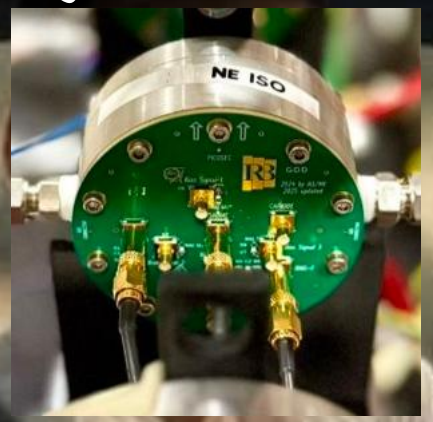
Fast & Robust:

R&D towards MPGDs improvement

Matteo Brunoldi

II year PhD student



Supervisors: I.Vai, P.Vitulo, C.Aimè

Introduction

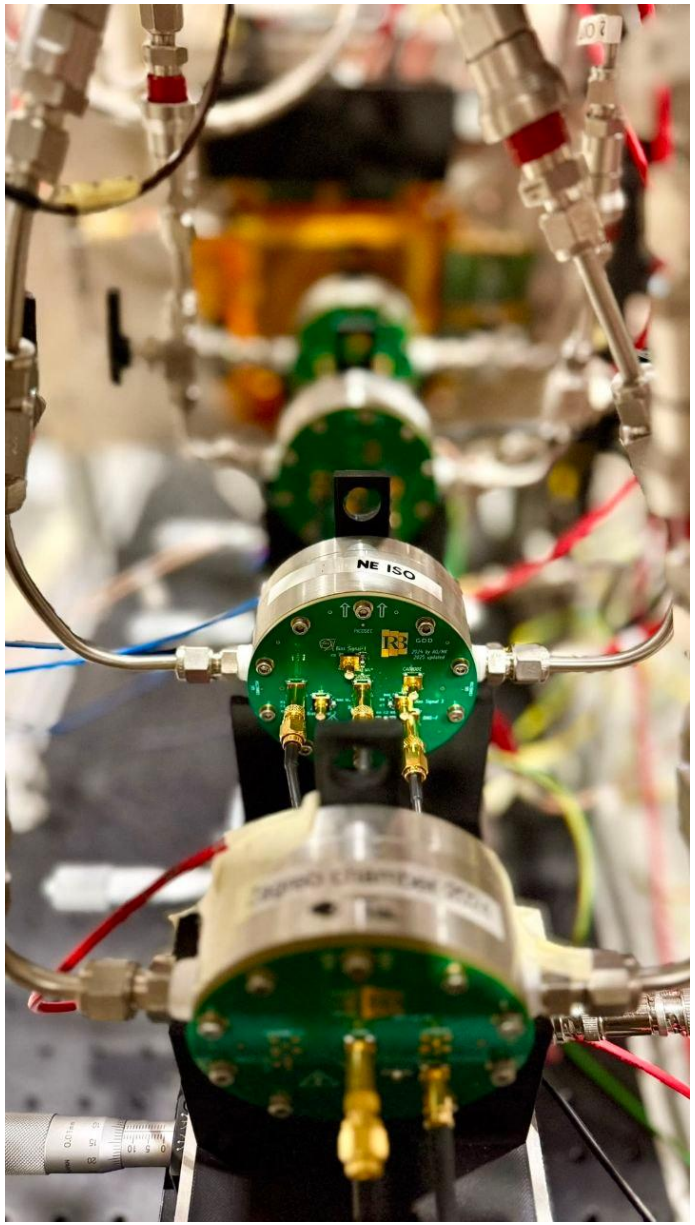
- What is a gaseous detector?
- How to create a gas mixture

Introduction

- What is a gaseous detector?
- How to create a gas mixture

Fast…

- Picosec concept
- Why looking for a new gas mixture?
- Test beam results



Introduction

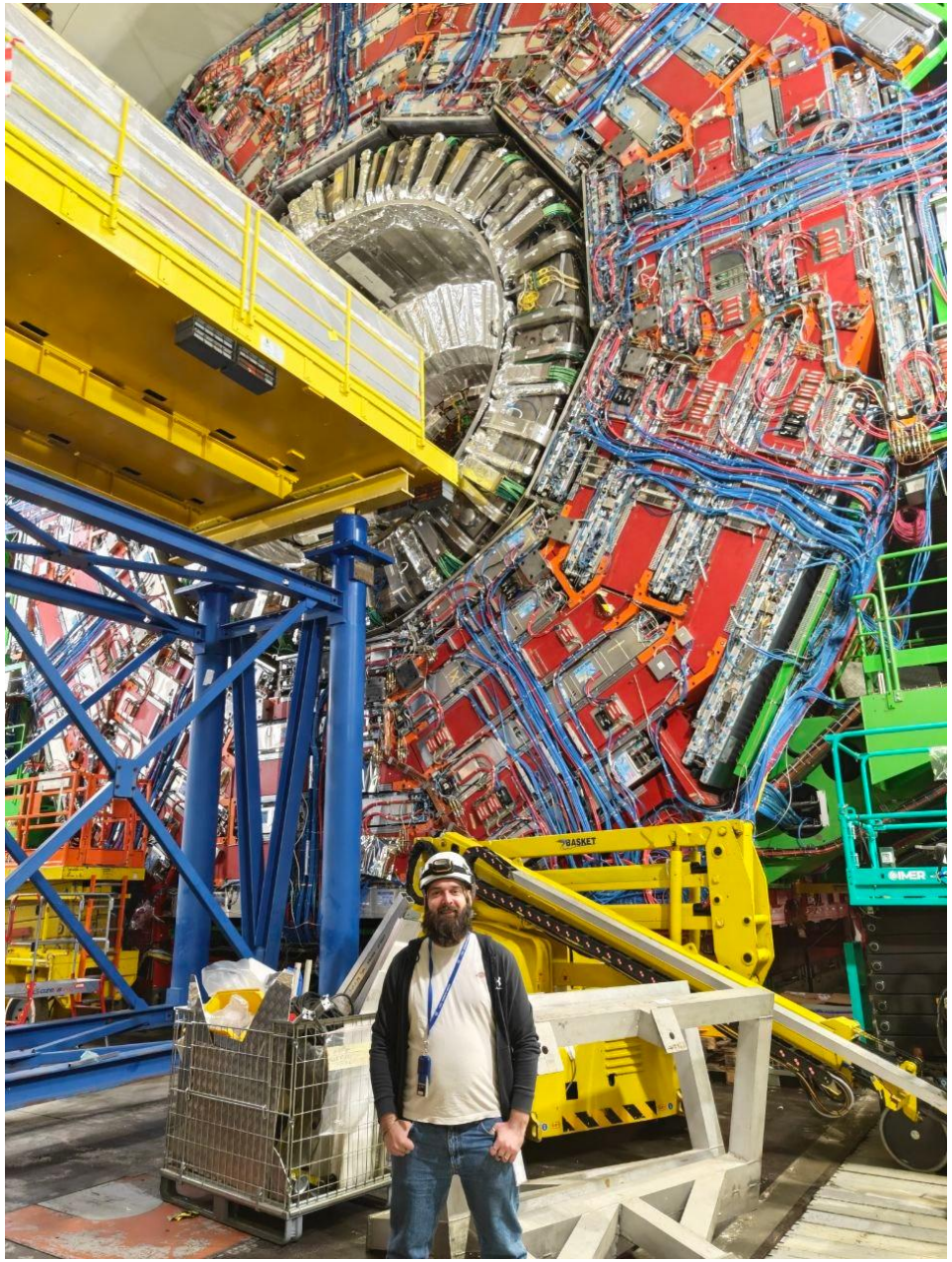
- What is a gaseous detector?
- How to create a gas mixture

Fast…

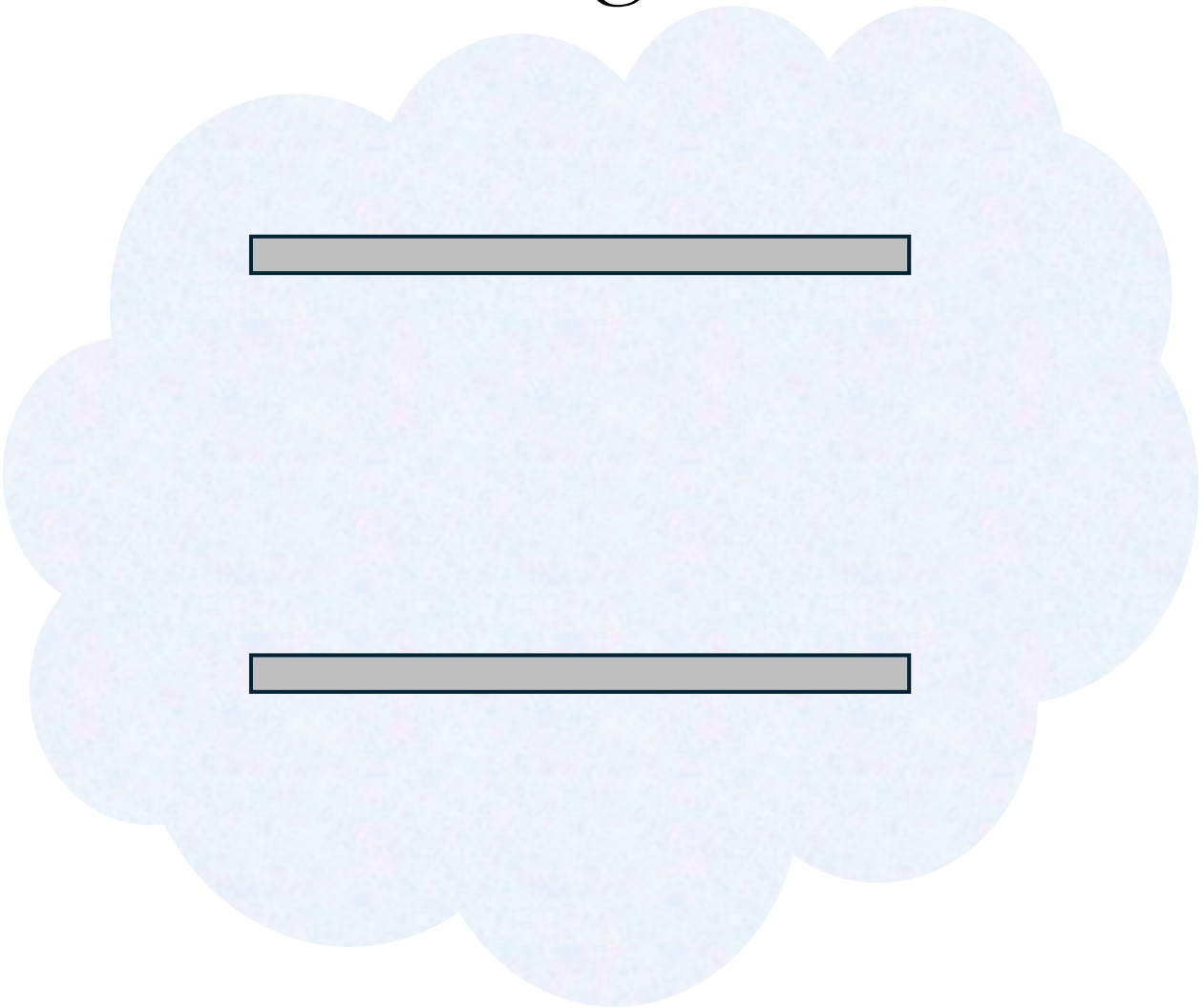
- Picosec concept
- Why looking for a new gas mixture?
- Test beam results

… & Robust

- What is a GEM?
- The basin effect
- Focus on my last year



What is a gaseous detector?

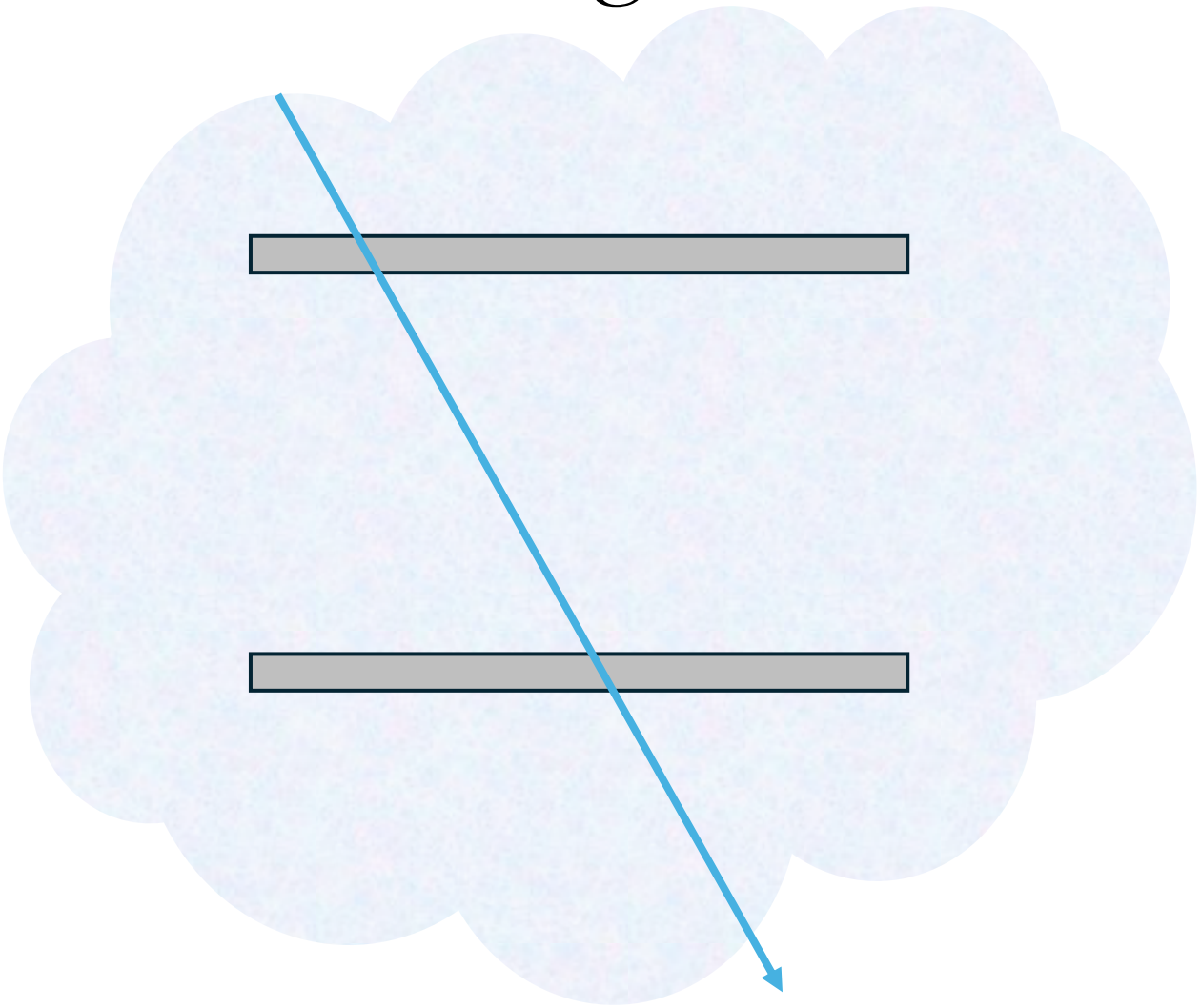


gas·eous de·tec·tor

['gæs.i.əs dɪ'tɛk.tər] : noun

a particle detector whose active medium is a gas, widely used to detect charged particles in high-energy physics experiments (e.g., at CERN) and for medical imaging applications.

