The URANIA-V project: thermal neutron detection for radioactive waste and borders monitoring

Riccardo Farinelli
on behalf of the URANIA-V collaboration

Outlook

Neutron detection technique

Simulations

Test with a neutron source

Single neutron counting

The project objective and application

μ-RWELL Advanced Neutron Imaging Apparatus (uRANIA)

funded within the call ATTRACT, European Union Horizon 2020 research and innovation programme under grant agreement No 777222

Objective

develop an innovative detector for diffractive neutron imaging based on micro-Resistive WELL (μ-RWELL) technology

Possible applications

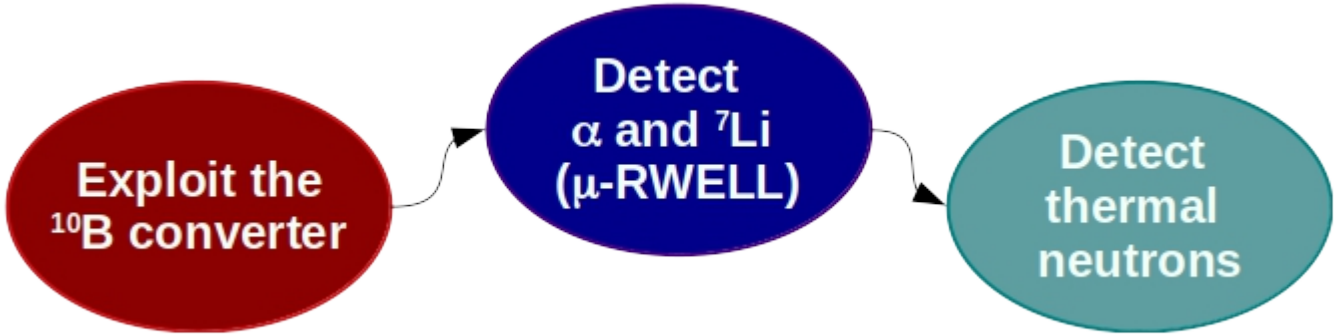
Monitoring

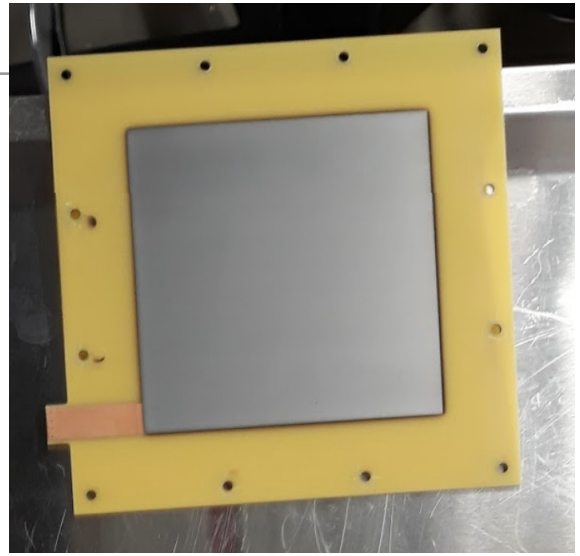
- homeland security
- radiation waste
- neutron fluxes at spallation source

Imaging

- crystals for material studies
- proteins, virus, bacteria
- neutron-based radiography

