ABCD-2 Proton Irradiation

- functionality of digital circuitry
- changes in analog performance

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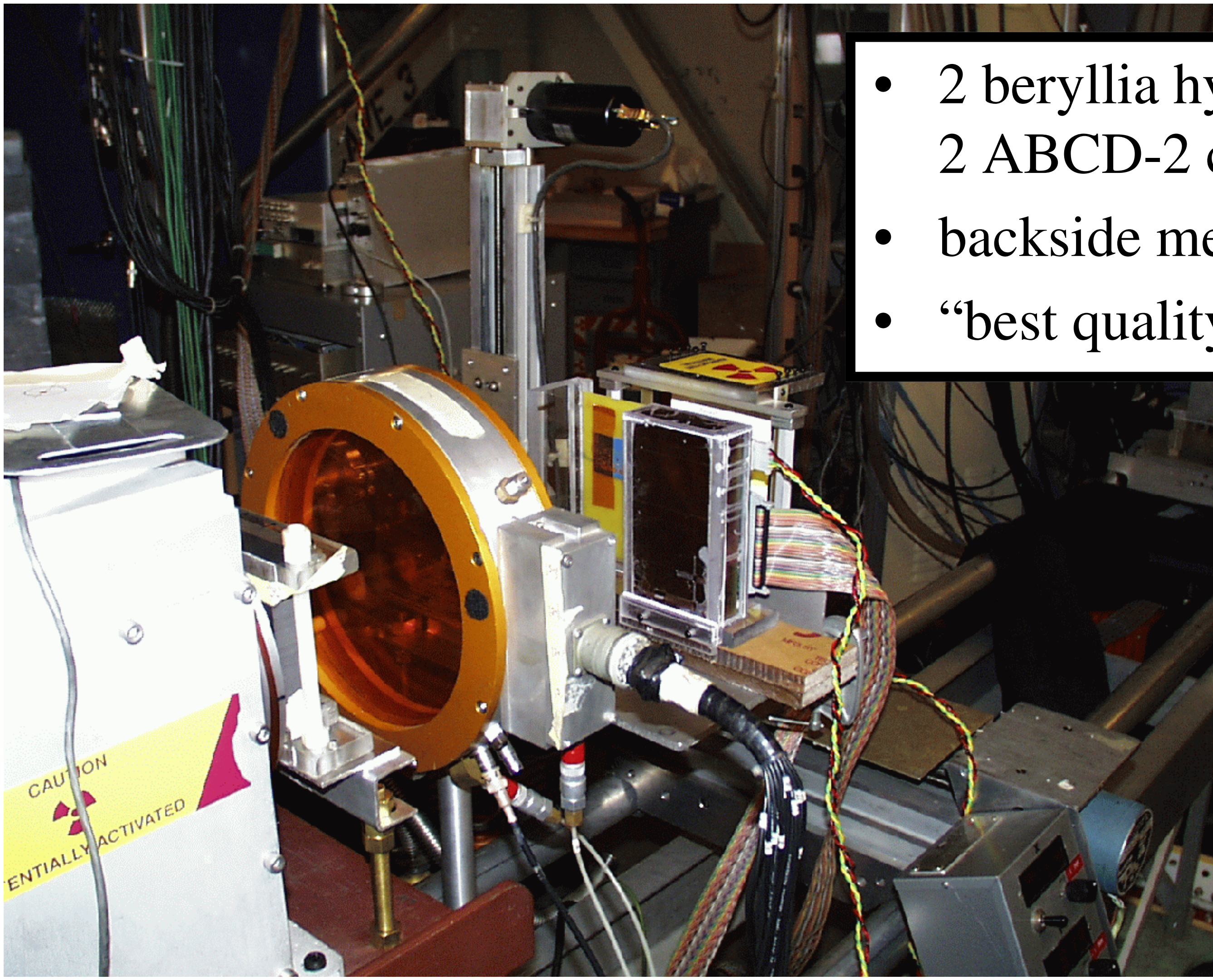
Conditions

- Fluence: $6 \cdot 10^{13}$ protons (55 MeV)
- Dose: 10 MRad
- Dose rate: $\approx$ 100 kRad/min
- Chips powered and operated during irradiation
- All bits in DAC's set to 1 $\rightarrow$ minimizes changes
- Room temperature, sample frozen after irradiation
- Measurements at 0, 2.5, 5, 7.5 and 10 MRad

Sample and Setup



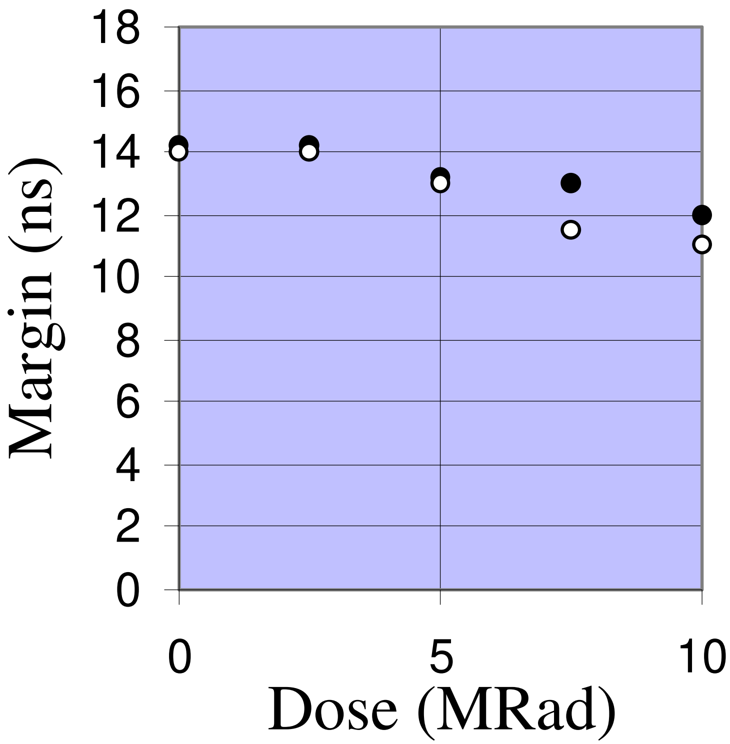
- 2 beryllia hybrids with 2 ABCD-2 chips each
- backside metallised
- “best quality”

Tests of Digital Circuitry

Questions addressed:

