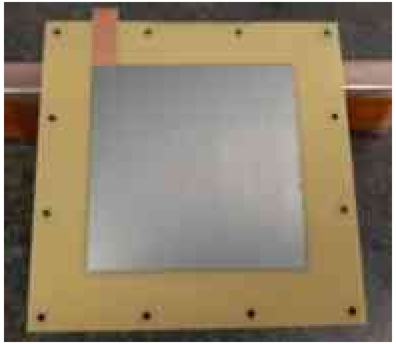
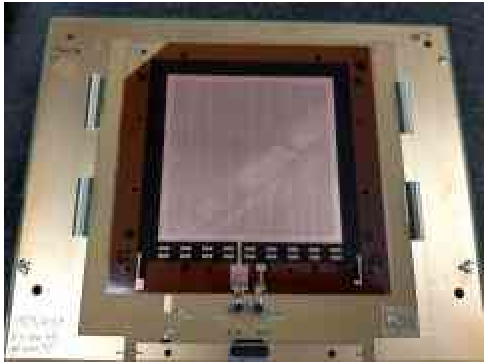
Summary on Urania
&
Summary on Cremlin+

ATTRACT-uRANIA: cosa è stato fatto



B4C-coated converters design and simulation: standard planar cathodes

Detector production and technology transfer to Industry: several devices realized in collaboration with ELTOS and TECHTRA, 10×10 cm^2 active area (*oltre che CERN*)

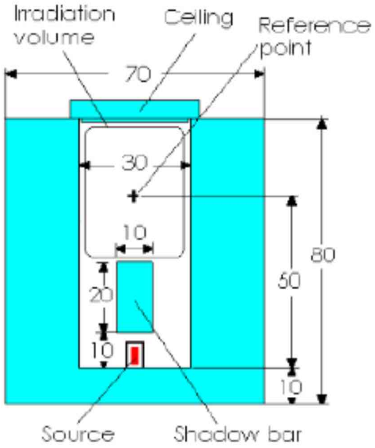


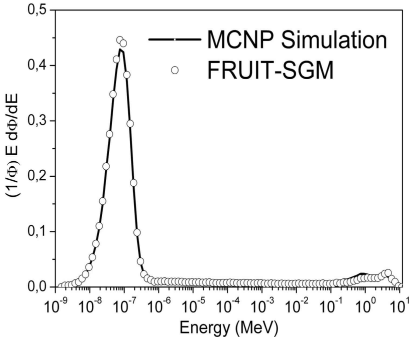
Simulation, GEANT + Garfield: conversion and re-absorption of the products of neutron interaction with different thickness of Boron layer; effect of the other materials of the detector on neutron flux taken into account → deposited energy in the gas gap (number of ionizations) determined

Experimental Test of detectors @ the neutron ENEA-HOTNES facility

ATTRACT-uRANIA: test @ ENEA–HOTNES

- Homogeneous Thermal Neutron Source
- Source: ^{241}Am-B
- Cylindrical simmetry, polyethylene walls
- Iso-fluence on disks (within 1-2%) with diameter 30 cm
- Fluence ~750 Hz/cm^2
- Shadow bar to stop gammas (4-9 μS/h)
- Angular distribution down to 8 mrad from surface
- Energy spectrum peaked at 100 meV (FWHM = 290 meV)





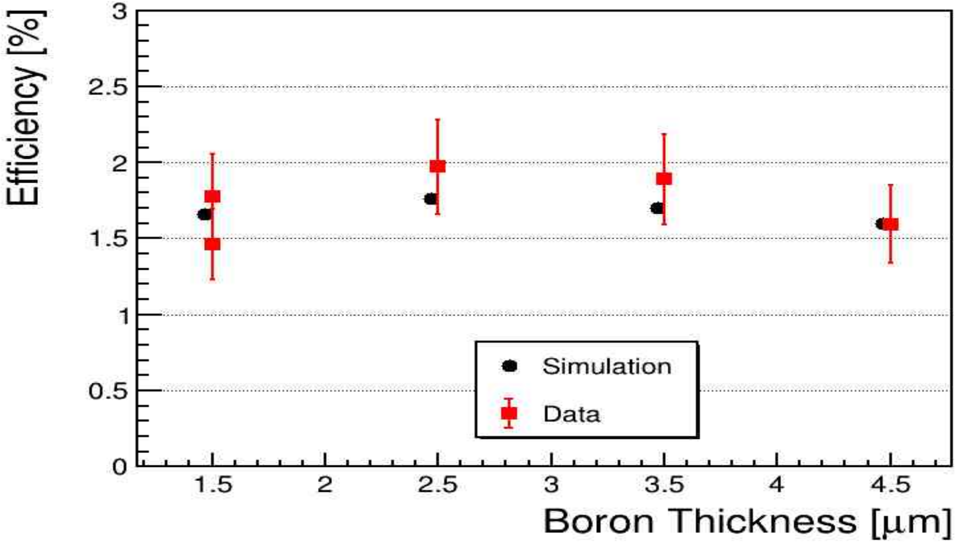
R. Bedogni et al., Nucl.Instr.& Meth. A 843(2017)18-21

goal of the test: measure the conversion efficiency and compare it to simulation

$$i = e\cdot\Phi\cdot G\cdot\epsilon\cdot <N>\cdot\Sigma \quad\Longrightarrow\quad \epsilon = \frac{i}{e\cdot\Phi\cdot G\cdot <N>\cdot\Sigma}$$

- i = current measured with a picoamperometer
- e = electron charge
- Φ = fluence from HOTNES calibration (758 Hz/cm^2)
- G = gain from X-ray calibration
- $<N>$ = number of ionization from GARFIELD++ simulations
- Σ = chamber surface (10 × 10 cm^2)

