These comments (from Referee #1) were received during the time of producing the discussion version of the paper. However, some of them are already considered and included in the published discussion version of the paper and the rest will be discussed here.

Note: The page and line numbers will be given in agreement with the page and line numbers of the published discussion version of the paper.

Interactive comment on **'First correlated stereo imaging and polar scattering of cloud particles using PHIPS'** by A. Abdelmonem, M. Schnaiter, P. Amsler, E. Hesse, J. Meyer and T. Leisner.

Recommendation: The paper needs a lot of work before it is ready for publication, particularly with regards to several important issues listed below.

General comments :

This paper describes a new instrument which provides the simultaneous measurements of the particle shape (on two observation planes) and the corresponding scattering phase function of individual particles. This new and innovative technique has already been tested in the AIDA cloud simulation chamber during two campaigns with ice crystals formed between -5°C and -70°C. This instrument named 'Particle Habit Imaging and Polar Scattering', is the first step towards PHIPS-HALO which is part of the new probes that are currently developed for the new German research aircraft HALO. The PHIPS combines a stereo particle system using two identical devices for the imaging the same particle under an angular viewing of 60° and a polar nephelometer for the simultaneous measurement of a single scattering phase function. The setup, operation and detection system are first presented with the calibration of the imaging and polar scattering system. The data analysis and some results from the AIDA chamber are presented and discussed.

As a general point of view, the instrument performances and the results which are presented are convincing and promising. Nevertheless there are several aspects that should be discussed with more details or that are missing.

1/ Detection volume

The detection volume is a very important characteristic of the probe. The description of this volume is very difficult to understand from both the text and Fig. 2.

- For example, on page 5 the FOV = 0.76 mm whereas on page 8 FOV = 0.8 mm ??
- On Fig. 2, in addition to a perspective view of the detection volume, two perpendicular cross-sections would be very useful for clarity reasons with indications of pinhole diameter, laser beam diameter, FOV, DOF, ..
- What are the definitions of FOVh and FOVw ?
- How does the intersection between a cylinder of Aph/ 2 base area and FOV_w = 0.8mm height with a beam of w=0.5mm results in a quasi cylindrical detection volume ? The citation of Schön et al. (2011) is inadequate here to explain the ratio ½.
- Is the detection volume for the stereo imagers the same for the scattering volume defined for the scattering measurements ? This is an important point to be presented with

Comment [Dr.1]: This part is clarified in more details in the discussion version of the paper. (See page 2889 lines 5 to 8 of the AMTD version)

Comment [Dr.2]: Done in the discussion version of the paper (see the new version of Fig.2)

Comment [Dr.3]: Done in the discussion version of the paper (See page 2889 lines 5 to 8 in the discussion paper)

Comment [Dr.4]: This should be clear now after the new version of Fig. 2

One can see that the intersection between the laser beam and the optical viewing path of the particle detector through the pinhole (which is placed in the telescope unite of the particle detector) is a semi-cylindrical shape.

Comment [Dr.5]: "The telescope unit has a magnification power=1/2. The mentioned pinhole has an image of diameter equals to ½ of its real diameter."

Is it enough here to add the word "power" after the word "Magnification" in page 2892 line 13? Or should I explain it by the first sentence of this comment?

details because combined particle image information and scattering properties should address similar volume.

- More generally the two volumes should be clearly defined and mentioned with the evaluation of the probability that two or more particles (coincidence errors) could be present at the same time in the defined volumes and as a function of the particle concentration, the airspeed and the sampling rate.

2/ Polar nephelometer system

This system is poorly described regarding the sampling volume (see above) and the non-evaluated errors on the measurements due to the optical system design.

2.1 Astimatic errors

Due to the fact that the sampling volume has a finite size, the optical system is not stimatic. Therefore, a particle located outside the focal point in the sampling volume scatters energy following a certain angle which may not reach the corresponding detector. Numerical simulations could be made in order to evaluate the subsequent errors on the measurements. These simulations may use a ray tracing technique for the characteristic determination of the light beams which emanate from the sampling volume and reach one considered detector. For a given detector, the statistical distribution of the polar scattering angle provides information on the subsequent astigmatism error for each detector.

