# STUDY OF SURFACE PASSIVATIONS ON HPGe DETECTORS

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STUDY OF SURFACE PASSIVATIONS ON HPGe DETECTORS

# Outlines

- Characterization by γ-spectroscopy of a planar HPGe detector prototype
- Study of the passivated surface with low energy γ-ray
- Comparison between different passivation processes:
  - Methanol passivation
  - Sulfide termination
  - Low H: hydride termination in 10% concentration acid
  - High H: hydride termination in 50% concentration acid
  - Hyper H: same as High H but with an additional etching NEW

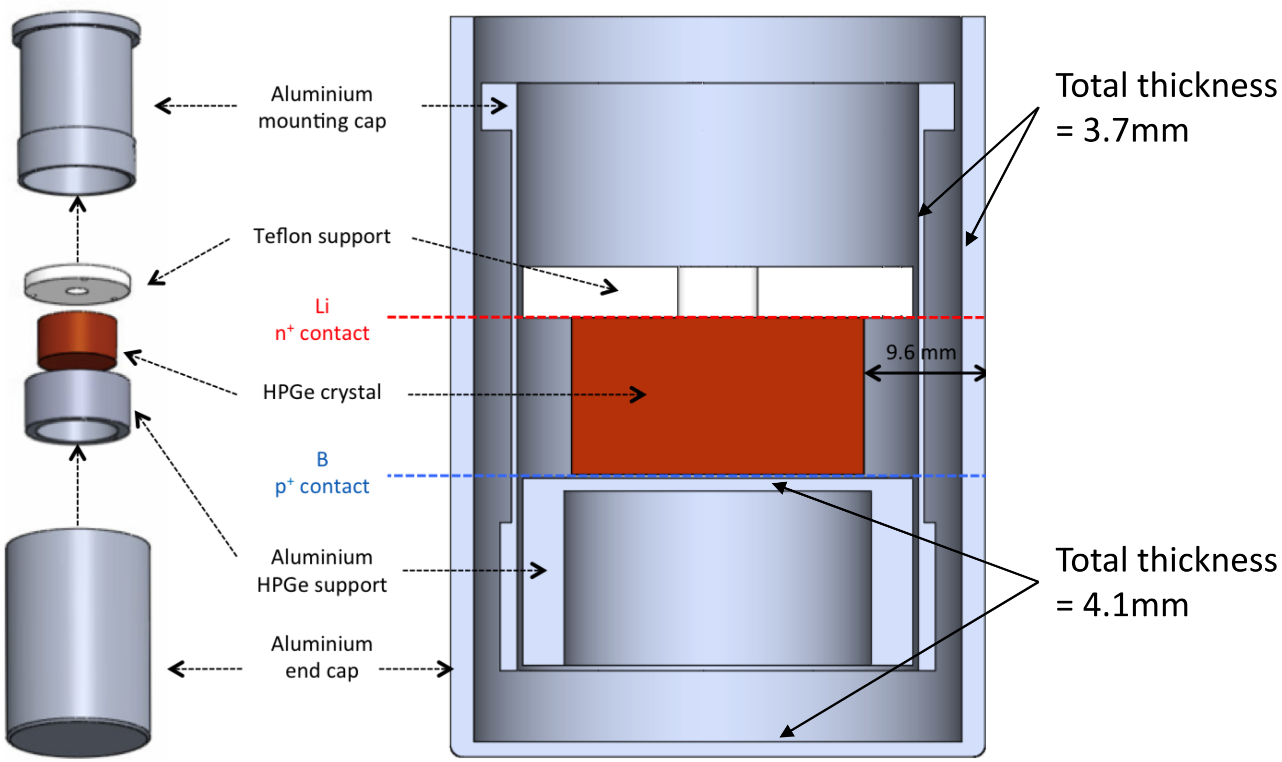
Previous work (Methanol passivation, Sulfide termination, Low H, High H)

This work (Low H, High H, Hyper H)

# New experimental set-up

Several HPGe detector passivations have been realized in the LNL's Materials Laboratory and a new experimental setup has been constructed to allow a better study of their properties.

- Always the same planar HPGe n-type crystal (21 mm height - 39 mm diameter)
- Reduced lateral thickness of the mounting cap
- Lead collimator on a micromotional device

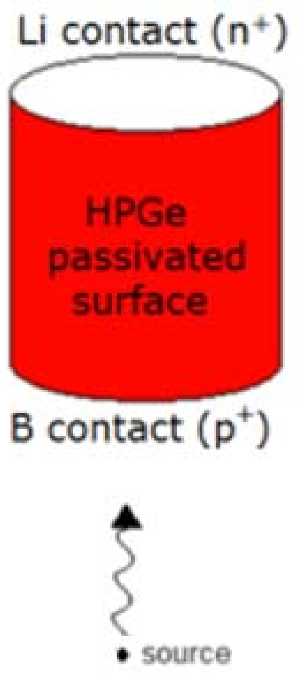


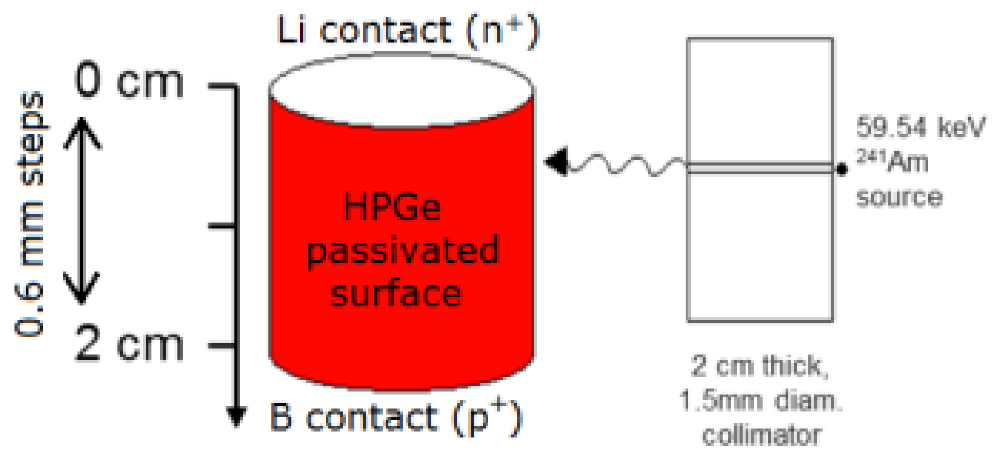
# Measurements

After every passivation procedure, the detector was mounted in the special cryostat, cooled and subjected to a complete characterization with γ sources.

