Low Temperature Characteristics of SiPMs After High Radiation

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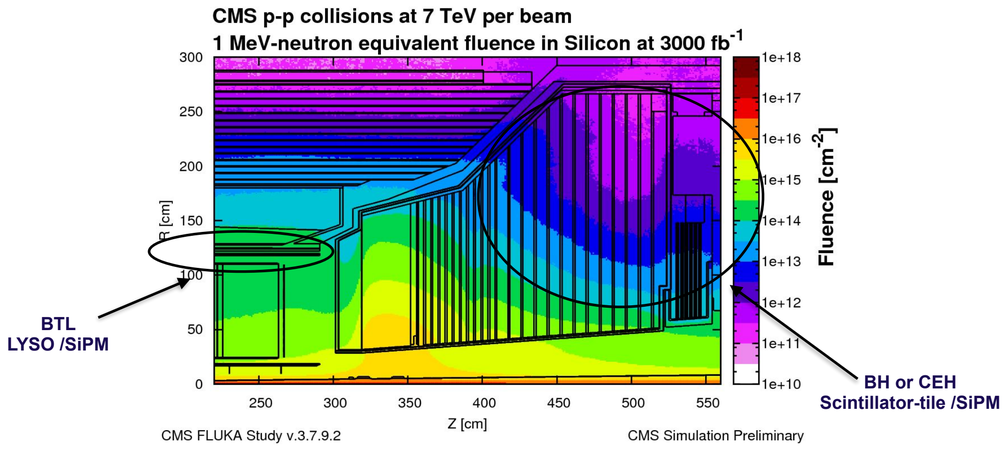
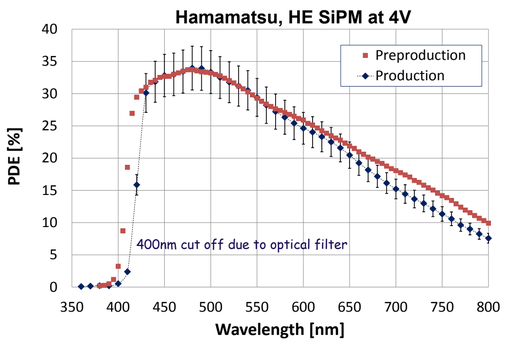
Radiation Damage in CMS

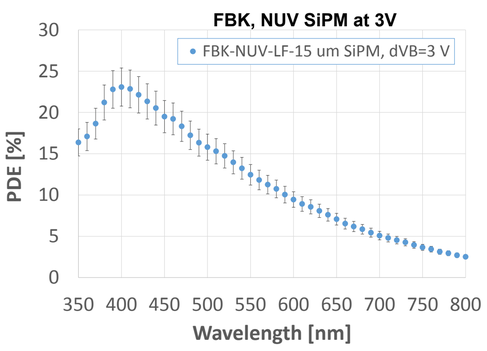


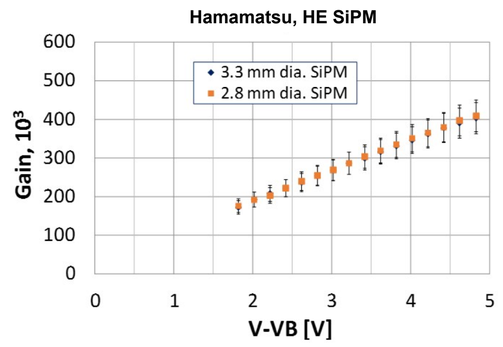
Two new projects in CMS called BTL (Barrel Timing layer) and BH (The Behind Hadronic Calorimeter) have proposed to use SiPMs as photodetector. The very high radiation damage environment of the proposed location in CMS is a challenge for operation of the SiPMs. However the proposed temperature of operation is -30°C.

