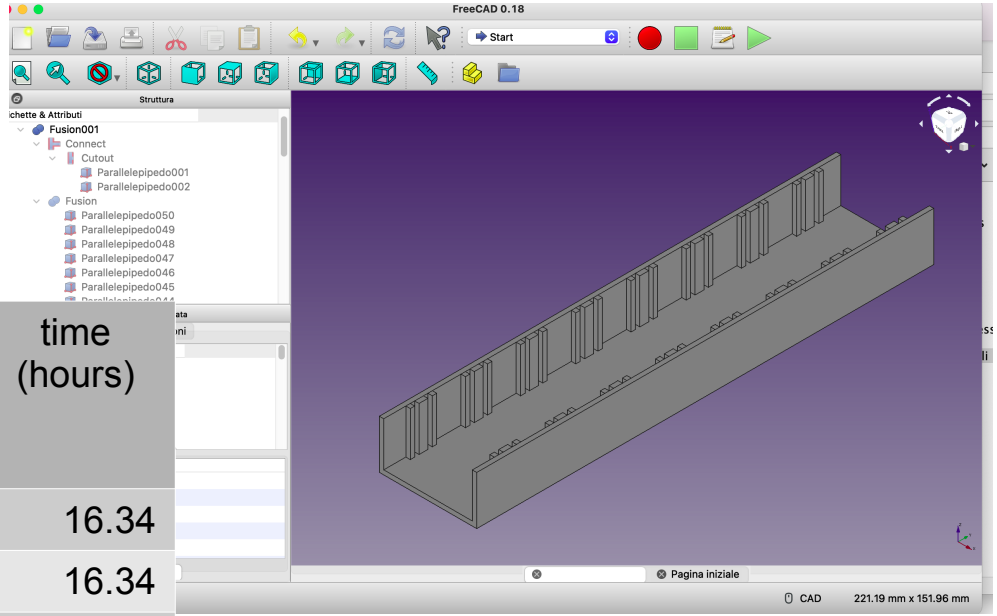
First results on irradiated SiPMs in Padova

R. Stroili, F. Dal Corso, E. Torassa

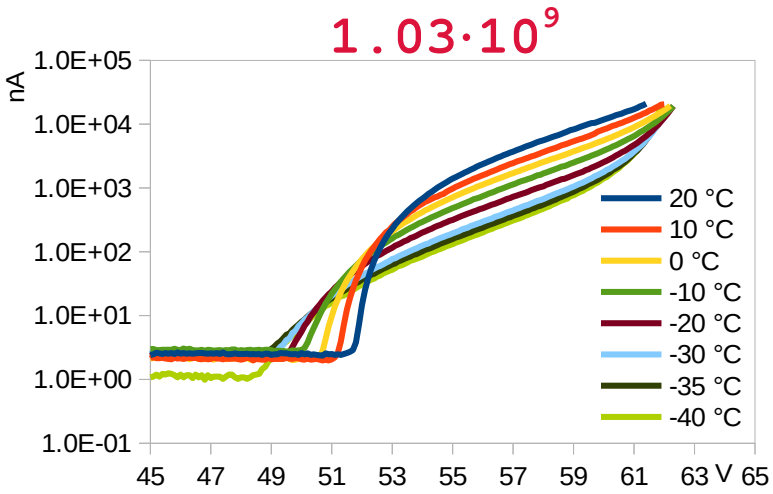
irradiation test

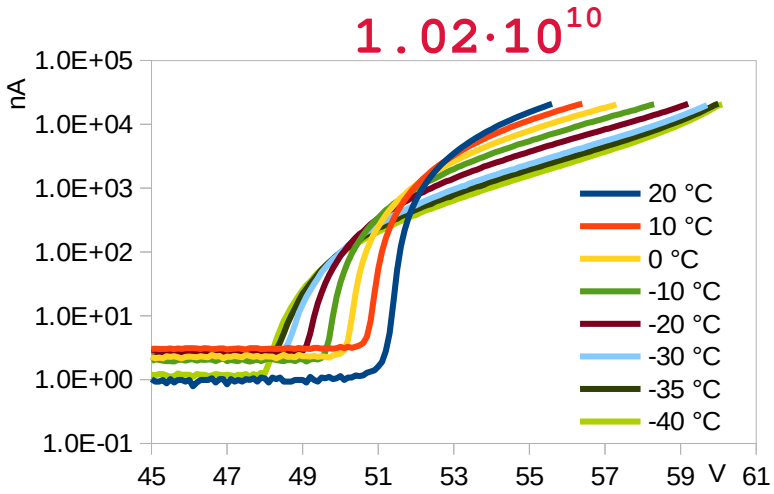
- irradiated the 8 Hamamatsu S13360-1350PE SiPMs that were characterized before irradiation



SiPM #	distance from target (cm)	neutron 1 MeV eq. /cm^2 fluence	charge (μC)	time (s)	time (hours)
0	4.30	$5.07 \cdot 10^{11}$	$7.94 \cdot 10^{3}$	58829	16.34
1	6.80	$2.03 \cdot 10^{11}$	$7.94 \cdot 10^{3}$	58829	16.34
2	9.30	$1.01 \cdot 10^{11}$	$7.43 \cdot 10^{3}$	55073	15.30
3	11.80	$5.07 \cdot 10^{10}$	$5.98 \cdot 10^{3}$	44310	12.31
4	14.30	$2.45 \cdot 10^{10}$	$4.25 \cdot 10^{3}$	31451	8.74
5	16.80	$1.02 \cdot 10^{10}$	$2.44 \cdot 10^{3}$	18098	5.03
6	19.30	$5.06 \cdot 10^{9}$	$1.60 \cdot 10^{3}$	11839	3.29
7	21.80	$1.03 \cdot 10^{9}$	$4.13 \cdot 10^{2}$	3059	0.85

IV curves


1.03·10^9
nA
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
45 47 49 51 53 55 57 59 61 63 V 65
20 °C
10 °C
0 °C
-10 °C
-20 °C
-30 °C
-35 °C
-40 °C


