SC Diamond Detector FE Electronics for MIPs Timing

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of

NoRHDia Project

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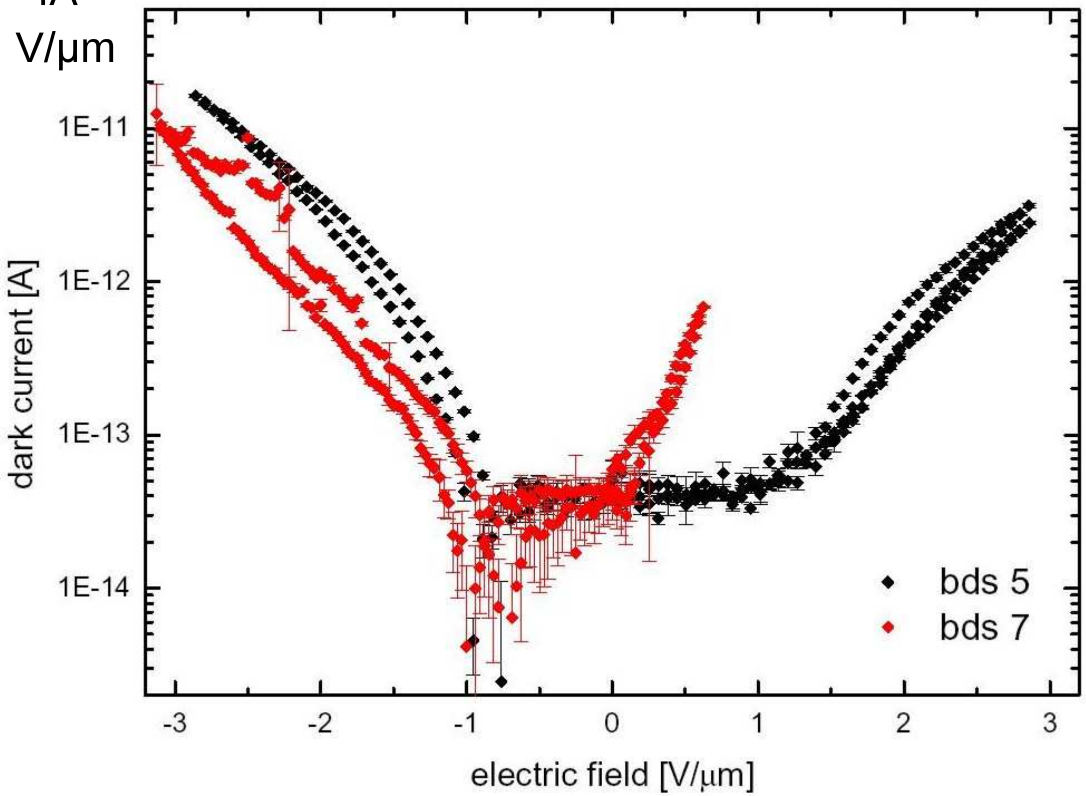
Signal Source

SC-DD characteristics

Det. no.	bds5	bds7	
Crystal dim.	5x5x0.315	5x5x0.320	mm^3
Contact diam.	3.5	3.5	mm
area	9.62	9.62	mm^2
nature	50 nm Cr + 100 nm Au		
Capacitance	1.54	1.52	pF
Dark current	50	50	fA
Electric field	±1	-1	V/µm

$$C_D(pF) = 50.46 \bullet \frac{S(mm^2)}{d(\mu m)}$$

Dark current vs. electric field



Signal Source

SC-DD signal

Shape: trapezoidal

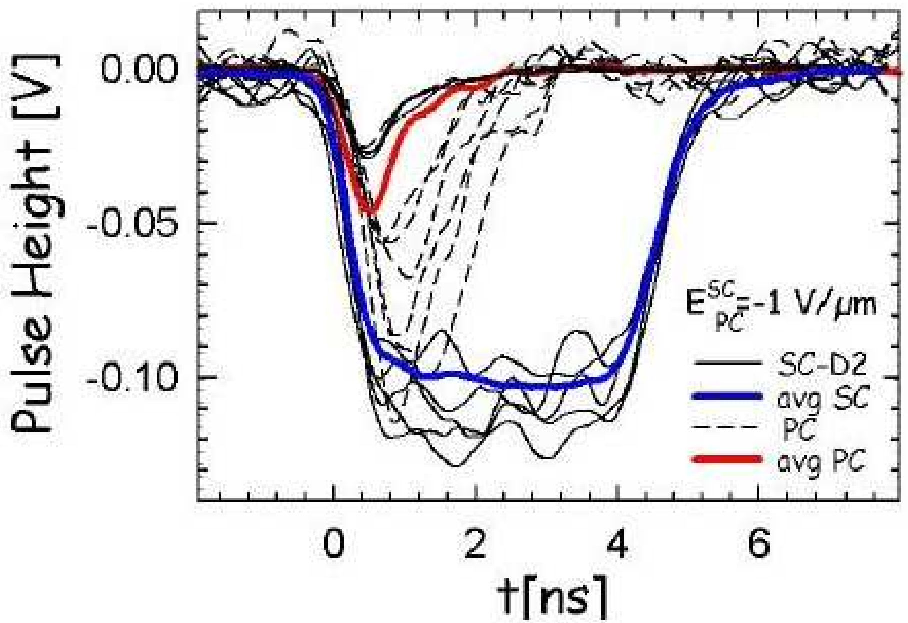
t_r < 200ps (incl. 150ps DBA contribution)

t_{FWHM} ~ 1ns/100µm

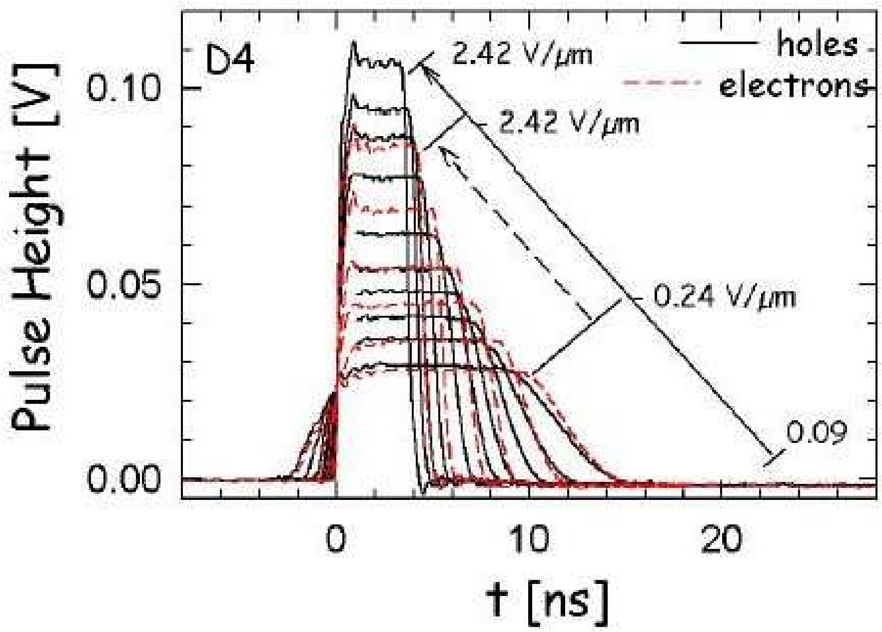
$\left.\frac{\Delta Q}{\Delta x}\right|_{MIP}^{DD} \approx 36$ e/µm