2.2 Reduction of the optical interferences

It is imperative to minimize the spurious reflected light from both the incident illumination and the scattered radiation and also to reduce the effects of outside light which may enter the optical chamber. On solution consists into the reduction of the cone-aperture of the detectors so that they can only be reached by the beams coming from the sampling volume. Are the fibers for angles from 1° to 10° located in a hole drilled into the detector array? The sink will therefore occult part of the scattered light. Otherwise, it is imperative to reduce the aperture of these detectors because of the (usual) large numerical aperture of the optical fiber (30° ?). How are housed the fibers for angles from 1° to 10° ?

2.3 Sensitivity of the scattering measurements

Nothing is indicated about the reliability of the scattering measurements performed at small forward angles (1° to 10°). How is removed the direct light from the laser beam. How are reduced the effects of diffraction near the edges of the laser beam and what are the order of magnitude (signal on noise ratio) of the offsets on the measurements ?

What is the minimum particle size which is expected to be measured with all scattering angles with the fibers ?

Calibrated and monodisperse glass beads (down to a few micrometers diameter) could be used to control and calibrate the instrument.

3. Calibration

Comment [Dr.6]: Yes, since the detection volume is defined by the diameter of the mentioned pinhole and the laser.

As written from page 2888 line 26 to page 2889 line 5 , this volume is limited by the intersection of the three volumes arise from maximum detection volume of each camera, the cylinder like stream of particles and the cylinder like laser path at the scattering centre.

Comment [Dr.7]: As mentioned in page 2894 lines 20 to 22, it is rare that more than one particle is detected within one image as the probability for two particles being accidently present in the tiny volume of detection at the same time is low.

However, coincidence errors can be recognized by two means:

1. Since the maximum detection volume of each camera is larger than the effective detection volume, coincidence error in the effective detection volume will show (in the images) those particles which were in that volume during detection.

2. Since the scattering part records a time resolved scattering signal (see page 2890 lines 15 to 18 and page 2902 line 12), any particle coincidence happens within the intersection volume of the laser beam and the particles stream will be observed as several peaks in time of the scattered signal.

Comment [Dr.8]: In PHIPS, there is only one sampling volume for both systems (imaging and scattering) and is described in detail in section 2.3

Formatted: Highlight

Comment [Dr.9]: This point will be discussed separately and posted in a later comment.

Comment [Dr.10]: As one can read in the figure caption of Fig. 1, The 1° to 10° fibers are retreat 140mm away from the arc front of the chamber (where the other fibers are fixed). The scattered signal travels along this distance through a dark tube which ends at one side of a blacked cell where the array of fibers are placed on the other side of the cell along the scattering signal path. With this configuration, stray light has no chance to reach the detector array. ... [1]

Comment [Dr.11]: In order to be able to measure the scattered signal at 1° and larger in the forward direction, it was necessary to reflect the incoming laser beam from the optical axis away during measurement. To this end, a movable mirror (Elliptical Plano-mirror) is installed, which can be moved with a linear ... [2]

Comment [Dr.12]: This value can be lower than few µm. The smallest detected particle size during PHIPS operation was about 5µm. Both parts of the instruments could record this size successfully.

How are calibrated the different channels in order to translate raw measurements to physical data (for instance sr-1 micrometers-1).

Minor comments :

The manuscript refers many times to the work by Schön et al. (2011). This is not comfortable for the reader, and some explanations should be useful to be recalled (see above).

Page 1: The title of the paper should be modified with the complete name of the instrument (not only the acronym). For example: The new Particle Habit Imaging and Polar Scattering (PHIPS) probe for the correlated measurements of the shape and scattering properties of cloud particles (or equivalent).

Page 1: Abstract: Same suggestion as above. The name of the probe should be first indicated rather than the acronym.

