Picosec: optimization of a fast timing detector for its application at a future Muon Collider experiment

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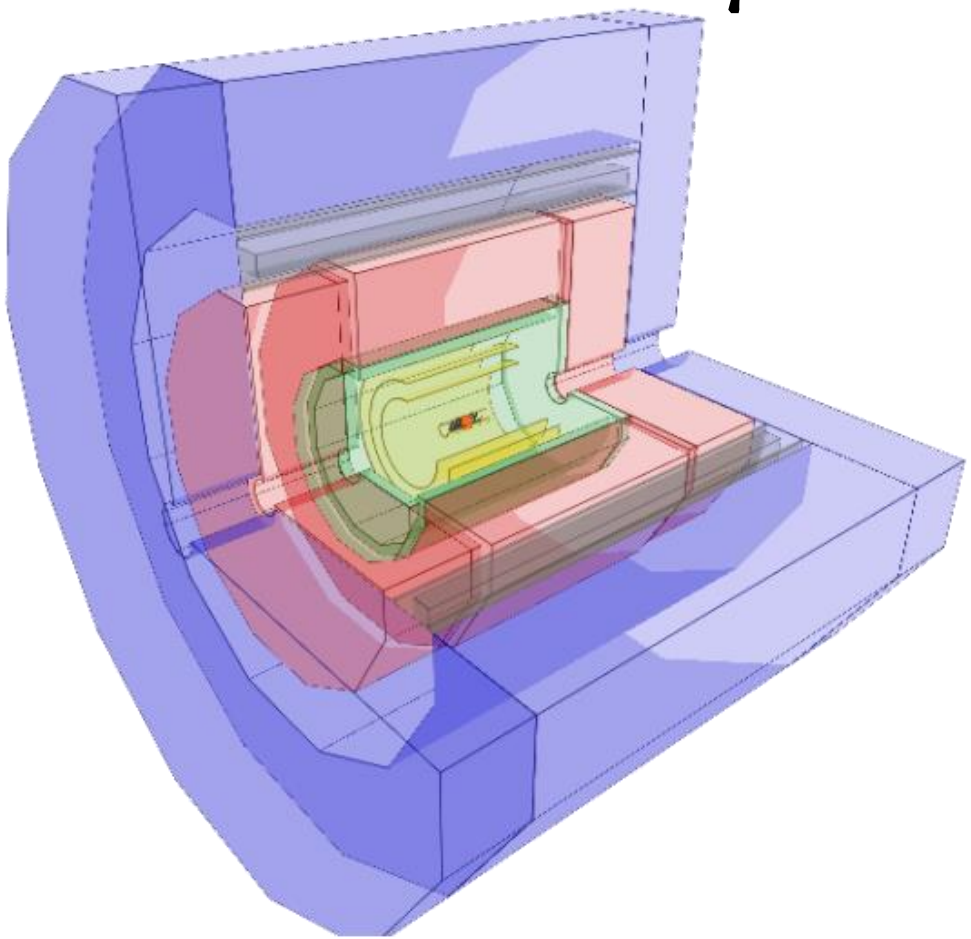
on behalf of the
International Muon Collider Collaboration

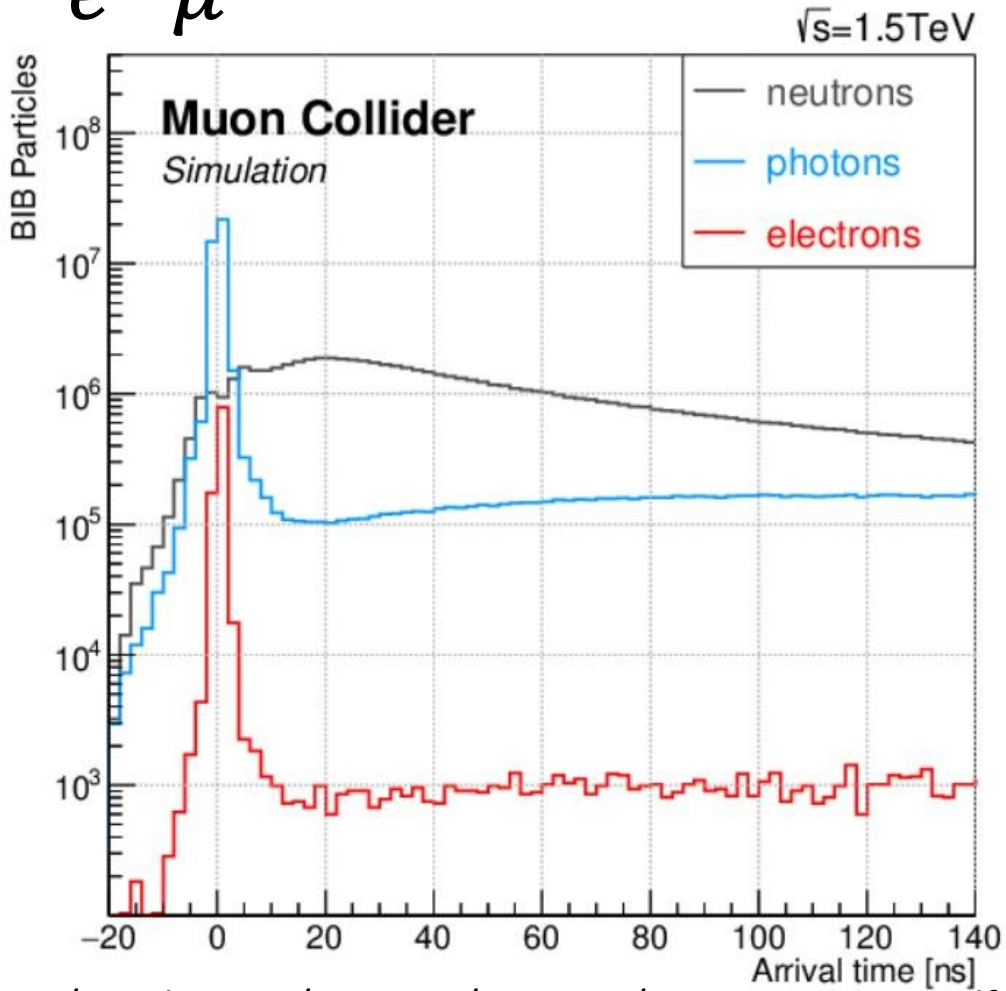
12° Beam Telescopes and Test Beams Workshop

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.

Beam Induced Background (BIB)

$$\mu^- \rightarrow e^- \bar{\nu}_e \nu_\mu$$



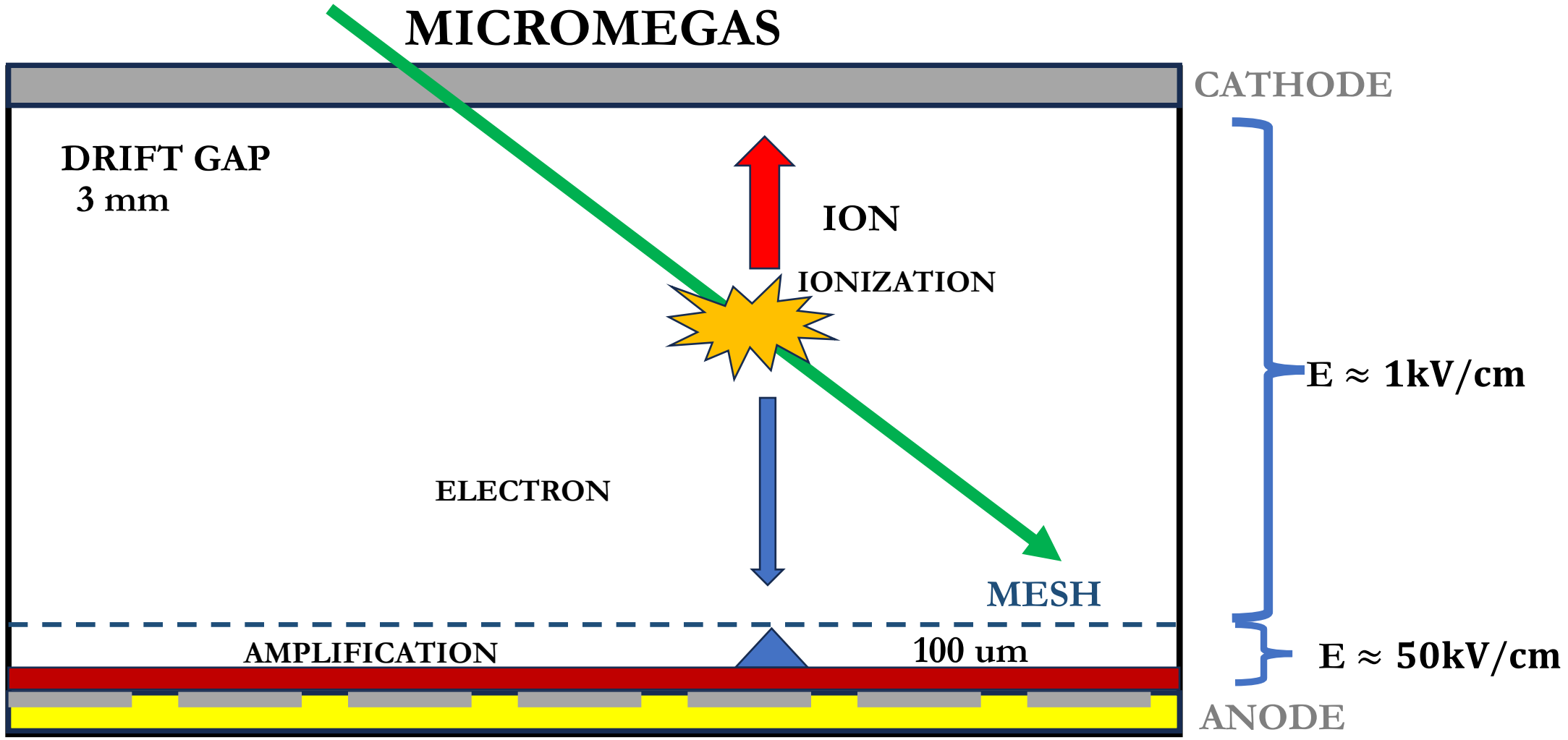


See also: https://indico.cern.ch/event/1323113/contributions/5878555/attachments/2839892/4964894/MuC-BTTB-2024.pdf

