Low-noise fast CS preamplifiers for SC diamond detectors

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4° NoRHDia Workshop   8-10 June 2008

OUTLINE

- SC diamond detector characteristics
- Previous work
- Electronics features:

  for Fano factor: very low- noise

  for general applications: low-noise and fast
- Front – end electronics
- Simulation data
- Conclusions

SC diamond as radiation detector

- High radiation resistance
- Fast response time
- High band–gap (5.45 eV)

→ Very low leakage current
Low noise, even at high temperature

Previous and current work

- 2006 : Very low noise CS preamplifier (20 e^- rms)

  (not very fast, 100 ns rise time!)

- 2007 : Fast CS preamplifier (1 ns rise time)

  (not very low noise, 600 e^- rms @ 2 us!)

- 2008 : Fast and low noise CS preamplifier

Design criteria

- Low Noise (100 e rms @ 0.5 us)

  ↓

  Low Noise Input Device

- Fast response (1 ns rise time)

  ↓

  300 MHz Bandwidth Overall Circuit

Design criteria

- Low leakage current from detectors

↓

Voltage Controlled Input Device

↓

JFETs, MOSFETs, not BJTs

↓

JFET (lower 1/f noise than CMOS)

↓

BF862 (NXP semiconductors)
(already used for HPGe in the Agata experiment)

Design criteria

- BF862 noise performance

Experimental measurements :
100 e rms @ 4 us, Ctot = 40 pF (30 pF det + 10 pF fet)

↓

Expected noise :

$$100 \text{ e rms} * \sqrt{(4 \text{ us} / 0.5 \text{ us})} * (15 \text{ pF} / 40 \text{ pF})$$

↓

≈ 100 e rms (@ 0.5 us, Cdet < 5pF)

Design criteria

- Large Bandwidth + Closed Loop Circuits

↓

Stability is an issue!

(a couple of parasitic elements
have been taken into account)