1.02·10^10
nA
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
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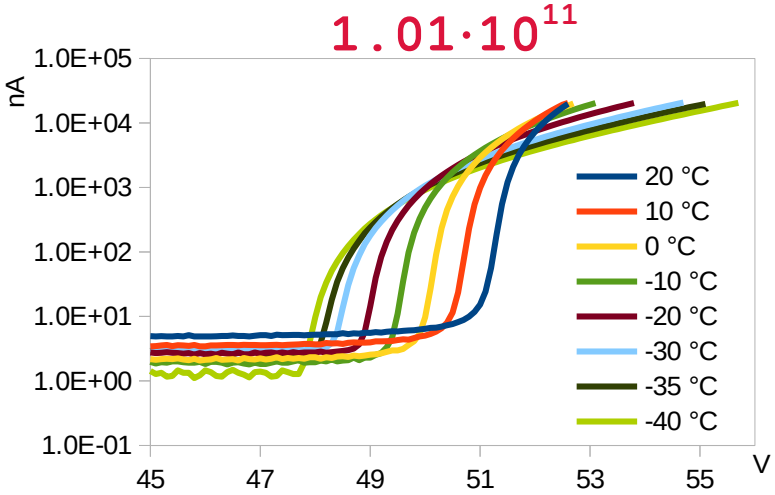
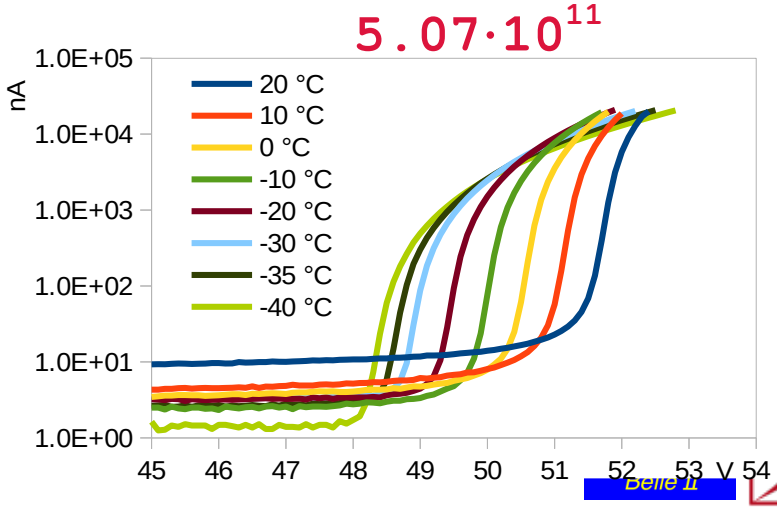
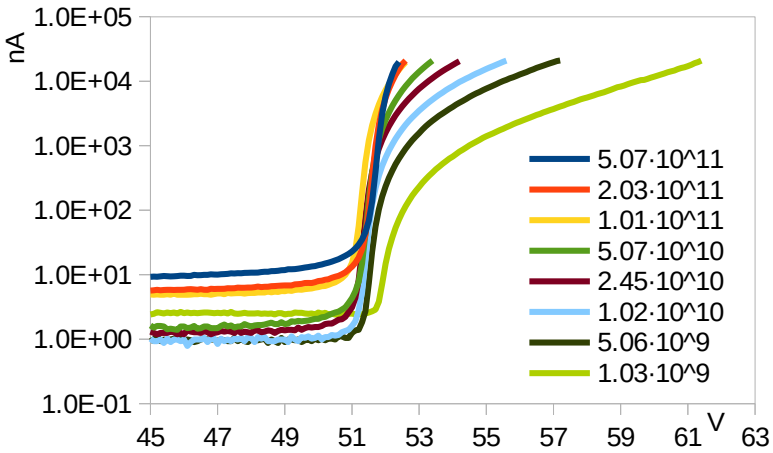
20 °C
10 °C
0 °C
-10 °C
-20 °C
-30 °C
-35 °C
-40 °C


1.01·10^11
nA
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
45 47 49 51 53 55 V
20 °C
10 °C
0 °C
-10 °C
-20 °C
-30 °C
-35 °C
-40 °C

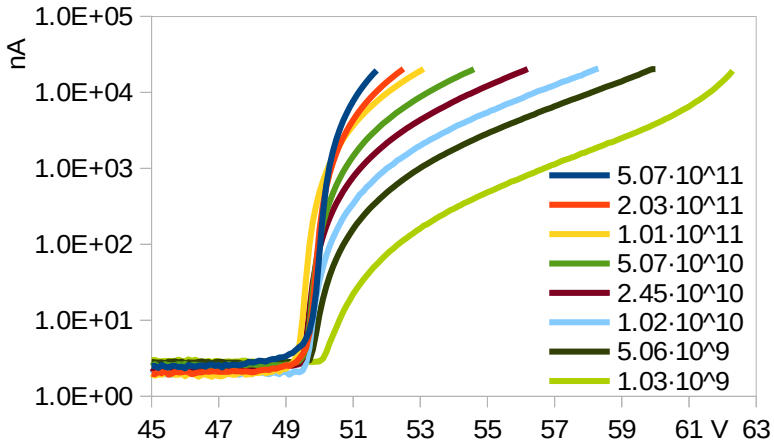

5.07·10^11
nA
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
45 46 47 48 49 50 51 52 53 V 54
20 °C
10 °C
0 °C
-10 °C
-20 °C
-30 °C
-35 °C
-40 °C

