Precise and fast timing with PICOSEC Micromegas:

towards a higher technology readiness level for future HEP applications

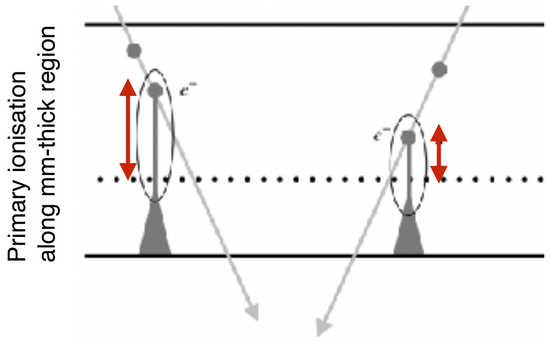
Florian M. Brunbauer
on behalf of the EP-DT-DD GDD team and the PICOSEC Micromegas collaboration

EP R&D Day, November 11, 2021

Precise timing with MPGDs

MicroPattern Gaseous Detectors provide high gain, robustness and allow for large area coverage but timing resolution is inherently limited by **timing jitter** introduced by ionisation along **gaseous active volumes**.

Conventional MPGDs

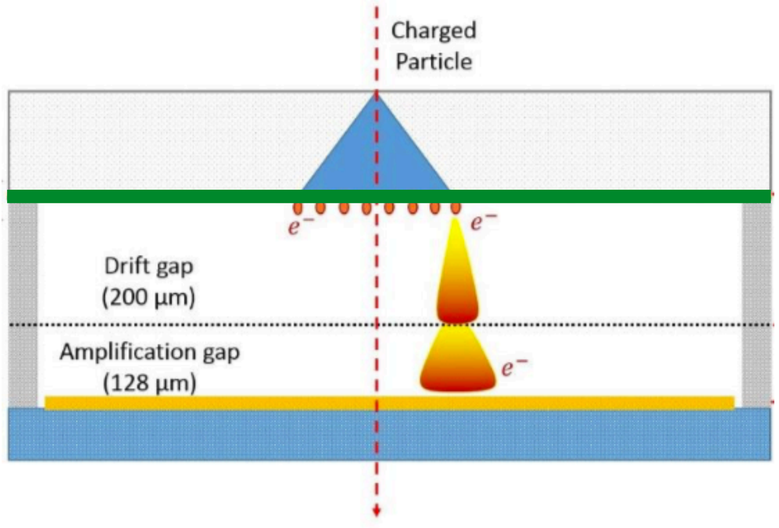


Giomataris Y. et al., NIMA 376 (1996) 29

Timing jitter of ≈ ns

PICOSEC Micromegas

Primary electrons → minimised time jitter



https://doi.org/10.1016/j.nima.2018.04.033

Cherenkov radiator
+
Photocathode
+
Micromegas

↓

All primary electrons produced at photocathode → well-defined location & time

Timing jitter of ≈ **tens of ps**

PICOSEC precise timing detectors

Tileable multi-channel detector modules for larger area coverage

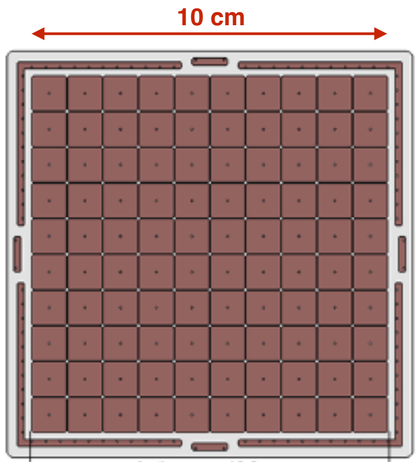
Robustness
- Resistive Micromegas
- Robust photocathodes

Integration
- Mechanics to preserve planarity
- Tileing and sealed detectors

Electronics
- Signal routing and sharing
- Dedicated fast preamplifiers
- Multi-channel digitisers