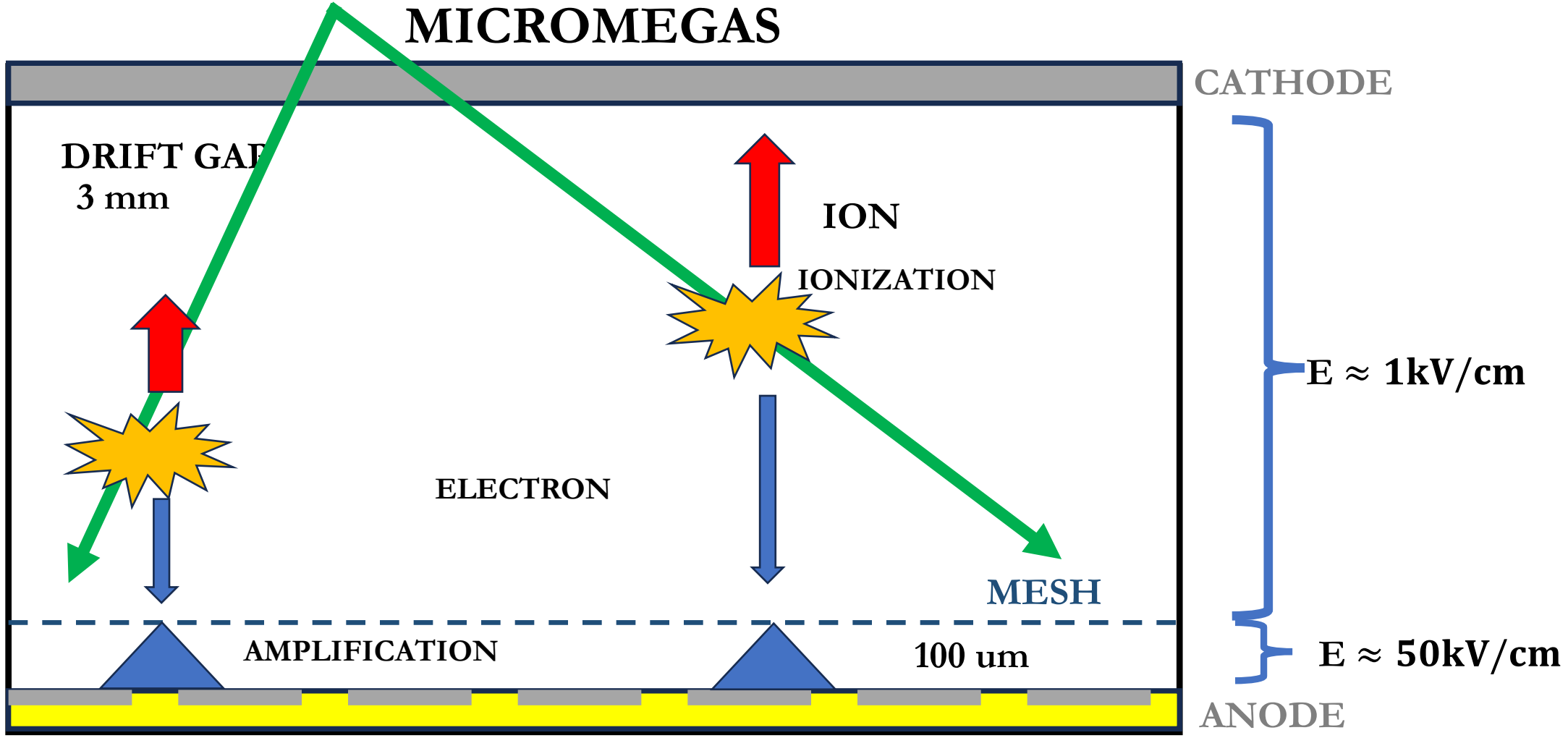
S. Jindariani, F. Meloni, N. Pastrone, C. Aimè, N. Bartosik, E. Barzi, A. Bertolin, A. Braghieri, L. Buonincontri, S. Calzaferri, et al. Promising technologies and r&d directions for the future muon collider detectors. arXiv preprint arXiv:2203.07224, 2022.

Bartosik, Nazar, et al. "Simulated detector performance at the muon collider." arXiv preprint arXiv:2203.07964 (2022).

