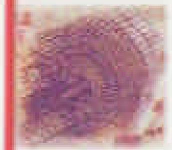
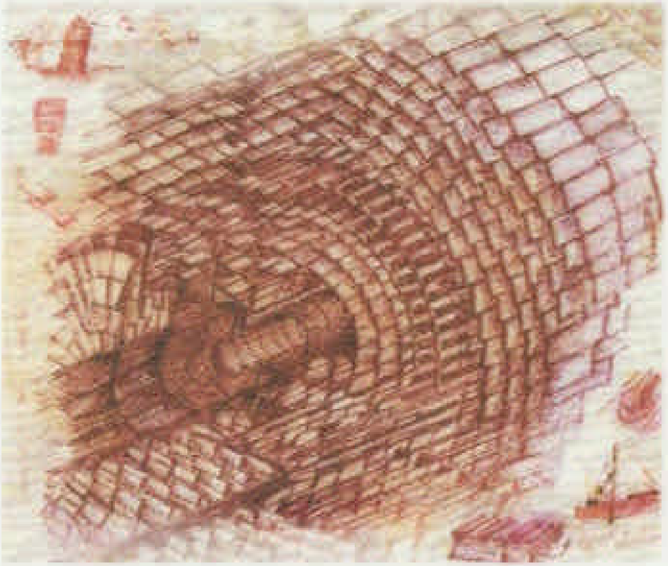
The challenge of the CMS Silicon Strip Detectors at LHC