What is a gaseous detector?

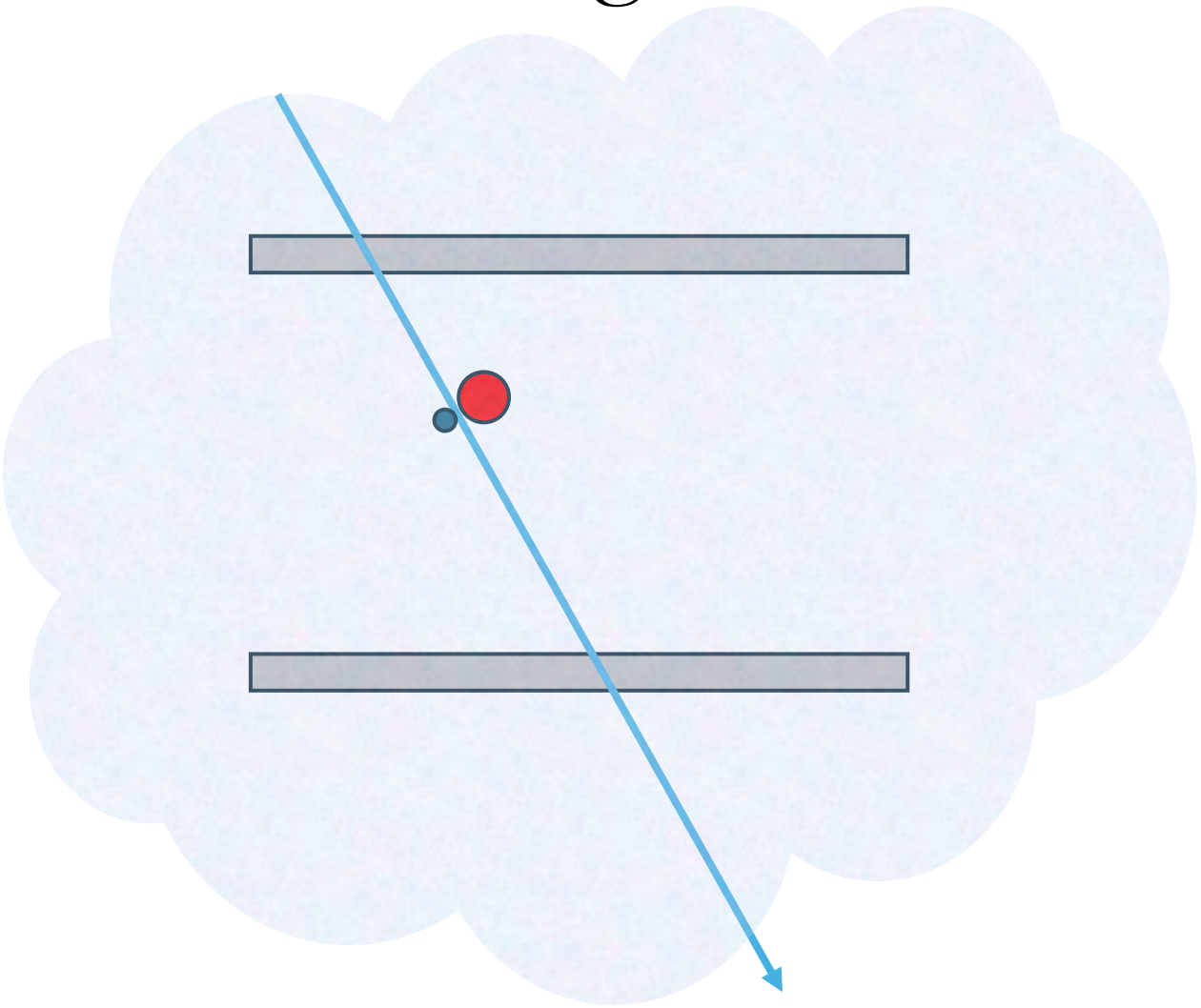


gas·eous de·tec·tor

['gæs.i.əs dɪ'tɛk.tər] : noun

a particle detector whose active medium is a gas, widely used to detect charged particles in high-energy physics experiments (e.g., at CERN) and for medical imaging applications.

What is a gaseous detector?

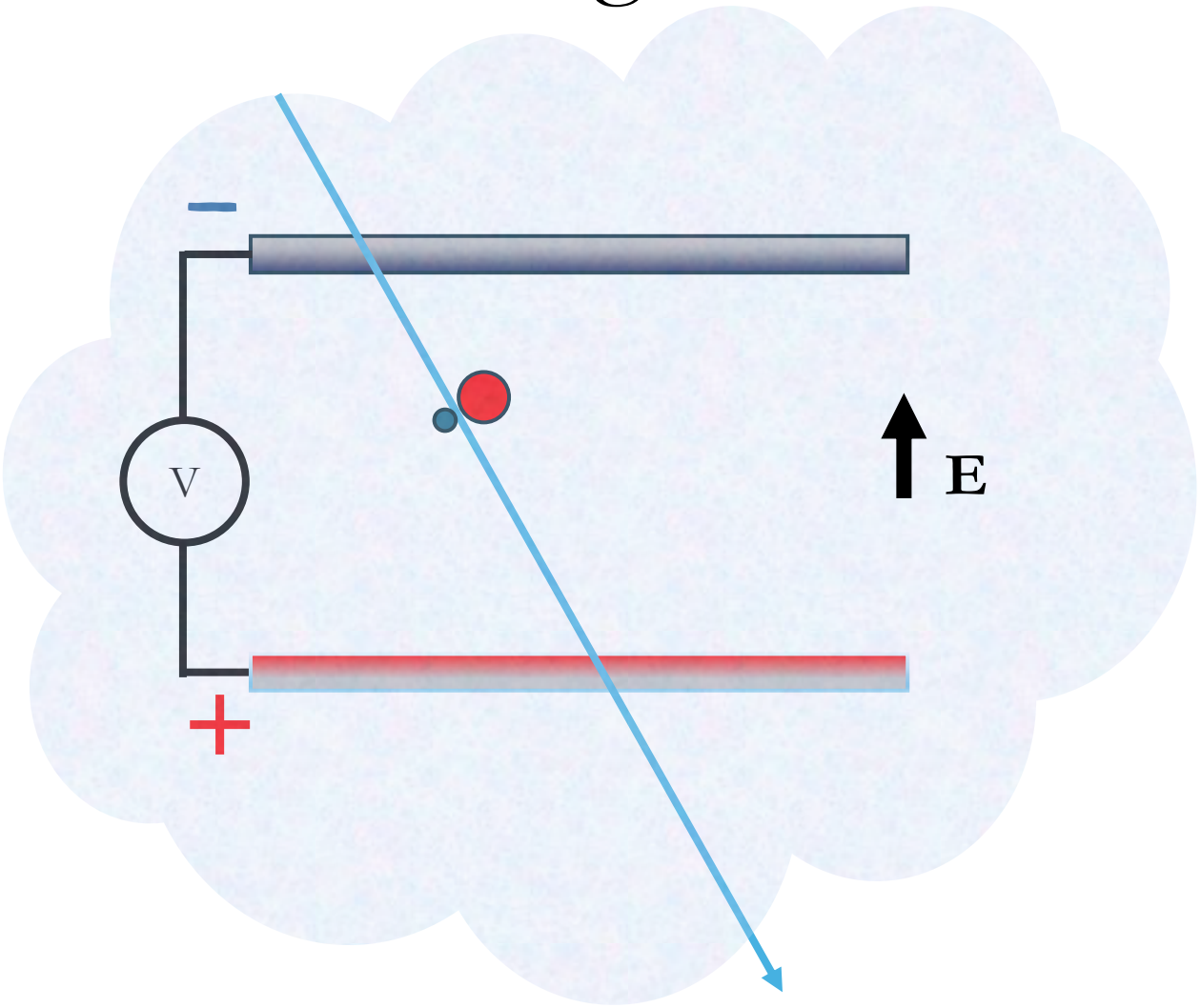


gas·eous de·tec·tor

['gæs.i.əs dɪ'tɛk.tər] : noun

a particle detector whose active medium is a gas, widely used to detect charged particles in high-energy physics experiments (e.g., at CERN) and for medical imaging applications.

What is a gaseous detector?

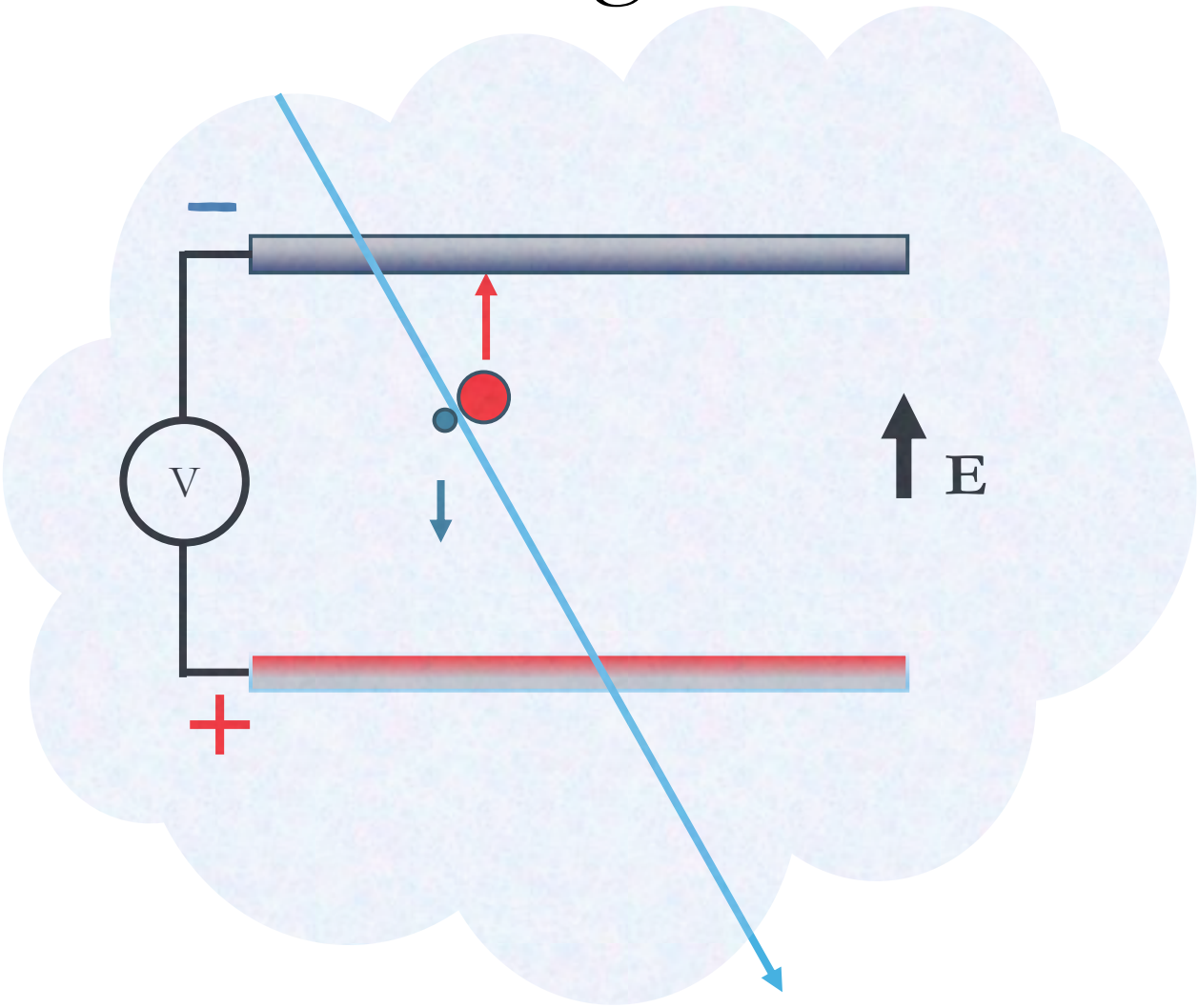


gas·eous de·tec·tor

['gæs.i.əs dɪ'tɛk.tər] : noun

a particle detector whose active medium is a gas, widely used to detect charged particles in high-energy physics experiments (e.g., at CERN) and for medical imaging applications.

What is a gaseous detector?

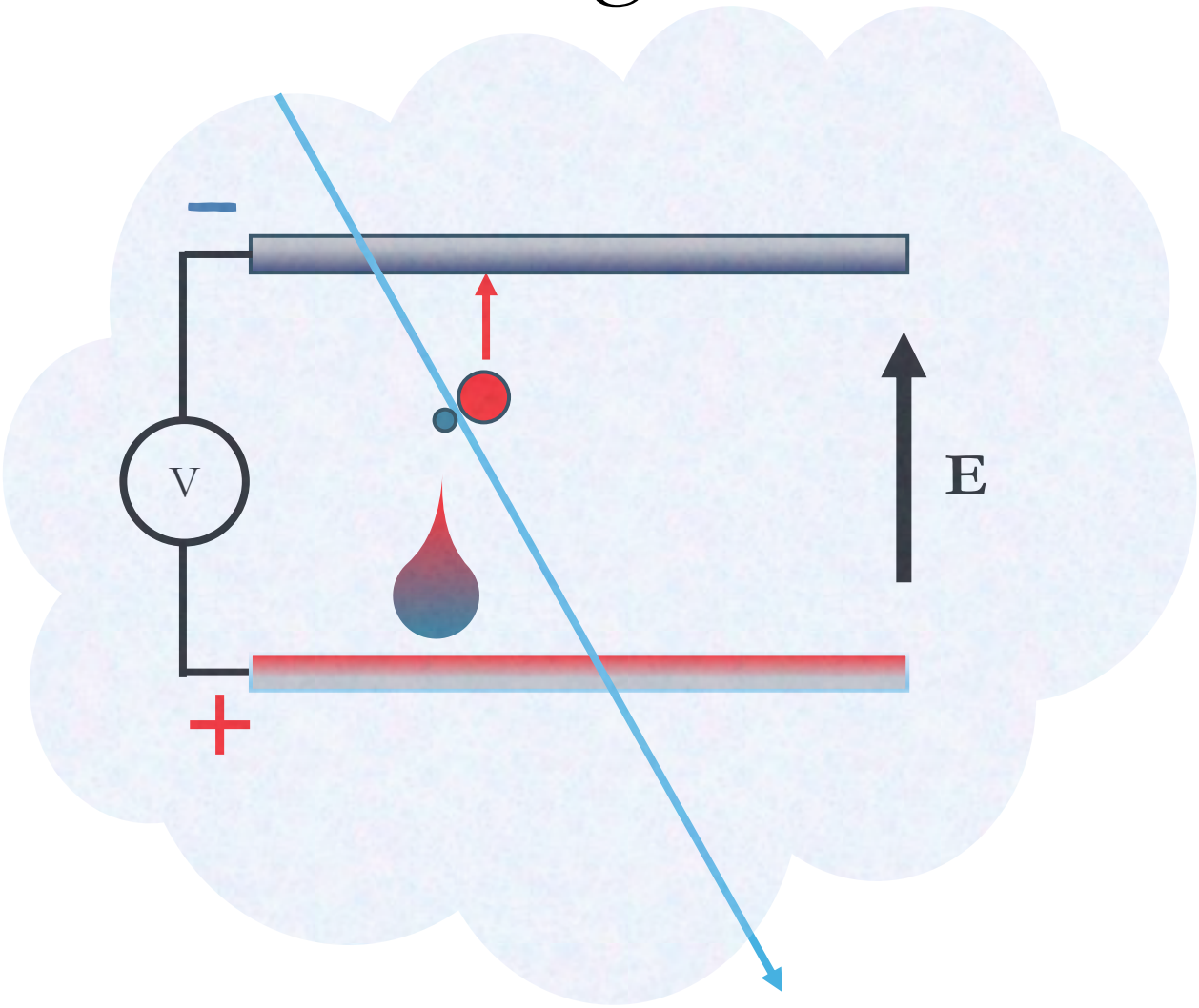


gas·eous de·tec·tor

['gæs.i.əs dɪ'tɛk.tər] : noun

a particle detector whose active medium is a gas, widely used to detect charged particles in high-energy physics experiments (e.g., at CERN) and for medical imaging applications.