$Q_{MIP}^{300\mu m} \approx 11000e = 1.75fC \xrightarrow{CSA} 1.75mV\ (C_F=1pF)$

Comparison of a 295µm PC-DD signal and a 500µm SC-DD signal



Averaged α-induced signal from a 393µm SC-DD at different electric fields



(E. Berdermann et al., Int. Winter Meeting on Nuclear Physics, Bormio-Italy, 2005)

Timing errors

The resolution of TOF measurements is affected by:

- **Walk** = time error due to signal amplitude spread

  ➡ can be compensated knowing amplitude (energy) spectra

  ➡ spectrometric chain ➡ SA

- **Jitter** = time error due to electronic noise and finite signal slope

$$\sigma_t = \frac{\sigma_N}{\left.\frac{dV}{dt}\right|_{thr}}$$

  ➡ can be minimized by high S/N and fast Tr

  ➡ fast, low noise chain ➡ CSA+FA

Reasons for a CSA solution

S/N ratio – formula

Dominant noise sources are considered:

- thermal noise of input resistor(Rin) for VA $= \sqrt{4KTR_{in} f_{VA}}$
- channel noise (gm) of input device for CSA $= \sqrt{4KT \frac{0.7}{g_m} f_{CSA}}$

$$\frac{(S/N)_{CSA}}{(S/N)_{VA}} = 1.2 \cdot T_w \cdot \sqrt{\frac{g_m}{R_{in}}} \cdot \frac{1}{C_T} \cdot \sqrt{\frac{f_{VA}}{f_{CSA}}}$$

where:

(DD) • T_w = transit time in detector = W/V_s

(W = DD thickness, V_s = saturation velocity)

(CSA) • g_m = slope of CSA input device

• C_T = total input capacitance

• f_{CSA} = bandwidth of CSA

(VA) • R_{in} = input impedance of VA

• f_{VA} = bandwidth of VA

MIP signals referred to input are:

- $U_{VA} = V_S \cdot \left(\frac{\Delta Q}{\Delta x}\right) \cdot R_{in}$
- $U_{CSA} = W \cdot \left(\frac{\Delta Q}{\Delta x}\right) \cdot \frac{1}{C_T}$

where:

$$\left.\frac{\Delta Q}{\Delta x}\right|_{MIP}^{DD} \approx 36 \text{ e/µm}$$

Reasons for a CSA solution

S/N ratio – estimation

(DD)
- $T_w = 3ns$ (W = 300μm)

(CSA)
- $g_m = 45mA/V$
- $C_T = C_D+C_{in}+C_P+C_F=7pF$

  $C_D=1.5pF$ $C_P=1.5pF$

  $C_{in}=3pF$ $C_F=1pF$
- $f_{CSA} = f_{VA}$

(VA)
- $R_{in} = 50\Omega$
- $f_{VA} = f_{CSA}$

	CSA	VA
MIP input signal (μV)	247	28.8
Spot noise, input ref. (nV/SR Hz)	0.51	0.91
S/N	$\frac{484\cdot 10^3}{\sqrt{f_{CSA}}}$	$\frac{32\cdot 10^3}{\sqrt{f_{VA}}}$
$\frac{(S/N)_{CSA}}{(S/N)_{VA}}$	15.3	

Reasons for a CSA solution

Rise time – formula

$$T_r^{CSA} = 2.2 \cdot \tau_r = 2.2 \cdot \frac{C_T}{C_F} \cdot \frac{C_C}{g_m}$$

where:

$C_T = C_D + C_{in} + C_P + C_F$

C_F=feedback capacitance

C_C= dominant pole capacitance

g_m = slope of CSA input device

$$T_r^{VA} = \sqrt{\left[2.2 \cdot (C_D + C_P) \cdot R_{in}\right]^2 + t_{VA}^2}$$

where:

t_{VA} = gain stage rise time

Rise time – estimation

T_r^{CSA}= 1ns ⇐ C_T = 7pF, C_F=1pF, C_C = 3pF, g_m = 45mA/V

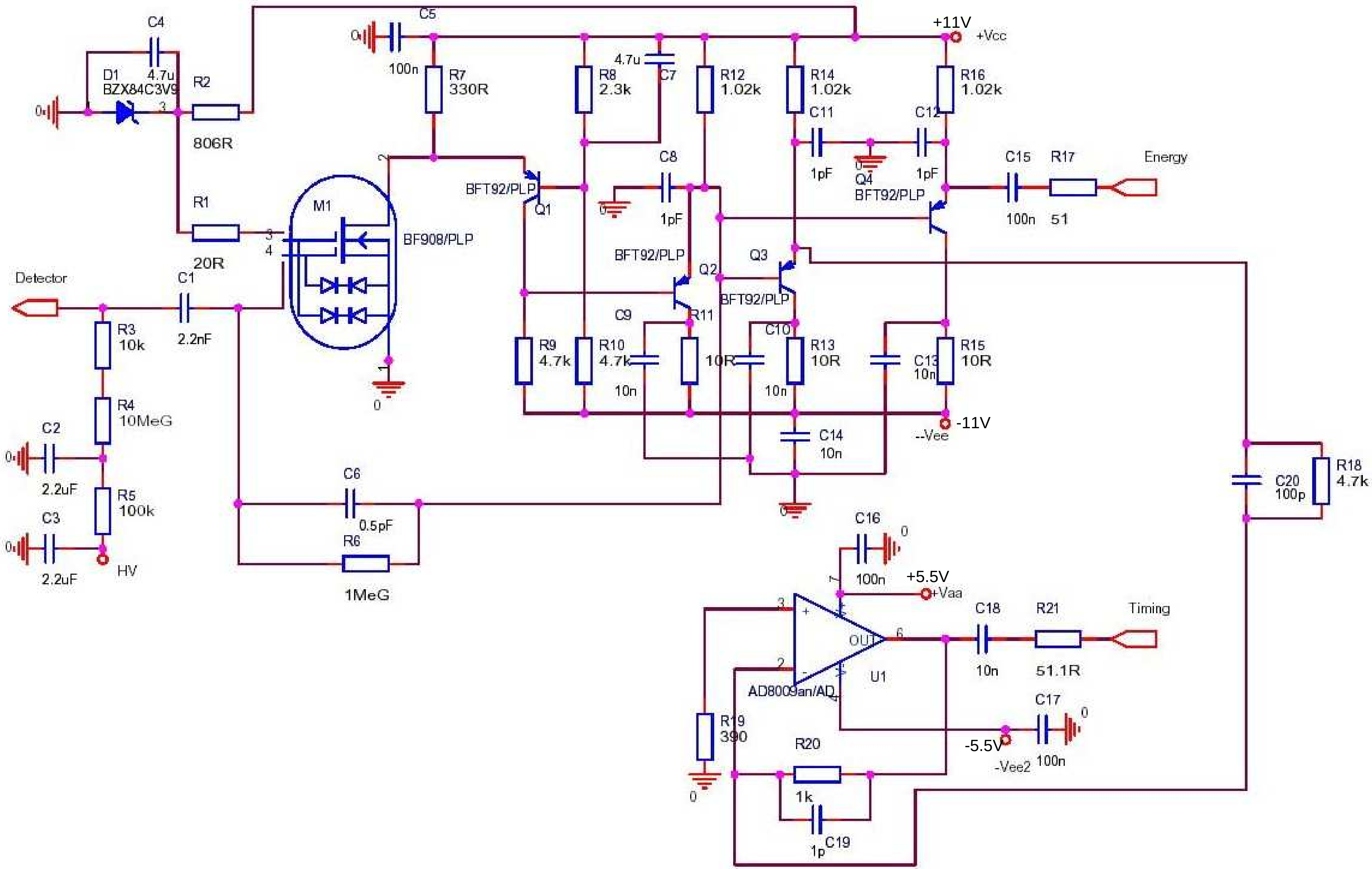
T_r^{VA}= 360ps ⇐ C_D=1.5pF, C_P=1.5pF, R_{in} =50Ω, t_{VA} =150pS

