

# Particulate cleaning for ultra-low background experiment

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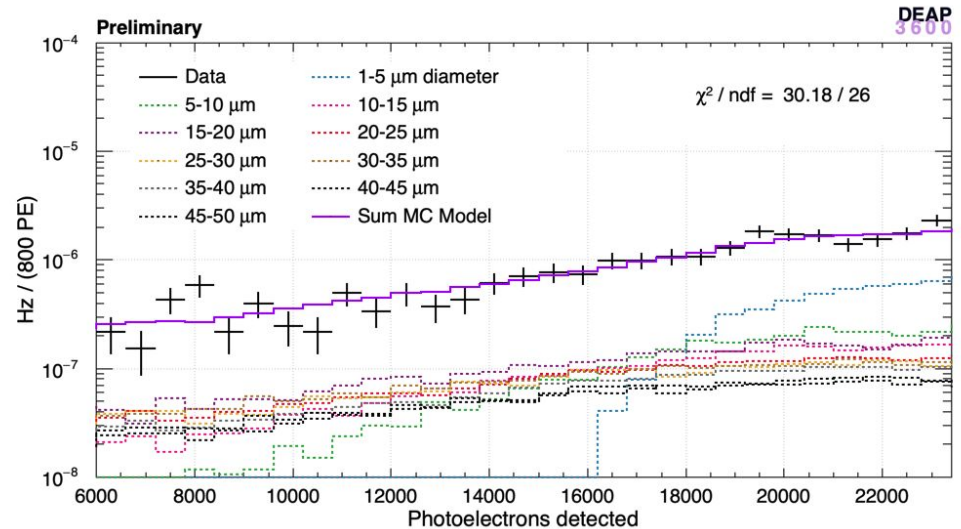
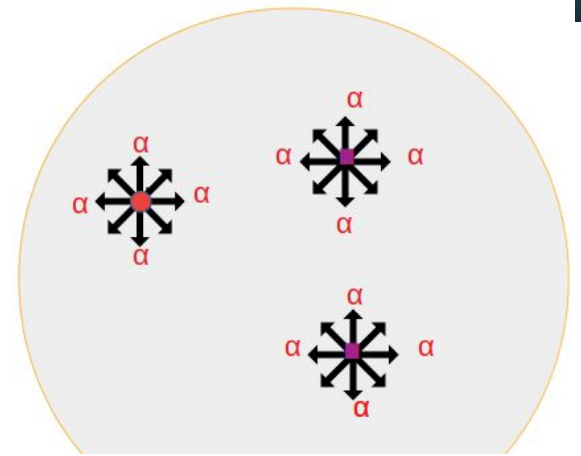
**Carleton**  
UNIVERSITY



# Motivation

Dust presents in the detector materials may affect the purity of the materials and produces backgrounds.

$\alpha$ -decay from the radioactive elements like U, Th, Pb in the dust can be the major background for future dark matter search experiments.



# Degraded alpha energy

Metal dust of size larger than  $\sim 6$  micron and acrylic dust of larger than  $\sim 20$  micron can affect the low energy background region (WIMP ROI).

Photoelectron deposited on LAr

Generated alpha (U238/Th232 full chain)

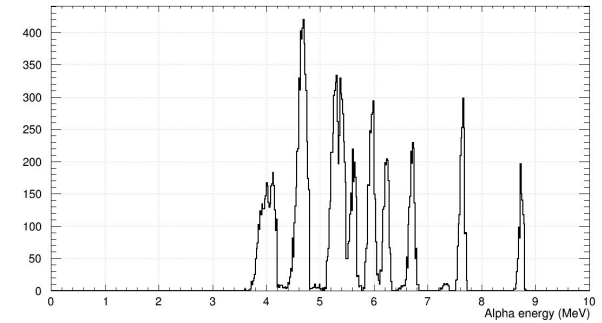
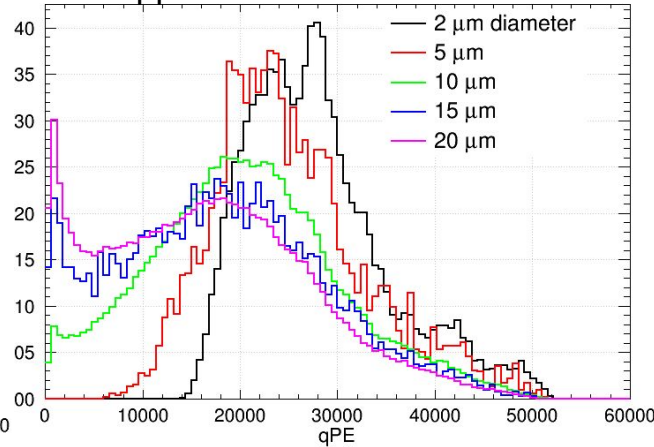
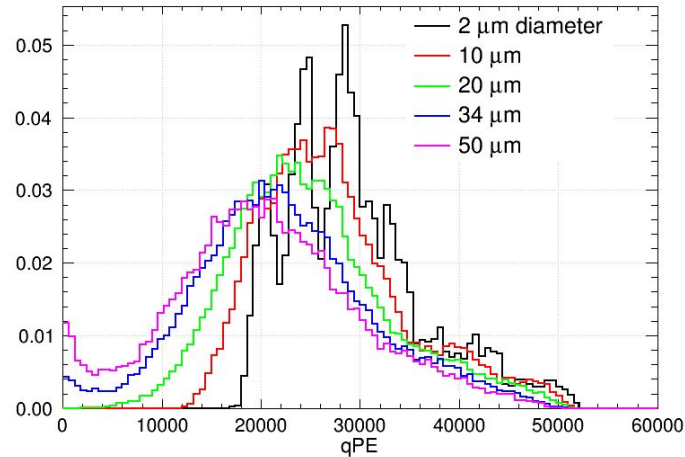


Table 5.1. Range-Energy Values for Alpha Particles in Various Absorbers\*

$E_0$ (MeV)	Ranges (mg/cm <sup>2</sup> )			
	Copper	Nickel	Gold	Helium
0.25	0.79	0.74	1.31	0.181
0.50	1.09	1.02	1.90	0.245
0.75	1.38	1.29	2.50	0.316
1.00	1.69	1.58	3.12	0.399
1.25	2.01	1.88	3.79	0.490
1.50	2.36	2.21	4.47	0.601
2.00	3.11	2.91	5.97	0.850
2.50	3.93	3.68	7.59	1.14
3.00	4.82	4.50	9.34	1.48
3.50	5.80	5.44	11.0	1.86
4.00	6.81	6.39	13.1	2.29
4.50	7.9	7.40	15.2	2.76
5.00	9.1	8.51	17.4	3.27
5.50	10.3	9.66	19.7	3.82
6.00	11.6	10.87	22.1	4.41
7.00	14.3	13.46	27.1	5.70

