PICOSEC Micromegas precise-timing gaseous detectors and studies on robust photocathodes

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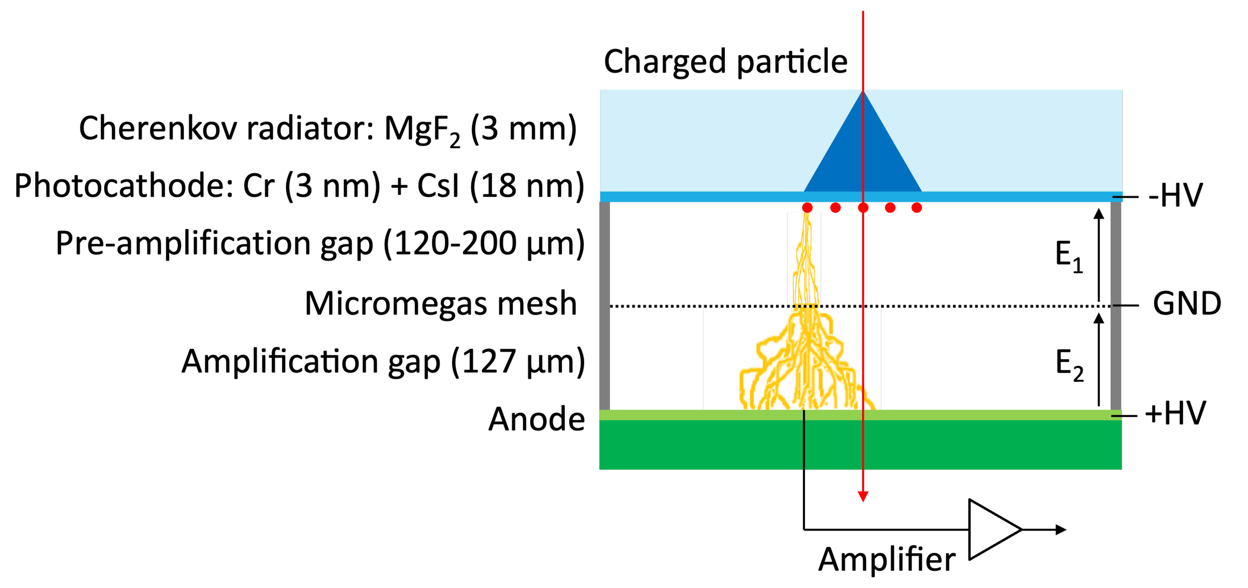
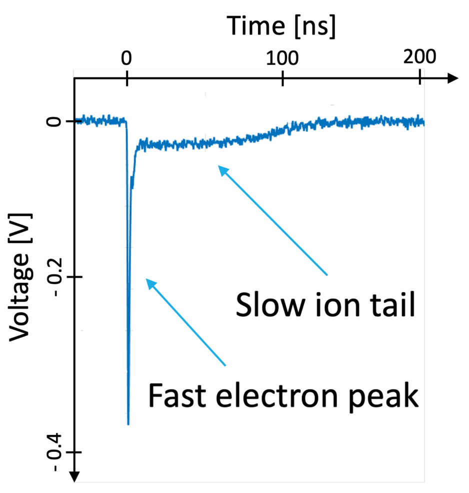
1. Introduction

The challenges of future HEP experiments have aroused intense interest in advancing detector technologies with good time resolution. **First PICOSEC Micromegas (MM) single-pad prototypes have demonstrated a time resolution below $\sigma = 25$ ps, prompting ongoing developments to adapt the concept for physics applications.** The objective is to build robust multi-channel detectors suitable for large-area detection systems.

