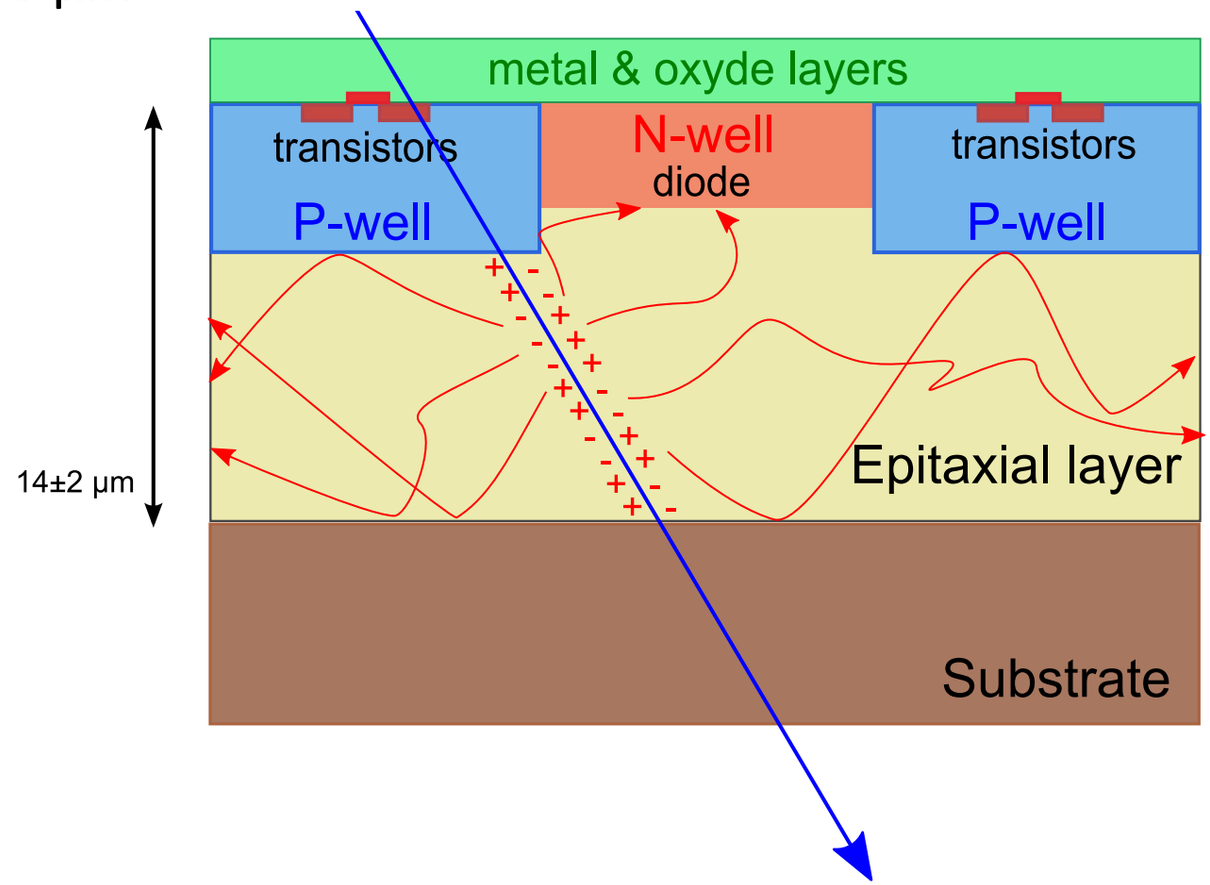
CMOS pixelized sensor for high ionising particles
(Mimosa28 - TIIMM chips)

Introduction

- CMOS (Complementary Metal Oxide Semiconductor) sensor

- High granularity: pitch size 20-50 µm
- Very thin: epitaxial layer < 20 µm and total size 50 µm
- Reasonable size: ~2x2 cm^2
- Rate capability: > MHz/ cm^2
- Low power consumption: < 300mW/cm^2

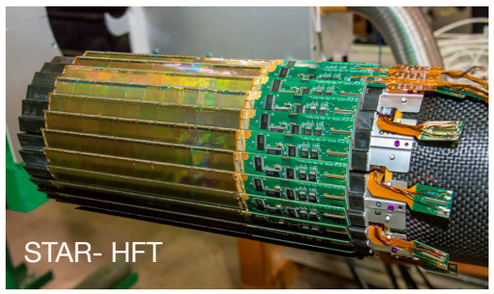
➡ Spatial resolution: << 10 µm and
➡ Low material budget
➡ High dose tolerance: 10^{15} neq/cm^2
➡ High time integration: > 150 µs

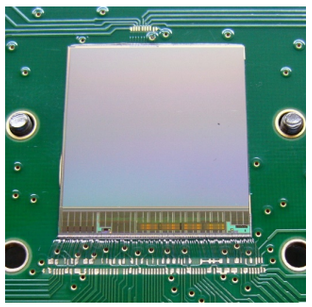


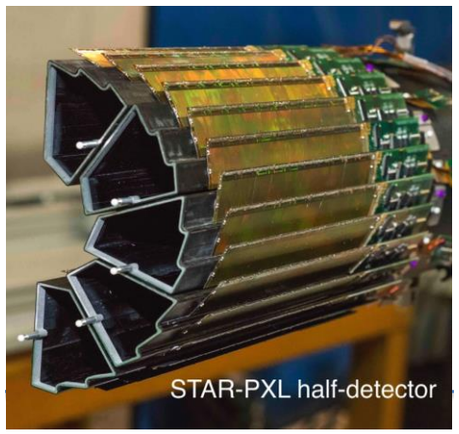
➡ Ideal for charged particle tracking
➡ Used in high energy physics experiments (MIP)

Introduction

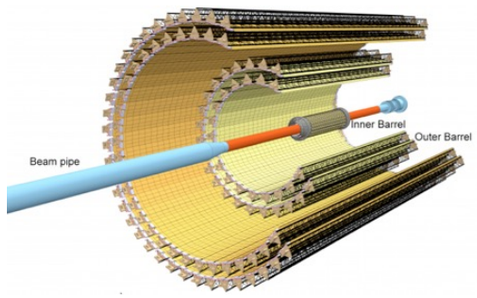
- Partially depleted sensor
  - STAR @ BNL:

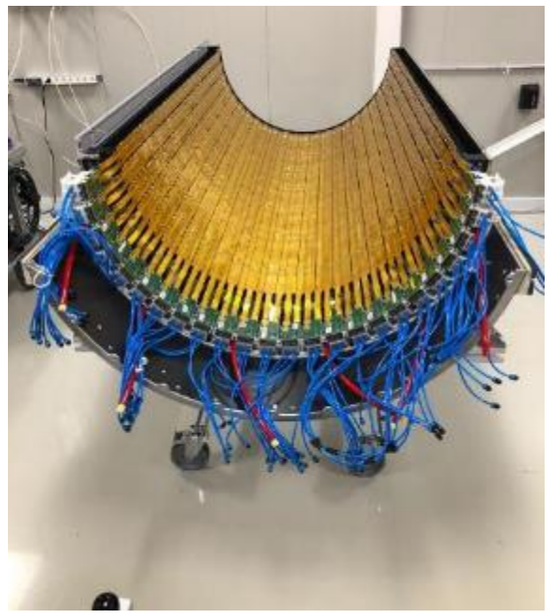




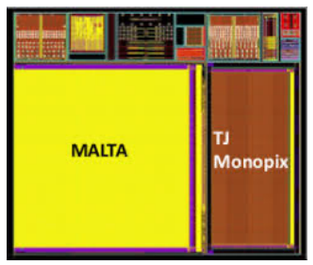


  - ALICE @ CERN

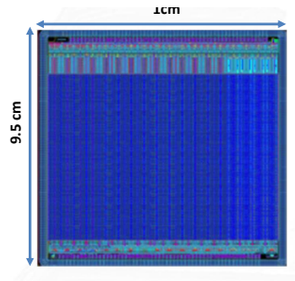




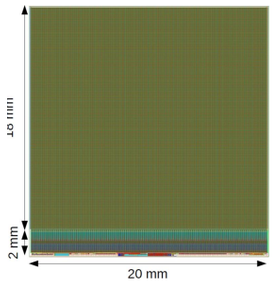
- Fully depleted sensor
  - ATLAS R&D



MALTA and TJ-MONOPIX
180 nm TJ



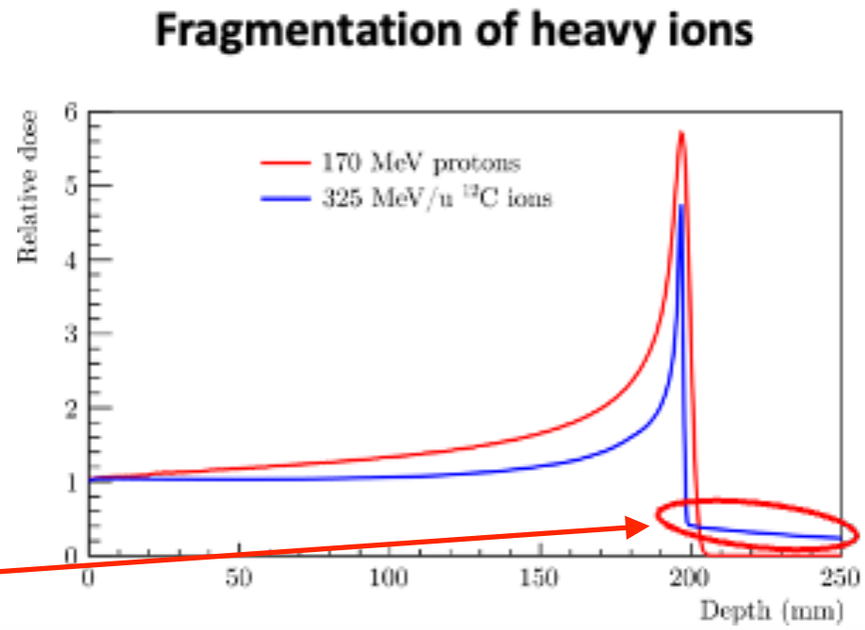
LF-MONOPIX
150 nm LFoundry



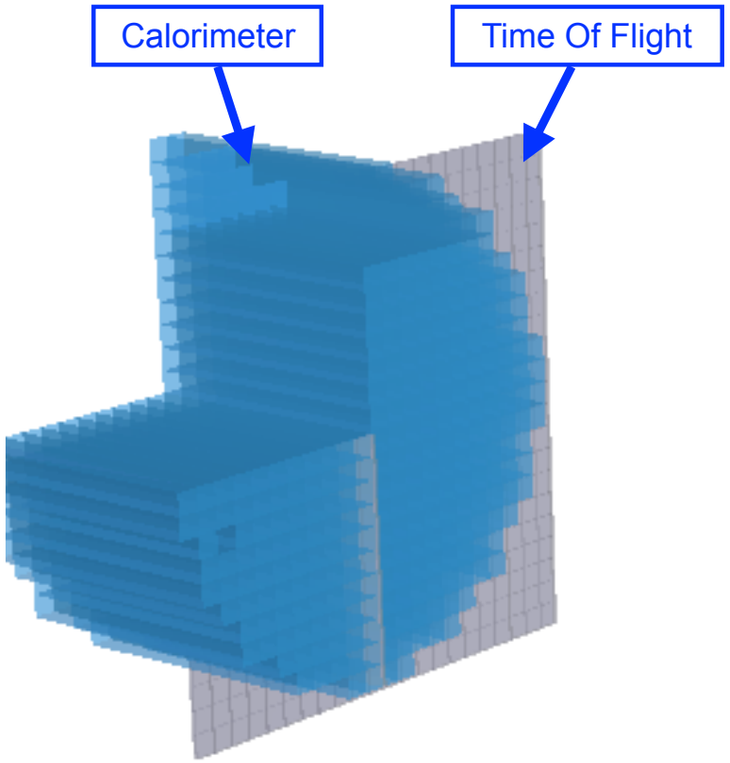
ATLASPix3
180 nm TSI

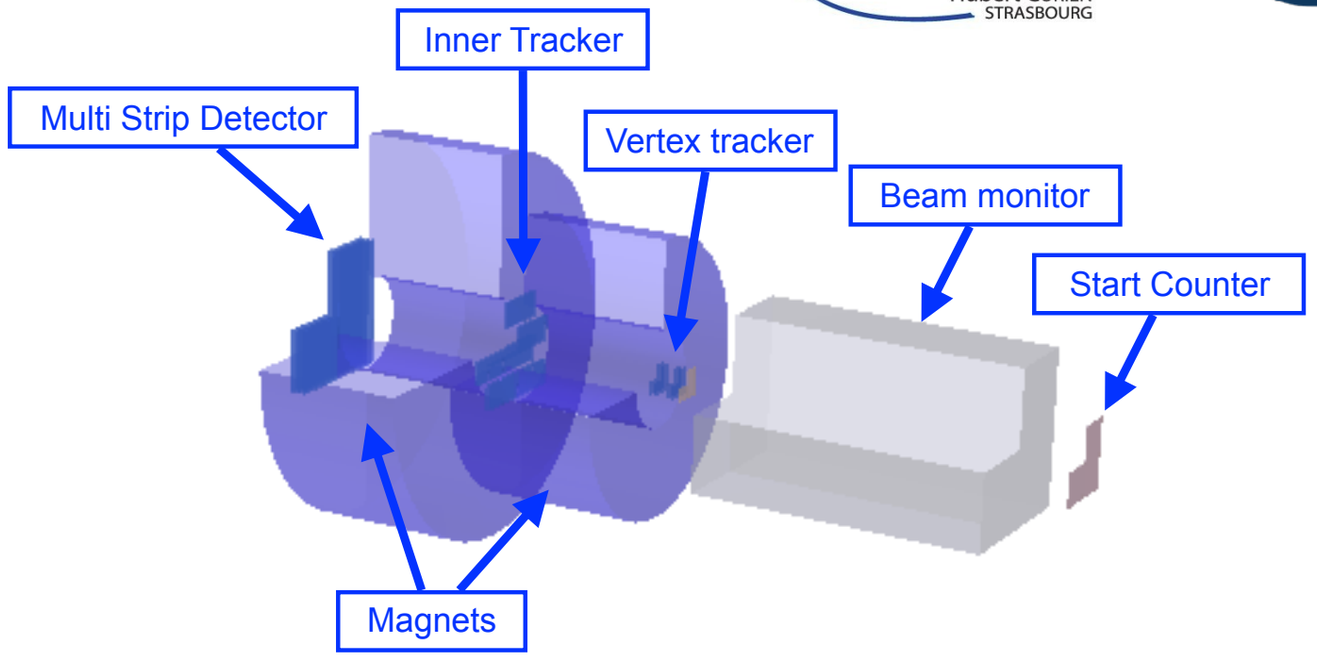
➡ Of interest for hadrontherapy (high ionising particles)

