CMOS Pixel Sensors for High Precision Beam Telescopes and Vertex Detectors

Rita De Masi

IPHC-Strasbourg

on behalf of the IPHC-IRFU collaboration

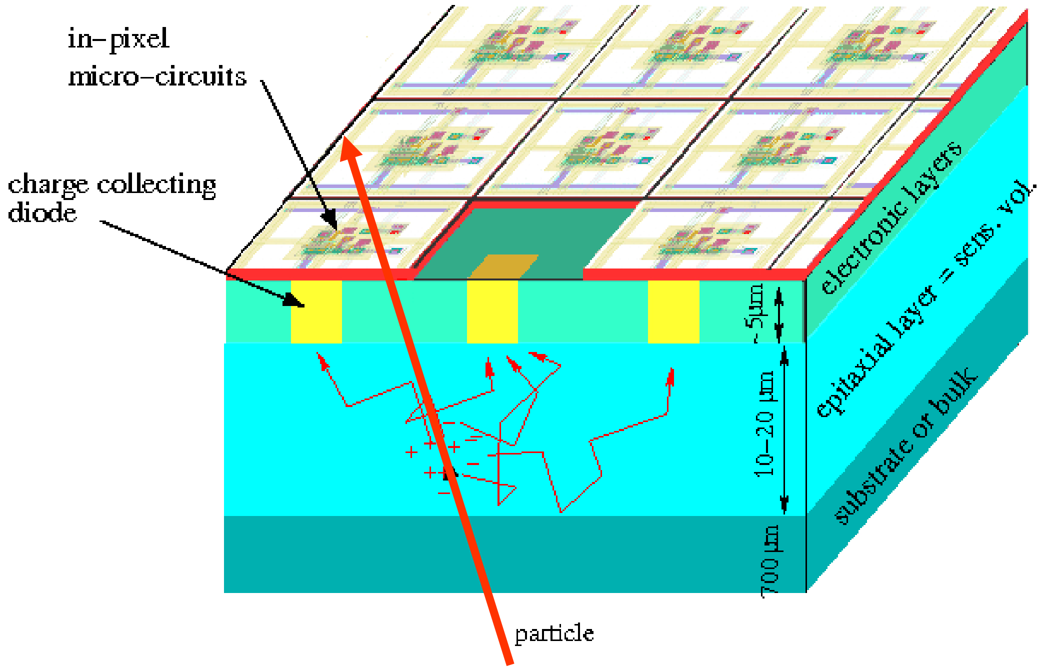
- Principle of operation
- Achievements and applications
- Developments
- Summary and conclusions

CMOS sensor principle

- Signal collection
  - Charges generated in epitaxial layer → ~1000 e^- for MIP
  - Charge carriers propagate thermally
  - In-pixel charge to signal conversion

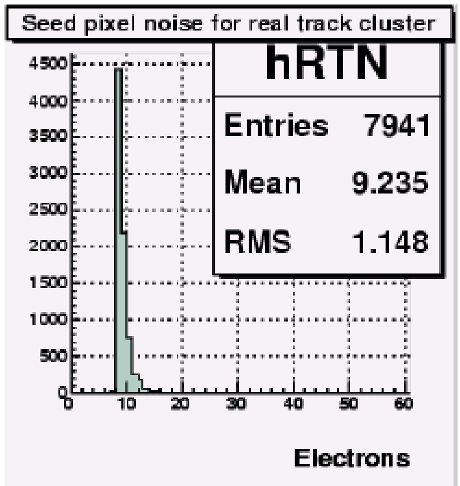
- Advantages
  - High granularity
  - Thickness (~O(50μm))
  - Integrated signal processing

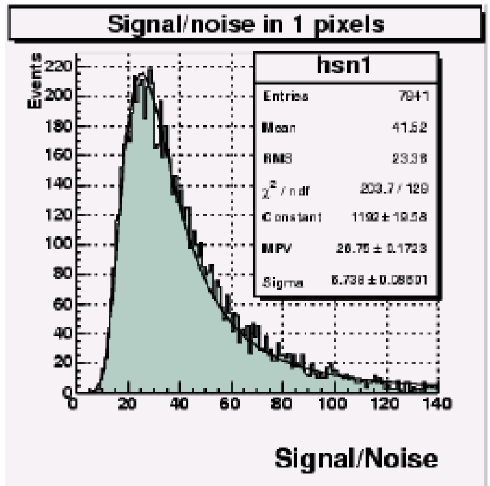
- Issues
  - Undepleted volume limitations
    - radiation tolerance
    - intrinsic speed
  - Small signal O(100e^-)/pixel
  - In-pixel μ-circuits with NMOS transistors only