2. Detection concept

- **PICOSEC Micromegas:** a gaseous detector aiming at achieving **a time resolution of tens of picoseconds** for MIPs

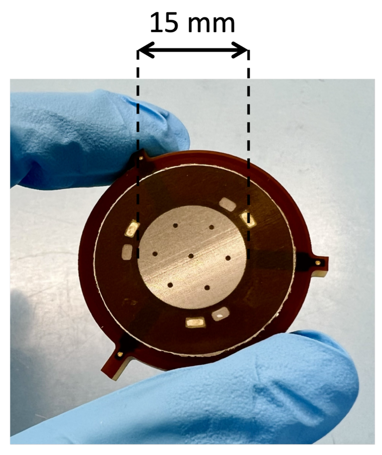




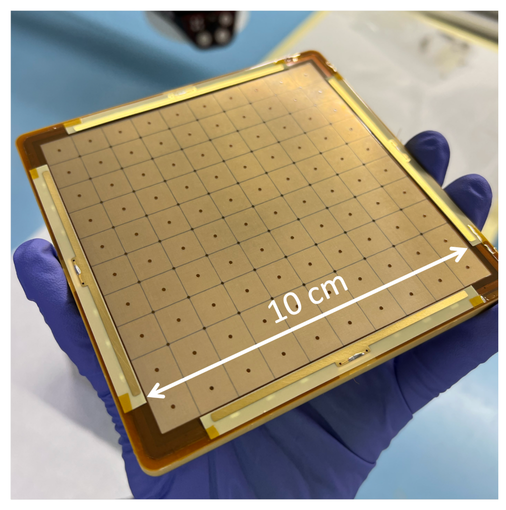
- **Typical PICOSEC waveform:** fast electron peak + slow ion tail
- Rising edge of the electron peak determines a signal arrival time (SAT)

3. Developments towards applicable detector

- **Objective:** robust multi-channel detector modules for large-area coverage
- **Developments:**
  → design optimisation
  → stability and robustness
  → scalable electronics



