A novel acoustic resonator for speed of sound measurement

Application with siloxane D6

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Context

- Primary objective:

  Investigate the propagation of acoustic waves in BZT fluids

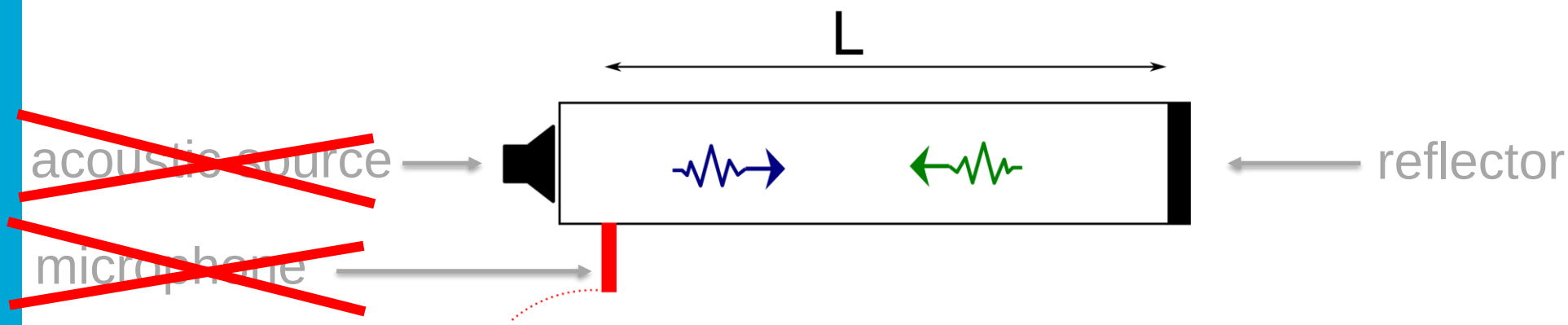
- Main challenge:

  Siloxane D6 is a promising BZT fluid
  Thermodynamic model must be consolidated with speed of sound data

▸ Need for a new setup to achieve speed of sound measurements at high pressure and temperature

Measure the speed of sound

- Pulse echo method



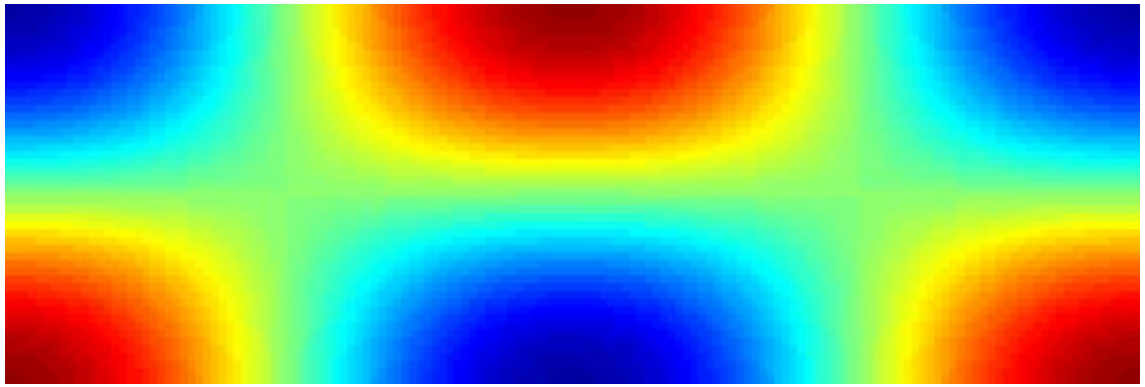
No rapid source for high temperature
No sensitive microphone for high temperature

