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Study of Nitrogen Two-phase Flow Pressure Drop in Horizontal and Vertical Orientation

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- Summary

Thermal Shield Cooling of Large Scale Liquid Argon Detectors

Constraints for the detector cooling thermal shield:

- Outer heat flux of 20 W/m² - foam insulated vessels
- Temperature gradient along shield panel dT< 500 mK
- High purity aluminum 1050A
- Boiling nitrogen as coolant at 87 K

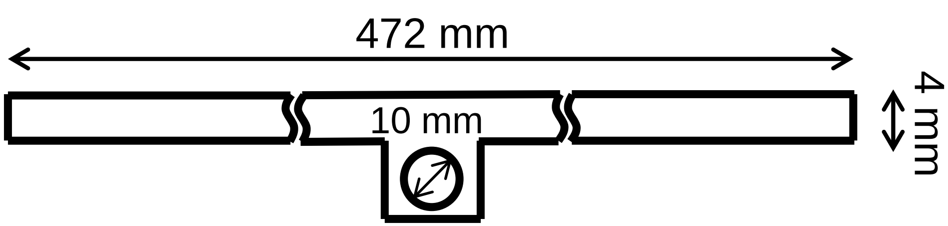


Fig.: Dimensions of one Al1050A cooling panel

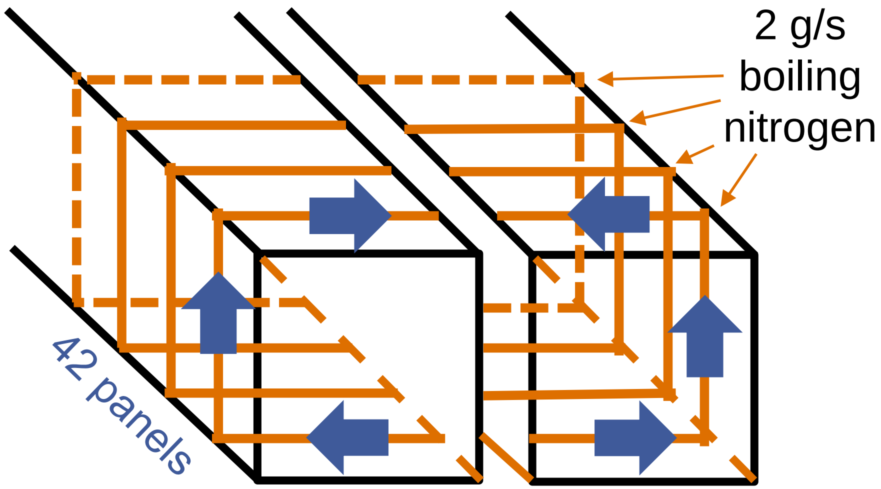
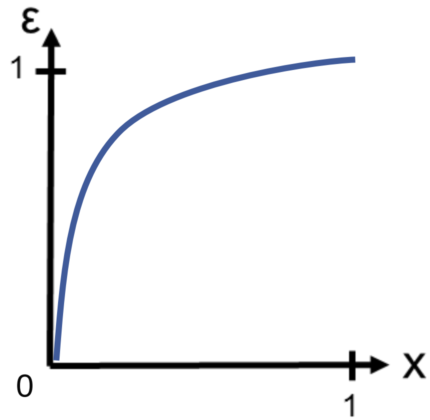


