High granularity resistive Micromegas for future detectors

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The RHUM project

RHUM

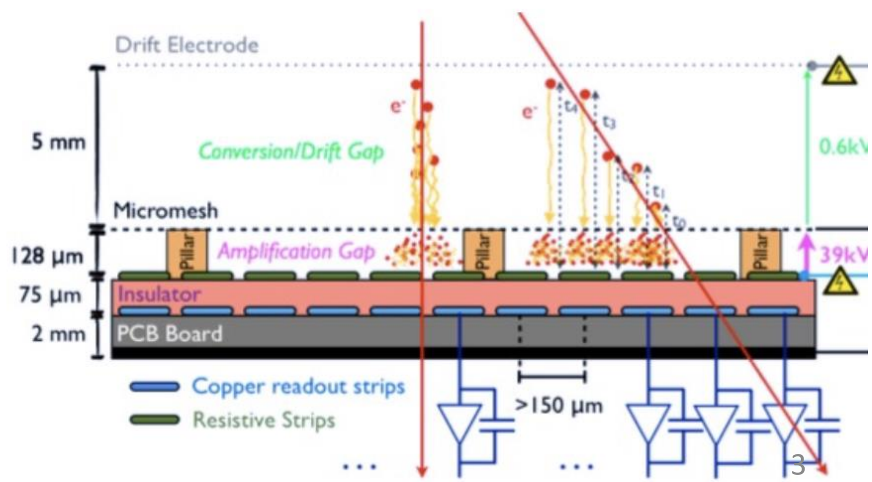
Resistive
High
gran**U**larity
Micromegas

- Consolidation of resistive Micromegas for measurements at rates up to several MHz/cm^2
- High-granularity low occupancy readout on pads of the order of mm^2, for good spatial resolution and capable of withstanding high radiation
- Optimize the spark protection resistive scheme to achieve stable operation at high rate and gain
- Demonstration of the scalability of detectors on large surfaces
- Simplification of the construction technique for industrial production

Micromegas Detectors

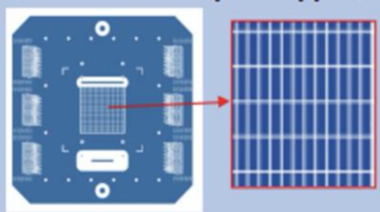
- Resistive Micromegas developed from a dedicated R&D for ATLAS NSW →
  - resistive anode strips on the top of the readout strips (with insulator in between) to suppress discharge intensity
  - The signal is capacitively induced to the readout strips

- now operational in ATLAS → demonstrated to be a solid detector technology for HEP experiments

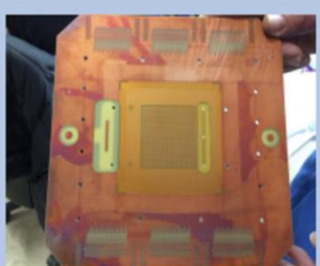


The small-size Prototypes

Readout PAD anodic plane (common to all prototypes)



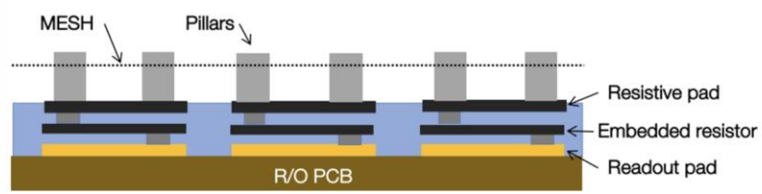
4.8 x 4.8 cm^2 active region
768 pads, 0.8 x 2.8 mm^2 each
48 pads – 1 mm pitch ("x")
16 pads – 3 mm pitch ("y")



Signals routed to six Panasonic connectors

CONFIGURATIONS of the resistive layers
two main categories: Pad-patterned and uniform DLC layers

