



# ENSAR2 JRA2 - PSeGe

**A.Gadea (IFIC-Valencia) for the PSeGe Collaboration**

**3rd Position Sensitive Germanium Detectors and application Workshop  
10th – 14th September 2018, IPHC, Strasbourg**

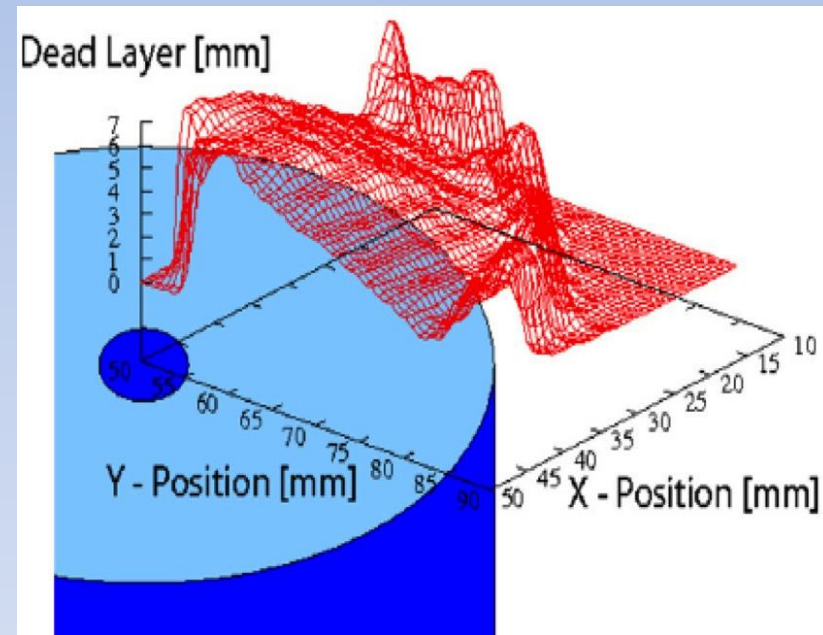
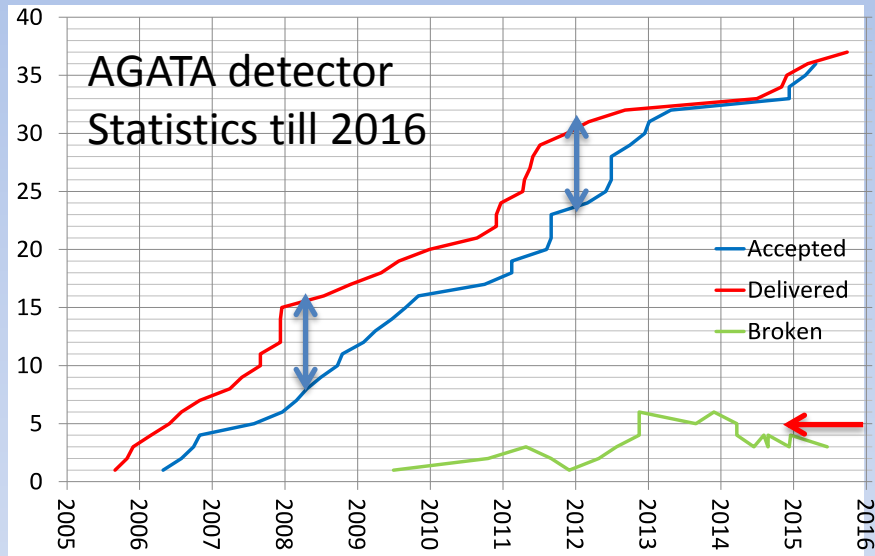




- **ENSAR2 (project number: 654002) is the integrating activity for European nuclear scientists who are performing research in three of these major subfields: Nuclear Structure, Nuclear Reactions and Applications of Nuclear Science.**
- **Its core aim is to provide access to eleven of the complementary world-class large-scale facilities: GANIL-SPIRAL2 (F), INFN (LNL & LNS) (I), CERN-ISOLDE (CH), JYFL (FI), ALTO (F), GSI (D), KVI-CART (NL), NLC (IFJ PAN-Krakow & HIL-Warsaw) (PL), IFIN-HH/ELI-NP (RO) and to the theoretical physics facility: ECT\* (I).**
- **It provides as well Network and Joint Research Activities funding.**
- **ENSAR2 started on March 1st, 2016. It will last 4 years**
- **ENSAR2 is funded by the European Commission within its HORIZON2020 Programme under the specific programme 'Infrastructures'.**

# JRA2 PSeGe Background

1. Fragility of the Passivation on Highly Segmented Ge Detectors, Dead-Layers in Passivated Areas and Increasing Difficulties and Costs in the First Encapsulation Technique developed in the 90's.



