

Large cryogenic process cycle modeling

Jakub Tkaczuk
ESR4, WP4

mid-term review
December 10, 2018, Brussels

Background & status

- Previous experiences:    COPERNICUS SCIENCE CENTRE   TECHNISCHE UNIVERSITÄT DRESDEN
- Contract start date: March 1, 2018
- Host institute:     UNIVERSITÉ Grenoble Alpes
- EASITrain Supervisor: François Millet
- PhD supervisor: Nicolas Luchier
- Planned secondments:  



Objectives

Assess the cooling architectures for large-scale cryogenic infrastructures

- Develop a reliable model describing the helium/neon mixture properties
- Validate the mixture model with existing Brayton / J-T cycle
- Study the process cycles with large cryogenic installations

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« Thermodynamic properties : for the moment, there is lack of reliable data for Helium-Neon mixture properties... »

FCC industrial study conclusion – Air Liquide and Linde statement

« To further evaluate the potential of Helium in hydrogen liquefaction processes, more work is needed to close present knowledge gaps related to the thermophysical properties of this mixture. »

W. Oivind et al., NTNU, Trondheim, Norway



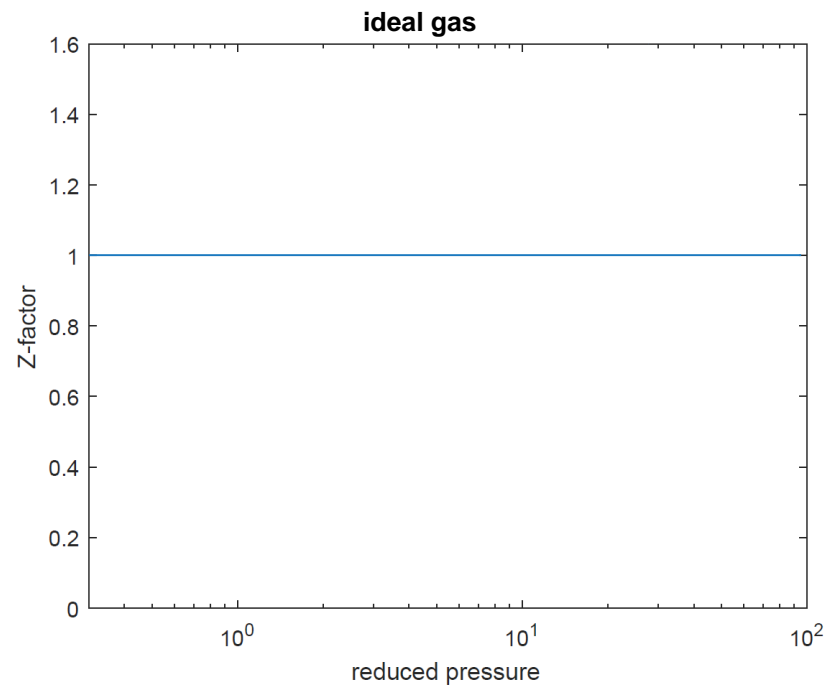
Ideal gas law

$$\frac{pv}{RT} = 1$$



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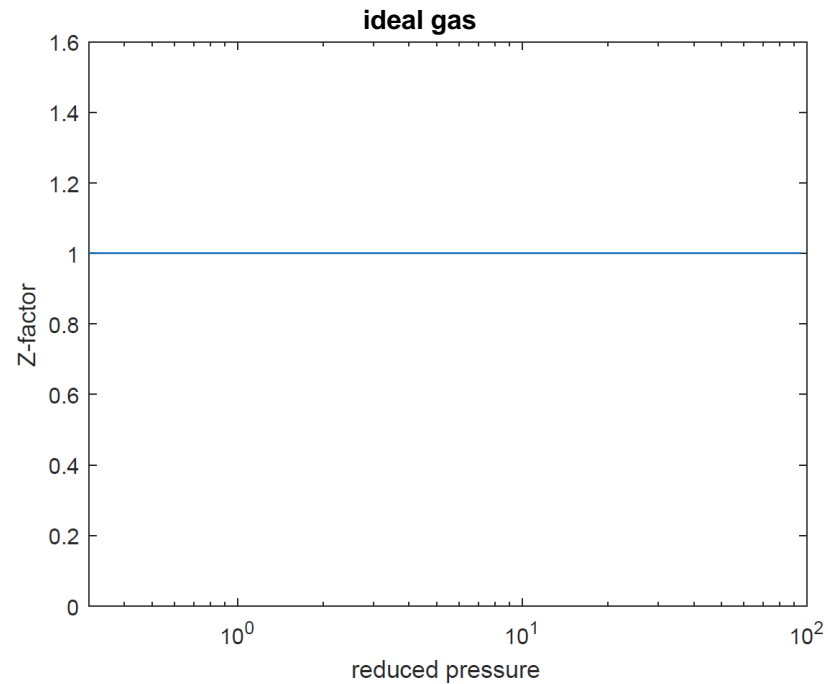


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Real gas and its virial expansion

