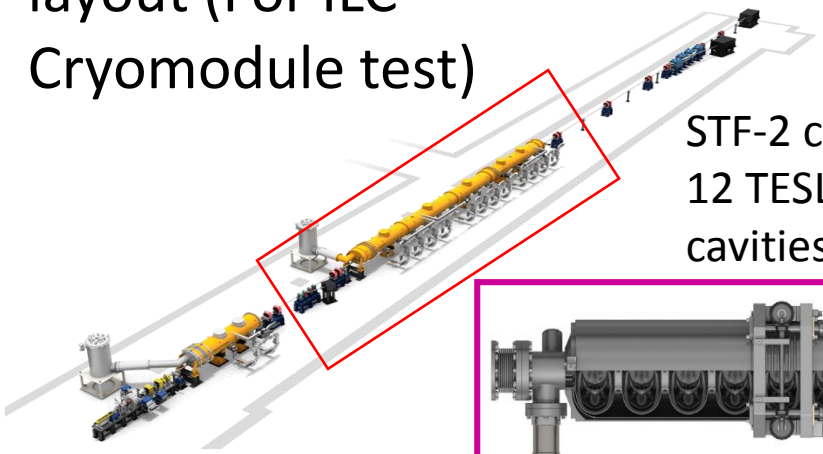
Measurement results of moving particles during STF cryomodule assembly under slow pumping/venting in KEK

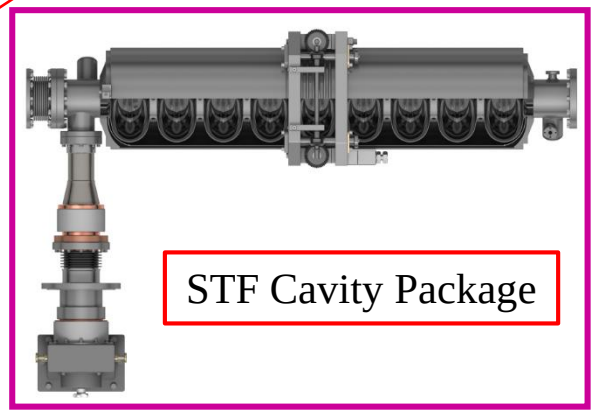
Hiroshi Sakai (KEK)

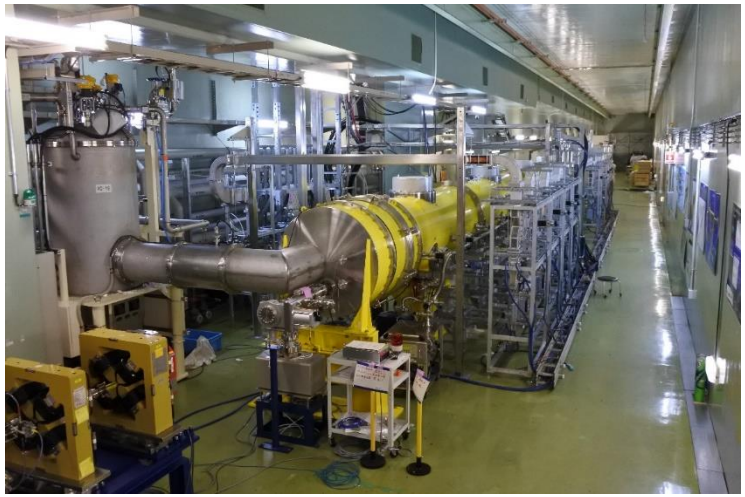
on behalf of SRF Grp.

STF cryomodule layout (For ILC Cryomodule test)



STF-2 cryomodule
12 TESLA like cavities

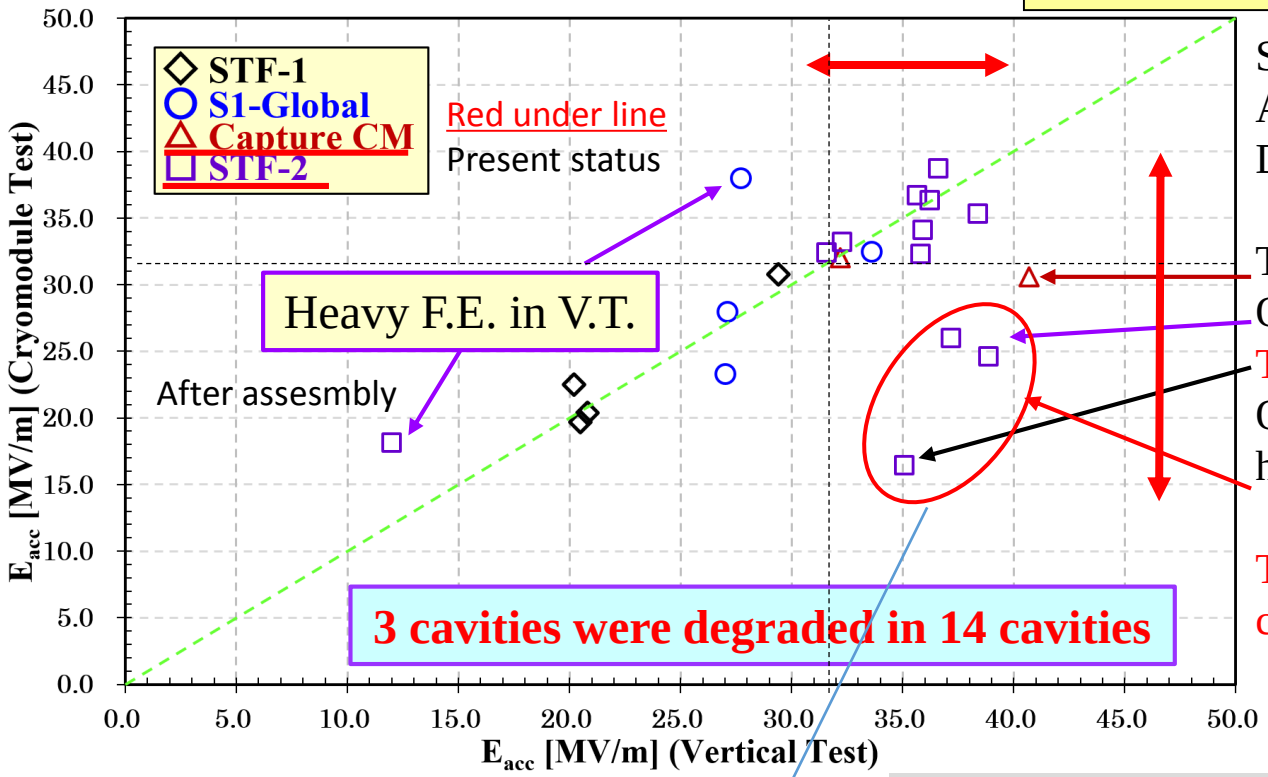




Motivation for slow pumping/venting system

(before 2018)

Y. Yamamoto *et al.*, "High Gradient Cavity Performance in STF-2 Cryomodule for the ILC at KEK", IPAC'16, Busan, Korea, p.2158 (2016).

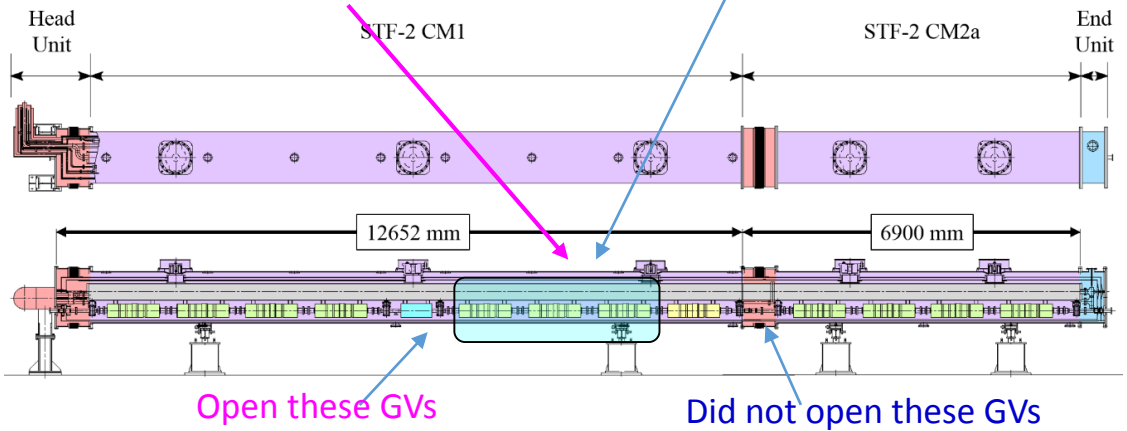


Statistics for cavity performance;
Above 31.5 MV/m: 11 cavities
Degradation: 4 cavities

Three types of performance limit;
One cavity: Quench w/o F.E.
Two cavities: F.E. Quench
One cavity: Quench by enormous heat loss

Three degraded cavities in STF-2 are connected in series.
→ Common cause for degradation

Three degraded cavities in series



Why the severe field emission was found ?

Possible reason of the degradation.