ATTRACT-uRANIA: exp. *vs* sim. results



The most basic detector option with a B4C coated cathode

The agreement between simulated data and experimental results is remarkable
→ this validates the simulation code and procedure

w/2.5 μm ^{10}B a 2% efficiency obtained @ HOTNES (100 meV, FWHM 290 meV)
→ around 4% with 25 meV neutrons

I. Balossino et al., "u-RANIA: a neutron detector based on micro-RWELL technology, 2020_JINST_15_C09029
[*https://doi.org/10.1088/1748-0221/15/09/C09029*](https://doi.org/10.1088/1748-0221/15/09/C09029)

uRANIA-V: obiettivi del progetto

- Sviluppo di un **dispositivo innovativo** per la rivelazione di neutroni termici ad **alta efficienza** (→ ~10% per singolo detector layer), basato su **tecnologia µ-RWELL per applicazioni in homeland security** (→ *planar large area*) **e radioactive waste monitoring** (→ *cylindrical/roof-tile shape – sinergia con CREMLINplus project*)
- Realizzazione di **nuovi convertitori basati su deposizioni di B4C** realizzate da ESS-Linkoping Coating Workshop (Sweden) → *migliorando i risultati ottenuti in ATTRACT*
- Realizzazione di **detector di grandi dimensioni con readout di vario tipo** (*large pad, strips …)* e **convertitori di varie geometrie**

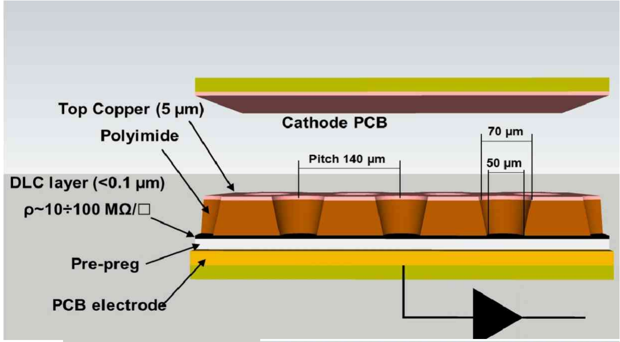
- Sviluppo di **nuova elettronica low cost** per operazione in **counting-mode** per **applicazioni in Radiation Portal Monitor (RPM), Radioactive Waste Monitoring (RWM)**

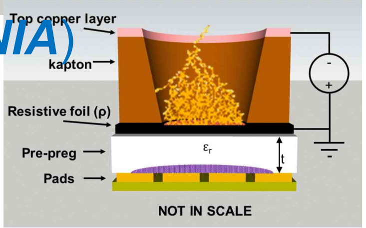
- Test di **µ-RWELL ad alta granularità** (*strip-readout*) **operata in *tracking-mode*** per applicazioni in **radiografia comparata neutronica/raggi-x**

Metodologia della ricerca

- **μ-RWELL:** MPGD compatto, con singolo stadio di amplificazione in Kapton+Cu (GEM-like) accoppiato capacitivamente attraverso **stadio resistivo** (DLC) direttamente con il PCB readout (strip/pad/pixel) → ***large area e geometria flessibile cilindrica/roof-tile***
- **Convertitori:**

  catodi planari con vari spessori di B_4C (***EU ATTRACT-uRANIA***)
  - ***mesh metalliche borate*** inserite nello spazio di deriva
  - ***grooved-cathode*** per aumentare la superficie efficace borata
  - catodi ***multi-blade***, con lamelle perpendicolari (*floating, side-on operation*)

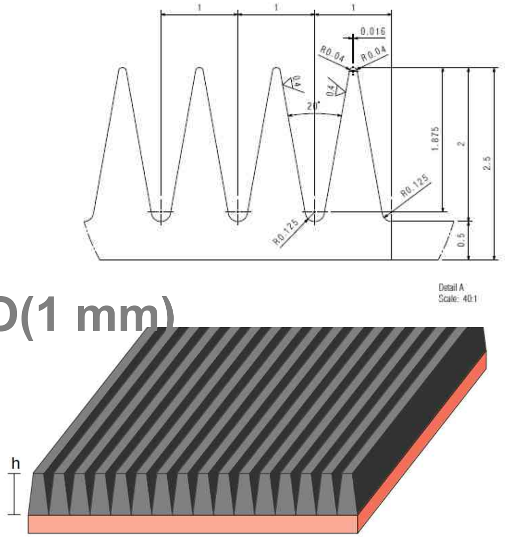




The µRWELL detector: a compact spark-protected single amplification-Stage MPGD, G. Bencivenni, et al., 2015_JINST_10_P02008.

- **Misure in *current-mode*:** efficienza di conversione estratta dalla misura della corrente che fluisce sul DLC (→ *simulazioni con GEANT4 – Ferrara*)
- **Misure in *counting-mode*:** lettura diretta del segnale indotto *sul top di amplifcazione* o sul readout a p
- ***Imaging***, per *neutron-radiography*, **con readout a micro-strip** con APV25 (σ_X ~*100 µm*)

NEW Cathode Converter geometries

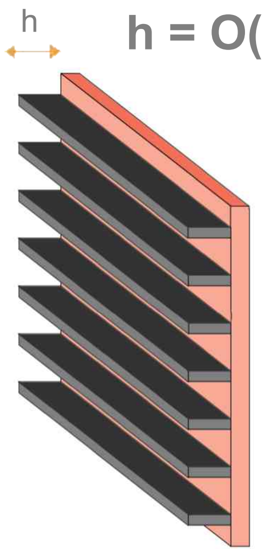


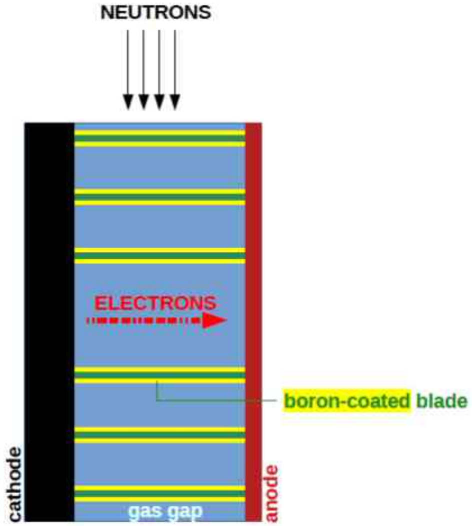
h = O(1 mm)

