

TIIMM project: Monolithic silicon pixel sensors for particle tracking & identification

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on behalf of STRONG-TIIMM

- DKFZ, Heidelberg
- GSI, Darmstadt
- INFN, Trento
- IPHC, Strasbourg
- LNF / INFN, Frascati



- TIIMM goals & concept
- Initial work
- Sensors prototyped

Tracking ions with MAPS

Requirements =

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



Low material budget $\ll \% X_0$

■ A well know recipe

- **~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 m²
 - **~0.2 % X_0**
 - FOOT prototype over 30 cm²

[J.Phys. Nucl.Part. G 41 \(2014\) 087002](#)
[NIM A845 \(2017\) 583-587](#)

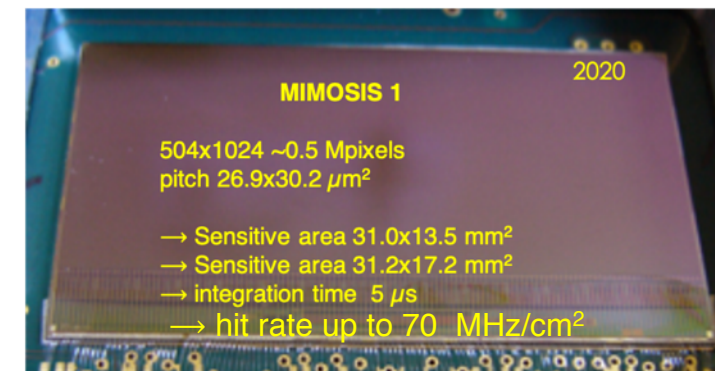
E.Spiriti et al. [Nucl.Phys. B215 \(2011\) 157](#)

With powerful sensors:

[JINST 7 \(2011\) C01102](#)
 IPHC



[J.Phys. Nucl.Part. G 41 \(2014\) 087002](#), CERN+

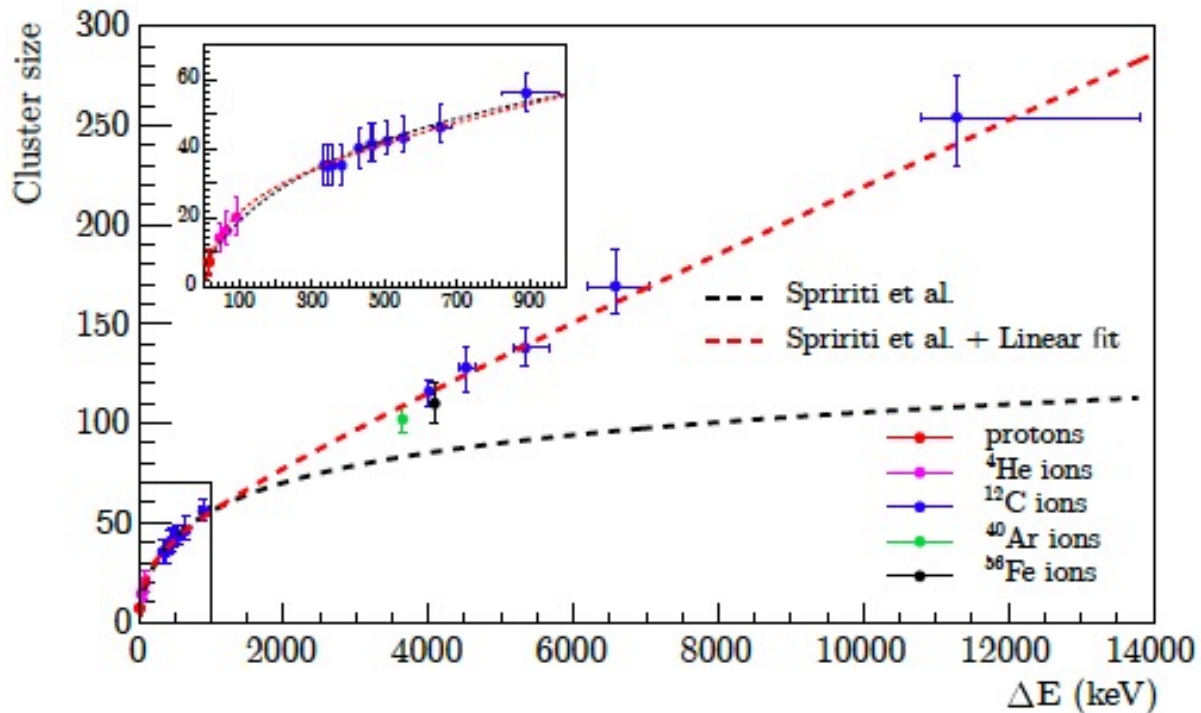


F.Morel [talk at TIPP 2021](#) IPHC

Identifying ions with MAPS

- Currently with binary pixels

- Measurements with MIMOSA-28 (partially-depleted)
- Rely only on cluster size

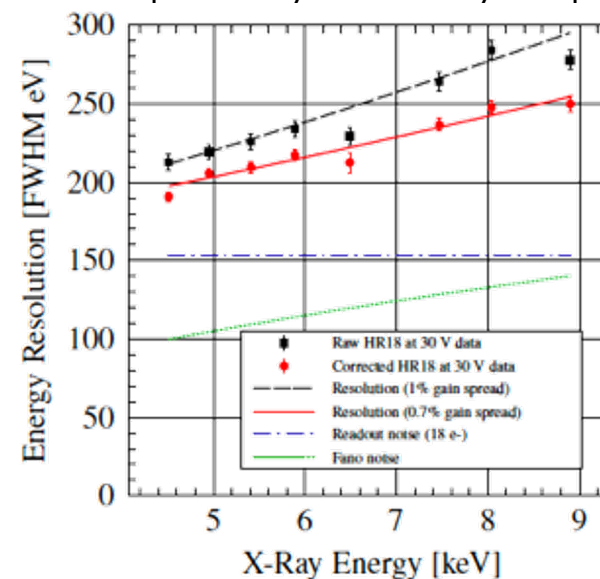


C.Reidel, E.Spiriti et al.: [NIM A875 \(2017\) 35-40](#) & [NIM A1017 \(2021\) 165807](#)

- Expected improvement

Energy loss measurement

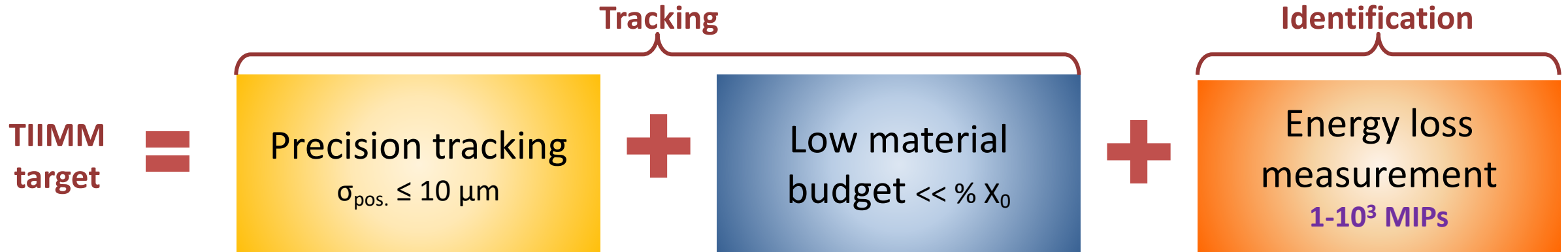
- Especially with fully-depleted MAPS



Analogue output
Pitch 22x22 μm^2
18 μm thickness

Z.El Bitar et al. [Proceedings 5th ICABME 2019](#)