- Use of a local clean booth without laminar flow
- Sudden extra argon gas purging when the gate valve opened

→ Need improved clean assembly work and sophisticated vacuum pumping & venting system.

slow pumping & venting system in KEK (First model 2018 @ KEK)

H. Sakai, et. al. “Development of the slow pumping & venting system” ,Proc. of 15th annual workshop of Particle Accelerator Society of Japan, THP111, Nagaoka, Japan (2018)

RGA

Slow pumping & venting system block diagram(setup)

Ion gauge

SRF cavity

Mass flow (for slow venting)

Vacuum particle sensor

Mass flow (for slow pumping)

TMP & scroll pump

Slow pumping & venting system (in KEK)

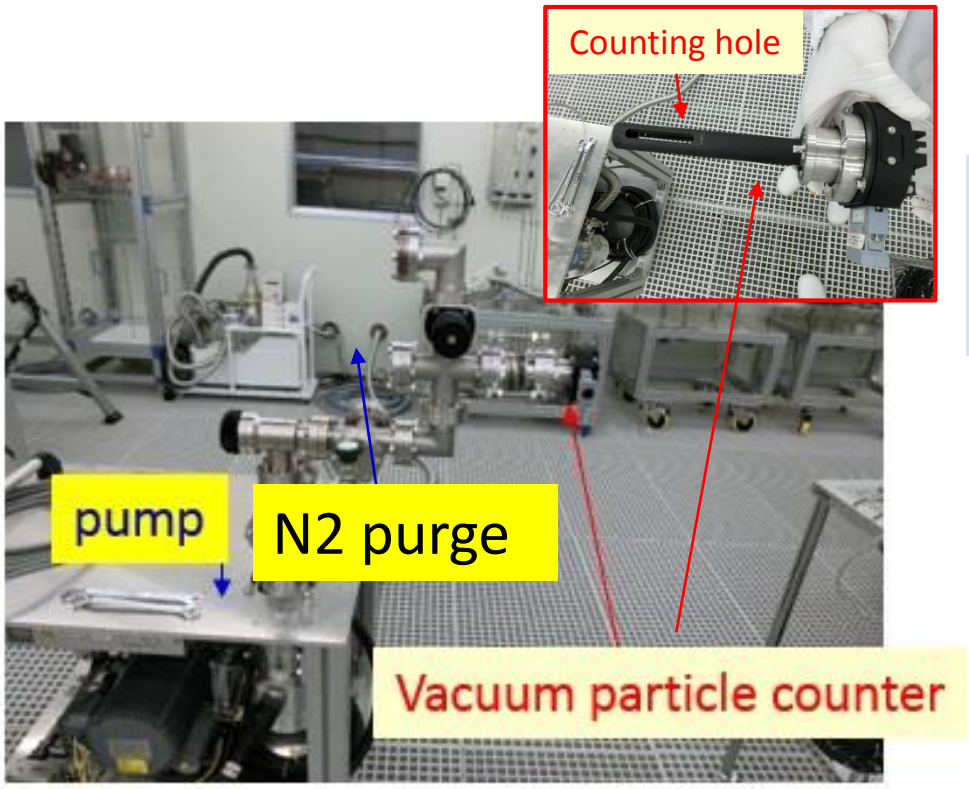
Slow pumping & venting system (parts)
Light blue line is main pumping line.
Green (red) line is slow pumping (venting) line.

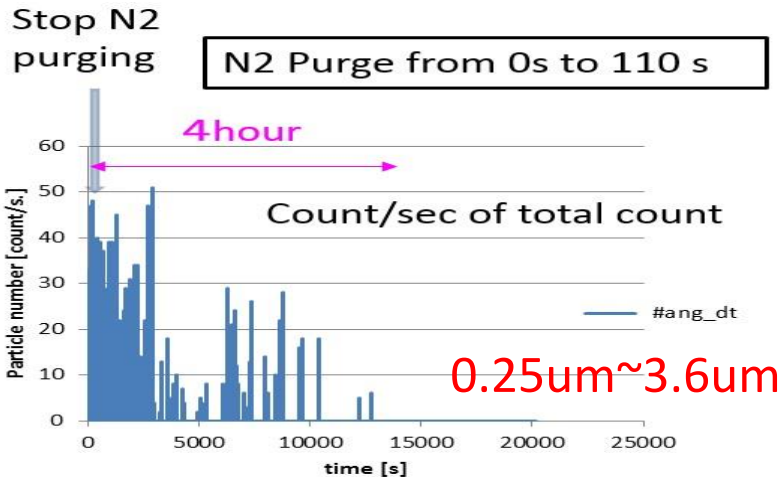
Test of vacuum particle sensor

We saw many particles after purging N2 gas w/o filter.
Many particle come and stay in vacuum during 4 hours.

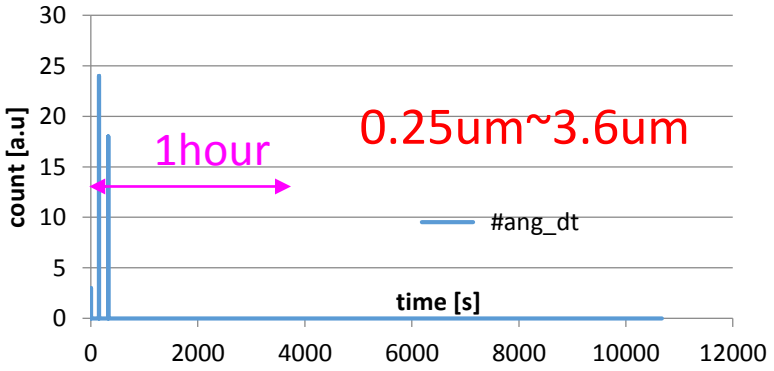
Setup of vacuum particle sensor

Particle measurement results after purging N2 with/without filter





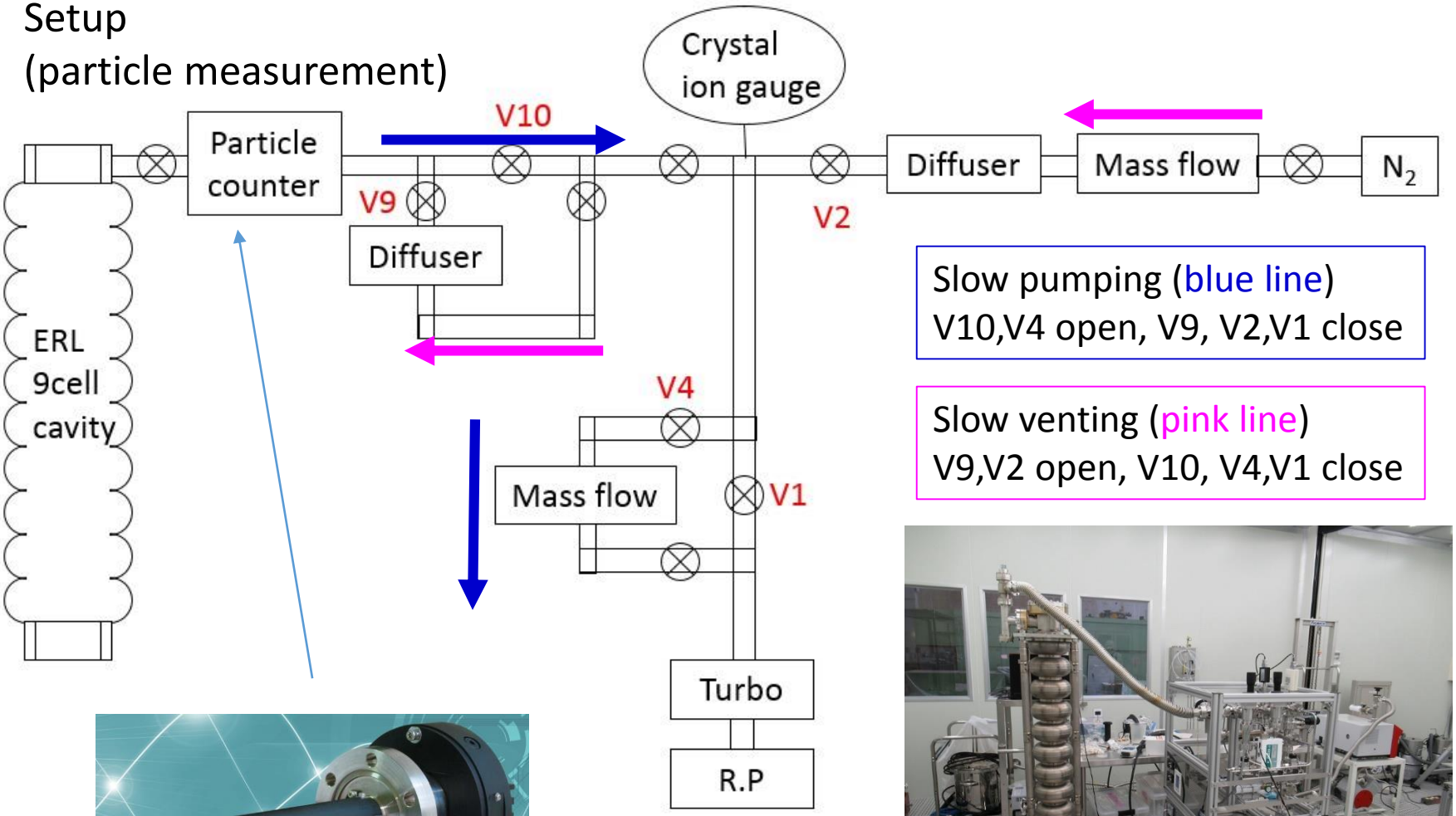
Particle was smaller than w/o filter case. Filter works to reduce particle contamination. But we saw the particle count during N2 purging both with and without filter of 5L/min flow



Venting is more dangerous than pumping. More slow pumping venting speed and optimization are needed to make slow pumping & venting system.

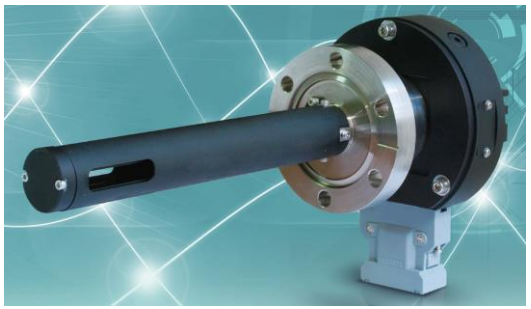
Test of slow pumping & venting system by using SRF cavity

Setup
(particle measurement)



