R&D of the Picosec detector in the context of the Muon Collider

new gas mixture results

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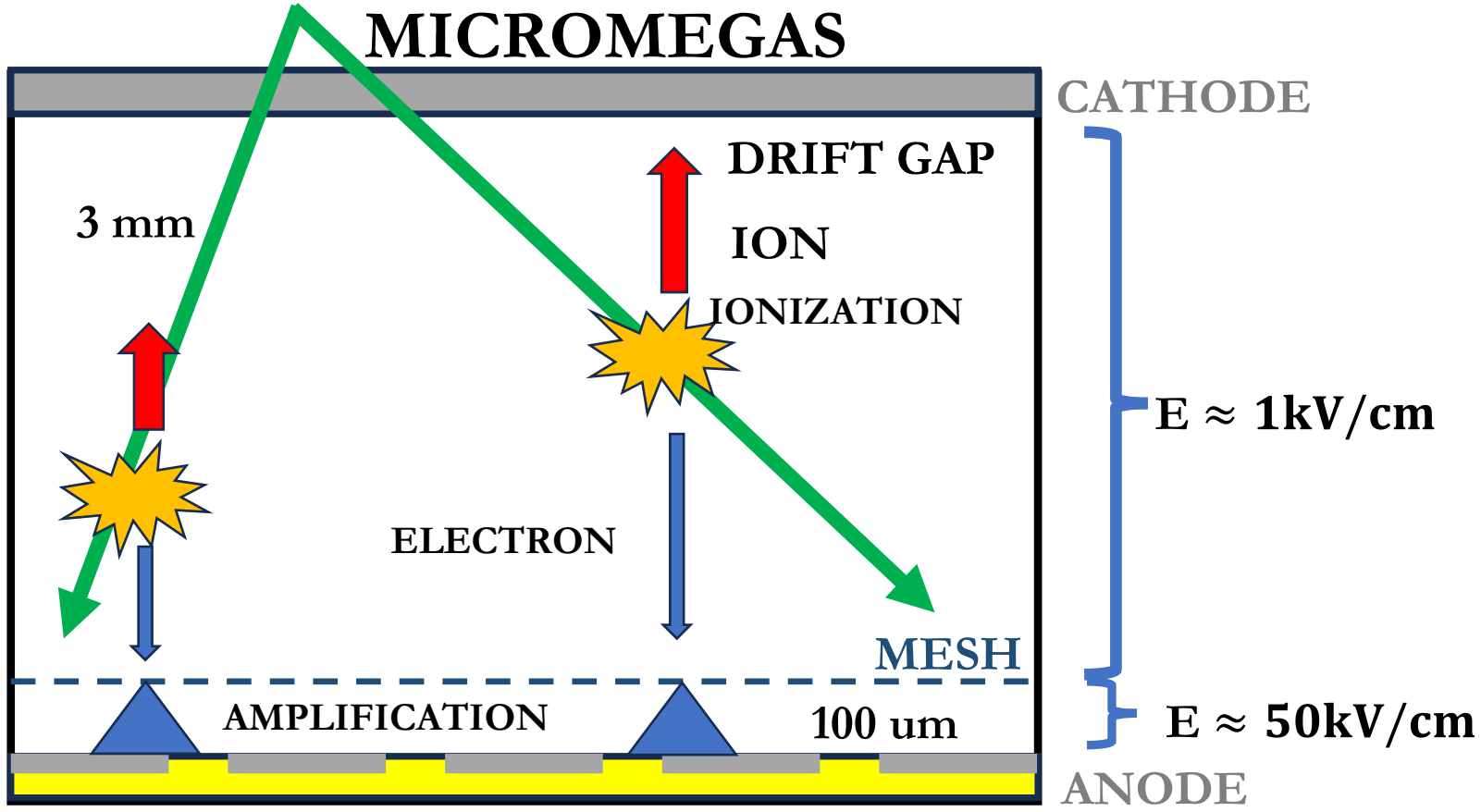
For the Pavia team on behalf of the Picosec Collaboration

Funded by the European Union (EU). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the EU or European Research Executive Agency (REA). Neither the EU nor the REA can be held responsible for them.

Limitation of MPGD time resolution

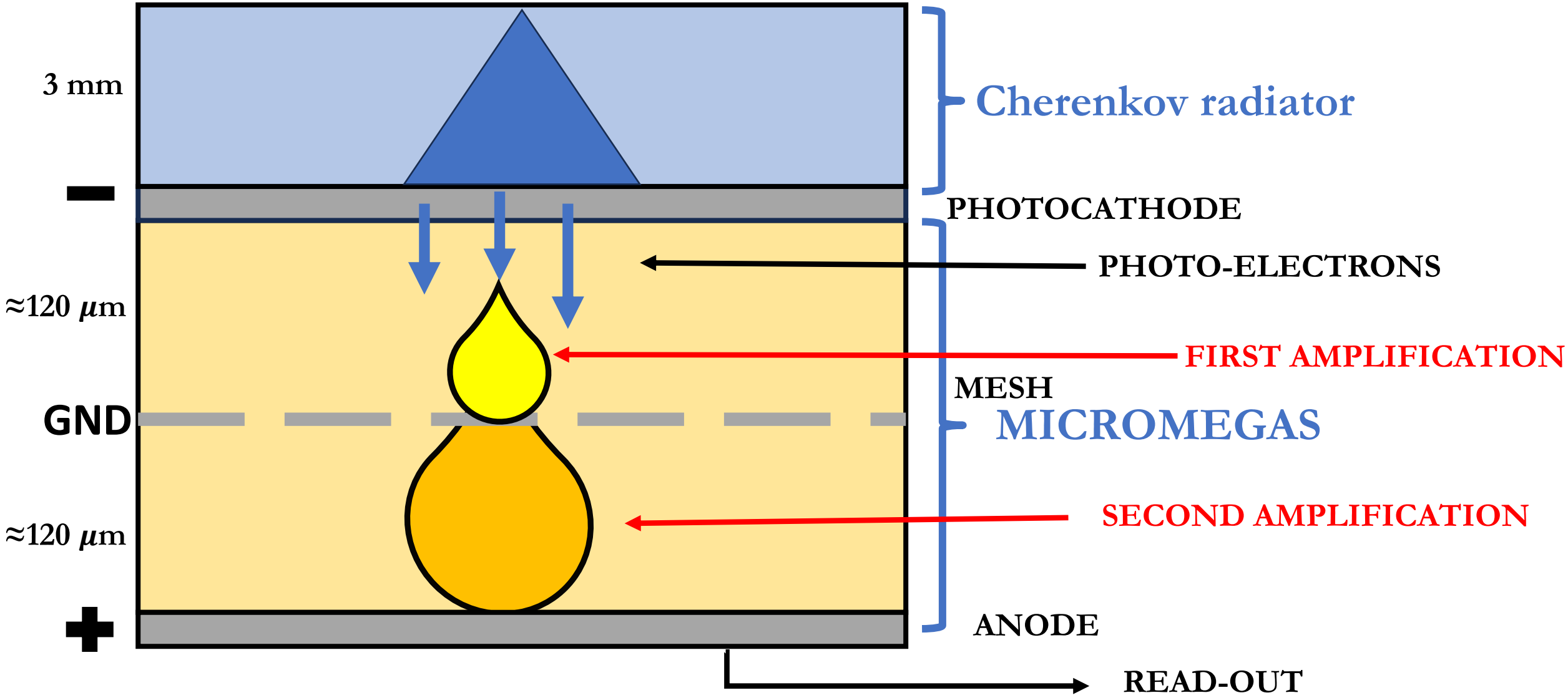


The fluctuations in the position of the ionization occurrence point limit the temporal resolution to few nanoseconds