J. Eberth, J. Simpson, Prog.  
Part. Nucl. Phys.60,283.

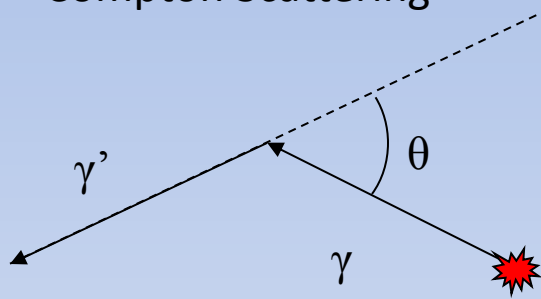


**INFN-LNL and University of Padova**  
**IKP-University of Cologne**

# JRA2 PSeGe Background

## 2. R&D on High-Position Resolution Ge Detectors without Dead-Layers. From Tracking to Imaging Arrays.

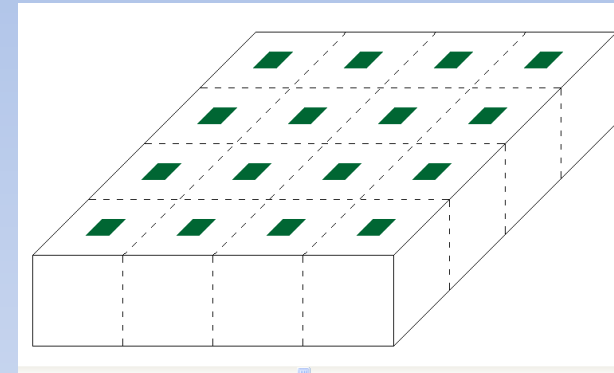
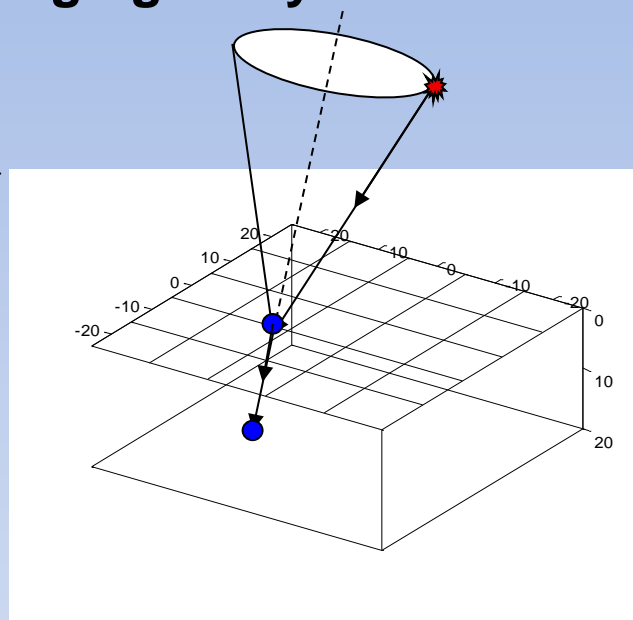
Compton Scattering



Energy deposited in a Compton interaction point

$$E_{e^-} = \frac{\frac{E_\gamma^2}{m_e c^2} (1 - \cos \theta)}{1 + \frac{E_\gamma}{m_e c^2} (1 - \cos \theta)}$$

