Rapid fire

Fast Timing MPGD

INFN Workshop on Future Detectors (IFD)

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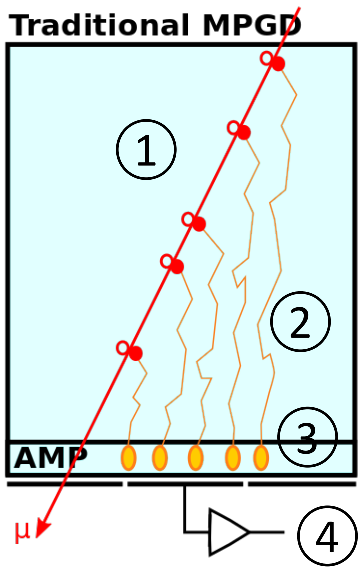
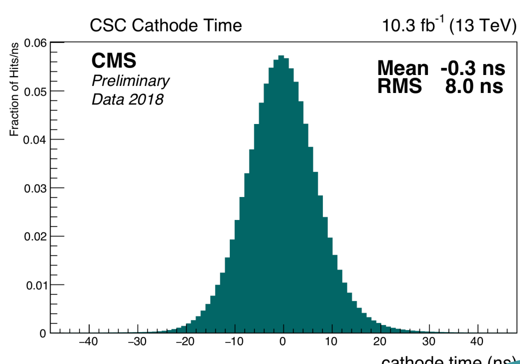
Timing with Gaseous Detectors in Proportional Mode (wires, MPGDs)



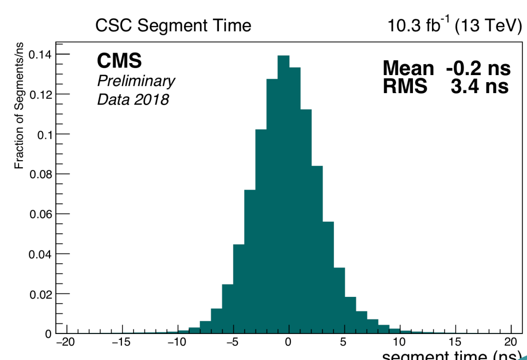
- with primary electron creation in gas (“Primary Ionization”) typically in a so-called ”Drift Volume” is limited to 5-10ns [1]
- Independent of Electric Field: parallel or circular wire detector
- Time resolution limited due to fluctuations in primary ionization
- Typical Fluctuation of closest primary electron to amplification structure. Example: Triple-GEM in **$Ar:CO_2$ (70:30)** λ~ 2.8mm^{-1} $\langle d \rangle$ = 350μm, v_{drift} = 70μm/ns (3kV/cm) → $\sigma_t^{primaries} = 5$ ns ①
- Next factors that influence time resolution in these detectors are:
  - Long diffusion flucts: σ_t^{drift} = few 10s – few 100 ps ②
  - Avalanche flucts: $\sigma_t^{avalanche}$ = few 10s – few 100ps ③
  - *Electronics jitter, system time distribution, start time,…* ④

