Sofiya Savelyeva, Christoph Haberstroh

Technical University Dresden // Bitzer Chair Of Refrigeration, Cryogenics And Compressor Technology

“Development of a Nelium Turbo-Brayton cryogenic refrigerator for the FCC-hh”

EASITrain project status overview

FCC Week 2019, Brussels // 27.06.2019

EASITrain – European Advanced Superconductivity Innovation and Training. This Marie Sklodowska-Curie Action (MSCA) Innovative Training Networks (ITN) has received funding from the European Union’s H2020 Framework Programme under Grant Agreement no. 764879

Outline

- ✓ Motivation
- ✓ Work performed:
  - Former cycle baseline
  - Limiting factors
  - Improved design
- ✓ Secondments & Trainings & Dissemination events
- ✓ Next steps

Motivation

Cryogenic system for the FCC-hh

Total power consumption:

~ ∑ **200 MW** : 20 MW // 10 Plants // 100 km

Cooling capacity per plant:

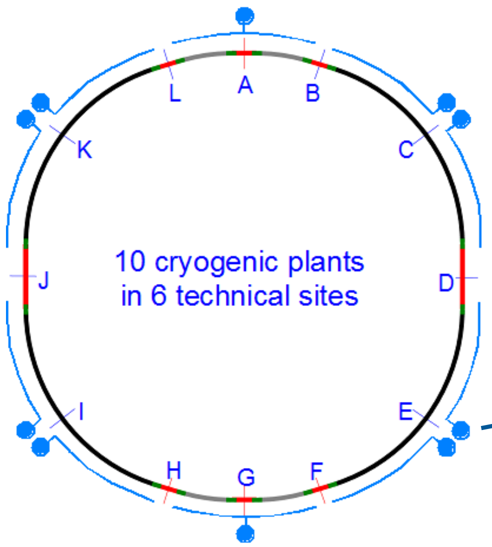
- from 60 to 40 K

    thermal shields – **78 kW**

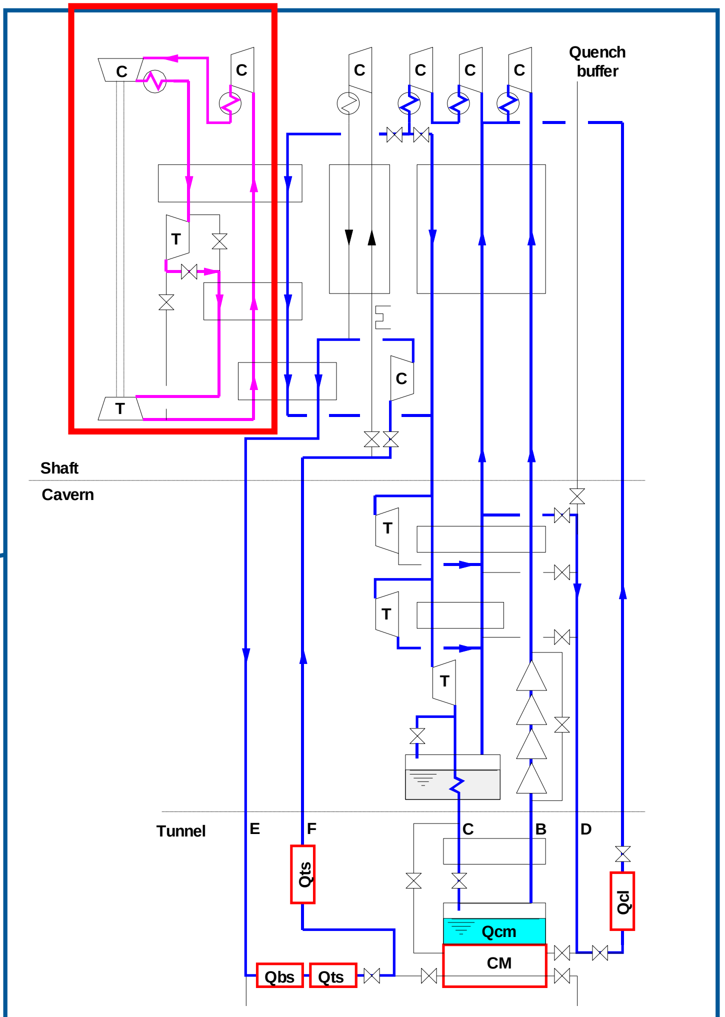
    beam screens – **504 kW**

- from 300 to 40 K

    pre-cooling of the helium cycle – **270 kW**



Ring layout (L. Tavian)



Cryoplant layout
(L. Tavian)