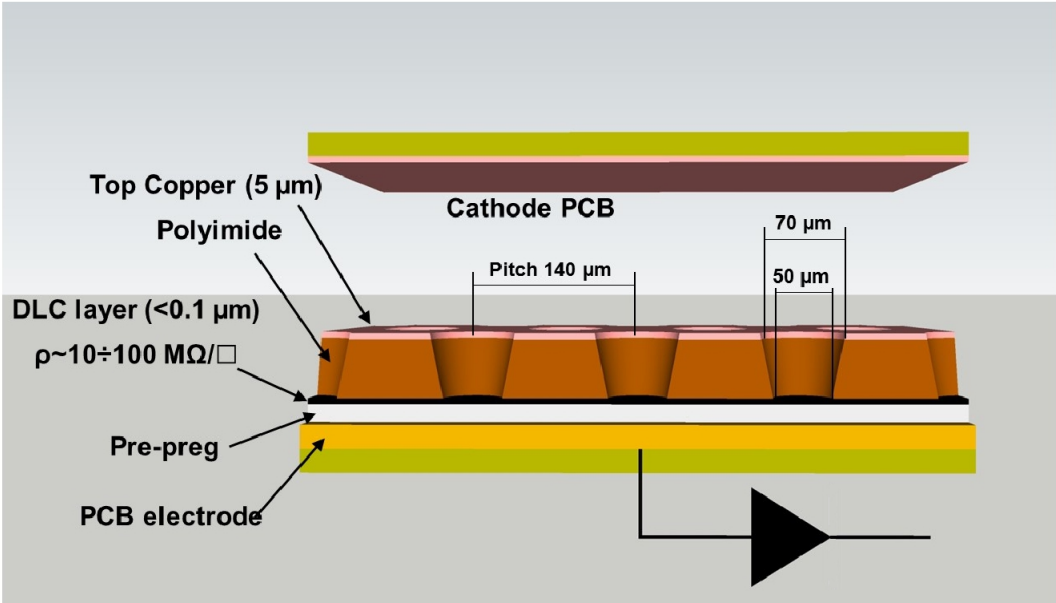
Neutron detection technique





The cathode must be boron coated

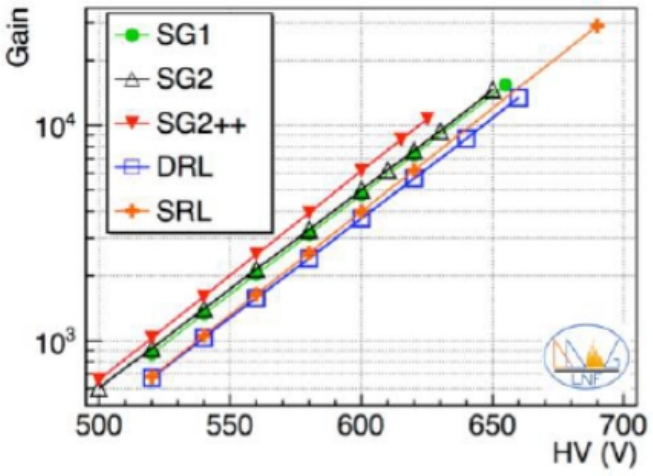
- B_4C enriched with ^{10}B @97% is sputtered on the copper surface @ ESS Linköping Coatings Workshop with direct current magnetron sputtering technology
- The neutron hitting the cathode converts to α and ^{7}Li according to the cross section
- Charged particles are emitted back-to-back → only one enters the gas



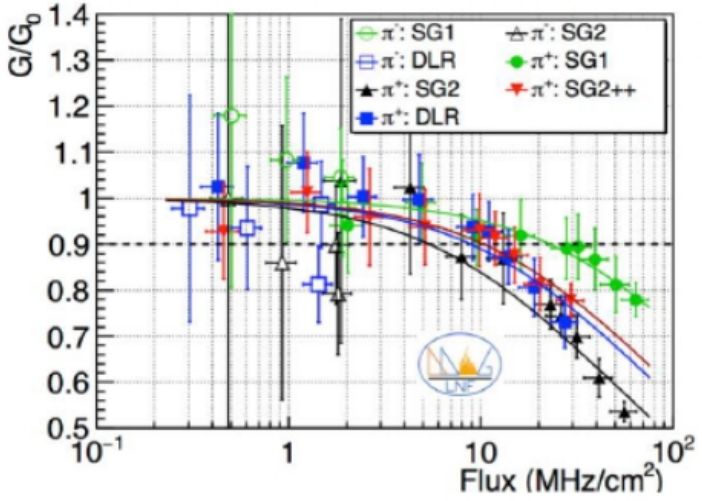
- Ionization → electrons drift to the amplification stage → avalanche → readout

