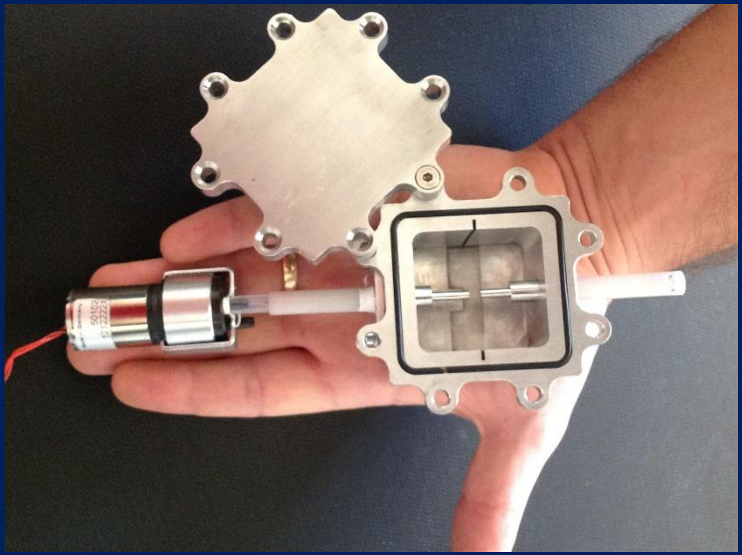
Monitoring the atmospheric dust on Mars: the MicroMED sensor



Exomars Atmospheric Science and Missions Workshop

Saariselka, Finland, 26-30 March 2017

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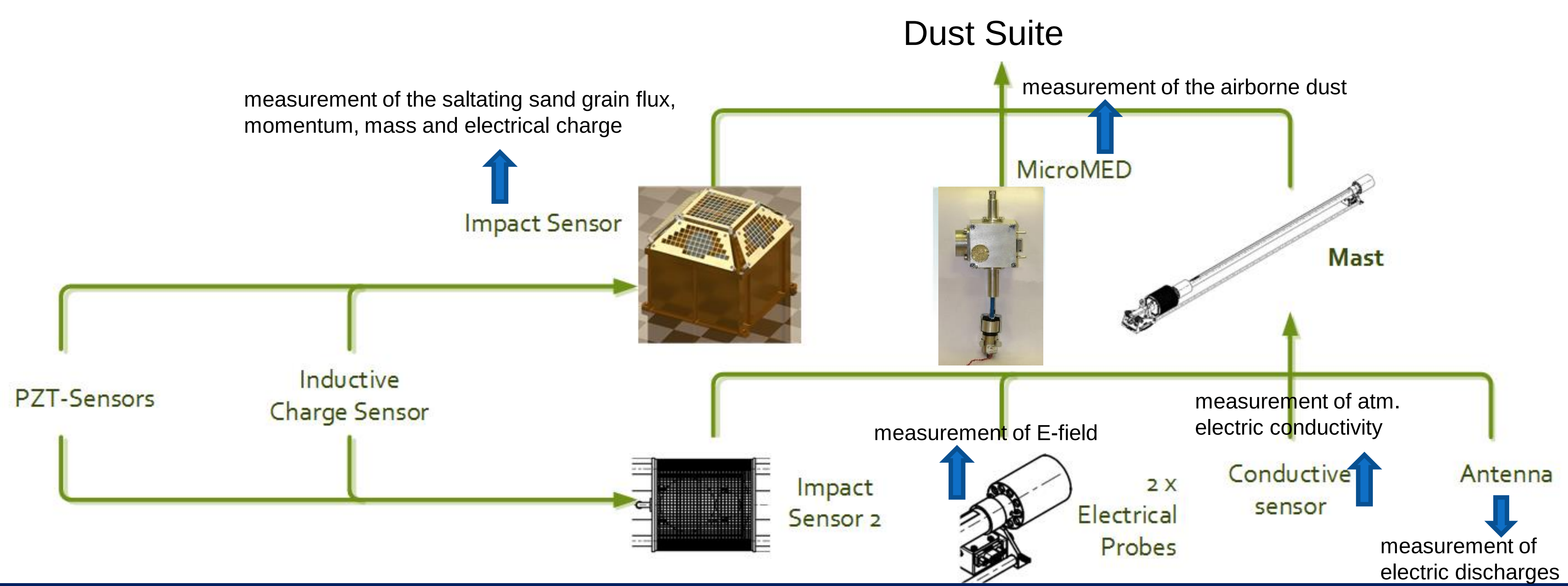
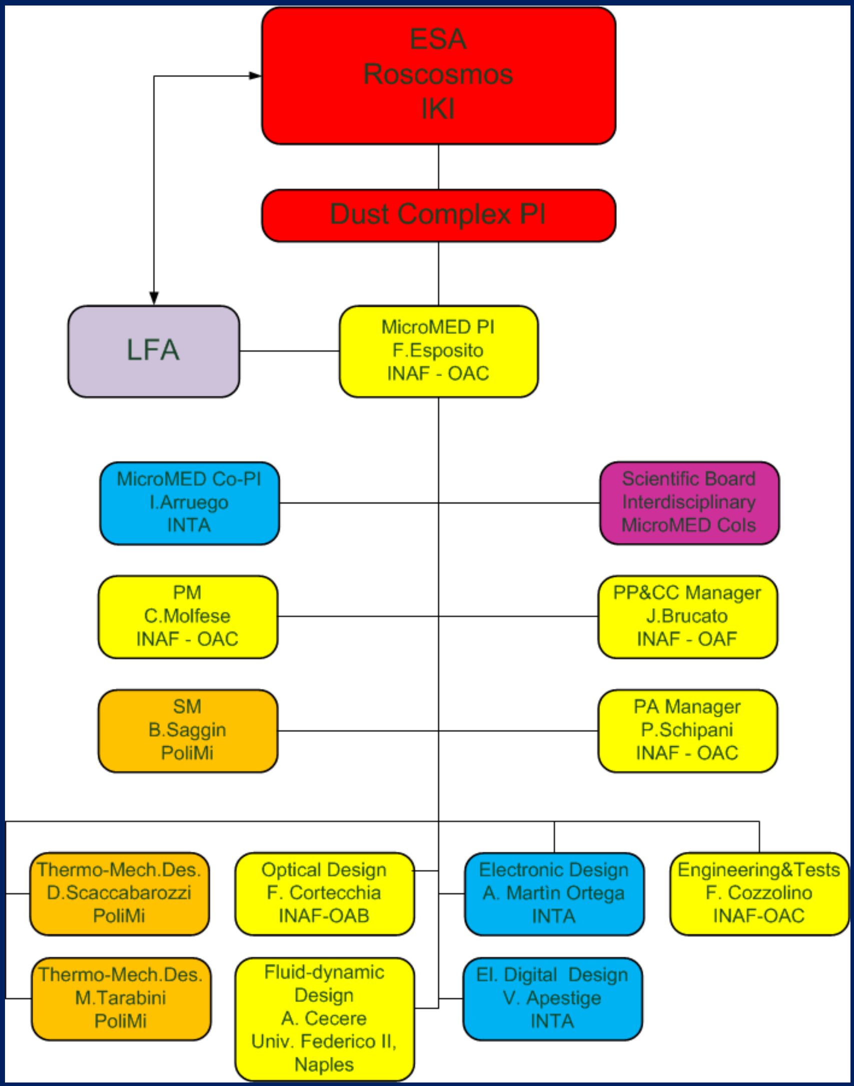
MicroMED is a sub unit of the Dust Suite Instrument – Surface Platform – ExoMars 2020

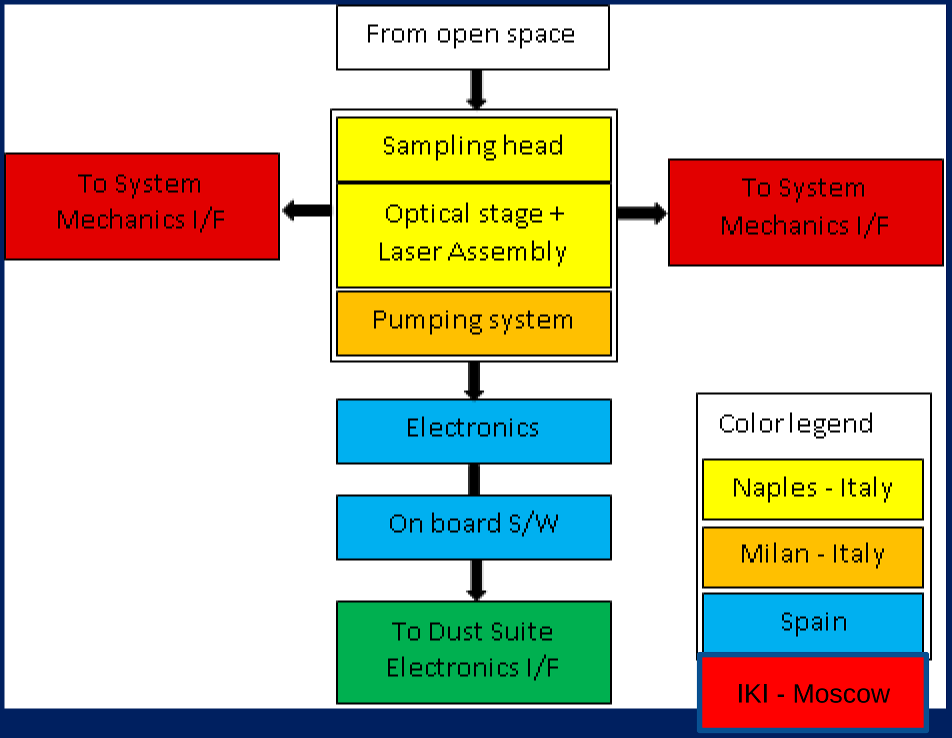
The Dust Suite is a suite of sensors devoted to the study of Aeolian processes on Mars. It includes 3 units.



