Characterization of multilayer Thick-GEM geometries as ^{10}B converters aiming thermal neutron detection

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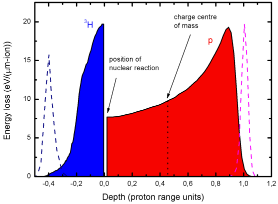
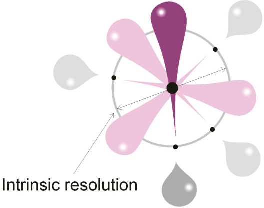
Sumário

Motivation - Helium-3 is vanishing

$$\mathrm{n} + {}^{3}\mathrm{He} \rightarrow {}^{3}\mathrm{H} + {}^{1}\mathrm{H} + 0.764\,\mathrm{MeV}$$



- Centroid of the charge cloud
- Possible avalanches due to the tritons
- Possible neutron interaction points
- Possible avalanches due to the protons



- Most interesting solution,
- High efficiency,
- Used during many years,

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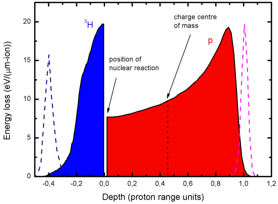

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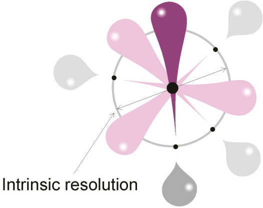
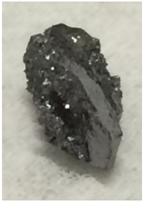


- Most interesting solution,
- High efficiency,
- Used during many years,
- ^{3}He is currently unavailable!

Motivation - Boron-10

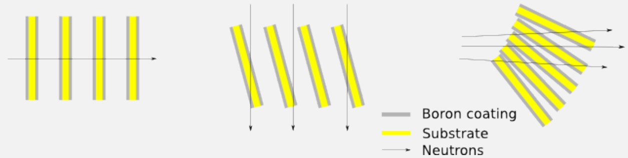
$$n + {}^{10}\mathrm{B} \rightarrow {}^{7}\mathrm{Li}^{*} + {}^{4}\mathrm{He} \rightarrow {}^{7}\mathrm{Li} + {}^{4}\mathrm{He} + 0.48\,\mathrm{MeV}\gamma + 2.3\,\mathrm{MeV}\,(93\,\%)$$
$$\rightarrow {}^{7}\mathrm{Li} + {}^{4}\mathrm{He} + 2.8\,\mathrm{MeV}\,(7\,\%)$$



- Solid state at NPT,
- Challenging to deposit on surfaces,
- Limited efficiency when too thick, due to self absorption of reaction products.

Some ^{10}B-based solutions:

Multi-grid [1] Inclined detector [2] Jalousie [3]

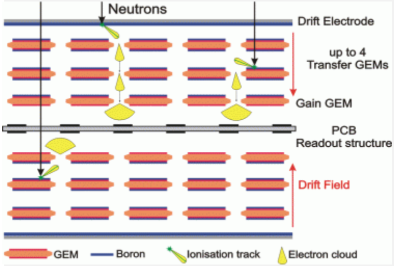


Boron coated microstructured cathodes in stacked MPWC [4]
Boron coated straw tubes [5].

[1] J.C. Buffet et al., IEEE NSS 15 Conf. Rec., p. 171, 2012.
[2] J. Buffet et al., NIM A, 554, 1-3, p. 392, 2005.
[3] C.J.Schmidt, M. Klein, CDT: www.n-cdt.com/
[4] I.Stefanescu et al., Jinst, 8 P12003, 2013.
[5] Proportional Technologies Inc., www.proportionaltech.com

Thick-GEMs as neutron absorbers

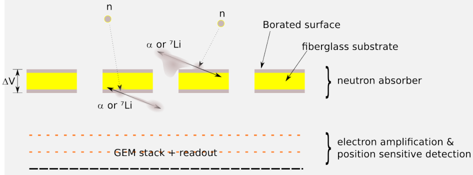
The CASCADE concept



M. Klein and J. Schmidt, NIM A, 628, p. 9, 2011

- Many ^{10}B layers improve efficiency,
- Transfer of electrons to the multiplication stage using GEMs at gain 1,
- No need to use GEMs if gain is 1.

