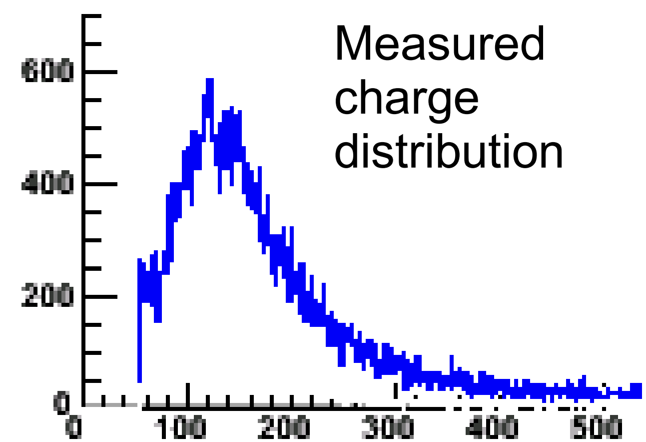
Converting pulse charge to width of discriminator output

Base width remotely adjustable 15-30 ns

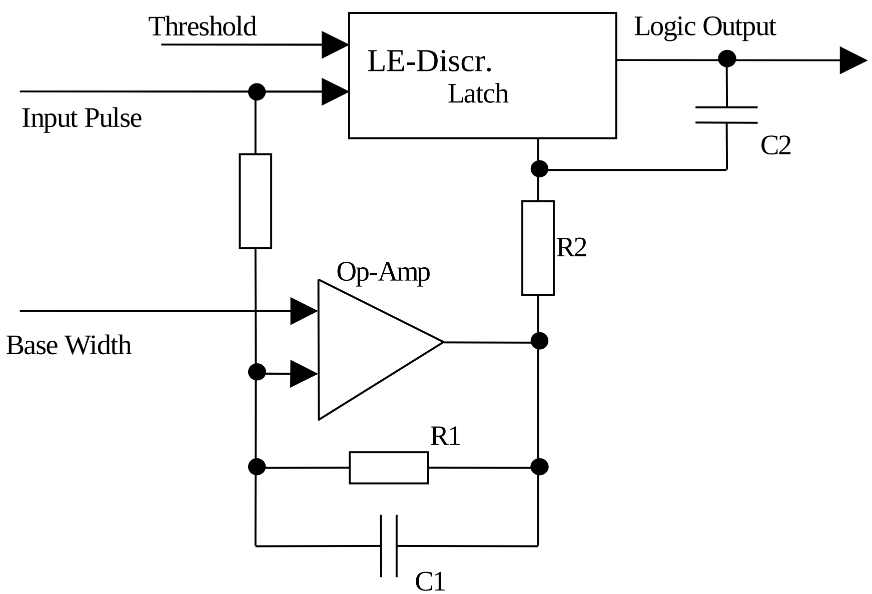


Proton rate (1.25 GeV): 4.5 * 10^6 / s
Mean pulse-height well above threshold (2* peak noise)





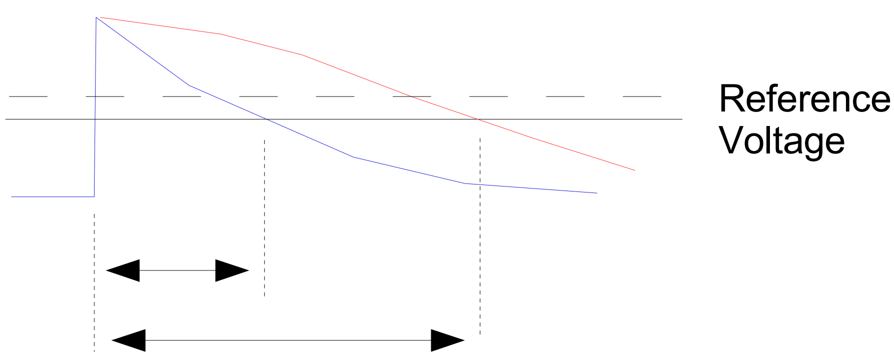
Charge to Width (Q2W):
A simple scheme avoiding extra electronics for charge (pulse height measurement