Team organization & Funding scheme

Block diagram of MicroMED instrument





LFA: Regione Campania through ASI

Dust in the atmosphere of Mars

Martian atmosphere contains always a significant load of suspended dust

Airborne dust has important effects on morphological evolution of the surface.

Moreover, airborne dust severely impacts on the climate of Mars, influencing the thermal behaviour of the troposphere.

- Indeed, dust absorbs solar irradiation mainly in the VIS (re-emiting it in the IR), locally warming the troposphere.
- Even in case of moderate dust scenario, the influence of dust on Martian thermal structure is critical, while during global dust storms > 80% of sunlight is absorbed by dust.

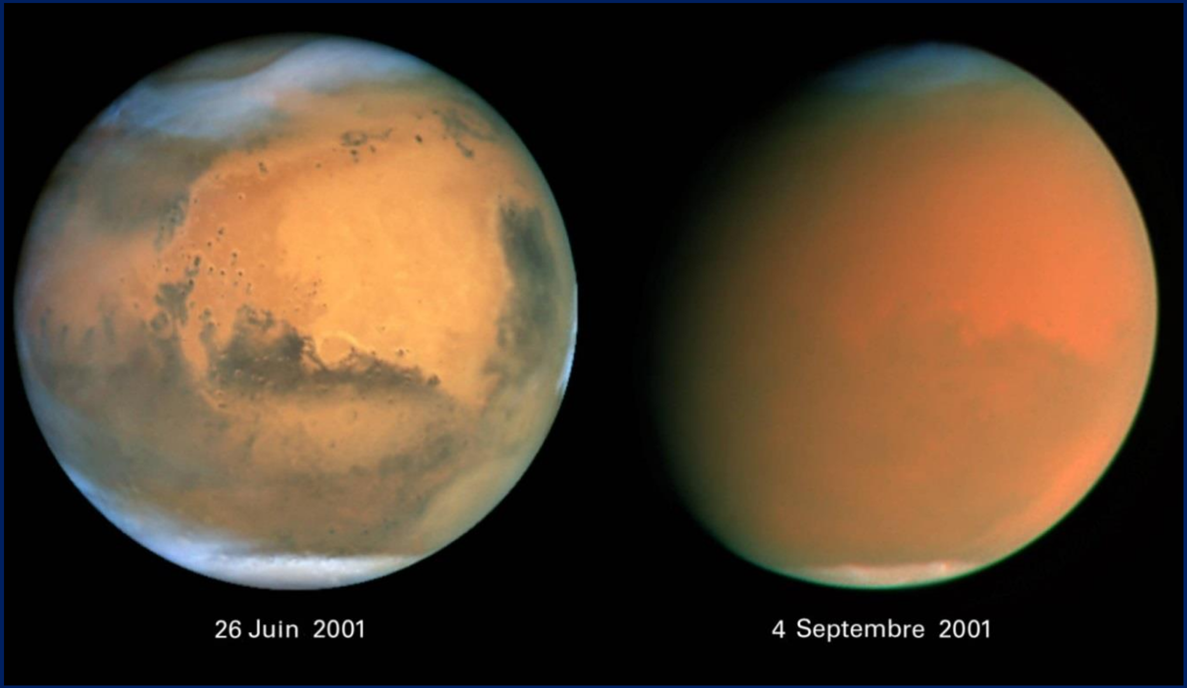
The amount and size distribution of dust in the atmosphere is controlled by lifting processes and wind transport.

Dust in the atmosphere of Mars

Up to now, mechanisms for dust lifting and feedbacks on the atmospheric circulation are not well understood.

As an example, the irregular occurrence and mechanisms for the growth of global dust storm are not explained by models.

In order to understand and proper model Martian atmospheric circulation and meteorology it is necessary to understand how dust is lifted and maintained in the atmosphere and which is the amount and size distribution of the lifted dust.



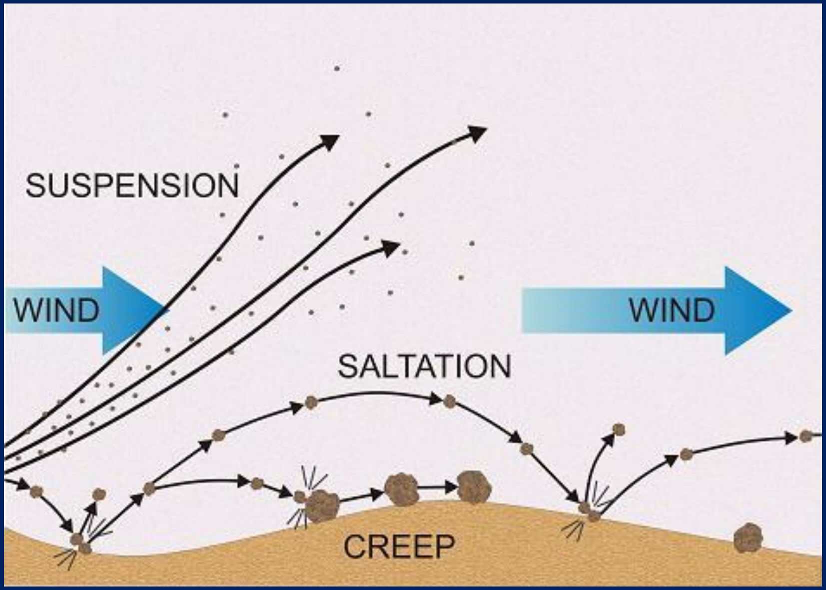
Dust in the atmosphere of Mars

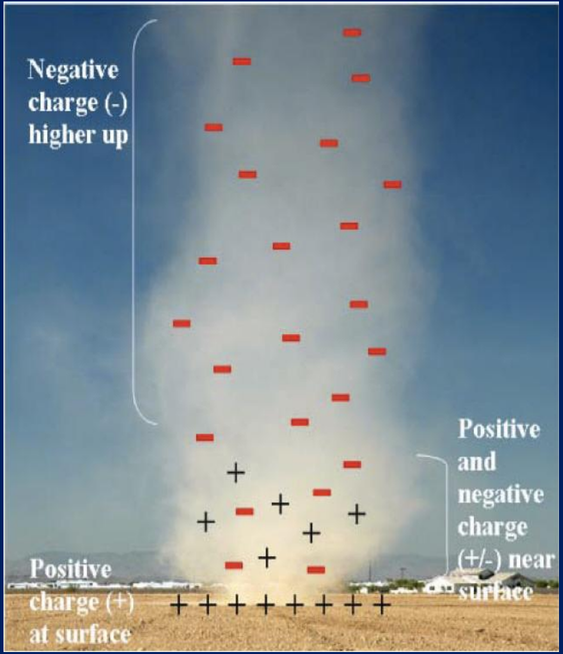
Mechanisms for dust entrainment

Dust on Earth is generally emitted due to the drag force of wind.

As wind speed increase, sand particles of ~ 100 μm size are first moved by fluid drag.

After lifting they hop along the surface → saltation





Saltation can mobilize particles of a wide range of sizes (splashing, creep, suspension).

During saltation sand and dust particles collides each other and with the surface causing charge transfer among them.

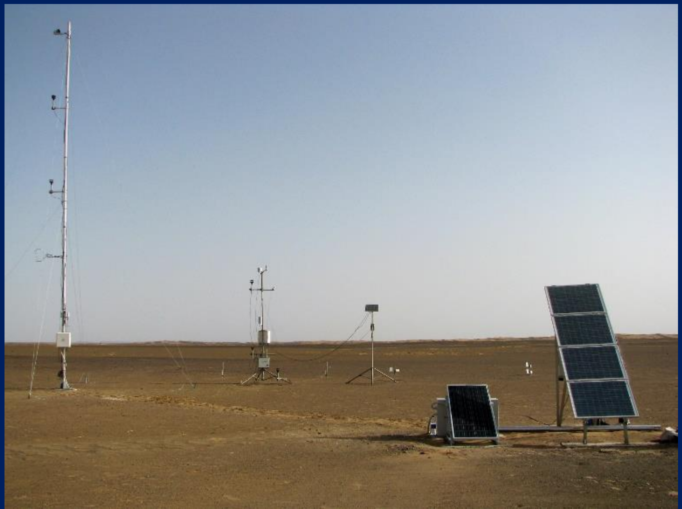
Charge separation produces intense E-field.

