# TDC-based readout electronics for a GEM TPC

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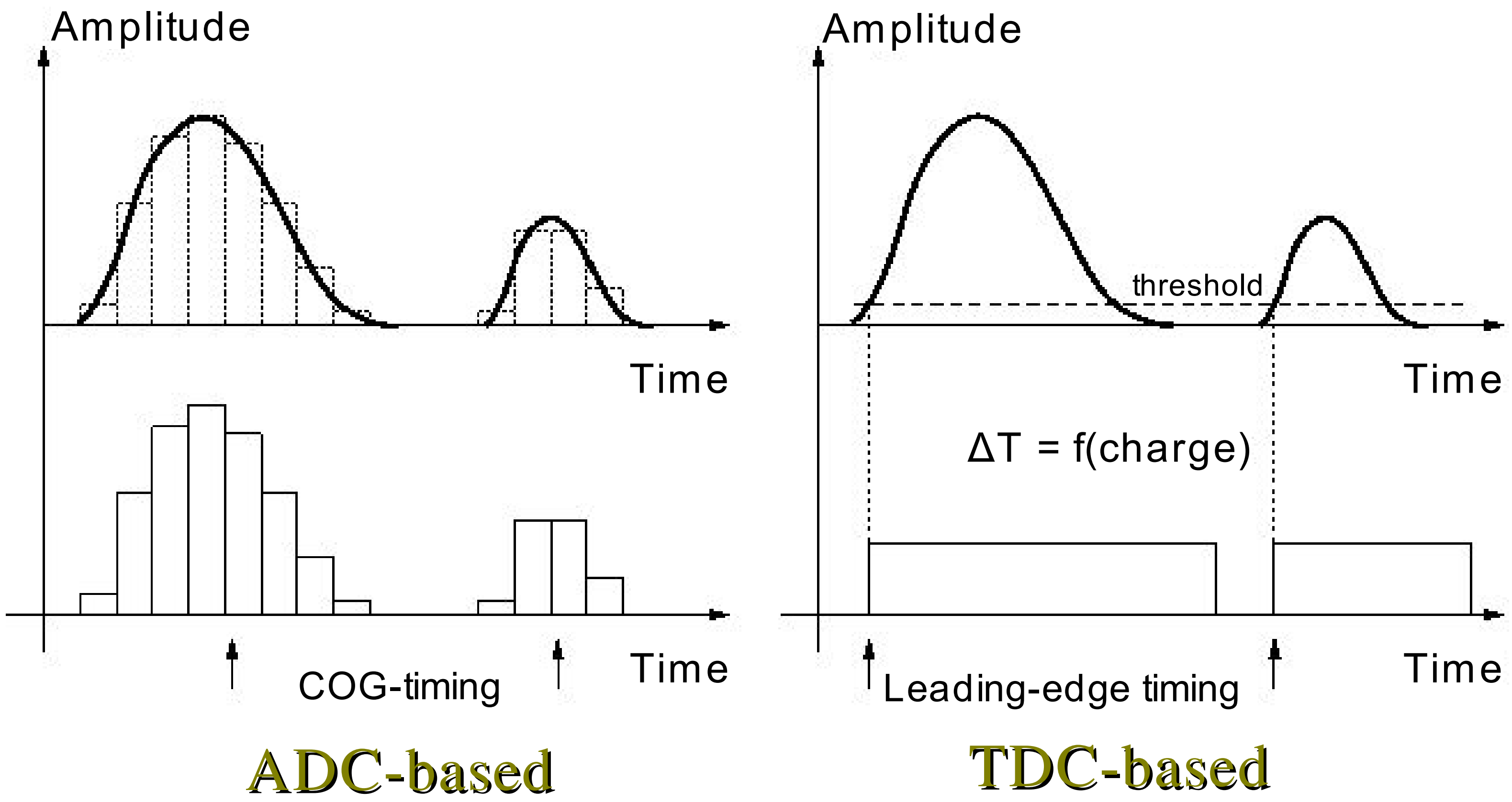
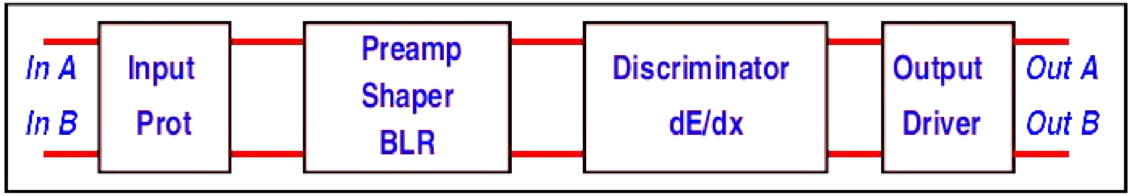
# TDC-based readout electronics for a GEM TPC



