University of Hertfordshire

Contributions to
WP L1 (AIDA) and L2 (LACIS)

apologies!

Contributions to VI-ACI from UH

- **Probes for particle characterization (size, shape).**
- **Light scattering computations for ice particles.**

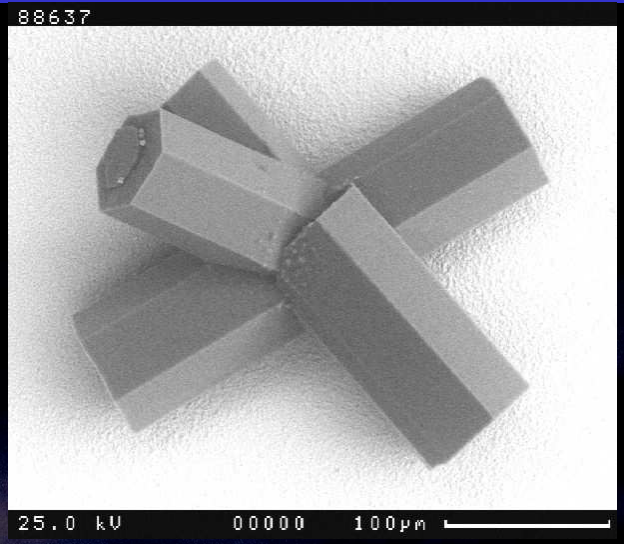
Problem: limited “shape resolution” of imaging cloud probes

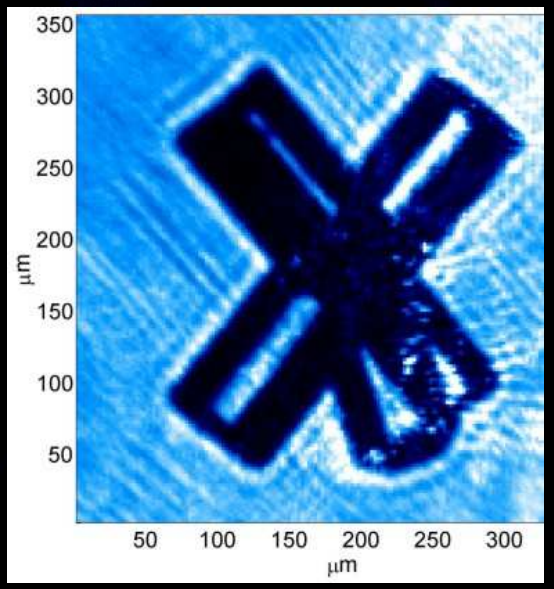
Examples recorded using the Manchester CPI and UH ice analogues

SEM and optical microscopy **Cloud Particle Imager**

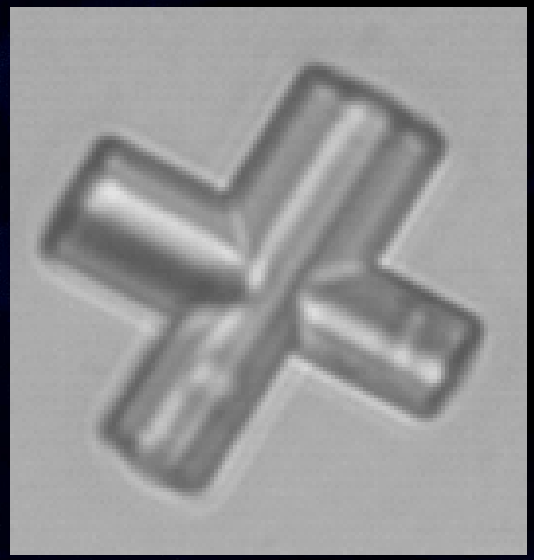
Size

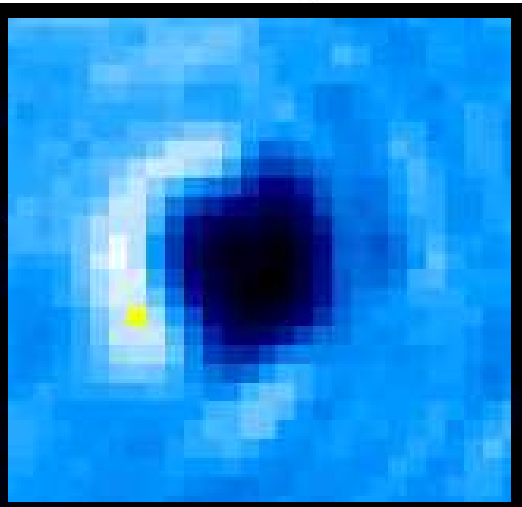
189 μm





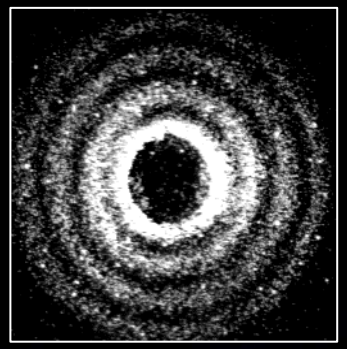
22 μm



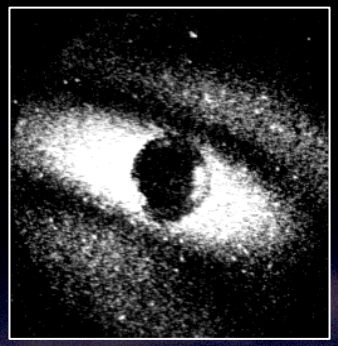


Solution: 2D scattering patterns

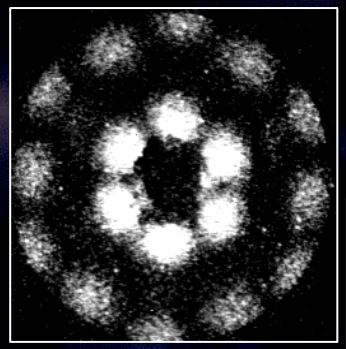
- Example patterns measured from particles about 2 – 20 μm in size



