SiPM Radiation results at 5E13 n/cm2 for CMS - Barrel Timing Layer

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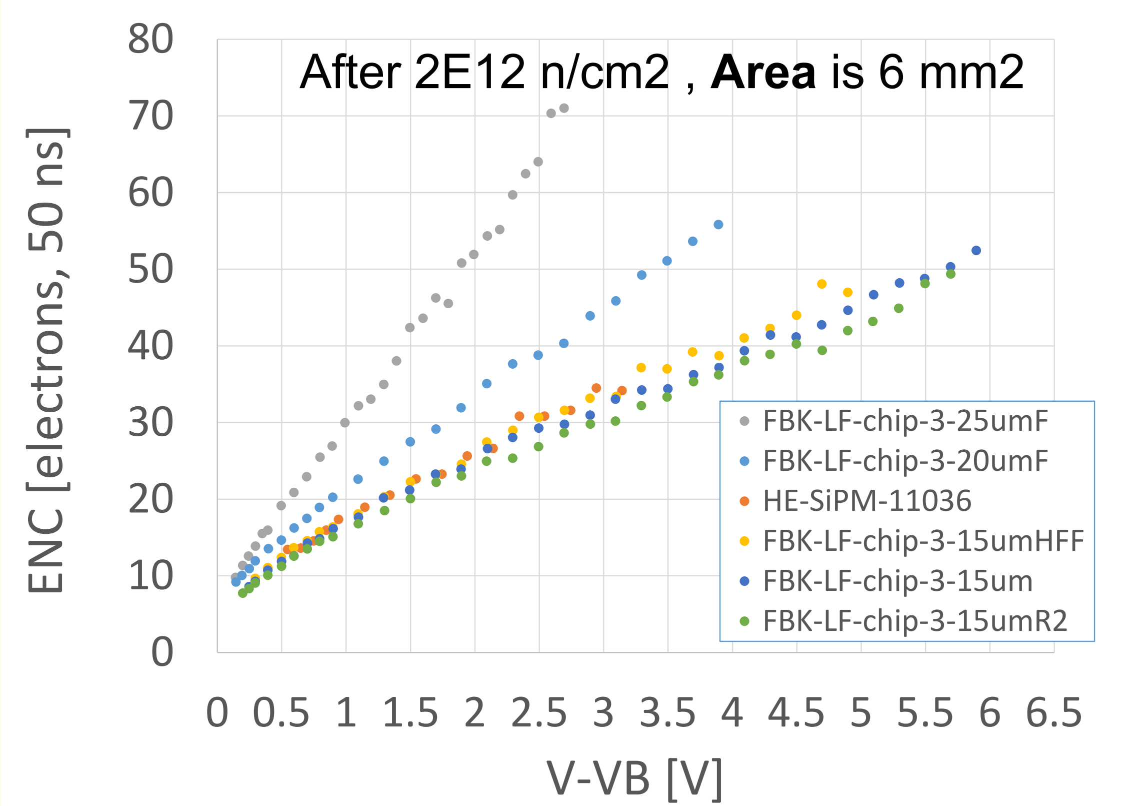
Radiation at JSI

Samples were submitted in DEC 2016 returned and in MAR 2017

	2.00E+12 n/cm²	5.00E+13 n/cm²	Number of samples (2E12)	Number of samples (5E13)
	FBK-LF-chip-3	FBK-LF-chip-5	6	6
FBK NUV	FBK-SF-chip-6	FBK-SF-chip-8	6	6
	FBK-5um-1	FBK-5um-2	1	1
RGB UHD2	FBK-7.5um-1	FBK-7.5um-2	1	1
	FBK-10um-1	FBK-10um-2	1	1
	CMS-5706-3	CMS-5703-5	1	1
		HPK-S12571-010-C-406		1
HPK catalog		HPK-S12571-015-C-183		1
		HPK-S13360-1325CS-10326		1
	NDL-2	NDL-4	1	1
	S10943-4732-11036	S10943-4732-11064	8	8
HE HPK	KETEK-PP-array-39	KETEK-PP-array-40	4	6
	MAPD-3N-1	MAPD-3N-2	1	1
New HPK	HD-1015CN-SMPA_2	HD-1015CN-SMPA_3	1	1
	HD-1025CN-SMPA_5	HD-1025CN-SMPA_6	1	1
	CMS-5701-2	CMS-5706-4	1	1
			33	38
	HB	BH/BTL		

HE HPK = production SiPM developed for CMS HCAL ENDCAP

NUV FBK (23C, after annealing) vs HPK

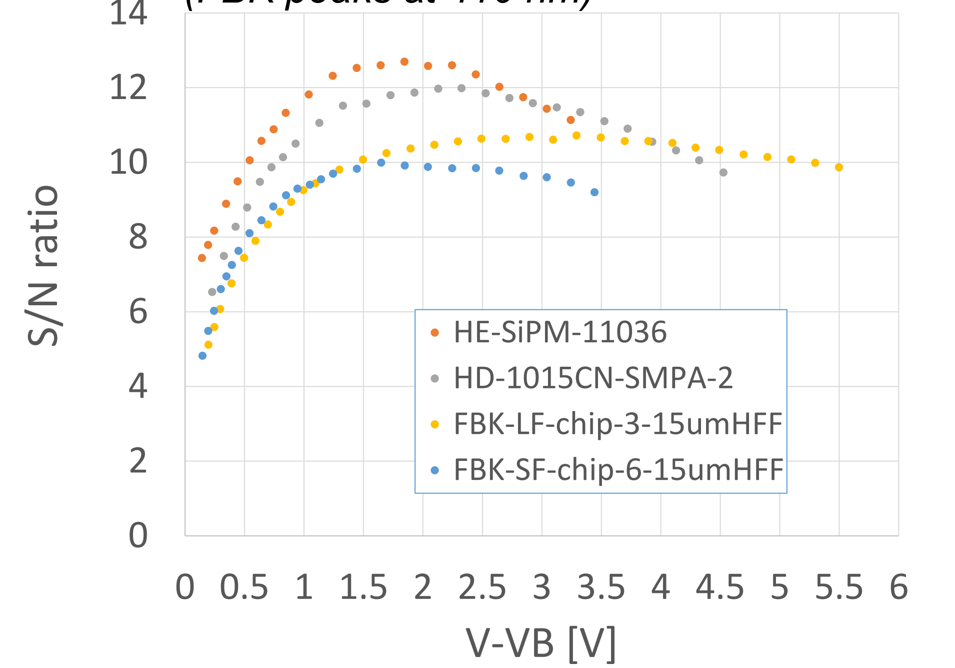


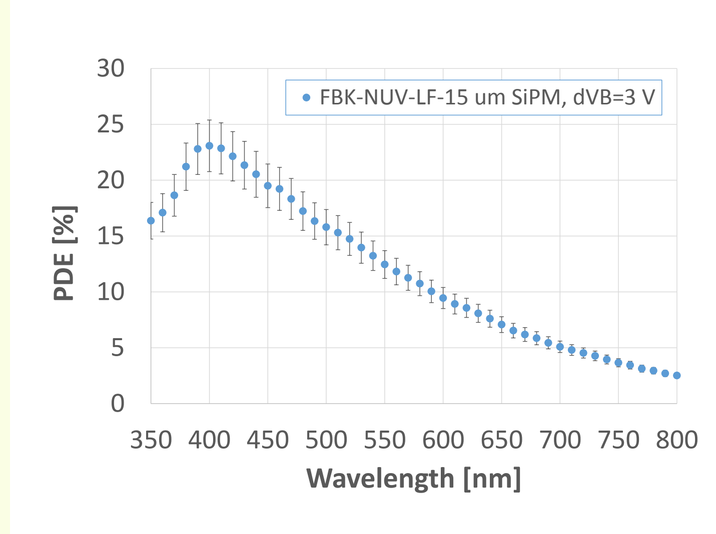
March 2017 analyses using pulsed LED

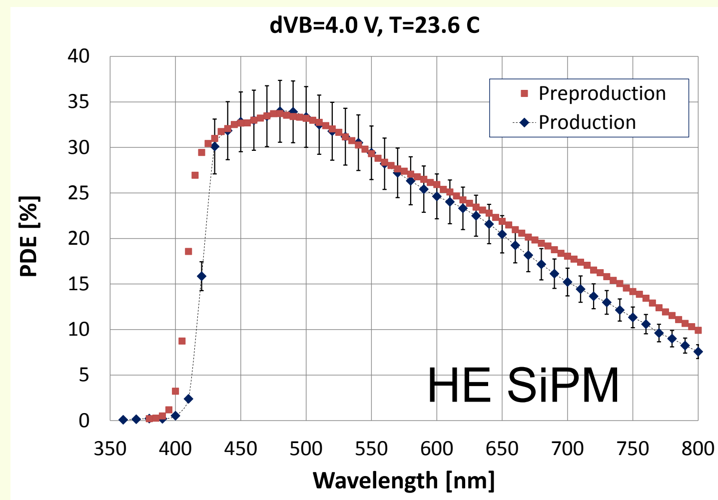
We found 25p.e. noise in 50 ns gate at 23C ; We estimated in GHz :
25^2/50 ns = 12.5 GHz
60 C lower temperature -> 12.5/ (1.8)^6 = 0.37 GHz
At 100 *dose we expect 37 GHz for 6mm^2 at 2E14

