BAND-GEM demonstrator

Presented by G. Gorini

The BAND-GEM team

DETECTING THERMAL NEUTRONS WITH GEMS

- Gas Electron Multiplier (GEM) detectors used for tracking and triggering applications (detection of charged particles)....

- GEM advantages
  - High rate capability (up to MHz/mm^2)
  - Submillimetric space resolution (suited to experiment requirements)
  - Time resolution as short as 5 ns (gas mixture dependent)
  - Can be realized in large areas (~ m^2) and in different shapes
  - Radiation hardness
  - Low sensitivity to gamma rays (depends on threshold)

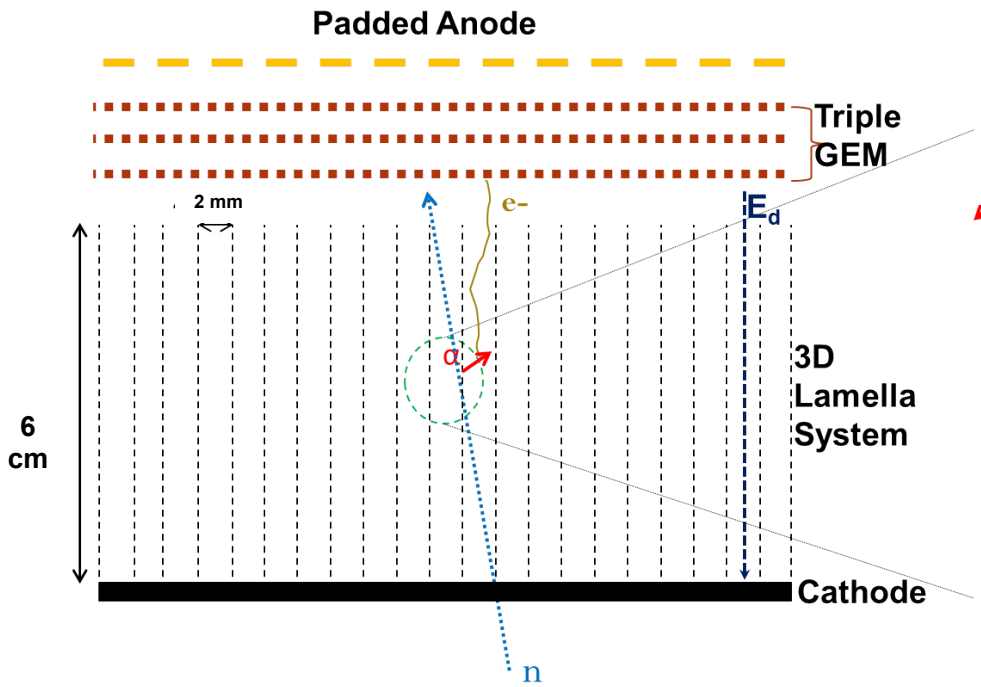
- Need a converter to detect neutrons.
  - ^{10}Boron converter: $^{10}B(n,\alpha)^7Li$
- Converter-dominated performance limitation: ongoing R&D
- Need specific read-out (new ASIC chip)

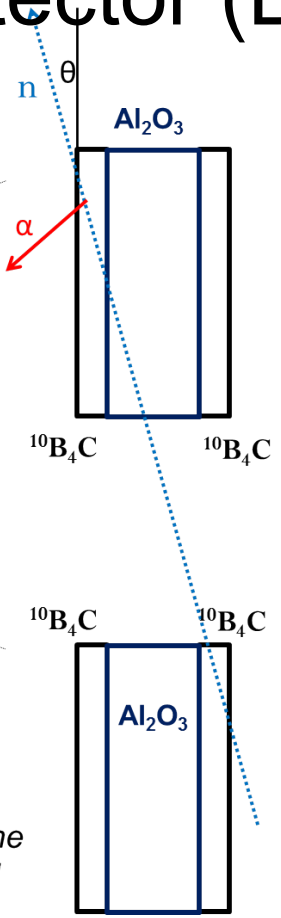
OUTLINE

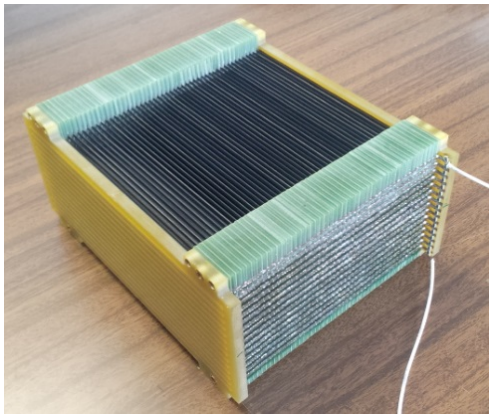
- THE BAND-GEM DETECTOR
  - Principle of operation
  - Simulation of detector performance

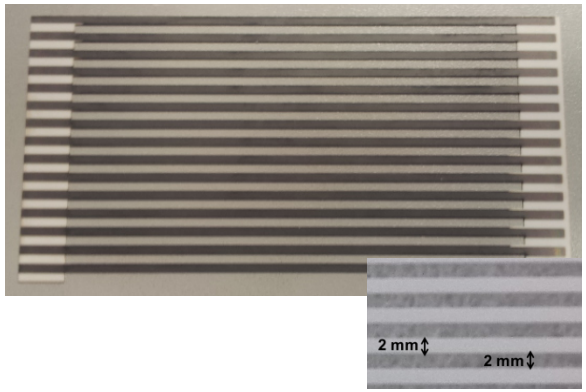
- APPLICATION @ LOKI
  - LOKI Demonstrator

Boron Array Neutron Detector (BAND) - GEM



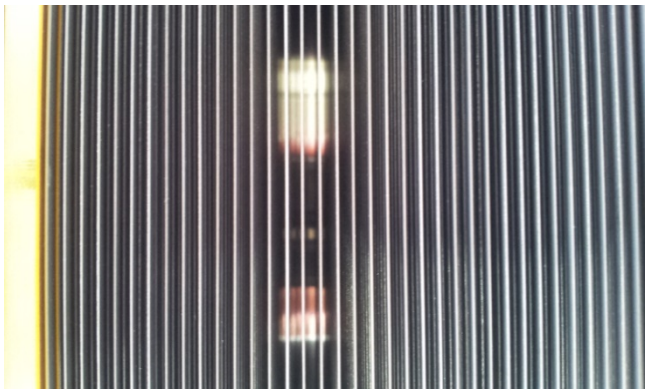


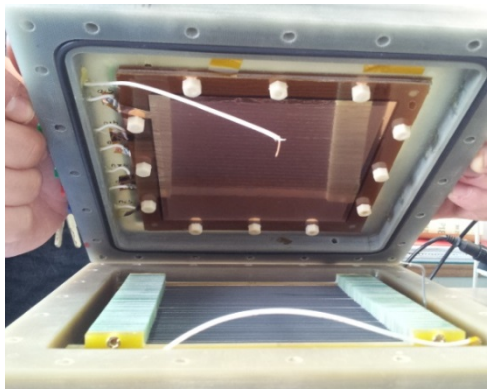


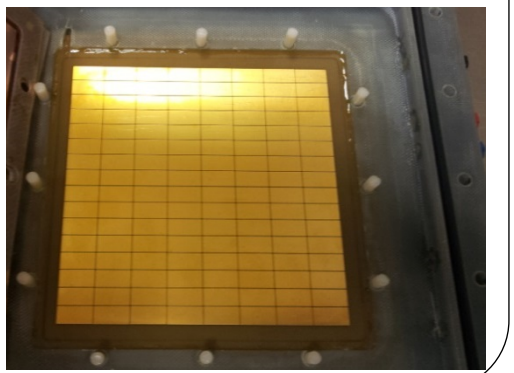


Lamellas coated on both sides with $^{10}B_4C$

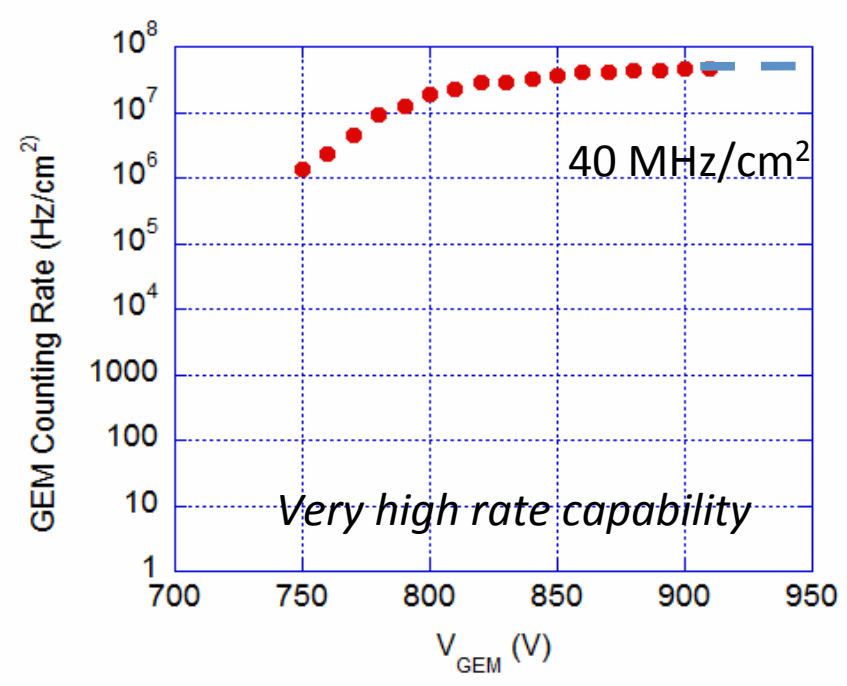
Using low θ values (few degs) the path of the neutron inside the B_4C is increased → Higher efficiency when detector is inclined

