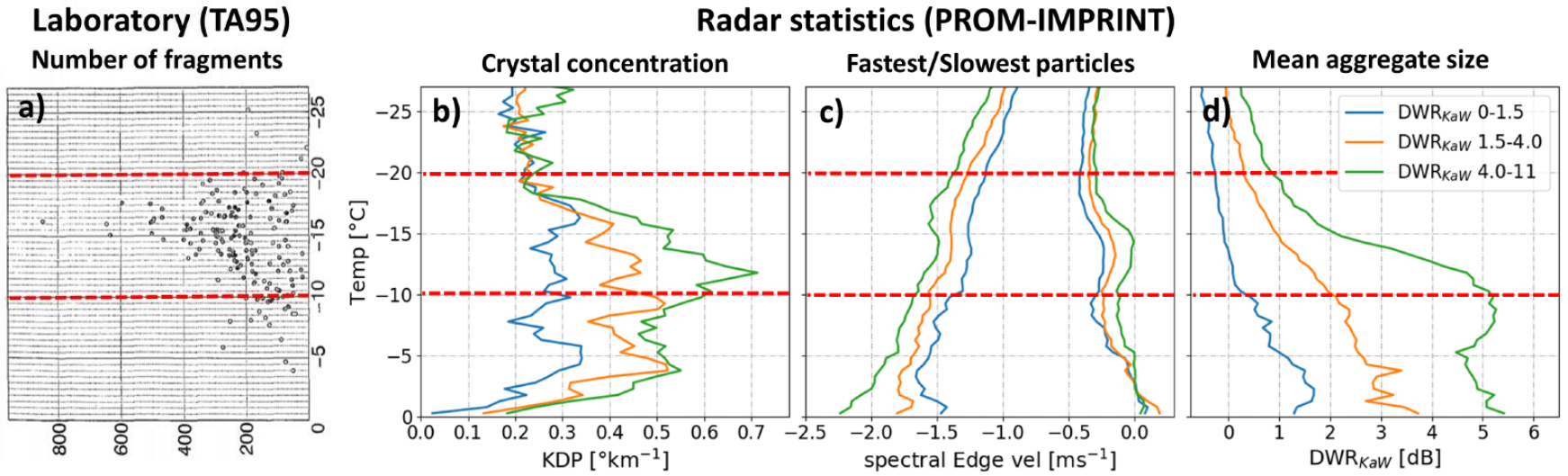
FRAGILE- EXPLORING THE ROLE OF FRAGMENTATION OF ICE PARTICLES BY LAB STUDY OF ICE-ICE COLLISIONS

Discrepancy in INP and ICNC



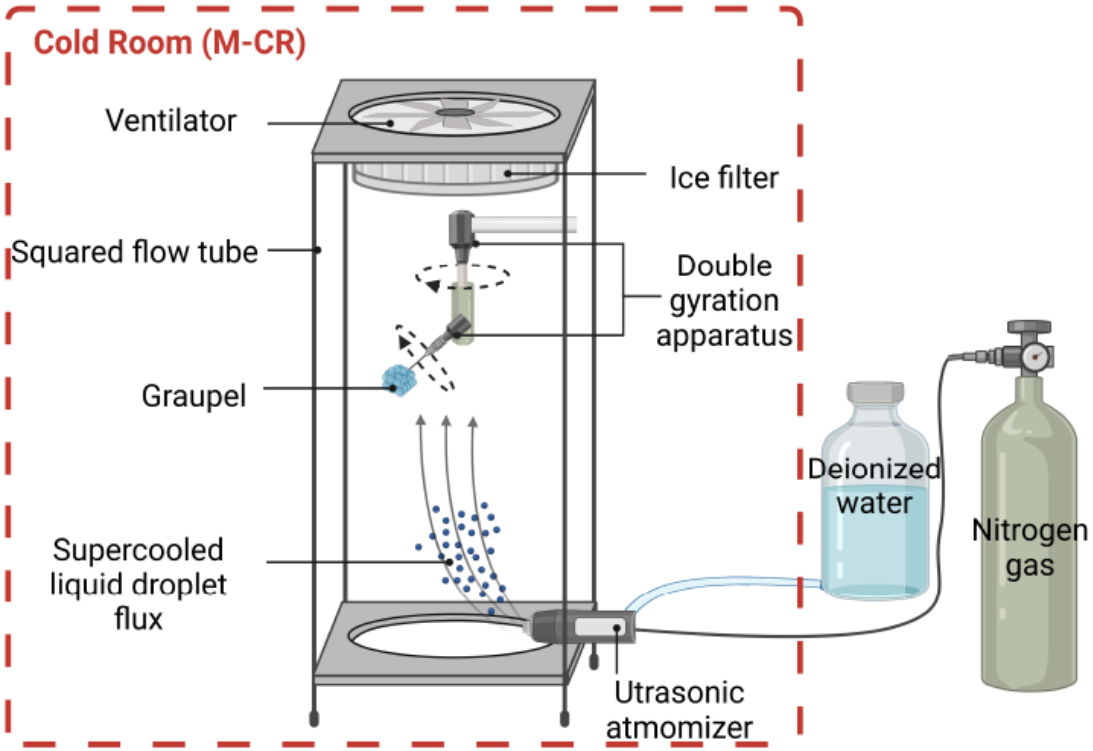
MAIN GOAL: EXPERIMENTAL STUDY OF FRAGMENTATION DUE TO COLLISION

- Collision induced fragmentation in walk-in M-CR(1st phase)
- Collision induced fragmentation in M-WT
- Fragmentation w/o collision

