Annealing effects in irradiated HPK strip detectors measured with SCT128 chip

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

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 non-irradiated detector

Detectors:

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

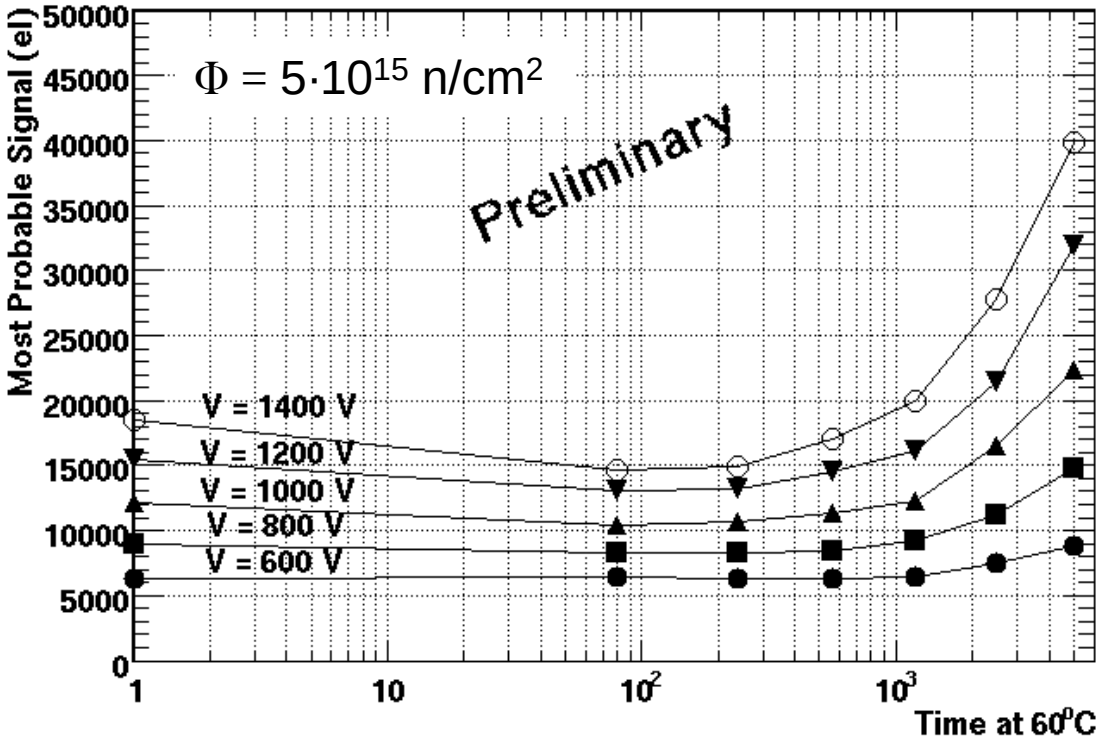
  1) ATLAS07-PSSSSD_Series I, W16, BZ3-P21: $\Phi = 5 \cdot 10^{15}$ n/cm^2
  2) ATLAS07-PSSSSD_Series I, W22, BZ3-P3: $\Phi = 1 \cdot 10^{15}$ n/cm^2

- detectors irradiated with neutrons in reactor in Ljubljana

Motivation

- large rise of collected charge with annealing time at high bias voltage measured with detector (ATLAS07A, Z3, W44) irradiated to $5 \cdot 10^{15}$ n/cm^2

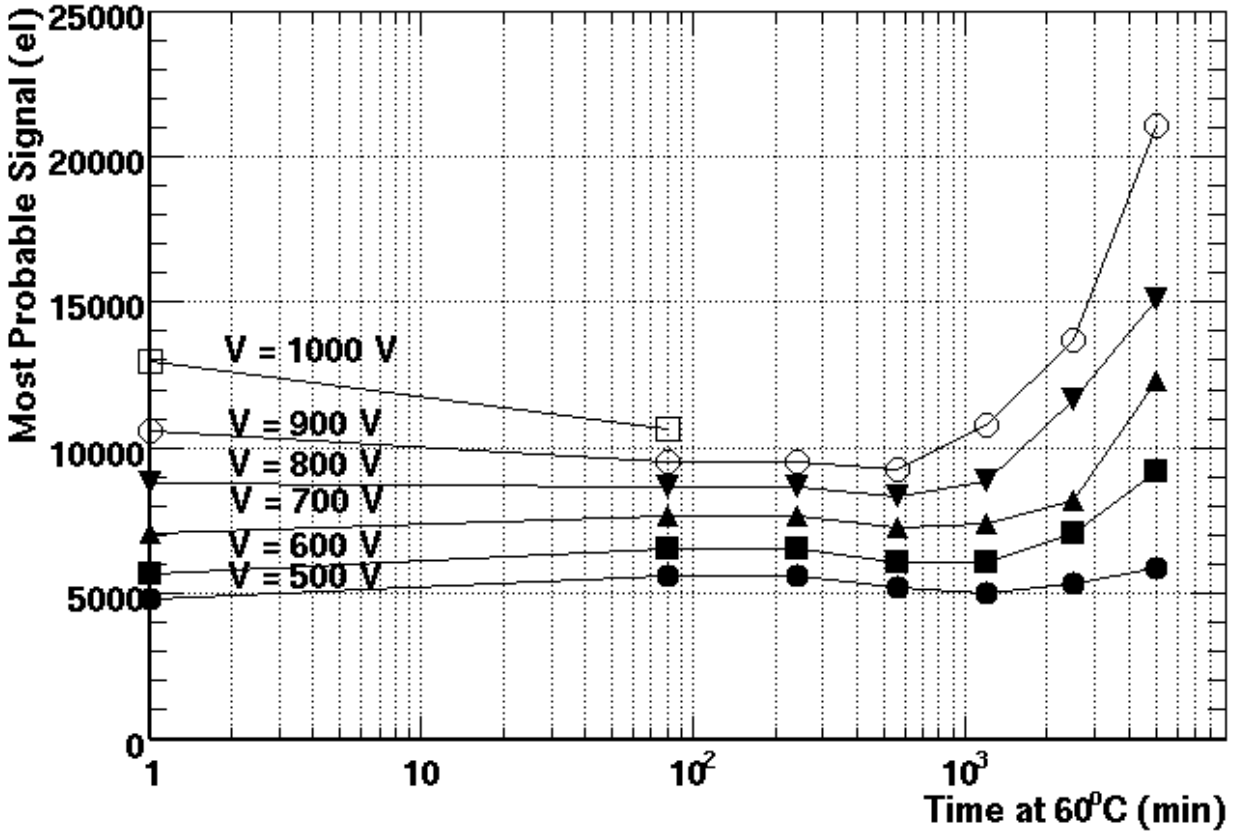
Plot showed at the last RD50 workshop at CERN:



