Micromegas detector development

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Our aim

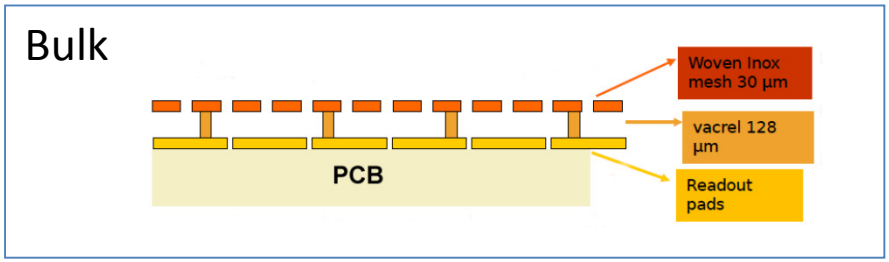
- *Use developments of **Micromegas** technology in Saclay to demonstrate the feasibility of a **large high-efficiency neutron detector with several $^{10}B_4C$ thin layers** mounted inside the gas volume.*

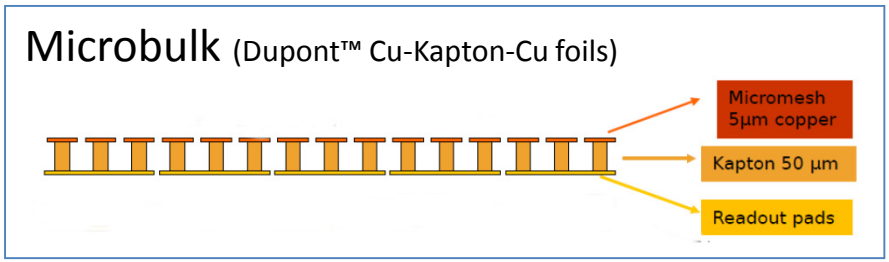
- *Built a **single detector unit prototype** with overall dimension of ~ 15 x 15 cm^2 and a flexibility of modifying the number of layers of $^{10}B_4C$ neutron converters.*

- *Evaluate **bulk(NMI3)/microbulk (SINE2020)** technologies for the construction of large sizes detectors made a mosaic of such detectors.*

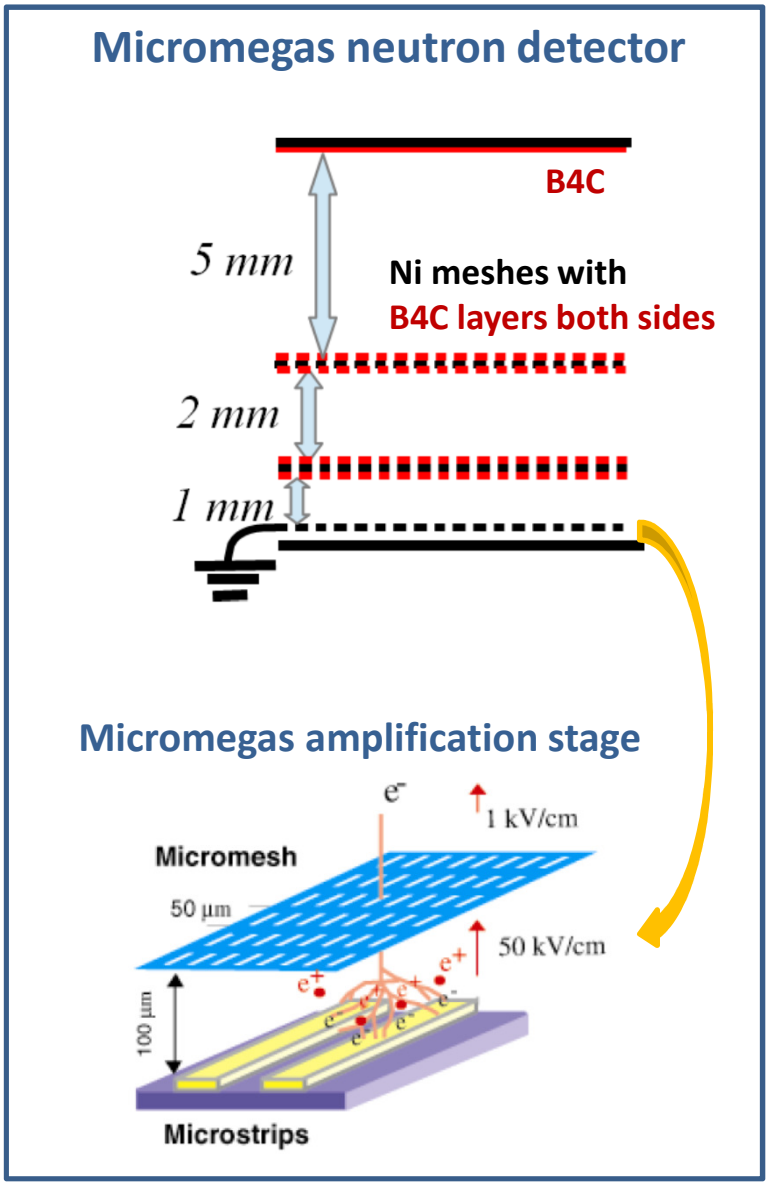
Outline

- *Last results on the Micromegas thermal neutrons detectors with bulk technology*
- *First results Last results on the Micromegas thermal neutrons detectors with microbulk technology*

