CCE measurements with SCT128A chip on strip dtectors irradiated with pions

Igor Mandić[1], Vladimir Cindro[1], Andrej Gorišek[1], Gregor Kramberger[1], Marko Milovanović[1], Marko Mikuž[1,2], Marko Zavrtanik[1]

[1]Jožef Stefan Institute, Ljubljana, Slovenia
[2] Faculty of Mathematics and Physics, University of Ljubljana, Slovenia

Outline:

- ATLAS07 mini strip detectors from Hamamatsu irradiated with pions at PSI in 2010
- CCE measurement with Sr90 source on SCT128 setup in Ljubljana
- measurements repeated after several annealing steps at 60 C

Detectors:

- p-type, FZ, 320 μm thick, 75 μm strip pitch, 1x1 cm^2 , produced by Hamamatsu

1) A07, W19, Z3, P21: $\Phi = 1.65 \cdot 10^{14}\ \pi/cm^2 = 1.8 \cdot 10^{14}\ n_{eq}/cm^2$, irrad. time: 2 days

2) A07, W49, Z1, P19: $\Phi = 4.14 \cdot 10^{14}\ \pi/cm^2 = 4.6 \cdot 10^{14}\ n_{eq}/cm^2$, irrad. time: 4.5 days

3) A07, W22, Z3,P1: $\Phi = 1.43 \cdot 10^{15}\ \pi/cm^2 = 1.6 \cdot 10^{15}\ n_{eq}/cm^2$, irrad. time: 16 days

→ long irradiation times

→ detectors at T ~ 26 ° C during irradiation

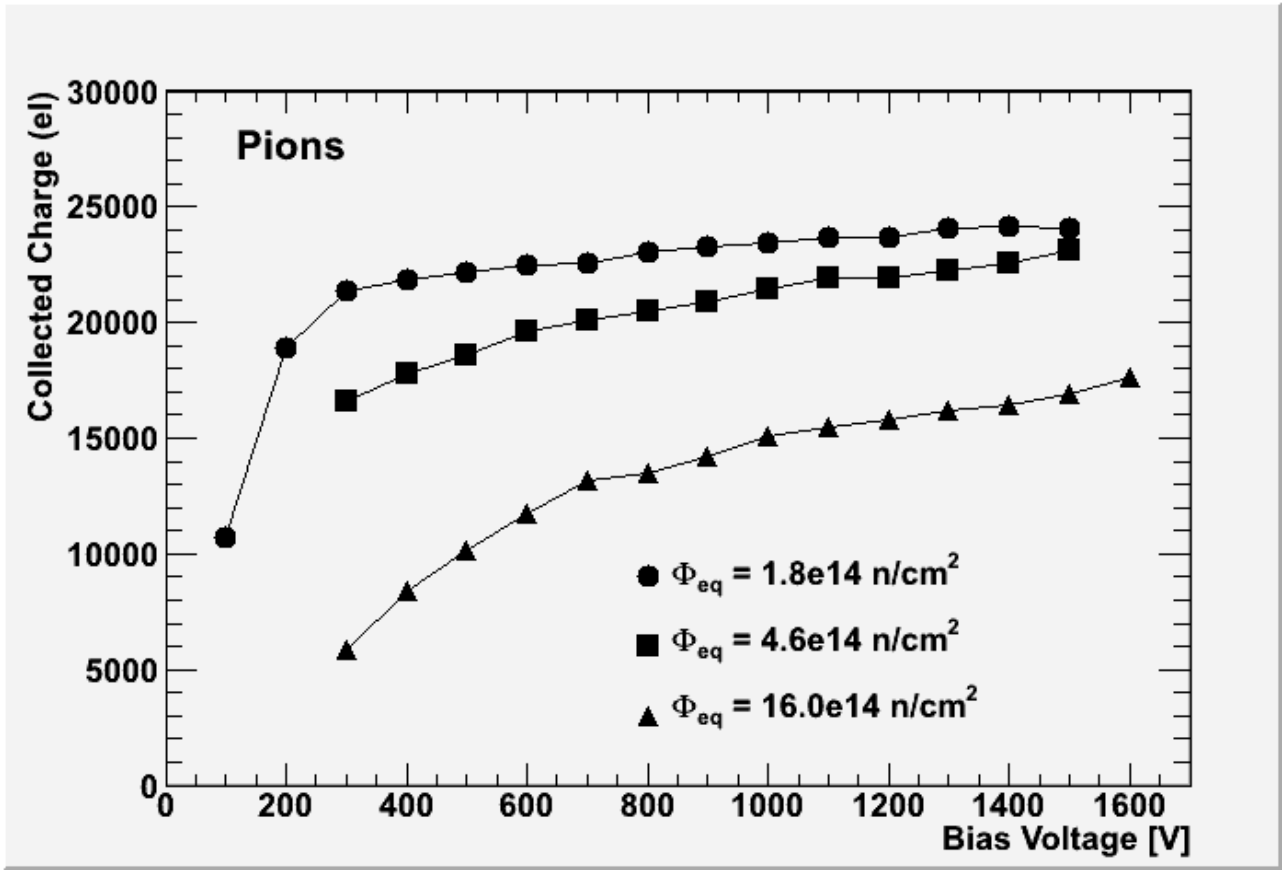
Setup:

- SCTA128VG chip
- VME module SEQSI (for clock, commands...)
- Tektronix digital scope for data acquisition
- ^{90}Sr source, photomultiplier, scintillator,
  power supplies, coincidence circuit .....
- Most probable value (MPV) from fit of Landau + Gaus
  to distribution of measured signal cluster heights

  ➔ scale defined with signals from not irradiated detector:
  → 320 um thick detector, full charge = 25000 electrons

- measure collected charge and leakage current at different bias voltages,
  after annealing steps at 60 C
- measurements done before annealing and
  after: 80, 240, 560, 1200 and 2480 minutes at 60 C.