➔ repeat this measurement with new detector and new SCT128 chip

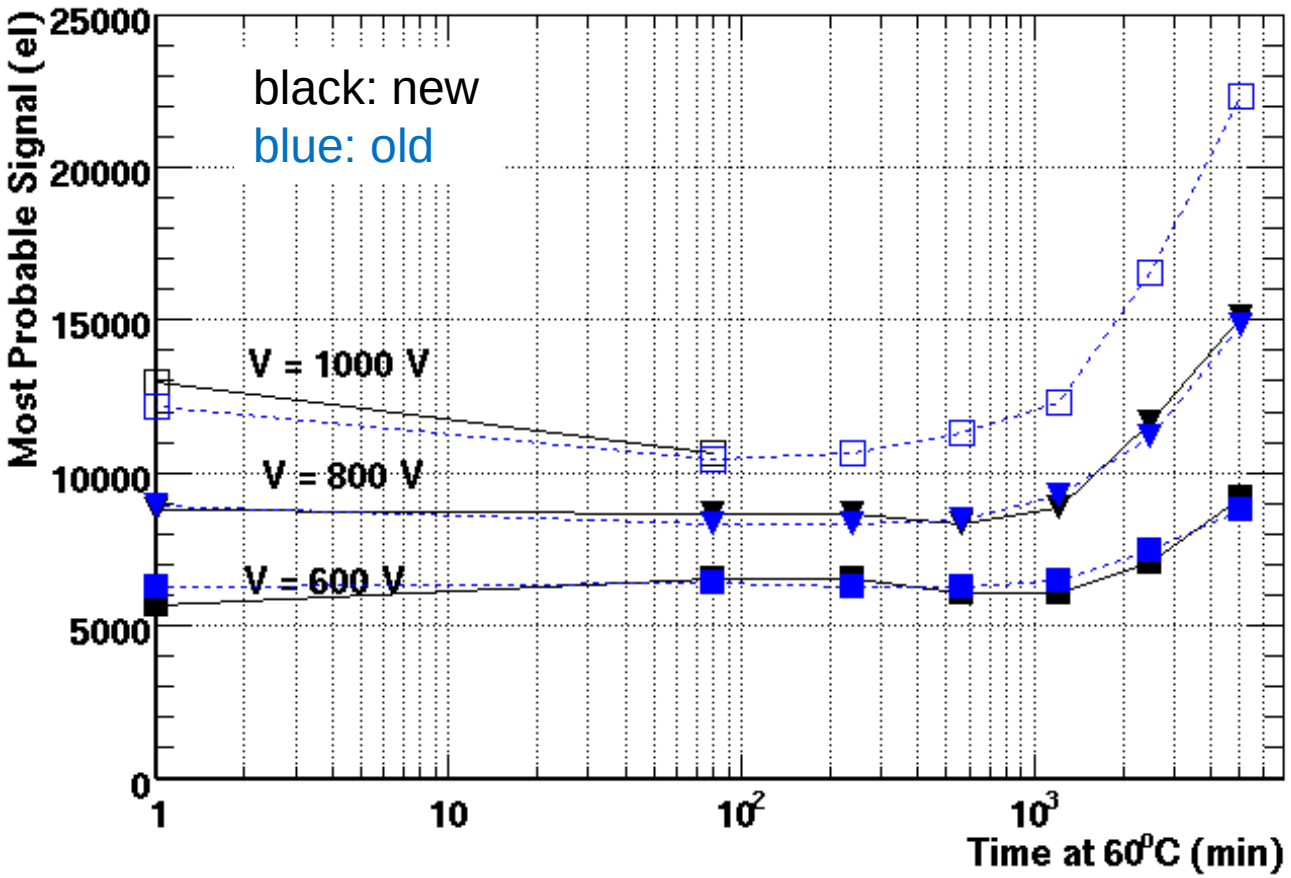
$\Phi = 5 \cdot 10^{15}$ n/cm^2, MPV vs time, new measurement

- because of problems with test board, annealing measurements made only up to 1000 V.



➔rise of MPV with annealing time confirmed

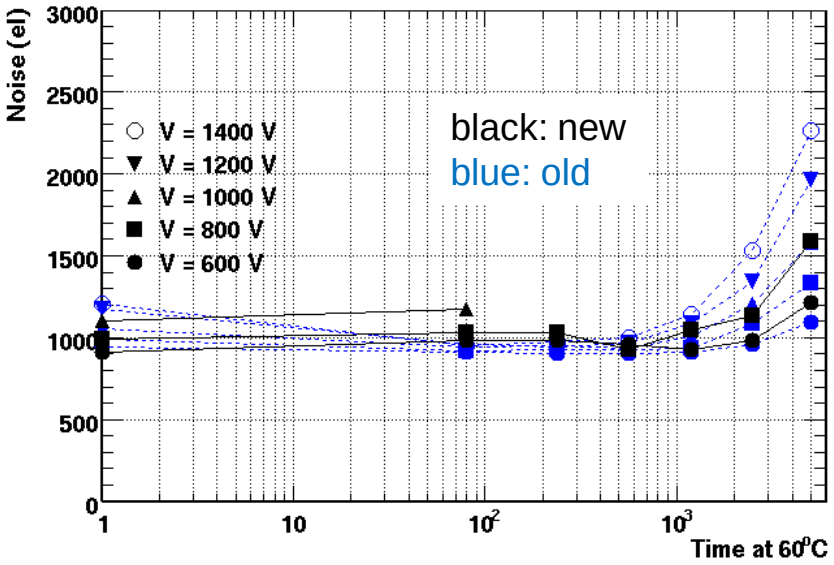
$\Phi = 5 \cdot 10^{15}$ n/cm^2, comparison with old measurement



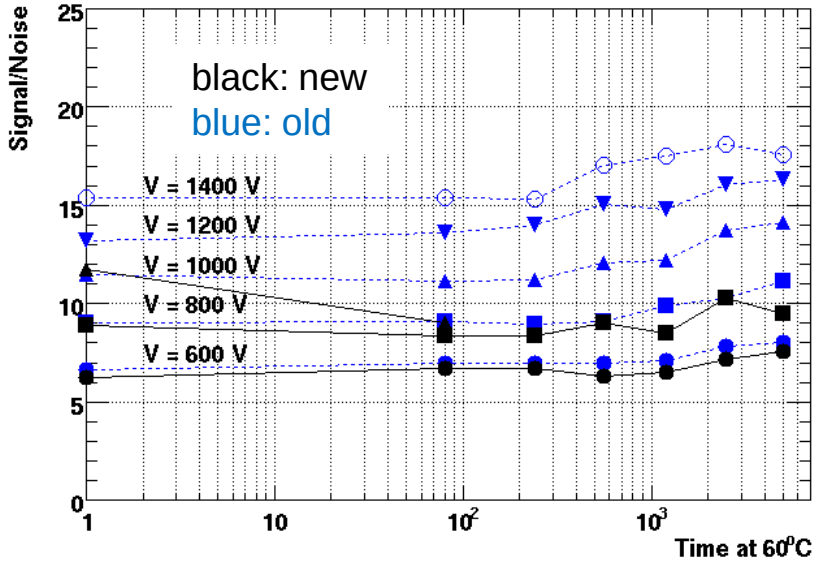
➔ Good agreement with first measuremnt

$\Phi = 5 \cdot 10^{15}$ n/cm^2, comparison with old measurement

Noise:



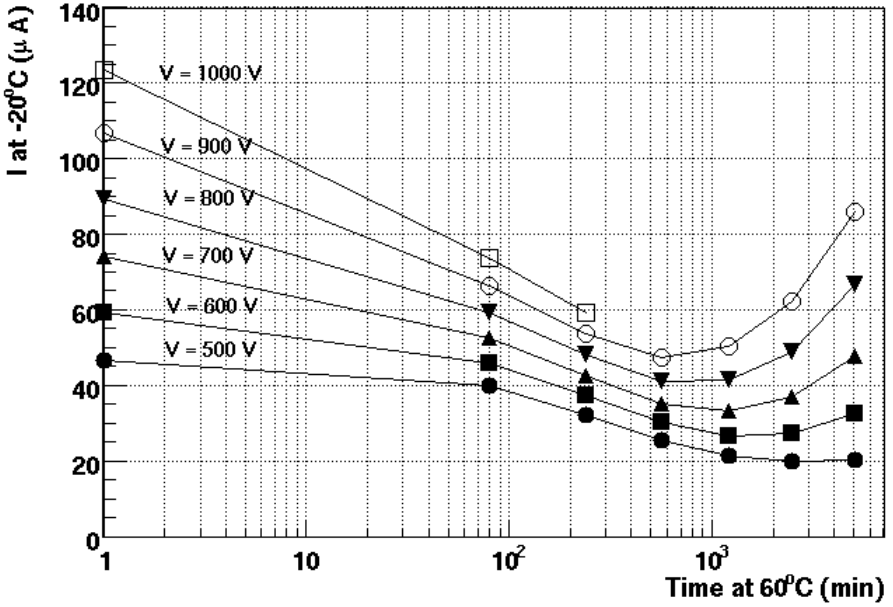
Signal/Noise:



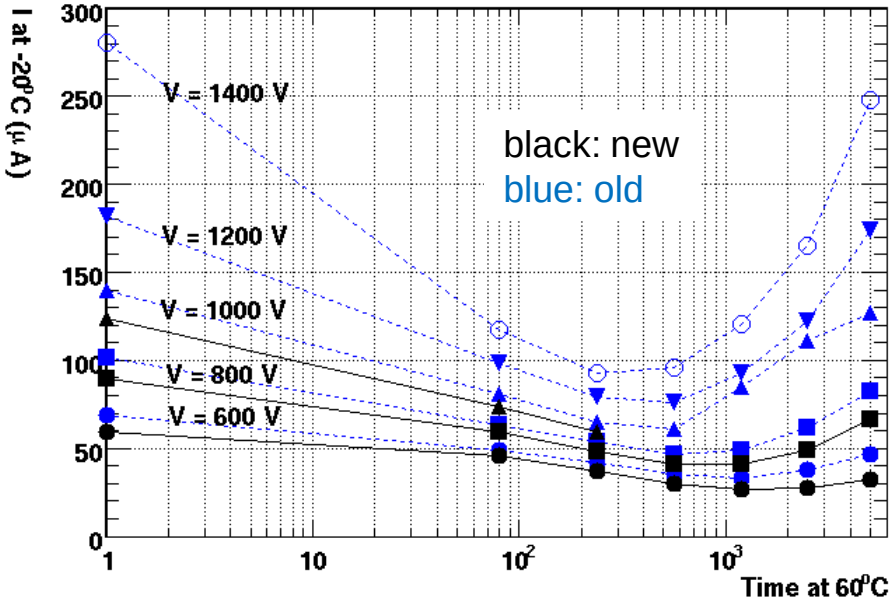
$\Phi = 5 \cdot 10^{15}$ n/cm^2, current:

New measurement:

➔ rise of leakage current with annealing time

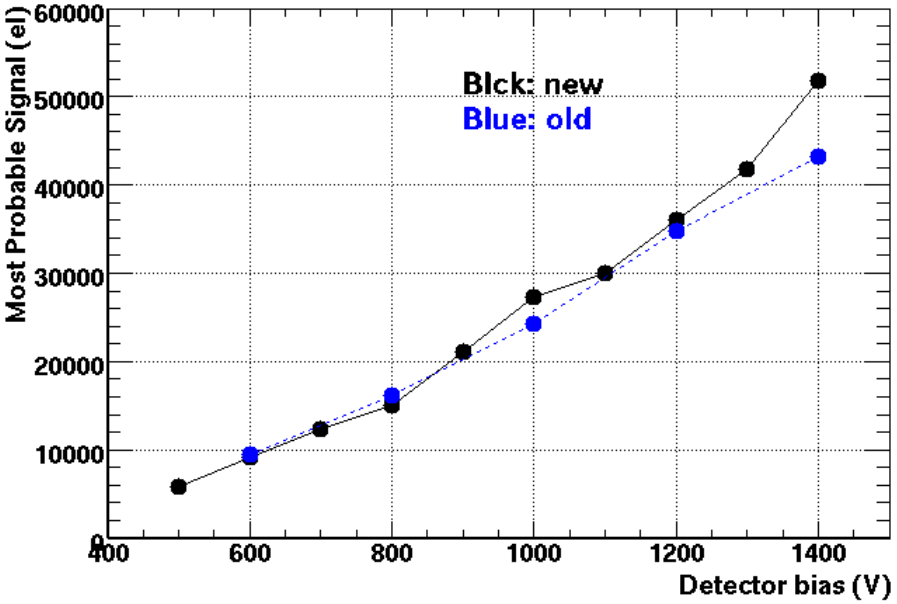


➔ Good agreement with previous measuremenet

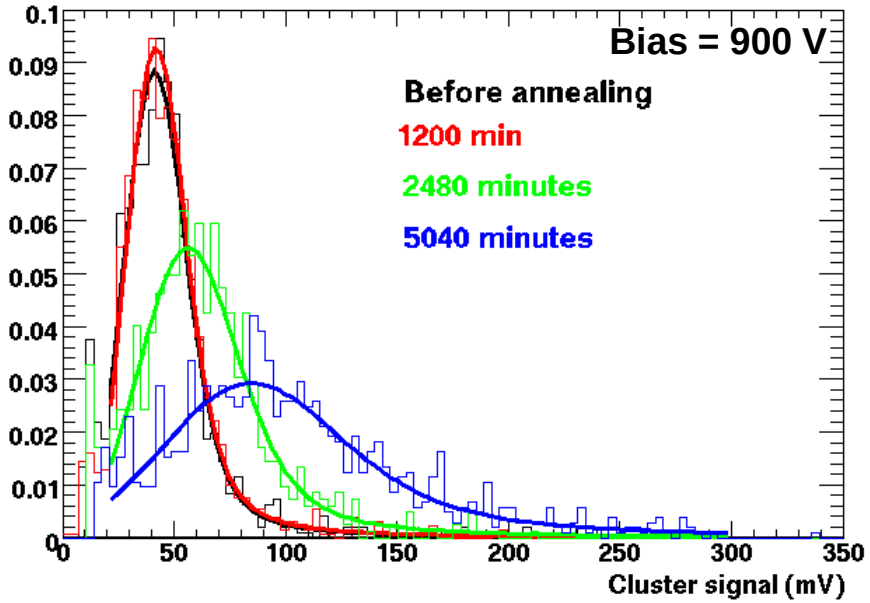


$\Phi = 5 \cdot 10^{15}$ n/cm^2:

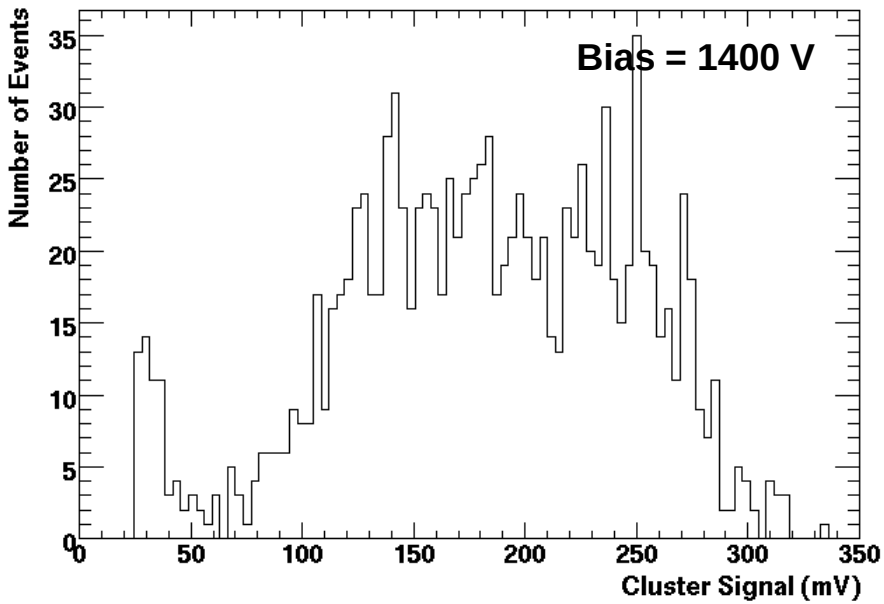
- problem on test board was fixed, measurements up to 1400 V
- good agreement with old data also at high voltage
- at high voltages spectra not Landau →multiplication



Bias = 900 V,Φ = 5e15, Annealing at 60 C

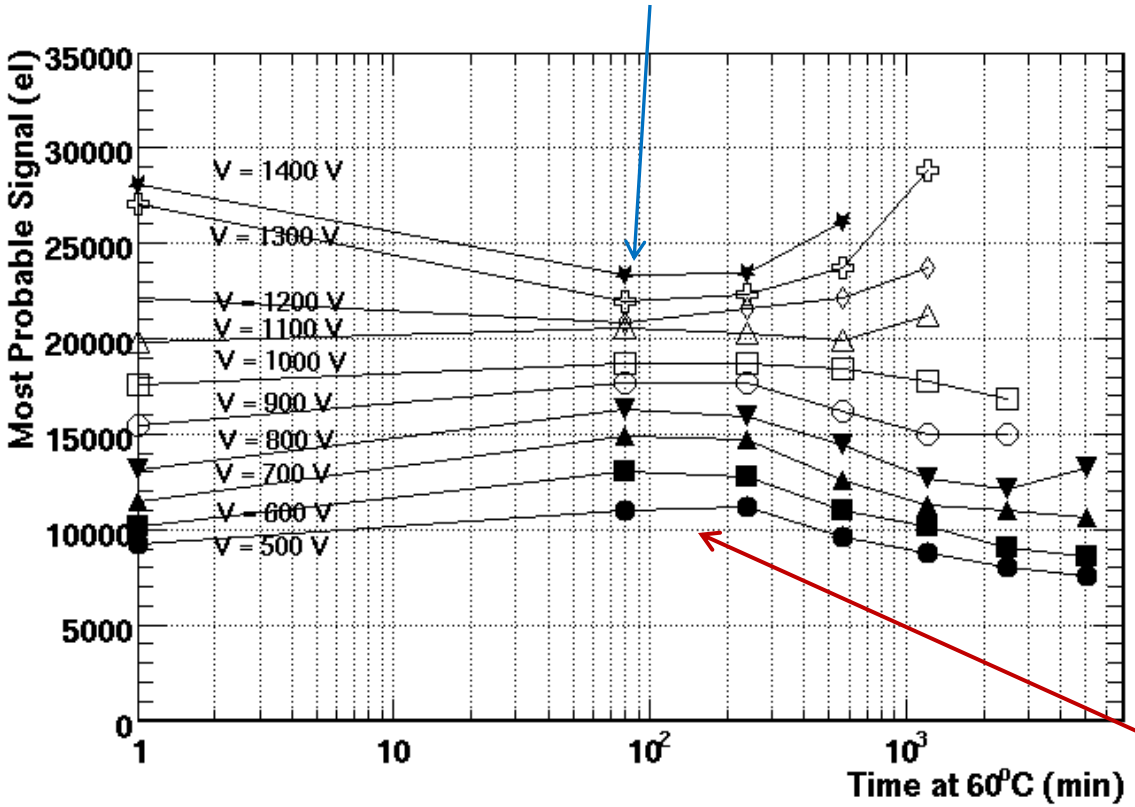


Bias 1400 V,Φ = 5e15, Annealed



Measurements with detector irradiated to Φ_{eq} =1·10^{15} n/cm^2

Space charge anneals, electric field drops:
high voltage: less multiplication ➔ less charge



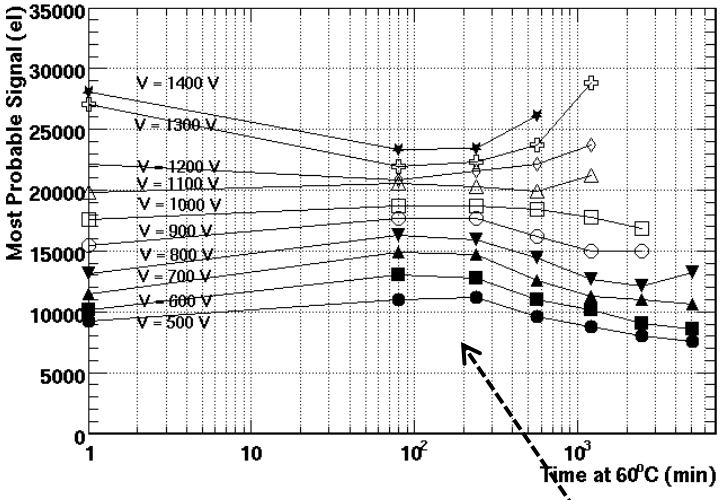
lower voltages: larger depleted region, less trapping
➔ more charge