Acrylic dust

Copper dust



<https://www.if.ufrj.br/~toni/exp05.pdf>

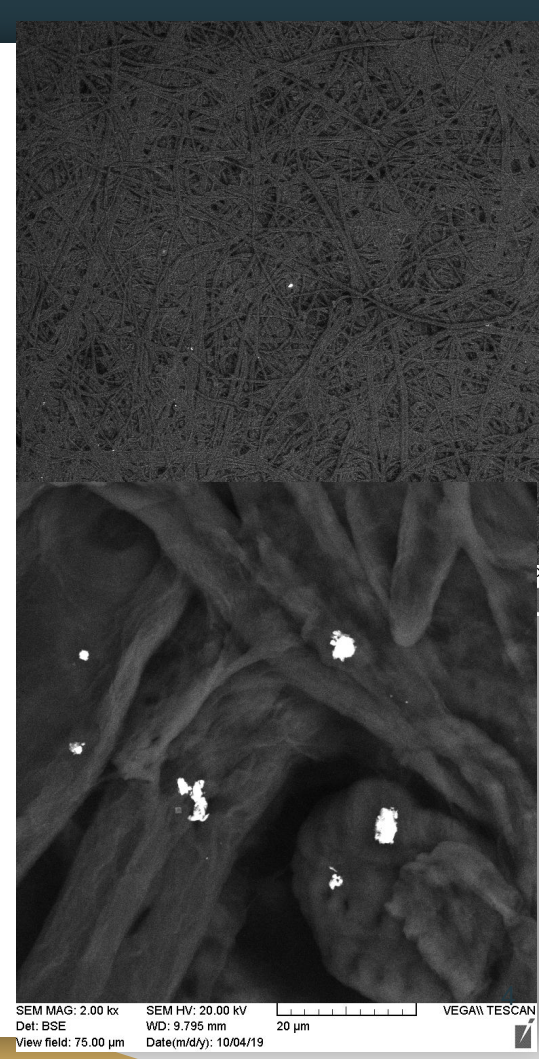
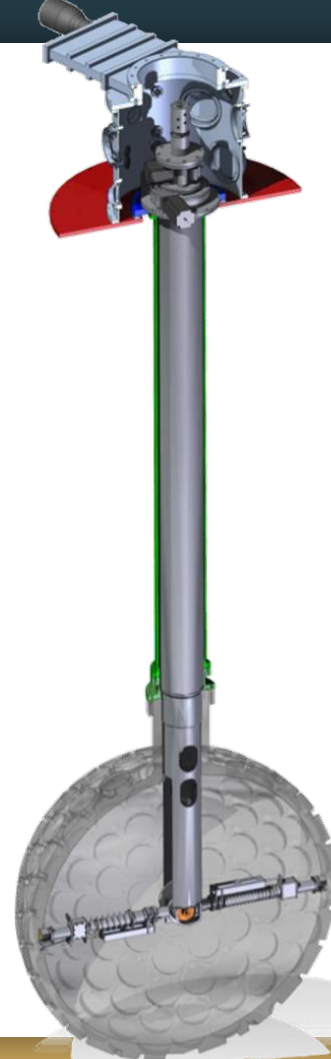
# Possible sources of dust

Dust on the underground surface.

(Early observation made by SNOLAB:  
activities of U-238 and Th-232 in the lab are  
1.2e-6 g/g and 3.3e-6 g/g respectively in  
norite dust.)

Dust from the detector material (acrylic  
dust ... ).

Dust contains in compressed gas (metallic  
dust from the cylinder).



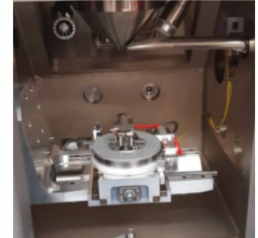
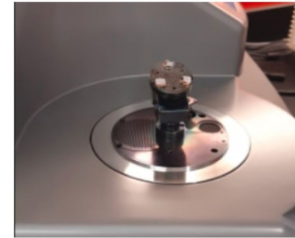
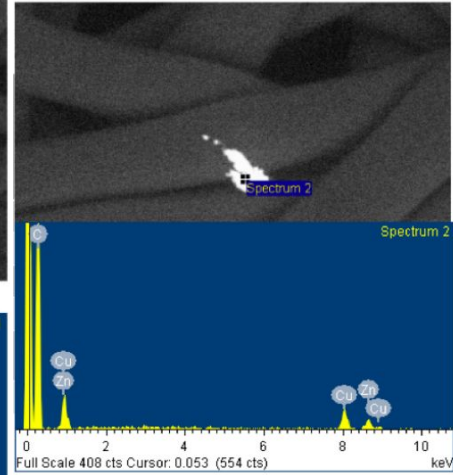
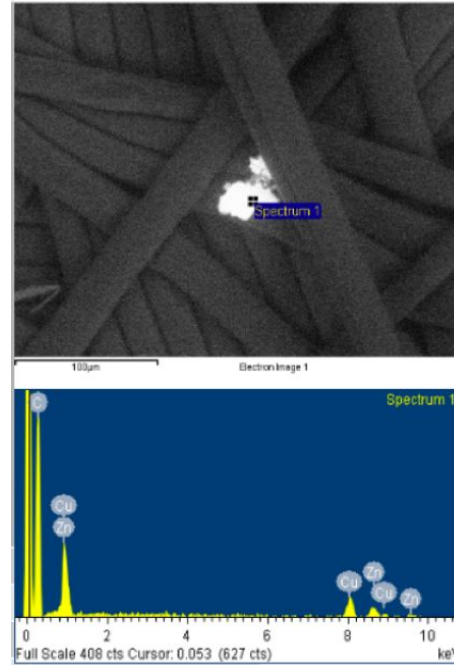
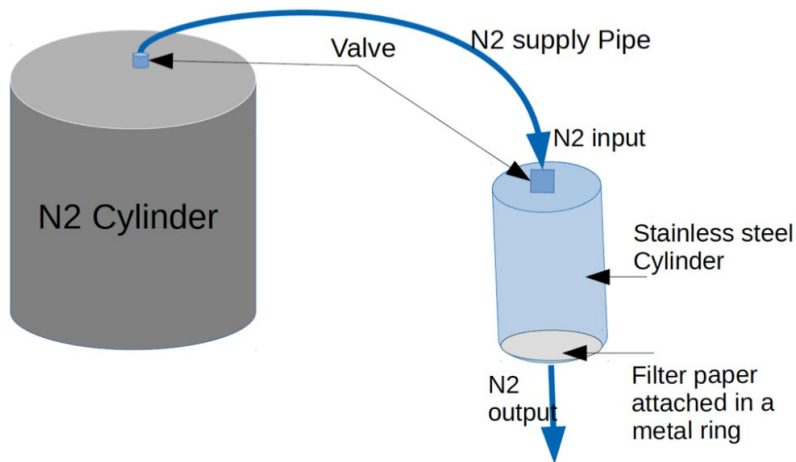
SEM MAG: 2.00 kx SEM HV: 20.00 kV  
Det: BSE WD: 9.795 mm 20 µm  
View field: 75.00 µm Date(m/d/y): 10/04/19 VEGA\\ TESCAN

# Dust in compressed gas

Filtered the liquid nitrogen and collected dust from it.

Sample are scanned on the scanning electron microscope (SEM).

The dust on the gas are made up of brass (copper and zinc) which may due to the corrosion in cylinder surface.

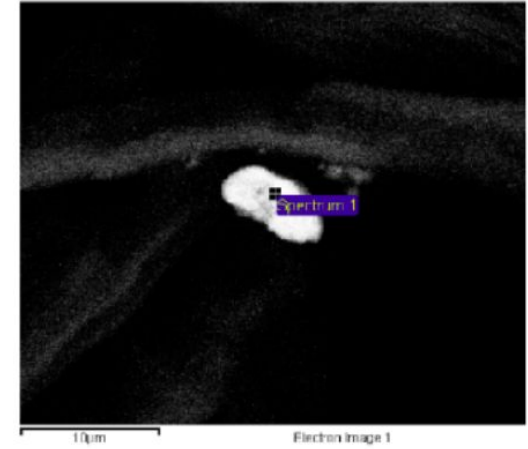
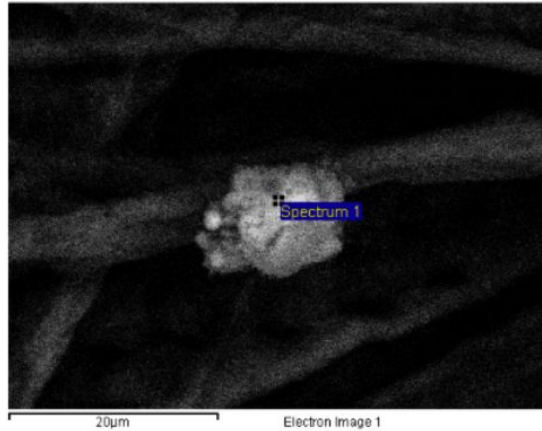


# Dust in the experimental site

Placed the paper on the different place of snolab cubehall for 24 hrs.

Collected the sample and scan in SEM.

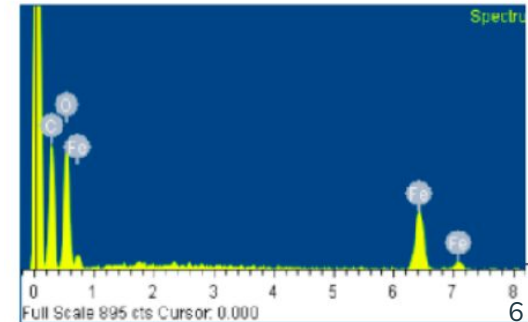
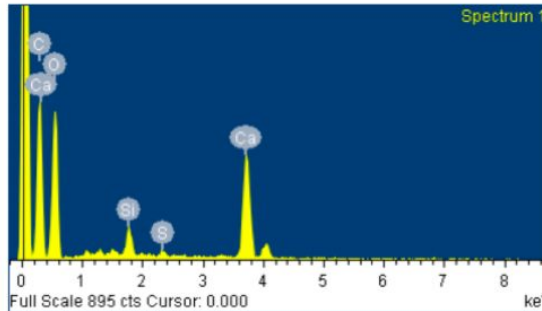
Different types of dust are observed mainly carbon, iron, calcium.