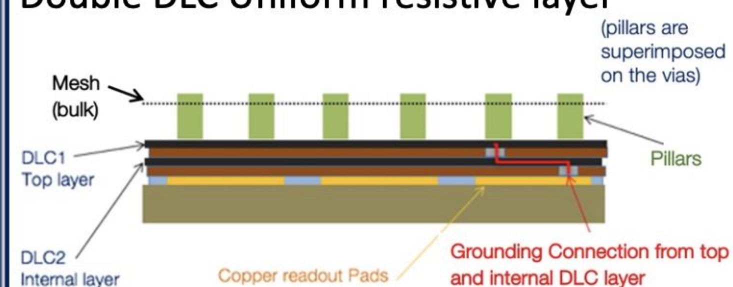
PAD-Patterned



PAD-P3

- EMBEDDED RESISTORS between resistive and readout copper pads
- Each pad completely independent form neighbors

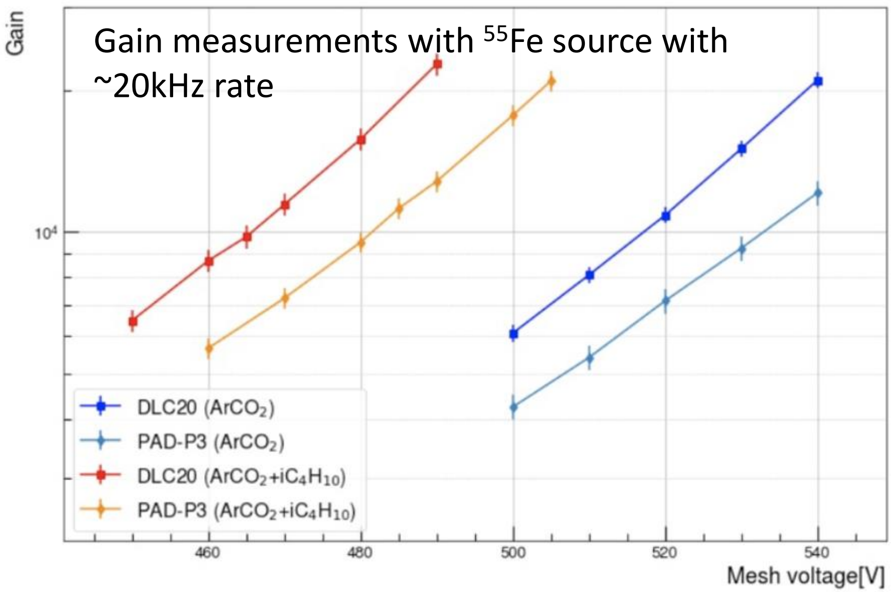
Double DLC Uniform resistive layer



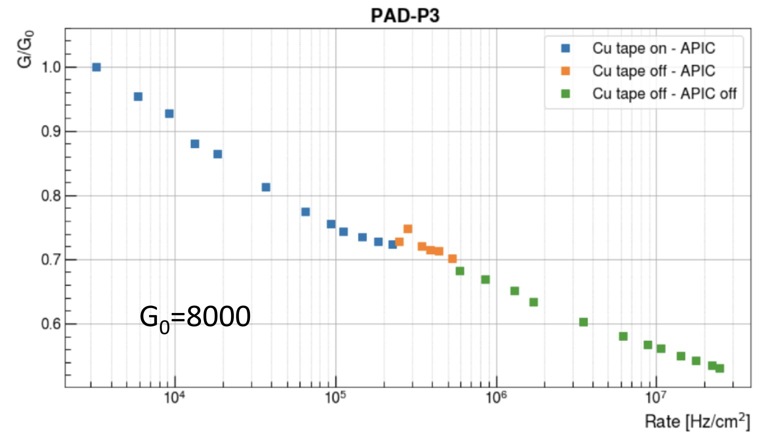
DLC20 (20 MΩ/sq)

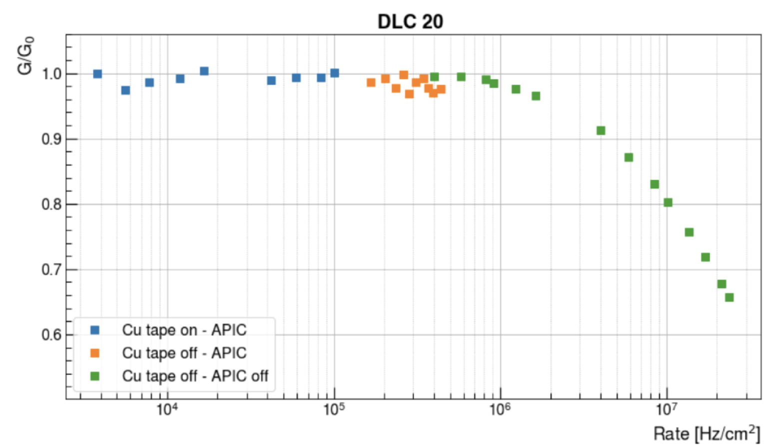
- Uniform double DLC layers with DOT grounding connections