➔ rise of MPV at long annealing times at high voltage:
space charge concentration rises => higher electric field => more multiplication

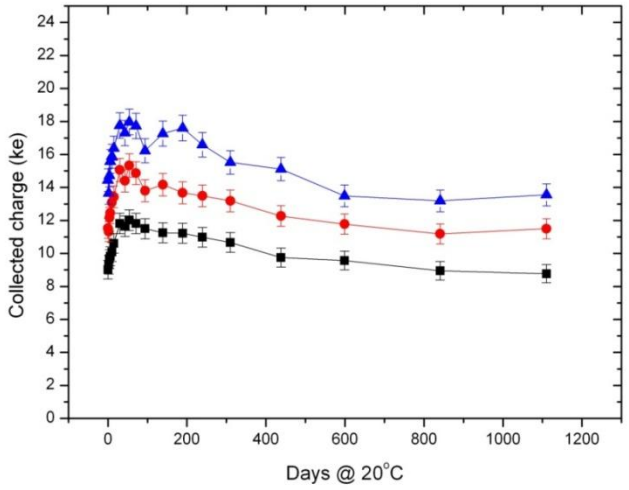
➔ the highest voltage at which measurements can be taken falls with increasing annealing time: too much multiplication

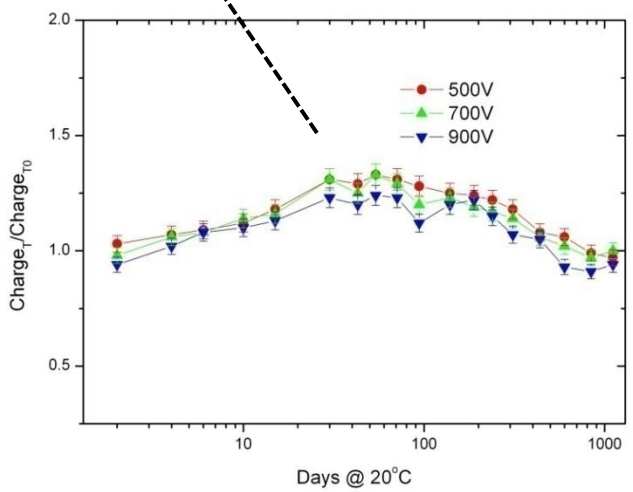
$\Phi = 1 \cdot 10^{15}$ n/cm^2

➔ agreement with Liverpool measurements if annealing acceleration factor $t_{60}/t_{20} \sim 500$
→ 1000 days at 20 C ~ 3000 minutes at 60 C



Plots showed by G. Casse at Trento 2010 workshop:

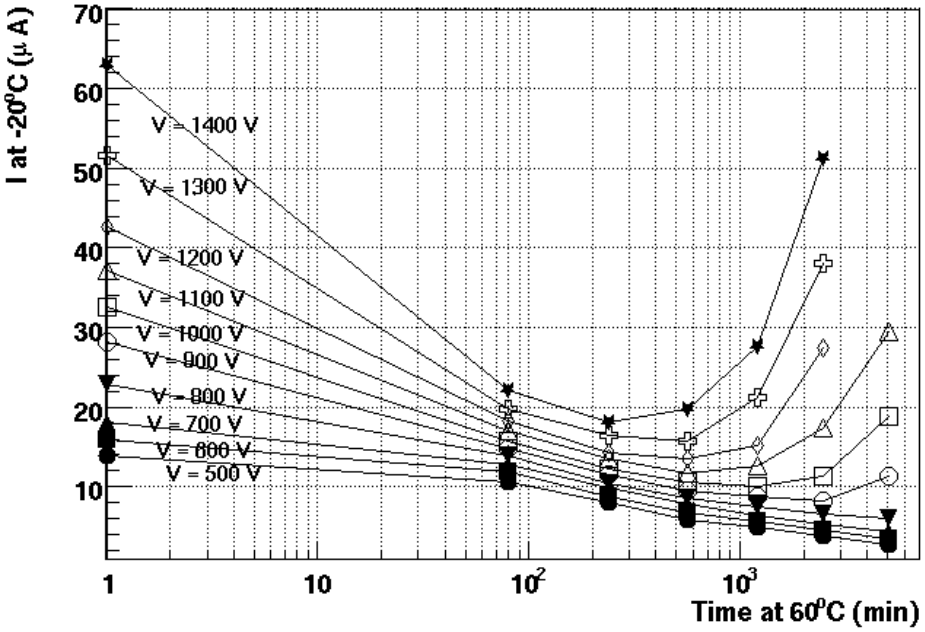


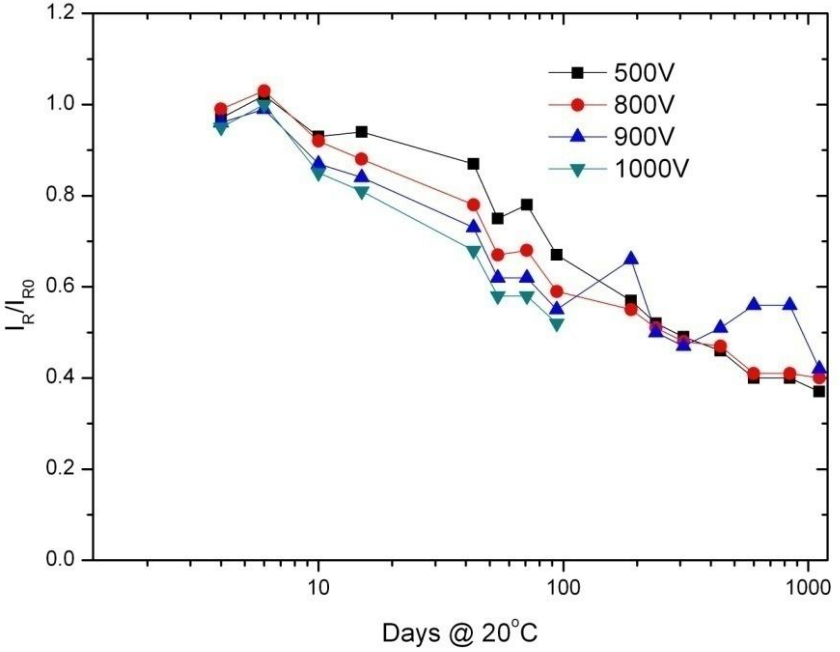


Φ_{eq} =1·10^{15} n/cm^2, Current:

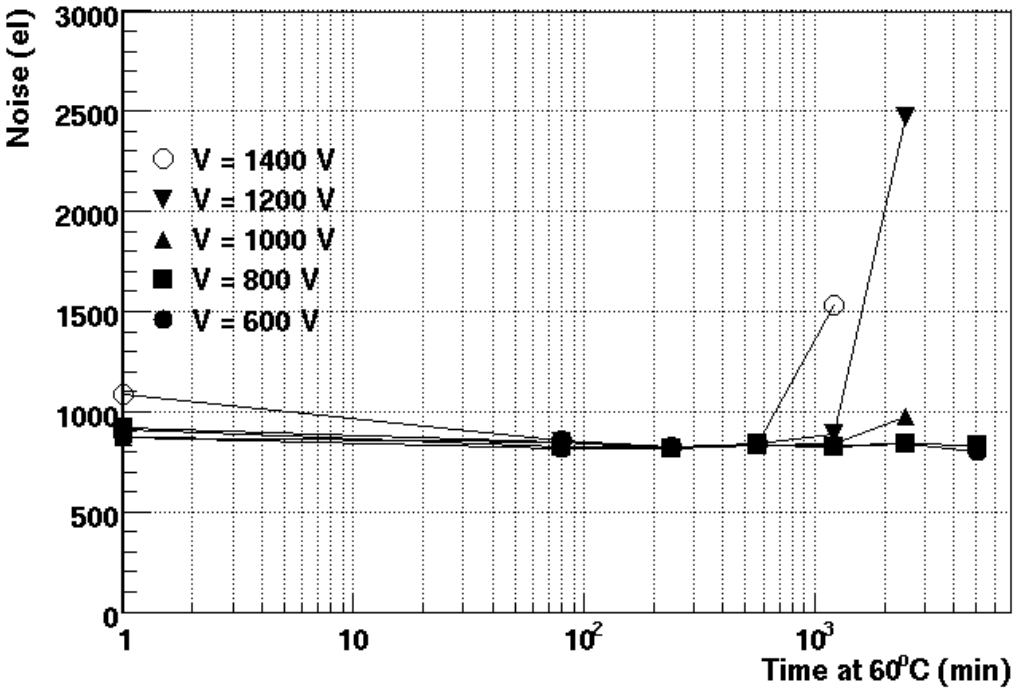
➔ increase of current with annealing at high voltages

➔ agreement with Liverpool measurements





Φ_{eq} =1·10^{15} n/cm^2, Noise:

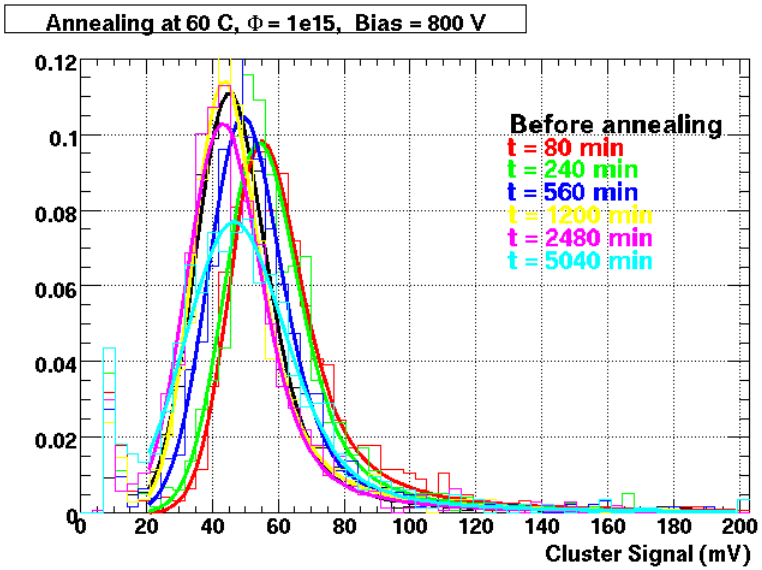


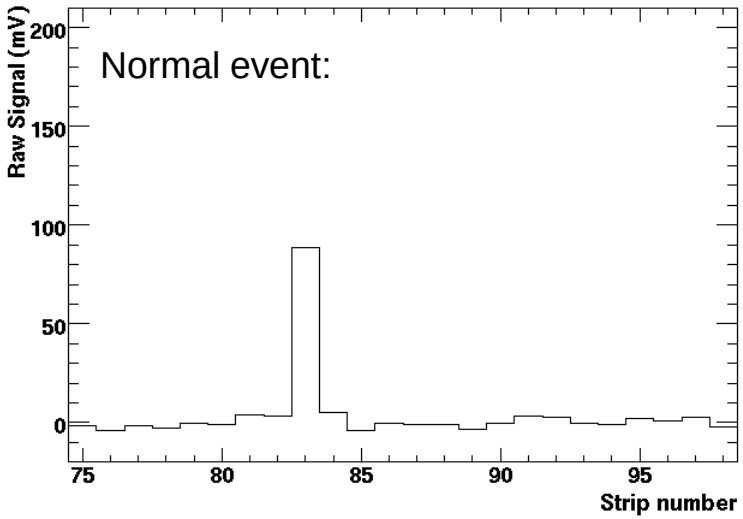
➔ after certain annealing time sharp increase of noise at bias above 800 V

➔ signal becomes very unstable, measurements not possible at this or higher voltage any more

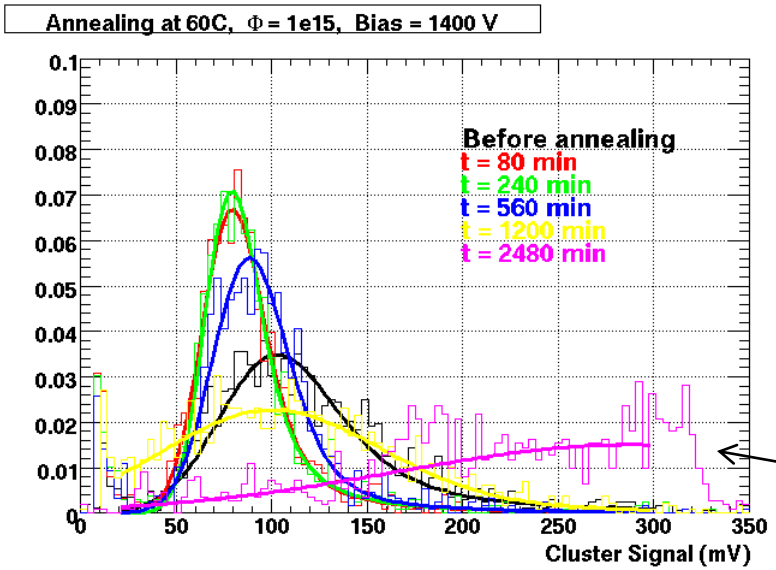
Φ_{eq} =1·10^{15} n/cm^2

Bias = 800 V:

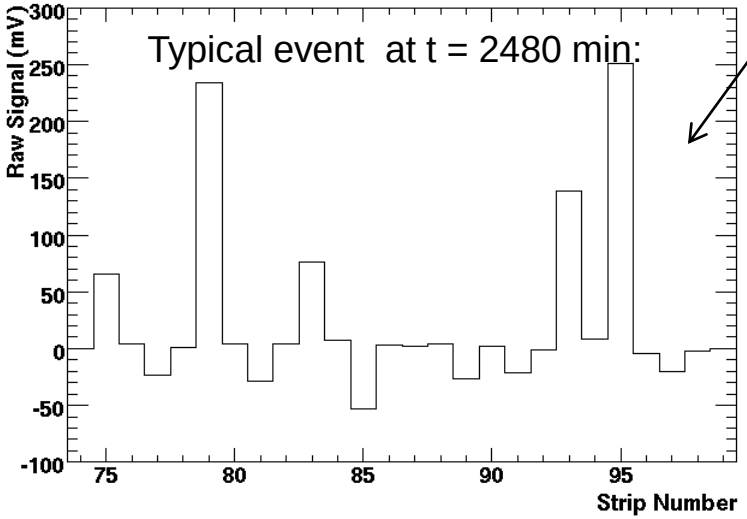




Bias = 1400 V:

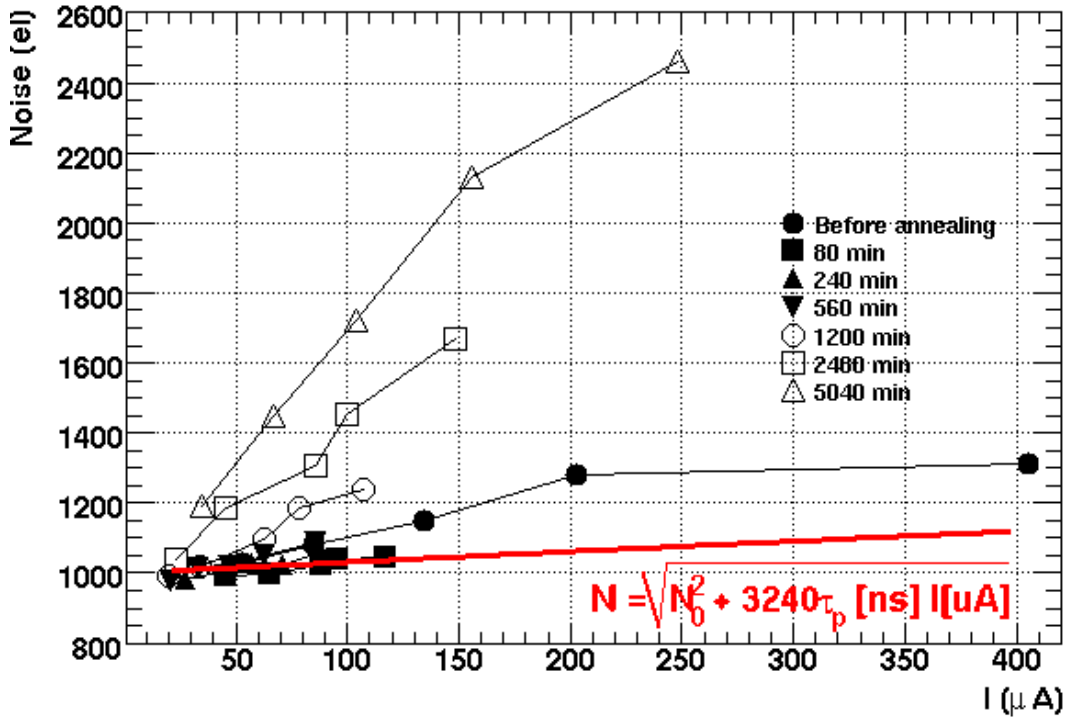


Not used



$\Phi_{eq}=5\cdot10^{15}$ n/cm^2

- noise vs. current, measured at different annealing times



➔at same current higher noise measured in more annealed detector

→ after annealing: more multiplication, larger noise at same current

→ if multiplication not large noise scales with current as expected

Φ_{eq} =5·10^{15} n/cm^2, anneald for 5040 min.

- distribution of hits measured in dedicated noise run (no ^{90}Sr source):

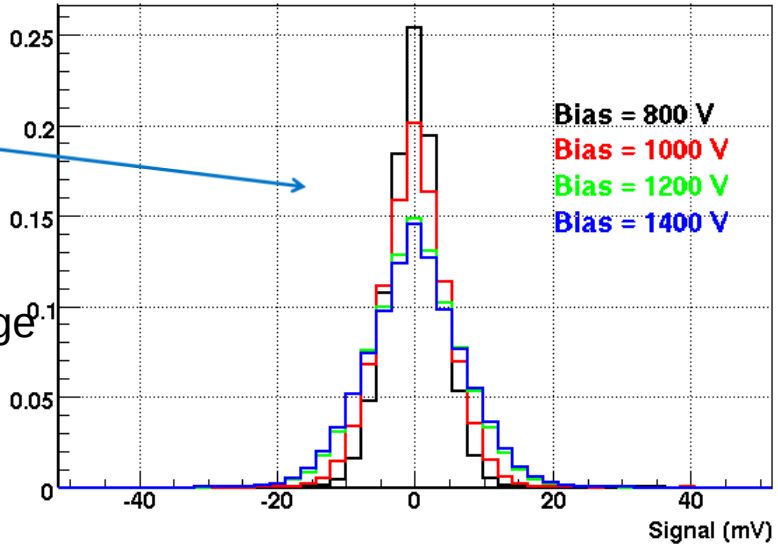
→ pedestals and common mode subtracted

- cumulative distribution of noise → measures probability to find a noise hit above given voltage