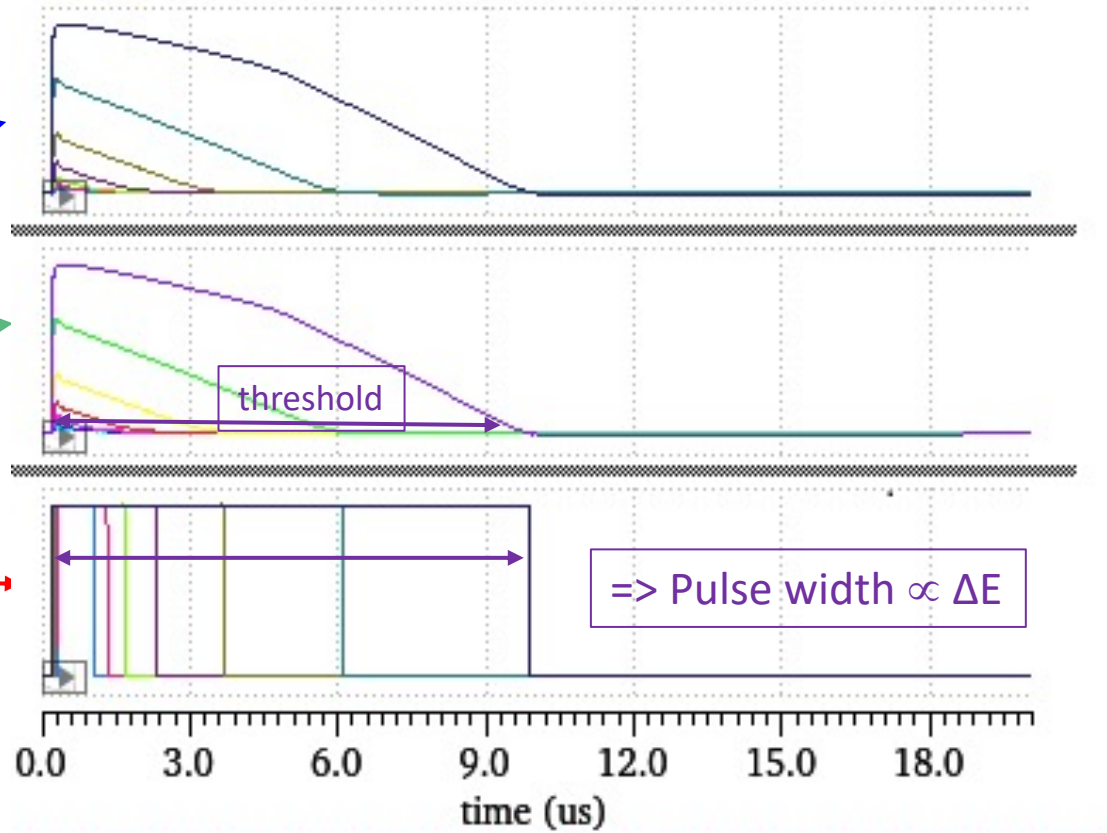
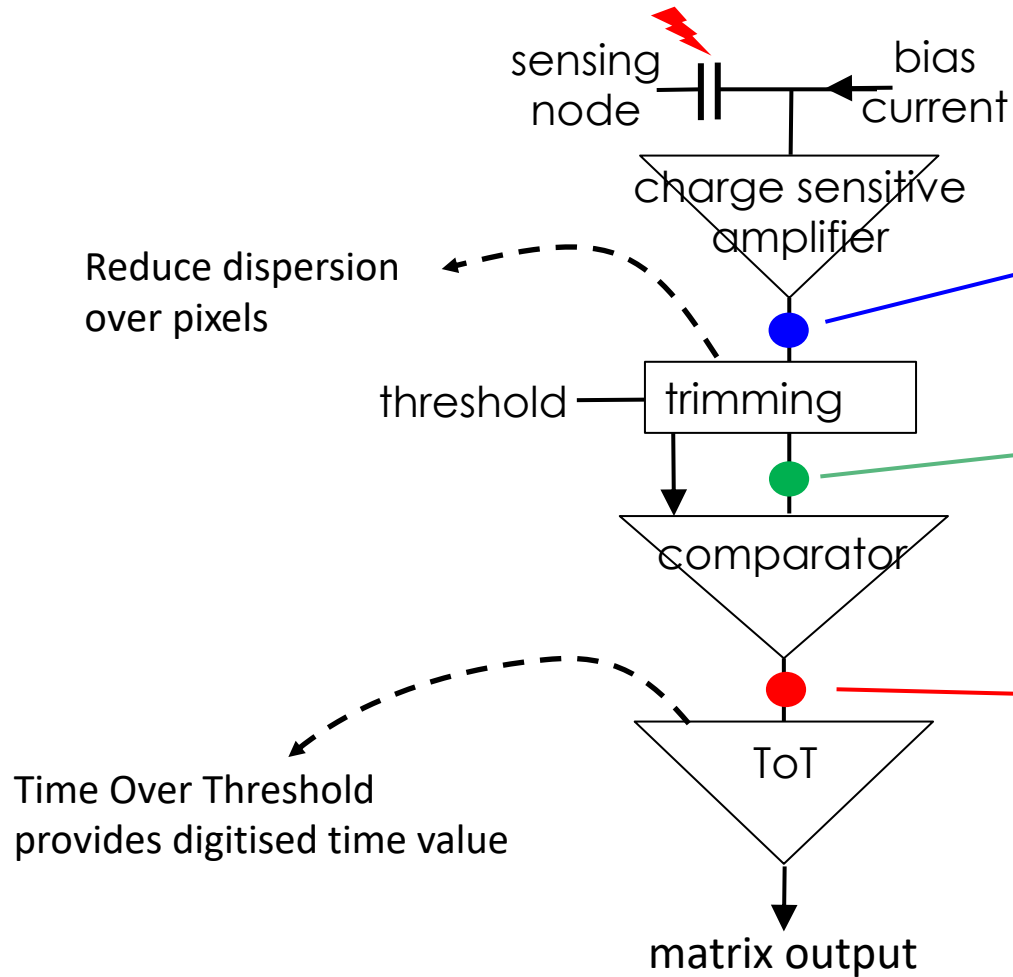
The TIIMM project