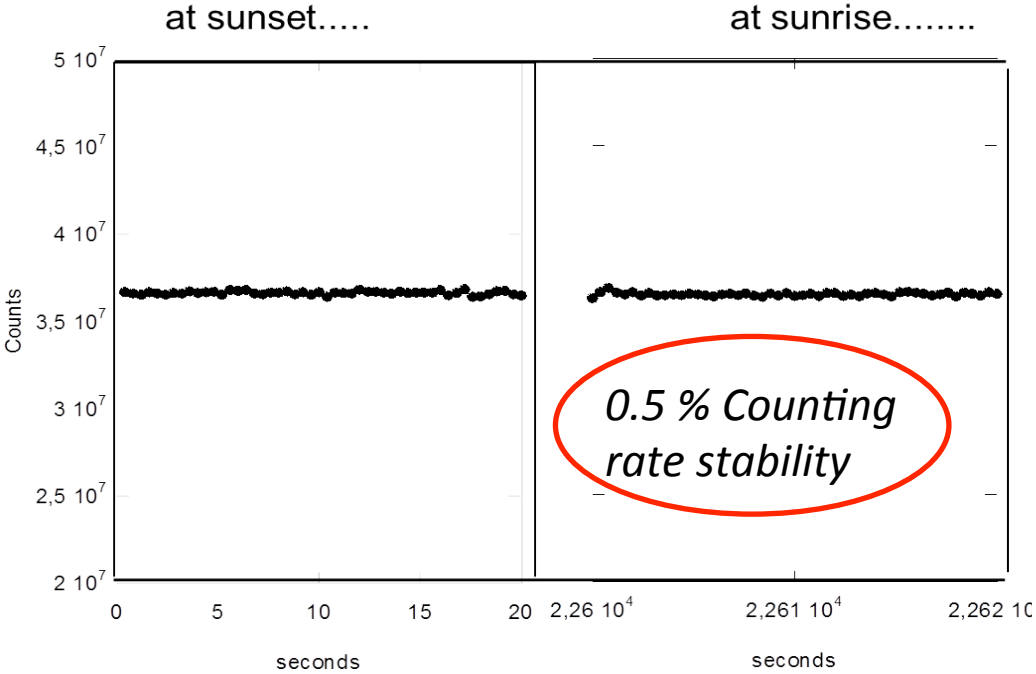


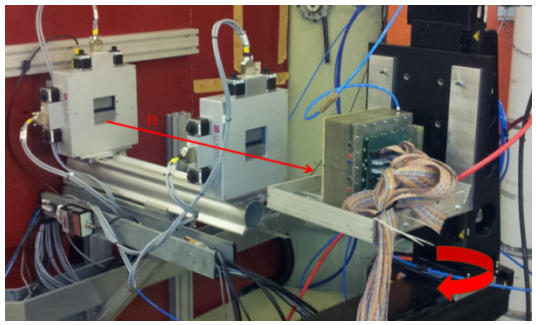




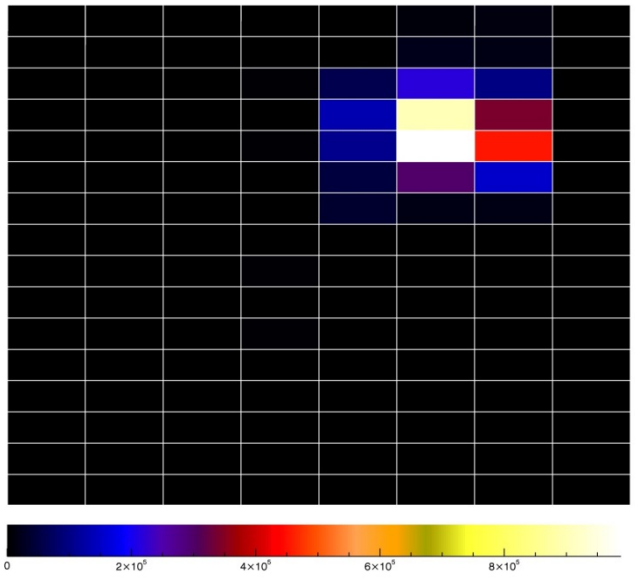
First Prototype Performance (Highlights)







Efficiency @ 1.54 Å about 20% as expected
→NEED TO INCREASE
→WORK ON GEOMETRICAL PARAMETERS



Beam Profile Reconstruction

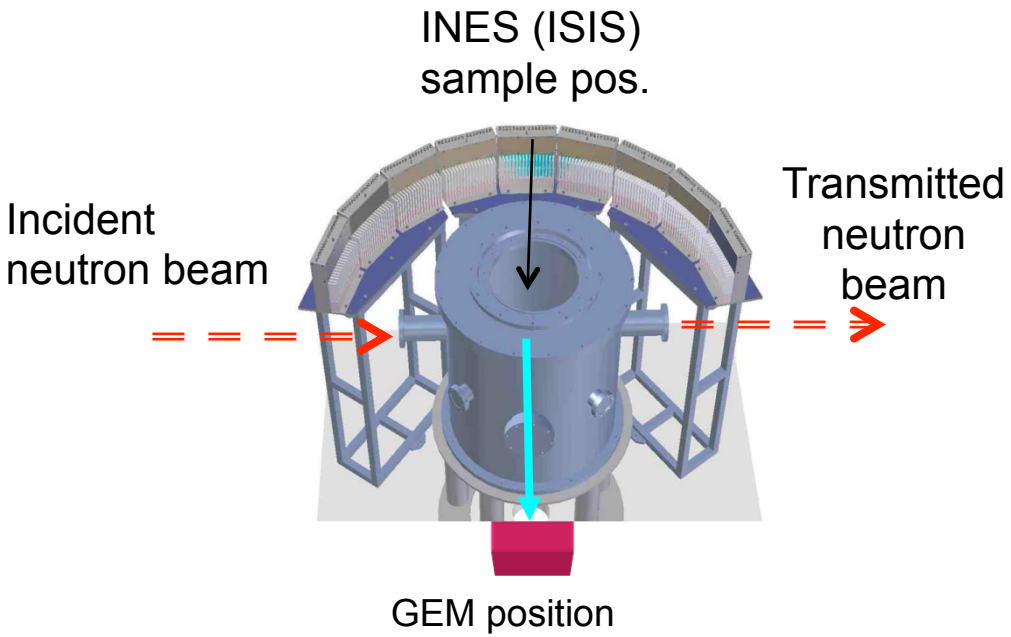
E_d = 230 V/cm
E_{t1}=E_{t2}= 3 kV/cm;
E_i = 5 kV/cm

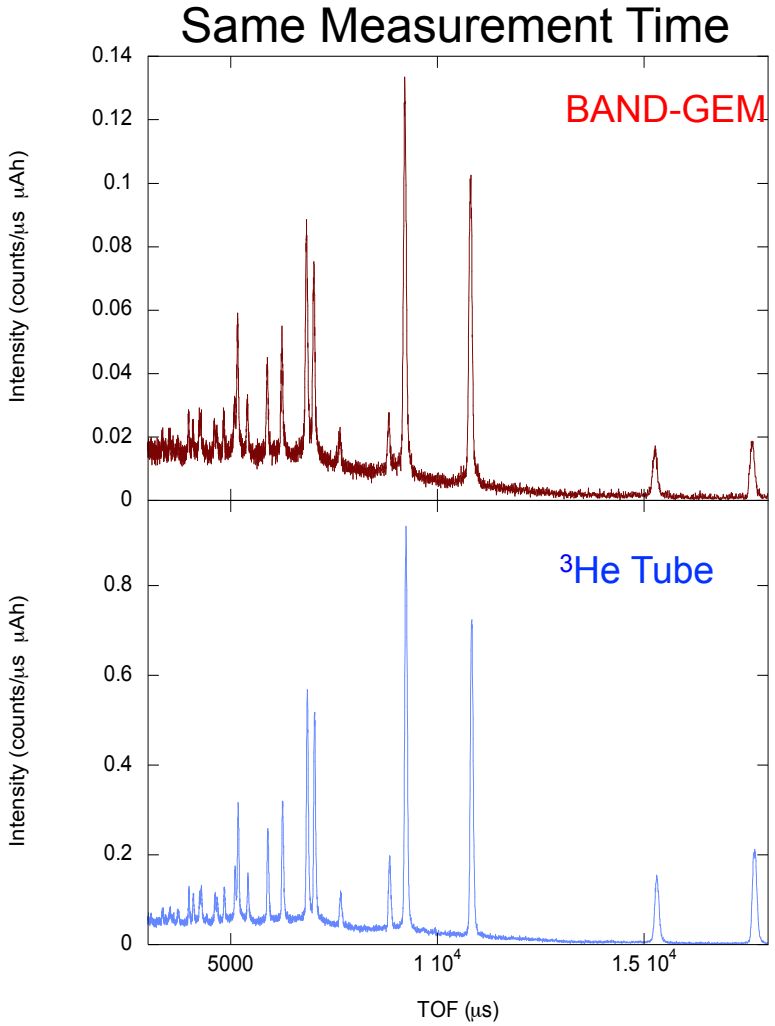
Mixture Ar/CO2 70%/30%
Angle = 10 degrees

