Micropattern Gaseous Detectors with Charge and Optical Readout for Charged Particle and Photon Detection

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BLIN4: Fourth Workshop on Beam Line and Instrumentation

June 29th 2020

Idea & Motivation

charged particles and X-rays → ionization of gas volume

- lowest material budget: sensitive volumes & electrodes
- highly segmented electrodes possible
- adjustability of operational parameters (gas mixture & pressure, electric fields, ...)
- delayed signal formation possible due to charge drift time → immunize DAQ against EMP
- ionization charge detection
  - direct → ionization chambers (integrating)
  - amplified charge → Micromegas with charge readout (single particles to integrating)
  - amplified light → Micromegas with optical readout (single particles to integrating)

in-house production capabilities

- photolithography: conductive electrodes (Al & Cu on insulating substrates of 2μm to mms)
- photolithography: insulating & spacer structures on polyimide basis
- metal plating
- screen printing: conductive & resistive structures O(0.1mm) width
- ISO 3 & ISO 5 clean rooms: detector development & assembly

Photolithography: Thin & Structured Electrodes

etch-resist lamination/spray

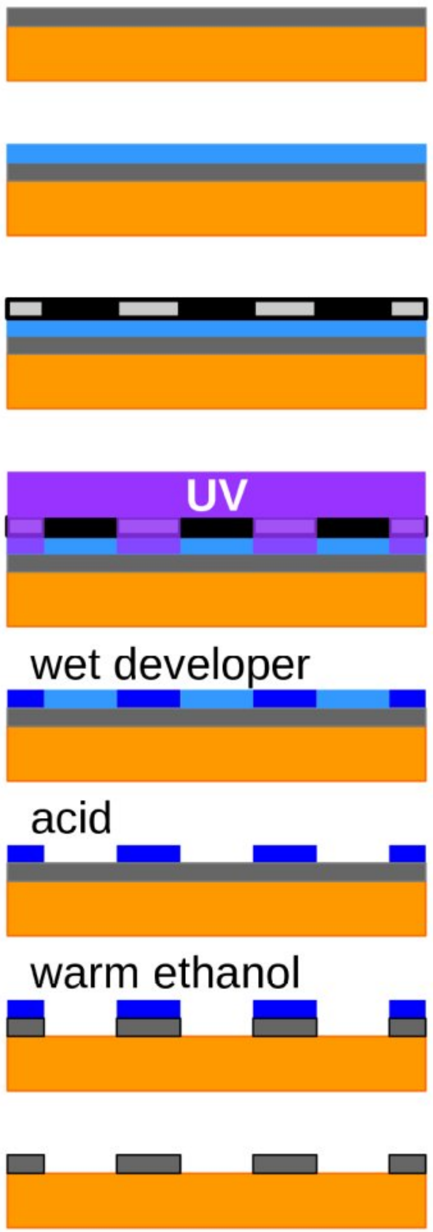
mask positioning

UV illumination

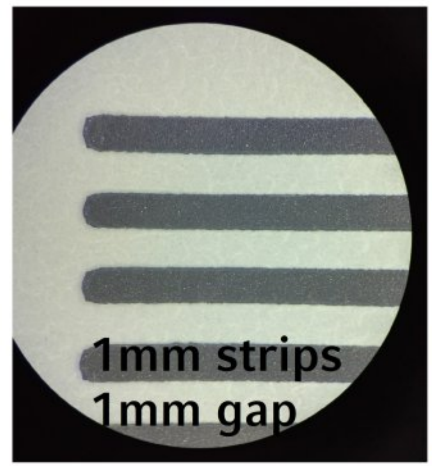
resist development

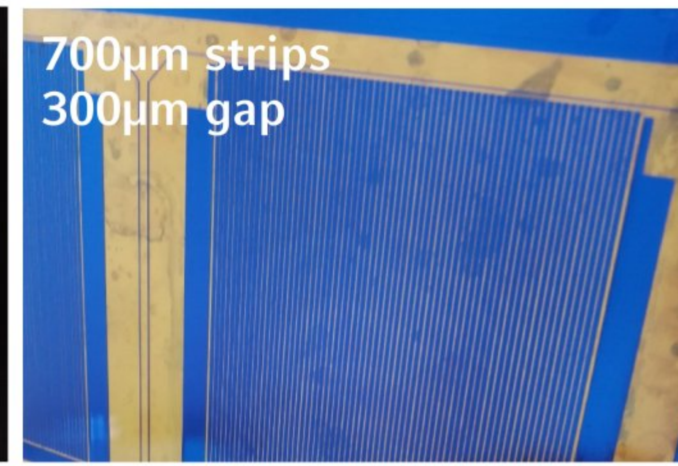
alu etching

resist stripping

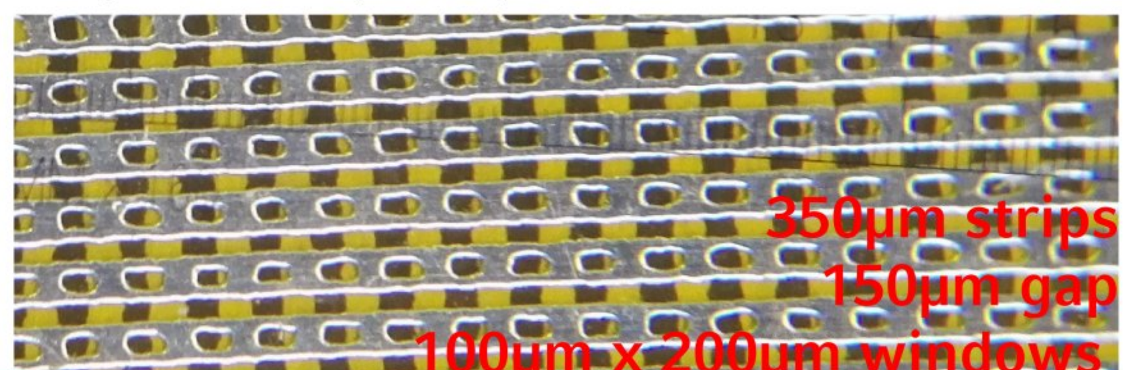


- standard process for copper clad material
- ultra-thin (ionization chambers, field cage): 40nm alu + 10µm Kapton or 50µm Mylar