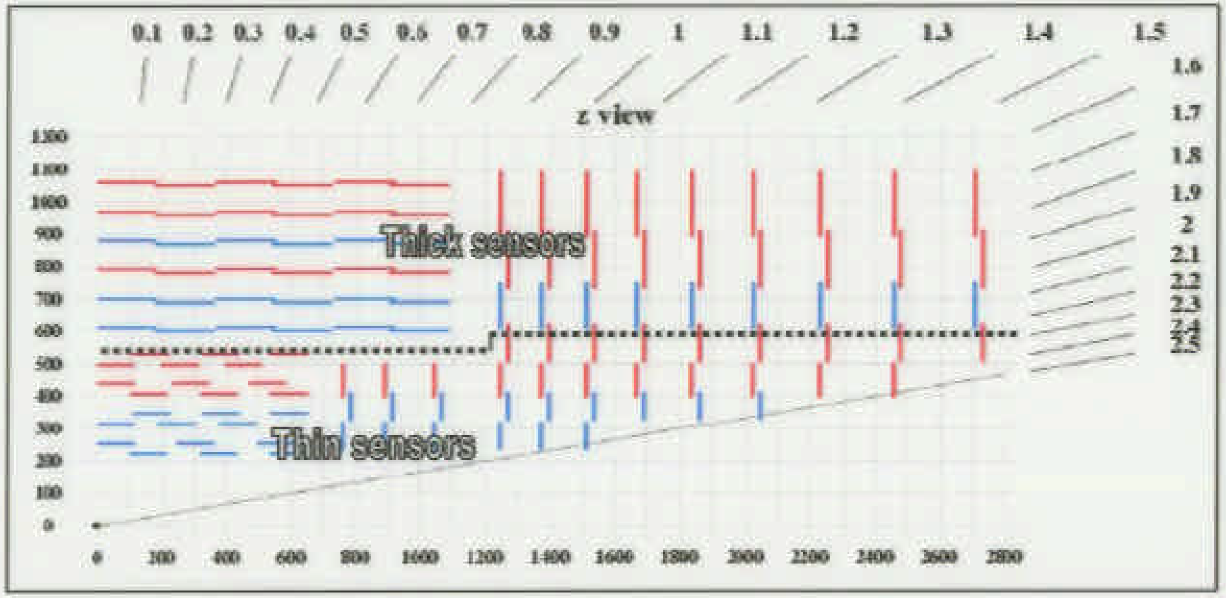


Gian Mario Bilei

On behalf of the CMS Silicon Tracker Collaboration

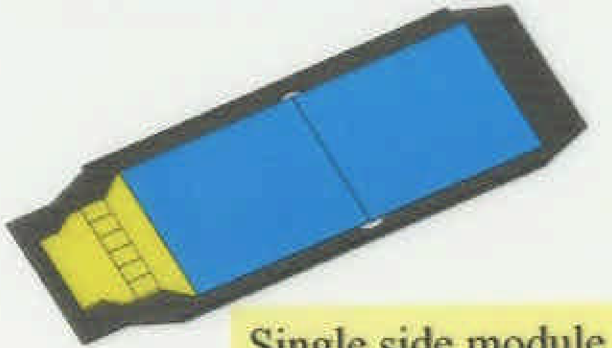
ICHEP 2000, July 27 - August 2, 2000 Osaka, Japan

The tracker layout

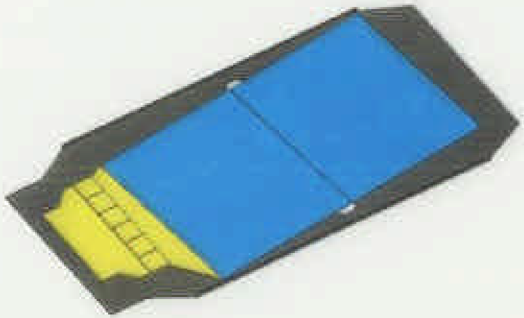


Thin si sensors ~ 320 μm thick — Double layers (back to back detectors)
Thick si sensors ~ 500 μm thick — Single layers

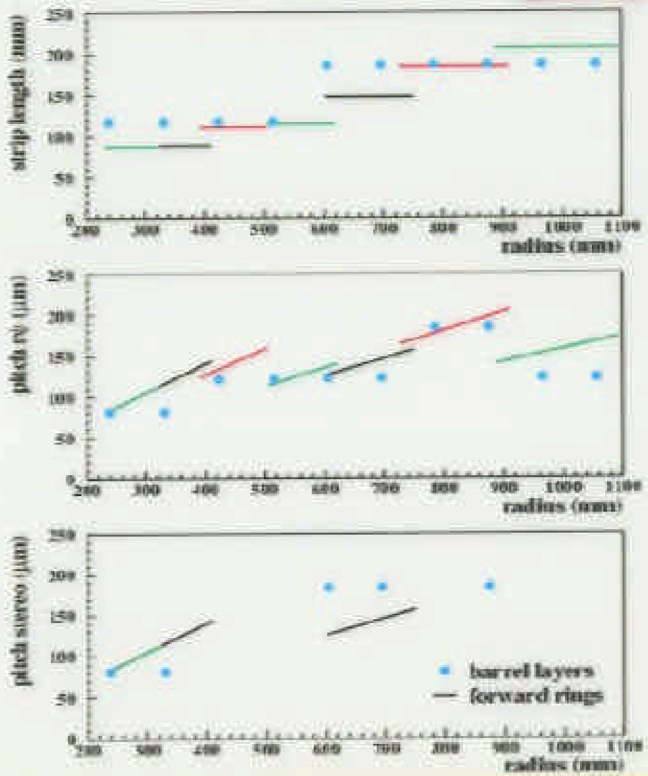
Silicon modules



Single side module



Stereo side of
back to back module



Strip length ranges from 12 cm (inner barrel) to 20 cm (outer barrel).
Pitch ranges from 80 μm to 200 μm

Silicon Sensor choice of technology

Requirement: To operate the detector up to 10 years of LHC with a S/N >10

Major issue: Radiation damage greatest source of concern (1 Mrad/year in the inner layer)

Radiation damage bulk effects

- Increasing of leakage current (e.g. noise)
- Increasing of depletion voltage after inversion (e.g risk of breakdown)
- Decreasing of charge collection (e.g signal)

Radiation damage surface effects

- Increasing of interstrip capacitance (e.g noise)

