Development of a Floating Strip Micromegas Detector for a Clinical Proton Computed Tomography System

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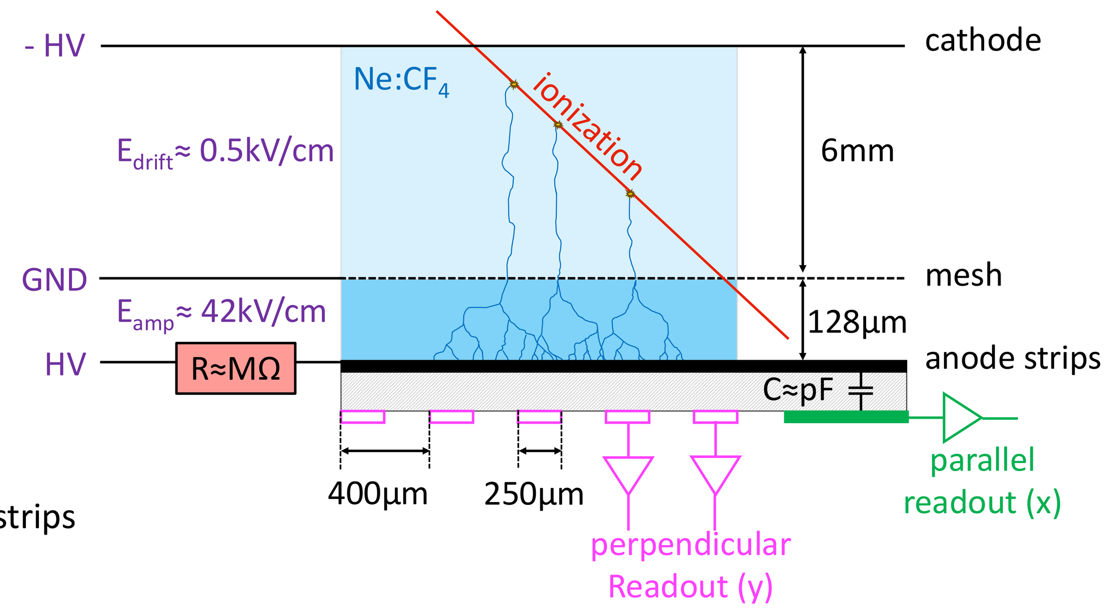
Floating Strip Micromegas

micromesh gaseous detector principle

- traversing charged particles: ionization
- drift region
  - 6mm with E_{drift}≈0.5kV/cm
  - separation of ions and e^-
- amplification region
  - 128µm with E_{amp}≈42kV/cm
  - avalanche-like gas amplification 10^3
  - timing O(ns)
- fine anode segmentation
  - pitch of 400µm
  - parallel and perpendicular readout strips
  - spatial resolution O(50µm)