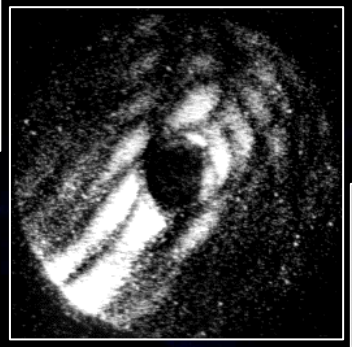
droplet



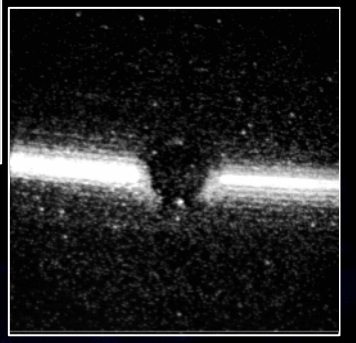
ellipsoid



salt crystal



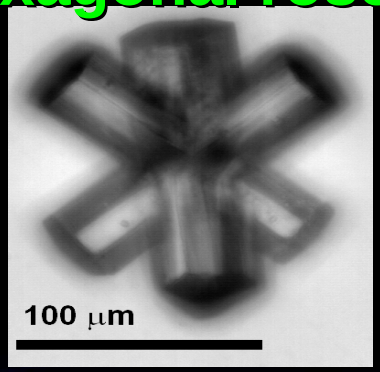
flat grain

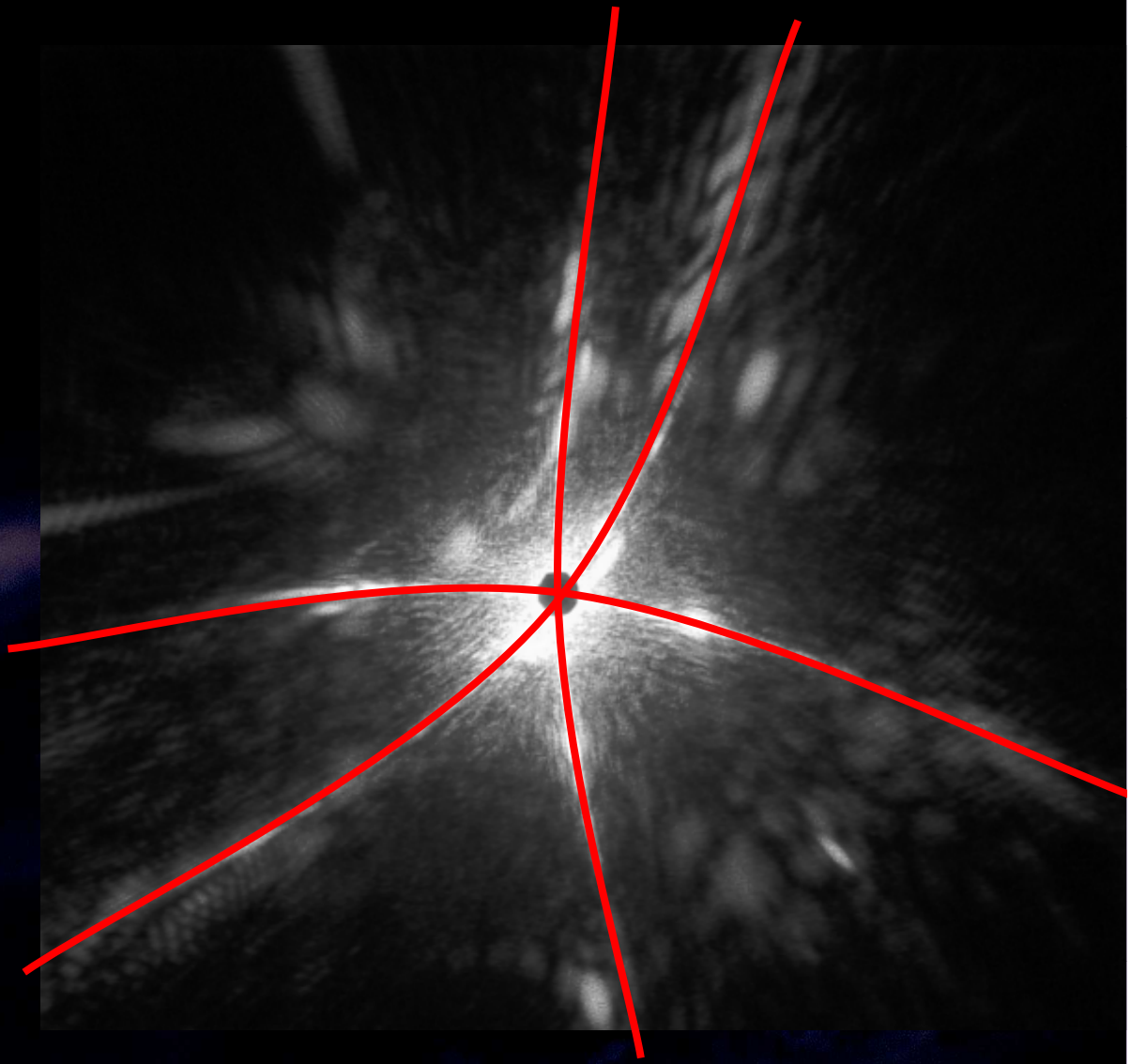


fibre

2D scattering patterns: ice-analogues

Hexagonal rosette

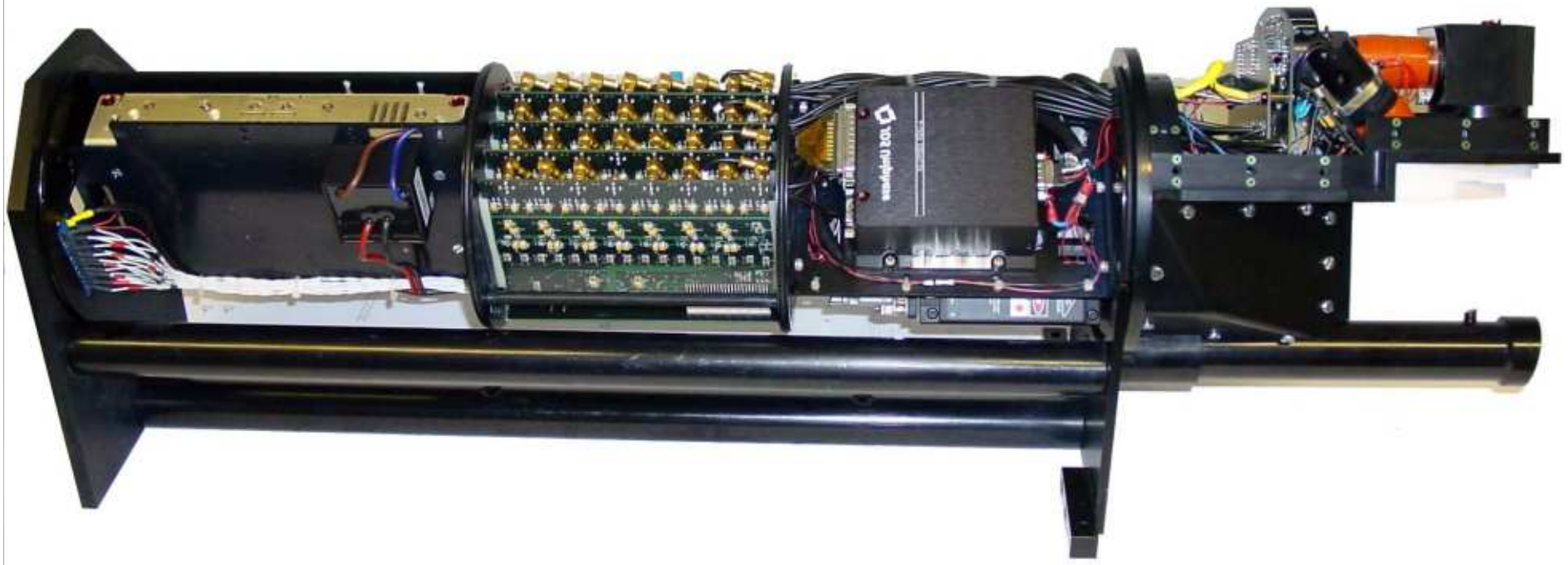




Each hexagonal column contributes a separate arc (conic section)

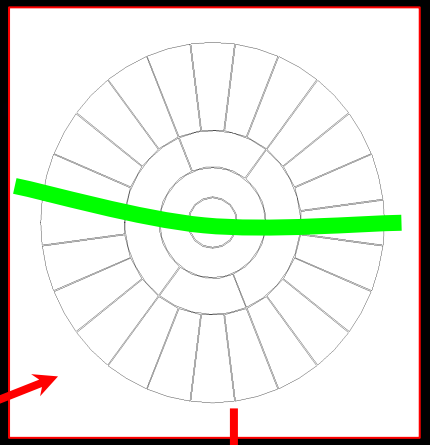
Small Ice Detector (SID-2) - cloud particle measurement

- measures "spatial" scattering patterns from single particles

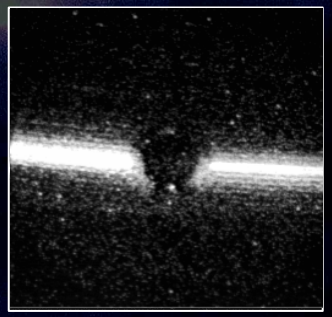


SID2 – scattering patterns

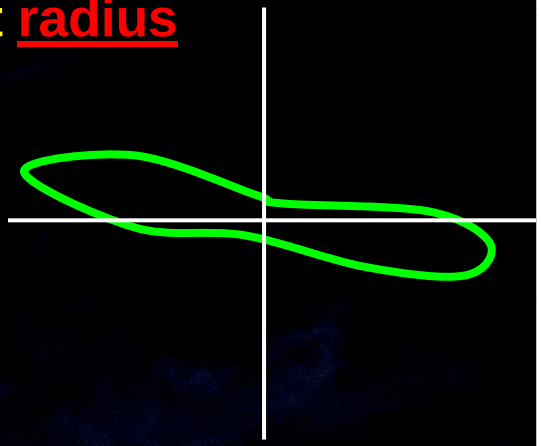
Scattering patterns recorded using custom detector array (24 + 3 elements)



