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A comprehensive overview of the extensive studies on the irreversible breakdown of the LGAD's behavior at ELI Beamlines in fs-laser beam-tests with the sensors irradiated at critical LHC-HL fluences

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The HL-LHC presents unprecedented challenges and timing information that is expected to play a key role to mitigate the impact of pile-up in both CMS and ATLAS. Broadly speaking, a timing detector is considered to improve the assignment of tracks to vertices in the forward region, which impacts electron ID, jet reconstruction, missing transverse energy and b-tagging. For future accelerators, LGADs as timing sensors, are also an interesting option in lepton accelerators, where timing can improve performance in particular for PID. However, after irradiation timing performance degrades due to loss of gain. To recover, it is important to increase the HV bias. Some devices show am irreversible breakdown while operating in these conditions and this remains a serious concern for both, yield and the LGAD's operation stability. Many systematic studies and dedicated beam-tests at DESY, FNAL and CERN have been performed. Here we present an overview of the fatality tests performed in few dedicated test-campaigns on LGADs at ELI beamlines where we developed a powerful fs-laser based TCT-SPA/TPA experimental infrastructure. Both SPA and TPA were applied. Stable, unstable, critical, and irreversible breakdown phases were distinguished and safety HV bias thresholds set. The images of damaged sensors and HV threshold points for safety LGAD operation will be discussed as well as future strategies pointed out.

Your name

Gordana Lastovicka-Medin

email

gordana.medin@gmail.com

Title

Prof

Nationality

Montenegrin

Institute

University of Montenegro

Author: LASTOVICKA MEDIN, Gordana (University of Montenegro (ME))

Co-authors: KRAMBERGER, Gregor (Jozef Stefan Institute (SI)); Dr REBARZ, Mateusz (Extreme Light Infrastructure); Dr ANDREASSON, Jakob (Extreme Light Infrastructure); Dr KROPIELNICZKI, Kamil (Extreme Light Infrastructure); KROLL, Jiri (Czech Academy of Sciences (CZ)); LASTOVICKA, Tomas (Czech Academy of Sciences (CZ)); TOMASEK, Michal (Acad. of Sciences of the Czech Rep. (CZ)); CARTIGLIA, Nicolo (INFN Torino (IT)); SOLA, Valentina (Universita e INFN Torino (IT))

Presenter: LASTOVICKA MEDIN, Gordana (University of Montenegro (ME))

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