Precision position and timing detectors for CMS

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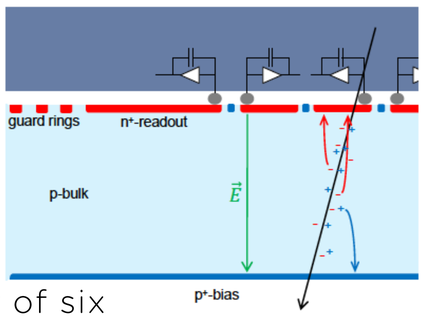
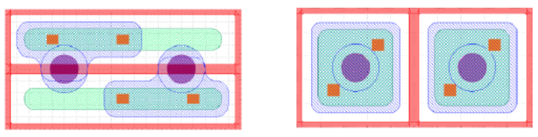
Sensor development

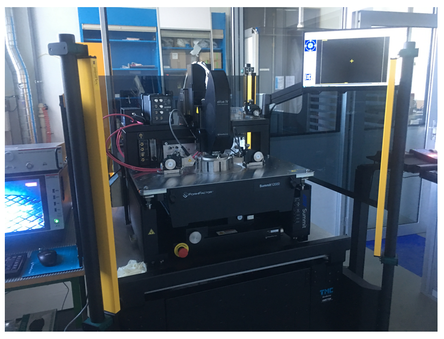


- Planar pixel sensors for hybrid modules:
  - High production yield
  - Large area sensors
- Radiation tolerance → Thin sensors
  - $150\,\mu$m thickness
- Track density → reduced pixel size by factor of six
  - $25\times100\,\mu\text{m}^2$ or $50\times50\,\mu\text{m}^2$ geometry under study
- High efficiency → pixel cell design
- Isolation, biasing scheme, layout details
- Extensive tests at high radiation fluences on going to reproduce the conditions at the end of the lifetime of these detectors!

25x100 µm² (baseline) 50x50 µm²

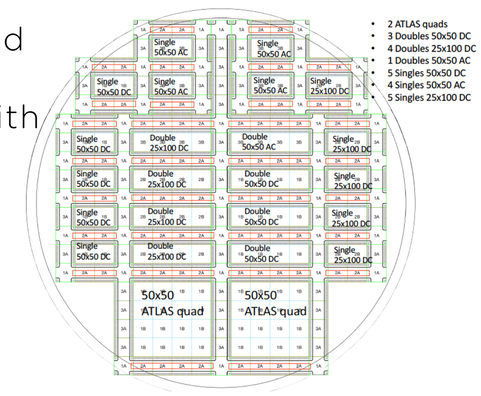


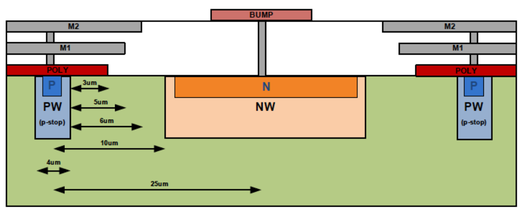
Test and validation of the sensors with the probe-station in our clean-room



- Explore the feasibility of using established CMOS foundries for the production of our specialised pixel planar sensors
  - commercial CMOS technology on high resistive silicon substrate
  - high volume production
  - production on larger 8” and 12” wafers allows wafer to wafer bonding to electronics
  - use of multiple implant, polysilicon and metal layers available allows for an optimisation of the pixel cell design with respect to standard planar sensors

8” wafer



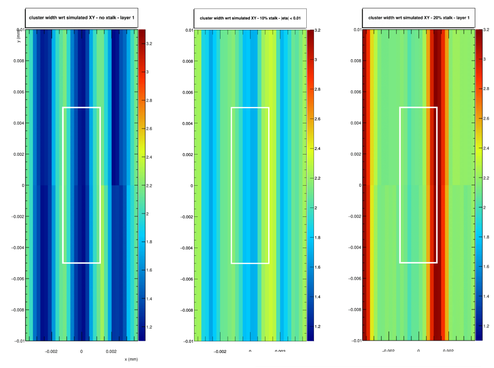


Cross-section of a passive sensor across and the metal field plates

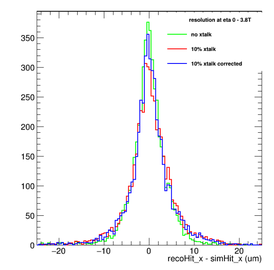
Performance

- Charge induction between pixels (crosstalk) in $25\times100\,\mu\text{m}^2$ geometry
- Complications in:
  - cluster position reconstruction
    - track reconstruction
  - higher data rates
- Implemented in CMS offline software
- Asymmetrical cluster enlargement

