The PICMIC concept

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on behalf of the PICMIC group

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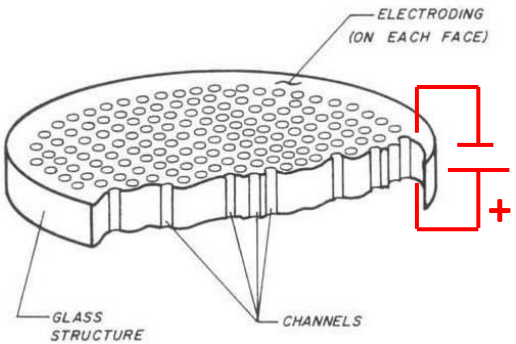
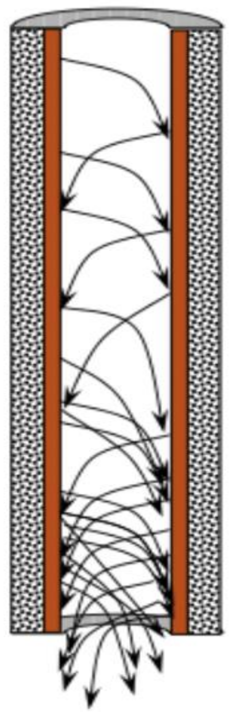
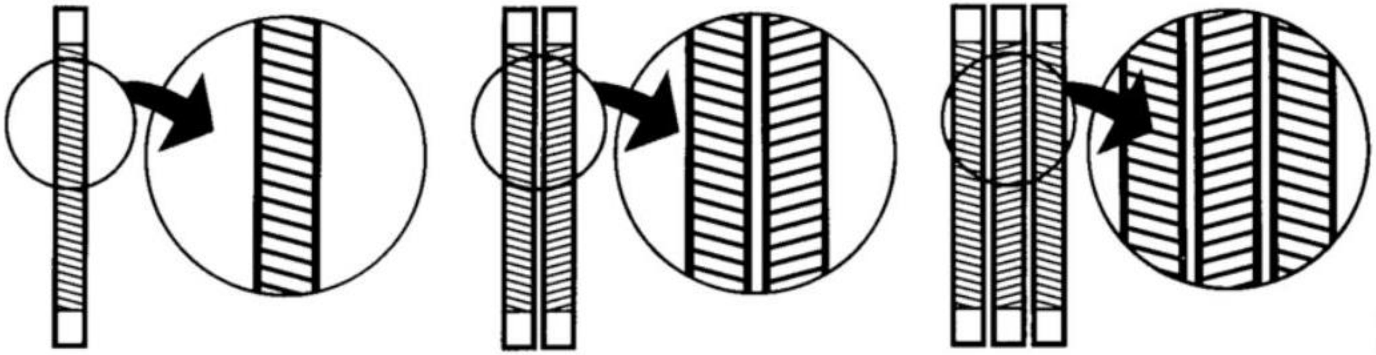
Micro Channel Plate (MCP)





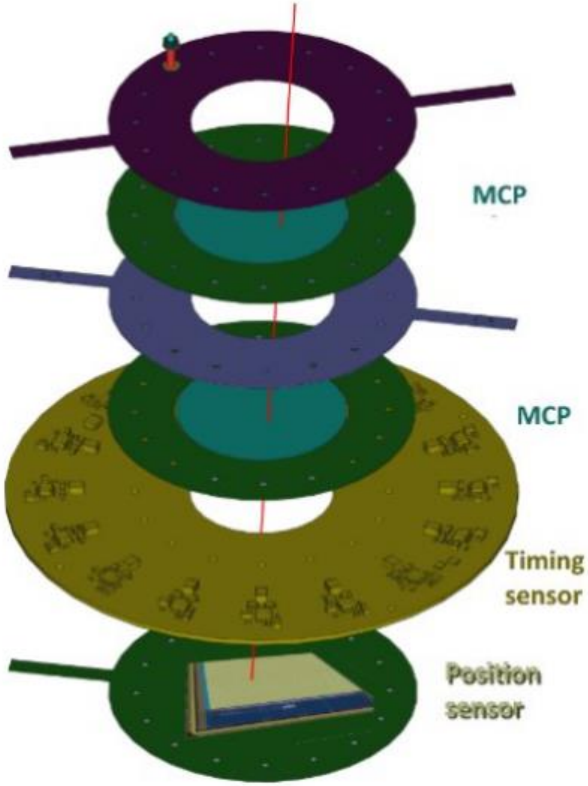
- electron multiplier with a an excellent time resolution (~10ps)
- excellent spatial resolution (~10um)
- it can be stacked into 2-stack (chevron shape) or 3-stack (z-shape) to improve the gain
- Typical gain :
  - 1 MCP : ~10^4
  - 2 MCP : ~10^7
  - 3 MCP : ~10^8



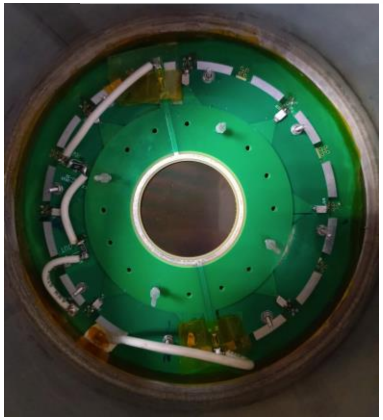
The PICMIC concept

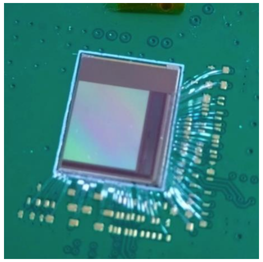
- The goal of the PICMIC detector is to fully exploit the excellent time and position resolution of the MCP

- It is composed of two independent detectors working together :
  - a time detector (delay plane concept)
  - a position detector (interconnected micrometric pixels)



The acquisition is done using a customised SAMPIC module



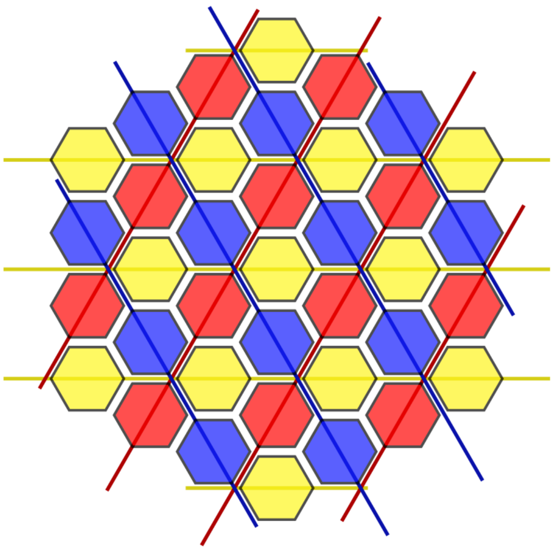


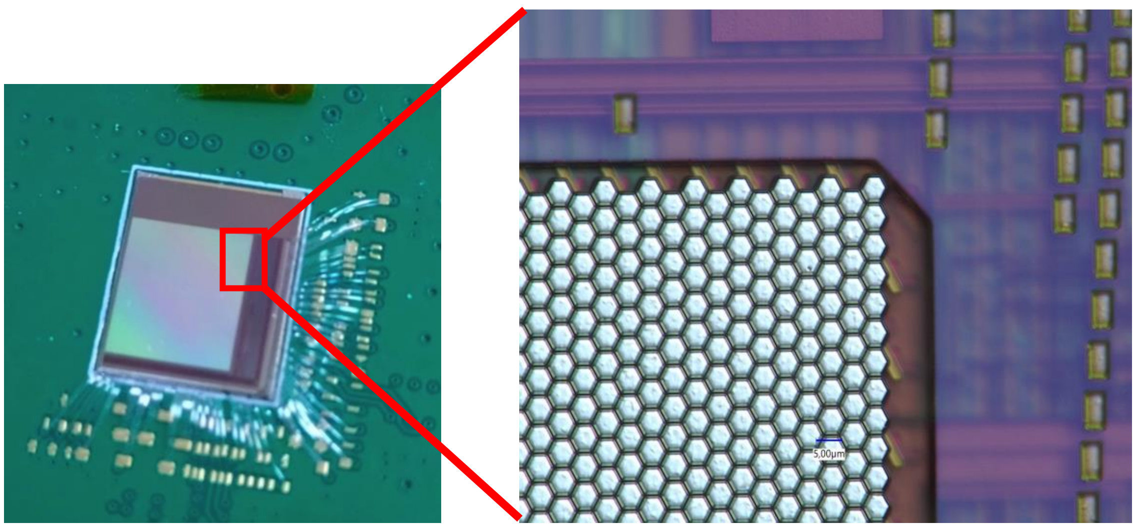
Spatial detector – PICMIC-0 chip

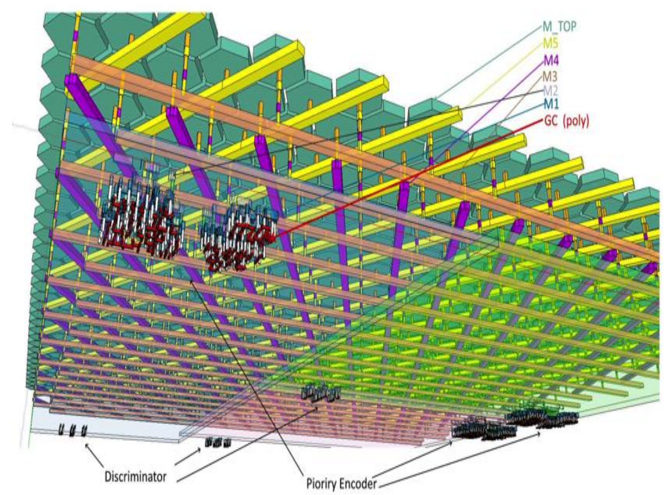
- Grid of 5 µm hexagonal pixels interconnected into lines in 3 directions :
  - 0°, -60°, 60°
- Line pitch : 7.5 µm

