A fast, full-scale, CMOS pixel sensor with integrated zero-suppression and its evolution towards ultra-light, double-sided ladders for the ILD vertex detector

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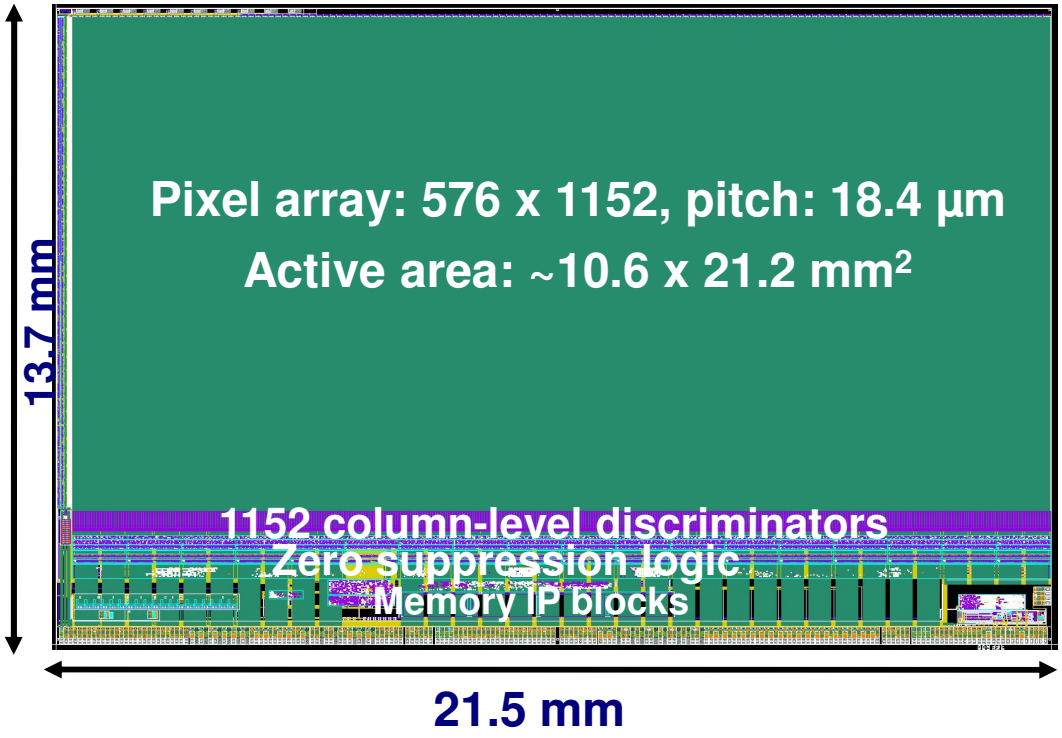
on behalf of the IPHC-IRFU collaboration

- Main features of MIMOSA-26
- Laboratory test results
- Beam test results
- Applications
- PLUME
- Summary

Mimosa 26

Fast full scale sensors: ~10kFrame/s
column parallel architecture + integrated zero-suppression
(MIMOSA-22 for binary output + SUZE-01 for ∅)



- active area ~2 cm²
- 0.35 µm technology.
- binary output

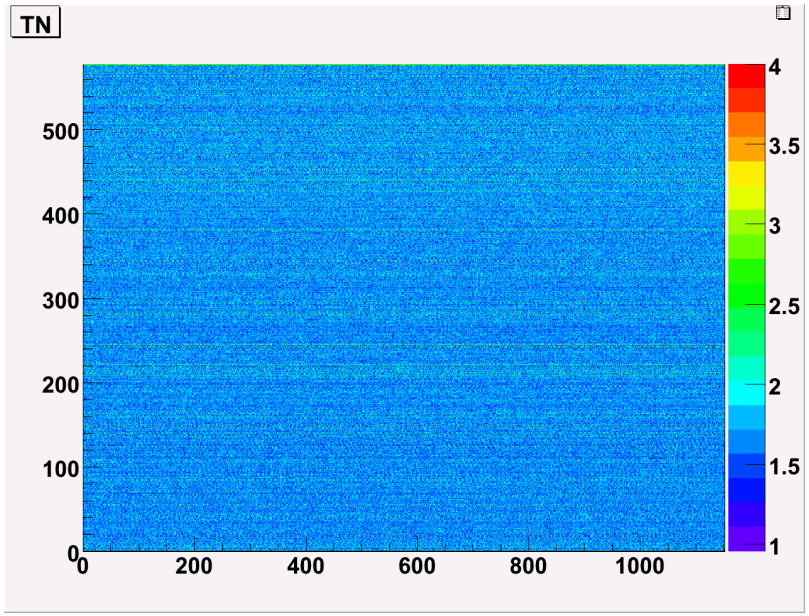
(3.5 - 4 µm spatial resolution)

- in-pixel CDS + preamp.
- column level discrimination
- power dissipated ~280 mW/cm²

(rolling shutter)

- integration time ~100µs
- 120 µm thickness.
- Next step to thin down to 50 µm.