(DBA – Peter Moritz)

$$\frac{T_r^{CSA}}{T_r^{VA}} \approx 3$$

Charge Sensitive Amp and Fast Amp

CSA and FA – circuit diagram



Charge Sensitive Amp and Fast Amp

CSA and FA – view

BF908

- Dual-gate MOSFET, 1GHz
- Depletion type
- y_{fs} = 43 mA/V (typ)

  C_{iG1-s} = 3.1pF (typ)
- NF = 0.6 db (typ) / 200MHz

  =1.5 db (typ) / 800Mhz
- I_{DSS} = 3-27 mA

  (U_{DS} = 8V, U_{G2-S} = 4V, I_D = 15mA)

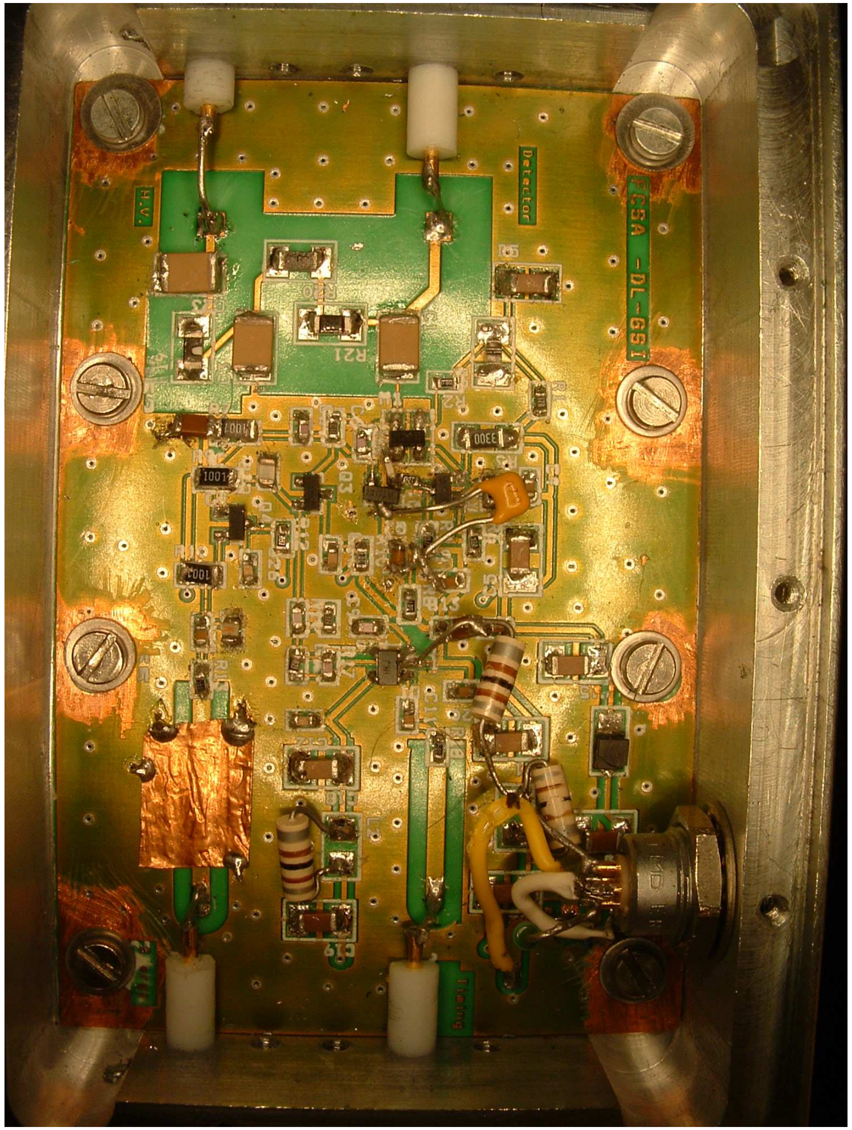
AD8009

- Current feedback type
- GBP = 1GHz

  G = 10 B = 350 MHz
- e_n=1.9 nV/SR Hz

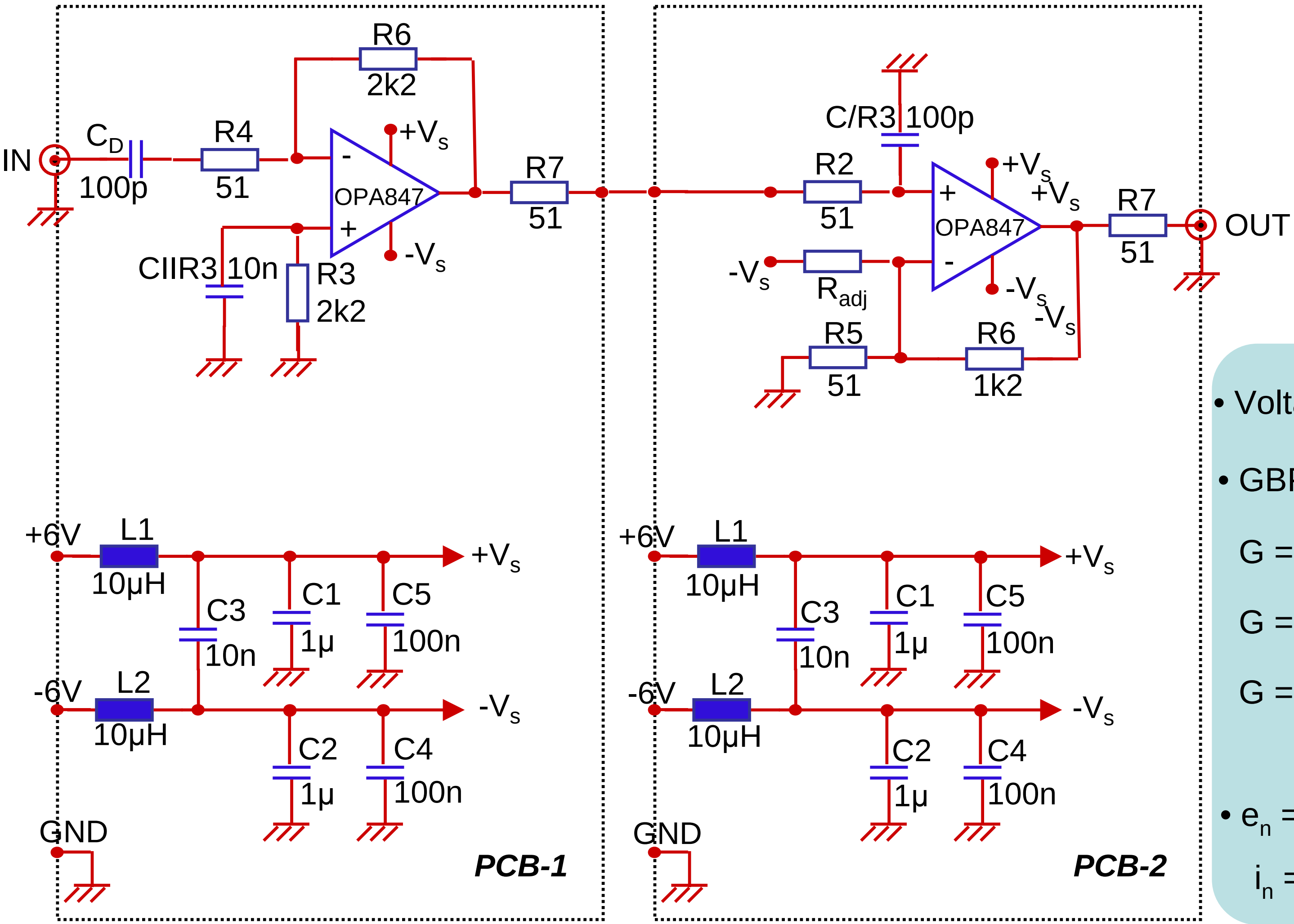
  i_n^+ = 46 pA/SR Hz

  i_n^{--} = 41 pA/SR Hz



Shaping Amp

SA – circuit diagram



OPA 847