- Active area : 7.4x6.4 mm²

- Great reduction of the required number of channels : O(N²) => O(3N)
  - ~2M channels => 2556 channels (3x852)



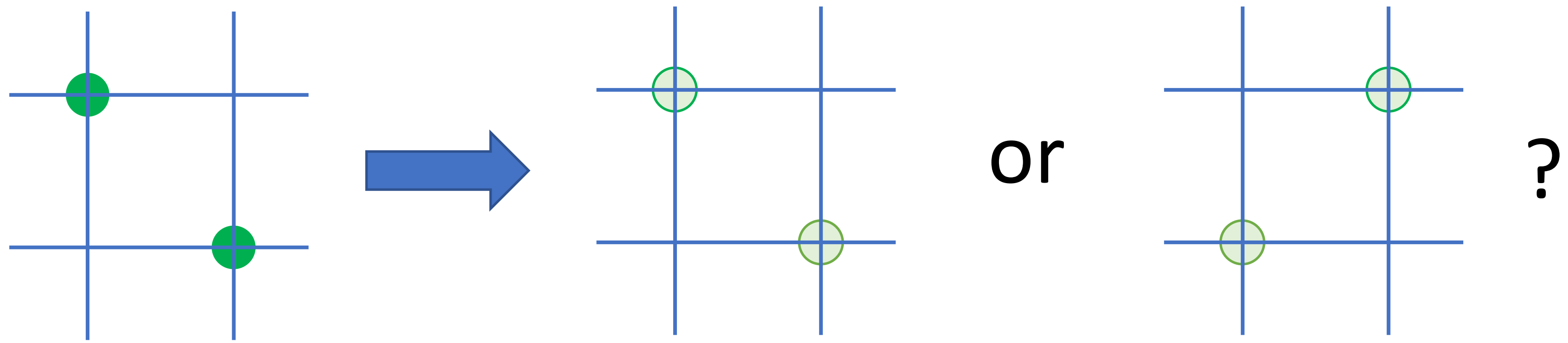




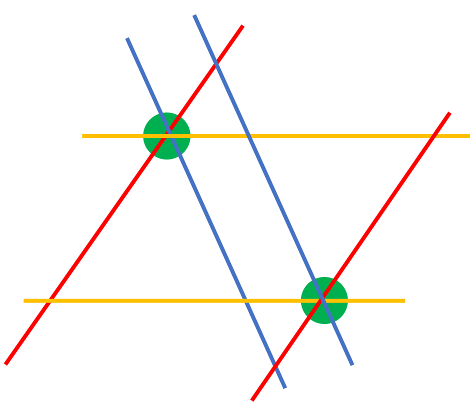
Spatial detector – PICMIC-0 chip

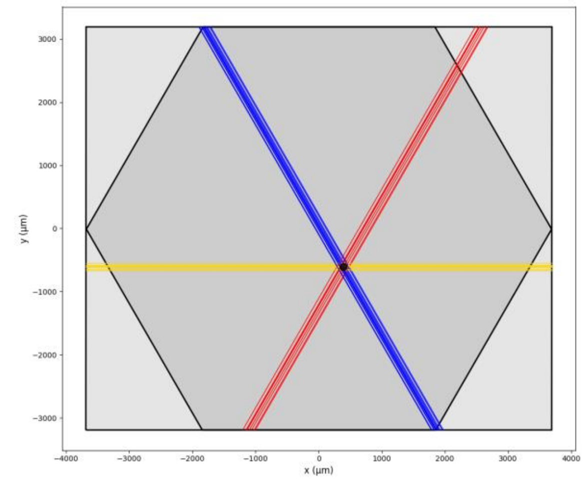
- why 3 directions ?
  - to remove ambiguities in case of simulaneous particles

2 directions case :



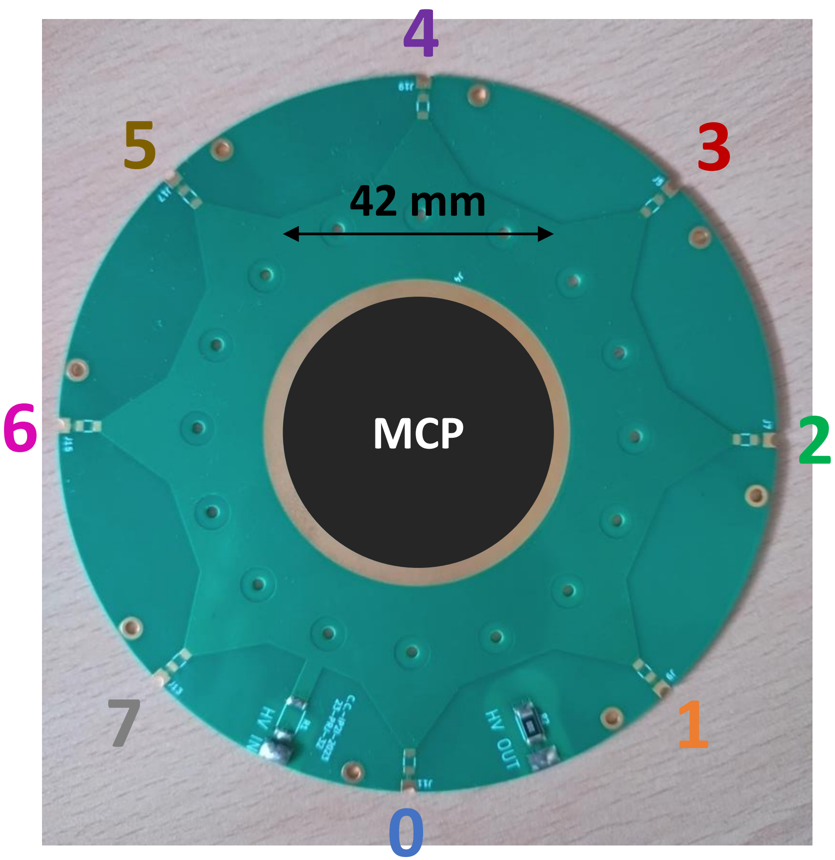
3 directions => no ambiguities

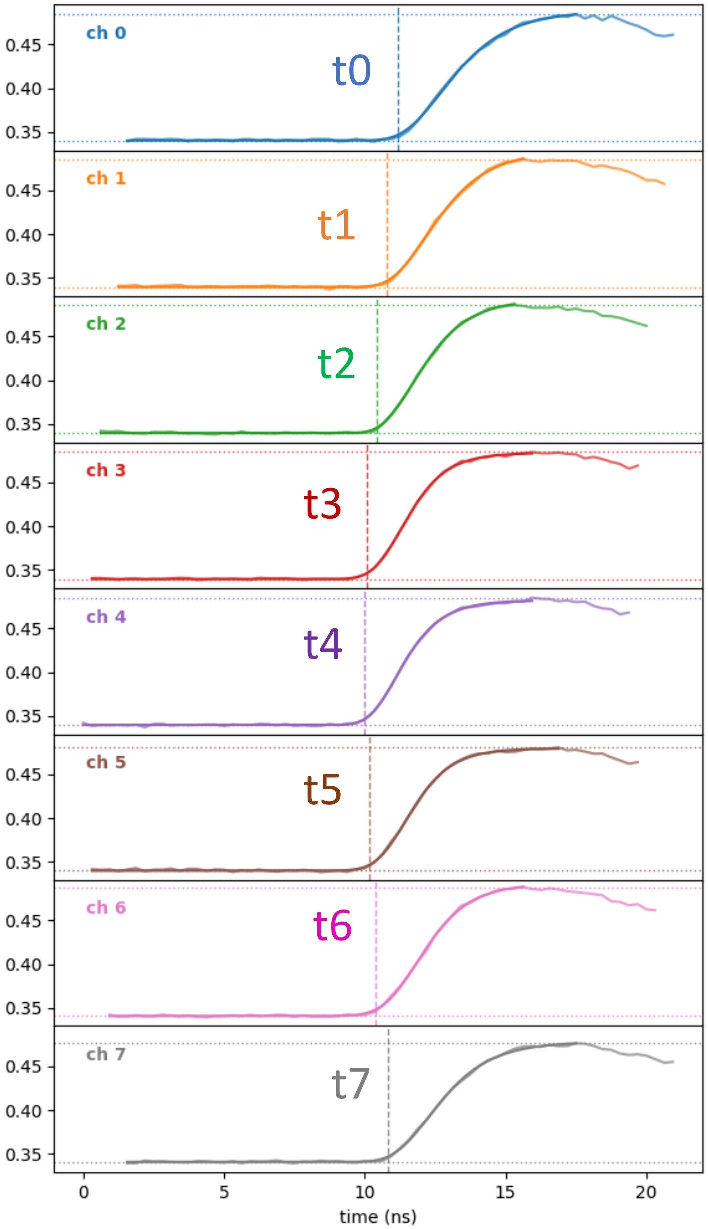




Timing detector – delay plane

- The SAMPIC TDC provides 64 samples per hit (3.2 GHz sampling rate)
  - makes possible to fit the curve to reduce the signal fluctuations and also to apply CFD techniques to get rid of the timewalk effect

