Performance Test of a Resistive Micromegas Quadruplet

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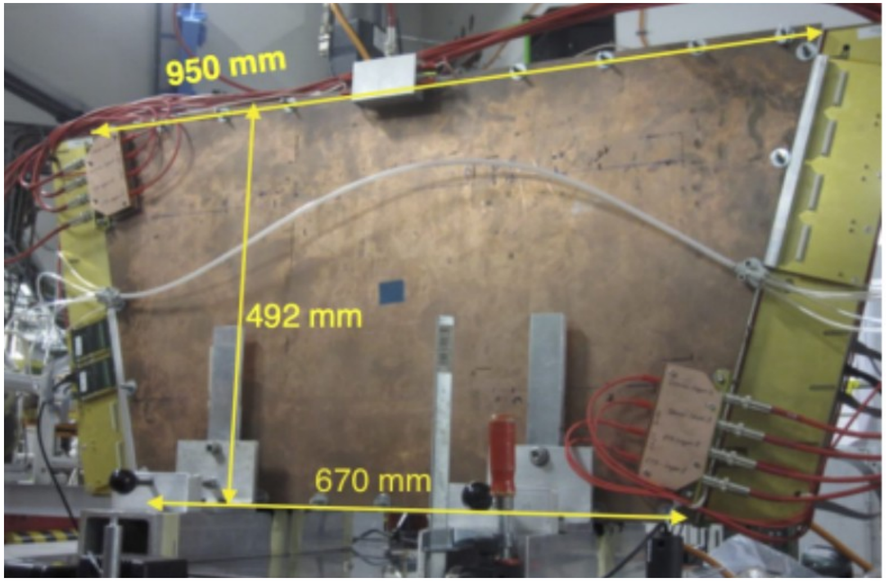
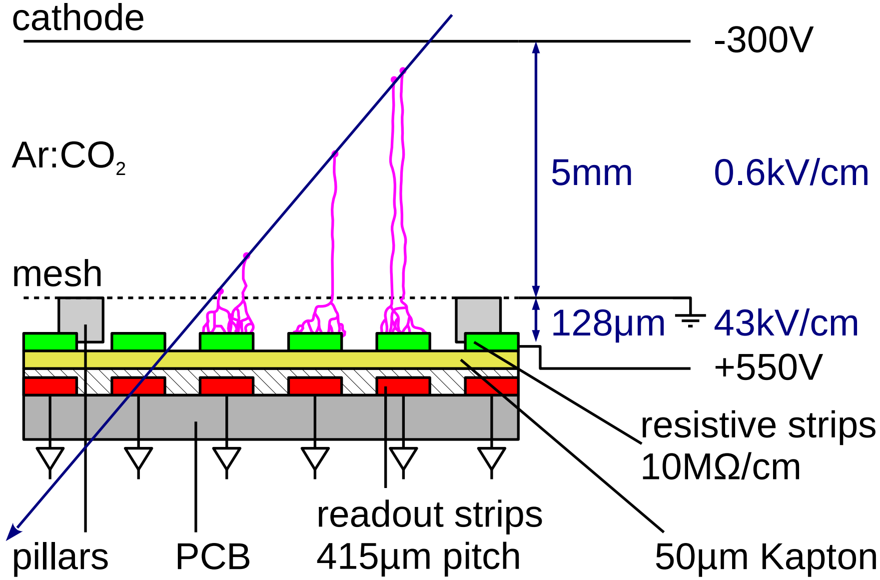
Motivation & Introduction

continuously increasing collision & background rate at the Large Hadron Collider

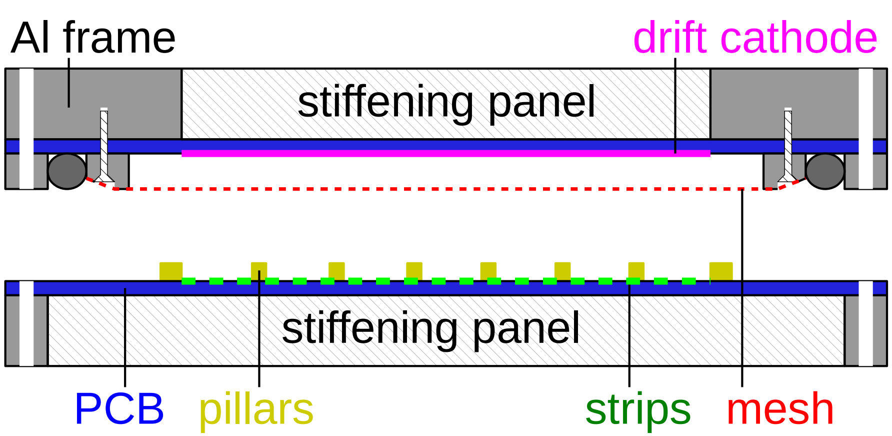
- several LHC experiments face an upgrade of sub-detectors
  - large detection areas
  - high rate capable, high resolution tracking detectors
- one of the most challenging: upgrade of ATLAS forward Muon Spectrometer (New Small Wheels)
  - precision tracking detectors: four-layer resistive strip Micromegas modules ($1280 m^2$ active area)
  - maximum background hit rate: $15 kHz/cm^2$
- 2014: designed & constructed resistive strip Micromegas quadruplet prototype at CERN
  - study construction methods
  - investigate chamber tracking performance in high-rate background
  - study and optimize reconstruction algorithms

