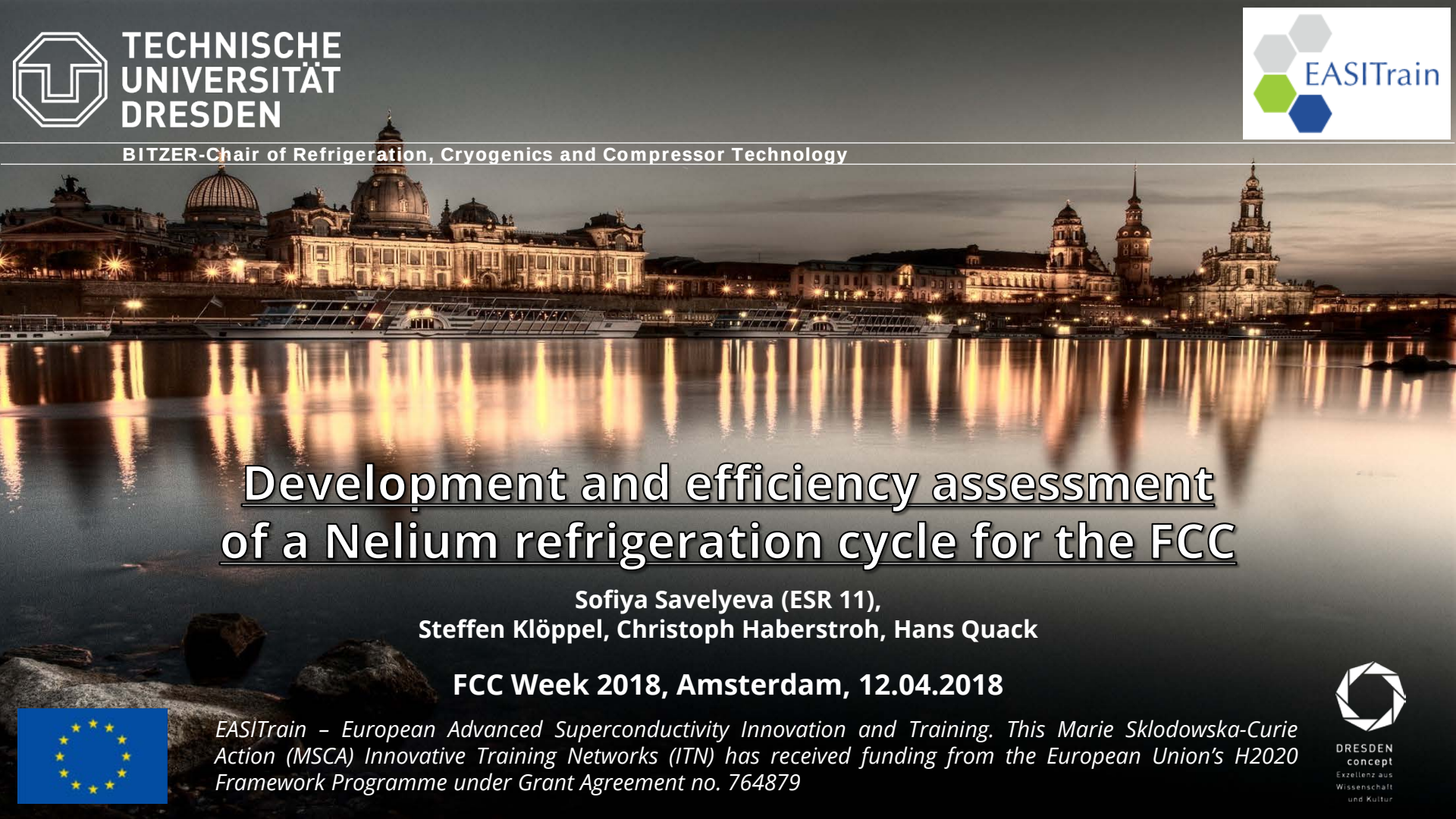


TECHNISCHE UNIVERSITÄT DRESDEN

BITZER-Chair of Refrigeration, Cryogenics and Compressor Technology

EASITrain

Development and efficiency assessment of a Nelium refrigeration cycle for the FCC