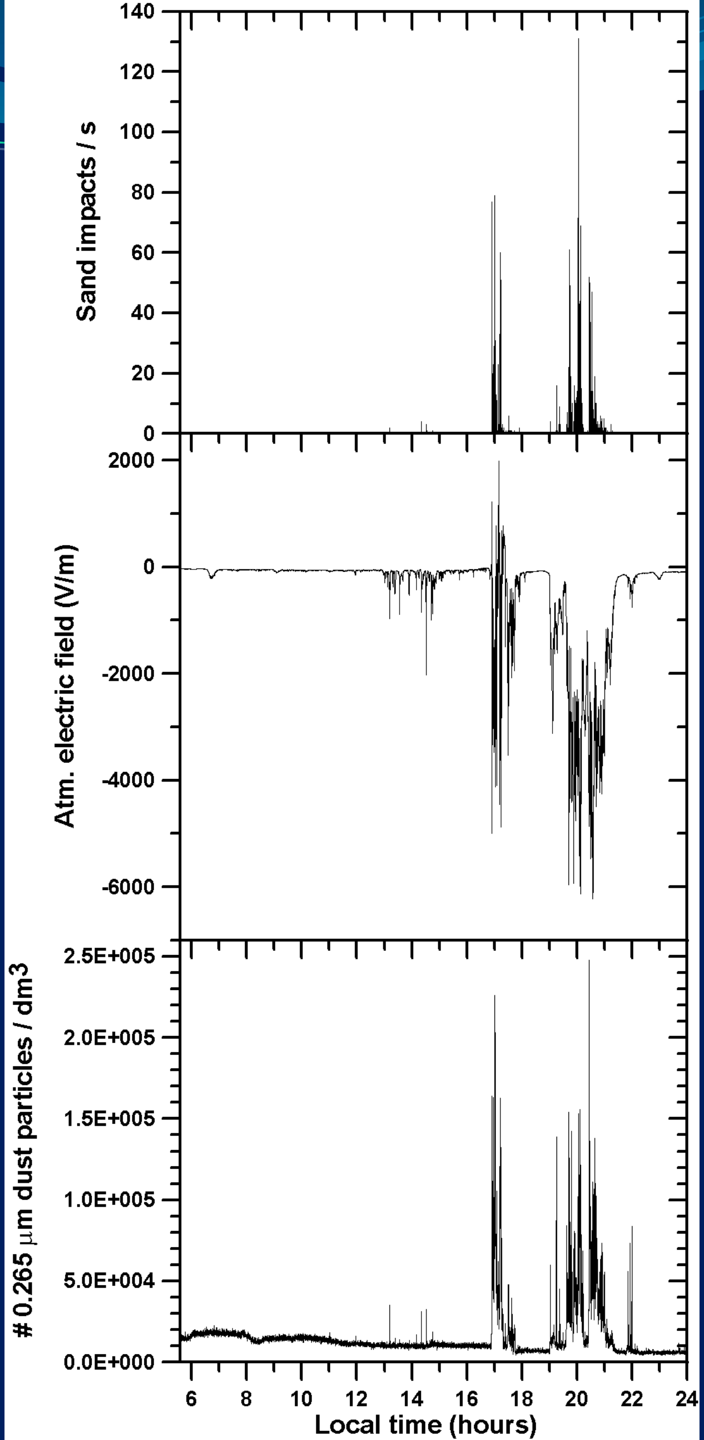
The same process is expected on Mars

Field campaigns in the Moroccan desert

Data acquired show a large enhancement of the atmospheric electric field during dust storm events.

Strict correlation with the increase of lifting of fresh dust.



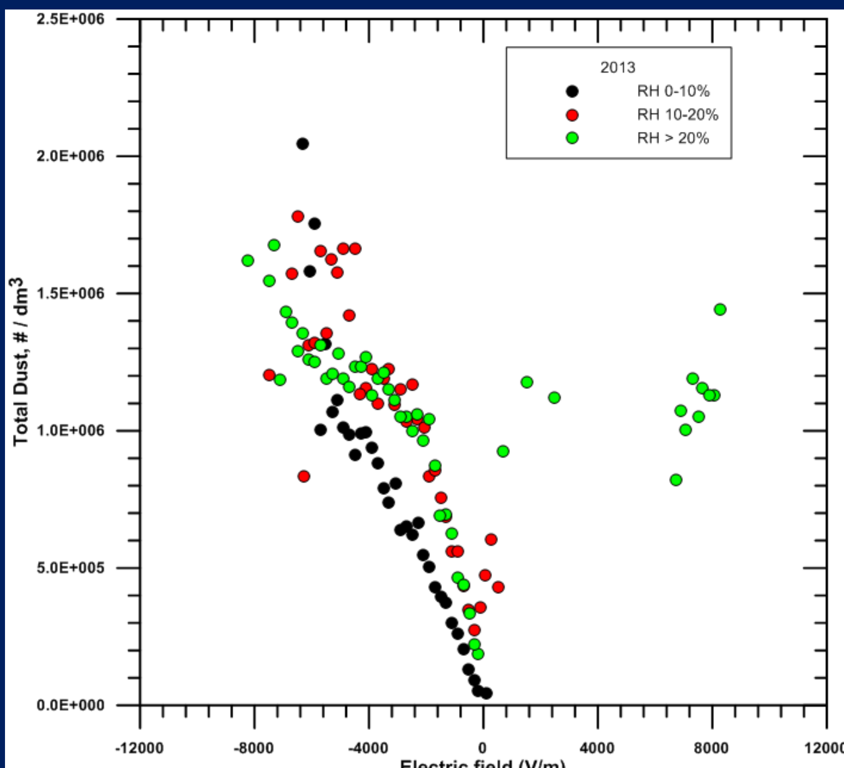


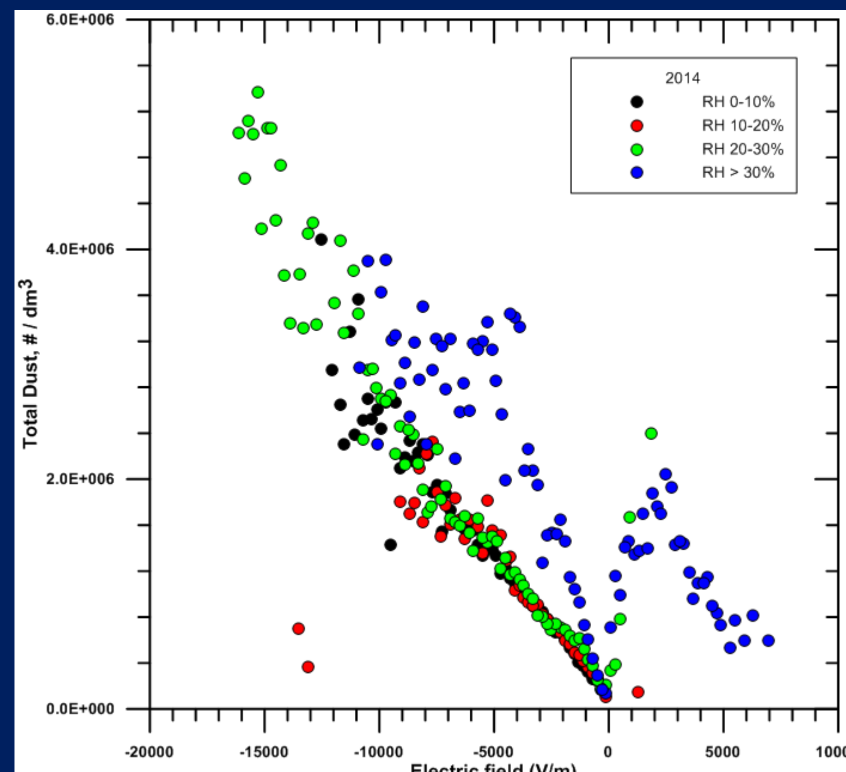
Dust lifting process and particle electrification

Relative Humidity as a key parameter in dust lifting process

The critical value changes with soil moisture.
Average soil moisture in 2013 and 2014 measurement sites:

Soil moisture in H2O Vol / Soil Vol	2013 meas. site	2014 meas. site
	0.49 ± 0.03	0.067 ± 0.010