Possible source of

Calcium: concrete wall and paints

Iron: machining and hoist transport



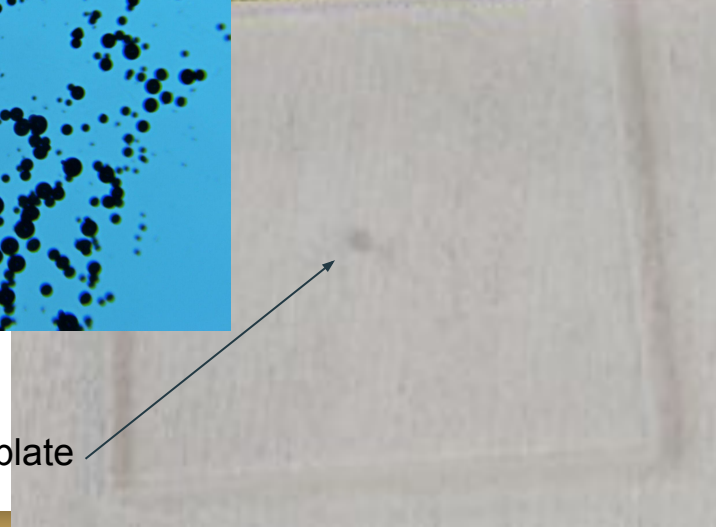
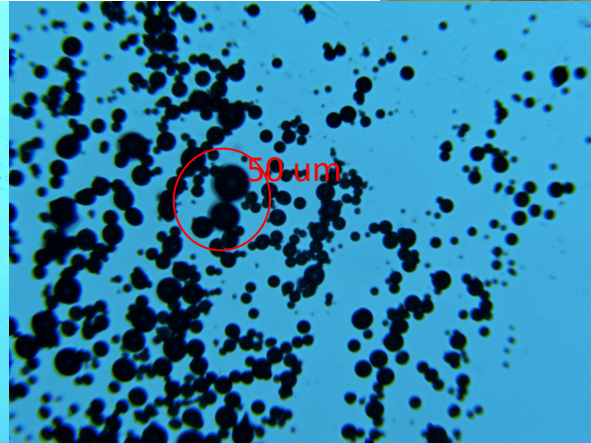
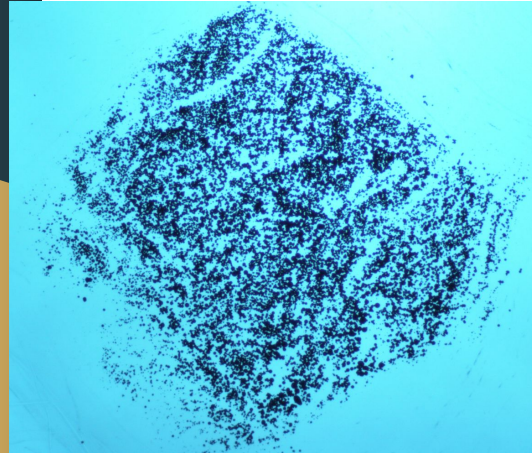
# Stainless steel dust from cospheric

Dust size 1-22  $\mu\text{m}$  (sphere)

Microscope images

4X

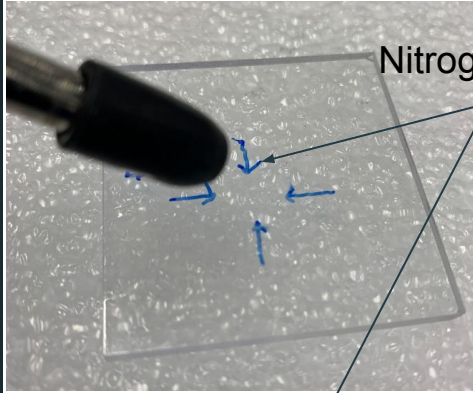
40X



Dust spread on an acrylic plate



# Clean the dust with nitrogen flow



Nitrogen flow to the acrylic surface



Dust sample is spread on the acrylic surface.

Use nitrogen gas flow to clean the dust from the acrylic surface.

Flow rate 10 m/s (36 km/hr): not any observable change on the sample.

Flow rate is 20 m/s (72 km/hr): large size dust reduced significantly.

Flow rate is 30 m/s (108 km/hr): most of the dust larger than 5 micron are gone.

Observed the cleaning efficiency in an optical microscope.

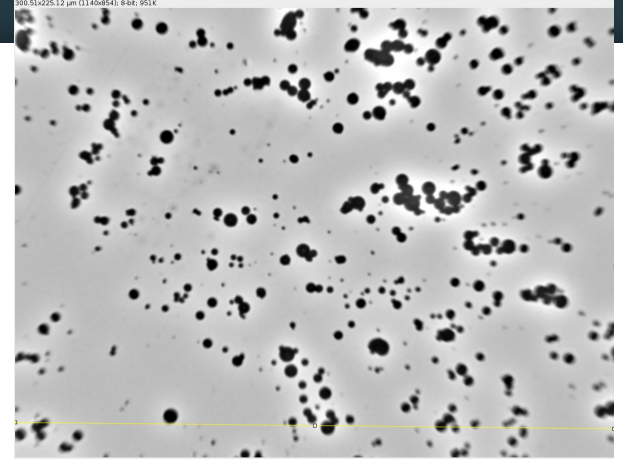
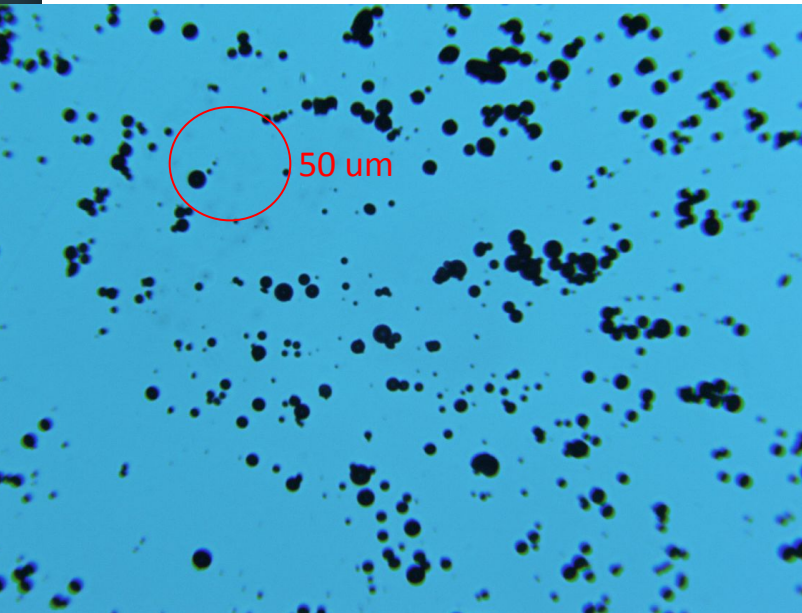


# Particle distribution analysis

Analysis is done using ImageJ software.

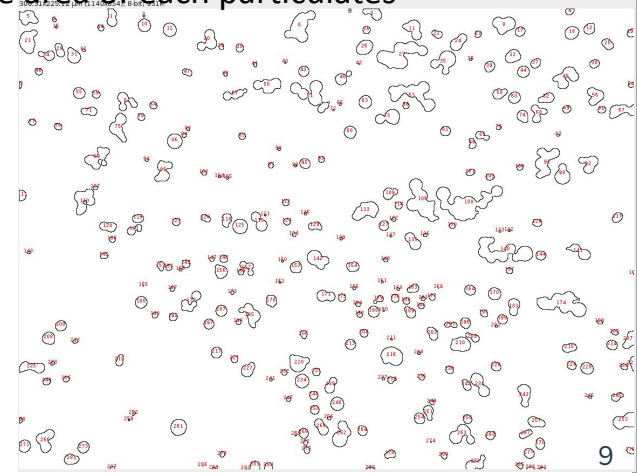
It gives the size of the particulate from the optical microscope image.

40X images of before and after cleaning are analysed and estimate the cleaning efficiency.

