VI-ACI: Work Package L3
- Laboratory Experiments at ETH Zurich -
CCN – IN – Hygroscopicity – Aerosol-MS

Olaf Stetzer, Ulrike Lohmann
Zamin Kanji, André Welti, Luis Ladino

ETH Zurich, Switzerland
Institute for Atmospheric and Climate Science
IAC*ETH*

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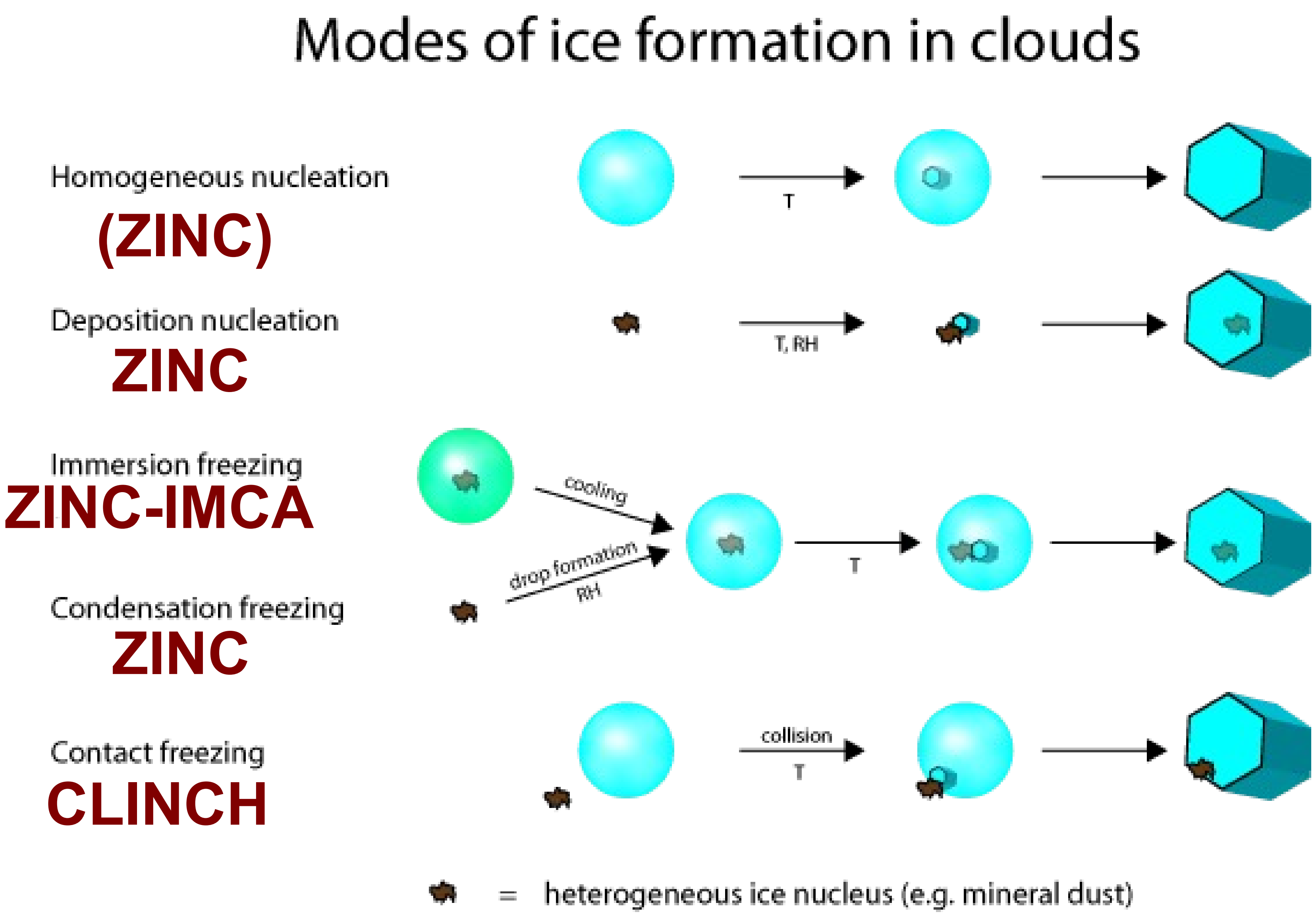
Experimental activities at ETH Zurich related to VI-ACI Work Package L3:

- Immersion freezing studies (ZINC-IMCA) and a closer look at depolarization detection (linear vs. circular)
- Collision Efficiency studies between aerosol particles and cloud droplets
- Aerosol tank for ageing studies of mineral dust particles (as IN) with trace gases e.g. ozone
- PINC: two campaigns at AIDA chamber, data is still being processed
- HOLIMO: A new PhD project started to improve the instrument and make it ready for field campaigns

P. Amsler, O. Stetzer, U. Lohmann, M. Schnaiter, S. Benz, O. Möhler and E. Hesse: “Ice crystal habits from cloud chamber studies obtained by in-line holographic microscopy related to depolarization measurements”, Applied Optics, 48(30):5811–5822 (2009).

IN – mixed phase and cold clouds

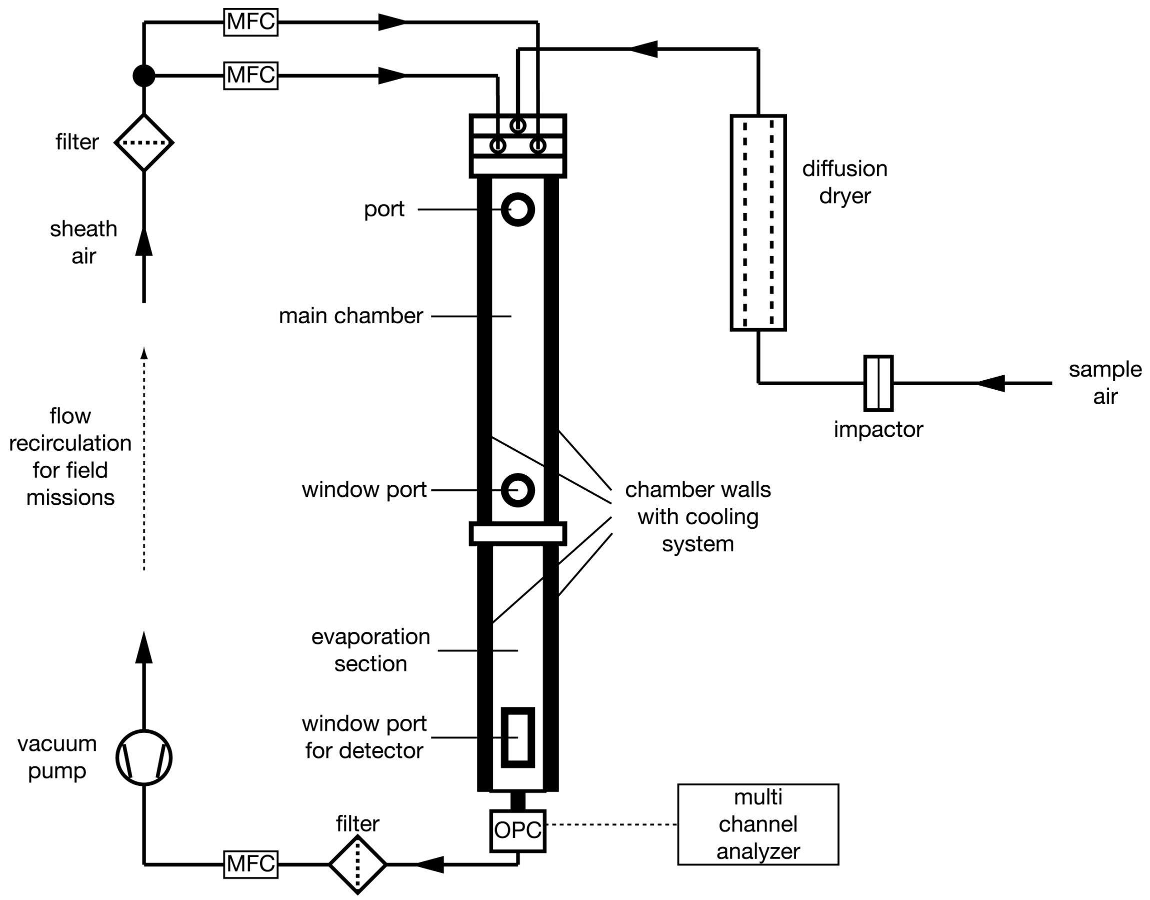


Design concept of ZINC/PINC

Operation principle:

Aerosols are drawn through a chamber which is cooled and supersaturated with respect to ice → ice crystals may form and grow and are finally detected optically

Supersaturation is obtained by diffusion of water vapour between two ice covered walls held at different temperatures



IODE depolarization detector

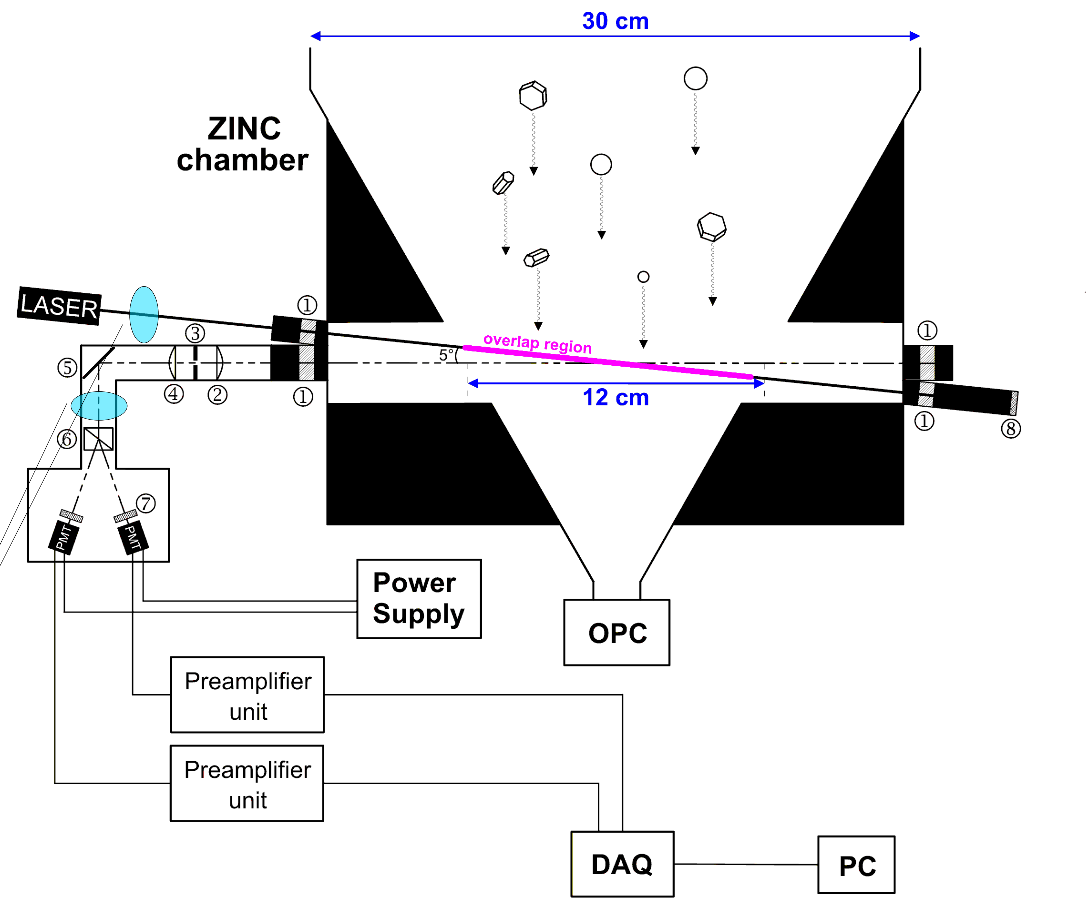
One such detector was developed in our group in the last years: IODE

Hypothesis:

Circular depolarization may be more sensitive in distinguishing ice crystals from water droplets than linear depolarization.

Modifications needed:

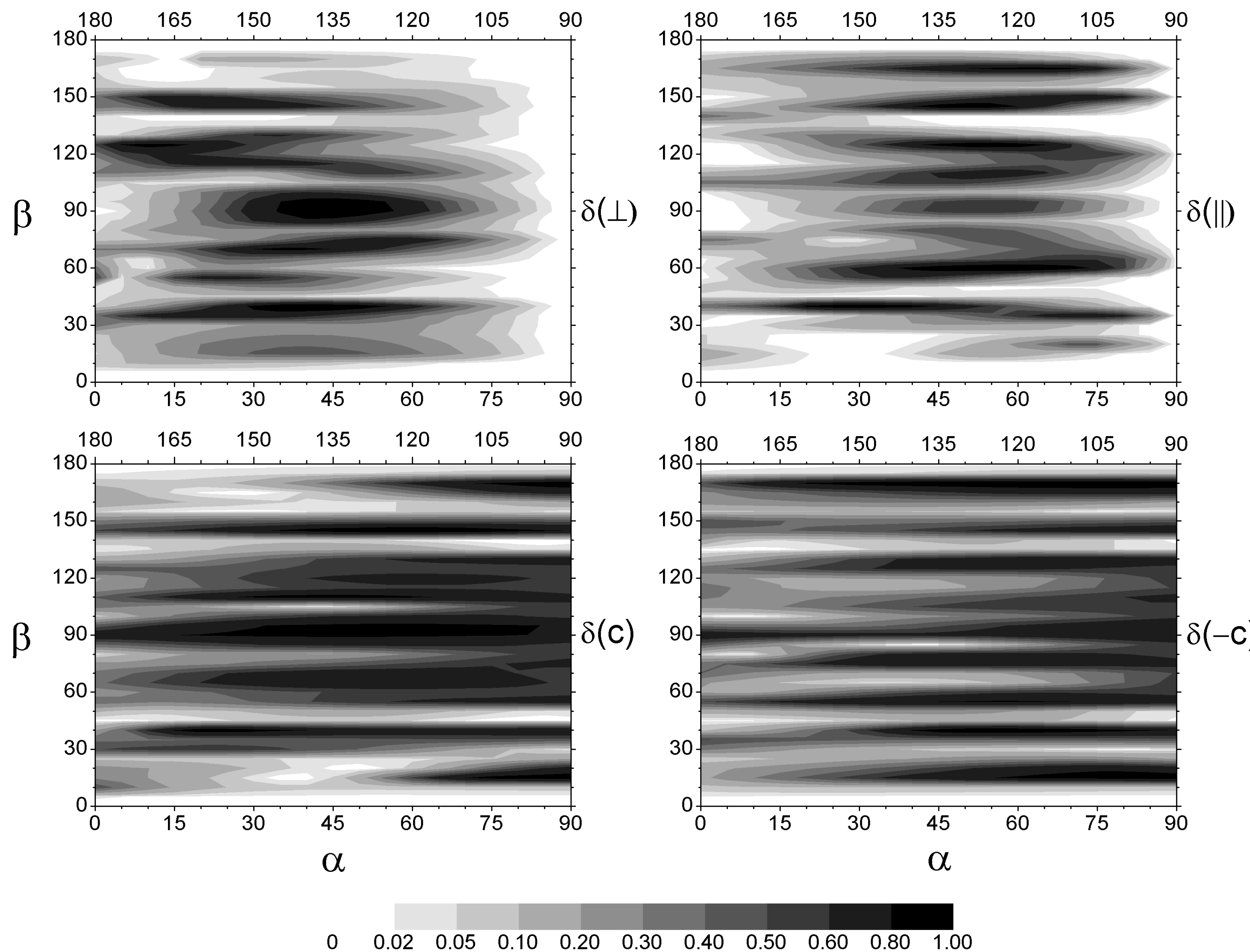
Insertion of two /4 plates



① coated windows
② convergent lens (f=25mm)
③ pinhole
④ convergent lens (f=19mm)
⑤ mirror
⑥ Wollaston prism
⑦ bandpass filter
⑧ beam dumper

