DEGAS Critical Items

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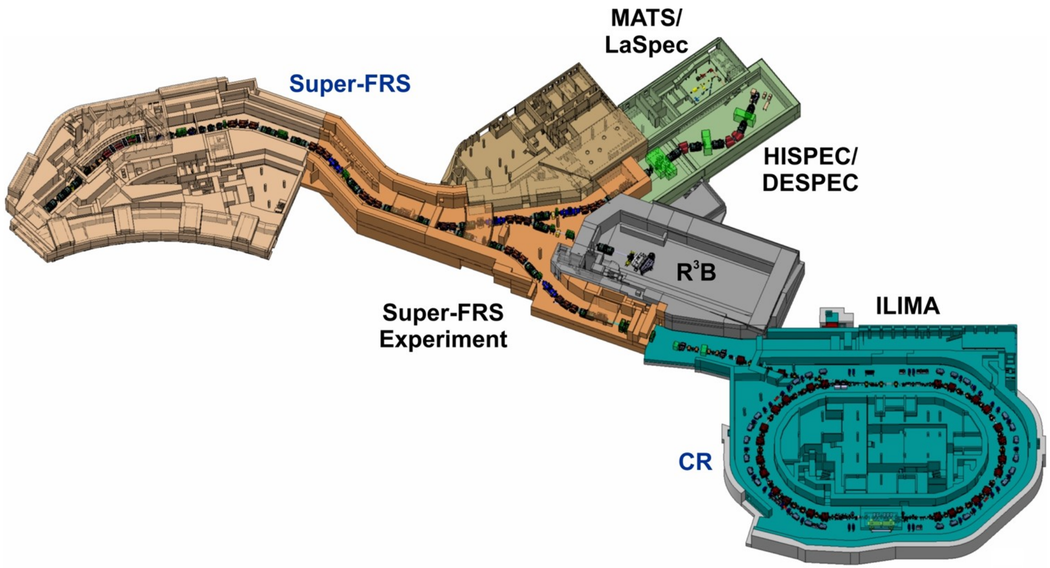
Outline

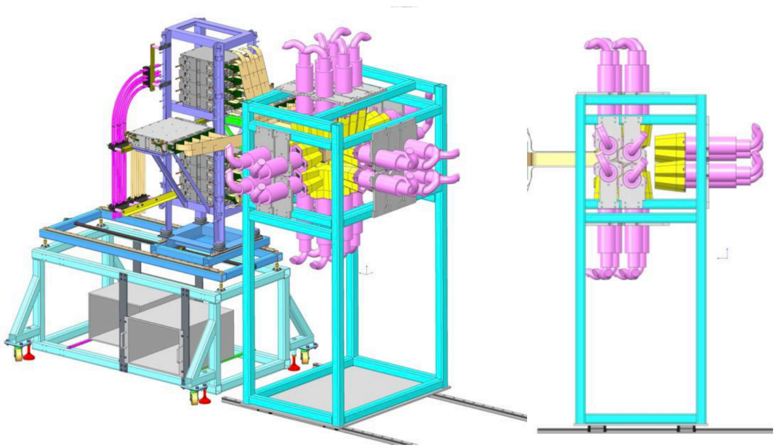
- Brief description
- Status of various sub-components
  - Mechanics of cryostat and vacuum
  - Electronics
  - BGO back catcher
  - Cooling machine
- Challenges
- Timeline

DEGAS – the HPGe array spectrometer for NUSTAR

1. HISPEC/DESPEC at NuSTAR



DESPEC (DEcay SPECtroscopy)
Runs DEGAS as the basic spectrometger



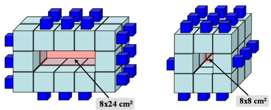
Collaboration of:

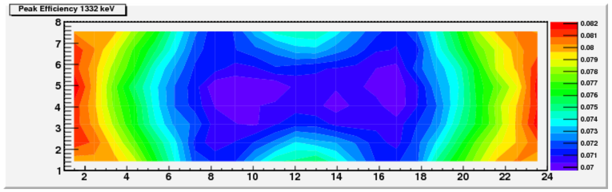
- Germany
- India
- Turkey
- Romania
- Spain
- Sweden
- UK
- Finland

DEGAS – the HPGe array spectrometer for NUSTAR

2. DESPEC setup

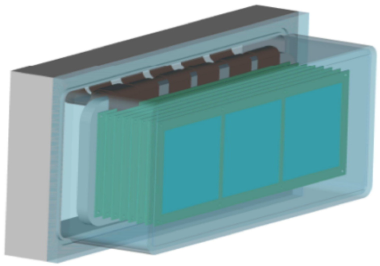
Extensive simulations have been done over the years in order to evaluate the efficiency and the overall performance of the HPGe detector array. Starting from a planar detector array…



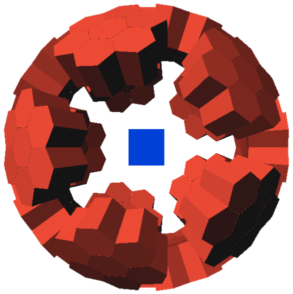


The planar array (2004) and the peak efficiency (2008)

Property	RISING	Phase I	Phase II	Phase III
Array type	Composite Ge detector array	Composite Ge detector array	Phase I complem. by γ-tracking dets.	γ-imaging array
Energy range (keV)	50-5000	50-5000	50-5000	50-5000
Noise threshold (keV)	24	15	15	10
Energy resolution (at 1.3 MeV)	2.3 keV	2.3 keV	2.3 keV	2.0 keV
Full energy γ-detection efficiency (at 1 MeV)	16%	16%	18%	>20%
Effective full energy efficiency after prompt flash blinding	13.9%	14%	16%	20%
P/T-value	34%	34%	40%	>50%
Time resolution (at 1.3 MeV)	13 ns	10 ns	10 ns	< 10 ns
Overload recovery time	≤ 1ms	100 ns/MeV	100 ns/MeV	100 ns/MeV
Relative background suppression	1	5	10	100
Coverable implantation area	16 x 8 cm^2	24 x 8 cm^2	24 x 8 cm^2	24 x 8 cm^2
Max. acceptable event rate (kHz)	3.5	10	10	10



The model of the AIDA implantation detector with its Al housing as considered in the simulations



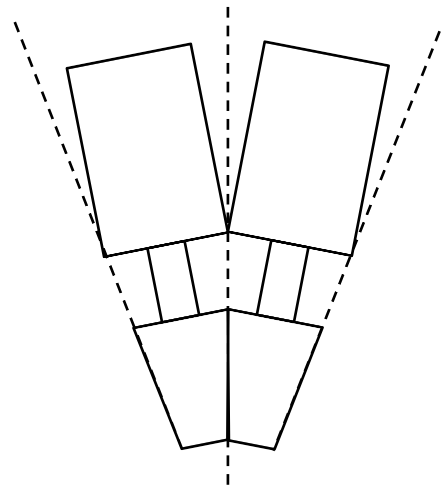
RISING "stopped beam" configuration coupled with the short AIDA implantation detector.

