Fast Time Front End with CSPA's made with discrete elements

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Towards the CBM-XYTER Project Plan, GSI, Mars 21 2007

Basic error of a Time Measurement

" JITTER"

$$\sigma_t = \frac{\sigma_n}{\left.\frac{dV}{dt}\right|_{V_{THR}}}$$

$$\sigma_t = \frac{\sigma_n}{\left.\frac{dV}{dt}\right|_{V_{THR}}} + \delta t$$

if $\sigma_n \sim \sqrt{Nd*BW}$

$dV/dt \sim As/t_r$

$t_r = 0.35/BW$

then

$$\sigma_t \sim \sqrt{Nd}/(As*\sqrt{BW})$$

IEEE Nuclear Science Symposium 1999
Radiation Detection and Measurement
Pulse Processing and Analysis, Helmuth Spieler,
Lawrance Berkeley National Laboratory

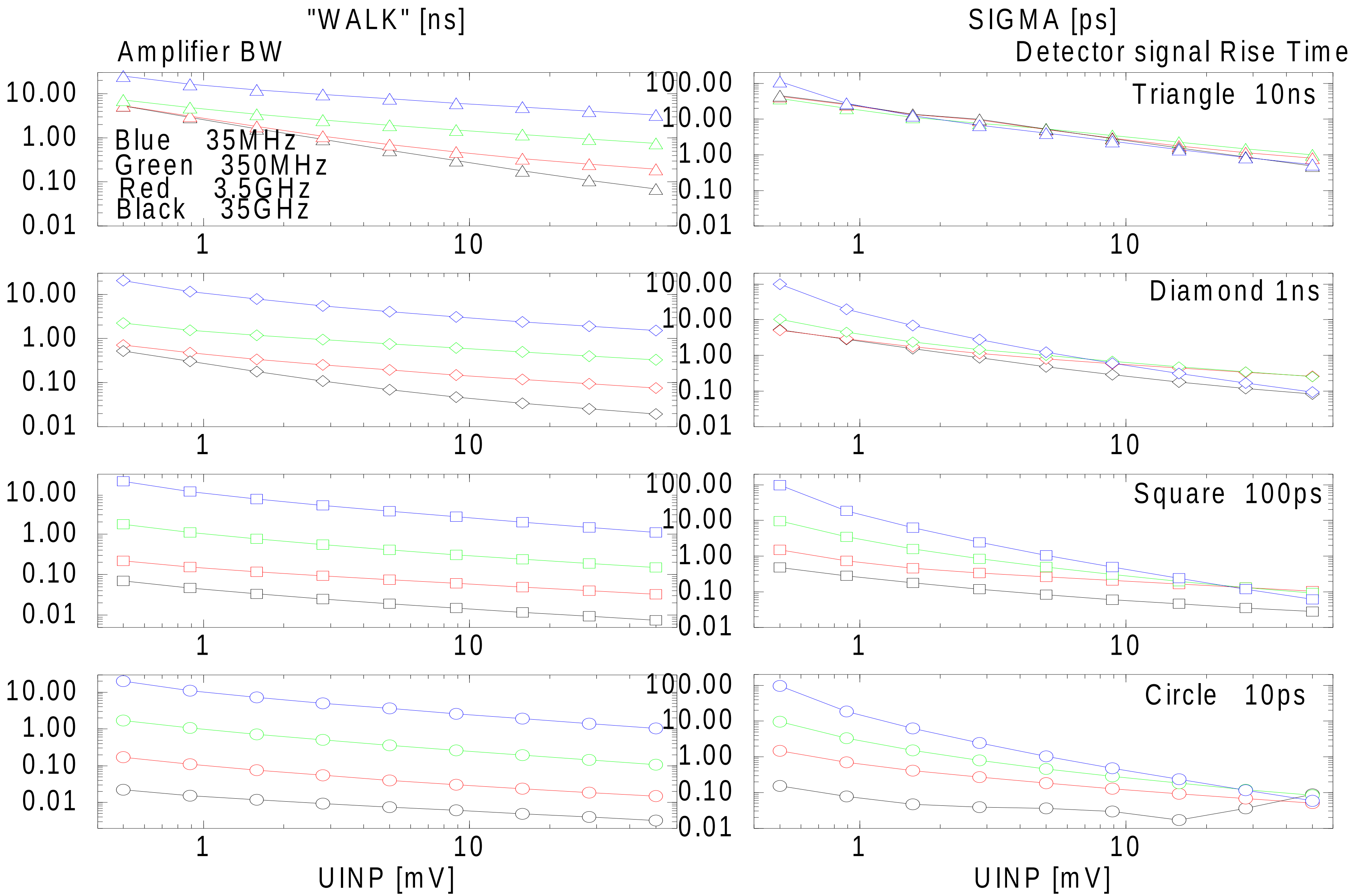
if $t_r^2 = t_{ra}^2 + t_c^2$

$$\sigma_t \approx \frac{\sqrt{t_c}}{V_o}\underbrace{\sqrt{\frac{t_c}{t_{ra}} + \frac{t_{ra}}{t_c}}}$$