Polar plots: amount of light falling on detector element → plot radius



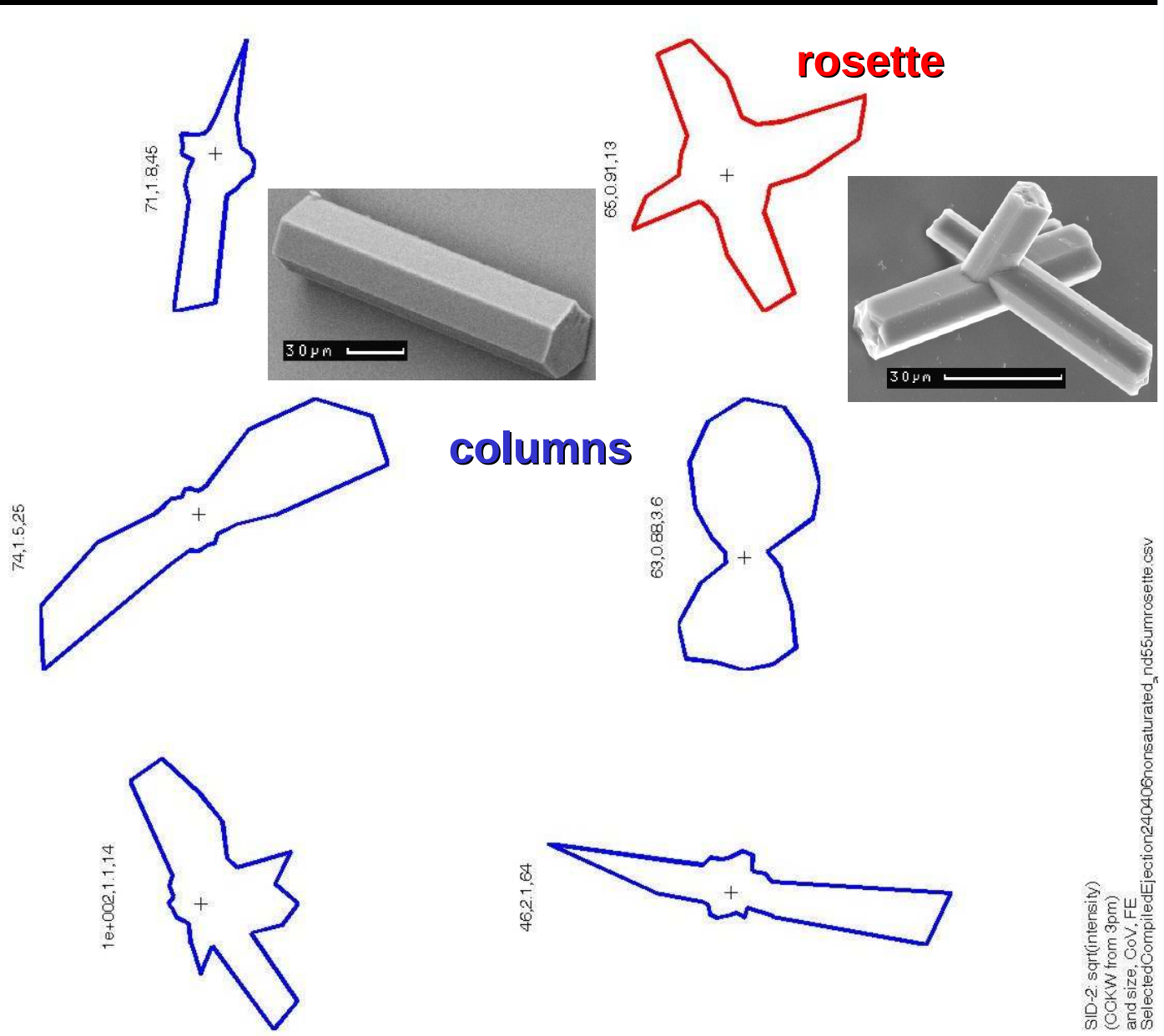
2D pattern from elongated particle



"Azimuthal scattering pattern"

SID2 - example scattering patterns from ice analogues

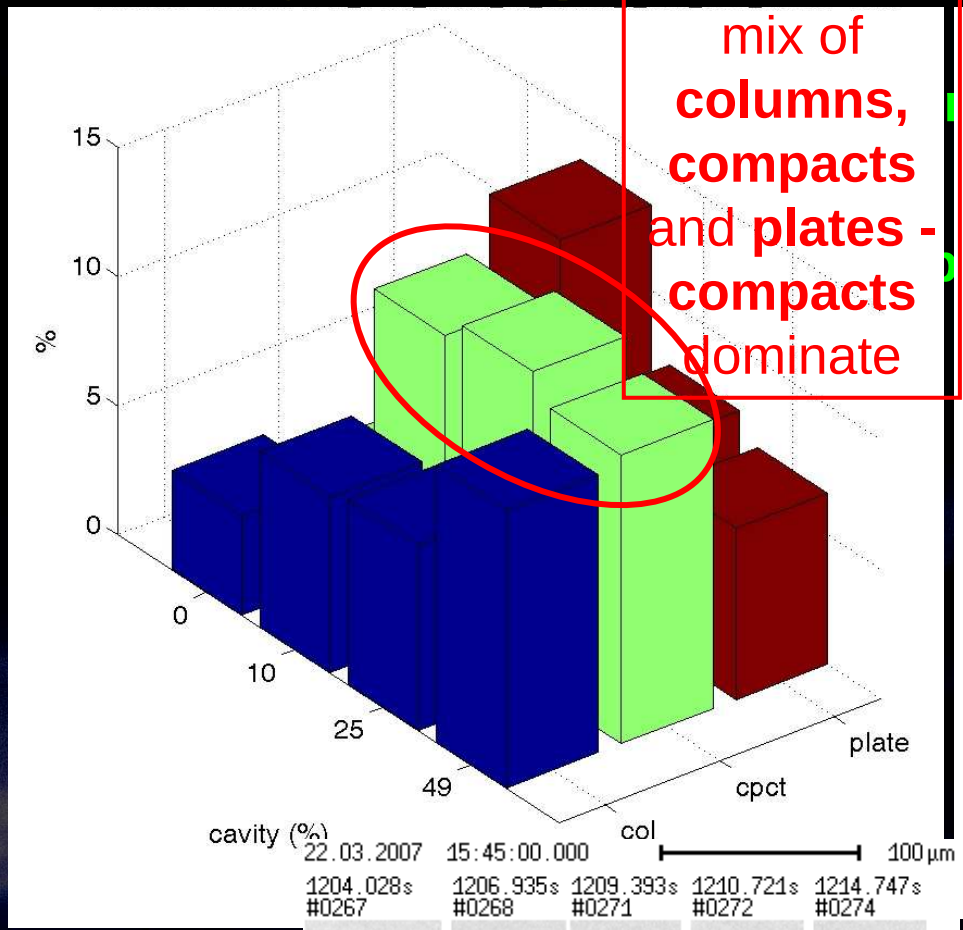
Azimuthal patterns:
amount of light falling on detector element
→ plot radius



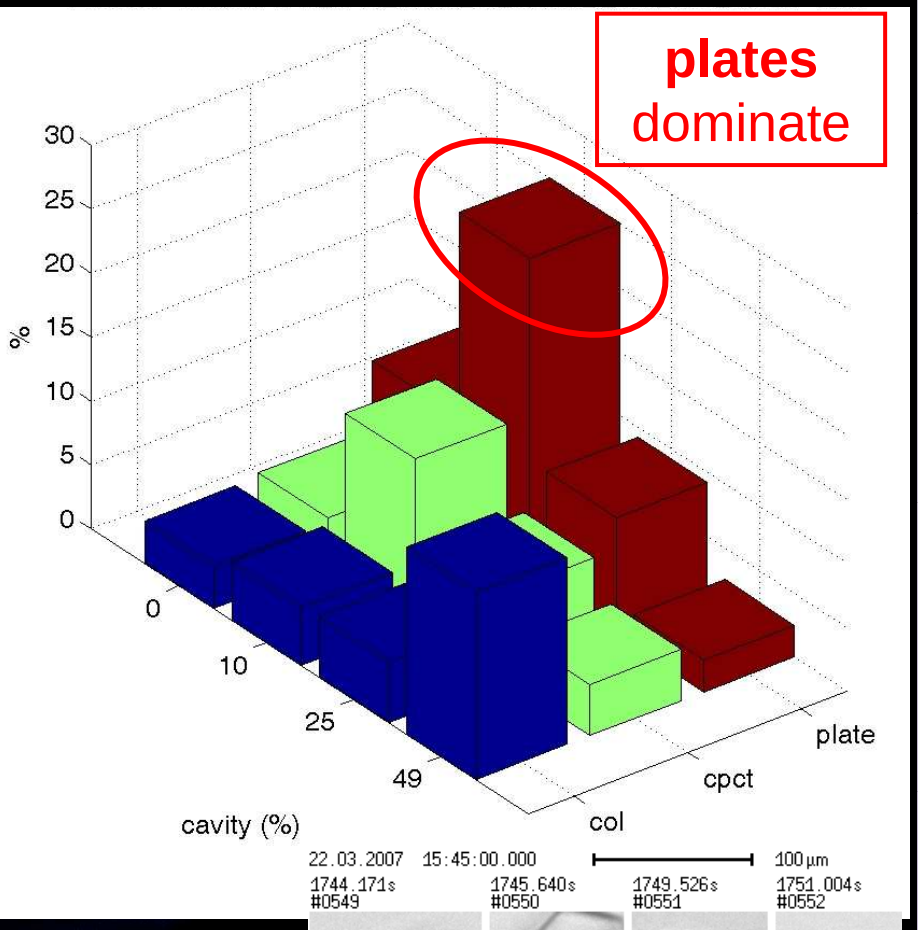
The azimuthal patterns carry information about particle shape