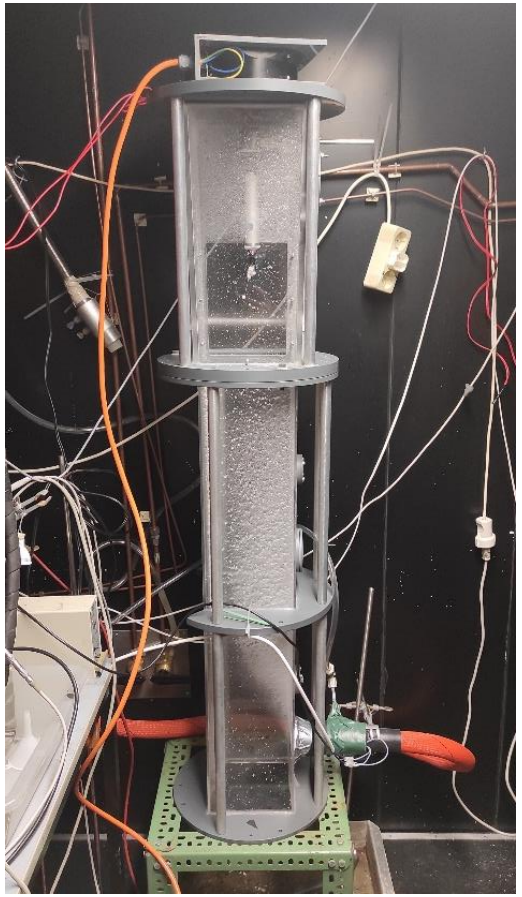
→

- Generation of graupel
- Generation of dendritic ice crystals
- Growing dendrites on graupel surface
- Graupel-graupel with dendrite collision
- Graupel-graupel without dendrite collision (reference case)

GRAUPEL PRODUCTION (GEORG)



simulating the rotation and tumbling motion of a freely falling graupel

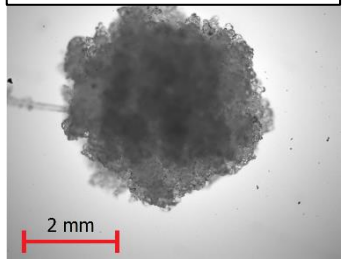


Graupel starter

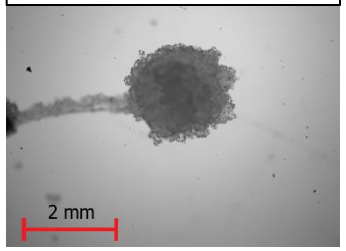
Epoxy sphere embryo and thin wire

Cannula

Large 4 mm graupel



Small 2 mm graupel



SETUP IMPROVEMENTS – LWC GEORG CHARACTERIZATION

- **To quantify lwc at the graupel site**

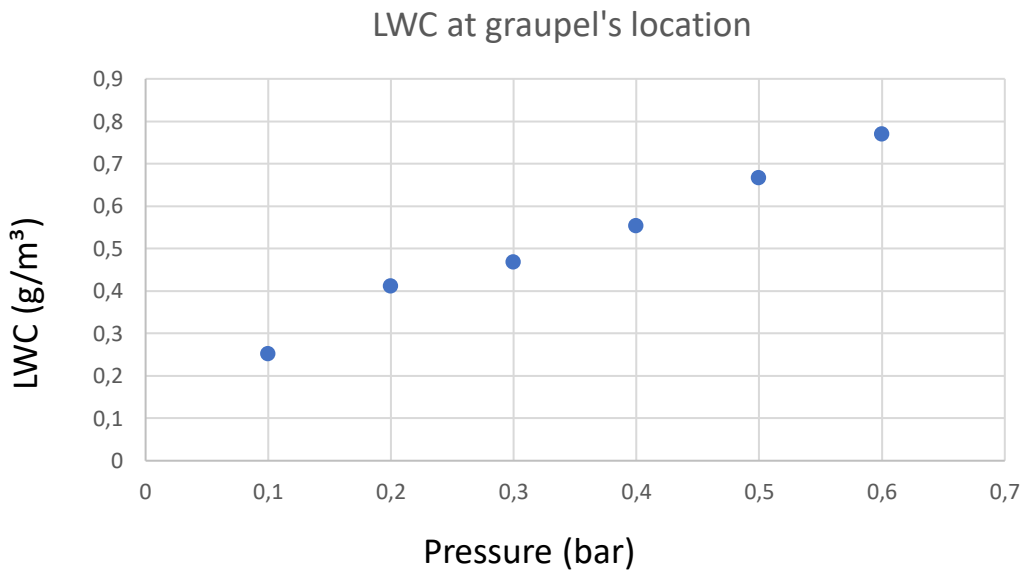
- **Changing quantities that influence graupel characteristics:**