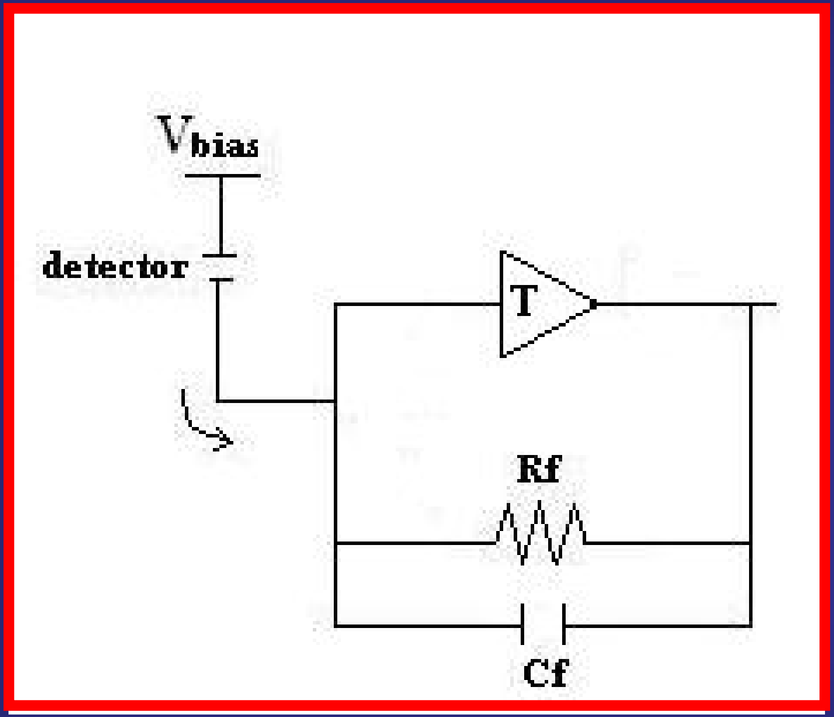
Rise Time ≈ 1 ns

↓

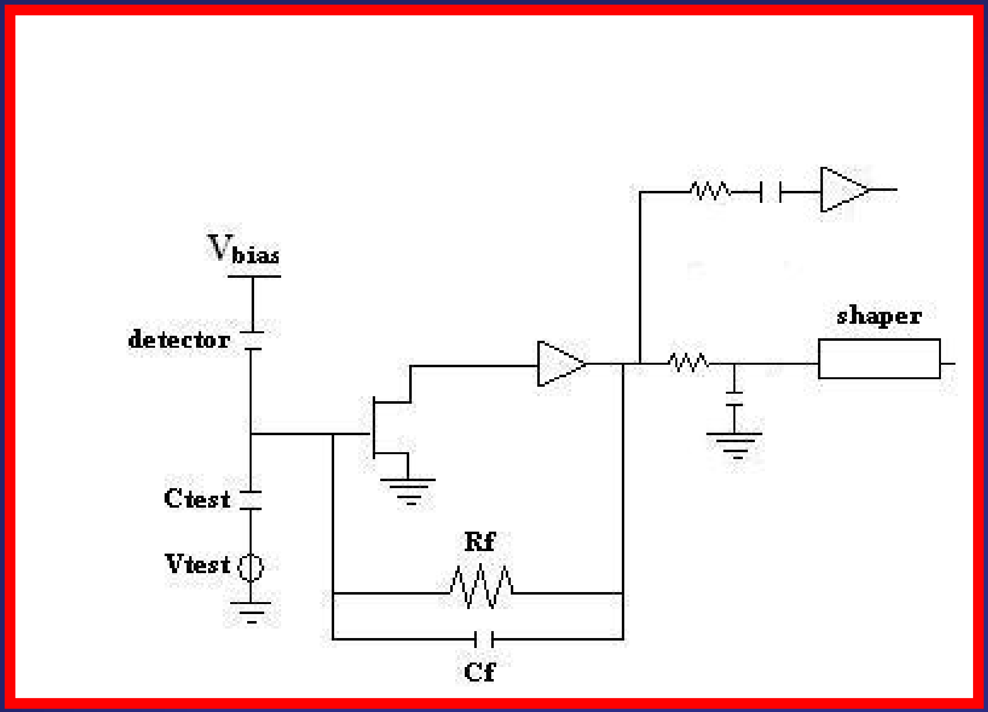
Closed Loop GBWP ≈ 300 MHz

Low Frequency Gain (linearity & stability) ≈ 100