has a minimum for

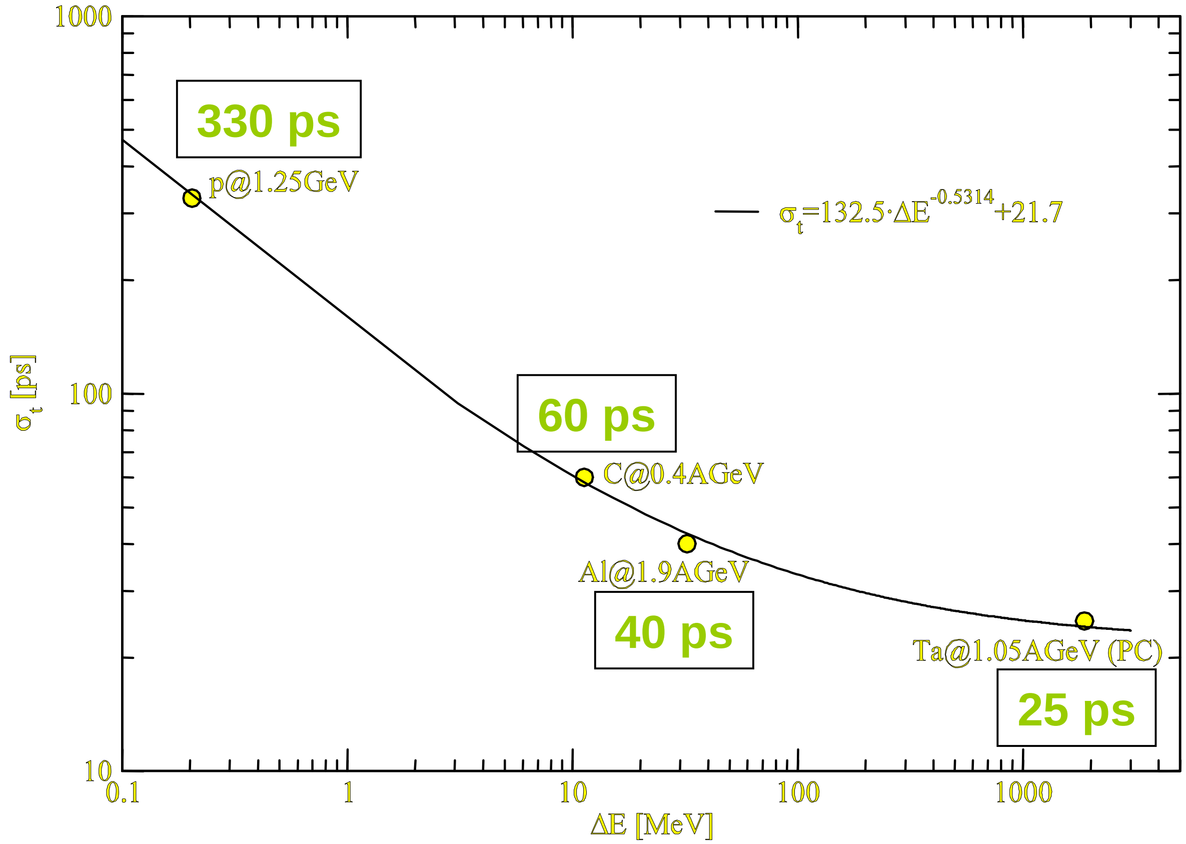
$t_c = t_{ra}$

"Walk" and Sigma versus: UINP, Amplifier BW, Detector Rise Time
Detector signal is Step with variable Rise Time, Noise=3uV, THR=100mV



Motivation: Fast CSPA for MIP's

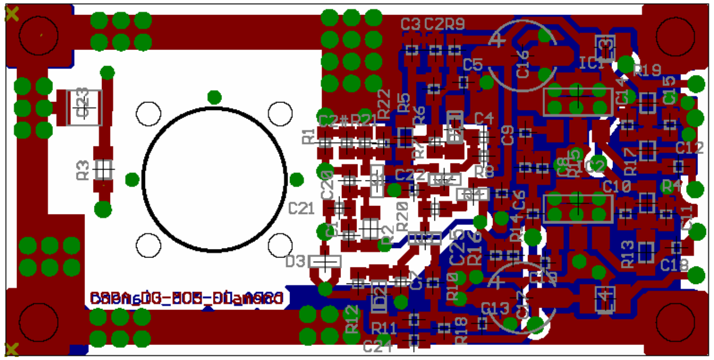
We used FEE1 also to measure timing with single- and polycrystalline diamond detectors. For minimum ionizing particles the signal amplitude fairly small (16000 e). For protons, we used due to that a CSPA in front of FEE1, to increase the overall sensitivity.