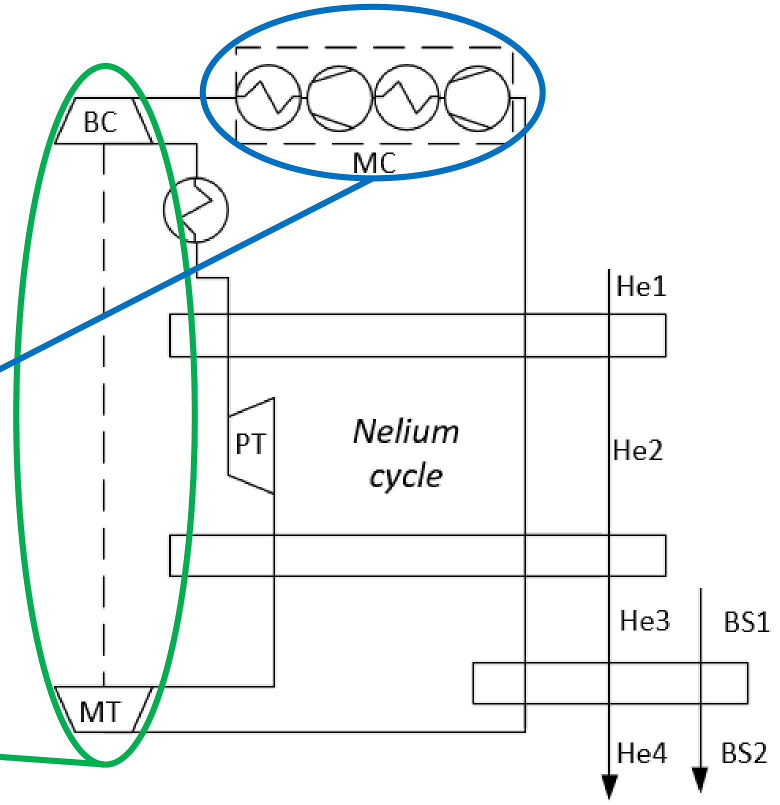
Baseline cryogenic cycle

Key components:

- multi-stage centrifugal compressor (~10 MW range)
- turbo-expander ~700 kW ⟶ power recovery in compressor

Previously considered Nelium composition: 33 vol. % of neon

*Nelium Turbo-Brayton cycle: **former baseline** cycle layout*



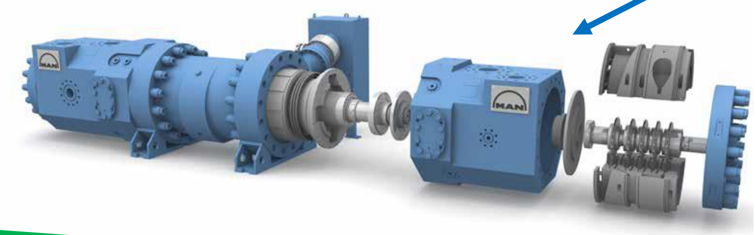


Image courtesy: MAN Diesel and Turbo

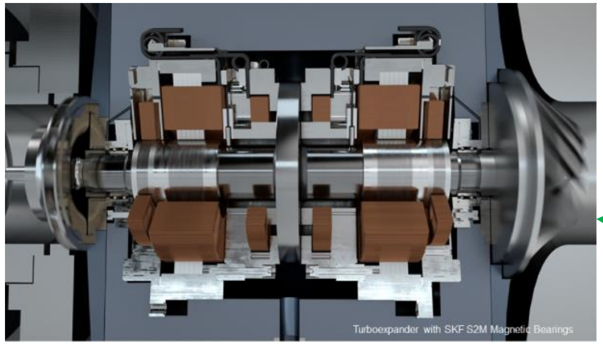


Image courtesy: SKF

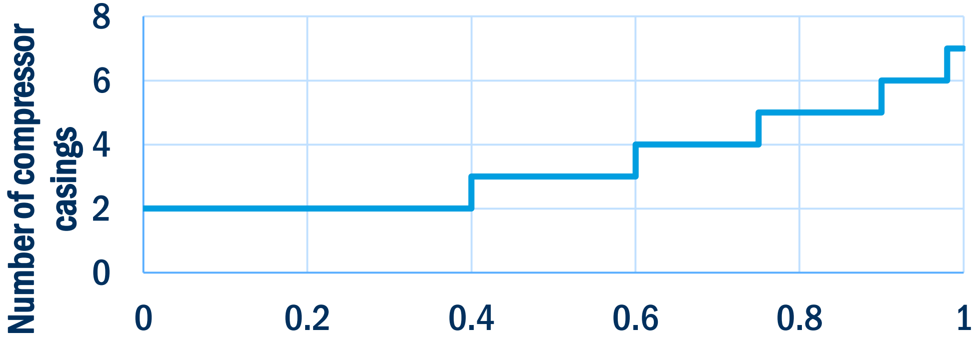
Limiting factors

1. Turbo-compressor design

Currently developed **1-tandem design**:

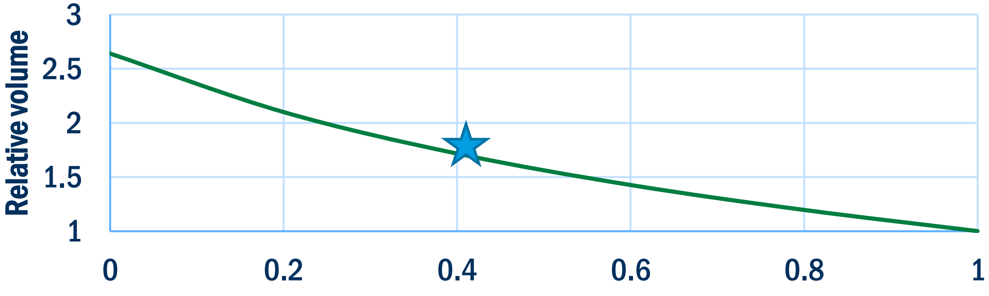
- up to 40 vol. % He;
- total compressor isentropic efficiency: ~73 %