Sofiya Savelyeva (ESR 11),
Steffen Klöppel, Christoph Haberstroh, Hans Quack

FCC Week 2018, Amsterdam, 12.04.2018

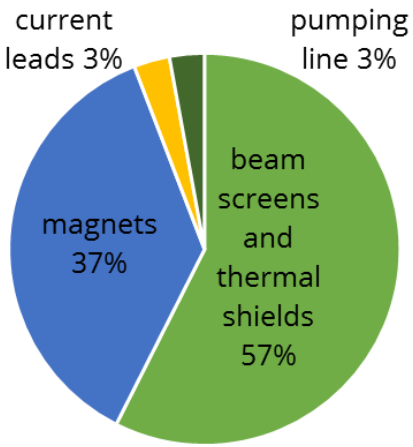
EASITrain – European Advanced Superconductivity Innovation and Training. This Marie Sklodowska-Curie Action (MSCA) Innovative Training Networks (ITN) has received funding from the European Union's H2020 Framework Programme under Grant Agreement no. 764879

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Background

- FCC-hh cryogenic system:
  10 plants 20 MW (200 MW in total) over 100 km ring
- Heat loads at 40 K per plant:
  thermal shields – 78 kW
  beam screens – 504 kW
- Pre-cooling of He-plant: 300 to 40 K
  heat load – 270 kW

Exergetic heat load distribution



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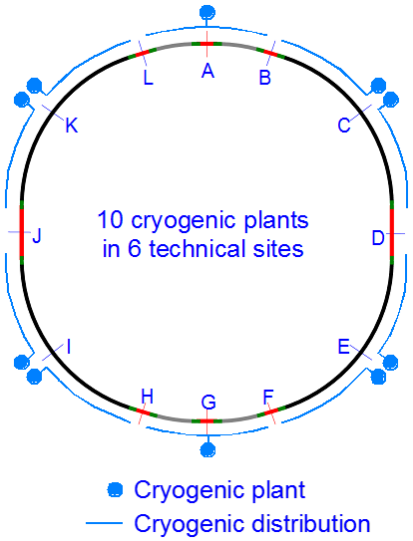
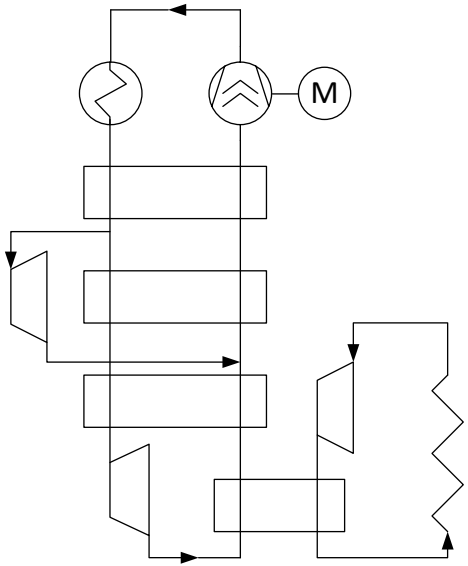
FCC-hh cryogenic facilities layout