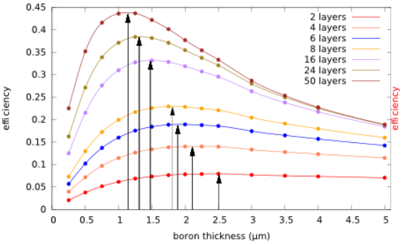
Replacement by THGEMs

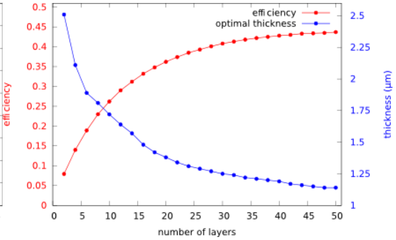


- Simplify detector production (can be done in Brazil),
- Study alternative multiplication stage.

Simulations

- No energy threshold (all α and ^{7}Li considered),
- Neutron energy: 25 meV (1.8 Å)





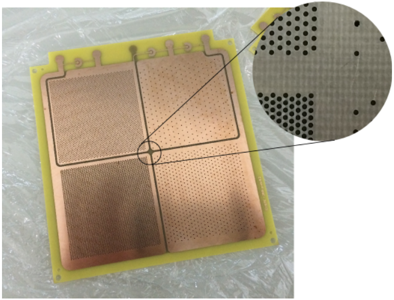
Competing processes:

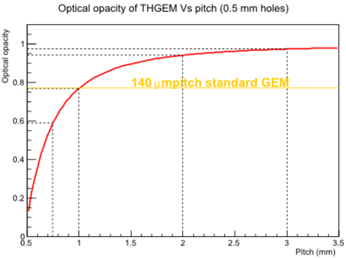
As thickness of ^{10}B increases:

- Probability for neutron absorption increases,
- Probability of α and ^{7}Li loosing their whole energy before leaving the ^{10}B layer.

- Must be aware of optimal thickness (depends on number of layers),
- Optimal thickness decreases when more layers are used,
- But: deposition must be more precise in each layer.

THGEM geometry optimization

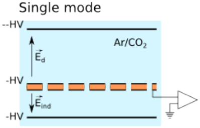


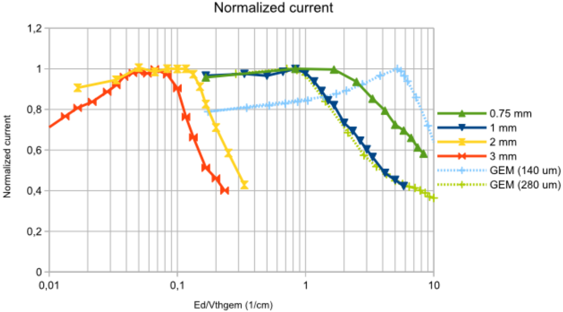


Optical opacity influences the absorption efficiency

- Prototype with four sectors with hole pitch 0.75, 1, 2 and 3 mm,
- 0.5 mm thickness, no clearance between copper and hole in FR4.
- Larger pitch leads to larger area covered by ^{10}B,
- Loss of primary on the top surface between the holes.

Detector characterization - Collection efficiency (normalized)

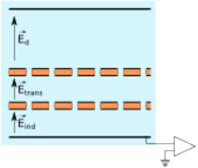


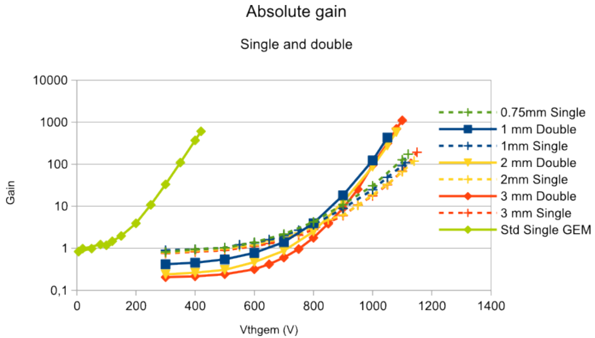


- 3 mm pitch: very narrow optimal zone between recombination and primary electron loss,
- Possible future position resolution problems.

