The Frontier of Gas Detectors: the micro-RESISTIVE WELL

The Particle Detectives:

M. Poli Lener, G.Bencivenni, M. Gatta, G. Felici, G.Morello

Laboratori Nazionali di Frascati – INFN, Frascati, Italy

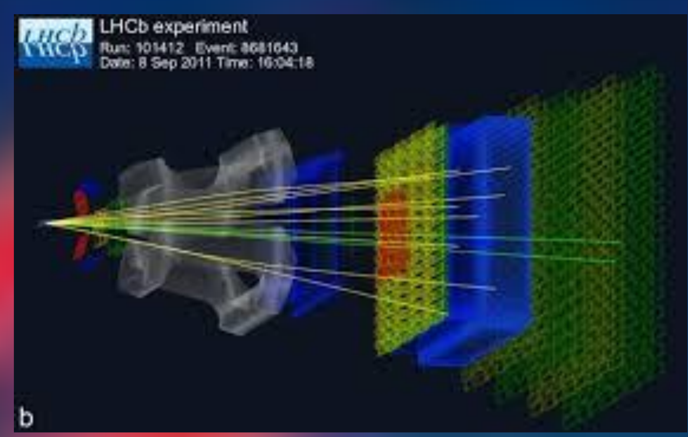
The Detectives Group:
The Detector Development Group (DDG LAB Frascati INFN), has long been involved (since 1985) in the R&D, design and manufacturing of classical gaseous detectors, such as wire tubes operated in proportional or streamer mode (1983-1990), RPC with glass electrodes (1991-1994), large drift chamber (1995-1997) and Micro-Pattern-Gaseous-Detector (MPGDs – since 2000) for large high energy physics experiments.

Muon Apparatus in LHCb

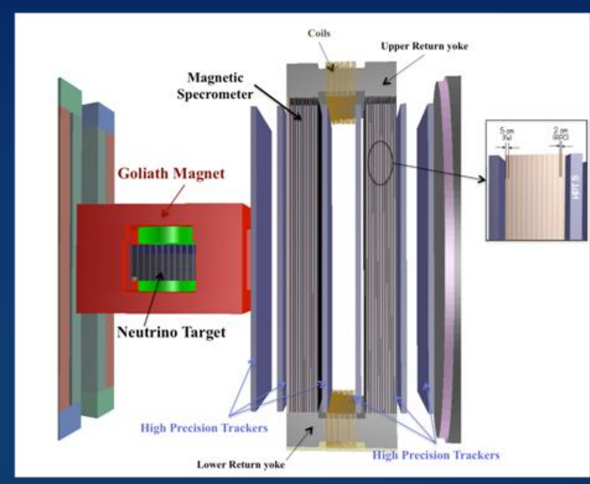
Cylindrical GEM in KLOE

Particle Detectives at Work

The Portfolio:
The R&D activity of DDG on MPGDs focused on GEMs and other innovative architectures in the framework of the LHCb experiment (CERN) with the development of planar GEM detectors (2000-2006), and the pioneering construction of the first Cylindrical-GEM (2006-2013) for KLOE experiment (Frascati).
The last DDG artefact is an innovative gas detector, named micro-Resistive-WELL (μ-RWELL - 2014): a compact MPGD with a single amplification stage based on the "well" concept intrinsically protected against the sparks.
The μ-RWELL has been recently proposed for the upgrade of the Muon stations of the apparatus of the LHCb experiment as well as Target Tracker of the SHIP experiment at CERN.