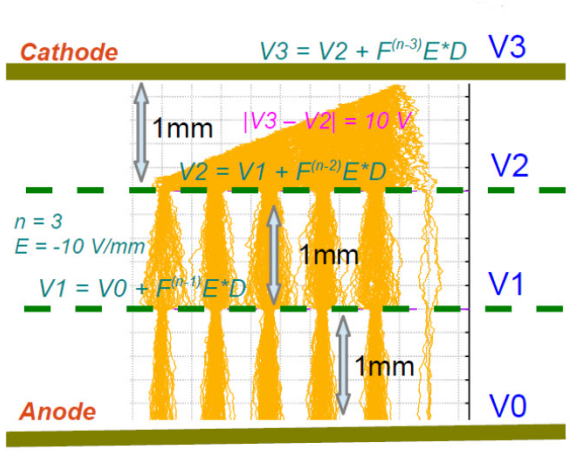




B4C deposition done in Linköping or Saclay

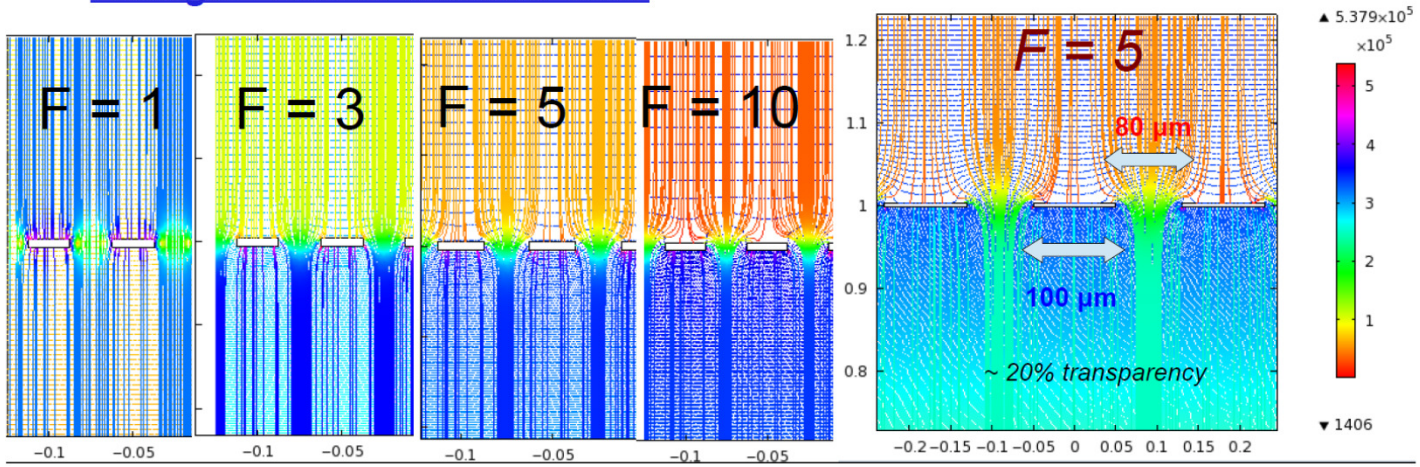


Electric field configuration – COMSOL simulations

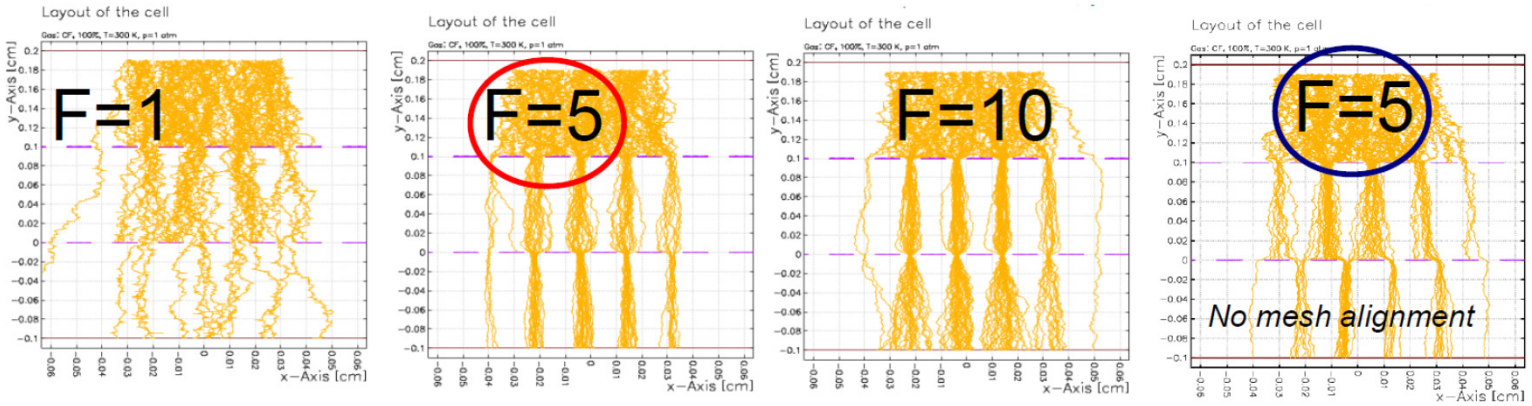


F	1	3	5	7	10
V3 (V)	-330	-430	**-610**	-870	-1410
V2 (V)	-320	-420	**-600**	-860	-1400
V1 (V)	-310	-390	**-550**	-790	-1300
V0 (V)	-300	-300	**-300**	-300	-300

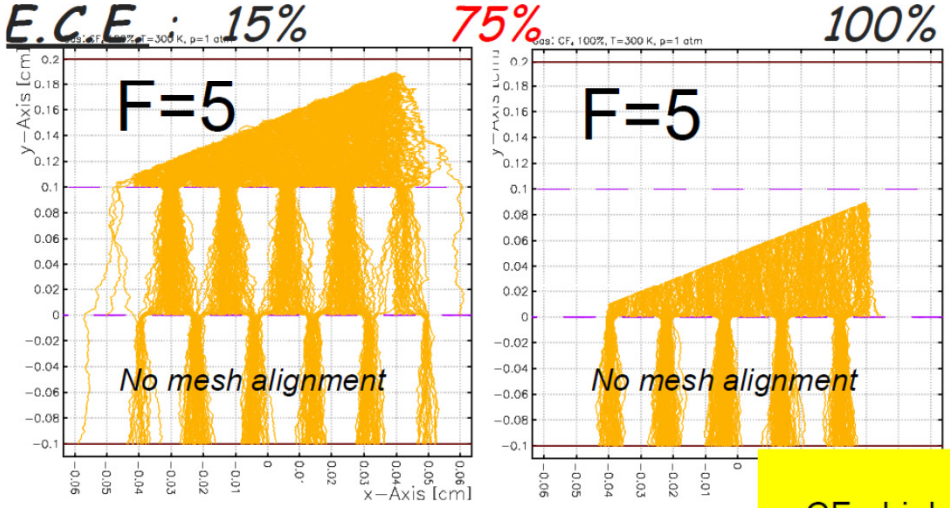
A single 2-mesh detector unit



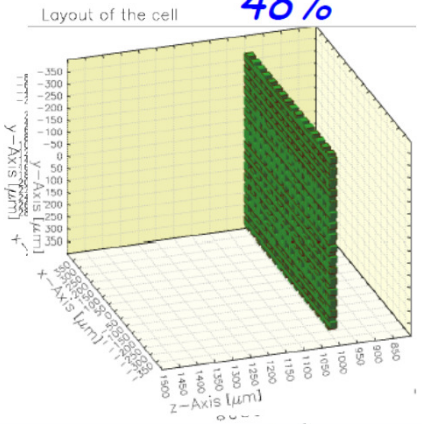
Electron Collection Efficiency – Garfield simulations



E.C.E. : 15% 75% 100%



48% 77%



Stripes : 100 µm
Holes : 80 µm

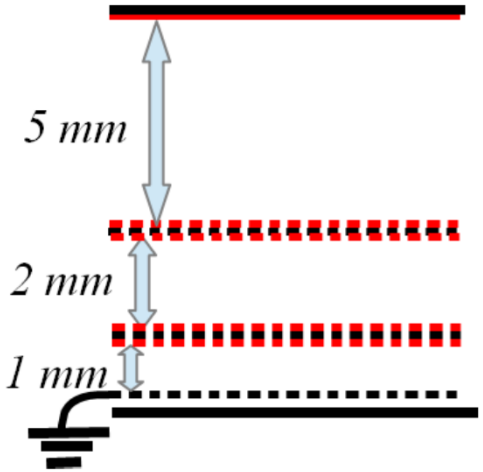
CF_4: high electron collection efficiency (small diffusion), good performance at high voltages

