TOWARDS THE REALIZATION OF A COAXIAL AND SEGMENTED DETECTOR FOR GAMMA SPECTROSCOPY EXPERIMENTS

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N3G collaboration

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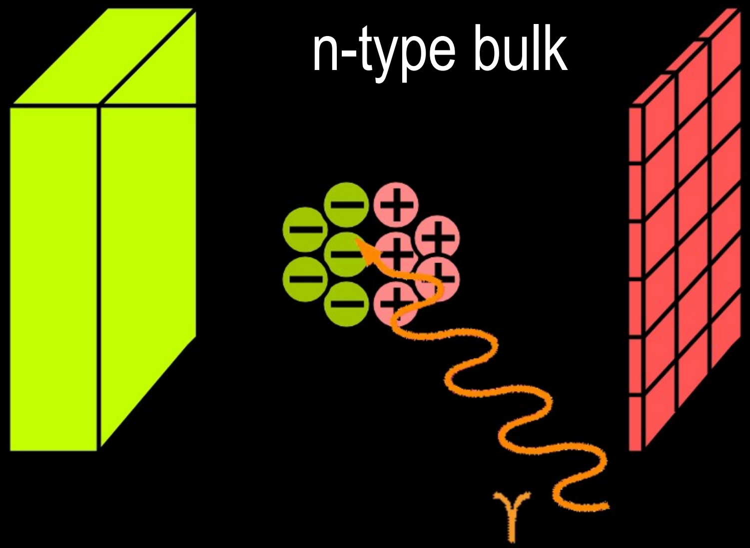
STATE OF THE ART HPGE DETECTORS

n+ contact:
electrons collection

diffusion of lithium:
thick layer that can not
be segmented



p+ segmented contact:
holes collection

ion implantation of boron

- Segmentation of the p+ contact: **<u>tracking analysis with holes signals</u>**
- Holes are much more subjected to **<u>trapping induced by neutron damage</u>** than electrons

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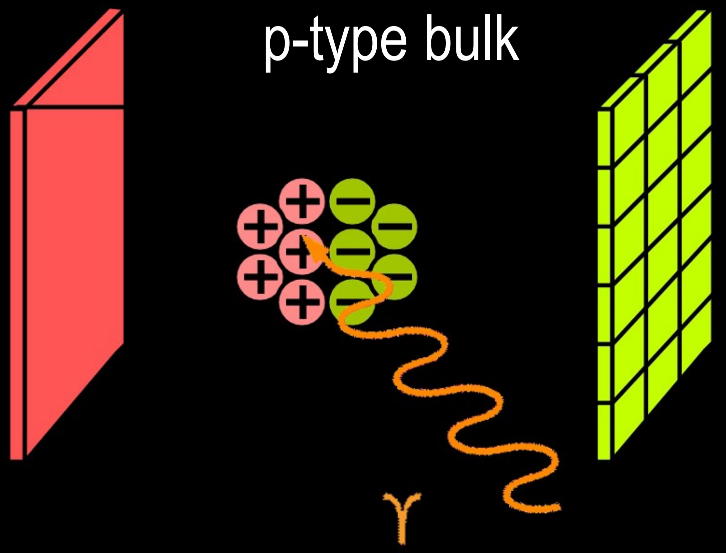
THE N3G HPGE DETECTOR

p+ contact:
holes collection

ion implantation of boron



n+ segmented contact:
electrons collection

PLM based doping

- PLM – Pulsed Laser Melting – technology: **segmentation of the n+ contact** (100 nm-300 nm thick)
- Tracking analysis with electrons signals: **resolution improvements**

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WHAT DO WE NEED TO MAKE THE DTECTOR ?

High-Purity Germanium (HPGe)

Reliable Doping-Technology (PLM)