Monolithic CMOS pixel sensors (MAPS)

- $\sim 5 \mu\text{m}$ ALICE – ITS2
 - with 1-10 MIPs
- $5-10 \mu\text{m}$ FIRST, hadrontherapy
 - Ions 150-300 MeV/u
- $0.3 \text{ to } 0.8 \% X_0$
 - ALICE – ITS2 over 10 m^2
- $\sim 0.2 \% X_0$
 - FOOT prototype over 30 cm^2
- Available for MIP level
 - σ_E not investigated
- Initial work for $\gg \text{MIPs}$
 - Indirect estimation of ΔE

Pixel concept



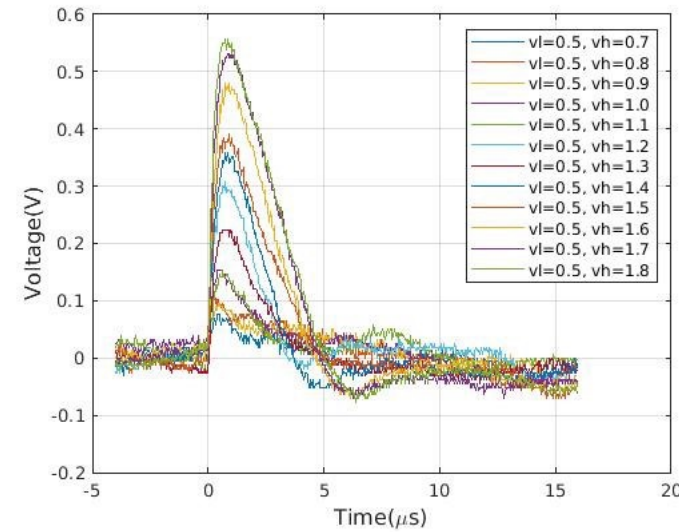
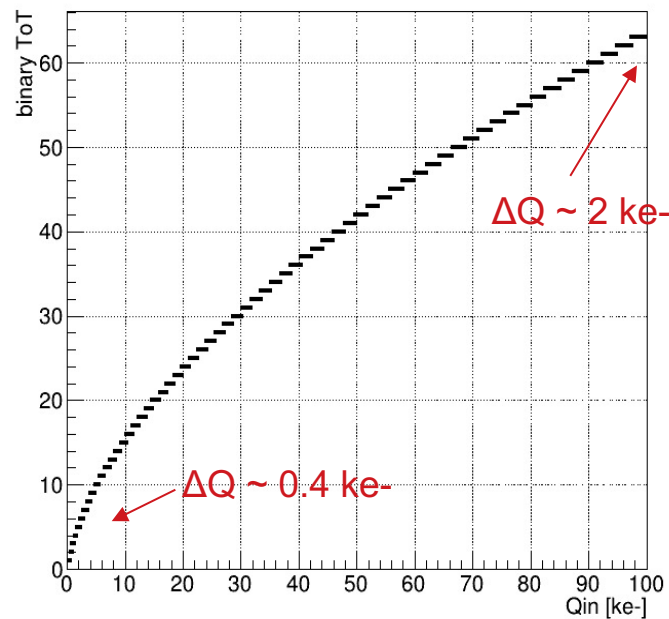
Initial work

