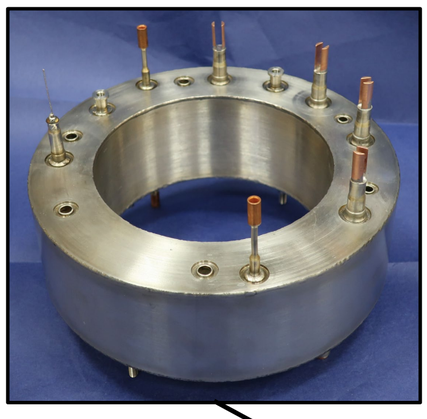
^{3}He–^{4}He Dilution Refrigerator, used to obtain ultra-low temperature (down to 25mK)

Anton Dolzhikov*, Gorodnov I.S., Borisov N.S., Usov Yu.A.
Dubna, JINR, Dzhelepov Laboratory of Nuclear Problems
**Corresponding author: dolzhikovant@yandex.ru*
URL: https://dlnp.jinr.ru/snt/en/

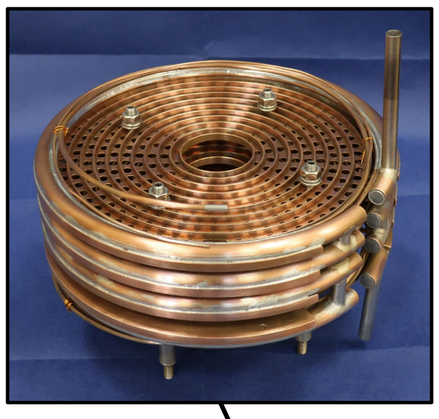
Joint Institute for Nuclear Research
SCIENCE BRINGING NATIONS TOGETHER

^{3}He–^{4}He Dilution Refrigerator is the only device at the moment that allows to obtain an ultra-low temperature (down to 5mK) in a continuous mode (for several months and more). In 1966, one of the world's first ^{3}He–^{4}He dilution refrigerators was created in Dubna under the leadership of B.S. Neganov. Since then, more than 10 ^{3}He–^{4}He dilution refrigerators have been created in the Low Temperature Department of the DLNP JINR. At present, ^{3}He–^{4}He dilution refrigerators are widely used in various fields of physics and technology: in elementary particle physics - for cooling a target material; in quantum computers - for cooling qubits; in condensed matter physics - to study the properties of matter at ultralow temperatures; in aerospace industry - for cooling detectors of telescopes; etc.

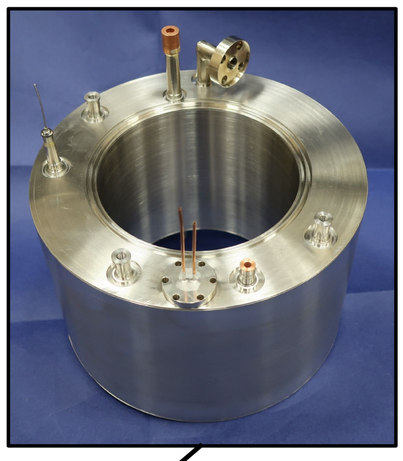
Separator (volume with ^{4}He at T≈4K)



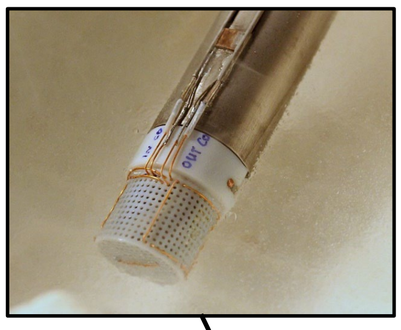
Intermediate heat exchanger (T≈1.5 – 3K)

