**Atmospheric
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Interactive
Comment

Interactive comment on "Development of a bioaerosol single particle detector (BIO IN) for the fast ice nucleus chamber FINCH" *by* U. Bundke et al.

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Authors answer to anonymous referee # 2 We wish to thank the referee for his/her helpful comments which draw our attention to some points in the manuscript which needed to be elaborated more in detail.

General Comments:

RC: A new detector presented in the current report is based on well known principles, already successful implemented in commercial sensors (e.g. TSI UV-APS 3314).

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Advantage of the current design is its low impact on the aerosol sample, major part of which should be available for further analysis. Undoubtedly, this detector will be useful addition to the suite of instruments on FINCH chamber; however creditable and useful results can be expected only after scrupulous calibration and characterization of the detector. Unfortunately, current report presents examples, impressions, and some circumstantial evidence, which is not sufficient basis for evaluation of capabilities, limitations, and practicality of the detector.

AC: The BIO-IN Detector was specially designed to be coupled to the FINCH chamber, has to operate with high sample flow, and to be small, compact, and not too expensive. These criteria required some compromises. Therefore the capabilities and limitations of commercial sensors are certainly superior in the field of ambient aerosol sampling and size analysis. However, for FINCH only two information about the particles which pass the detector are relevant: is there a depolarization of circular polarized light (water/ice/not activated), and do they show fluorescence? An exact size calibration is for this purpose nice to have, but not necessary; we only need an estimate of the threshold size for the depolarization channels (as the trigger channel), which is lower than the size to which the ice crystals grow in the FINCH chamber. Our conservative (upper) estimate for this threshold is 3 μm and given in the text, which we believe, is sufficient to detect all ice crystals which will grow to sizes larger 5 μm diameter, depending on the temperature and relative humidity used in FINCH. We plan to do this extensive calibration in the near future: We are aware that we are not able to classify 100% particles of biological origin by their fluorescence correctly. For some biological particles the fluorescence could be below our detection limit caused by manifold reasons (now discussed in the text). Using the fluorescence method it is clear that the number of bio-particles detected is a lower limit. We did changes in the introduction and discussion section of the manuscript to clarify this.

Specific Comments:

RC: 2404/Abstract It will be helpful if the abstract was focused on current work rather than general discussion of state of IN research

AC: We changed the abstract accordingly

RC: 2405/29-2406/6 Any other compounds with similar fluorescent characteristics that could be a source of false signals? While NADH and derivatives may be good "biofluorophores", it is not quite clear, at least for non-biological reader, if they are good markers for all airborne bio-particles. Or they are good indicators for bacterial viability only (see discussion in Hairston et al., 1997). Please elaborate.

AC: We added some information about that in the introduction section of the manuscript.

RC: 2406/17-2407/4 This description of the FINCH optical detector seems to be excessive; interesting and inquiring reader is already referred elsewhere. However, it will be helpful if relevant features of the optical sensor are just listed here; such as laser wavelength, filers used, beam size, particle size sensitivity or range, etc.

AC: We considered the FINCH optical detector to be important because its scattering signal is used as the trigger for the fluorescence detection and its properties like the laser wavelength affect the capabilities of the fluorescence channel. However, we changed Figure 3 and added a Table listing all optical parts, their specifications and functions.

RC: 2407/22 Is light scattered on a particle at 35 deg. Used for normalization? Obviously, this signal depends on optical properties of the particle, particle position inside the laser beam, etc. Please elaborate

AC: This detection channel is mainly used for housekeeping data. We use the background signal of the not ideally focused beam (not the scatter signal of particles) in this channel for normalizing the signal to LED Power- which is necessary for size calibration in future work. Signals of scattered UV –light by particles detected with this channel are used for coincidence measurement and to check the alignment of the two different beams. We made some changes in the text to clarify that.

RC: 2408/15 Technically, flow rate in FINCH is about 60 LPM, it becomes 6 LPM after the virtual impactor

AC: We changed the text accordingly

RC: 2408/19 The test aerosol was composed of two kinds of particles of the same size – 10μm. Why are the particles in question different? Is it possible to estimate and/or compare sizes of both particles from the scattered signal?

AC: According to the general specifications of the distributor only the test particles smaller than 1,5 μm are monodisperse and non porous, while the larger have a porous surface and a wider size distribution. So one cannot expect them to have exactly the same size. The 10μm must be considered as an average size.

RC: 2408/22-2409/8 Please show "frequency histograms" in question. It would also be helpful to present scatter plot similar to Fig. 8

AC: We added these three figures.