cluster width with respect to the impinging position

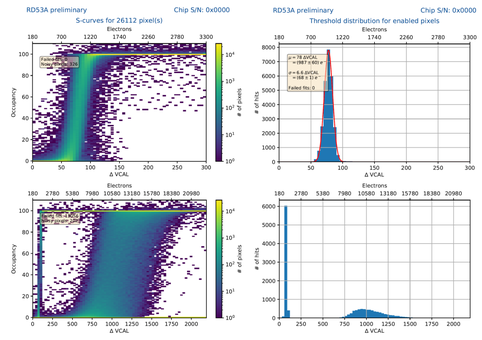


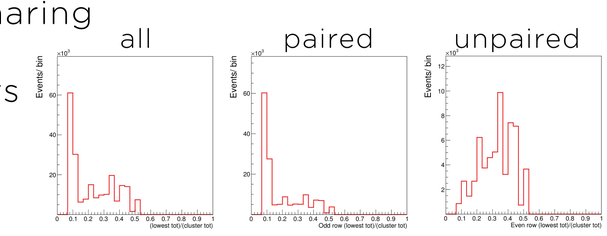
- Cluster Reconstructed Position:
- Residual plot
  - defined as the “cluster reconstructed position” – “precise simulated position”
  - tails due to asymmetrical cluster enlargement
  - width increase due to charge induction
- Mitigation algorithm developed



Measurements of crosstalk

- With direct charge injection
  - various charges injected in a pixel
  - occupancy of that pixel is read
  - threshold defined to be at 50% occupancy
  - read neighbouring pixel occupancy
  - second threshold (crosstalk threshold) seen
  - crosstalk value is the ratio of these thresholds
- With an electron beam
  - selecting size-two clusters
  - lowest pixel charge over total charge
    - flat distribution for charge sharing
    - peak due to crosstalk
  - peak seen only in paired clusters