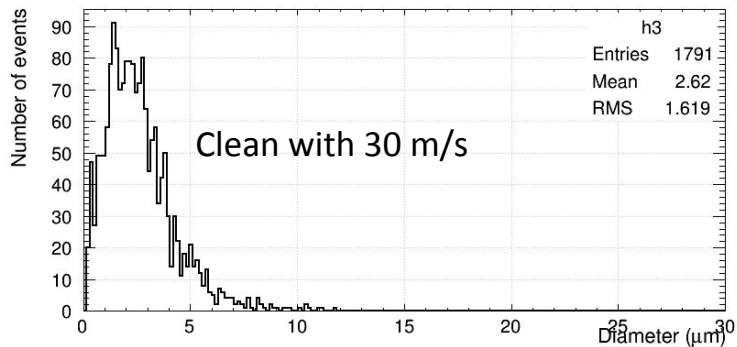
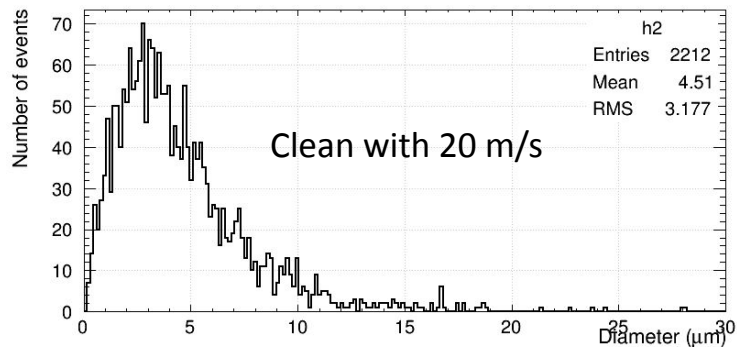
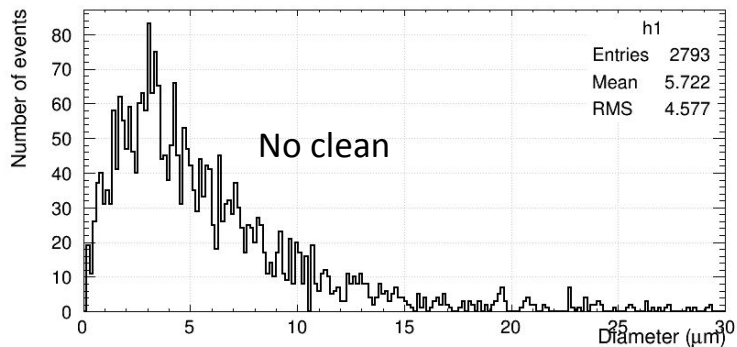


Dust boundary is shown in ImageJ, it gives the area of each particulates

		Area
1		
2	1	31.964
3	2	1.668
4	3	33.215
5	4	10.145
6	5	44.194
7	6	119.450
8	7	0.973
9	8	66.917
10	9	3.127
11	10	29.463
12	11	53.158
13	12	32.937
14	13	22.306
15	14	6.879



# Cleaning efficiency

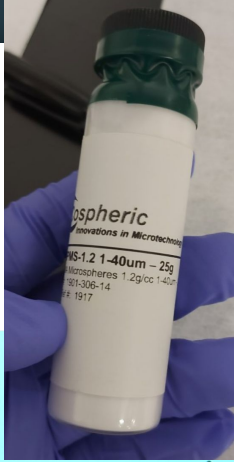
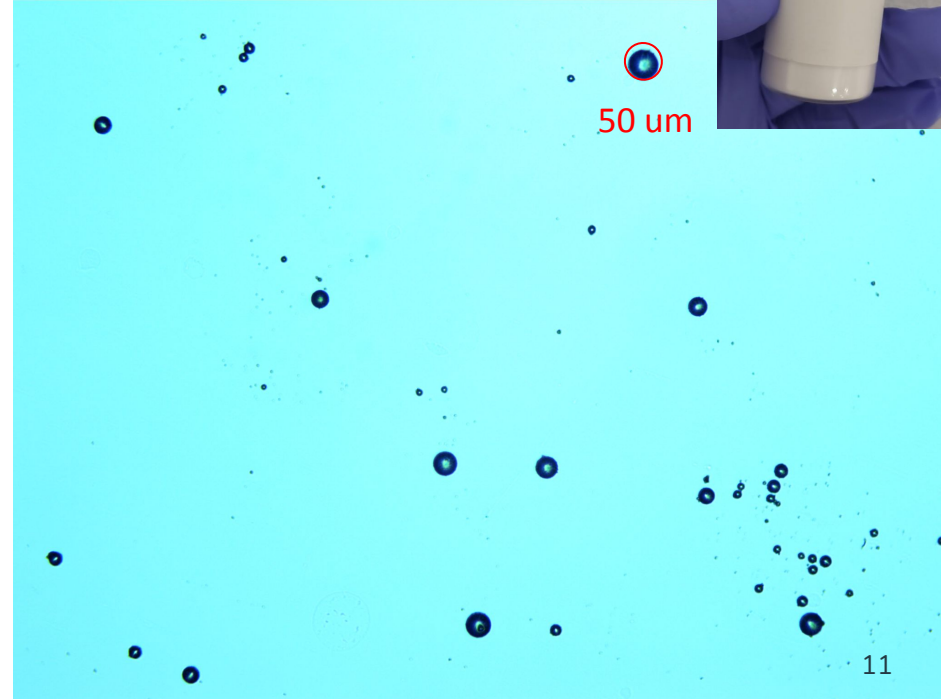
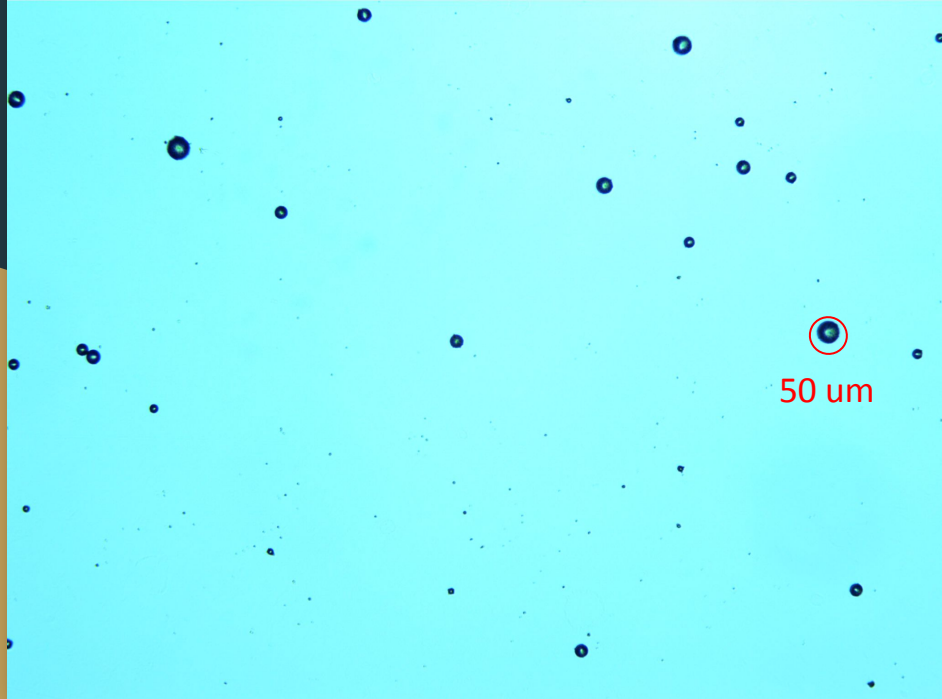


Dust removal efficiency (%) of different size dust

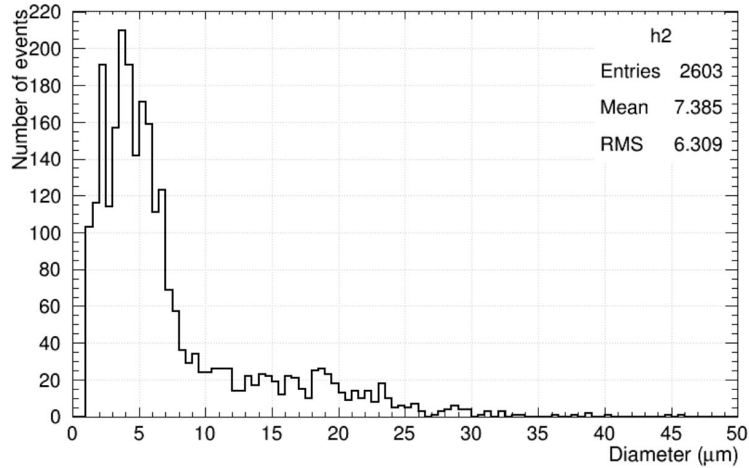
Air speed	5-10 $\mu\text{m}$	10-15 $\mu\text{m}$	15-20 $\mu\text{m}$	20-25 $\mu\text{m}$
10 m/s	5	7	11	21
20 m/s	27	62	64	90
30 m/s	77	96	100	100