DEGAS – the HPGe array spectrometer for NUSTAR

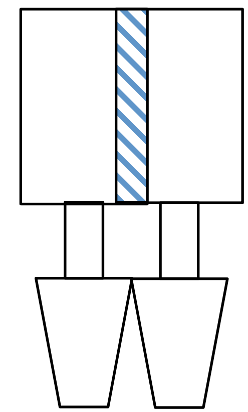
3. DEGAS detector

DEGAS Constraints

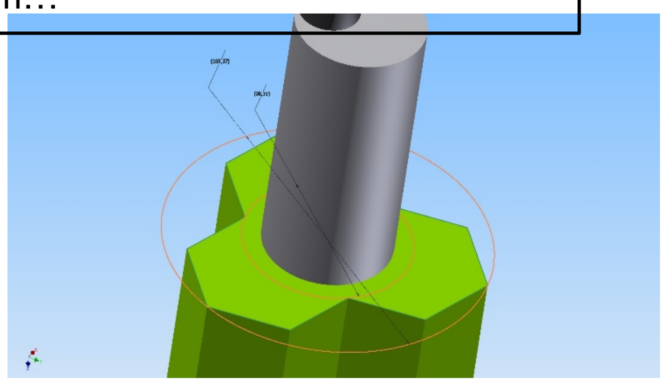
- Physical - The geometry
- Functional - Too small dewar would require too frequent filling – LN2 boiling interference, reliability, too little time for reaction by alert etc.
- Reliability – LN2 systems for refilling are not sufficiently reliable and too frequent filling increases the risk of failure unacceptably. Not only the filling system…

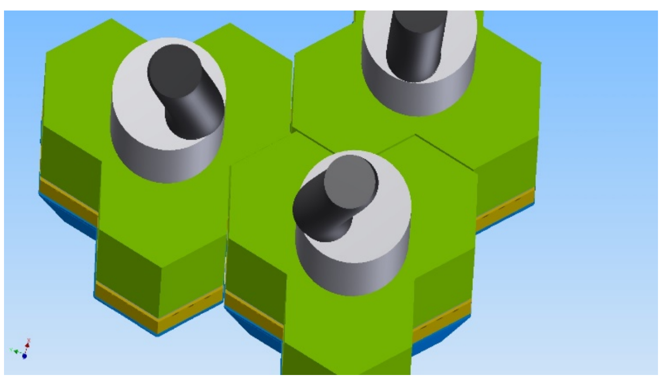


The spherical geometry tolerates any size of the dewar

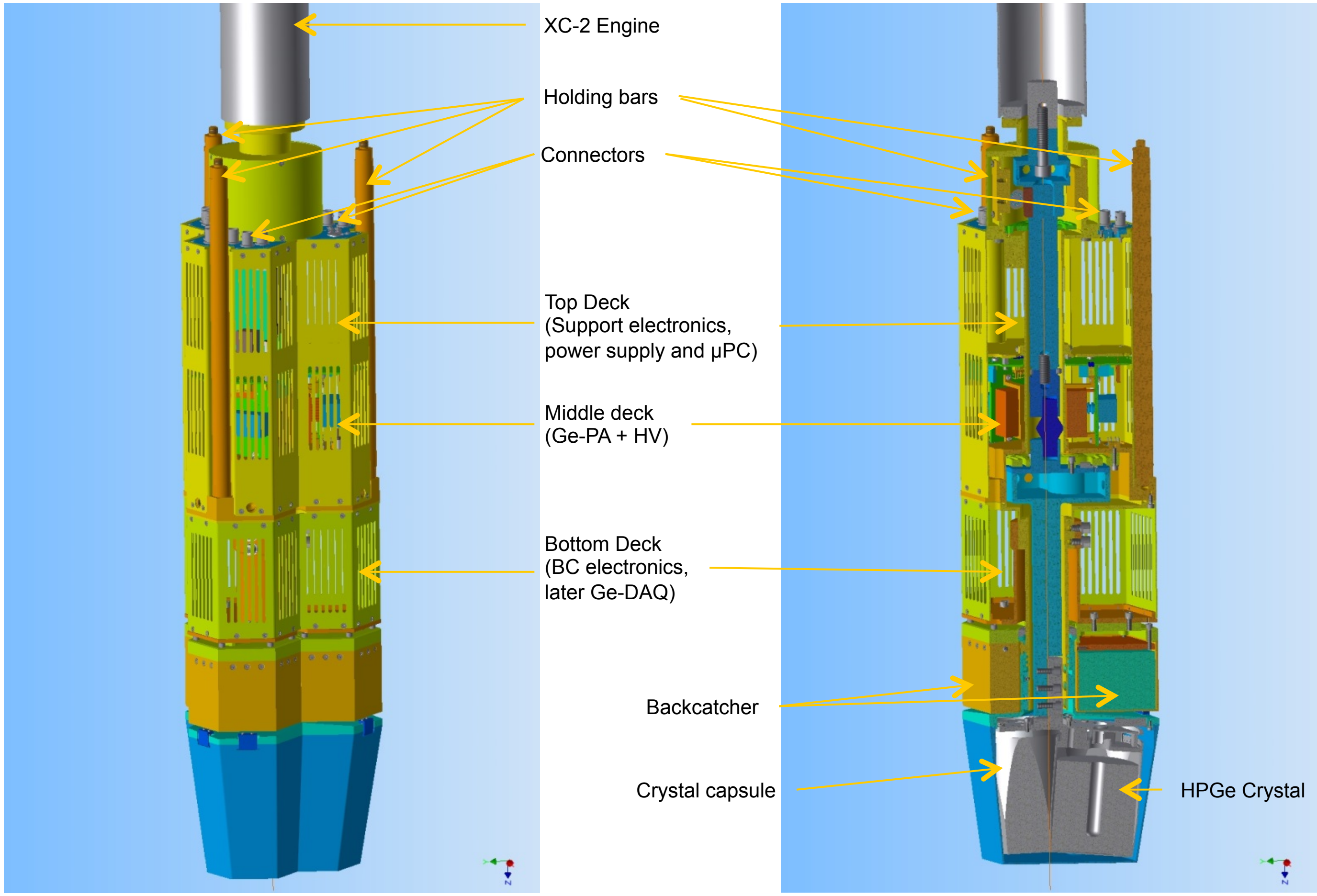


The “box” geometry does not, the dewar diameter must be no larger of the detector head size.