Slow pumping (blue line)
V10,V4 open, V9, V2,V1 close

Slow venting (pink line)
V9,V2 open, V10, V4,V1 close

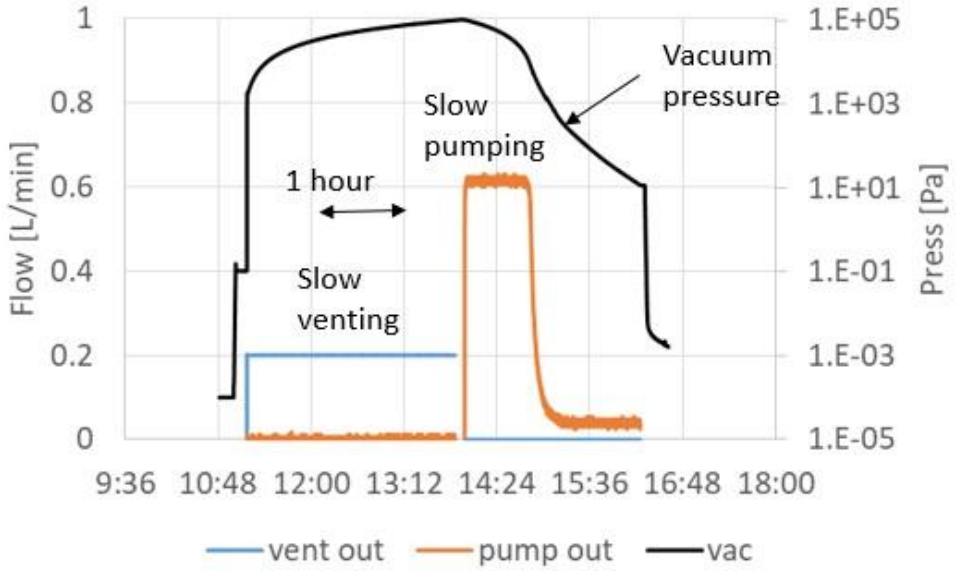


Vacuum particle sensor

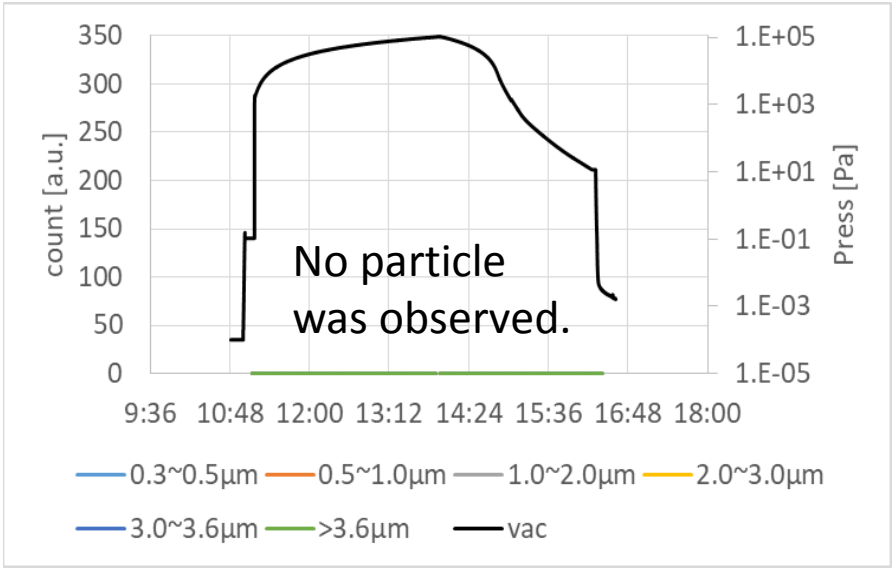
Flow of both lines were controlled by mass flow controller.

Particle measurement results

Flow ratio and pressure under Slow pumping & venting



particle measurement results under slow pumping & venting as shown in left figure

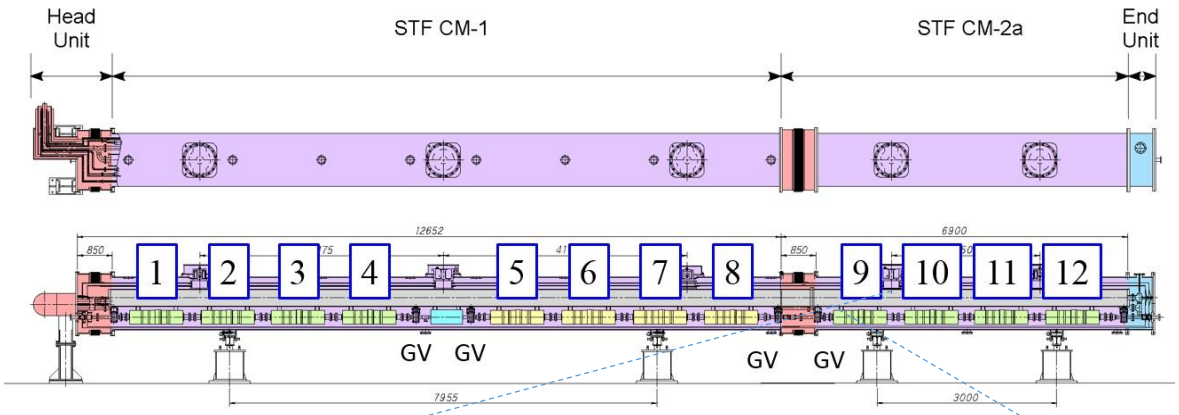


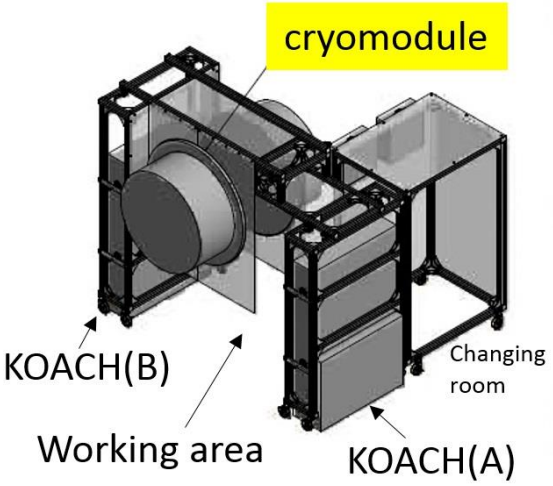
- No particle of 0.3 um size was during slow pumping & venting of a few l/min speed.
- But during changing from the slow pumping to normal pumping by closing V1 valve. We found the particulate. Valve made particulate and need control closing/opening speed not to make particulate.

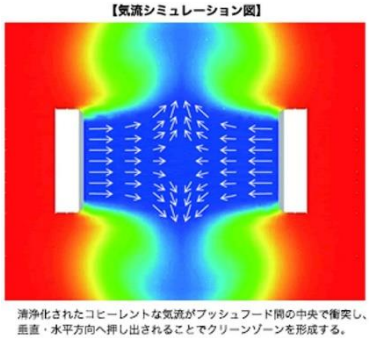
speed	Gate Valve condition	Opening/closing time of vale	Particle number (0.3-0.5um)
slow	V1 open	1min 19sec	0
	V1 close	1min 4sec	0
normal	V1 open	14sec	0
	V1 close	12sec	0
fast	V1 open	5sec	32
	V1 close	6sec	6

Anyway, this slow pumping & venting system can apply our cryomodule in STF if optimize the valve control.

Setup for clean assembly between GVs





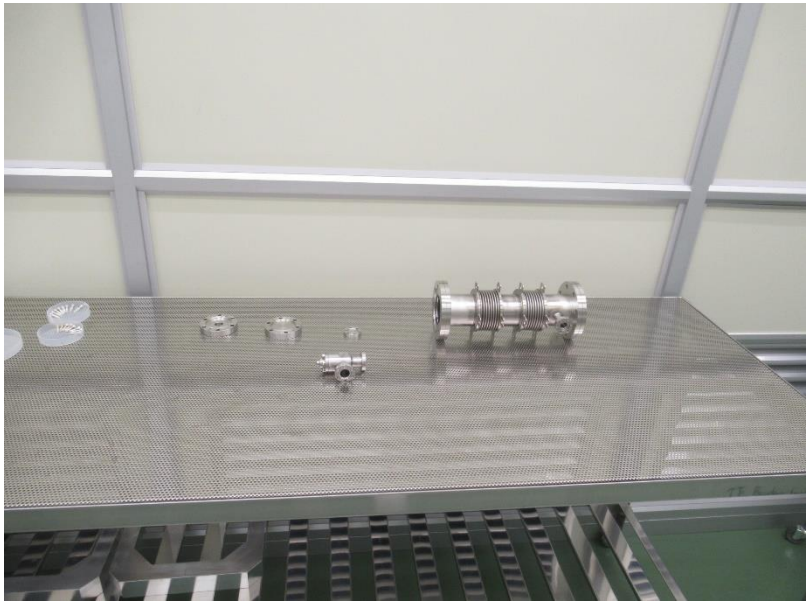


The KOACH makes ISO class 1 clean environment

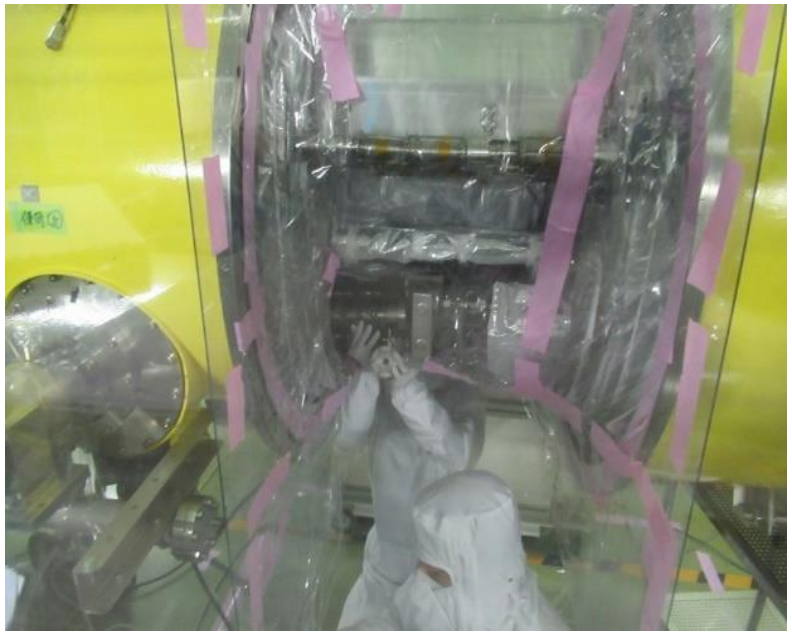
Layout of STF-2 cryomodule with the numbering of cavities.

