Development of Micromegas Detectors with Novel Floating Strip Anode

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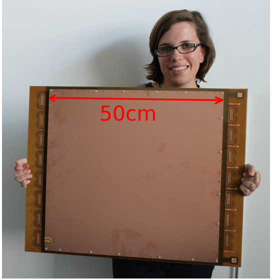
Motivation

- large area Micromegas based muon detector $\mathcal{O}\left(\mathrm{m}^2\right)$
- high spatial resolution $\leftrightarrow$ small strip pitch
- robust and very little aging $\leftrightarrow$ avoid non-metal materials inside active volume as much as possible
- high efficiency $\leftrightarrow$ discharges should have negligible influence on performance
- possible application: spatially resolving X-ray detector
- build detectors in Munich

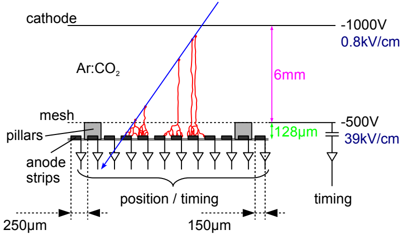
$\rightarrow$ novel concept: Floating Strip Micromegas



Outline

1. Introduction
   - Standard, resistive & floating strip Micromegas
   - $50 \times 48\,\mathrm{cm}^2$ Floating Strip Micromegas
2. Pion Testbeam Setup at H6
   - Testbeam Setup
   - Readout Electronics
3. Performance of $50 \times 48\,\mathrm{cm}^2$ Micromegas
4. Floating Strip Principle
   - $6.4 \times 6.4\,\mathrm{cm}^2$ Floating Strip Micromegas
   - LTSpice Simulation
   - Voltage Drop Measurement with $6.4 \times 6.4\,\mathrm{cm}^2$ Micromegas
5. Summary

Up to now: Standard Micromegas



- ionization in 6 mm drift gap, 0.5 kV/cm
- gas amplification in 128 µm amplification gap, 39 kV/cm, gas gain 10^3 to 10^4
- signal detection on strips (150 µm width and 250 µm pitch) → spatial resolution (35µm)/ timing (ns)
- gas: Ar:CO_2 93:7 @ NTP

PRO

- well tested
- relatively easy to produce
- metal strips → no aging expected, no charge up

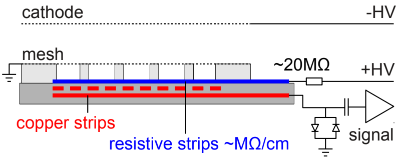
CON

discharges:

- induced by strongly ionizing particles ($> 10^7$ e in avalanche)
- complete discharge of mesh → large voltage drop on whole detector
- large detector capacitance (nF) → long recharge time

→ considerable deadtime and efficiency drop

Solution 1: Resistive Strip Micromegas



- resistive strips: carbon loaded epoxy, R∼MΩ/cm
- capacitively coupled copper readout strips, same pitch and width
- discharges: only local charge up, very fast suppression

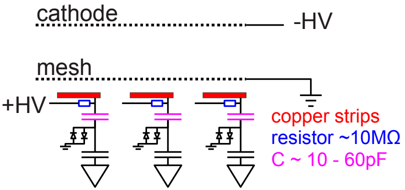
PRO

- well tested
- very efficient discharge suppression even in high-rate γ- & neutron-background ($\Phi_n \sim 10^7$ Hz/cm^2)

CON

- more complicated production
- might be more prone to ageing (although we don't observe that yet)
- spatial gas gain variation
- temporal gas gain variation $\rightarrow$ influence on spatial resolution?

