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R esistive
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Thermal neutron detection based on resistive gaseous devices

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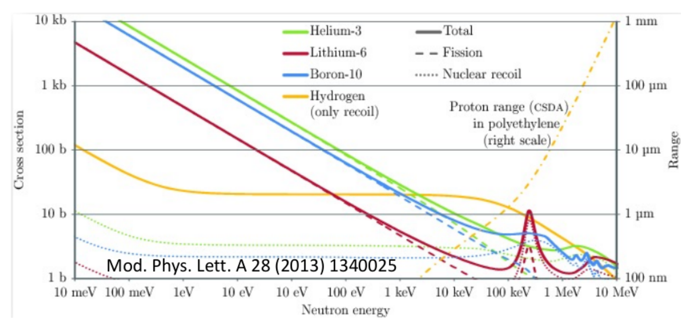
uRANIA-V

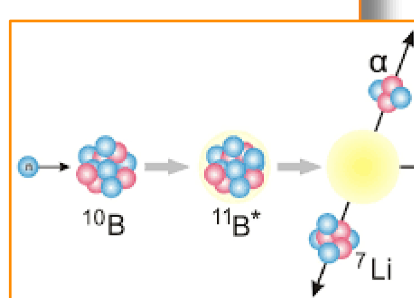
The goal of the **uRANIA-V** project is the development of an innovative **thermal neutron detector** using $^{10}B_4C$ converters. The R&D is focusing on two gaseous detectors: the **μ-RWELL**, a reliable and scalable resistive MPGD, and the **sRPC**, a new concept of RPC based on surface resistivity electrodes. One or more thin layers of $^{10}B_4C$ allow the **thermal neutron conversion** into ^7Li and α ions, detected in the active volume of both devices. Results from tests performed with different converter layouts show that a thermal neutron (25meV) **detection efficiency of 7% (5%)** can be achieved with a single detection layer of μ-RWELL (sRPC).

Thermal neutron detection and converter material

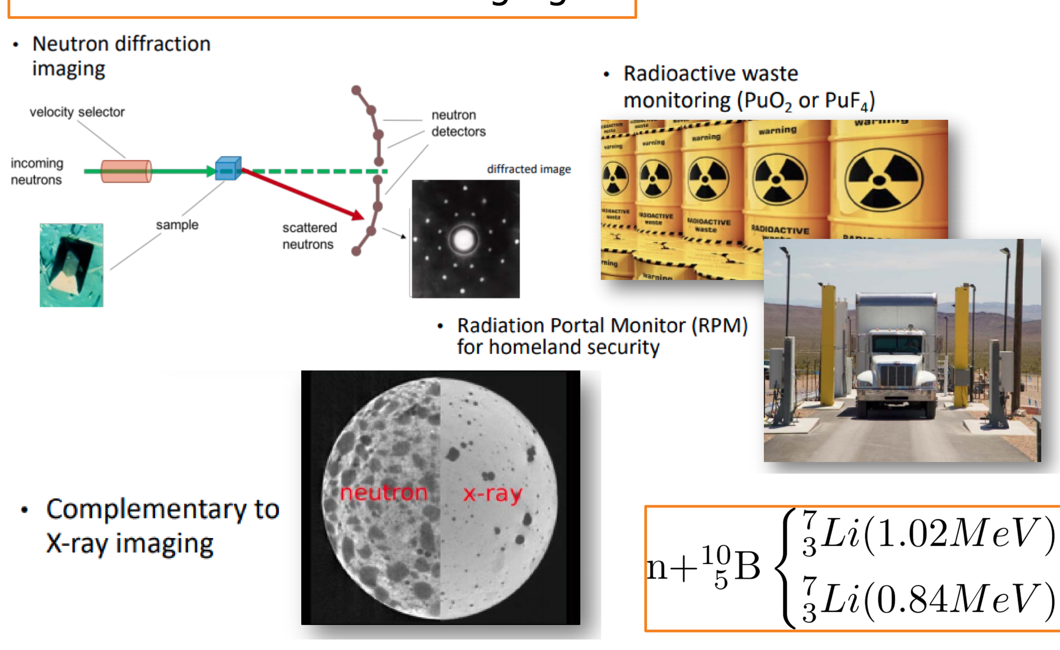
WHY

- Probing heavy structure in motion
- Unique probe
  - for magnetism
  - for fundamental properties
- Radioactive waste monitoring
- Radiaton Portal Monitor (homeland security)
- Neutron diffraction imaging