What is a gaseous detector?

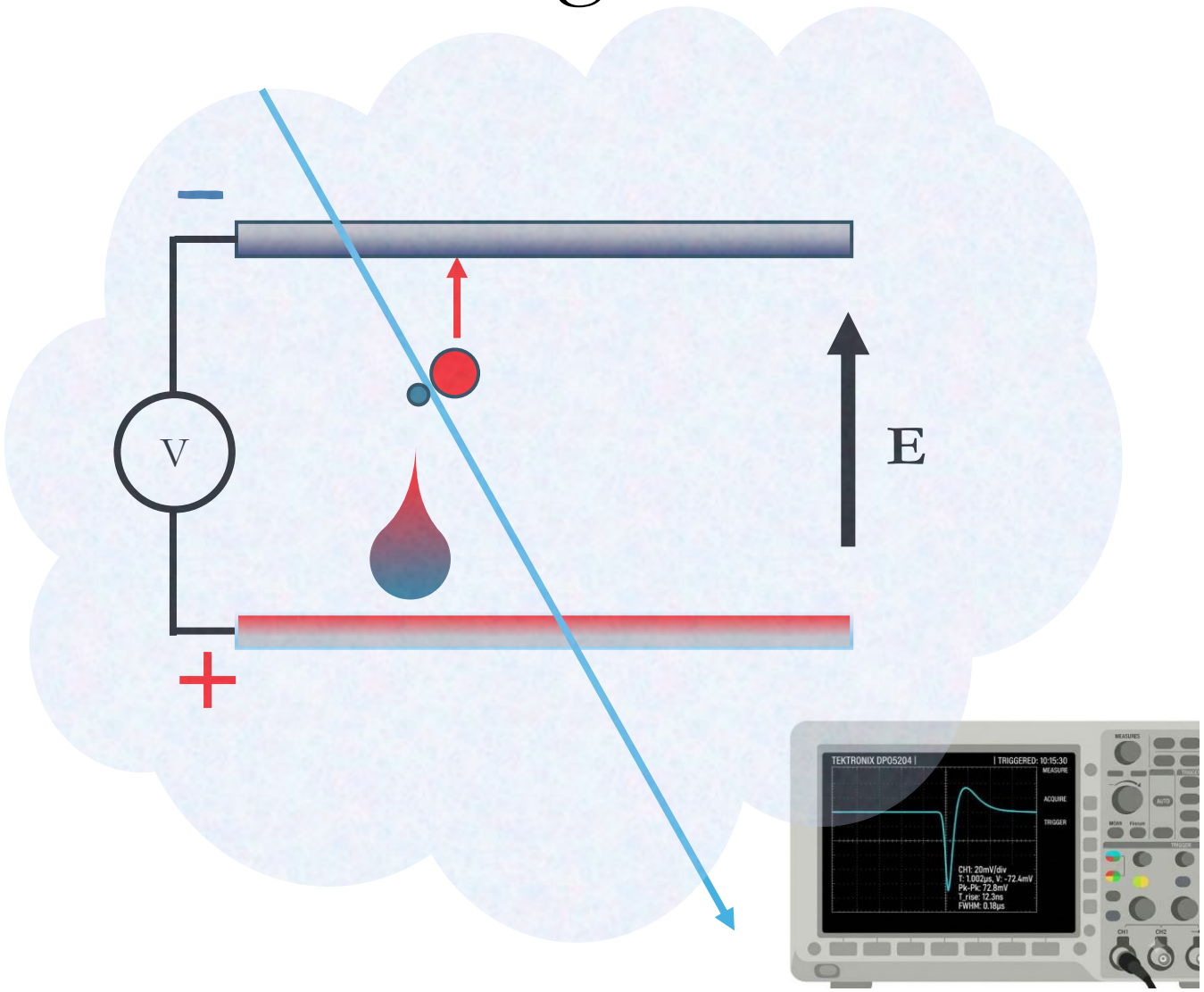


gas·eous de·tec·tor

['gæs.i.əs dɪ'tɛk.tər] : noun

a particle detector whose active medium is a gas, widely used to detect charged particles in high-energy physics experiments (e.g., at CERN) and for medical imaging applications.

What is a gaseous detector?



gas·eous de·tec·tor

['gæs.i.əs dɪ'tɛk.tər] : noun

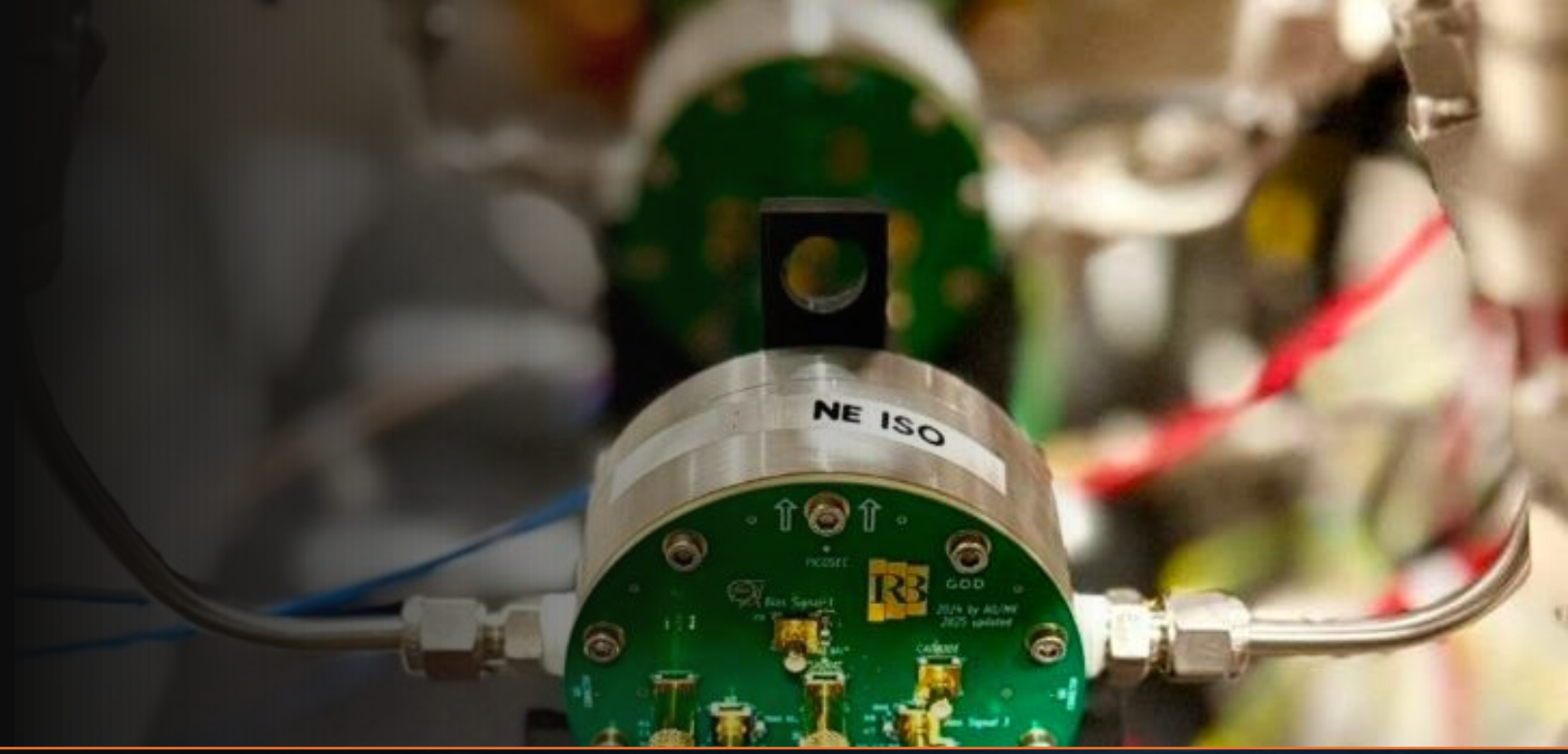
a particle detector whose active medium is a gas, widely used to detect charged particles in high-energy physics experiments (e.g., at CERN) and for medical imaging applications.

The gas mixture

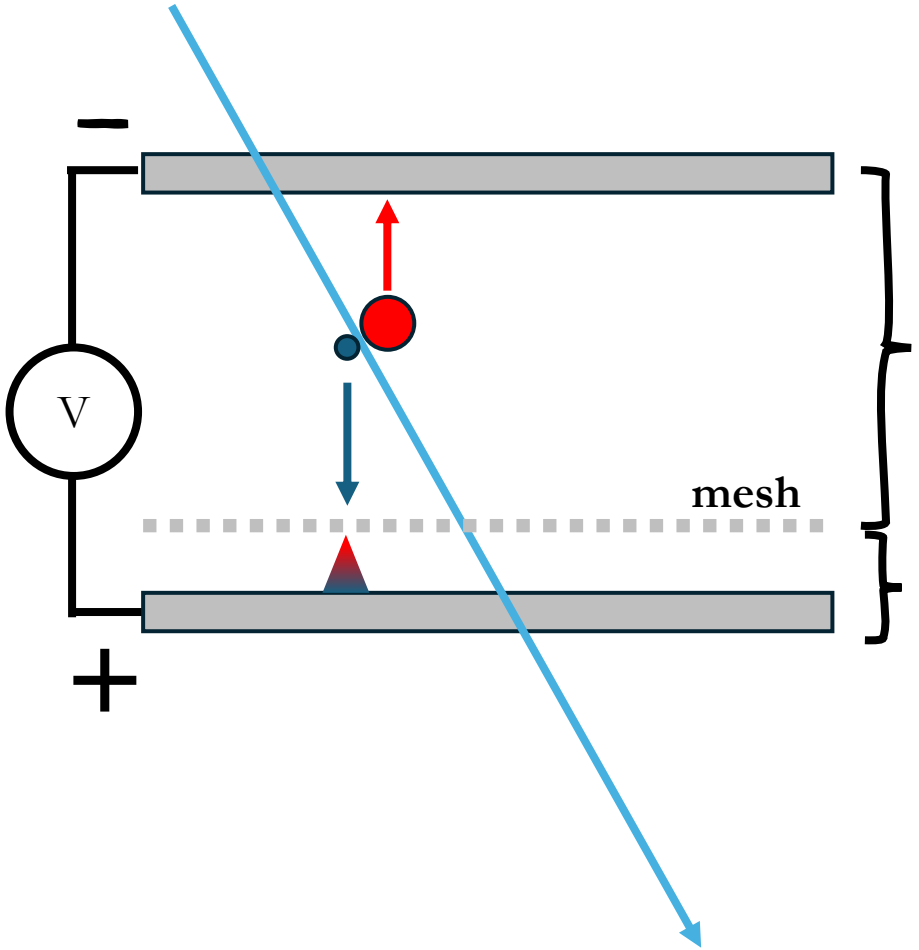
The choice is crucial to get:

- Low working point
- High number of primaries
- High gain
- High rate capability