- Voltage Feedback type
- GBP = 3.9 Ghz

G = +12 B = 600 MHz

G = +25 B = 350 MHz/1ns

G = -44 B = 240 MHz/1.5ns

- e_n = 0.85 nV/SR Hz

i_n = 2.5 pA/SR Hz

Shaping Amp

SA – specifications

GAIN: ≈200, inverting

SHAPING: CR-RC, 10 ns

$T_R \leq 6.4$ ns $T_P = 12$ ns

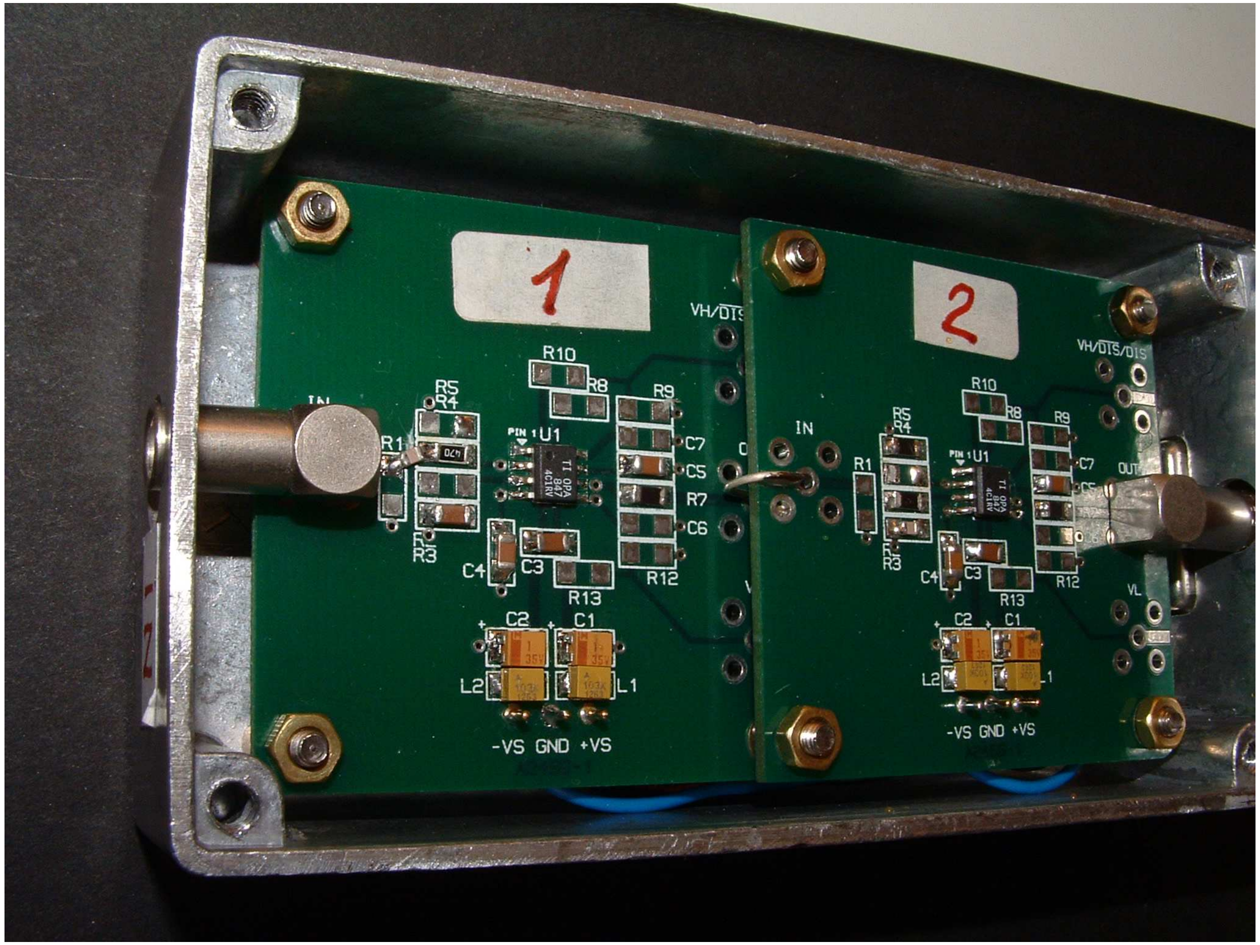
$T_F \leq 28$ ns $T_{FWHM} \leq 20$ ns

BANDWIDTH: 31.6 MHz
(6.6 MHz – 38.2 MHz)

OUTPUT RANGE: linear ±2V,
max. ±2.2V

DC OUTPUT LEVEL: ≤ 1mV

NOISE: ≤ 10mV$_{pp}$ (output)
≤ 8.5μV$_{RMS}$ (input)
≤ 1.5 nV/SR Hz (input)



INPUT: 50 ohms, AC coupled, SMB connector

OUTPUT: 50 ohms, DC coupled, SMB connector

POWER SUPPLY: ±6V/36mA, 9 pins connector (NIM)