Lab Measurements : Gain and Rate Capability



measurement with 8keV X-rays (x4 ionisation wrt MIPs)





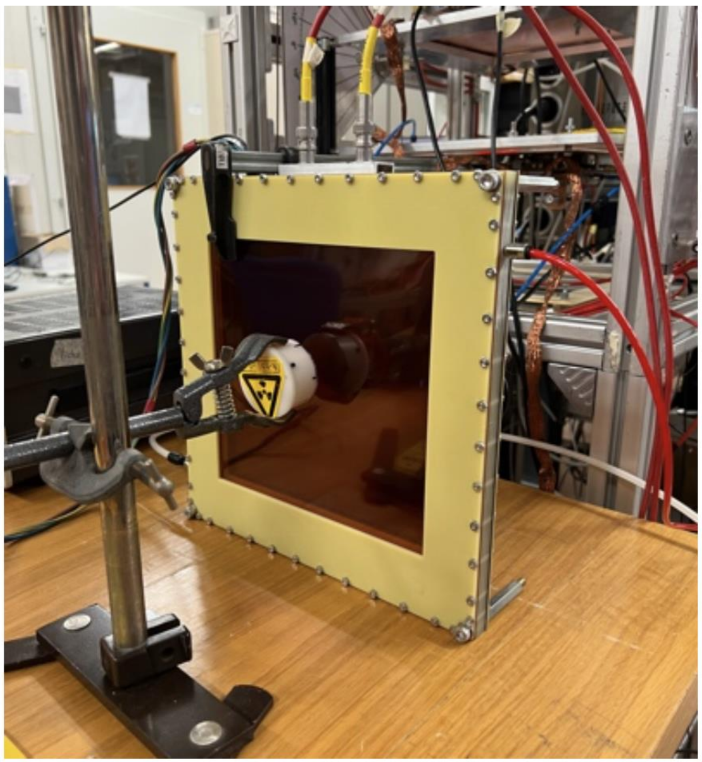
Lower gain of PAD-P type wrt DLC type due to the dielectric charging-up of the kapton surrounding the resistive pads.

PAD-P resistive scheme: relatively fast gain loss due to charging-up

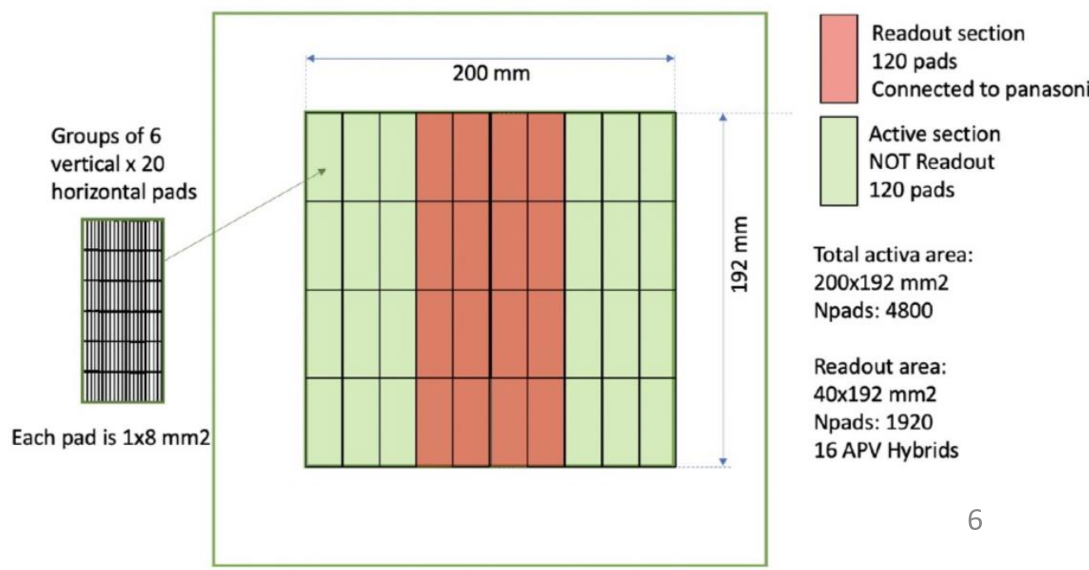
DLC resistive scheme : Gain stable up to >1MHz/cm^2 loss at high rate from ohimc voltage drop