Measure the speed of sound

- Acoustic resonator

  Excitating acoustic modes of a cavity

Example: k = 2 m= 0



k: longitudinal mode number
m, n: transverse mode numbers

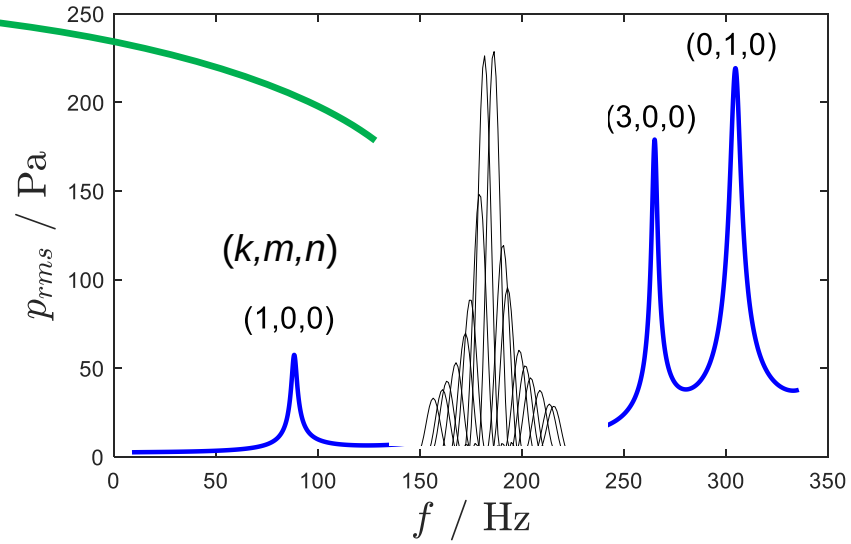
Measure the speed of sound

- Resonance frequency for a cavity of **length L, width & height H**

Measured from the freq. response

$$f_r = \frac{c}{2}\sqrt{\left(\frac{k}{L}\right)^2 + \left(\frac{m}{H}\right)^2 + \left(\frac{n}{H}\right)^2}$$

Know from the geometry

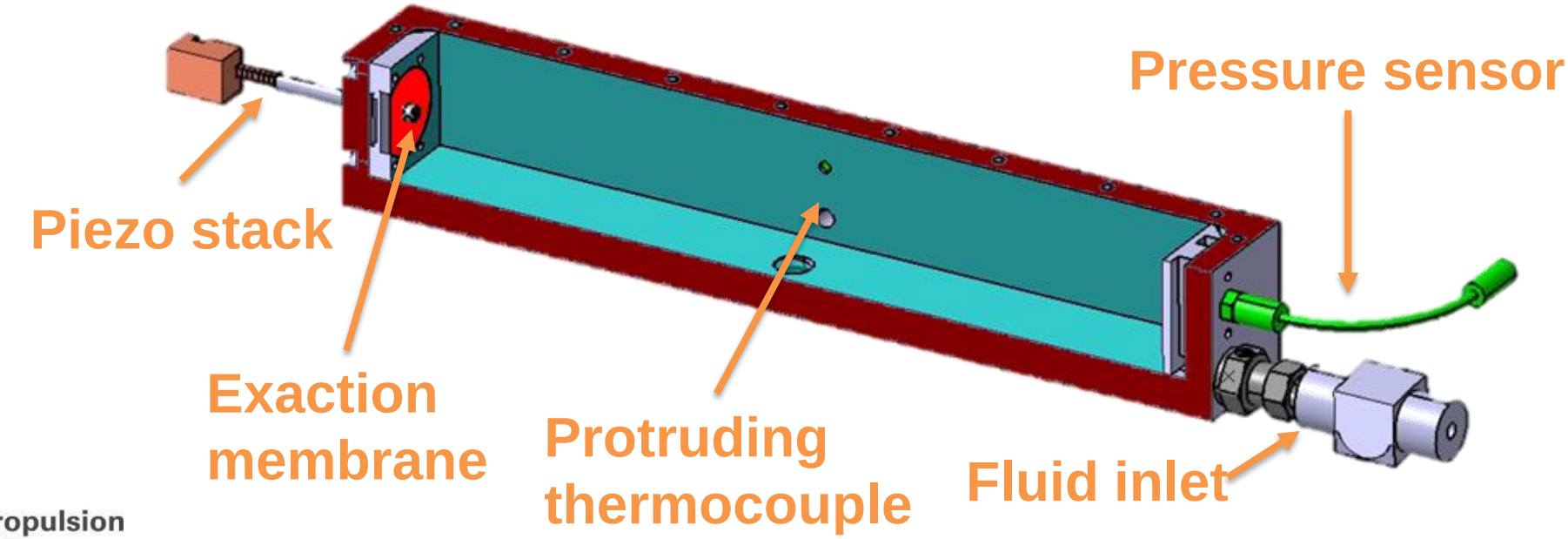


Sound speed c deduced straightforwardly

Features of the Resonator

- Cylindrical resonator

  284 mm x 40 mm x 40 mm
  Max pressure : 10 bar / Max temperature 400 ºC
  Sound speed 40 m/s → 150 m/s



