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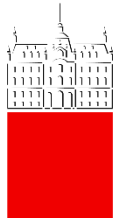

Charge collection in passive structures on proton irradiated CHESS 2

Strip CMOS regular meeting, 25.05.2017

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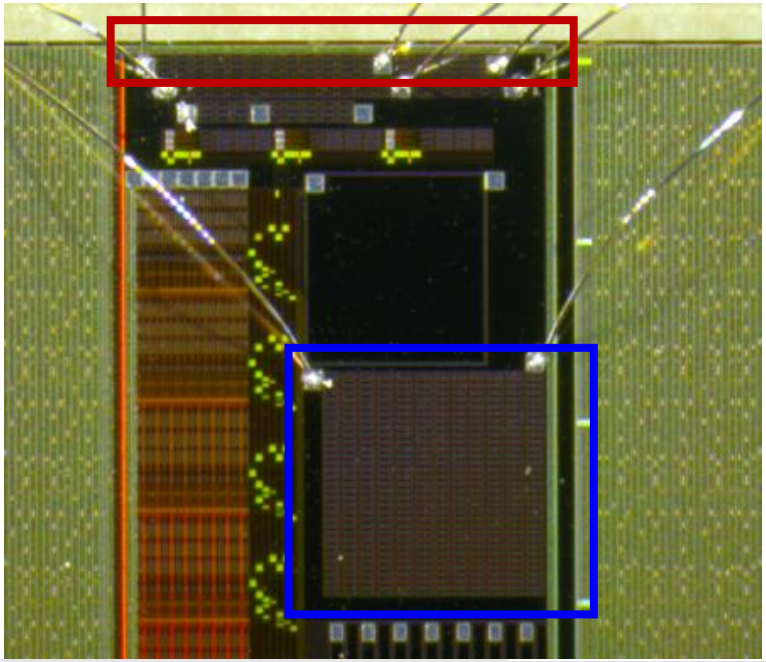
Samples

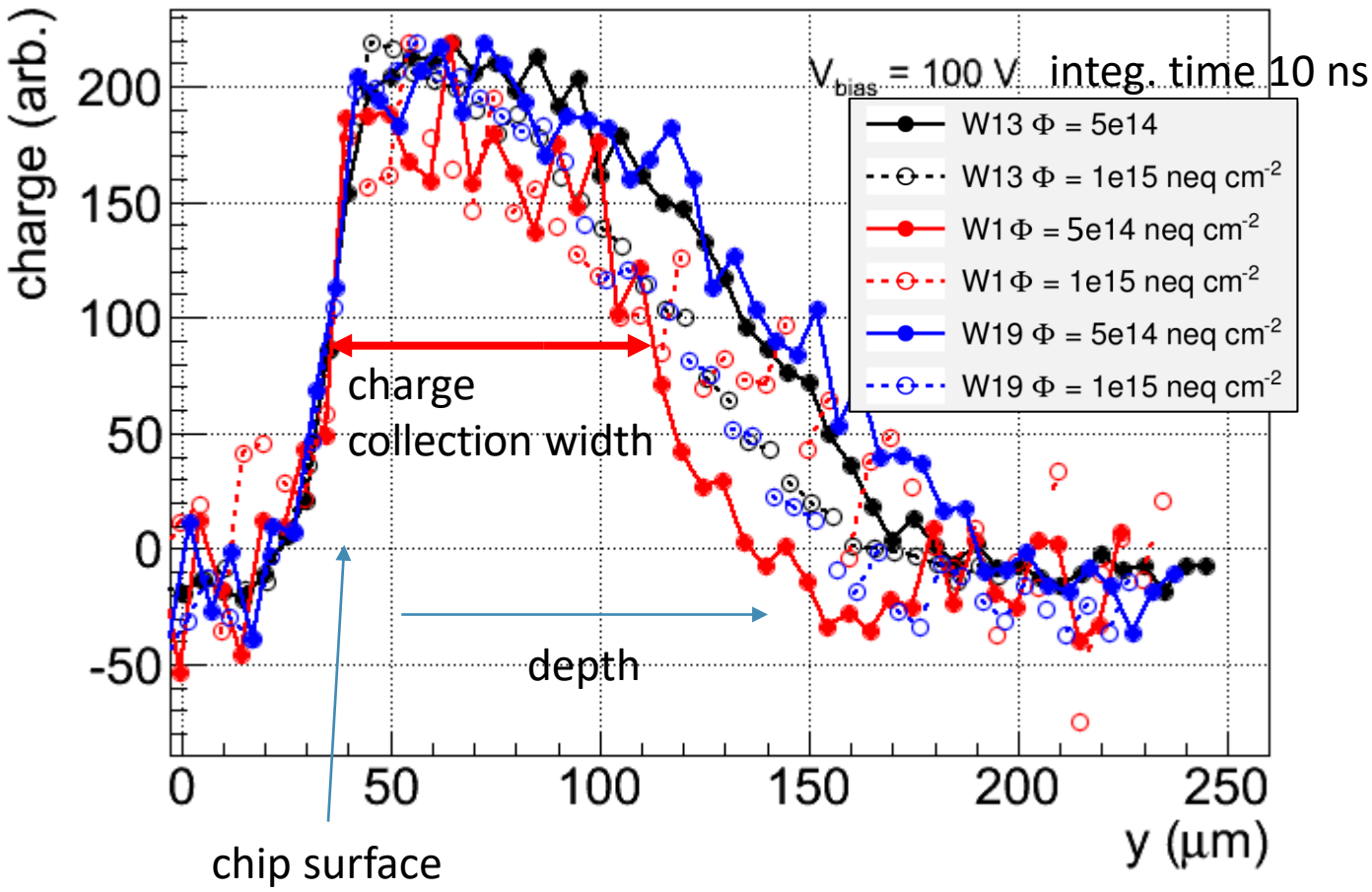
- Proton irradiated CHESS 2 (24 GeV p at CERN PS, Oct 2016)
- Samples mounted and bonded on analog daughterboards