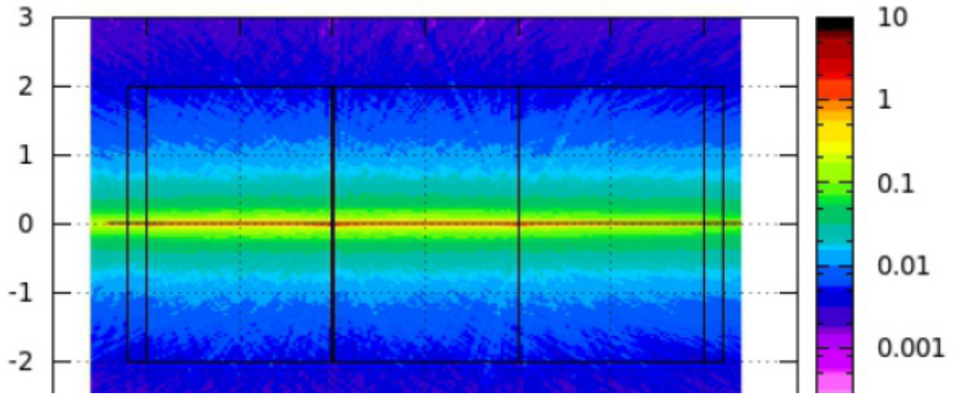
Detection Efficiency – Fluka MC

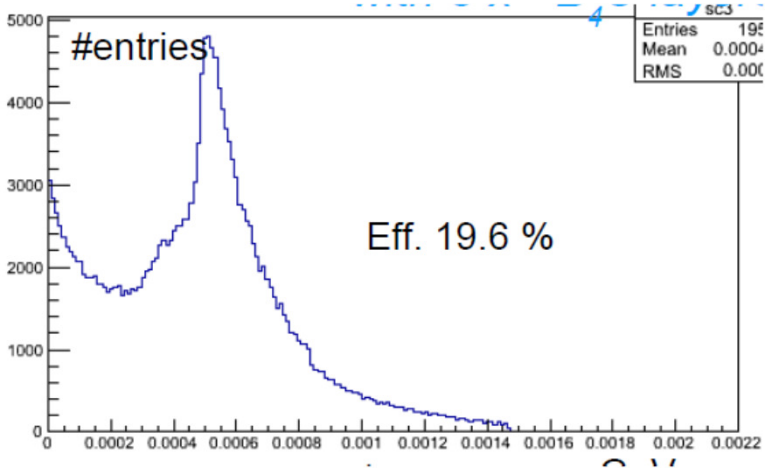
Simplified geometry of a Micromegas prototype

- 2 mesh of Nickel: 4 μm
- 3 Gas layers CF_4: 1-2-5 mm
- 5 layers of converter B_4C: 2 μm
- Neutron beam of 25 meV pencil-like parallel to z-axis
- Energy Deposition is scored at the gas volumes

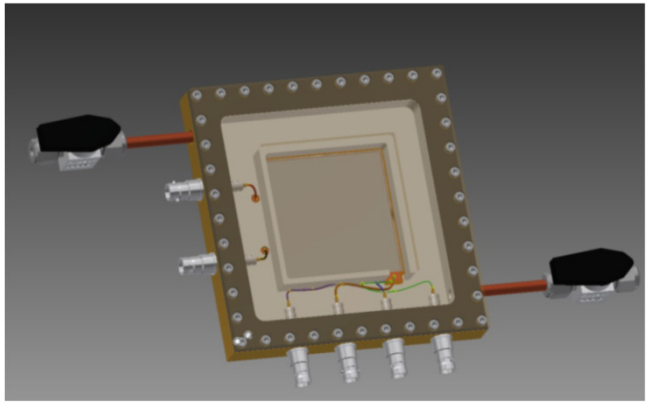
- Calculated efficiency of detection : 19.6%



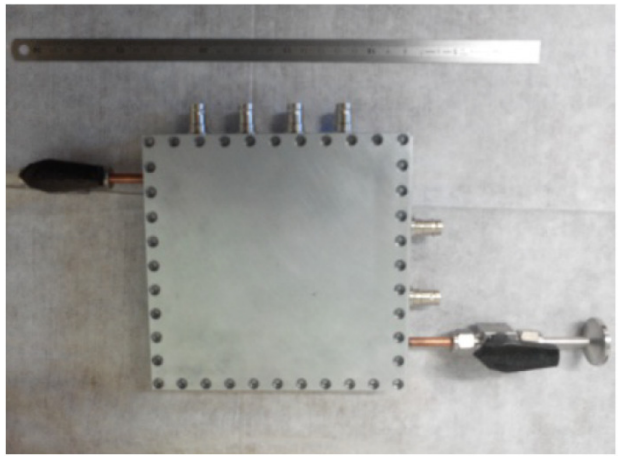


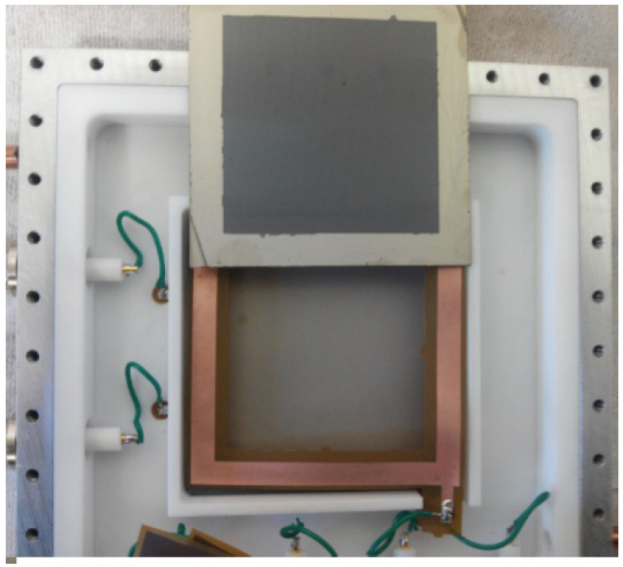


Our NMI3 detector

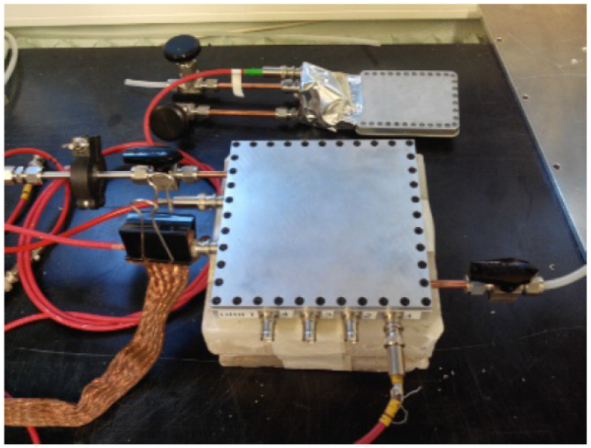


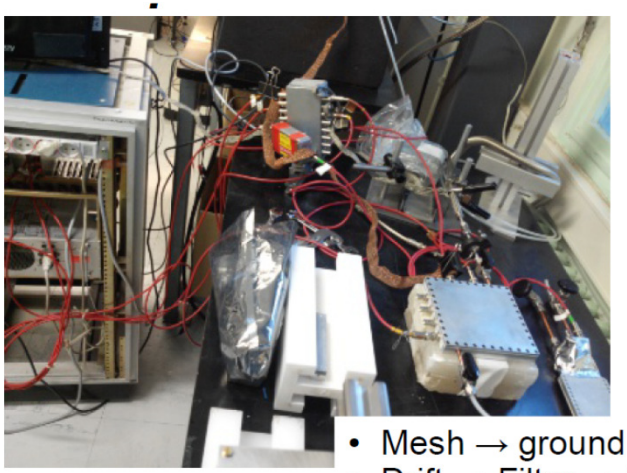
- Overall dimension: ~ 15 x 15 cm^2
- Frame: 7 x 7 cm^2
- Active zone: 5.4 x 5.4 cm^2
- Mess thickness: 4 µm