VGEM = 980 V

BAND-GEM detector for neutron diffraction measurements

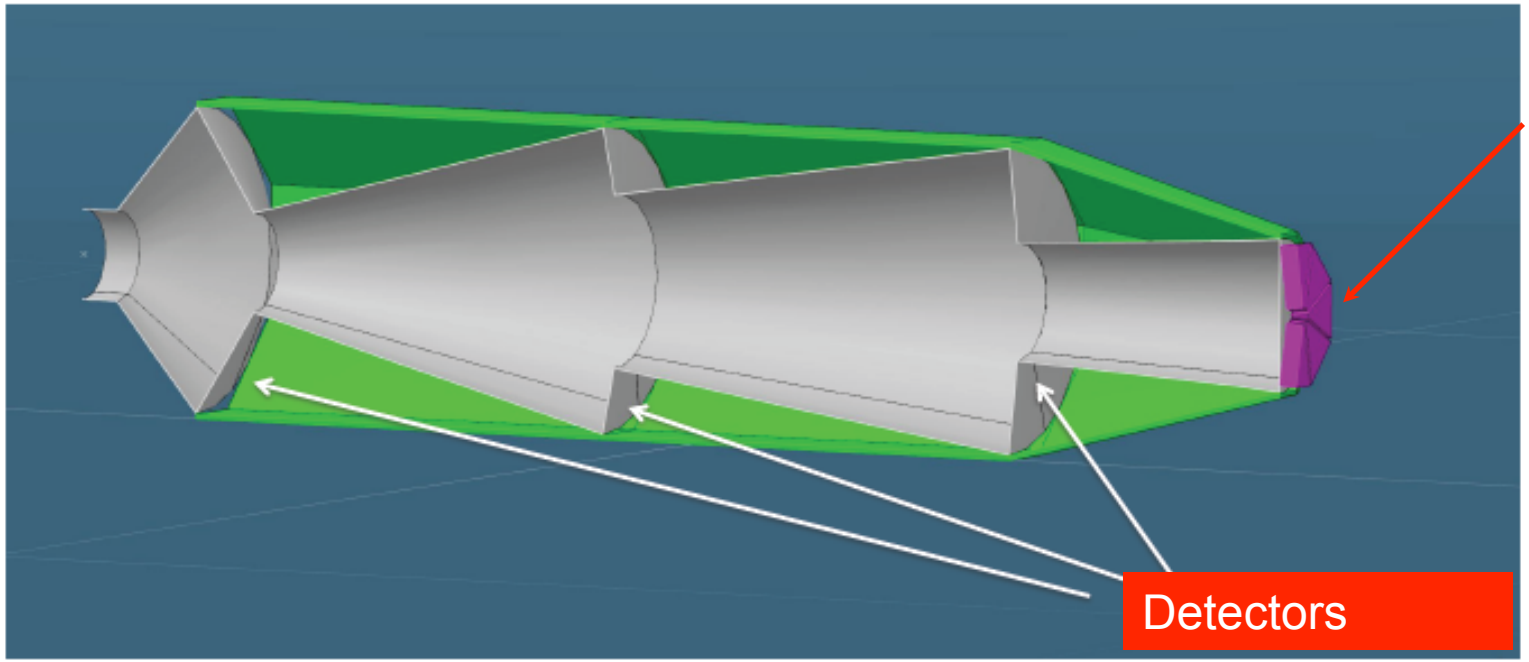
- First BAND-GEM Prototype
- Bronze sample
- BAND-GEM/^{3}He Solid Angle Ratio = 0.45





BAND-GEM application @ LOKI

Illustrative LOKI vessel Configuration

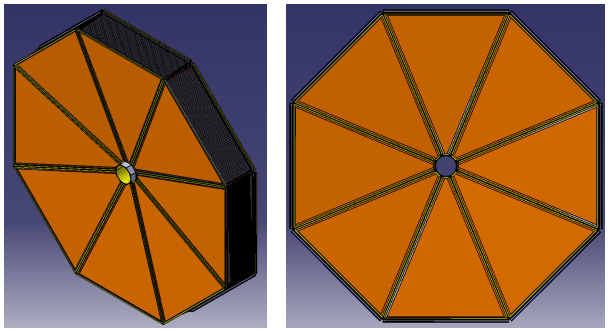


Rear detector panel: BAND-GEM Umbrella

Requirements for rear detector panel
- Peak rate Capability = 200 kHz/cm^2
- Time resolution better than 1 ms
- Efficiency of about 60% at 4 Å
- X-Y Space resolution of about 4 mm