2e12n/cm2, 450 nm, T=23C

For T= 23 C and 450 nm
(FBK peaks at 410 nm)







For both we expect about 20% PDE at 420 nm and 2V overvoltage

Anti reflective coating also blocks the light < 400 nm

Dark current after 5E13 at low T

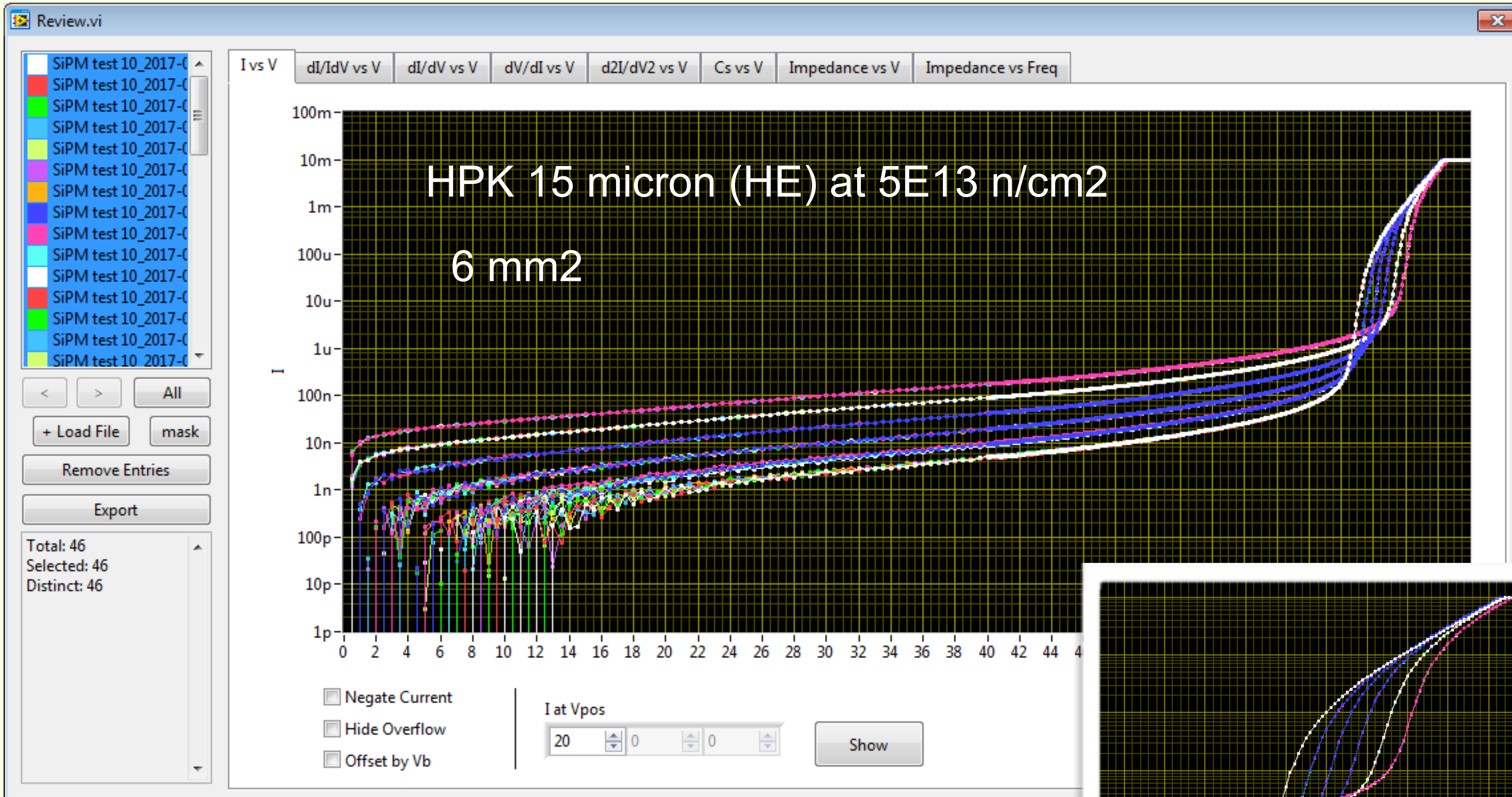
Devices radiated at 5E13 n/cm2 were shipped in cold from JSI to CERN
Then left in the freezer at around -20C for 6 months

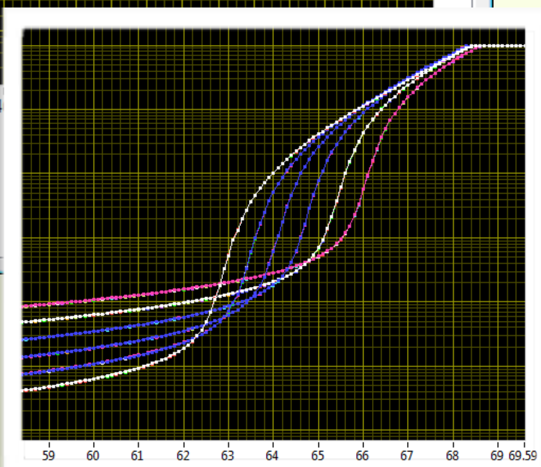
Setup and measurements in Lab in CERN Bat28 Climat Chamber (M.Moll) were done by:

J. Gonzalez

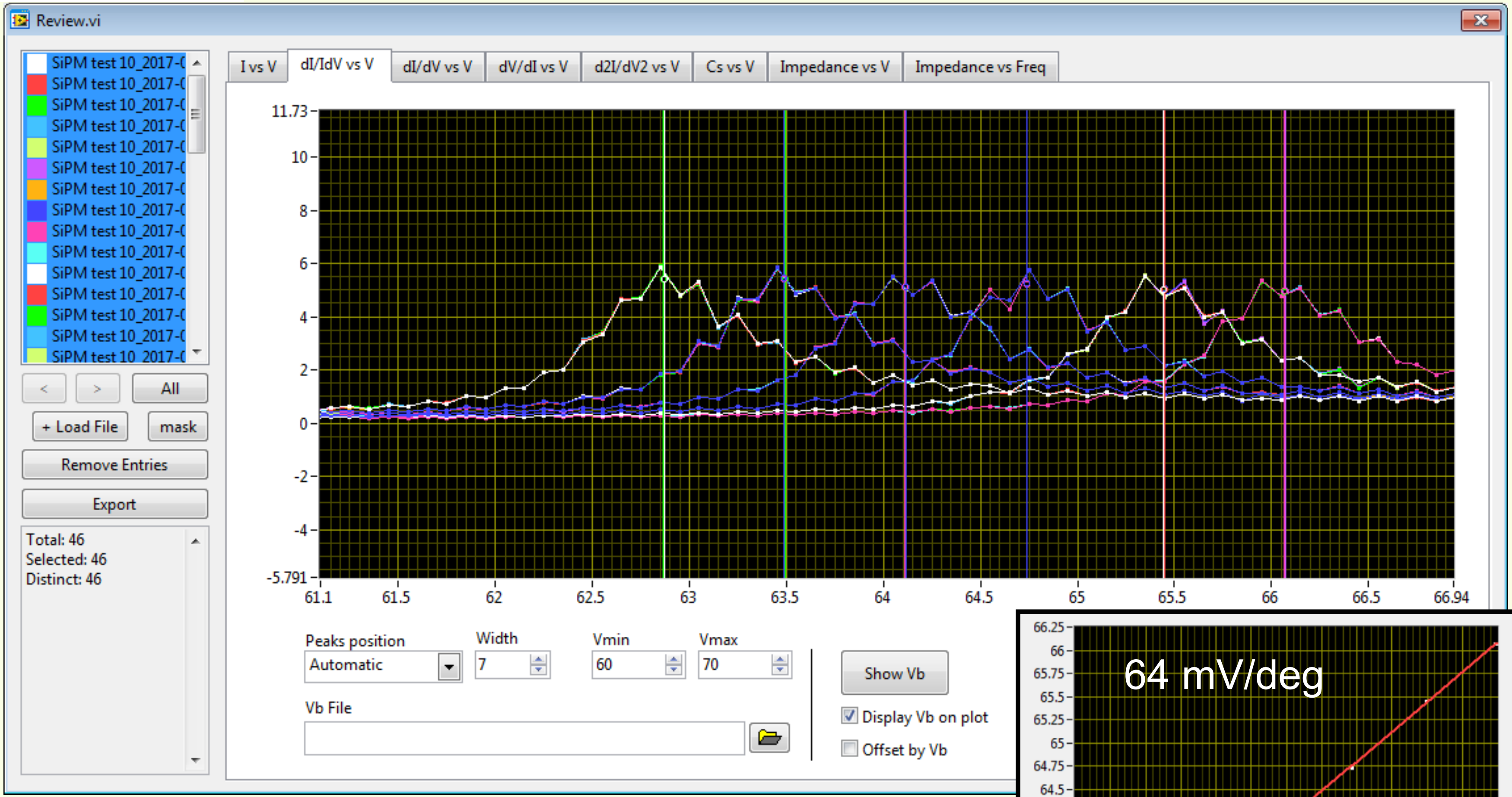
We focus here on the best candidates:
FBK NuV 15 micron low field and HPK 15 micron (HE device)