➡ Measurement of beam fragmentation



FOOT experiment

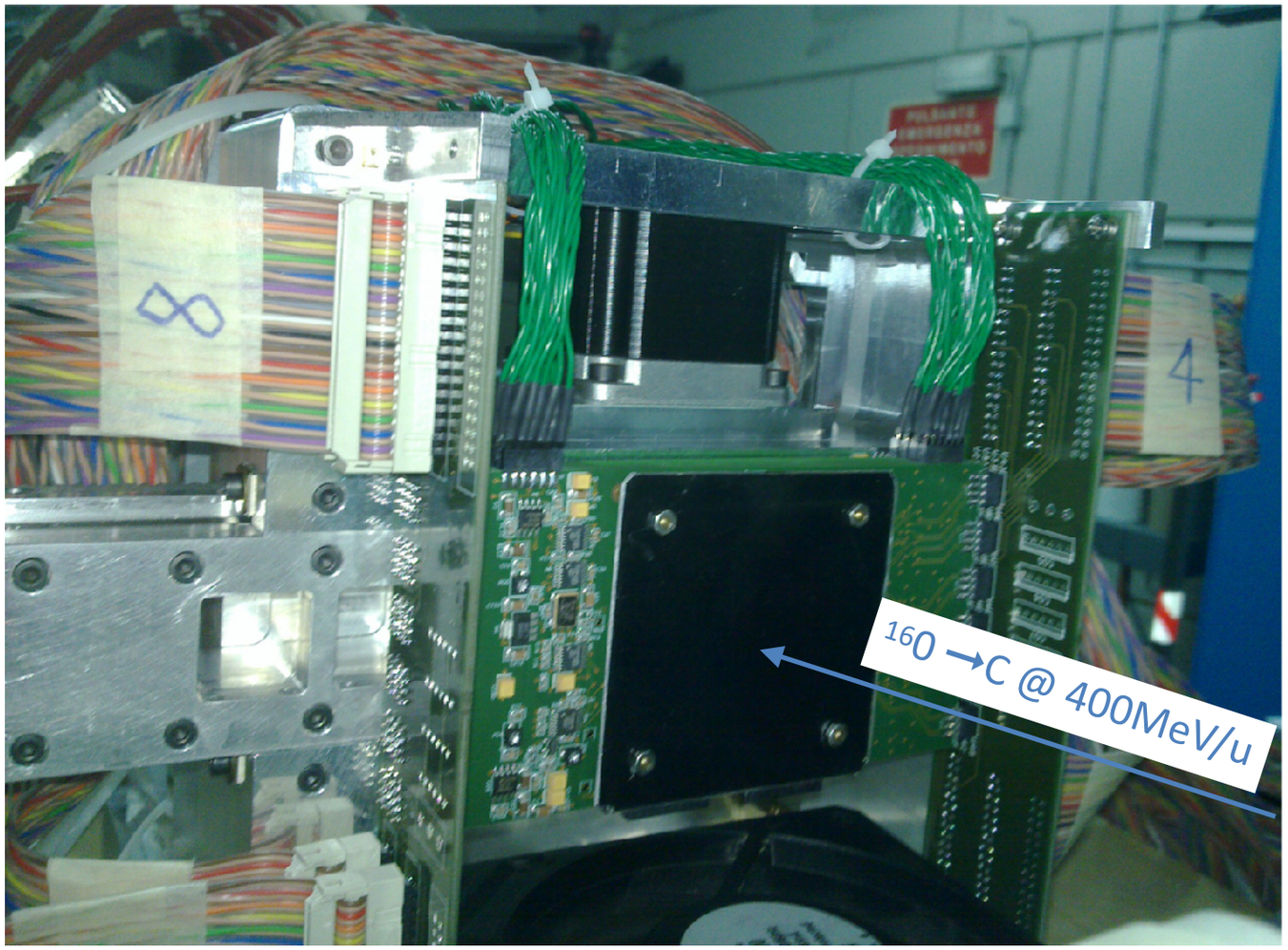




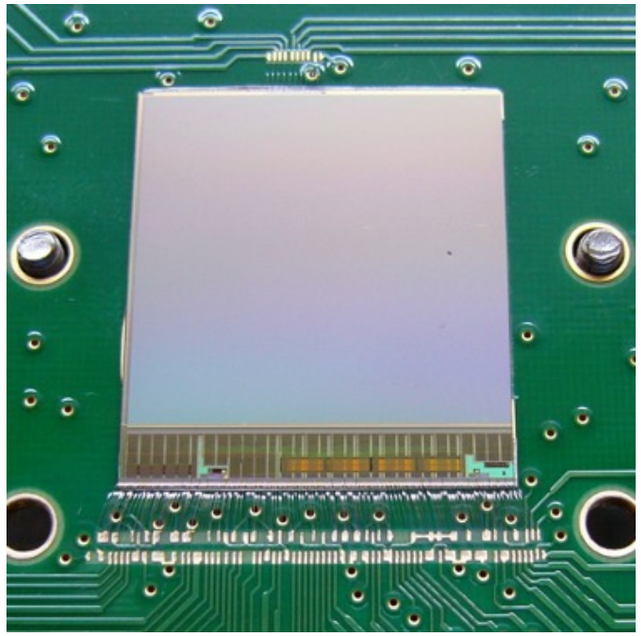
- STC: plastic scintillator
- BM: drift chamber
- VTX: 4 planes of M28
- ITR: 32 sensors of M28 in 2 planes
- DI: permanent magnetic dipole
- MSD: 6 planes of micro-strip detector (X-Y)
- TW: 44 plastic scintillators
- CAL: 288 BGO in 32 modules

Vextex detector

- VTX setup:
  - 4 planes of M28 sensors



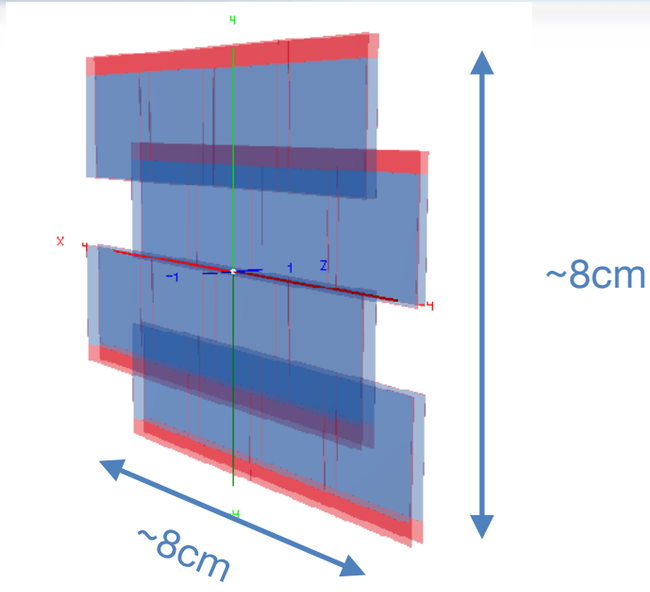
M28

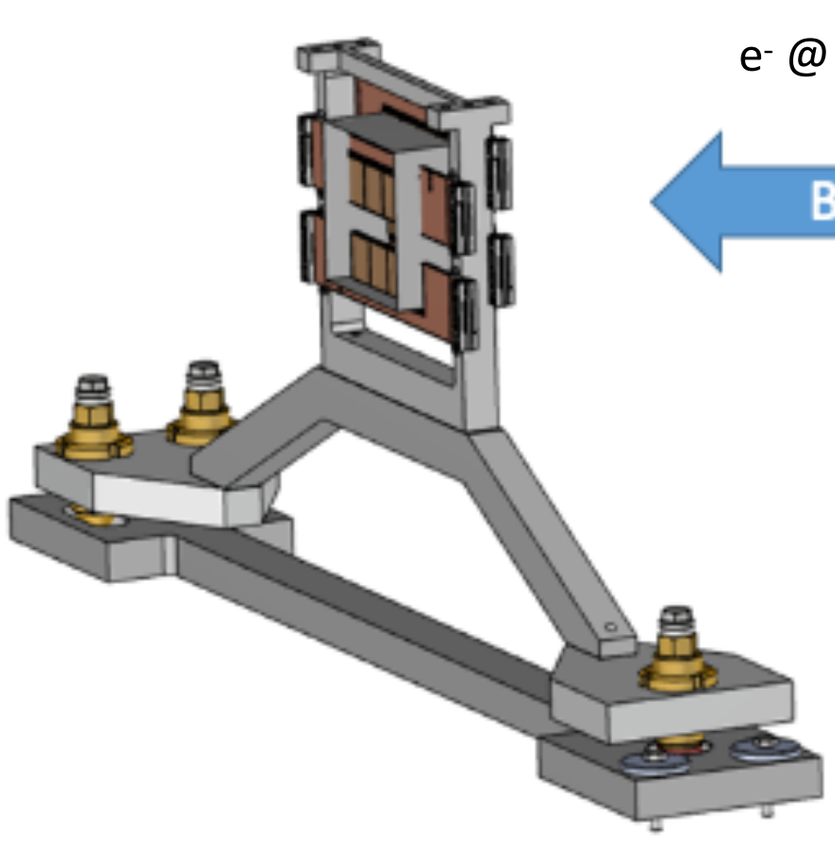


- MAPS (AMS 0.35 µm, 14 µm epi-layer)
- Thickness: 50 µm
- 928 (rows) x 960 (columns) pixels
- Pitch: 20.7 µm
- Size: 20.22 mm x 22.71 mm
- Chip readout time: 185.6 µs
- Digital ouput