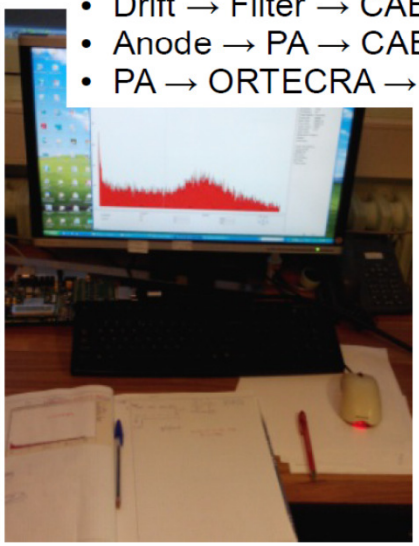


Our test lab

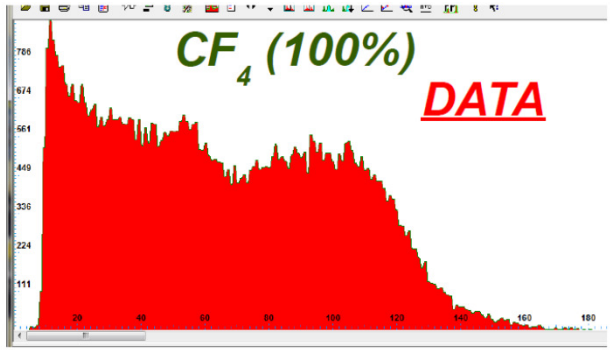




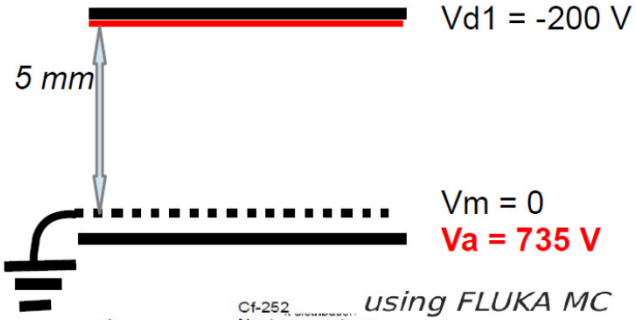
- Mesh → ground
- Drift → Filter → CAEN
- Anode → PA → CAEN
- PA → ORTECRA → OSCI+PC



Measurements and simulations

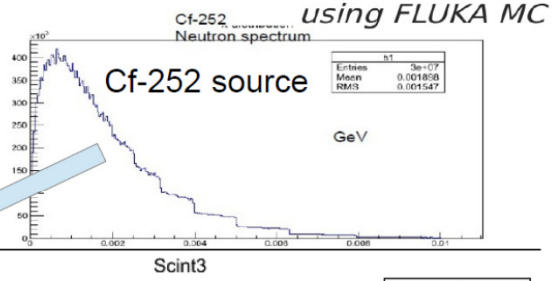


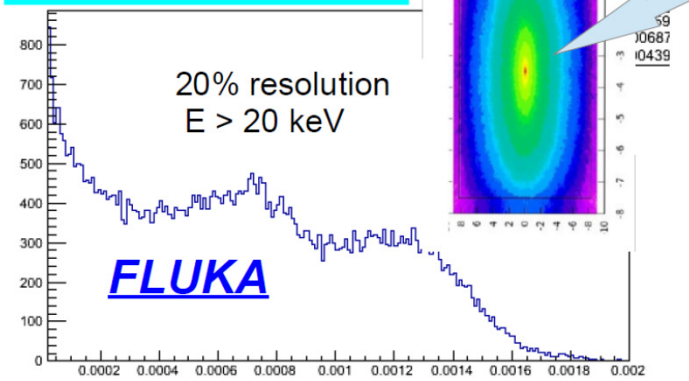
Total Rate ~ 13.16 Hz

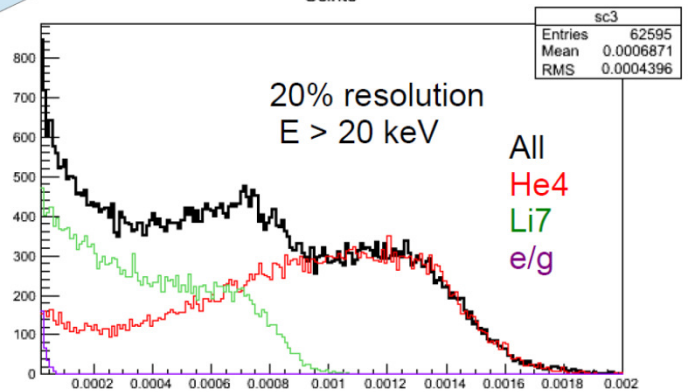


- *The detector signal spectrum was measured and well reproduced by the simulations*