	W1 (20 Ω·cm)	W13 (200 Ω·cm)	W19 (> 600 Ω·cm)
5e14 n_{eq}/cm^2	could not connect for ^{90}Sr	✓	✓
1e15 n_{eq}/cm^2	✓	✓	✓

- Measured before and after annealing (80 min at 60°C)
- Passive test structures:
  - 3 x 3 passive array for E-TCT
  - Large passive array for ^{90}Sr

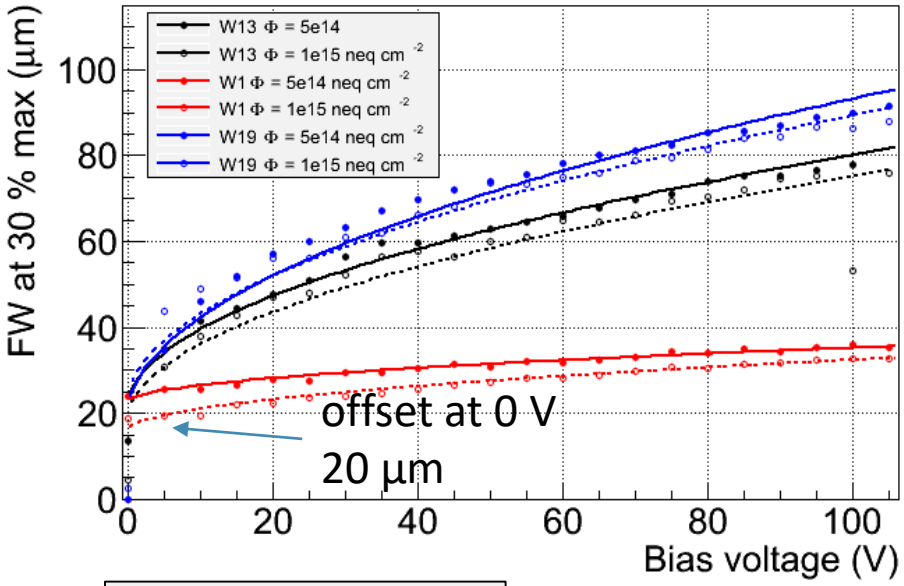


E-TCT charge collection profiles

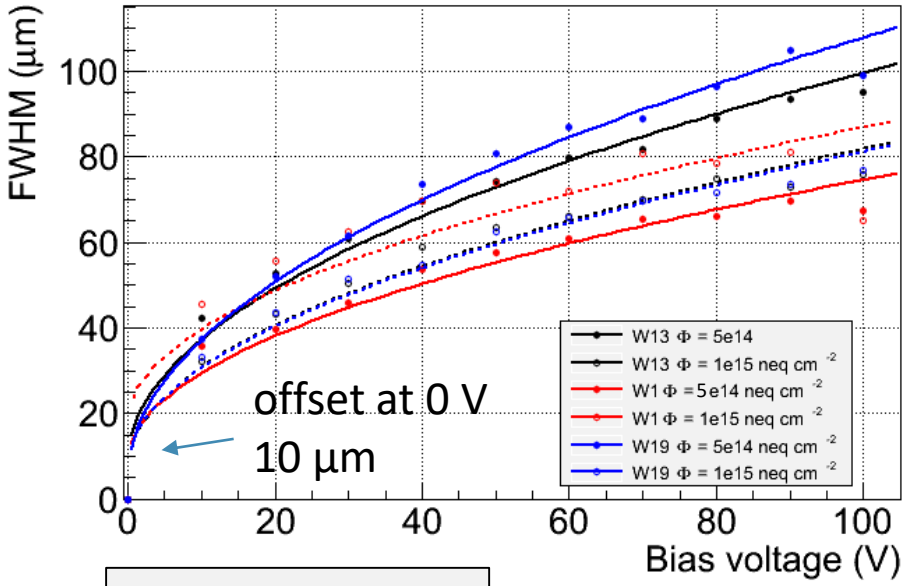


E-TCT: measure width from which charge is collected. Width = FWHM of charge collection profiles