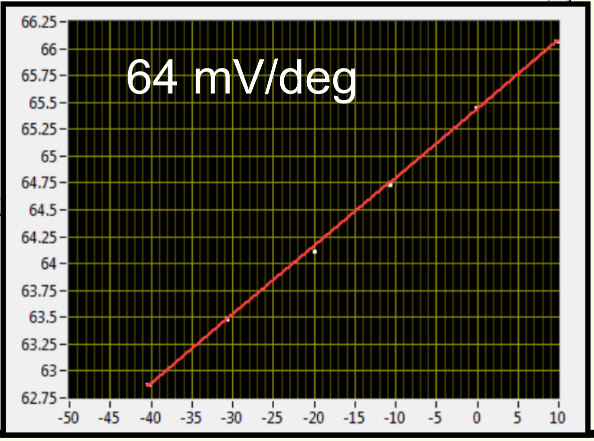
HPK: IV at T= 10,0,-10,-20,-30 and -40V



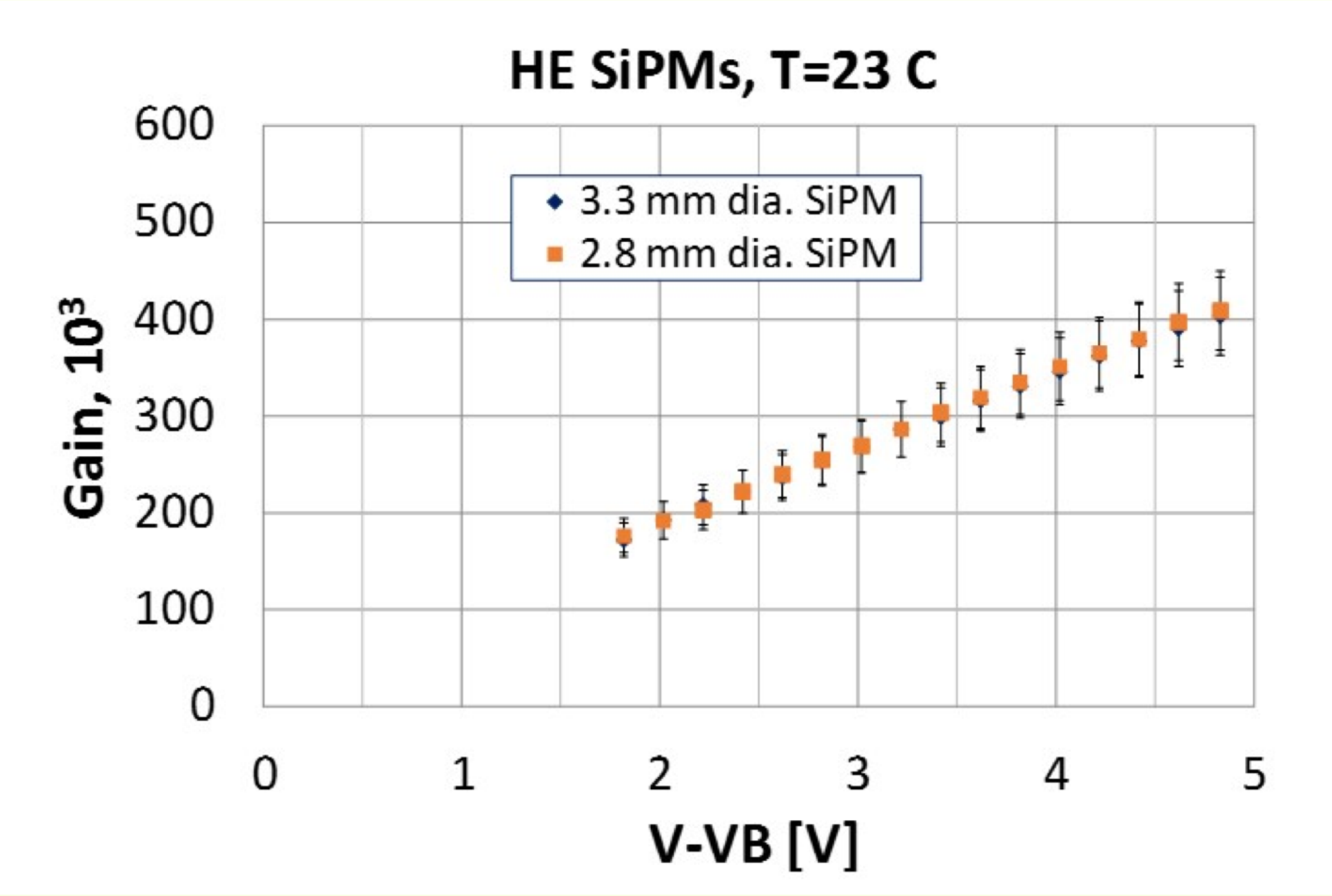


Calculation of Breakdown voltage

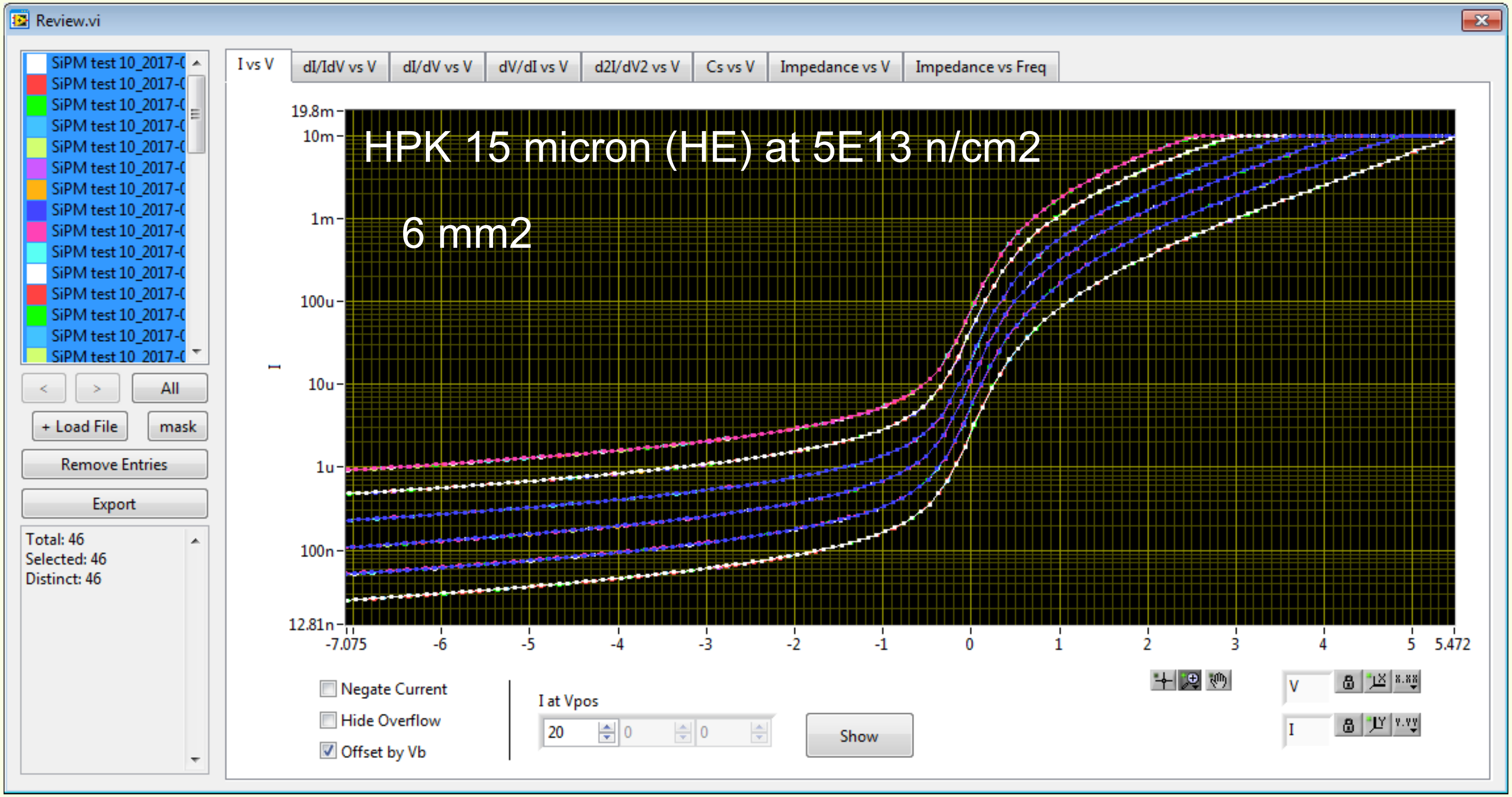




HPK HE SiPM gain



