AC—coupled pitch adapters for silicon strip detectors

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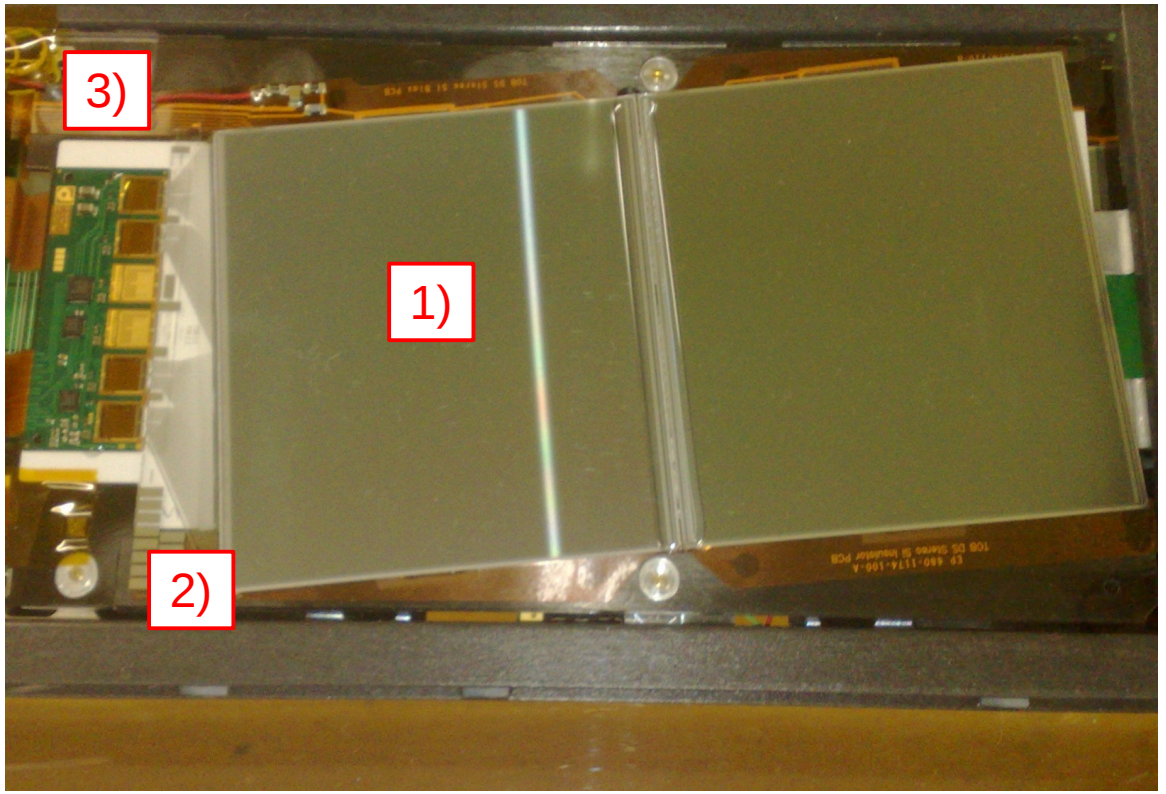
- Idea of the concept
- Processing technology
- Performance of AC-coupled pitch adapter
- Test beam data
- Summary

Concept

Strip detector hybrids in modern HEP experiments consists usually of

1) AC-coupled strip sensor
2) Pitch Adapter (PA)
3) Printed Circuit Board (PCB) with readout IC's.



Capacitive coupling is needed in harsh radiation environment in order to prevent leakage current to be couplet into readout circuit input.