Features:

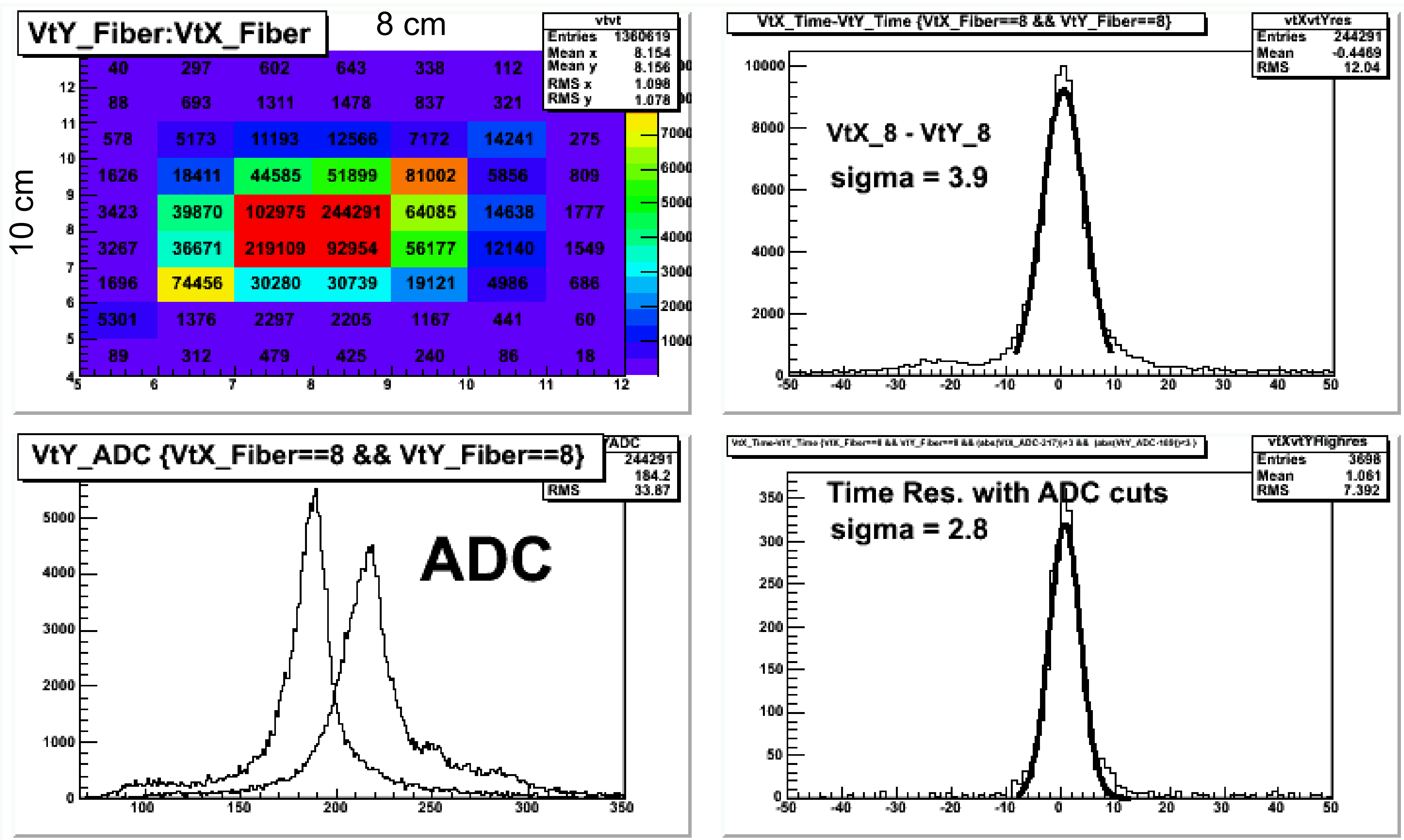
- Feedback capacitor C2 from Output to Latch guaranties minimum pulse width.
- Integrated signal increases this width proportional to pulse charge.
- Resolution better 0.4% independent of width variation.

