µRtube

a new geometry concept for MPGD detectors

Candidate: Riccardo Farinelli

on behalf of Ferrara, Turin and LNF INFN sections

µRtubes in a nutshell

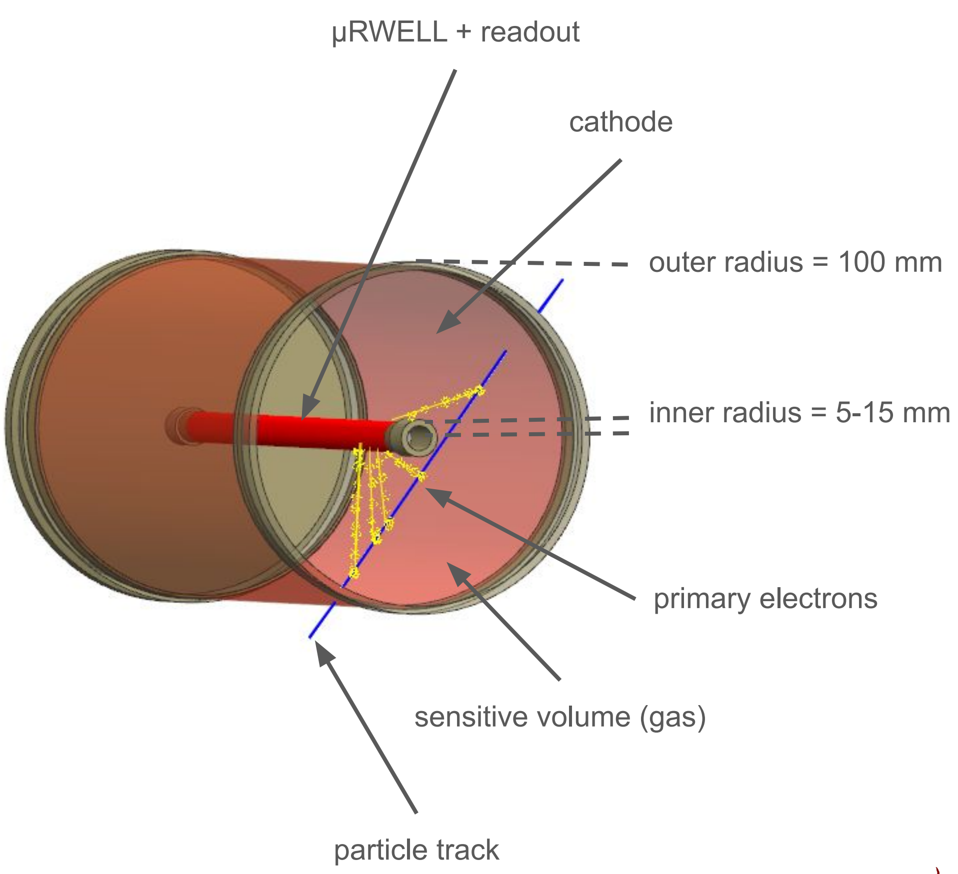
The basic idea is to develop a **tubular MPGD** working as a radial TPC: the readout on the inner cylinder and the cathode on the outer one.

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



Goals of the project

Carry out a full **proof-of-concept** of a tracking (+ PID) detector for charged particles based on a Micro Pattern Gas Detector for low-cost and a large area application.

- Detector **performance**:

  100 µm spatial resolution

  rate capability 50 kHz/cm^2 in the proposed configuration

  PID from dE/dx better than 10-15% and improvements dN/dx to be investigated

Develop a full detector characterization **to promote its application** in both HEP and non-HEP fields using the single element µRtube or modular configuration.

- neutron detector
- large sensitive area for HEP

The candidate

Competence and responsibility:

R&D on MPGD and TB data analysis since **2014**

Test beam and data taking **responsible** in BESIII

HV stability and mechanics quality control expert for the CGEM-IT

Time-based reconstruction **algorithm** and calibration in BESIII CGEM-IT

Electronics WP responsible in Urania-V

Cooperation experience in **international** working **groups**

PhD and Postdocs:

2021: Development of a parametric simulation for resistive MPGD (INFN - **AIDAINNOVA**)

2020: Simulation and test of a cylindrical detector based on μRWELL (INFN - **CREMLINplus**)

2018: Development of reconstruction algorithms for a cylindrical GEM detector for the BESIII experiment (INFN - **RISE**)

2015: Research and development in a cylindrical triple-GEM detector with μTPC readout for the BESIII experiment (**PhD**)

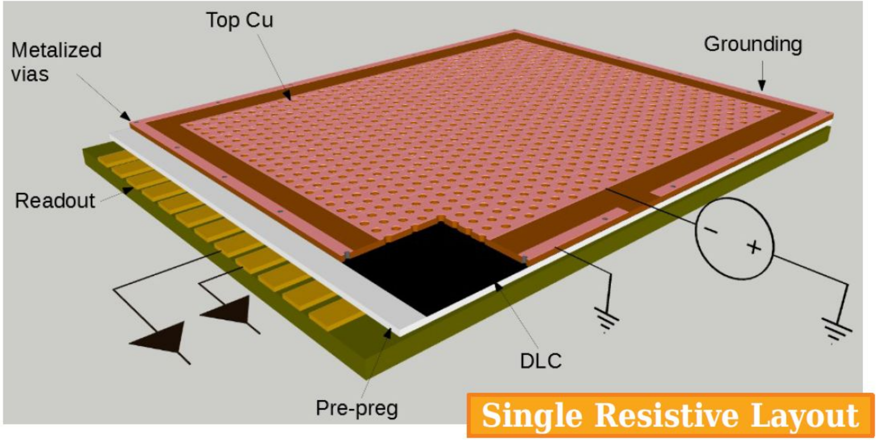
State of the art

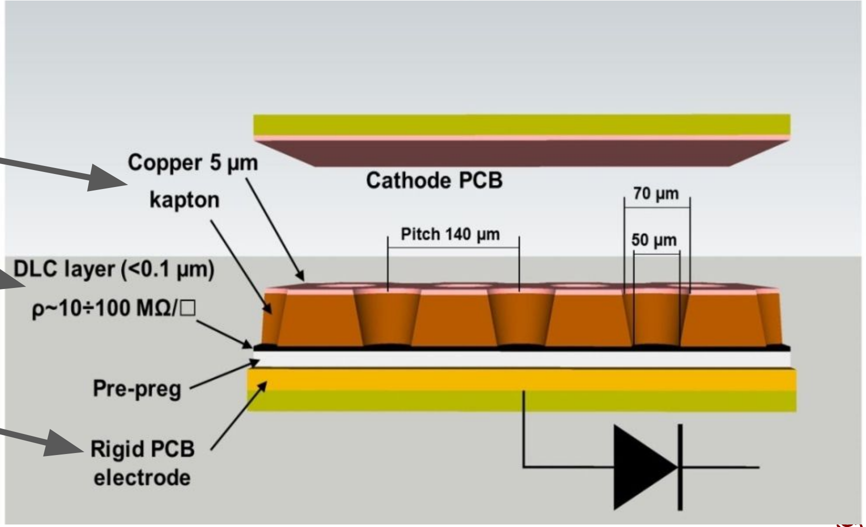
State of the art: μRWELL

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





State of the art: cylindrical MPGD

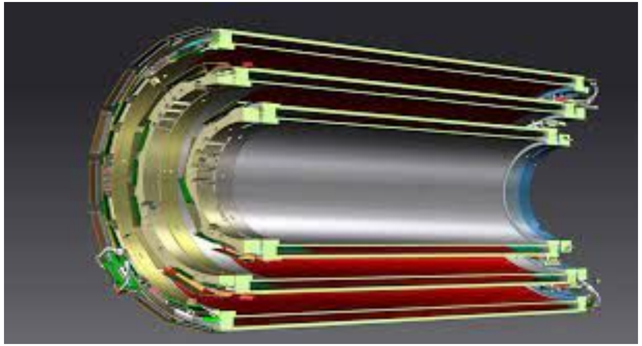
PCB and amplification stages used in MPGD can be shaped to cylinders; examples are the triple-GEM for the IT in KLOE-2 and BESIII, and the μRWELL for CREMLIN+

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

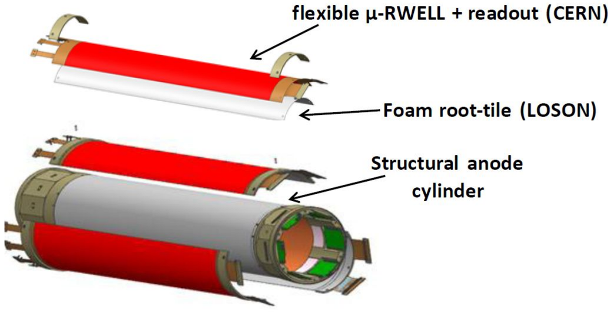
The shapeability of the MPGD is the initial driver of the μRtube idea

Cylindrical triple-GEM **KLOE-2**

Cylindrical triple-GEM **BESIII**



Cylindrical μRWELL **CREMLINplus**



State of the art: Signal readout and reconstruction

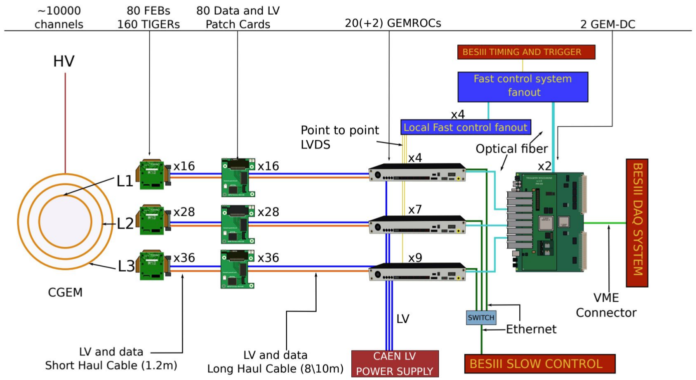
TIGER chip features:

- 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

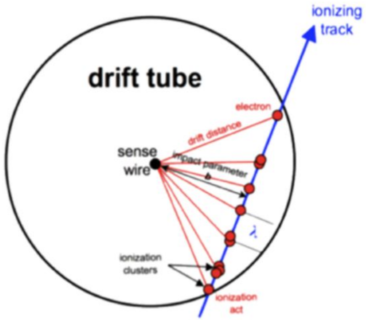
Readout chain:

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

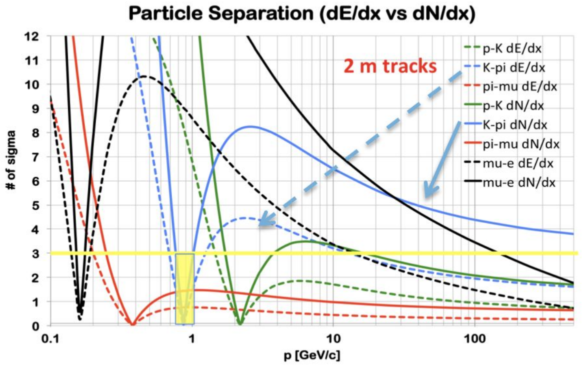
Readout chain



Drift tube



Separation power from IDEA DC



Cluster counting and PID

The cluster counting is a PID technique under development for drift chambers such as the one for IDEA experiment (FCC/CEPC). A GHz sampling electronics improves the **PID separation power by a factor 2**.