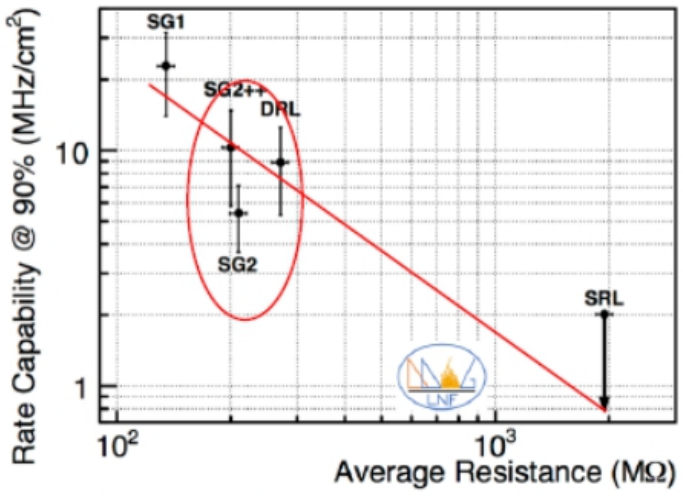
μRWELL on literature

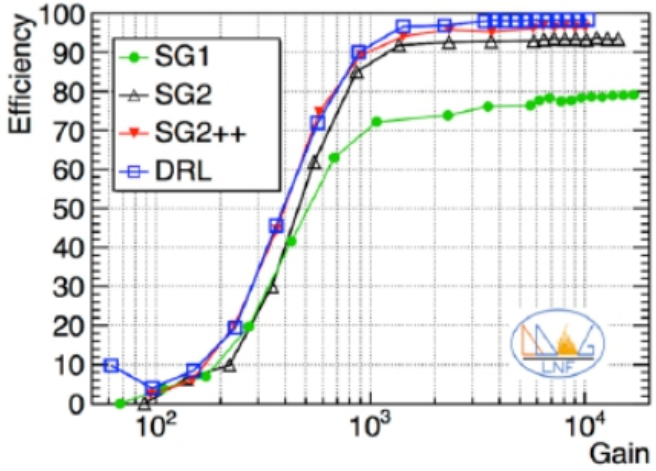
Gain up to ~ 10^4

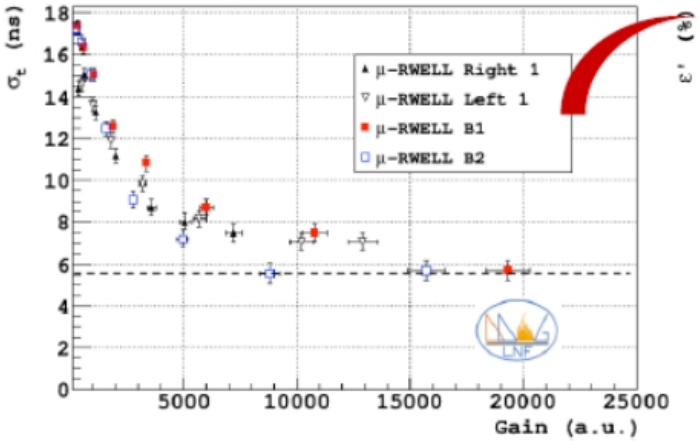


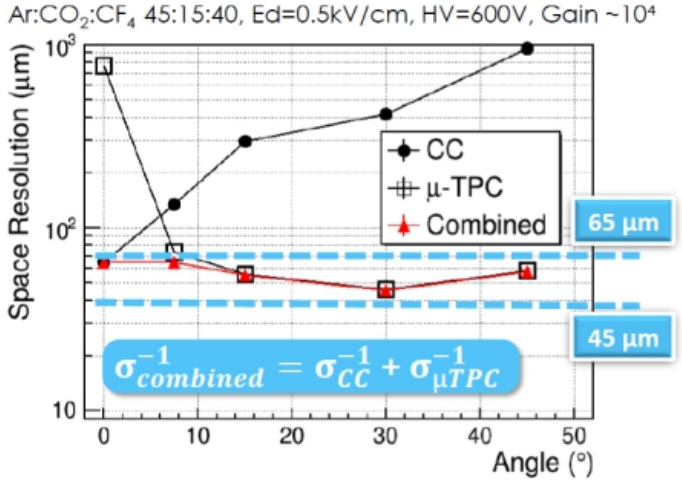
Rate capability (@ G = 5000) ~ 5-10 MHz/cm^2











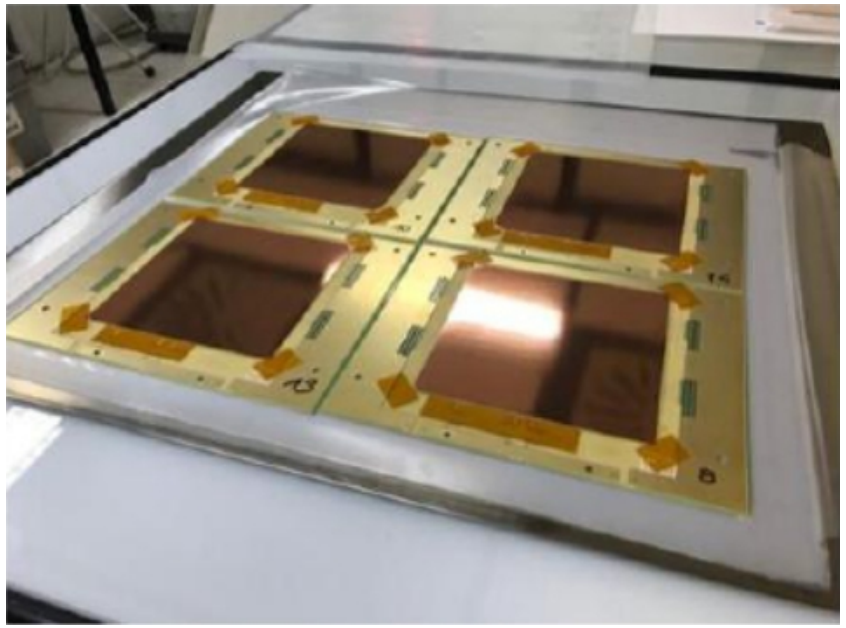
Efficiency ~ 98%

σ_t ~ 5-6 ns

Space resolution

μRWELL on literature

Large area μRWELL have been already developed and a technological transfer is ongoing together with the ELTOS industry