Grooved cathode
(head-on operation)

neutrons

h = O(1 cm)

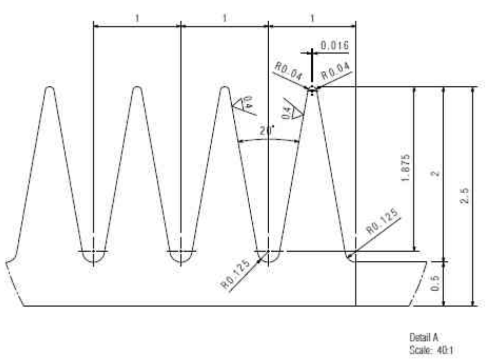


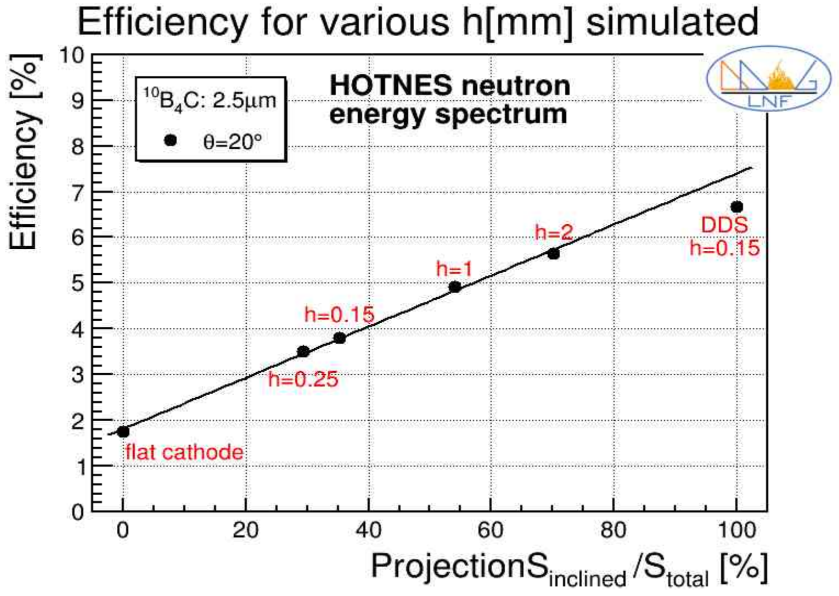


multi-blade cathode
(side-on operation)

neutrons

Grooved cathode: preliminary simulation

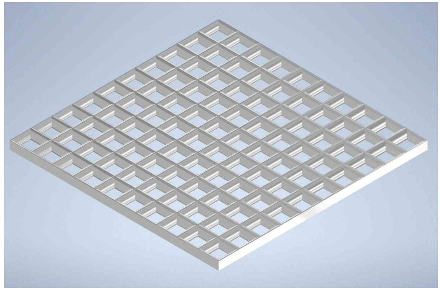




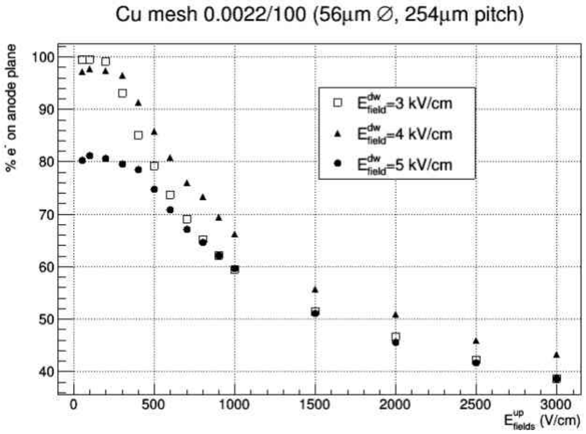
For E_n = 0,025 eV
×2 efficiency

Efficiency studies for various grooved cathodes configurations (h, θ), considering the HOTNES energy spectrum

Mesh based converters



- L’idea è di inserire tra il catodo (borato) e lo stadio di amplificazione della μ-RWELL una mesh metallica opportunamente ricoperta di Boro.
- I neutroni interagendo con il boro delle mesh produranno **particelle alfa e ioni Litio che verranno emessi sia sopra che sotto la mesh.** La ionizzazione prodotta nel gas da tali ioni verrà quindi convogliata con una **certa efficienza (tipicamente funzione del rapporto E_d/E_t) dai campi elettrici di trasferimento/deriva verso lo stadio di amplificazione del rivelatore**



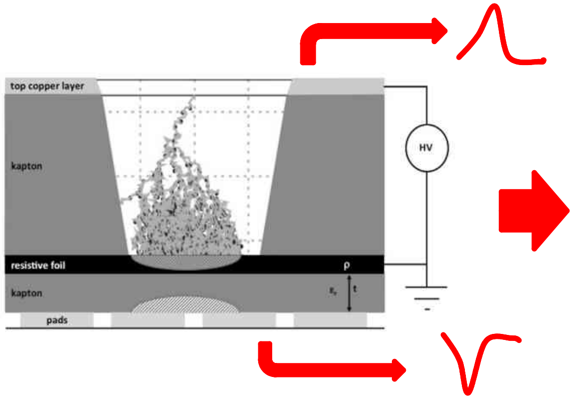
- La **trasparenza elettronica di una mesh** dipende anche dalla **trasparenza ottica** della stessa (definita come rapporto “R” tra spazio vuoto e pieno della maglia della mesh)

