

# $^{10}\text{B}$ -based detector with stacked macrostructured cathodes and resistive wire readout

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# The working framework

**German In-Kind  
Contribution to  
the ESS Upgrade  
Phase (WP 2.3)**



**FP7 – NMI3-II  
(Task 21.2)**



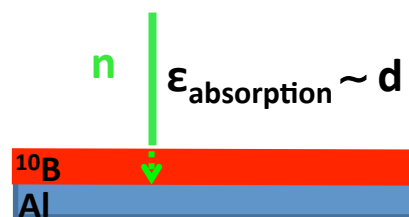
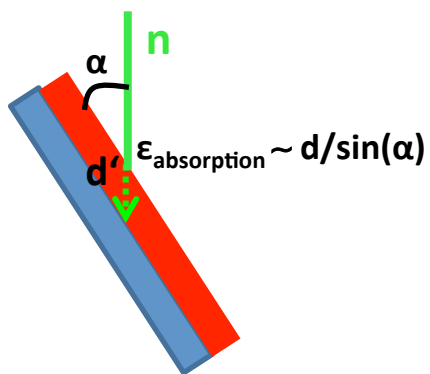
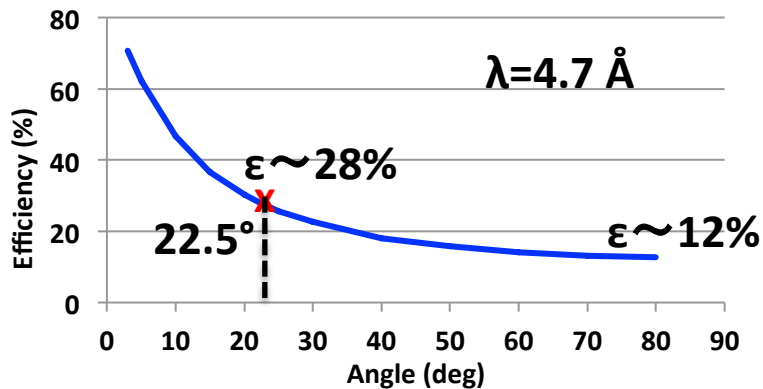
**International  
Collaboration  
for Neutron  
Detector  
Development  
(ICND).**

[icnd.org](http://icnd.org)

**Main objective: development of alternative technologies to replace the  $^3\text{He}$  tubes in large-area detectors for neutron scattering applications.**

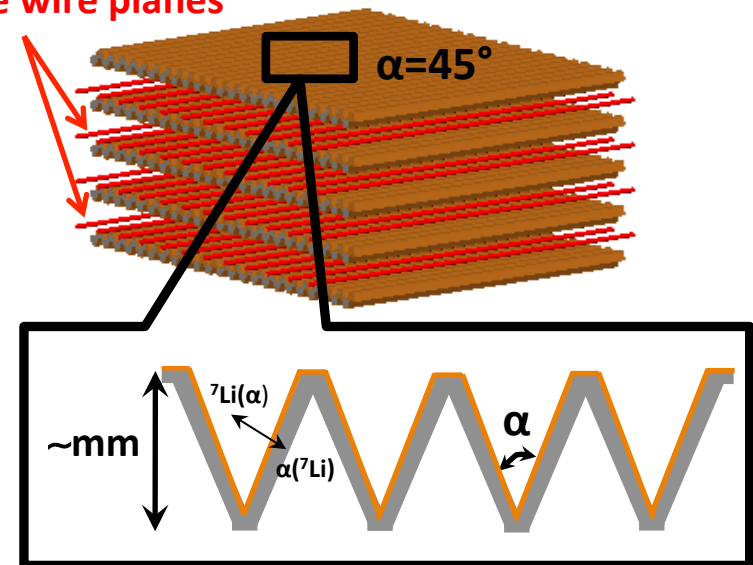
# The detector concept

Concept exploits the increase of detection efficiency with angle



Stack of MWPCs with Boron-lined “macrostructured” cathodes

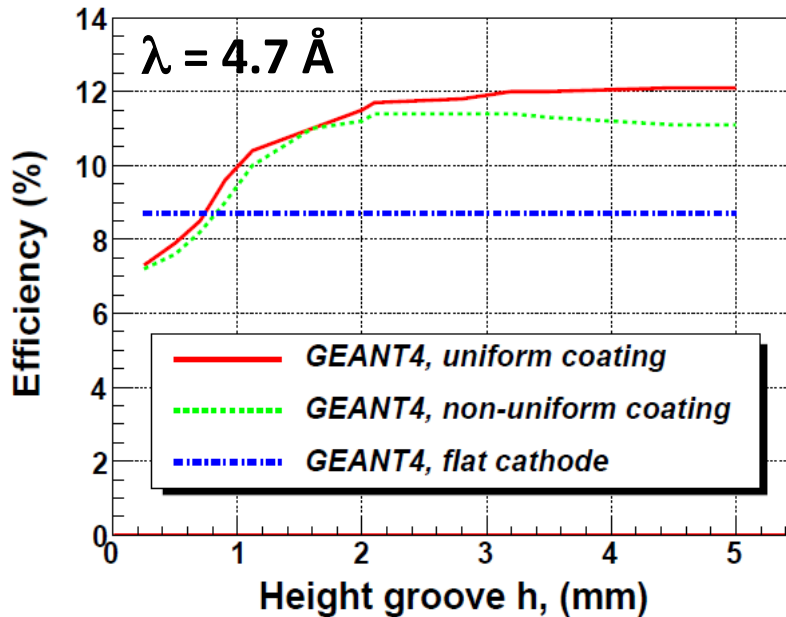
Sense wire planes



3D regular pattern consisting of grooves that can be created in the substrate material by milling, extrusion, forming, etc.

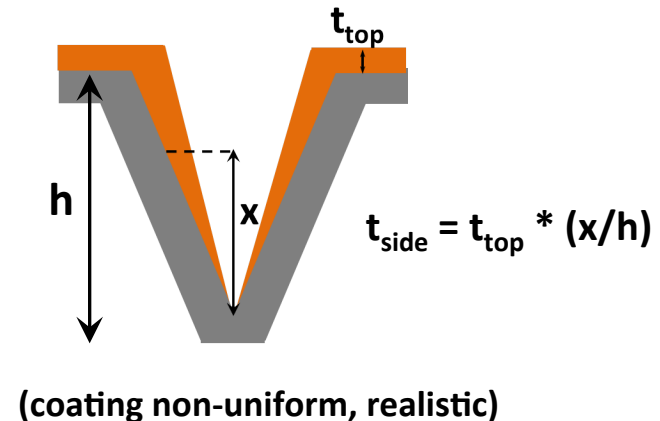
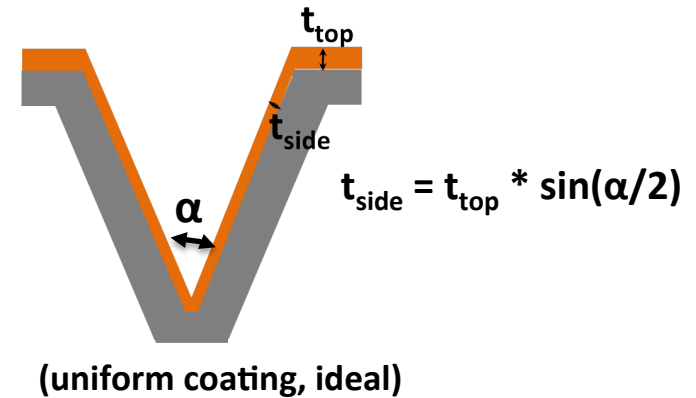
## GEANT4 simulations

- Optimal geometry of the groove to maximize the detection efficiency of the coated plate.