Boron conversion and efficiency simulations

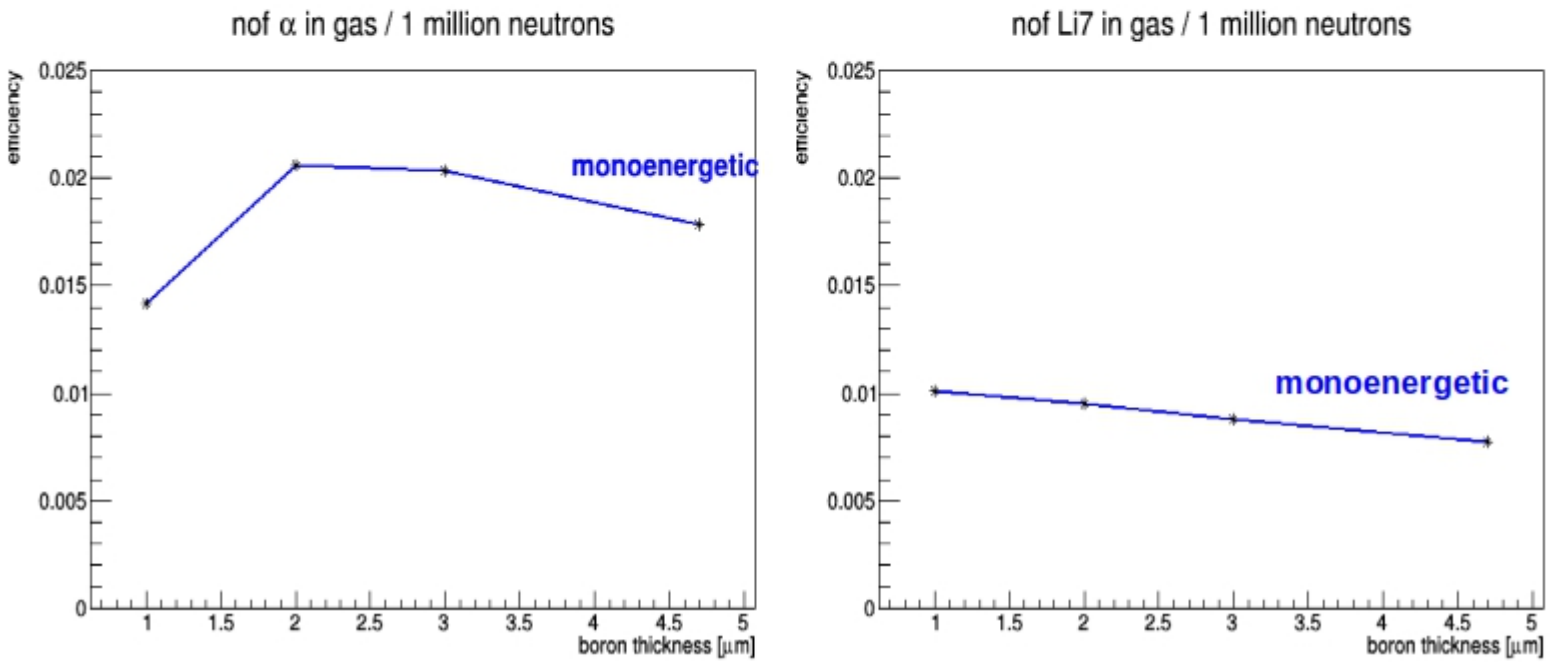
Setup geometry

- 10 x 10 cm^2 chamber: boron-coated cathode + gas (no anode, no electric field)
- chamber orthogonal to z axis
- boron coating thicknesses of 1, 2, 3, 4.7 μm have been simulated