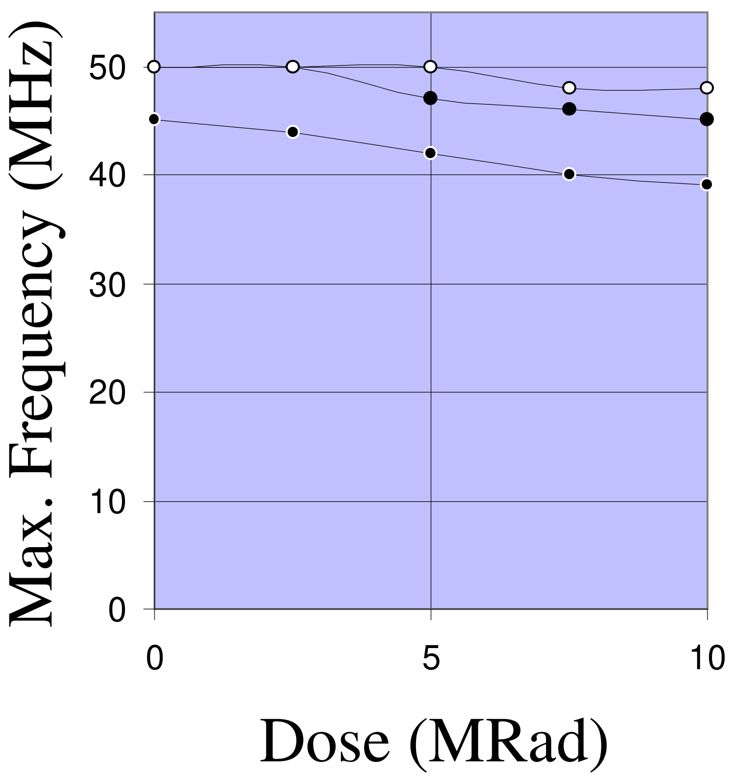
- Is the ABCD still operational after 10 MRad?
- How much margin exists in the timing?
- How much margin exists in the frequency?
- What happens to the critical subcircuits after irradiation: Counters, DCL?
- How changes the internal calibration strobe?

Clk-Cmd Phase Margin



- at 40 MHz, VDD=4.0 V
- DS90C031 LVDS line driver on support card
- test vectors:
  - external calibration pulse, no data sparsification
  - single to few hits in mask register, data compression logic used

Maximum Frequency



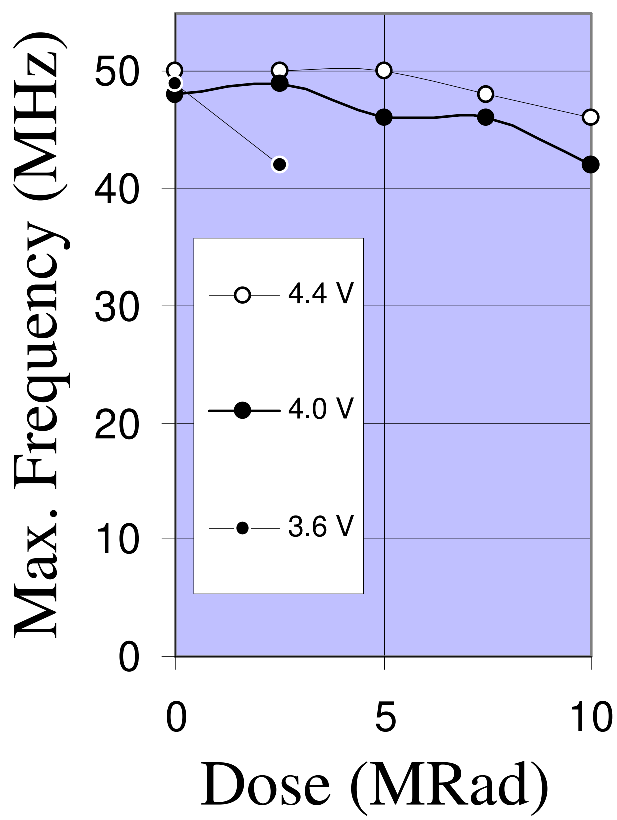
- VDD=3.6 V, 4 V, 4.4 V
- calibration pulses,
  no data compression
- not sensitive to timing
- max test freq. = 50 MHz
- data from one hybrid shown, second is similar

Counters

- known to be the “slowest” part of the ABCD
- bunch crossing counter failed on both parts after 5MRad (at 4 V, 40 MHz)
- L1 counter better: max. frequency 46 MHz after 10 MRad (not all states tested)

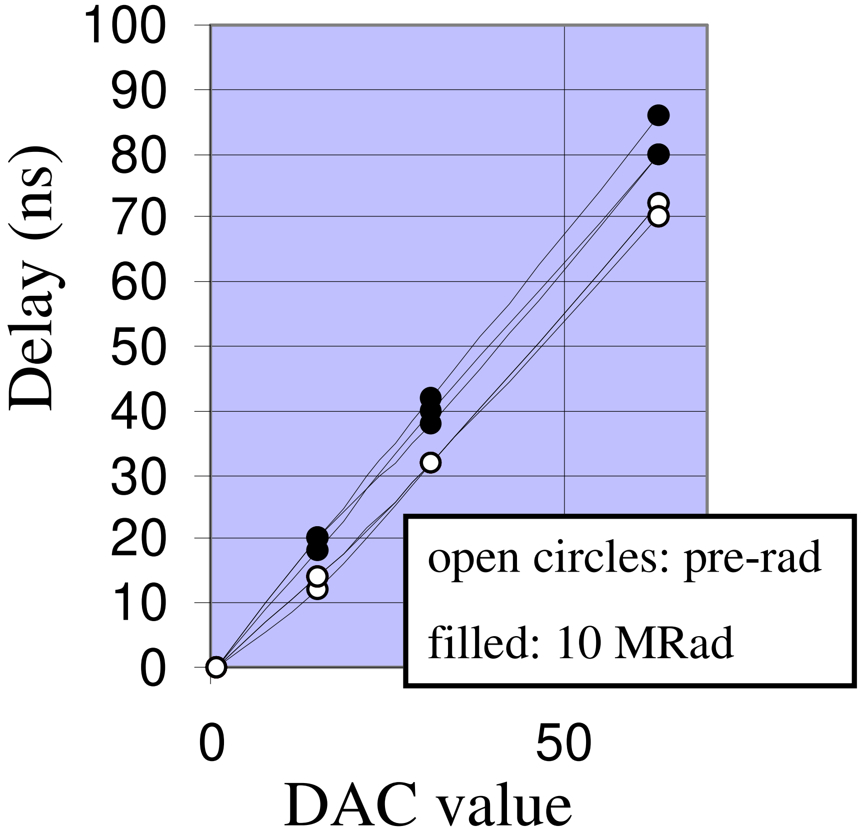
maximum operating frequency decreased more than expected
$\rightarrow$ need to speed up the bunch crossing counter

DCL?



