μRtube

a new geometry concept for MPGD detectors

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on behalf of Ferrara, Turin and LNF INFN sections

µRtubes in a nutshell

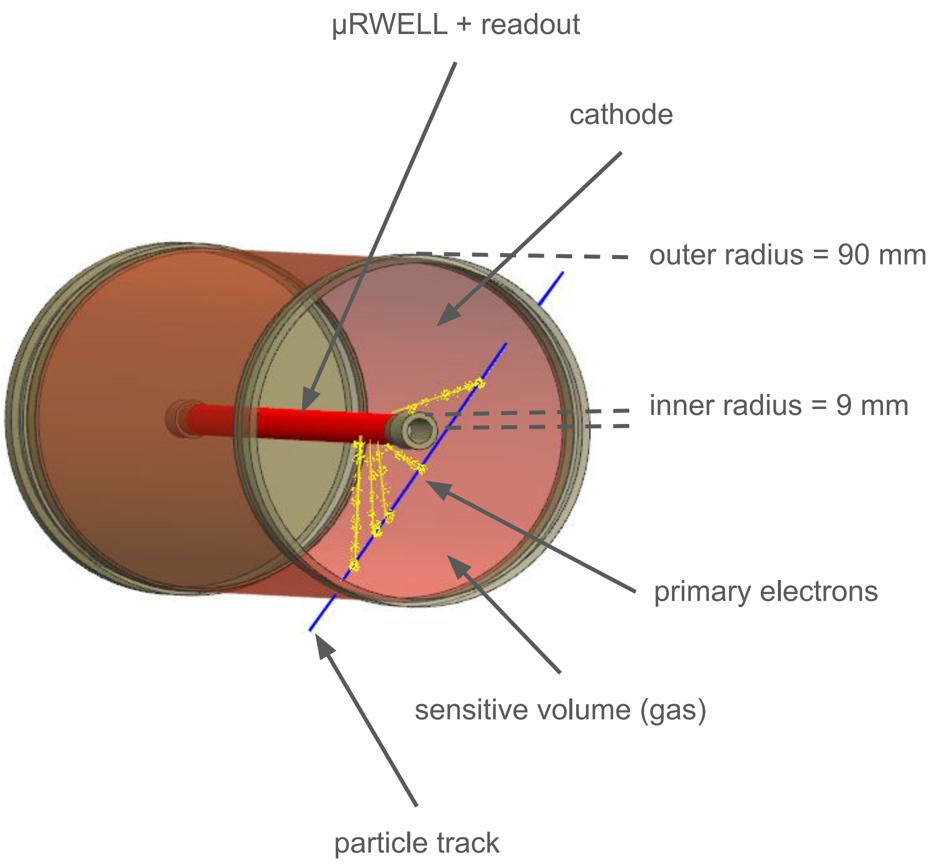
The basic idea is to develop a **tubular MPGD** working as a radial TPC: the readout on the inner cylinder and the cathode on the outer one.

The signal is **amplified** by a µRWELL as a single stage amplification and the readout is instrumented with strips parallel to the axis.

The main concept of the project is based on the convergent electrical field lines which introduce two important points:

1. it reduces the transverse diffusion of the electrons

2. it **minimizes the number of channels** with respect to the sensitive volume



State of the art

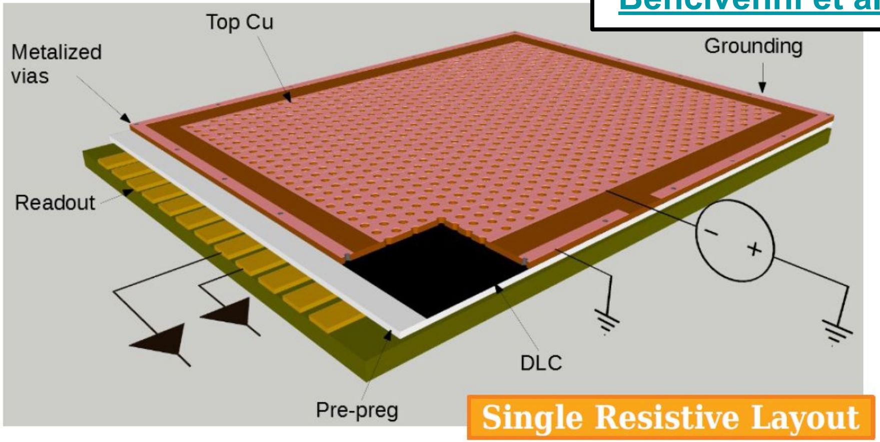
µRWELL technology

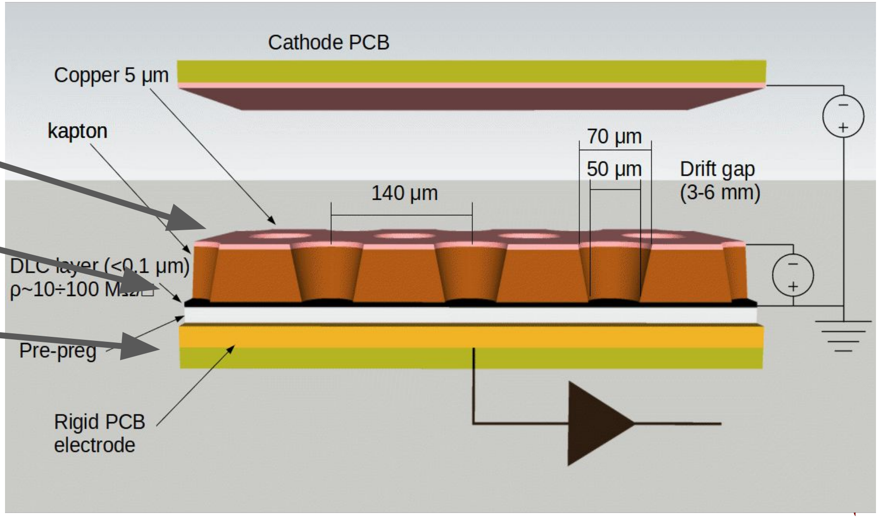
[Bencivenni et al.]

