Ice particle characterization with Small Ice Detector 3 probe

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Small Ice Detector 3 - SID3

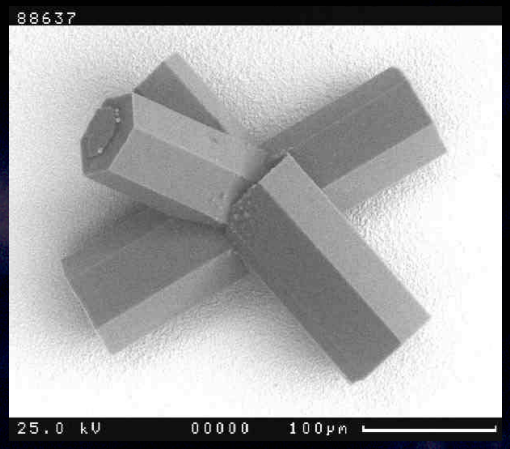
Original motivation: limited resolution of imaging probes

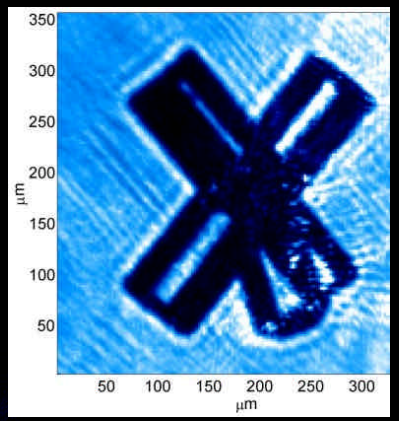
Examples recorded using the Manchester CPI and UH ice analogues

SEM and optical microscopy **Cloud Particle Imager**

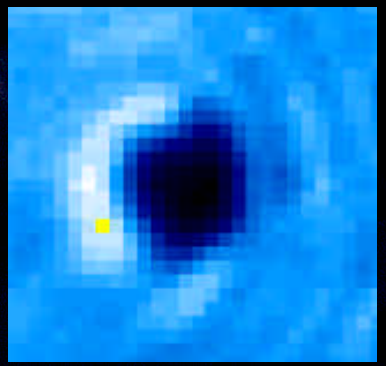
Size

311 mm





22 mm



SID-3

- Exists in 2 versions:

- aircraft versions, PMS canister, on-board data storage or real-time data transfer + display via Ethernet:

  FAAM version.

  AIDA chamber version, also for HALO aircraft.

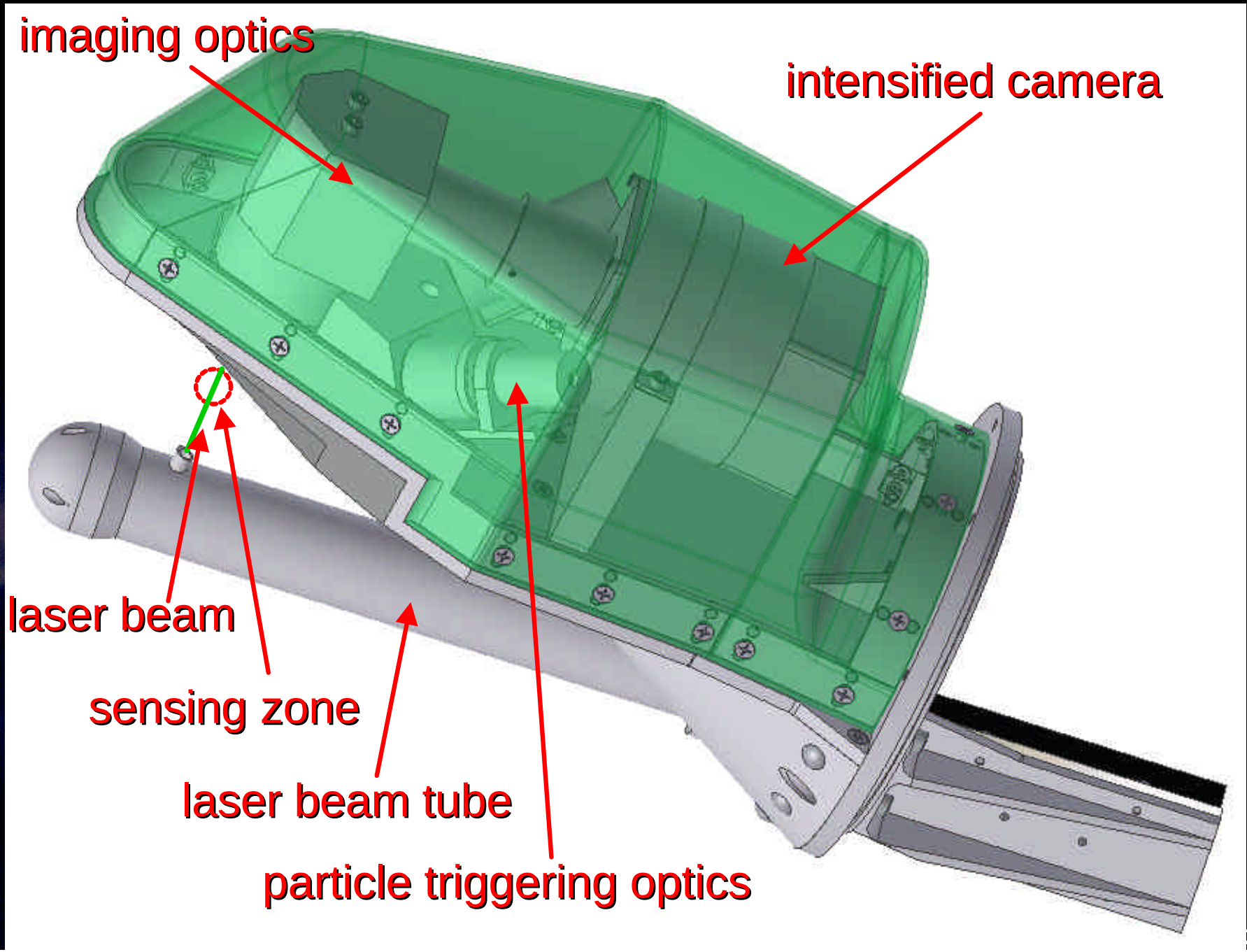
- lab versions, real-time data transfer/display via Ethernet:

  "PPD-1" (Colorado CFDC),

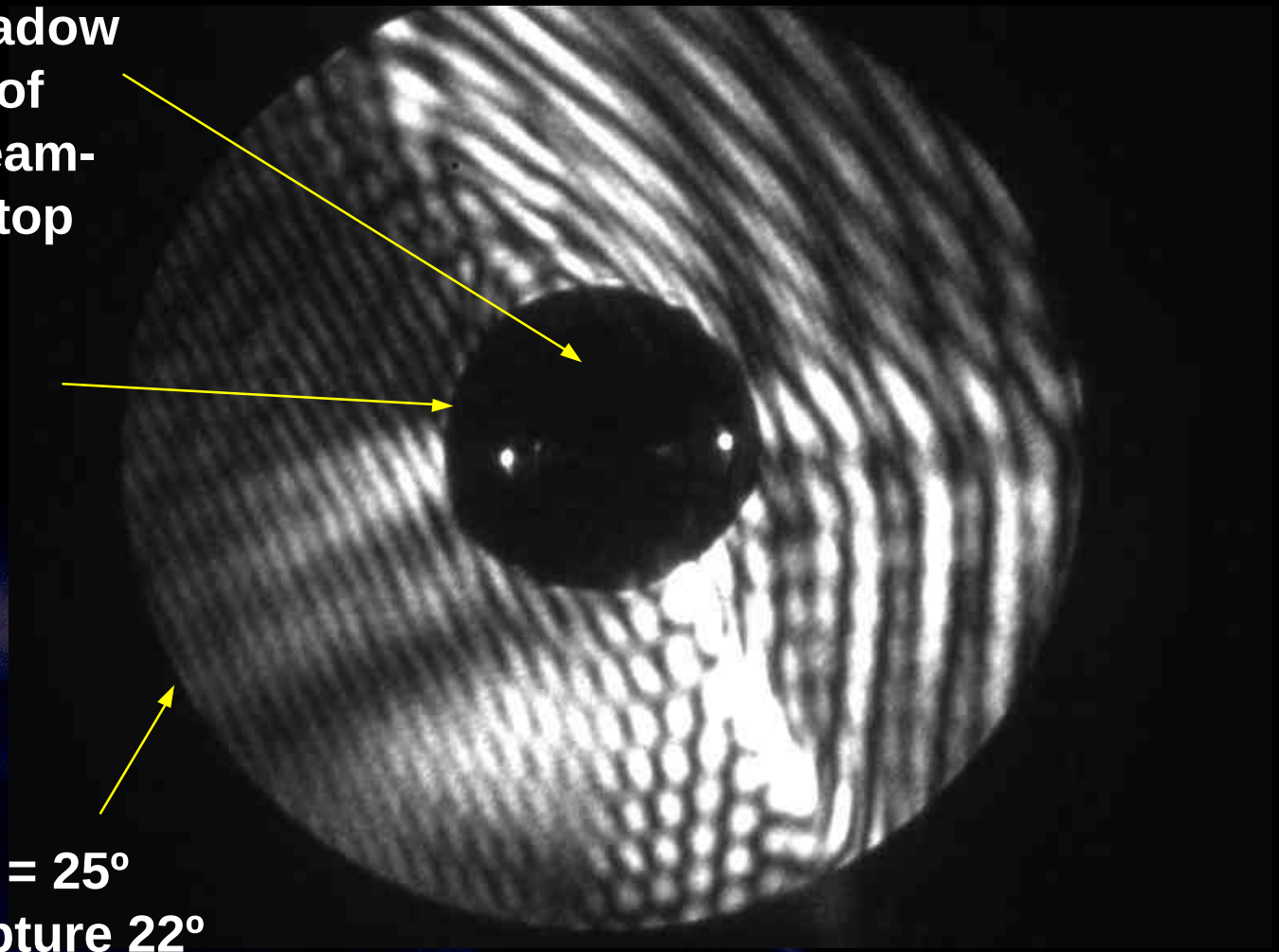
  "LISA" (LACIS chamber at IfT Leipzig),

  own version under construction in Hertfordshire (PPD-2, ready summer 2010)

SID-3 - close-up of head



SID-3 Scattering pattern image format

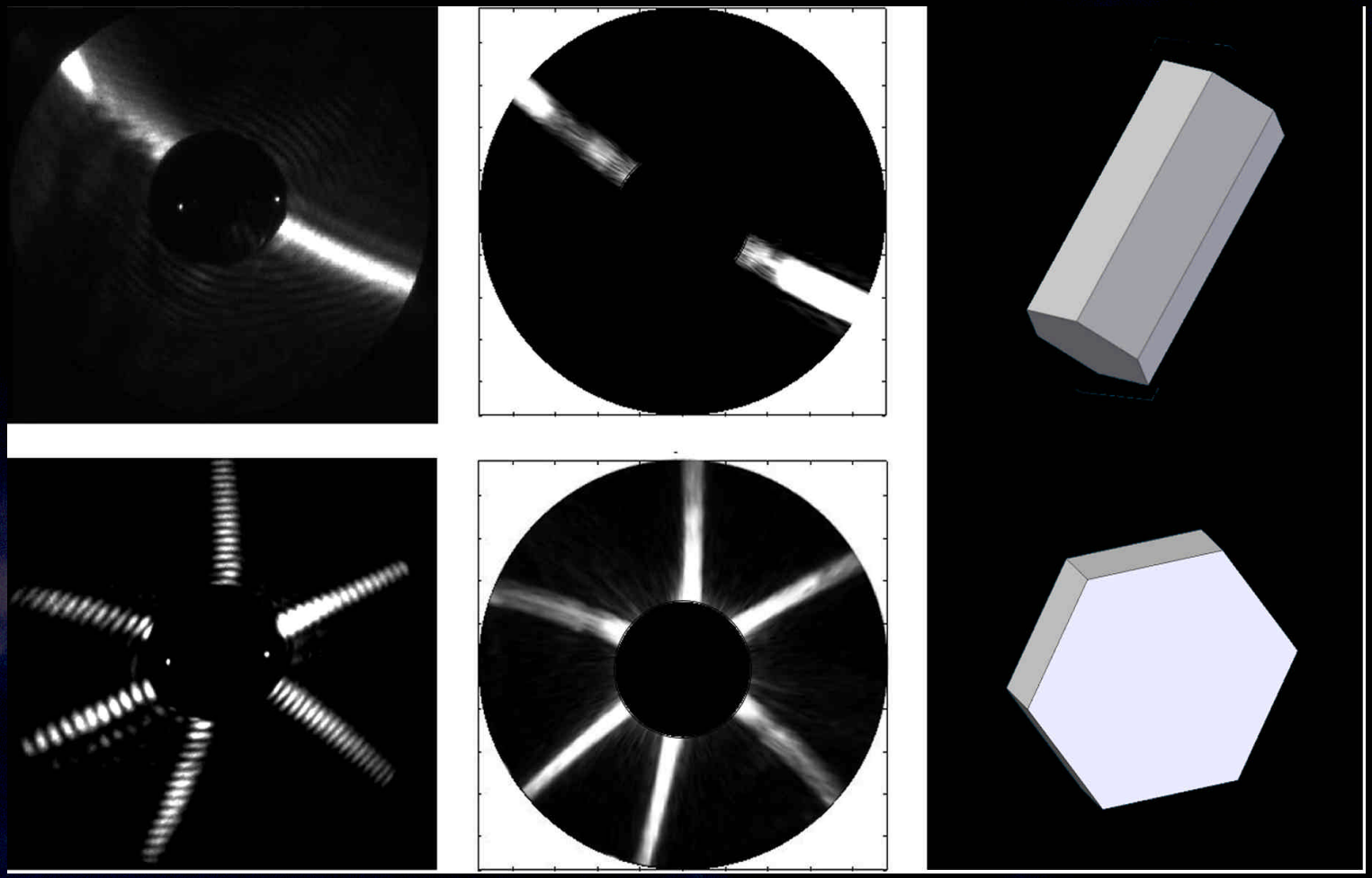


Shadow of beam-stop

Lowest scattering angle ? = 6º

Highest angle ? = 25º (sufficient to capture 22º halo from hexagonal ice crystals)

