DE LA RECHERCHE À L'INDUSTRIE

Monday, 19th June 2023

Preliminary Results on PICOSEC – MM using 7-pad resistive prototypes

Alexandra Kallitsopoulou

CEA, IRFU, Université Paris – Saclay

on behalf of PICOSEC Micromegas Collaboration

RD51 Collaboration Meeting 19-21 June 2023

www.cea.fr

Outline

The PICOSEC Micromegas Technology

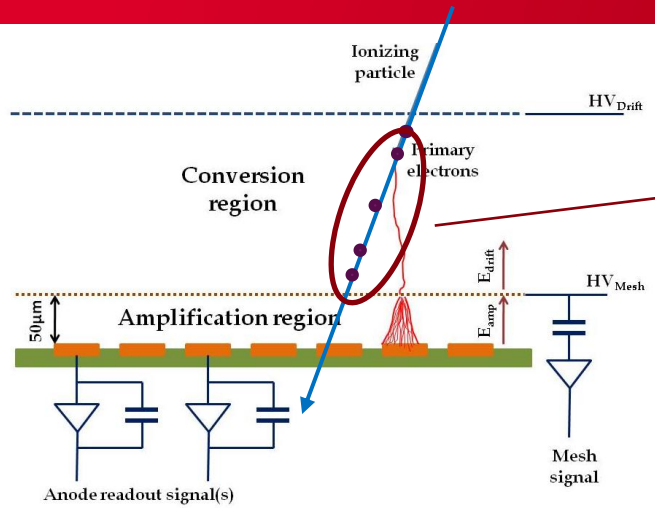
April 2023 TestBeam Setup & Measurements

7-pad resistive prototypes tested

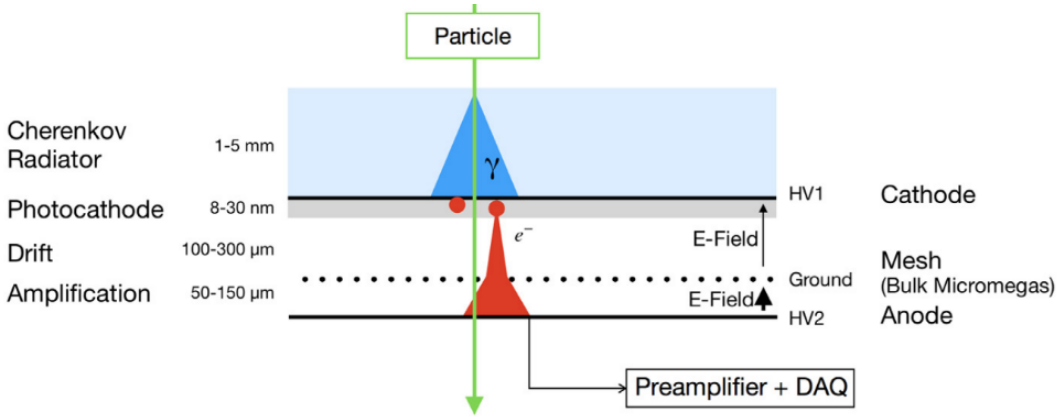
7-pad resistive prototypes comparison

alexandra.kallitsopoulou@cea.fr

The PICOSEC Micromegas Technologie



Y. Giomataris, P. Rebourgeard, J.P. Robert and G. Charpak, *"Micromegas: A high-granularity position sensitive gaseous detector for high particle-flux environments",* Nuc. Instrum. Meth. A 376 (1996) 29



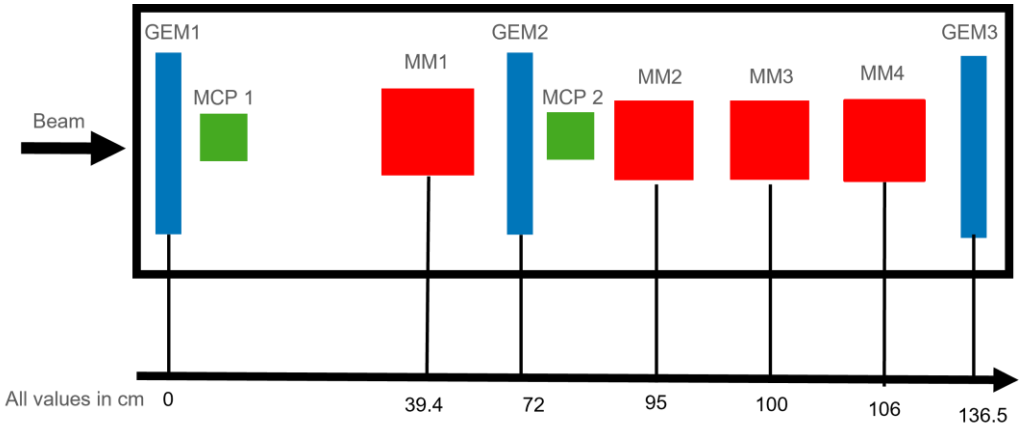
J.Bortfeldt, et al., *"PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector",* https://doi.org/10.1016/j.nima.2018.04.033

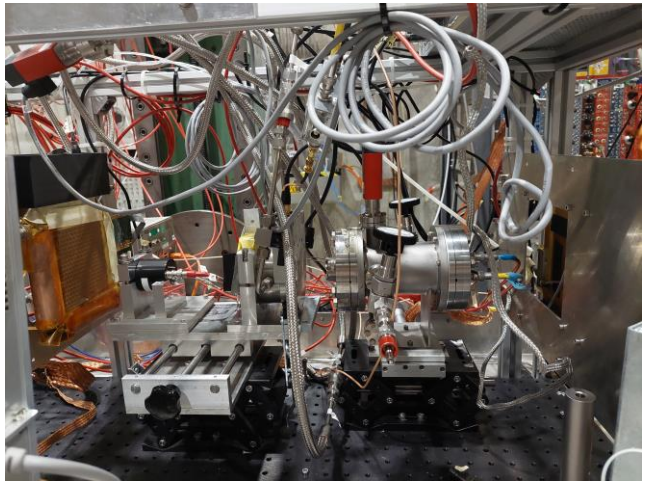
- Limitations of the Micromegas Timing Potential
  - Stochastic nature of ionization
  - Randomness of last ionization
  - Time jitter of a few ns
- The PICOSEC Concept
  - Timing with tens of picosecond precision
- Modifications in MM Geometry
  - Smaller Drift Gap (up to 200μm)
  - Elimination of the stochastic nature of ionization
  - Higher applied Drift Voltage ⟶ Pre-avalanche
- Additional Components in MM geometry
  - Cherenkov radiator +
  - Photocathode (CsI, B4C, Diamond, DLC)

    Prompt photoelectrons

April 2023 TestBeam Telescope

- Particle Beams @ CERN SPS H4 Beamline
  - Muons 80-150GeV
  - Scalability (robustness and efficiency)
  - Photocathode studies (robustness and efficiency)
  - Gas Mixture studies *
  - Radiation Hardness studies **





- The Setup
  - Use GEMs for tracking
  - Use MCP PMTs as timing reference devices and for triggering
  - Electronics: CIVIDEC preamp. / Customade electronics + LeCroy scopes

- Crystals & Photocathodes :
  - MgF2 crystal +
  - Metallic (Cr, Al)
  - Metallic substrate(Cr) + CsI
  - Metallic substrate(Cr) +B4C

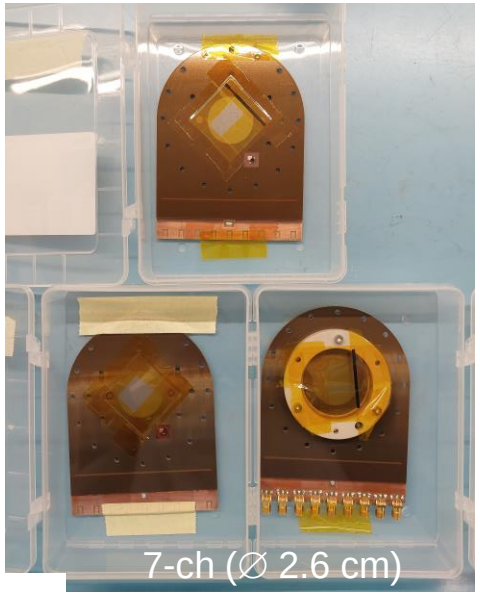
- Gas : 80% Ne – 10% CF_4-10%C_2H_6

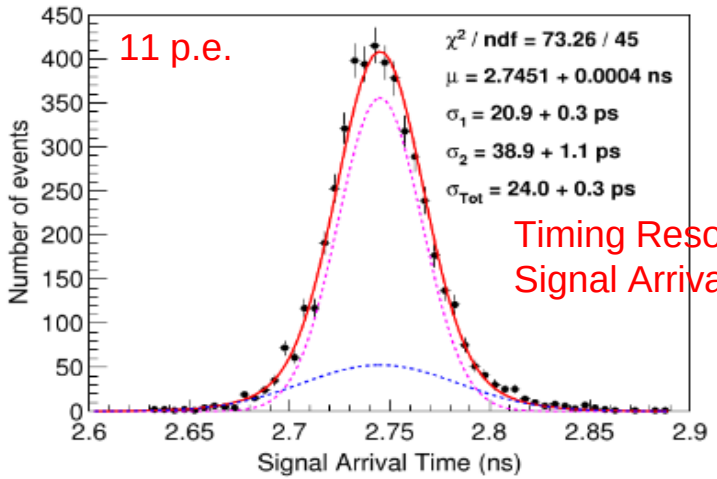
*/** *See "PICOSEC Micromegas" presentation on Wednesday by Florian Brunbauer*
https://indico.cern.ch/event/1273825/contributions/5409283/

7-pad resistive Detectors Under Test

- Multi-Pad Prototypes
  - Hexagonal pads ø 1cm
  - MgF2 crystal
  - CsI photocathode

- Measurements of interest focus on Timing properties & Robust Prototypes
  - Different resistivity values (10 MΩ, 200kΩ)
  - Different resistivity layer architectures (resistive & capacitive sharing)
  - Voltage scans → Stable operation voltage at a high rate
  - Timing runs on individual pads
  - Long scan for uniformity map on amplitude and timing
  - Signal Sharing
  - Tilted detector relative to beam direction in 45 and 35 degrees
  - Effectively spatial resolution studies





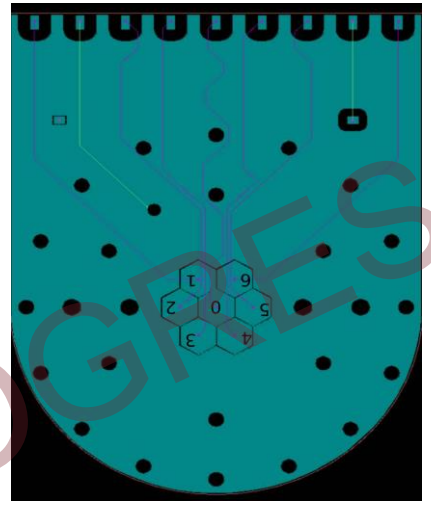
Timing Resolution → RMS of Signal Arrival Time Distribution

