uRANIA: a μ-RWELL based thermal neutron detector

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I. Balossino[a,b], G. Bencivenni[c], P. Bielowka[i], G. Cibinetto[a], R. Farinelli[a], G. Felici[c], I. Garzia[a], M. Gatta[c], P. Giacomelli[e], **M. Giovannetti[c,j]**, R. Hall Wilton[g], C.-C. Lai[g], L. Lavezzi[d], F. Messi[f], G. Mezzadri[a,b], G. Morello[c], M. Pinamonti[h], M. Poli Lener[c], L. Robinson[g], M. Scodeggio[a], P.-O. Svensson[g]

[a] INFN-Ferrara, Ferrara, Italy
[b] Institute of High Energy Physics, Beijing, China
[c] INFN-National Laboratory of Frascati, Frascati, Italy
[d] INFN-Torino, Torino, Italy
[e] INFN-Bologna, Bologna, Italy
[f] Lund University, Lund, Sweden
[g] Detector Group, European Spallation Source (ESS), Lund, Sweden
[h] Eltos SPA, Arezzo, Italy
[i] TECHTRA, Wroclaw, Poland
[j] Università degli Studi di Roma 'Tor Vergata', Roma, Italy

INFN Istituto Nazionale di Fisica Nucleare

ATTRACT

Outline

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R esistive
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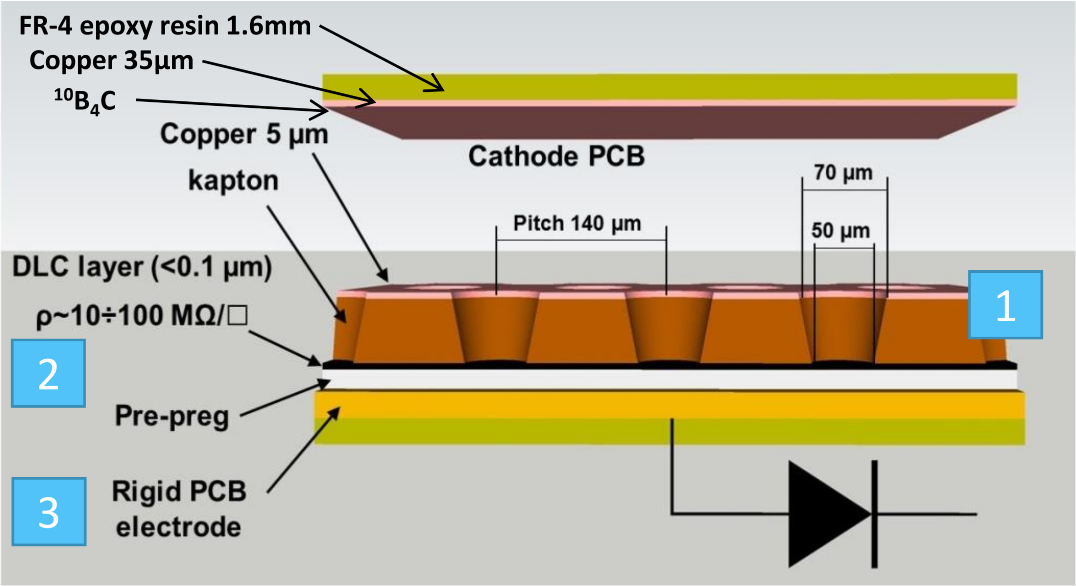
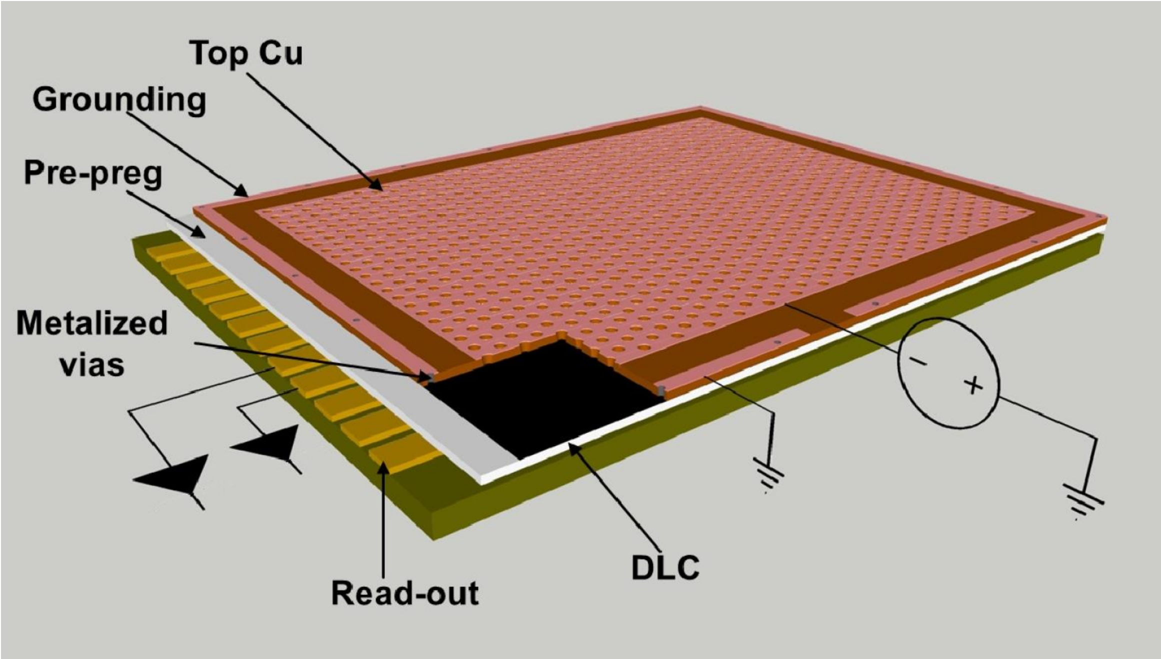
- The uRANIA project
  - µ-RWELL principle of operation
  - n-B conversion
- The Source Test
  - ENEA-HOTNES facility
  - Simulation framework
- Preliminary Efficiency results