Problem:
Settling time about equal to width.



Time Resolution: two 16 Rod Hodoscopes (X,Y) as Reference

X,Y distribution 5.5m downstream

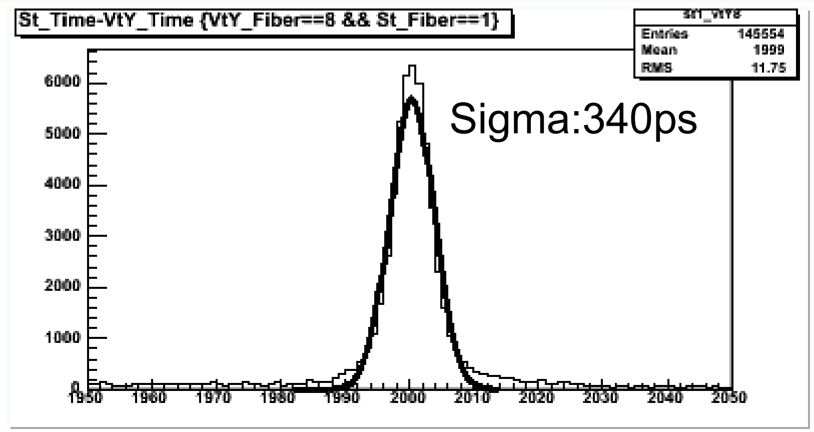


signal width ∝ pulse charge

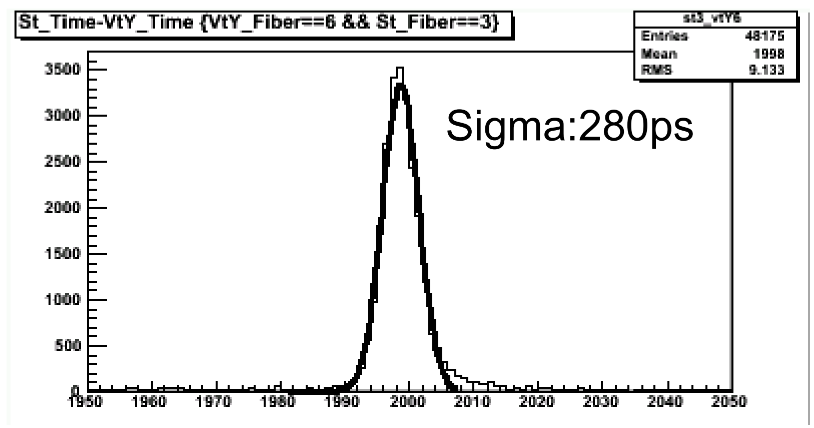
time difference [100ps]

Estimate of Time Resolution Diamond: No walk correction

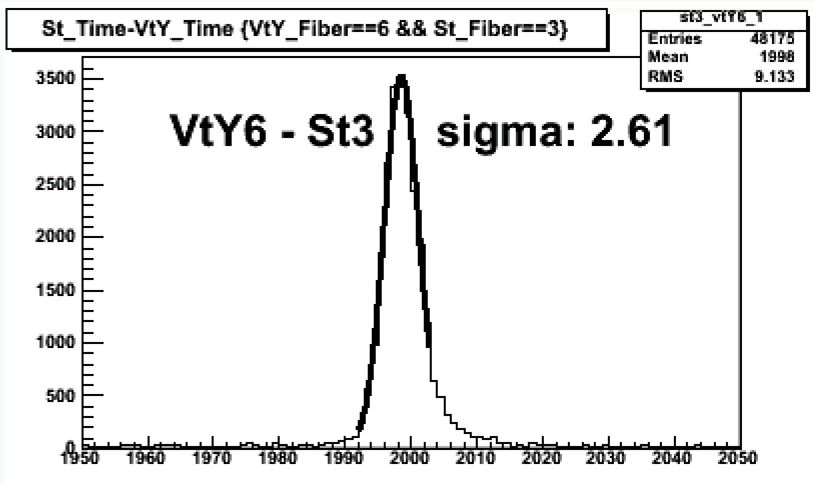
Corrected for Plastic Fiber resolution: 275 ps
sigma-diamond: 200 ps