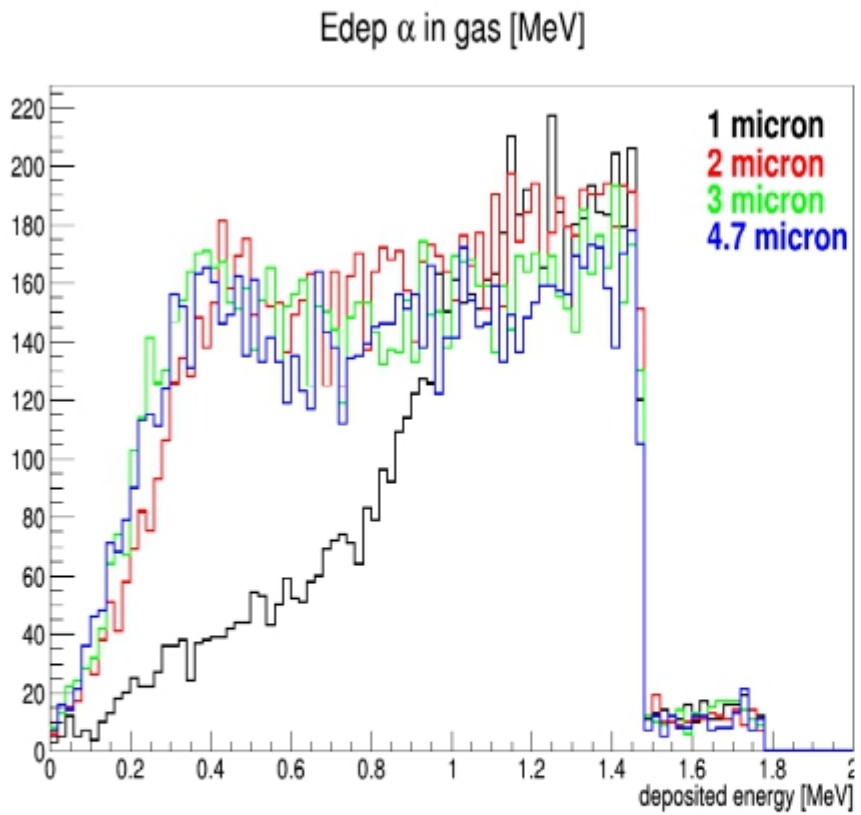
Particle generation

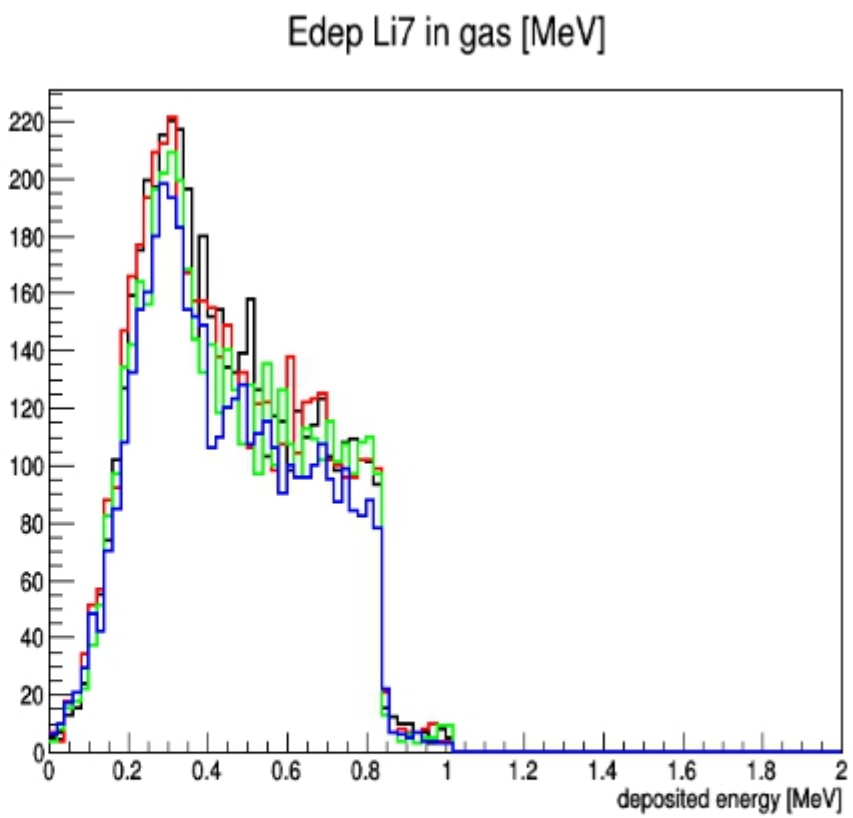
- 1 million thermal (25 meV) neutrons
- origin on a plane parallel to the chamber, same x/y dimensions, distance in z = 1 mm

Conversion efficiency = #α or ^{7}Li entering the gas/ #incident neutrons



Deposited energy by α and Li7 in gas





$$^{10}\mathrm{B} + n \rightarrow {}^{7}\mathrm{Li}^{*}\,(0.84\,\mathrm{MeV}) + \alpha\,(1.47\,\mathrm{MeV})$$
$$^{7}\mathrm{Li}^{*} \rightarrow {}^{7}\,\mathrm{Li} + \gamma\,(0.477\,\mathrm{MeV})$$
$$^{10}\mathrm{B} + n \rightarrow {}^{7}\mathrm{Li}\,(1.01\,\mathrm{MeV}) + \alpha\,(1.78\,\mathrm{MeV})$$

- Our gas mixture has a ionizing energy ~ 31.5 eV
- Particles have range < 6 mm of gas