I. Stefanescu et al., Nuclear Instruments and Methods in Physics Research A727 (2013) 109.

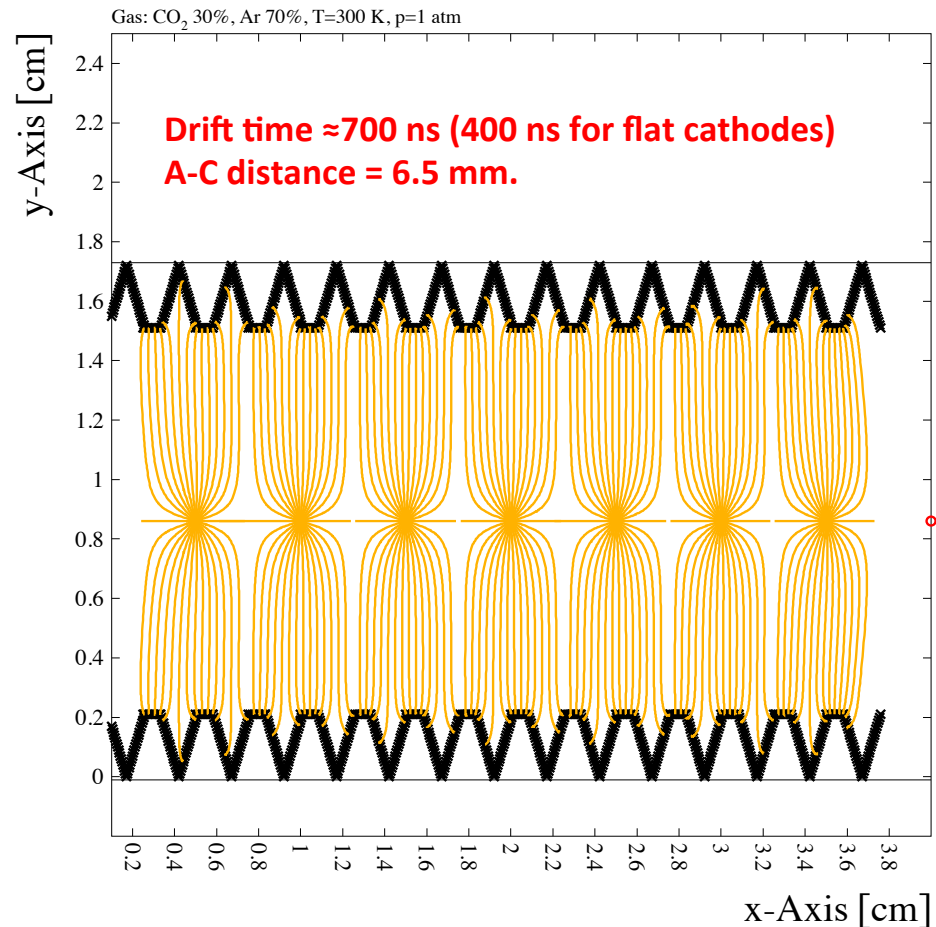
- Effects of the conformality of the coating on the detection efficiency.



## GARFIELD simulations

- Electric field inside a MWPC with macrostructured cathodes.
- Drift lines and times for electrons.

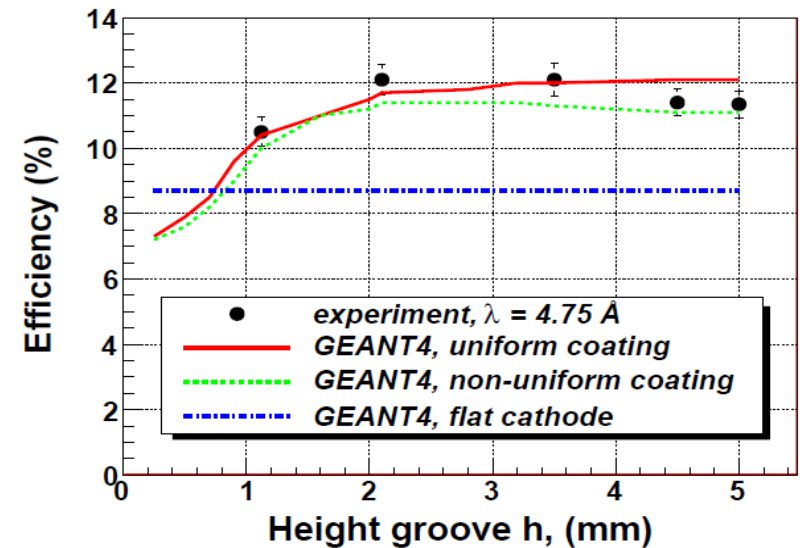
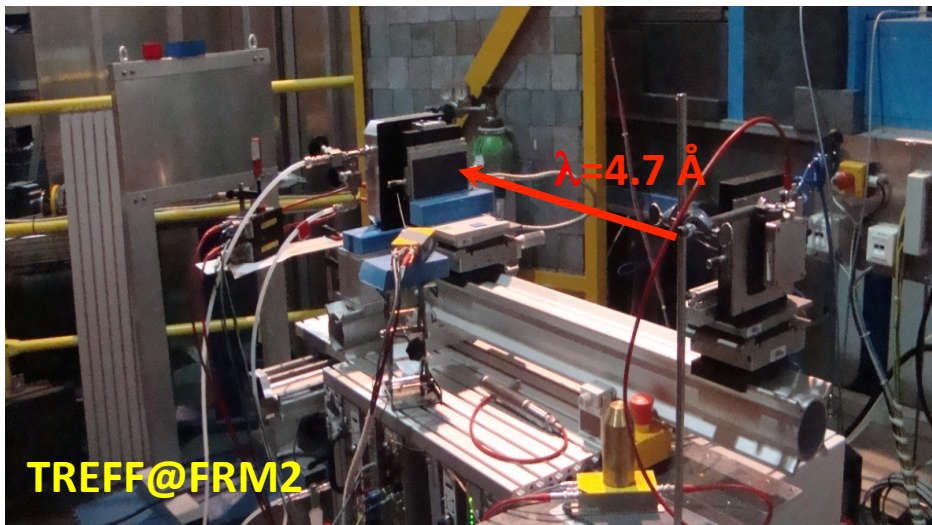
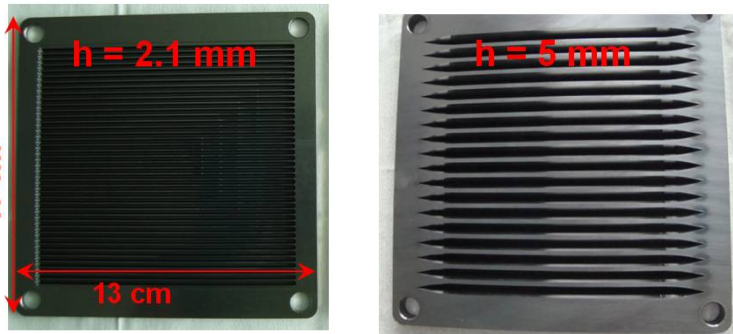
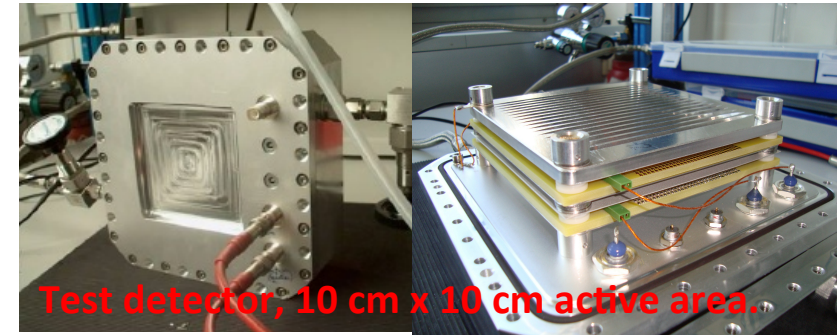
Positron drift lines from a wire