Number of required compressor casings depending on the helium content
(M. Podeur, University of Stuttgart; MAN)

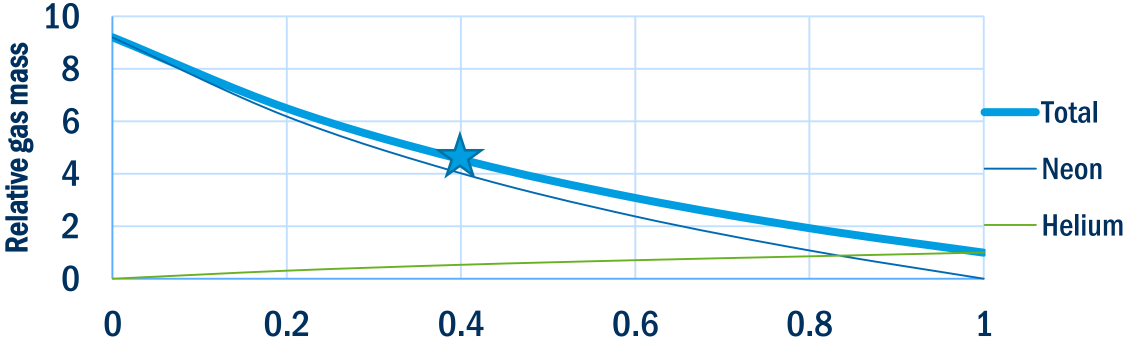


2. System size and gas mass

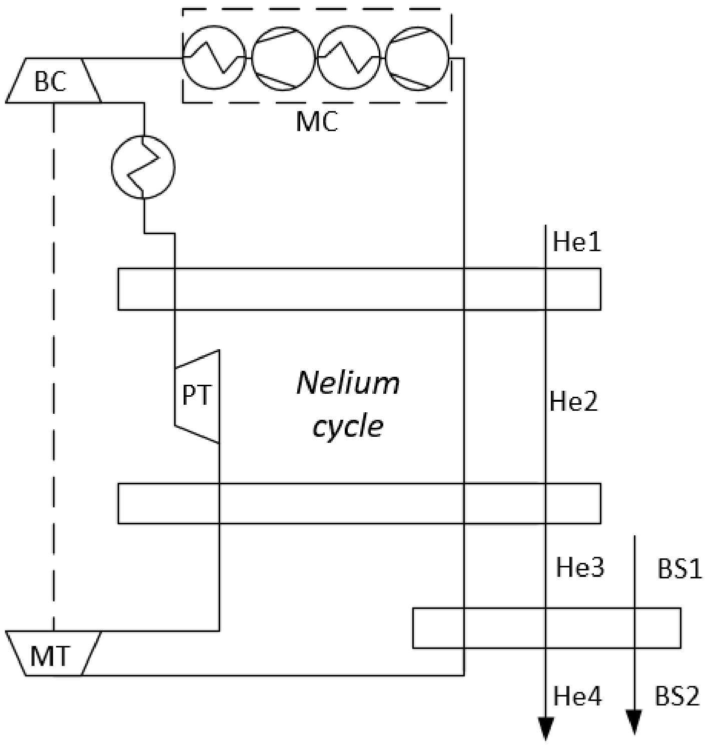
Relative heat exchanger sizes



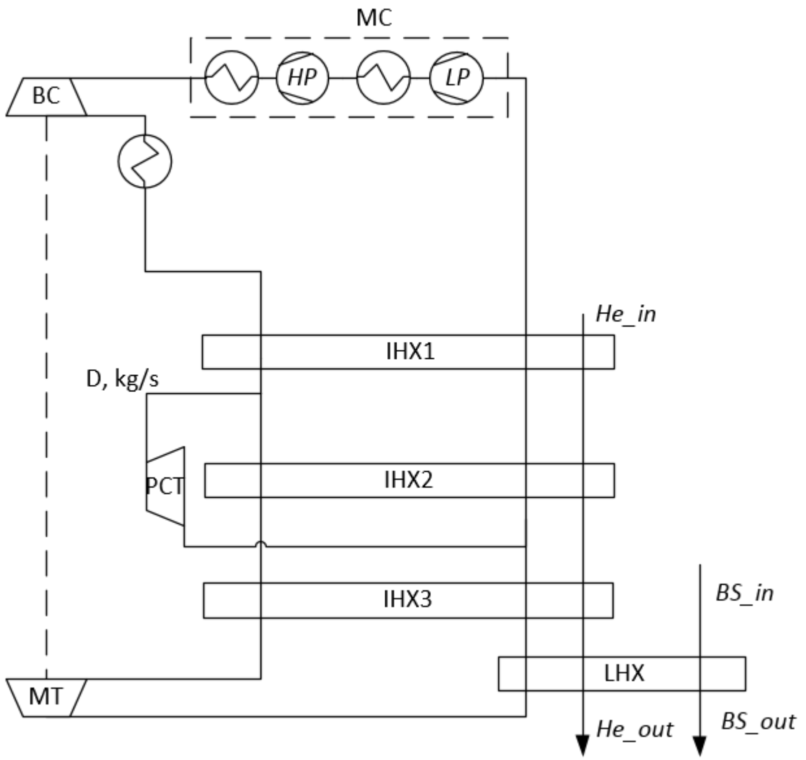
Theoretical relative gas mass compared to a pure helium cycle (excluding the buffer)



