Status of the BAND-GEM detector: improved demonstrator

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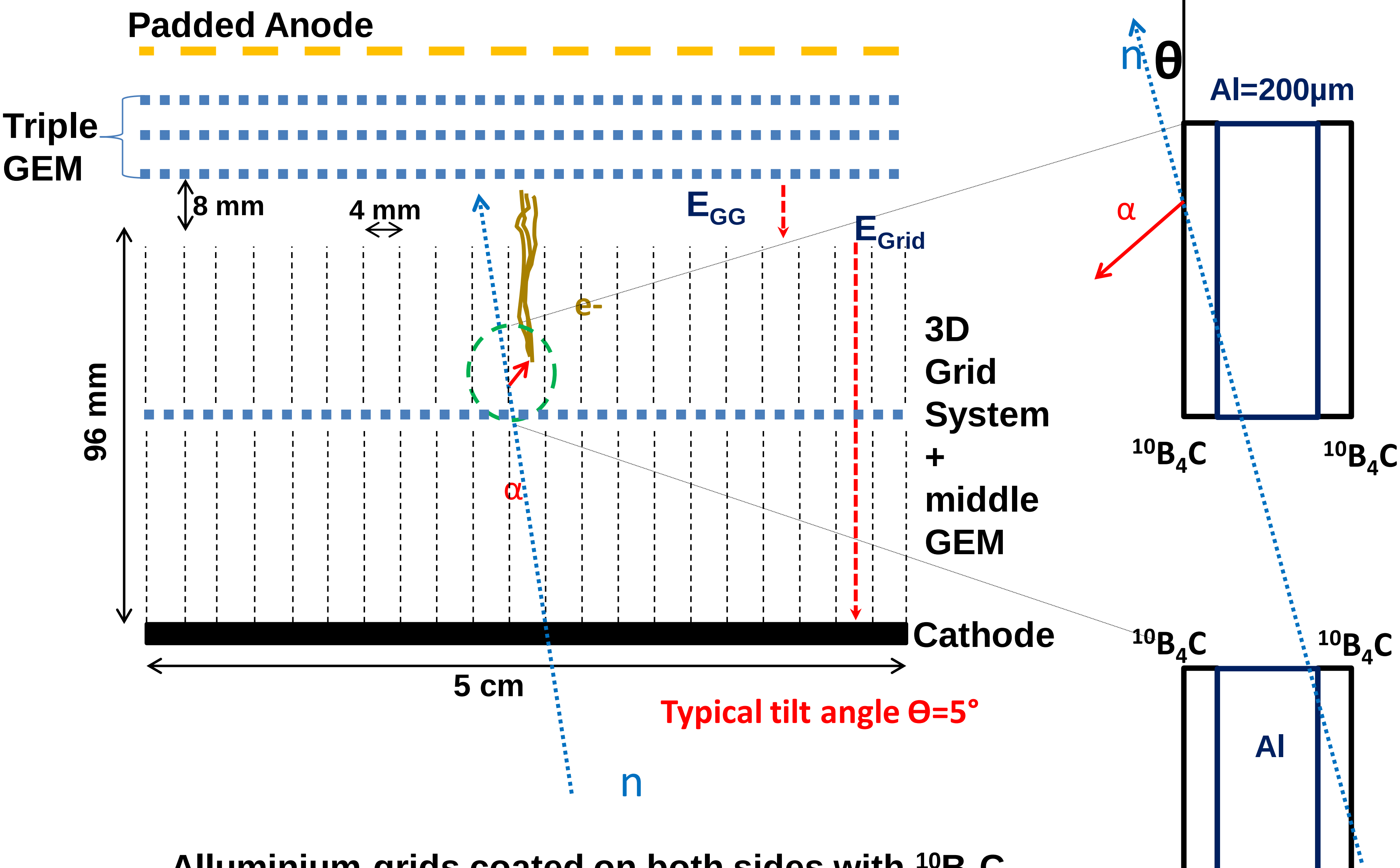
SHOULD WE DETECT THERMAL NEUTRONS WITH GEMS?

- GEM detectors born for tracking and triggering applications (detection of charged particles)....
- ...but if coupled to a solid state converter they can detect
  - Thermal Neutrons → ^{10}Boron converter
    - Neutrons are detected using the productus (alpha,Li) from nuclear reaction ^{10}B(n,alpha)7Li
    - **Face ^{3}He world shortage**

- GEMs offer the following advantages
  - High rate capability (up to MHz/mm^2) suitable for high flux neutron beams like at ESS
  - Submillimetric space resolution (suited to experiment requirements)
  - Time resolution from 5 ns (gas mixture dependent)
  - Possibility to be realized in large areas and in different shapes
  - Radiation hardness
  - Low sensitivity to gamma rays (with appropriate gain)

G. Croci et Al JINST 7 C03010; *F. Murtas et Al*, JINST 7 P07021; *G. Croci et Al,* NIMA 720, 144;
G. Croci et Al, NIMA, 712, 108; *G. Croci et Al*, JINST 8 P04006; *G. Croci et Al*, NIMA 732, 217;
G. Albani et Al, JINST 10 C04040; *G. Croci et Al*, EPJP 130, 118 *G. Croci* et Al, EPL, 107 12001
G. Croci et Al, Prog. Theor. Exp. Phys. 083H01;

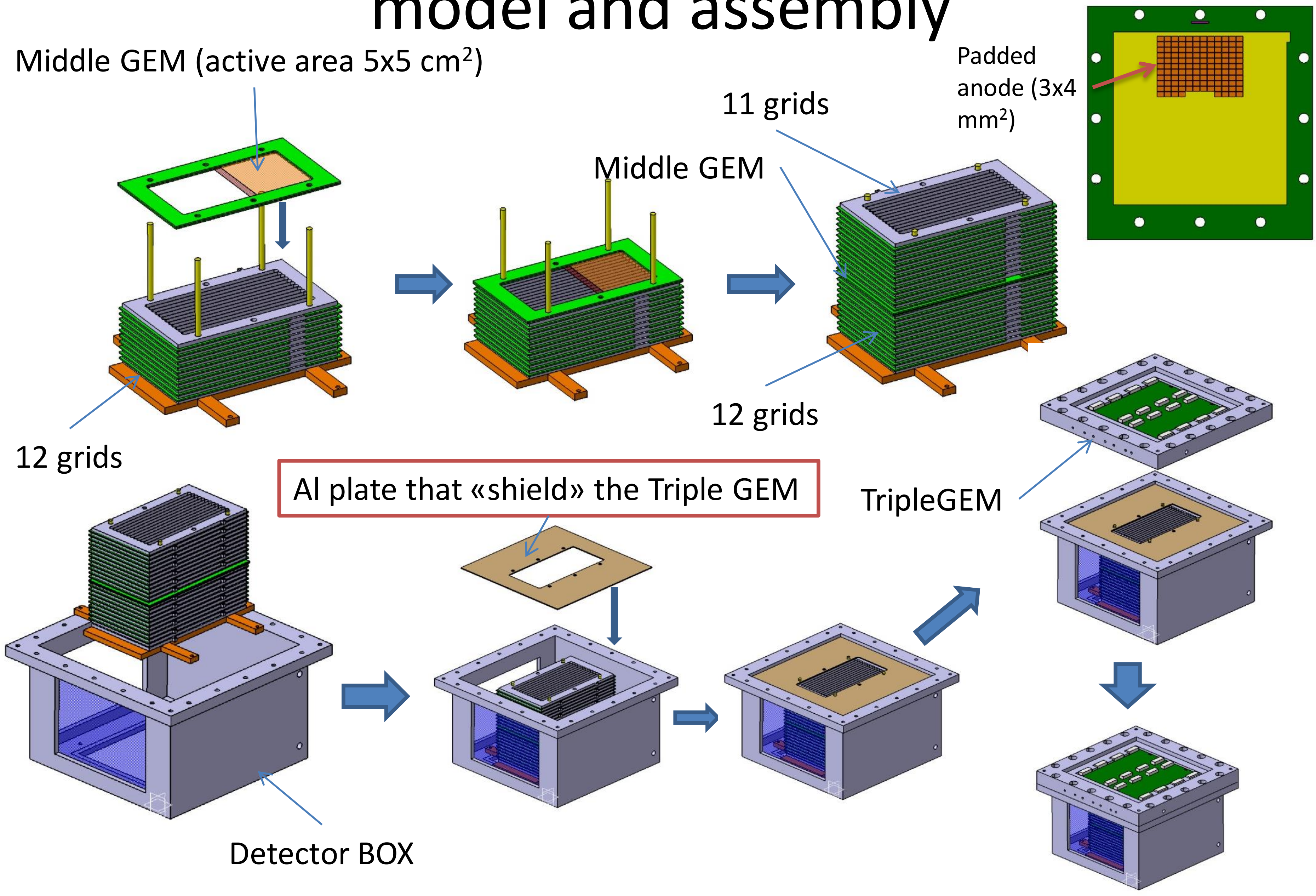
Improved BAND-GEM detection principle



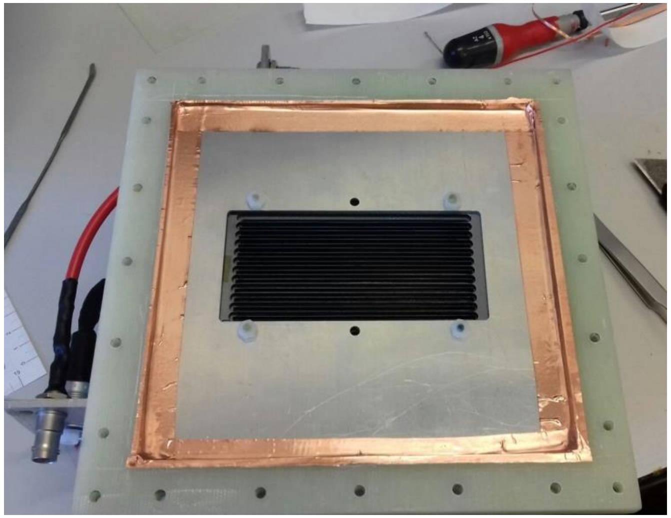
Alluminium grids coated on both sides with $^{10}B_4C$

Using low θ values (few degs) the path of the neutron inside the B_4C is increased → Higher efficiency when detector is inclined

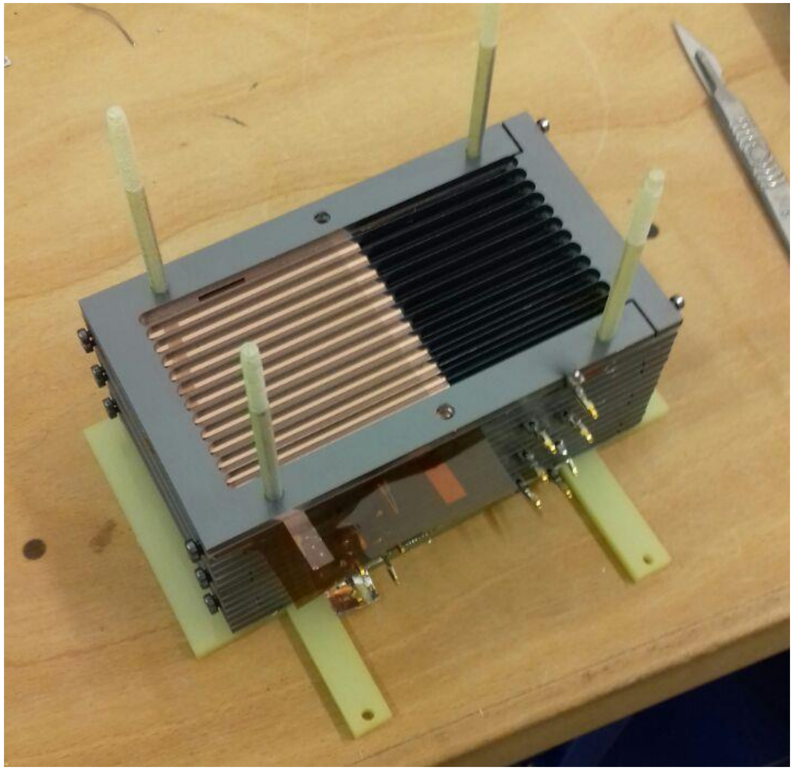
ImprovedBANDGEM demonstrator: CAD model and assembly