IV curves

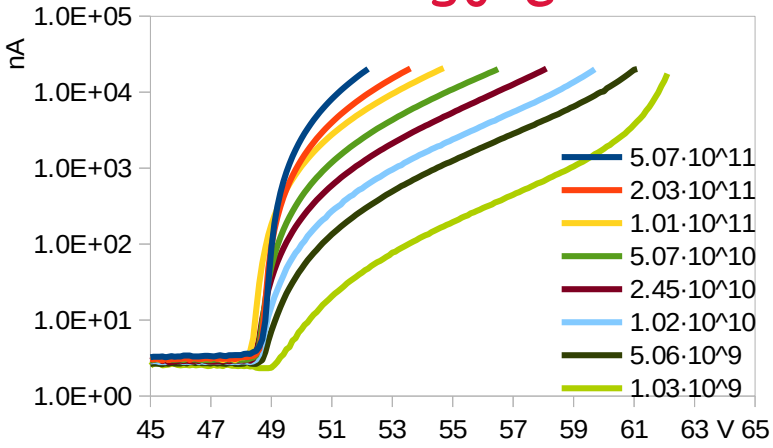
20°C



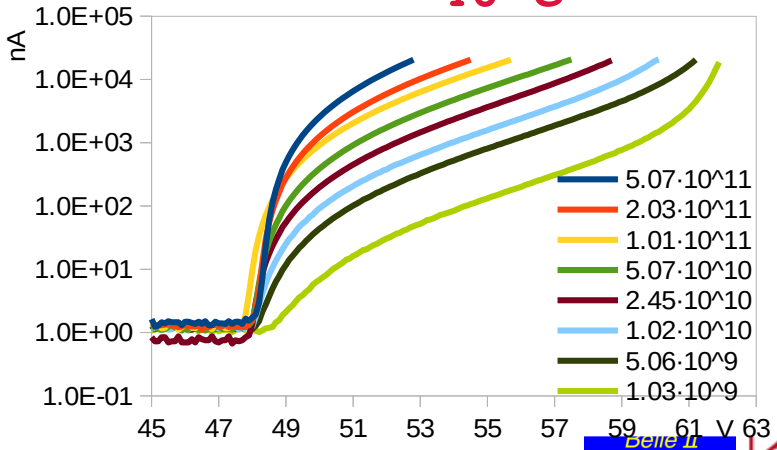
−10°C



−30°C



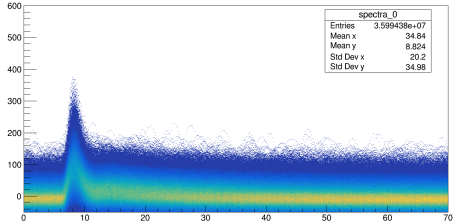
−40°C



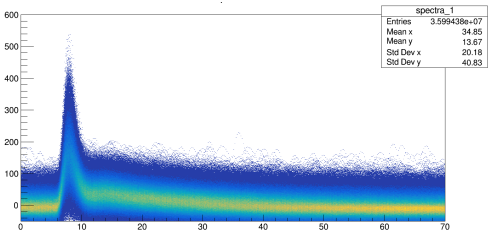
laser spectra

T = 20 °C

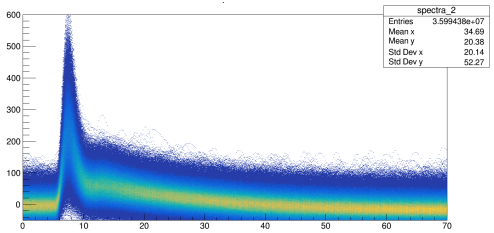
$5.07 \cdot 10^{11}$



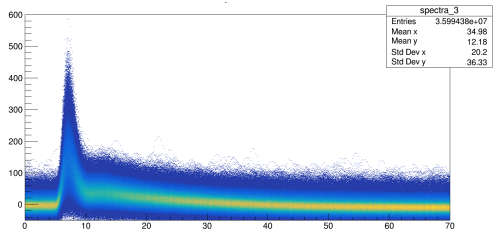
$2.03 \cdot 10^{11}$



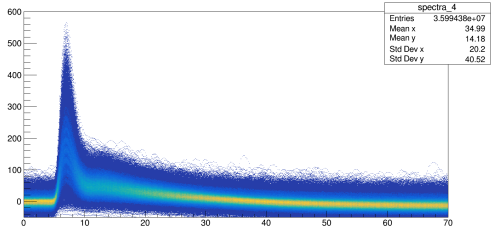
$1.01 \cdot 10^{11}$



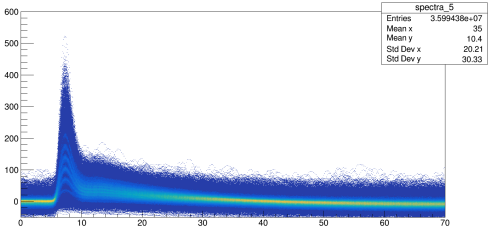
$5.07 \cdot 10^{10}$



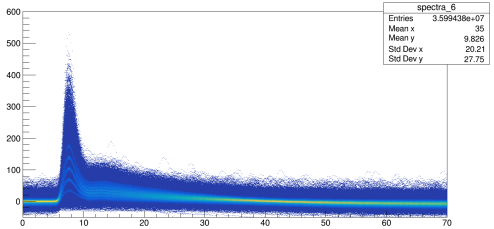
$2.45 \cdot 10^{10}$



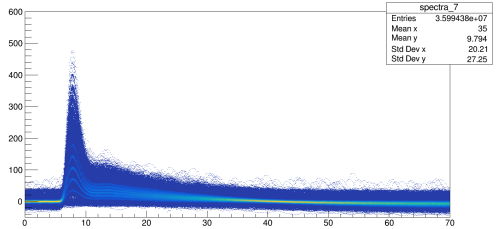
$1.02 \cdot 10^{10}$



$5.06 \cdot 10^{9}$



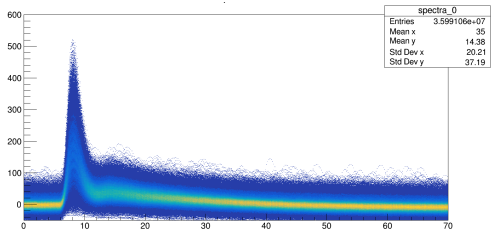
$1.03 \cdot 10^{9}$



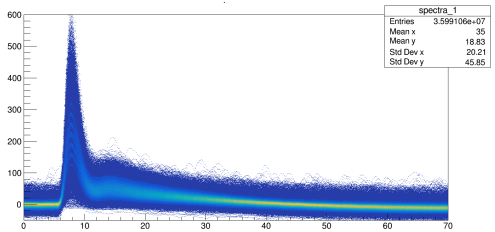
laser spectra

T = -20 °C

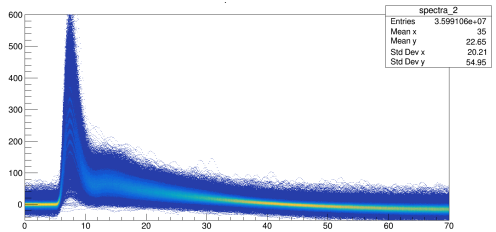
$5.07 \cdot 10^{11}$



$2.03 \cdot 10^{11}$



$1.01 \cdot 10^{11}$



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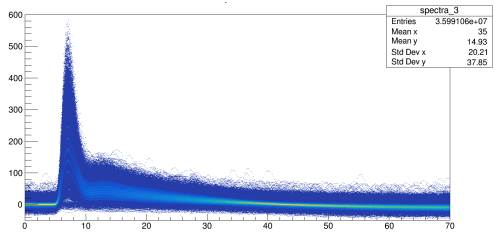
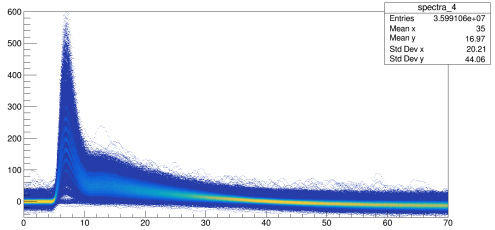
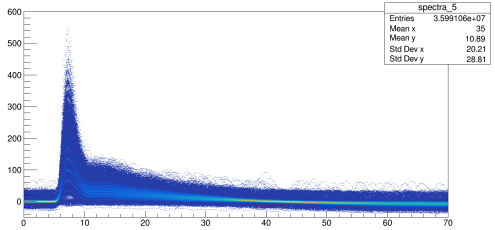