SID3 2D patterns



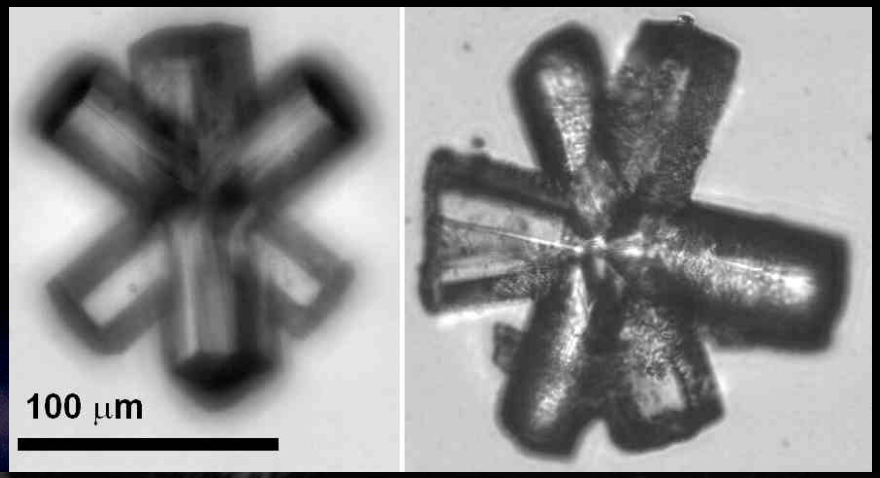
Experiment **RTDF theory** **shape+orientation**

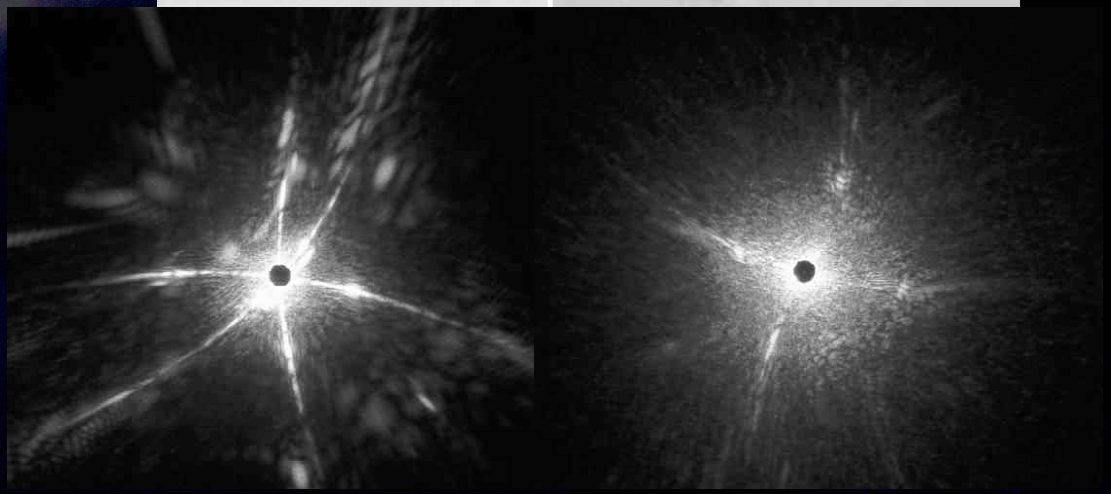
Method works down to around 2 micron size

SID3 - fine detail of particle structure

Ice-analogue rosettes:

smooth and rough



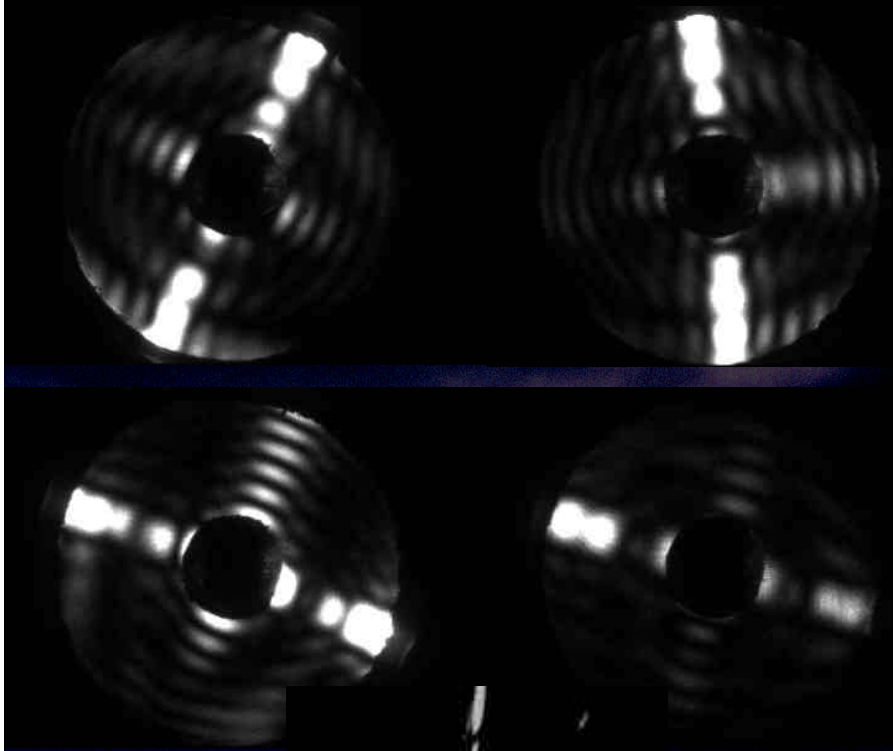


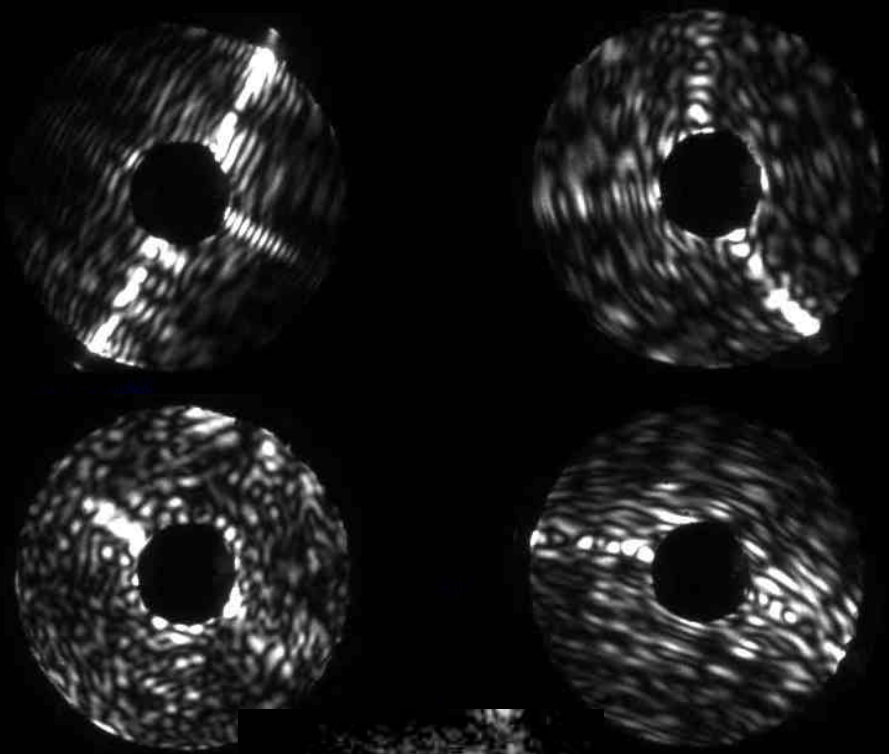
Rough analogue pattern is more irregular and random