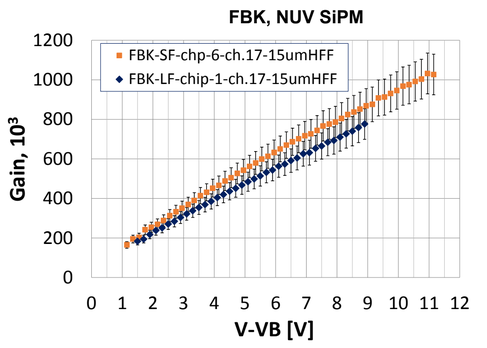
R&D is needed to achieve development of SiPMs capable of operating at these high doses but low temperature

PDE and Gain of samples







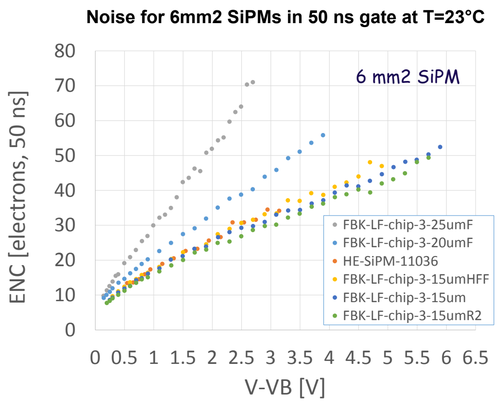


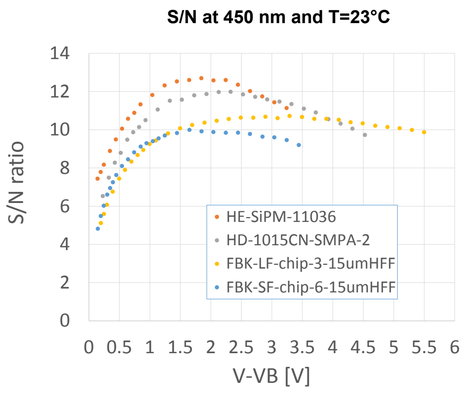
We compared 15 micron cell size SiPMs from two companies, Hamamatsu and FBK. The Hamamatsu samples we also used in a production run for the Hadronic Endcap in the CMS experiment in 2017. We refer to it as HE SiPM. The samples from FBK have high sensitivity in the Near UV. FBK developed two different structures, Standard Field (SF) and Low Field (LF). The low field SiPMs have a higher breakdown voltage and therefore a lower internal electric field The main parameters, PDE and Gain, are plotted. At 2 Volt over-voltage we expect the PDE to be very comparable of around 20% at 410 nm for both manufactures.

Noise after radiation

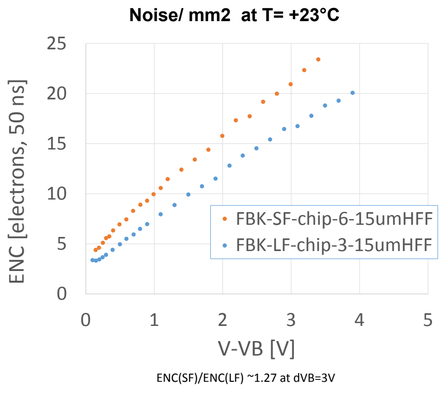
Radiation Damage after 2*10¹² n/cm², (JSI, AIDA 2020)

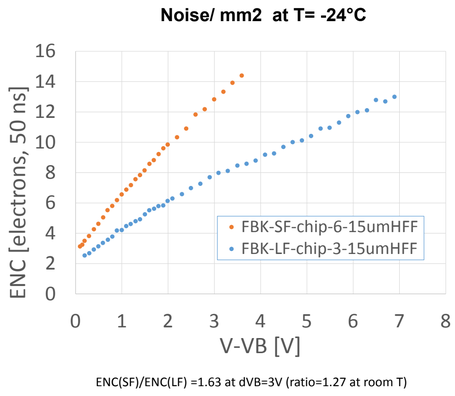
Samples were annealed for 24 hours at 60C





Noise and Signal over noise (S/N) at 450 nm after radiation in a 50 ns gate at room temperature. We found that the best operating point after radiation is around 2V over-voltage.