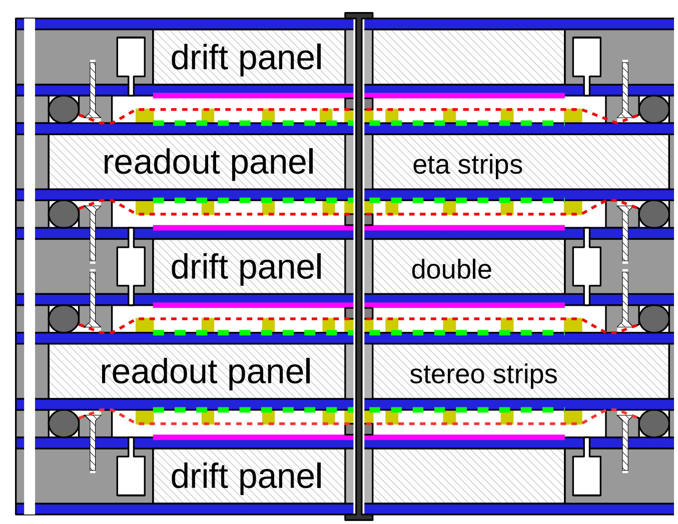


Resistive Strip Micromegas Quadruplet



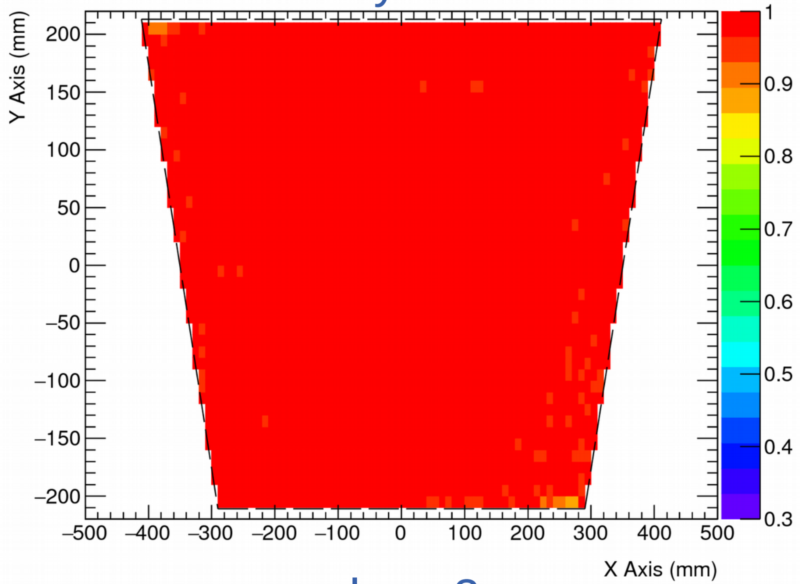
- sputtered resistive anode strips
  → suppress discharge influence on efficiency
- 1024 readout strips with 415µm pitch
- active area: 0.32m² per layer
- floating mesh, attached to cathode
  → facilitates cleaning and simplifies commissioning
- based on stiff & light-weight panels
  → cathode on drift panel
  → mesh supported by drift panel
  → readout structure on readout panel
- two planes with parallel strips,
  two stereo planes with ± 1.5° strip angle



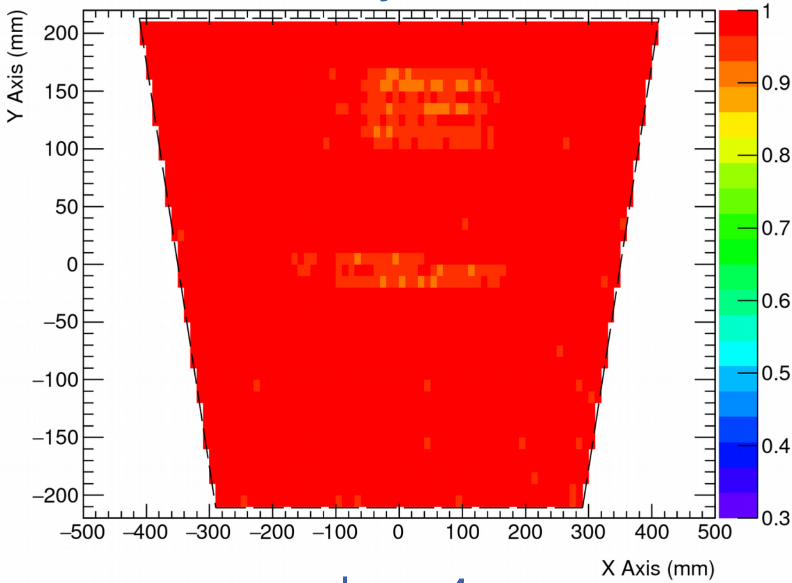


Efficiency Mapping with Cosmics

layer1



layer2



track cosmic muon using 3 out of 4 layers → efficient if matching hit in the fourth layer (within 15mm)

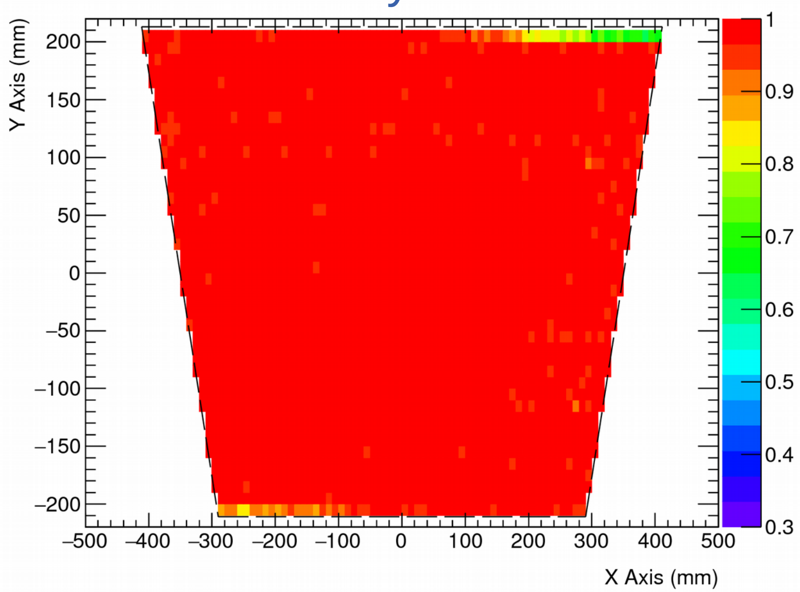
efficiency above 95%

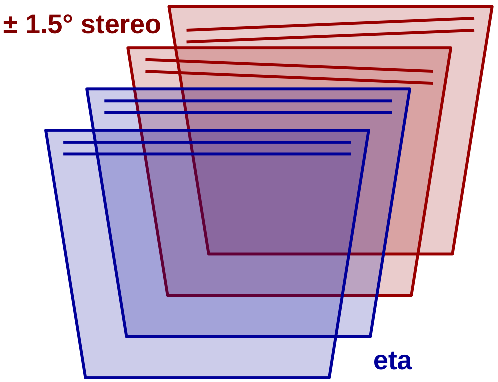
stereo layers: inefficiency in corners due to absence of readout strips