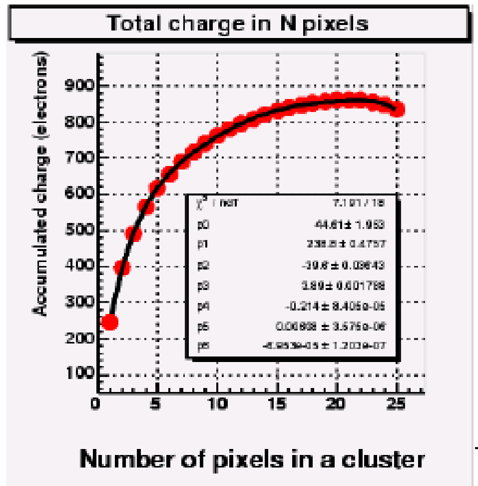


Basic performances

- more than 30 different sensors designed, fabricated and tested (lab & beam)
- extensive use of AMS 0.35μm OPTO process
- room temperature operation
- noise ~10-15e^-
- S/N ~ 15-30
- detection efficiency ~100%
- fake hit rate ~10^{-4} -10^{-5}
- Radiation tol. > 1MRad and $10^{13} n_{eq}/cm^2$ with 10μm pitch ($2x10^{12} n_{eq}/cm^2$ with 20μm pitch)
- spatial resolution 1-5 μm (pitch and charge-encoding dependent)

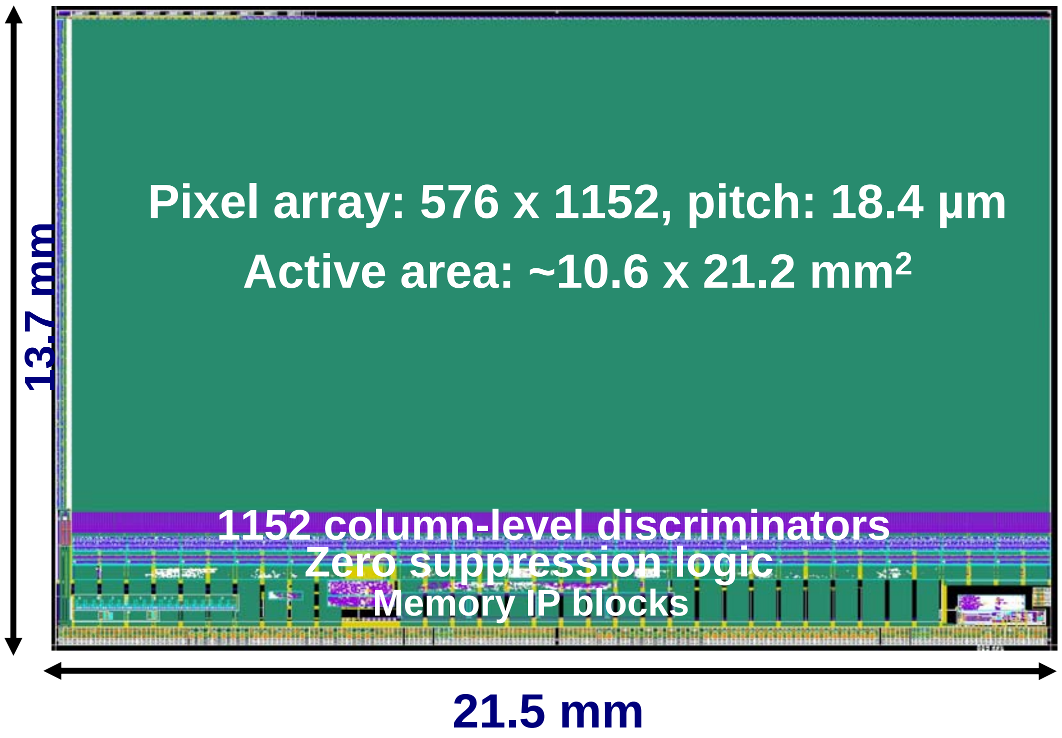






Mimosa 26

Fast full scale sensors: 10kFrame/s
column parallel architecture + integrated zero-suppression



