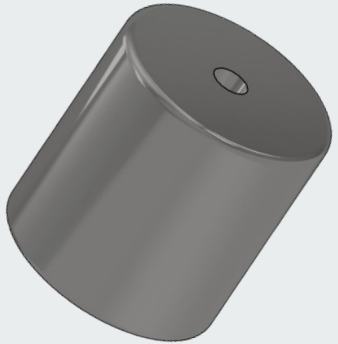
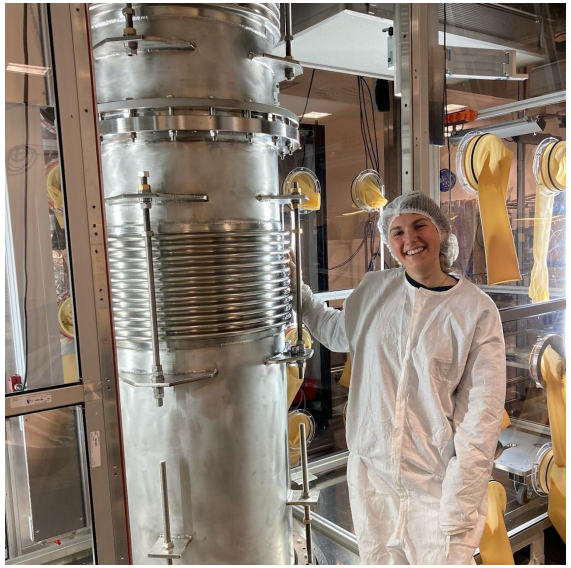
A LEGENDary PhD Journey…
Following Germanium detectors in LEGEND-200



LEGEND UK Workshop
31-03-2022

Abigail Alexander*, Matteo Agostini*, Valentina Biancacci, George Marshall*, David Waters*, Ruben Saakyan*
*University College London

Introduction

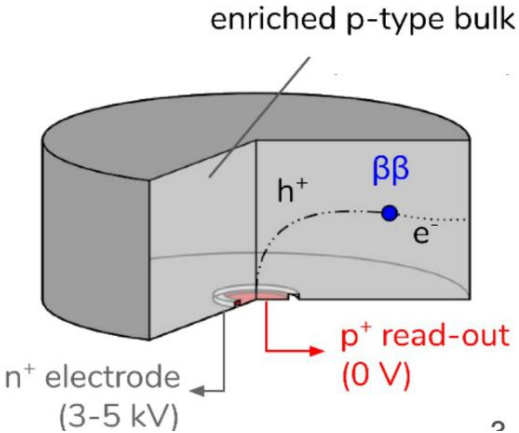


- 3rd year HEP PhD student at UCL
- Research focus (so far):
  - Characterisation of Germanium detectors for LEGEND-200
  - Germanium detector R&D
- Currently on “Long Term Attachment” at LNGS, Gran Sasso, in Italy
  - -> assisting with the installation and commissioning of LEGEND-200

Germanium Detectors

High Purity Germanium (HPGe) Detectors:

- Semiconductor detectors
- Enriched detectors: 92% of detector material is ^{76}Ge
- High spatial and superior energy resolution
- ~100 individual detectors for L-200 of 3 key geometries: PPCs, BEGe, ICPCs

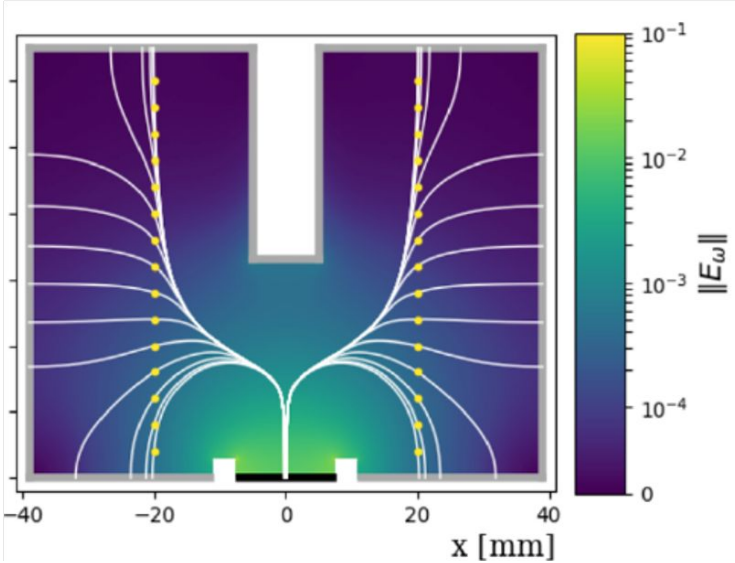


String of HPGe detectors

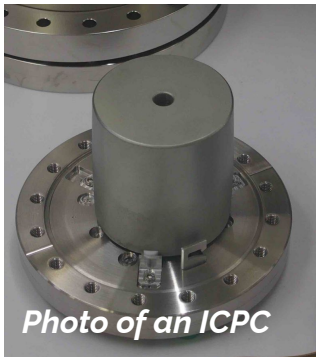
Germanium Detectors

Inverted Coaxial Point Contact (ICPC) Detectors:

- New design with unique geometry
- Large detector mass (up to 4 kg)
- Strong Pulse Shape Discrimination (PSD) power



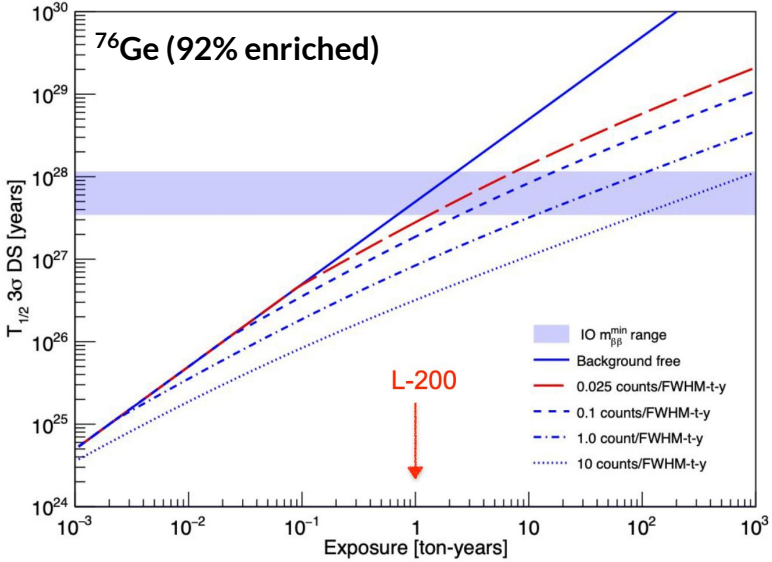
All detectors must be thoroughly characterised before deployment at LNGS!



Detector Characterisation

- **Characterisation Tasks:**
  - Operational voltage
  - Pulse Shape Discrimination (PSD) performance
  - Energy resolution
  - Active volume determination

- **Why:**
  - Low background requires good energy resolution and background rejection from PSD
  - The 0νββ signal strength/half life sensitivity - proportional to total active detector mass