Printed at 17:05:14 on 08/03/13 with Garfield version 7.41.

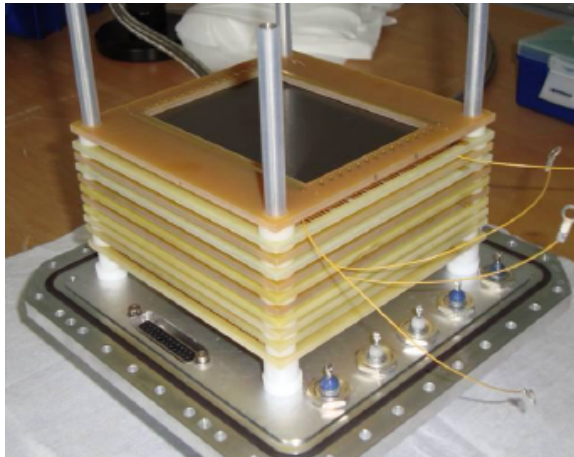
# Proof-of-concept measurements

First proof-of-concept measurements with a small size test detector and grooved cathodes made by milling and coated by magnetron sputtering at the Univ. of Linköping, Sweden.



# Efficiency of stacked MWPCs

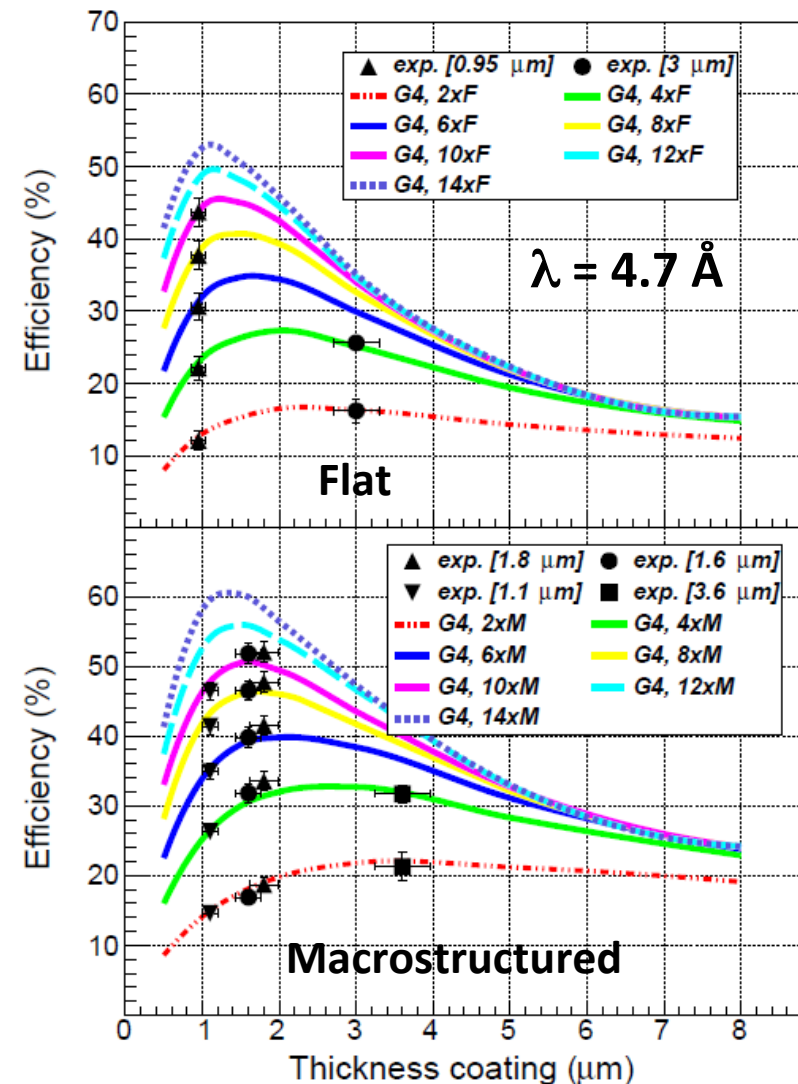
A realistic detector must incorporate several Boron layers in order to be competitive with the He-3 tube.



Detector stack used to test the efficiency of up to 5 MWPCs (10 Boron layers).

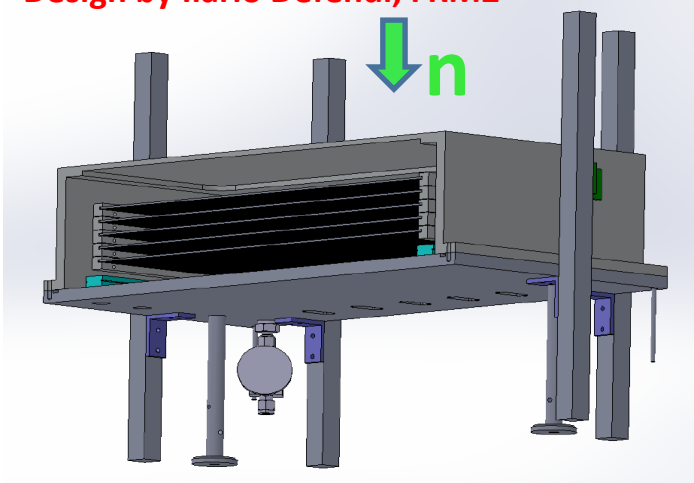
*I. Stefanescu et al., JINST 8, P12003 (2013).*

The larger efficiency obtained with the stack with macrostructured cathodes could be beneficial especially for instruments using thermal neutrons.



