Tutorial on Cavity Preparation SRF 2007 Workshop Beijing

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Dep.MKS3

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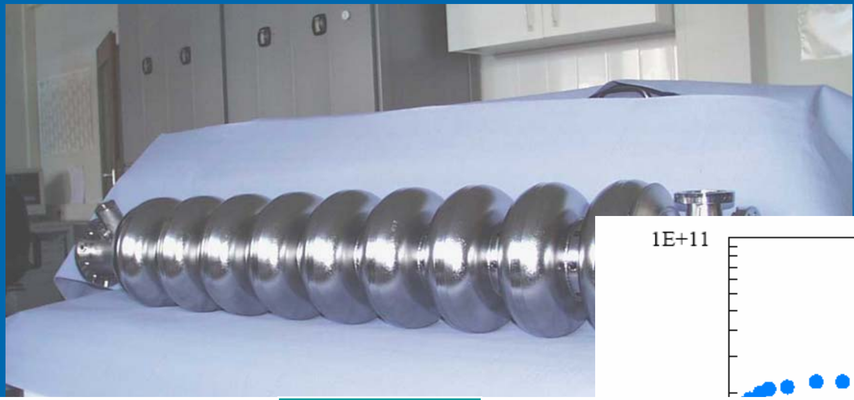
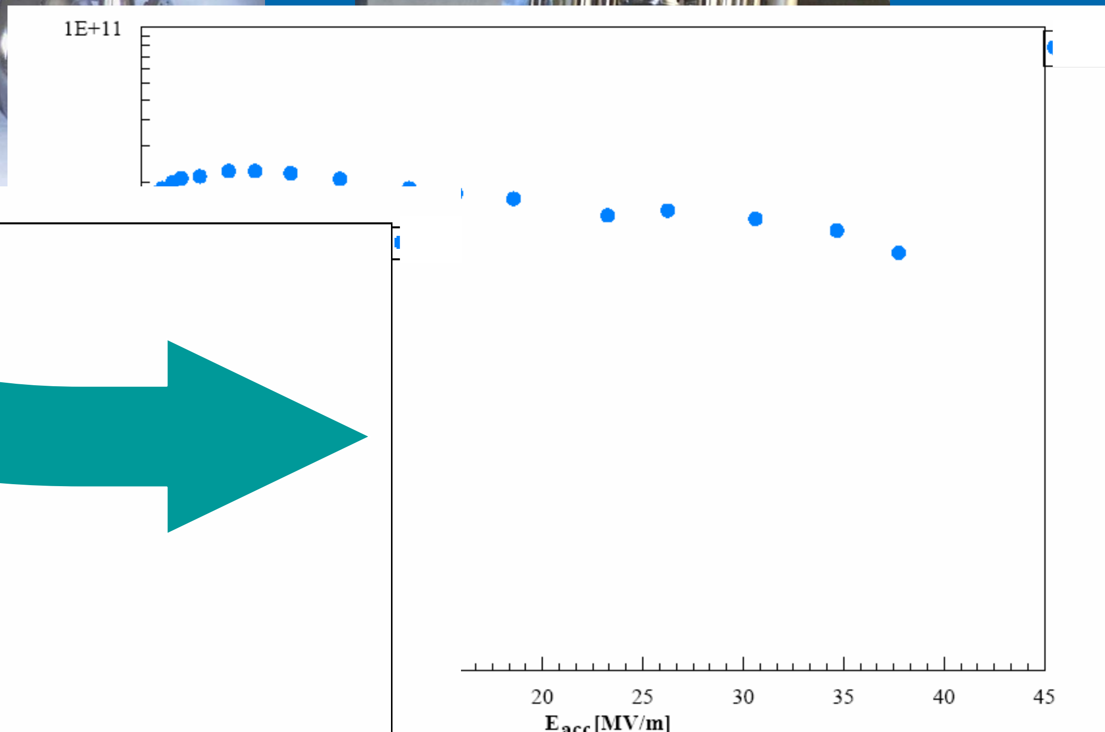
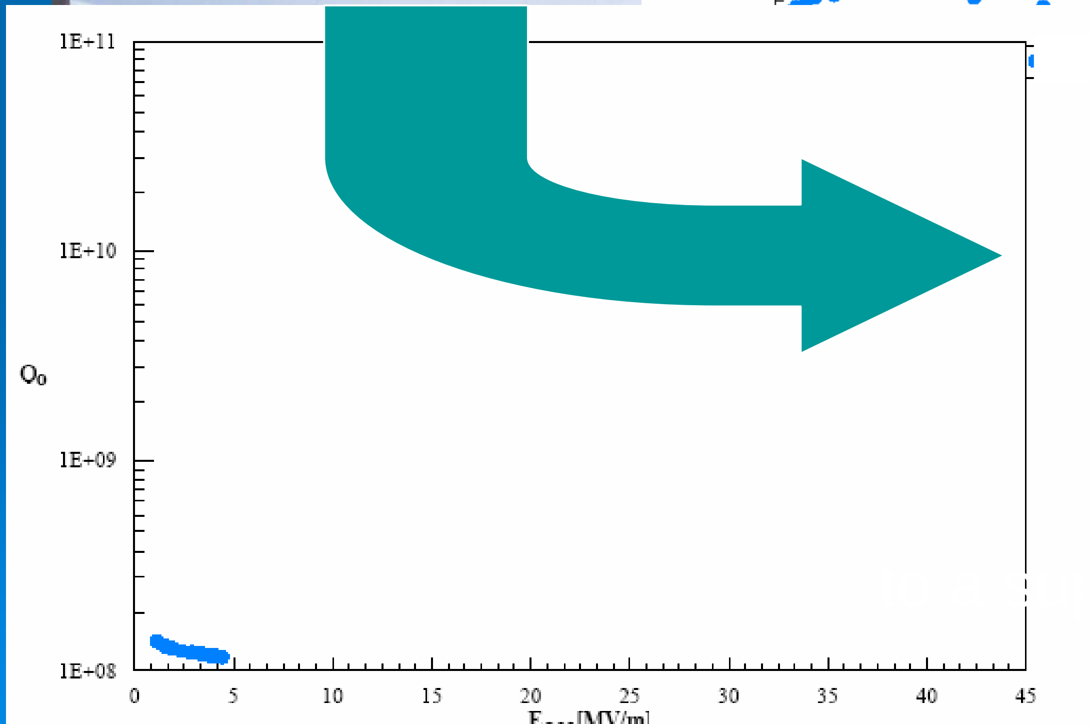
Subtitle how to come from a Niobium Cavity







er conducting resonator

7

Some background information to understand what is the difference ?

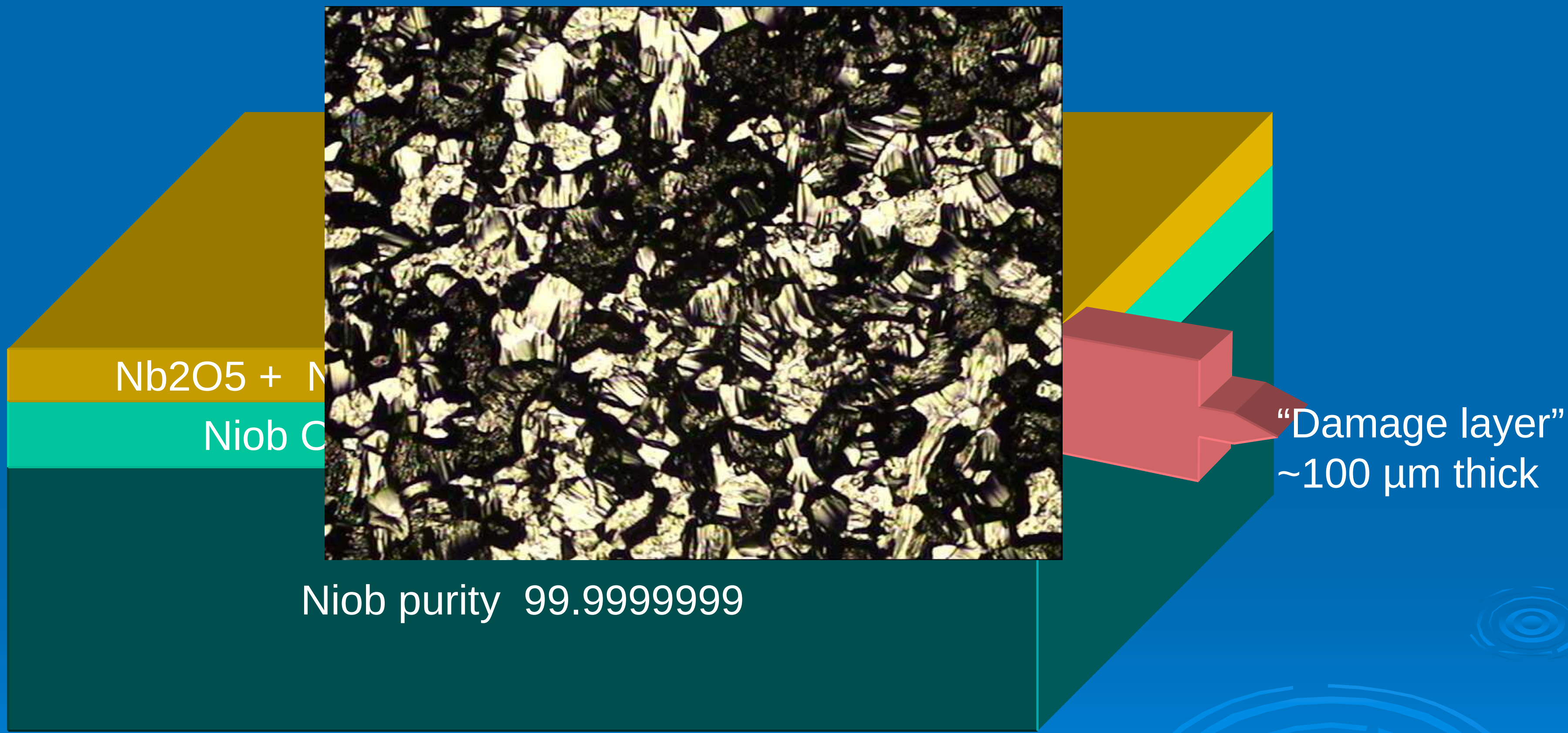
1) Surface preparation methods

2) Infrastructure for Cavity preparation

3) Handling and Know how on cavity preparation

1) Surface preparation methods

Virtual micro cut of a Niobium sheet



Removal of “damage” layer

Method's

Mechanically by

- Grinding
- barrel polishing (tumbling)

Chemically by

- chemical etching (buffered chemical polishing [BCP])
- Chemical polishing (electro polishing [EP])
- + + different new solution under development
- For instance
  - *see EU JARY1 program WP 5*
  - *Accel / Poligrad*
  - *Electro bright*

Mechanical removal of damage layer

Grinding

+ Simple handling

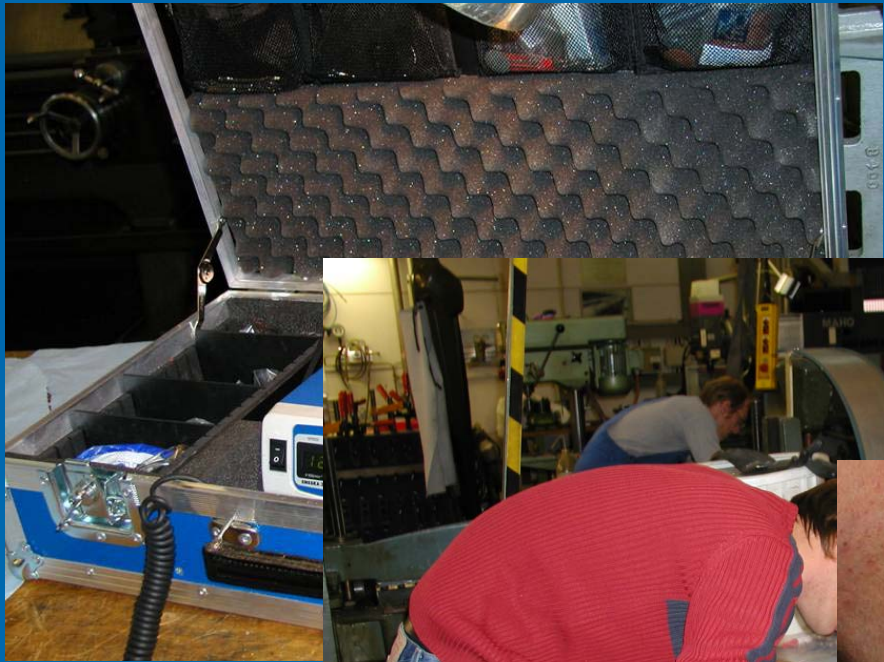
+ low cost standard mechanic

+ Mostly in use for removal of local defects non uniform abrasion !

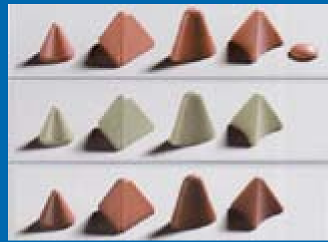
- Abrasives need to be qualified on s.c. Cavties!!

- Remain of C; Si ; glue; scratch size

- Produces a new damage layer of about 40 µm thickness!!!



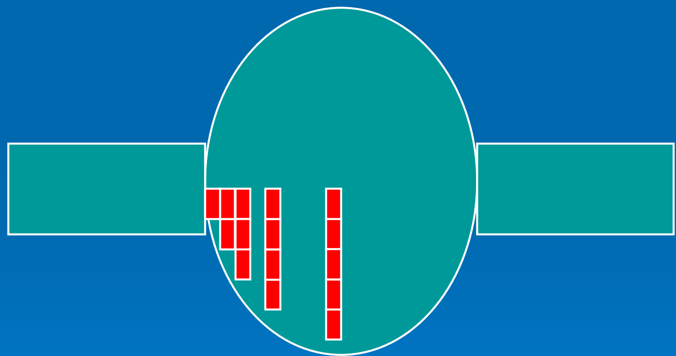
Tumbling



Material :"Stones" made in
different shape and material

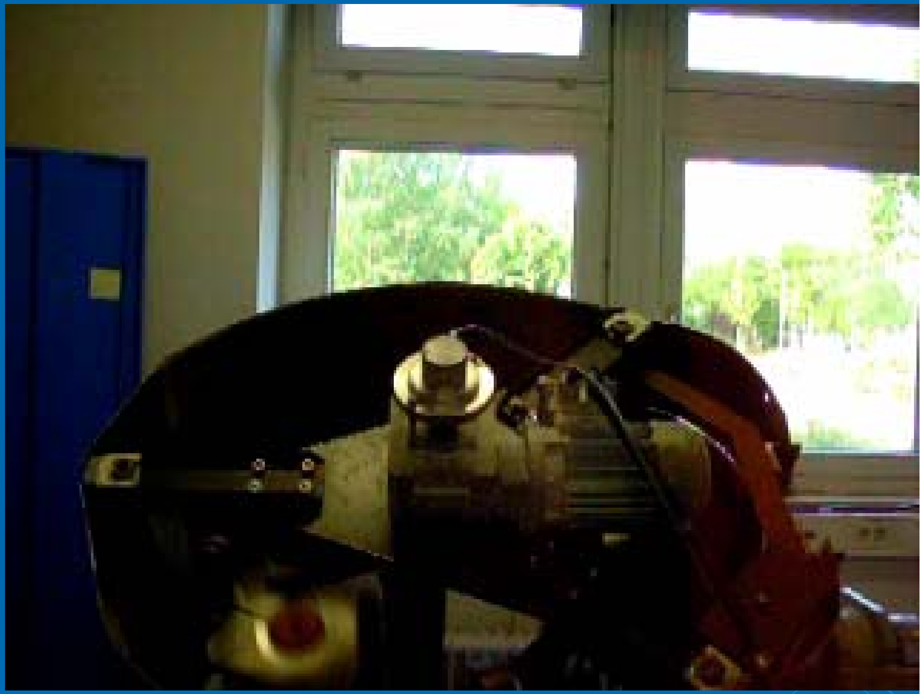
Application: Global
Effect: Smoothening and removal of local enhancement
(Sparcs from EB welding weld in area)

Removal: Non uniform contact pressure ➔



For optimum removal you need to design machines that make use of centrifugal forces to uniform the forces
(Complicated design)

Example of a tumbling machine
Designed an manufactured by DESY group MPL Waldemar Singer



Chemical removal of “demage” layer

Two types chemical removal are most commonly in use

BCP

Buffered chemical polishing

(Mixture of Hydrofluoric acid; Nitric acid and Phosphoric acid)

EP

Electropolishing

(Mixture of Hydrofluoric acid and Sulfuric acid)

Receipt:

BCP Acid

Mixed by volume from

1:1 HF(49%) /HNO3(70%)

to (1:1:2 HF(49%):HNO3(70%) :H3PO485%)

removal rate

1:1 at 20C >20 µm/min Removal Rate

1:1:2 t 20 C 1µm/min

Mixture is self exiting ! Spontaneous reaction with Nb!!

EP Acid

Mixed by volume from

1:8   HF(45%) /H2SO4 (96%)

to 1:10 (HF(45%)/H2SO4 (96%)

(+ H2O due to hygroscopic reaction of H2SO4!)

removal rate with 17 V applied

1:9 at 20C 0,3-0,5 µm/min

1:10 a t 20 C 0,3 – 0,4 µm/min

No reaction on Niobium without voltage applied!