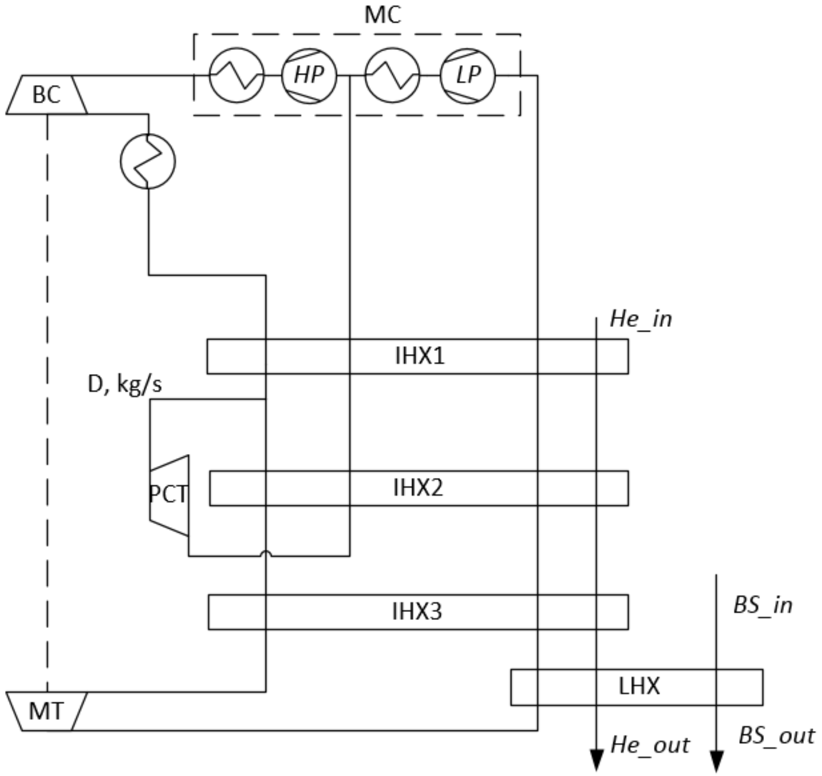
Compared cycle arrangements



Cycle A (baseline)

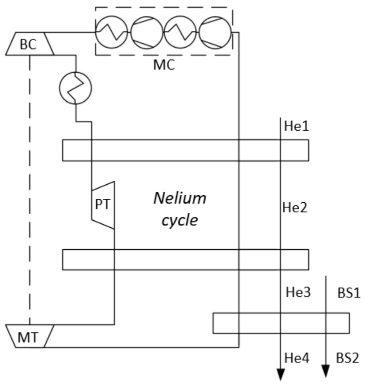


Cycle B



Cycle C

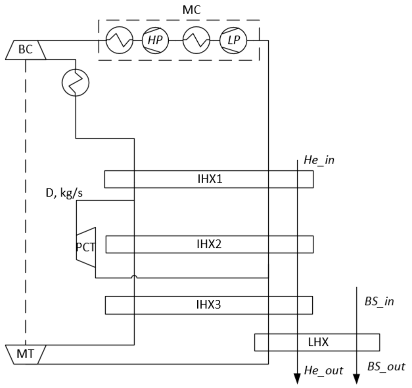
Compared cycle arrangements



✓ 2 inner heat exchangers

✗ higher pressure ratio

Cycle A (baseline)



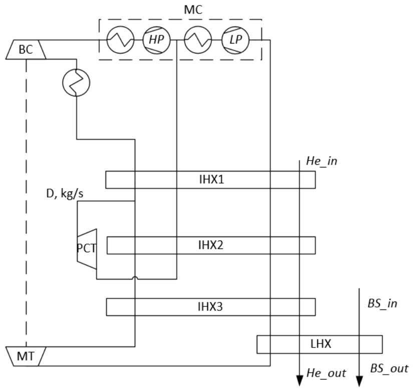
✓ reduced pressure ratio

✓ easier pressure control

✗ additional heat exchanger

Cycle B

✗ high speed of the pre-cooling turbine (high pressure ratio)