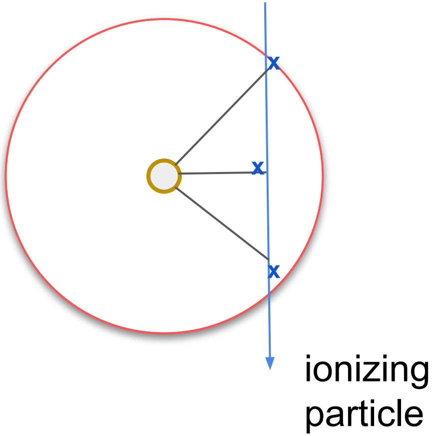
Innovations

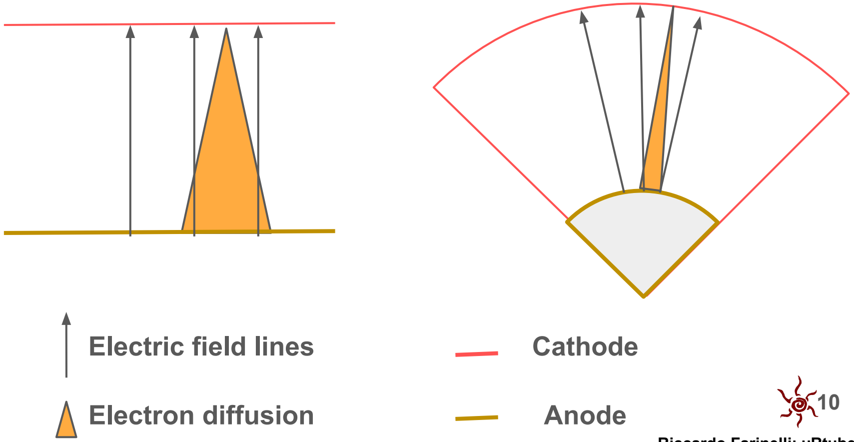
µRtube reconstruction method

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

The 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.





Channel number comparison

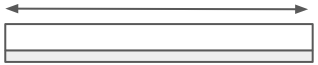
The µRtube geometry reduces the number of strips/wire/channels of about a **factor 5** with respect to other technologies with the same active volume and performance. This has a large impact on the **detector cost**.

This is an important point to produce **large area** detectors with a reduced production and instrumentation cost:

- due to µRWELL technology (low cost and TT already started)
- the small number of readout channels.

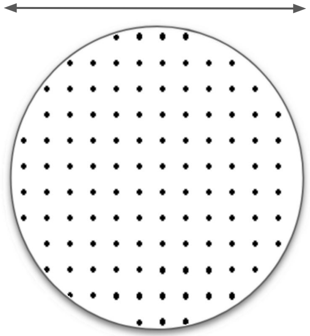
Planar µRWELL

22 cm - 550 channels



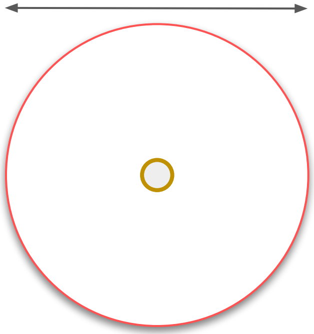
Wire drift chamber

22 cm - 800 channels



µRtubes

22 cm - 128 chs



Methodology

Working packages and tasks

WP3: Electronics

3.1 - Design
3.2 - Material procurement
3.3 - Readout chain assembly

WP1: Mechanics, design and construction

1.1 - Material tests
1.2 - Mechanical drawing cylindrical layout
1.3 - Material procurement cylindrical layout
1.4 - Construction cylindrical layout
1.5 - Mechanical drawing wire layout
1.6 - Material procurement wire layout
1.7 - Construction wire layout
1.8 - Boron Sputtering

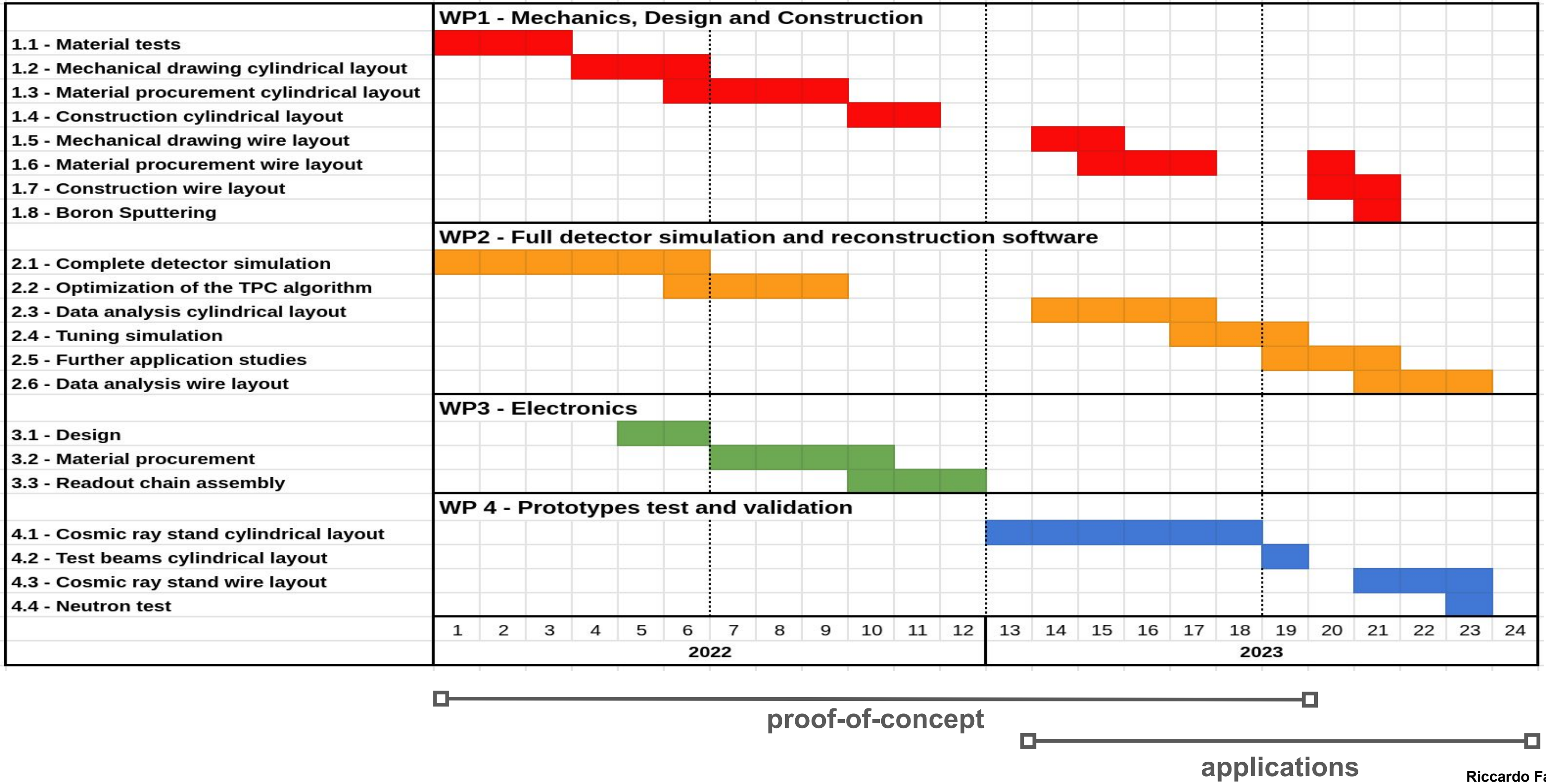
WP2: Full detector simulation and reconstruction software

2.1 - Complete detector simulation
2.2 - Optimization of the TPC algorithm
2.3 - Data analysis cylindrical layout
2.4 - Tuning simulation
2.5 - Further application studies
2.6 - Data analysis wire layout

WP4: Prototypes test and validation

4.1 - Cosmic ray stand cylindrical layout
4.2 - Test beams cylindrical layout
4.3 - Cosmic ray stand wire layout
4.4 - Neutron test

Timeline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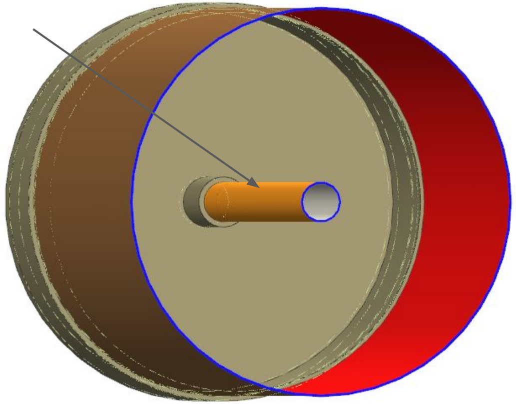
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
2022
2023
proof-of-concept
applications

Milestones

M1: Mechanical test of the materials	**(month 3)**
M2: Complete simulation of a µRtube with PARSIFAL	**(month 6)**
M3: Cylindrical µRtube prototype construction completed	**(month 11)**
M4: Cylindrical layout validation with a testbeam	**(month 18)**
M5: Wire layout validation with a cosmic ray stand	**(month 22)**
M6: Testbeam results presented in conference/workshop	**(month 24)**

WP1: Mechanics, design and construction

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



M1: Mechanical test of the materials (month 3)

more details in the backup

WP1: Mechanics, design and construction

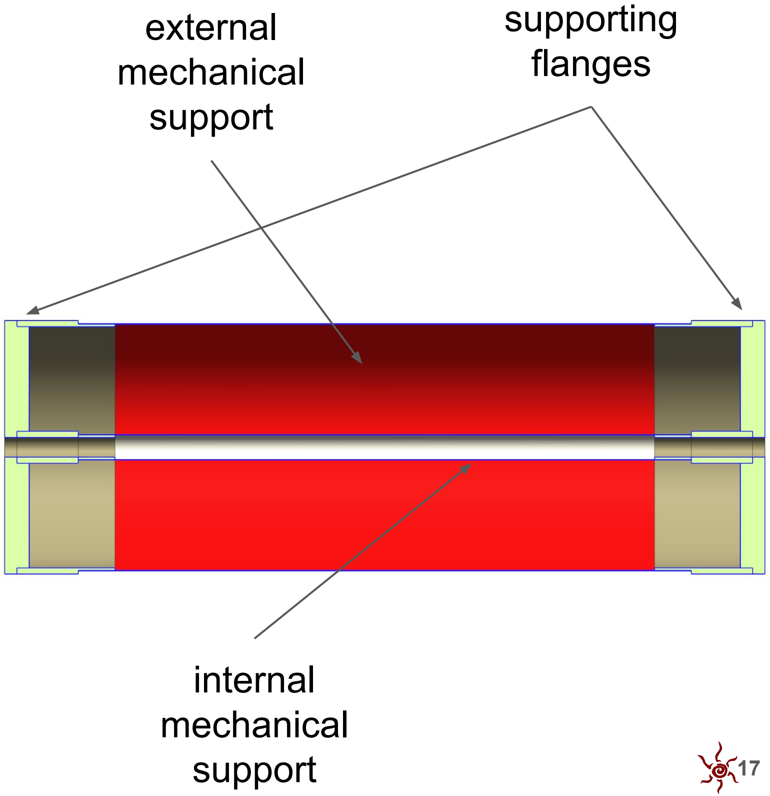
Inner radius = 1 cm
External radius = 11 cm
Length = 50 cm
} optimized design

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

The mechanical support for the inner layer will be built optimizing the material budget and the construction.