Measurements after irradiation

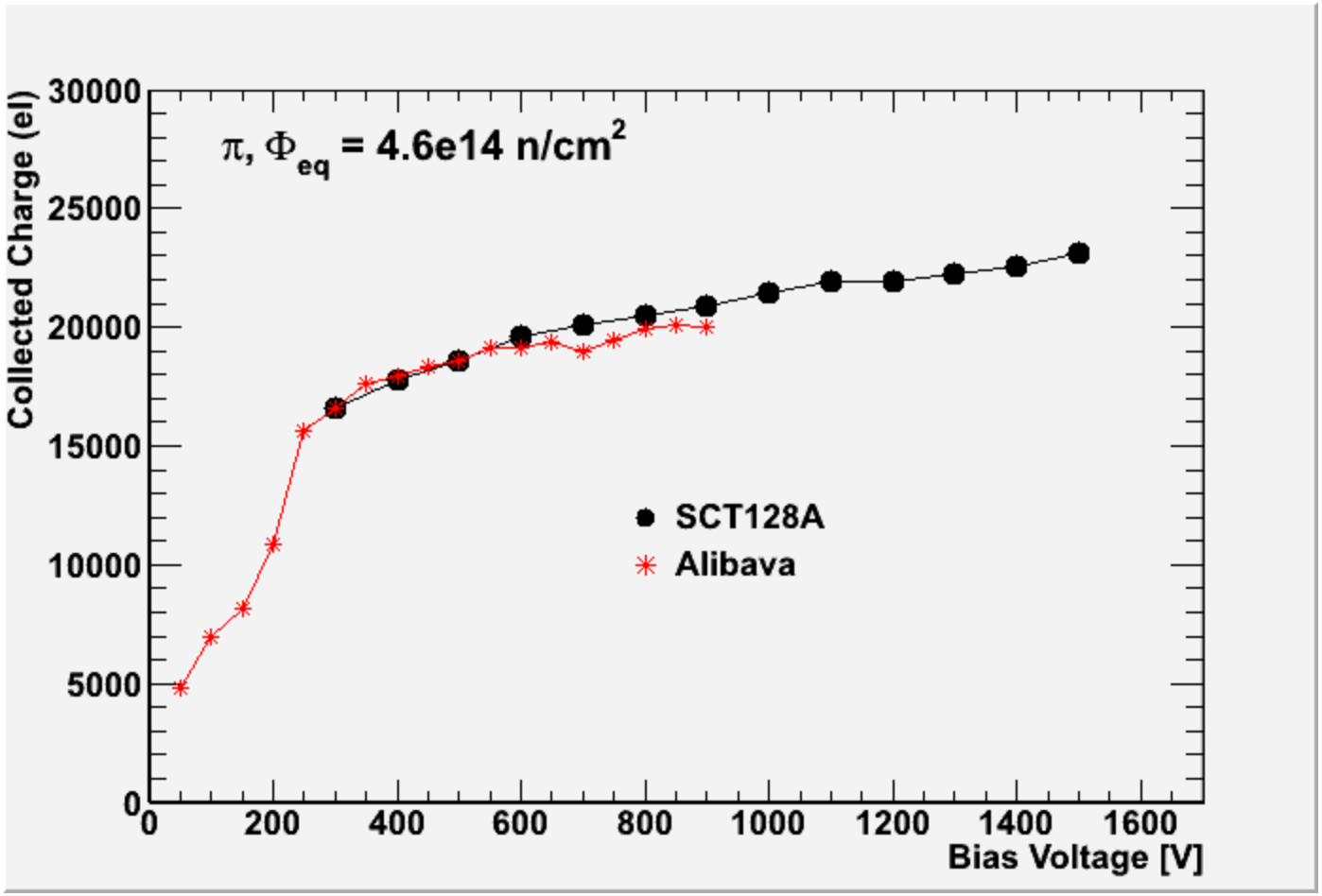


→ low full depletion voltage for 1.8e14 n/cm^2,

- if g_c = 0.017 and V_{fd} before irradiation = 200 V,
  expected minimum V_{fd}: 490 V, 940 V and 2800 V for the three fluences
  (if g_c = 0.013 → V_{fd}: 430 V, 800 V and 2300 V)

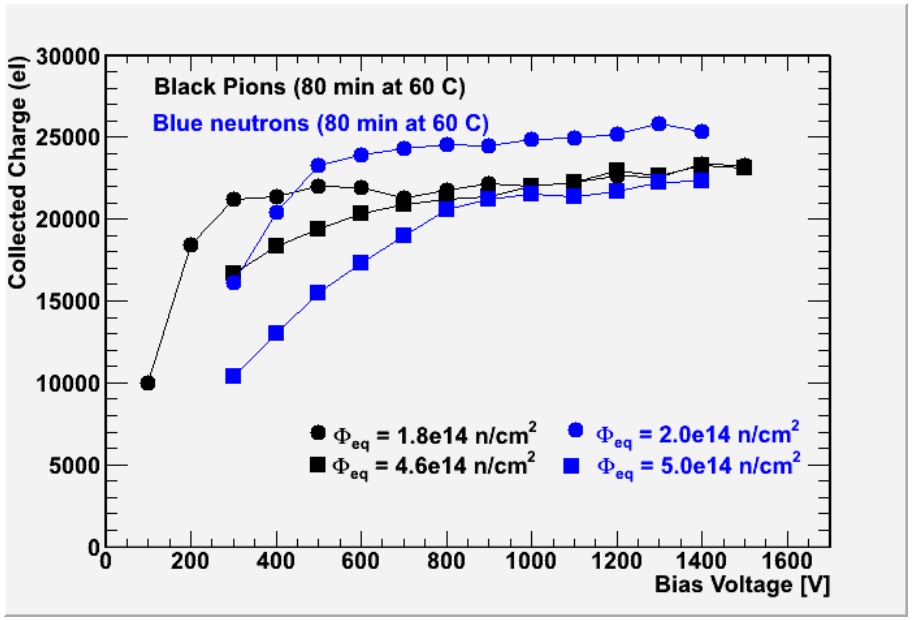
→ no obvious signs of charge multiplication