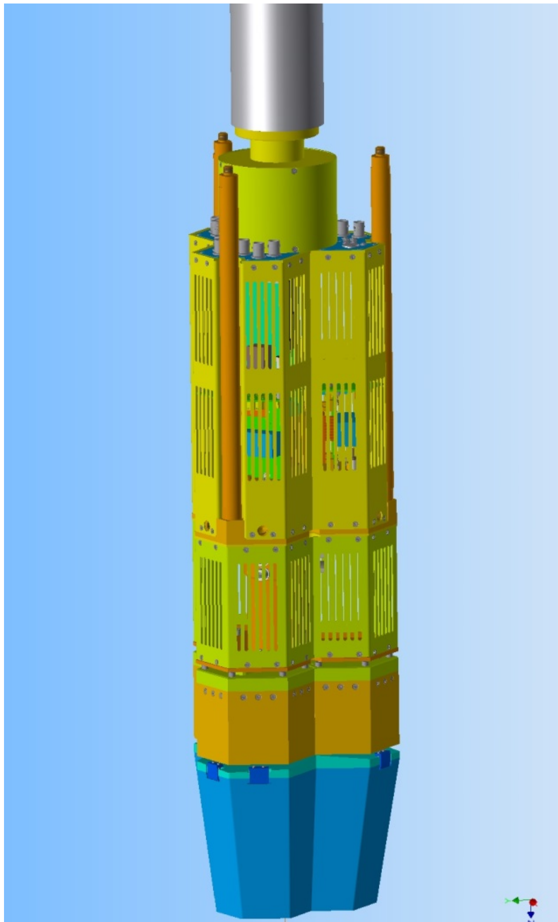


DEGAS detector

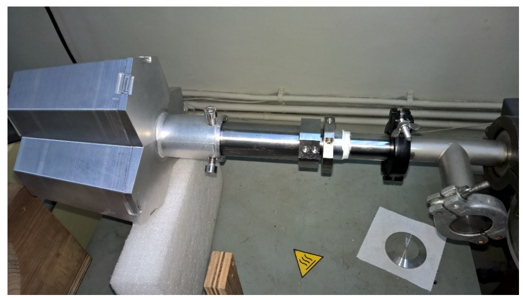


DEGAS Components

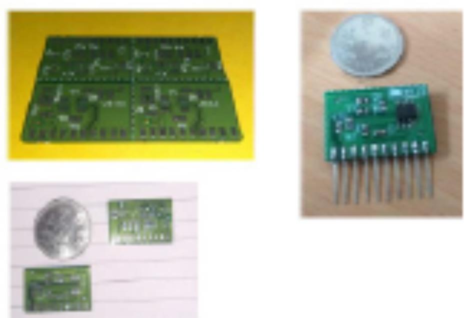
DEGAS detector



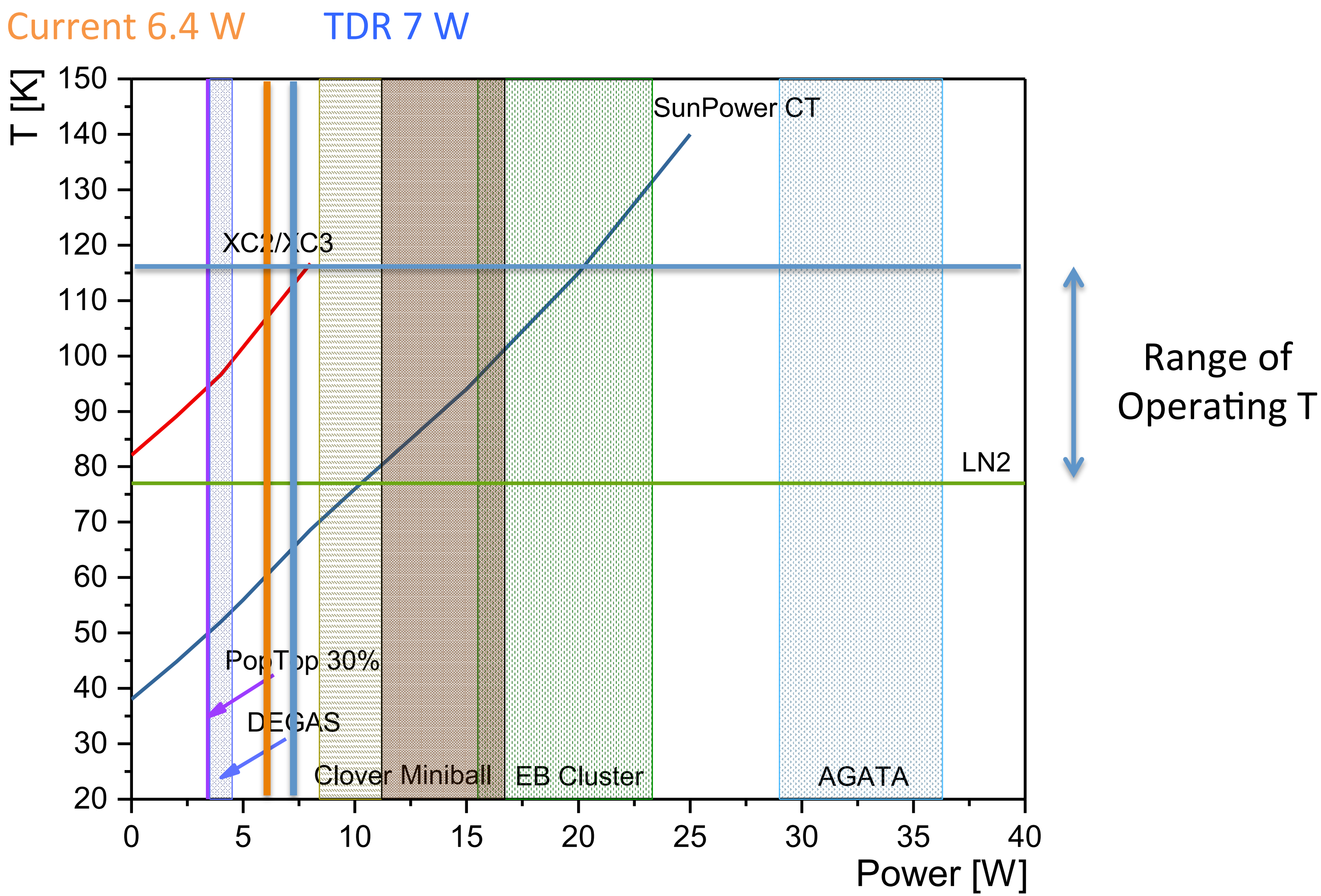
- Encapsulated HPGe crystals in the cryostat with electrical cooling.
- The detector consist of: 38 producible components (some of them several pieces per cryostat)- Cu, stainless steel, Al.
- High vacuum.
- Signal processing electronics.