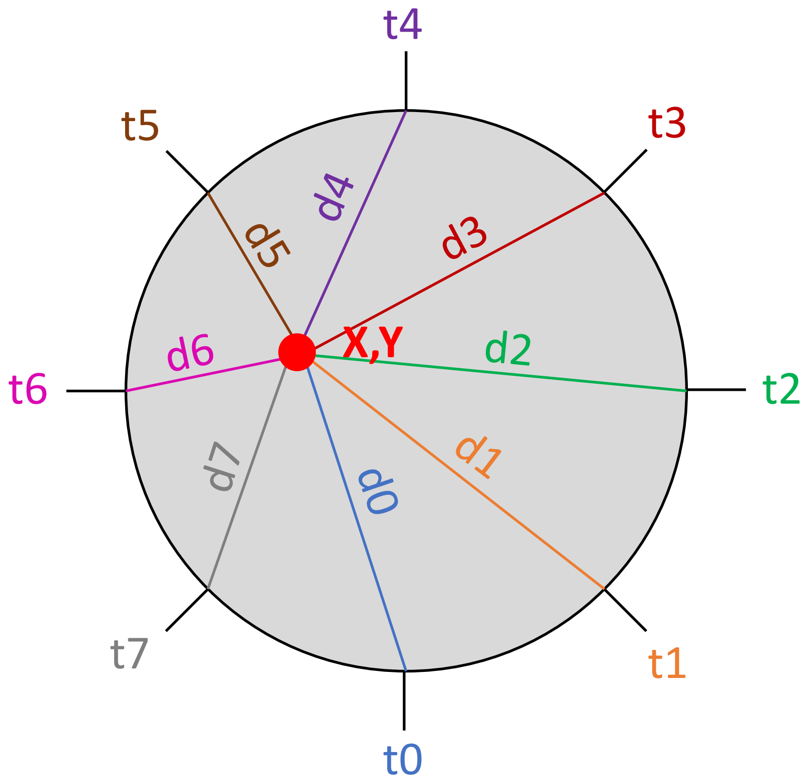




Timing detector – delay plane

- Using the X,Y position given by the PICMIC-0 chip, we can substract the propagation times from the measured times

- then average on the 8 channels

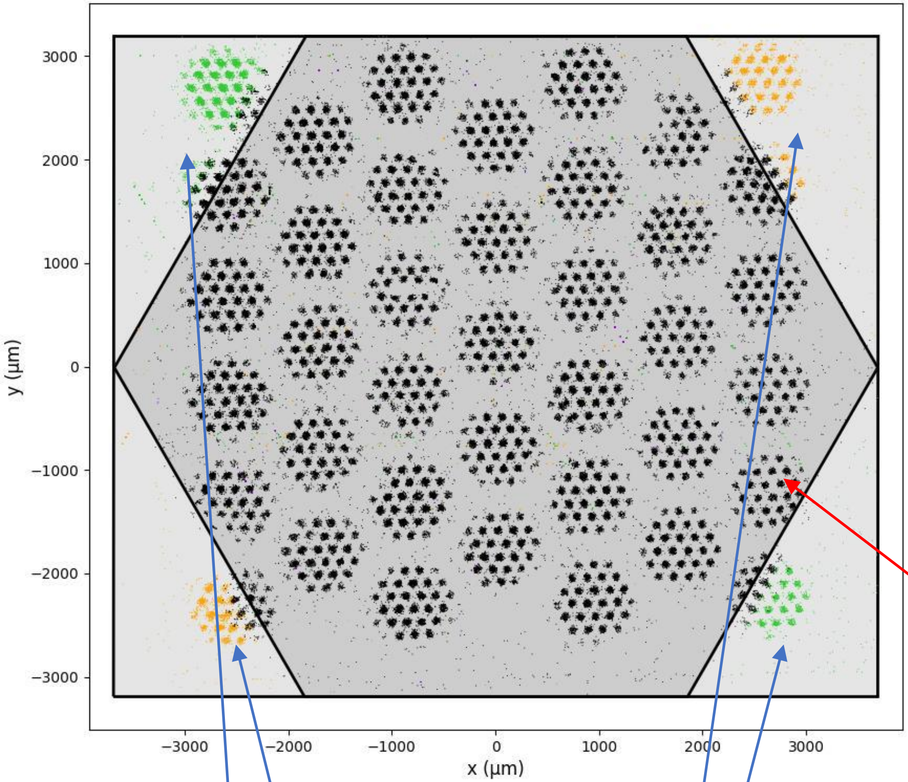


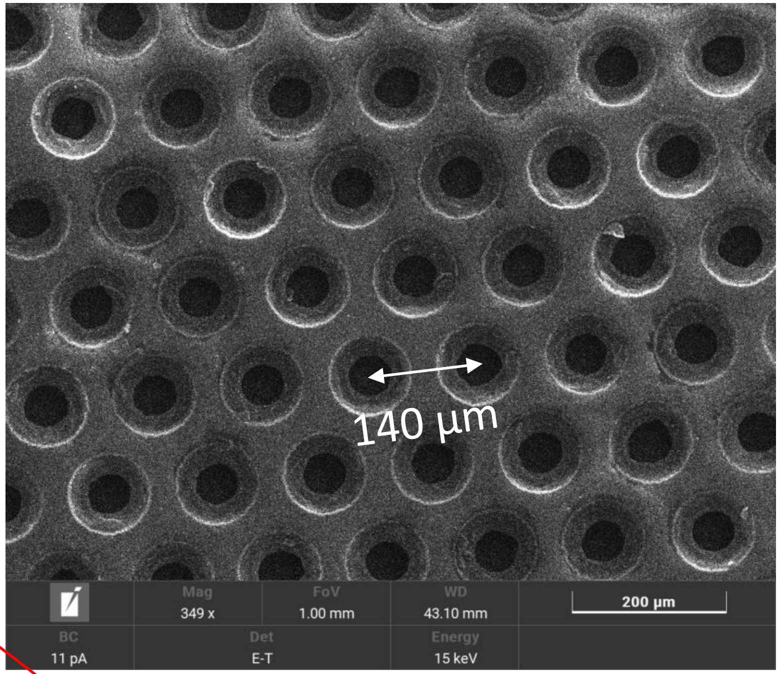
$$T = \frac{1}{8}\sum_{i}(t_i - \frac{d_i}{v})$$

propagation speed

Spatial resolution

- Image of an alpha source through a GEM foil with 50 µm holes with a 140 µm pitch

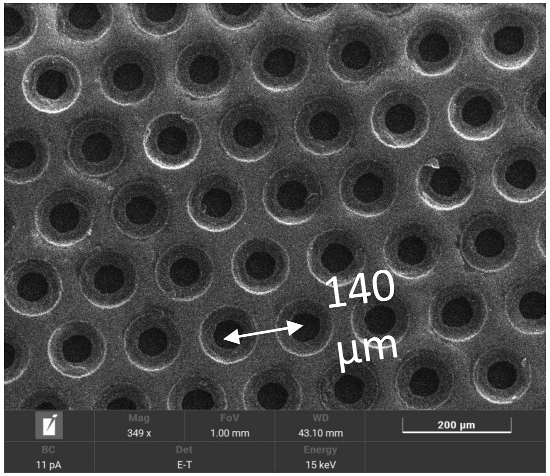




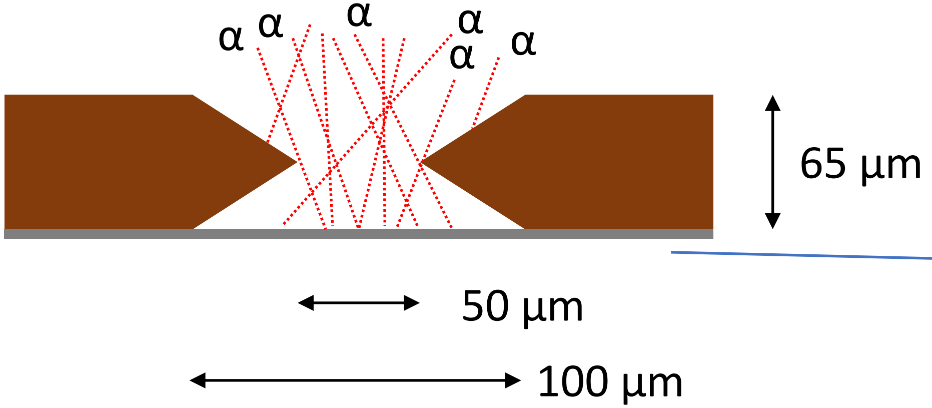
only 2 directions are present in the corners

black dots : 'triple intersections'