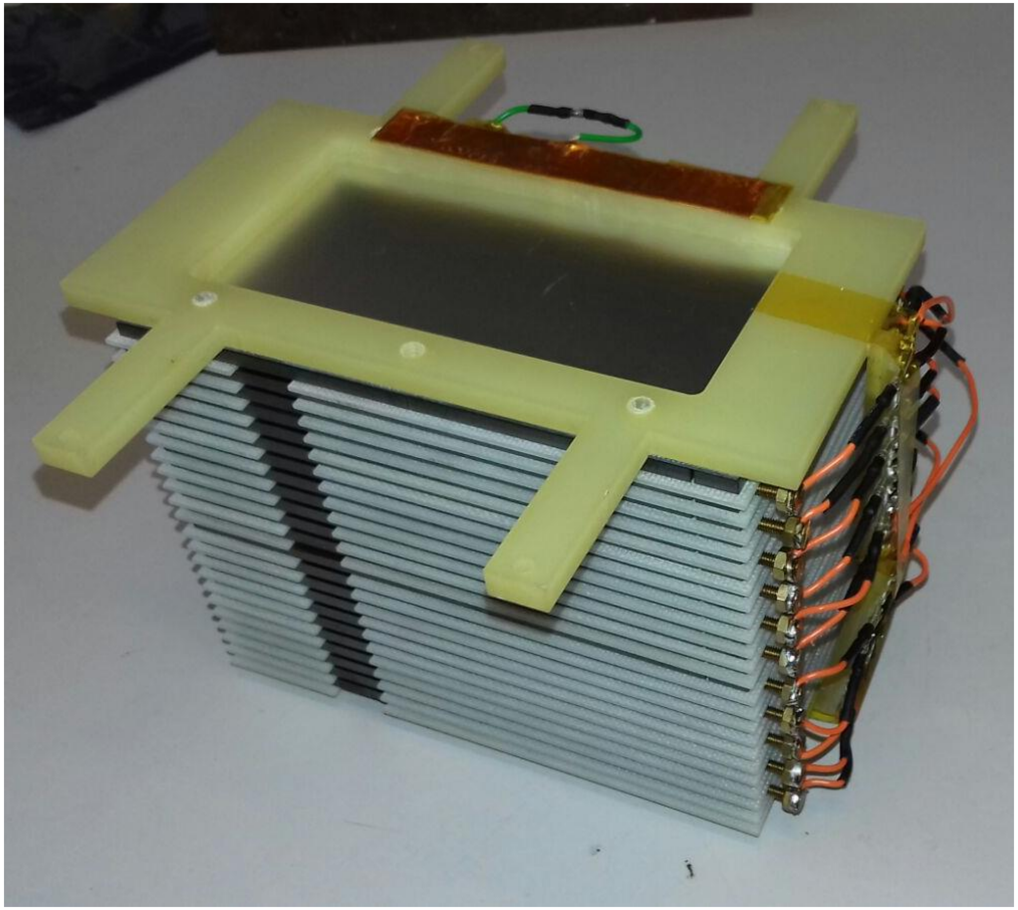


ImprovedBANDGEM demonstrator



Detector box equipped with three diagnostic windows 75 mm x 100 mm
Borated Grids – 0.91 µm of $^{10}B_4C$
GEM in the middle of the stack
Cd sheet on one side for 3D stack

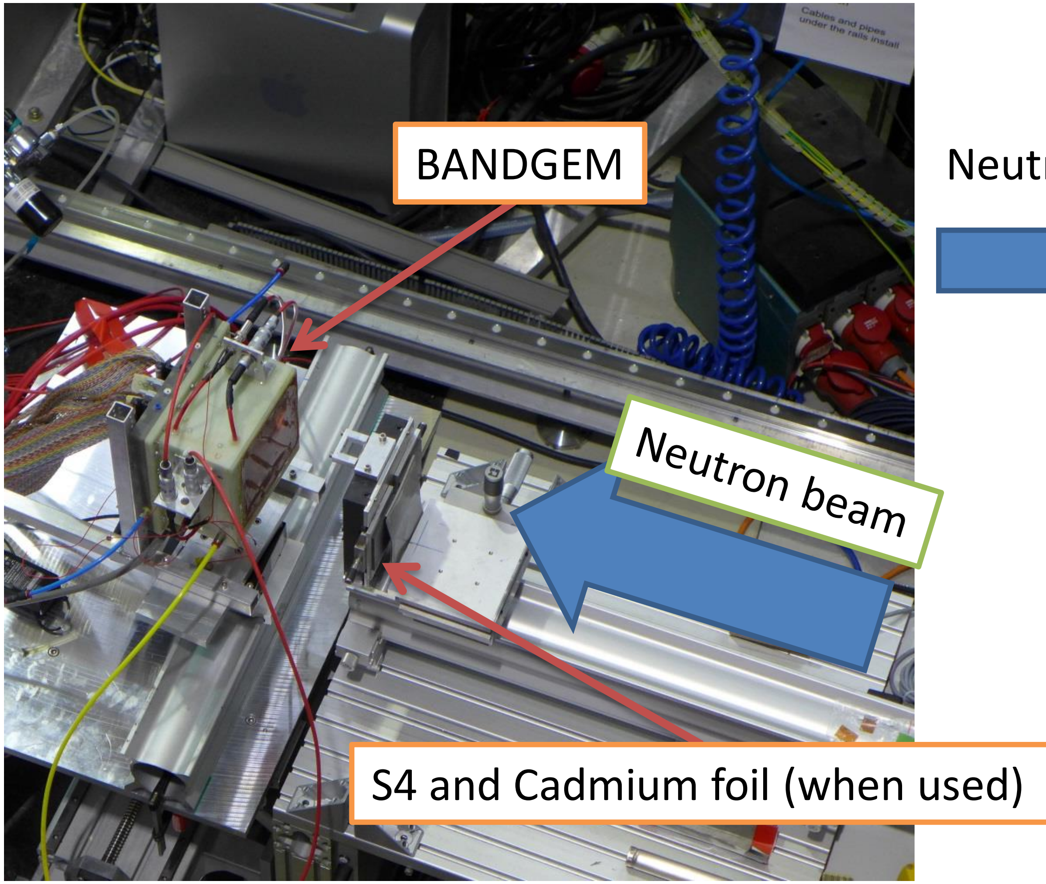


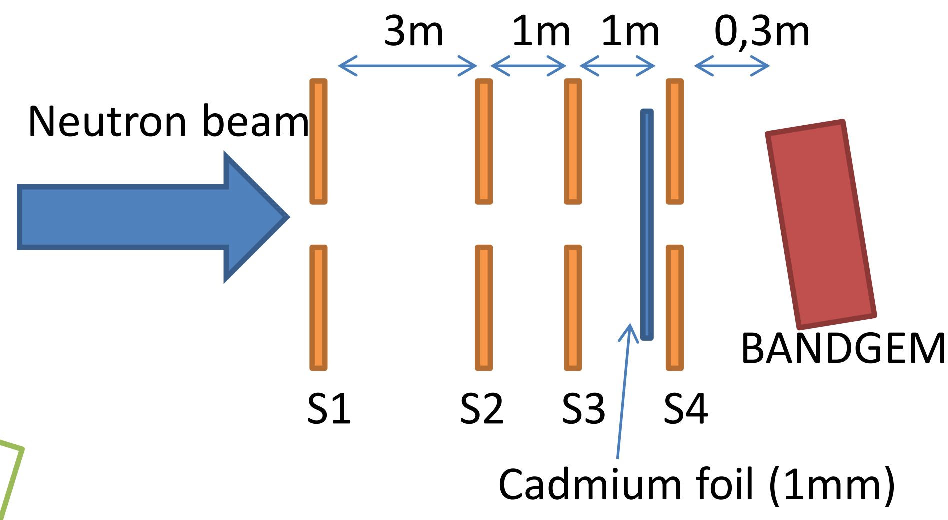


Autumn Tests

- X-Rays characterization @ UNIMIB/IFP-CNR
  - 4/09/2017 → 11/09/2017
- TREFF line @ FRM-II (Karl Zeitelhack)
  - 18/09/2017 → 22/09/2017
- EMMA @ ISIS (Davide Raspino)
  - 09/10/2017 → 15/10/2017