Fig.: Arrangement of the cooling panels around the detector

Two-phase Flow Pressure Drop

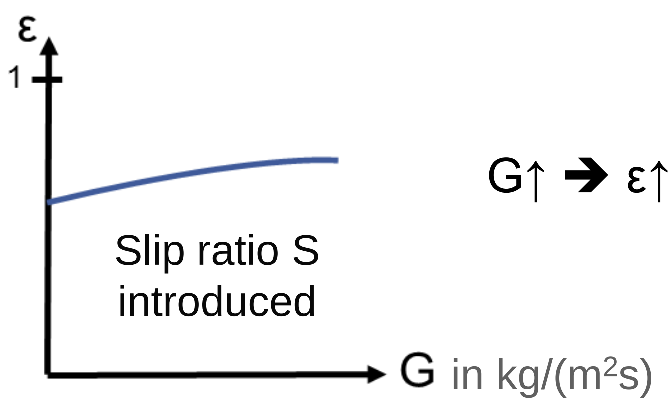
- **Void fraction:**

Void fraction versus vapor quality



x↑ ➔ ε↑

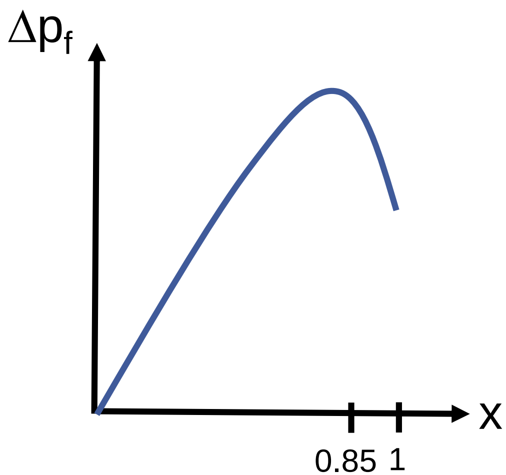
Void fraction versus mass velocity



