UNIVERSITÀ
DI PAVIA

INFN

Picosec: toward a greener detector for the future

End of the year seminar – First year

Matteo Brunoldi

Supervisors: dr. C. Aimè, prof. I. Vai, prof. P. Vitulo

18/09/2025

Future colliders

Colliders are essential instruments for research in the high-energy physics (HEP) field

Need for a new generation of machines:

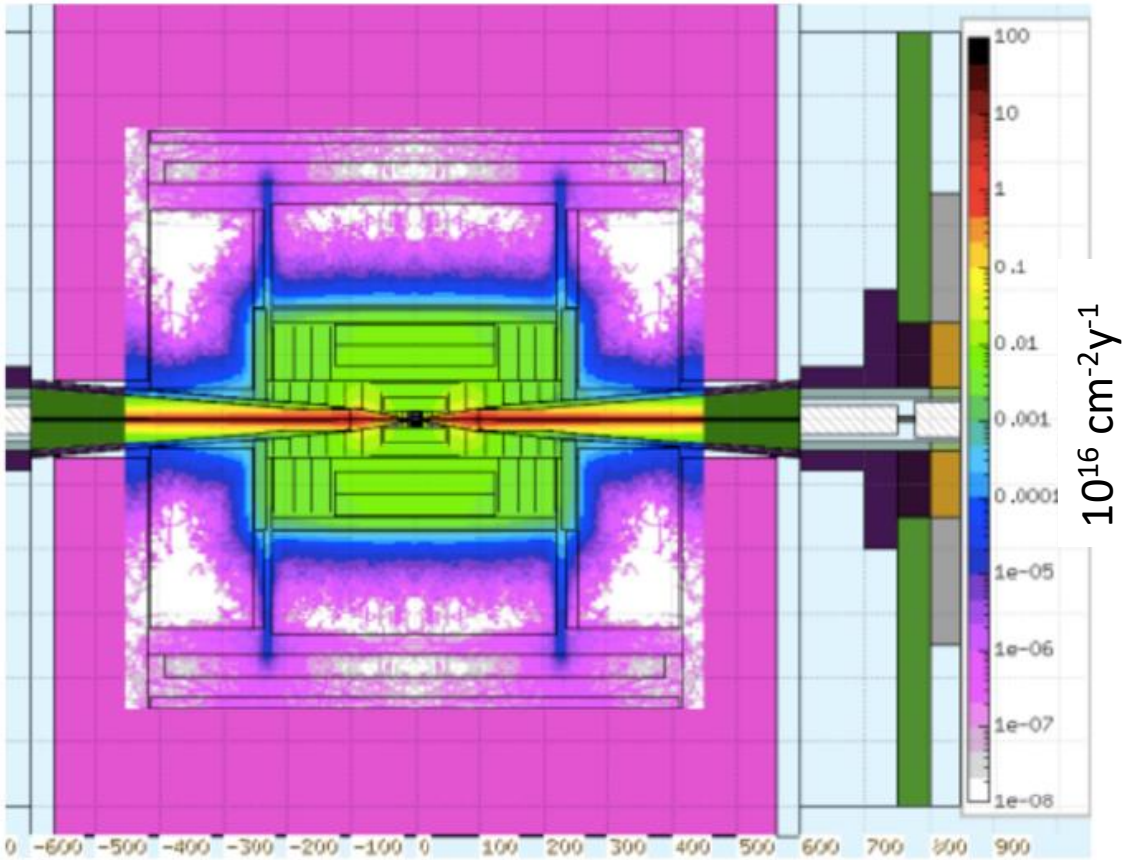
- Higher luminosity
- Higher center-of-mass collision energy

⇓

Need for a new generation of (gaseous) detectors:

- Better time resolution
- Eco-friendly mixtures

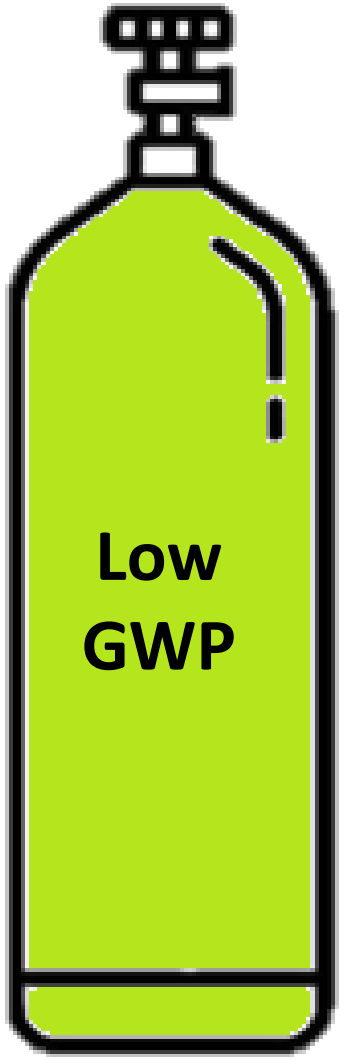
Muon Collider



1MeV-neq fluence in the detector region

C. Accettura et al., Towards a muon collider, Eur. Phys. J. C 83 (2023) 864

Aim of my PhD project



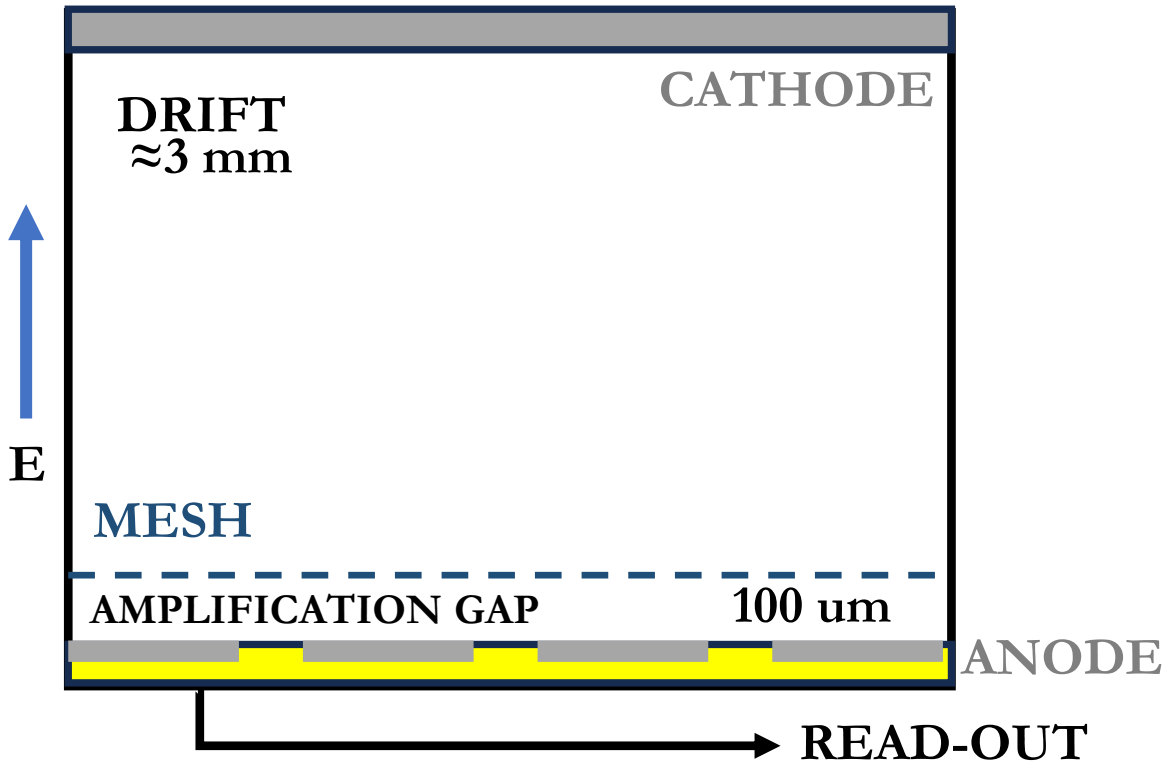
- R&D of the Picosec detector:
  - Focus on eco-friendly gas mixtures
- Develop applications in non-High Energy Physics (HEP) field

- Work in the upgrade of the Gas Electron Multiplier (GEM) subsystem of the CMS experiment at CERN

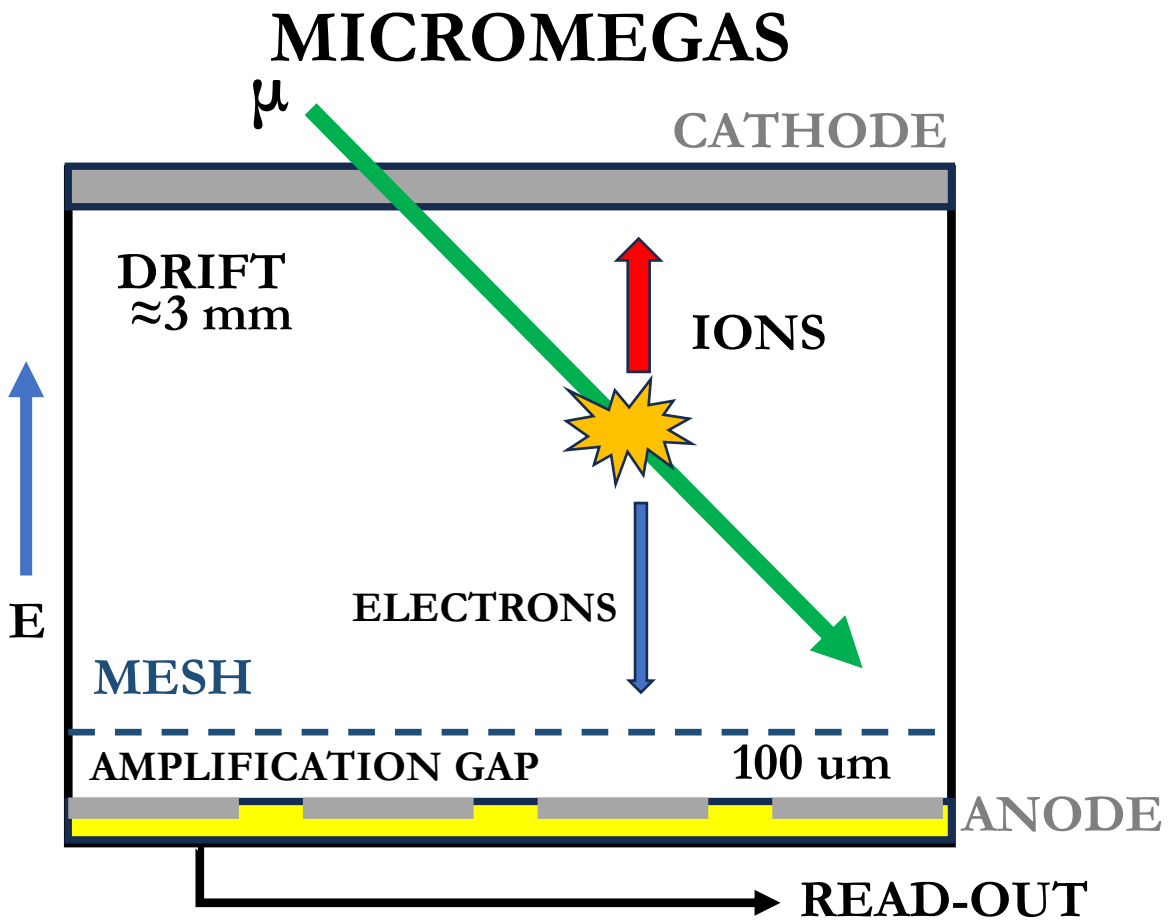
Gaseous detectors

MicroPattern Gaseous Detector (MPGD):
amplification structures less than 1mm thick