BAND-GEM demonstrator for LOKI: one octant of rear detector panel

BAND-GEM umbrella

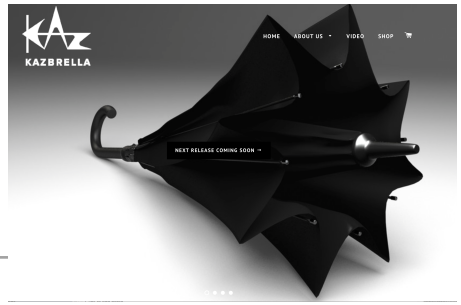


TWO POSSIBLE CONFIGURATIONS

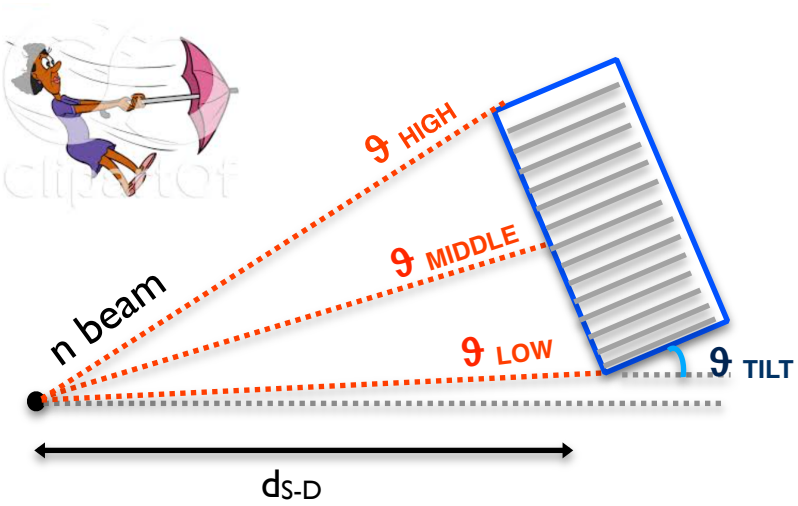
OPEN UMBRELLA

INSIDE-OUT UMBRELLA

Inside-out is better…



OPEN UMBRELLA



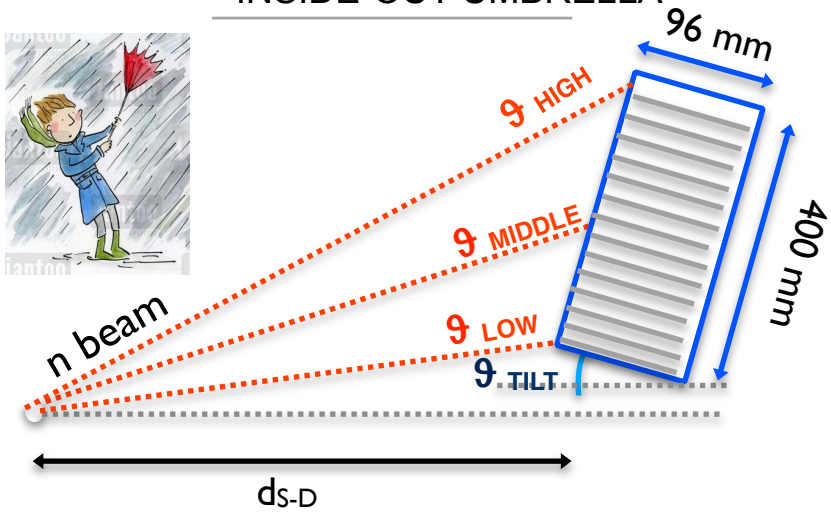
d S-D = 10 m

5°	4.83°	3.68°	2.54°

d S-D = 5 m

ϑ TILT	ϑ LOW	ϑ MIDDLE	ϑ HIGH
7.5°	7.16°	4.87°	2.57°

INSIDE-OUT UMBRELLA



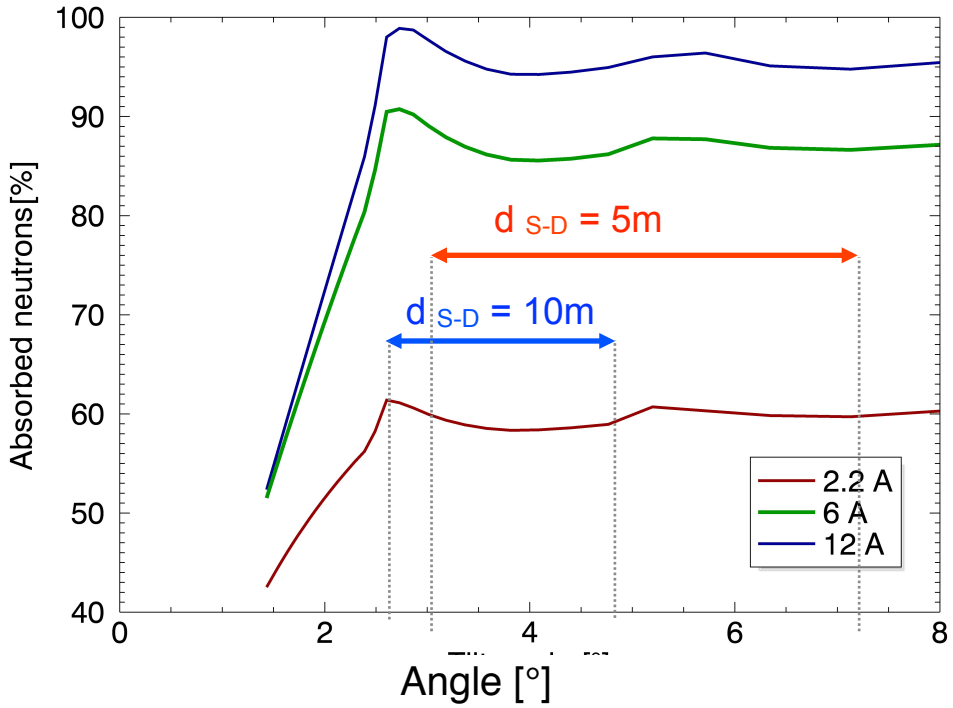
d S-D = 10 m

2.4°	**2.57°**	**3.72°**	**4.85°**

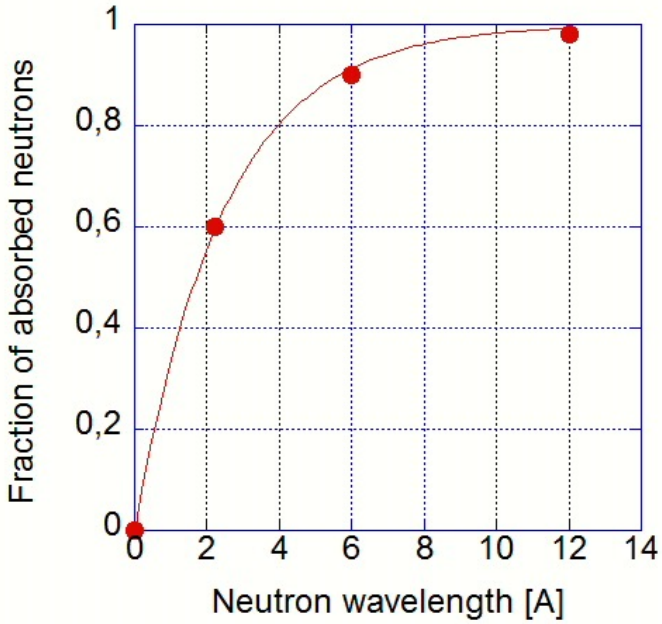
d S-D = 5 m

ϑ TILT	ϑ LOW	ϑ MIDDLE	ϑ HIGH
2.4°	2.83°	4.86°	7.41°

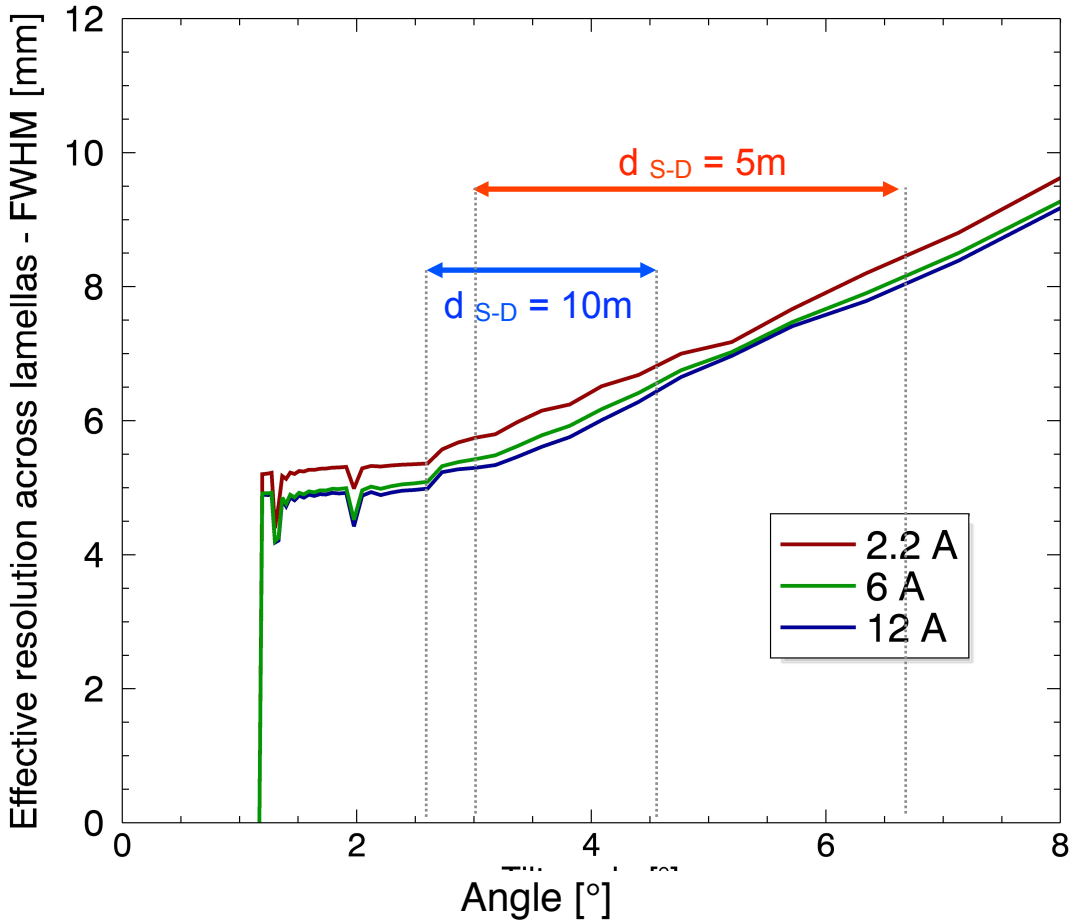
Neutron absorption probability



$\vartheta = 3.7\ °$



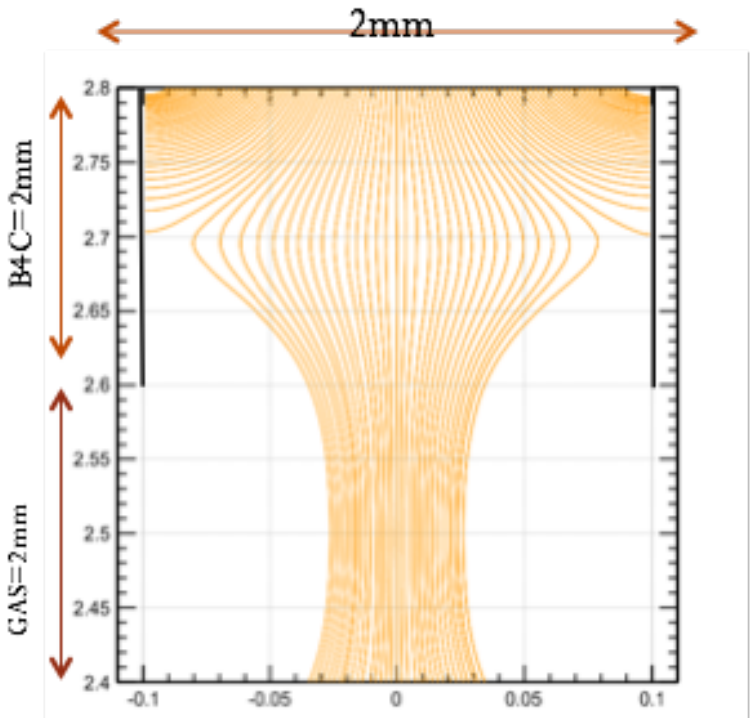
Effective resolution across lamellas



EFFECTIVE RESOLUTION ~ INDEPENDENT OF λ