SID2 - crystal shape classification

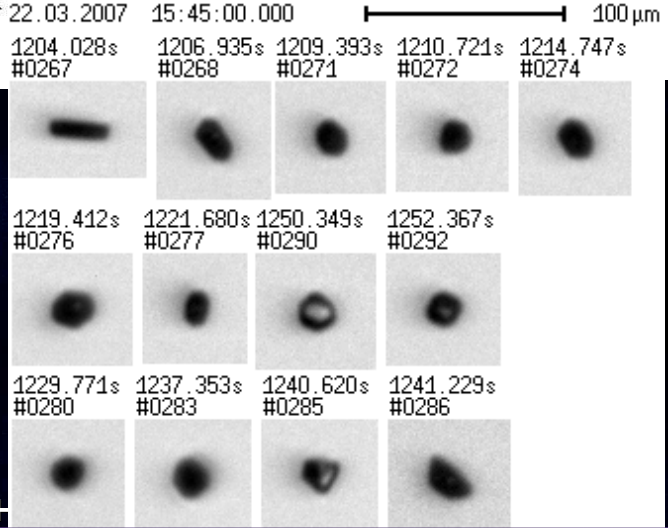
HALO-01 experiment 18



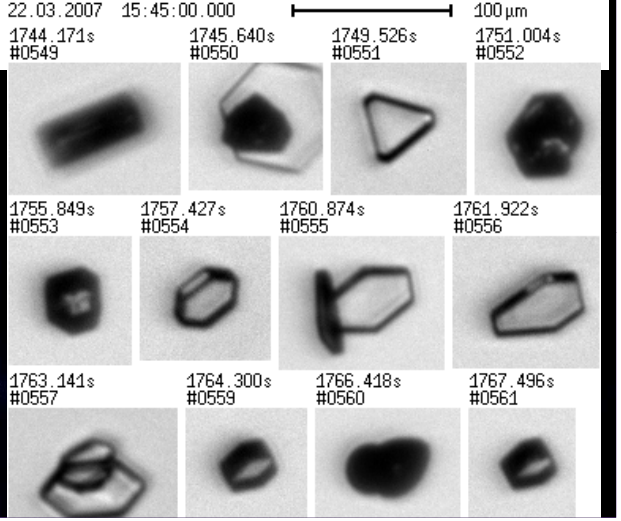
mix of **columns, compacts** and **plates - compacts** dominate



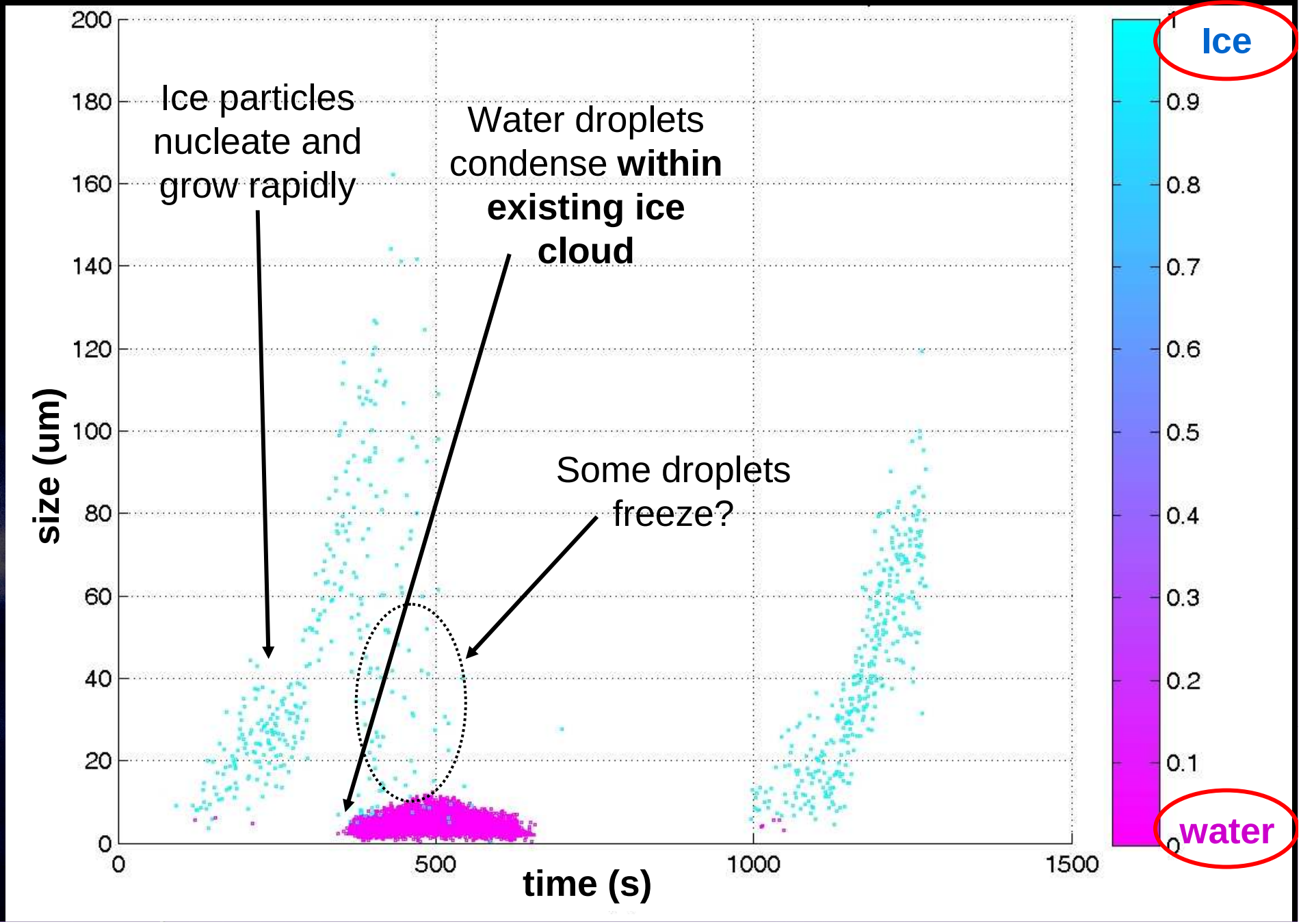
plates dominate



AIDA PHIPS images



SID2 Ice/water classification - HALO-1 26



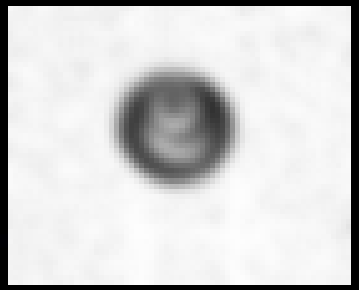
SID-3

- Measures high-resolution 2D patterns
- Because of this, much detail of particle geometry can be retrieved...