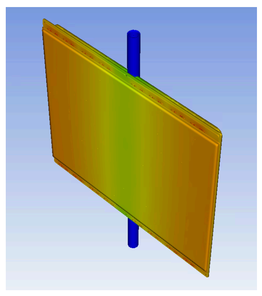


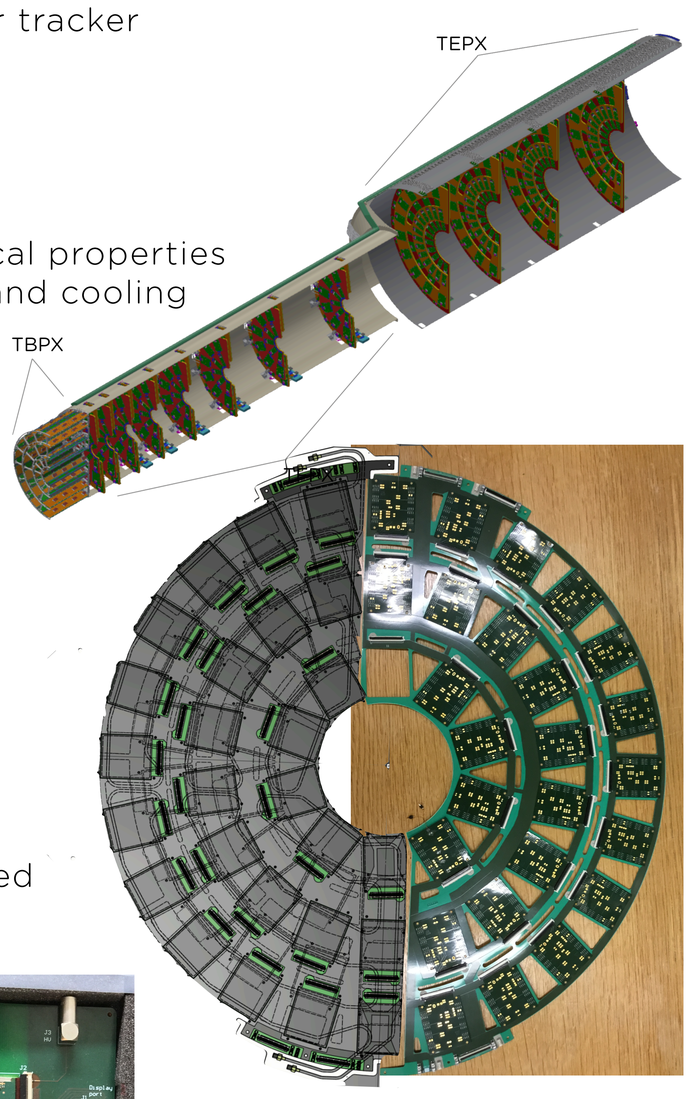


Tracker Endcap PiXel Detector

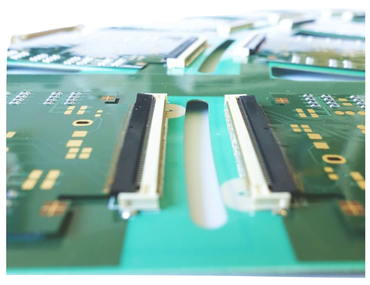
- Inner detector of CMS will be upgraded to match the needs of the high luminosity LHC
- UZH CMS group responsible for designing and building the TEPX detector
  - largest system of the inner tracker
  - 4 disks per end
  - 2 dees per disk
  - 88 modules per dee

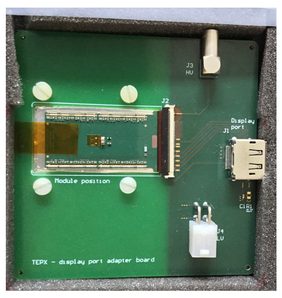
- Prototype disk ready
  - currently testing mechanical properties
  - study thermal properties and cooling of modules and compare with simulation





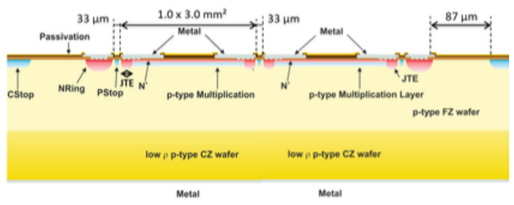
- Prototype module produced
  - tests on-going
  - 1400 modules will be assembled at PSI and tested in UZH!

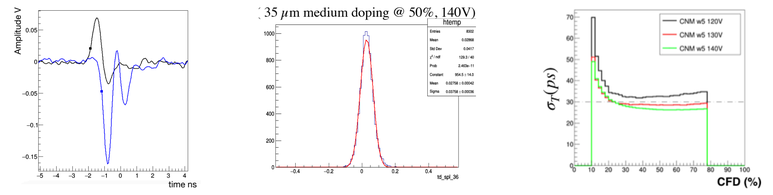




Timing

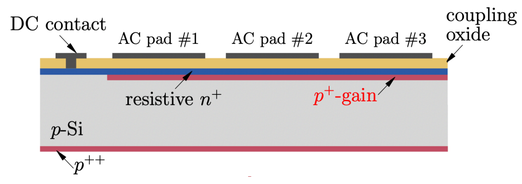
- LGAD (Low Gain Avalanche Detector) sensors are silicon sensors developed for fast timing measurement
- Low doping in the bulk
- Internal amplification achieved by a gain layer
- Uniform electric field
- Small capacitance
- Proven time resolution below 30 ps!





Due to the inter-pad isolation structures standard LGAD have a low fill factor

- AC-LGAD, fabricated at FBK (Trento, Italy), propose to solve the problem
- Segmented readout pads
- Continuous gain and resistive readout layer



- AC-LGAD have been produced
- Different doping
- Different readout pad pitch and size
- Currently testing the performance in our laboratory!