The GERDA Phase II detector assembly

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Outline

- Introduction to Phase II of the GERDA experiment
- Phase II detector array
- Contacting solution
- Integration test
- Conclusion

GERDA Phase II

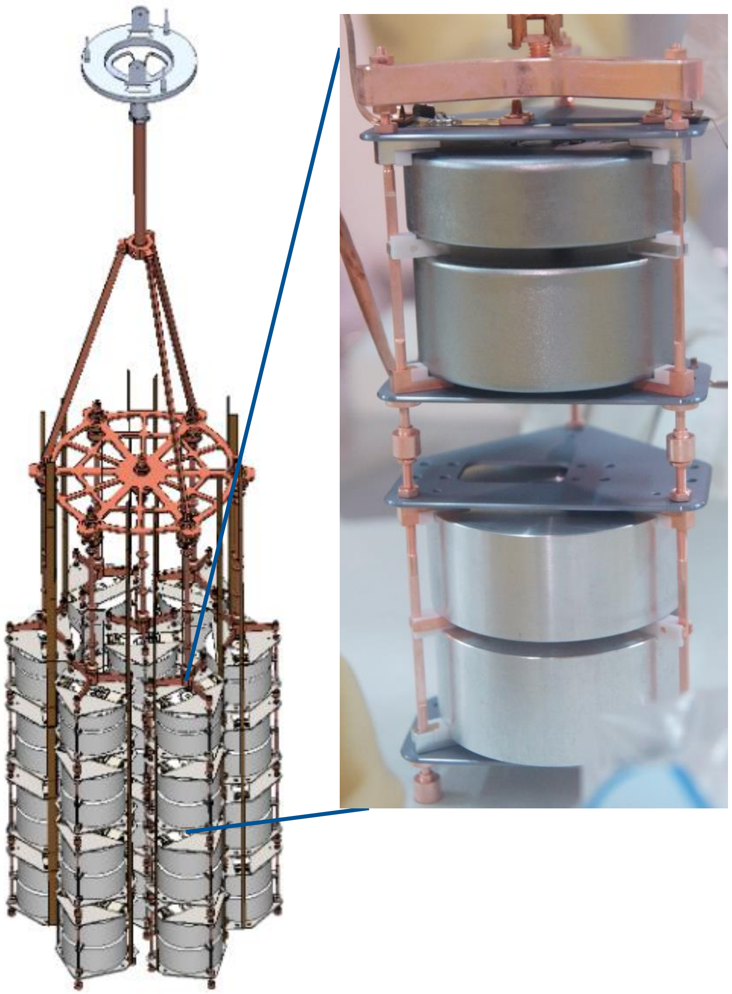
- New custom-made detectors (BEGe) of ~20 kg total mass
- Improved energy resolution Δ (E) & pulse shape discrimination capabilities
- Background index aim 10 times lower than Phase I: < 0.001 cts/(keV·kg·yr)
- Active & passive reduction of background events
  - Pulse Shape Discrimination (PSD) (T 105.4)
  - Instrumented liquid argon volume (T 65.4, T 32.7)
  - Passive shielding by rock, copper, water & argon
  - Radio pure & low mass components e.g. holder structure, front-end electronics, cables, etc (This talk)

Sensitivity for limit of $T_{1/2}$ of neutrinoless double beta decay

$$T_{1/2} \propto \epsilon a \sqrt{\frac{Mt}{BI\ \Delta(E)}}$$

ε: detection effiency
a: abundance of Ge-76
M: mass [kg]
t: exposure time [yr]
BI: background index $[\frac{\text{counts}}{\text{keV}\cdot\text{kg}\cdot\text{yr}}]$
Δ (E): energy resolution at ROI around 2039 keV