Depletion depth



neutron irradiated



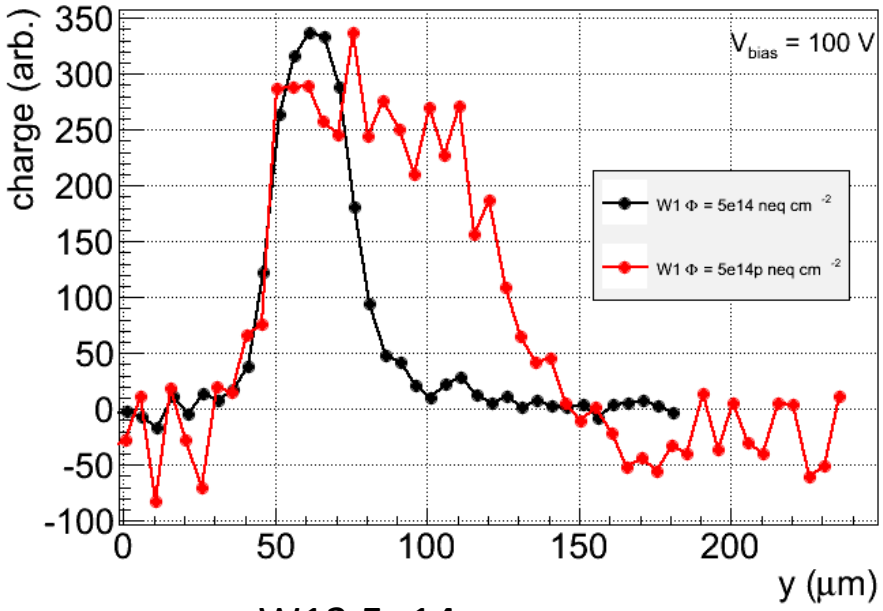
proton irradiated
NEW

Measured charge collection width with E-TCT:

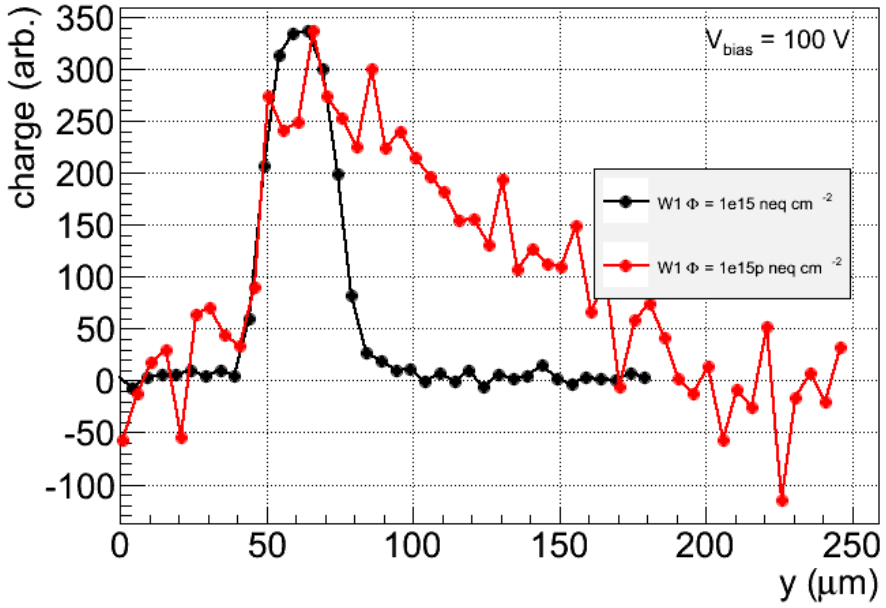
- **W13** and **W19** slightly larger with protons than neutrons
- **W1** (standard res.) significantly larger with protons (observed also with CHESS 1)

- similar collection widths for all three proton irrad. wafers: **80 µm at 100 V at 1e15**