Fast…



MPGDs and MICROMEGAS



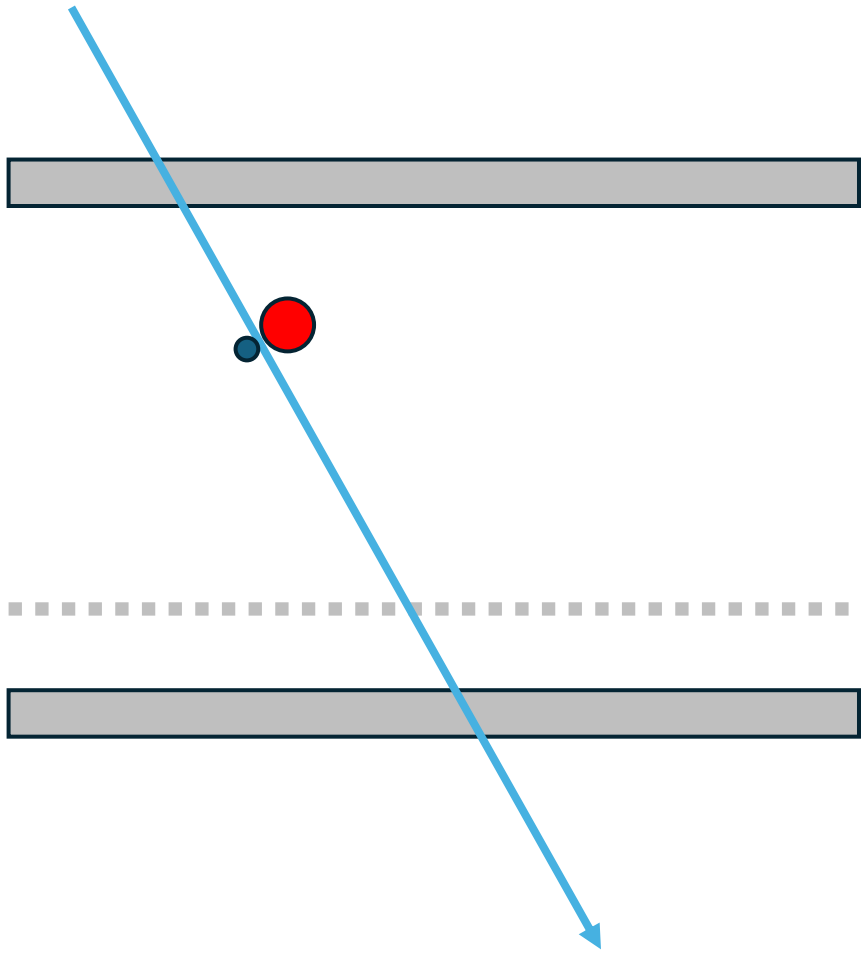
Drift gap

Amplification gap

MicroPattern Gaseous Detector (MPGD): amplification region smaller than a mm

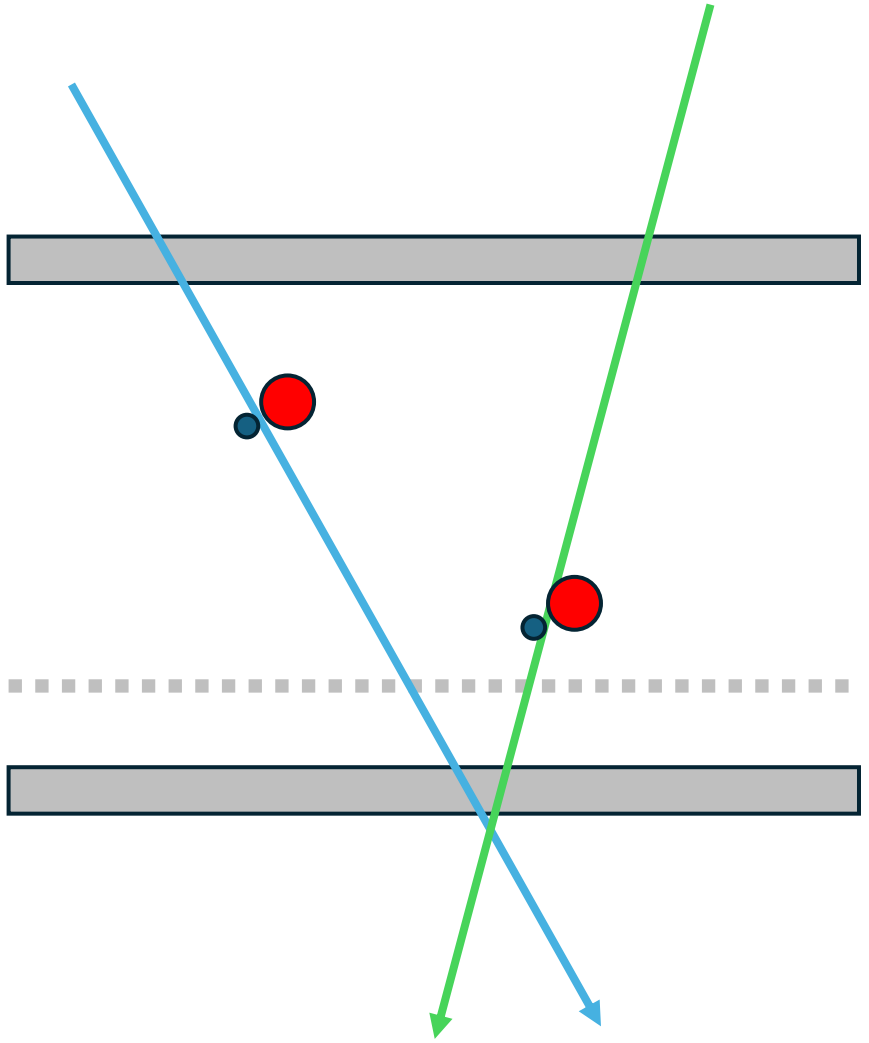
Drift and amplification gaps separated by the mesh

Micromegas and time resolution



Ionization is a statistical process

Micromegas and time resolution

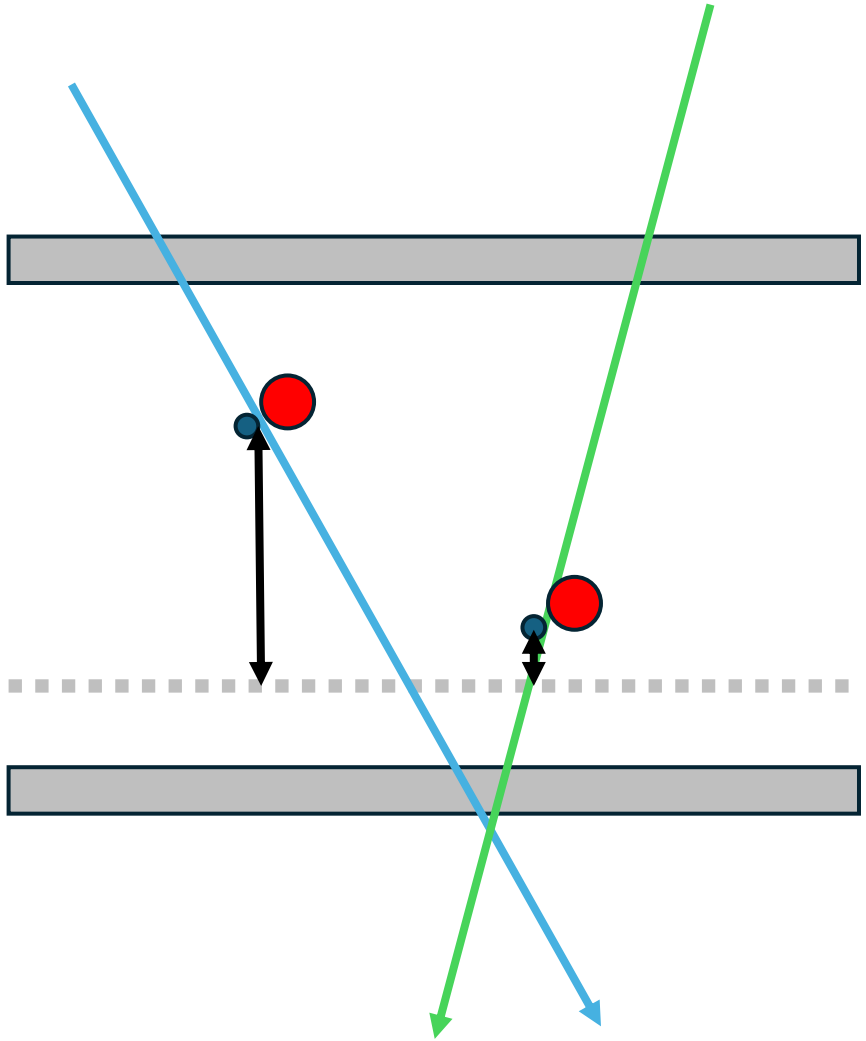


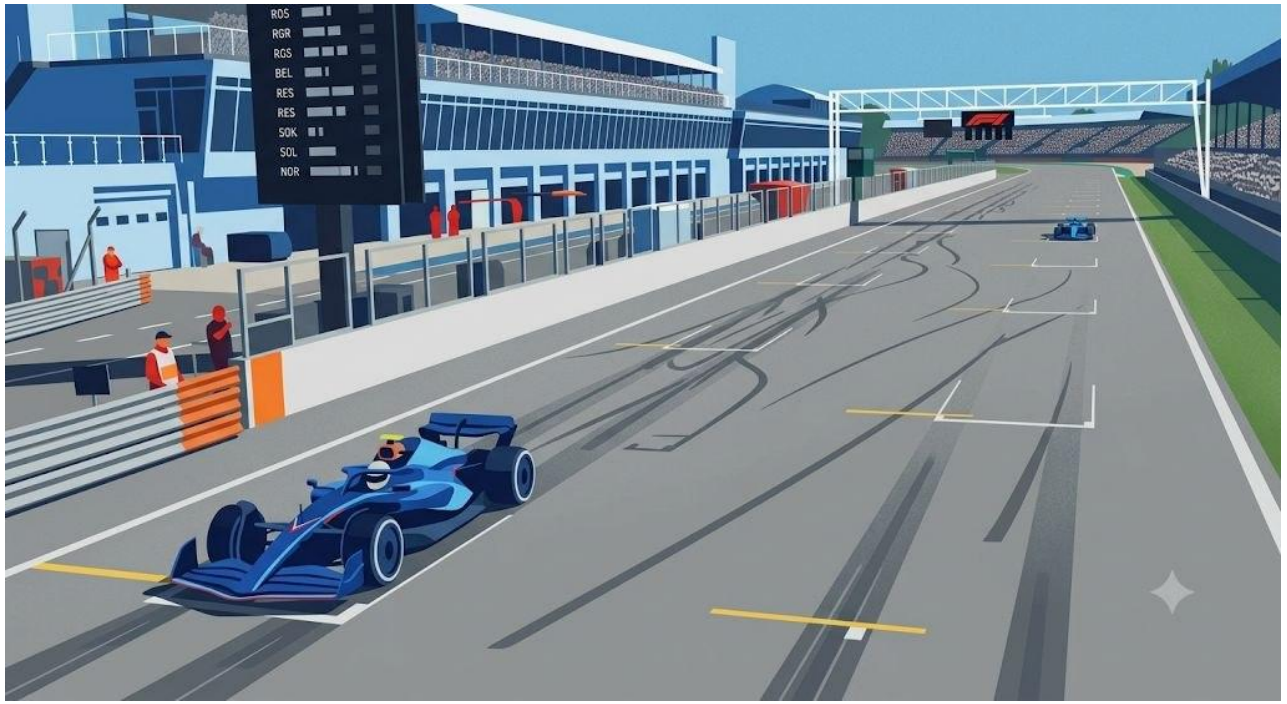
Ionization is a statistical process

Different arrival time depending on the position of the ionization

The longest is the drift gap the bigger is the fluctuation in the ionization position

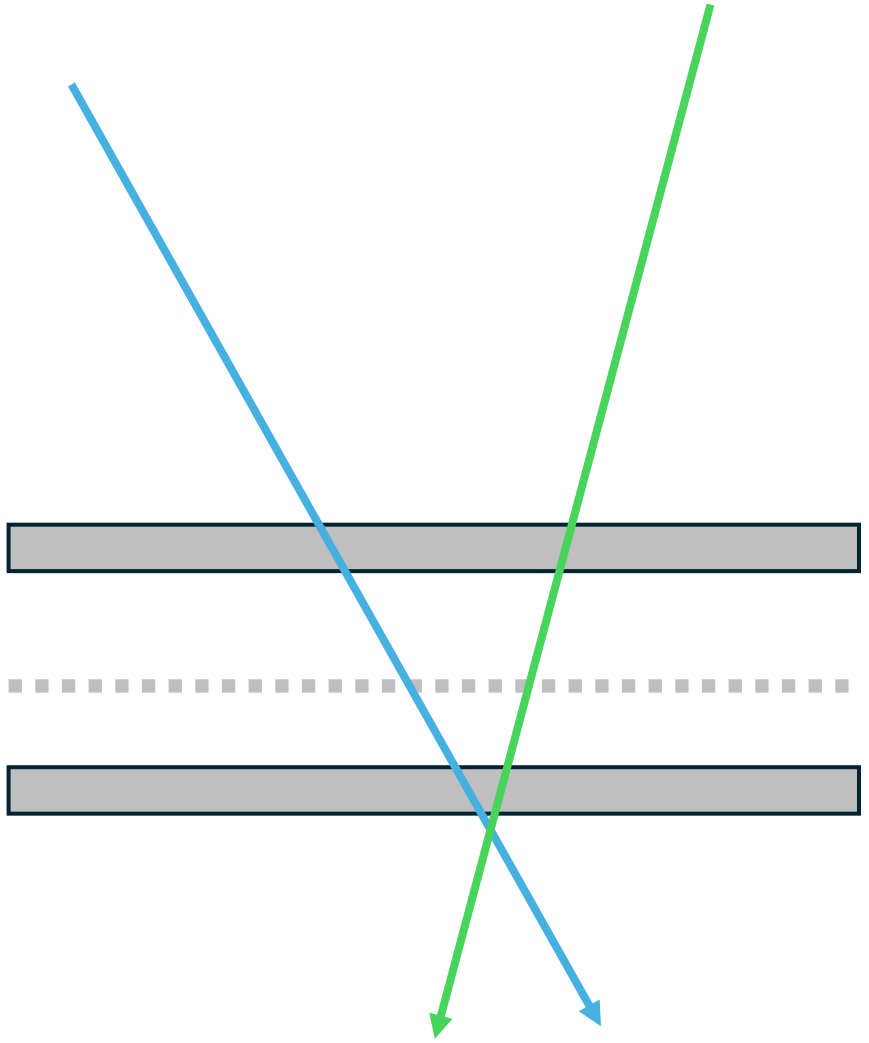
Micromegas and time resolution





Time resolution limited to few ns

Micromegas and time resolution

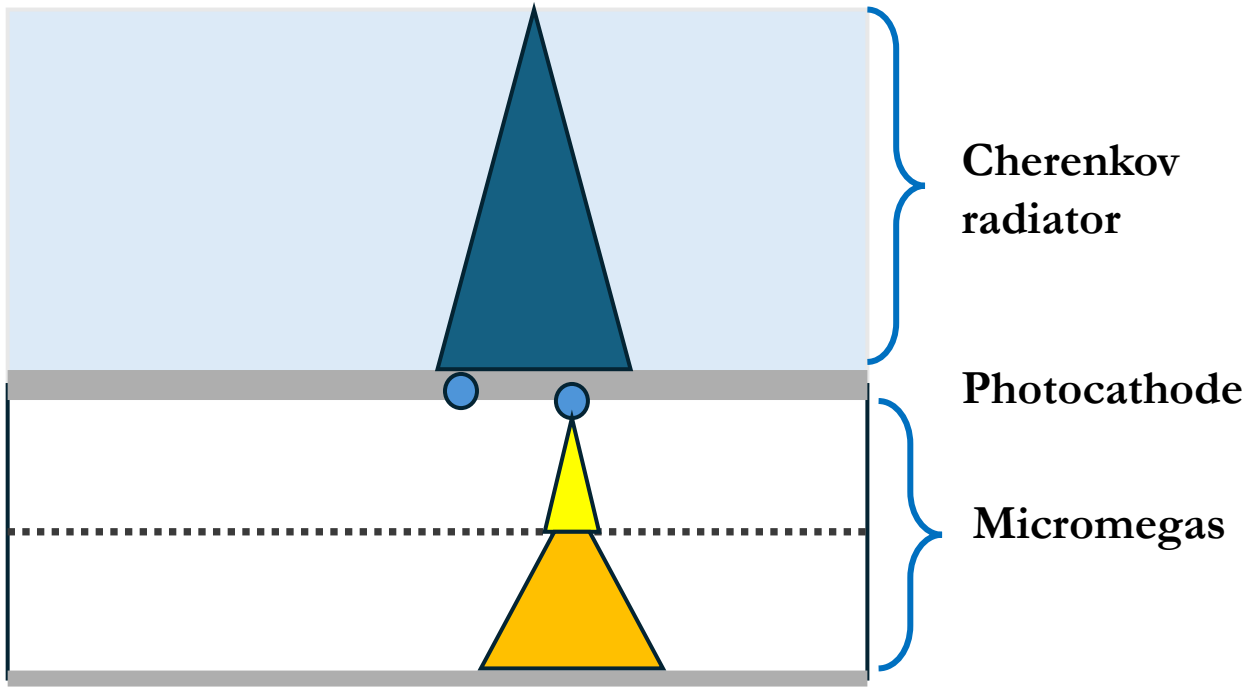


Reducing the drift will improve the time resolution by reducing the ionization position fluctuation

but

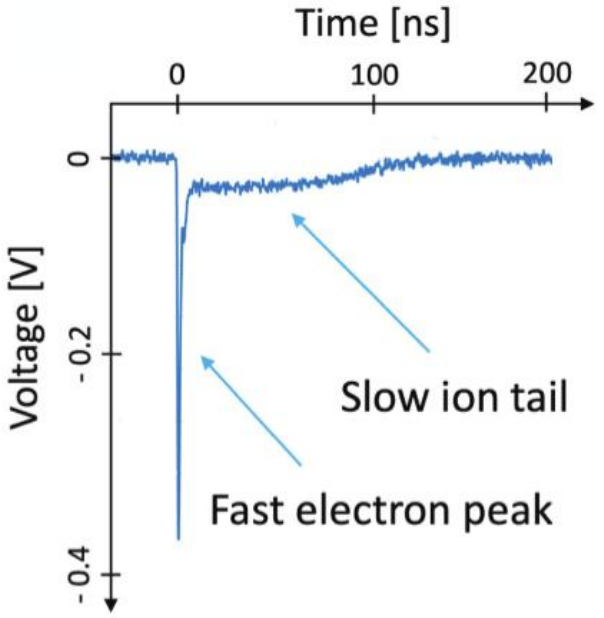
Too thin drift means lower ionization probability