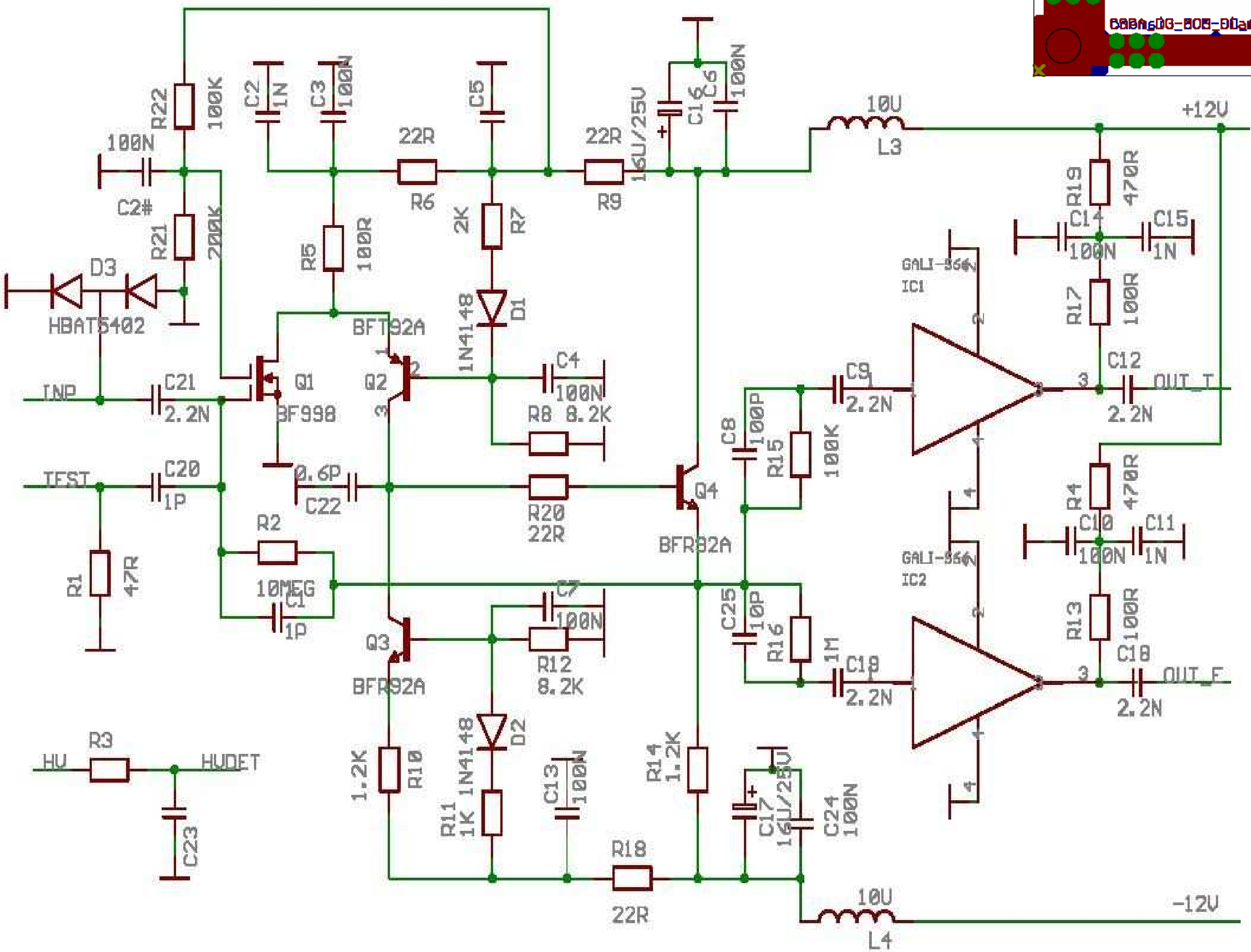


FEE1 for diamond detectors, σ_{tSTART} versus Δ E

Measurements

CSPA – circuit diagram





CS stage

- BF908, DG-MOS
- C_F=1pF (S=1mV/fC)
- τ_D=10μs

Diff+PZC

- τ_{diff} =5ns
- pasive

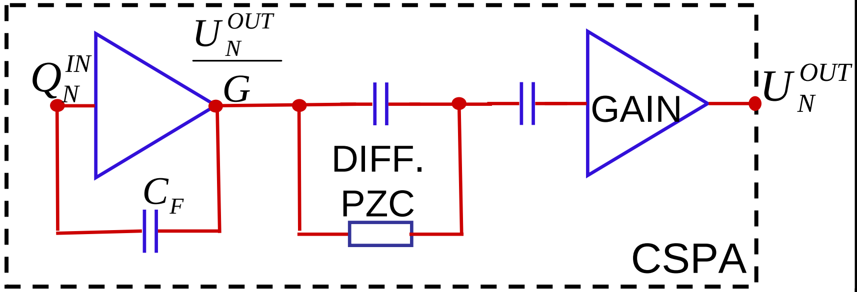
BB stage

- GALI 66, RF block
- Gain ≈10

Measurements

CSPA – Noise

► Output noise



Preamp	Output noise (U_N^{OUT})					Units
No. 1	860	994	970	946	928	μV_{RMS}
No. 2	875	979	994	970	947	μV_{RMS}
Amplit. scale	2	5	10	20	50	$\frac{mV}{div}$

20mV/div
50ns/div
20GS/s

Oscilloscope noise subtracted

► Input noise

$$Q_N^{IN}(e_{RMS}) = \frac{U_N^{OUT}(RMS)}{G} \cdot C_F \cdot \frac{1}{q_e}$$

where: $C_F = 1pF$

$G = 10$

$U_N^{OUT} \approx 1000 \mu V_{RMS}$

$q_e = 1.6 \cdot 10^{-19} C$

$$\Rightarrow Q_N^{IN} = 625 e_{RMS}$$

(1fC=6250e)