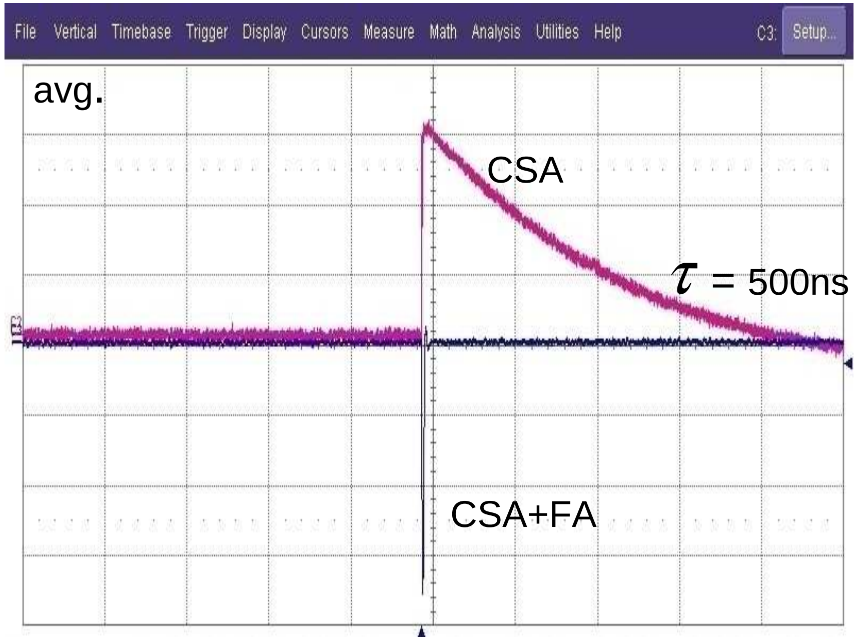
Measurements

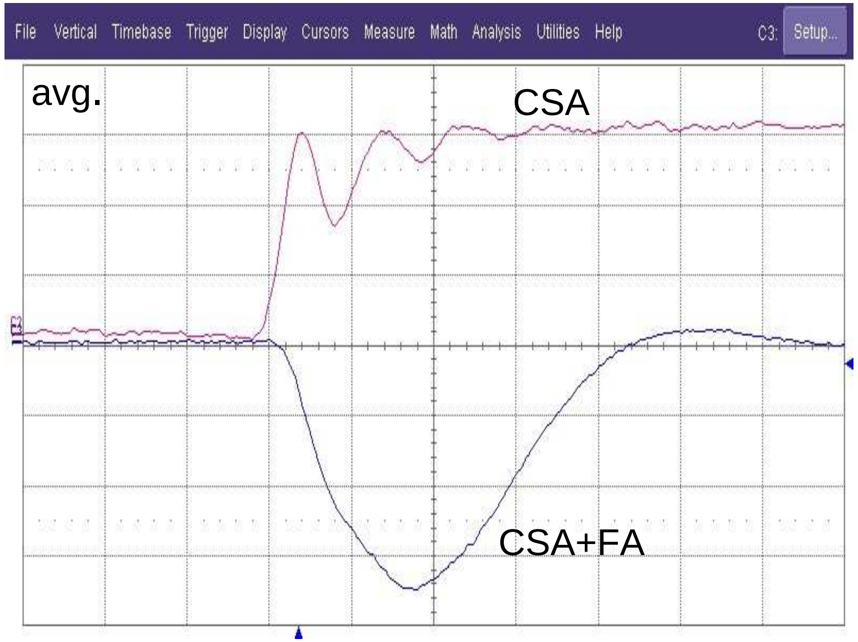
Pulser tests (A)

CSA output (avg.)

CSA+FA output (avg.)