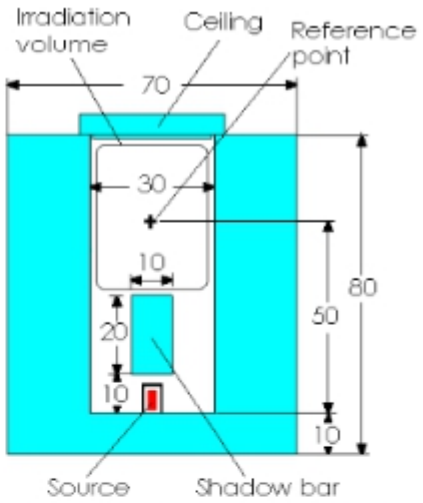
→ they release all the energy in the gas

→ ~10^4 number of primaries

Testbeam setup and efficiency measurement

Facility HOTNES* @ ENEA, Frascati, Italy

- 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 block gammas (4-9 μSv/h)
- Angular distribution down to 8 mrad from surface
- Energy spectrum peaked @100 meV (FWHM = 290 meV)



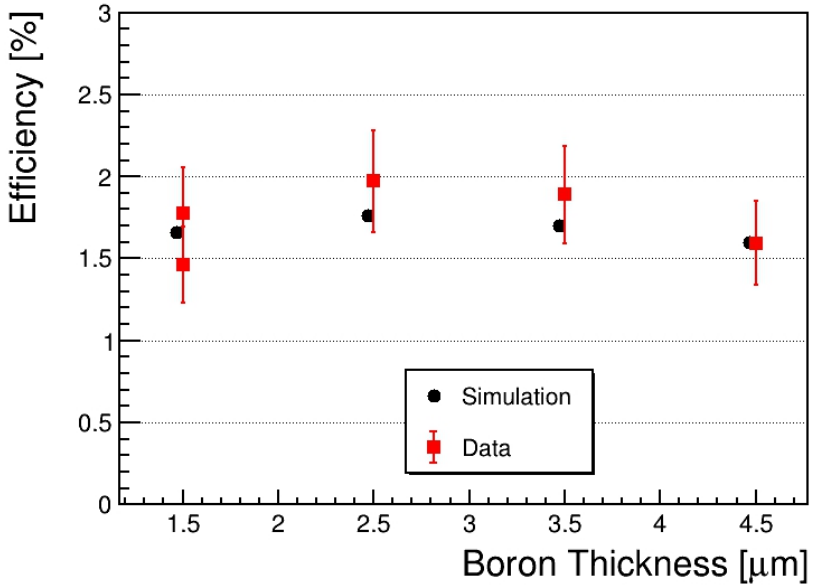
*[R. Bedogni *et al.*, Nucl. Instr. & Meth. A 843 (2017) 18-21]

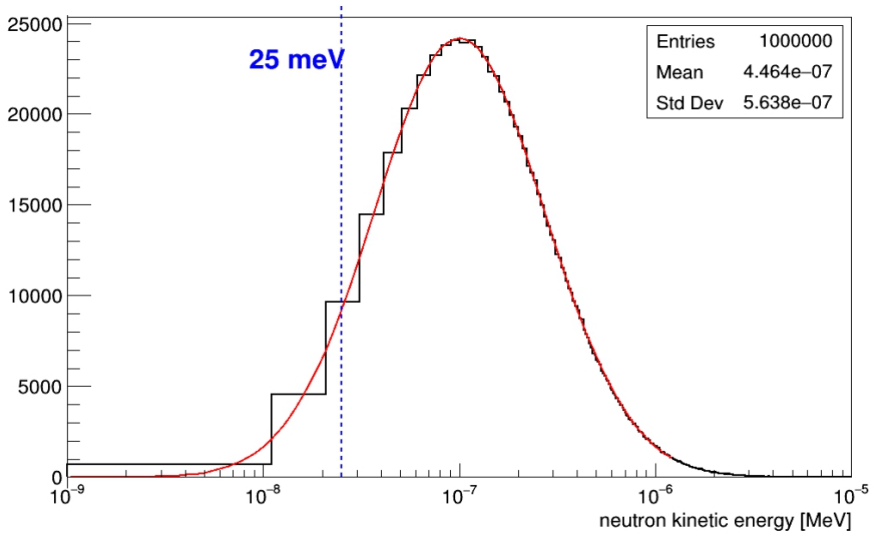
goal of the test: measure the conversion efficiency and compare it to simulation

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

- 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)