Phase II detector array

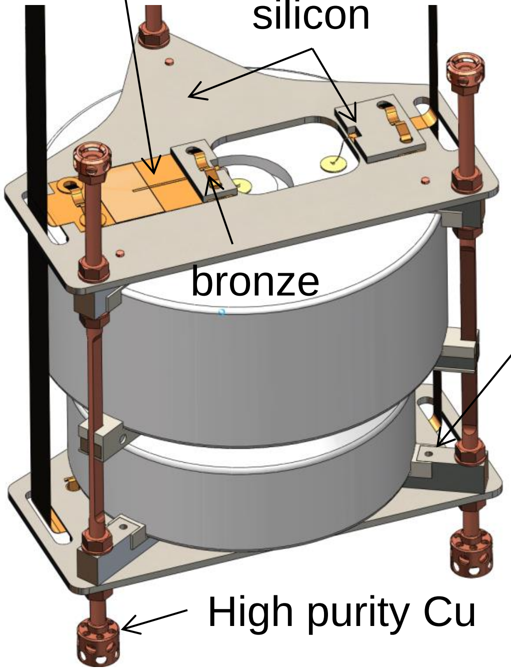


- 7 strings of detectors
- 15 pairs of BEGe detectors mounted back-to-back
- 7 semi-coaxial detectors also from enriched Ge & 4 from natural Ge
- Dense packing allows better anti-coincidence cut (detectors from natural Germanium help)

Phase II detector mount

The Phase II detector mount

- Material in vicinity of detectors to be reduced
  - Detector mount & Front-end electronics
- Reduction of holder mass per kg detector mass necessary (BEGe smaller than semi-coax!)
- Replace as much copper as possible with intrinsically pure mono crystalline silicon
- Design achieves factor ~1.5 reduction copper & PTFE mass per kg detector mass
- New contacting scheme (wire bonding) allows holder with reduced mass & material strength i.e. Si



Material	Phase I holder		Phase II holder	
	[g]	[uBq]	[g]	[uBq]
Cu	80	<1.6	26	<0.5
Si	1	-	40	-
PTFE	7	0.3	2	~0.1
Bronze	-	-	1	<0.02

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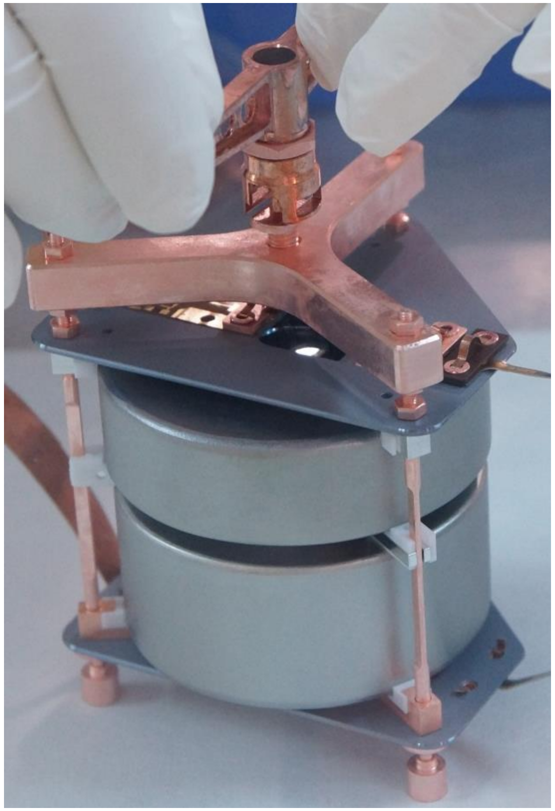