L. Tavian

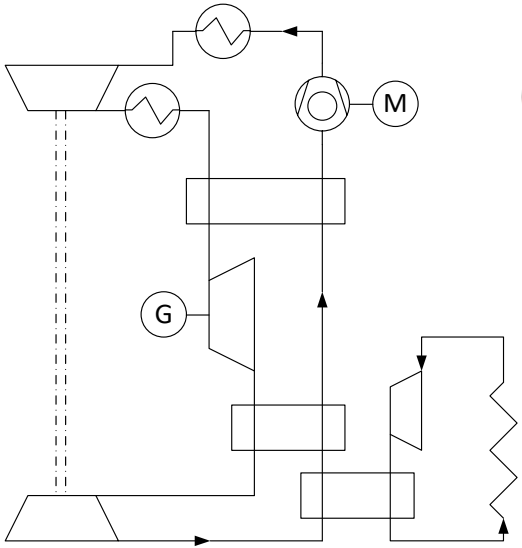
Motivation

Conventional He cycle
Screw compressor



≈30 % of Carnot efficiency
➔ 13 MW input power

Alternative Ne He cycle
Turbo compressor



≈41 % of Carnot efficiency
➔ 9.1 MW input power

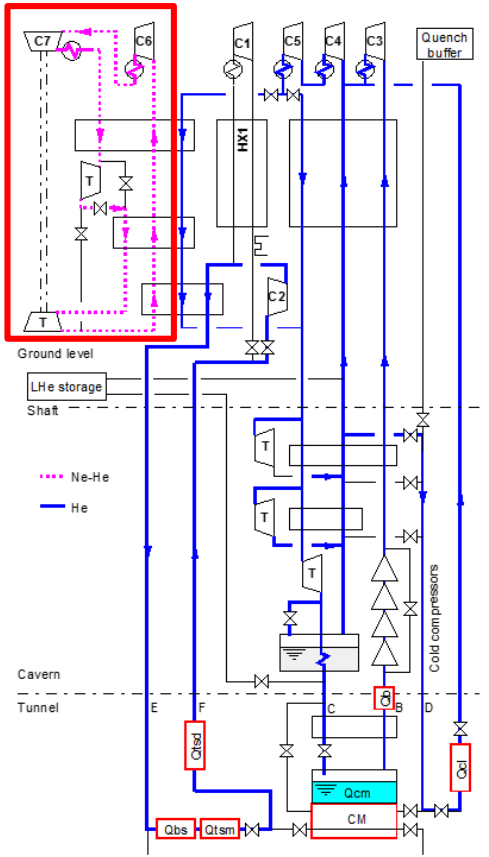
S. Klöppel

Photo courtesy : MAN Diesel and compressor

Objectives

- Improving the cooling system for beam screens, thermal shields and the He-cycle pre-cooling, using Nelium Turbo-Brayton cycle – *in cooperation with CEA (ESR 4), CERN*
- Industrial applications of cryogenic mixture cycles below 80 K
- Turbocompressors for the light gases – implementation in cryogenic cycles – *in cooperation with University of Stuttgart (ESR 15)*

Nelium cycle



Scheme of the full cryogenic cycle of FCC-hh

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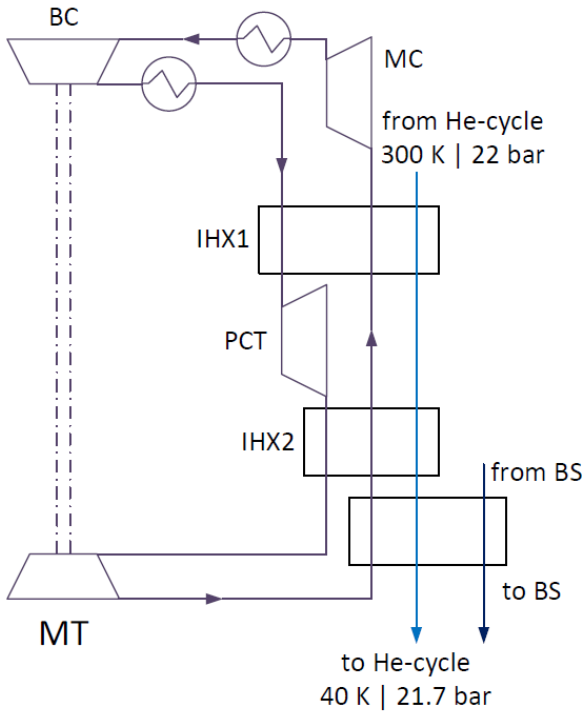
Tasks