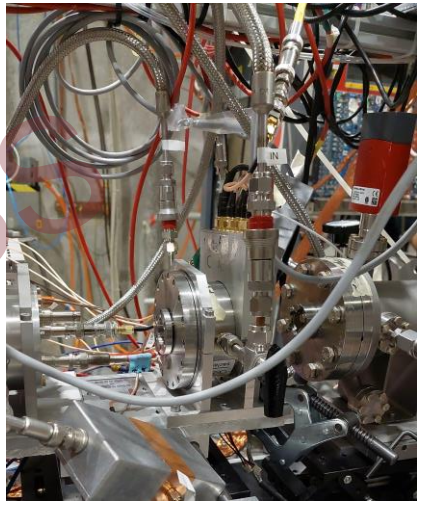
J.Borteldt, et al. "PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector", Nuc. Instrum. Meth. A (2021)https://doi.org/10.1016/j.nima.2018.04.033

7pad-resistive sharing

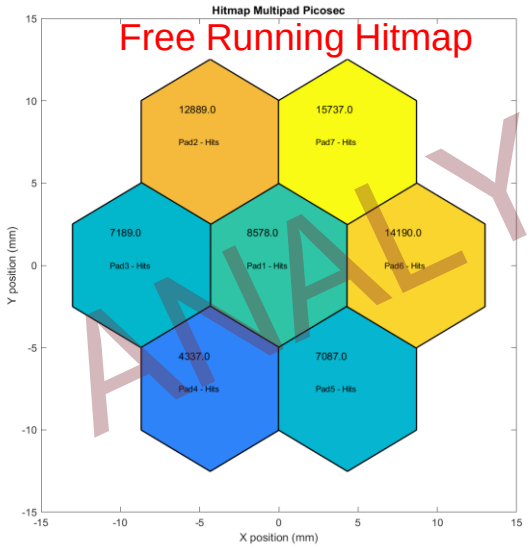
7-pad 10MΩ - CsI photocathode - 10ch Preamp card

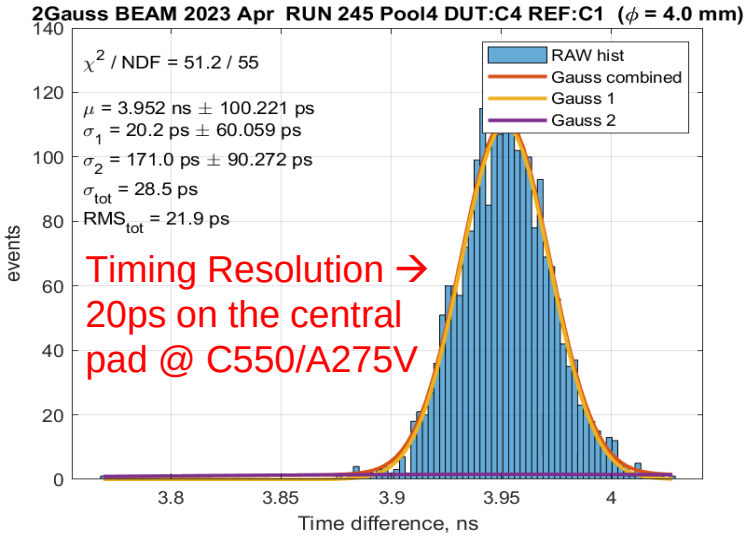
- Uniformity of response
  - Timing Runs with MCP-PMT (trigger) centered on each pad center
  - Voltage scan on the central pad to determine the operational voltage





Operation Voltage	Timing Resolution
500/290	~31ps
510/290	~27ps
530/275	~25ps
550/275	~21ps

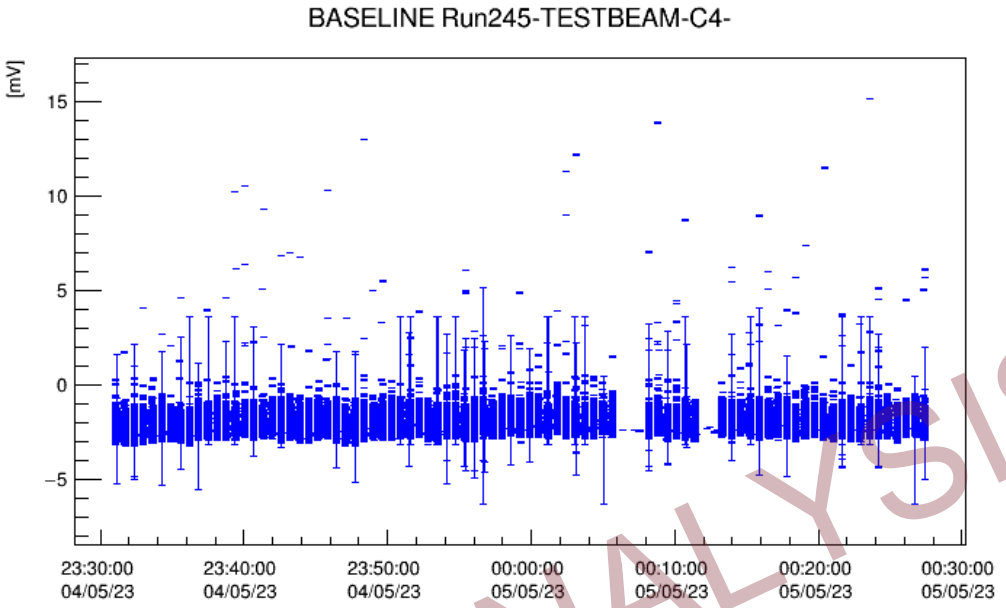




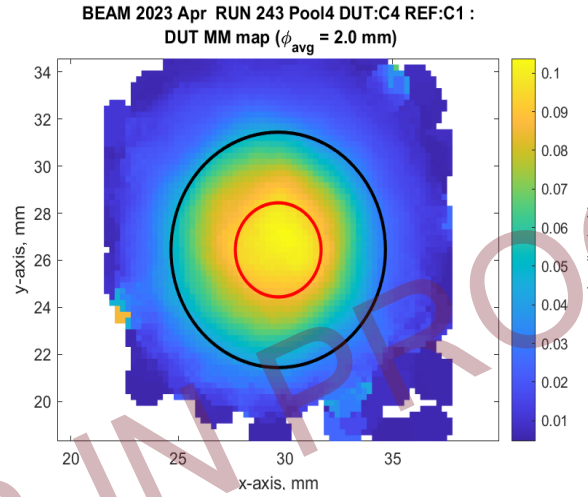
alexandra.kallitsopoulou@cea.fr

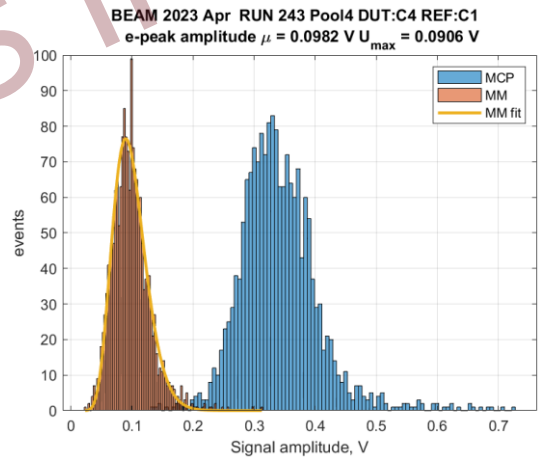
7-pad 10MΩ - CsI photocathode – 10ch ampl card