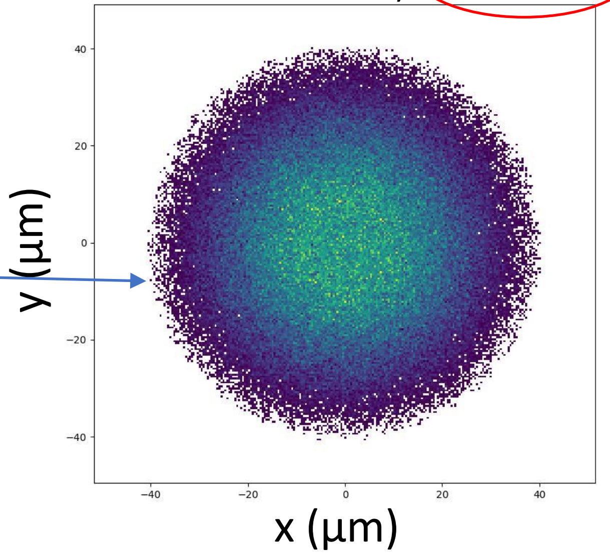
Spatial resolution



- Spatial resolution estimation procedure:
  - 1st step : reproducing a ‘perfect detector’ by simulating the passage of alpha particles through a single GEM hole and registering the X,Y positions

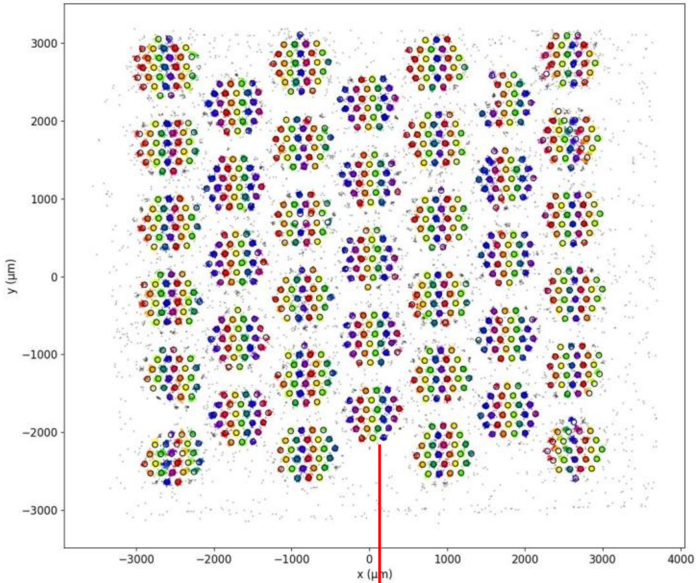


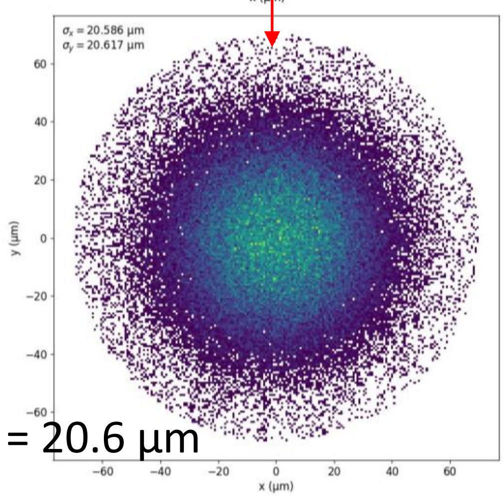
$\sigma_x = \sigma_y = 14.8$ µm



Spatial resolution

- 2nd step : overlap the data with a 140 µm hexagonal grid and regroup all the clusters into a single one





$\sigma_x = \sigma_y = 20.6$ µm

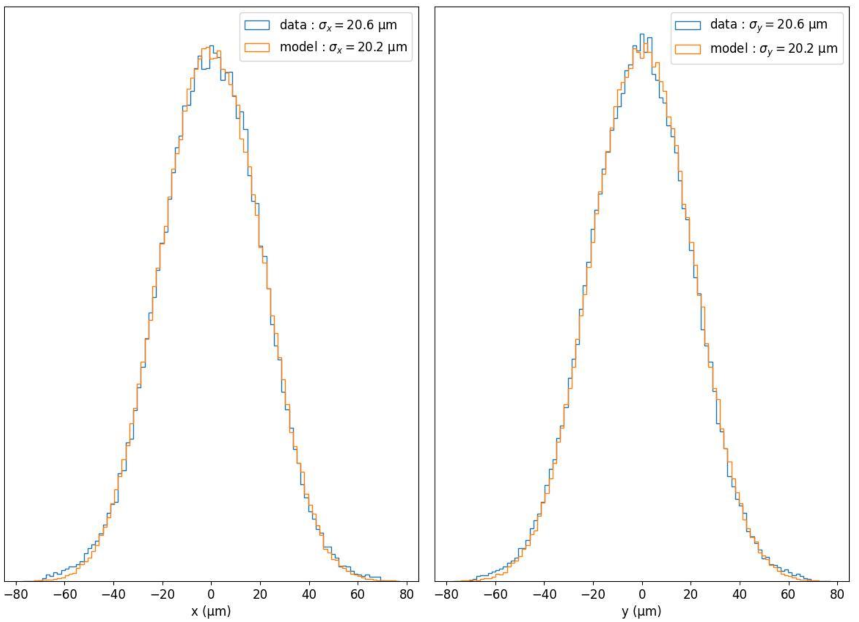
data

'perfect detector'