- **L’efficienza di conversione dei neutroni** oltre che dallo spessore di Boro dipende anche da “R “

Counting mode (preliminary)

La moltiplicazione generata nel pozzetto della μ-RWELL induce un segnale negativo sul readout (*quello normalmente utilizzato*) e **positivo sul TOP dello stadio di amplificazione**. Disaccoppiando capacitivamente il TOP (alimentato con HV) e collegandolo ad un pre-amplificatore **CAEN A1422 è stato osservato un segnale di ~100 mV/50Ω (mip) , che discriminato può essere inviato ad uno scaler.**

Il circuito riportato necessita la sostituzione di alcuni componenti per accoppiarsi in maniera opportuna **alla μ-RWELL e alla sua capacità di ingresso (dell'ordine di 2 nF - 100cm^2).** La riduzione del rumore gioca un ruolo chiave per massimizzare l'efficienza di **questa tecnica di lettura che permette la misura in counting mode della singola particella, semplificando la rivelazione del neutrone** (*vs il current-mode*) e aprendo la possibilità di costruire un **rivelatore auto-triggerante.**



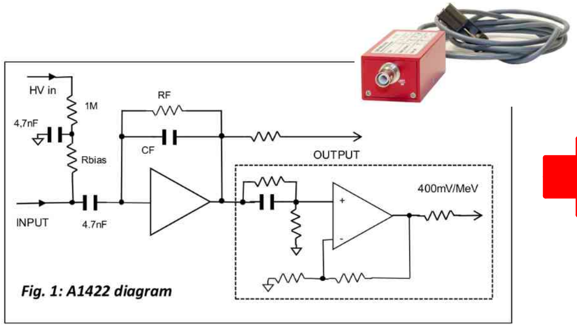
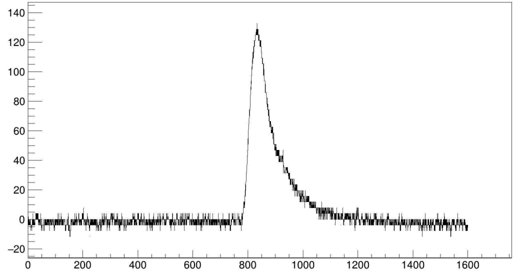


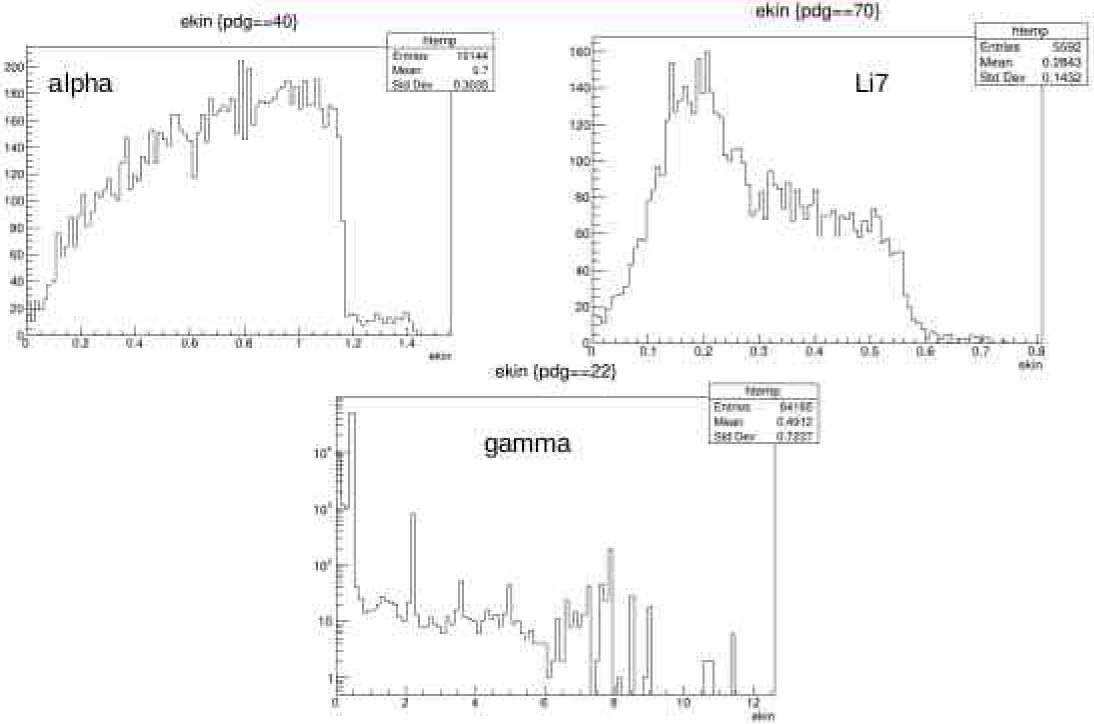
Fig. 1: A1422 diagram



Urania

Simulation with DEFAULT cathode – kinetic energy of particles at first step in gas

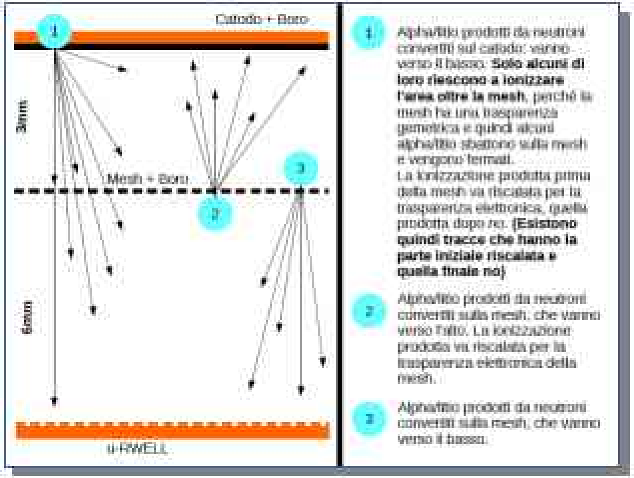
BORON THICKNESS 1.5 micron



Current calculation

Without the mesh: $i = \Phi * \varepsilon * N_{ION} * G * S$

- i = current ($C\ s^{-1}$)
- Φ = neutron flux (758 $cm^{-2}\ s^{-1}$)
- ε = efficiency = #α seen/#neutrons → from simulation
- N_{ION} = # ele from ionization = primaries & secondaries = E_{DEP}/E_{ION}
- G = gain
- S = surface 10 x 10 cm^2