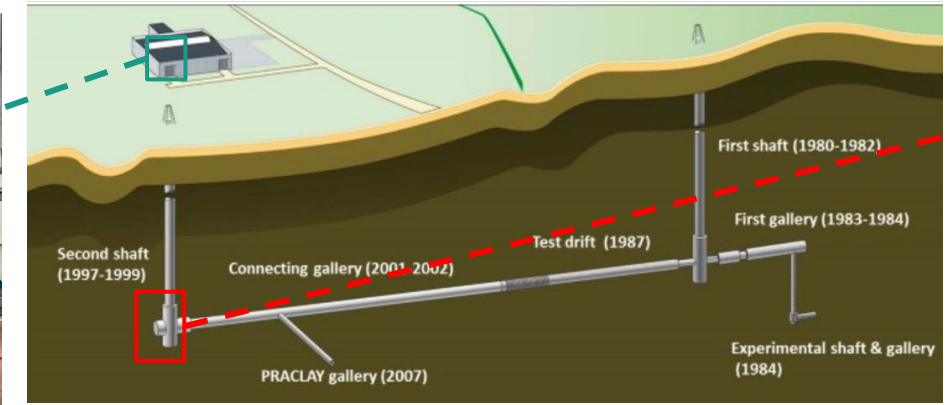


$$T_{1/2}^{0\nu} \propto \sqrt{\frac{M.t}{b.\Delta E}}$$

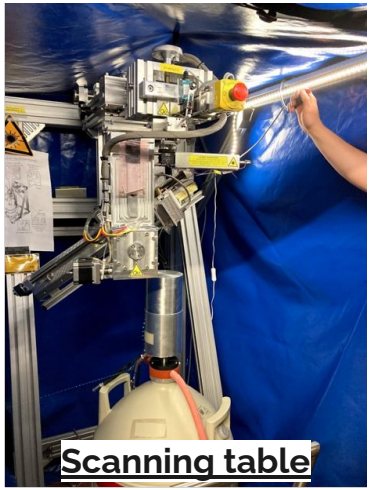
Half life sensitivity

M = active mass, t = time, b = background index, ΔE = energy resolution

Detector Characterisation at HADES

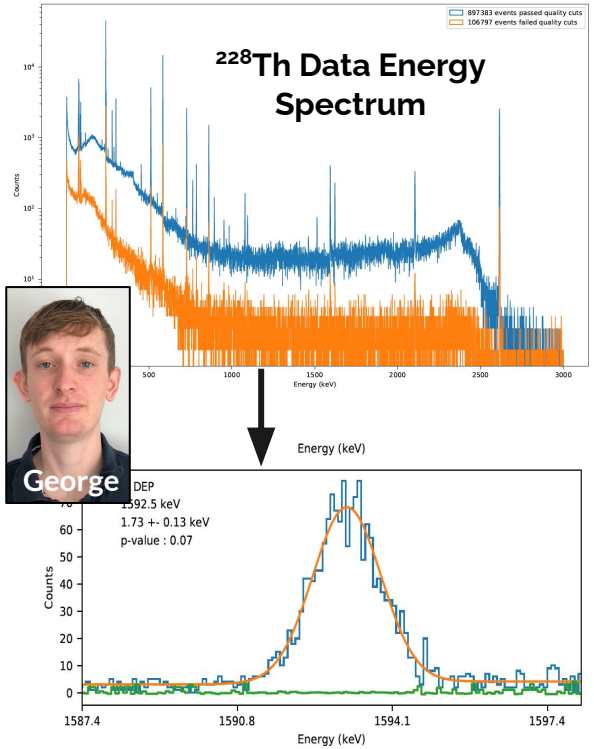


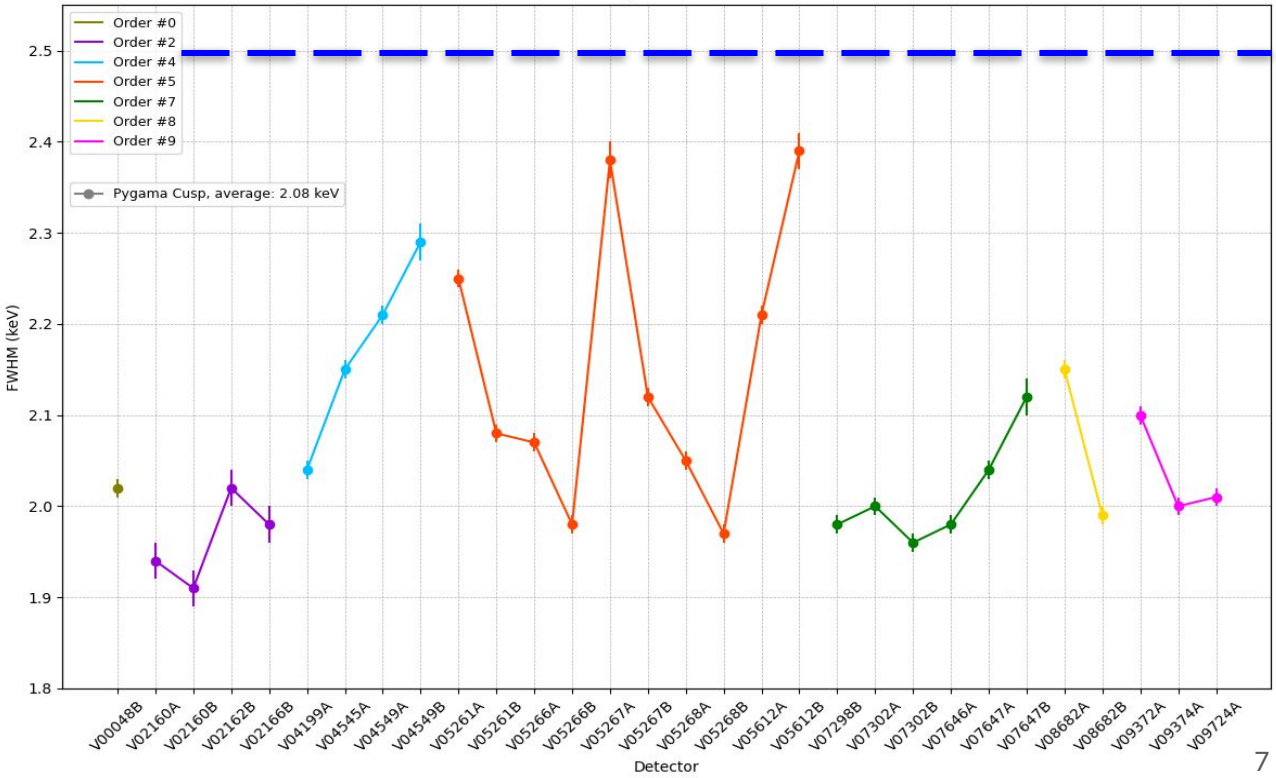
- Detectors are exposed to different radioactive sources and data is taken. E.g.:
  - ^{228}**Th** -> Energy resolution
  - ^{133}**Ba,** ^{241}**Am** -> Active volume
- Ongoing work



Energy Resolution

Current average energy resolution exceeds 2.5 keV target!