Electron extraction – ANSYS field maps

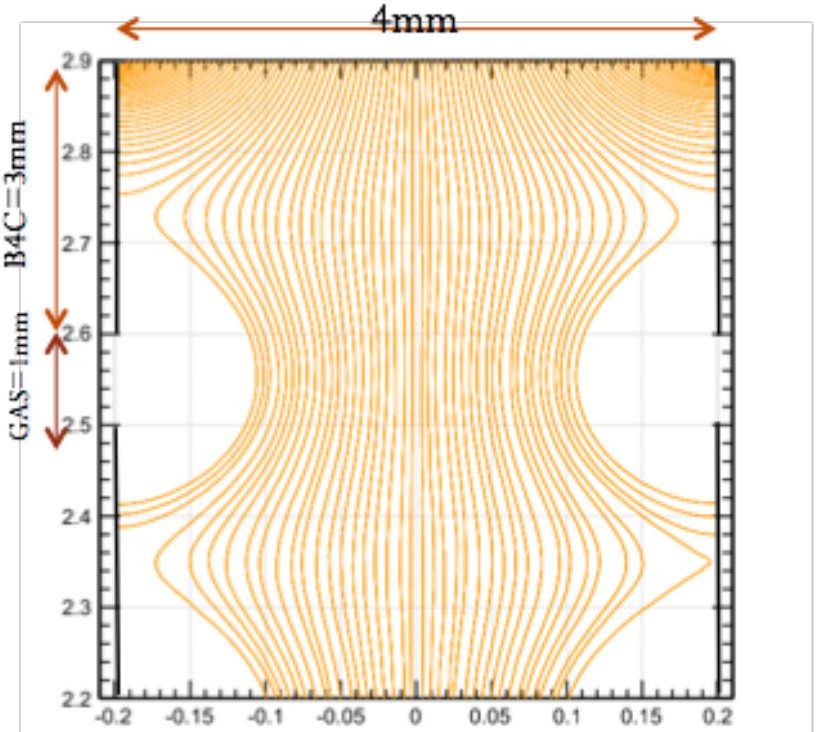
Prototype



Volumetric Simulation (1000 e-) Diffusion ON
Good Electron 1000, Out Electron 263
Percentage 26.3

Volumetric Simulation (1000 e-) Diffusion OFF
Good Electron 1000, Out Electron 486
Percentage 48.6

Demonstrator

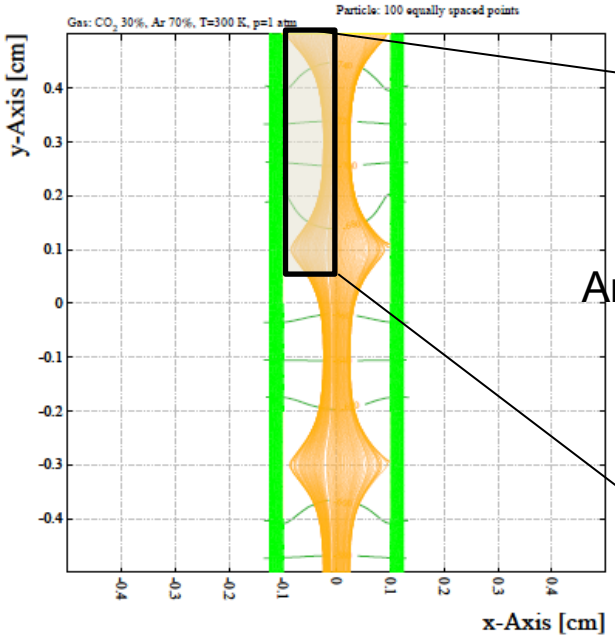


Volumetric Simulation (1000 e-) Diffusion ON
Good Electron 1000, Out Electron 544
Percentage 54.4

Volumetric Simulation (1000 e-) Diffusion OFF
Good Electron 1000, Out Electron 670
Percentage 67

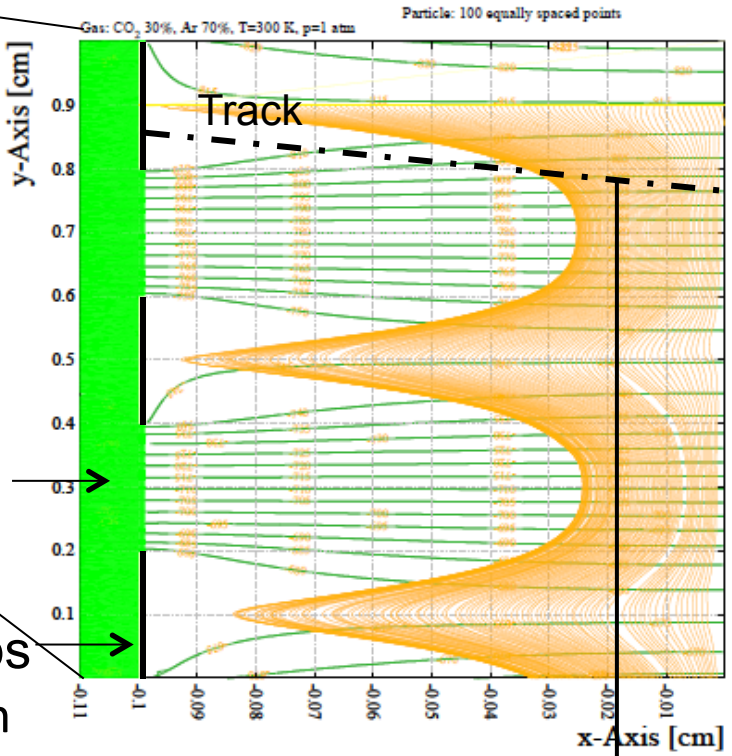
Charge extraction simulations (1/2)

:



Gas:
Ar/CO2 70%/
30%

Zoom: 0 cm < y < 1 cm and -0.11 cm < x < 0 cm



Ti

B_4C
Strips
1 µm

The elementary cell of the detector composed by two sides of two lamellas plus the gas in between. This view is -0.5 cm < y < 0.5 cm.

