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

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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)**

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**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**

- Exploit the $^{10}\text{B}$ converter
- Detect $\alpha$ and $^7\text{Li}$ ($\mu$-RWELL)
- Detect thermal neutrons

The cathode must be boron coated

- $\text{B}_2\text{C}$ enriched with $^{10}\text{B}$ @97% is sputtered on the copper surface @ ESS Linköping Coatings Workshop with direct current magnetron sputtering technology.

- The neutron hitting the cathode converts to $\alpha$ and $^7\text{Li}$ 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 $\sim 10^4$

Rate capability (@ $G = 5000$) $\sim 5$-10 MHz/cm²

Efficiency $\sim 98%$

$\sigma_t \sim 5$-6 ns

Space resolution
μR WELL on literature

Large area μR WELL 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 cm² 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 ⁷Li entering the gas / #incident neutrons

Conversion efficiency vs. boron thickness for monoenergetic neutrons.
Deposited energy by $\alpha$ and Li7 in gas

$^{10}\text{B} + n \rightarrow ^7\text{Li}^* (0.84 \text{ MeV}) + \alpha (1.47 \text{ MeV})$

$^7\text{Li}^* \rightarrow ^7\text{Li} + \gamma (0.477 \text{ MeV})$

$^{10}\text{B} + n \rightarrow ^7\text{Li} (1.01 \text{ MeV}) + \alpha (1.78 \text{ MeV})$

- Our gas mixture has an ionizing energy $\sim 31.5$ eV
- Particles have range $< 6$ mm of gas
  - they release all the energy in the gas
  - $\sim 10^4$ number of primaries
Testbeam setup and efficiency measurement

Facility HOTNES@ ENEA, Frascati, Italy

- Homogeneous Thermal NEutron Source
- Source = $^{241}$Am-B
- Cylindrical symmetry, polyethylene walls
- Iso-fluence on disks (within 1-2%) with diameter 30 cm
- Fluence ~750 Hz/cm²
- Shadow bar to block gammas (4-9 $\mu$Sv/h)
- Angular distribution down to 8 mrad from surface
- Energy spectrum peaked @100 meV (FWHM = 290 meV)

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

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

- $i$ = current measured with a picoamperometer
- $e$ = electron charge
- $\Phi$ = fluence from HOTNES calibration (758 Hz/cm²)
- $G$ = gain from X-ray calibration
- $< N >$ = number of ionization from GARFIELD++ simulations
- $\Sigma$ = chamber surface ($10 \times 10$ cm²)
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 hundreds 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.
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.

Neutron diffraction