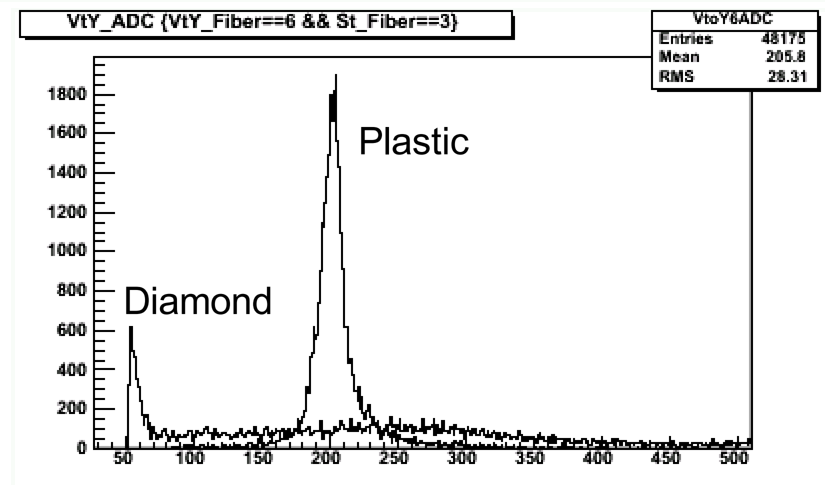


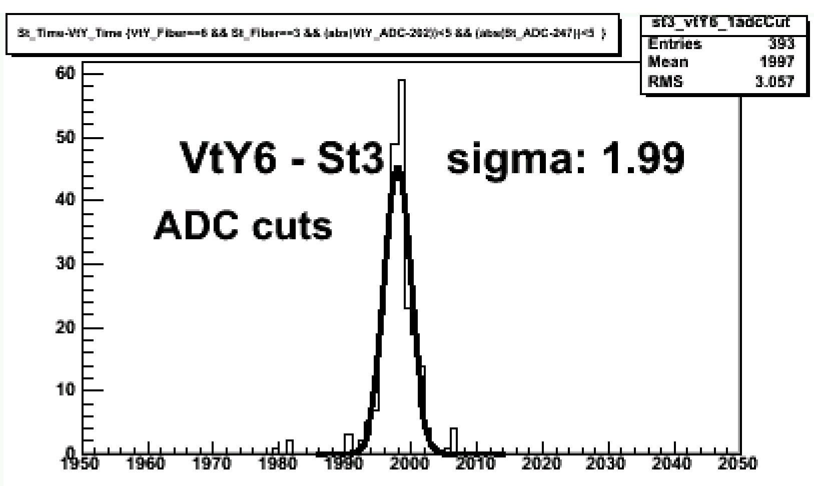
Corrected for Plastic Fiber resolution: 275 ps
sigma-diamond: 50 ps