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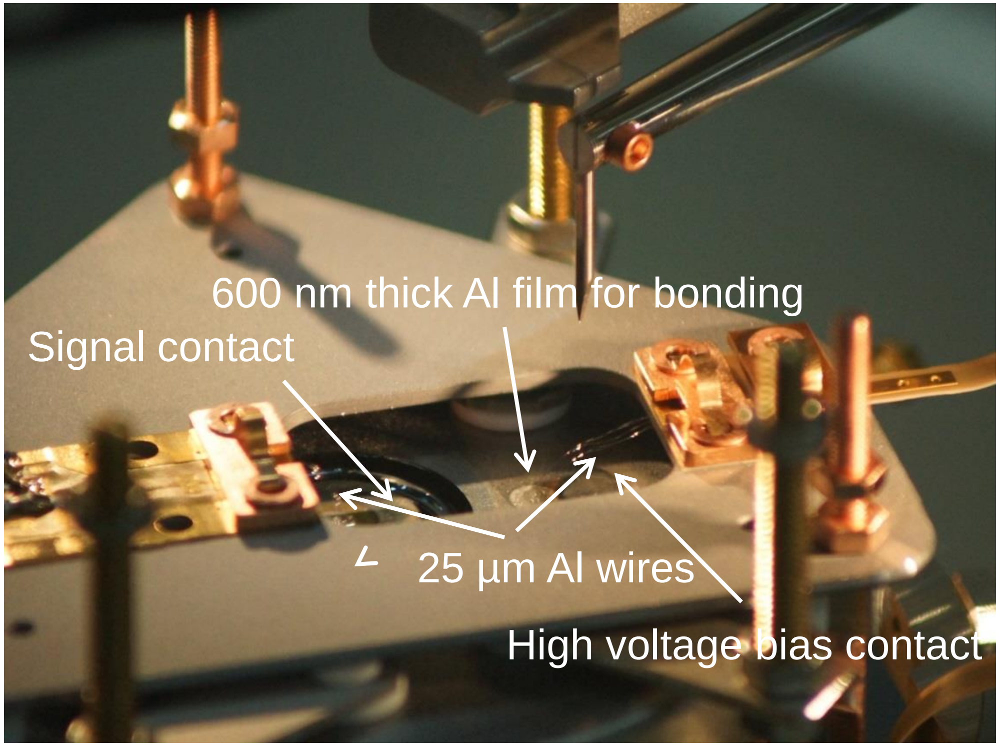
The Phase II detector mount - contacting

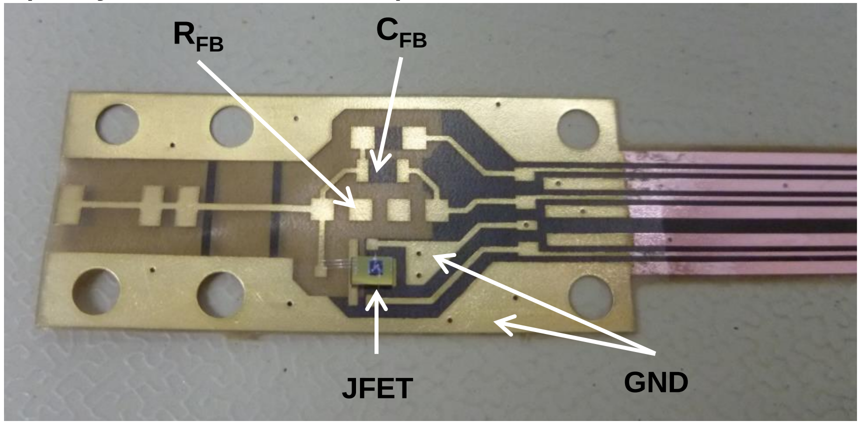
- Ultrasonic wire bonding identified as a low-mass, reliable electrical contact between detector, amplifying electronics and HV supply
- First time large volume Germanium diode detectors contacted with wire bonding
- Deposition of Al thin film on germanium diodes to allow bonding at manufacturer‘s site
- All 30 BEGe‘s from enriched Ge modified