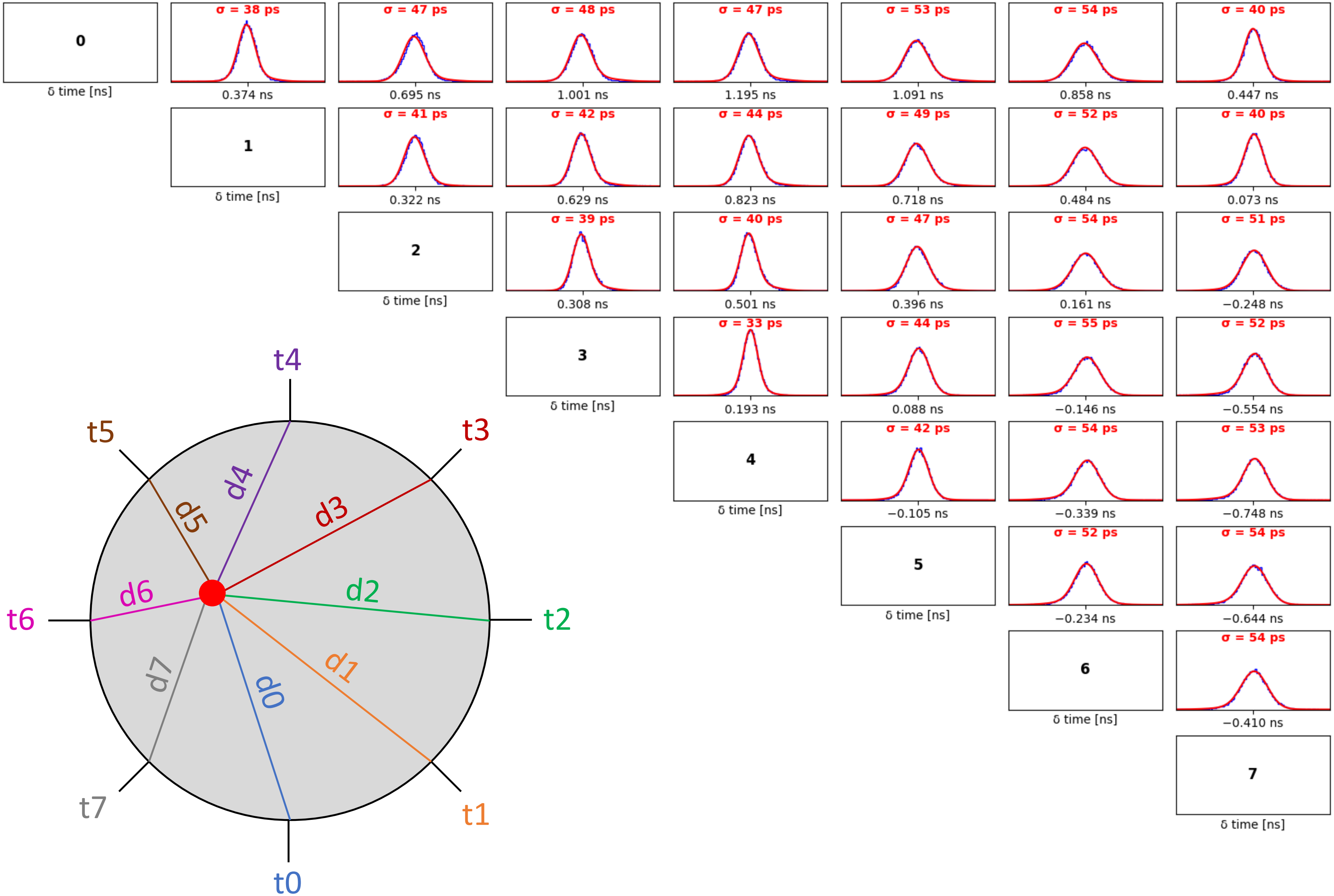
√(20.6² - 14.8²) = **14.3 µm**

blue : data

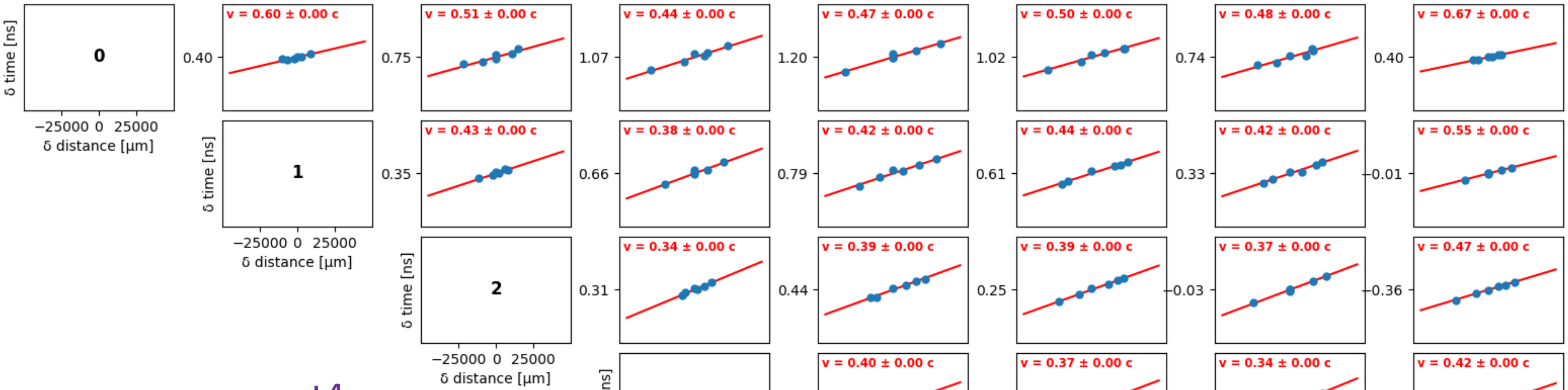
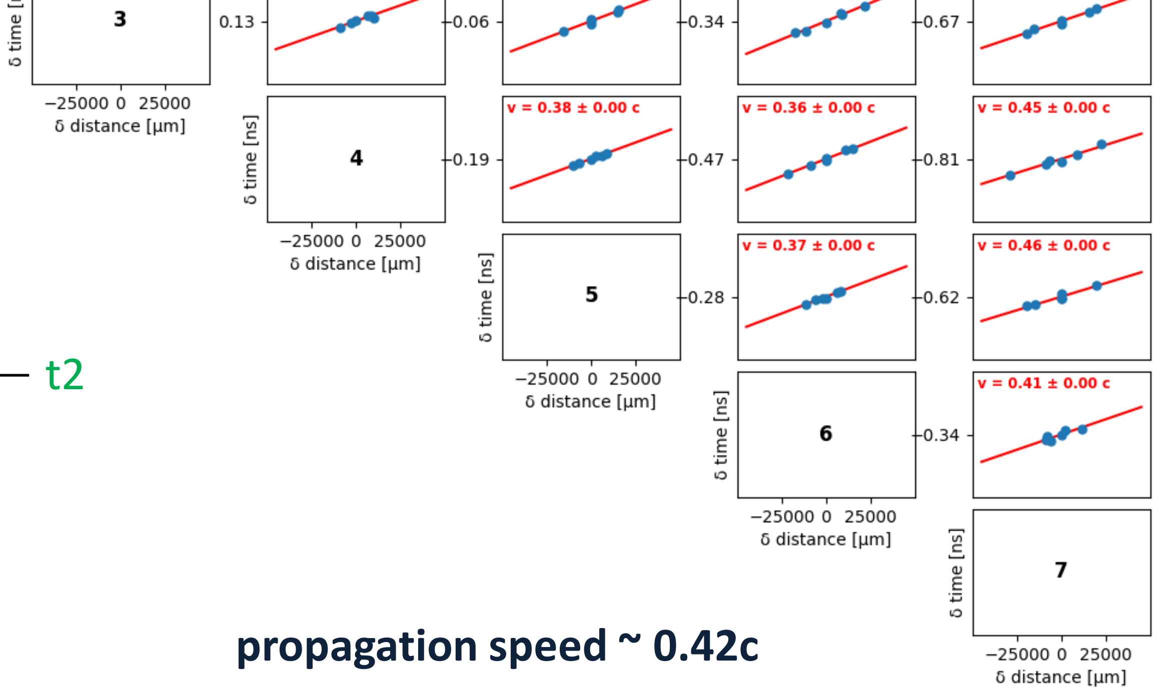
orange : perfect detector convoluted by a 2D gaussian of σ=14.3 µm