Gain ~20k reached at very high rates (>10 MHz/cm^2) in stable conditions

Paddy400: The 20x20 cm^2 Prototype

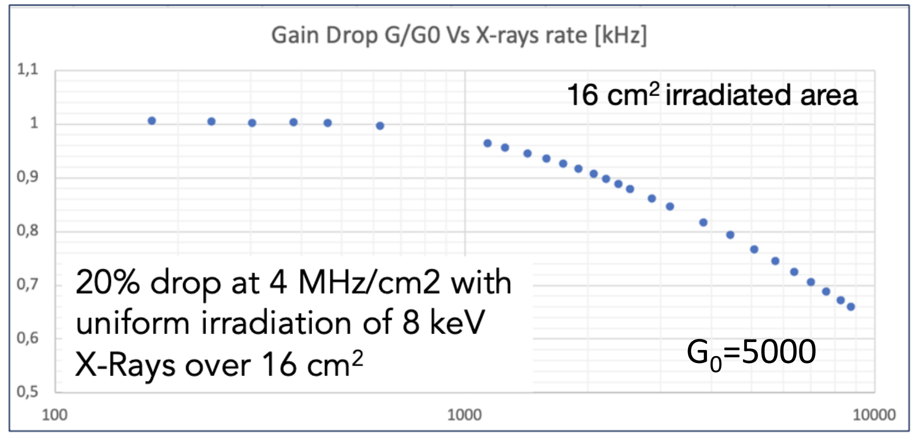


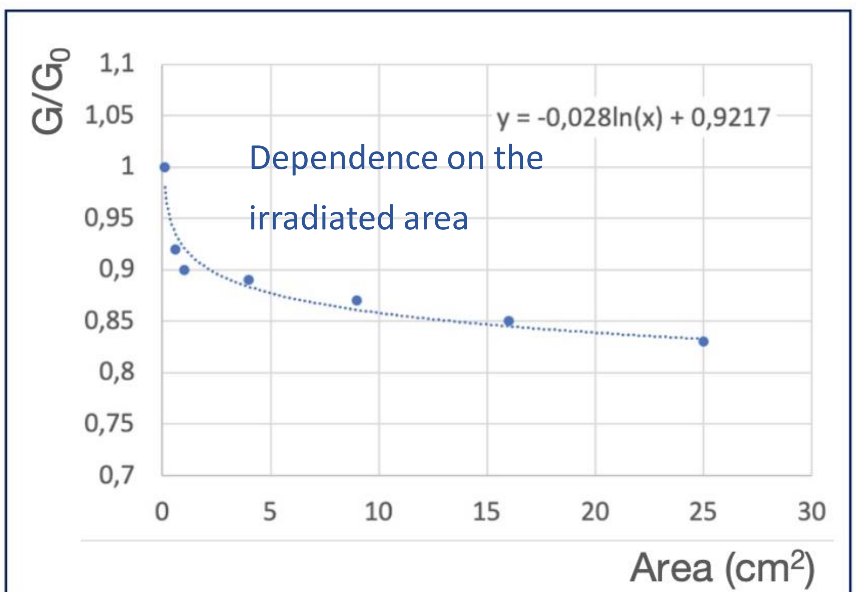
- Active area: 200x192 mm^2
- Pads 1x8 mm^2 - Total Number of Pads: 4800
- Double DLC layer (30-40 Mohm/sq) with grounding vias every 8 mm
- Panasonic connectors on the back of the detector
- Partially readout: 1920/4800 connected pads



