Signal height in Silicon Pixel Detectors irradiated with Pions and Protons

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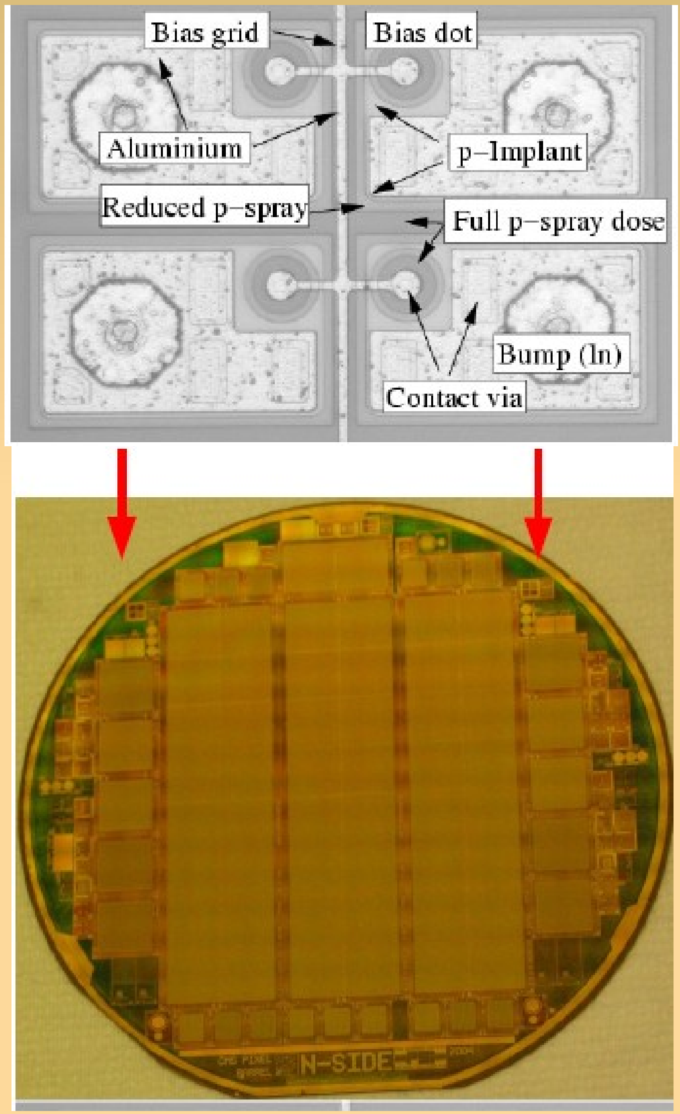
Goals

- Study the change of the sensor behavior due to irradiation.
  - The following parameters were measured:
    - Signal height
    - Depletion voltage
    - Noise
    - Leak current

The Samples



- Single chip sensors from CMS Barrel Pixel Detector
  - production wafers
    - N-on-n
    - DOFZ (ρ~3.7 K Ω cm)
    - P-spray isolation
  - 4 non-irradiated sensors (for contrast)
  - 7 groups of irradiated sensors exposed to fluences up to 5.1×10^{15} Neq/cm^2

Irradiation

- Pions (300 MeV, PSI, Aug 2007)
  - 14 samples up to 6.2×10^{14} Neq/cm^2
  - Irradiation was not smooth, lost several days of good beam
  - Thanks
    - Maurice Glaser (CERN)
    - Mark Gerling and Christopher Betancourt (UCSC)
    - Financial support from RD50
- Protons (26 GeV, CERNPS,July 2007)
  - 32 samples up to 5.1×10^{15} Neq/cm^2
  - Went smoothly
    - thanks to Maurice Glaser and the CERN team
  - Transport of samples out of CERN difficult