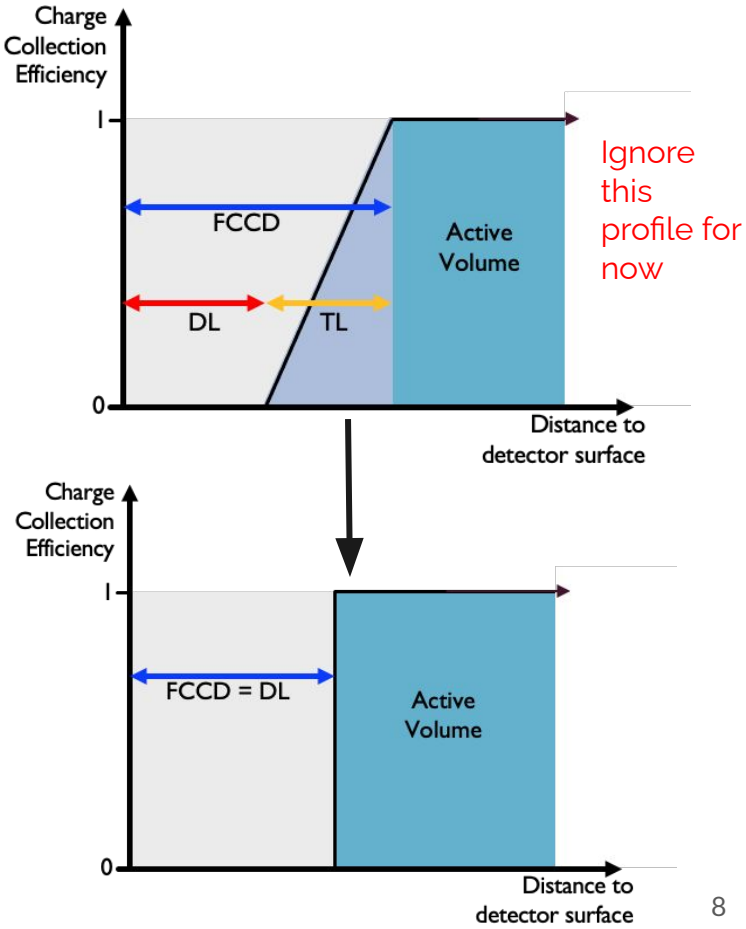




Active Volume

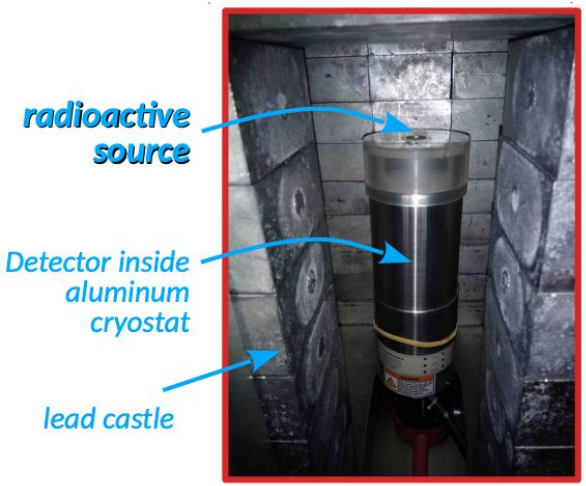
- **Dead Layer** = region of no charge collection on surface of semiconductor detectors. A conductive layer, created by Lithium diffusion.
- **Transition Layer** = partial charge collection
- **Full Charge Collection Depth (FCCD)** = Transition Layer + Dead Layer
  - NB: the TL is ignored currently at first order such that FCCD=Dead Layer

- **Determination of detector active volume is important for LEGEND because:**
  - The 0νββ half-life is a function of active mass
  - Degraded events could mimic 0νββ signature