The µ-RWELL architecture

The µ-RWELL: a Micro Pattern Gaseous Detector (MPGD) composed of only two elements: the µ-RWELL_PCB and the cathode.

Cathode:
- Copper layer on an epoxy glass substrate
- Sputtered **layer of $^{10}B_4C$** (with variable thickness: 1.5~4.5µm)





µ-RWELL_PCB:

1. **a WELL** patterned Apical foil acting as **amplification stage** (GEM-like)
2. **a resistive DLC layer** for discharge suppression w/ surfaceresistivity ~ 10÷200 M /□
3. a standard readout PCB

The n+B reaction

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

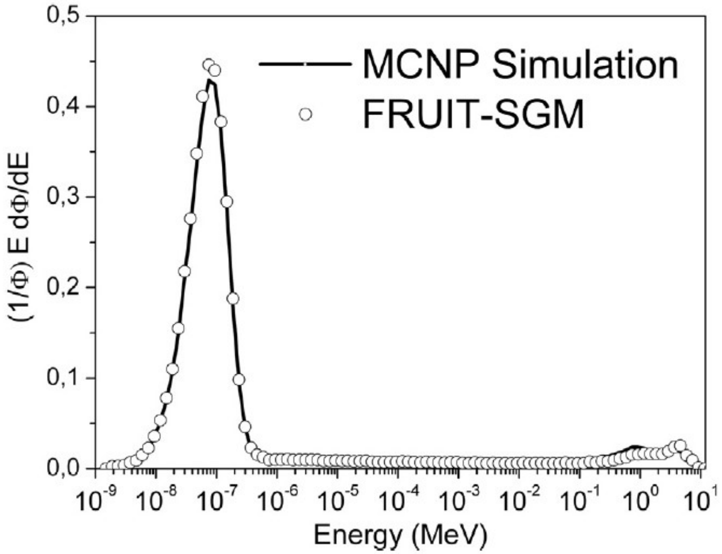
Detection of thermal neutrons (kinetic energy ~0.025 eV):