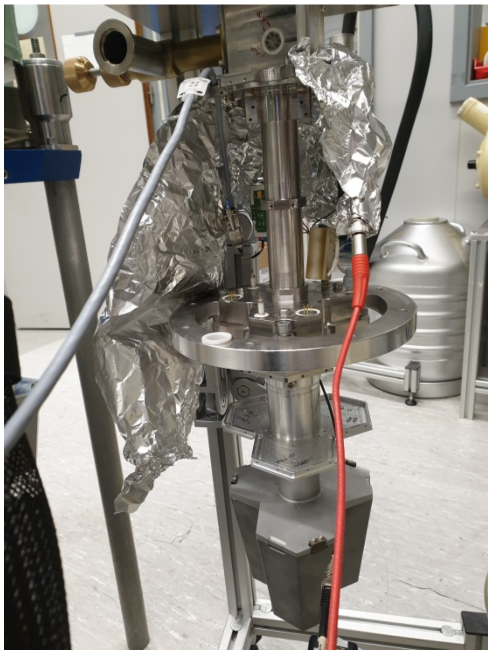
DDH PCB

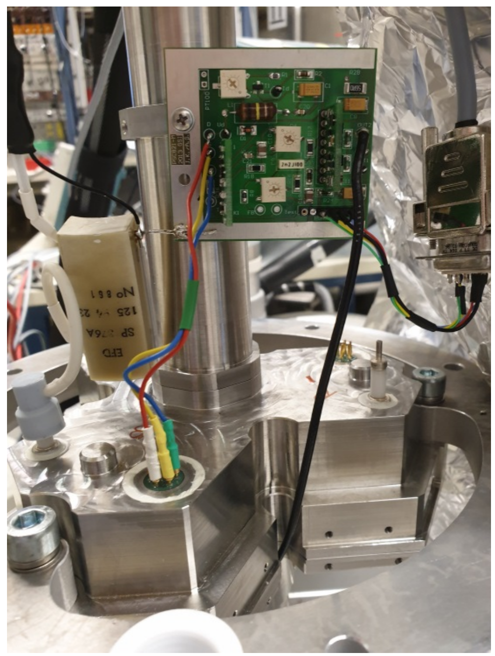


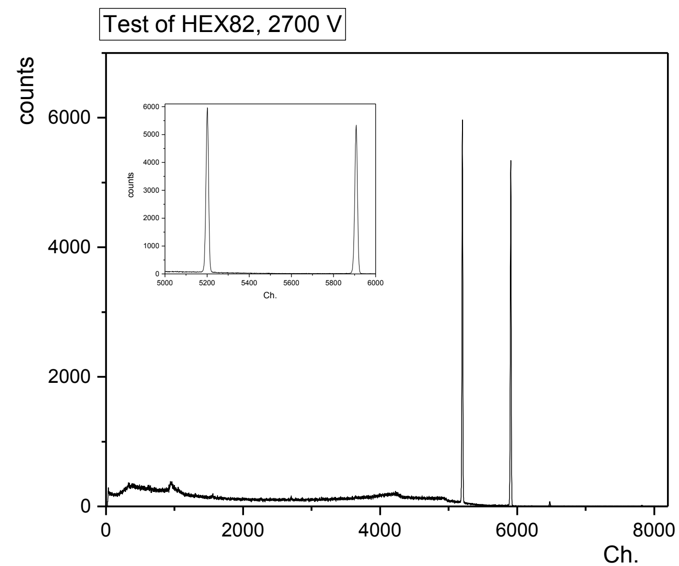
Power Dissipation



Assembly and spectroscopy test of DEGAS, June 2019







The energy resolution of 2.8 keV (with 3 μs shaping time) is measured at 1332 keV line of 60-Co. The reason for the poor energy resolution is the too high temperature of the capsules which does not allow full biasing of the capsules.