- thin (MPGD readout structures): 12µm alu + 32µm Kapton

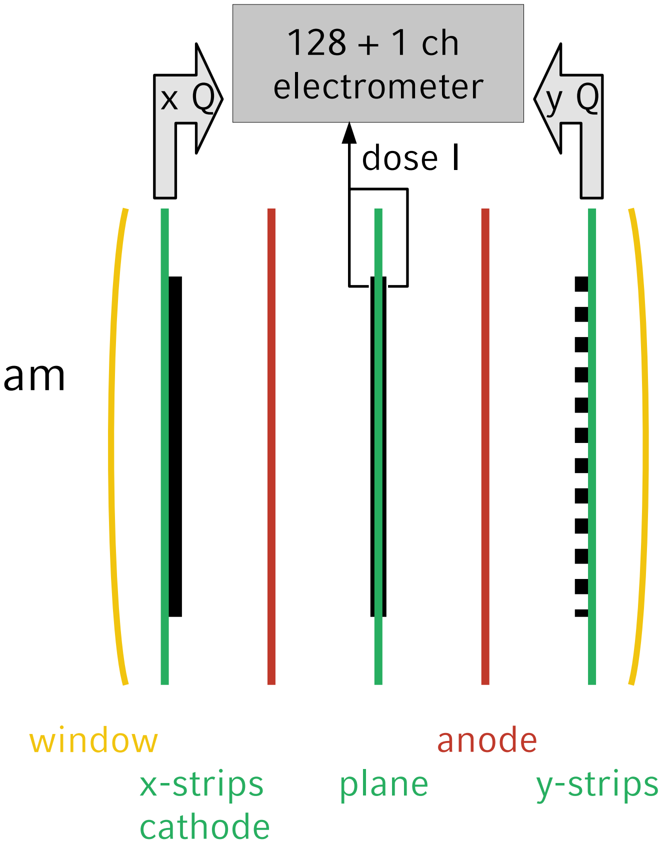


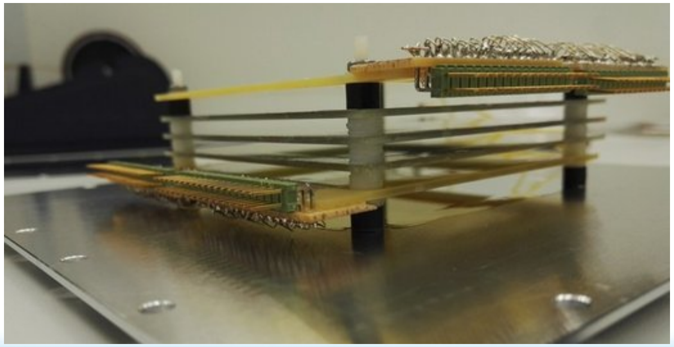
Transparent Ionization Chamber

application
- beam monitoring in pre-clinical proton irradiation

requirements
- minimum impact on beam
- spatial resolution in two dimensions < 50µm for 1mm FWHM beam
- dynamic range: 10^5 p/s to 10^{10} p/s
- current monitoring accuracy O(1%)

minimized material budget
- 4x 5mm gas gaps
- 2x 2µm Mylar + 2x40nm alu (non-segmented anode)
- 1x 2µm Mylar + 2x40nm alu (non-segmented dose planes)
- 2x 10µm Kapton + 40nm alu (strips, 1mm pitch)
- 2x 10µm Kapton windows

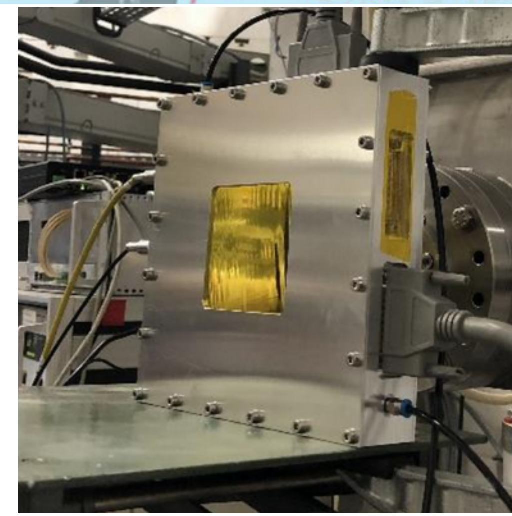




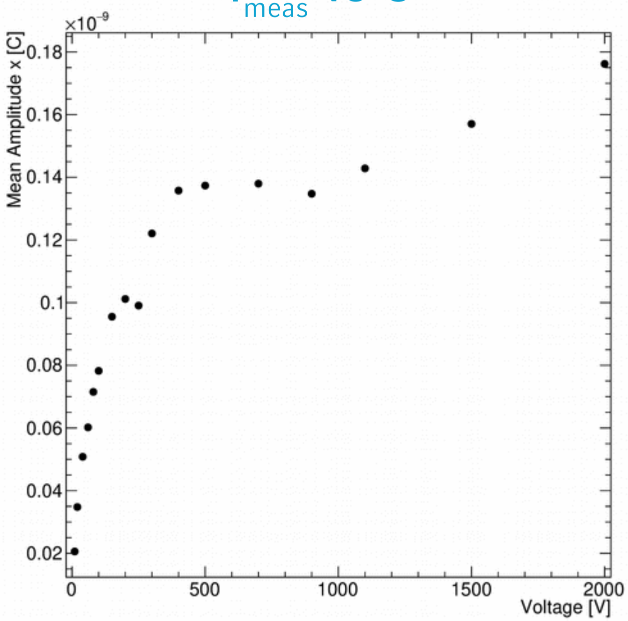
Ionization Chamber
22MeV p @ Tandem/Garching