► Comment: S/N ratio for MIPS in SC-DD

W_{DD}	100	200	300	400	500	µm
Q_{MIP}	3k6	7k2	11k8	14k4	18k	e
$\frac{Q_{MIP}}{Q_N}$	5.8	11.5	17.3	23.0	28.8	

Measurements

CSPA – Rise time

▶ Output signal level ≈60mV

10mV/div
1ns/div
20GS/s

Generator+osc. rise time subtracted

Preamp.	Input transition		Units
	neg.	pos.	
No. 1	753	719	ps
No. 2	666	619	ps

▶ Output signal level ≈200mV

50mV/div
1ns/div
20GS/s

Generator+osc. rise time subtracted

Preamp.	Input transition		Units
	neg.	pos.	
No. 1	775	670	ps
No. 2	688	570	ps

▶ Comment:

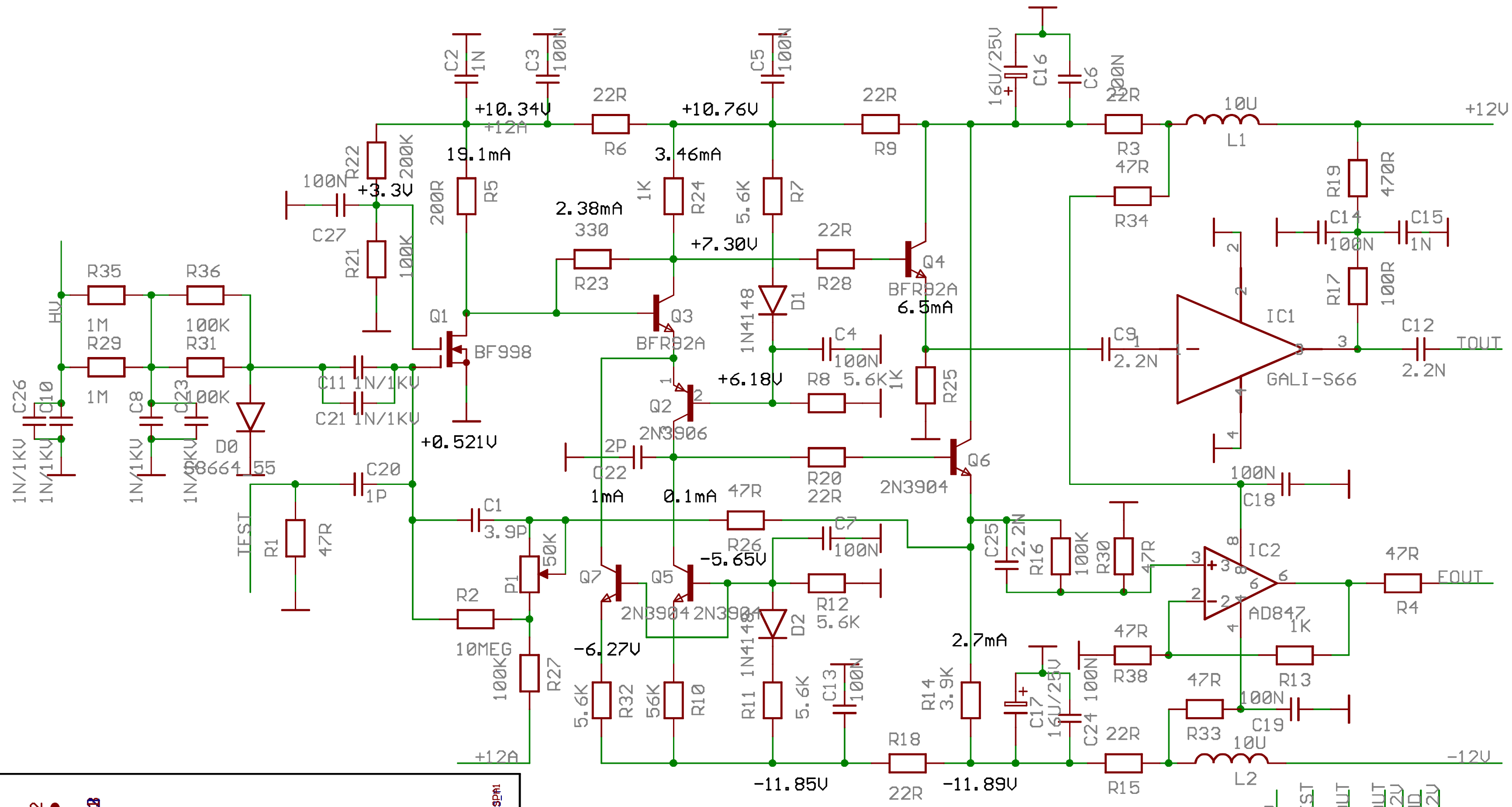
T_R≈700ps   B≈500MHz

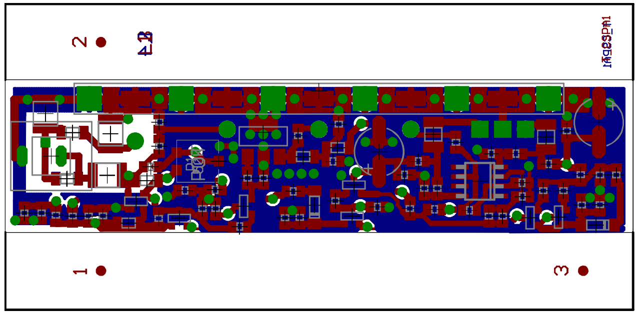
T_W≈1ns/100µm

(transit. time in SC-DD)