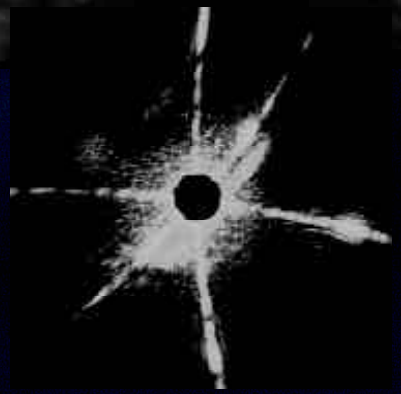
SID3 AIDA campaign HALO-02, Dec. 2008

Exp.8a IN soot T=-45°C, low RHI

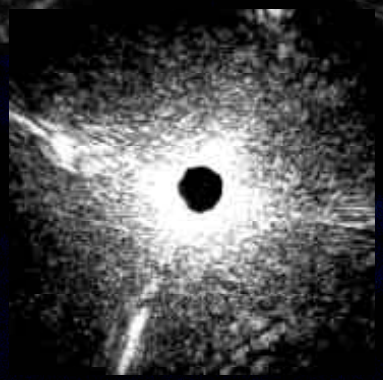
Exp.7 IN soot T=-45°C, high RHI



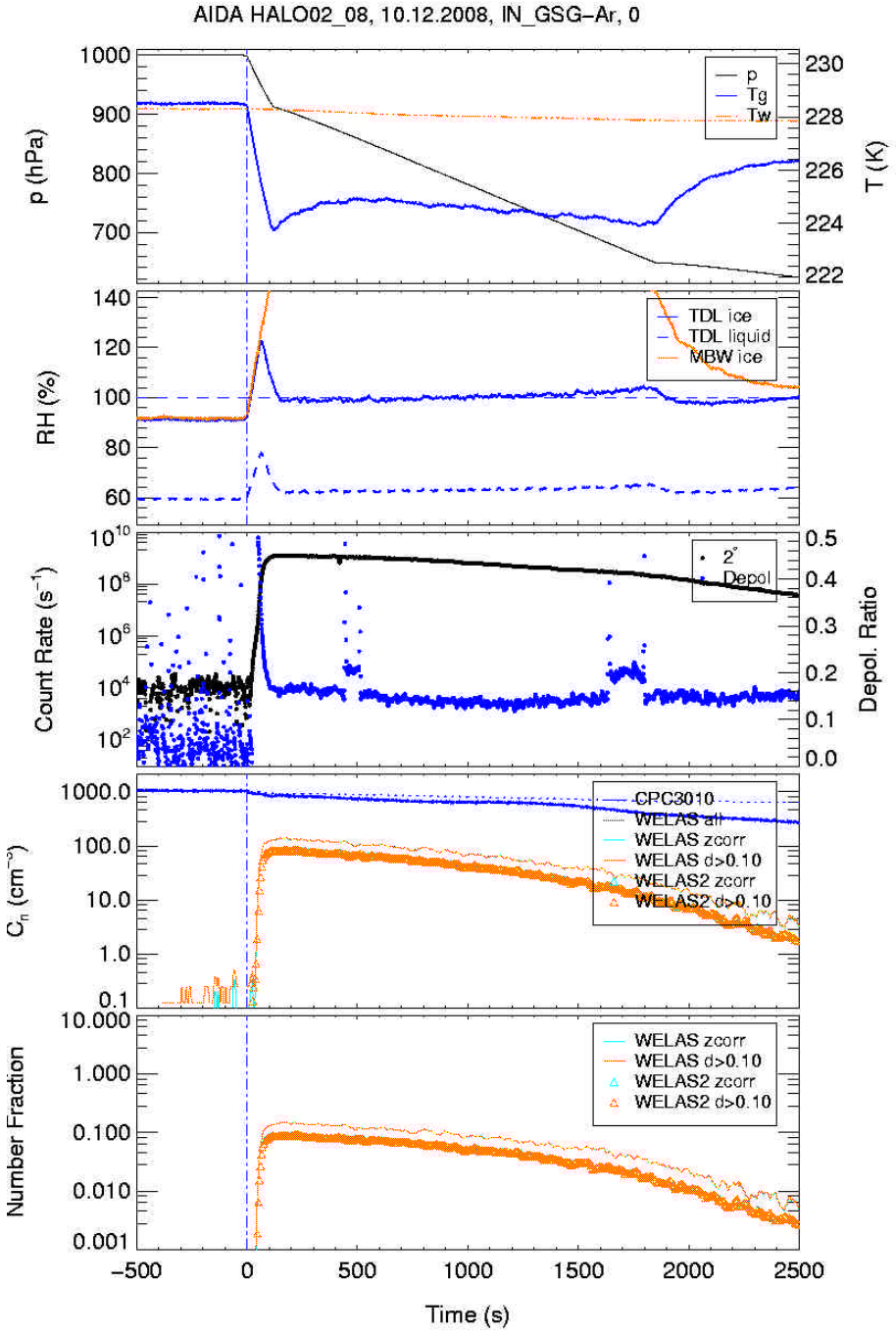




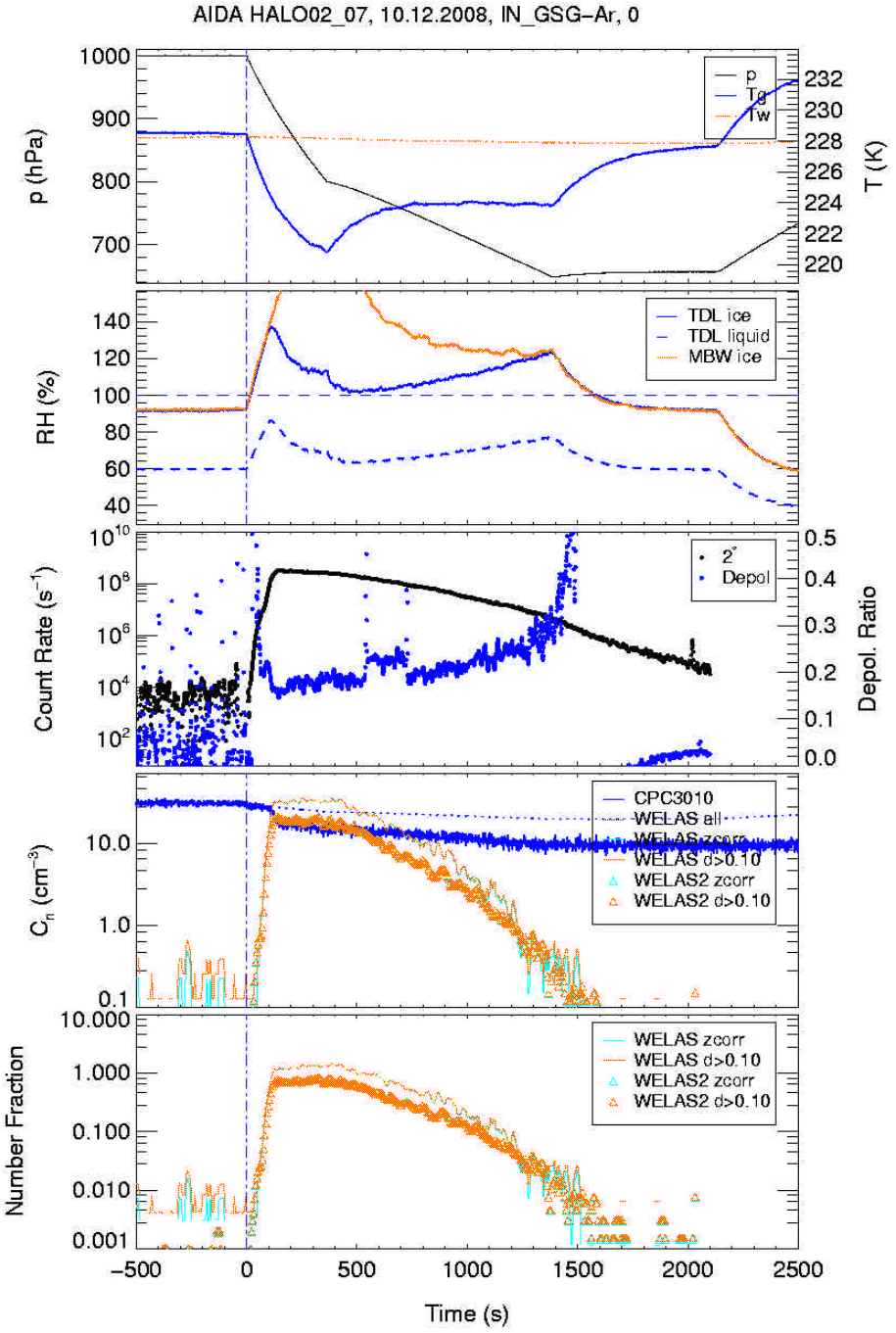
Ice-analogue rosettes:
smooth rough



HALO2-8a - low RHI



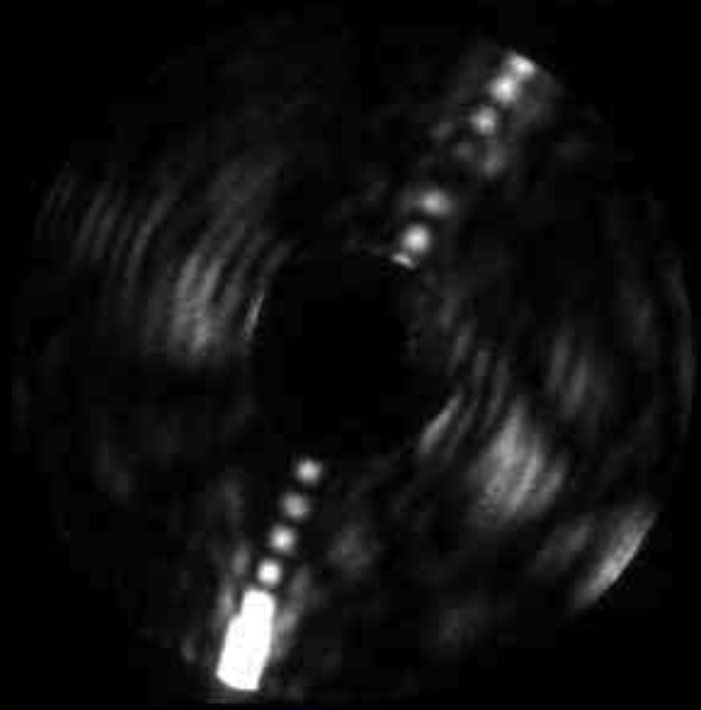
HALO2-7- high RHI



SID3 Attempt to replicate HALO-02 7/8: AIDA ACI-03, Oct. 2009

Exp.22 soot T=-40°C, low RHI

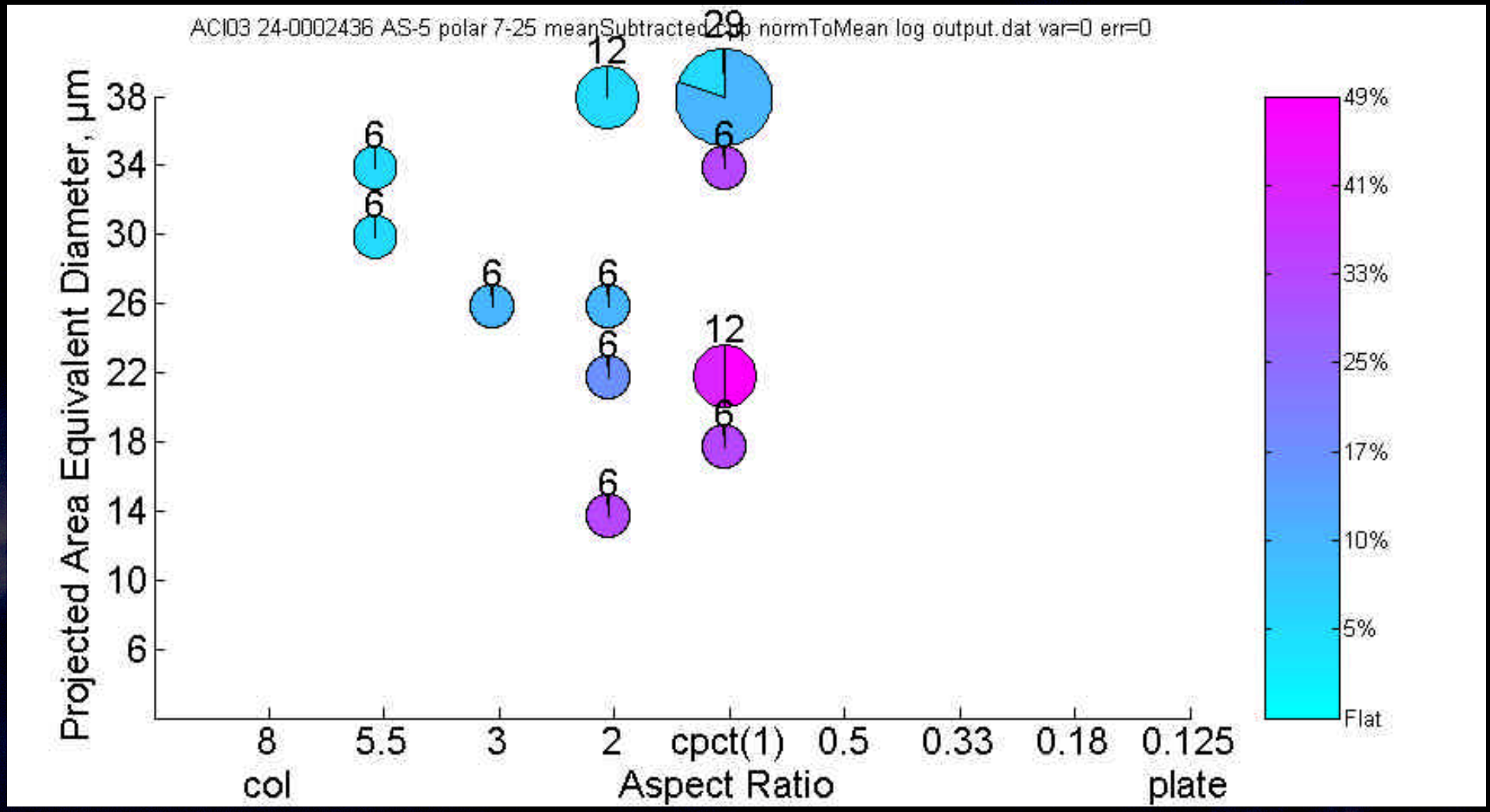