Testbeam results





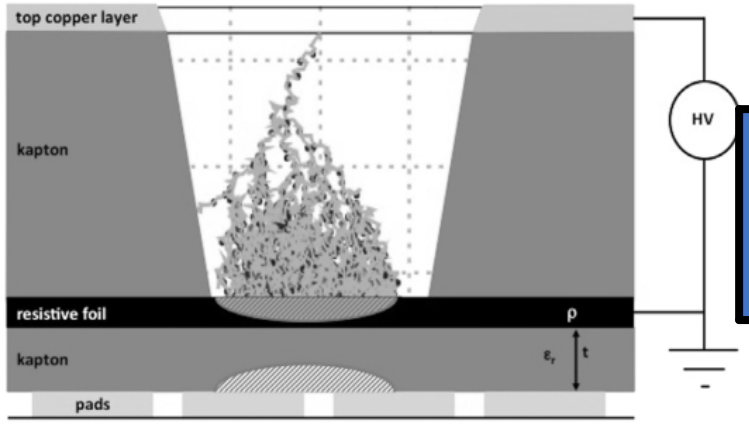
The energy is higher *w.r.t.* 25 meV → the conversion efficiency is roughly a factor 2 lower

Simulations and measurement are in agreement.
This allows us to extend the simulation to further studies to improve the efficiency

Counting mode

The large number of electrons induces a sizeable current on the μRWELL amplification electrodes. A preamplifier is used to generate a signal of few hundres of mV.

This technique allows to detect the single neutron with a simplified readout.
The noise play a key-role in the detection efficiency and in the energy resolution.



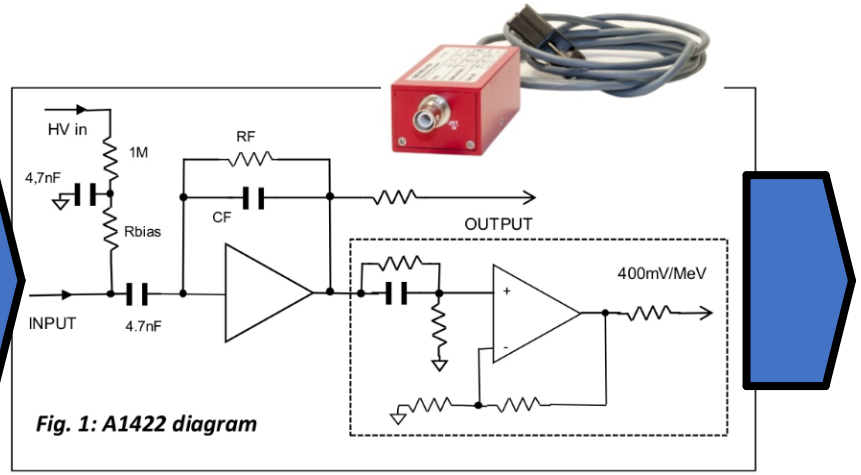
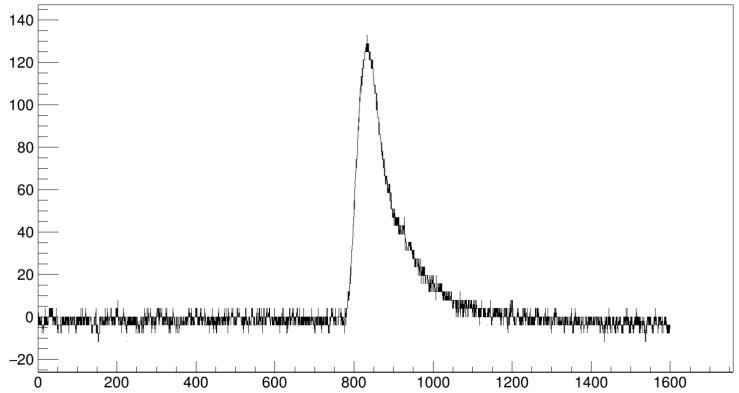
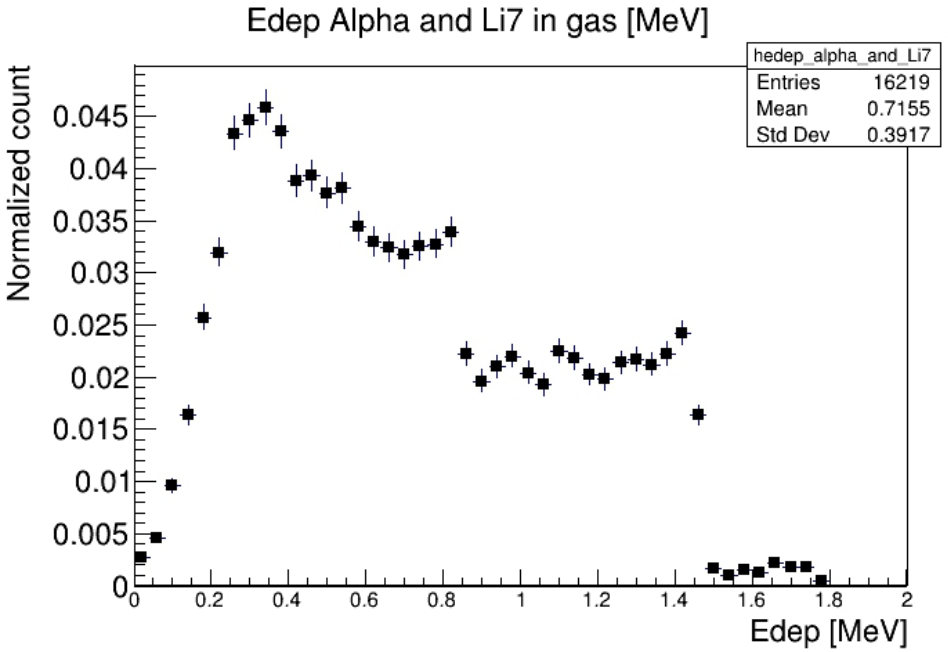
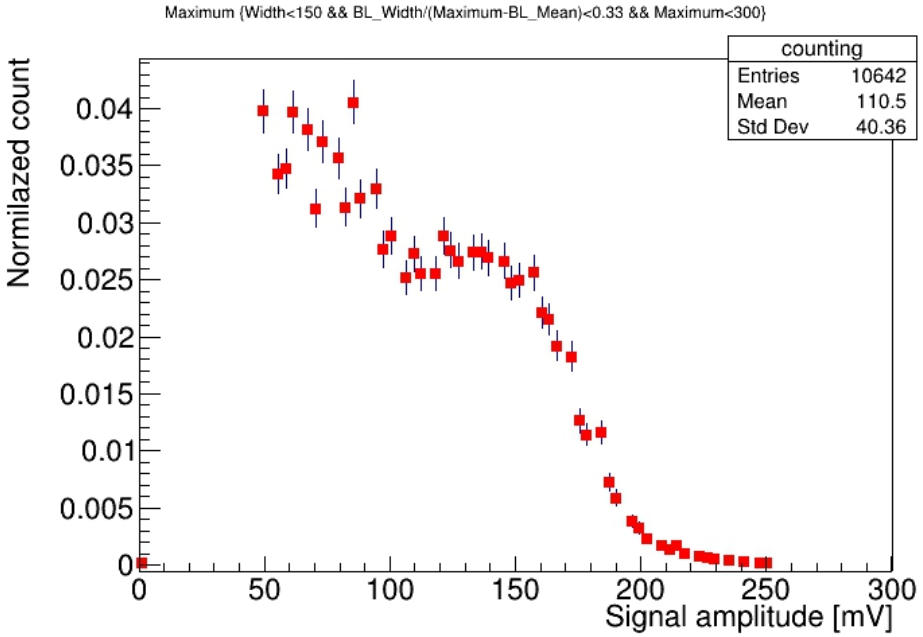