Future Upgrade of the Muon Apparatus at LHCb



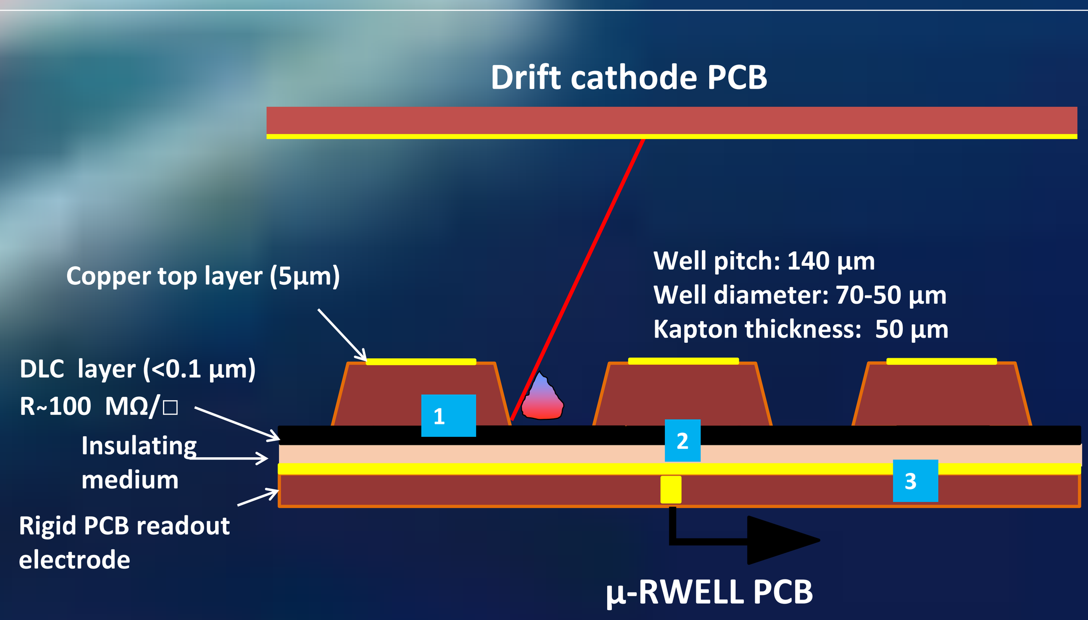
Sketch of the SHIP Experiment

The μ-RWELL Architecture

The μ-RWELL consists of two elements: the μ-RWELL_PCB and the cathode

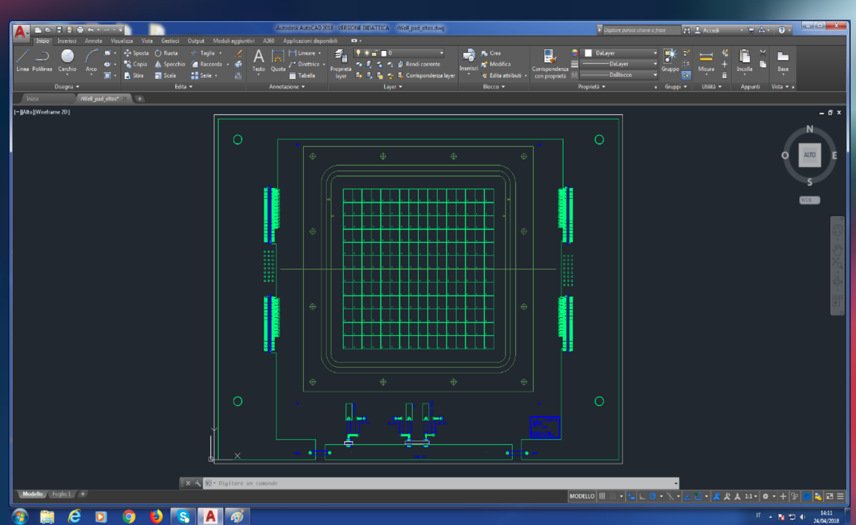
The μ-RWELL_PCB, the core of the detector, is realized by coupling:

1. WELL patterned kapton foil as amplification stage
2. resistive layer for discharge suppression & current evacuation:
   i. Single resistive layer <100 kHz/cm²: single resistive layer → surface resistivity ~100 MΩ/☐ (LHCb-Muon Upgrade & SHIP experiment)
   ii. Double resistive layer > 1 MHz/cm²: more sophisticated resistive scheme must be implemented suitable for LHCb-Muon upgrade & future experiment at future collider (FCC-ee/hh & CepC)
3. a standard readout PCB