G↑ ➔ ε↑

- **Frictional pressure drop:**

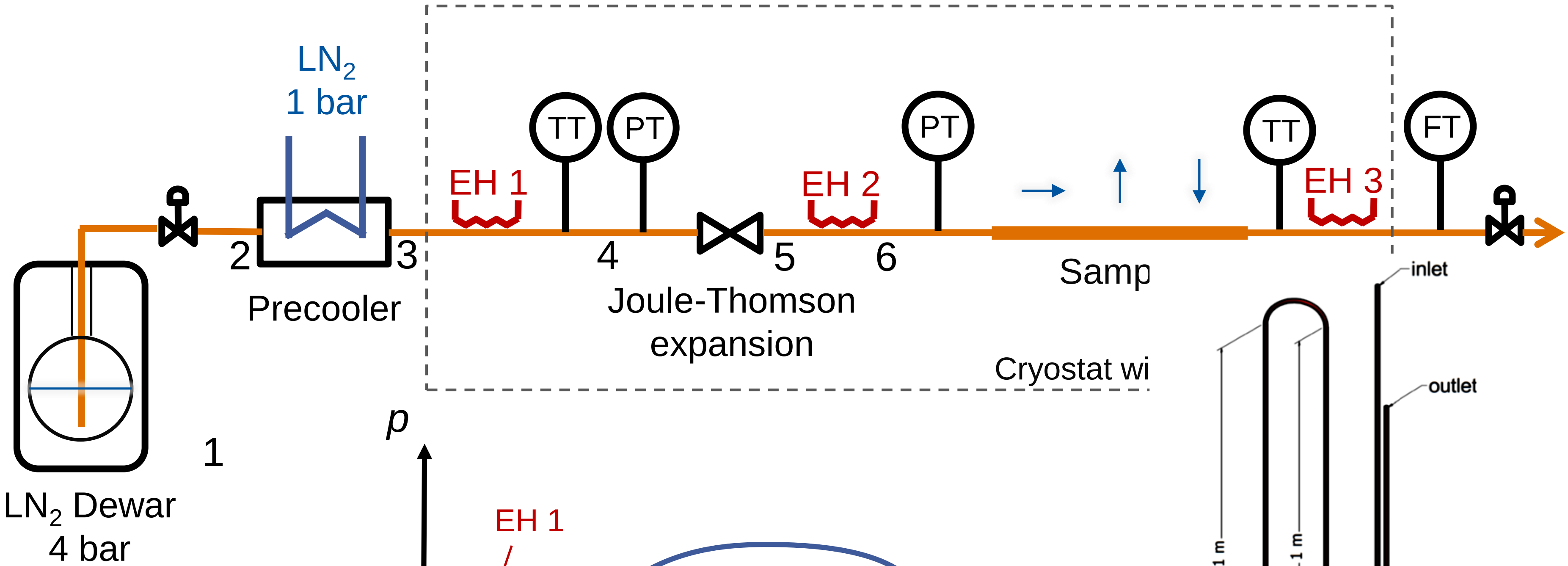
Frict. press. drop versus vapor quality

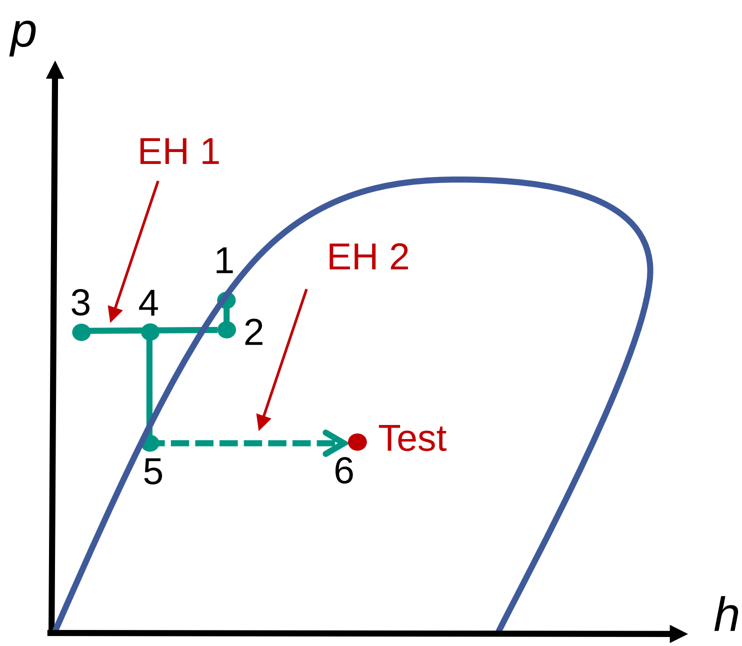


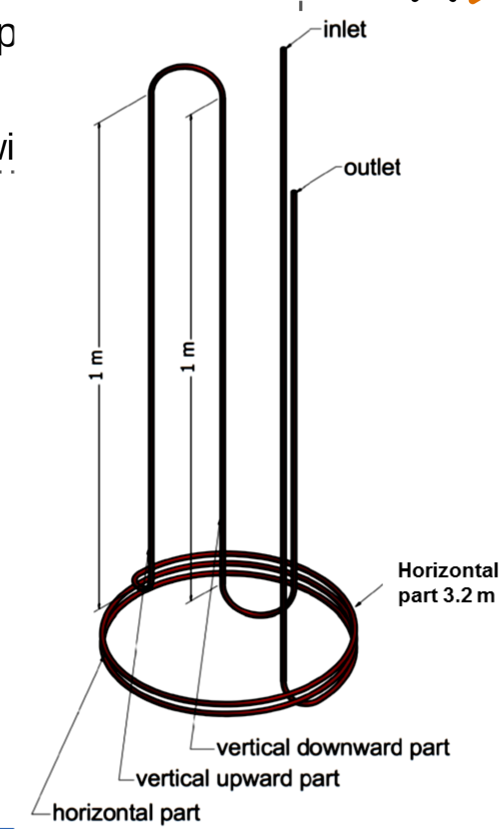
$$\frac{\delta \Delta pf}{\delta x} = 0$$