Micromegas

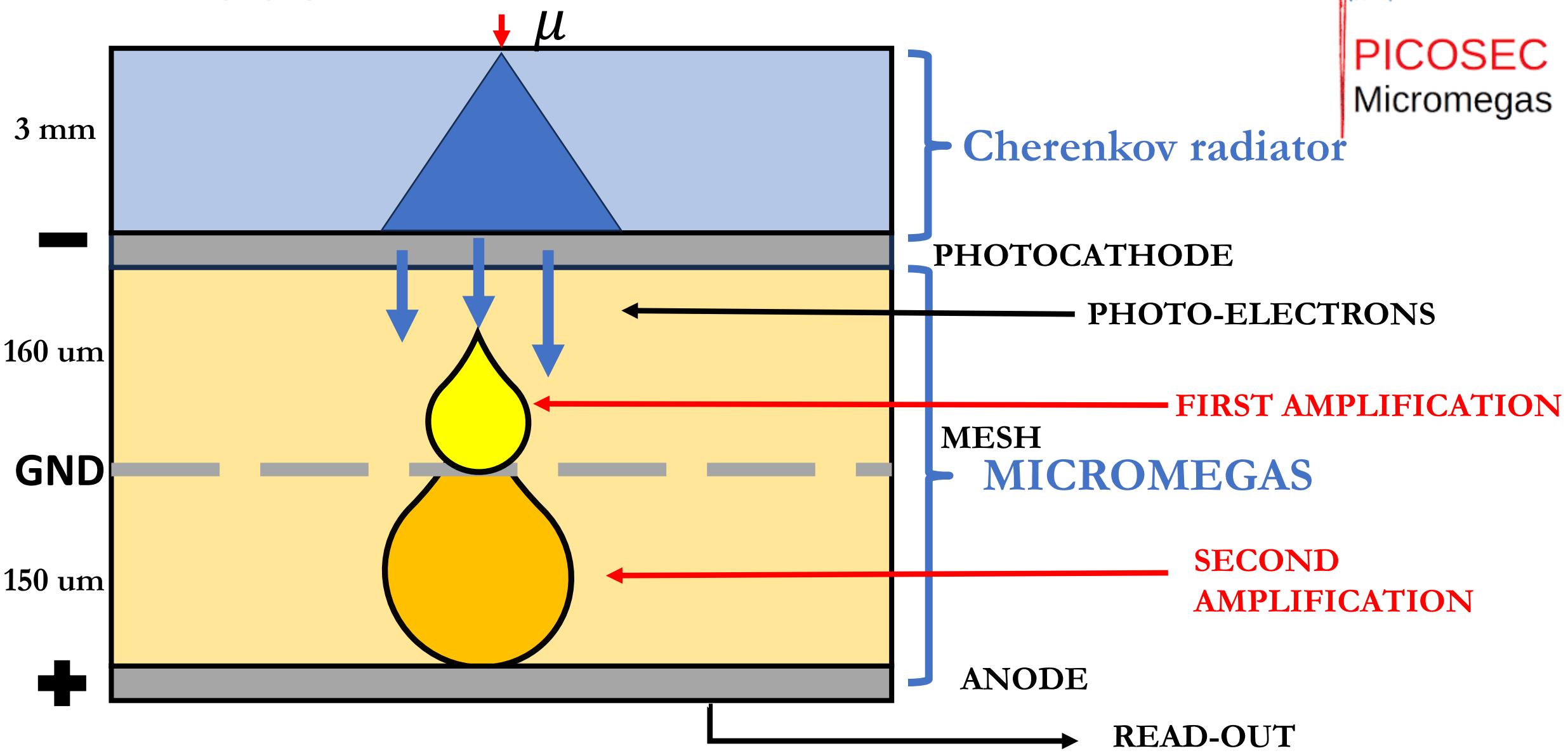

MICROMEGAS
CATHODE
DRIFT GAP
3 mm
ION
IONIZATION
ELECTRON
MESH
AMPLIFICATION
100 um
E ≈ 1kV/cm
E ≈ 50kV/cm
ANODE

Jitter and time resolution



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

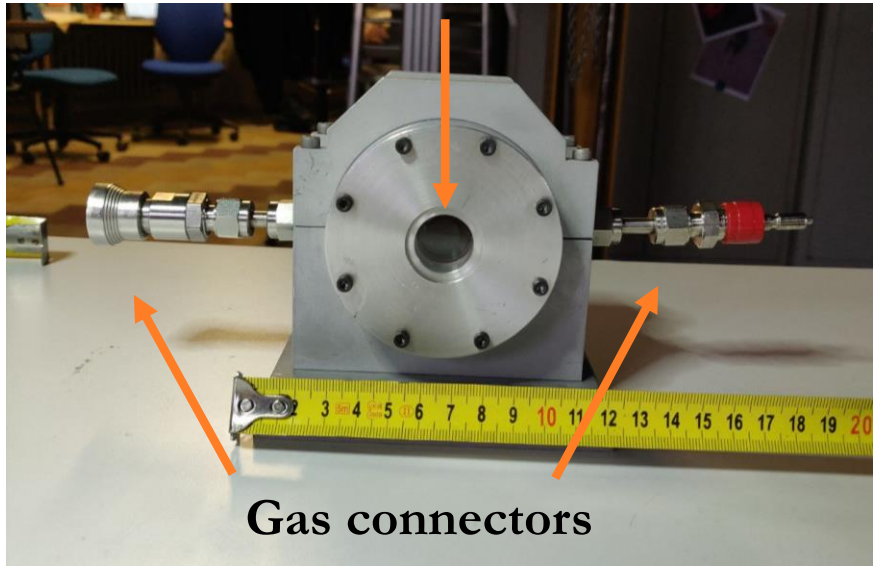
Picosec

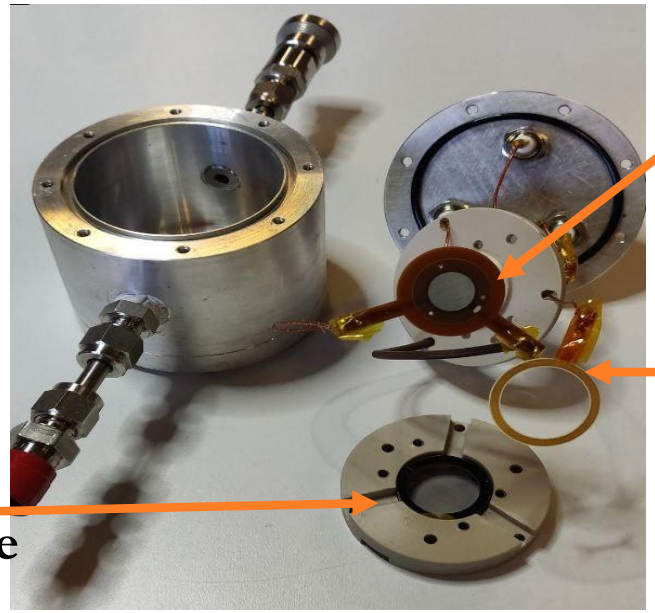


not to scale

Picosec

Window





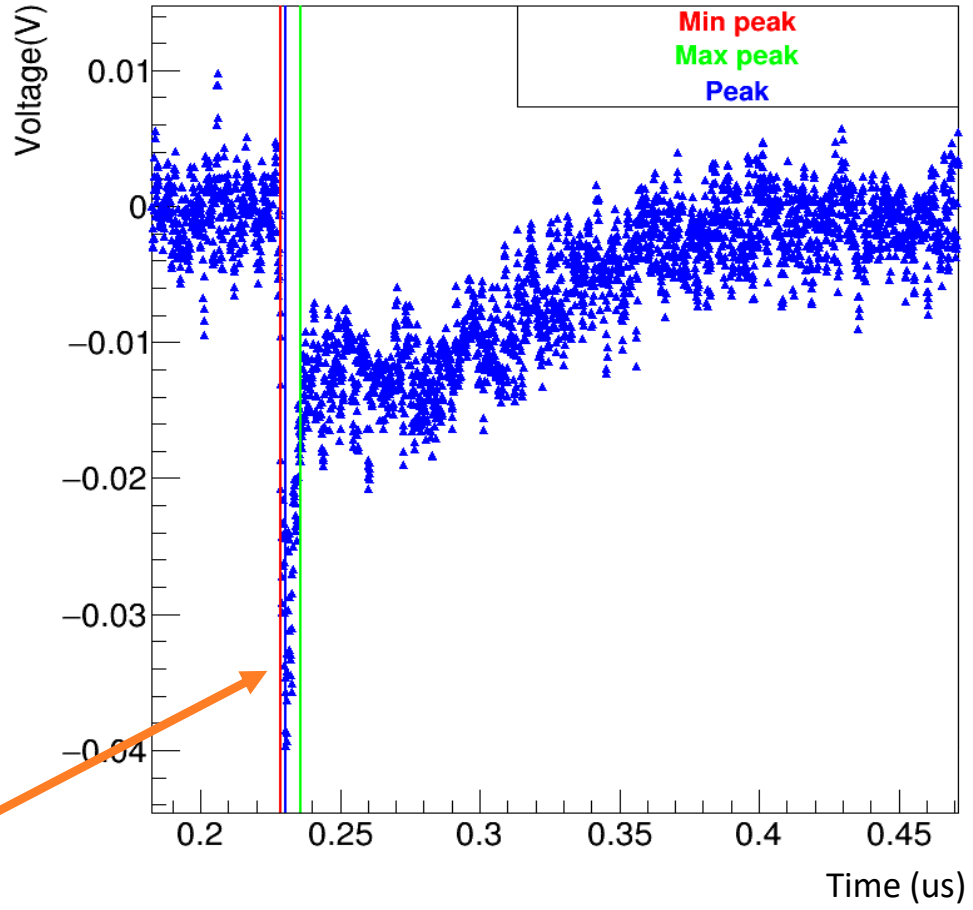
Mesh and anode

Spacer and electrical contact

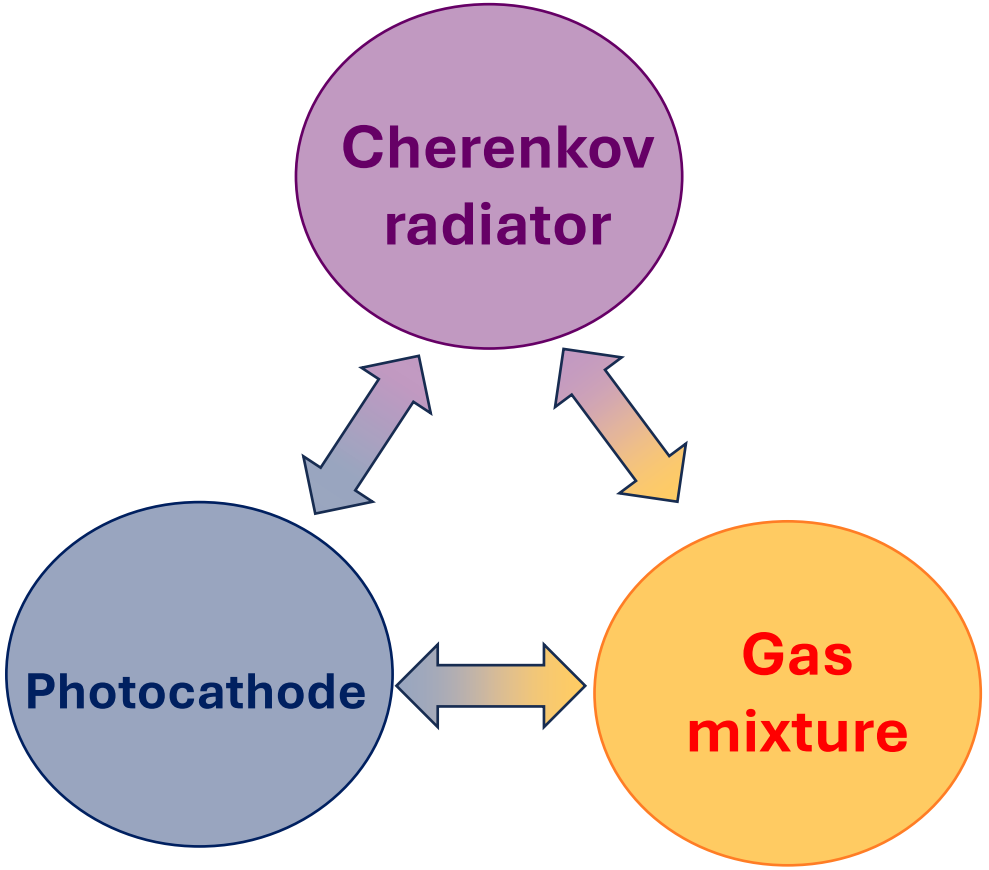
Radiator crystal and photocathode

Electron peak

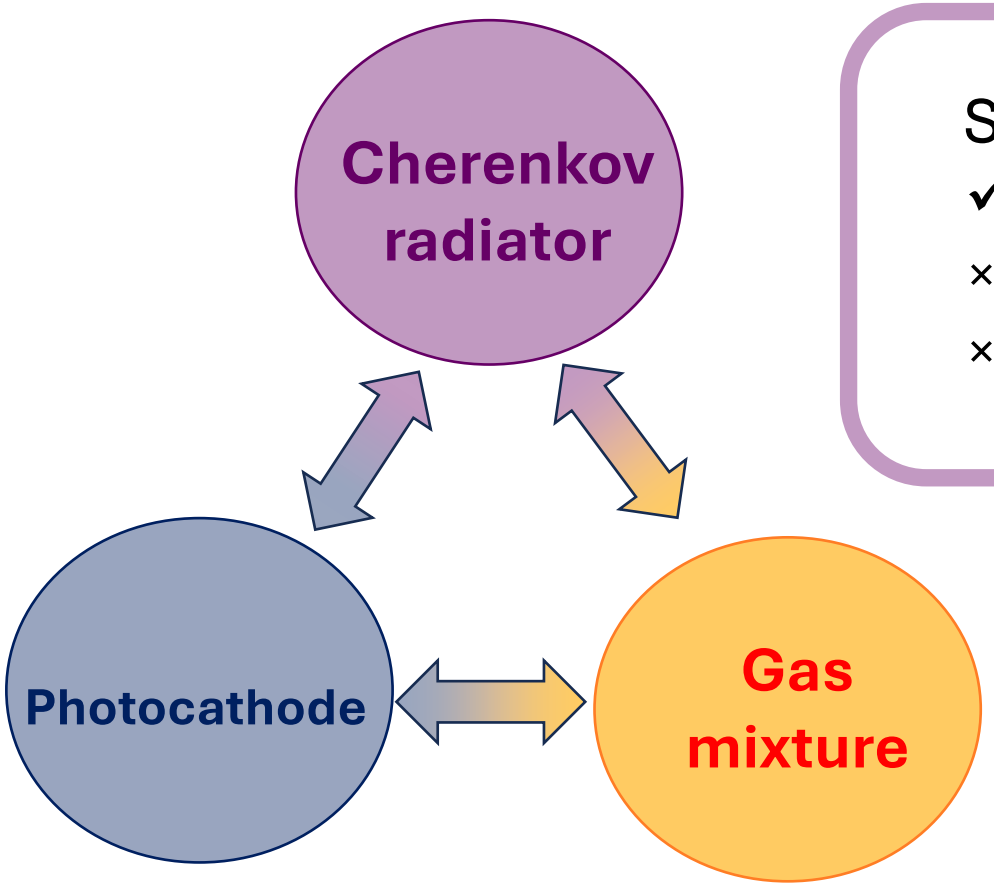