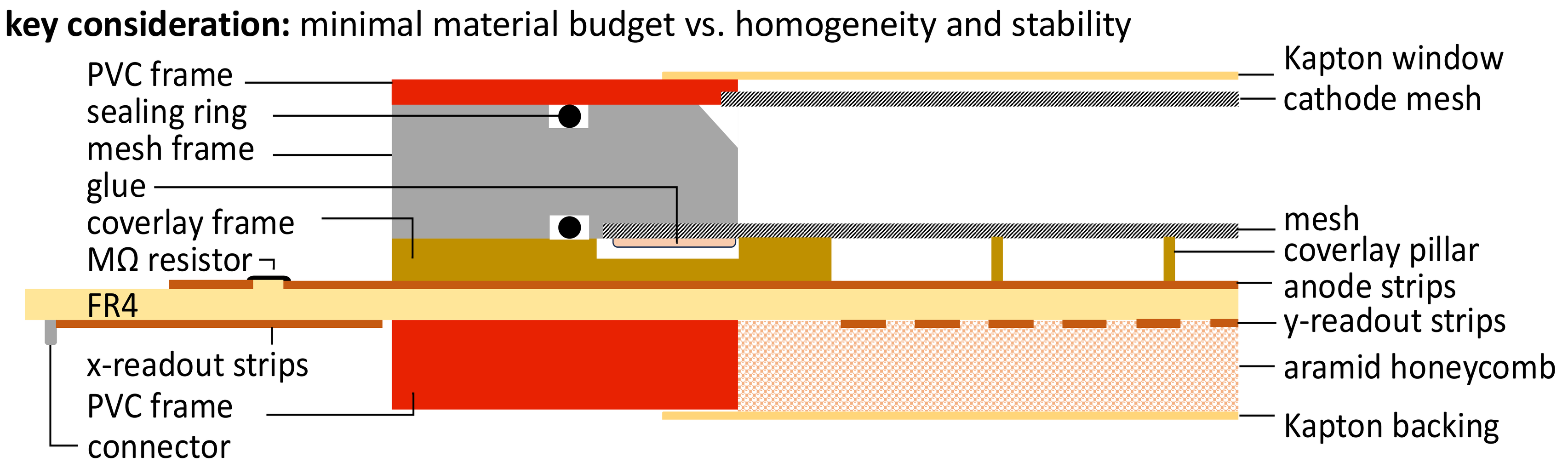


Floating Strip Micromegas principle

- copper anode strips individually connected to HV via MΩ resistors
  - in case of a discharge only local collapse of the amplification field
    → reduction of the efficiency loss and the dead time to O(1.5ms)
- parallel readout strips: capacitively coupled O(2pF)
- perpendicular readout strips: positive signal

Detector Design

key consideration: minimal material budget vs. homogeneity and stability



gas window: 10µm Kapton foil – deformation due to overpressure

cathode: 19µm wires stainless steel calendered mesh – decoupled from the deformation of the gas window
calendered ≙ pressed after weaving to reduce height at the intersections (38µm→27µm)

mesh: 19µm thick stainless steel calendered mesh glued with high tension (15N/cm) to an aluminum frame

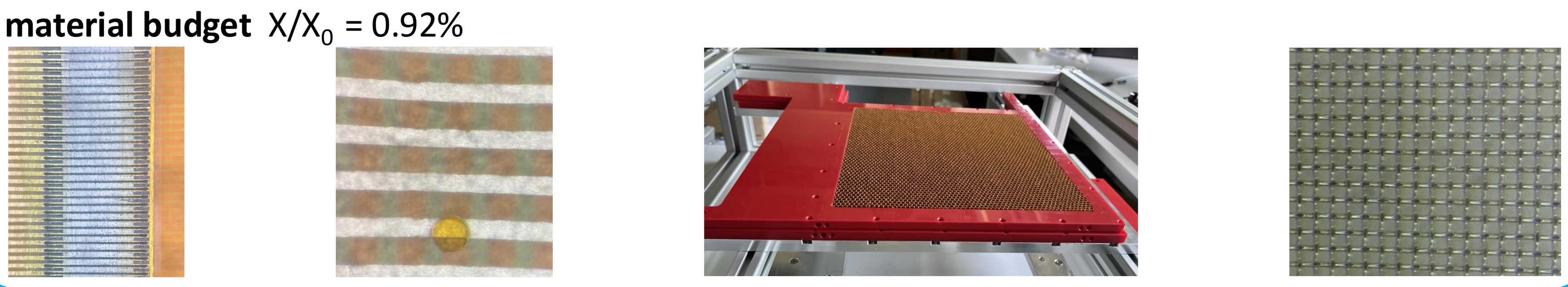
readout structure: 125µm FR4 with 35µm copper cladding
two orthogonal sets of strips with 400µm pitch
active area of 200x200mm²
covered with 128µm insulating coverlay
- structure of pillars and a frame
- defining the width of the amplification gap