Fast (and noisy) CS Preamplifier



The new CS Preamplifier



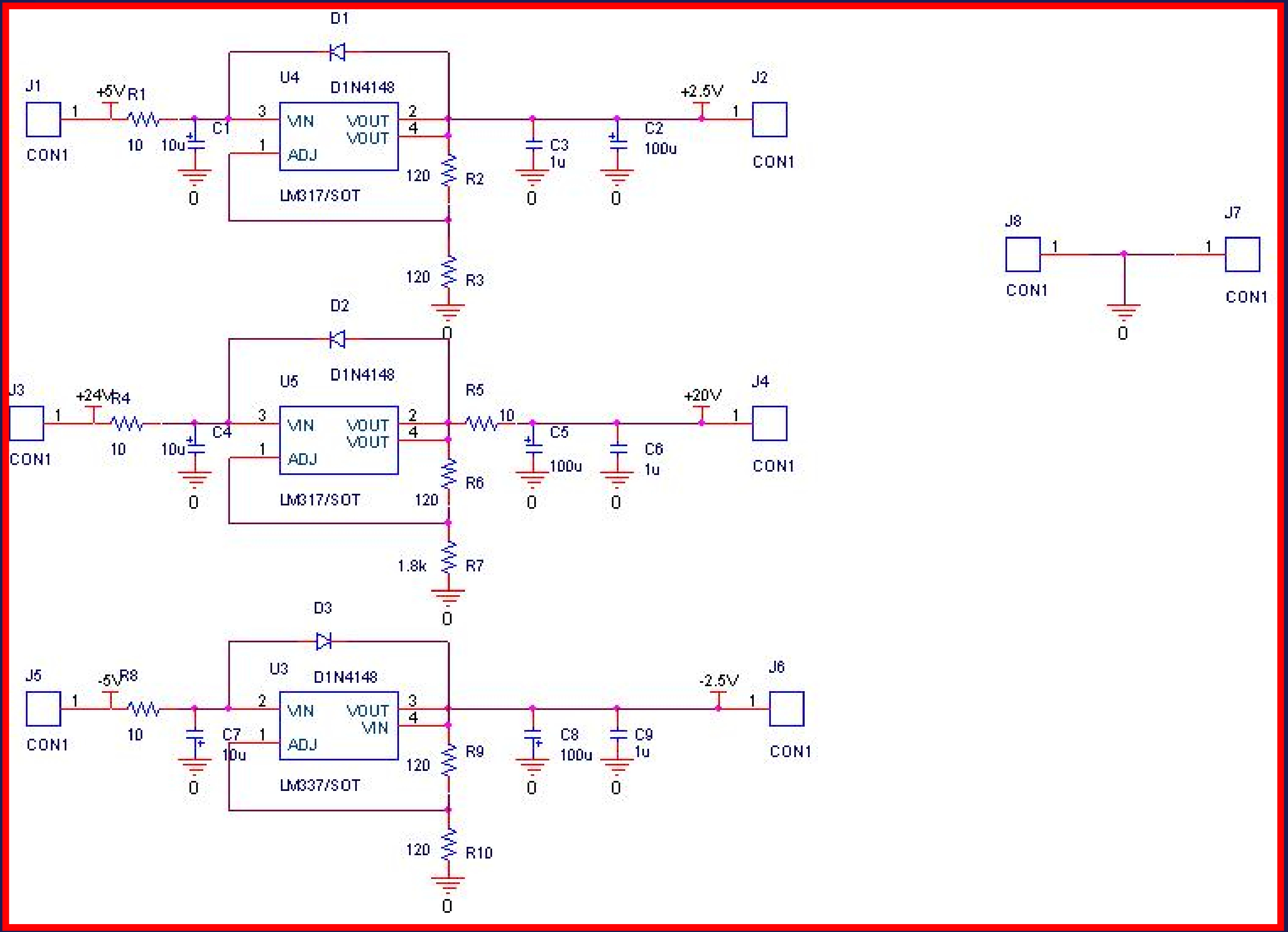
characteristics

Input eq. noise: 100 e⁻ rms @ 0.5 us