commissioning & characterization

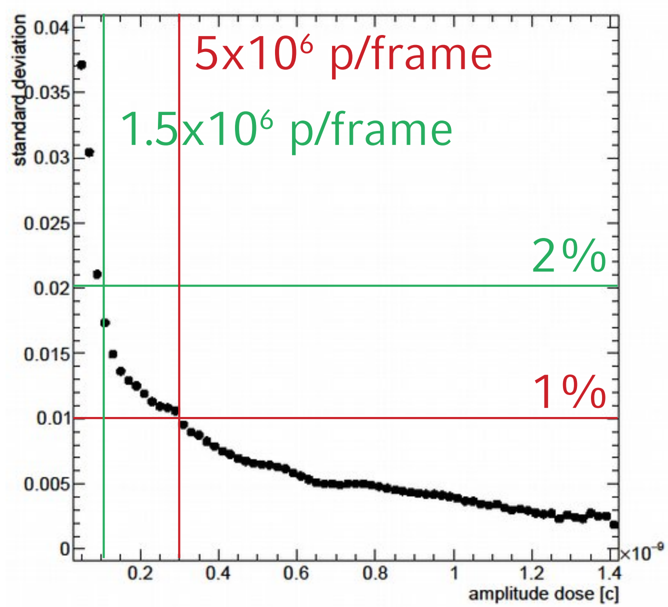
- 64 + 1 ch electronics: Pyramid USA
- 10^5 to 10^{10} p/s
- beam: 1.3mm diameter, not fully stable
- 3 independent layers → linearity <1%
- chamber mounted on precision linear stage
  → spatial resolution   << 10μm (full statistics)
                                        ~50μm (single frame)



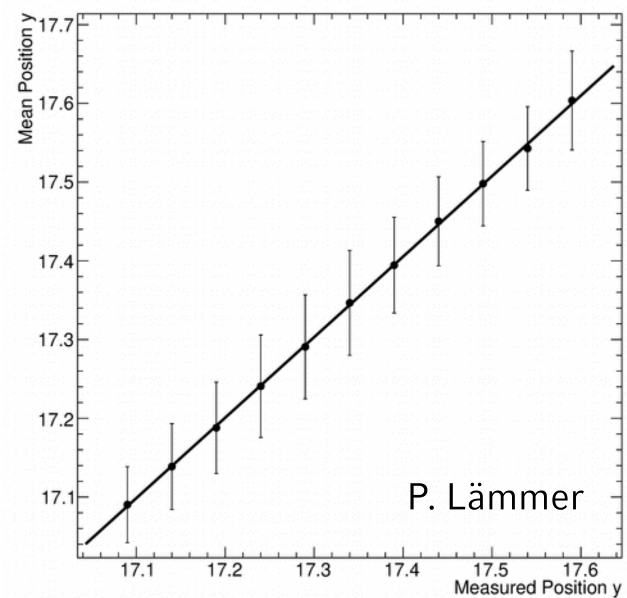
I_{meas} vs U



measured I resolution, strips



measured position vs position



Ultra-Thin Dual Readout IC

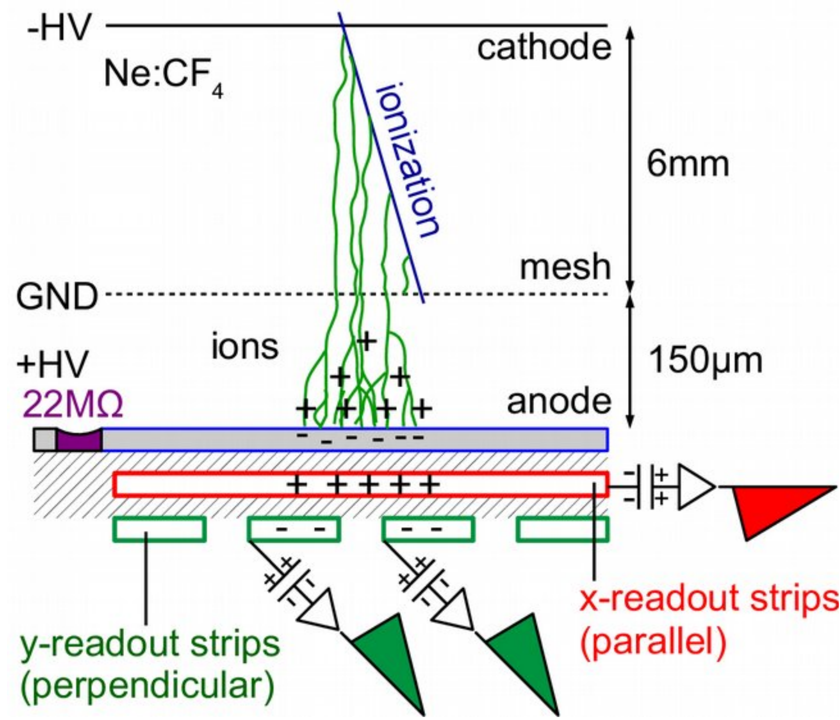
→ Lotta Flaig's talk today: ***A transmission ionization chamber for online monitoring of ion bunch fluence and trajectory***

IC development based on experience gained with strip IC

development of custom amplifier electronics → EMP resistant

Floating Strip Micromegas* with Low Material Budget

copper anode strips: individually connected to HV via 22MΩ
x-readout strips: signals capacitively decoupled via O(10pF)
y- readout strips: signals directly inductively decoupled
→ fast discharge interruption
→ negligible impact on efficiency