support: aramid honeycomb with 50µm Kapton backing

MΩ-resistor: screen printed resistor using polymer resistive paste

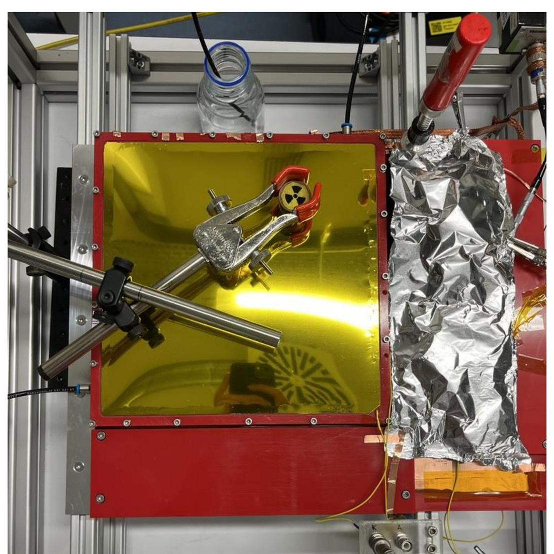
readout electronics: scalable readout system (SRS) based on the VMM3a ASIC

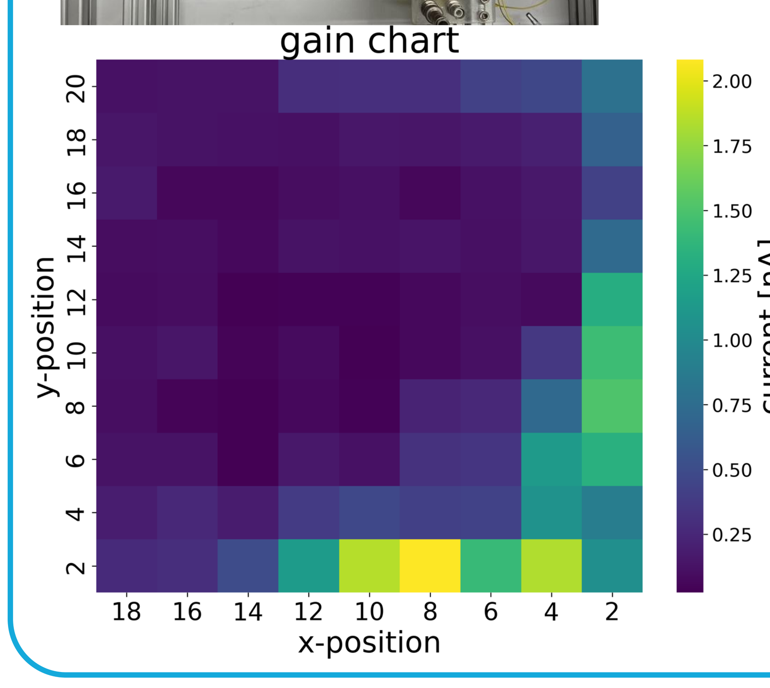
material budget X/X_0 = 0.92%

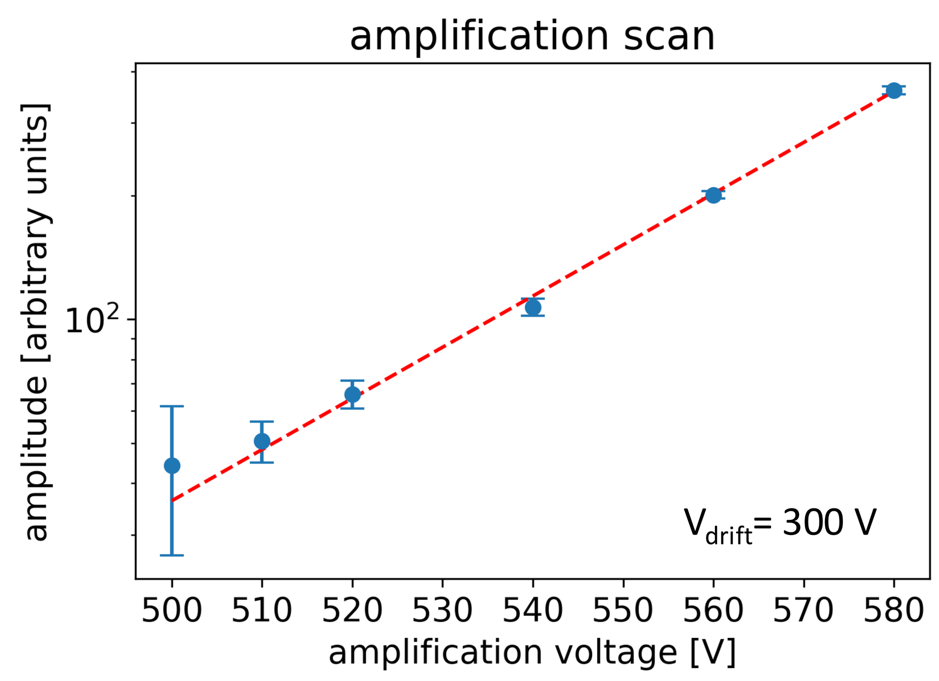


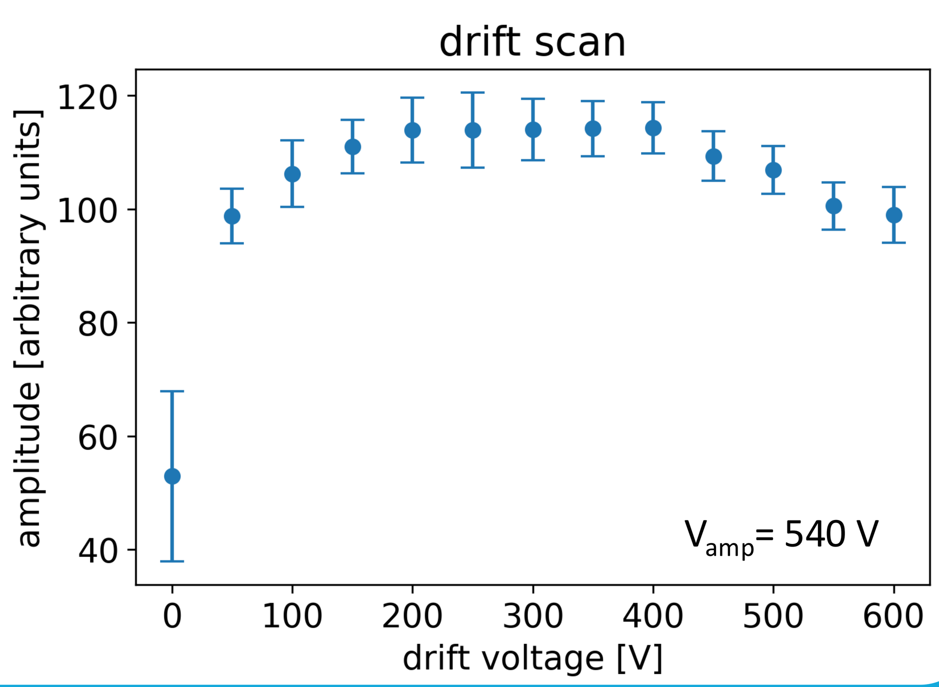
Characterizing Measurements

Fe55 source and single channel charge sensitive readout
gas mixture Ne:CF_4 80:20 vol.%









Proton Computed Tomography

proton therapy:

- Bragg peak + low lateral deflection→ good sparing of healthy tissue + high targeting precision
- treatment planning requires relative stopping power* map of the patient
  - current approach: X-ray CT (measured in HU*) → RSP:HU calibration → RSP image
    → calibration leads to range uncertainties O(3%)