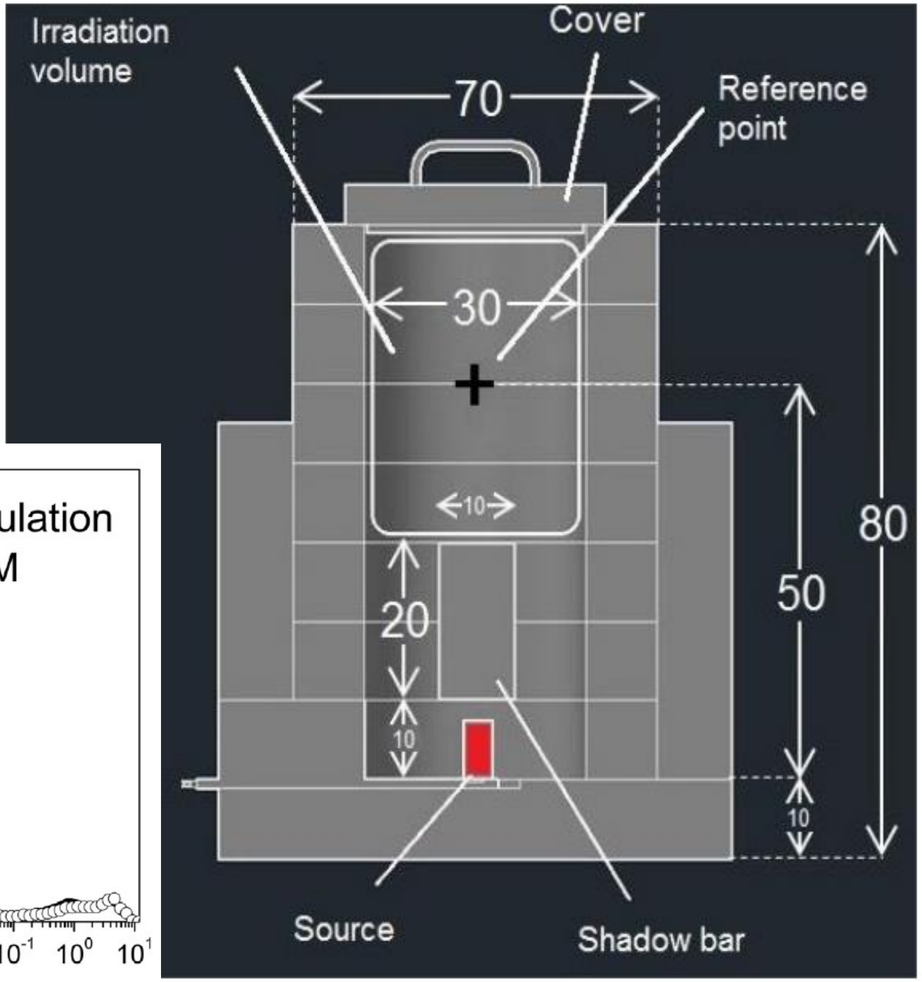
- **conversion** to **ionizing particle**: ^{7}**Li** and **α**
- ^{7}Li/a **back to back emission**
    - mutually excluded event
- **Not negligible** ^{7}Li/a **cross-section** with $^{10}B_4C$
    - optimization coating thickness to ensure the products reach the gas

The ENEA-HOTNES facility

The **HO**mogeneous **T**hermal **NE**utron **S**ource:

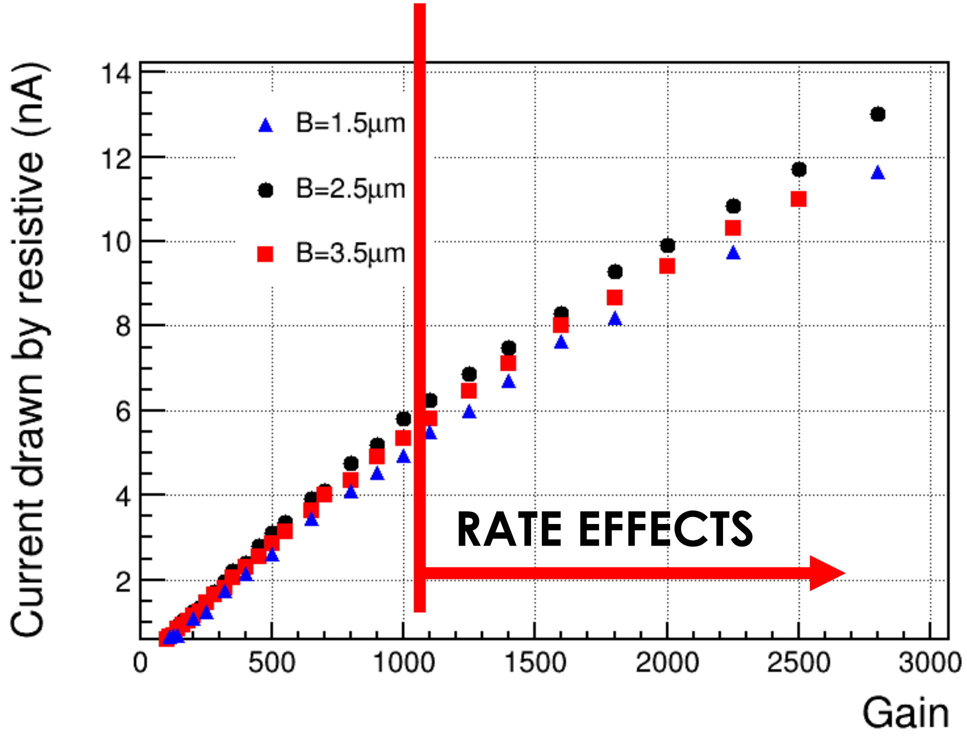
- thermal neutron produced by ^{241}Am-Be source using polyethylene as moderator
- Fully caracterized thermal neutron: energy spectrum and fluence at various Z height.
  - At reference point (Z=50) 758 ± 16Hz/cm^2 fluence
- With the cover in place, nearly uniform fluence: known angular spread distribution. Without the cover a parallel beam is obtained with a 20% reduction of the neutron flux.
- Very low gamma background at reference point

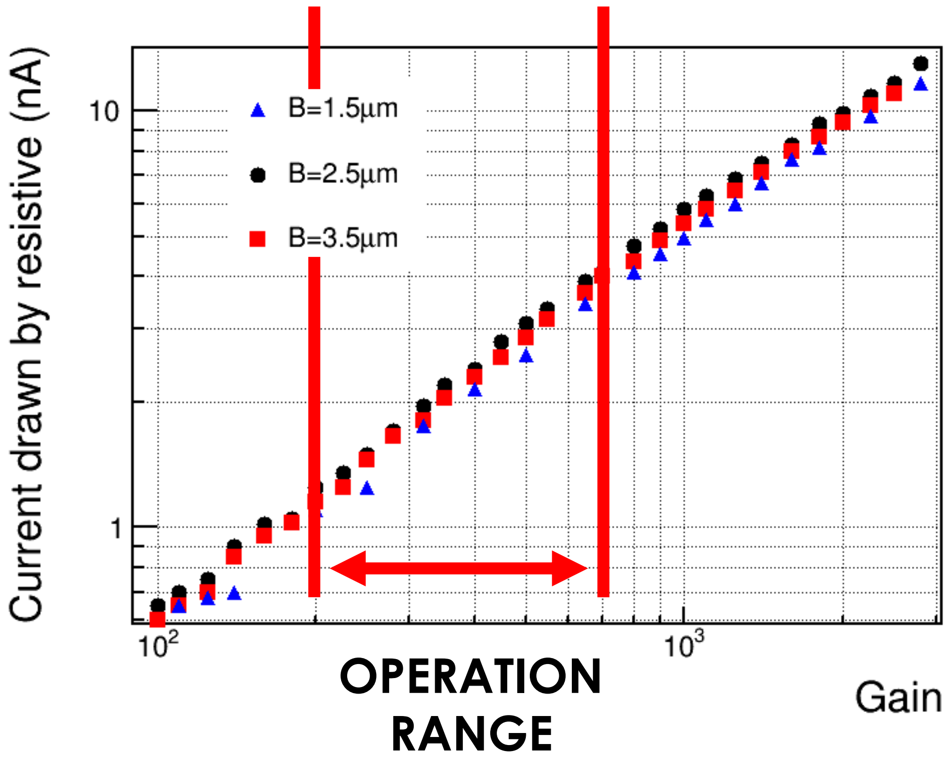




Detector working point

Gas mixture: $Ar/CO_2/CF_4$ 45:15:10





Large ionization from alpha and Li:

$<N_\alpha>2.2*10^4$, $<N_{Li}>1.1*10^4$

Rate effects begin at lower gains than for m.i.p.