Flanges will seal the gas volume and provide the support for the services (gas, HV, FEB and field cage).

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

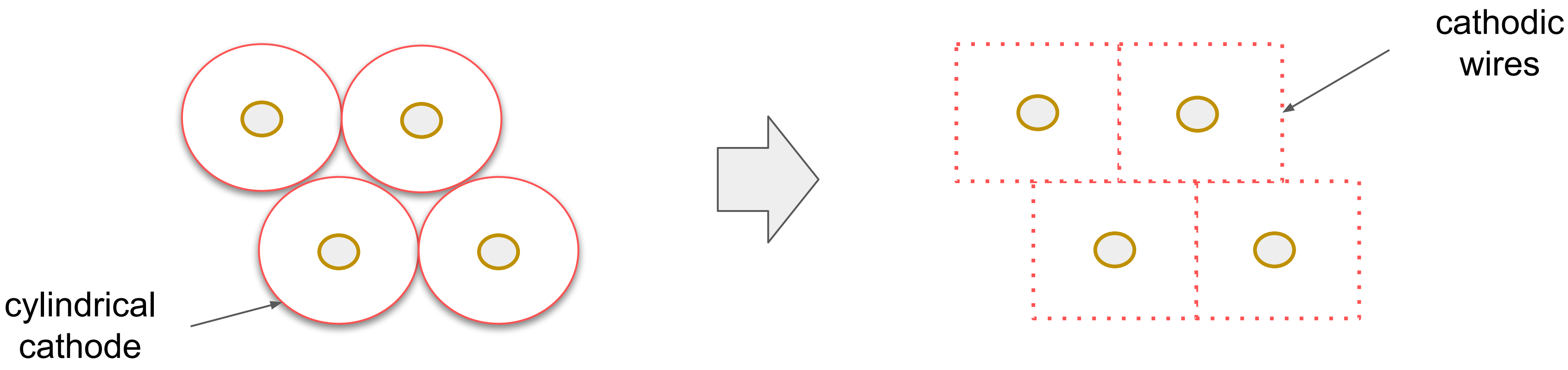


M3: Prototype construction complete (month 11)

more details in the backup

WP1: Mechanics, design and construction

On the second year a **wires layout** will be developed and tested to extend the μRtube application to reduce dead-area in modular configuration and a lower material budget ($6 \cdot 10^{-2}\%\ X_0$).

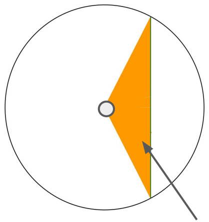


WP2: Full detector simulation and reconstruction software

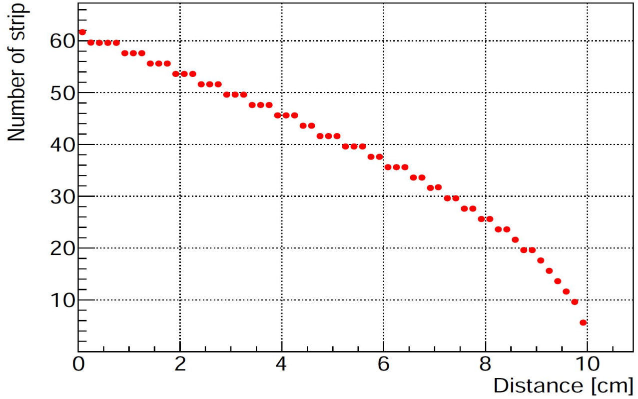
A toy-MC maps the spatial and temporal **diffusion** of the primary electrons to estimate **multiplicity** and **spatial resolution**.

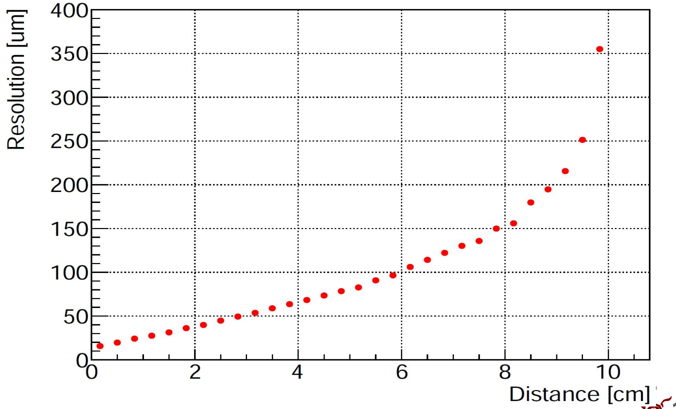
A complete study of the primary electron diffusion for this geometry and electric field will be developed.

The electron drift property will be merged with the µRWELL simulation to complete the one of the µRtube

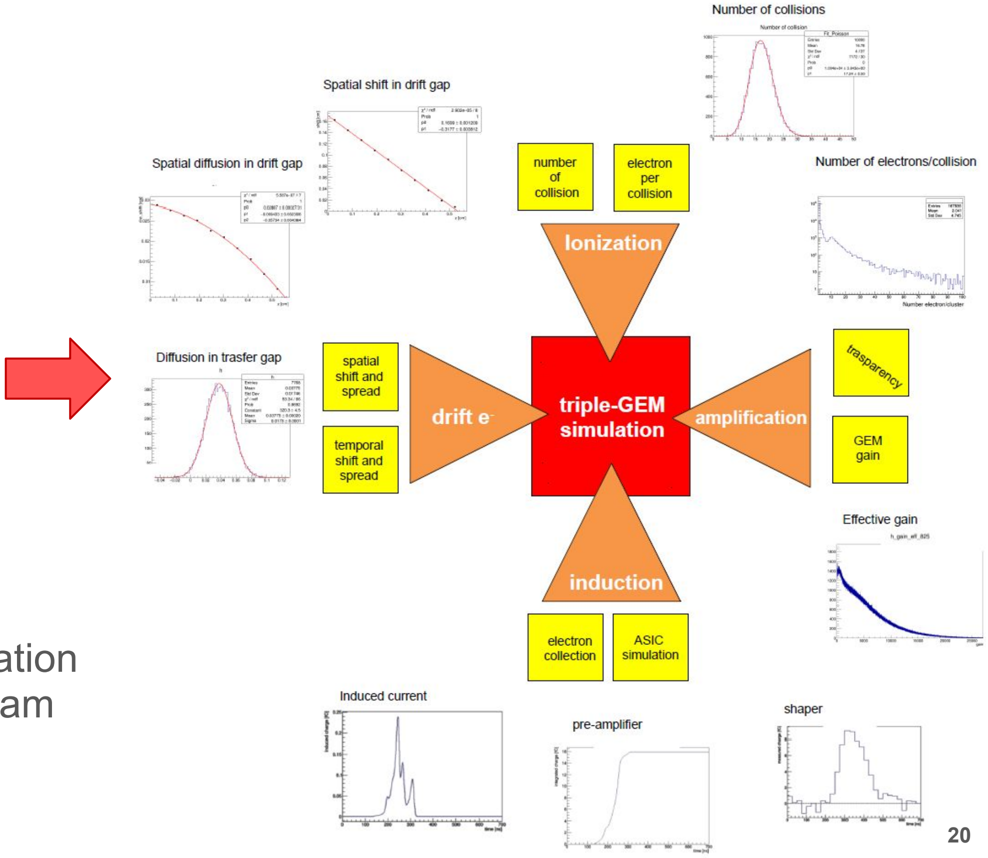


GARFIELD simulation





WP2: Full detector simulation and reconstruction software



A **complete μRWELL simulation** is under development from a complete triple-GEM simulation and the μRWELL characterization from a testbeam

M2: Complete simulation of a μRtubes (month 6)

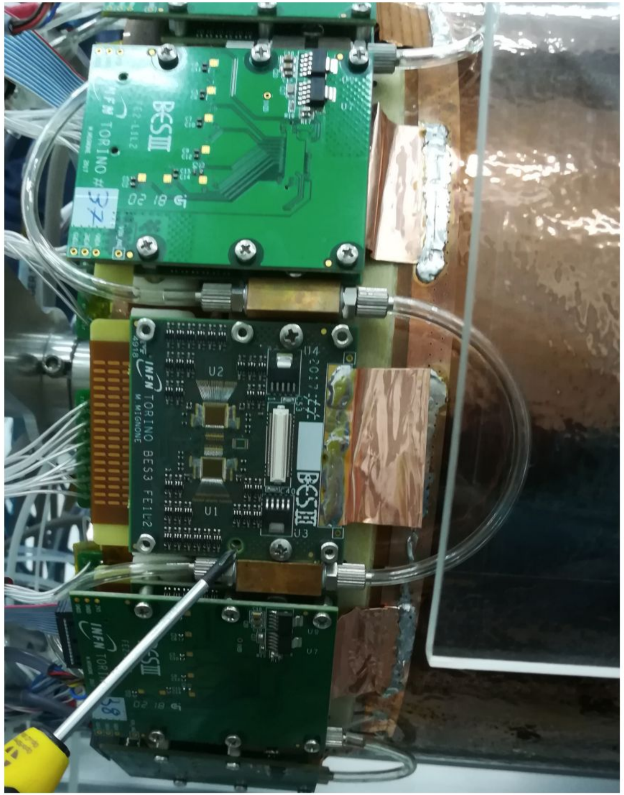
WP3: Readout electronics

The readout chain development will profit of the BESIII **working group experience**.

The TIGER chip is well optimized for μTPC signal then no chip upgrades are planned.

The time window of the event has to be extended **from 1.5μs to 5-10μs** to collect the whole signal.

Design and development of a **2D readout** are not planned but they will be **investigated** through **simulations**.



WP4: Test and validation

Once the prototype will be manufactured, a **cosmic ray stand** will be used for the first studies, debug and Test Beam preparation.

The **TB** will be performed at SPS-H4 beam line at the Prevessin North-area within the **RD51 collaboration**.