Thermal neutron detection relies on the neutron capture and thus conversion to ionizing particle: ^3He shortage → ^{10}B as alternative: a $^{10}B_4C$ **converter**.



Advantages of $^{10}B_4C$

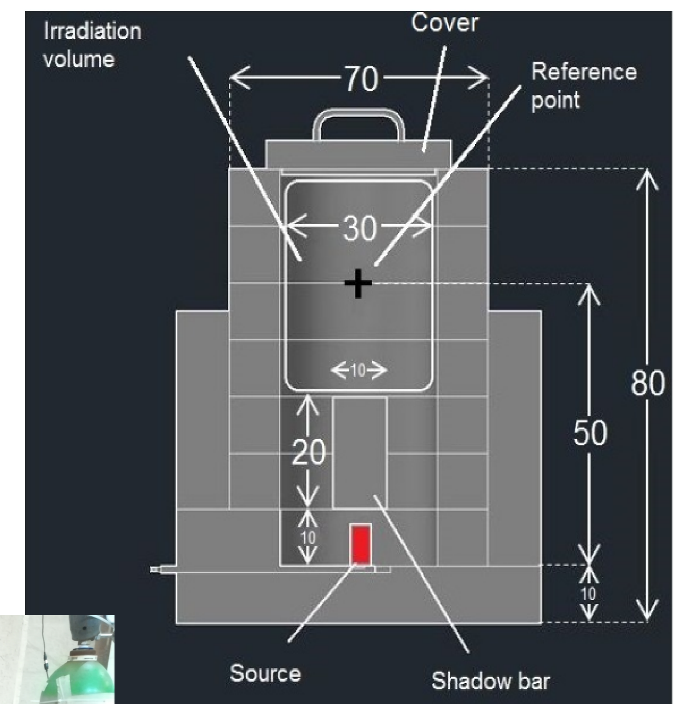
- Chemically stable
- Mechanically robust
- Good adherence on substrates
- Uniform sputtering thickess over large surfaces
- Deposition based on industrial technology

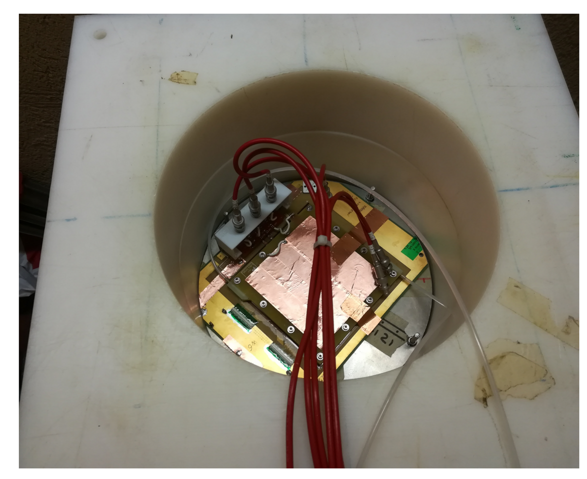
$$n + {}^{10}_{5}B \begin{cases} {}^{7}_{3}Li(1.02MeV) + \alpha(1.78MeV) & 6\% \\ {}^{7}_{3}Li(0.84MeV) + \alpha(1.47MeV) + \gamma(0.48MeV) & 94\% \end{cases}$$