Single pad (2016)
⌀1 cm

Multi pad (2017)
⬡ 1 cm



10x10 module
▫ 1 cm

PICOSEC precise timing detectors

Tileable multi-channel detector modules for larger area coverage

Robustness
- Resistive Micromegas
- Robust photocathodes

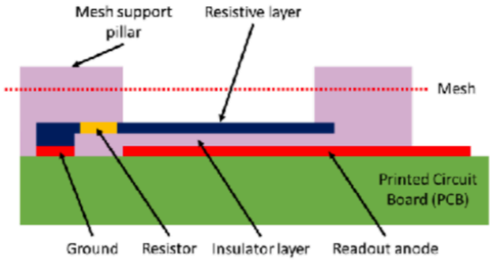
Integration
- Mechanics to preserve planarity
- Tileing and sealed detectors

Electronics
- Signal routing and sharing
- Dedicated fast preamplifiers
- Multi-channel digitisers

Resistive Micromegas

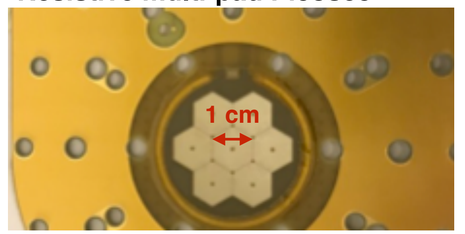
Resistive layers limit the destructive effect of discharges. Different resistive readout approaches (layer, discrete, resistivities 10kΩ/sq - 80MΩ/sq) were evaluated.

- Good timing performance of **σ = 41ps**
- Stable operation in intense **Pion beams**
- Sharing of signals in **multi-pad resistive** detectors



T. Alexopoulos et al., NIMA **640** (2011) 110-118

Resistive multi-pad Picosec

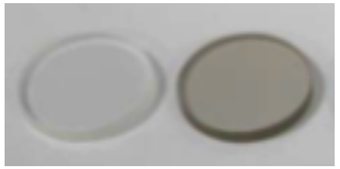


T. Papaevangelou, L. Sohl, CEA Saclay

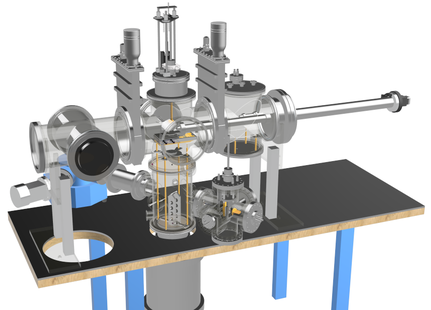
Robust photocathodes

CsI is baseline photocathode but suffers from humidity and ion back flow. Alternatives explored and validated in test beams.

- Up to σ = 34ps with **DLC** in test beam campaign + large DLC photocathode used in multi-channel prototype
- Dedicated **ASSET setup** for QE and ageing studies
- Study of **alternative photocathode** materials (DLC, B_4C, nanodiamonds) and ion-bombardment robustness



https://indico.cern.ch/event/709670/contributions/3020862/attachments/1672921/2684467/



PICOSEC precise timing detectors

Tileable multi-channel detector modules for larger area coverage

Robustness
- Resistive Micromegas
- Robust photocathodes

Integration
- Mechanics to preserve planarity
- Tileing and sealed detectors

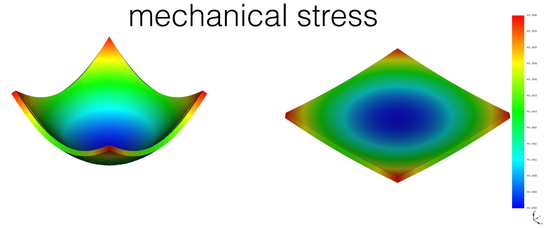
Electronics
- Signal routing and sharing
- Dedicated fast preamplifiers
- Multi-channel digitisers

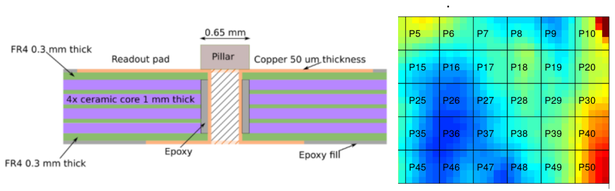
Mechanics to preserve planarity

Precisely maintained preampfification gap thickness is crucial to minimise signal arrival time differences which can degrade timing resolution.