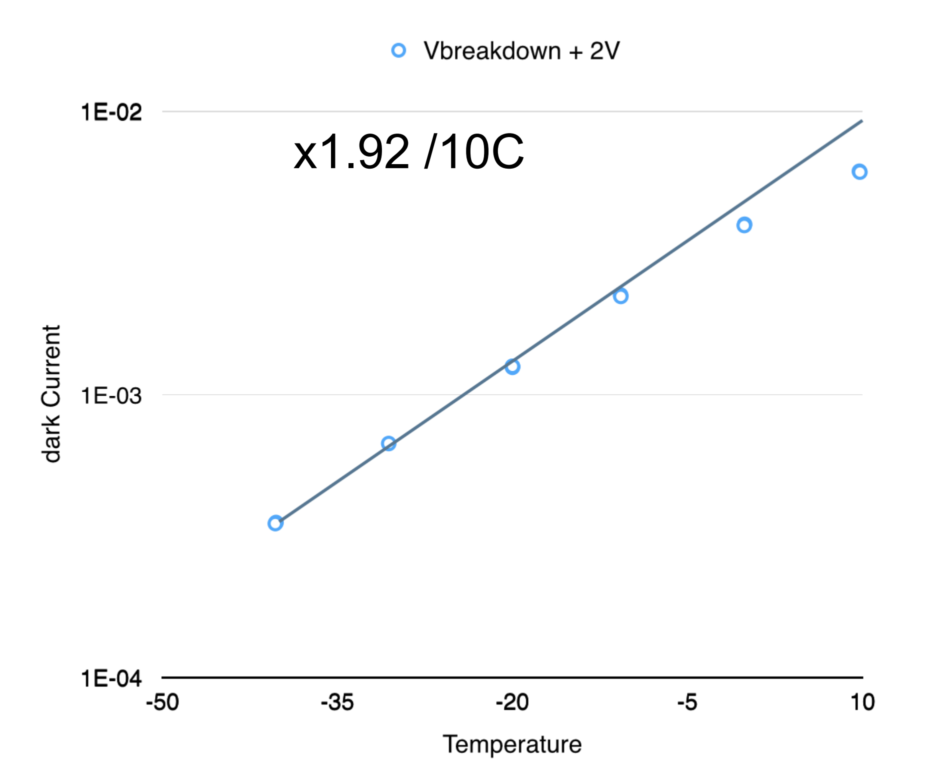
HPK: IV at T= 10,0,-10,-20,-30 and -40V

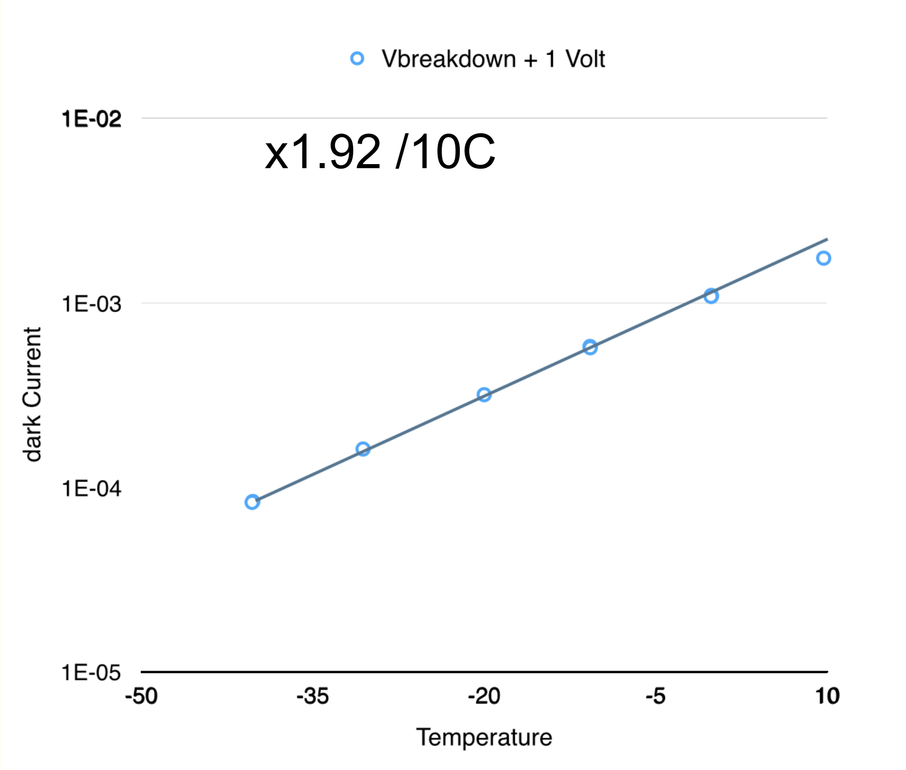


Estimate of the DCR at 2V (I /Gain *1/q) = 15 GHz at -35C
for 6mm2 (or 2.5 GHz/mm2)