Reassembly work at new clean booth

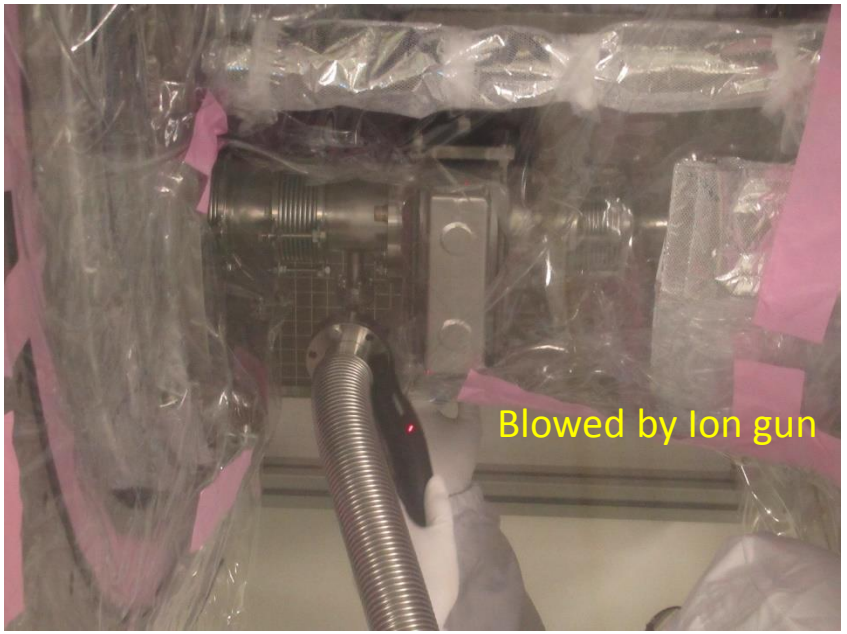
Remove the bellows between CM1 and CM2a in KOACH



Wash the bellows by ultra-pure water and dried in class 10



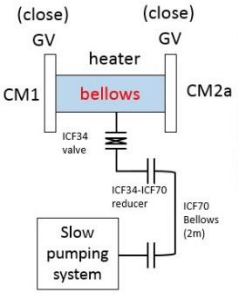
Reconnect the bellows between CM1 and CM2a in KOACH

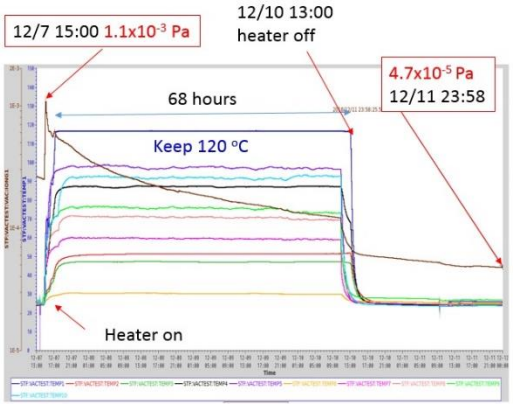


pumped by new slow pumping & venting system

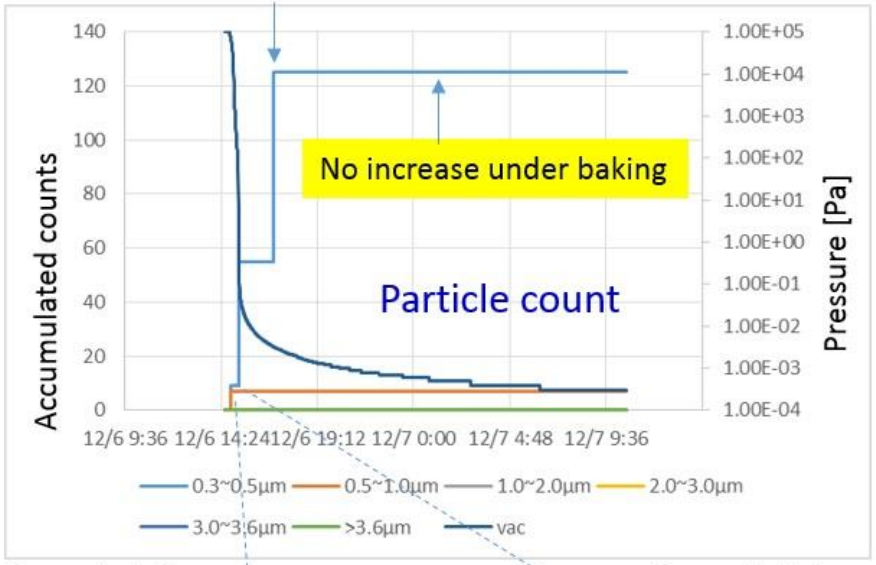
During slow pumping of bellows of STF cryomodule

Baking trend

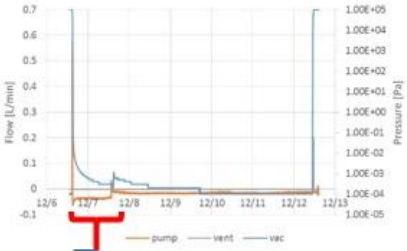




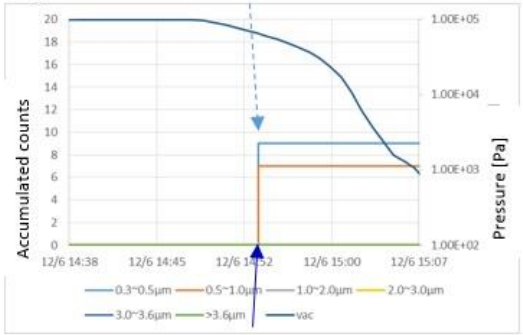
Hit bellows under fastening bellows



All pressure trend under pumping

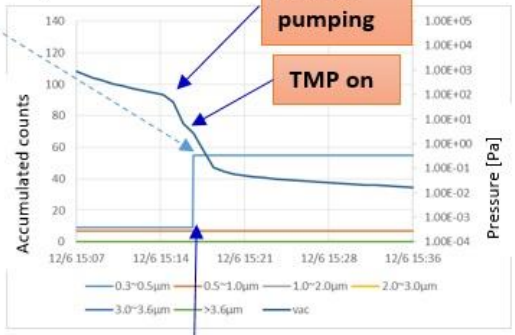


Expanded view



9 counts (0.3 μm - 0.5 μm)

Expanded view

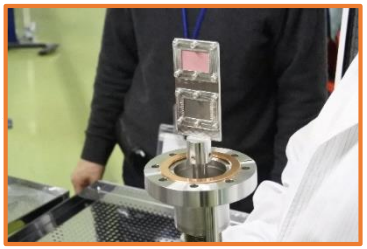


55 counts (0.3 μm - 0.5 μm)

- After reaching 100 Pa, we changed the normal pumping by changing the GVs in slow pumping system.
- Totally, 125 counts with size between 0.3 μm and 0.5 μm was found when we start slow pumping.
- TMP is one of the source of particulate.
- Valve was slowly open in more than 1 min.
- Finally, we opened the GVs between CM-1 and CM-2 after baking.

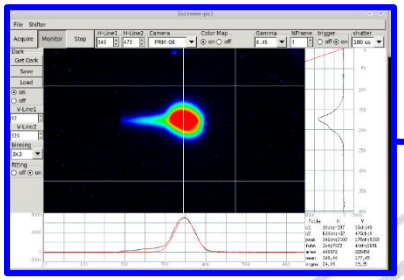
STF-2 high-G module study after clean assembly work (2019.Mar)

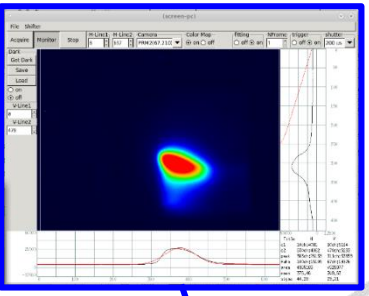
Courtesy of
Y. Yamamoto

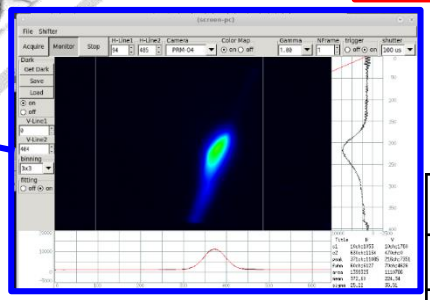


Beam profile monitor

2019.Jan (beam line construction)
-> beam operation (2019.Feb- Mar.)







~280 MeV

~40 MeV

~3 MeV

33.1 MV/m (averaging for 7 cavities)

Consistent within 2%!

Achievements in STF-2 beam commissioning	
Beam energy	280 MeV
Beam power	75 W
Beam current	275 nA
Charge	55 nC/pulse
# of bunches	1000 / pulse
Average gradient estimated from beam energy	33.1 MV/m
Average gradient measured by power meter	33.8 MV/m

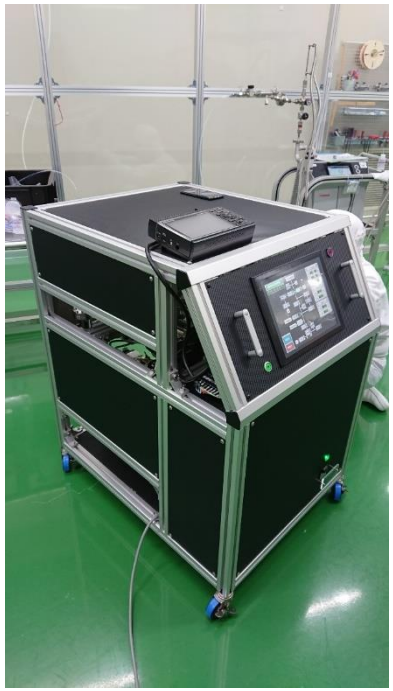
STF-2 satisfy **ILC requirements** (KEK news)

