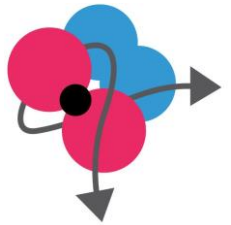

Depressurization of CO_2-N_2 and CO_2-He in a tube

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Outline of presentation

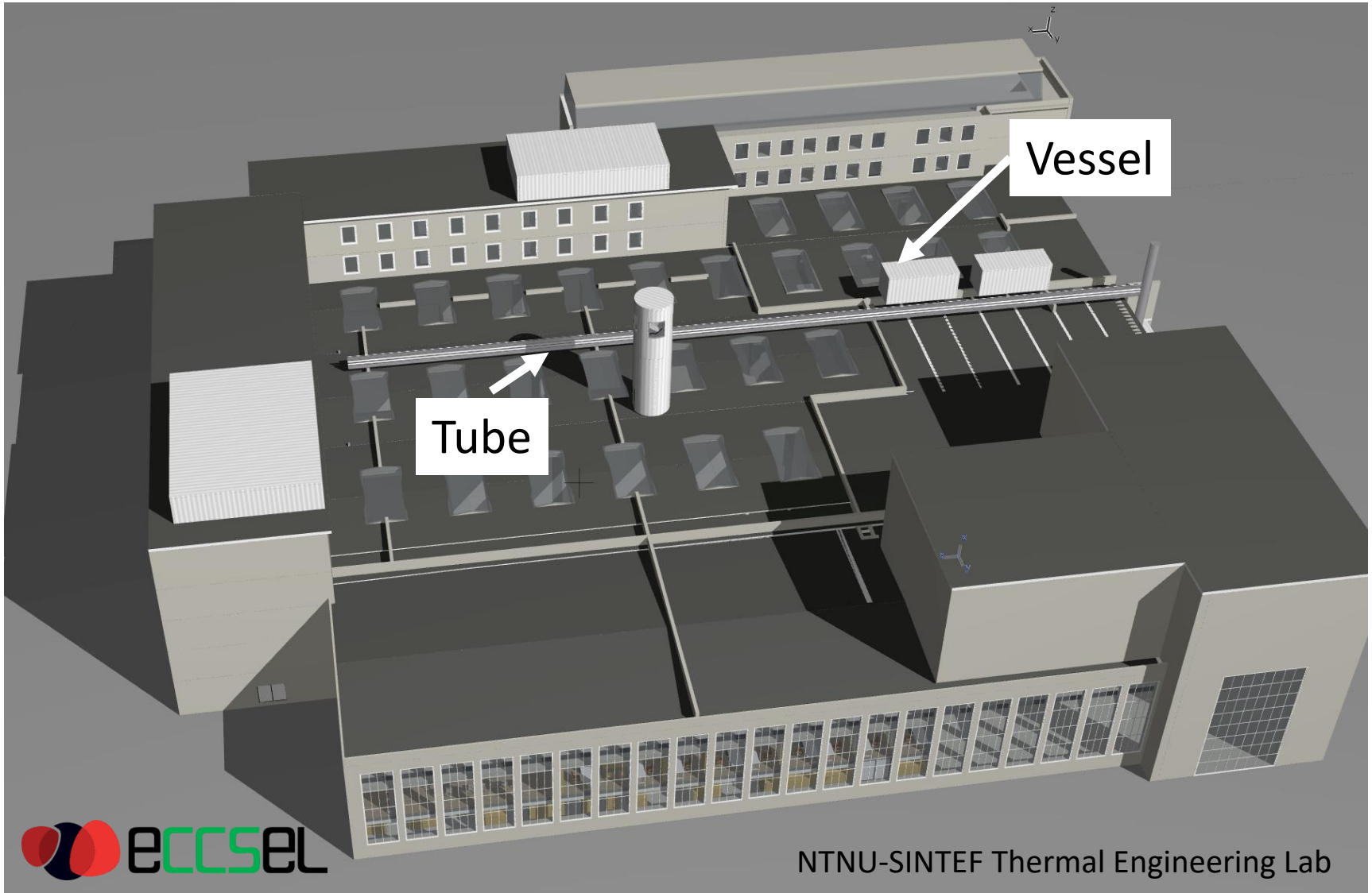
- Motivation
- ECCSEL depressurization facility
- Results
- Conclusions

