How to measure time in a MPGD Readout TPC

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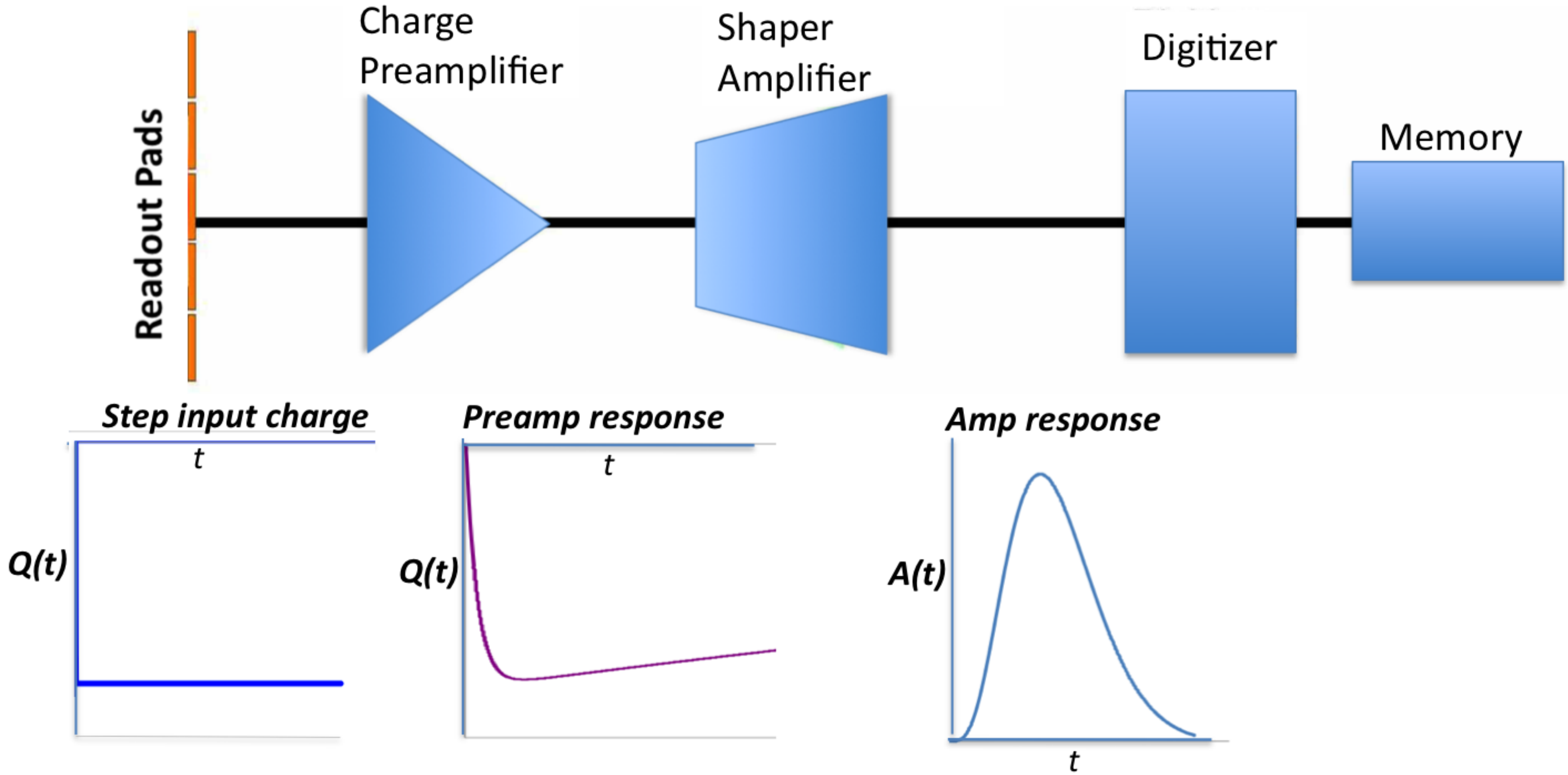
Front end electronics and signal processing in MPGD-TPC