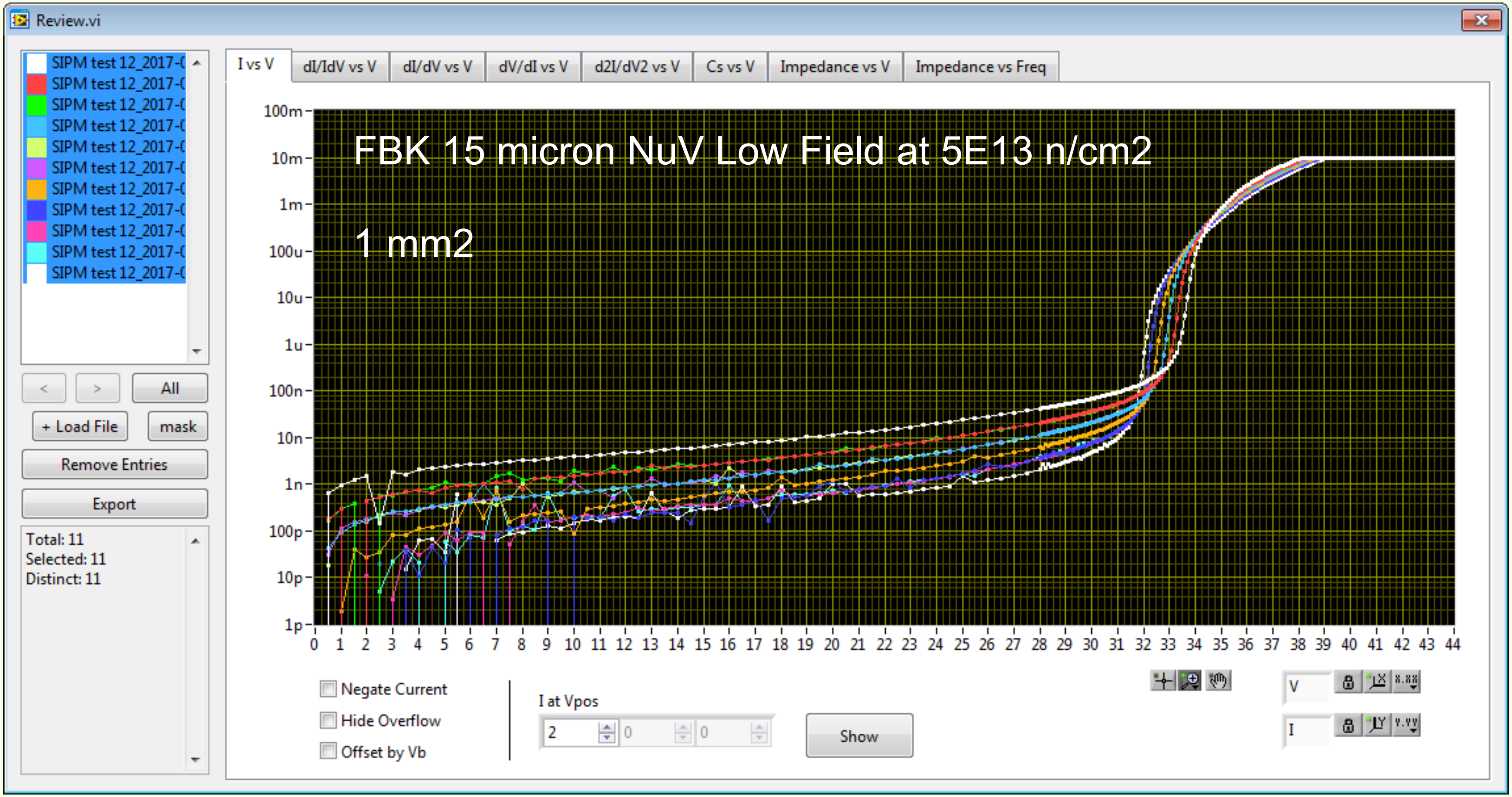
Dark current vs Temp

6 mm2 HPK 15 micron (HE) at 5E13 n/cm2



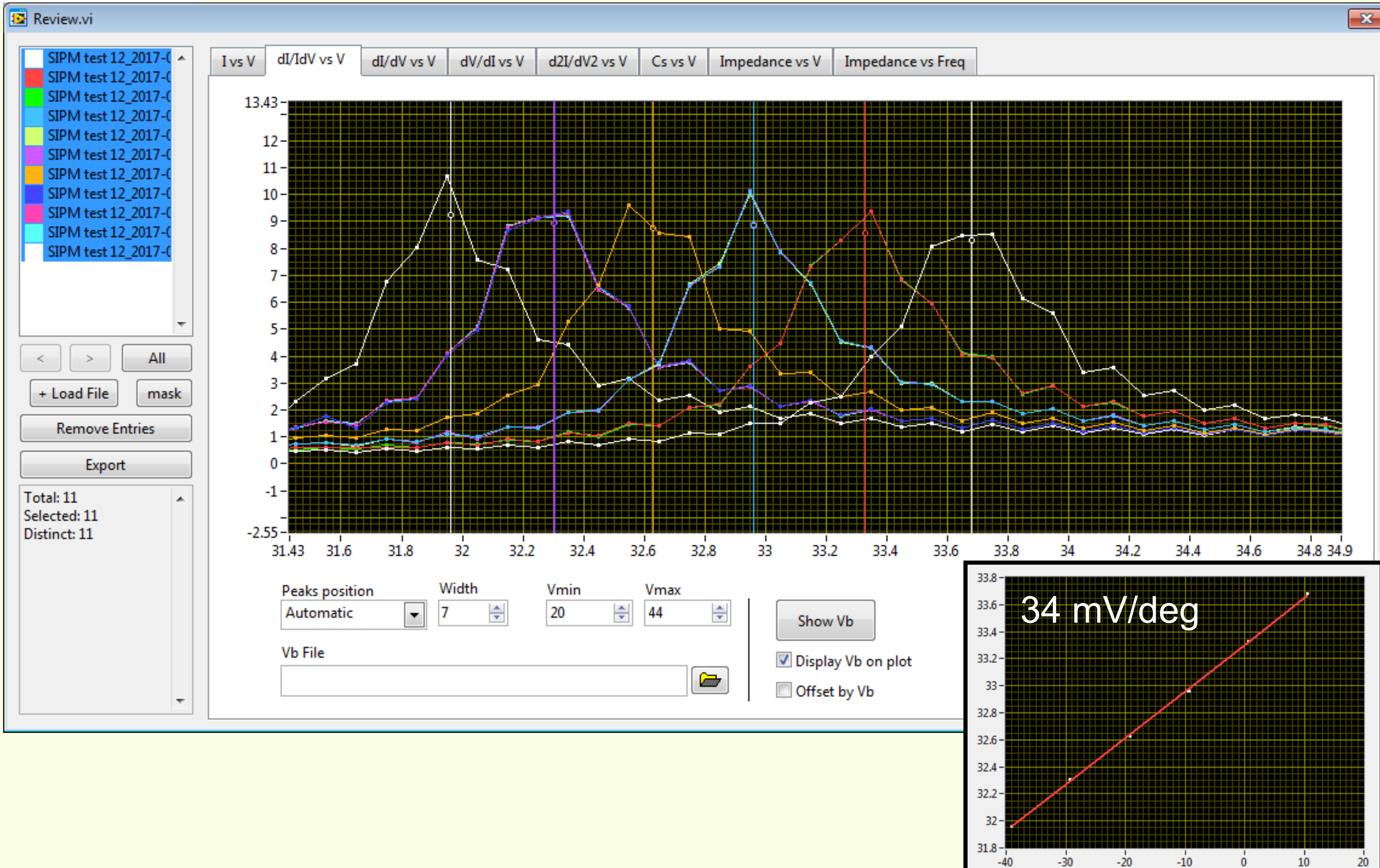


FBK : IV at T= 10,0,-10,-20,-30 and -40V

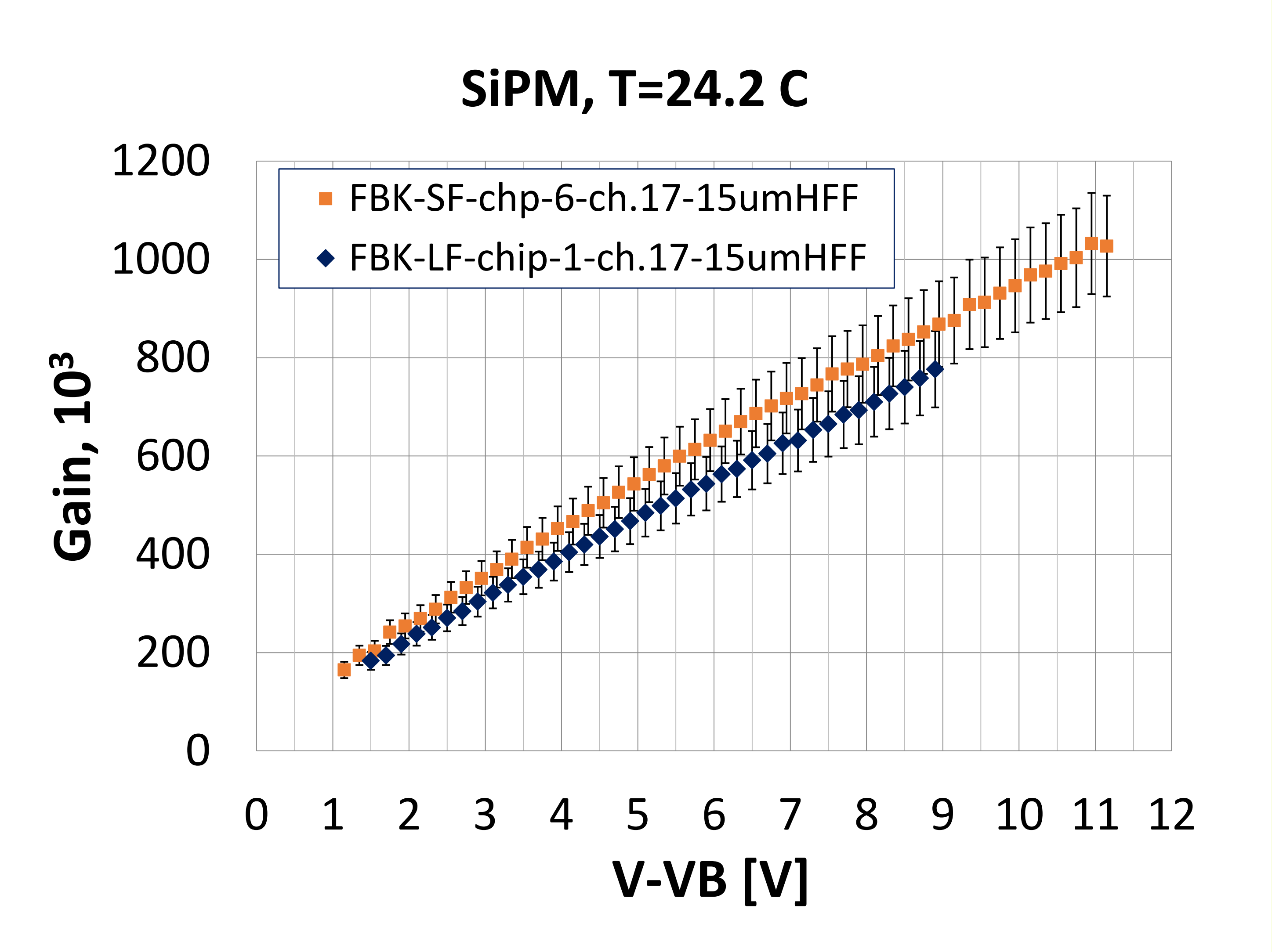


Vb is lower ; around 34V

FBK : IV at T= 10,0,-10,-20,-30 and -40V

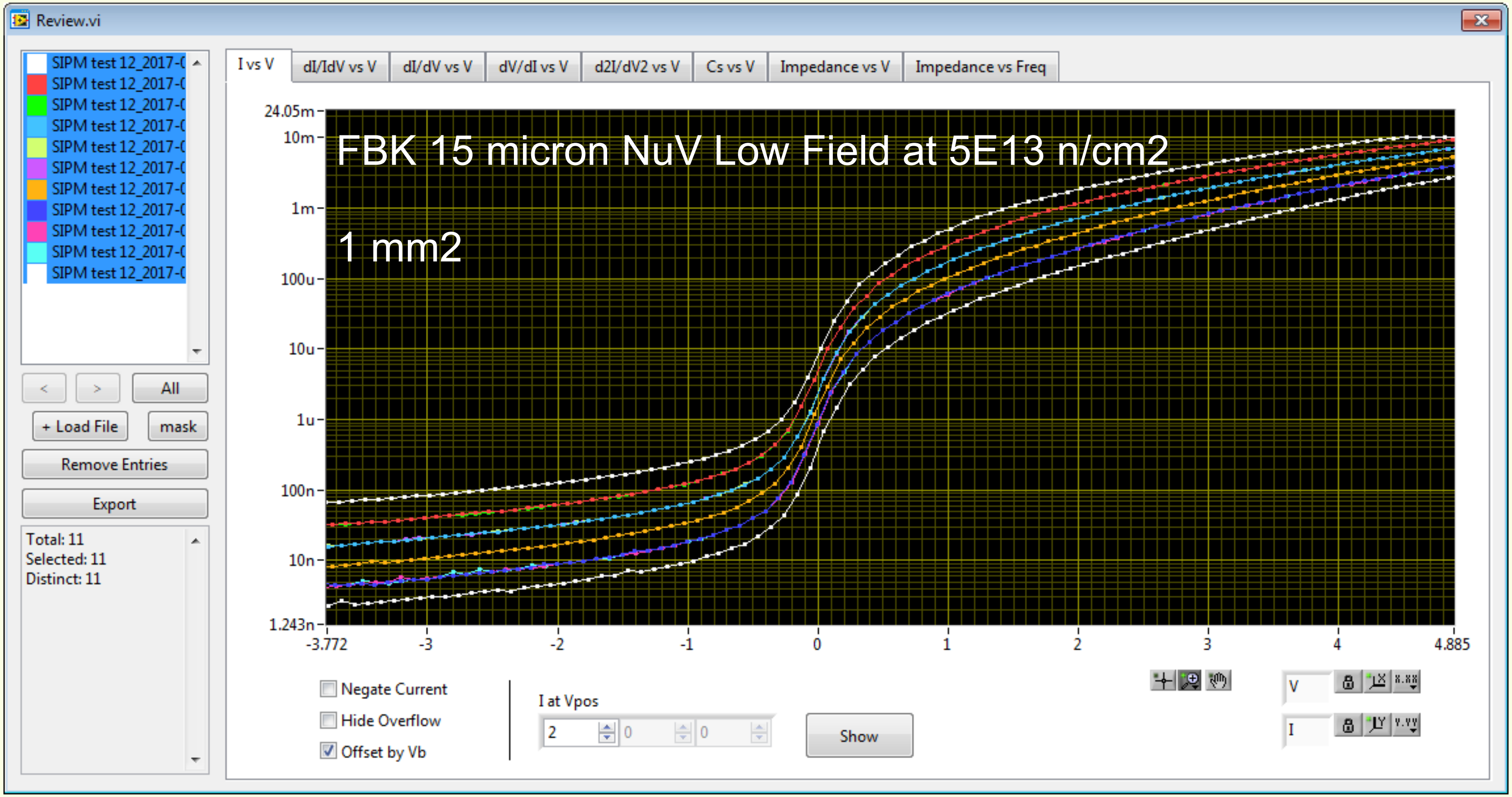


FBK NuV gain



SiPM, T=24.2 C
FBK-SF-chp-6-ch.17-15umHFF
FBK-LF-chip-1-ch.17-15umHFF
Gain, 10³
1200