Picosec-Micromegas concept



Time resolution: tens of ps

- Cherenkov radiator to replace primary ionization
- Photocathode to convert photons
- Reduced time jitter

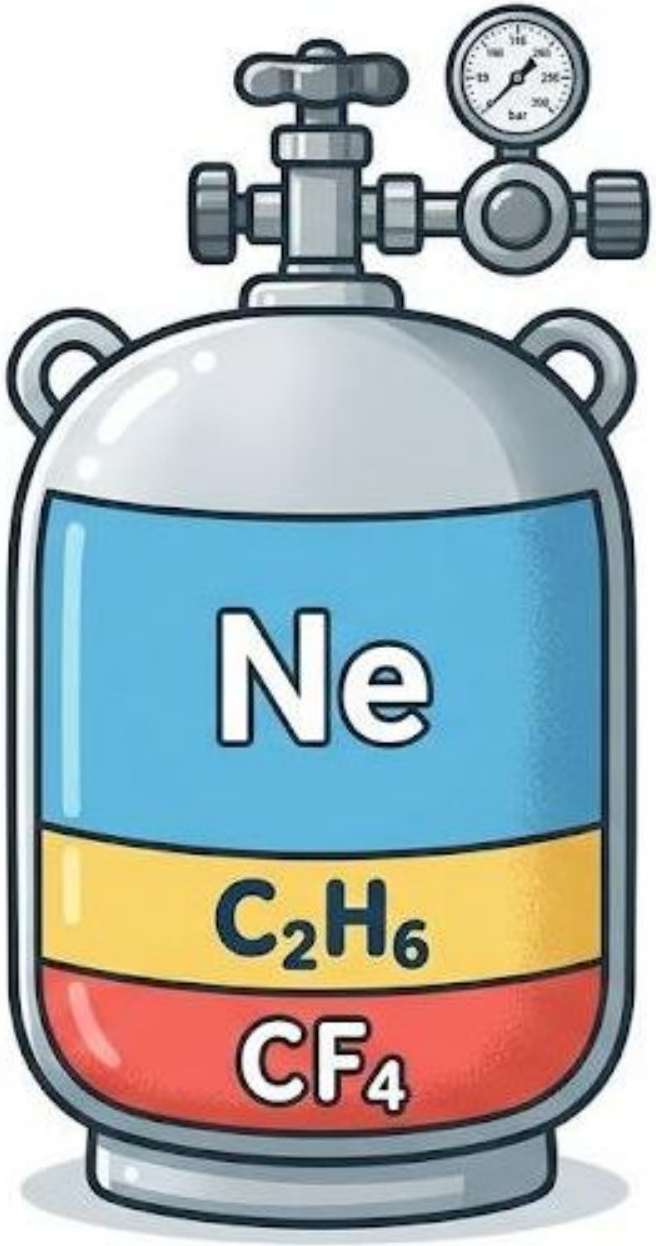


Gas mixture: composition

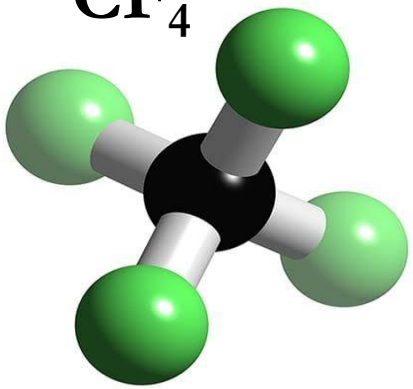
Neon (Ne)
80%
Expensive

Ethane (C_2H_6)
10%
Flammable

Tetrafluoromethane (CF_4)
10%
High Global Warming Potential



Why looking for alternatives?



$GWP_{100} \approx 4400$

Global Warming Potential (GWP):

Ratio between the greenhouse effect produced by a compound and the one produced by the same amount of CO_2 during a given time (100y)

https://www.chemtube3d.com/cf4/

Goals of the study & alternatives

Keep the performance

Lower GWP

Optional: cheaper and less flammable

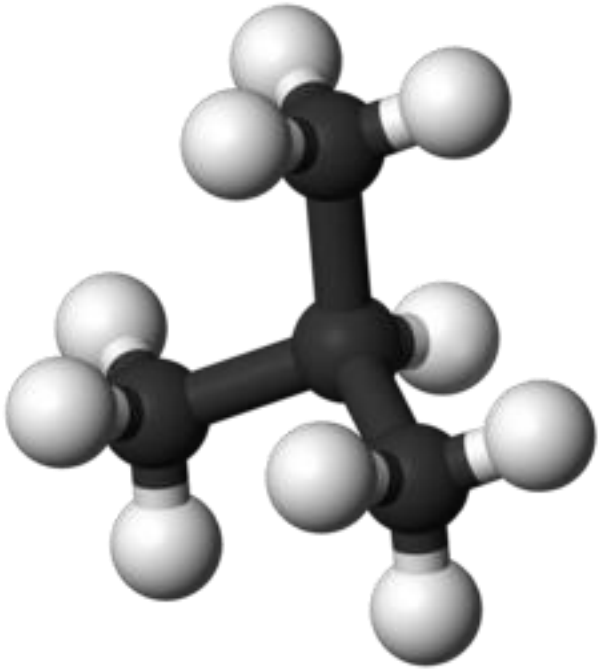
Goals of the study & alternatives

Keep the performance

Lower GWP

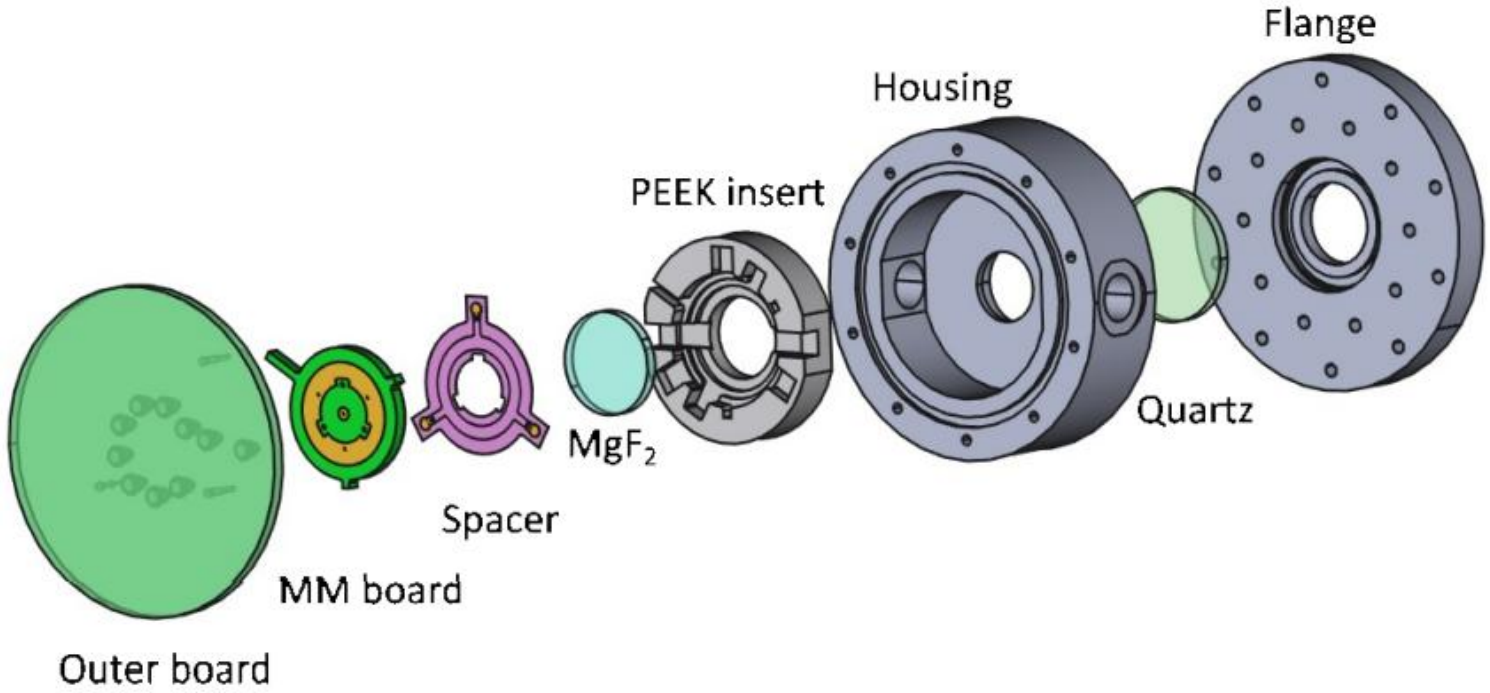
Optional: cheaper and less flammable

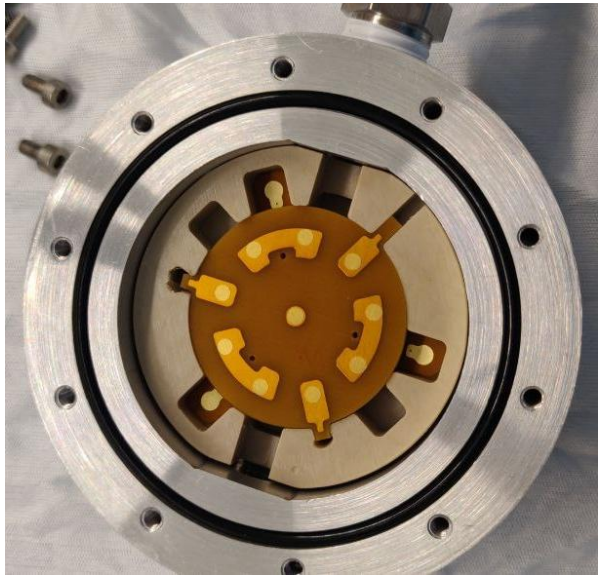
https://en.wikipedia.org/wiki/Isobutane

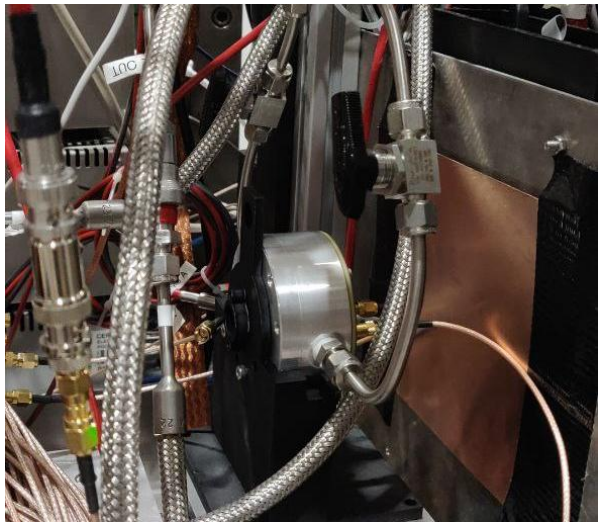


Isobutane iC_4H_{10} (GWP < 1)

Experimental setup – Detector

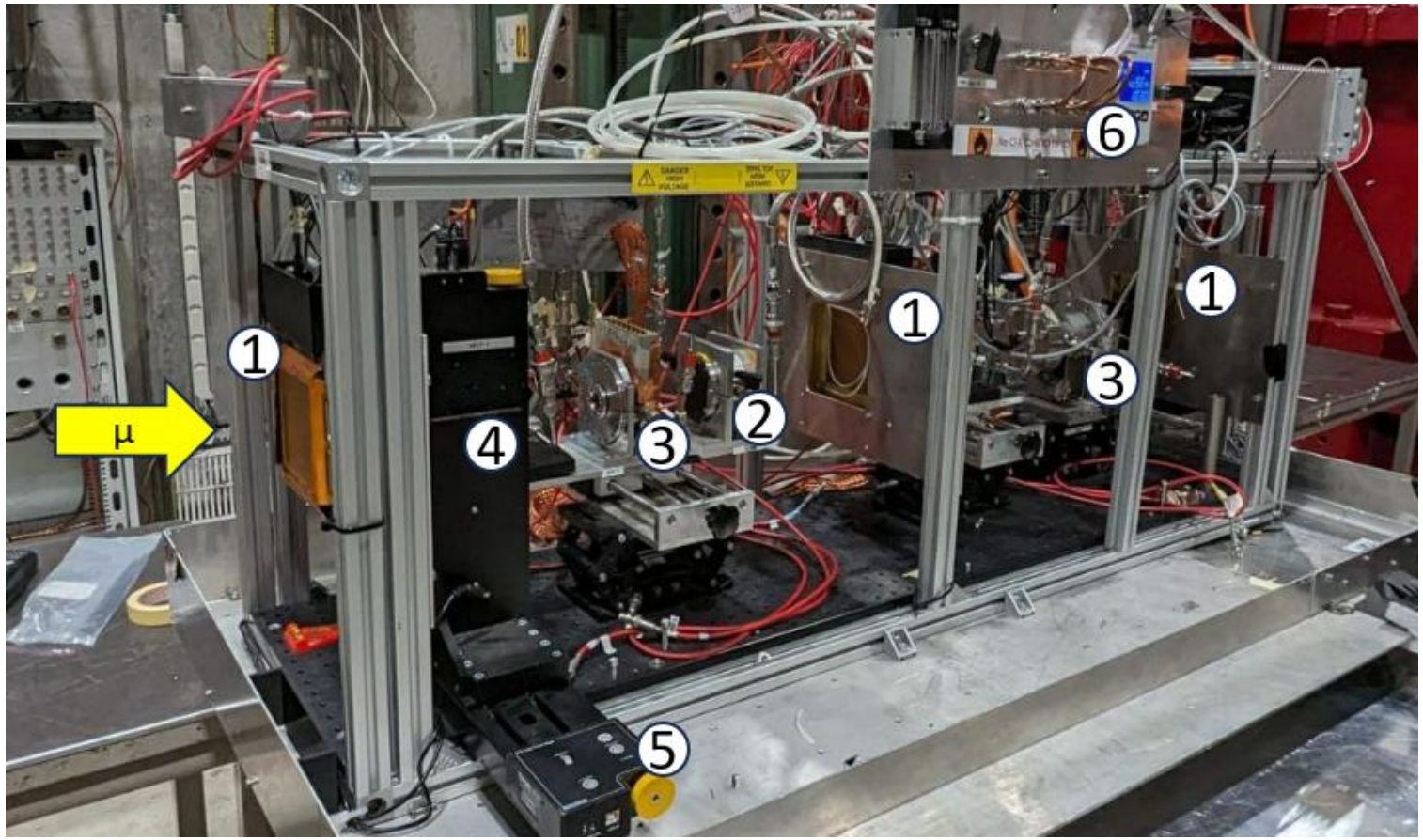






Utrobicic, A., et al. "Single channel PICOSEC Micromegas detector with improved time resolution." NIM A 1072 (2025): 170127. https://doi.org/10.1016/j.nima.2024.170127