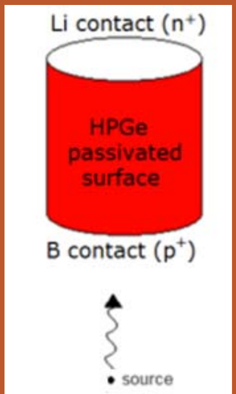
Two different kinds of measurements:

- determination of detector bulk properties by putting different standard calibration γ sources in front of the end cap;
- scanning of the lateral intrinsic surface by irradiating from the side of the crystal with an $^{241}Am$ collimated source on a micrometrical motion device that moves with 0.6 mm steps



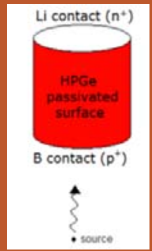
# Bulk properties




Determination of:

- the best response working voltage or depletion voltage $V_d$, defined as the reverse bias voltage required to extend the depletion region through the full thickness of the semiconductor bulk
- the energy resolution for the 1.33 MeV $^{60}Co$ peak as a function of voltage
- the detector efficiency as a function of the radiation energy

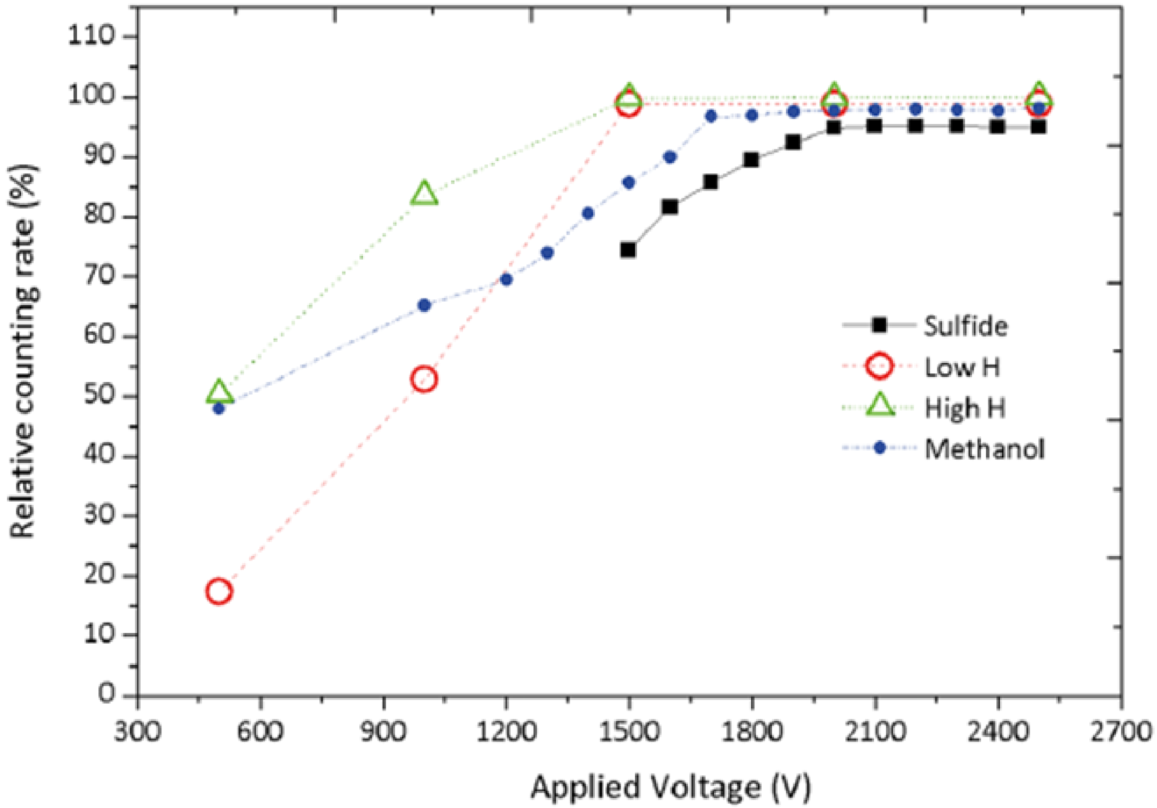
# Bulk properties




**Depletion voltage $V_d$**

- The depletion voltage is not the same for the different passivations: 2000V for the sulfide, 1700V for the methanol and 1500V for the two hydrides
- The counting rate at the plateau is different for the sulfide: it was proved to be related to a smaller active volume

- $^{60}Co$ source, in front of the detector
- Integrals of the peak at 1.33 MeV, normalized to the acquisition live times



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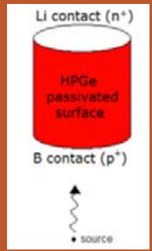
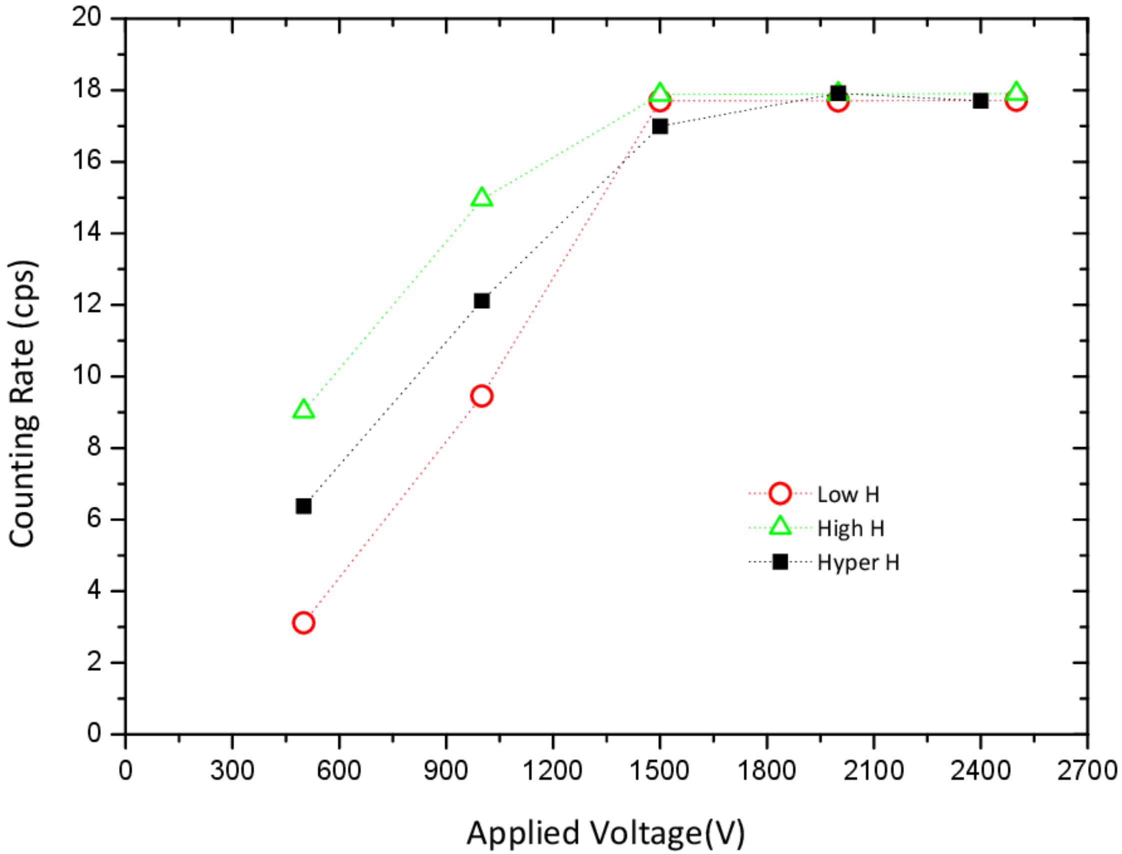