Estimate of Time Resolution Diamond: Walk eliminated







Top right: Pulse charge distribution
Top left: no cuts on pulse height

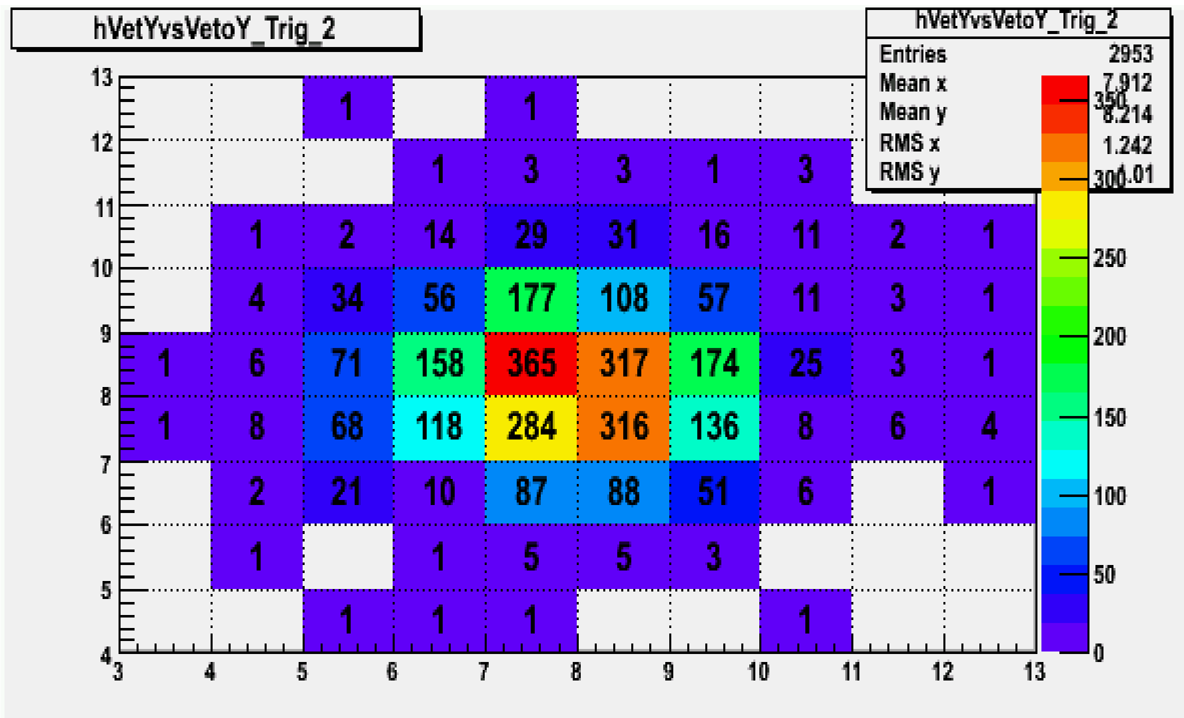
Bottom left: narrow cuts on pulse charge:

Sigma-Plastic: 198 ps

Sigma-Diamond: 20ps ??

Diamond Efficiency

- Reference: Coincidence of X-Y plastic Hodoscopes behind experiment (16cm *16 cm) mainly illuminated by beam: 4 cm * 4 cm
- Check whether or not diamond (23 m downstream of Hodoscopes fires in coincidence (10ns)



Mean Beam intensity:

$4.5 * 10^6$ / s

Burst intensity

$4.5 * 10^7$ / s

corrected mean intensity:

$1 * 10^7$ / s

beam extraction time: 10 s

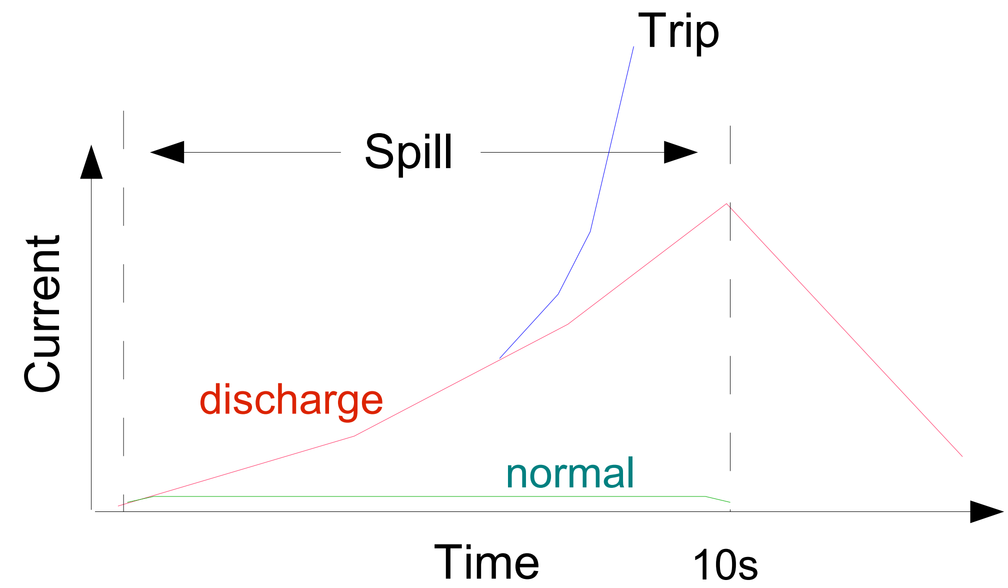
- Efficiency before 'Spark', high threshold: **93,4%**, corrected **95.4%**
- Efficiency after 'Spark', low threshold: **90.2%**, corrected **92.2%**
- Estimate of beam particles bypassing Diamond but hitting (much larger) Plastic Hodoscopes: **> = 2%** (very conservative)

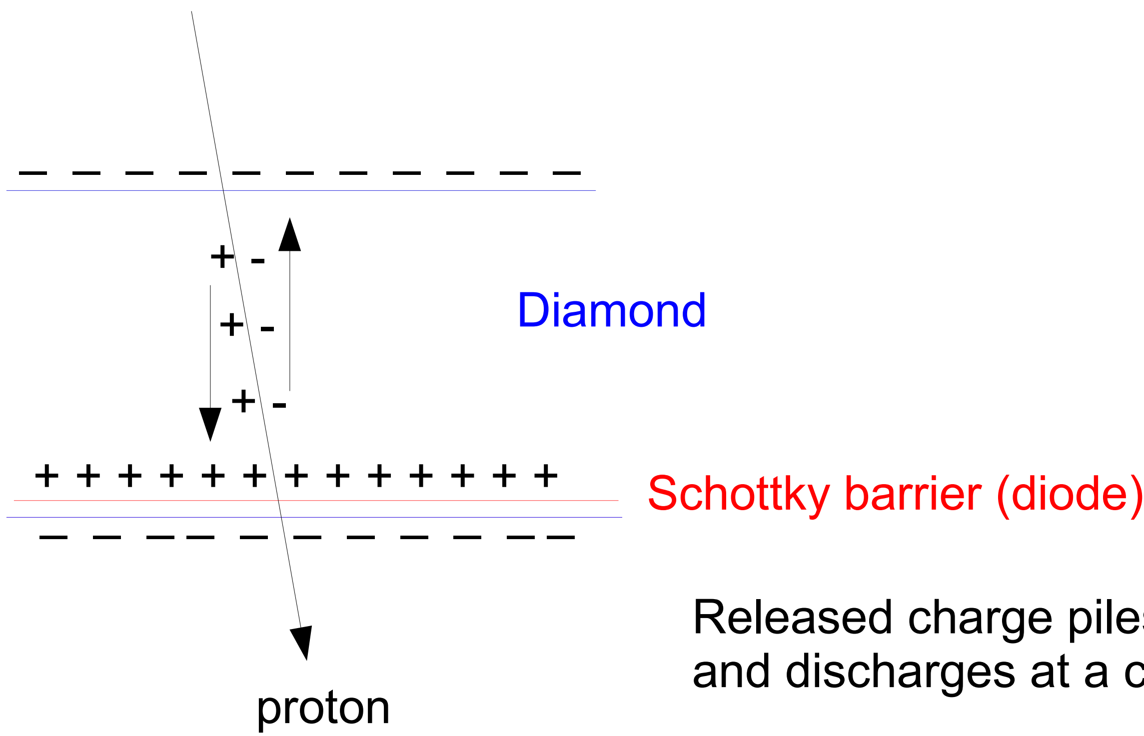
up-charging / sudden discharging effects at high rates

Massive increase of current once every few hours (red, factor 10).