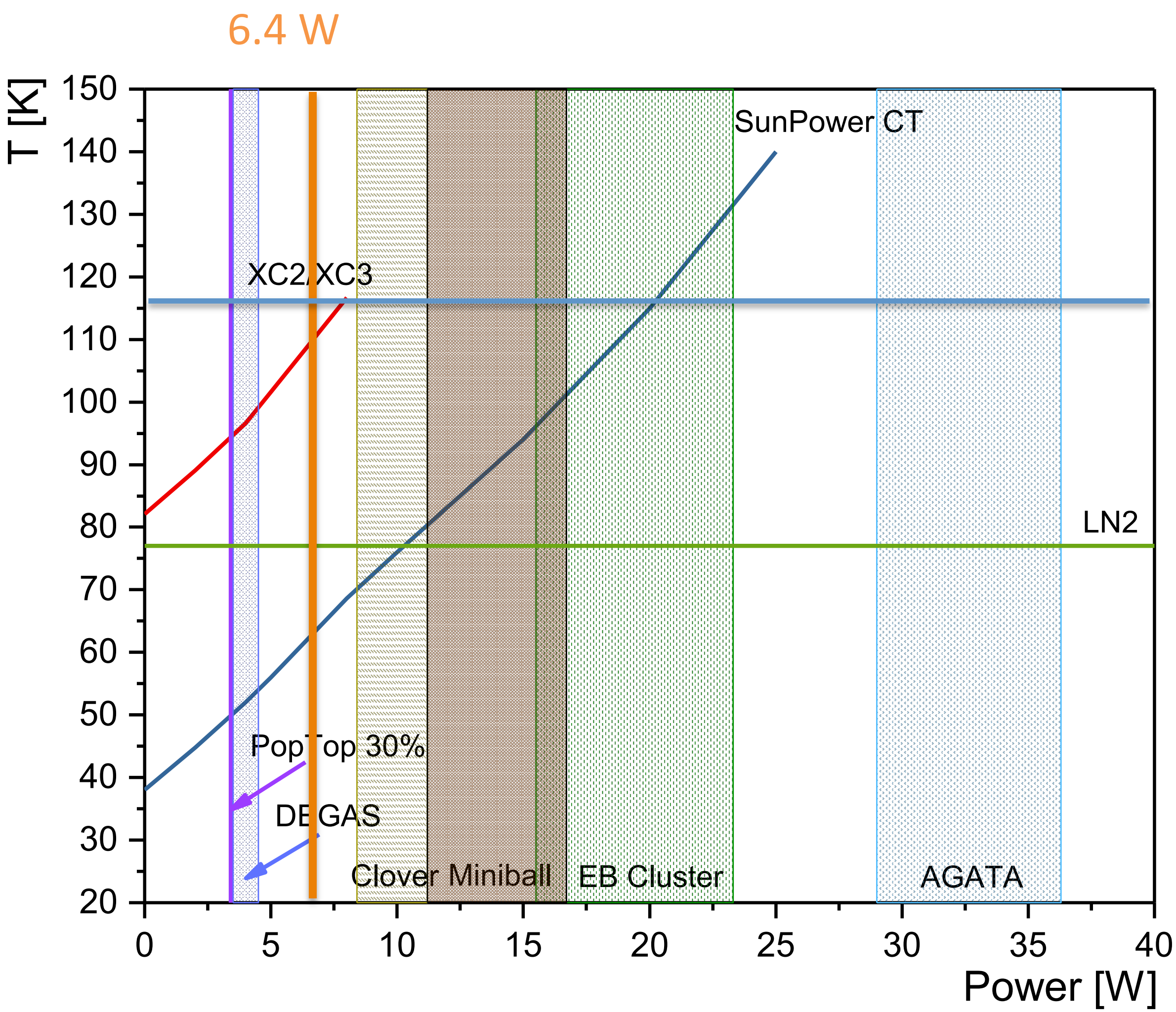
Flying assembly! The DEGAS preamplifier is developed and tested, however not in the DEGAS form factor. In this test a preamplifier PSC821M, successfully operating with EURIKA, has been used.

I. Kojouharov et al., *GSI, Darmstadt*

What is the thermal transfer from the various components?

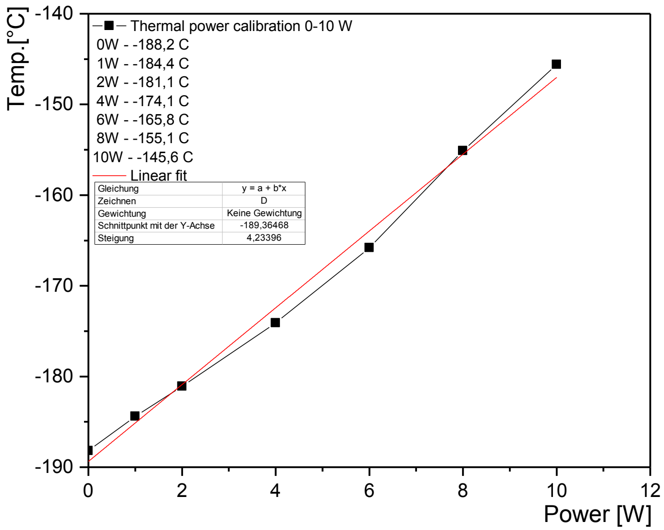
What is the lifting power of the XC?

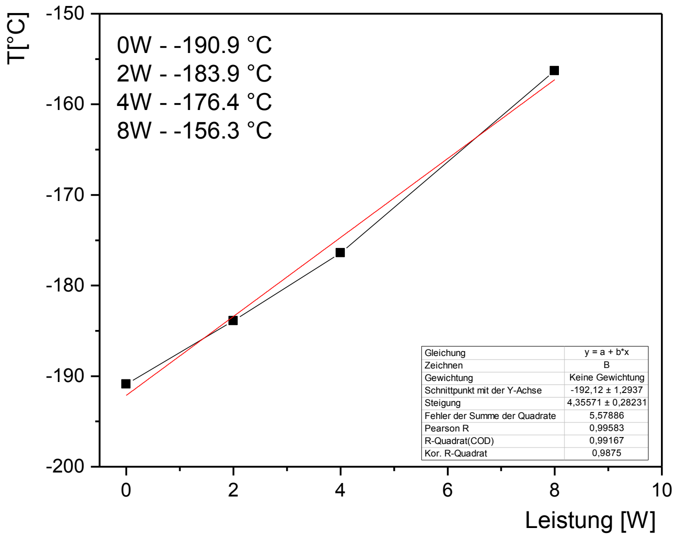
Power Dissipation



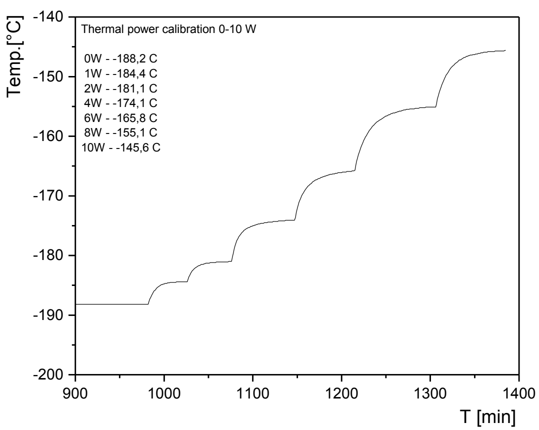
Thermal Calibration and cooling deficit

The Cold Flex calibration. Further it will be used to measure the overall thermal transfer through the Cold Finger.

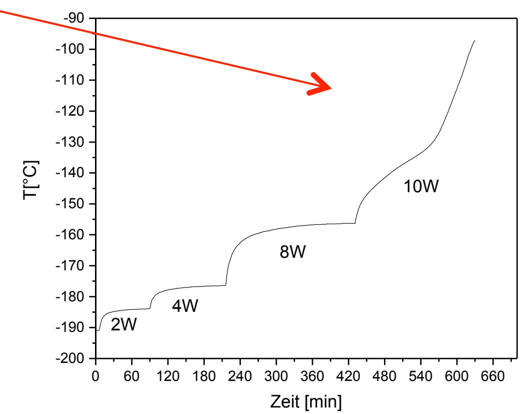




The XC shows sign of exhausting



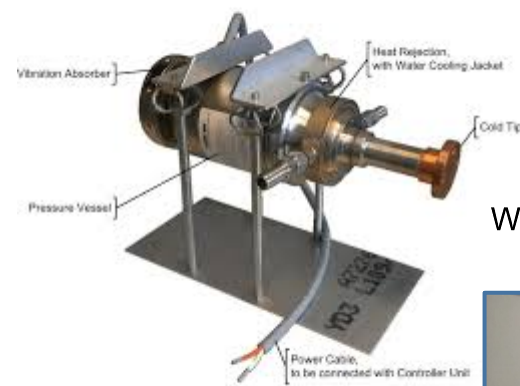
The same thermal calibration, but on June 2019. A cooling deficit is observed and this is also a signature for the forthcoming X-Cooler failure.