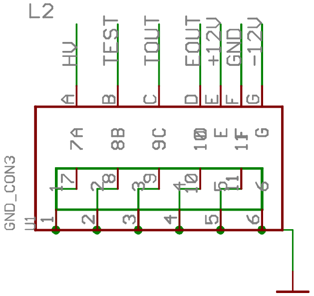
CSPA is fast enough to handle signals from SC-DD having W>100µm

Time CSPA use a modified architecture with a Time Branch

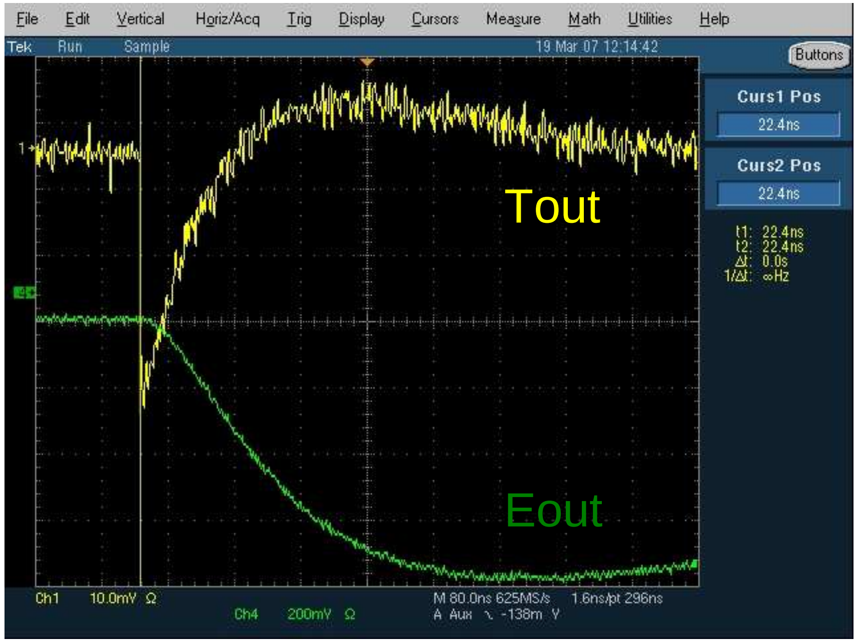