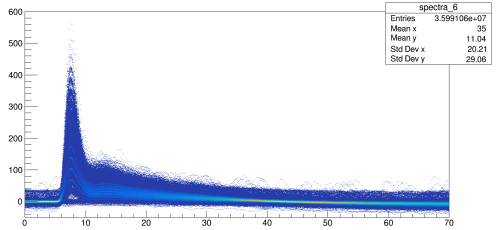
$2.45 \cdot 10^{10}$



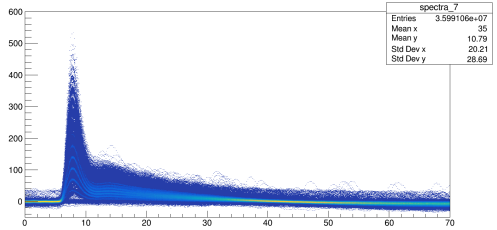
$1.02 \cdot 10^{10}$



$5.06 \cdot 10^{9}$



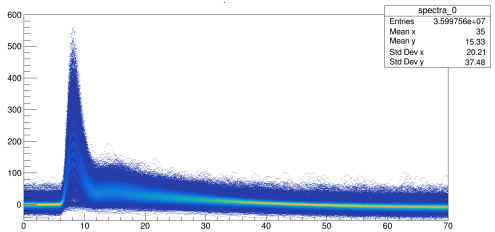
$1.03 \cdot 10^{9}$



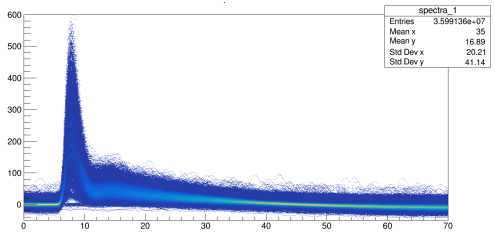
laser spectra

T = -40 °C

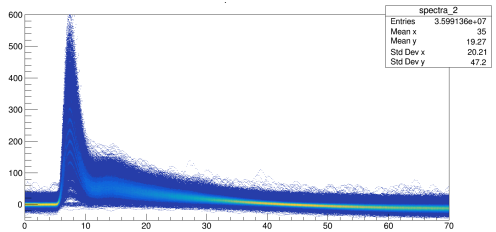
$5.07 \cdot 10^{11}$



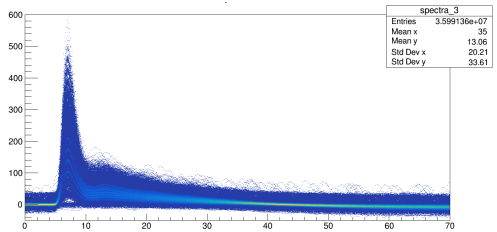
$2.03 \cdot 10^{11}$



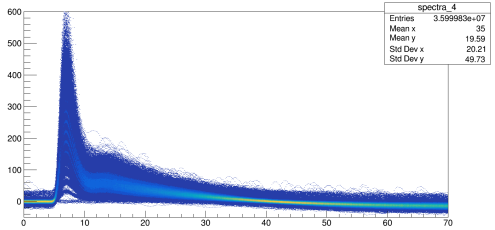
$1.01 \cdot 10^{11}$



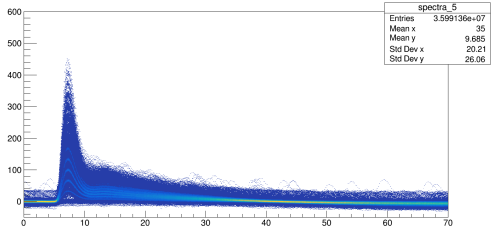
$5.07 \cdot 10^{10}$



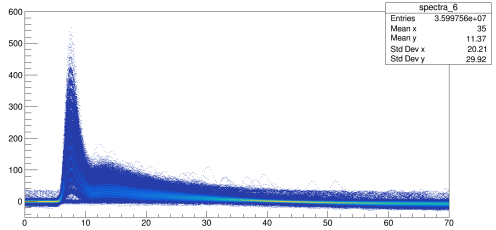
$2.45 \cdot 10^{10}$



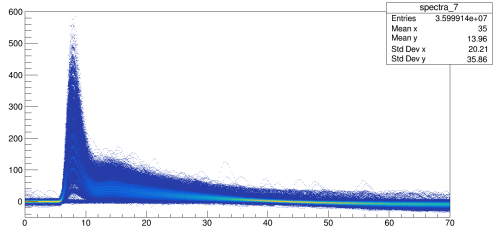
$1.02 \cdot 10^{10}$



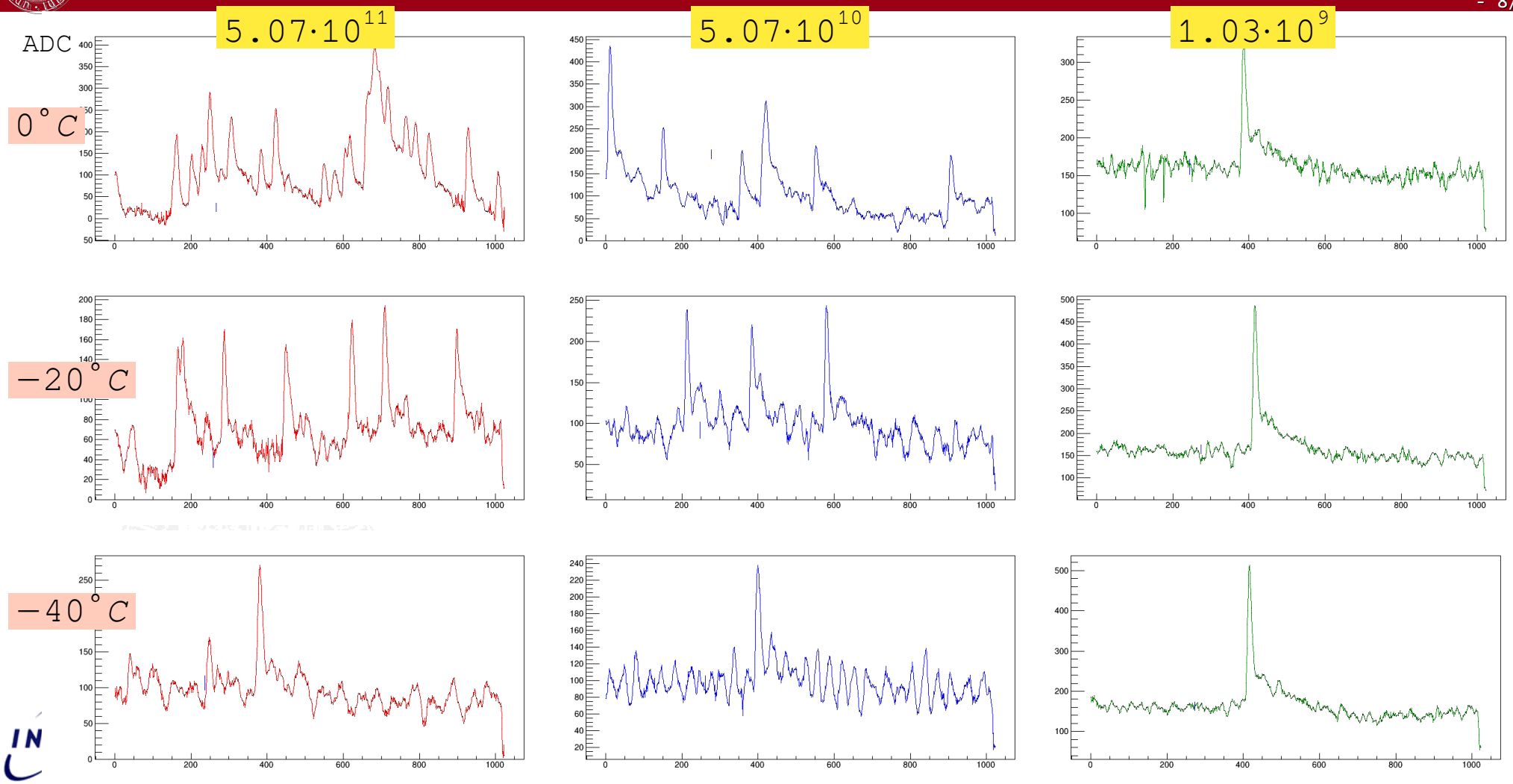
$5.06 \cdot 10^{9}$



$1.03 \cdot 10^{9}$



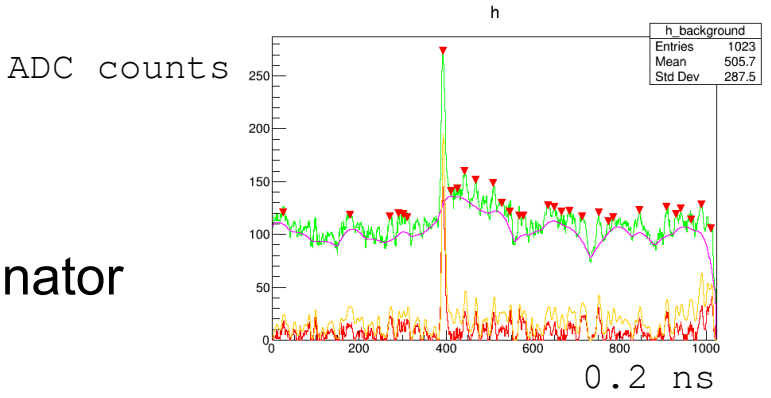
waveforms with laser on

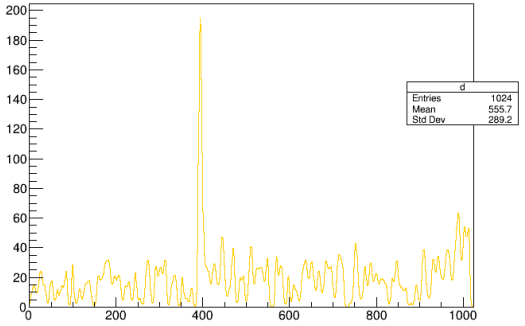


0.2 ns)

new peak finder

- the peak finder algorithm used on non-irradiated devices was quite simple:
  1. find the waveform baseline
  2. subtract it
  3. find the maximum amplitude
  4. get the time with a constant fraction discriminator
- quite simple but working
- with irradiated devices this simple procedure doesn't work
  - the problem is the baseline
- use ROOT TSpectrum SearchHighRes method
  - it makes some deconvolution
  - results (amplitudes) are not the same with the two approaches