E_{amp} = 45.3kV/cm

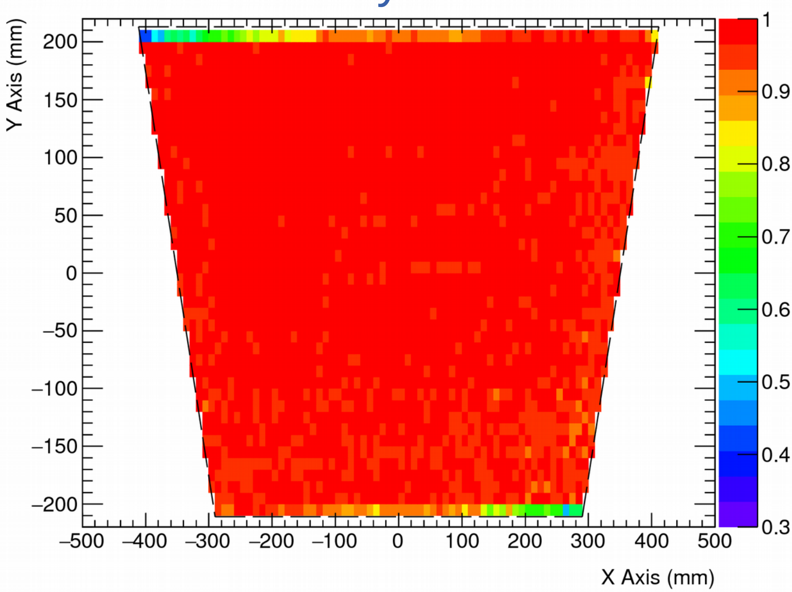
E_{drift} = 0.6kV/cm

layer3

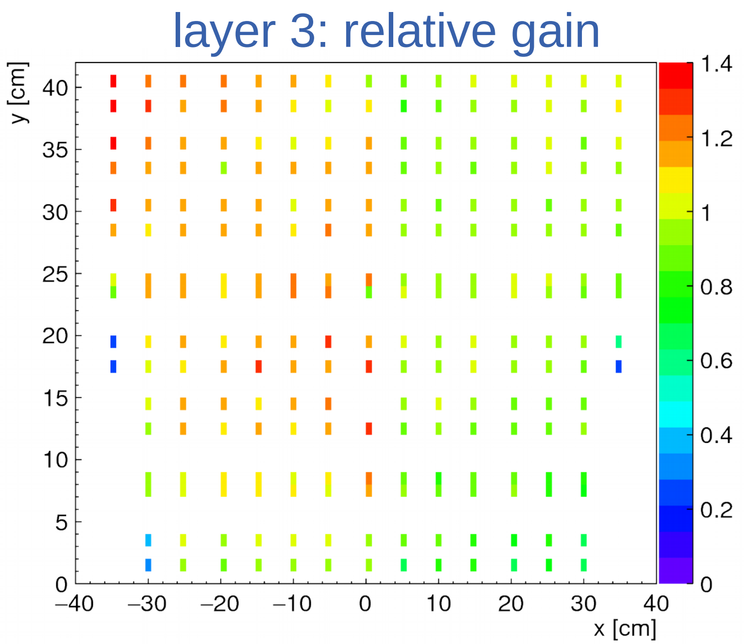


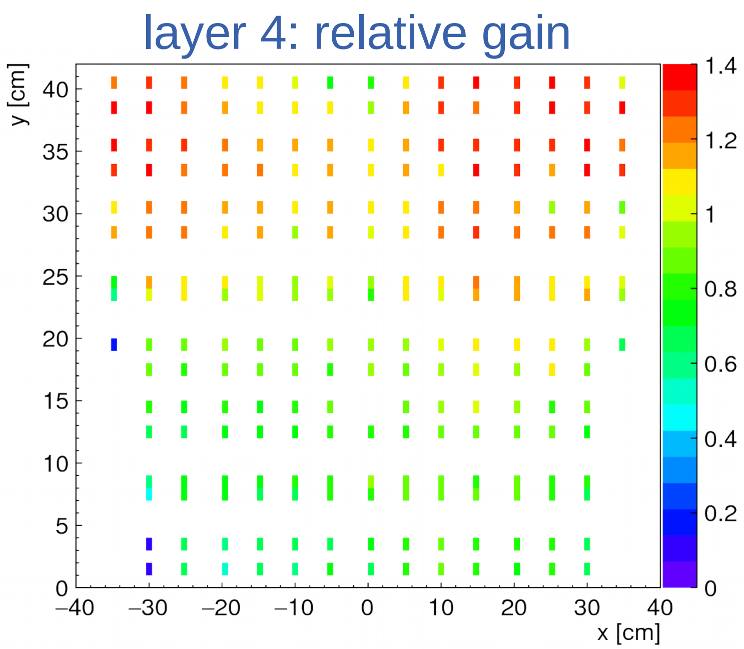


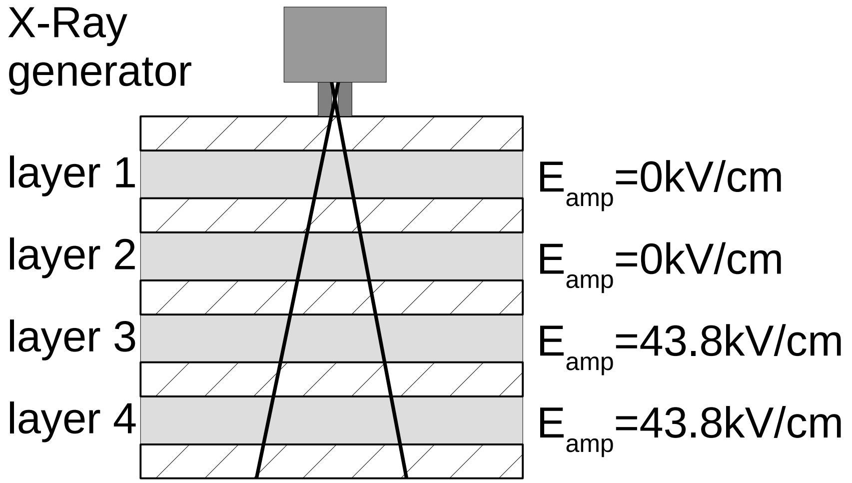
layer4



Gas Gain Mapping with X-Rays

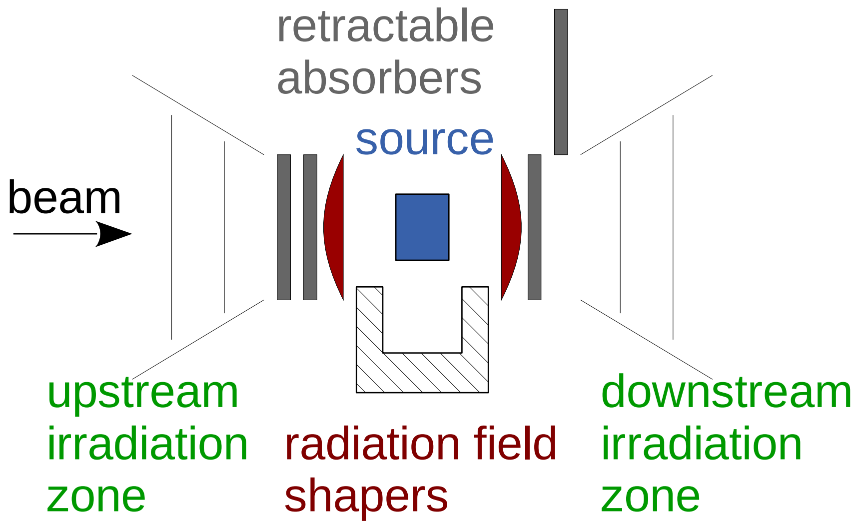






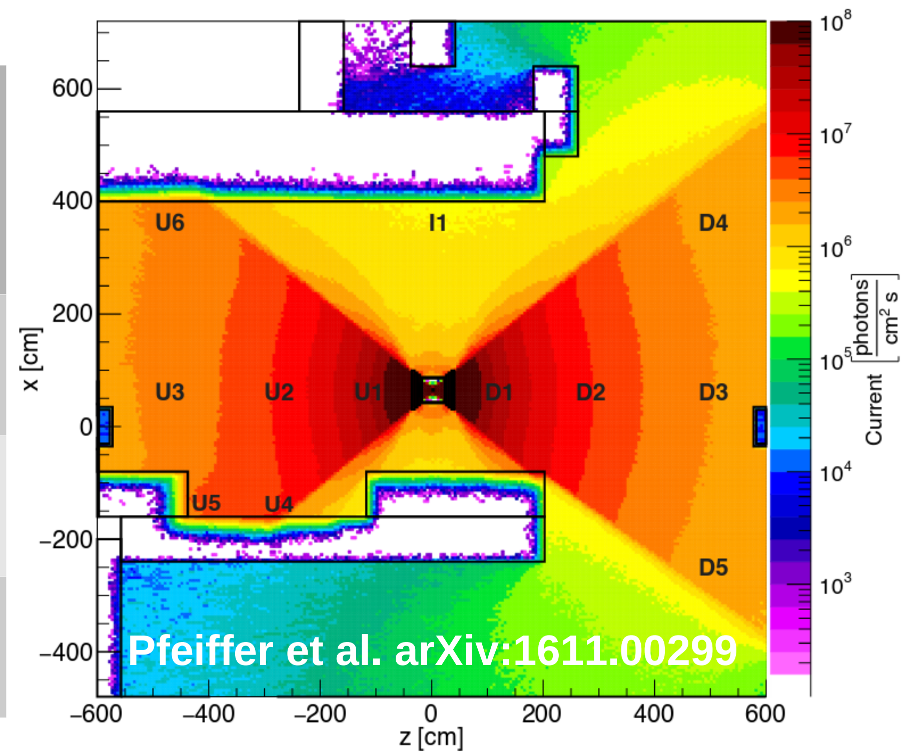
- collimated X-Ray beam with 5° opening angle
- tube settings: 50kV & 50µA
- measure amplification current
  → scan chamber on 228 points
- relative gas gain homogeneous ± 20%
  → very good

Performance in High-Rate Photon Background: Gamma Irradiation Facility GIF++ @ CERN

