Joint Institute for Nuclear Research

SCIENCE BRINGING NATIONS TOGETHER

Dilution cryostats as a part of Atomic Hydrogen Target for electron beam polarimetry.

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«The XXVI International Scientific Conference of Young Scientists and Specialists»

JINR, Dubna, Russia

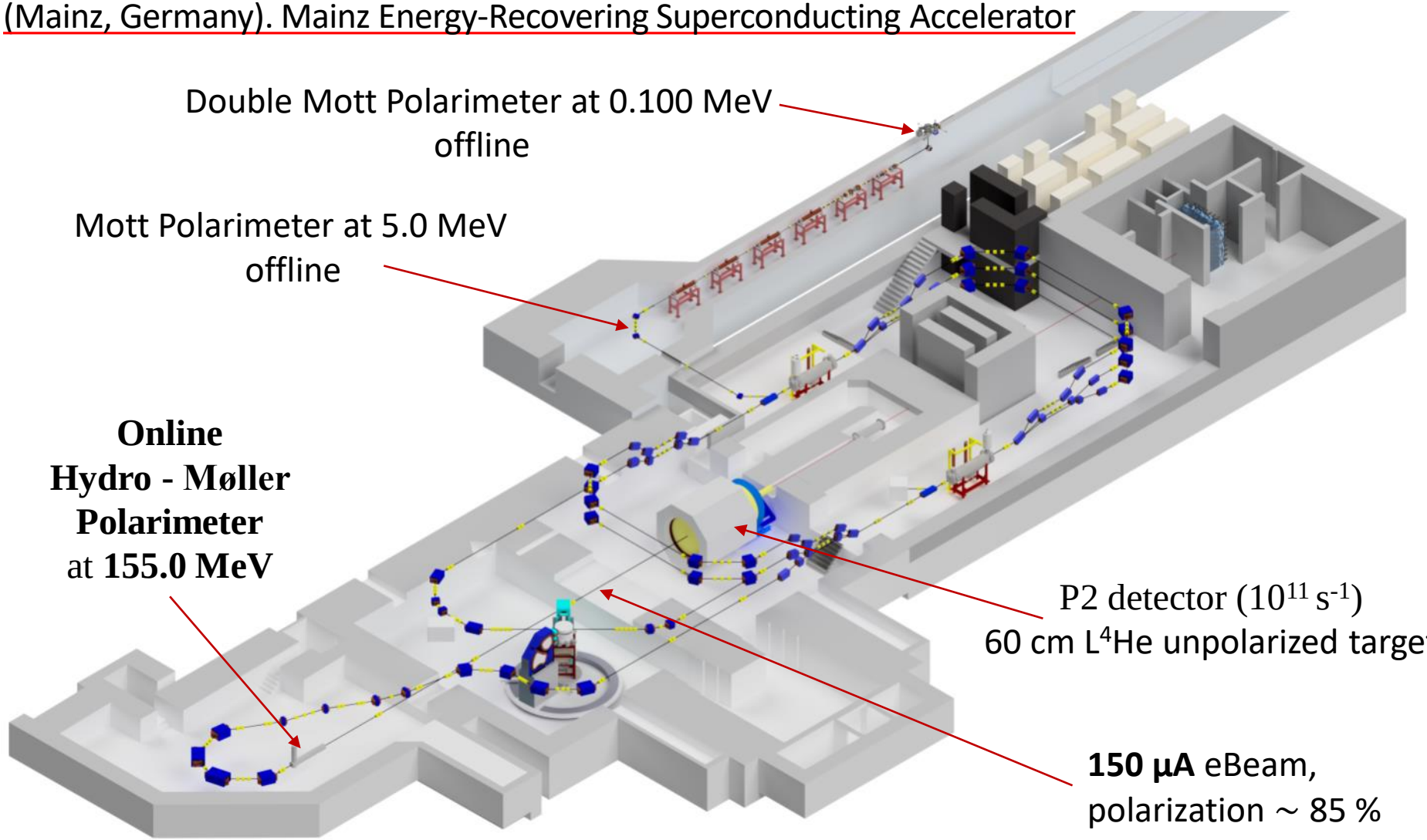
24 Oct 2022

P2 Experiment @ MESA

- Germany, Johannes Gutenberg University Mainz.
- The new Mainz Energy-Recovering Superconducting Accelerator (MESA).
- P2-experiment: precision measurement of the weak mixing angle.