Temperature

Liquid water content

Rotation speed

Important for graupel's density



Pressure (bar)	Average lwc (g/m³)
0.1	0.251
0.2	0.411
0.3	0.468
0.4	0.553
0.5	0.667
0.6	0.769

AQUARIUM SETUP

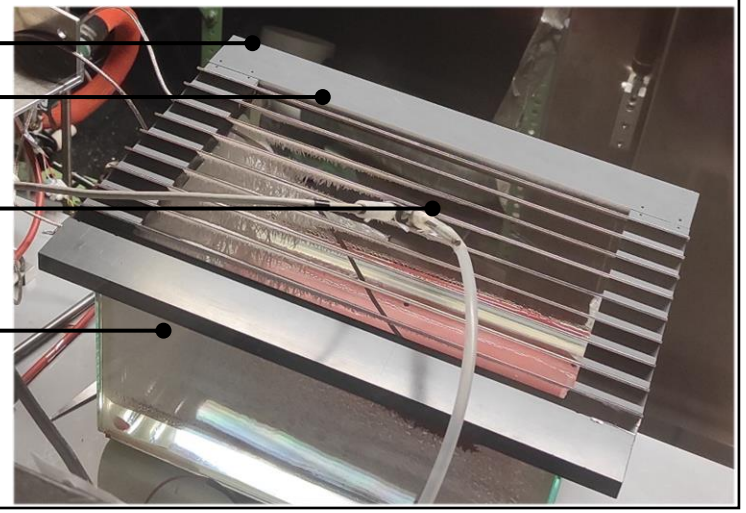
- **Challenge**

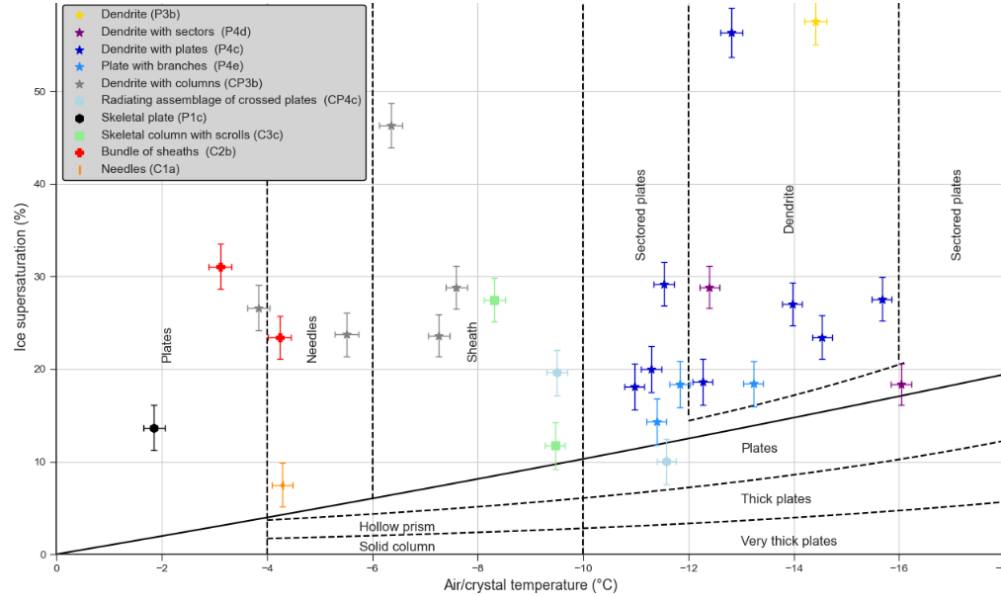
  Reliable & controllable closed system (constant supersaturation, humidity set up)

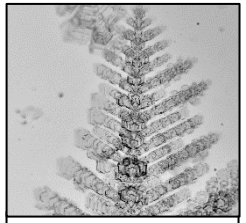
  Mixing of warm moist air from aquarium and cold dry air from cold

  ondensing on

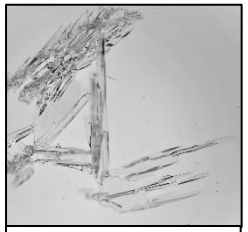
Glass aquarium setup



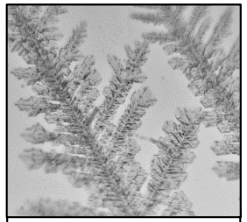




Plates with dendrites



Needles



Dendrite with sectors

Crystals characterized and compared to Kobayashi's experiments (1961)