→ no significant change of shape with bias

- calculated from fit of Landau + Gauss

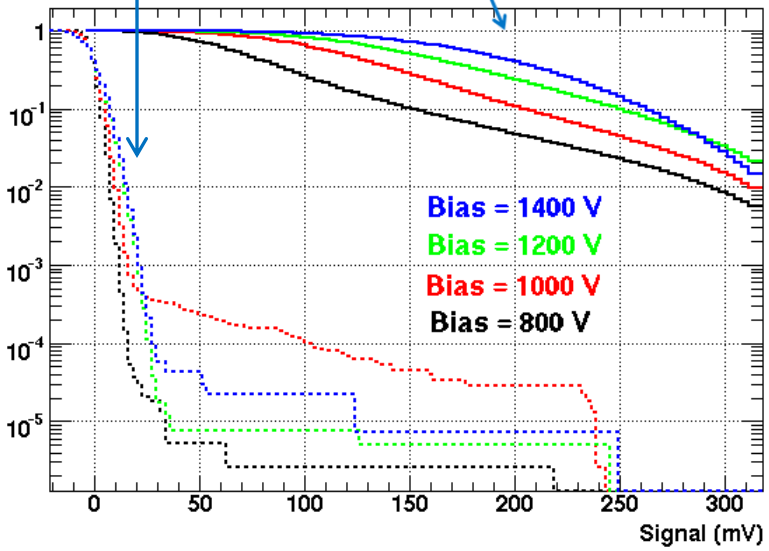
→ estimate of signal efficiency

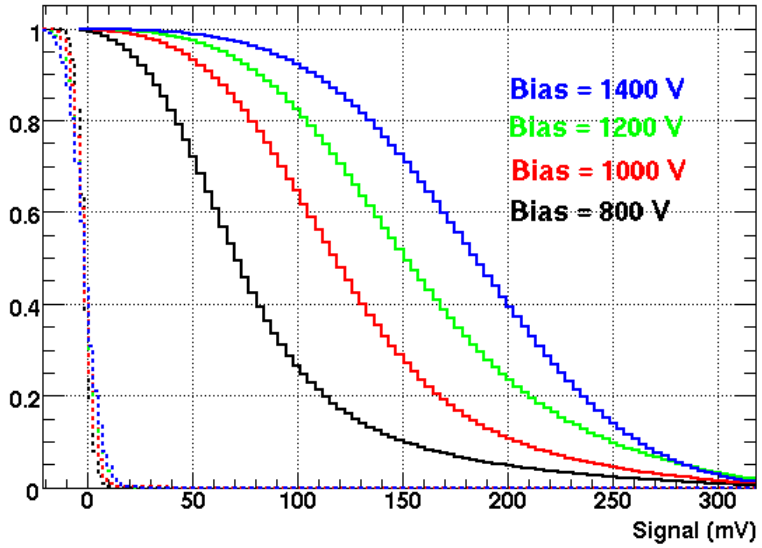


Log scale

22 mV = 1 fC

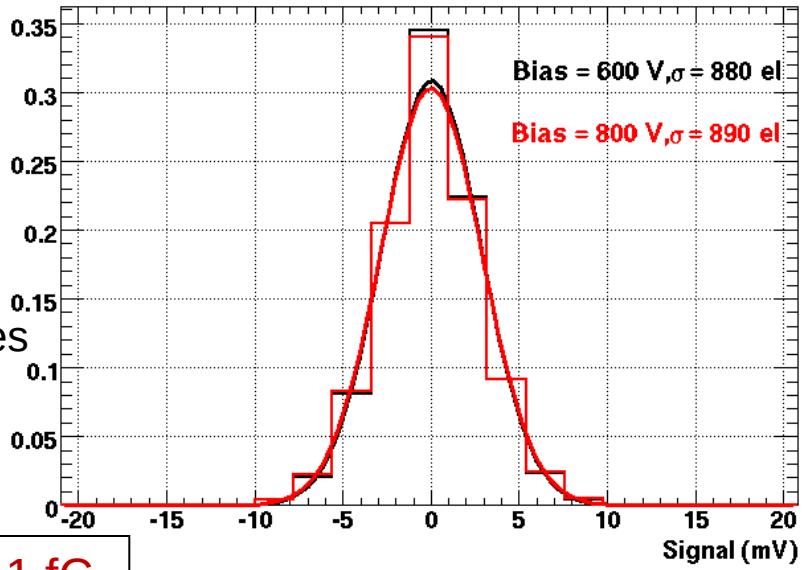
Lin scale





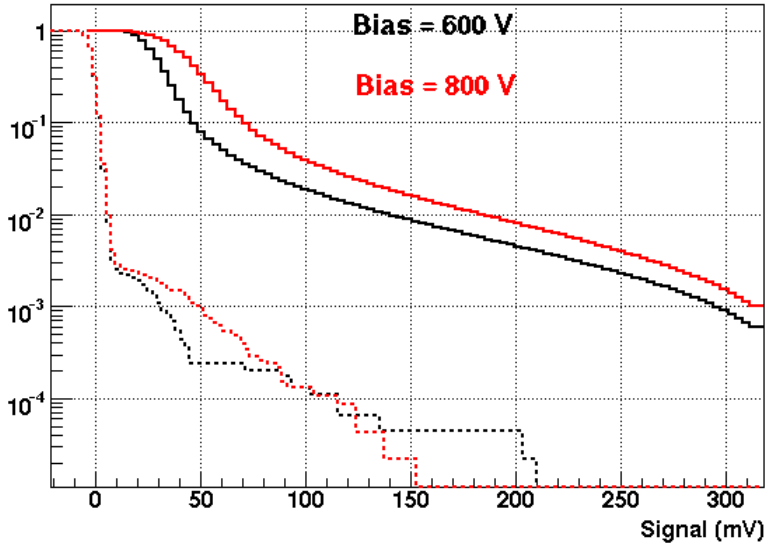
Φ_{eq} =1·10^{15} n/cm^2, annealed for 5040 min.

- no lagre multiplication at these voltages (no increase of leakage current, no increase of MPV)
- if noise distribution Gaussian (no significant tails), good signal efficiency achieved at low noise occupancy already at modest bias voltages
- in real application many noise sources
  ➔ good to have large signals

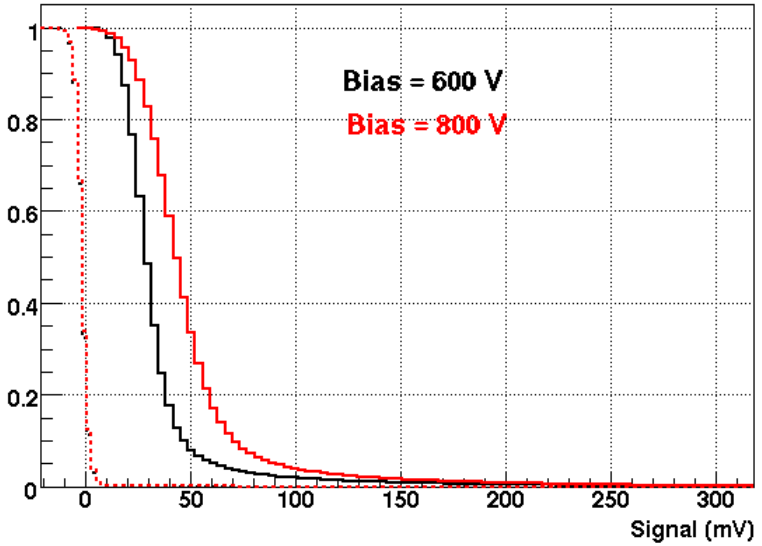


20 mV = 1 fC

Log scale



Lin scale



Conclusions

- at high fluences and high bias voltages multiplication effects influence annealing behavior:
  ➔ multiplication effects increase with annealing time larger than
  ~ 500 minutes @ 60°C (~170 days @ 20°C)
  ➔ increase of space charge concentration ➔ higher electric fields ➔ more multiplication

- with detector irradiated to $5 \cdot 10^{15}$ n/cm^2 measurements could be done up to Bias = 1400 V at all annealing times

- with detector irradiated to $1 \cdot 10^{15}$ n/cm^2 bias voltage at which output gets unstable lowers with increasing annealing time
  ➔ at lower fluences operation in high multiplication regime not stable

- higher collected charge can be measured with more irradiated detectors after annealing because running in high multiplication mode possible

- noise increases because of multiplication
  ➔ shape of noise distribution does not change significantly