Silicon Sensor technology

After an extensive R&D program our choices for the Silicon Sensors are:

- Single sided p-type implant strips on n-type substrate
- Integrated AC coupling of read-out strips
- Polysilicon resistor biasing of the p^+ implant strips
- Low resistivity substrate (1.5-3.0 MΩ/□ in the inner tracker)
- Silicon lattice orientation <100> in place of the common <111>
- Metal overhanging the p^+ strip

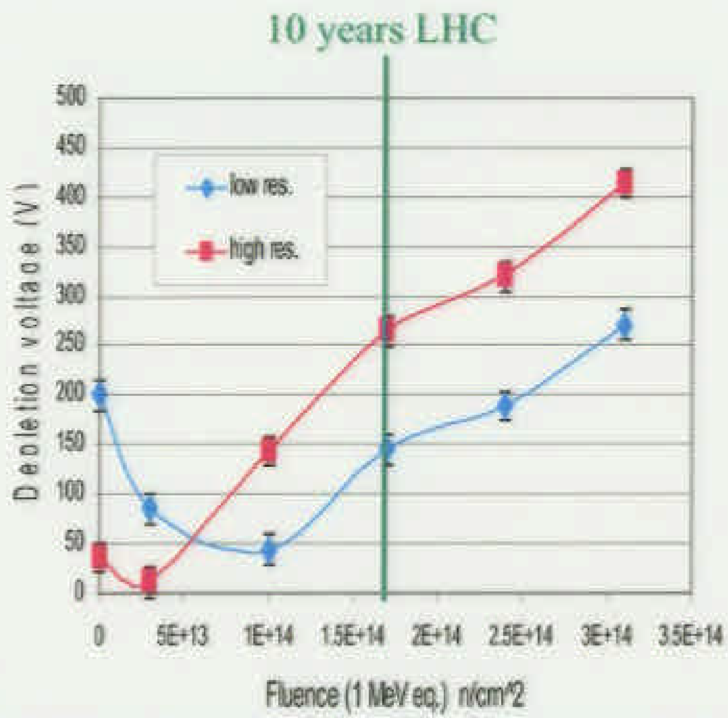
- The design and the choice of the materials are well suitable for meeting our requirements with a good safety margin.
- They are compatible with high volume industrial production on 6" wafer.
- Well established and relative inexpensive technologies.

Low resistivity substrate

Choice of low ρ (1.5-3.0 kΩ/□) in the inner region where the sensors are more exposed to the effects of the radiation damage.

After inversion the low ρ material offers significant advantages providing lower depletion voltage w.r.t. standard high ρ substrate.

The lower depletion voltage will allow to operate the sensors with an extra safety margin with respect to the a breakdown.



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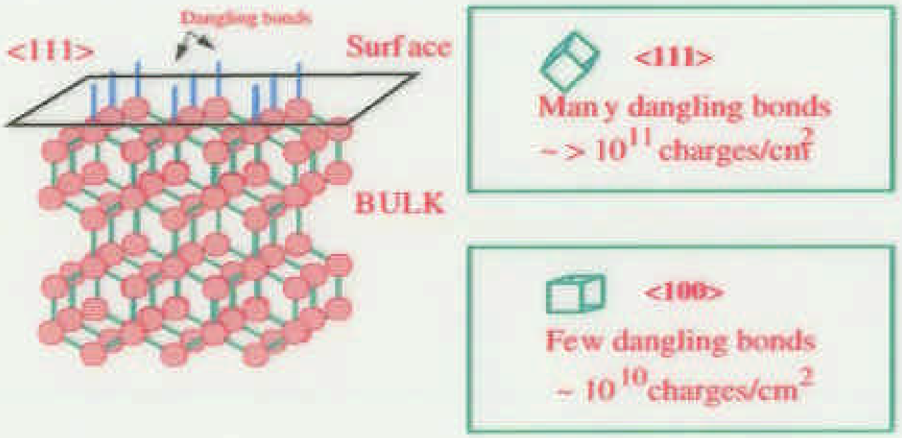
Lattice orientation