# The $^{10}\text{B}$ -demonstrator

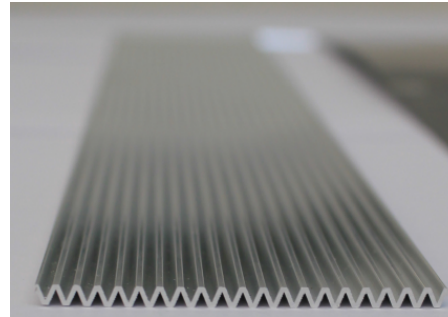
Design by Ilario Defendi, FRM2



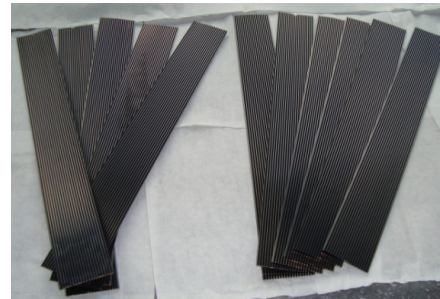
40 cm x 40 cm active area

Incorporates a stack with 3 layers of macrostructured planes (2 MWPCs) each coated with  $1.4 \mu\text{m } ^{10}\text{B}_4\text{C}$  by magnetron sputtering.

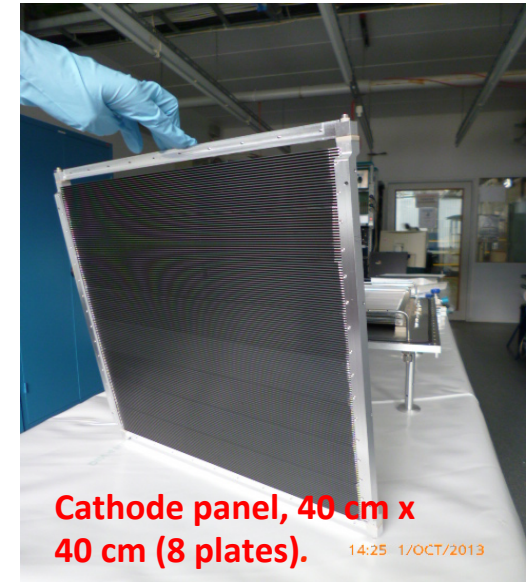
Operated in a continuous flow of  $\text{Ar}/\text{CO}_2$  gas.



5 cm x 40 cm macrostructured plate fabricated by extrusion (MIFA, Holland).



$^{10}\text{B}_4\text{C}$ -coated plates for the demonstrator (Univ. Linköping, Sweden).

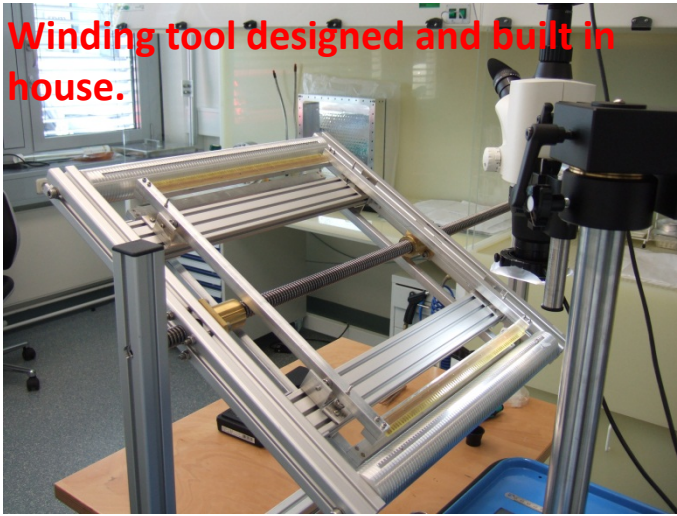


Cathode panel, 40 cm x 40 cm (8 plates). 14:25 1/OCT/2013

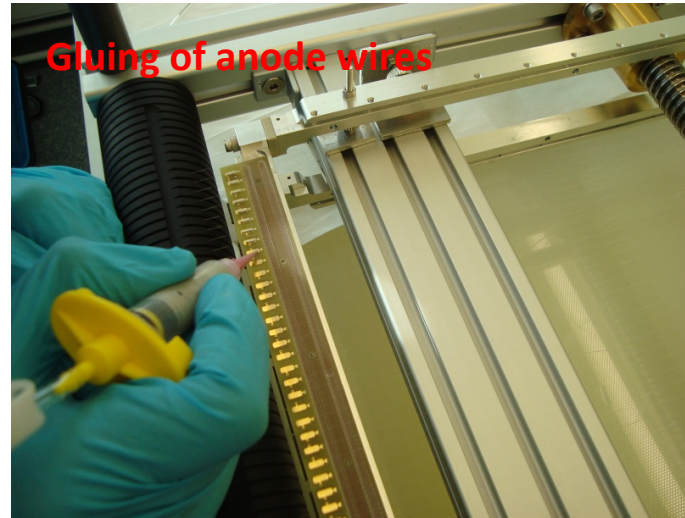
Meant to answer questions concerning upscaling and procurement of the various components.

# The $^{10}\text{B}$ -demonstrator

Winding tool designed and built in house.