✓ reduced pressure ratio

✓ higher volumetric flow to the second compressor casing

✓ reduced pressure ratio of pre-cooling turbine compared to cycle B

✗ additional heat exchanger

Cycle C

Chosen arrangement

Compared cycle arrangements

Cycle C - > new baseline

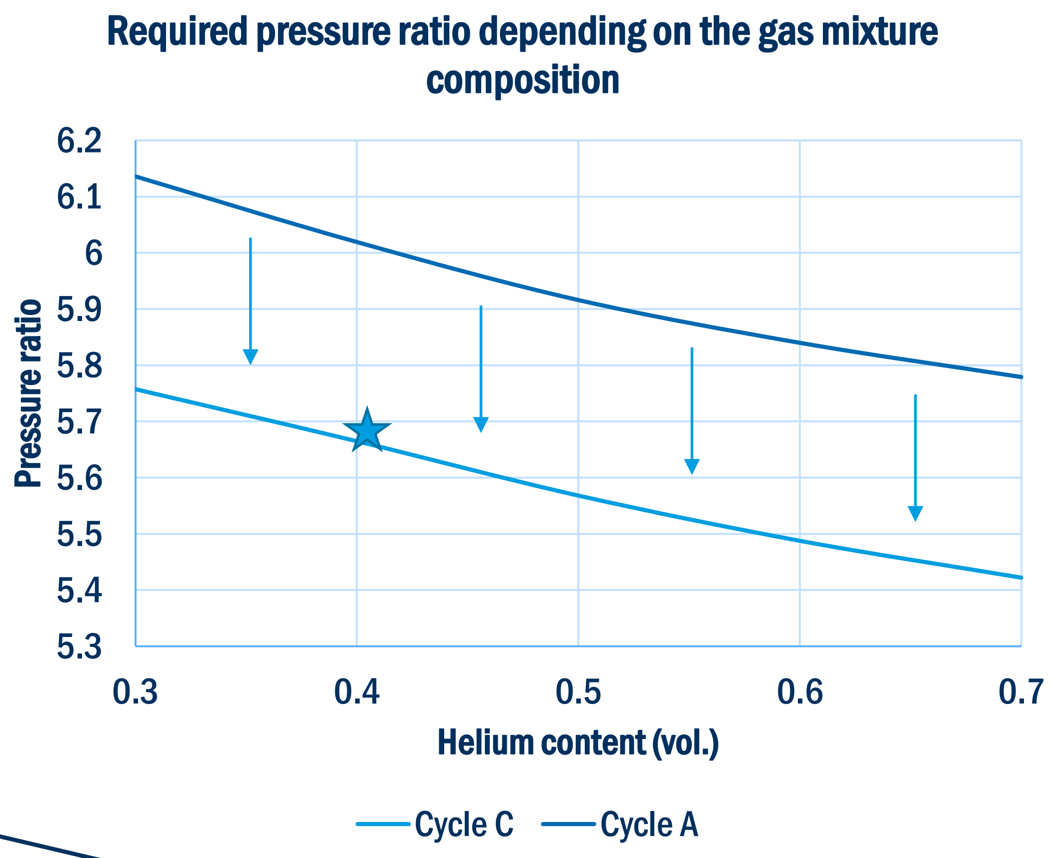
Advantages:

- Reduced pressure ratio
- Higher volumetric flow on the inlet of the second casing

Thus, for 40 % helium:

Cicle A: $\frac{V_{1\ casing}}{V_{2\ casing}} \sim 2{,}4$

Cycle C: $\frac{V_{1\ casing}}{V_{2\ casing}} \sim 1{,}9$ (var)