Signal



Goals



Goals



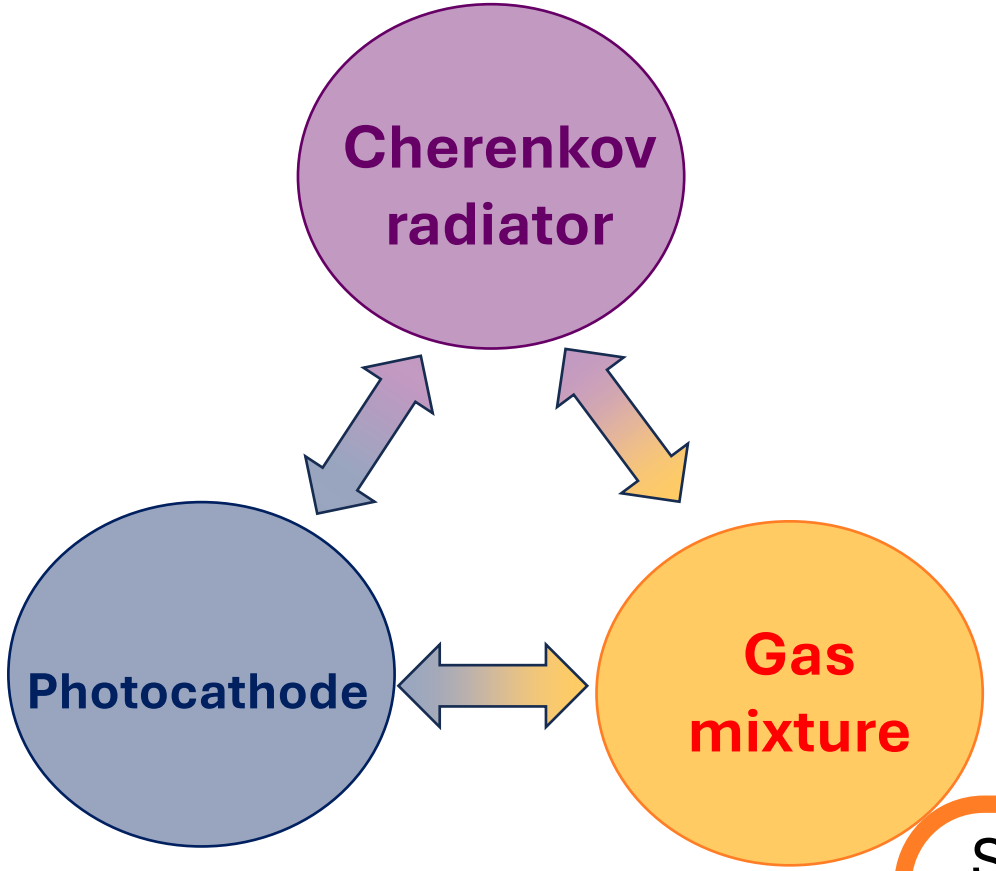
Standard: MgF_2

✓ High UV transparency

× Fragility, cost

× **Test**: Quartz

Goals



MIXTURE	GWP 100y
$Ne/C_2H_6/CF_4$ 80/10/10	740
Ne/iC_4H_{10} 90/10	0.34
Ne/iC_4H_{10} 94/6	0.2

Standard: $Ne / C_2H_6 / CF_4$

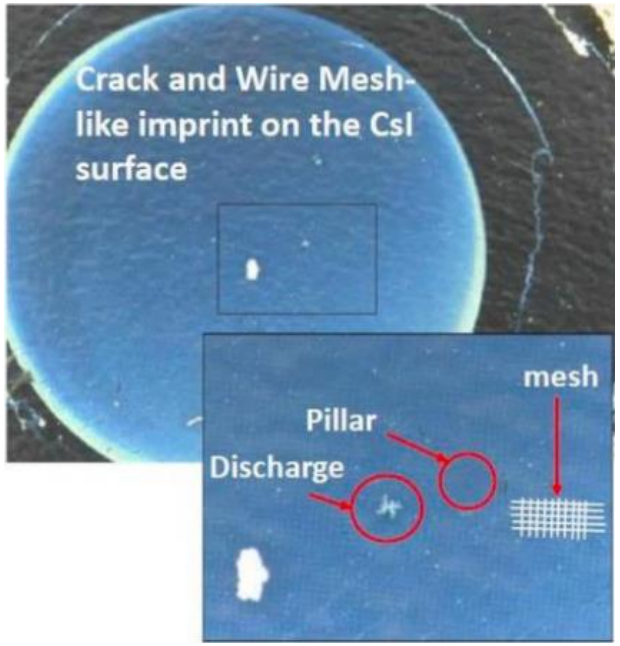
✓ High gain and drift velocity

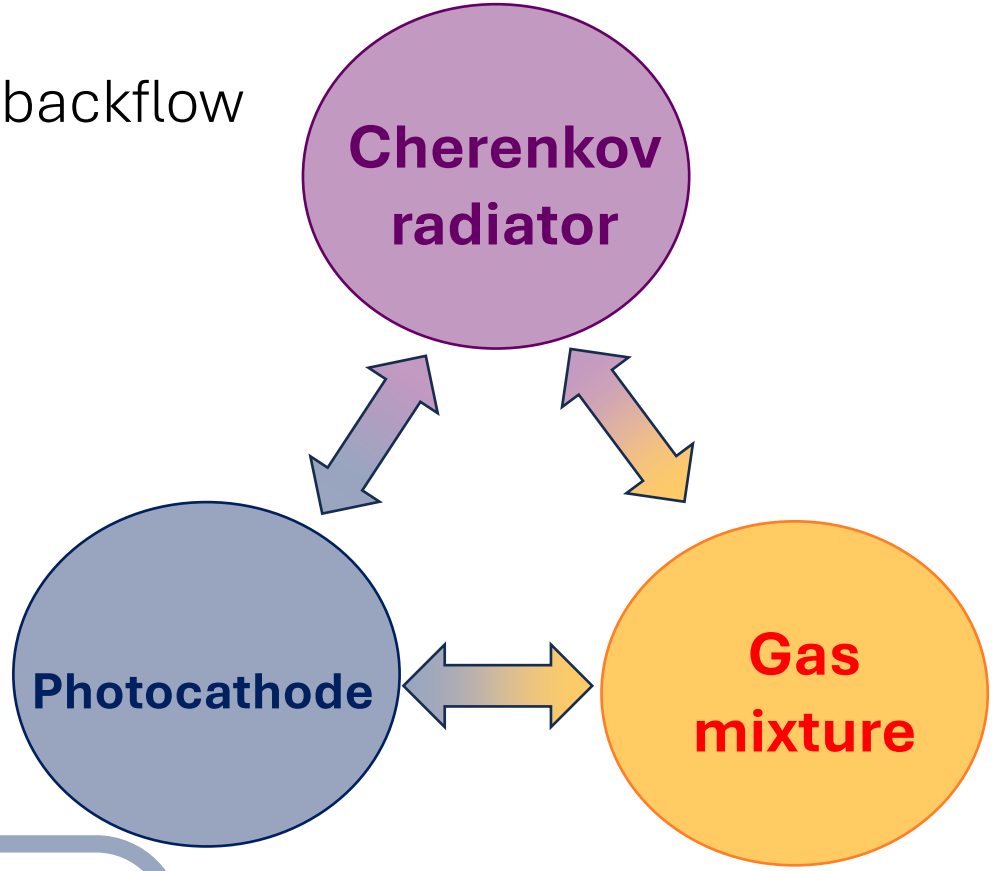
× Cost, Global Warming Potential

Test: Ne/iC_4H_{10}

Goals

CsI damaged by the ions backflow





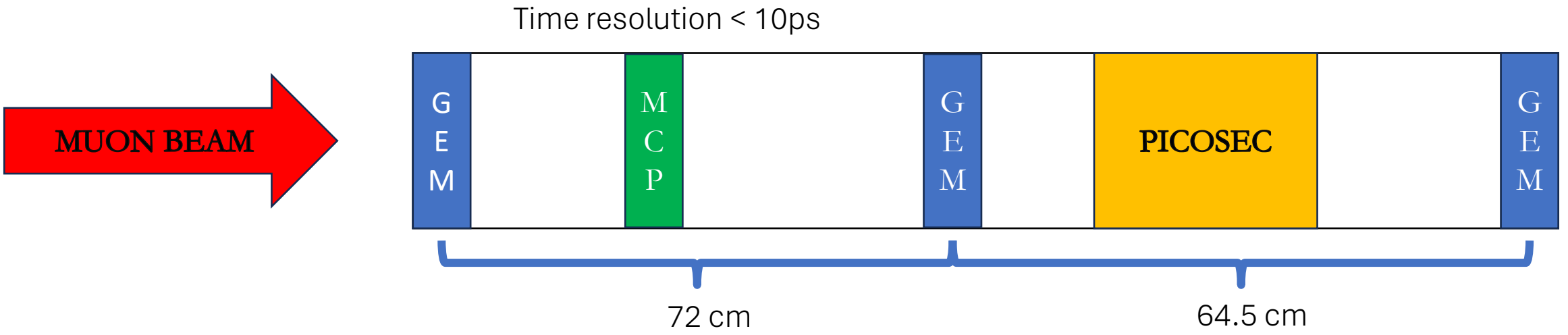
Standard: CsI (+ Cr)