# Spherical acrylic dust from cospheric

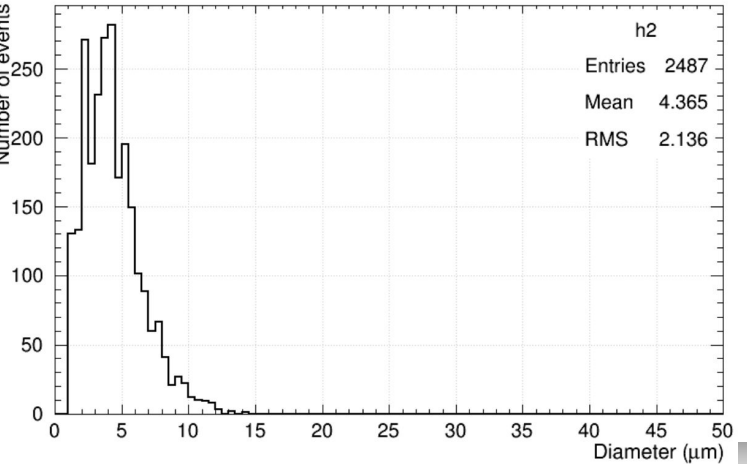
10x images



# Particulate distribution



Cleaning with 7 m/s (25km/h) air speed

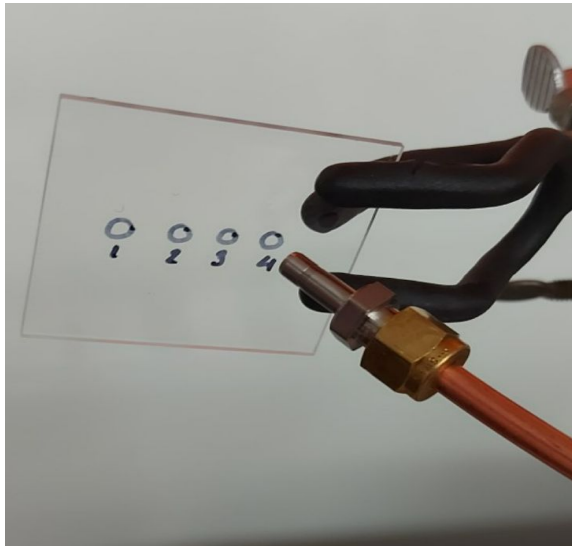


100% of cleaning efficiency for larger than 15μm dust

# Nitrogen flow + electrostatic gun

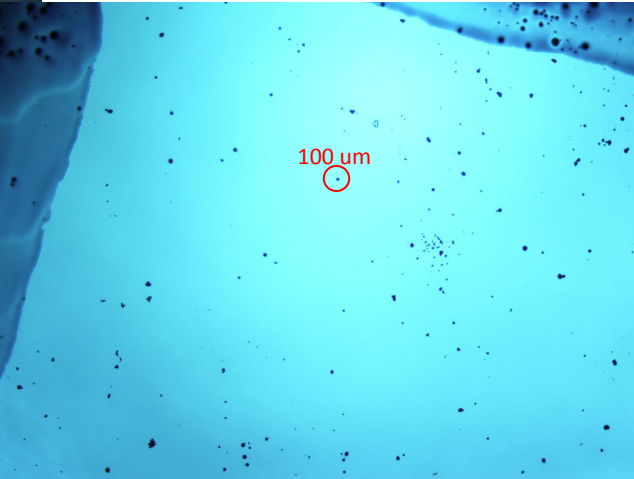
Stainless steel dust (spherical 0-22  $\mu\text{m}$ )

Clean the dust with different speed of gas applying zero static gun

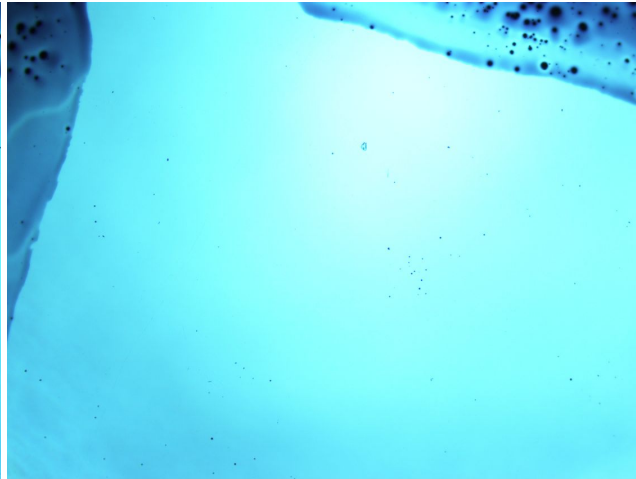


# 4x images

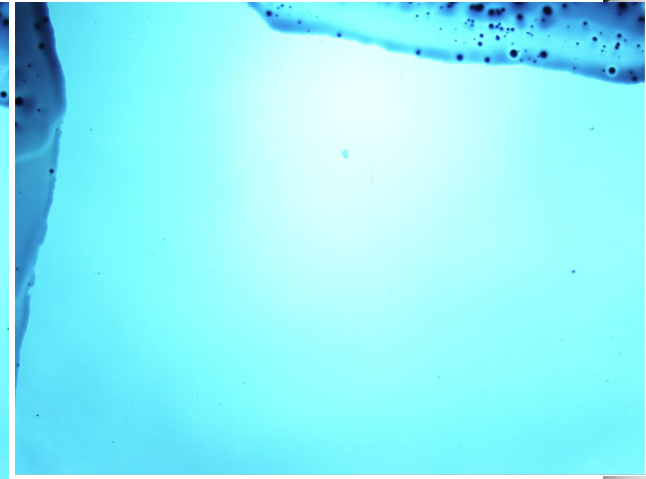
Before clean



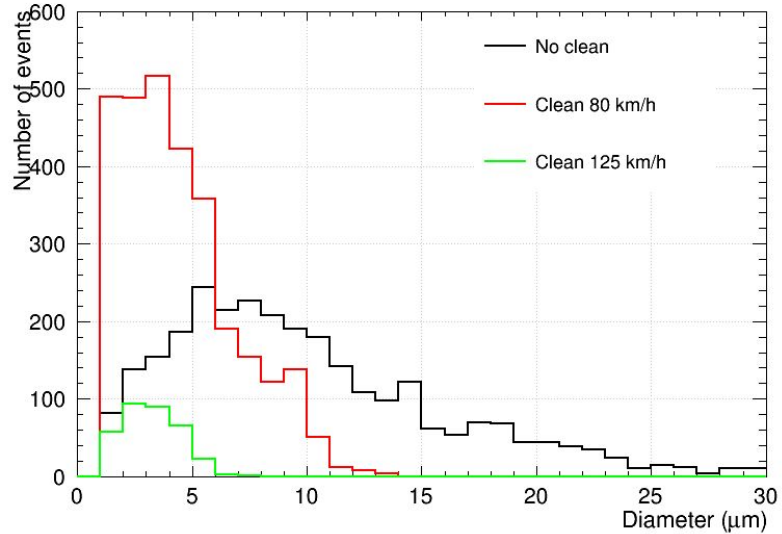
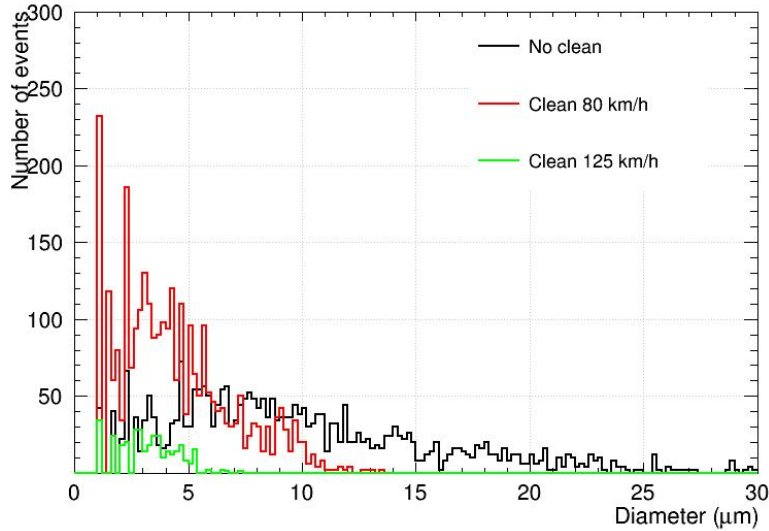
Clean with 80 km/hr speed