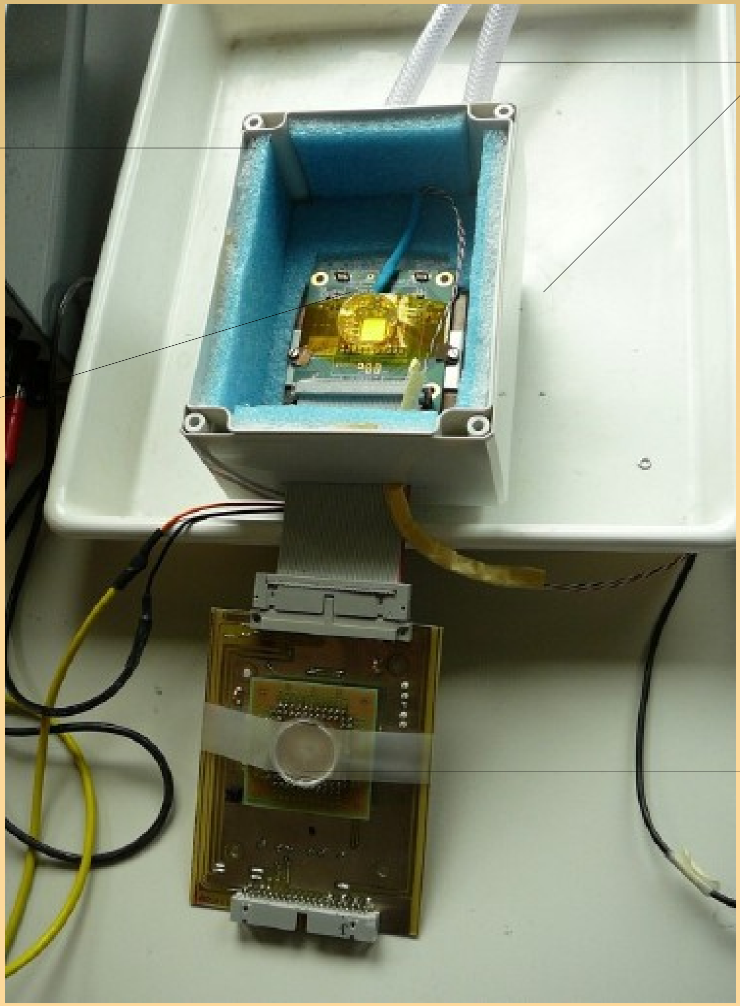
Setup Description

The Cooling box was Flushed with dry N2.

Humidity and temperature sensors

-H<5%

Sr90 source (~2 MBq)



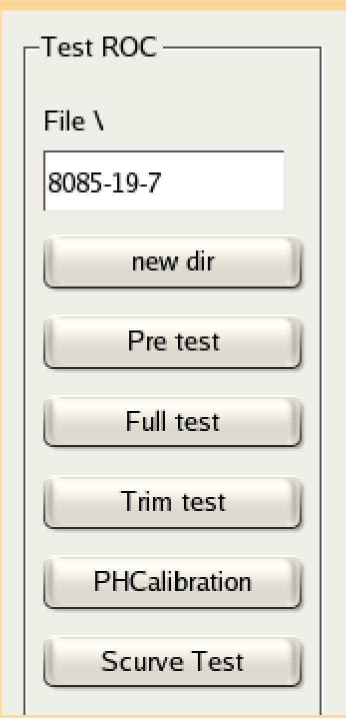
Colling with Peltier system -T~-10° C

Random triggers

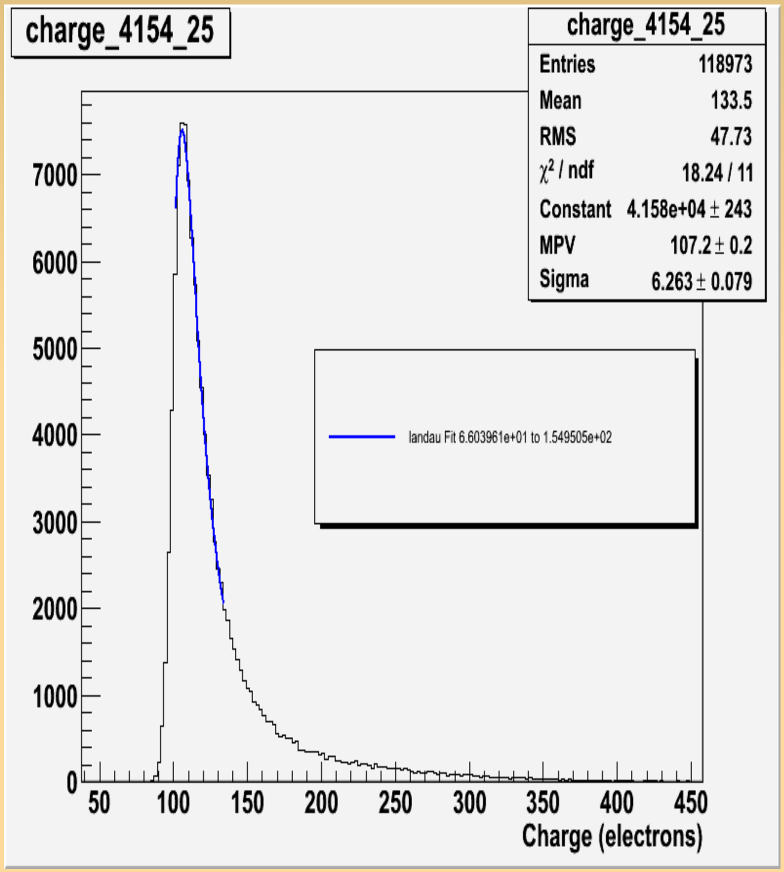
• Sensitive clock cycle
• stretched by a large factor
• Efficiency ~80%

Calibration procedure

- For each sensor we reduced the temperature
  - Temperature during the test ~ -10° C
- Dry with N_2
  - Humidity during the test < 5%
    - Calibrate the sensor at Bvias = -150V
      - Pretest (find the correct Dac Parameters).
      - Fulltest (Test address decoding pixel by pixel).
      - Trim Test (small pixel by pixel threshold corrections)
      - Pulse Height Calibration (Calibration between signal in (Vcal) and signal out “Pulse Height” per pixel).
      - S-Curve Test (to scan noise pixel by pixel).