Single-pad prototype

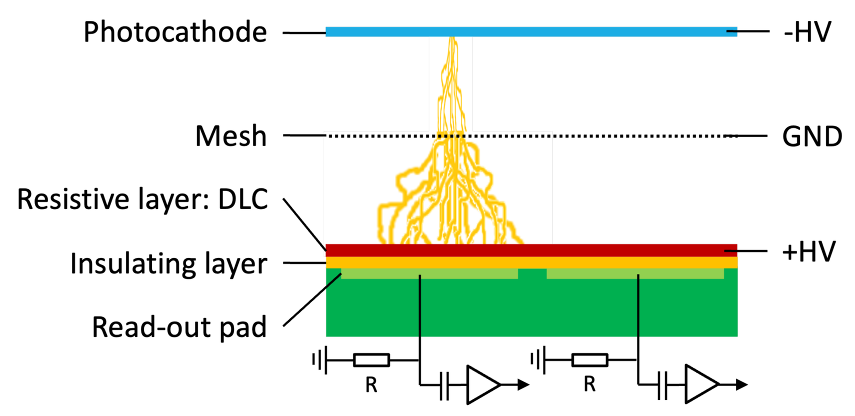


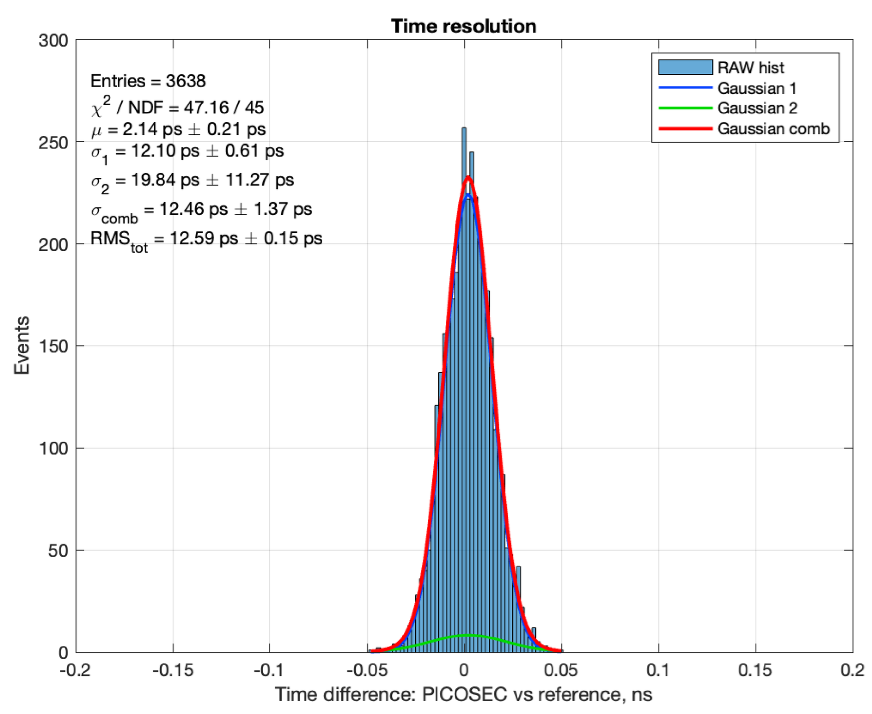
100-channel module

- **Intensive R&D activities**: from simulations and design, through production and assembly, to measurements and analysis
- **Beam campaign:** CERN SPS H4 beam line, 150 GeV/c muon beam
- **Experimental setup:** tracking/triggering/timing telescope
- **Time resolution:** standard deviation of the SAT distribution

4. Resistive Micromegas

- **Resistive Micromegas**
  + protecting detector from highly ionizing events
  + stable operation under intense particle beams
  + better position reconstruction by signal sharing
- **Single-pad resistive MM of 20 MΩ/□** equipped with a CsI photocathode obtained equivalent precision to a non-resistive prototype [4], exhibiting **an excellent time resolution of $\sigma \approx 12$ ps**
- First measurements of a single-pad resistive detector assembled with an **amplifier integrated on the outer PCB** showed comparable timing properties