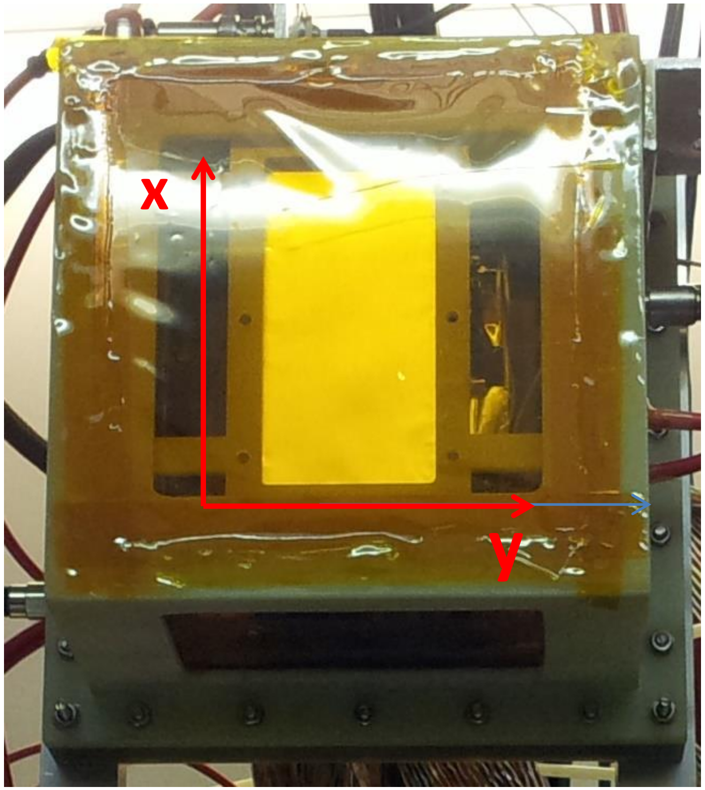
Test @ TREFF: Experimental Setup

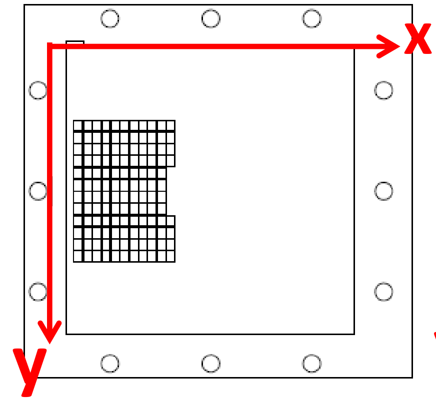


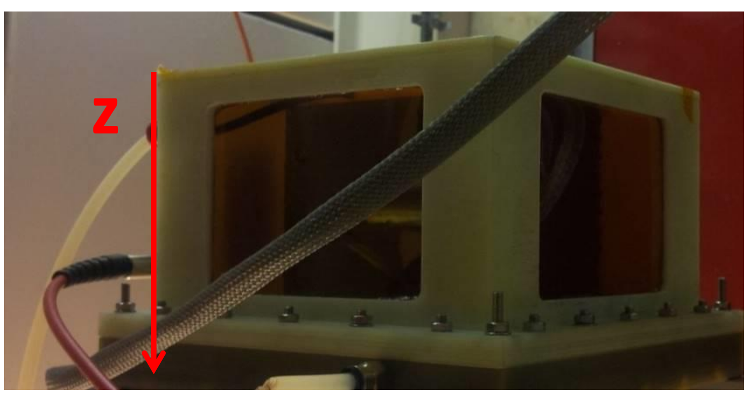


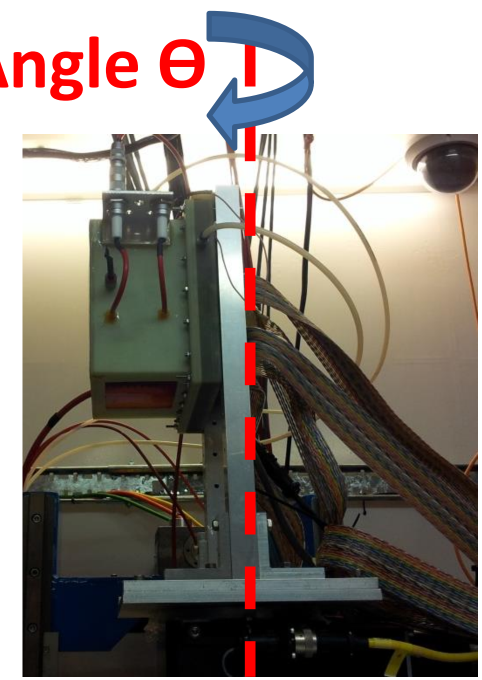
The BANDGEM detector was mounted on a rotational stage fixed to a x-y positioner

Experimental Setup Scheme

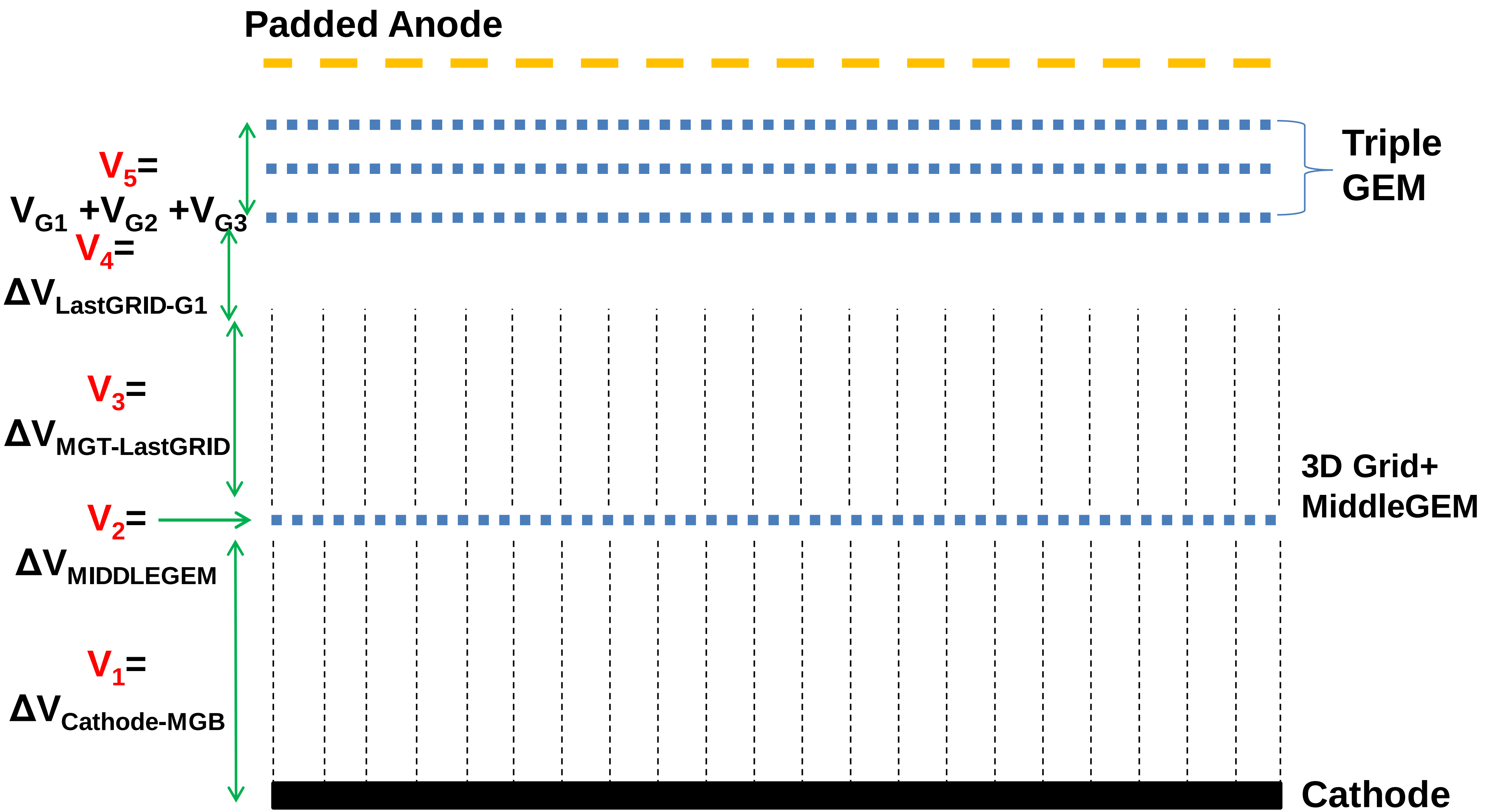






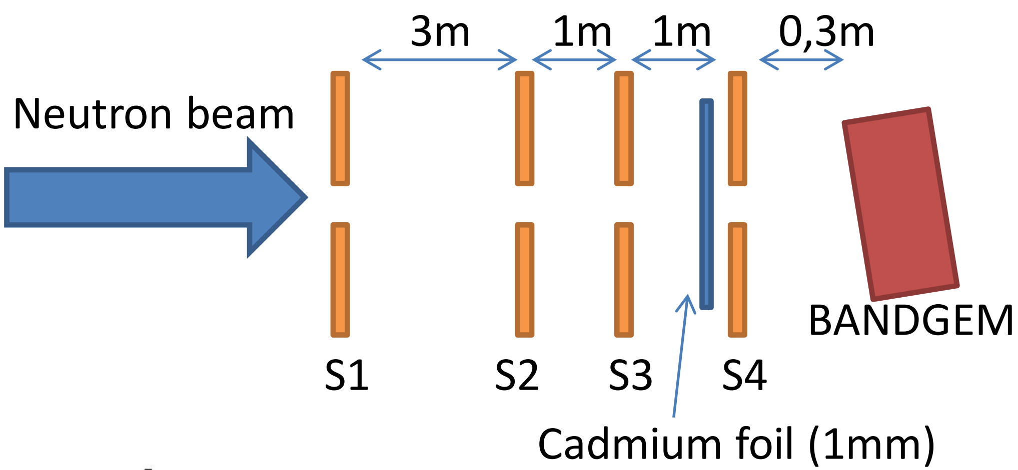


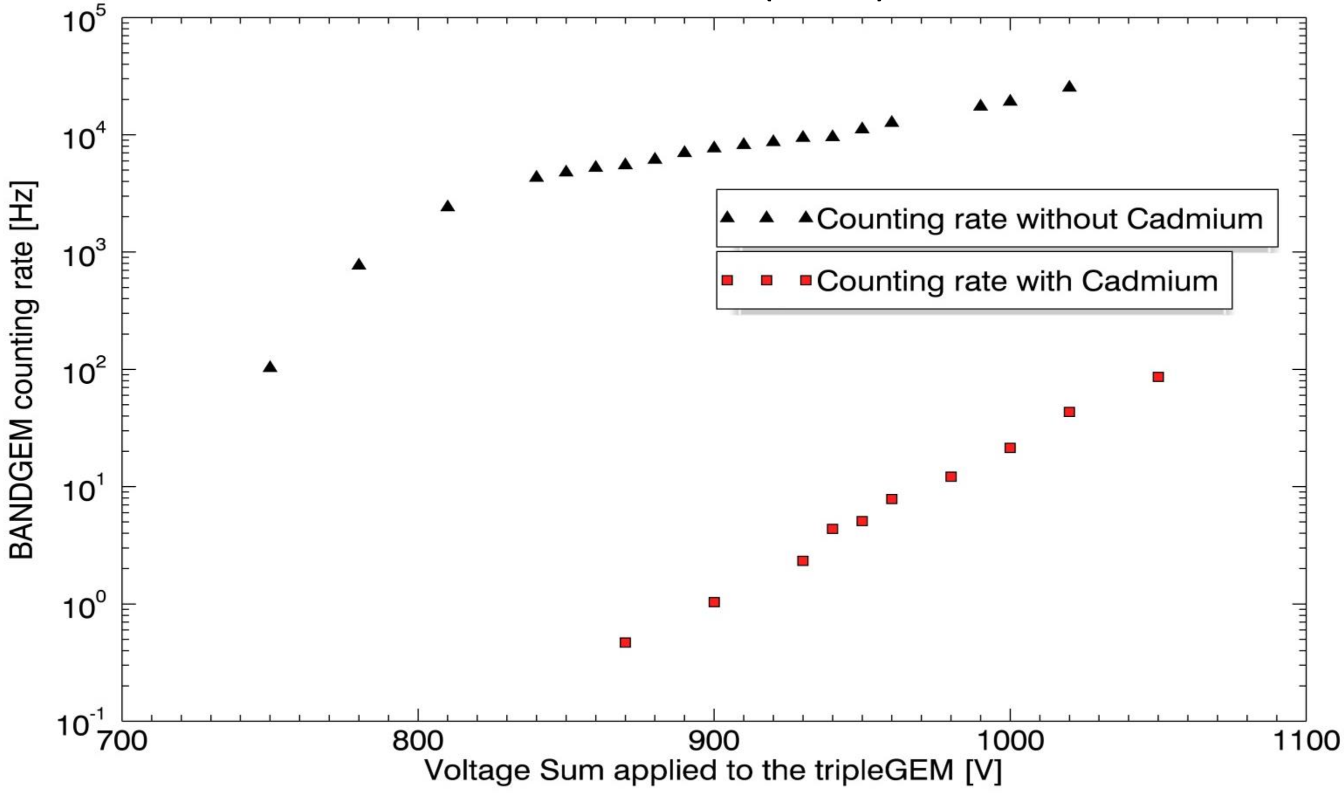
Electrical configuration



Reference values:
V1= 5230 V (14000-8770)
V2= 230 or 270 V (8770-8500)
V3= 4900 V (8500-3600)
V4= 1300V (3600-2300)
V5= 900V
Et1=300 V
Et2=600V
Ei=500V