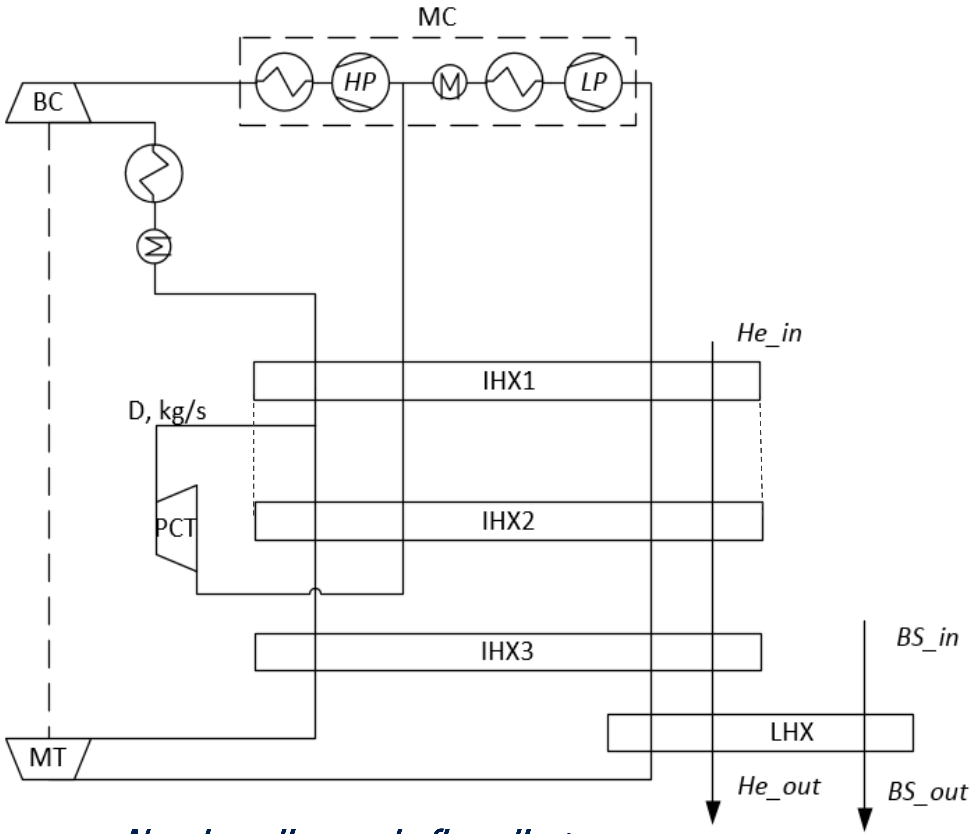


Increase helium content up to 60 vol. % He

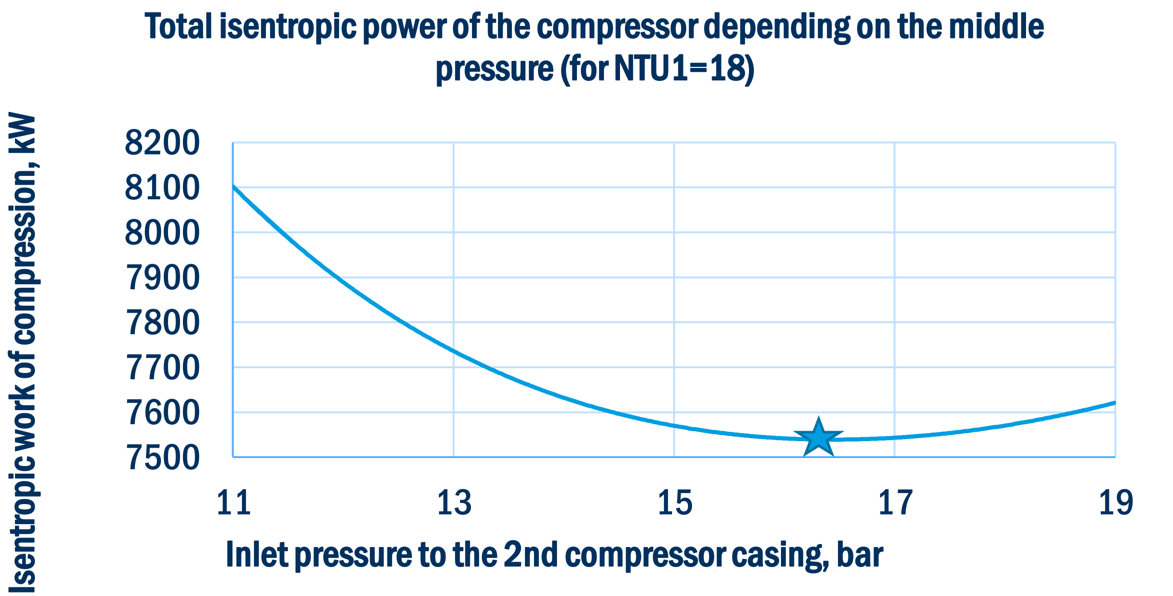
or

- 1 compressor impeller → +4..5 % to the total compresor η_s↑

Improved cycle concept



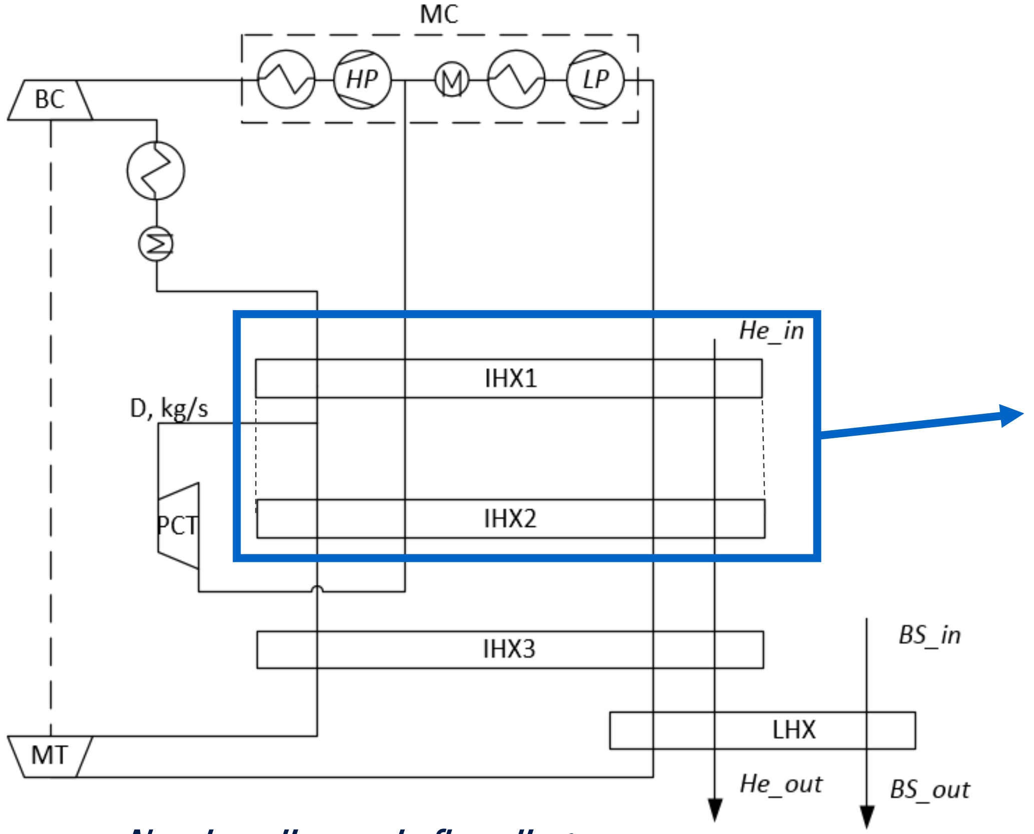
New baseline cycle flow diagram



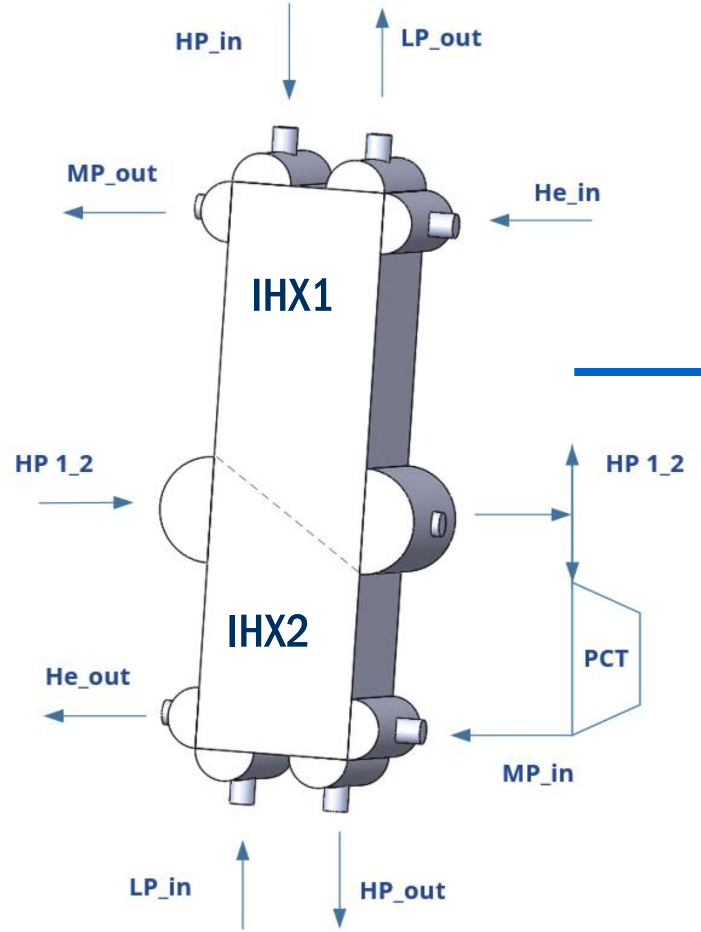
- Case study (under progress): matching the turbo-compressor middle pressure with the cycle parameters
