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Installation and cleanliness requirements

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Introduction

Goal: set cleanliness requirements for the installation of ET pipes

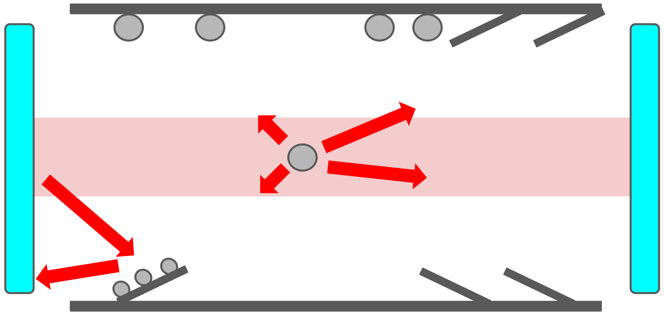
Focus on straylight caused by dust (D≳0.1µm) contamination in the arms (assessment of dust impact on TM towers and baffles requires dedicated study)

Dust can **enter inside the arms**:

- during installation: construction of the pipe with installation of baffles
- during storage of the installed tube sections, before the full pipe is built
- when in vacuum due to the pumps and gate valves

Dust produce **different effects**:

- dust deposited on baffles contribute to scatter light reaching the baffles
- deposited particles can detach, cross the light beam circulating in the arm and scatter light



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Pumps/gate valves contribution is shown to be negligible (details in ET Beampipe Requirements document or ET-0341A-23)

Dust produce **different effects**:

- dust deposite[…] light reaching[…]
- deposited pa[…] circulating in the arm and scatter light

Dust on Baffles: Introduction

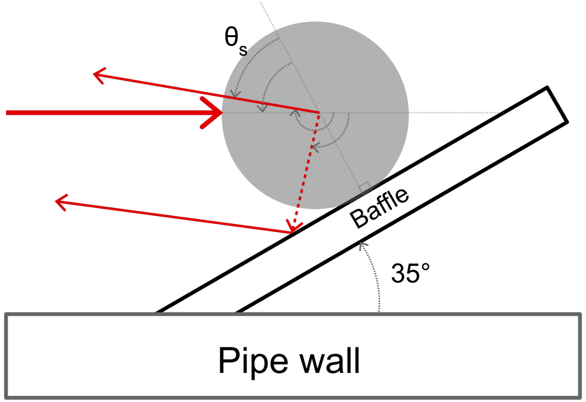
The effect of dust deposited on baffles is to increase baffle's BRDF: higher scattering and higher strain noise.

strain noise due to baffles backscattering →

$$h(f) = \frac{\varepsilon\kappa}{\sqrt{3}\pi}\frac{\lambda X(f)}{LR}\boxed{\sqrt{\mathrm{BRDF(\text{-}55^\circ)}}}\sqrt{\frac{z_{last}}{z_{first}}}$$

↑ $\mathrm{BRDF}_{baffle} + \mathrm{BRDF}_{dust}$

Given our specific geometry, light must be scattered at θ_s=-55° to return to the TM.



Dust deposits:

- **during baffles handling and installation** in clean rooms
- **after installation:**
  - storage of the tubes in air, after installation and before pumping
  - from pumping/venting or shaking of tube walls

Dust on Baffles: Introduction

Goal: set the cleanliness requirements to have the straylight noise below a certain level.

How:

- from size-numerosity of dust particles on baffles, the BRDF of the dust is computed
- dust BRDF is compared with the clean baffle's BRDF

Size-numerosity of dust particles deposited is computed from dust fallout models. They depend on:

- exposure time
- clean room ISO class
- surface orientation

→ Deposited dust distributions at different steps are computed:

- handling in clean rooms and installation inside the tube
- Tube sectors exposure before pumping

(details in ET Beampipe Requirements document or ET-0341A-23)