GSI-Darmstadt



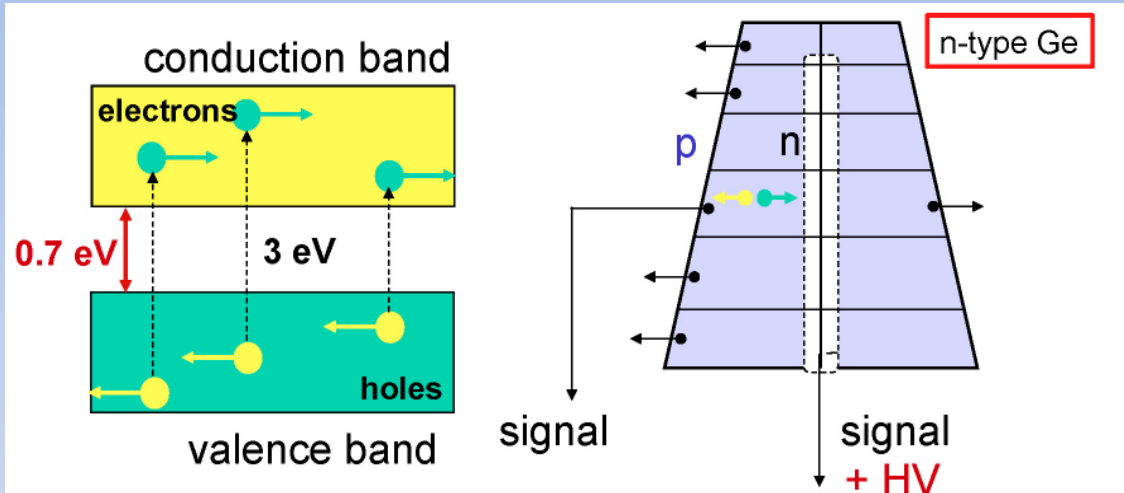
Multi-point contact Ge-detector structure

Quasi-planar Ge-detector

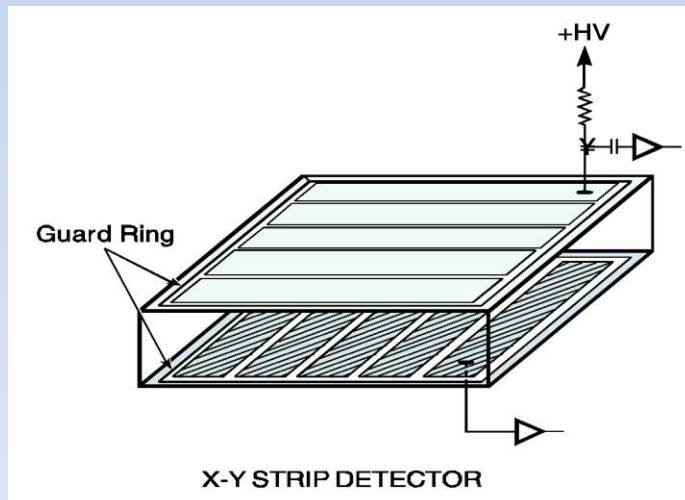


# JRA2 PSeGe Background

## 3. R&D on Segmented n-Contacts for p-Type Ge Detectors: Exploring the Possibility to Reduce the Effect of Neutron-Damage in Segment Signals



All segmented coaxial detectors are n-type because the technology of stable segmented p-type contacts is missing or unreliable. Required investigation on p-contacts with enough hole barrier.