Calibration of the resonator

$$F_r = \alpha k \frac{c}{L}$$

Fr: resonance freq.
k: mode number
c: sound speed
α: calibration constant

- Need for high accuracy reference measurements:
  → Available for siloxane D4 and D5 in Nannan *et al. 2007*

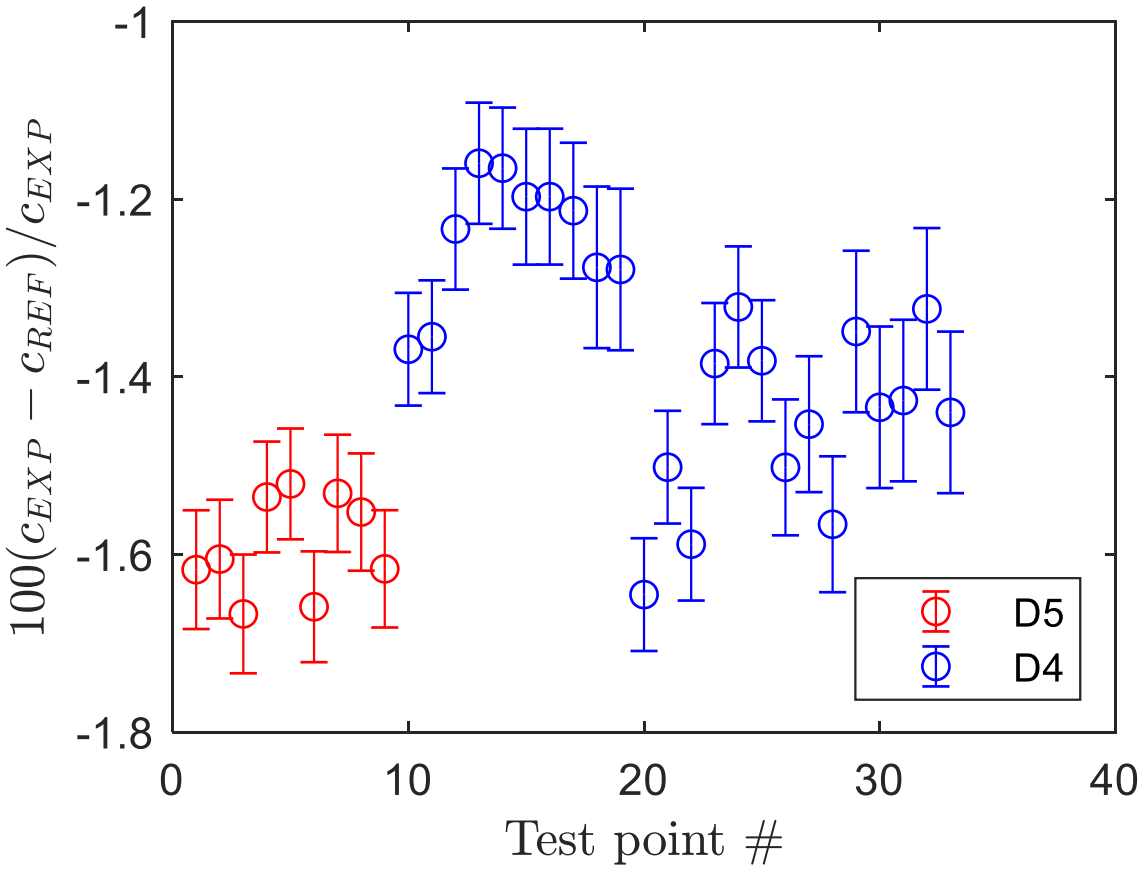
D4 – $T = 495$ K $\quad 1.4 < \mathrm{p} < 2.2$ bar
D5 – $T = 510$ K $\quad 0.9 < p < 1.0$ bar