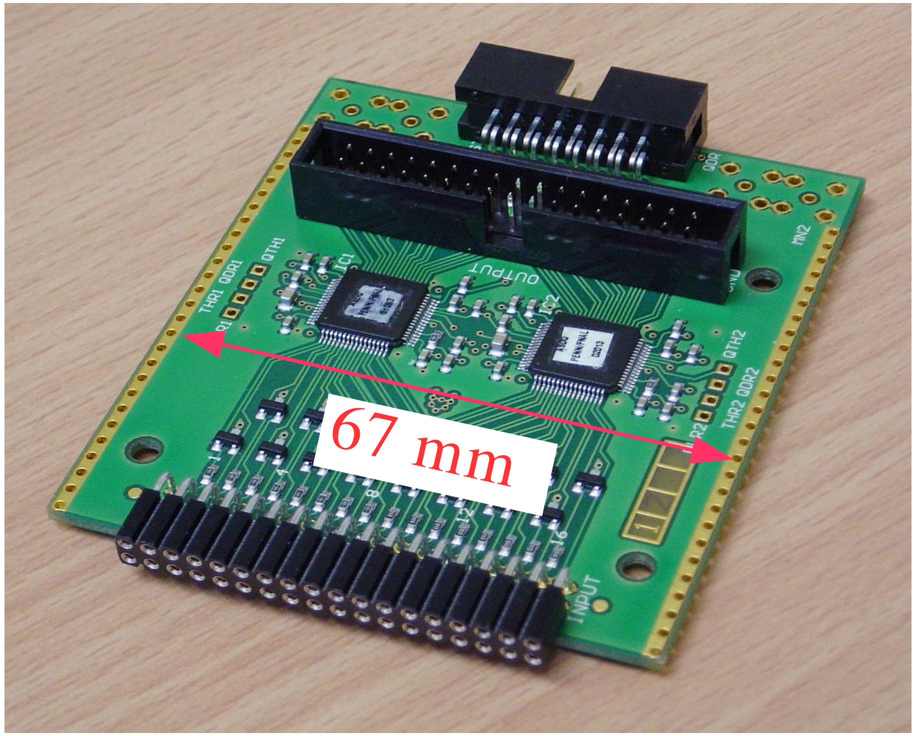

- The time of arrival is derived using the leading edge discriminator.
- The charge of the input signal is encoded into the width of output digital pulse.

# ASDQ ASIC

**ASDQ**: **A**mplifier – **S**haper - **D**iscriminator - **Q**(charge measurement)




Time-to-Digit Converter (TDC)




“*First version*” 16 channel ASDQ board:
preamplifier
and charge-to-time converter

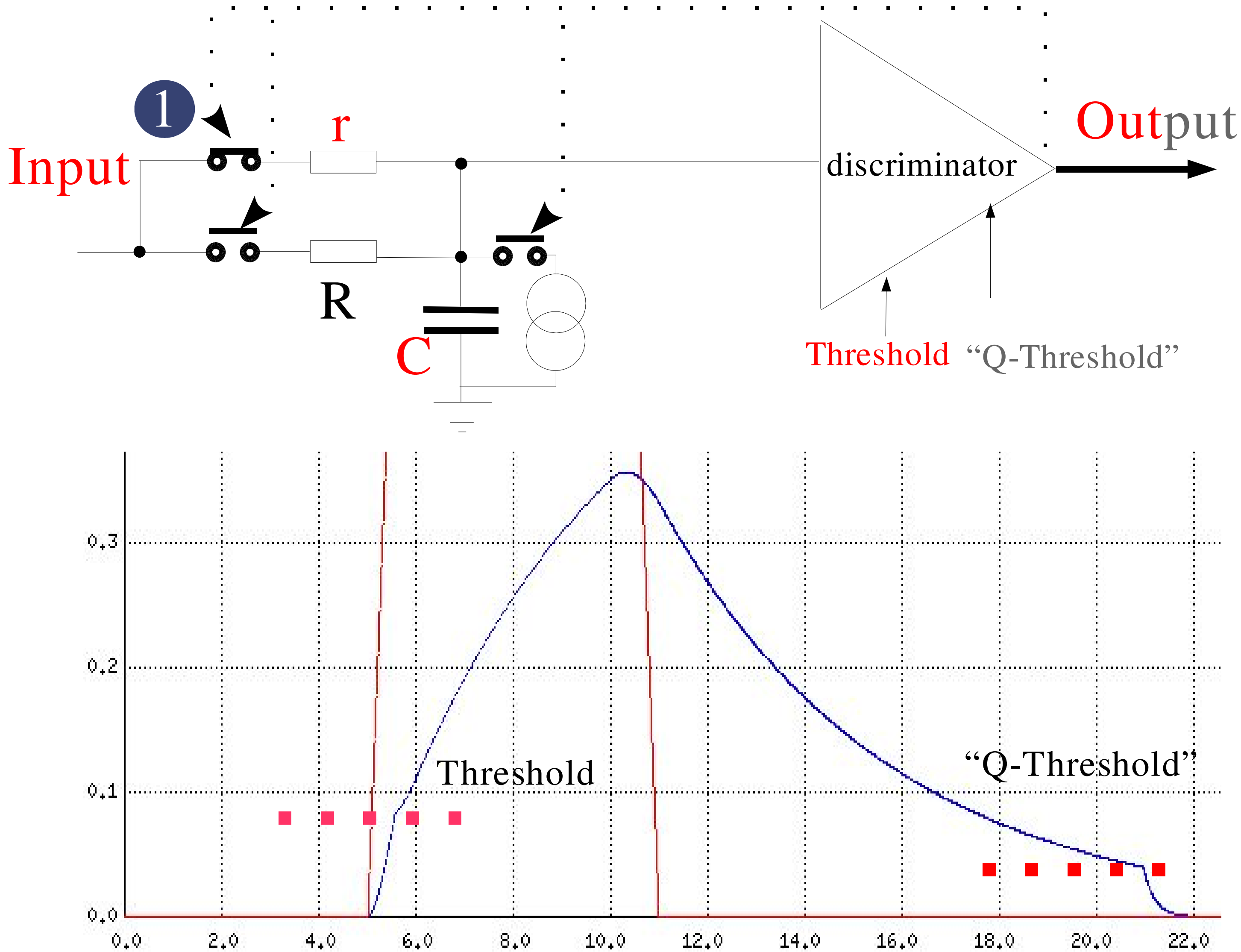
Switching technique of the charge measurement :
Run-down ADC (Wilkinson-ADC)