■ First prototype: TIIMM-0

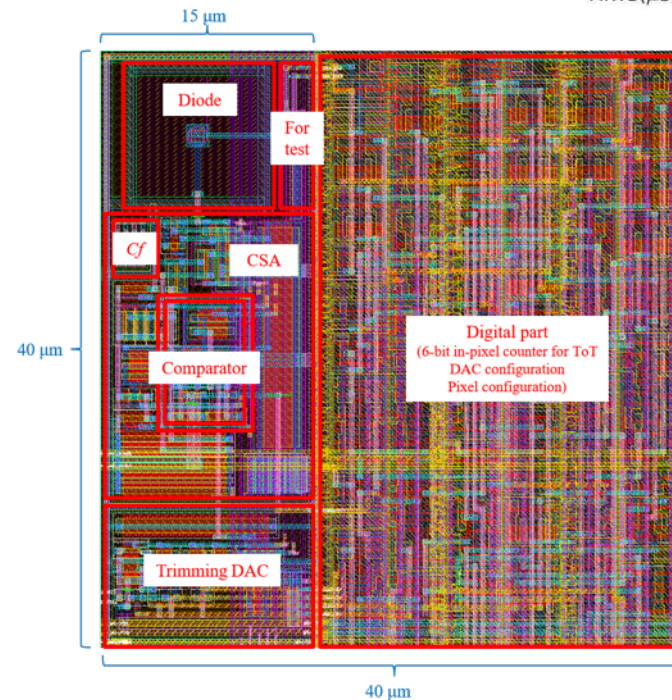
- Design by M.Kachel & W.Ren (IPHC)
- Fabricated first-half of 2020



First expectation for $ToT=f(Q_{in})$



CSA architecture validated



Pixel pitch 40 μm validated

Initial work

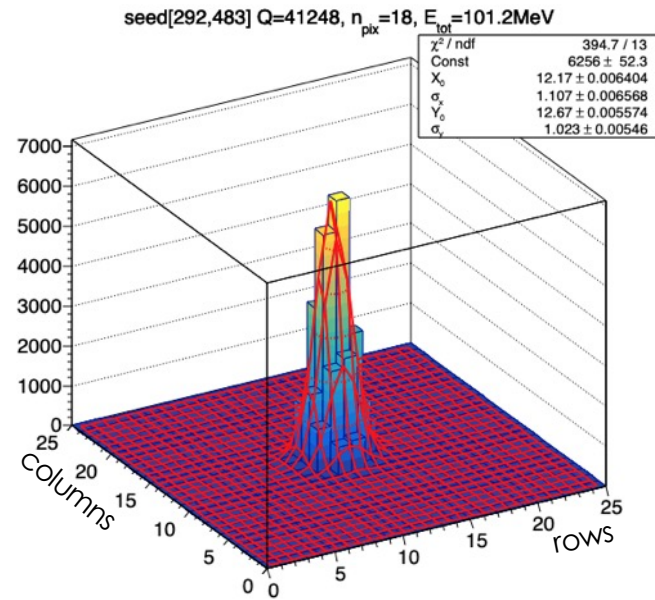
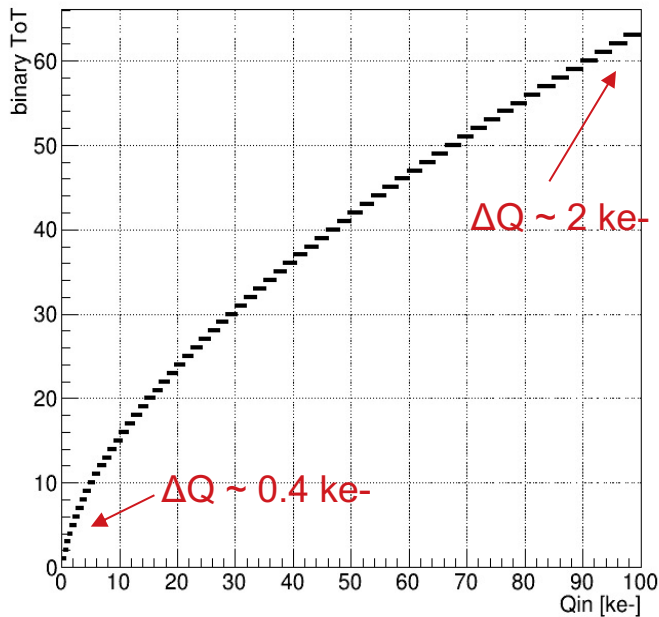
■ First prototype: TIIMM-0