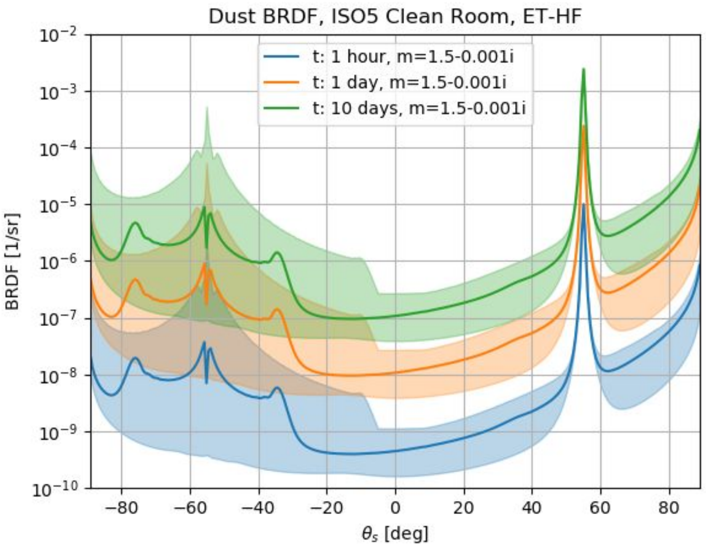
Dust on Baffles: BRDF

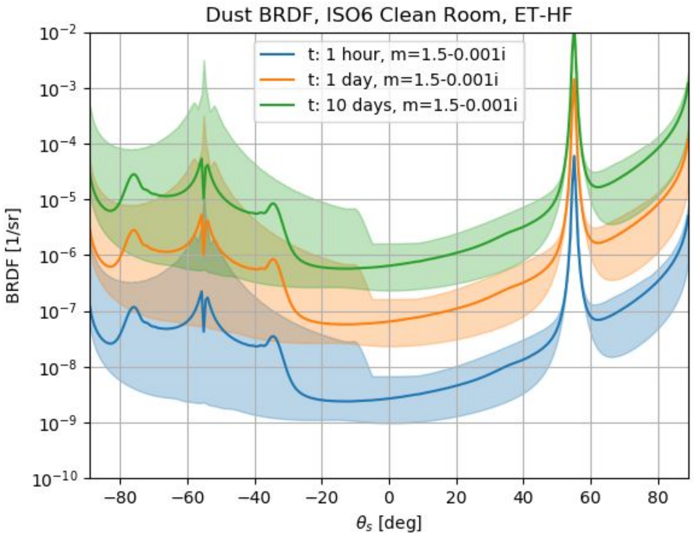
Different cleanliness scenarios are tested: from the deposited dust distribution the BRDF of the dust is computed with Mie Theory.

E.g. assuming each baffle is exposed **1 day** inside an **ISO6** clean room:

$$BRDF_{baffle} + BRDF_{dust} \approx 2*BRDF_{baffle}$$

In mobile cleanroom tents in accelerator tunnels local environments of class ISO 5 can be established





- baffles BRDF=10^{-4}/sr
- baffles reflectivity: 10^{-2}
- shaded area covers different dust's index of refractions

Tubes Storage: Introduction

Dust can **enter inside the arms**:

- during installation: construction of the pipe with installation of baffles
- during storage of the installed tube sections, before the full pipe is built
- when in vacuum due to the pumps and gate valves

We now deal with the issue of tubes storage: important to understand the scenario for installation of baffles and soldering tube modules.
Depending on the scenario we can work on setting the requirements

Open for discussion

Tubes Storage: Problem

After soldering a module of the tube, it is kept in air till a 5km section is complete

- this will take ~17 months
- if kept unattended dust can enter
- This stage risks to be the most critical for dust contamination compared to baffle exposure during installation (1h-1day)

Major events responsible for possible contamination:

- tube modules soldering
- storage of already prepared sections (soldered pipes with baffles) before vacuum is pumped