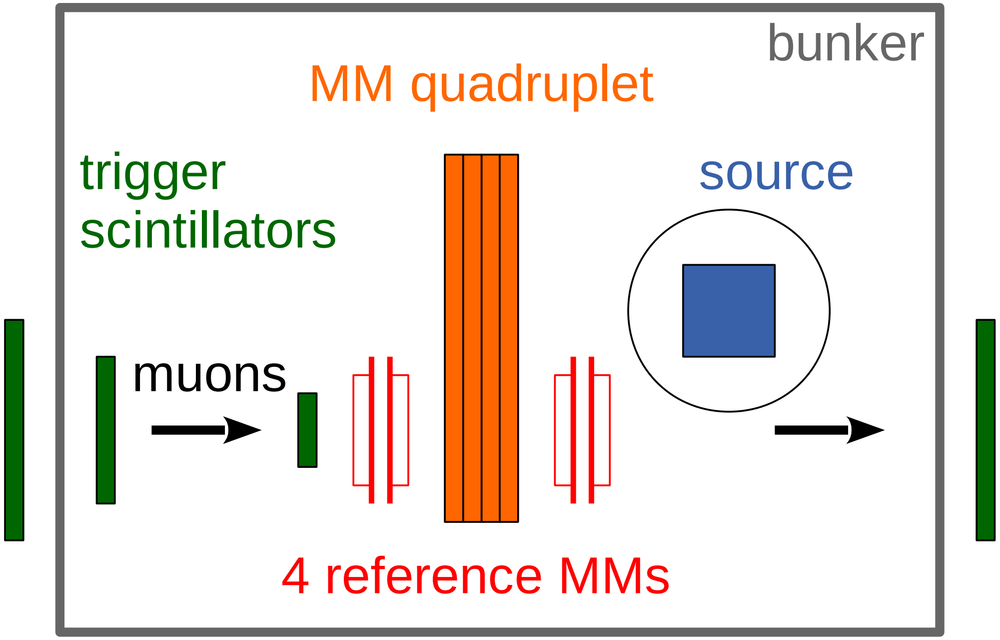


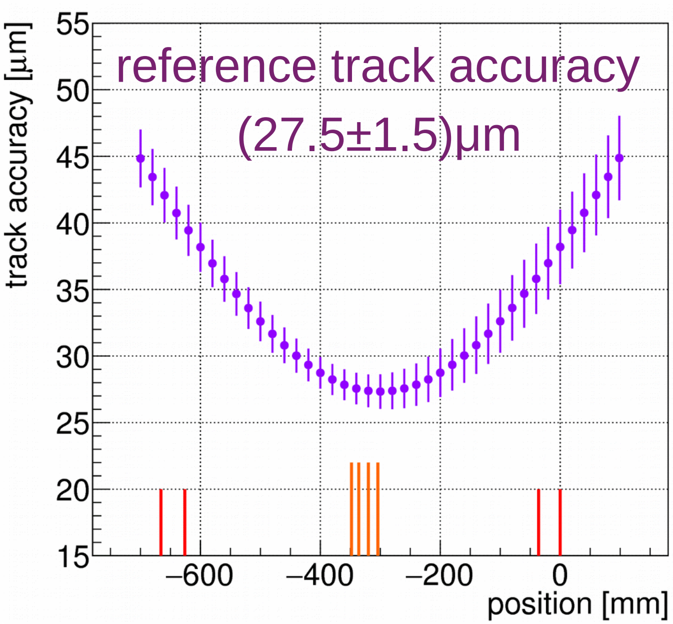
- 13 TBq ^{137}Cs source, SPS North Area
  → 662keV peak O(50%) + continuum (scattering)
- field shaper: constant photon current in plane
- retractable absorbers → adjust photon flux
- high-energy muon beam: 10^4 per spill
- talk: Dorothea Pfeiffer, Thu. 03.11.16, 8:45, N48-4

nominal attenuation	observed attenuation	observed photon current [$cm^{-2}s^{-1}$]	measured hit rate small chamber [$cm^{-2}s^{-1}$]	measured sensitivity small chamber
4.6	4.5	9.8×10^6	34×10^3	3.5×10^{-3}
10	**8.8**	**5.0×10^6**	**18×10^3**	**3.6×10^{-3}**
46	(29)	(1.5×10^6)	5.3×10^3	assuming 3.6×10^{-3}



Muon Tracking in High-Rate Photon Background





- MM quadruplet, fully exposed to source, Ar:CO_2 93:7 vol.% @ atmosph. pressure
- four 9x9cm² reference Micromegas with spatial resolution O(60µm)
- RD51 Scalable Readout System with APV25 frontend boards, O(3600) channels
- muon trigger: 2 large scintillators outside + 2 scintillators inside bunker

investigate quadruplet performance for four irradiation settings: 4.6, 10, 46 & without source

Reconstruction & Analysis

analysis strategy

- in all Micromegas layers: reconstruct all clusters
- translate cluster positions in all layers into cluster positions (line) in 3d space
- iterative Kalman filter based tracking algorithm, three-dimensional
  - identify clusters belonging to track (spatially & temporally)
  - determine reference track parameters and select good tracks

  → verify correct cluster identification by intentionally shifting quadruplet
- draw pulse height, position, efficiency etc for these clusters

spatial resolution

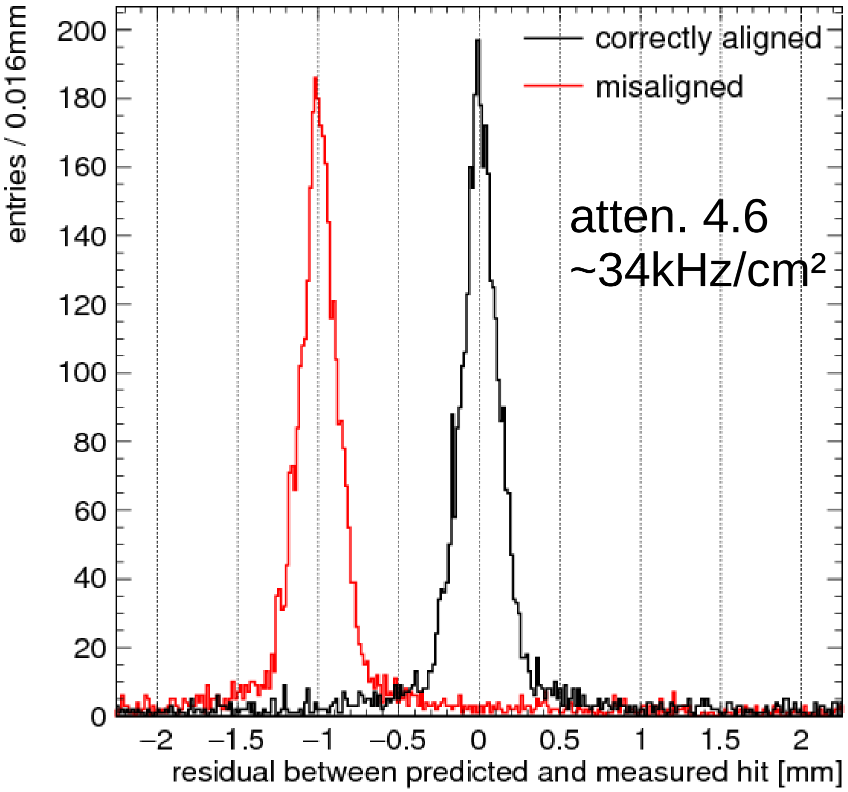
- residual between hit position predicted by track and measured hit position

  → width of residual distribution (std. deviation)