- Design by M.Kachel & W.Ren (IPHC)
- Fabricated first-half of 2020

■ Simulation

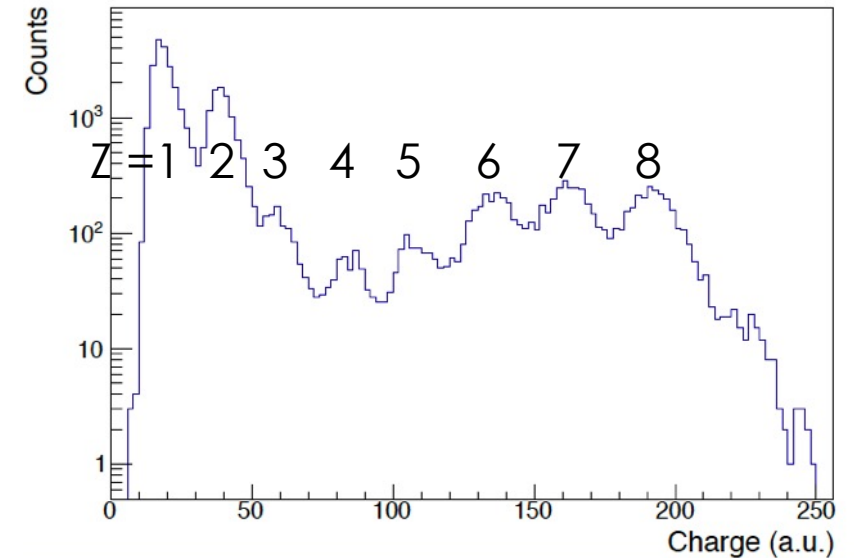
- ^{16}O (200 MeV/u) on ^{12}C observe by a stack of 8 sensors (by C.Finck, IPHC)

First expectation for $\text{ToT} = f(Q_{\text{in}})$



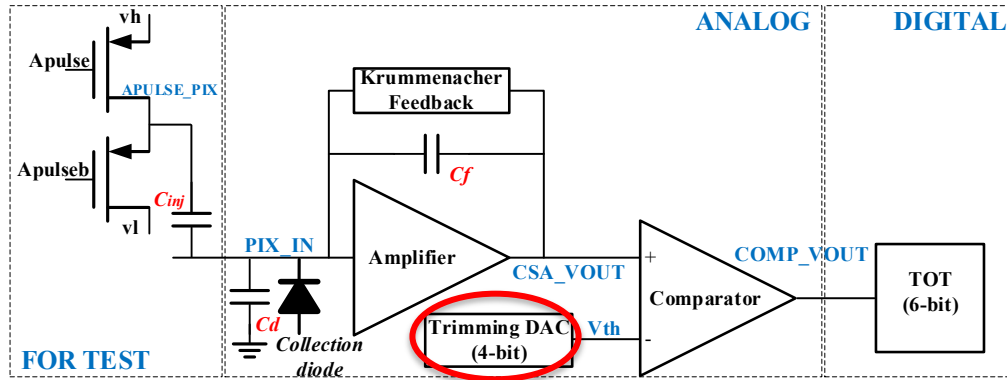
Old sensing layer model
not depleted!