- Observation plots
  - Smooth operation of the detector



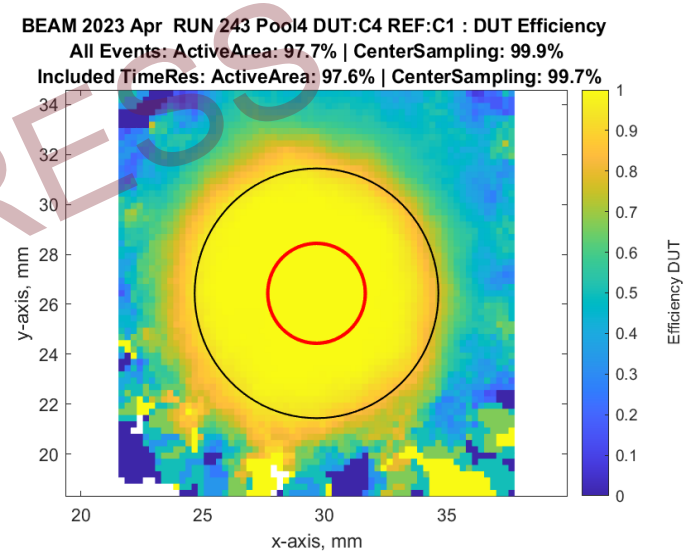
- Detector Alignment with MCP – PMT

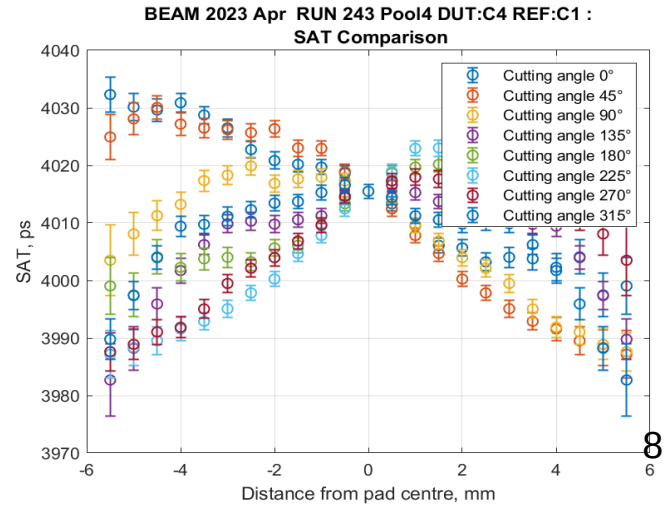




Signal Amplitude Detector vs. Reference

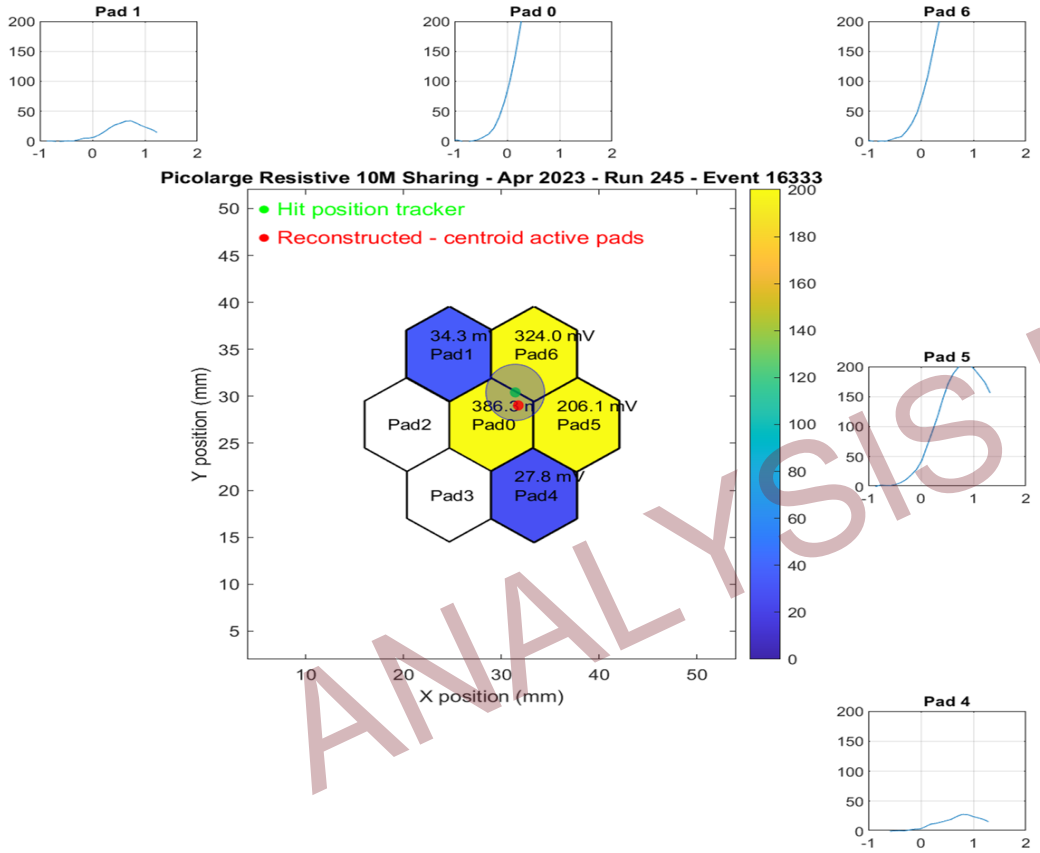
- Efficiency map

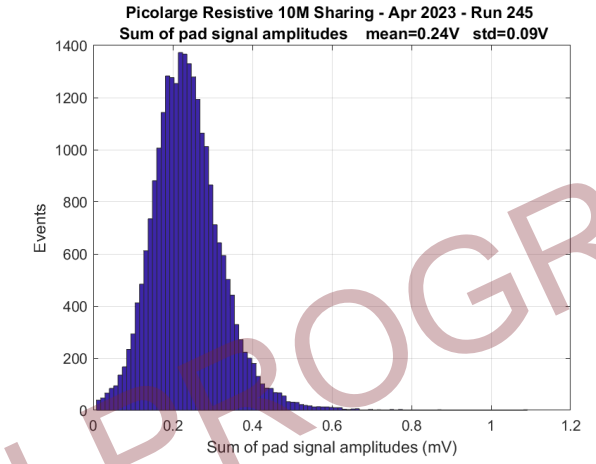


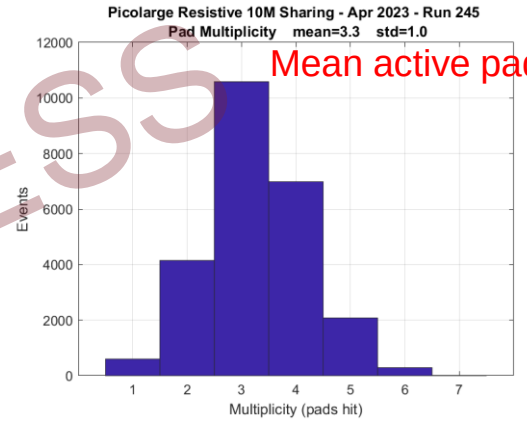


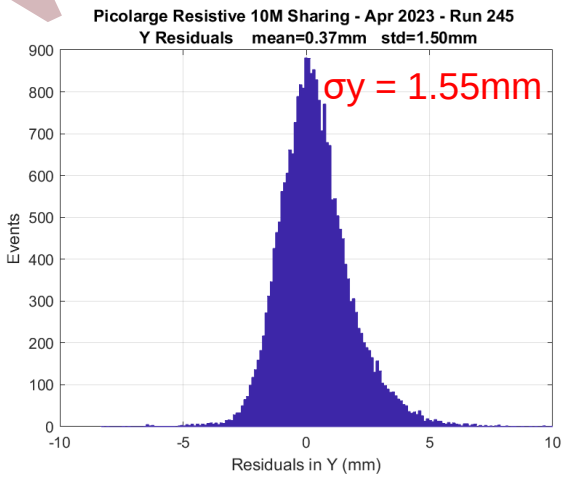
7-pad 10MΩ CsI photocathode, signal sharing

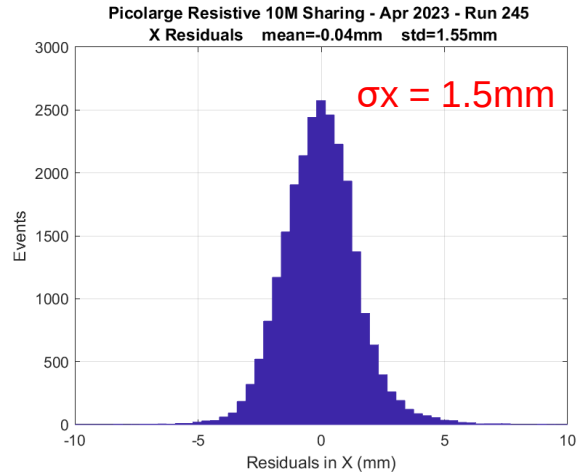
- Being centered on the central pad with MPC-PMT
  - Record all pad signals in the meantime to observe signal spreading