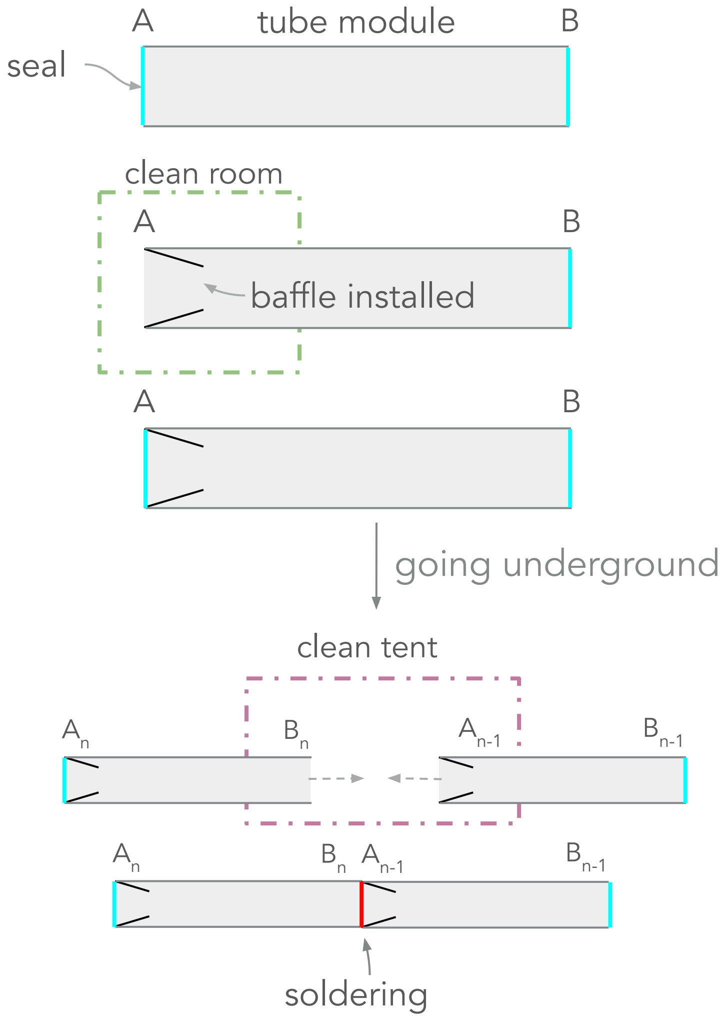
↓

➢ need a solution to prevent dust accumulation
➢ Good to monitor dust deposition and eventually alert if something goes wrong

Tubes Storage: Proposal A

We do not know the procedure for pipe and baffle installation.
Possible procedure: **open to discussion**

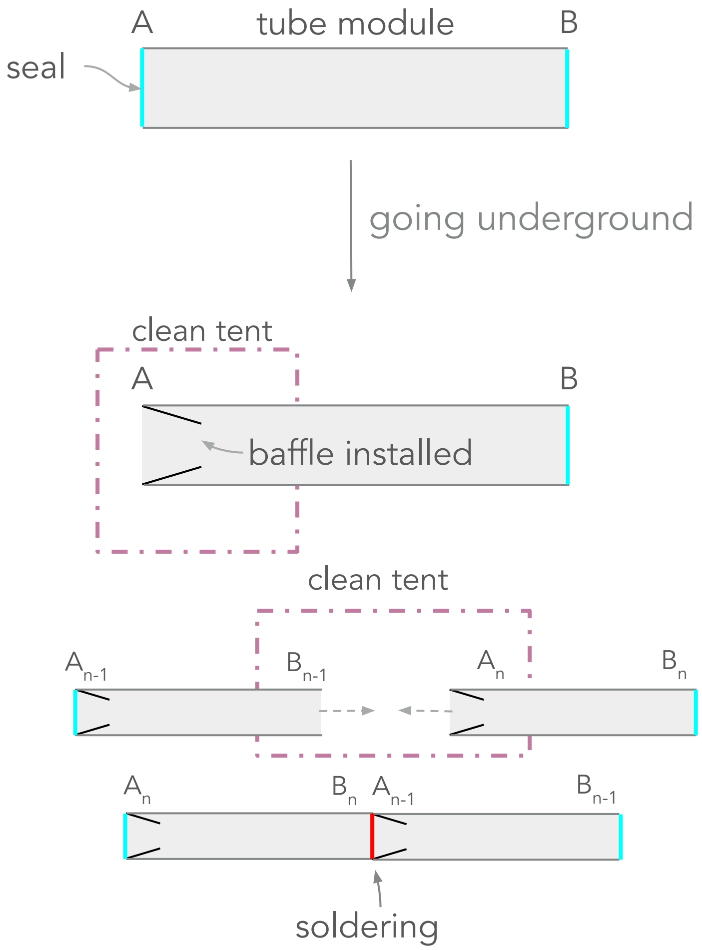
1. Tube module is produced on surface.
2. Tube module cleaned, sealed at both ends (end A, end B) and shipped.
3. Tube module end A open and baffle installed: in a clean room on surface, and/or fluxing clean dry air inside. Both ends are sealed.
4. Baffled tube module is brought underground: end B under movable clean tent.
5. End B of module *n* is faced to end A of module *n-1,* both under the movable clean tent
    a. the sealings of these ends are open and the two ends brought to contact
    b. move juncture outside of clean tent (if necessary)
    c. end B soldered to end A of module n-1