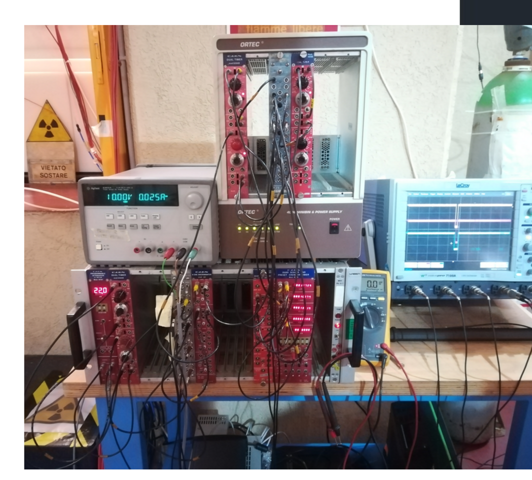
The ENEA-HOTNES facility

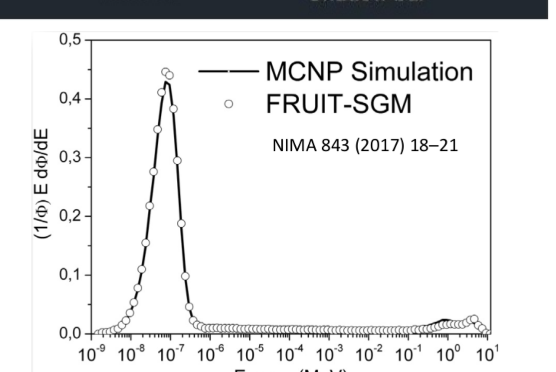
HOTNES:
Homogeneous Thermal NEutron Source[3]

- **Calibrated ^{241}Am-B** thermal neutron **source**
- Cylindrical polyethylene cavity
- Isofluence on disks (within 2%) w/ 30cm ⌀
  - **758±16cm^{-2}s^{-1}** @ reference plane
- Shadow bar to stop gammas (4-9 μS/h)
- Energy spectrum peaked @ **100meV**
- FWHM = 290meV
- Angular distribution down to 8 mrad from surface



