Picosec Micromegas performance on muon beam with eco-friendly gas mixtures

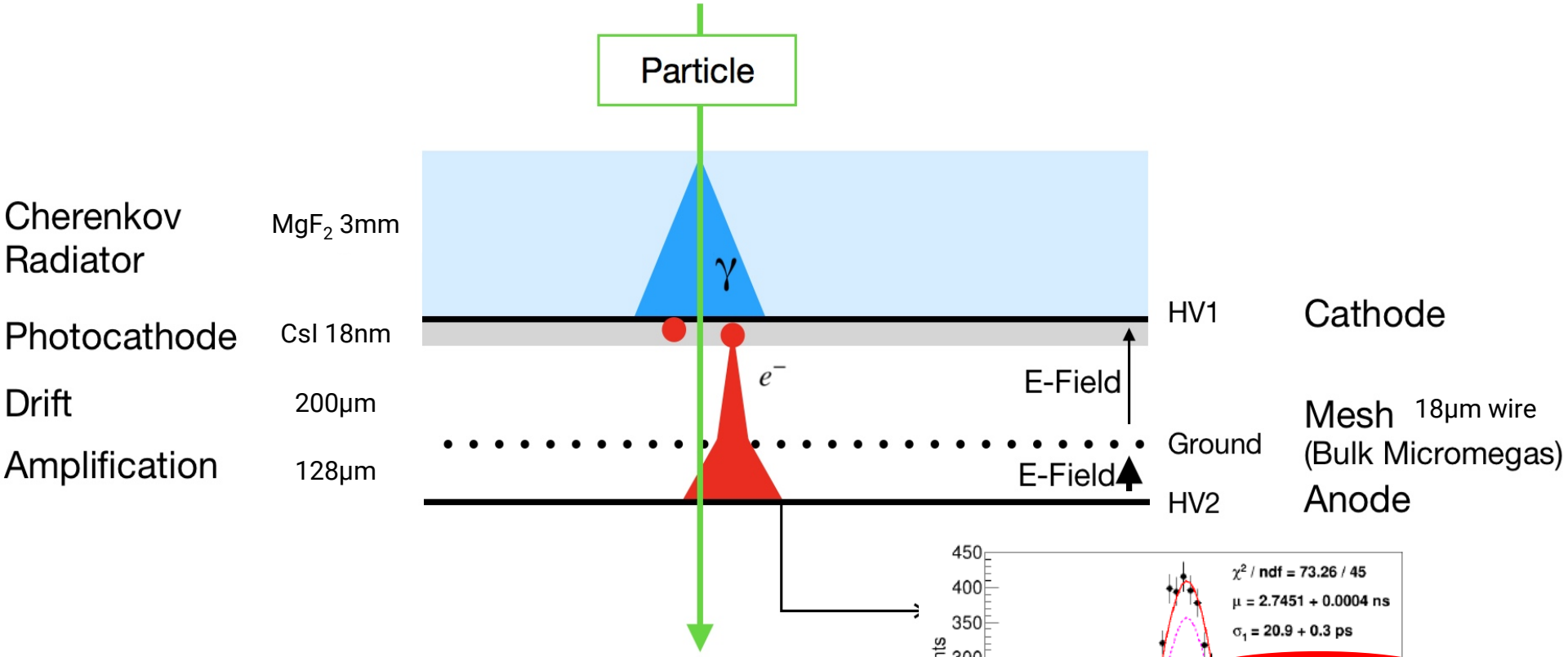
D.Fiorina – C.Aime – I.Vai – S.Calzaferri
C.Riccardi – P.Salvini – P.Vitulo – A.Braghieri