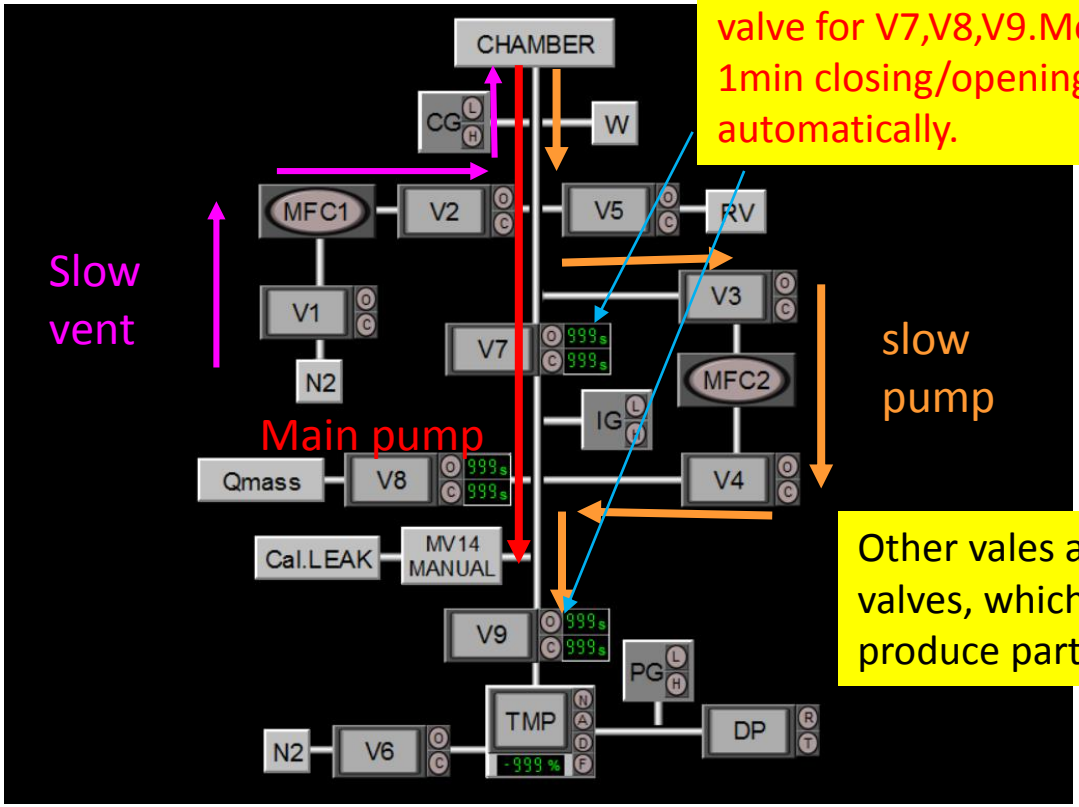
https://www.kek.jp/ja/newsroom/2019/05/22/1700/

Summary & future plan

- Slow pumping & venting system works well. Slow closing/opening valve is important.
- This clean assembly work in new local clean booth and slow pumping/venting system with vacuum particle monitor helps keep clean environment of cryomodule assembly.
- Vacuum particle monitor give the important information duting slow pumping/venting

Already made 2nd slow pump in KEK





Slow closing/opening gate valve for V7,V8,V9.More than 1min closing/opening time automatically.

Other vales are needle valves, which did not produce particulates

Acknowlegments

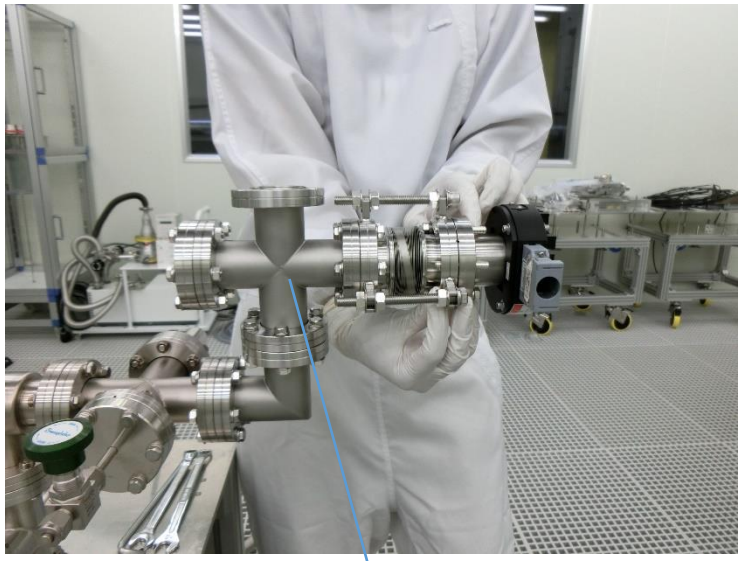
Yasuchika Yamamoto, Eiji Kako, Kensei Umemori, Taro Konomi, Takafumi Okada & All STF members
Takashi Nogami & all cERL members
Hiroki Yamada, Shinichi Imada, Asano, Tainaka, Ishihara of NAT
Hirokazu Okada of K-vac
Naomi Sasaki , Ichiro Mine of Fujikin company
Kazuhiro Iimura of R-dec company, N. Sato of ELC company
Hiroyuki Asada, Keiji Toriyama, Izumi Hattori of Wexx company

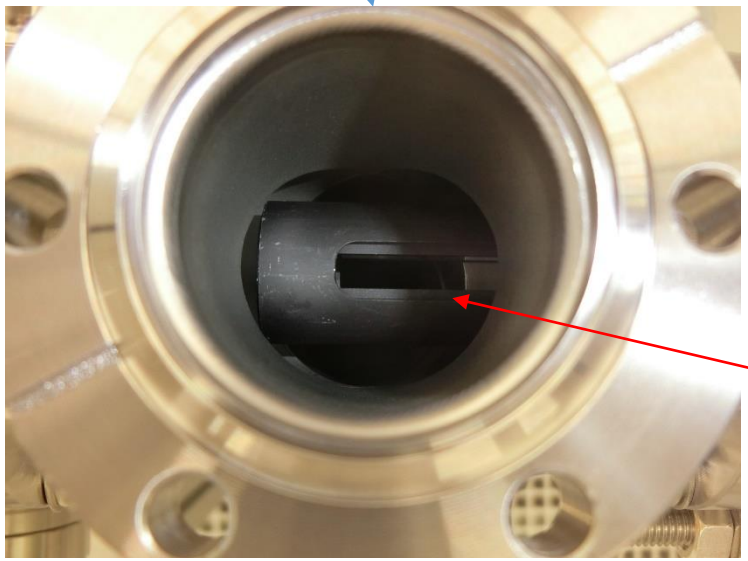
backup

Setup

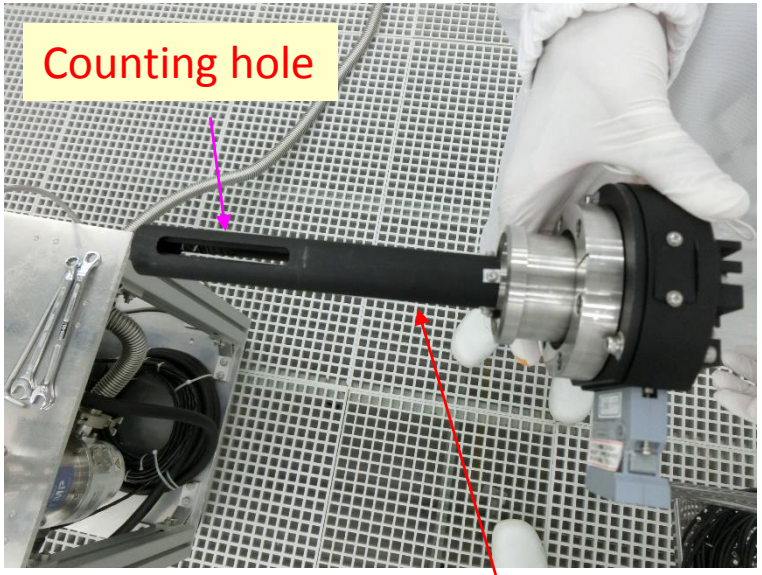
All chambers except for monitor and gate valve are rinsed by high pressure water. All components are assembled in ISO class 4.

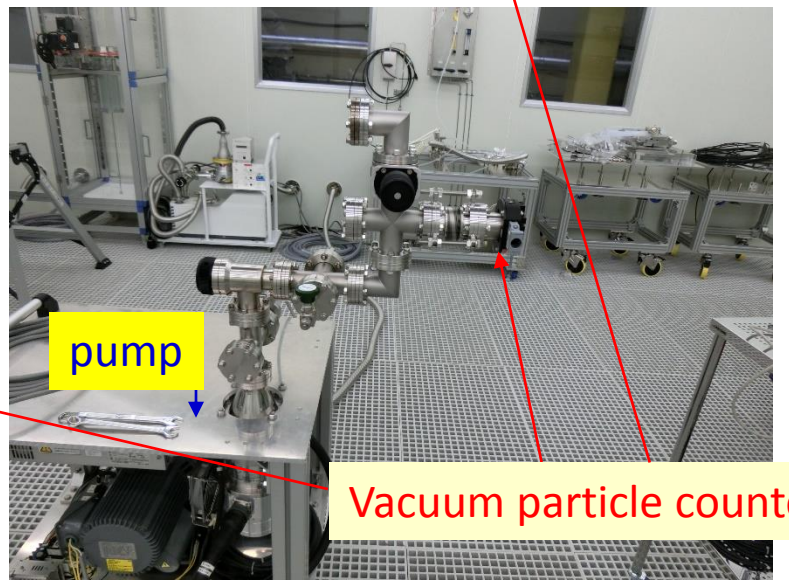
Particle counter & setup.
Browed by ion gun before setting.