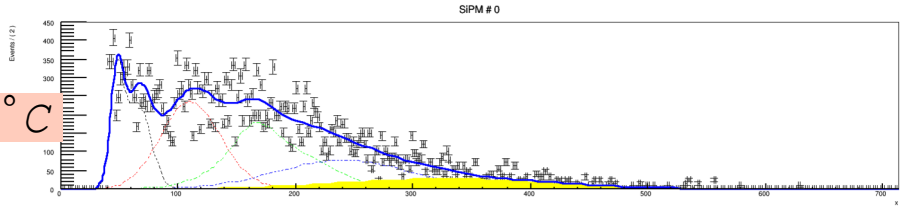


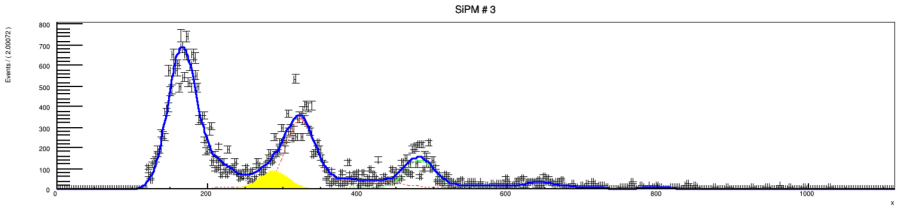
spectra

$5.07 \cdot 10^{11}$

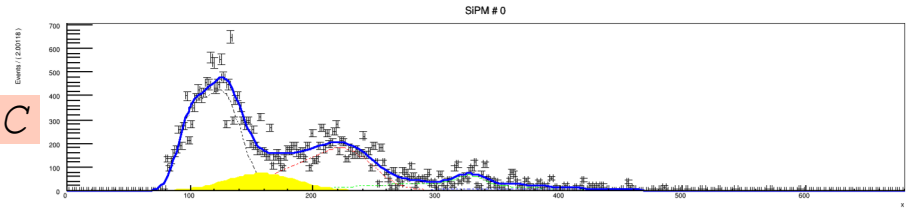
$5.07 \cdot 10^{10}$

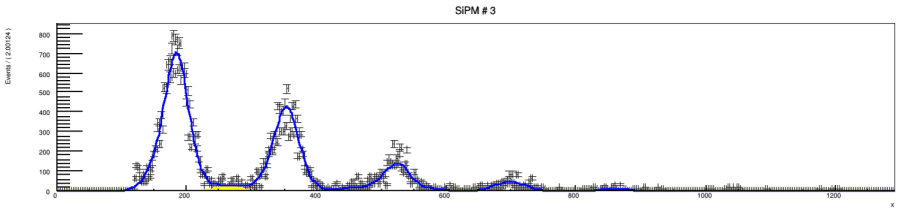
20°C



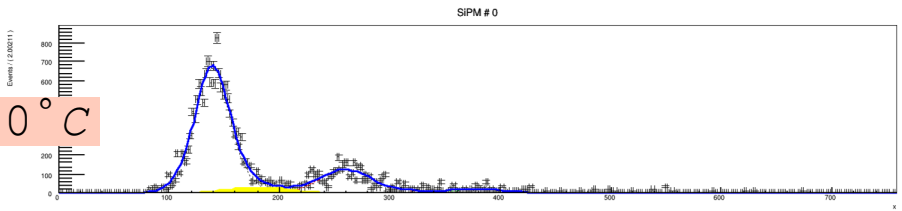


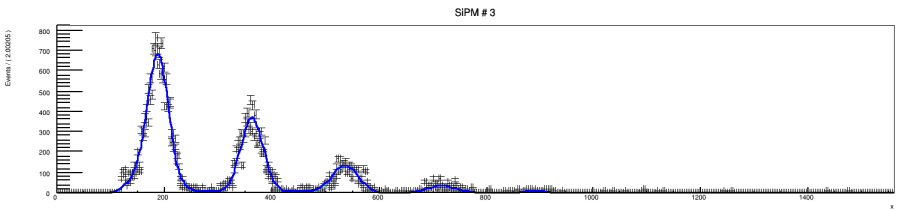
0°C



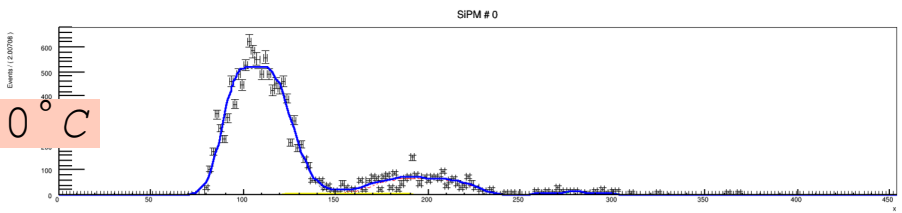


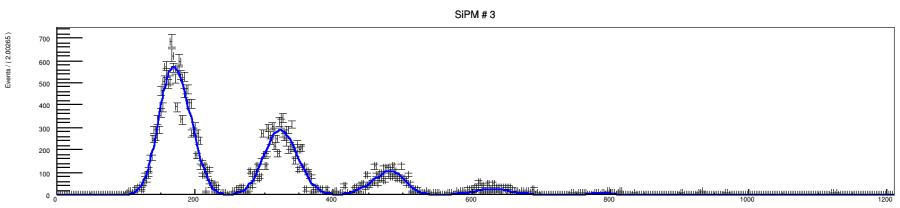
−20°C





−40°C





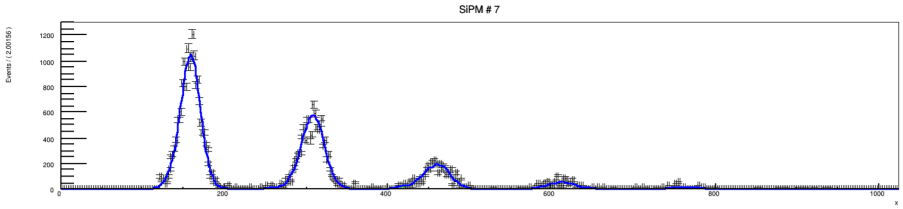
ADC counts

ADC counts

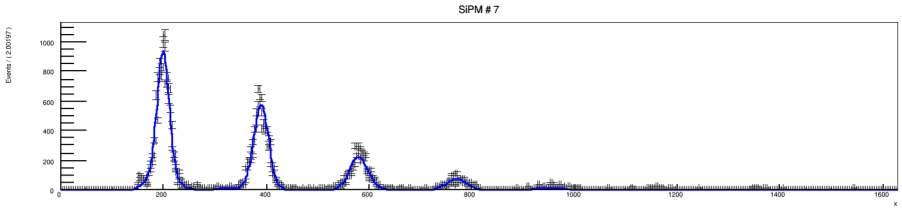
spectra

$1.03 \cdot 10^9$

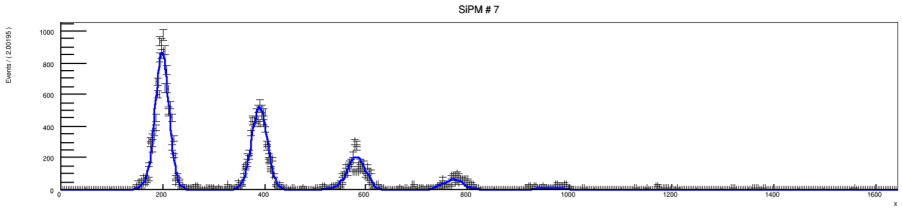
20°C



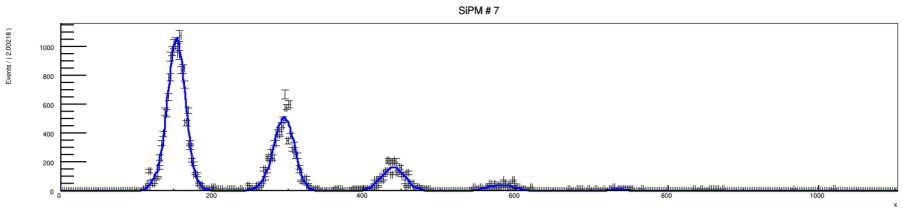
0°C



−20°C



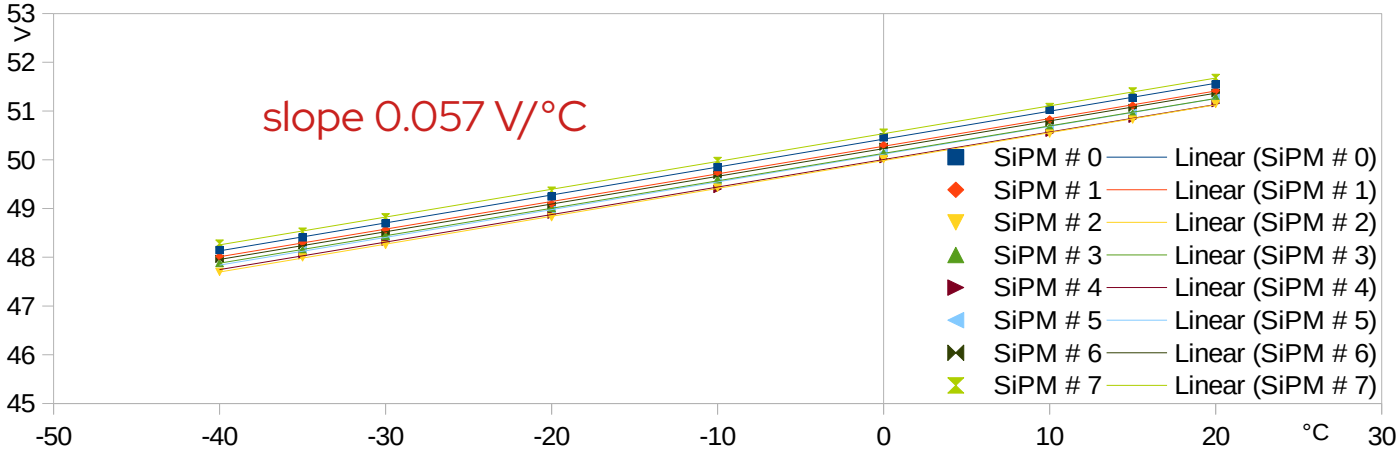
−40°C



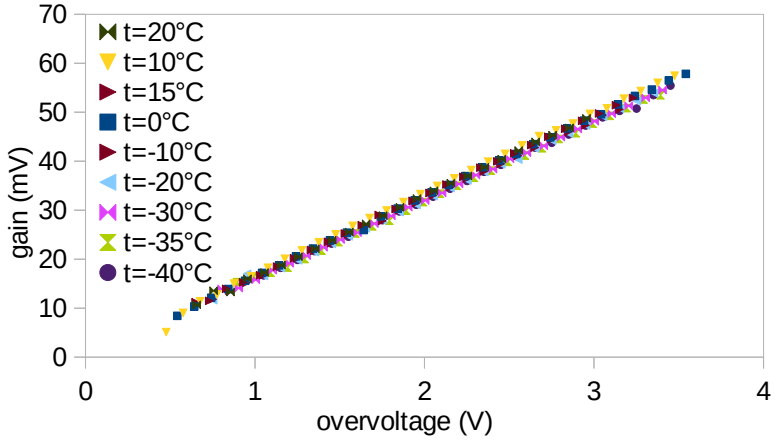
