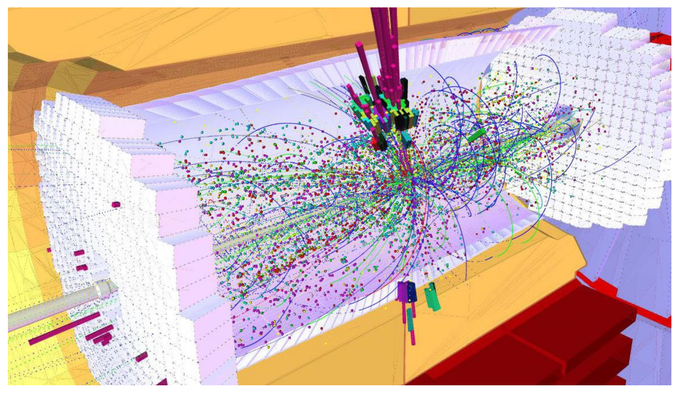
Karlsruhe Institute of Technology

Institut für Experimentelle Teilchenphysik

Sensor R&D for the Phase II Upgrade of the CMS Outer Tracker at KIT

The LHC Phase II Upgrade

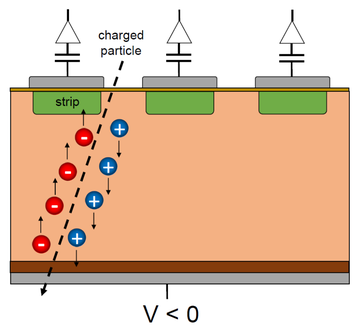
- Reduction of the beam cross-section is going to increase the LHC luminosity, which leads to:
  - higher collision rates
  - more interesting events
  - more significant statistics
  - higher data output (about 1000 TB/sec of raw data)
  - higher radiation levels and radiation damage
- New specifications for the Phase II Upgrade of the CMS Tracker:
  - higher sensor granularity to increase spatial resolution and to reduce occupancy
  - new concepts to reduce and filter the amount generated data
  - radiation-harder sensors and electronics which have to perform reliably and sufficiently detect particles for at least 10 years



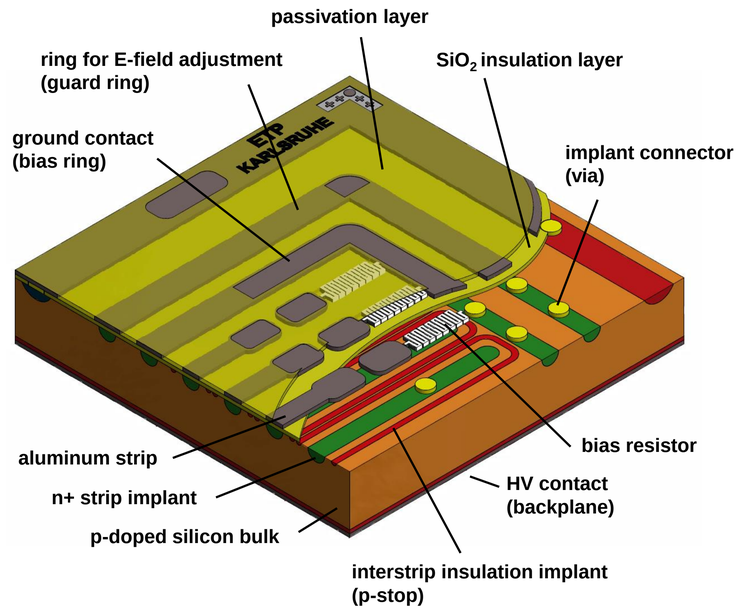
Simulated particle tracks within the CMS Tracker resulting from a single bunch crossing

Silicon Strip Sensors in a Nutshell

- Sensor channels are realized by exploiting the characteristics of p-n-junctions
- Sensors are operated under reverse-bias → inner electric field → sensor is depleted
- Depletion is important since the noise of an undepleted sensor would completely superpose a particle signal → low full depletion voltage desired
- Traversing particles generates electron-hole pairs → separated by the electric field → charge is collected by strips → induce signal in read-out channel
- Despite reverse-biasing, a relatively small but significant *leakage current* is measurable for every sensor → leakage current is the main source of noise and heat dissipation
- Radiation within the CMS Tracker creates defects in the silicon material which
  - trap charge carriers → reduce charge collection efficiency
  - generate additional states within the band gap → increase leakage current
  - increase full depletion voltage

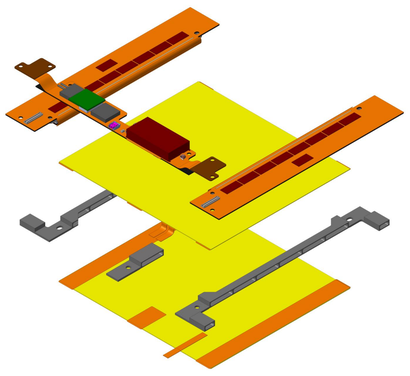


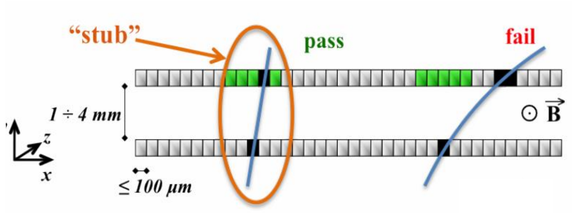
Our goal: find a radiation hard material and design which provides a sufficient signal at an operation voltage of 600 V (desired maximum operation voltage of the CMS Tracker).