at x ≈ 0.85

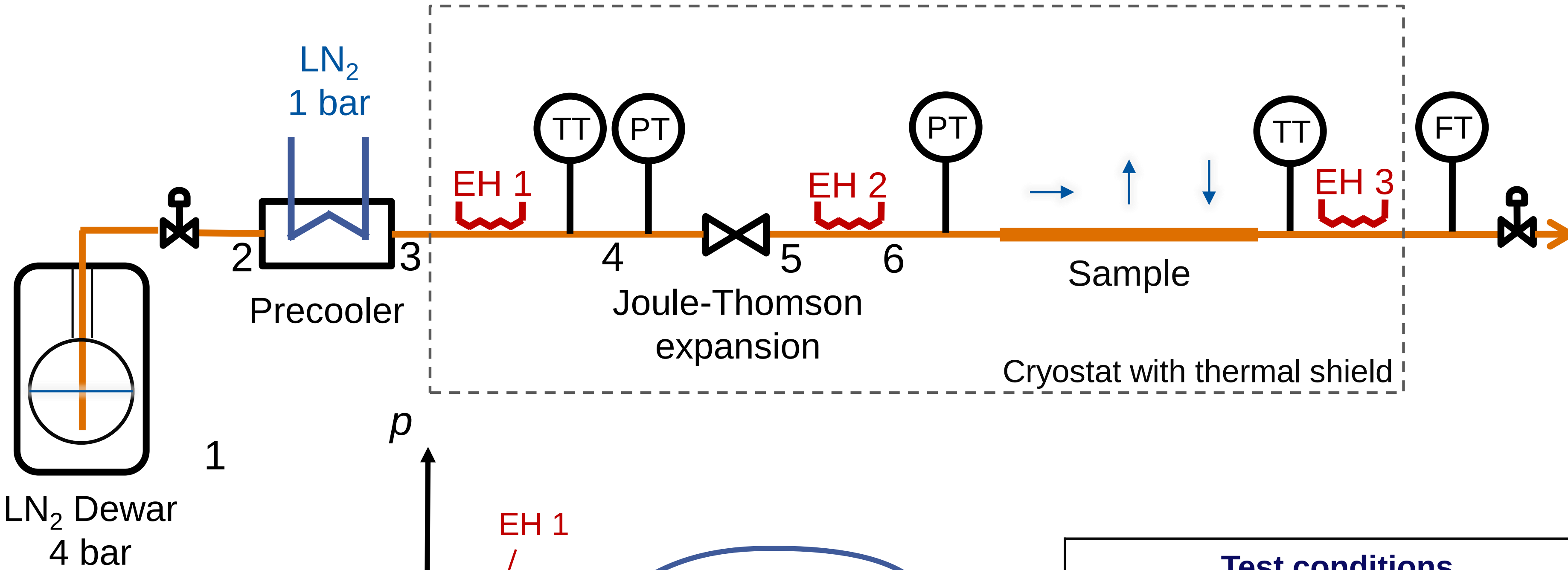
Experimental Set-up

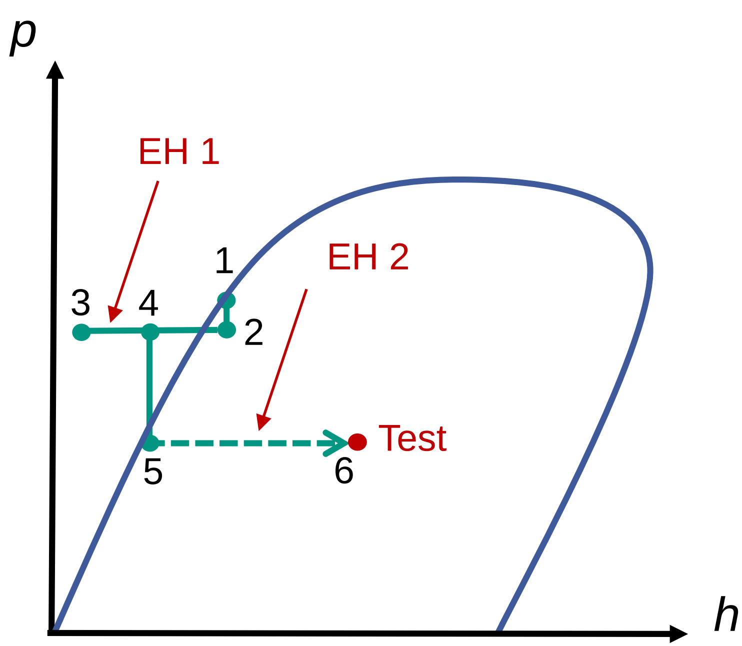






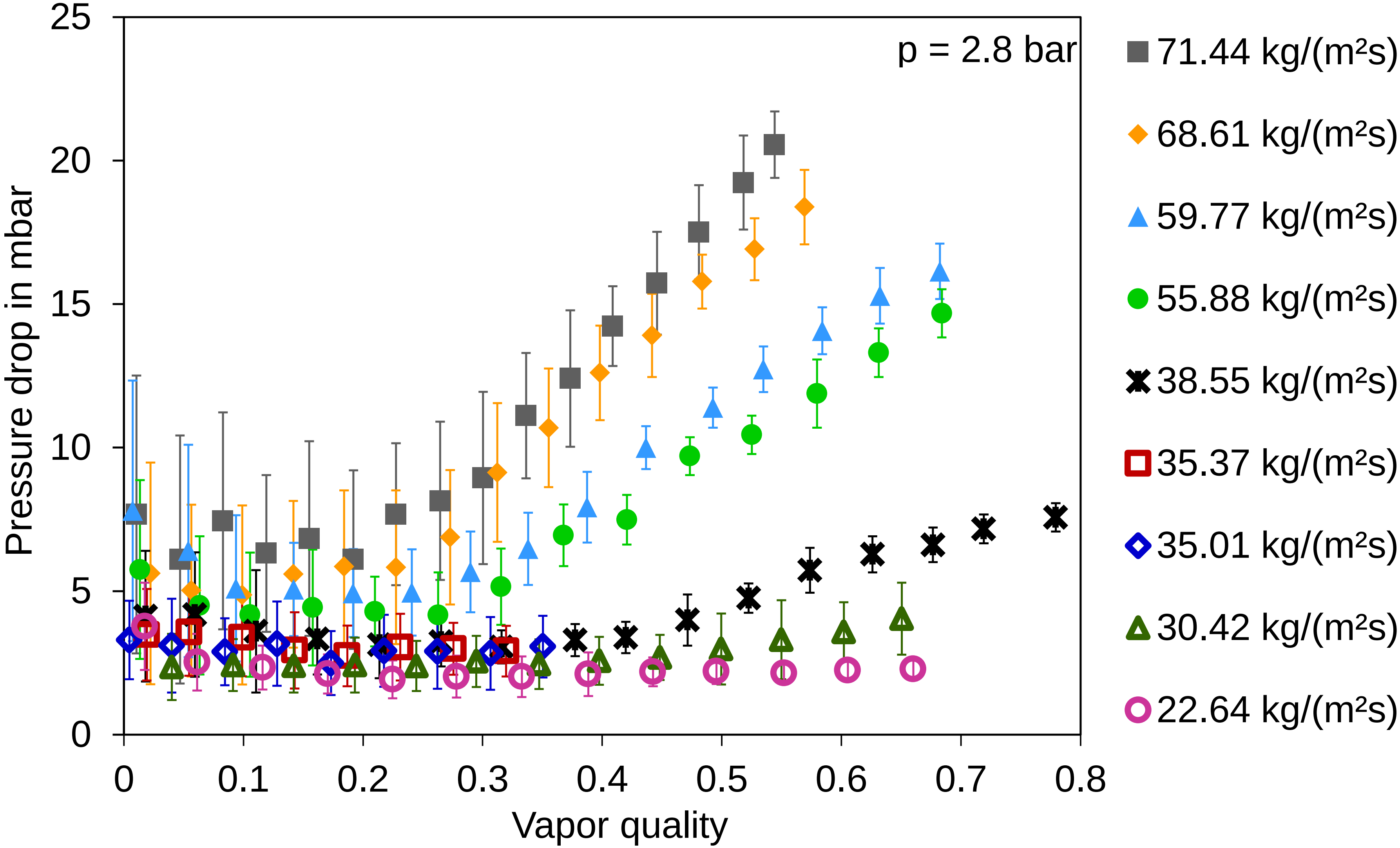
Experimental Set-up