The µRWELL is a Micro Pattern Gaseous Detector (MPGD) composed of only two elements: the µRWELL-PCB and the cathode. **The core is the µRWELL-PCB**, realized by coupling three different elements:

1. a WELL patterned kapton foil acting as **amplification stage** (GEM-like)
2. a resistive DLC layer (**Diamond-Like-Carbon**) for discharge suppression w/ surface resistivity ~ 100 MΩ/□
3. a standard **readout PCB**

The **construction technique is simplified** with respect to GEM or MicroMegas





Cylindrical MPGD

Balossino et al.

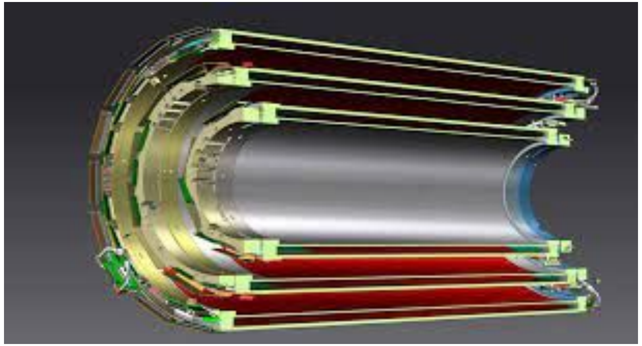
PCB and amplification stages used in MPGD can be shaped to cylinders;
examples are the triple-GEM for the IT in **KLOE-2** and **BESIII**, and the µRWELL for **EURIZON**

Curvature radius in literature ranges from 77 mm to 205 mm.
µRWELL technology, with a single stage of amplification, has an easier construction.

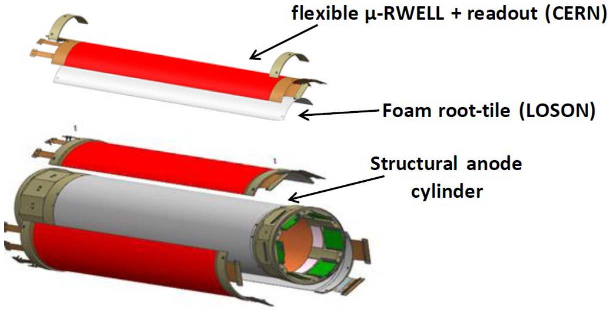
The shapeability of the MPGD is the initial driver of the µRtube idea

Cylindrical triple-GEM **KLOE-2**

Cylindrical triple-GEM **BESIII**



Cylindrical µRWELL **CREMLINplus**



TIGER for signal readout

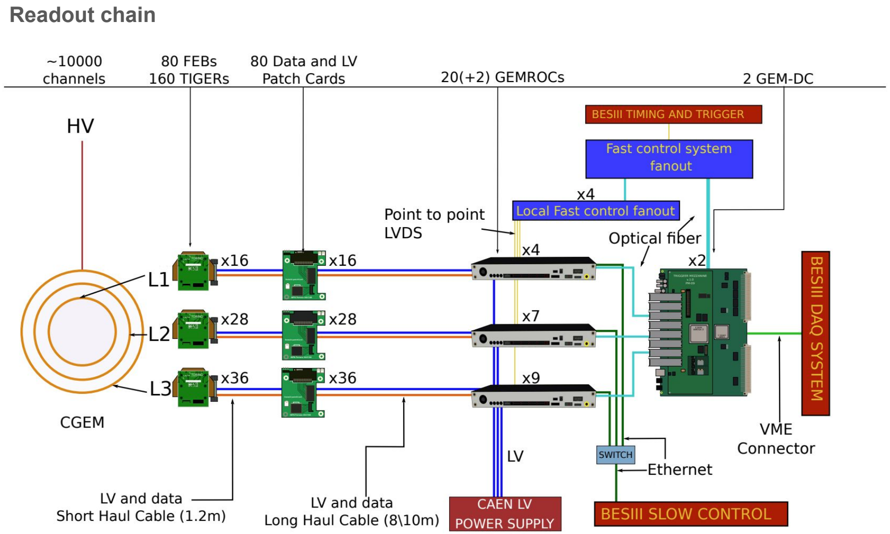
Amoroso et al.

TIGER chip features:

- 64 channels
- Event rate 100 kHz/channel
- Input dynamic range up to 50 fC
- Time resolution < 5 ns
- ENC < 2000 e$^-$ rms with 100 pF input capacitance

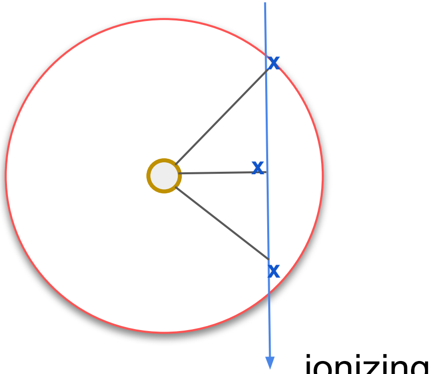
Readout chain:

The full readout chain proposed is well known. A complete setup is under deployment in Beijing for the BESIII CGEM-IT where a cosmic ray data taking is ongoing since Dec. 2019



Innovations

µRtube reconstruction method



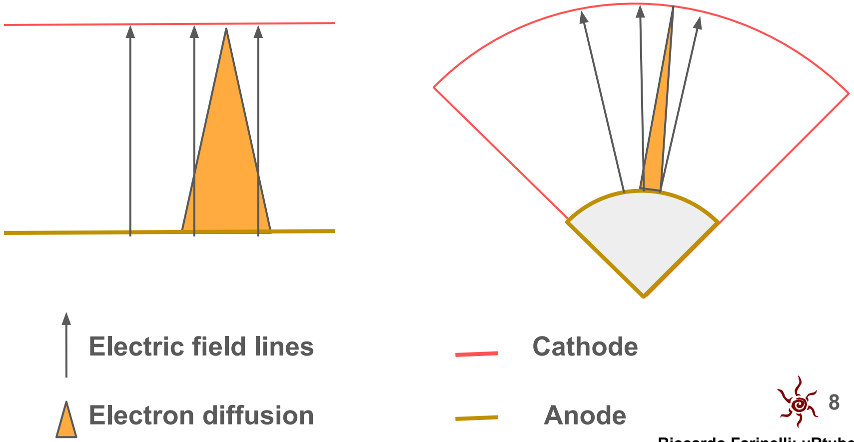
Time information together with the drift velocity can be used to reconstruct the particle path in the gas volume therefore the impact parameter.