Better time resolution obtained: $\sigma_t/\sqrt{N}$

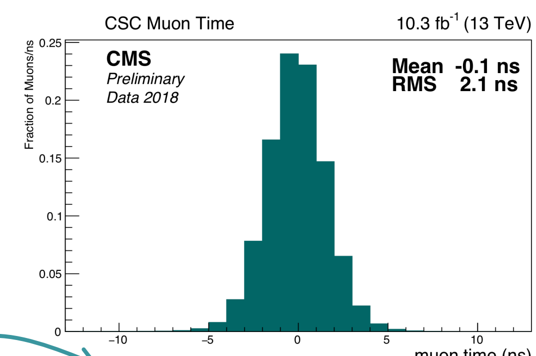
Example at LHC: CMS CSC



Single-hit $\sigma_t = 8$ns



6-hit stub $\sigma_t = 3.4$ns

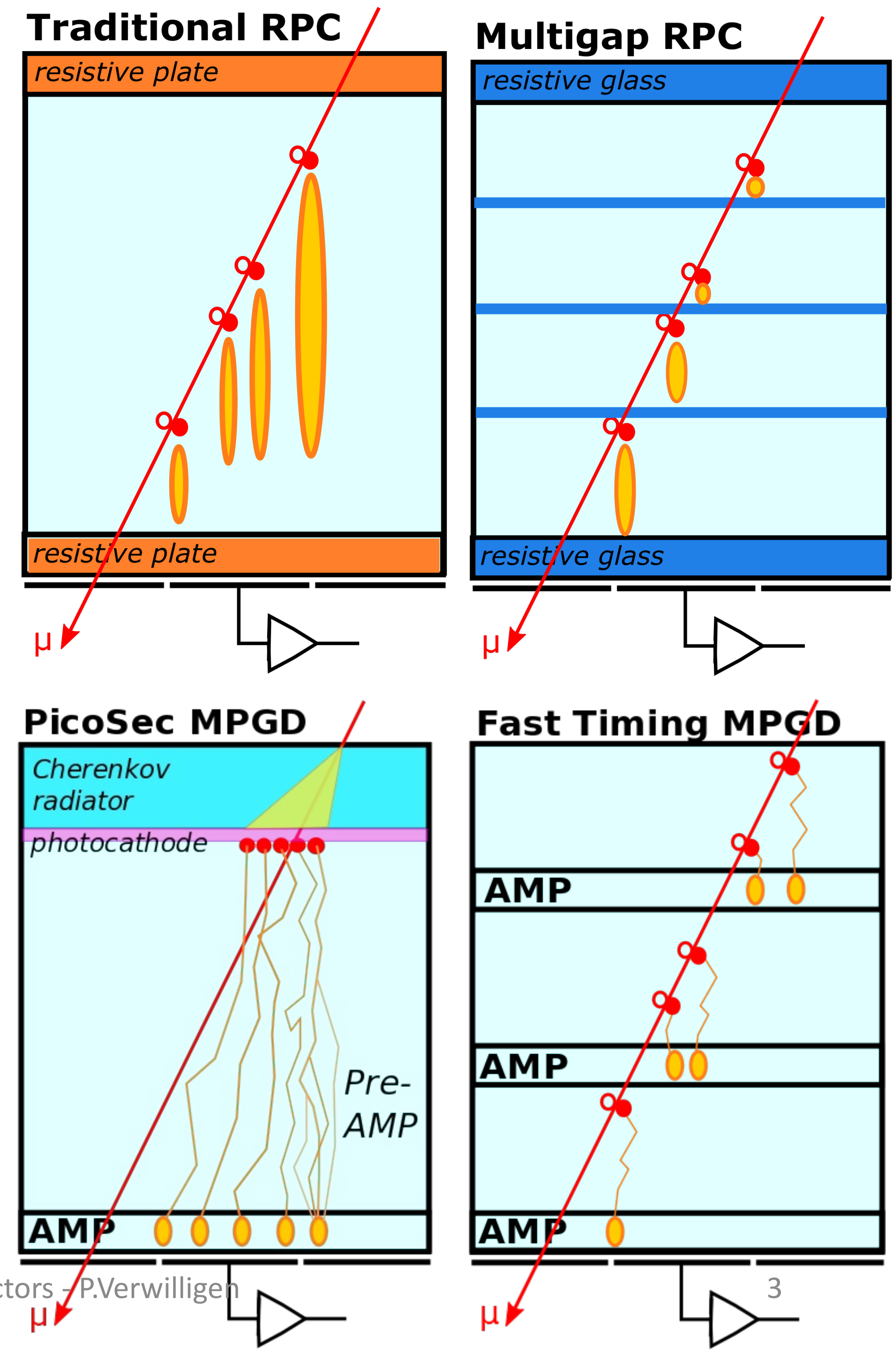


4-stub muon $\sigma_t = 2.1$ns

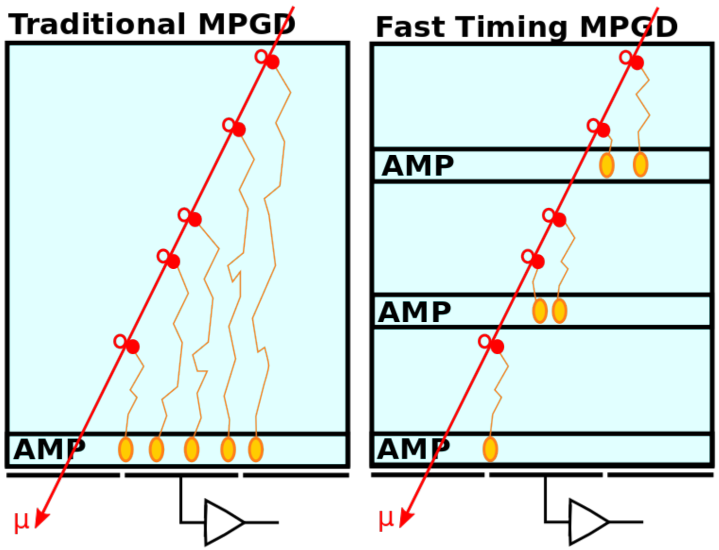
Overcome limits time-resolution

Possible Solutions:

- No drift volume, amplify immediately: **Resistive Plate Chamber**(2ns – 300ps)
  - at cost of loss of Proportionality, reduced Rate Capability & σ_x
- Reduce gap width with order of magnitude and use multiple gaps: **Multigap-RPC (100ps – 20ps)**
  - same as RPC, but difficult for large area
- Create all primary electrons at same place (use Radiator+PC): **PicoSec** (<25ps)