A complete **characterization** of the detector will be performed to **validate** and **tune** the simulation; to **test** the HV stability and the design.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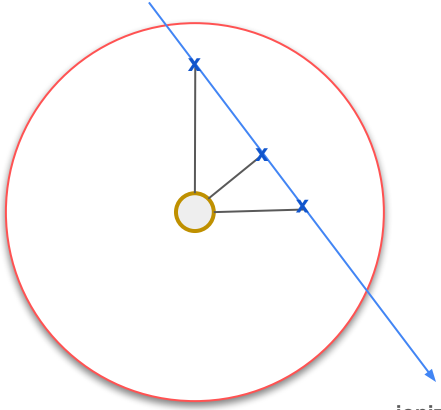
M4: Prototype validation with a Test Beam    (month 18)
M6: Test Beam results presented
     in conference/workshop                  (month 24)
```

WP4: Test and validation

Both **stand-alone** and **modular** configuration will be studied for different application evaluation and the same setup will be used for the cosmic-ray stand and the testbeam for the cylindrical layout.

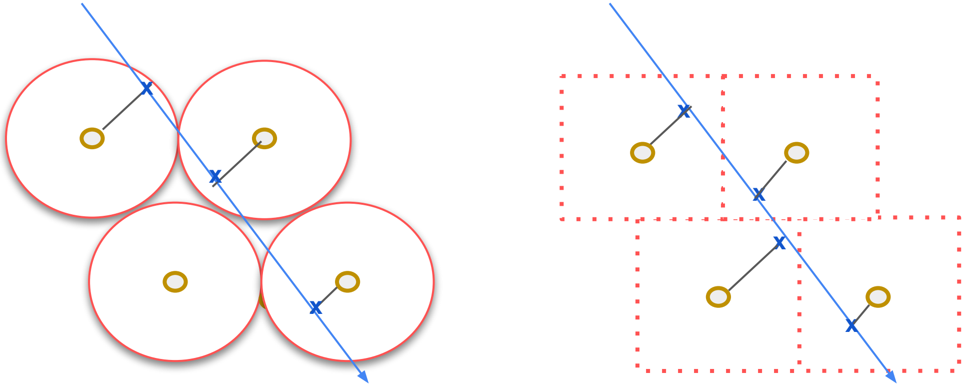
The wires layout will be tested only with a cosmic-ray stand (with this schedule)

Stand-alone



ionizing particle

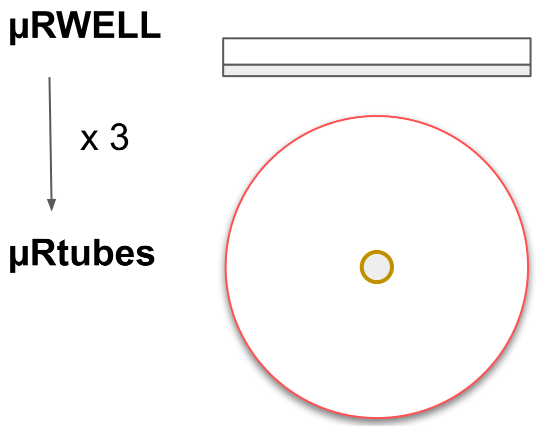
Modular



ionizing particle

Applications

Stand-alone applications



The µRtube has a simplified construction procedure, one FEB only readout and a large the sensitive volume. It is suitable for a large number of applications with a reduced cost.

The first example to be shown is a **neutron detector**: following the Urania-V project, a Boron sputtering (**ESS Coating Workshop in Linköping**) procedure on the cathode allow the thermal neutron detection:

Since the neutron efficiency scales with the Boron surface and the impinging angle then **at least factor 3 is expected** with the µRtube geometry.

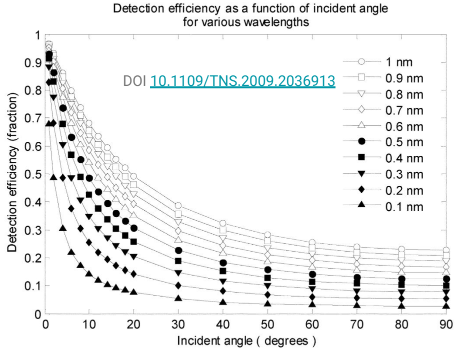


Fig. 2. Simulation results for detection efficiency given a 2 μm thick ^{10}B absorber layer as a function of incident angle, given for neutron wavelengths from 0.1 nm (82 meV) up to 1 nm (0.82 meV).

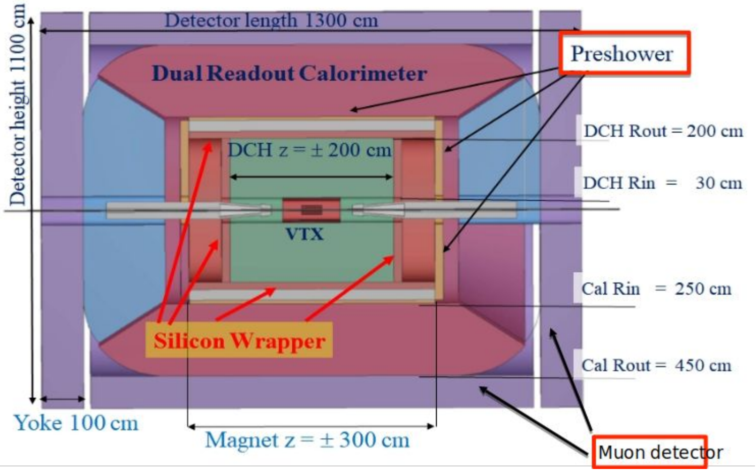
M5: Feasibility studies for the applications completed (month 23)

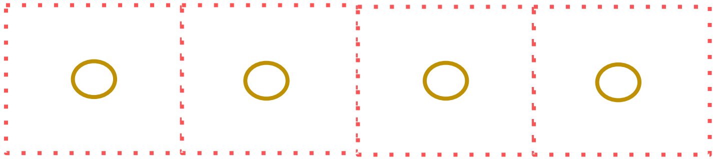
HEP application: Muon Chamber

Tracking capabilities are required in the muon detector of IDEA/FCC to measure **L**ong-**L**ived **P**article whom decay inside the spectrometer, far away from the interaction point.

For this reason the project is **already available** for this application.

A multiple stack of µRtube can cover a large area with a reduced number of channels, then with a **reduced cost** of the apparatus.





M5: Feasibility studies for the applications completed (month 23)

Impact on Muon Chamber

Looking at the cost evaluation of the IDEA experiment for FCC, the 70% of the muon detector cost is given by the electronics.

A reduction of a factor 5 in the number of channel will save about **10M€** as shown previously

Muon detector cost

	Cost [Meuro]	Engineers [years]	Technicians [years]	Operators [years]
Detectors	4,9	0,4	1,0	0,0
Installation	0,7	0,6	2,8	2,9
Electronics	12,3	0,3	1,5	0,0
HV/LV Systems	0,7	0,2	1,4	0,0
Gas System	0,3	0,2	1,3	0,0
TOTAL	**18,9**	**1,7**	**7,9**	**2,9**

Assumed 3 euro/channel

Assuming the following manpower costs:

Engineer	80 euro/hour
Technician	40 euro/hour
Operator	30 euro/hour

36 hours/week * 48 week/year = 1728 hours/year

Electronics is by far the dominant cost

	Cost [Meuro]
Detectors	4,9
Installation	0,7
Electronics	12,3
HV/LV Systems	0,7
Gas System	0,3
TOTAL	**18,9**

Assuming 300 MEuro as the cost of a FCC-ee or CEPC detector, the Muon detector would be ~ 7% of the total

Application: tracking system

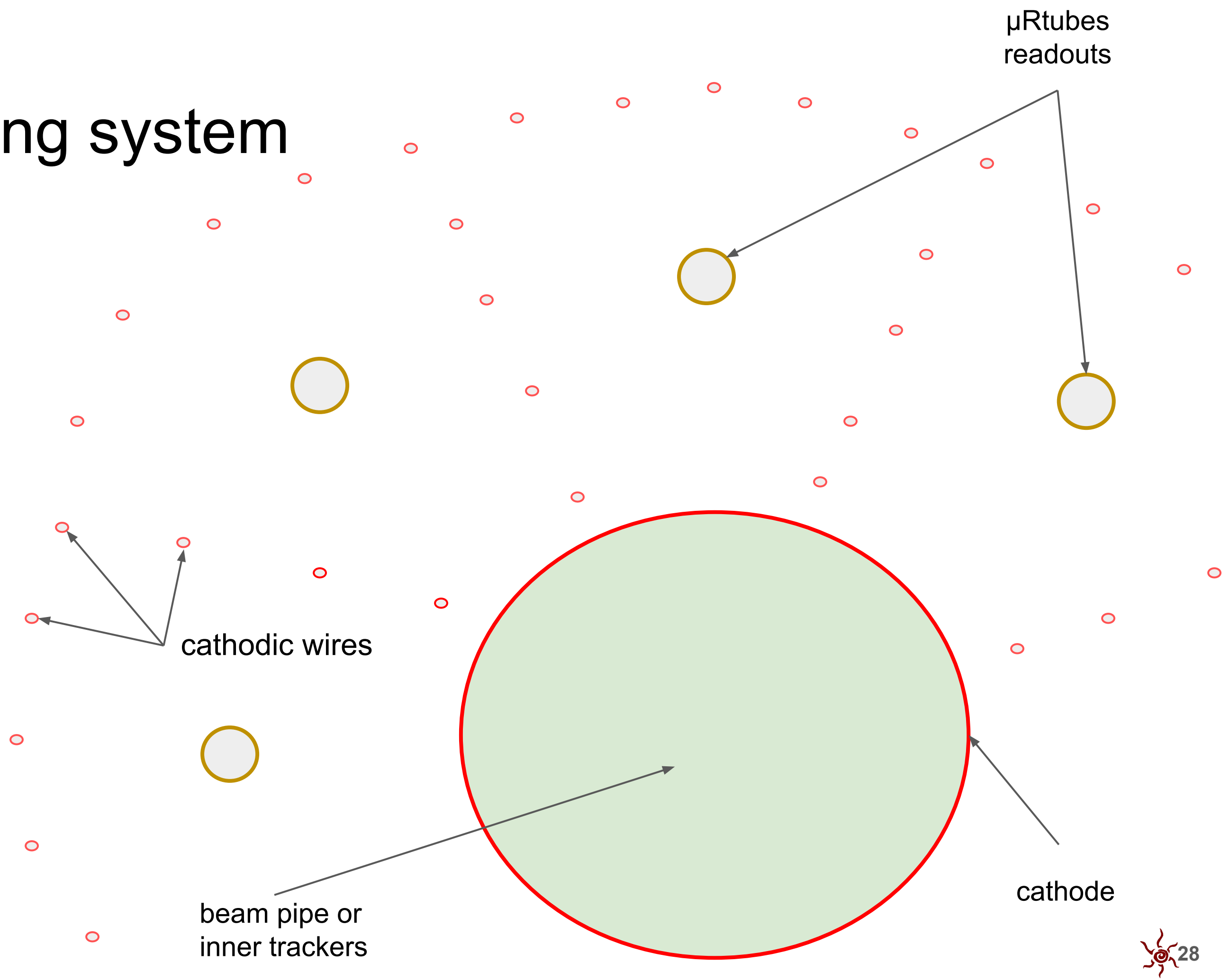
Very challenging!
Above the goals of this project

If the technology is as good as expected then it could be suitable to substitute wire chambers.

If this is the case, several points have to be considered:

- material budget: $6 \cdot 10^{-2}$ % X_0
- rate capability: above 50 kHz/cm²
- readout 2D and channel density
- Ion Back Flow

It would allow to measure low momentum particles: at 15 MeV a pion descrive a circle of 10 cm with 1T magnetic field.