- tried to test max operating frequency of the data compression logic (DCL) by writing hits to mask register and reading out in a data compression mode
- unclear if writing to the mask register or the DCL sets the frequency limit

Calibration Strobe Delay

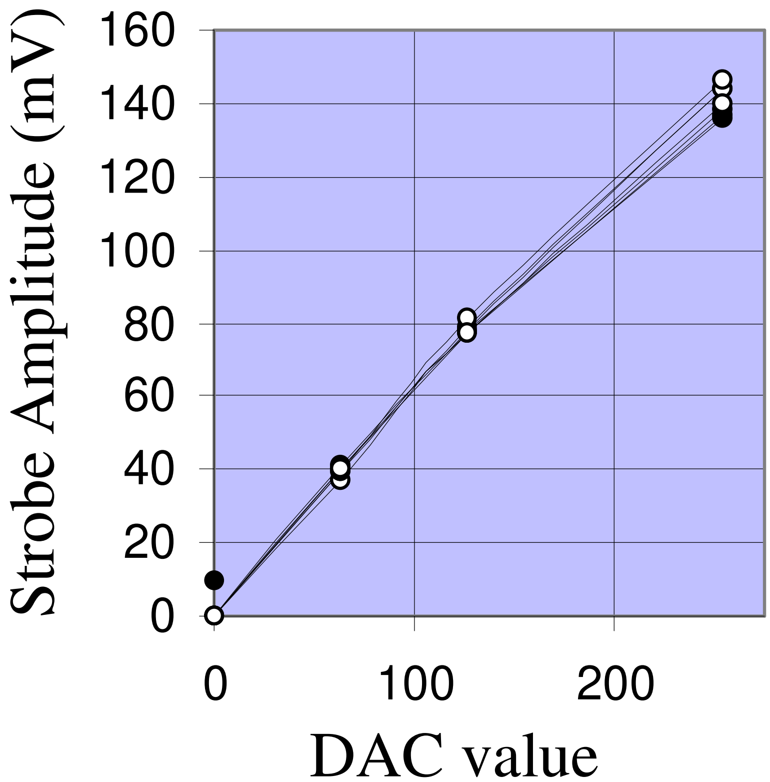


delay increment:

- pre-rad: 1.09 ns
- post 10 MRad: 1.25 ns

offers simple way to check post-rad SPICE parameters

Calibration Strobe: Amplitude and Shape



- Shape:

  No radiation effects observed

- Amplitude:

  Smaller by 5% after 10 MRad

Data Passing Signals

	Signal Amplitude	Terminating Resistor	Current
hybrid 1, pre-rad	150 mV + 156 mV	152 Ohm	2.01 mA
hybrid 1, post-rad	106 mV + 108 mV	126 Ohm	1.70 mA
hybrid 2, pre-rad	144 mV + 148 mV	146 Ohm	2.00 mA
hybrid2, post-rad	110 mV + 110 mV	125 Ohm	1.76 mA

→ 15 % decrease of the current after 10 MRad

Datalink Signal

	Signal Amplitude	Terminating Resistor	Current
hybrid 1, pre-rad	384 mV + 408 mV	103 Ohm	7.69 mA
hybrid 1, post-rad	368 mV + 384 mV	103 Ohm	7.30 mA
hybrid 2, pre-rad	392 mV + 388 mV	102 Ohm	7.65 mA
hybrid2, post-rad	376 mV + 372 mV	102 Ohm	7.33 mA

4.0%-5.3 % decrease of the current after 10 MRad

Summary Digital Tests

- All 4 exposed parts are still operational after 10 MRad
- The clk-cmd timing margin is comfortable
- Margin in frequency is about 10% at nominal VDD, except for the BC counter. Enough if production spread is taken into account?
- The internal calibration strobe circuit survives (DAC is radiation resistant if all bits set), strobe delay slows down by 15%
- Currents in datalink and data passing signals decrease by 4% to 15 %

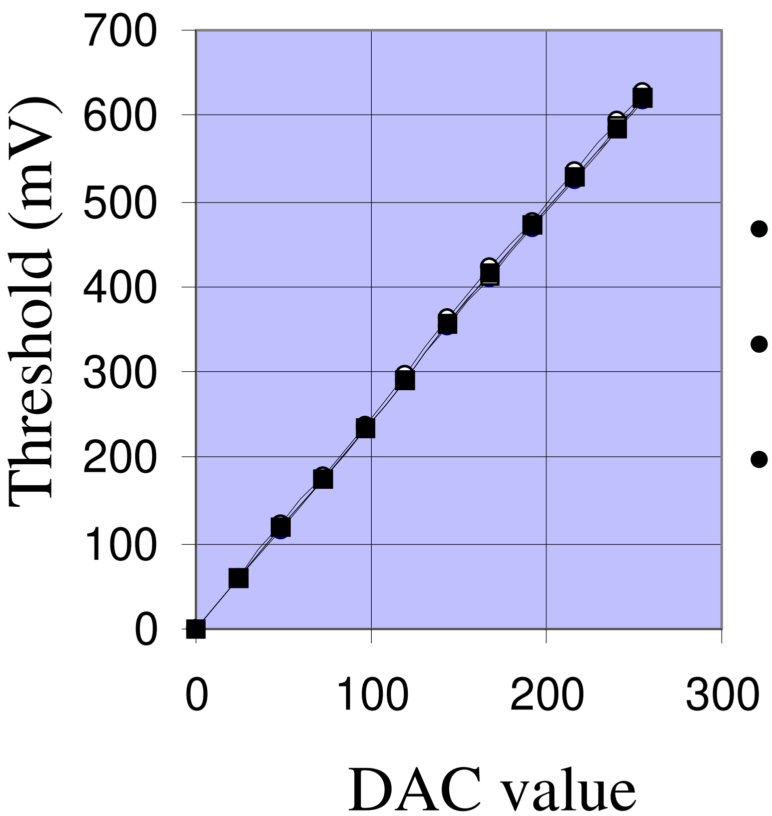
Analog Performance

Questions addressed:

- Do the chips operate stably pre- and post irradiation
- What are the changes in the
  - Gain
  - Threshold
  - Noise

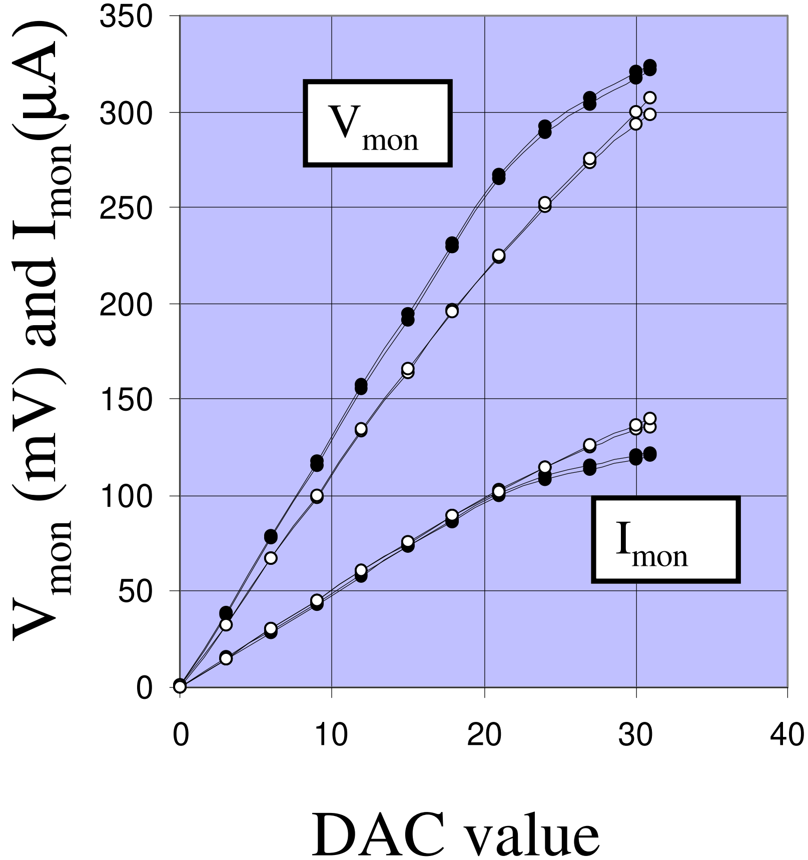
  in dependence of the radiation dose?

DAC's under control? Threshold:



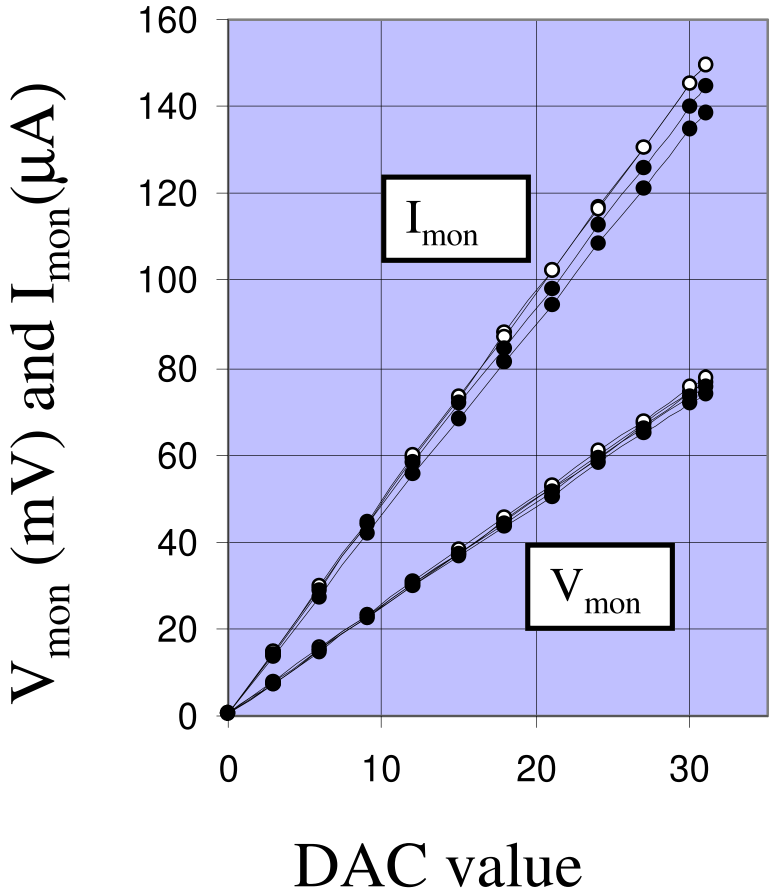
- all bits set to 1 during irradiation
- data pre-/and post irradiation shown
- no changes seen