ADC counts

breakdown voltage

- breakdown voltage before irradiation vs. temperature



- gain vs over-voltage for SiPM # 0
  - before irradiation



breakdown voltage

- average slope (over temperature) of gain vs V_{bias}:

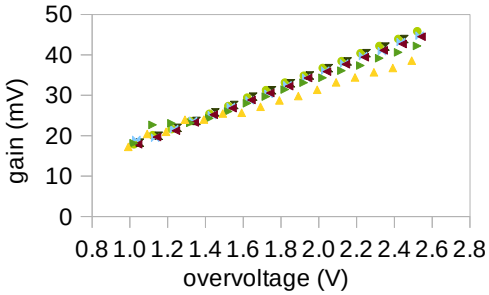
	before irradiation		after irradiation		
SiPM #	average slope	stdev	average slope	stdev	fluence
0	16.226	0.287	16.828	2.137	$5.07 \cdot 10^{11}$
1	16.071	0.316	17.076	1.749	$2.03 \cdot 10^{11}$
2	16.946	0.118	18.365	0.951	$1.01 \cdot 10^{11}$
3	17.712	0.241	20.103	0.514	$5.07 \cdot 10^{10}$
4	16.670	0.244	18.646	0.590	$2.45 \cdot 10^{10}$
5	17.383	0.190	19.949	0.193	$1.02 \cdot 10^{10}$
6	17.373	0.115	19.921	0.232	$5.06 \cdot 10^{9}$
7	17.519	0.172	19.914	0.349	$1.03 \cdot 10^{9}$