Mechanical Developments

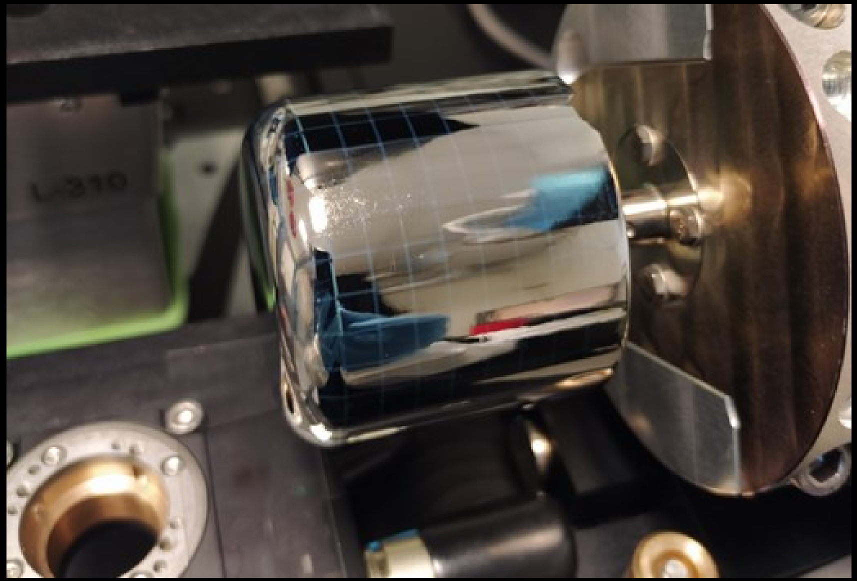
Advanced Photolithography

Electronics

People (with different skills)

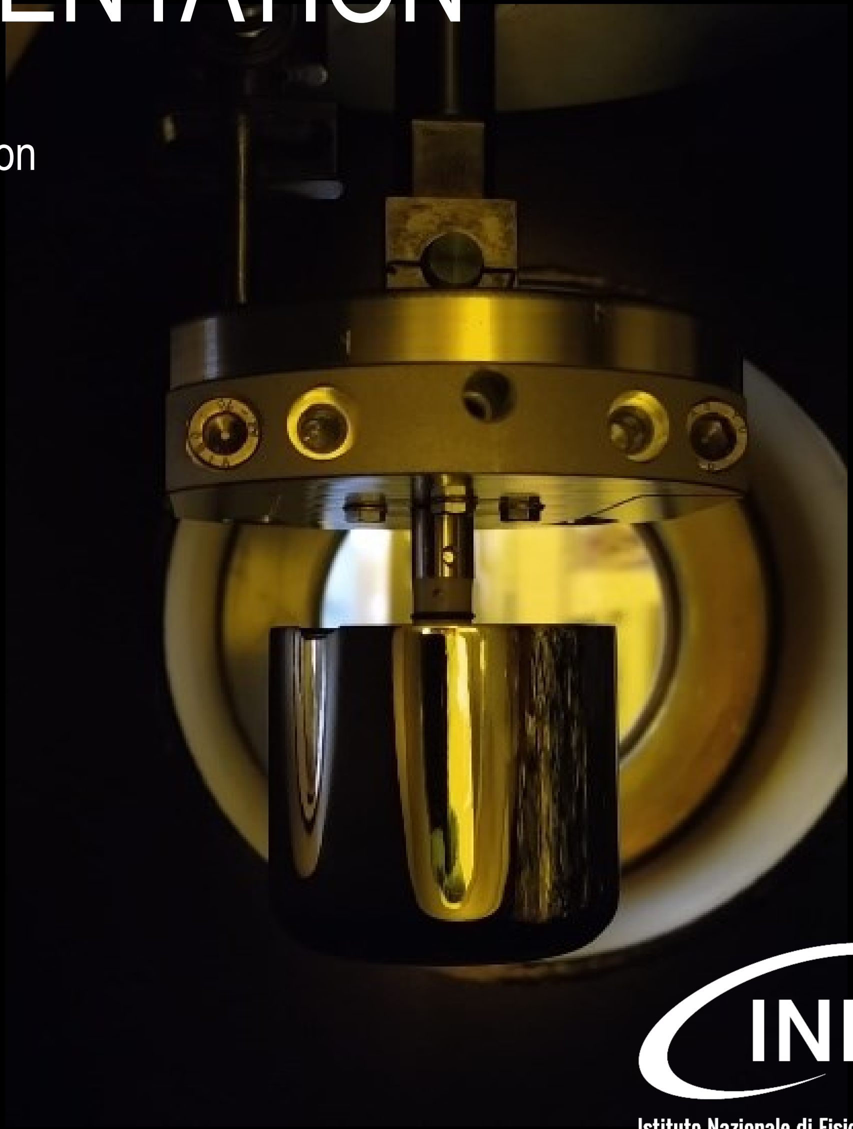
PULSED LASER MELTING TECHNOLOGY

- The HPGE crystal is **lapped and etched** with acid solution (3 : 1) HNO_3 : HF
- **Sputtering deposition** or **evaporation** of a thin (2 nm – 20 nm) pure layer of dopant on Ge
- Followed by **cycles of Pulsed Laser Melting** (spatial and tempo-ral control)
- **Diffusion** of high dopant concentrations (3 x 10^{20} cm^{-3}) into the melted Ge subsurface layer
- Fast **epitaxial regrowth**
- Junction depth on the order of **100 nm – 300 nm**