Calibration of the resonator

$$\alpha = 0.986$$

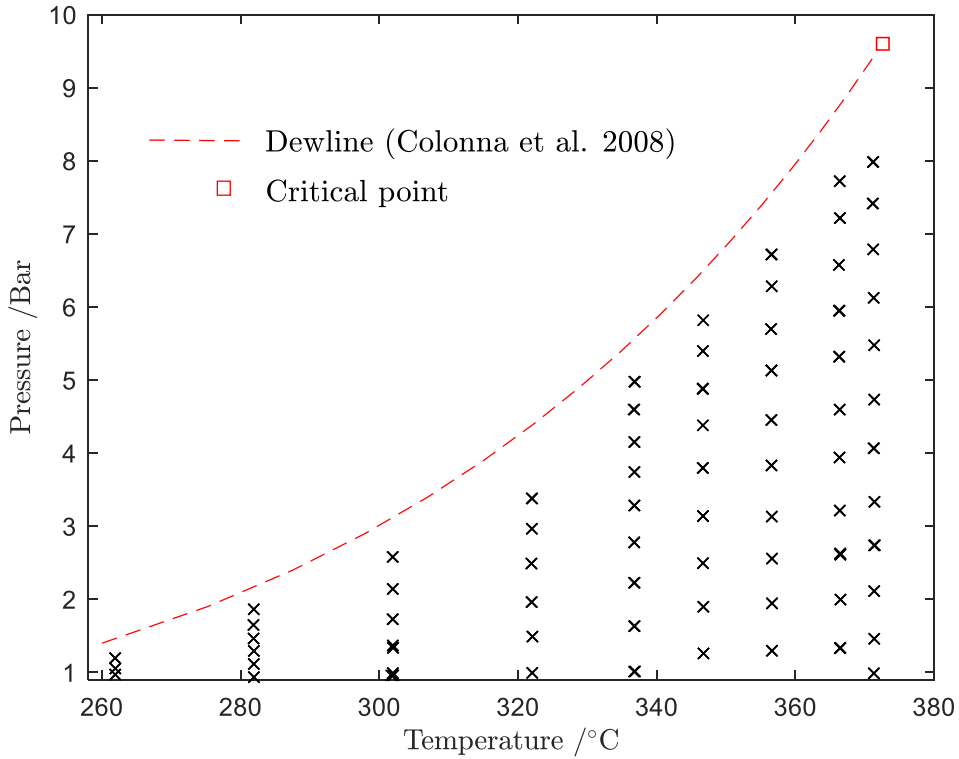
$$\sigma_\alpha = 0.0016$$

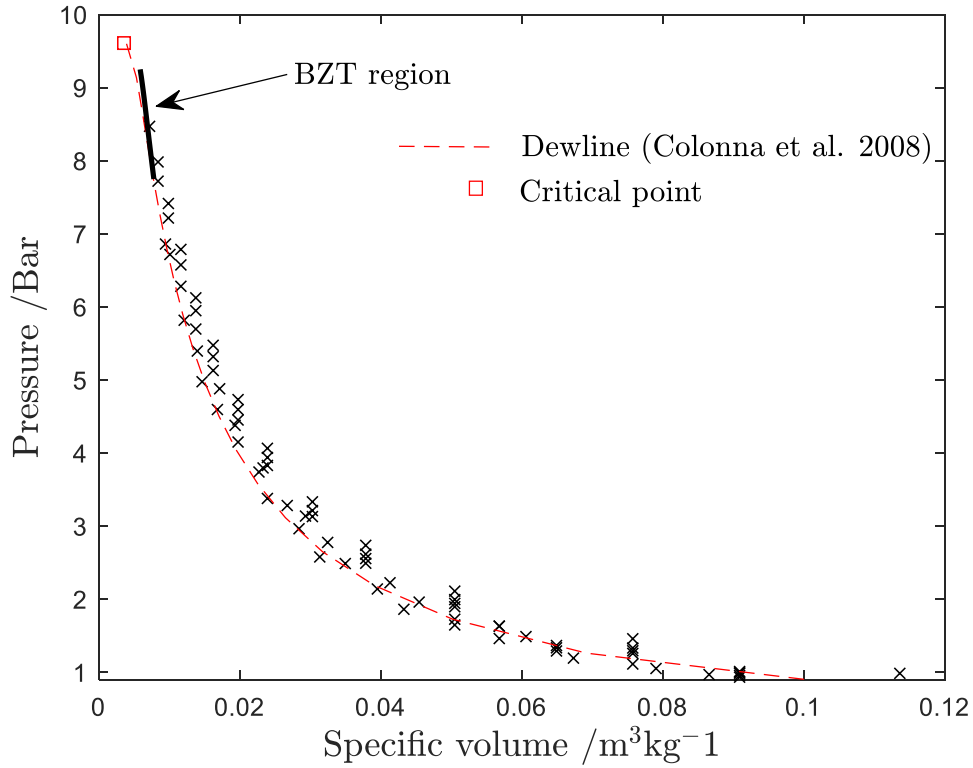
Accuracy after calibration:
+/- 0.3% **(95% CI)**