**Depletion voltage $V_d$**

- The depletion voltage is essentially the same for these three passivation methods, as well as the final plateau value

- $^{60}Co$ source, in front of the detector
- Integrals of the peak at 1.33 MeV, normalized to the acquisition live times



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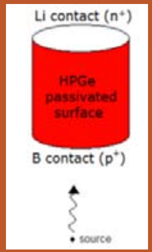
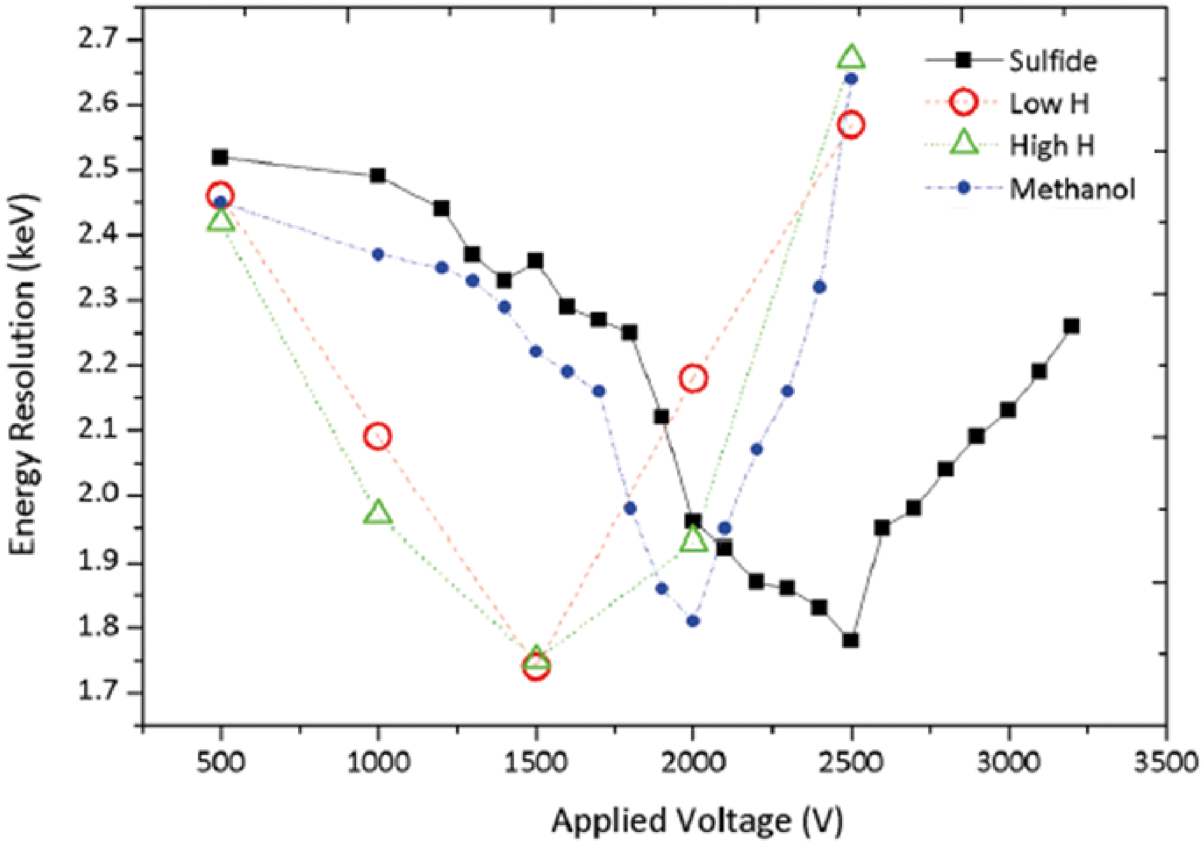



**Energy resolution**

- The best resolution does not depend on the passivation, it is essentially the same for all the methods [1.74-1.79 keV]

- $^{60}Co$ source, in front of the detector
- Resolution (FWHM) of the peak at 1.33 MeV



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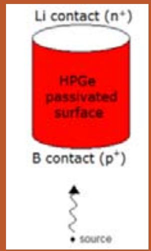
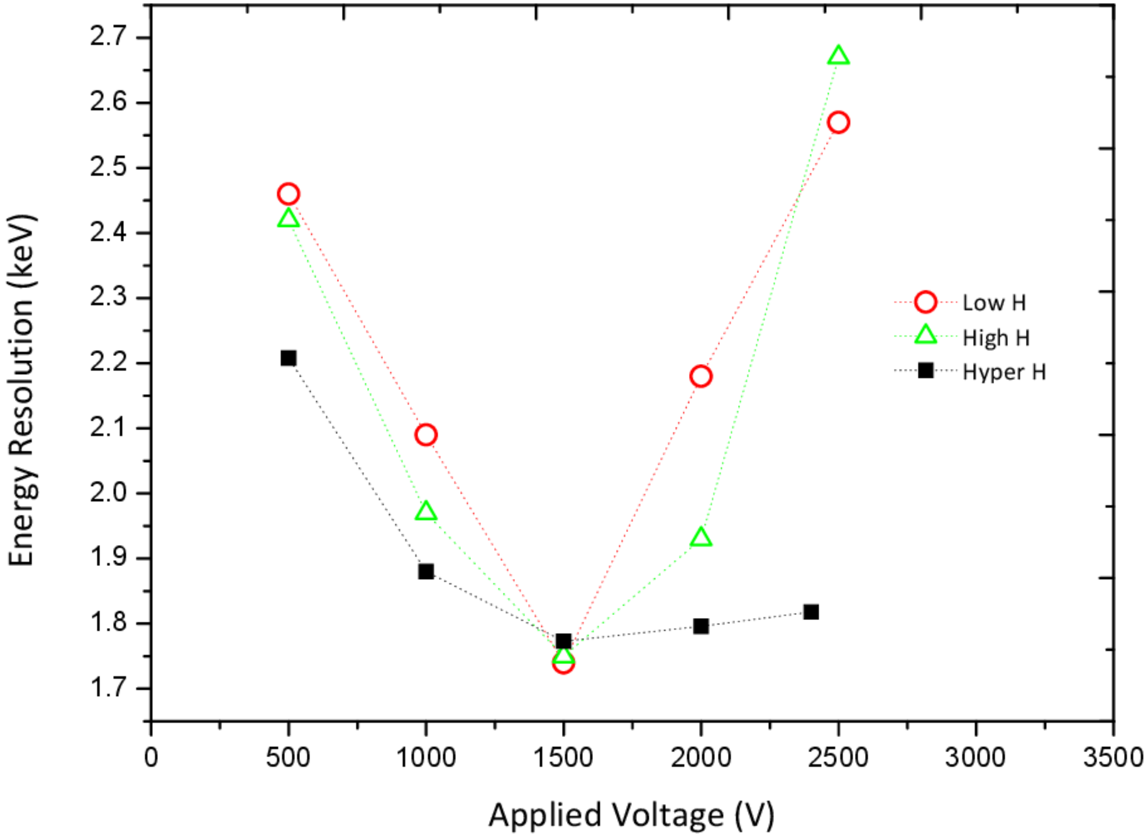