Motivation

SINTEF I

- Transport and injection of CO_2 is different from production of oil and natural gas, and this has implications on operation and design.
  - Operation close to critical point and triple point in some situations.
- Safety aspects are also different
  - Running-ductile fracture: CO_2 boils and sustains a higher pressure on the opening pipe flaps.
  - Potential clogging of vent lines due to dry-ice formation.
- Here we focus on an experiment to help development of models describing transient flow in pipes.

ECCSEL depressurization facility



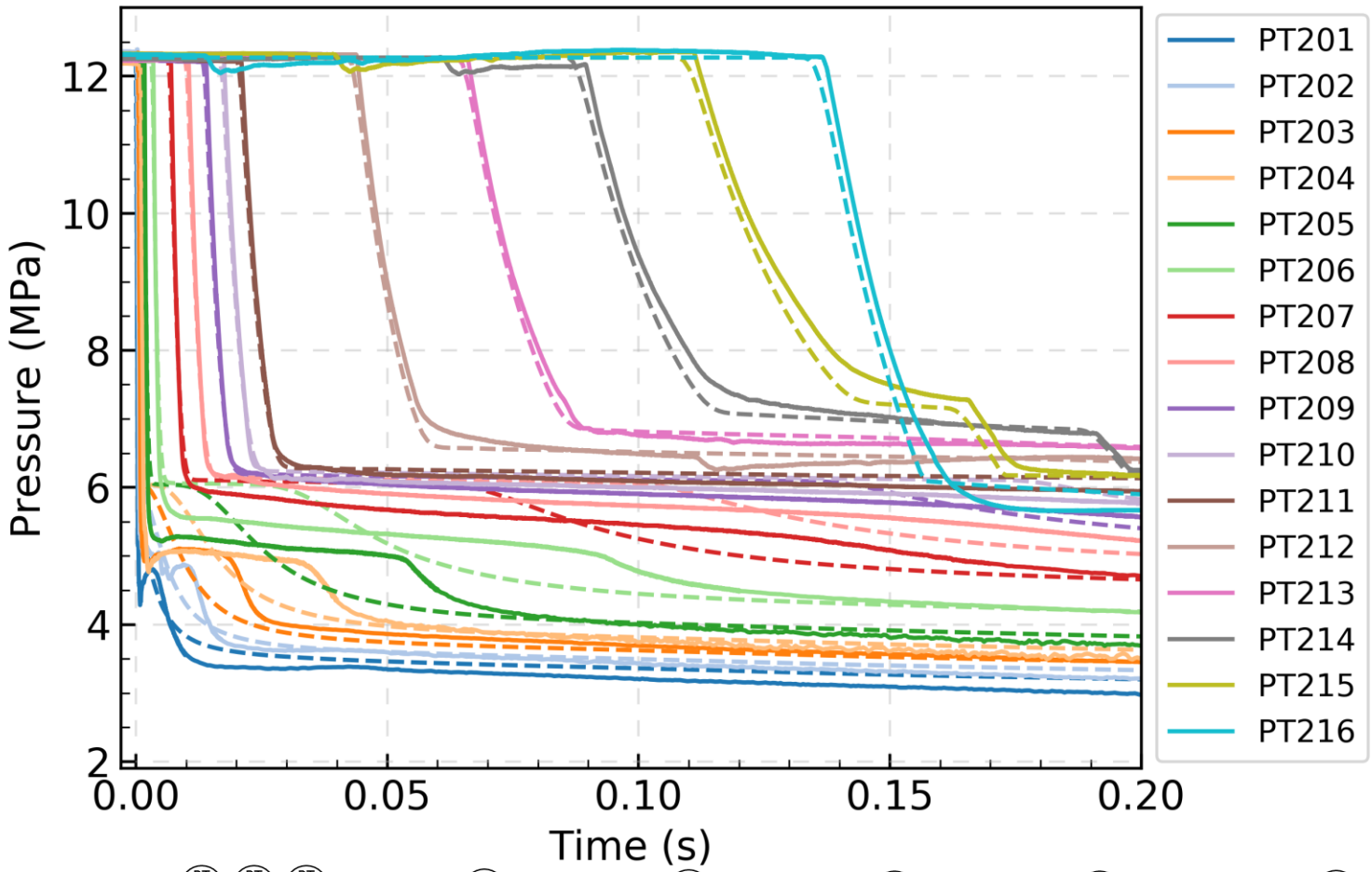
ECCSEL depressurization tube

- Length 61.5 m
- Inner diameter 4 cm
- Specifically instrumented to capture decompression waves
  - 16 fast-response pressure transducers, sampling rate 200 kHz (here: 100 kHz)
  - 23 temperature sensors: 1 kHz
- Pressure up to 200 bar
- Initial temperature: 5–40 °C

Tube depressurization

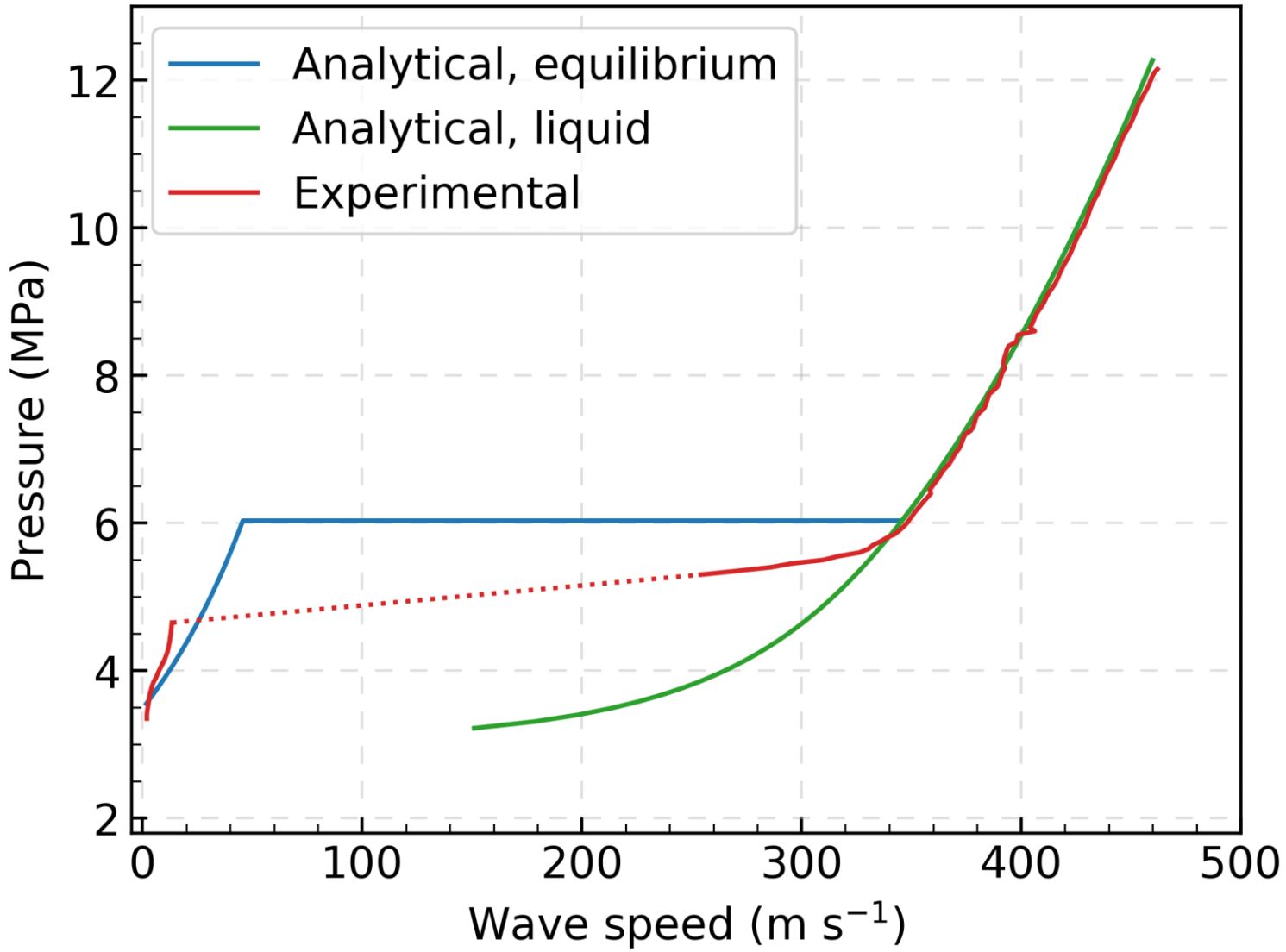
- Pressure: 12 MPa
- Temperature: 25 °C
- 100% CO_2 / CO_2 + 1.8% N_2 / CO_2 + 1.92% He