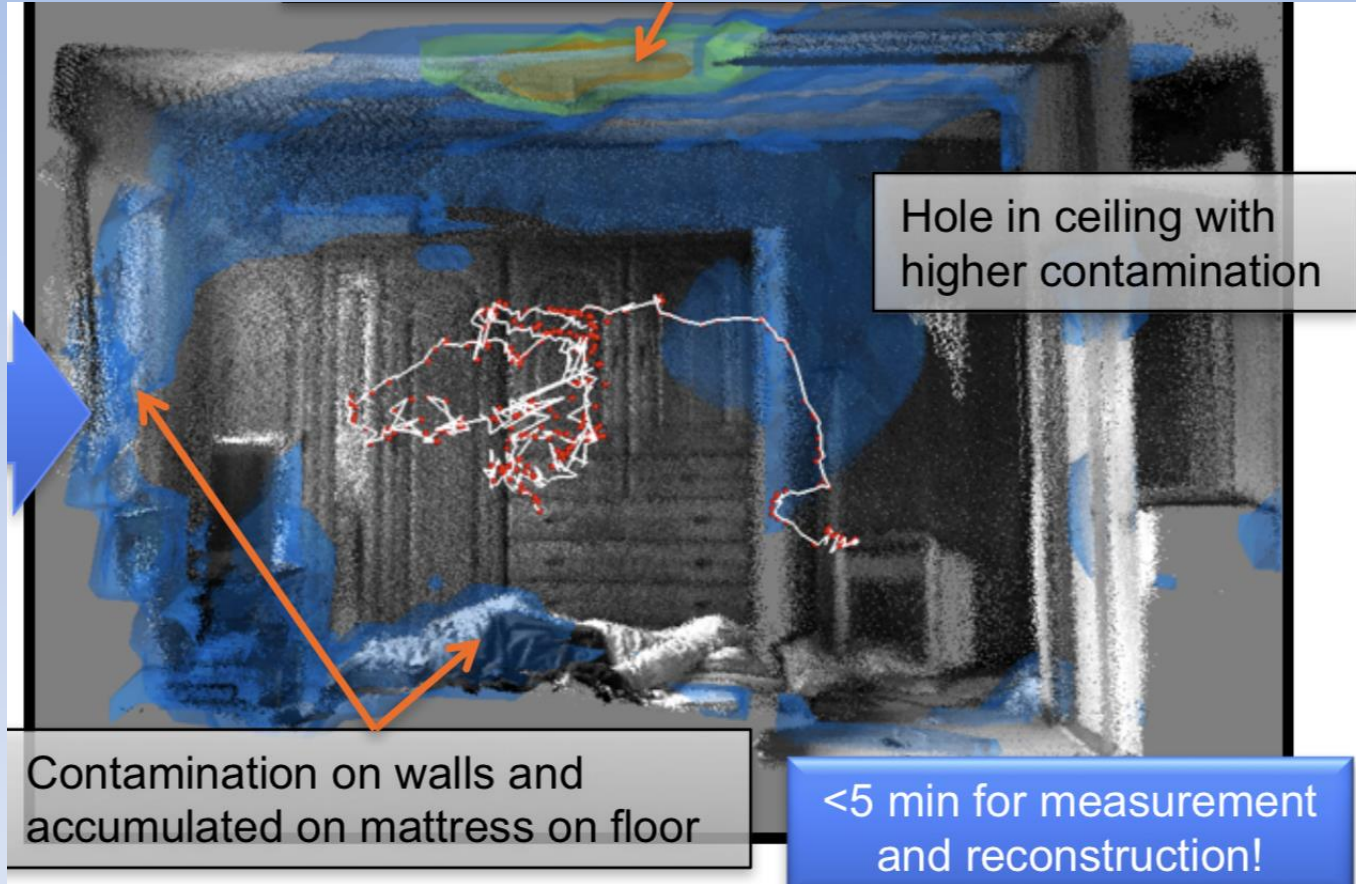
Planar DSSD have always a Lithium segmented contact, thus they can not be annealed. The investigation of p-type contacts is also fundamental for planar detectors if they will need annealing after sometime

**IFIC-Valencia**

**INFN-LNL and University of Padova**

# JRA2 PSeGe Background

3. Network Activity on Imaging Applications and Detector Technologies. Sizeable part of the collaboration working on Imaging developments. Considered most relevant by the E.C.



Example of scene data fusion (courtesy LBNL)

**University of Liverpool**  
**IKP-University of Cologne**

The present project is contributing to the R&D of detector technology for position-sensitive HPGe detector arrays. R&D on key areas as detector technology. **The work of the JRA2 is proceedings according to plan.**

## Participants:

- IFIC-CSIC: personnel funds for Task3
- INFN-LNL: personnel funds for Task 1
- Uni. Cologne: personnel funds for Task 1
- GSI: personnel funds for Task 2
- Uni. Liverpool: networking funds for Task 4
- CNRS: networking funds for Task 4

## Associated partners:

KTH & University of Uppsala, Sweden, ELI-NP, Romania, University of Milan, Italy, STFC, UK, University of Salamanca & University of Valencia, Spain, CEA-Saclay, France

### **Task 1: New technologies on passivation and segmentation**

R&D of segmented contacts in HPGe detectors and of the passivation of the boundary regions between contacts, charge collection and electric-field exploration via 2D scans.