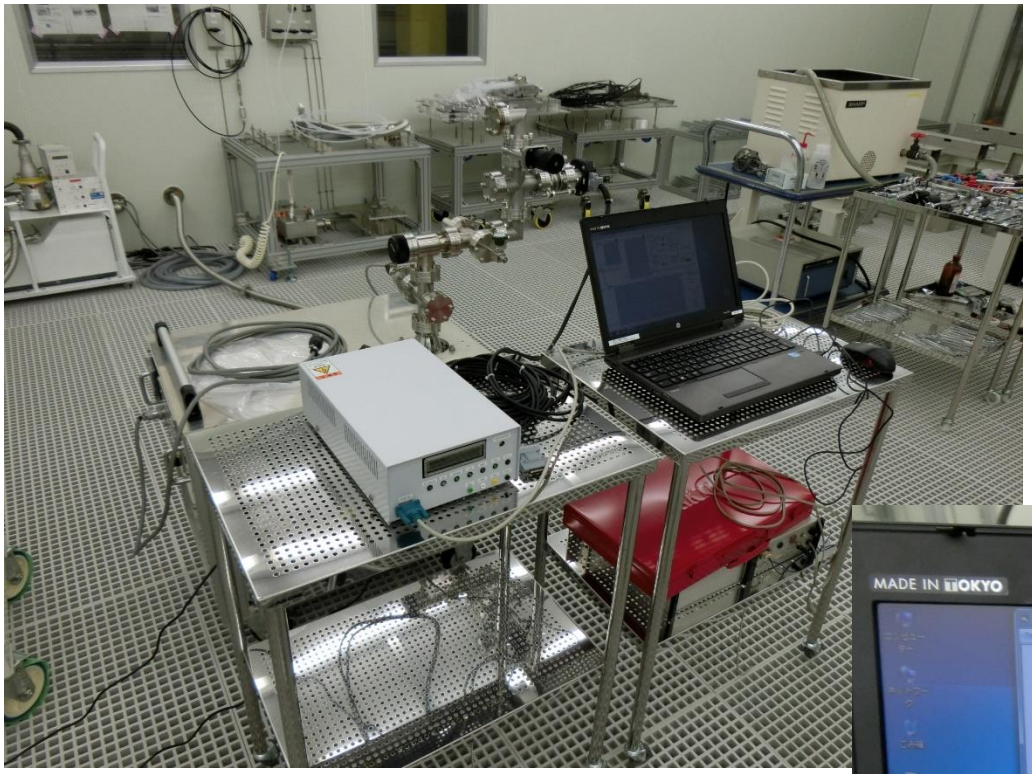
Position of the open area of vacuum particle counter in chamber



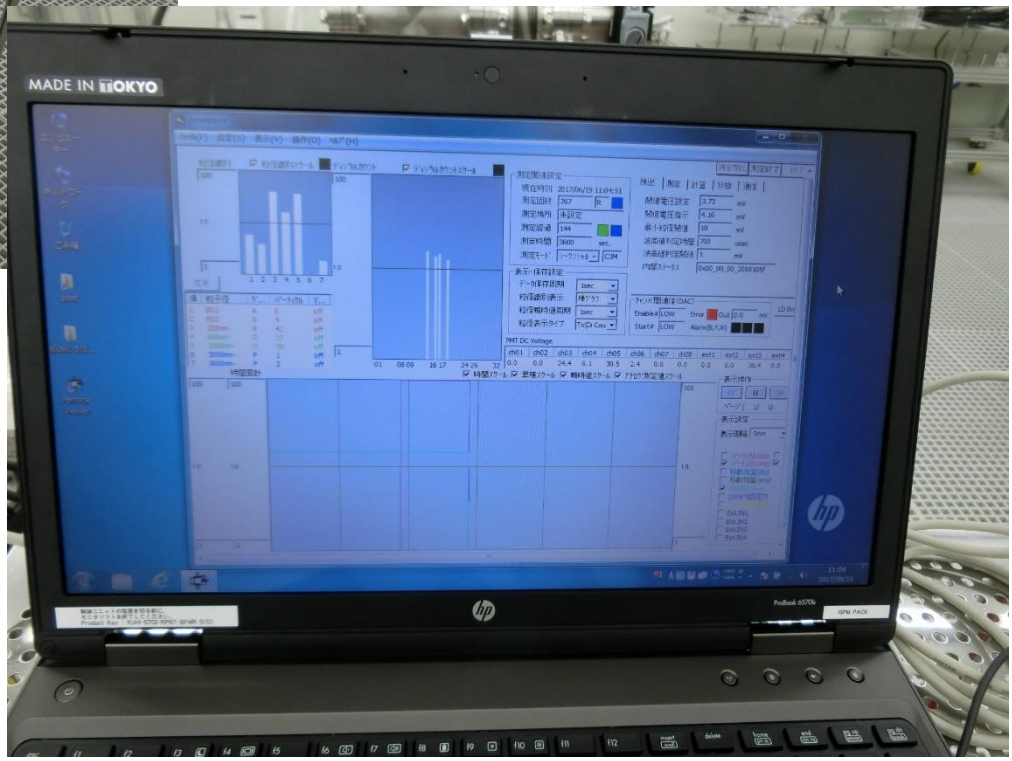


Final setup

Measurement setup in clean room



All PC and controller and cable was cleaned in clean room

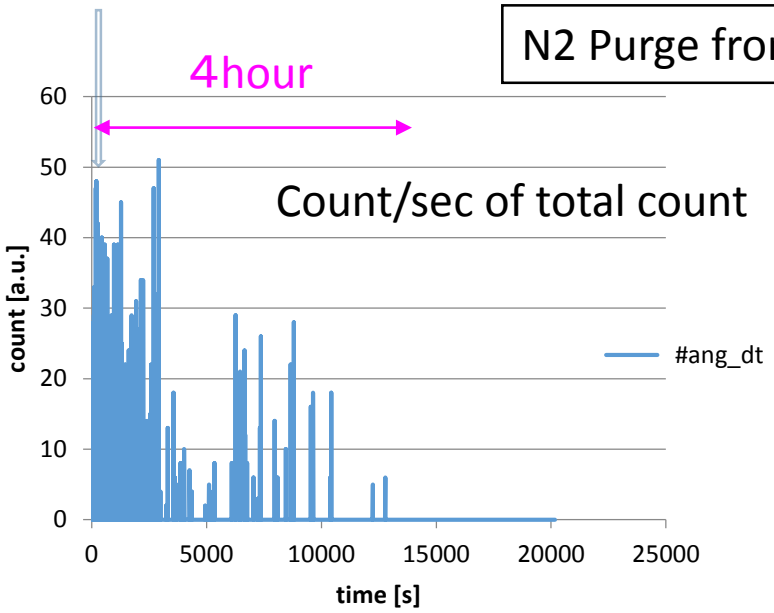


Measurement of particle in N2 purge

Stop N2 purging

We saw many particles after purging N2 gas w/o filter.
Many particle come into and stay in vacuum during 4 hours.

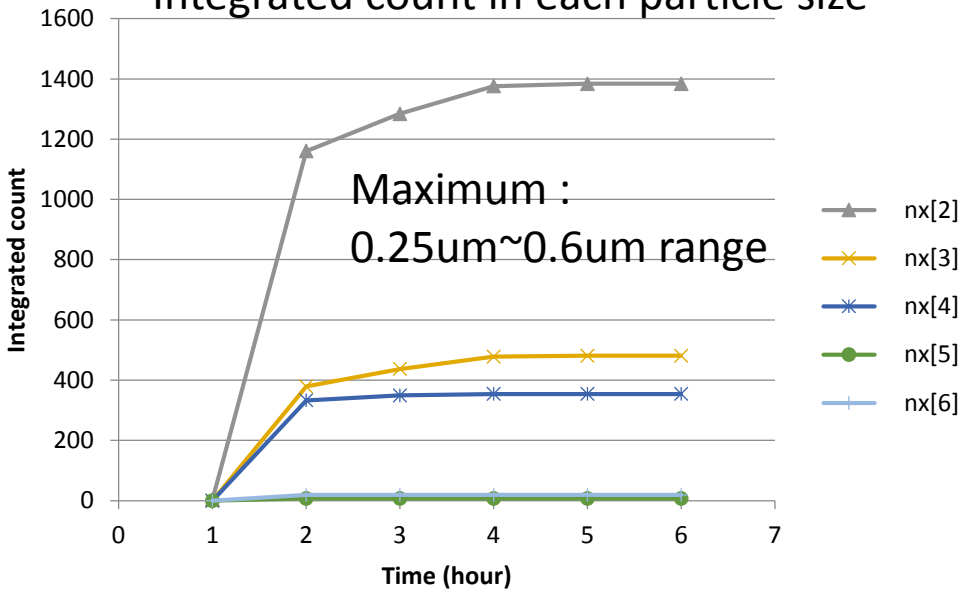
N2 Purge from 0s to 110 s

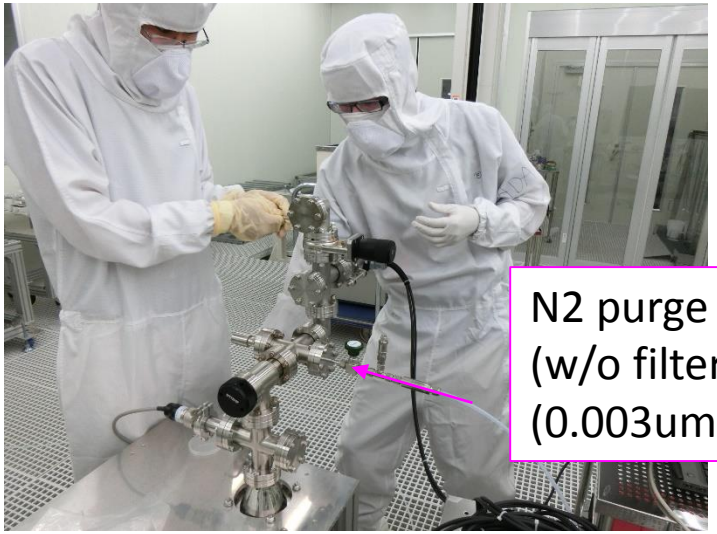


Particle range

number	Particle size
nx[2]	0.25um~0.6um
nx[3]	0.6um~1.0um
nx[4]	1.0um~3.0um
nx[5]	3.0um~3.6um
nx[6]	3.6um~

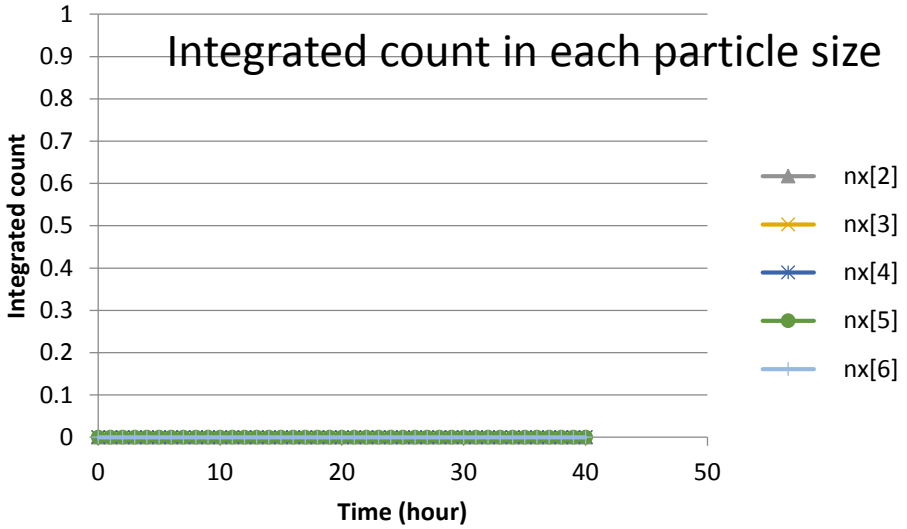
Integrated count in each particle size





N2 purge (w/o filter (0.003um))