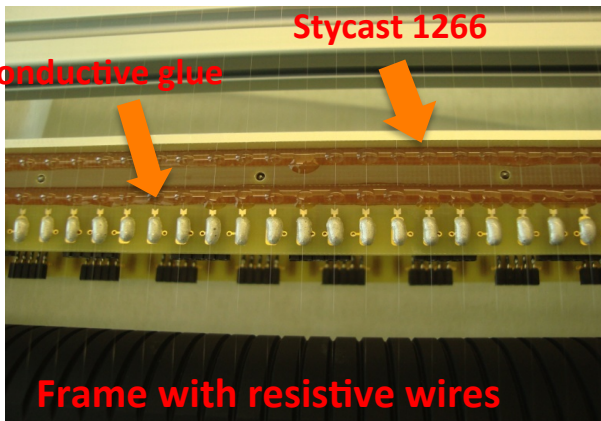


Gluing of anode wires



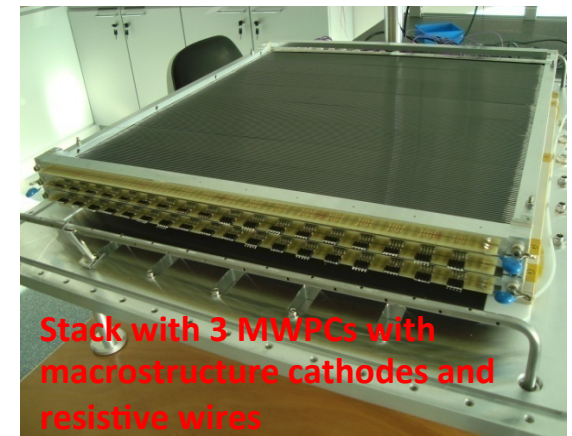
Stycast 1266

Conductive glue



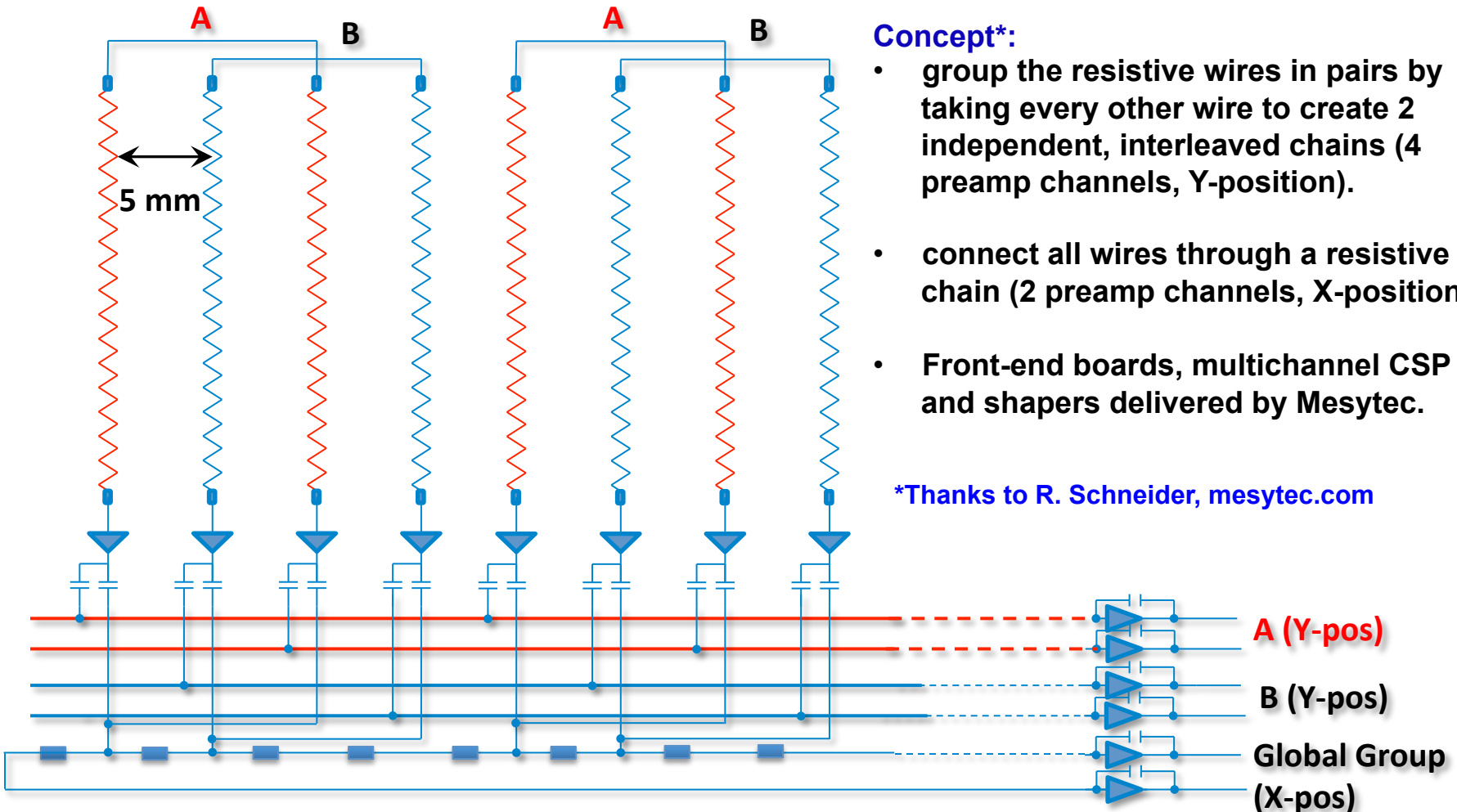
Frame with resistive wires

Stablohm 875 (resistive) wire  
 $\text{Ø}=17\ \mu\text{m}$   
 wire pitch = 5 mm  
 anode - cathode distance: 7 mm  
 72 wires/plane  
 each wire 40 cm long  
 resistance wire:  $\sim 3\ \text{k}\Omega$



Stack with 3 MWPCs with macrostructure cathodes and resistive wires

# Resistive wire readout concept



Aimed position resolution: 5 mm x 5 mm.

# Performance tests with a $^{252}\text{Cf}$ source: charge released in detector

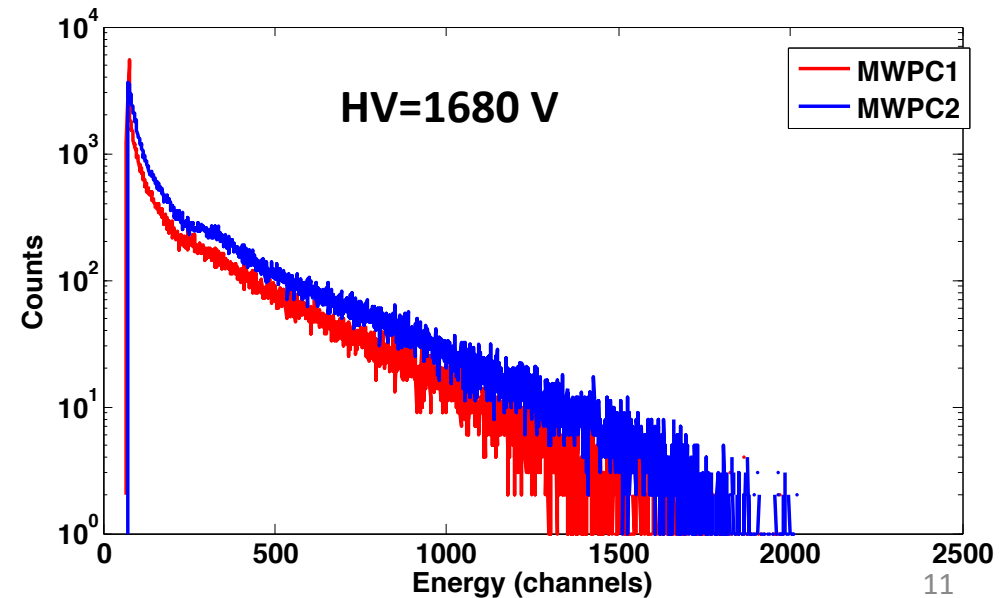
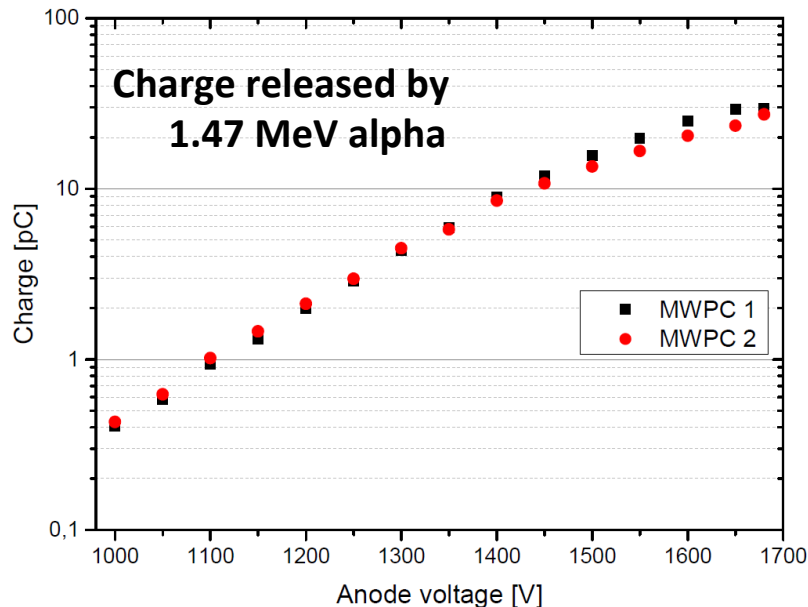
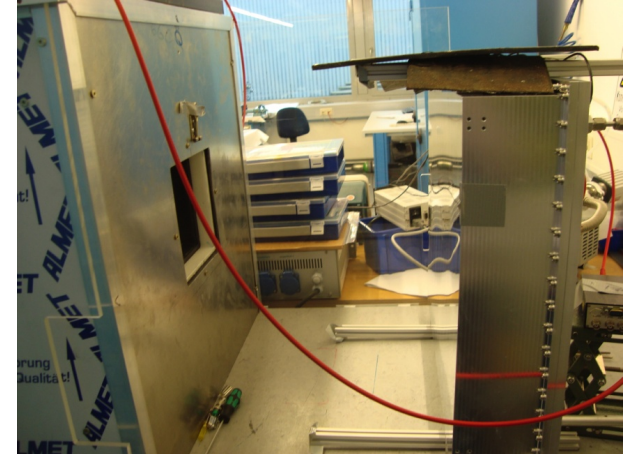
Gas: 1 atm Ar-CO<sub>2</sub> 80/20