Measurements in D6

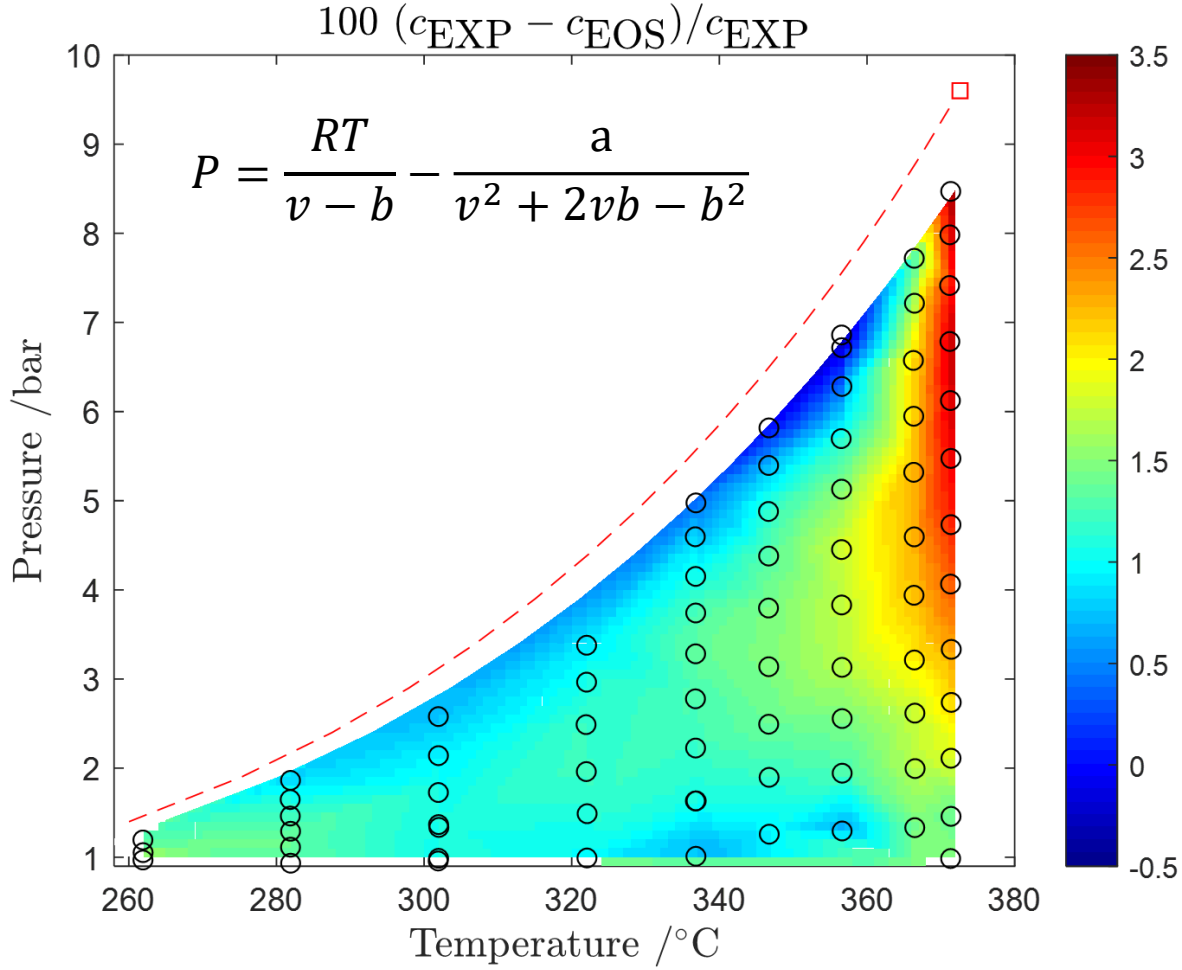
- Data set : 77 conditions explored between 266 °C and 371 °C