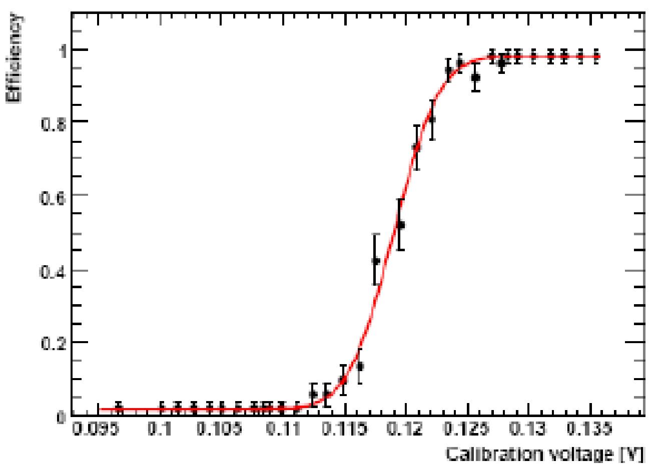


Test Procedure



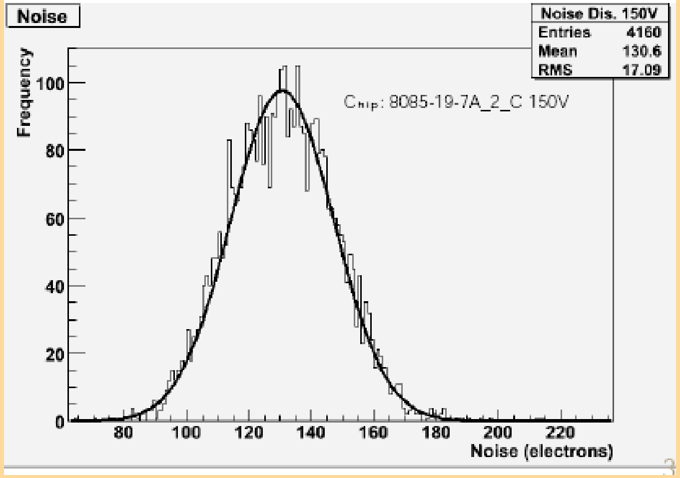
- For each sensor we varied the Vbias from -25V to -600V
- For each Vbias Value:
  - "S-curve test" to calculate noise variations.
  - Take data with Sr-90 source

Noise measurement ("S-curve Test")



Typical S-curve From: S. Dambach, C. Eggel, P. Trub. DAC Optimization of the Pixel Detector Readout Chip. CMS Note 2005/000, 2008.

$$Fit(x) = P_0 \cdot Erf\left(P_2(x - P_1)\right) + P_3 \quad Erf(y) = \frac{2}{\sqrt{\pi}} \int_0^y e^{-t^2} dt$$

