Particle identification with HIgh spatial resolution and Low Material budget (PHILM*)

Town Meeting, Hadron Physics in Horizon Europe
(Subatech - Nantes)

* follow-up of TIIMM and IMPACT projects

STRONG2020 - TIIMM (i)

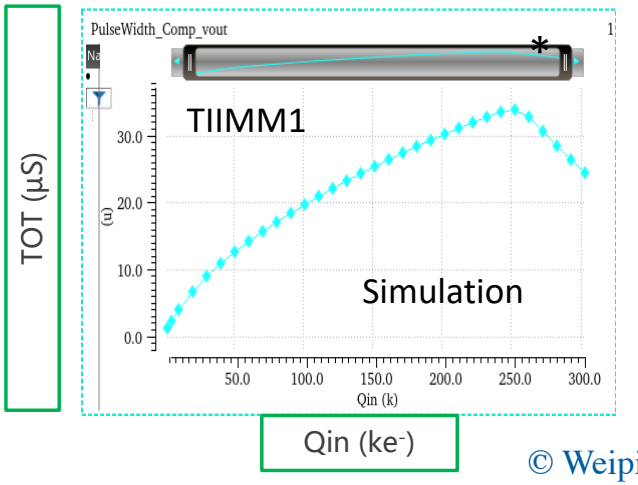
Remind of the workpage goals

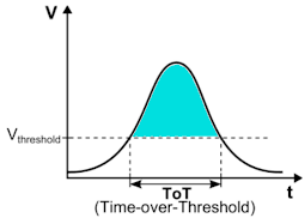
- Rate: < 1 MHz/cm^2
- Area: few cm^2 (2x2 or 1x3 cm^2)
- Power dissipation: < 200 mW/cm^2
- Charge output (ToT) over 6 bits
- Pixel pitch 20 to 40 μm
- Epitaxial layer: 25-50 μm

STRONG2020 - TIIMM (ii)

❑ Dynamic range:

TOT: Time Over Threshold





TIIMM0: range < 110 ke-

TIIMM1: range < 250 ke-

TIIMM1b: range < 700 ke-

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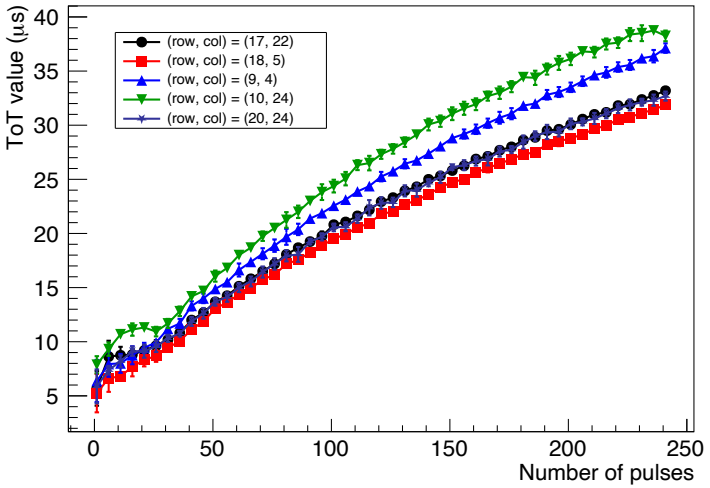
TIIIMM1B: laser test



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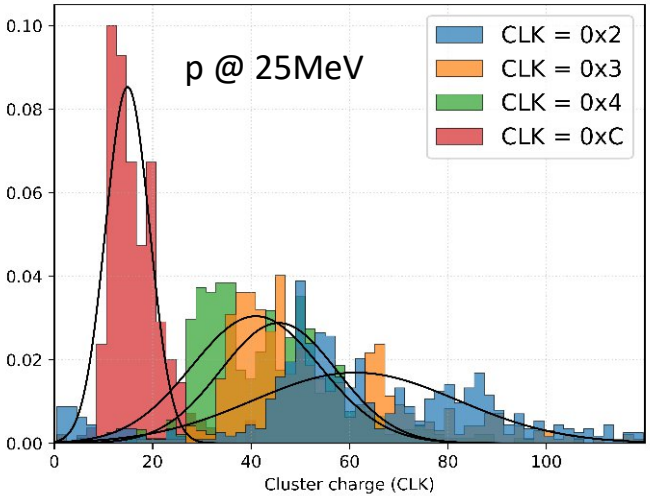

- The pre-scaler adapted to ToT signal dynamics

➡ Useful for high dynamics signals

➡ Assess the analog part

IMPACT project

- Sensor:
  - Front end => TIIMM1B:
    - Linearity up to ~800 ke-
  - TOT measurement:
    - 12bit
  - Matrix:
    - Pixels: 128x64
    - Pitch: 50 µm
    - Active area: 6.4 x 3.2 mm^2