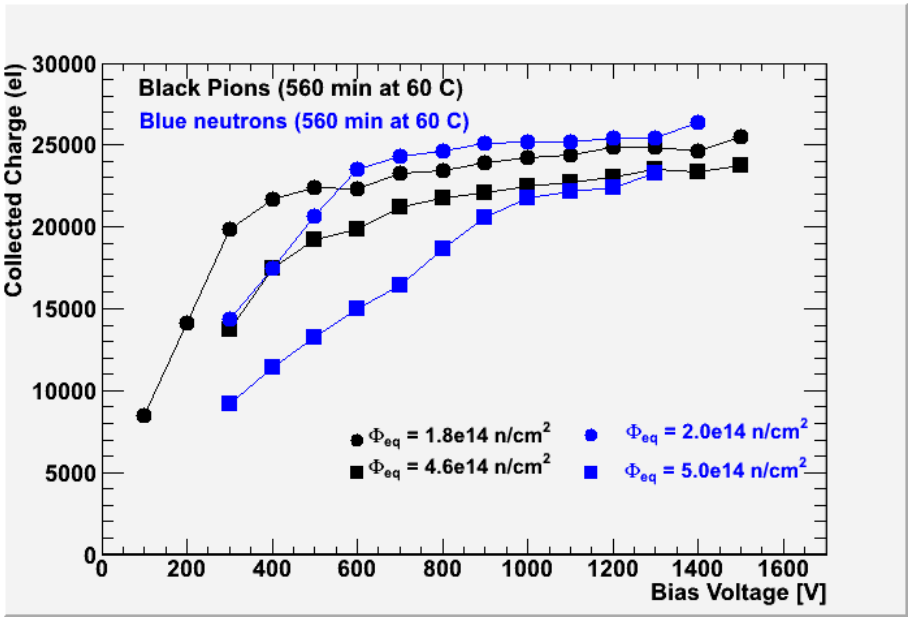
Comparison with ALIBAVA



➔Good agreement

Comparison with HPK detectors irradiated with neutrons



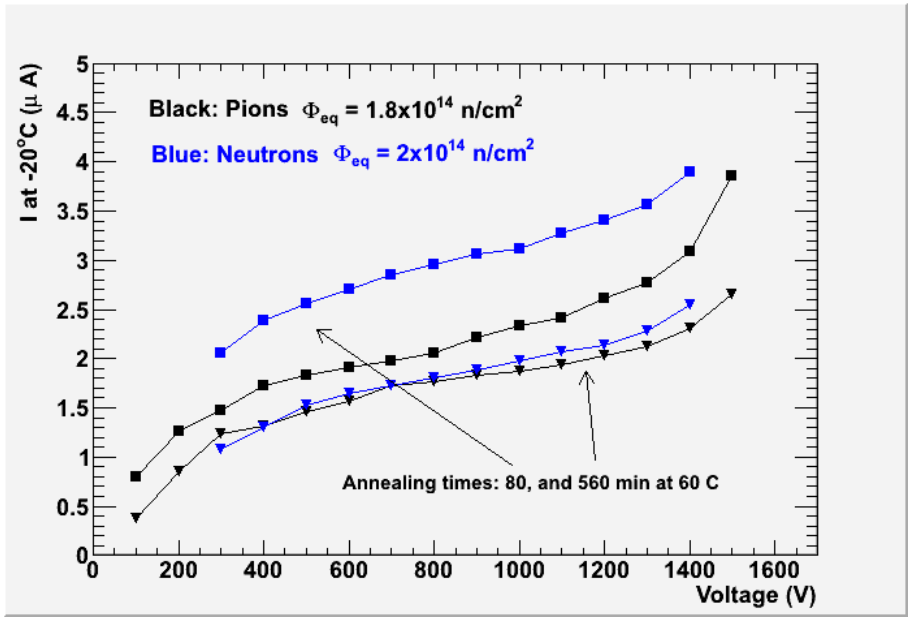


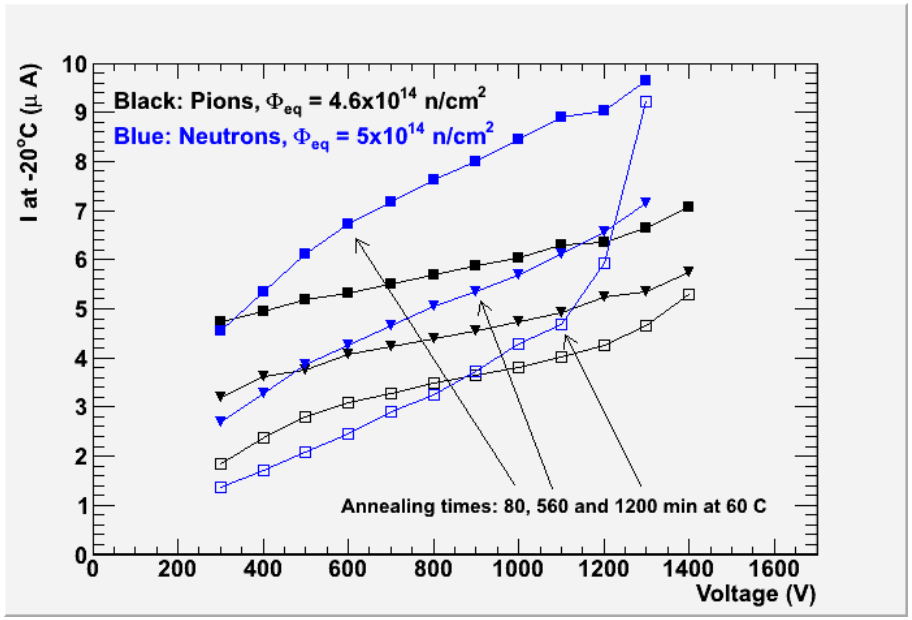
- HPK A07 detectors irradiated with neutrons to 2e14 and 5e14 n/cm^2, measured with SCT128A setup in Ljubljana

- looks that at the lowest fluence better agreement after longer annealing at 60°C
  → space charge annealing during pion irradiation equivalent to time at 60°C:
  ~ 40 min. beneficial (E_i = 1.1 eV) or 11 min. reverse (E_i = 1.3 eV) for Φ_{eq} = 1.8e14 n/cm^2
  ~ 80 min. beneficial (E_i = 1.1 eV) or 48 min. reverse (E_i = 1.3 eV) for Φ_{eq} = 4.6e14 n/cm^2

➔ much higher CCE at low voltages after irradiation with pions compared to neutrons

Leakage current





- Φ_{eq} = 1.8 ·10^{14} n_{eq}/cm^2 :

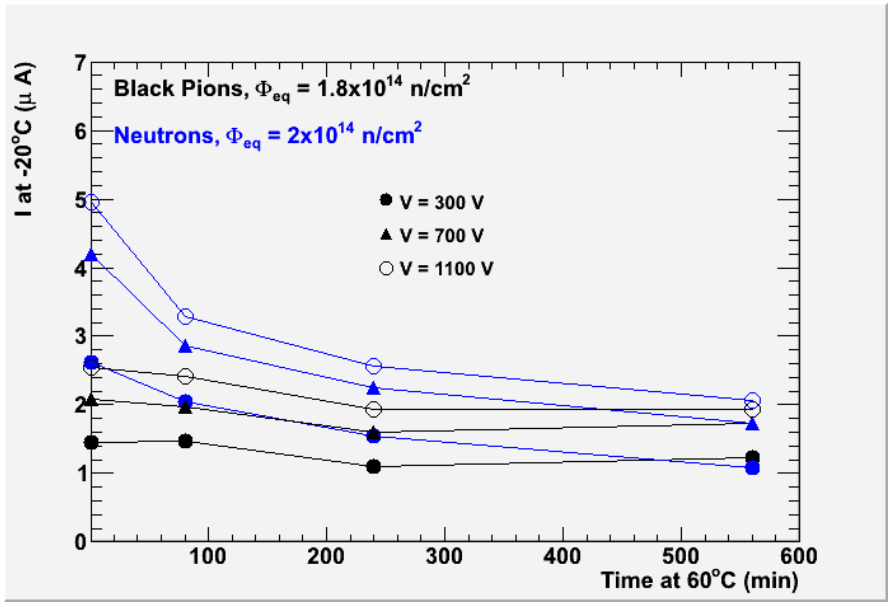
  - irradiation time = 48 h, T = 26 C → ~ 40 minutes at 60 C