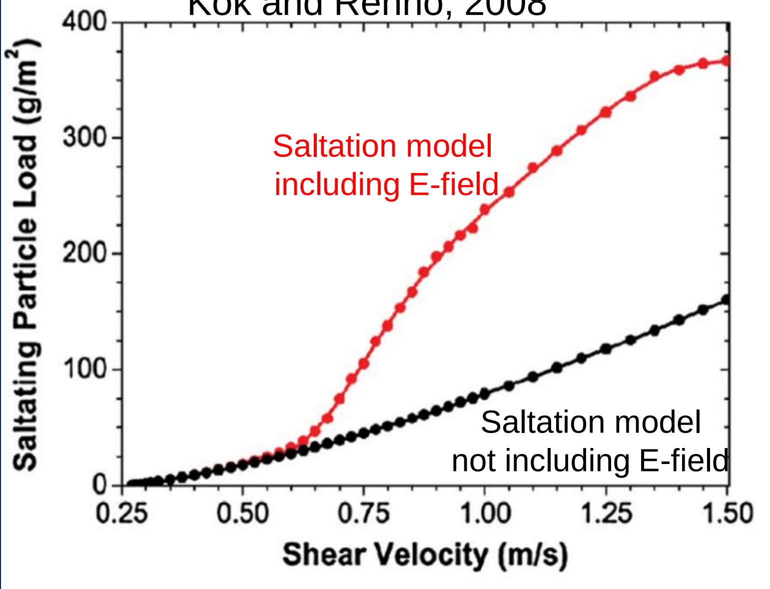


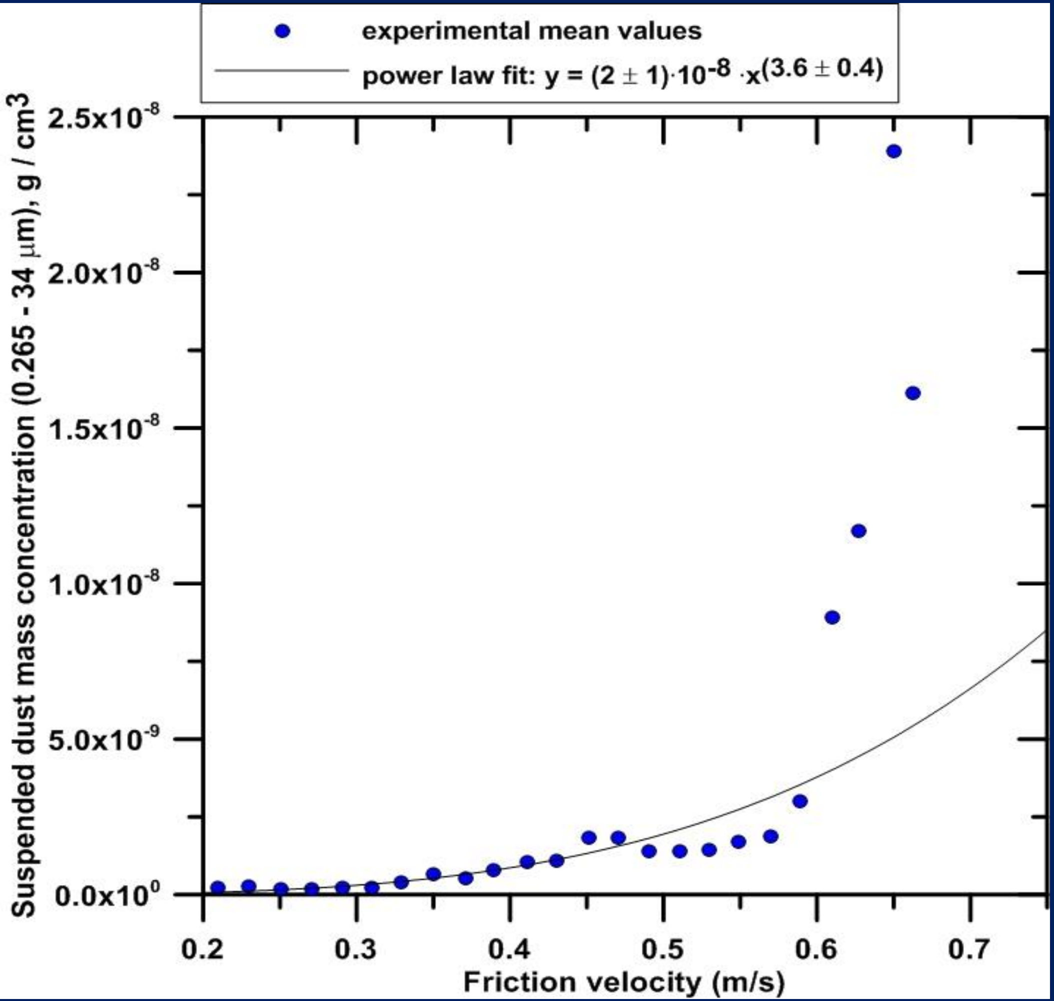
Dust lifting process and particle electrification

Feedback of E-field on saltation process

Observed an abrupt increase in emitted dust at high u*.

Kok and Renno, 2008

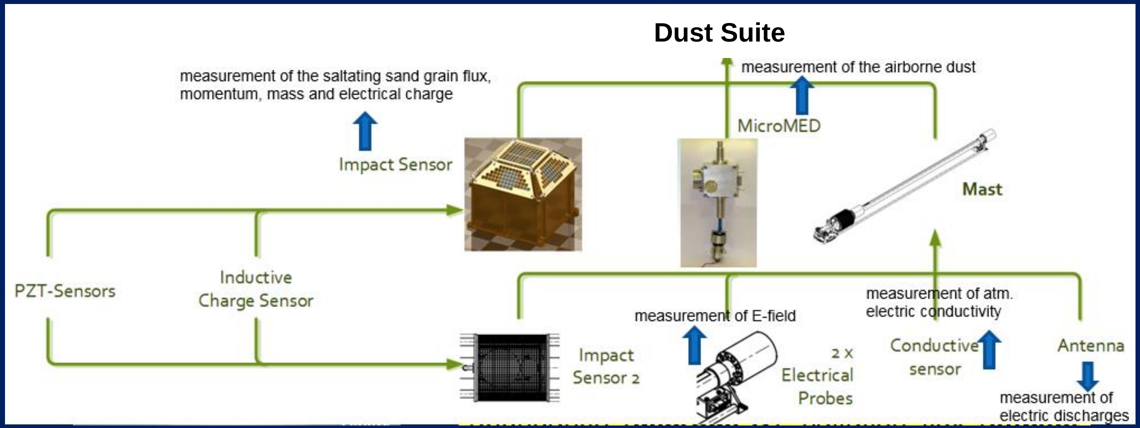


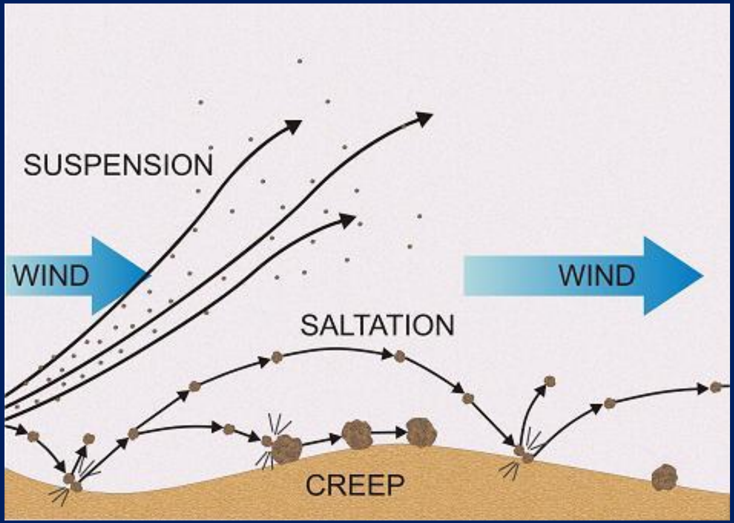


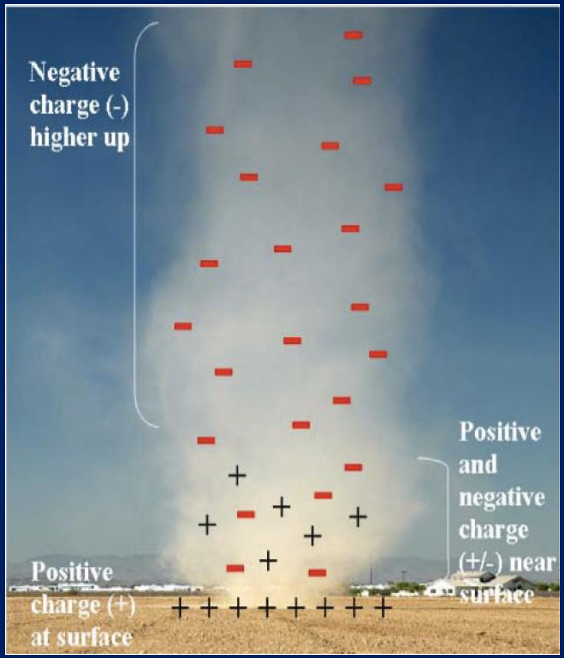
Field data – Esposito et al., GRL 2016

Dust in the atmosphere of Mars

Mechanisms for dust entrainment







The Dust Suite will help in understanding dust lifting process by monitoring (daily and seasonally) airborne dust granulometry and abundance (**MicroMED**), saltation flux (**Impact sensors**) and the role of electric field in dust lifting processes (**Electrical Probe**).

Strong synergy with Meteo Suite

Dust lifting process and particle electrification

Applications to Mars

• Few wind measurements have been performed from landers on Mars.

• These have shown that the light Martian atmosphere **rarely** exceeds the saltation fluid threshold (also confirmed by the results of mesoscale and global circulation models).

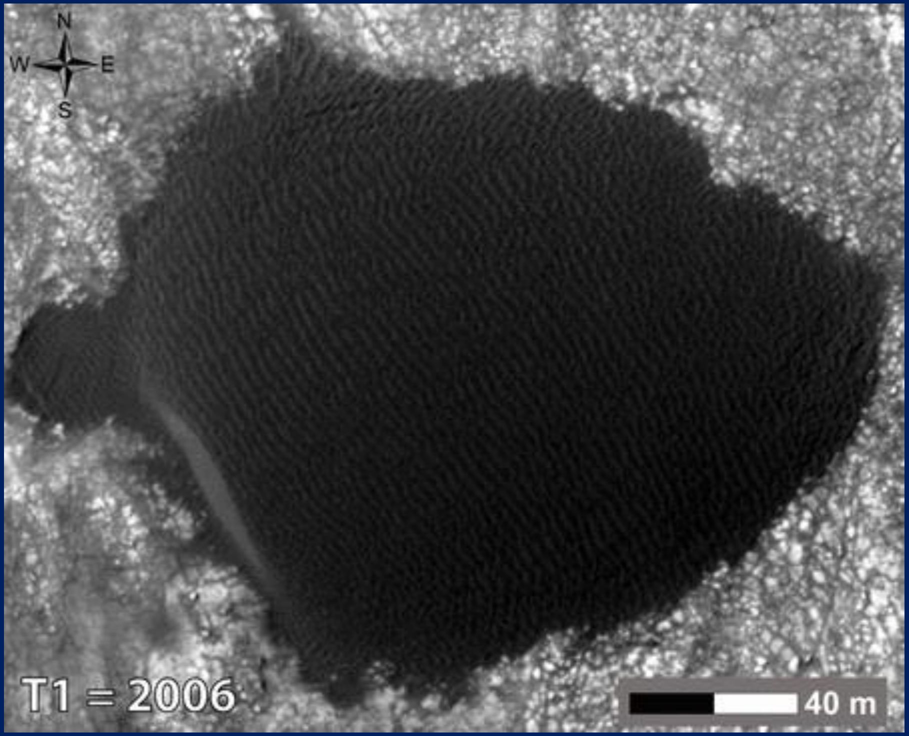
• The ubiquitous sand dunes on Mars appeared almost motionless by lander and orbiter observations, and were supposed to be formed in a previous climate, in a thicker atmosphere.