MIXING CHAMBER

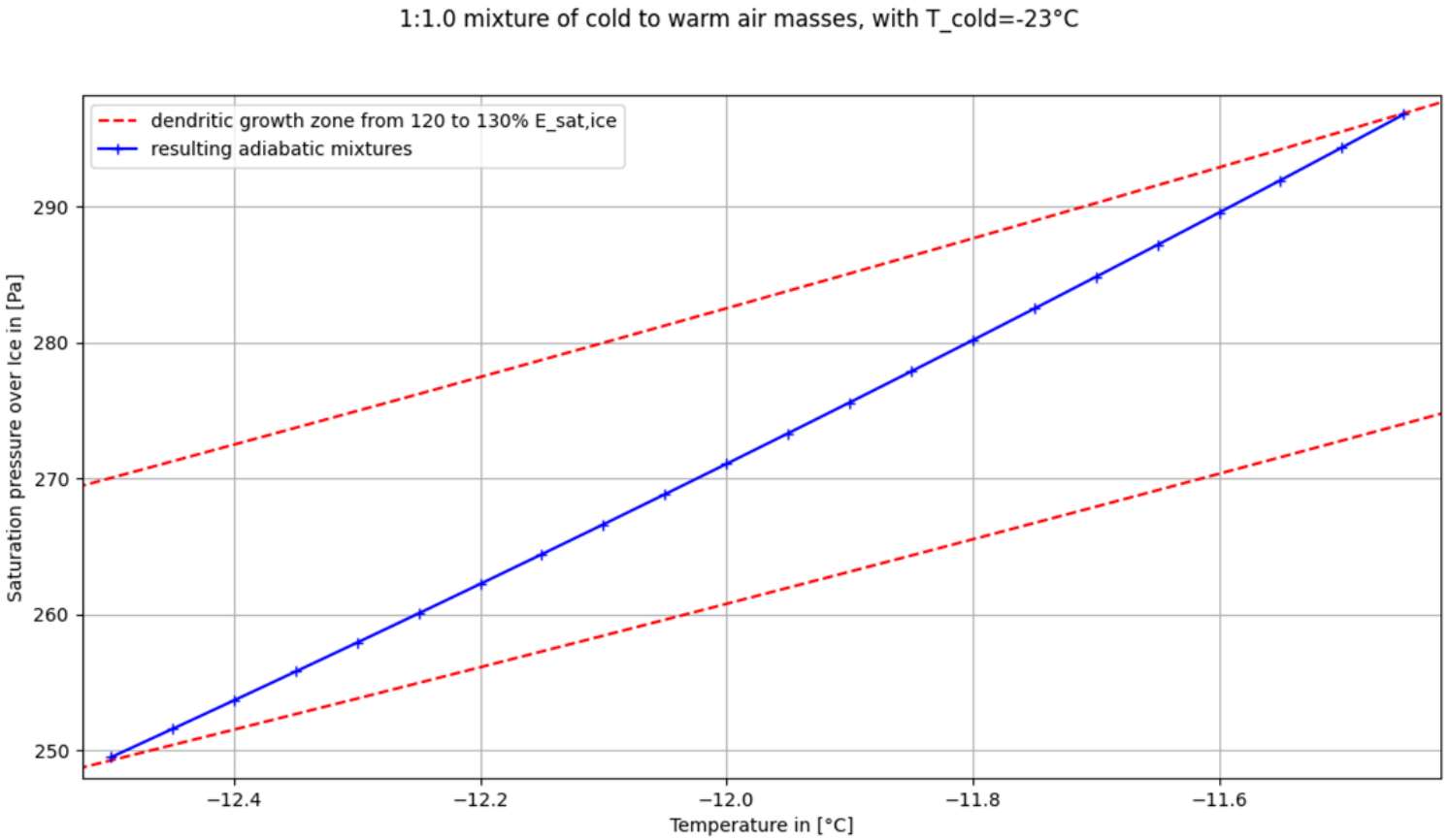
- Basic idea: mix cold, dry and “warm”, humid air inside a chamber

- Try to reach typical values for Dendritic Growth Layer (DGL) with the resulting mixture