Inner Tracker

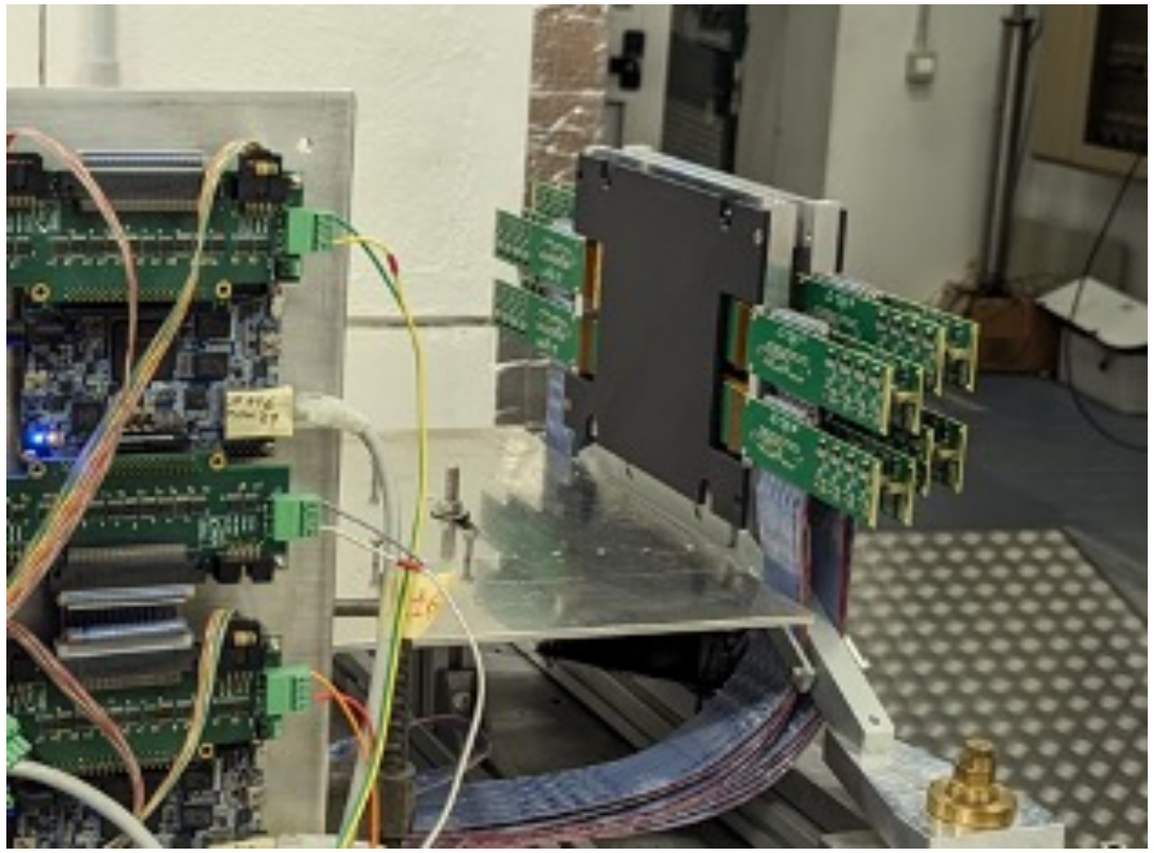
- ITR Setup
  - 32 sensors M28 in 4 staggered planes
  - 28 Mpixels to read via 8 bus patches





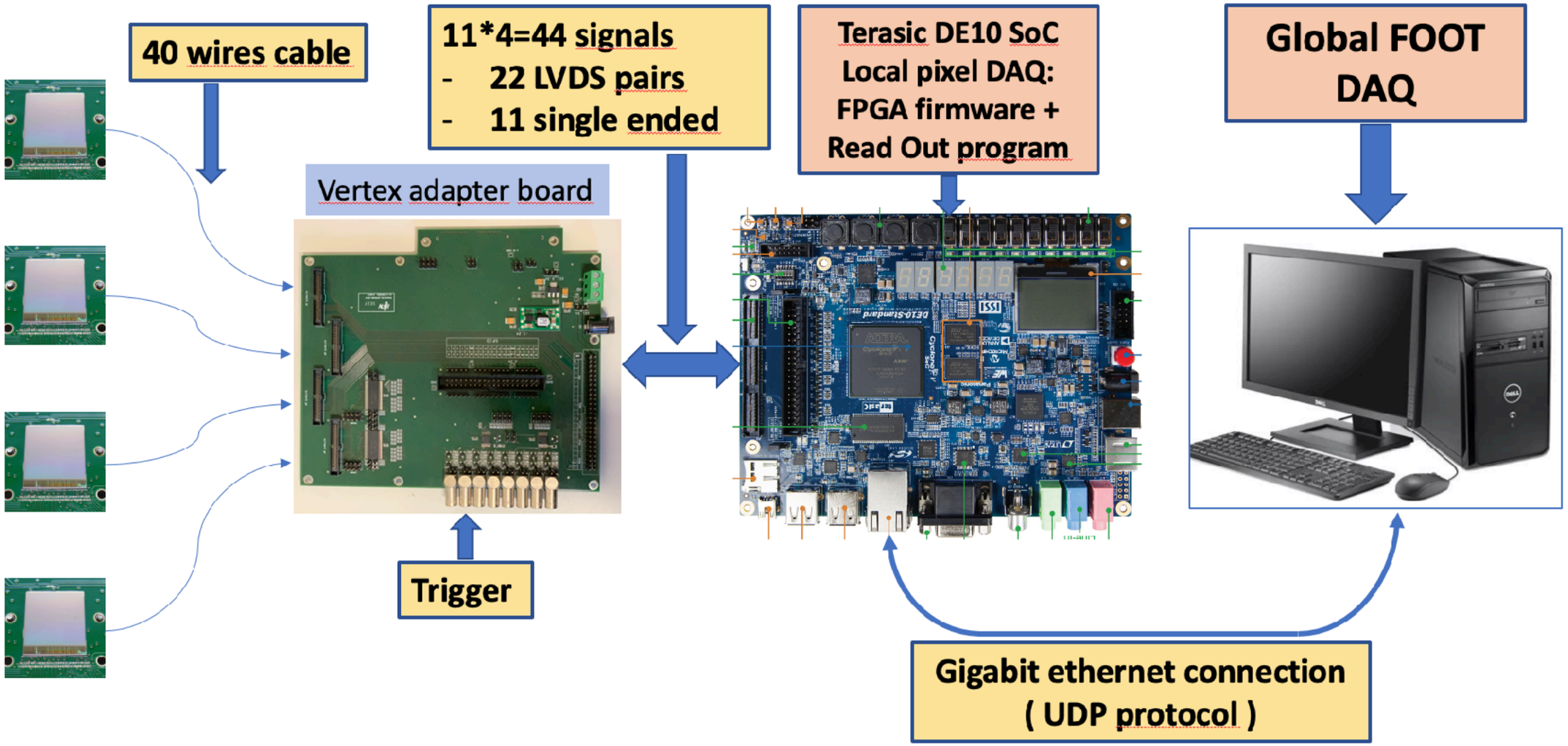
e⁻ @ ~400MeV

Beam



VTX/ITR

- Electronics:

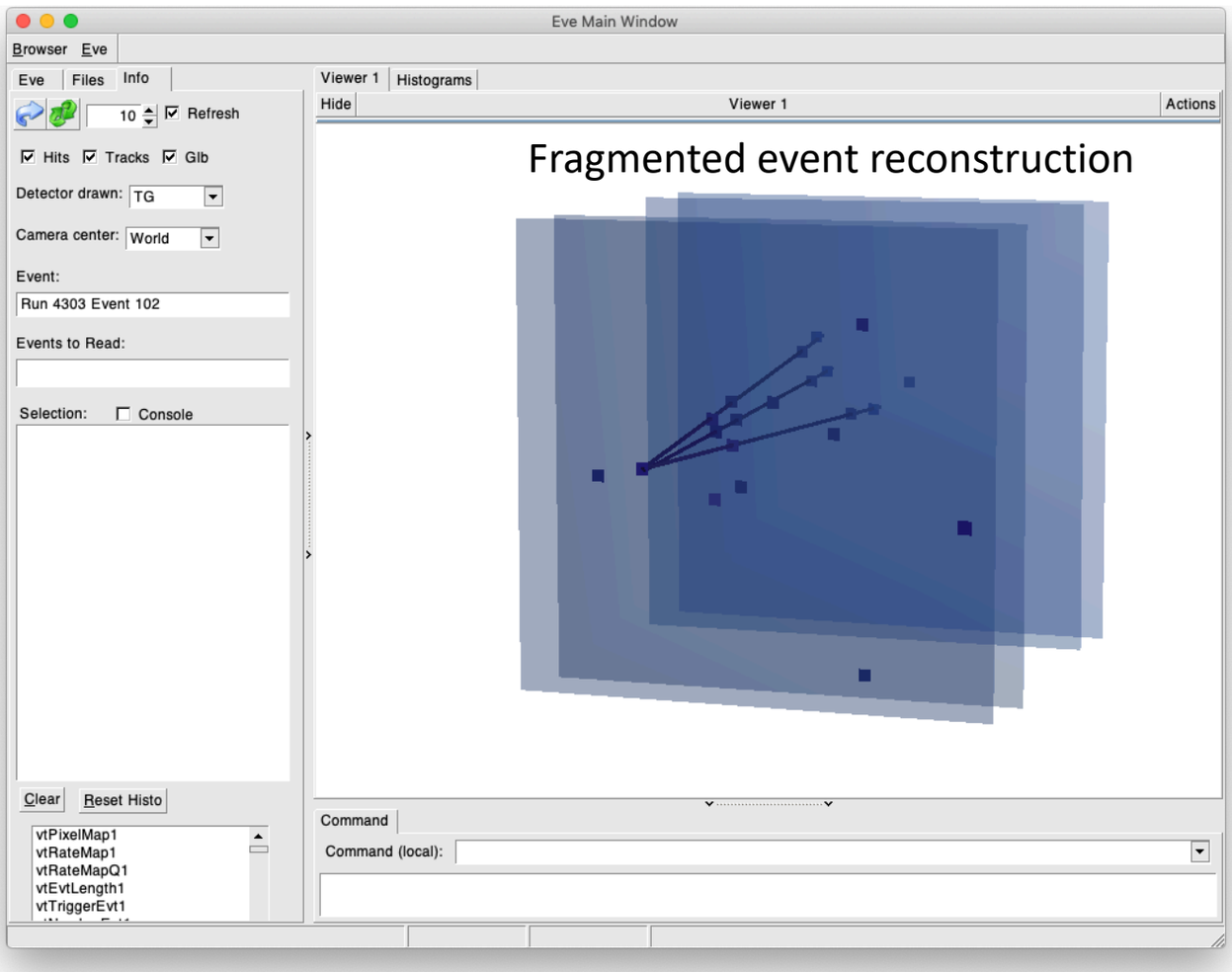


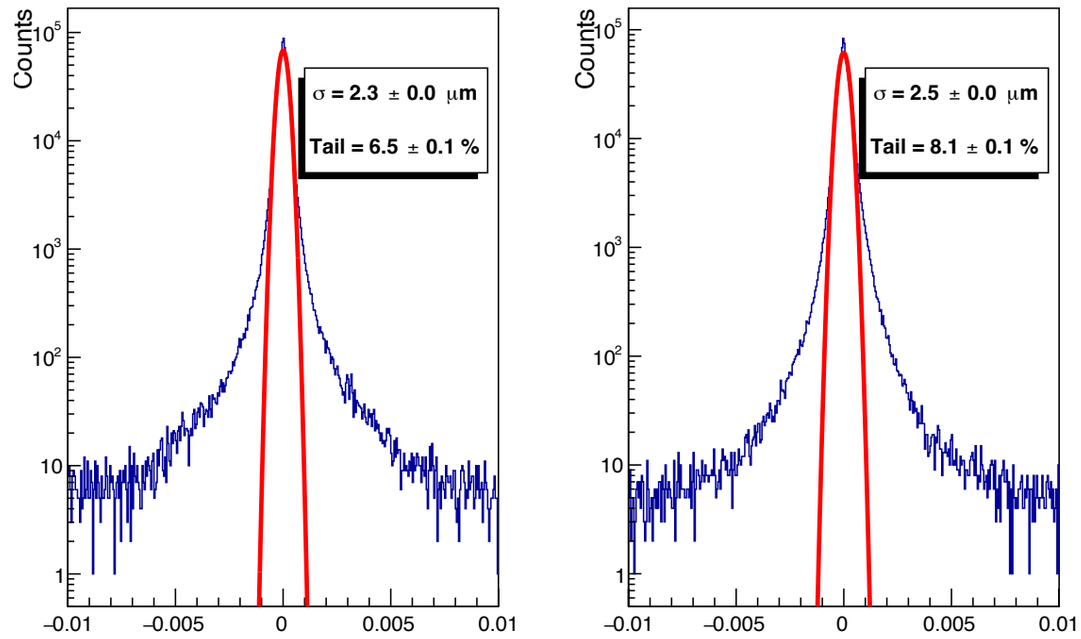
- ➡ Scheme for each 4 sensors
- ➡ 1 data link for VTX and 8 for ITR

Test beam @ GSI

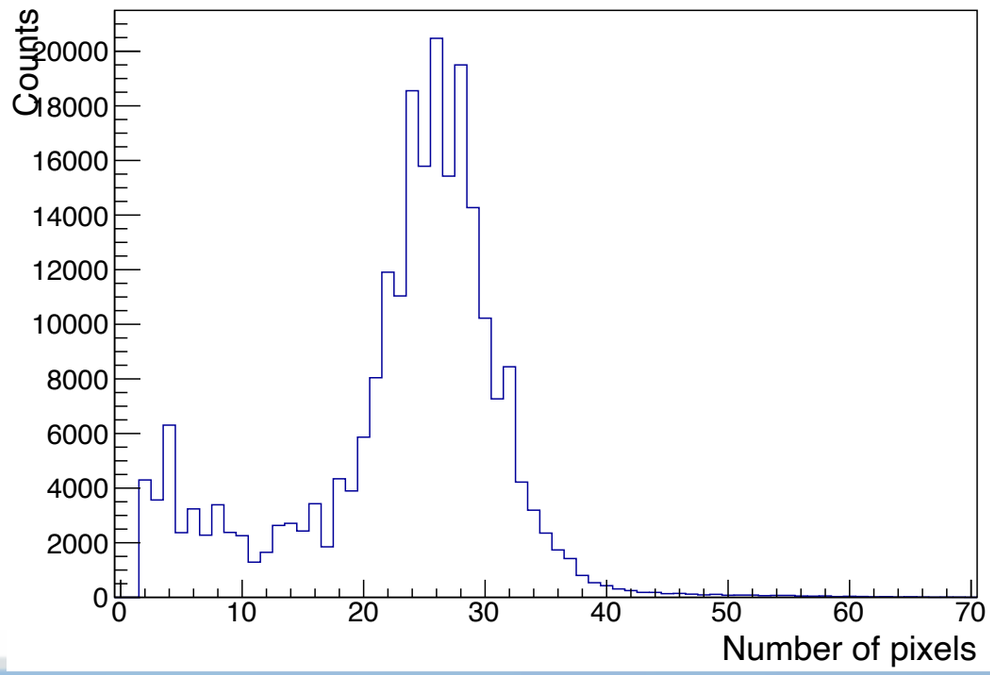
- Vetex:

$$Res = \sum_{i=0}^{nclus} [X_i^{clus} - X_i^{track}]$$





Oxygen with target

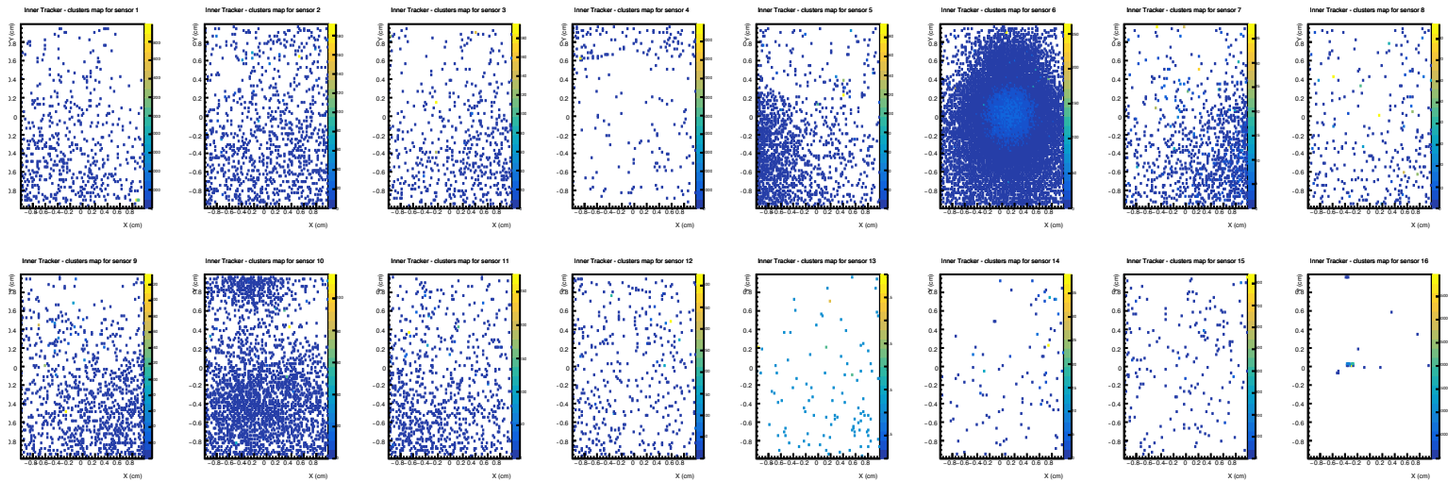


- Residual: << 5 μm
- Cluster size as function of E_{dep}

Test @ Frascati

- VTX+ITR

1st plane cluster hit map

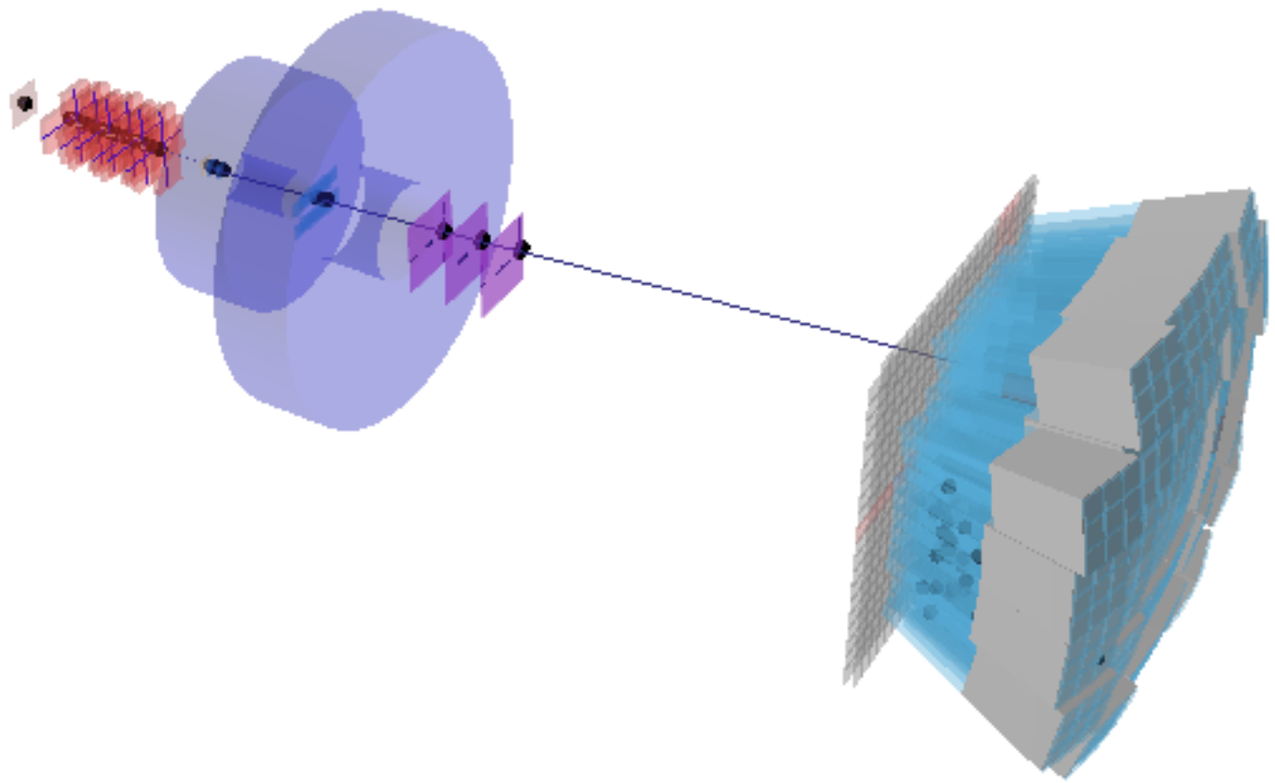


➡ Next beam time, end of this week @ CNAO, full setup including magnet & ITR

Conclusion (i)

- CMOS shows excellent results VTX or ITR (first time under beam)
- Analysing data of GSI campaign
- Ready for next beam time @ CNAO

➡ Measurement of fragmentation cross-sections



➡ M28: only digital output

➡ Next step analogue output, TIIMM project

TIIMM Project

(Tracking and Ions Identification with Minimal Material budget)

❑ Introduction:

TIIMM target =

Tracking

Precision tracking
$\sigma_{pos.} \leq 10\ \mu m$

+

Low material budget $<<$ % X_0

Identification

+

Energy loss measurement
1-10^3 MIPs

Current achievements

↓

Monolithic sensors

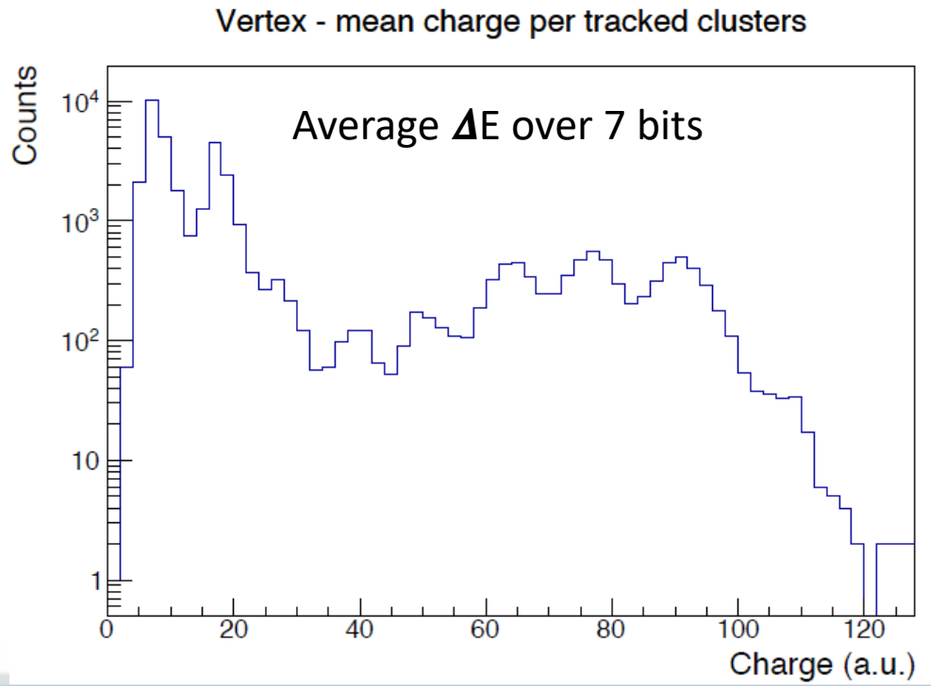
- ~5 µm ALICE – ITS2
  - with 1-10 MIPs
- 5-10 µm FIRST, hadrontherapy
  - Ions 150-300 MeV/u

- 0.3 to 0.8 % X_0
  - ALICE – ITS2 over 10 m^2
- ~0.2 % X_0
  - FOOT prototype over 30 cm^2

- Available for MIP level
  - σ_E not investigated
- Initial work for >> MIPs
  - Indirect estimation of E

- Simulation:
  - Reaction: $^{16}O+^{12}C$ @ 200 MeV/u
  - 8 partial depleted sensors (50 μm)

➡ Observed peak for each species in Z

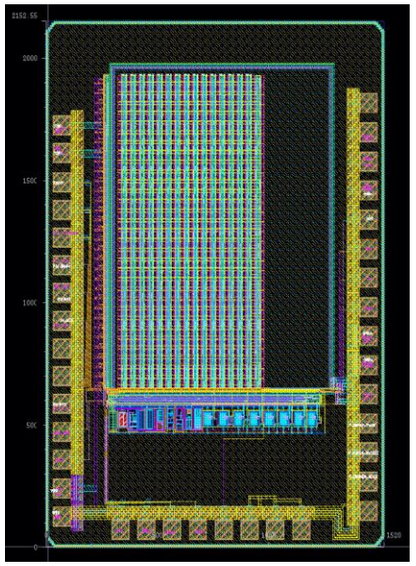


TIIMM sensors

(Tracking and Ions Identification with Minimal Material budget)

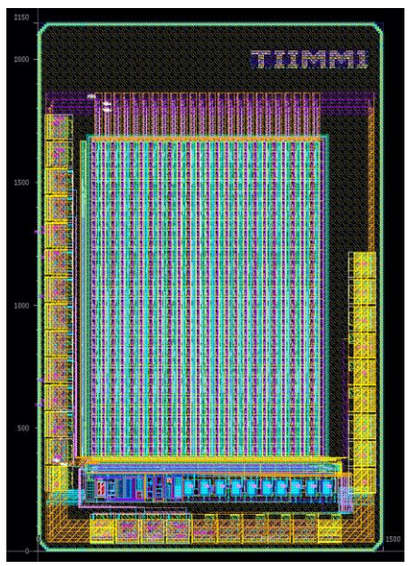
❑ Design:

- 4 different prototypes



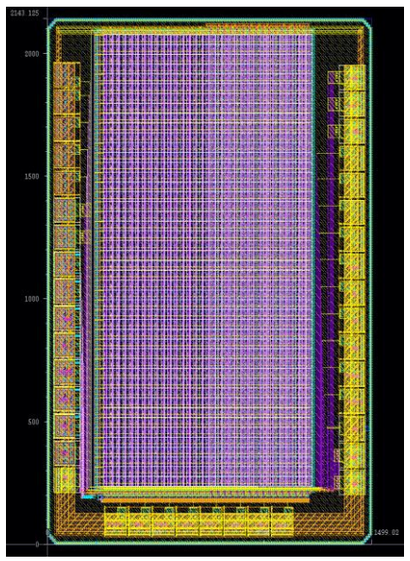
TIIMM0 (second submission)
Chip area: 2.2 mm * 1.5 mm
Matrix: 32 (rows) * 16 (col)
Pixel pitch: 40 µm×40 µm