The reconstruction method resembles a drift tube, except it uses 128 strips instead of a wire.

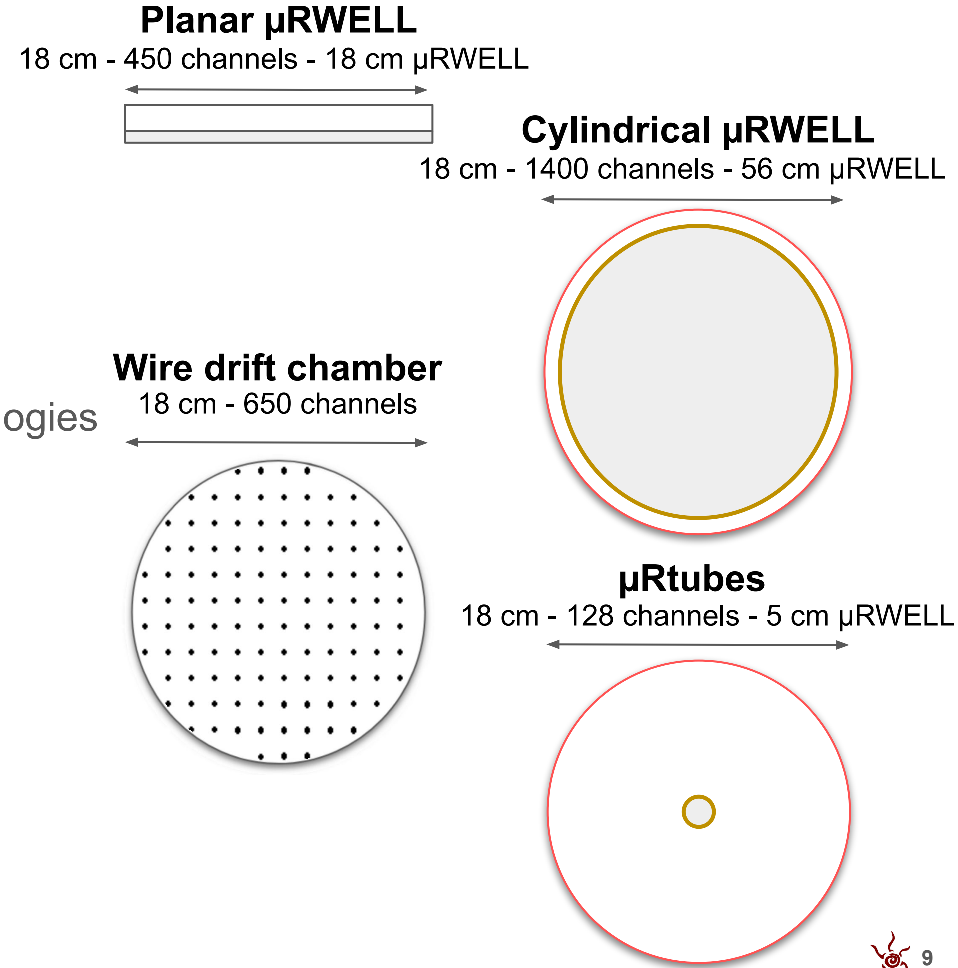
The electric field lines in a **planar geometry** are parallel and the electron diffusion depends on the drift path.

In a **cylindrical geometry** the field lines are convergent and the electron diffusion is strongly reduced even with large drift paths.

i.e. for 8cm drift length and 5000V the transversal diffusion goes from 1mm to few µm while the temporal diffusion has similar values.



Channel number comparison

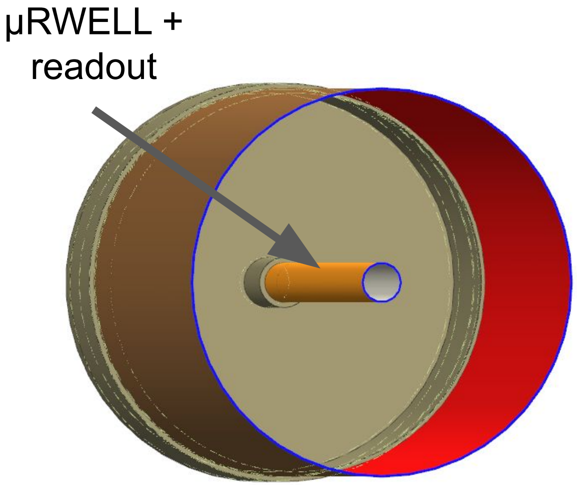


The µRtube geometry reduces the number of strips/wire/channels with respect to other technologies with similar dimension but different geometries.

This has a large impact on the **detector cost**.

Construction

Mechanics, design and construction



The first challenge of this project is to shape a µRWELL at this unprecedented **curvature radius of 9mm**.

Using a flexible PCB approximately 150µm thick, a specific procedure can be employed to achieve success without causing damage to the amplification stage.

Mechanics, design and construction

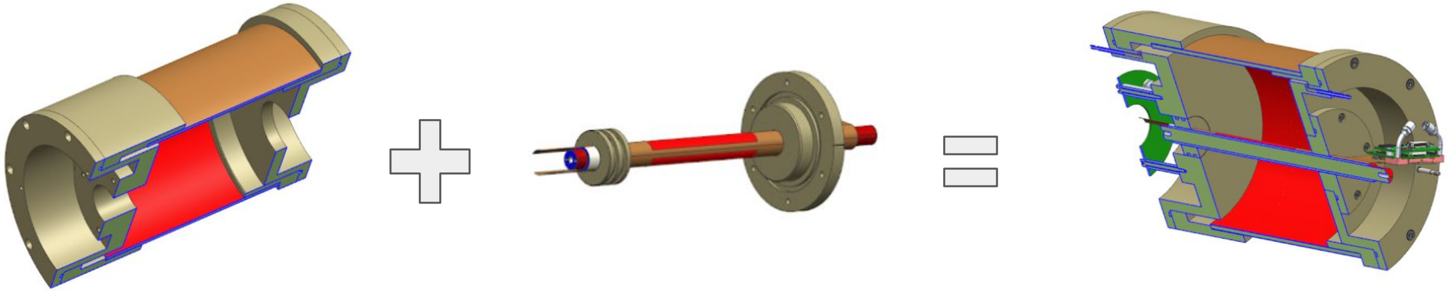
Inner radius	= 0.9 cm
External radius	= 9 cm
Length	= 10 cm

The mechanical support of the cathode is built up by a **fiberglass, kapton and honeycomb sandwich**.