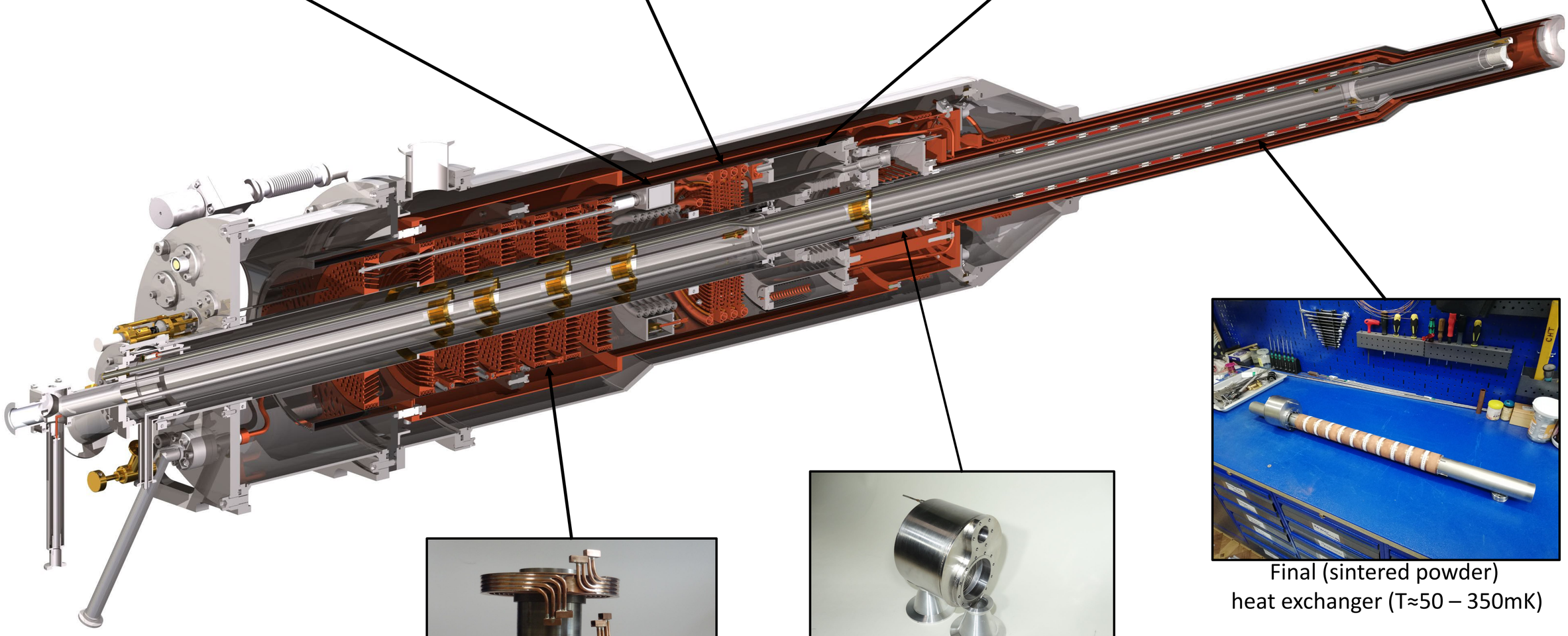


Evaporator (volume with superfluid ^{4}He at T≈1.1…1.5K)



Target cell (container with target material at T≈30mK)





Main (gas) heat exchanger (T≈5 – 250K)

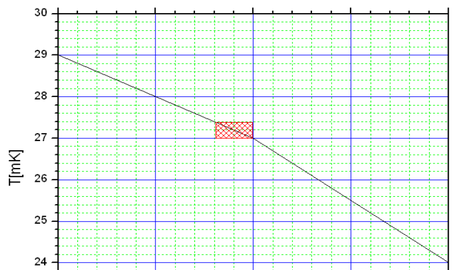
Still (volume with ^{3}He/^{4}He mixture at T≈0.8K)

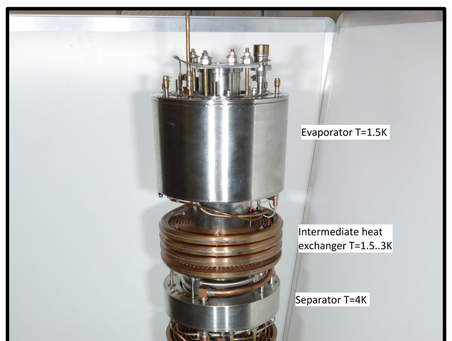
Final (sintered powder) heat exchanger (T≈50 – 350mK)

Dilution Refrigerator main parameters:

- Mixing chamber temperature <30mK
- Cooling power at 300mK > 30mW
- Liquid ^{4}He consumption <3 L/hr
- Sample dimensions: L=20 mm, Ø=20 mm
- Angle for outgoing particles: 0°<Θ<160°

Temperature stability:
ΔT≈± 0.2mKelvin (one day)
(typical one week measurement period)





Dilution Refrigerator during assembly

Dilution Refrigerator during the experiment: first, the target material is exposed to a strong magnetic field (up to 2.5T) at a temperature of about 250mK (so that the polarization process goes faster), then, when the polarization of 75% or higher is reached, the holding field is switched (0.5T) and the target is cooled to a temperature of less than 30mK (the lower the temperature, the slower the target polarization decreases)