+

CAEN TDC (VME, model v767)
0.8 ns time bin
0.8 us time measurement range

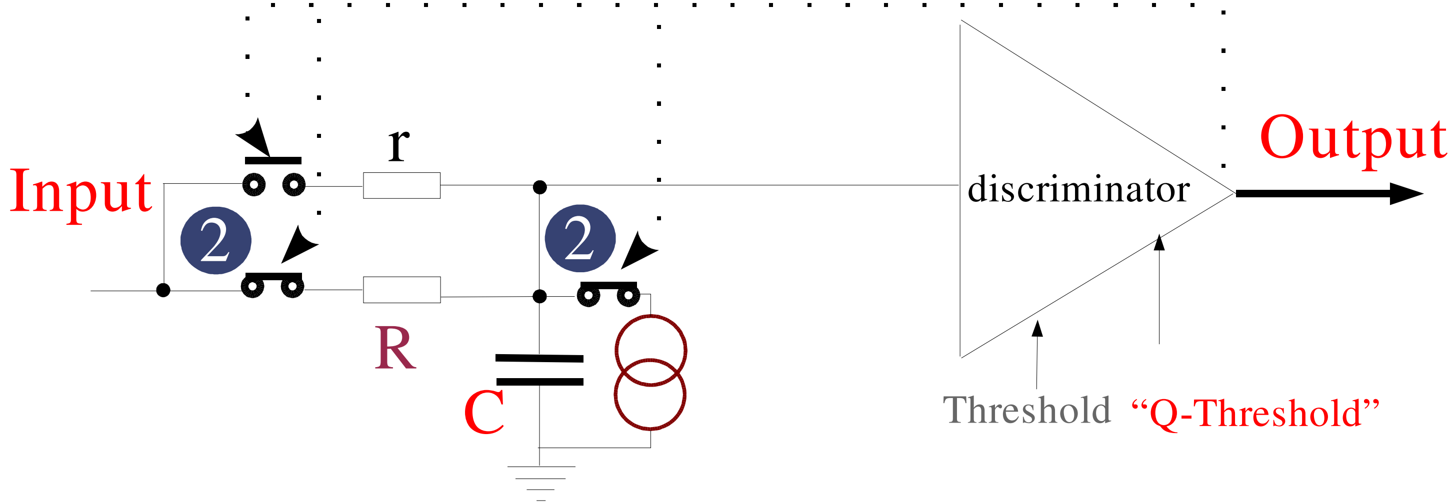
First tests: 128 channels

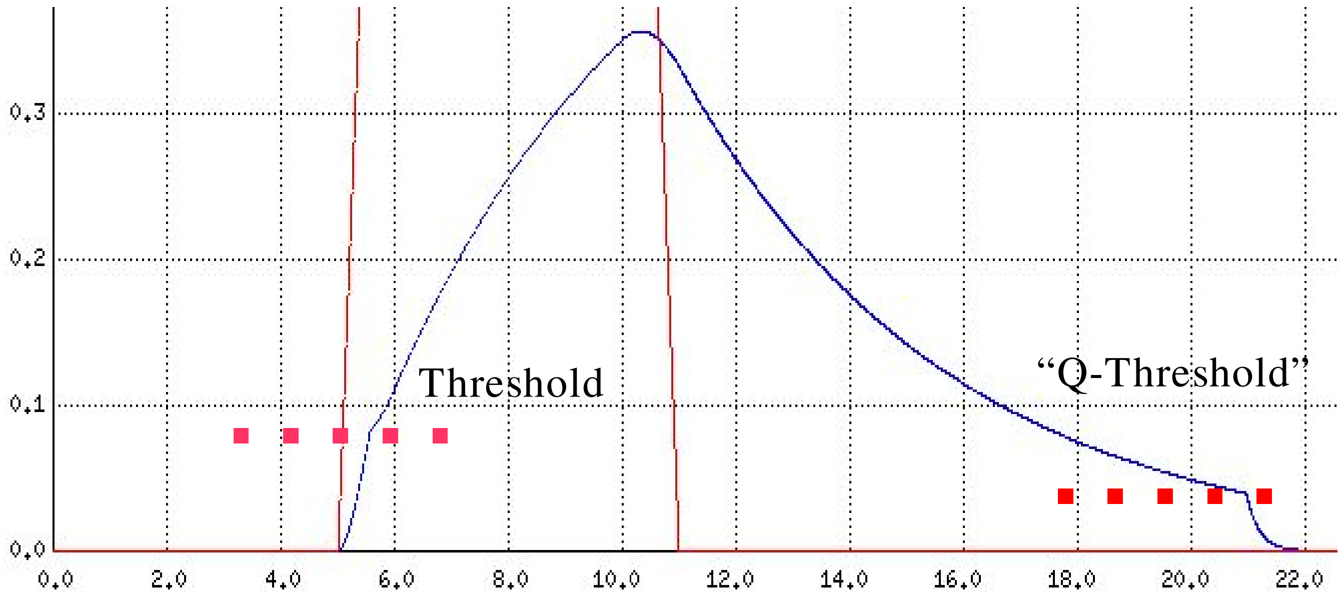
# Charge-to-Time Conversion with ASDQ: I