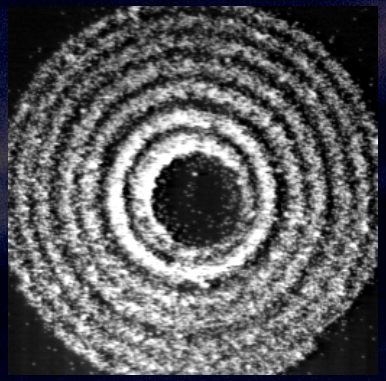
SID3 2D patterns - inhomogeneous particles

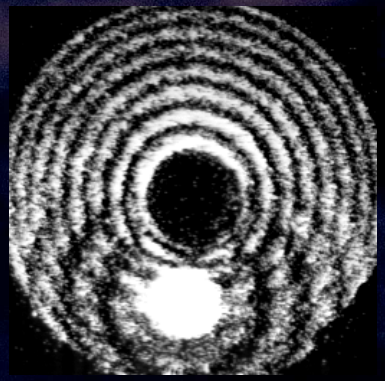
20 μm droplet

... with inclusion



inclusion can barely be seen in image



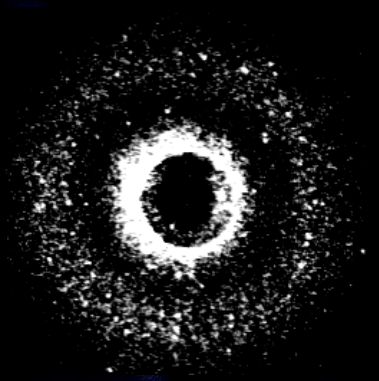


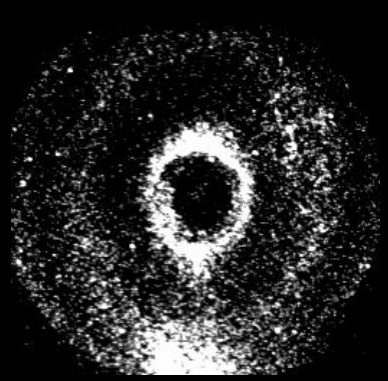
but 2D pattern is significantly altered

3 μm droplet

... with sub-μm inclusion

even the entire droplet cannot be resolved in image

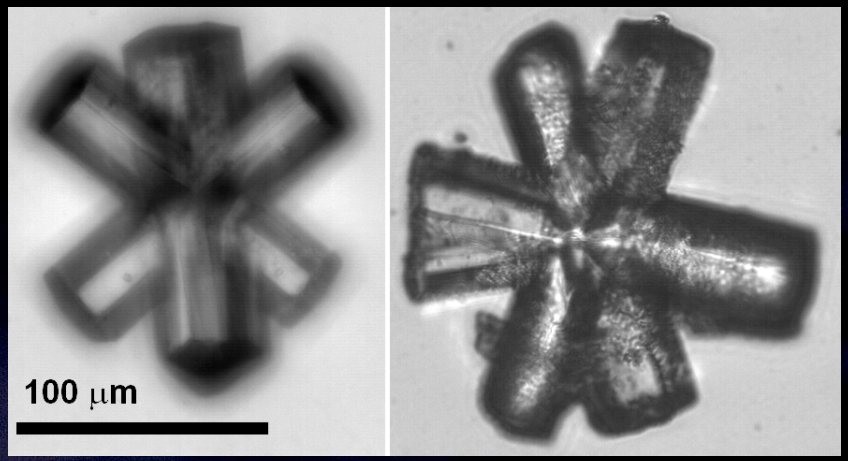


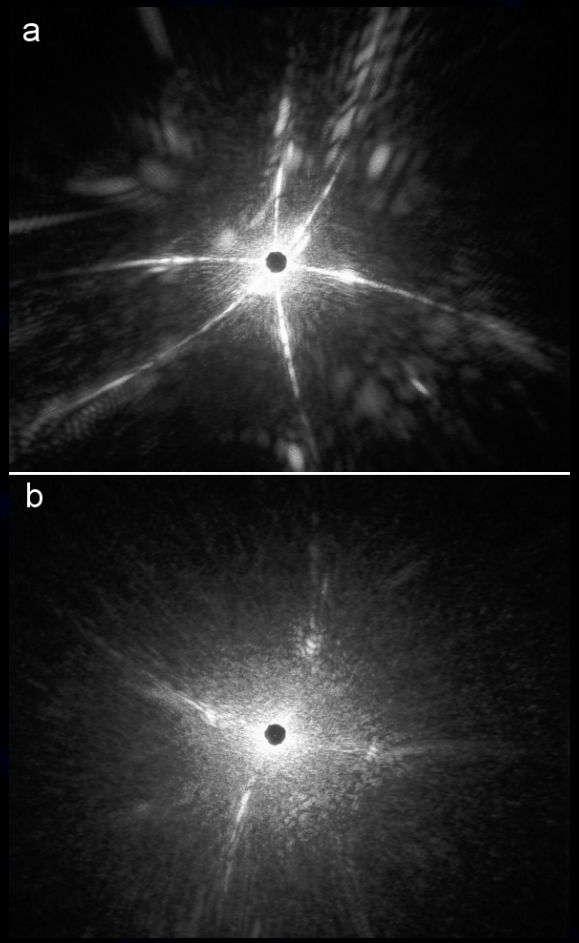


2D pattern is still altered

SID3 - smooth and rough crystals