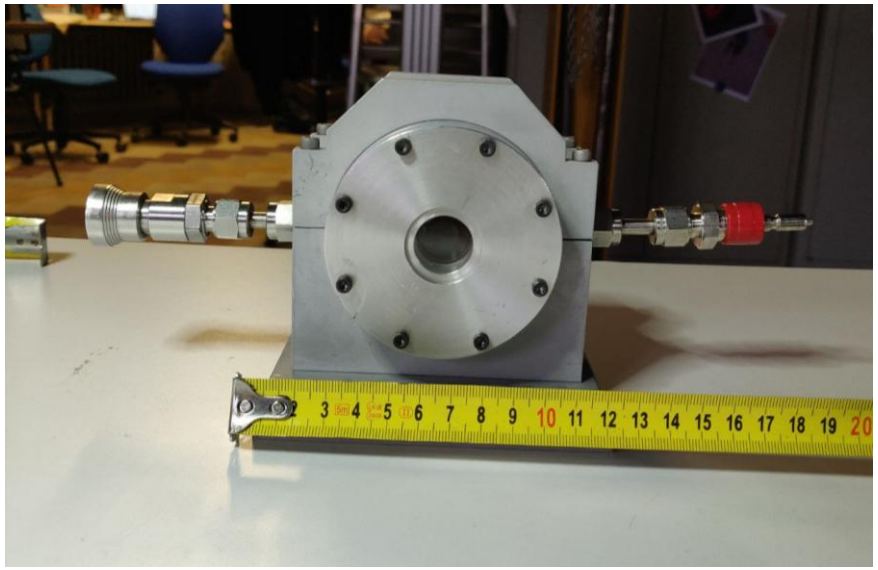
Brunoldi Matteo. "Picosec: optimization of a fast timing detector for applications at a Muon Collider experiment Picosec: ottimizzazione di un rivelatore ad alta risoluzione temporale per applicazioni ad un esperimento al Muon Collider." (2022).

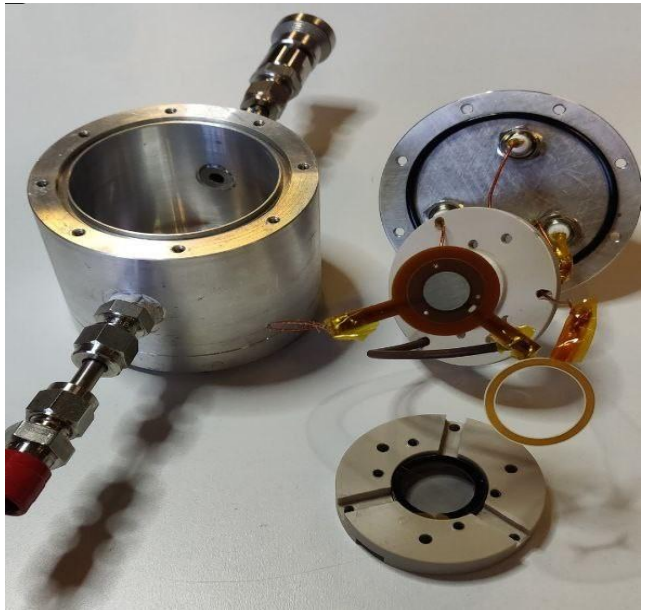
Picosec detector

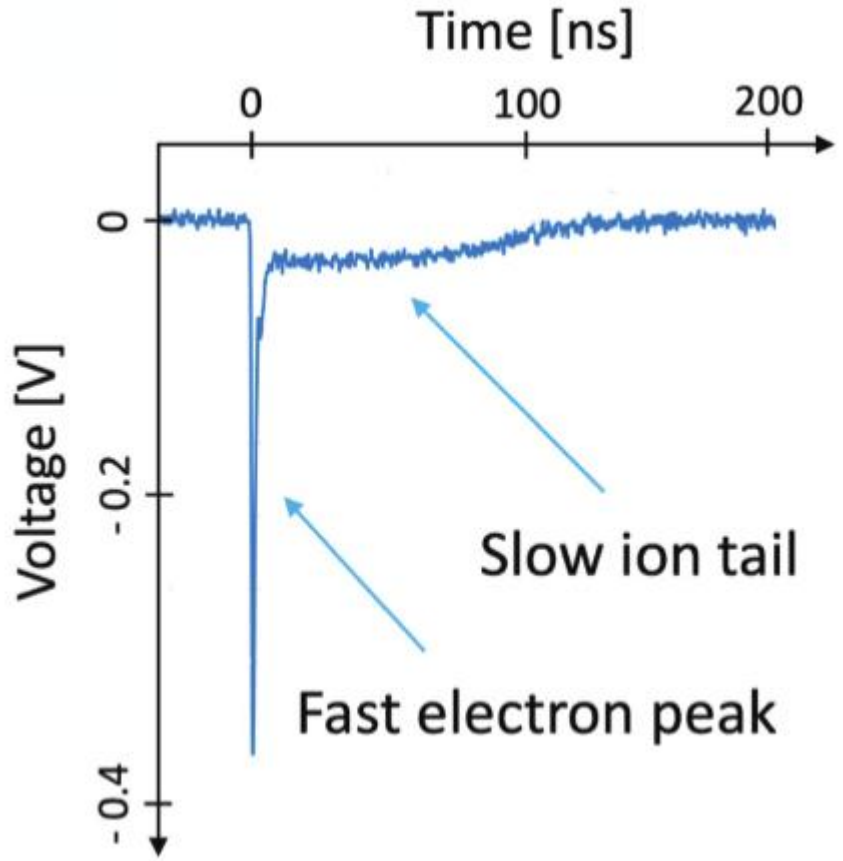
Bortfeldt, J., et al. "PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector." NIM A 903 (2018): 317-325.
link: https://www.sciencedirect.com/science/article/pii/S0168900218305369