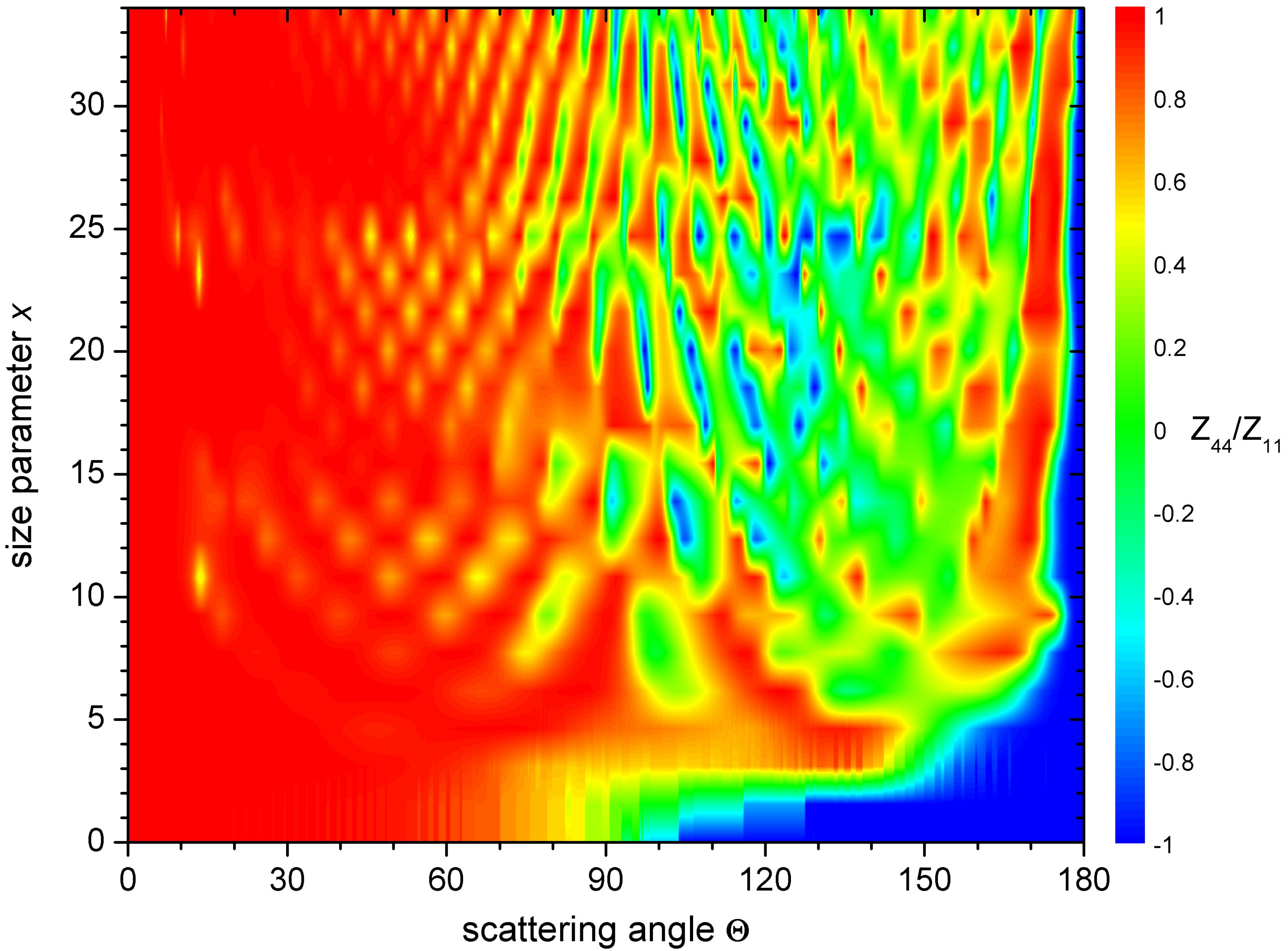
Circular vs. linear depol: T-matrix results

Comparison of linear and circular depolarization ratios at 177° for 2 μm particles as a function of orientation



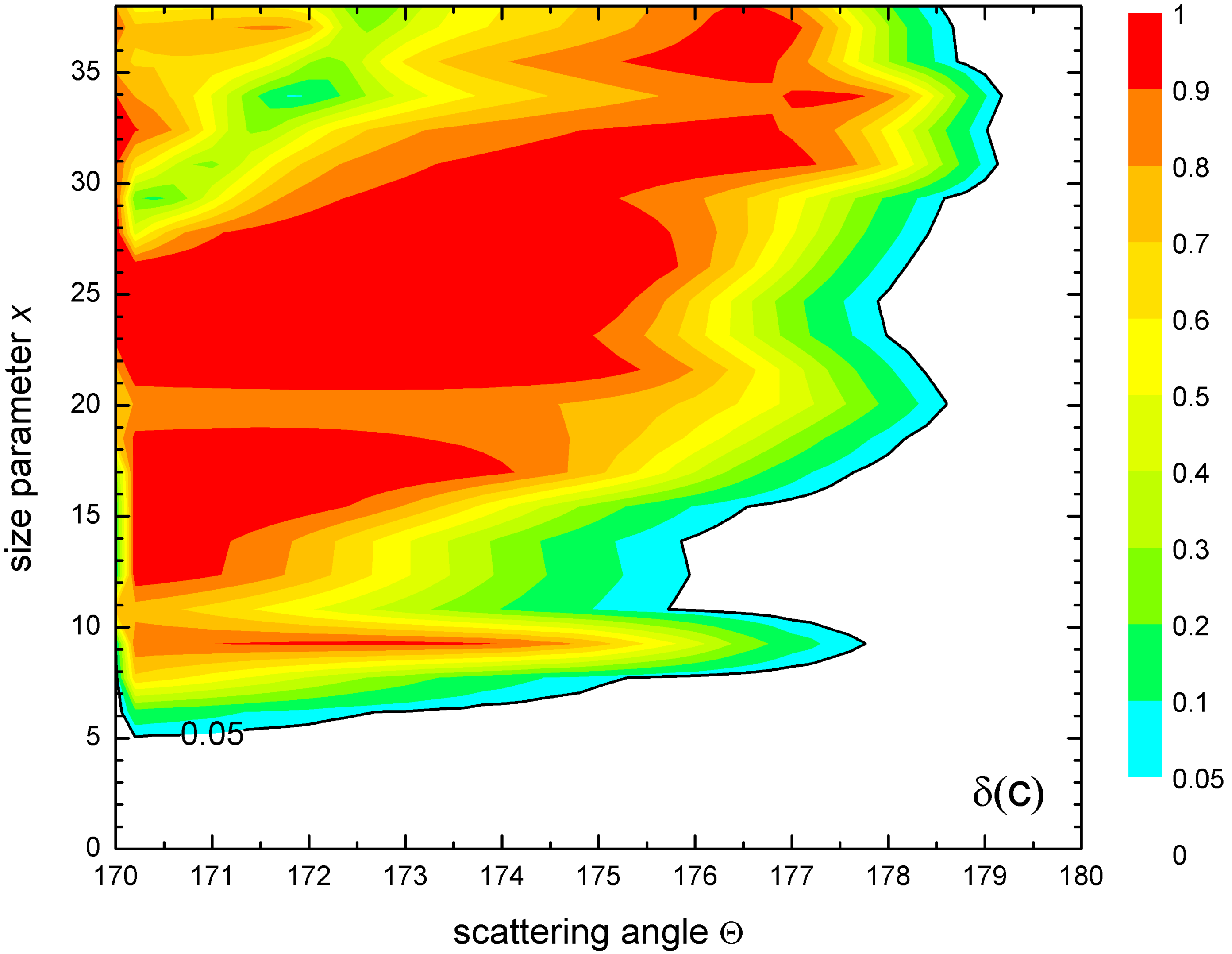
Results

Results for spherical particles Z44/Z11:



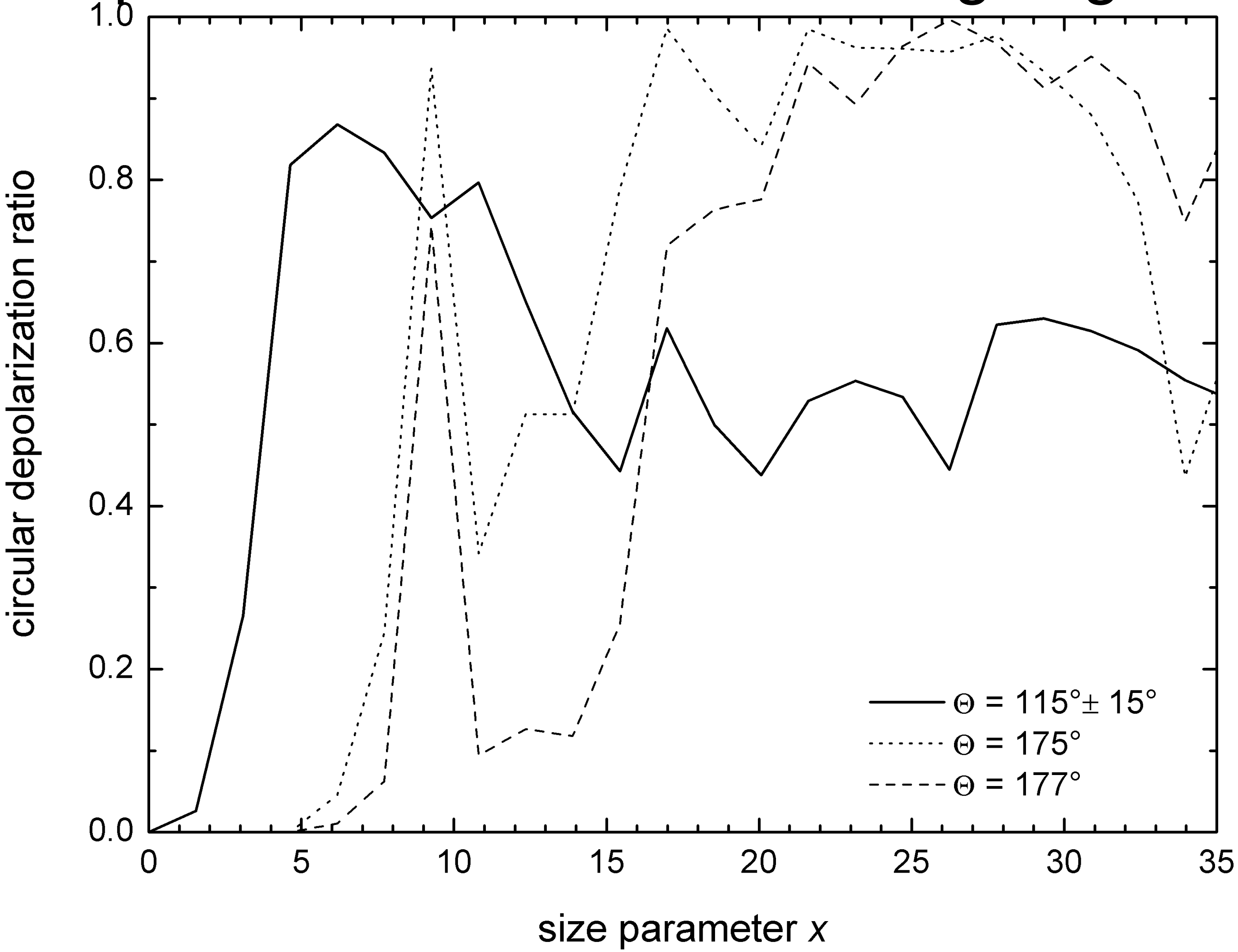
Results

Circular depolarization ratios for spherical particles at scattering angles in the IODE range:



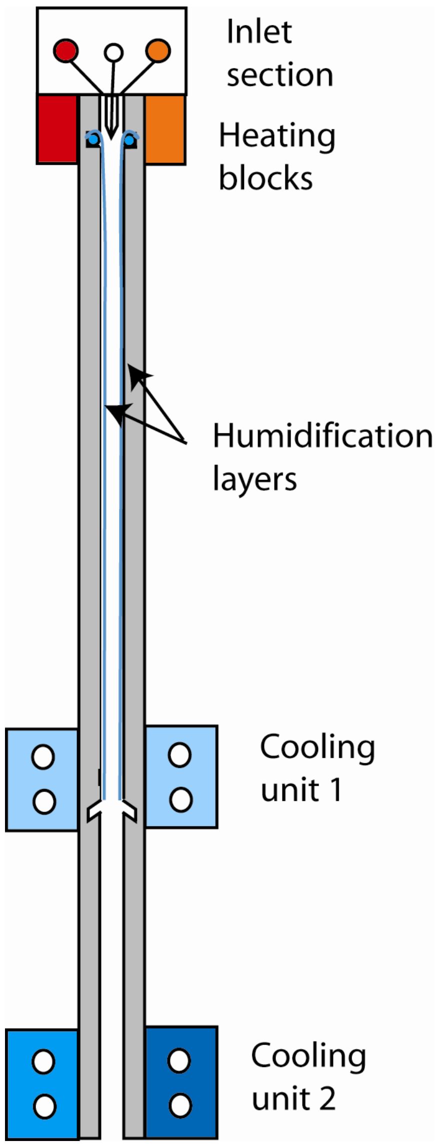
Results

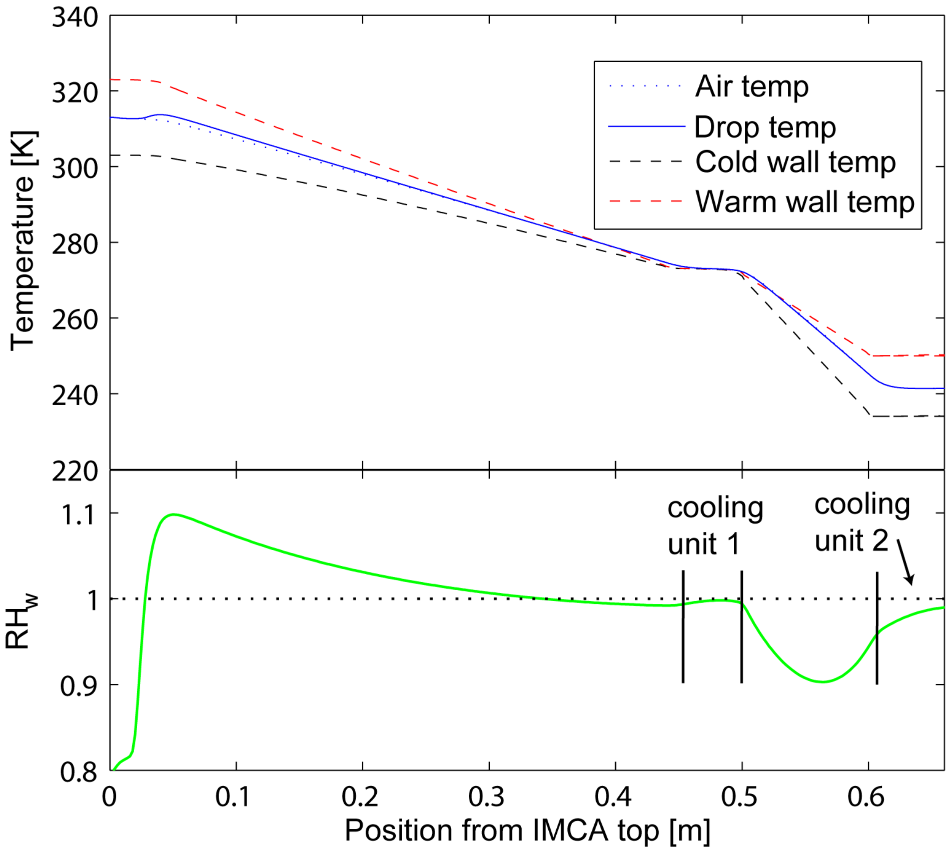
Comparison of circular depolarization ratios for spherical particles at different scattering angles:



M. Nicolet, O. Stetzer, M. Schnaiter and U. Lohmann: "Circular depolarization ratios of single water droplets and finite ice circular cylinders: a modeling study", Applied Optics (draft in preparation).