Dust lifting process and particle electrification

Applications to Mars

• Recent observations by high resolution images (e.g. HiRISE) have revealed widespread movements of dunes and ripples at many locations on Mars.

• Results show that the Martian thin atmosphere blows sand in this dune field at rates not much lower than Earth's much thicker atmosphere does on terrestrial dunes.



Silvestro et al., *Geology*, 2013

Dust lifting process and particle electrification

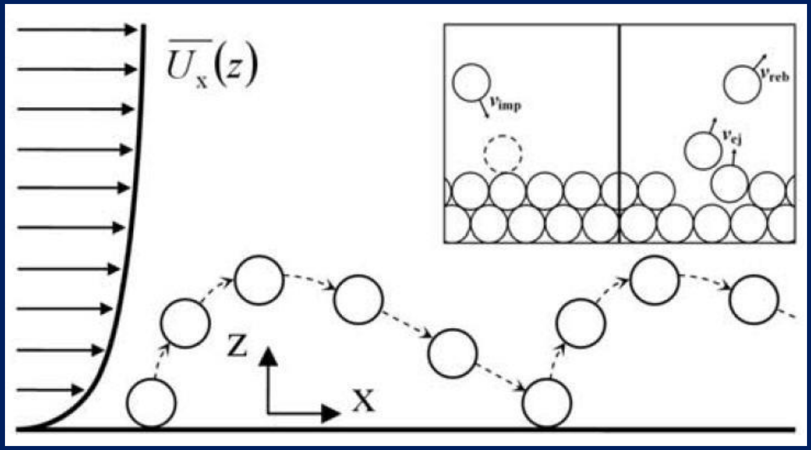
Applications to Mars

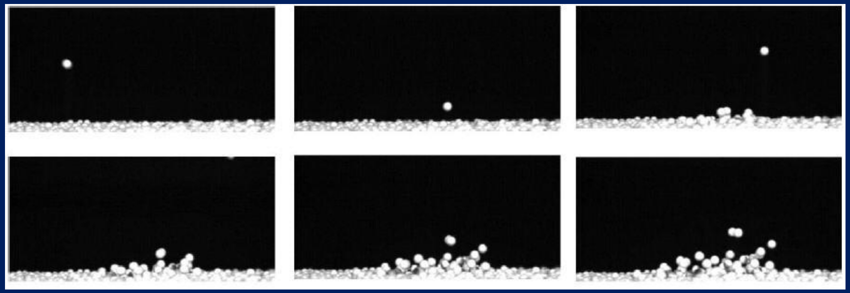
• This could be explained by the recent results that, once initiated, saltation can be sustained down to speed of only 10% of the initiation threshold, thus allowing saltation to occur at << wind speed.

• On Mars lower g and air density imply that grain trajectories are higher and longer than on Earth → grains are accelerated by wind for longer time → impact threshold $u^*_{t\_impact}$ comparable with that on Earth.

• But lower air density → higher fluid threshold on Mars (~ 1 order of magnitude)

• → The ratio of impact to fluid threshold on Mars is lower (10%) than on Earth (80%).



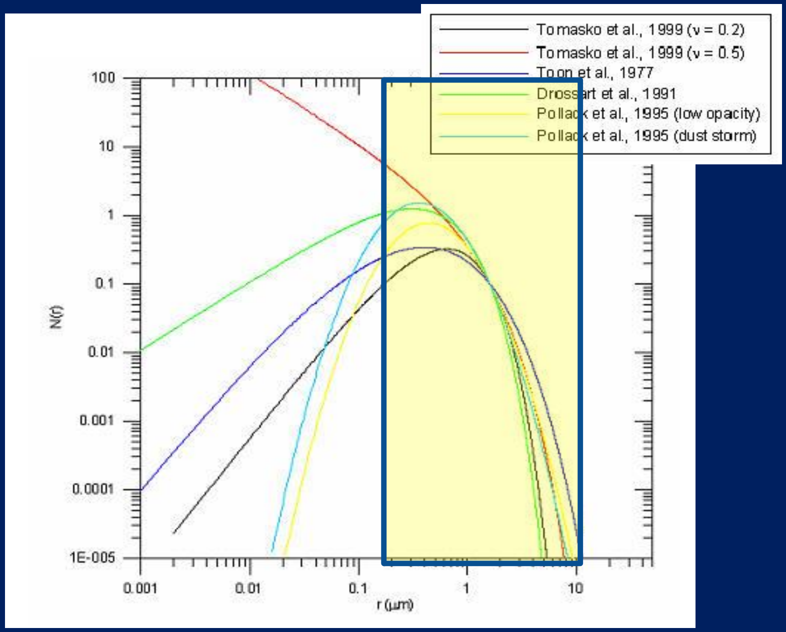


MicroMED:
Physical quantities to be measured

The scientific goal is the characterisation of airborne dust properties close to the Mars surface.

Measurements concern with the following physical quantities:

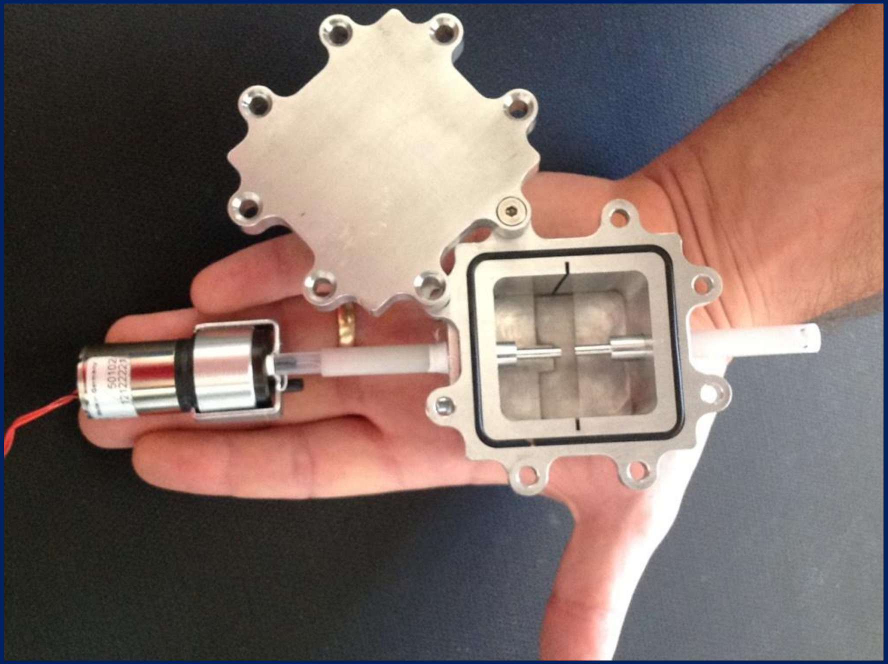
- Atmospheric dust particle size distribution (single grain detection) in the range 0.4-20 μm
- Number density of particles vs. size
- Time evolution of the former quantities, vs. short (e.g. gusts, dust devils, dust storms) / local events and long term variations (daily, seasonal)