- ✓ High conversion efficiency
- × Hygroscopicity, durability

Test: B_4C, DLC

Picture: Florian Brunbauer, Precise charged particle timing with the PICOSEC detection concept @ INSTR'20

Timing setup

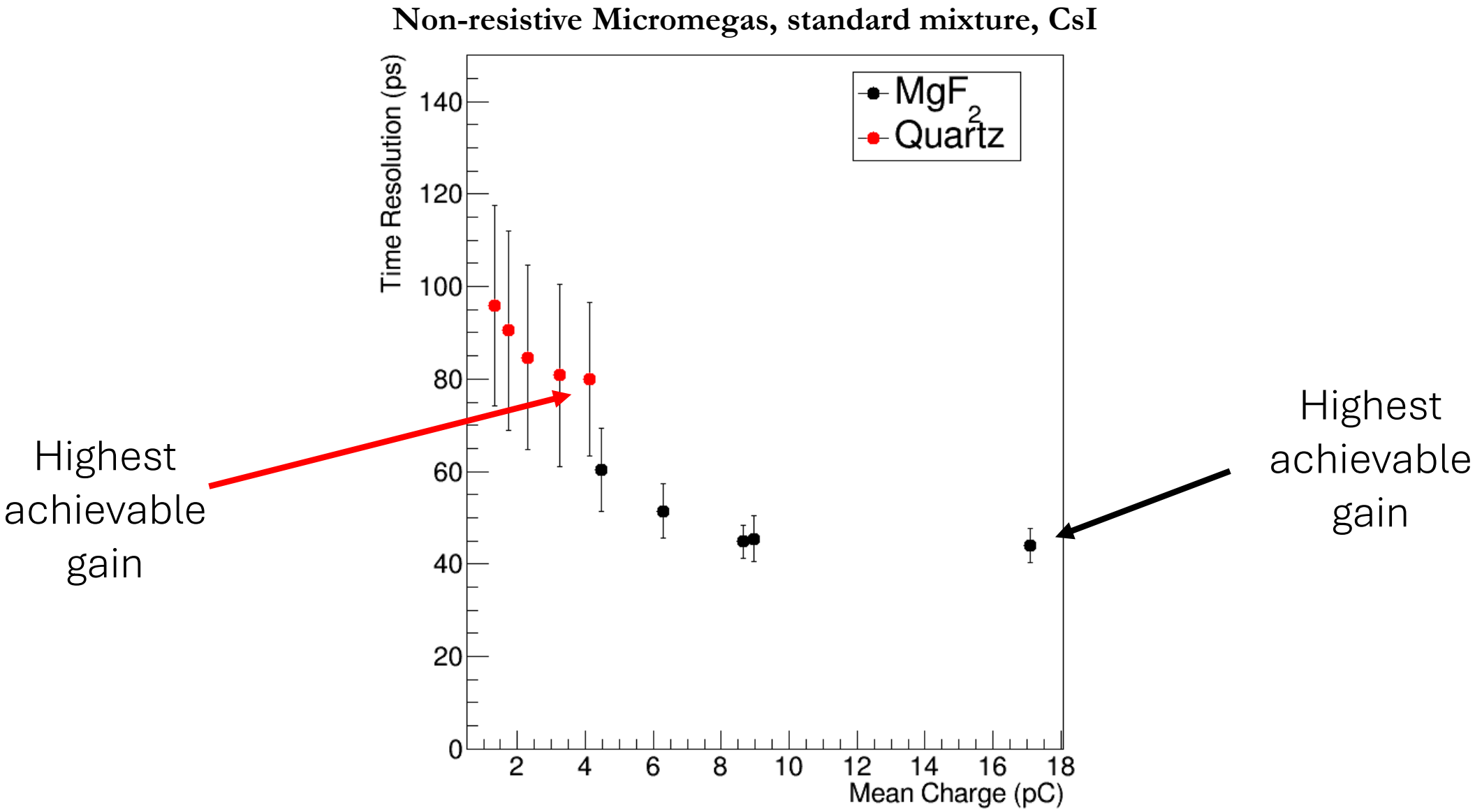


Timing measurements:

- Muon beam
- **Linear** amplifier
- GEM for the tracking
- MCP-PMT as trigger and **time reference**

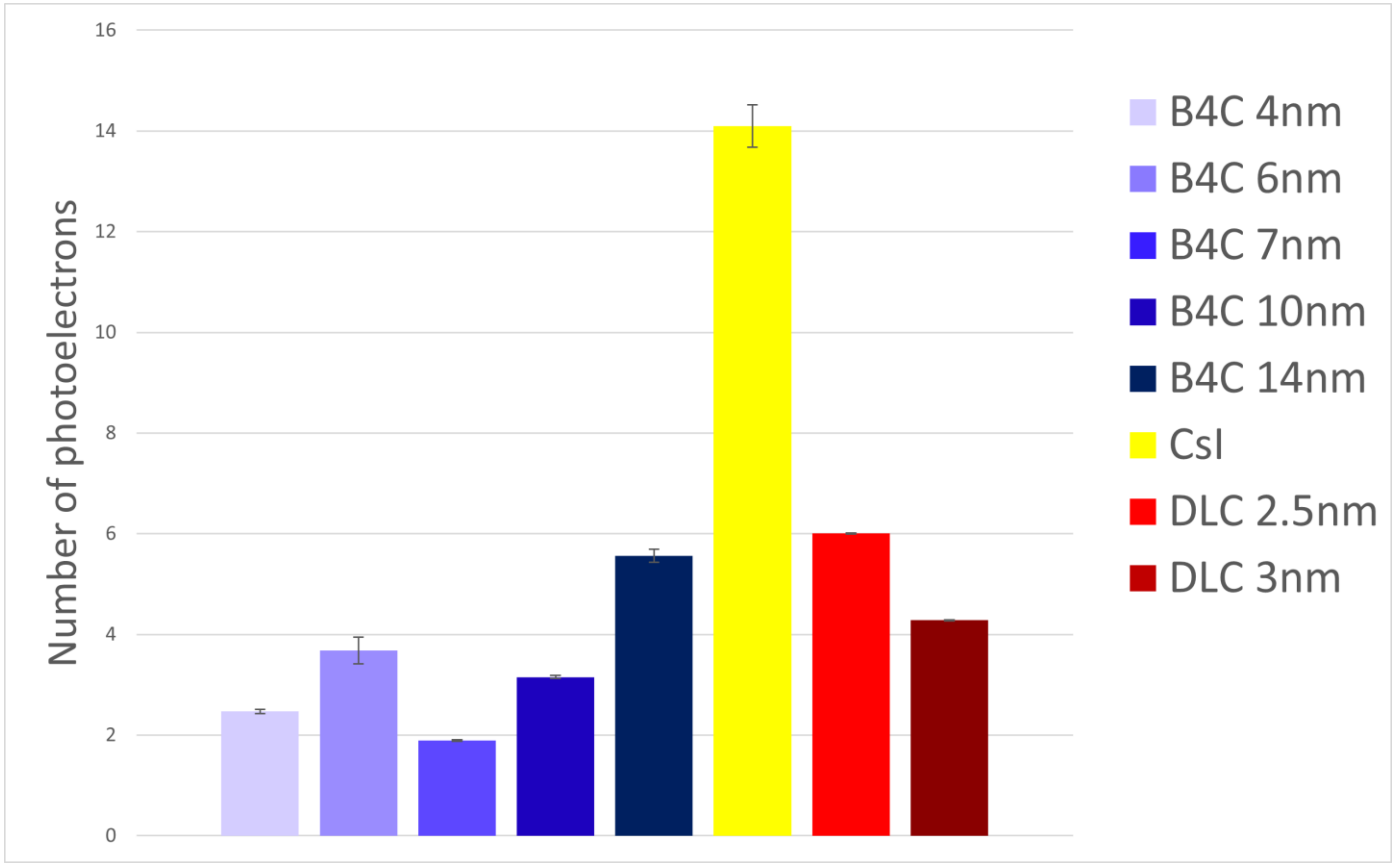
Test beam measurements performed in the joined RD51 and DRD1 test beam campaigns at the H4 beam line of the CERN SPS