Page 3, line 20 : ASTAR not ASTRA

Page 5, line 28 : Add (see section 4.1.3), after … shown below.

Page 6, line 12 : PMMA acronym needs to be explained.

Page 6, line 26 : ACD acronym needs to be explained.

End of page 9 and Fig. 4: Some discussion should be useful for the comparison between the measured scattering function and the theory. Should a mean scattering function from numerous quasi-monodisperse particles more relevant for calibration purposes ???

Page 10, line 8 : Therefore …

Page 17, line 26 : Formulae X = 2a / L : Please use the same letters on Fig. 8 (i.e. H, W).

Page 20: The end of section 5.1 is not clear about the comments on comparisons on measurements with theoretical results. The observations should be reported on Fig. 13 to show differences between the two approaches.

Page 21: End of section 5.2 and Fig. 14. The scattering angle at 115° is strongly underestimated compared with theory. The theoretical model should used with small variations of the Euler angles in order to evaluate the sensitivity of the results.

Section 4.1.5 : Particle classification : Should be the object of an Annex.

Figure 10. Please re-write the legend with more concise details. What are the instruments shown on panels c, d, e and f respectively ?

Comment [Dr.13]: I hope I have understood this comment right, if not please let me know. However, The calibration process was carried using either quasi-monodisperse Glass beads or water droplets produced from a piezo driven nozzle which produces water droplets at constant size. Water droplets have shown better results.

Water droplets are allowed to pass through the detection volume. The scattered intensity at each channel is recorded and correlated to the corresponding theoretical value after being processed. Processed means:

- Offset values (of amplifier) were subtracted from each channel.
- Background light is subtracted.
- Scattered signals are divided by the amplification factor of the amplifier.

At the end, a calibration value is obtained for each channel.

Comment [Dr.14]: Yes, I absolutely agree. This will be reduced reasonably in the final version.

Comment [Dr.15]: Done in the published discussion version

Comment [Dr.16]: Same as above

Comment [Dr.17]: Same as above

Comment [Dr.18]: Same as above

Comment [Dr.19]: Same as above

Comment [Dr.20]: Same as above

Comment [Dr.21]: As mentioned in comment Dr.13, water droplets have shown better results than quasi-monodisperse. This is because of the reliability of the operation of the piezo driven nozzle.

Comment [Dr.22]: I mean here thereof (or, from that).
i.e. From that sharp and flake free images, the region of interest (ROI) can be located.

Comment [Dr.23]: Done in the published discussion version

Comment [Dr.24]: Will be considered and published in a separate comment

Comment [Dr.25]: Will be considered and published in a separate comment.

Comment [Dr.26]: Will be considered and published in a separate comment.

Page 2: [1] Comment [Dr.10] **Abdelmonem** **24.05.2011 13:19:00**

As one can read in the figure caption of Fig. 1, The 1° to 10° fibers are retreat 140mm away from the arc front of the chamber (where the other fibers are fixed). The scattered signal travels along this distance through a dark tube which ends at one side of a blacked cell where the array of fibers are placed on the other side of the cell along the scattering signal path. With this configuration, stray light has no chance to reach the detector array.
In addition, in order to suppress interfering reflections, the complete optical chamber inside is painted matt black.

Page 2: [2] Comment [Dr.11] **Abdelmonem** **30.05.2011 12:54:00**

In order to be able to measure the scattered signal at 1° and larger in the forward direction, it was necessary to reflect the incoming laser beam from the optical axis away during measurement. To this end, a movable mirror (Elliptical Plano-mirror) is installed, which can be moved with a linear positioning device in the beam. The axial laser beam is reflected at the edge of this mirror toward a beam dump. Since the Forward detectors are placed a 200mm from the scattering signal, the 1° fiber is separated from the axial beam by about 3.5mm. Remembering that the fiber radius is 0.5mm and incoming beam is about 0.5 mm diameter, the coupled light from the axial beam into the 1° fiber is negligible. However, as mentioned in page 2894 lines 6 to 8, the measured scattering signal is normalized to the no particle event background on all channels.