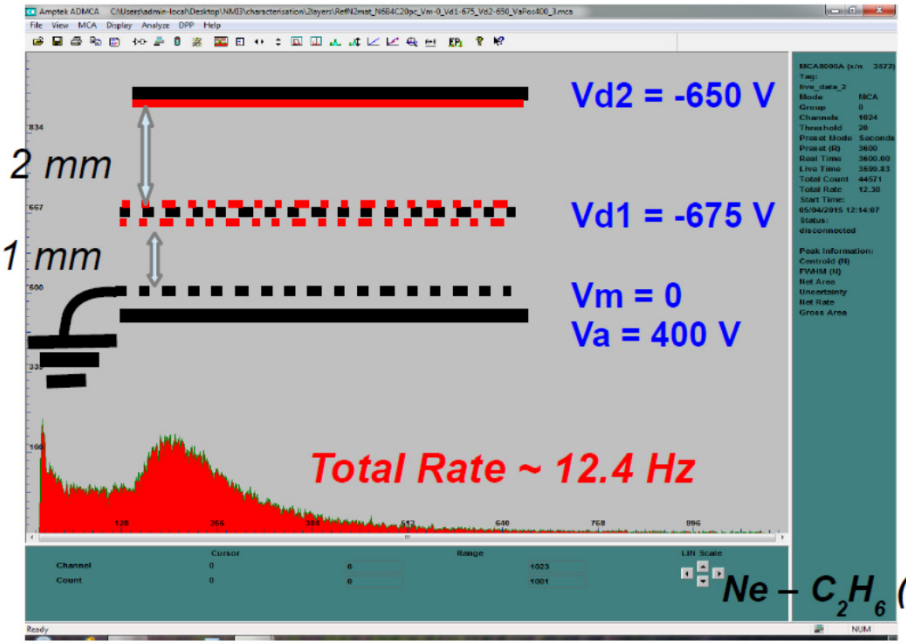
using FLUKA MC

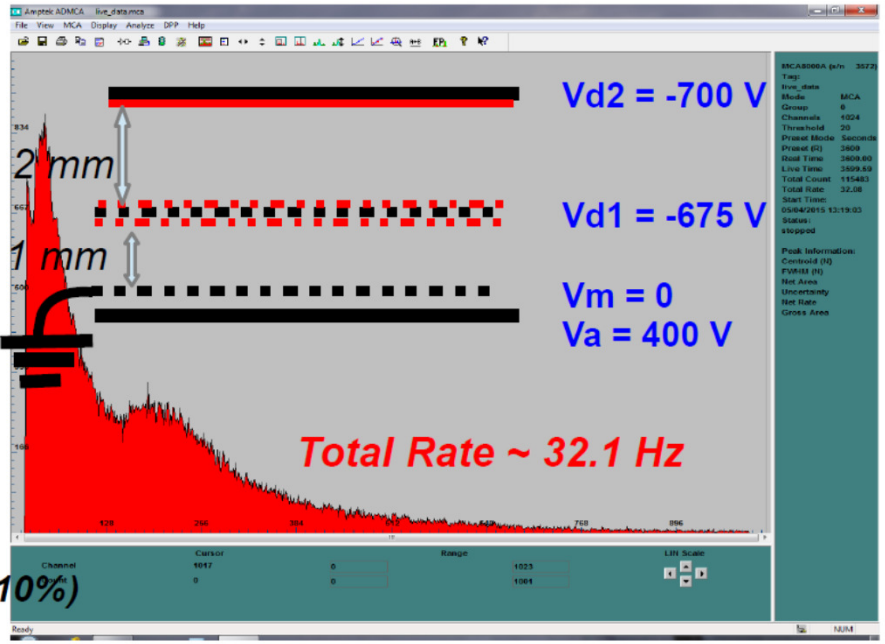






Demonstration of the transmission through the mesh

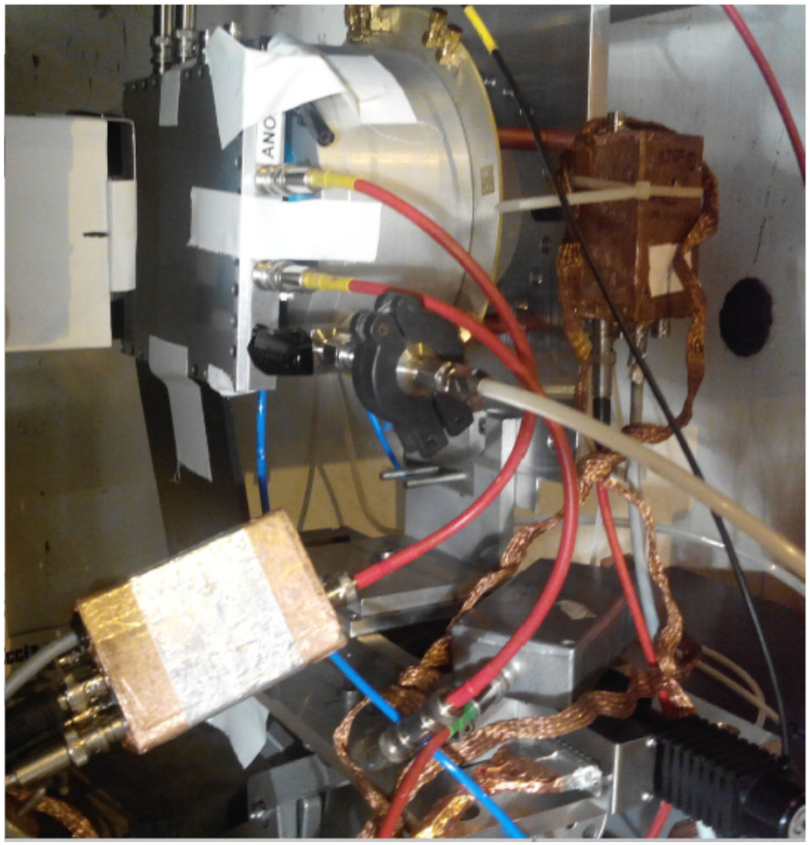


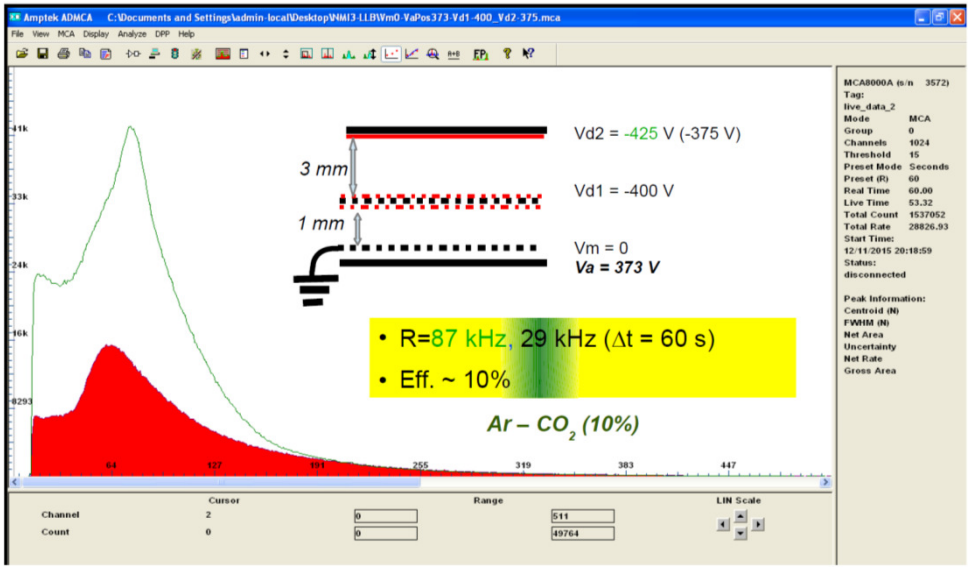


Test with different gaz, different voltages.

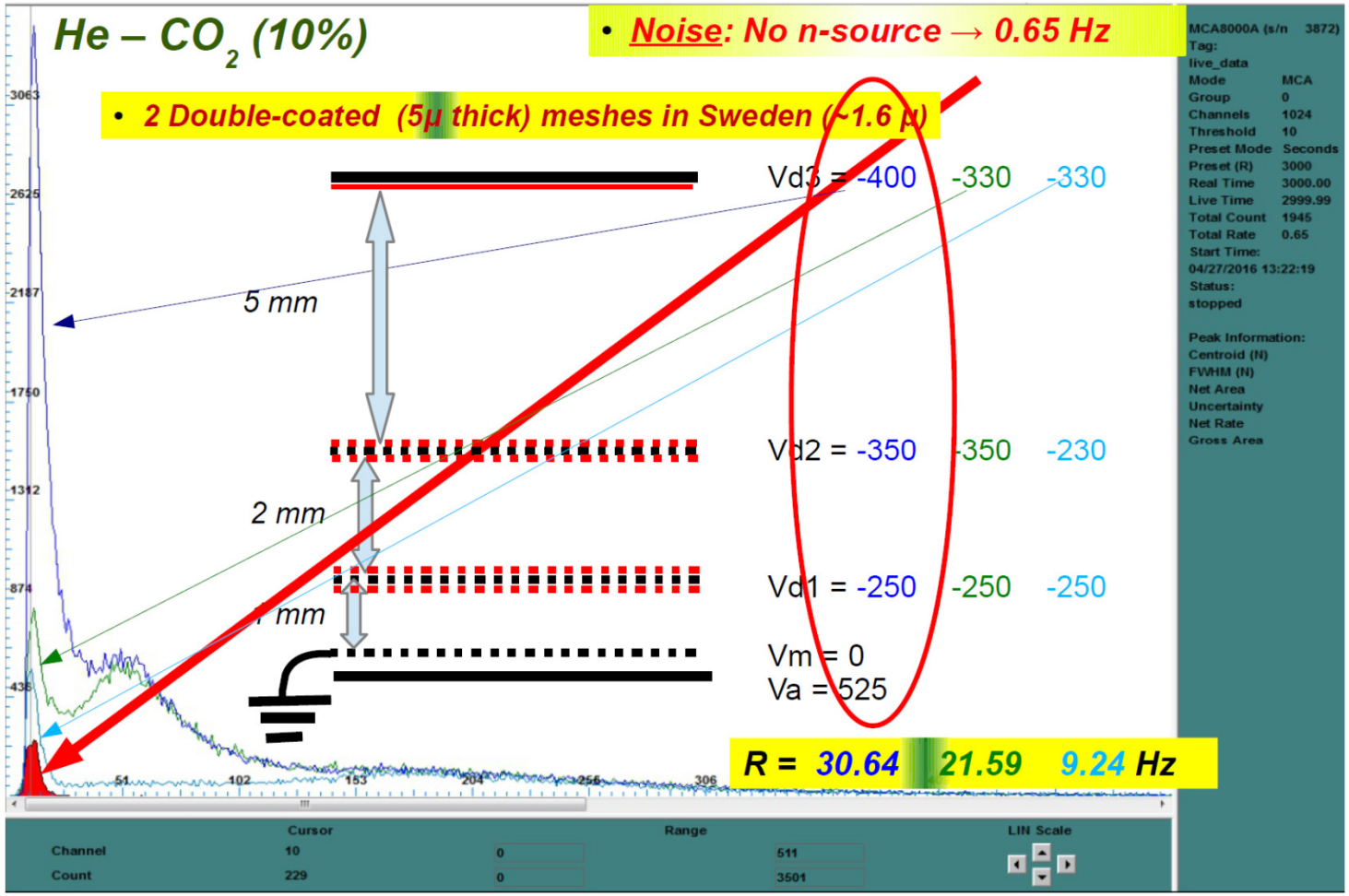
But small transmission through the first set of meshes because of wrong thickness (130 µm instead of 5 µm) confirmed by Garfield simulations