- slope may differ because of convolution in peak amplitude extraction

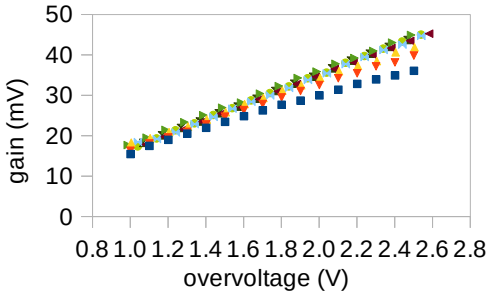
gain vs. overvoltage

- gain vs. overvoltage for all SiPMs

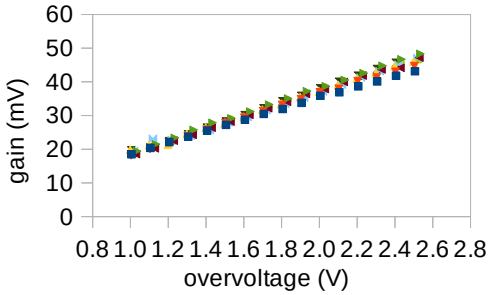
$5.07 \cdot 10^{11}$



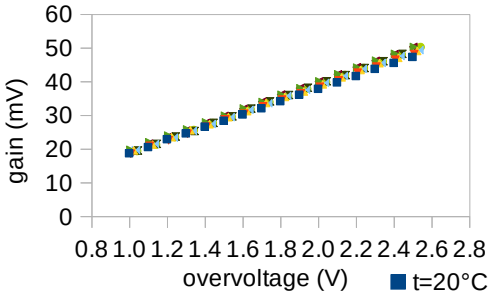
$2.03 \cdot 10^{11}$



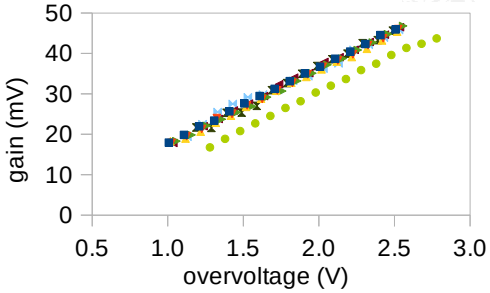
$1.01 \cdot 10^{11}$



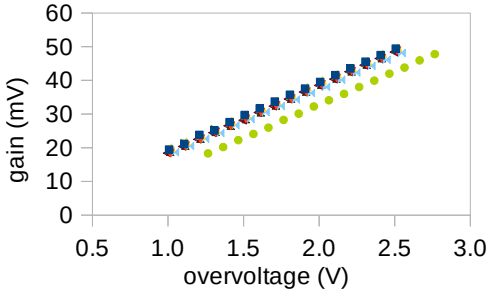
$5.07 \cdot 10^{10}$



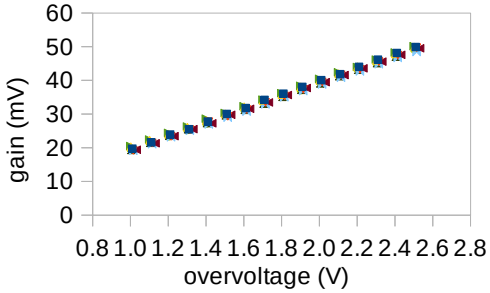
$2.45 \cdot 10^{10}$



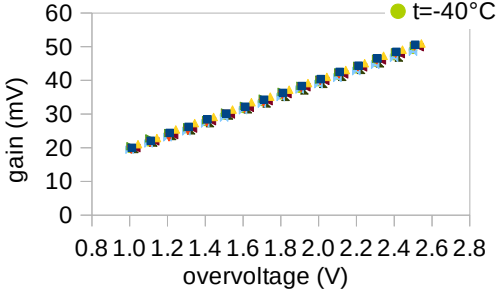
$1.02 \cdot 10^{10}$

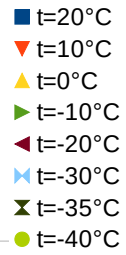


$5.06 \cdot 10^{9}$



$1.03 \cdot 10^{9}$





breakdown voltage

- variation of breakdown voltages before and after irradiation averaged on all the temperatures

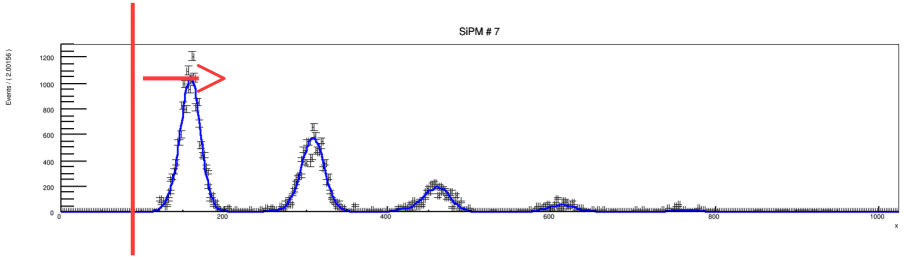
SiPM #	average variation (V)	stdev (V)	fluence
0	-0.082	0.193	$5.07 \cdot 10^{11}$
1	-0.004	0.107	$2.03 \cdot 10^{11}$
2	-0.021	0.060	$1.01 \cdot 10^{11}$
3	0.052	0.030	$5.07 \cdot 10^{10}$
4	0.097	0.115	$2.45 \cdot 10^{10}$
5	0.100	0.100	$1.02 \cdot 10^{10}$
6	0.023	0.036	$5.06 \cdot 10^{9}$
7	0.014	0.030	$1.03 \cdot 10^{9}$