1 *Short integration time for signals below "leading threshold": rC (8 ns)*

# Charge-to-Time Conversion with ASDQ: II

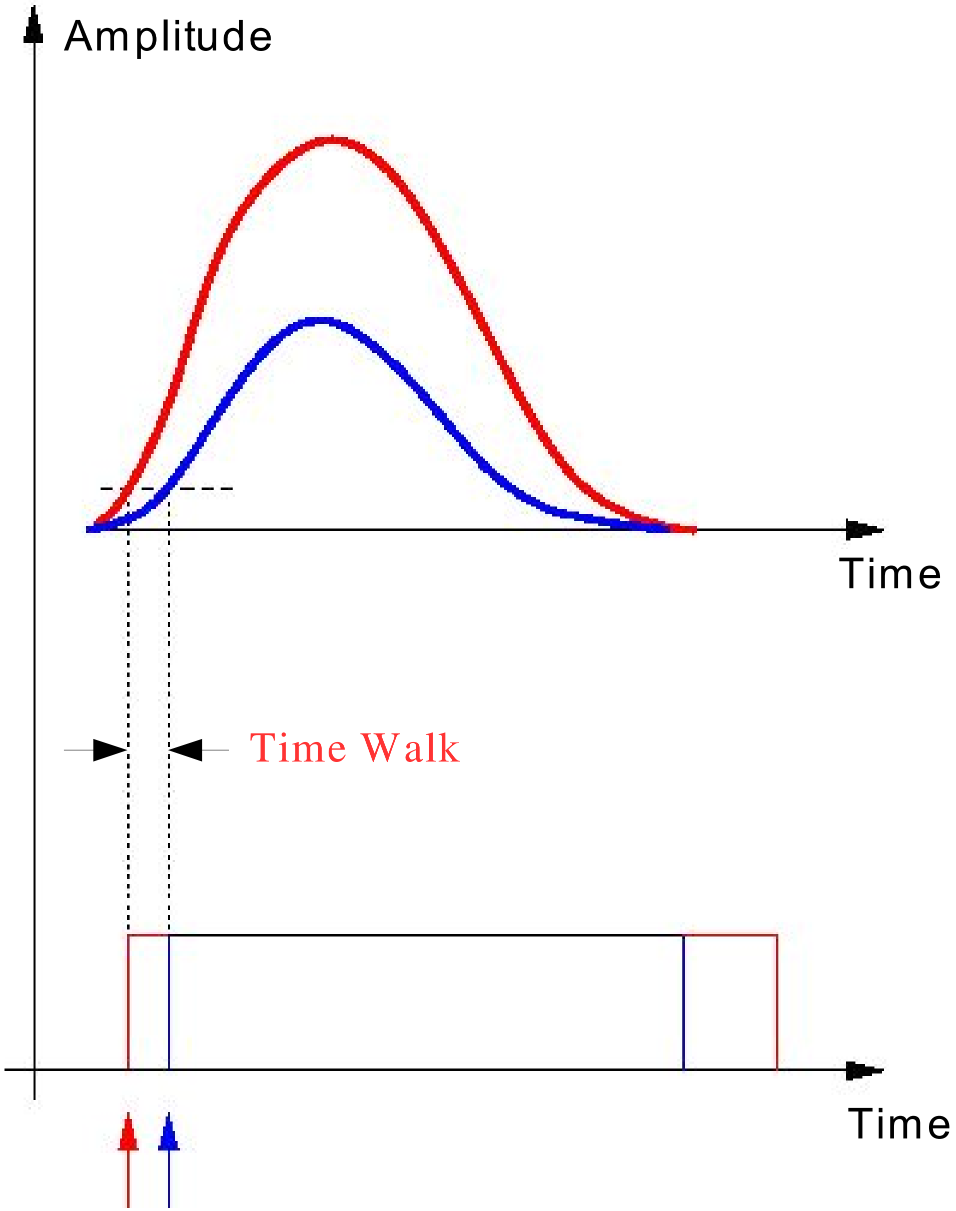



2 *Once signal over threshold detected, switch to longer integration time: RC* *(28 ns)*