Electrical cooling of HPGe detectors

1. Cooling and coolers – available engines

Air cooled



Water cooled

MMR/ORTEC X-Cooler II or III

SunPower/ORTEC Type CT or GT

Cooling Scheme

- XC II
  - (Original XC2 for DEGAS)
  - (Company will not provide service) (Upkeep is impossible)
- XC III
  - (Designed to improve the vacuum degradation)
  - (Thermal link will be weak for composite detectors)
- CT
  - High power (Stirling cycle)
  - Microphonics noise, special adapter for noise cancellation
  - Costly, Long Delivery time
- Small LN_2 dewar
  - With improved design thermal load can be reduced

Assembly Phase 2

The DEGAS structure has been rebuilt in a way to simplify the cold line and to reduce the thermal bridges (Fig.1). Four Pt100 have been applied (initially only three):

- one at the start absorber container, close to the cold flex.
- one at the cold finger, close to the cold flex (additionally installed)
- one at the main absorber container
- one at the cold frame.

The section of the cold finger between the second spacer and the main absorber container has been wrapped with super-insulation and additionally with 14 turns Al-Mylar. The section of the cold finger between main absorber container and the cold frame has been wrapped with Al-Mylar 28 turns. Thermal bridges are:

- first spacer – fixed to the cryostat wall, loose connection to the cold finger.
- second spacer – fixed to the cold finger, loose connection to the cryostat tube.
- main labyrinth – fixed to the main absorber container (which is fixed to the cold finger) and fixed to the cryostat wall

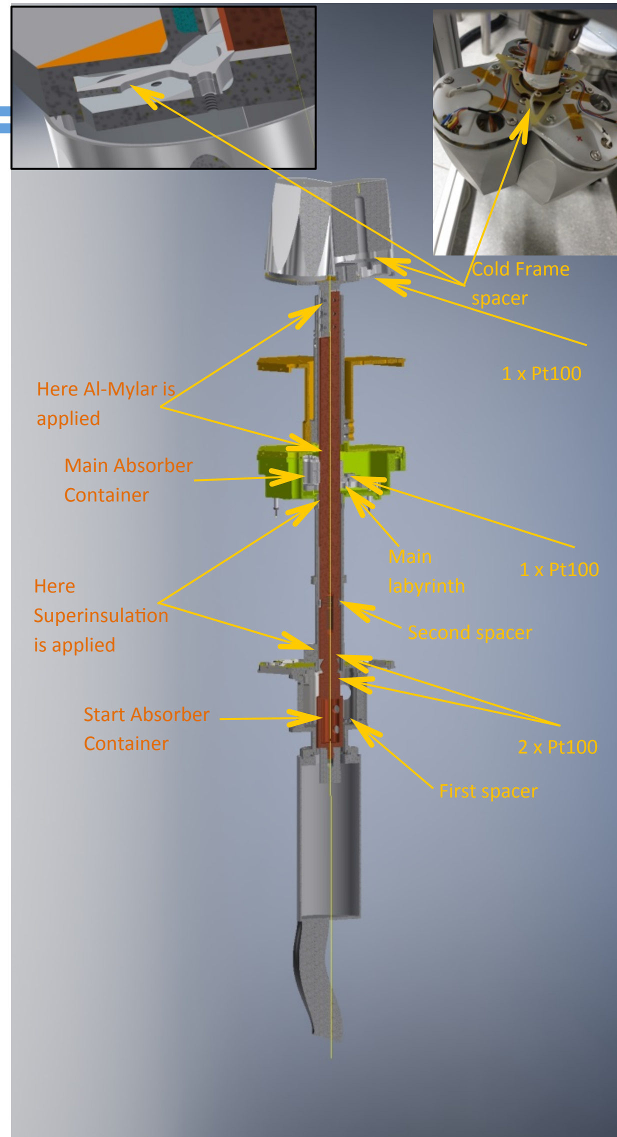
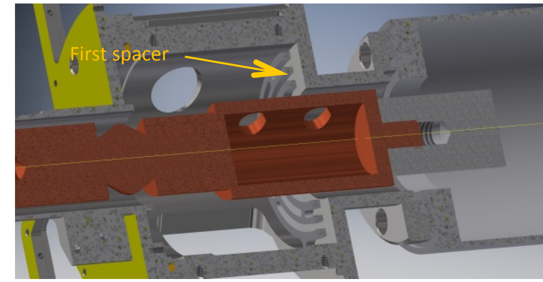
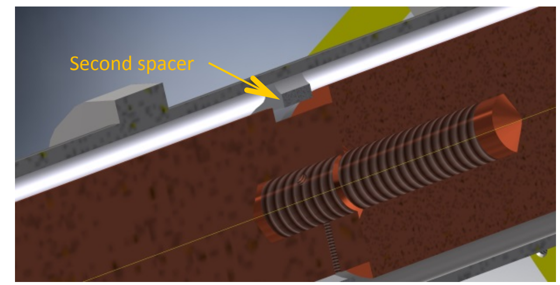


Fig.1. DEGAS Structure.





- cold frame spacer- fixed to the cold frame, loose connection to the end cap lid.
- connection wires – 3 x HV in teflon tubes, 12 x signals, 8 x Pt100 and 2 x heating resistor. All the wires except the heating resistor are very thin – 0.15 mm^2, teflon insulation.

Cold Flex from XC used.

Conclusions

- Further optimization of the Cold Line of DEGAS.

- Change/repair of the cooling engine.

- Change the type of the cooling engine.
 (Replace the X-Cooler II cooling engine with the SunPower CT cooling engine.)

- Further development, test and production of the Backcatcher readout electronics. Equipping the Back-catchers with the readout, test and commissioning.