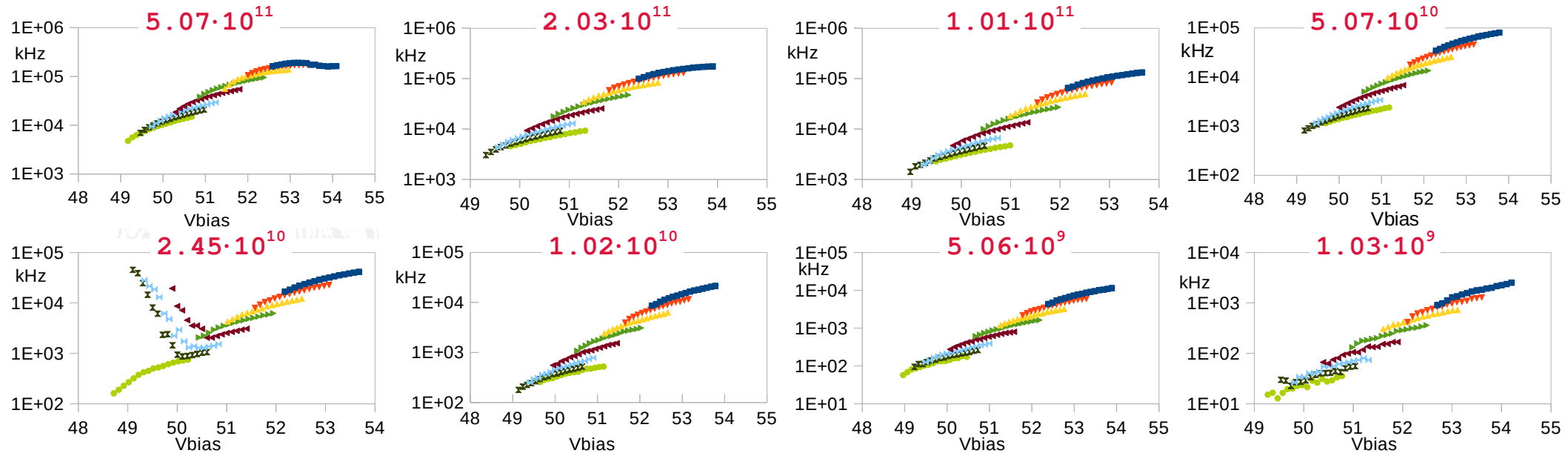
gain vs. overvoltage

- we already saw that SiPM # 4 had problems at low temperatures
- we have to measure again the SiPMs
- currently we are planning for annealing
  - waiting for an oven to become free

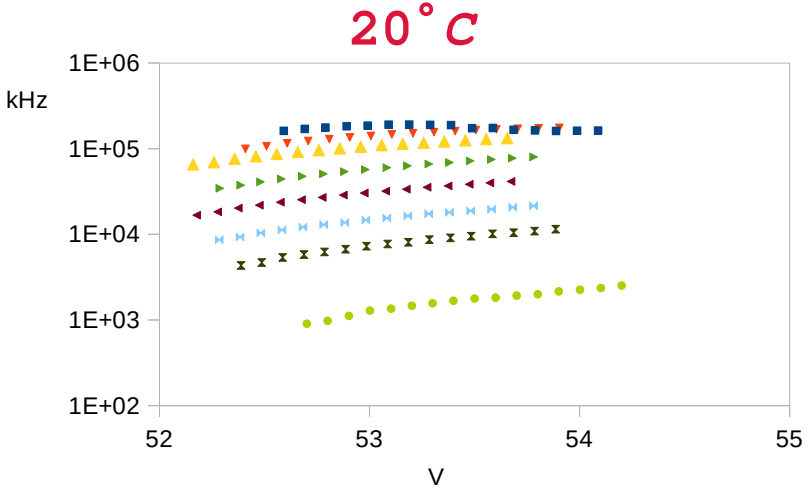
dark count rate

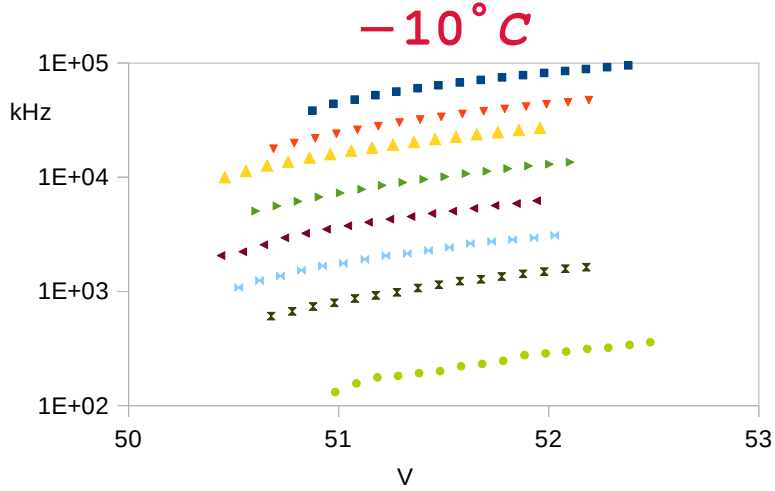
- set a threshold below the one photon peak and count

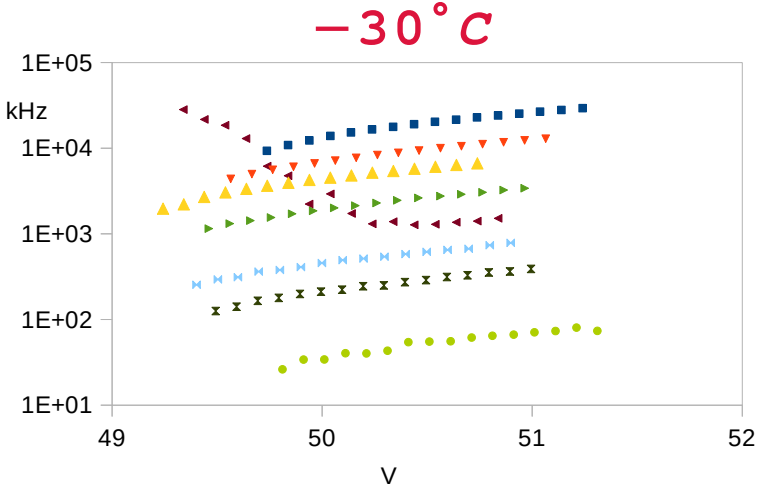


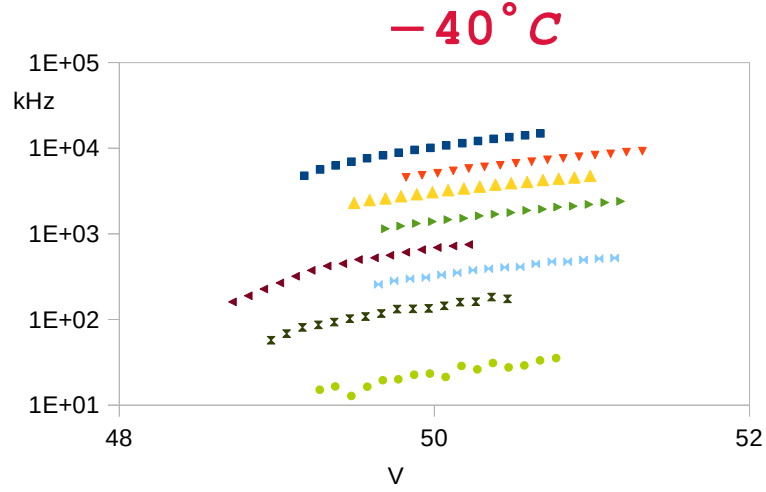


dark count rate









next steps

- new irradiation at the beginning of July
- next time limit fluences at ~10^{11}
- will irradiate 16 SiPMs
  - 8 are under test (three 3x3 mm^2 from FBK, one 3x3 mm^2 from Hamamatsu and four 1x1 mm^2 from FBK)
  - other 8 from other vendors, not yet decided
- anneal the irradiated batch and make full measurements again
- still improving software to detect peaks in high background environments