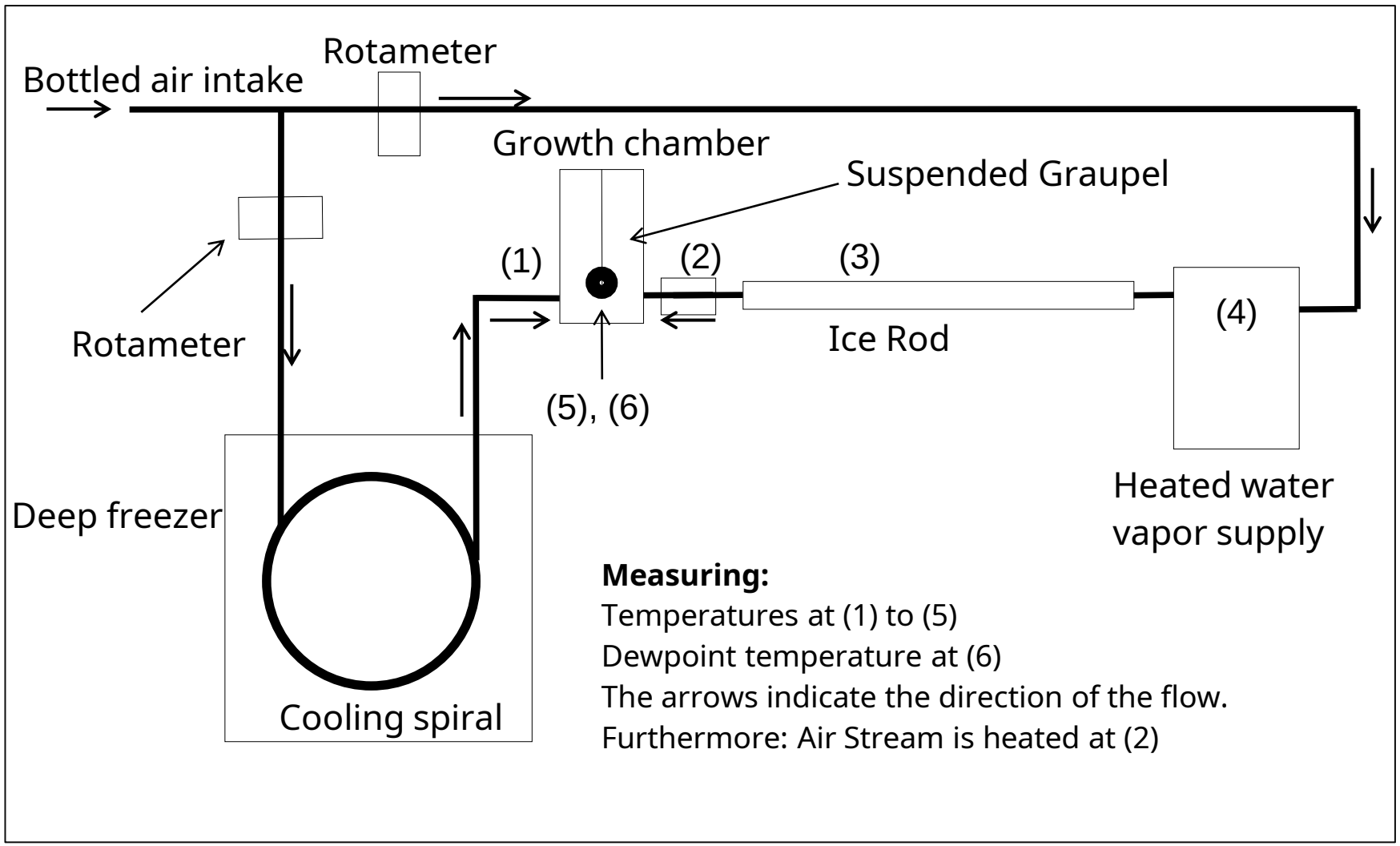
- Control the mixture by manipulating:

  Flow rates of warm and cold air streams

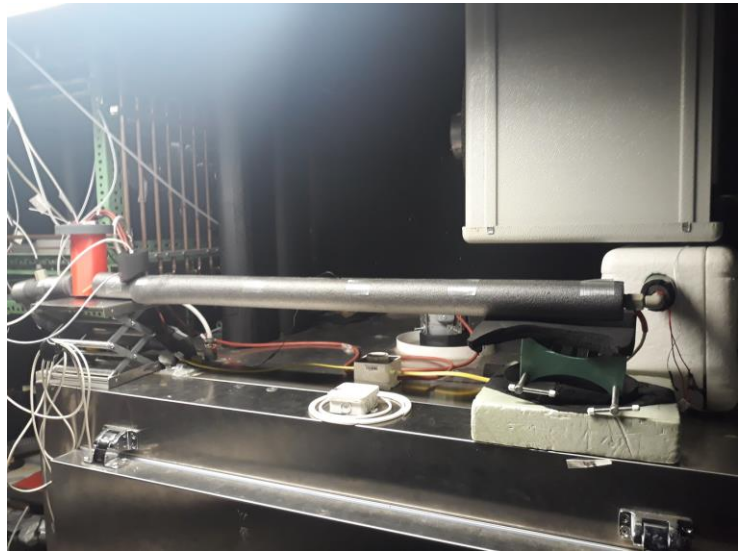
  Temperatures of the air streams



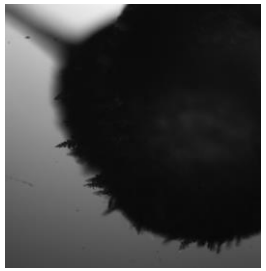
MIXING CHAMBER



Measuring:
Temperatures at (1) to (5)
Dewpoint temperature at (6)
The arrows indicate the direction of the flow.
Furthermore: Air Stream is heated at (2)