- binary output

(3.5-4 µm spatial resolution)

- in-pixel CDS +preamp.
- column level discrimination
- power dissipated ~150 mW/cm^2

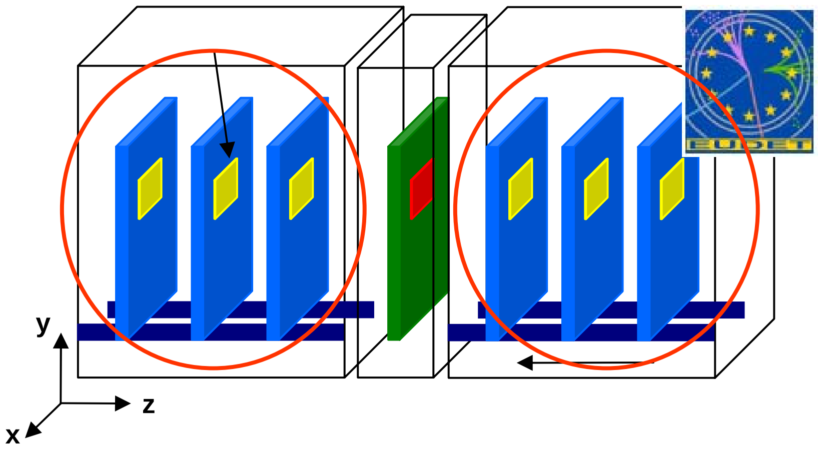
(rolling shutter)

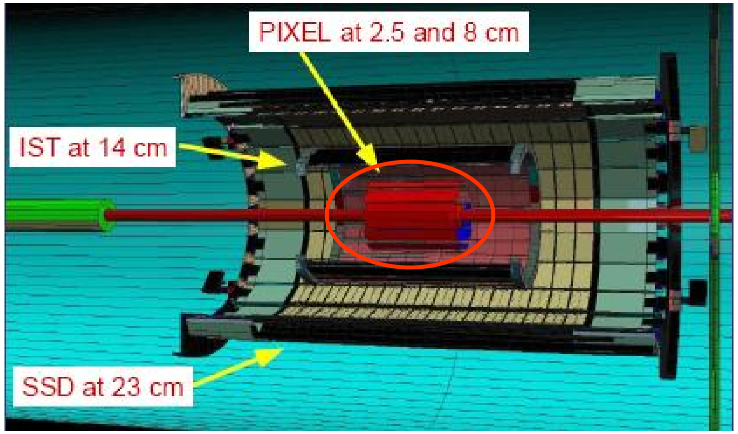
- integration time ~100µs
- validated in lab

Characterisation @ CERN-SPS this summer

Mimosa 26 applications

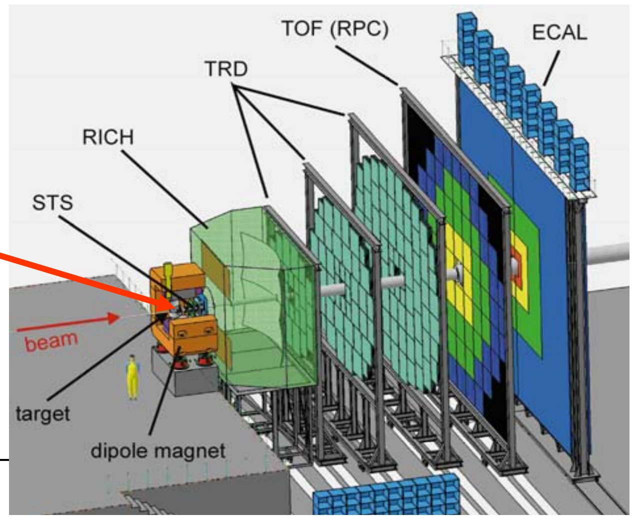
- Reference planes of EUDET Beam Telescope
  - Supported by EU FP6
  - Infrastructure to support the ILC detector R&D
  - Commissioning @ CERN summer 2009





- STAR @ RHIC Heavy Flavour Tracker
  - 1152 x 1024 pixels; 200μs integration time
  - Submission end 2009
  - First data 2011/2012