PA is needed as long as sensor segmentation is something else than deep sub-µm IC bonding pitch

CMS TOB sensor module

Comparison of AC and DC coupled sensor technology

- Strip implant
- Field insulator growth/deposition
- Contact opening
- Poly-Si CVD deposition (high T)
- Poly-Si implant
- Bias resistor etching
- Resistor implant activation (high T)
- Contact opening
- Metallization
- Passivation

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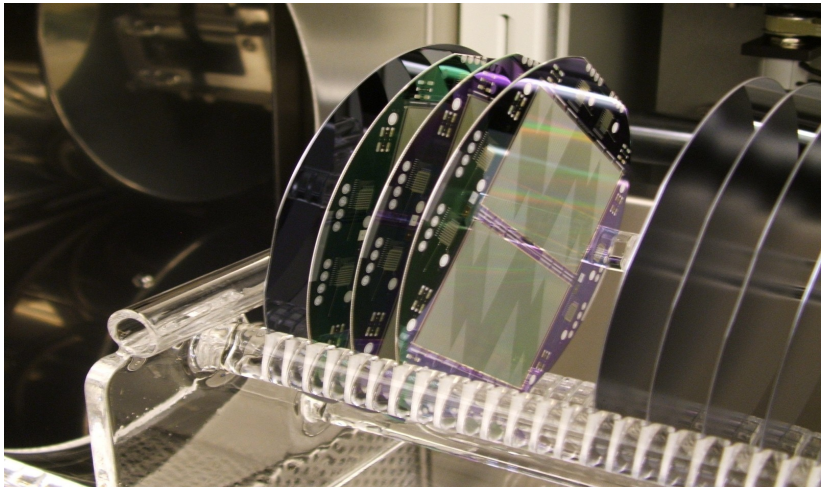


Requirements for AC coupled Pitch Adapter

- Must be made of glass (parasitic capacitance)
- Must include bias resistors for every channel
- Resistance should be ~MΩ
- Signal is directly proportional to the coupling capacitance >> C_{coup} should be high $C = A \times (\varepsilon_0 \varepsilon / t)$
- Thinner dielectric increases C_{coup} but reduces voltage tolerance and risk for pinholes
- Even though strip insulator is between grounded strip implant and floating ground of RO input, some voltage tolerance is required e.g. because of unexpected transients.

Benefits of AC coupling integrated PA

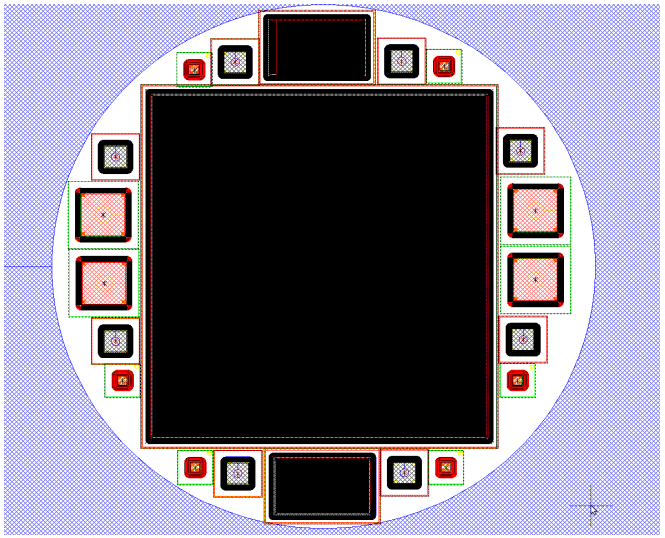
- Consider upgrade project of 10 000 wafers/sensors.
- Let's assume that AC coupled strip sensor costs 1000 and DC coupled sensor 500
- AC PA's cost 500 per wafer and standard DC PA's 100 per wafer.
- One gets 10 PA's from one wafer