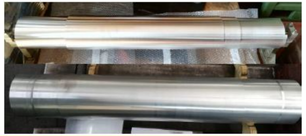


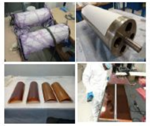
Technological transfer

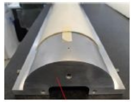
The **design** of the prototype has been **completely revised and finalized**

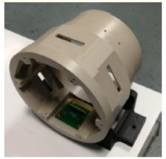
- Orders of **flex-detector tiles** (CERN – Rui) done → delivery by the end of November
- Orders of **mechanics/tools** (anode/cathode, end-caps, plugs, tiles) done → **construction in progress (@LOSON):**

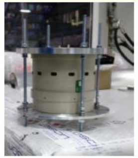
• anode mould	DONE
• cathode mould	DONE
• end-caps/plugs in peek →	DONE
• tiles (still) under test →	DONE
• HV, signal interface boards →	DONE
• Detector assembly →	Nov – Dec 2021











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Built a second large area μRWELL: DLC sputtering

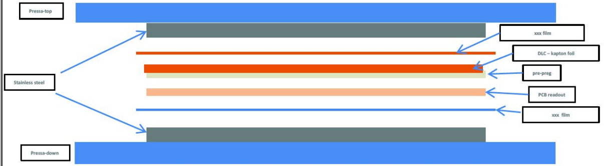
INFN Istituto Nazionale di Fisica Nucleare

A proposal for a DLC sputtering facility is under discussion between CERN and INFN. A DLC sputtering machine will allow to study DLC production for large area surfaces and to optimize the resistivity of the foils as a function of their purpose. The scientific interest for the DLC is central for the MPDG technologies and their developments.

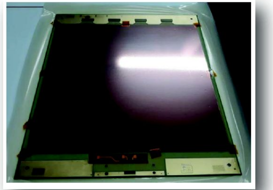
2021.02.25 Riccardo Farinelli - CEPC DAY 11

Technology transfer: μ-RWELL_PCB @ELTOS

- ELTOS performs the coupling of the DLC-foil with the readout PCB (only for low-rate layout)
- The max size of the μ-RWELL-PCB that can be produced by ELTOS is about 600x700 mm^2. Up to 8 PCBs of such a size can be manufactured at the same time
- The PI etching to be done @ CERN



33x33 cm^2 active area LR - RWELL



INFN and ELTOS participate to the AIDAinnova project for further TT

https://cordis.europa.eu/project/id/101004761

Neutron capture through Boron coating

$$n + {}^{10}B \rightarrow {}^{11}B^* \rightarrow \alpha + {}^{7}Li$$

- chemically stable
- not too expensive
- adherence to substrate
- low impurity level uniform sputtering thickness on large surface

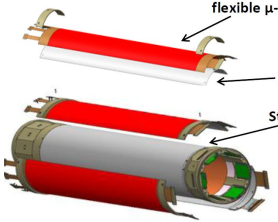
8

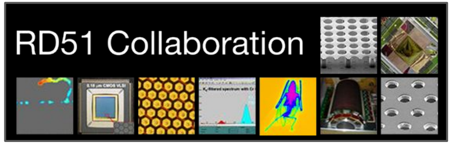
- B_4C enriched with 97% of ^{10}B sputtered on a copper surface at the ESS Coating Workshop in Linköping (Sweden) with direct current magnetron sputtering technology
- About 94% of the time the recoiling ^{7}Li ion is produced in an excited state and de-excites in flight, emitting a 477 keV γ ray
- α particle and a ^{7}Li ion are produced back-to-back, only one enters the gas volume and produces detectable signal

G. Cibinetto - uRANIA (uRWELL Advanced Neutron Identification Apparatus)

Synergies and existing collaboration

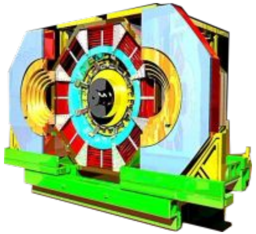
CREMLIN PLUS
Connecting Russian and European Measures for Large-scale Research Infrastructures



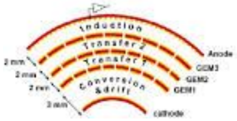


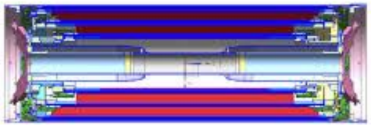
Urania-V
ATTRACT

AIDA innova



BESIII





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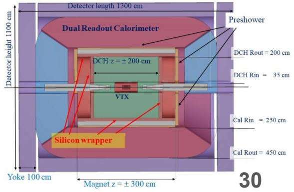


Costs 1° year

The budget for the two years of the project is proposed.

About 25k€+IVA will be co-funded by the other projects and synergies.

Mechanics
Electronics
Validation
Co-founded

Item	Quantity	Unitary cost	Total cost	WP
CONSUMABLES				
Readout and μRWELL 52x500mm2	4	2,5	10	1
Fiberglass cylinder	4	1	4	1
Supporting flanges	8	1	8	1
End Cap (2 each prototypes)	8	1	8	1
Mechanical tools	2	2	4	1
INVENTORY				
Boards LV, HV CAEN	1	6	6	3,4
Mainframe CAEN	**0**	4	**0**	3,4
TIGER FEBs	**0.5*8**	0,5	2	3
GEMROC	**0.5*2**	2,5	2,5	3
chiller	**0**	3	**0**	3
Laptop	**0**	1	**0**	2,4
MISSION				
Mission for construction	1	5	5	1
	Total first year			**49,5**
			+IVA	**60,39**

Costs 2° year

The budget for the two years of the project is proposed.

About 25k€+IVA will be co-funded by the other projects and synergies.