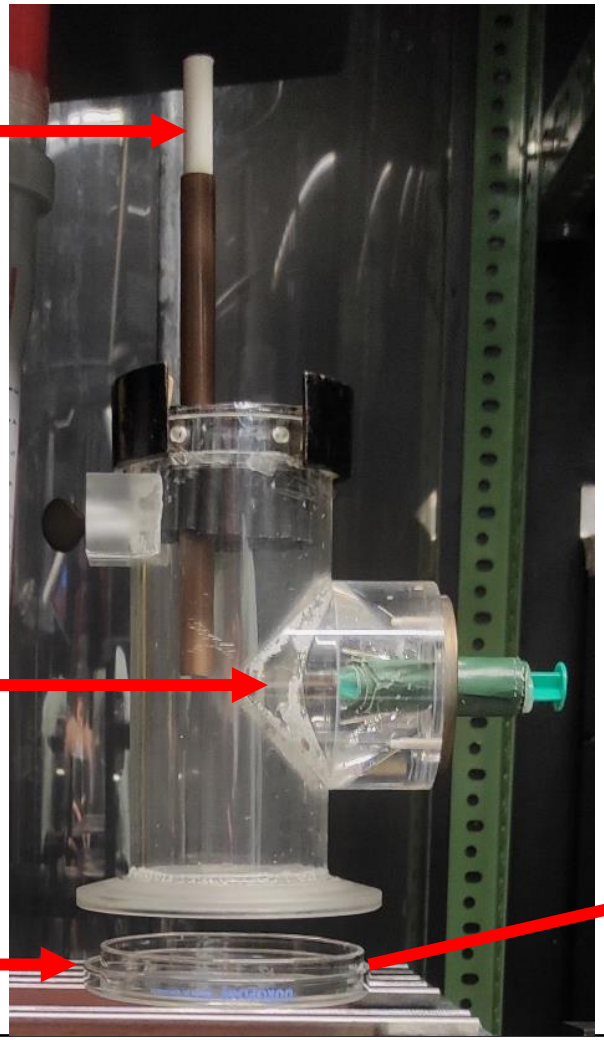
- First success in growing ice crystals
- Different habits can be generated



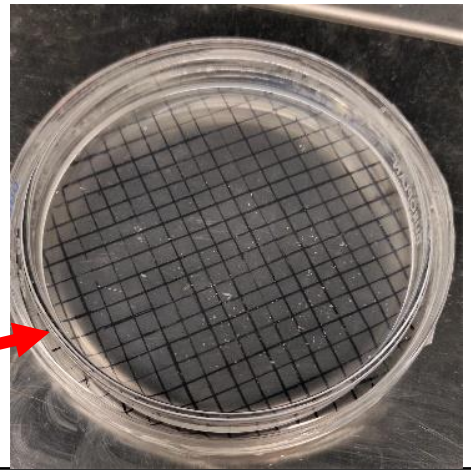
Dendrites & Fern-like

GRAUPEL-GRAUPEL COLLISION

Collision setup



Collision tube upgraded!