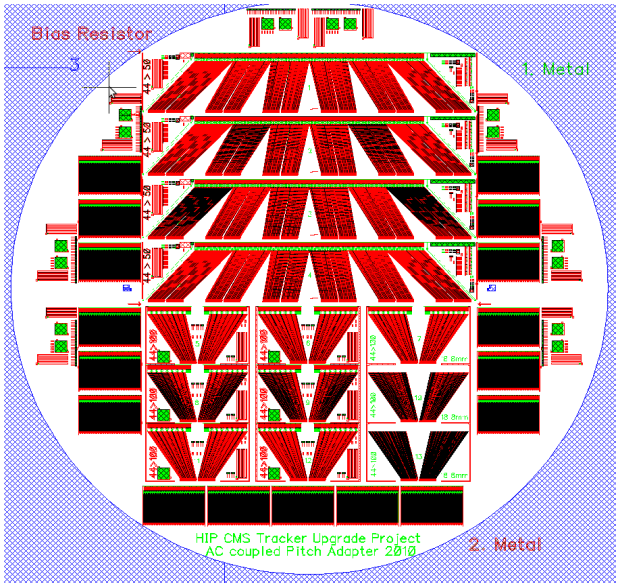
Total cost with AC sensors

10M + 100k (sensors + PA's)

Total cost with DC sensors

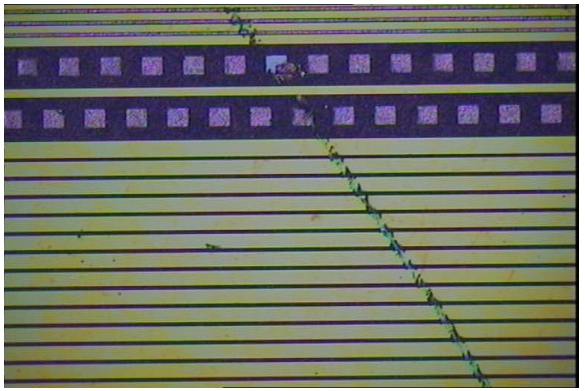
5M + 500k





...more benefits of AC PA's

What happens if sensor gets scratched ?



AC coupled strip sensor
- Strip capacitor is broken resulting in noisy strip

DC coupled strip sensor
- Probably nothing because under Al metal there is highly conductive p+ (or n+) implant

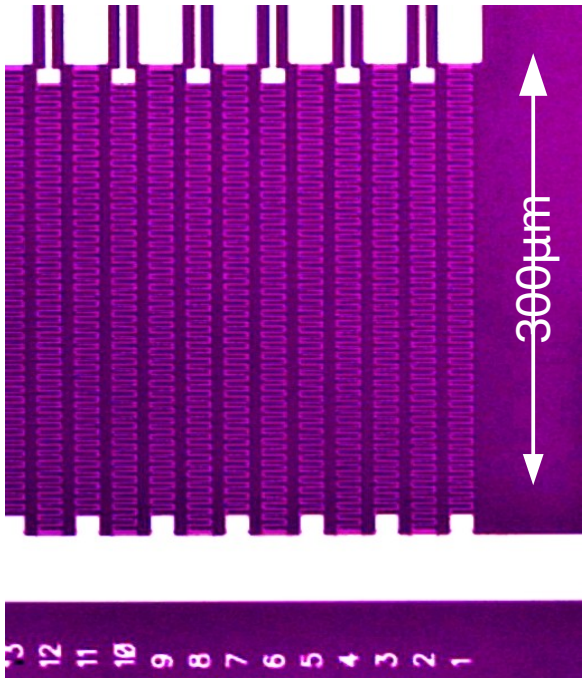
Processing of AC coupled adapter

- Bias resistors

  - Sputtered tungsten nitride (WN_x)