Mechanics
Electronics
Validation
Co-founded

Item	Quantity	Unitary cost	Total cost	WP
CONSUMABLES				
Mechanical support for the testbeam	1	2	2	4
Four µRWELL for tracking system	**0**	12	0	4
Handling table	1	1	1	4
Gas bottles	4	0,5	2	4
Expedition testbeam	2	1	2	4
Readout and µRWELL 52x500mm2	4	2,5	10	1
Mechanical support for the wires	4	1	4	1
Wires	1	1	1	1
Supporting flanges	8	1	8	1
Endcap	8	1	8	1
TB expedition	2	1	2	4
Boron sputtering	**0**	2	0	4
MISSION				
Mission TB at CERN	3	2	6	4
Mission TB at HOTNES	3	1	3	4
	Total second year			**49**
			+IVA	**59,78**

The working group

A group of 10 colleagues will share the tasks. The project will profit also from the synergies and the strong collaboration with a large number of colleagues with a wide competence range:

- Mechanics (BESIII, CREMLIN+, FCCee and UraniaV):
  - LNF -> µRWELL experience
  - FE -> design and construction support
    -> support from mechanical design and workshop
- Electronics (BESIII):
  - TO -> front-end developer
  - FE -> readout developer
- Software (BESIII and CREMLIN+):
  - TO & FE -> detector full simulation and data analysis
- Validation:
  - All -> long lasting cooperation and large experience in R&D on MPGD

The working group

G. Cibinetto: project coordinator CGEM-IT; Urania-V local coordinator; INFN-FE mechanics service coordinator.

G. Bencivenni: μRWELL inventor; CREMLIN+ and Urania-V coordinator; senior physicist.

S. Spataro: Software coordinator in BESIII and BELLE2; associate professor

L. Lavezzi: CGEM-IT QAQC and Urania-V simulation responsible

I. Garzia: CGEM-IT software coordinator; light quark meson expert; physics RTDb.

M. Maggiora: INFN-IHEP joint laboratory director; FEST-RISE coordinator; full professor

I. Balossino: CGEM-IT operation manager; CLAS12 RICH developer.

M. Greco: BESIII national coordinator; CGEM-IT electronics responsible; associate professor

A. Bortone: CGEM-IT electronics expert for online and offline analysis

Conclusions

A two years project is proposed to develop a **full proof-of-concept** (design, construction and test) of a new geometry concept MPGD and to define a set of suitable **applications** for HEP and non-HEP fields.

Tracking and PID performance in agreement with the state of the art are achieved from a blue-sky R&D to **optimize** and reduce the production **cost** of the detector (easy construction, low electronics impact and ongoing TT).

A large saving, **~10M€**, can be achieved in large sensitive area apparatus such as the muon detector for IDEA.

The project has a reduced amount of risk thanks to the experience of the **candidate** and the **synergy** with existing working groups.

Thanks

Backup

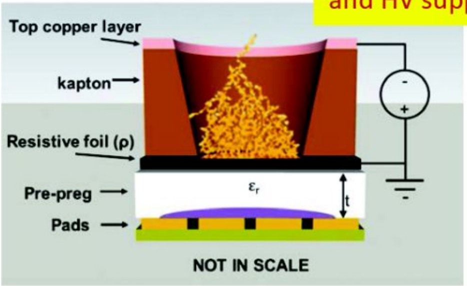
State of the art

more info in the literature1 and literature2

μ-Resistive Well Detector

- Single amplification stage resistive MPGD composed of
  - μ-RWELL_PCB
  - drift/cathode PCB defining the gas gap
- μ-RWELL_PCB
  - ampl.-stage
  - res.-layer
  - r/out PCB (with suitable segmentation)
- Large area & flexible geometry
- Comes in two flavors: low rate and high rate

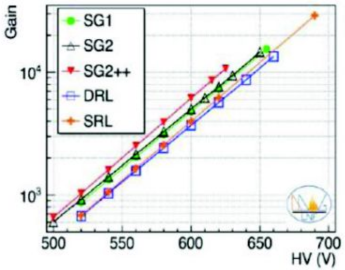
easy assembly and HV supply



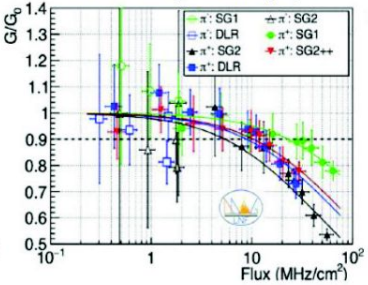
The "WELL", suitably polarized applying HV between top and DLC, acts as a multiplication channel for the ionization produced in the gas

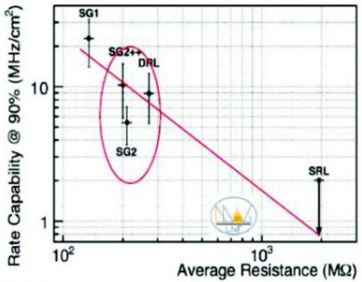
JINST **14** P05014 (2019)

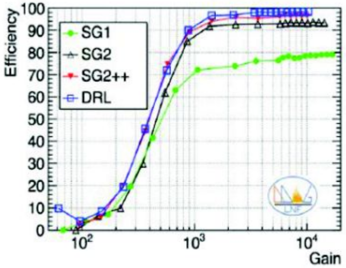
Gain up to ~ 10^4

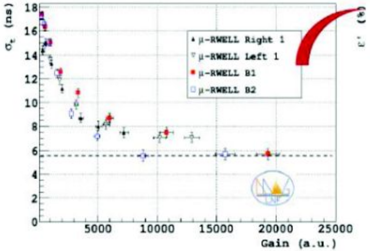


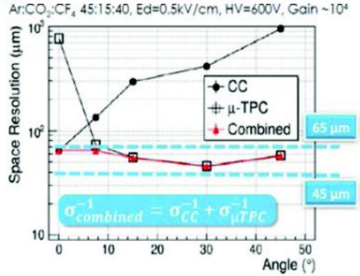
Rate capability (@ G = 5000) ~ 5-10 MHz/cm^2











Efficiency ~ 98%

σ_t ~ 5-6 ns

Space resolution in u-TPC-mode

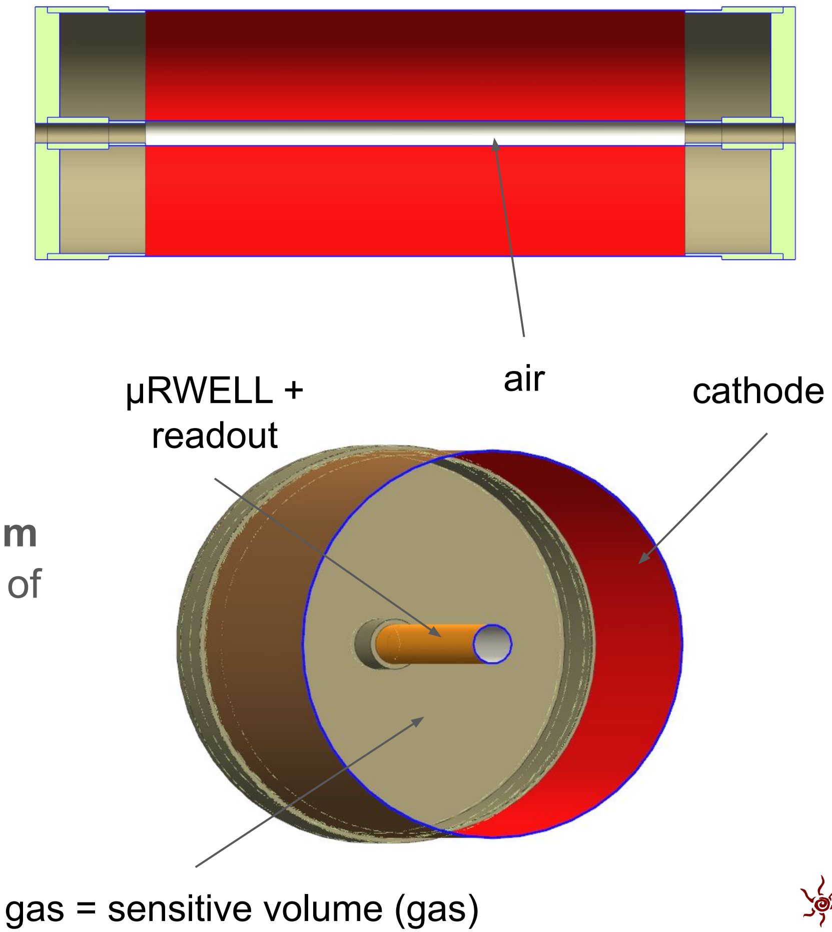
Mechanics

Size and dimension

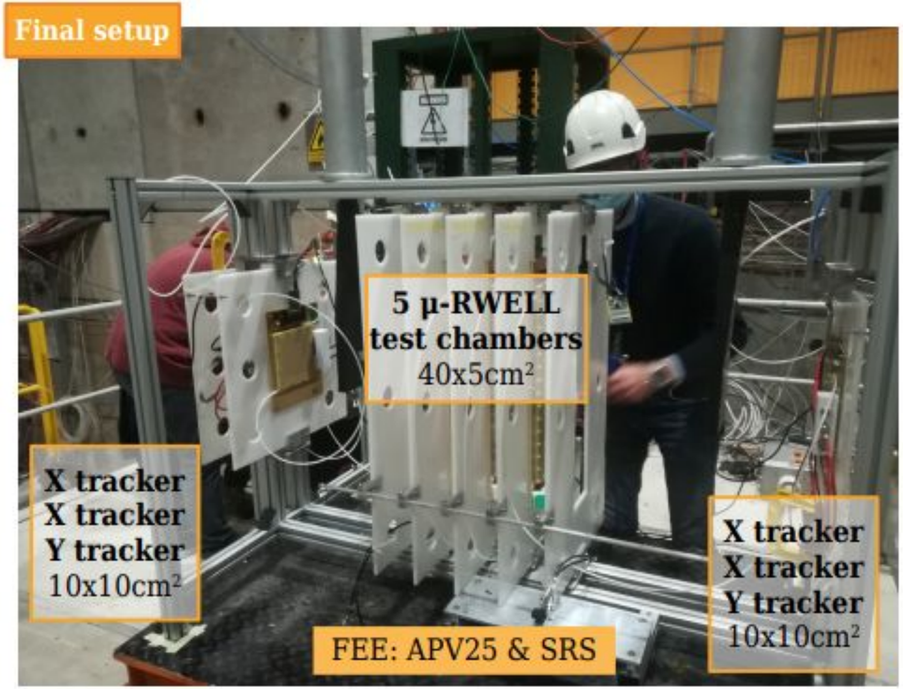
Starting from the literature it is possible