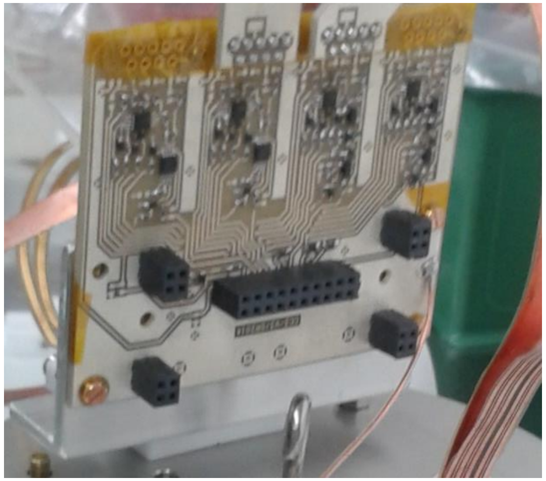


Integration test

Phase II Front-End electronics

Resistive feedback circuit of FE electronics (Very front-end VFE)



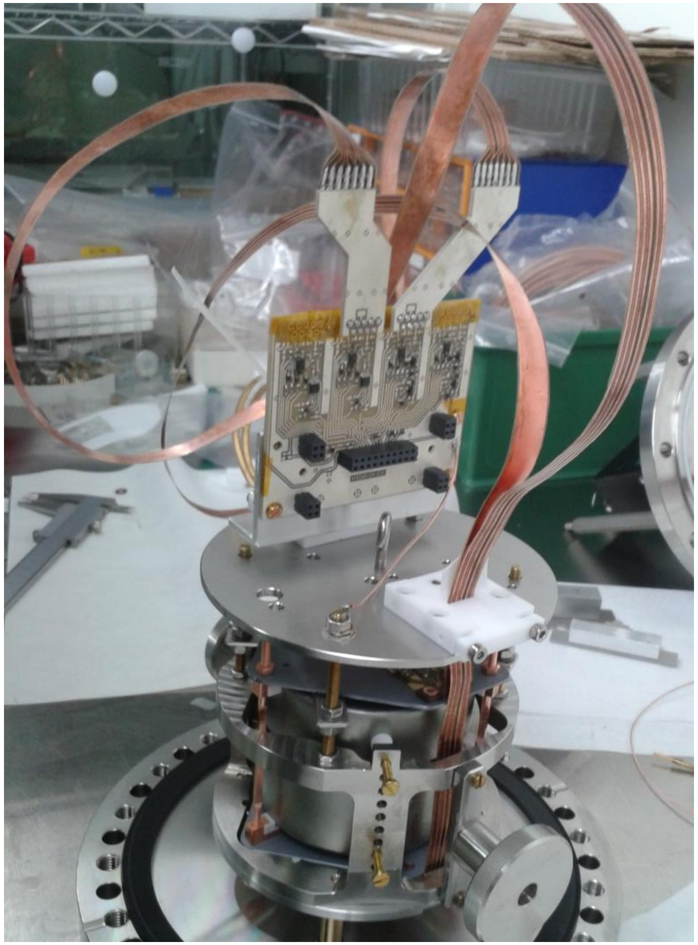


2nd stage (CC3) for 4 channels

- Seperation of Very Front-End and second stage of FE charge sensitive amplifier (CC3)
- Advantages
  - Minimal mass and radiopure components for VFE possible
  - More radioactive & complex 2nd stage further (~50 cm) from detectors
  - Additional capacitances between signal contact and JFET minimized, eg. from cables etc -> less noise