Test at Orphée (end of guide G3)





Final results with good meshes

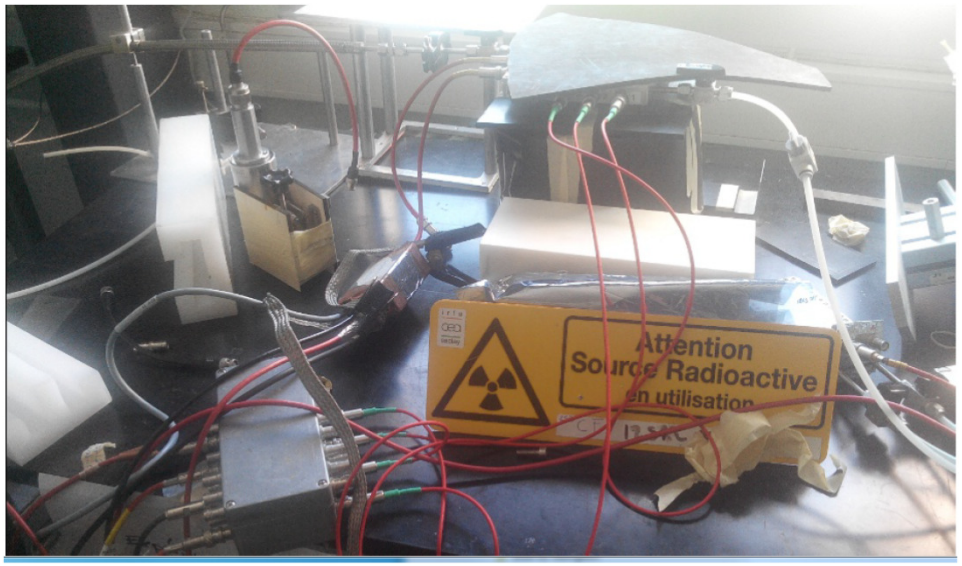


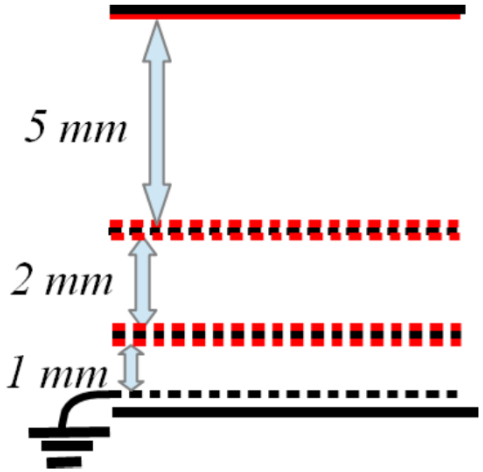
Test of different gaz

Test of different voltages (F factor; 5 for this plot, but F=9 give best results)

Test of different gaps (use 9-3-1 is better than 5-2-1)

Comparison with ^{3}He tube





- [Signal – BGR] ***^{3}He*** / [Signal – BGR] ***NMI3*** = 5.6
- Assuming Eff. ^{3}He ~ 100%
- ***Eff. NMI3*** ~ 18% → Agrees with simulations (19.6% expected)

Conclusion of NMI3 work

- **The proposed detector works**
- **The efficiency of detection of a 2 meshes detector (5 B4C layers) is 18%**

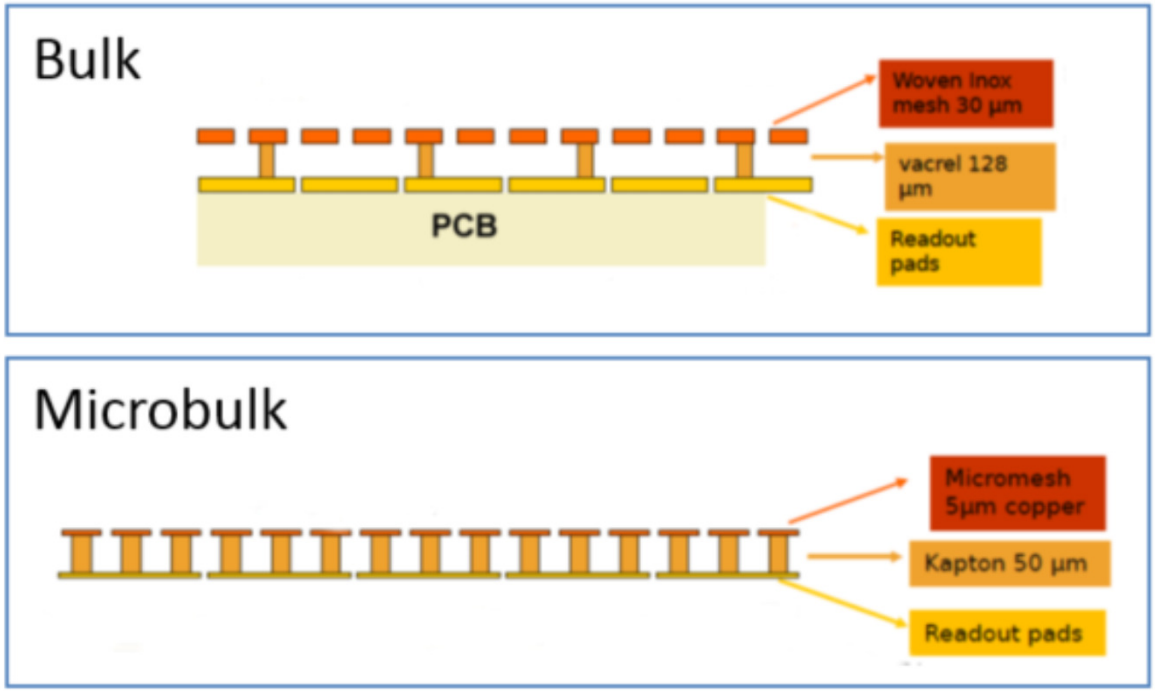
But

- **Difficulties with obtaining the meshes (difficult discussions with sub-contractor)**
- **Difficulties with keeping the correct geometry after coating**
- **Maximum efficiency of detection without tilting the detectors ~50%**