PHOTOLITHOGRAPHY SEGMENTATION

- **Gold deposition** (<100 nm) by RF Magnetron Sputtering on the n+ junction
- **Photoresist deposition** (<1 μm) and **soft bake**
- **UV irradiation**
- Irradiated **photoresist removal**
- **Soft bake** to harden the unremoved photoresist on gold layer
- Gold etching to remove gold between segments
- Hot acetone bath to **remove the photoresist**



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ETCHING & PASSIVATION…*the detector is almost ready*

- The **diode is etched** with (3 : 1) HNO_3 : HF (<10 s) to remove the junction diffusion on the gaps…gold is not chemically attacked by the solution
- The p+ contact and the back surface are protected with Kapton
- Segmented detector **methanol passivation:**
  - **Chemical barrier** for external agents (humidity, condensable vapour)
  - **Electrical barrier** which isolates contacts/junctions or segments from one another

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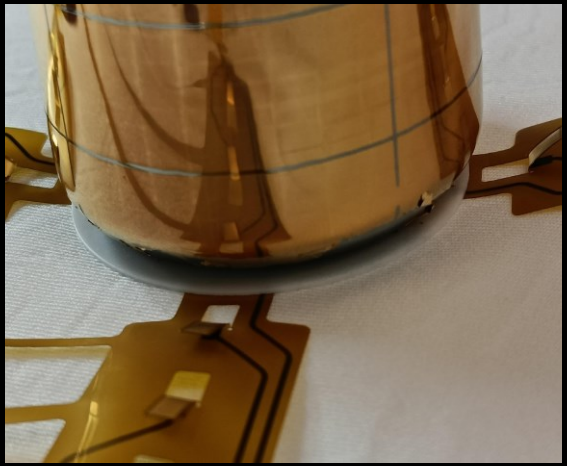
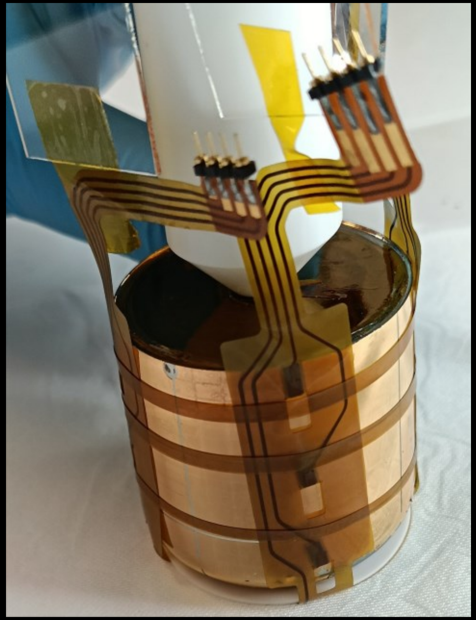
ELECTRICAL CONNECTIONS

- Flower-shaped **flexible PCB** (Printed Circuit Board) to be wrapped around the detector
- **Good electrical contact**, even at cryogenic temperatures
- **No demage** to the detector surface…damages would increase the detector leackage current