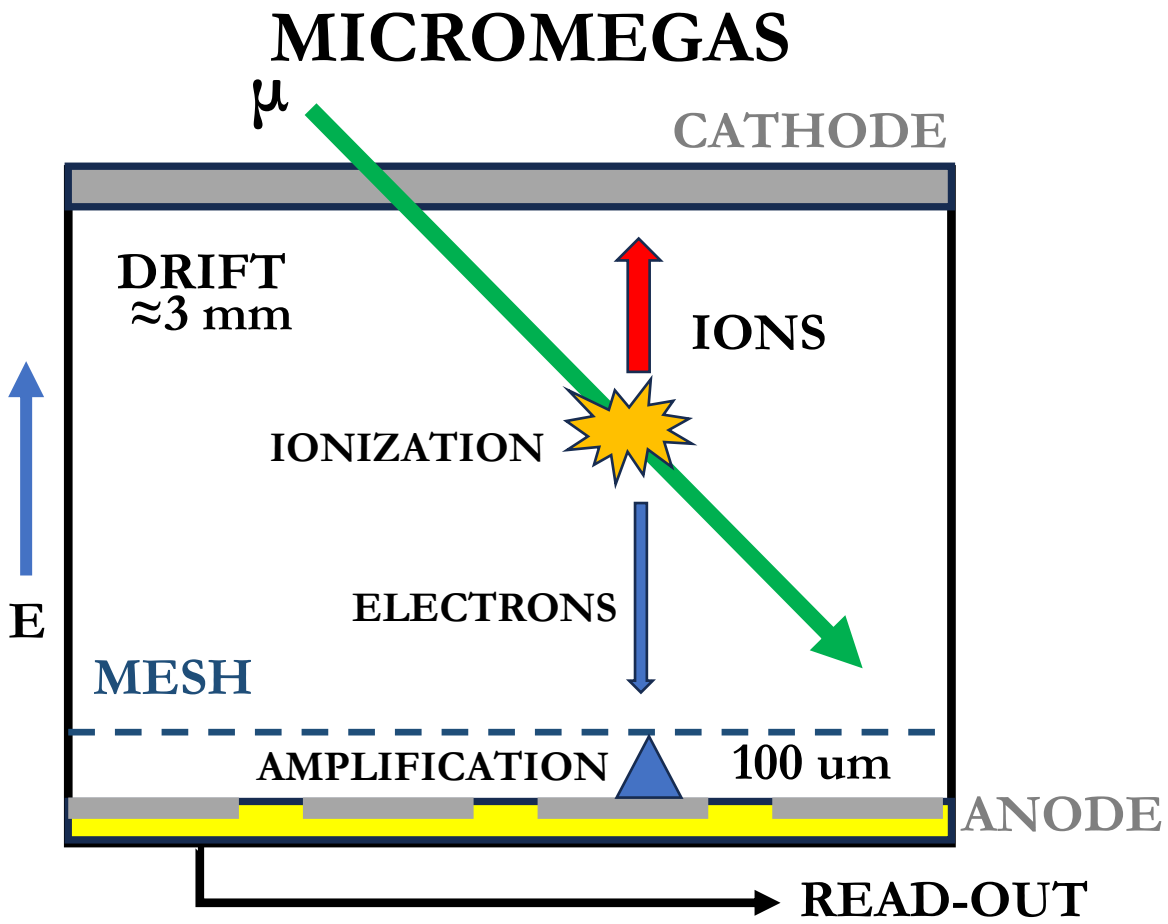
MICROMEGAS



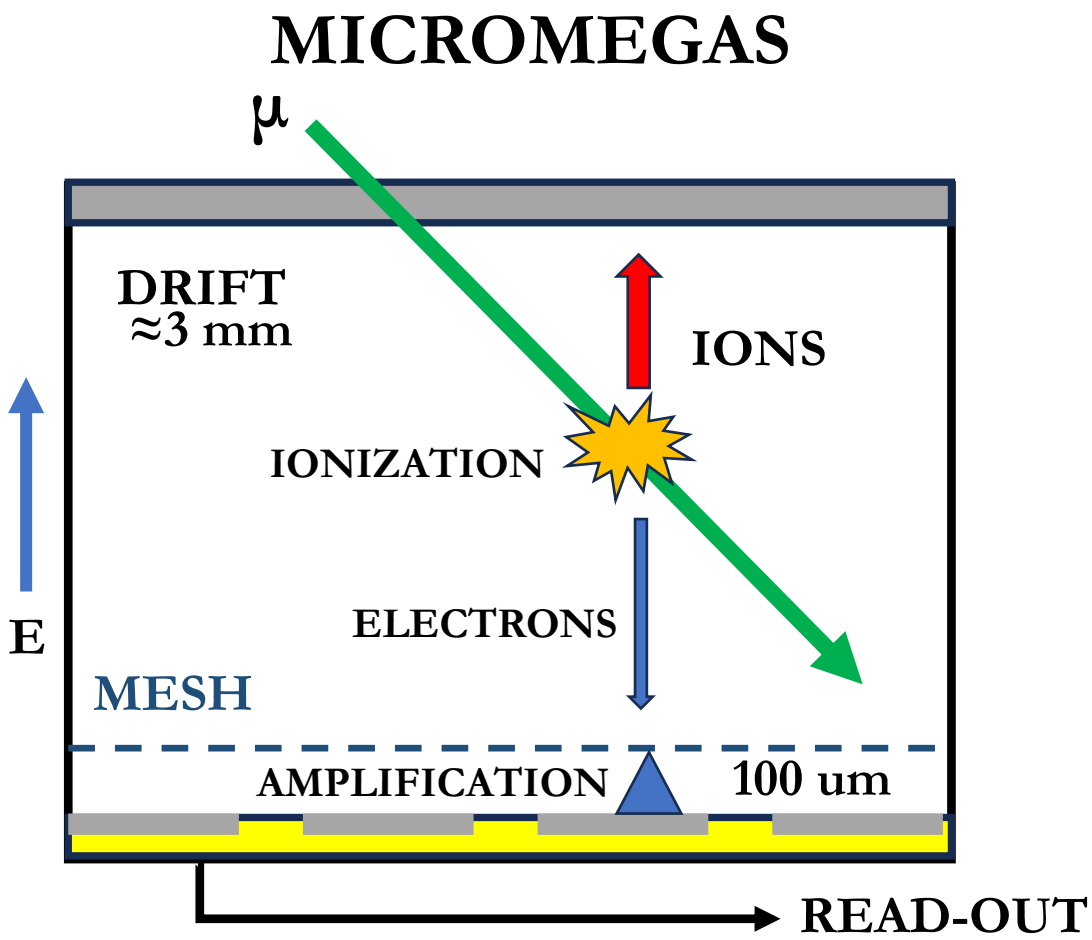
Gaseous detectors

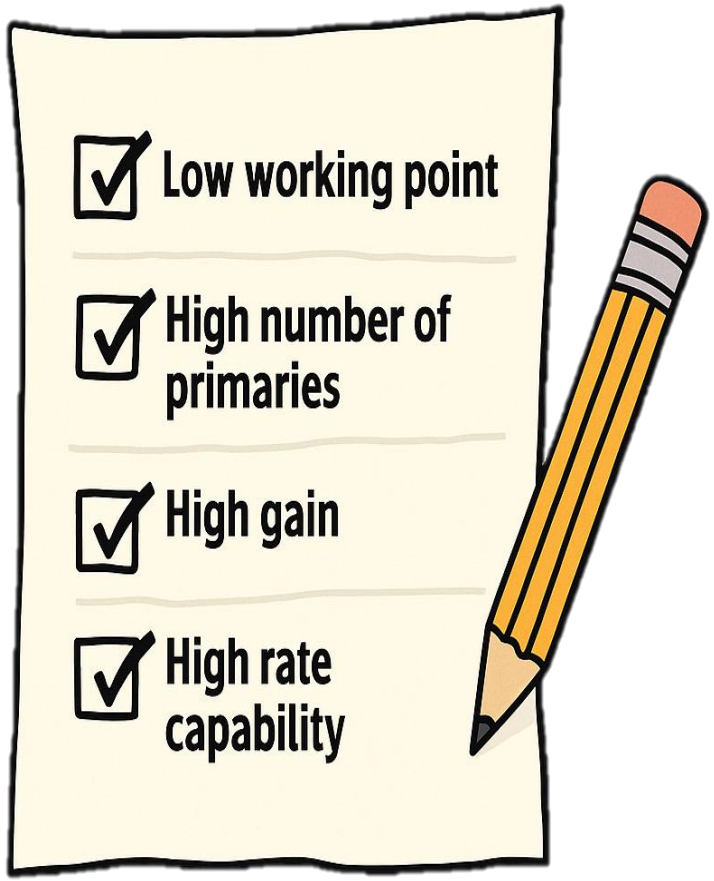


Gaseous detectors

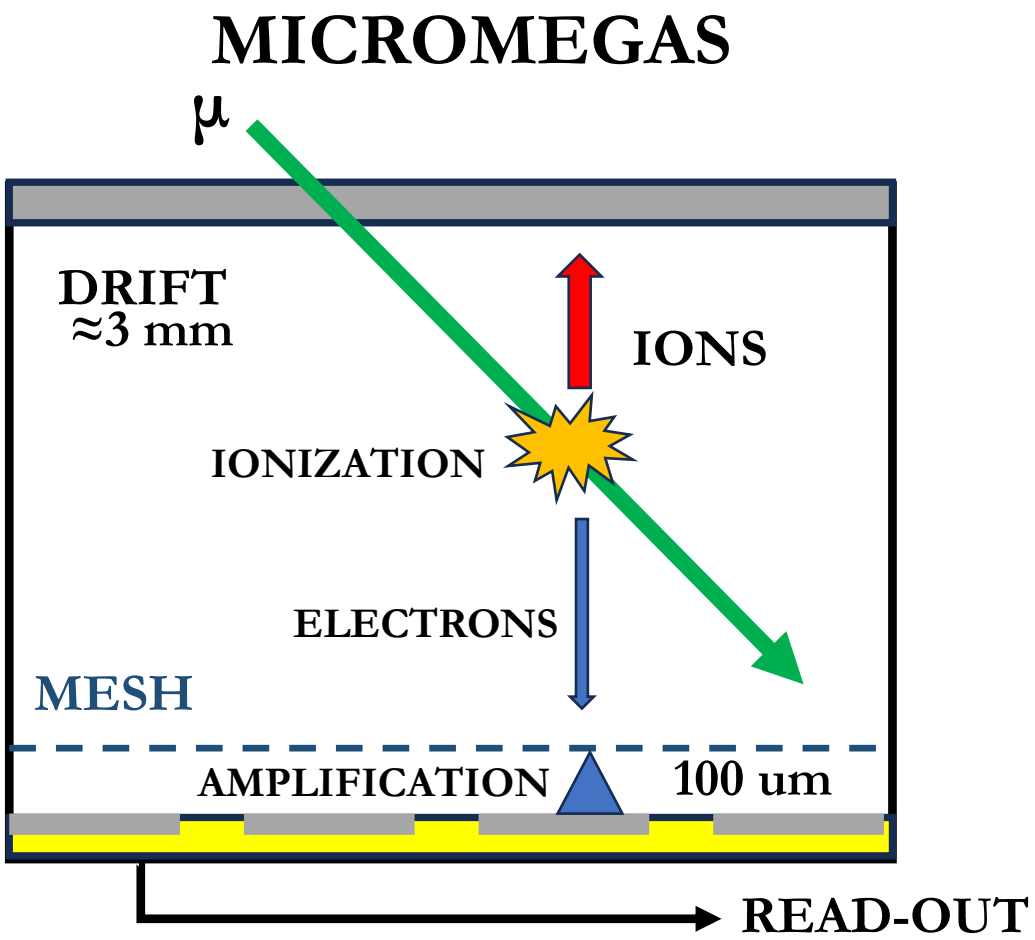


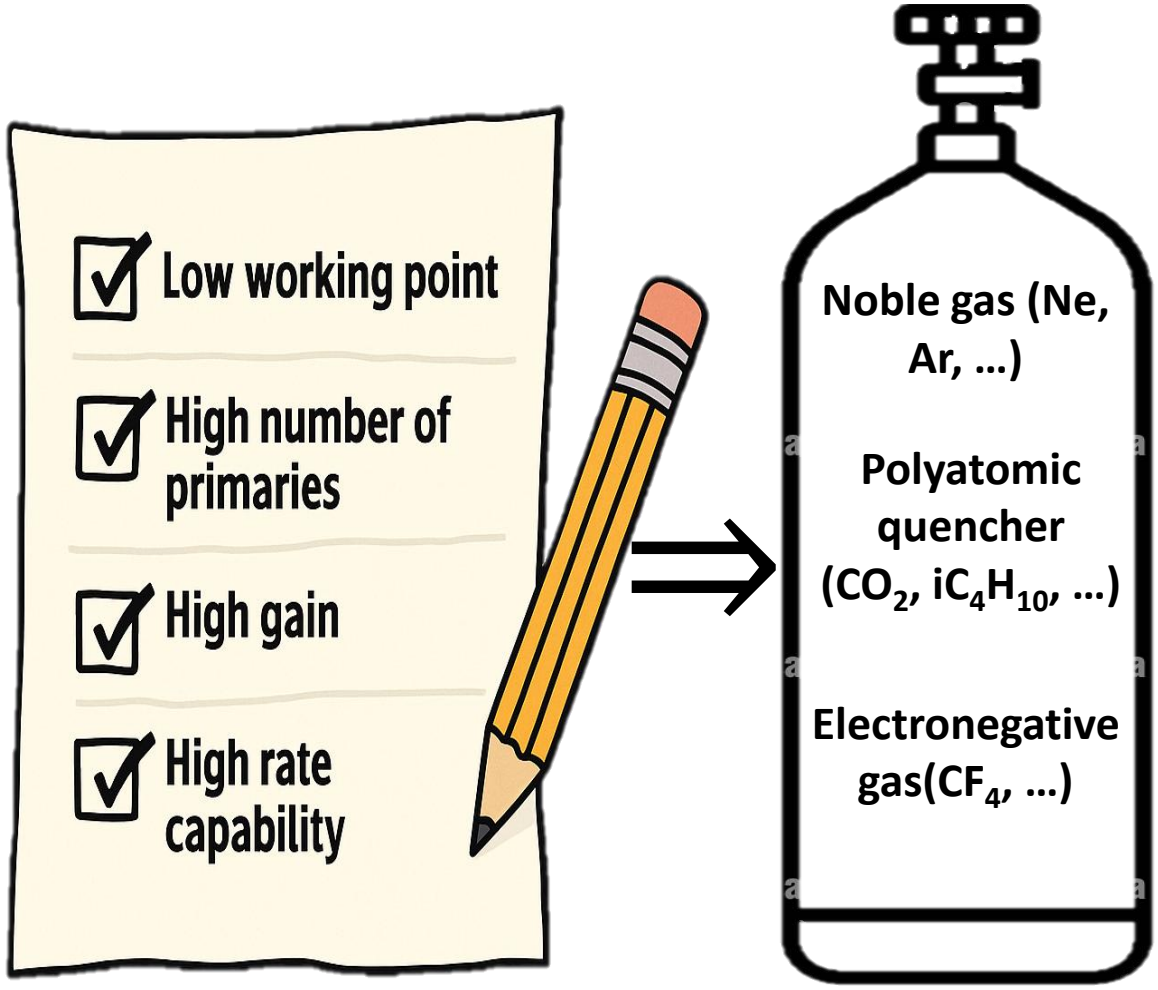
Gaseous detectors



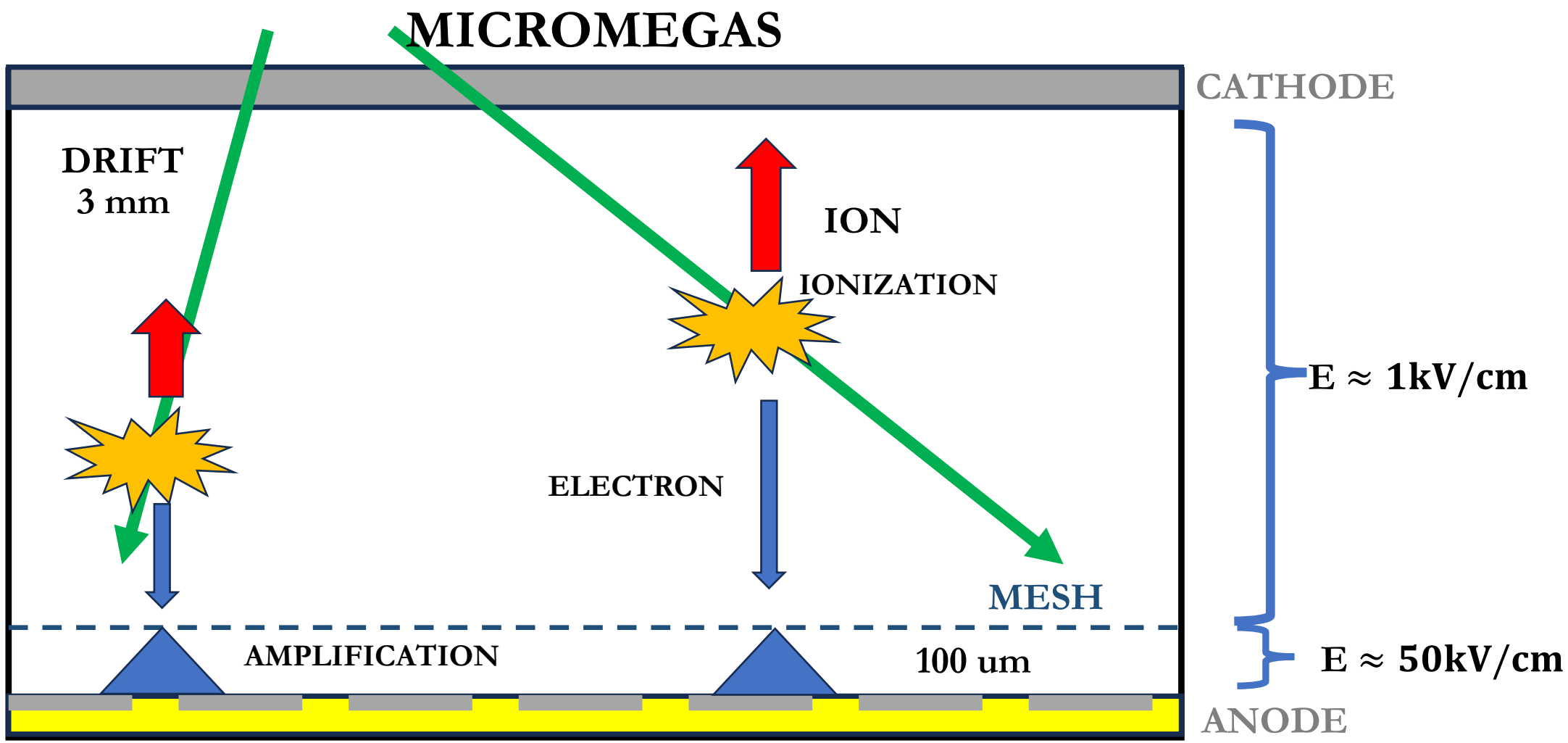


Gaseous detectors



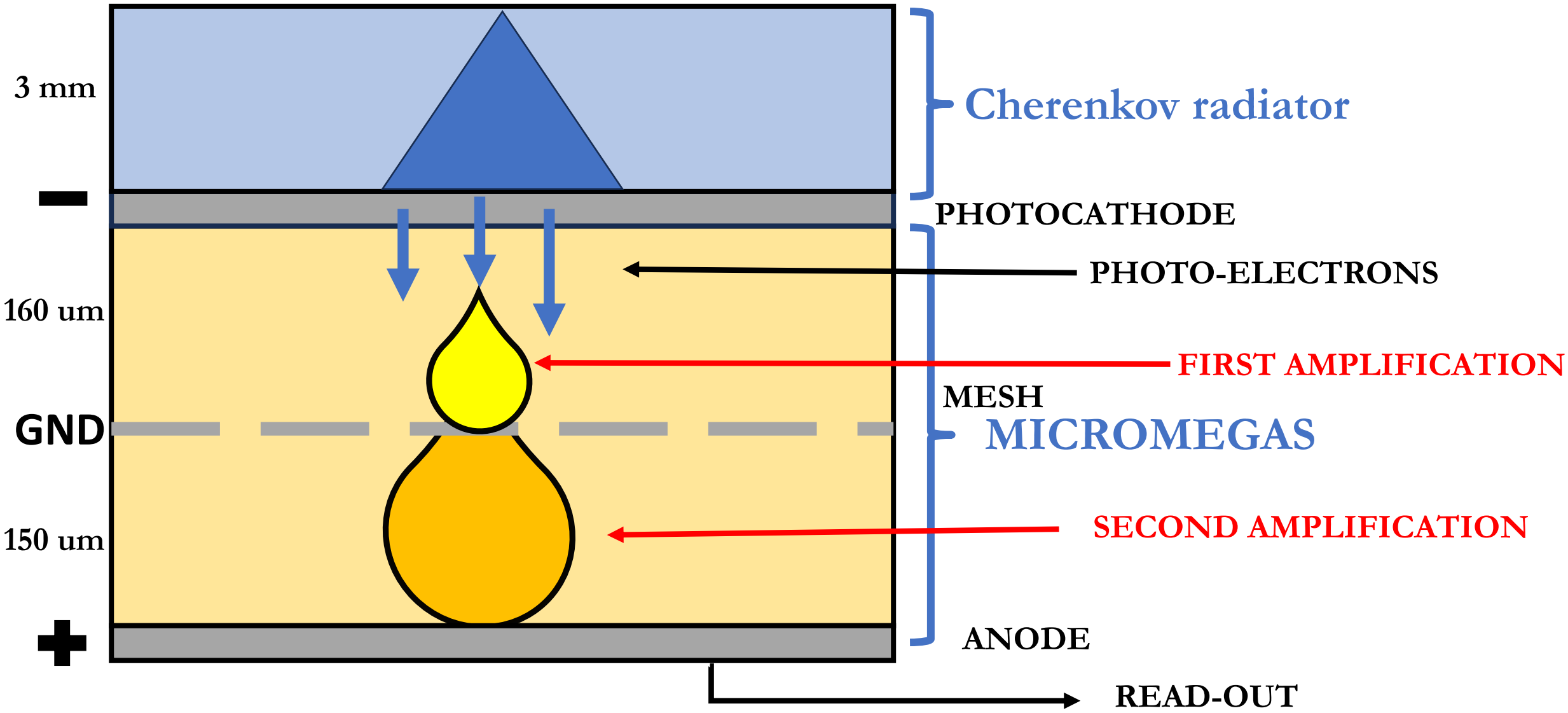


Time resolution of an MPGD

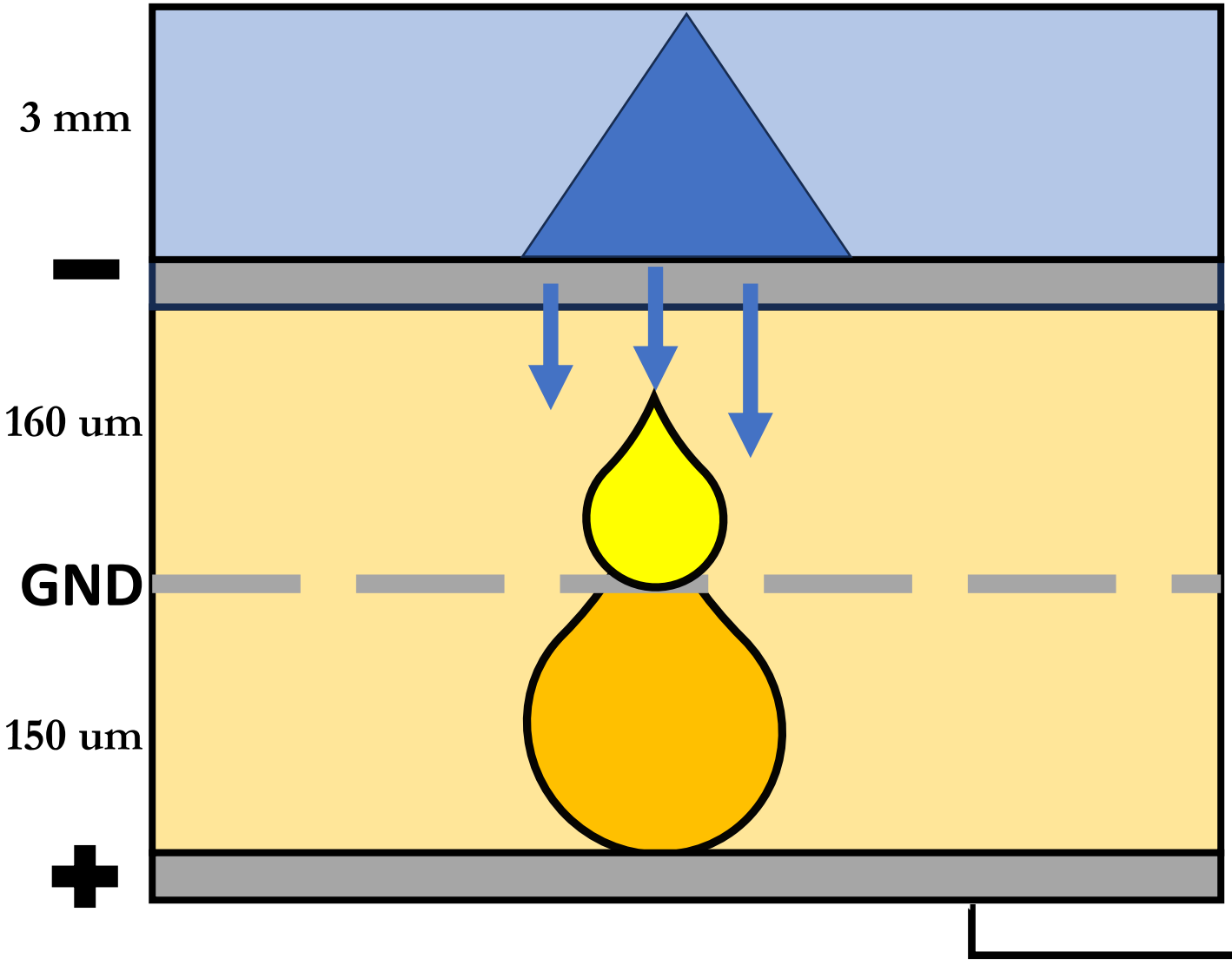