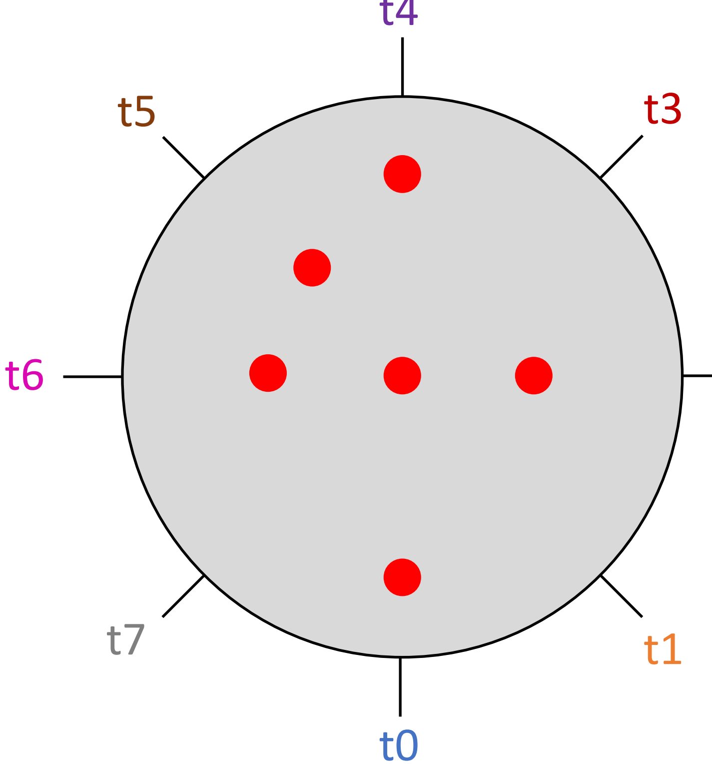


Time resolution



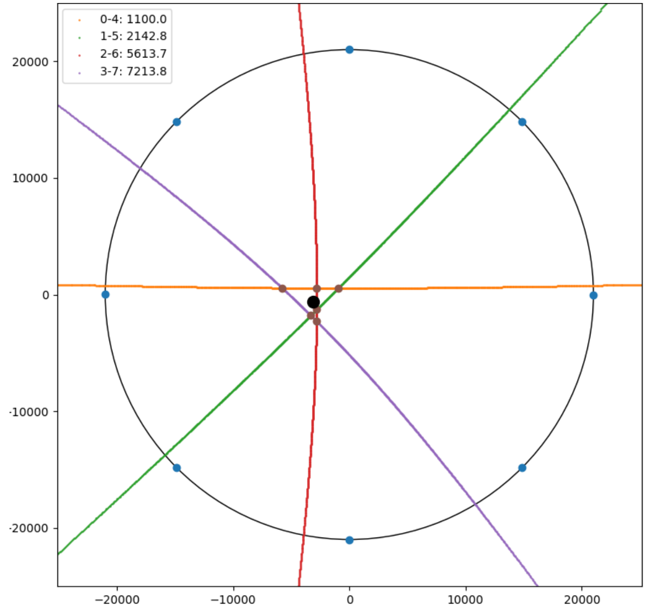
Time resolution

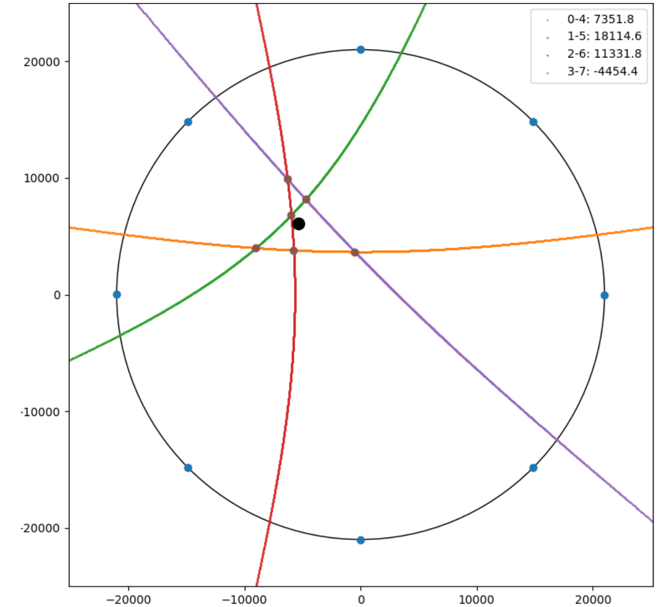



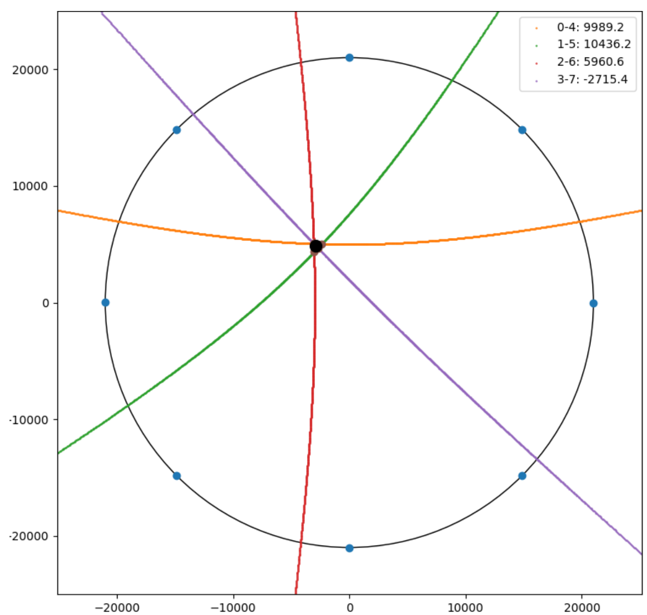


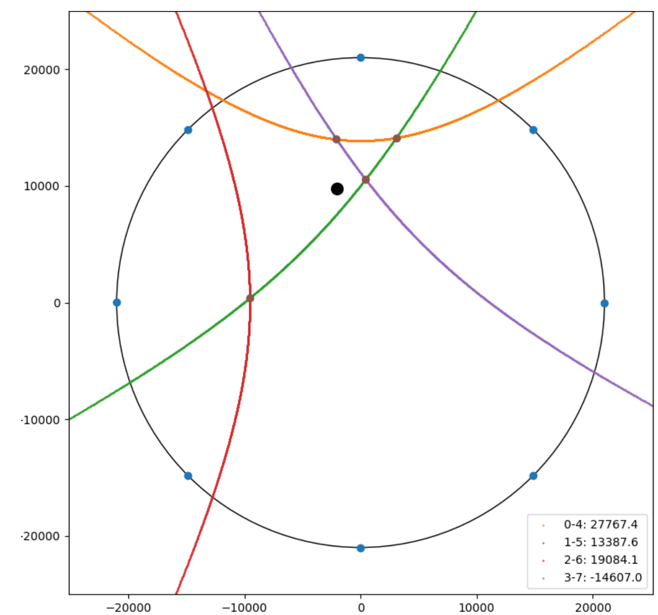
propagation speed ~ 0.42c

Time resolution

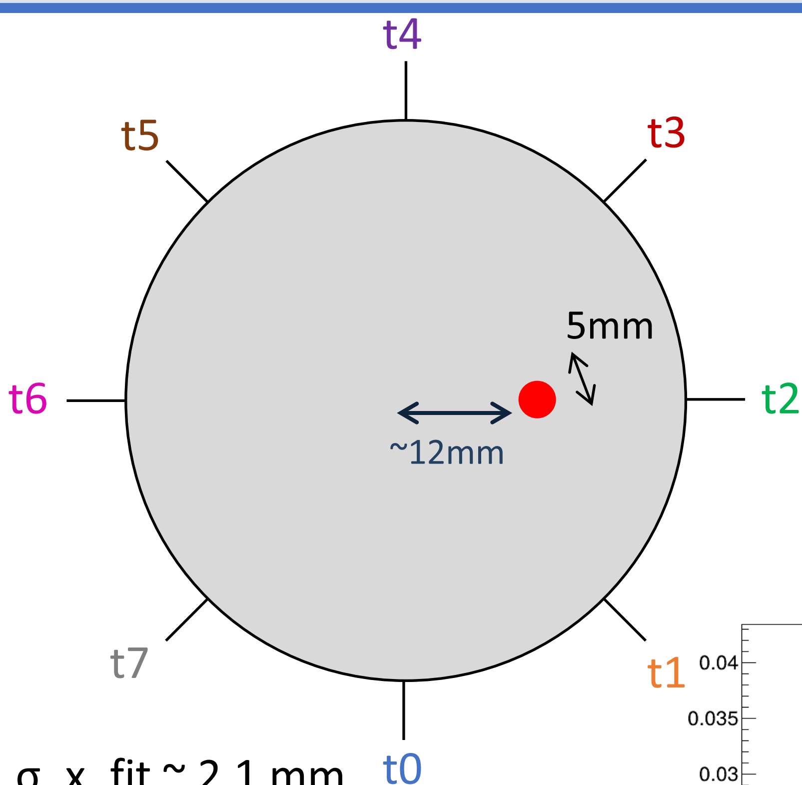


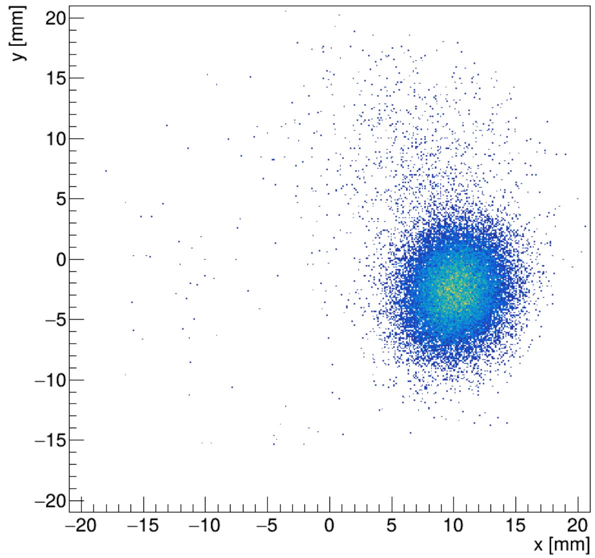


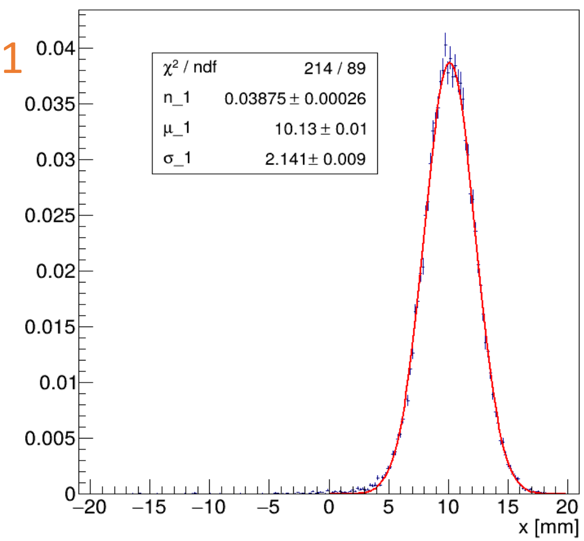


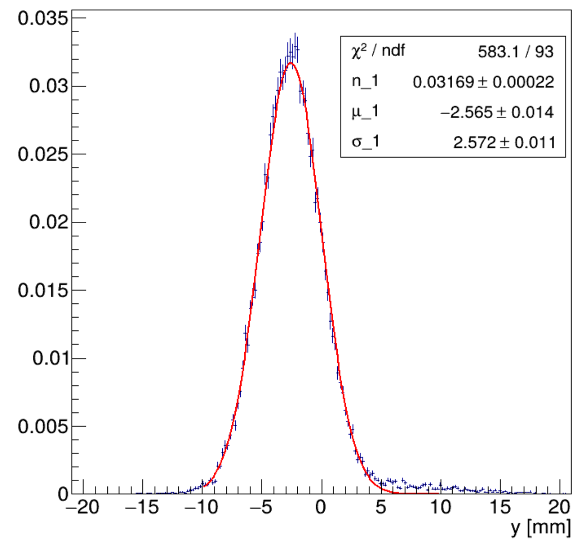


Time resolution









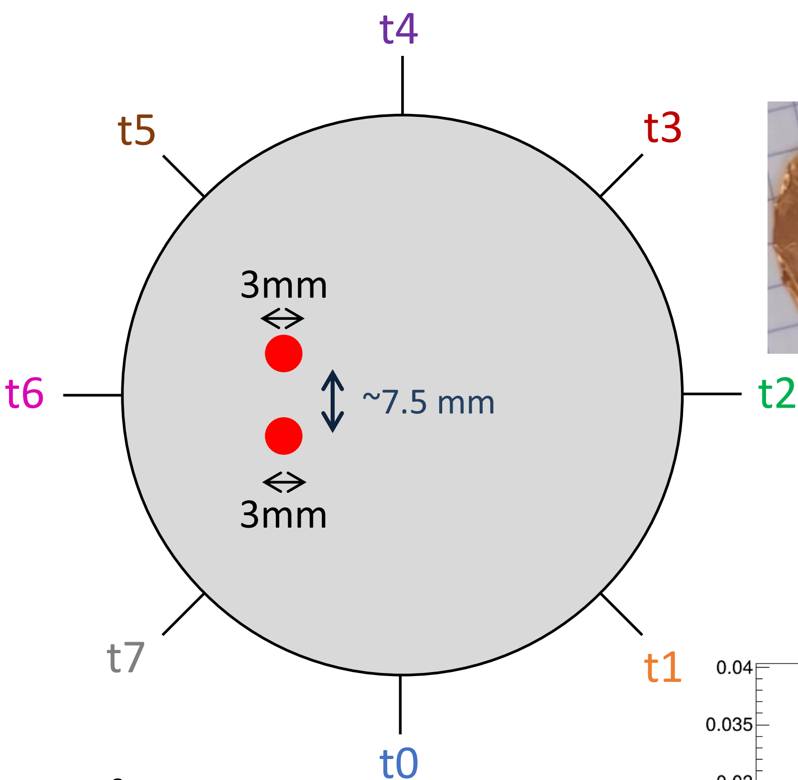
σ_x_fit ~ 2.1 mm
σ_y_fit ~ 2.6 mm

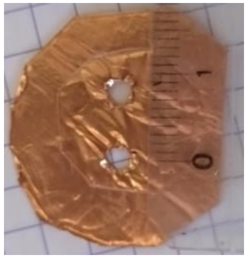
- removing the hole size :