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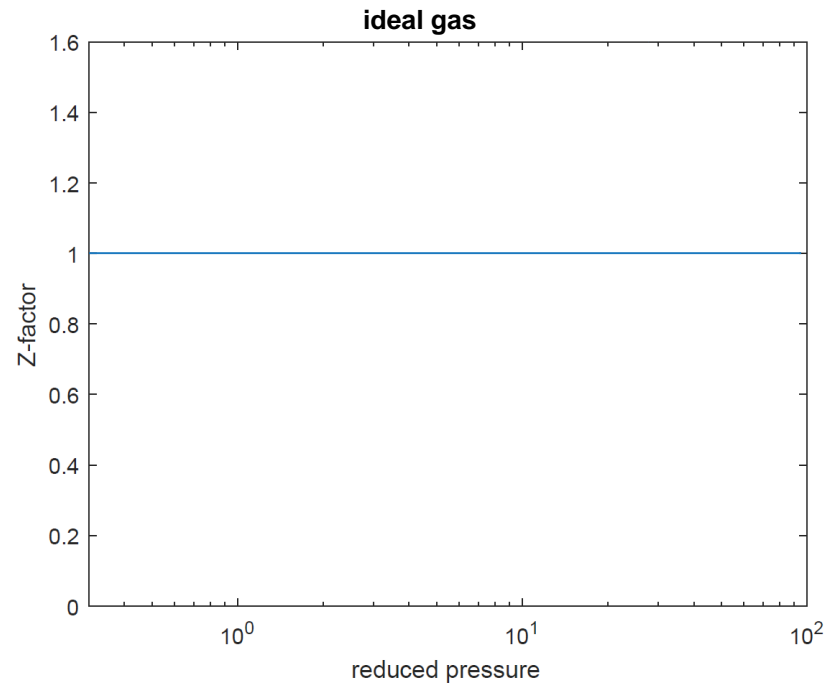


Ideal gas law

$$\frac{pv}{RT} = 1$$

Real gas and its virial expansion

$$\frac{pv}{RT} = Z = 1 + B(T)\rho + C(T)\rho^2 + D(T)\rho^3 + \dots$$



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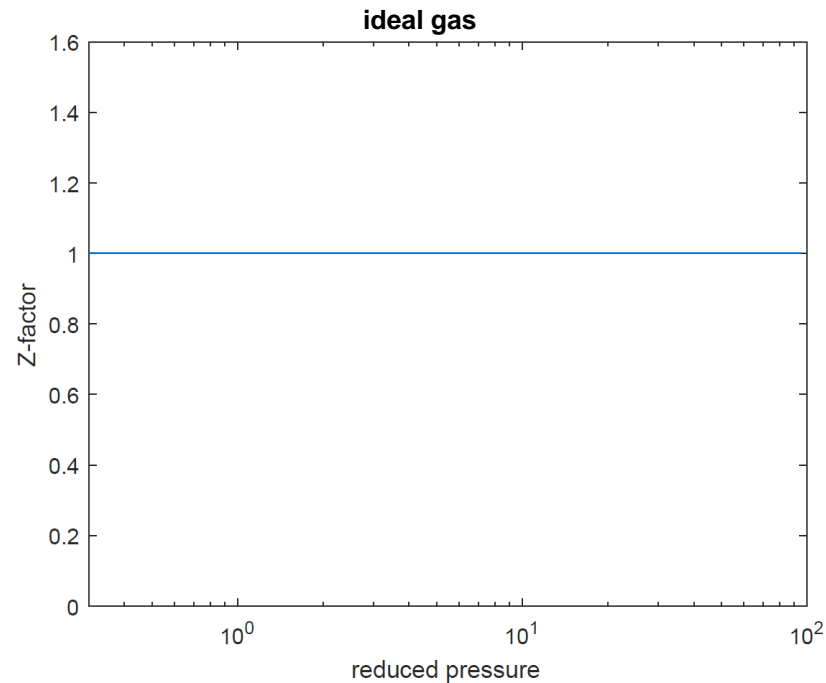
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Helmholtz energy formulation

$$\alpha(\delta, \tau, \bar{x}) = \alpha^0(\rho, T, \bar{x}) + \alpha^r(\delta, \tau, \bar{x})$$