Shaper Current DAC



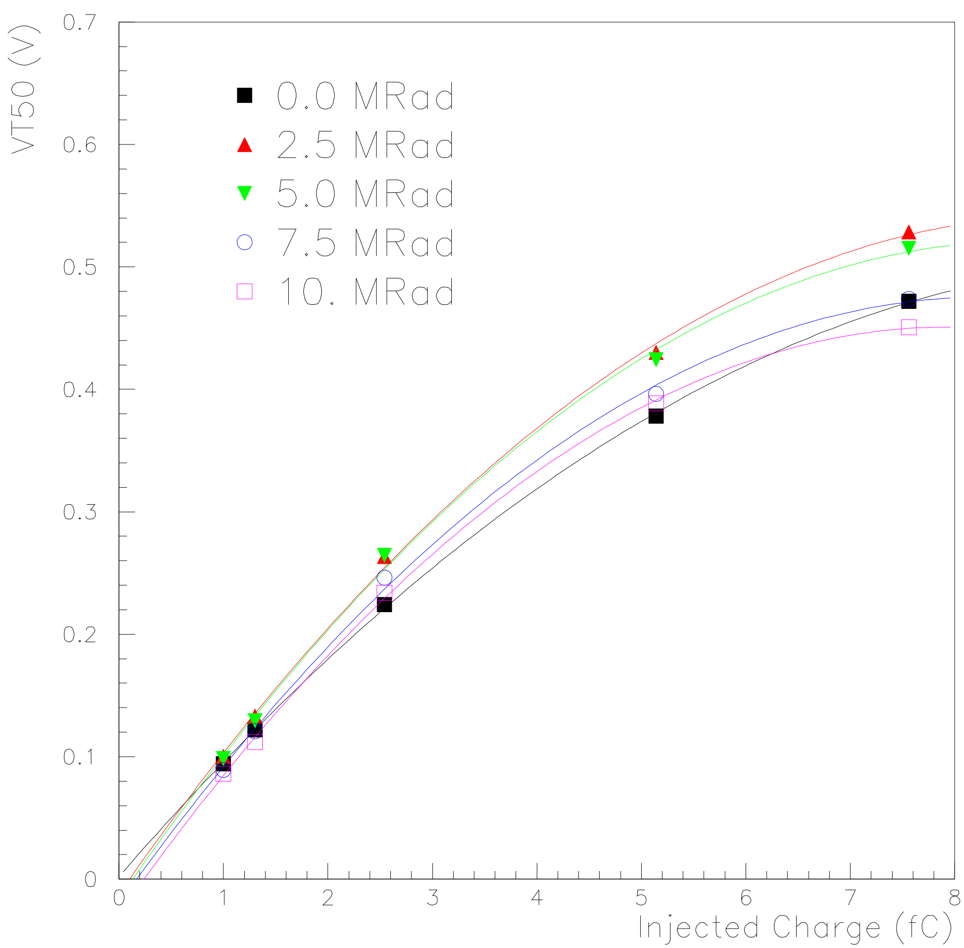
- change in monitor voltage from change in resistor
- saturation effect after irradiation?

Preamplifier Current DAC



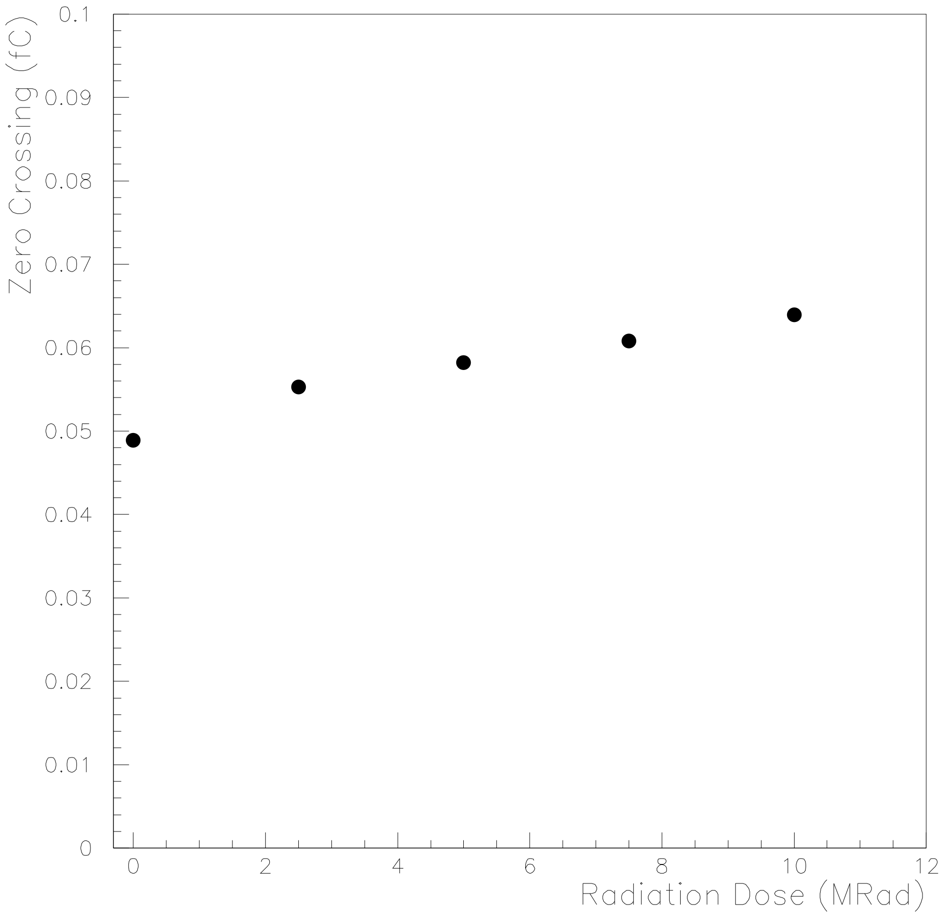
- resistor changes smaller than 4%
- current changes smaller than 7%
- no saturation effects

Response after Irradiation



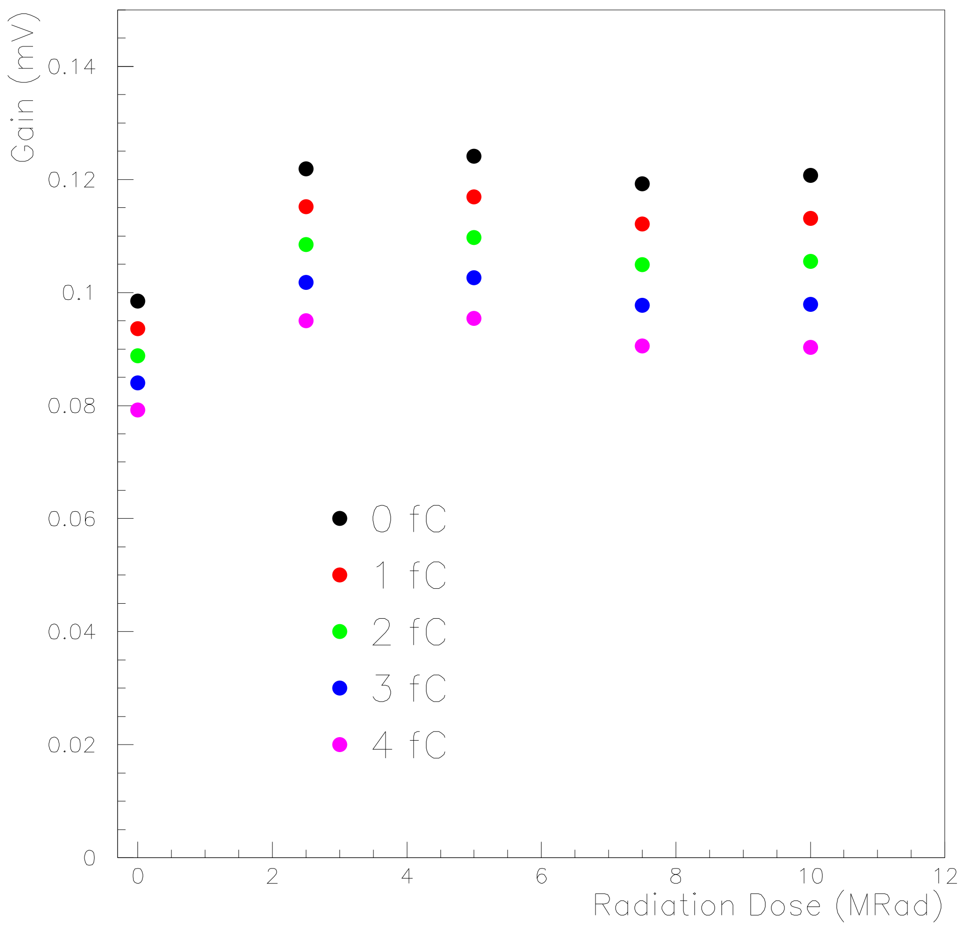
- data from one chip shown, others similar
- assume 100fF calibration capacitor
- fit: 2nd order polynomial