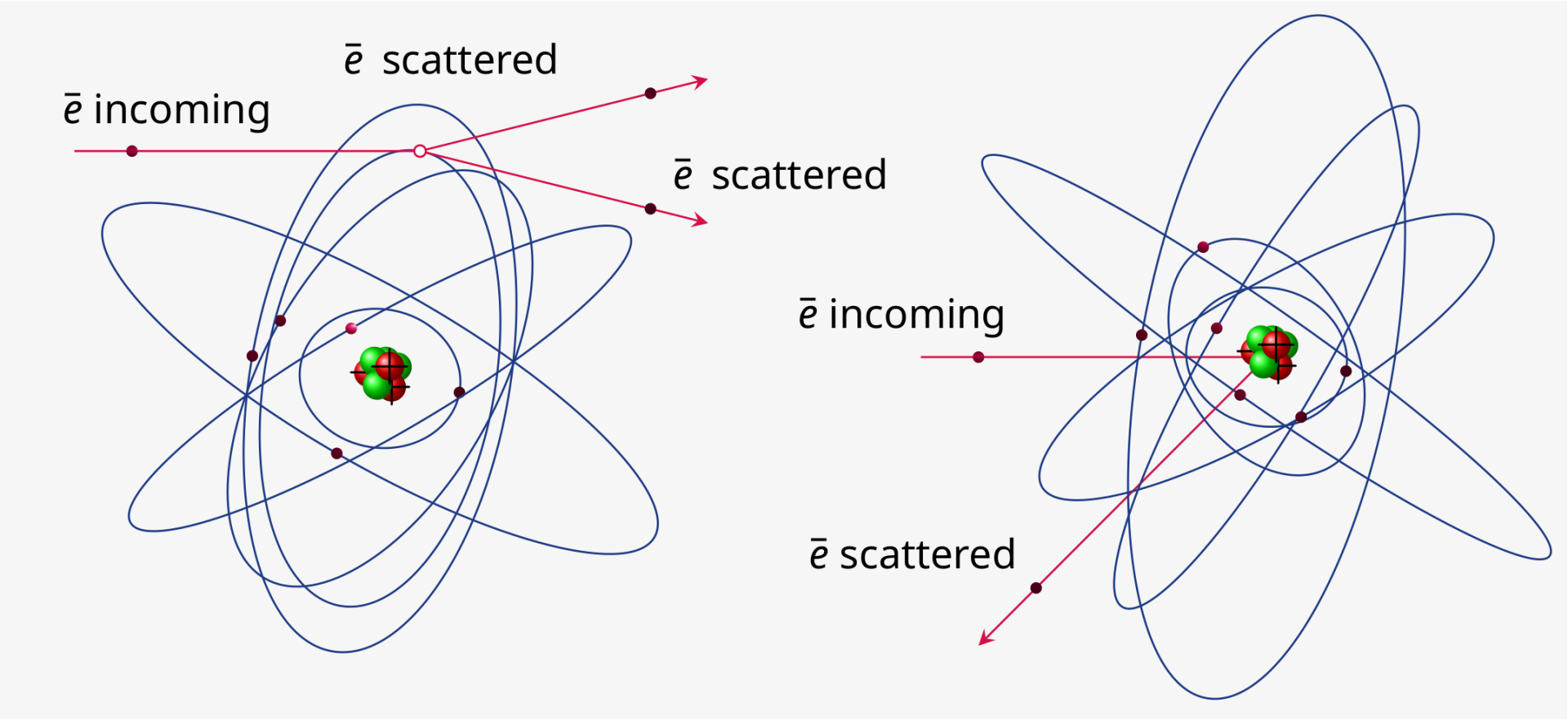
  $\Delta \sin 2(\theta_W) = 0.14\%$.
- Experiment collect $\sim 10^{11}$ s^{-1} for 11000 h ($\sim$ 1,25 yr).
- *e*-Beam current $\sim$ 150 μA, beam energy $\sim$ 155 MeV.
- Continuous spin polarized electron beam, polarization $\sim$ 85%.
- High stability of position, energy and intensity of beam.
- High beam polarization and polarization measurement accuracy significantly contributes in the precision.

Schematic arrangement of units of experimental installations @ MESA accelerator (Mainz, Germany). Mainz Energy-Recovering Superconducting Accelerator



The goals at MESA: $P_{\text{Mott, double}}$ (offline) = $P_{\text{Mott, 5.0 MeV}}$ (offline) = $P_{\text{Møller, H,}}$ (online) Accuracy $\Delta P/P \leq 0.5\%$

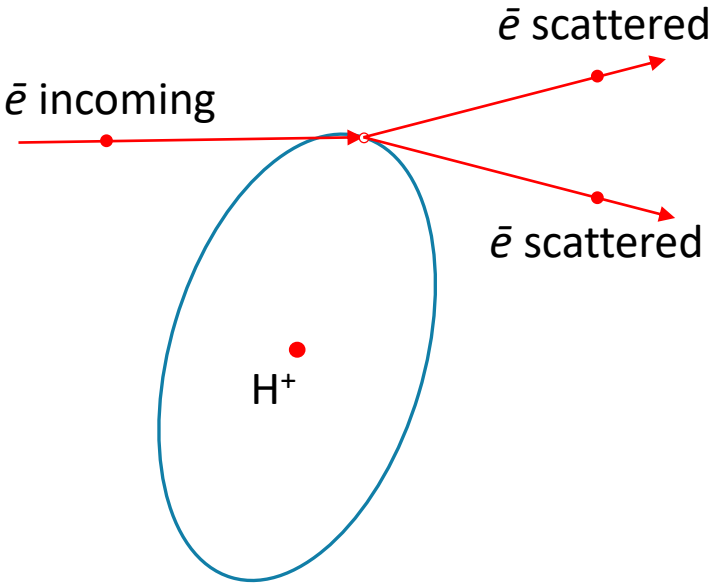
Møller and Mott scatterings



Møller
electron-electron scattering

Mott
spin-coupling inelastic
Coulomb scattering

Hydrogen target for Møller polarimeters (Hydro- Møller)



- Scattering on hydrogen electron
- Target H, Z=1, A=1
- Ionization energy = 13.6 eV
- Cell density: $\rho_H[cm^{-3}] \times L_H = \mathbf{6.0 \times 10^{16}}$ cm^{-2}
- Energy range: 0.15 – 12.0 GeV
- Current up to 1000.0 μA
- Overall accuracy of ≤ 0,5%

Gas properties:

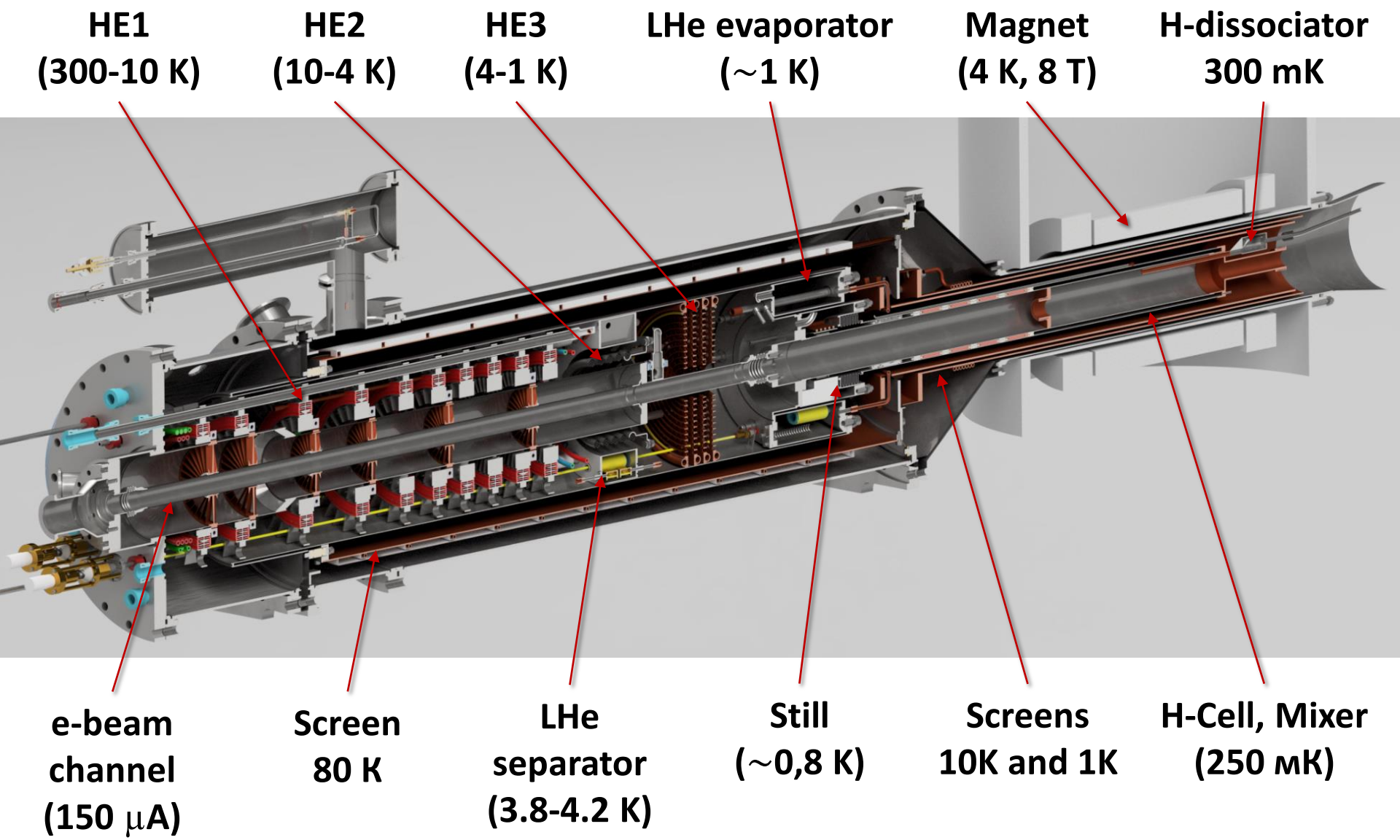
- Atom velocity ≈ 80 m/s
- Atomic collisions ≈ 1.4×10^5 s^{-1}
- Mean free path λ ≈ 0.6 mm

Molecular hydrogen H_2 opposite electron spin
Atomic hydrogen H : $\vec{\mu} \approx \overrightarrow{\mu_e}$ in magnetic field

Polarization of hydrogen target $P^T \sim 0.9999$

Idea was proposed by Chudakov and Luppov

Cross-section of a model of a new Hydro Møller polarimeter based on a dilution refrigerator for the P2 experiment @ new MESA accelerator in Mainz (Germany).



Technical parameters of a new dilution cryostat

For precision polarimeter Hydro Møller @ MESA:

- Mixer temperature 250 mK in a long term mode.
- Horizontal oriented dilution cryostat – mixing ^{3}He in ^{4}He.
- Cooling power 60 mW at temperature level 250 mK

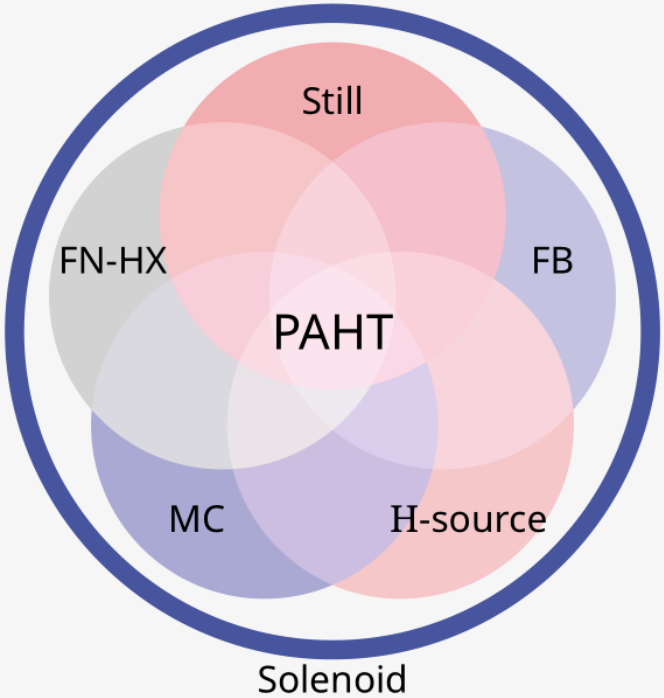
  and circulation $\dot{n}_{^3He} \sim 40$ mmol/s.
- Superconductive magnet separated from cryostat