Bortfeldt et al., NIM A 2017, 845, 210 - 214

*: inspired by the COMPASS MM, considerably improved in: Bortfeldt, The Floating Strip Micromegas Detector, Springer, 2014

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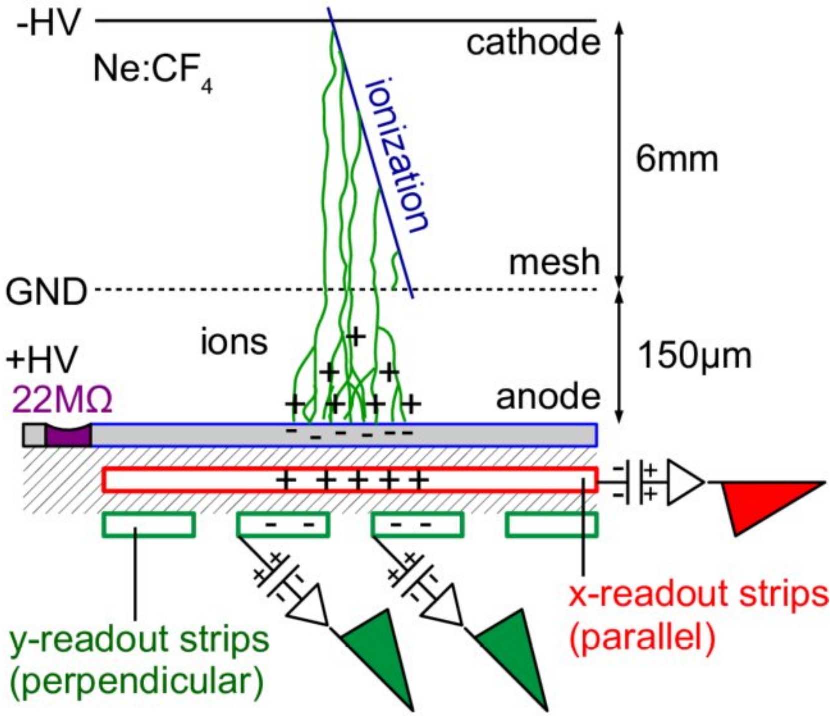

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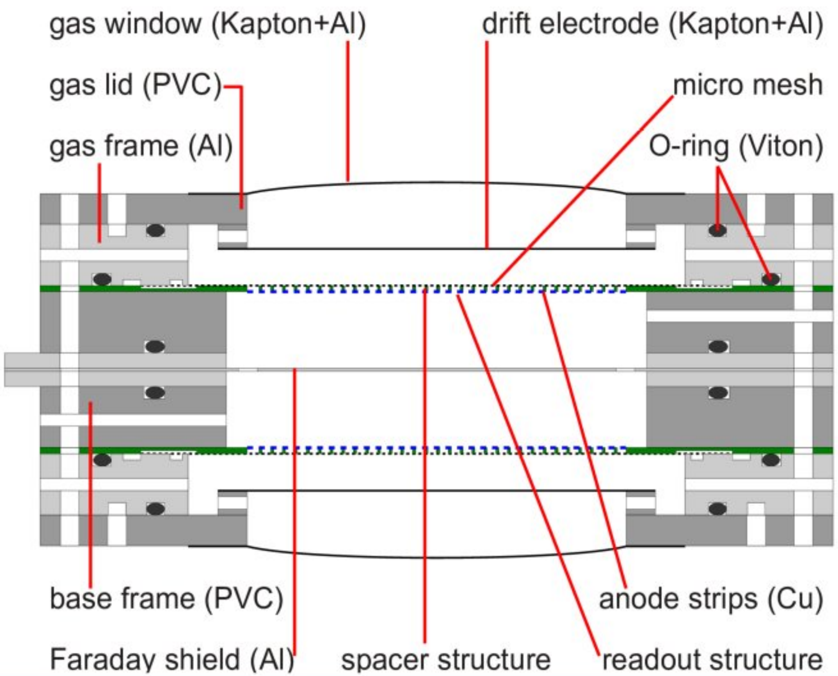
prototype with flex-PCB readout structure (1.1%X_0)

- two detectors back-to-back → 80mm distance
- flexible readout structures: overpressure stabilized



performance

- spatial resolution (0.5mm pitch): < 100µm
- single particles: ≤ 7MHz/cm^2
- integrating: > 2GHz