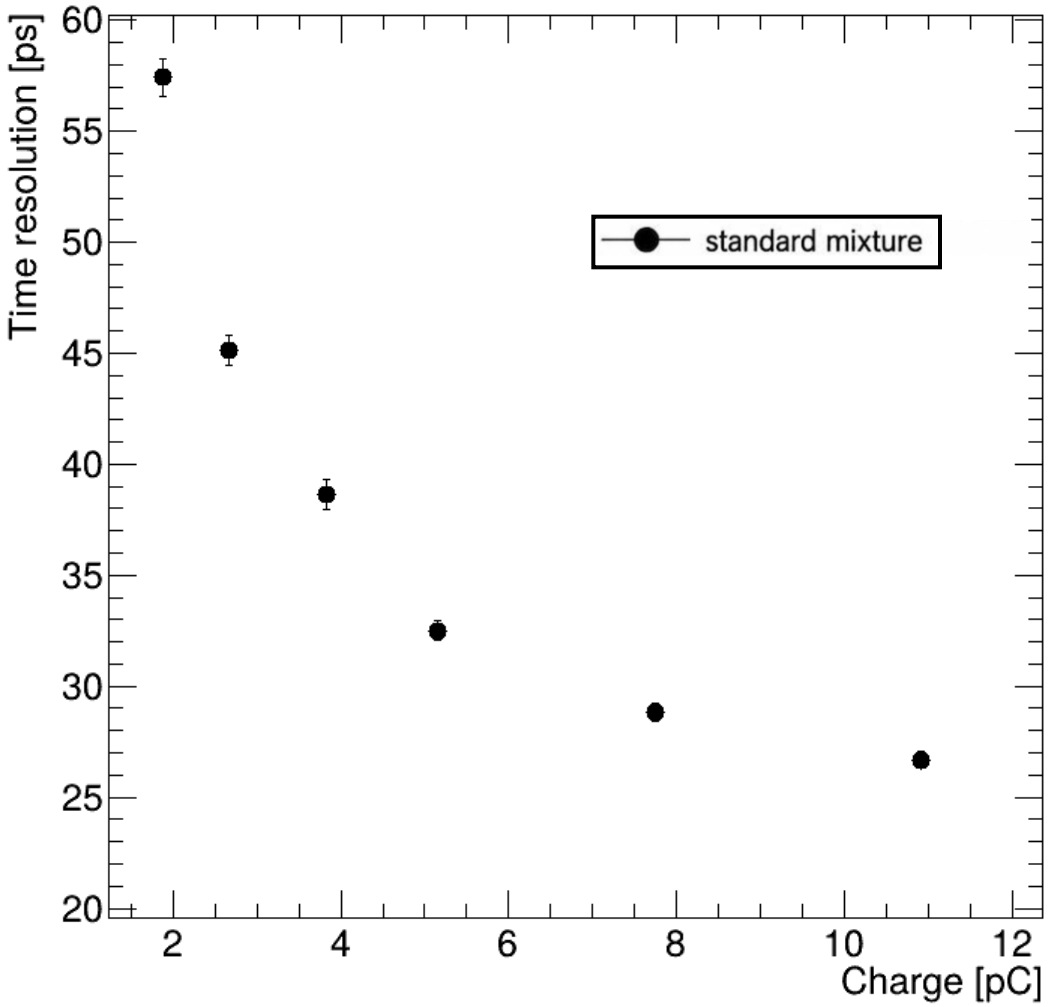
Test beam setup



1. Tracker
2. Detector under test
3. Other Picosec detectors
4. Time reference/trigger
5. Moving stage
6. Gas distribution

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.

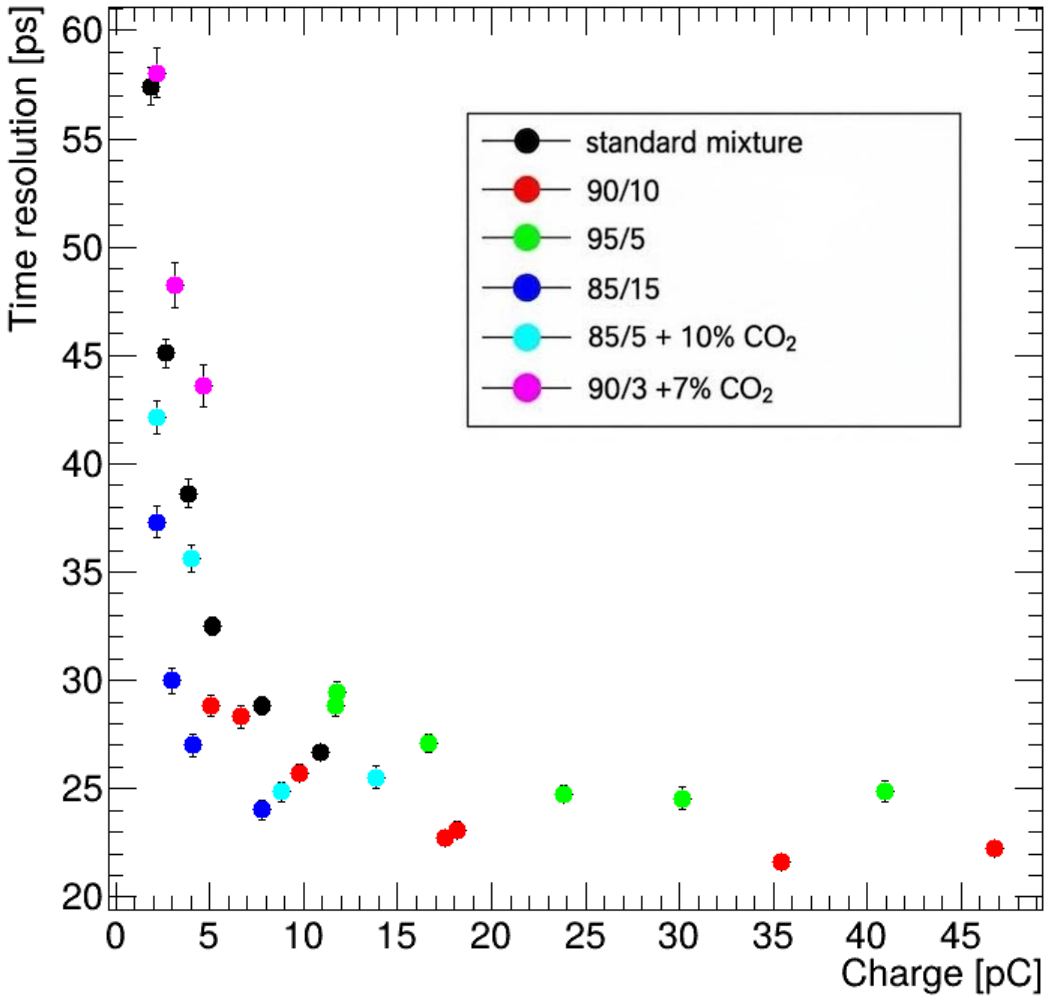
Test beam results



Voltage scan: going from left to right the voltage is increasing

After the last point on the right the detector starts to be unstable

My test beam results – Ne/isobutane mixtures

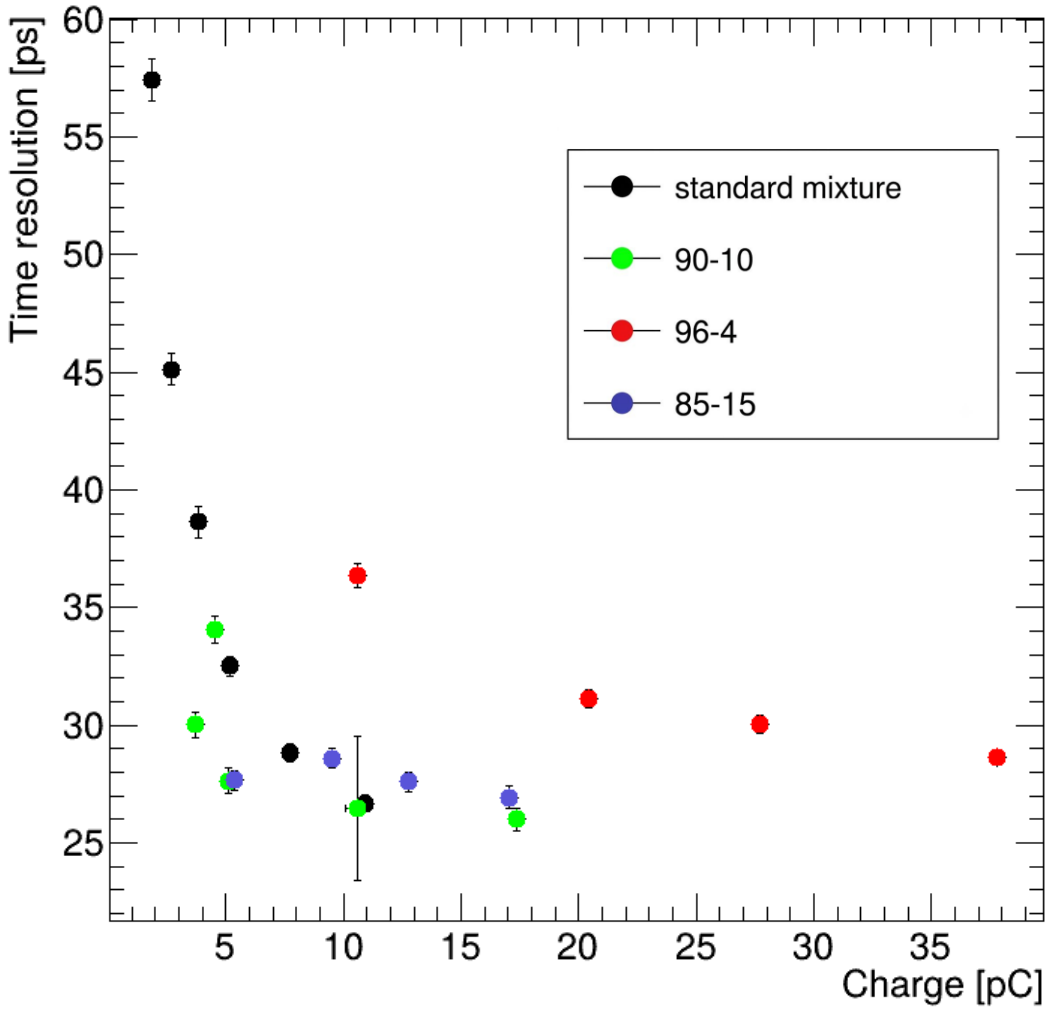


Ne-isobutane mixtures can perform as well as the standard mixture

It is possible to operate the detector safely in a wider amplification range

The addition of CO_2 makes the mixture less flammable

My test beam results – He/isobutane mixtures



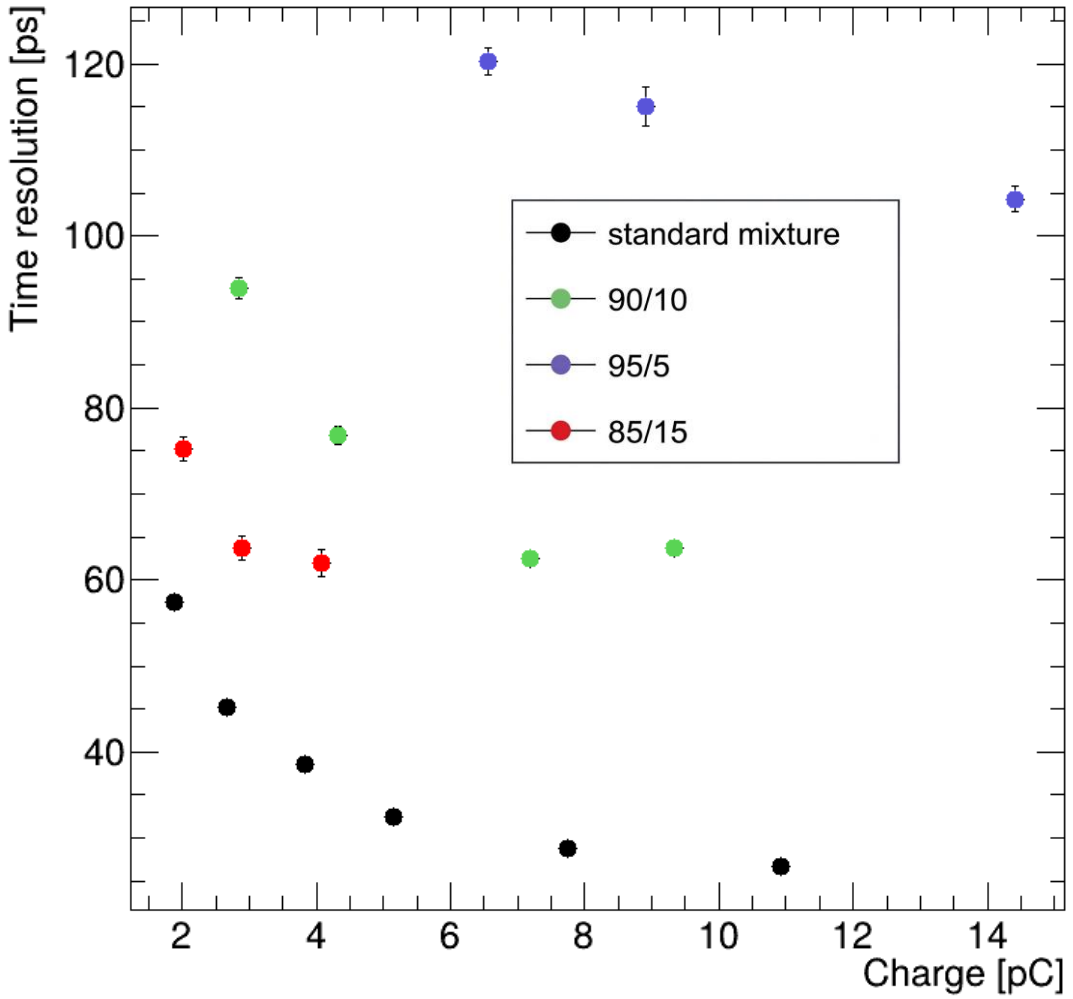
Helium can be a good candidate:

- Good performance
- Helium is cheaper than Neon

But:

- Time resolution is slightly worse than Ne
- Helium can not be used in all experiments