Flanges will seal the gas volume and provide the support for the services (gas, HV, FEB) are built by **PEEK**.

The detector will be **easily open** in case of failure of the component or replacement of the cathode/readout.

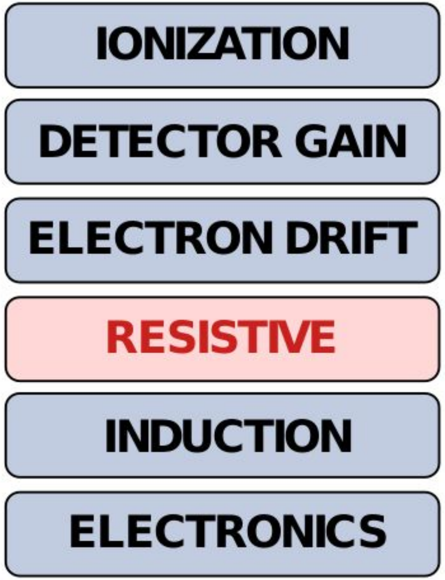
μRtube have cleaned successfully by Rui.



Simulation

Full detector simulation

Farinelli et al.



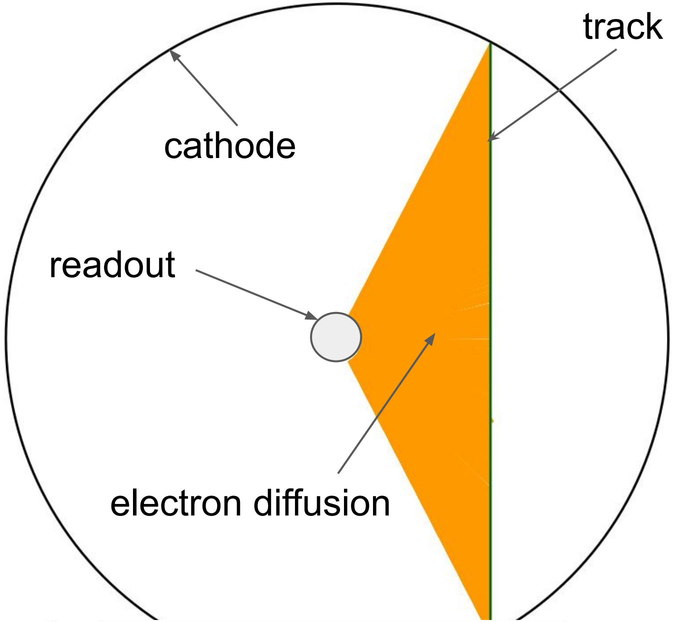
A full complete simulation consist of a **parametric** description of the **detector response** thats includes the detector **geometry** and the **signal** reconstruction.

The full simulation is divided in different physical processes.

The μ-RWELL parametrization with PARSIFAL is been presented in previous RD51 collaboration meeting

To achieve the complete μRtube simulation, the new electron drift parametrization and new electronics (TIGER) are implemented.

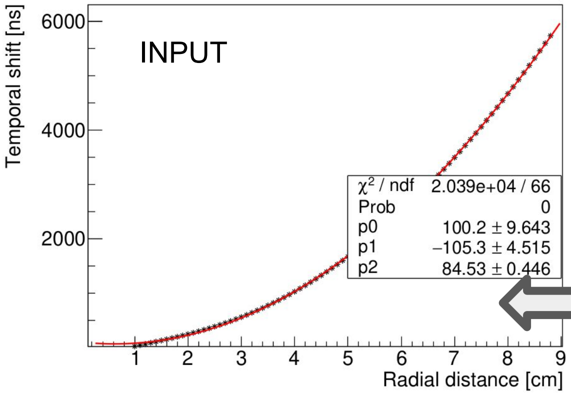
Full detector simulation - Electron drift

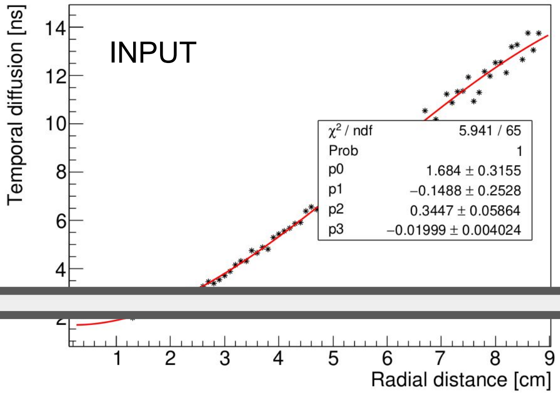


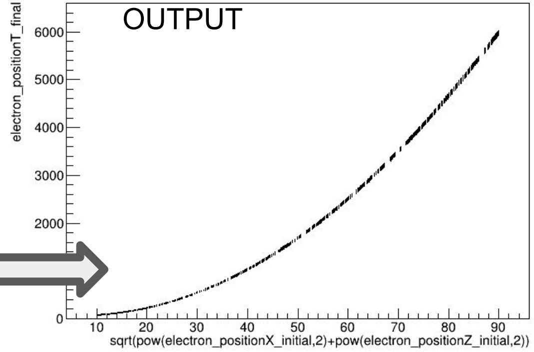
A study performed with GARFIELD++ generated a map of spatial and temporal **diffusion** of the primary electrons as a function of the readout distance.

Different gas mixture and HV configuration will be tested.

-> Parametrization of the electron drift property







Cossio F.

Full detector simulation - TIGER electronics

TIGER electronics is simulated for the first time together with μRWELL.

A different transfer function is used for each branch (T and E).