Instrument concept:
From MEDUSA to MicroMED

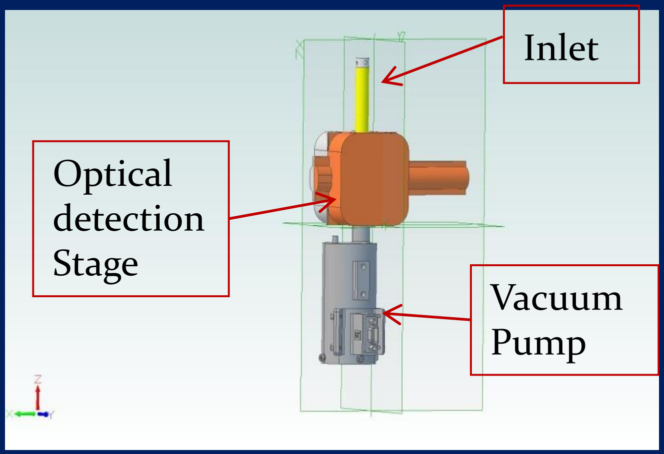
MEDUSA BB for ExoMars Humboldt

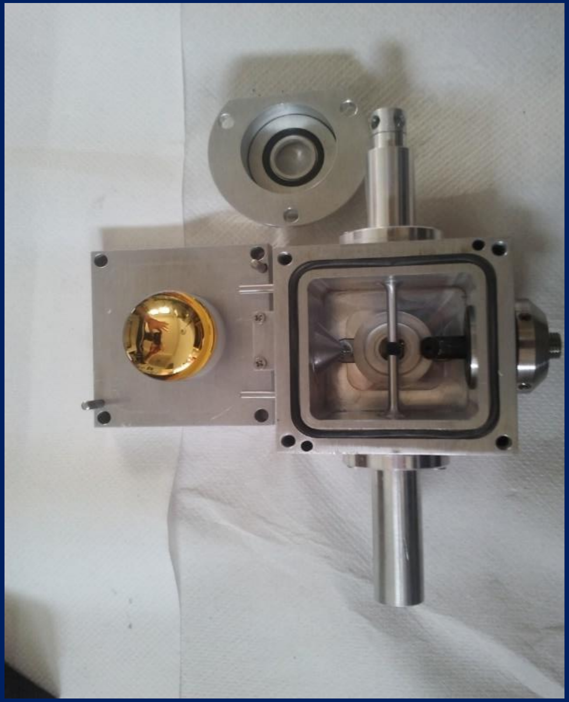
MicroMED BB for fluid-dynamics tests

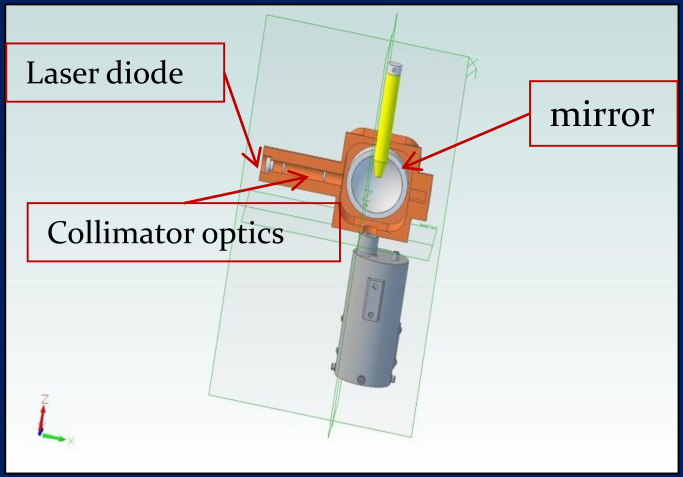


2243 g → **< 500 g**

MicroMED configuration







MicroMED BreadBoard Envelope 190 x 70 x 147.5 mm^3

MicroMED fluid-dynamic design

Inlet and outlet shape design, sampling rate, sampling volume and air and dust flow section have been designed in order to be compliant with the following technical requirements:

- to have a small fraction of coincidence *f* (e.g. < 0.05), in order to have a single particle counter, and a large number of particles detected in a short time (120 s)

- to concentrate the dust and air flux in a small area (e.g. 1×1 mm^2) coincident with the sampling volume generated by the laser beam

- to avoid turbulence inside the instrument

- not to alter the size distribution and volume density of sampled dust particles

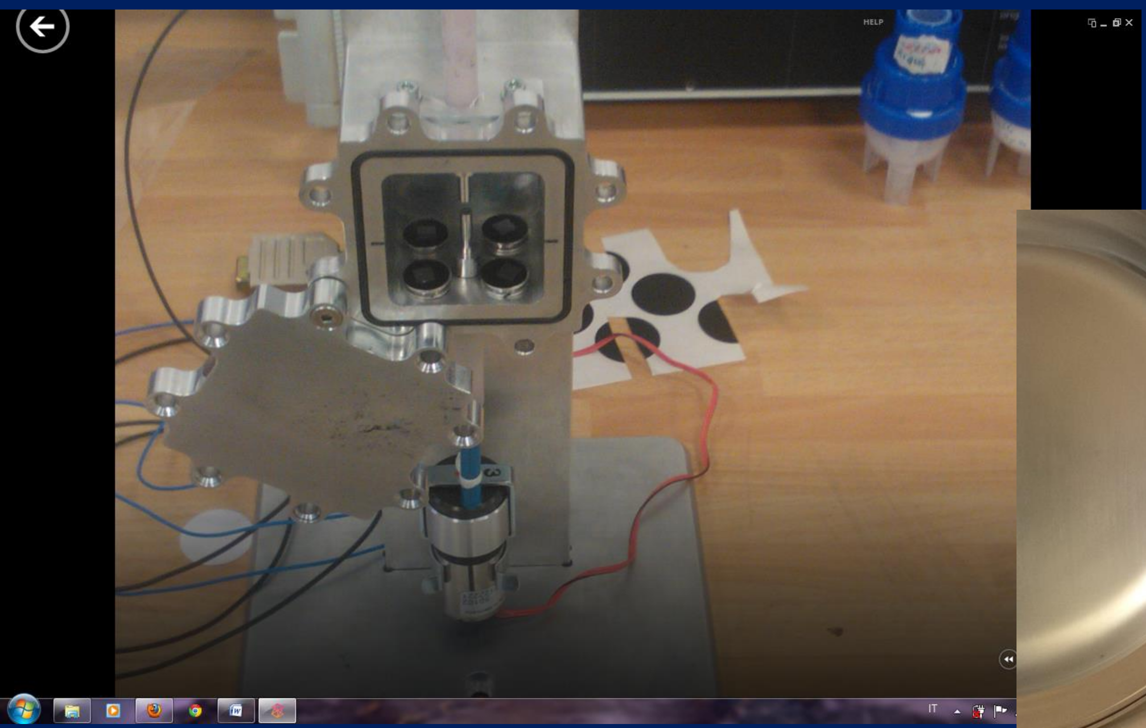
- to be able to sample particles with size ≤ 20 μm

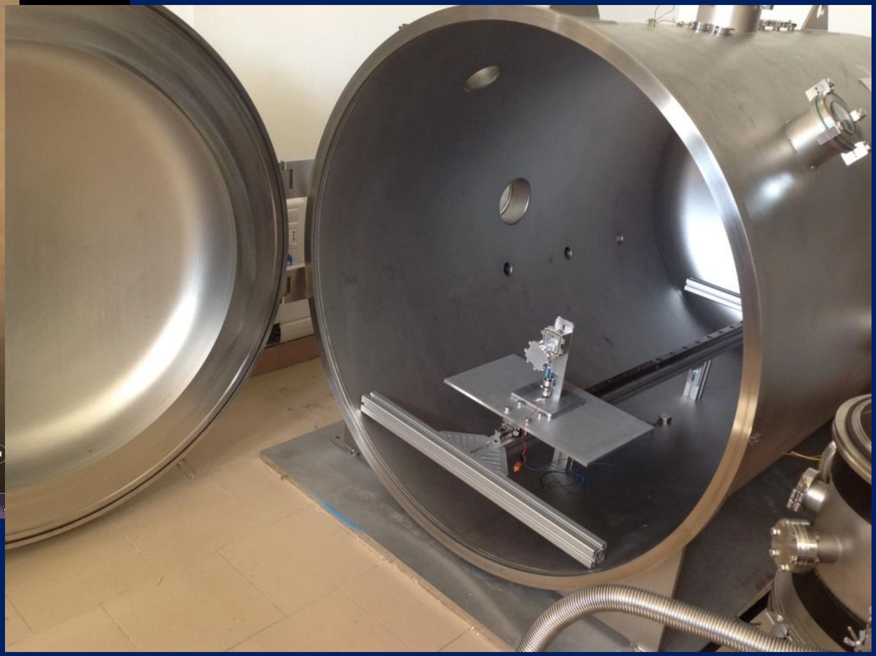
- inlet and outlet tubes protruding inside the MicroMED body shall not be invasive: they shall not intercept the laser beam, nor produce shadow on the mirror or detector.

MicroMED fluid-dynamic design

Fluid-dynamic design has been tested in a Martian simulation chamber.

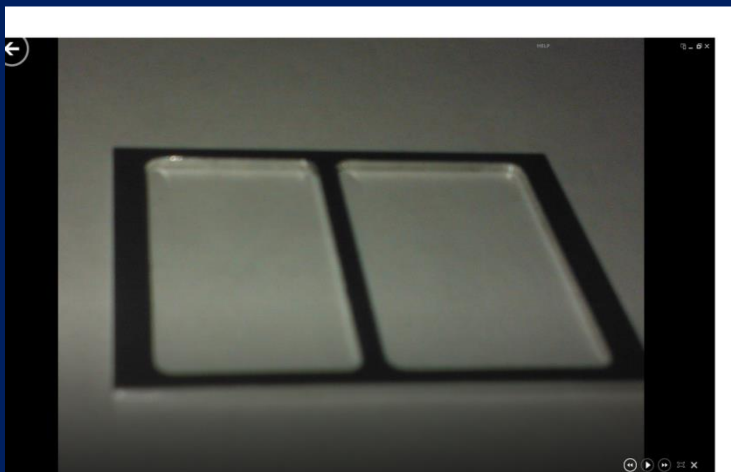
Tests results show that particles captured by MicroMED are conveyed in a section 1 x 1 mm^2 perpendicular to the flow, as predicted by Fluent simulations.



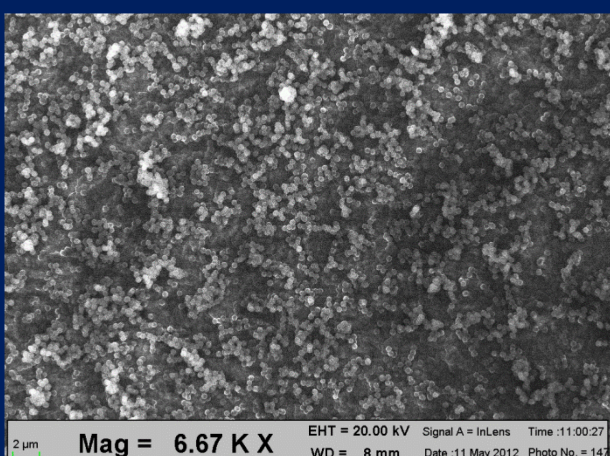


MicroMED fluid-dynamic design

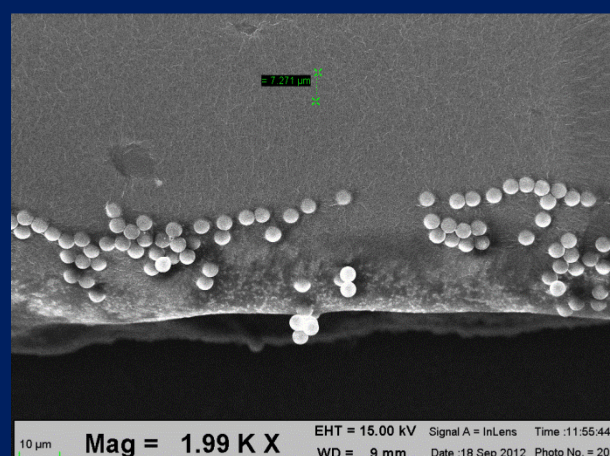
Experimental set-up



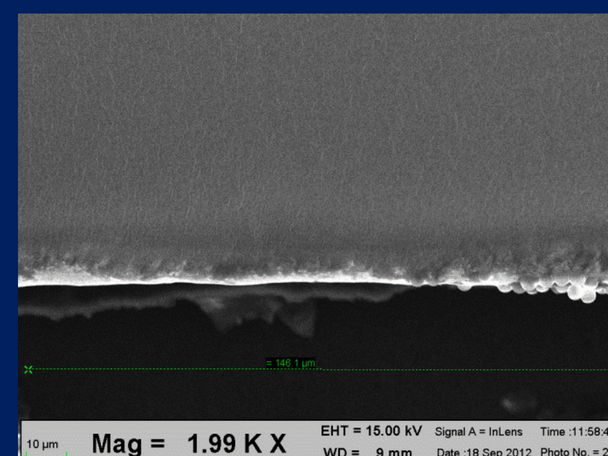
Inside sampling vol.
0.4 mm from the centre