E-TCT W1



W13 5e14

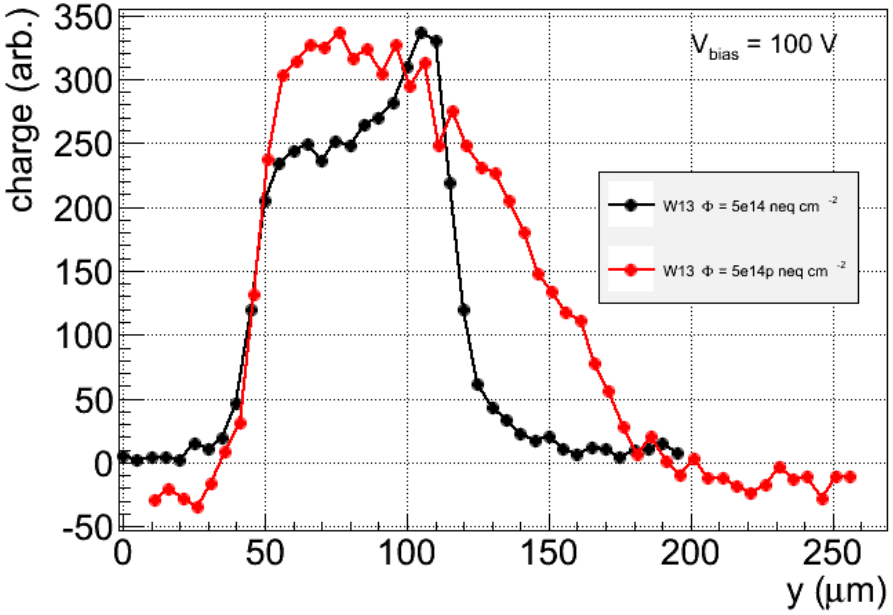


W13 1e15

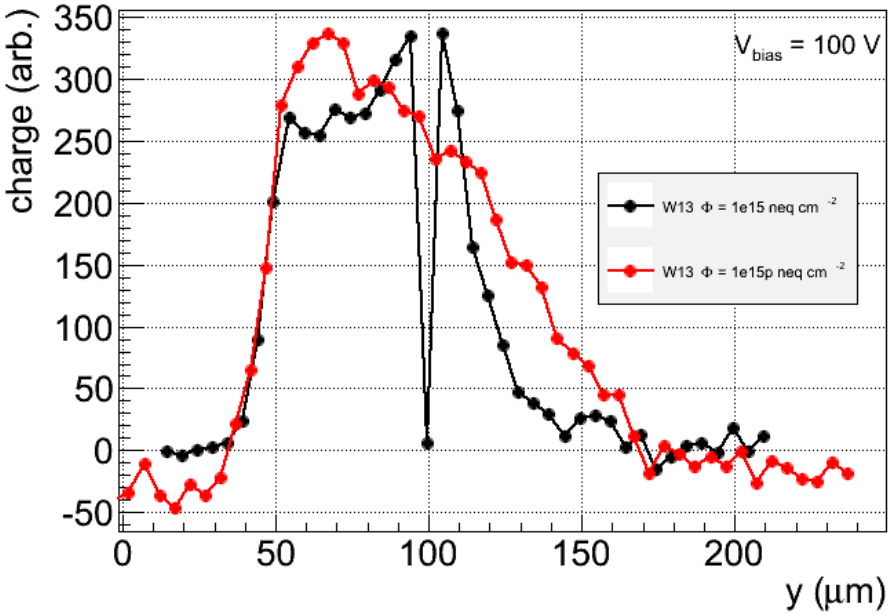
black – neutrons

red – protons

E-TCT W13



W13 5e14

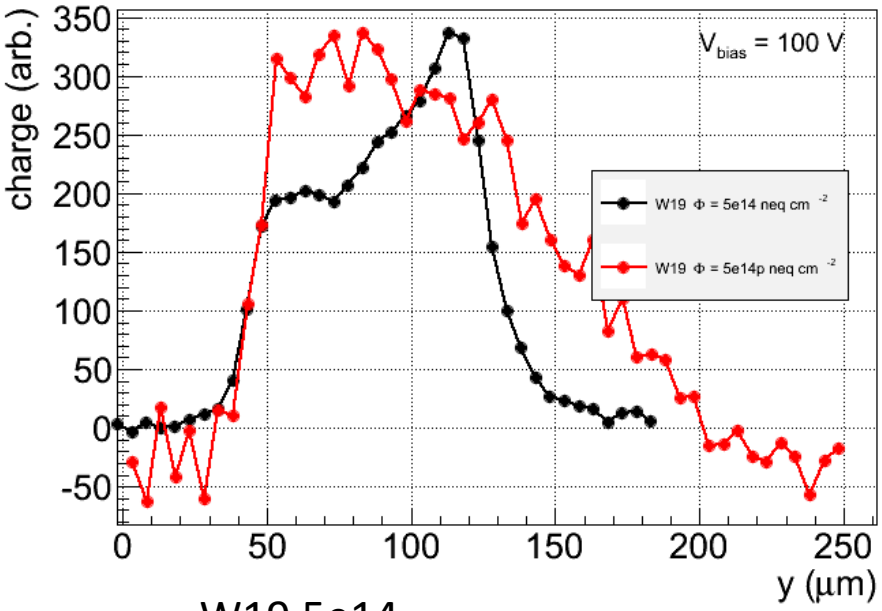