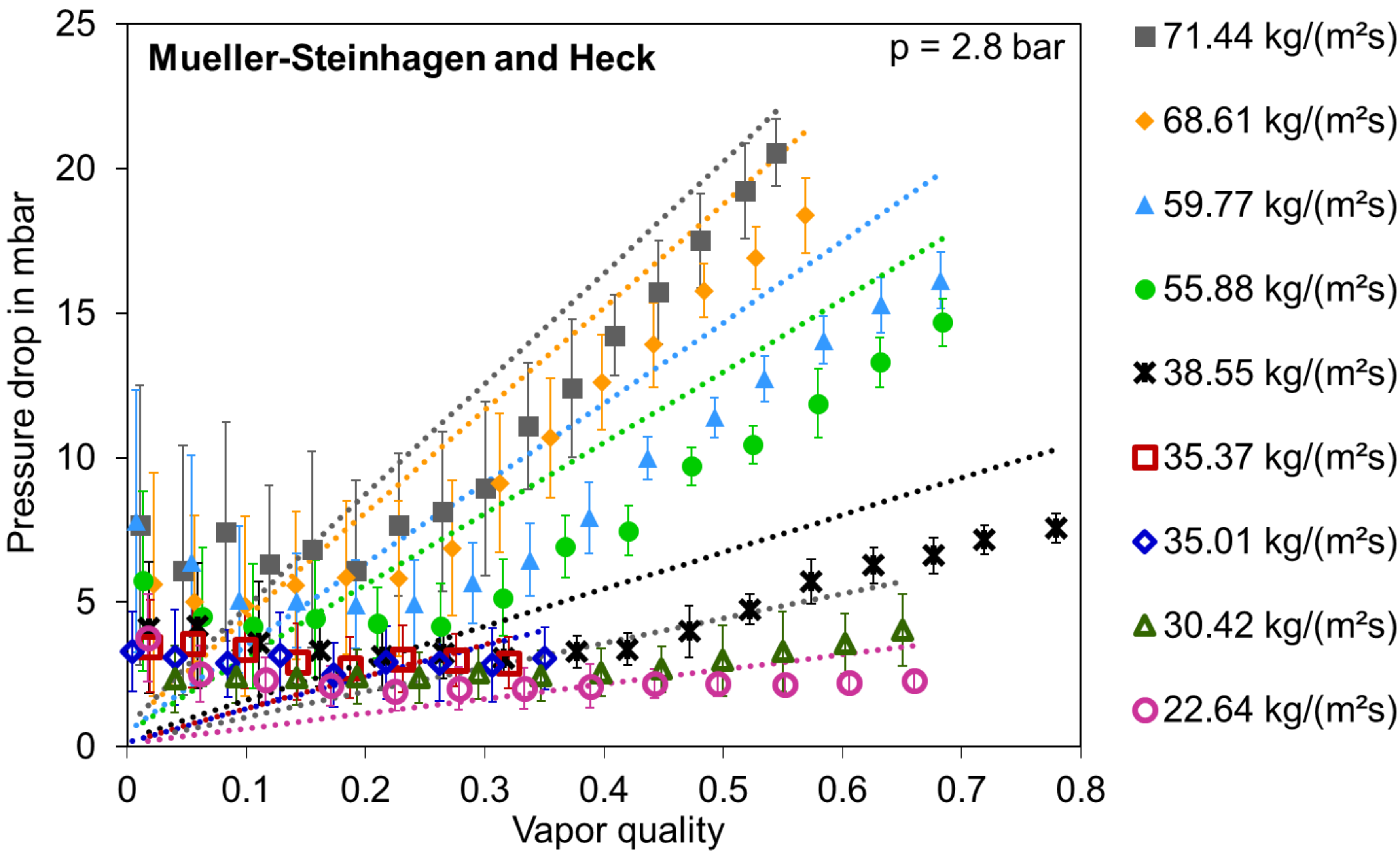


Test conditions	
Pressure (bar abs.)	2.8
Internal diameter (mm)	6.0
Mass flow (g/s)	0.6 – 2.0
Mass velocity (kg/m^{2}s)	22 - 72