Vertex - mean charge per tracked clusters

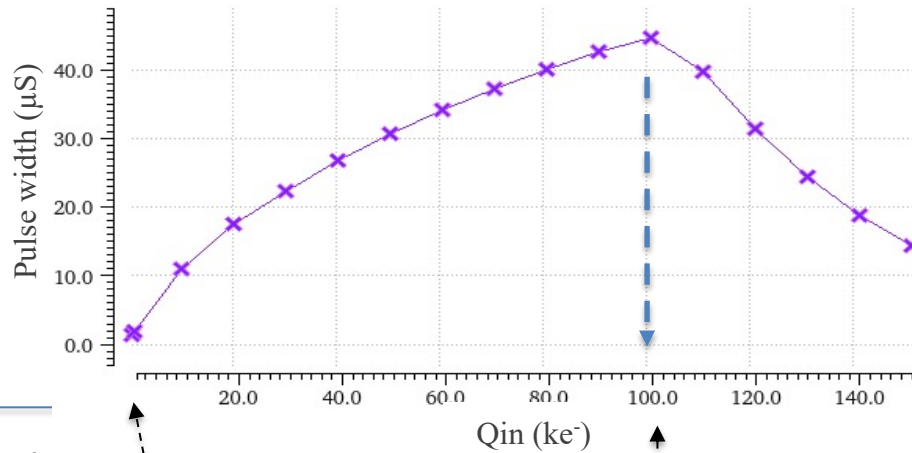


=> Room for improvement

Design of prototype sensors

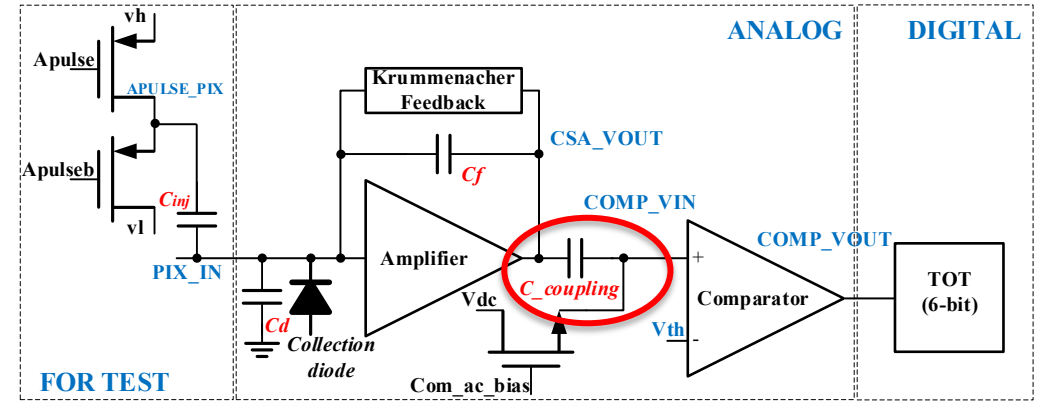


TIIMM-0

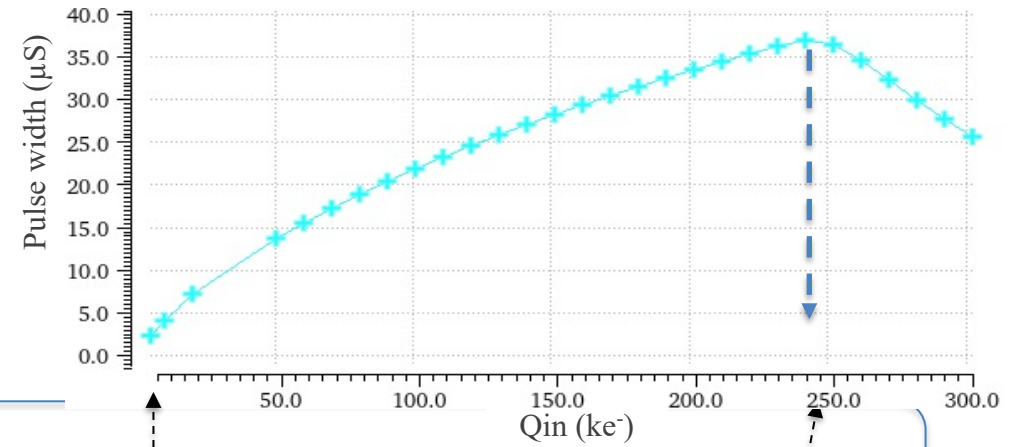


Simulated fluctuation: 21%

20%



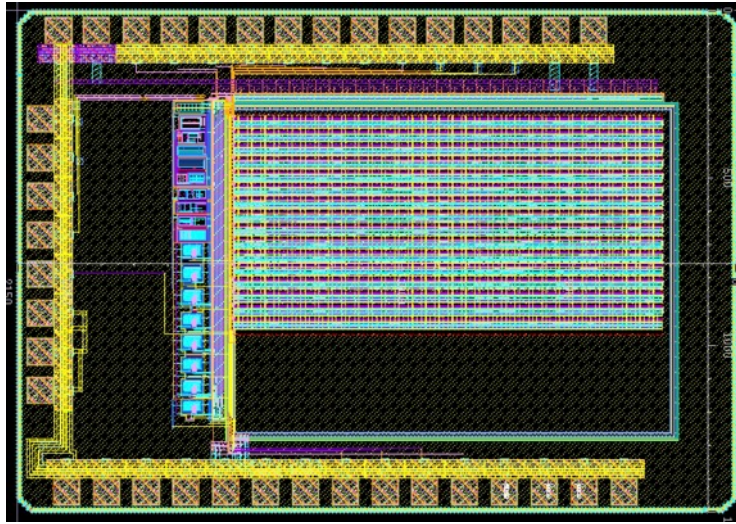
TIIMM-1



6%

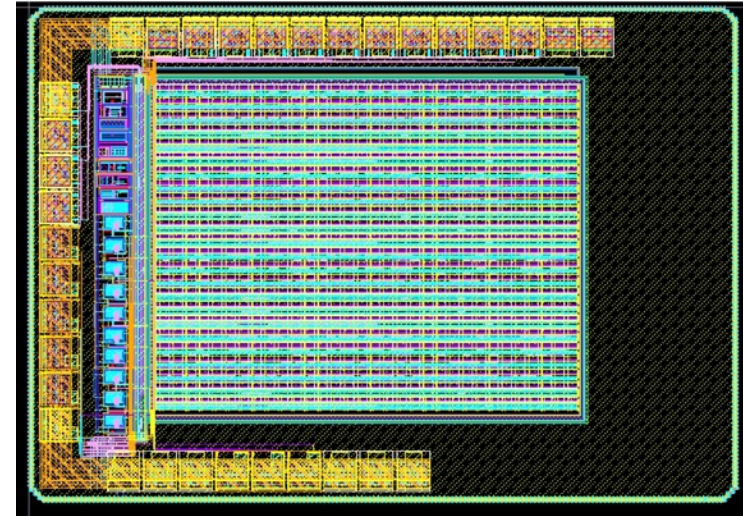
9%

Design of prototype sensors



TIIMM-0(bis)

Pitch 40x40 (41) μm^2
 Matrix 32x16 pixels
 Area 2.2x1.5 mm^2

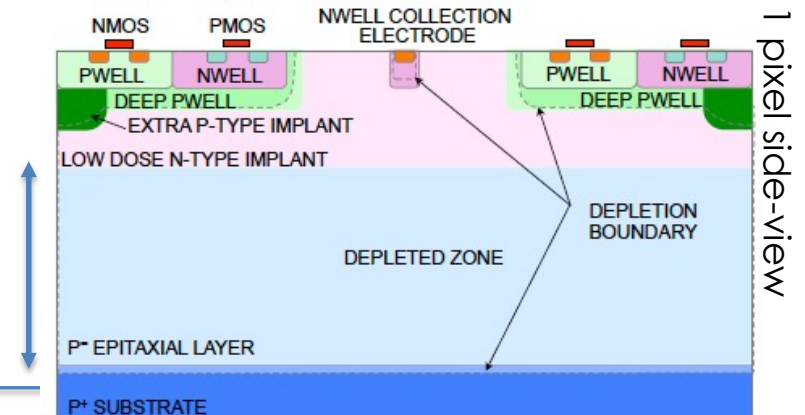


TIIMM-1

- Design by:
 M.Kachek, W.Ren, R.Sefri from @IPHC
 L.Federici, E.Spiriti (LNF) [presented at PSD12 \(2021\)](#)

- Sent to fabrication (Tower 180 nm) in November 2021
- Sensing node allowing full depletion

– Thickness investigated:
 25, 50, 100 μm



■ Within present STRONG-2020 project

- TIIMM prototype series tests in 2022



- Validation of ToT dynamic range
- Impact of full-depletion on cluster-size

- Last proto in 2023 = **optimized front-end & sensitive layer for ion identification**