Paddy400: Rate Capability

Rate Capability : behaviour similar to small DLC prototypes





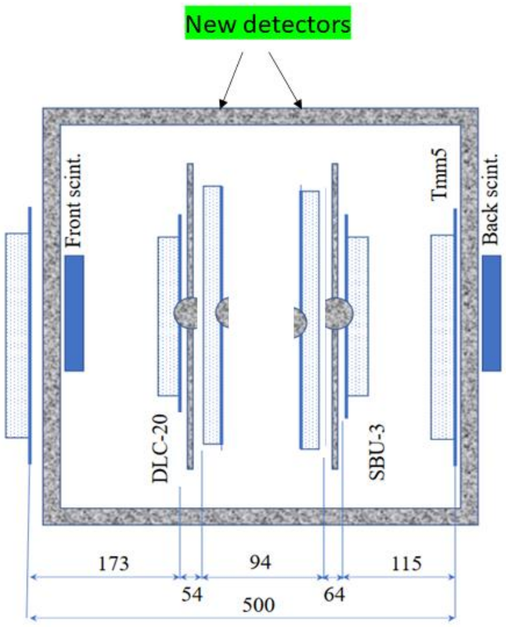
- Fixed rate: 3 MHz/cm² (Equivalent to > 10 MHz/cm2 for MIPs)

- Logarithmic dependence
- G/G0 ~75% extrapolated to 20x20 cm²
    - Can be compensated with +10 V

Test Beams @ CERN H4 beam line

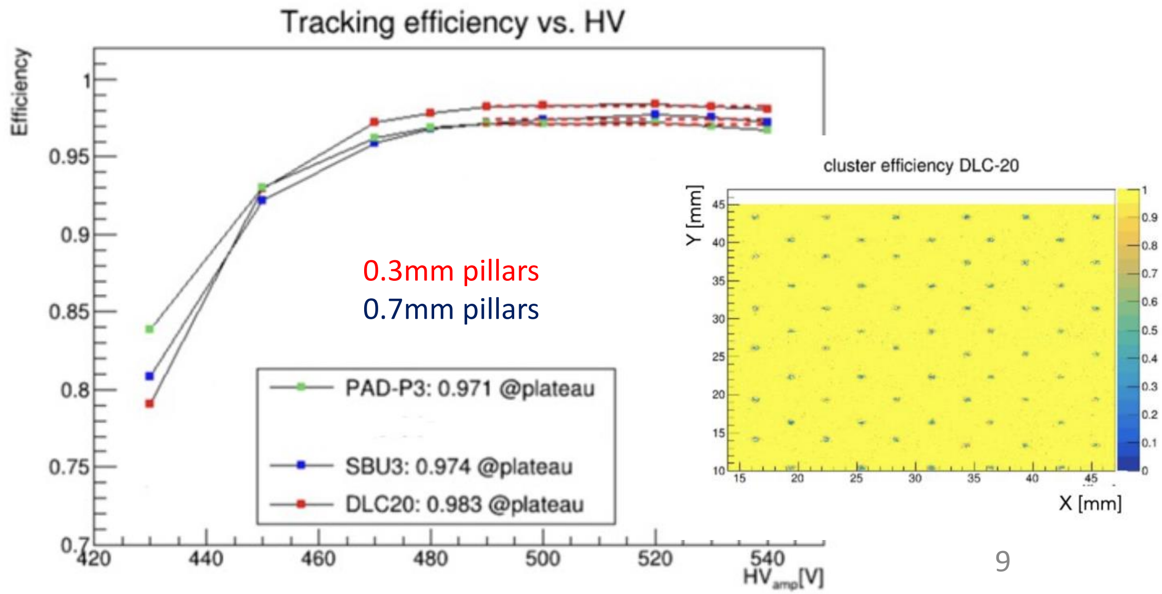
several Testbeams,
different configurations and studies

- July 2023
  - muon beam, 2 small-size prototypes with reduced drift gaps, 2 20x20cm^2 large prototypes, different beam incident angles, fast gas mixure Ar:CF4:iC4H10 (88:10:2)
- October 2022
  - muon and pion beams, 3 small-size prototypes, 1 20x20cm^2 large prototypes, different beam incident angles , different gas mixure for timining studies Ar:CO2: iC4H10 (93:5:2) and Ar:CF4: iC4H10 (88:10:2)
- October 2021
  - muon and pion beams, 4 small-size prototypes, different beam incident angles, different gas for optimisation Ar:C02(93:7) Ar:C02: iC4H10 (88:10:2)
- … 2021 (at GIF++), 2018, 2017, 2016