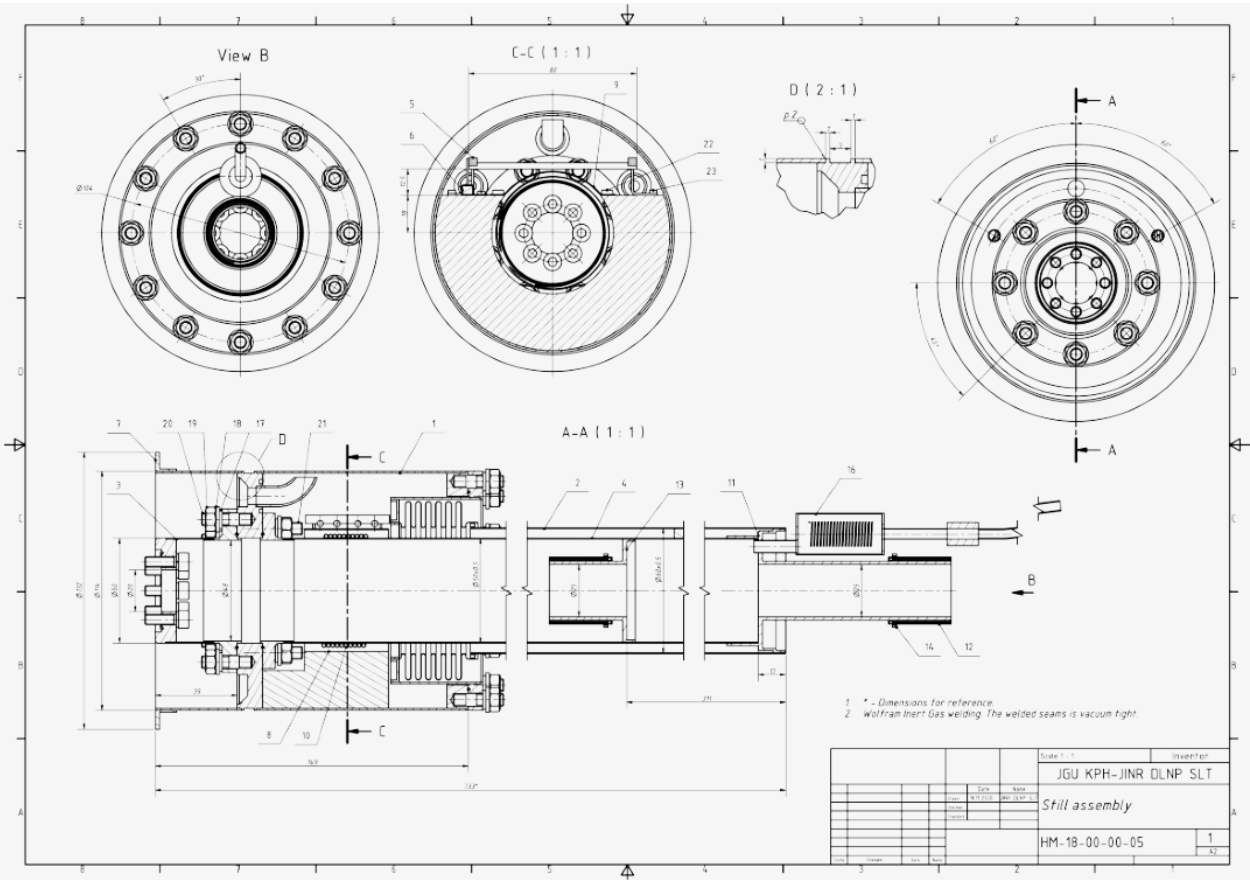
  Holding field B = 8 T, field homogeneity $\Delta B/B < 10^{-4}$,

  Warm hole: D_{sole} =110-130 mm.
- H cell dimensions: L=400 mm, Ø=49 mm.
- L^{4}He consumption < 8 L/hr.
- Evaporator tempetarure ~ 1.2 K, Separator tempetarure ~ 4 K.
- Wall of storage cell is coated ~ 50nm film of superfluid ^{4}He

  at T_{wall} = 0.25 – 0.30K.
- Film burners for prevent leakage of superfluid ^{4}He film.
- No screens in the *e*-beam path