Exp.24 soot T=-40°C, high RHI



Superficial resemblence to "rough ice" patterns, but…

SID3 AIDA campaign ACI-03, Oct. 2009

Exp.24 soot T=-40°C, high RHI - shape classification

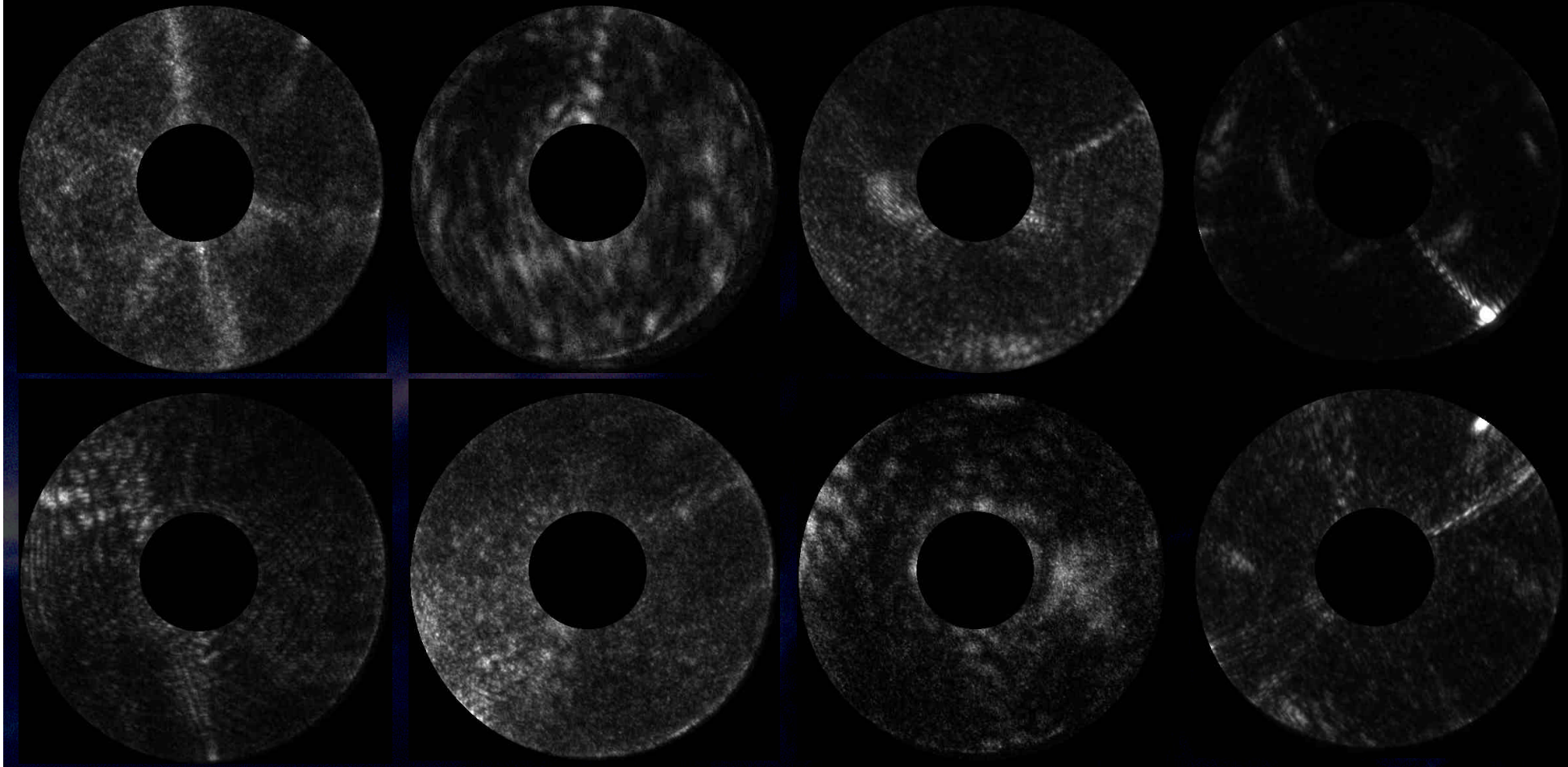


This indicates that hollow crystals were present at high RHI

SID3 scattering patterns

CONSTRAIN Feb. 2010 – cirrus and mixed phase flights

Smooth ice analogue

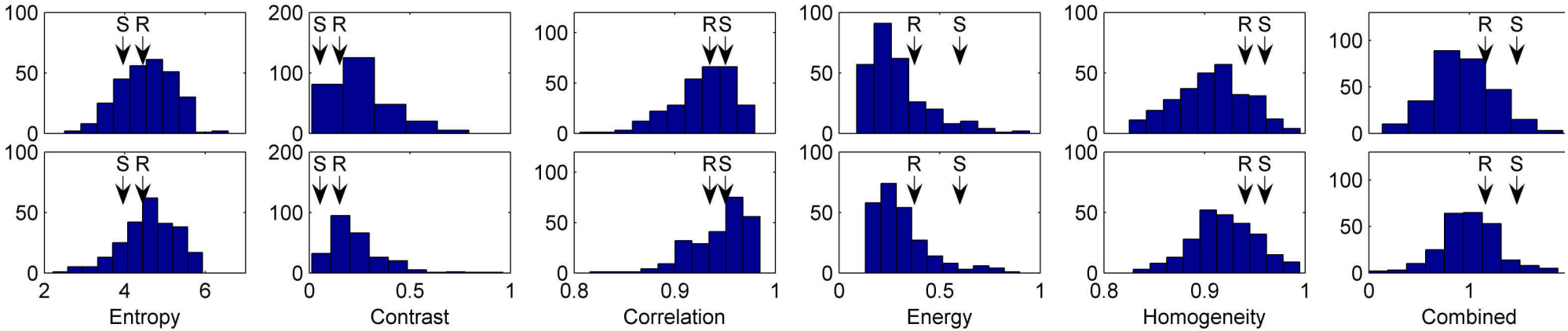


Rough ice analogue

SID3 CONSTRAIN Feb. 2010