➡ Assess the digital part

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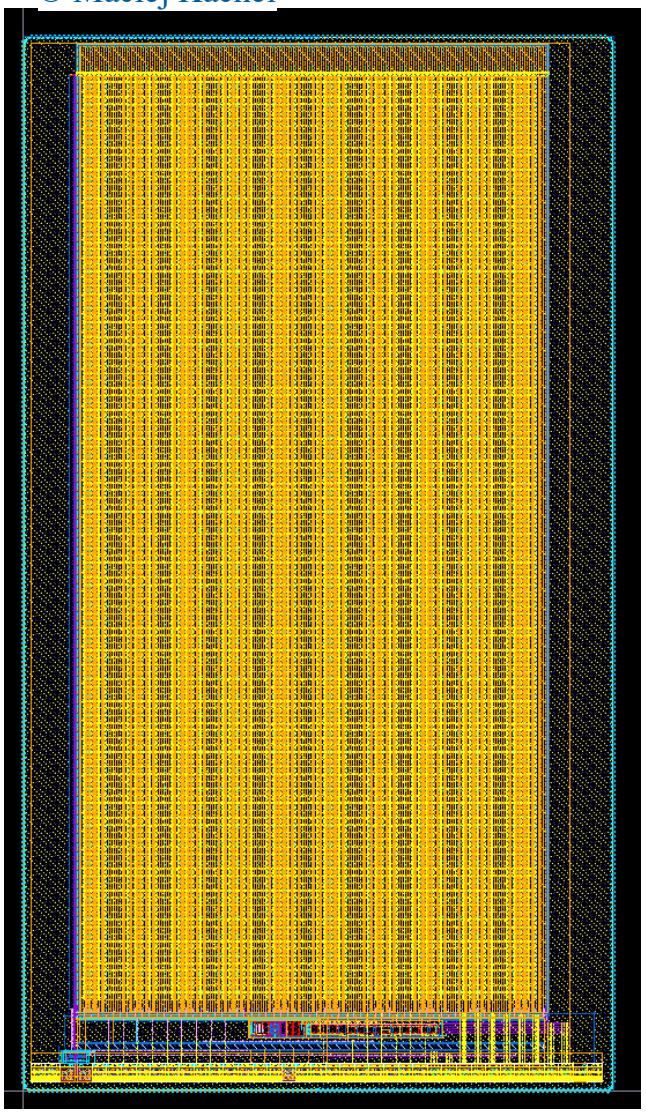


STRONG2025 - PHILM (i)

- New requirements:
  - Rate: < 1 MHz/cm^2
  - Area: few cm^2 (~4-6 cm^2)
  - Power dissipation: < 200 mW/cm^2
  - Spatial resolution: 5 to 10 μm
  - Epitaxial layer: 25 μm
  - Range: 500 to **800ke**- for MIP to ions (100-400 MeV/u)
  - Time stamp ~ **1** ns
  - Charge output (ToT) over ≲ **12** bits
  - Pixel pitch ≲ **50** μm

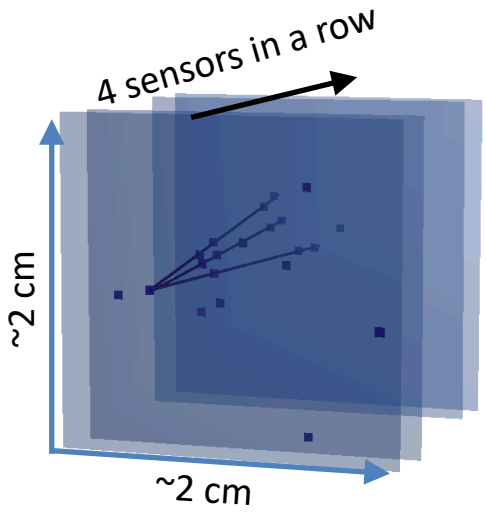
TIIMM

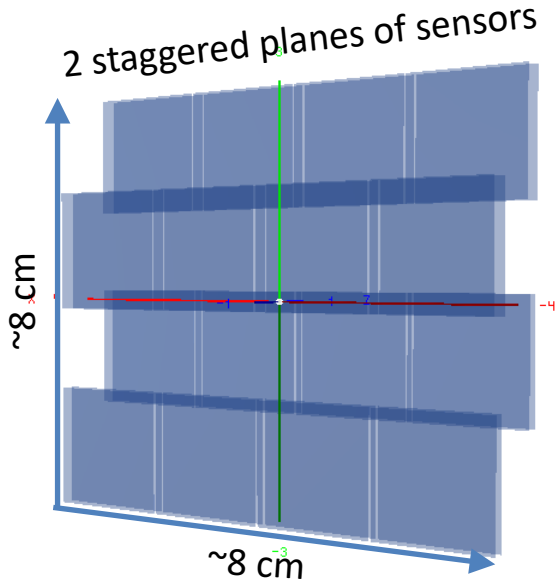
IMPACT

STRONG2025 - PHILM (ii)

❑ Proposal:

- Build a multi-plane system in order to assess simultaneously tracking & identification.