Q_{TEST} = 6fC





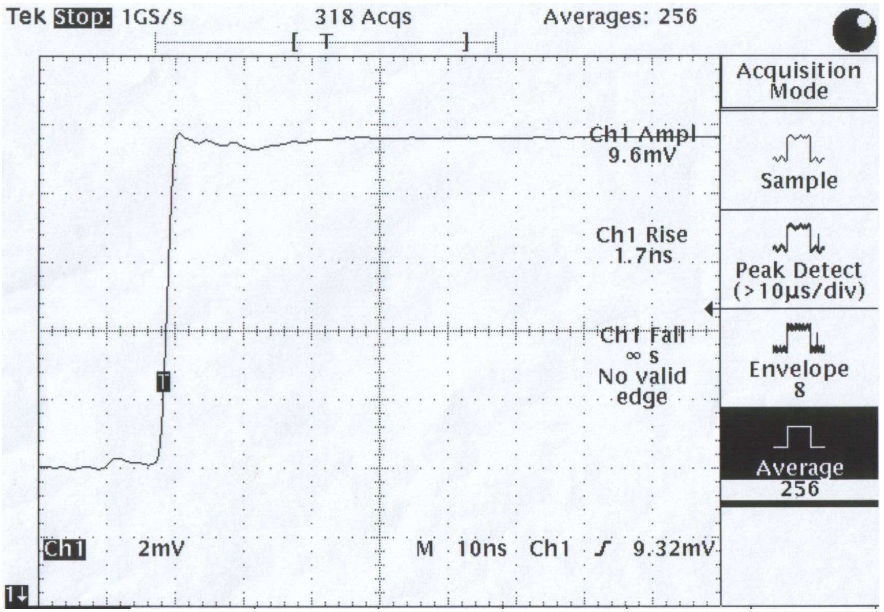
2mV/div
32mV/div
200ns/div

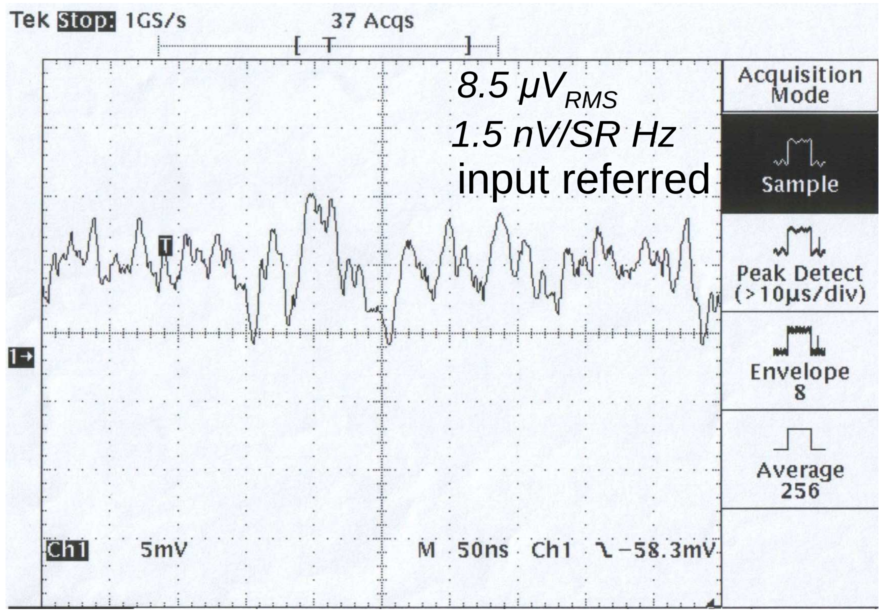
2mV/div
32mV/div
2ns/div

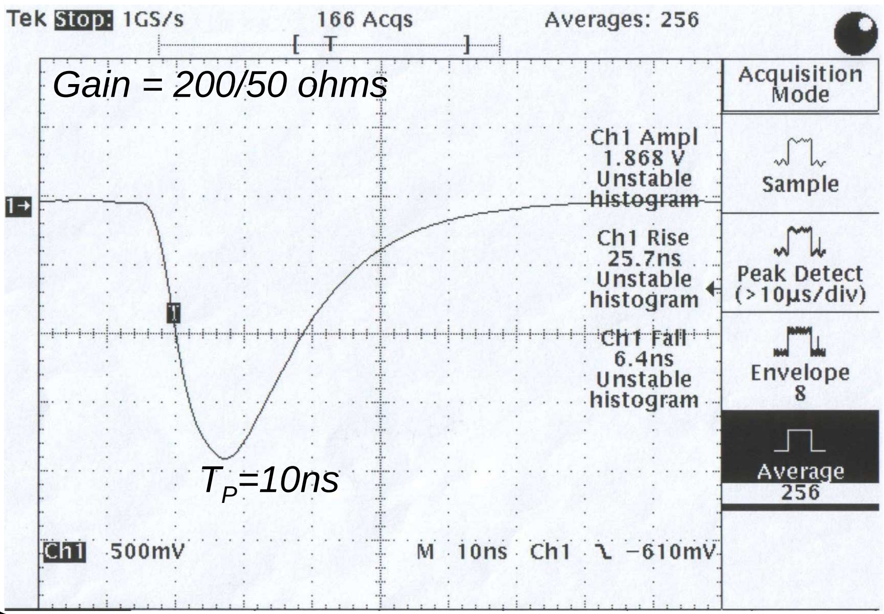
Measurements

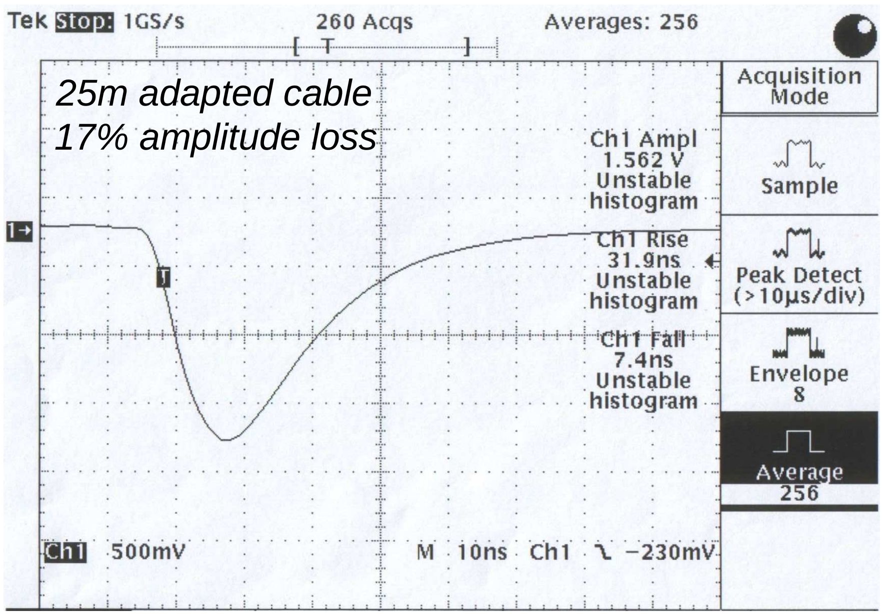
Pulser tests (B)