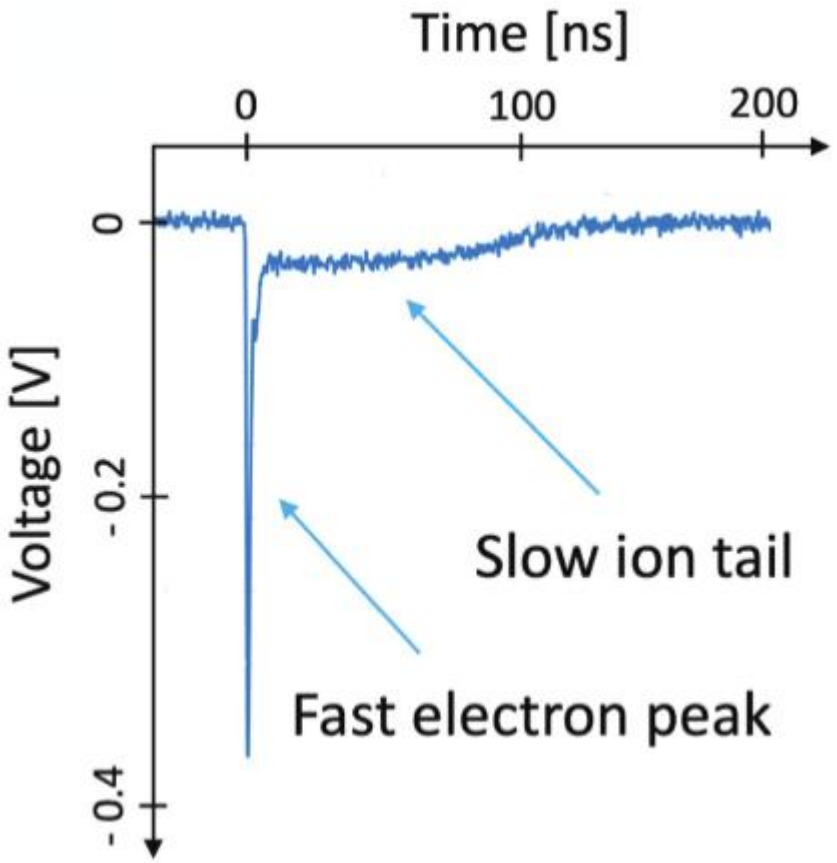
Time resolution limited to **few ns**

Picosec detector



Picosec detector



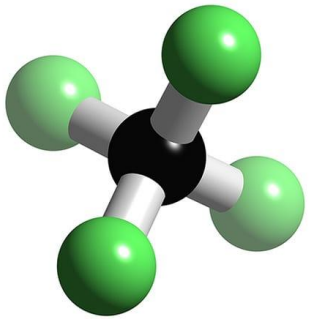


READ-OUT

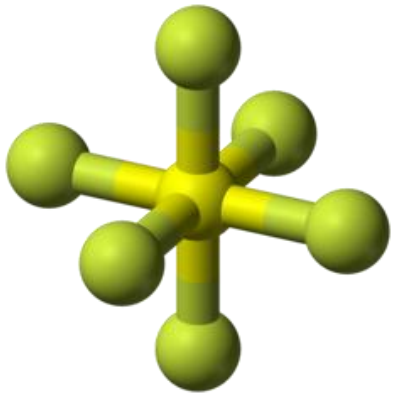
Picture: M. Lisowska et al. “Photocathode characterisation for robust PICOSEC Micromegasprecise-timing detectors”,NIMA, 1072.170151(2025)

Gas mixtures problems

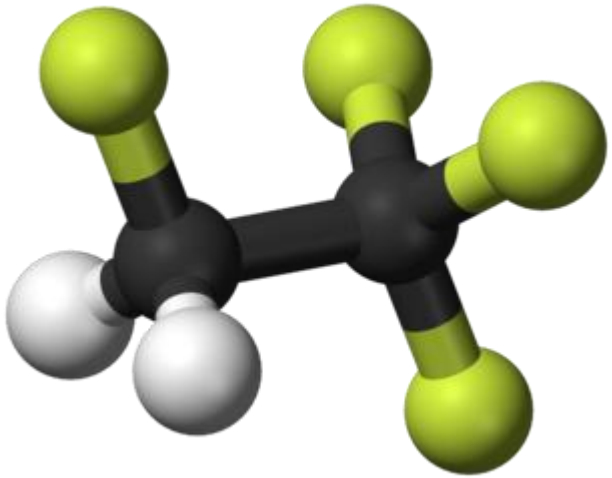
CF_4



SF_6



$C_2H_2F_4$

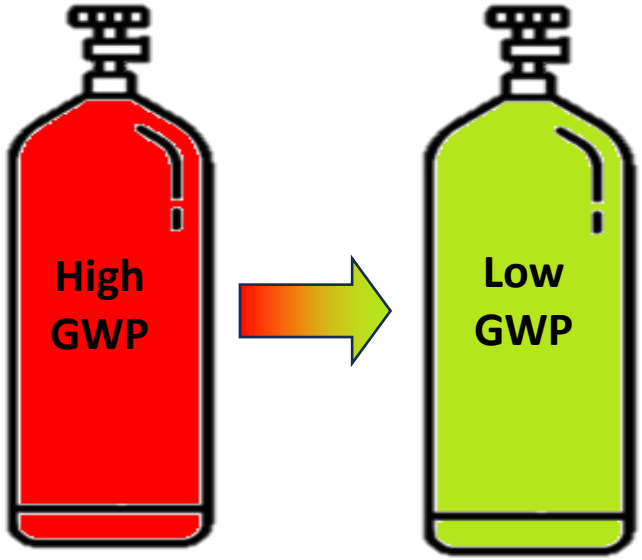