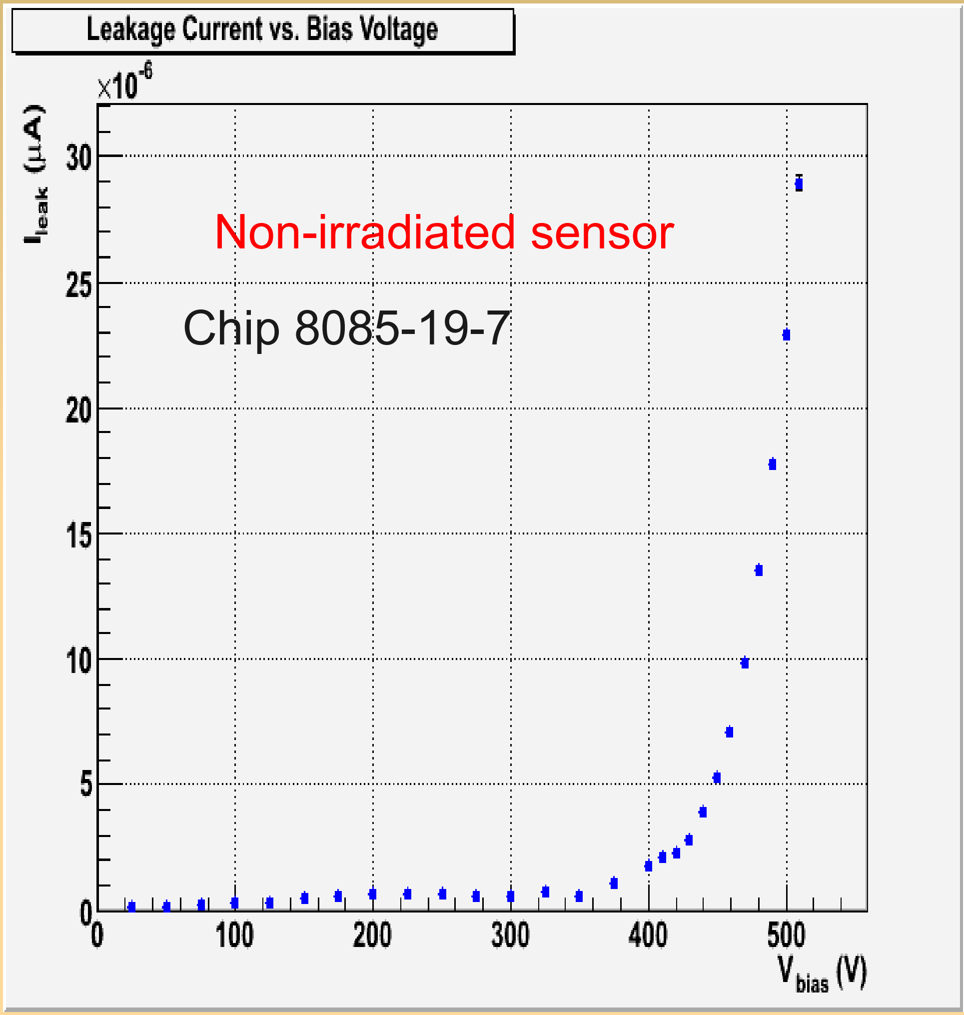


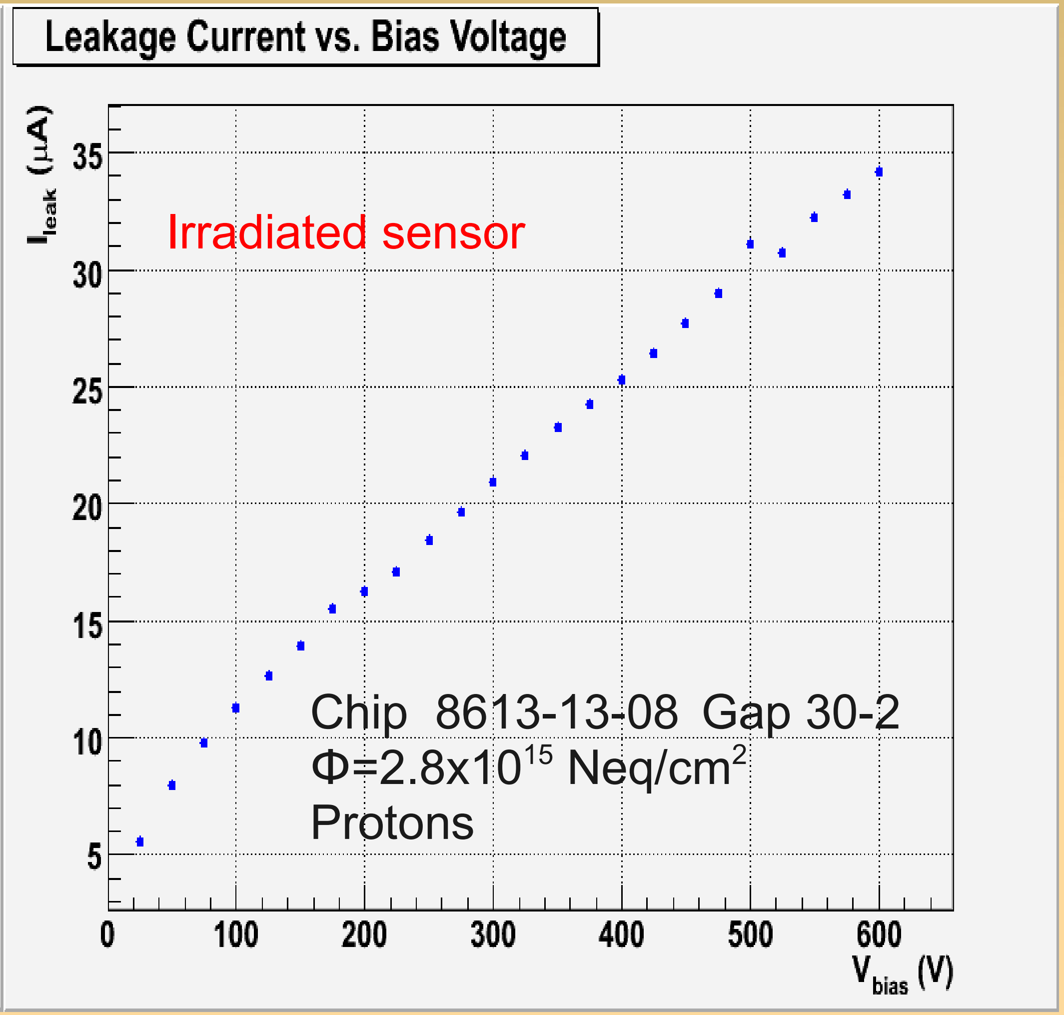
- For each pixel fix the threshold Voltage, and send n signals with different amplitude.
- Increase the value of the amplitude of signal (calibration voltage).
- Measure the efficiency (top graph)
- Fit with error function to determine sigma.

$$\sigma = \frac{1}{P_2 \cdot \sqrt{2}}$$

- Build the distribution for each sensor and calculate the mean.