Detector capacitance 5 pF

Rise Time 1 ns

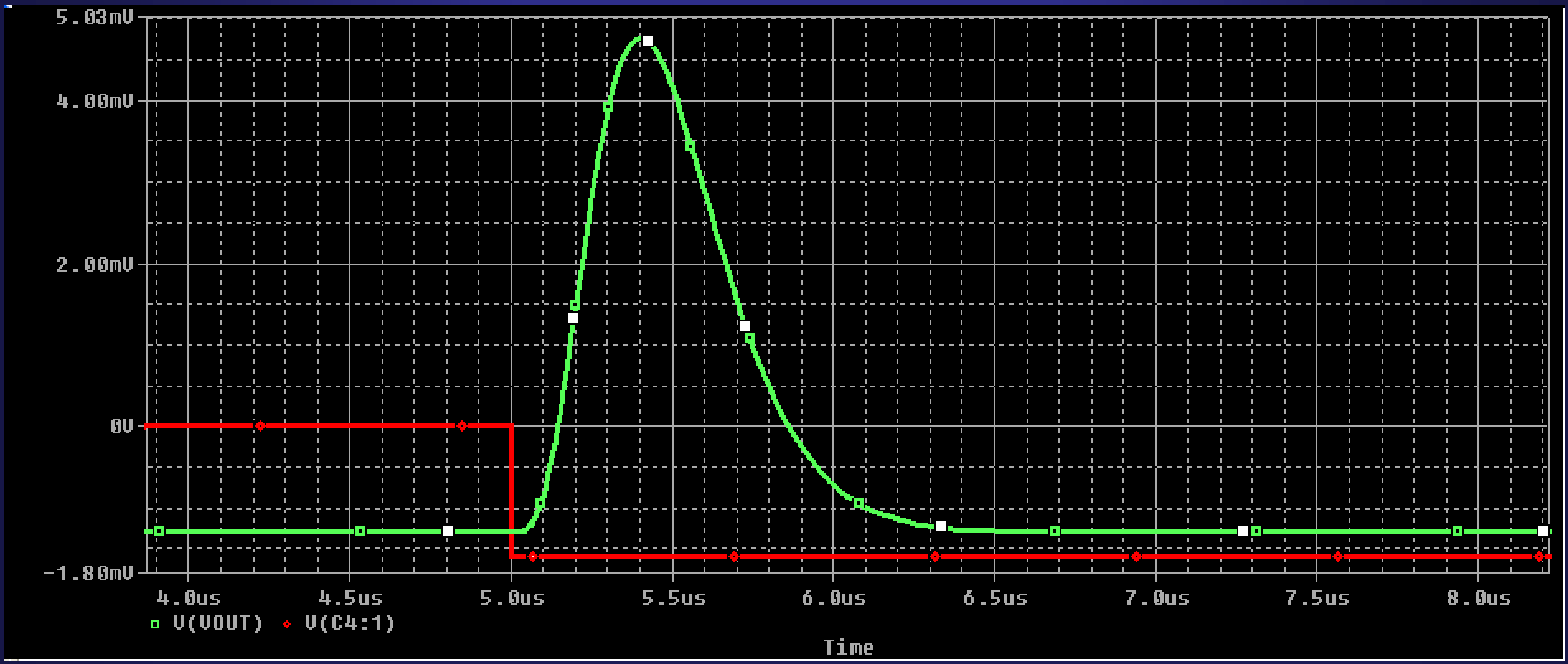
Power Supply Board: +20V, 2.5V, -2.5V (from NIM / VME)