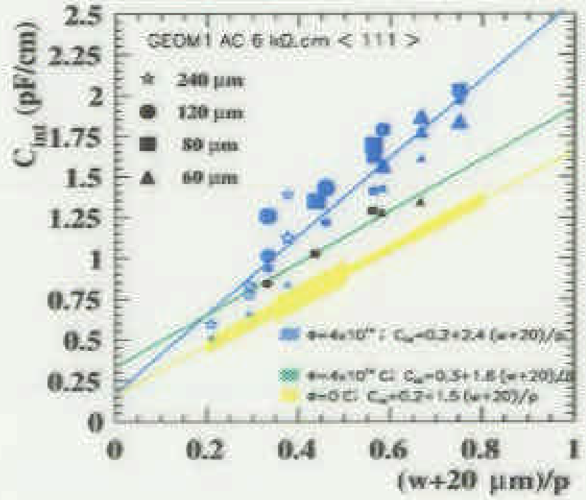
The choice of <100> in respect to <111> crystal orientation offers a definite advantage for what concerns the interstrip capacitance.
Surface damage effects due to radiation are responsible for increasing the trapped charge at the Si/SiO_2 much more in <111> w.r.t <100>.



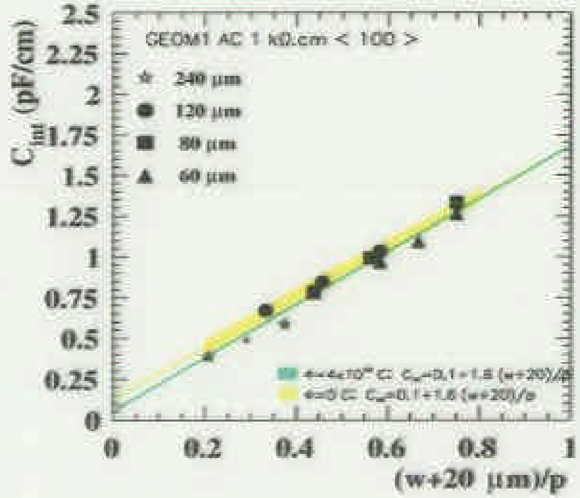
Lattice orientation

The increase of trapped charge due to radiation in <111> type crystal brings a significant increase of interstrip capacitance. The capacitance is basically left unchanged by radiation in <100> type sensors (independently by the bulk resistivity)