Removal of niobium by chemical reactions

Niob Oxid Nb2O5 + XXX

Niob purity 99.9999999

Niob Oxid Nb2O5 +XXX

+HF ⇨ Nb_2O_5 +HF → H_2NbOF_2+NbO_2F

Niob Purity 99.9999999

Oxidizer [H_2SO_4 + voltage = EP]or [HNO_3 = BCP]

Niob Oxid Nb2O5

Niob Reinst 99.9999999

Niob Oxid Nb2O5

Chemistry

BCP (buffered chemical polishing)
Mixture by volume 1/1/2 HF/HNO3/H3PO4

$$2Nb + 5NO_3^- \Rightarrow Nb_2O_5 + 5NO_2 + 5e^-$$

$$Nb_2O_5 + 6HF \Rightarrow H_2NbOF_5(\text{l編}.) + NbO_2F \bullet 0.5H_2O(\text{unl編}.) + 1.5H_2O$$

$$NbO_2F \bullet 0.5H_2O + 4HF \Rightarrow H_2NbOF_5 + 1.5H_2O$$

EP (electro chemical polishing)
Mixture by volume 1/9 HF/H2SO4

$$2Nb + 5SO_4^{2-} + 5H_2O \Rightarrow Nb_2O_5 + 10H^+ + 5SO_4^{2-} + 10e^-$$

$$Nb_2O_5 + 6HF \Rightarrow H_2NbOF_5(\text{l編}.) + NbO_2F \bullet 0.5H_2O(\text{unl編}.) + 1.5H_2O$$

$$NbO_2F \bullet 0.5H_2O + 4HF \Rightarrow H_2NbOF_5 + 1.5H_2O$$

2) Infrastructure for Cavity Preparation

Super conduction surface will be covered by normal conducting material after standard wet surface treatments
(residues from chemical reaction and particulates)

- **Large areas of n. c. Material reduce the Q value**
- **Particulates are origin of field emission**

➔Need of particle and residue free
➔surface cleaning; Ultra pure water (UPW)
➔particle free storage and working atmosphere (Cleanroom)
➔and particle fee handling adapted tools and processes

Particulates on surfaces

Are there

Typical materials?

Non !

All air born substances of the world perform particulates

Typical size?

No!

Every size from ideal ball geometry to multi complex geometries

Common behavior?

Yes !

transportation in air make them flow every where

well know forces making them stick on surfaces

Other sources of particles and particle motion

Mechanical vibration

**** Hitting, banging, “tapping”**

(tightening bolts with wrench!!!)

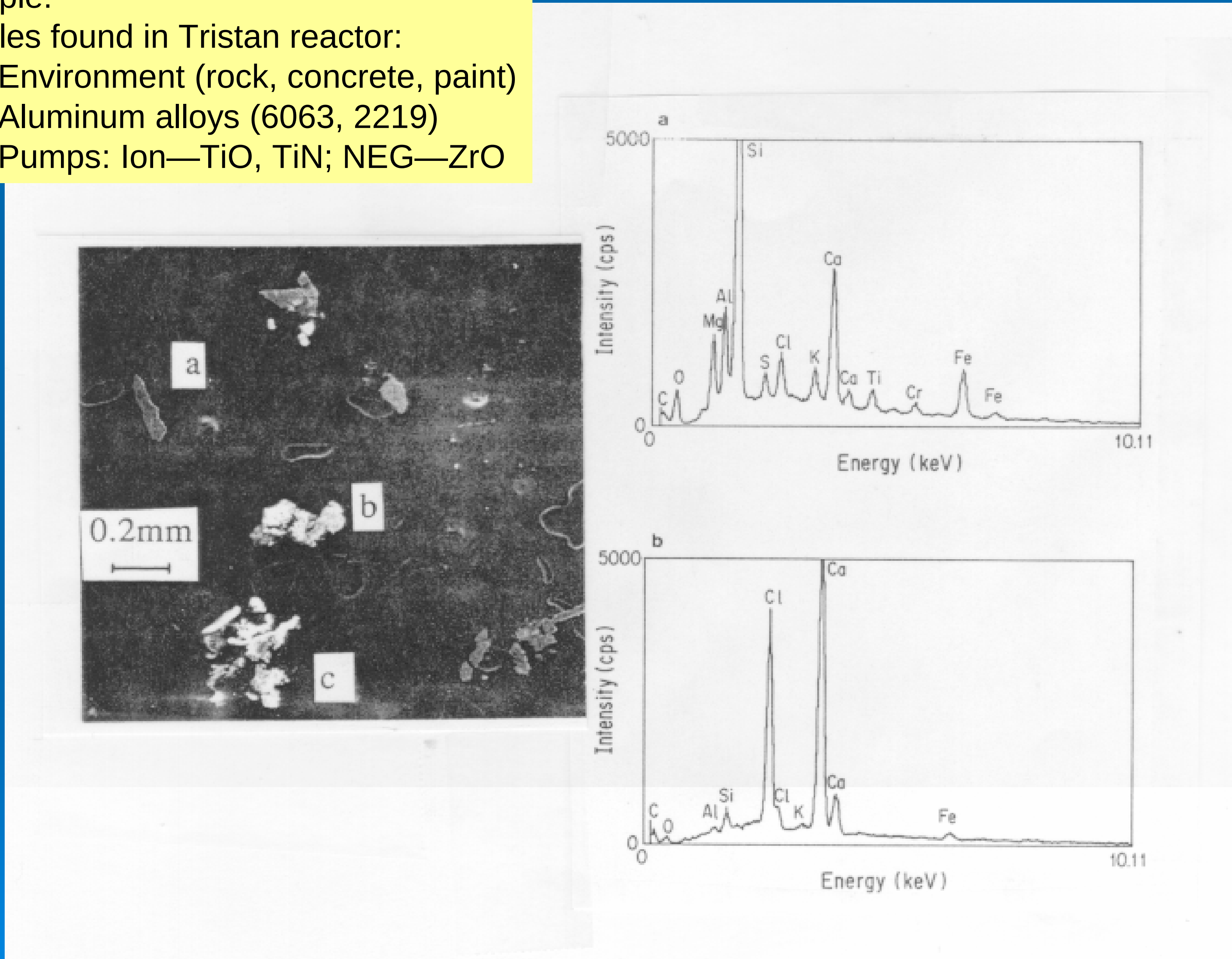
**** Closing a valve quickly**

Thermal cycling.

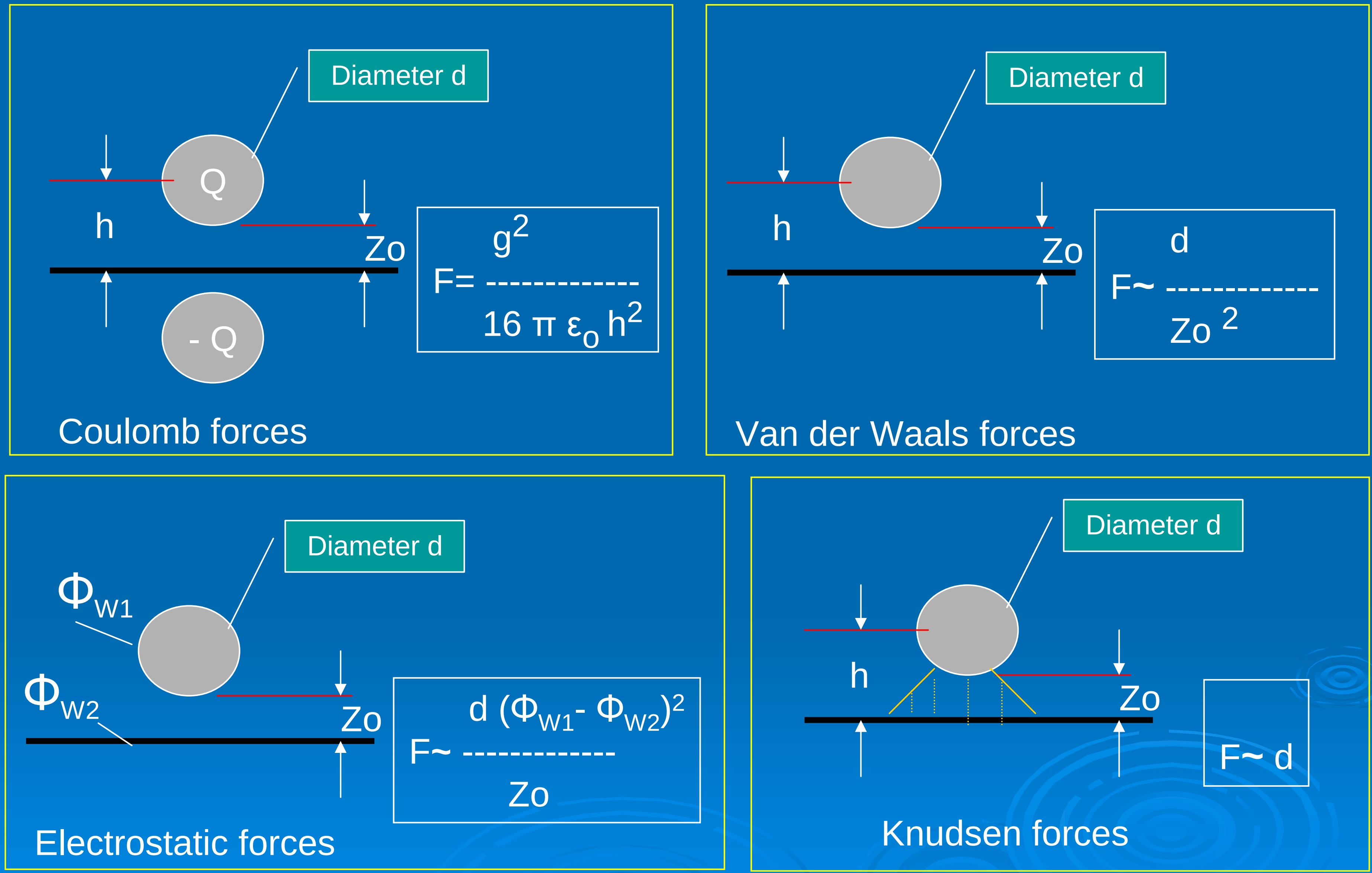
One cannot avoid cycling to 2 K!

Particles can be dislodged by thermal stress differences.

Example:
Particles found in Tristan reactor:
- Environment (rock, concrete, paint)
- Aluminum alloys (6063, 2219)
- Pumps: Ion—TiO, TiN; NEG—ZrO



Forces that make attractive potential to particulates facing a surface



How to introduce forces (energy) to the particles on a surface ?

Ultrasonic cleaning		
Discharge of static loads	→	Ionized Gases (air N2)
Reduce surface tension	→	Alcohol / Detergents
Rinsing	→	High Pressure Rinsing
Enforced gas flow	→	air guns (N2 ; Ar)

Problem speed on surface = 0

oder aufgrund der Distanz von der Plattenkante x

$$Re_x = \frac{U_o x}{\nu} \qquad (7.16b)$$

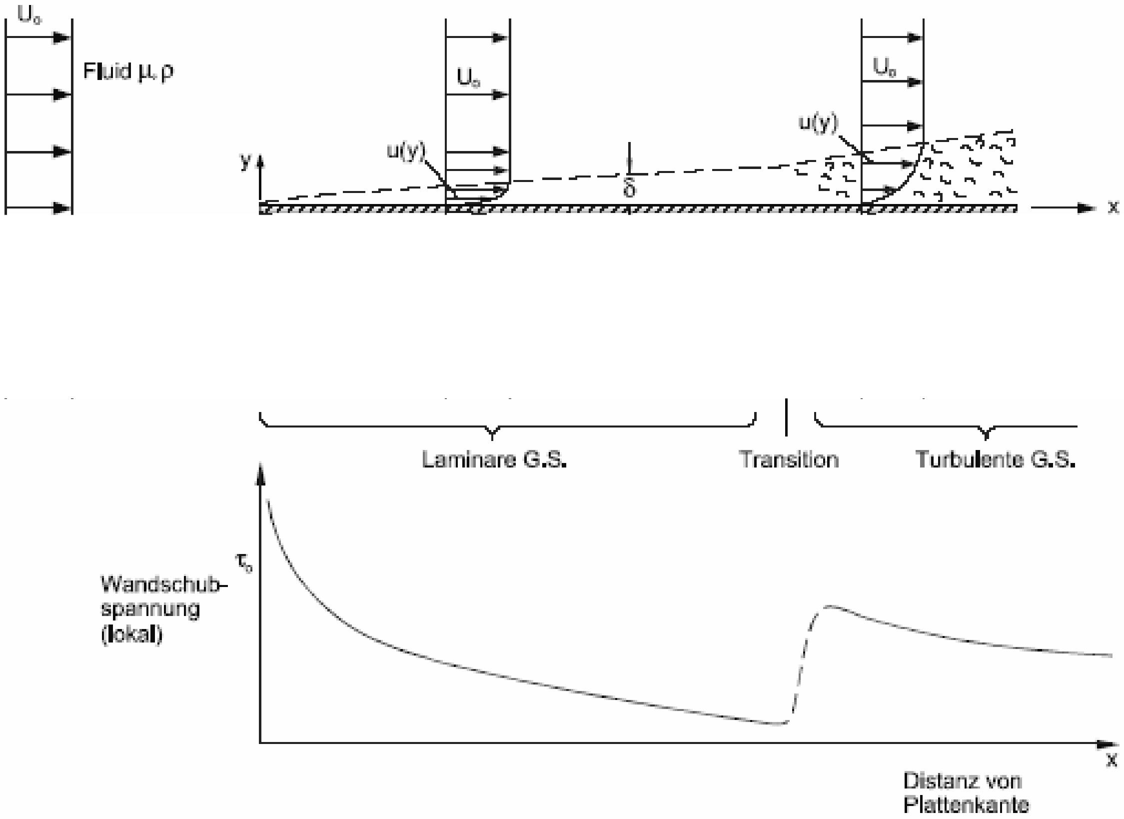
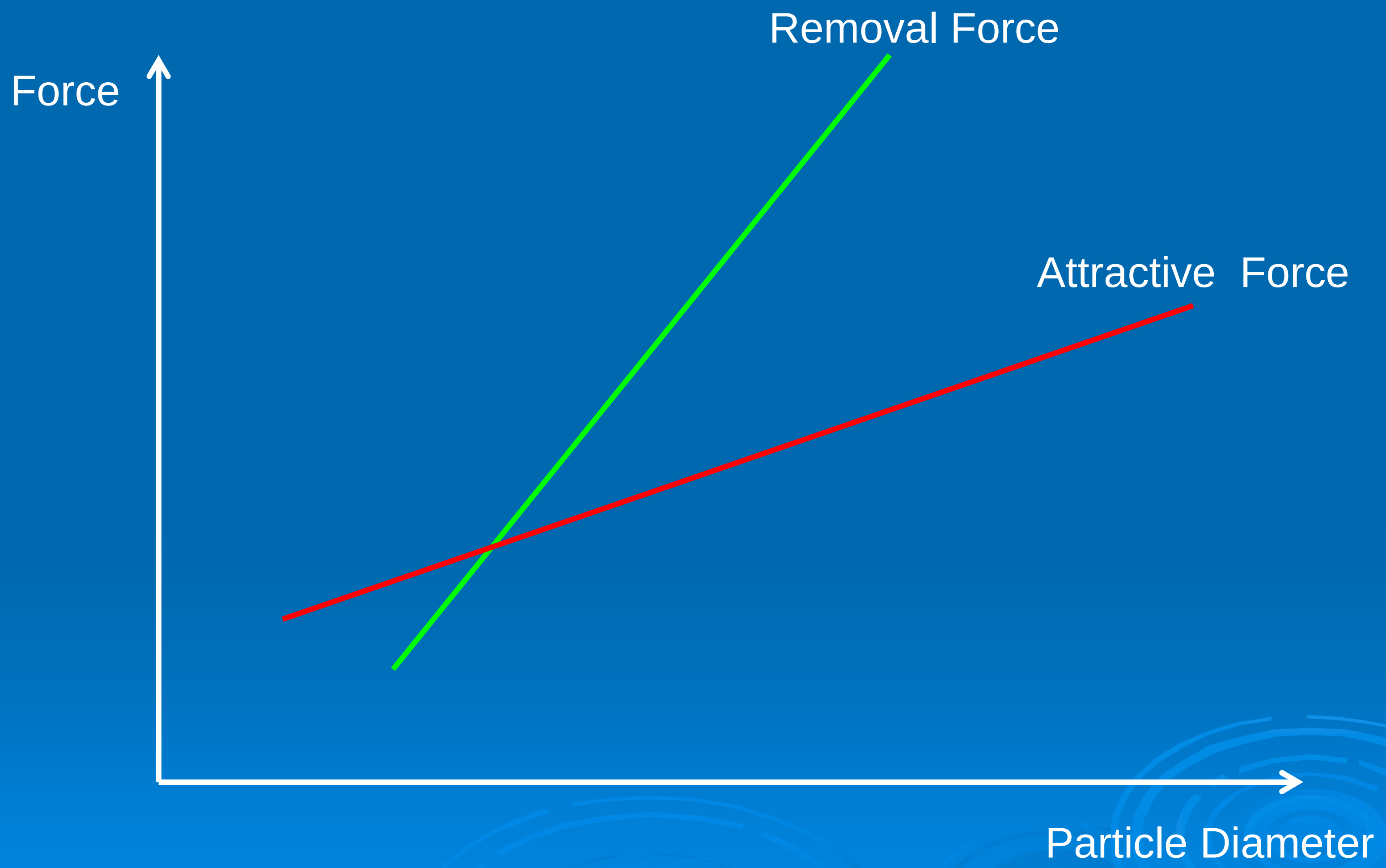