W13 1e15

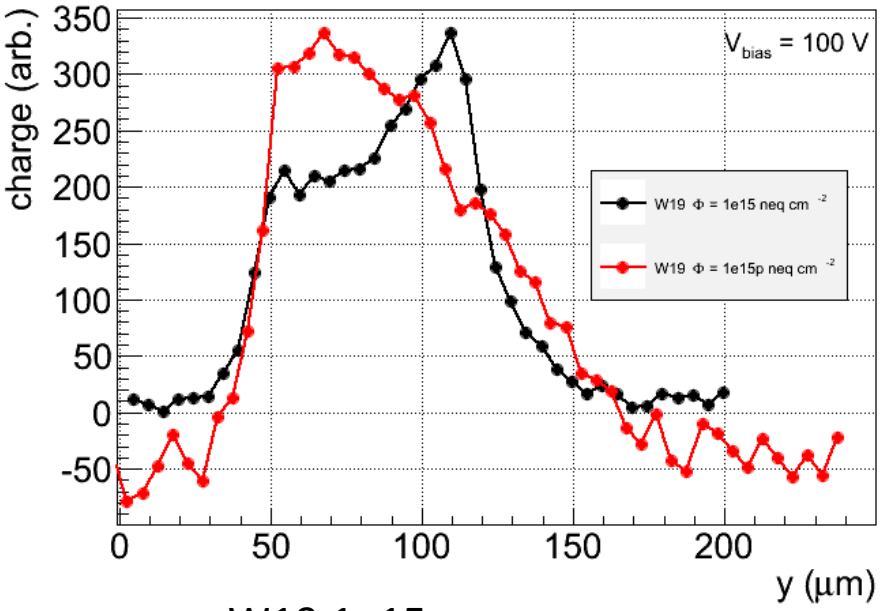
black – neutrons

red – protons

E-TCT W19



W19 5e14



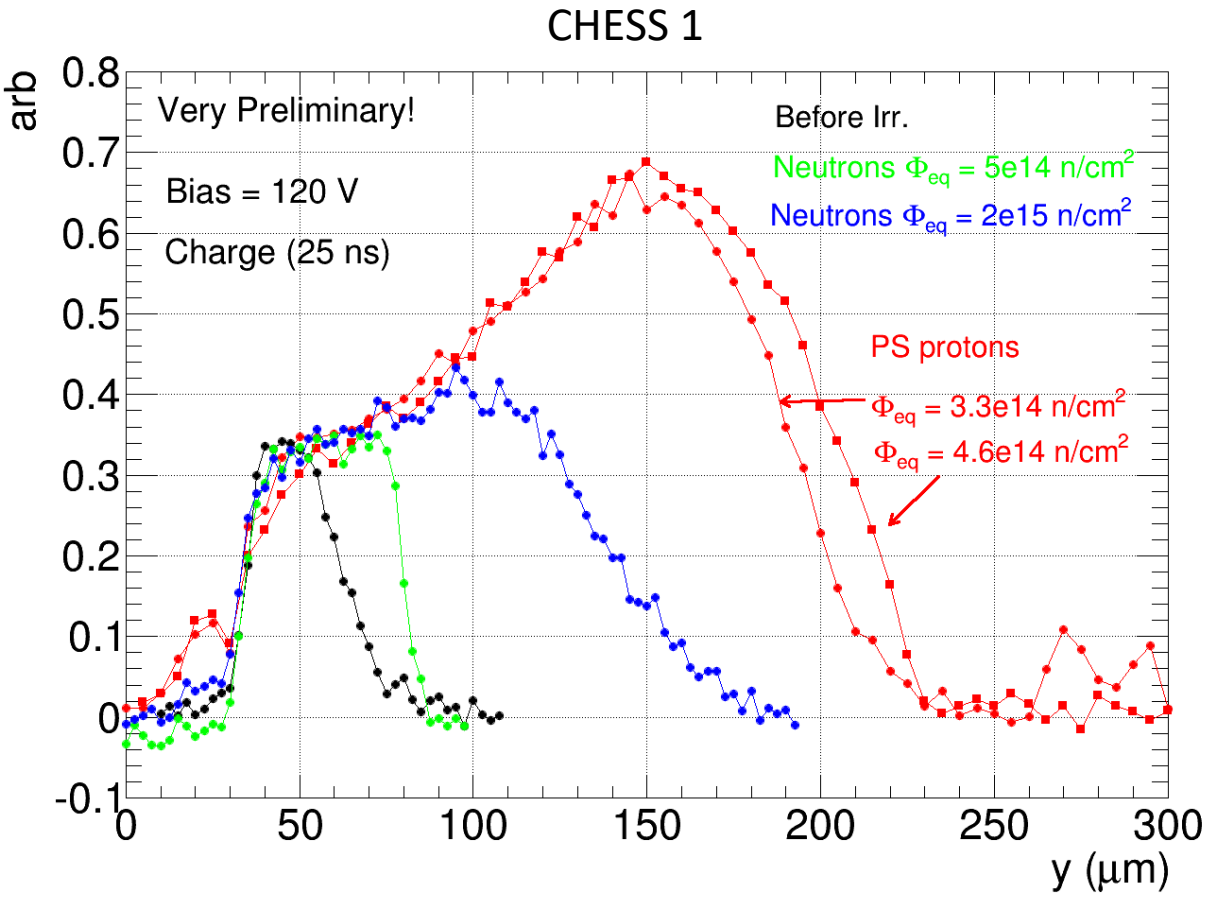
W19 1e15

black – neutrons

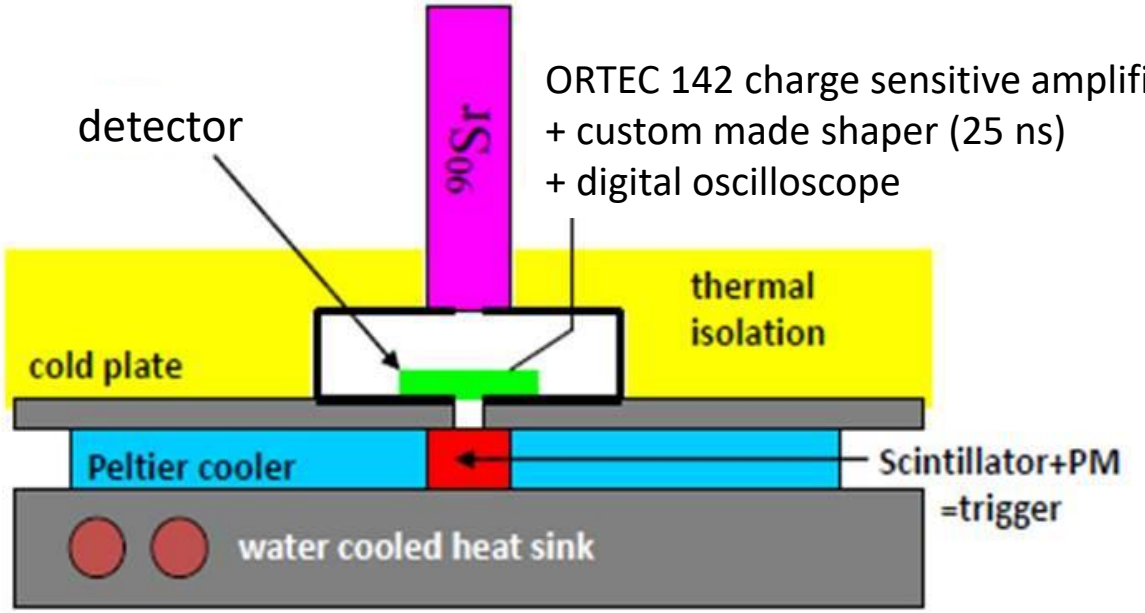