Solution 2: Floating Strip Micromegas



"floating" copper strips:

- individually connected to HV via 10MΩ
- capacitively coupled to readout electronics via pF HV capacitor
- discharges: only two or three strips charge up

proposed by: A. Bay, I. Giomataris et al., Nucl.Instrum.Meth. A488:162-174, 2002

PRO

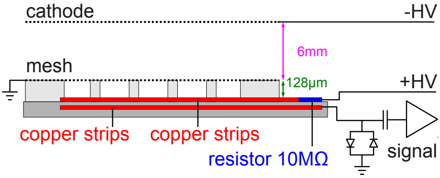
- relatively easy to produce
- no rate dependant charge up
- metal strips → less aging expected
- discharges: small capacitance $C_{\mathrm{FS}} \sim C_{\mathrm{std}} \times 0.01$ ($\tau = RC$)
- discharges: only one or two strips affected, 1/#strips efficiency decrease

→ low deadtime and efficiency drop

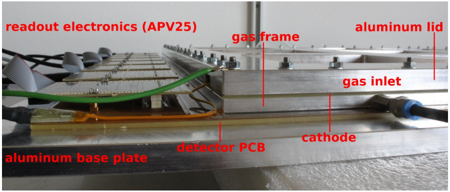
CON

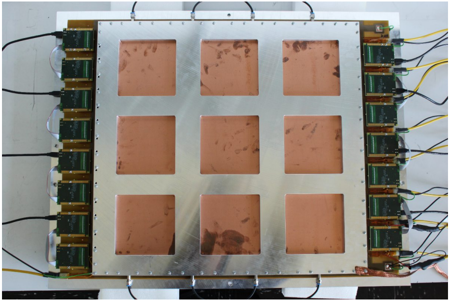
- discharge suppression not as effective as in resistive strip Micromegas
- 2-dim. readout questionable

$50 \times 48\,\text{cm}^2$ Floating Strip Micromegas

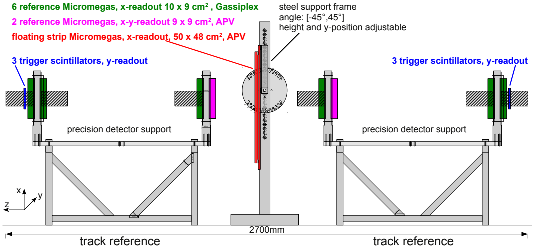


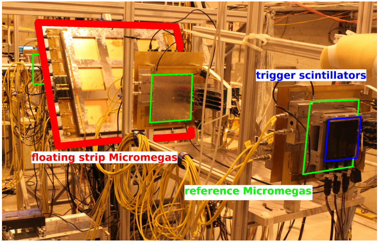
- bulk Micromegas with 128 µm amplification gap and 6 mm drift region
- $50 \times 48\,\text{cm}^2$ active area, 1920 copper strips, 150 µm width, 250 µm pitch
- integrated floating strip solution: ∼50 pF coupling capacitance & 10 MΩ recharge resistor
- gas: Ar:CO_2 93:7 @ 1013mbar





$50 \times 48\,\mathrm{cm}^2$ Micromegas in 120 GeV Pion Beam @ H6 SPS



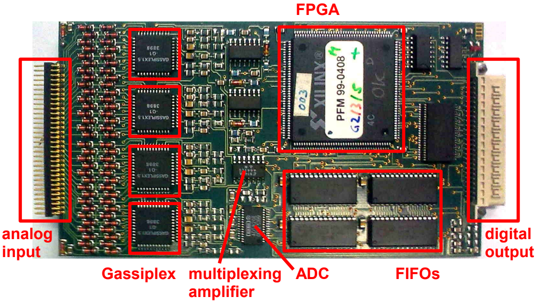


floating strip Micromegas
x-y- and angular scans
Scalable Readout System

tracking system:

- six non resistive Micromegas
  active area $10 \times 9\,\mathrm{cm}^2$, 360 strips
  Gassiplex readout (VME)
- two resistive Micromegas
  active area $9 \times 9\,\mathrm{cm}^2$, 2d readout anode, 2×358 strips
  Scalable Readout System
- 2×3 trigger scintillators
  TDC readout (VME)

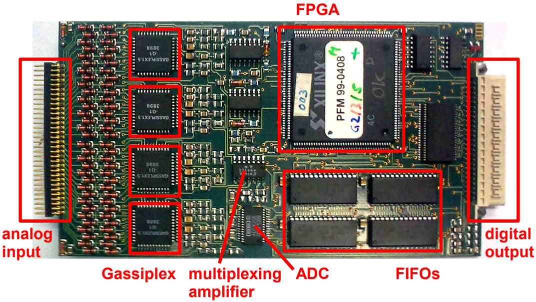
Gassiplex Readout Electronics



frontend boards:

- 4×16 channels, charge sensitive Gassiplex chips
- A/D conversion $\rightarrow$ 1 ADC value per channel and trigger = pulse height
- digital baseline suppression

Gassiplex Readout Electronics



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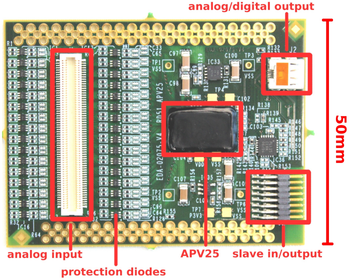
backend:

- RIO2: VME embedded PowerPC
  - readout control
  - data transfer
- two 16 channel VME TDCs: get scintillator hits & trigger number (→ later)

DAQ computer:

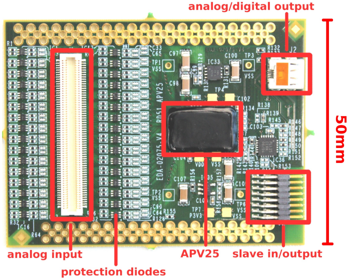
- ssh interface to RIO2
- data storage
- slow control (HV, flux, pressure)

Scalable Readout System



- **16 APV25 frontend boards:**
  - 128 channels, charge sensitive, pipelined APV chip
  - 3 to 21 charge values with 25 ns spacing per channel and trigger
  - 8 master: direct communication with digitizer
  - 8 slave: communication via master

Scalable Readout System



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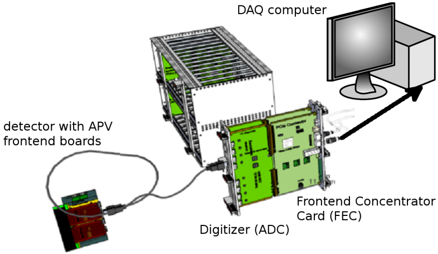
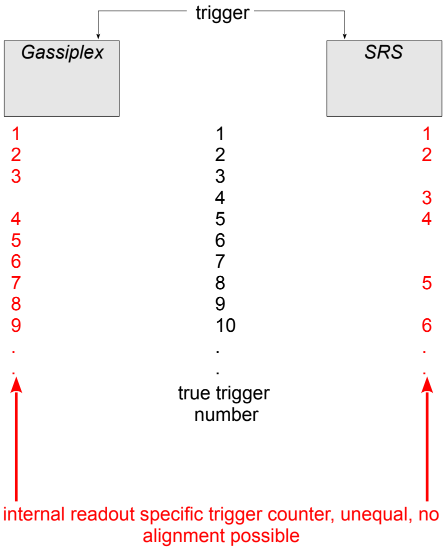


- **40 MHz digitizer:** parallel digitization of 8 master/slave pairs
- **Frontend Converter Card:** sequence control, Gigabit Ethernet link to DAQ computer

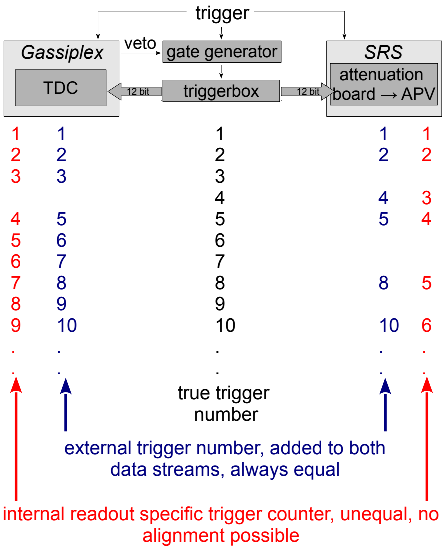
Synchronization of Data Streams



challenge: how to align two data streams?

- triggered by same scintillator trigger
- both systems (especially SRS) miss triggers

Synchronization of Data Streams



challenge: how to align two data streams?