Phase II Front-End electronics

Test setup with realisitic cables length



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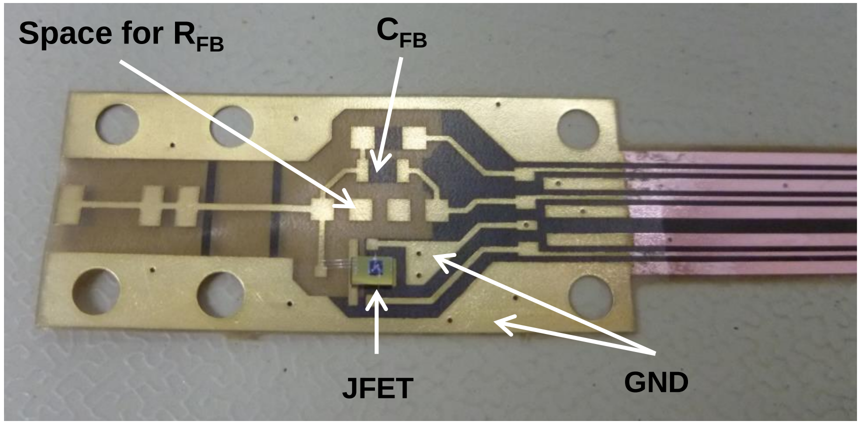
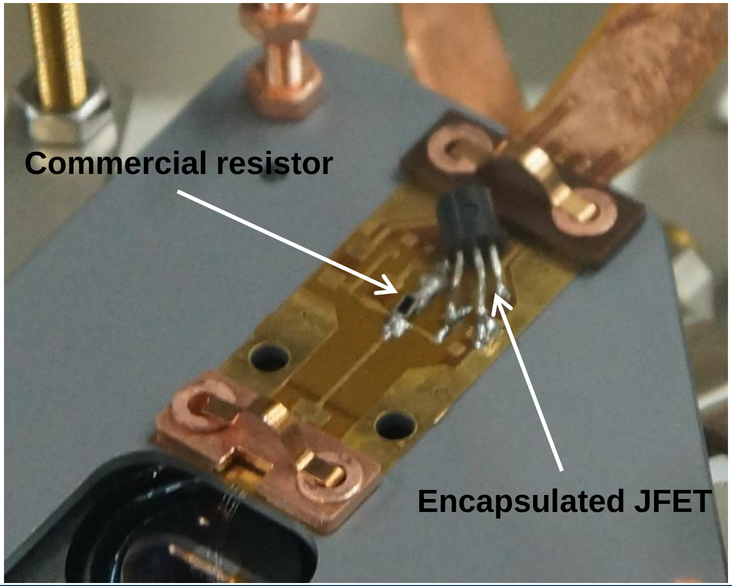
Phase II Very Front-End electronics

- Components integrated on flexible cable
- Cable made from CuFlon (PTFE + Copper surface)
- Components:
  - JFET: in-die, low capacitance, glued on traces, bonding for contact
  - Capacitor: stray capacitance between traces
  - Resistor: High resistance, low background, no ceramics! Several options available



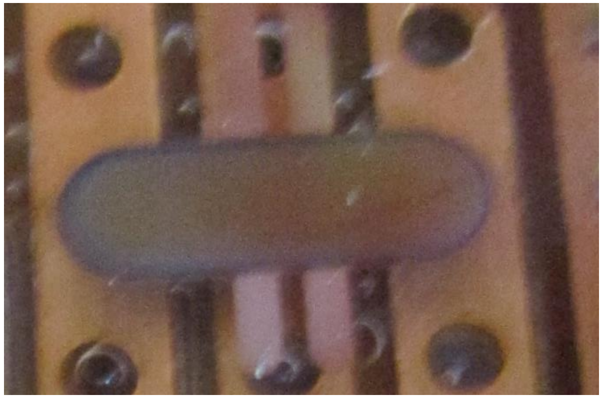


Feedback resistor for Phase II

- High resistance of feedback resistor reduces thermal noise
- Too high resistance causes pile-up
- ~ GOhm aimed at for GERDA
- Parasitic capacitances must be avoided
- One option: amorphous Germanium*
- Other options: TiN & Tungsten being investigated

For a-Ge option:

- Advantages:
  - High resistivity at LAr temperature, compact design possible
  - low radioactivity, high quality Germanium extremely radiopure



- Test production at TUM on going
- Dimensions: 0.5mm x 2 mm x 1 µm
- Passivated with SiO2