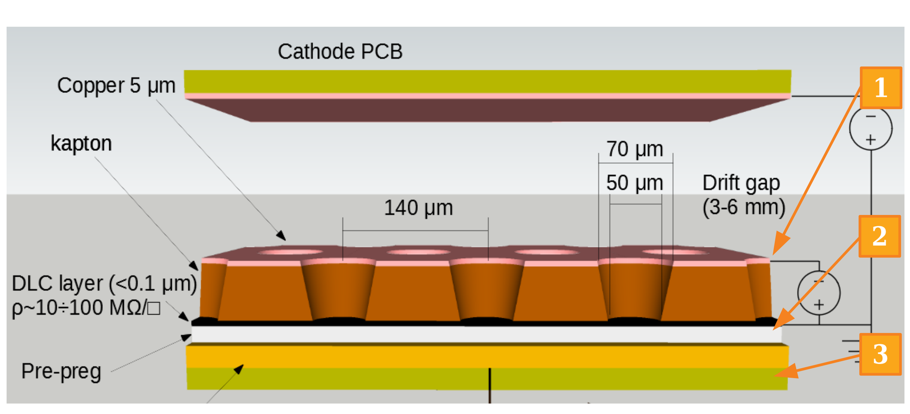




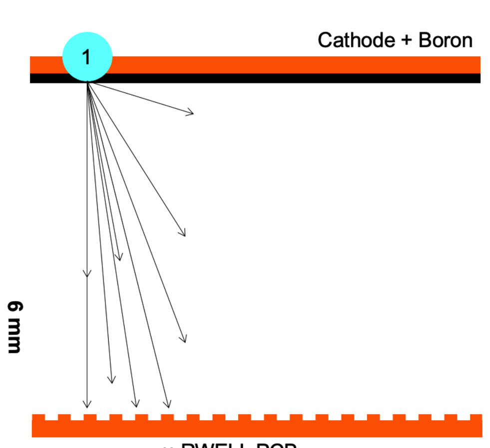


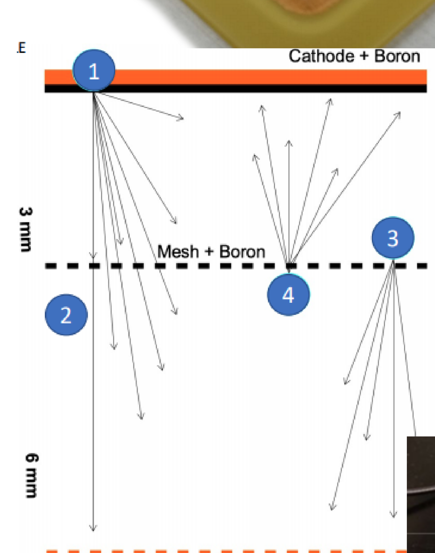
The μ-RWELL – three converter geometries

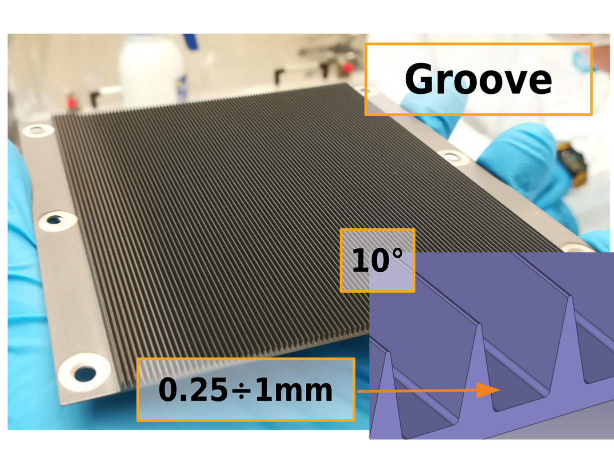
The **μ-RWELL** is a **resistive** Micro Pattern Gaseous Detector (**MPGD**): compact, spark protected and with a single amplification stage[1]. A surface facing the gas, **sputtered with $^{10}B_4C$**, is used as a **neutron converter.**

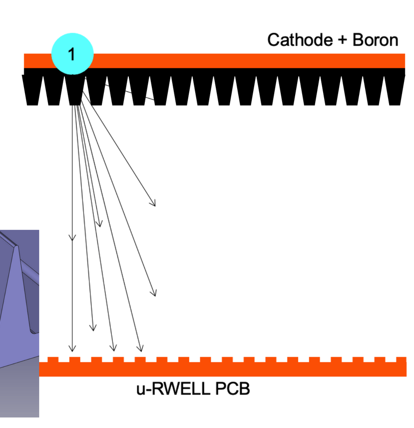


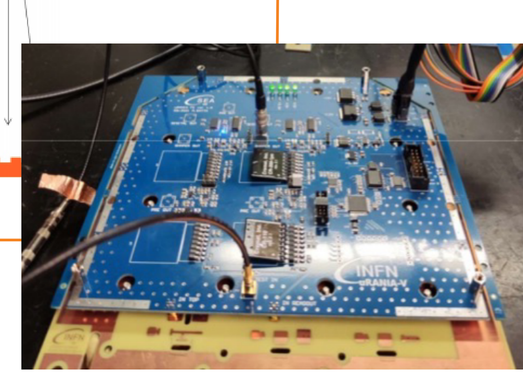
1. **A WELL** patterned kapton foil acting as **amplification stage**
2. A **resistive layer of DLC (Diamond-Like-Carbon)** w/ ρ_S~80 MΩ/□
3. A standard readout PCB