Cherenkov radiators

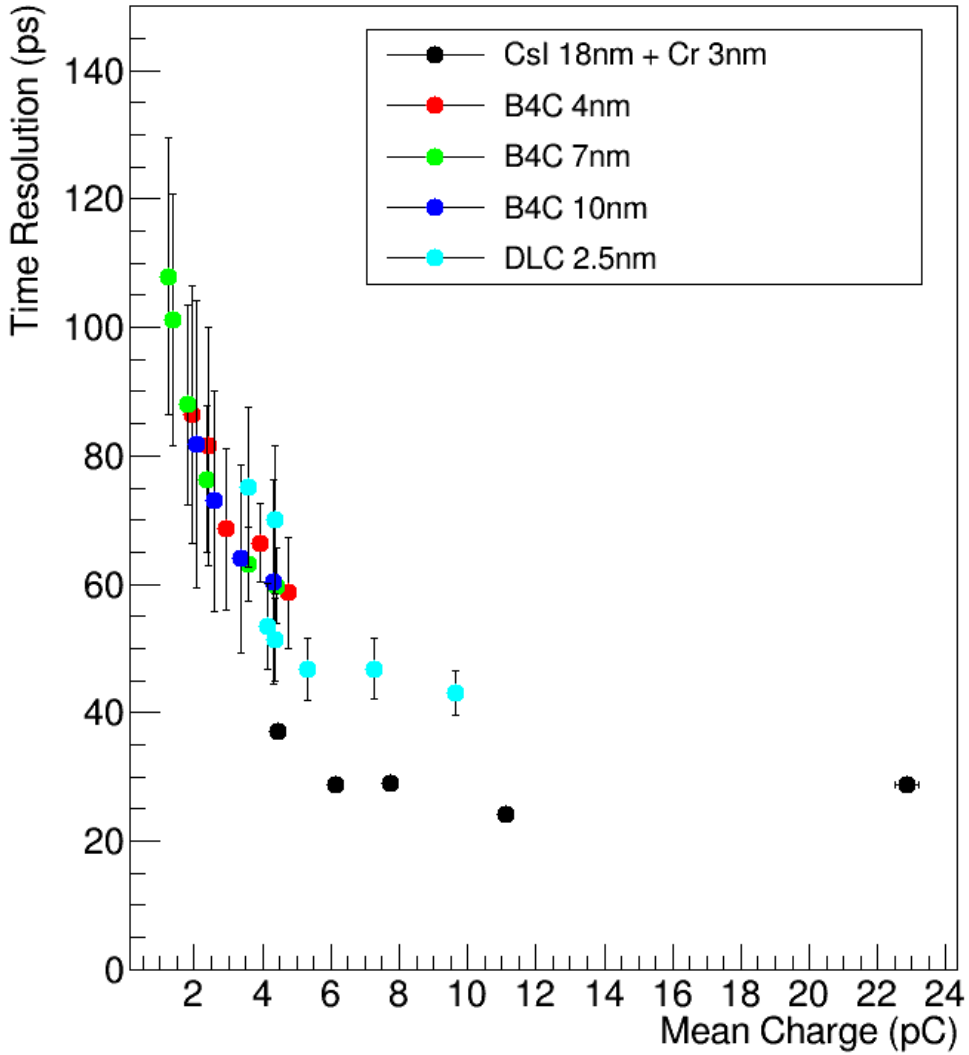


Confirmation of better performance with the standard radiator

Photocathodes

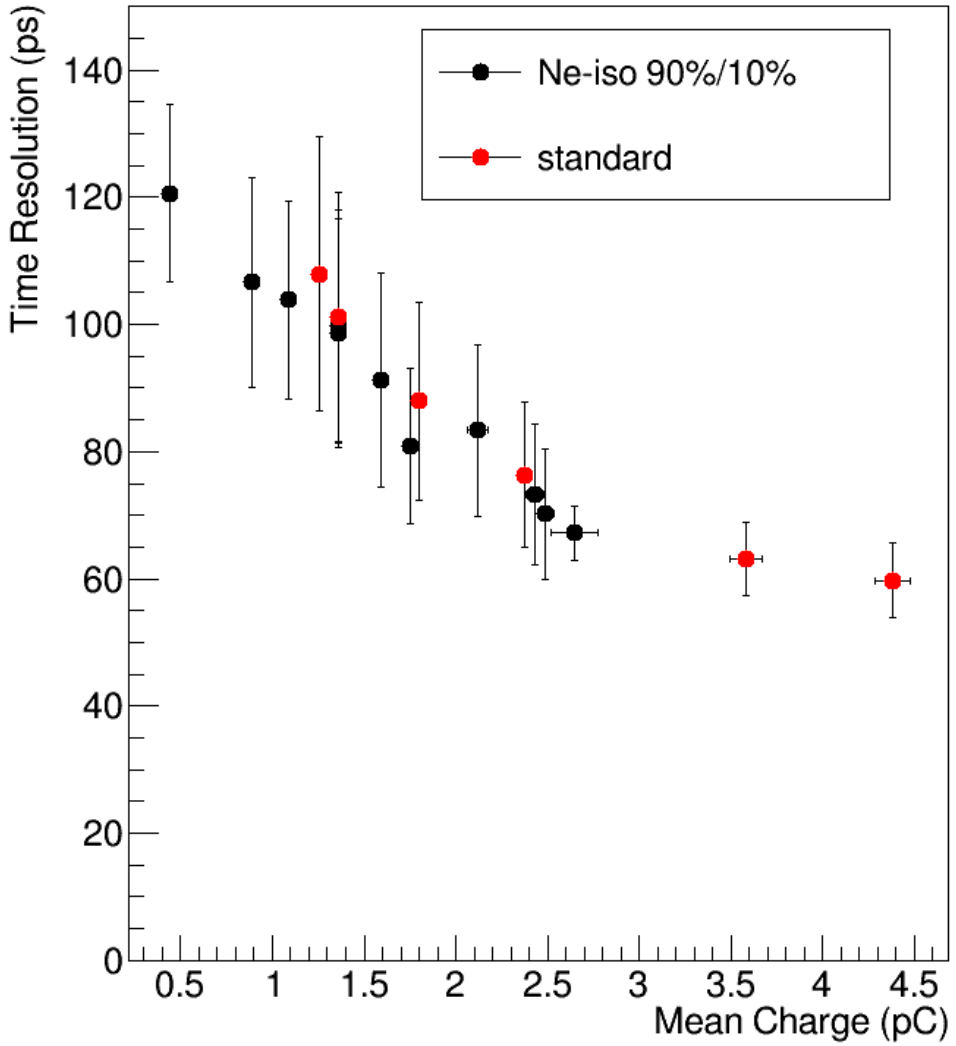


380 kOhm resistive Micromegas, standard mixture

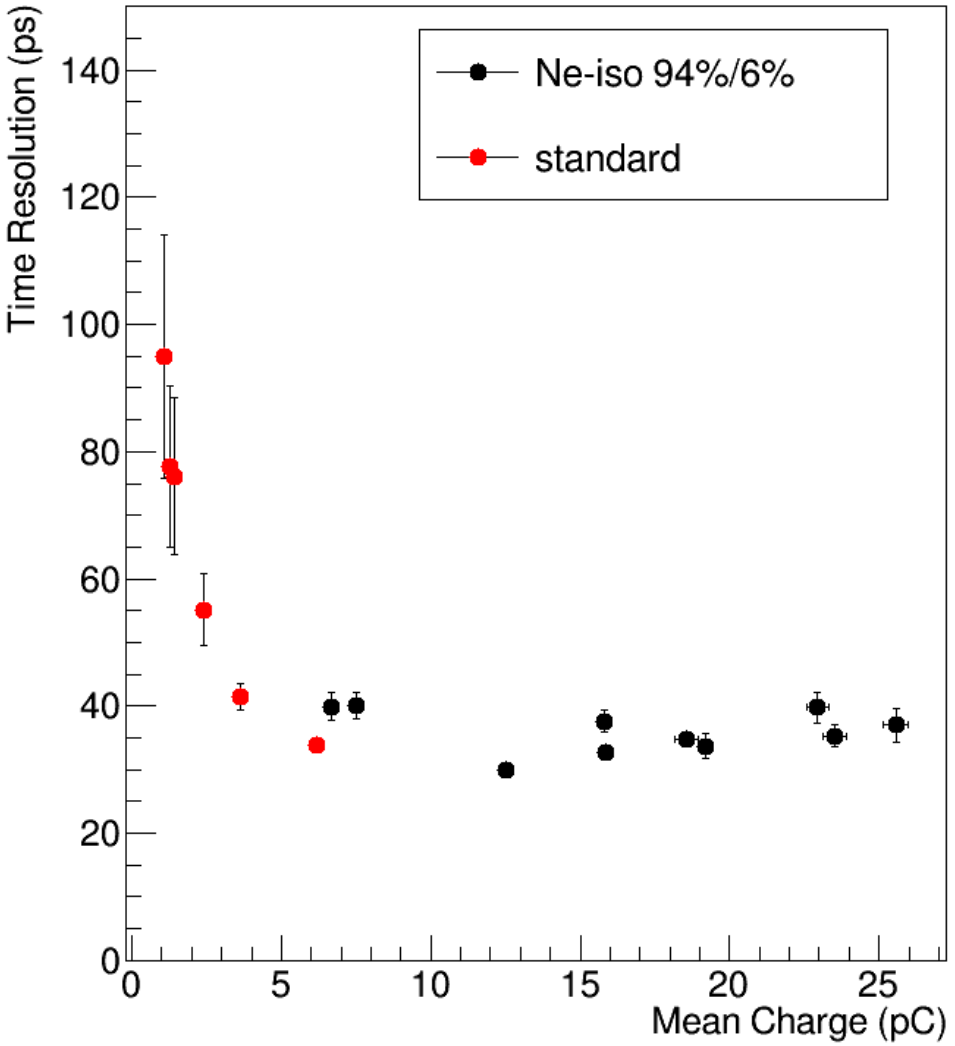


Gas mixtures

380kOhm resistive Micromegas, B4C 7nm



82MOhm resistive Micromegas , CsI



Future perspectives

New materials:

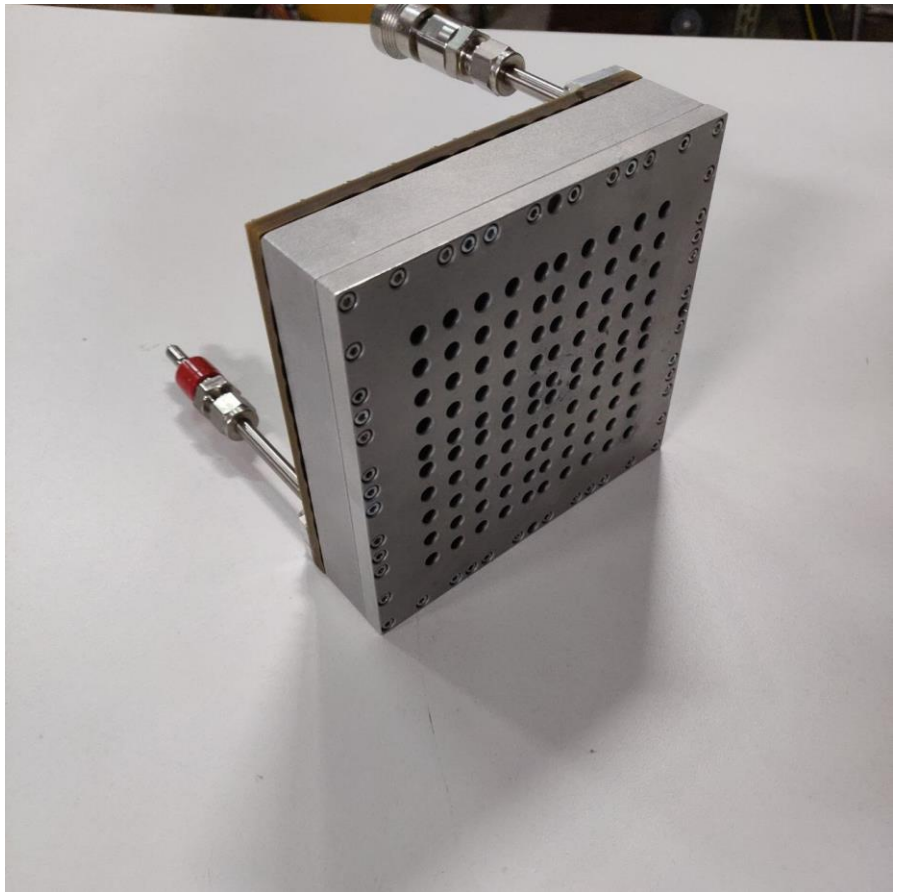
Gas: Ne/CO_2 90%/10%
Radiators: CaF_2, UV Broadband Fused Silica
Photocathodes: further tests