  $= \sqrt{(\text{spatial resolution}^2 + \text{track accuracy}^2)}$

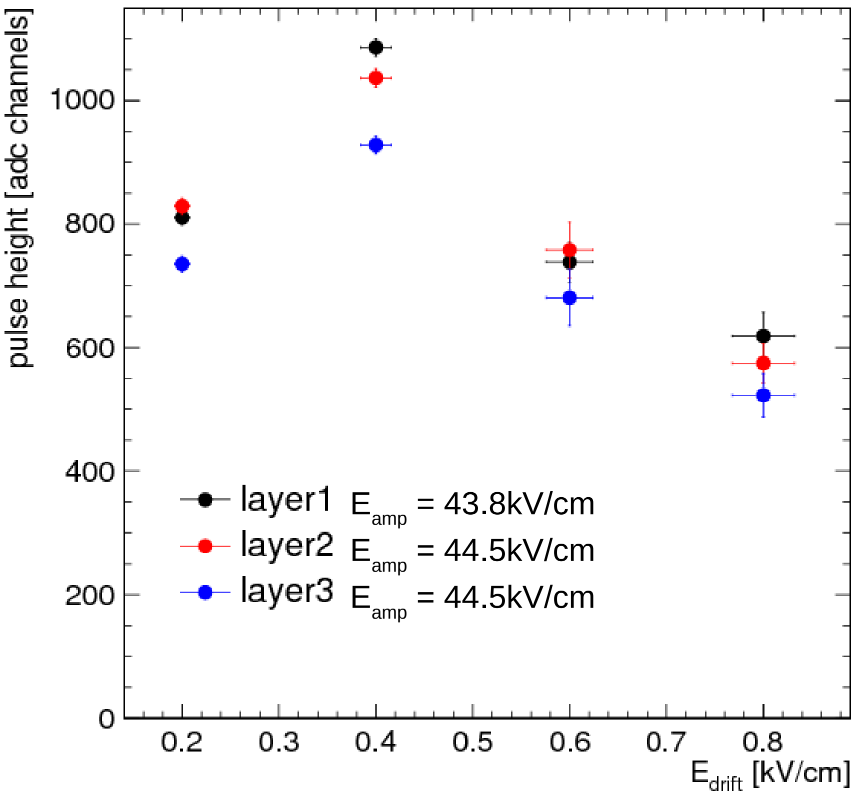
efficiency

- exclude detector from tracking algorithm
- search for valid cluster in region around expected hit ($\pm 5\sigma_{SR}$)