1000
800
600
400
200
0
0 1 2 3 4 5 6 7 8 9 10 11 12
V-VB [V]

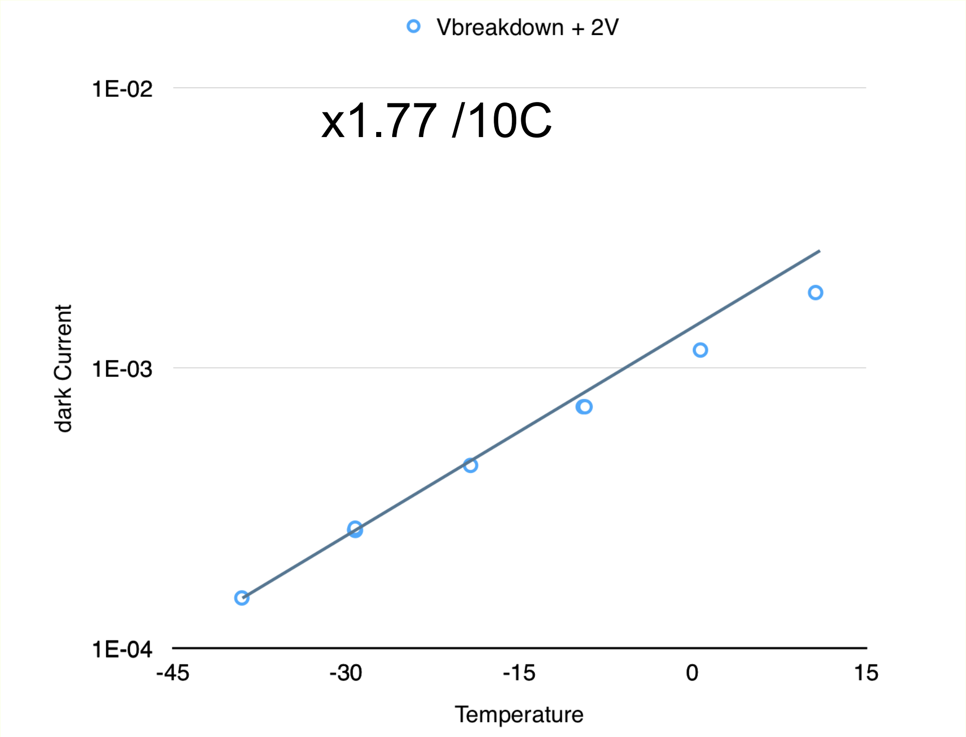
FBK : IV at T= 10,0,-10,-20,-30 and -40V

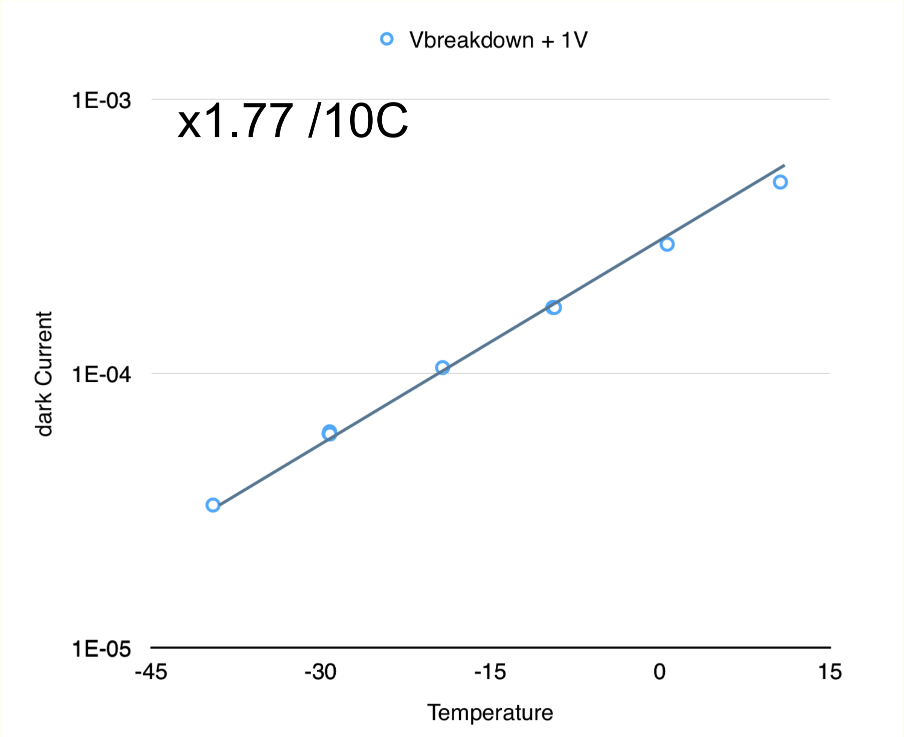


Estimate of the DCR at 2V (I /Gain *1/q) = 5 GHz at -35C for 1mm2

Dark current vs Temp

1 mm2 FBK 15 micron NuV Low Field at 5E13 n/cm2





SF (standard field) has a coefficient of only 1.65

Advantages /Dis- of LF devices

Low Field SiPM advantages:

- Lower current/noise at Low Temperatures
- Lower Capacitance (linear with voltage)
- Lower Gain (power consumption)

Disadvantages:

- higher Voltage (power)
- Cross talk higher (trench technology is harder with thick epo)
- Larger Breakdown voltage shift vs radiation

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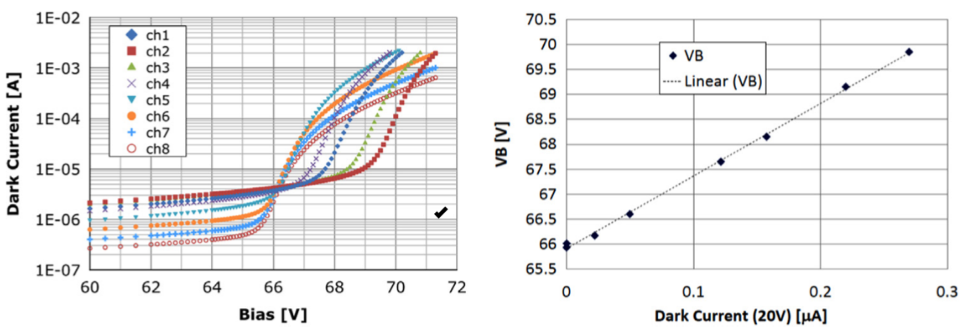
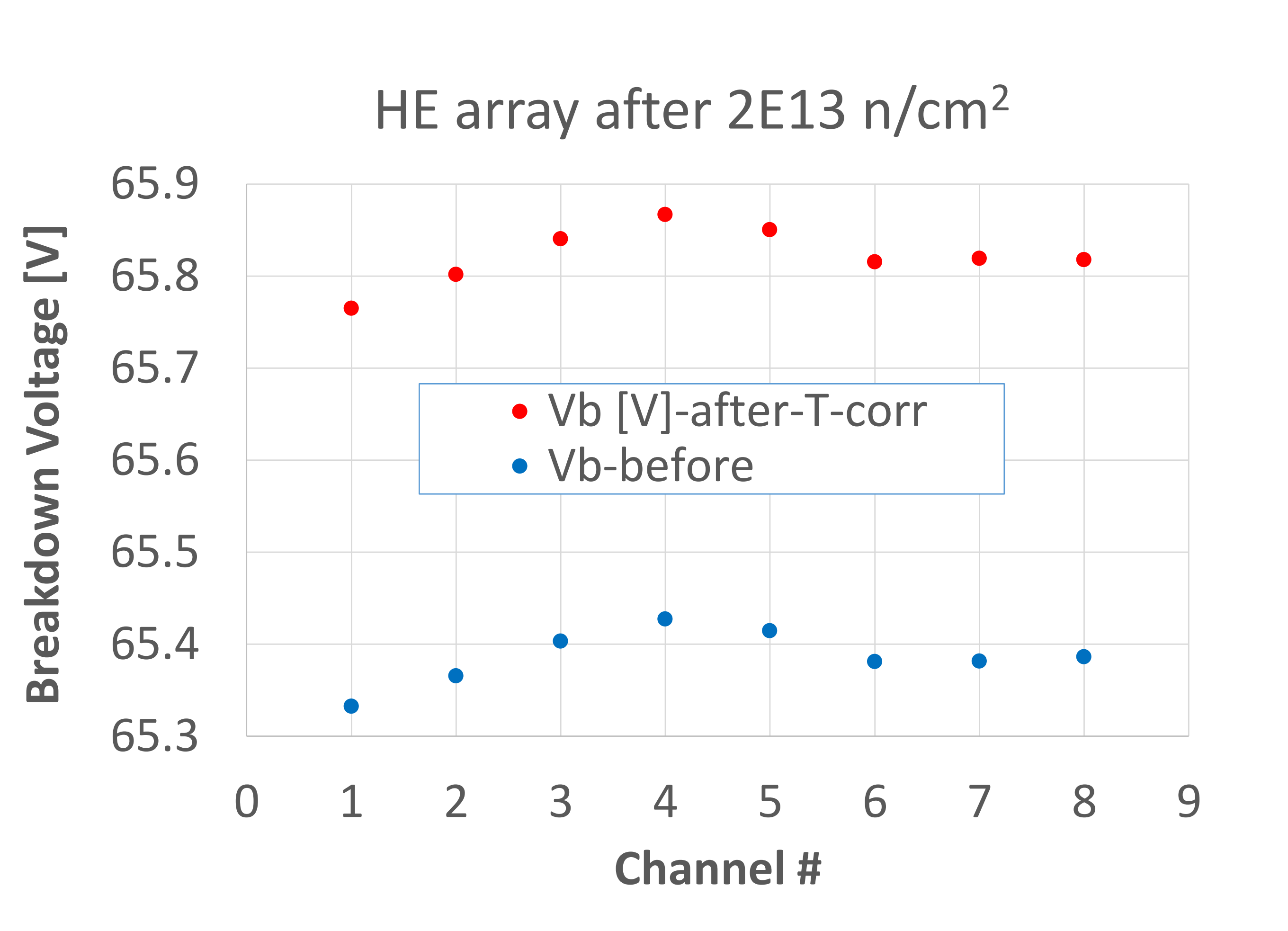


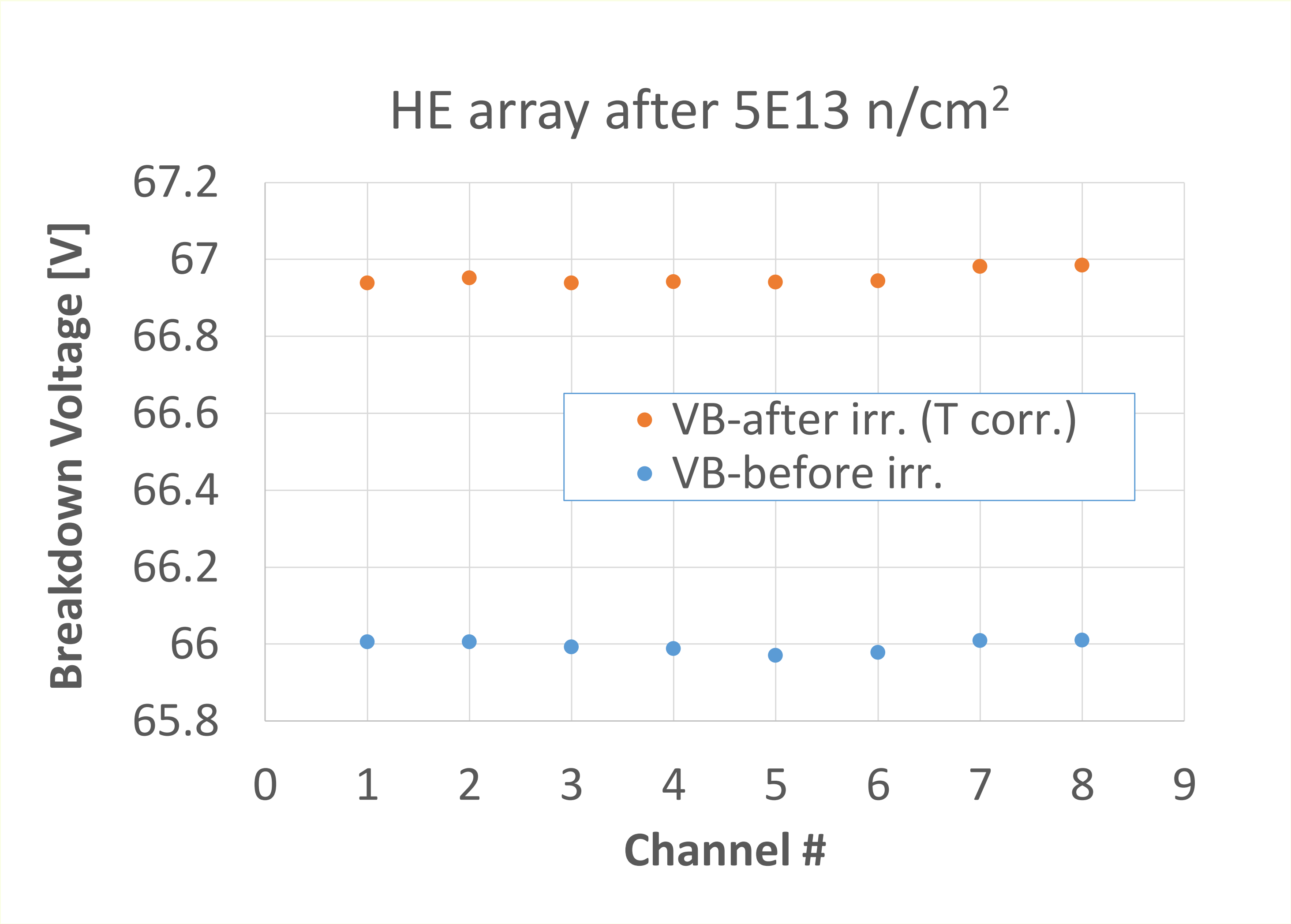
Fig. 3. 10 μm cell HPK 8 channel array with ø 2.8 mm SiPMs with a maximum dose of 2.2×10^{14} n/cm^2 in channel 2. (a) Dark current vs. bias voltage. (b) Bias voltage shift vs. dark current at gain 1.