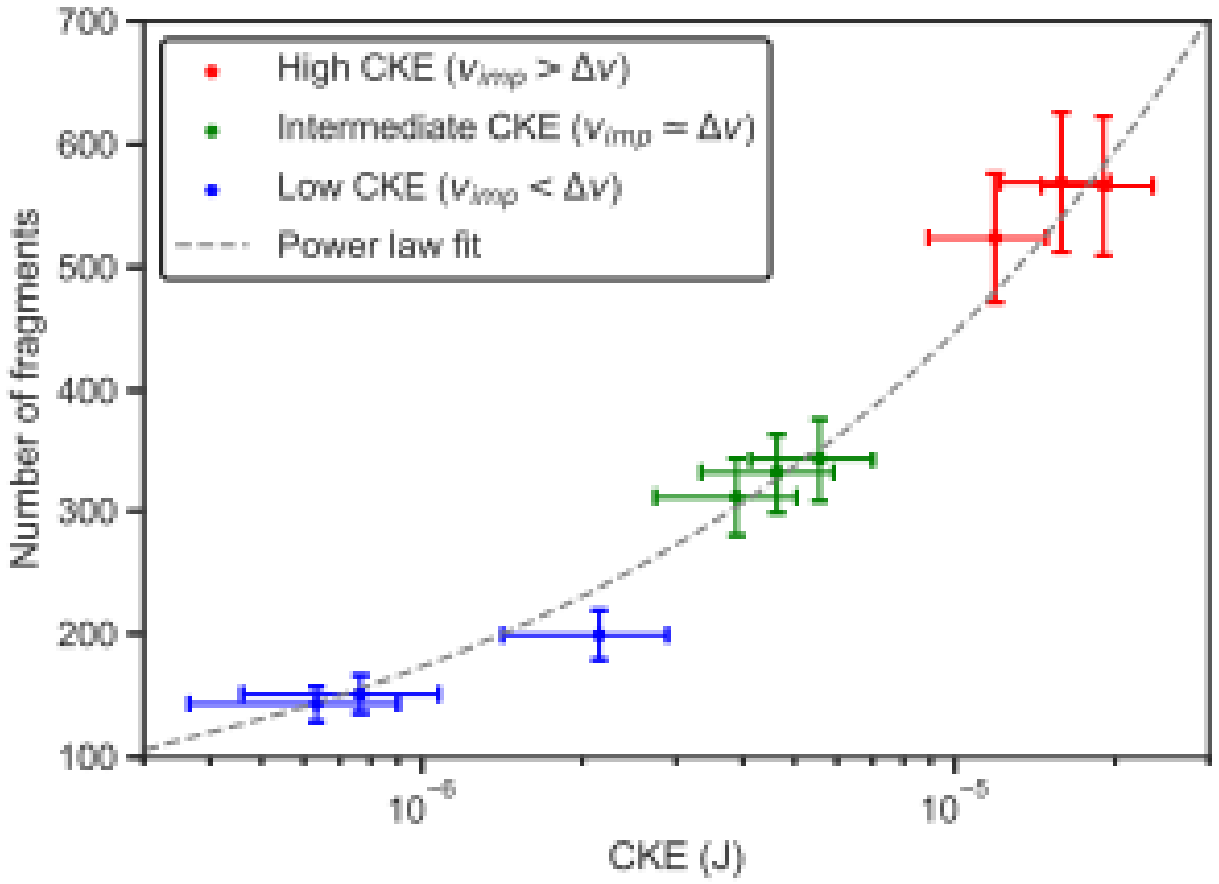


- Microscope pictures
- Data analysis

High speed camera video

GRAUPEL-GRAUPEL COLLISION RESULTS

- **Paper** in review process: https://egusphere.copernicus.org/preprints/2023/egusphere-2023-



Number of fragments produced by graupel-graupel collisions

Collision kinetic energy (CKE)

$$\mathrm{CKE} = \frac{1}{2}\frac{m_1 m_2}{m_1 + m_2}(v_1 - v_2)^2$$

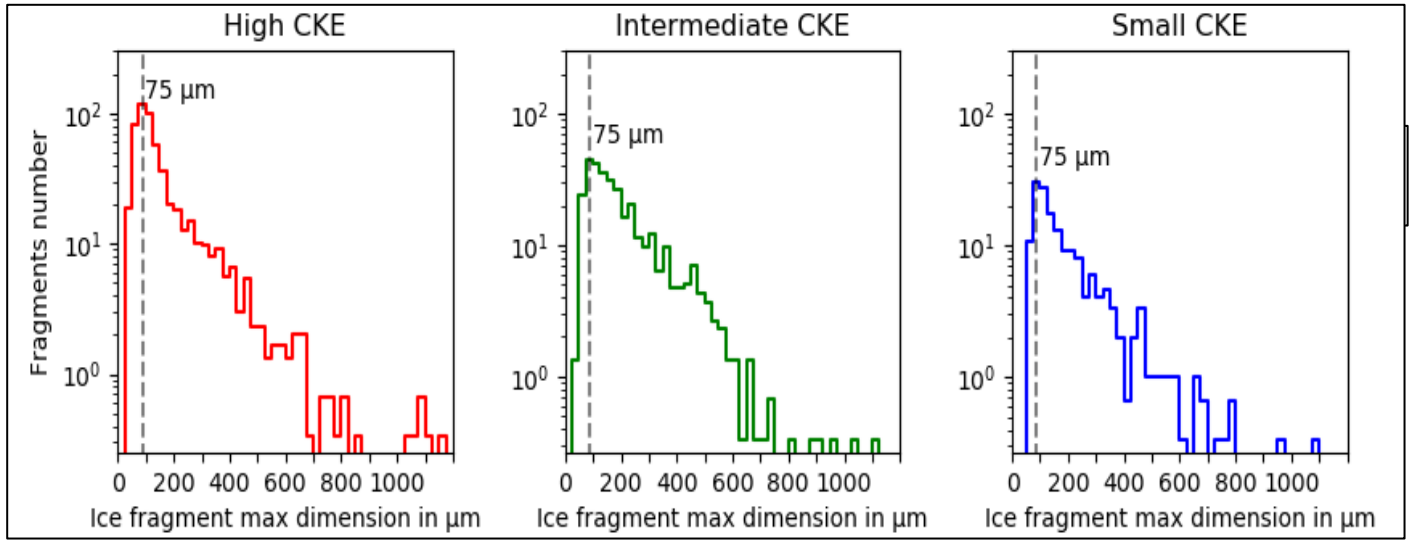
From the collision theoritical formulation of Phillips et al. (2017)