Multi-geom. <111>



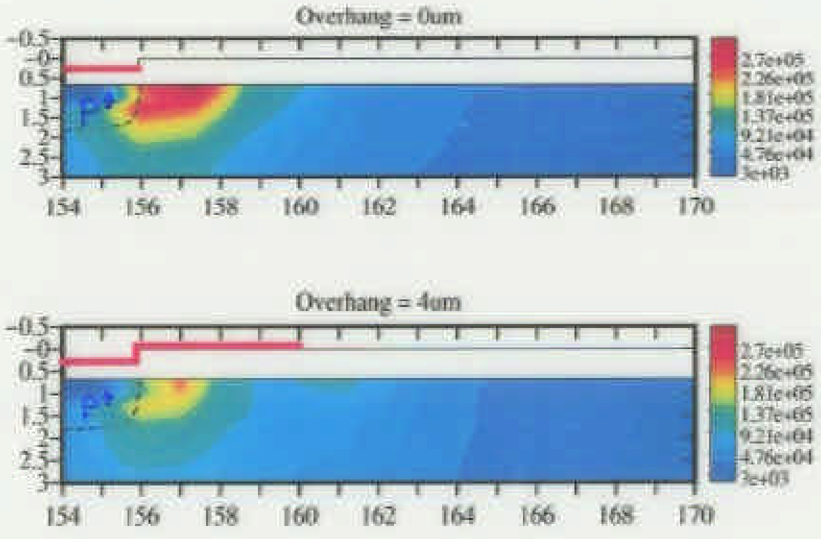
Multi-geom. <100>

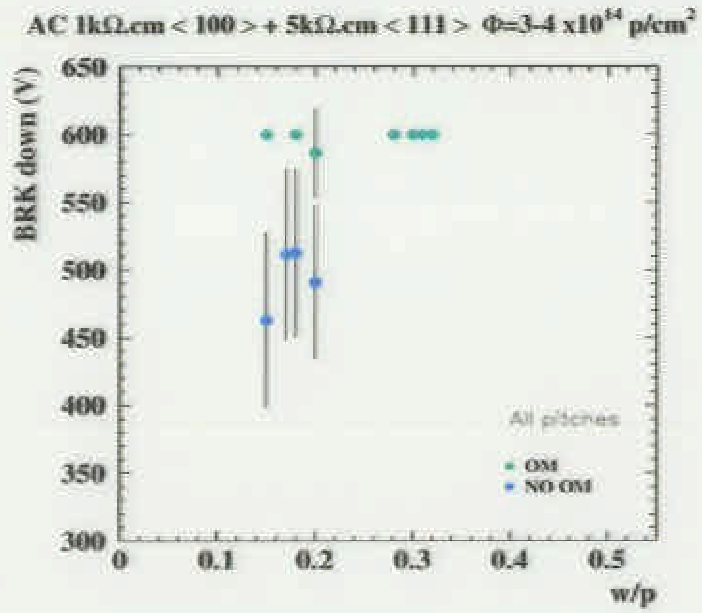


Metal overhang

The choice of metal overhanging the p^+ implant offers definite advantages in terms of the breakdown voltages.

Overhang effectively reduces the electrical field at the critical p^+ implant corner regions.





Breakdown voltage with overmetal and no overmetal

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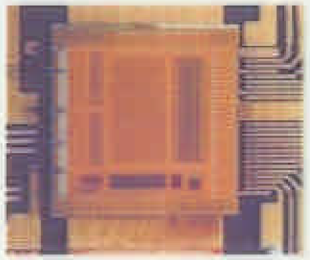
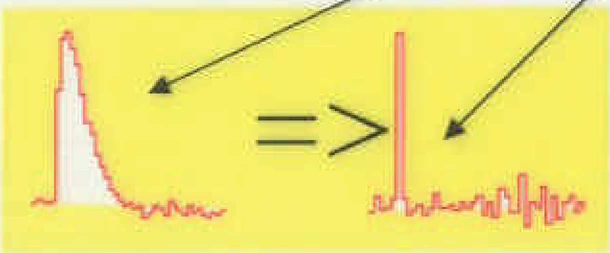
The Front-End electronics

APV25 chip designed in 0.25μm CMOS technology

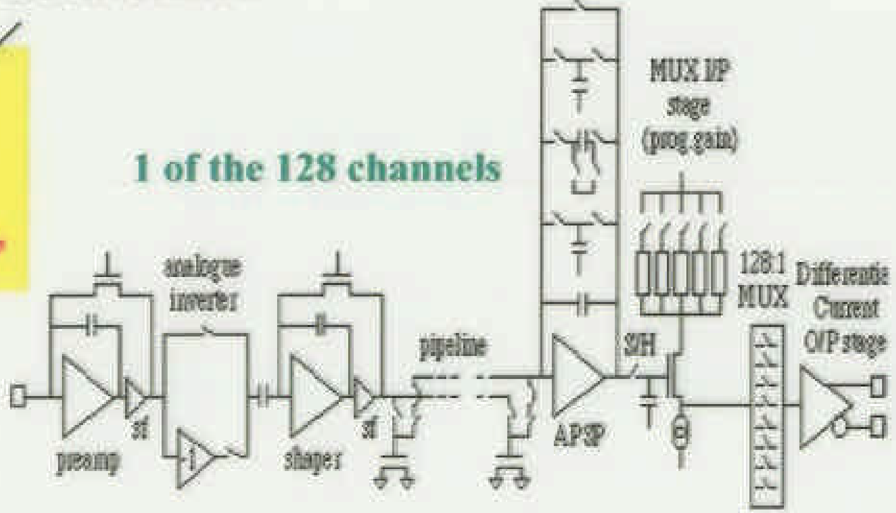
128 channel analogue amplifier
50 ns shaping time pulse 100mV/25000 e^-
40 MHz sampling rate
192 cells analogue pipeline for storage
Data readout mode: peak and deconvolution



57 mm^2
2.3 mW/ch
2.5 V p.s.