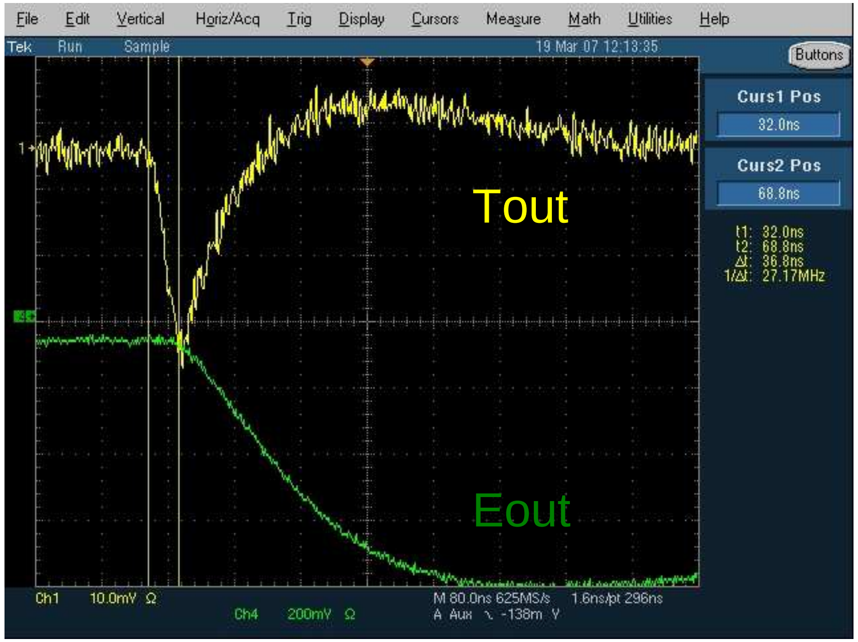


TCSPA1



Measurements: Pulse with short and long rise time

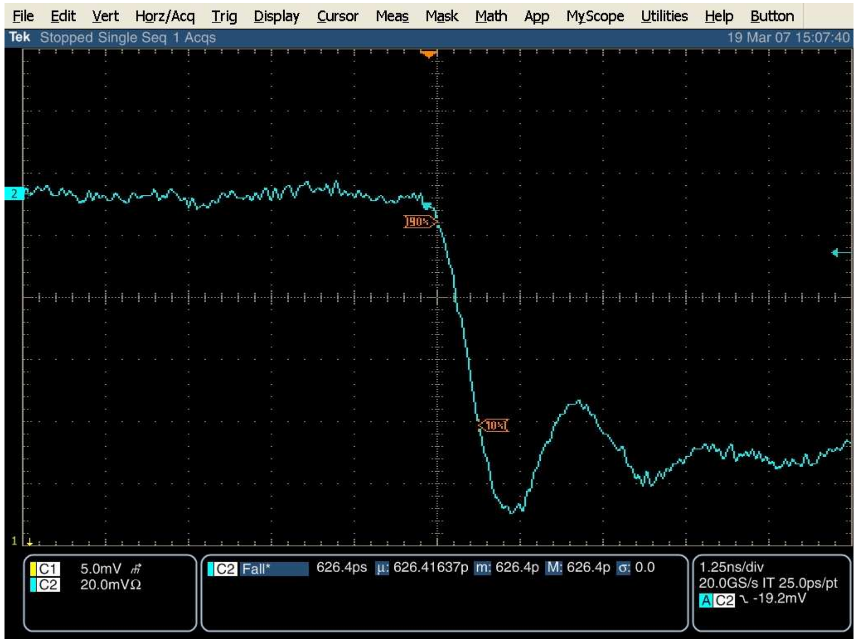




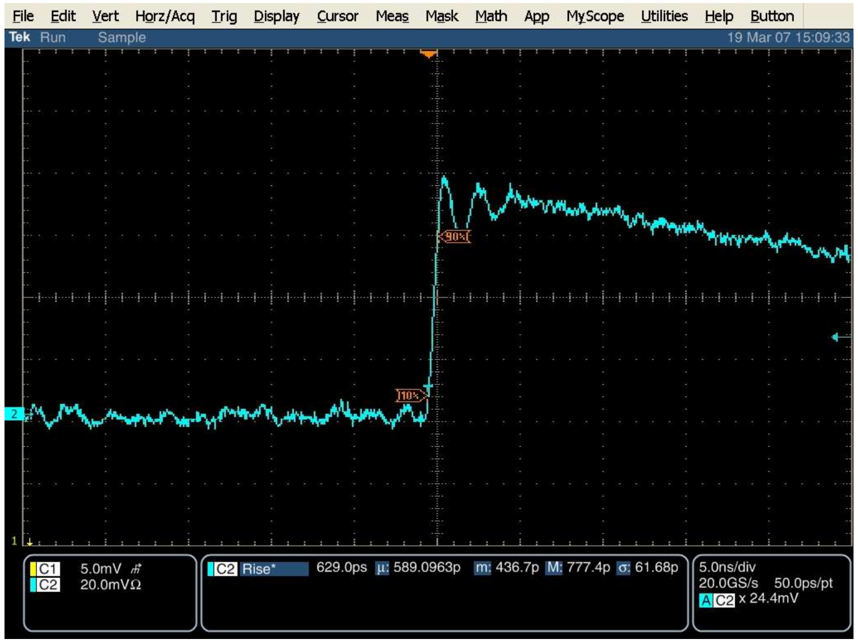
Input signal: step with ~1ns and ~25ns rise time