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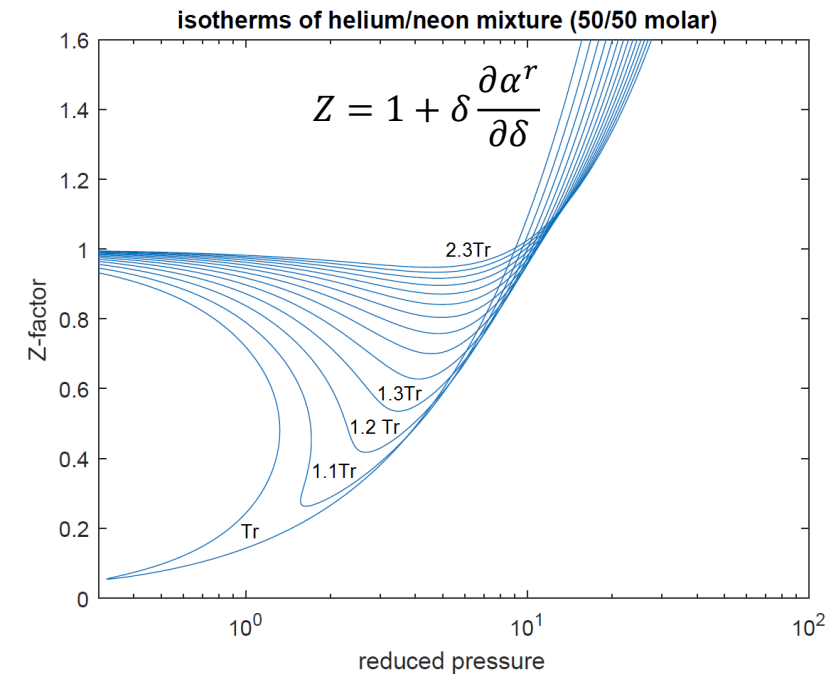
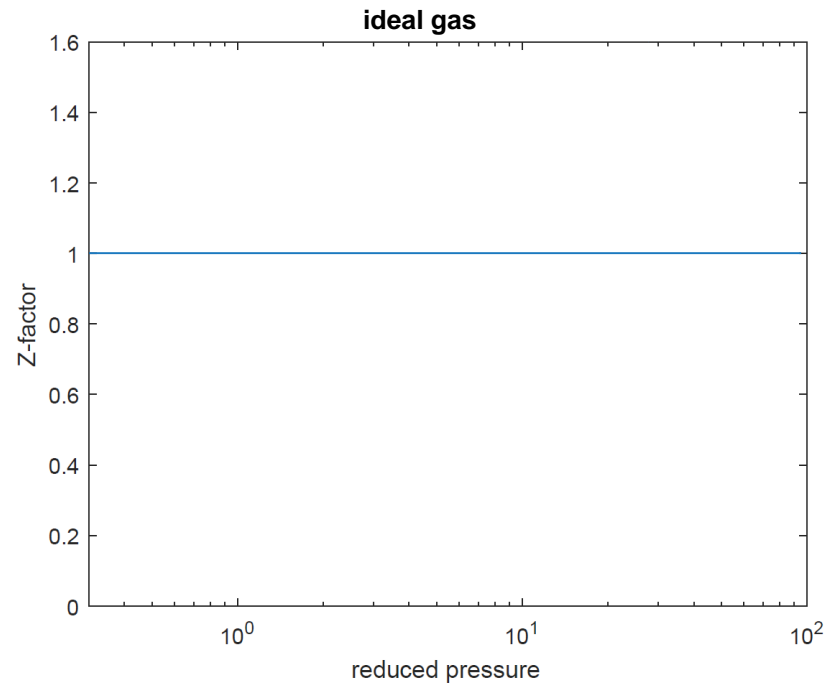
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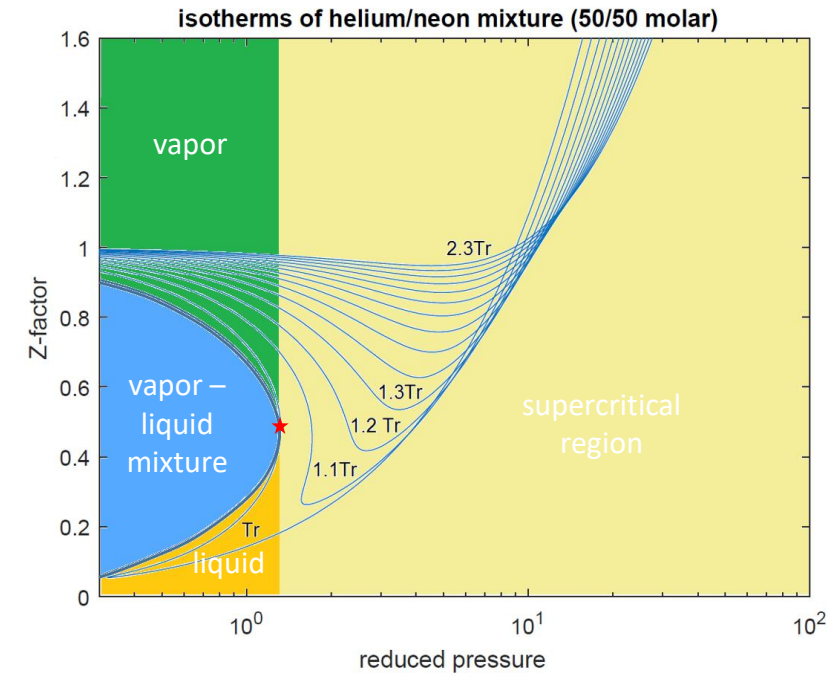
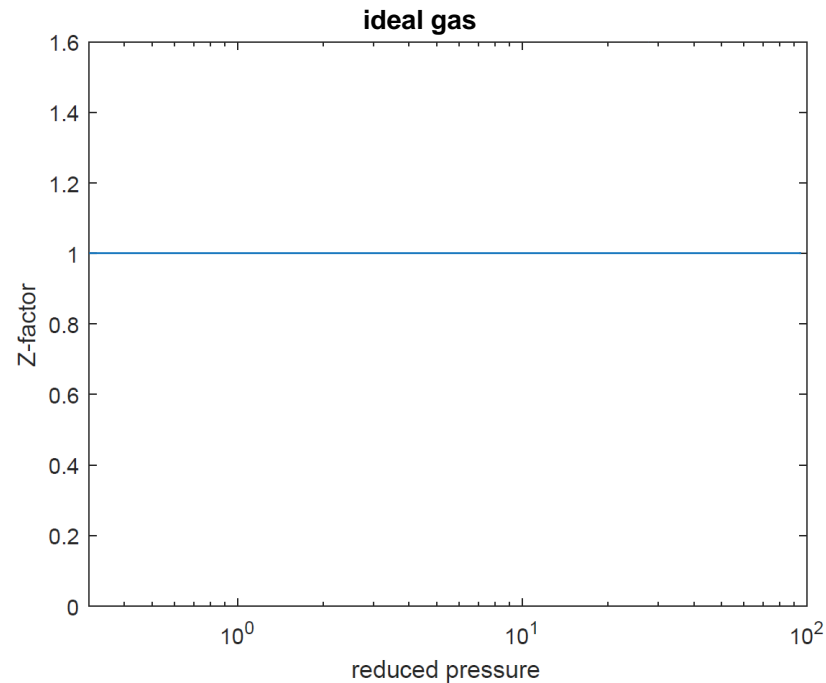
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Research & methodology

Helmholtz energy formulation

Advantages

- Continuous over liquid/vapor boundary
- It is a function of measurable properties
- Purely analytical derivatives

Challenges

- Requires large number of experimental data in a wide temperature-density range
- Nonlinear fitting combined with multiple constraints to control curvature of different properties



