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

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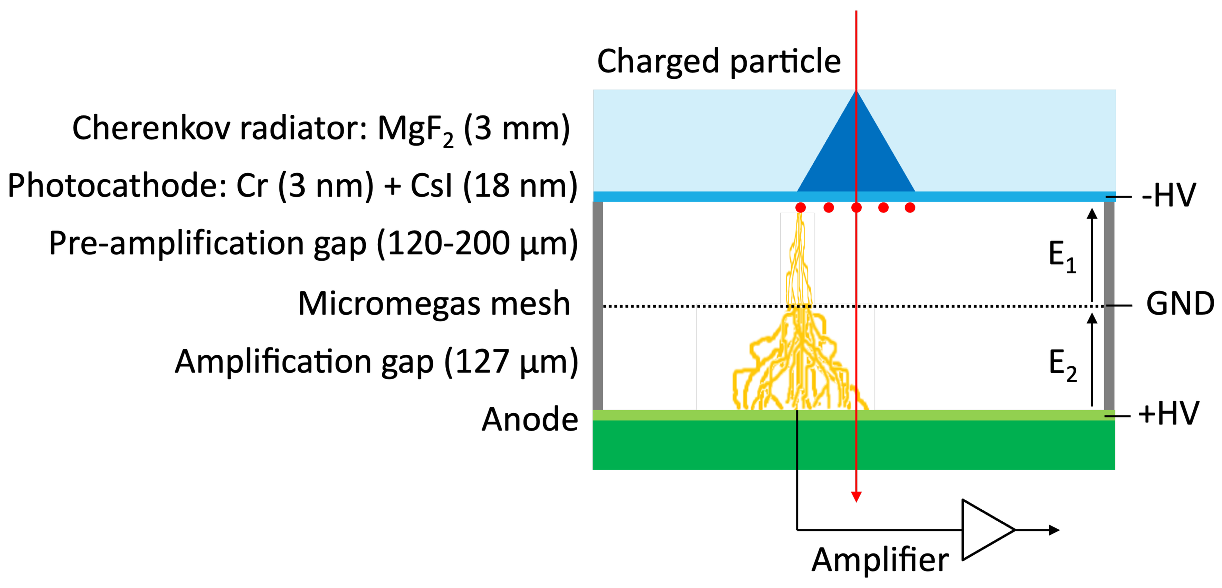
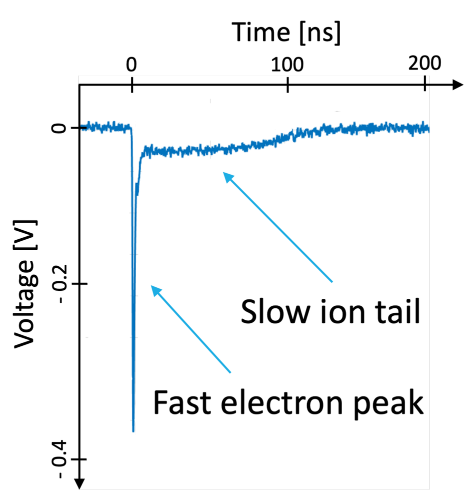
1. Introduction

The challenges of future High Energy Physics 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** [1]**, prompting ongoing developments** [2, 3] **to adapt the concept for physics applications.** The objective is to build robust multi-channel detector modules suitable for large-area detection systems requiring excellent timing precision.

2. Detection concept

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

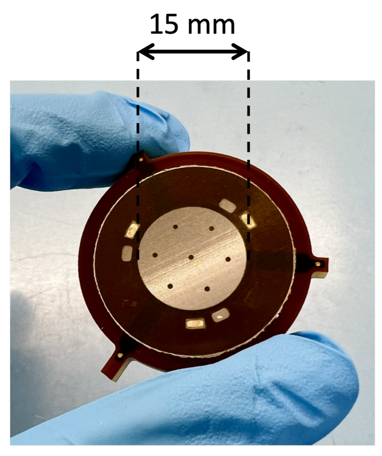




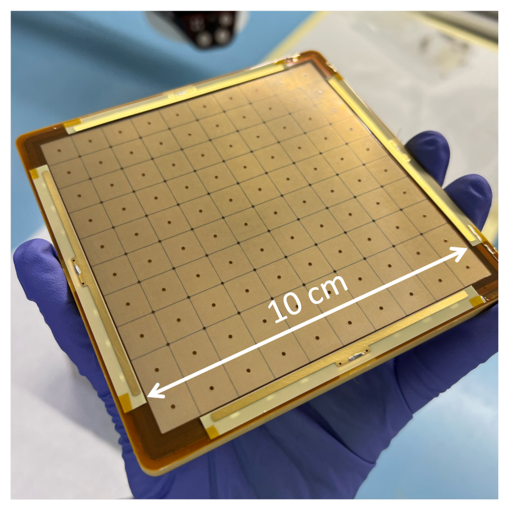
- **Typical PICOSEC waveform:** fast electron peak + slow ion tail
- Rising edge of the electron peak determines a signal arrival time (SAT)