**Energy resolution**

- The best resolution is essentially the same for all these three methods, as well as the voltage at which those resolution are reached

| Passiv. | Depletion Voltage [V] | Best resolution Voltage [V] | Best resolution [keV] |
|---|---|---|---|
| Low H | 1500 | 1500 | 1.74 |
| High H | 1500 | 1500 | 1.75 |
| Hyper H | 1500 | 1500 | 1.77 |

- $^{60}Co$ source, in front of the detector
- Resolution (FWHM) of the peak at 1.33 MeV



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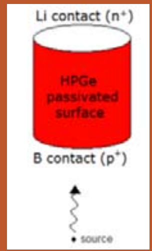
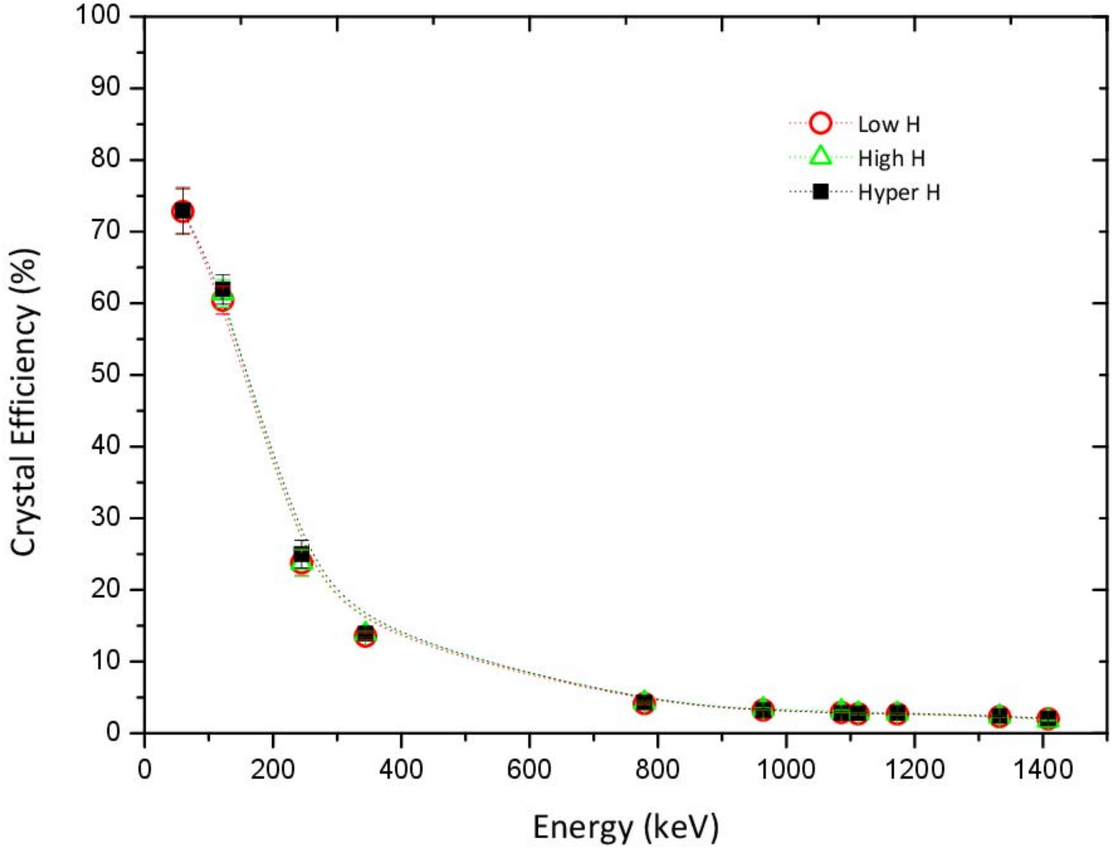



**Efficiency**

➢ The efficiency shows not to depend on the H-type passivation process and it is comparable with the expected values and with the results of the other passivations

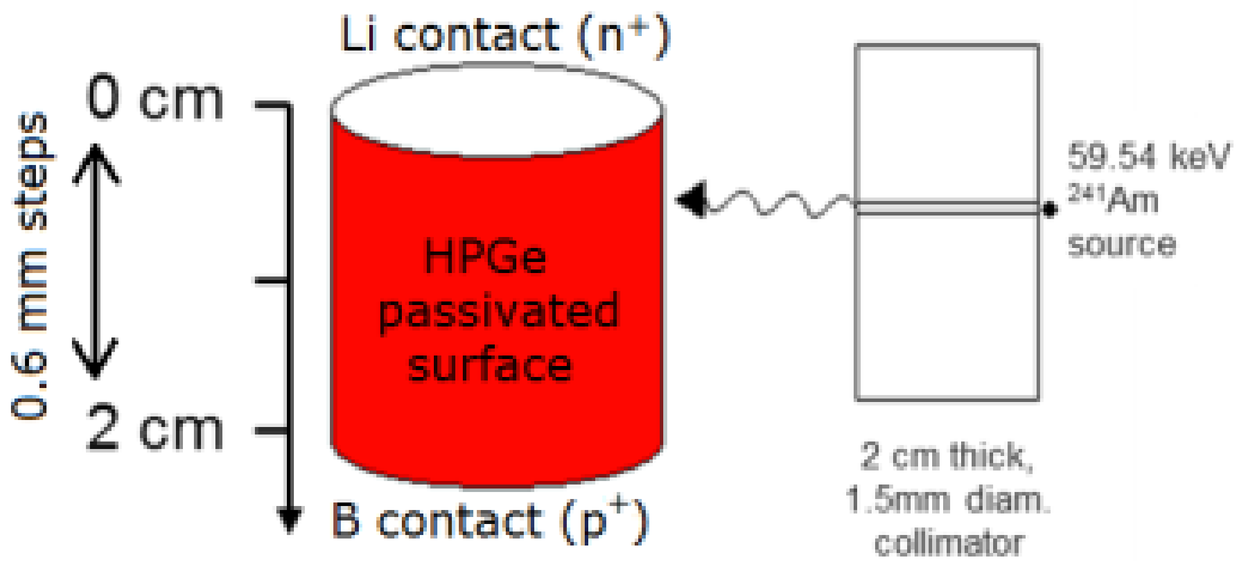
- Different standard sources, in front of the detector



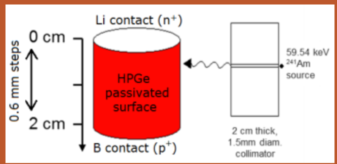
# Passivation properties

Lateral scanning with collimated source for the:

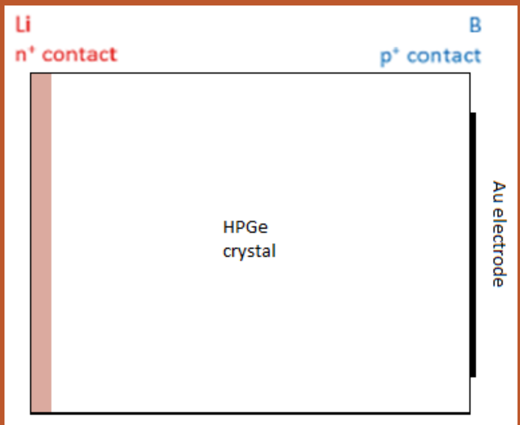
- determination of the dead layer below the lateral surface induced by the passivation, estimated starting from the counting rate and applying the Beer-Lambert law for γ rays absorption
- study of the Am spectra as a function of the distance between the collimated γ beam and the detector contacts, for each passivation treatment at its best resolution voltage and in some cases at different voltages