Pulse Height Behavior

pulse height vs drift field



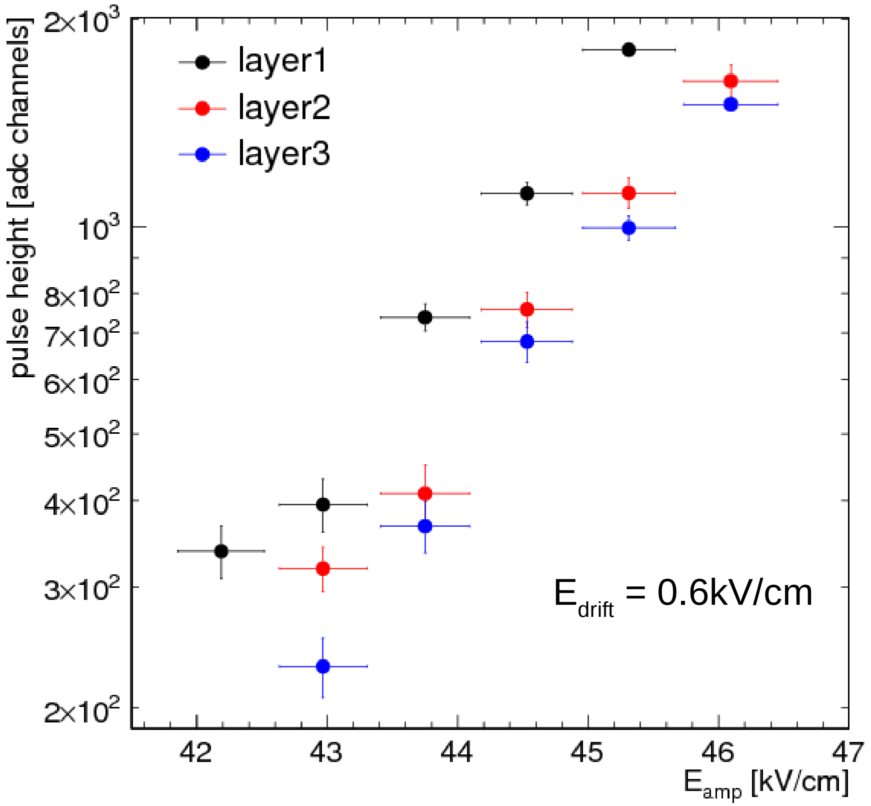
low E_{drift}

- electron attachment
- long signal duration

high E_{drift}

- low electron mesh transparency

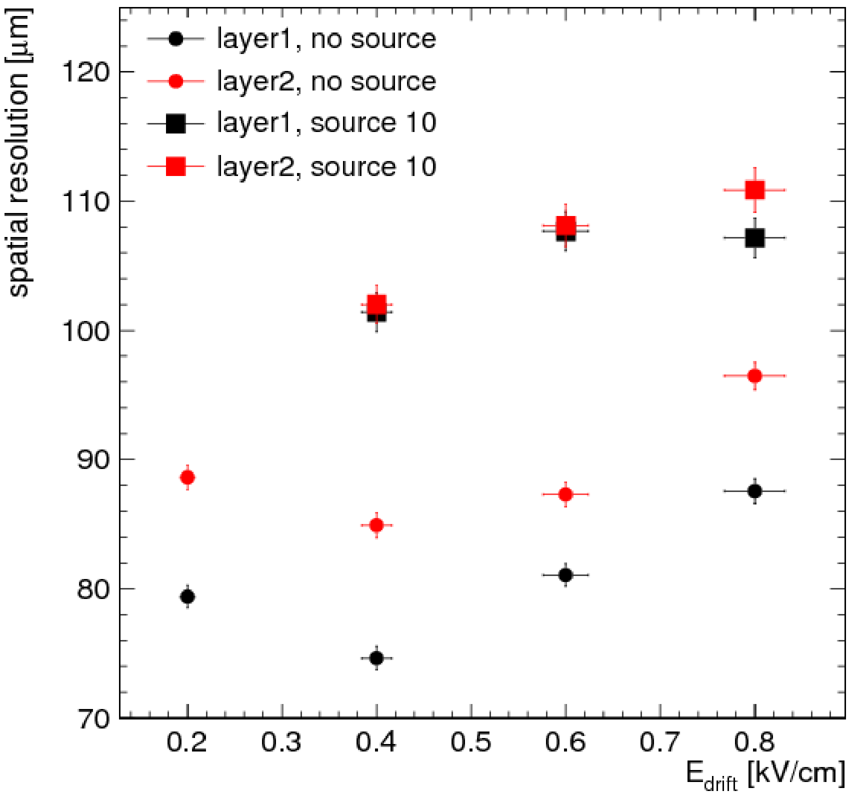
pulse height vs amplification field



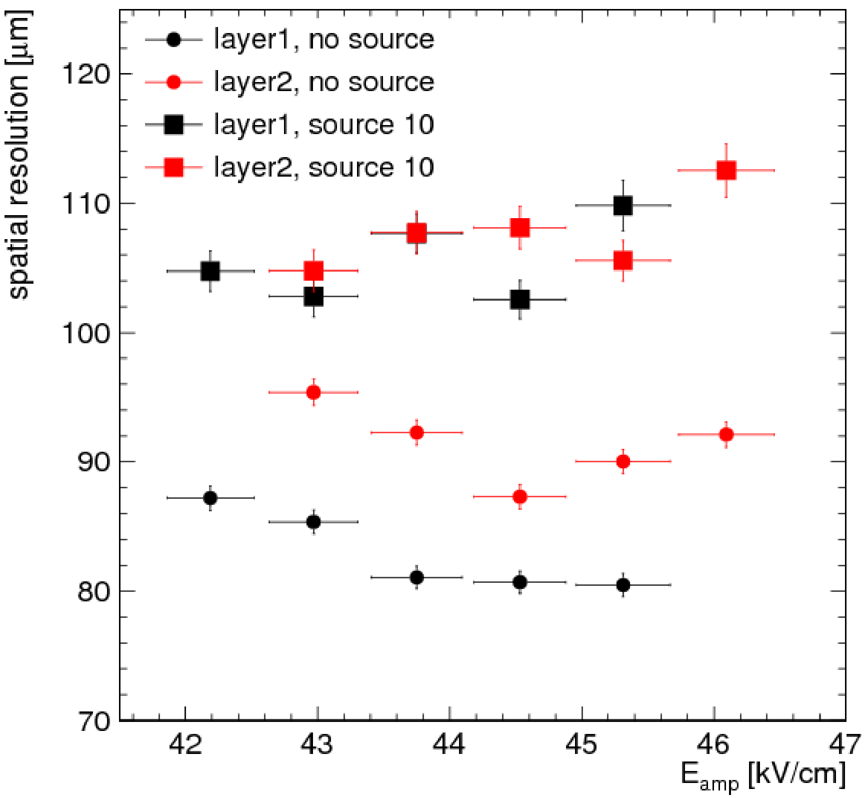
- exponential increase as expected
- slight differences between layers, differences in amplification gap width

Spatial Resolution

spatial resolution vs drift field



spatial resolution vs amplification field