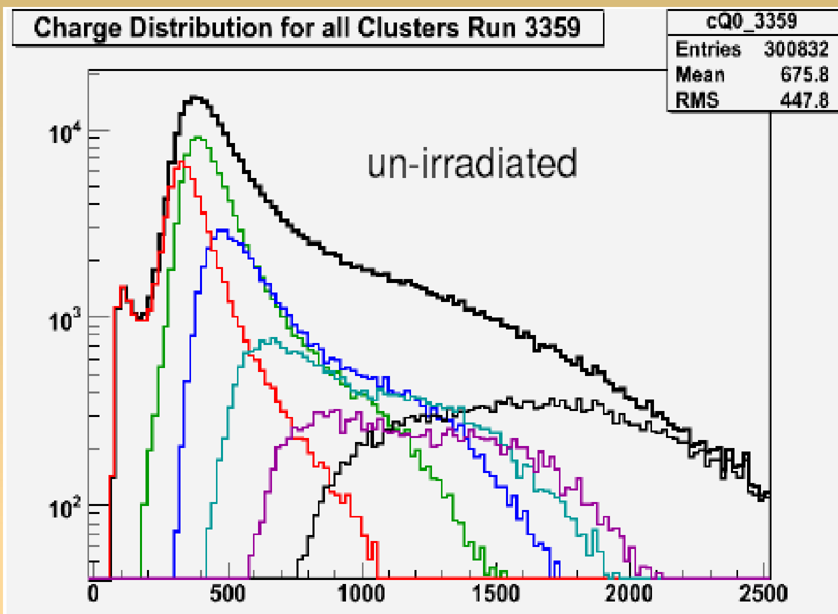
Leakage Current

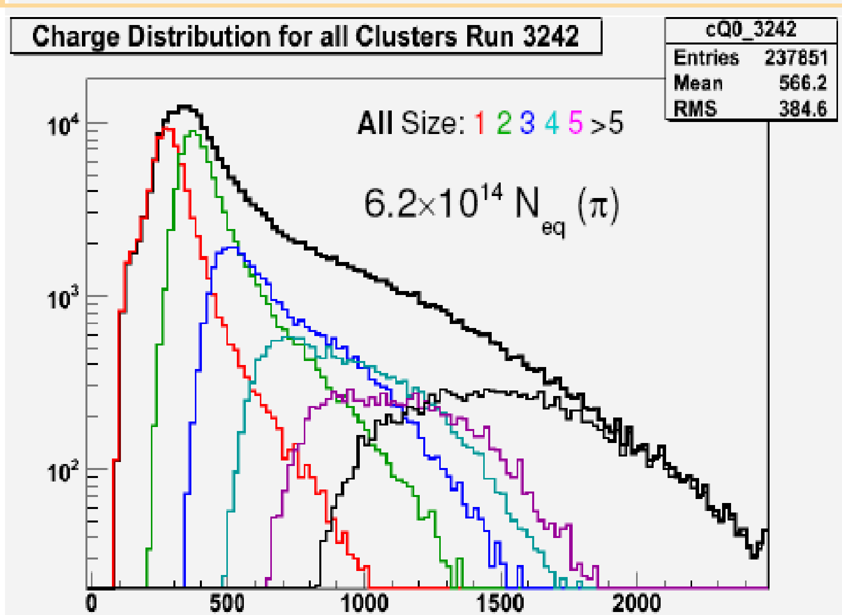




- Simply measure the current for each Vbias across the sensor

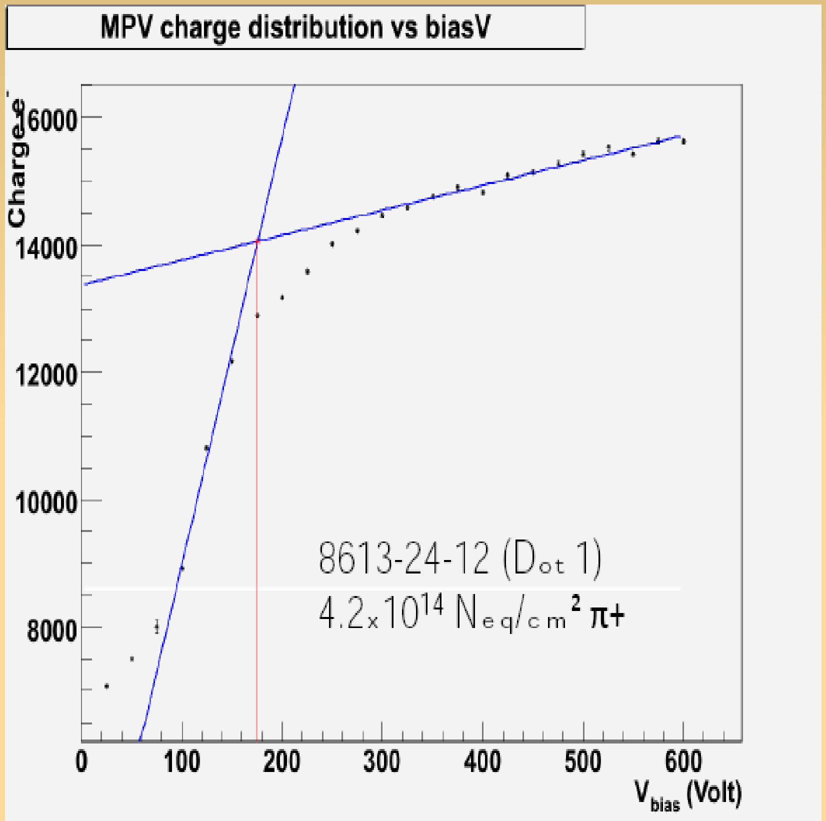
Pulse Height Spectra





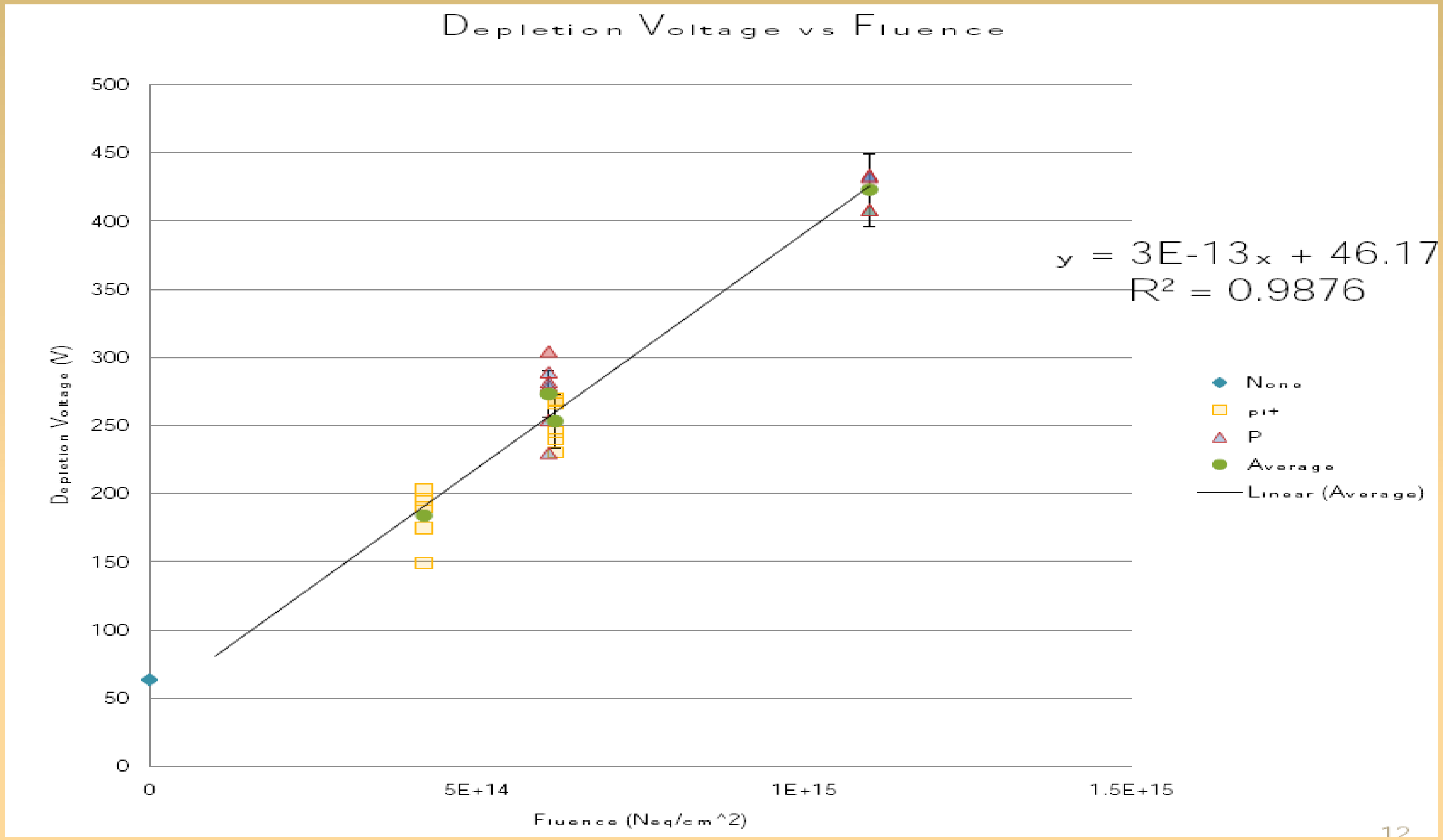
- Landau-like shape only for clusters < 3 pixels
  - Large cluster come from:
    - low energetic electrons
    - deltas
- Pulse height depends on cluster size
  - Restrict to 1(+2) hit clusters
  - Fit Landau convoluted with a Gaussian.
  - Peak of low signals in 1-hit clusters

Depletion Voltage estimation



- For each Vbias we Fit charge distribution from Sr-90 souse using Landau convoluted function, and take the MPV (most probable value).
- Build the graph MPV vs Vbias
  - Extrapolate a line from points where sensor is Depleted
  - Another from the points where the Charge Collection is increasing
  - Intersection is what we call the Depletion Voltage