Pressure versus time for different positions



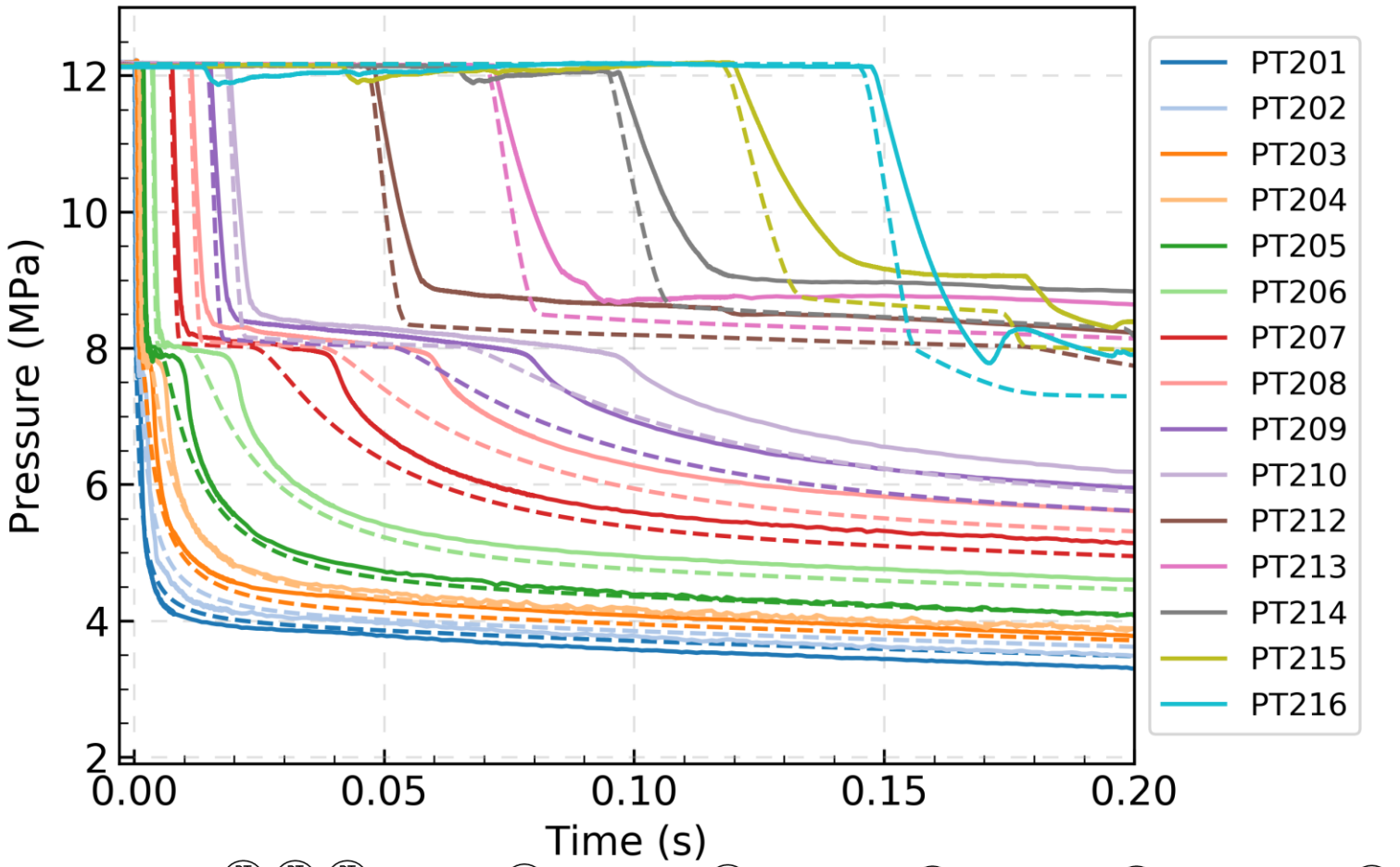
- CO_2 + 1.8% N_2
  - Full lines: Exp
  - Dashed: CFD (HEM) with EOS-CG
- Good agreement