Zero Crossing



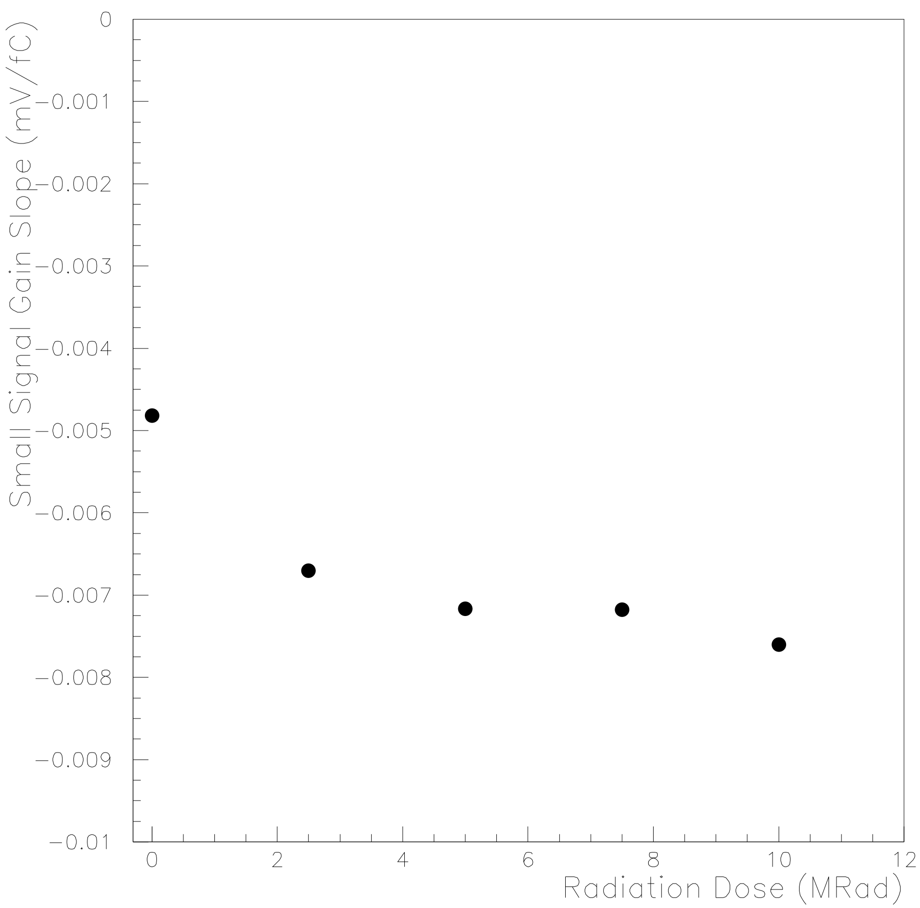
- zero crossing determined from fit parameters
- very small systematic shift

Gain



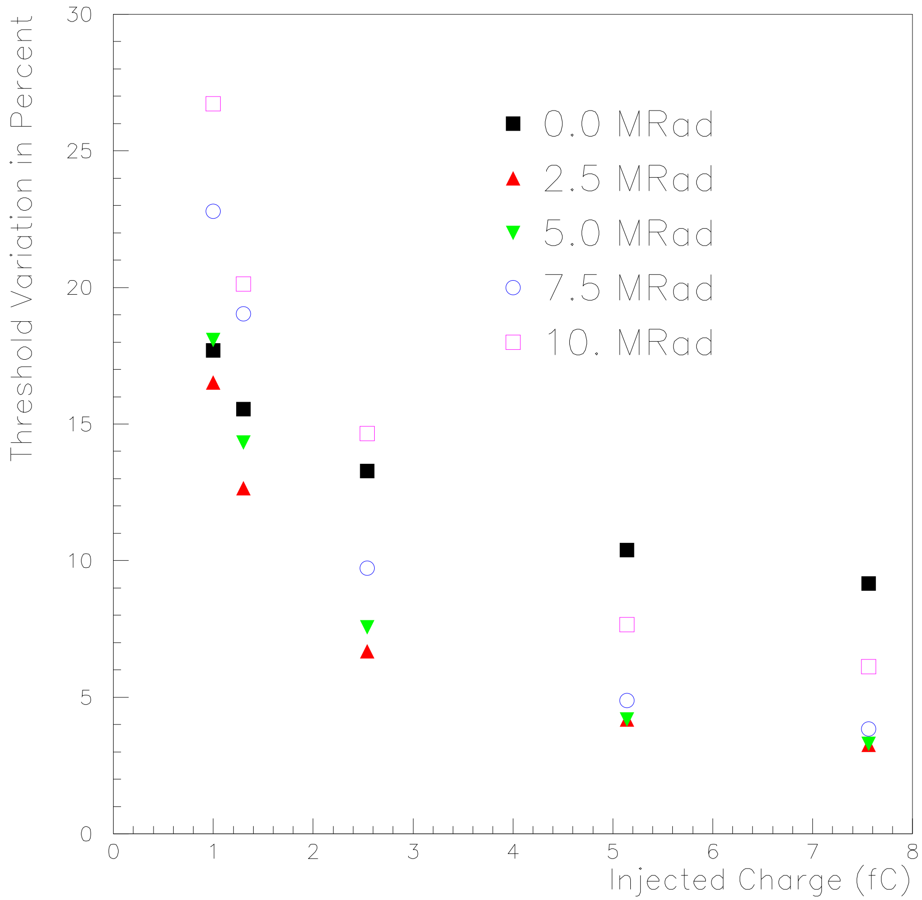
- gain=derivative of response curve
- determined from fit parameters