Pumping (not slow) after purging N2

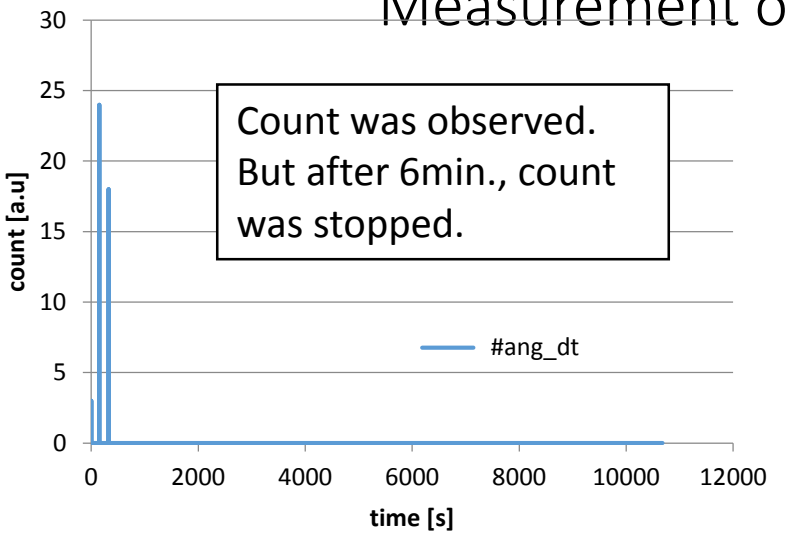


- Scroll ON
- start measurement
- TMP on

number	Particle size
nx[2]	0.25um~0.6um
nx[3]	0.6um~1.0um
nx[4]	1.0um~3.0um
nx[5]	3.0um~3.6um
nx[6]	3.6um~

We did not count by the vacuum particle counter when only we pump the vacuum.

Measurement of particle in N2 purge with filter



Count was observed.
But after 6min., count was stopped.

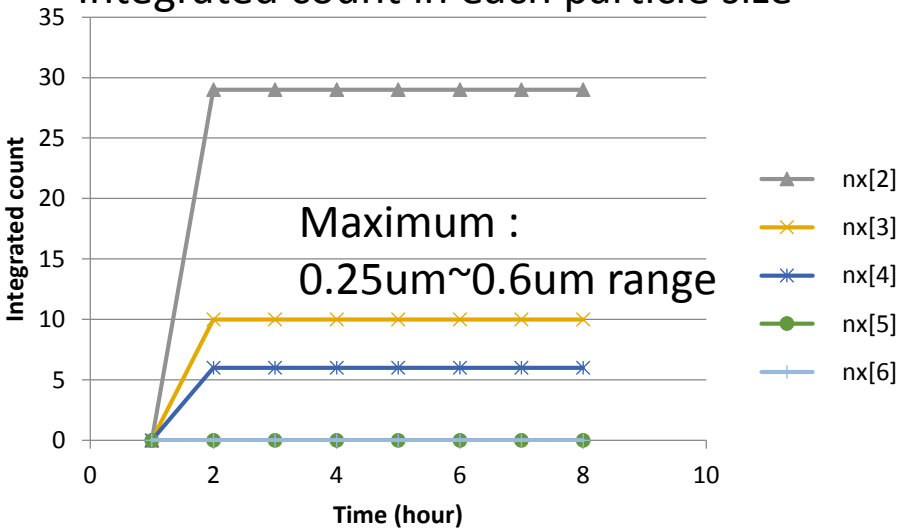
N2 flow: 5 L/min
N2 stop after 1min.

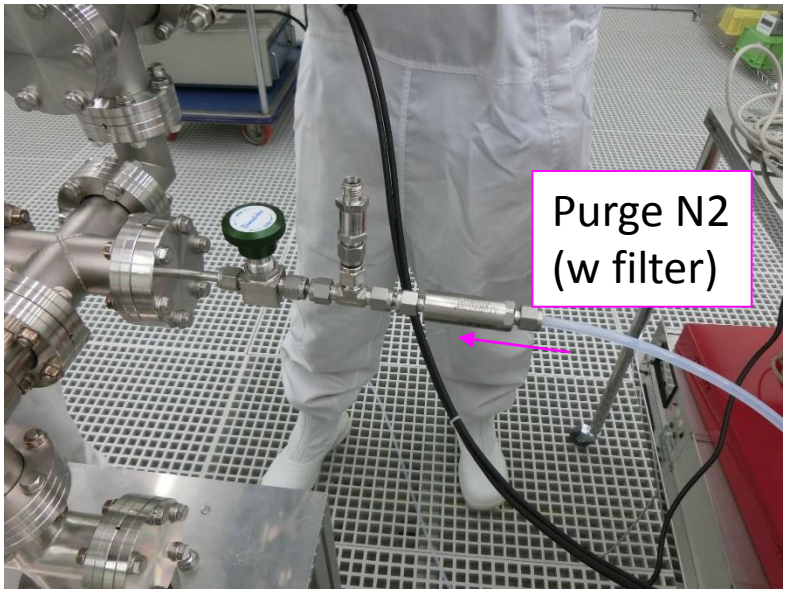
Particle range

number	Particle size
nx[2]	0.25um~0.6um
nx[3]	0.6um~1.0um
nx[4]	1.0um~3.0um
nx[5]	3.0um~3.6um
nx[6]	3.6um~

Particle was smaller than w/o filter case. Filter works to reduce particle contamination.

Integrated count in each particle size



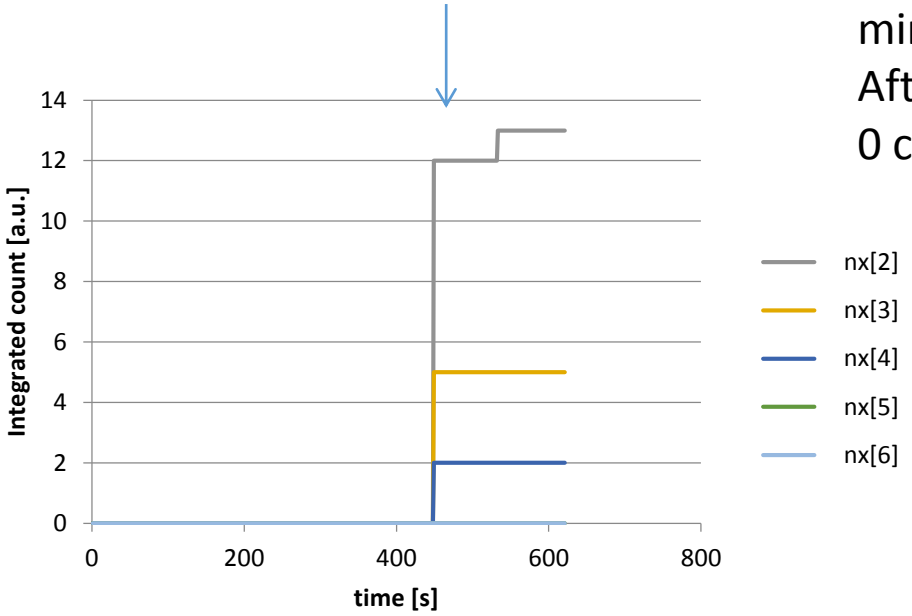


Anyway, we saw the particle count during N2 purging both with and without filter of 5L/min flow

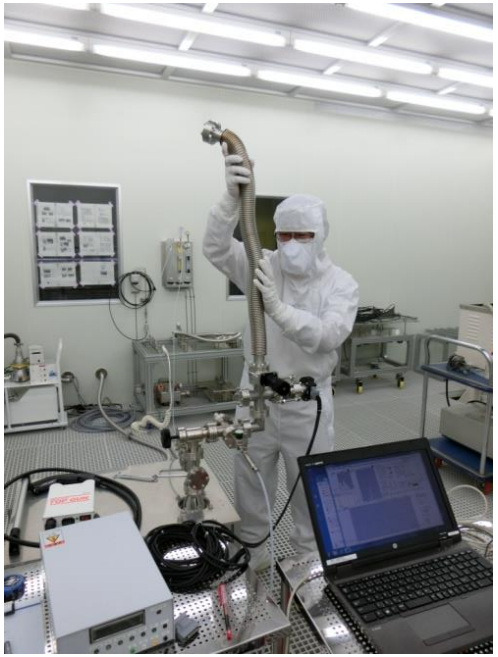
Venting is more dangerous than pumping. More slow pumping speed and optimization are needed to make slow pumping system.

Hit the bellows after pumping

Hit the bellows



Bellows was connected after 10 min. ion gun blowing. After blowing, we saw 0 count in the bellows.