Tubes Storage: Proposal B

We do not know the procedure for pipe and baffle installation.
Possible procedure: **open to discussion**

1. Tube module is produced on surface.
2. Tube module cleaned, sealed at both ends (end A, end B) and shipped to ET.
3. Tube module is brought underground.
4. Tube module end A open and baffle installed: in a clean tent underground, and/or fluxing clean dry air inside.
5. End A of module *n* is faced to end B of module *n-1,* both under the movable clean tent
    a. the sealings of these ends are open and the two ends brought to contact
    b. move juncture outside of clean tent
    c. end B soldered to end A of module n-1

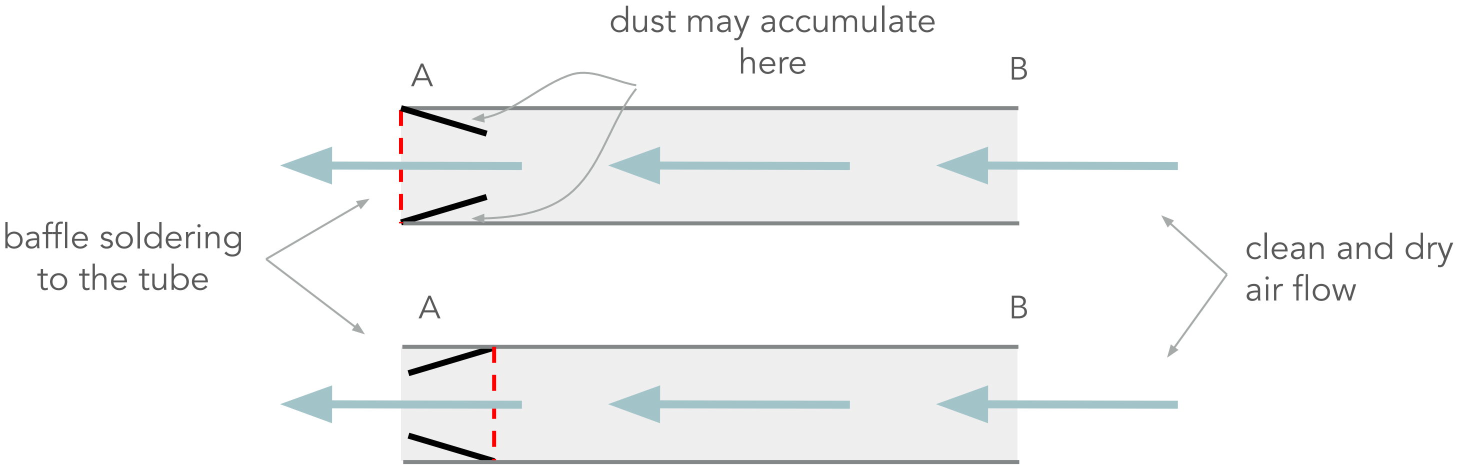


Tubes Storage: Baffle installation

The other point to consider is how the baffle is fixed to the tube:

- if baffles are mechanically attached it is preferable to do so inside a clean room/tent
- if baffles are soldered to the tube flowing clean and dry air from inside the tube towards the baffle is mandatory

If baffles are soldered flowing air, there is the risk to accumulate dust under the baffle if this is oriented toward the tube center. Two possibilities:

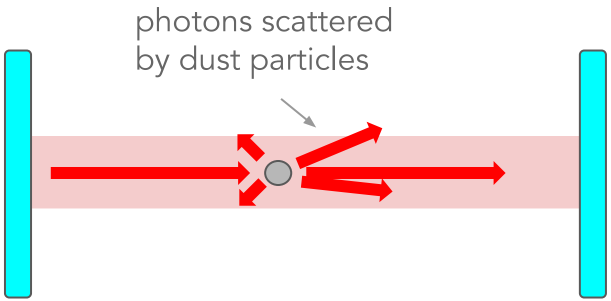


Dust Crossing the Beam

Dust particles crossing the beam can scattered light that reach the TMs: we focus only on light scattered and directly reaching one TM.