- Hybrid ceramic+FR4 PCB for rigidity implemented in MPT workshop achieving **planarity** on the level of **≈10μm**
- Excellent timing response across **10x10cm²**

Simulation of **PCB deformation** under mechanical stress





Integration on **ceramic/FR4** PCB with planarity <10μm across 10x10cm²

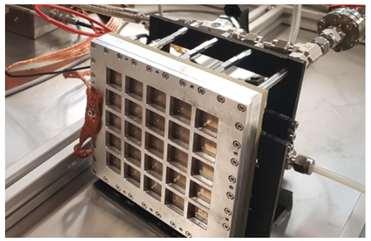
Antonija Utrobičić

Tileing and sealed detectors

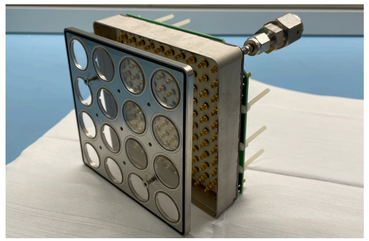
Compact detector vessels with 10x10cm² active area with systems (HV, bias, readout) on the back of module.

- **4-side tileable** detector module prototypes with **100 channels** (1x1 cm² pads) validated in test beam campaigns
- **Hermetically sealed detector** module being developed with support from EN-MME & EP-DT-EO: simplified services, increased fill factor, cleanliness for photocathode)

Detector module



Sealed vessel



Marta Lisowska

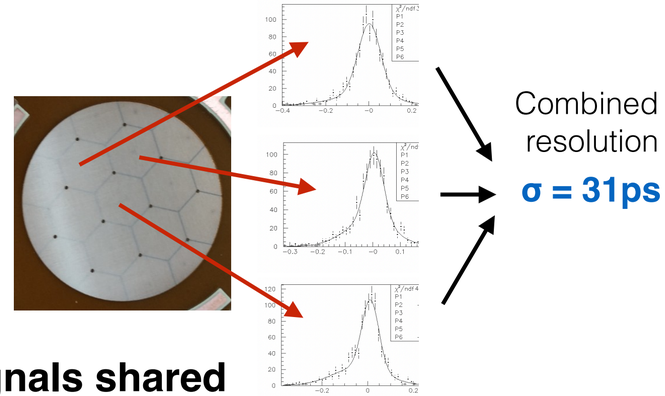
PICOSEC precise timing detectors

Tileable multi-channel detector modules for larger area coverage

Robustness
- Resistive Micromegas
- Robust photocathodes

Integration
- Mechanics to preserve planarity
- Tileing and sealed detectors

Electronics
- Signal routing and sharing
- Dedicated fast preamplifiers
- Multi-channel digitisers



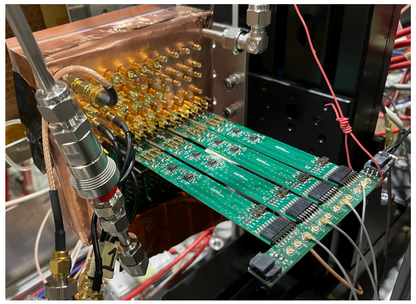
Signal routing and sharing

Signals from readout pads routed through **multi-layer PCBs** to preamplifiers.
- Good timing resolution can be preserved for **signals shared** across multiple readout pads of different geometries

Dedicated fast preamplifiers

Custom development of preamplifiers dedicated for precise timing PICOSEC detectors.

- Evaluation of different approaches and implementations to **preserve timing** precision
- Readout of multi-channel detectors with **preamplifier cards** integrated on back of PICOSEC modules



Custom preamp. cards on 10x10 module in test beam

Multi-channel digitisers

SAMPIC waveform TDC evaluated for timing performance with PICOSEC Micromegas detectors
- Good reproduction of timing performance measured at **8.5 GS/s sampling frequency**
- Evaluation of alternative readout approaches (e.g. multi-threshold ToT ongoing)

16 channel SAMPIC (D. Breton et al.)