Corrected from the first submission



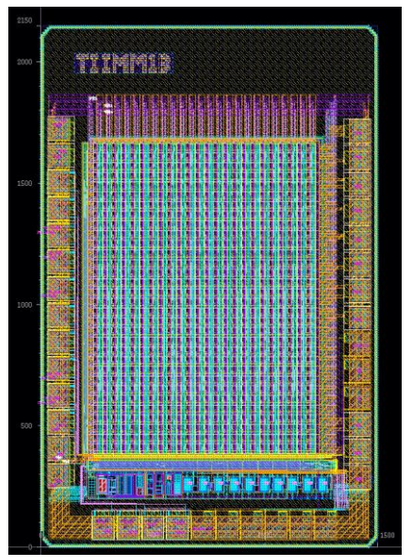
TIIMM1 sensor
Chip area: 2.2 mm * 1.5 mm
Matrix: 32 (rows) * 24 (col)
Pixel pitch: 41.2 µm×40 µm

New front-end



TIIMM1A sensor
Chip area: 2.2 mm * 1.5 mm
Matrix: 46 (rows) * 32 (col)

New front end
Analog part study only



TIIMM1B sensor
Chip area: 2.2 mm * 1.5 mm
Matrix: 32 (rows) * 24 (col)
Pixel pitch: 41.2 µm×40 µm

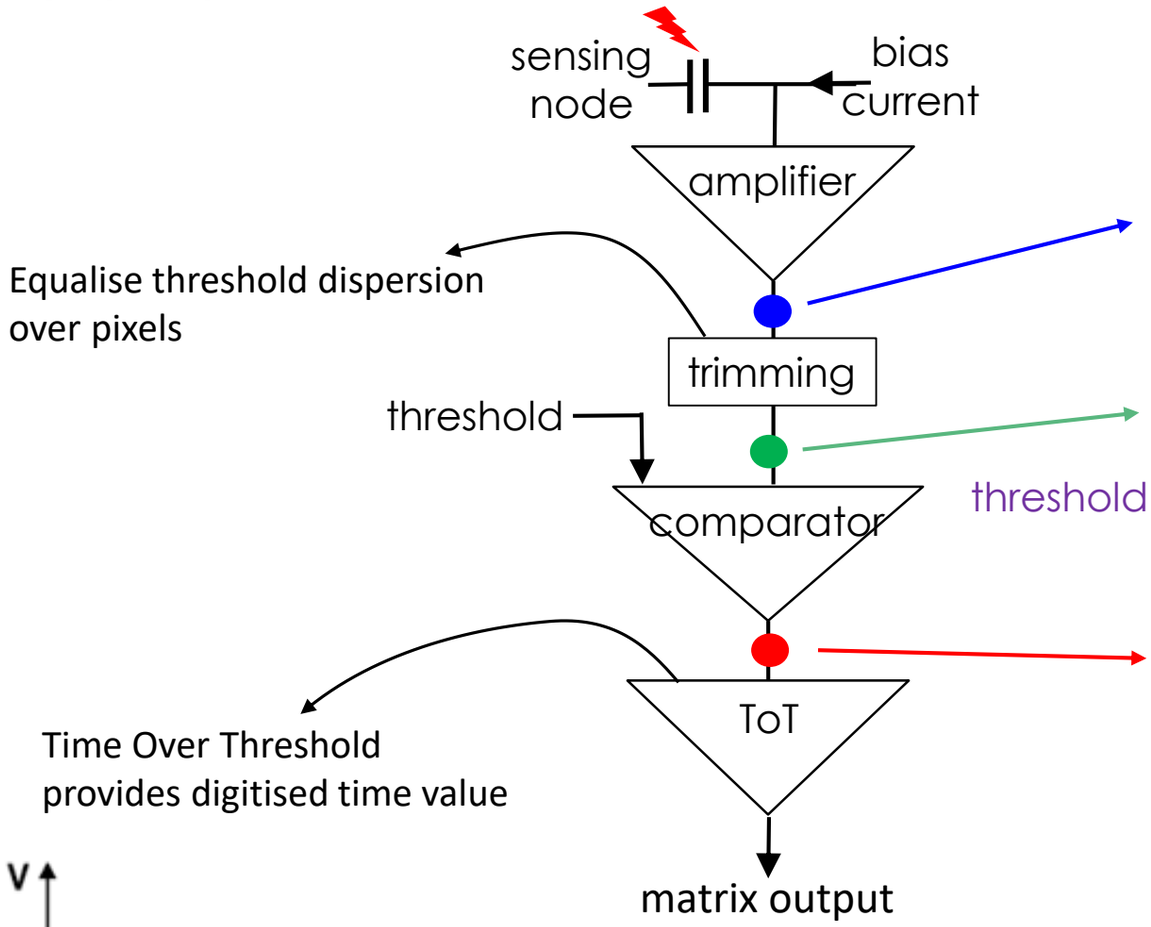
New front-end enhanced

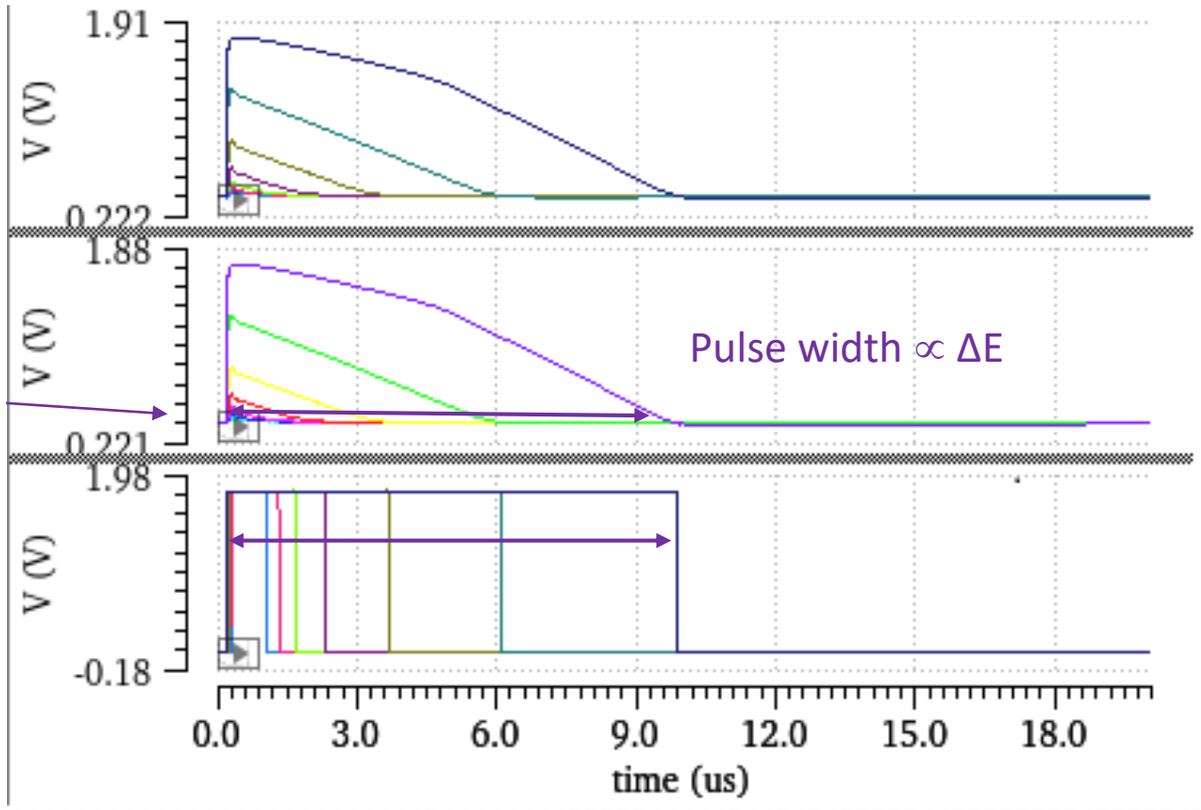
➡ Fully depleted sensor with analogue output

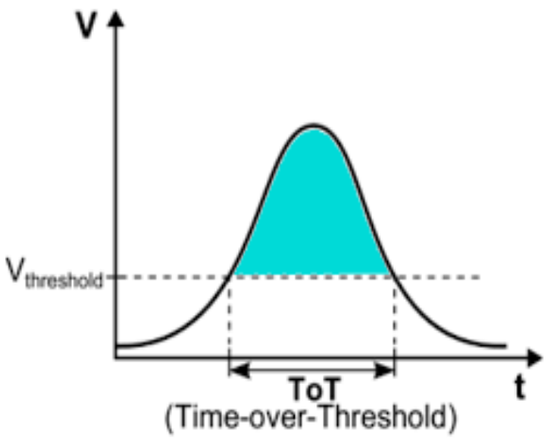
TIIMM sensor

(Tracking and Ions Identification with Minimal Material budget)