Calculation performed using the measured boron resistivity.

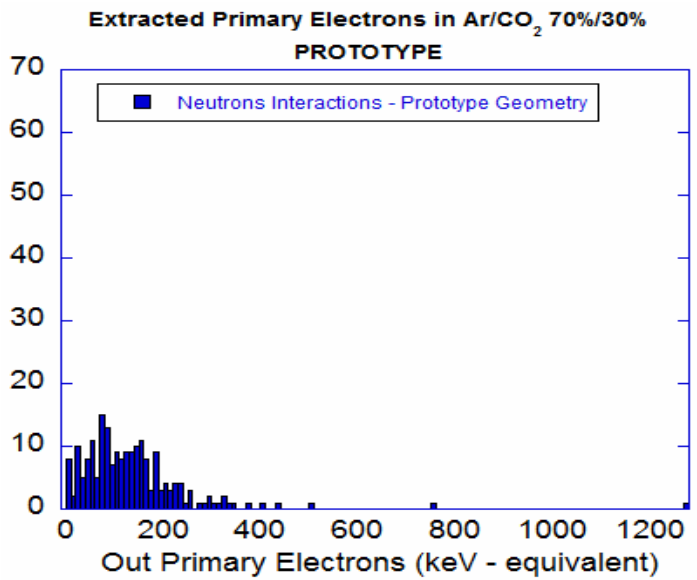
Boron strips on top of Ti/Al

The drift electric field allows to extract primary charge from the lamella system

Collected charge fraction in the one intercepted by the drift lines

Charge extraction simulations (2/2)

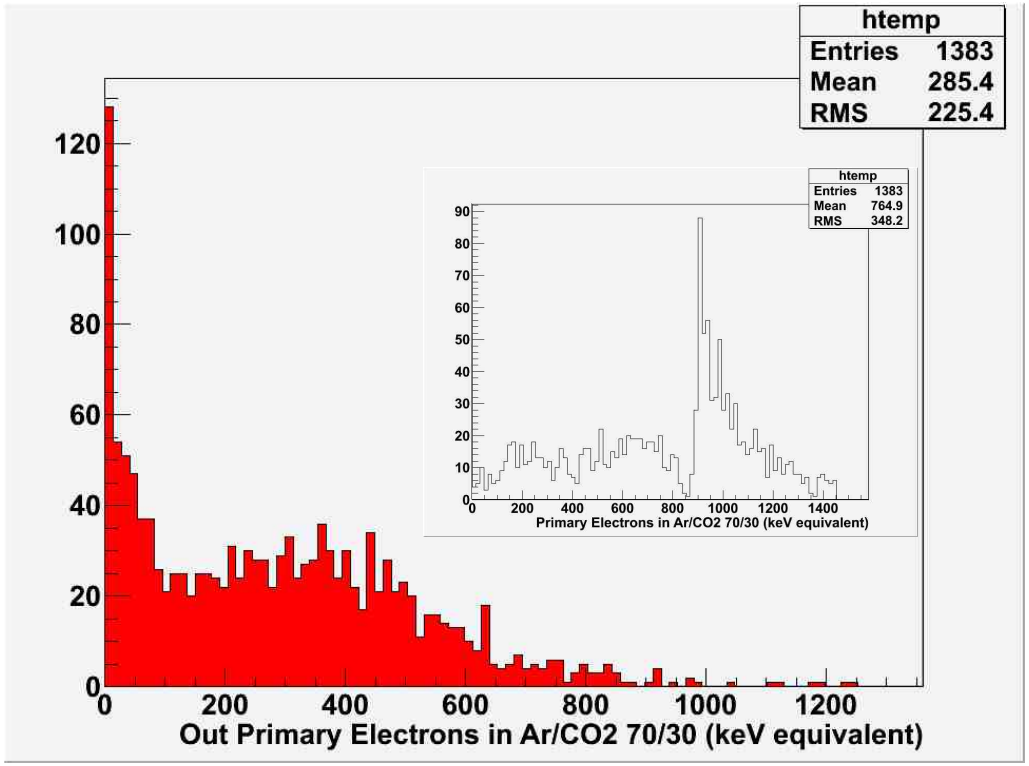
OLD SIMULATION
Prototype



Using a threshold of 100 keV we obtain an extraction efficiency of 77%.

NEW SIMULATION
Demonstrator

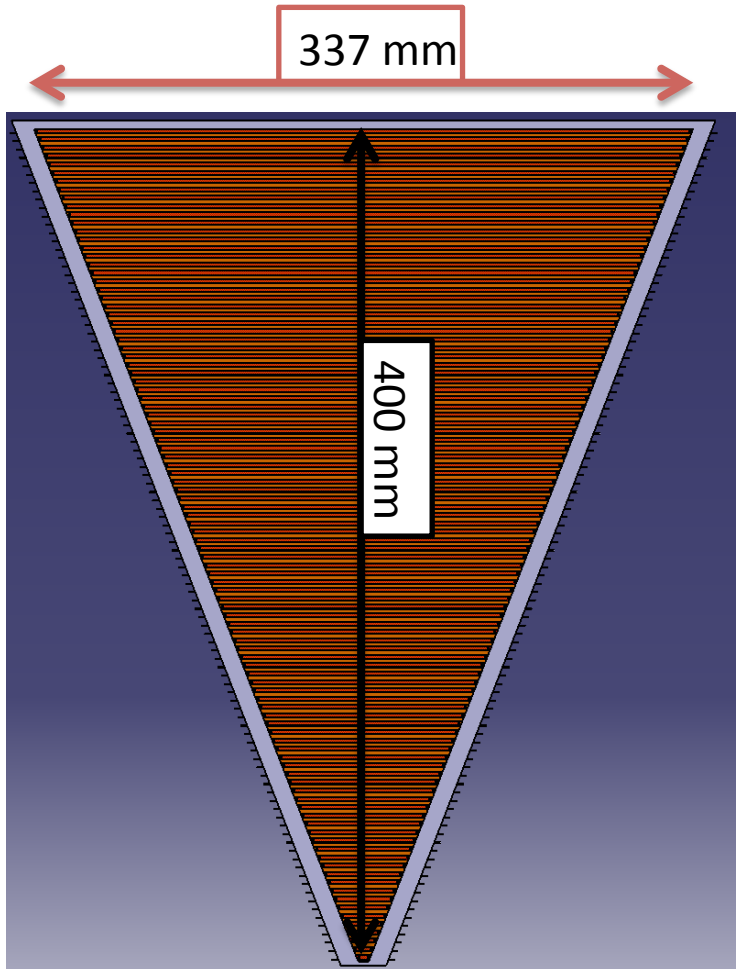
IDL&Garfield++ Simulation taking into account the real absorption point of the neutrons



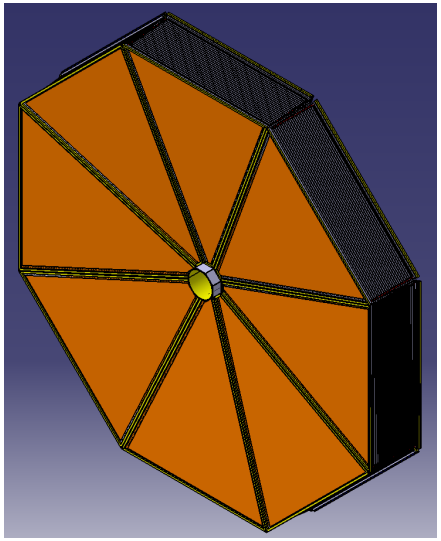
Performance: Prototype and Demonstrator

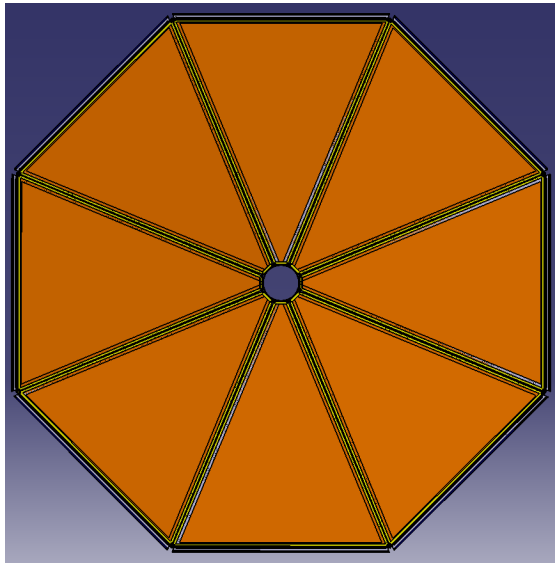
	Prototype - Achieved	Demonstrator - Projected
Lamella Distance	2 mm	4 mm
B_4C/empty ratio on lamellas	1	3
Full Lamella System length	6 cm	9 cm
Lamella Thickness	250 µm	20 µm
Lamella Material	Aluminium Oxide	Titanium
Optimal tilt angle	7 degrees	5 degrees
Pulse Height Threshold	70 keV	120 keV
Cathode geometry	10x10 cm2 - Square	Triangle (Trapezoidal)
Count Rate Capability	10 MHz/cm^2	12 MHz/cm^2
Gamma Ray Sensitivity	$5*10^{-5}$	$<5\ 10^{-7}$
Measured Efficiency @ 1.5 Å	18.5%	
Expected Efficiency @ 1.8 Å	21.2%	33%
Expected Efficiency @ 4 Å	49%	64%
Front-end ASIC	CARIOCA – 8 channels/chip	GEMINI – 16 (32) channels/ chip