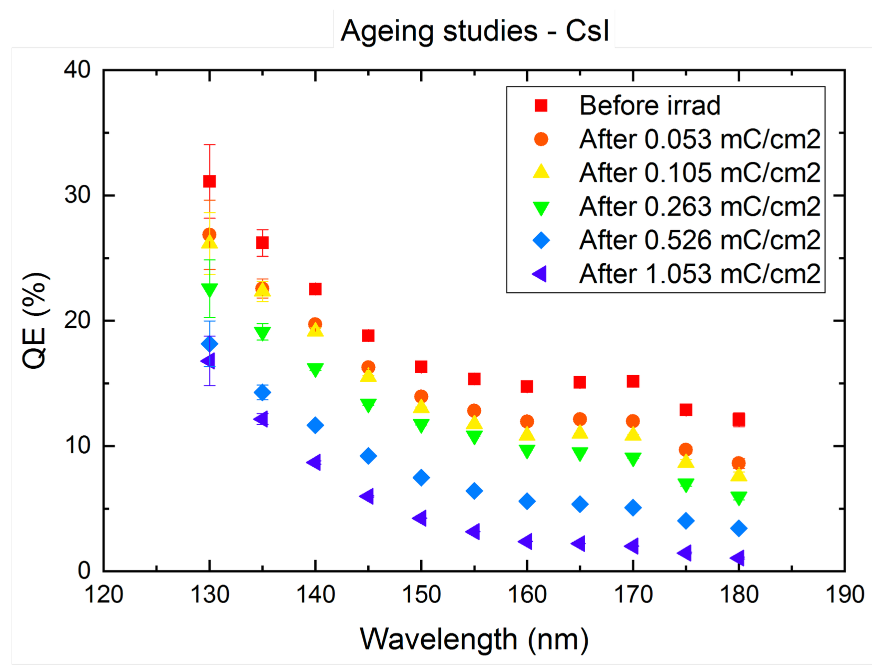




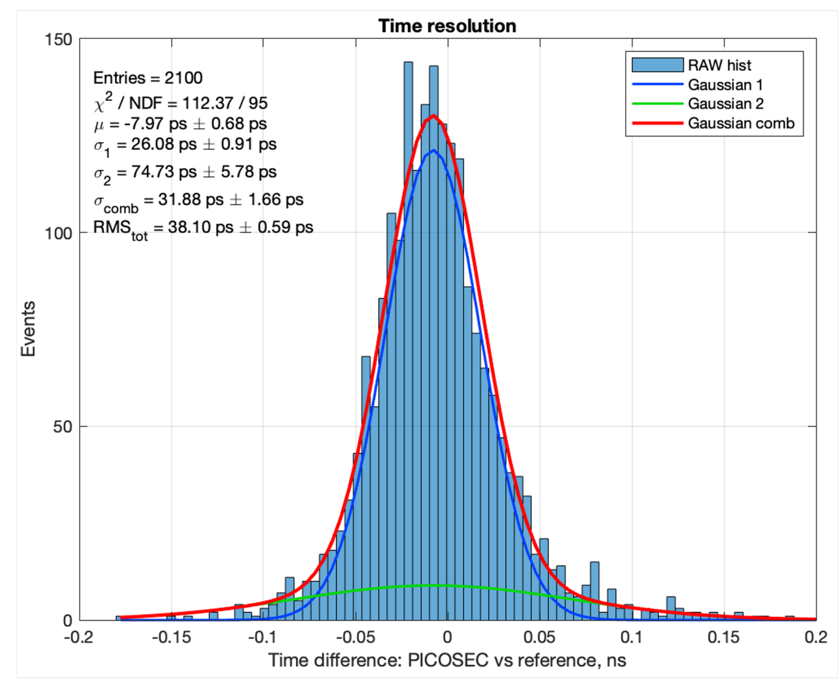
- **Next step:** production of a high-rate 10×10 cm^2 MM with double-layer DLC for charge evacuation and evaluation of rate capability

5. Robust photocathodes

- **First prototype: CsI**
  + high QE (~12 p.e./µ) in comparison to other materials
  − vulnerable to damage from IBF, discharges and humidity
- **Alternative photocathodes**: B_4C, DLC, carbon-based nanostructures



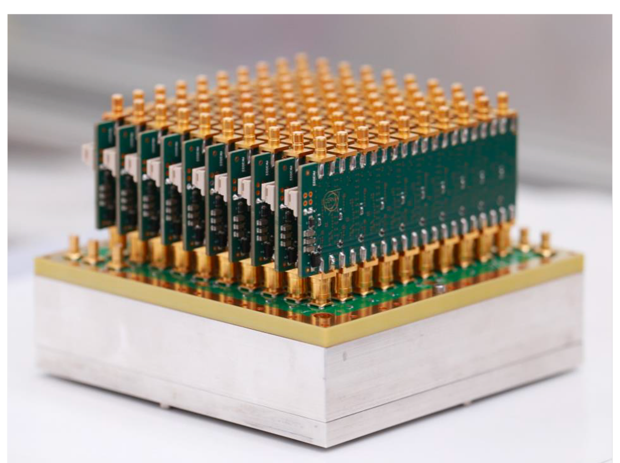
- Measurements conducted with **B_4C photocathodes** exhibited the best time resolution of $\sigma \approx 35$ *ps* for the 9 nm layer [3]
- **First depositions of DLC photocathodes** carried out at **the CERN MPT workshop**
- The best results for a single-pad detector achieved with a **1.5 nm DLC**, yielding **a time resolution of $\sigma \approx 32$ ps**