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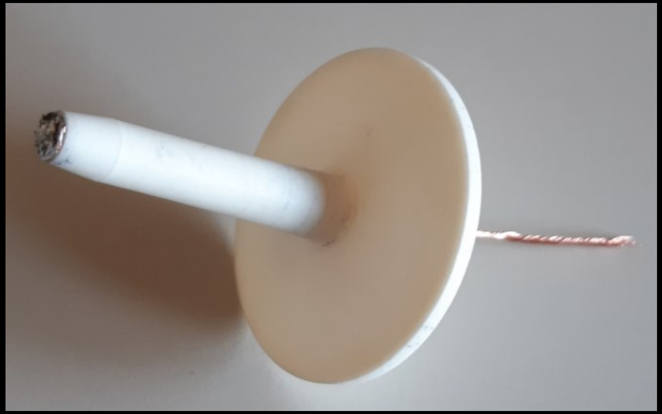
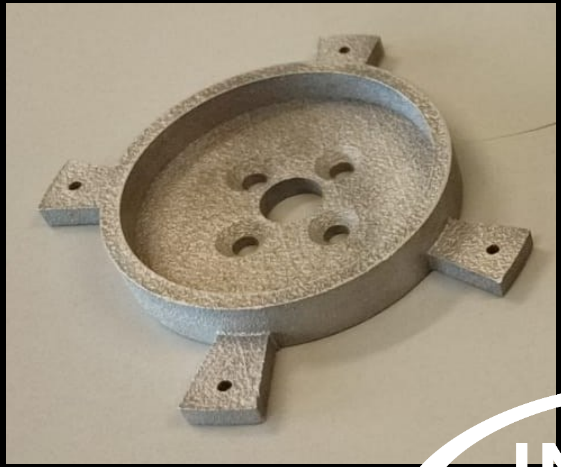
DETECTOR CASE

- The detector is located on an **insulated conical body** made of alumina
  - The cone prevents the detector passivated surface from touching the other mechanical components of the canister
- The dector position is kept through a mechanical system made of:
  - **PEEK (PolyEther-Ether-Ketone) case**
  - **Spring-holder**
  - **Single-wave spring**





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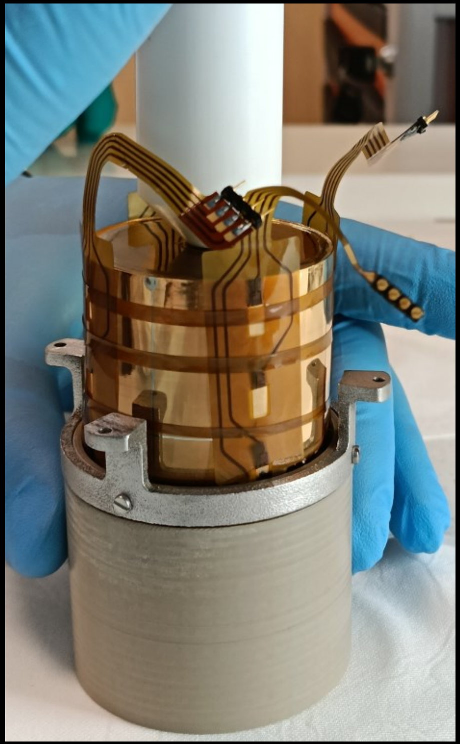
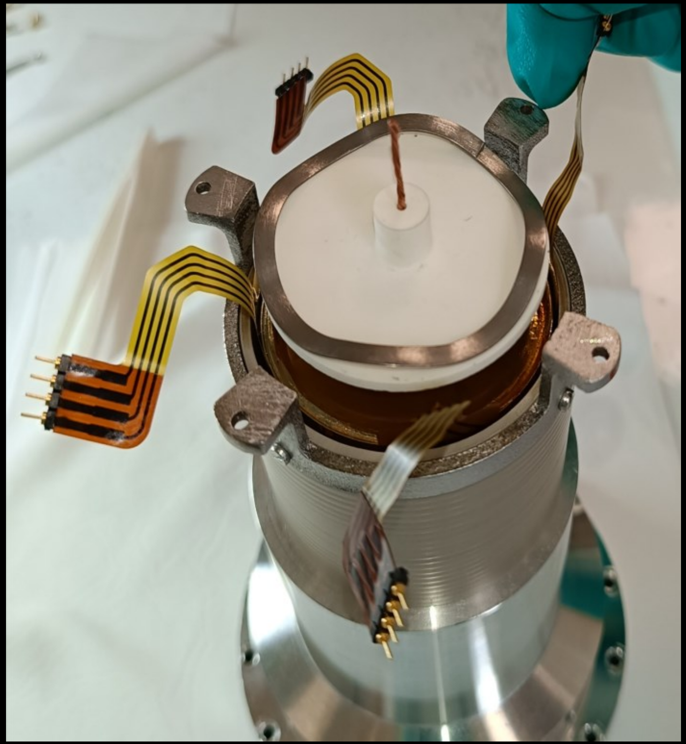
DETECTOR CASE: ASSEMBLY SEQUENCE