- Timeline 2021 (phase 0) Early implementation 2025

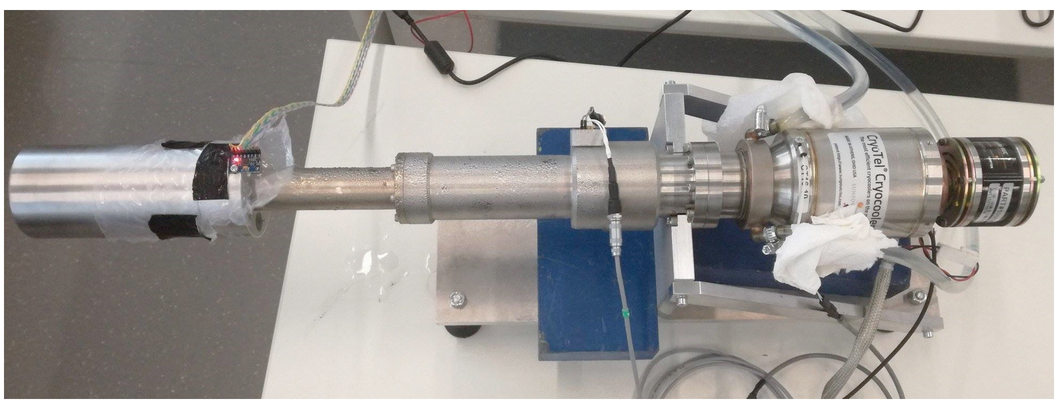
- Funding issue 15 to 20%

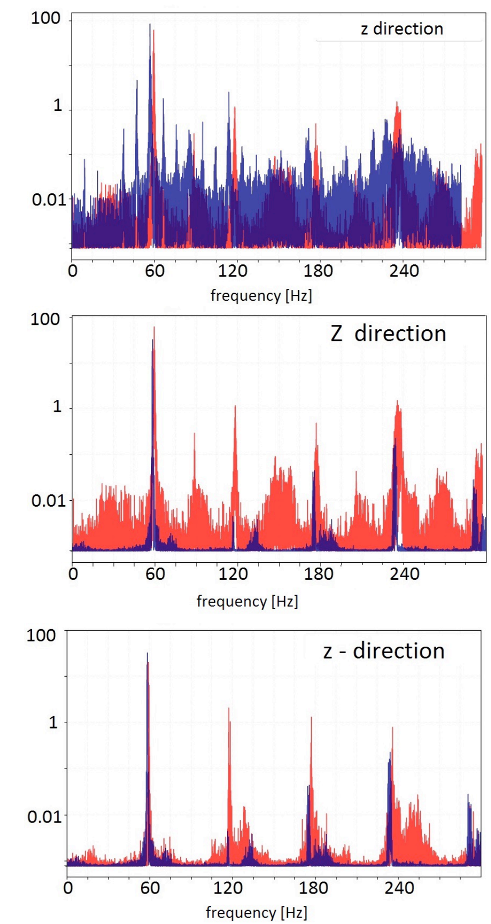
Thank you

Electrical cooling of HPGe detectors

1. Cooling and coolers – available engines

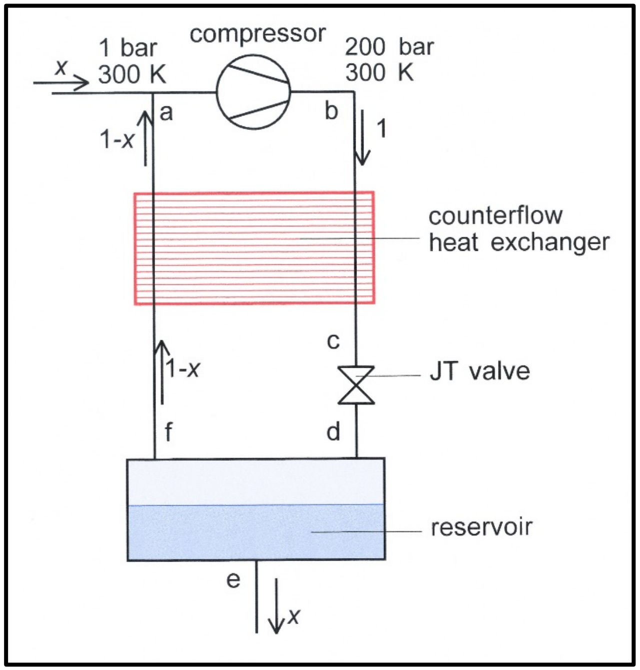
	MMR XC	SP CT
Cooling (total) power	11 W (240V/500W)	11W (24V/120W)
End temperature	-187 °C	-220 °C
Vibrations	very low	high
Life (reliability)	unknown, 3-7 Years	unknown, >200 000 h
Compactness	low	high
Principle	J-T	Stirling