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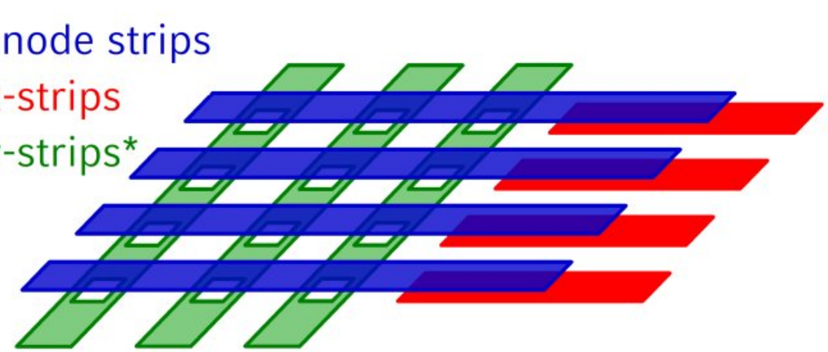
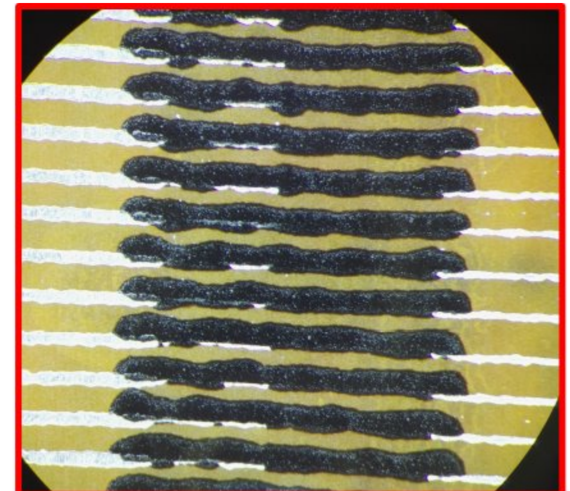
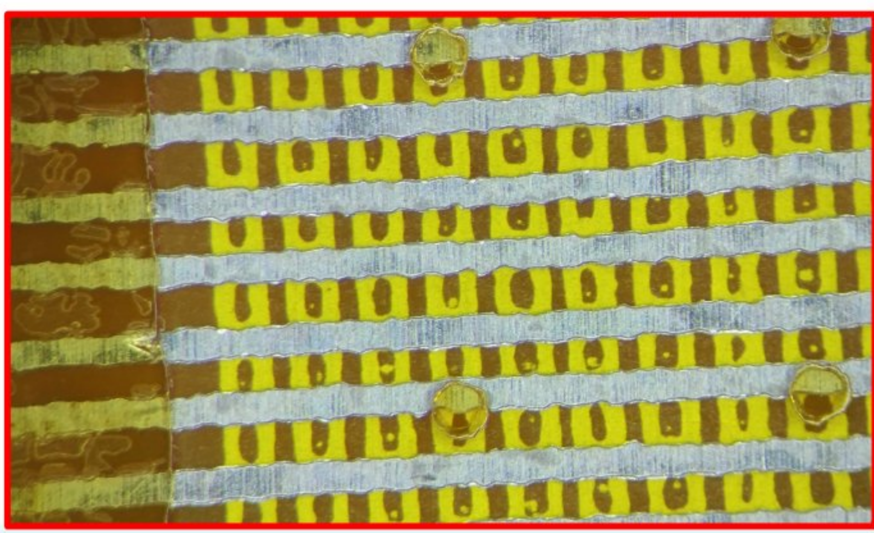
Floating Strip Micromegas with Ultra-Low Material Budget

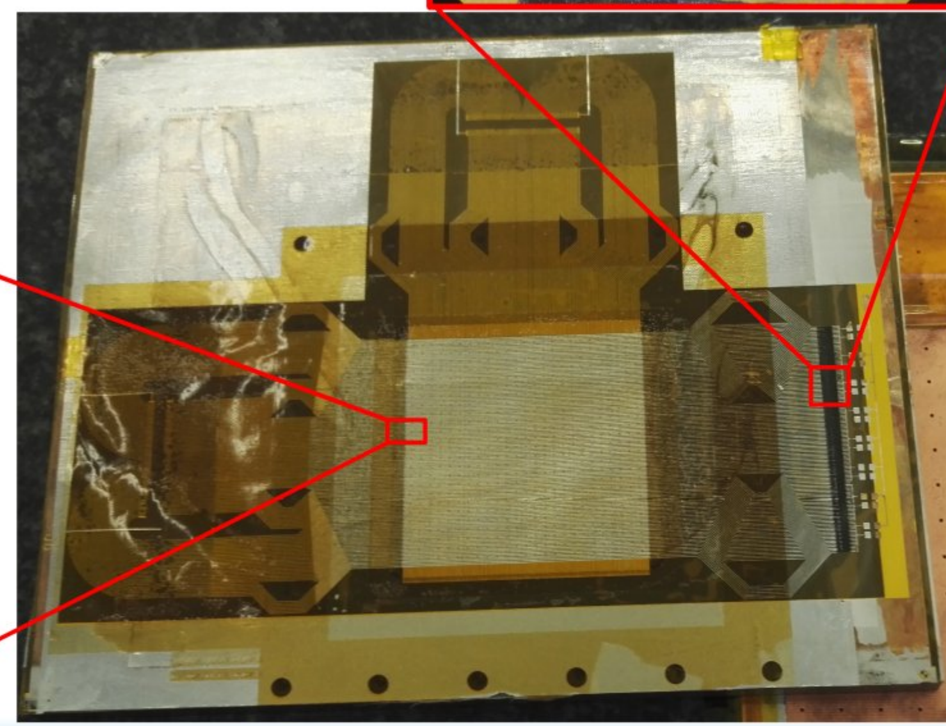
12µm Al anode & y-strips on 32µm Kapton & glue
→ x-readout strips outside active area
→ 0.15 X_0 per detector (70% from mesh)