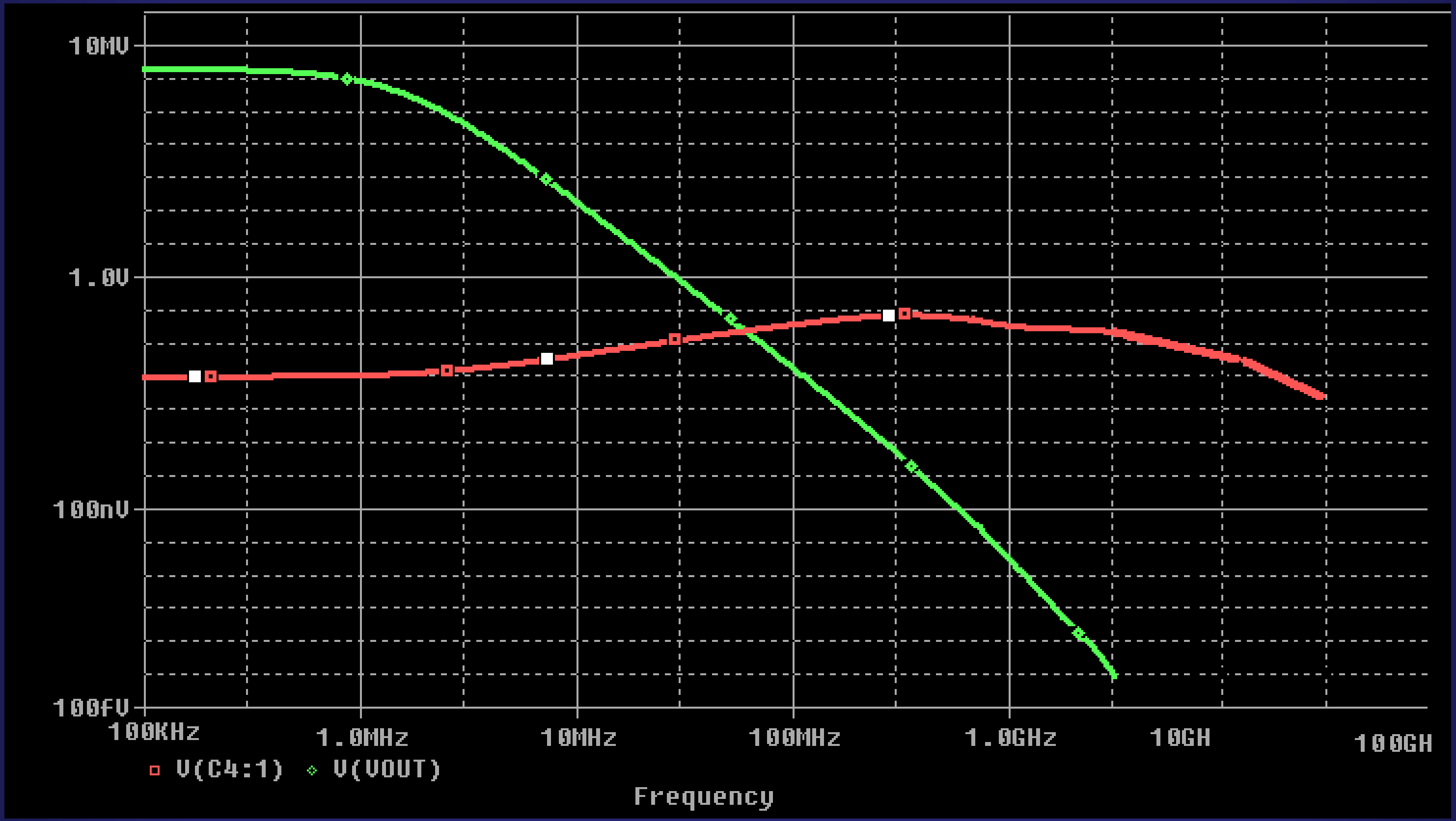
Simulation data

Input : 10k e⁻ → **red line**

Output : 6 mV → **green line**



Signal shaping for Energy and Time