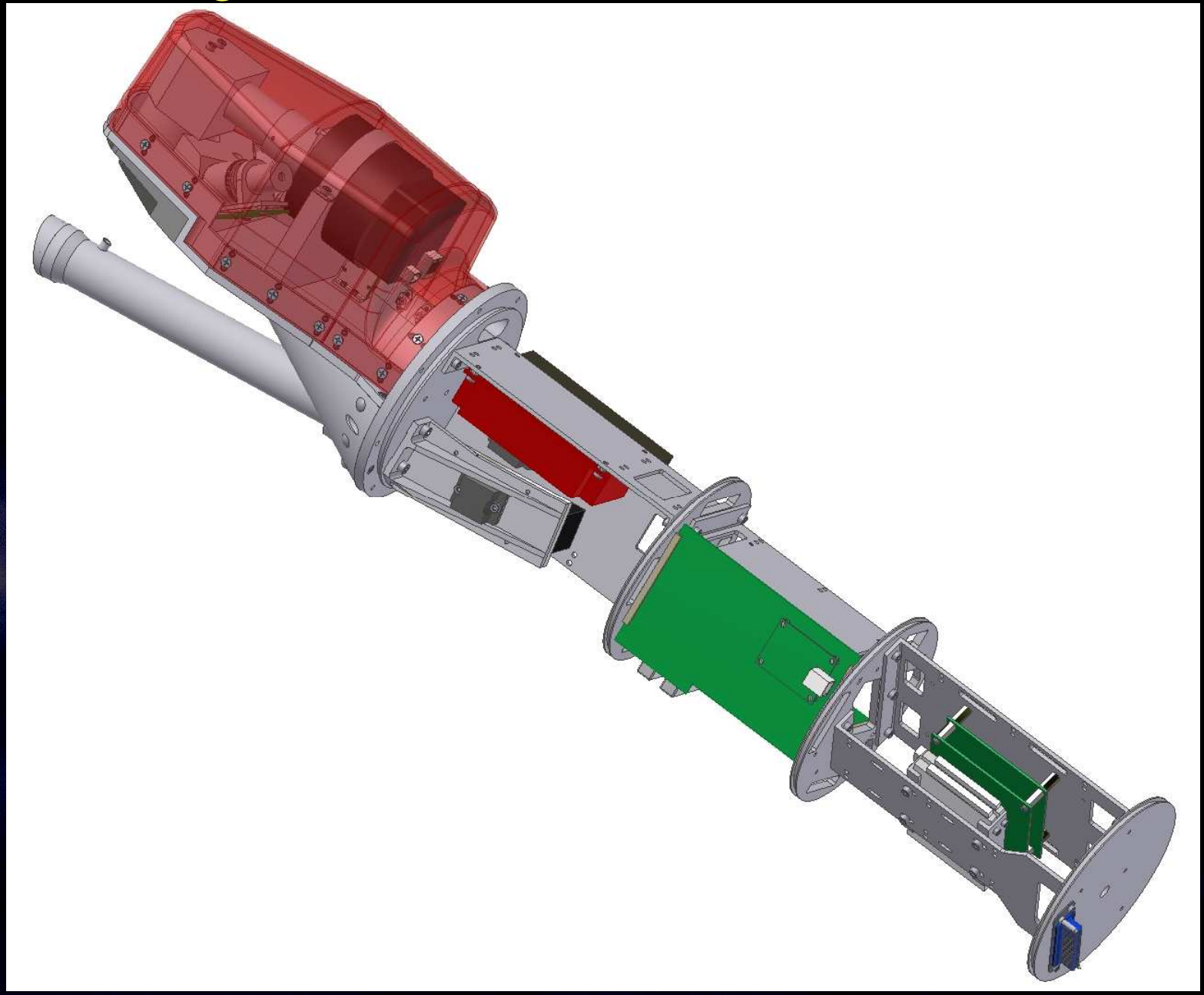
Smooth and rough ice-analogue rosettes



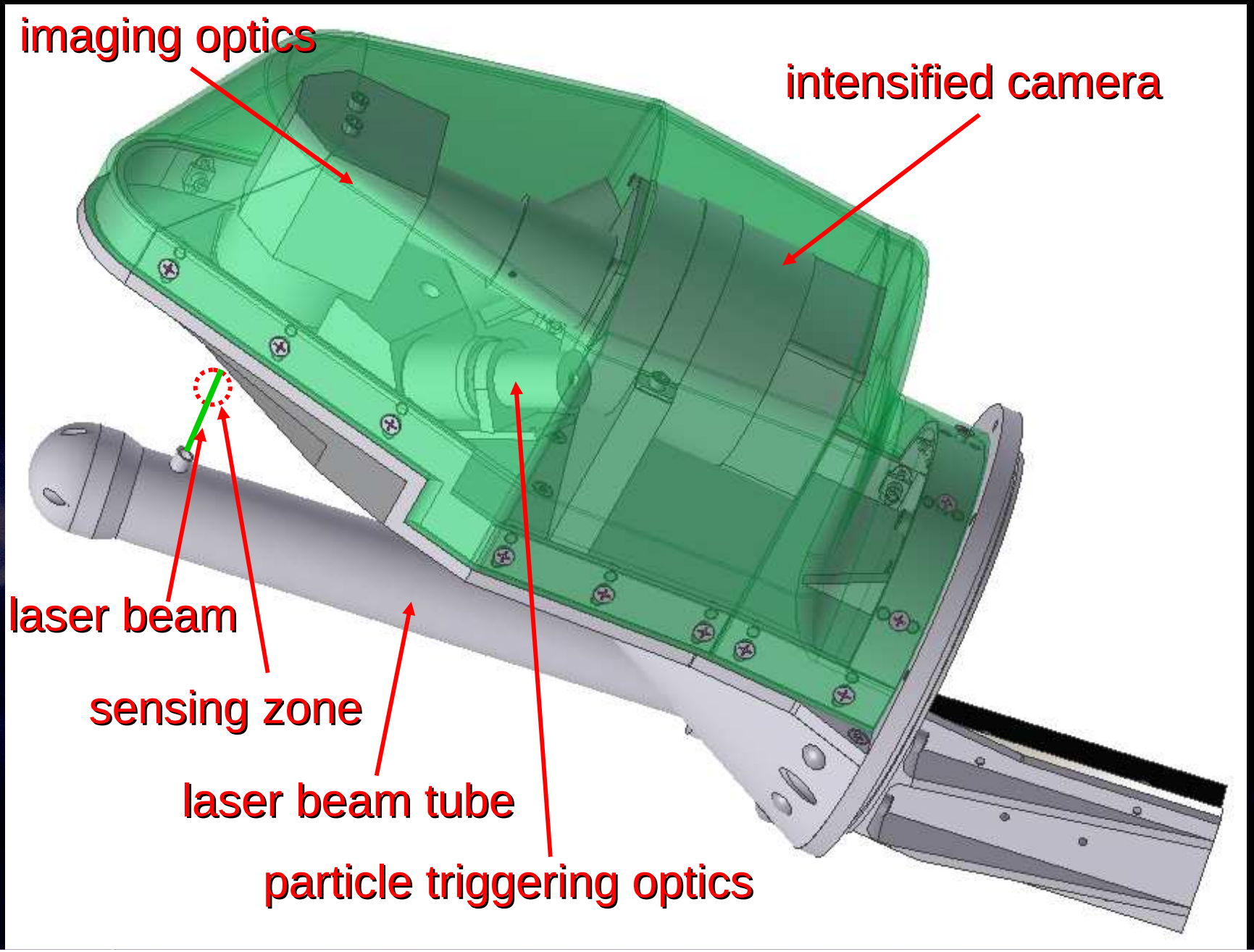


Surface rougness can be derived from 2D scattering

SID-3 - design



SID-3 - close-up of head



SID-3

- Planned delivery to AIDA: <u>September 2008</u>

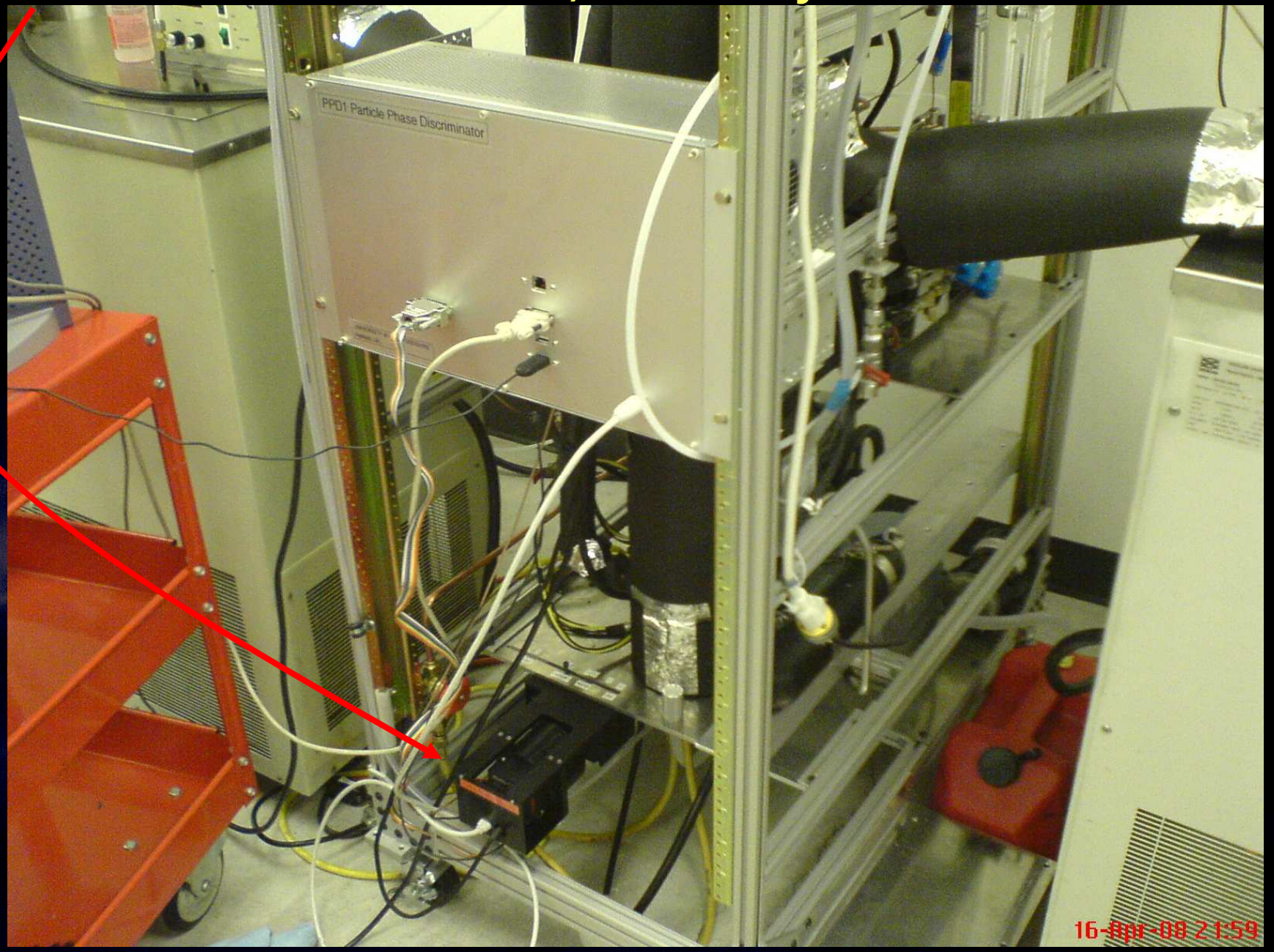
in the meantime, a lab version has been built:

"PPD1" ...

Particle Phase Discriminator - PPD1

- Lab version of SID3
- Intended for diffusion chamber
- Delivered to Paul DeMott in March 2008

PPD1 - mounted in CFDC, University of Colorado



PPD2 ?