- High drift velocity
- Better timing
- High electronegativity

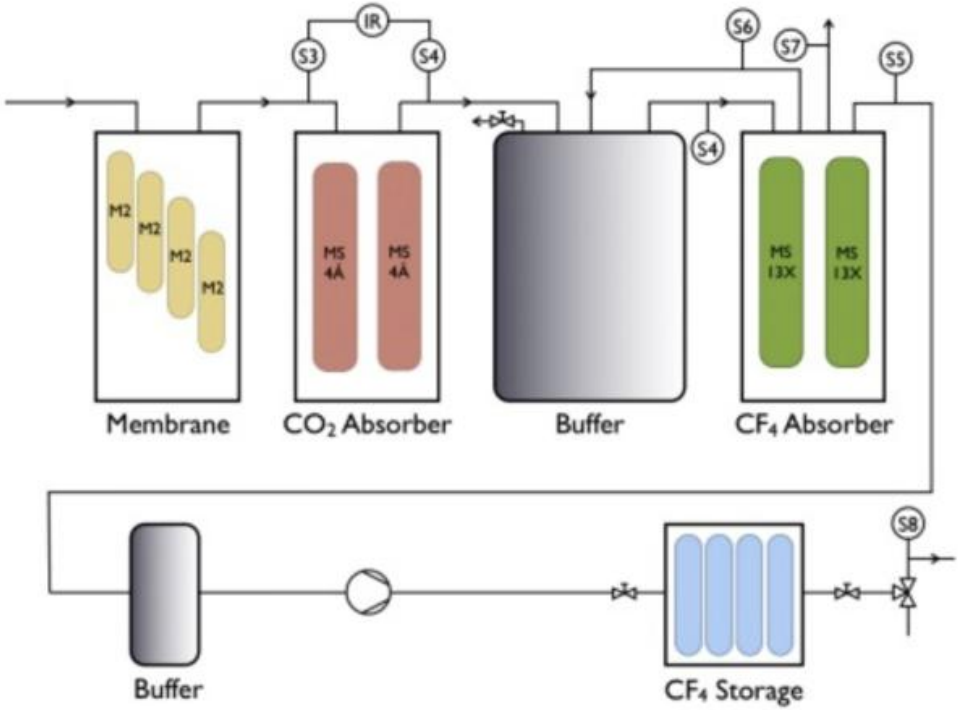
- **High Global Warming Potential**
- **Strict regulations in EU**

	GWP_{100}
CF_4	7380
$C_2H_2F_4$	1530
SF_6	24300

Search for solutions



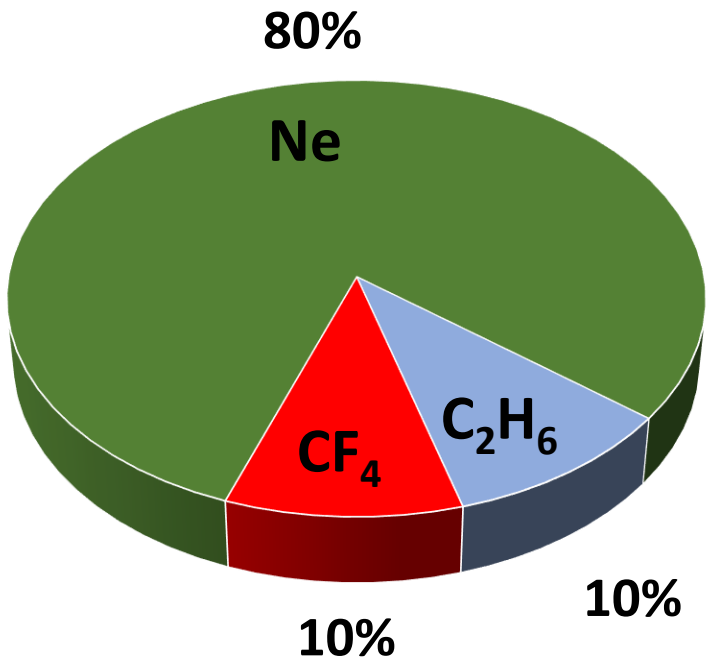
1. R&D to find new gases



2. Recovery and recirculation of the problematic gases

Picture: https://indico.in2p3.fr/event/32778/contributions/137709/attachments/84145/125472/PhDday_Verzeroli.pdf