- Developments for dedicated DAQ and control system
- Test under beam condition for prototype: FAIR/GSI (CNAO/Pavia, Cyrcé/Strasbourg)

STRONG2025 - PHILM (iii)

- Time line (48 months)
  - M1-M10: test of IMPACT sensor
  - M1-M18: multi-plane DAQ development, advanced tests with IMPACT
  - M6-M24: design of PHILM (~cm2) sensor
  - M24-M36: test of PHILM sensor
  - M30-M48: assembly of multi-plane system with PHILM, beam tests for final demonstration

STRONG2025 - PHILM (iv)

❑ Estimated budget request:

• **Multi-project run at Tower Jazz for PHILM prototypes**		**100 k€**
• **Development of data acquisition system**		**100 k€**
• Development of mechanical system		20 k€
• **1 PhDs contracts (3 years)**		**120 k€**
• Travel money for tests		30 k€
• Travel money for meetings		10 k€
	Total request	380 k€

❑ Participating and partner institutions :

- J. Baudot, L. Federici, Ch. Finck, M. Kachel, R. Sefri, IPHC - Strasbourg (France)
- E. Spiriti, INFN - Frascati (Italy)
- M. Toppi, M. Marafini, INFN - Roma (Italy)
- Ch. Schuy, GSI - Darmstadt (Germany)
- Possibility for industrial partner: Weeroc (France), under discussion

Backup

STRONG2020 - TIIMM (i)

❑ Budget:

• Run at Tower Jazz for large area sensor		150 k€
• Multiproject run at Tower Jazz for prototype		50 k€
• Development of data acquisition system		60 k€
• Development of mechanical system		20 k€
• 1 PhDs contracts (2 years)		80 k€
• Travel money for tests		30 k€
• Travel money for meetings		10 k€
	Total request:	400 k€
• overhead		100 k€
	Total:	500 k€

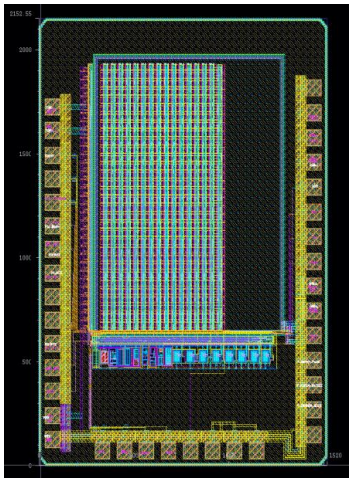
❑ Participants:

- L. Federici, J. Baudot, Ch. Finck, C. Hu-Guo, M. Kachel, W. Ren, R. Sefri and E. Spiriti

STRONG2020 - TIIMM (ii)

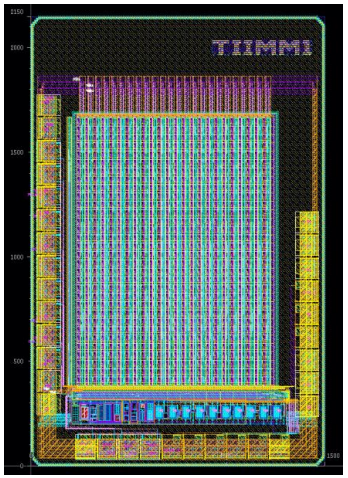
❑ Sensor's prototype overview:

- First submission: preliminary prototype (TIIMM0) submitted in March 2020
- Second submission: TIIMM0/TIIMM1/TIIMM1A/TIIMM1B prototypes received in August 2022



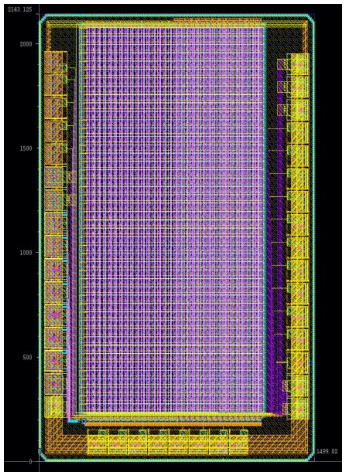
TIIMM0 (second submission)
Chip area: 2.2 mm * 1.5 mm
Matrix: 32 (rows) * 16 (col)
Pixel pitch: 40 µm×40 µm

Corrected from the first submission



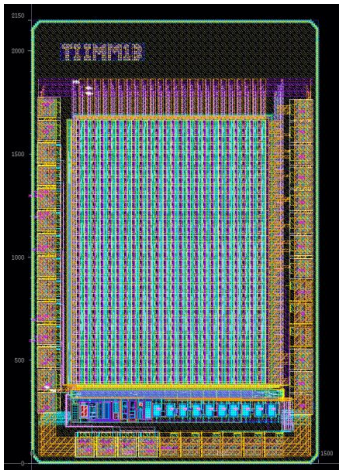
TIIMM1 sensor
Chip area: 2.2 mm * 1.5 mm
Matrix: 32 (rows) * 24 (col)
Pixel pitch: 41.2 µm×40 µm