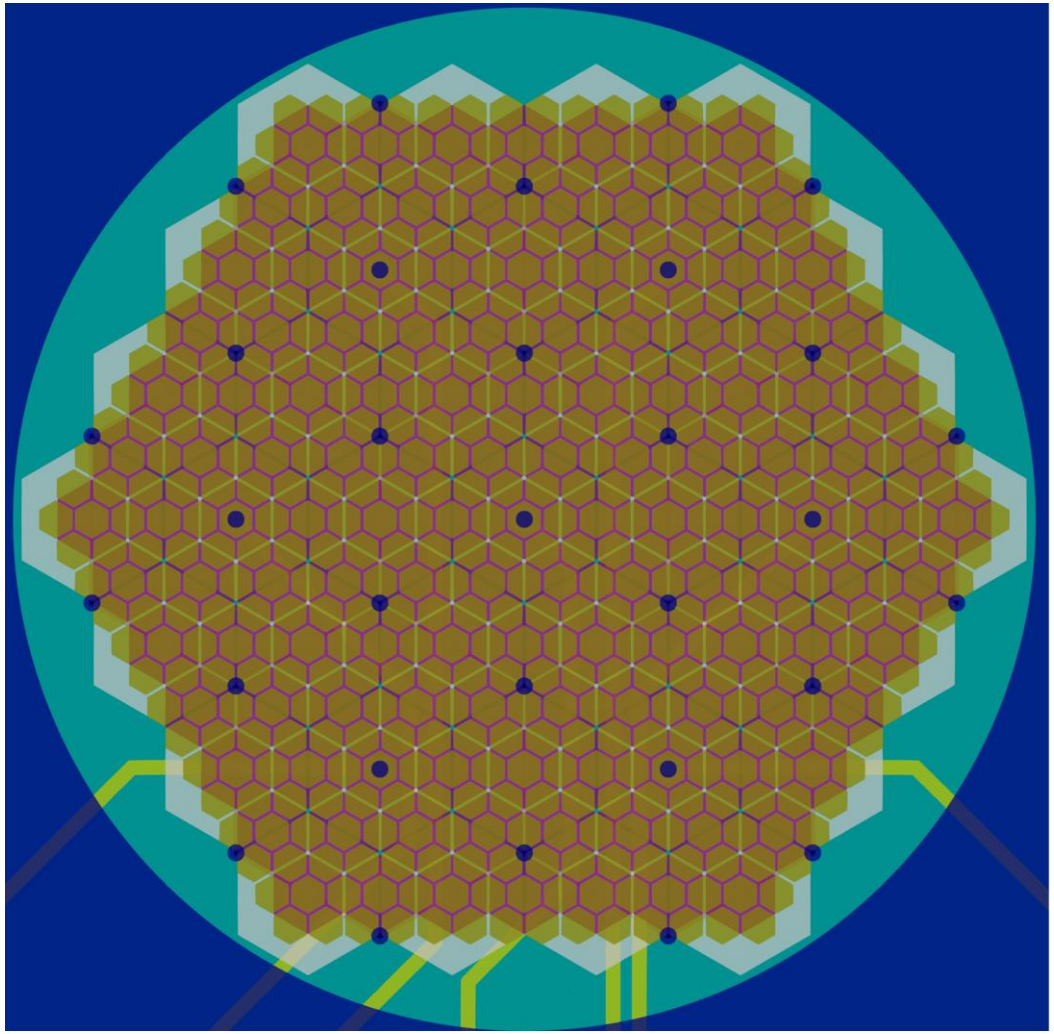


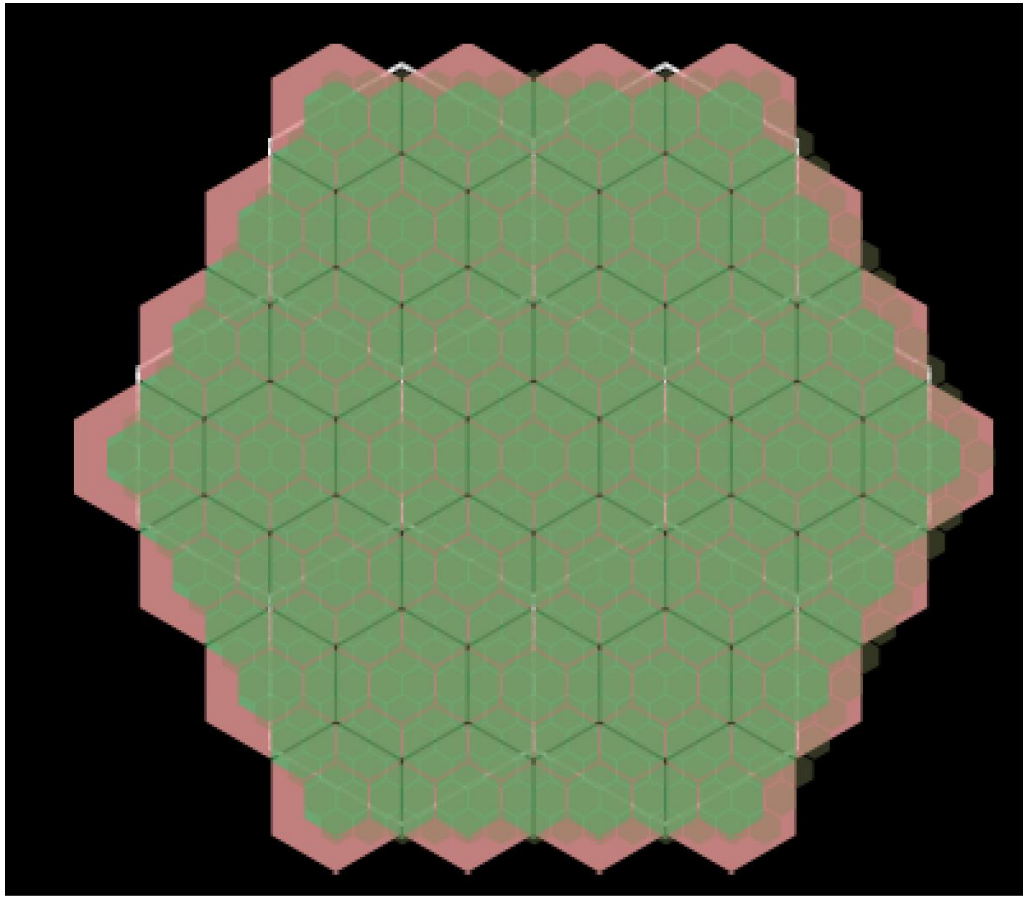


alexandra.kallitsopoulou@cea.fr

7pad-capacitive sharing

7-pad 10MΩ CsI photocathode, capacitive sharing

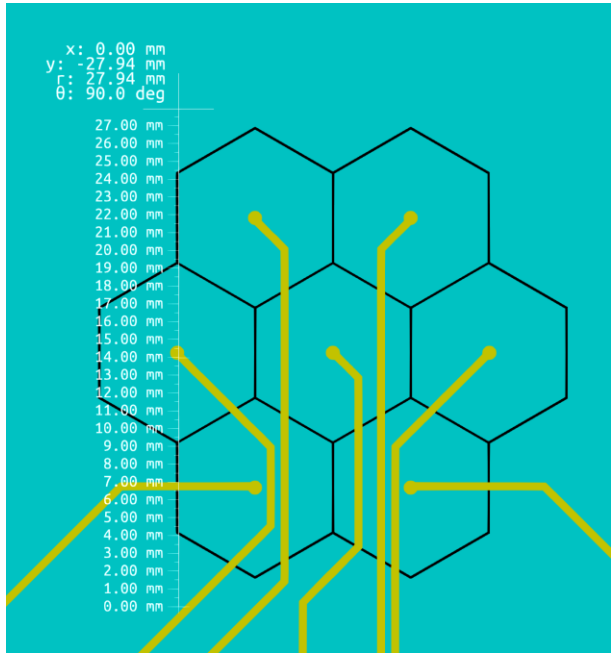




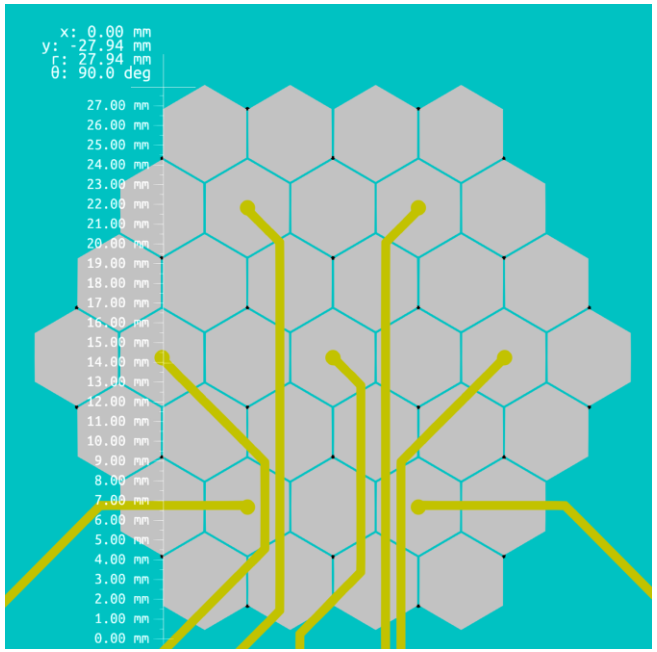
alexandra.kallitsopoulou@cea.fr

7-pad 10M CsI photocathode, capacitive sharing

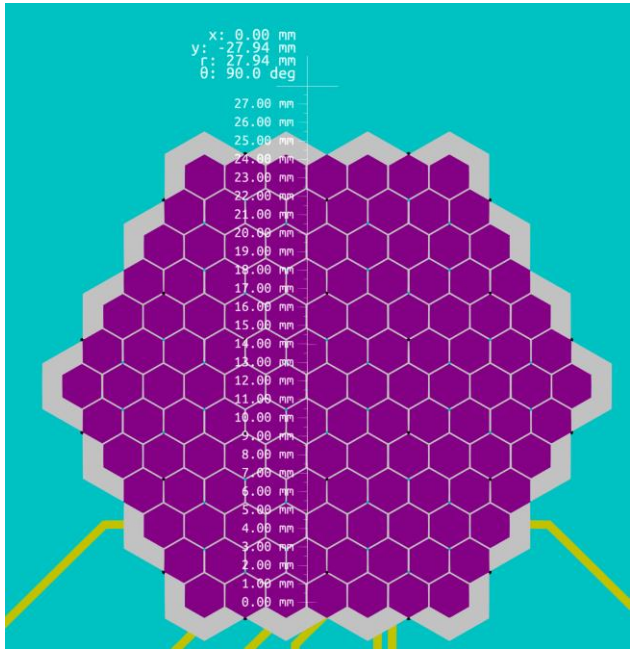
Hexagon size : 10mm
Cerenkov cone 3mm radius



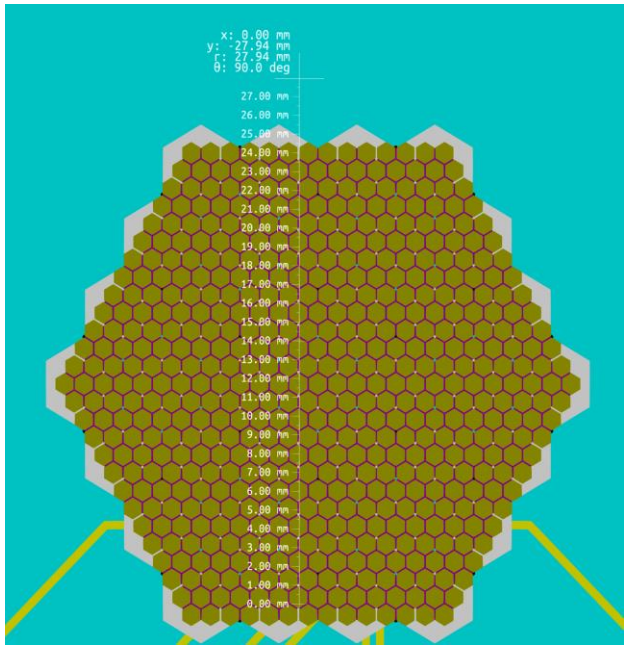
3rd layer of capacitive sharing
Hexagon size: 5mm



2rd layer of capacitive sharing
Hexagon size: 2.5mm



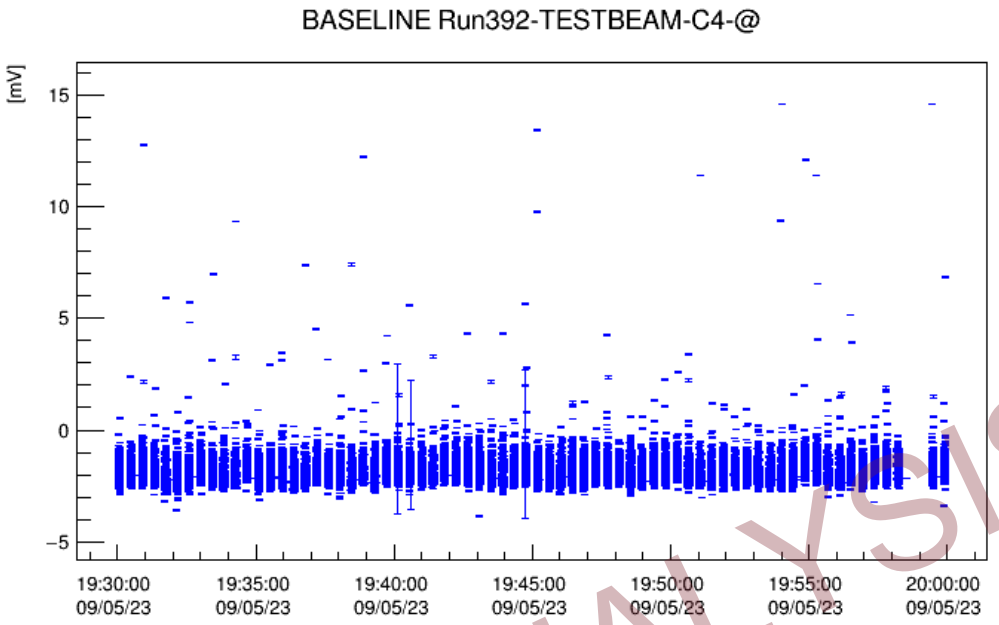
1st layer of capacitive sharing
Hexagon size: 1.25mm