- Estimated total power for the chosen case: ~9.7 MW

26.06.2019: *"Improved concept of the Nelium Turbo-Brayton cycle for the FCC-hh beam screen cooling"*,
S. Savelyeva, S. Klöppel, Ch. Haberstroh, H. Quack

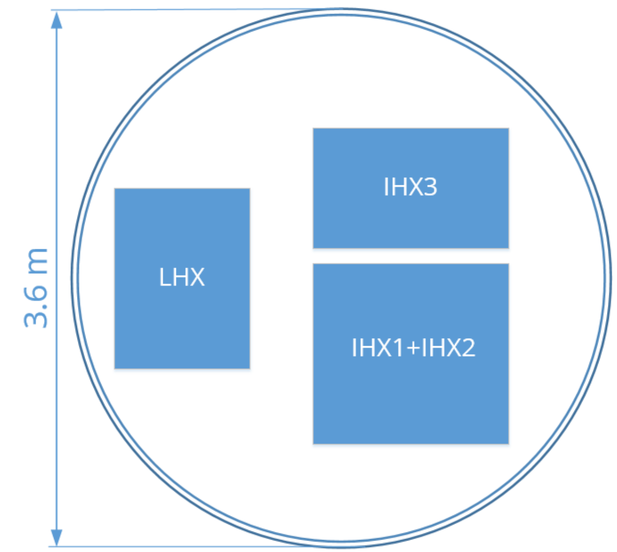
Upper heat exchanger design



New baseline cycle flow diagram



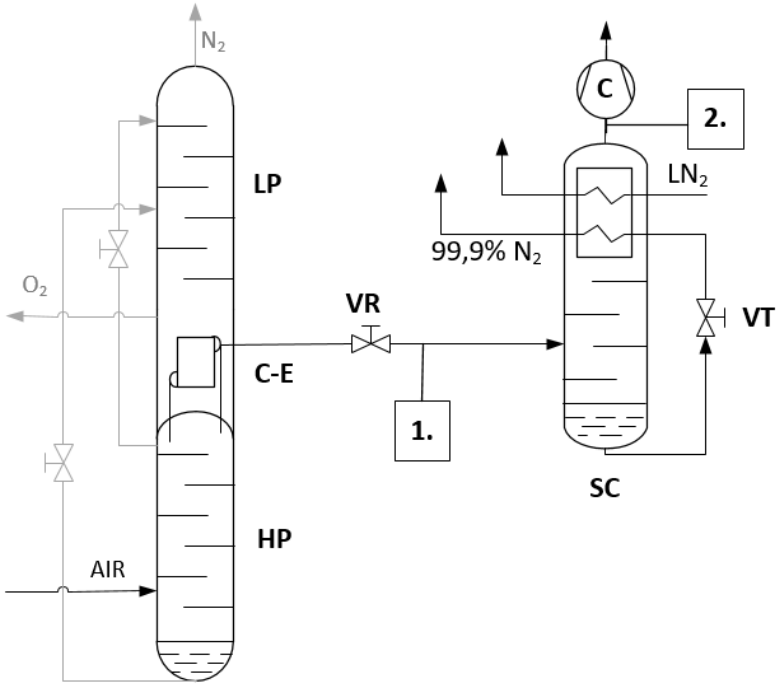
Reduction of the heat exchanger cross-section area and the cold box diameter