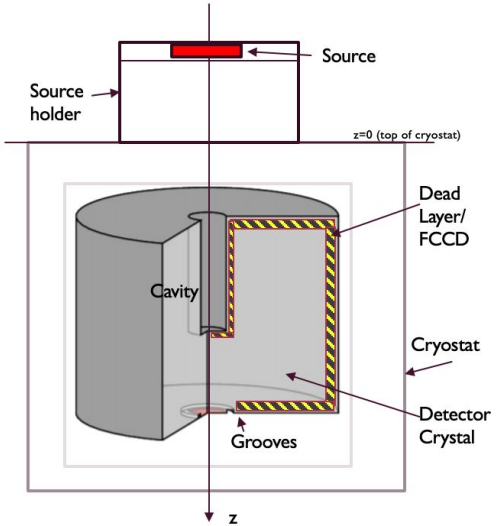


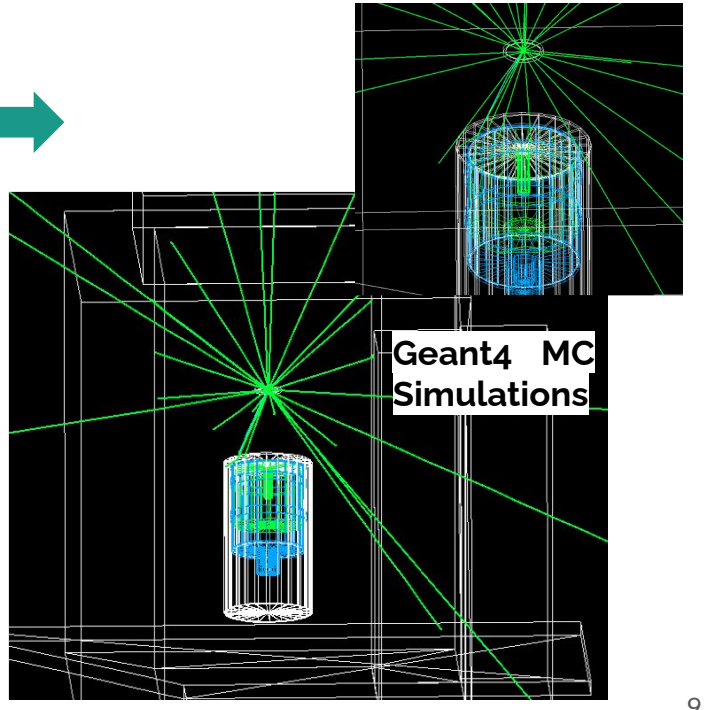
Active Volume: from Data to Simulations

- To determine the FCCD of each detector, we compare the **data** to **simulations** processed with different FCCDs.