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

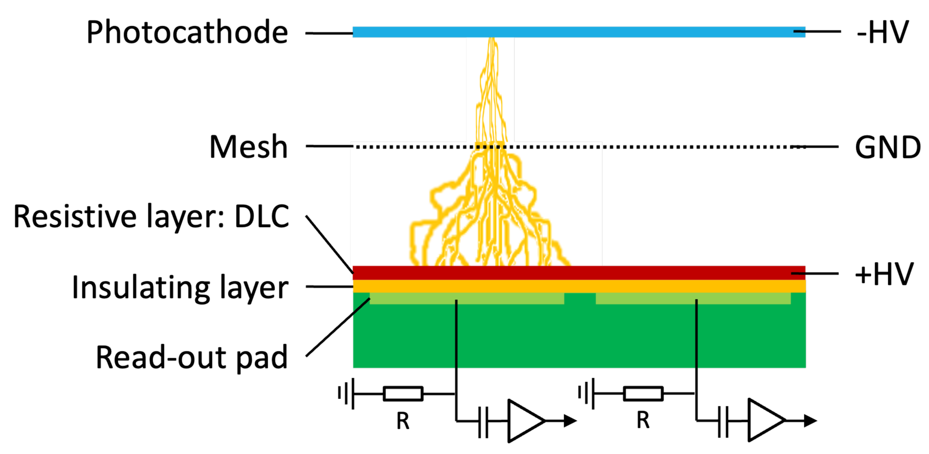


100-channel module

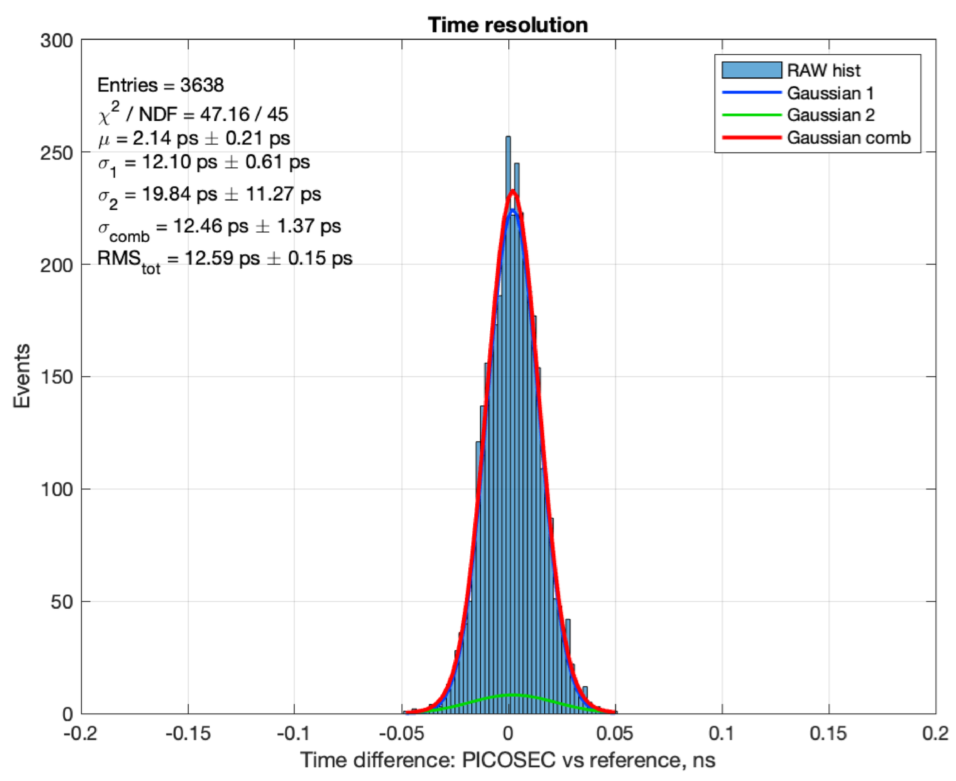
- **Intensive R&D activities**: from simulations and design, through production and assembly, to measurements and analysis
- **Beam campaign:** CERN SPS H4 beam line, 150 GeV/c muon beam
- **Experimental setup:** tracking/triggering/timing telescope
- **Time resolution:** standard deviation of the SAT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