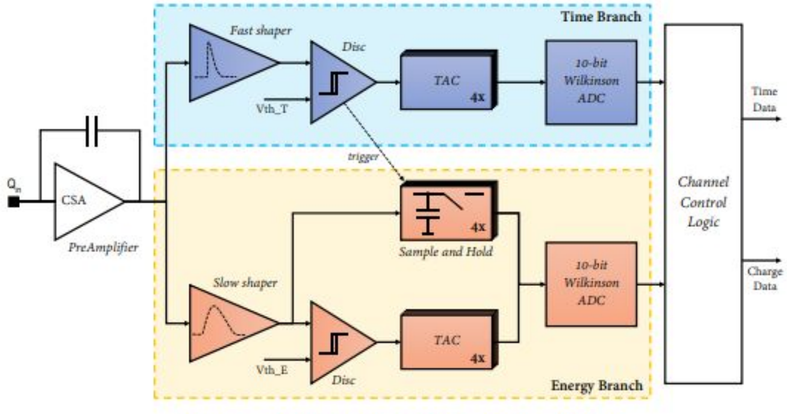
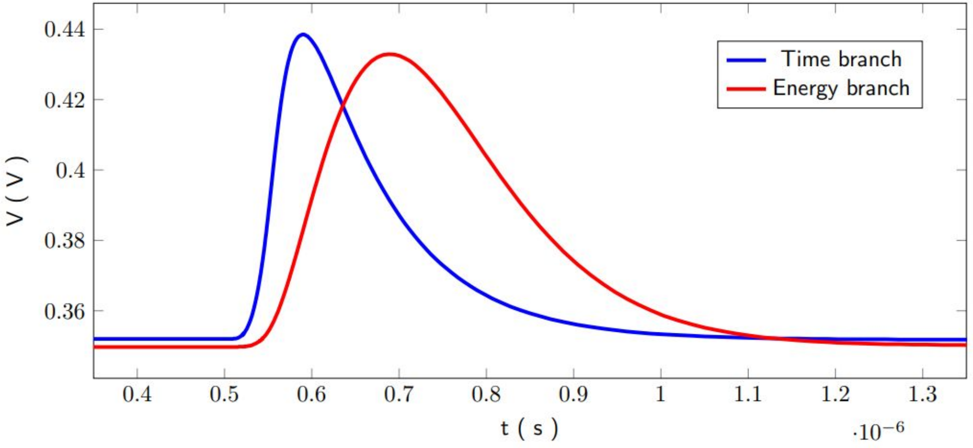
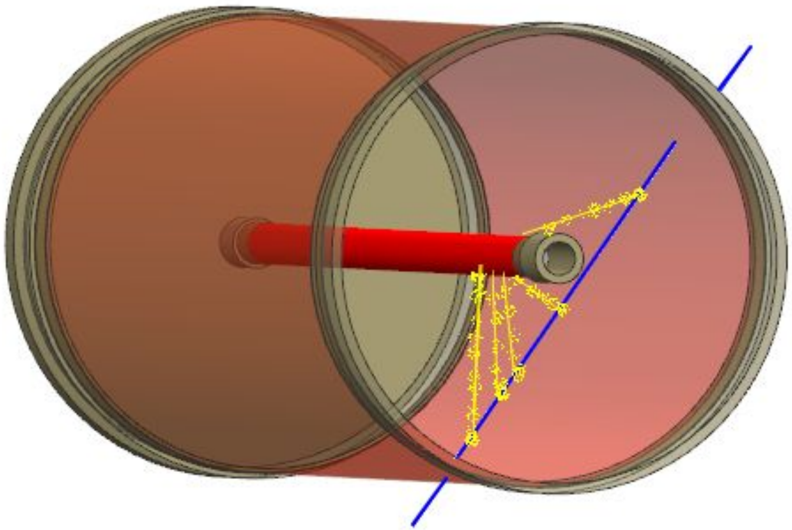
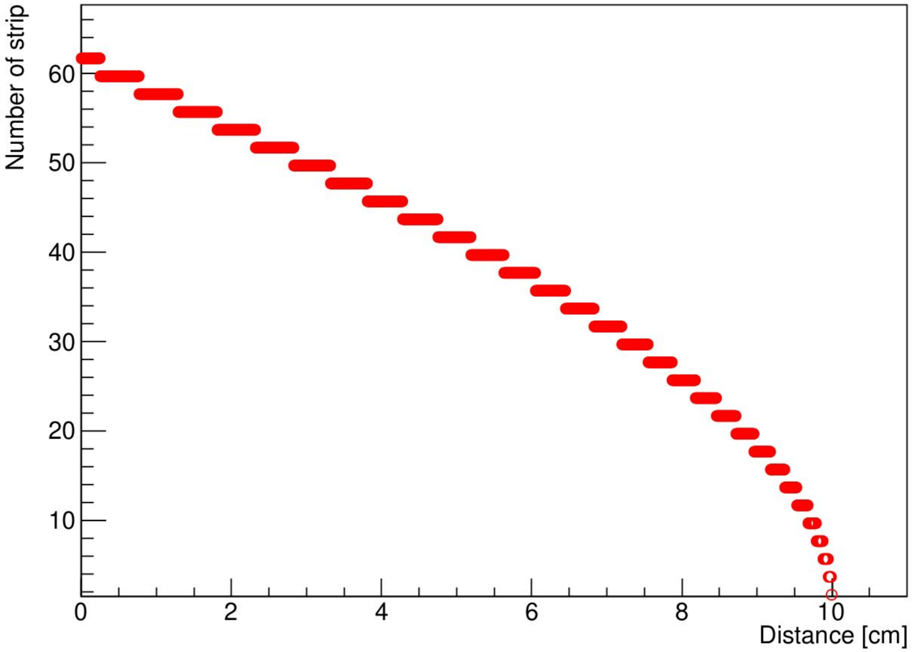


Figure 3.1: TIGER channel architecture scheme.