The Outer Tracker Module (2S Module)

- A *module* consists of two 10 x 10 cm^2 strip sensors with 2032 strips each (yellow planes), read-out and service electronics as well as support structures (red, orange, gray)
- We are going to build and test 2000 modules for the Outer Tracker Upgrade at KIT

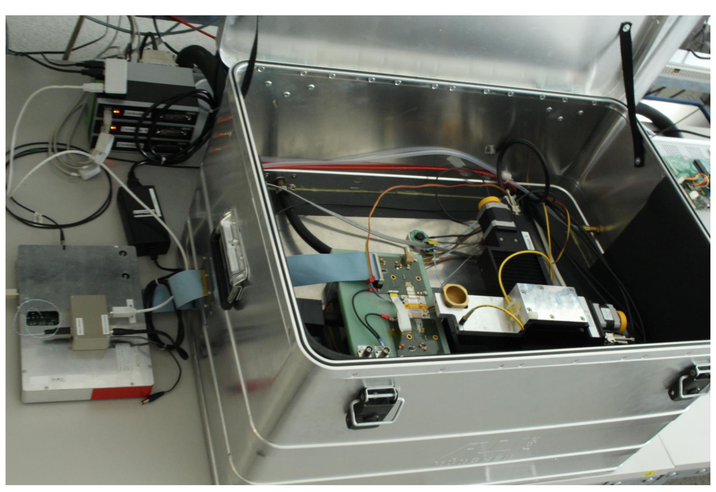




- As a result of the magnetic field of CMS, charged particles move along a bent trajectory
- High energy particles will traverse both sensors within a narrow search window
- Such a hit-doublet is called *stub*
- Stubs will serve as additional trigger information

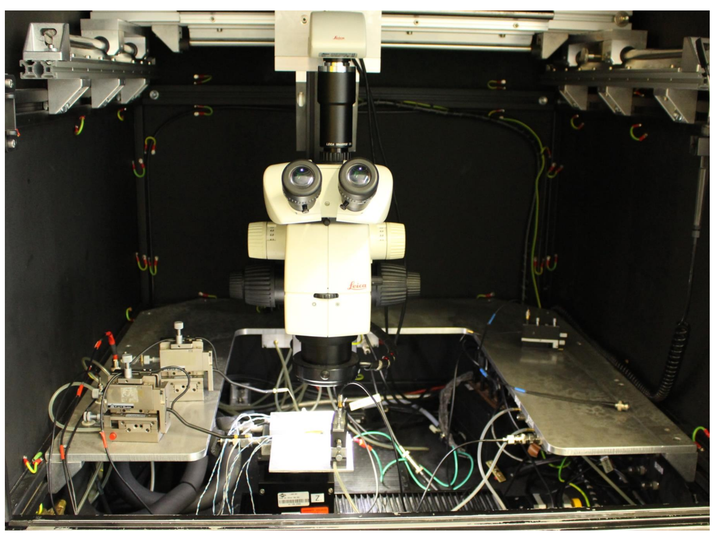
Ongoing Sensor Studies

- *Charge collection efficiency* studies on unirradiated and irradiated sensors



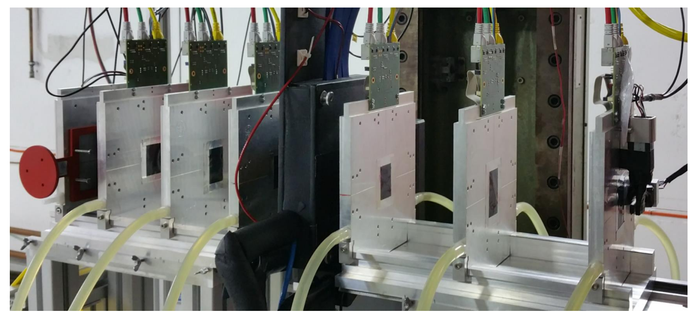
Self-designed, automated and temperature-controlled test environment including an analog read-out system; the signal is induced by a radioactive source and the read-out is triggered by a scintillator

- Qualification of silicon sensors and test structures



One of two self-designed, automated and temperature-controlled probe station setups that measure leakage currents, capacitances and resistances

- Test beam experiments, whereas the signal is induced by a high energy particle beam



- Simulations of new sensor design approaches using a trapping model developed at KIT