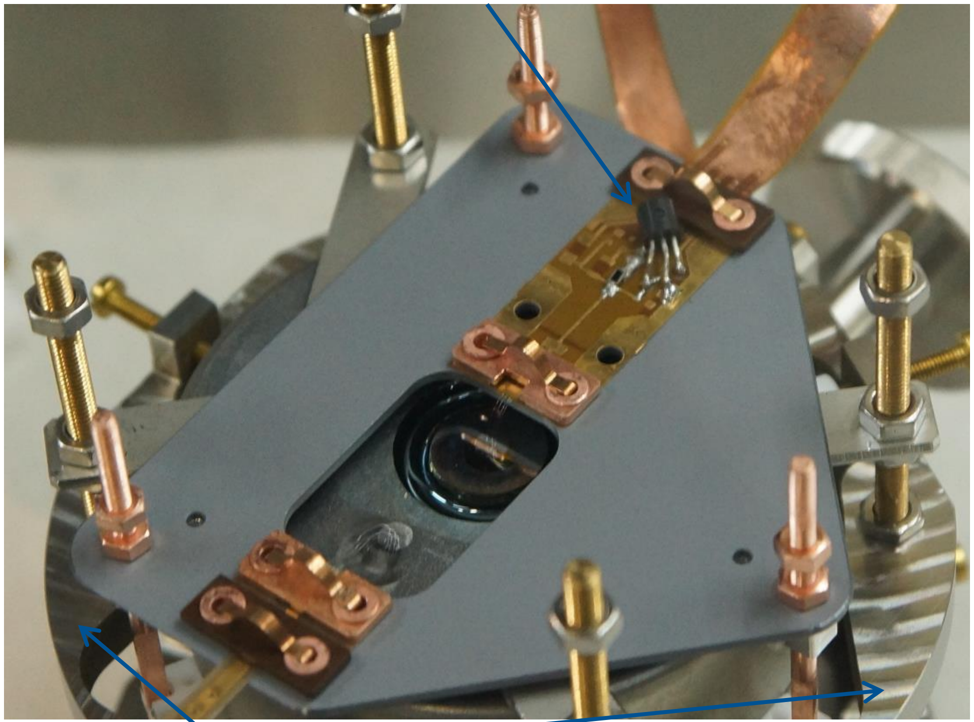
- Disadvantages
  - Low resistivity at 300K, testing of circuits only possible at 80 K
  - Germanium oxidation changes resisitivity
  - Amorphous materials are meta-stable, by thermal activiation reordering of atoms possible

*P. Barton et. al., 2011 IEEE Nucl. Sci. Symp.,Conference Record N40-6

Tests of integrated detector pair

- Two test detectors with Al films mounted in Phase II holder
- Bonded to make electrical contact
- Tests of newly designed Phase II electronics; also with JFET in-die
- Test of assembly in liquid argon cryostat (Noise, microphonics, handling in glove box, stability)
- No principal issues with designs of holder, contacts & electronics found
- Th-228 calibrations taken like in GERDA