Final operation range: **G=[300:700]**

Preliminary Efficiency Results

Measured efficiency: from the current drawn by the detector.

$$i = eRGN = eRG\,\epsilon < N >$$

$$\epsilon = \frac{i}{eRG < N >}$$

i: current drawn by the resistive layer of the detector
e: electron charge
R: rate of neutron impinging on the detector
G: detector gas gain
ϵ: overall efficiency (conversion + yield)
<N>: average primary ionization of ^{7}Li/a (simulated)

Simulated efficiency: # of ^{7}Li/a entering the gas over # of total impinging neutrons .
GEANT4 simulation:
information from the calibrated HOTNES facility
measured attenuation by the FR-4 epoxy cathode substrate

$^{10}B_4C$ width [μm]	<q_alpha>	#alpha/#n	<q_lithium>	#lithium/#n	<q_total>
1.5	0.93 MeV	1.01%	0.44 MeV	0.55%	0.76 MeV
2.5	0.83 MeV	1.17%	0.45 MeV	0.53%	0.71 MeV
3.5	0.83 MeV	1.12%	0.45 MeV	0.50%	0.71 MeV
4.5	0.84 MeV	1.06%	0.45 MeV	0.47%	0.72 MeV

Preliminary Efficiency Results

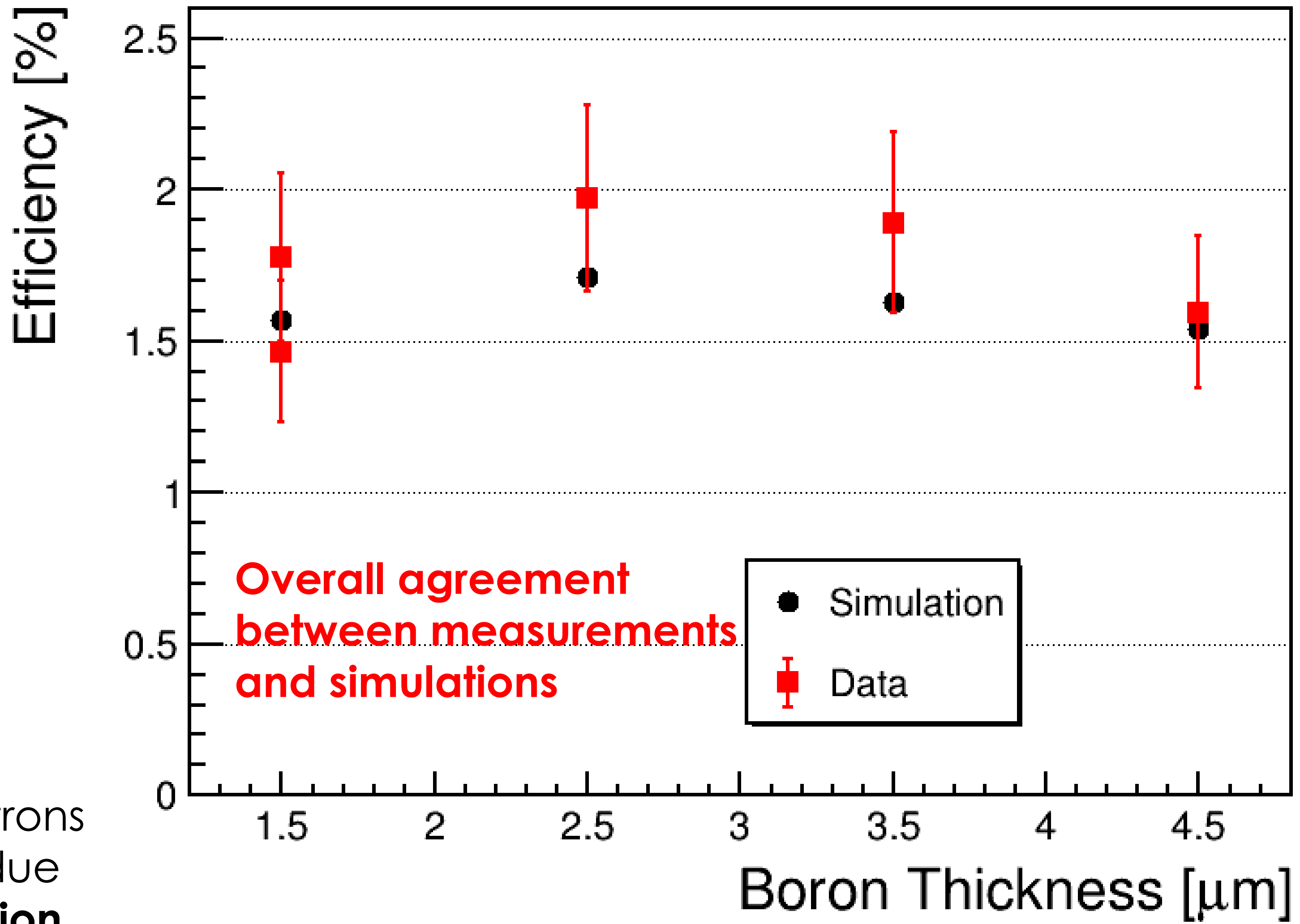
Measured efficiency

$$i = eRGN = eRG\,\epsilon < N >$$