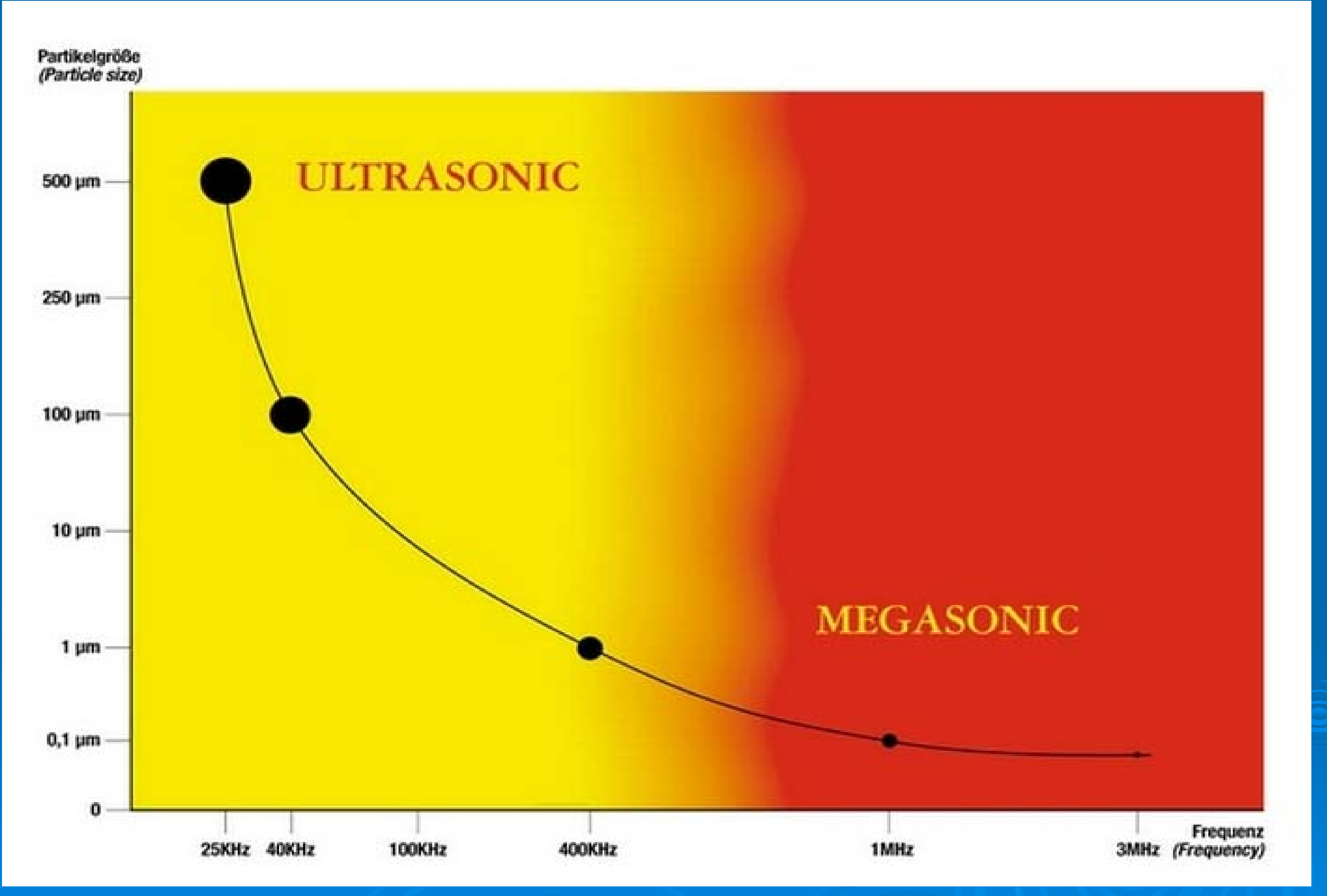
Abb. 7.5: Grenzschichtverhalten entlang einer dünnen Platte ohne Druckgradienten, $dp/dx = 0$.

But what to do when particulates already rest rest on a superconduction surface?

Apply forces larger than the active ones (static; v.d. Waals etc.) to remove them



Surface cleaning with sound waves in ultra pure water



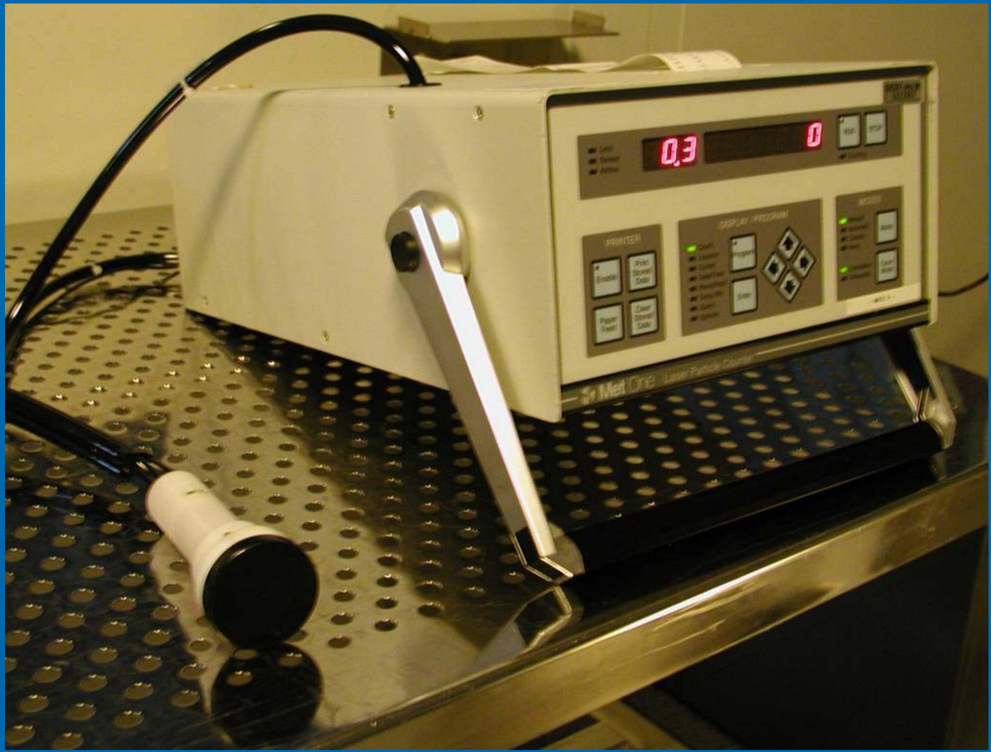
Preparation of flange surface:

a) - 20 Min US cleaning within DESY US basin
- Automatic rinsing with DESY UPW rinsing basin (R >= 12 MOhmcm)
- Drying in class 100

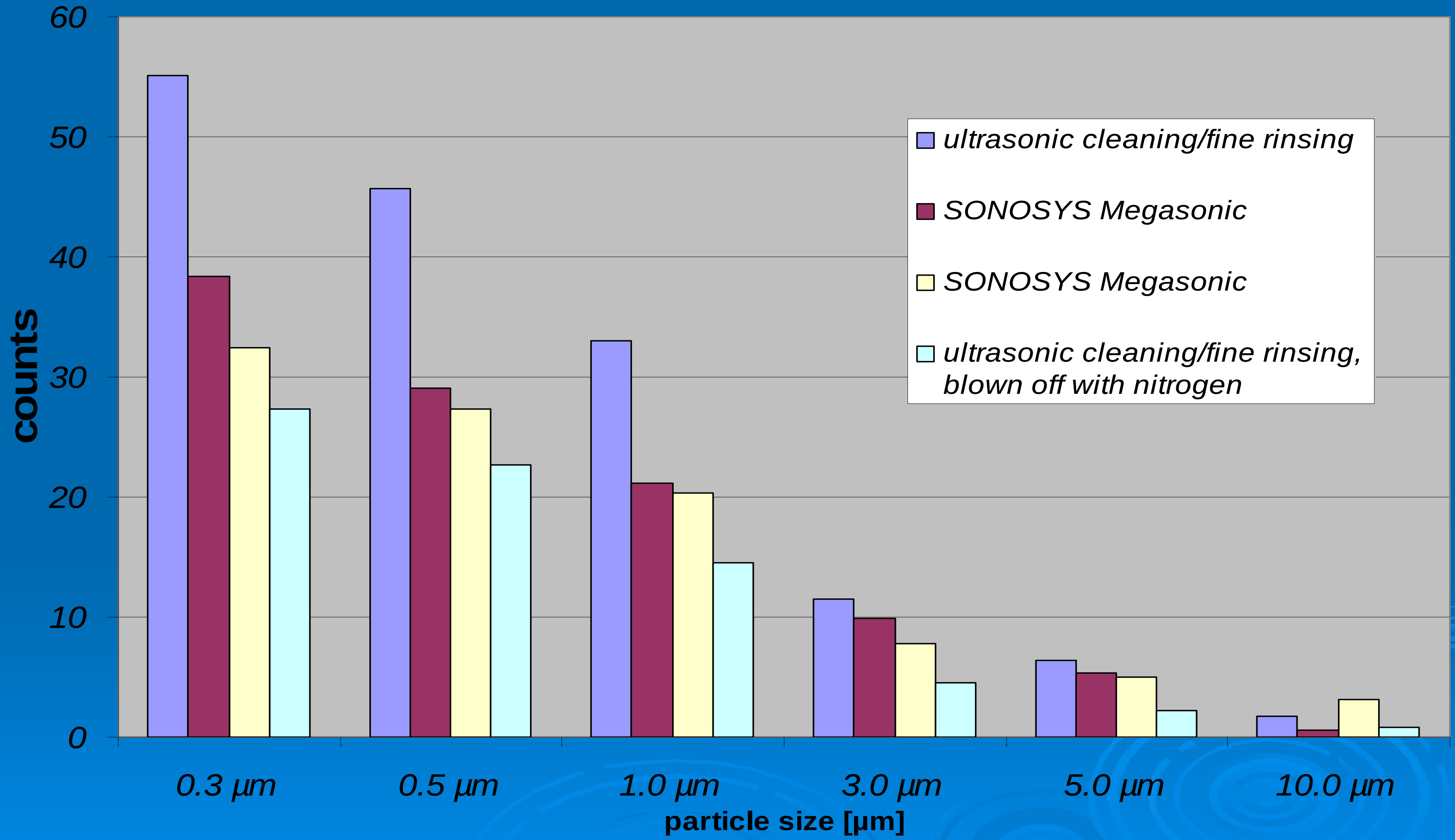
b) - cleaning with hand held megasonic cell®$_2$ at optimized distance of 20 cm between Object and Cell (Nozzle)
Drying in class 100

c) - 20 Min US cleaning within DESY US basin
- Automatic rinsing with DESY UPW rinsing basin (R >= 12 MOhmcm)
- Drying in class 100
Blowing of surface by ionized nitrogen of the pulsed gun

Surface scanning to measure particle concentrations on surfaces



Studies on most efficient cleaning



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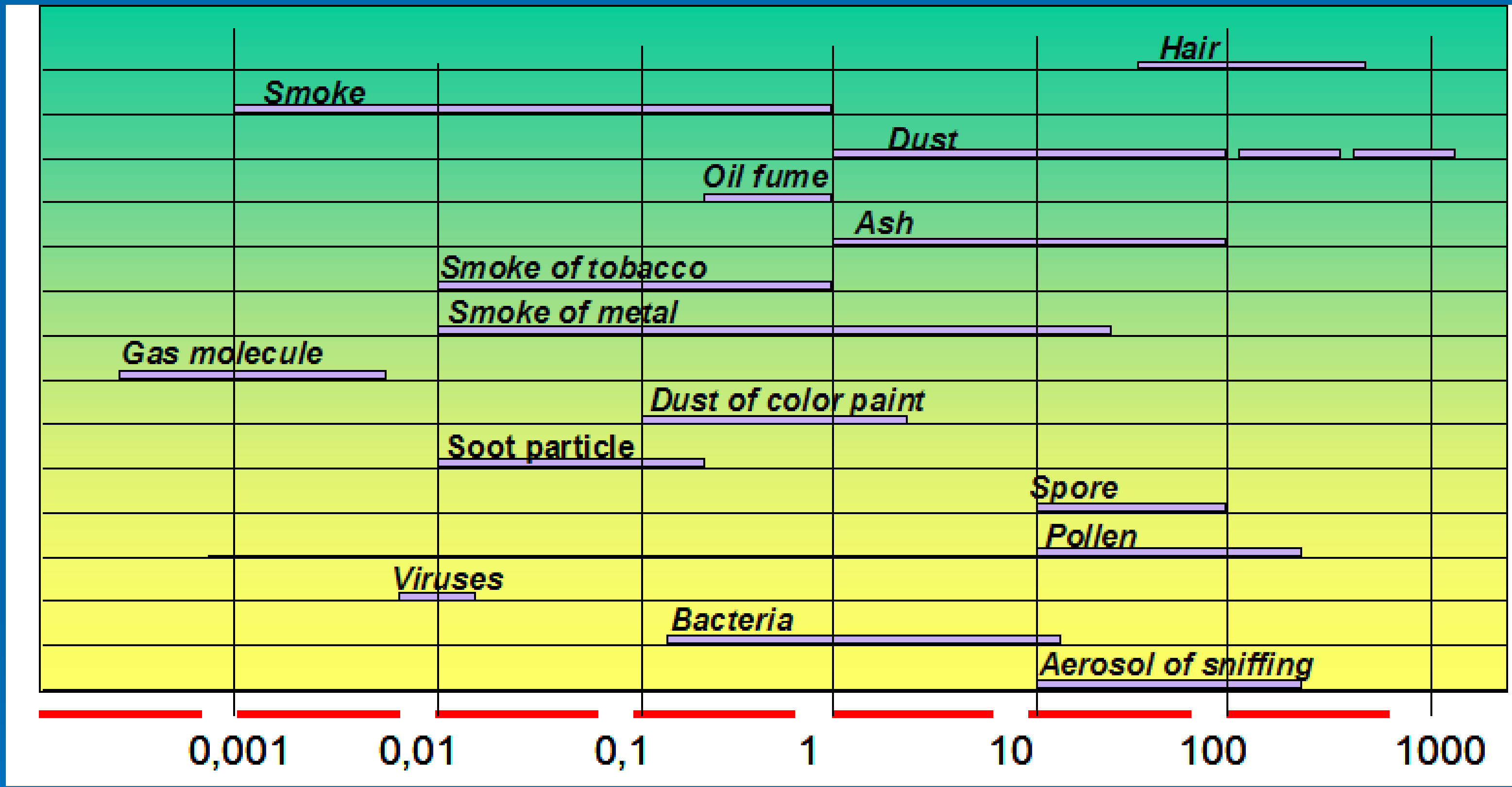
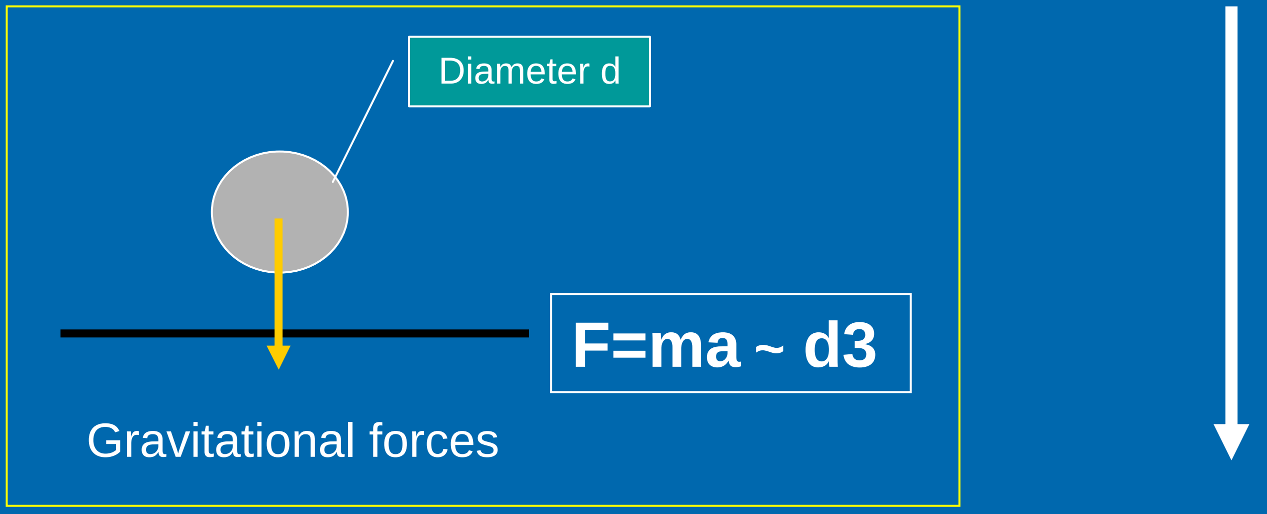
Particulates in the air