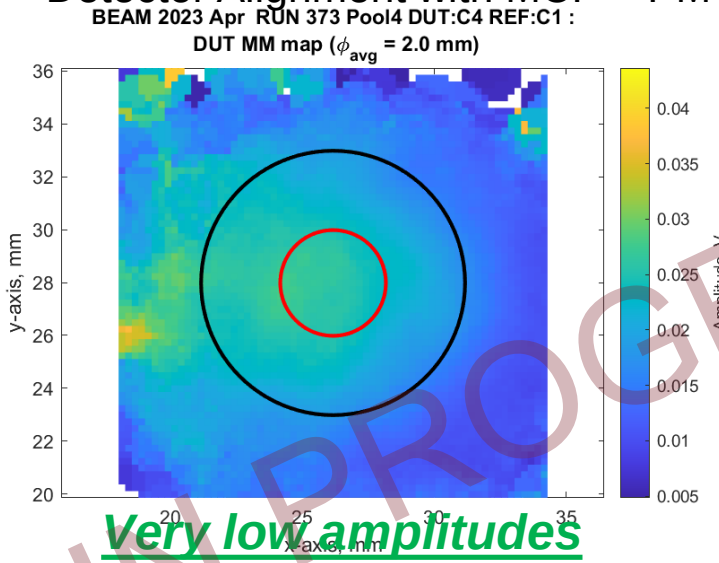
alexandra.kallitsopoulou@cea.fr

7-pad10MΩ CsI photocathode - capacitive sharing

- Observation plots
  - Smooth operation of the detector

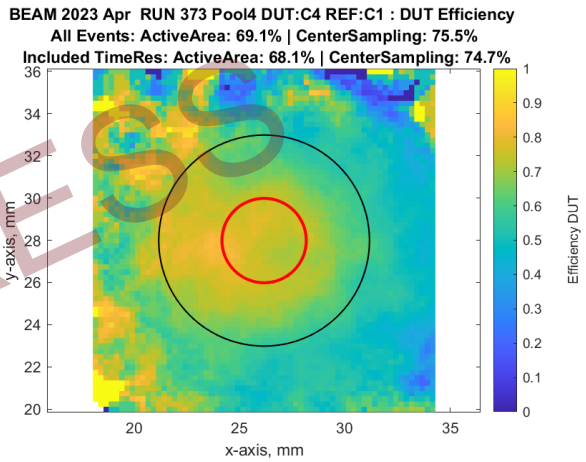


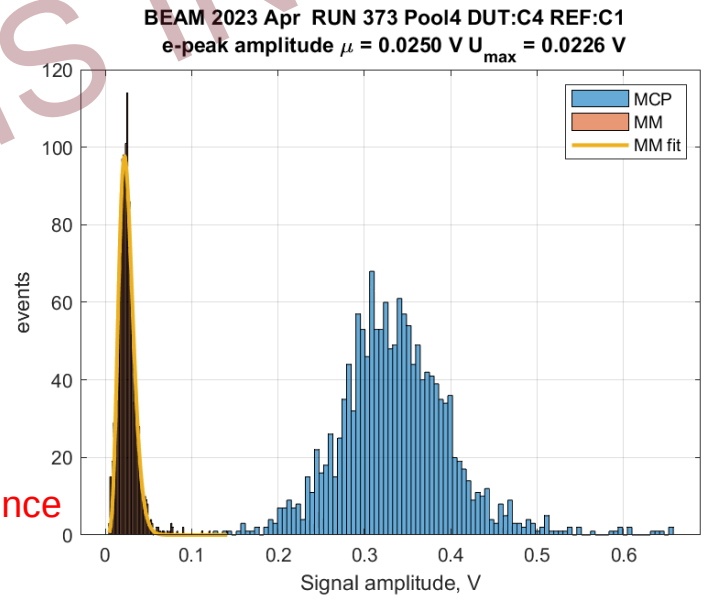
- Detector Alignment with MCP – PMT



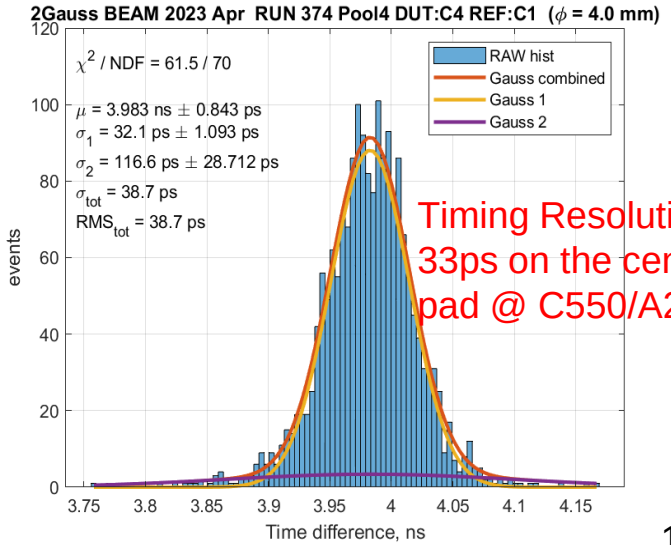
Very low amplitudes

- Efficiency map





Signal Amplitude Detector vs. Reference

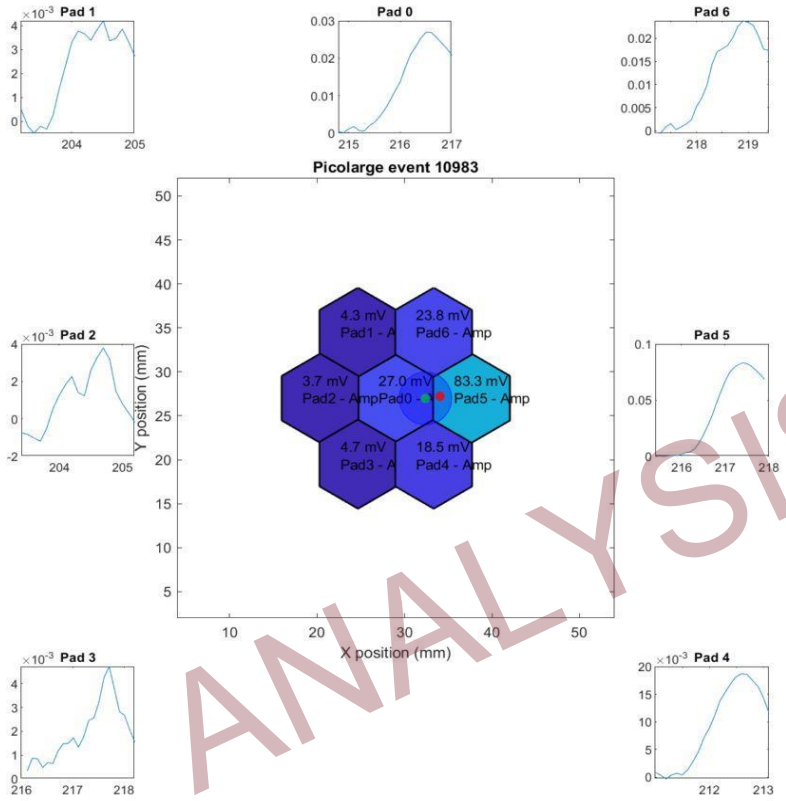


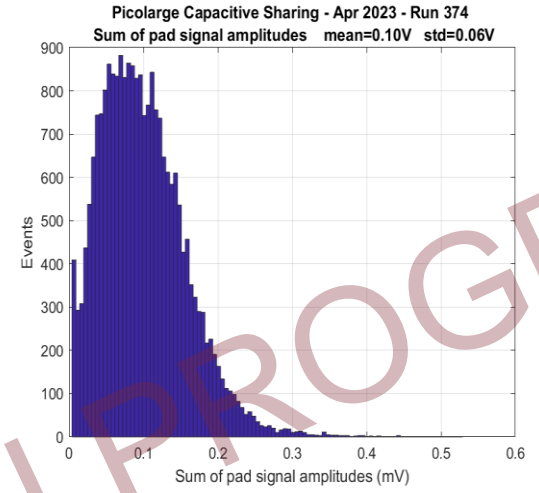
Timing Resolution → 33ps on the central pad @ C550/A275V

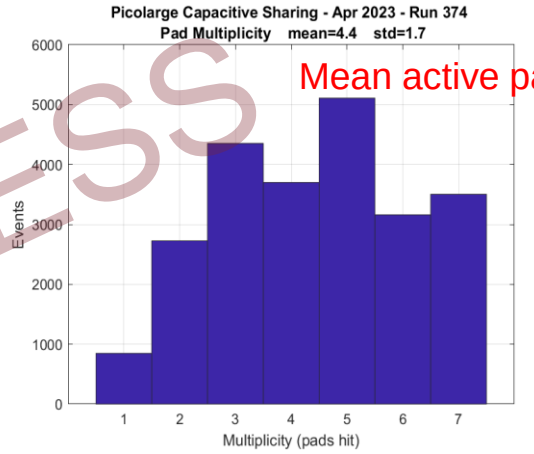
alexandra.kallitsopoulou@cea.fr

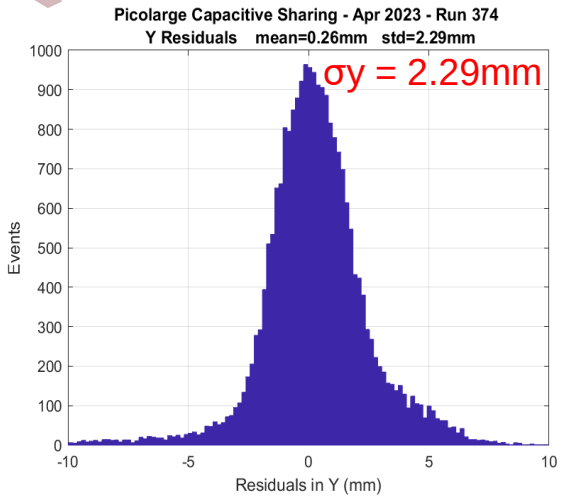
7-pad 10MΩ CsI photocathode - capacitive sharing

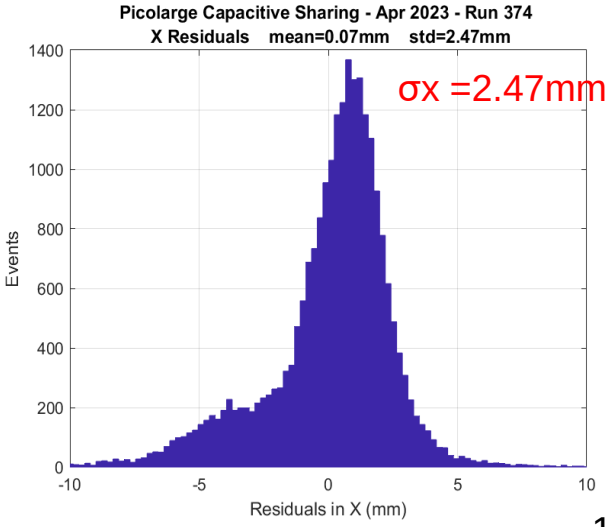
- Being centered on the central pad with MPC-PMT
  - Record all pad signals in the meantime to observe signal spreading