Sine 2020 Work program

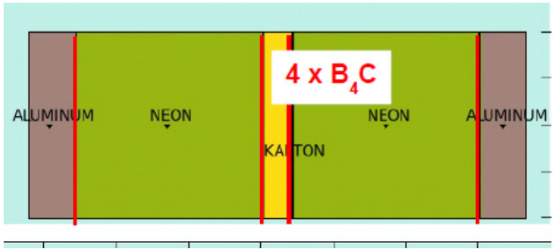
Original idea :

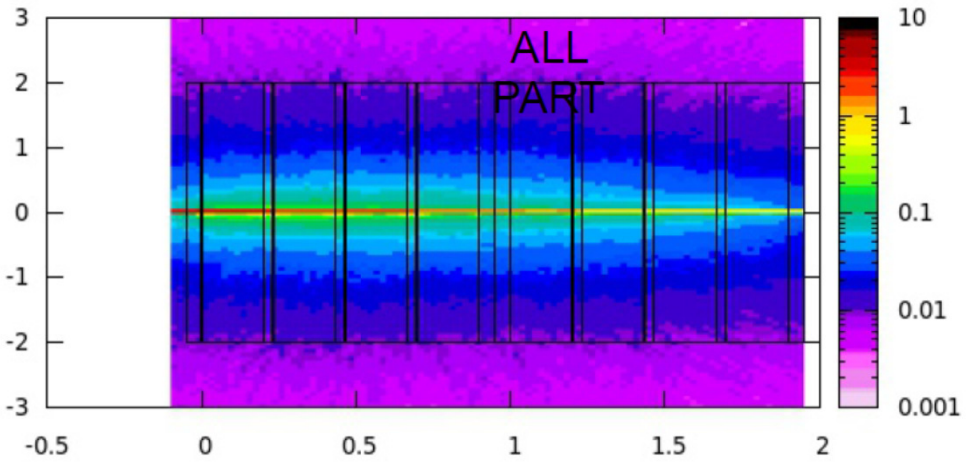
Move to microbulk to have thinner PCB layer and enable the stacking of detectors to improve the detection efficiency