The beam power on the particle depends on

- the particle's motion, i.e on time
- particles position along the tube
- particles properties, e.g. dimension



Montecarlo simulation:

1) ensemble of N particles detaching at random times and positions
2) compute the scattered field using Mie Theory
3) compute amount of scattered field that couples with cavity mode
4) compute phase and amplitude fluctuations
5) compute strain noise

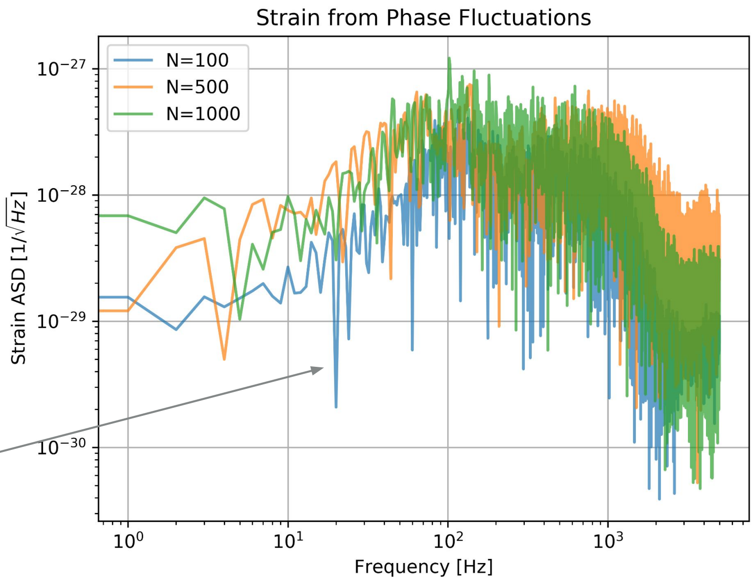
Dust Crossing the Beam: preliminar results (I)

Preliminar results: strain noise from phase fluctuations

$$\delta\phi(t) = \left|\frac{E'(t)}{E_0}\right| \sin\Delta\phi(t) \longrightarrow S_h^{1/2}(f) = \frac{S_{\delta\phi}^{1/2}(f)}{\mathrm{TF}_{h\to\delta\phi}(f)}$$

- E_0: cavity field
- E'(t): scattered field recoupling to the cavity fundamental mode
- ΔΦ(t) phase difference between scattered and cavity field
- TF: ITF transfer function from strain to differential phase in the arms

Preliminar:
- particles with uniform size distribution
- total number and size of particles not representative
- noise from phase fluctuations only
- assumed TF for L-shape ITF



Dust Crossing the Beam: preliminar results (II)

Preliminar results: strain noise from phase fluctuations

In progress:

1. strain noise from power fluctuations

$$\frac{\delta P(t)}{P_0} = \left| \frac{E'(t)}{E_0} \right| \cos \Delta\phi(t)$$

→ radiation pressure noise

→ arms power imbalance

2. test different scenarios:
   - number and size of particles
   - location of particles
   - falling rates
   - …