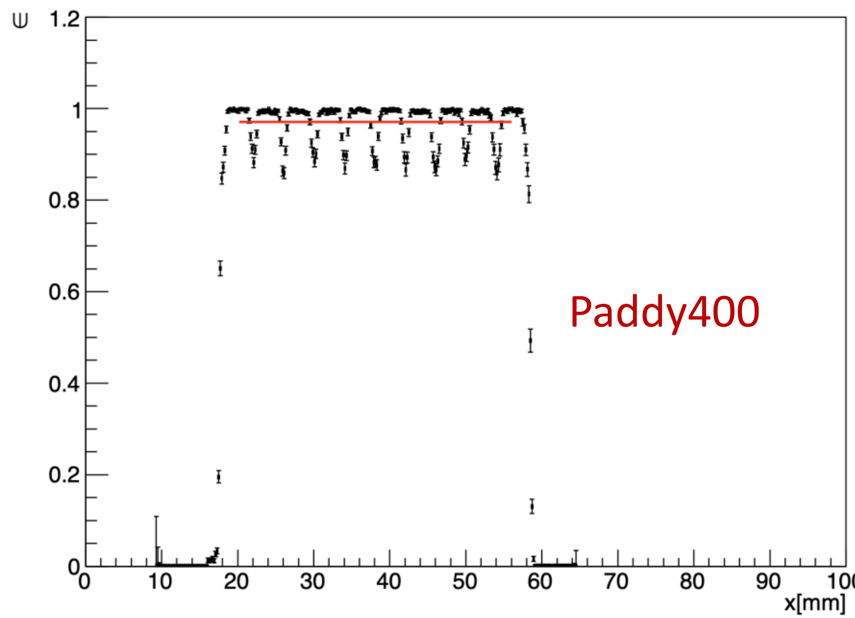


Performances at Test-Beam

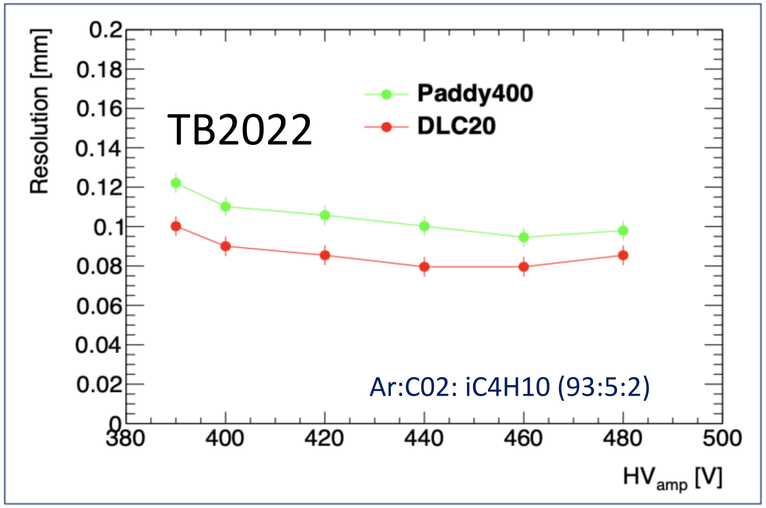
Tracking efficiency:
1.5 mm fiducial range of the clusters wrt extrapolated position from external tracking chambers