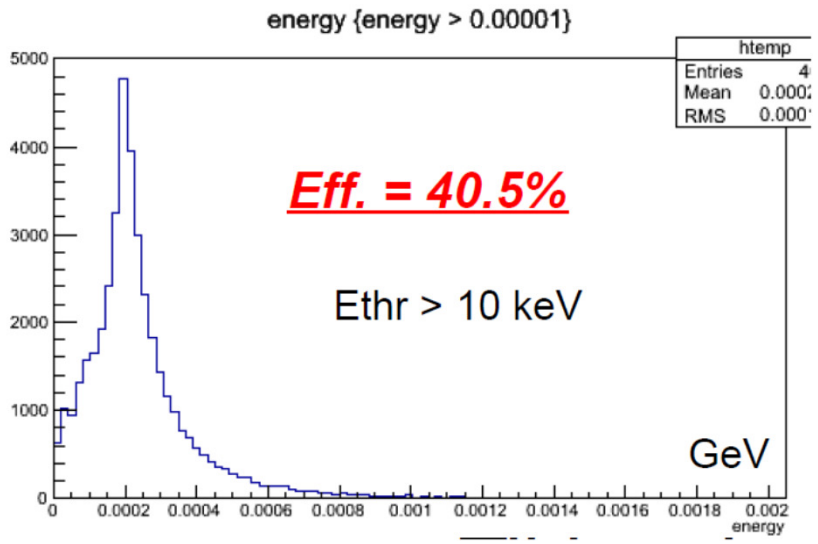


Georgios first simulations

2x4 detectors units
8 gas layers
16 B4C layers

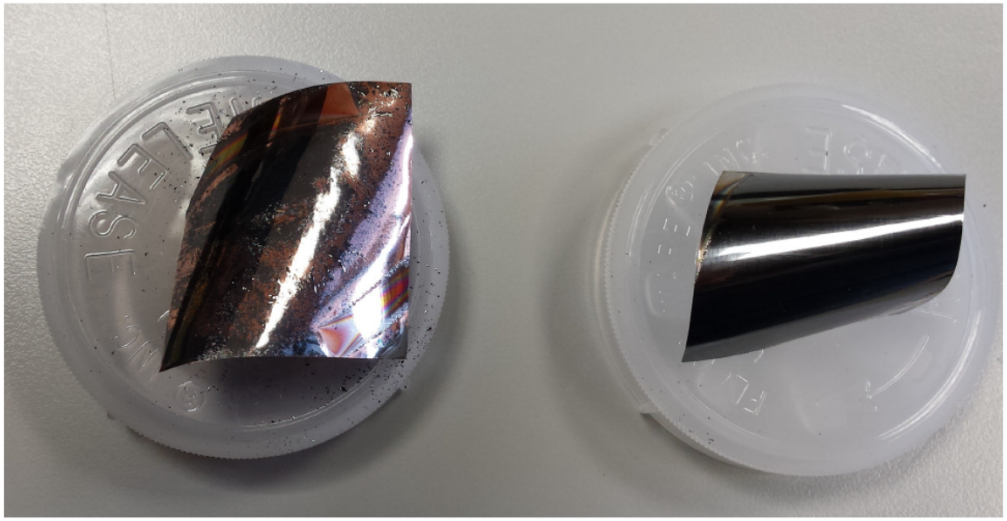






Difficulties

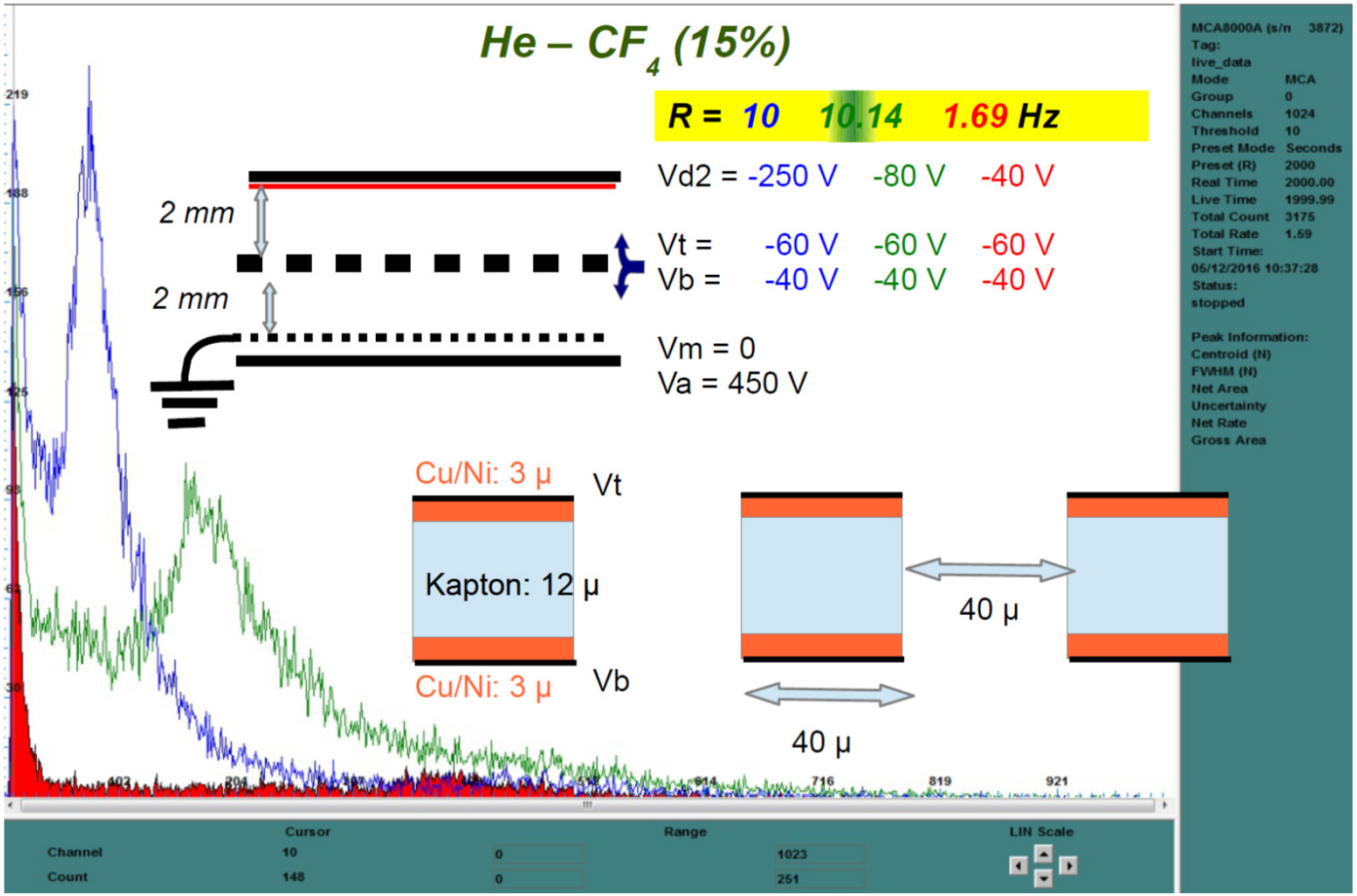
B4C peels off from micobulk material



Developments of the microbulk amplification part more difficult than expected

New ideas

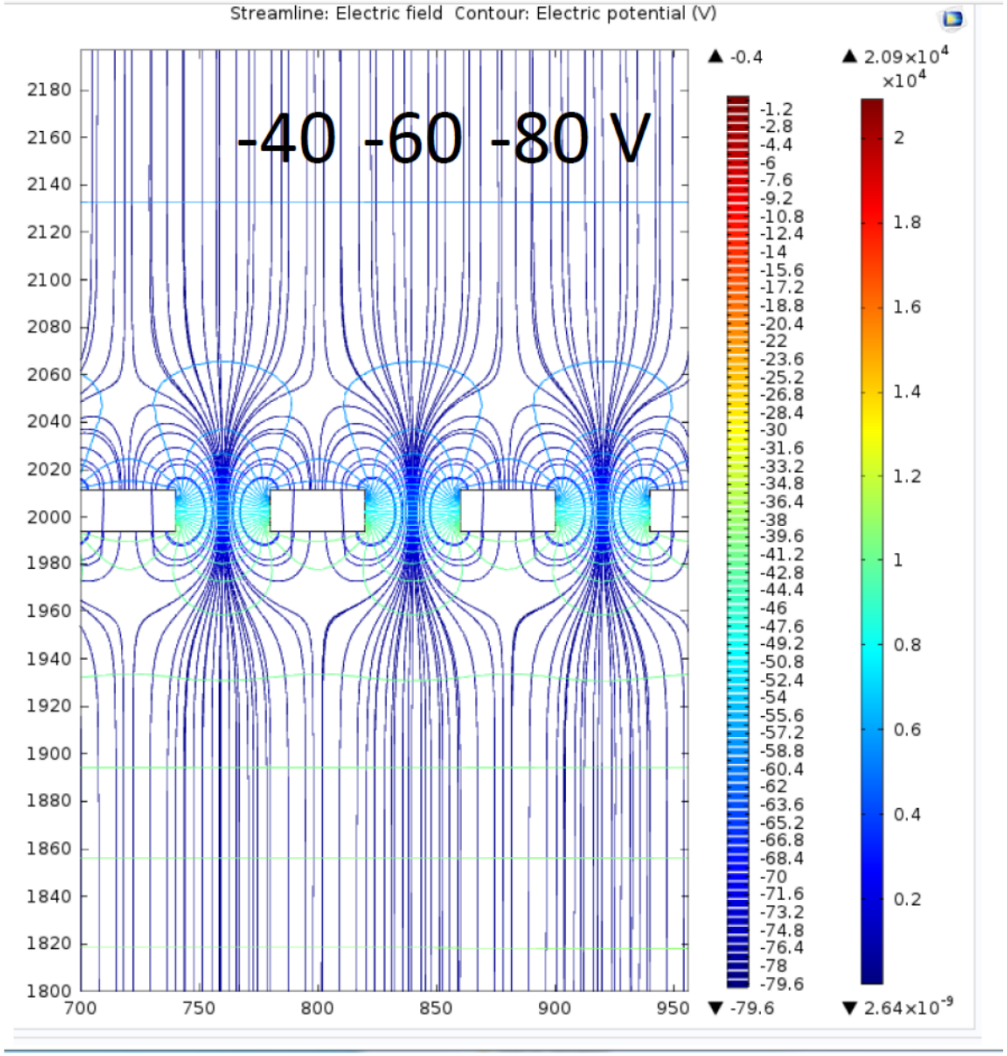
Use microbulk material to replace the meshes



Field calculations

Comsol 2D shows that less stream lines are stopped by mesh body : higher electron transmission expected

Georgios will come back in Saclay next January to continue the work



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Summary and future plans

.***NMI3 achievements***

.***Irfu/LLB*** → Development of an innovative concept for a cost-effective, large scale neutron detector: a compact stack of multi-stages ^{10}B covered meshes with a Micromegas gaseous amplification.
.***Simulations***: By placing two double 2-mesh or 3-mesh detector units, the neutron efficiency is 49% and 57% respectively. Tilting the detectors may improve the efficiency up to 64%
.A ***prototype*** was designed and built: a modular 15x15x2 cm^3 gas chamber in which up to 4 meshes can be stacked above a micromegas amplification structure, either a standard bulk-micromegas or a Kapton micro-bulk micromegas.

.***We demonstrate that the principle of the multi-layer structure works!***
.*Measured detection efficiency agrees with simulations*

.***But***
.*Getting proper meshes and coating them without bending them is difficult*

.***SINE2020 project***

.***Micro-bulk micromegas*** → Novel geometry of large scale neutron detector: a mosaic of micro-bulk micromegas coated with $^{10}B_4C$.
.***Simulations***: of first concept by placing eight micro-bulk micromegas detector units, the neutron efficiency is 40%
.A ***prototype*** was designed and built: a modular 15x15x2 cm^3 chamber in which up to 4 kapton micro-bulk micromegas can be stacked
.***Tests to deposit B_4C*** on Micro-bulk raw material are on going, but first trials was unsuccessful
.**Simplified concept : Start testing** of a prototype where mesh is replaced by micro-bulk layer : encouraging