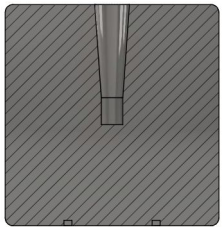


Experimental set up with a flood ^{133}Ba source, in top position



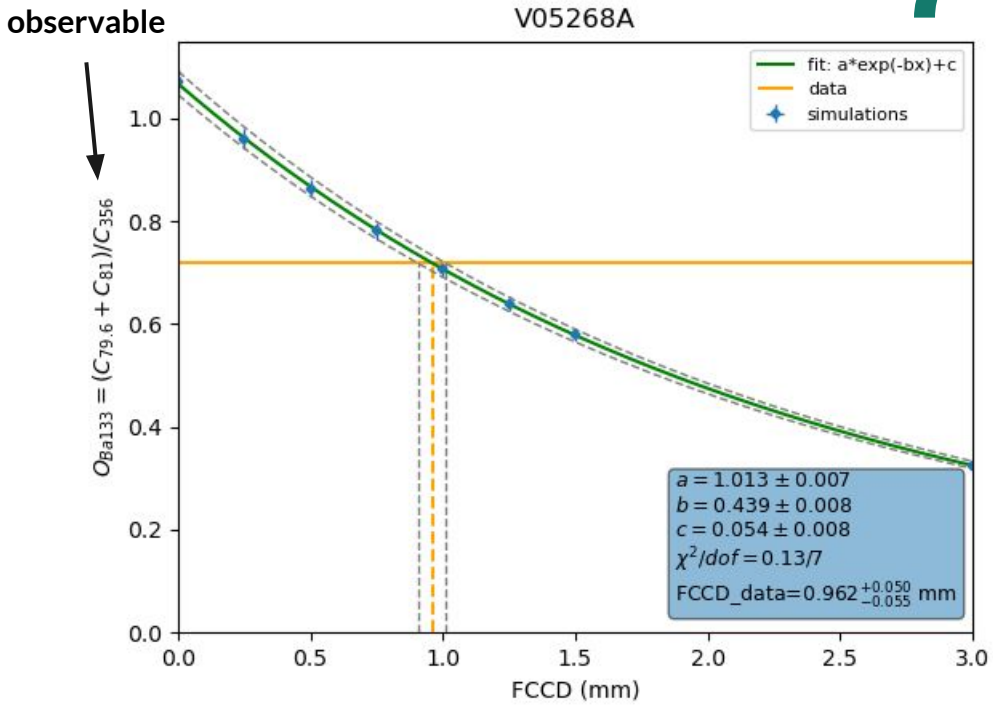


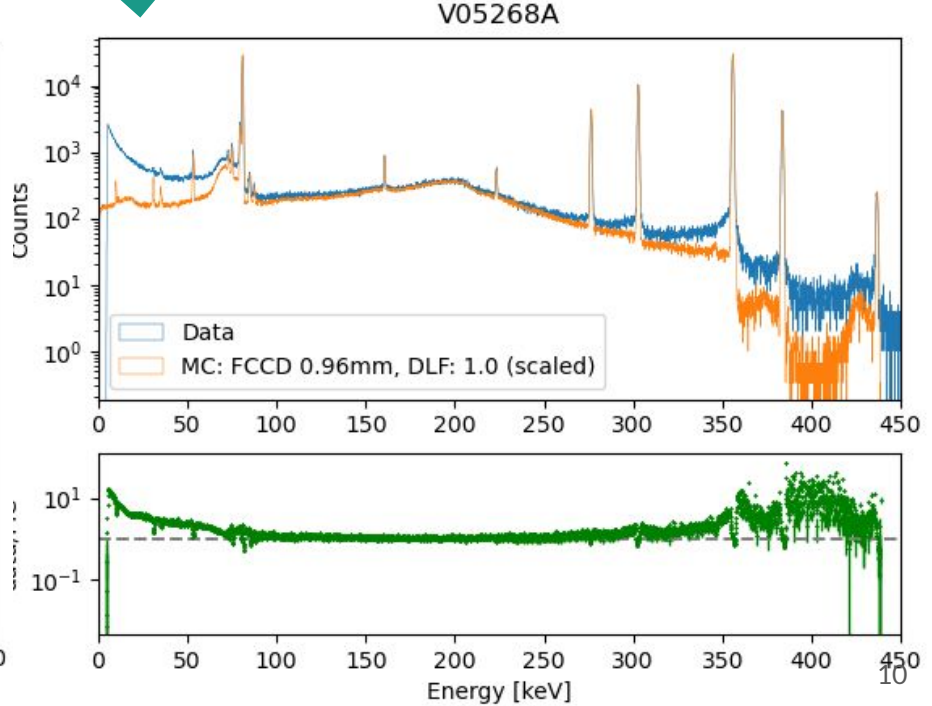
Active Volume: FCCD Determination



FCCD sensitive observable

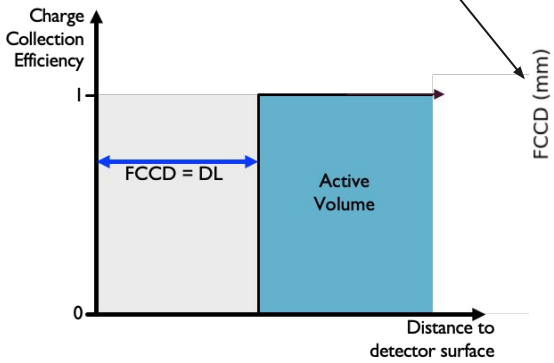