Encapsulated JFET



Mounting structure

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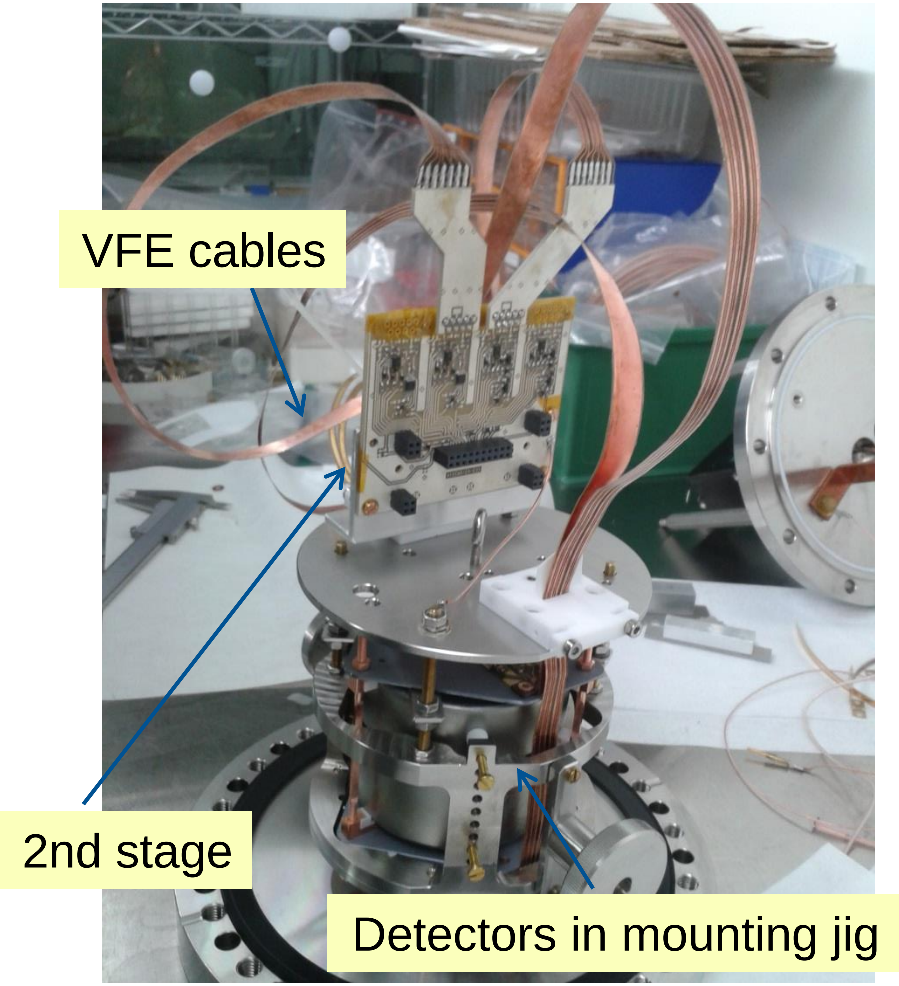
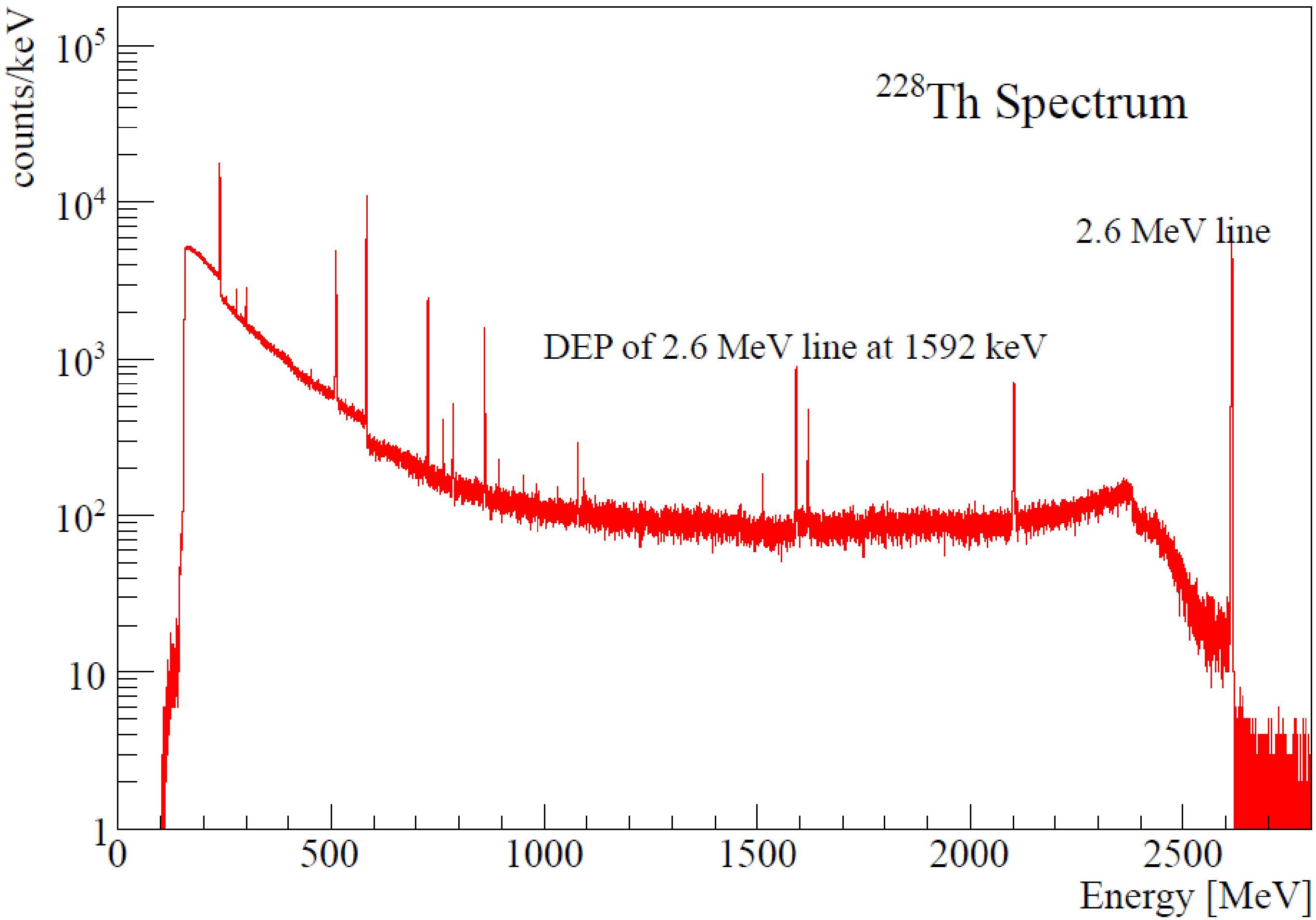


