Sensor Quality Assurance for the CBM Silicon Tracking System

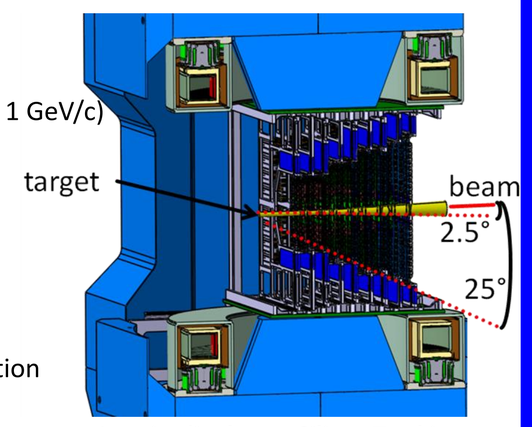
Iaroslav Panasenko, E. Lavrik, H. R. Schmidt, for the CBM Collaboration

CBM Experiment at FAIR

Cryonic Matter exper

CBM Silicon Tracking System

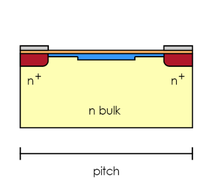
- CBM aims to explore regions of high-baryonic densities of QCD phase diagram
- Requires detection of rare probes
  - → 10^5 – 10^7 collisions/sec (Au-Au)
  - → Momentum Resolution $\Delta p/p \approx 1.8\%$ (p > 1 GeV/c)
  - → High track reconstruction efficiency with pile-up free track point determination
- Silicon Tracking System:
  - → 8 Tracking Stations inside 1Tm field
  - → 896 double-sided microstrip sensors
  - → Low Material Budget: 0.3% - 1.5% X_0/station
  - → Radiation tolerance: ≥ 10^{14} n_{eq} cm^{-2}
  - → Signal-to-noise ≥ 10
  - → Self-triggering front-end electronics located outside acceptance
  - → **~1.8 million strips** (= r/o channels) + ~16000 r/o ASICs "STS-XYTER"
  - → Hit spatial resolution ≈ 25 μm
  - → Time stamp resolution≈ 5 ns

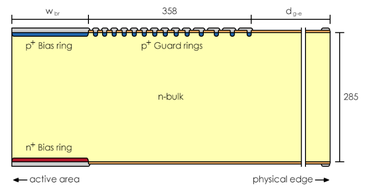


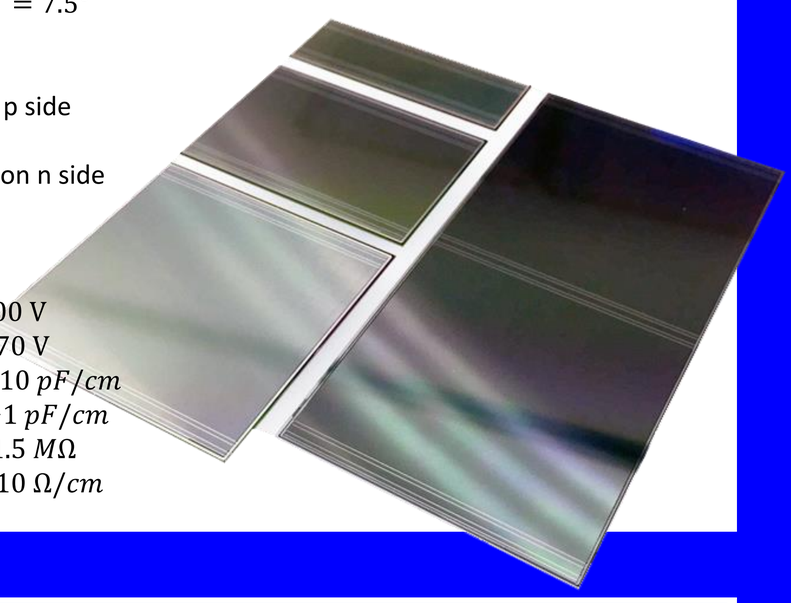
Longitudinal cut – Silicon Tracking System inside Dipole Magnet