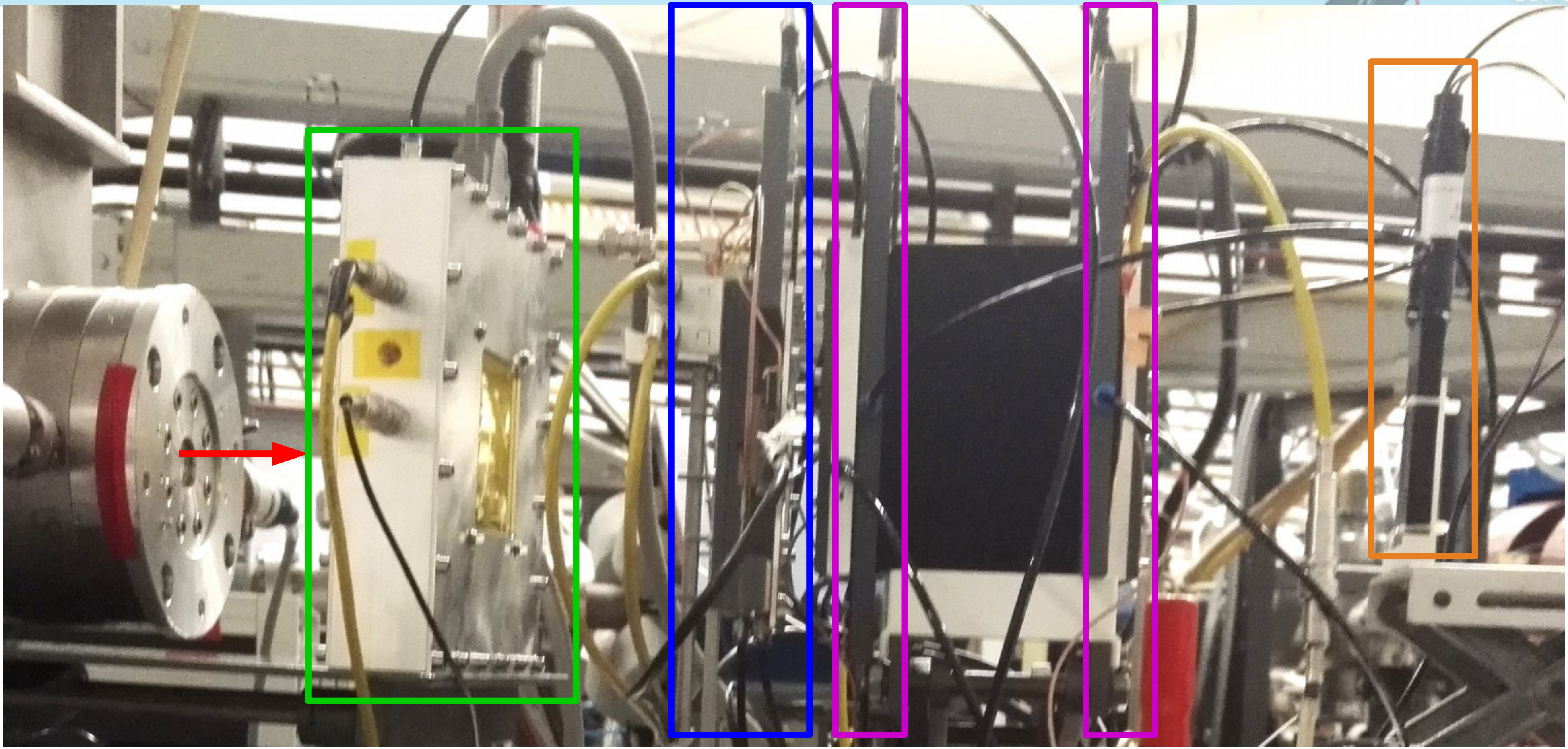
*: pattern inspired by F. Klitzner, LMU Munich







Tests in 22 & 21MeV Proton Beams @ MLL Tandem late 2019



beam
kHz to 5MHz
4x5mm² FWHM
(pCT<0.5MHz/cm²)