My test beam results – Ar/isobutane mixtures

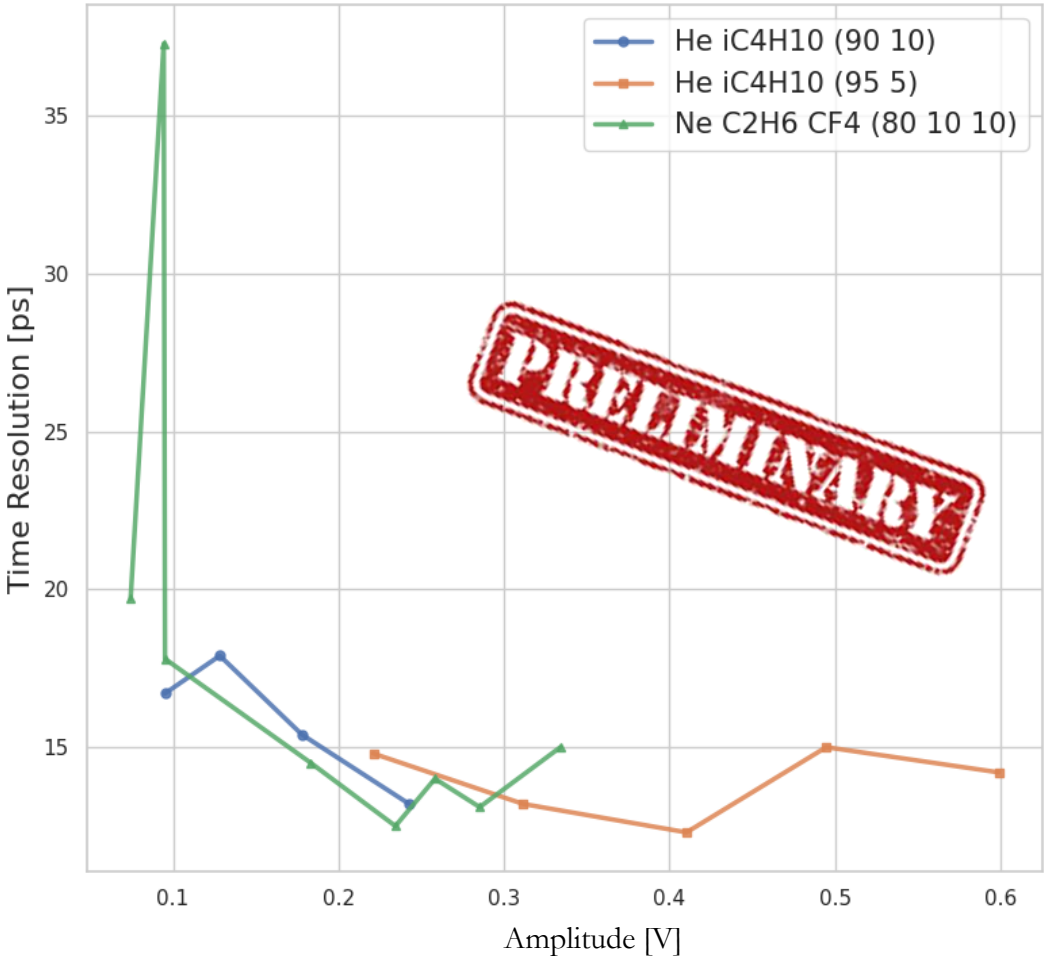


Argon based mixture could not perform as well as the standard one

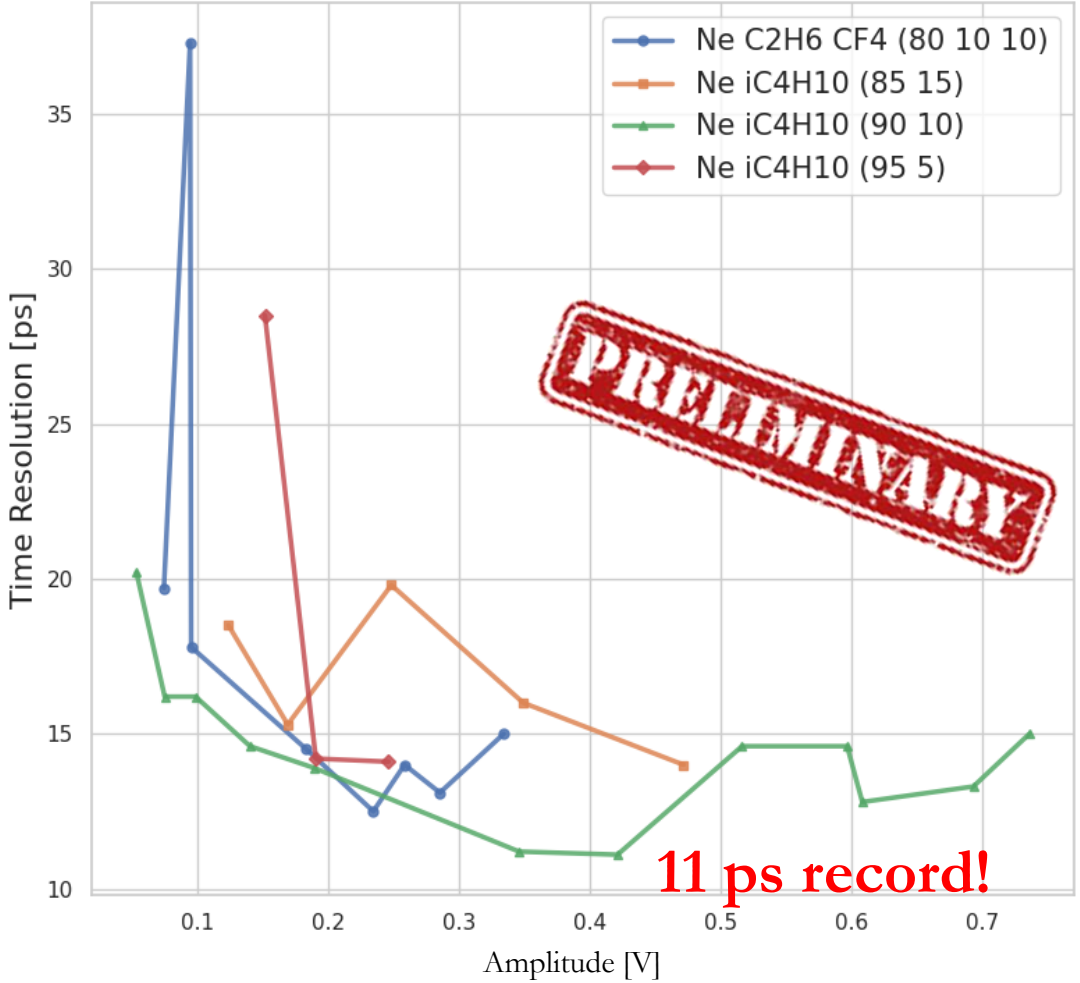
These mixtures were discarded because of the poor performance

Preliminary results from the last test beam

He-iso mixture (94 μm drift gap, metal anode)



Ne-iso mixture (94 μm drift gap, metal anode)



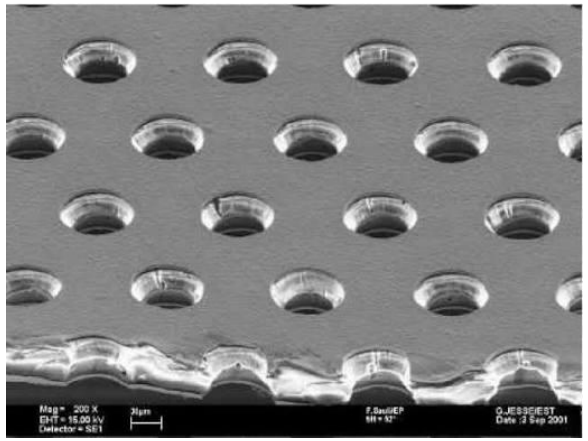
… Robust

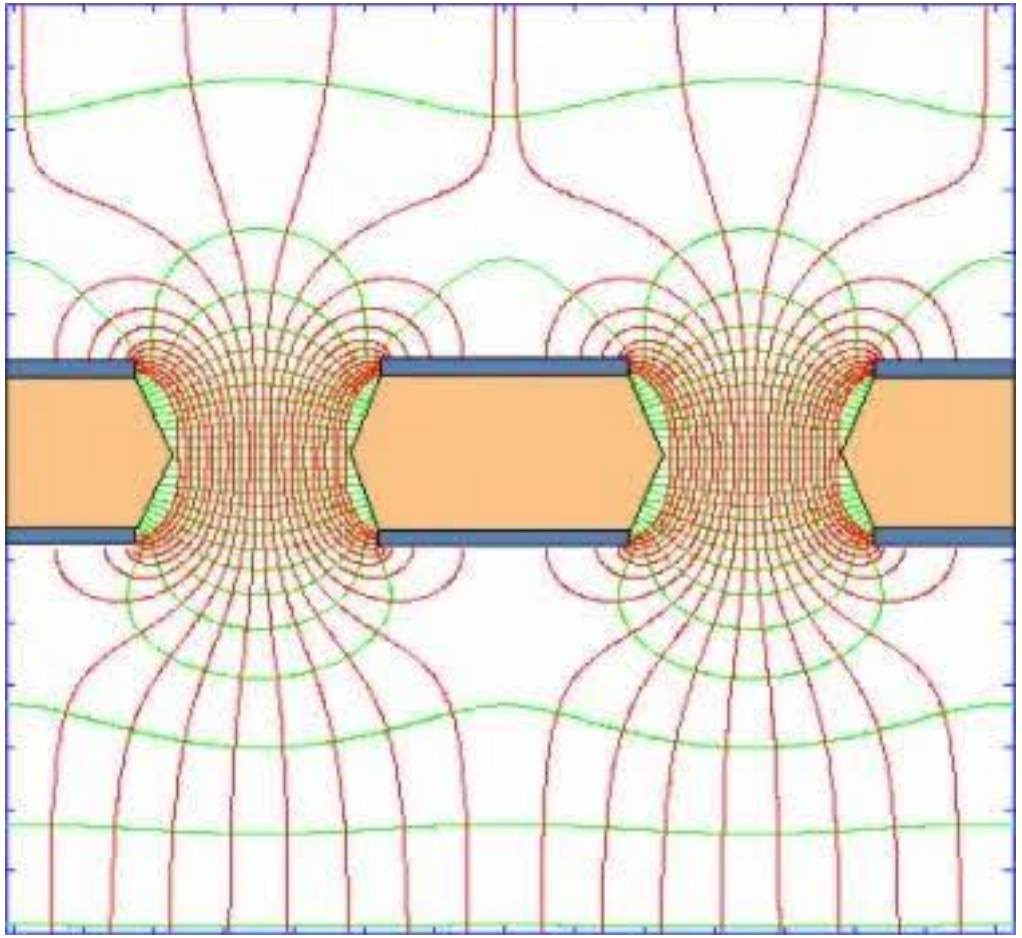
The GEM detector

Thin Kapton foil with small holes with both surfaces deposited with copper

Strong field between the top and bottom surfaces

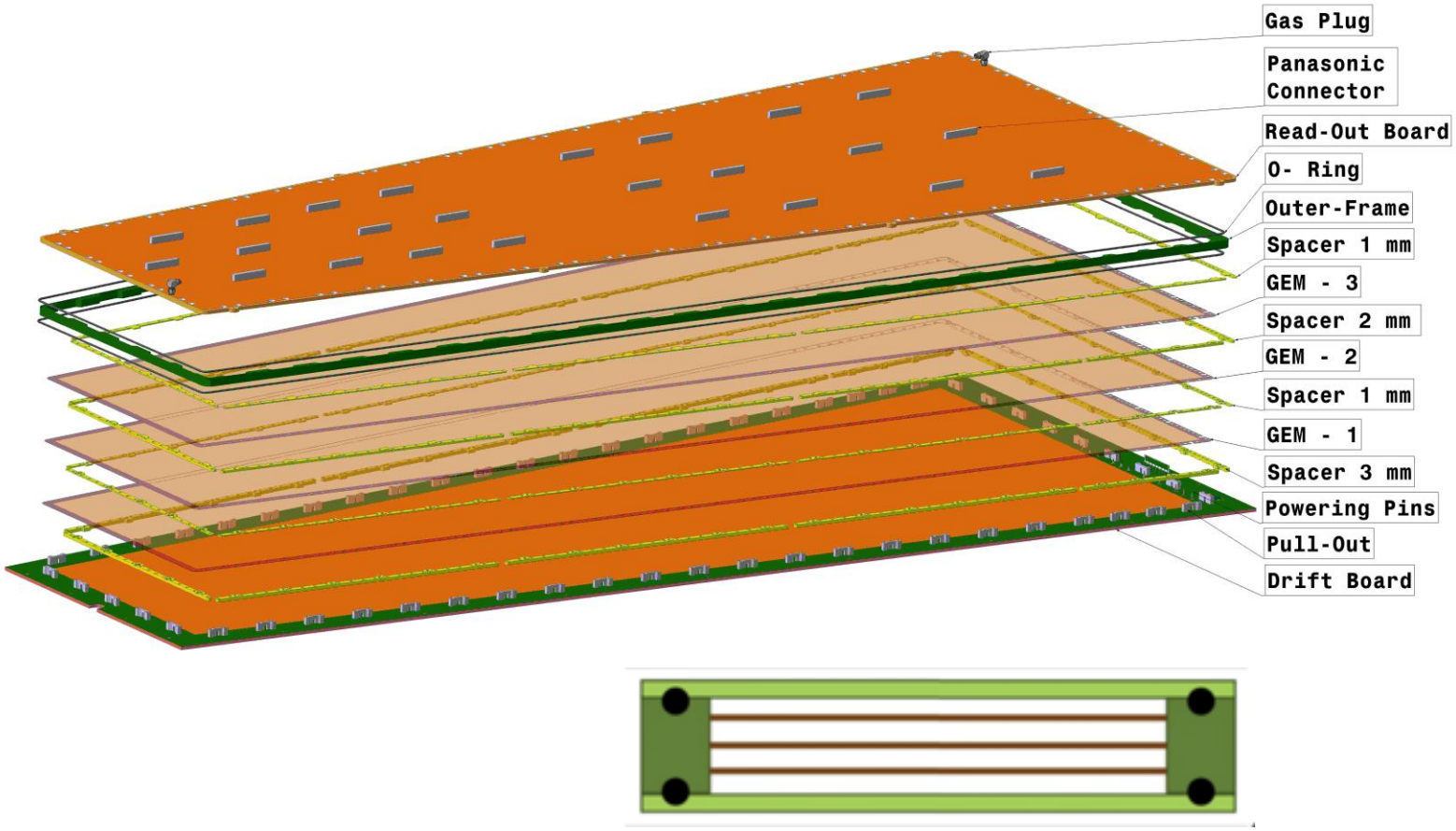
Amplification happens inside the holes





https://gdd.web.cern.ch/gem/

GEM detectors in Compact Muon Solenoid



Triple-GEM configuration

Foil stretched to make the structure planar

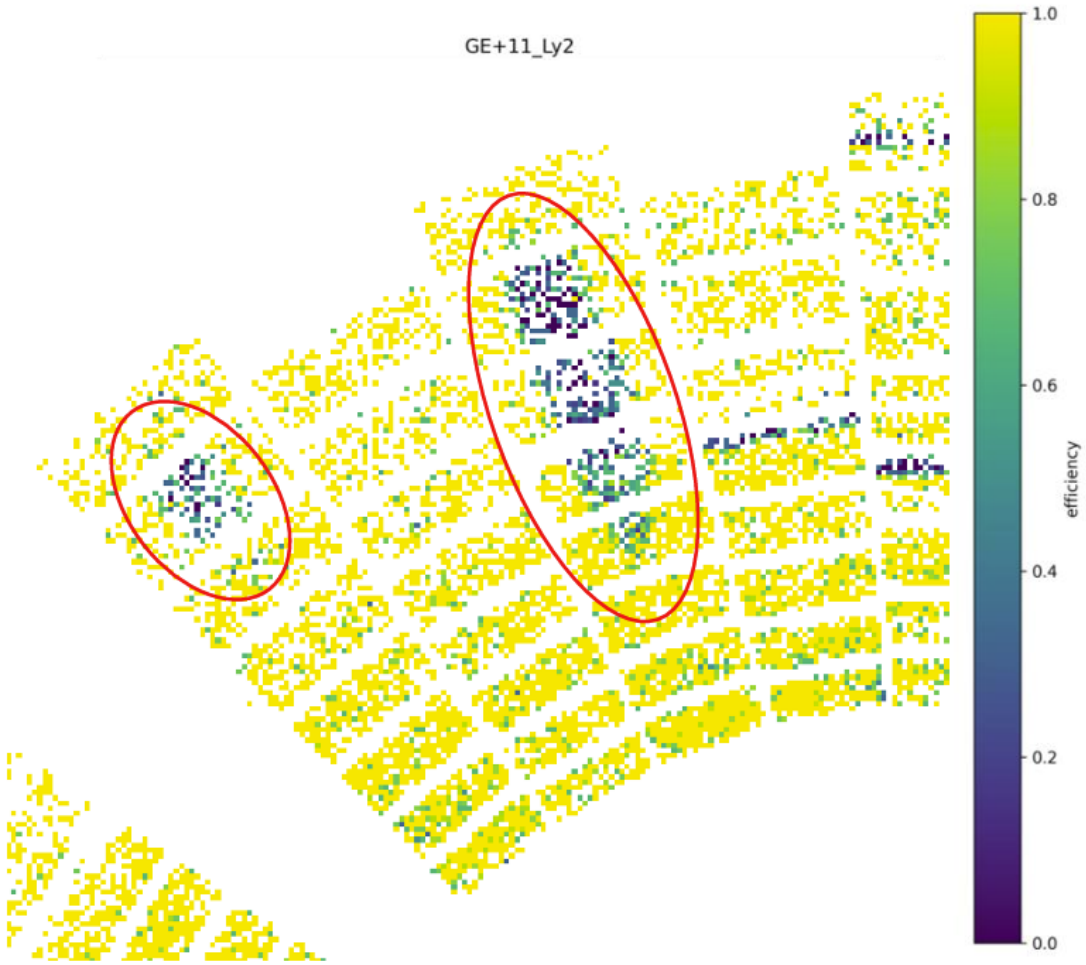
https://cds.cern.ch/record/2649934/plots