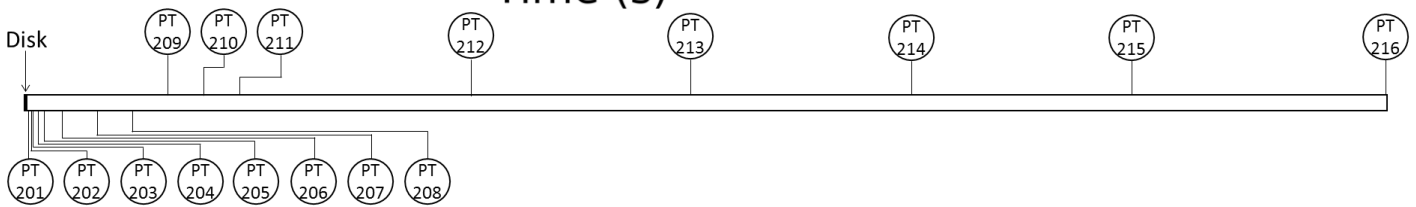
Pressure-propagation speed



- CO_2 + 1.8% N_2
- Wave travelling upstream (sound speed vs flow speed).
- Calculated analytically assuming a ‘long’ tube and steady decompression wave.
- EOS-CG
  - Very good agreement for single-phase decompression speed

