Velocity determination of hydrogen clusters at a cluster jet target

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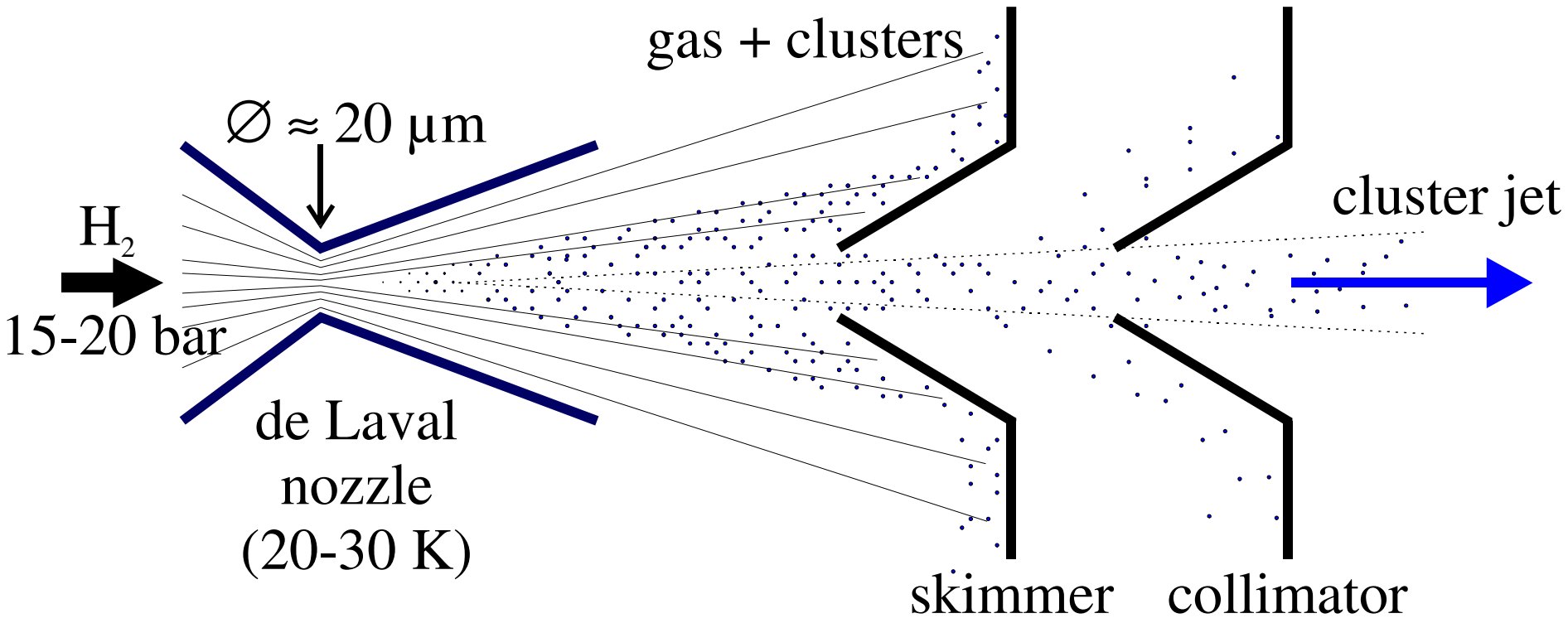
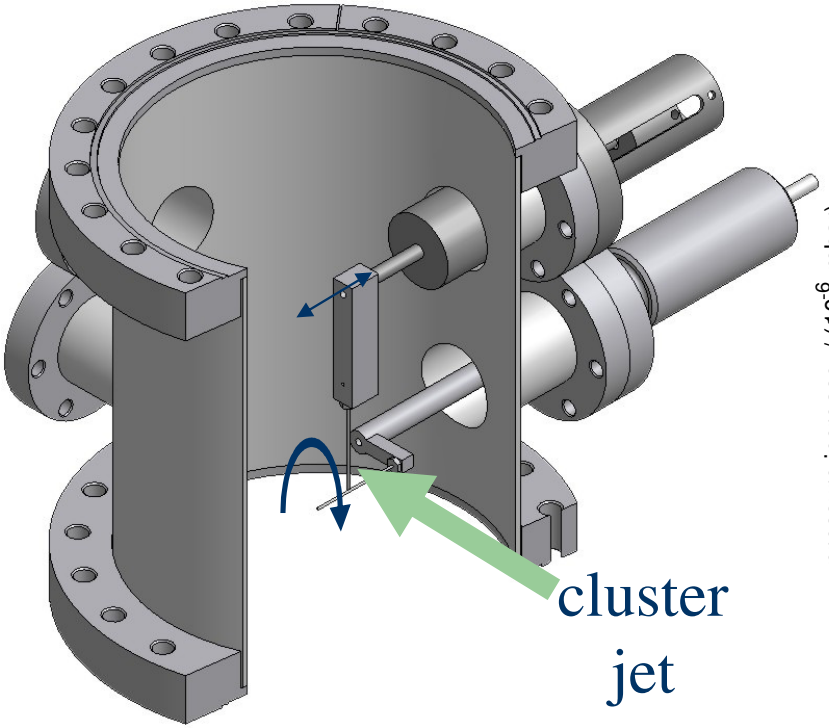
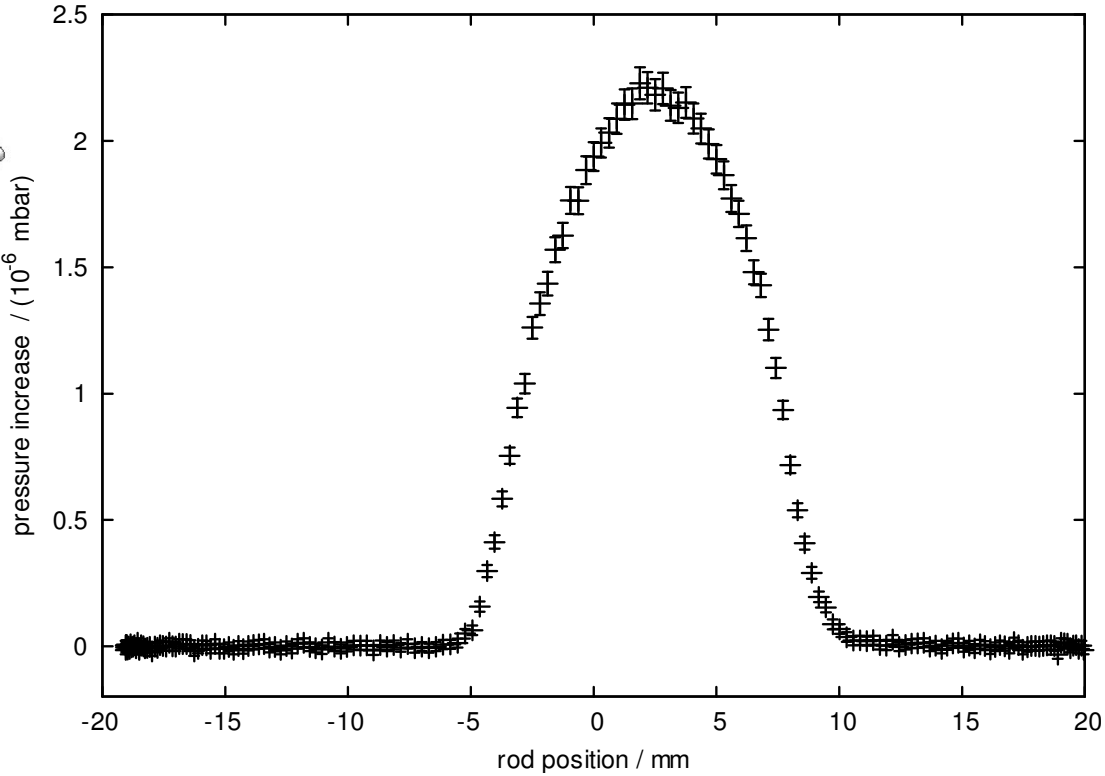
Cluster jet targets

Principle of operation:
purified H_2 or D_2 gas passes a de Laval nozzle
$\Rightarrow$ formation of clusters surrounded by gas



Measurement of the target thickness





target thickness n_T:

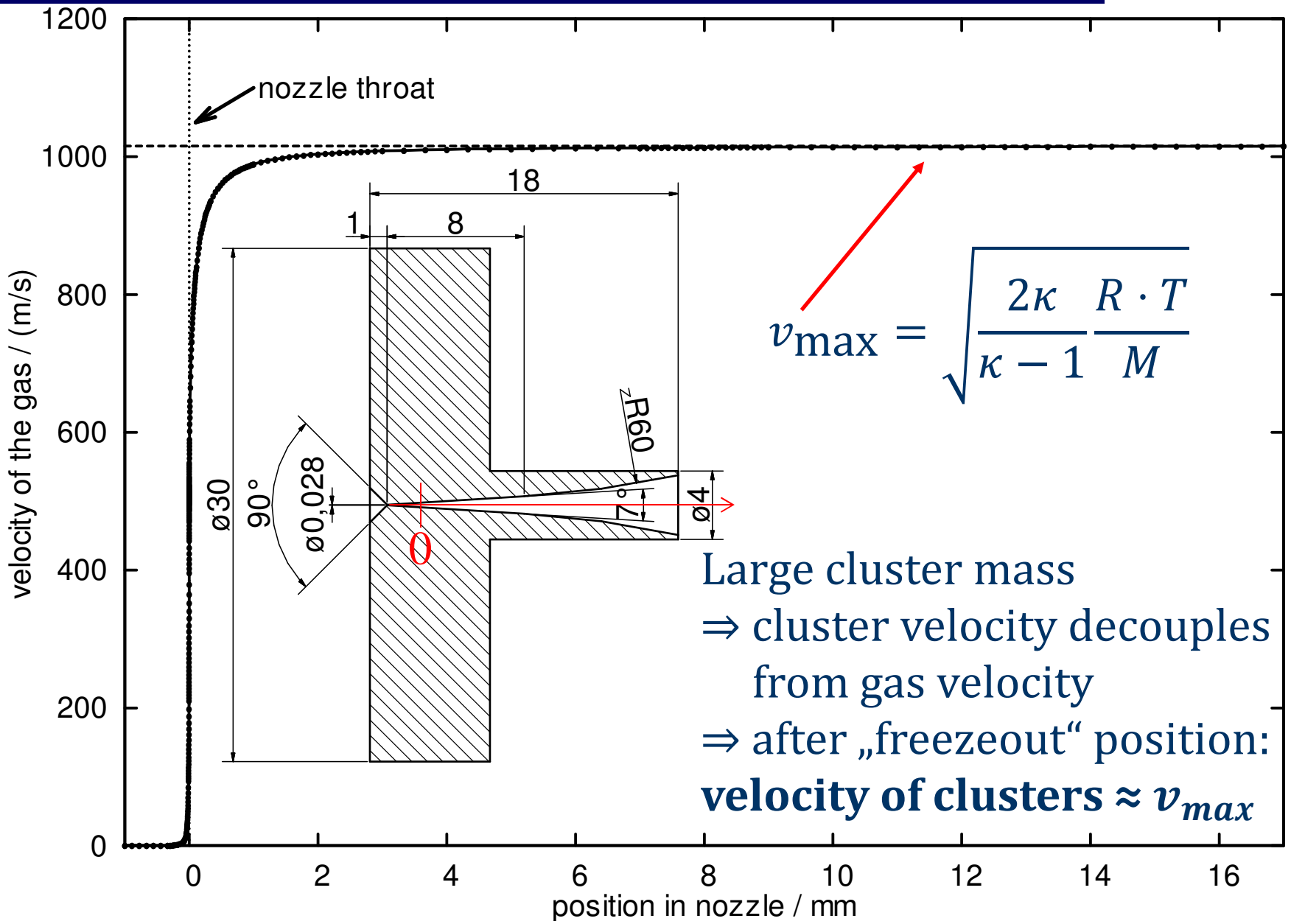
$$n_T = \frac{\Phi_{\text{jet}}}{A \cdot v_{\text{jet}}}$$

Φ_{jet} = cluster jet flow (atoms/s)

A = cluster jet cross section

v_{jet} = cluster jet velocity

Gas velocity calculation



$$v_{\max} = \sqrt{\frac{2\kappa}{\kappa - 1}\frac{R \cdot T}{M}}$$

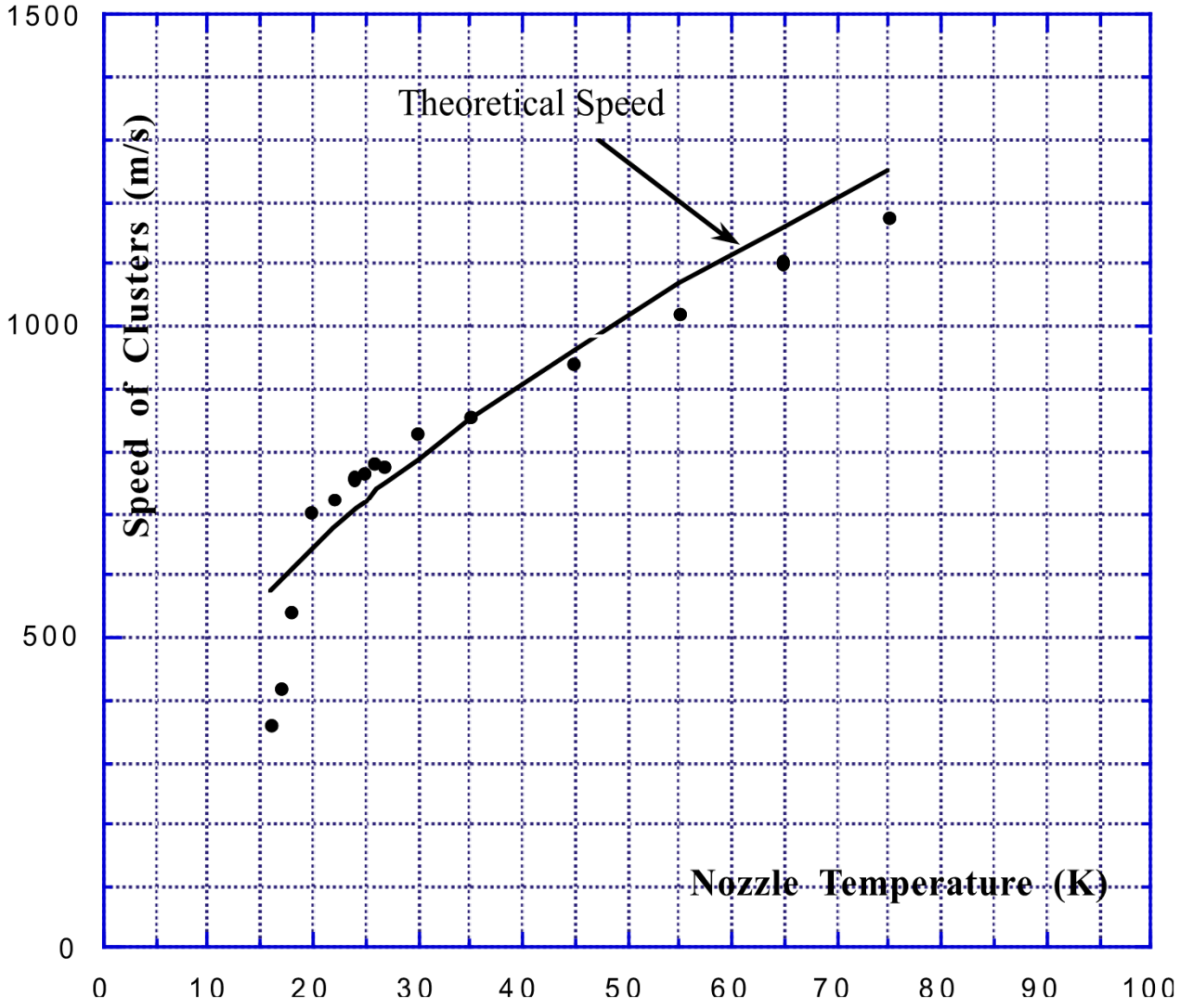
Large cluster mass

⇒ cluster velocity decouples from gas velocity

⇒ after „freezeout“ position:

velocity of clusters ≈ v_{max}

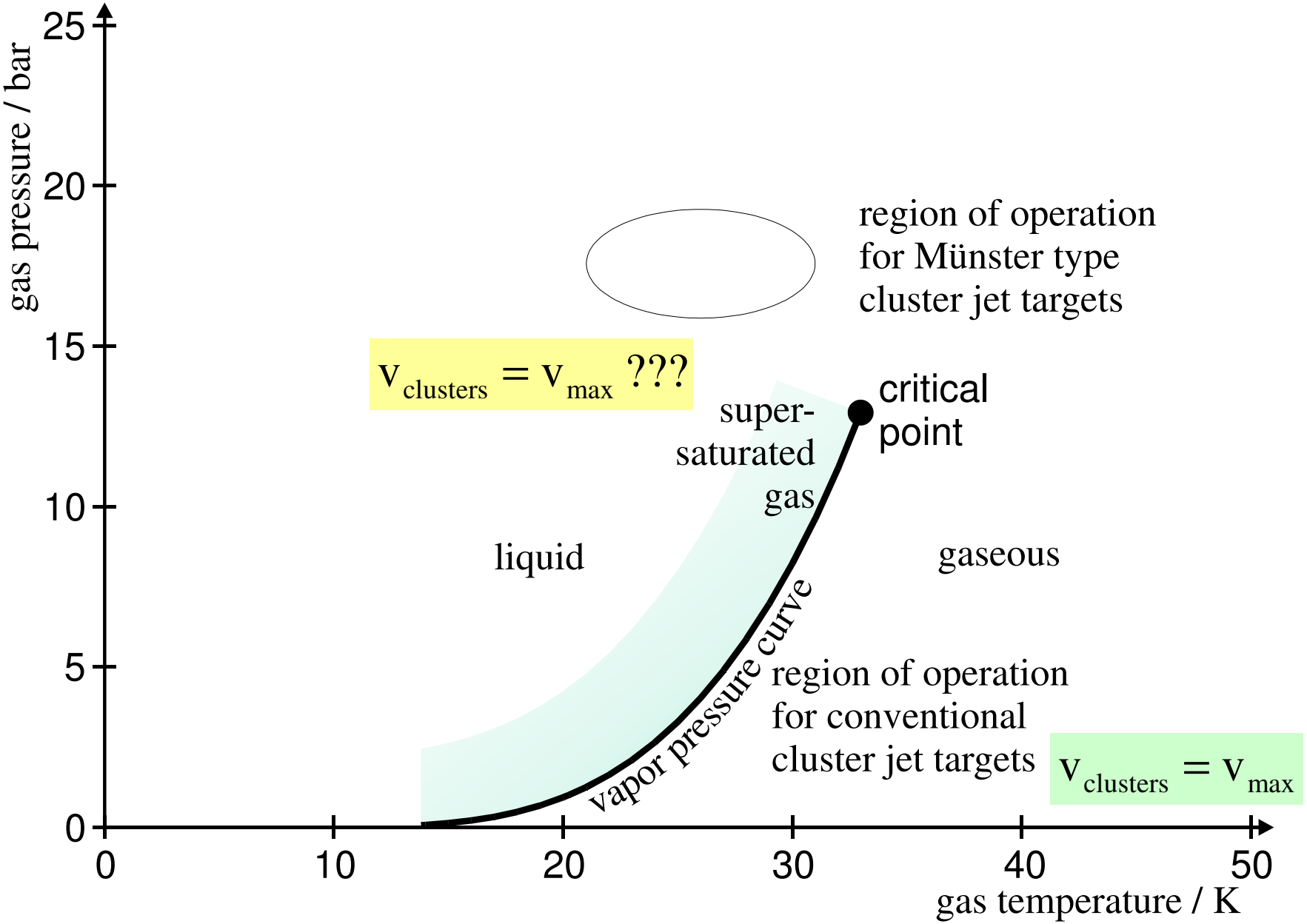
Measurements at FERMILAB E835



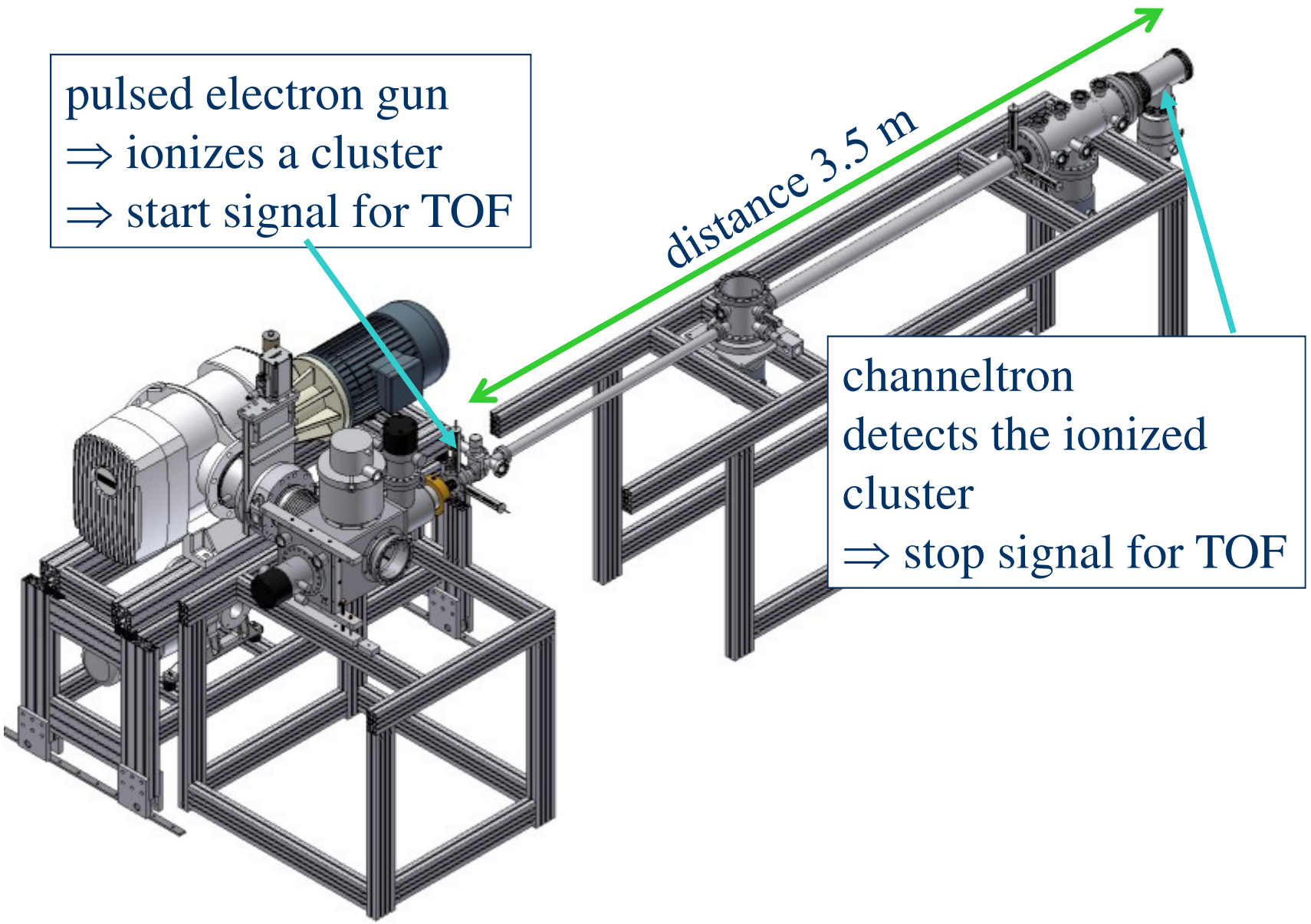
good agreement between theoretical speed of the perfect gas and speed of the clusters

[graduation thesis G. Garzoglio]

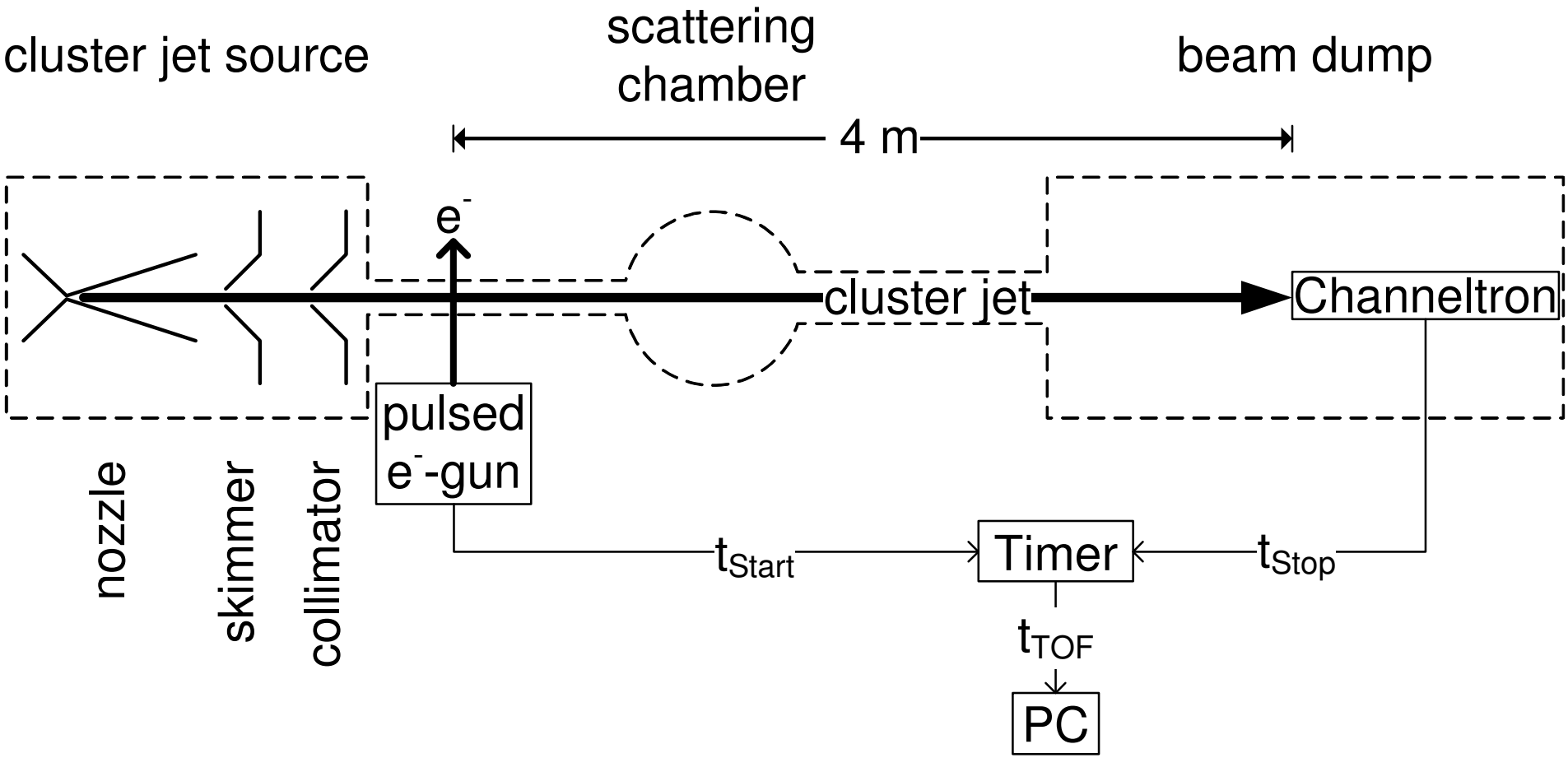
Region of operations for cluster jet targets