Picosec detector used in Pavia



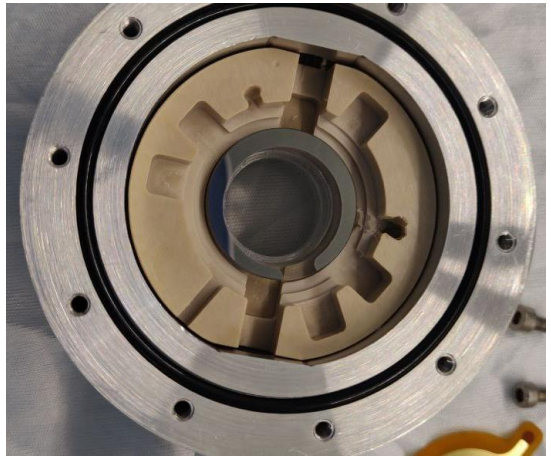


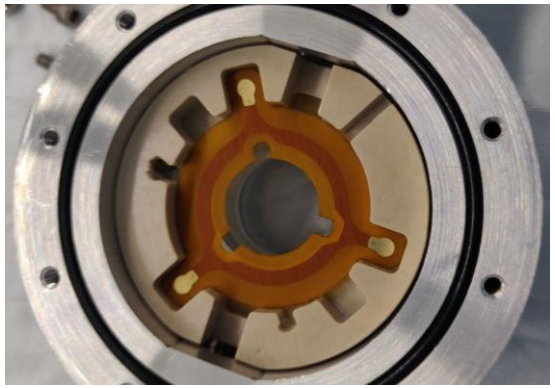


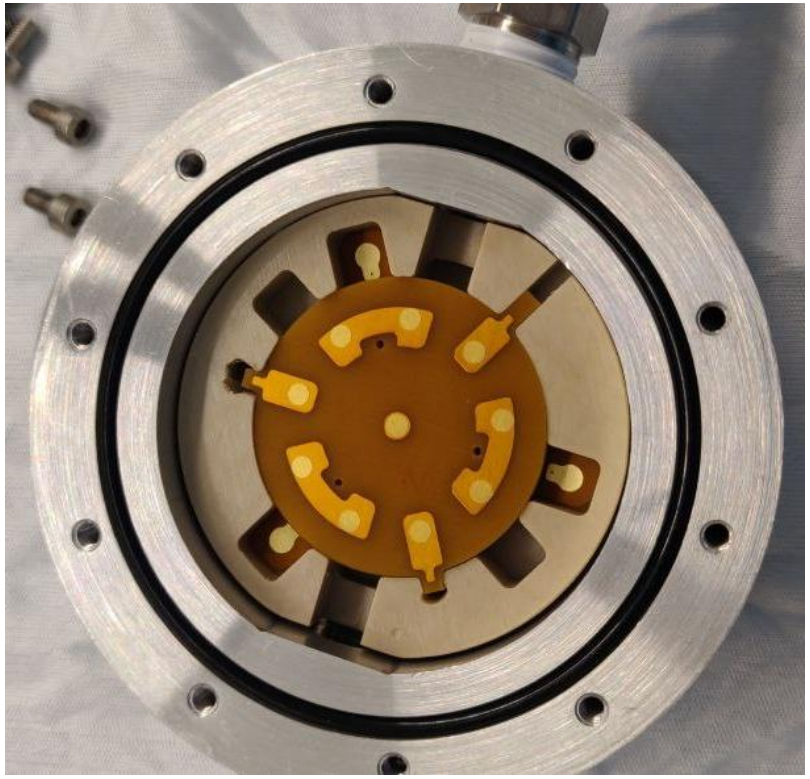
Papaevangelou, Thomas, et al. "Fast timing for high-rate environments with micromegas." EPJ Web of Conferences. Vol. 174. EDP Sciences, 2018.
Link: https://www.epj-conferences.org/articles/epjconf/pdf/2018/09/epjconf_mpgd2018_02002.pdf

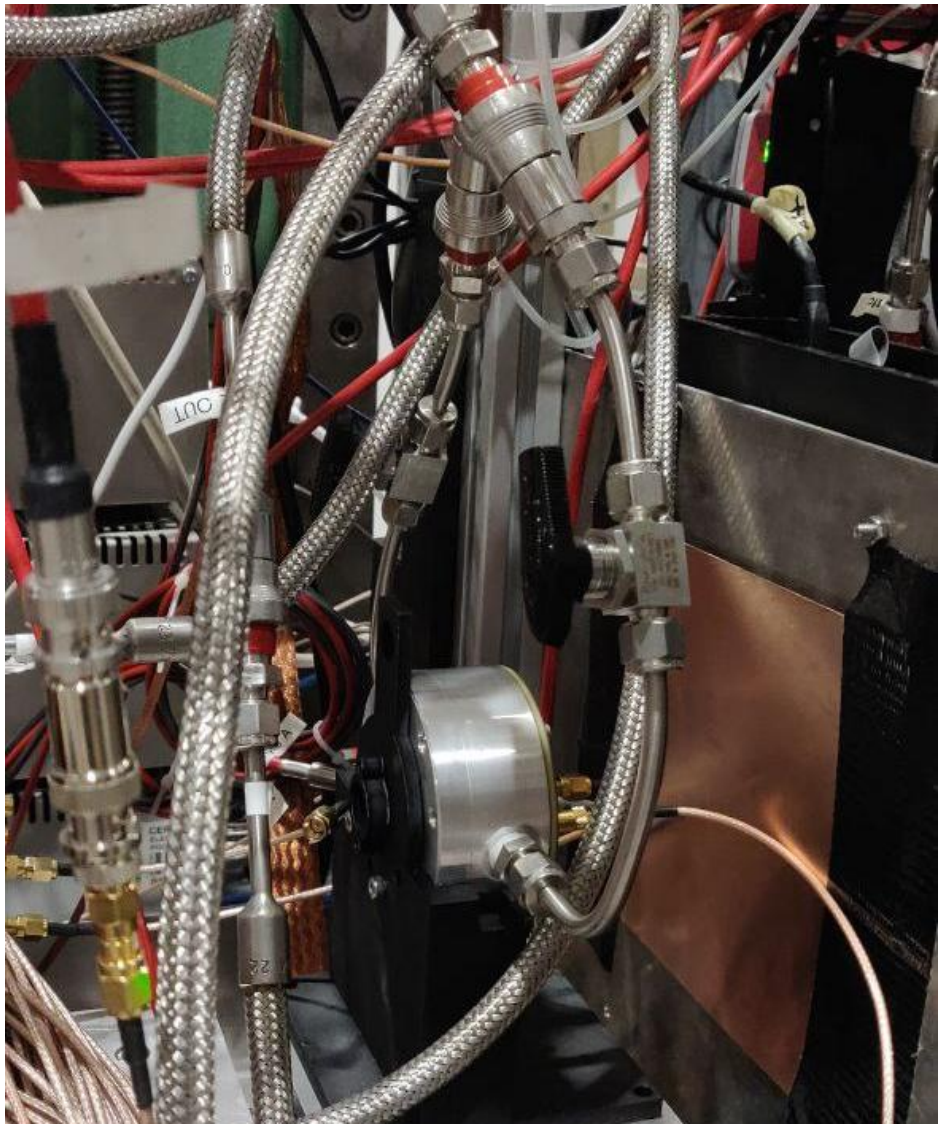
M. Lisowska et al. “Photocathode characterisation for robust PICOSEC Micromegasprecise-timing detectors”,NIMA, 1072.170151(2025) https://www.sciencedirect.com/science/article/pii/S0168900224010775?via%3Dihub