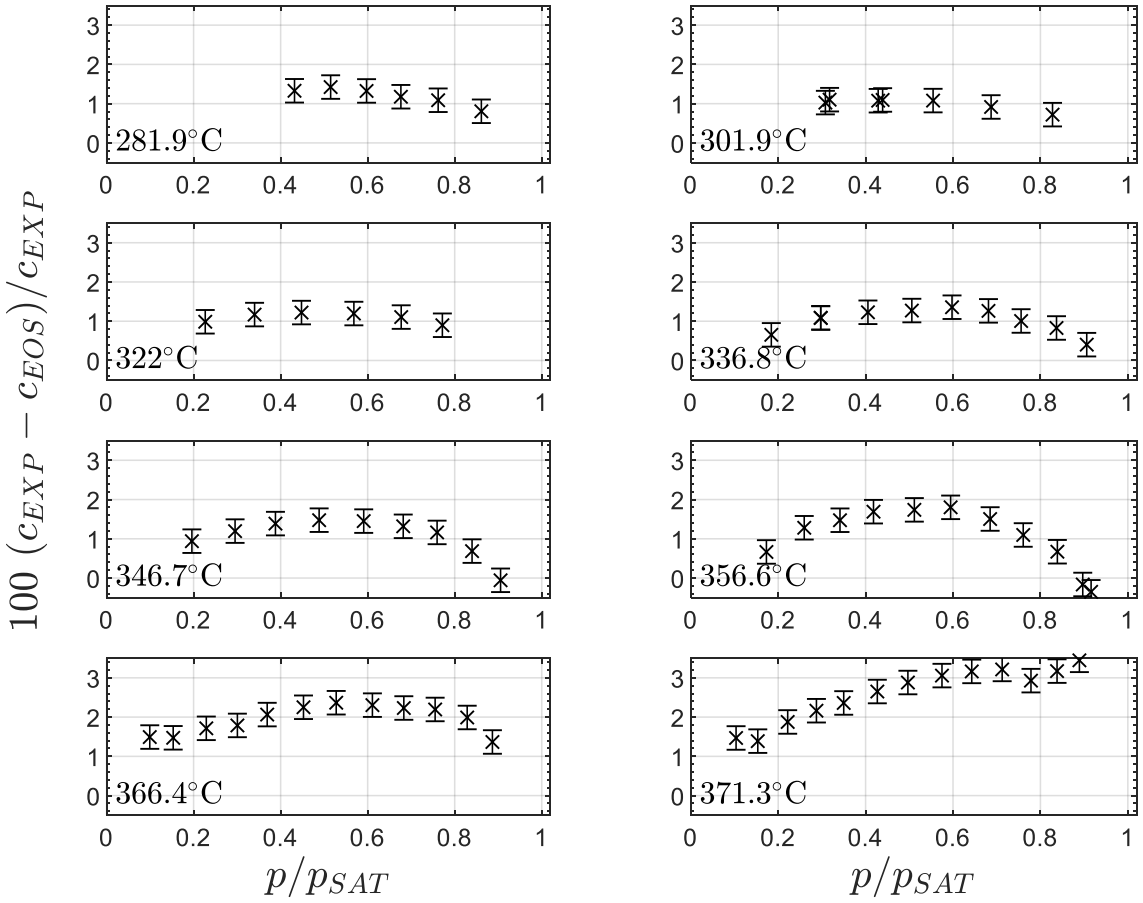
Measurements in D6

- Comparison SoS measurements / cubic EoS (p, T)