GEMs refurbishment

GEMs in CMS were taking data with good but still sub-optimal performance

Complete refurbishment is ongoing

One of the major issues is the «basin effect»



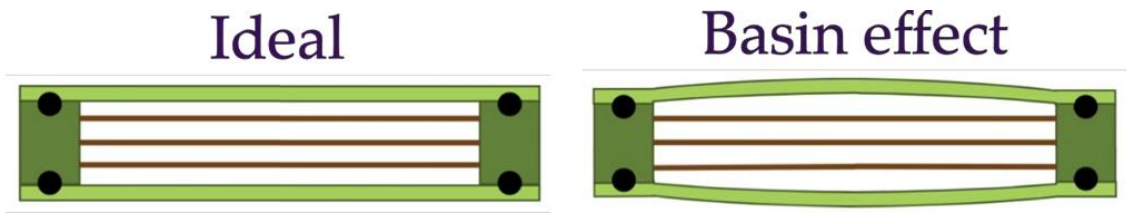
https://indico.cern.ch/event/1644738/

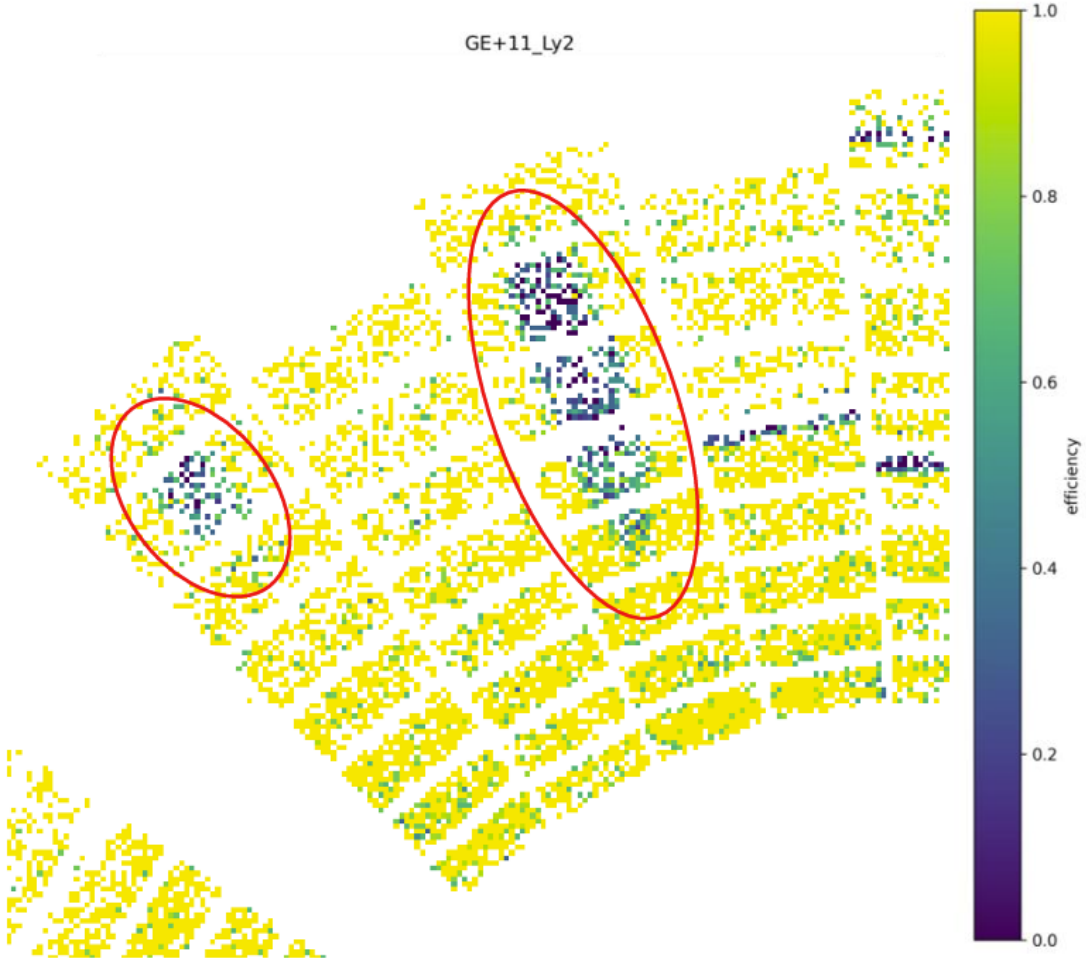
GEMs refurbishment

GE1/1 was taking data with good but still sub-optimal performance

Complete refurbishment is ongoing

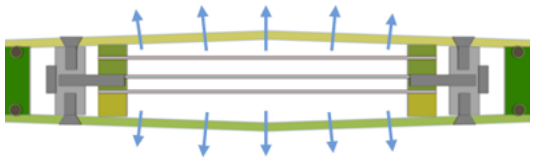
One of the major issues is the «basin effect»





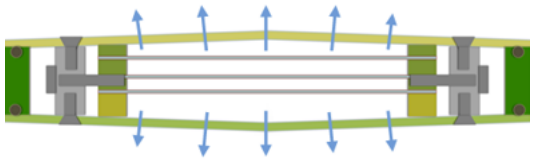
https://indico.cern.ch/event/1644738/

Why do we have the basin effect?

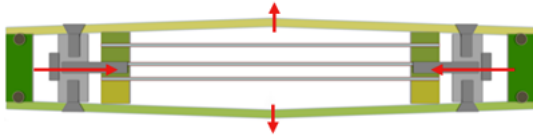


Balooning: the gas pressure is inflating the detector causing is to swell

Why do we have the basin effect?

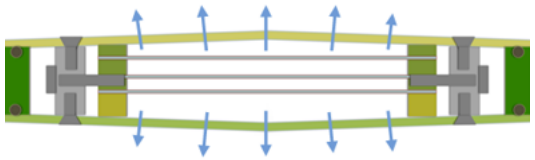


Balooning: the gas pressure is inflating the detector causing is to swell

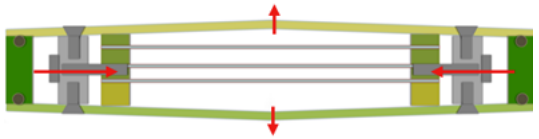


Mechanical stress: the tension of the foils is bending the boards

Why do we have the basin effect?



Balooning: the gas pressure is inflating the detector causing is to swell



Mechanical stress: the tension of the foils is bending the boards

Dimension mismatch between the internal and external frames

R&D toward a solution

https://indico.cern.ch/event/1644738/

R&D on a new metallic frame:

- Single piece to better distribute forces
- Ensure gas tightness
- Provide a more solid support to keep the board flat
- The expected results are better efficiency, time resolution and signal arrival time

Conclusions & future perspectives

Fast…

The study on a new gas mixture for the Picosec detector provided good candidates to replace the standard gas

Ne/isobutane mixture seems to perform better than the standard one

He/isobutane mixture are comparable with the standard gas in terms of performance but less expensive

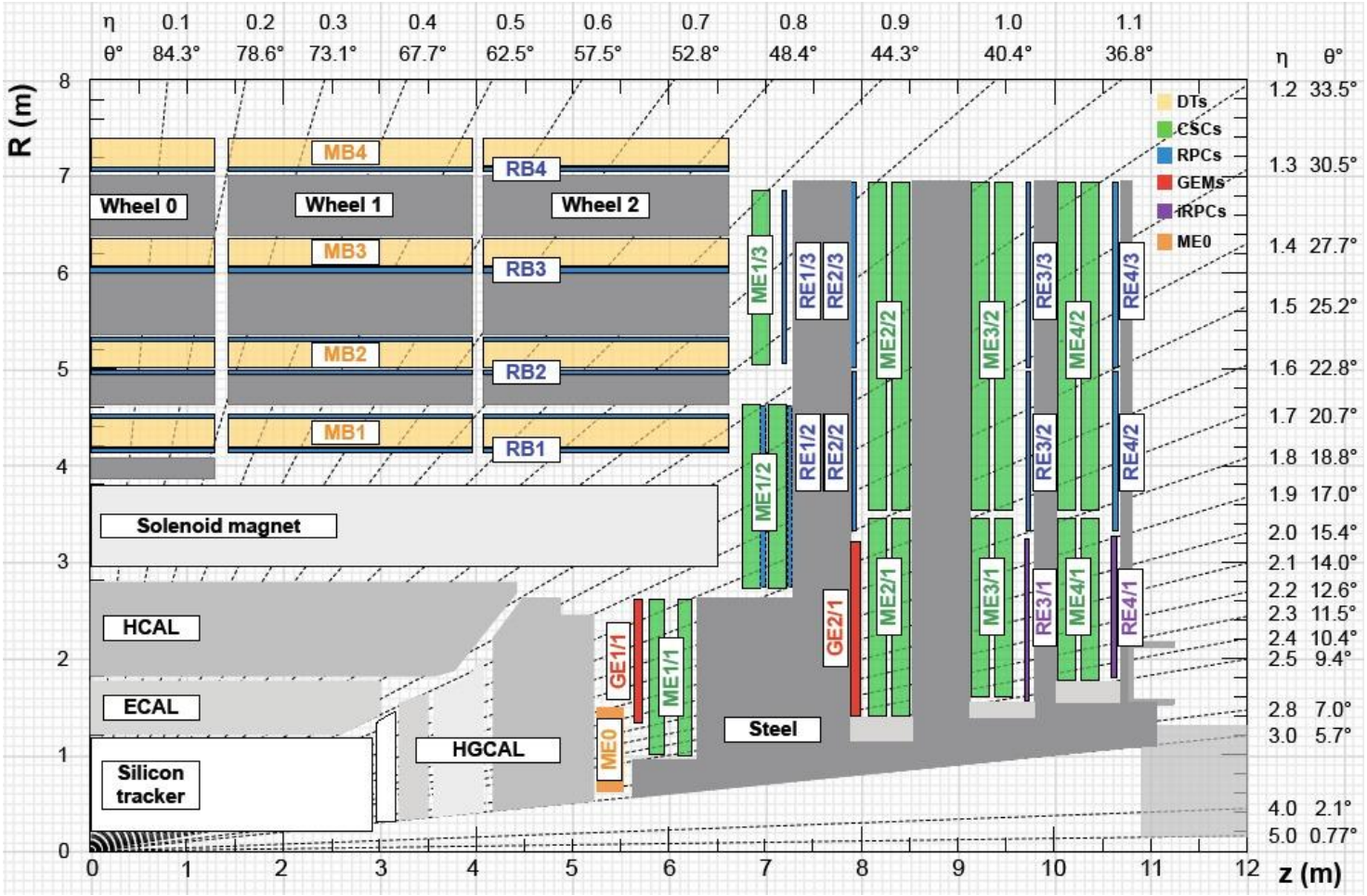
Ongoing work to write the paper as first author

During my year at CERN I will focus on the R&D of a new frame for the GEM detectors

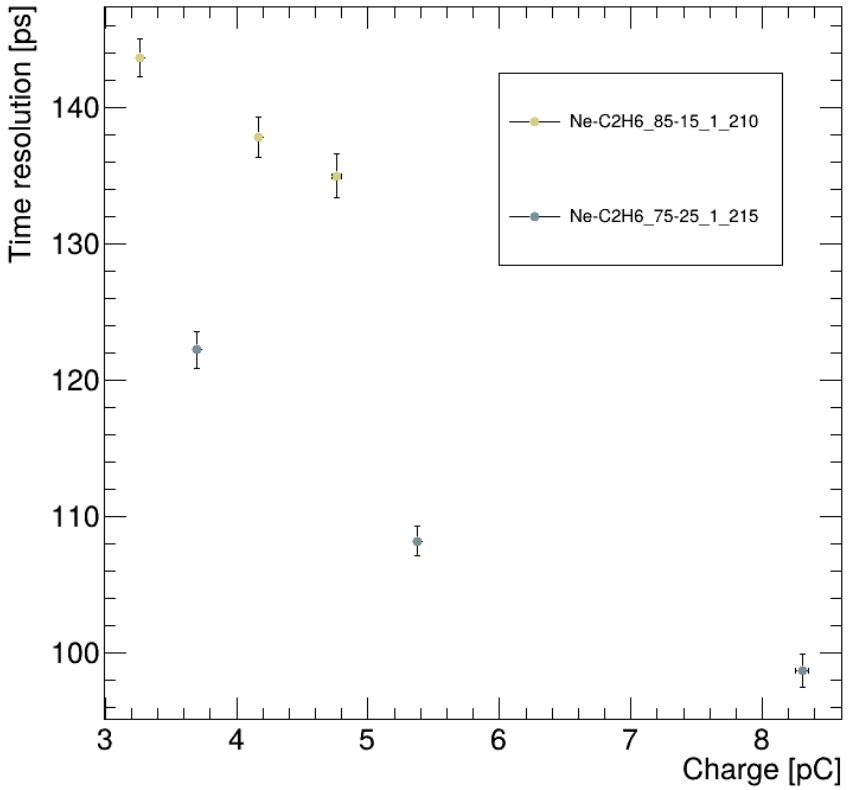
The expected results are better efficiency, time resolution and signal arrival time

… & Robust

Compact Muon Solenoid and its GEMs



ethane



Bad results with ethane