Picosec detector used in Pavia



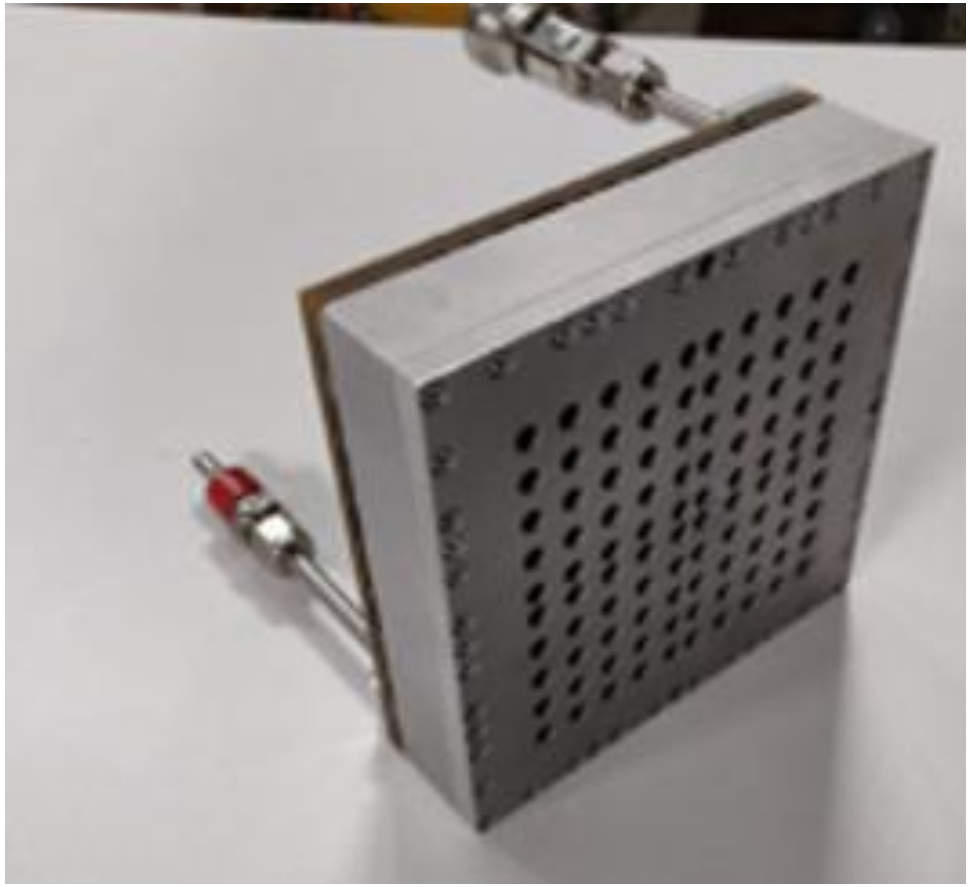






Utrobicic, A., et al. "Single channel PICOSEC Micromegas detector with improved time resolution." NIM A 1072 (2025): 170127. Link: https://doi.org/10.1016/j.nima.2024.170127

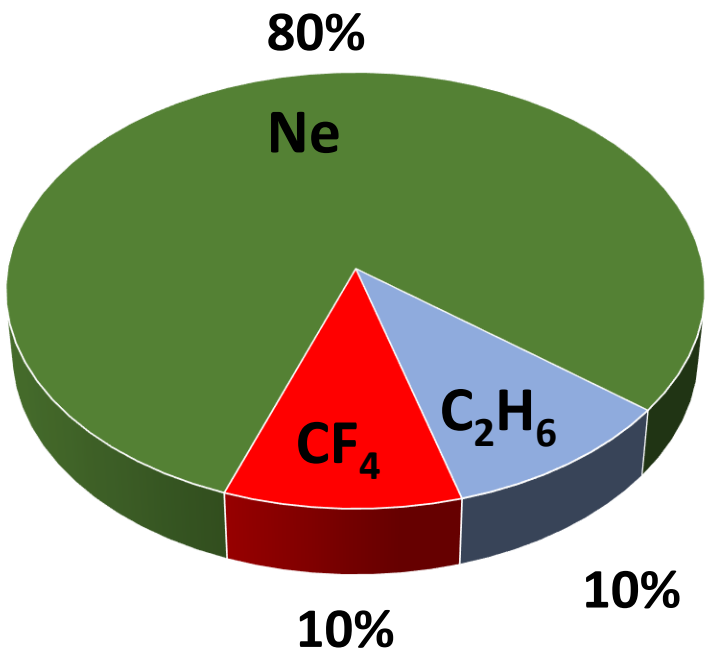
Picosec detector used in Pavia



10x10 cm^2 prototype for scalability studies

A. Utrobicic, et al., A large area100-channel PICOSEC Micromegas detector with time resolution at the 20 ps level, JINST 18 (07) (2023) C07012.
Link: https://iopscience.iop.org/article/10.1088/1748-0221/18/07/C07012

Picosec gas mixture



$Ne/C_2H_6/CF_4$ 80/10/10

GWP ≈ 740

Neon (Ne)