red – protons

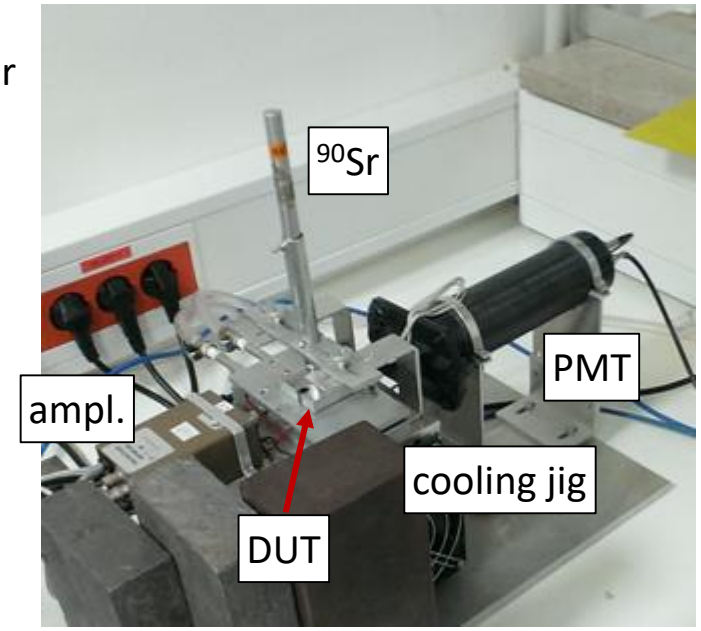
CHESS 1 results

Reminder: different space charge behavior for proton and neutron irradiation on standard AMS substrate was also observed with CHESS 1