At the edge of sampl. vol.
0.5 mm from the centre



Outside sampling vol.
0.6 mm from the centre



MicroMED optical design

Optical design is driven by the following requirements:

- To concentrate the laser beam in a small area in order to obtain high power density with a low power laser

- To produce a beam with uniform intensity inside the sampling volume (in order to avoid that the same particle could produce different signal if intercepting the beam in different points)

- To be able to detect particles in the size range 0.2 – 10 μm in radius

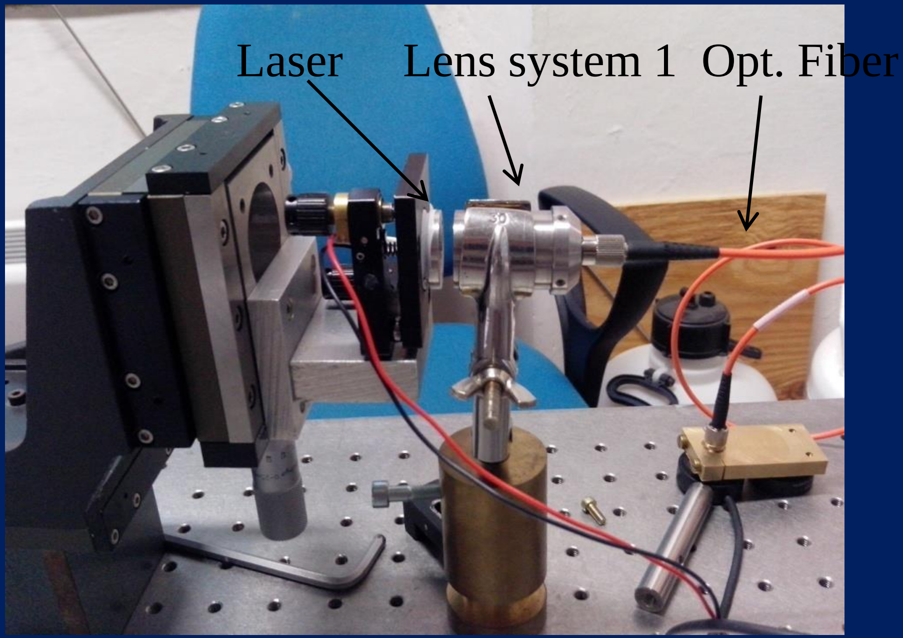
MicroMED optical design

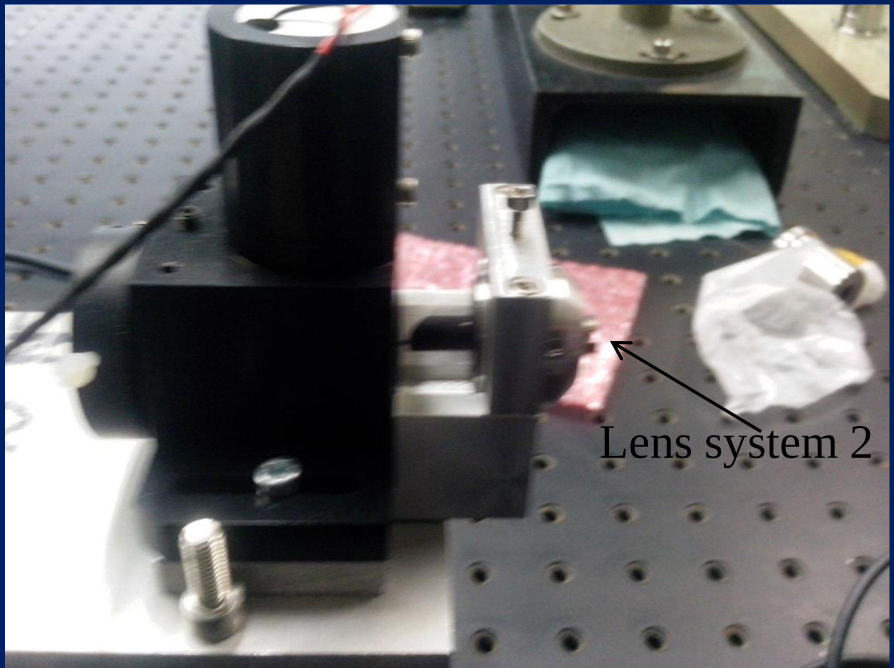
The Optical Stage has been built and it consists of :

- Lens system (1) for the collimation and focusing of the laser source into the optical fiber - this system shall be placed in a warm environment inside the lander.

- Optical fiber

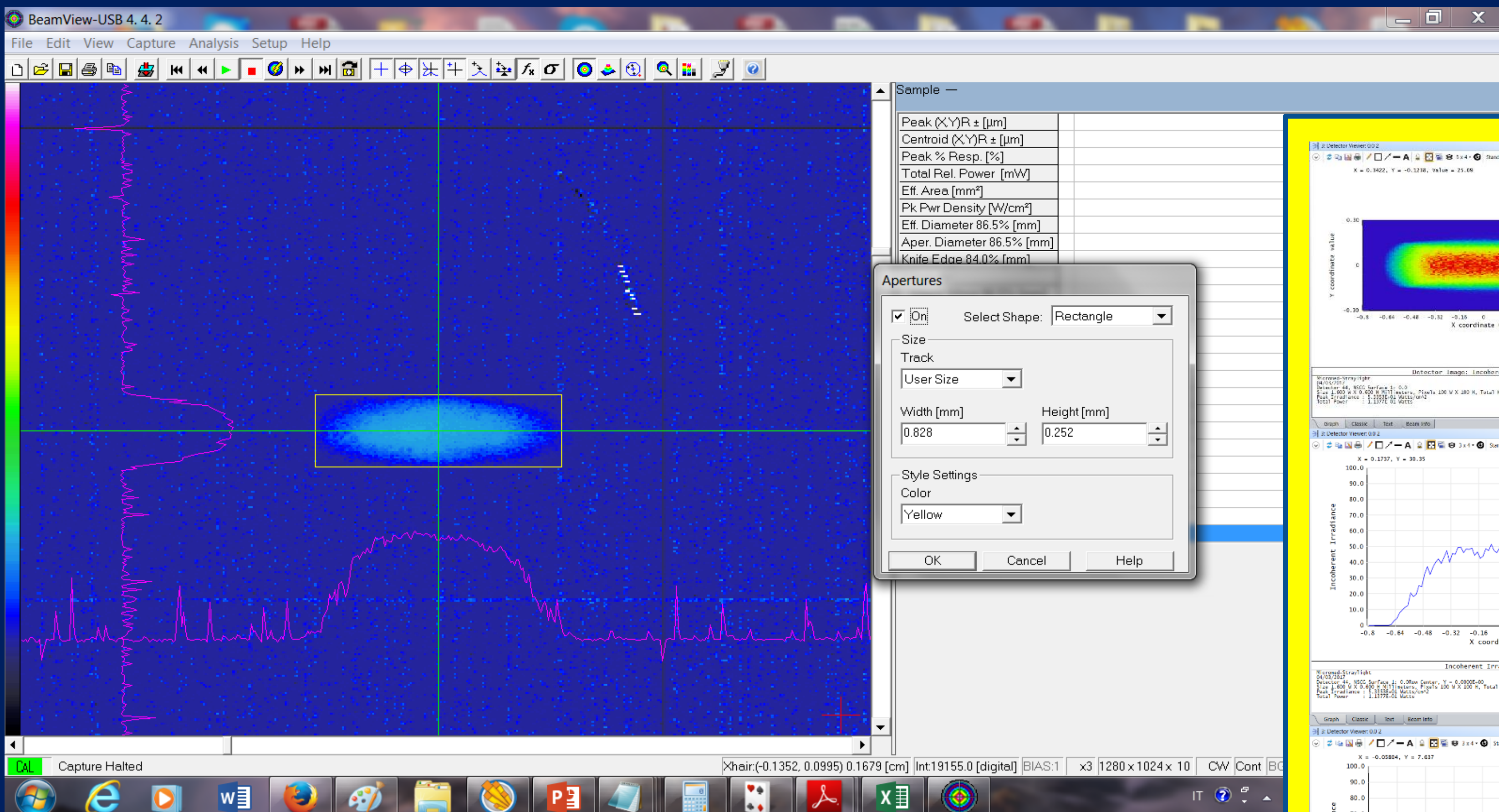
- Lens system (2) for the focusing of light from the optical fiber into the sampling volume – this system is inside the MicroMED body.