  - Room temperature process

  - patterning by hydrogen peroxide wet etching



- Dielectric

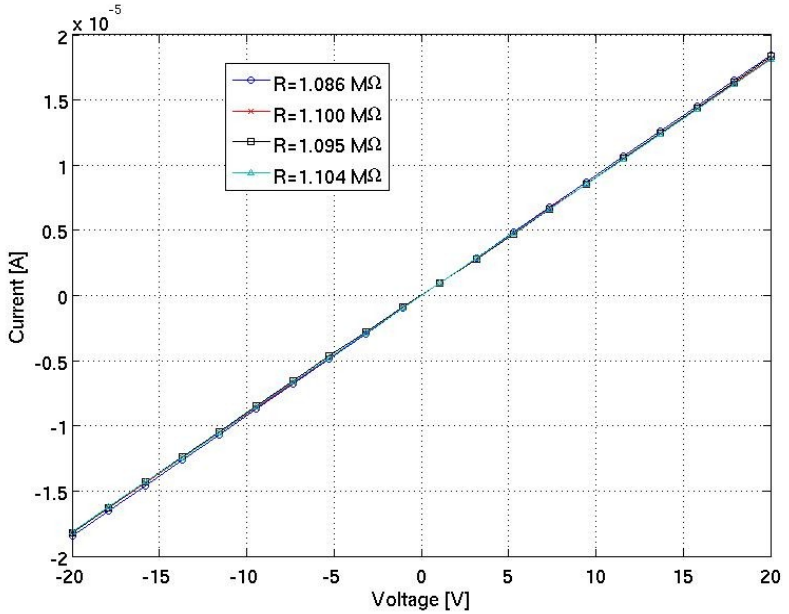
  - Aluminum oxide (Al_2O_3) grown by Atomic Layer Deposition

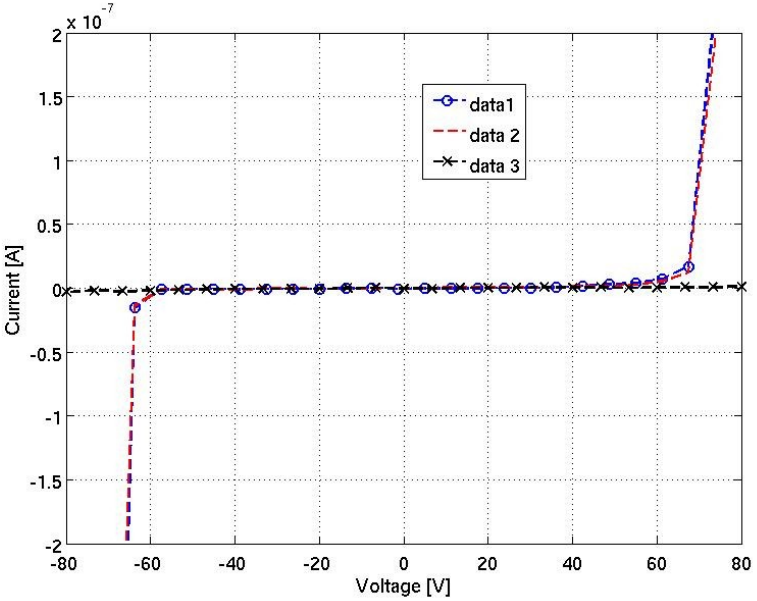
  -ALD is a self-limiting (the amount of film material deposited in each reaction cycle is constant), sequential surface chemistry that deposits conformal thin-films