IMCA-ZINC: Immersion freezing

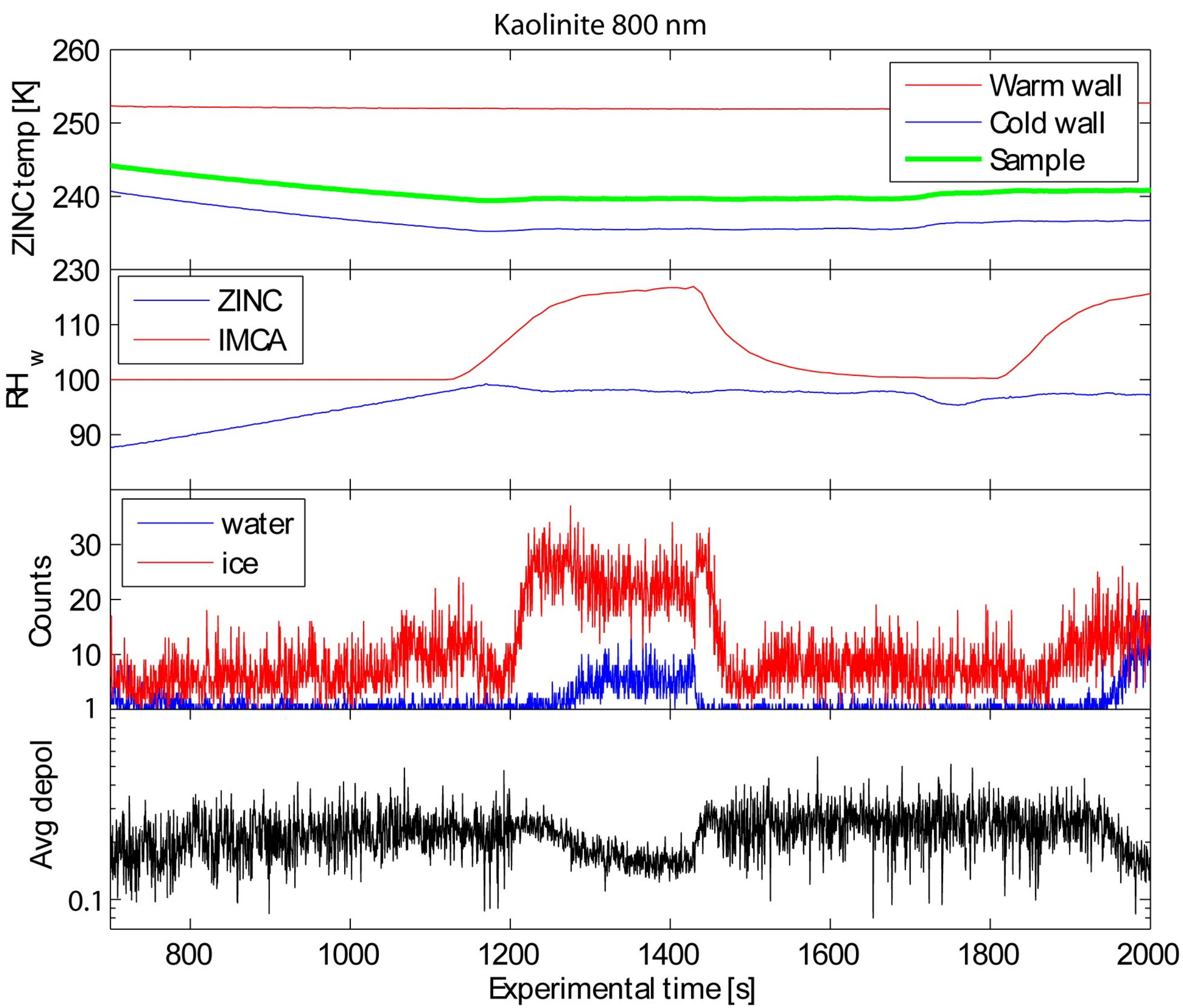




- Profiles obtained from FLUENT simulations
- Top of IMCA walls heated to different temperatures leads to a supersaturation profile
- Nucleation and growth of cloud droplets in the supersaturated top part
- ZINC chamber close to water saturation to prevent droplet evaporation prior to freezing

IMCA-ZINC: Immersion freezing

Results – Immersion vs Deposition



- No IMCA SSat: Deposition.
- IMCA SSat increasing: Reduced deposition nucleation.
- IMCA SSat increasing further: Frozen droplets reach IODE, increase in ice counts.
- IMCA SSat at max: Frozen AND liquid droplets reach IODE. Frozen fraction can be calculated.
- Depolarisation of ice crystals nucleated by immersion is lower than the one of deposition crystals.

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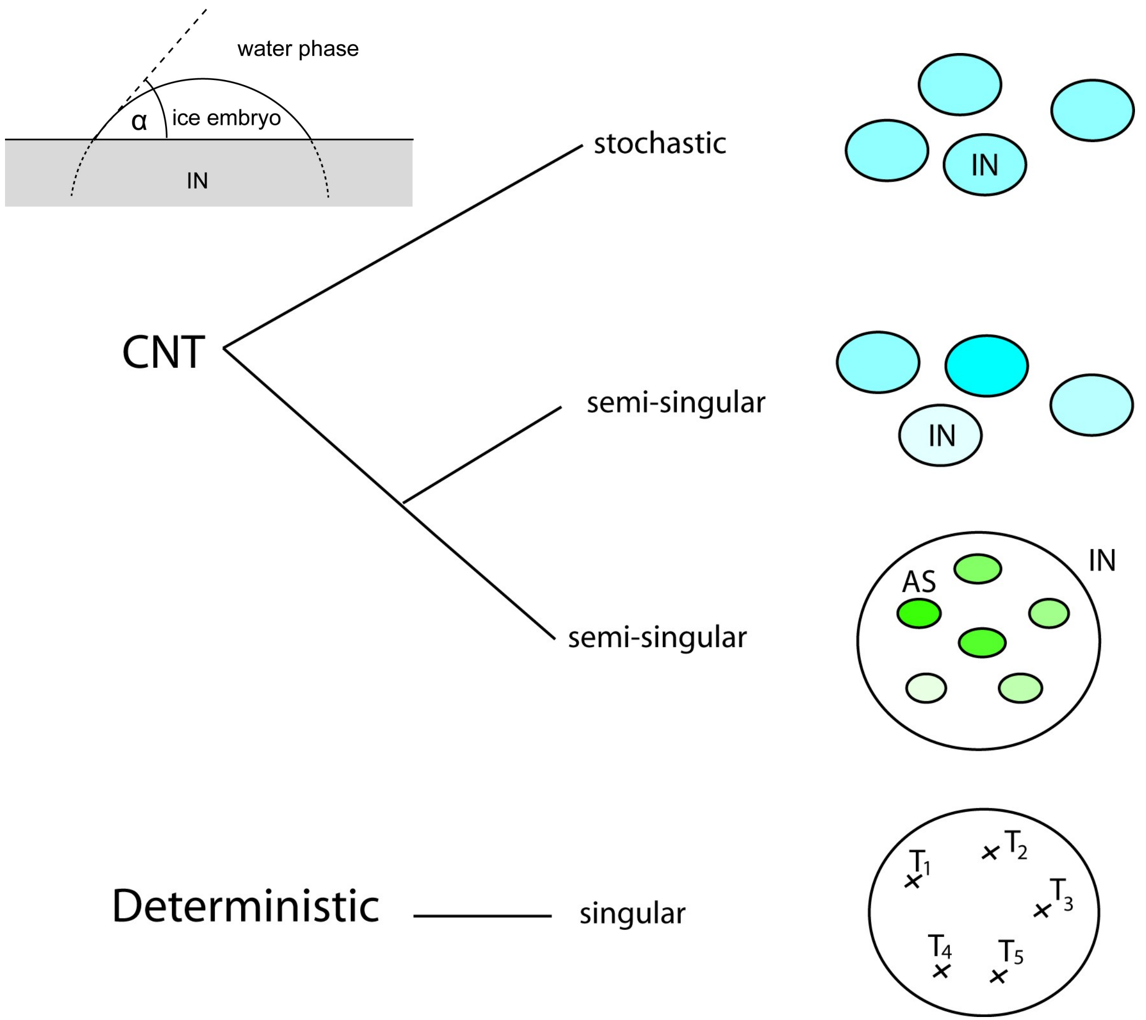
IMCA-ZINC: Immersion freezing