CBM Silicon Microstrip Sensors

- Two vendors: CiS, Hamamatsu
- 4/6 in. wafer n-type silicon
- Resistivity $2 - 8\ k\Omega cm$
- Thickness $285/320 \pm 15\ \mu m$
- Double-sided segmentation
- Stereo angle $\theta^n = 0^0, \theta^p = 7.5^0$
- 58 μm strip pitch
- 1024 strips per side
- Double-metallization on p side
- Polysilicon bias resistors
- p-spray/p-stop isolation on n side
- AC coupled readout
- 4 form factors 2/4/6/12



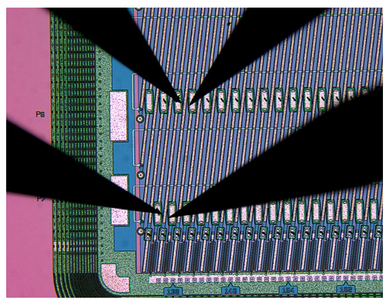


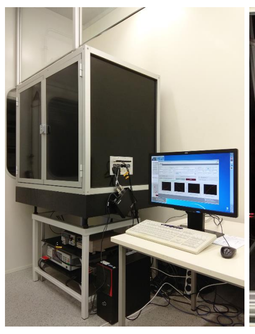


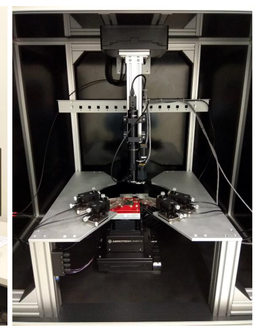
- Breakdown voltage > 200 V
- Full depletion voltage ~70 V
- Coupling capacitance ≥ $10\ pF/cm$
- Total strip capacitance ~$1\ pF/cm$
- Polysilicon resistance ~$1.5\ M\Omega$
- Strip metal resistance ~$10\ \Omega/cm$

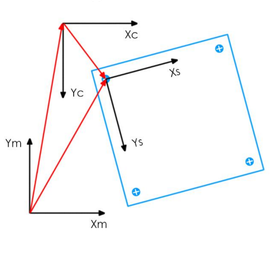
Custom-Built Probe Station @ Uni-Tuebingen

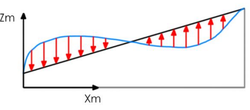
- Light-tight box, instruments (voltage source, picoammeter, LCR-meter, switching matrix), computer-controlled
- Vacuum chuck carrying the sensor mounted on movable table in X, Y, Z and θ
- 4 Needles to contact sensor DC and AC pads
- Motorized 12xZoom optical system with CCD camera
- High positioning accuracy ($< 1\ \mu m$);
- large travel range ($100\ mm$) of both positioning and optical systems;

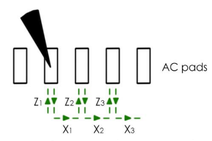












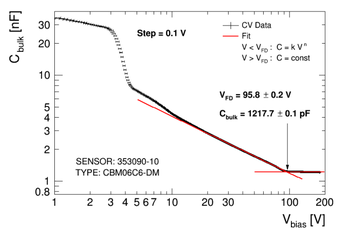
Dedicated custom software comprises advanced coordinate calibration motor-pixel-sensor, precise alignment, Z-profile mapping and height correction, flexible stepping procedure with fully customizable measurement procedures

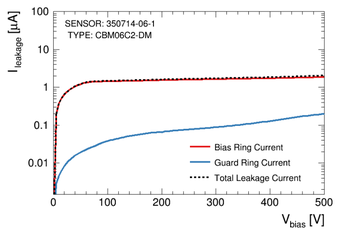
Sensor Electrical Characteristics

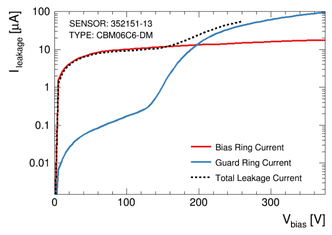
Most important global parameters of the silicon sensors:

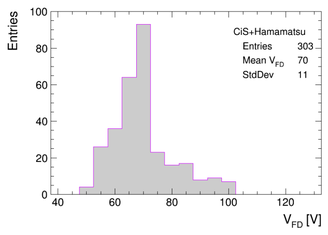
- Leakage current
- Breakdown voltage
- Full Depletion Voltage

Bulk breakdown > 500 V!