4. Resistive Micromegas

- **Resistive Micromegas**
  Advantages:
  + protecting detector from highly ionizing events
  + stable operation under intense particle beams
  + better position reconstruction by signal sharing



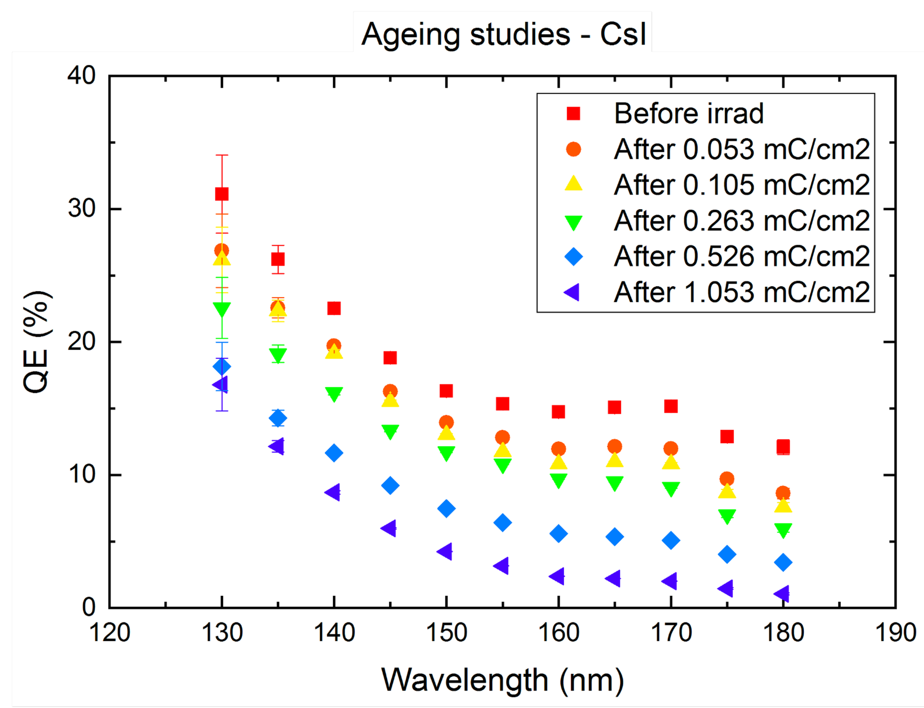
- **Single-pad resistive MM of 20 MΩ/□** equipped with a CsI photocathode obtained equivalent precision to a non-resistive prototype, exhibiting **an excellent time resolution of $\sigma \approx 12$ ps**
- First measurements of a single-pad resistive detector assembled with a **preamplifier integrated on the outer PCB** showed comparable timing properties



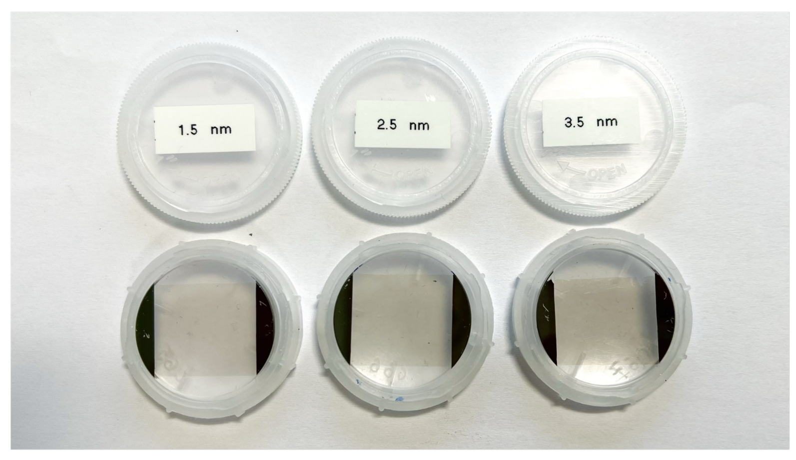
- 100-channel detector with **a 10×10 cm² resistive MM 20 MΩ/□** yielded a time resolution of $\sigma \approx 20$ *ps* for an individual pad [3]
- **Next step:** production of a high-rate 10×10 cm² MM with double-layer DLC for charge evacuation and evaluation of rate capability