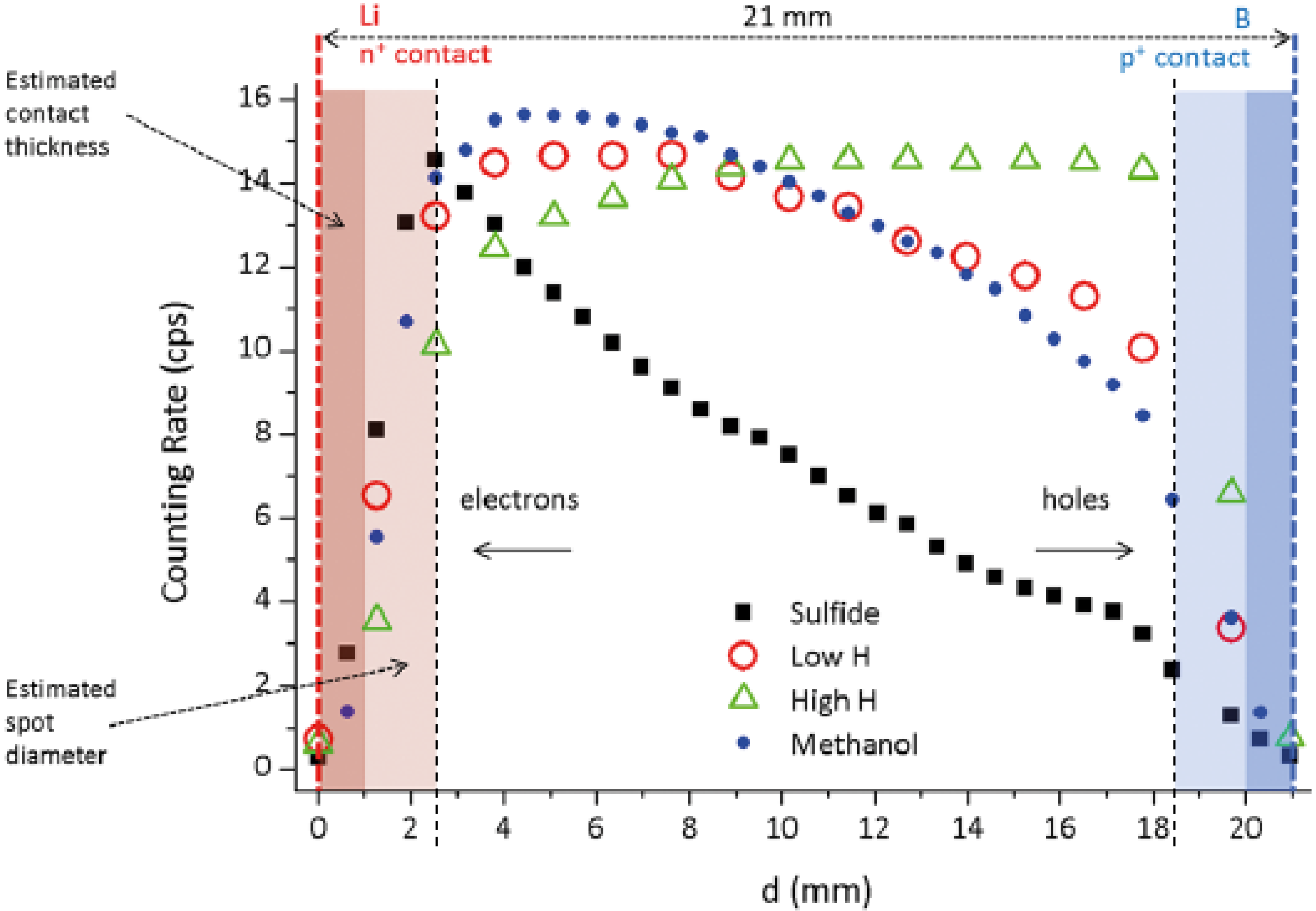
# Passivation properties




- S passivation is the most used in microelectronics because it's stable, but it has the larger dead layer




- $^{241}Am$ collimated source, from the side of the detector
- Integrals of the full-energy peak at 59.54 keV, normalized to the acquisition live times



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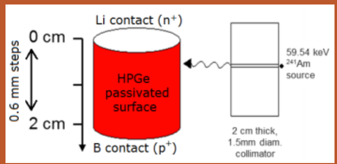


The counting rate in:

- Low-H passivation decreases moving from the $n^+$ to $p^+$ contact, giving rise to a slightly n-type surface;
- High-H passivation increases from $n^+$ to $p^+$ contact, giving rise to a slightly p-type surface;
- Hyper-H passivation remains constant along all the scan, giving rise to an ideal passivation.

- $^{241}Am$ collimated source, from the side of the detector
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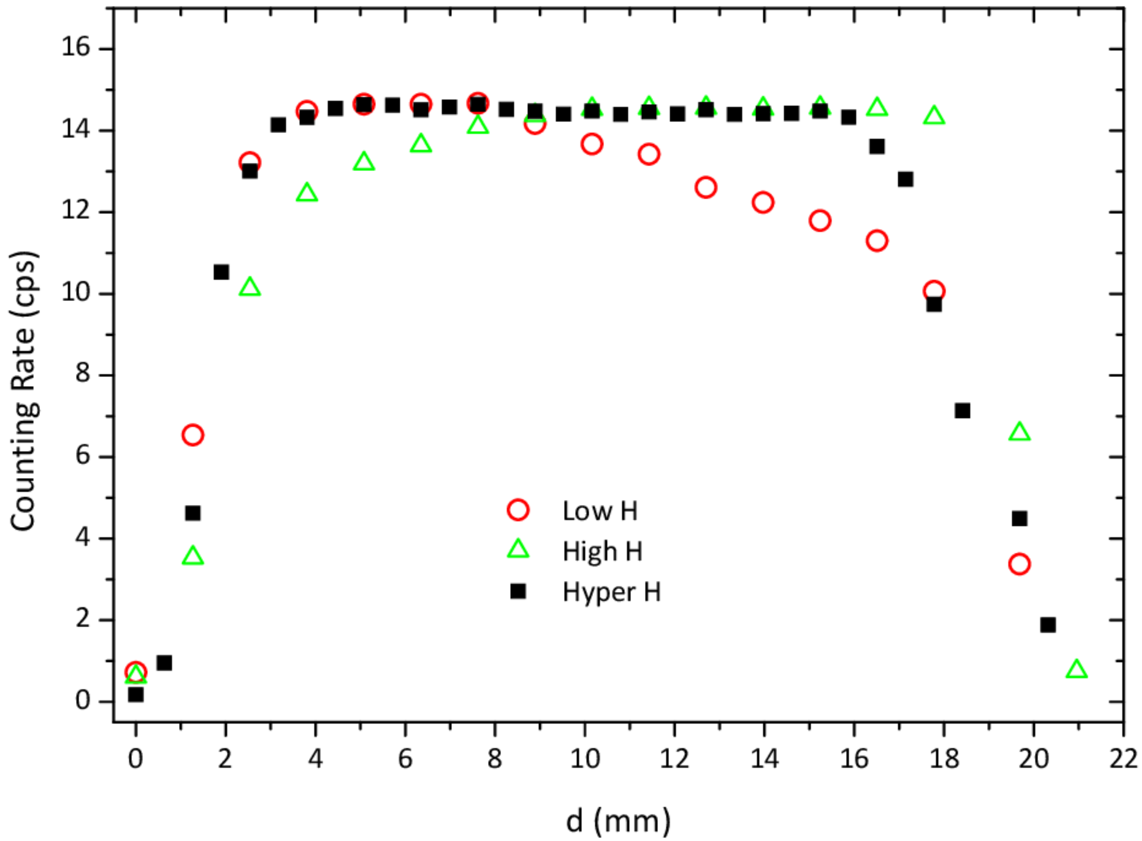