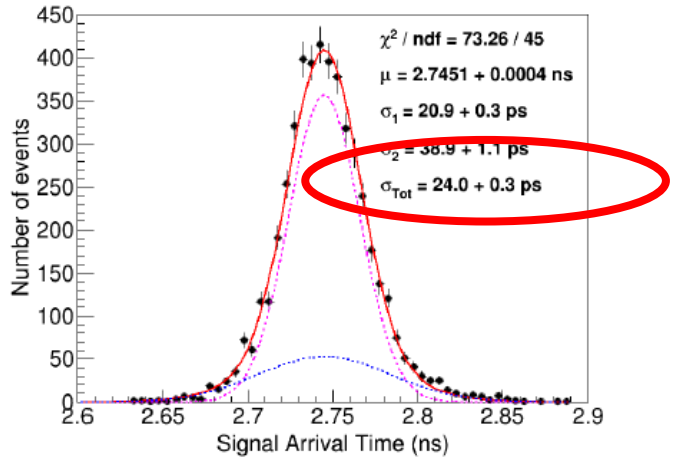
INFN & Università Pavia

Picosec Concept

Gas Mixture:
$Ne/C_2H_6/CF_4$
80/10/10

Field(kV/cm)	Gain
~40	$\sim 10^3$
~20	$\sim 10^2$



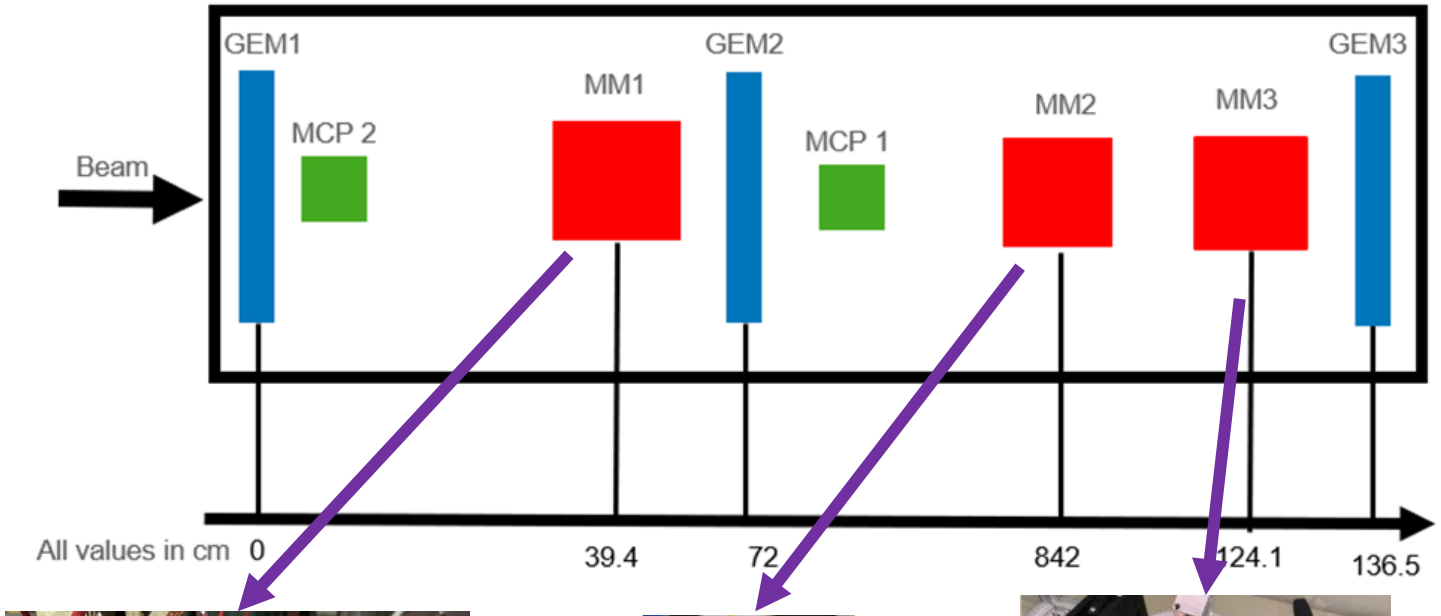


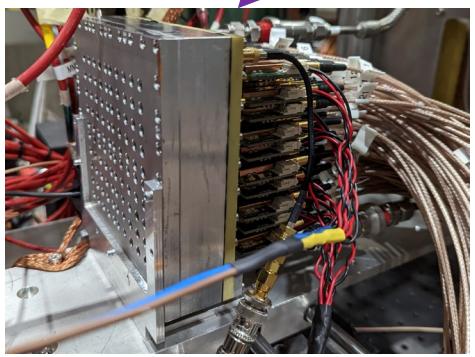
1. **Look at Cherenkov, not the ionisation**
   Photo-electrons created promptly with the MIP passage
2. **Remove the drift gap and start the avalanche as soon as possible**
   Avalanche propagate faster

Bortfeldt, J., et al. "PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector."*Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*903 (2018): 317-325.