Scalability:

10x10 cm^2 prototype
100 readout channels

New Tests:

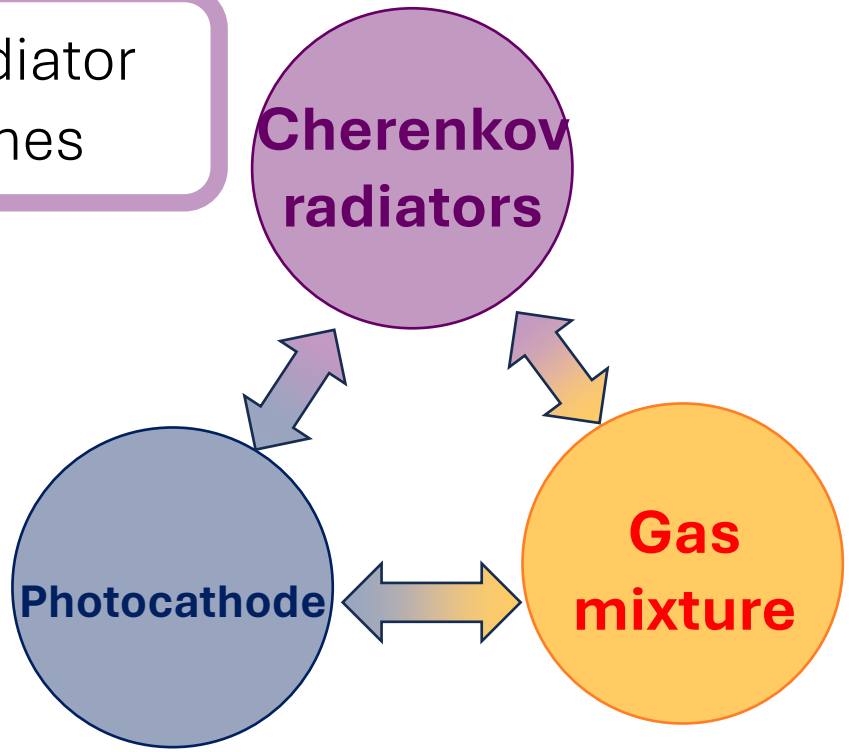
New tests are being performed at the Test Beam at the H4 beam line of the CERN SPS



Conclusions

- Picosec is an MPGD capable of reaching high performance in terms of time resolution (order of tens of ps) and is suitable for future experiments at a Muon Collider facility

MgF_2 is the best radiator among the tested ones



CsI grants higher performances but **DLC 2.5nm** could be a good alternative

Ne/iC_4H_{10} 94%/6%
Comparable to the standard but:

- wider operating range
- reduced GWP

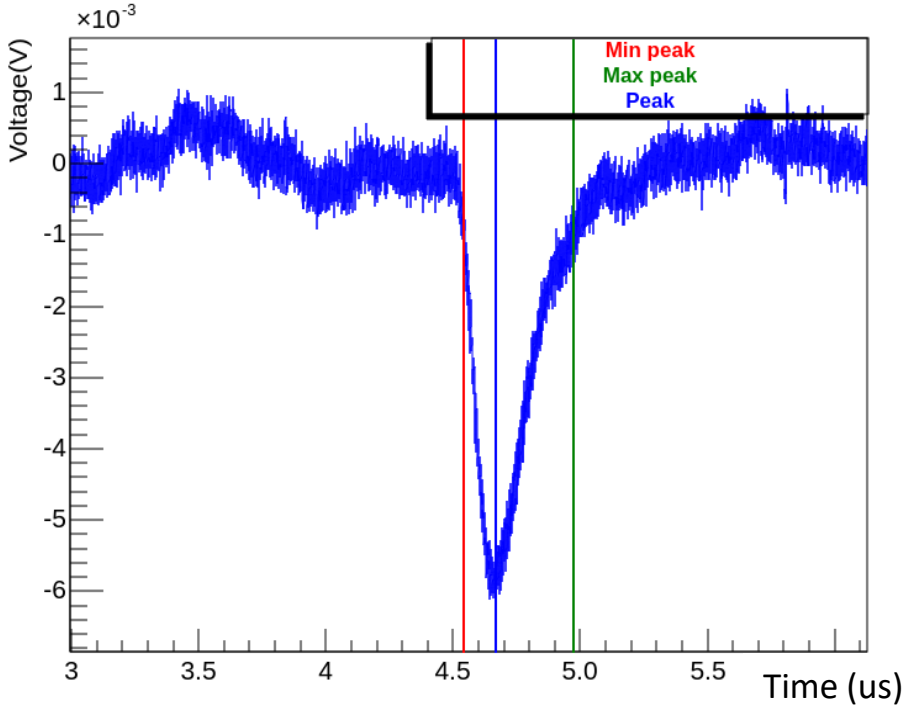
- Ongoing study aimed at proving the feasibility of a bigger Picosec detector and the scalability of this technology

backup

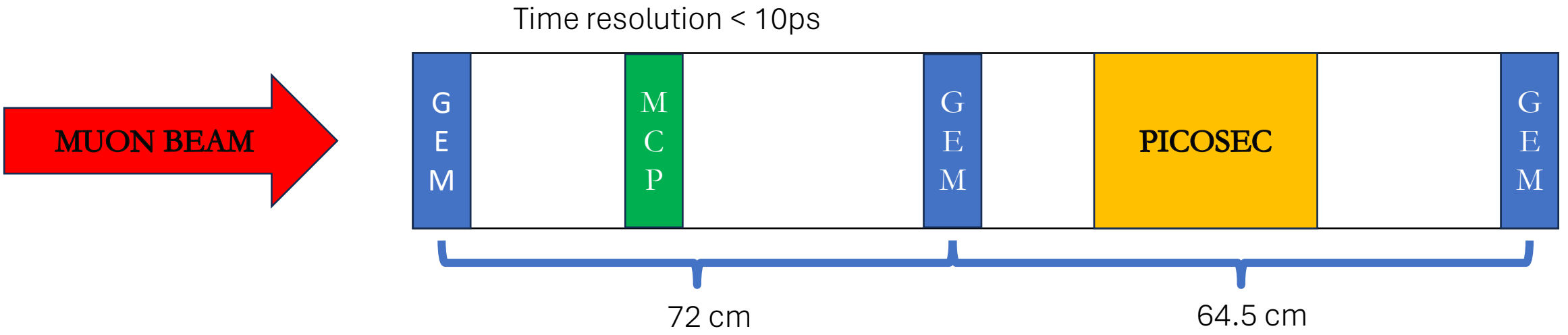
Single PhotoElectron (SPE)

Single PhotoElectron measurements (SPE):

- UV LED pointed directly to the window
- Extraction of a single electron from the photocathode
- Charge amplifier with long integration time (≈ 100ns)



PE / Timing



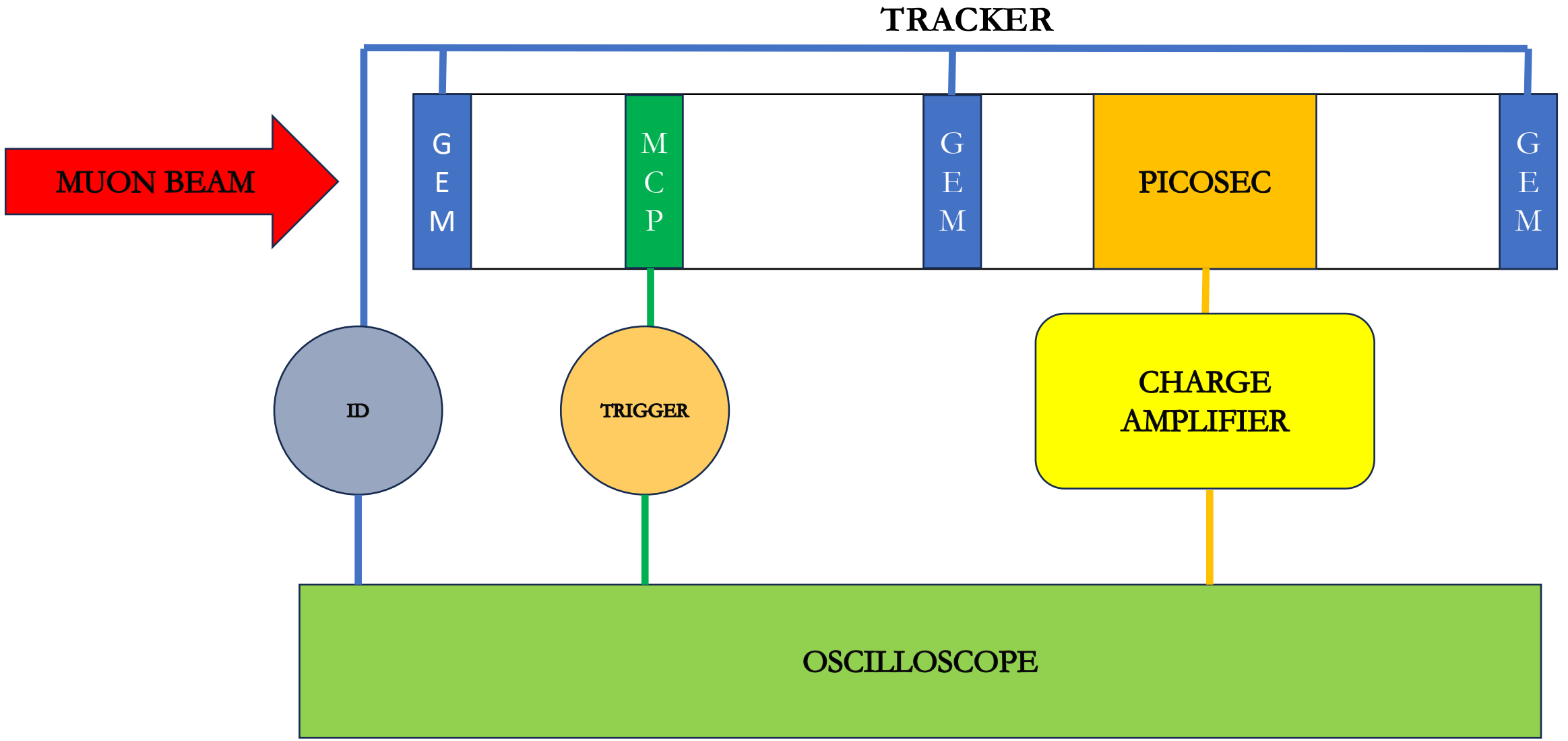
Multiple Photoelectron measurements (PE):