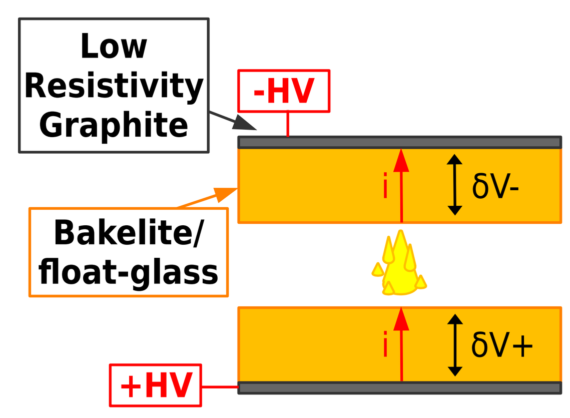






Common custom FEE by LNF electronic pool (CR-110 & CR-200)
Gain ≈ 2mV/fC – Shaping 1μs
FWHM = 2.4 x Shaping Time

The surface RPC – a new paradigm

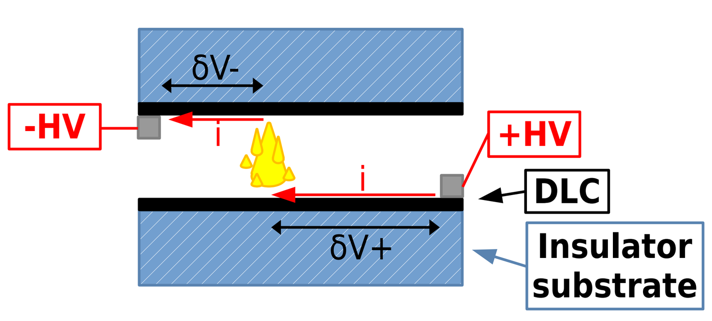


Classical RPCs

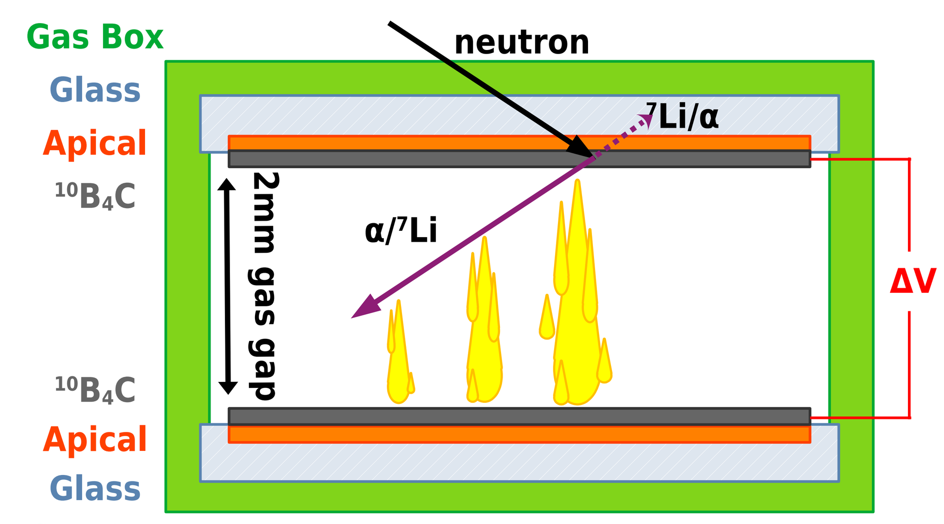
- Bulk resistivity ρ_V electrodes (bakelite, float-glass)
- Recovery time proportional to ρ_V and electrode thickness

The sRPC[2]: surface RPC

- Surface resistivity **DLC** electrodes manufactured with sputtering techniques on flexible supports
- The technology allows to realise large electrodes with a DLC **surface resistivity** in a very **wide range: 10 MΩ/□ ÷ 10 GΩ/□**