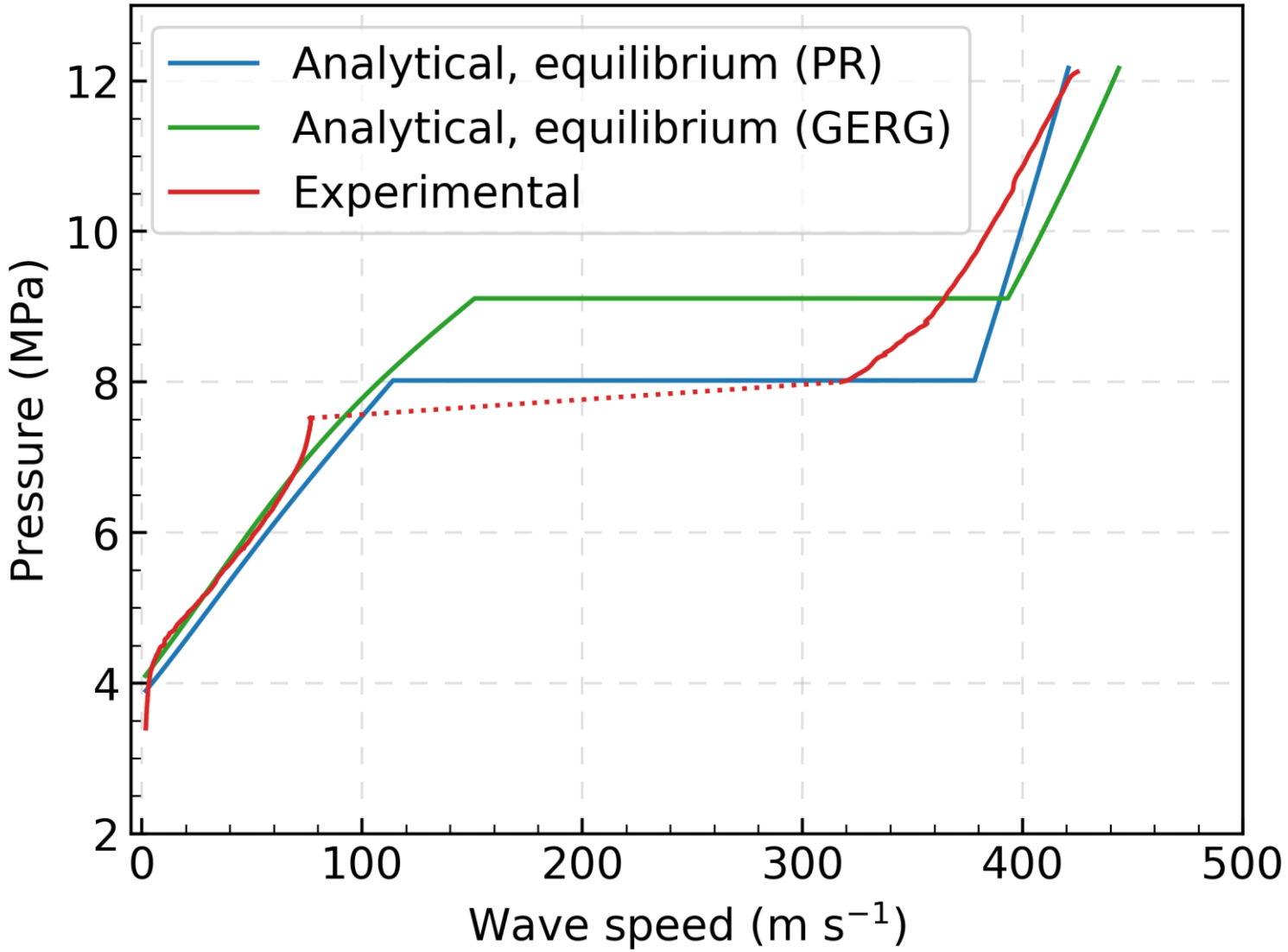
Pressure versus time for different positions