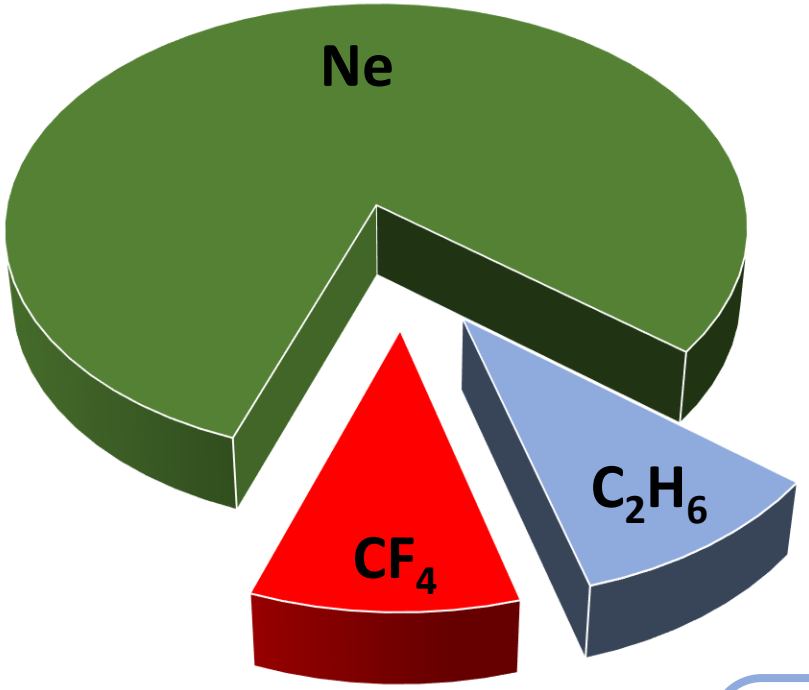
Picosec gas mixture



Picosec gas mixture

Ne

- Noble gas
- Expensive



GWP ≈ 740

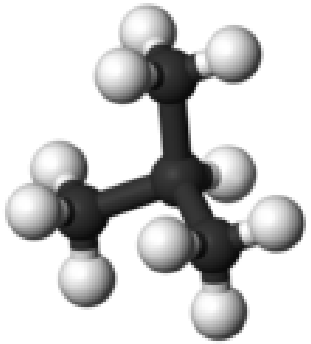
CF_4

- High GWP
- Supplies scarcity
- Costs

C_2H_6

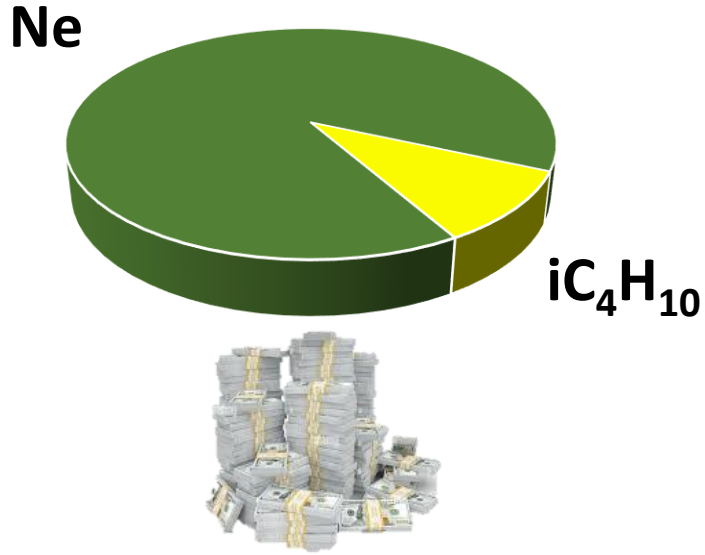
- Flammable

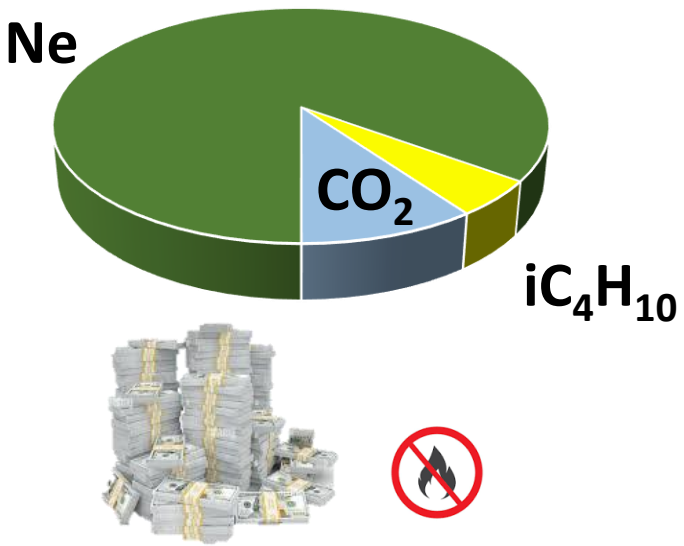
Alternative gas mixtures

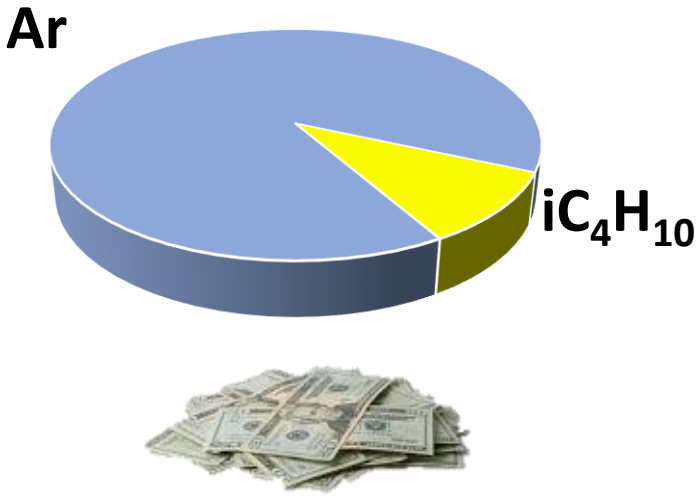


iC_4H_{10}

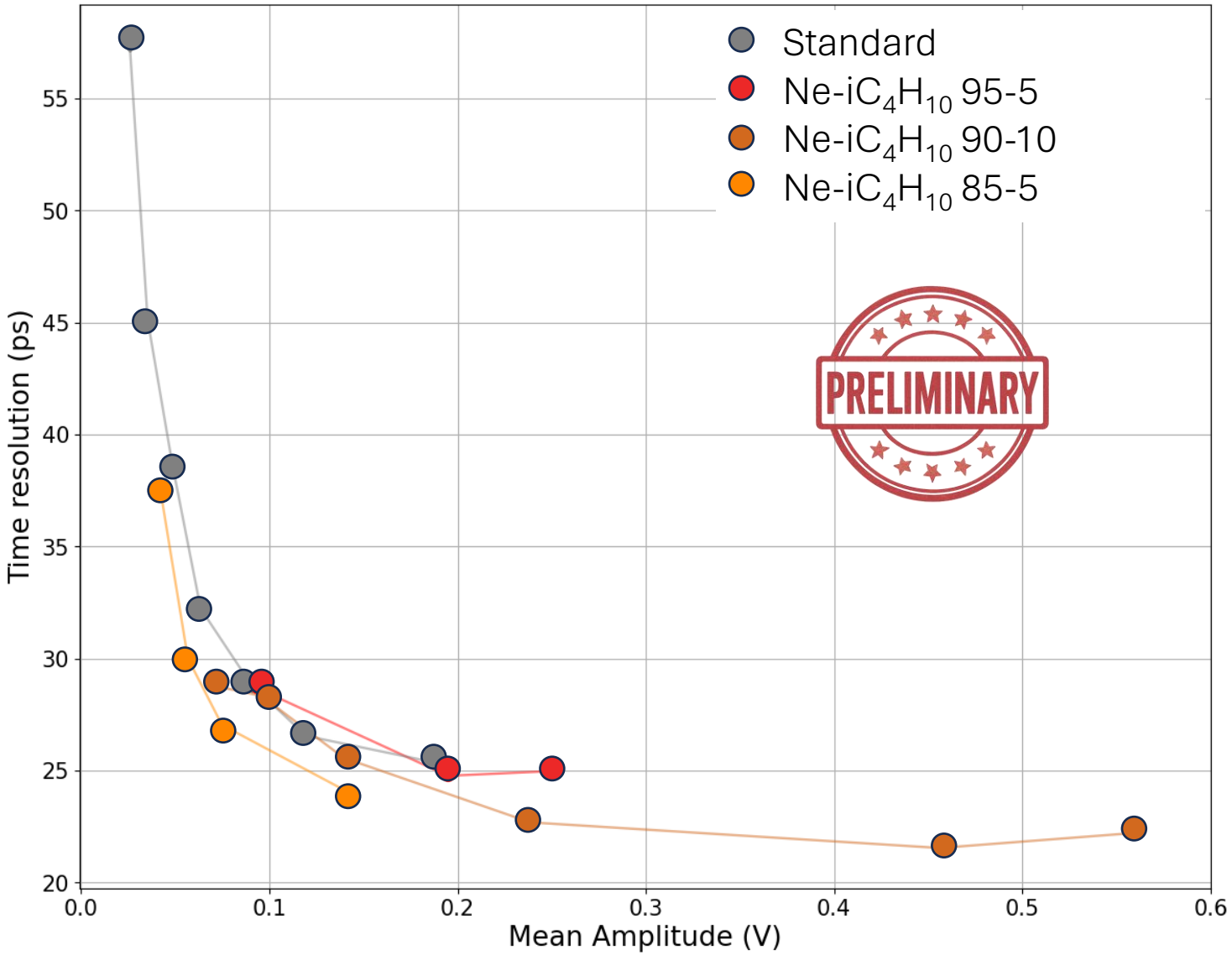
GWP 0.006







Preliminary results



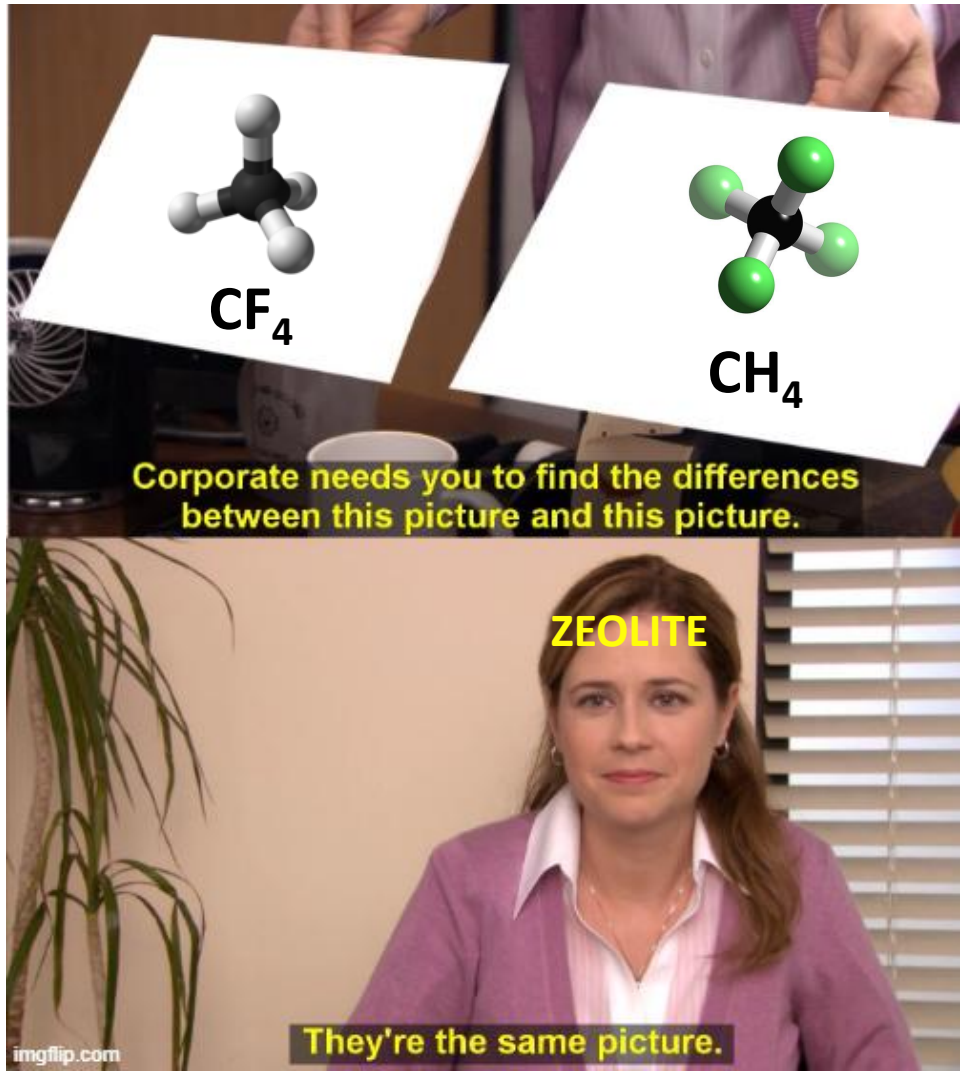
Test beam July- August 2025:

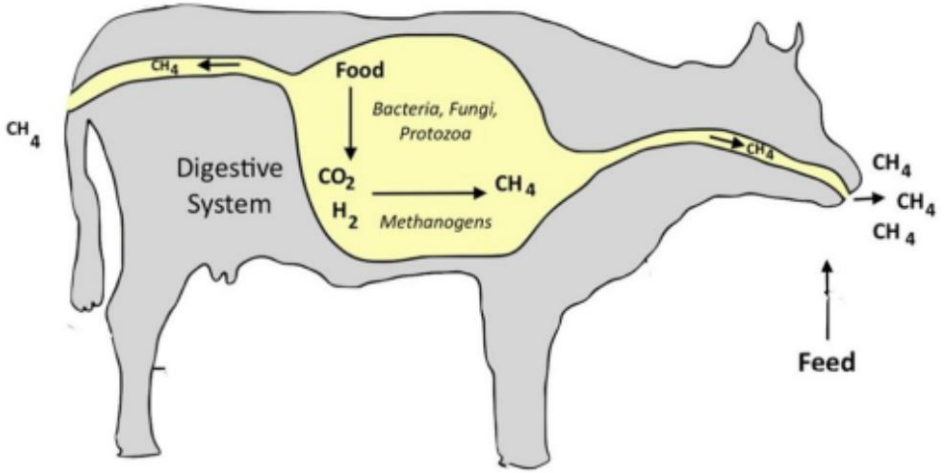
Ne-isobutane (iC_4H_{10}) mixtures

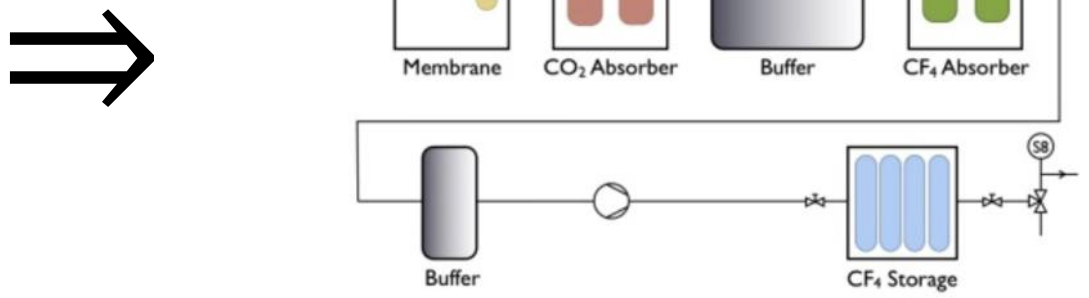
- Comparable time resolution
- Wider gain range
- Less GWP

Errors analysis ongoing

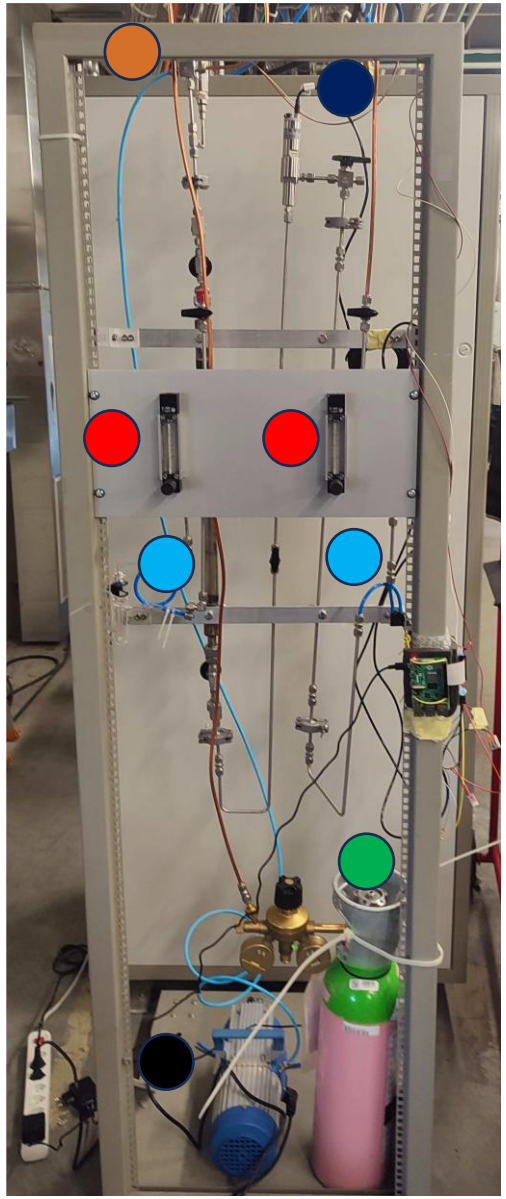
Applications in non-HEP

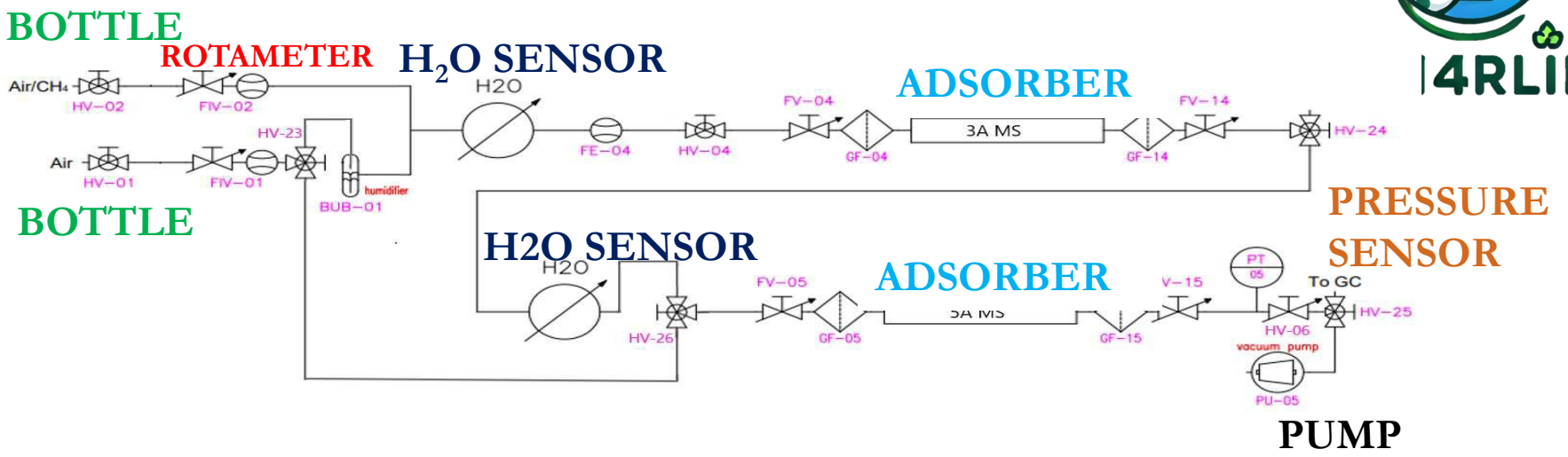






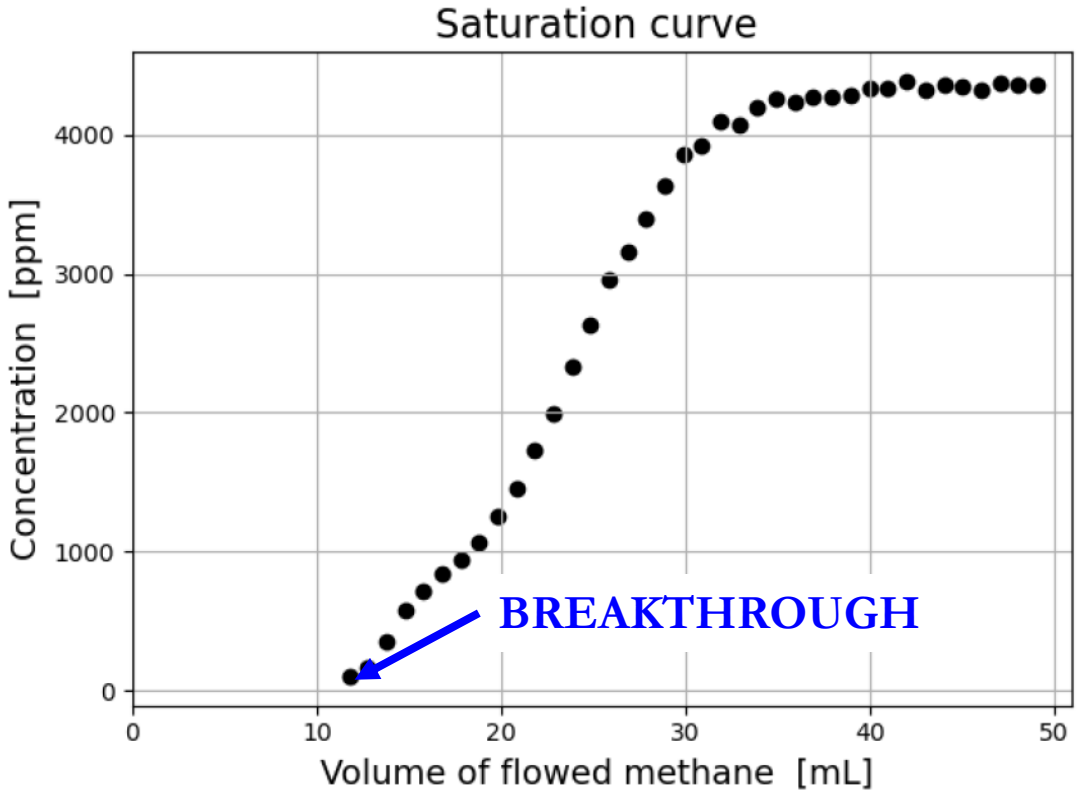
CH4rLiE

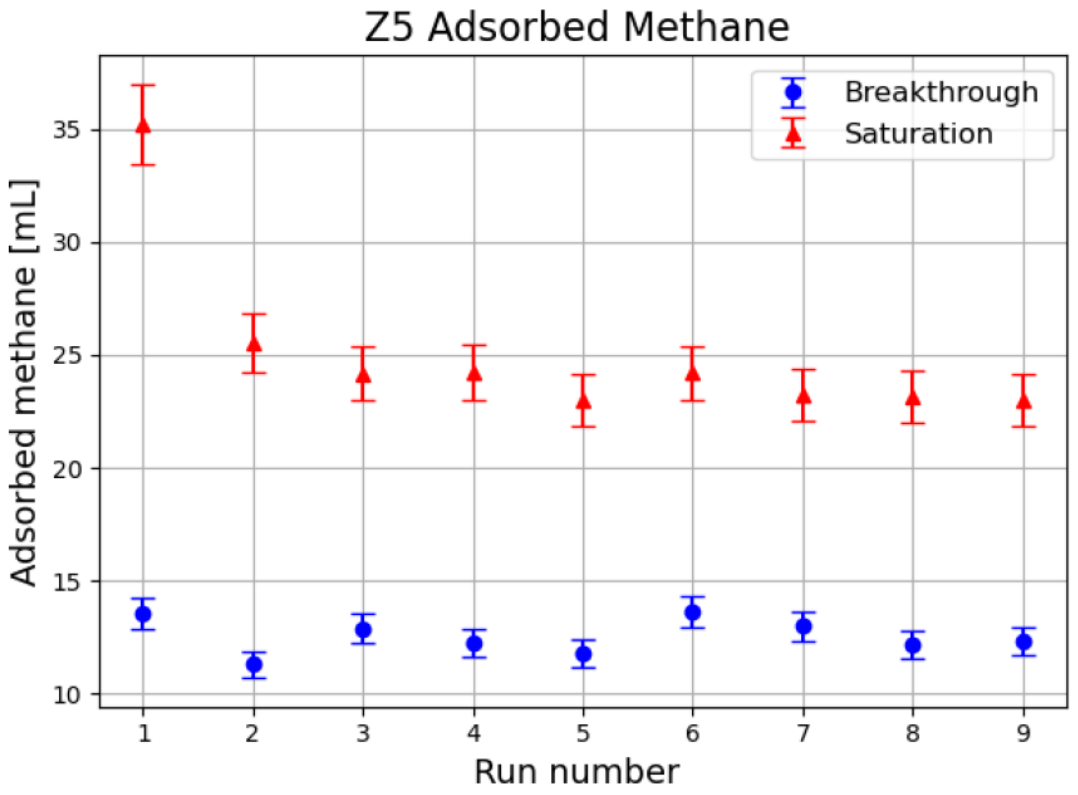




- How much methane can we adsorb?
- What is the effect of humidity?
- What is the effect of other pollutants?