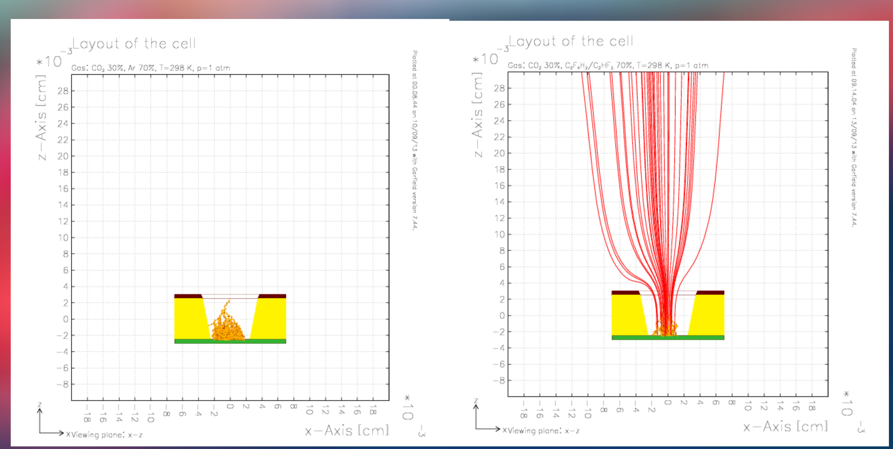
G. Bencivenni et al., 2015_JINST_10_P02008

The μ-RWELL Step by Step



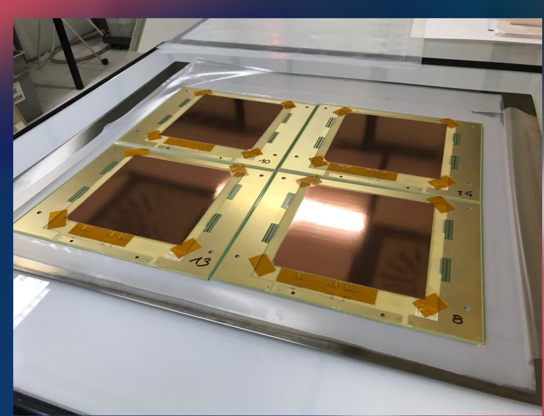
CAD Detector Design

MonteCarlo simulation

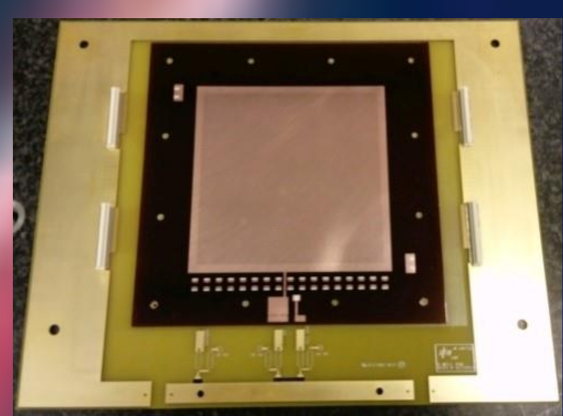


Orange lines represents the electron inside the well

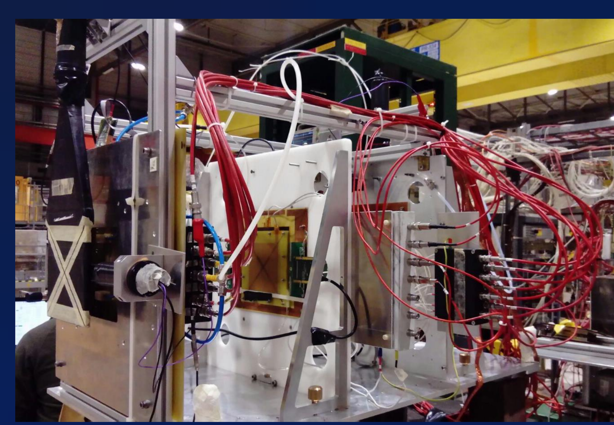
Red lines represents ions backflow towards the cathode