Clean with 125 km/hr speed



# Particulate distribution



Cleaning efficiency (%)

Air speed	5-10 μm	10-15 μm	15-20 μm	20-25 μm
80 km/hr	-	75	100	100
125 km/hr	98	100	100	100

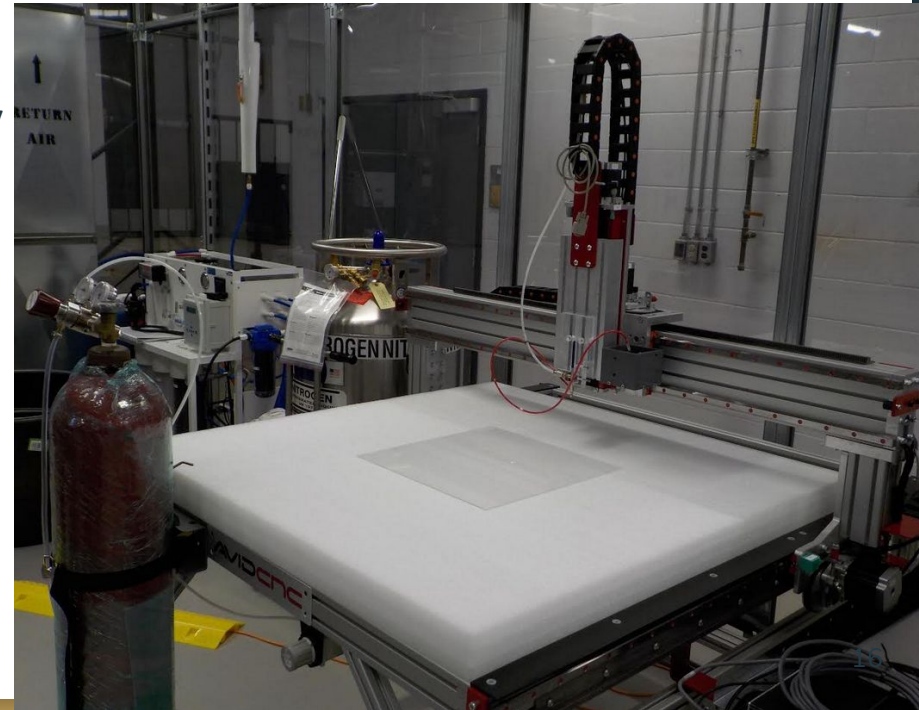
# Discussion and plan

Prepared a test station at Carleton to clean surface dust by the gas flow.

Scan and estimated the dust removal efficiency in different velocities of gas vs particulate size.

Test the dust removal with electrostatic force and gas flow on the surface.

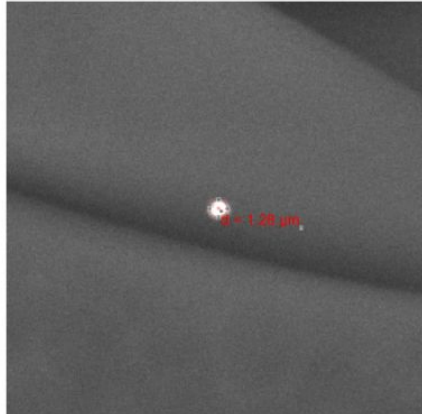
Use X-Y table to setup cleaning station and make it automated.



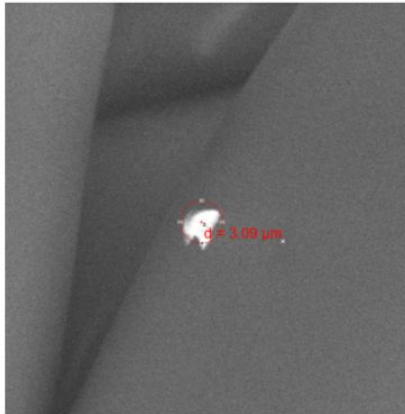


# Backup

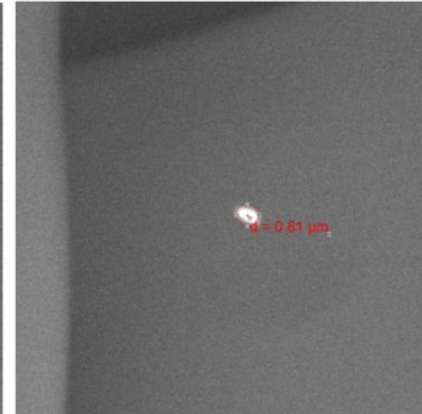
# Dust in compressed gas



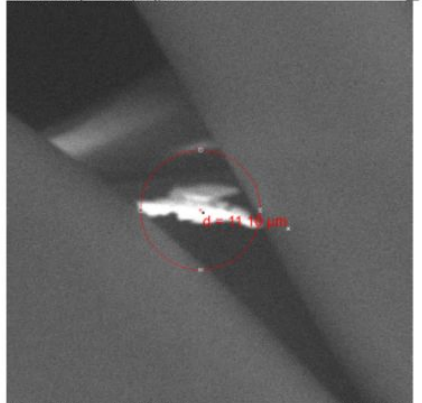
SEM MAG: 5.00 kx SEM HV: 20.00 kV  
Det: BSE WD: 10.41 mm  
View field: 30.00  $\mu\text{m}$  Date(m/d/y): 08/16/19



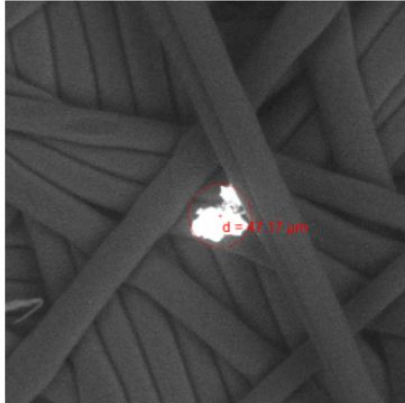
SEM MAG: 5.00 kx SEM HV: 20.00 kV  
Det: BSE WD: 10.49 mm  
View field: 30.00  $\mu\text{m}$  Date(m/d/y): 08/16/19



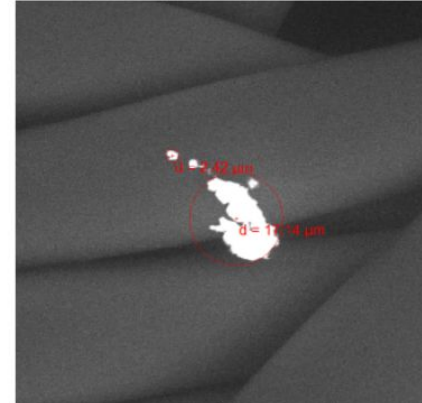
SEM MAG: 10.00 kx SEM HV: 20.00 kV  
Det: BSE WD: 10.43 mm  
View field: 15.00  $\mu\text{m}$  Date(m/d/y): 08/16/19



SEM MAG: 3.99 kx SEM HV: 20.00 kV  
Det: BSE WD: 10.49 mm  
View field: 37.63  $\mu\text{m}$  Date(m/d/y): 08/16/19



SEM MAG: 500 x SEM HV: 20.00 kV  
Det: BSE WD: 11.02 mm  
View field: 300.0  $\mu\text{m}$  Date(m/d/y): 08/16/19



SEM MAG: 2.00 kx SEM HV: 20.00 kV  
Det: BSE WD: 11.23 mm  
View field: 75.00  $\mu\text{m}$  Date(m/d/y): 08/16/19