Much more pronounced for AL metallisation (minutes instead of hours) even at lower bias voltage.

Low statistical significance (1 sample only)





Released charge piles up in front of electrode and discharges at a critical value ?

Consequence: Diamond removed because of unreliable behaviour during a production run

Summary

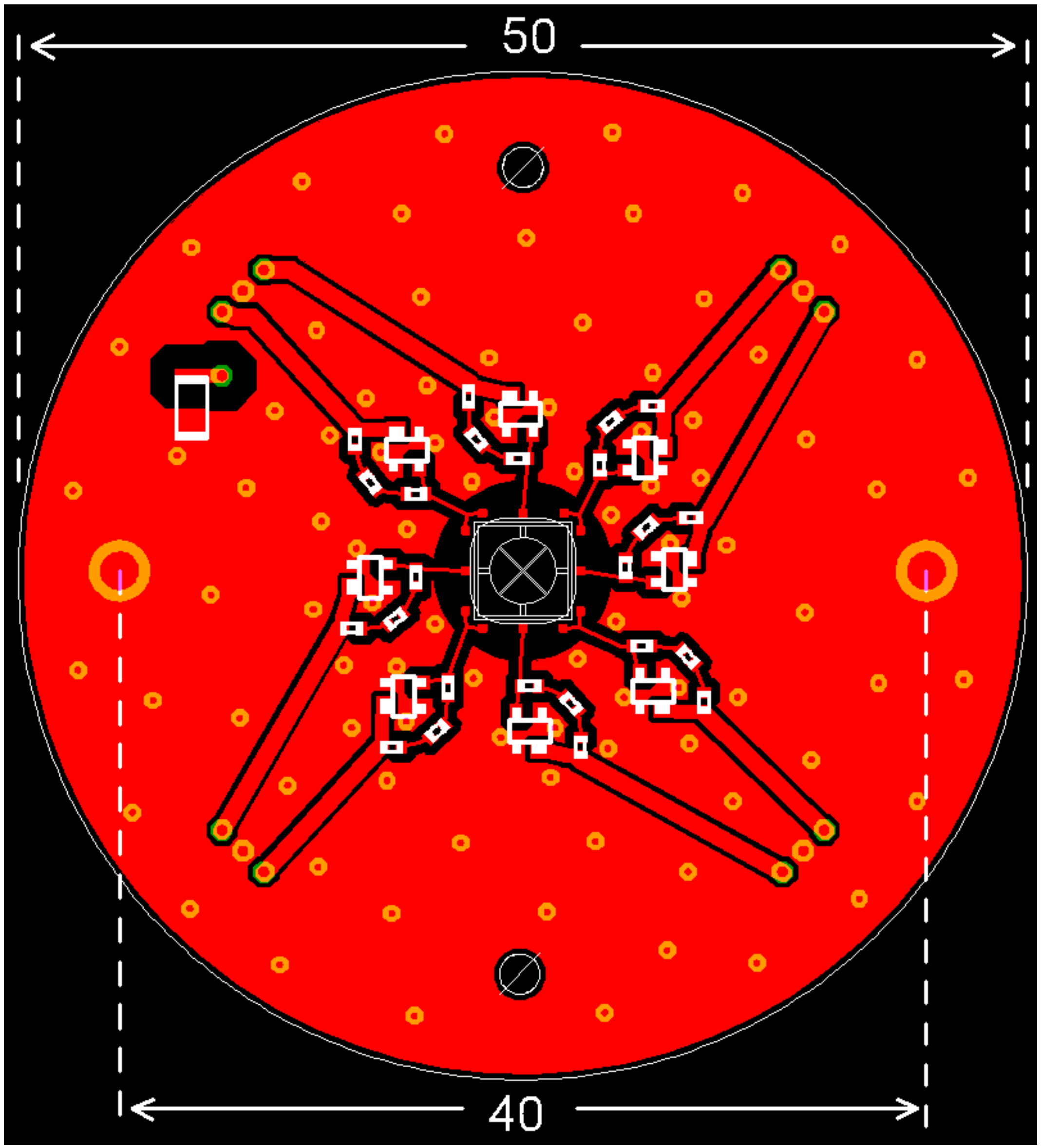
- **A dedicated readout concept for MIPS traversing diamonds was developed**
- **Time resolution < 100ps**
- **Efficiency > 95%**
- **Count rate capability limited by diamond properties (currently about 5*106 / s)**