- Cycle variation
- Study of turbocompressor efficiency
- Mixture specification
- Dynamic calculations
- Hardware (components specification, detailed modelling)
- Industrial applications

Nelium Turbo-Brayton cycle



S. Klöppel

Challenges

Study of compressor efficiency (centrifugal compressor, 7-9 MW)

- Experiments on the test rig (10 kW) with different impellers working on Ne-He mixture *(together with ESR 4, TU Stuttgart)*
- Precise compressor model for cycle calculations
- Ne-He mixture specification according to the experimental results

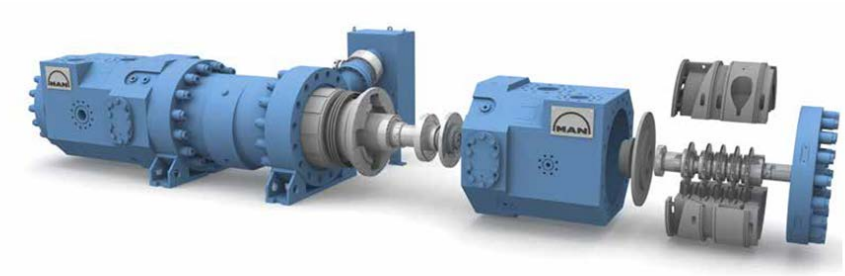
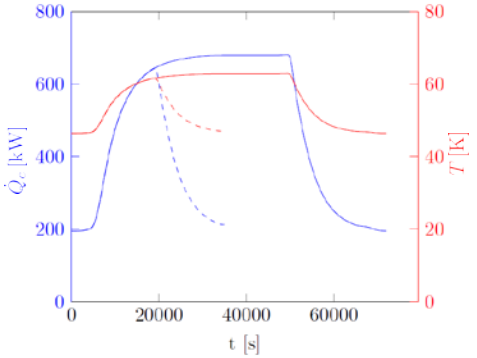


Figure 5. Warm centrifugal compressor (Courtesy of MAN Diesel & Turbo)

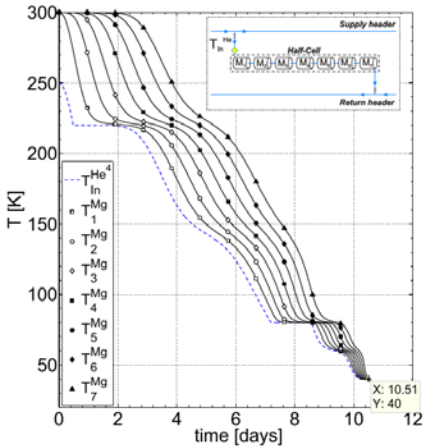
Challenges

Dynamic calculations:

- Transient operation – beam loads
  - Cool-down
  - Warm-up



High- and low-luminocity beam load



Cool-down operation

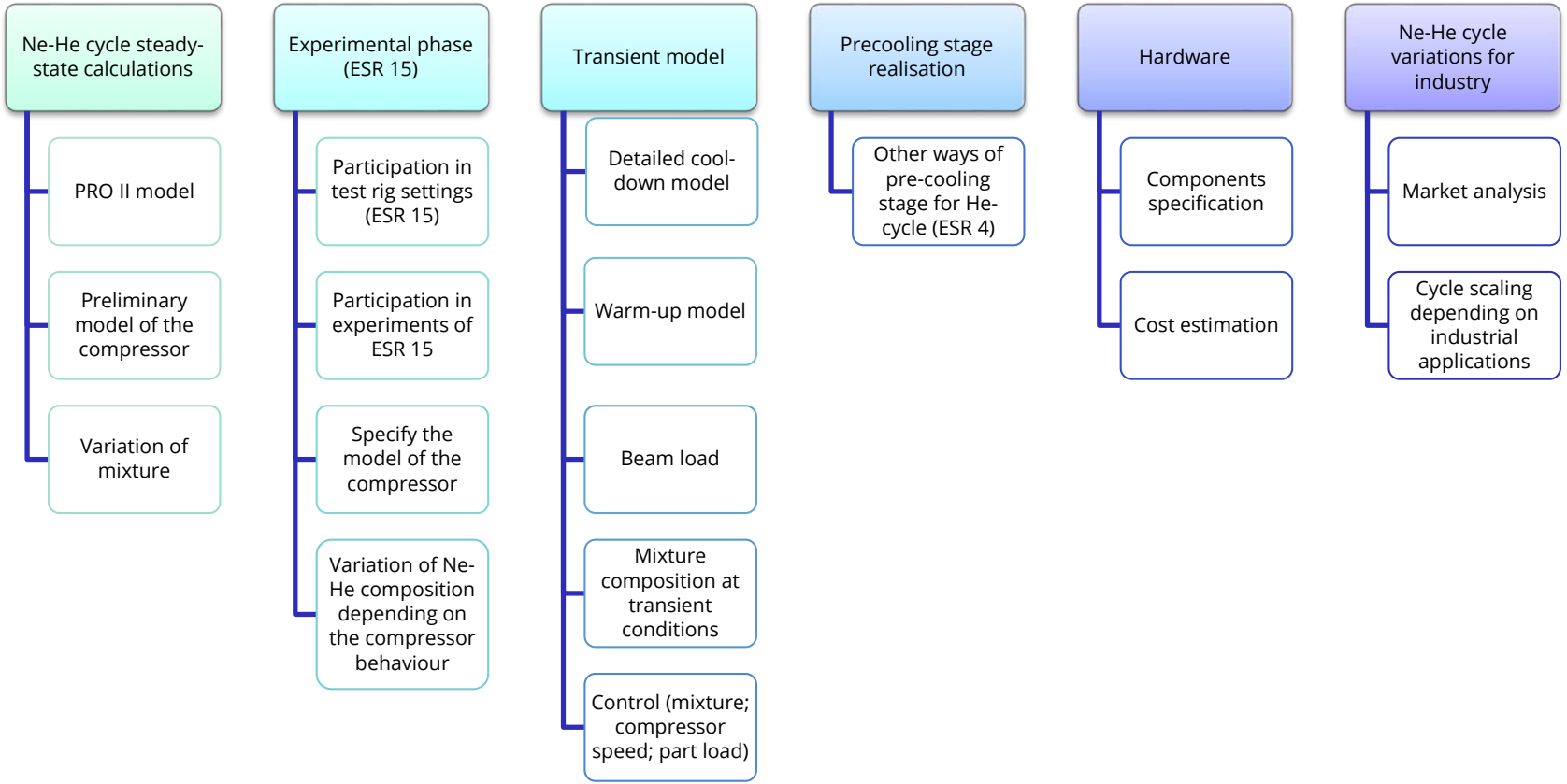
H. Rodrigues

Challenges

Industry

- Possible applications of developed cycle
- Cost estimation
- Cycle adjustment for the customer needs (working mixture, power range)
- Collaboration with companies
- Secondments

Work plan


Ne-He cycle steady-state calculations
PRO II model
Preliminary model of the compressor
Variation of mixture
Experimental phase (ESR 15)
Participation in test rig settings (ESR 15)
Participation in experiments of ESR 15
Specify the model of the compressor
Variation of Ne-He composition depending on the compressor behaviour
Transient model
Detailed cool-down model
Warm-up model
Beam load
Mixture composition at transient conditions
Control (mixture; compressor speed; part load)
Precooling stage realisation
Other ways of pre-cooling stage for He-cycle (ESR 4)
Hardware
Components specification
Cost estimation
Ne-He cycle variations for industry
Market analysis
Cycle scaling depending on industrial applications

Status

Start: 1st of February 2018

Project duration: 3 years

Deliverables planned:

4.2 – Specification for Nelium refrigeration system (main)

5.1 – Potential performance improvement and cost reductions for future accelerators

5.2 – Overall refrigeration system description

5.3 – Potential performance improvement and cost reductions for industry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Thank you for your attention!
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