Dilution unit, FN-HX, still, MC, H-source, FB
The star of success





1) Still, 12) FB, 16) H-source at 1K, 2,4) MC, 2,4,10) FN-HX, Solenoid not shown

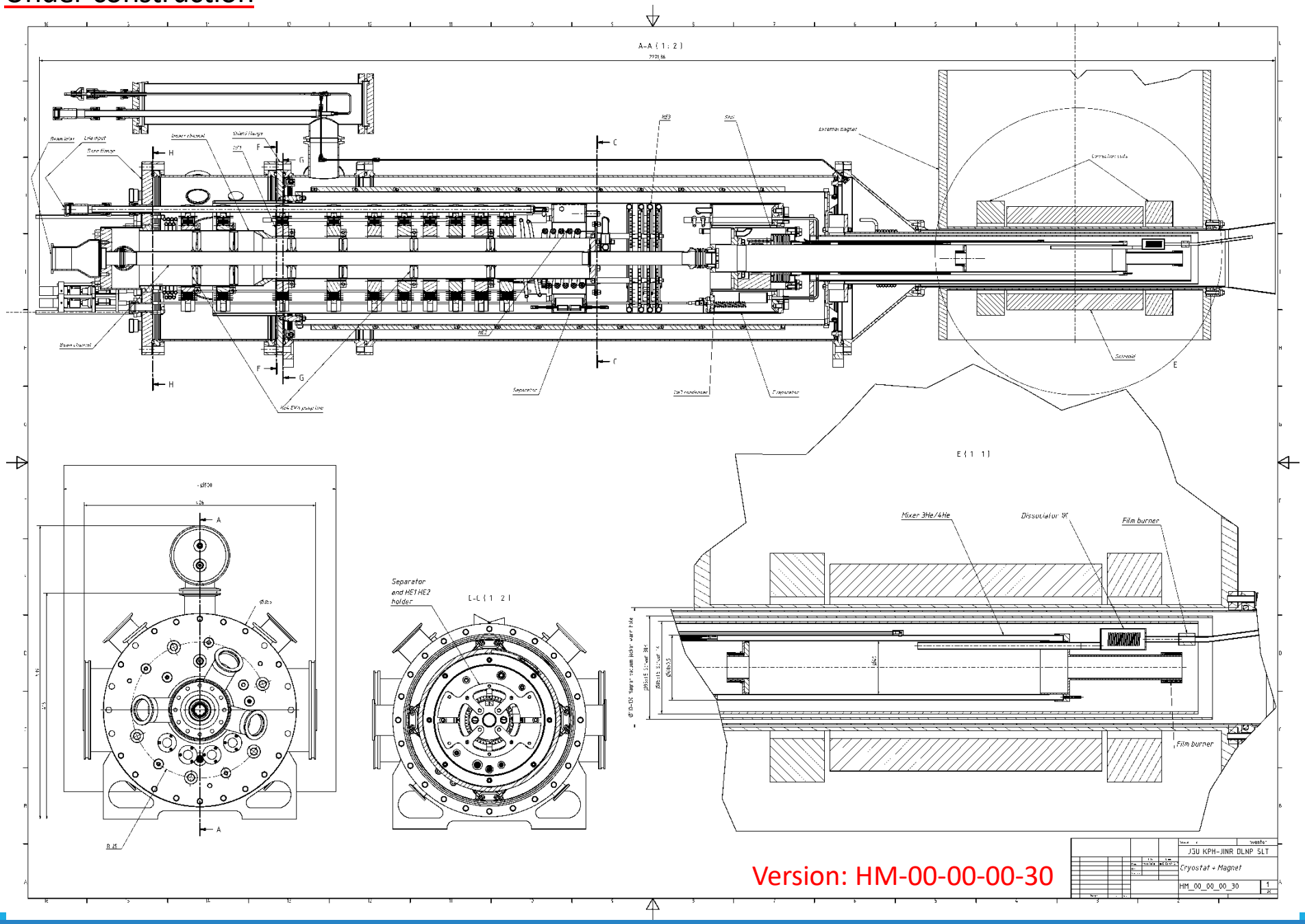
- The star of success
- All elements are highly interconnected

- The key unit of cryostat
- Discussed at JINR 2019, 2020

Valery, Tyukin (KPH, JGU)

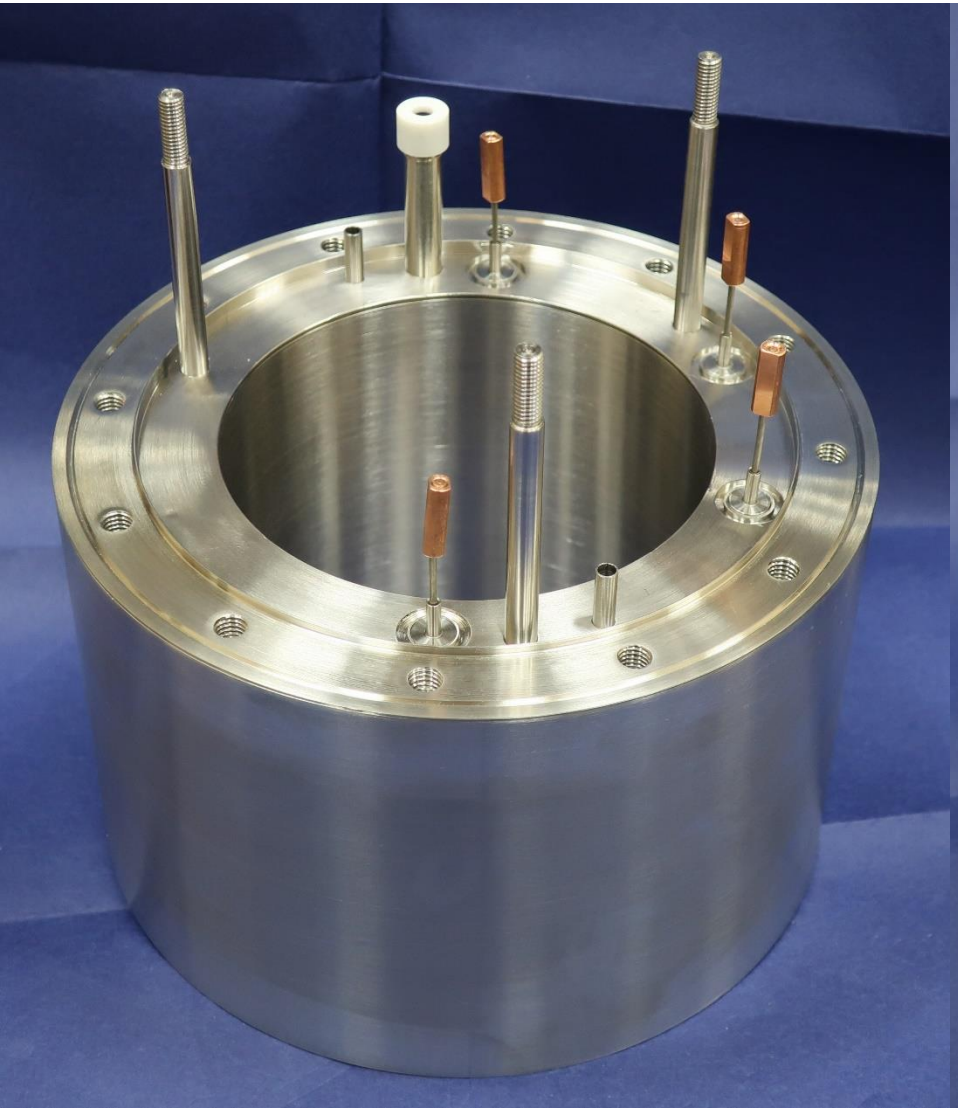
Original technical drawing by N. Borisov, I.Gorodnov, JINR