Strips involved as a function of the distance from the center

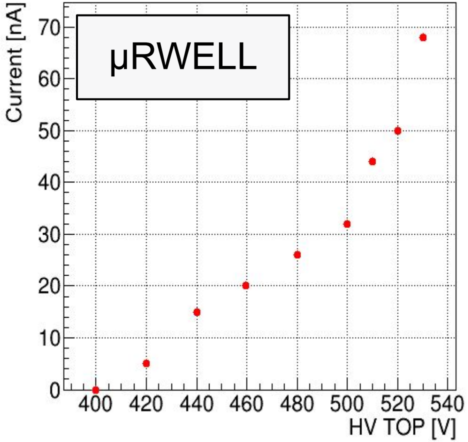




Validation

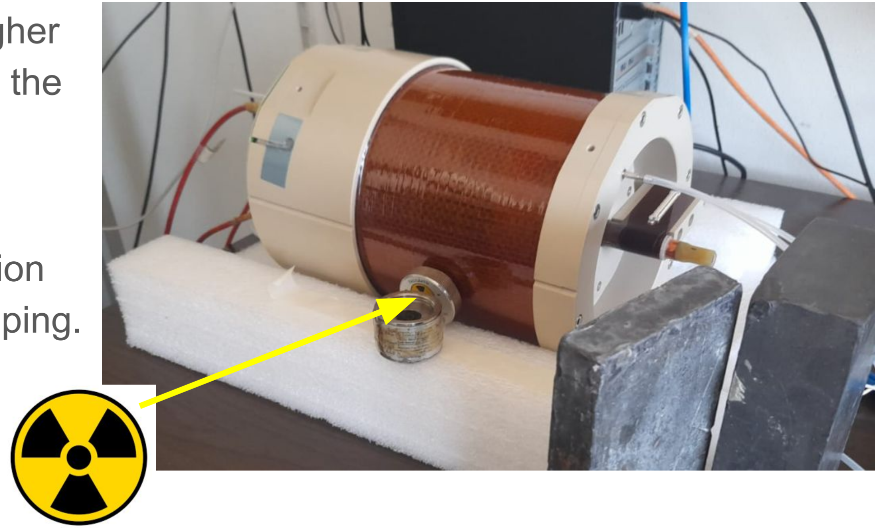
Radioactive source test

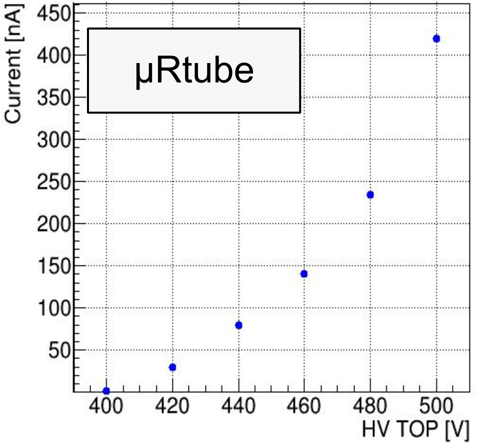
A Sr90 beta source with 4 MBq has been used to test the detector. Thank to the high activity of the source, it is possible to measure the detector gain with a leakage current measurement. The same test has been performed on planar µRWELL and µRtube.



The data show a much higher current in µRtube due to a the larger ionization volume.

The test shown the good operation of the amplification stage after the tubular shaping.





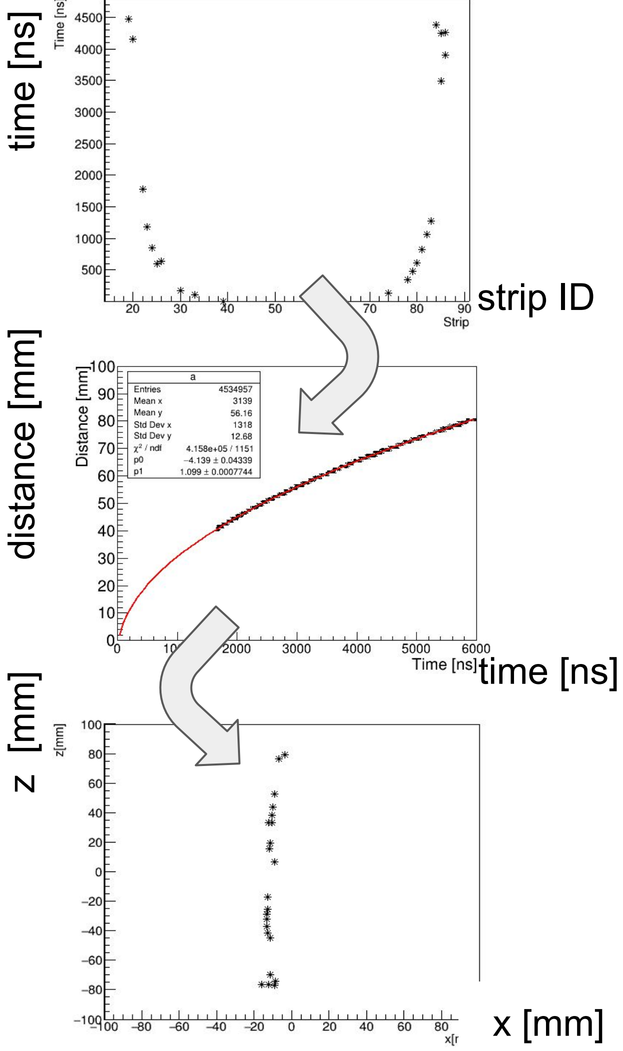
Reconstruction algorithm

Cosmics ray acquisition is performed with **TIGER** readout.

The algorithm developed in the simulation are used to reconstruct the event in the experimental data.

The space-time correlation curve is evaluated in the **simulation**.

Experimental **reconstructed tracks** are reasonable straight and will be compared with a tracking system.