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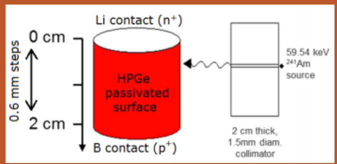


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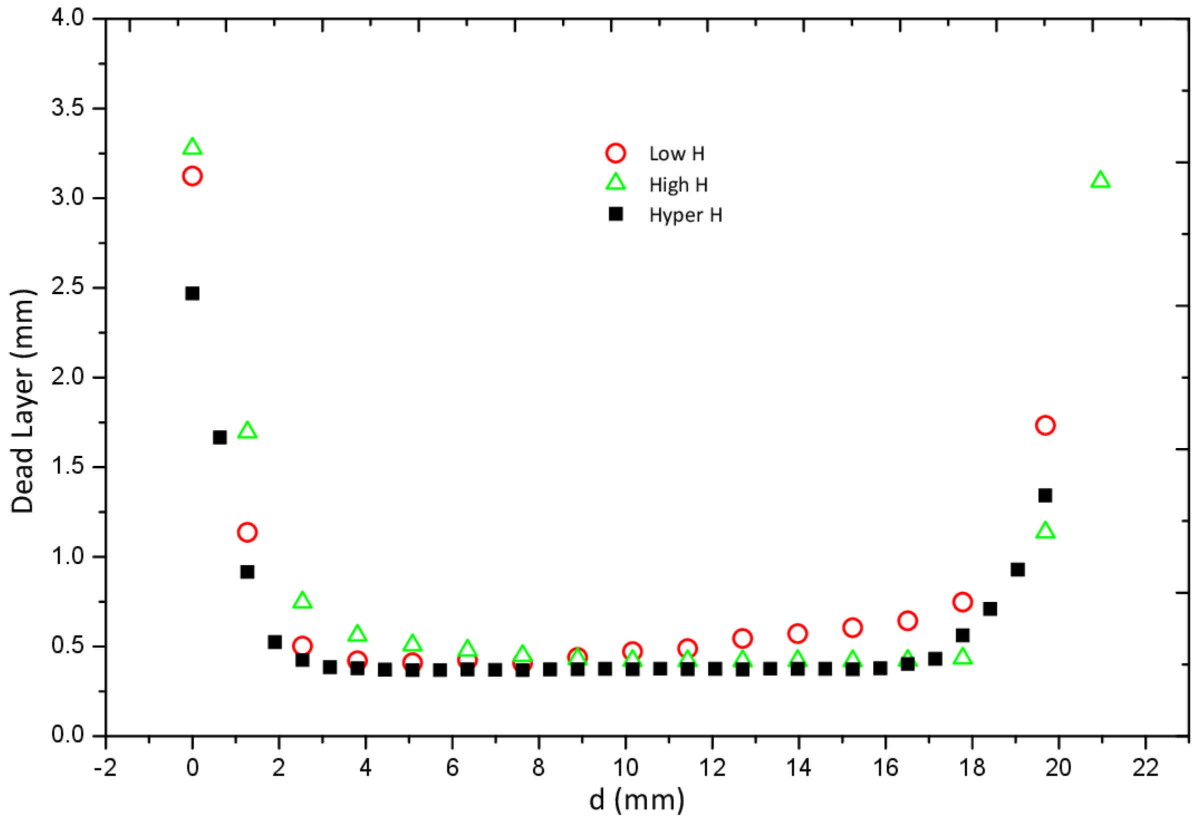
- Hyper-H passivation remains constant along all the scan, giving rise to an ideal passivation.

- Dead layer thickness determination from the counting rates applying the Beer-Lambert law for gamma absorption



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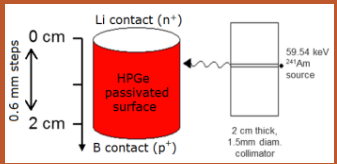
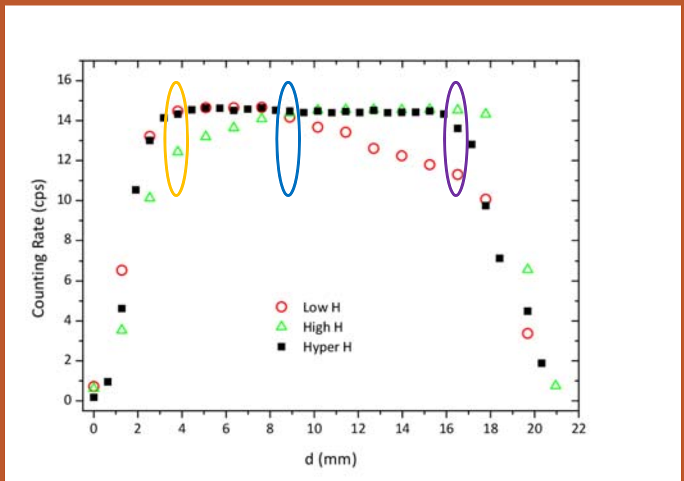