SA input, output and noise





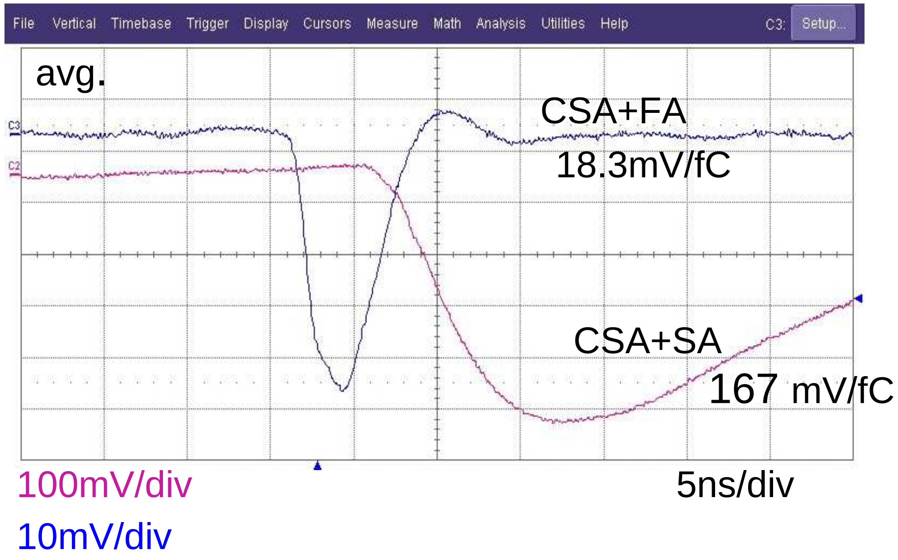


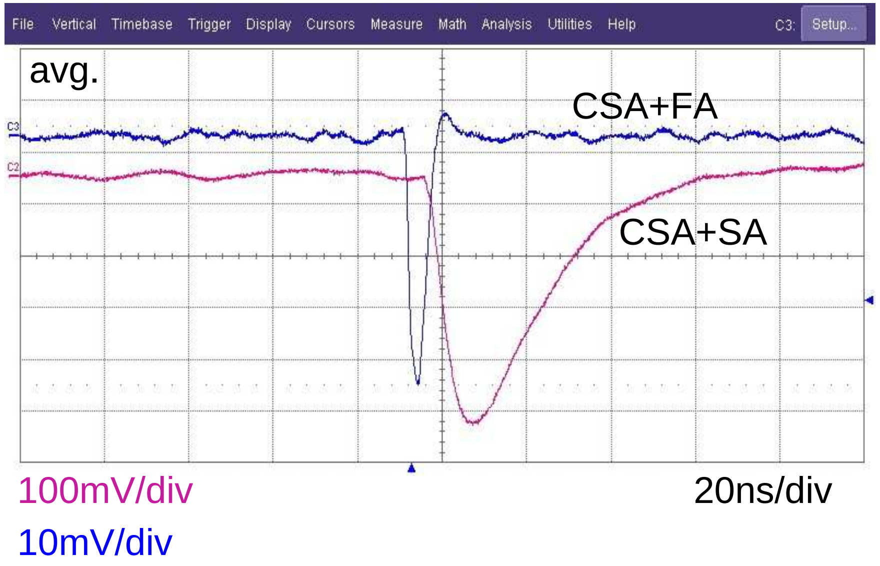


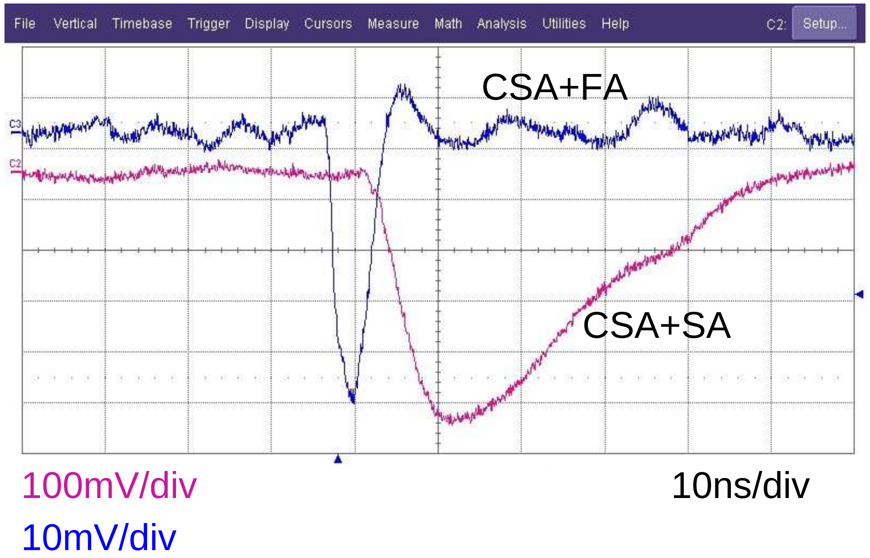
Measurements

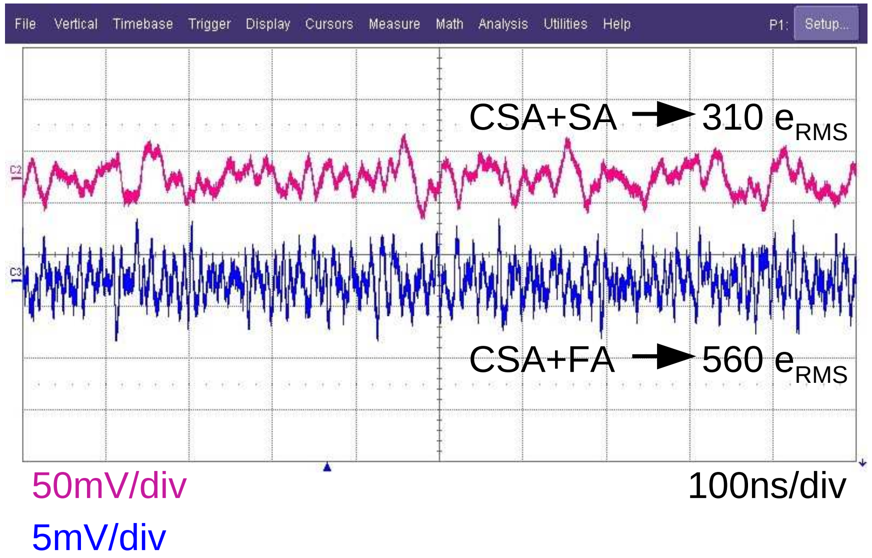
Pulser tests (C)