Fig. 1: A1422 diagram



Calibration of the TR and TW using simulated TW





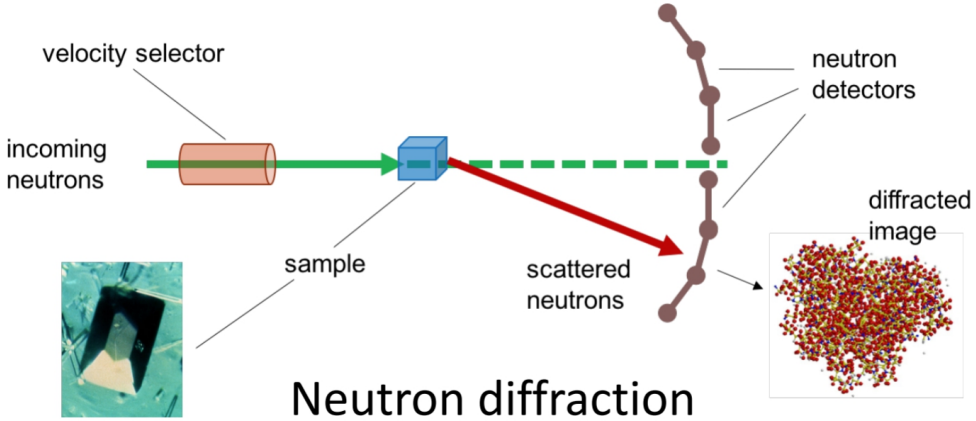
The shape of the simulation and the experimental data are similar, within the energy resolution of the readout system. The distribution is truncated at 45 mV due to noise limitations.

What next

The URANIA project shown the feasibility to measure neutron with MPGD.

The advantages of gas detector can be used to develop large active area to be used in the nuclear waste monitor or the homeland security.

From the other side, the high spatial resolution of the MPGD can be used to measure the time and the position of neutrons for imaging purposes



Thanks