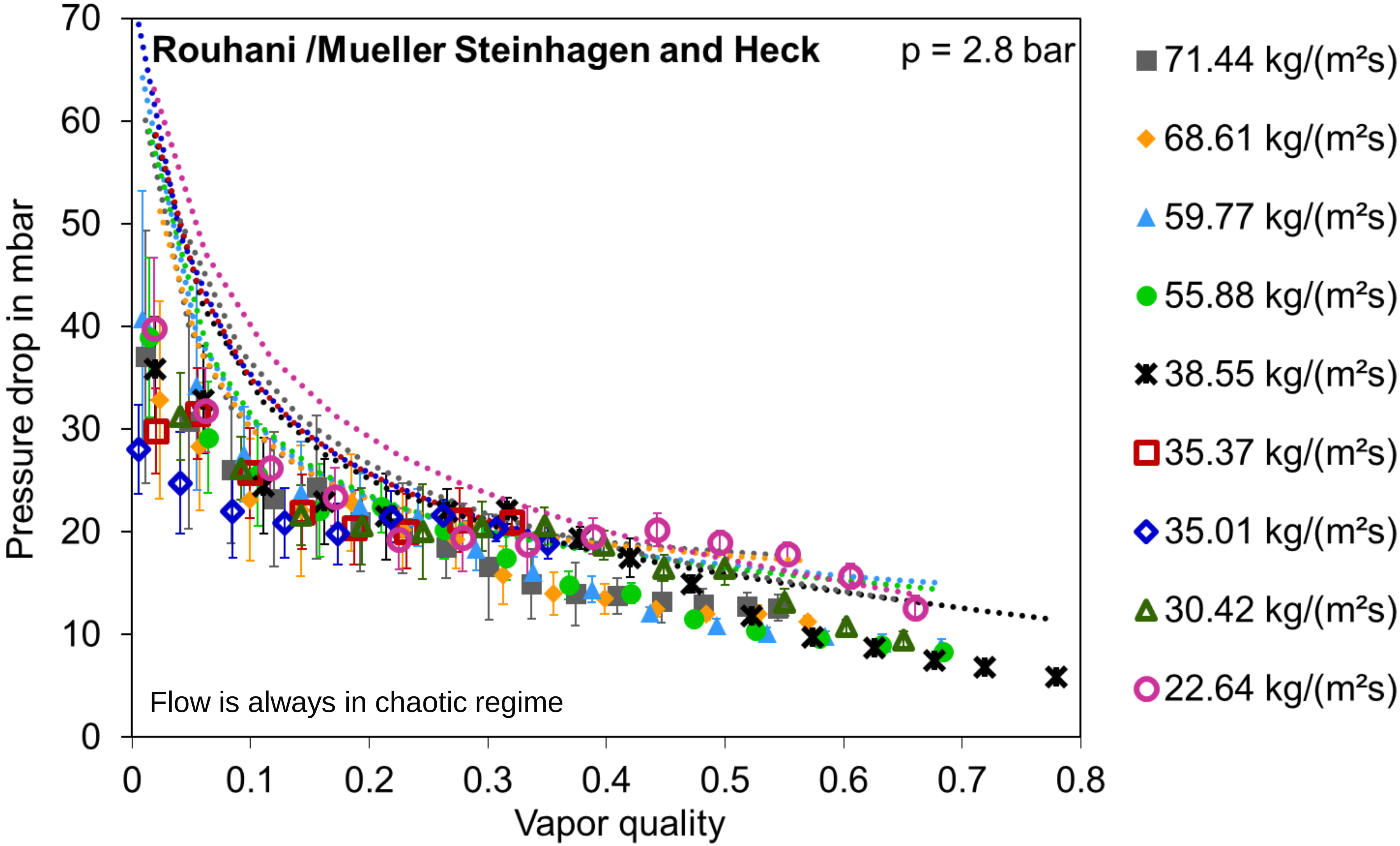
Results – Horizontal Orientation



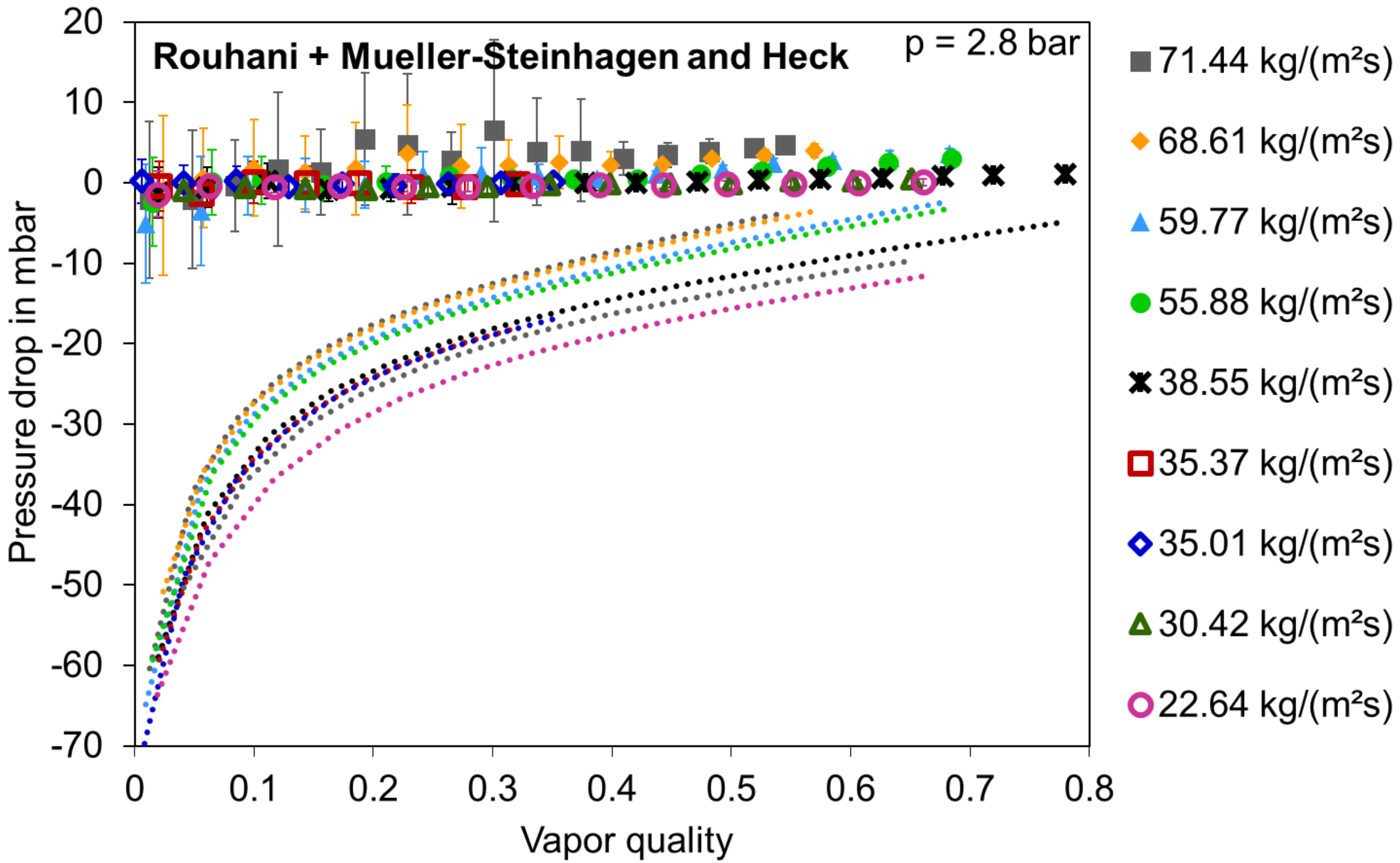
Results – Horizontal Orientation



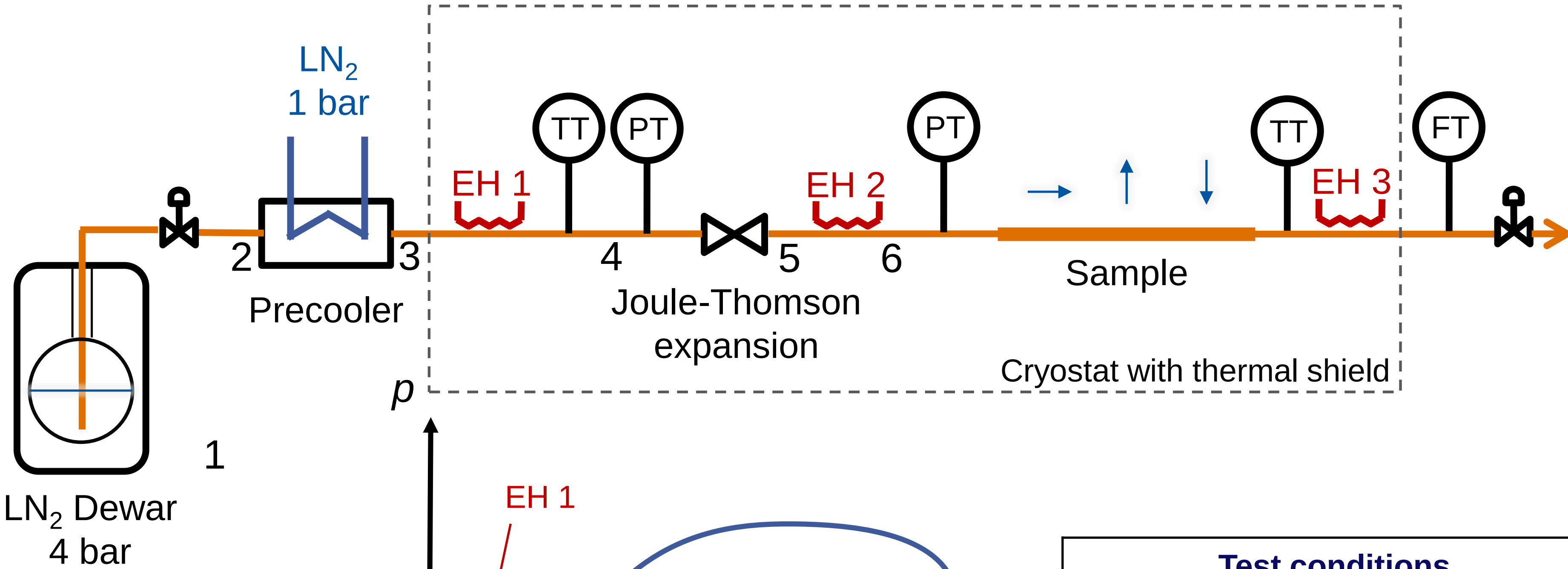
Results – Vertical Upward Orientation

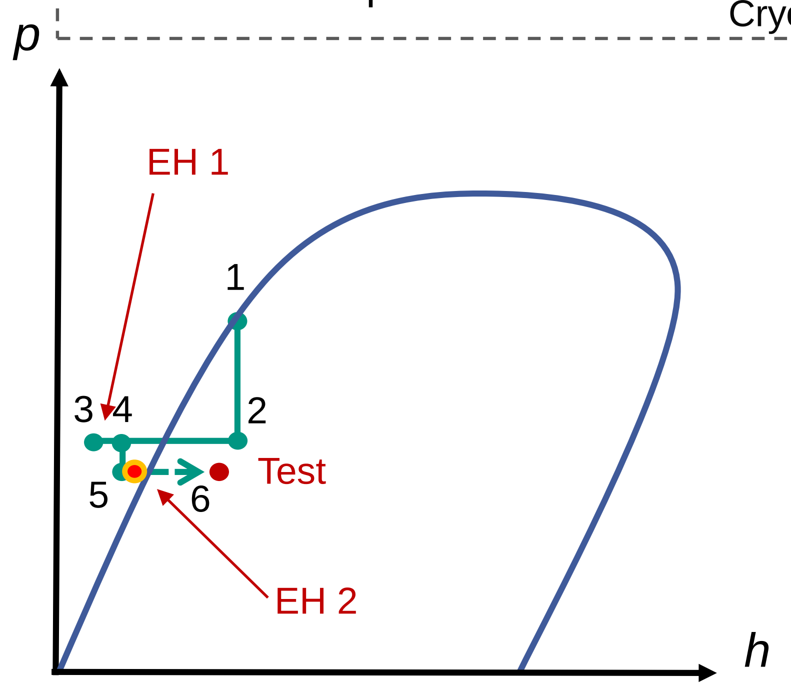


Results – Vertical Downward Orientation



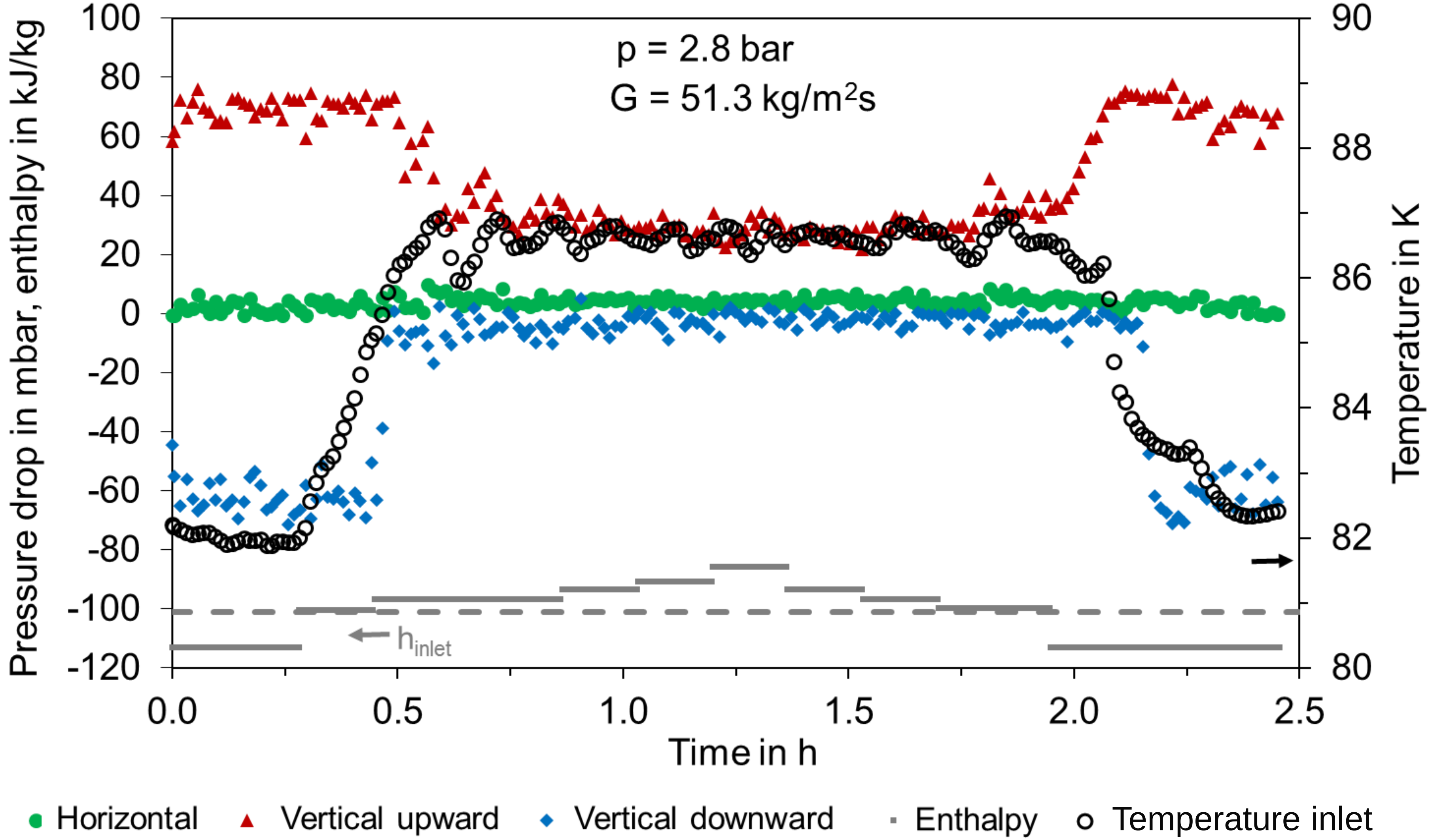
Experimental Set-up





Test conditions	
Pressure (bar abs.)	2.8
Internal diameter (mm)	6.0
Mass flow (g/s)	1.44
Mass velocity (kg/m^{2}s)	51

Results – Verification Test



Summary

- Test set-up for two-phase flow pressure drop measurement
- Measurement in horizontal and vertical up- and downward direction
- Quasi-adiabatic sample conditions at a pressure of 2.8 bar. The mass velocity has been varied in the range between $20\ \mathrm{kg\,m^{-2}s^{-1}}$ and $70\ \mathrm{kg\,m^{-2}s^{-1}}$
- Good agreement with void fraction correlation of Rouhani and several pressure drop models in horizontal orientation esp. Mueller, Steinhagen and Heck
- Deviation in vertical upward orientation of the models for small vapor quality
- Models fail to predict pressure drop for vertical downward direction
- First bubbles create buoyancy effect that overcomes gravitational influence

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