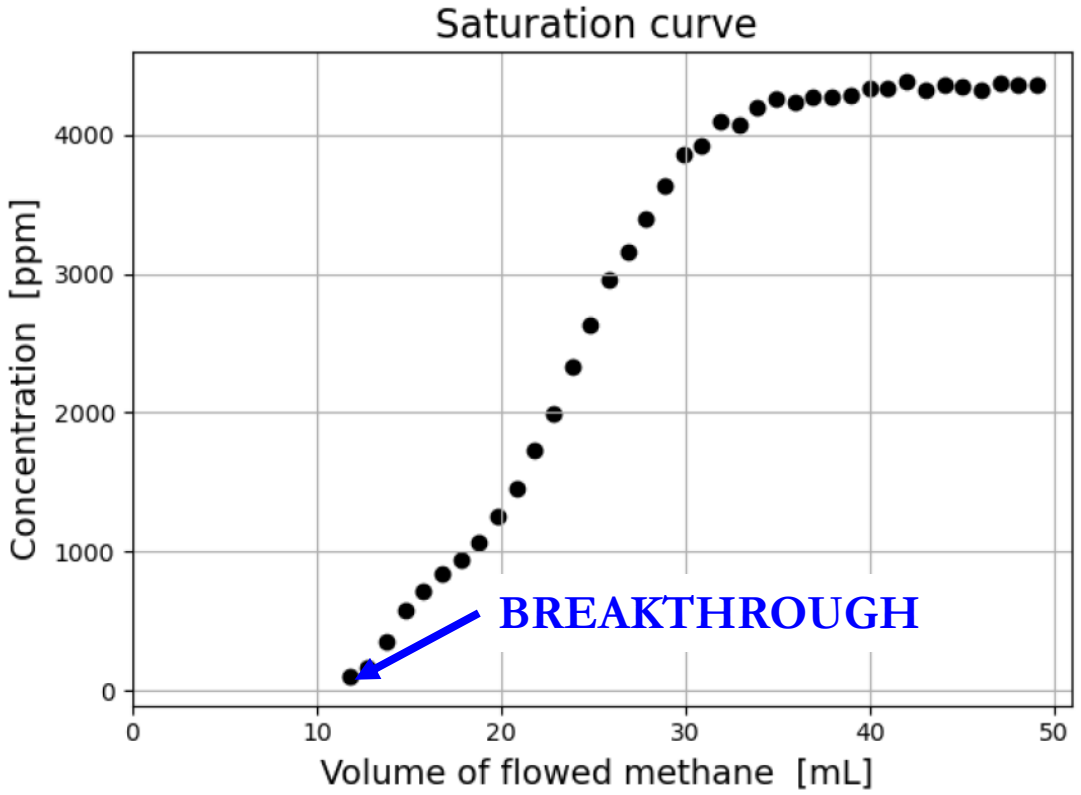
CH4rLie results

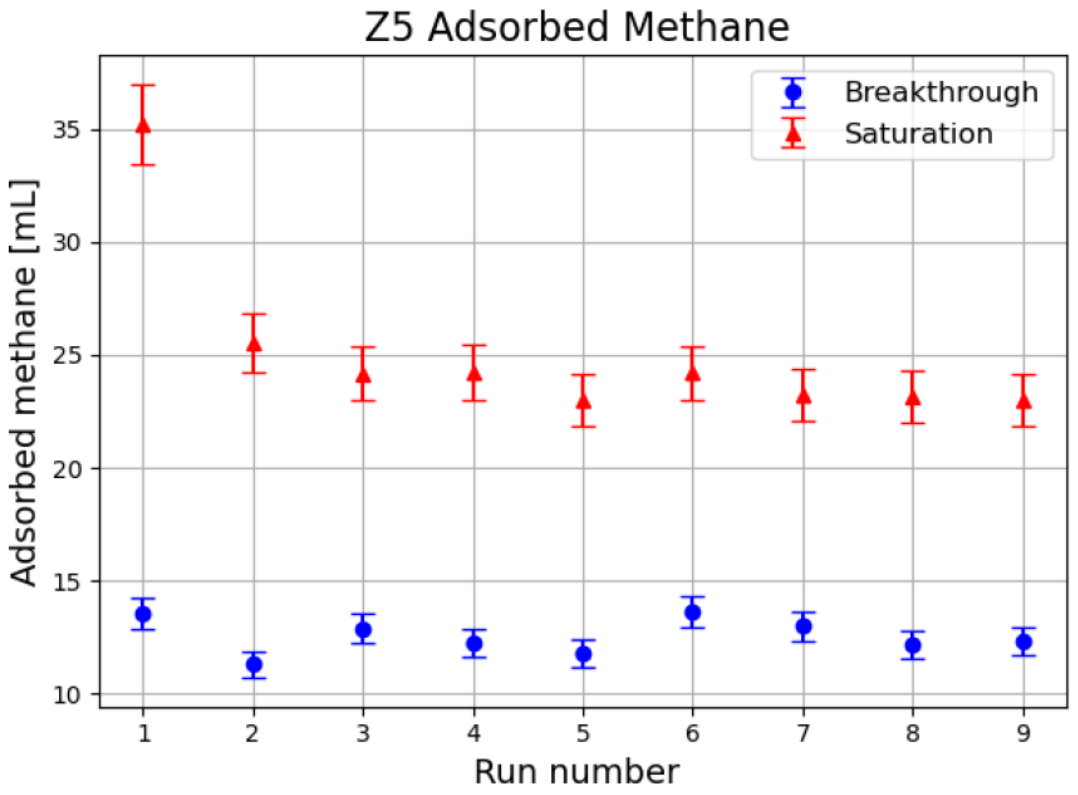




- Adsorbtion of ≈25ml of methane in 250g of adsorber
- Initial CH_4 concentration of 4500ppm

CH4rLie results





- Adsorbtion of ≈25ml of methane in 250g of adsorber
- Initial CH_4 concentration of 4500ppm
- Water can be completely adsorbed by another catridge filled with a different type of zeolite

Future perspectives…

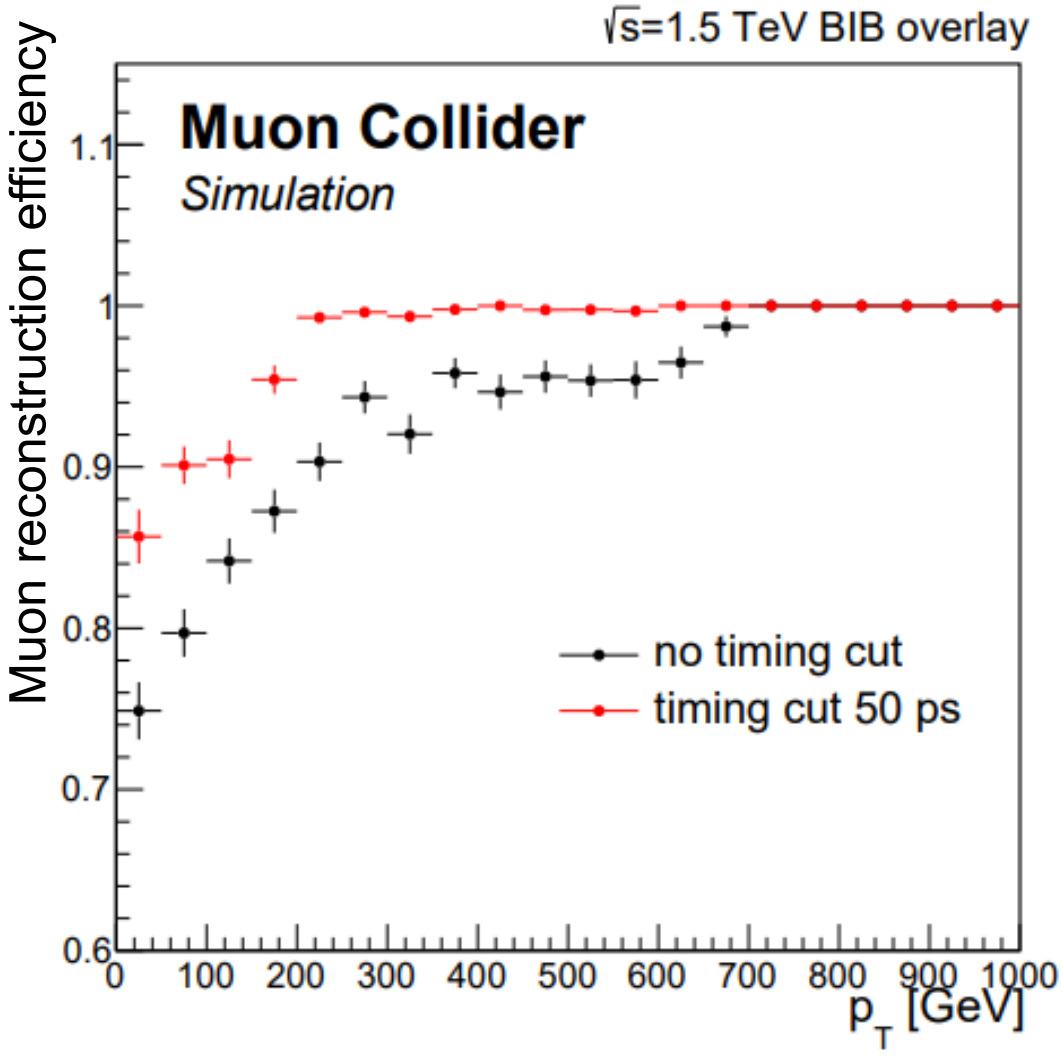
- R&D of Picosec detector
- Focus on gas mixture
- Scalability

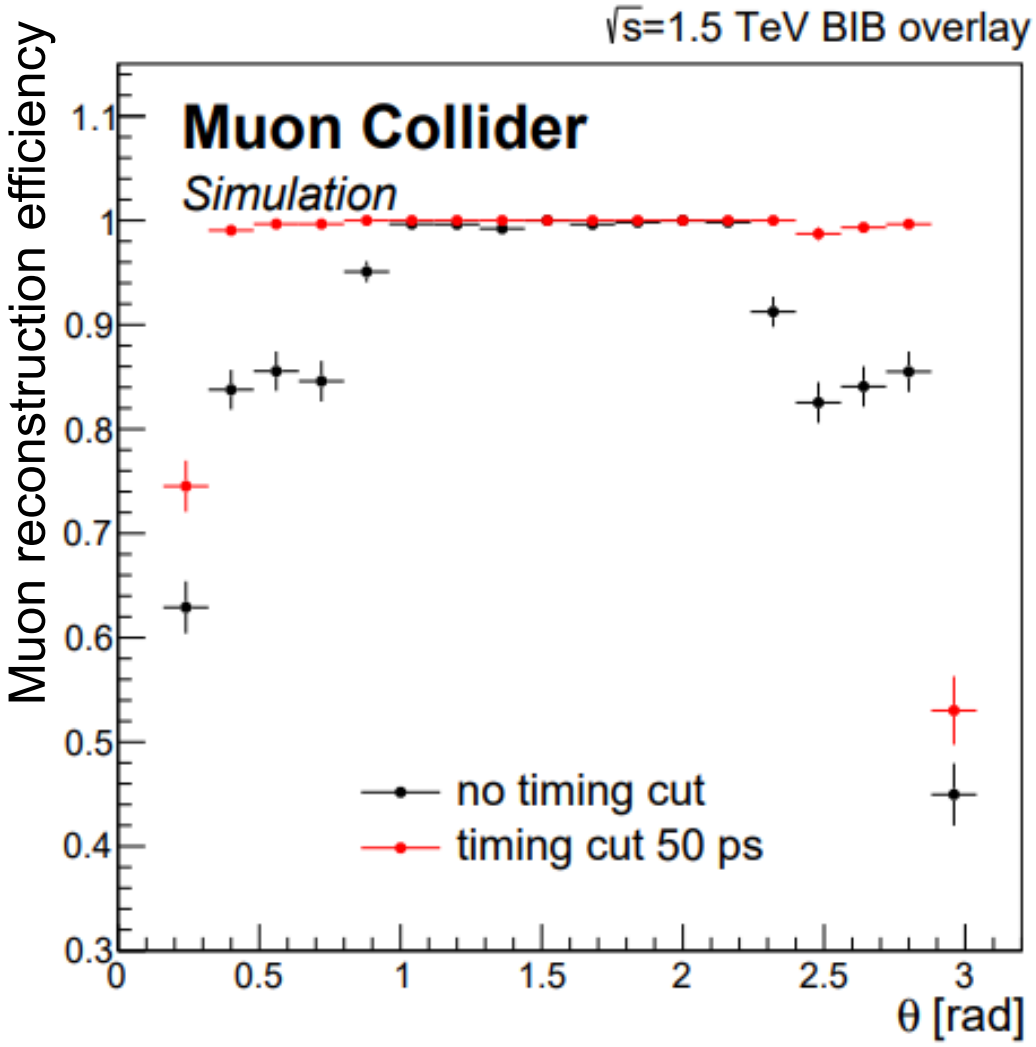
- Pursue social outcomes in non-HEP field