Expensive

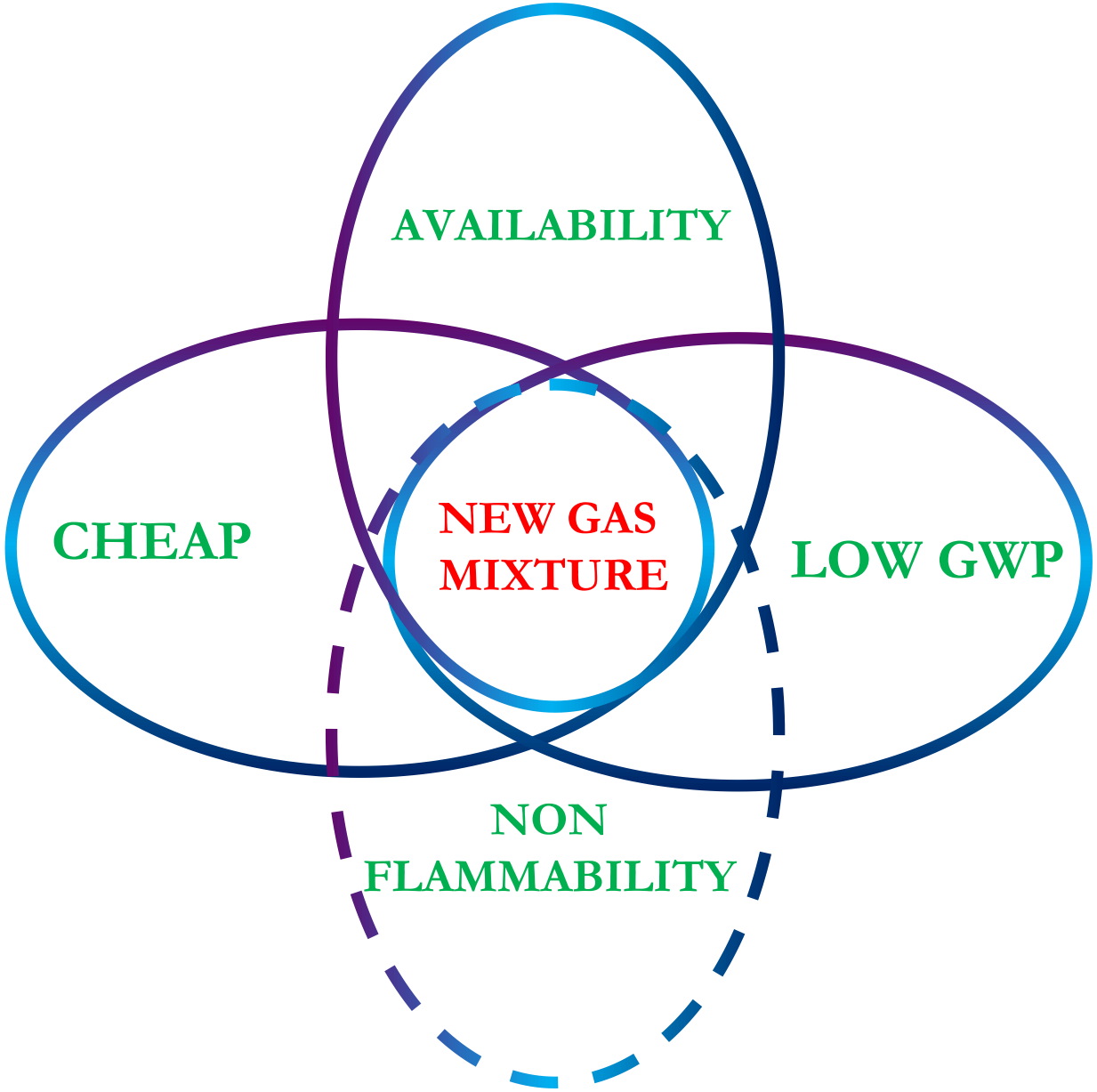
Ethane (C_2H_6)

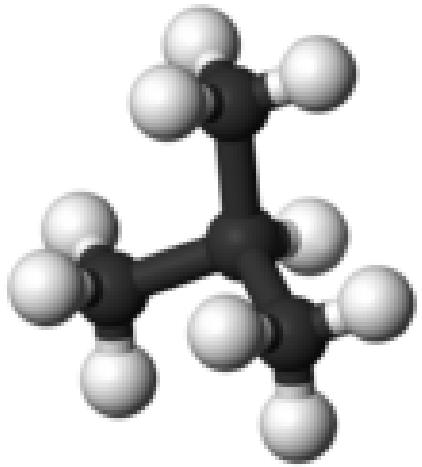
Flammable

Tetrafluoromethane (CF_4)

Scarsity of supplies
Expensive
Very high Global Warming Potential (GWP)