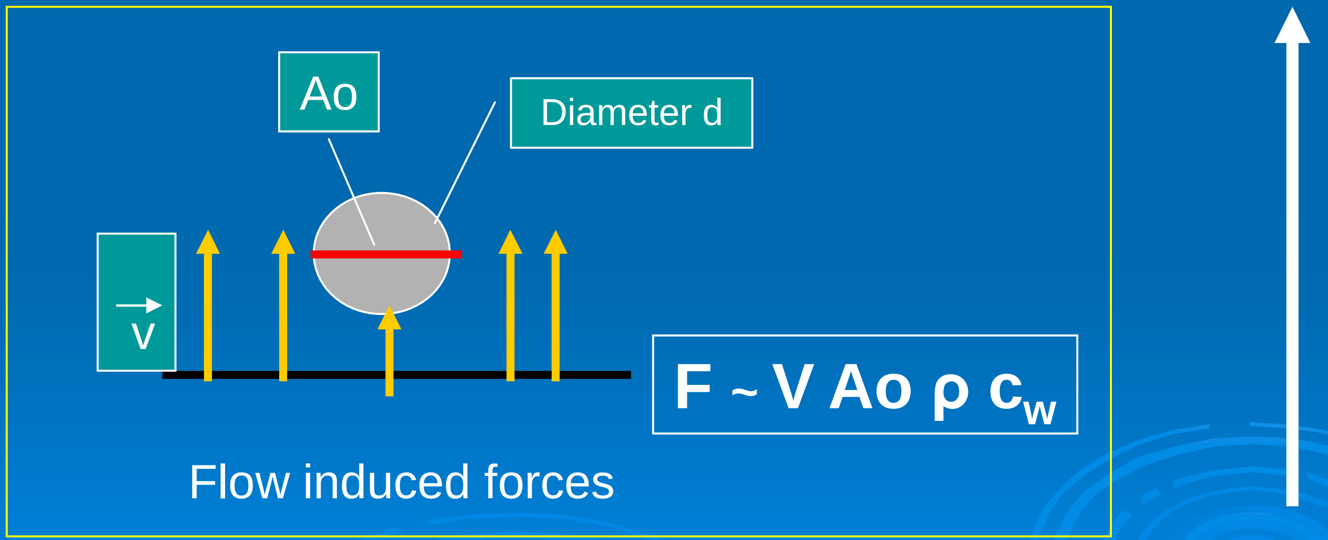
Which particles do we find in our normal air ? ?



(Particle size) [µm]

Particulates in air





Example fro

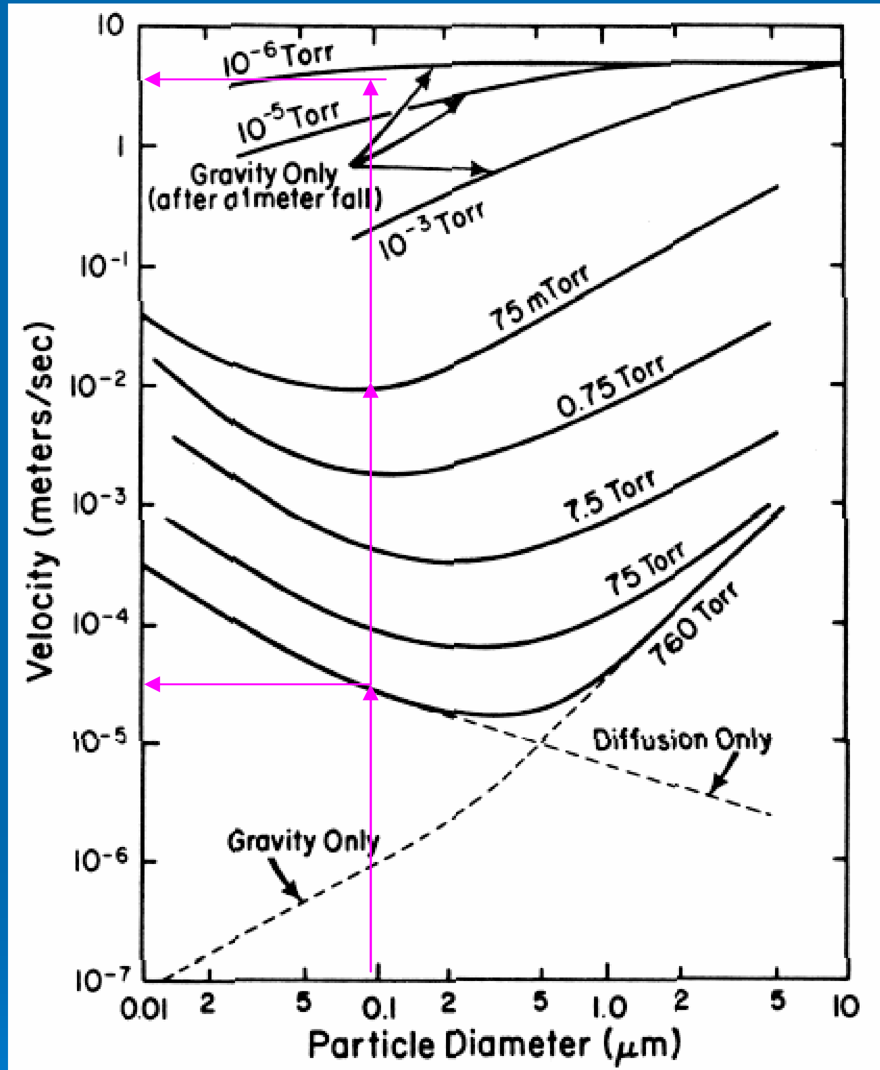
Settling velocity for particles

Gas :Air

Temperature = room temperature

Electric fields: non

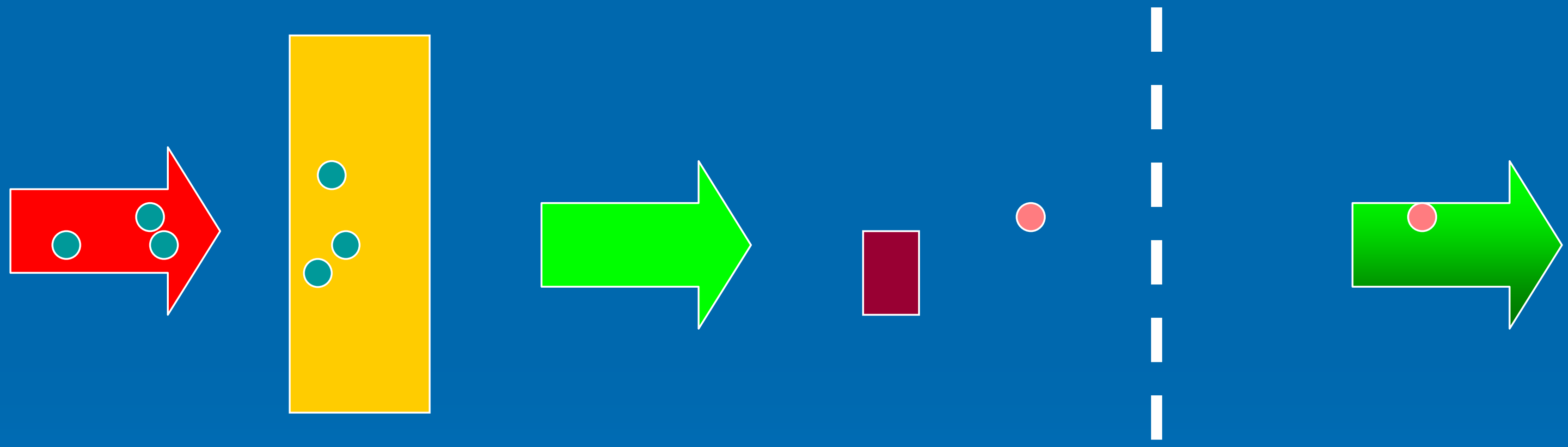
airflow: not enforced (normal air)



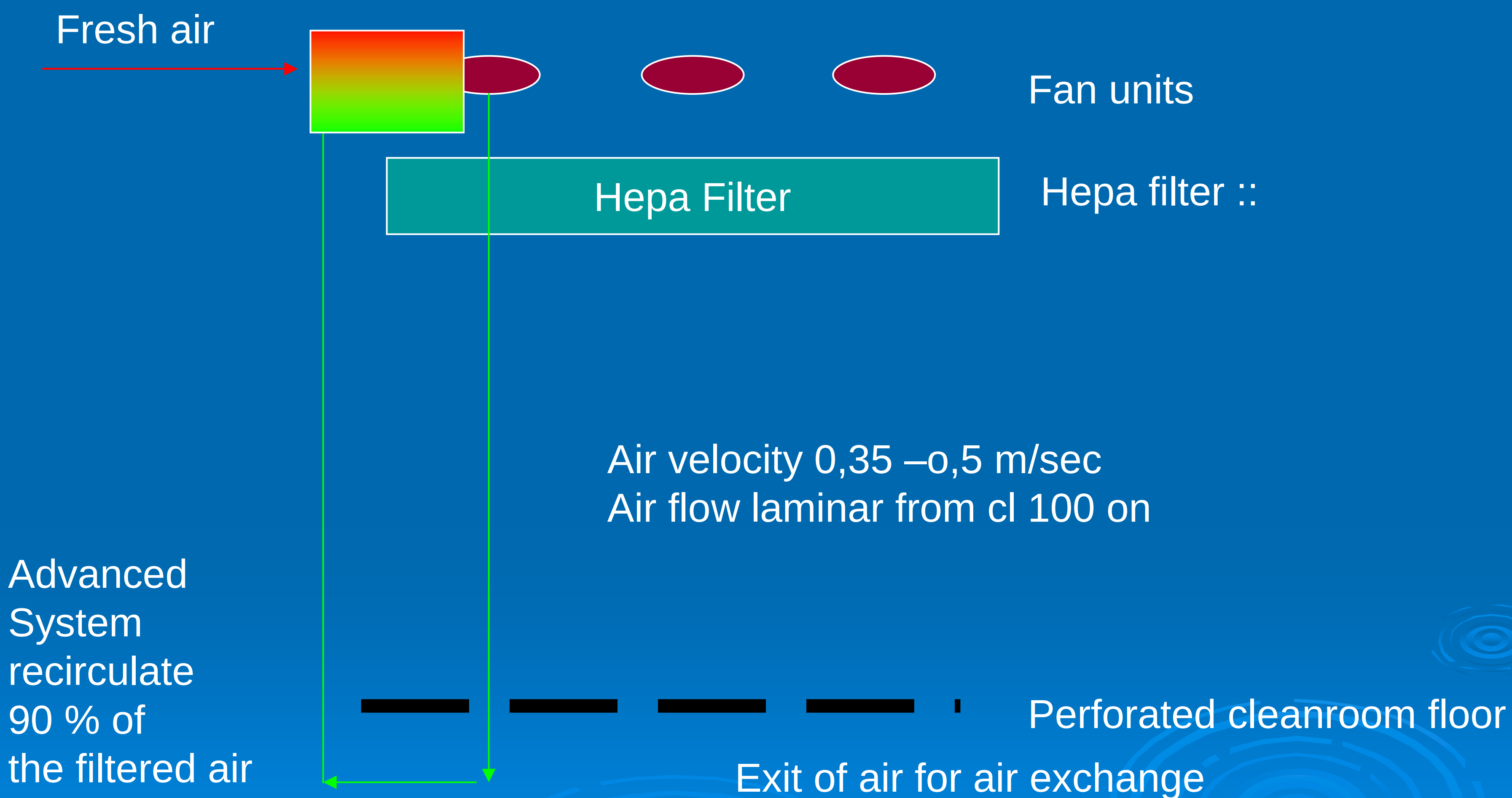
Overview talk of John O'Hanlon
vacuum@dakotacom.net

For super conduction cavities clean water and cleanroom technology is required to prevent air born particulates from settlement on surfaces

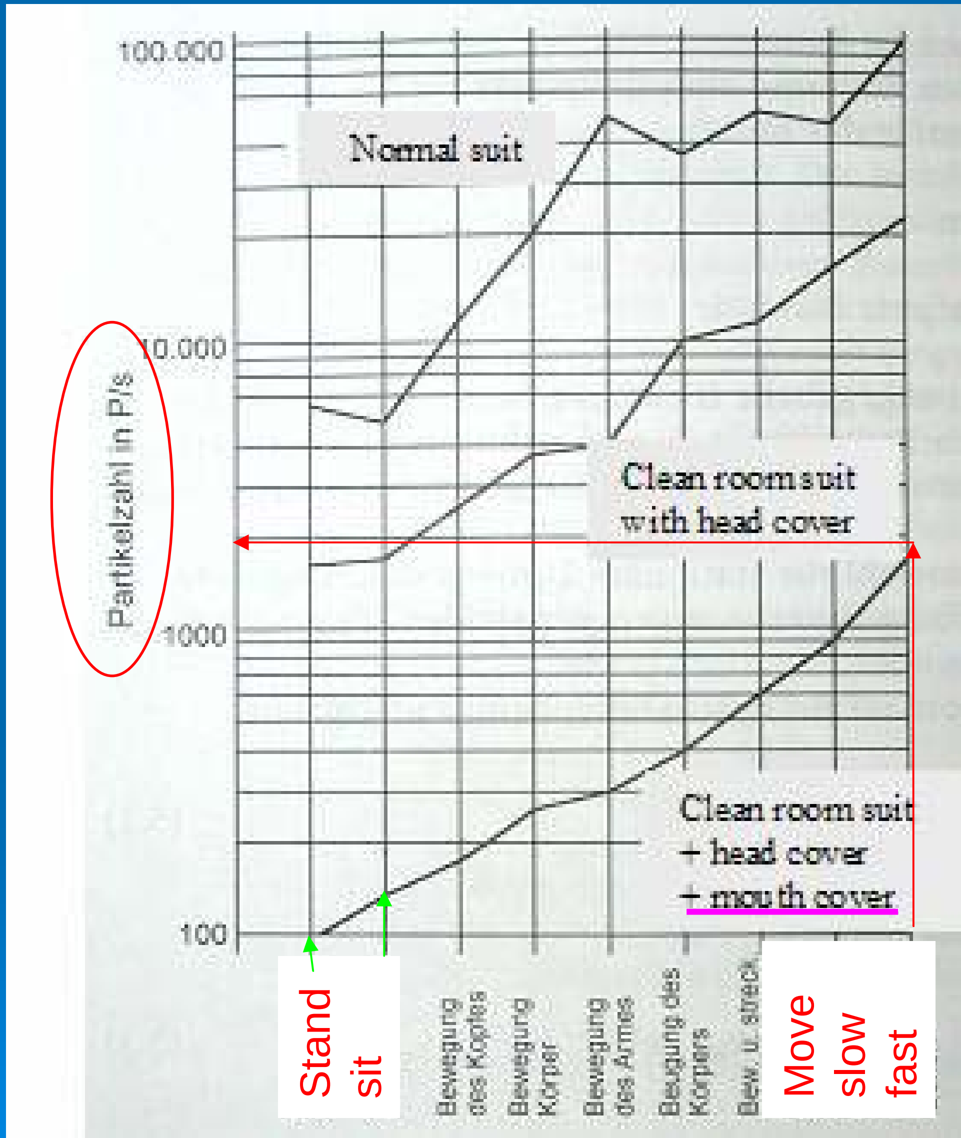
Basics of cleanroom technology



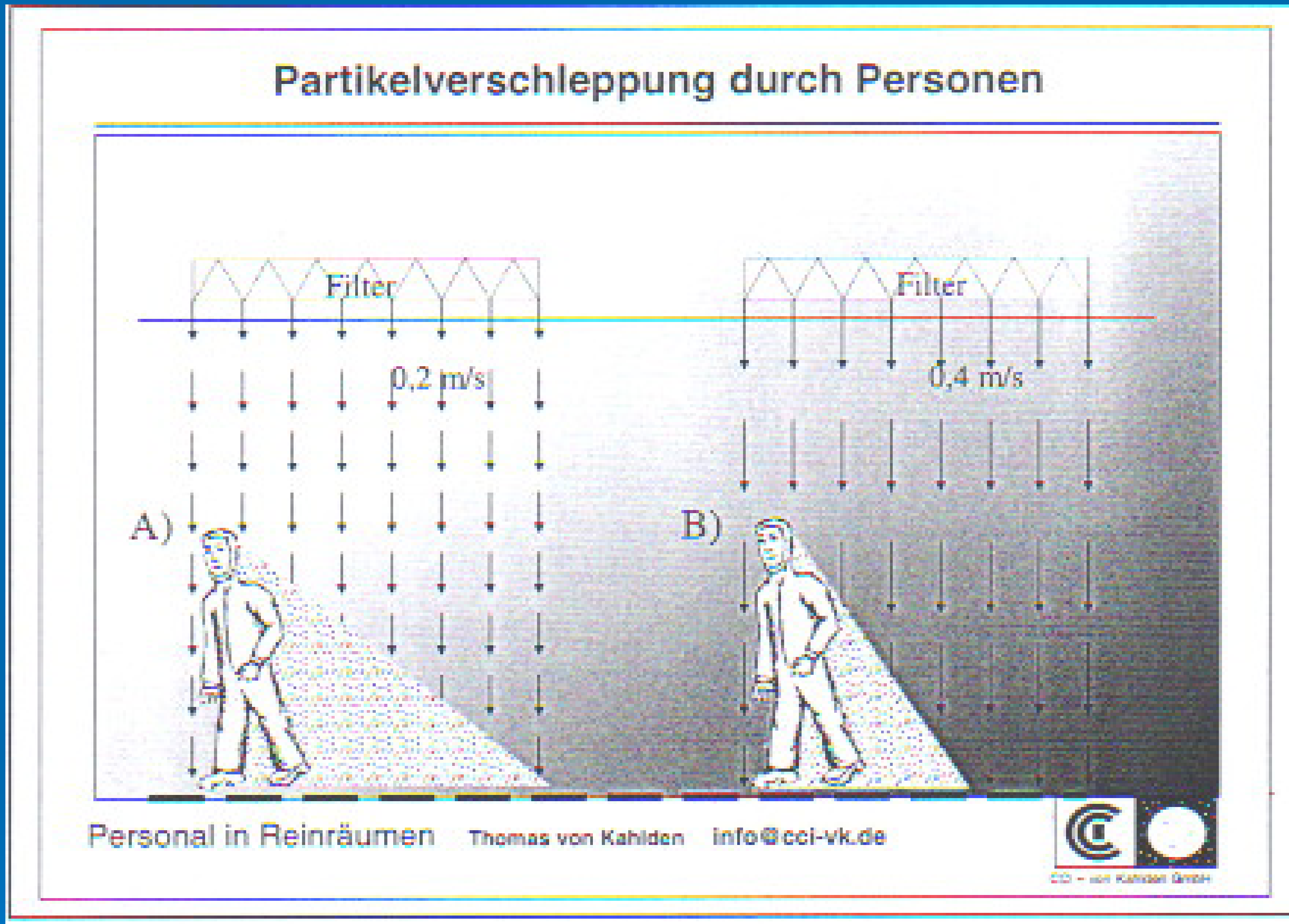
Basic function of a cleanroom



One major part inside a cleanroom is PERSONAL



1st Dress code


Partikelverschleppung durch Personen
Filter
0,2 m/s
A)
Filter
0,4 m/s
B)
Personal in Reinräumen
Thomas von Kahlden
info@cci-vk.de

3) Handling and know how on cavity preparation

Behavior of personal inside a cleanroom

Wrong !!!!