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

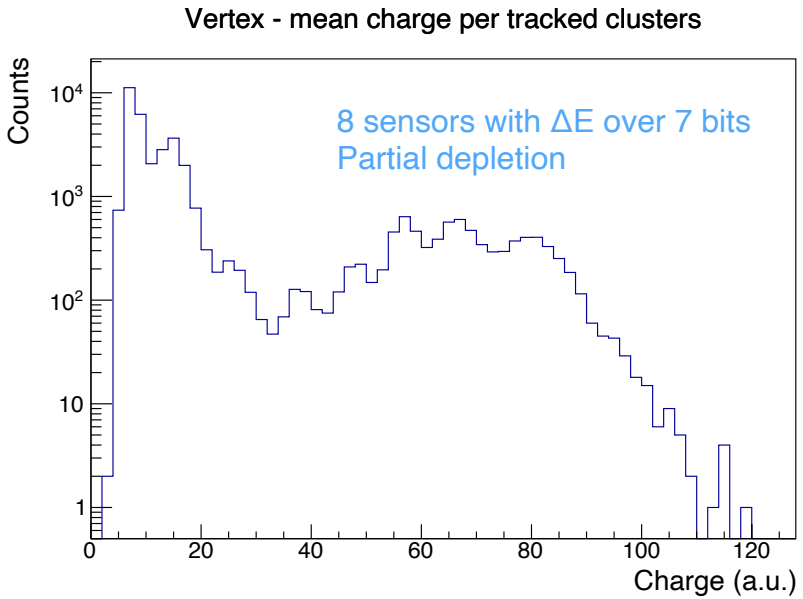
New front-end enhanced

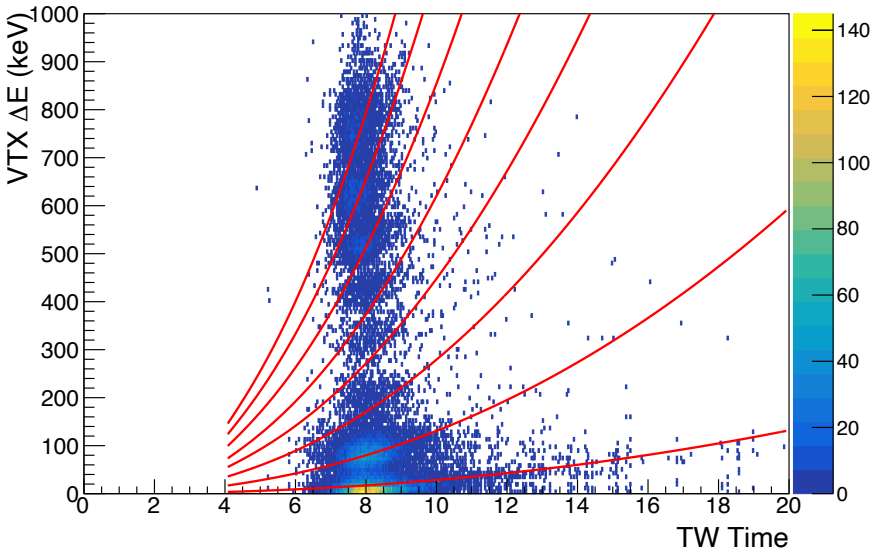
7 sensing layer variants

Thickness	Process	
25 µm Epi High Res.	Standar	1. Non-uniform N- layer 2. Uniform N- layer + Extra Deep
50 µm Epi High Res.	1. Non-uniform N- layer 2. Uniform N- layer + Extra Deep P	
100 µm Epi High Res.	1. Non-uniform N- layer 2. Uniform N- layer + Extra Deep P	

STRONG2020 - TIIMM (iii)

- Particle identification:
  - Produced in ^{18}O + ^{12}C @ 200 MeV/u
  - 4-8 sensors coupled with a TW
  - Simulation based on TIIMM0 response