[by Matteo]

With mesh, there are four contributions:

1- α from cathode not crossing the mesh
$i_1 = \Phi * \varepsilon_1 * N_{ION,1} * G * S * T_{ELE}$

2- α from cathode crossing the mesh
$i_2 = \Phi * \varepsilon_2 * N_{ION,2} * G * S$

3- α from mesh forward
$i_3 = \Phi * \varepsilon_3 * N_{ION,3} * G * S$

4- α from mesh backward
$i_4 = \Phi * \varepsilon_4 * N_{ION,4} * G * S * T_{ELE}$

Current calculation

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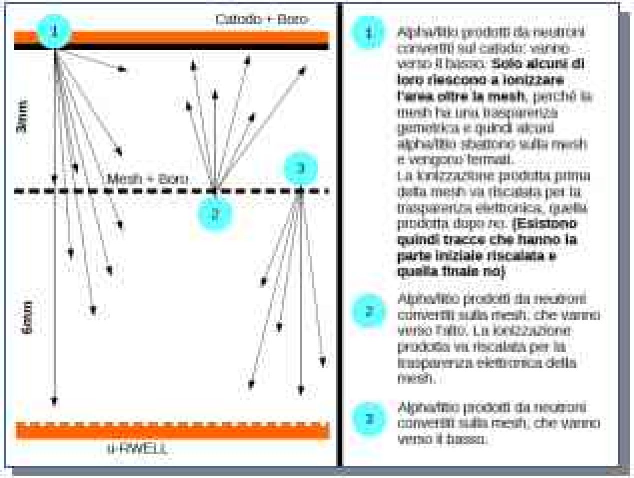

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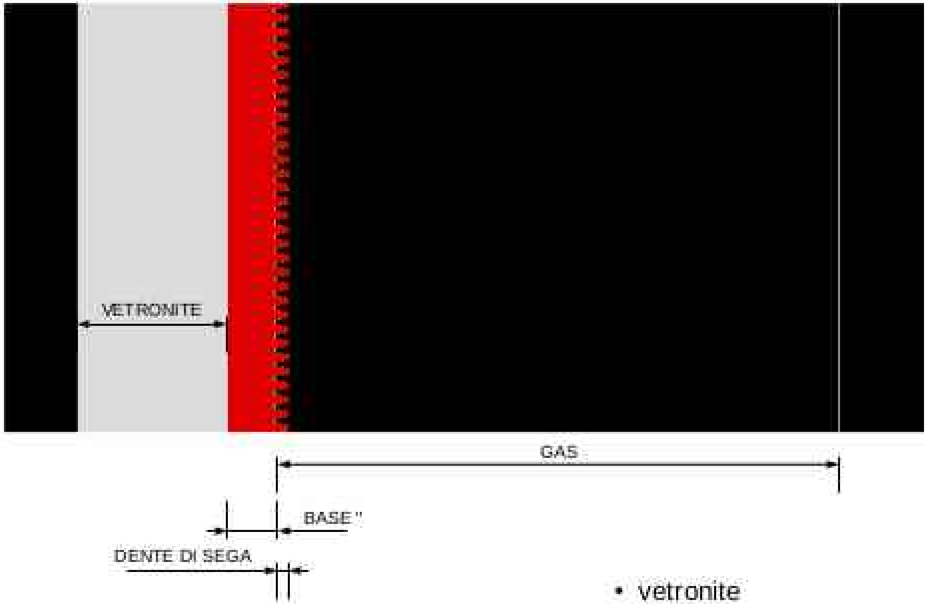
$i_4 = \Phi * \varepsilon_4 * N_{ION,4} * G * S * T_{ELE}$

Urania

Full r-WELL



- vetronite
- copper base, boron coated
- dente di sega, boron coated
- gas

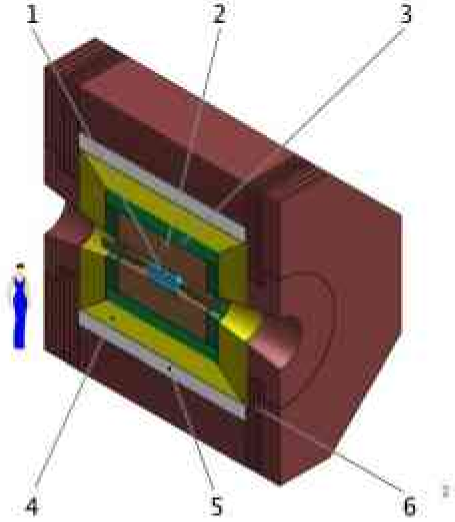
Cremlin+

Detector for Super Charm-Tau Factory

Collider parameters
- Luminosity 10^{35} cm^{-2} s^{-1}
- Energy range 2 — 7 GeV

1 Inner Tracker 3cm<R<20cm -30cm<Z<30cm
2 Drift chamber
3 FARICH identification system
4 Calorimeter on pure CsI
5 Superconducting coil
6 Yoke with a muon system

Tasks
- Rare decays
  - τ lepton
  - D mesons
  - D^0 — anti-D^0 oscillations
- Search for τ→μγ