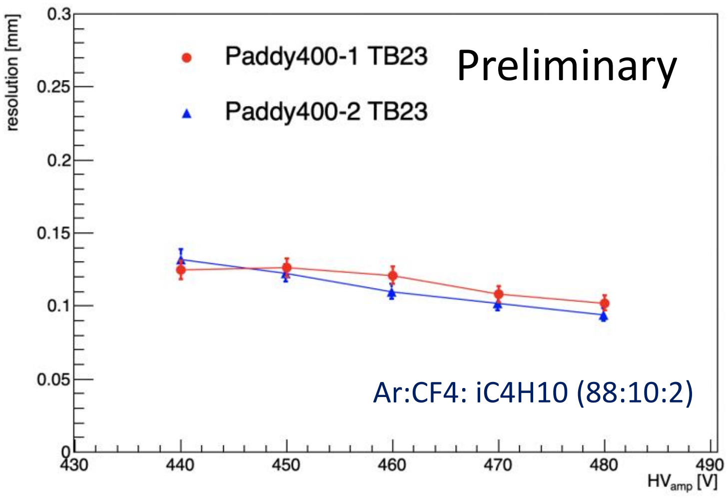


INEFFICIENCIES from local circular pillars



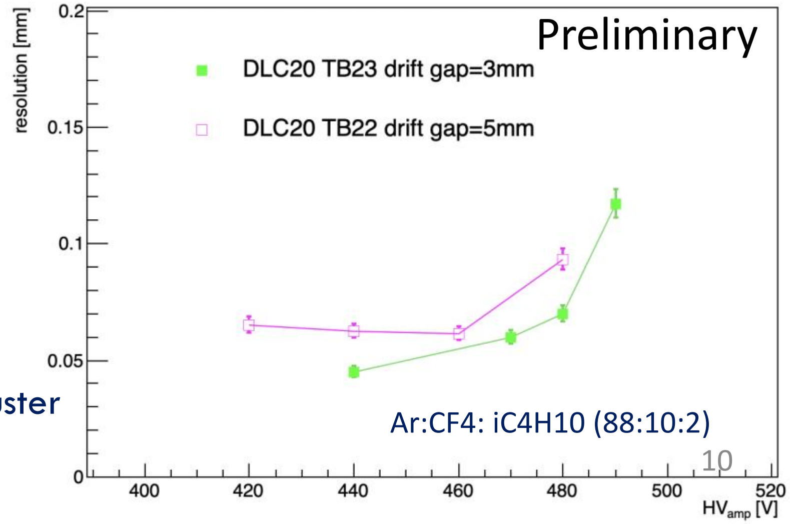
Spatial Resolution



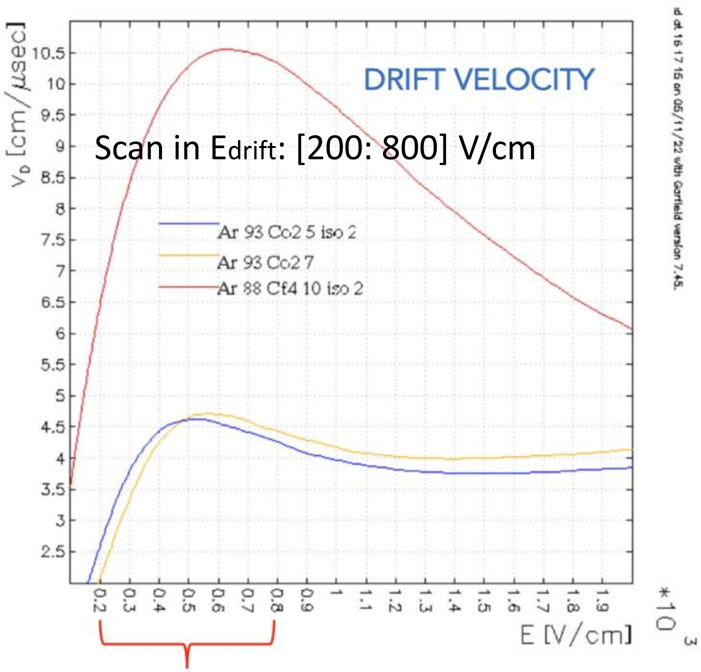


- Unbias position resolution from cluster residuals wrt extrapolated position from external tracking chamber
- extrapolation uncertainty subtracted (~50μm)
- systematic uncertainty (fit procedure) ~5%

- Different resolution according to resistive/coupling scheme
- Large area detector resolution around 100μm
- Stable with different gas mixures and drift gap sizes
- Optimisation charge centroid algorithms to determine the cluster position can improve the resolution