μ-RWELL_PCBs construction at ELTOS



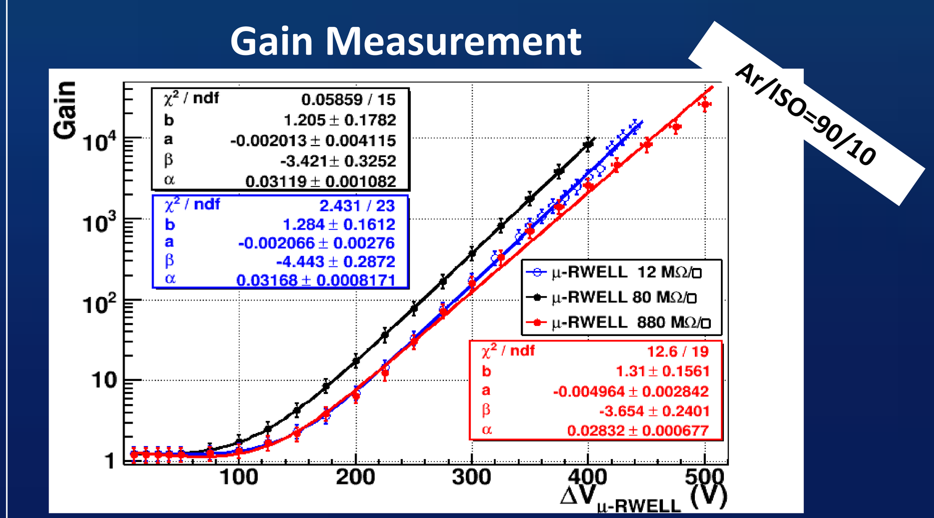
Quality Control & Detector Assembly



Detector test with muon/hadron beams

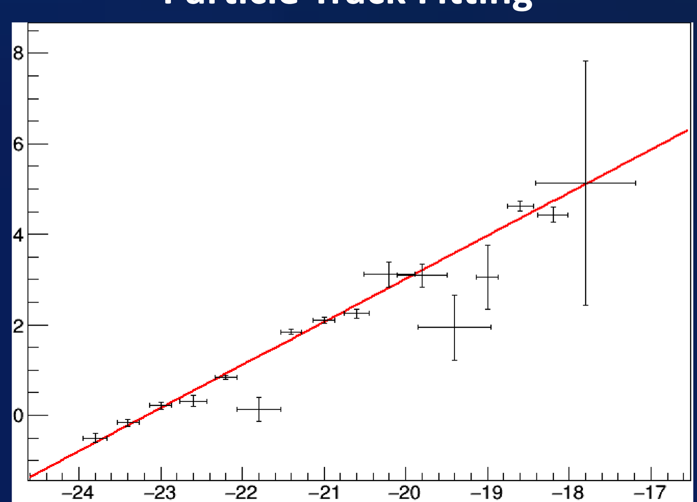
Detector Performance

Gain Measurement



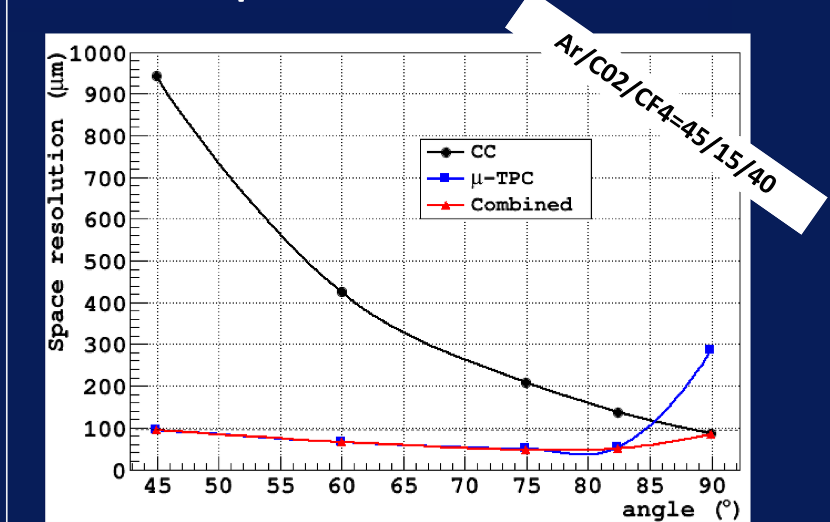
The prototypes, with different surface resistivities, have been tested with X-rays with several gas mixtures in current mode. Detectors safely reach a gain ≥ 10000