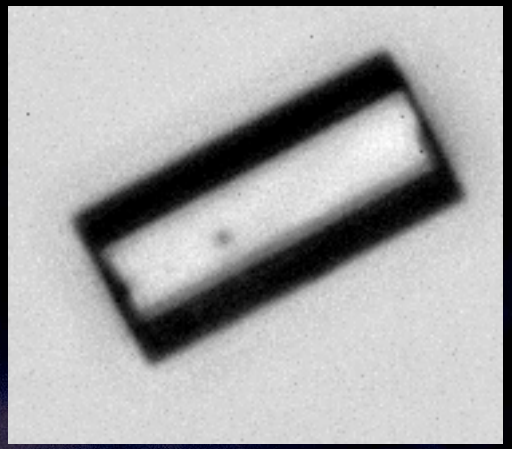
A similar instrument will be delivered to IfT Leipzig for use with LACIS in 2009.

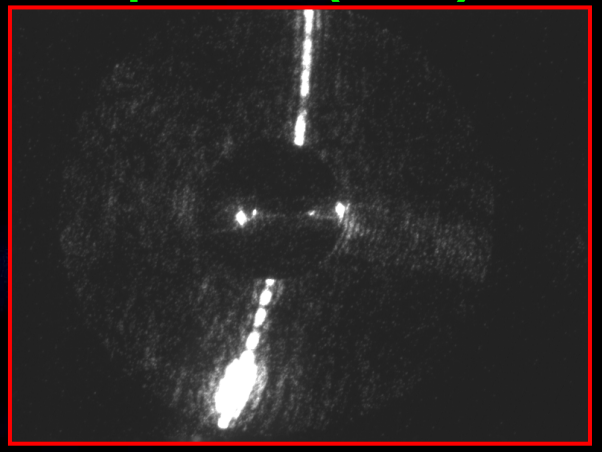
Instrument will be enhanced by the addition of backscattering depolarization.

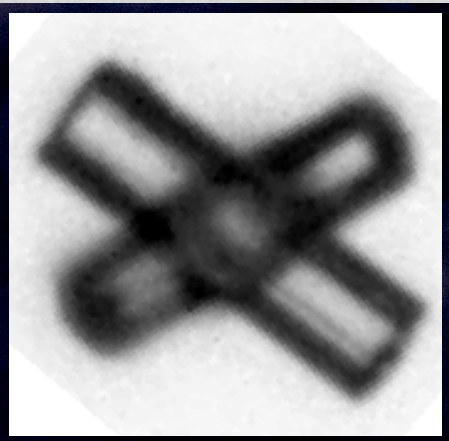
PPD1 Laboratory tests with ice analogues

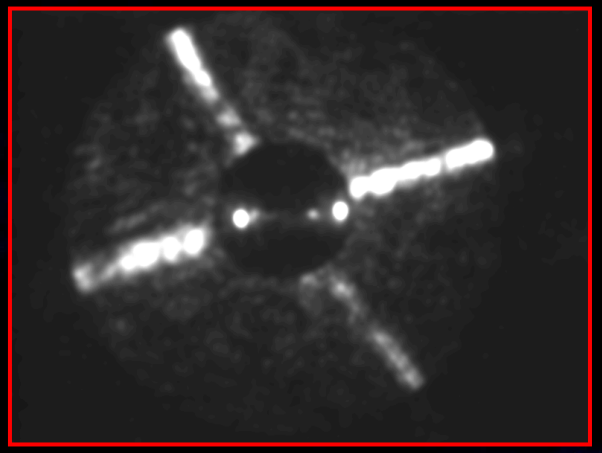
optical microscope image

PPD1 2D scattering pattern (6-25°)