Fitting of the Data with nucleation theory



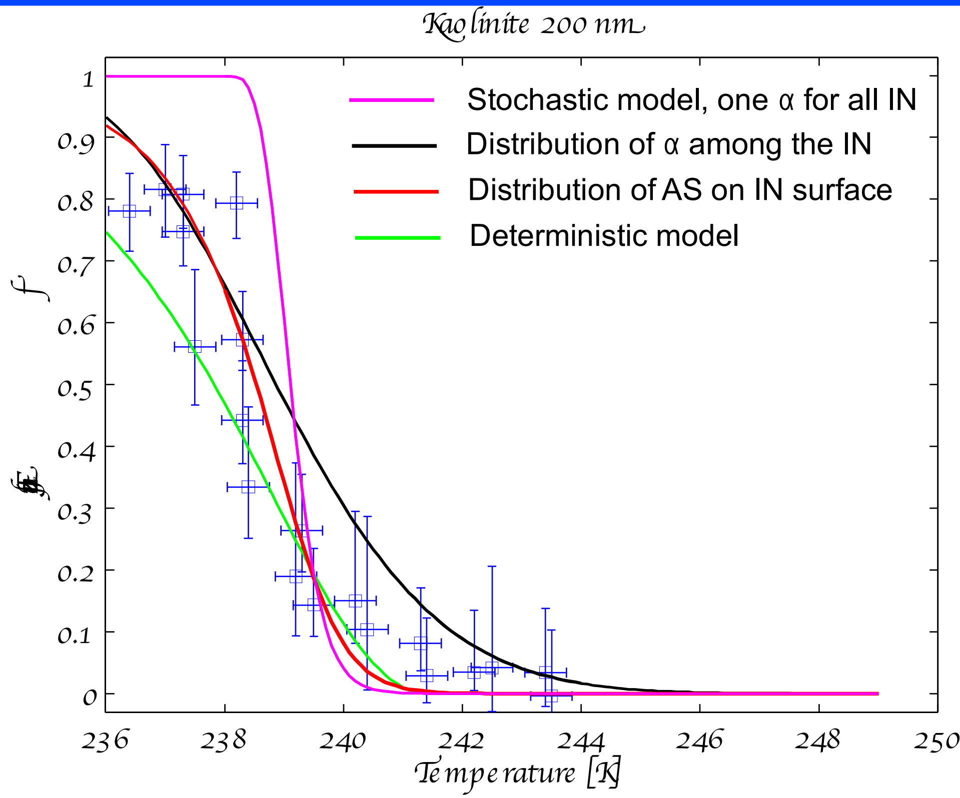
Stochastic model: All IN have the same contact angle α

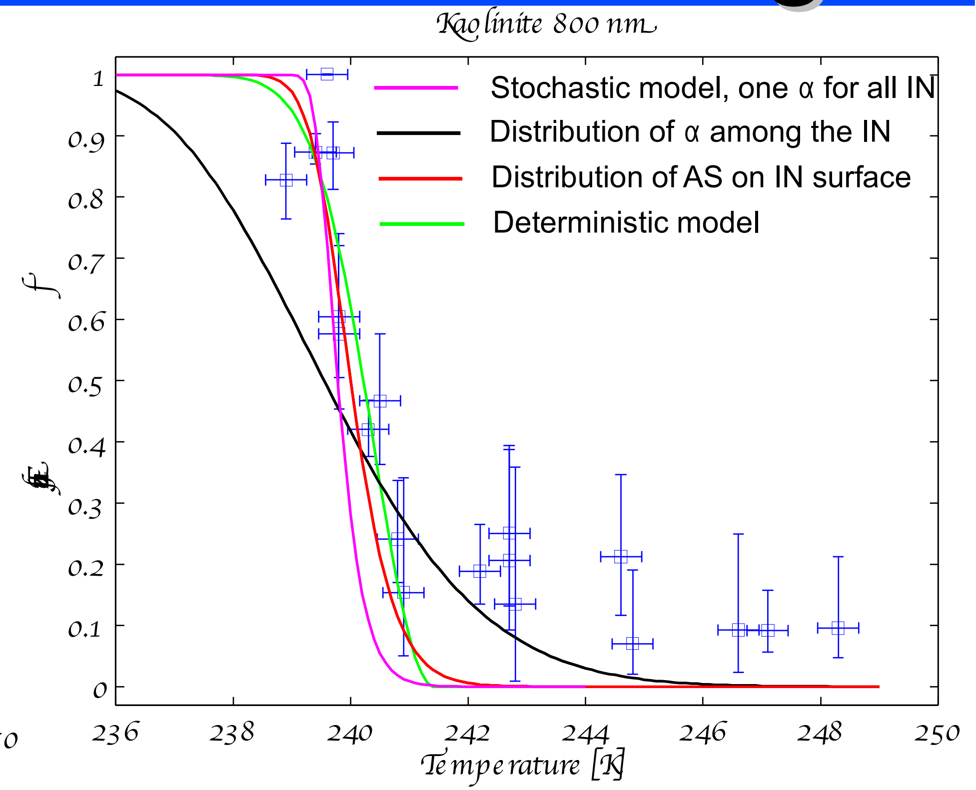
α-PDF model: IN have different contact angles, α is constant over each IN surface (Marcolli et al., 2007)

Active site model: Active sites with varying α are randomly distributed over the IN surface (Marcolli et al., 2007)

Deterministic model: Active sites with distinct freezing temperatures are randomly distributed over the IN surface (Connolly et al., 2009)

IMCA-ZINC: Immersion freezing





- Fit parameters are size independent, i.e. fits for different particle sizes are calculated with the same set of parameters

- Fit curves suggest that the stochastic model is less suitable to describe the data than the other models

- Only the models distributing active sites on the IN surface are able to capture different slopes

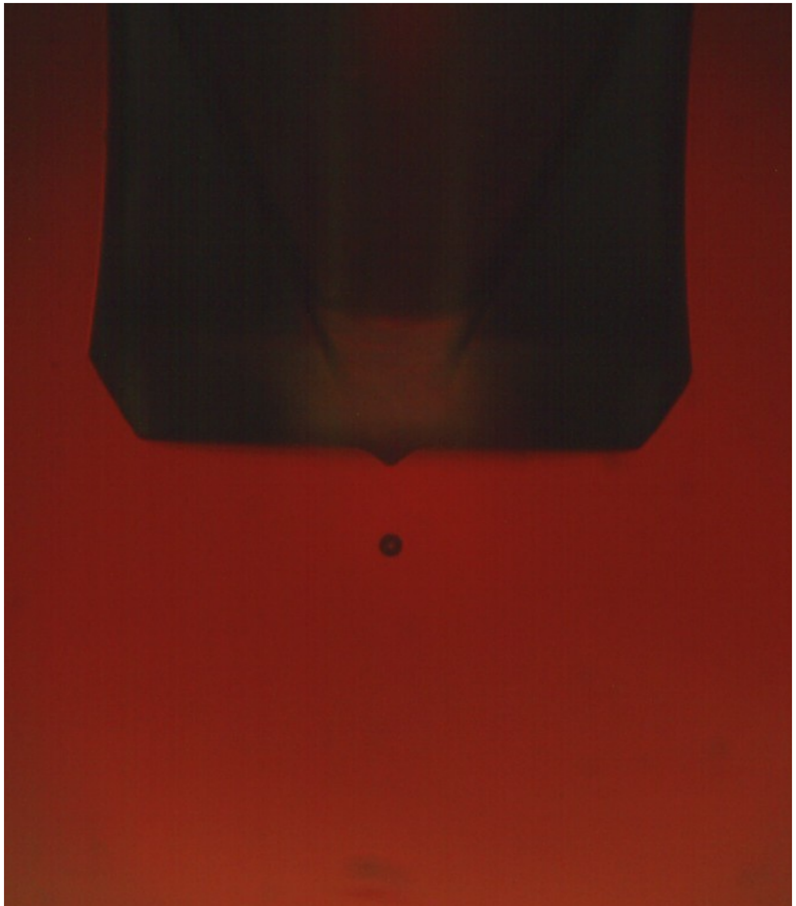
- Data with smaller uncertainty are required to assess the relative performance of the different models and to deduce physically relevant surface properties of kaolinite (e.g. surface density of active sites)

