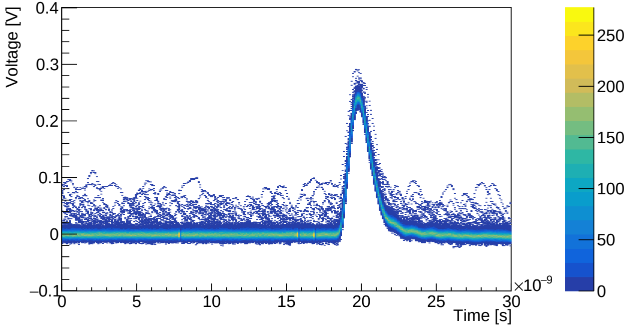
APD “Dark Pulses” and Discussion for PSD11

CERN group

29.8.2017

Dark Pulses $\Phi_{eq} = 10^{15}$ cm^{-2}

1735 V, -20 C, 1500 WF, 40 dB amplification



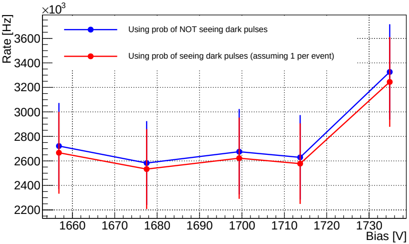
Only the sensor irradiated to the highest fluence shows this effect

Rate Estimation

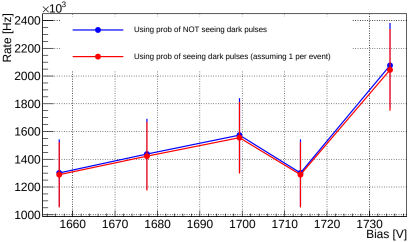
- Use first 15 ns of WF to avoid effects from laser pulse
- Two strategies: count pulses, count events without pulses
- Use a threshold to discriminate events (30, 50, 70 mV used)
- 1 MIP at highest bias $\rightarrow$ 17 mV
- Simple algorithm used:
  one WF point above threshold $\Rightarrow$ event with pulses
  no baseline correction
- Counting 0s: use Poisson statistics to extract average number of pulses per event
- Counting 1s: ASSUME 1 pulse per event
- Error estimation using Binomial statistic

Rate Estimation $\Phi_{eq} = 10^{15}\ \mathrm{cm}^{-2}$

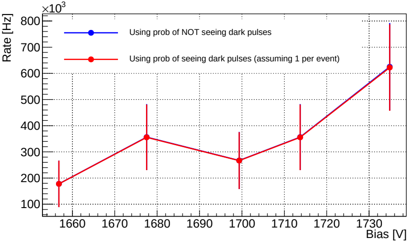
30 mV threshold



50 mV threshold



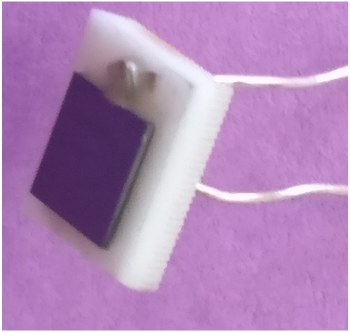
70 mV threshold

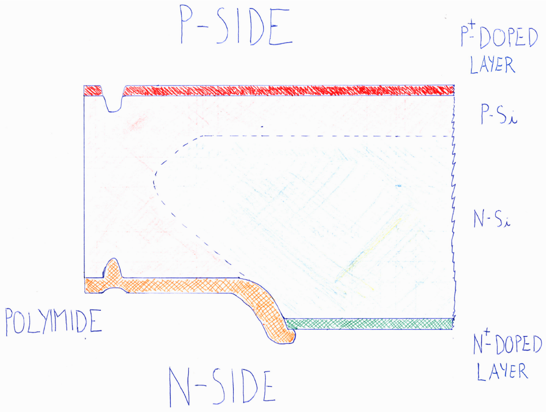


In proceedings:
The frequency at which “dark pulses” with an amplitude above a threshold of 50 mV occur was found to be around 2 MHz for the highest bias voltage applied to the sensor.

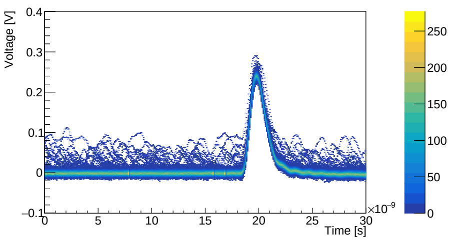
Additional plots for the proceedings

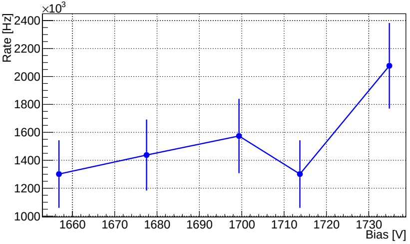
Detector





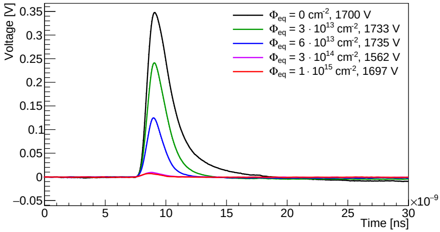
“Dark Pulses”