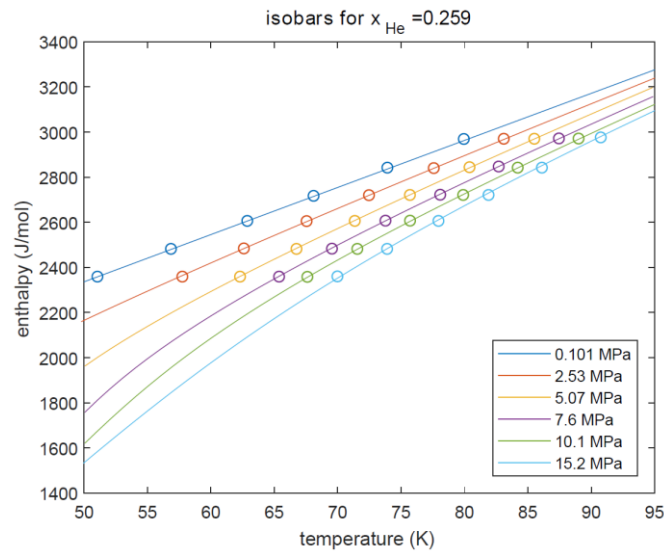
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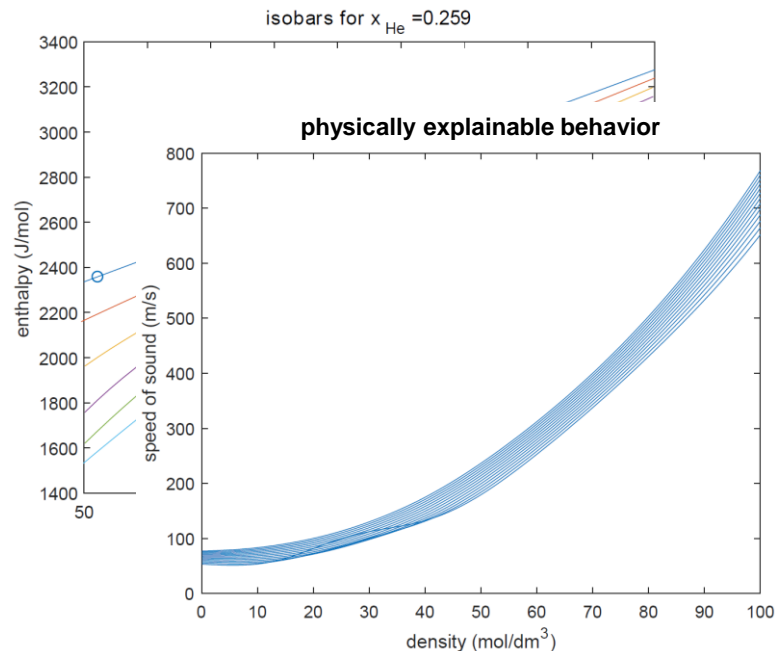
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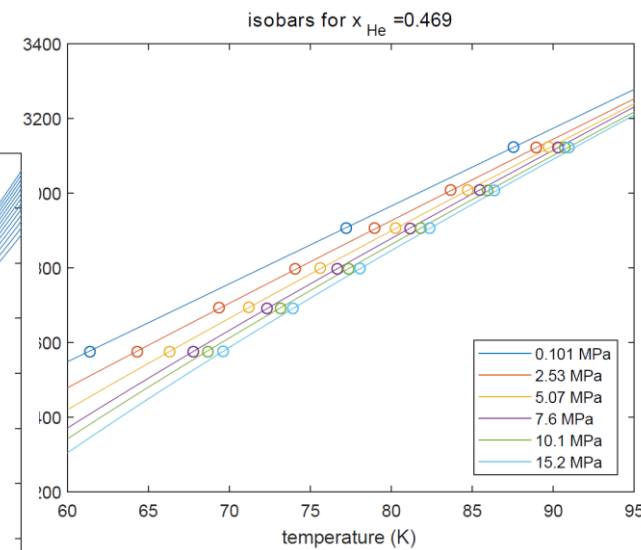
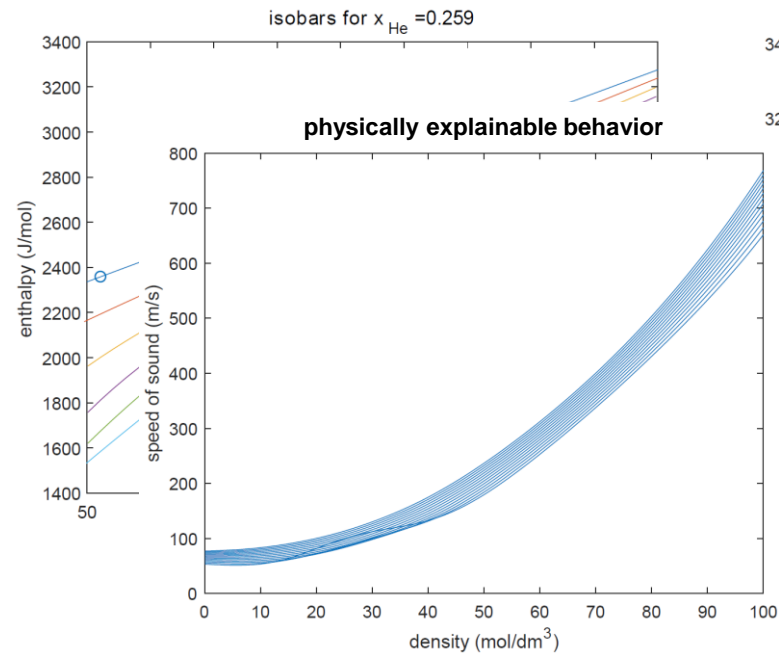