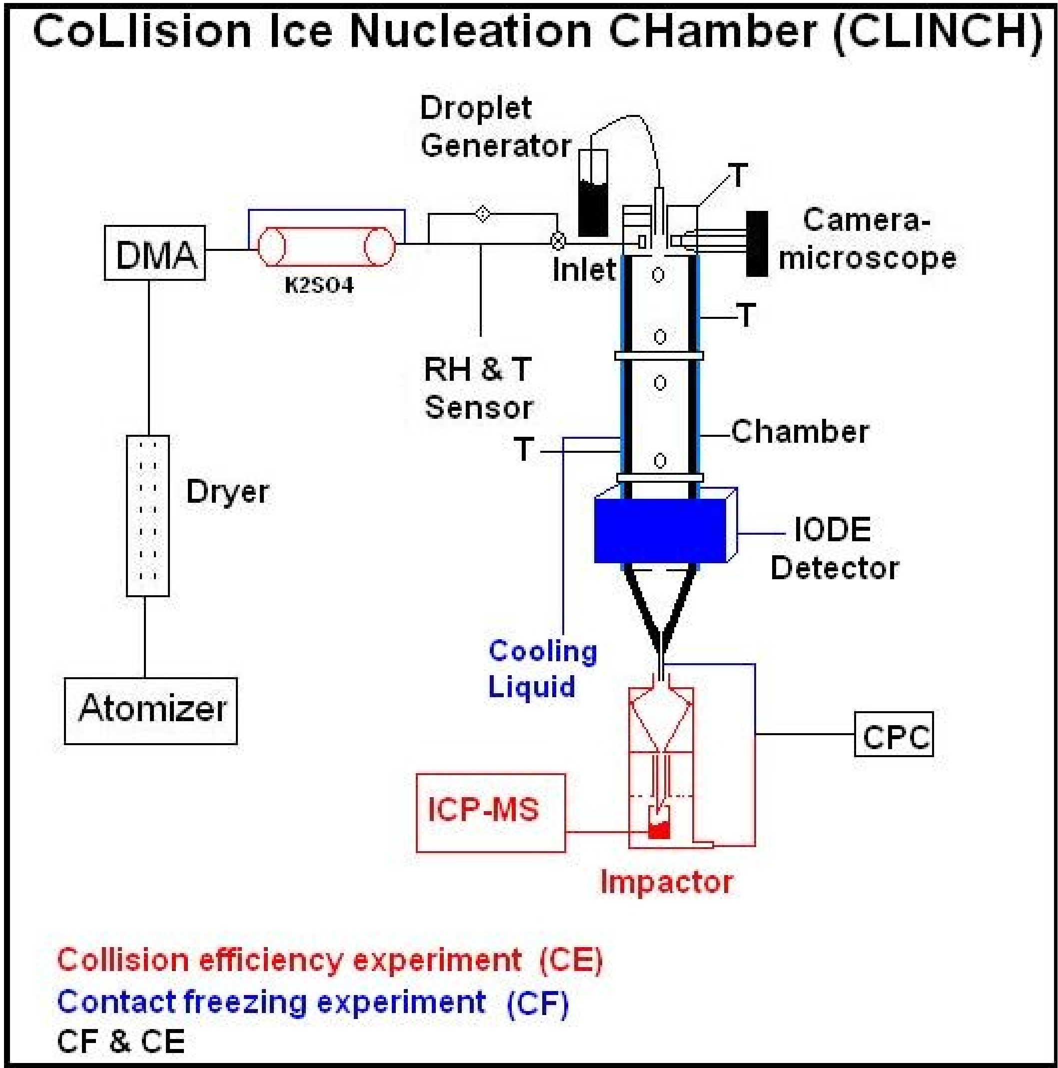
F. Lüönd, O. Stetzer, A. Welti and U. Lohmann: “Experimental study on the ice nucleation ability of size selected kaolinite particles in the immersion mode”, Journal Of Geophysical Research-Atmospheres (in press).

CLINCH: collision efficiencies

New collision efficiency data for submicron aerosols with cloud droplets

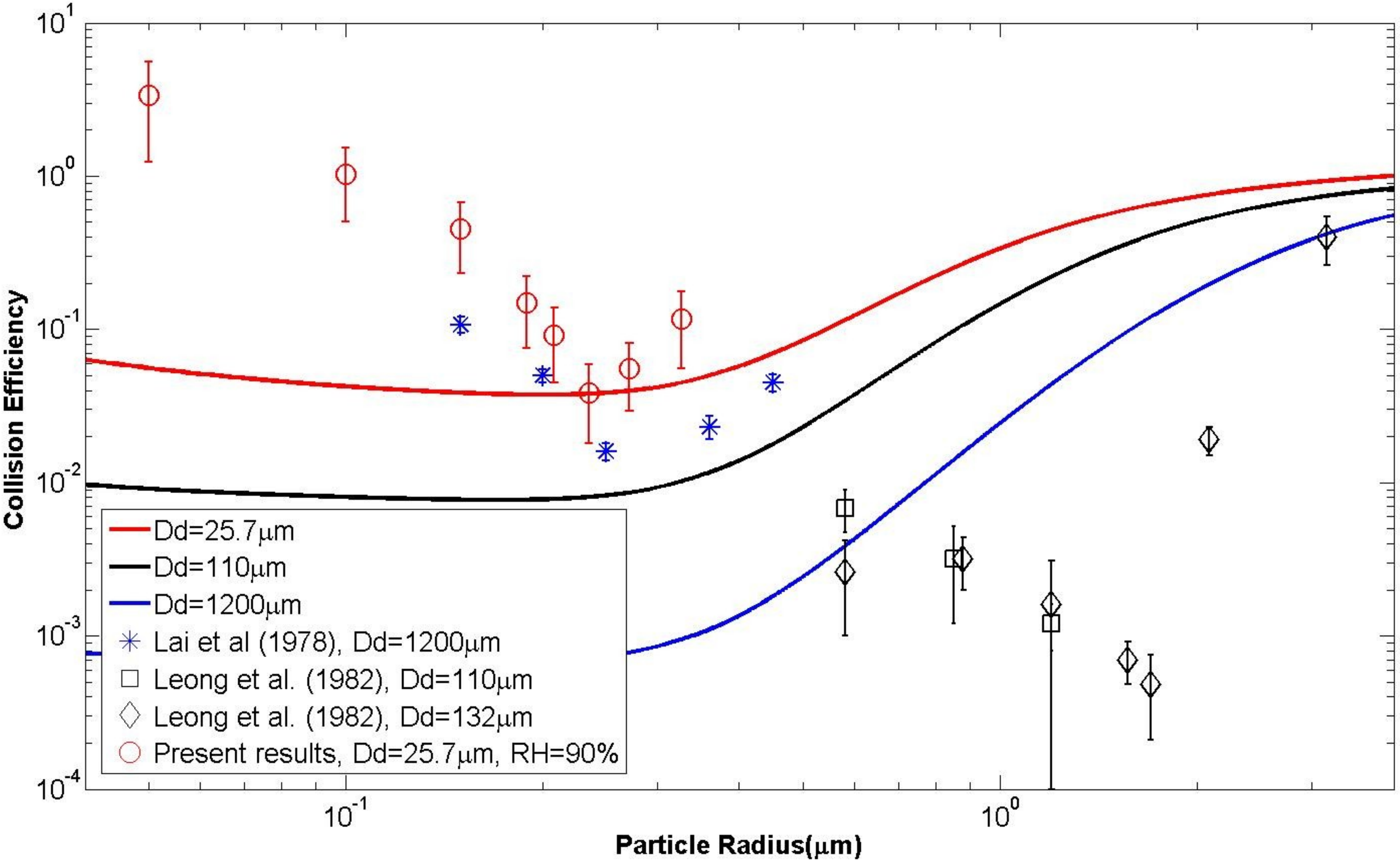
Next step: Concentration dependent freezing rates for collision freezing