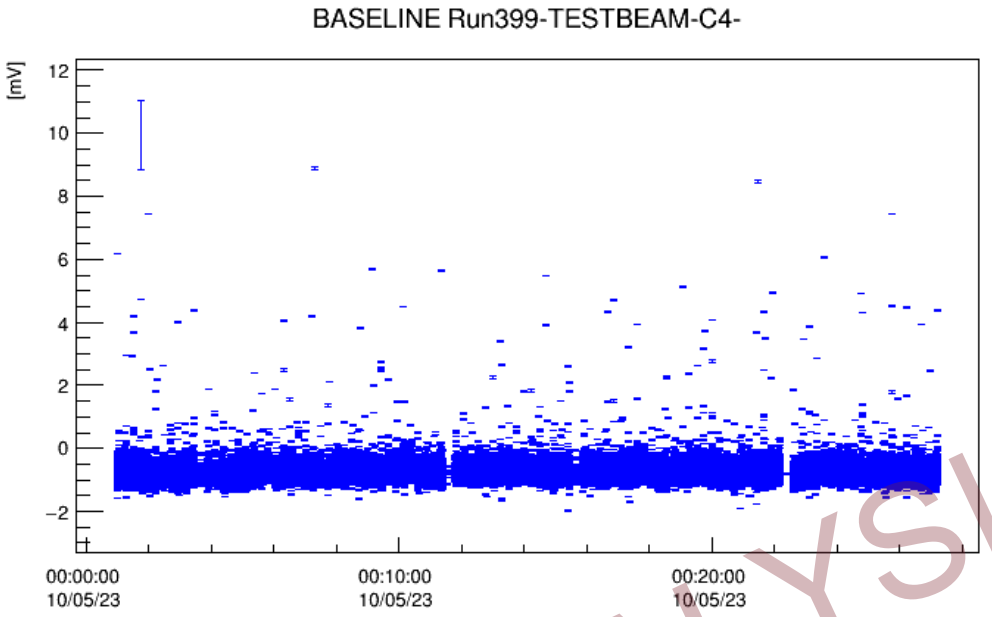


alexandra.kallitsopoulou@cea.fr

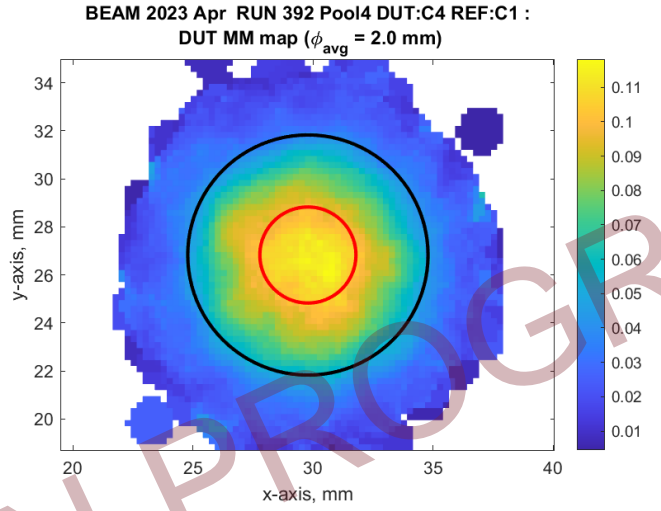
7pad-resistive sharing 200kΩ

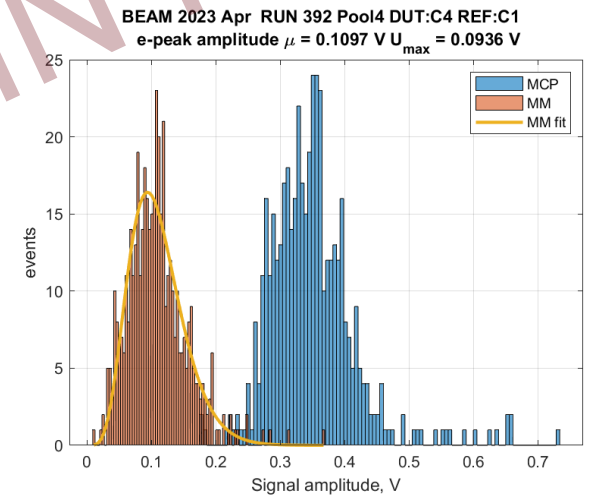
7-pad 200kΩ CsI photocathode - resistive sharing

- Observation plots
  - Smooth operation of the detector



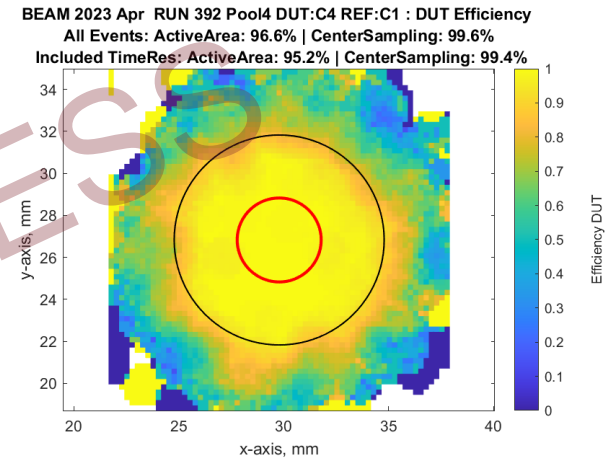
- Detector Alignment with MCP – PMT

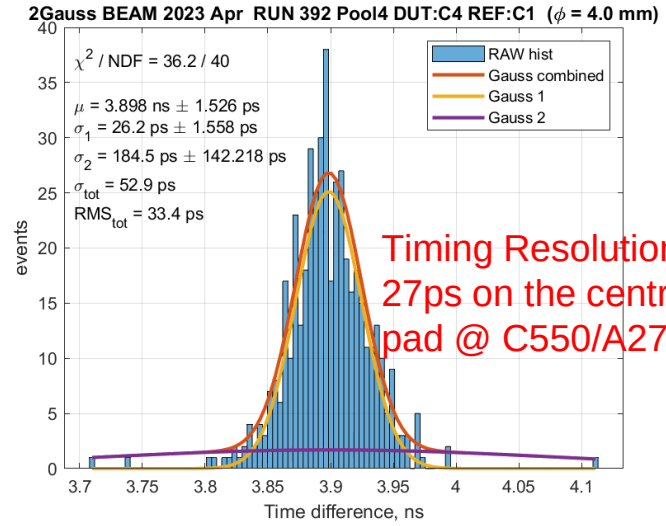




Signal Amplitude Detector vs. Reference

- Efficiency map

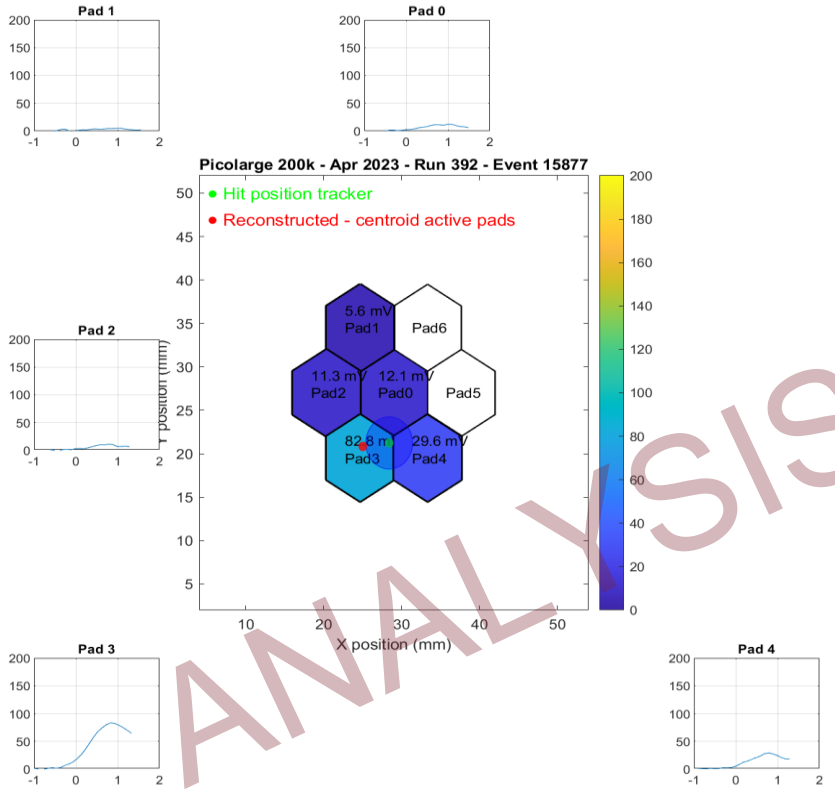


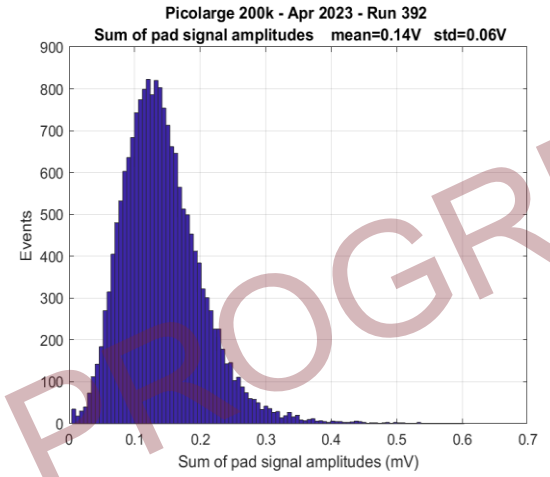


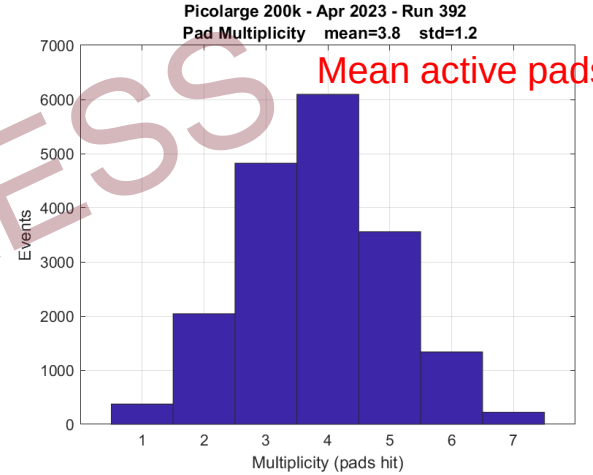
Timing Resolution → 27ps on the central pad @ C550/A275V

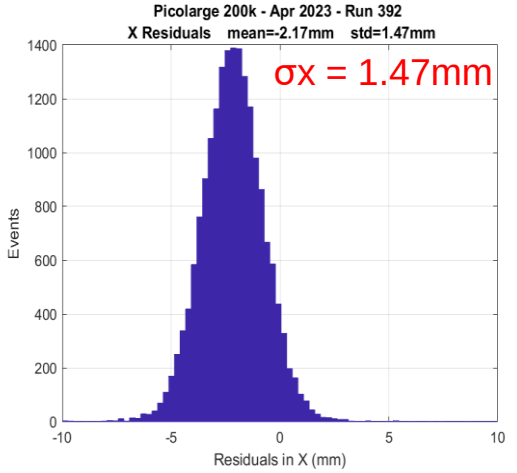
7-pad 200kΩ CsI photocathode - resistive sharing