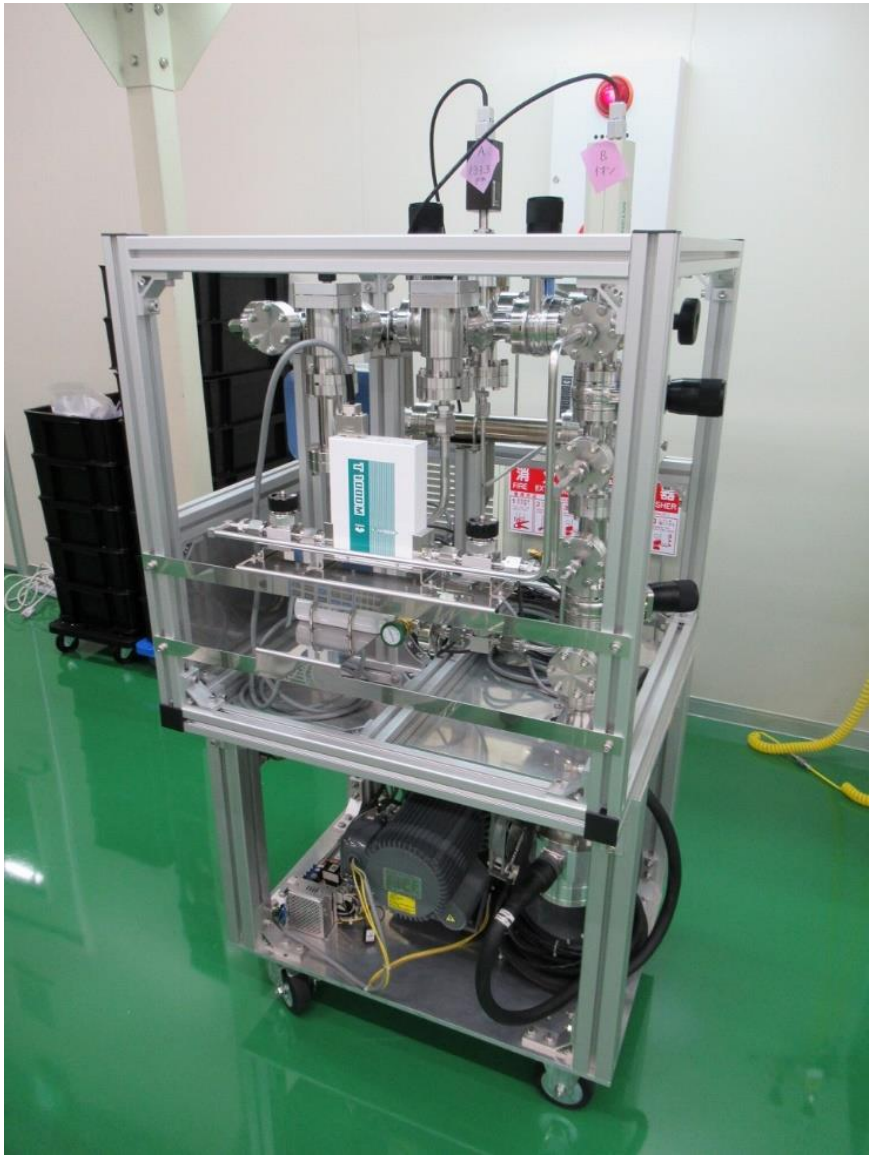


After hitting the bellows, we saw the particle count. Particle exists even though we blow inside the bellows by the ion gun.

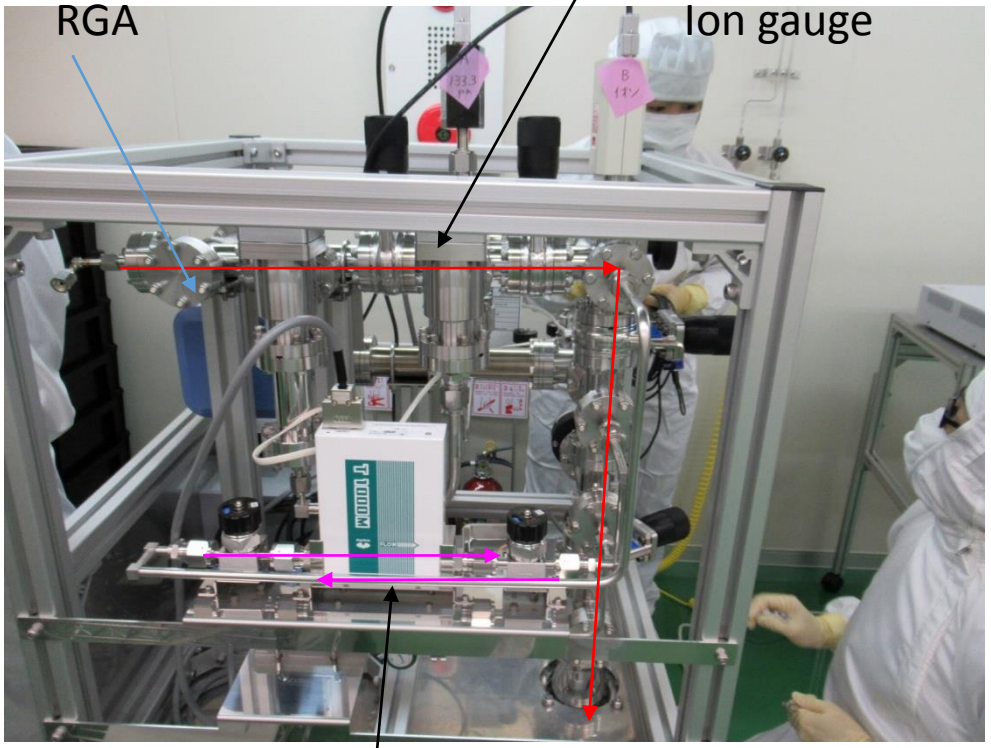
Particle range

number	Particle size
nx[2]	0.25um~0.6um
nx[3]	0.6um~1.0um
nx[4]	1.0um~3.0um
nx[5]	3.0um~3.6um
nx[6]	3.6um~

Slow pump system



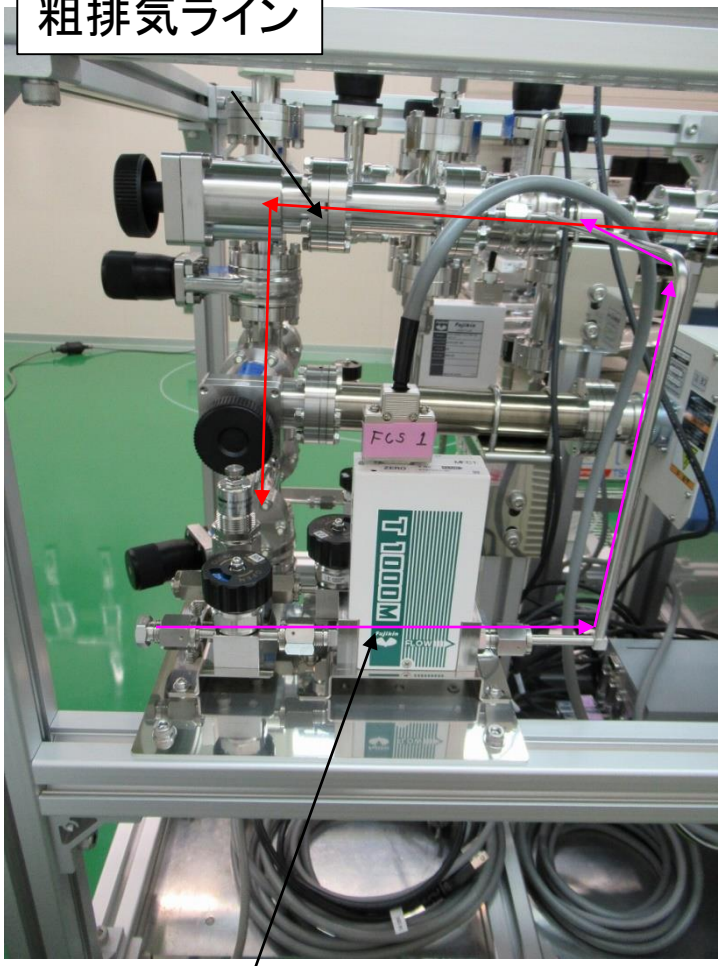
全体図

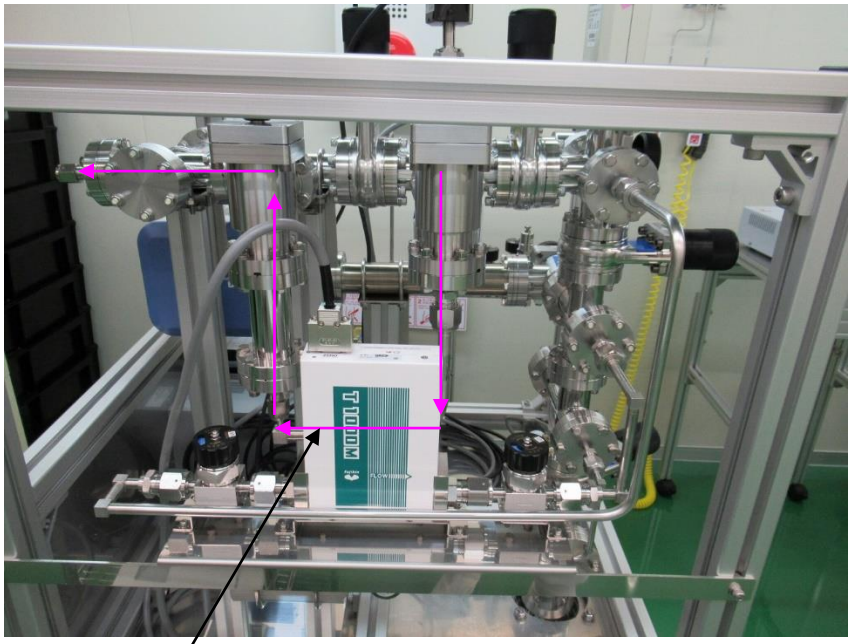


高さ1.4m × 横0.7m × 縦0.7m

Slow pump system (2)

粗排気ライン



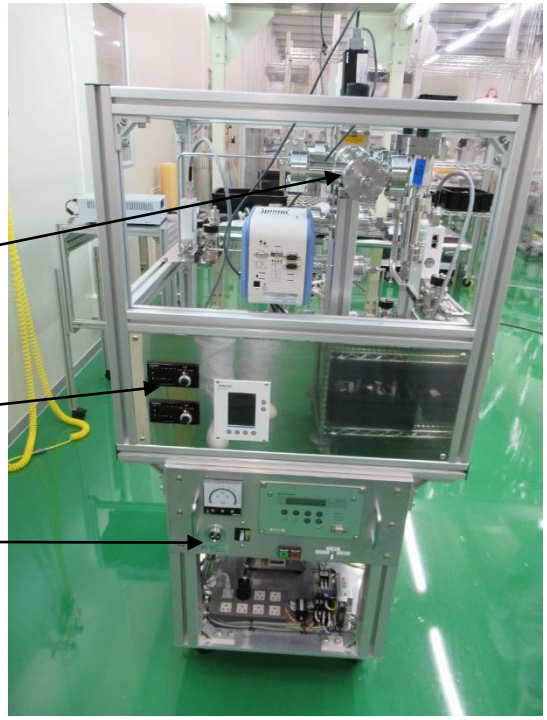


Slow purge ライン
裏面

空洞引き口

Mass flow
操作パネル

粗排気一式



Mass flow+N2 slow purgeライン