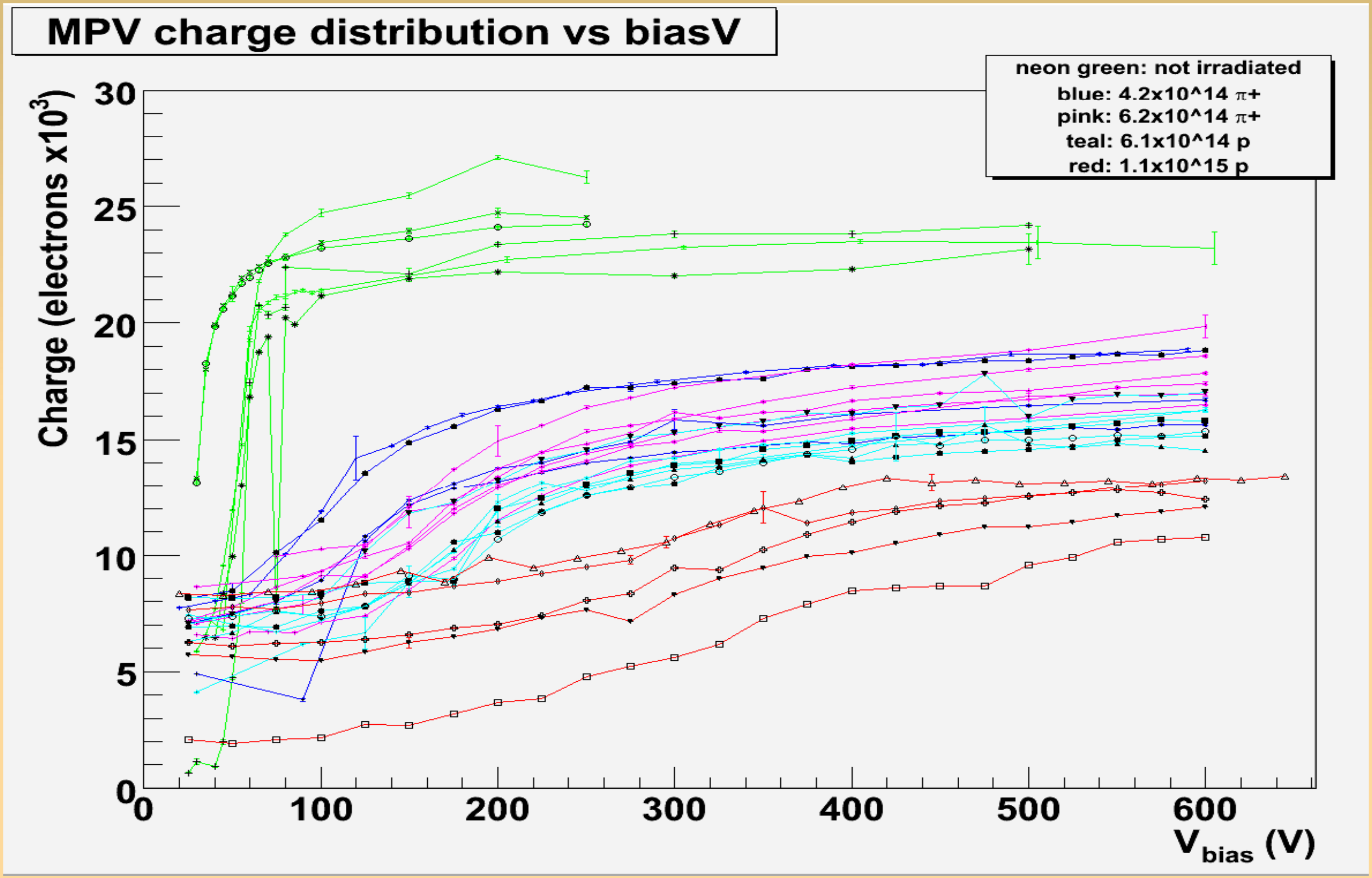
Depletion voltage



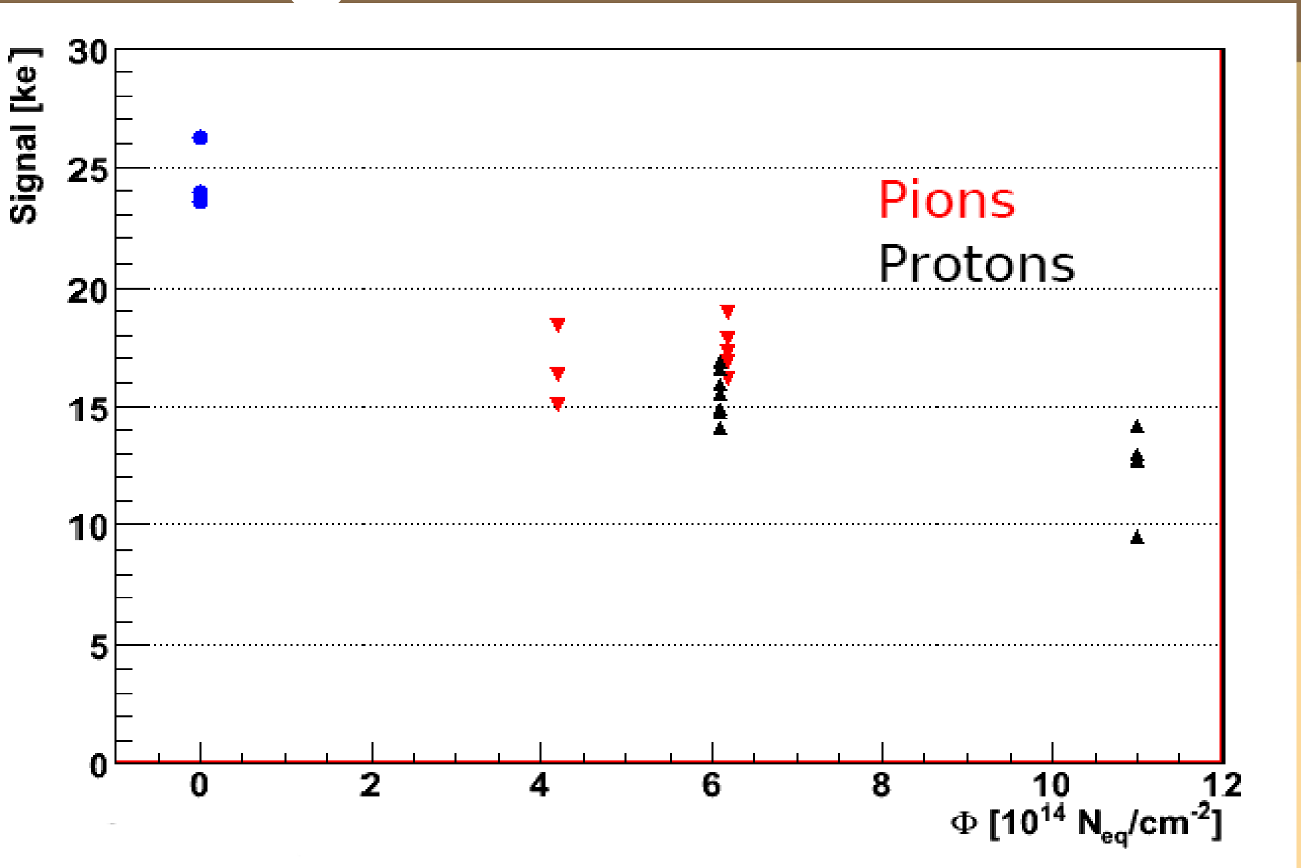
$$V_{depletion} = 3 \cdot 10^{-13} \left[\frac{Volt \cdot cm^2}{\text{Neq}}\right] \left(Fluence \left[\frac{\text{Neq}}{cm^2}\right]\right) + 46.17 [Volt]$$

The Values are spread in irradiated sensors and there are large uncertainties in the method

Charge collection vs Vbias

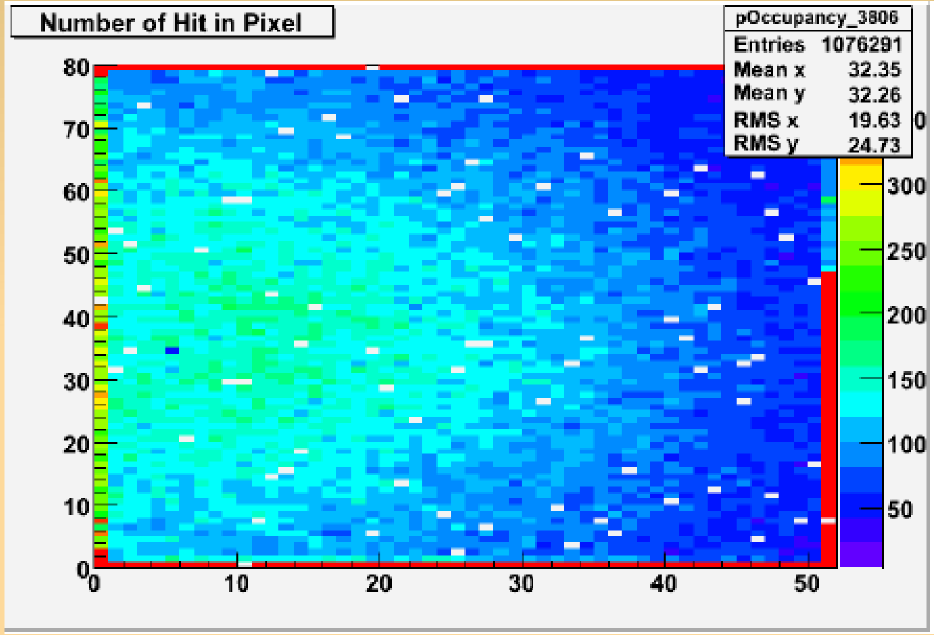


Signal vs Fluence



- Large spread between samples
  - Problems with calibration?
  - Excluded
    - Wafer thickness variations
    - Small temperature variations

What is above 10^{15}?



- For samples with $\Phi >> 10^{15}$
  - ROC operation becomes difficult
  - Dacs have to be adjusted which are not part of the standard calibration procedure
  - Has to be done manually by expert (not me)
- (Not yet succeeded)
  - For a sample with 2.8×10^{15} Neq/cm^2 particles are clearly

seen, but no quantitative measurements yet.

Conclusions

- Charge Collection studies could reproduce the values from previous measurements.
- • Measurements for fluences > 10^{15} Neq/cm^2
- See particles
  - No quantitative measurement yet
- Short term
  - Understand the operation of highly irradiated ROCs
  - Understand the reason for the wide spread
  - Analysis of 2hit clusters
- Longer term
  - Scintillator trigger
  - Efficiency measurement
  - Cut of low energetic electrons
  - Better cooling