CSA+FA output and noise
CSA+SA output and noise
Q_{TEST} = 3fC









Measurements

Sr 90/SC-DD tests

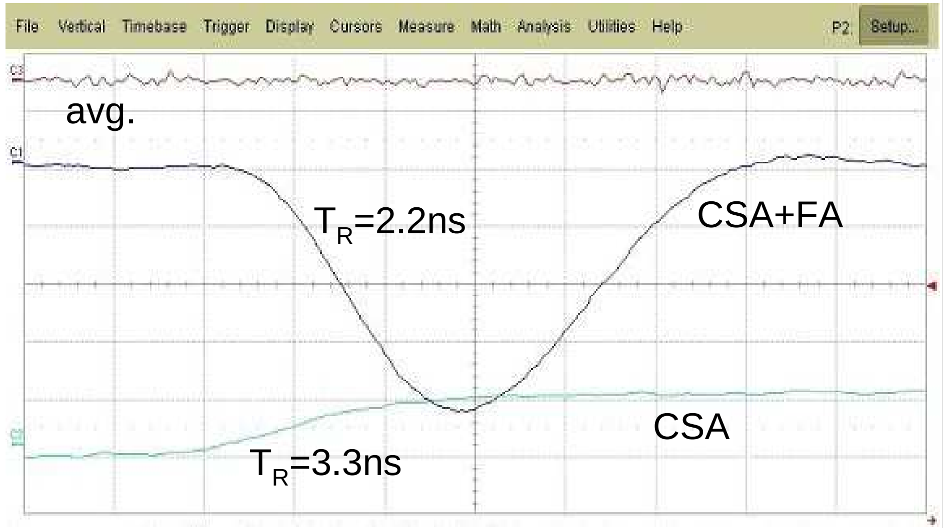
CSA output

CSA+FA output and spectrum

SciP trigger output

SC-DD: bds5/315μm

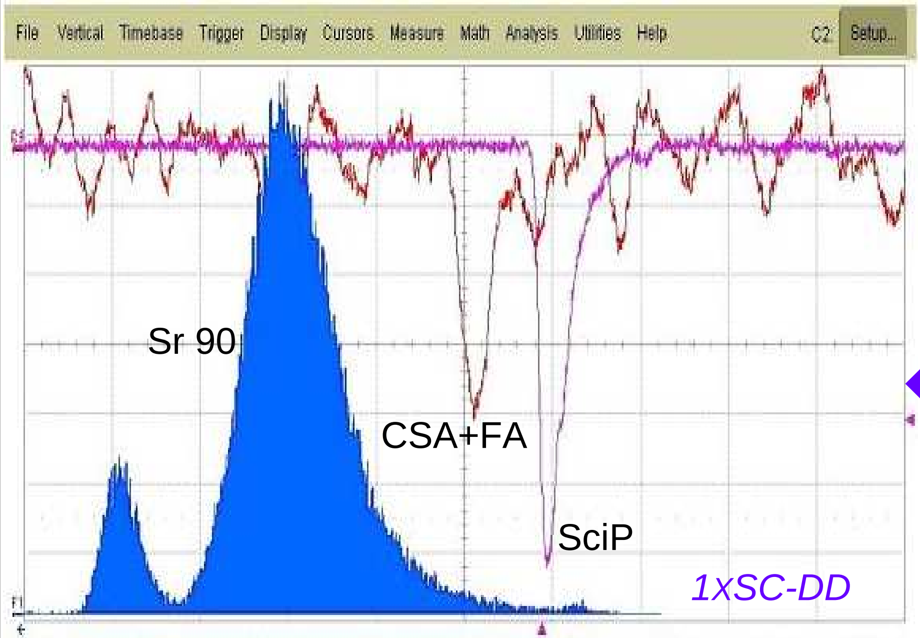
bds7/320μm



4mV/div

2mV/div

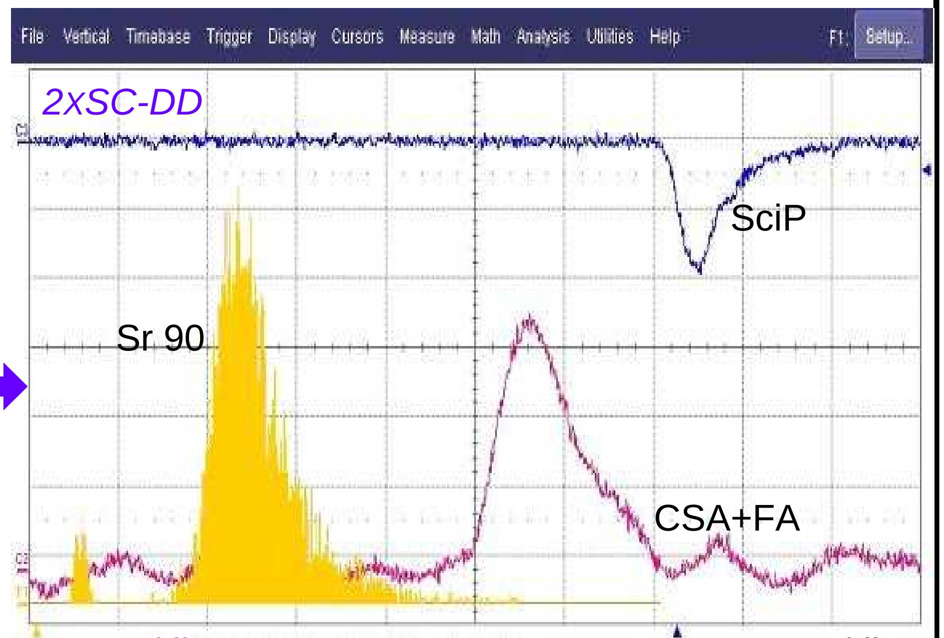
2ns/div



4.5mV/div

65mV/div

20ns/div



13mV/div

100mV/div

10ns/div

Measurements

Sr 90/SC-DD tests

Time and energy spectra

Start: SciP

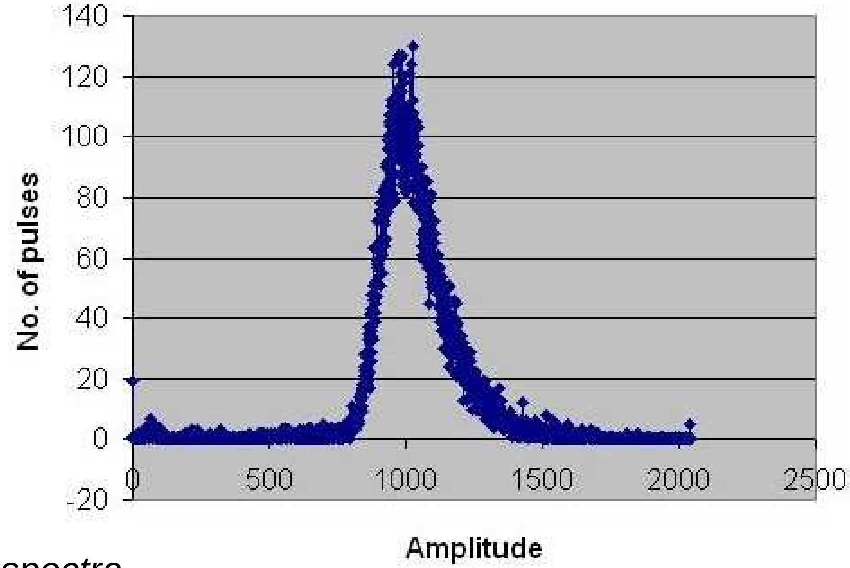
Det. : 2xSC-DD (bds5+bds7)

Electronics: CSA+FA, SA

Time calibration: 46ps/ch.

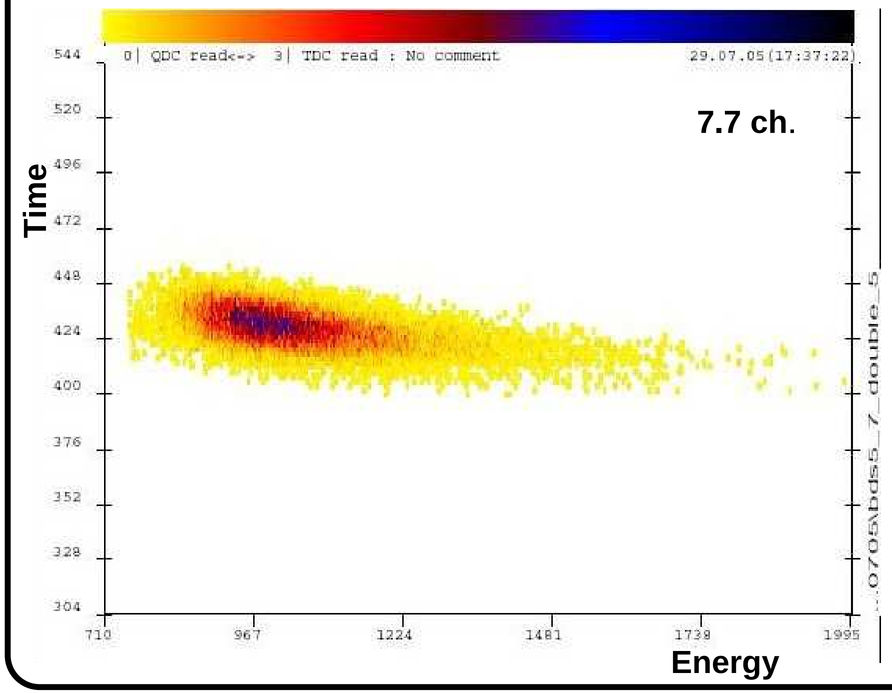
MIP selected

Energy spectrum

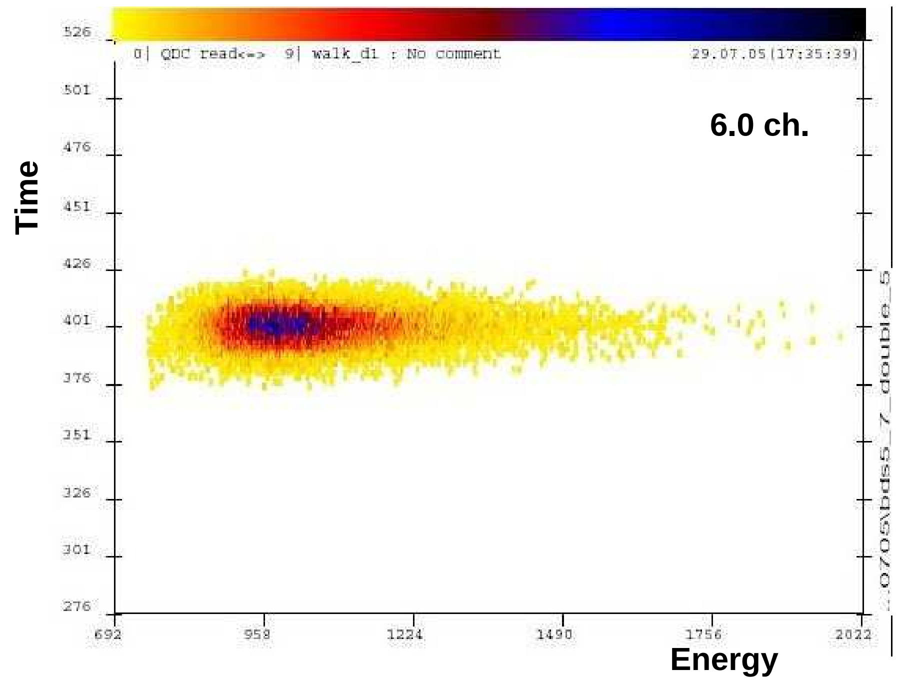


Time – Energy spectra

No walk correction



After walk correction



Summary

First results are promising :

S/N ≈ 20, T_R ≈ 1ns

Next steps:

- focus on S/N, T_R
- improvements in:
  - -DD-CSA connection, mounting
  - - PCB layout design
  - - schematic
  - - components
- systematic noise measurements/optimisation
- beam tests

List of participants

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