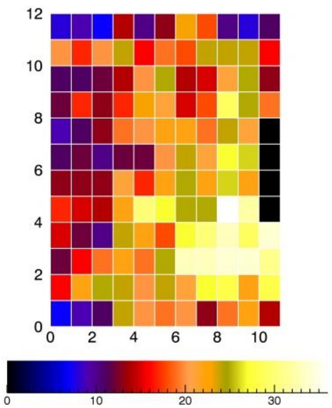
Test @ TREFF: HVSCAN



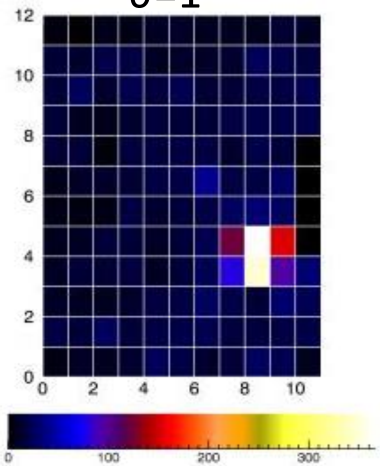


Test @ TREFF: Theta Scan

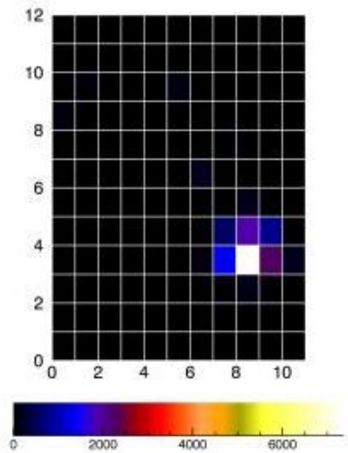
ϑ=0°



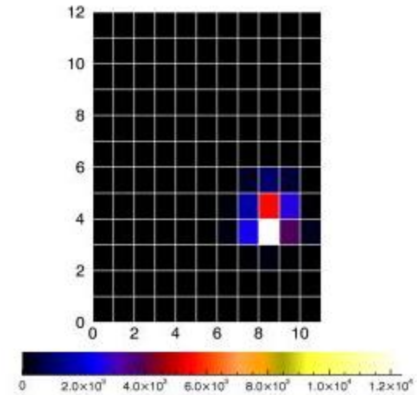
ϑ=1°

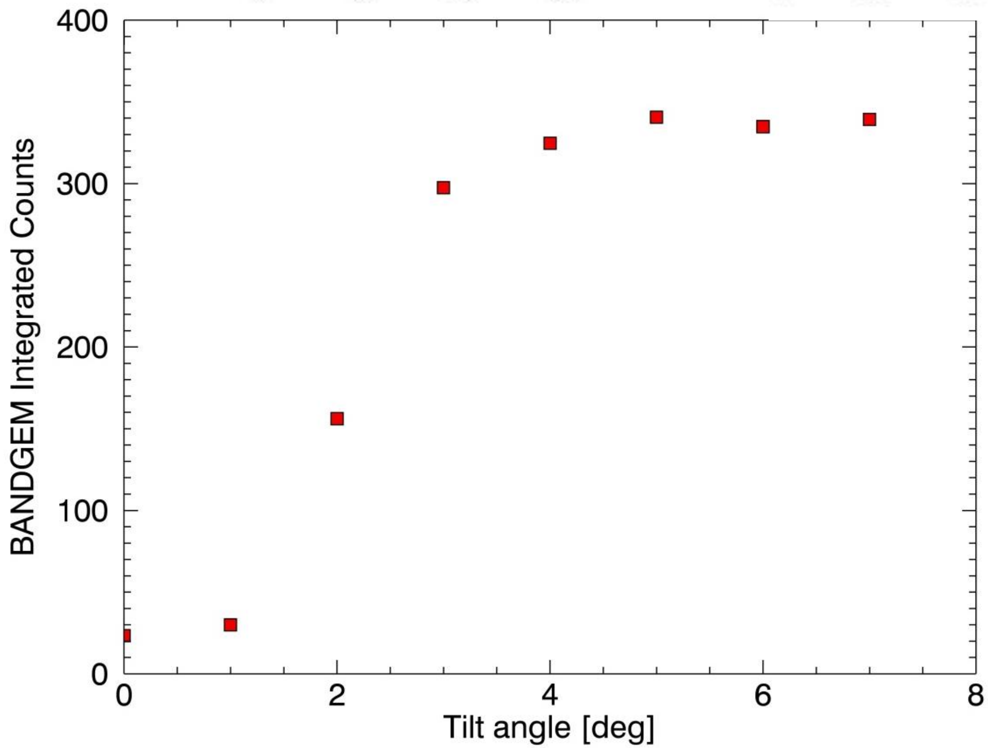


ϑ=2°

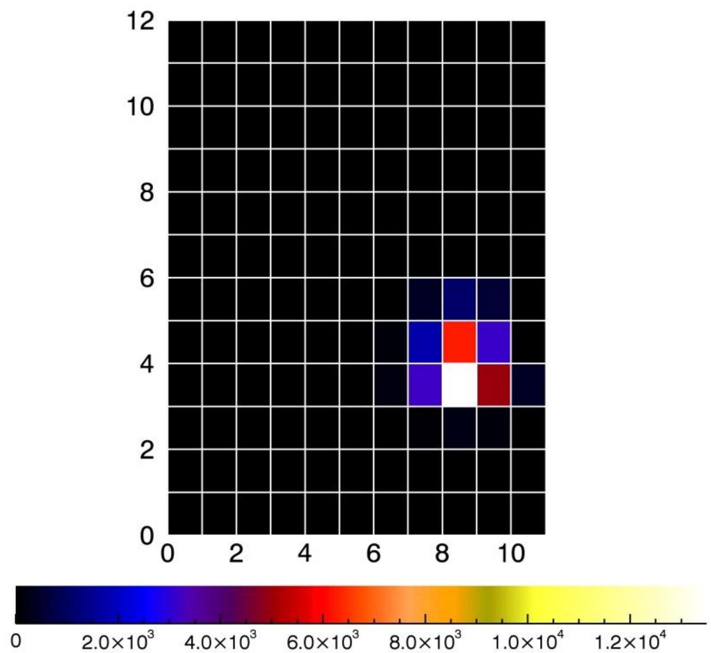


ϑ=3°

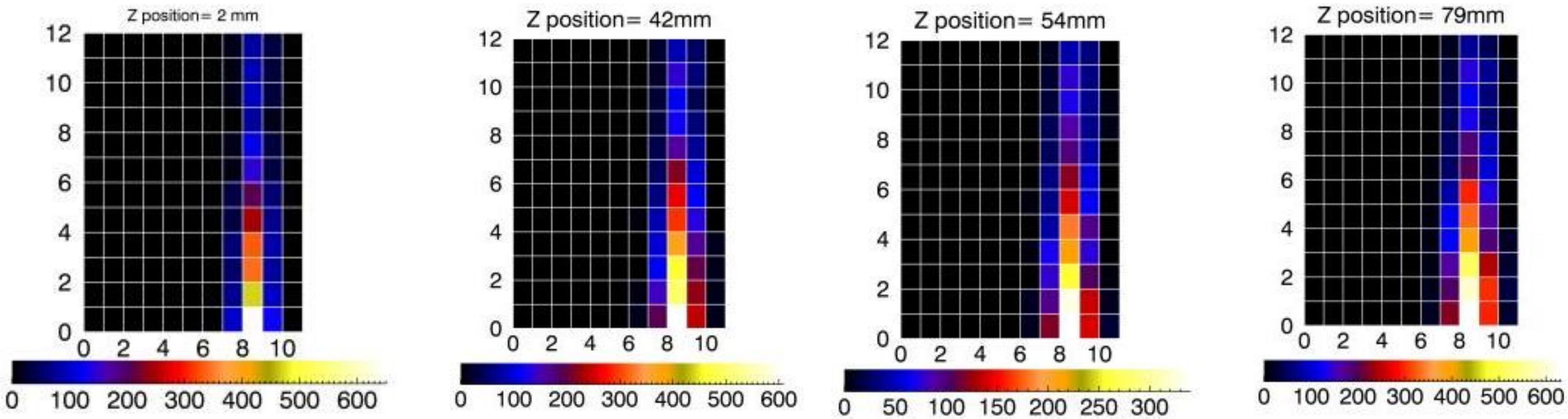


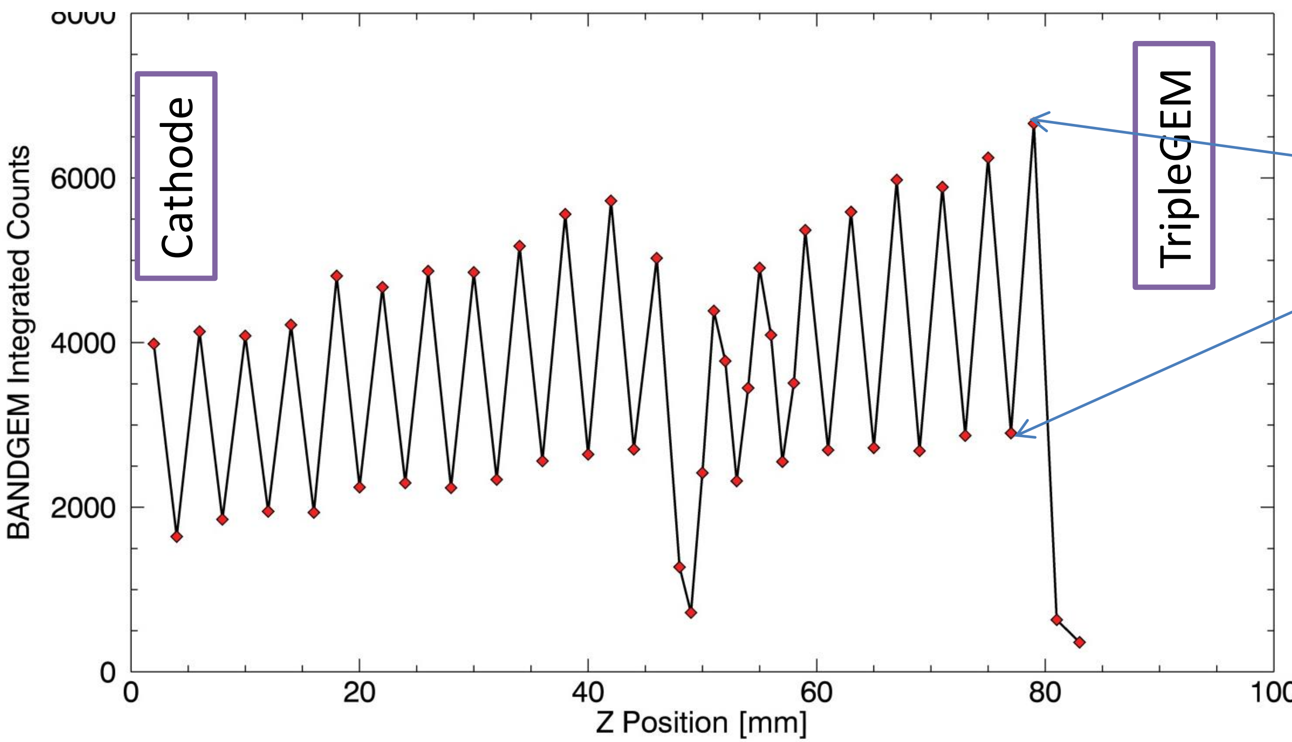


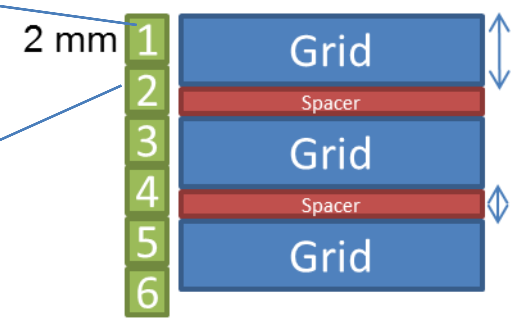
ϑ=5°



Test @ TREFF: Scan @ ϑ=90°

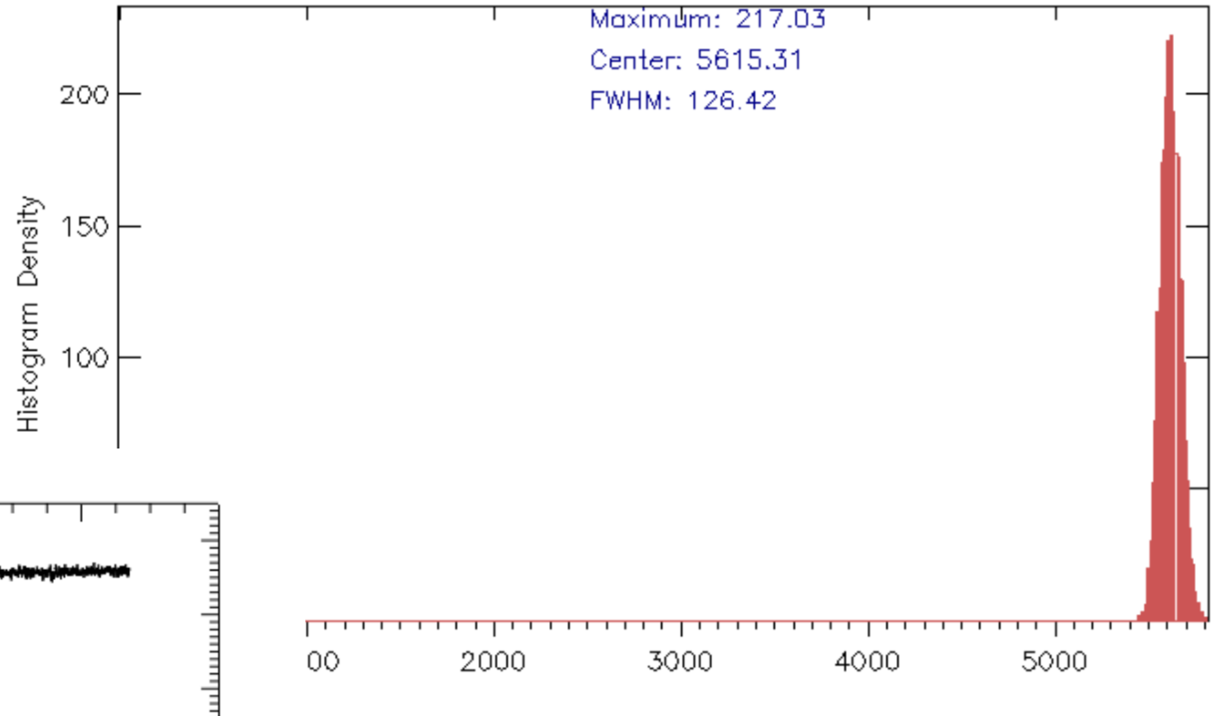


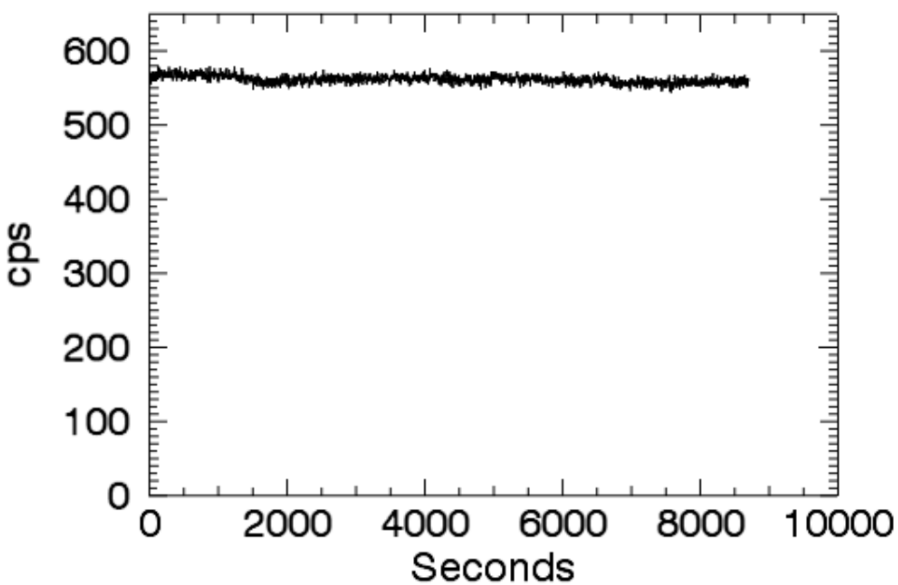




(Beam size 2x2 mm^2)

Test @ TREFF: Stability measurment





Test @ TREFF: Cluster Size measurement

The cluster size measurment was performed with neutrons and with a acquiring window equal to 10 μs. Given that the counting rate of the BANDGEM detector is about 400 Hz (in average one signal every 2.5 ms) , in an acquiring window equal to 10 μs we can see the footprint of each single neutron.