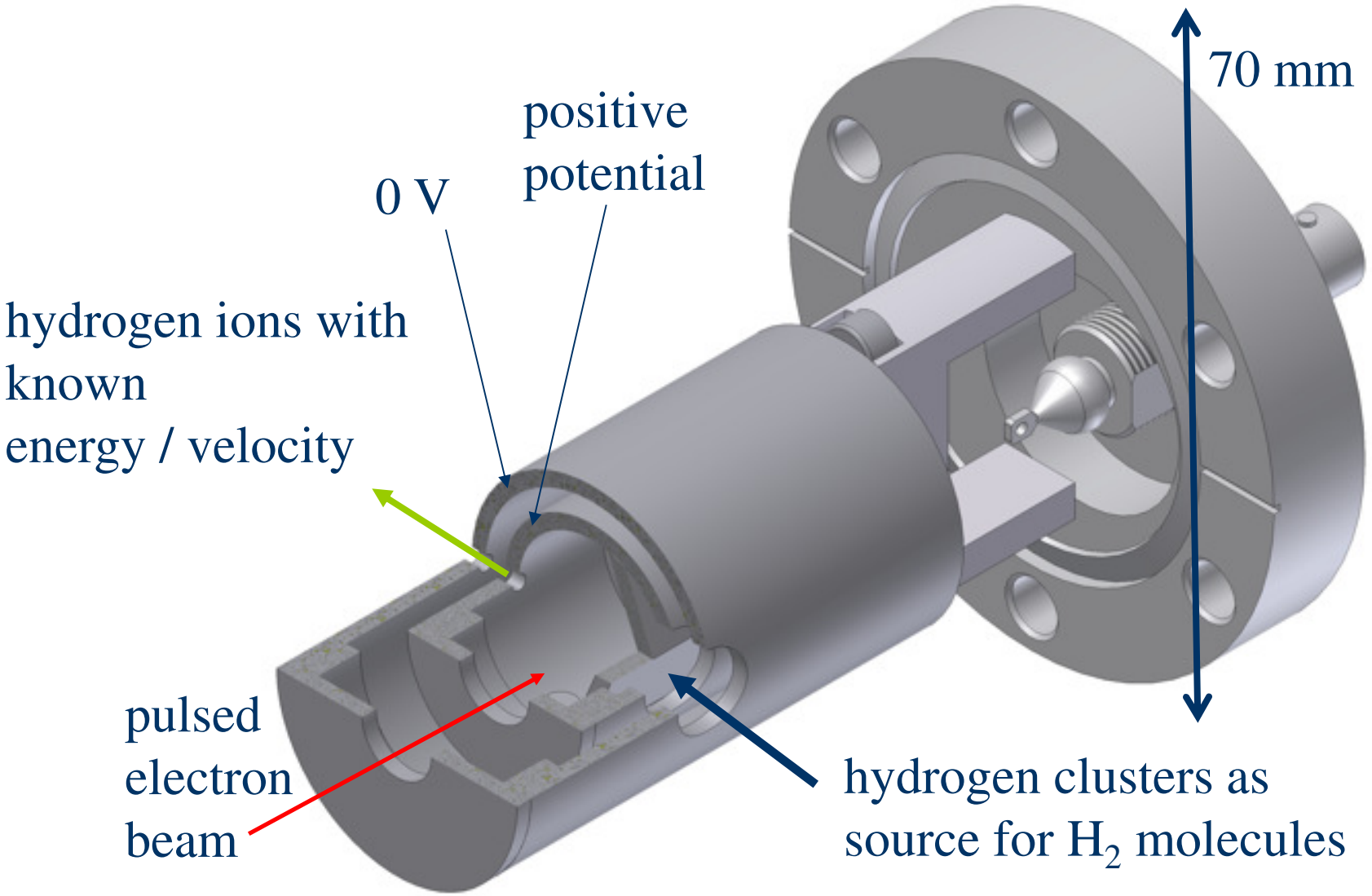
Velocity determination via time-of-flight