Look for new mixtures



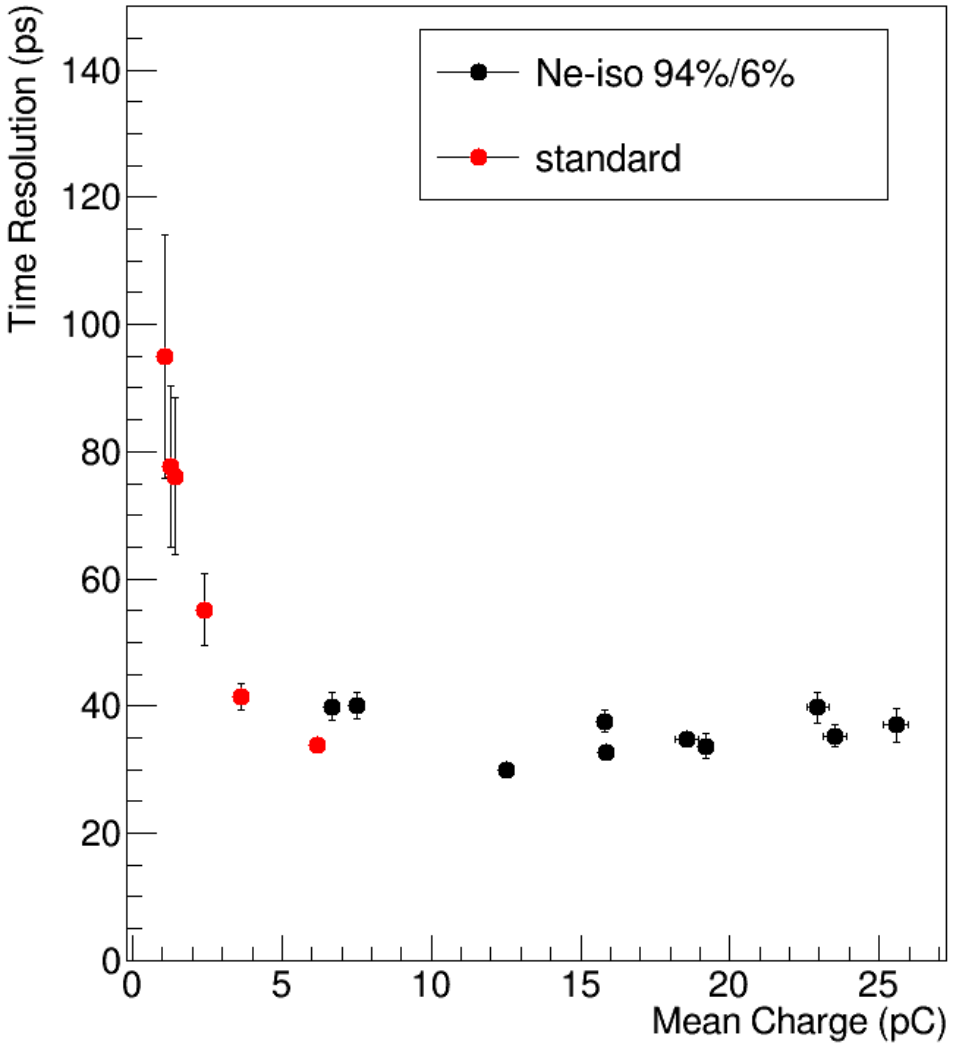


iC_4H_{10}

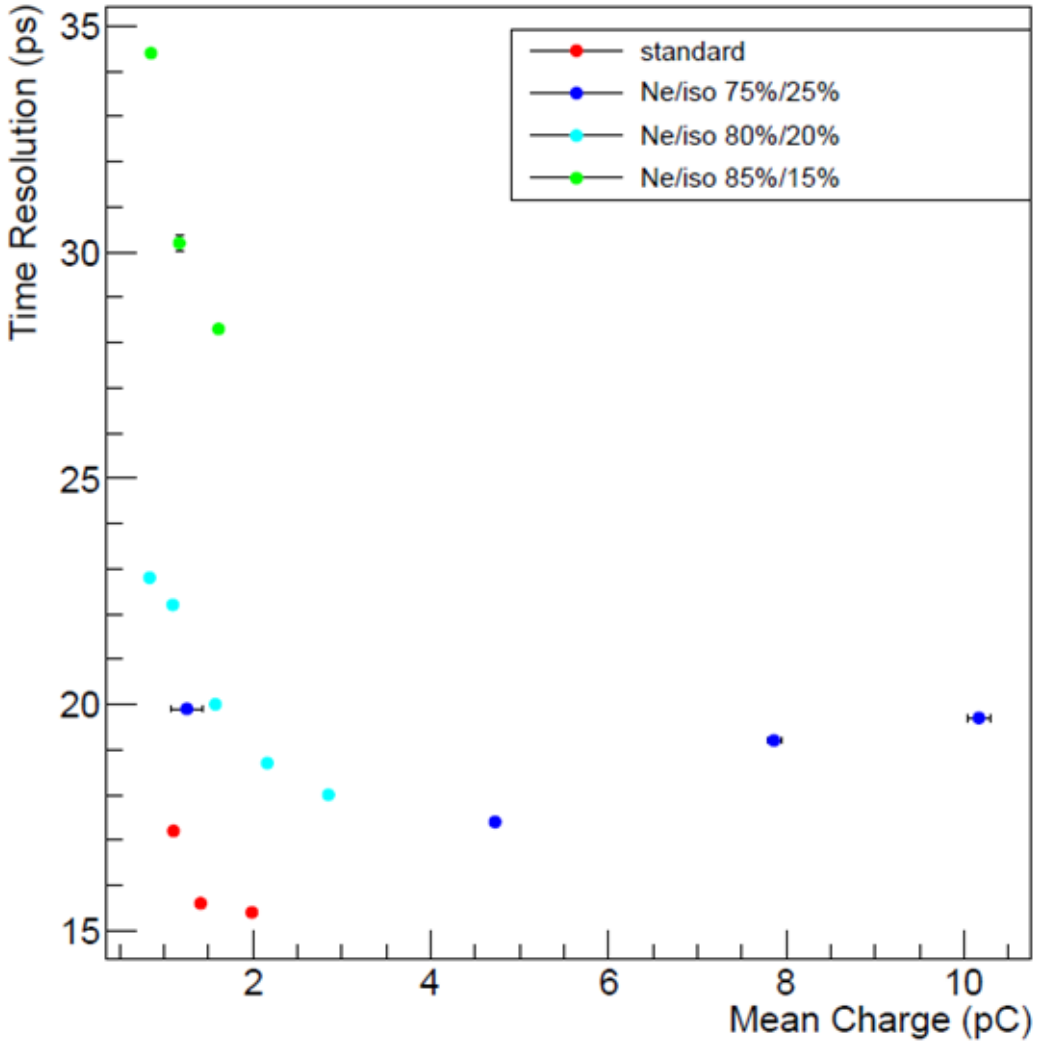
GWP 0.006

Previous results

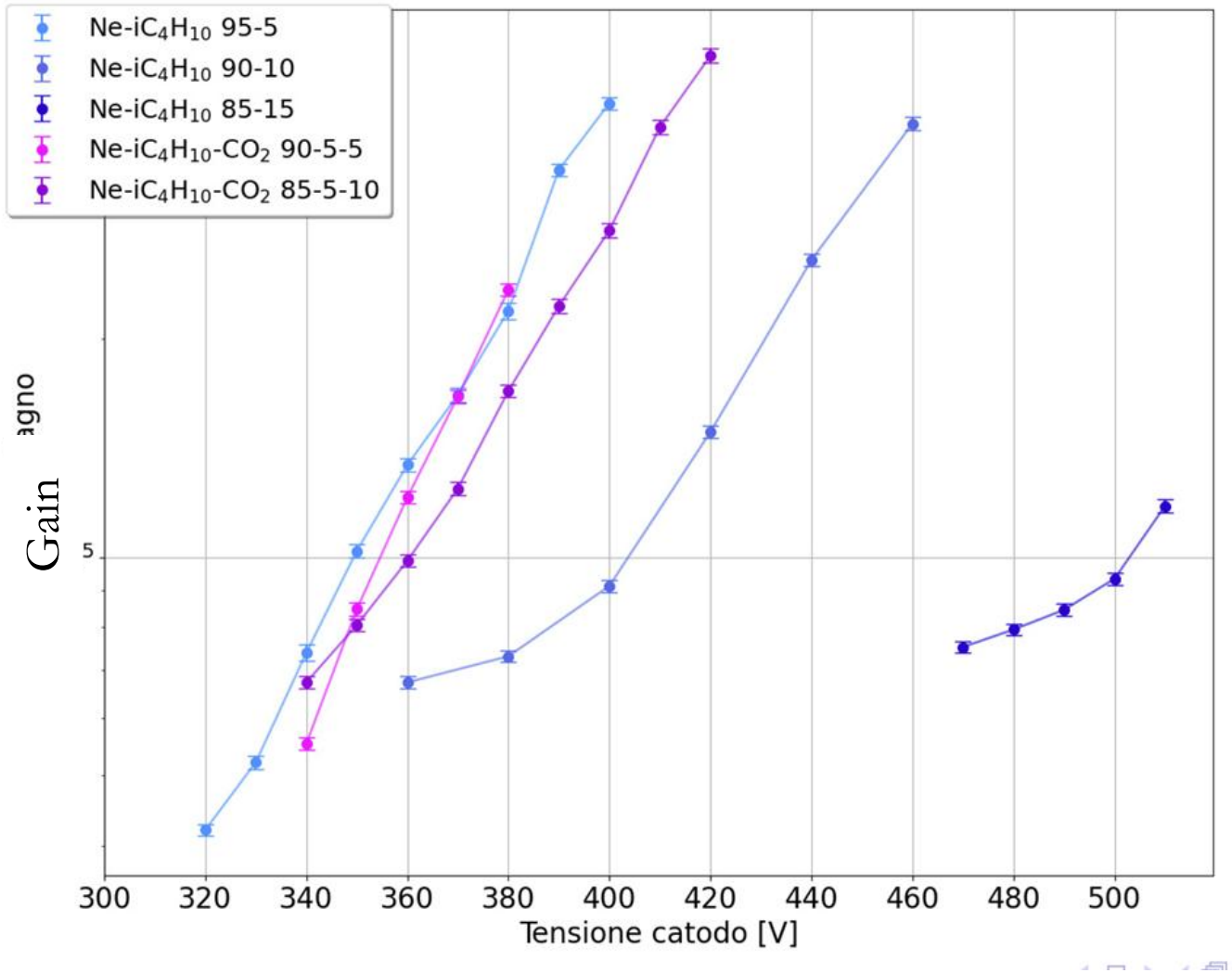
July 2023, Resistive MM, 82MOhm



April 2024, Non-resistive MM



Gain results