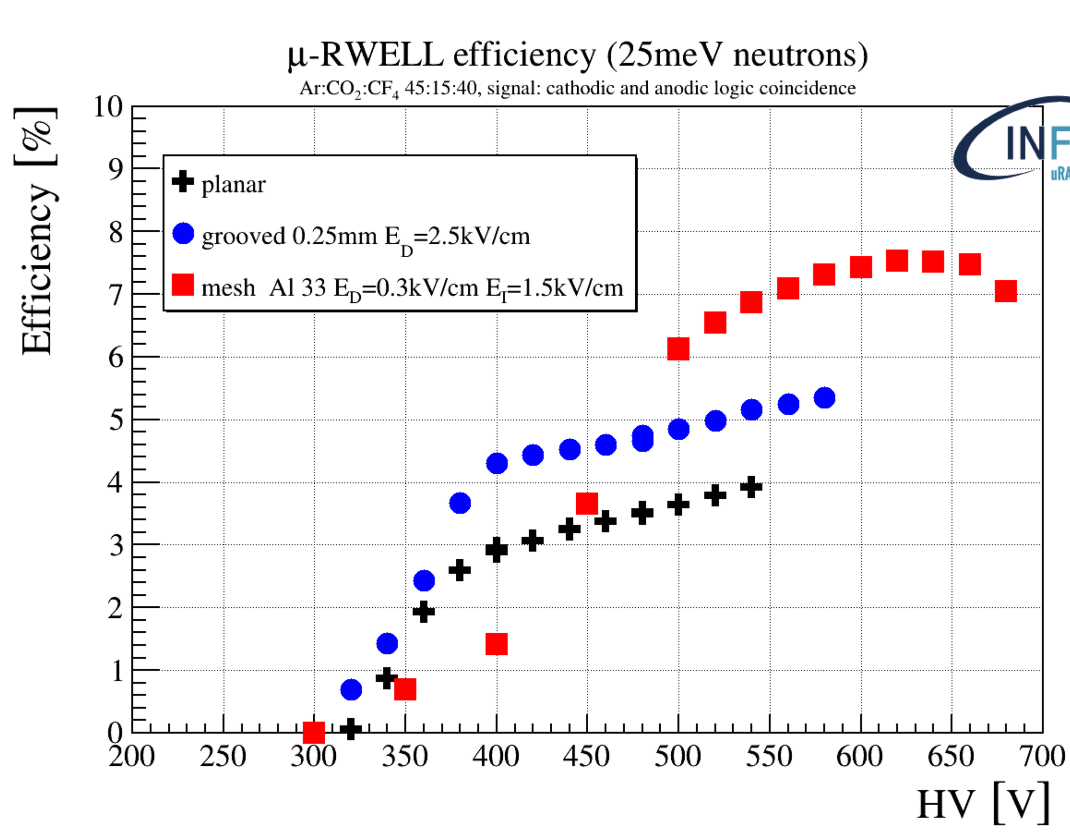


Since the $^{10}B_4C$ surface resistivity is **O(1 MΩ/□)**, it is possible to **switch one (or both)** of the DLC electrodes. The $^{10}B_4C$ will act as a converter surface facing the gas gap, ensuring also the high voltage for detector operation.



- α/^{7}Li emission is **uniform** ⇒ they enter the gas gap with a random angle
- α/^{7}Li **mean path** < **2mm** ⇒ cathode and anode have different behaviors