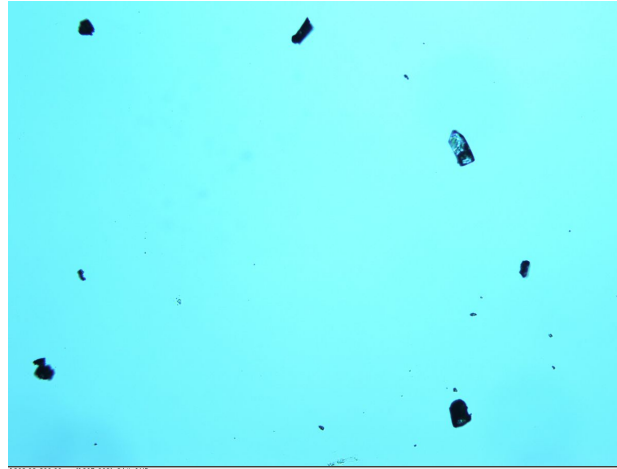
# Analysis in ImageJ

Imagej analysis steps:

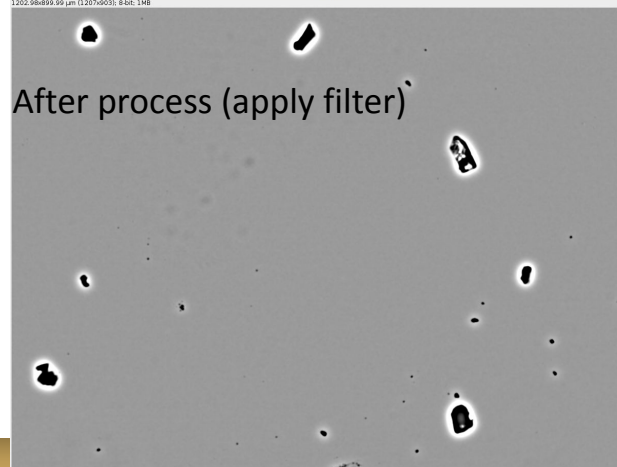
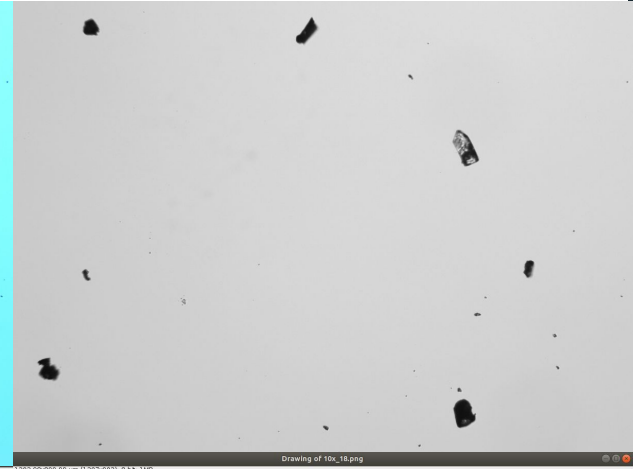
1. Convert to grayscale
2. Calibrate the image:  
Analyze->set scale
3. process->FFT->bandpass filter
4. image->adjust->threshold
5. Analyse particle-> outline display
6. Save the txt file (area info),  
convert in root and plot

	Area
1	
2 1	977.448
3 2	731.100
4 3	11.920
5 4	81.454
6 5	17.880
7 6	1396.639
8 7	8.940
9 8	21.854
10 9	2.980
11 10	13.907
12 11	492.698
13 12	8.940
14 13	238.402