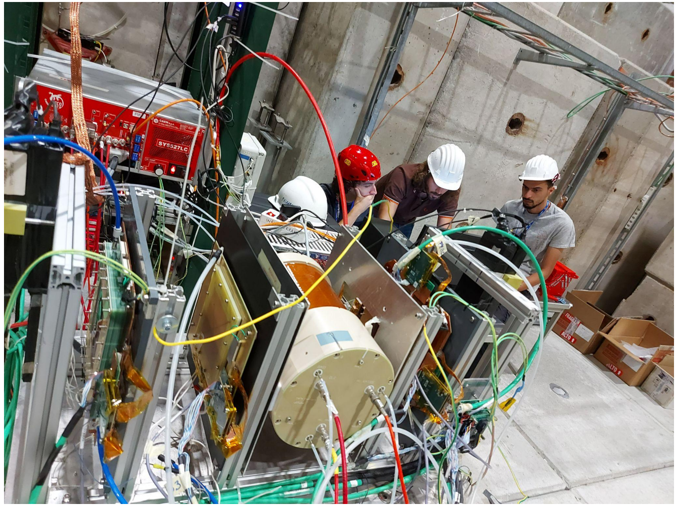
Test beam

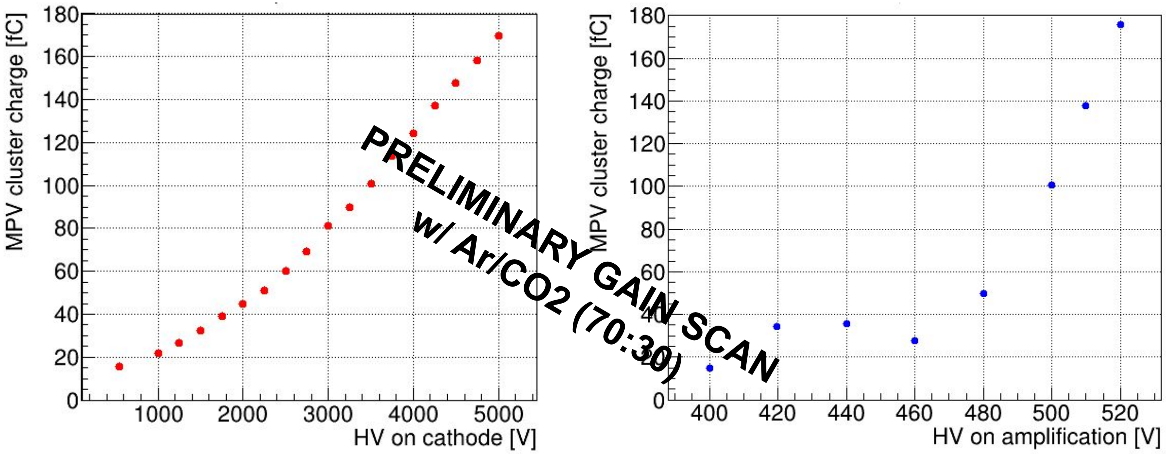
During the RD51 **testbeam**, a µRTube is tested together with a tracking system.
TIGER threshold set lower than 0.5 fC.

Two scans performed:

- Drift Field [0V - 5000V]
- HV scan [400V - 540V]

Analysis on going.
The spatial resolution is of about 1 mm for the single strip but calibration are still needed to improve the resolution of the full detector





Conclusions

A novel mechanical test was conducted on the flexible PCB with µRWELL, achieving a **curvature radius of 9mm**.

The updated geometry of µRTUBE optimizes both the number of readout channels and the amplification region for larger volumes.

Validation of the construction technique was accomplished through the use of a radioactive source and a test beam, confirming the proof-of-concept.

In the future, there are plans to test the modularity of this detector on a larger scale, and to complete the data analysis aimed at extracting the spatial resolution and efficiency of the detector.

Thanks

Backup

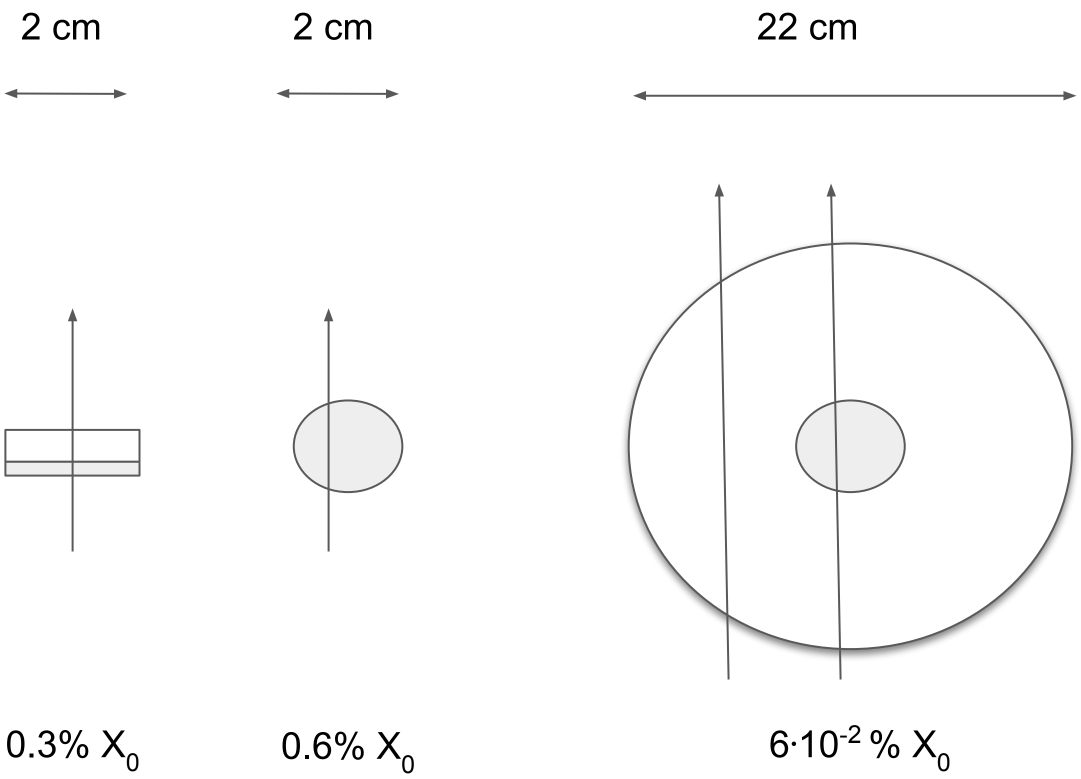
Ideal material budget

The material budget of a µRWELL is 0.4% of X_0; it is 0.3% in the wire layout.