to estimate the optimal detector geometry:

- standard number of channels in a FEB: **128**
- compact detector, chip and shapeable: **μRWELL**
- easiest readout segmentation: **strip** 1D
- μRWELL strip pitch with known performance: **400μm**
- maximum drift length to characterize a large range of application: **10cm**

-> inner radius = 400μm * 128 / 6.28 ~ 1 cm
-> external radius = 10+1 cm



µRWELL-PCB for FCC R&D



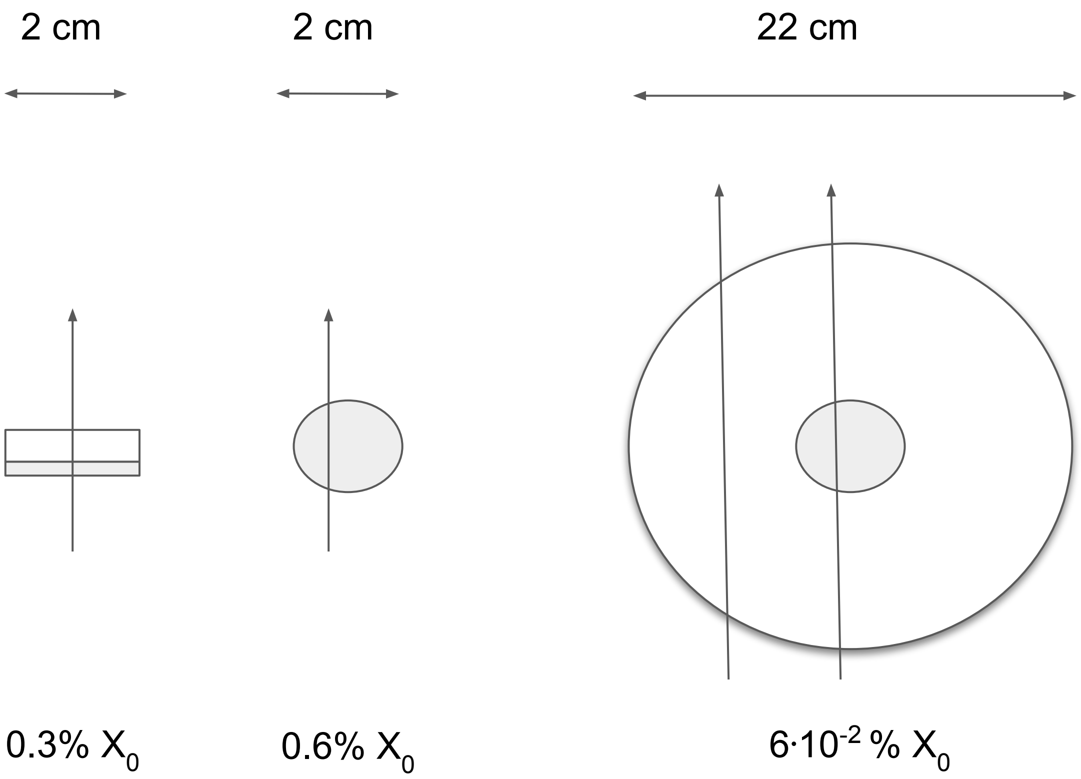
Material budget

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.**

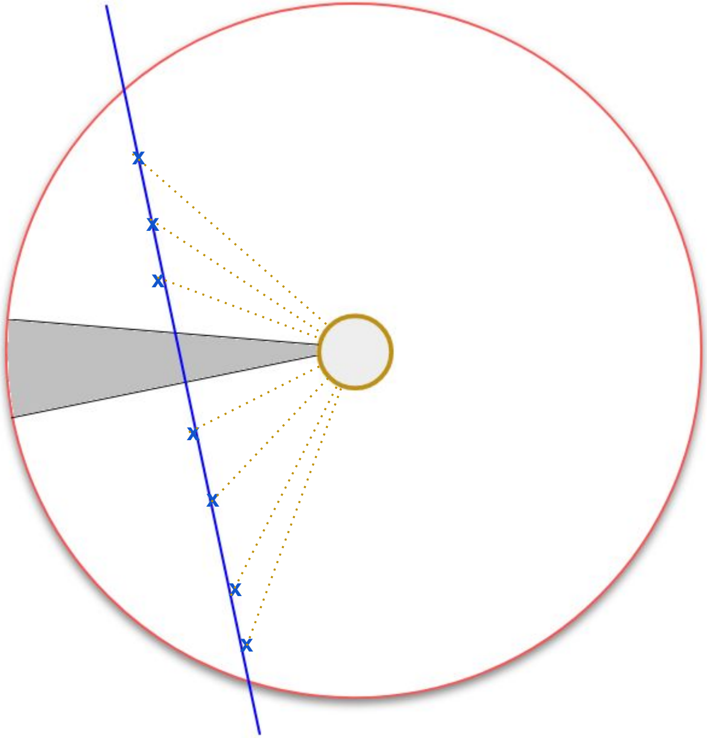
This value has to be compared with a drift chamber with 1.5 10^{-3} % of X_0 or a silicon IT with 0.4% of X_0.



Dead area

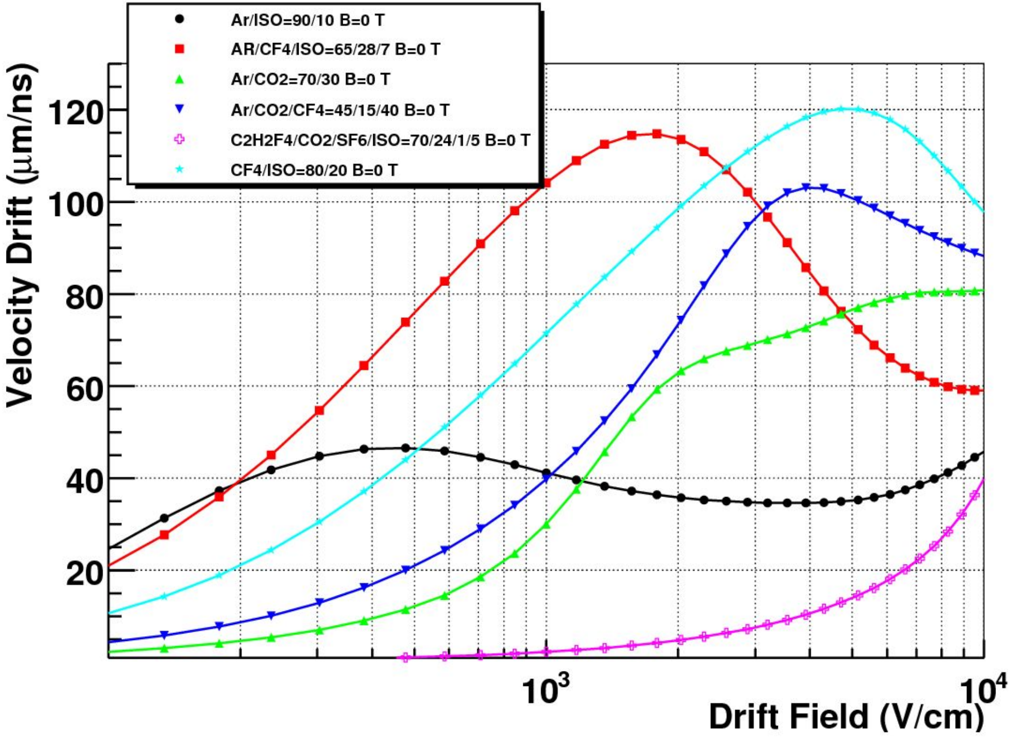
The µRWELL has to be glued with 3 mm kapton foil. It might be reduce to 2 mm.

3mm of dead area corresponds to 5% of the active volume that does NOT correspond to 5% inefficiency



Software

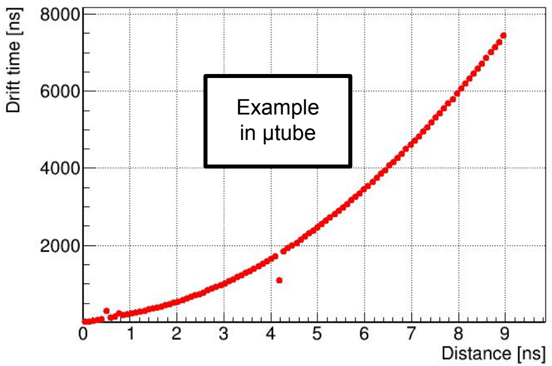
Drift velocity



$E(r) = const / r$

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

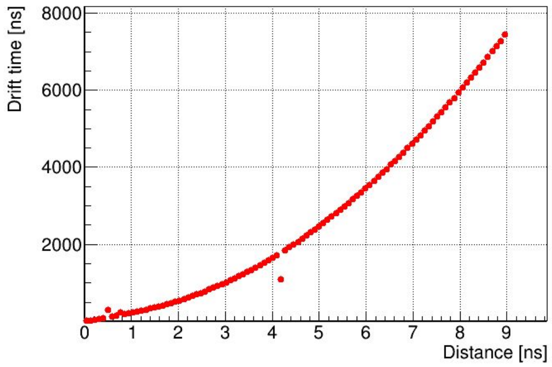
A correlation map between time-distance is mandatory

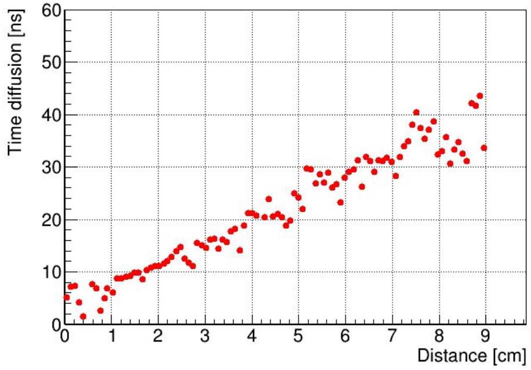


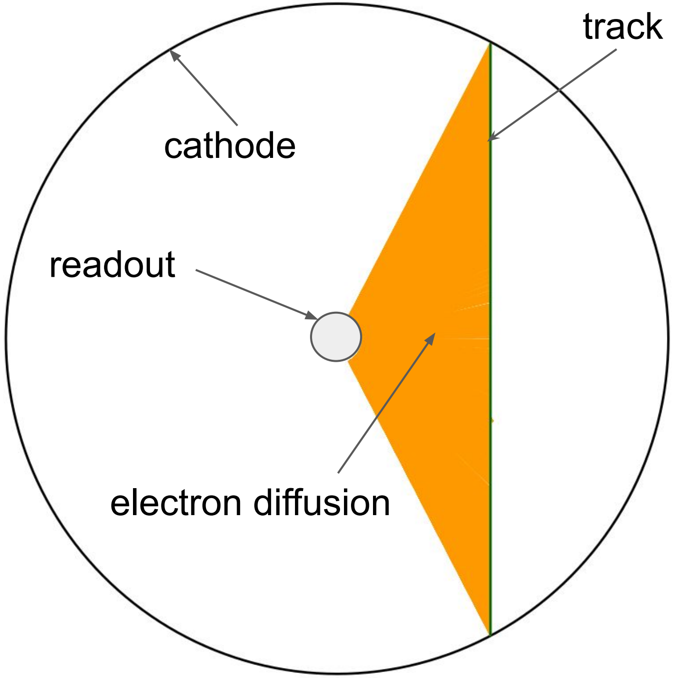
WP2: Full detector simulation and reconstruction software

A very preliminary study performed with GARFIELD++ generated a map of spatial and temporal **diffusion** of the primary electrons as a function of the readout distance to develop a first **toy-MC** to evaluate the detector operation with TPC reconstruction.

$ArCO_2$ gas mixture and $\Delta V_{cathode}$ = 5000V







WP2: Full detector simulation and reconstruction software

Thanks to PARSIFAL simulator, developed within CREMLIN+ project for the µRWELL and the BESIII project for CGEM-IT, it is possible to define a **full detector simulation**: ionization, drift, amplification, resistive charge dispersion, induction, electronics and signal reconstruction.

Due to the large drift gap, a new parametrization of the electron diffusion has to be studied.

The simulation results will be used to **optimize the reconstruction software**.

Once the tuning of the simulation with experimental data will be complete, then it will be possible to **extend the µRtube studies with different configuration** (i.e. dimension and readout design) and applications.

Electronics

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

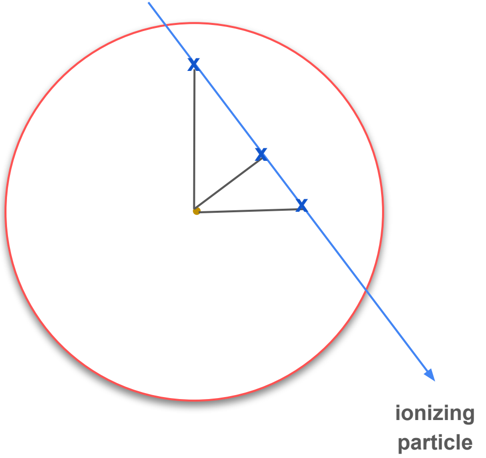
noise amplitude -> 0.5-1 fC

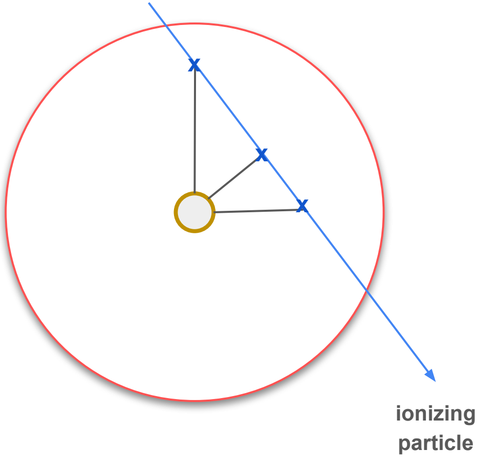
Applications

more results in the literature

Drift tube vs μRtube

	Drift tube	**μRtube**
n° channels	1	128
max drift length	0.5-1 cm	10 cm
reconstruction	DOCA	tracklet
max rate	10^4-10^5 Hz/cm^2	10^5-10^6 Hz/cm^2

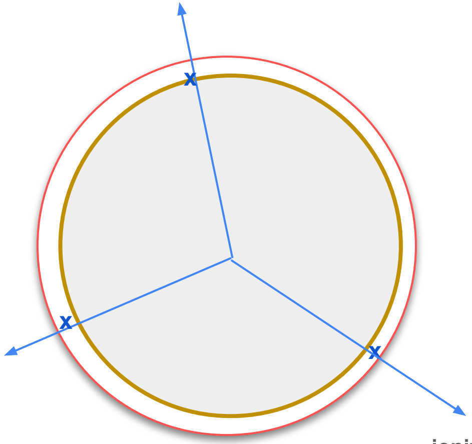


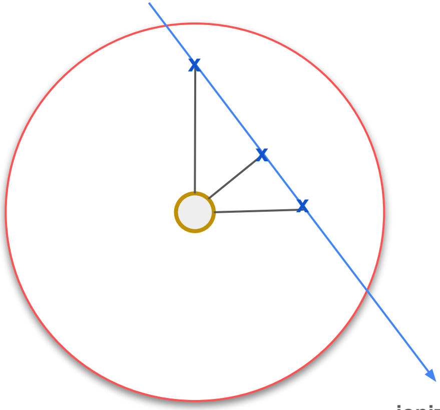


more results in the literature

Cylindrical µRWELL vs µRtube

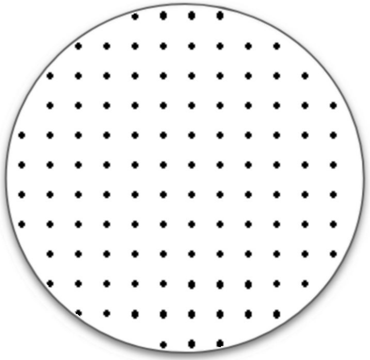
	C-µRWELL with same dimensions	**µRtube**
n° channels	1700	128
max drift length	0.5 cm	10 cm
reconstruction	1 point only inner tracker	tracklet
configuration	concentric cylinders	stand-alone or multi-stack

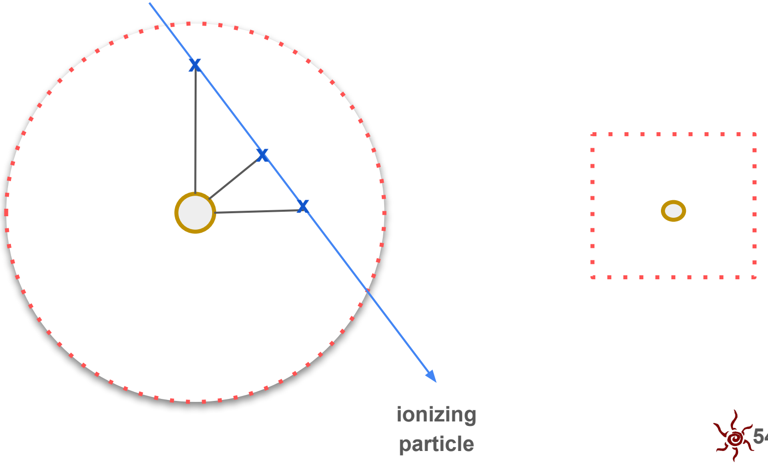




Drift chamber vs μRtube (wire)

	Drift Chamber with same dimensions	**μRtube**
n° channels	800	128
n° of HV wires	2500-4000	70-100
max drift length	0.5-1 cm	10 cm
material budget	$1.5 \cdot 10^{-3}\% \ X_0$	$6 \cdot 10^{-2}\% \ X_0$



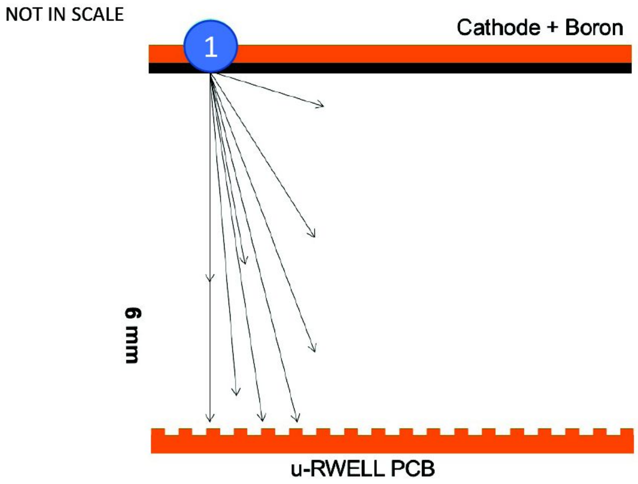


Urania-V

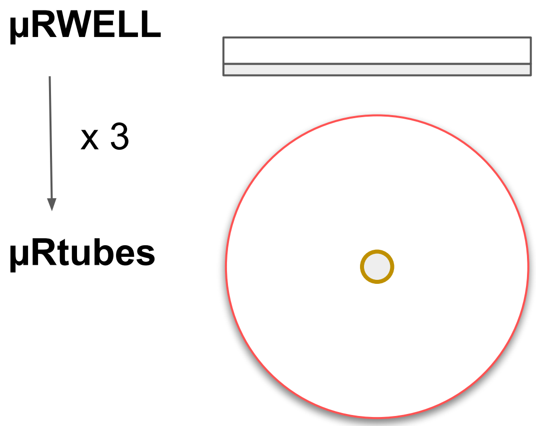
$$n + {}^{10}B \rightarrow {}^{11}B^{*} \rightarrow \alpha + {}^{7}Li$$

B_4C enriched with 97% of ^{10}B sputtered on a copper surface at the ESS Coating Workshop in Linköping (Sweden) with direct current magnetron sputtering technology