Measurements: Pulse and scope with 380ps rise time

Time Output

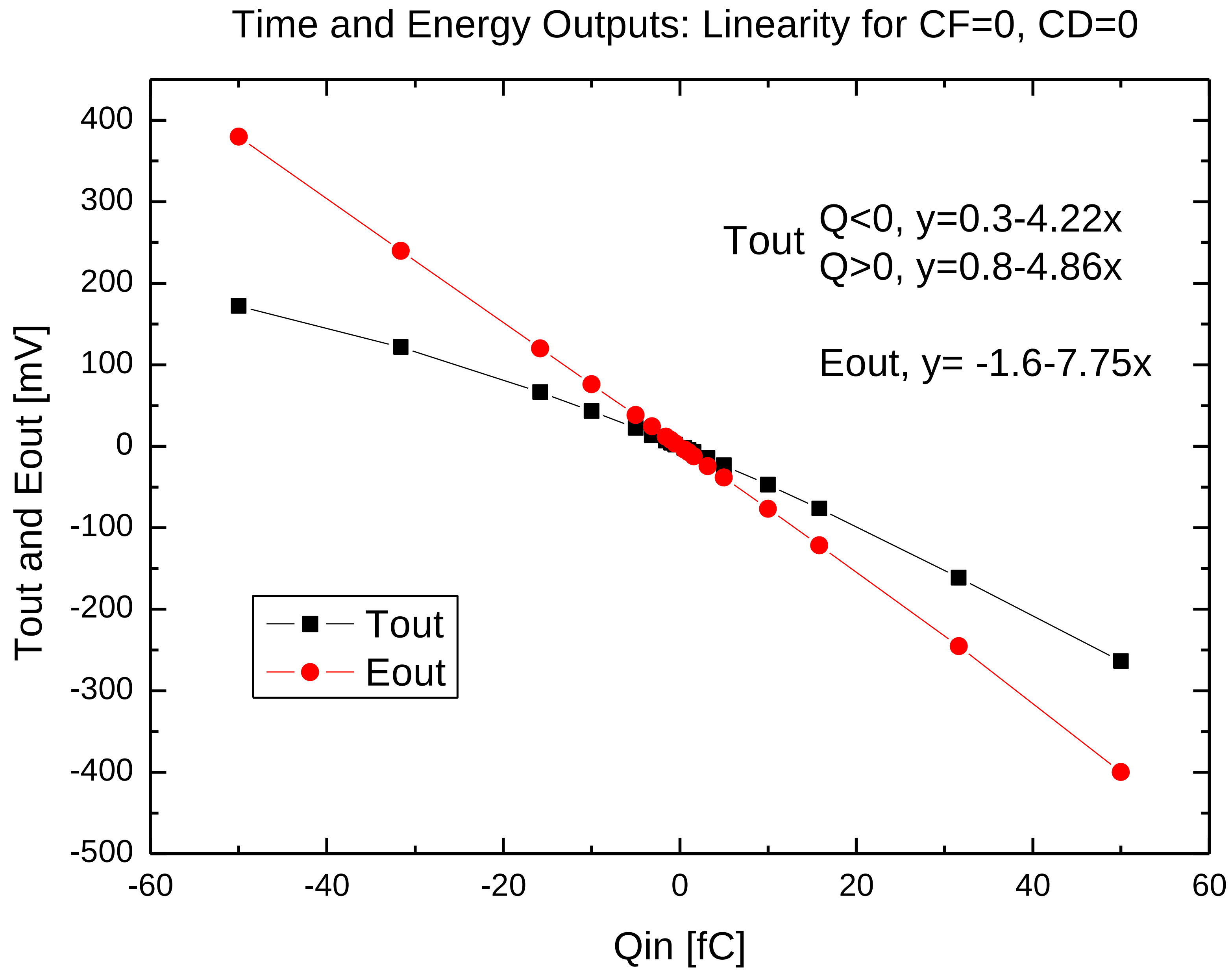


negative outputs: t_F=558ps



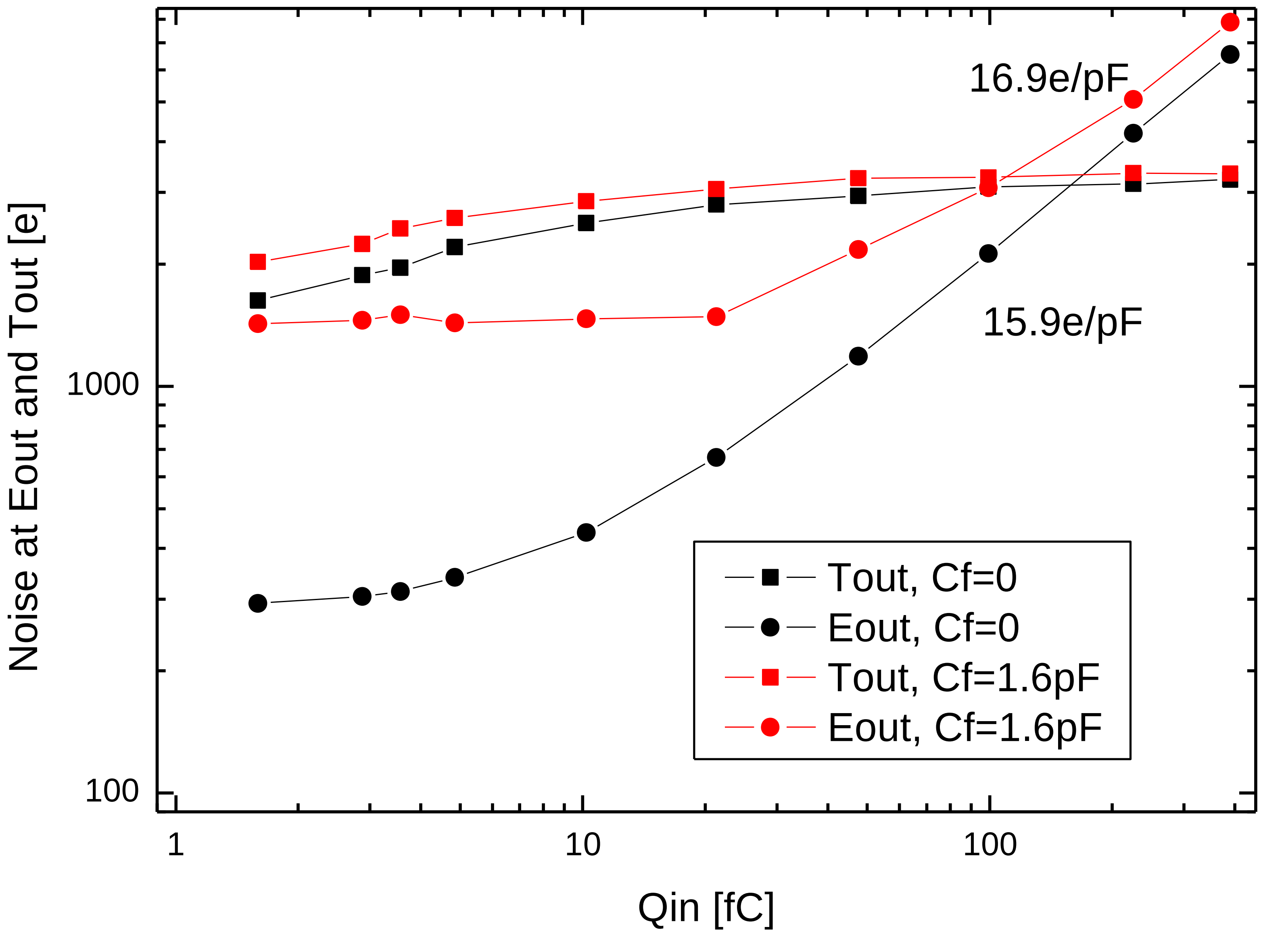
positive outputs: t_R=517ps

Linearity

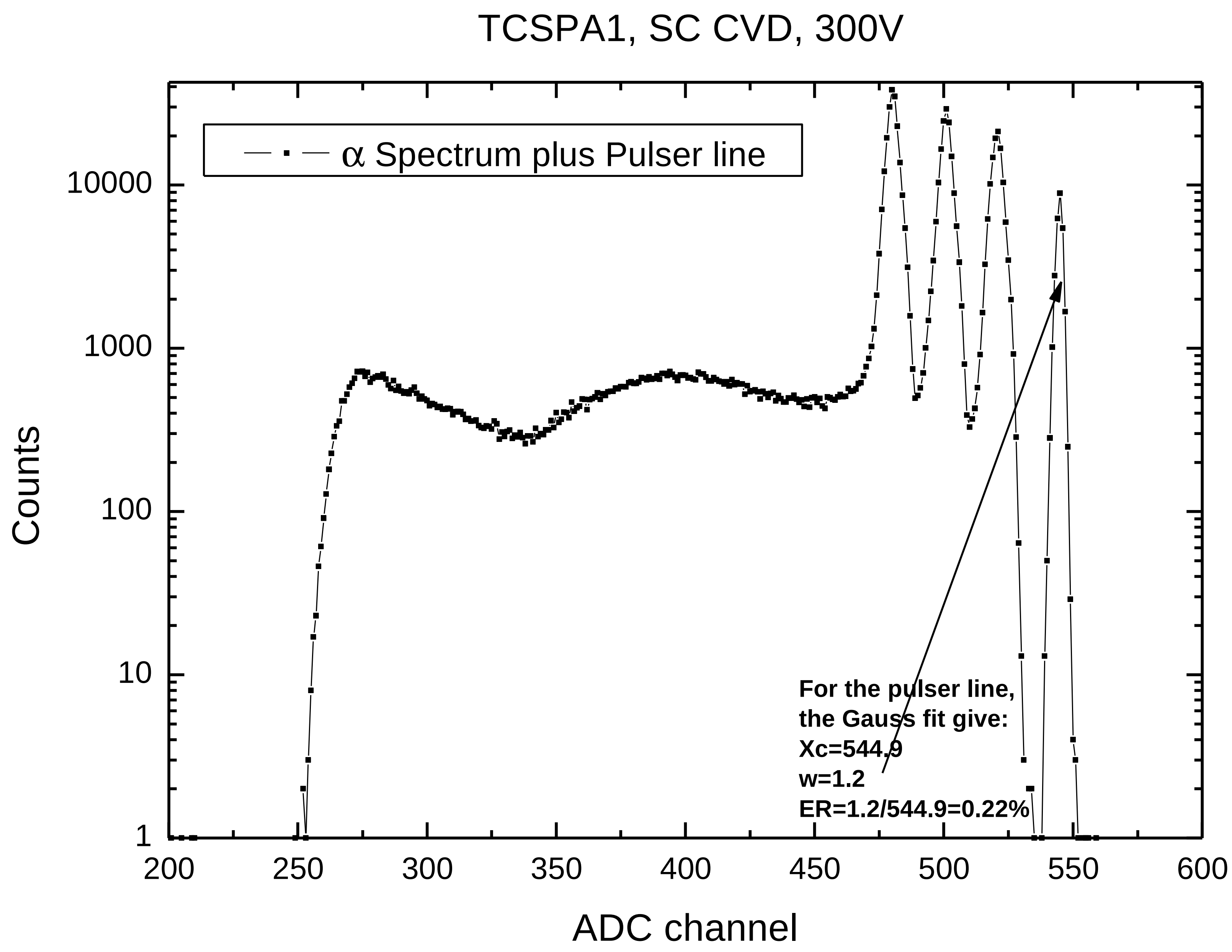

Time and Energy Outputs: Linearity for CF=0, CD=0
Tout
Q<0, y=0.3-4.22x
Q>0, y=0.8-4.86x
Eout, y= -1.6-7.75x
Tout
Eout
Tout and Eout [mV]
Qin [fC]
400
300
200
100
0
-100
-200
-300
-400
-500
-60
-40
-20
0
20
40
60

Noise

TCSPA1, Noise versus detector capacitance, for Cf 0 and 1.6pF



α Spectrum



TCSPA1, SC CVD, 300V
α Spectrum plus Pulser line
Counts
ADC channel
10000
1000
100
10
1
200
250
300
350
400
450
500
550
600
For the pulser line,
the Gauss fit give:
Xc=544.9
w=1.2
ER=1.2/544.9=0.22%