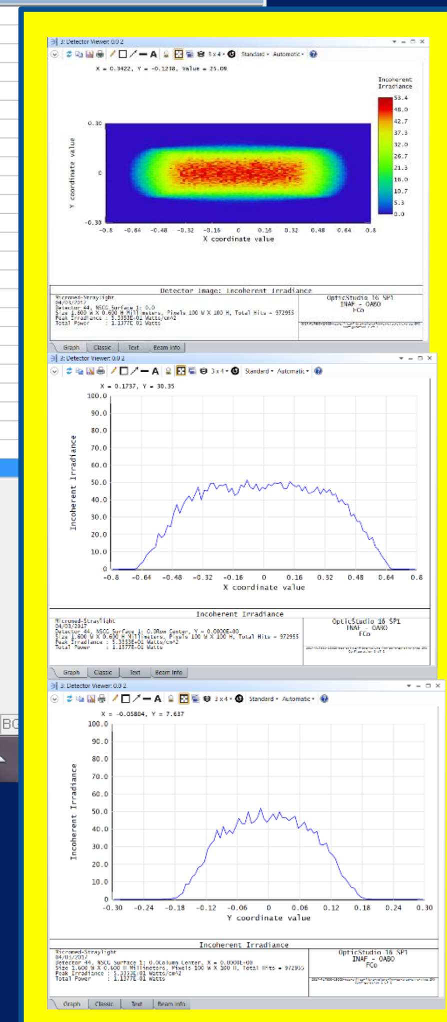




MicroMED optical design

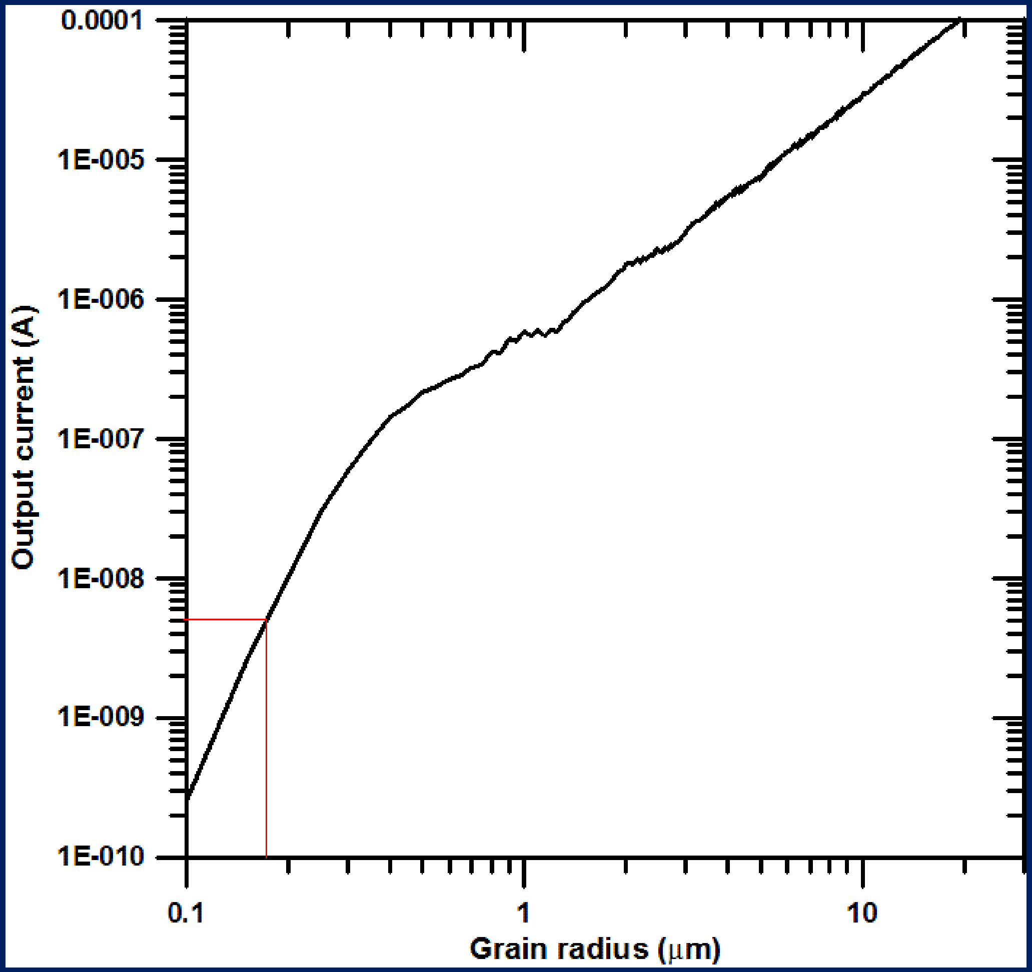
Test results: profiles of the sampling volume

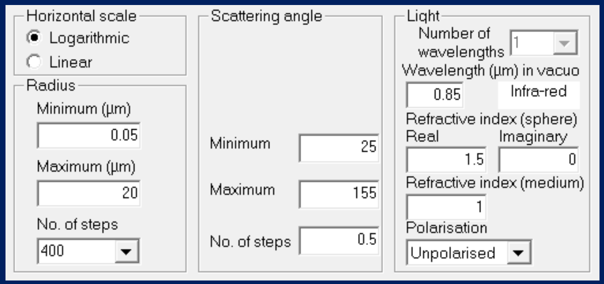




The shape is similar to the one predicted through Zeemax simulations.

MicroMED: performances evaluation
Signal vs. size





Scattered light

Evaluation considering:

- Spherical dust particles (Mie theory)
- optical power: 150mW
- angle of collected scattered light: 130°

Minimum detectable dust particle size:
< 0.2 µm in radius

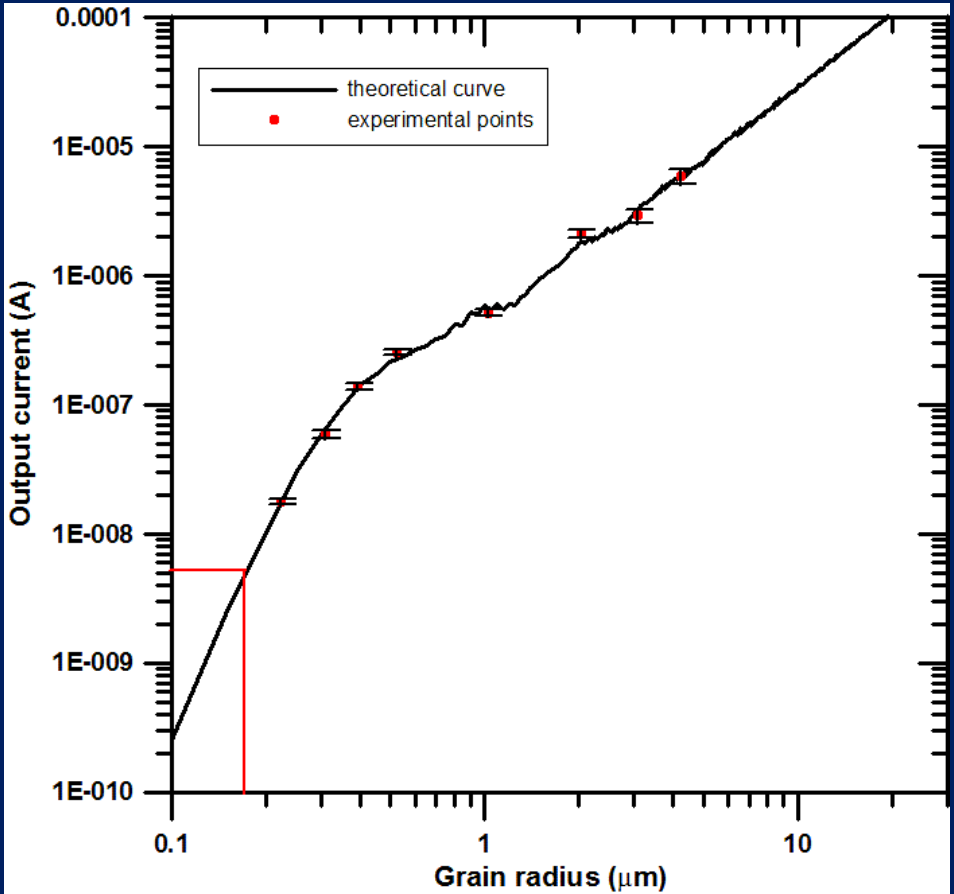
Coincidence fraction $f = 1.2 \cdot 10^{-4}$ in constant haze and $4 \cdot 10^{-3}$ during dust devils

MicroMED: performances evaluation
Signal vs. size

Optical System is ready and aligned.

OS has been integrated in the MicroMED Breadboard.

Performance have fully demonstrated instrument performances.



Conclusions

- MicroMED is an optical particle counter able to measure the size distribution and number density of dust particles suspended into the atmosphere of Mars.
- It is part of the Dust Suite on-board the Surface Platform of ExoMars 2020.
- The Dust Suite will help in understanding dust lifting process by monitoring (daily and seasonally) airborne dust granulometry and abundance (**MicroMED**), saltation flux (**Impact sensors**) and the role of electric field in dust lifting processes (**Electrical Probe**).
- The information that will be provided by MicroMED and Dust Suite are crucial for climate modelling and for future missions planning (hazard).
- Strong synergy with Meteo Suite.
- An Elegant Breadboard of MicroMED has been fully developed and assembled.
- Functional and Performance test completed and fully successful.
- Waiting for funds from Regione Campania to continue the development for ExoMars.