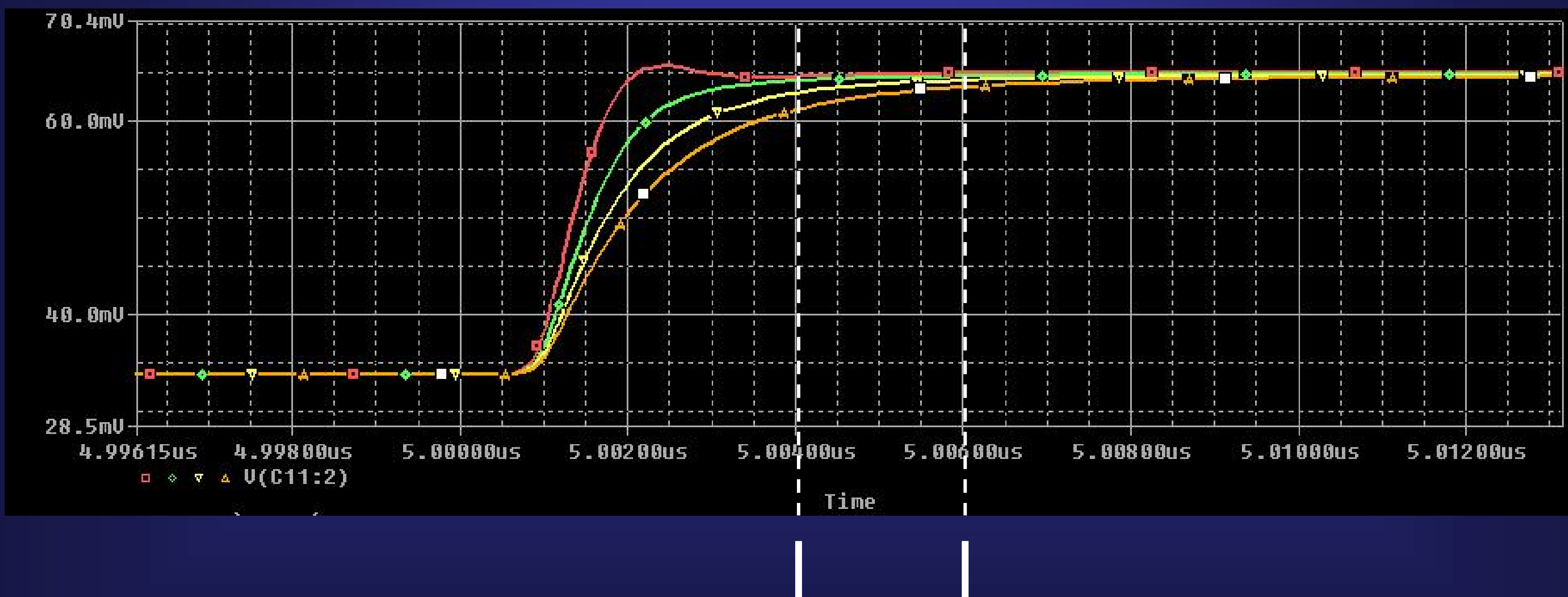
red line → **timing**

green line → **energy**

CSA output signal for different detector capacitance:

(Cf = 0.5 pF)