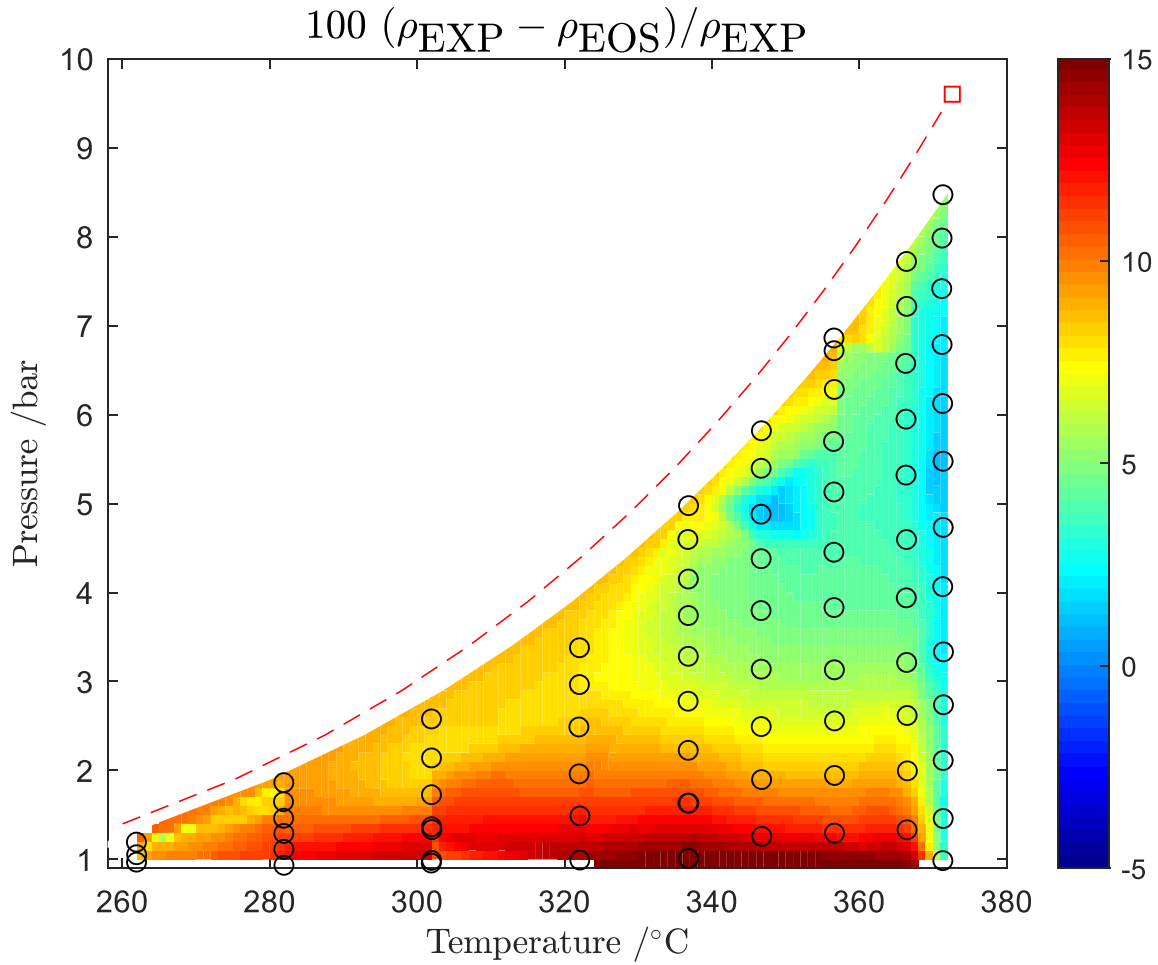
Measurements in D6

- Comparison SoS measurements / cubic. EoS (p, T)