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Connecting Russian and European Measures for Large-scale Research Infrastructures

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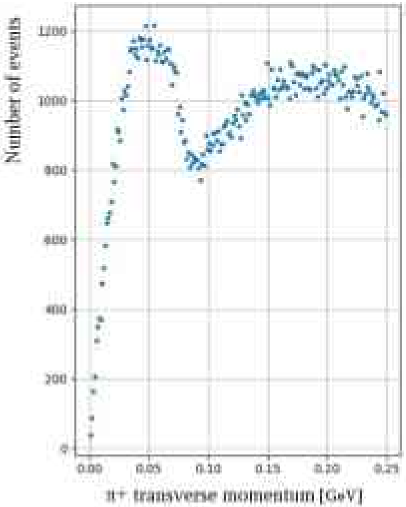
Inner Tracker (IT)

Tasks
- Detect secondary vertices from the decays of short-lived particles such as K^0_S or Λ
- Complement the drift chamber in measuring the momenta
- Soft $\pi^{\pm}$ mesons registration (with momenta < 100 MeV/c)



Simulation of π^+ transverse momentum distribution in $e^+e^- \rightarrow DD^*$ (V. Vorobyev)

Inner Tracker

- Located between vacuum chamber and drift chamber
- Detection solid angle up to 98%
- Cylinder
  - Length 60 cm
  - Inner diameter 3 cm
  - Outer diameter 40 cm

Simulation in DD4hep
dd4hep.web.cern.ch

Options
- Cylindrical silicon strip 4-layer detector (Si-strips)
- Cylindrical GEM (Gas Electron Multiplier) (CGEM) 4-layer detector
- Time Projection Chamber (TPC)

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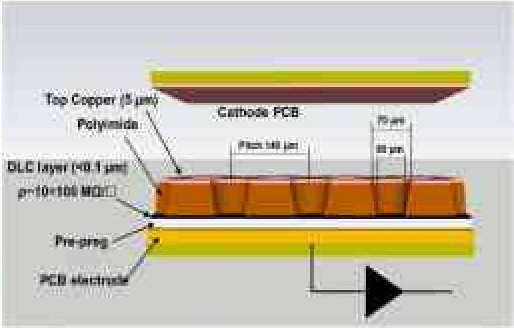
The μ-RWELL technology

The IT is based on the μ-RWELL technology.
The device is composed of two elements:

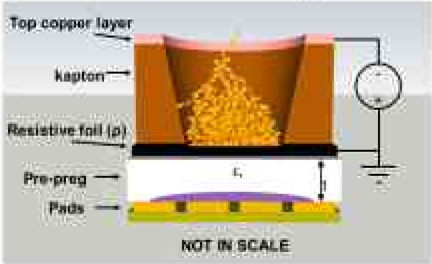
- μ-RWELL_PCB
- drift/cathode PCB defining the gas gap

μ-RWELL_PCB = amplification-stage ⊕ resistive stage ⊕ readout PCB

large area & flexible geometry (i.e. cylindrical shape)



- The "WELL" acts as a multiplication channel for the ionization produced in the gas of the drift gap
- The charge induced on the resistive layer is spread with a time constant, τ ~ ρ×C



$C \equiv \varepsilon_0 \times \varepsilon_r \times \frac{S}{t} \cong 50\ pF/m$ (pitch-width 0.4 mm)

The μ-RWELL detector: a compact spark-protected single amplification-stage MPGD, G. Bencivenni, et al. 2015 JINST 10 P02008.

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Possible IT layouts

- N. 4 independent C+layers → 2.5 % X0
- 1 cm gas gap/layer
- 4 cm global sampling gas

- N.2 small gap B2B C+layers → 2.0 % X0
- 1 cm gas gap/layer
- 4 cm global sampling gas

- N.1 large gap B2B C+layers → 1.0 % X0
- 5 cm gas gap/layer
- 10 cm global sampling gas

Operation of large gas gap to be proved

All these layouts require the design, construction and test of a Cylindrical RWELL prototype.
The prototype under discussion is based on a new innovative concept: the ***modular roof-tile shaped detector.***