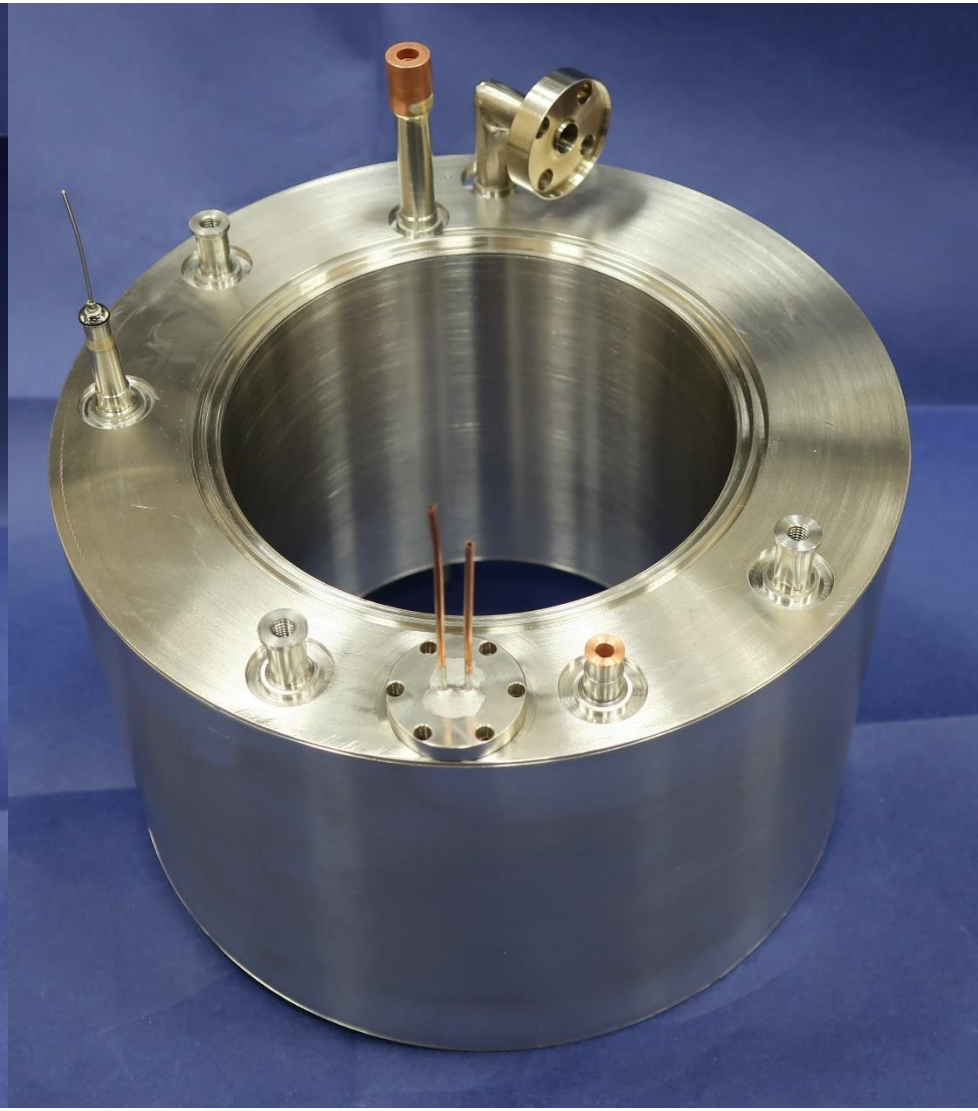
Under construction



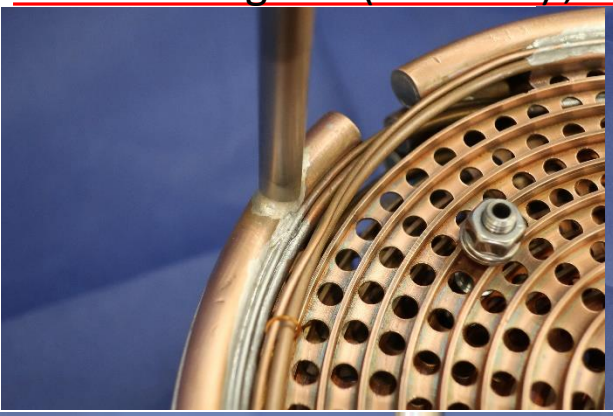
LHe Separator (4 K), Dubna 2022

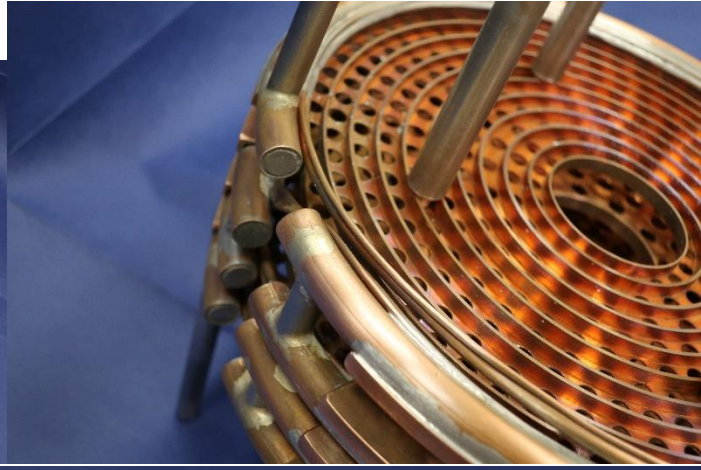
Evaporator (1 K), Dubna 2022

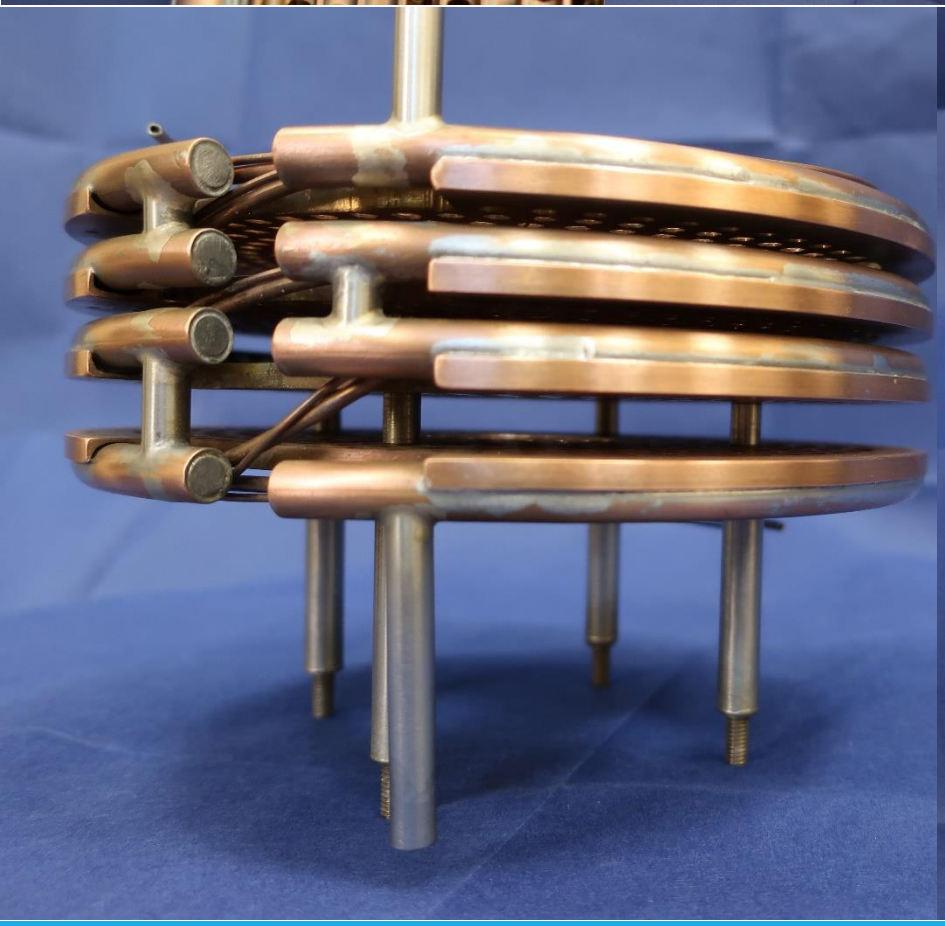




Heat Exchanger 3 (1.5-4.5 K) , Dubna 2021

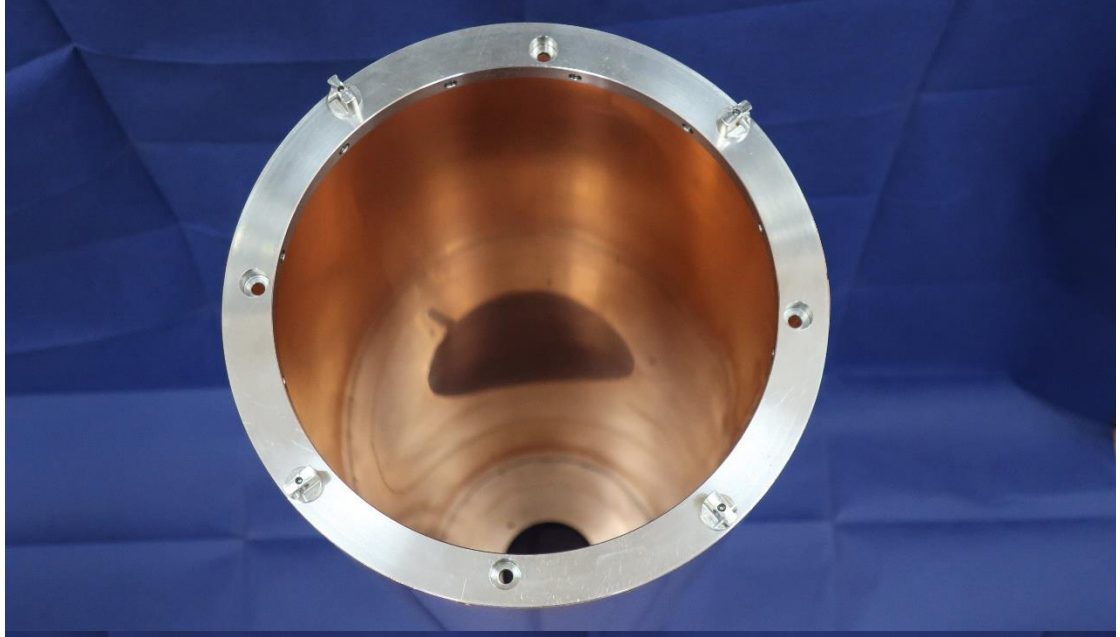


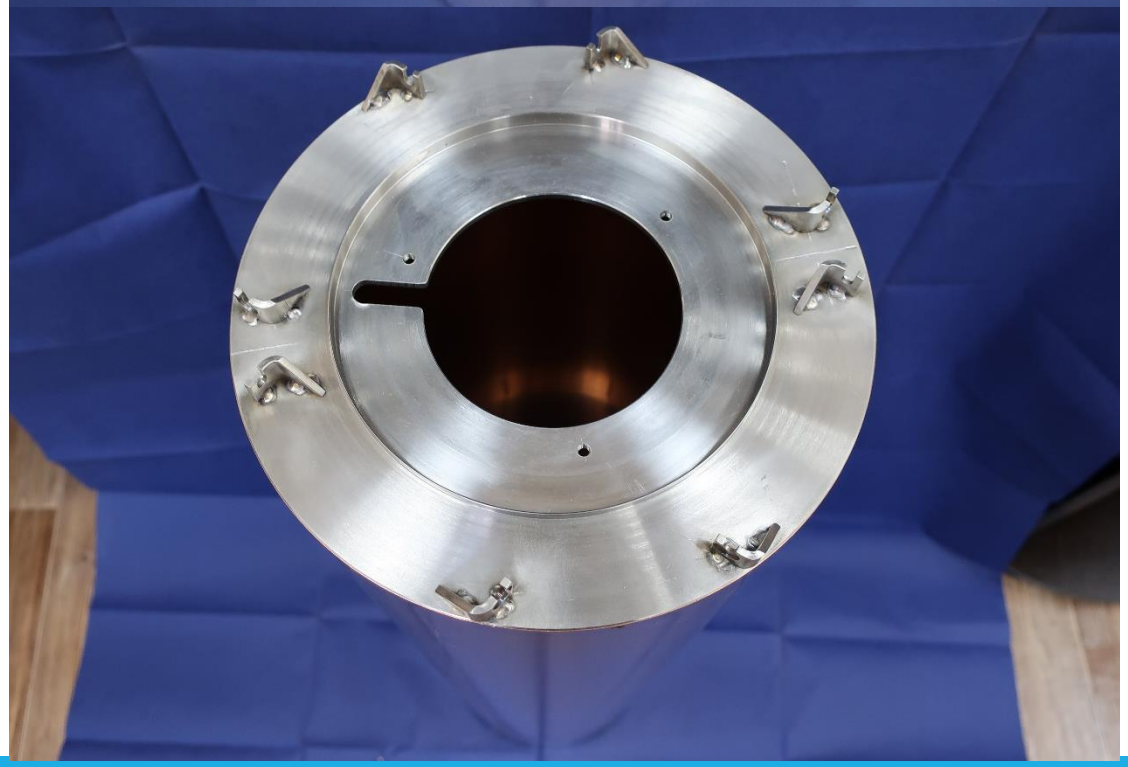




Needle valves, Dubna 2022

Screen 80 K (50-80 K, Gas ^{4}He) ,2021





Works performed in JGU Mainz

Under construction, ready in 2022

The map of LTD DLNP JINR activities

Thank you
for your attention!

Physikalisches Institut
Universität Bonn

Bonn, Germany

Contract 200/1548

https://www1.cb.uni-bonn.de/

2460 km

ПИЯФ /PINP

Gatchina, Russia

JINR Preprints 13-10253, 10-10257,
Dubna 1976 Prib Techn. Exp. 2 (1978) 32

645 km

2435 km

Institut für Kernphisik
Johannes Gutenberg
University

Mainz, Germany

A2 collaboration on MAMI
2007-2018
https://wwwa2.kph.uni-mainz.de

P2 experiment at MESA
Hydro-Möller Polarimeter
https://www.mesa.uni-mainz.de

JINR
DUBNA

NIM A 372 (1996) 349

260 km

2000 km

Czech Technical University

Prague, Czech Republic

NIM A 345, (1994) 421-428

Protvino, Russia

JINR Preprint 1-80-93, Dubna 1980