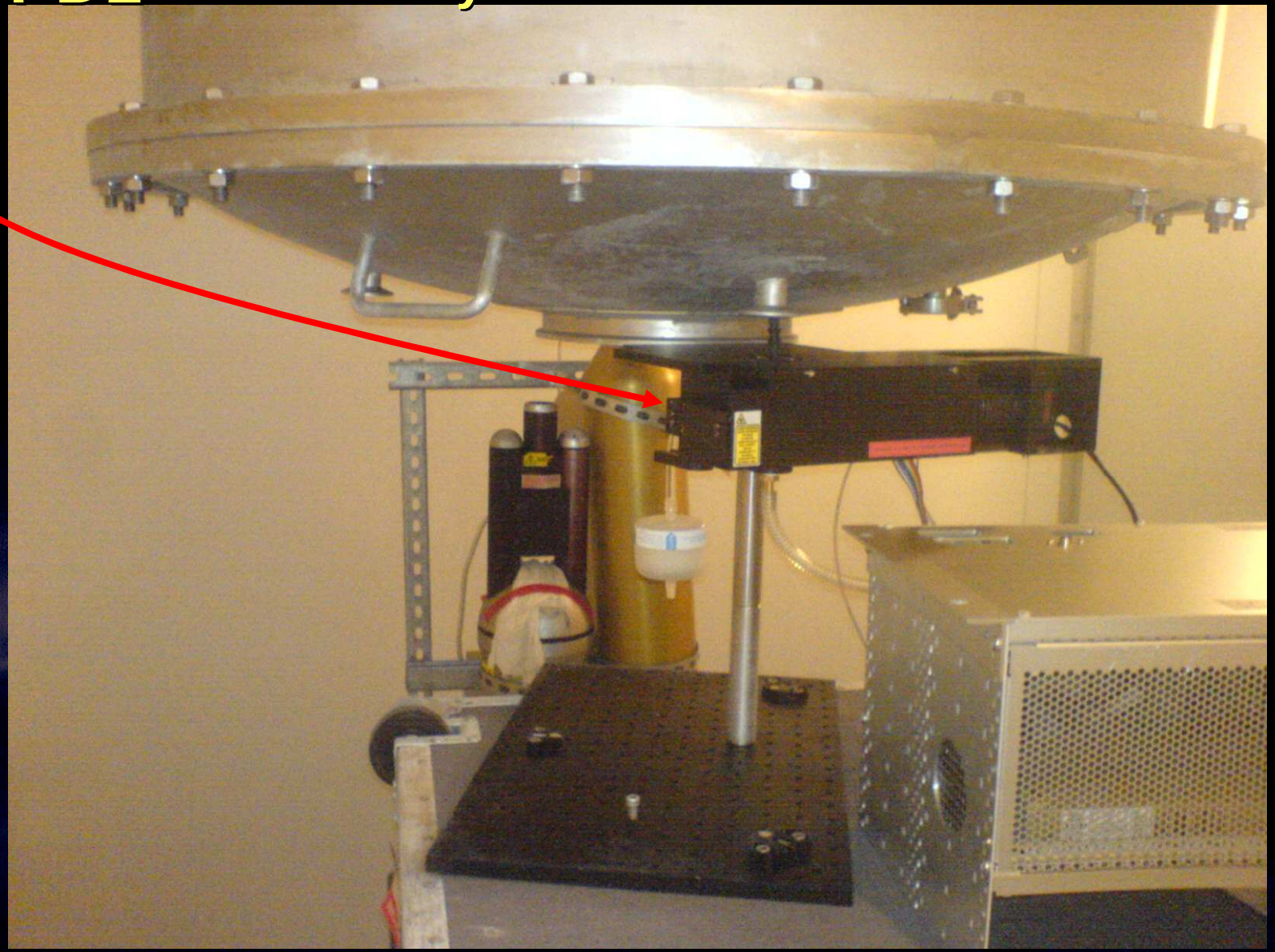




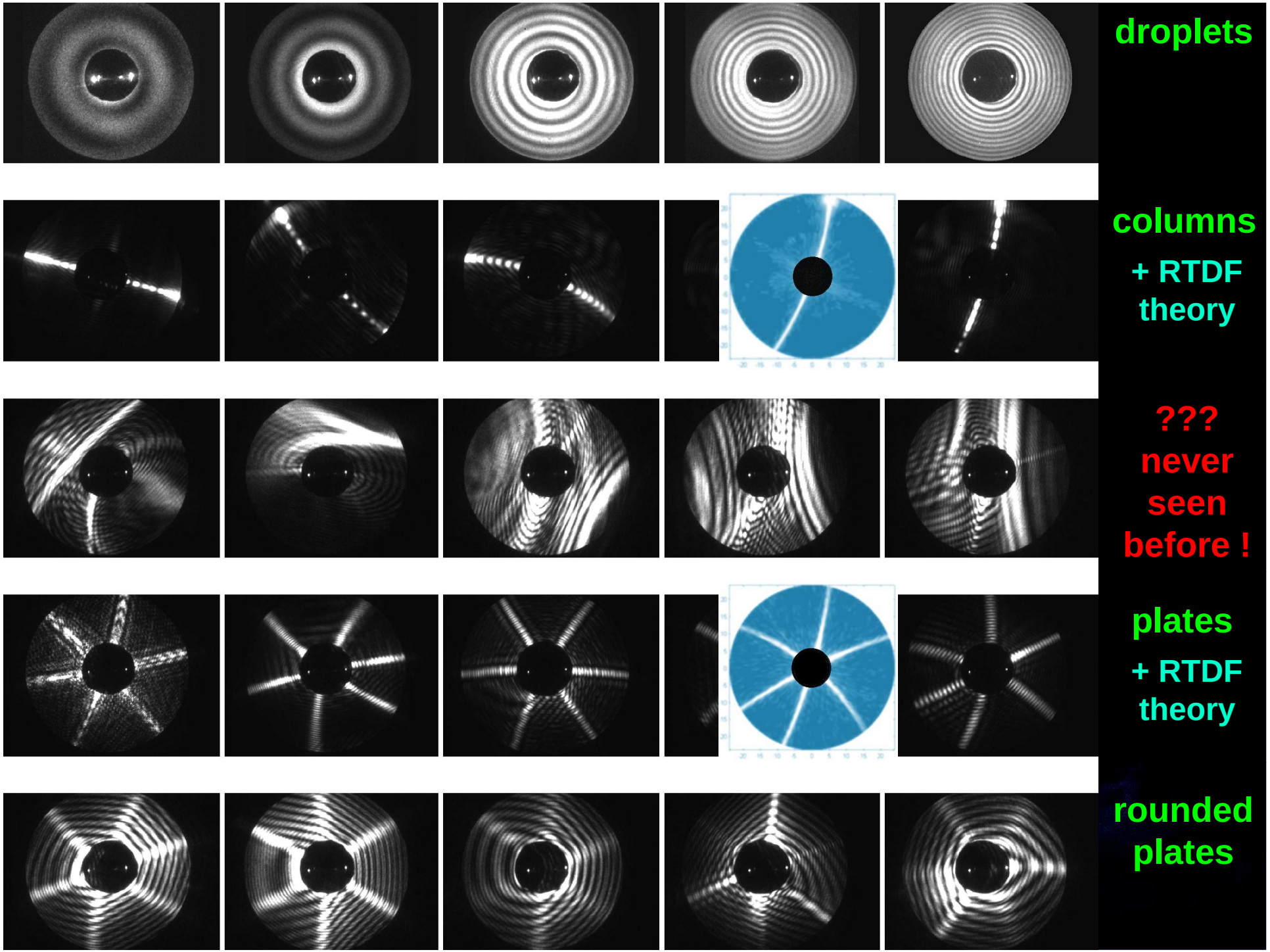




PPD1 Laboratory tests in Manchester cloud chamber

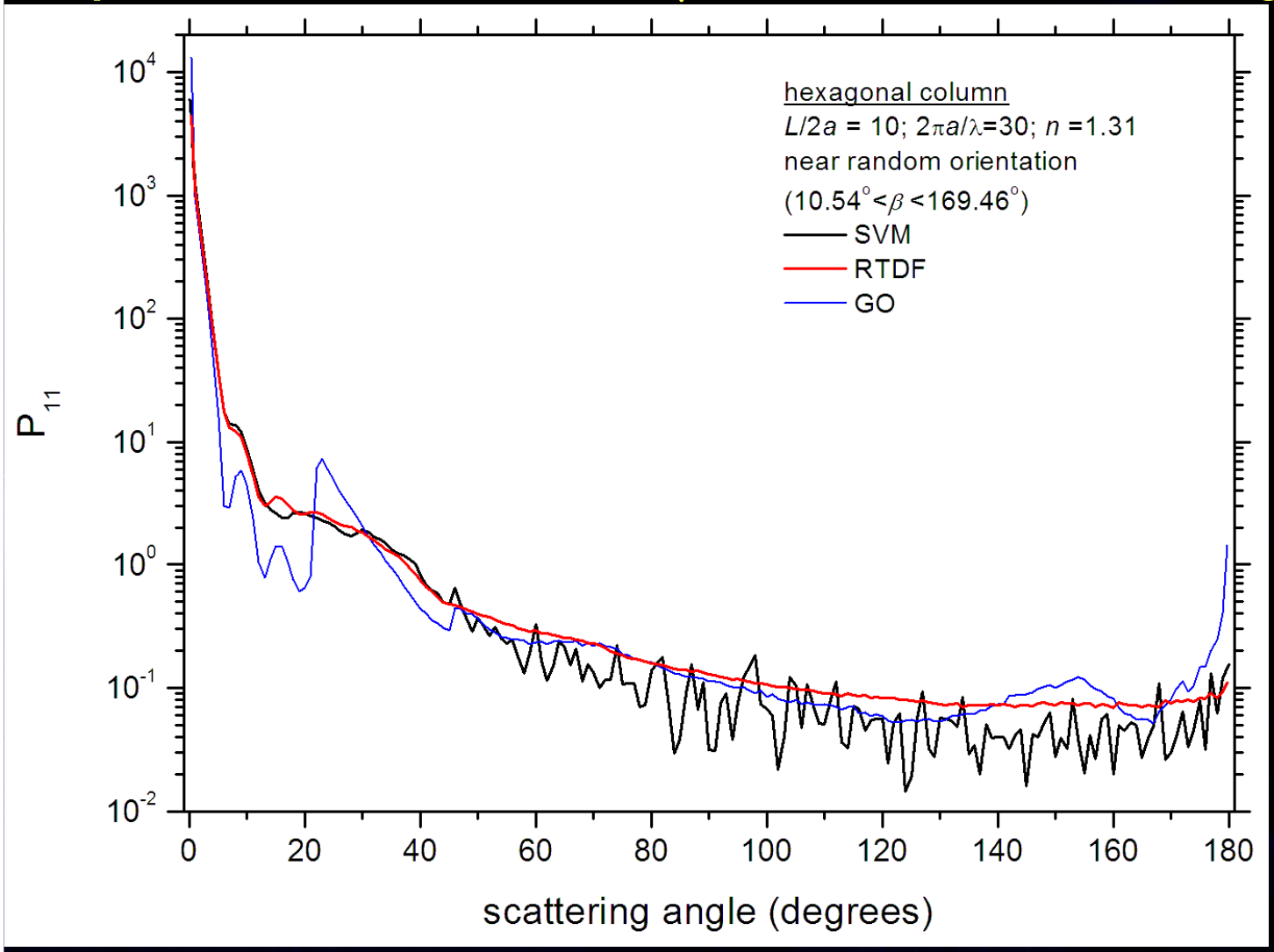


Example 2D scattering patterns follow...


droplets
columns
+ RTDF
theory
???
never
seen
before !
plates
+ RTDF
theory
rounded
plates

Associated work

- **The RTDF (Ray Tracing with Diffraction on Facets) scattering model, as used for the 2D patterns, has been extended towards smaller size parameters, down to 2 – 5 μm size at visible wavelengths.**



Example: 5 μm hexagon, randomly orientated - compared with Geometric Optics and SVM. Note failure of GO between 5 and 45°.

(SVM is near-exact but slow and restricted to narrow size and shape range)

E. Hesse (2008) J. Quantit. Spectr. Rad. Transf. 109 pp. 1374-1383

- **The RTDF model could in principle be used in WP M3 (climate modelling) for creating shape-dependent parametrizations of single scattering properties of ice particles.**

Summary - contributions from UH

- **Probes for particle characterization (size, shape):**

  - provision of SID-2 for AIDA campaigns,

  - dedicated SID-3 variants for AIDA (2008) and LACIS (2009).
- **Light scattering computations for the interpretation of laboratory measurements, e.g. backscattering depolarization (SIMONE, LACIS).**
- **Characterization and calibration of existing and new particle probes using RTDF theory and ice analogues**

FUTURE...

FUTURE:

- Continue probe and algorithm development; support campaigns.
- Probe calibration using analogues - include ZINC-DIHM at ETH?
- ECHAM parametrization of scattering properties of ice using RTDF?

Need for laboratory measurements:

At present, it is not clear how 2D scattering and backscattering depolarization changes when droplets freeze. Therefore interpretation of SID-3 data and depolarization from SID-3/LACIS will be difficult.

These difficulties might be resolved by measurements on freezing droplets in EDB traps:

- 2D scattering in forward region (<25°)

- depolarization in backscattering.

Can these be done at IMK/AIDA?