Gain Slope



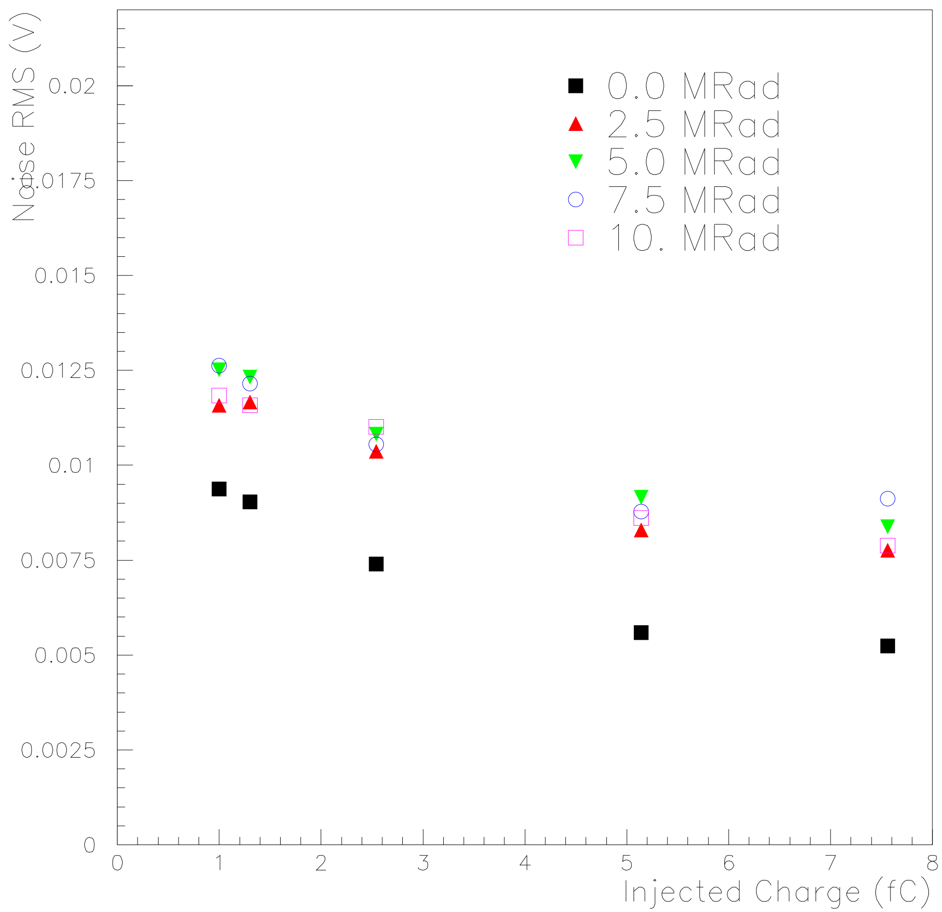
- gain slope = second derivative of response curve
- measures nonlinearity
- small changes with radiation

Threshold Variation



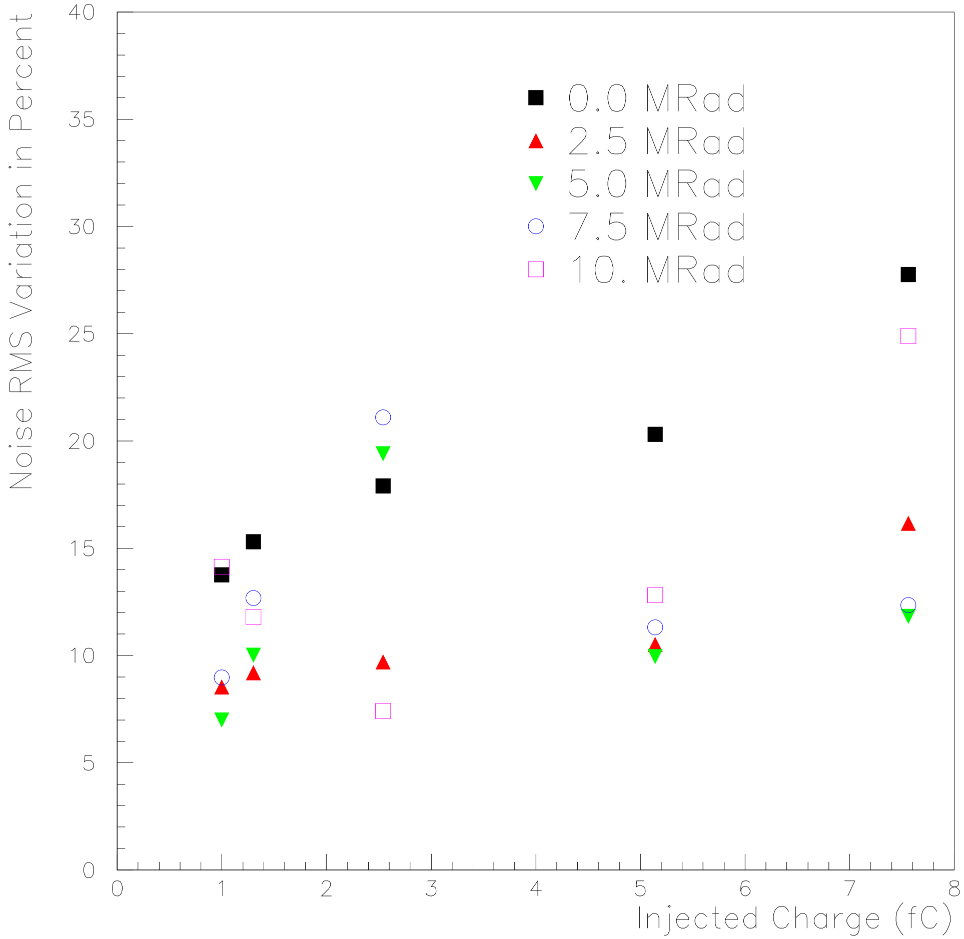
- not corrected for gain
- increase from 17% to 27% at 1fC