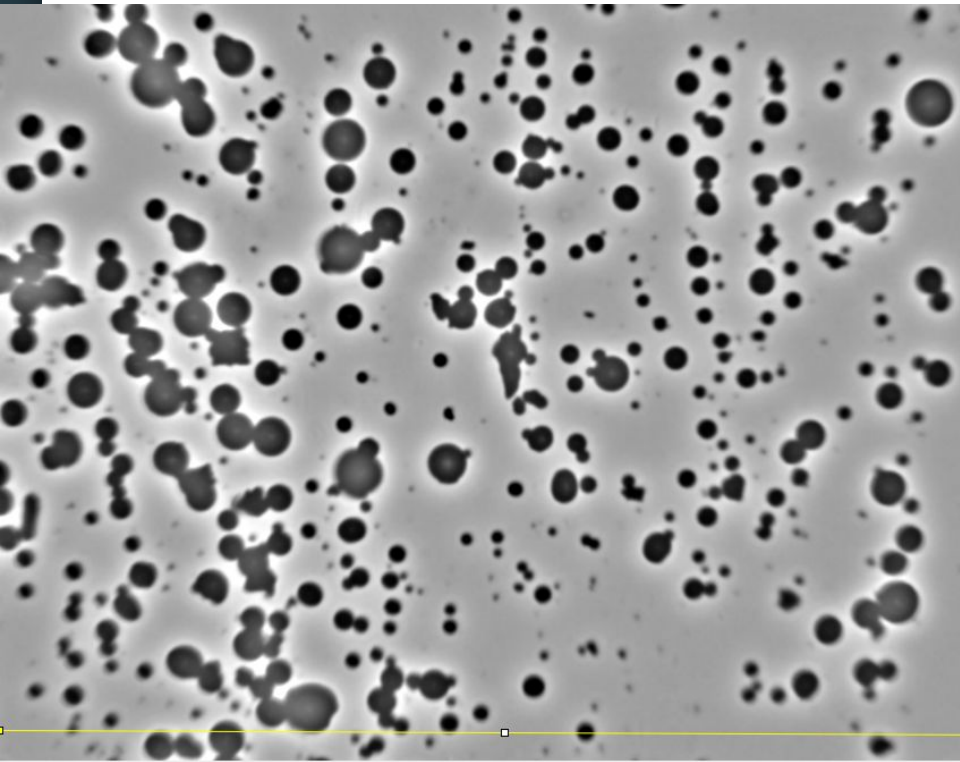
Original image



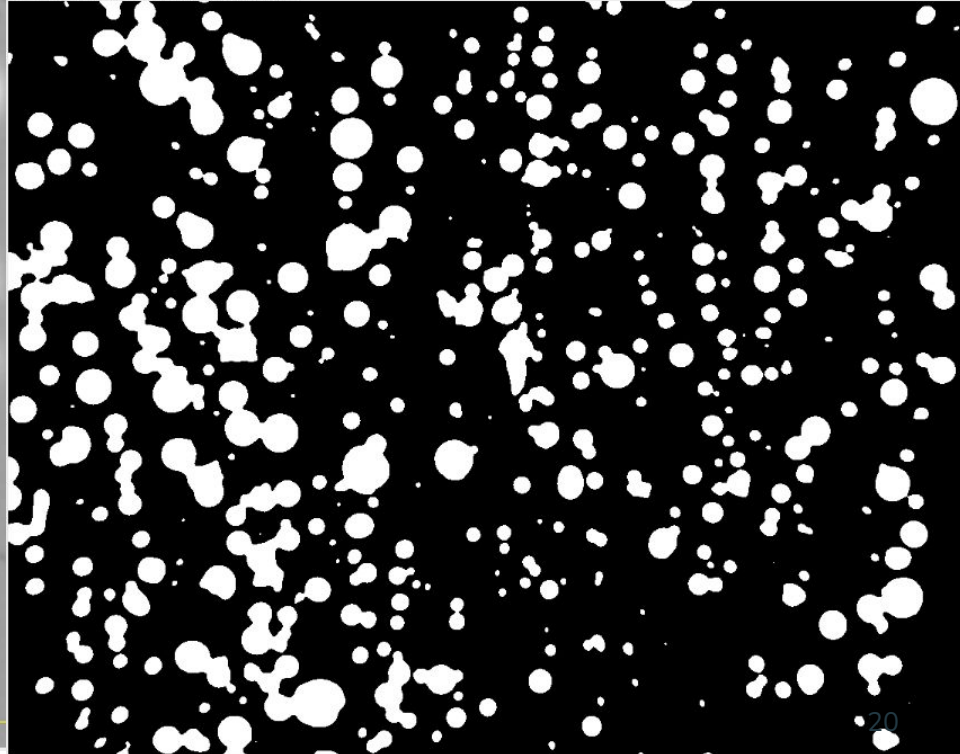
converted to grayscale



# Particle distribution analysis



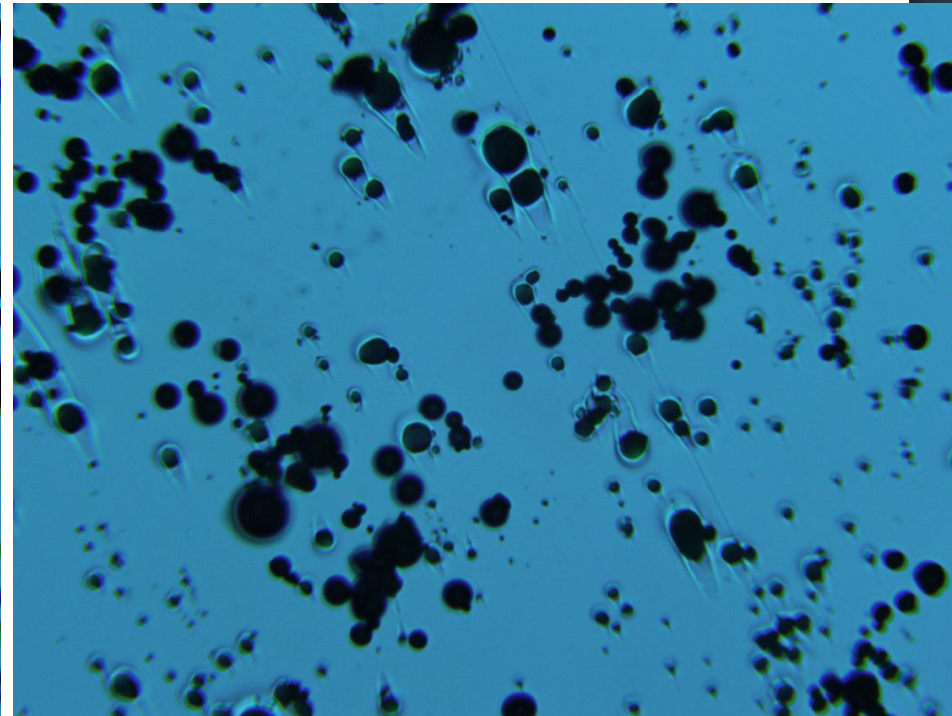
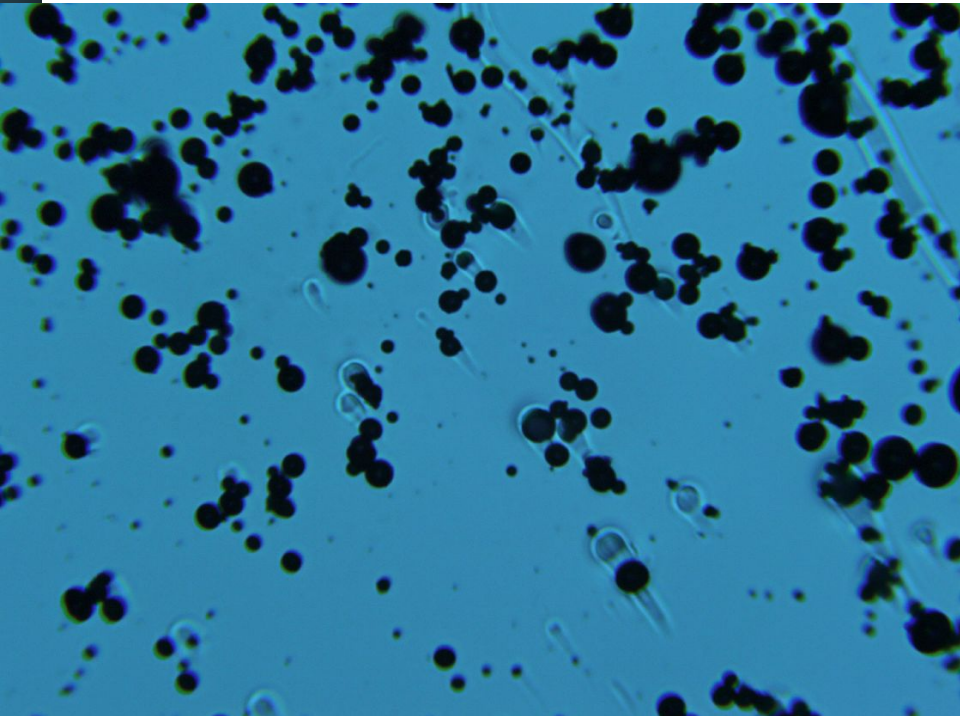
300.75x225.12  $\mu\text{m}$  (1193x893); 8-bit; 1MB

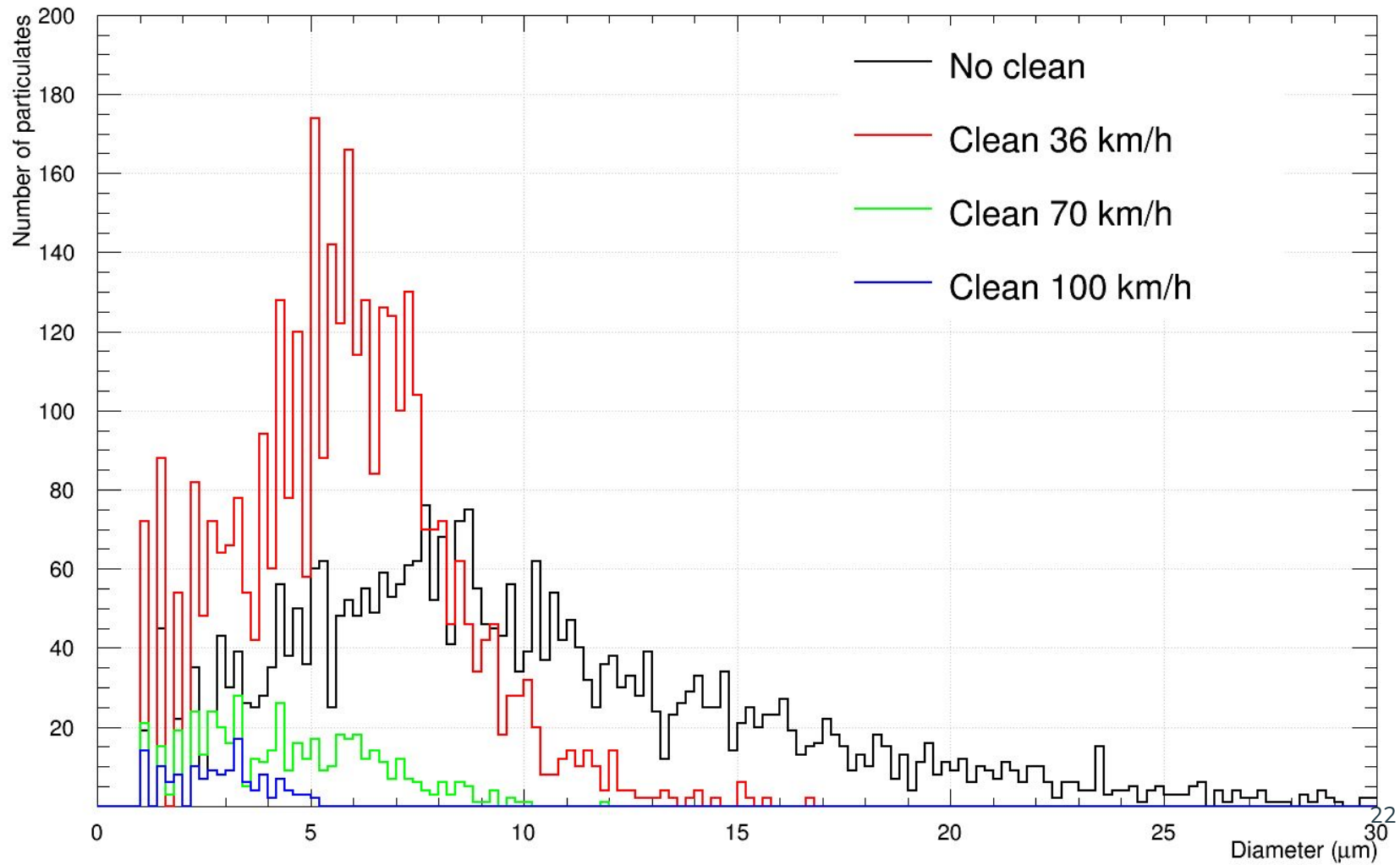


Gas flow rate 10m/sec

40X

Some particulates are moving slightly but they are stick on the acrylic surface.





# Use of X-Y table

G-code is written for automated moving.

Cleaned for 2.6 min, 40mm\*20mm area, with the rate 305 mmpm.

Gas speed 125 km/hr.