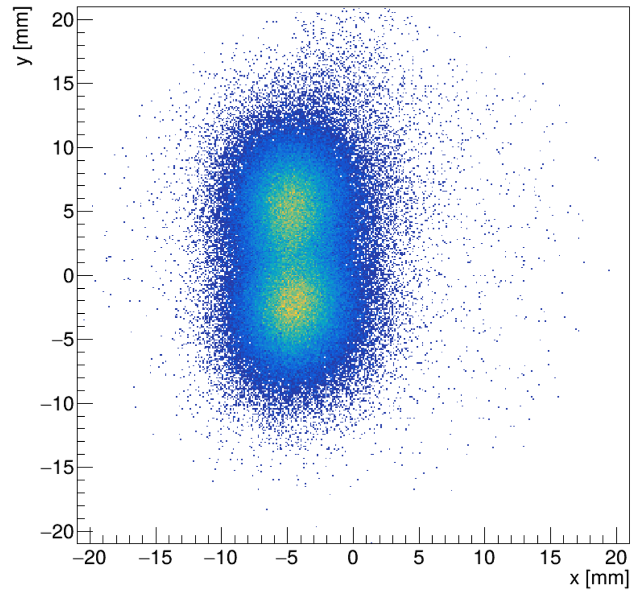
=> **σ_x ~ 1.7 mm**
=> **σ_y ~ 2.3 mm**

- By using the propagation speed of 0.42c we can convert the position resolution into time resolution => 2 mm / 0.42c = **16 ps**

Time resolution

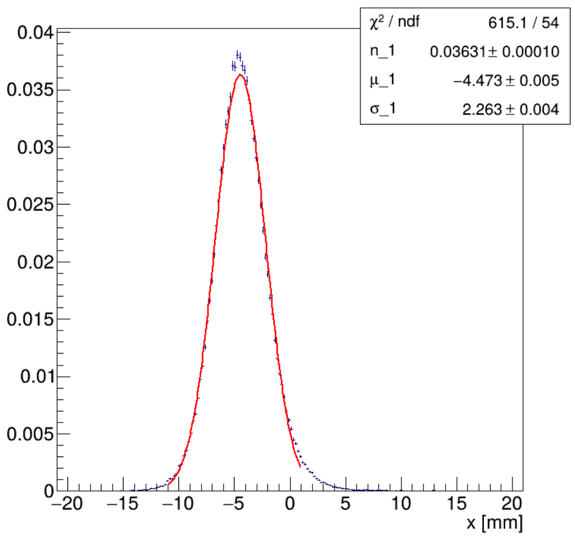


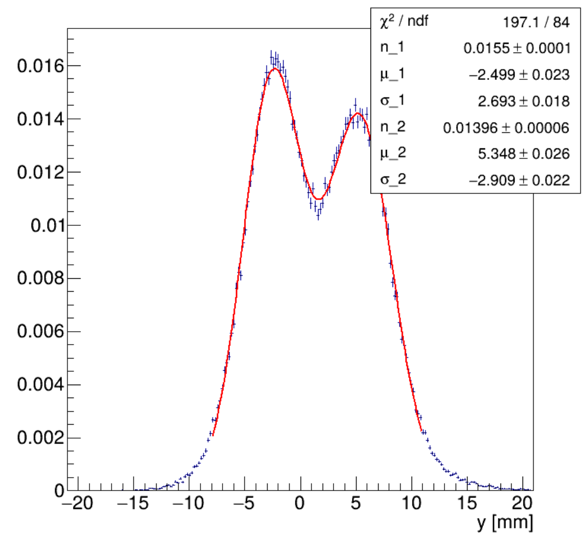




σ_x_fit ~ 2.3 mm
σ_y_fit ~ 2.8 mm

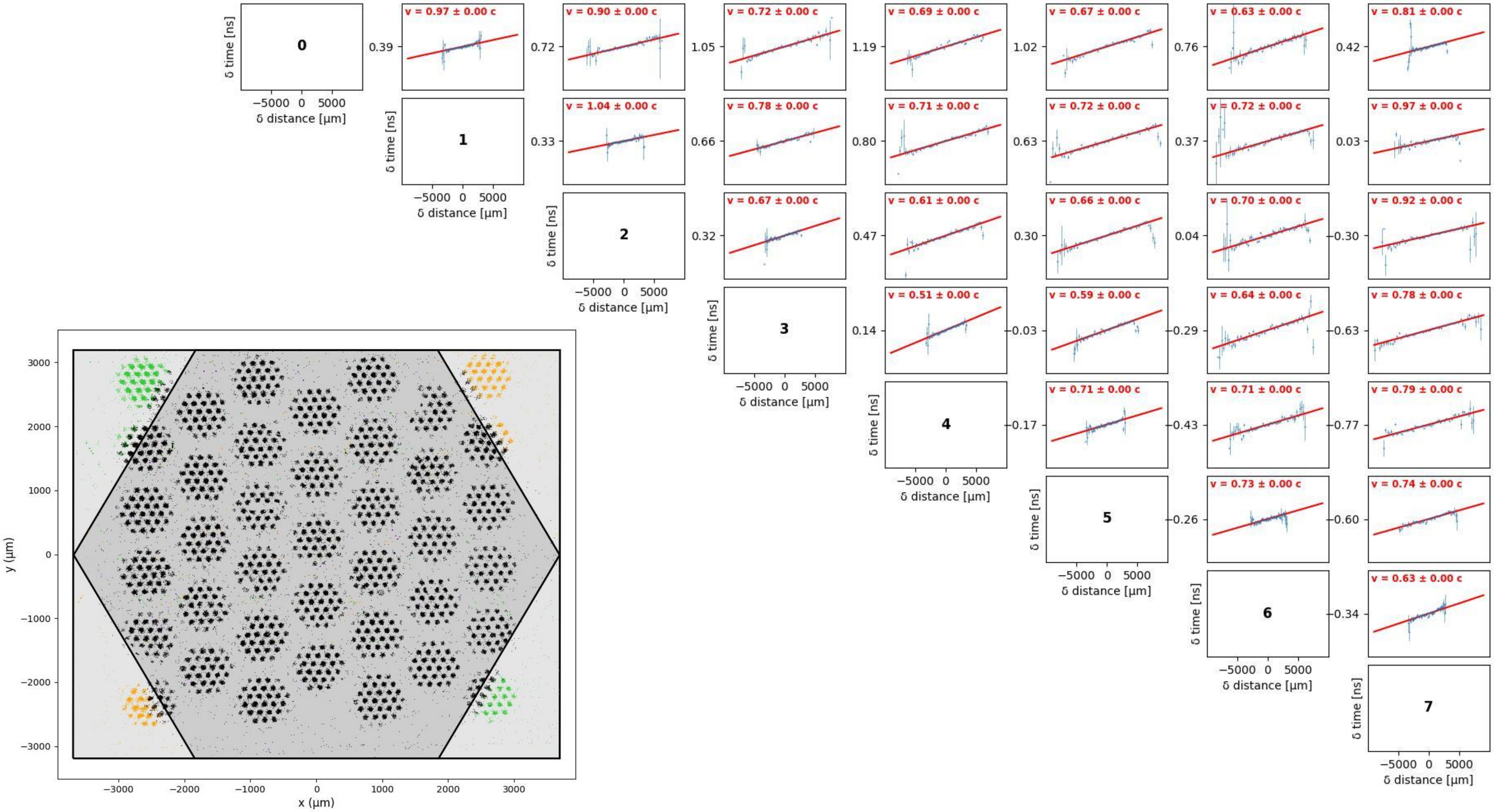
removing the hole size :
=> **σ_x = 2.2 mm**
=> **σ_y = 2.7 mm**





