Recent clean assembly study at KEK for keeping SRF cavity high performance in cryomodule

Hiroshi Sakai (KEK)

- Importance about clean assembly work for ILC
  (Example of STF & E-XFEl cryomodule)
- Clean assembly work R&D in KEK (for STF cryomodule)
  - Local clean assembly work in KEK
  - Slow pumping & venting system with vacuum particle monitor
- Summary & future plan

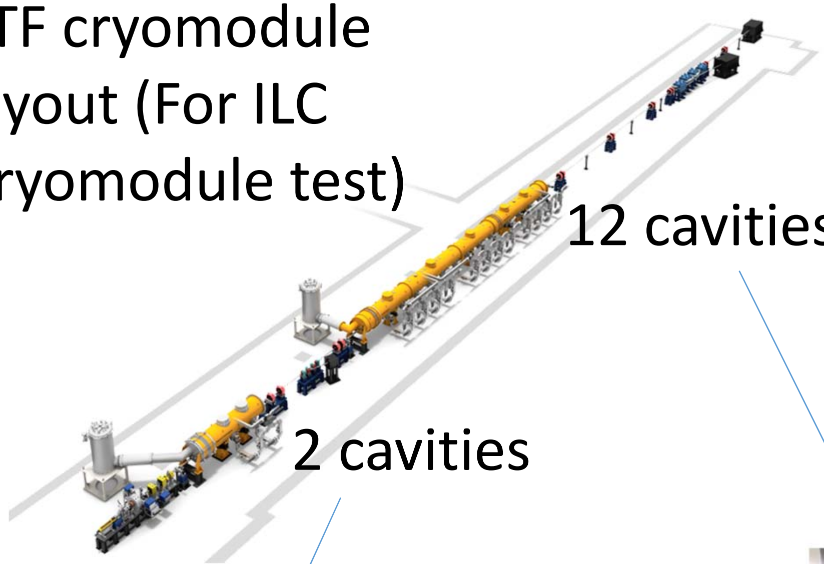
18 pages

LCWS2018 in Texas, 2018.Oct.25

STF Cryomodule

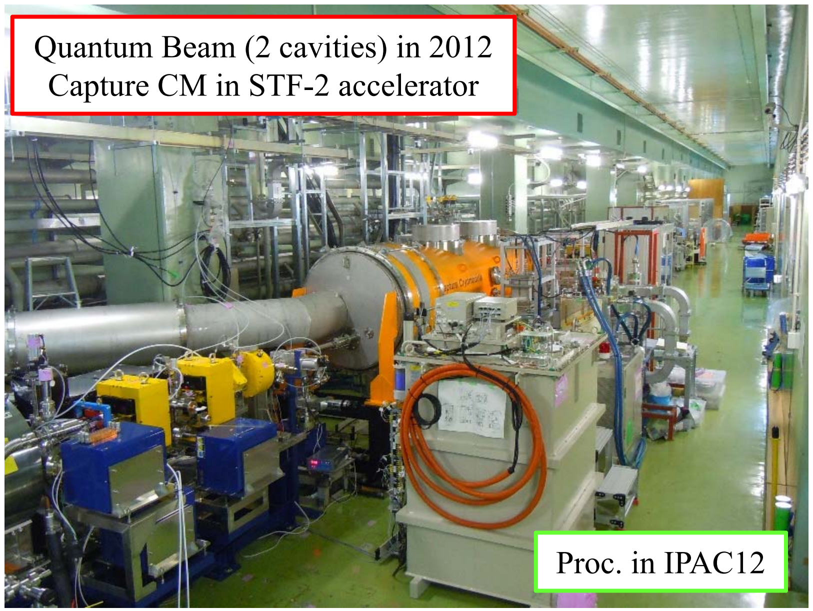
Yasuchika Yamamoto "Performance Degradation in STF Cryomodules from STF-1 to STF-2"
WG1 in TTC Meeting 2016 @Saclay