Right !!!

Open the door
But right !

Be careful where your hands and your body is close to an open cavity

But from where do we know that all this technology works as designed?

Quality control during cavity preparation

1) Air; gasses; liquids
2) surfaces
3) Flow pattern
4) Degreasing and rinsing

Schematic of particle counters

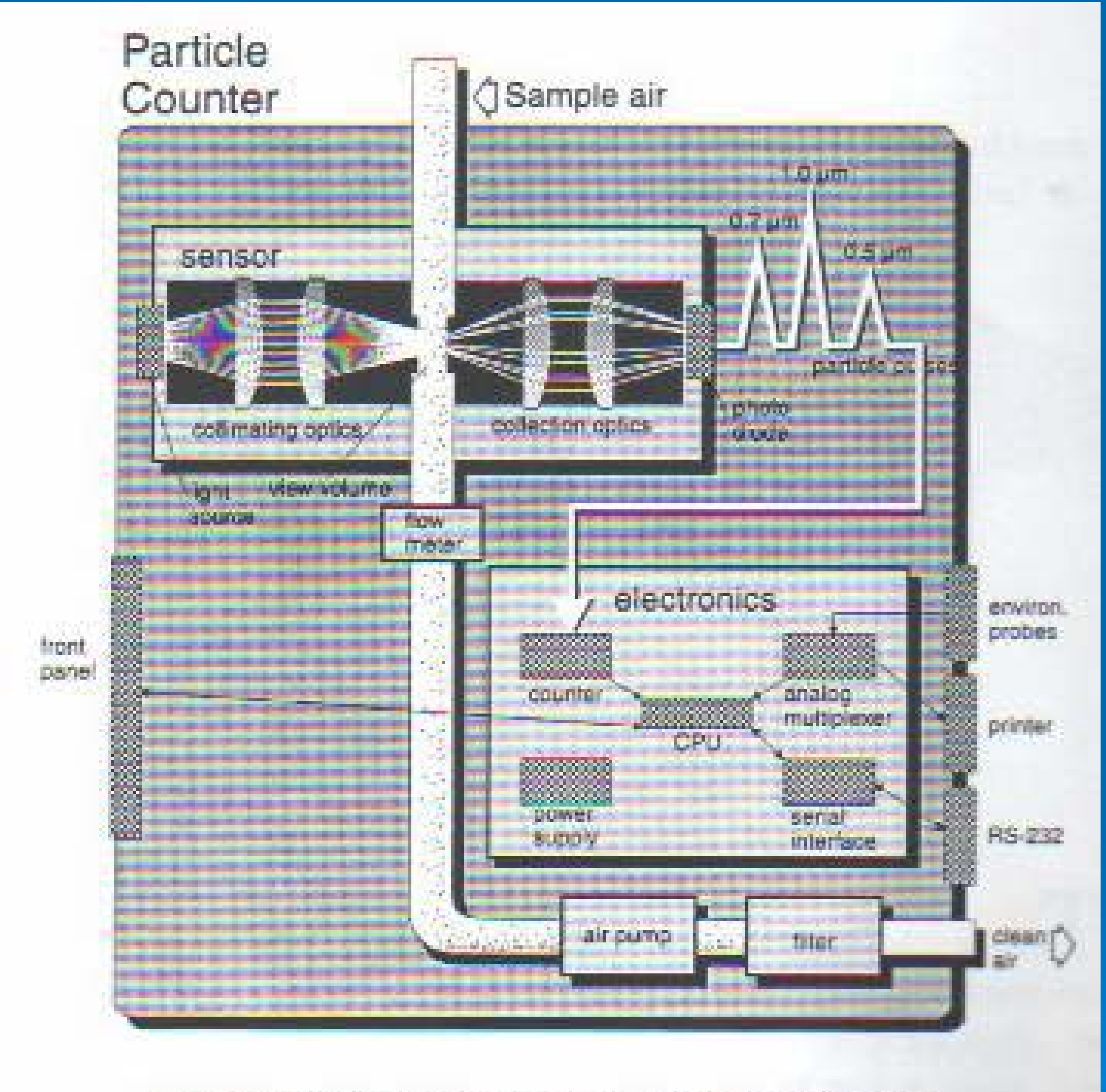
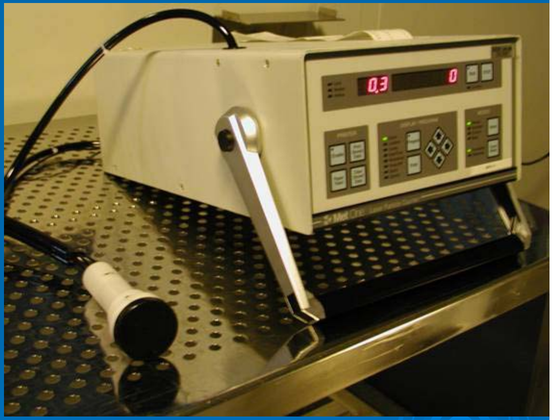


Figure 1-1. Particle Counter Simplified Flow Diagram



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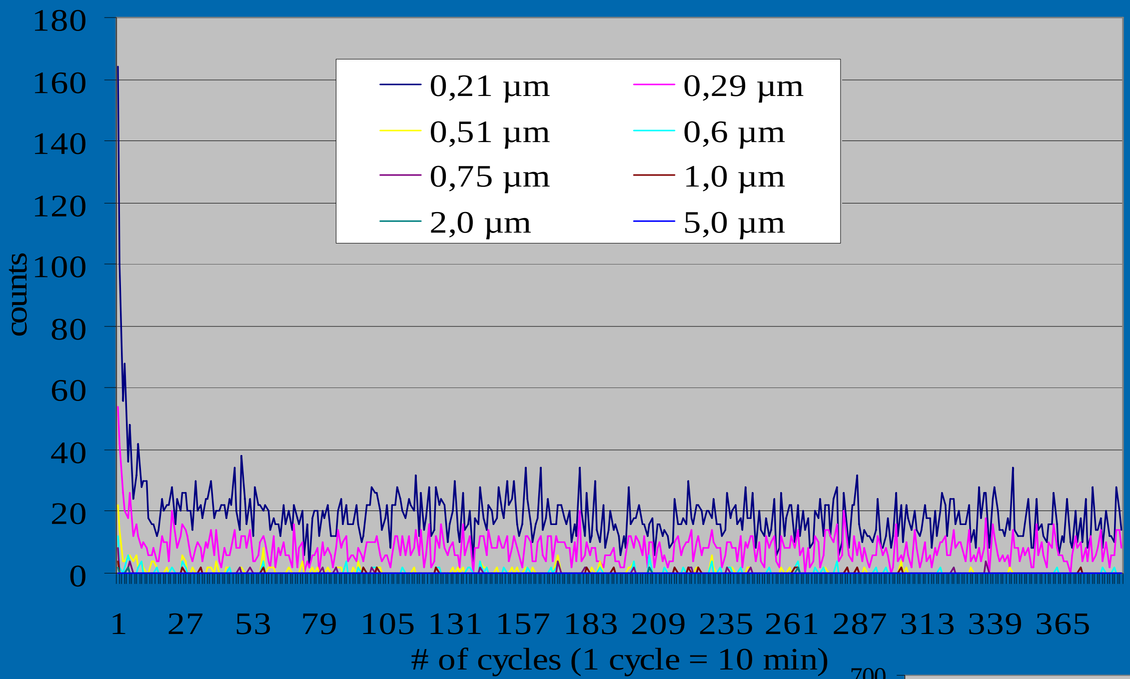
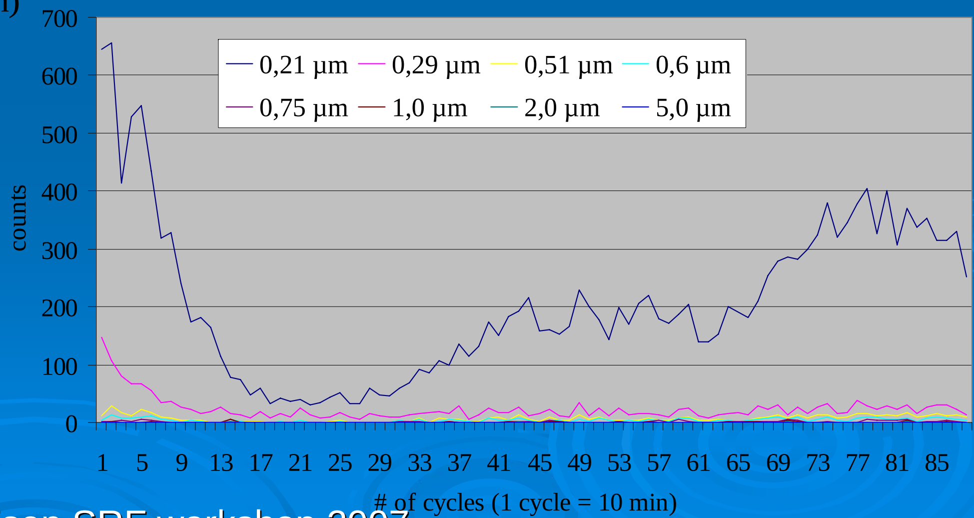
Air; gasses; liquids

Some example on particle detection in ultra pure water



Particle concentration of the HPR filter after 72 h of rinsing

Particles found after installation of a new filter to the HPR stand, total sampling time 16 hours



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Air; gasses; liquids

unit	hardness [Deutsche Härte]	Restitvity [Mohm cm]	Bacteria colonies [per liter]	TOC [ppb]	Particulates [Counts >0,3 µm/ liter]
Tap water	7-10	<< 0,0001	>= 100 (@DESY tap connection)	Not defined	Not defined
Decalcification of tap water	<=1	<< 0,0001	50-100	<10	Not defined
Reverse osmosis	<=1	R<= 0,2	50-100	< 10	Not defined
UV light	<=1	R = 18,2	1-5	1-3	Behind filter 20- 100
Ion exchanger / Polisher	<=1	R = 18,2	1-5	<10	Behind filter 20-100
UV light	<=1	R = 18,2	1-5	1-3	Behind filter 20- 100
Point of use filtration	<=1	R = 18,2	1-5	1-3	<=10