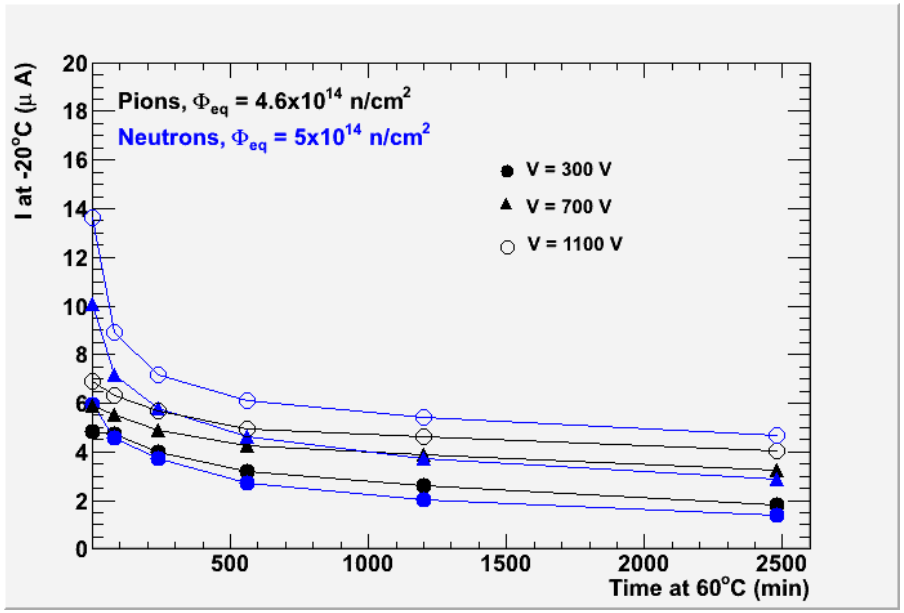
- Φ_{eq} = 4.6 ·10^{14} n_{eq}/cm^2 :

  - irradiation time = 108 h, T = 26 C → ~ 83 minutes at 60 C

(acceleration factor t_{60}/t_{26} for leakage current is 78 if E_i = 1.1 eV)