- Example analysis using ^{133}Ba

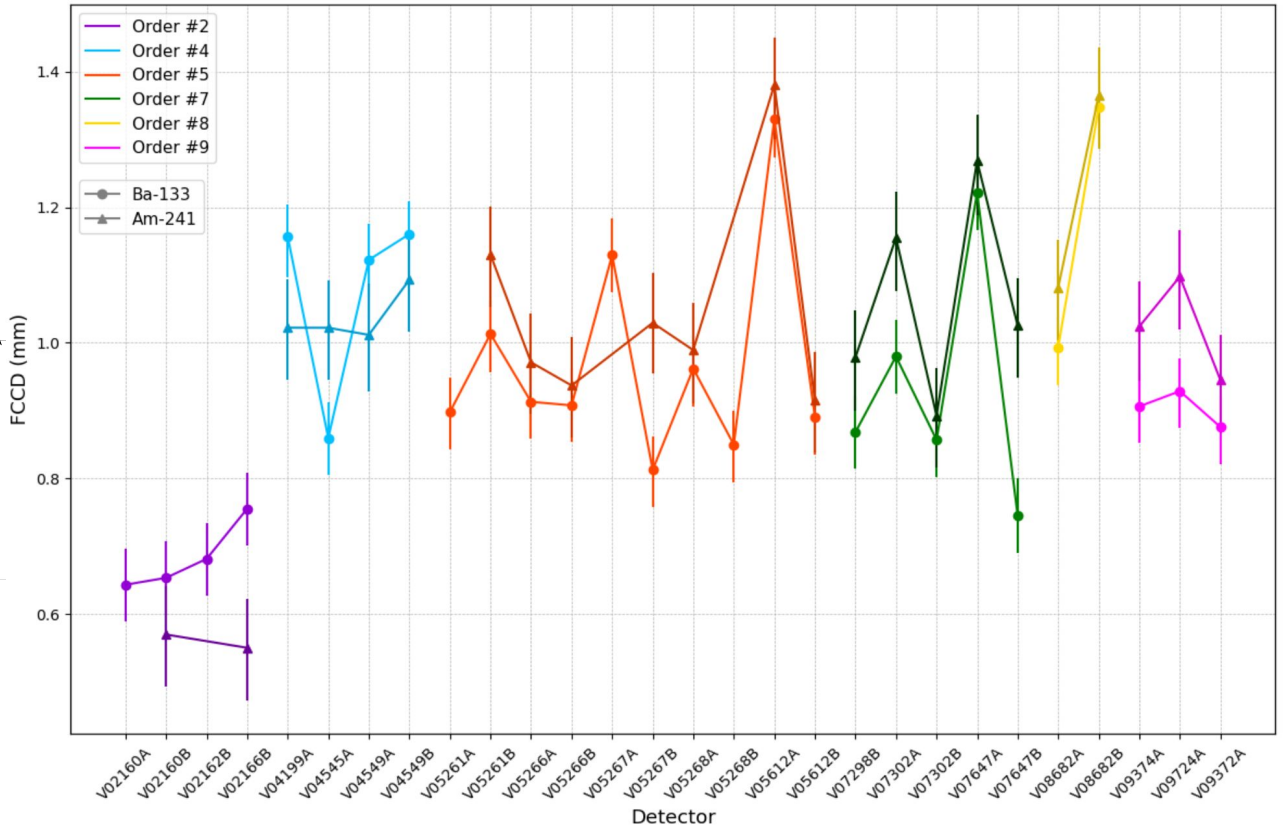




Active Volume: FCCD Determination

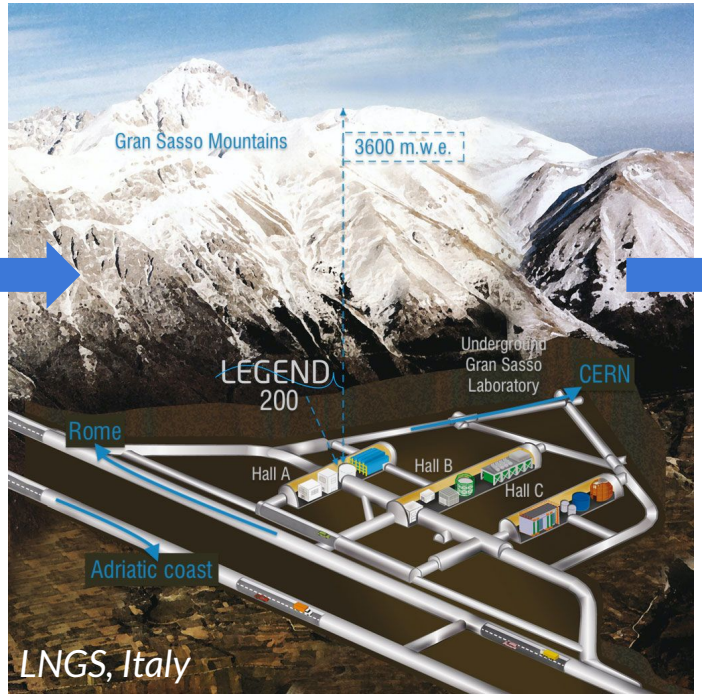
Full Charge Collection Depth = Dead Layer, to first order





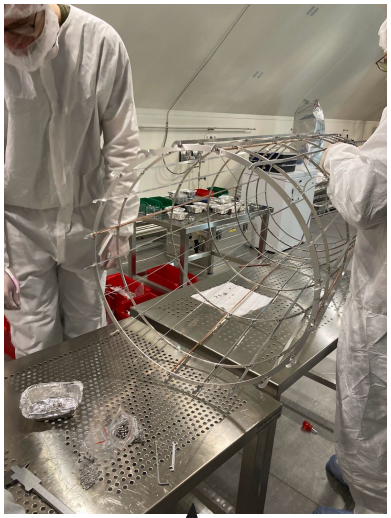
Next step: Model the Transition Layer!