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DETECTOR CANISTER

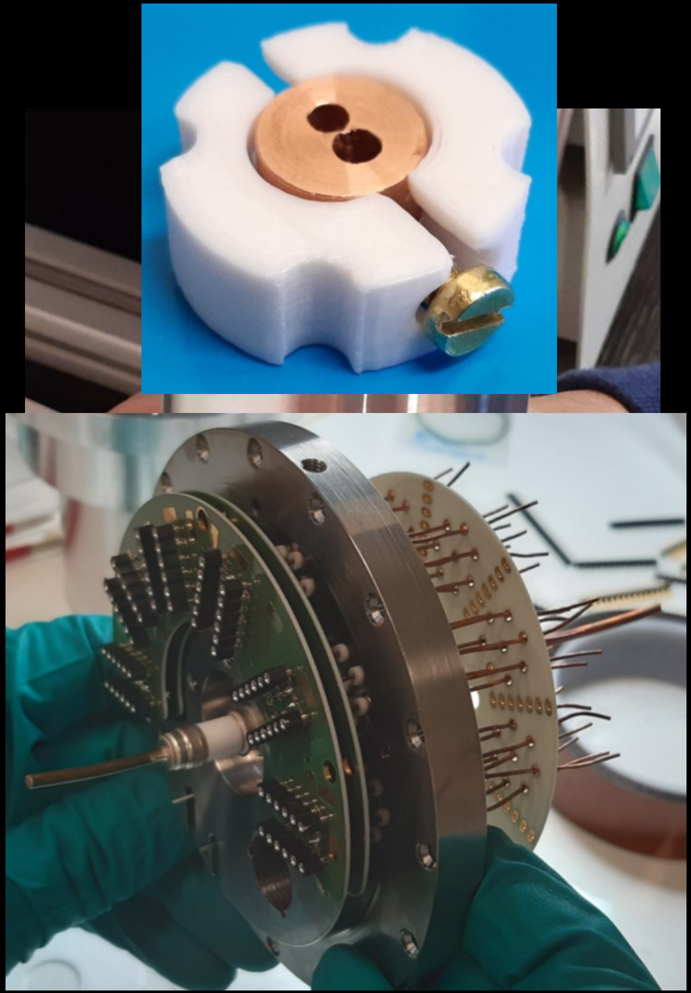
- The detector with its PEEK-case is housed inside a **vacuum-tight canister**

- The canister consists of an aluminum chamber closed at the bottom by a **specifically designed flange**

- The flange is equipped with six **feedthrough connectors** for signals, a **high-voltage rod** and a **vacuum inlet**

    - The high-voltage rod must be connected to the cable coming from the alumina conical body