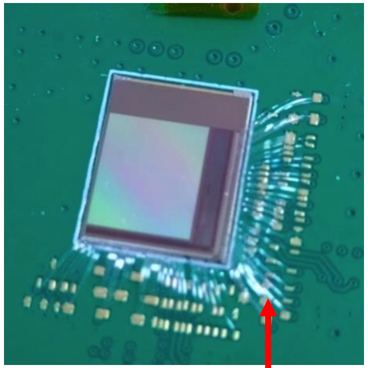
Combined time and spatial resolutions

- Combined measurements with the PICMIC-0 chip

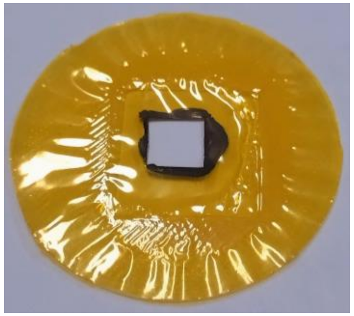


Combined time and spatial resolutions

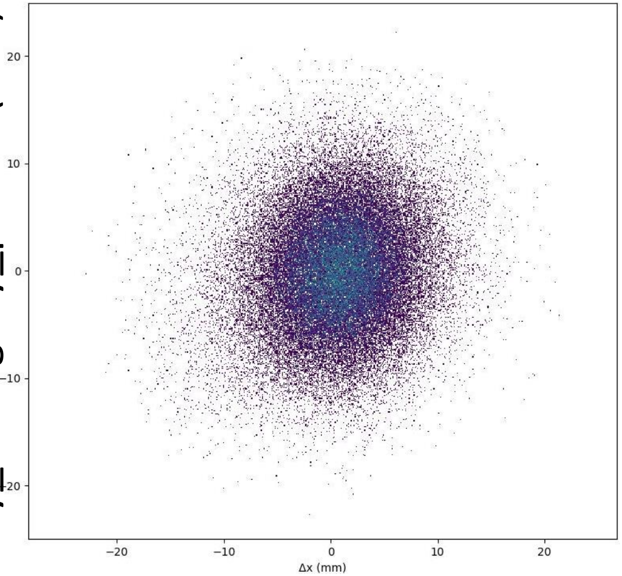
- The time measurements are deteriorated when the PICMIC chip is present due to :
  - the wire bondings which acts like antennas that radiate electromagnetic waves which are detected by the timing detector
  - the kapton mask used to protect those wire boundings which impact the electromagnetic environment



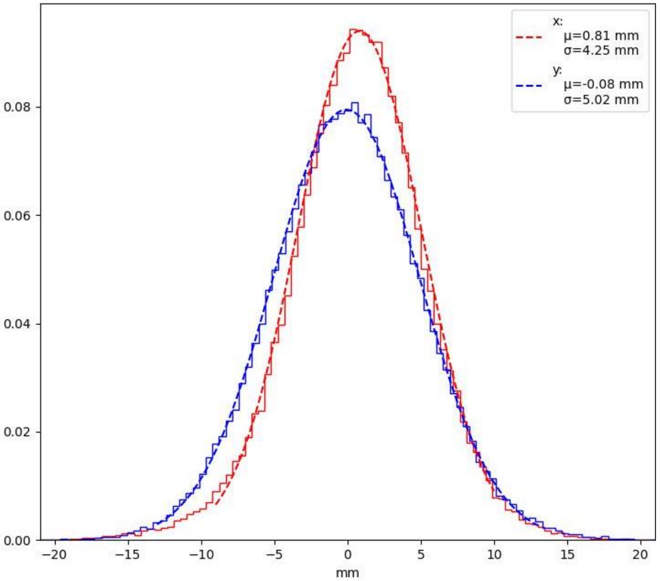
wire bondings



y_timing – y_picmic (mm)



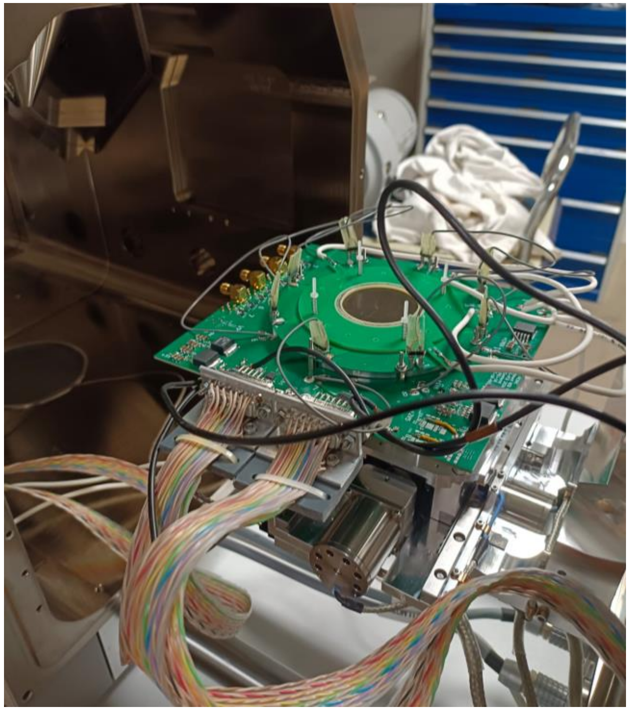
x_timing – x_picmic (mm)

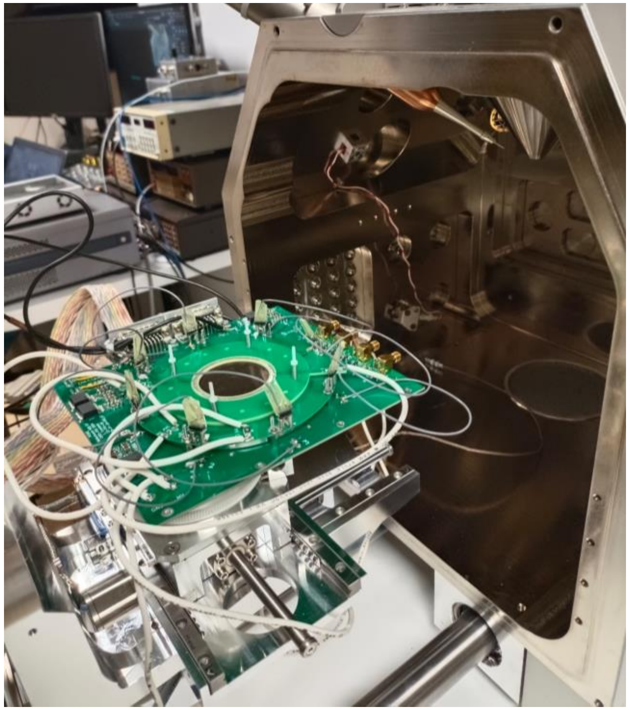


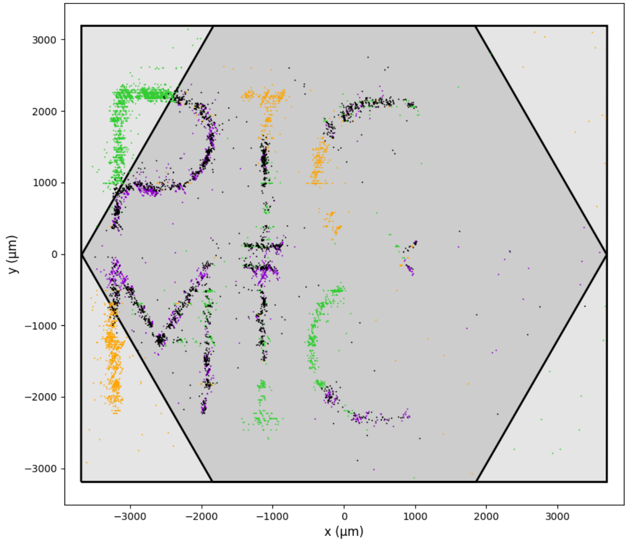
σ_x_fit ~ 4.3 mm
σ_y_fit ~ 5.0 mm

=> **32 ps**

Test with a SEM







People involved in the project

- IP2I-Lyon : I.Laktineh, E. Bechetoille, H. Abreu, H. Mathez, Ch. Combaret, G. Garillot, X. Chen, K. Sabra, L. Balleyguier, G. Noel, G. Grenier, L. Mirabito

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- OMEGA: S. Callier, C. de la Taille
- SDU: L. Zhang
- Nankai University: Y. Zhao
- IHEP: J. Ye, Q. Sen, L. Chen

- IMP: A. Serghei, L. Leveque, L. David
- INL: J-L. Leclercq, P. Pittet, C. Chevalier, P. Kleimann, B. Rea, N. Terrier
- ILM: A. Ayari
- XIOPM: P. Chen, X. Zhng

- A replica of the PICMIC setup has been recently installed in Shandong University

Conclusion and future

- The PICMIC concept of simultaneously measuring the time and position using two independent detectors is validated
  - simultaneous 15 µm position resolution and 32 ps time resolution
  - the time resolution can reach ~15 ps if we disable the PICMIC chip

- Future :
- A new version of the PICMIC chip (PICMIC-1) is currently produced and is expected very soon
  - surface increased by a factor 4
  - better calibration possibilities (8 bits for local adjustment instead of 5)
  - higher acquisition rate (1MHz => 10-30 MHz)
  - LVDS transmission to reduce the impact on the timing measurement

- The SAMPIC can deliver very good precision but has a big dead time of 1µs
  - a board integrating a LIROC (preamplifier and discriminator) and picoTDC has been developed and produced