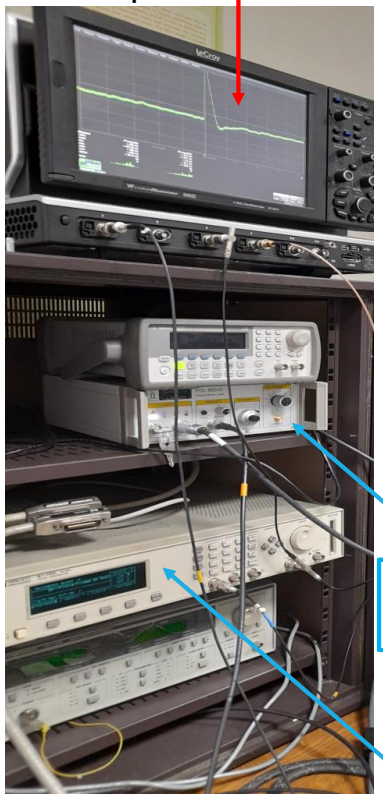


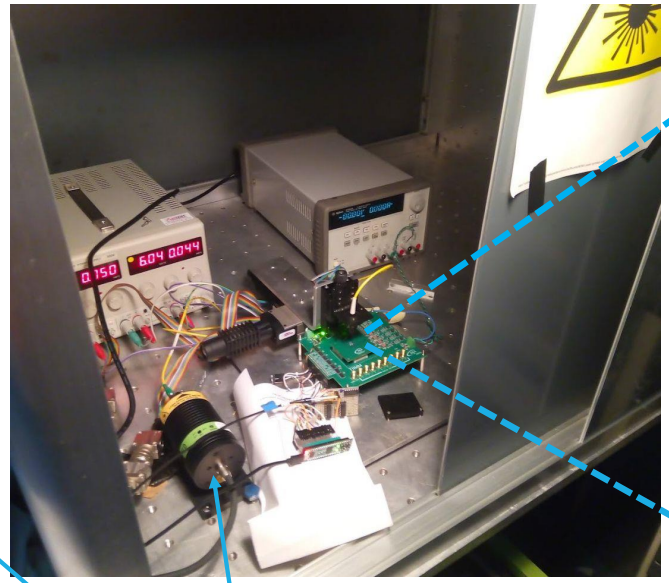
➡ 7 bits is the lower limits in that case to disentangle the different Z

STRONG2020 - TIIMM (iv)

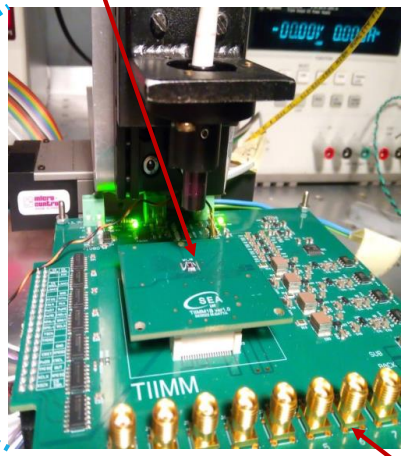
TIIIMM1B: laser test (i)

Single pixel CSA output signal with 2 laser pulses





TIIMM1B sensor



- We can move the laser spot in x/y direction with 1µm step precision
- We are able to inject charge in a single pixel
- Positioning and number of laser pulses are remotely controlled

Pulsed Diode LASER
(Model LDH-P-C-N-1060)

- Selectable repetition frequencies: 3.25 KHz to 80 MHz
- Wavelength *(average): 1061 nm*
- Peak power *(intensity): from 18 mW to 400 mW*
- *FWHM (time-width): 88 ps to 500 ps*

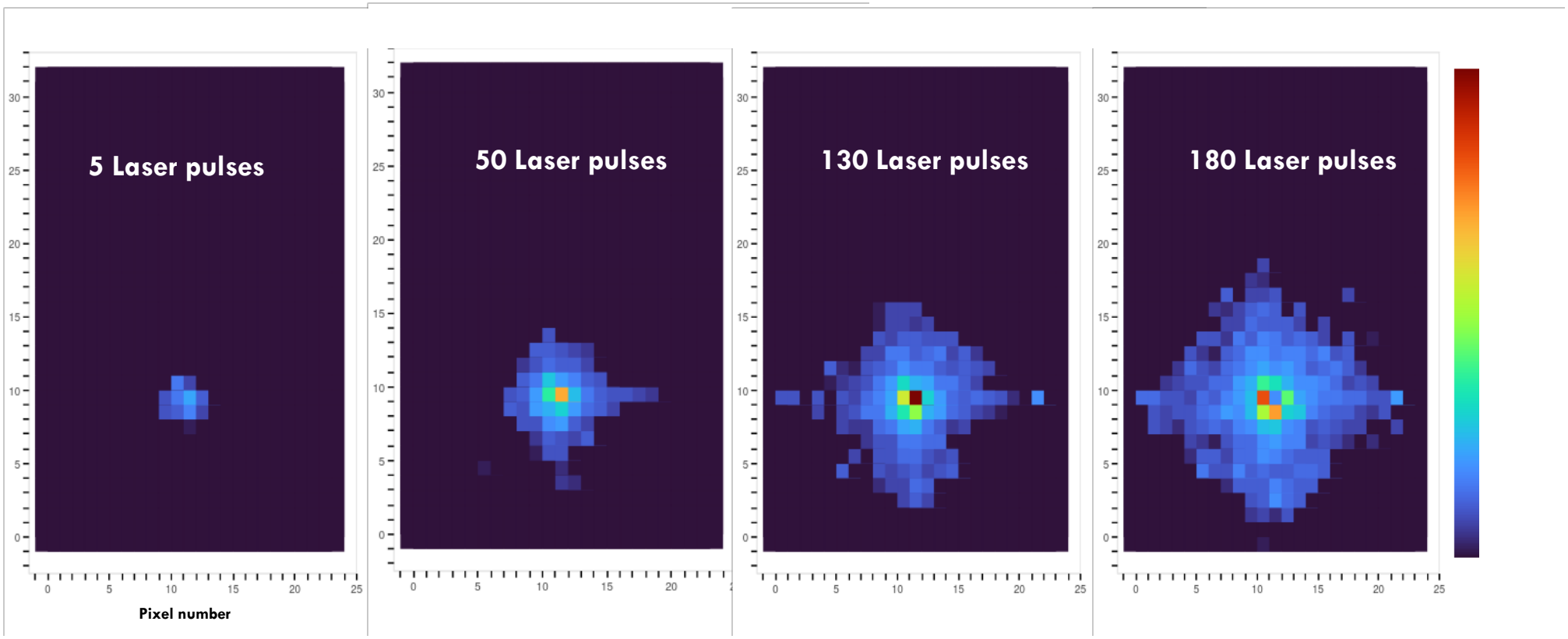
Pulse generator
(Model HP 811A)