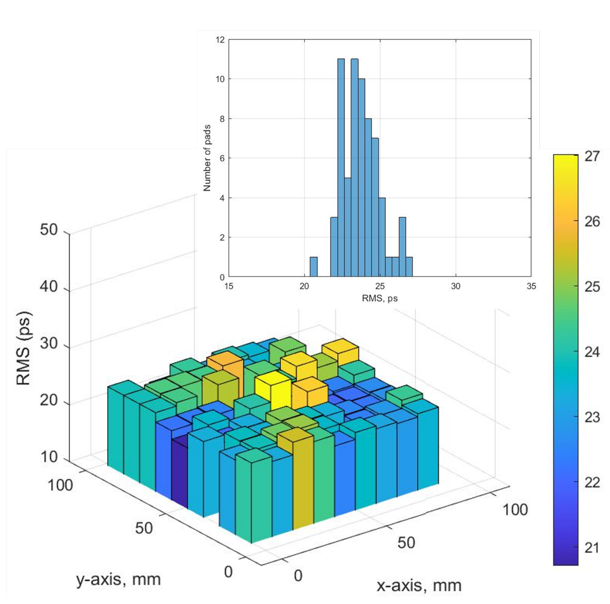


- **Next step:** evaluation of a 10×10 cm^2 robust photocathode, incorporating a conductive interlayer to prevent a voltage drop, to be tested with a 100-channel prototype and a SAMPIC digitiser

6. Multipad: 100-channel module

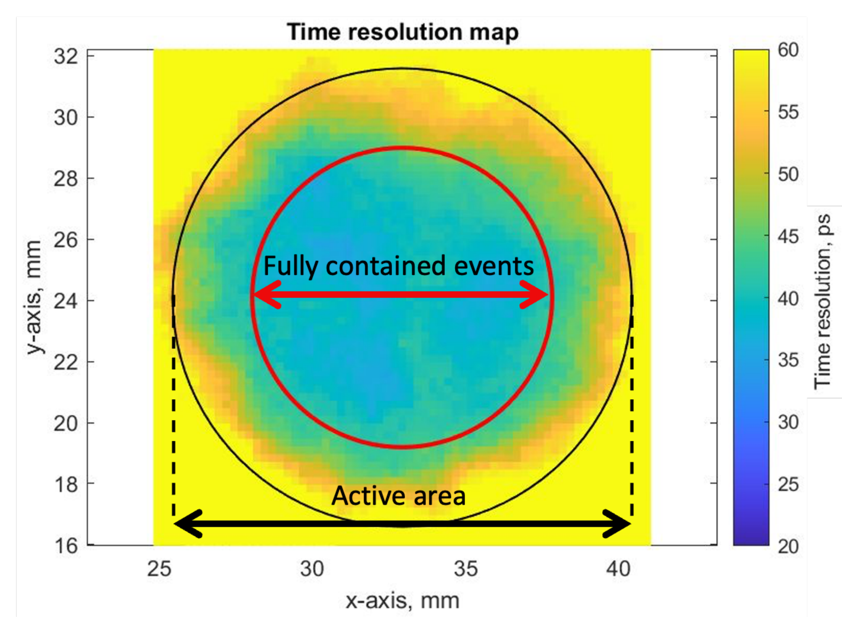
- **Multipad**: a 100-channel PICOSEC MM module with a uniform thickness (< 10 µm) of the pre-amplification gap
- Excellent timing performance of the single-pad proof-of-concept transferred to **a 100-channel prototype**, exhibiting **a time resolution of $\sigma \approx 18$ ps** for individual pads [1, 2]
- **Multipad with a 10×10 cm^2 resistive MM 20 MΩ/□** yielded a time resolution of $\sigma \approx 20$ *ps* for individual pads [3]
- **Scalable electronics**: successful readout of multiple channels using a complete readout chain consisting of dedicated amplifiers and a SAMPIC digitiser [3]





7. Conclusions

- First measurement **combining a single-pad resistive MM, a DLC photocathode and an integrated amplifier** showcased **great performance and outstanding timing properties**
- Efforts dedicated to detector developments enhance the feasibility of the PICOSEC concept for experiments requiring precise timing



References

[1] M. Lisowska *et al.* 2023 *NIM A*, **1046** 167687
[2] A Utrobicic *et al.* 2023 *JINST*, **18** C07012
[3] M. Lisowska *et al.* 2023 *JINST*, **18** C07018
[4] A Utrobicic *et al.* 2023 *RD51 Collab. Meeting*