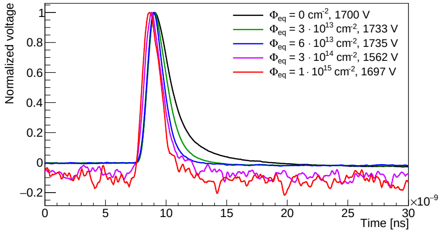

Voltage [V]
Time [s]
×10^−9
0.4
0.3
0.2
0.1
0
−0.1
0
5
10
15
20
25
30
250
200
150
100
50
0


×10^3
Rate [Hz]
Bias [V]
2400
2200
2000
1800
1600
1400
1200
1000
1660
1670
1680
1690
1700
1710
1720
1730

Pulse shape

10 dB ampli, 256 averages, -20C



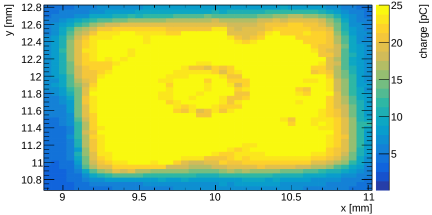


Charge and Amplitude Maps

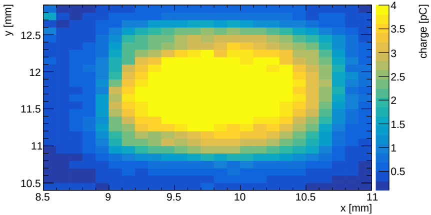
Max of color scale is the center value $\Rightarrow \approx$ normalized to det. center

Charge integrated in 25 ns, -20C, 10 dB ampli

$\Phi_{eq} = 0\,\mathrm{cm}^{-2}$, 1700 V

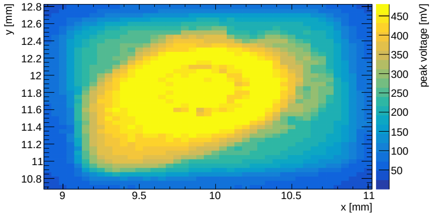


$\Phi_{eq} = 6 \cdot 10^{13}\,\mathrm{cm}^{-2}$, 1735 V

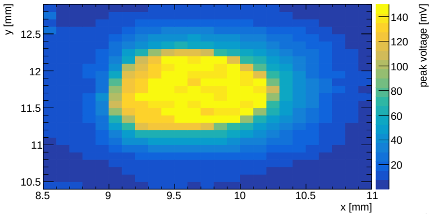


Amplitude, -20C, 10 dB ampli

$\Phi_{eq} = 0\,\mathrm{cm}^{-2}$, 1700 V



$\Phi_{eq} = 6 \cdot 10^{13}\,\mathrm{cm}^{-2}$, 1735 V

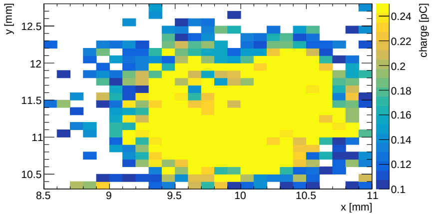


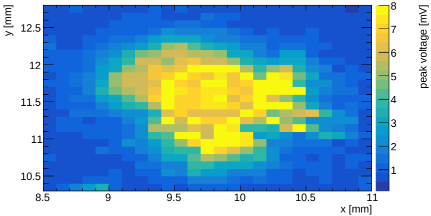
Charge and Amplitude Maps

Max of color scale is the center value $\Rightarrow \approx$ normalized to det. center

$\Phi_{eq} = 10^{15}\,\text{cm}^{-2}$, 1695 V, -20C, 10 dB ampli

Charge in 25 ns | Amplitude





- At $\Phi_{eq} = 6 \cdot 10^{13}\,\text{cm}^{-2}$, the sensitive area does not seem to shrink
- I think that 2 maps could be show: non-irradiated and $\Phi_{eq} = 6 \cdot 10^{13}\,\text{cm}^{-2}$, since $\Phi_{eq} = 10^{15}\,\text{cm}^{-2}$ seems to be out of the range of this sensor design
- The charge maps would be better than the amplitude ones
- Amplitude is not as uniform as charge, and we know how to solve this problem

Backup Material

Equations Rate Estimation (counting 0s)

Poisson statistic

$$P(k|\mu) = e^{-\mu}\frac{\mu^k}{k!} \Rightarrow \mu = -\ln(P(k=0)) \quad P(k=0) = \frac{n_0}{n_{tot}} = e^{-\mu}$$

$n_0 \rightarrow$ events without dark pulses
$n_{tot} \rightarrow$ tot events
Rate: $R = \mu/t$ $\qquad t \rightarrow$ measurement interval

Variance of Binomial

$$Var(x) = np(1-p)$$

$x \rightarrow$ number successes or failures
$n \rightarrow$ number of trials
$p \rightarrow$ probability of success or prob. of failure

$$\Delta n_0 = \sqrt{n_{tot}e^{-\mu}(1-e^{-\mu})}$$

$$\Delta R = \frac{\Delta n_0}{tn_0}$$

Other sources of uncertainty are disregarded

Equations Rate Estimation (counting 1s)

Assuming one dark pulse per event $P(k > 1) \approx 0$

$$\mu = \frac{n_1}{n_{tot}}$$

$n_1 \rightarrow$ events with dark pulses
Rate: $R = \mu / t$

$$\Delta n_1 = \sqrt{n_{tot} e^{-\mu}(1 - e^{-\mu})}$$

$$\Delta R = \frac{\Delta n_1}{t n_{tot}}$$

Other sources of uncertainty are disregarded