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RC: 2409/13 Comparison with Huffman et al. seems to be nonsensical: 100 Minute measurement with unspecified size range is being compared to 4 month data set obtained in a different large city

AC: Mainz and Frankfurt are both located in the same metropolitan area called the Rhein-Main area in a short distance of less than 30 km. Thus a comparison is definitely not nonsensical but necessary. Now the question is which data set of Huffmann et al is comparable to our results. Here the coarse mode (particles larger 1μm (Huffmann et al.)) data seems to be the best of choice data set for comparison. With this comparison we want to express that our first result on ambient aerosol seems to be reasonable, because it is not far from the typical values Huffman et al. found in his long period measurement. We agree with the referee that the time base of the average value of 6 month is not the best choice. Thus, we changed the manuscript accordingly now using the 95% and 75 % Quartiles based on 5 min average values reported by Huffman et al.

RC: 2409/17-22 Please substantiate (hidden) assumption that fluorescent particles are the largest in population

AC: We do not assume that. We changed the text phrase to clarify.

RC: 2409/23-25 Another possible explanation is: because of beam misalignment the particle may have crossed one beam through the center and the other one on periphery, hence the difference in the signals

AC: This explanation seems reasonable, but we can exclude it for this particular case. The signals in both graphs have typical half-widths. If the particle would have passed only through the periphery of one beam, it would be illuminated for a shorter time, and the half-width of the corresponding signal would be smaller.

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This is not the case. Only the detection time is shifted. This is a good indication that both beams are only misaligned in the vertical direction. This was also found checking the alignment after the measurement.

RC: 2410/5-8 Not relevant here because it is not a result of the current work

AC: We wrote these sentences to mention the scientific background, and why the FINCH BIO IN detector could be helpful to clear up an open scientific question.

RC: 2410/15 Percentage could be misleading since "coarse mode" is not specified and size estimate (3μm) is questionable

AC: The percentage is just the ratio of: fluorescent particles detected vs. all particles detected. We changed the text accordingly to clarify this and underline that the size threshold estimate is a first estimate.

RC: 2410/Outlook It is a bit surprising, hat no tests, calibrations, comparisons with similar instrumentation are planned

AC: We definitely plan more tests and changes to improve the signal/noise ratio. Surely we also would like to make a comparison with the TSI UV-APS 3314. We are in close cooperation with the group of Ulrich Pöschl where the work of Huffmann et al was made.

RC: 2410/20 Power ratings of the laser in the cited paper is 30mW, while TSI data sheet for UV-APS (model 3314) lists UV laser as 80mW at 355nm; both values are much less than 250mW of the current design

AC: The raw output powers of the UV sources are absolutely not comparable. Using the LED we lose approx. 80% of the original power by fiber coupling, collimation lenses and the emission filter (see also new Table 1). Moreover, a laser is monochromatic, much more collimated than a LED, causes less background light (which corresponds to better the S/N ratio), can be operated in high-power pulsed mode (like in UV-APS 3314), and can be focused to a much smaller spot. Therefore the particle is exposed to a higher radiant flux density, which makes a laser much more favorable for excitation of fluorescence. But one should mention that a solid state UV laser of this power level is much more (Factor 15) expensive than the LED, needs additional cooling, and an explicit high voltage power supply. In addition, the high sample flow rate of the FINCH demands a larger beam diameter and correspondingly a larger focus.

The advantages of the LED are its low cost, little weight, less power consumption and no need for additional cooling.

RC: 2420/Fig 6. Is Beam misalignment corrected here? Signals from depolarized channels for second particle show substantial difference – why? It is supposed to be spherical silica particle.

AC: In this case the beams have been aligned shortly before the measurement. We attribute the differences in the depolarized channels to the porous particle surfaces reported by the manufacturer specifications.

RC: 2422/Fig.8 Which scattering channel was used here? There are three different markers and un-annotated thick line on the plot – any special meaning?

AC: We displayed the sum of both scattering channels, which represents the total scattering signal from the individual particles and is also used as trigger for

detection. The thick line at 0,004 is the 5- sigma separation we used for discrimination between fluorescent and not - or very low fluorescent particles. The different markers are an artifact from conversion between graph formats. We have added a revised figure.

Technical corrections:

RC: 2404/20 Morris et. Al. 2008 is missing in the References

AC: Sorry for that! We solved the problem in the End-Note data base. Now it appears in the References.

RC: 2406/20 Subscript: P44/P11

AC: Corrected

RC: 2421/Fig. 7: Incorrect capitalization in "x-axis"; if V means V, then labels on Plots should be accordingly, 25 samples at 200kHz is 25μs

AC: We corrected that.

RC: 2422/Fig. 8: "Signal PM" and "Signal PD" are not referred either in caption or in the main text

AC: PM and PD means photomultiplier (fluorescence) and photodiode (scattering). We changed the figure captions

Interactive comment on Atmos. Meas. Tech. Discuss., 2, 2403, 2009.