Cold box cross section

Length: 5.6...6 m;
Diameter: 3.6..3.8 m

Natural Nelium concept

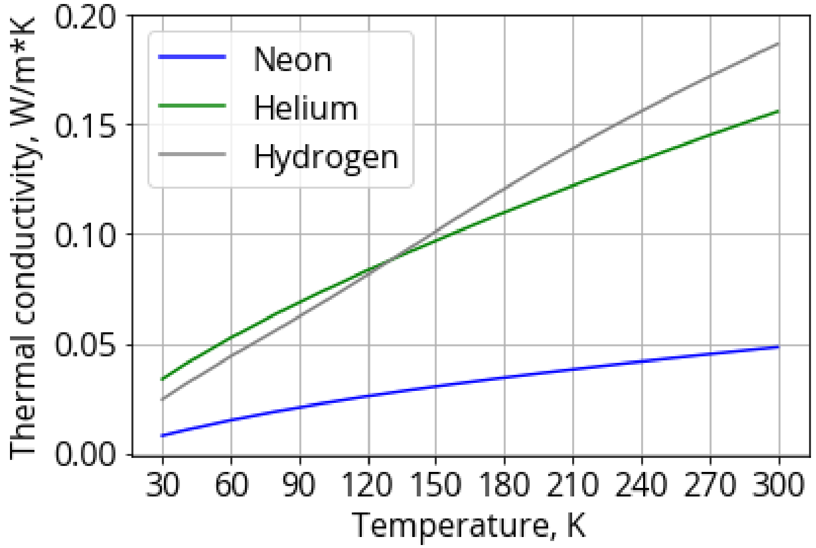


Crude nelium mixture production flow diagram

- Corresponds to the neon-helium ratio in the air:

  Natural Nelium: (Ne:He) ~(3:1) + (3...8 %) H_2

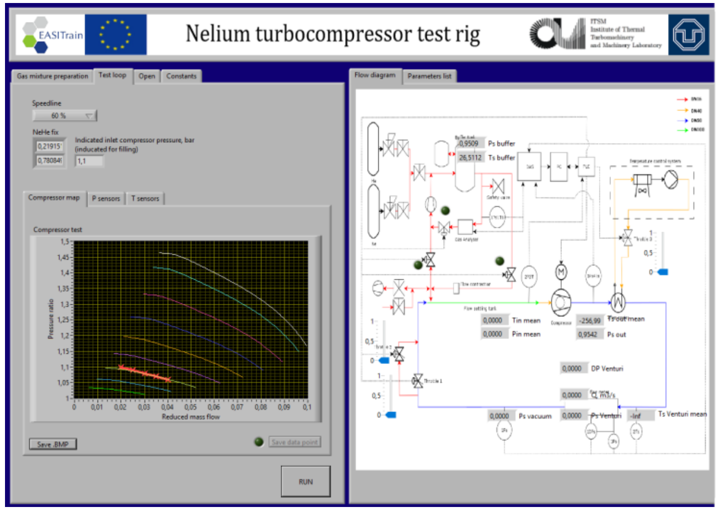
- Economically advantageous
- Current target composition: 60 % neon, 40 % helium → cheaper helium can be added
- Hydrogen presence in the mixture: good thermophysical properties
- Problem: instability of composition



Secondments & Trainings & Dissemination events

- Secondment – Linde Kryotechnik, *Pfungen, Switzerland (29.04.-14.06.2019)*

- Scientific cooperation with ESR 15 – University of Stuttgart, *Germany (18.03.-05.04.19)*



- Cryogenics conference 2019, *Prague, Czech Republic (07.04.-11.04.19)*

Next steps

- Case study for the cycle design matching with the turbo-compressor design
- Part-load operation and buffer optimisation for the new cycle baseline
- Review of the cycle performance calculation
- Compander design
- Cool-down operation of the new cycle baseline

- Further study of the Natural Nelium concept
- Participation in experiments on the neon-helium turbo-compressor test rig (University of Stuttgart)
- Secondment 2

Thank you for your attention!

"Development of a Nelium Turbo-Brayton cryogenic refrigerator for the FCC-hh"
EASITrain project status overview

S. Savelyeva, Ch. Haberstroh

EASITrain – European Advanced Superconductivity Innovation and Training. This Marie Sklodowska-Curie Action (MSCA) Innovative Training Networks (ITN) has received funding from the European Union's H2020 Framework Programme under Grant Agreement no. 764879