PXD Emergency Shutdown Investigation

PAULA SCHOLZ
Physikalisches Institut der Universität Bonn

1 Belle II Pixel Detector

To find physics beyond the Standard Model, such as CP violation, the Belle II experiment studies rare decays produced in the high-luminosity accelerator SuperKEKB ($L_{target} = 8\times10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$). The Pixel Detector (see Fig. 1), short PXD, is the innermost subdetector of Belle II and is based on the DEpleted P-channel Field Effect Transistor (DEPFET) technology to reconstruct particle vertices.
Each of the 40 detector modules consists of an array of 768×250 pixels. For each readout cycle (50 kHz) the transistor voltages are switched in a rolling-shutter mode. This is accomplished by Application-Specific Integrated Circuits (ASICs) called „switchers“.

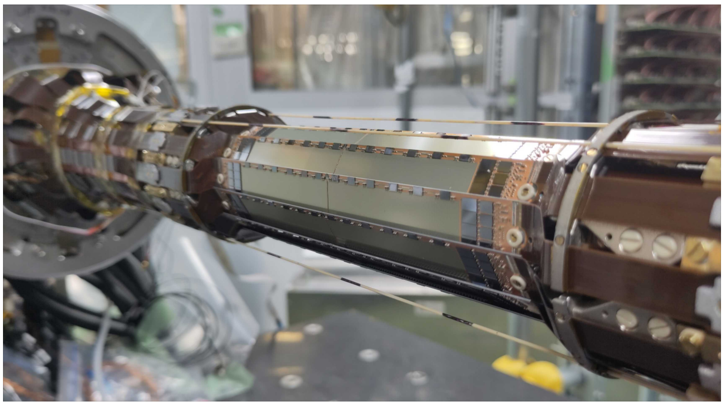

Figure 1: Photograph of PXD2.

2 Beam loss events

During the operation of Belle II, several beam loss events with severe consequences for PXD occurred. This was particularly evident during an event in May 2020, when a sudden beam loss resulted in an effective radiation dose of approximately 500 rad within 40 µs. PXD exhibited several non-responsive pixel rows afterwards, resulting in an overall efficiency drop of 3 %. Based on irradiation studies with small-scale PXD demonstrators, the switchers appear to be the vulnerable element. It was also shown that the switchers are protected from damage when only digital voltages are applied. This insight led to a seemingly simple solution: implementing an emergency shutdown for the PXD modules.

3 Electrical circuit simulation

PXD requires a complex power network with 23 different voltages needed for each module. Due to dependencies between voltage levels, a specific power-down sequence of the detector must be followed to avoid damaging the ASICs. Electrical circuit simulations offer a non-destructive and versatile way to investigate how the modules can be switched off as quickly and safely as possible.

Long cables in the order of 15 m affect the transmission of emergency shutdown signals and are therefore a focus in the simulations. Different simulation tools („HyperLynx“ and „LTSpice“) as well as different cable models (S-parameter model and transmission line model) are evaluated to accurately replicate the physical properties of the cables. These simulations are compared to experimental data from a test setup to validate their accuracy. The goal is to find possible hardware modifications that can be implemented in the experiment.