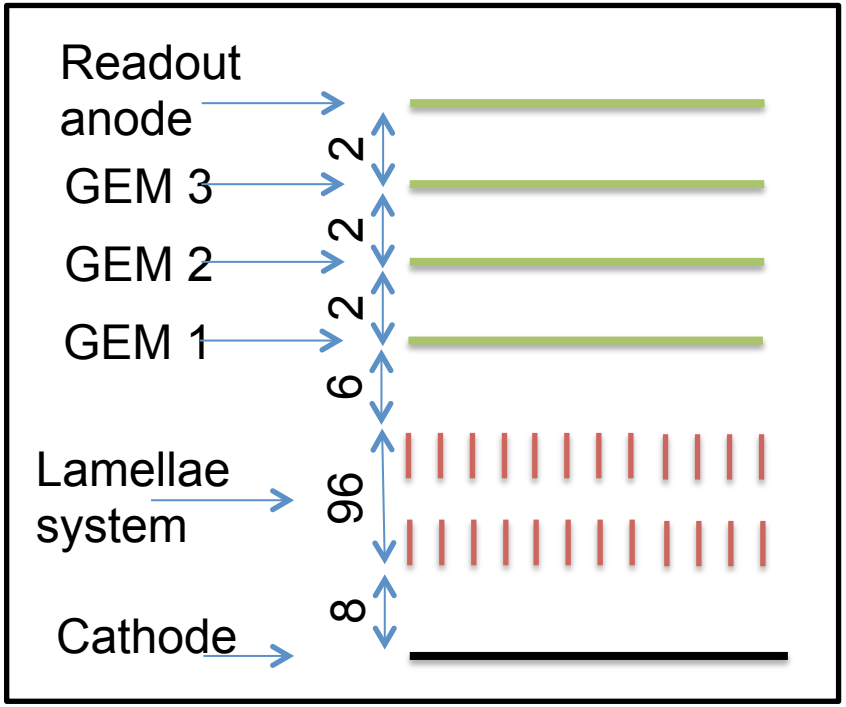
The BAND-GEM demonstrator



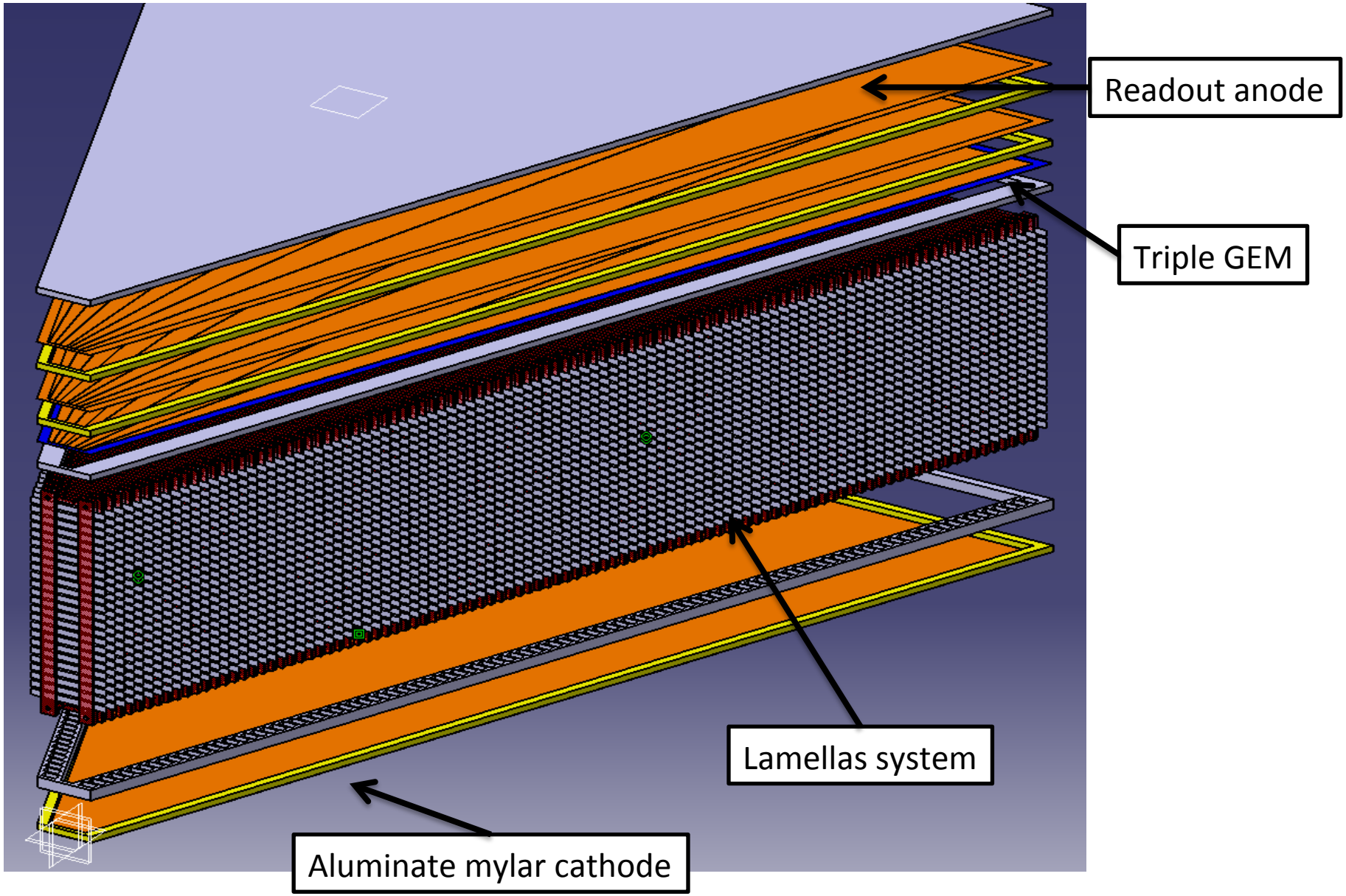
Total active area: 647 cm^2





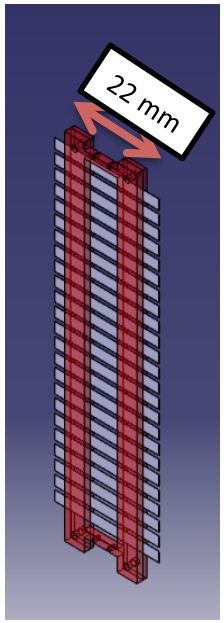


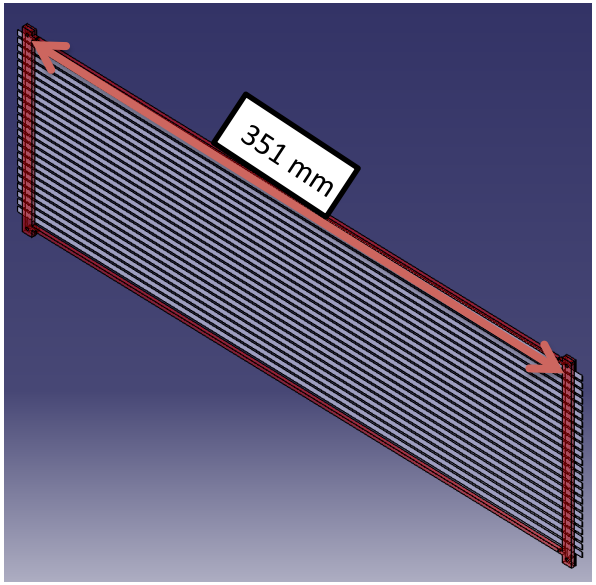
Detector Assembly – The cake

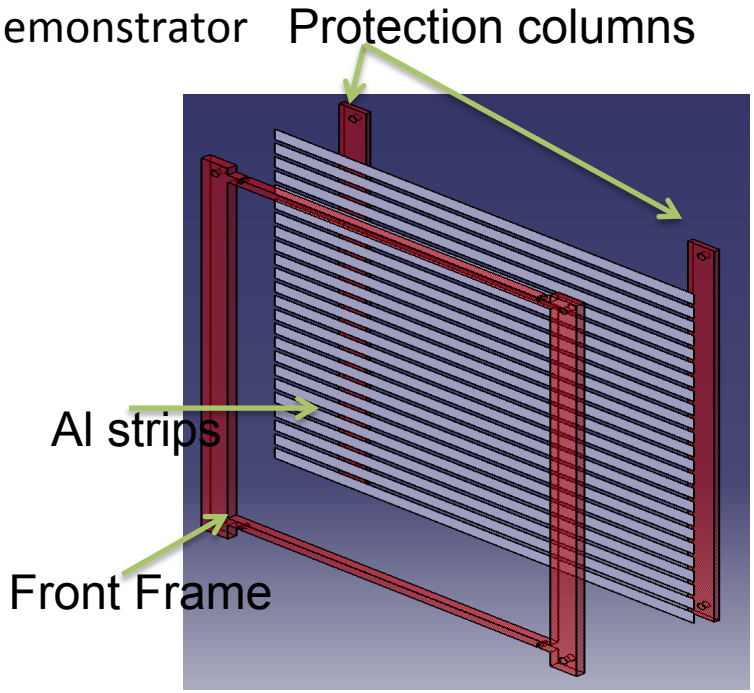


Lamellae system

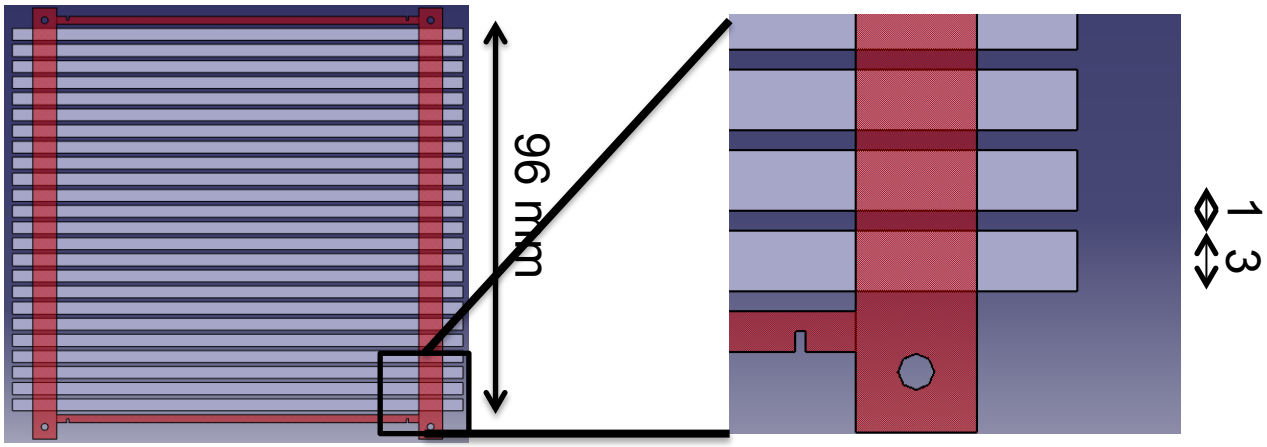
A total of 100 lamellae is needed for the BAND-GEM demonstrator





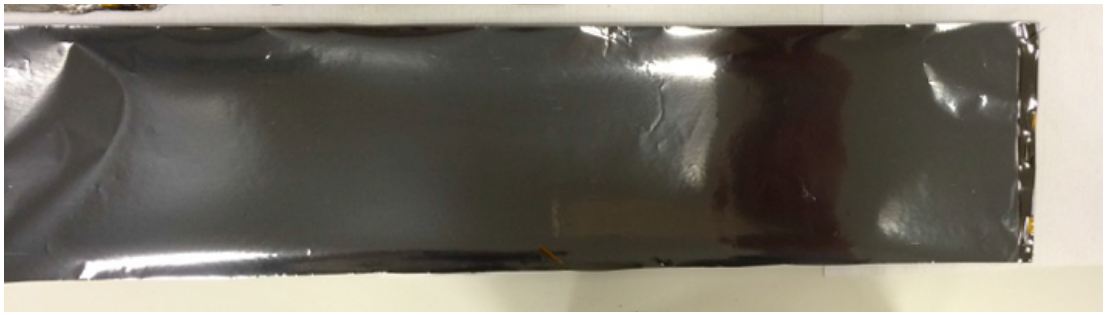


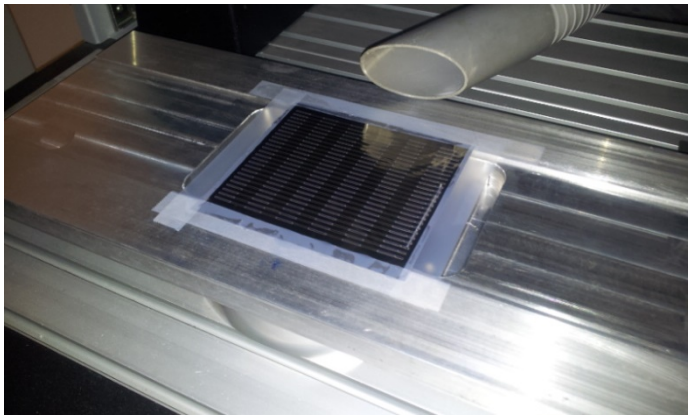
Each lamella is composed by a glass frame, 24 titanium strips and two glass columns.

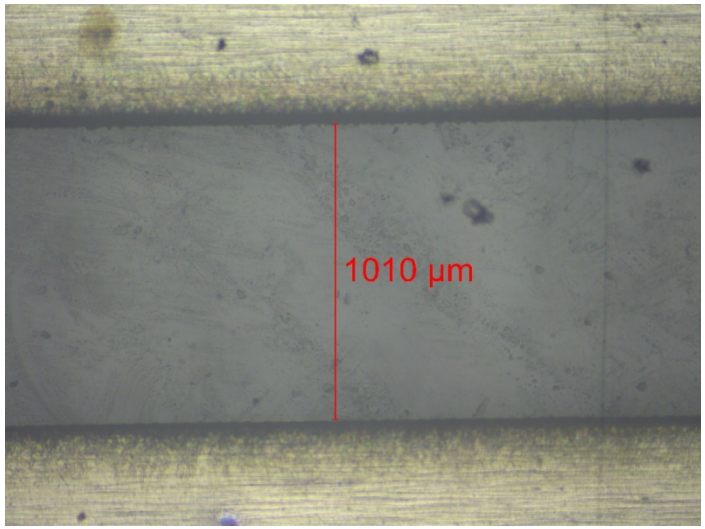


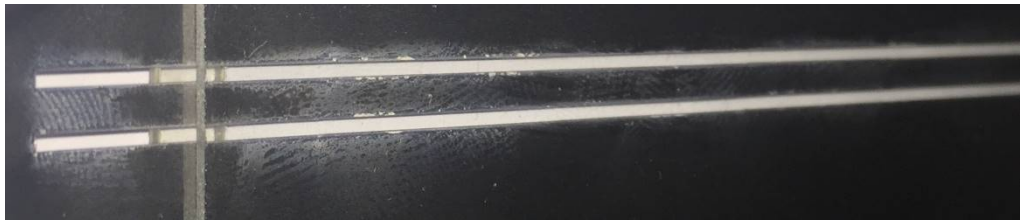
Lamellae system: production method

- Ti foil (25 μm thick) coated with enriched B_4C
- Glass Frame is glued on top
- Strips are laser cut
- Lamella is ready



