R&D for Picosecond Timing with Novel Micromegas Detectors

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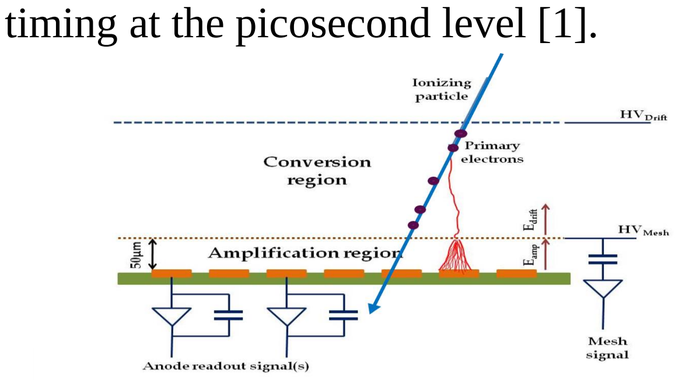
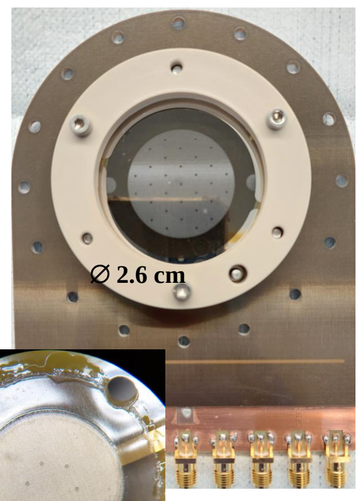
Motivation

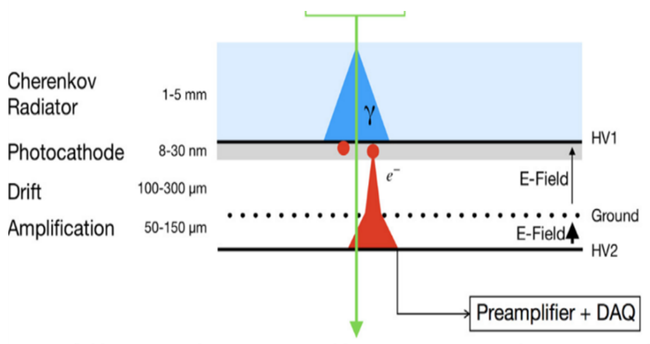
The motivation is to achieve timing with **a picosecond level accuracy**. The idea arises from the need for high-rate experiments to deal with pile-up phenomena which makes event reconstruction more complex. The **new 4D tracking era** can include timing as an extra parameter for **triggering or event selection.**

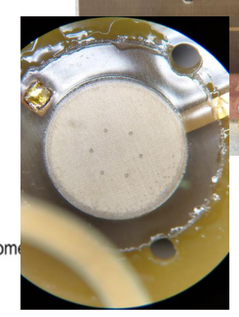
1. Detector Concept

The PICOSEC Micromegas Detector has the potential for precise timing at the picosecond level [1].



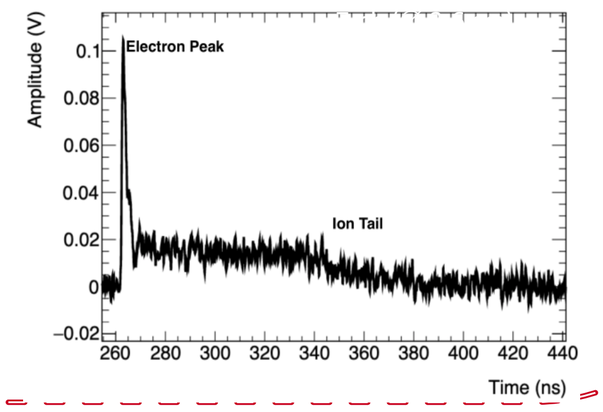






- Cherenkov radiator + photocathode (CsI, B4C, DLC) → prompt photoelectrons
- Small drift gap → High field → Pre-avalanche

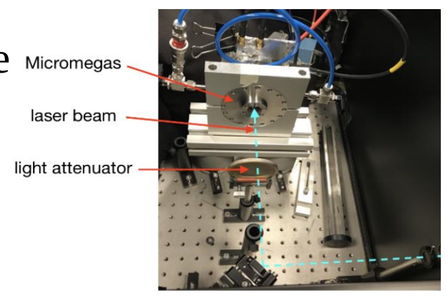
- Two component Signal
  - Fast electron peak
  - Slow ion tail



2. Detector Testing

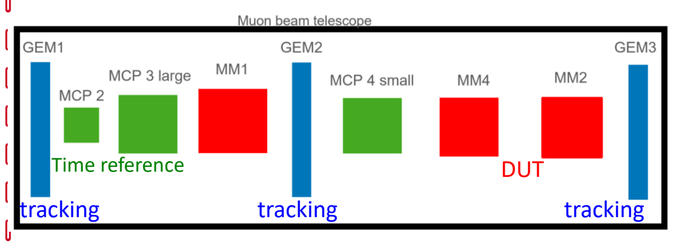
I. Pulsed Laser Beam (IRAMIS/CEA)

- Detector response on controllable number of photoelectrons
- Independent measurements from photocathode material