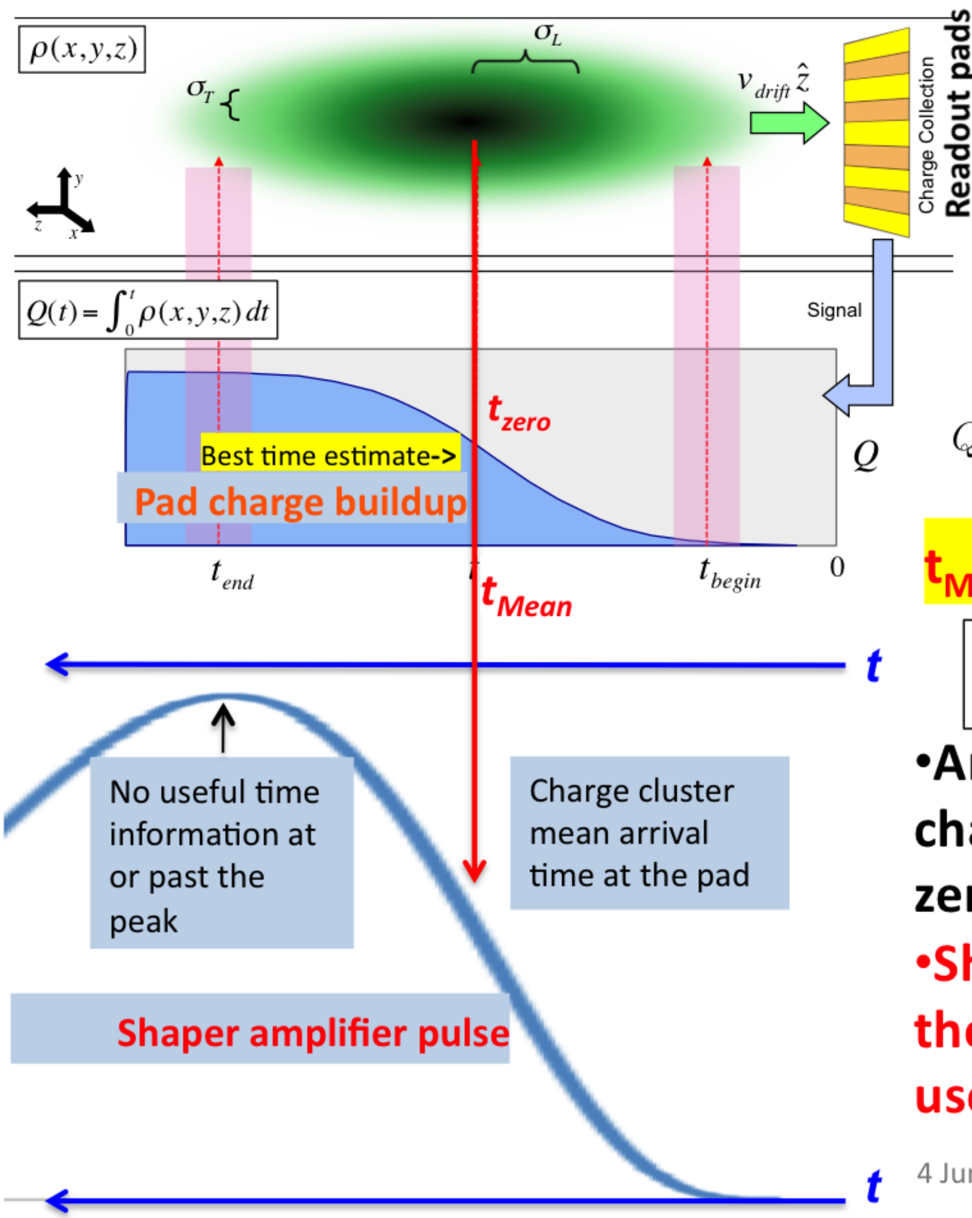


$$Q(t)=e^{-t/tfall}(1-e^{-t/trise})$$

$$A(t)=A_0(t/\tau)^3\sin(t/b\tau)e^{-t/\tau}$$

AFTER amplifier response function

Charge collection, signal formation & time measurement in MPGD TPC



Cluster longitudinal diffusion during drift

$$L(t) = \frac{1}{\sigma_L\sqrt{2\pi}} exp\left(-t^2/2\sigma_L^2\right) \qquad \sigma_L = D_L\sqrt{z}$$

Charge pulse (charge on the pad as a function of time) is an error function

$$Q(t) \approx Erf(t) = \frac{A}{\sigma_L\sqrt{2\pi}} \int_0^t exp\left[-\frac{1}{2}\left(\frac{t - t_{zero}}{\sigma_L}\right)^2\right] dt$$

t_{Mean} ≈ Inflexion point of error function

Ref. Time Resolution of the COSMo TPC Prototype, Russ Woods, Carleton University MSc Thesis 2011

- **Amplifier pulse is derived from the charge pulse after differentiation, pole zero cancelation & integration**
- **Shaper pulse peak is at the tail end of the diffusion Gaussian does not have useful information to measure time.**

Some criteria to measure time from the amplifier pulse

- No. of electrons collected by a 7 mm pad ≈ 70 (*average & not N_{eff}*).
- T2K gas at 230 V/cm; V_{drift}≈ 76 μm/ns; D_{Long}≈ 226μm/√cm ≈ 3 ns/√cm.
  - σ_L ≈ 22 ns (LP TPC for 55 cm drift length)
  - It will take 88 ns (±2σ) for the pad to collect 95% of 70 electrons
  - 180 ns to collect 95% of the electron signal for the 225 cm drift ILD TPC
- The peak amplitude of the amplifier pulse is a measure of total collected pad charge, *provided the shaping time is long enough to integrate all electrons arriving at the pad.*
- The position of peak in time does not have useful timing information due to fluctuations in the arrival time of the last of ~70 electrons at the tail end of longitudinal diffusion Gaussian.
- The shape and the width of the amplifier pulse after the peak is largely determined by the settings of electronics, and for the Micromegas readout, by the charge dispersion process.

How to measure time from the amplifier pulse

- To measure time, one needs to know the position corresponding to the charge pulse error function inflexion point on the rising edge of the shaper amplifier pulse.
- Not obvious where that is due to complicated pulse processing.
- Possible options:
    - Fit a Gaussian or the amplifier response function to the rising edge of the amplifier pulse starting from the baseline and including one or two time bins beyond. Inclusion of additional points past the peak in the fit could distort time measurement.
    - Use half amplitude point, or the inflexion point of the fitted pulse to measure time.
    - Other ideas??
- Since the shape of the amplifier pulse after the peak is largely determined by electronics & for Micromegas charge dispersion, use of time estimators such as weighted mean, Gaussian mean of the entire pulse, the box method, etc. is not recommended.