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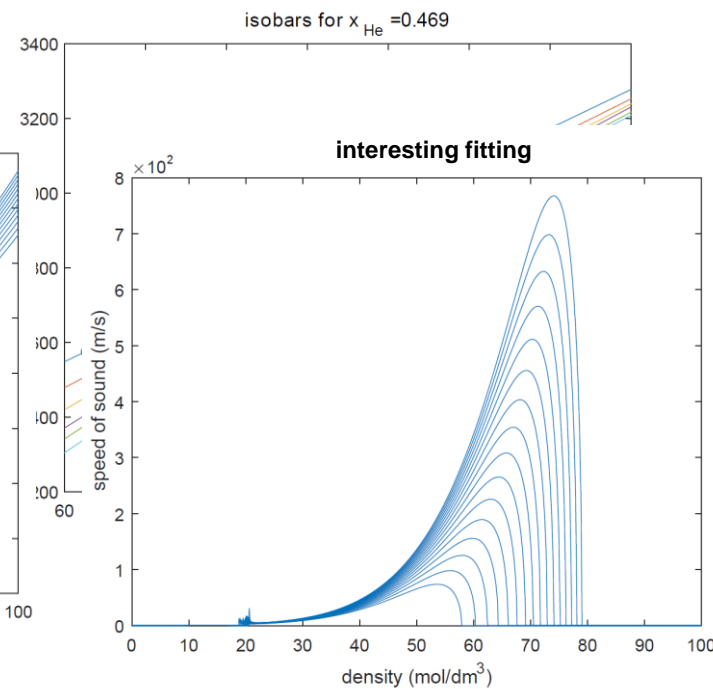
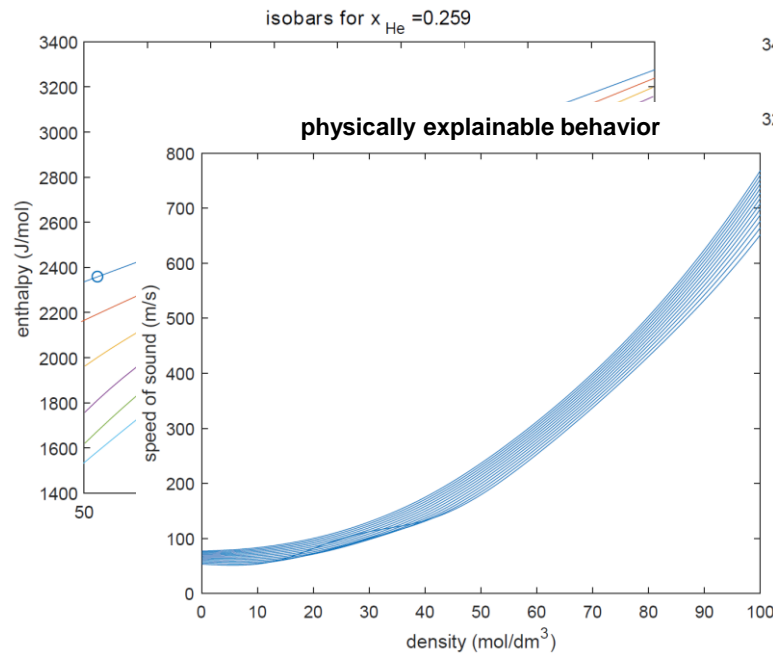
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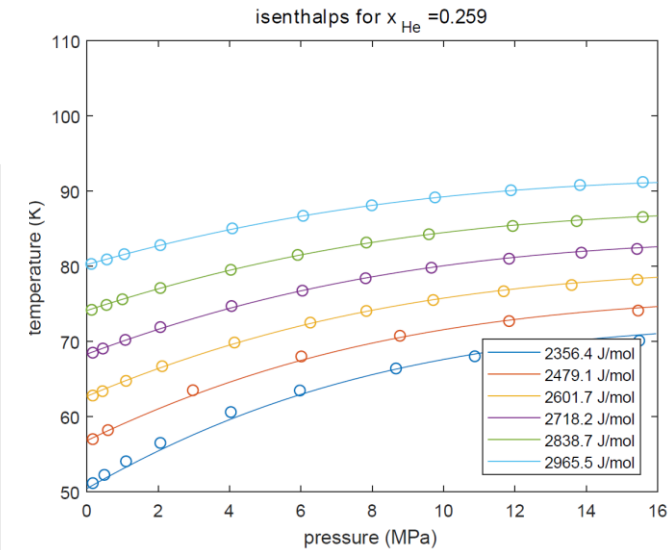
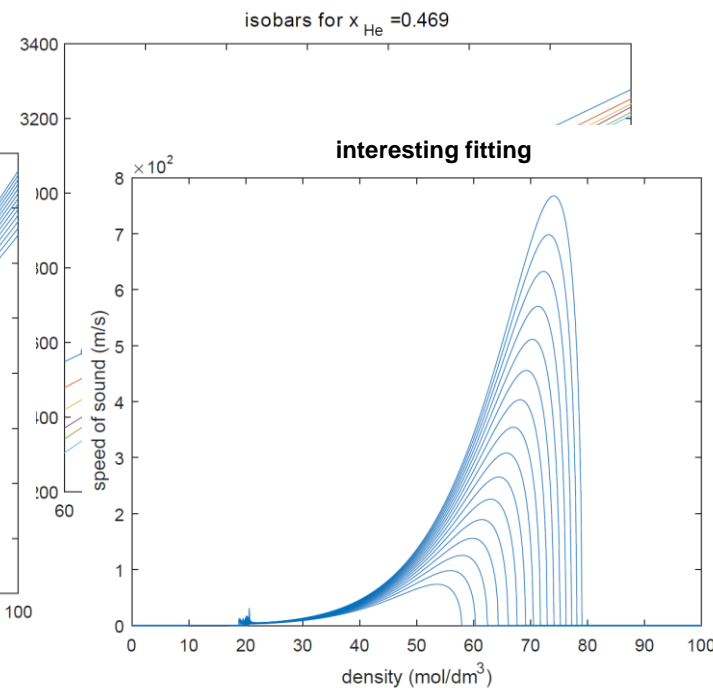
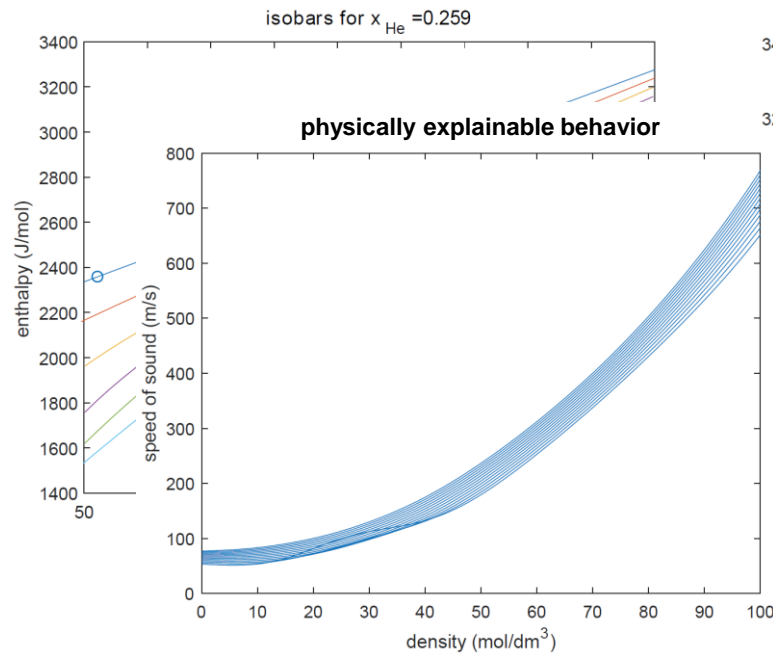