Previous and further progress limited by available Hades manpower
(which is perfectly understandable)

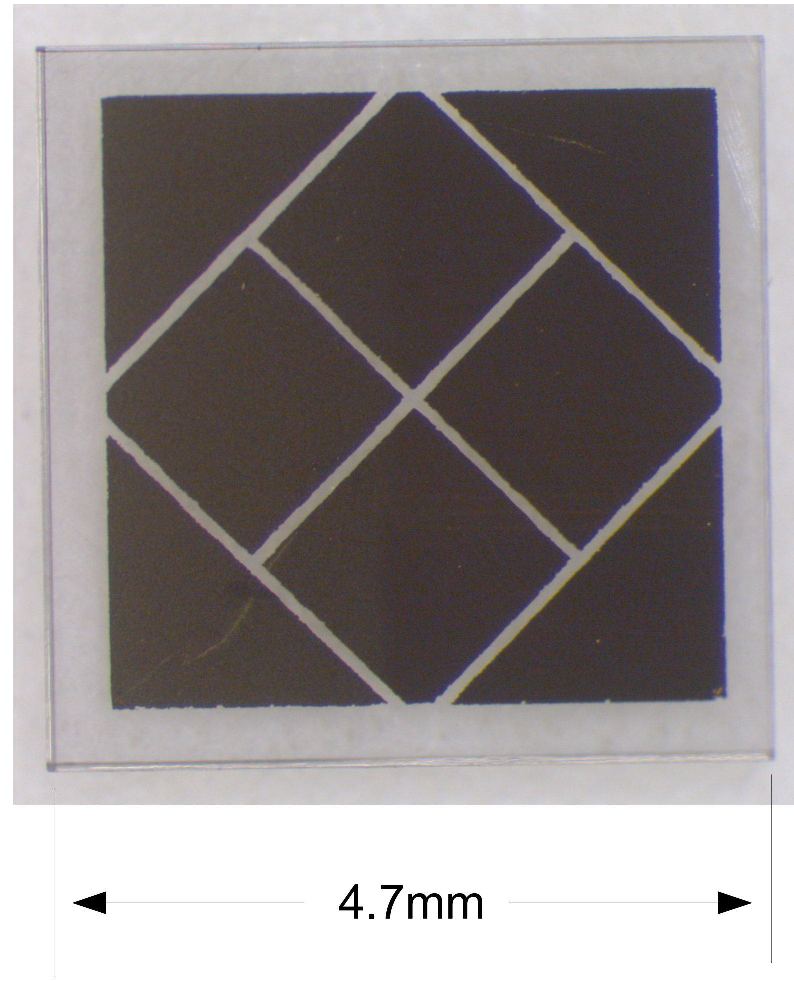
Outlook: next proton beamtime

Diamond mounted 4 cm in front of target

Amplifier 1st stage directly attached to diamond



8 fold segmented diamond
including 4 Beam Halo segments



50 μm gap between segments

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