CH4RLIE

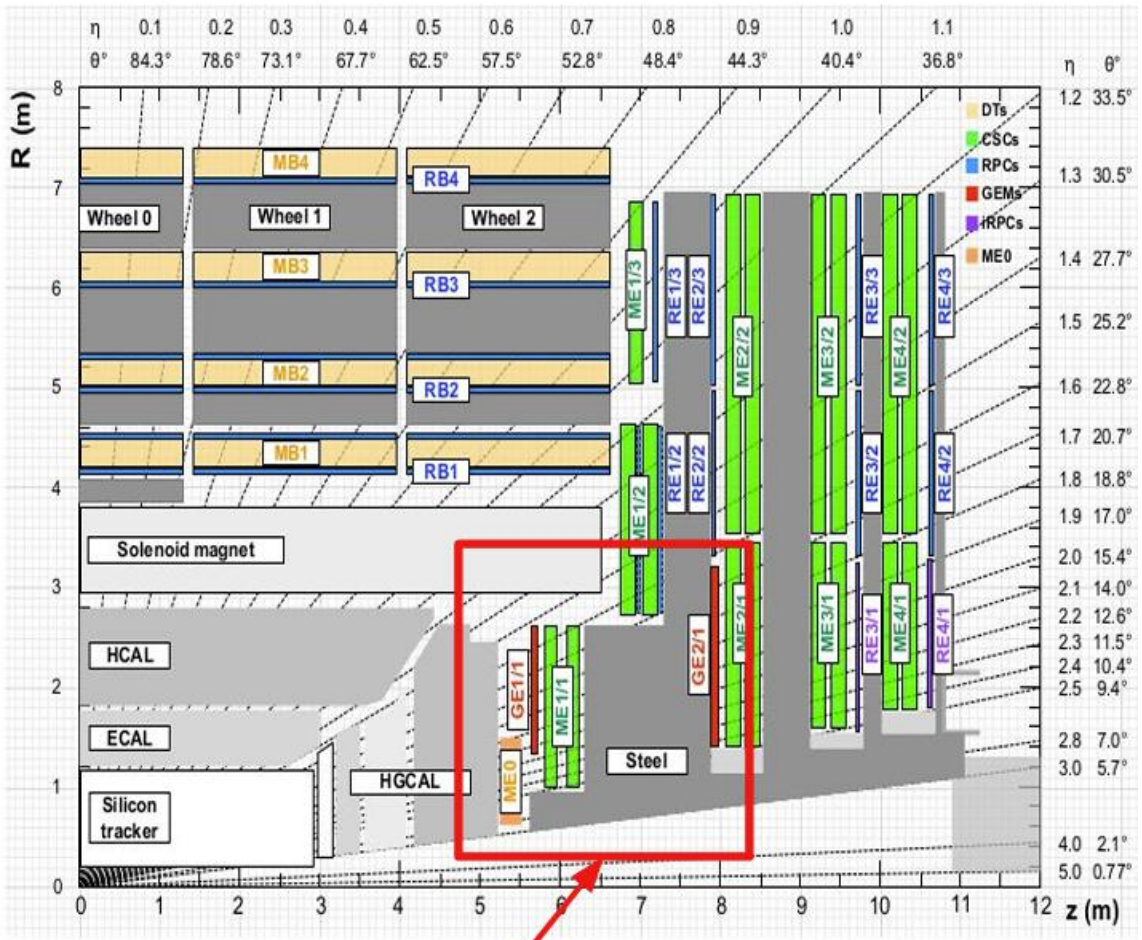
backup

Muon reconstruction efficiency

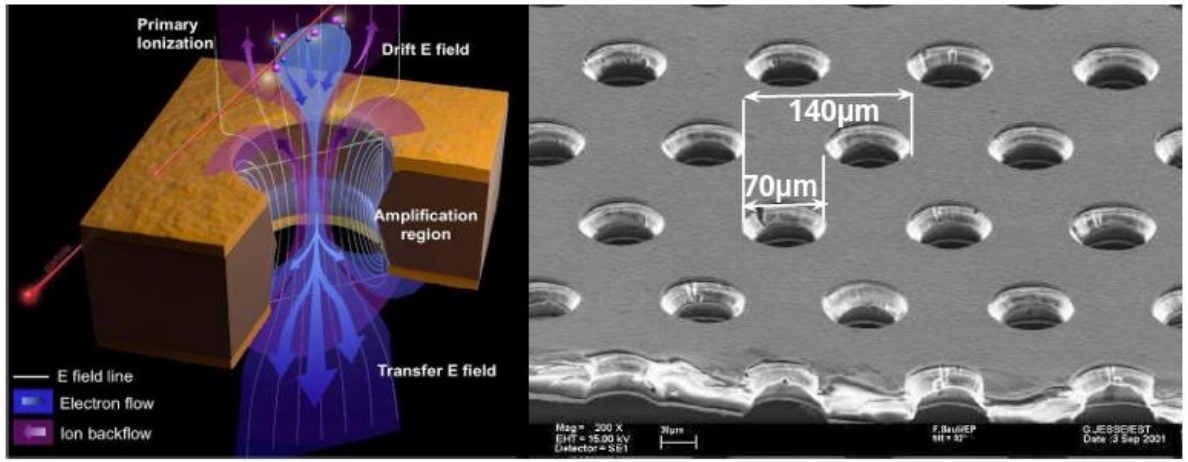


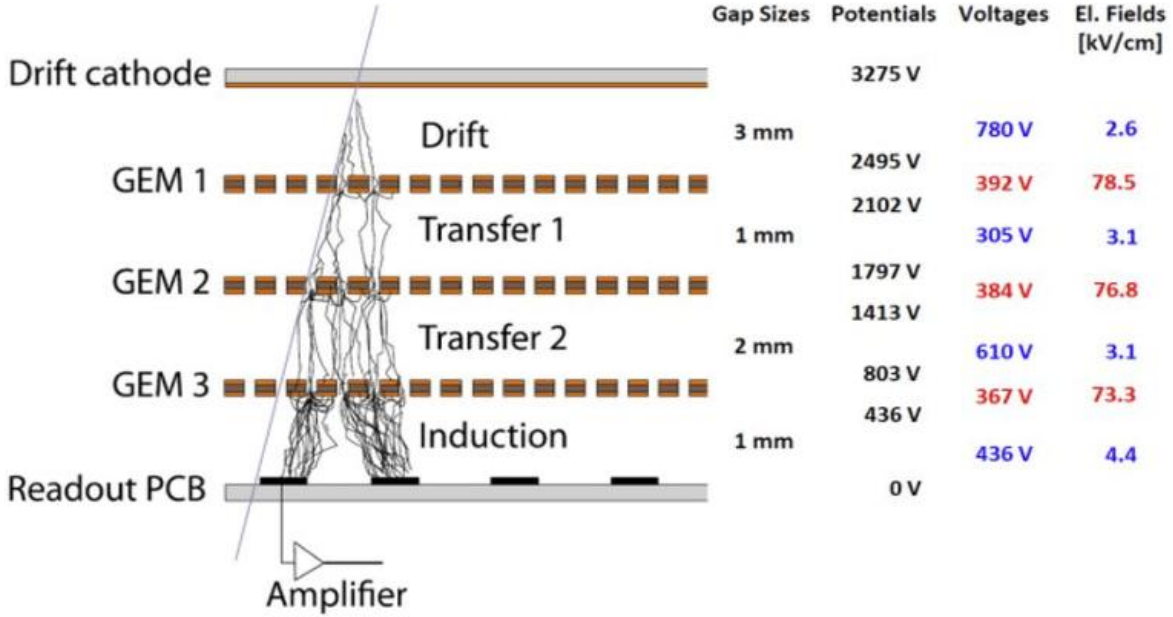


ME0

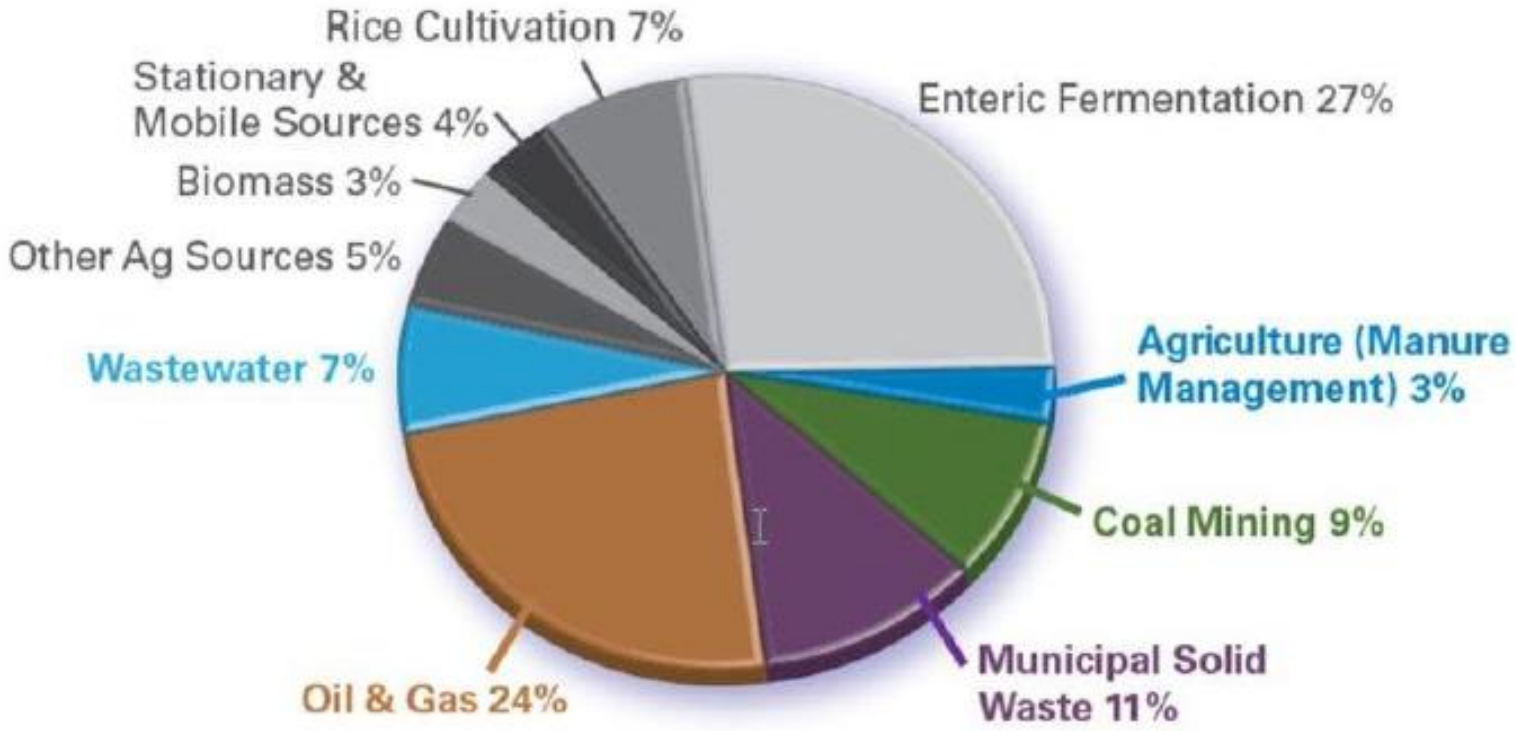


The GEM upgrade: three new stations GE1/1, GE2/1 and ME0 based on the triple-GEM technology





Contribution to global warming



Wang, W., Ren, J., Li, X. *et al.* Enrichment experiment of ventilation air methane (0.5%) by the mechanical tower. *Sci Rep* **10**, 7276 (2020). https://doi.org/10.1038/s41598-020-63698-x