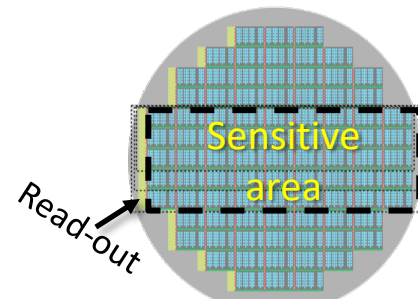
■ The future is smart...

- Data driven read-out architectures improve cont'ly
- Monopix-2 (2021) / OBELIX-1 (2022)
 - 25-100 ns integration time
 - ToT over 7 bits (low dynamic)
 - Triggering capability

J.Dingfelder [talk at VERTEX 2021](#)

... and very large

- ~30x10 cm² sensors developed for ALICE-ITS2



12" silicon wafer

Proposal
[ALICE-PUBLIC-2018-013](#)

Recent news

<https://indico.cern.ch/event/1071914/>



Thank you ...

... additional slides ahead

FOOT inner tracker with MIMOSA-28

■ Scientific case

- better knowledge of fragmentation cross-section(E, θ) for **Carbon ions** onto tissues

⇒ Impact on Treatment Planning System

■ Vertex det. and tracker

- FIRST (2011) → FOOT (2019...)
- Fixed target experiments
- Collaboration with IPHC, INFN/LNF, GSI
- Vertex detector
single MIMOSA-28 sensors stacked
- FOOT inner tracker:

Two-sided plane

4x4 MIMOSA-28

8x8 cm² active area

29 Mpixels