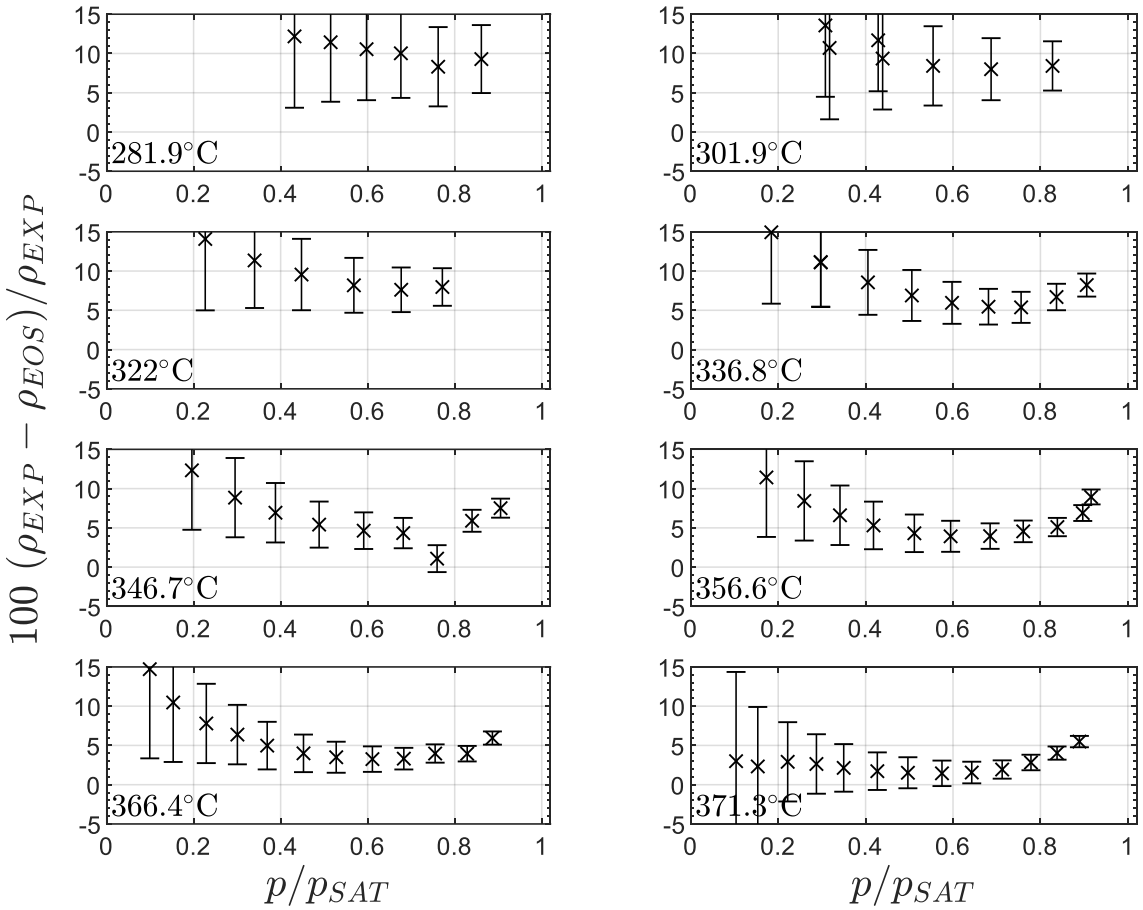
Measurements in D6

- Comparison ρ measurements / cubic EoS (p, T)



Measurements in D6

- Comparison ρ measurements / cubic. EoS (p, T)

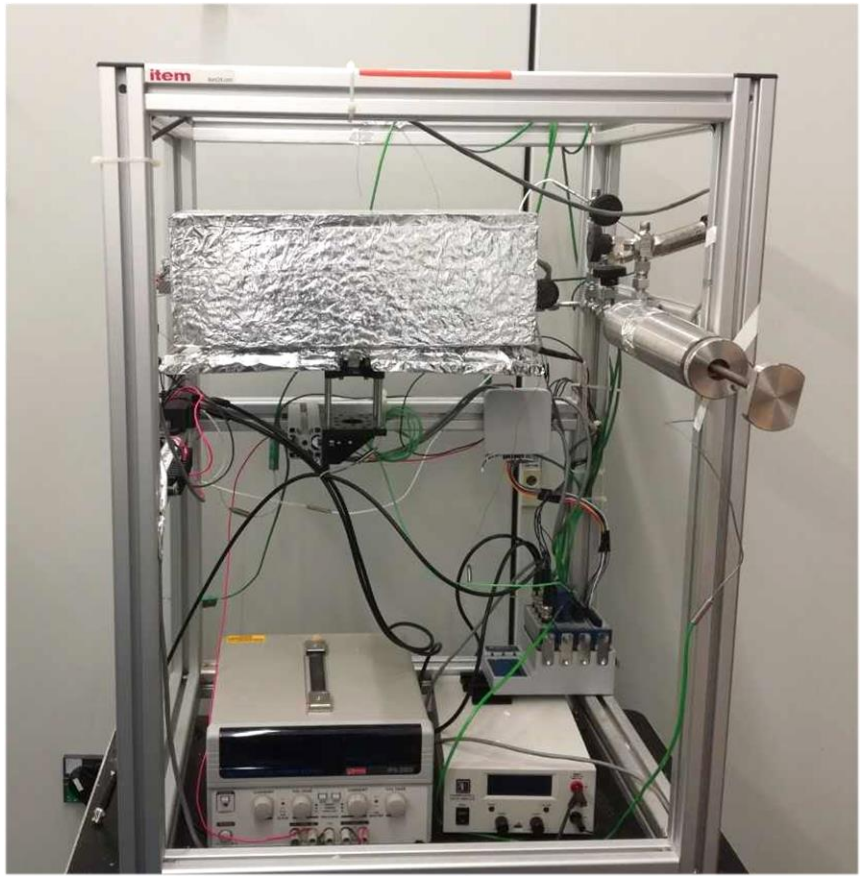


Conclusion

- Accuracy demonstrated to be better than +/- 0.3%
- Speed of sound underestimated by EoS at low pressure

  → Probable overestimation of heat capacities
- Speed of sound increase faster with pressure than EoS prediction along isotherms near BZT region

  → BZT region likely to be larger than expected
  Need to develop a new equation of state



Thank you