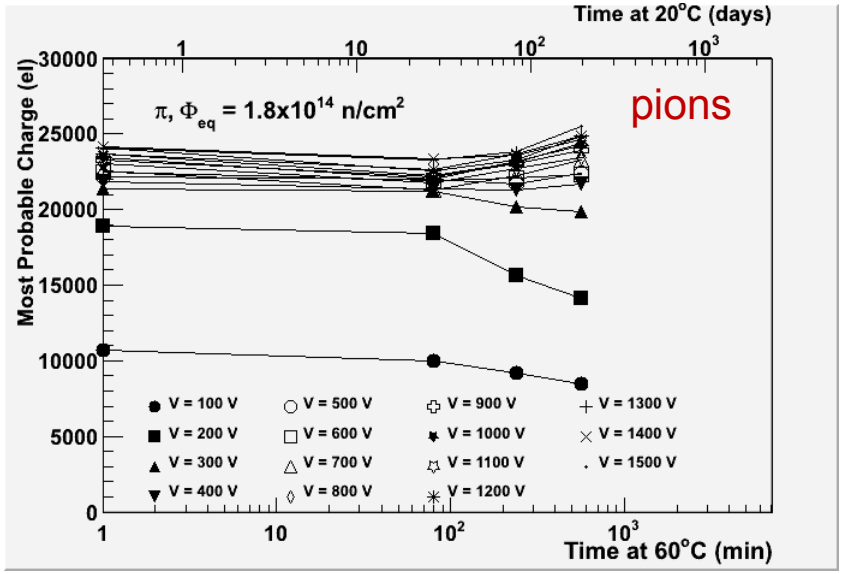
Leakage current

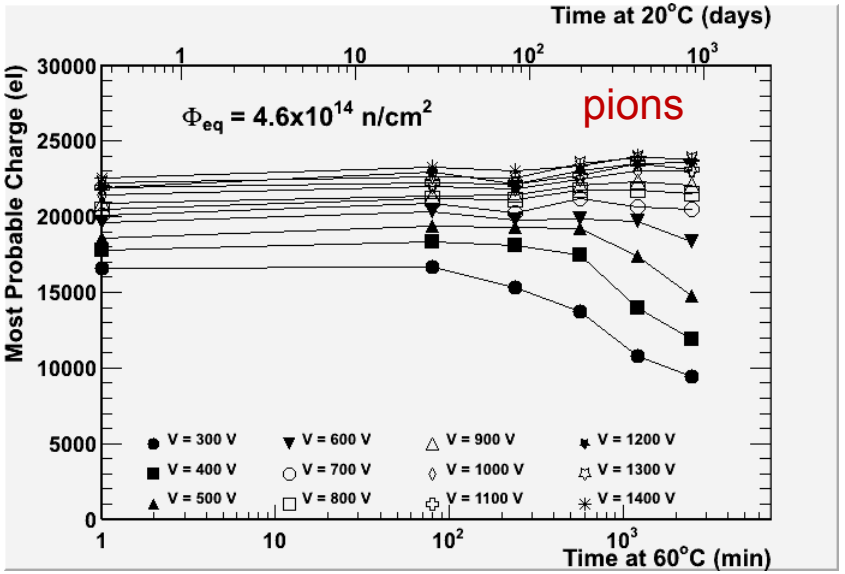




➔agreement between pions and neutrons after sufficient annealing

Collected charge - annealing

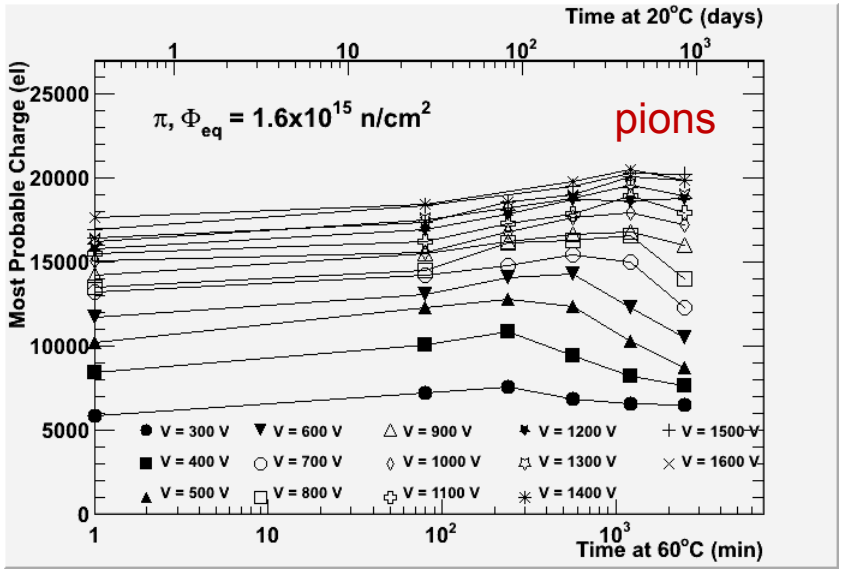




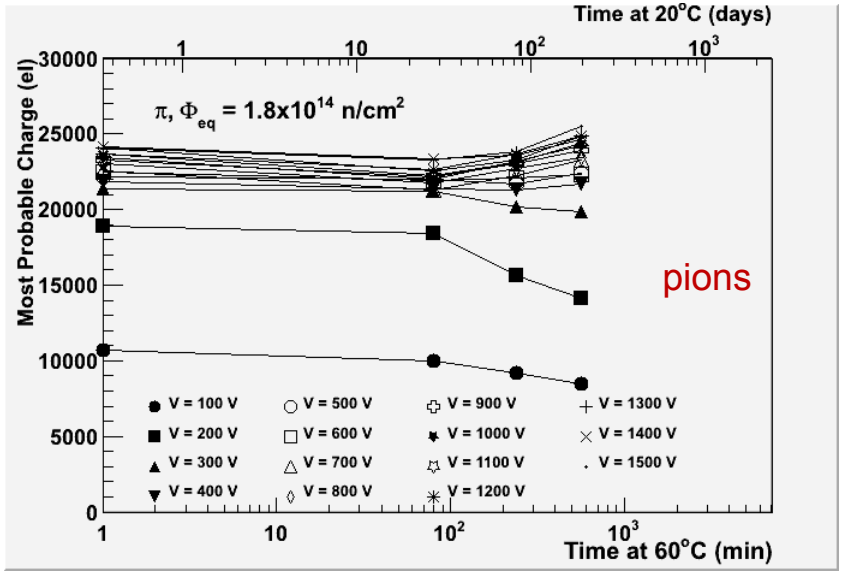
- no obvious signs of charge multiplication

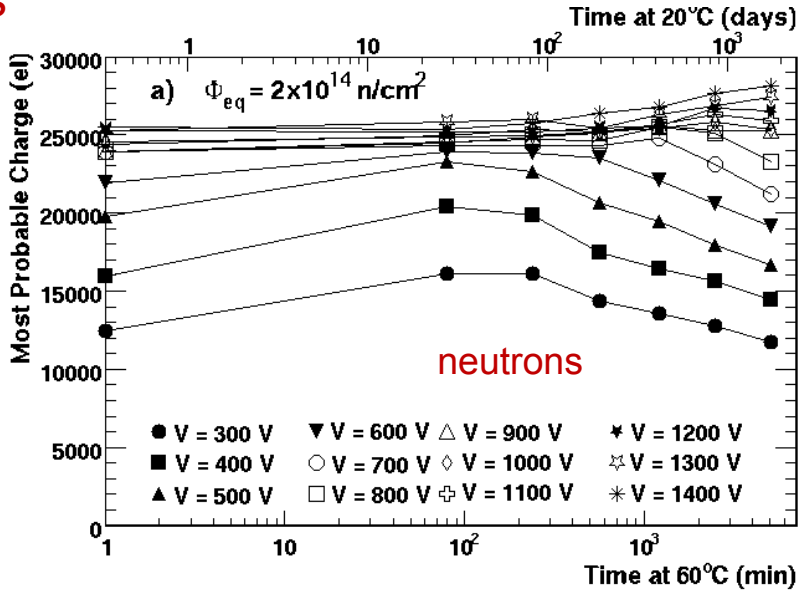
- rise of CCE with annealing time could be due to annealing of trapping time

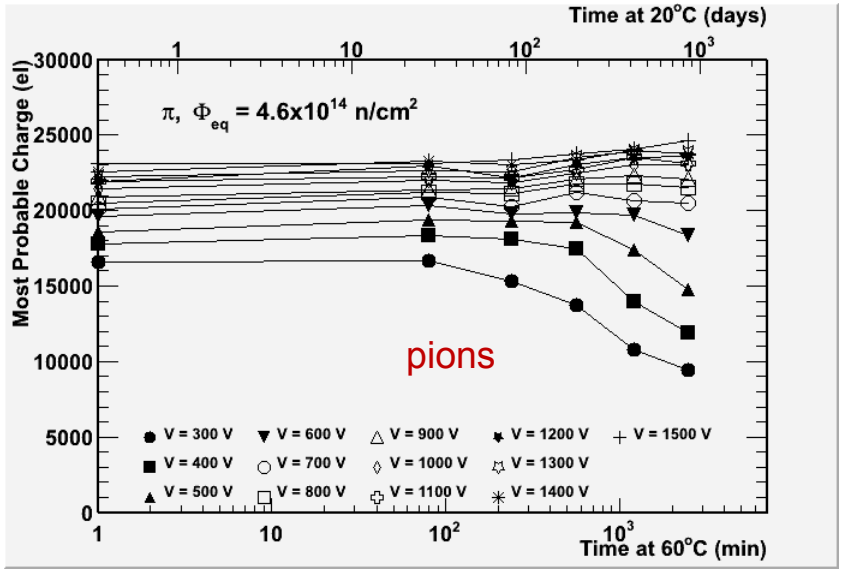
Annealing during irradiation equivalent to (E_i = 1.3 eV): 11, 48 and 172 minutes at 60° C for the three fluences