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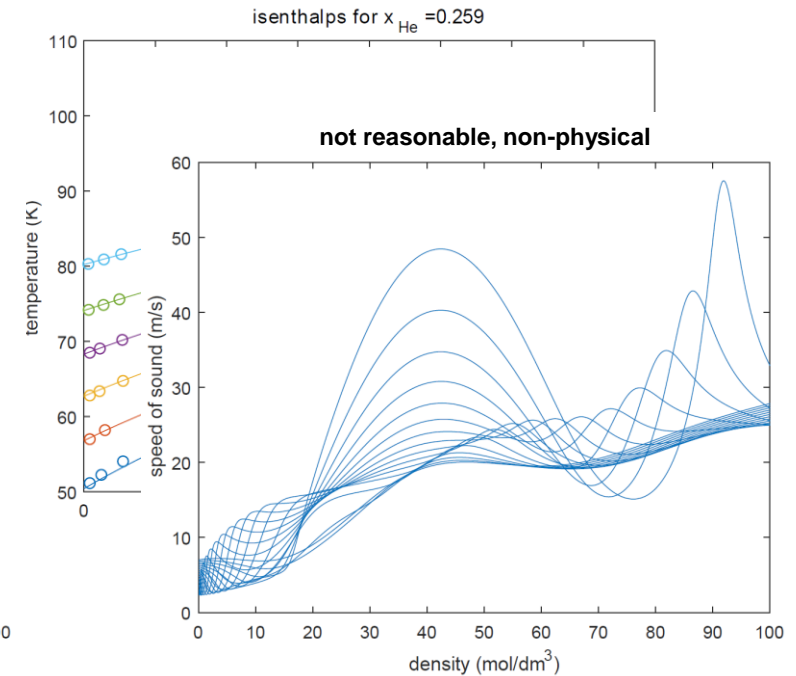
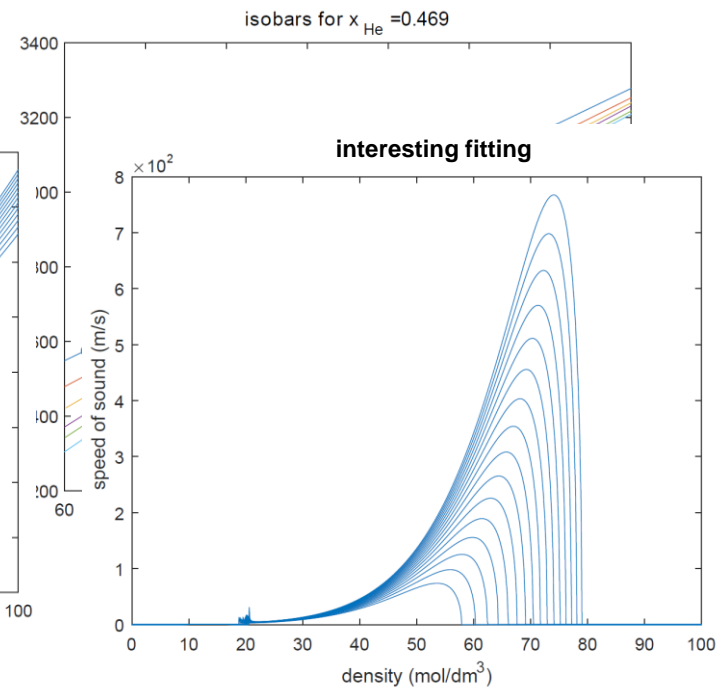
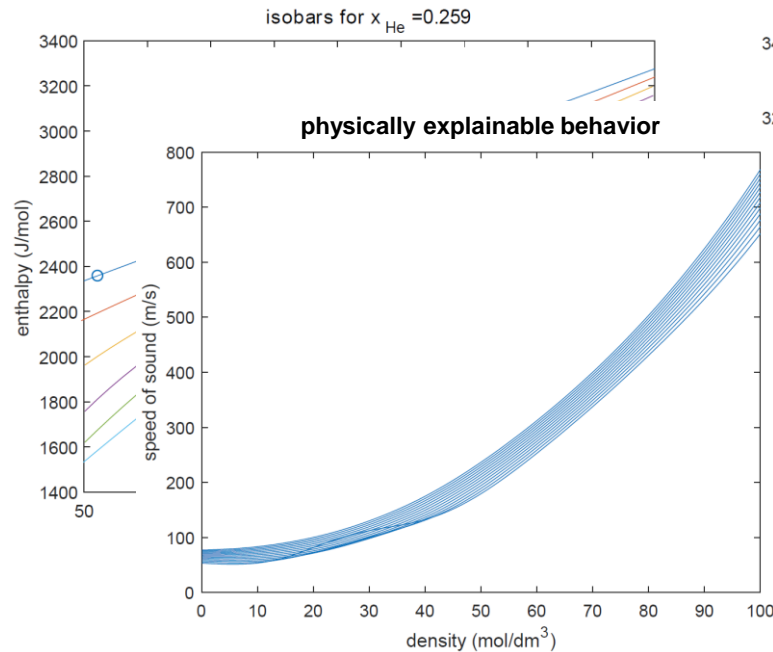
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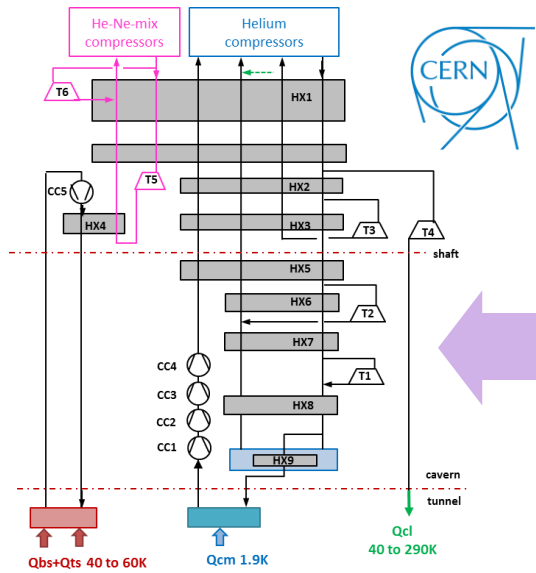