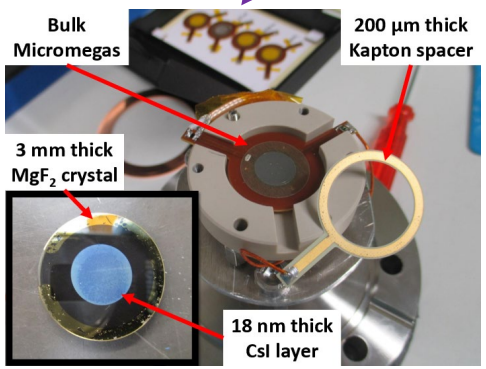
Test Beam Setup

MCP for time reference $\sigma_t \approx 5$ps

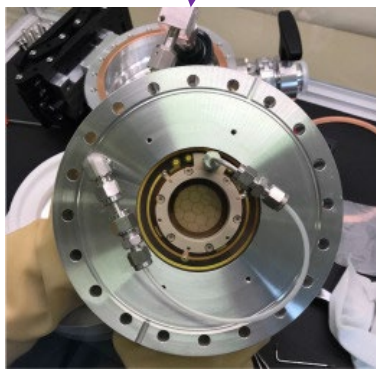




10x10 (RD51)



Single channel (Pavia)



Multi-pad exagonal (Saclay)

Test beam in CERN EHN1 26Apr-10May 2023

- Shared infrastructure during RD51 test beam

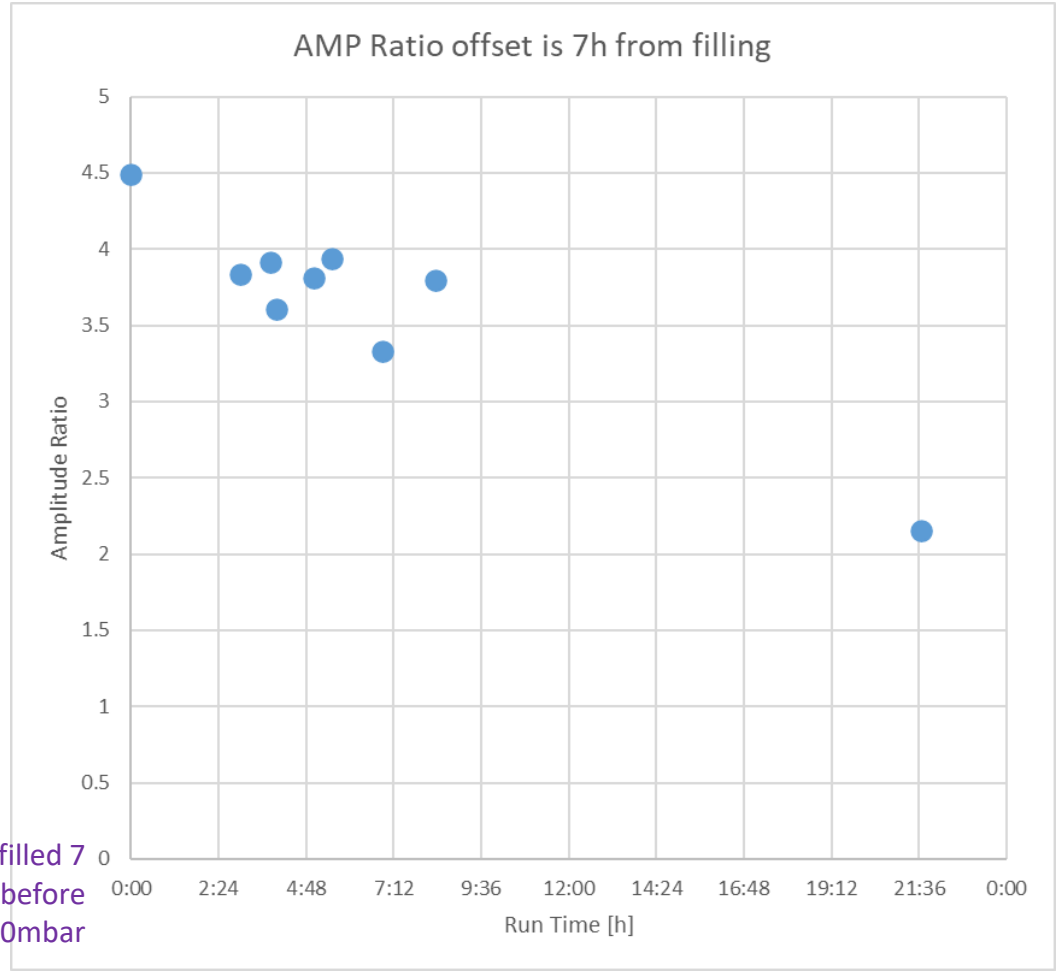
Pavia Single-channel:

- Operation with eco-friendly gas
- Operation with resistive photocathode (B4C)
- Operation in pion beam (≈1MHz/cm^2)
- Operation with reduced preamplification gap