Particle detection on rinsing water of the HPR system

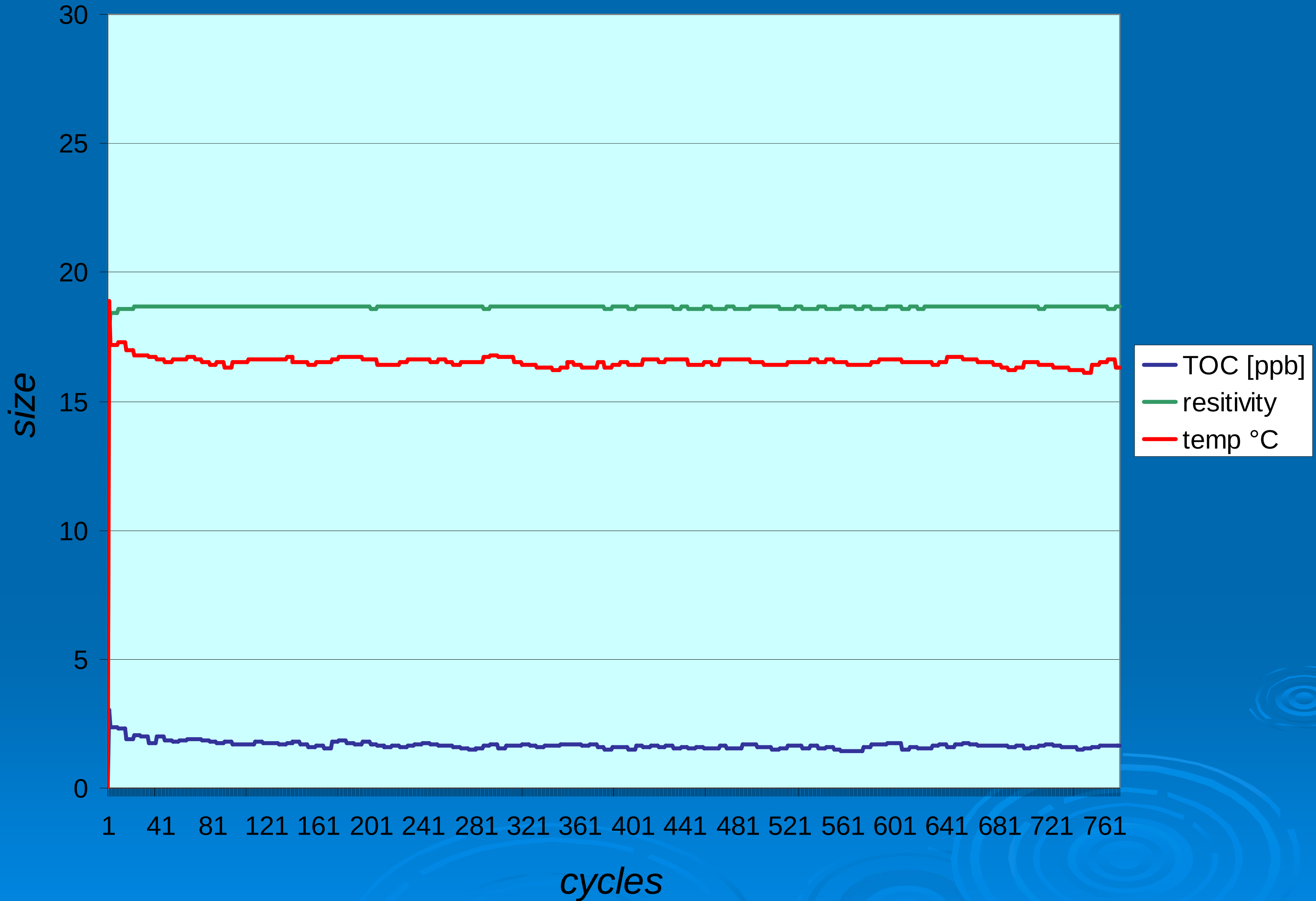
HPR ejection nozzles and QC funnel

Particle filter <=2 µm
in HPR draining line

Air; gasses; liquids

Scanning microscope for particle filter counting and visual analysis

Monitoring of the total oxydable carbon (TOC) in ultra pure water



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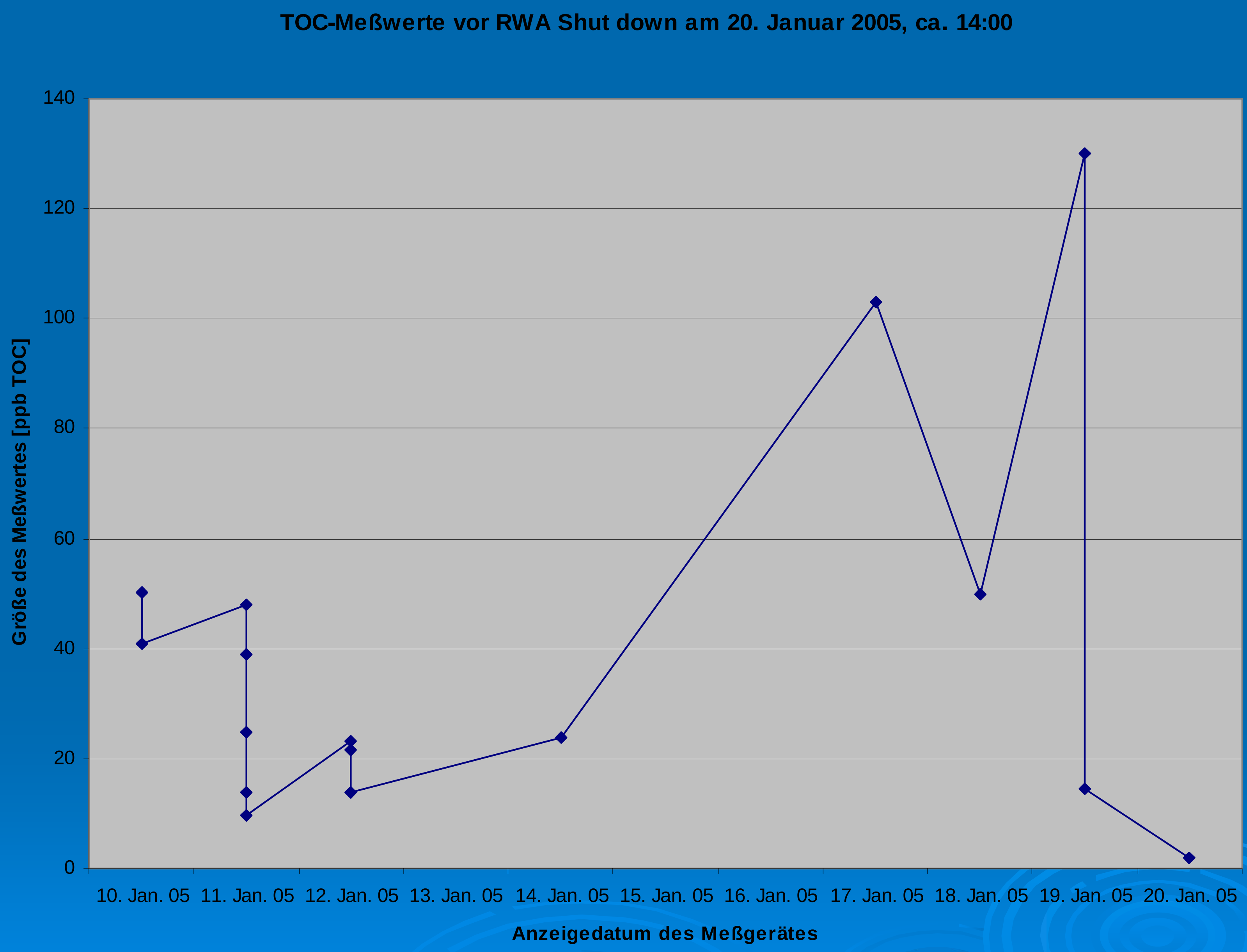
Air; gasses; liquids



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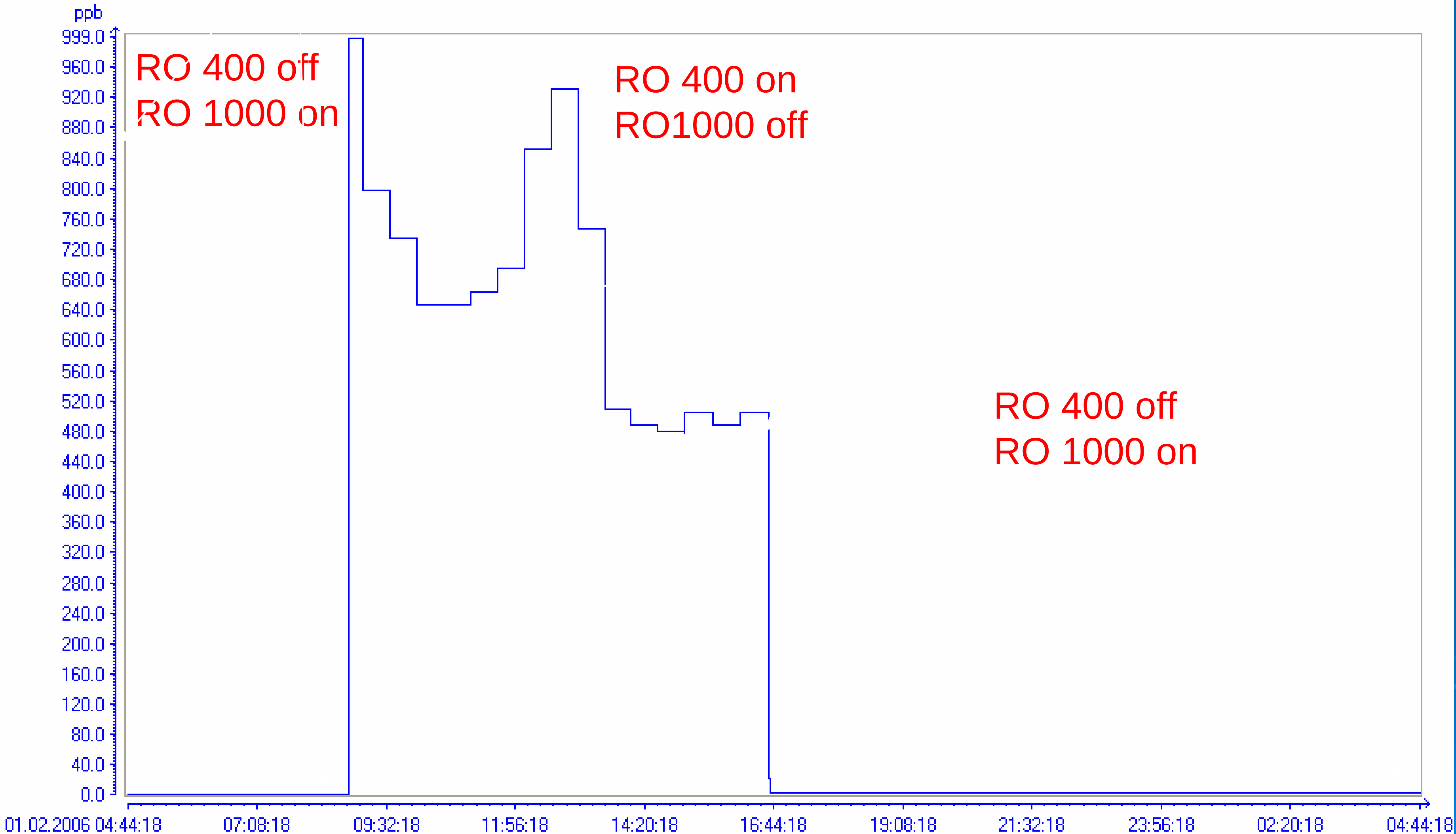
Example on bacteria contamination in
one of the two reverse osmosis unit of the cleanwater plant



Quality control on particulates removed from a surface by ionized air (top gun)

QC of studs before installation to a cavity

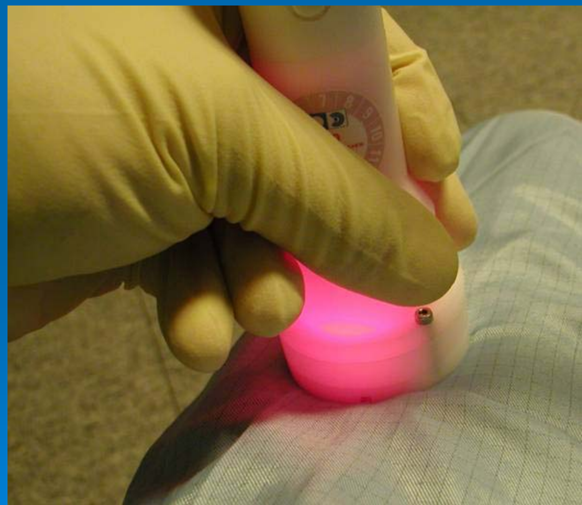
QC of washers before installation to a cavity

Air; gasses; liquids

Quality control on particle concentration on surfaces

Air particle counter modified for measurement on surfaces

Particle detection on a cleanroom wall



Particle detection on a cleanroom overall

Particle detection on a cleanroom table

Instrument : modified Air Particle Counter

Add on surface instrumentation: designed by CCI von Kahlden GmbH ®[1]

Definition of particle density on surface

Particle density : $P= C/A$ [counts per cm^{2}]

Static application : $P= C/ A$ counts / $(\pi d^2)/4$

Dynamic application: $P=C/Ax$

Scanned surface: $Ax= A_1 +A_2$

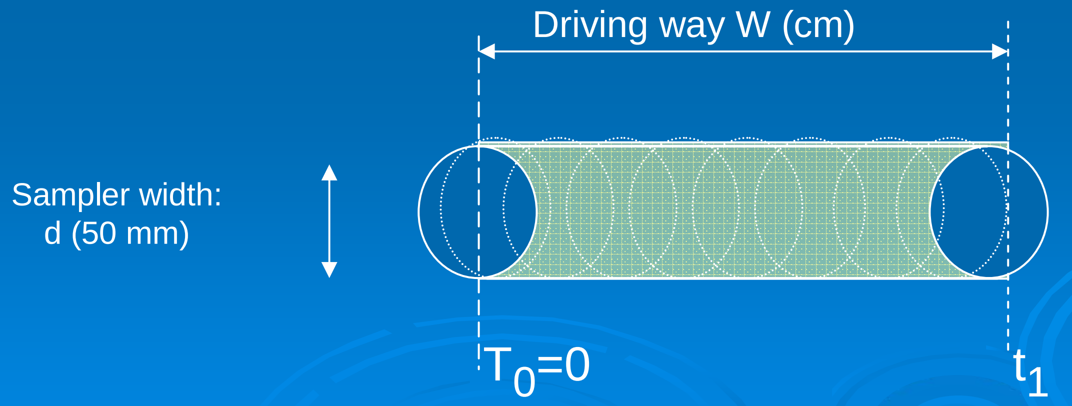
$A_1=(\pi d^2)/4$ [mm2]

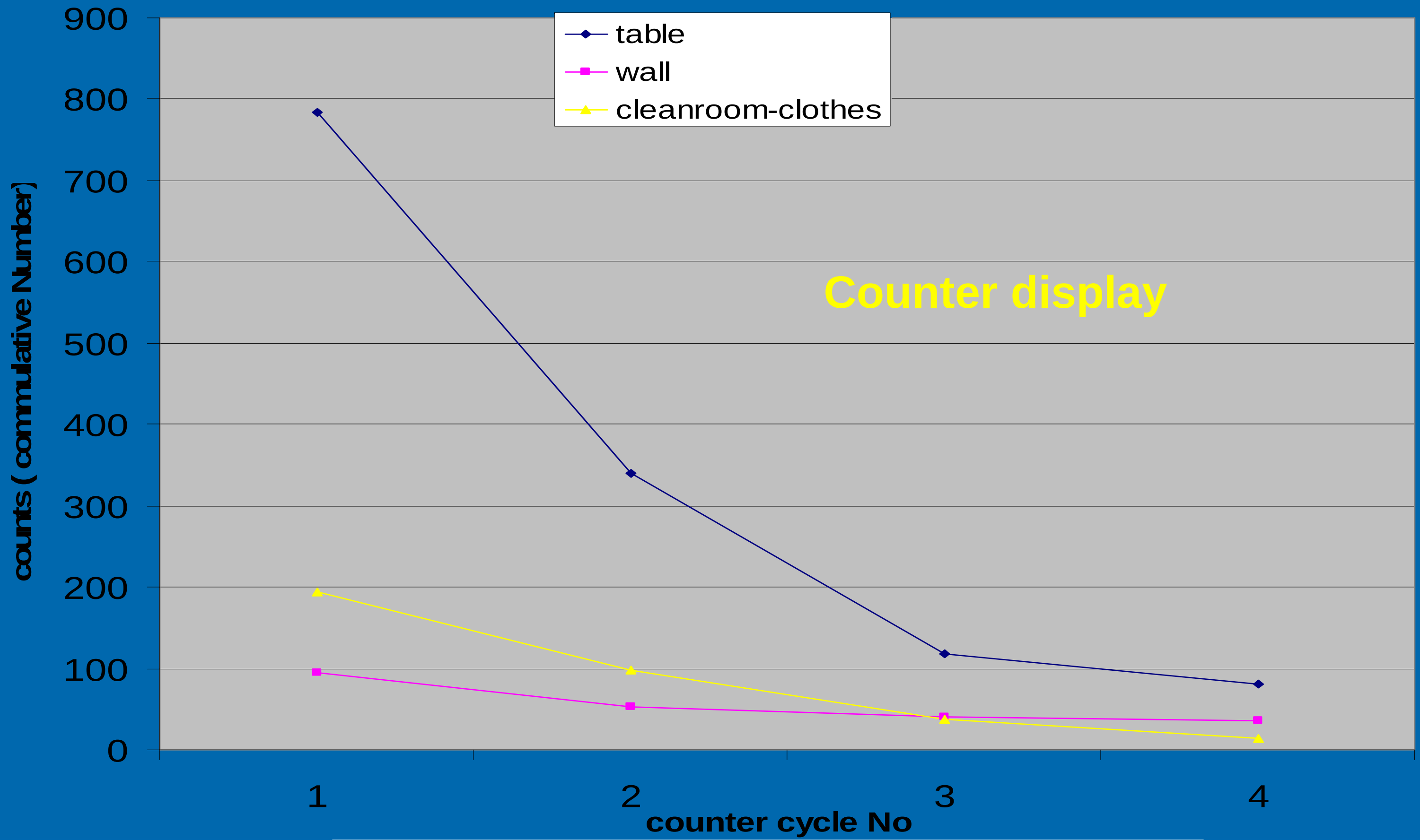
$A_2= W*d$ [mm^2]

Sampler speed: $V= W/ t_1$

setting of counter: Sampling time t [sec]

Dynamic application: **$P=Ct / (V*t1*d+ 1964)$**

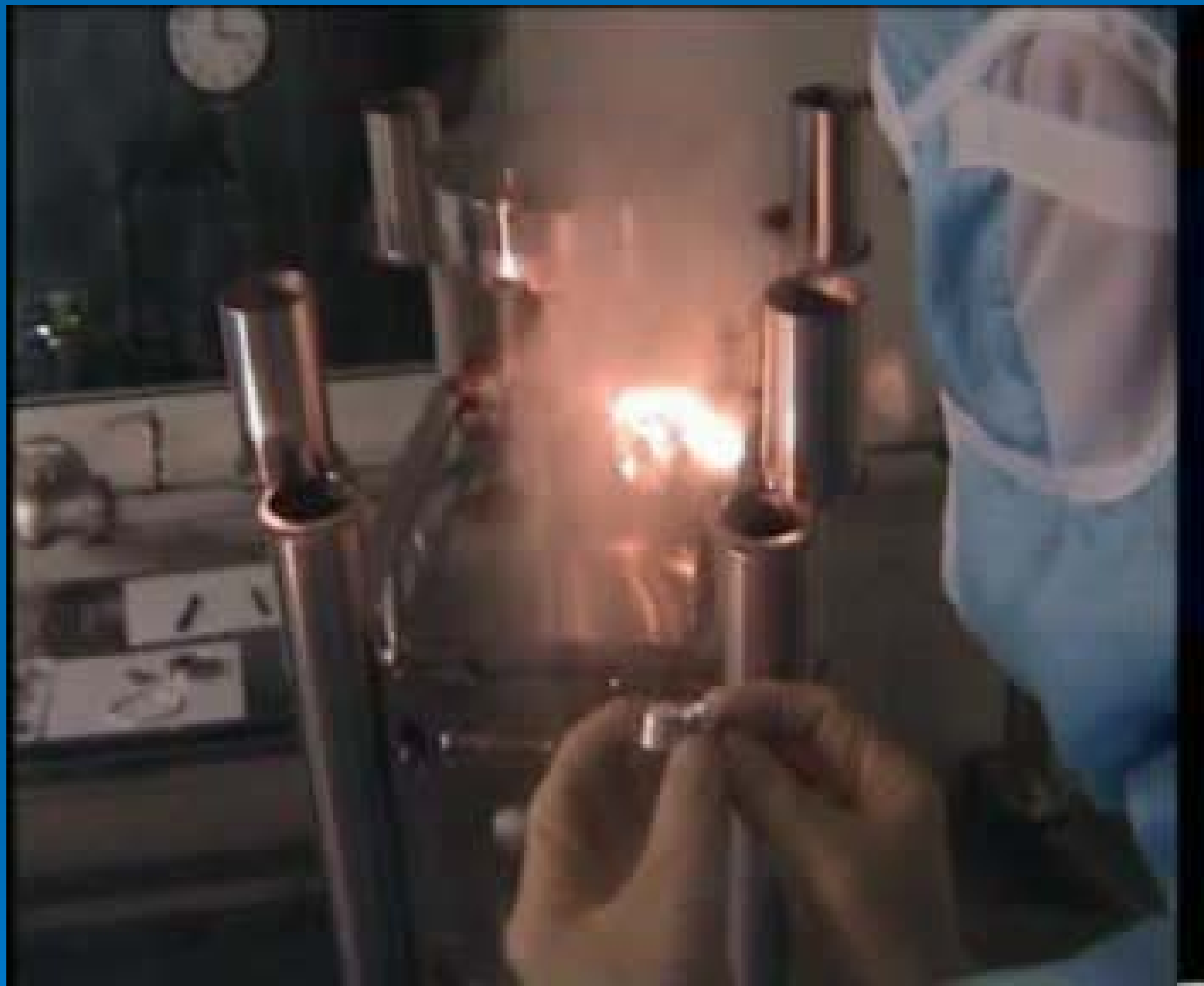




Particle concentration on:
Table = 67,3 [Particles/mm^2]
Wall = 11,5 [Particles/mm^2]
Cleanroom overall = 17,4 [Particles/mm^2]

related numbers of particle density

surfaces



Flow pattern

Degreasing and Rinsing

Test on cleaning procedure/ detergent

Nb sample polluted with grease and oil

Not efficient cleaning

After Ultrasonic cleaning with sufficient detergent and procedure

New method to control the High pressure rinsing jet **(INFN Milano**)