### **Task 2: R&D on novel Ge-detector geometries for ultimate position resolution and efficiency**

Modeling and simulation of electrical-field distributions, evaluation of the 3D position resolution obtainable, production of a prototype detector in cooperation with the industrial partner, experimental determination of the performance figures with the produced prototype.

### **Task 3: R&D on segmented p-type coaxial detectors**

R&D on basic properties of the dopants producing high hole-barrier n-contacts, evaluation of the barrier and study of segmentation with these materials.

### **Task 4: Demonstration of imaging applications and associated detector technologies**

- 4.1: Demonstration of imaging applications
- 4.2: Detector encapsulation techniques
- 4.3: R&D on associated Detector technologies
- 4.4: PSA and neutron-gamma discrimination

The present project is contributing to the R&D of detector technology for position-sensitive HPGe detector arrays. R&D on key areas as detector technology. **The work of the JRA2 is proceedings according to plan.**

Participant	Personnel Costs/€	Other Direct Costs/€	Indirect Costs / €	Requested grant / €	Spending M1-18 / €	To be Spend M19-48 / €
CSIC	70.000 €		17.500 €	87.500 €	337 €	87.163 €
INFN	82.000 €	0	20.500 €	102.500 €	42.445,00	60.055,00
University Cologne	70.000 €	12000	20.500 €	102.500 €	18.295 €	84.205 €
GSI	70.000 €	0	17.500 €	87.500 €	20.836 €	66.664 €
University of Liverpool		48000	12.000 €	60.000 €	11.043 €	48.957 €
CNRS		24000	6.000 €	30.000 €	8.527 €	21.473 €
<b>Total JRA2</b>	<b>292.000 €</b>	<b>84000</b>	<b>94.000</b>	<b>470.000 €</b>	<b>101.483 €</b>	<b>368.517 €</b>

About **22%** expended in the 18 months review.  
 About **50%** expended in the 30 months period.  
 Expected to be completed within the ENSAR2 48 months duration.

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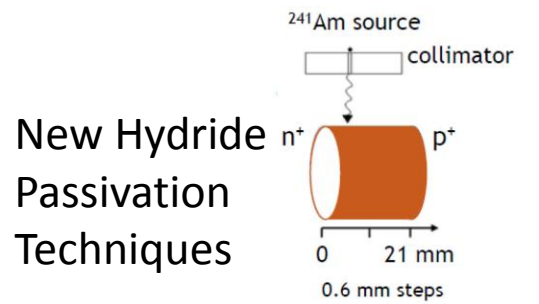
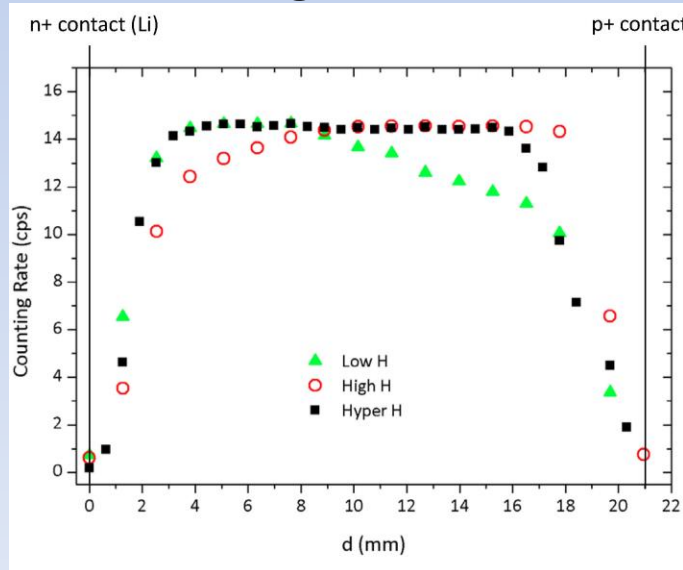
- 4.1: Demonstration of imaging applications
- 4.2: Detector encapsulation techniques
- 4.3: R&D on associated Detector technologies
- 4.4: PSA and neutron-gamma discrimination



# Task 1: New technologies on passivation and segmentation

- Assigned Contracts on-going since 2016 at INFN-LNL and IKP
- Done the first test of implantation of Boron in planar detectors to produce new contact technologies
- Now working in the preparation of a coaxial detector from a raw Ge-HP crystal in order to check the new contact technology in quasi-coaxial detectors.
- Cryostat development is ongoing for new detector prototypes in collaboration between IKP-Cologne and INFN. Encapsulation completed.