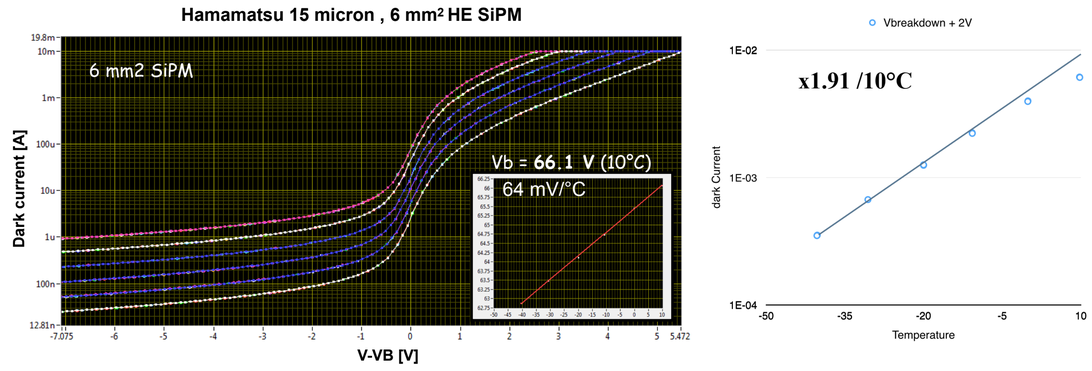
Comparison of noise between Standard field and Low field FBK SiPM after radiation at room temperature and low temperature. Much larger reduction in noise vs temperature was found for the low field SiPMs

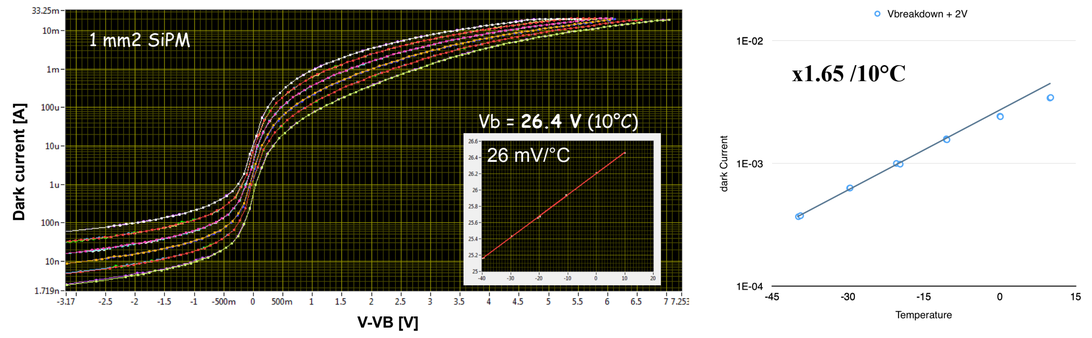
Current Noise vs temperature

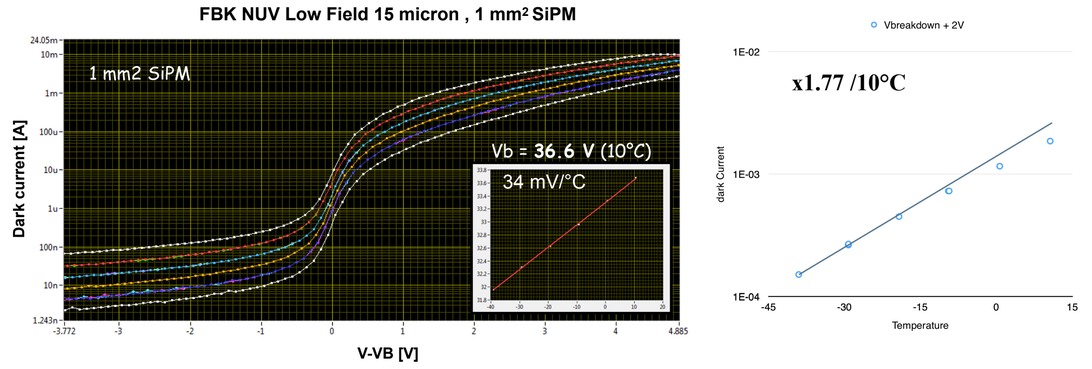
Radiation Damage after 5*10¹³ n/cm², (JSI, AIDA 2020)

Samples were shipped in cold and kept in freezer (non annealed)