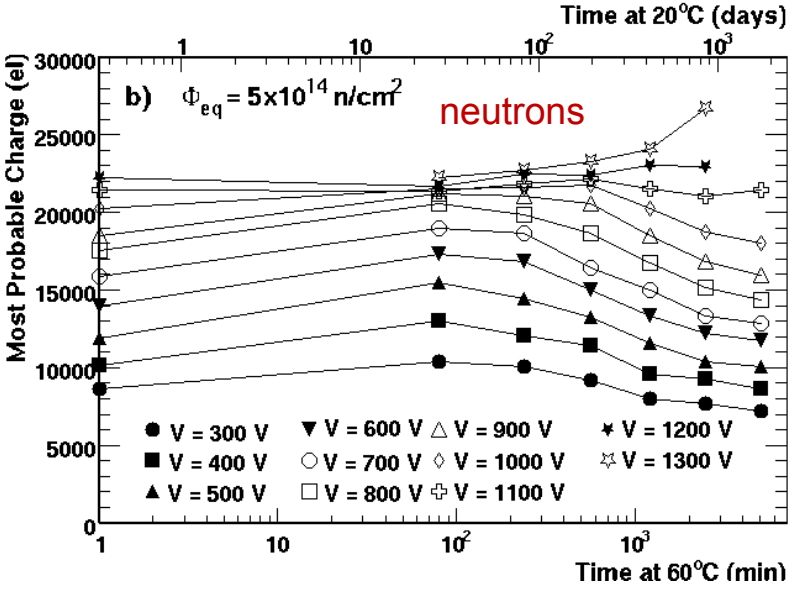


Collected charge – compare with neutrons



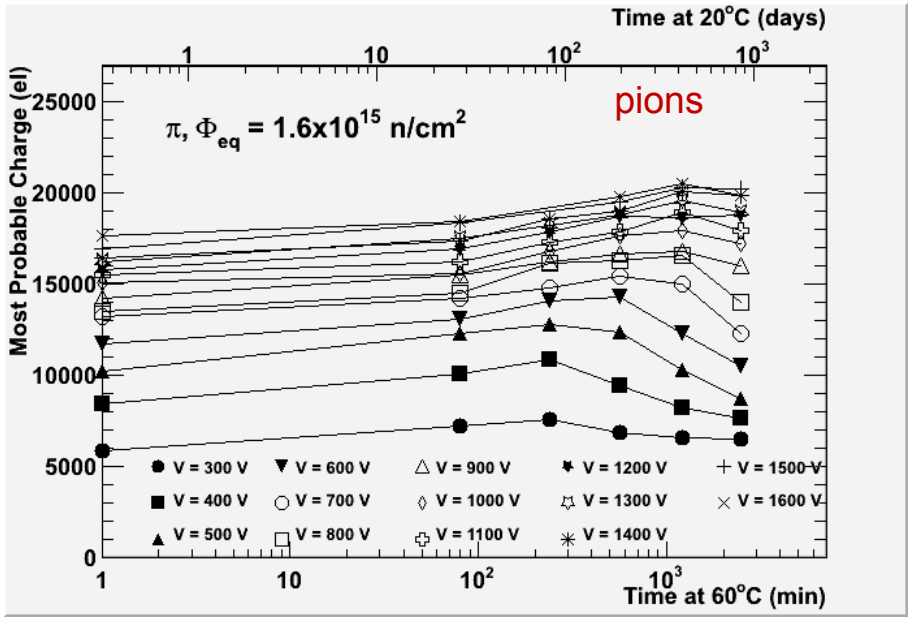




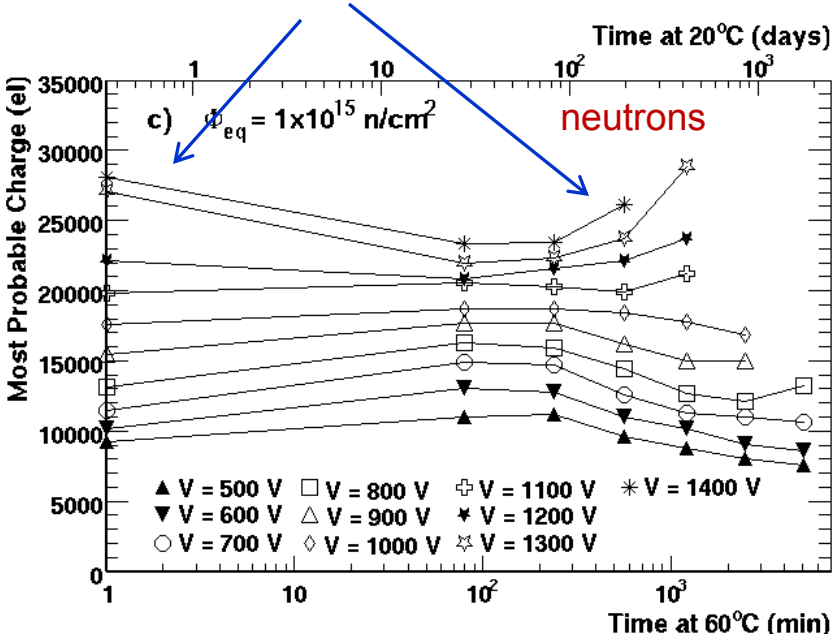


➔Similar behaviour for pions and neutrons at high voltage (except at the highest voltage for neutrons)

Collected charge



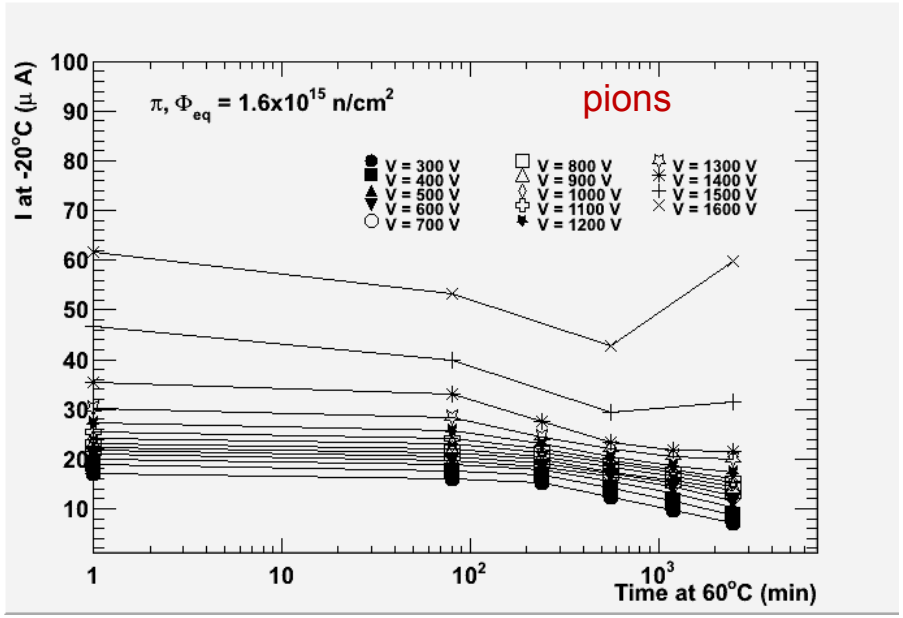
multiplication

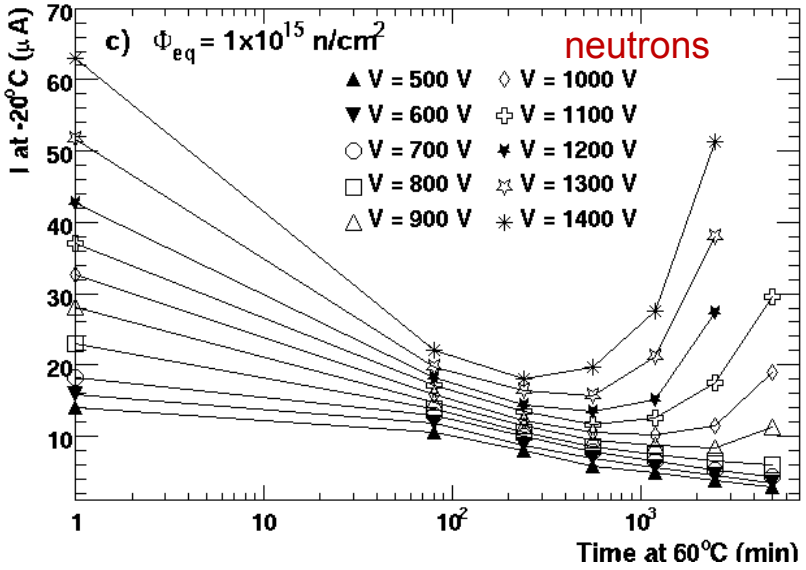


➔signs of multiplication seen for neutrons

→ no large difference between neutrons and pions at low voltage (but neutron fluence lower)