Next steps

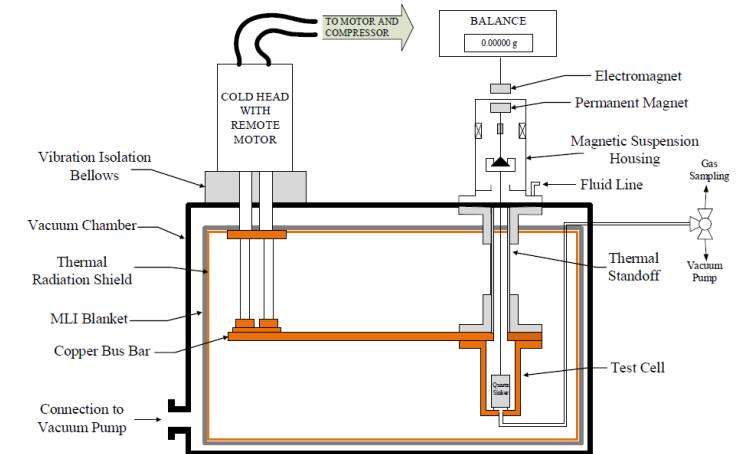
Form the foundations for the next generation of mixture models for binary fluid systems

Model validation with existing installations

Cryogenic process cycles concept validation



Concept A – Ne/He precooling



I. Richardson, J. Leachman (WSU)

- **EASITrain trainings** (*past ones*)

CEA and CERN introduction

CEA and CERN safety courses

European Course of Cryogenics 2017

CSA Safety Courses

- **EASITrain conferences** (*past ones*)

FCC Week 2018

Cryogenic Safety Seminar 2016, CEC 2017, Cryogenics 2017

FCC Weeks 2016, 2017

Superconductivity for Accelerators for Medical Applications 2016

- **EASITrain events**

Spring lectures at CERN

Summer school at TU Vienna



- **Outreach** (*past ones*)

Science days at Université Grenoble Alpes

Copernicus Science Center

Science nights: WUT, TU Dresden

- **Dissemination** (*past ones*)

