Comments to the draft proposal „Study of the Si-SiO2 interface damage and its interplay with bulk damage by M. Bomben, et al.

It is proposed to form a collaboration to address both experimentally and by simulations the interplay of surface and bulk damage for HL-LHC doses and hadron fluences. The aim is to extend the work made by the Hamburg group on X-ray damage for n-type Si to p-type Si, and to study for both materials the interplay of surface and bulk damage. The structures to be irradiated are MOSCs, GCDs and dedicated strip structures. The irradiations proposed range from 0.5 Gy to 10 MGy for X-rays, and 1013 to 2 1016 n.

Here our comments:

1. Understanding the interplay of bulk and surface damage is important for the development of HL-LHC detectors, and also a central topic of the Hamburg group.
2. One central difficulty is that, at least to our understanding, surface damage and its influence on the electric field in the sensor depends on many parameters, actually more than bulk damage does. Examples are oxide technology and thickness, electric field during irradiation, electric field and biasing history during the measurements, including long-term (> h) effects, boundary conditions on the passivation again with long-term effects. 🡪 a detailed irradiation and measurement program for the test structures has to be set up, and we are happy to contribute.
3. From 2. follows that a systematic approach is needed, and the number of technologies, which can be investigated with a reasonable effort is limited; in any case the technological parameters have to be well known 🡪 technology information from the vendors has to be available, or at least structures should be available, which allows determining them; not having this information may mean wasting time.
4. Agreement on the parameters to be determined and the analysis methods should be reached; an essential part is that the parameters are fed back into TCAD simulation, and see if the simulations agree with the data on the test structures from which the parameters were extracted. 🡪 We are happy to discuss these issues in detail.
5. There is quite some information on surface radiation damage available, and various groups have made efforts to combine this information with bulk damage models. From the way the proposal is written one gets the impression that most of this information is ignored by the authors. 🡪 The proposal should make clear, how it goes beyond the efforts completed and ongoing in other groups.

To conclude: We support a systematic program of studying the interplay between surface and bulk damage, and are interested in helping to set up a concrete and realistic proposal.

**ad. 2.** More information on the multi-parameter aspect of the problem can be found at:

# [1] Impact of outer surface boundary conditions on the charge collection in strip sensors, T.Poehlsen et al., Charge losses in segmented silicon sensors at the Si–SiO2 interface, [doi:10.1016/j.nima.2012.10.063](http://dx.doi.org/10.1016/j.nima.2012.10.063)

# [2] Impact of the dependence of the charge collection in strip sensors on damage with a ß source: CMS Collaboration, <http://arxiv.org/pdf/1505.02672.pdf>

# [3] Impact of the oxide thickness on the breakdown voltage of pixel sensors as function of X-ray dose: J.Schwandt et al., <http://arxiv.org/abs/1210.0430>

# [4] E-field dependence of X-ray radiation damage, I. Kopsalis et al., http://iopscience.iop.org/article/10.1088/1748-0221/11/02/C02017/meta *JINST* 7 C01006; doi: 10.1088/1748-0221/7/01/C01006

**ad. 4.** The proposing group has made already many measurements on test structures and analysed the results. It is strongly encouraged to demonstrate the consistency of their analysis using above approach or a similar “closure” procedure.

**ad. 5.** From previous work it can be predicted that oxide-charge densities will saturate at some values between 2 – 6 1012, and interface traps at approximately 1/3 of this value. Surface generation currents also saturate at levels of order 5-10 μA. Data are also available for the dependence on the magnitude and direction of the electric field. Also the time dependence of the charge distribution on the outer surface of the sensors has been determined. 🡪 As step in parallel to collecting sensors and setting up irradiations these numbers should be implemented into the TCAD simulations in order to better understand the impact of these surface effects on the electric field in the sensor and thus on parameters like the CCE.