12 anode wires per counter grouped for readout

Readout with Mesytec CSPs (MPR-1), Silena amplifiers, and commercial MCA.

$n + {}^{10}\text{B} \rightarrow {}^7\text{Li} (0.84\text{MeV}) + \alpha (1.47\text{MeV}) + \gamma (0.48\text{MeV})$  (93%)

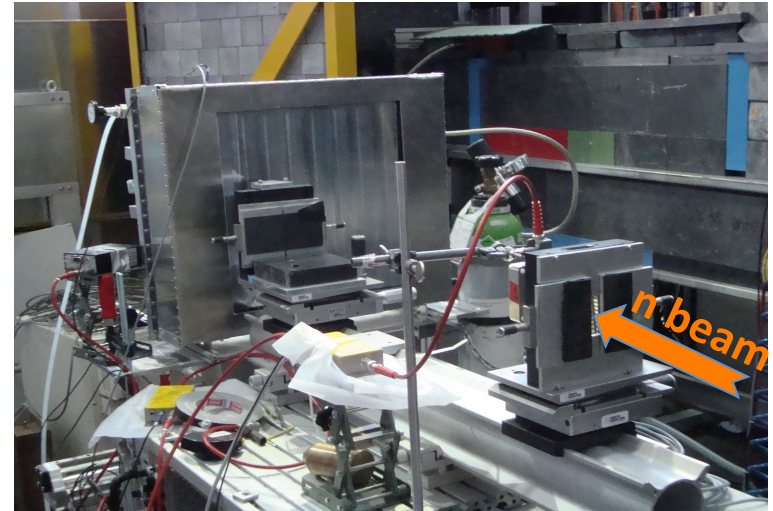
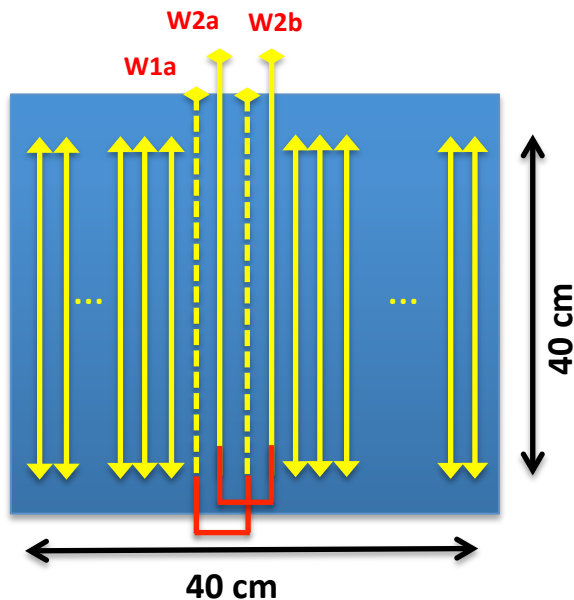
$\rightarrow {}^7\text{Li} (1.02\text{MeV}) + a (1.78\text{MeV})$  (7%)



# Performance tests with collimated beam: position resolution

4.7 Å collimated beam delivered by the TREFF instrument @FRM2. Detector placed on a XY moving table.

Group of 4 consecutive wires selected, 2 independent chains created by connecting each second wire ( $l_{\text{chain}} = 80 \text{ cm}$ ).



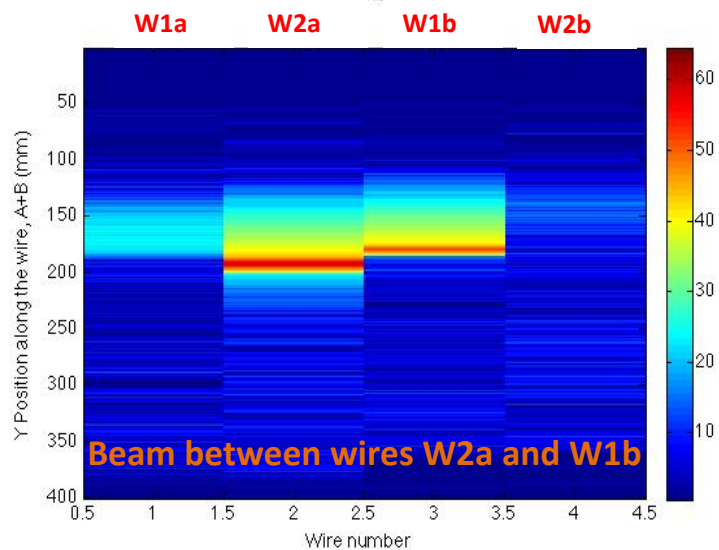
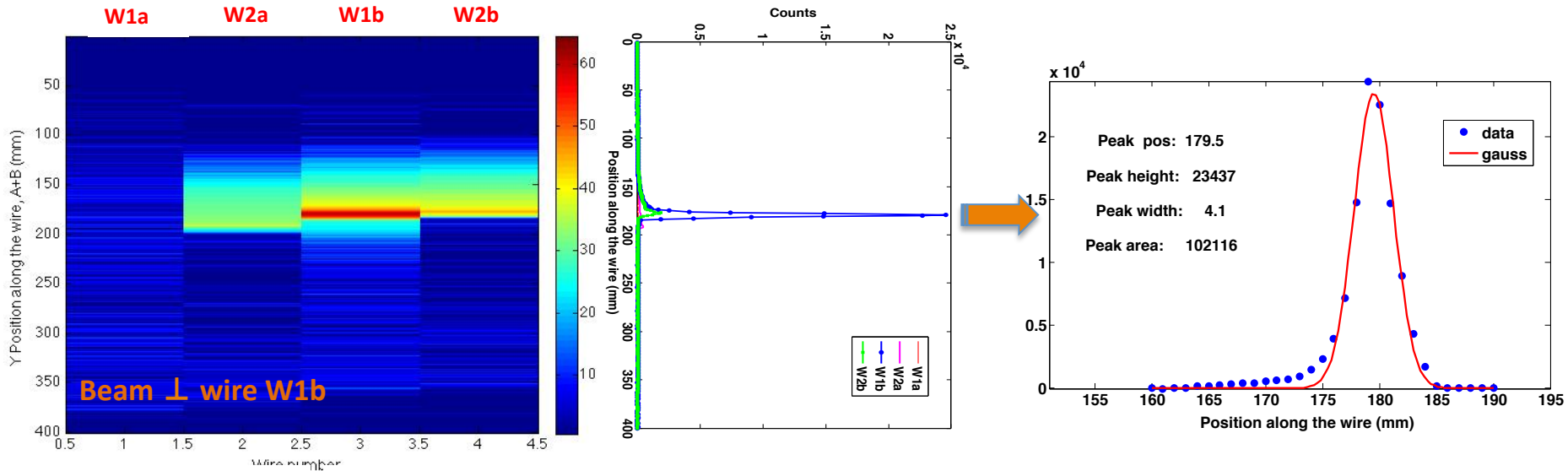
*Photograph of the  $^{10}\text{B}$ -demonstrator during the in beam tests at TREFF@FRM2 ( $\lambda=4.7 \text{ \AA}$ ).*