  -Deposition temperature ~300^{0}C i.e. feasible with glass

  -ALD thin-films are pinhole free

Properties of AC PA





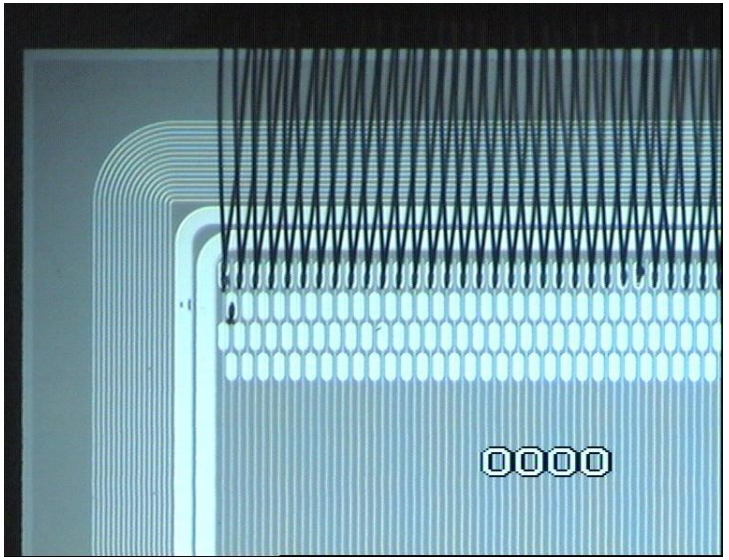
Bias resistor 1.1MΩ ±0.8%

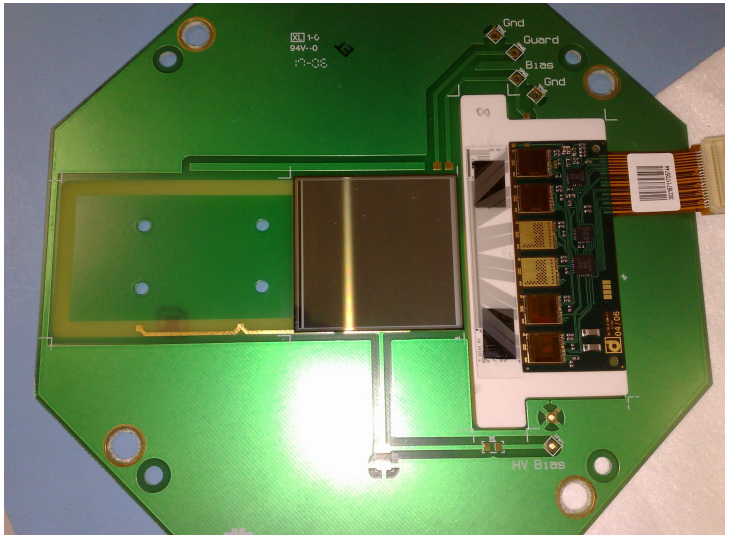
Al_2O_3 thickness 45nm
Dielectric breakdown at 60V

Detector modules with AC PA and DC coupled sensors

1) $p^+/n^{-}/n^+$ 768 channels DC coupled sensor, irradiated 1×10^{14} n_{eq}/cm^2. Processed at HIP on high resistivity Fz-Si. Pre-irrad V_{fd} about 30V