μ-RWELL efficiency for different converters



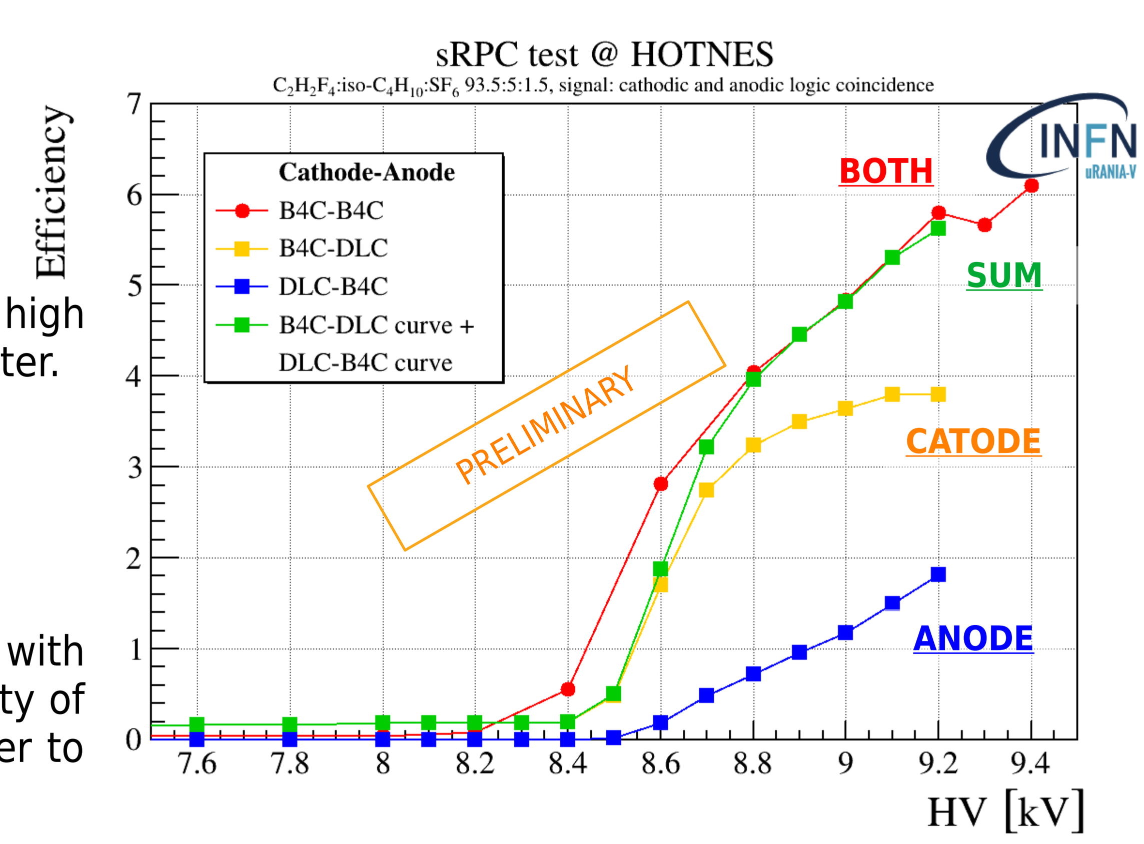
For **μ-RWELL** the use of not-planar converters allow to reach high efficiencies for 25meV neutrons: above 7% with the mesh converter.

The **sRPC** efficiency is measured with 3 electrode configurations:

- **$^{10}B_4C$ CAT** – **DLC AN** : the expected 4% plateau was reached
- **DLC CAT** – **$^{10}B_4C$ AN** : efficiency depends on the HV
- **$^{10}B_4C$ CAT – $^{10}B_4C$ AN** : the "double $^{10}B_4C$ performs as the **SUM**

A detection efficiency above 5% is achieved with a single sRPC with both the electrodes as converters. Thanks to the overall simplicity of the detector is possible to think of a multistack structure in order to achieve a global efficiency of the order 20-30%.

sRPC measurement results



More on μ-RWELL? → M. Giovannetti talk – *The μ-RWELL in HEP and beyond*

More on sRPC? → M. Poli Lener talk – *The surface Resistive Plate Counter*

[1] G. Bencivenni et al., *The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD*, 2015 JINST 10 P02008
[2] M. Giovannetti et al., *The surface Resistive Plate Counter (sRPC): an RPC based on MPGD technology*, 2023 JINST 18 C06026
[3] A. Sperduti et al., *Results of the first user program on the Homogeneous Thermal Neutron Source (ENEA/INFN)*, 2017 JINST 12 P12029

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