$$\text{Cluster Size}=\frac{\sum number\ of\ highlighted\ PAD\ per\ event}{number\ of\ acquired\ event}$$

Cluster size measured @ TREF = 1.45
Combatible with measurments @ EMMA

Efficiency estimation @ TREF

The efficiency of the BANDGEM detector @ 4.78 Å was estimated using an ^{3}He tube with an efficiency @ 4.78 Å equal to 96%.
The recorded counting rate of the ^{3}He tube with a 1x2 mm^2 beam was:

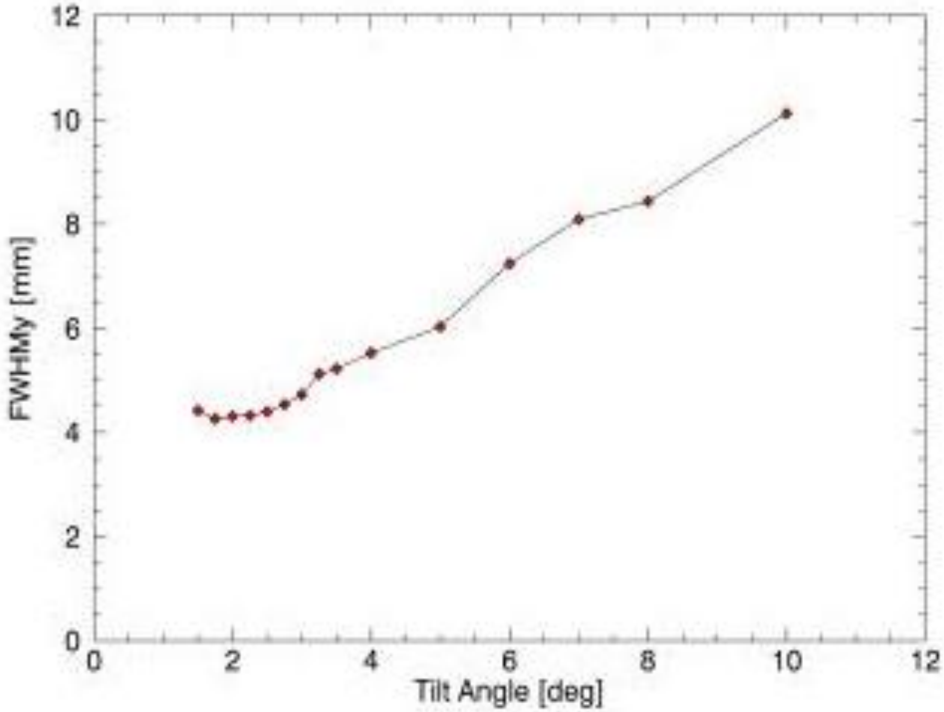
cps_{3He}=340 [Hz]

$cps_{BANDGEM@5^\circ}$=271 [Hz]

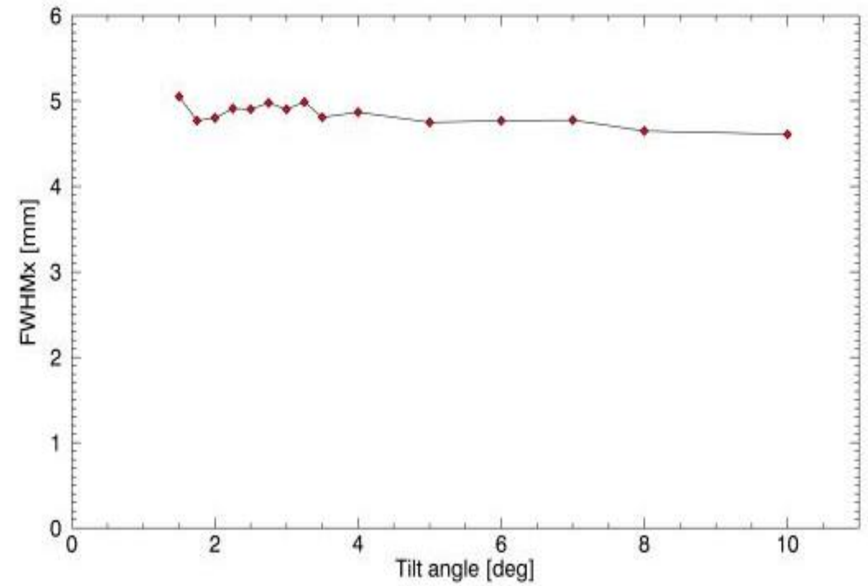
$$Efficiency_{@4.78\text{Å}} = \frac{\text{cps}_{\text{BANDGEM@5°}}}{\text{cps}_{\text{3He}}} x \frac{0{,}96}{Cluster\ Size} \approx 0{,}52$$

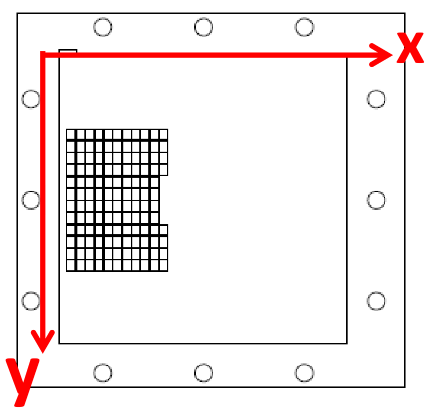
Space Resolution measurements

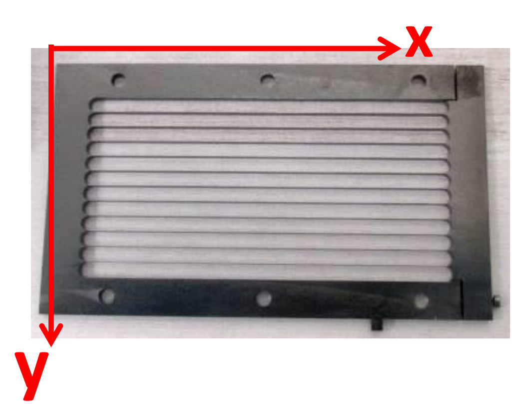
FWHMy (along the 4mm PADs size)