$$\epsilon = \frac{i}{eRG < N >}$$

Simulated efficiency

$^{10}B_4C$ width [μm]	-	total efficiency
1.5	-	1.57%
2.5	-	1.71%
3.5	-	1.63%
4.5	-	1.55%

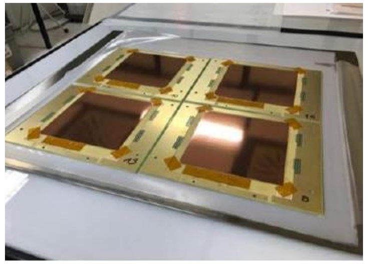
Values for HOTNES energy spectrum:
for **monocromatic 0.025eV** thermal neutrons the efficiency will be a **factor 2 higher**, due to the **increase** of the **n-$^{10}B_4C$ cross section**.



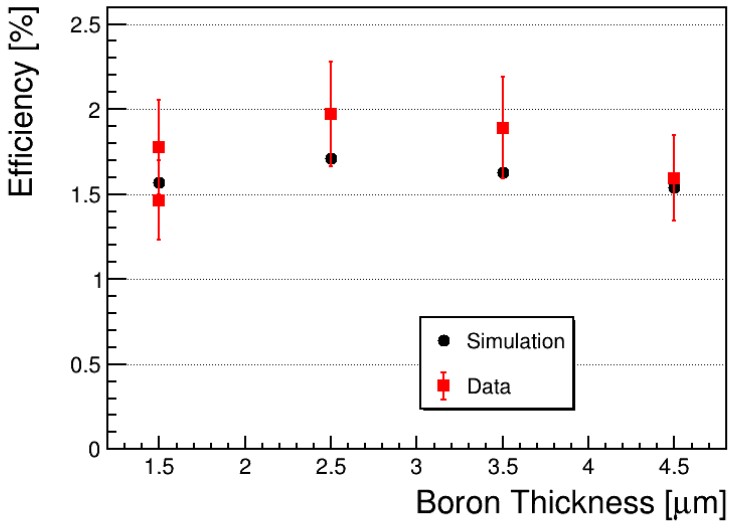
Overall agreement between measurements and simulations

Summary

The **uRANIA-ATTRACT** project aim at the **development of a detector** based on **µ-RWELL technology** to perform neutron imaging with a few µm **$^{10}B_4C$** thermal neutron **conversion stage**.



Overall neutron detection efficiency: **1.5~2.0(±0.2)%**
showing agreement between **measurements** and **simulations**.



Futurel plans:

- Placing a stack of boron coated aluminum mesh between the cathode and the PCB
- Study different 3D structures of the cathode to increase the conversion surface in a fixed volume (e.g. honeycomb structures)
- Counting mode measurements