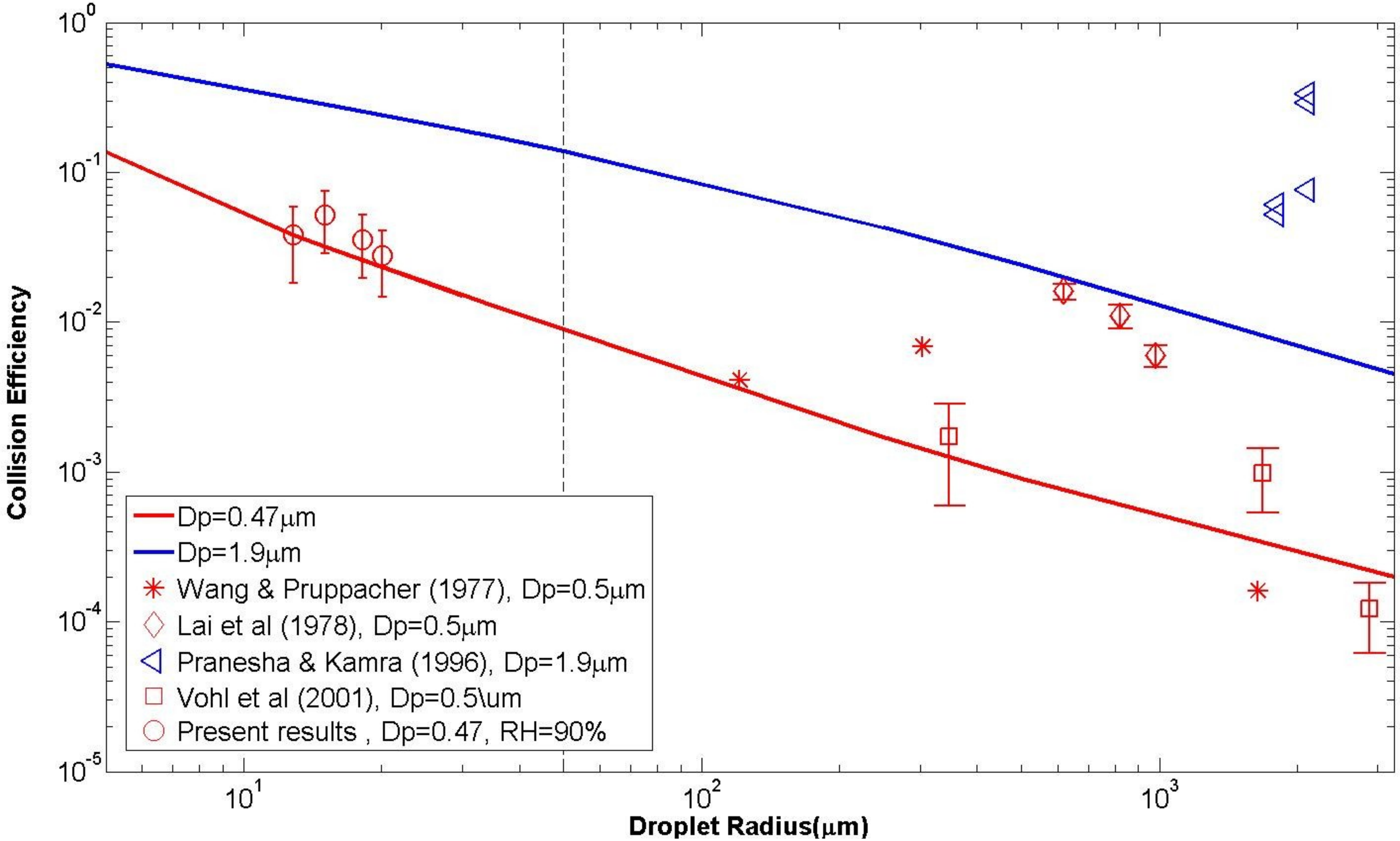
CLINCH: collision efficiencies

Collision efficiencies at a constant droplet size with varying Particle size. Experimental data vs. theory



CLINCH: collision efficiencies

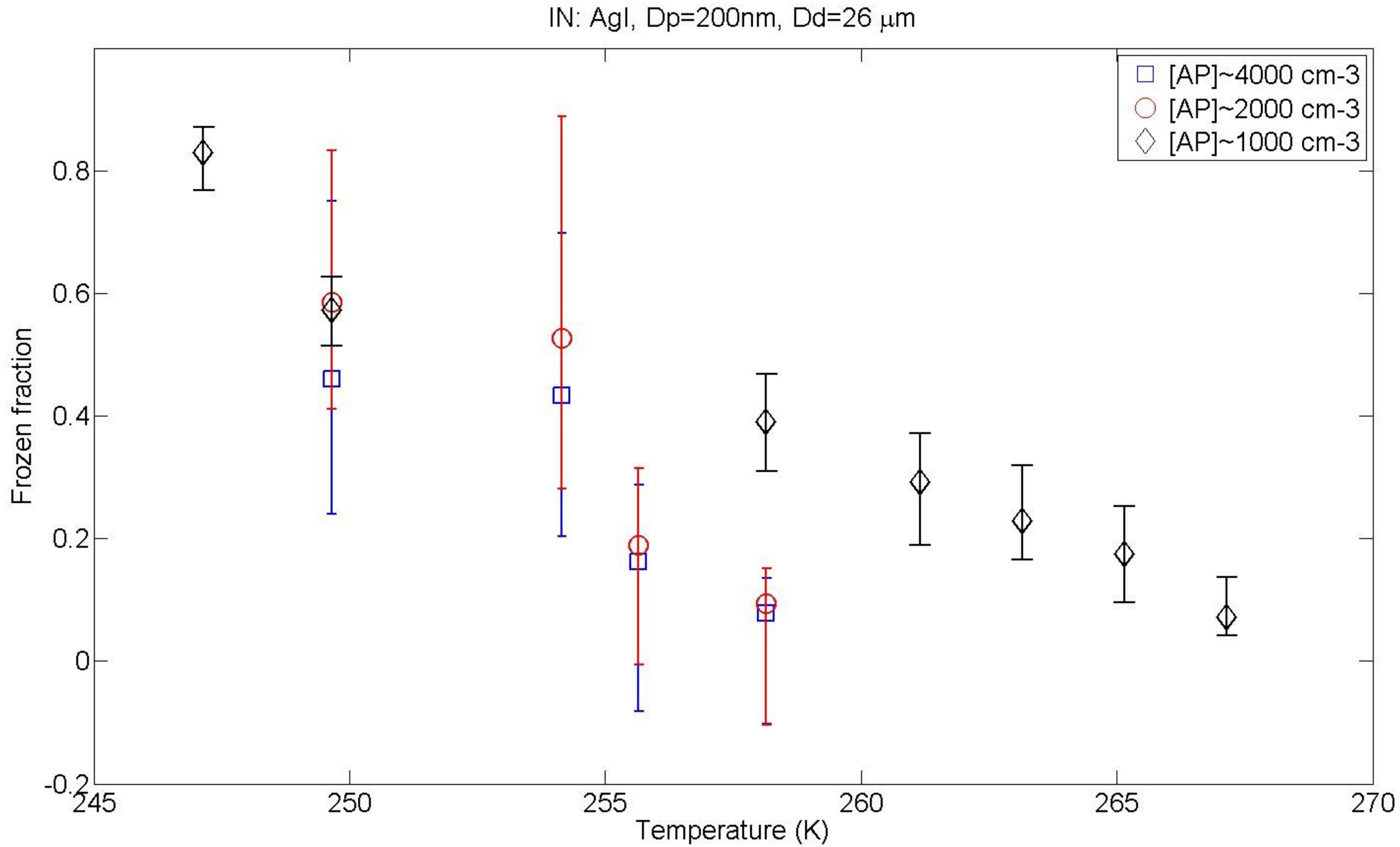
Collision efficiencies for constant particle size but with varying droplet size. Experimental data vs. theory



L. Ladino, O. Stetzer, B. Hattendorf, D. Günther and U. Lohmann: “Experimental study of collision eff ciencies of submicron aerosol particles with cloud drops in a new collision chamber.”, Journal of Atmospheric Sciences (draft in preparation).

CLINCH: collision efficiencies

First preliminary data on contact freezing with different number concentrations of aerosol particles:



Aerosol tank for ageing studies

Aerosol particles can be exposed to trace gases such as ozone and then be directed to various experiemts to monitor changes in CCN-, and IN-properties and chemical composition.