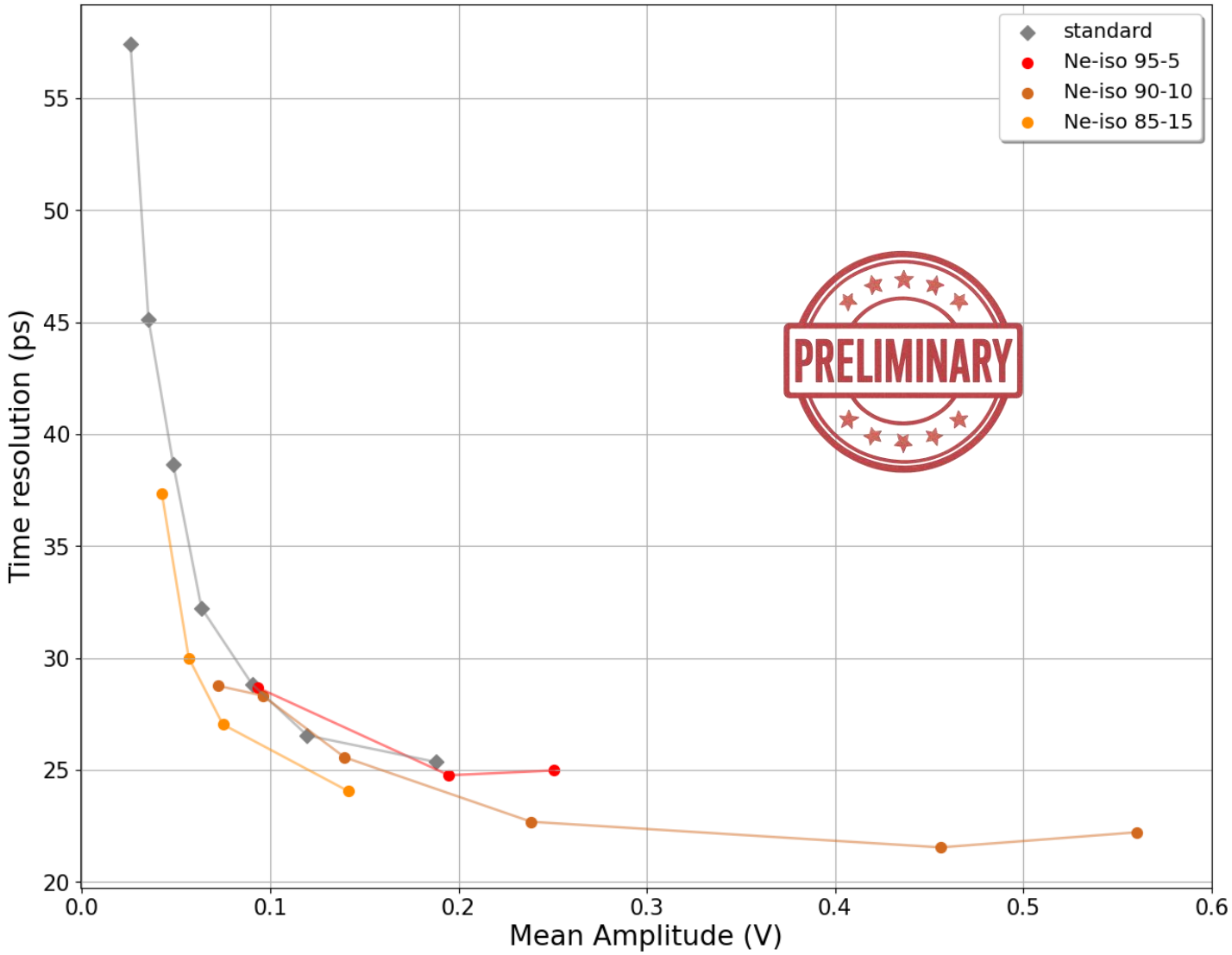


Cathode voltage [V]

Study of the gain with different mixtures (bachelor thesis)

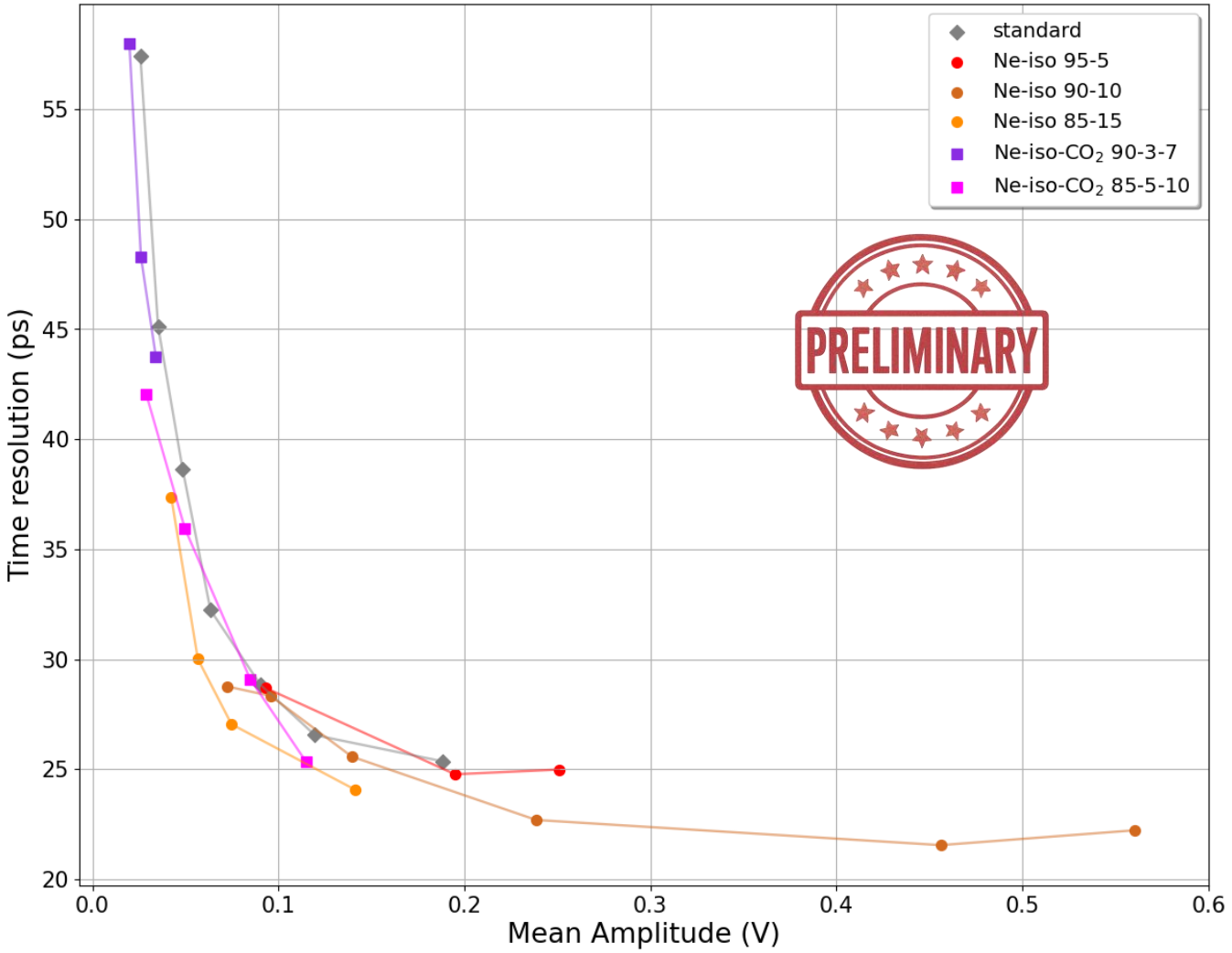
- Gain measurement to test different mixures
- Similar results for the Ne – iso 95-5, 90-10 and Ne – iso – CO_2 90-5-5 mixtures