Dark current measurements at resp. T = 10,0,-10,-20,-30 and -40°C

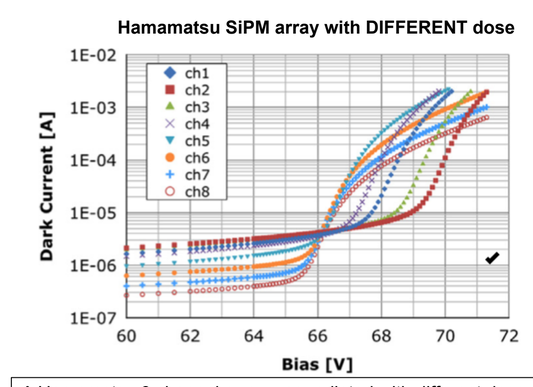


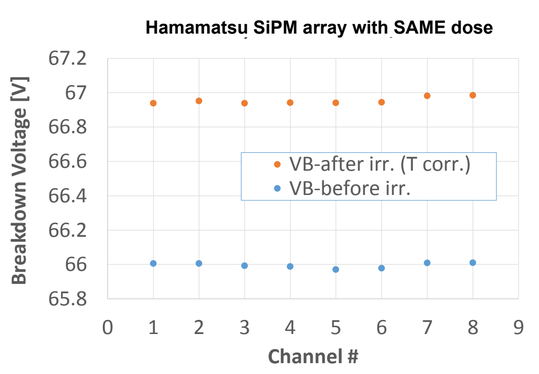




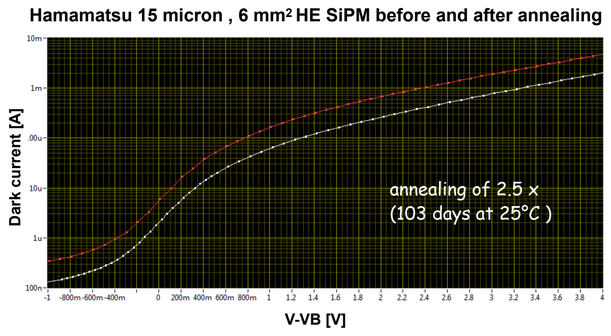
We observe a much weaker dependence on the dark current vs temperature of SiPMs with silicon based simple PIN diodes (typically 2.42/10°C). However we find different dependence of this behavior for SiPMs with different internal field (breakdown voltage). High Electric Field effects (such as tunneling and field enhanced generation) play a significant role in the SiPM dark noise.

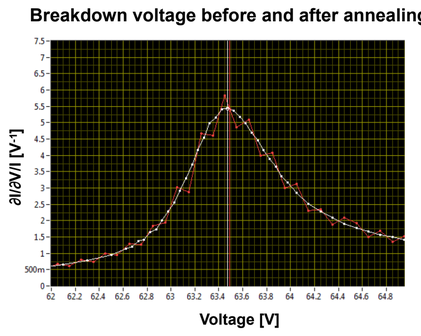
Breakdown shift and annealing

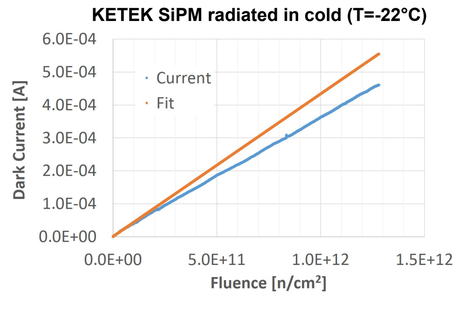


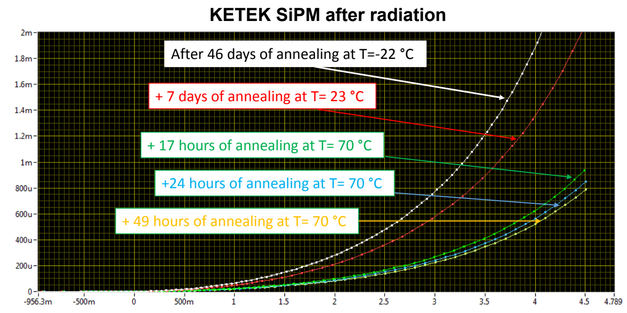


A Hamamatsu 8 channel array was radiated with different doses for each pixel (1E12 to 2E14). We found a linear behavior vs dose of up to 4 volt shift at highest dose. The 15 micron HE SiPM array radiation at 5E13 n/cm2 for all 8 channels shows very uniform behavior of the breakdown voltage shift.









A KETEK 3x3 mm2 SiPM with peltier cooler was radiated at the CHARM facility at CERN at -22C. The current was monitored during radiation. From the fit of the lower dose we can see that the current vs dose is nonlinear showing visible annealing even at -22°C