- Width: 5 ns ; Period: 10 ns
- Amp: 2 V
- Leading-edge: 2ns ; Trailing-edge: 2ns

8 analog outputs to perform different measurements with the oscilloscope

STRONG2020 - TIIMM (v)

- TIIIMM1B: laser test (ii)



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- TIIIMM1B: laser test (iii)

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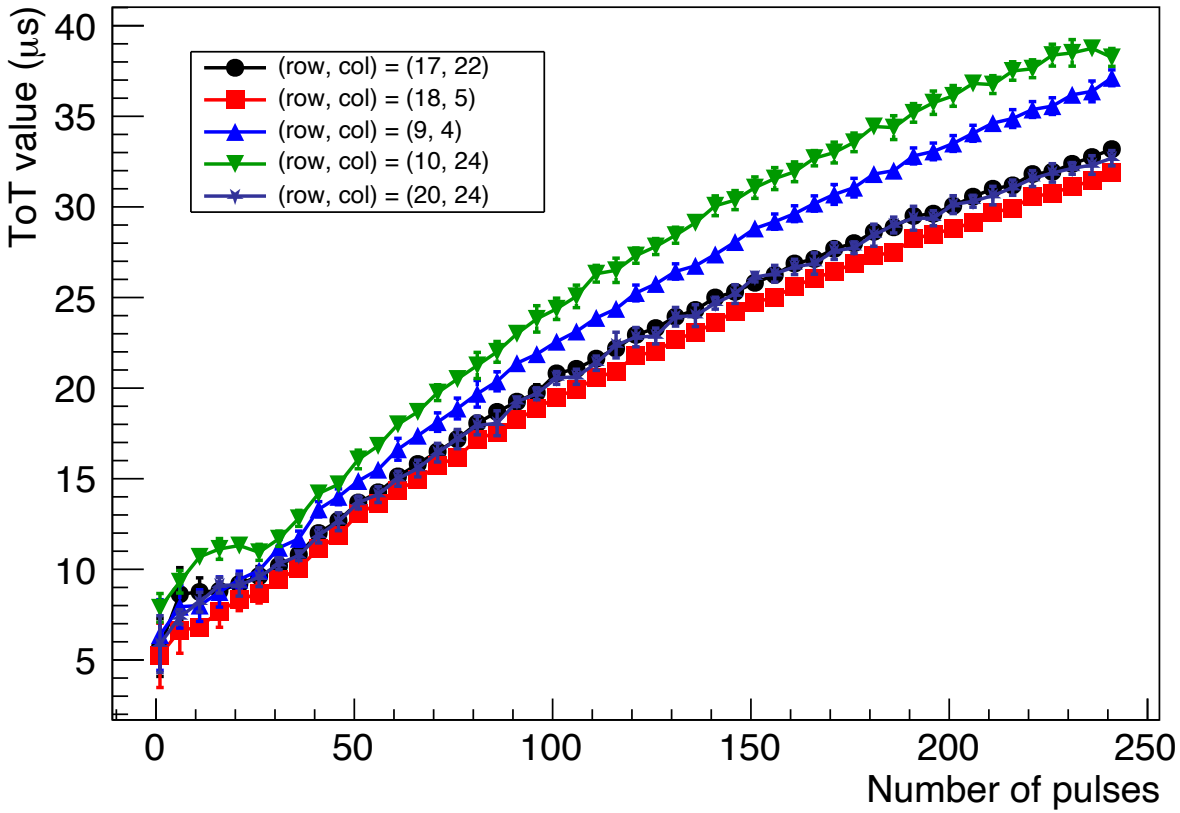
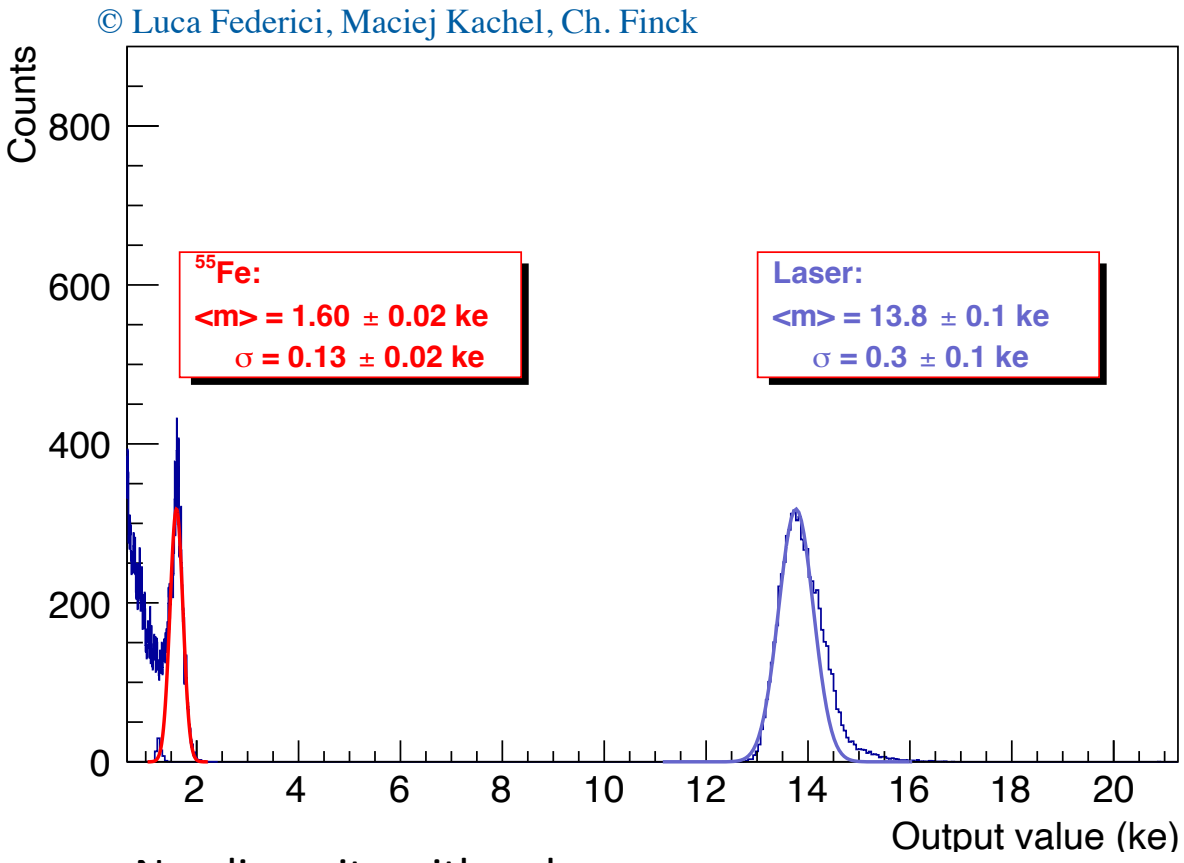


➡ Pb conversion pulser number to input charge

STRONG2020 - TIIMM (vii)