Current

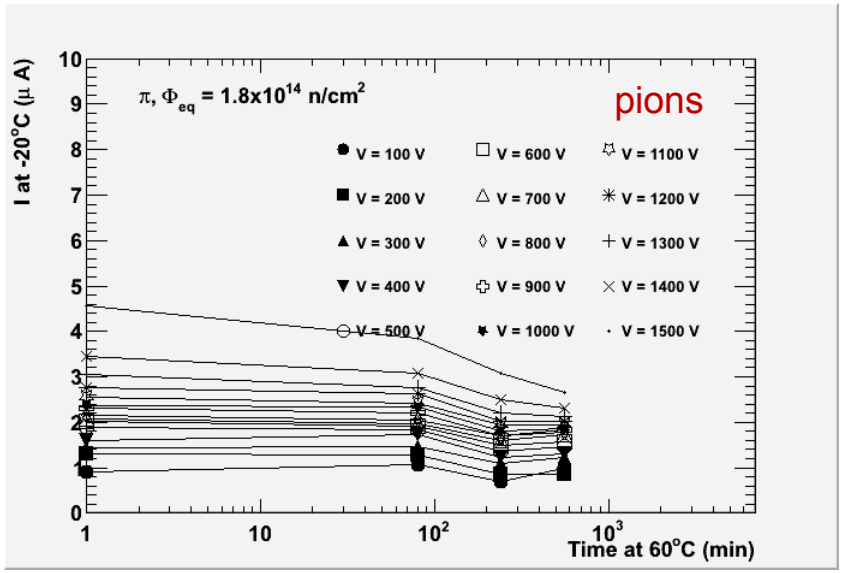


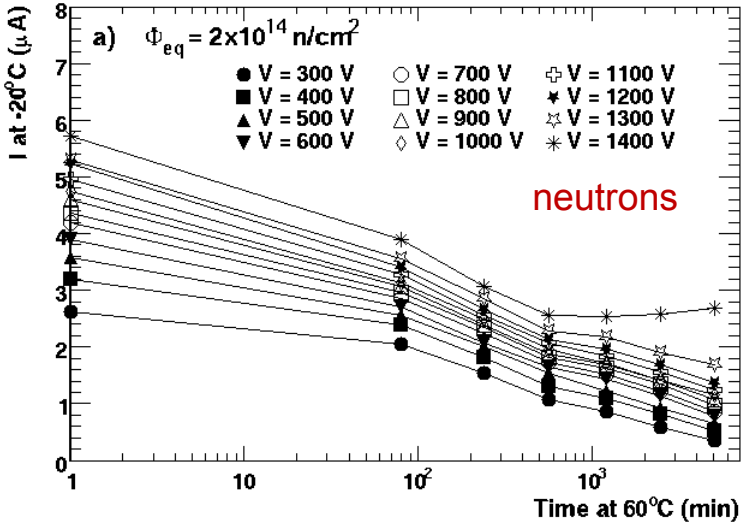


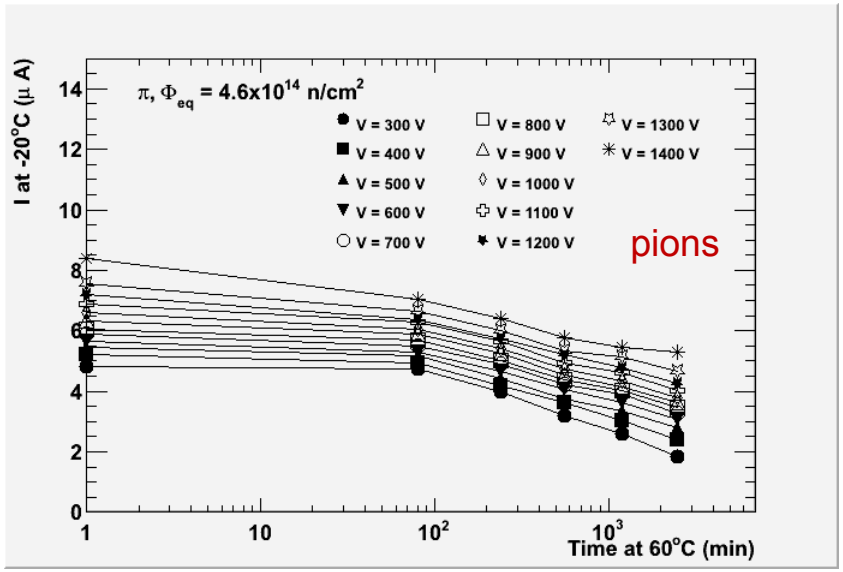
➔ the difference is clearly seen in leakage current:

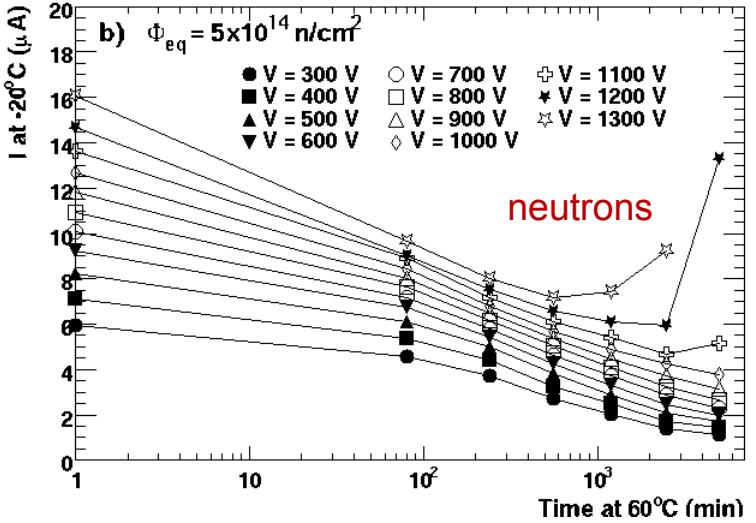
- pions: no (or only small) increase of current with annealing at high voltages