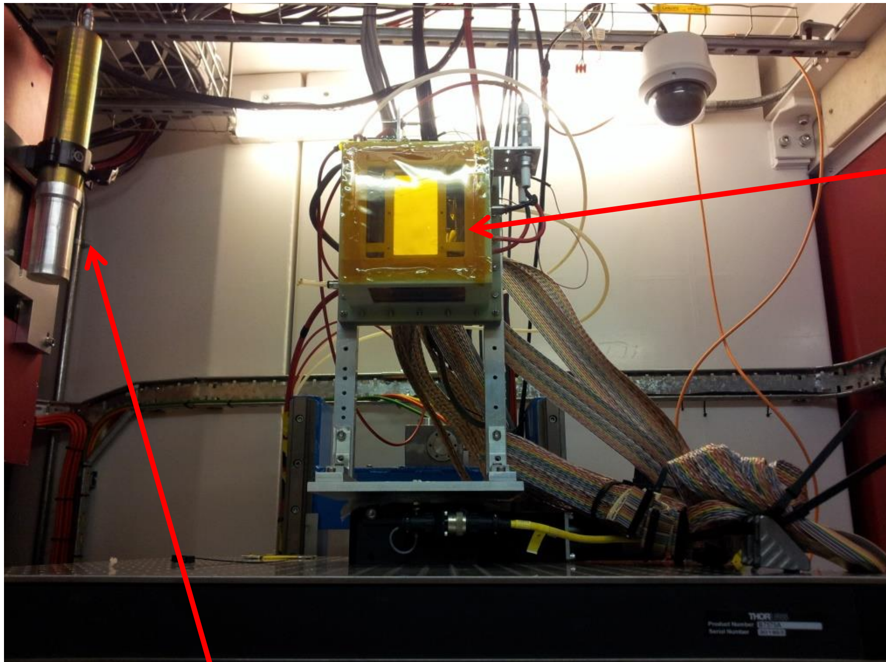
FWHMx (along the 3mm PADs size)



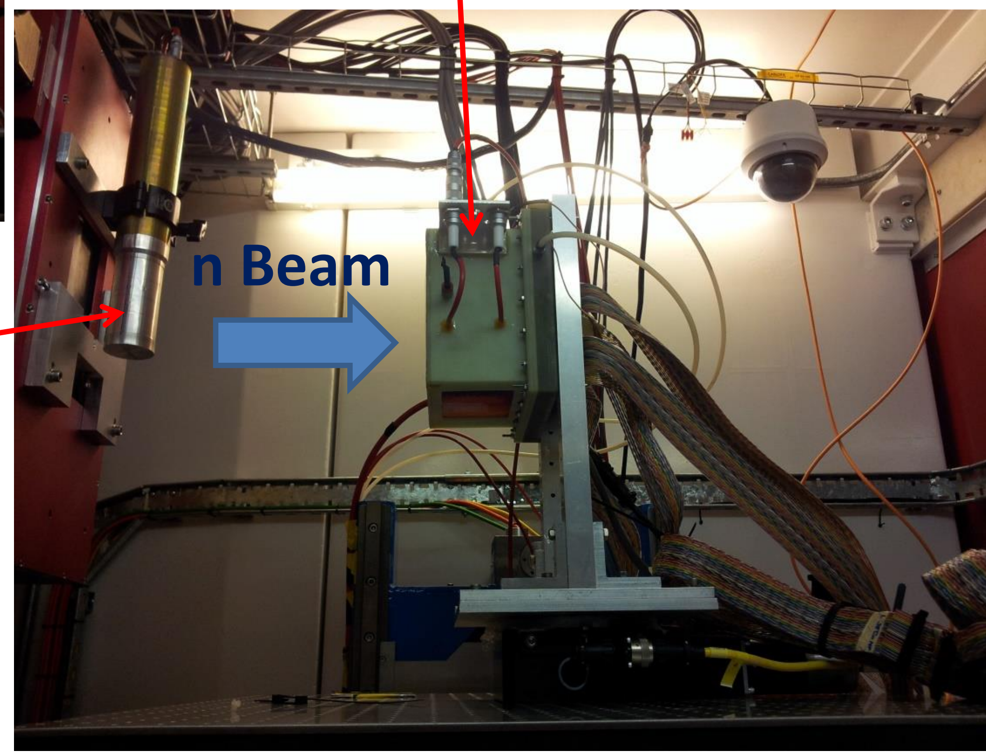




Test @ EMMA: Experimental Setup

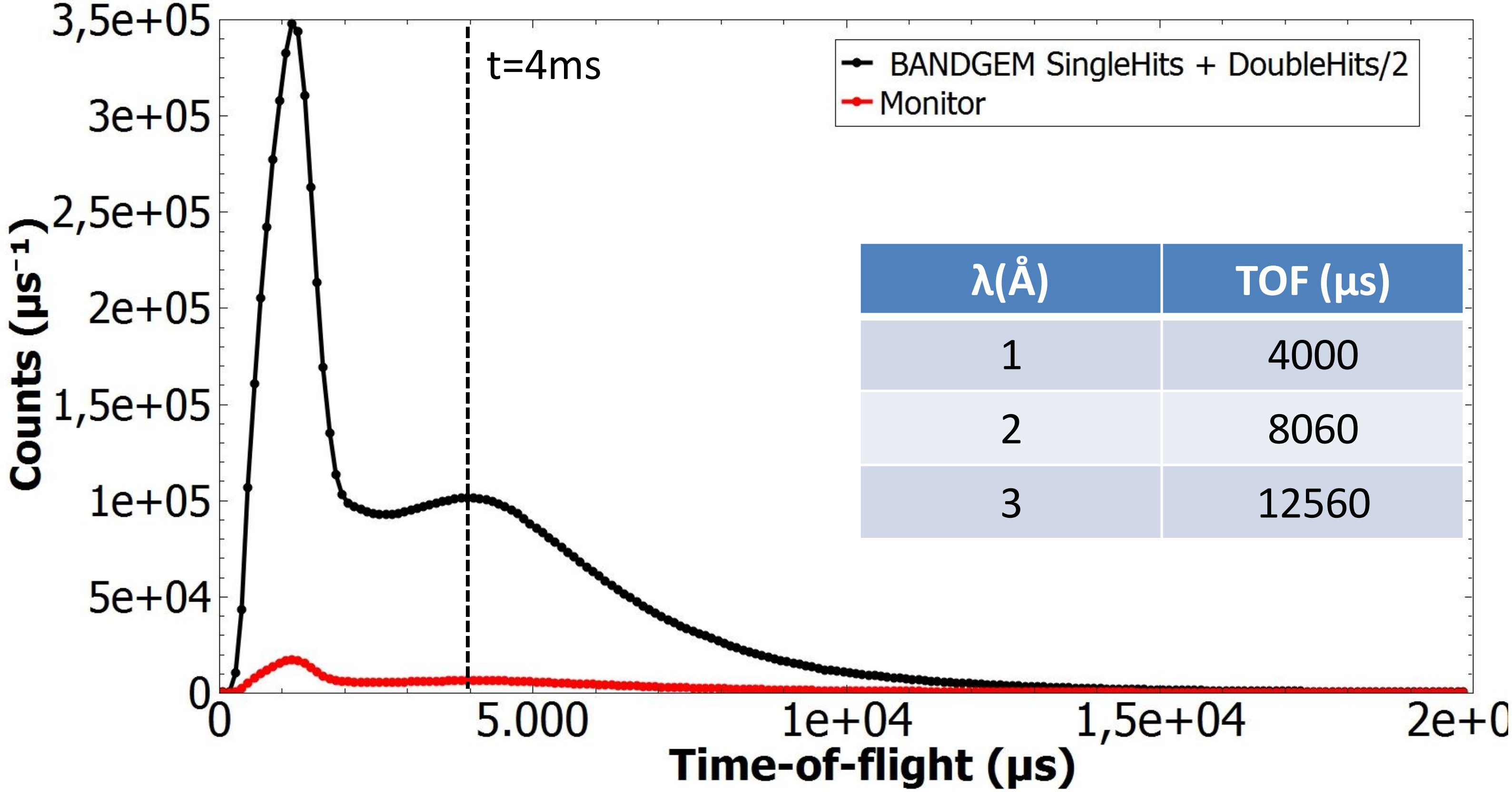


BAND-GEM
on turntable



BEAM MONITOR
Lithium Glass Scintillator
ε(1 Å) = 1.8%

Time of Flight Spectra – EMMA 1 Å < λ < 4 Å



λ(Å)	TOF (μs)
1	4000
2	8060
3	12560

$$C_{BANDGEM,PAD\ i}(t=\lambda) = \int_{t=t_1\ ms}^{t=t_2\ ms} BandGEM_{\ i}(t)dt$$

$$C_{Mon}(t=\lambda) = \int_{t=t_1\ ms}^{t=t_2\ ms} Monitor(t)dt$$

$\varepsilon_1 = \varepsilon(1 \text{ Å}) = 1.8\%$

Error: 10%

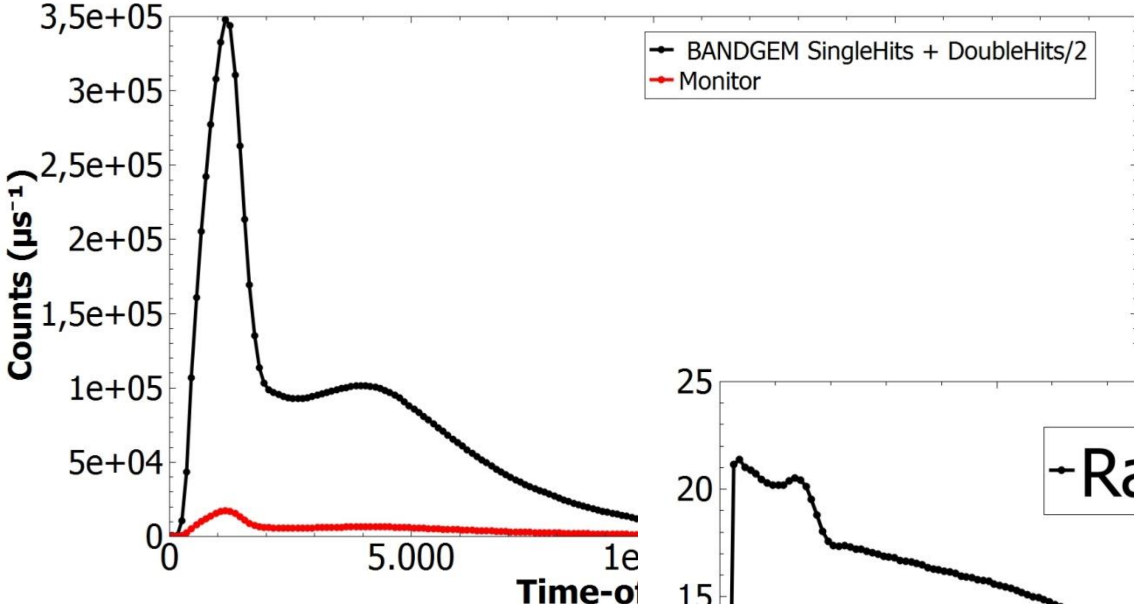
$\varepsilon(\lambda) = \varepsilon_1 * \lambda$