Picosec Micromegas

The **PICOSEC detection concept** has demonstrated **24 ps** for MIPs and can provide precise ps-timing to meet the challenging timing needs of future HEP experiments.

Resistive Micromegas, robust **photocathodes,** sealed prototypes and tileable **multi-pad modules** and **scalable readout electronics** are developed and validated in beam test campaigns.

Detector prototypes with **optimisations for different use cases** under study and in preparation.

Future perspectives

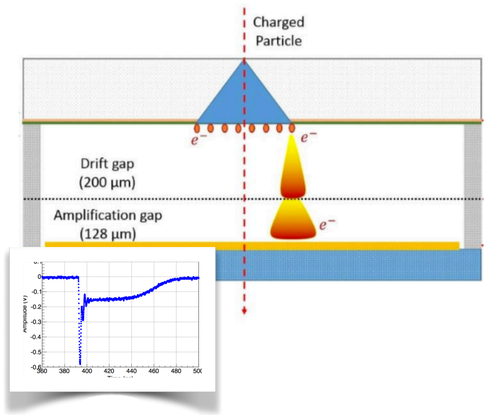
Spatial resolution: exploiting signal sharing with resistive anodes, adjusting pad size

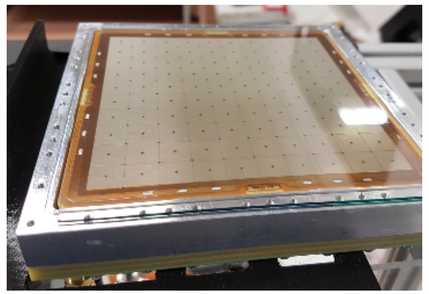
Robust photocathodes: alternative materials, protection layers

Optical readout: e.g. SiPMs for granularity

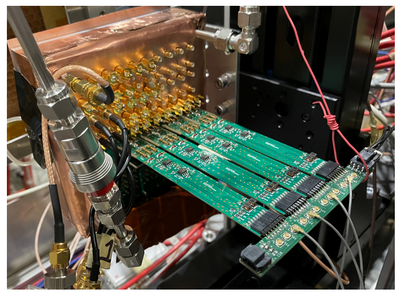
Amplification structure: optimised double/single gaps, mesh geometries/ technologies, resistive multi-pad

Electronics: waveform digitisation, threshold based timing

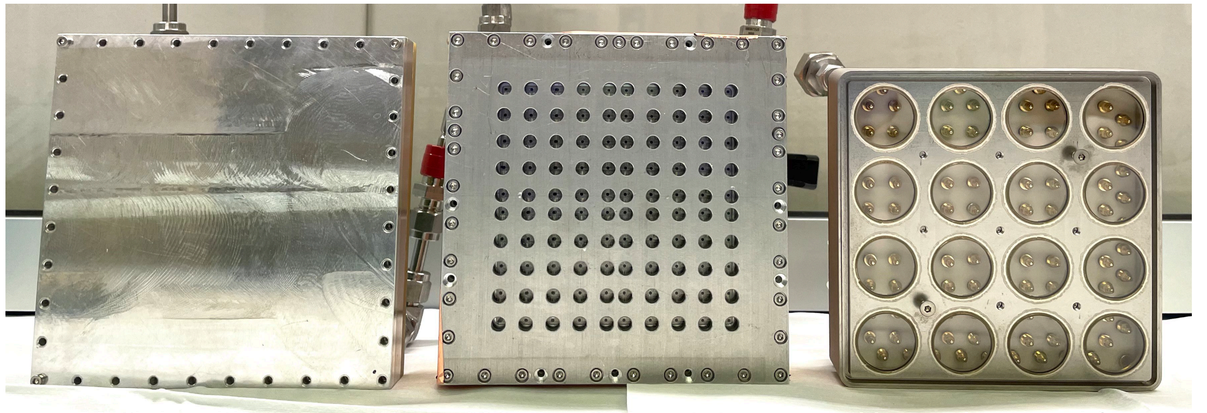




10x10 pad Picosec Micromegas detector



Preamplifier cards



Module with robust DLC photocathode

100 channel prototype with CsI photocathode

Hermetic vessel for higher fill factor tileing