*Discriminator remains “ON”, until signal falls below “trailing threshold” (“Q-Threshold”)*

# Discriminator Time Walk

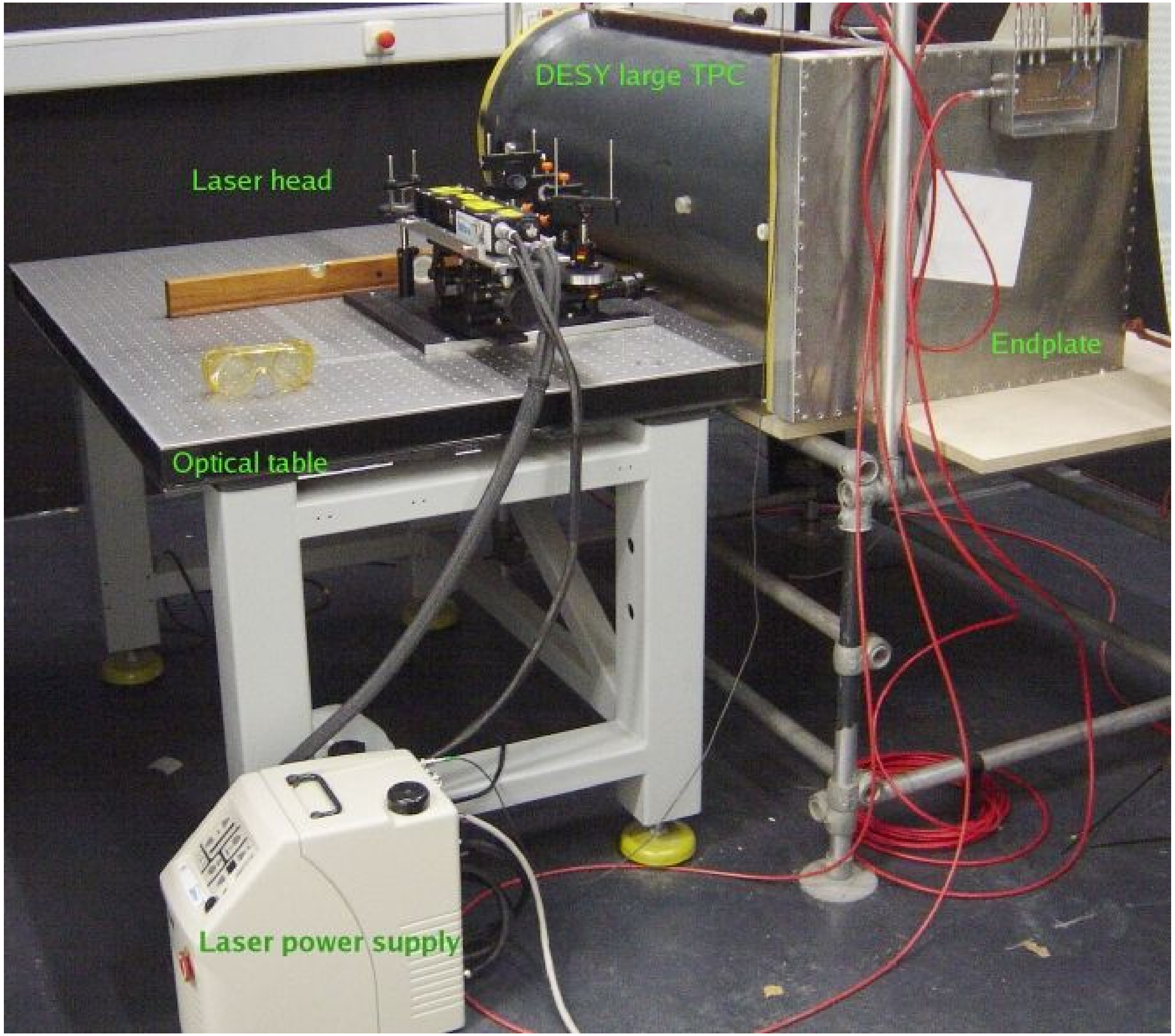



Signal with larger amplitude arrives earlier than the one with smaller amplitude.