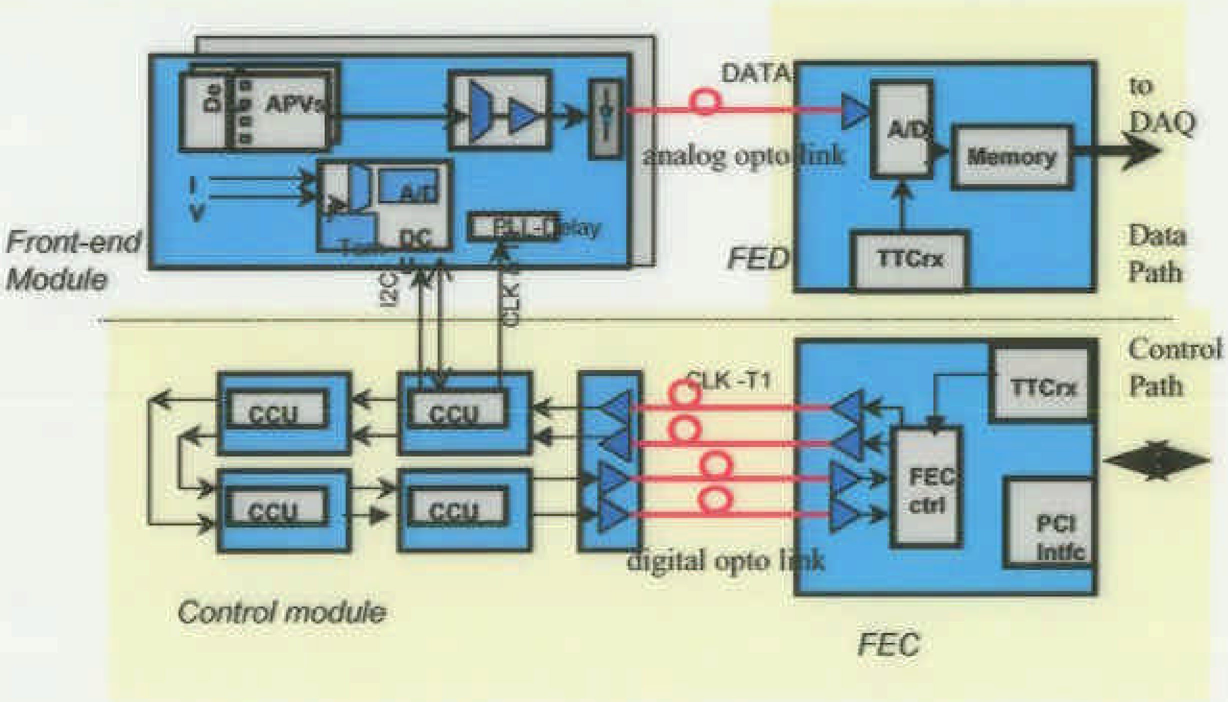


1 of the 128 channels



Control system and DAQ

Most of the components available as prototype.
First system test on 25 ns beam LHC-like successful.