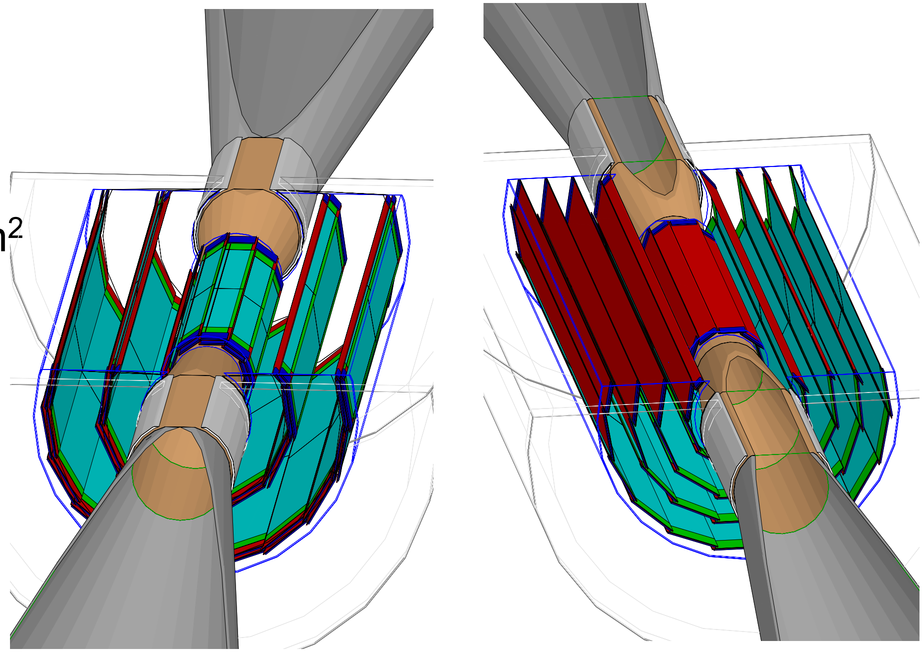
- CBM @ FAIR Micro Vertex Detector
  - Double sided readout (40→20μs integration time)
  - Prototyping until 2012



A VTX detector for the International Linear Collider

Physics requirements

- single point resolution ~ 3μm
- material budget ~0.2% X_0/layer
- integration time 25 – 100 μs
- radiation tolerance ~0.3MRad, few $10^{11} n_{eq}/cm^2$



$$\sigma_{IP} = a \oplus b/p\sin^{3/2}\theta$$

$a = 5\mu m$, $b = 10\mu m$ GeV

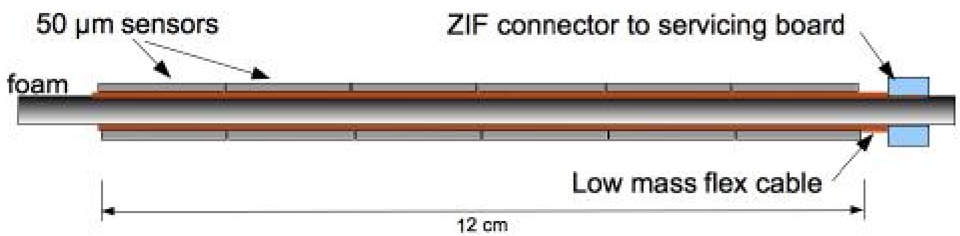
(LHC $a = 12\mu m$, $b = 70\mu m$ GeV)

A modified Mimosa 26

- Double sided readout
- 0.18 μm technology
- Integration issue → PLUME project : double sided ladder equipped with 2x6 M26 (TDR 2012)

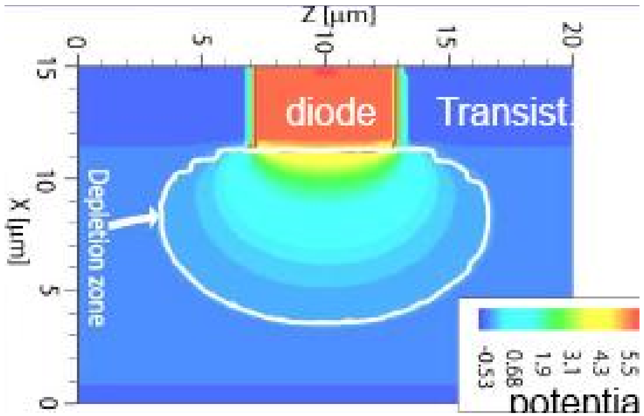
first prototype to be tested in SPS beam next November