Latest results



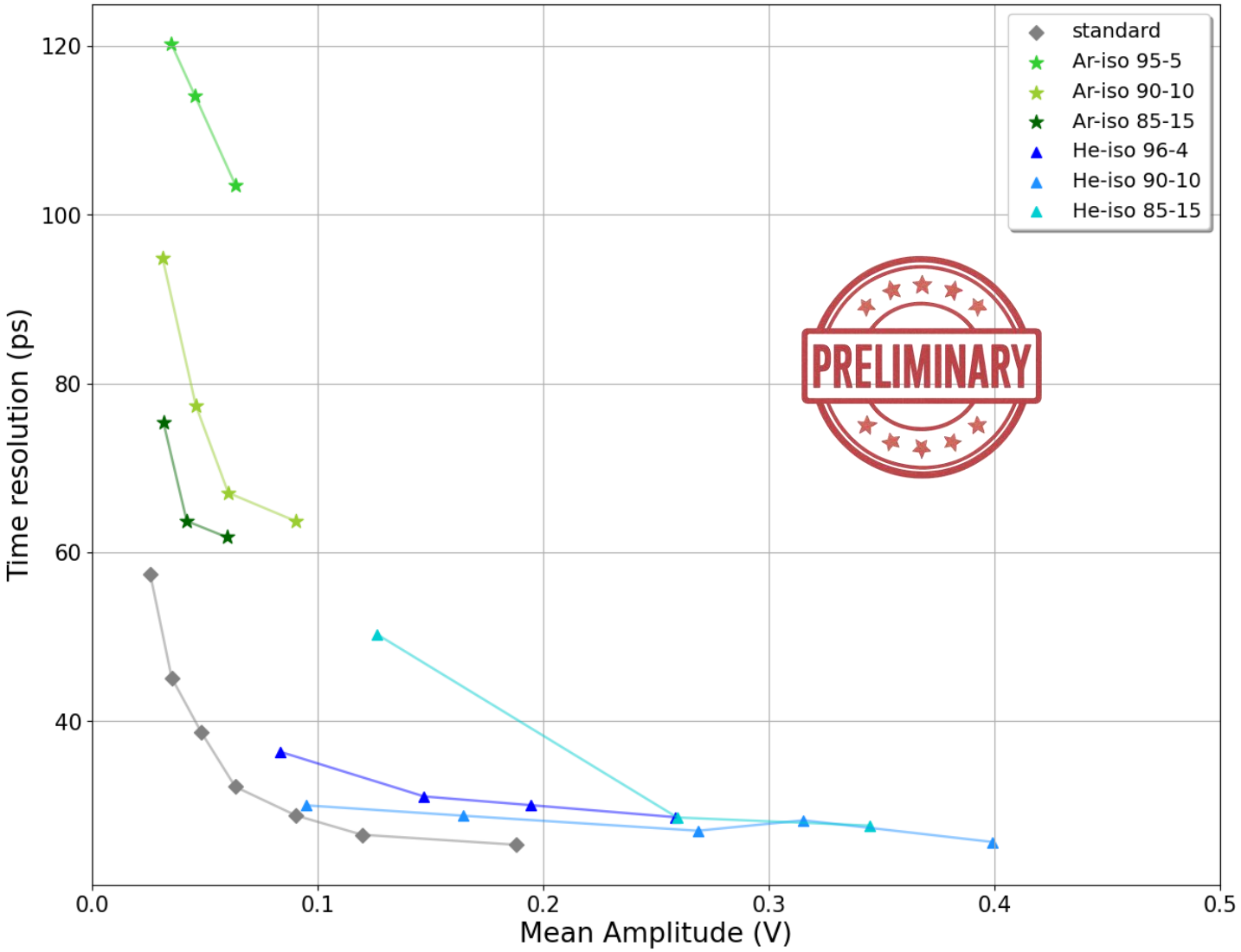
- Comparison standard mixture vs Ne-iso ones
- Comparable time resolution achieved with the new mixtures

Latest results



- Comparison standard mixture vs Ne-iso ones
- Comparable time resolution achieved with the new mixtures
- Mixture with added CO_2
- The 2 mixture with CO_2 are non flammable

Latest results



- Comparison standard mixture vs Ar based ones and He based ones
- Ar based mixtures show a worse time resolution
- He based mixture show a good time resolution (not as good as Ne)

Ongoing

- Analysis of the latest test beam (November)
  - Goal: confirm the previous results and optimize concentrations
  - Address the possibility of having ageing due to isobutane
  - Tested new mixture with ne/iso/CO2
  - Tested ethane as a quencher
- Writing a paper on the gas studies

- Starting soon:
  - Restart of the simulation work of the Picosec detecotr in the Muon Collider framework

Thesis

Bachelor thesis

- Thesis completed
- Study of the gain with different gas mixtures
- Results useful for the two tests beam

Master thesis

- Ongoing
- Continuing the gain studies
- Study of the multipad: uniformity

Master thesis

- Not yet started
- Work on the geant4 simulation of the detector
- ML techniques to be applied to the test beam results

Conclusion and future perspectives

- Work on scalability of the detector
- Start simulation of the signals of the detector in different conditions
- Restart the simulation work

- Ne-based mixtures confirmed to reach comparable time resolution to the standard one
- Ar- based mixtures has worse time resolution than Ne-based ones (but they are way cheaper)
- He-based mixtures show good time resolution (also costs are in the middle)