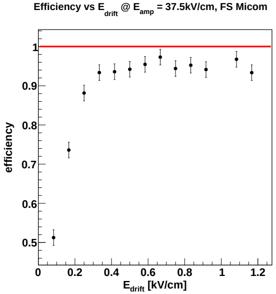
- triggered by same scintillator trigger
- both systems (especially SRS) miss triggers

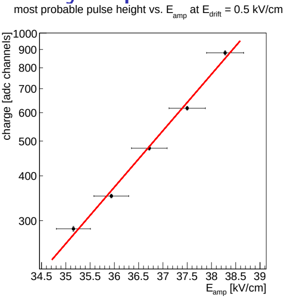
solution: add the true trigger number to each data stream

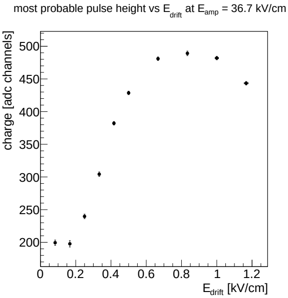
- triggerbox = 12 bit scaler, counts triggers, output: trigger number as 12 bit NIM signal
- Gassiplex system: VME based, use additional 16 channel TDC to record trigger number
- SRS: attenuate NIM signals, record with an APV frontend board

→ offline synchronization possible

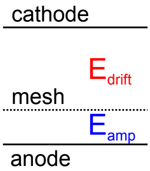
Pulse Height & Efficiency Optimization







efficiency vs. E_{drift}
optimum value: 97%, limited by mesh supporting pillars



pulse height vs. E_{amp}

- exponential rise as expected
- gas gain can be selected over wide range as needed

pulse height vs. E_{drift}

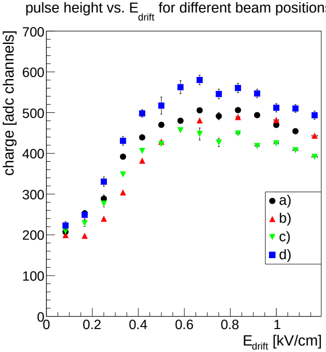
small E_{drift}:

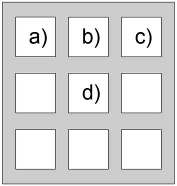
- low charge seperation
- attachement

large E_{drift}:

- low electron mesh transparency

Homogenity





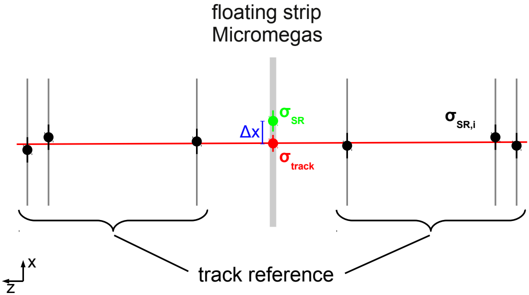
measure signal response at four different detector positions
compare pulse height vs. E_{drift}
at $E_{\mathrm{amp}} = 36.7\,\mathrm{kV/cm}$

- difference of max(charge(E_{drift})) between datasets
  $\rightarrow$ variation of gas gain
- shift of datasets
  $\rightarrow$ variation of drift gap

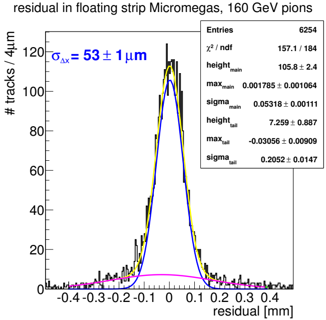
no shift visible
charge variation $\sim$ 15%
$\rightarrow$ gas amplification and ionization homogeneous for large area detector

Spatial Resolution

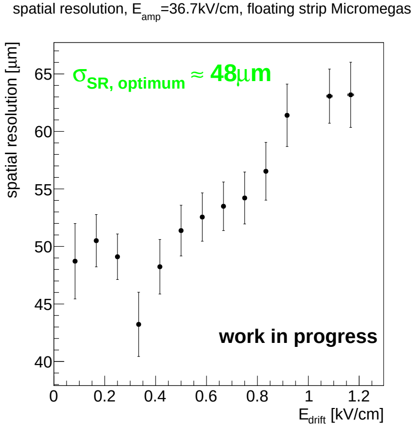
- $\Delta x = x_{\mathrm{track}} - x_{\mathrm{meas}}$
- doing this for many tracks $\rightarrow$ distribution
- $\sigma_{\mathrm{SR}} = \sqrt{\sigma_{\Delta x}{}^2 - \sigma_{\mathrm{track}}{}^2}$



the dots refer to a single event, error bars are given by spatial and track resolution respectively