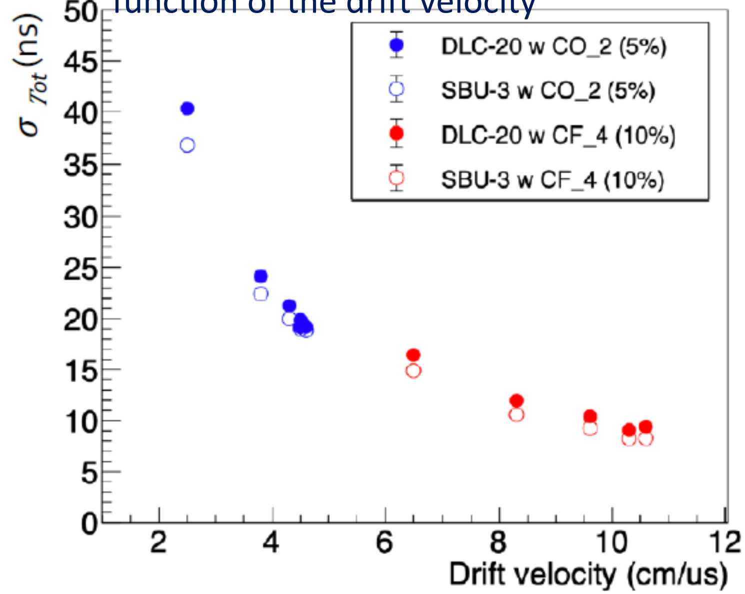


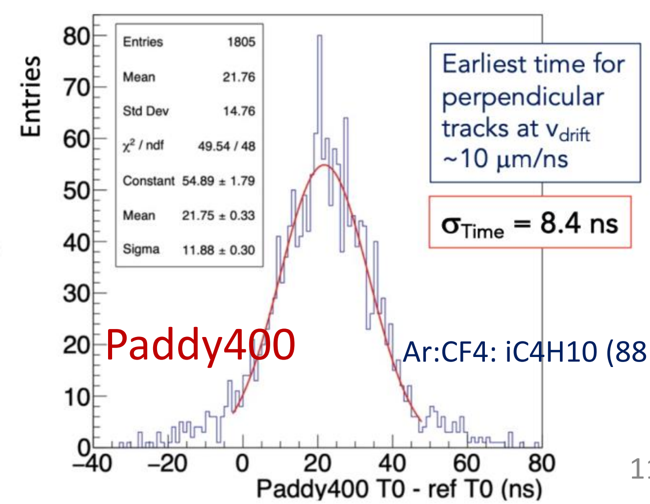
Timing Performance



200 < E_{drift} < 800 V/cm

Measurement of the time resolution as a function of the drift velocity





Ar:CF4: iC4H10 (88:10:2)

Time resolution from differences between the weighted mean time of clusters in two chambers all the pads in the cluster

$$\sigma_T = \sigma_{\Delta T} / \mathrm{sqrt}(2)$$

Includes contribution from electronics

Applications

- Proposed for muon veto for SHADOWS (proposal document in preparation)

- Under consideration : replacement of Muon detectors for AMBER (successor of Compass)

- Ongoing : R&D for sampling Hadron Calorimetry for the Muon Collider

- Possible future applications: detectors for high energy (tens/hundreds TeV scale) and very high intensity new particle accelerators (FCC-ee/hh) or for the Electron-Ion-Collider (EIC)

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

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04/11/2022

SHADOWS

Search for Hidden And Dark Objects With the SPS

Letter of Intent

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Executive Summary

We propose a new proton beam-dump experiment, SHADOWS, to search for a large variety of feebly-interacting particles possibly produced in the interactions of a 400 GeV proton beam with a high-Z material dump. SHADOWS will use the 400 GeV primary proton beam extracted from the CERN SPS currently serving the NA62 experiment in the CERN North area. SHADOWS will take data off-axis concurrently to the HIKE experiment when the P42 beam line is operated in beam-dump mode to accumulate up to $5 \cdot 10^{19}$ protons on target in 4 years of operation. This document describes the main achievements with respect to the Expression of Interest and represents an intermediate step towards the Proposal.

Summary and Outlook

Several Small Pads Micromegas prototypes were built and tested using different resistive layout for spark protection: embedded resistors or using uniform double DLC resistive foils

Performance achieved:

- stable operation up to 10 MHz/cm^2 with gain >10^4
- detector efficiency > 97%
- position resolution < 100 μm
- < 10 ns time resolution

Very promising new large(r) area prototypes built

- Rate capability well beyond 1 MHz/cm^2 with large area irradiation
- Resolutions and efficiencies compatible with smaller prototypes

Future R&D activities:

- tracking in high rate environment, performance studies with larger area prototype, time resolution and ageing studies