Performance - energy spectrum



Performance – energy resolution

Measurement with Th228 source & detector 2/B

Peak [keV]	Fitted peak position [keV]	FWHM [keV]	Rel. resolution [%]
583.191	583.09± 0.00	1.49 ± 0.00	0.26
1592.537	1592.17 ± 0.01	2.14 ± 0.02	0.13
1620.500	1620.03 ± 0.01	2.12 ± 0.03	0.13
2614.533	**2614.20 ± 0.00**	**2.71 ± 0.01**	**0.10**

- Energy resolution of BEGe‘s in **Phase I with not close VFE** (CC2): **3 keV** @ 2.6 MeV during calibrations
- Energy resolution with **new VFE** and **2nd stage** (CC3) **during** integration tests in **LAr** and **final cable length**: **2.7 keV** @ 2.6 MeV
- Resolution in **vacuum cryostat** (under ideal conditions): **2.4 keV** @ 2.6 MeV
- Despite radiopurity constraints CC3 & VFE achieve very good energy resolution with minimal amount of components and material
- Main advantage of Germanium detectors (resolution) further improved

Conclusion & Outlook

- GERDA Phase II will use active & passive reduction of radioactive backgrounds
- New detector supports introduce less radioactivity
- New reliable low mass contacting method (wire bonding) needed modification of diodes
- All enriched BEGe modified & available for integration
- Integration tests prove excellent energy resolution of electronics together with detectors in realistic environment

- For VFE a low-background resistor needs to chosen
- Further integration tests with prototype detectors on-going (Proof of pulse shape discrimination capabilities, stability over time etc.)
- In late spring /summer integration of detectors for GERDA should start

Thank you for your attention