Characterization - Gain

Double mode

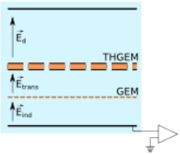


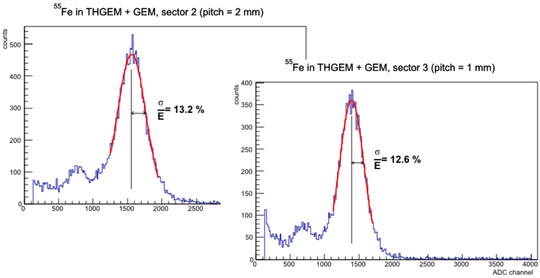


- Needed to operate stably at gain 1,
- In single mode, gain is already above 100 for all sectors,
- More holes do not mean less gain (good sign).

Characterization - Energy resolution

Hybrid mode (THGEM + GEM)

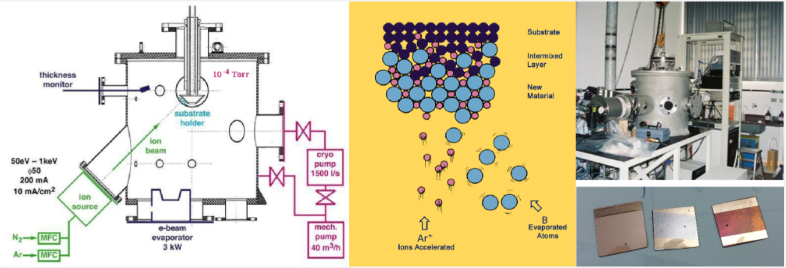




- 3 mm collimated,
- Operation at gain around 5000,
- For larger pitch, resolution slightly gets worse (more sensitive to non-uniformities in hole size).

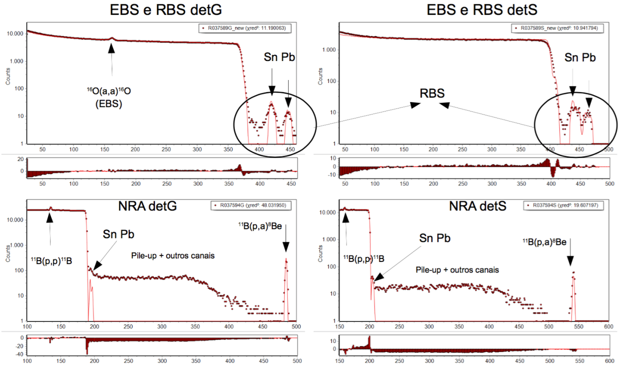
Boron layer

Ion Beam Assisted Deposition — IBAD



- 3 kW electron beam evaporates boron atoms,
- Argon ions are accelerated to bombard sample and improve film adherence.

Boron film characterization

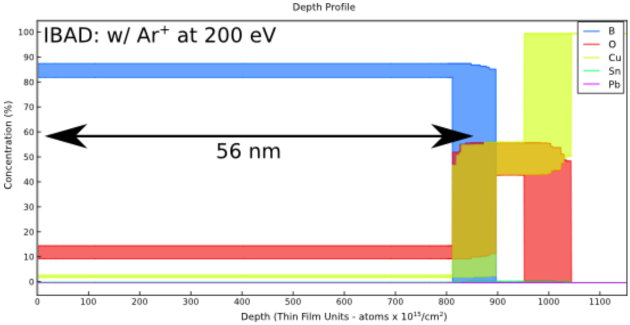


Nuclear Reaction Analysis:
2 MeV p beam to quantify boron through ^{11}B (p, α)^{8}B.
Emission of 8.53 MeV α, generating a peak completely isolated from background.

Elastic Backscattering Spectrometry:
Cross section peak of 3 MeV He ions for ^{16}O (α, α)^{16}O.
Quantification of oxydation in the boron film or in the copper substrate.

Rutherford Backscattering Spectrometry:
Identifies all other elements.

Bron film characterization



Depth Profile of the elemental concentration of the deposited layer crossing information from NRA, EBS and RBS.
Thickness achieved so far: 56 nm.

Concluding...

Conclusions

- THGEMs built in Brazil working,
- Gain and energy resolution to be worked out for other applications,
- Some problems in the deposition method,
- Well defined techniques for film characterization.

Future work

- Improve THGEM production quality for use with X-rays and other applications,
- Alternative deposition techniques (Chemical Vapor Deposition),
- Implementation of position capability.

Thank you for your attention!