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## Effects of very high radiation on SiPMs

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During the last 5 years we have successfully completed the R&D for instrumentation of SiPMs for the CMS HCAL Phase 1 upgrade in 2018. Much focus was put on radiation damage during these years of R&D. For the HCAL we expect a maximum total dose of 1012 n/cm<sup>2</sup> for an total lifetime integrated luminosity of 3000 fb<sup>-1</sup>. Good correlation between cell size and performance with high radiation was found during this R&D.

To evaluate the possibility of using the SiPMs in the wider CMS environment we have exposed the current state of the art smallest cell SiPMs to radiation of 1.3 10<sup>14</sup> p/cm<sup>2</sup> in the CERN PS 23 GeV proton beam in late 2014. In addition we are developing even smaller cell SiPMs ( < 5x5 micron cells ) together with FBK-IRST (Italy).

Here we report on the effects of noise and breakdown voltage shift due to the extreme high dose. We also report on the first results on spectral response and PDE for different layouts of these newly developed ultra small cell SiPMs.

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