Mesytec CSPs + CAMDA multichannel analyzer used to collect and analyze the signals at the ends of each chain.

$$Y_{\text{pos}} = W_{1(2)a} / (W_{1(2)a} + W_{1(2)b})$$

$W_{1(2)a}$ ,  $W_{1(2)b}$ : signals readout at the end of each chain

# Position resolution: preliminary tests with the $^{10}\text{B}$ demonstrator



**Beam spot: 2 mm x 2 mm.**

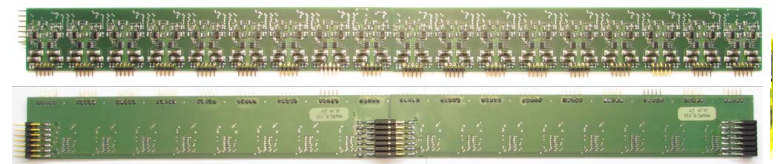
**Charge distributed to maximum 2 wires, which belong to different chains.**

**Measured FWHM  $\sim$  4 mm along the wire.**

# Coming soon....

- Next week Mesytec will deliver the MWPC9 custom-designed frontend boards → 6 output signal channels: Y-pos. group 0, Y-pos group 1, X-pos.
- 16-channel preamplifier (MPR-16) and shaper delivered earlier.
- Final set-up ready to be assembled at FRM2.
- Performance tests with the  $^{252}\text{Cf}$  source planned for July at FRM2.
- In-beam tests at the TREFF instrument at FRM2 foreseen for the upcoming reactor cycle (starting in Fall '14).

## Mesytec front-end boards



## Mesytec MPR-16 and shaper

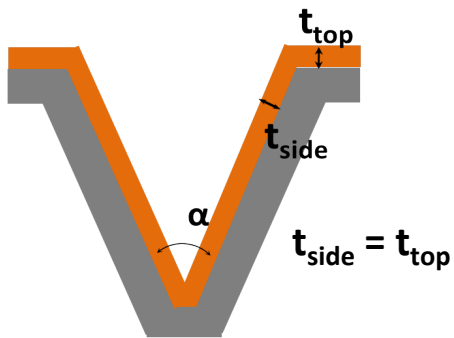


# Conclusions and outlook

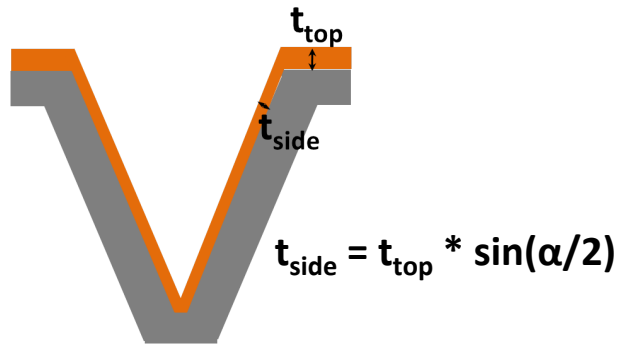
- **We propose a concept for a neutron detector based on the  $^{10}\text{B}$ -converter, stacked MWPCs with macrostructured cathodes and resistive wire readout.**
- **The concept was extensively studied in GEANT4 and GARFIELD calculations which were validated in a several experimental campaigns with a small area test detector.**
- **Design and construction of a realistic size demonstrator with 2 MWPCs (3 cathodes layers and 2 anode wire plans) almost completed. Intense testing planned with a moderated fission source and collimated neutron beam.**
- **The proposed detector could be an option for instruments that require large-area, moderate position resolution detectors.**

# Model simulations

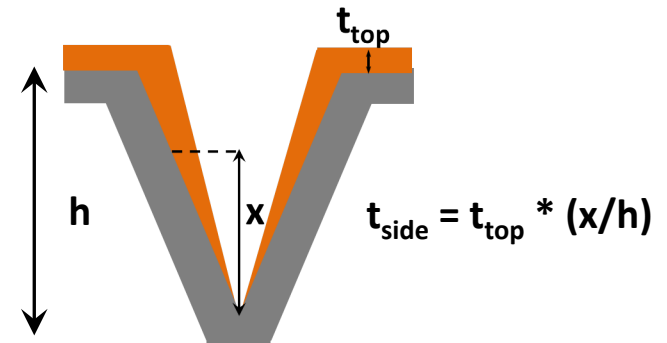
Possible scenarios for the conformity of the coating of a macrostructured plate



(forming after coating)