Frequency distributions of statistical measures of image features

cirrus



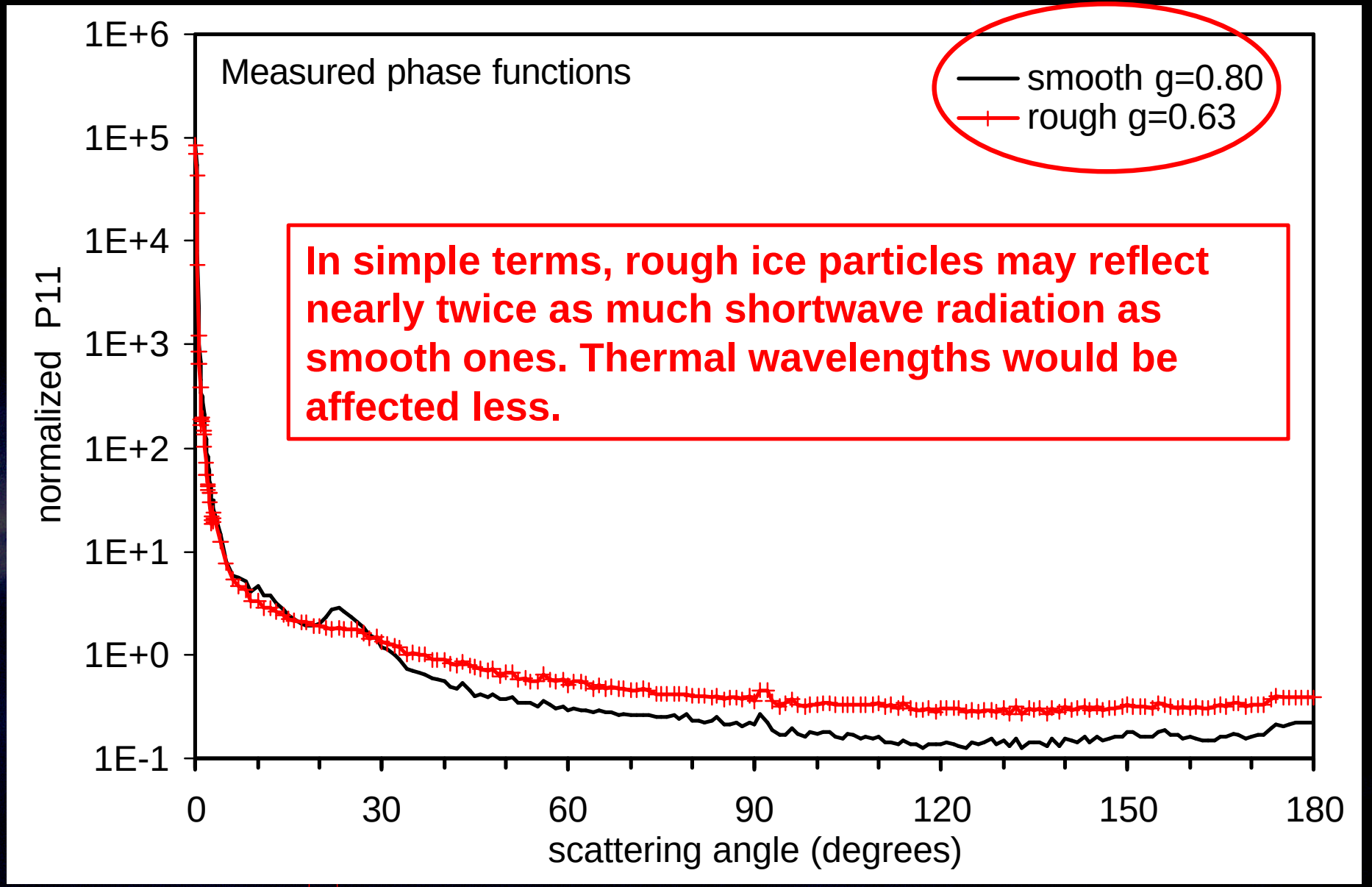
mixed phase

S=smooth
R=rough

Conclusion: in both cirrus and mixed phase clouds very rough particles predominated

Fine detail of ice particle structure: **why is it important?**

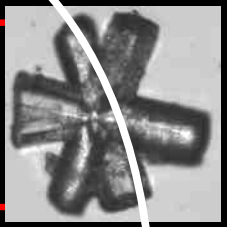
*P*11 and asymmetry parameter of smooth & rough analogs



Quantifying ice roughness and its impact

SID3 2D patterns from cloud chambers and/or aircraft

Rough ice analogues



Hypothetical !