RSP: relative stopping power of a material (bone, tissue) compared to water

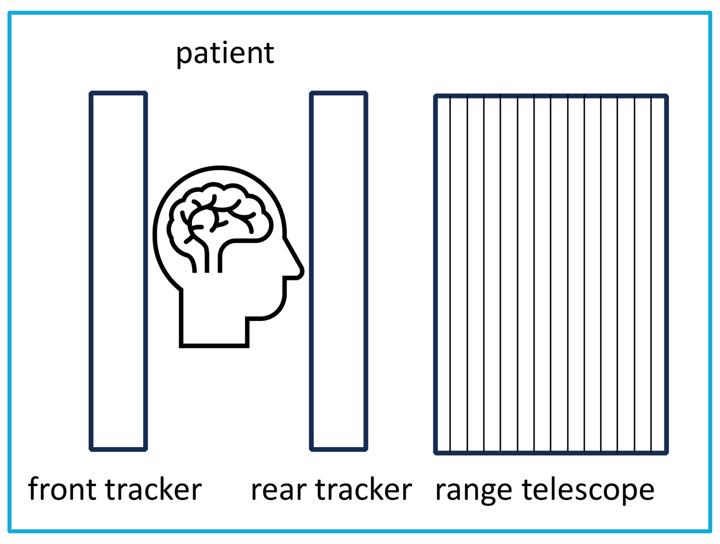
HU: Hounsfield unit = scale depending on the linear attenuation coefficient

proton imaging

- using transmitted protons for imaging directly yielding RSP
- dose reduction compared to X-ray CT up to an order of **factor of 10**
- possibility to unleash the full potential of proton radiation therapy

single particle tracking proton computed tomography

- two tracking detector stations + range telescope
- entrance and exit position and angle + residual energy



requirements for a clinical proton tomography system

- proton rates of the order of 10^6 – 10^7 protons/s
- active area of at least 300x300mm² for head scanner
- low material budget for the tracker detectors

motivation for gaseous detectors

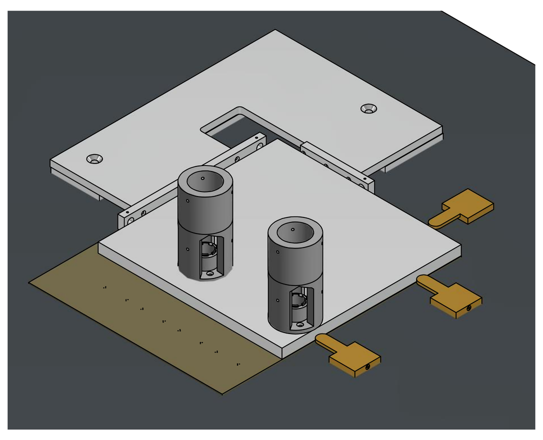
- high rate capability + excellent spatial resolution
- large dimensions feasible avoiding overlapping of individual detectors
- low material budget