  - but expensive radiators (Quartz, MgF2) & non rad-hard photo-cathodes (CsI)
- Sample the fluctuations in primary electron creation: **Fast Timing MPGD** (~300ps – *not proven yet*)
  - resistive MPGD: spark protection but reduced rate capability



Fast Timing with MPGDs: FTM

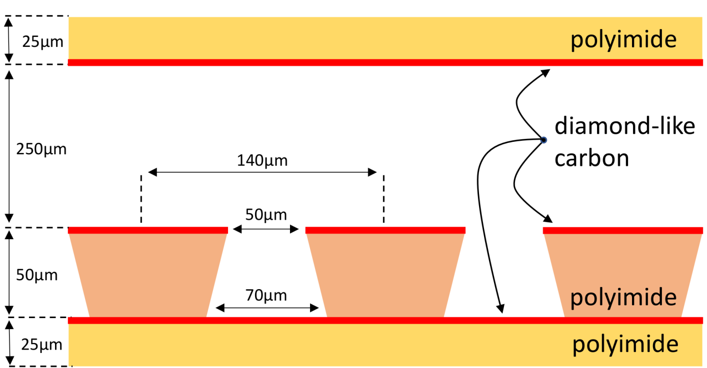


Fast Timing MPGD (FTM): Principle

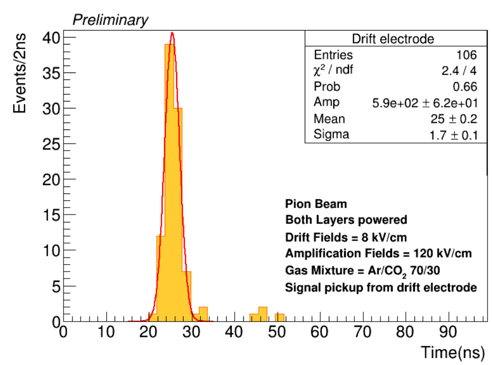
- Divide drift in multiple layers, each w/ own Amplification
- Resistive electrodes => Electrode Transparency
- Signal induced in External Pick-Up strips
- Closest primary electron => Fastest Signal
- Time Resolution $\sigma_t = 1/(\lambda \cdot v_{drift} \cdot N)$, where N = layers
- Observed: 2ns with 2 layer detector [4] (→ OK)

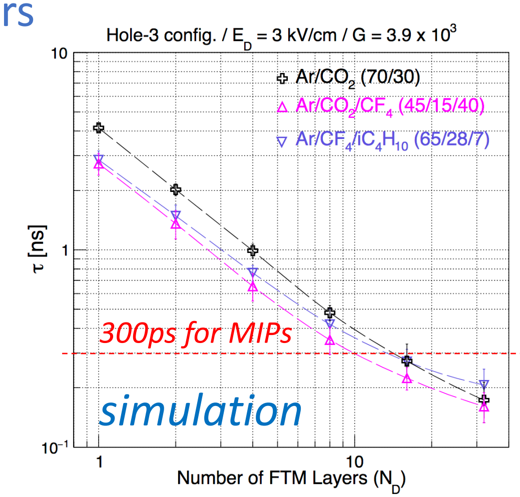
Fast Timing MPGD: Challenges:

- Detect single-electron (or single cluster) instead of many clusters
- **Requires High Gain Structures**
- **Requires sensitive front-end electronics**



Test Beam Results (2 layers)





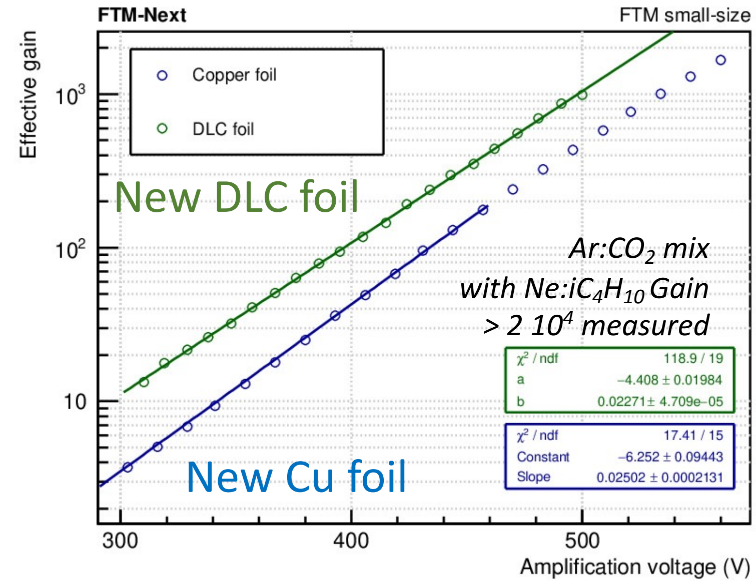
References:
[1] F.Sauli, Yellow Report, CERN-77-09 (1977)
[2] P.Verwilligen *et al.* J.Phys.Conf.Ser. 1498 (2020)
[3] M.Maggi *et al.* arXiv:1503.05330 (2015)
[4] I.Vai *et al.* NIM A 845 (2017) 313

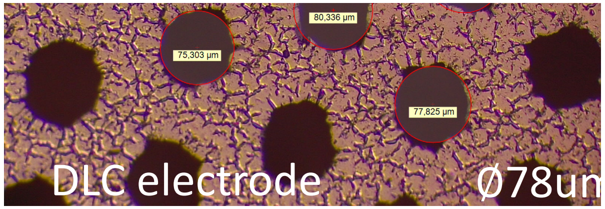
FTM: Technological Challenges

Single gain structure capable of gain > 10^4

- *with non-greenhouse, non-GWP, non-flammable gas*
- Main Challenge: production of high quality Amplification foils
  - Requires well adherent 2-sided Cu-DLC foils
  - CERN – INFN DLC Sputter machine is coming
  - In past years: collaboration with solid state physicist (INFN CSN-V)
    - High quality DLC production on small size prototypes 1-50cm^2
    - Strategies pioneered small scale can be brought to large scale production
- Side: understand details of capacitive signal induction in readout (first time for small Q)
- Future: 125um well height – Plasma Etching

⇒ Require technological advancements to make high quality detectors





Development of Fast and Sensitive electronics

Single-Stage MPGD have typical gain of 3 · 10^3 – max 10^4.

Assume signal not dispersed over strips, signals of 0.5-1fC

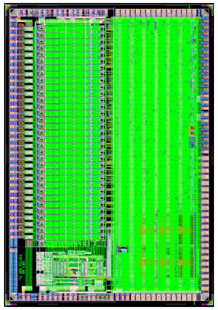
Fast Timing typically done for large signals:

$\sigma_t = \sigma_{noise}$ / dV/dt = t_{rise} / SNR

=> Now bring fast timing to smaller signals. Need very low noise amplifiers

FATIC (130nm Si CMOS)

- 32 channels + 1 test
- Gain: 10mV/fC & 50mV/fC
- ENC: 500e$^-$ @ 15pF
- Rise time: 7.5ns
- Analog: time & Charge
- Digital: TDC (100ps)



Want to develop new version in: AIDA innova

Backup