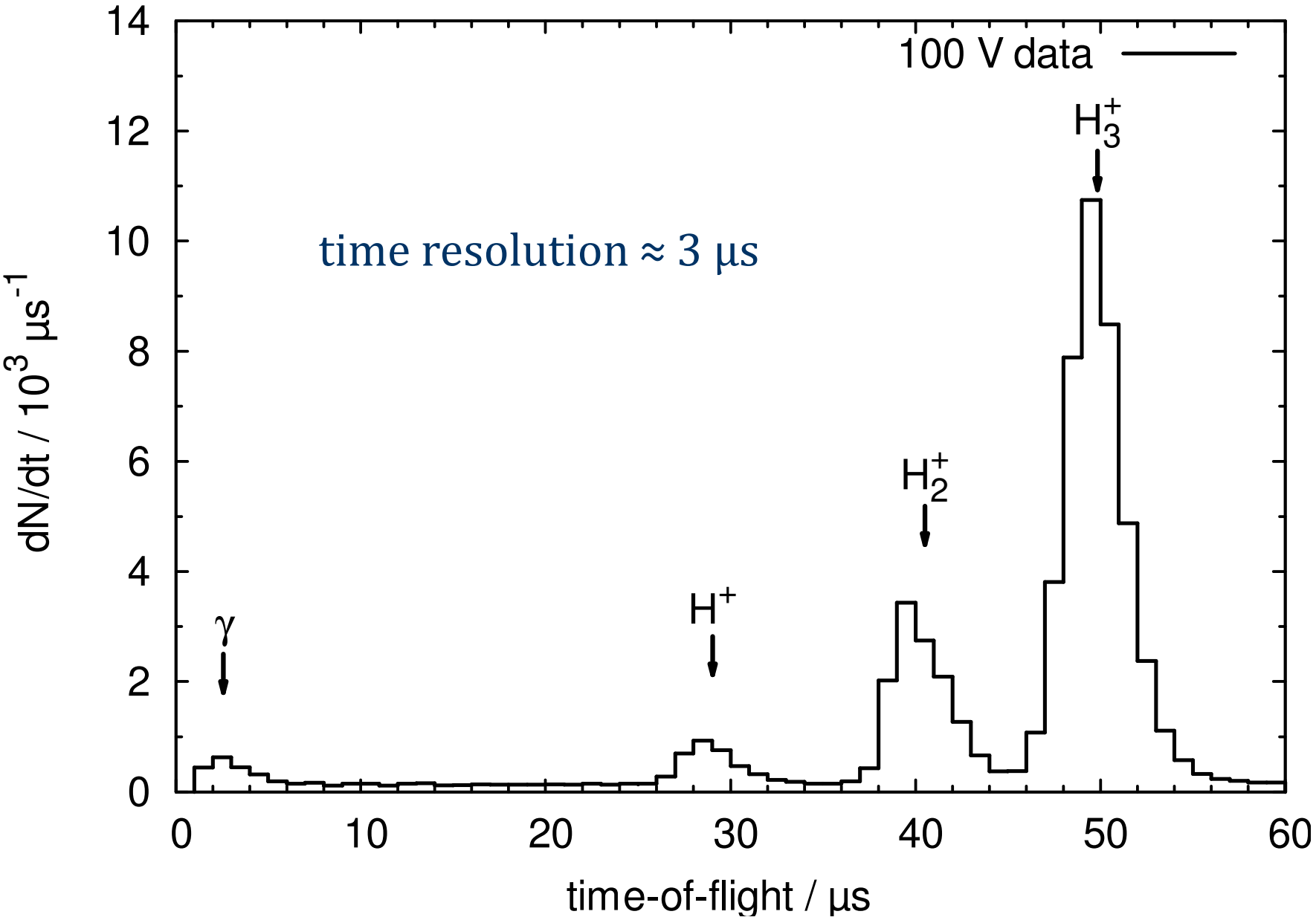
Time-of-flight method



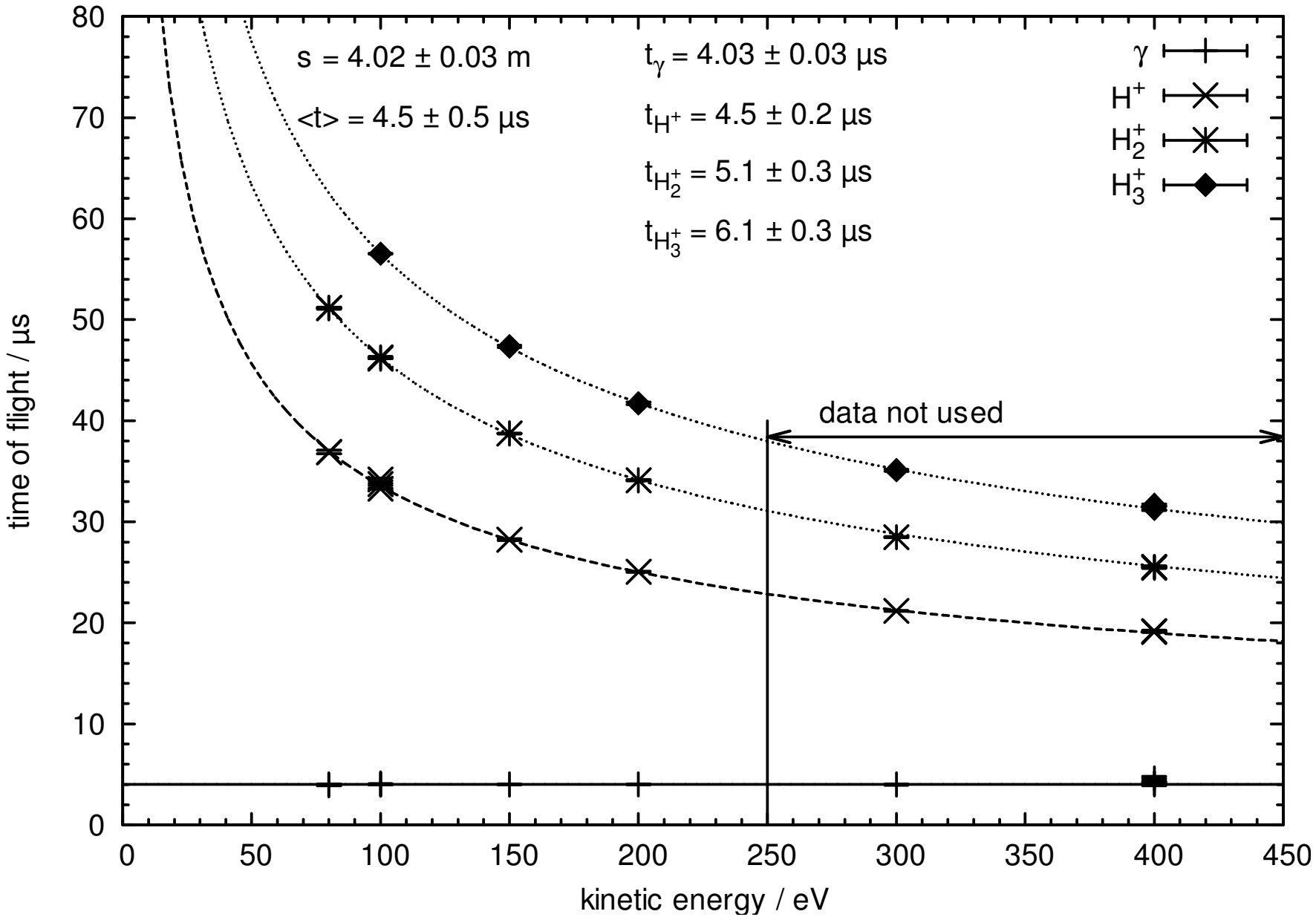
Calibration of the time-of-flight



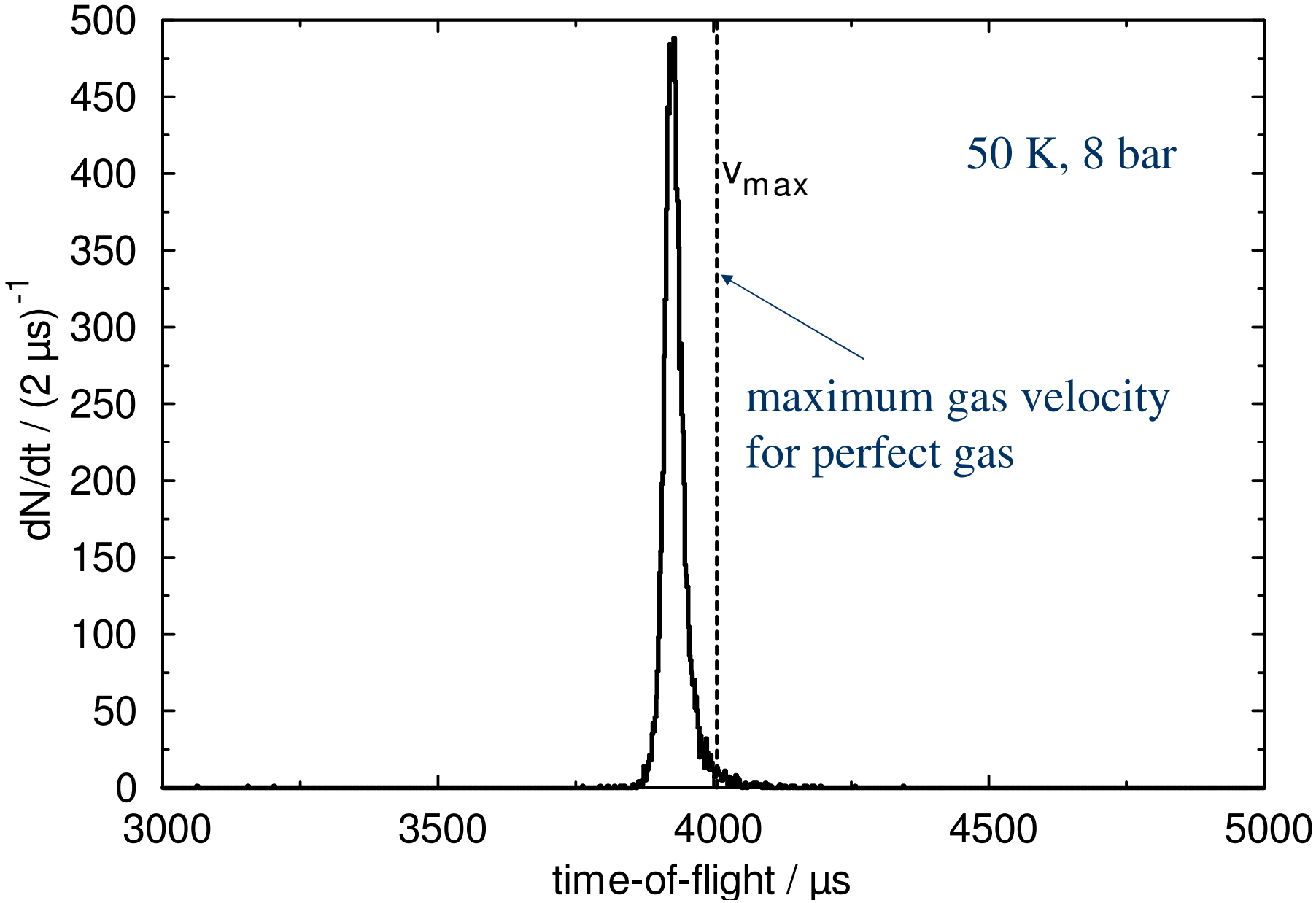
TOF spectrum of the calibration source



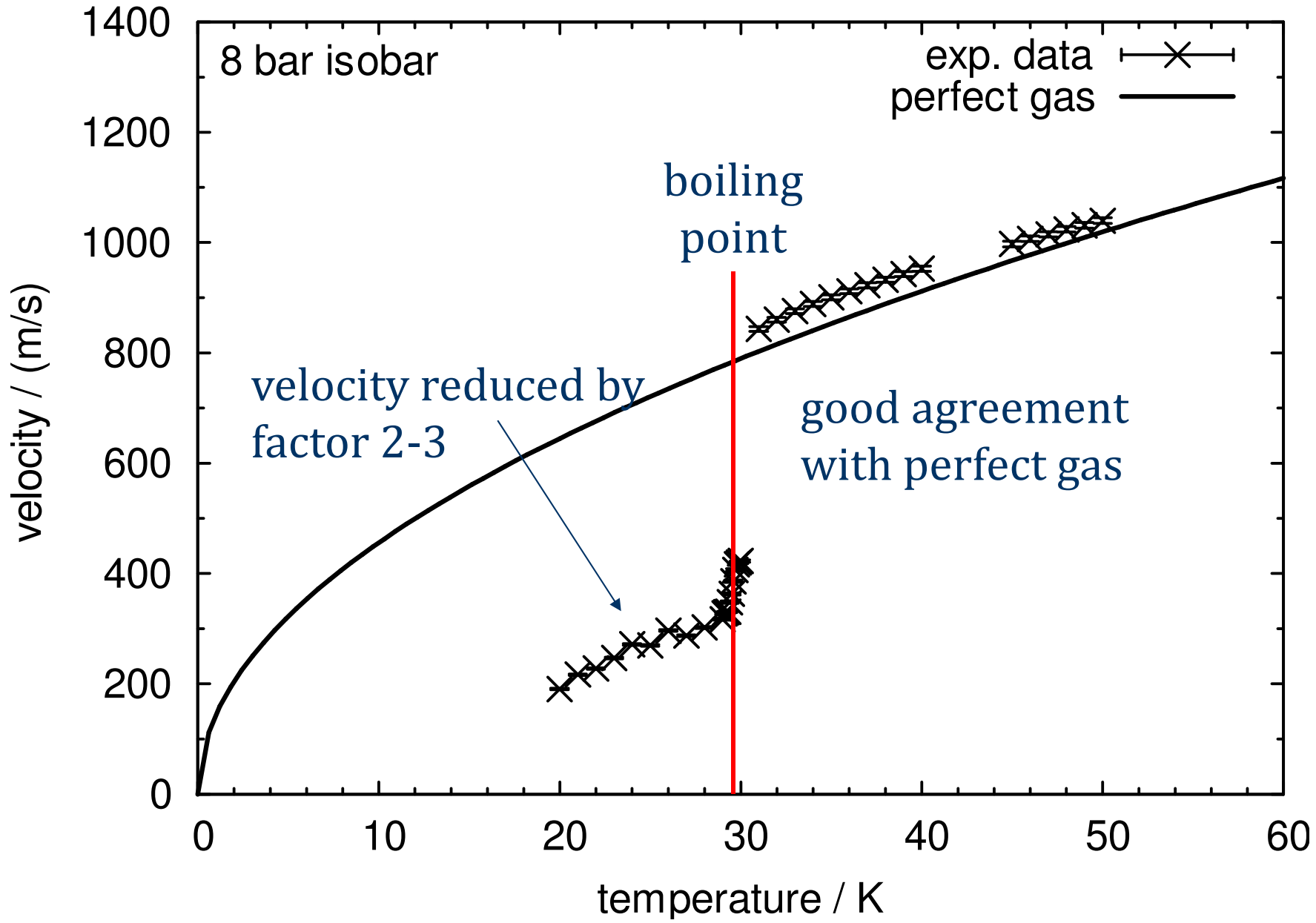
Calibration of TOF measurements



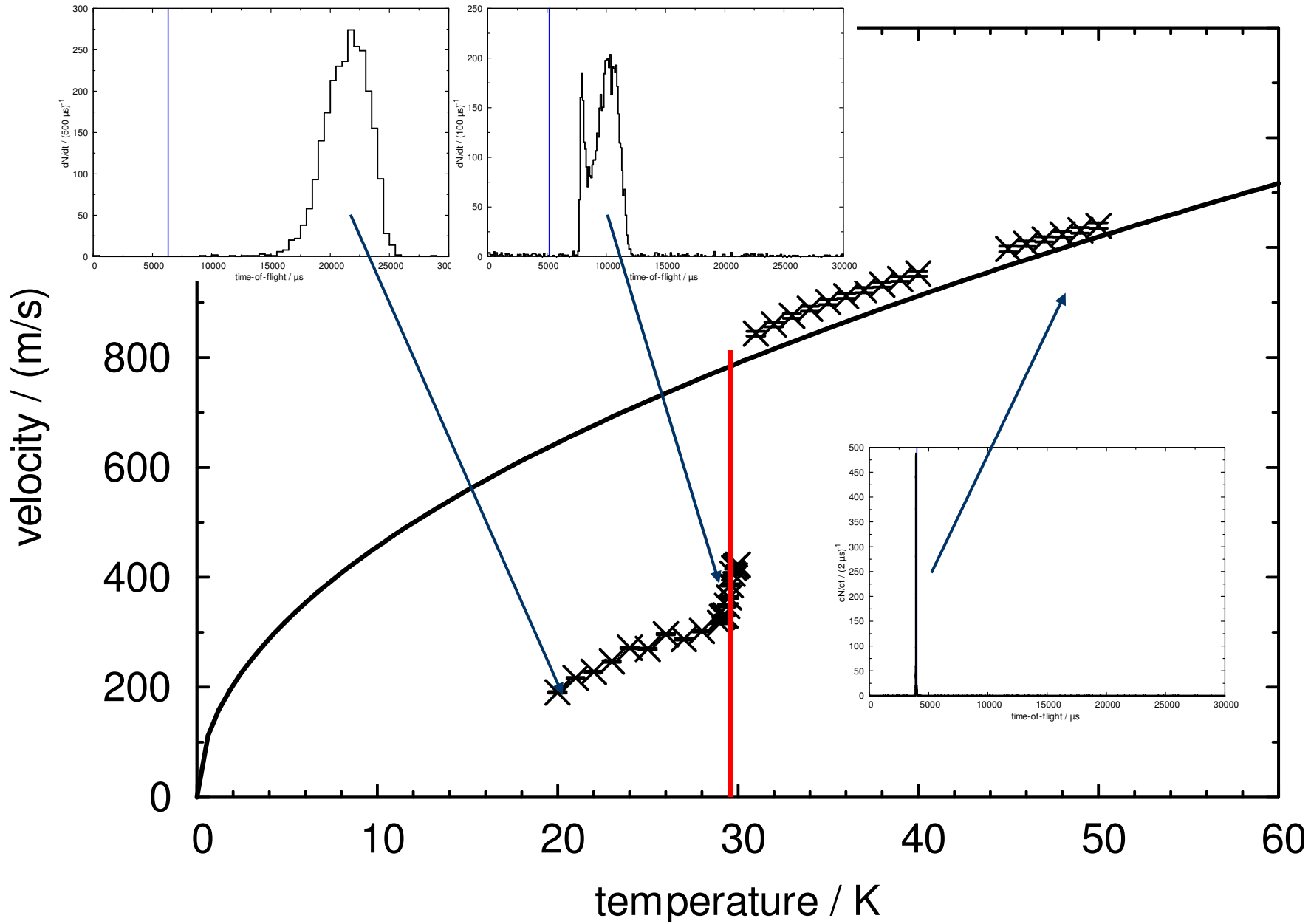
TOF spectrum of clusters



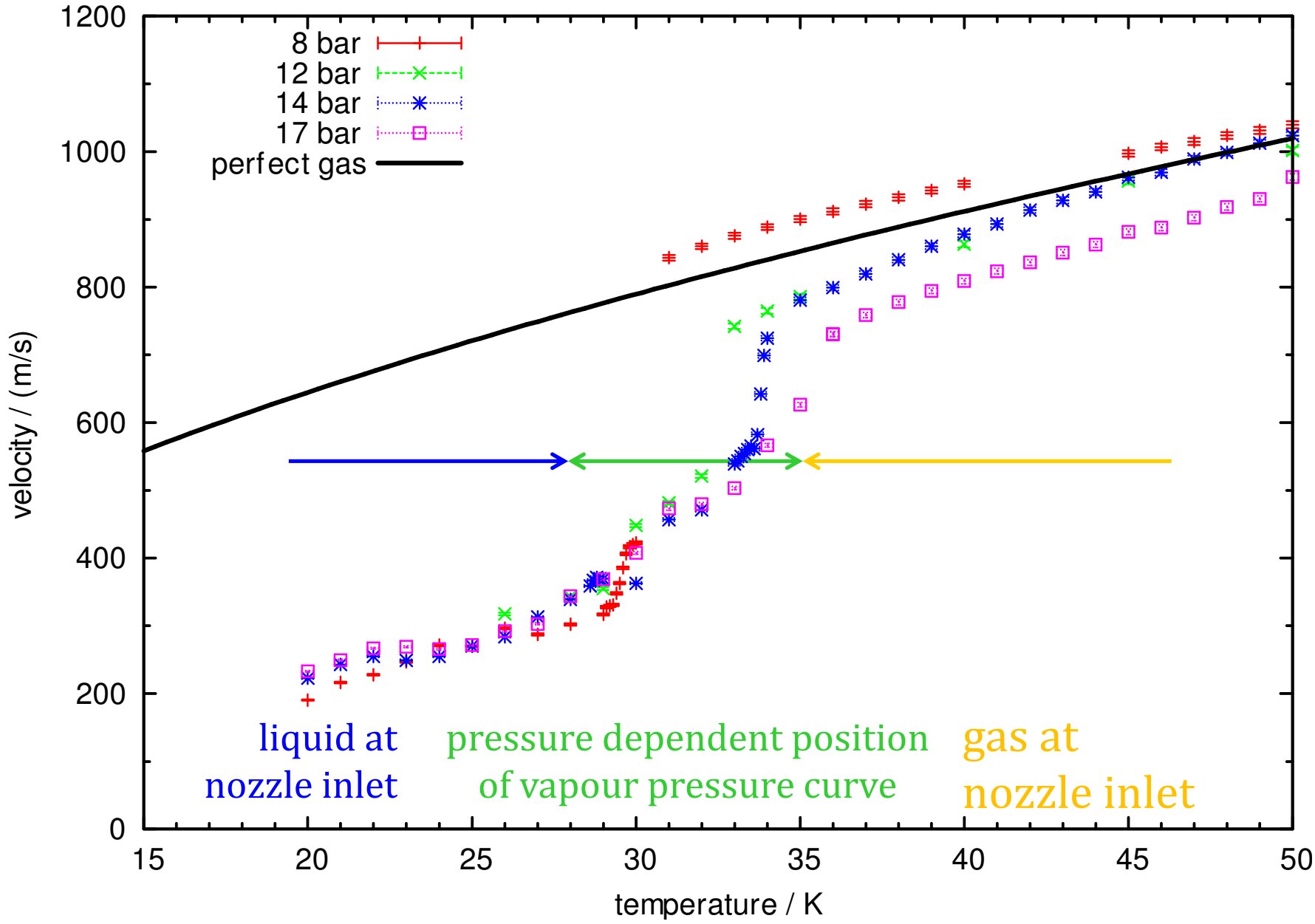