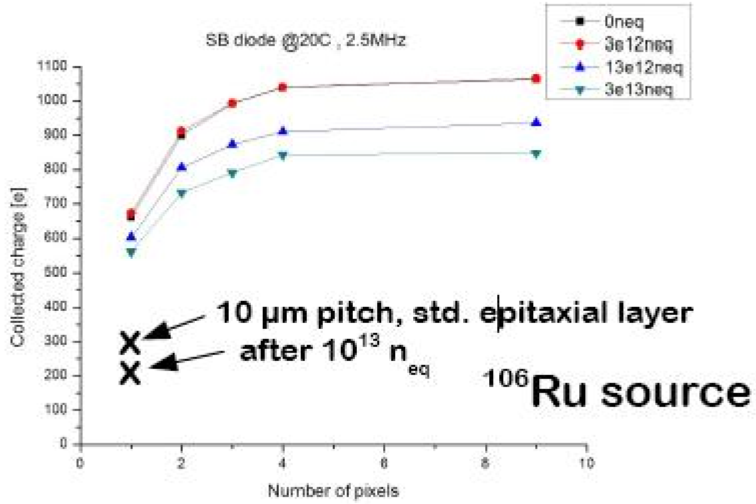
~0.2 - 0.3%X_0



Further developments: Mimosa 25

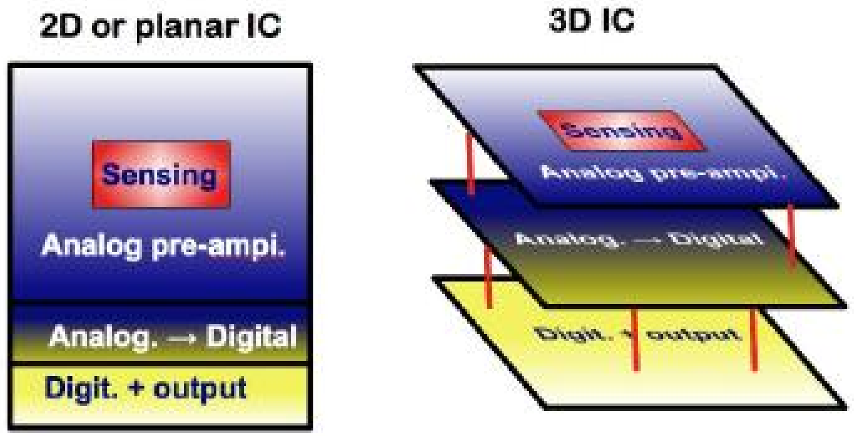
- High resistivity epitaxial layer (O(10^3) Ω·cm) from XLAB 0.6μm process





- 20 μm pixel pitch, 160 μs readout, ~1 mm^2 sensitive area
- Cluster size ~ 2×2 pixels (3×3 for low resistivity epi-layer)
- S/N ~ 50 for seed (20-25 for low resistivity epi-layer)
- S/N ~ 35 @ $10^{13} n_{eq}/cm^2$
- Improved tolerance to non-ionizing radiation (1-2 OM)
- Full characterization @ CERN-SPS this summer
- New: VDSM technology under study in coll. with CERN for sLHC

Further developments: 3D



Benefits:

- Increase integrated processing
- 100% sensitive area
- Select best process per layer task

To be assessed:

- Material budget?
- Power dissipation?

Example

- Tier1: charge collection
- Tier2: analog signal processing
- Tier3: digital signal processing
- Tier4: data transfer

FNAL + IN2P3 + INFN + … consortium

First run (2 Tiers) submitted to Chartered-Tezzaron

Summary and conclusions

- Current CMOS sensors
  - Mature technology for real scale applications
  - High resolution, very low material budget
  - Application under way
    - EUDET-BT, STAR-HFT, CBM-MVD (R&D)
  - ILC-VTX (Option)

- New perspectives
  - Depleted sensitive volume (Non ionizing rad. tol. improved by >1 OM → sLHC)
  - 3D integration technology

More information on

http://www.iphc.cnrs.fr/-CMOS-ILC-.html