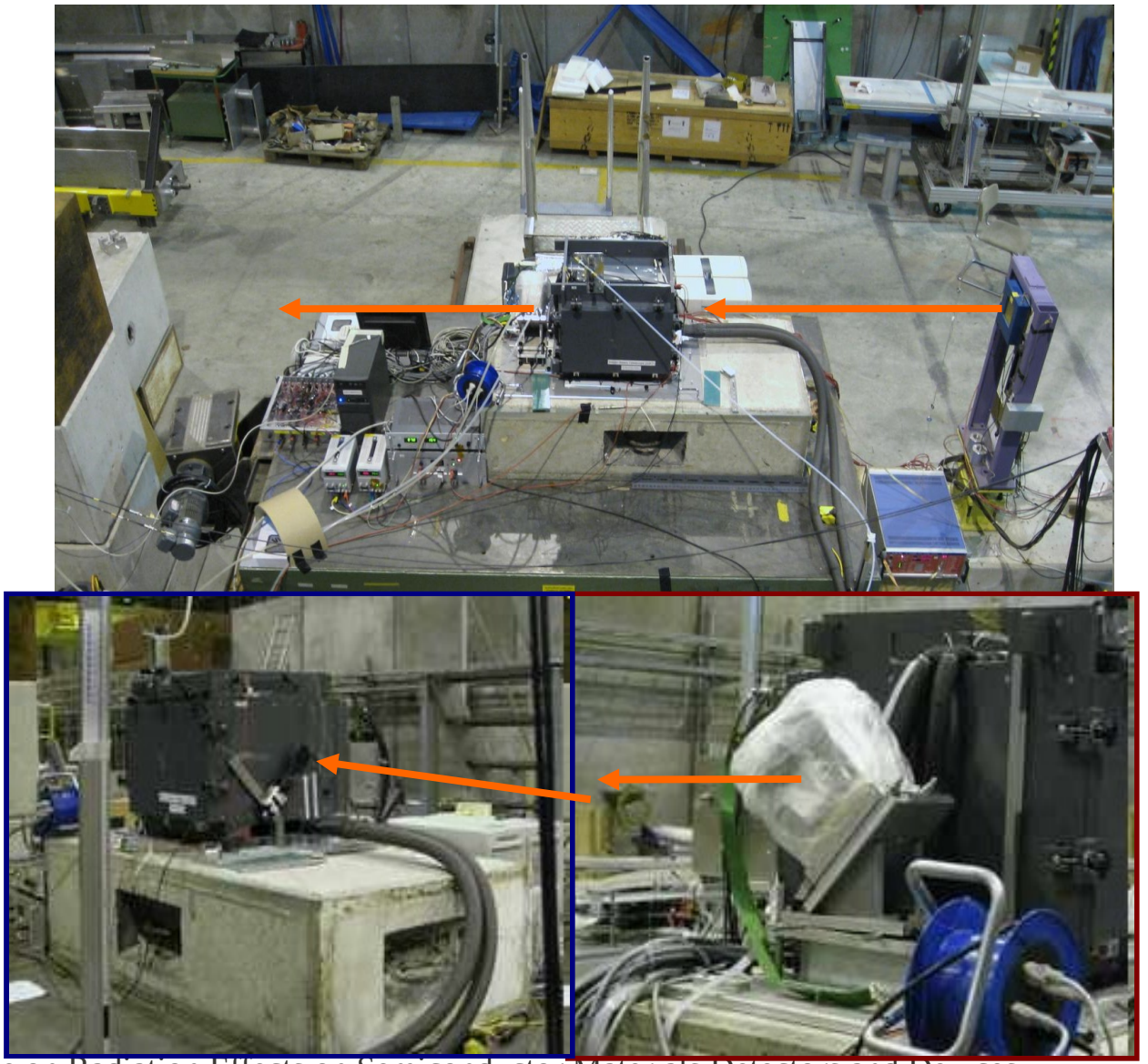
2) $n^+/p^{-}/p^+$ 768 channels DC coupled sensor, irradiated 3×10^{14} n_{eq}/cm^2. Processed at HIP on high resistivity Fz-Si. Pre-irrad V_{fd} about 20V