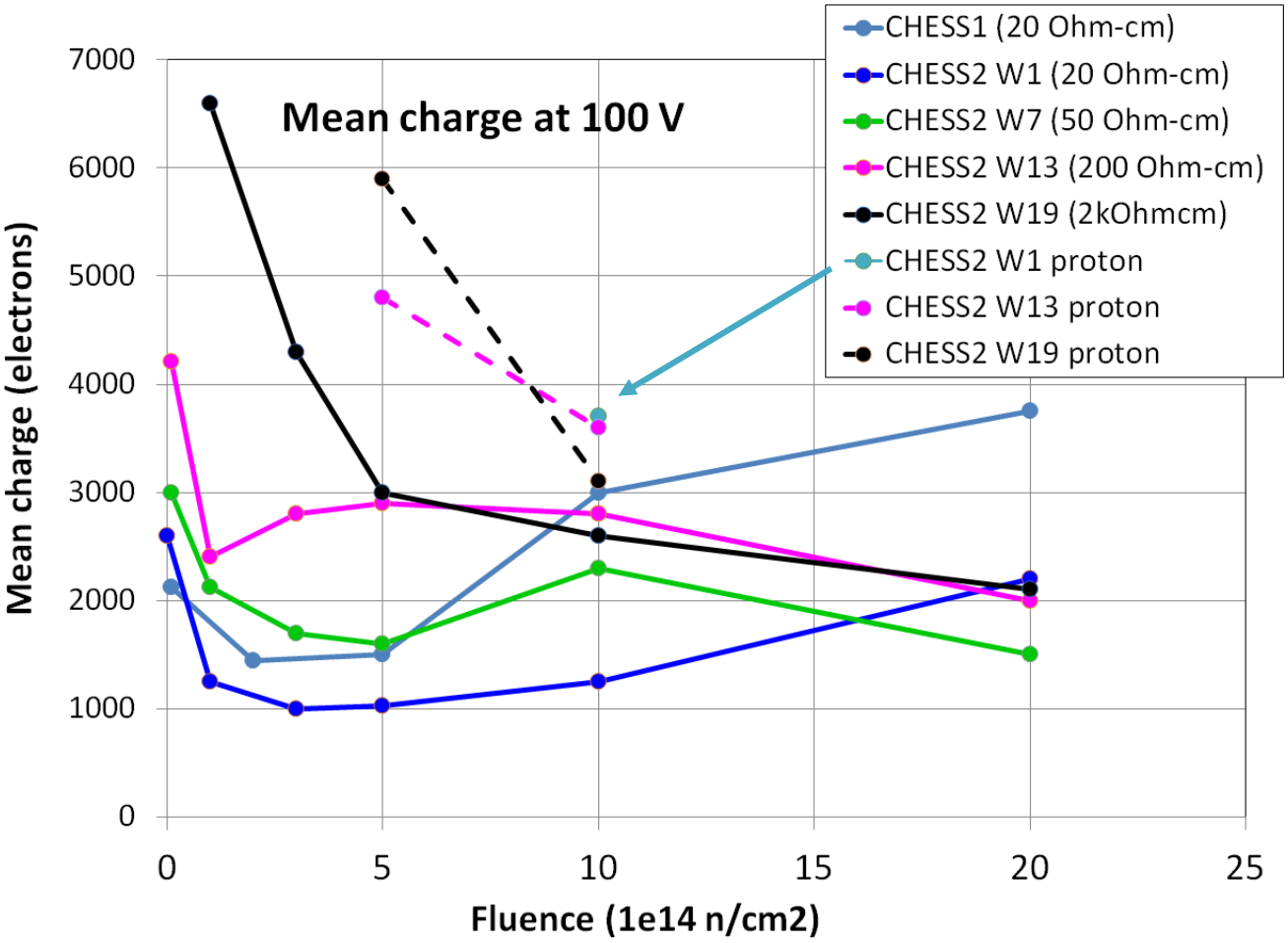
^{90}Sr setup





- HV-CMOS: small signals, large noise → S/N very low
  - clean sample of events needed (no hits missing DUT)
  - require a large detector (trigger rate), good collimation, small scintillator
- Measurement:
  - Calibration with a 300 µm thick Si pad detector
  - 1) Record *N* (= 2500) waveforms
  - 2) Average over all waveforms and determine time of the signal peak
  - 3) Sample waveforms at the peak
  - 4) Fill spectrum

Collected charge Sr90



charge (p irrad.) > charge (n irrad.)

From E-TCT at 1e15 expected mean charge 80 µm x 100 e/µm = 8000 electrons
The deficit might be due to top bias effects.

Summary

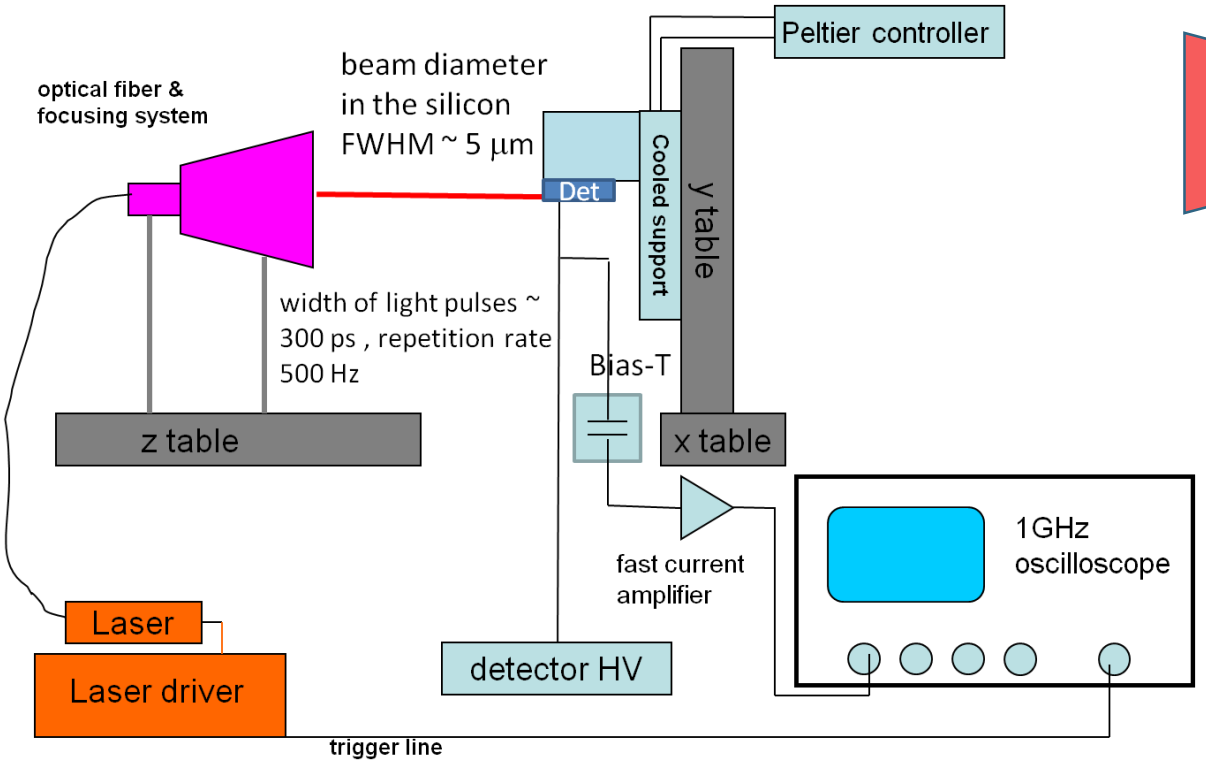
- Concluded measurements of charge collection in proton irradiated CHESS 2
  - 3 substrate resistivities (W1, W13, W19), 2 proton fluences (5e14, 1e15 neq/cm2, CERN PS)
  - E-TCT – depleted depth
  - Sr90 – collected charge