Laboratory tests



Array of 660,000 pixels coupled to 1152 discriminators works ~ as expected

Analogue response for 8 different sensors:

- All pixels are alive.
- Noise is uniform across the sensitive area (~2cm^2).
- Operated from 80 MHz (nominal) down to 20 MHz.
- Noise and CCE (from ^{55}Fe source) as expected (like MIMOSA-22).

Digital response for 21 different sensors:

- All discriminators are operational at nominal speed.
- Discriminator noise like MIMOSA-22.

Analogue + digital response:

- Total noise 0.7 mV (~12-13 e^- ENC) like MIMOSA-22.

Zero-suppression works as expected.

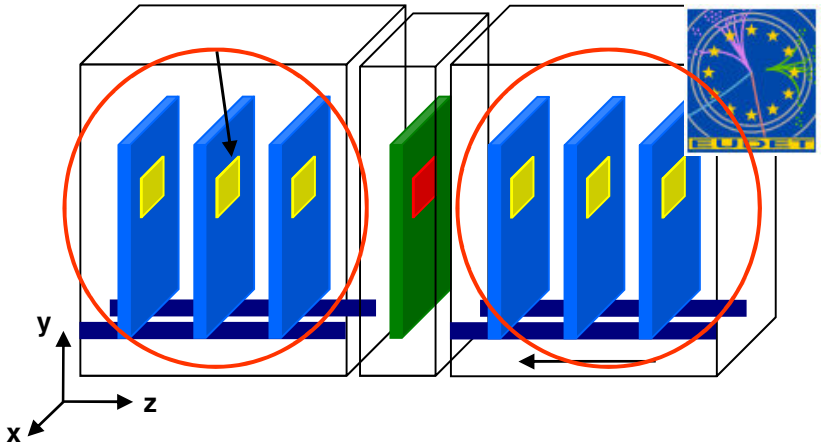
Full chain:

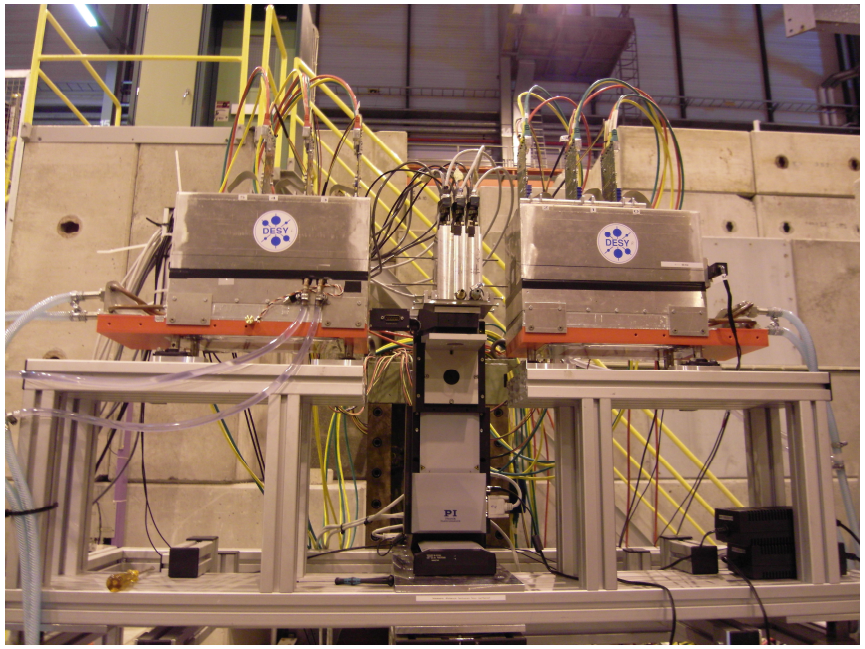
- Fake hit rate O(10^{-4}) @ 6N discri. threshold.
- Performances unchanged for 20° < T < 40°