One can use second threshold level, in order to measure rise time of the signal and correct for time walk.

There is a correlation between time walk and the measured charge.

# Proof-of-Principle Experiments with GEM TPC at DESY




Large (old) TPC:

100 cm drift path,
38 cm diameter

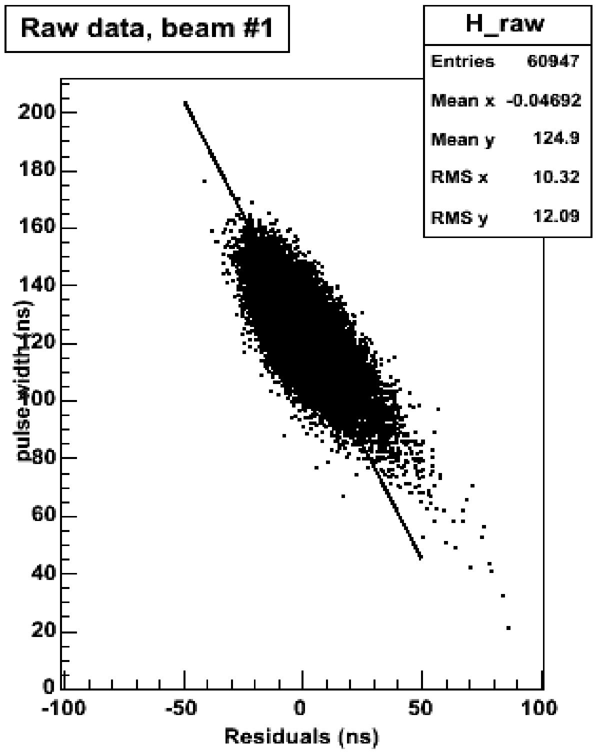
$Ar:CO_2:CH_4$ (93:2:5) %

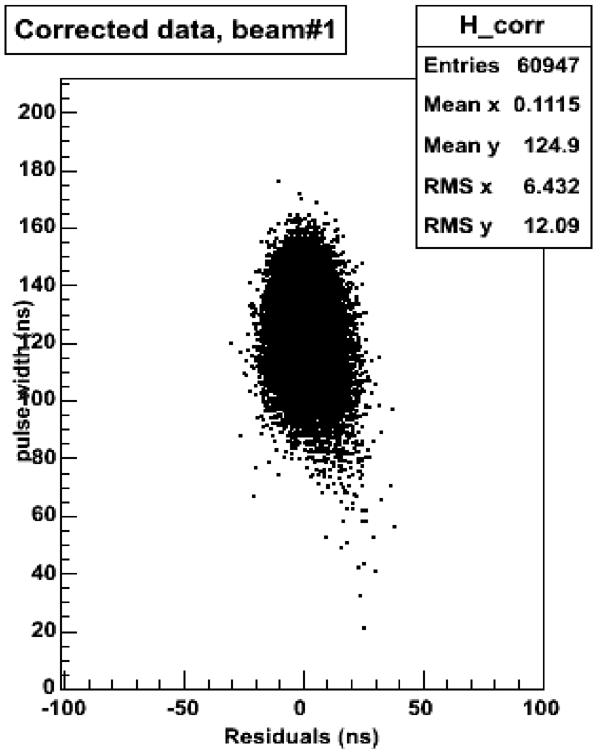
Double GEM (~ 400 V each)