α particle and a ^{7}Li ion are produced back-to-back, only one enters the gas volume and produces detectable signal



µRtube for neutron



Facendo un conto coi dati in letteratura, si misura una efficienza di rivelazione del 12% per ogni elemento di µRtube

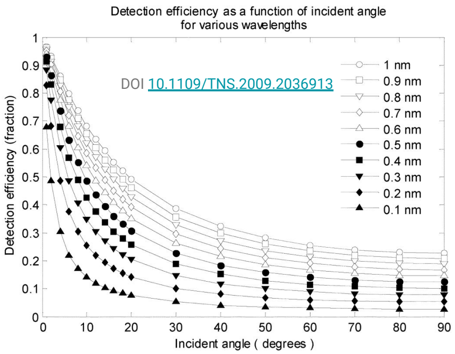
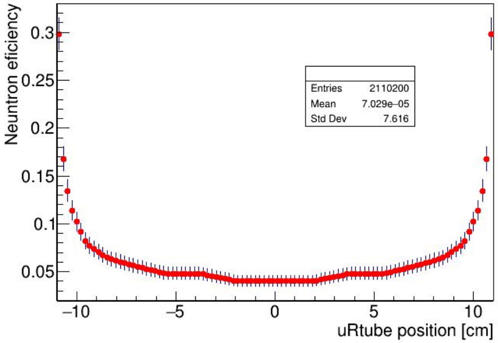


Fig. 2. Simulation results for detection efficiency given a 2 μm thick ^{10}B absorber layer as a function of incident angle, given for neutron wavelengths from 0.1 nm (82 meV) up to 1 nm (0.82 meV).



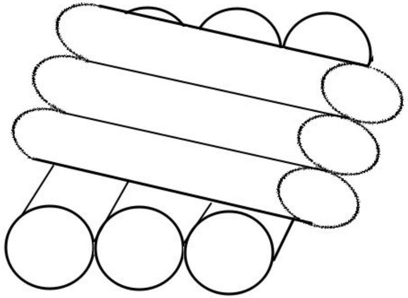
Rate capability

I limite dati dall’alto rate sono i seguenti:

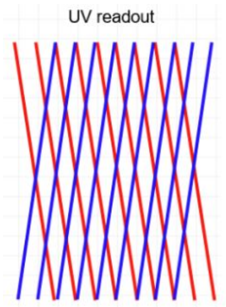
- elettronica è limitata a 100 kHz a canale in eventi ad alta molteplicità -> 10 µs
- µrwell ha guadagni stabili fino a 10^5 Hz/cm^2 nella versione “low rate”
- mentre nella versione high rate fino a 4 MHz/cm^2
- il tempo di drift degli elettroni è largo fino a 5µs -> 200 kHz
- readout monodimensionale rende insensibile a particelle lungo la vista non letta

Quindi il limite con l’elettronica attuale è di 50 kHz/cm^2 date le strip da 50x0.04=2cm^2

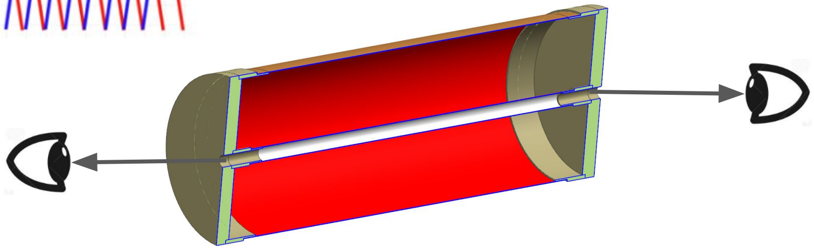
Readout 2D options



1. Multi stack μRtubes elements with 90° orientation



2. Stereo strips UV



3. Readout on both sides

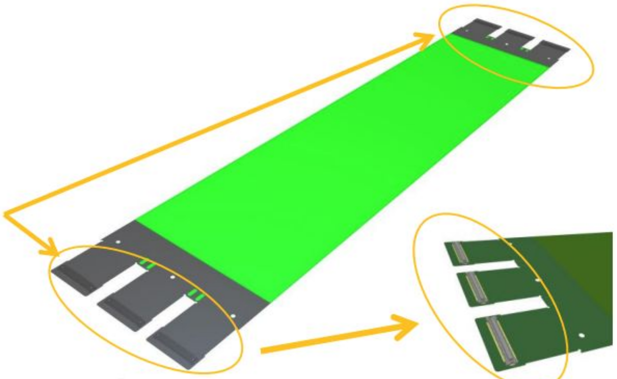
4. Pixel readout with a cleaver mapping

Detector Readout – 2D (future R&D)

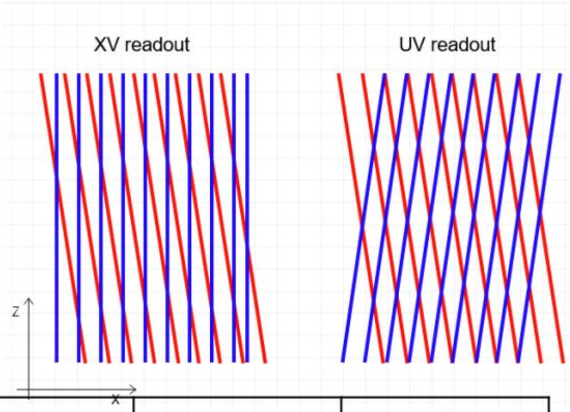
Constraint

Signal maximum tails/connectors that can be placed on each readout-tile

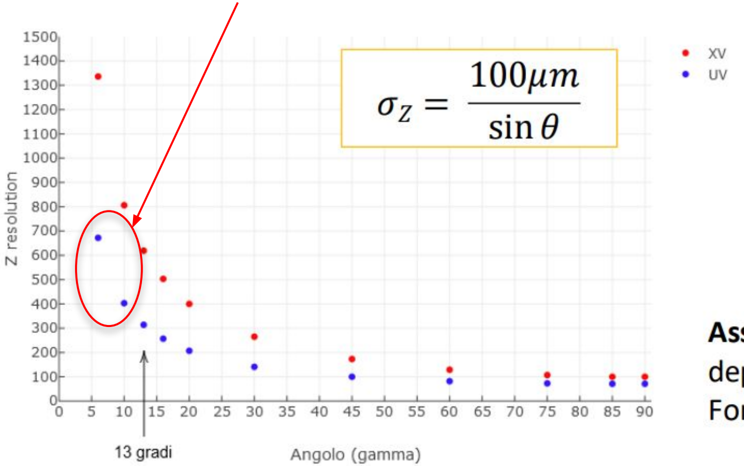
- **n. 6** for signals (3 each side)
- **n. 4** for HV (corresponding to n.4 **HV sectors)**



Two 2-D options can be considered



µRtubes



$$\sigma_Z = \frac{100\mu m}{\sin\theta}$$

2D readout type	# APV/side	#chs/side	#strips/side	Strip/pitch
XV	3	384	128X, 256V	660um
UV	3	384	192U, 192V	857um

Assuming σ_X / $\sigma_{U\text{-}V}$ ~ 100 µm for the single view (X or U/V), the **Z-space resolution** depends on the stereo angle.
For θ ~ 13°: **for XV (σ_Z ~ 600 µm)** – while for **UV (σ_Z ~ 300 µm)**

tube

Organizations

The working group

The support of the activity is not limited to the person involved in the project but it will profit of the synergies and the strong collaboration with a large number of colleagues with a wide competence range

Name	Units	FTE
Riccardo Farinelli	INFN, Sezione di Ferrara	0.7
Gianluigi Cibinetto	INFN, Sezione di Ferrara	0.1
Isabella Garzia	INFN, Sezione di Ferrara	0.1
Ilaria Balossino	INFN, Sezione di Ferrara	0.1
Giovanni Bencivenni	INFN, Sezione di Frascati	0.1
Marco Maggiora	INFN, Sezione di Torino	0.05
Michela Greco	INFN, Sezione di Torino	0.05
Stefano Spataro	INFN, Sezione di Torino	0.05
Lia Lavezzi	INFN, Sezione di Torino	0.05
Alberto Bortone	INFN, Sezione di Torino	0.05
	Totale	**1.35**

Task and manpower

WP1: LNF + FE

1.1 - Material tests	-> RF, GB, GC
1.2 - Mechanical drawing cylindrical layout	-> MM
1.3 - Material procurement cylindrical layout	-> CERN
1.4 - Construction cylindrical layout	-> MM, LOSON
1.5 - Mechanical drawing wire layout	-> MM
1.6 - Material procurement wire layout	-> CERN
1.7 - Construction wire layout	-> MM
1.8 - Boron Sputtering	-> ESS

WP2: TO + FE

2.1 - Complete detector simulation	-> RF, LL, SS
2.2 - Optimization of the TPC algorithm	-> RF
2.3 - Data analysis cylindrical layout	-> RF, IG
2.4 - Tuning simulation	-> LL, SS
2.5 - Further application studies	-> RF, SS, MM, GB, GC
2.6 - Data analysis wire layout	-> RF, IG

WP3: TO + FE

3.1 - Design	-> ACR, RM
3.2 - Material procurement	-> ALTERA
3.3 - Readout chain assembly	-> MG, AB

WP4: LNF + TO + FE

4.1 - Cosmic ray stand cylindrical layout	-> RF, IB
4.2 - Test beams cylindrical layout	-> RF, IB, AB
4.3 - Cosmic ray stand wire layout	-> RF, IB
4.4 - Neutron test	-> RF, GB, GC

Detector R&D since 2014