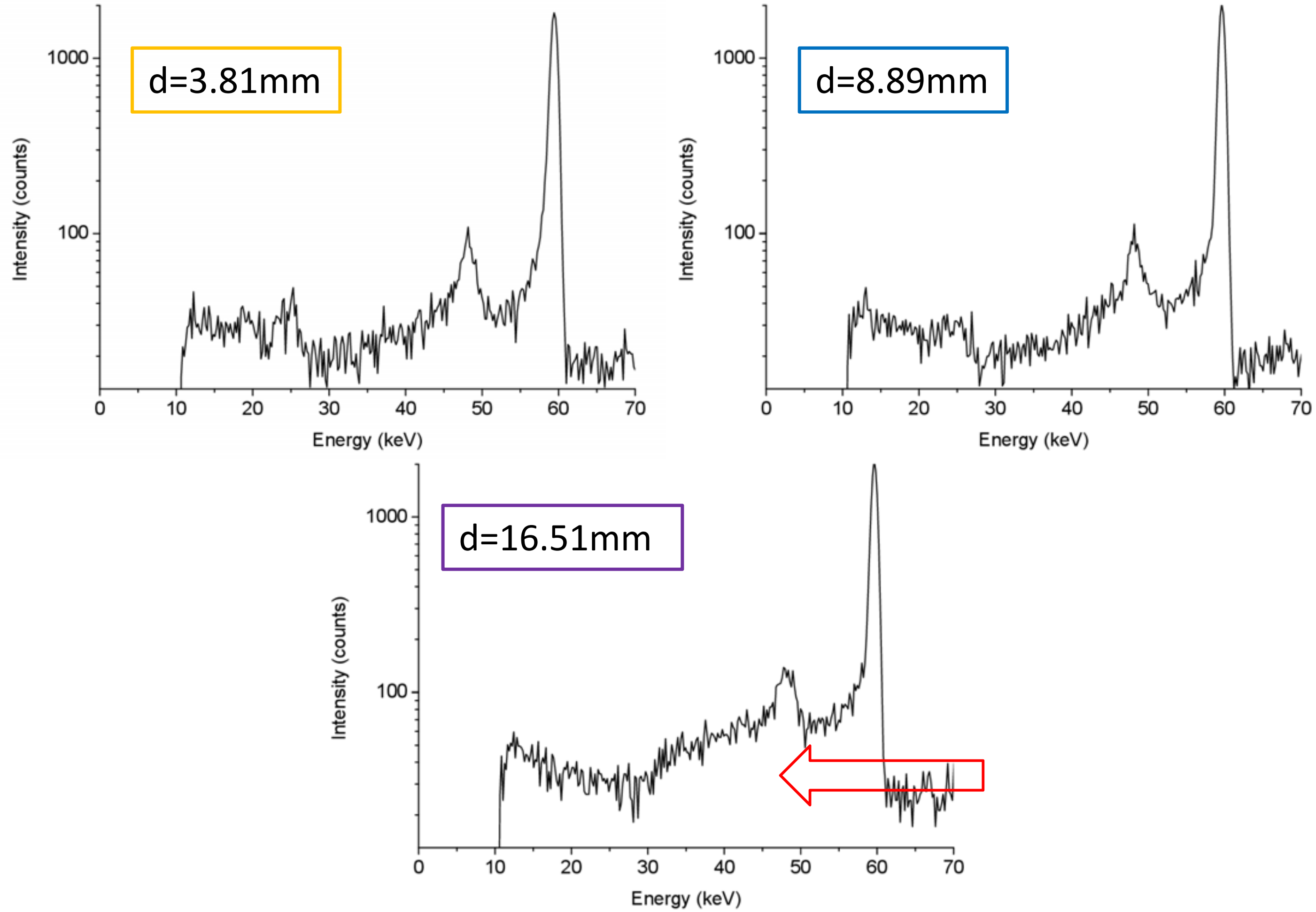

**Background and resolution**

- An increase of the background contribution to the spectra with the dead layer thickness is observed for all the different passivations




- $^{241}Am$ collimated source, from the side of the detector

LOW H



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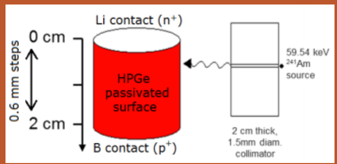


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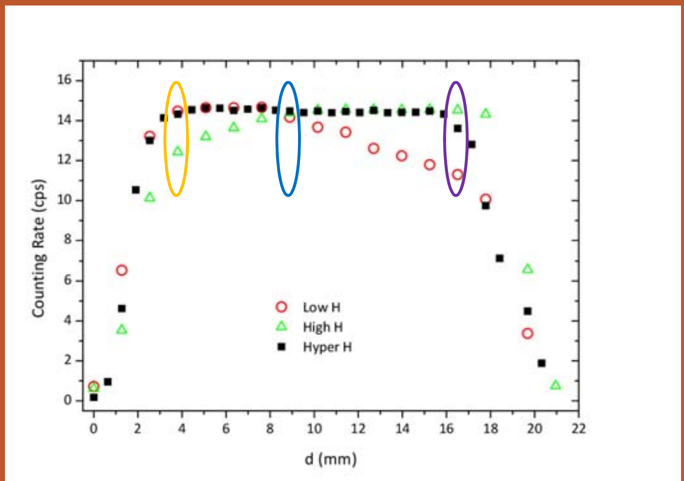
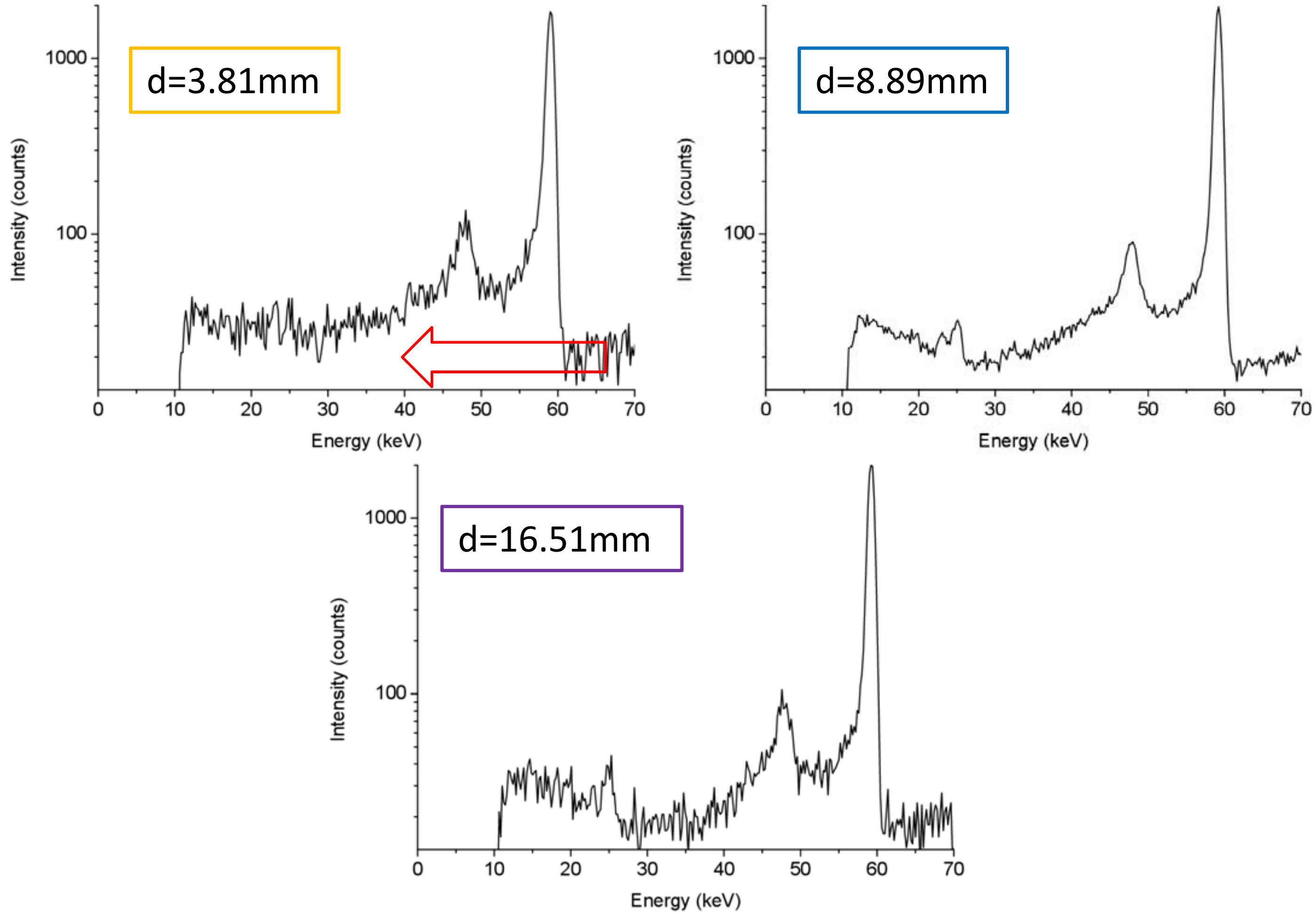