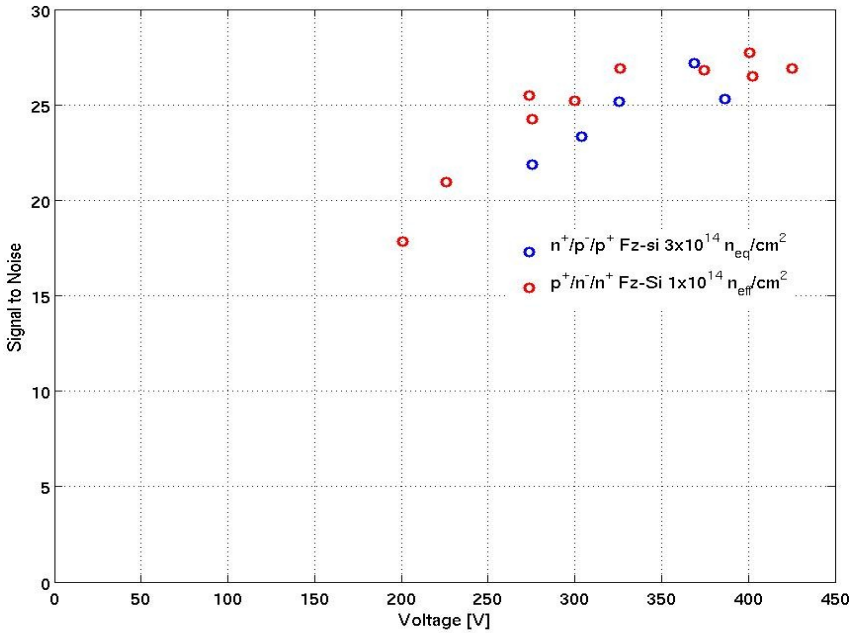
Test beam setup

- **CERN North area SPS H2 beamline**
  - **225 GeV muon, pion, and mixed beams**
- **10 slot beam telescope based on CMS module test station**
  - **8 reference modules and 1-2 DUTs in central slots**
- **CMS DAQ electronics with early version of the Tracker SW**
  - **CMSSW framework used for track reconstruction**