$$\mathrm{N} = 5.14 \times 10^4 \times CKE^{0.41}$$

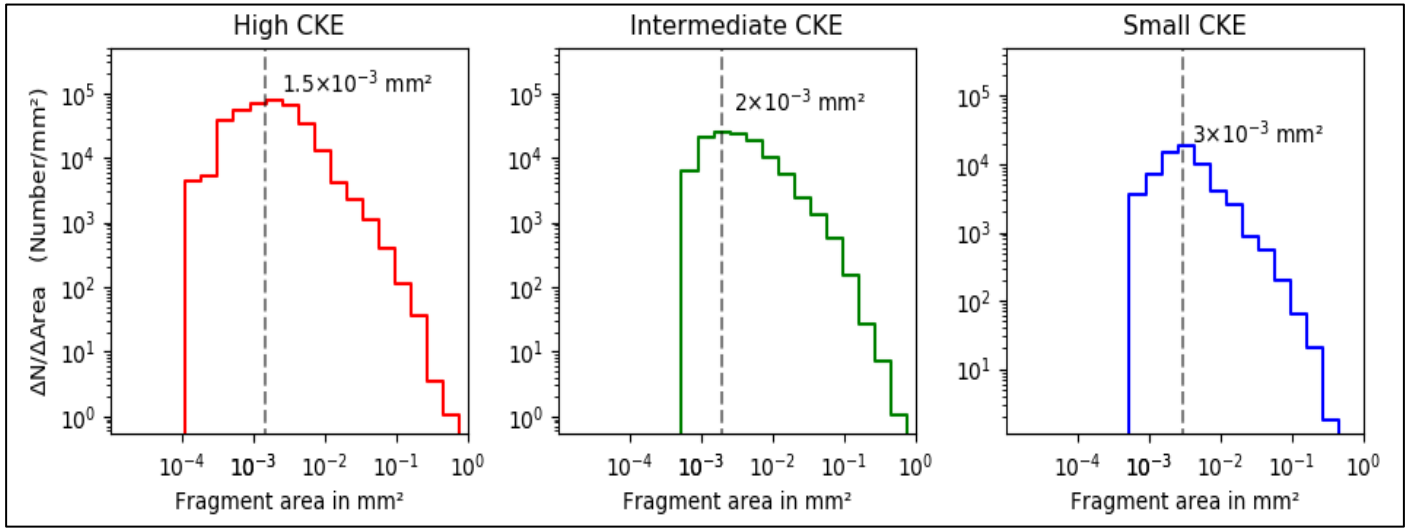
Philip's parametrization is based on Takahashi 1995 lab data

Comment: Contact Area parameter is missing

FRAGMENTS DISTRIBUTION CALCULATED FROM ICE CRYSTAL IMAGE ANALYSIS



- Same distribution shape
- All having a maximum of fragment at 75 µm
- Similar to Takahashi (1993) observation of 60/100 µm crystals
- Distribution shape is independent of CKE



- Distribution peak depends on CKE
- Minimum area depends on CKE
- Same distribution shape
- Caution - detection of ice fragments with the microscope is estimated to be around 20 µm for crystal max dimension and around 10−4 mm2 for crystal area
- decrease of the minimum fragment area - work done to break crystals is proportional to their cross-sectional area (Phillips et al., 2017)

FUTURE STEPS/GOALS

- Characterization of GEORG
- Mixing chamber (at difft. T & supersaturation)
- Graupel-graupel without dendrite collisions (initial condition)
- Graupel-graupel with dendrites collision
- Graupel-snowflake collision (also done by Pierre before)
- All of the above to be repeated at different temperatures between -15°C & 20°C (DGL)

THANK YOU!

References

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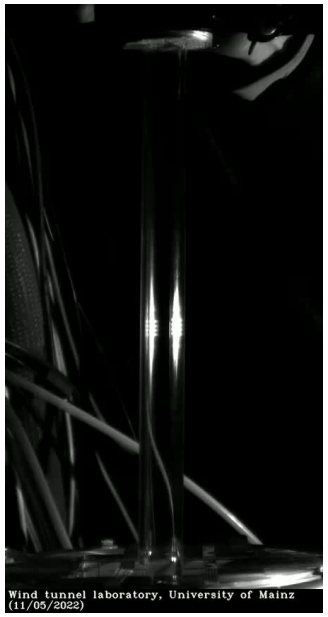
- Phillips, V. T. J., Yano, J.-I., & Khain, A. (2017). Ice Multiplication by Breakup in Ice–Ice Collisions. Part I: Theoretical Formulation. Journal of the Atmospheric Sciences,

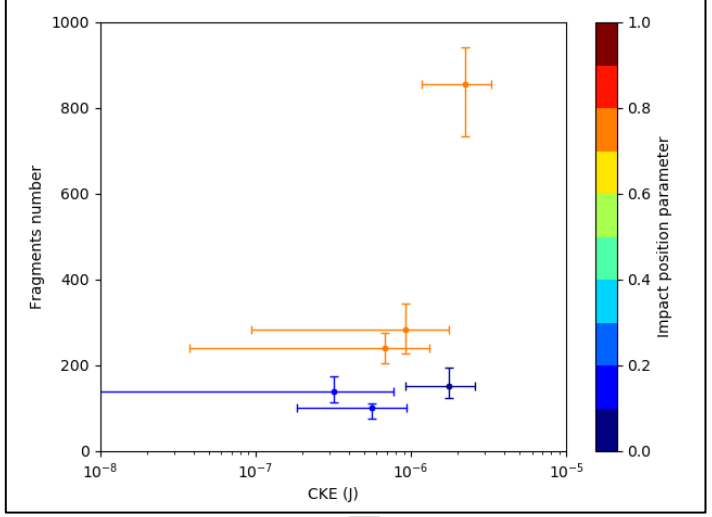
Graupel-snowflake collision

Side collision

Central collision



Number of fragments produced
by **graupel-snowflake** collision



- Number of fragments depends on { **CKE**, **Impact position**