Eco-friendly gas operation

Gas mixture used	Global Warning Potential 20-years (normalized to CO_2)
$Ne/C_2H_6/CF_4$ (80/10/10)	**441**
Ne/iC_4H_{10} (94/6)	0.2
Ar/CO_2 (93/7)	0.07
$Ar/CO_2/iC_4H_{10}$ (93/5/2)	0.11

- Nominal mixture has a non-negligible GWP mostly because of CF_4
- Moreover, with current and future regulations, CF4 usage will be heavily discouraged
- Remove CF_4 or substitute it



Detector filled 7 hours before +50mbar

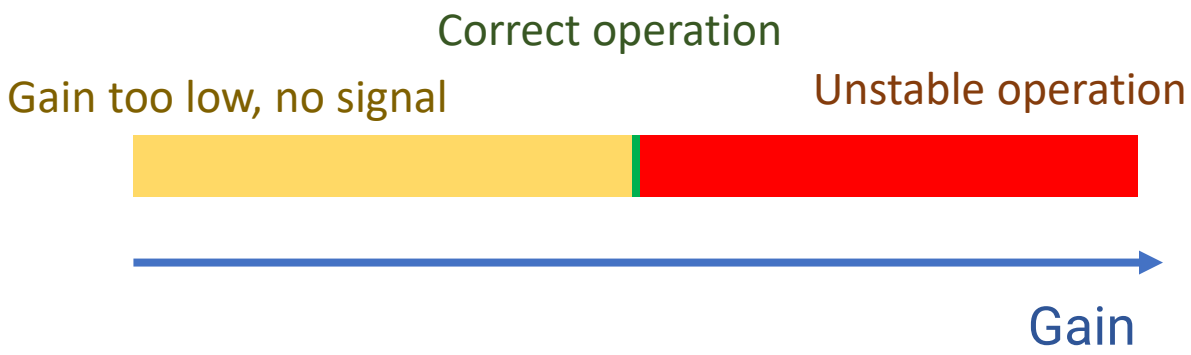
Gas quality degradation during test beam in sealed mode

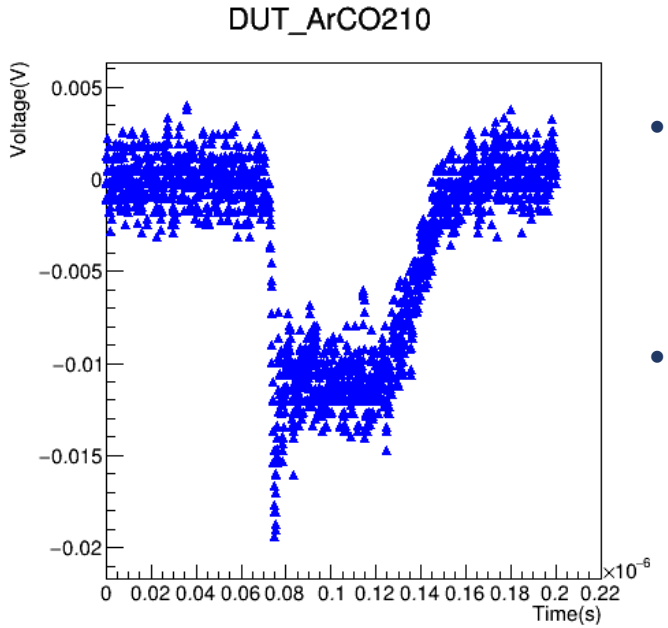
Eco-friendly gas operation

-Ar based mixtures-

Gas mixture used	Global Warning Potential 20-years (normalized to CO_2)
$Ne/C_2H_6/CF_4$ (80/10/10) -standard-	441
Ne/iC_4H_{10} (94/6)	0.2
Ar/CO_2 (93/7)	**0.07**
$Ar/CO_2/iC_4H_{10}$ (93/5/2)	**0.11**

- MIPs signal is on the order of several photoelectrons (depending on photocathode)
- We failed to find a suitable working point for such mixtures
- Immediate passage between np-signal region to spark region
- Such mixtures are not quenched enough to control the avalanche
- (more quencher needed