    - Signals are distributed to the feedthrough connectors by means of a rigid PCB



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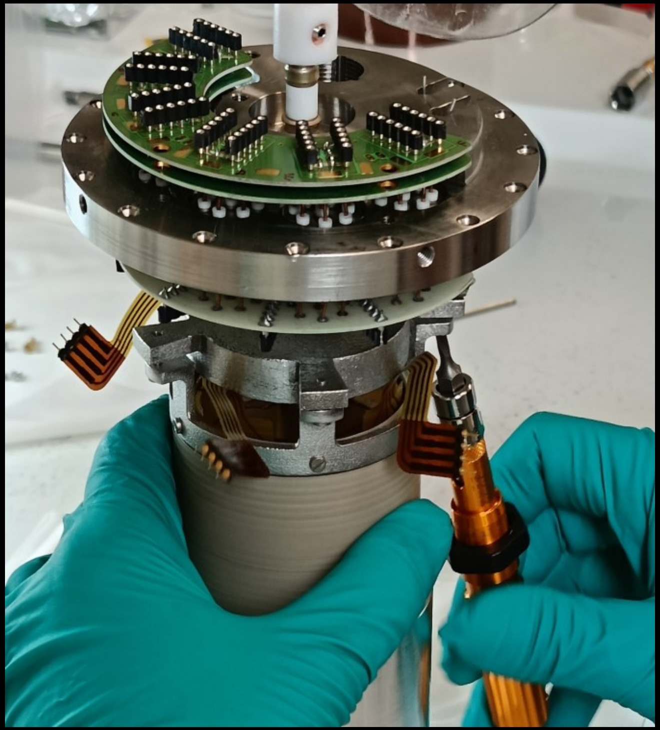
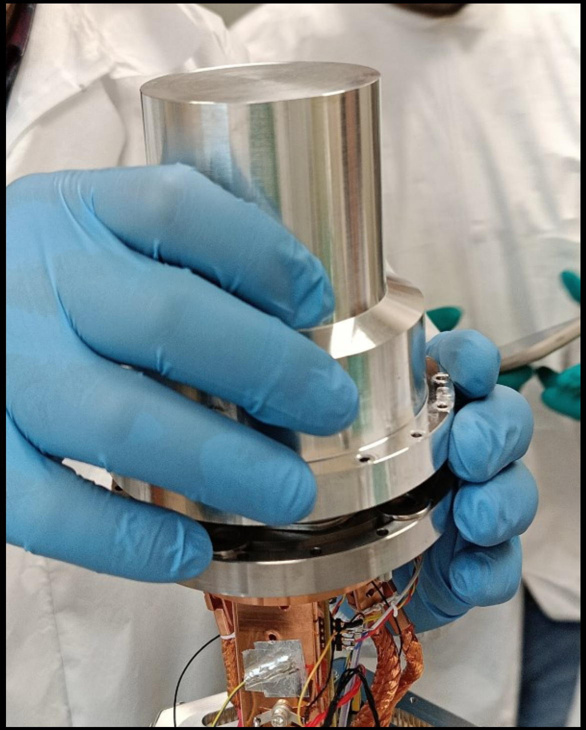
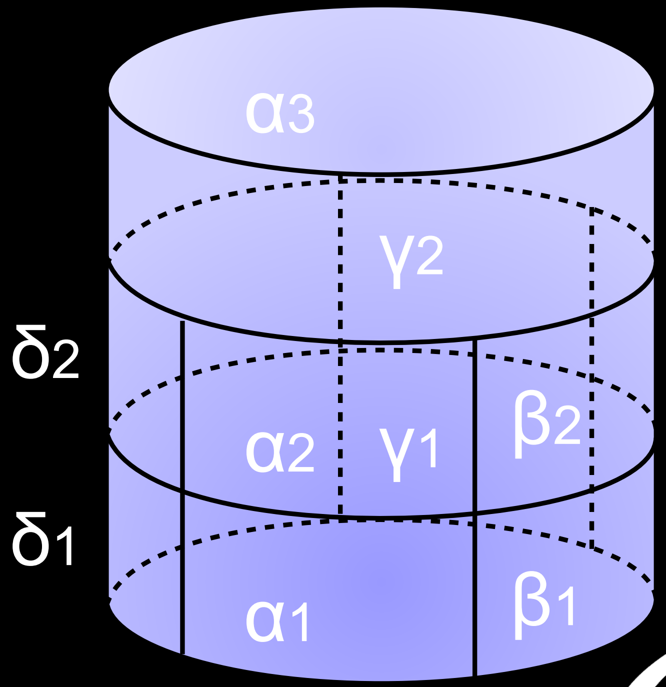




ROOM TEMPERATURE TEST

- Germanium behaves like a conductor at room temperature…
- Electrical continuity between segments and high-voltage rod → the flexible PCB ensures a good electrical connection to the detector electrodes
- Electrical resistance between adjacent segments:
  - 50 Ω between isolated segments
  - 15 Ω between shorts
  - Upper segments not isolated because of accidental gold removal during the etching procedure



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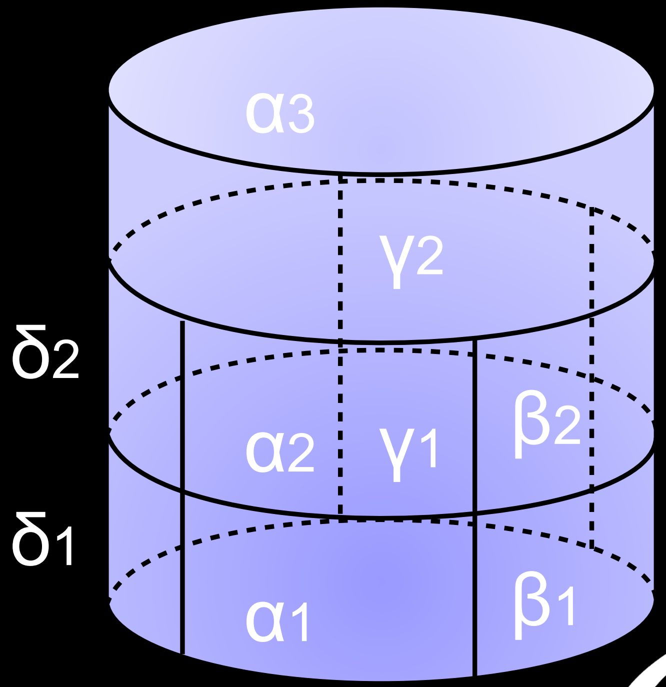
CRYOGENIC TEMPERATURE TEST