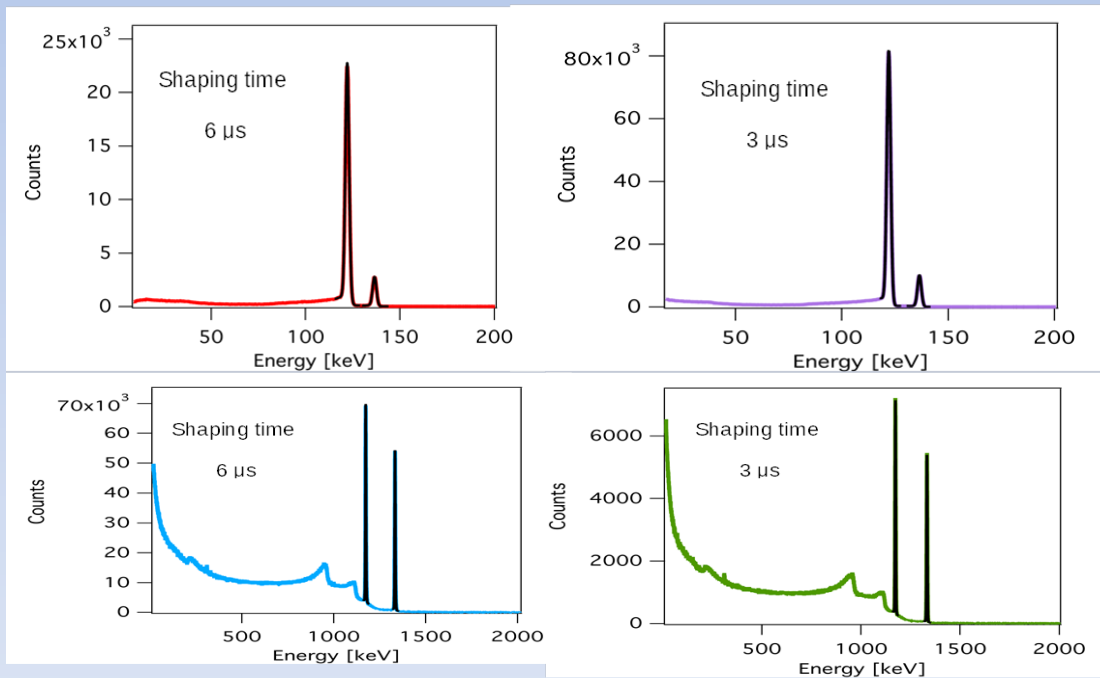
V.Boldrini: Thermally-induced defects and contamination in doping techniques.  
 W.Raniero: Ge detectors with new pasivation techniques.  
 F. Sgarbossa: P- Monolayer Doping in Germanium



New Hydride Passivation Techniques

G. Maggioni et al. Eur. Phys. J. A (2015) 51: 141  
 S. Ricetto et al. to be submitted

- **Task 2: R&D on novel Ge-detector geometries for ultimate position resolution and efficiency**
  - Contract on-going (Tugba Arici)
  - Proceeding with the prototype of quasiplanar geometry for position sensitive Ge detectors. First prototype is now been characterized.