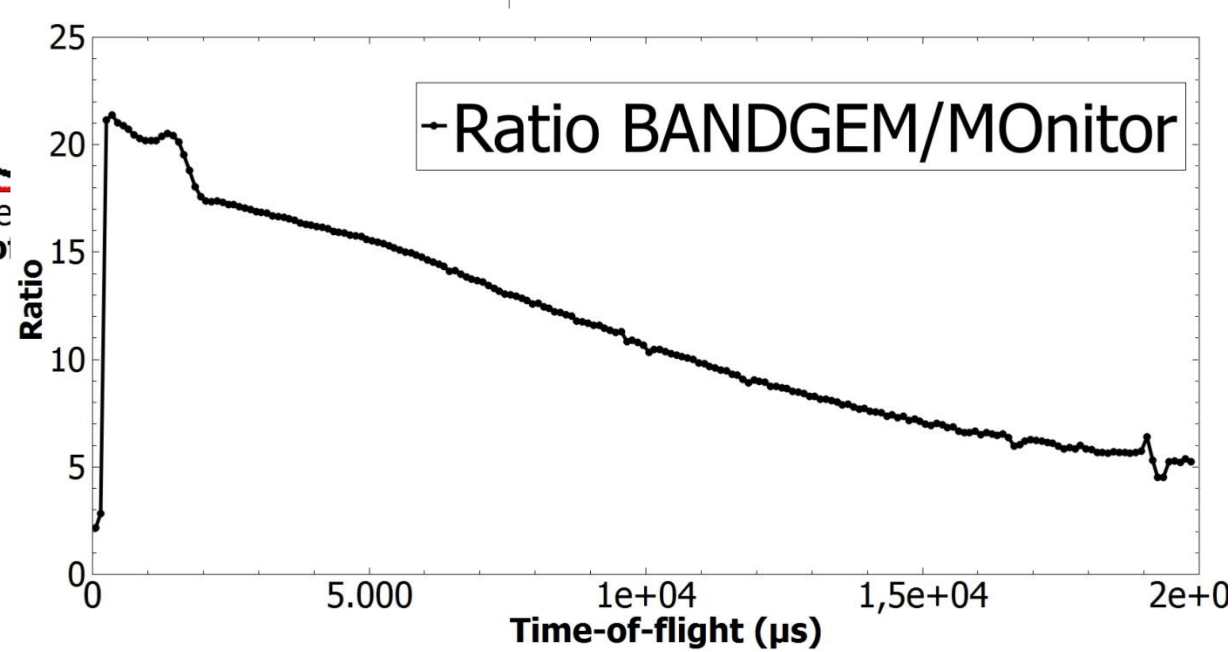
$$\varepsilon_{GEM}(\lambda) = \frac{C_{GEM}(t=\lambda)}{C_{Mon}(t=\lambda)} * \varepsilon_1$$