- TIIIMM1B: source



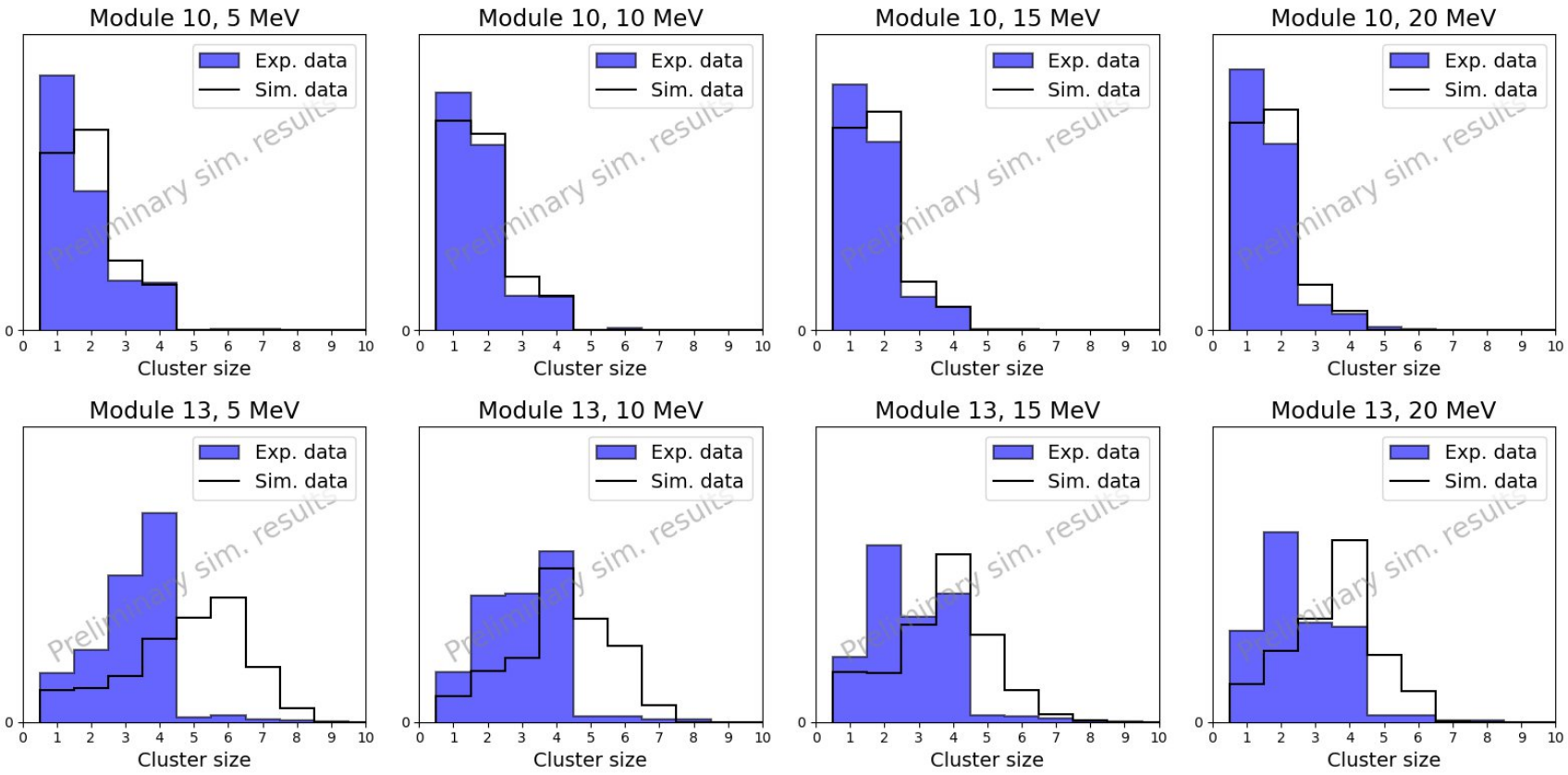
- Non linearity with pulse
- Far from the requested range ~ 500ke-

STRONG2020 - TIIMM (viii)

❑ TIIIMM1B: proton @ 5-20 MeV (i)

- Cluster size:

Module 10 (25 um EPI layer)
Module 13 (50 um EPI layer)

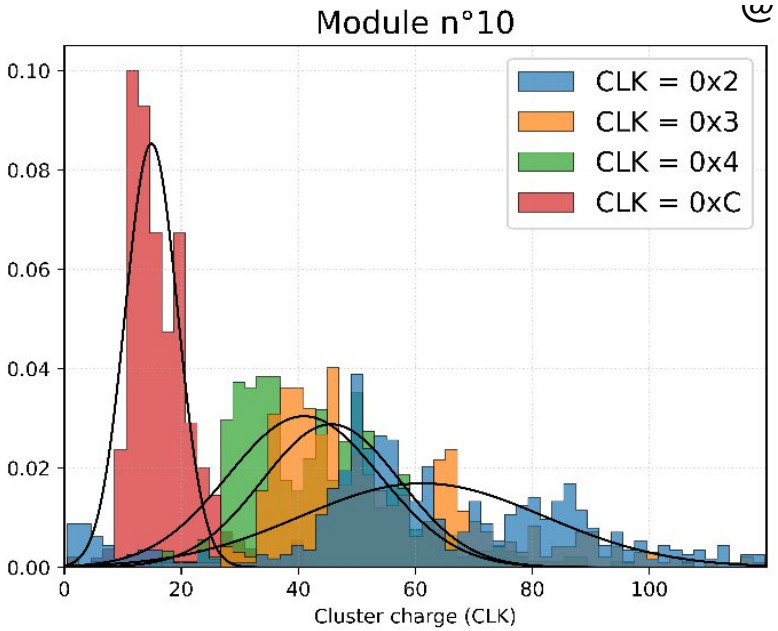


➡ Some modules not compliant with simulations

STRONG2020 - TIIMM (ix)

❑ TIIIMM1B: proton @ 24 MeV (ii)

- Pre-scale clock cycle



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- The prescaler permits to adapt the ToT counter to the signal dynamics
  - ➡ Useful for high dynamics signals

➡ Adapting the pre-scaler value to the impinging signal dynamics !