EUDET beam telescope

Reference planes of EUDET Beam Telescope

- Supported by EU FP6.
- Infrastructure to support the ILC detector R&D.
- Specifications:
  - extrapolated resolution <2 μm
  - sensor area ~2 cm^2
  - read-out speed ~ 10 kframe/s
  - up to 10^6 hits/s/cm^2





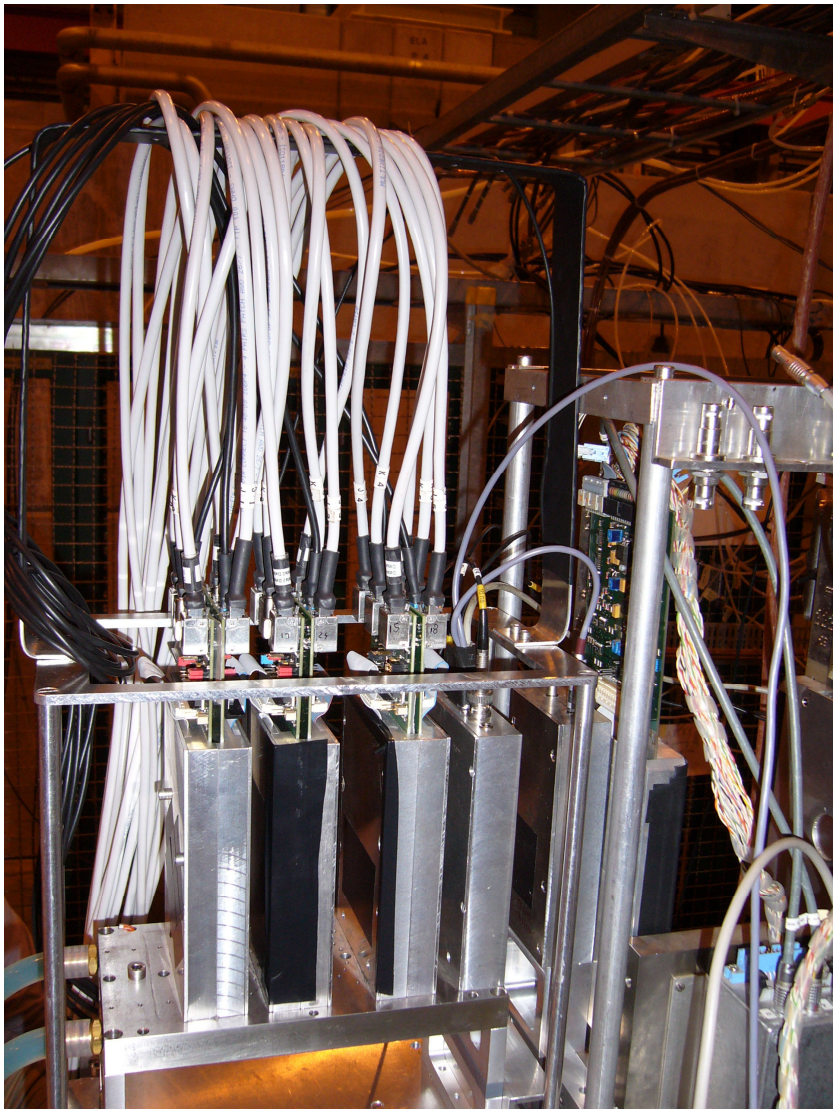
Commissioning @ CERN-SPS last Summer:

- 3 MIMOSA-26 mounted in the BT demonstrator.
- Residuals compatible with σ ~3.5 – 4μm .
- BT completely equipped with M26 (6 planes ~700 μm thick) this September.