- $^{241}Am$ collimated source, from the side of the detector

HIGH H



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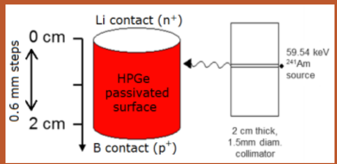


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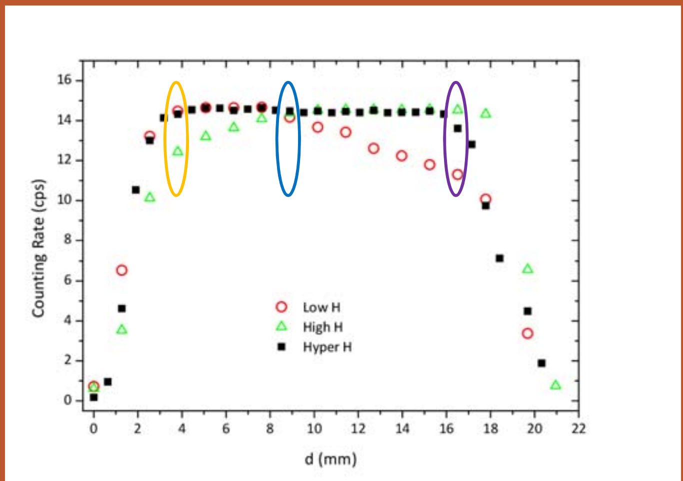
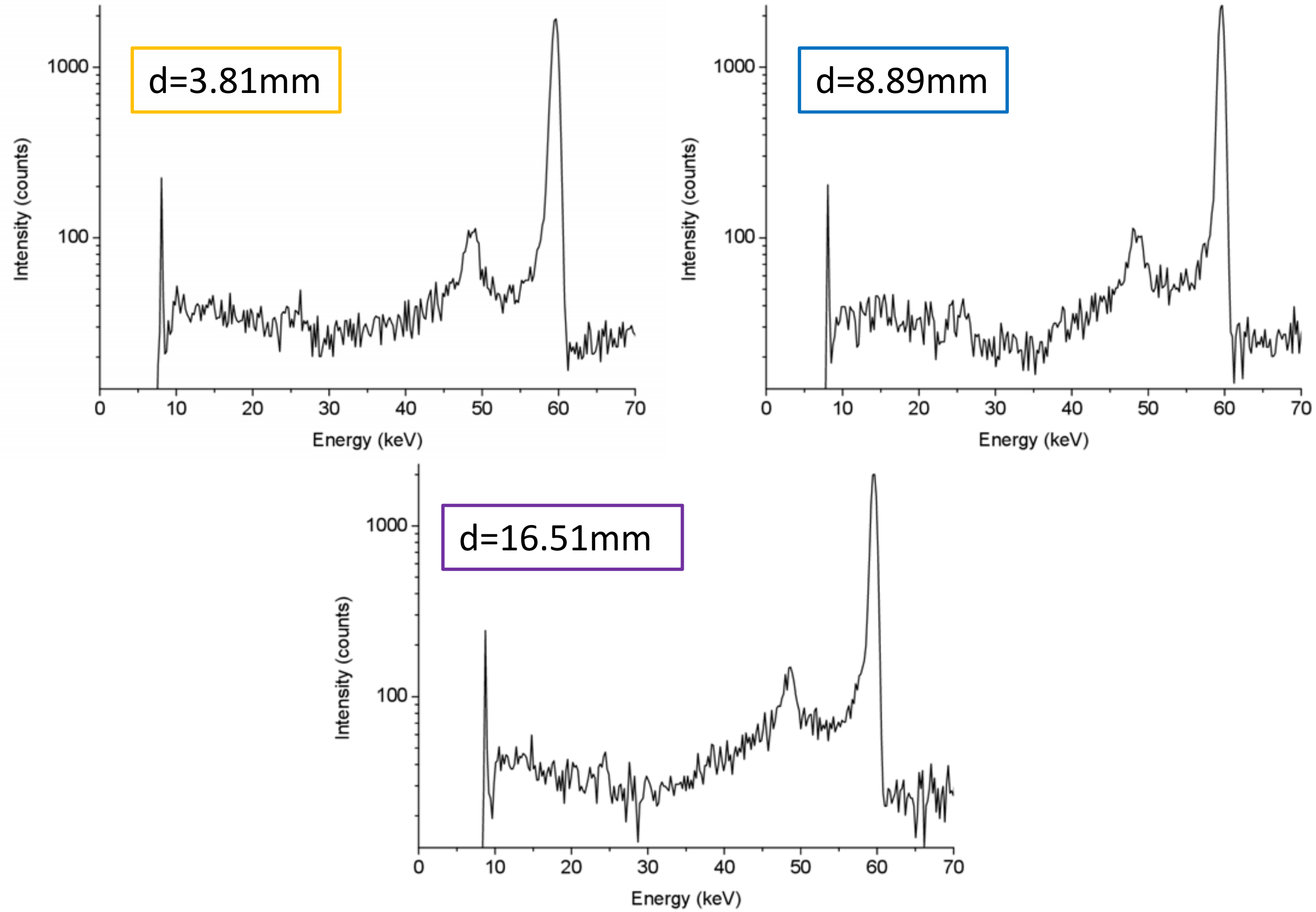



- $^{241}Am$ collimated source, from the side of the detector

HYPER H



## Conclusions

- The efficiency, the depletion voltage and the energy resolution of the detector are comparable for the three H-terminated passivations
- The estimated dead layers induced below the passivated surfaces are thinner and more homogeneous than the ones of common commercial detectors, but they have presented different trends: the Hyper H termination is the most uniform

## Collaborators

| | |
|---|---|
| INFN-LNL | D.R. Napoli, W. Raniero (ENSAR2) |
| INFN-LNL and University of Padova | D. De Salvador, G. Maggioni, S. Carturan, E. Napolitani, V. Boldrini, F. Sgarbossa |
| INFN-LNL and University of Verona | G. Mariotto |
| INFN-LNL and University of Trento | G. Della Mea |
| INFN-PG and University of Camerino | N. Pinto |
| INFN-PG and University of Perugia | S. Riccetto |
| IKP Cologne | J. Eberth |
| CNR-IMM Bologna | R. Nipoti, F. Mancarella, M. Bellettato |

THANK YOU FOR THE ATTENTION