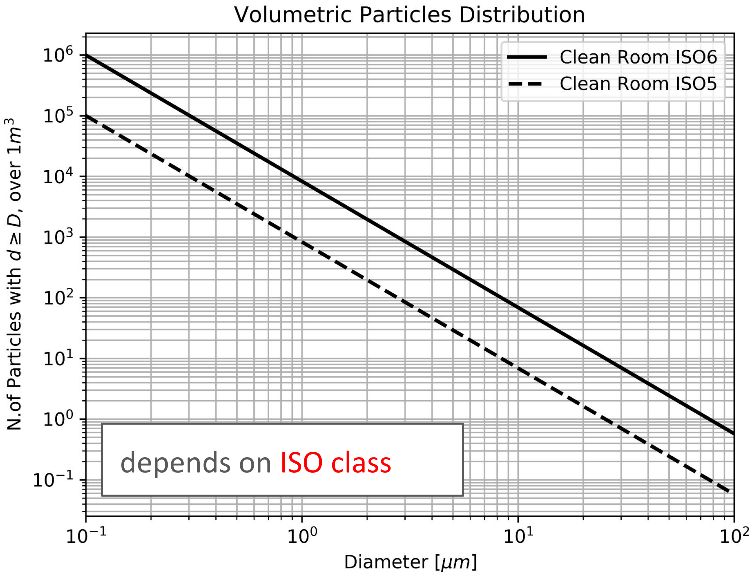
Summary

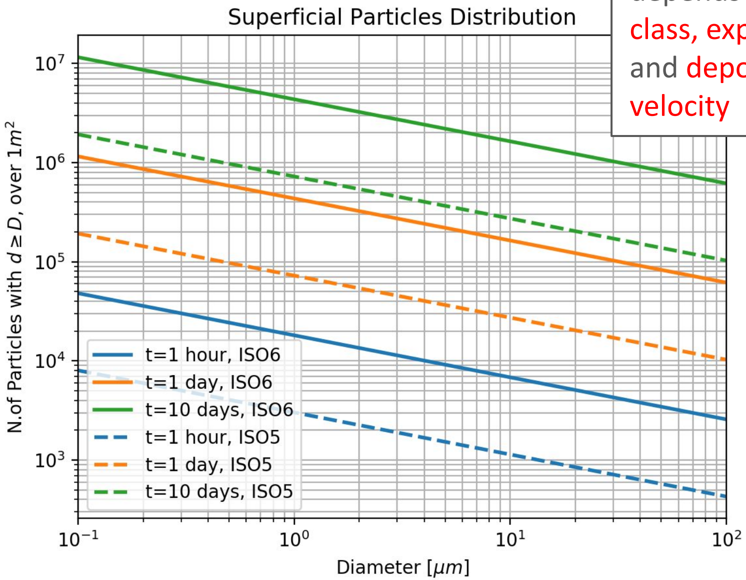
- **Dust particles** inside the arm:
  - deposit on baffles and add a BRDF term
  - cause scattering when falling and crossing the beam
- **Results**:
  - **running pumps/venting:** our estimate seems to suggest that it is not impacting as dust deposited during in-air operations
  - **handling and installation** of baffles: we estimated that 1 day of exposure in ISO6 clean room is tolerable
  - the issue of **tube modules storage** is emerged: risk of being the critical step
- **Open issues**:
  - storage of tube is the critical point: need discussion and a solution
  - particles crossing the beam: work in progress

Backup Slides

Dust on Baffles: Dust Fallout Model

The scattering contributed by deposited dust depends on the dimension and number density of dust particles on the baffle surface.





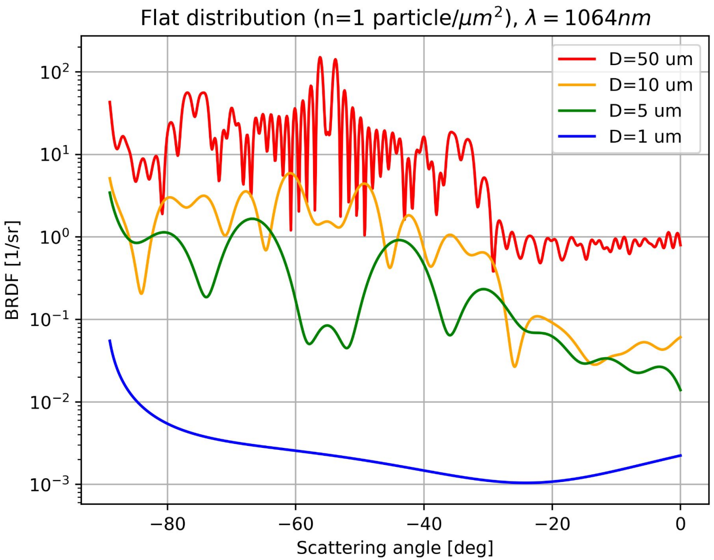
depends on ISO class, exposure time and deposition velocity