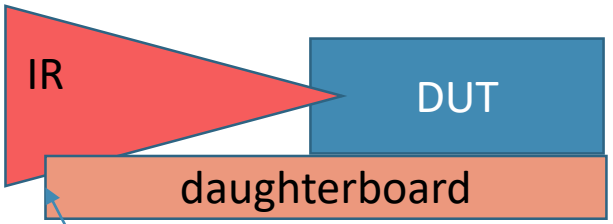
- W1: 5e14 → 1e15 depleted depth increases
- W13, W19: 5e14 → 1e15 depleted depth, charge reduces

- Depleted depth and charge larger for proton irradiated than for neutron irradiated samples at the same eq. fluence

- Outlook:
  - We have received p-irradiated chips from Los Alamos → can do similar measurements
  - Had a few tries to measure analog active pixels, but no results so far

BACKUP

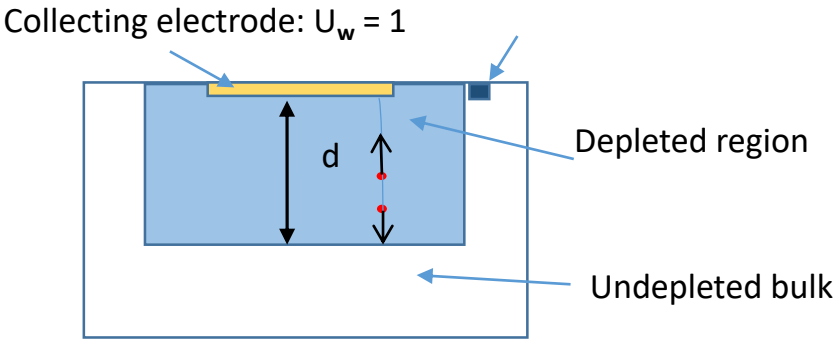




possible beam screening due to lack of E-TCT cutout on the daughterboard

Possible explanation: difference due to different weighting field in back or top bias after irradiation

No back plane, substrate biased via implant on top



Before irradiation:

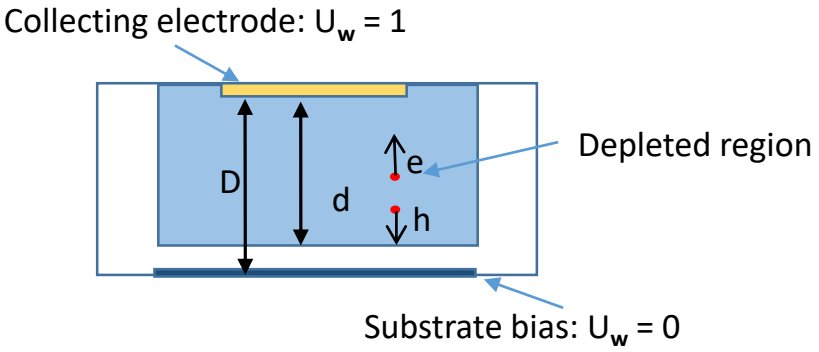
- Undepleted substrate before irradiation low resistivity (Ohmic) weighting potential Uw = 0

➔ carriers drift across whole weighting field: all charge collected

After irradiation:

- substrate resistivity (Ohmic) high, weighting potential 0 at the bias implant on top
  - ➔ Carriers trapped in low field at the end of depleted depth, before they reach the substrate bias electrode
  - ➔ carriers don't drift across all whole weighting field
  - ➔ partial charge collection

Back plane (and thinned), substrate biased via back plane



Before irradiation:

- Undepleted substrate before irradiation low resistivity (Ohmic) weighting potential Uw = 0

➔ carriers drift across whole weighting field: all charge collected

After irradiation:

- substrate resistivity (Ohmic) high
- weighting potential 0 at the back plane implant
  - ➔ if fully depleted D = d full charge collection (except trapping)
  - ➔ if not fully depleted carriers don't cross whole weighting field
    - → charge collection reduced by a factor **d/D**
  - ➔ depending on geometry and device thickness this factor can be much better than in the case of top bias

difference between top and back bias has been observed with LFoundry pixel CMOS chip