Current: lower fluences

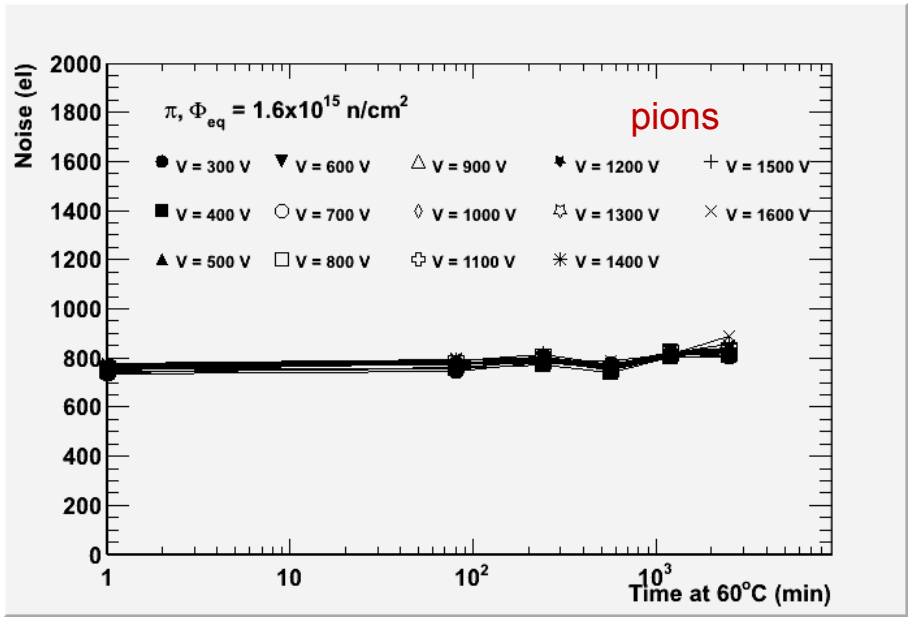


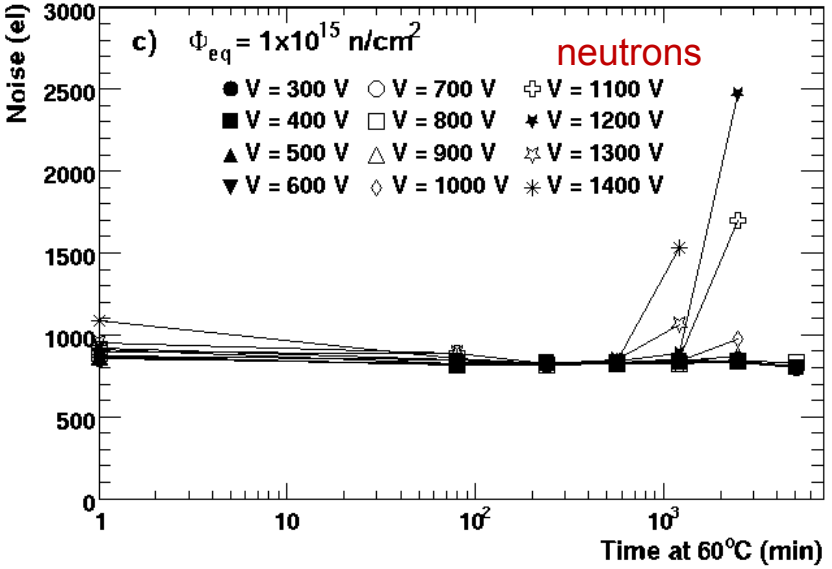






Noise

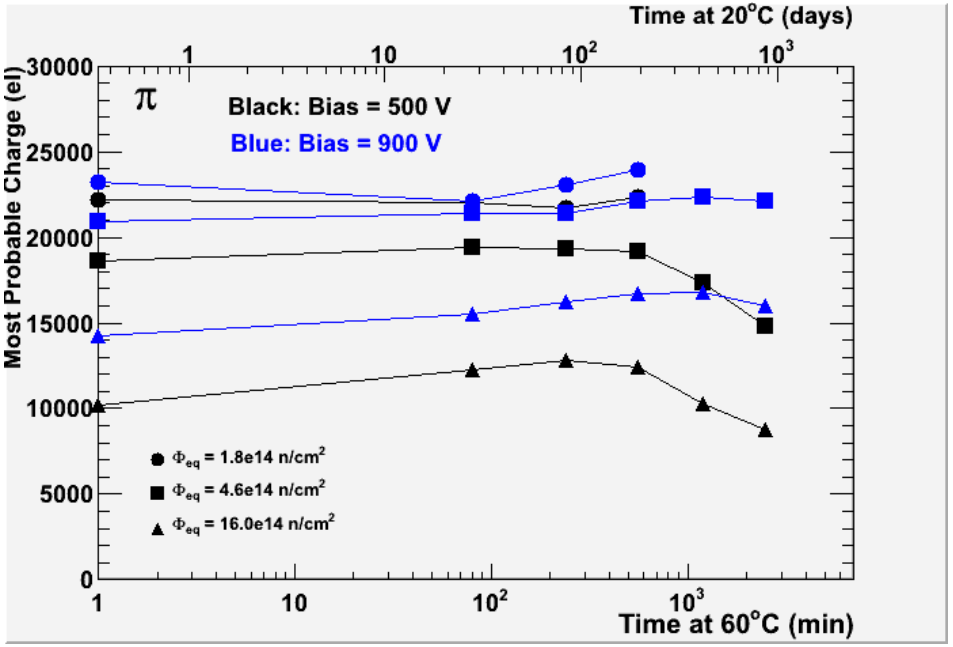




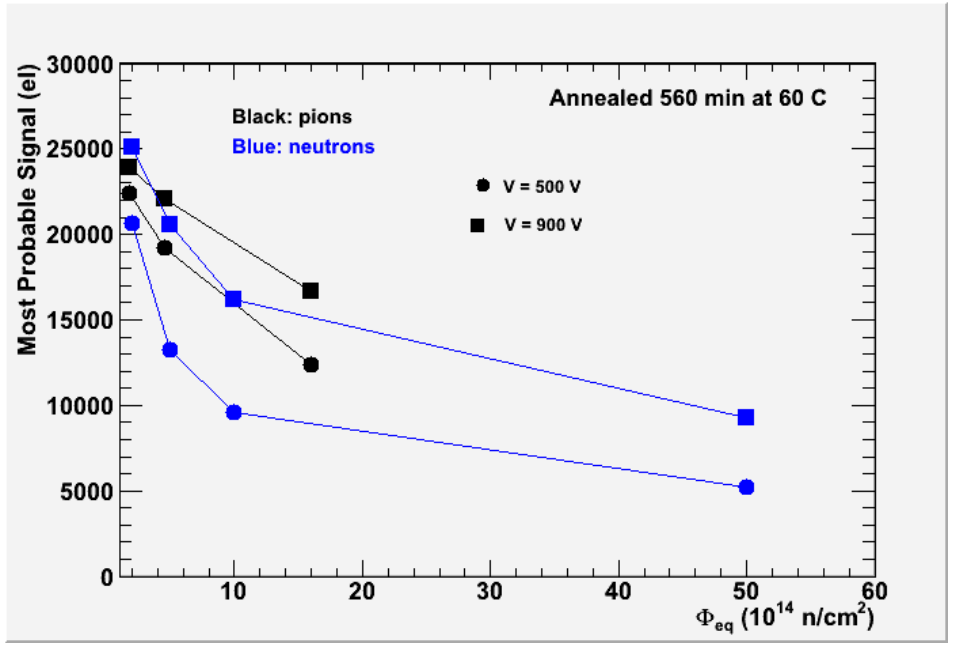
- no increase of noise with annealing time seen for pions

Summary plots

- at 900 V bias reverse annealing not a big problem for these fluences



- at low voltages higher charge collected after irradiation with pions than after neutrons



Conclusions:

Hamamatsu p-type detectors irradiated with pions up to $1.6 \cdot 10^{15}$ n/cm^2

- collected charge at lower voltages and lower fluences higher than after neutron irradiation
  - ➔ smaller space charge density after pion irradiation

- no obvious signs of charge multiplication observed
  - ➔ smaller space charge density ➔ lower el. field ➔ less multiplication

- leakage current in agreement with neutron irradiated detectors after sufficient annealing

- at sufficient bias voltage (900 V) no significant charge collection degradation due to reverse annealing