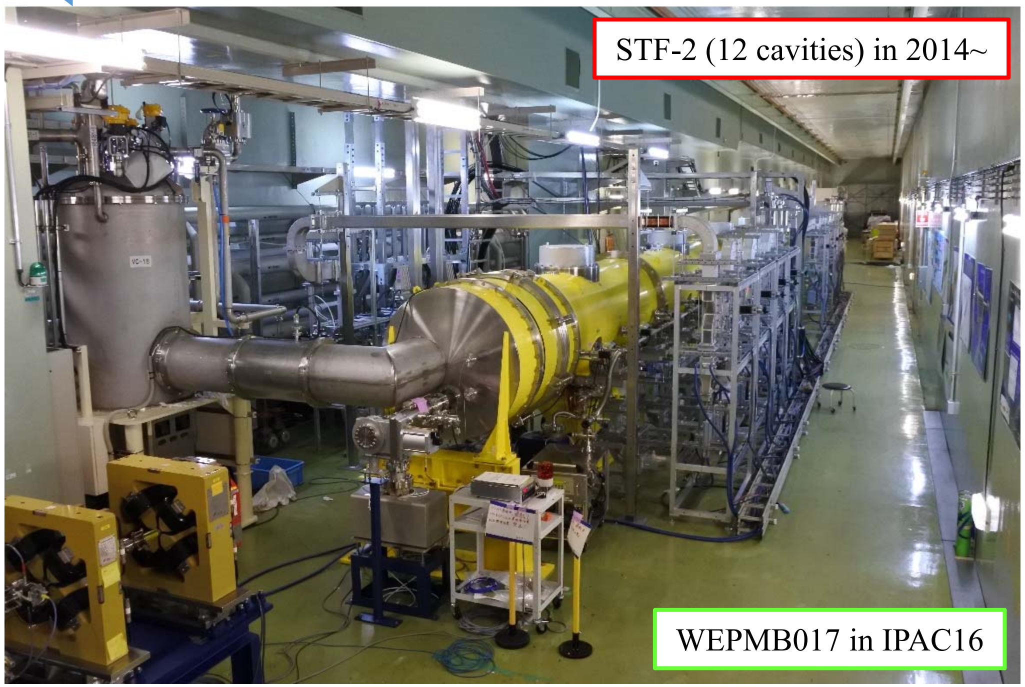
STF cryomodule layout (For ILC Cryomodule test)