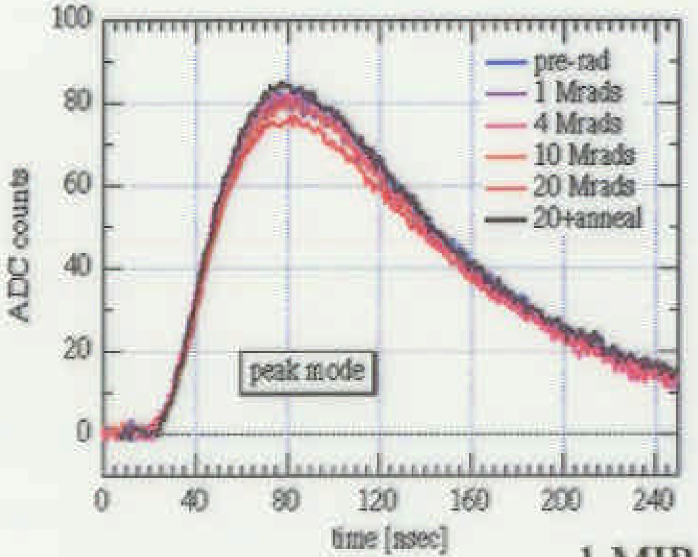
APV25

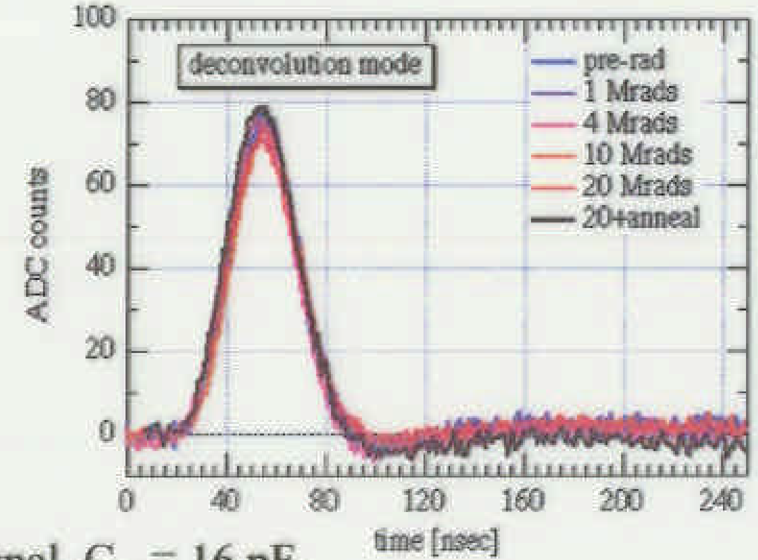
Excellent radiation resistance of the chip and technology