Inversion

Comparison

Laboratory 2D patterns

SEM

Roughness

Theoretical 2D patterns

Scattering model

2D version

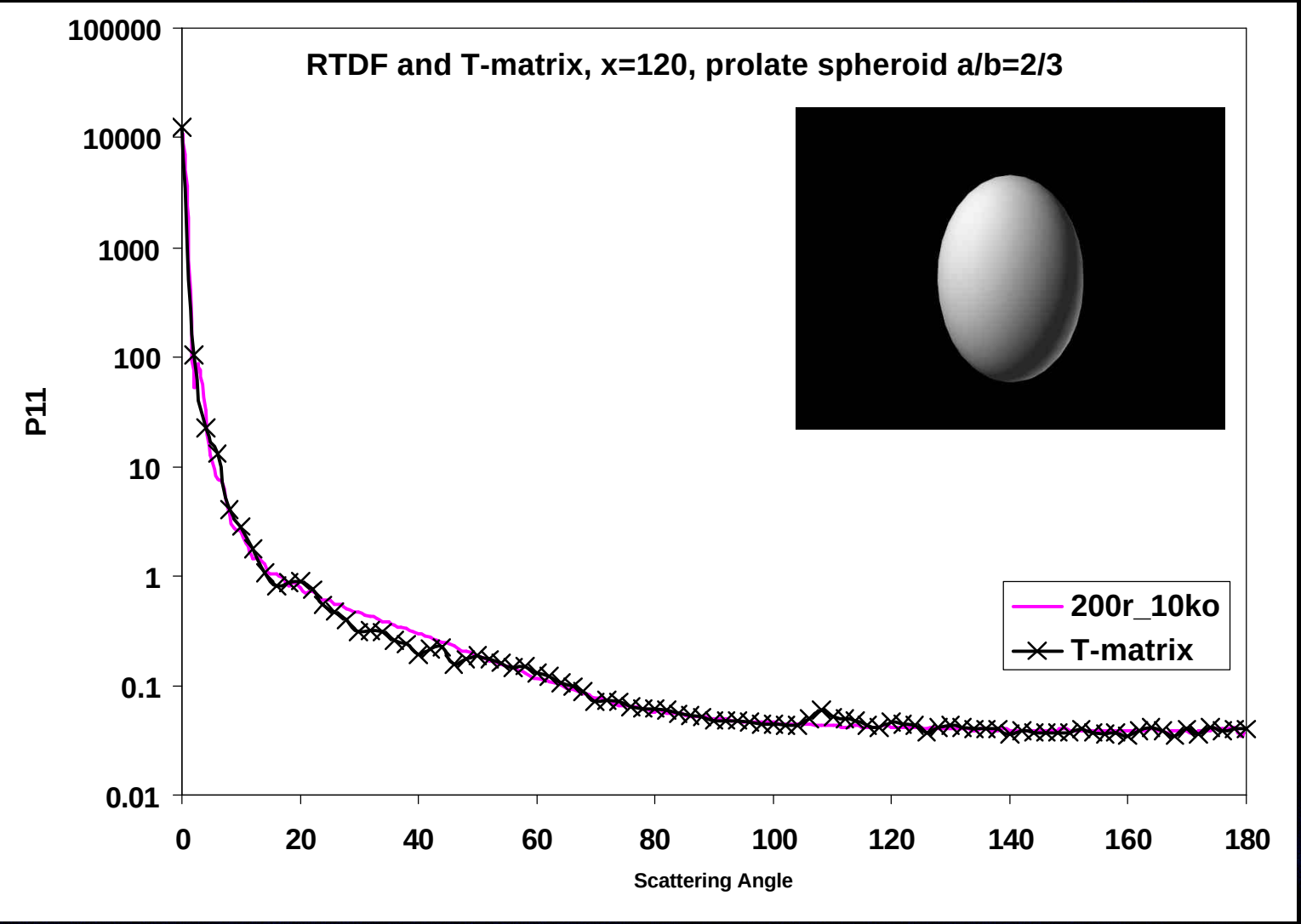
Single scattering properties

Complete closure can be achieved in these experiments!

Modelling of scattering

Ray Tracing with Diffraction on Facets (RTDF) model.

Extension of RTDF to curved surfaces - comparison with T-matrix



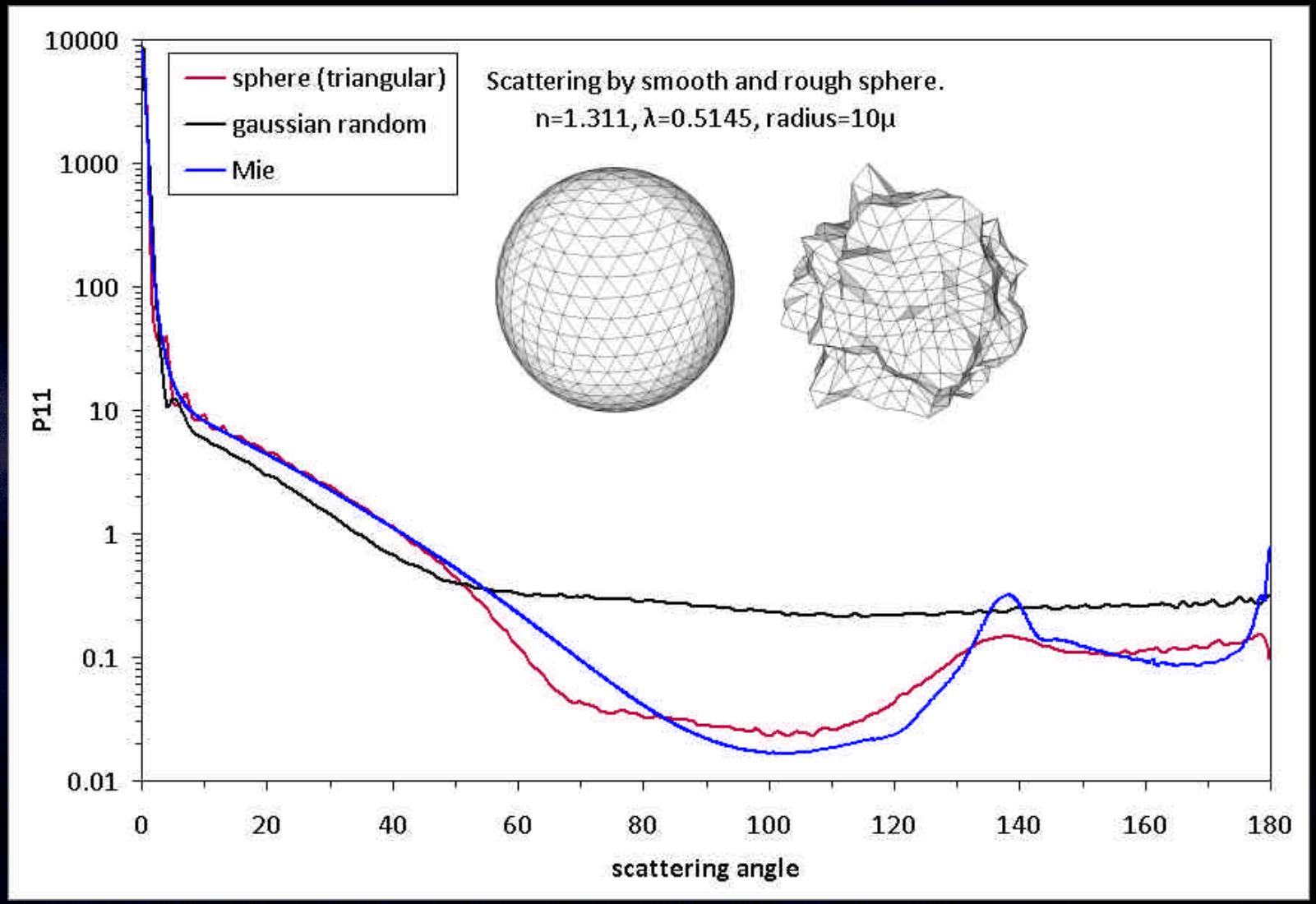
Example: ~30 μm spheroid, randomly oriented

Results in *JQSRT* 110, p.1599 (2009)

Modelling of scattering

RTDF applied to rough sphere

Comparison with smooth sphere – preliminary results



Conclusions

- Some experiments in AIDA indicate the presence of ice particles with rough surfaces when supersaturation is high.
- *In situ* data from mid-latitude cirrus and mixed phase clouds indicate strong roughness in the majority of ice particles.
- If confirmed, the roughness seen so far would have large impact on radiative properties of clouds.
- RTDF model is being extended to cater for rough ice particles.
- Further AIDA experiments are needed to establish:
  - is it possible to reproduce *in situ* data in cloud chambers?
  - when does roughness occur, and what is the mechanism?
  - what are the microscopic characteristics of ice surfaces?