dual strip IC
multi-channel
electrometer ro
ΔI/I ~ 1% @
1MHz

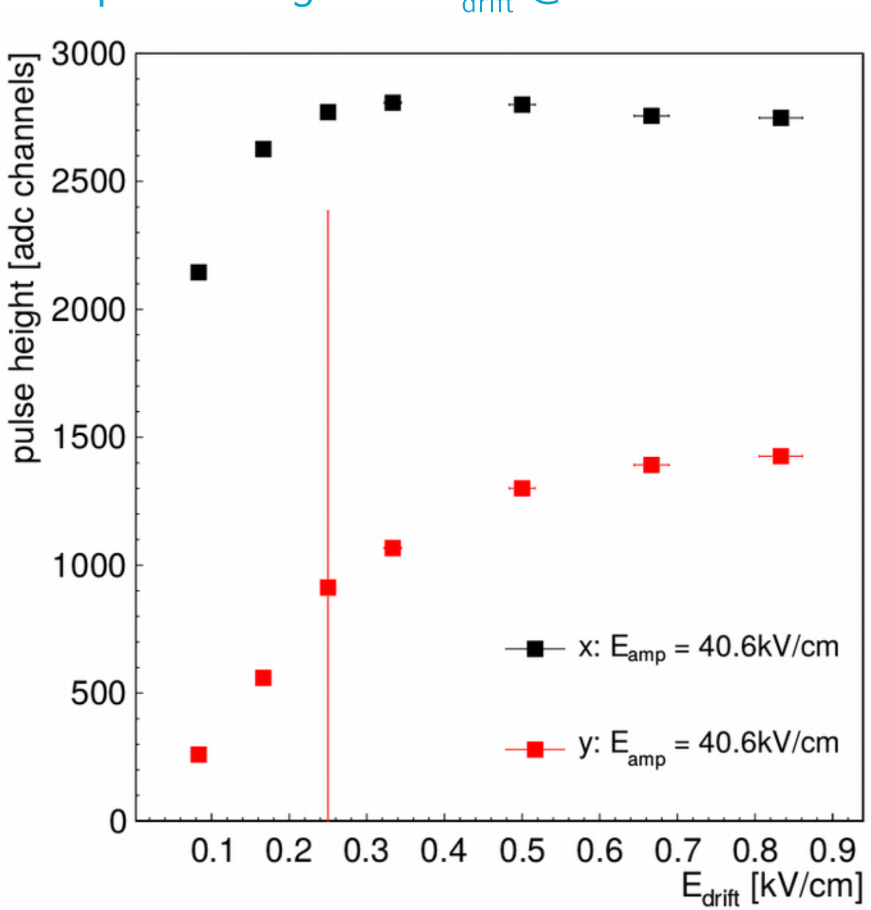
reference FSMs
4 x APV25 + SRS

aluminum FSM
single layer
2x APV25 + SRS
Ne:CF_4 80:20

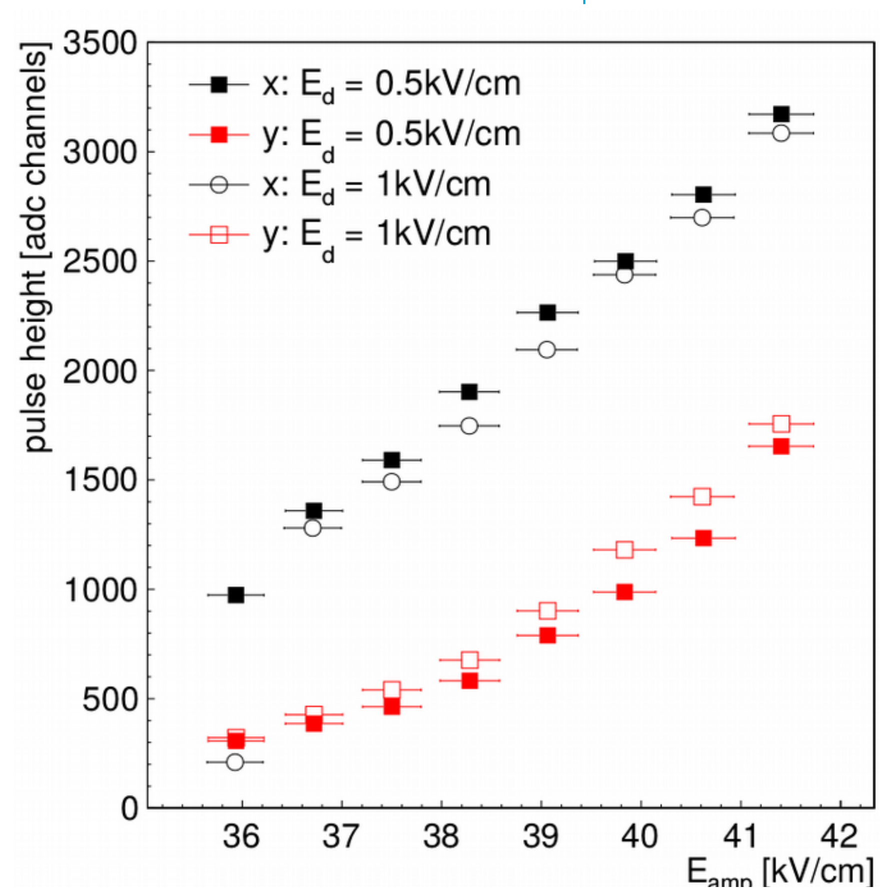
trigger scintillator
NIM electronics
APV25 → jitter correction

Pulse Height Behavior vs Voltages
November 19

pulse height vs E_{drift} @ 40.6kV/cm

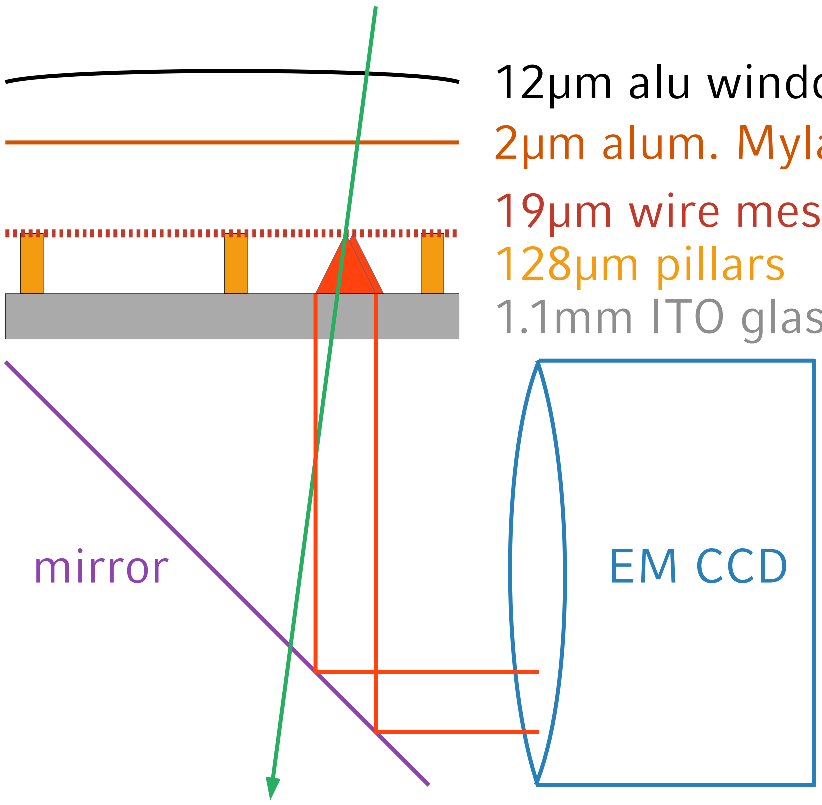


pulse height vs E_{amp} @ 1kV/cm



- pulse height ratio y/x ~ 0.5 → well usable
- tracking works well: analysis ongoing, limited by scattering in reference detectors
- no sign of aging in beam → long term irradiation in lab ongoing