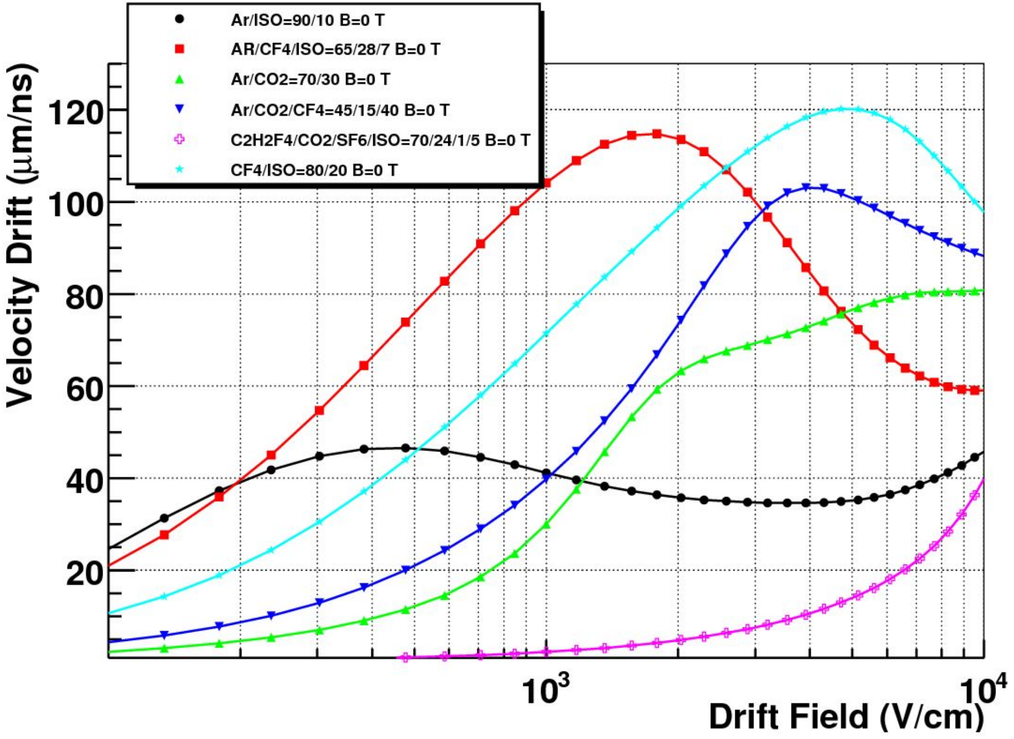
The readout cylinder material budget is approximately the double.

If a wide of 22cm is considered and the empty region is averaged with the other one then the mean **material budget is 0.06% of X_0.**

This value has to be compared with a drift chamber with 1.5 10^{-3} % of X_0 or a silicon IT with 0.4% of X_0.



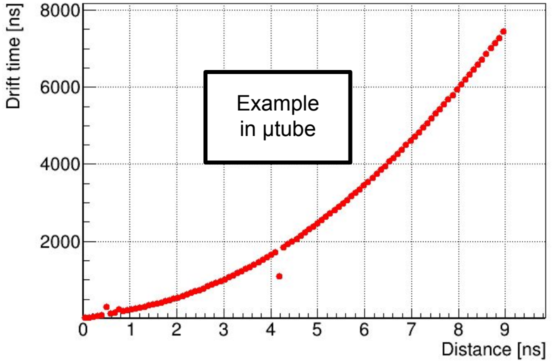
Drift velocity



E(r) = const / r

E(10 cm) = E_0 / 10
E(1 cm) = E_0

A correlation map between time-distance is mandatory



Expected signal

1 strip -> 2.6 deg

90°ionization path -> da 0.4mm a 4.5mm

number of primary -> 3-5 each mm

detector gain -> 8000

rising time -> 25-50 ns

signal duration -> 50-150 ns

strip capacitance -> 70 pF

signal amplitude -> 2-60 fC

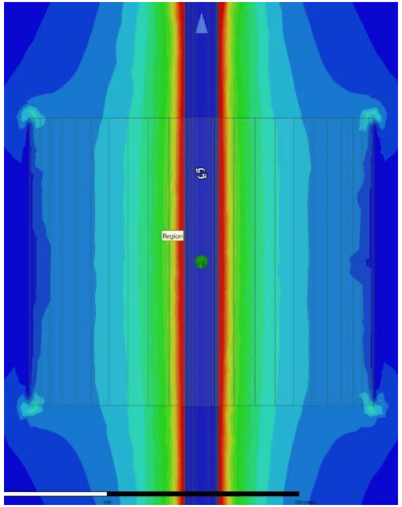
noise amplitude -> 0.5-1 fC

Full detector simulation - Field cage effects

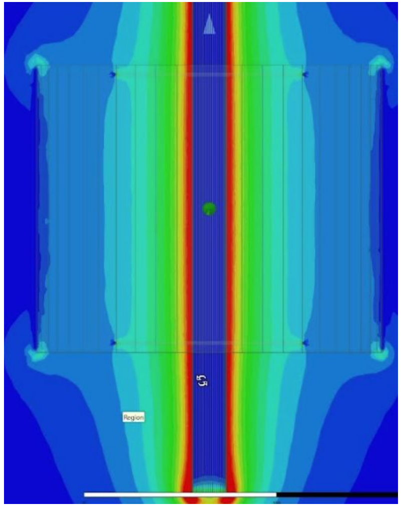
Field cage improve the homogeneity of the electric field along the Z direction. Electric field simulation have been developed with ANSYS to test it.

Being the active area shorter than the cathode length, the not homogenous region does not interfere with the performance of the detector.

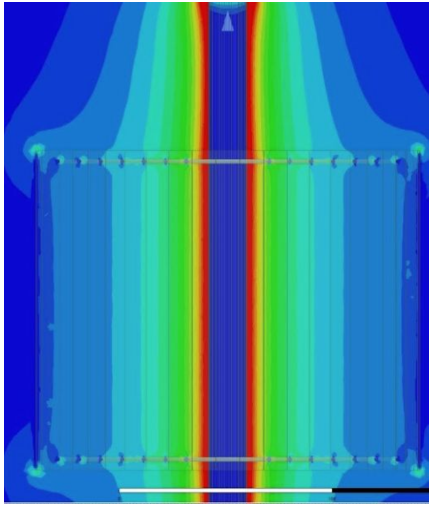
z axis



no cage



1 HV reference



7 HV reference