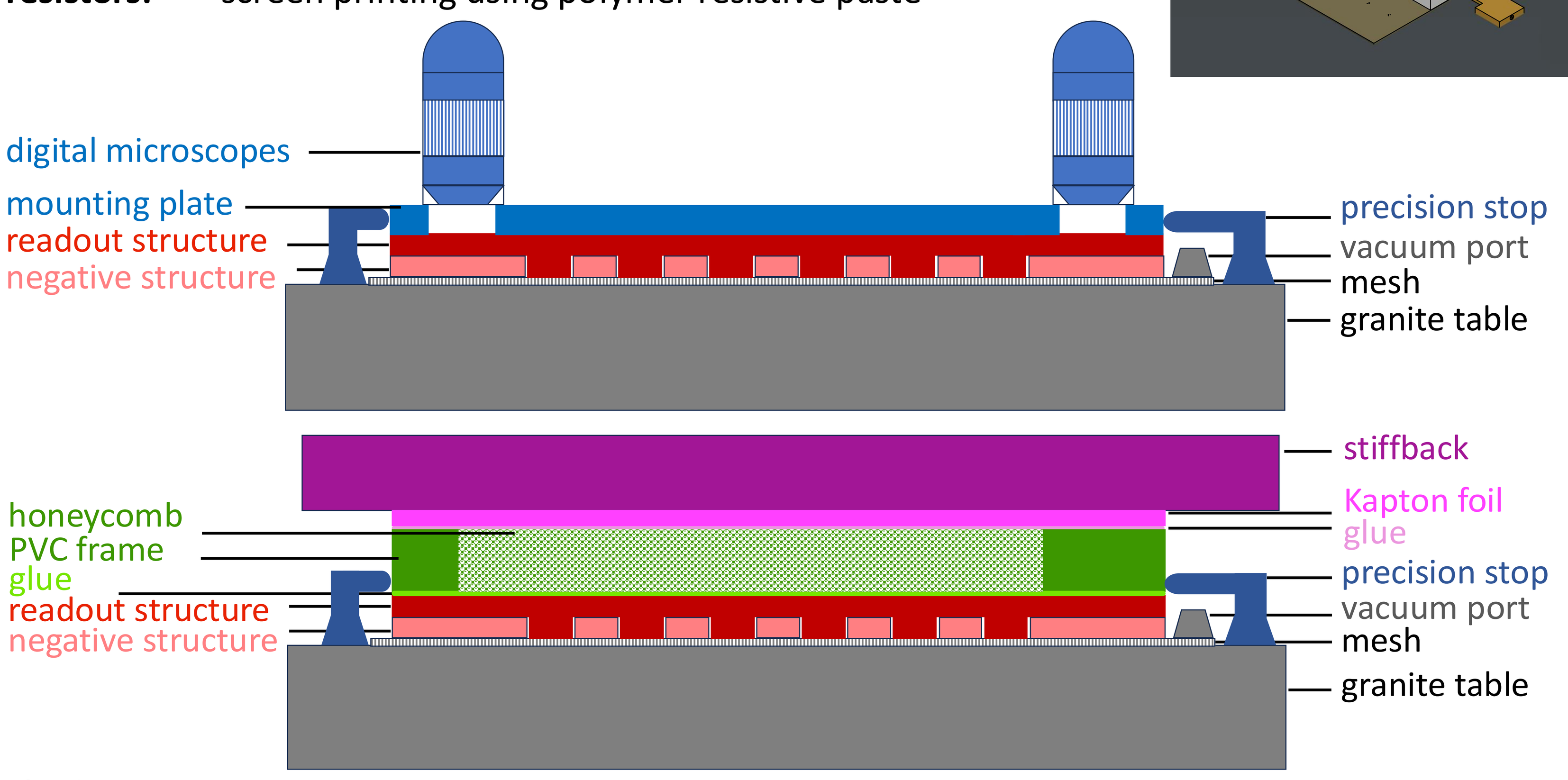
Manufacturing Processes

mesh: stretched using hydraulic clamps and glued to a frame

readout structure: photolithographic processes
– **complete in-house production** –
structuring of the copper structure and insulating coverlay pillars

resistors: screen printing using polymer resistive paste





glueing process

step 1: vacuum suction of the readout structure on a planar granite table using a negative structure to equalize the coverlay pillar structure

step 2: alignment of mechanical stop
a) microscopes on mounting plate are calibrated relative to the edge of the frame using a template with precise holes at the position of corresponding **markers** on the readout structure
b) optical alignment of the microscope plate on top of the markers O(30µm)
c) storing of its position using precision stops with vacuum suction

step 3: removing the microscope plate - applying a defined thin layer of epoxy glue - placing the PVC frame with the honeycomb in the stored position

step 4: Kapton foil sucked to the stiffback* covered with a defined thin layer of epoxy glue - pressed on the frame and honeycomb

stiffback: planar aluminum sandwich structure with holes for vacuum suction

assembly in cleanroom

cleaning: mechanical and chemical cleaning including heated high-pressure water cleaning
→ drying in N_2-atmosphere to prevent moisture contamination

HV test: applying high voltage to test the functionality of the detector

Summary

development of manufacturing processes for a low material budget floating strip micromegas with an active area of 200x200mm²
→ Use the results for the development of a detector with **400x400mm²** active area

first successful tests of the basic functionality

Outlook

commissioning of the scalable readout system

further characterizing measurements

- permeability with respect to H_2O and O_2
- homogeneity
- Argon based gas mixtures
  (e.g. Ar/CO_2, Ar/ CO_2 /Isobutane)

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