x-ray irradiation 50 kV source 1 - 2 - 4 - 10 - 20Mrad - anneal

dosimetry Si diode ~10% precision

Normal operational: bias during irradiation - clocked & triggered

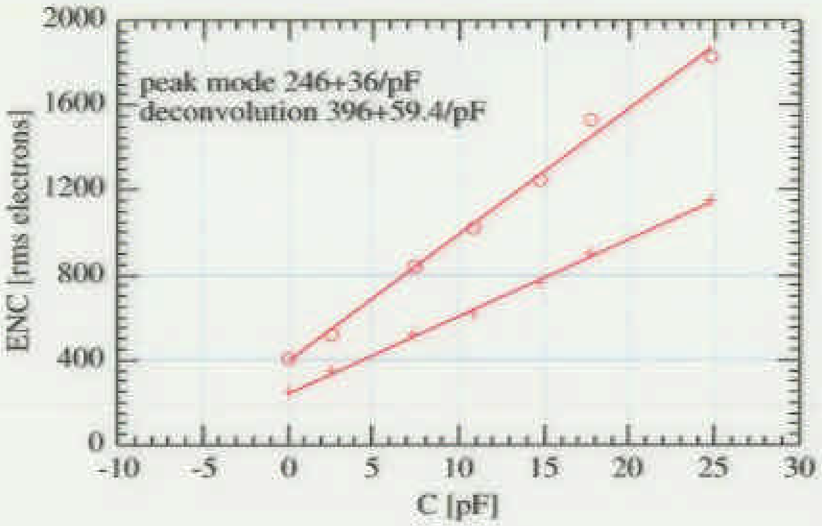




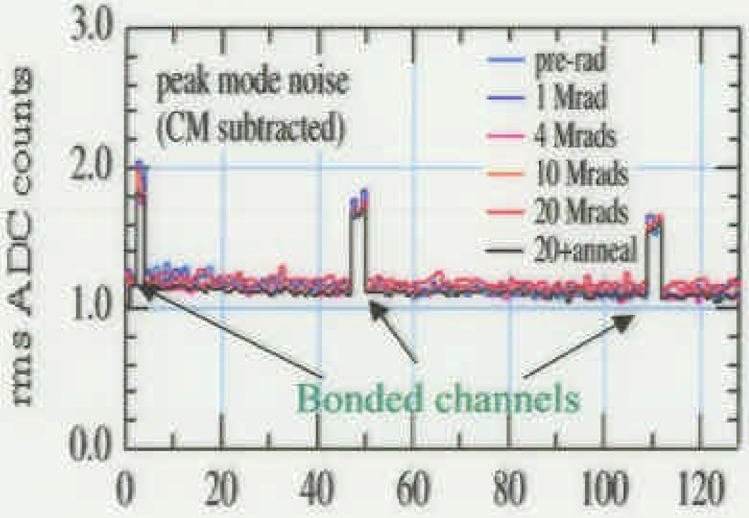
1 MIP signal $C_{in} = 16$ pF.

APV25 noise

ENC peak = 246+36/pF e^-
ENC deco. = 396+59/pF e^-



Minor changes in noise after heavy irradiation



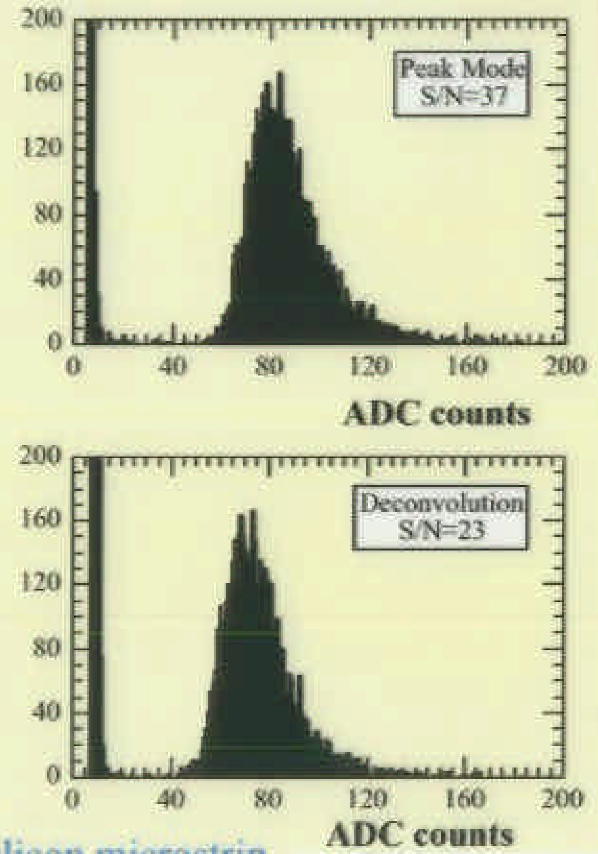
Detector performance

Extrapolating lab test results to CMS modules we obtain for S/N:

- Before irradiation
  - thin detectors ~ 17
  - thick detectors ~ 19

- After irradiation
  - thin detectors ~ 13
  - thick detectors ~ 19

Preliminary test beam data consistent with the expected performances.



Sr-90 β source 5cm silicon microstrip
350μm thick 50μm pitch

Conclusions

The design and choice of materials for the CMS Silicon Sensors are well suited for running the SST up to 10 years at LHC.

0.25μm APV development are almost completed and extremely successful.

The Silicon Sensors together with the APV25 chip, provide a good safety margin in term of S/N performance.

The CMS Silicon Tracker collaboration has completed the sensors R&D, and is now in the process of preparing the production.