FCC Week 2018 presentation

CEC 2017 poster

Publications: PRAB, ICEC 2018

- **Networking**

CEA and UGA seminars

M.Sc. interns co-supervision

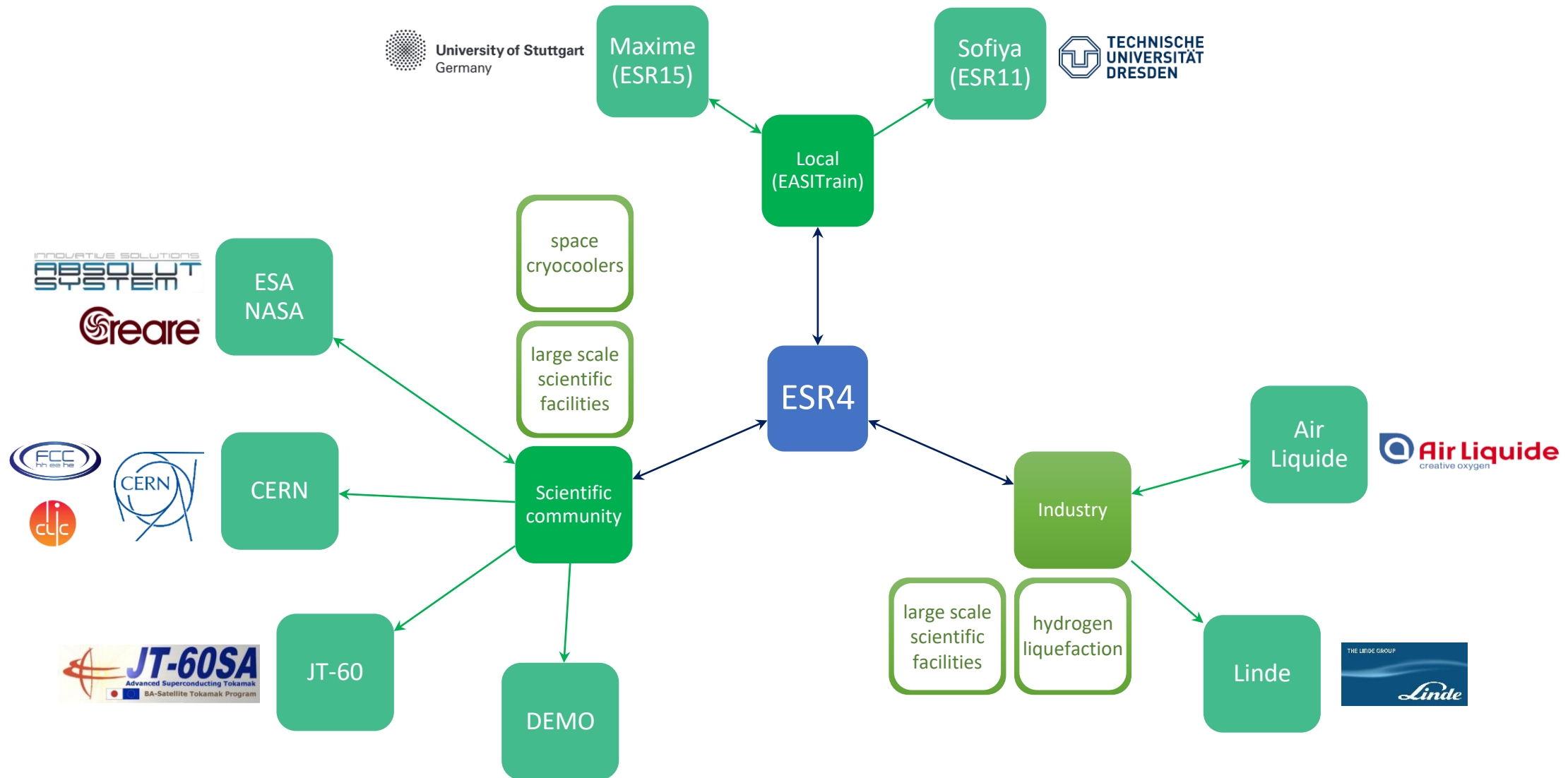
Secondments at NIST/ALaT

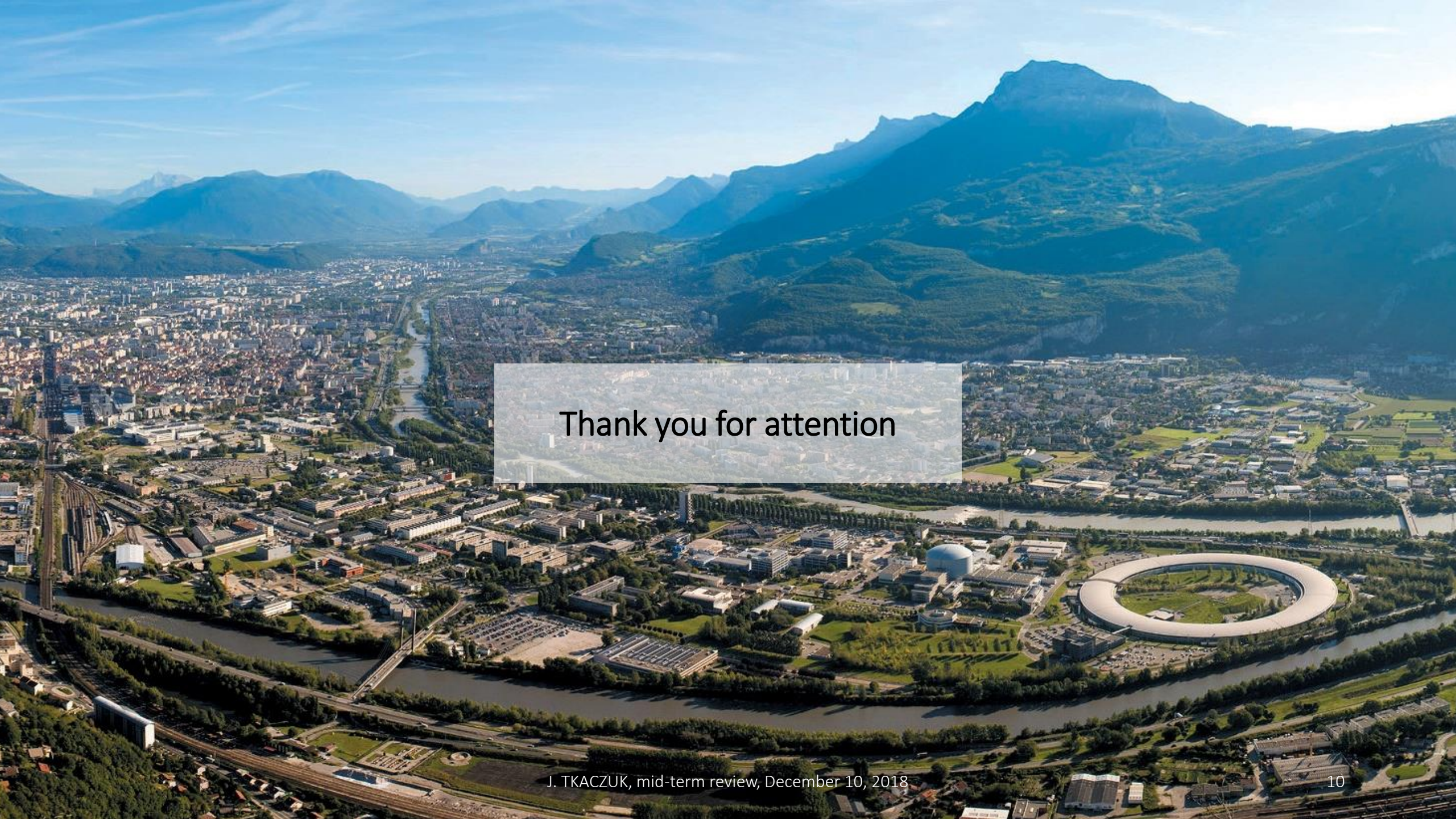


J. TKACZUK, mid-term review, December 10, 2018



Impact



An aerial photograph of Grenoble, France, showing the city built on a valley floor with the Isère river winding through it. In the background, the French Alps are visible under a clear blue sky. A semi-transparent white rectangular box is centered over the middle of the image, containing the text "Thank you for attention".

Thank you for attention