Noise RMS



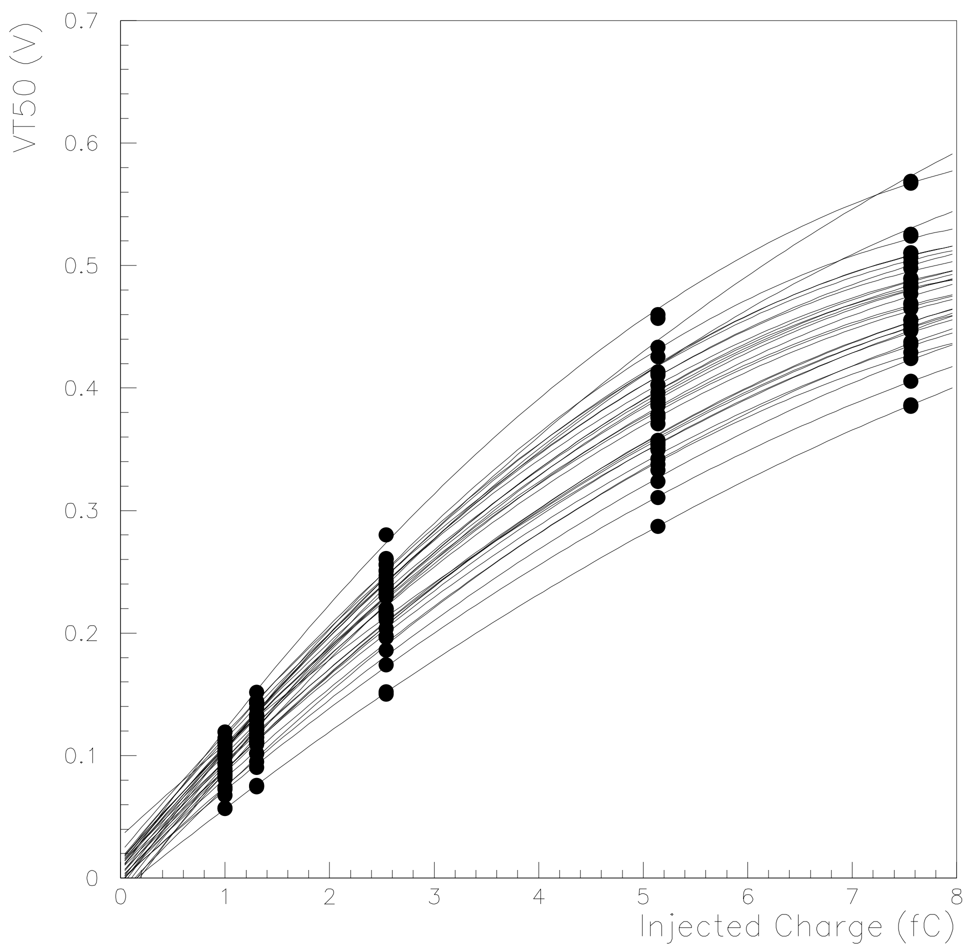
- not corrected for gain
- increase of output noise voltage by 33% at 1fC after irradiation
- increase of input noise charge by about 12%

Noise RMS Variation



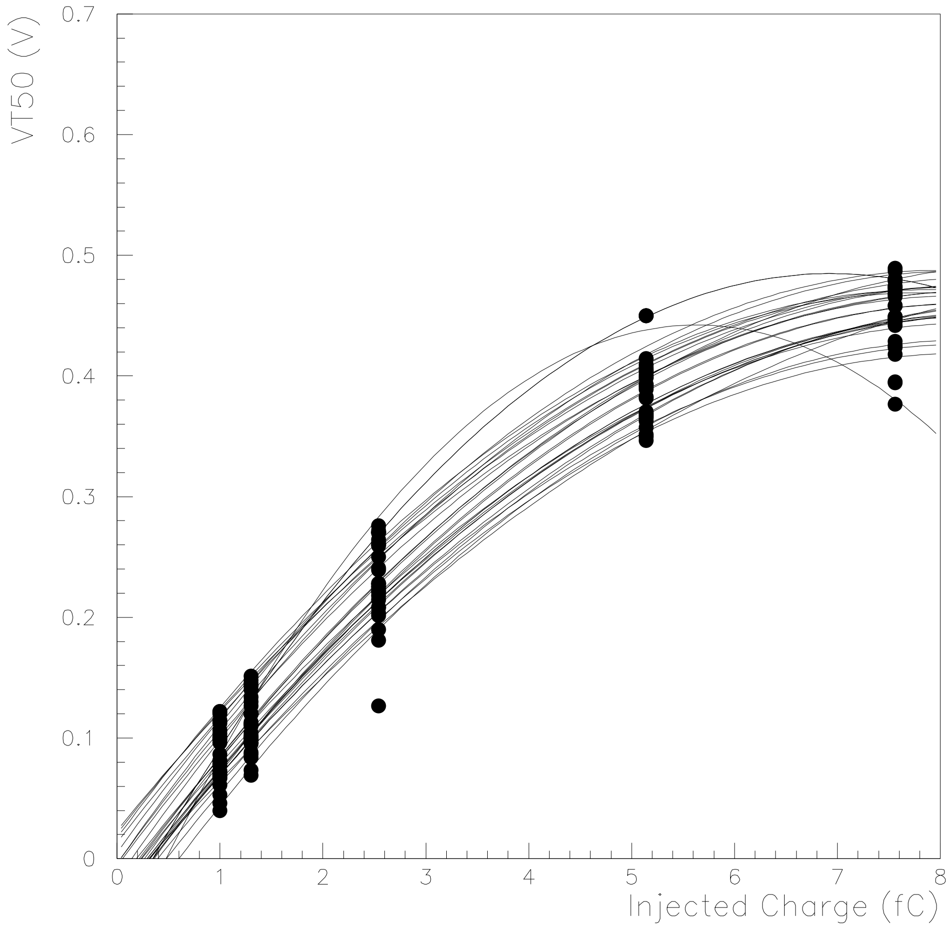
- not corrected for gain

Channel Variation before Irradiation



- DC offset shift causes threshold variations

Channel Variation post irradiation



- DC offset shift causes threshold variations

Summary Analog Front End

- stable operation of 2 chips (no detector) before and after irradiation
- already large threshold spread at 1fC of 17% increases to 27% $\rightarrow$ need DAC's
- changes in gain and noise are small