Spatial Resolution



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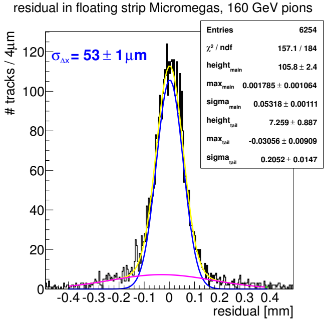
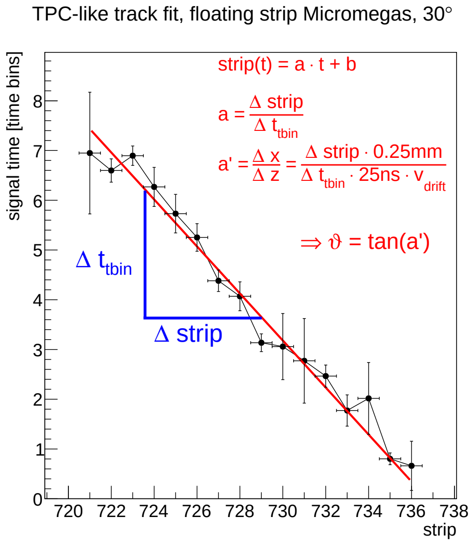
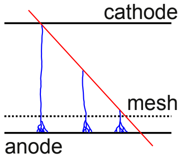


TPC-like Track Reconstruction for Inclined Tracks



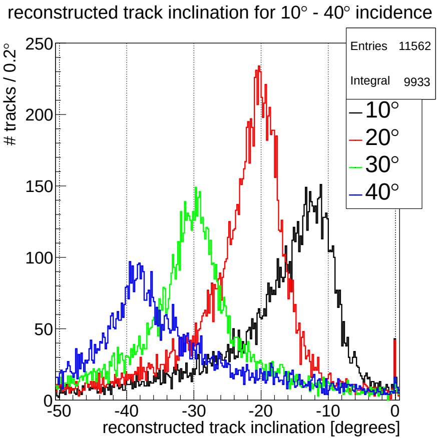


- with APV electronics: measurement of cluster arrival time
- maximum drift time in 6 mm drift region $\sim$ 180 ns

$\rightarrow$ arrival time $t \propto z$-position

$\rightarrow$ track inclination $\vartheta = \tan(\Delta x / \Delta z)$: single plane angular resolution possible

TPC-like Tracks: Reconstructed Angles



small inclination $\sim 10^\circ$:

- asymmetric distribution with higher tails towards larger angles due to δ-electrons
- reconstructed angles slightly too large

medium inclination:

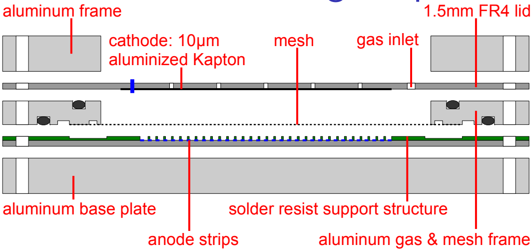
- narrower, more symmetric distribution with tails, resolution $\sigma_\vartheta \sim 5^\circ$

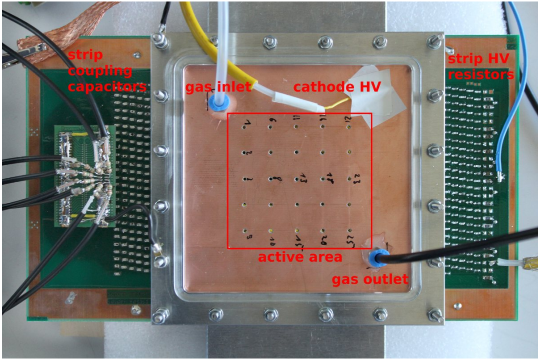
larger inclination $\sim 40^\circ$:

- asymmetric distribution with higher tails towards smaller angles due to δ-electrons
- reconstructed angles slightly too small

$\rightarrow$ **single plane angular resolution possible with resolution $\mathcal{O}(5^\circ)$**

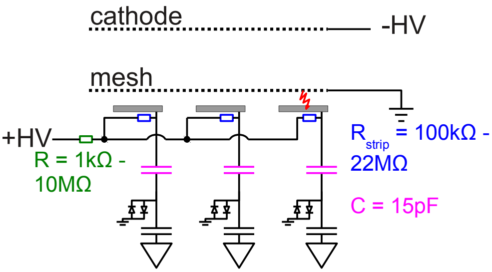
$6.4 \times 6.4\,\mathrm{cm}^2$ Floating Strip Micromegas

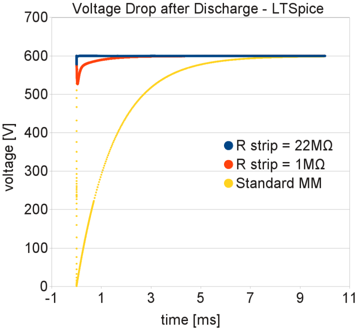




- non-bulk Micromegas with 150 µm amplification gap and 6 mm drift region
- $6.4 \times 6.4\,\mathrm{cm}^2$ active area, 128 copper strips, 300 µm width, 500 µm pitch
- discrete floating strip solution: 15 pF coupling capacitors & 10 MΩ recharge resistor, exchangeable
- mesh glued to gas frame, exchangable
- drift cathode: 10 µm aluminized Kapton → use α-source to trigger discharges

LTSpice Simulation





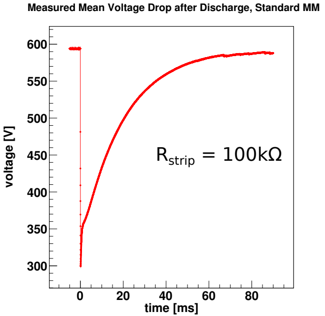
- simulate discharges from mesh onto one strip
- vary R_{strip}
- adapt recharge R such that $I_{\mathrm{recharge}} \leq 60\,\mu\mathrm{A}$

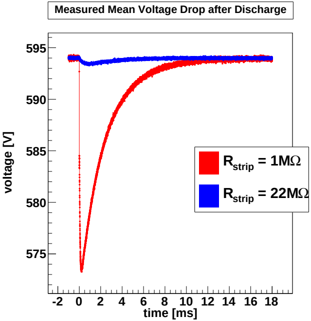
global voltage drop affects whole detector

- standard Micromegas: complete discharge of mesh possible
- Floating Strip Micromegas: massive reduction of voltage drop and recharge time

Voltage Drop Measurement in $6.4 \times 6.4\,\mathrm{cm}^2$ Micromegas

- mixed nuclide α-source: induce discharges in detector @ $\sim$1 Hz
- measure global voltage drop with high-ohmic voltage divider
- 100 kΩ strip resistor: standard MM-like
- 1 MΩ strip resistor: $\sim$25 V drop
- 22 MΩ strip resistor: $\sim$0.5 V drop → negligible





Summary

- commissioned $50 \times 48\,\text{cm}^2$ Micromegas with novel "floating strip" anode
- constructed, built and commisioned 6.4×6.4 floating strip Micromegas with exchangable capacitors and resistors
- pion test beam @ CERN:
  - synchronization of Gassiplex system (track telescope) with Scalable Readout System (floating strip Micromegas) possible and robust
  - pulse height homogeneous within 15%
  - efficiency 97%
  - spatial resolution better 50 µm - work in progress
- TPC-like track reconstruction → single plane angular resolution $\mathcal{O}(5^\circ)$ - work in progress
- LTSpice simulation of discharges in floating strip Micromegas in qualitative agreement with measurements
- optimum: global voltage drop $< 0.5\,\text{V}$

→ floating strip Micromegas is working!

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Thank you!