- **Current-Voltage curves**: by varying the voltage applied to the inner contact, the leakage current is extracted segment by segment using a precision ammeter
- alpha 3 high leakage current: accidental gold removal
- alpha1, beta1, gamma1,delta1 high leakage currents: gold on passivation
- **Promising results obtained on the central segments**

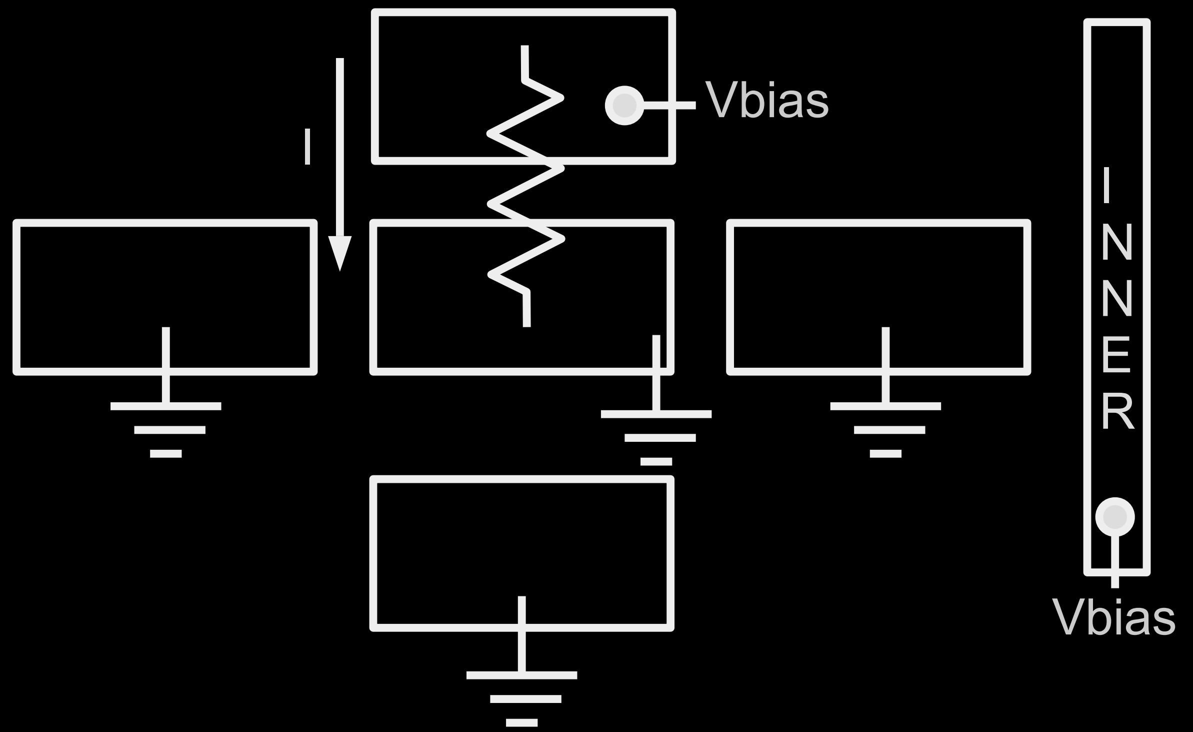
↓

THE ELECTRICAL CONNECTIONS BASED ON FLEXIBLE PCBs EFFECTIVLY WORK



CRYOGENIC TEMPERATURE TEST

- **Electrical Resistance Measurements**
- Resistance is obtained by applying the Ohm's law, knowing the voltage difference between segments and measuring the current through them
- **Resistance** between adjacent segments **on the order of several TΩ**



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CONCLUSIONS

- The **PLM doping** technology has been successfully applied to coaxial detectors
- **Lithography** on coaxial detectors has been **improved**
- The **flexible PCB** has been demonstrated a good way to contact the detector electrodes
- **Functional mechanics** to contain and protect the detector

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