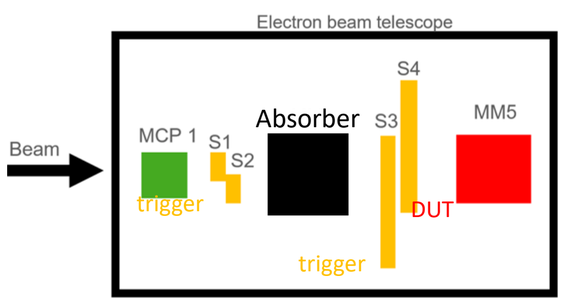
II. Muon Beam (CERN/SPS H4 Beam Line)

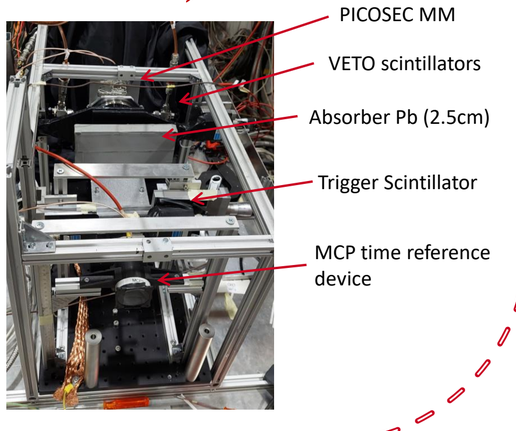
- Energy 80-150 GeV
- Multi-photoelectron response
- High-rate environment



III. Electron Beam (CERN /SPS H4 Beam Line)

- Energy 30-80 GeV



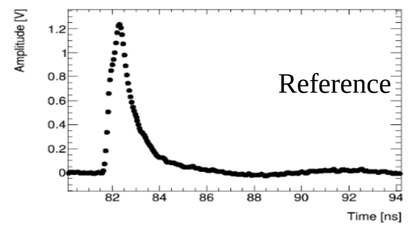


3. Waveform Analysis

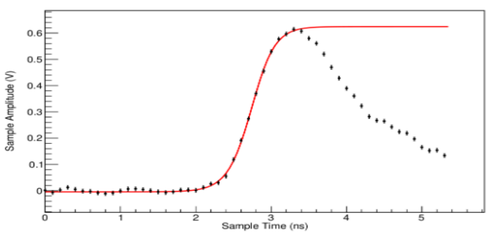
I. Time relative to a reference device with resolution < 5ps

II. Standard Signal Processing technique

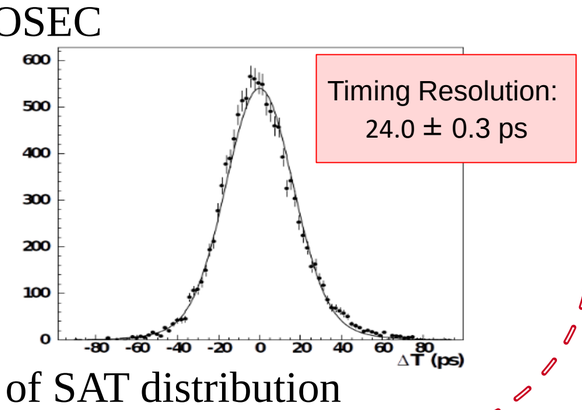
- Constant Fraction Discrimination (CFD) at 20% of the peak maximum



- Adjust a sigmoid function on the leading edge of the peak waveform



- Subtract SAT values of PICOSEC from the reference device



- Timing Resolution → RMS of SAT distribution

4. The Future

I. Scalable detector

- Single pad (∅ 1cm) → 7-pad (∅ 1cm) → 100-pad (□ 1cm)

I. Robustness & Efficiency

- Robust photocathode materials
- Resistive Micromegas prototypes

II. Pixelated Detector

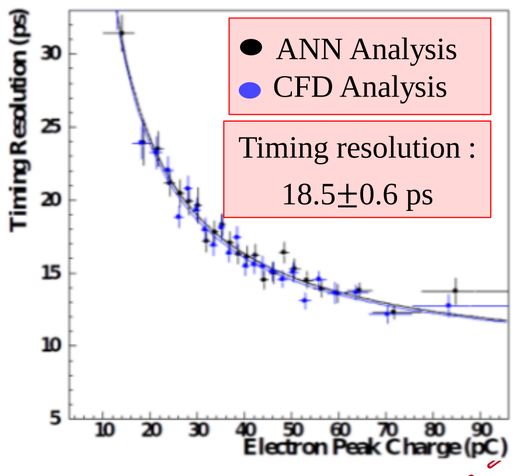
- Scalability of electronics (digitizers & custom-made amplifiers)

III. Applications

- Neutrino physics – ENUBET Experiment [2]
  - Detect individual particles (leptons) (as T0 layer)
  - Detect EM showers (embed in EM calorimeter)

IV. Alternative Signal Processing Algorithms

- Online Timing with ANN[3]



References

[1] J.Bortfeldt, et al., *"PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector"*, https://doi.org/10.1016/j.nima.2018.04.033
[2] F. Terranova*, et.al *" The ENUBET experiment "*, https://doi.org/10.22323/1.390.0182
[3] A.Kallitsopoulou -Master Theses- *" Development of a Simulation model and Precise Timing Techniques for PICOSEC-Micromegas Detectors"* https://arxiv.org/pdf/2112.14113.pdf