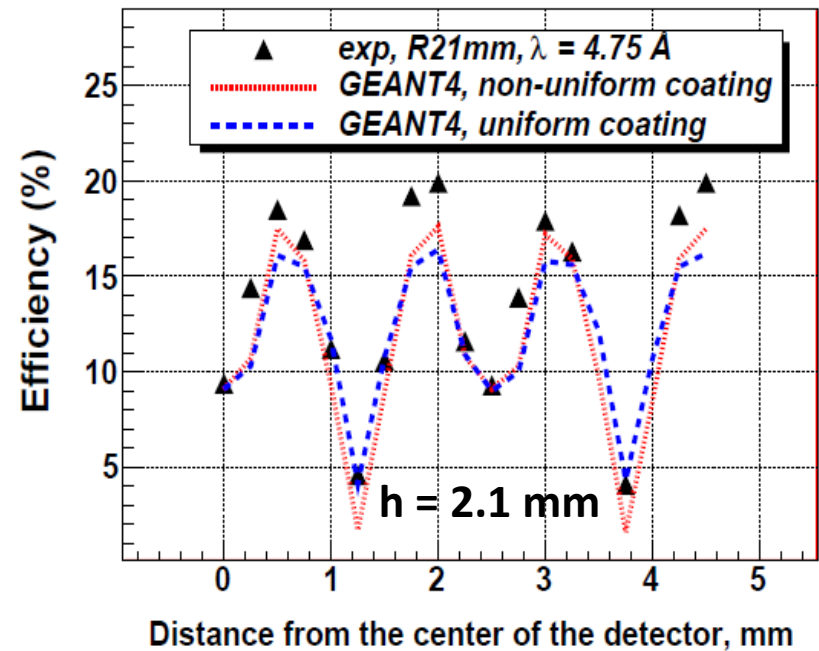
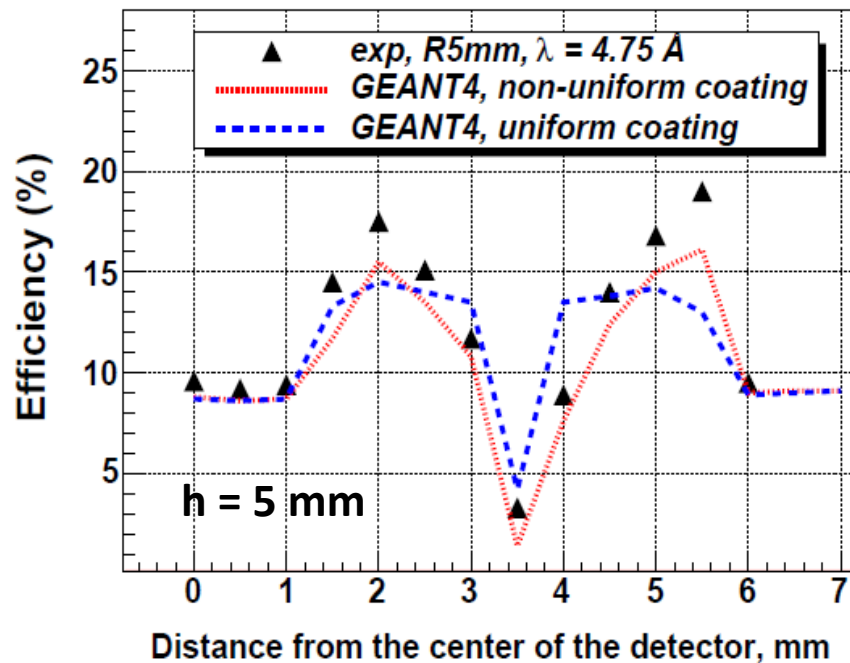


(coating after grooving, ideal)

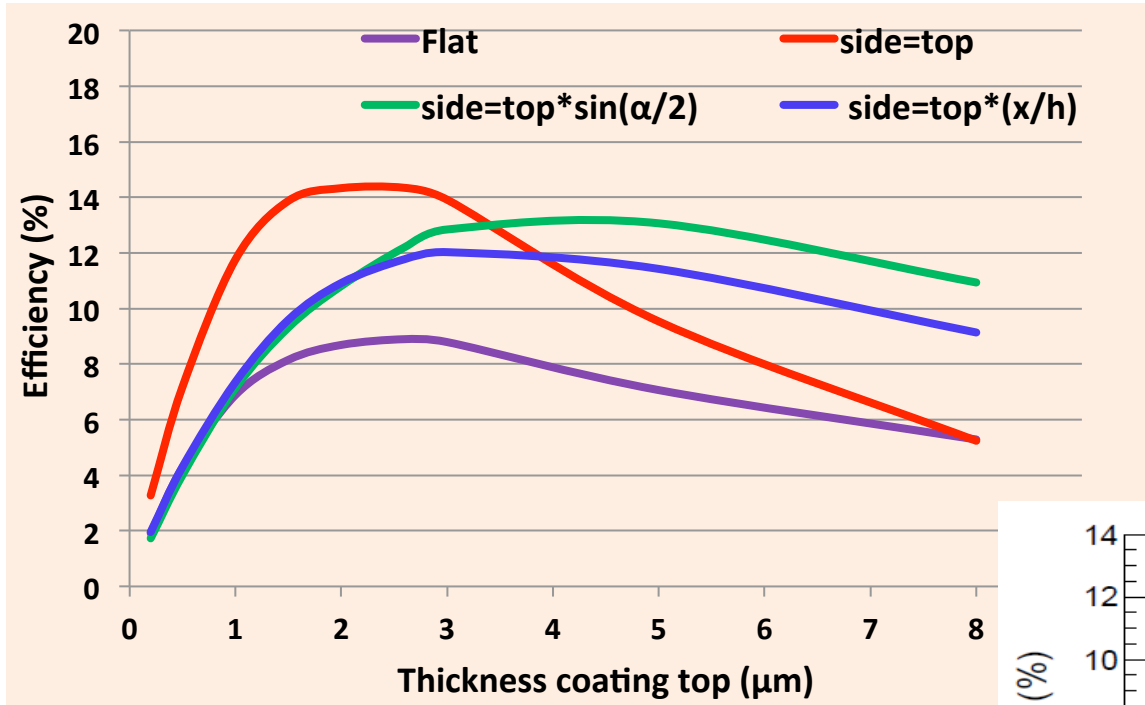


(coating after grooving, realistic)

# Model simulations

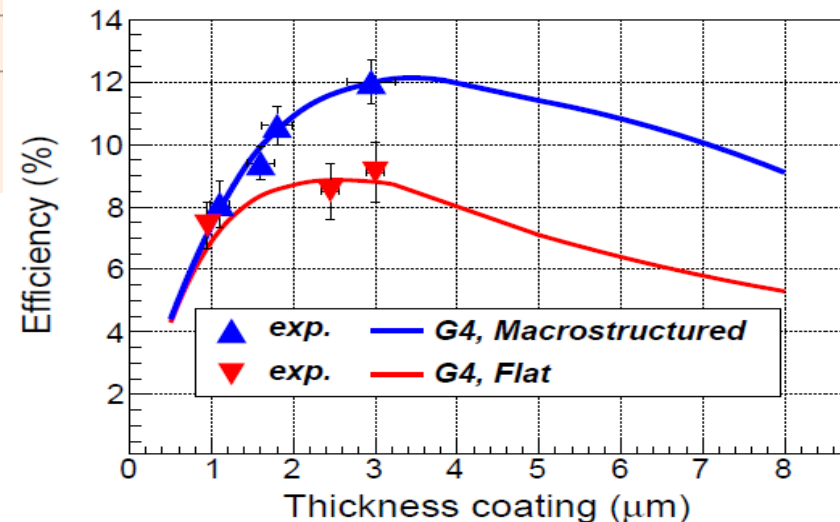


# Model simulations



Calculations for 45° grooves, 2 mm deep) and  $\lambda = 4.7 \text{ \AA}$

Results used in a general sense to understand trends in the performance of macrostructured cathodes.



# The $^{10}\text{B}$ -demonstrator

Design by Ilario Defendi, FRM2