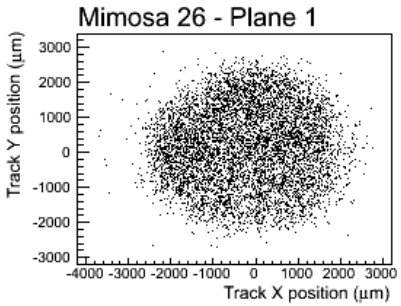
www.eudet.org

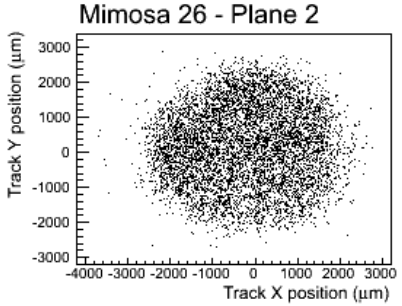
TAPI beam test

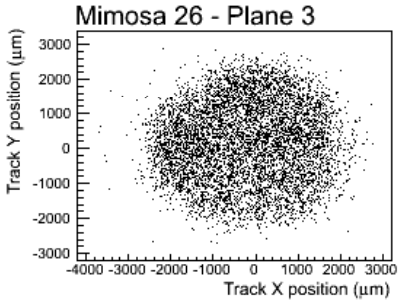
- TAPI = IPHC-Strasbourg BT for MIMOSA development.
- Test in September @ CERN-SPS.
- 6 MIMOSA-26 sensors running simultaneously at nominal speed (80 MHz).
- 3×10^6 triggers.
- Highly efficient tracking (~80% of triggers).
- Detailed characterization ongoing.