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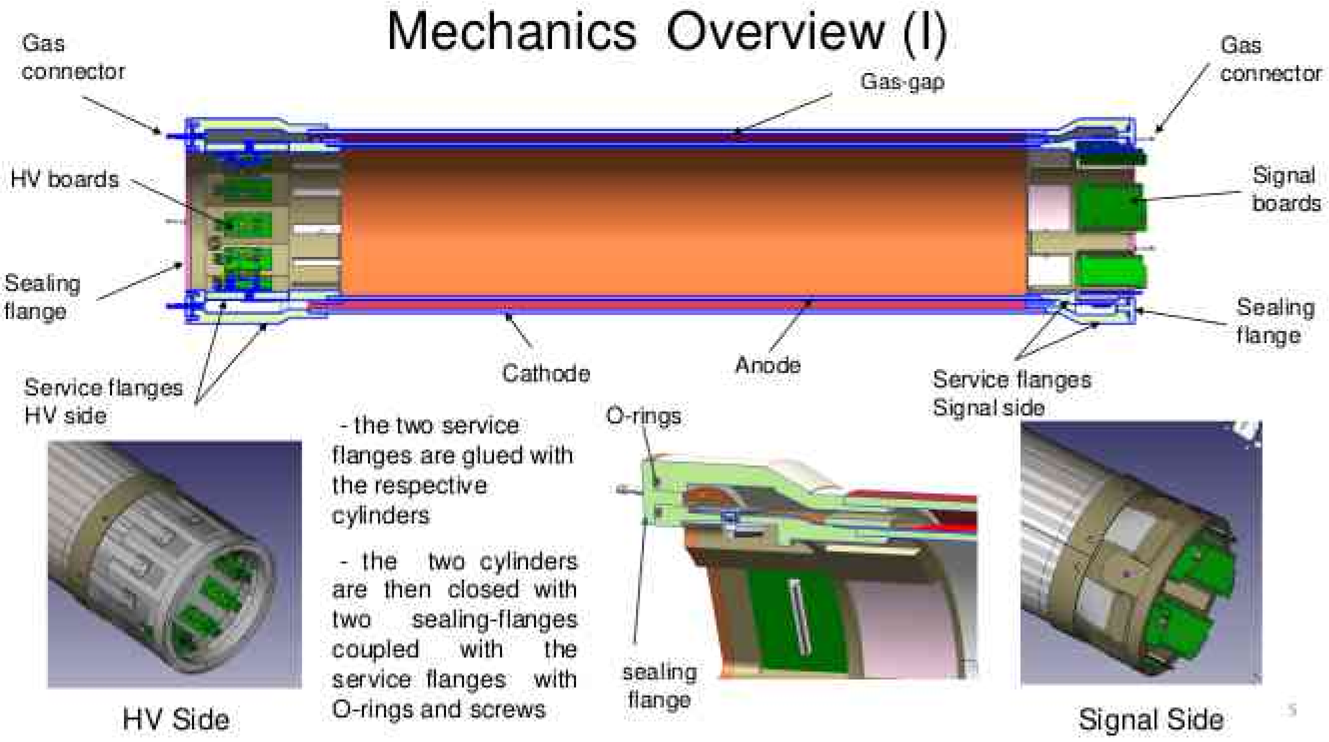
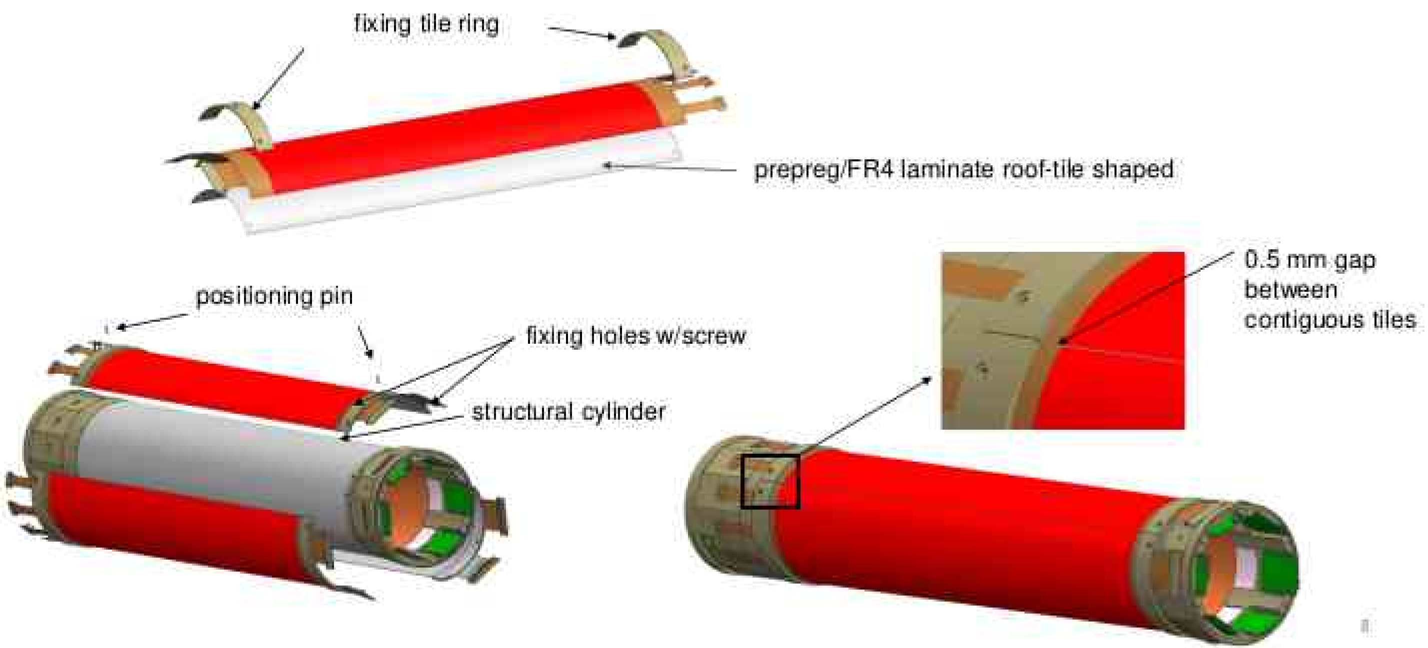

Mechanics Overview (I)
Gas connector
Gas-gap
Gas connector
HV boards
Signal boards
Sealing flange
Sealing flange
Cathode
Anode
Service flanges HV side
Service flanges Signal side
- the two service flanges are glued with the respective cylinders
- the two cylinders are then closed with two sealing-flanges coupled with the service flanges with O-rings and screws
O-rings
sealing flange
HV Side
Signal Side