- Muon beam
- **Charge** amplifier
- Gas Electron Multiplier (GEM) for the tracking
- Micro Channel Plate (MCP) as trigger

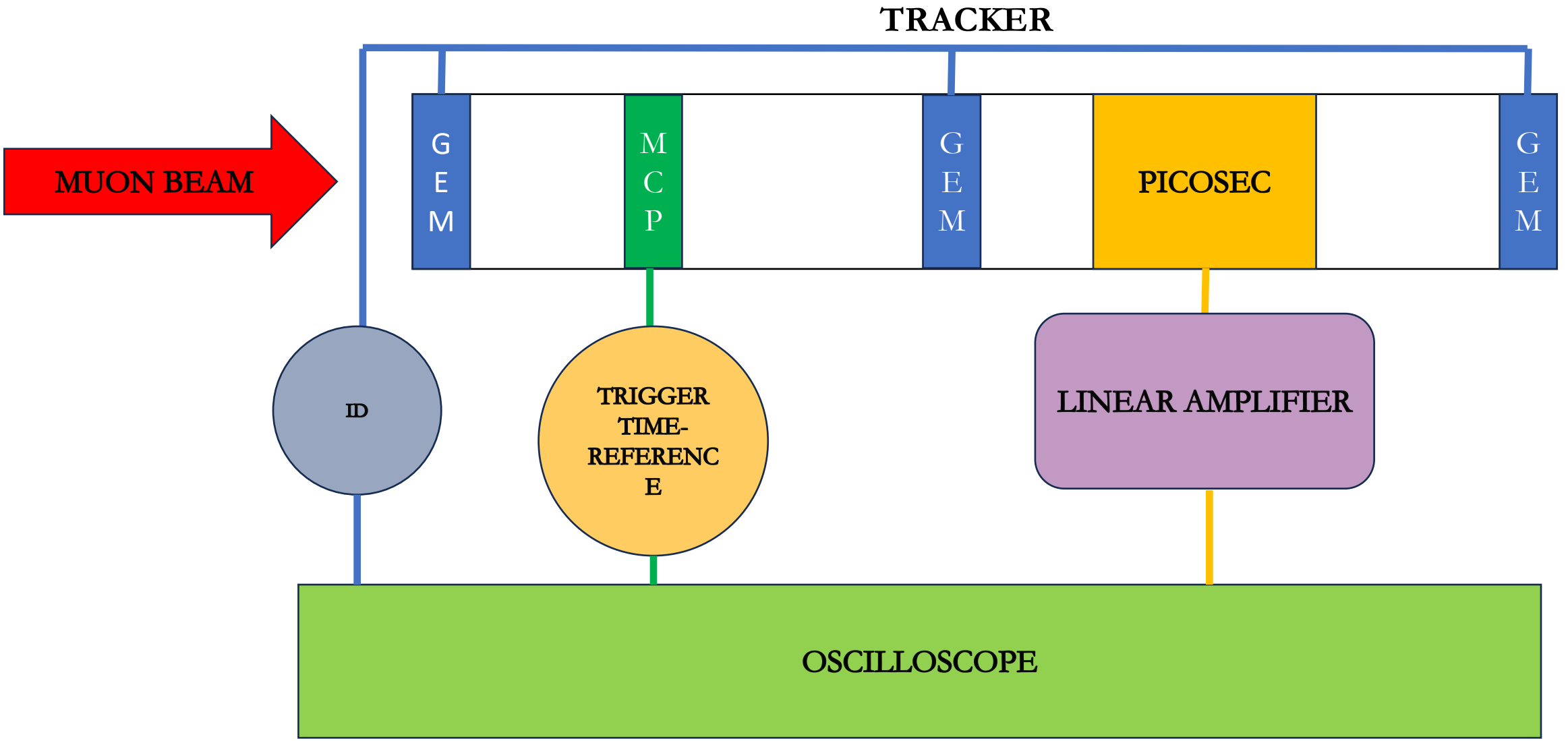
Timing measurements:

- Muon beam
- **Linear** amplifier
- GEM for the tracking
- MCP as trigger and **time reference**

PE setup

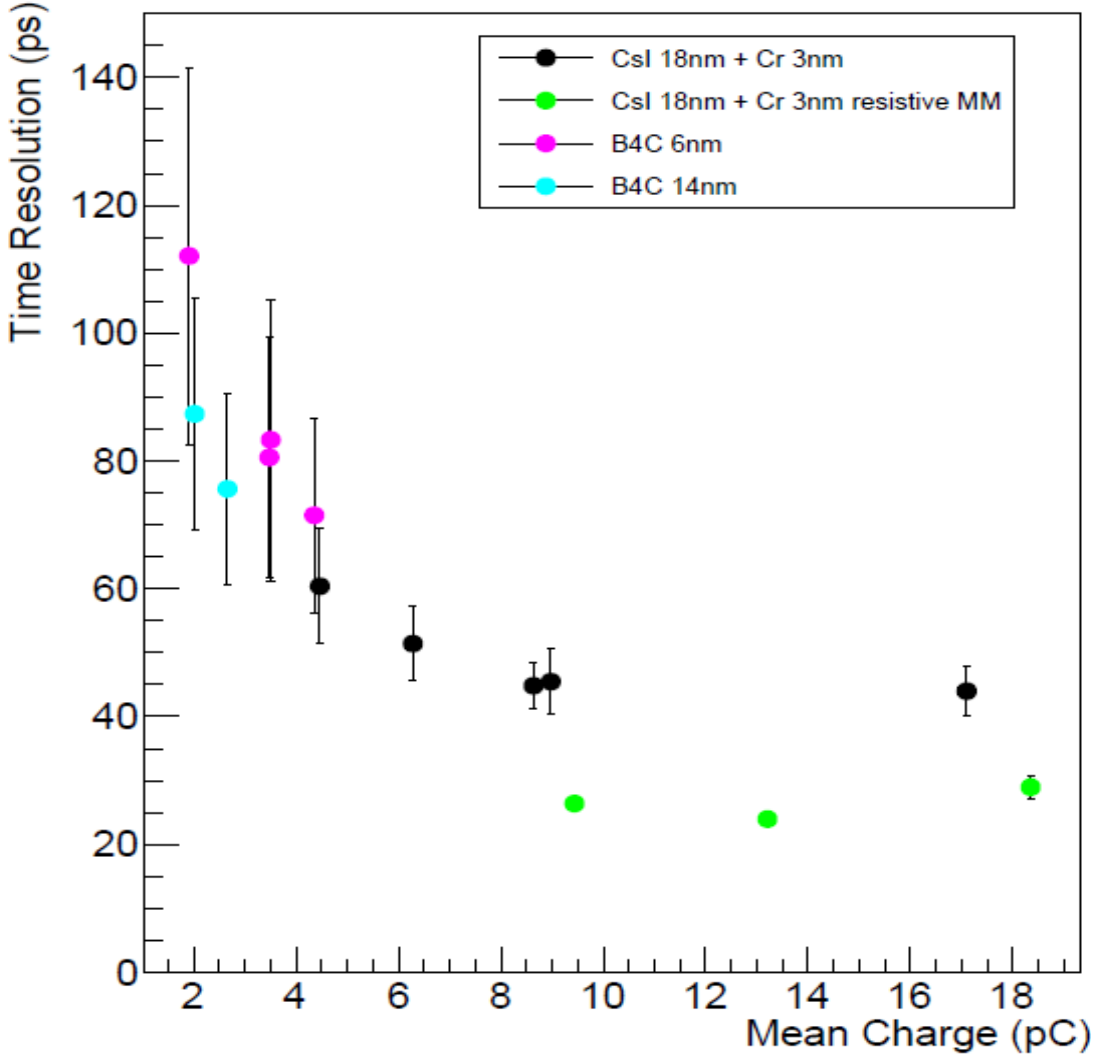

TRACKER
MUON BEAM
GEM
MCP
GEM
PICOSEC
GEM
ID
TRIGGER
CHARGE AMPLIFIER
OSCILLOSCOPE

Timing setup



Other PC results

Test Beam I
Non-resistive Micromegas, standard mixture



Test Beam II
Non-resistive Micromegas, standard mixture