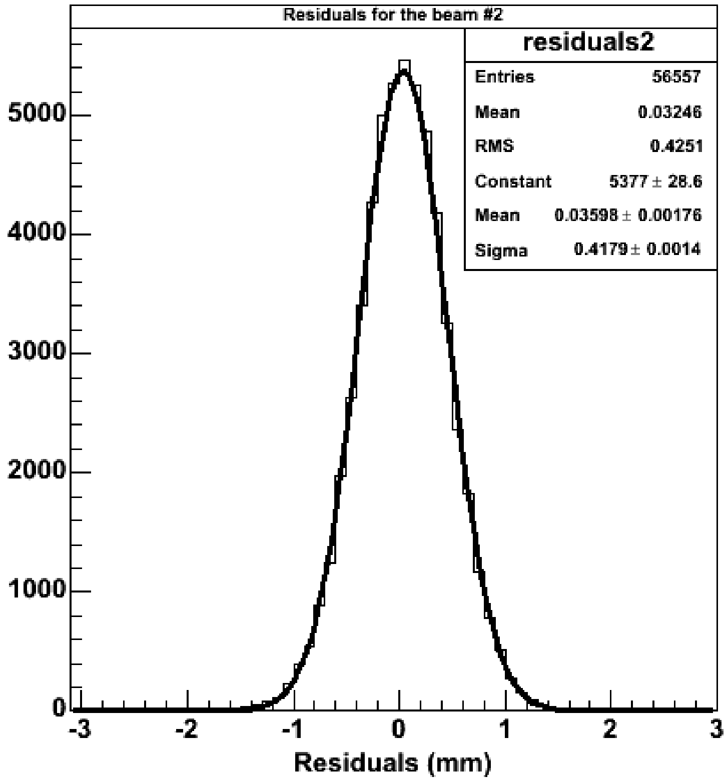
Pads: 7*7mm$^2$

Three UV-transparent windows:
$Z_i$ = 5.5; 30.5; 90.5 cm

# Time Walk corrections (laser induced tracks)



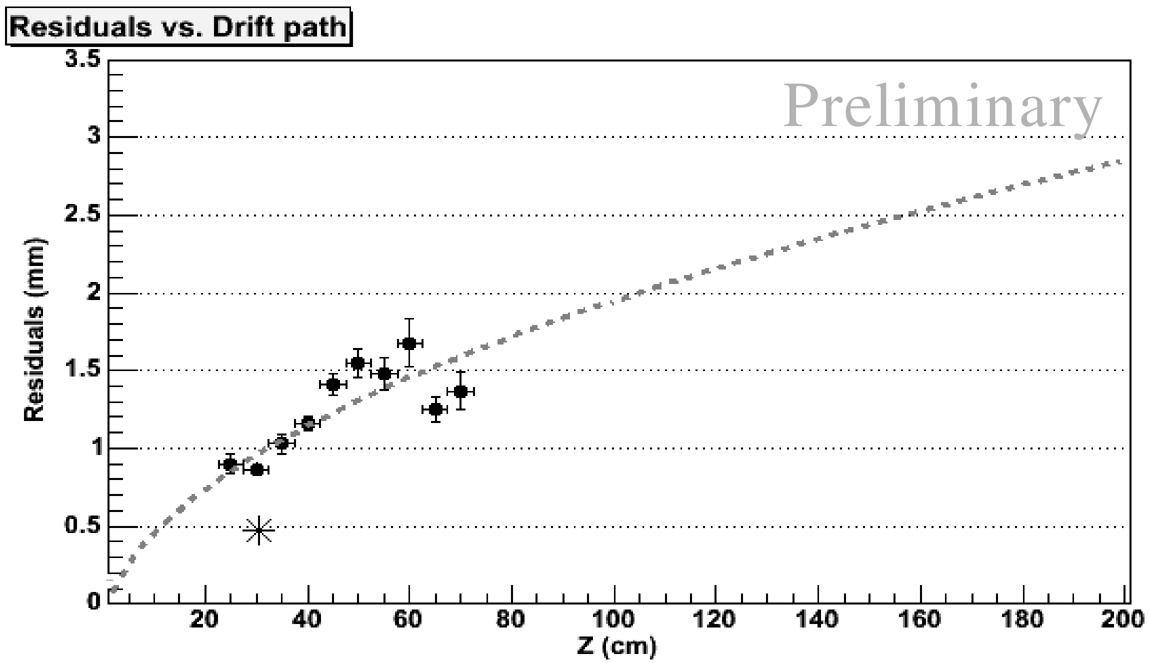

$$T_{corrected} = T_{raw} - C*Q$$

Resolution in Z:

$\sigma_z$=0.4 mm (@ Z=30cm)

# Time Walk corrections (cosmics particles)

Residuals for tracks from cosmic particles




Limited statistics of the data sample.

Low efficiency with double GEM setup (~ 1000 gas gain).

Time Walk correction have been applied.

Signal sampling with ADC can do better - ALEPH TPC: 1mm @ 200 cm

Higher efficiency can be reached with higher gas gain ($\sim 10^4$), if triple GEM setup is used, for example with Large Prototype TPC (EUDET).

## The goal is to provide several hundred channels of compact readout electronics.

- Unified interface to the endplate of the LP TPC.
  Allows concurrent or simultaneous data taking with TDC-based or ADC-based(ALTRO) readout electronics (University of Lund).

- Larger number of channels allows larger tracking area of the LP TPC endplate.
  a) Study of the tracking performance with multi-GEM modules.
  b) Calibration issues.
  c) dE/dx capability.
  d) ...even more exotic topics

- Data in LCIO format.
  TPC data analysis “regardless” of the data source: TDC or ADC.