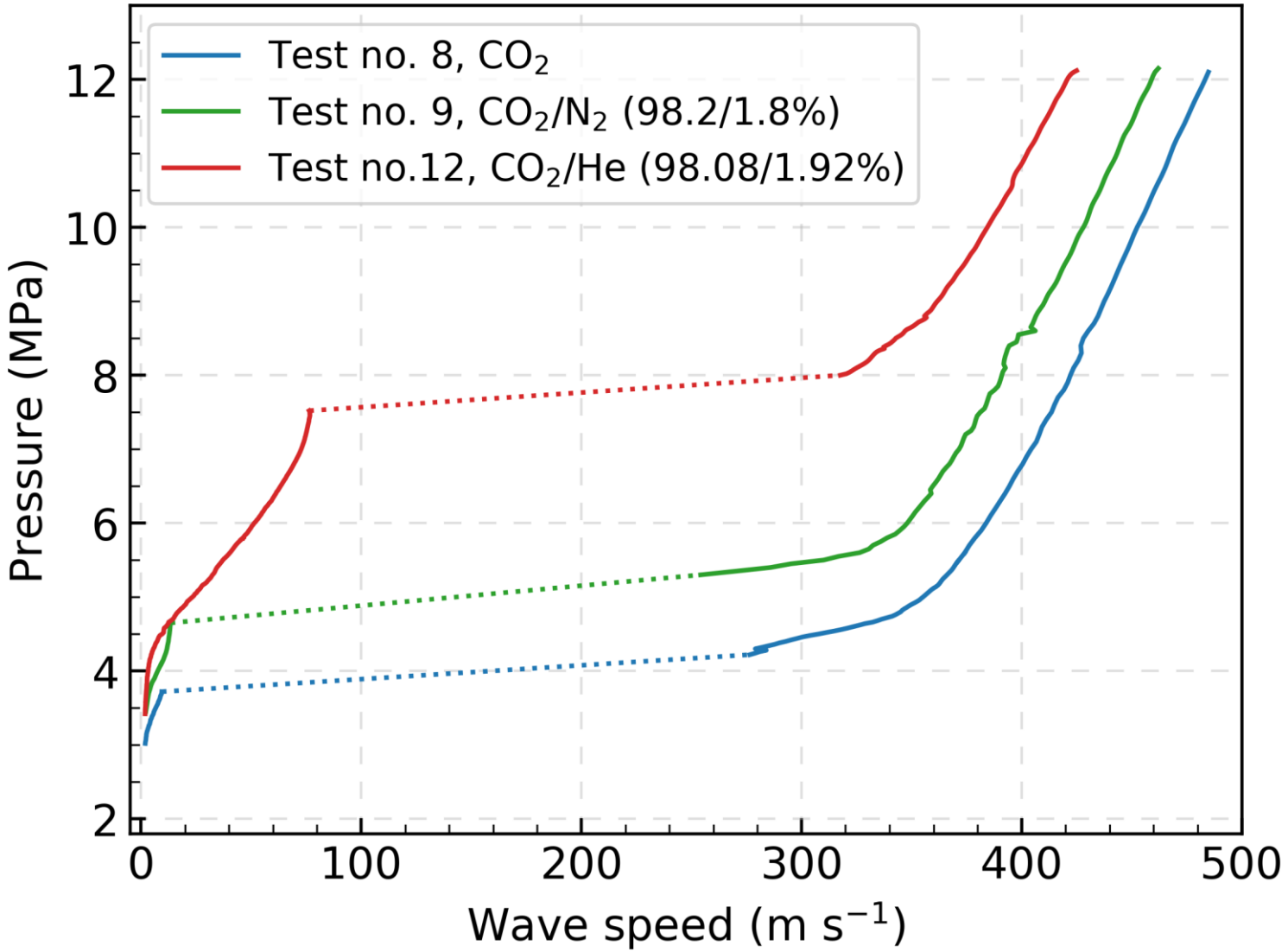
- CO_2 + 1.92% He
  - Full lines: Exp
  - Dashed: CFD (HEM) with Peng-Robinson (PR) EOS
- More regular behaviour in the two-phase region.
- Some discrepancy in single-phase decompression speed and ‘plateau’ level.

Pressure-propagation speed



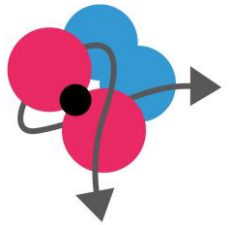
- CO_2 + 1.92% He
- GERG-2008
  - Too high single-phase decompression speed
  - But right slope
  - Too high ‘plateau pressure’
- Peng-Robinson (PR)
  - Adapted using VLE and PVT data
  - Too large single-phase slope
  - Probably too low ‘plateau pressure’

Pressure-propagation speed



- Used e.g. for running-ductile fracture assessment.
- Abrupt change in wave speed at phase boundary.
- Impurities give
  - Higher ‘plateau pressure’ levels
  - Lower single-phase decompression speed.

Conclusion



- The ECCSEL depressurization facility has been put into operation.
  - Models for transient flow of CO_2 and CO_2-rich mixtures can be validated and further developed using the data acquired.
- The CO_2-mixture decompression behaviour is sensitive to N_2 and He in the 1% range. (Here: 1.8 and 1.9%).
- The homogeneous equilibrium model describes fast depressurizations quite well.
- We observe that the Peng-Robinson EOS gives an inaccurate speed of sound whereas EOS-CG is accurate for CO_2-N_2.
- Understanding the transient multiphase flow of CO_2 and CO_2-rich mixtures enables safe and efficient operation of CO_2 transport and injection systems.

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