One example of Cavity preparation

Preparation of superconducting cavities at DESY

Cavies arrive from Industry and have undergone in comming inspection
After that

A) Main EP

1) Degreasing and rinsing
2) Prepare for EP
3) EP treatment
4) Clean cavity and rinse for cleanroom
5) out side etching for 800 C annealing
6) 800 C annealing
7) Tuning for vertical test

Ultra sonic rinsing (up to 4KW Power)
Rinsing by ultra pure water

Degreasing and rinsing

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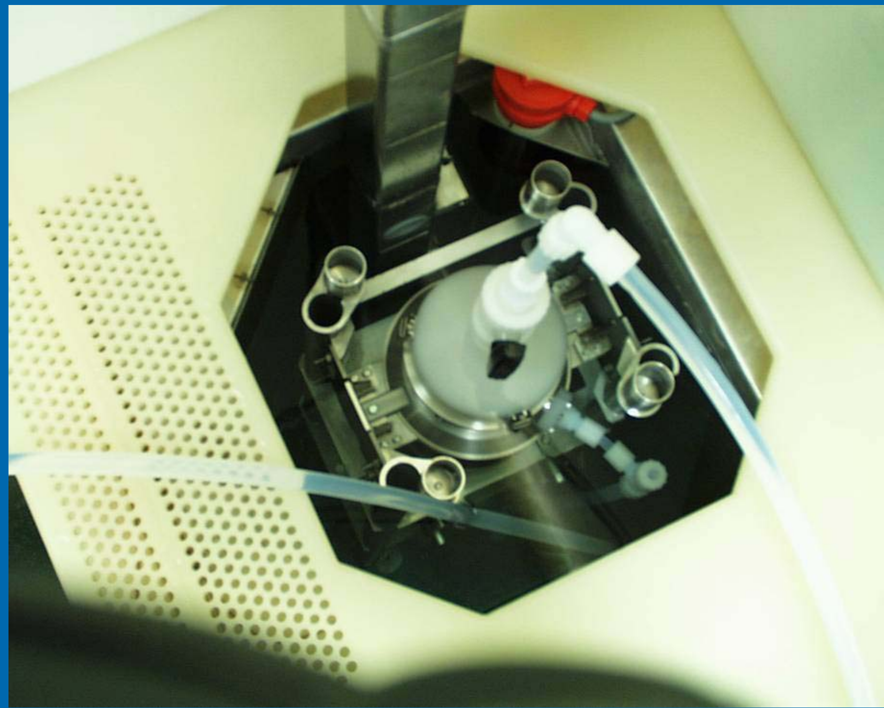
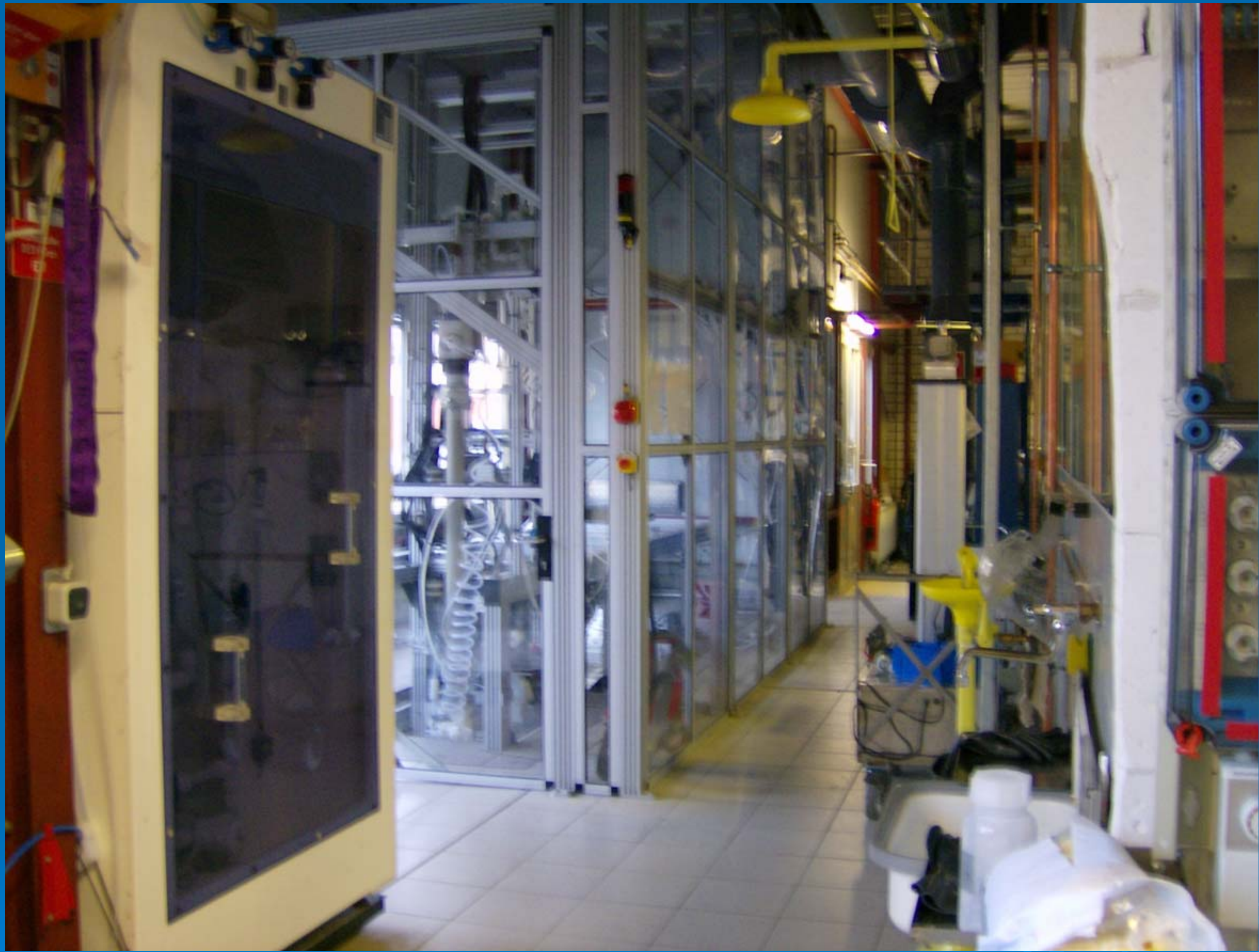
Degreasing and rinsing

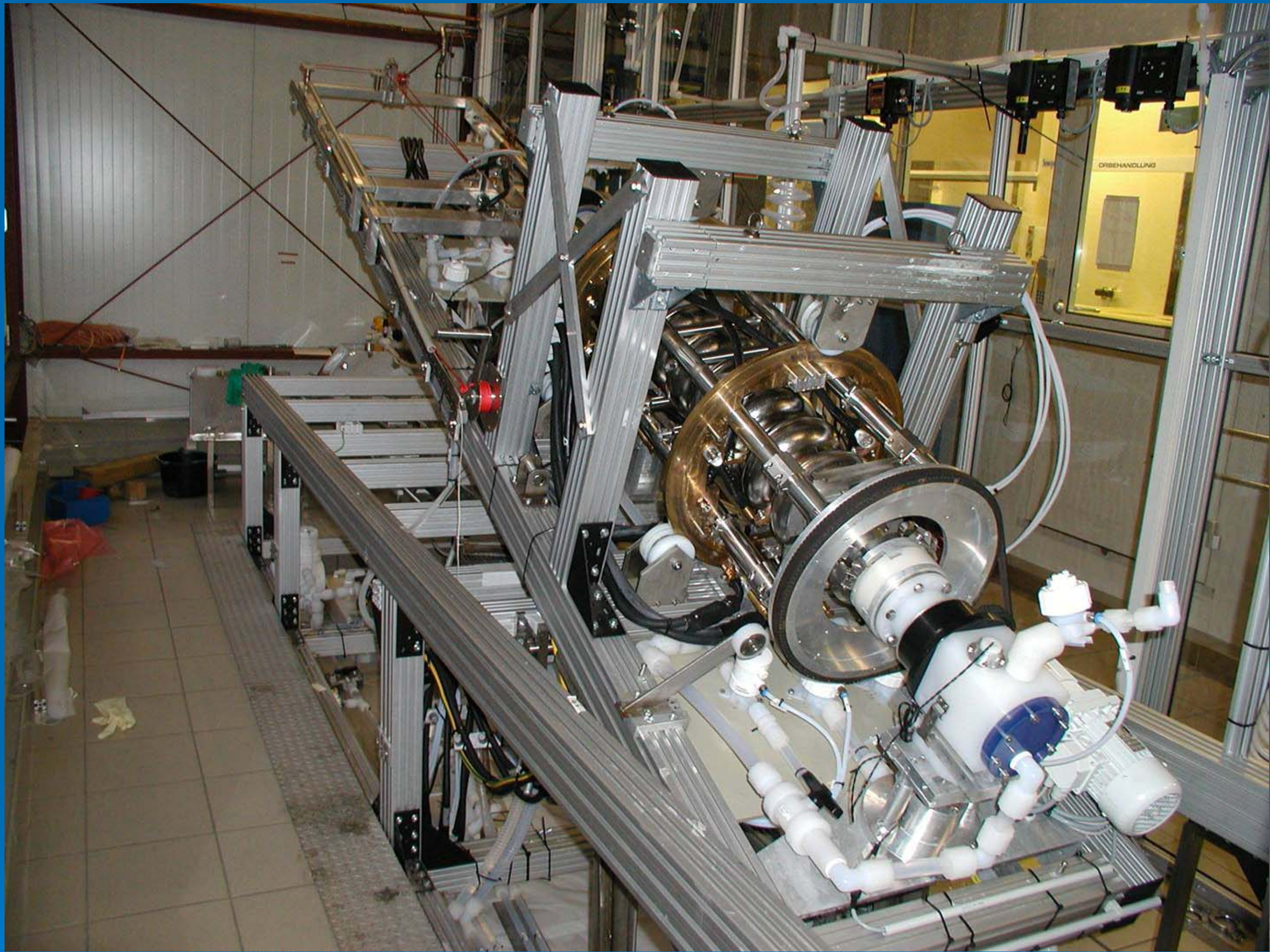


Degreasing and rinsing

Prepare for EP

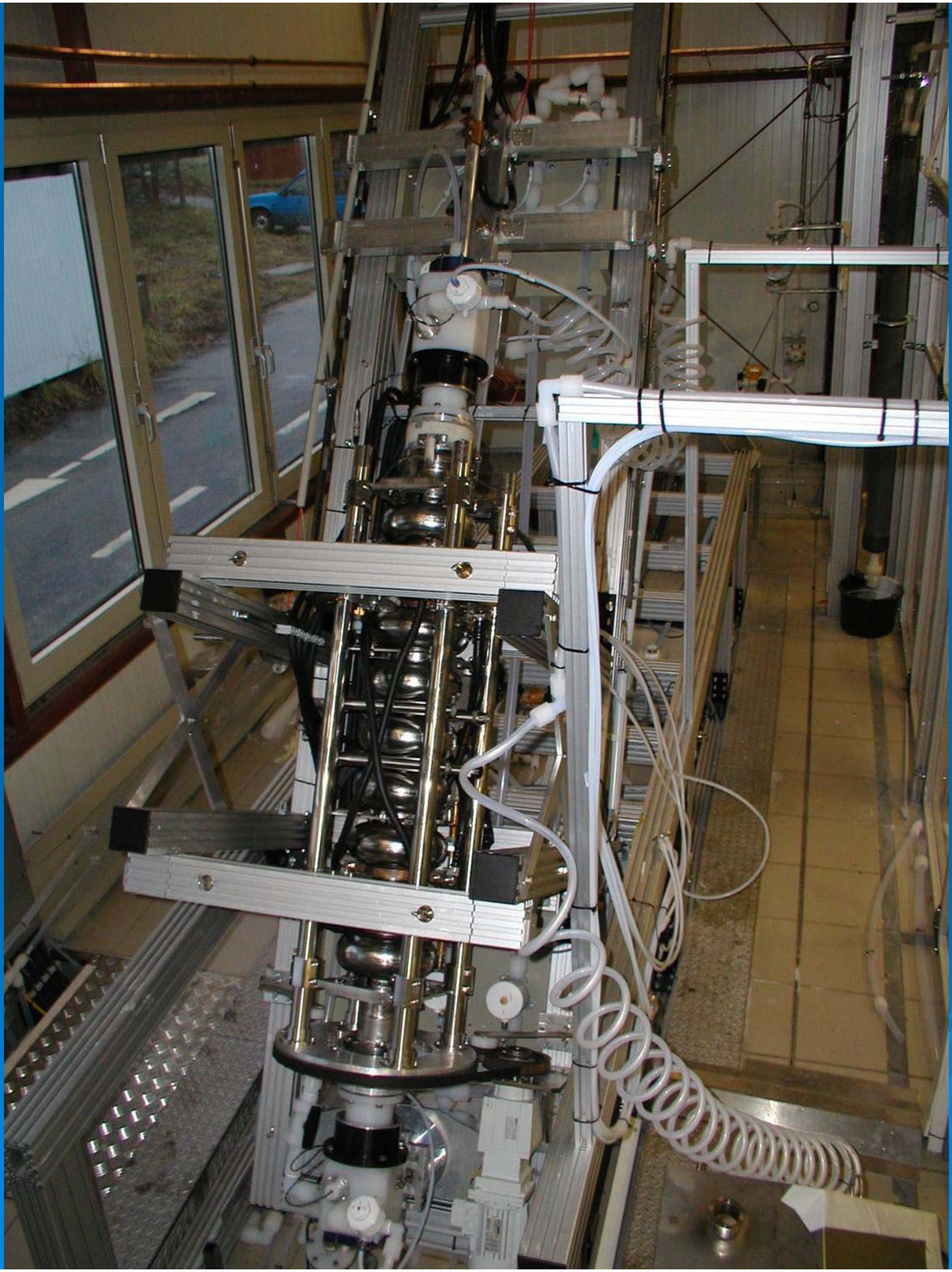


EP treatment



Cavity installed in electro polishing apparatus

1) EP treatment



Ep apparatus
during
draining of acid

EP treatment

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800 C annealing

Tuning for vertical test

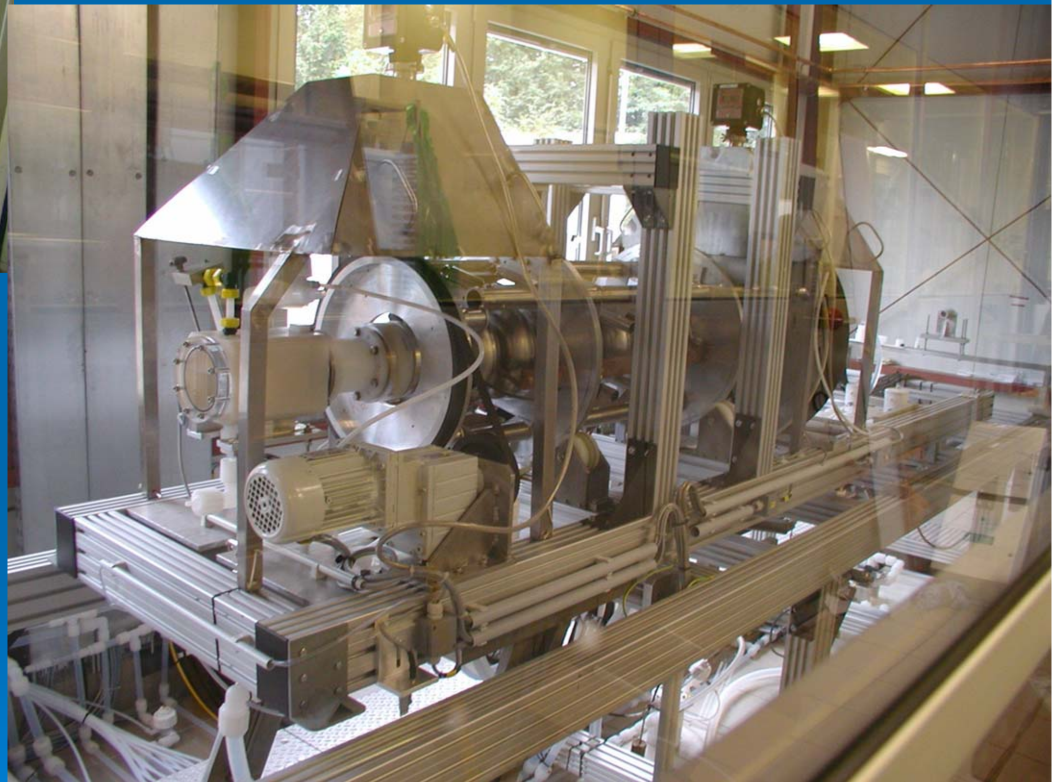
After that

B) Preparation for vertical test at 2K

1) "Car wash"
2) Degreasing and rinsing
2a) Prepare for EP and EP treatment
2b) or BCP treatment
4) Rinsing and 1st high pressure rinsing
5) Drying in class 10 (ASTM)
6) Assembly of accessories
7) Alcohol rinsing
8) Six times high pressure rinsing
9) Drying in class 10 (ASTM)
10) Assembly of test antenna
11) 120 C baking