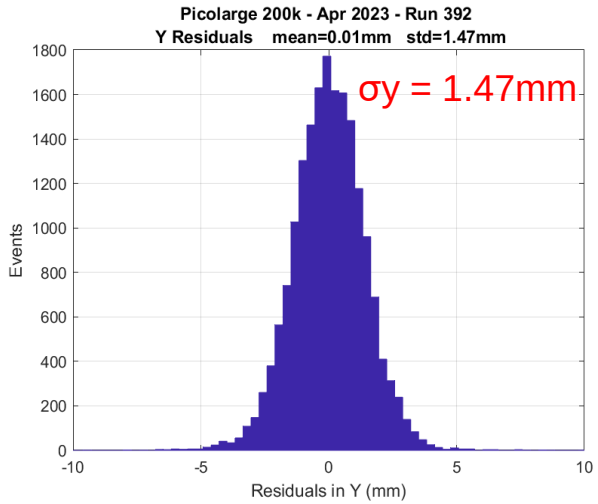
- Being centered on the central pad with MPC-PMT
  - Record all pad signals in the meantime to observe signal spreading











alexandra.kallitsopoulou@cea.fr

Prototype Comparison

alexandra.kallitsopoulou@cea.fr

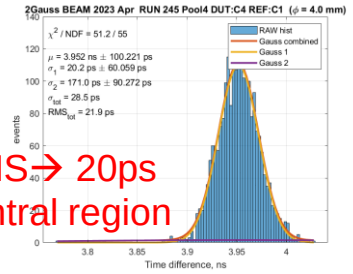
PICOSEC
Micromegas

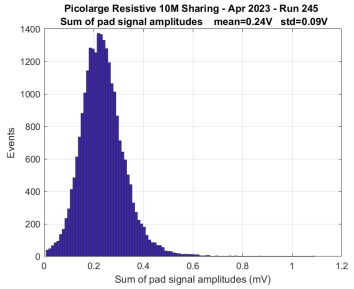
Prototype Comparison

université PARIS-SACLAY

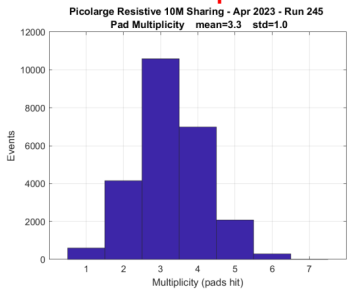
7-pad 10MΩ - resistive sharing - 275/550

RMS→ 20ps
central region

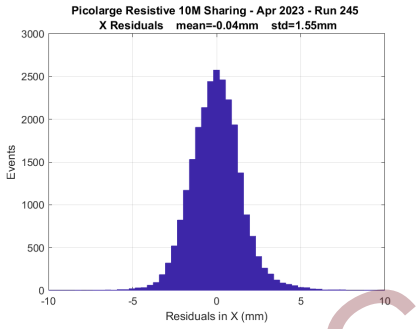




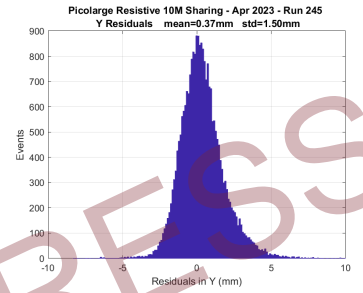
Mean active pads = 3

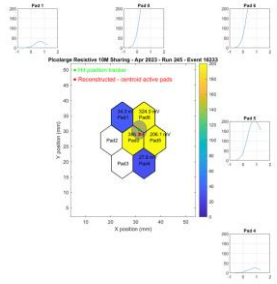


σx = 1.5mm



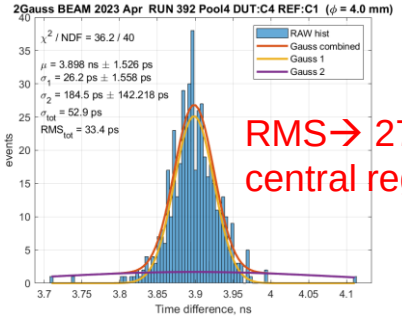
σy = 1.55mm

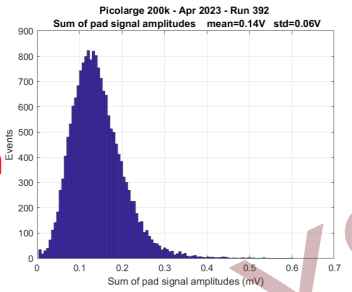




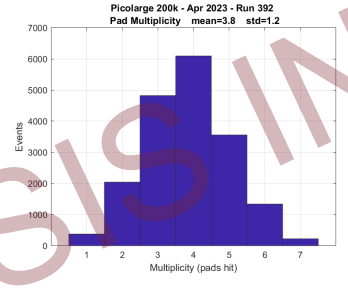
7-pad 200kΩ - resistive sharing - 275/550

RMS→ 27ps
central region

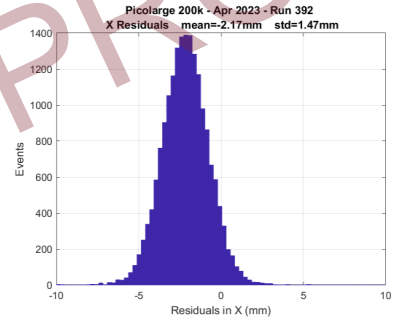




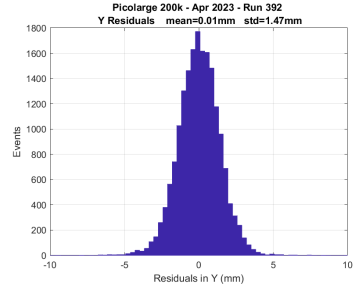
Mean active pads =4

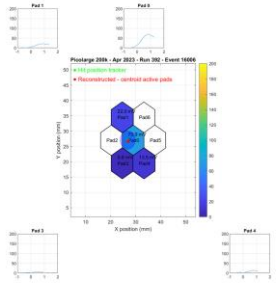


σx = 1.47mm



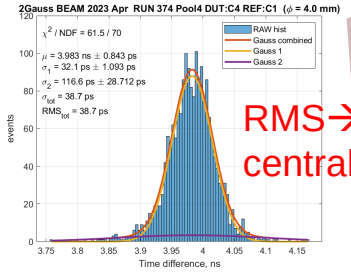
σy = 1.47mm

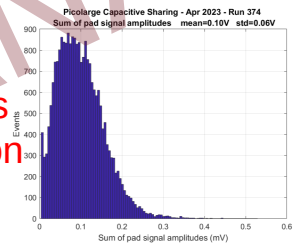




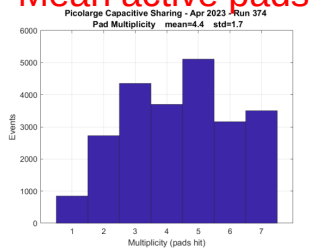
7-pad 10MΩ - capacitive sharing - 275/570

RMS→ 33ps
central region

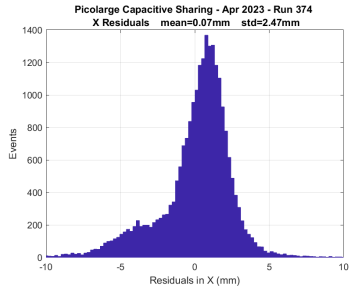




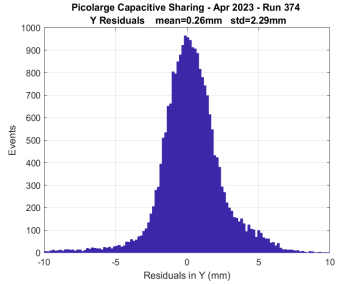
Mean active pads =5

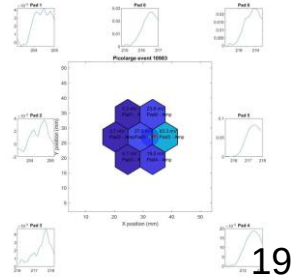


σx =2.47mm



σy = 2.29mm





alexandra.kallitsopoulou@cea.fr

7-pad resistive sharing

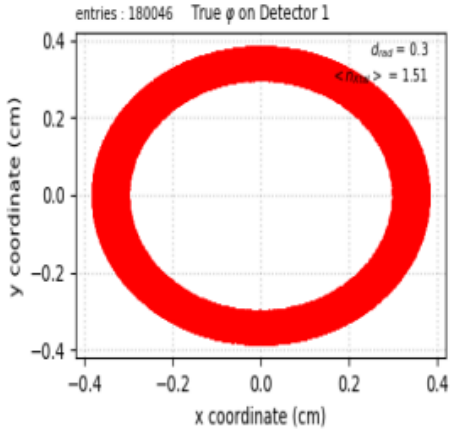
Tilted detector

alexandra.kallitsopoulou@cea.fr

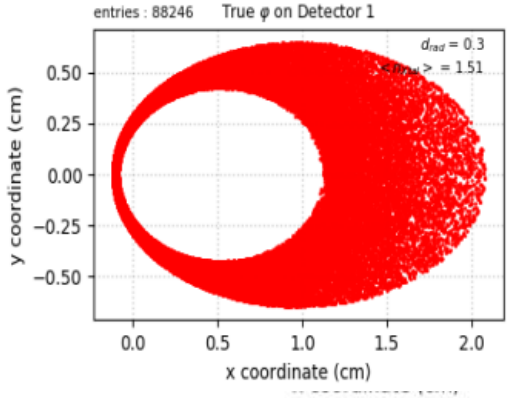
7-pad 10M CsI photocathode, aligned with central pad - tilted

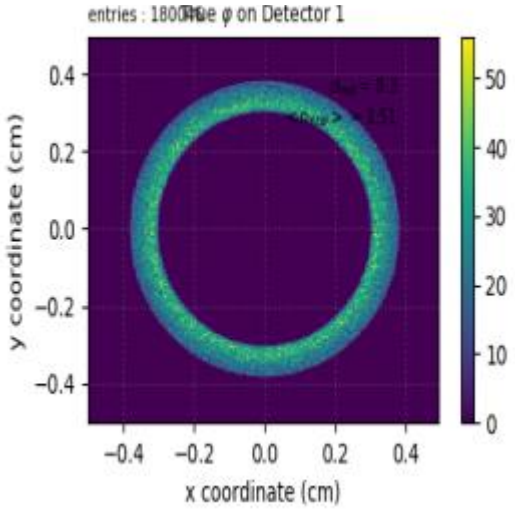
Based on Simulation Studies

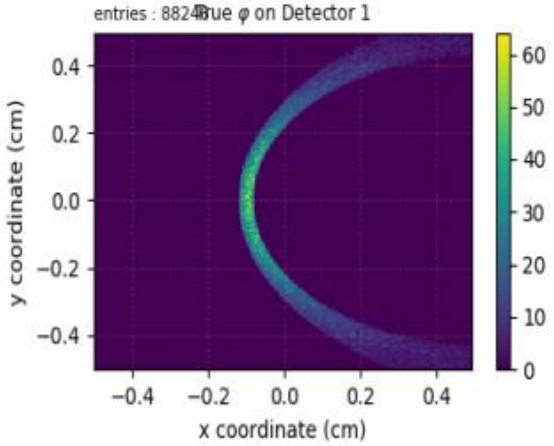
$\theta_{cosmic} = 0°, \beta = 1$
$n_{rad} = "true"$