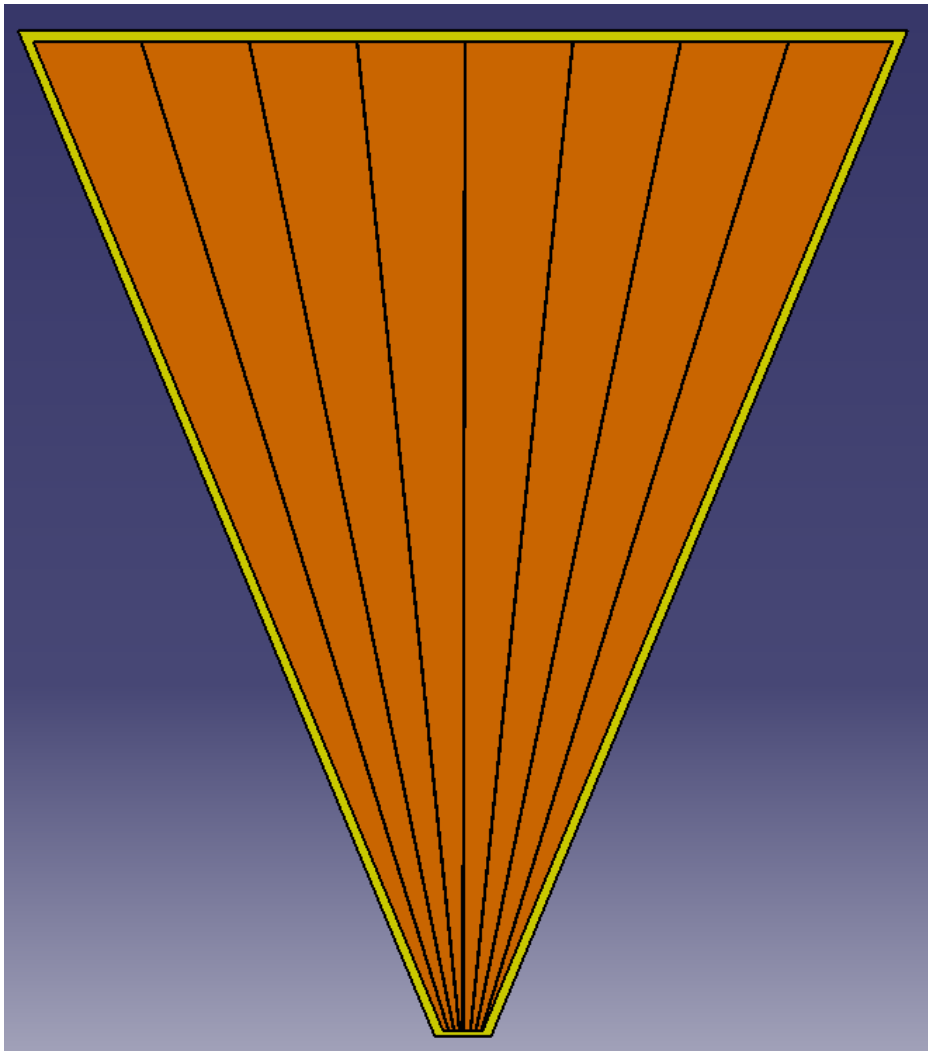






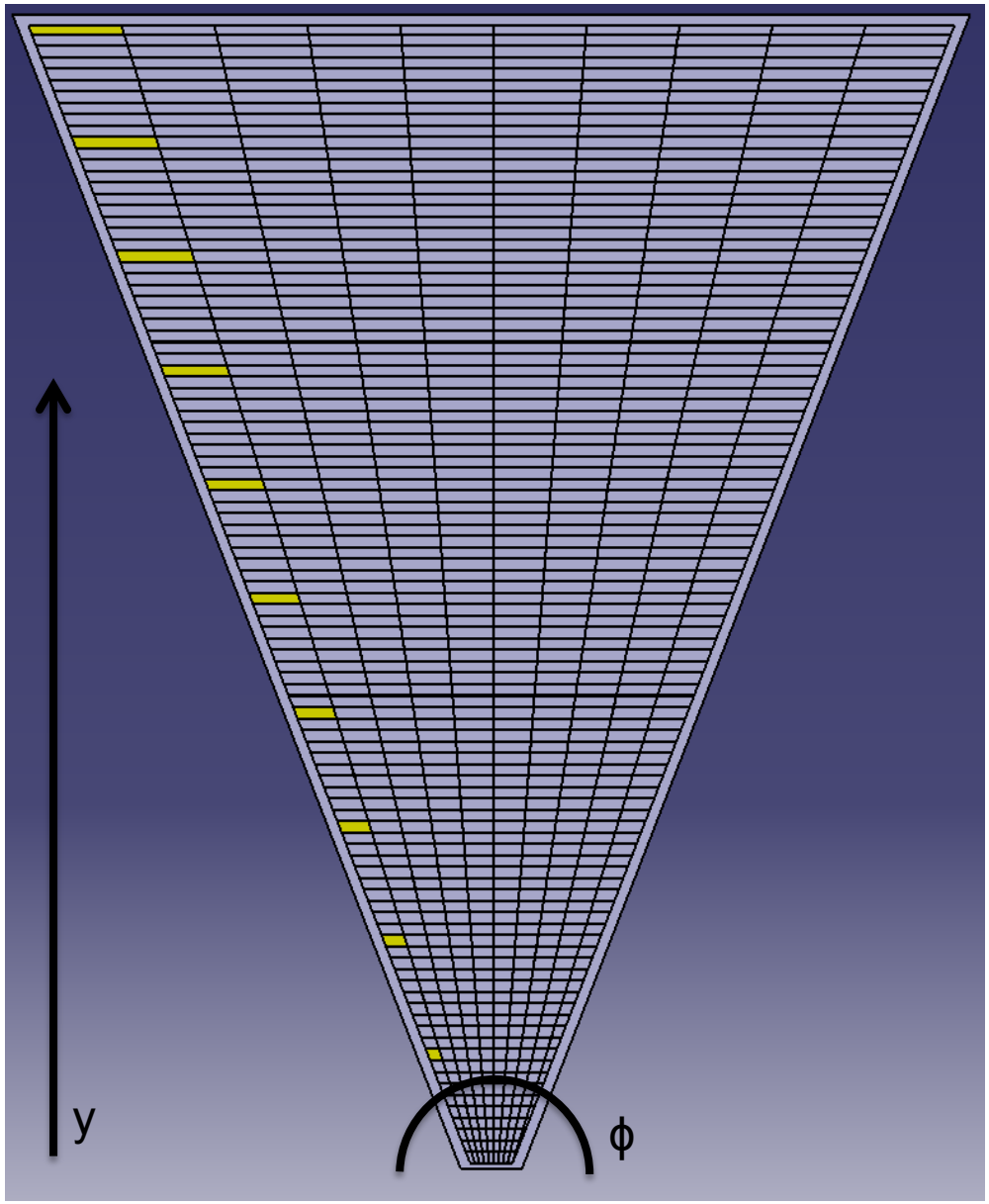
GEM Foil

The GEM foils will be realized at CERN and they will be glued to their frames using the same technique used for the production of the cathode.



Each GEM foil will be sectorized in 8 sectors, in order to reduce the possible damage caused by a spark.
A total of 3 GEM (triple GEM) will be installed in the detector and the gap between each GEM (Transfer gaps) is equal to 2mm.
All the GEM foils will be sandwiched and glued on the upper trapezoidal frame.

Padded Anode



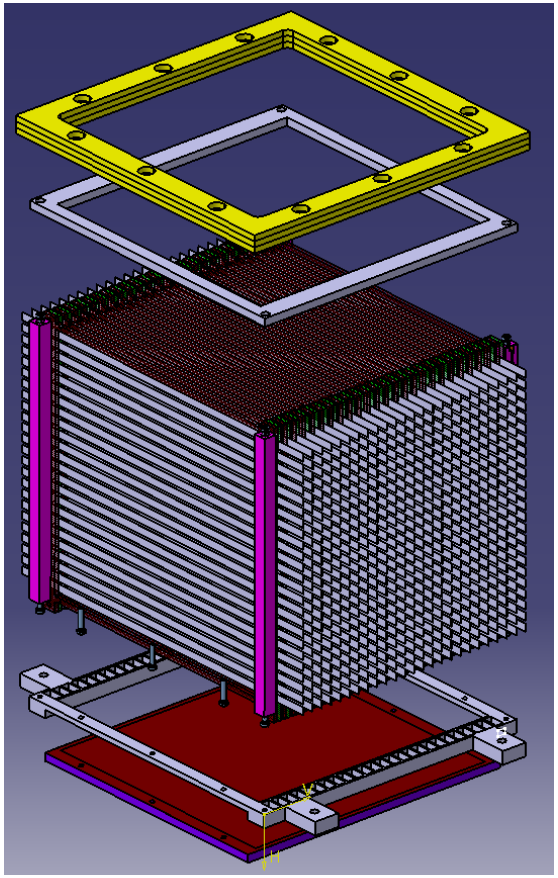
1024 pads.
Pad height is 4mm.
Pad size between 7.7 and 137 mm^2.
(Maximum pad size already tested)

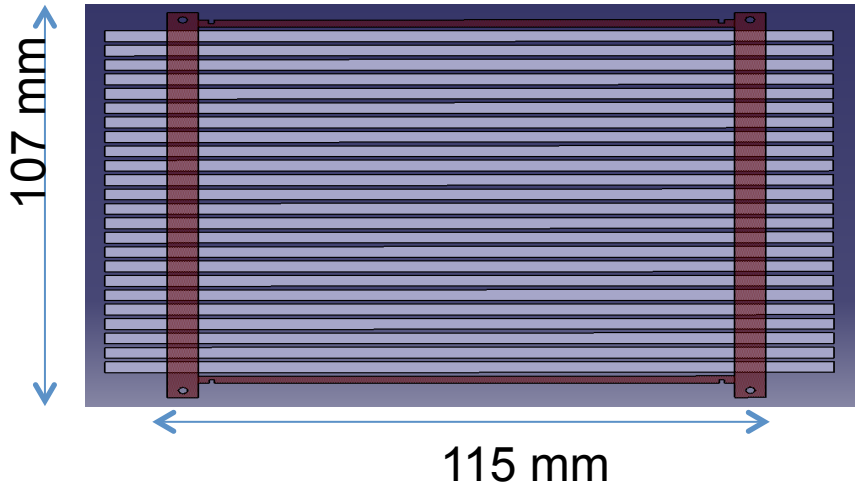
Anode will be glued on the GEM3 frame

Gap between the GEM3 and the PADs (induction gap) will be 2mm.

Small Area version

Needed in order to test the construction technology and validate simulations
Active area=10x10 cm^2.

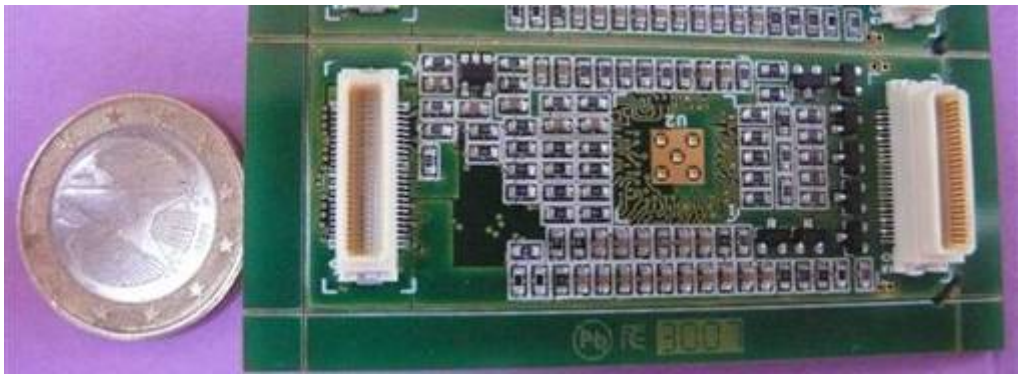


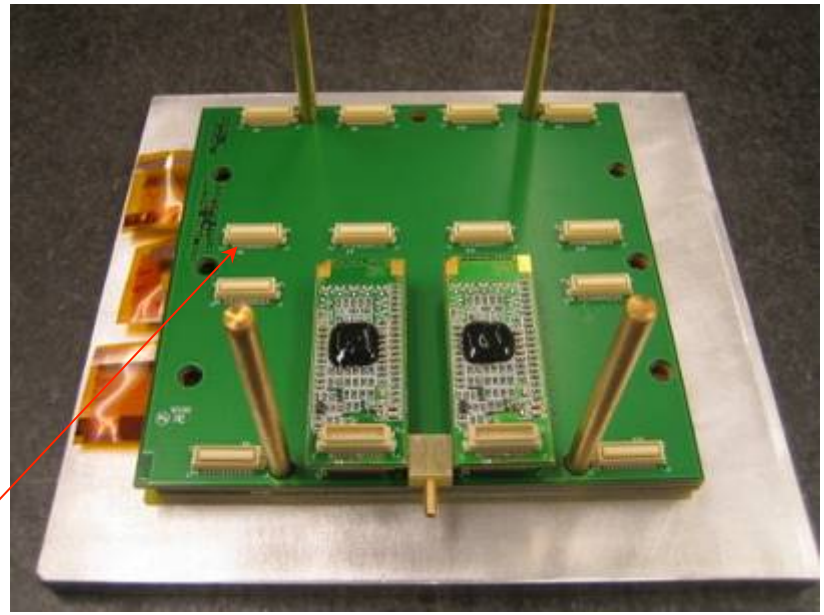


25 identical lamellae
Other parts: same as BAND-GEM prototypes.

The Front End Electronics

The first protoype electronics is based on Carioca Chip. Total dimension : 3x6 cm^2





Digital Chip with 8 channels
Equips the LHCb GEM detectors
Fast chip – used for triggering
Adapted from MWPC

A new chip is under development: the GEMINI chip.
Mixed analog and digital chip with 16 channels/chip.
Especially developed for GEM detectors

Conclusions

- First BANDGEM prototype successfully tested as neutron diffractometer
- BAND-GEM demonstrator for LOKI
  - Higher efficiency
  - New chip under design
  - Small area version available in May
  - Full size version available in September