LEGEND-200 Commissioning

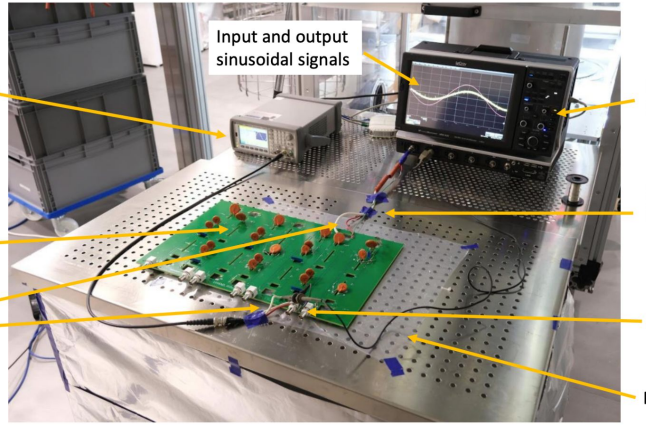


1x Brexit and 1x global pandemic later… and I've finally started my LTA here!

LEGEND-200 Commissioning

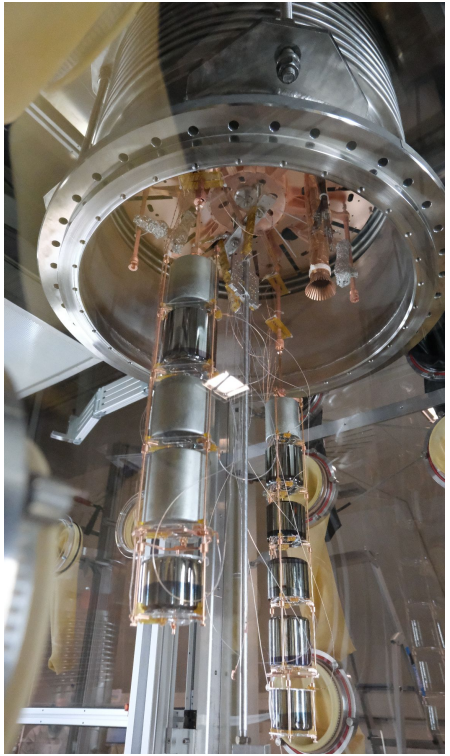


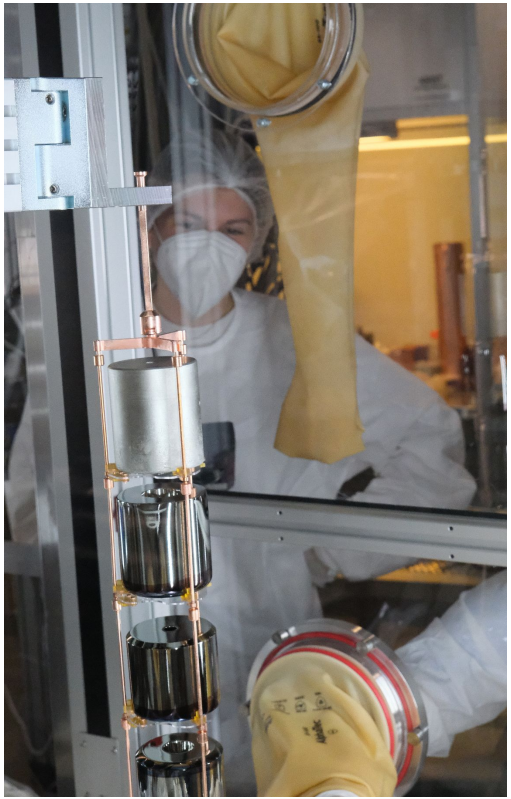
Liquid Argon instrumentation commissioning



Characterising the High Voltage filter

LEGEND-200 Commissioning: “2 String” Tests





Summary

- I'm a 3rd year PhD student at UCL, primarily working on detector characterisation for LEGEND-200
- Ahead of physics data taking, HPGe detectors must be characterised - this is ongoing work in underground laboratories such as HADES
- Two important characterisation tasks are the energy resolution and active volume determinations.
  - The energy resolution has been determined and currently exceeds target
  - The FCCDs have been estimated -> next step is to model the transition layer
- LEGEND-200 is now commissioning and we are currently testing detector strings
- Would definitely recommend living in Italy (and a PhD with LEGEND)