5. Robust photocathodes

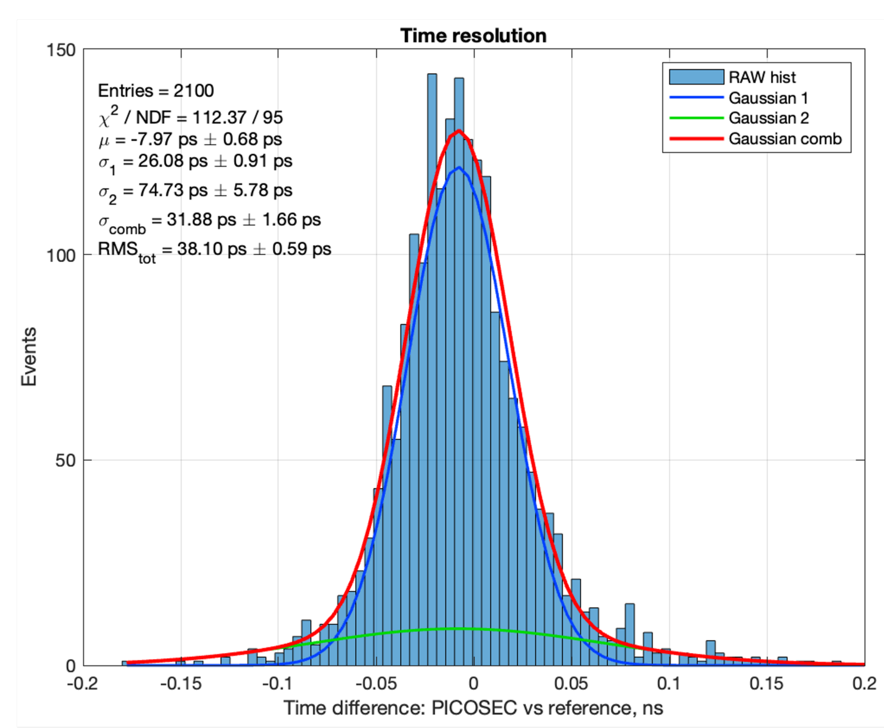
- **First prototype:**
  Cesium Iodide
  + high QE (~12 p.e./µ) in comparison to other materials
  − vulnerable to damage from ion backflow, discharges and humidity



- **Alternative photocathodes**: B_4C, DLC, carbon-based nanostructures
- Measurements conducted with **B_4C photocathodes**, ranging in thickness from 9 nm to 15 nm, exhibited the best time resolution of $\sigma \approx 35$ *ps* for the thinnest layer [3]
- **First depositions of DLC photocathodes** with layer thicknesses ranging from 1.5 nm to 4.5 nm carried out **at the CERN MPT workshop**

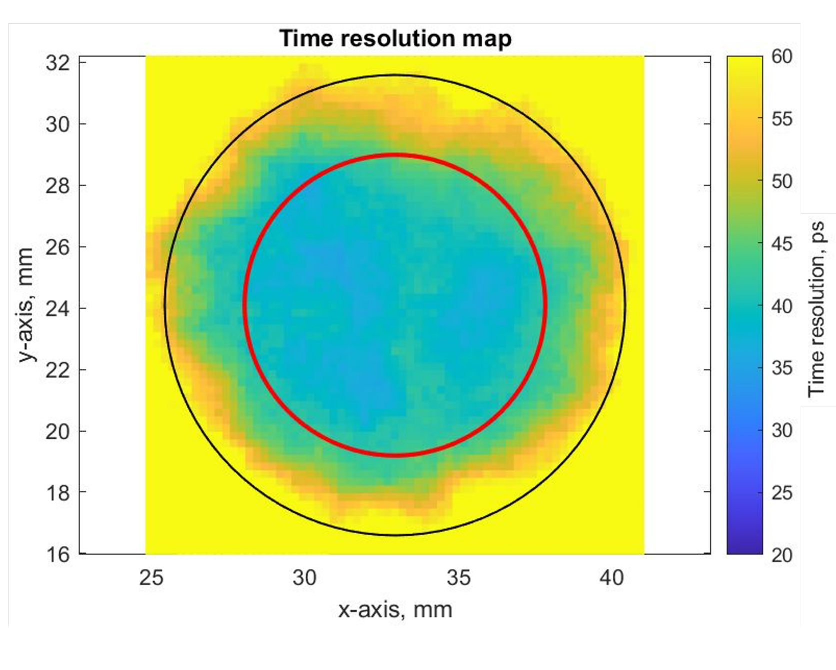


- The best results for a single-pad detector achieved with a **1.5 nm DLC photocathode**, yielding **a time resolution of $\sigma \approx 31$ ps**
- **Next step:** evaluation of a 10×10 cm² robust photocathode, incorporating a conductive interlayer to prevent a voltage drop, to be tested with a 100-channel prototype and a SAMPIC digitiser



6. Conclusions

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



References

[1] J. Bortfeldt *et al.* 2018 *NIM A*, **25** 317-325

[2] M. Lisowska *et al.* 2023 *NIM A*, **1046** 167687

[3] M. Lisowska *et al.* 2023 *JINST*, **18** C07018