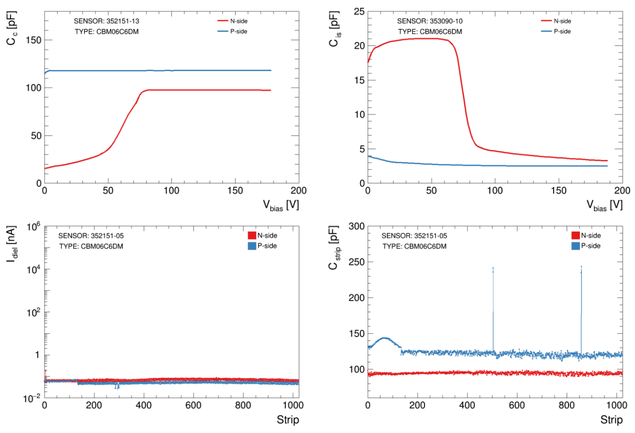




- Total leakage current of the Hamamatsu and CiS sensors is around 7 nA/cm^2 and 170 nA/cm^2, respectively.
- Full depletion voltage is determined from the bulk CV measurements: $V_{FD} \approx 70$ V
- Bulk capacitance is used to estimate single strip to backplane capacitance: $C_b = 0{,}2\ pF/cm$

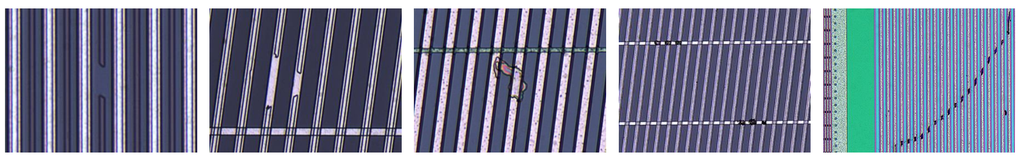
Strip Electrical Characteristics and Integrity

Coupling capacitance
$> 10\ pF/cm$ for all sensors
Interstrip capacitance
p-side – $0{,}45\ pF/cm$
n-side – $0{,}56\ pF/cm$



Most common strip defects:

- Pinholes
- Breaks/shorts
- Leaky strips

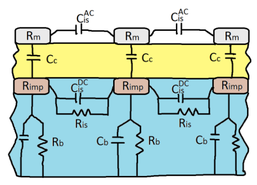


Acceptance criteria: 98, 5% of all strips is OK.
It corresponds to max. 15 defective strips per side.
Strip defect rate of final CBM06 prototypes $< 0{,}5\%$.

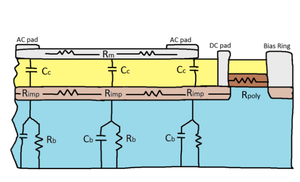
Device Simulation

SPICE Network simulator

- Silicon microstrip sensor can be modeled as a network of discrete passive elements distributed along strip length: understanding of strip RC circuits, access to electrical parameters that can not be measured directly, correctness of system calibration and applied capacitance corrections, etc.

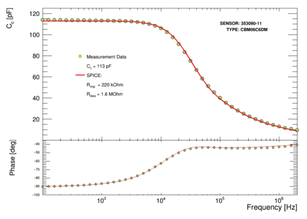


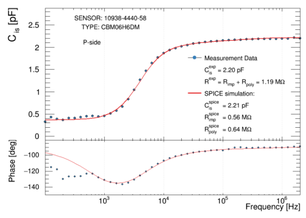
Longitudinal cross section

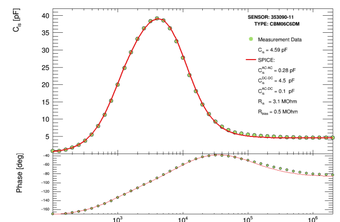


Lateral cross section

- 6-strip model with bulk, BP, BR, LCR
- ≈ 4000 capacitors and resistors organized in cells
- 17 cells per cm per strip of the CBM sensor







References

- J. Heuser et al., Technical Design Report for the CBM Silicon Tracking System (STS) (2013)

KINR FAIR EBERHARD KARLS UNIVERSITÄT TÜBINGEN MATHEMATISCH-NATURWISSENSCHAFTLICHE FAKULTÄT Physikalisches Institut GSI