# ASDQs and HPTDCs

Compact readout electronics can be built,
if one places ASDQs and HPTDC on the same board.


photo by B.Warmbein

200 ASDQ ASICs have been purchased.
Up to 1600 readout channels will be available.

5 HPTDC samples are available
(Thank J. Christiansen, CERN).

# An evaluation board (prototype "0")

The baseline design will use commercial TDC from CAEN (VME v1190A )

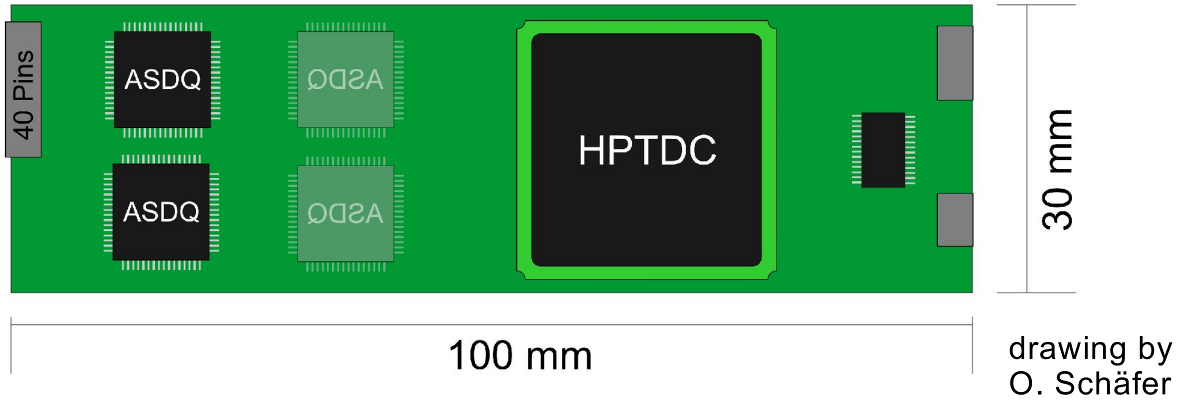
To study the feasibility of the operation of the sensitive analogue (ASDQ) and the digital (TDC ) components on the same board,
an *evaluation board* will be designed.

For standalone test of the readout electronics a simple mini-TPC detector (triple-GEM chamber) is being designed.

Main features of the chamber:

- Triple GEM (gas gain ≥ $10^4$)
- No field cage: only short drift path (up to few cm)
- Interchangeable endplates:
  - for the "first version" of the readout electronics and
  - for the evaluation board/Final design.

# Front End Card (FEC)/"Final design"




The Front End Card is (still) based on existing components:

- Four 8-channel ASDQ ASIC (UPenn/FNAL)
- 32-channel general purpose HPTDC (CERN)

The input connector: WR-40P-HF-HD (proposed by L. Jönsson, Lund)

The design of the FEC is (almost) the same as the design of the evaluation board.

Small footprint of the board allows TPC pads as small as 1x4 $mm^2$.

No clear mechanical interface to the LP TPC endplate exists *(yet)*.

# TDC data readout

Advantage of the TDC-based readout electronics: low output data rate.

A single TPC hit is encoded into 32-bit word:
Header & TDC ID (8 bit)
Channel ID (5 bit) + *Width* (7 bit) + *Leading time* (12 bit)

+ Event header & trailer (2 words per event)

HPTDC offers parallel (word & byte-wise) readout and serial readout.
Serial readout with programmable speed up to 80 MHz clock rate.

Independent data readout from every TDC.

- Simple FEC design. No token ring - no interconnections between FECs.
- Increases number of required LVDS links/cables from the TPC.

# Power consumption of the FEC

An estimated power consumption of a single FEC is 2 W.

4 ASDQ ASICs, 40mW/channel: *1.28 W*
HPTDC (typical power consumption): 0.65 W

TDC-based readout electronics: ~ 60 mW/channel.
The power consumption is similar to the ALICE TPC readout boards: ~54mW/channel.

Area occupied by 1600 readout channels (assuming 1x4 $mm^2$ pads) would have size of ~100 x 64 $mm^2$. Power dissipation: ~**100 W**.

It is relatively easy to implement air cooling, but it is not that effective as the water cooling, which is used for the ALICE TPC readout electronics.

The effect of the thermal influence of the FEC on the LP TPC performance shall be studied.

S.Popescu et al., "Thermal Influences of the Front-End Electronics on the Alice TPC Readout Chamber",
IEEE Trans. Nucl. Sci. 52 (2005) 2879.

# Summary & Outlook

The study of the TDC-based readout electronics for a GEM TPC is ongoing.

Readout electronics with larger number of channels (compared to smaller TPC readout systems) will be assembled for LP TPC.
The Front End Card is *still* based on existing components.

The performance of the TDC-based readout electronics can (to some limit) approach the performance of the signal sampling methods.

ASDQ parameters needs to be optimized:

- Longer shaping time ~ 50 ns
  - fits better to GEM signal
  - better signal-to-noise ratio

- No need for tail-cancellation circuit (needed for wire chambers).

- Low power consumption with newer CMOS technologies

New parameter set for the "upgraded ASDQ" is being discussed with developer (UPenn).