Micromegas with Optical Readout



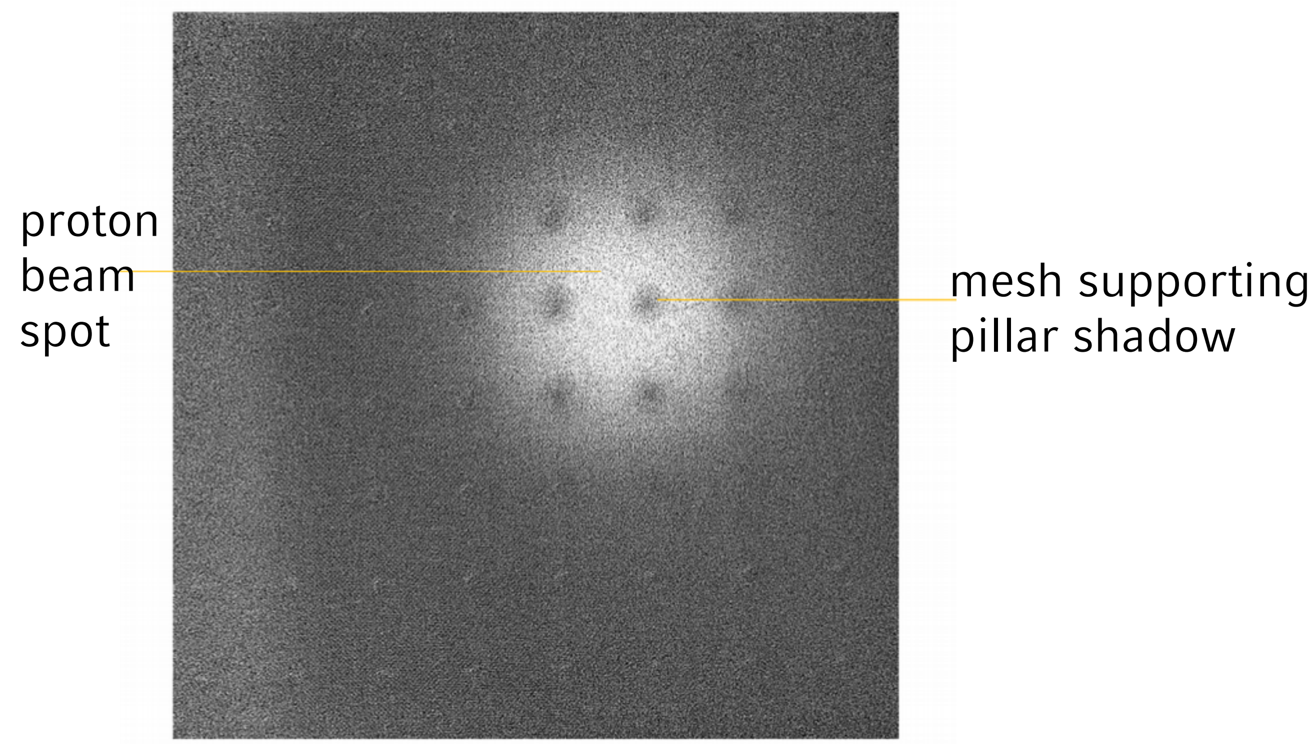
ionization by particle/X-ray beam

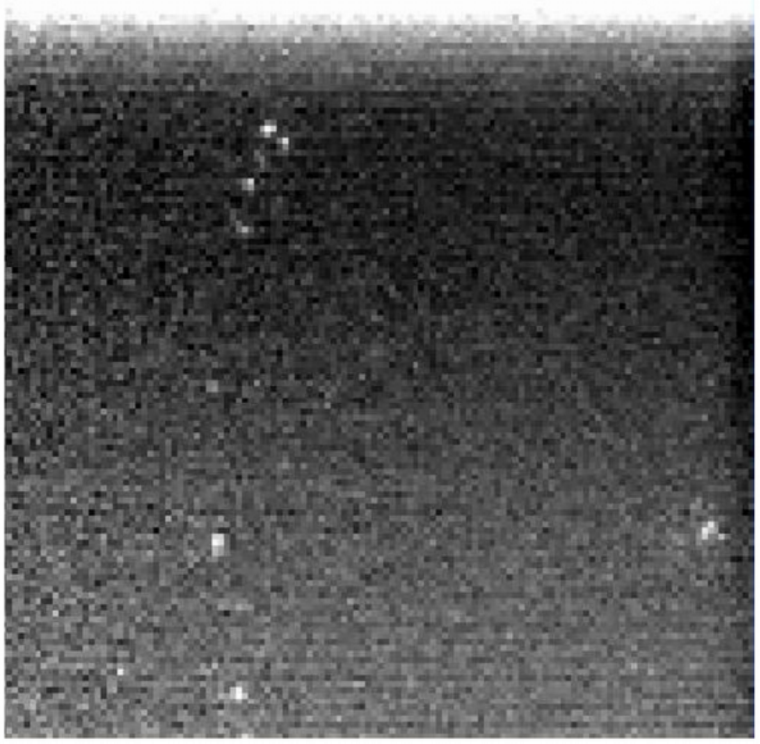
amplification avalanche in Ne:CF_4
→ local & proportional production of charge + **photons (620 & 300nm)**

optically transparent, unsegmened anode 25x25mm² with support pillar structure

detect optical photons with EM CCD
→ beam position & intensity
→ gas gain adjustable for integrating or single particle detection

Tests with 22MeV Protons @ MLL & Sources in Lab





first test in 22MeV proton beams

- lower detection limit: 6×10^4 p/frame
- tested up to 2.5×10^5 p/frame
- EM CCD coupling to detector not light tight
- correlation with beam monitor IC

improved light tightness: lab test

- enables higher CCD amplification
- individual events from ^{55}Fe and ^{90}Sr source (plot) visible

→ plan: reduce material budget by using double mesh structure instead of glass anode

Summary

micropattern gaseous detectors for charged particle & photon detectors

in-house development & production

transmission ionization chamber with aluminized electrodes

- strip ionization chamber
  - material budget: 46µm Kapton/Mylar + 0.4µm aluminum + 40mm gas
  - successfully tested in 22MeV p beams
  - beam fluence, position & shape
- unsegmented dual readout IC → Lotta Flaig's talk today

floating strip Micromegas with aluminum readout structure

- single particle & photon detection with high spatial resolution
- successfully tested in several 22MeV proton beams and with sources in lab

Micromegas with optical readout

- exploit optical photon production in gas amplification
- successfully tested beam detection with 22MeV protons & single particle/photon detection in lab

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Thank you!