Cremlin+

MODULAR LAYOUT: the detector tile



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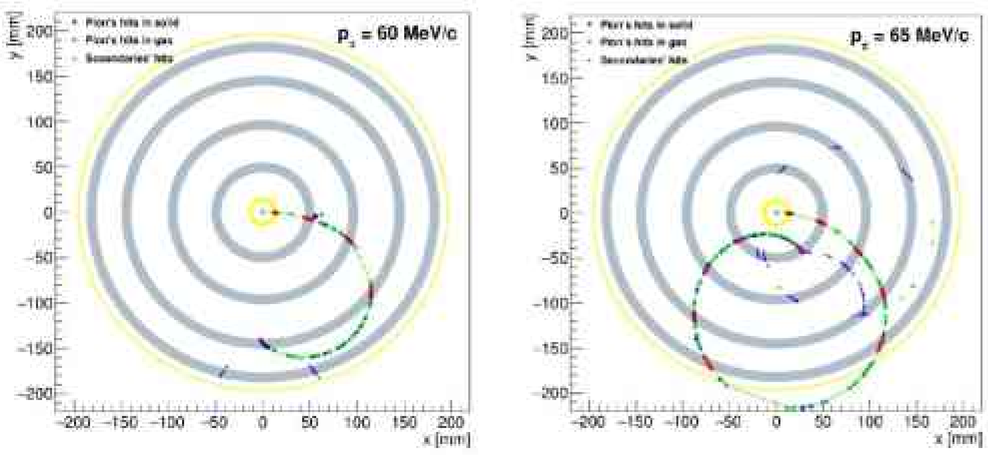
Inner Tracker   DD4hep simulation   CGEM



- Pions with momenta 60 MeV/c pass through three layers and curve back
- Starting from p_π = 65 MeV/c the all 4 layers are crossed by pions minimum twice

13

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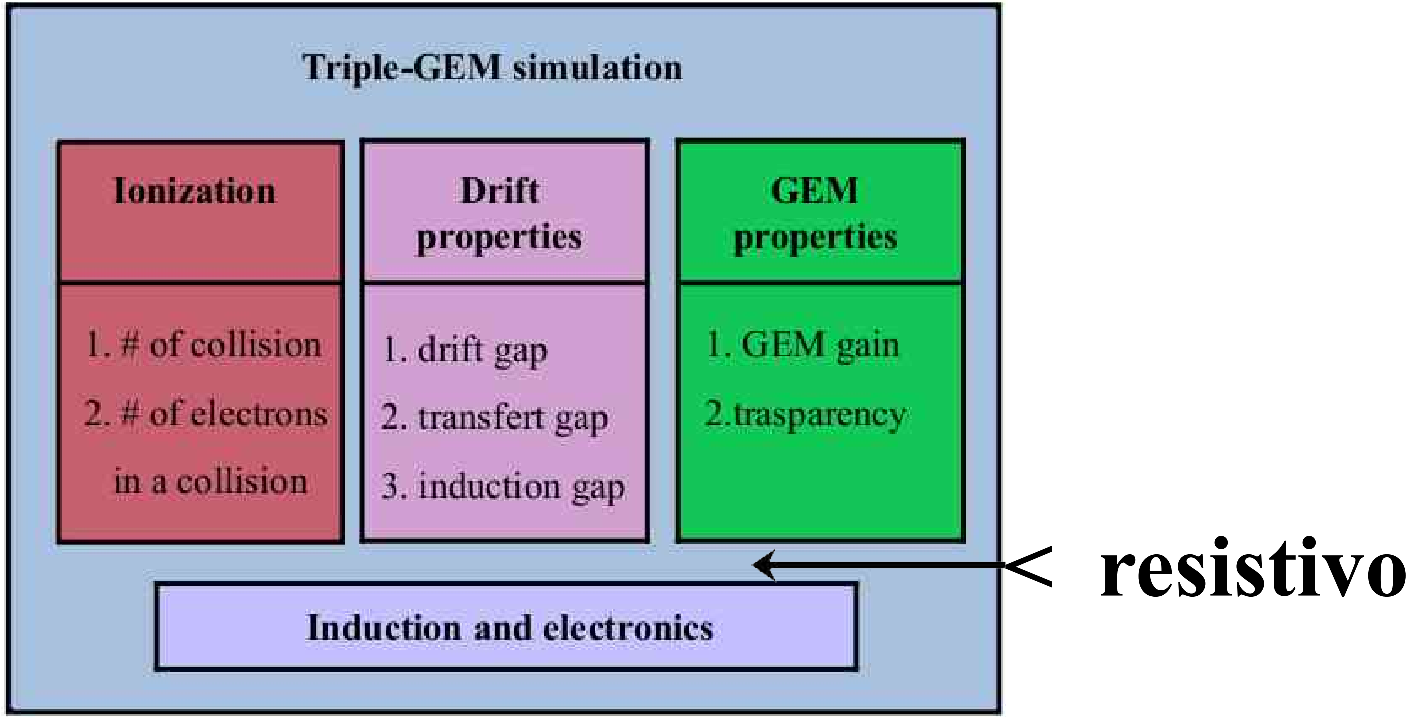
Triple-GEM simulation
Ionization
1. # of collision
2. # of electrons in a collision
Drift properties
1. drift gap
2. transfert gap
3. induction gap
GEM properties
1. GEM gain
2.trasparency
Induction and electronics
< resistivo

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SIMULATION OPEN ISSUES (UPDATED ON JAN 19TH)

Simulation

- 100 GeV muons wrt 180 GeV muon data reference
- 0.5 kV/cm drift field therefore we need to use data reference distributions accordingly
- DATA/MC mismatch without resistive simulation: at theta=0 deg 2.6 fired strips (MC) vs 5 fired strips (DATA).
  Studies reported by Riccardo today:
  - *Drift: transverse diffusion is different between PARSIFAL and GTS*
  - *Gain: in Parsifal 30% of the electrons has zero gain. In GTS this number is 4% (Transparency)*
  - *Cluster charge: we are loosing 50% of the charge both on strip x and y*
- Resistive simulation: software code written by Gianfranco Morello. *Implement APV shaper function from Riccardo Farinelli*
- Define materials to insert in Geant4. We need to identify the area in DD4HEP devoted to CGEM geometry and material description and ask our TPC colleagues the code that was used for the soft pion study.
  Geometry of 2 small gap B2B detectors implemented and Geant4 hits saved. Erika De Lucia together with Lia Lavezzi.

Reference Data

- Measure noise level and threshold in data ref as input for MC.
  Matteo Giovannetti sent reference plots and values to Riccardo Farinelli