- optimum resolution
  ↔ minimum transverse electron diffusion
- only minor degradation at hit rates > maximum ATLAS background hit rate
- long signal duration at low field
  → strongly influenced by background hits
- side note: rotational alignment < 0.1mrad

no background

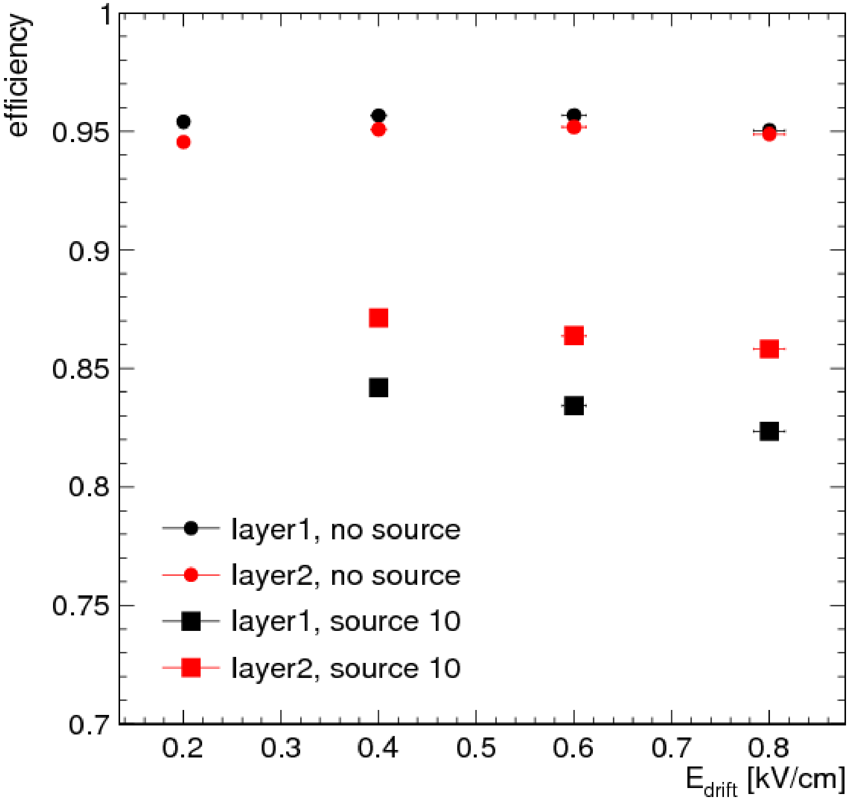
- minor improvement with increasing gas gain
- large field: APV saturation

with high-rate background

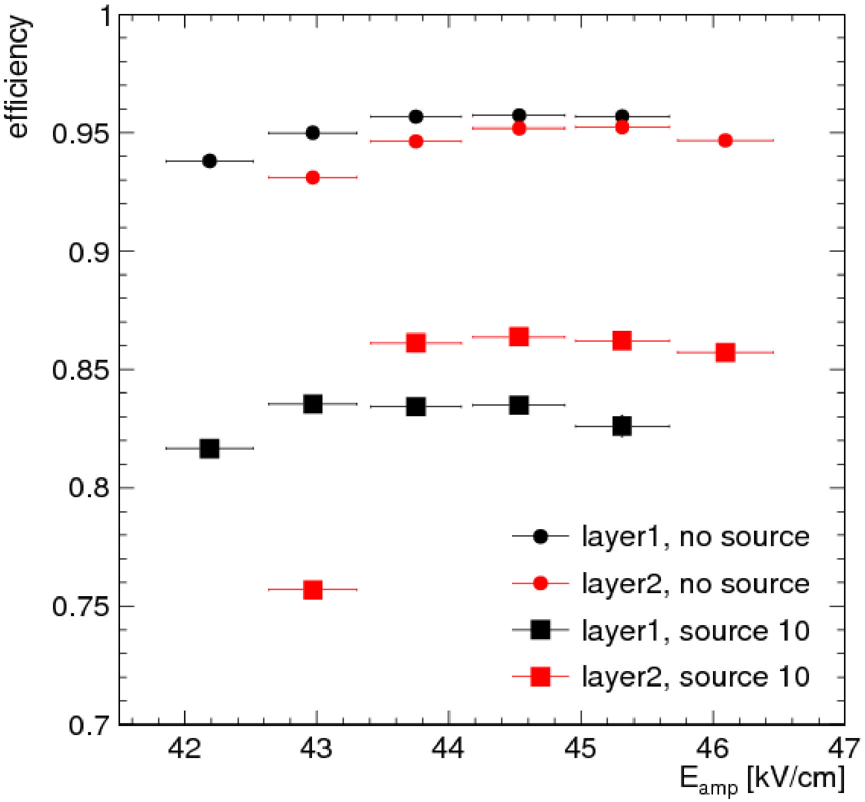
- minor worsening with gas gain increase: increasing efficiency to background