Monitor Efficiency previously calibrated using ^3He tube

First very preliminary results

λ(Å)	Estimated efficiency[%]
1	29,2
2	45,1
3	46,8

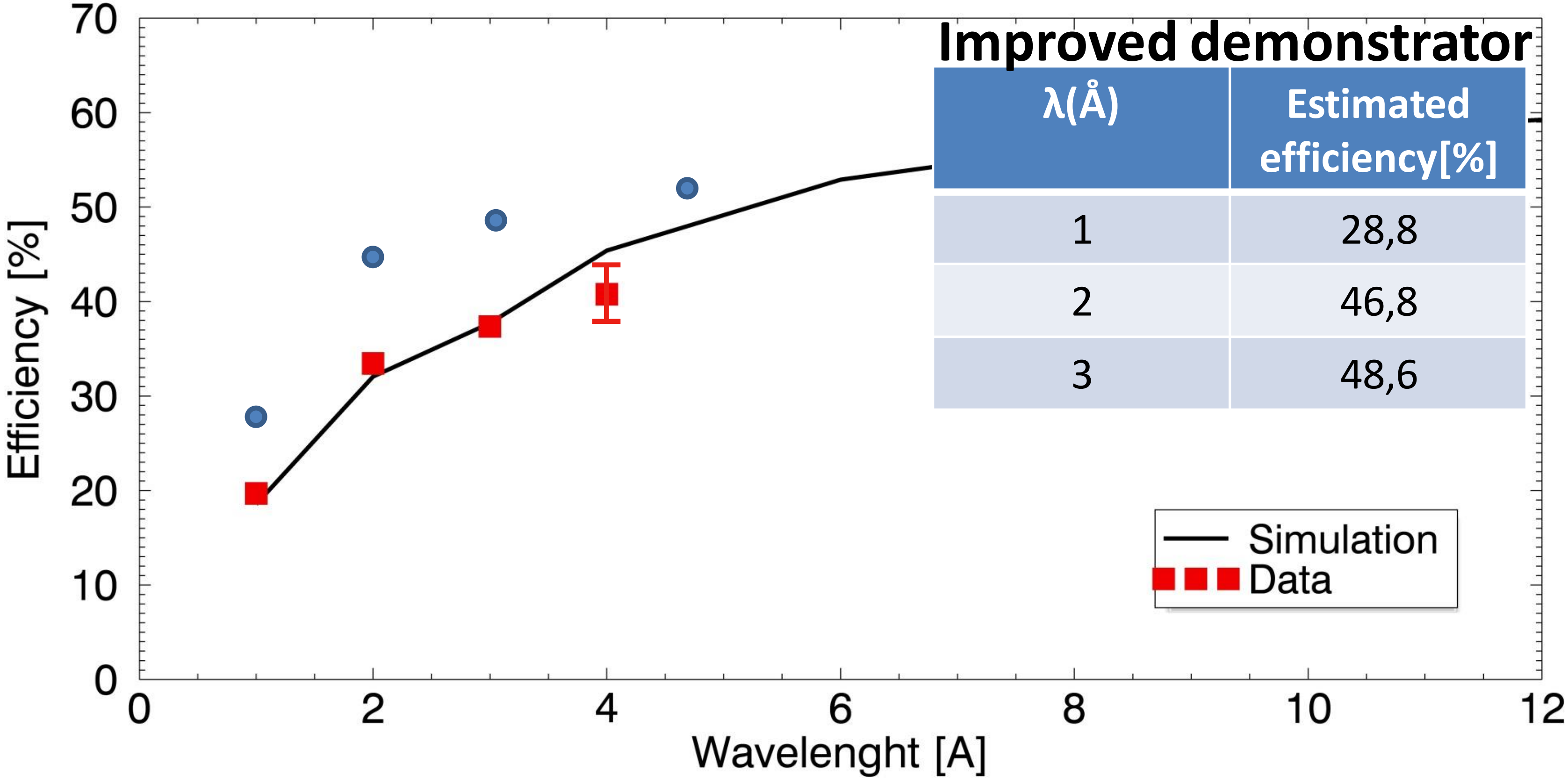




END

Spare

Efficiency as a function of λ

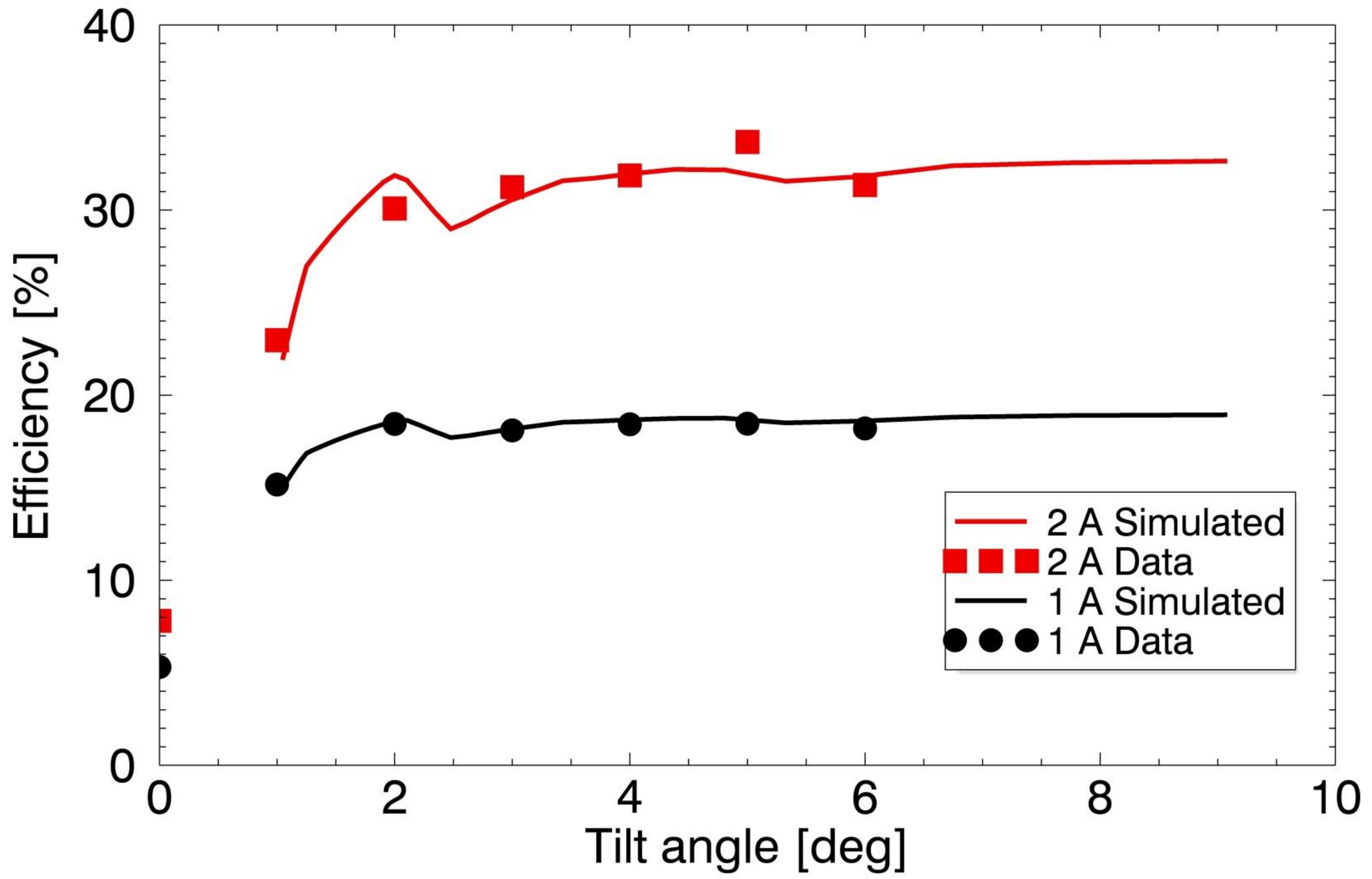


Improved demonstrator

λ(Å)	Estimated efficiency[%]
1	28,8
2	46,8
3	48,6

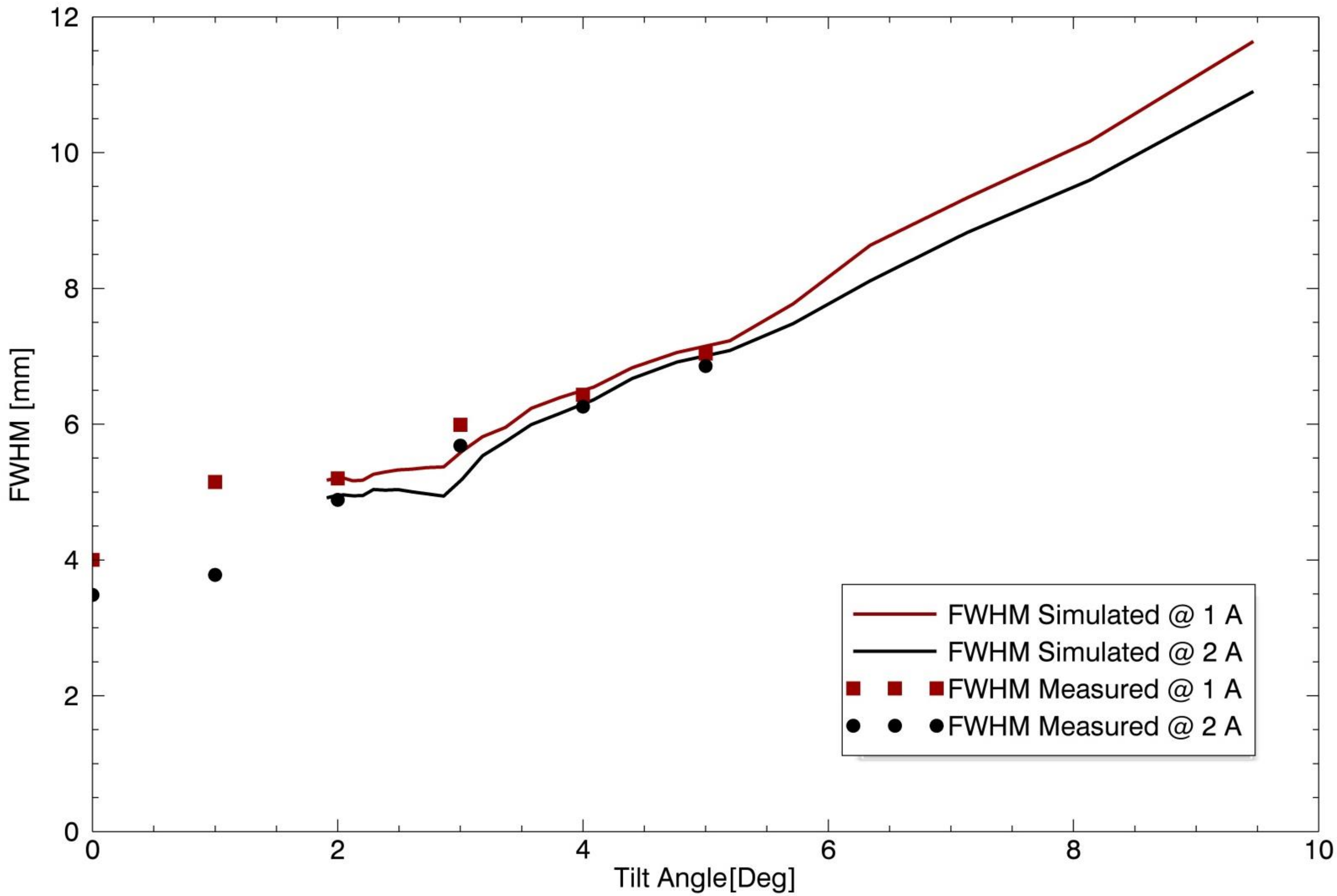
- Alpha and Li ion escape efficiency from a 550 nm thick $^{10}B_4C$ layer = 75%
- Assumes the measured extraction efficiency in the simulation model

Efficiency (at 1 and 2 A) vs tilt angle



Good agreement with simulated values

FWHM vs tilt angle – Space resolution



Good agreement with simulated values

Experimental corrected for offset by about 5 degrees

Effective resolution ~ independent of λ

High rate test at the ORPHEE Reactor @ LLB-CEA (2)

BAND-GEM linearity.
The count rate is the number of counts in 1 s of the pad that counts most normalised to the area of the pad (*A* = 4x3 mm^2).

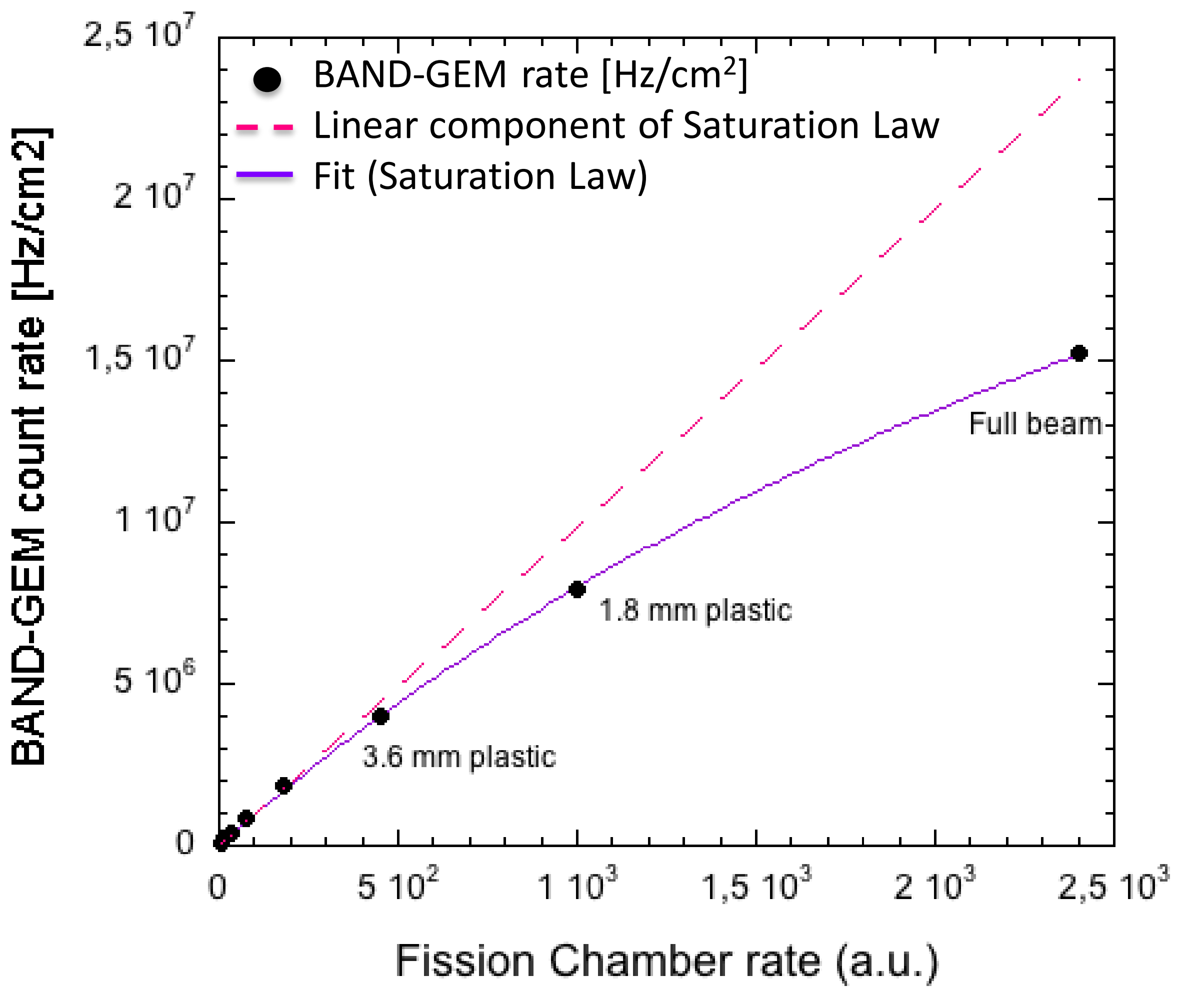
The BAND-GEM is **linear** (relative to the reference FC detector) **within a 10% error up to about 4 MHz/cm^2.**

BAND-GEM PARAMETERS:

- ΔV_{Grids} = 10 kV
- HVGEM = 870 V
- Tilt Angle = 5°

Neutron Flux = 7.88x10^8 n/cm^{2}s

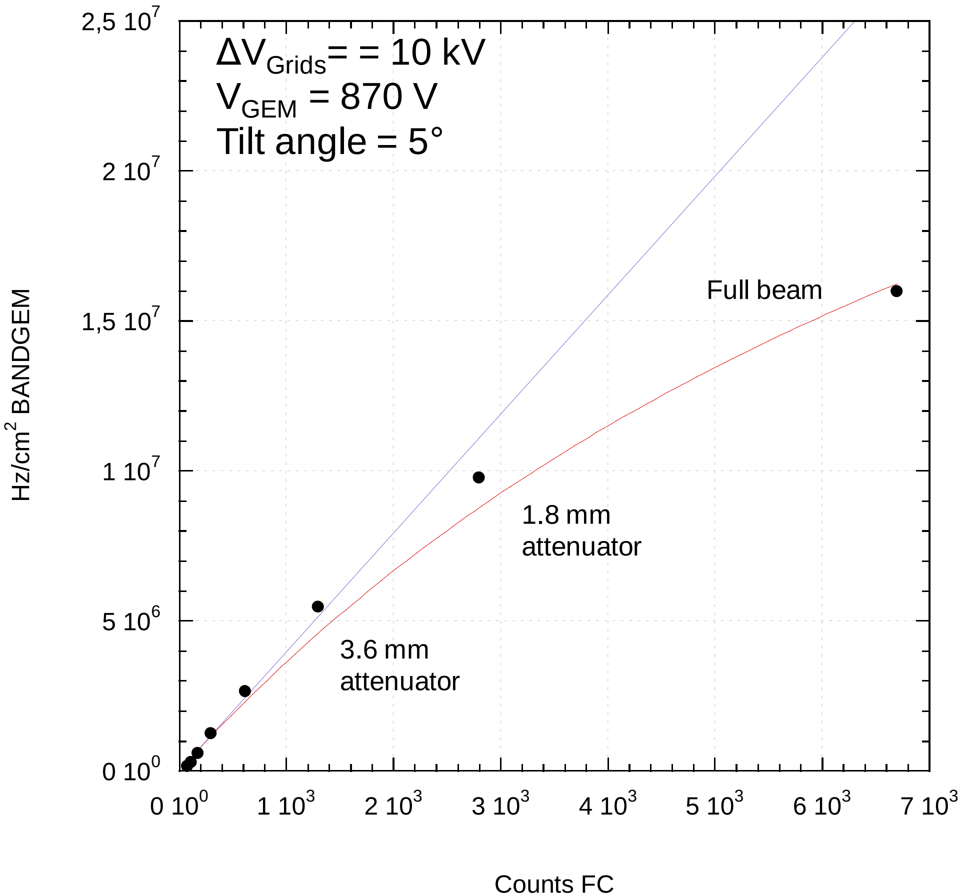
Reactor power 10.1 MW



High rate test at the ORPHEE Reactor @ LLB-CEA (BANDGEM without GEM in the middle)

Neutron Flux = 7.88×10^8 n/cm^{2}s

Linearity scan of BANDGEM with reference detector (Fission Chamber), performed at reactor power 10.1 MW.
The BANGEM is linear (respect to the reference FC detector) up to about 5 MHz/cm^2. It is linear within a 10% error up to about 10 MHz/cm^2.



Black dots: BANDGEM count rates per cm^2; red line: fit of the data with saturation law; purple line: linear component of the saturation law.

Simulation of detector efficiency as a function of $^{10}B_4C$ thickness (without GEM in the middle)