- Front-End:



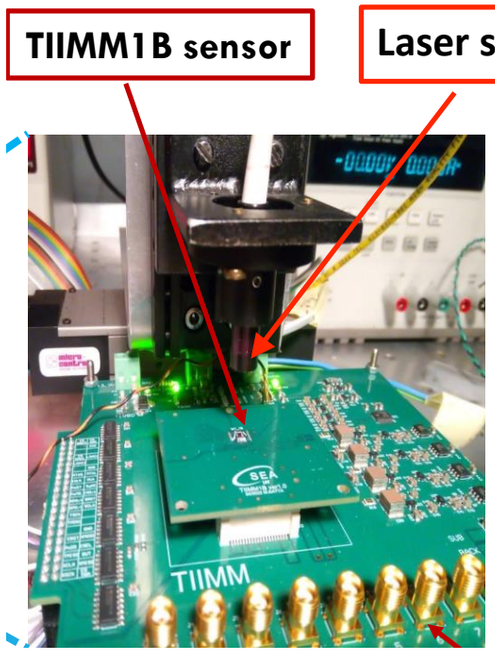




➡ From deposited energy to measured charge

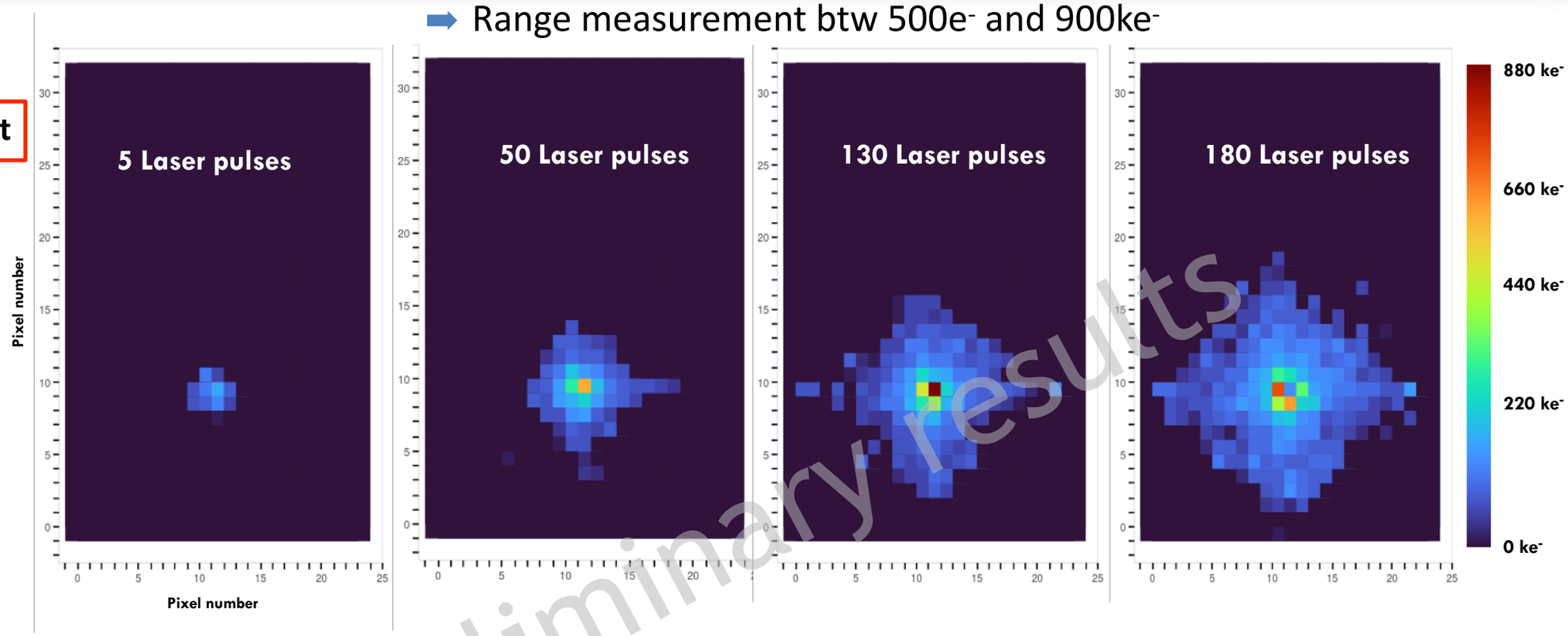
Test with laser

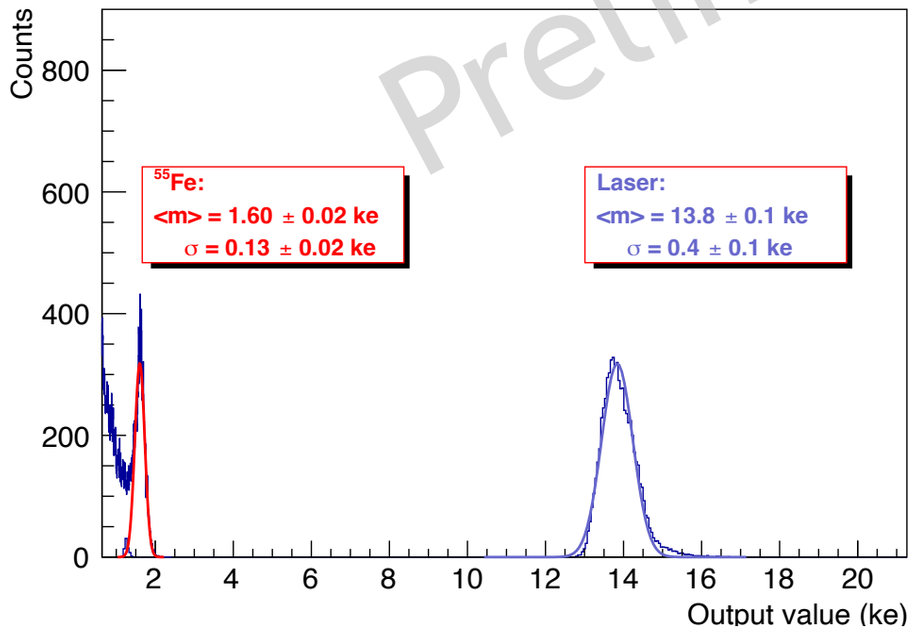
- TIIMM1b sensor:

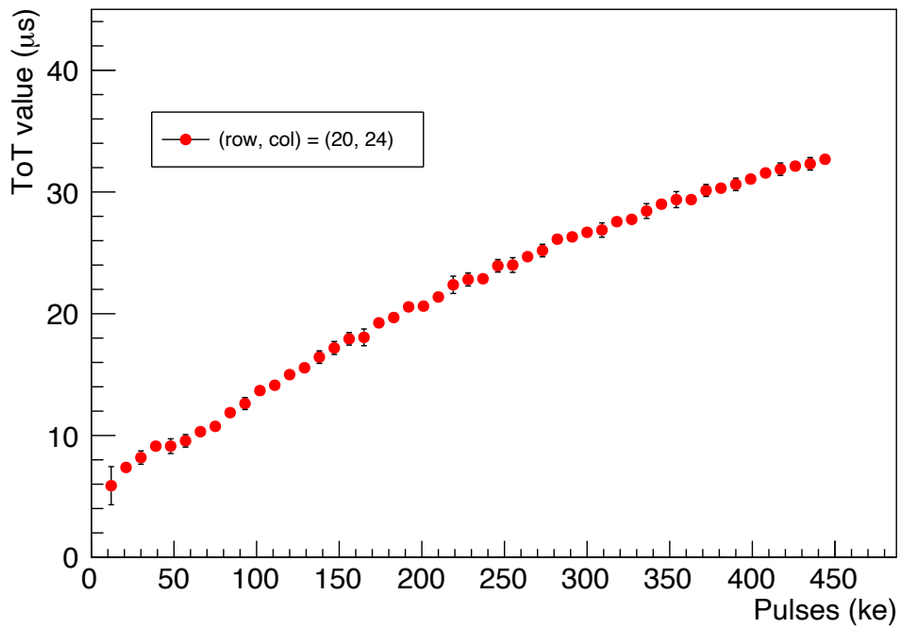


Test bench

➡ Range measurement btw 500e⁻ and 900ke⁻







Conclusion (ii)

- Test with laser show a good response of the TIIMM prototype

➡ Update the DAQ system

➡ Ready to go under beam conditions with high ionising particles:

- First time for the ITR detector
- First time also for TIIMM sensors

❑ Acknowledgements:

- CNRS-IPHC: J. Baudot, L. Federici, R. Sefri, M. Kachel, W. Ren, C. Hu-Guo and DeSIs team
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