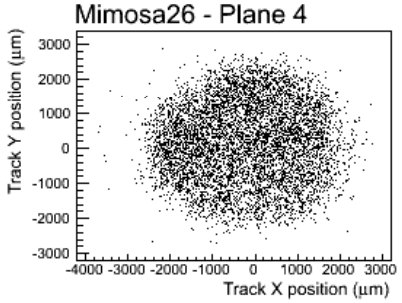


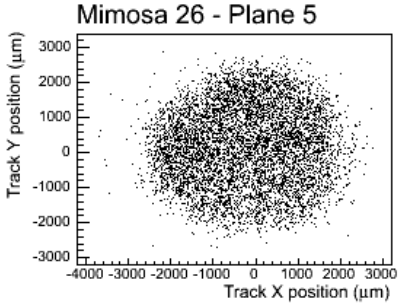
TAPI beam test results

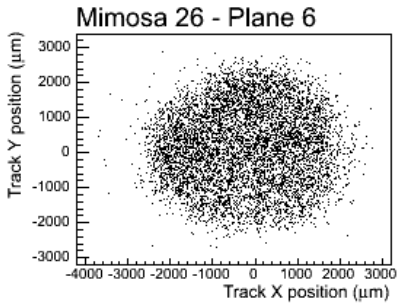


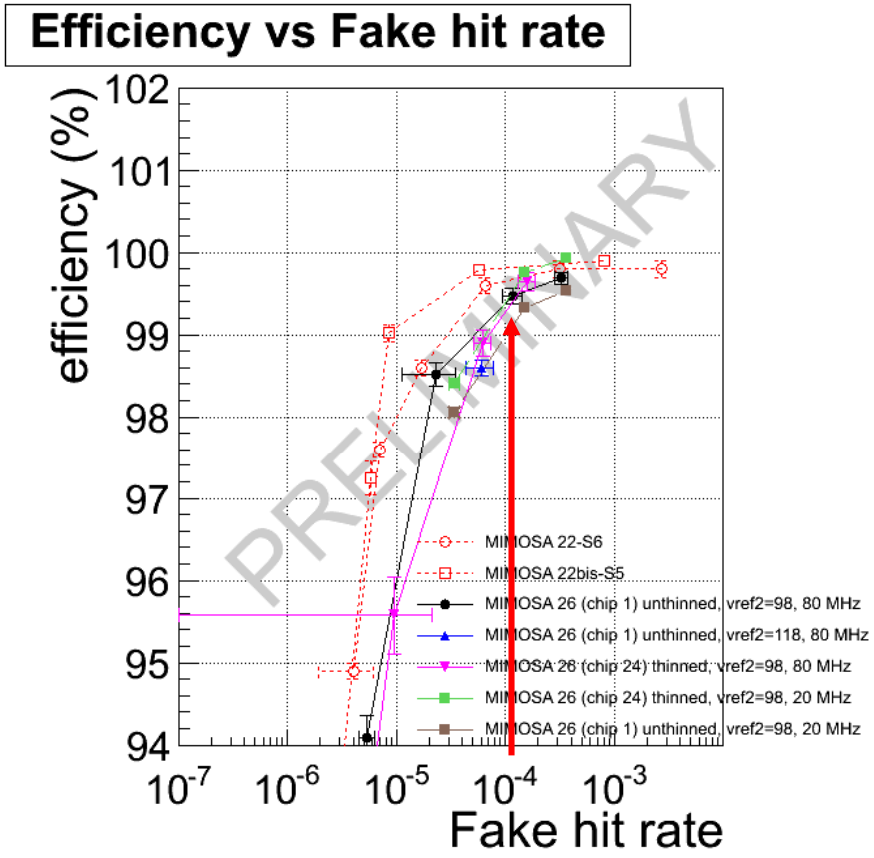






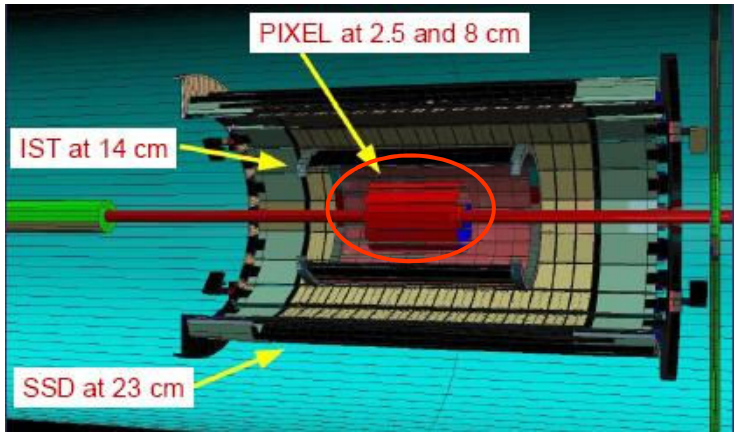






ε = 99.5 ± 0.1 (stat.) ± 0.3 (prel.) %

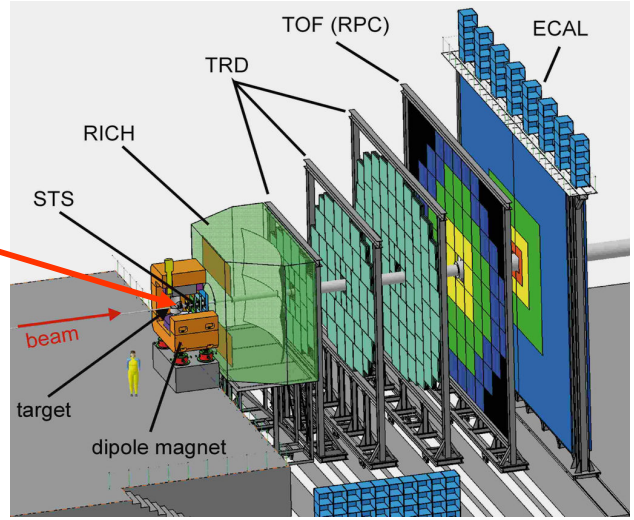
Mimosa 26 architecture: evolutions



- <u>STAR @ RHIC Heavy Flavour Tracker</u>
  - 1152 x 1024 pixels; 200μs integration time
  - Submission early 2010
  - First data 2011/2012

<u>CBM @ FAIR Micro Vertex Detector</u>

- Double sided readout
- 0.18 μm (40→20μs integration time)
- Prototyping until 2012

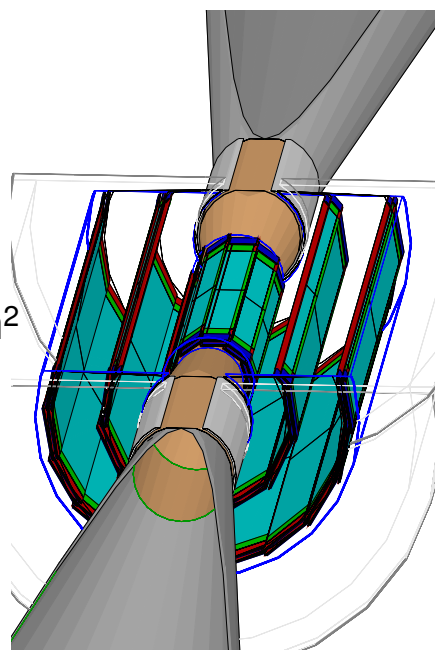


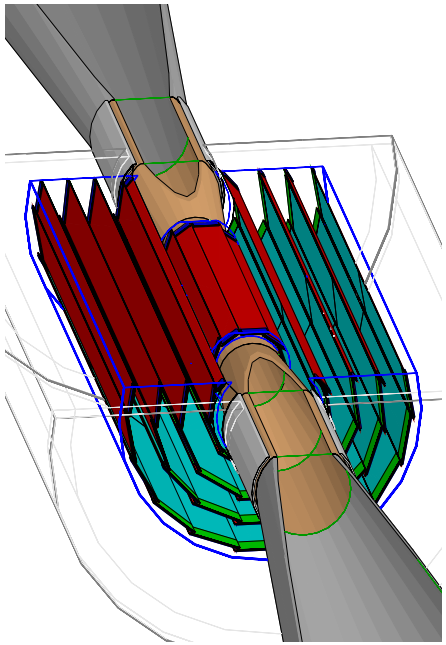
A vertex detector for the ILD

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





Extension for the outer VTX layers:

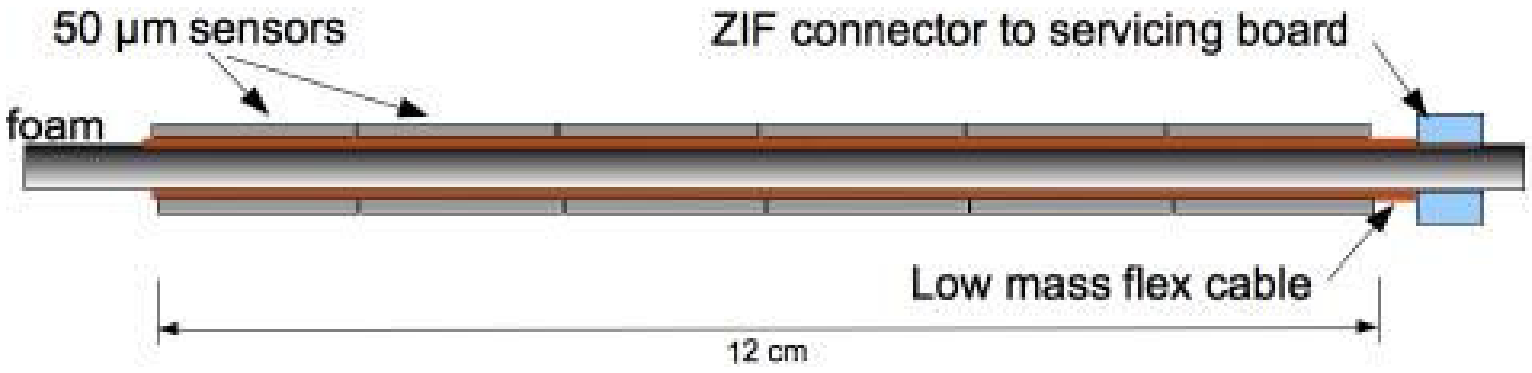
- σ ~ 3 μm: 4-5 bits ADC and a ~ 35 μm pitch (i.t. ~100 μs).

For the inner layers:

- ~ 15 μm pitch → binary readout.
- Double-sided r.o. → i.t. ~ 50 μs.
- Smaller feature size → 35 – 40 μs.
- Double sided ladders → << 35 μs

The PLUME project

- Pixel Ladder with Ultra-low Material Embedding.
- Double sided ladder equipped with 2x6 M26 (TDR 2012).
- 0.2-0.3 % $X_{0.}$
- Explore feasibility, performances and added value of double-sided ladders.
- Allows for improved time resolution (outer layer with larger and fewer pixels).
- First prototype (reduced scale) to be tested in SPS beam next November.
- Full scale prototype expected in 2010.



Other system integration studies

Thin film embedding

- Hadron Physics 2 EU project.
- <0.1% X_0 expected for sensor $\oplus$ flex $\oplus$ film (no mechanical support).
- may match cylindrical surfaces (pipe?).

Sensor stab butting

- Fabricate 6 sensors in a raw.
- < 20 mm inter-sensor (insensitive) zone.
- First trial under discussion with foundry.

Summary and future perspectives

- First full scale sensor with high read-out speed.
- Binary output + integrated zero-suppression.
- Tested in laboratory and on beam.
- Equips the 6 planes of EUDET BT.
- Optimized version for STAR-HFT.
- Architecture will be extended to CBM-MVD and is being adapted for ILD-VTX.
- System integration studies started: PLUME, HP2, butting.

New perspectives

- Depleted sensitive volume:
  - Technology prototyped with MIMOSA-25.
  - First engineering run expected soon.
- 3D integration technology:
  - 4 CAIRN prototypes submitted (low power, few μs r.o., delayed readout with timestamp).
  - Heterogeneous chip.