Particle Track Fitting



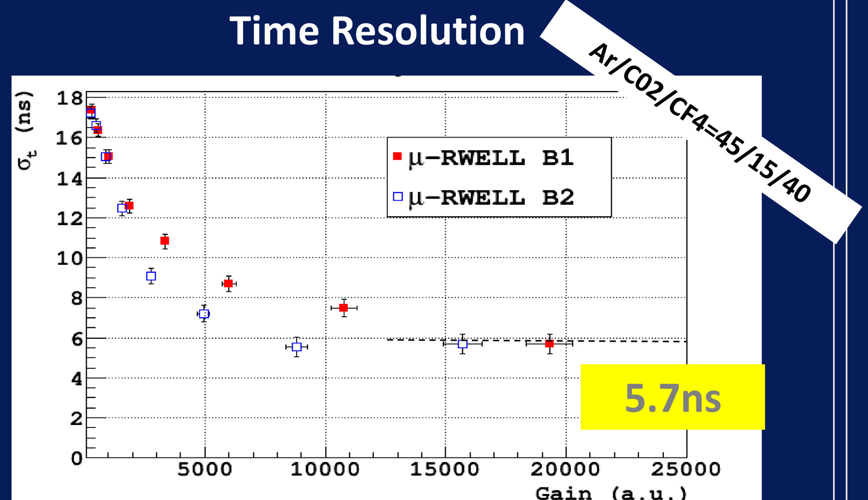
Reconstruction of inclined muon particle obtained with the μ-TPC mode

Space Resolution



Improving space resolution for inclined tracks: the combination of the Charge Centroid and the μ-TPC mode allows to achieve a space resolution below 100 μm

Time Resolution



A time resolution of 5.7 ns has been measured with fast electronics

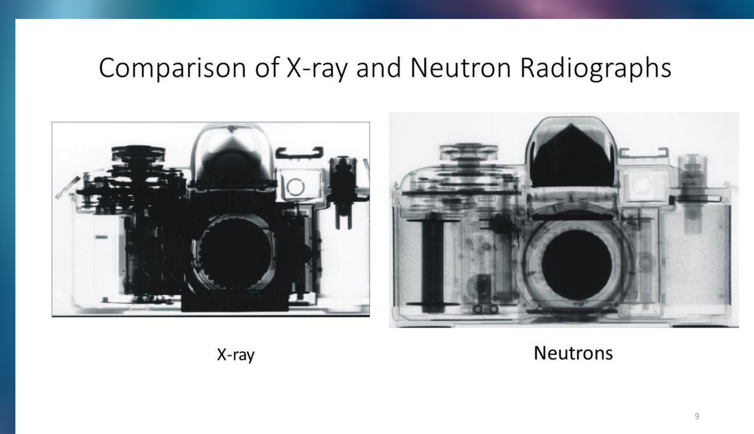
Applications Beyond High Energy Physics (HEP)

Gamma & X-ray
The μ-RWELL represents a suitable solution due to its compactness, construction simplicity and operational stability for non-HEP applications:

For the gamma detection, the detector must be equipped with a proper converter: just a fraction of photons interacting with the detector extracts a Compton electron; if this is emitted in the active gas volume then is detected with high efficiency (>98%). The compactness helps for the realization of a stack of detectors.

For X-ray detection in the keV energy region, the photons are converted in the gas volume of the device. A proper segmentation of the readout (pixel) bonded to an on-board front-end electronics, would allow the use of μ-RWELL for fine X-ray imaging, exploitable for medical, industrial, material science and archaeology diagnostics.

Neutron detection
Thermal neutrons can be also exploited for radiography: they are mostly stopped by light elements being then suitable for inspections within metallic shields.
A pixelated μ-RWELL represents a break-through in neutron imaging technology. Neutrons are converted in alpha particles on the boron sputtered cathode.
The layout of the readout should then be very similar to the one proposed for X-rays detection, in order to perform a 3D reconstruction of the charged particle path.



Radiation Portal Monitor for homeland security

Setup for X-ray test and X-ray recording of a crash-test dummy seated in a Smart