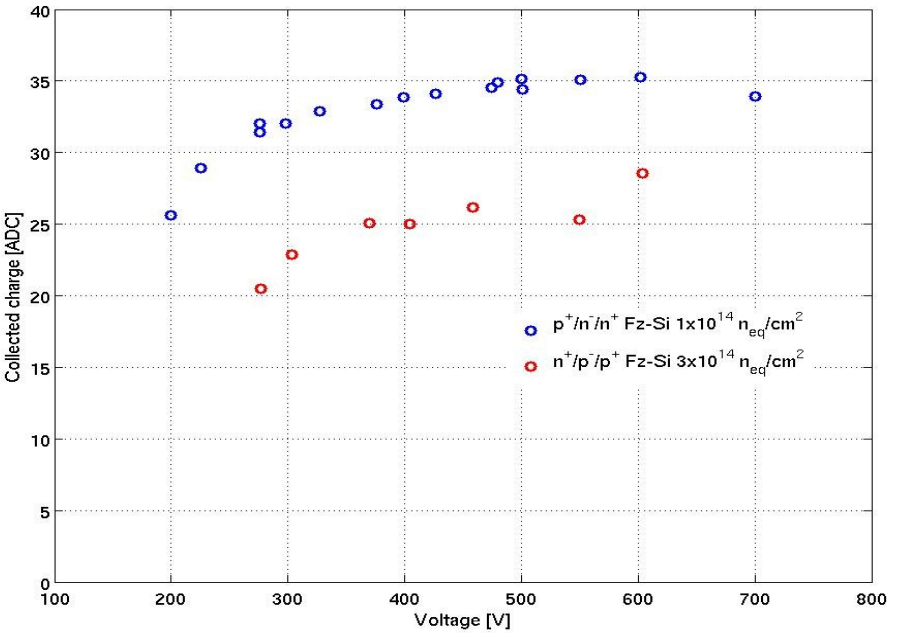


Test beam results

Signal to Noise



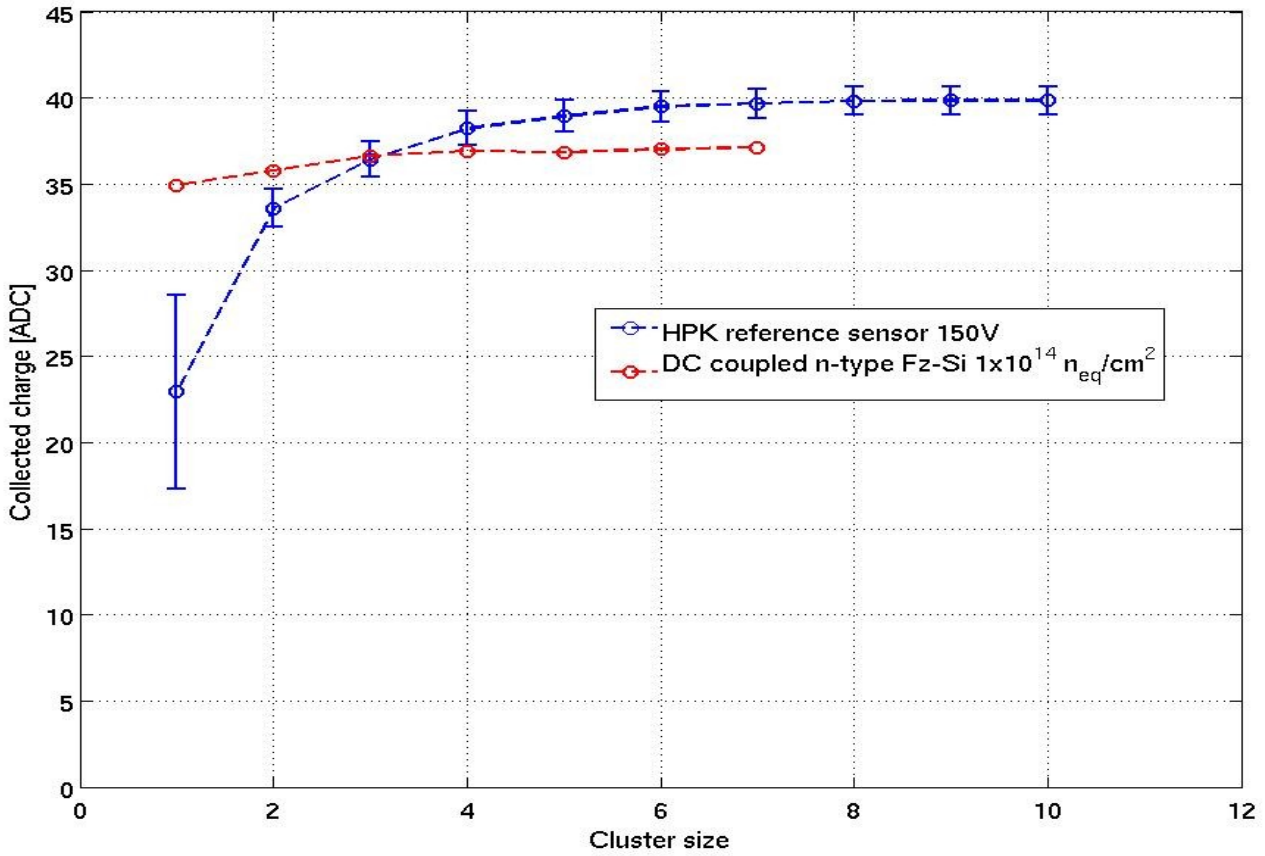
Collected charge



After 400-500V the noise of these detectors starts to increase and S/N goes down

100% CCE equals 40 ADC counts

Cluster size



HPK reference sensor pitch = 55µm
HPK sensors have inter-mediate strips which partly explain the larger cluster spread

Other studies using AC Pitch Adapters

Charge collection studies of heavily irradiated 3D Double-Sided sensors,
IEEE NSS Conference Records 2009, Richard L. Bates, C. Parkes, D. Pennicard,
B. Rakotomiaramanana, C. Fleta, G. Pellegrini, M. Lozano, U. Parzefall,
X. Blot, J. Härkönen and E. Tuovinen

Characterization of 75 and 150 micron thin strip and pixel sensore produced at MPP-HLL,
P. Weigell et al., 16th RD50 Workshop, Barcelona, Spain, 31 May - 2 June 2010

Summary

- The integration capacitive coupling into pitch adapter potentially reduces costs of a large scale tracker system because product number of wafers × process steps goes down
- Further benefits can be gained by simplified module assembly
- AC PA requires glass processing, i.e. bias resistors and strip dielectrics need to be made <400^{0}C
- Tungsten nitride and ALD grown Al_2O_3 are suitable materials for glass processing
- Test beam results indicate 70-90% CCE and good S/N for detector modules with DC sensor and AC PA.