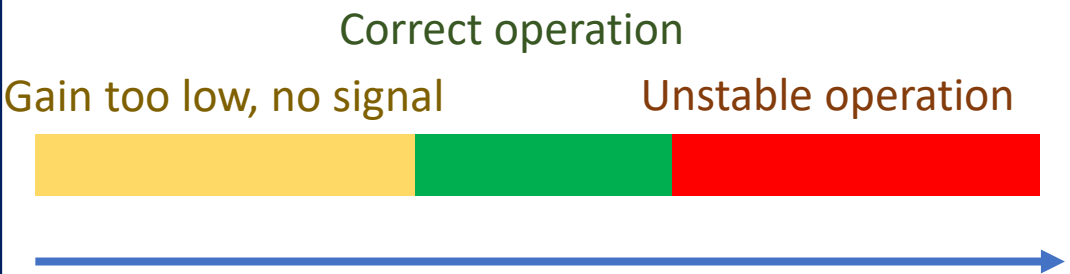




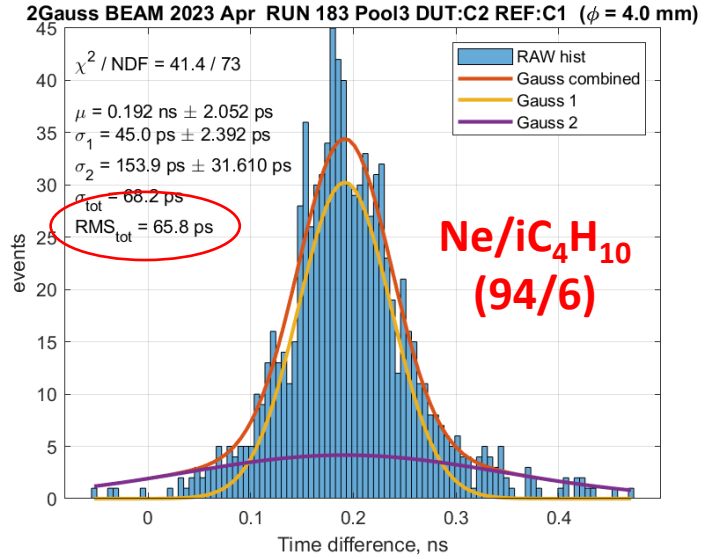
- We can see single-photoelectron signals in the lab
- Unstable detector (Sparks)

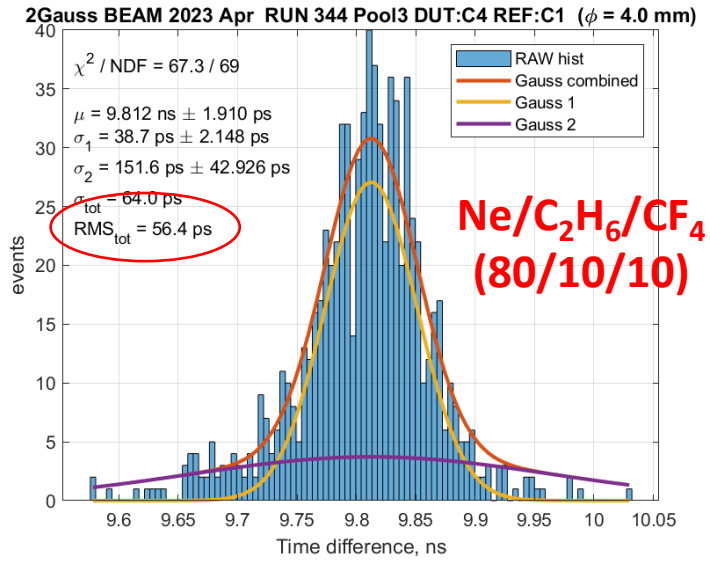
Eco-friendly gas operation
-Ne based mixtures-

Gas mixture used	Global Warming Potential 20-years (normalized to CO_2)
$Ne/C_2H_6/CF_4$ (80/10/10) -standard-	**441**
Ne/iC_4H_{10} (94/6)	**0.2**
Ar/CO_2 (93/7)	0.07
$Ar/CO_2/iC_4H_{10}$ (93/5/2)	0.11



- Photocathode used was **B4C 6nm**
  - Photoelectron yield is around 3 PE/MIP
  - Lower time resolution wrt CsI is expected (**with CsI ≈25ps**)
- Time difference distribution between Picosec and reference MCP
- The two distributions are measured at **similar gains** for the two mixture
- The impact of CF_4 in timing is **visible but not drastic (≈15%)**
- Still, the 3-component gas mixture has a wider operational range because is more quenched





Conclusions

- April/May test beam was successful, and many data was collected
  - **Operation with eco-friendly gas**
  - Operation with resistive photocathode (B4C)
  - Operation in pion beam (≈1MHz/cm^2)
  - Operation with reduced preamplification gap
- We demonstrated that **acceptable timing performance might also be achieved without CF_4** (≈15% lower time resolution)
- Future tests will exploit **different gas concentrations** and the possibility of using a **CF_4 substitute** (like R1234ze already tested among the RPC community)

These early results on gas mixture will be presented at the FAST2023 conference (28 May 2023 to 1 June) along with the results of previous test beams.