Cluster velocity on 8 bar isobar



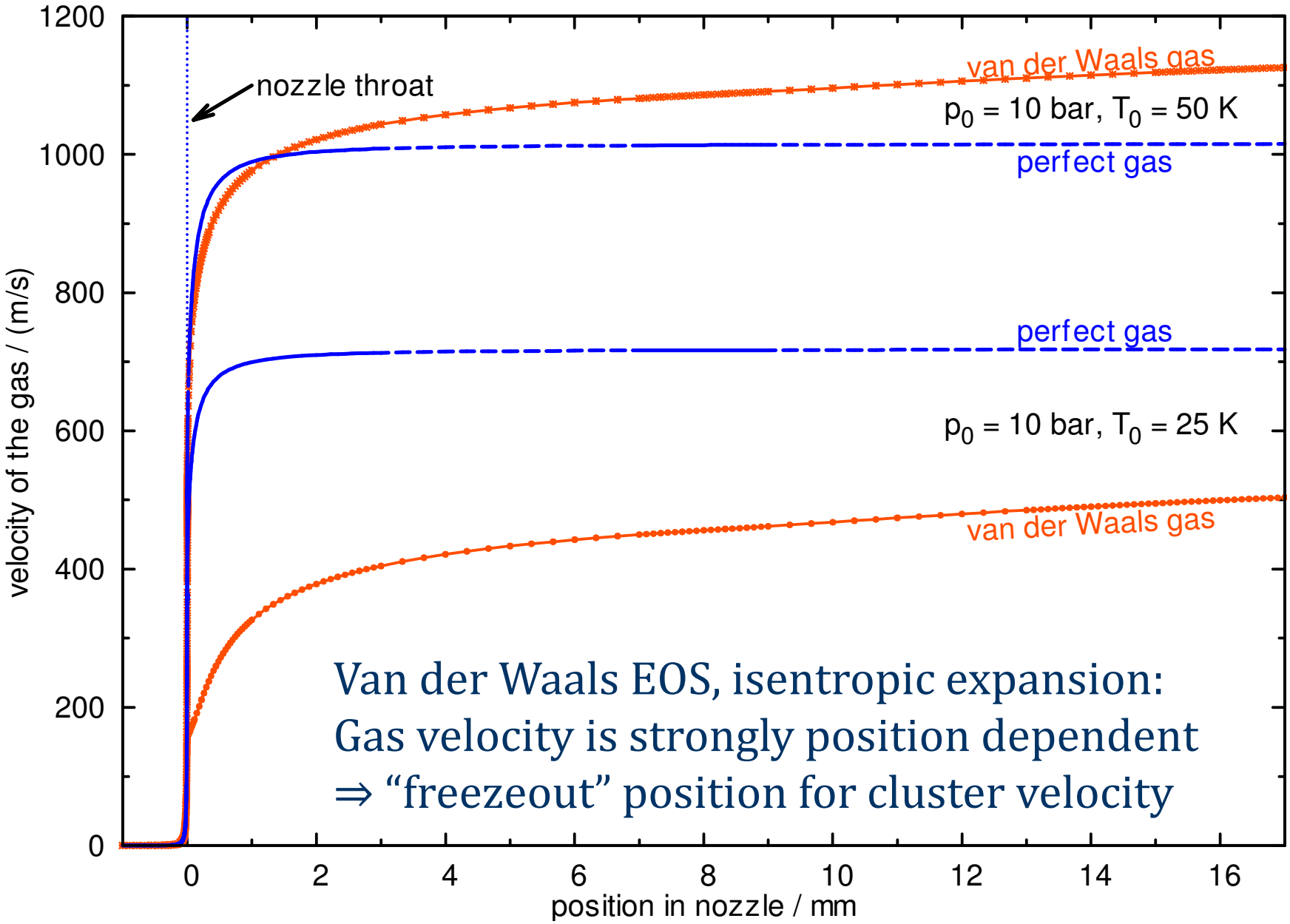
Velocity distributions on 8 bar isobar



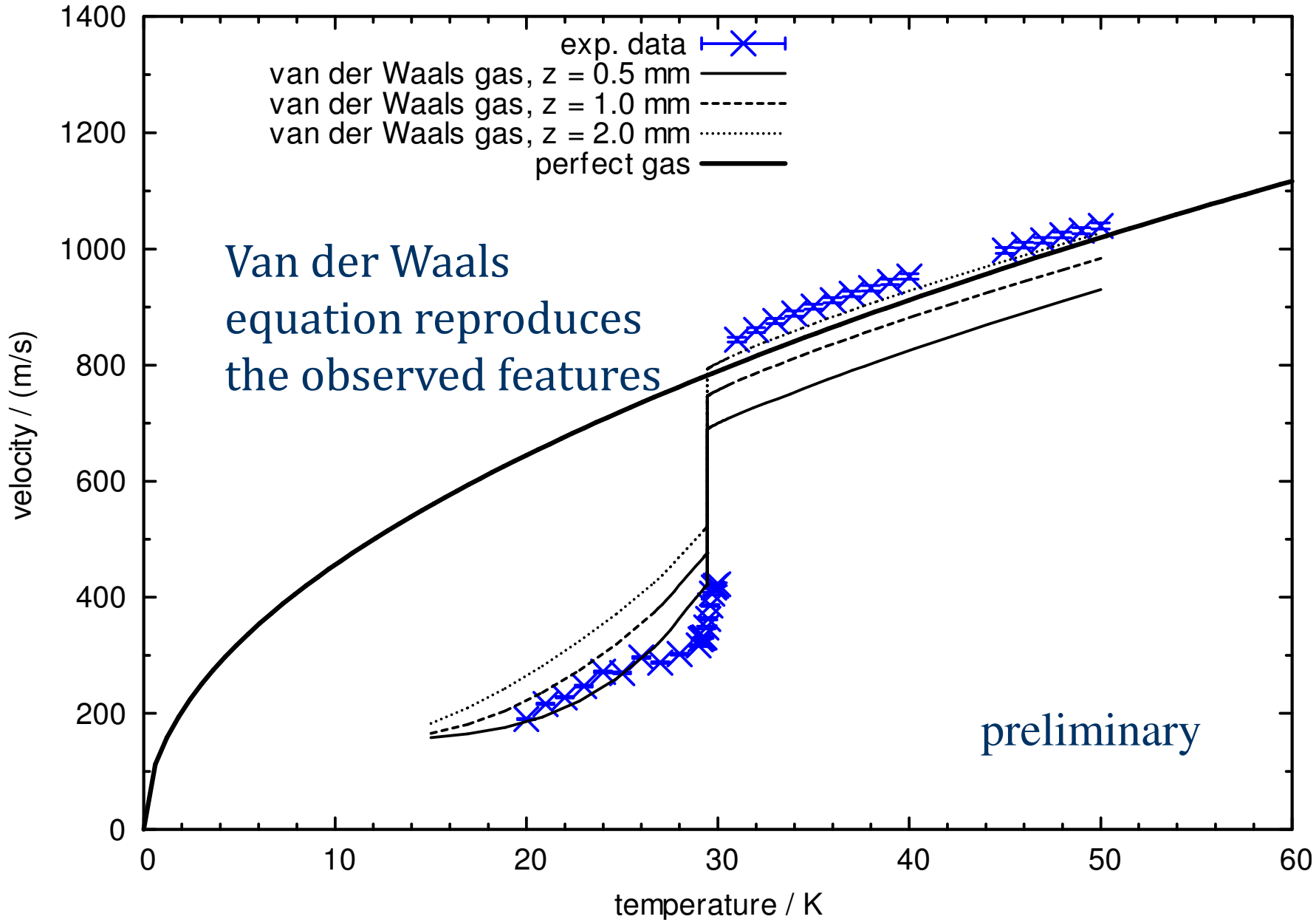
Cluster velocities on various isobars



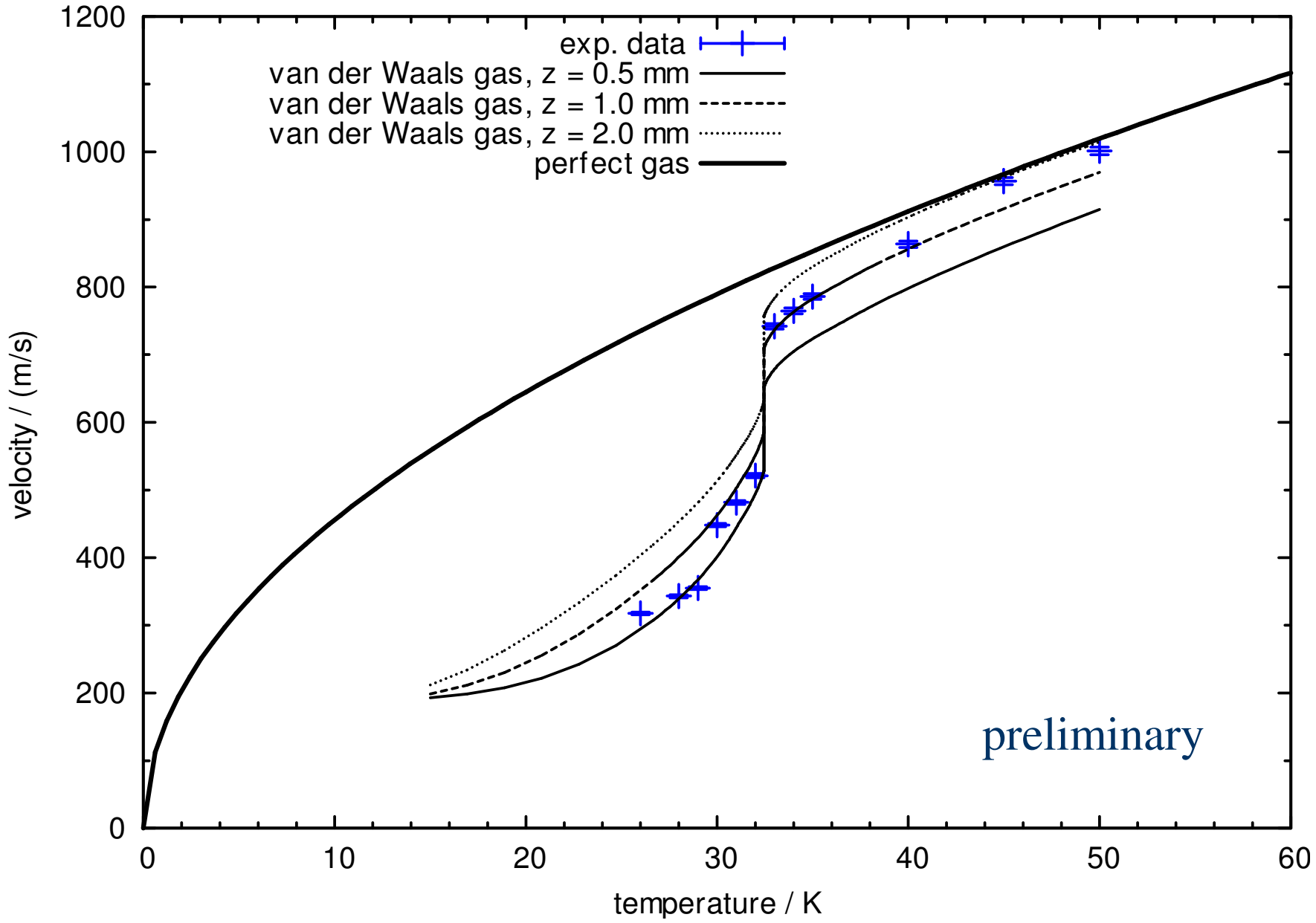
Gas velocity in a Laval nozzle



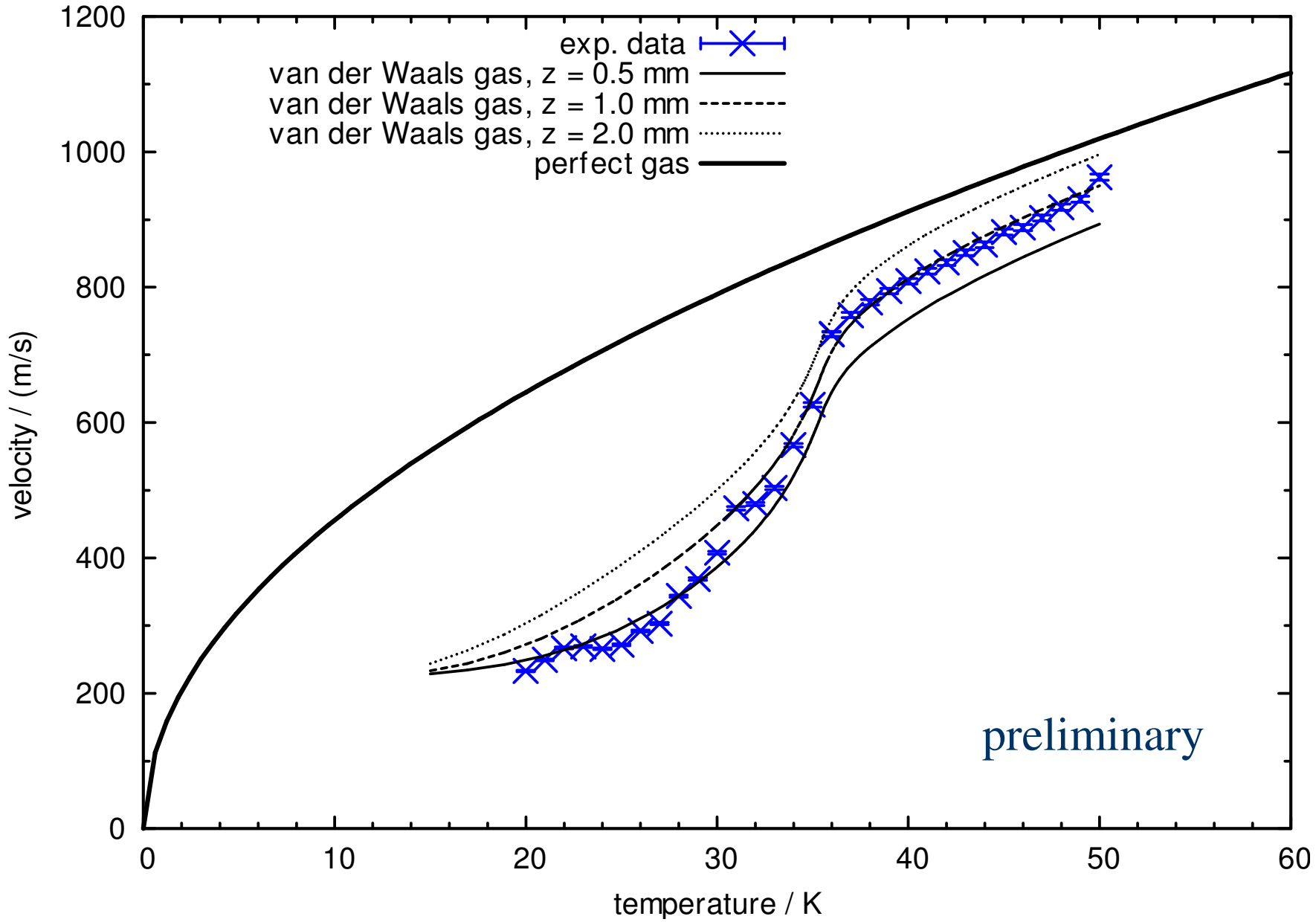
Real gas model for 8 bar isobar



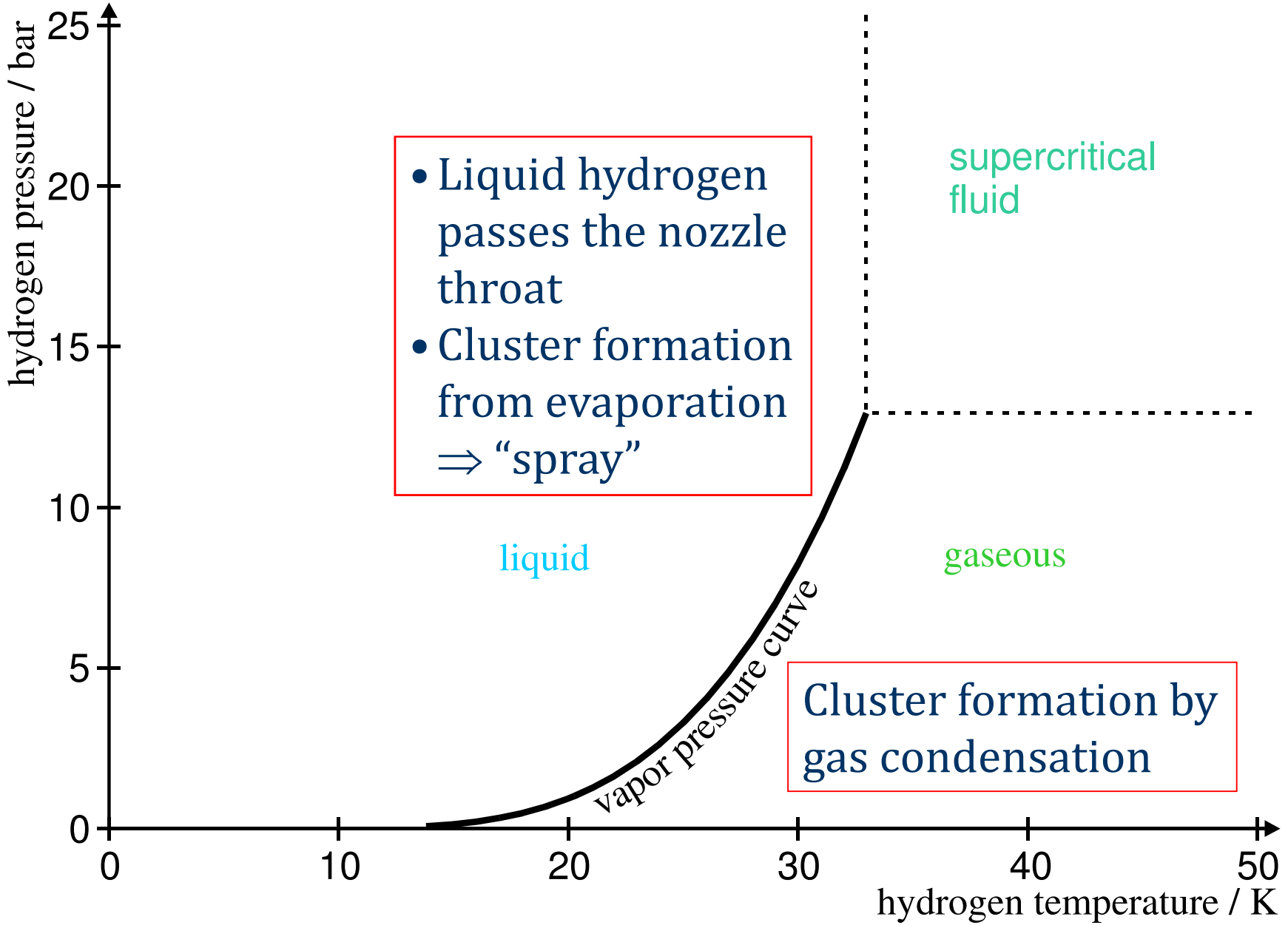
Real gas model for 12 bar isobar



Real gas model for 17 bar isobar



Cluster formation process



Summary and outlook

- Established precise technique for velocity measurements of clusters
- Comparison between measurements and simulation:
  - ⇒ better comprehension of the cluster production process
  - ⇒ important for improved nozzle design / cluster density
- Found **two cluster regimes**:

conventional targets	Münster type (at highest density)
- Clusters formed from **condensated gas**	- Clusters formed from **evaporation of liquid**
- Cluster velocity = perfect gas velocity	- Cluster velocity = velocity of real gas
- **Lower density**	- **Higher density**

→ see talk E. Köhler

- **In the future**:
  Investigation of the mass distribution of the clusters