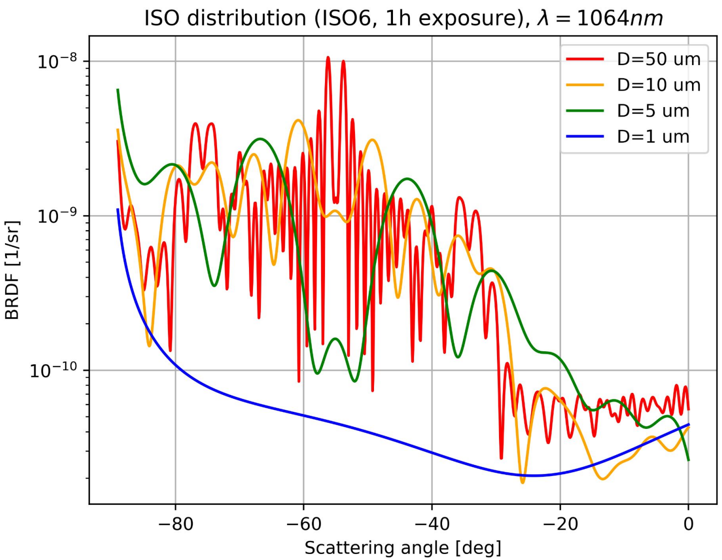
Dust on Baffles: BRDF vs Dimension

Size of particles also affects angular dependence of BRDF:

- larger particles tend to scatter more and at smaller angles wrt small particles
- smaller particles are typically more numerous

Accounting for the higher numerosity, the smaller particles contribution becomes relevant





Dust on Baffles: Pumps/Pipe walls/Gate valves

Dust is also released when the system is closed:

- pumps operation
- shocks on tube walls
- opening/closing of gate valves

In literature dust contamination is measured in UHV for different items:

- Ion Pump:
  - particles release only at ignition ($P_{ignition}=10^{-5}$mbar)
  - N=30 particles on average (new pump) + and not diminishing along successive start/stop cycles
- NEG pumps:
  - they are found to be compatible with ultra clean environments
- Shocks on walls:
  - after 5-10 impacts no more particles, but no data on number/size
  - if strength or place of impact is changed particles are released again
- Gate valves
  - 2400 particles (over 6 open-close cycles): 90% with D<2um, and 50% with D<0.5um
  - with more open/close cycles: half particles after 10 cycles, then constant up to 30 cycles

Dust on Baffles: Pumps/Pipe walls/Gate valves

Dust is also released when the system is closed:

- pumps operation
- shocks on tube walls
- opening/closing of gate valves

By accounting for all the pumps (~50) and gates (~75), we can compare the contamination (0.5um<D<2um) due to pumps and clean rooms:

- pumping + gate valves (no info on shaking): ~ $2*10^3$ particles per baffles
- for air exposure in clean room (neglecting storage):
  - 1 day in ISO6: ~ $8*10^4$ part per baffle
  - 1 hour in ISO6: ~ $3*10^3$ part per baffle

Contribution from pumps/valves (no info shaking) seems not as significant

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Dust particles crossing the beam can scattered light that reach the TMs: we focus only on light scattered and directly reaching one TM.

The beam power on the particle depends on

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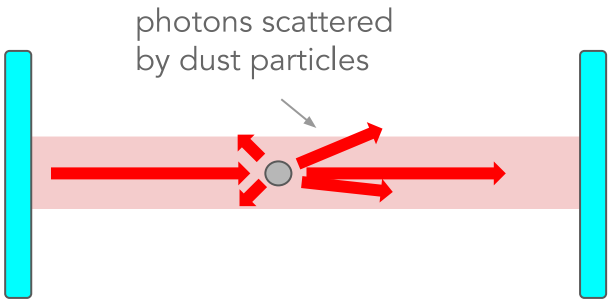

$$E^s_{1,2}(\vec{x_0},\vec{x},t,t_0) = \frac{e^{-ikr(t,t_0)}}{ikr(t,t_0)} \cdot S_{1,2}(\theta_s, D, m) \cdot \mathrm{TEM00}(\vec{x_0}(t,t_0))$$

scattered field

k: beam wavevector
r(t): vector from particle to point on TM

TEM00 mode incident on the particle

Mie scattering, depends on

- complex index of refraction (m)
- particles size (D)
- scattering angle