4 cavities per batch

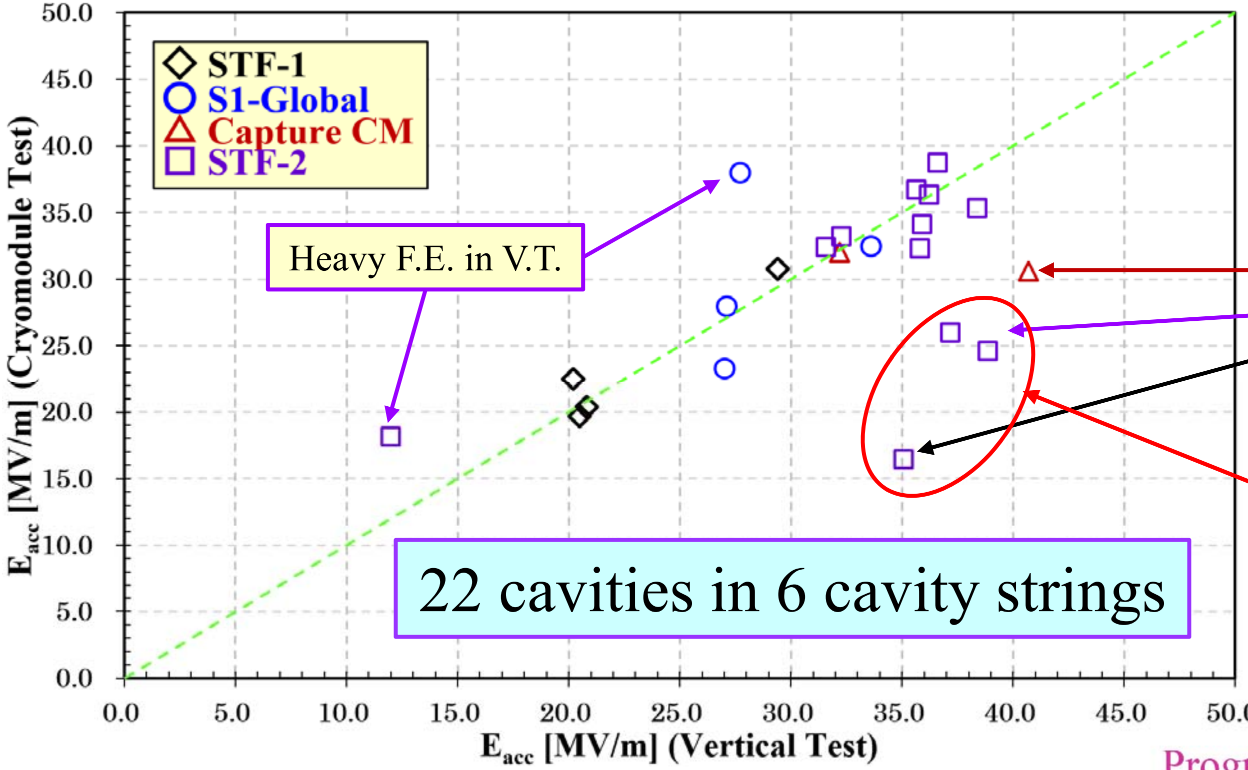
1.3 GHz
9-cell cavity





Performance Degradation in STF

Yasuchika Yamamoto "Performance Degradation in STF Cryomodules from STF-1 to STF-2"
WG1 in TTC Meeting 2016 @Saclay



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

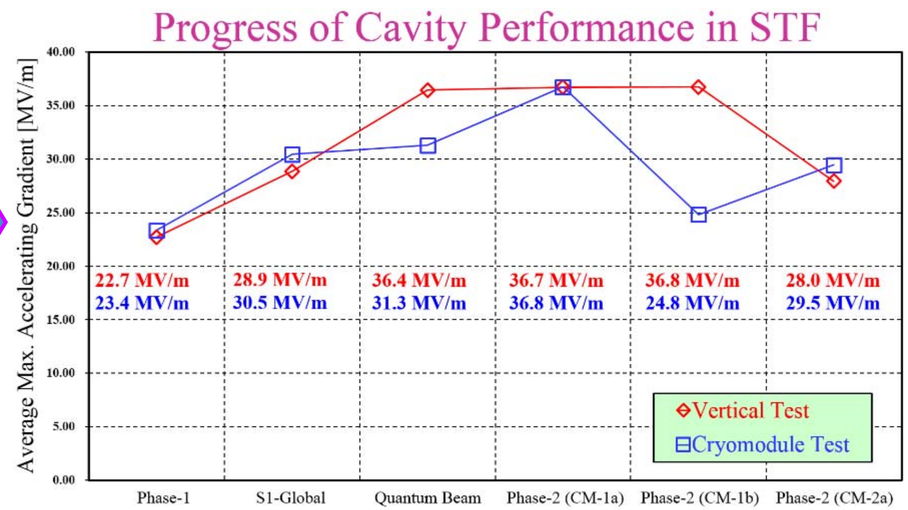
Three types of performance limit;
One cavity: Quench w/o F.E.
Two cavities: F.E. Quench
One cavity: Quench by enormous heat loss

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

Q_0 measurement is not done yet in STF-2.
It will start from this autumn.

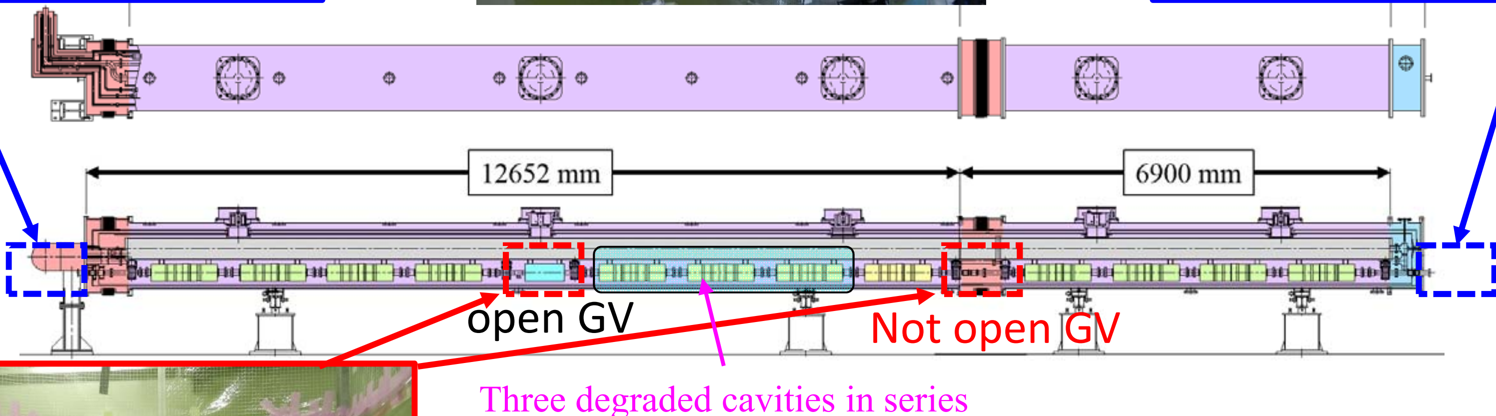
Statistics for cavity string (four cavities per batch);