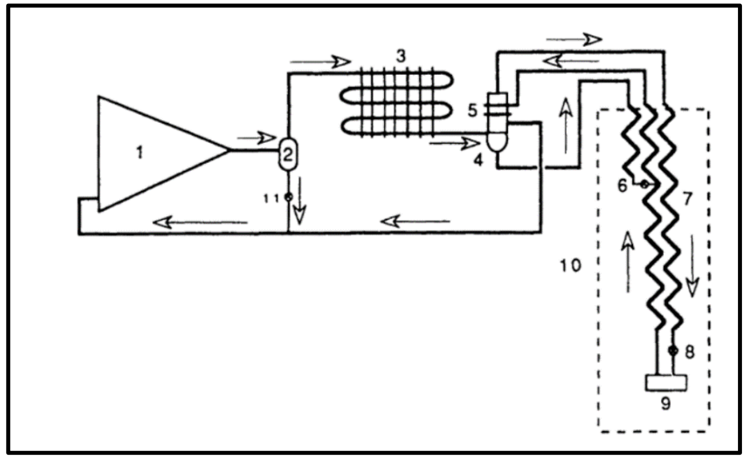


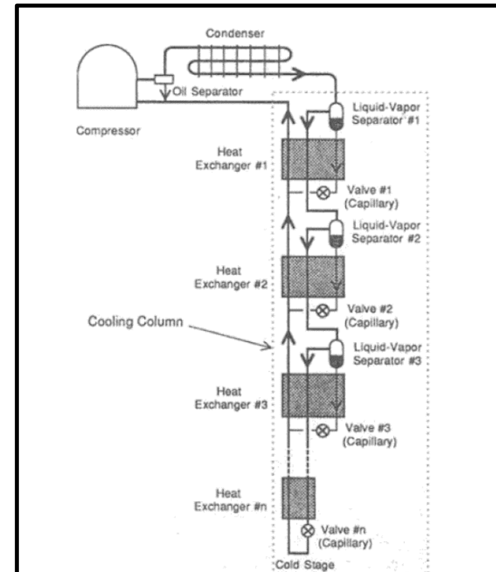


Electrical cooling of HPGe detectors

1. Cooling and coolers – the Linde cooler (Joule-Thompson cooler) and the Kleemenko cooler







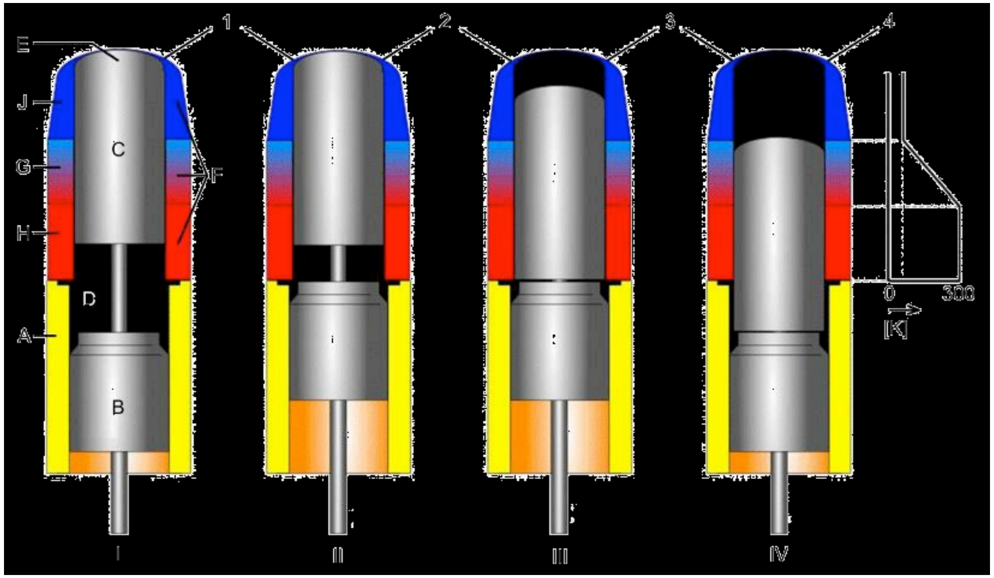
From Cryocoolers 9, edited by R.G.Ross Jr.

Kleemenko cycle(right) and the MMR cooler X-Cooler (left). Uses multicomponents cooling agent.

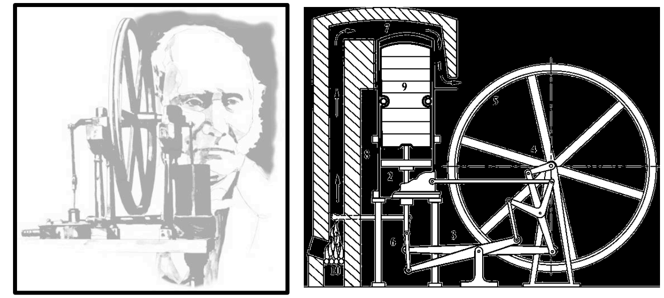
A schematic diagram of a JT liquefier is shown left. It consists of a compressor, a counterflow heat exchanger, a JT valve, and a reservoir. The pressures and temperatures refer to the case of a nitrogen liquefier. At the inlet of the compressor the gas is at room temperature (300 K) and a pressure of 1 bar (point a). The compression heat is removed by cooling water. After compression the gas temperature is ambient temperature (300 K) and the pressure is 200 bar (point b). Next it enters the warm (high-pressure) side of the counterflow heat exchanger where it is precooled. It leaves the exchanger at point c. After the JT expansion, point d, it has a temperature of 77.36 K and a pressure of 1 bar. The liquid fraction is x. The liquid leaves the system at the bottom of the reservoir (point e) and the gas (fraction $1 - x$) flows into the cold (low-pressure) side of the counterflow heat exchanger (point f). It leaves the heat exchanger at room temperature (point a).

Electrical cooling of HPGe detectors

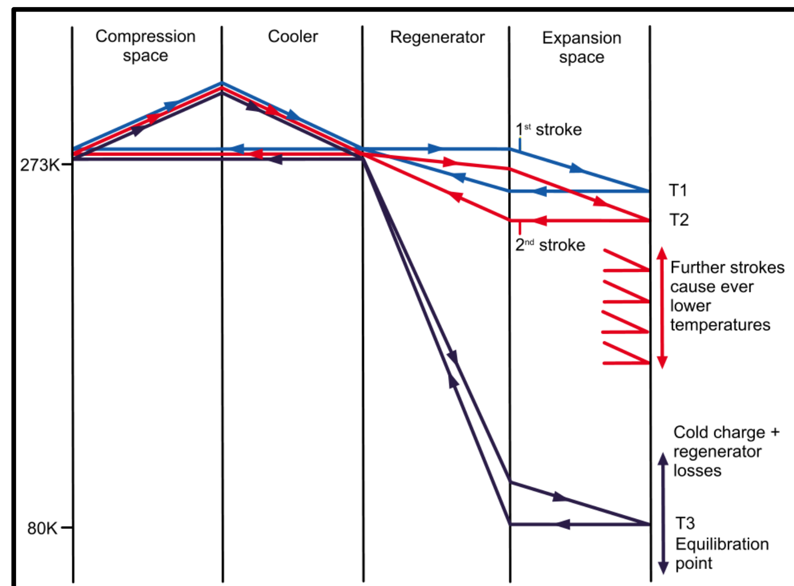
1. Cooling and coolers – the Stirling cooler



In position I, all helium is at room temperature in space D. Going to position II, this gas is compressed by piston B increasing the gas temperature to about 80°C, refer to figure 2, column 1. When the displacer C moves down from position II to III, the gas is displaced from space D to space E, forcing it first through the cooler H where the compression heat is dissipated into the cooling water, reducing the gas tempe-rature to about 15°C (column 2). Next, the helium flows through regenerator G. Using the cold which was stored in the regenerator by the previous cycle, the helium gas is cooled to almost the final liquefaction temperature when arriving in space E (column 3). The final and main action is the displacer and piston moving down to position IV, expanding the helium gas. This expansion creates the actual cooling power in the cold heat exchanger J (column 3), cooling the customers process.



The Stirling cycle is a thermodynamic closed cycle invented in 1816 by the Scottish minister Robert Stirling.



Graphics by Stirling Cryogenics BV, Netherlands