Efficiency

efficiency vs drift field



efficiency vs amplification field



no background

- above 95% for medium fields

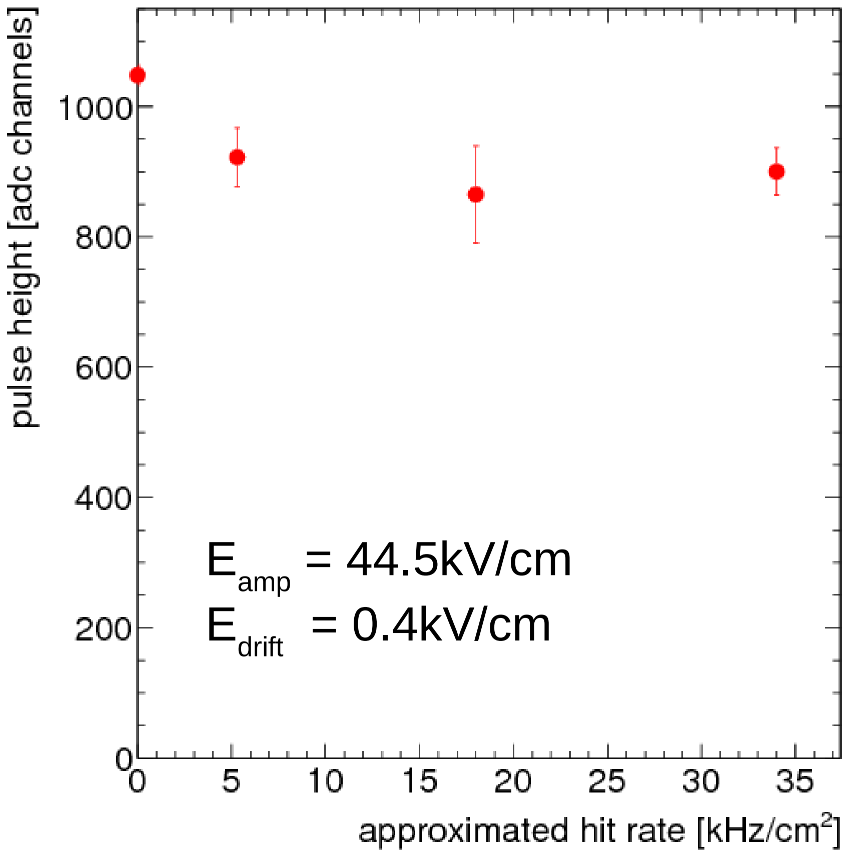
with high-rate background

- tolerable degradation
- correlation with spatial resolution

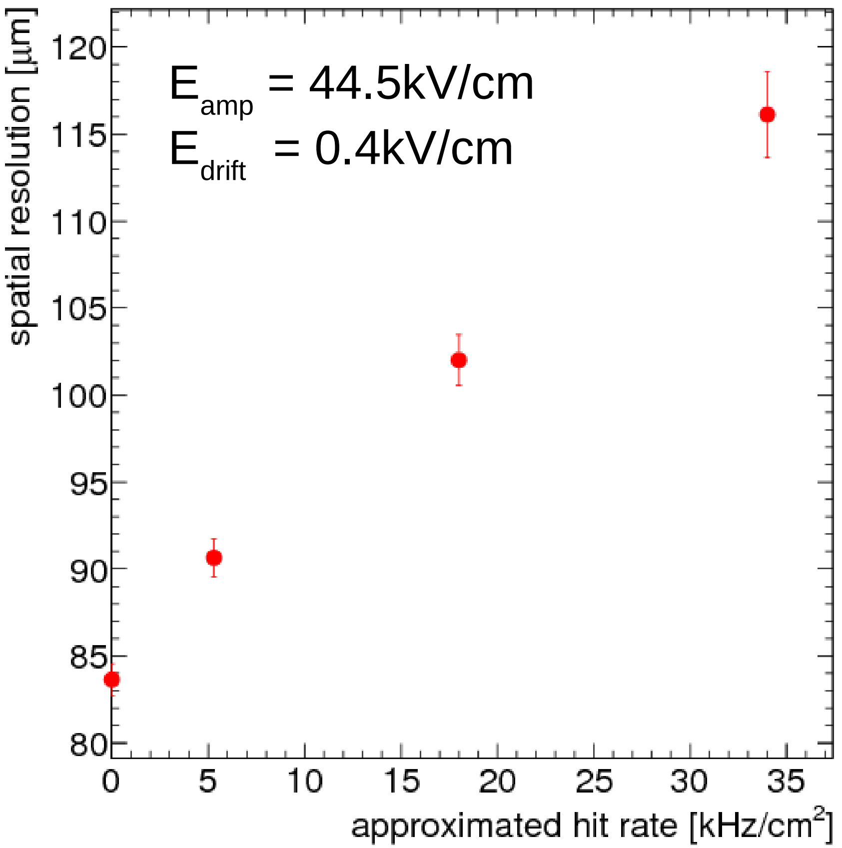
- increase with increasing gas gain
- large field: APV saturation

Pulse Height & Spatial Resolution vs Hit Rate

pulse height layer2 vs hit rate



spatial resolution layer2 vs hit rate



- 15% pulse height reduction @ 34kHz/cm^2
- muon well distinguishable from background

- 100µm spatial resolution at hit rate > maximum hit rate New Small Wheel

Summary

- first resistive strip Micromegas quadruplet constructed and built
  → **concept study** for large area and large size applications
- cosmics: homogeneous **detection efficiency above 95%** in all four layers
- X-Ray scans: good gas gain homogeneity ± 20%

muon reconstruction capabilities in high-rate photon background

- extended tests in GIF++ @ SPS/CERN
- **muon identification** at 18 kHz/cm² is **well possible** (>maximum hit rate in New Small Wheel)
- **spatial resolution** better than **105µm** at 18 kHz/cm²
- efficiency above 95% without background and above 85% at 18 kHz/cm²

outlook

- analysis of inclined particle track reconstruction currently ongoing
- continuation of aging tests in GIF++

Thank you!