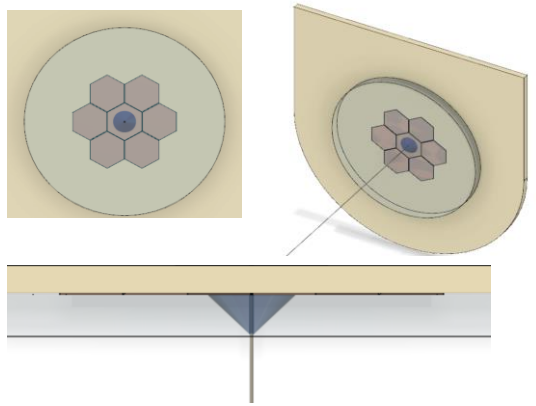
$\theta_{cosmic} = 30°, \beta = 1$
$n_{rad} = "true"$



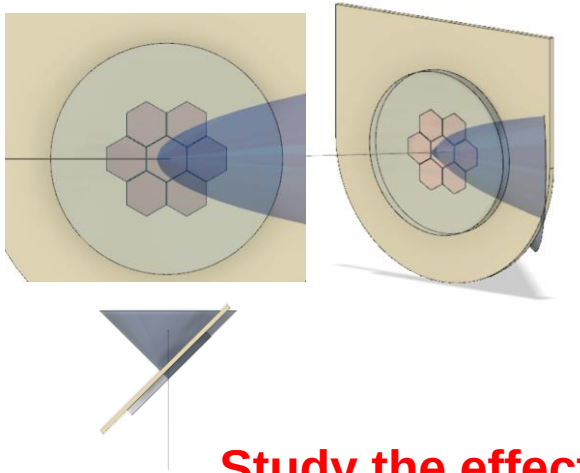


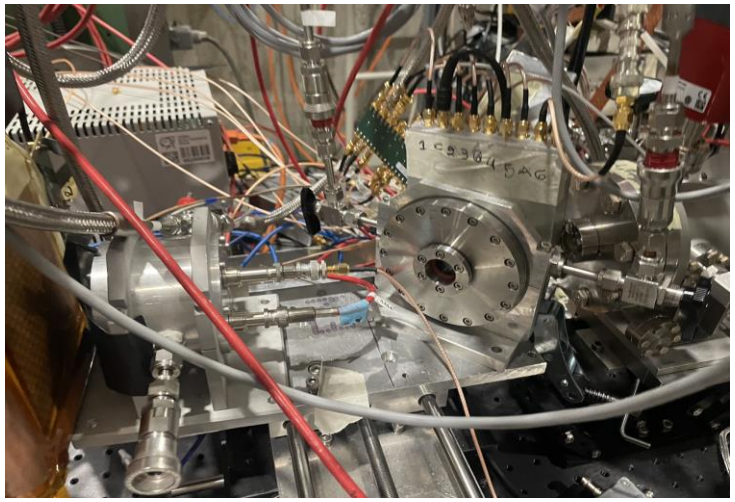


0 degree tilt



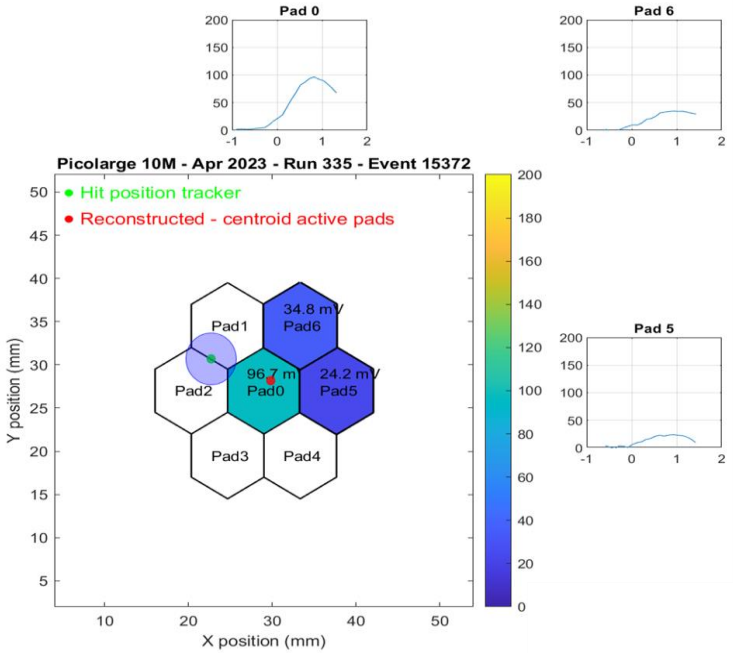
45 degrees tilt

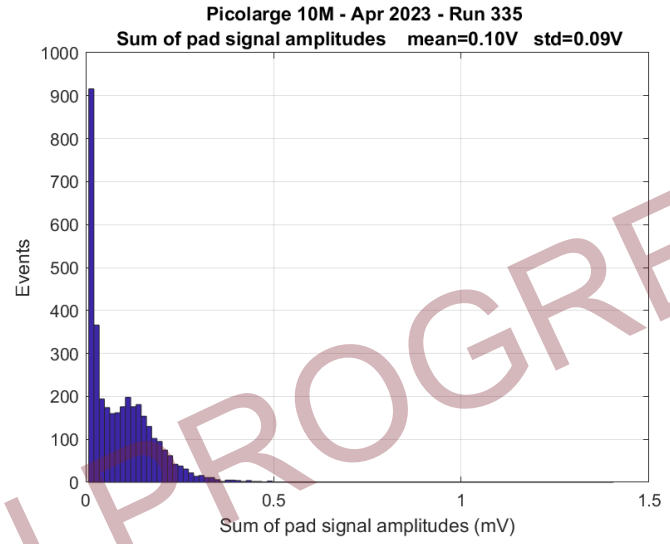


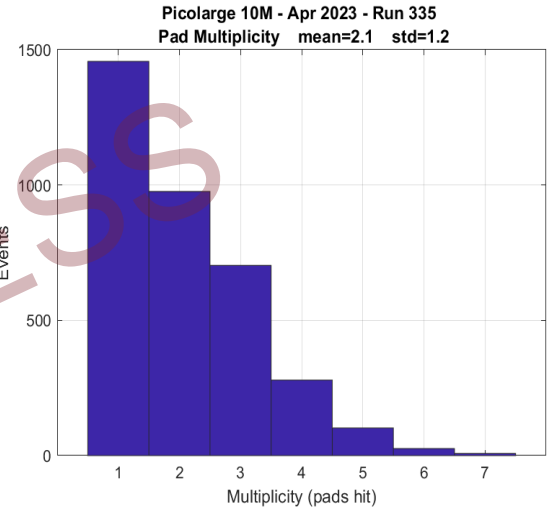


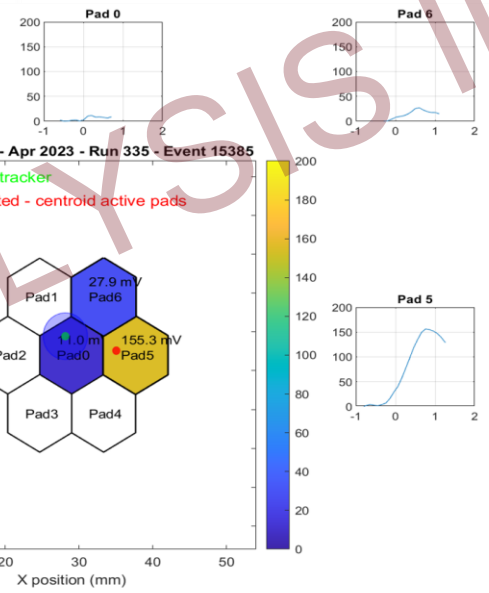
Study the effect of angle on signal sharing

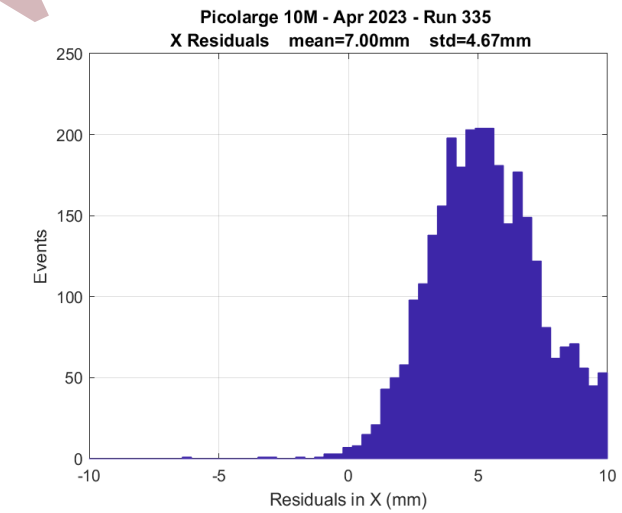
7-pad 10MΩ CsI photocathode - tilted

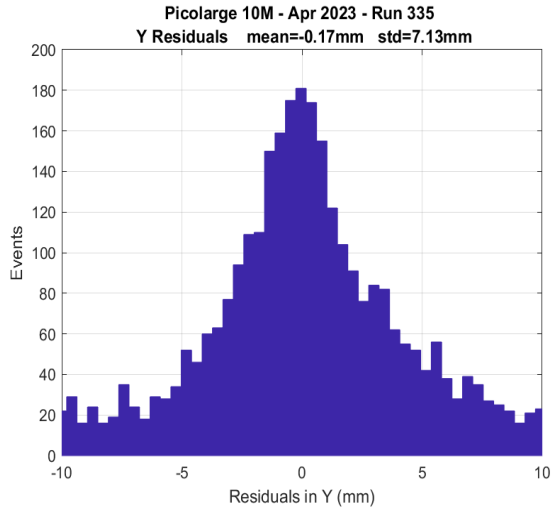












alexandra.kallitsopoulou@cea.fr

In the end it's all a matter of timing

Thank you!