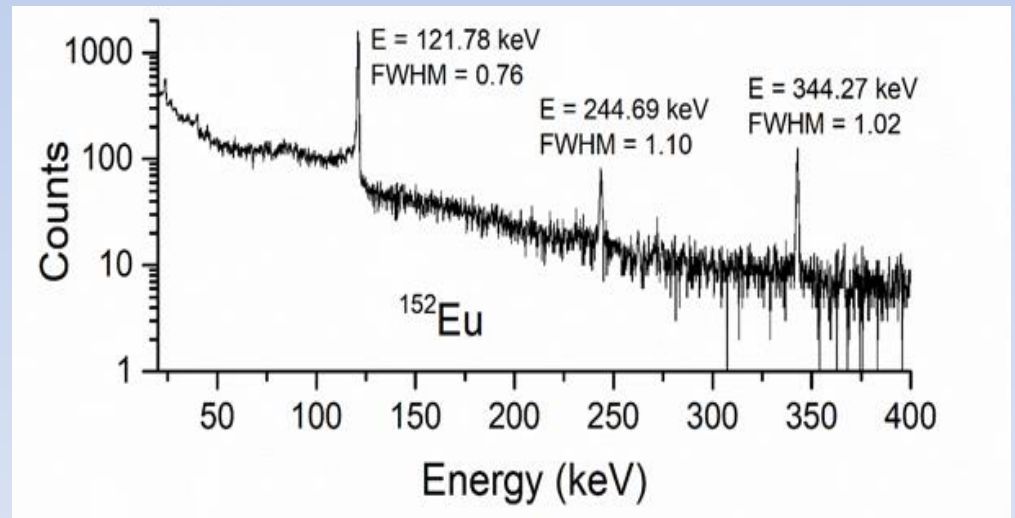
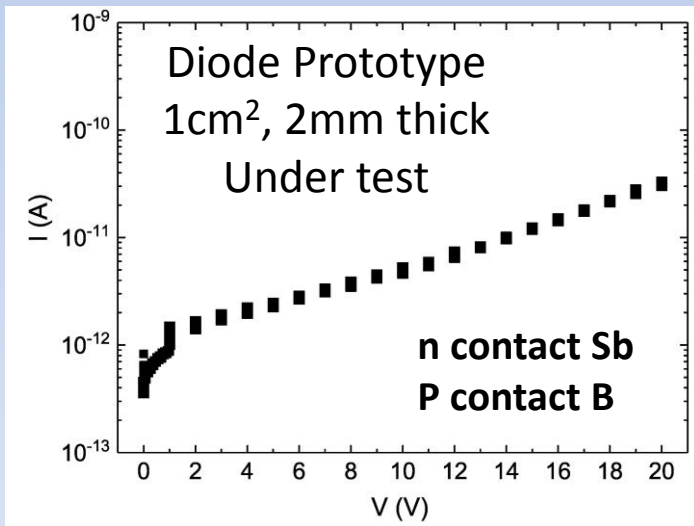


Shaping time (μs)	3	6
Energy (keV)	122	122
FWHM (keV)	2.13(1)	2.35(1)

Shaping time (μs)	3	6
Energy (keV)	1332	1332
FWHM (keV)	4.53(1)	4.32(1)

## •Task 3: R&D on segmented p-type coaxial Ge detectors

- Test on the use of Phosphorous for dopant diffusion and activation for the junction formation done, not good results. Now Sb as dopant being tested.
- Collaboration established with the Micro electronics group of the University of Padova, Italy
- Ongoing contract for a pre-doctoral collaborator Stefano Bertoldo.



- **Task 4: Demonstration of imaging applications and associated detector technologies**
  - Done the 1<sup>st</sup> and the 2<sup>nd</sup> workshops on Detector R&D, Applications and associated technologies. 3<sup>rd</sup> Ongoing
  - Training sessions on advanced detector technology organized.
  - Collaboration on-going on Position Sensitive Ge Detector Imaging applications.
  - A first Compton camera based on a hexagonal, tapered, 36-fold segmented HPGe detector and a DSSSD was developed, tested, and put into operation at IKP, Cologne. This work performed in collaboration with University of Liverpool.



## Summary:

- The PSeGe activity is progressing timely in several fronts.
- Prototypes in Task 1, i.e. new passivation techniques, Task 2, i.e. new geometries, and Task 3, i.e. p-type contacts, exist or are being produced.
- Promising p-type contacts based on Sb.
- Networking funds allow the organization of the workshops and training visits to the Laboratories with Ge detectors experts.
- Necessary a Discussion on Ideas for ENSAR-NEXT