vertical test

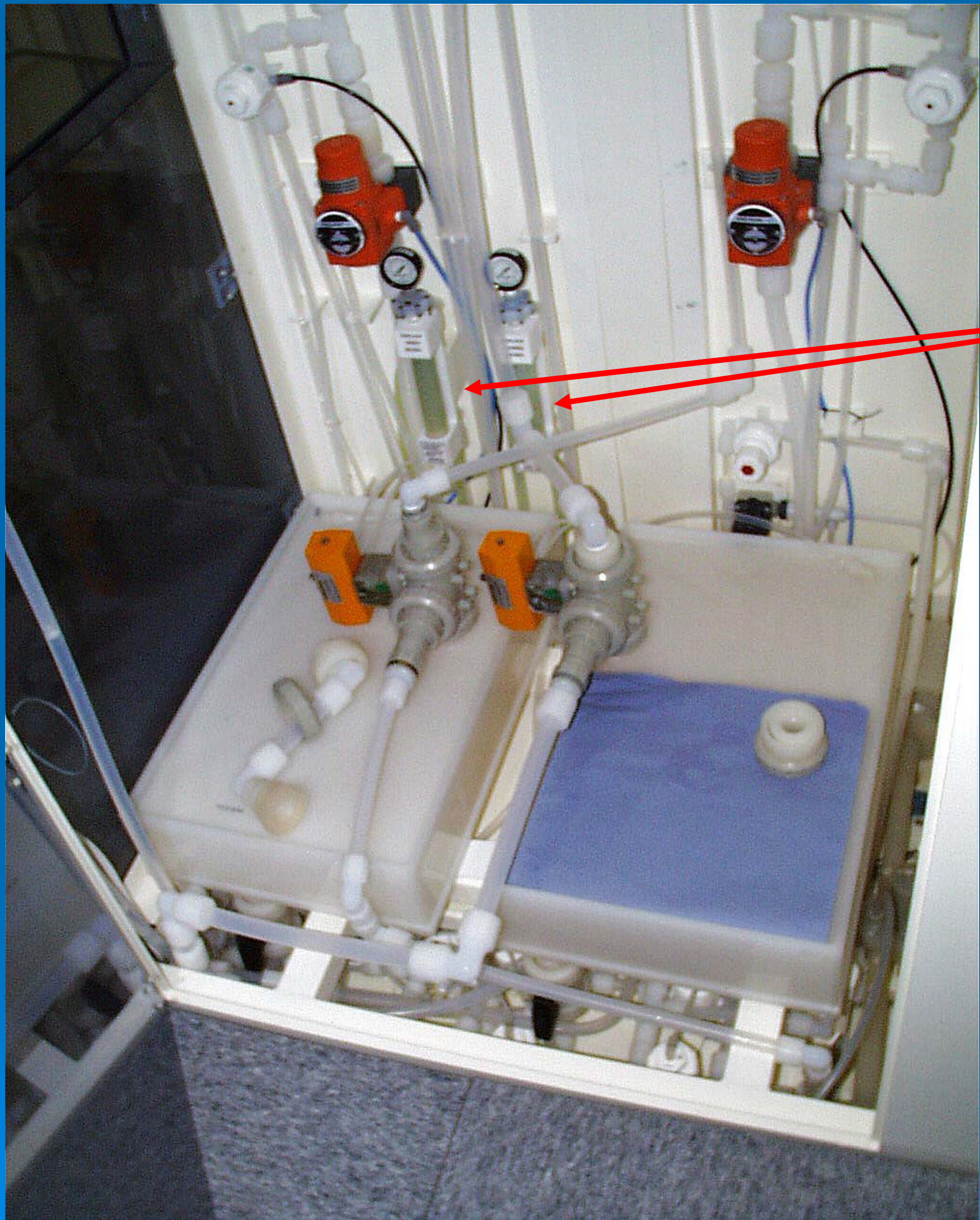
"Car wash"



Prepare for EP
and EP treatment

Cavity installed in BCP bench (Buffered chemical polishing

or BCP treatment



Valve box for BCP treatment

or BCP treatment

View into class 10000 cleanroom
“Wet preparation area”

Rinsing and 1st high pressure rinsing

Drying in class 10 (ASTM)

Assembly of accessories

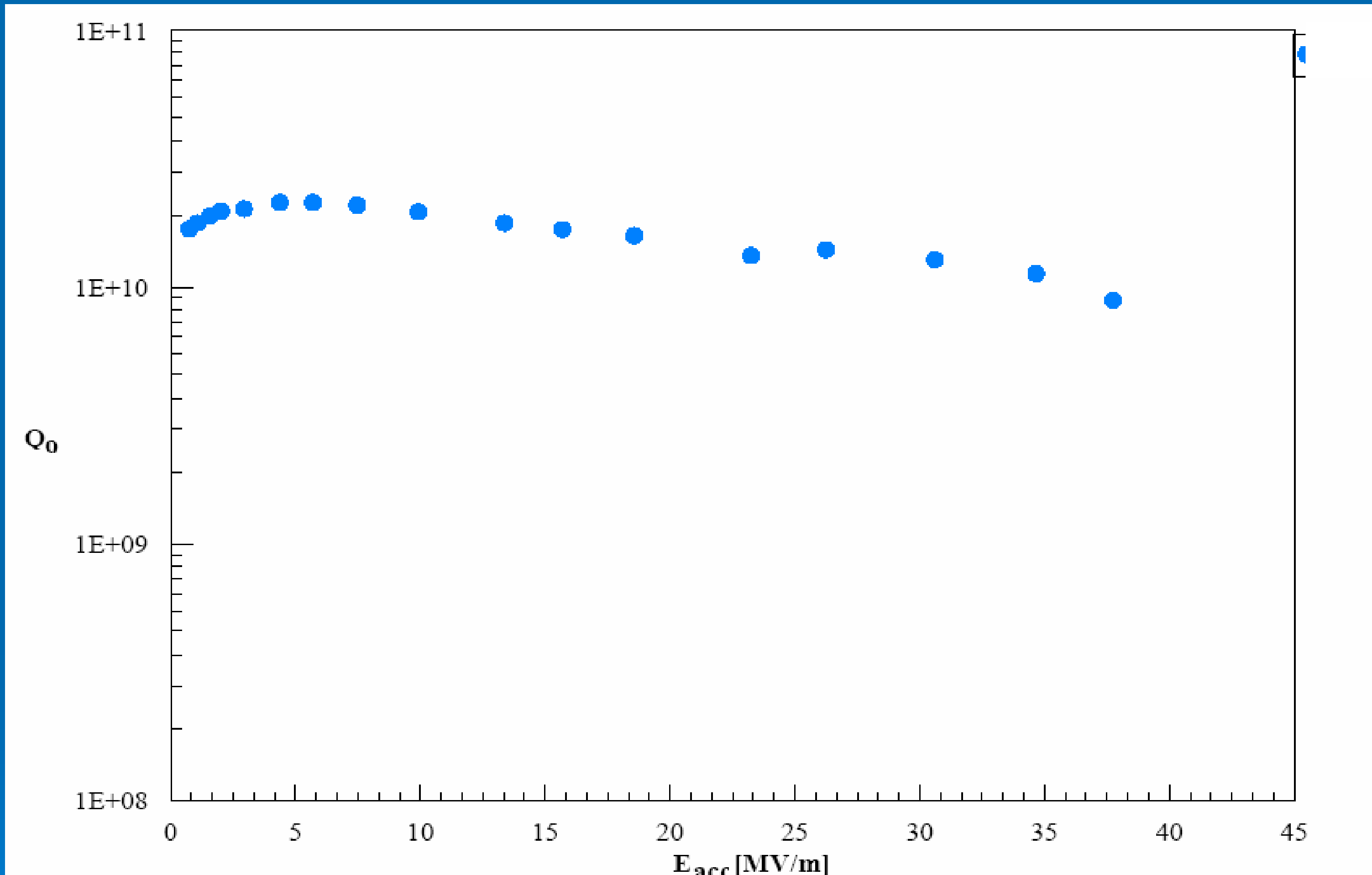
Alcohol rinsing

HPR Stand inside the claenroom

Six times high pressure rinsing

120 C baking

If ever things!!!! works perfect you will get

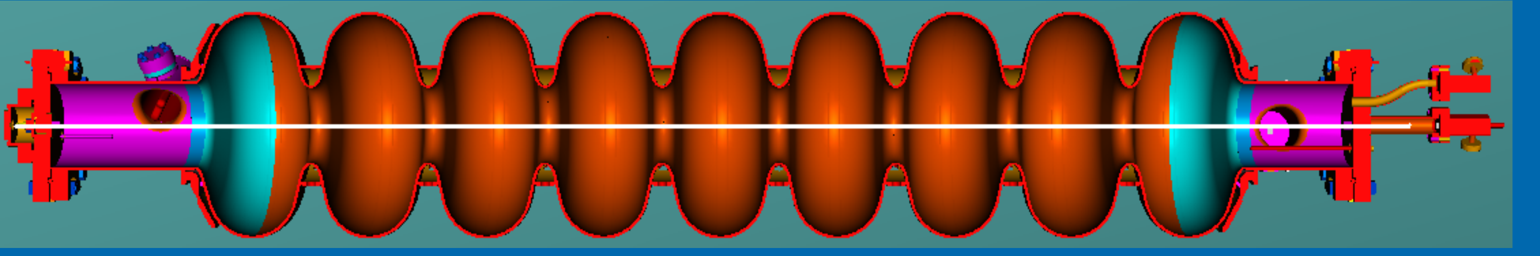


From vertical test to module

(Shortened version there are more steps than shown here necessary

Back to clean room
Install FEM (in sito bead pull measurement)
Tank welding
Remove FEM
Install Antennas
High pressure rinse cavity
Install power coupler
Assemble of module

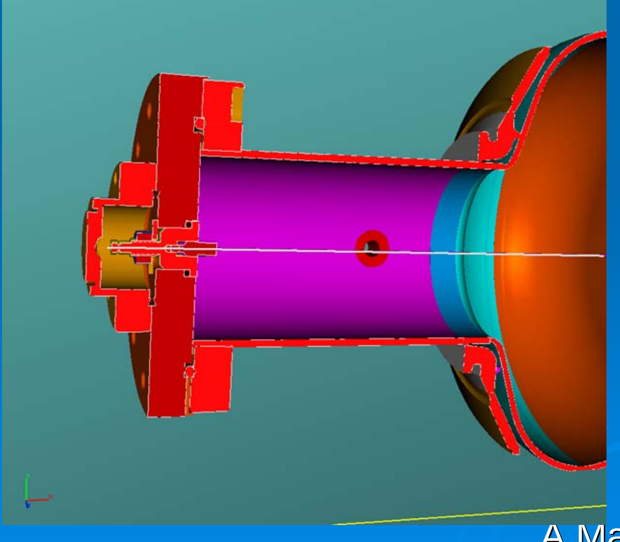
1) Cavity assembly for vessel weld



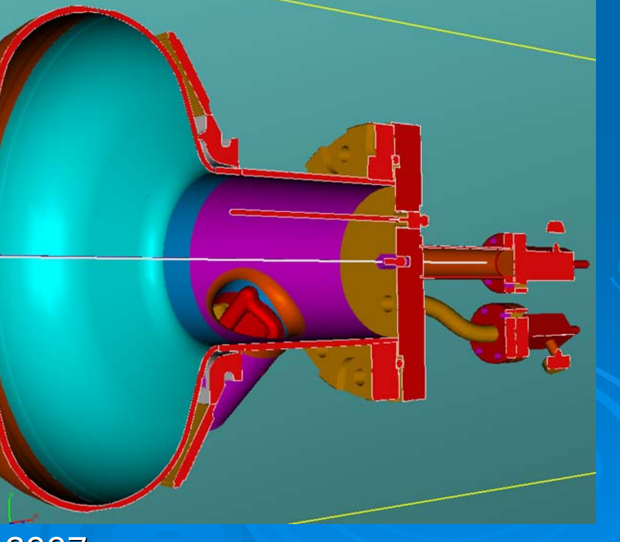
Cavity with FMS, Teflon tube on cavity axis

Requirements to the FMS:

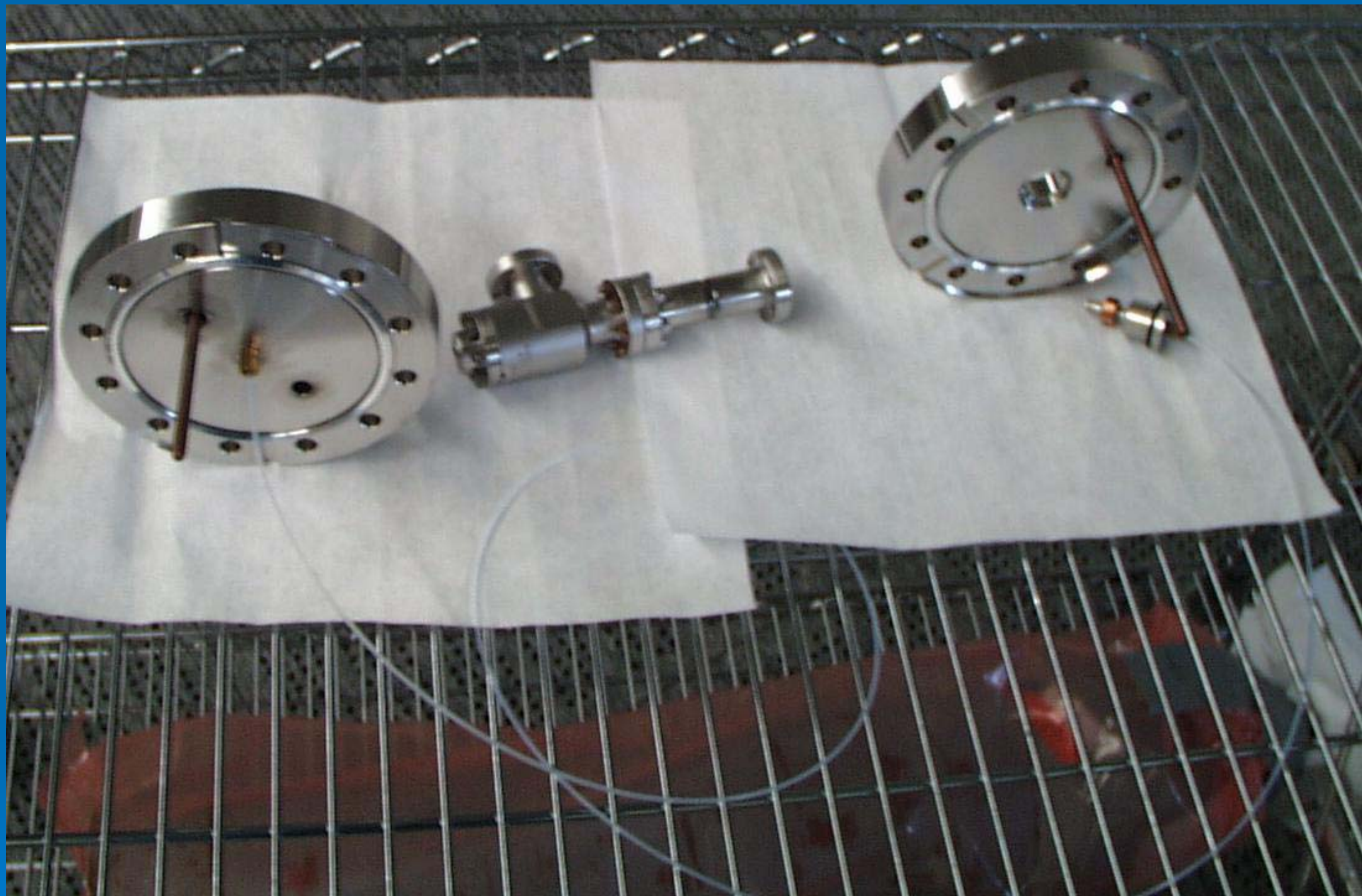
- Cleanroom class ISO 4 (ASTM: RK10)
- Protect inner surface of cavity from ambient air
- No desorption from FMS (Teflon tube and clamping system)
- Vacuum tightness



Cavity long end group



Cavity short end group




Ausgang

谢谢大家

会议愉快