Beam, p

Break down voltage shift uniformity



Break down voltage shift uniformity



Summery and R&D

The main issue with SiPMs with very high radiation is the large leakage current and gain.

We found that low field SiPMs perform better with radiation specially at low temperature.

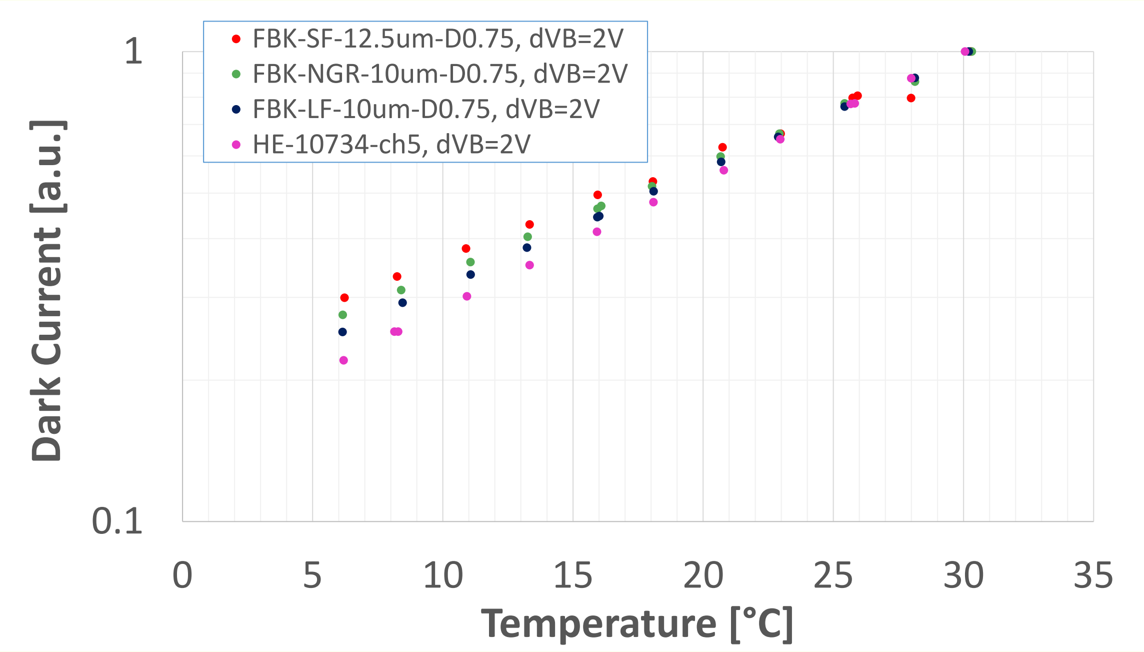
We like to continue further on going SiPM R&D focussed on:

- Low Field SiPMs with high Breakdown voltage (60,90,120 V).

We like to thank JSI for the radiation sessions in the last years!
In particular Vladimir Cindro

Backup

Dark current (dVB=2 V, norm.) vs T



Vbrd , coeficient (/10C)

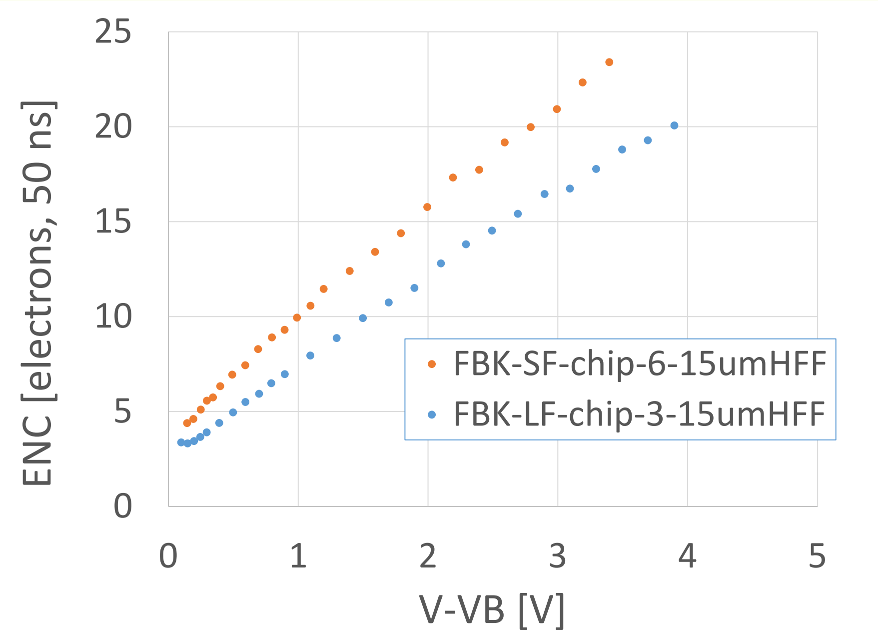
SF = 28V , 1.64
NGR = 30V, 1.71
LF = 34V, 1.77
HPK =65V, 1.87

Yuri Musienko: https://indico.cern.ch/event/645439/contributions/2623381/attachments/1478553/2291622/FBK_UHD-3_SiPMs-after-2E12n-v4.pdf

NUV FBK (after annealing)

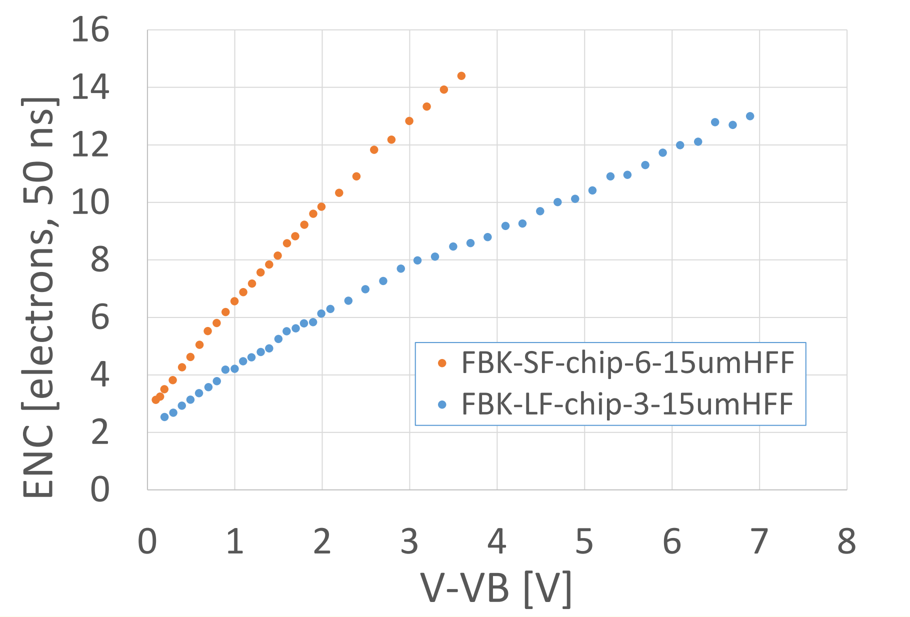
After 2E12 n/cm2 , Area is 1 mm2

T= 23C



ENC(SF)/ENC(LF) ~1.27 at dVB=3V

T= -24C



ENC(SF)/ENC(LF) =1.63 at dVB=3V (ratio=1.27 at room T)