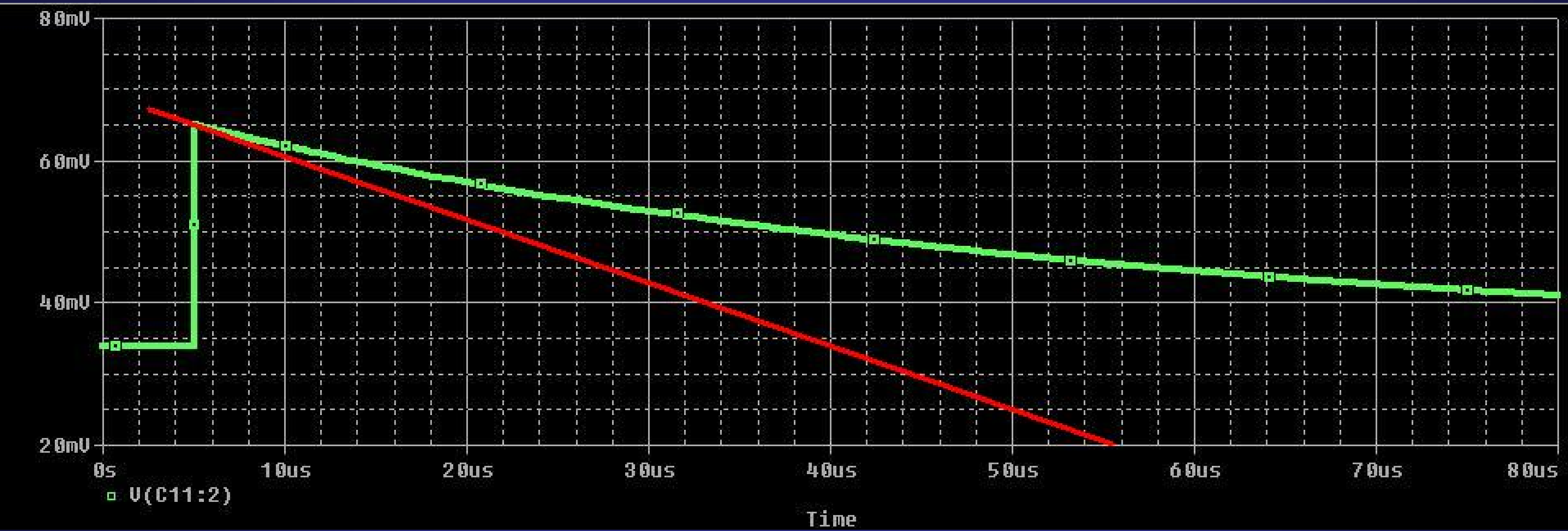
Red line	Cd = 5 pF
Green line	Cd = 10 pF
Yellow line	Cd = 15 pF
Orange line	Cd = 20 pF



2 ns

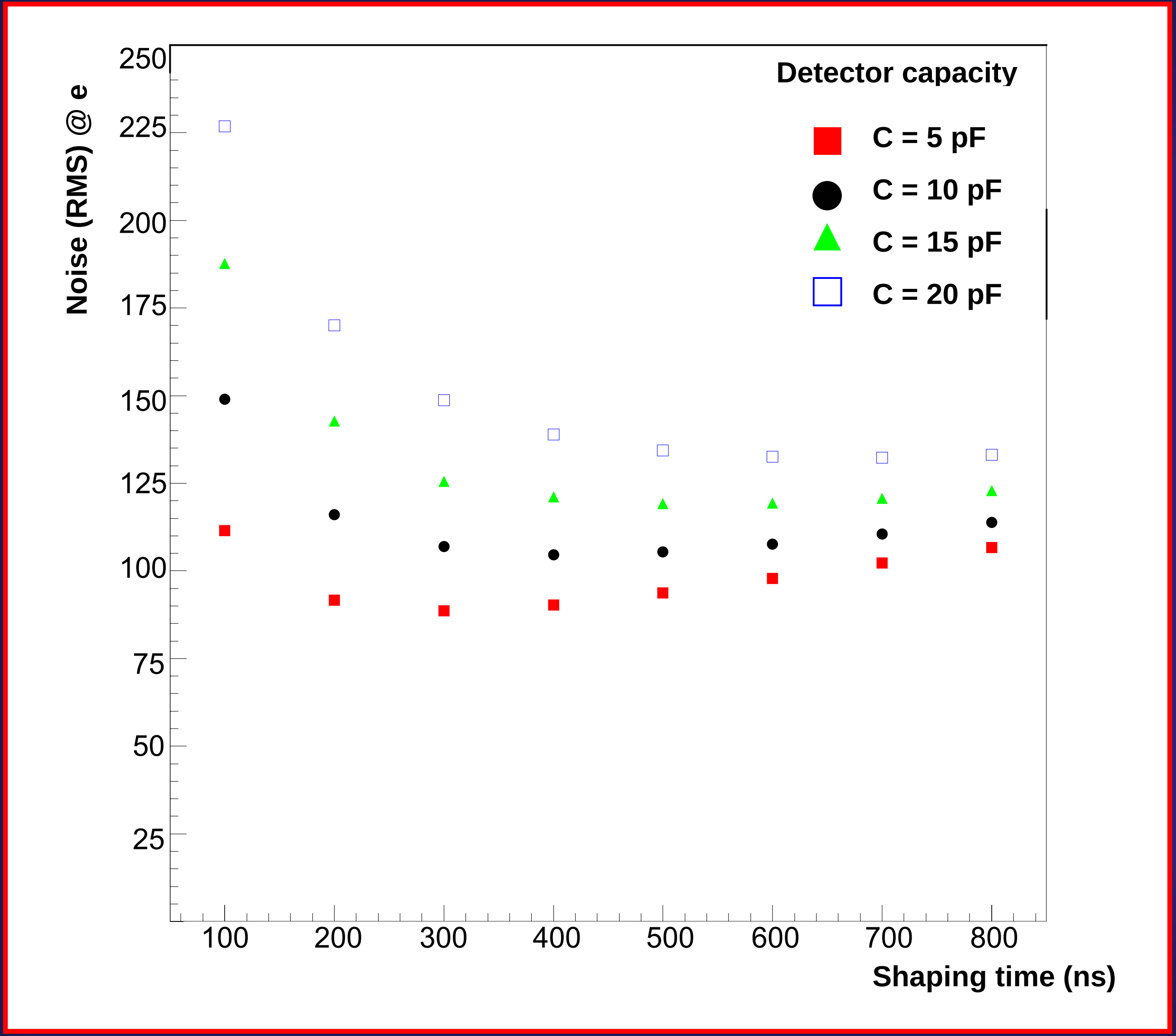
CSA output signal:

(Cf = 0.5 pF)

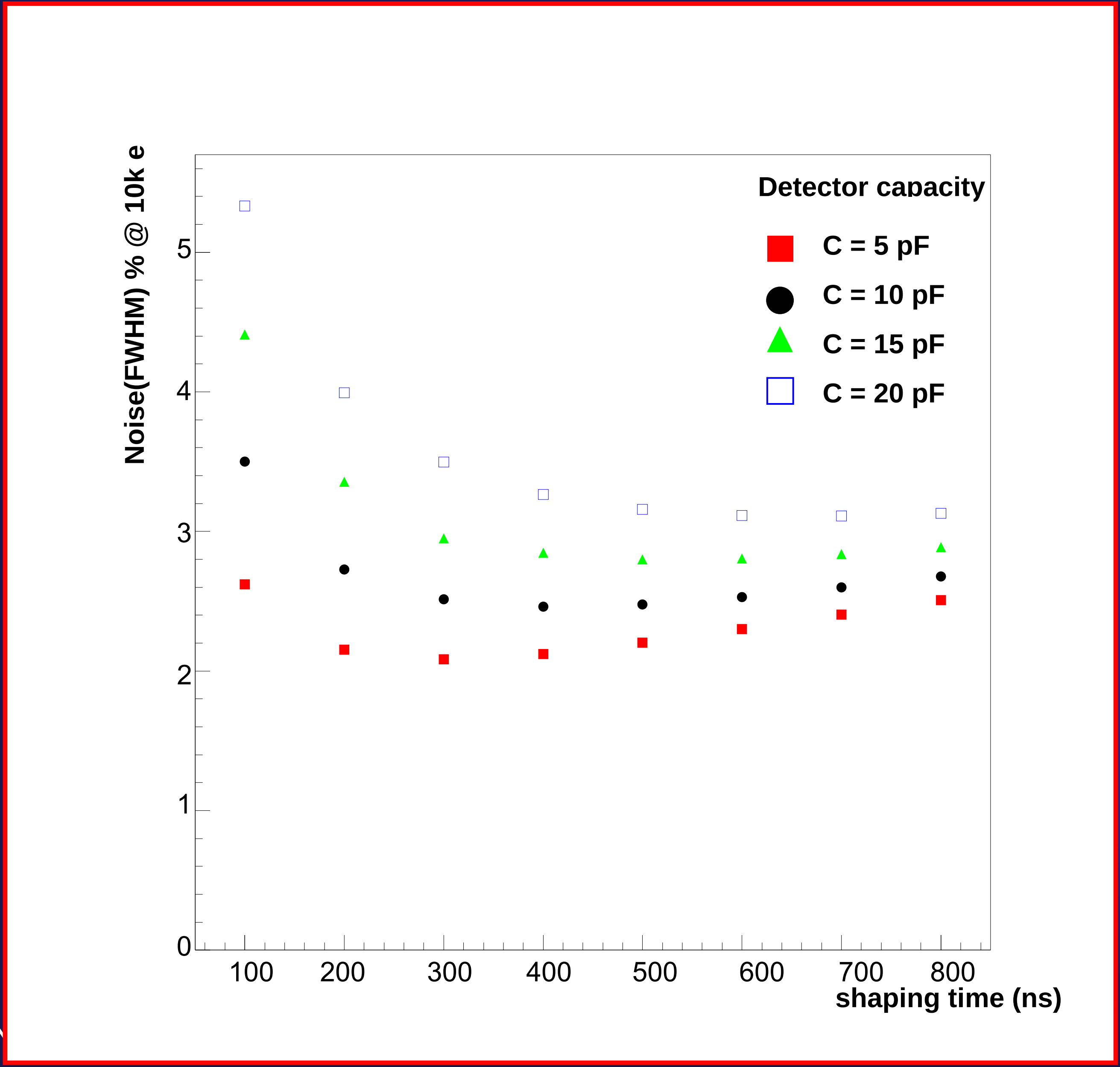


TAU = R · C = 100 MOhm · 0.5 pF = 50 µs

Noise (rms) vs shaping time (ns)



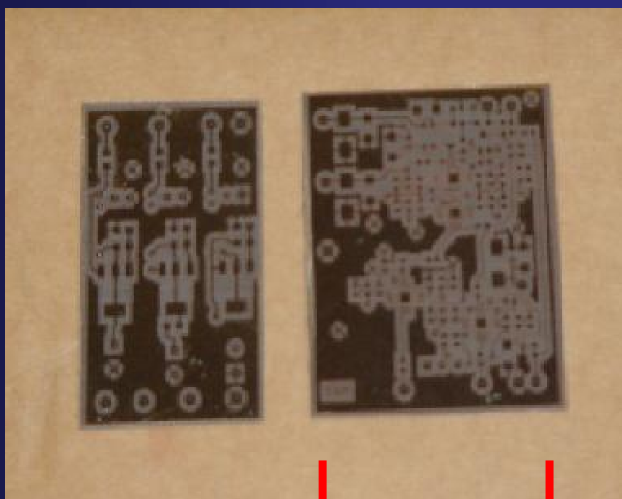
Noise (FWHM) % @ 10K e vs shaping time (ns)



4° N

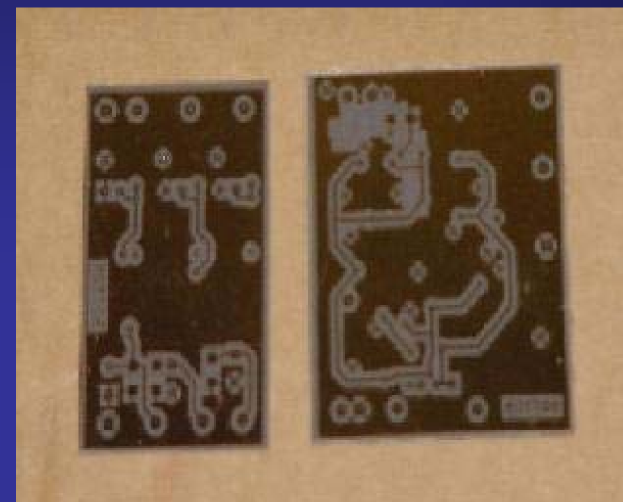
The CS Preamplifier

TOP



3.5 cm

BOTTOM



COMPONENTS

Experimental Set Up

SUMMARIZING …

CS preamplifier (10k electrons, with 500 um thick detector) :

- **rise time** → **1ns (CSA limited)**
- **fall time** → **50 μs**
- **input noise 100 e^- eq. @ 0.5 μs**
- **time resolution** → **< 1 ns FWHM** (**250 ps rms by simulation)**
- **power dissipation** → **750 mW**

CONCLUSIONS

This preamplifier should be very fast (1 ns rise time) and low-noise

It should work with a detector capacity of ~10 pF

… and OUTLOOKS

- The new board will be tested as soon as possible

  In order to obtain the comparison between the simulation data and real one

- THE NEXT STEP : develop a similar board with integrated technology

  - choose the technology
  - perform the simulation
  - test the board

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