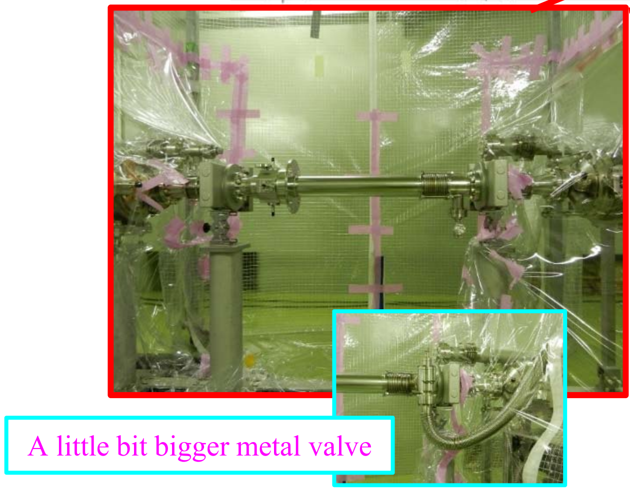
Four cavity strings:	No degradation
Quantum Beam:	Degradation, but around ILC spec.
CM-1b in STF-2:	Significant degradation



Previous STF cryomodule clean work in STF2

By Yasuchika yamamoto



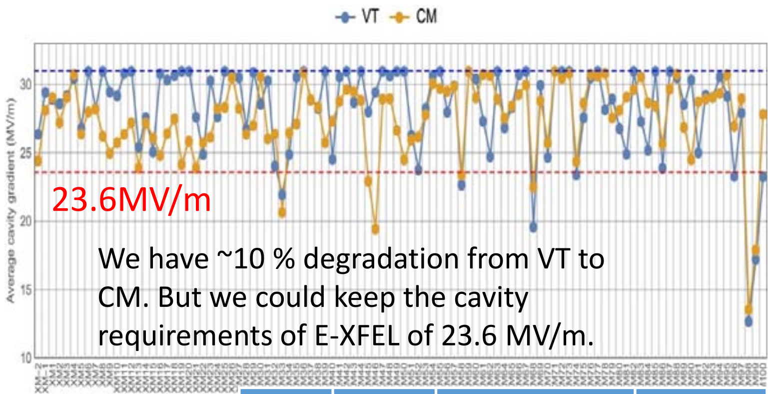


- Previous local clean booth has good clean environment ?
- Cavity was purged by normal vacuum pump → need slow pumping & venting system

Summary from E-XFEL experience about clean work

From "Report of workshop of Operating SRF Systems reliably in a "Dirty" Machine @ HZB (Berlin)" of *H.Sakai* talk in LCWS2017 *Strasbourg*

https://indico.helmholtz-berlin.de/conferenceTimeTable.py?confId=10#20170914



by Denis Kostin
In LCWS2017

	N_{cavs}	Average	RMS
VT	815	28.3 MV/m	3.5
CM	815	27.5 MV/m	4.8

- Remember the basic rules as follows
  - Avoid particulates at every stage and include it in the mechanical design
  - Remove particulates at every stage possible
  - Do not produce particulates especially during installation and operation
  - Never transport particulates
- **ILC needs higher gradient of more than 10 times larger SRF scale than E-XFEL. These clean work of E-XFEL must be learned more and brushed up.**

By Lutz

For ILC up to now, keep clean clean clean clean as much as possible.

Recheck our clean work in cryomodule assembly

- Can we use good clean booth ?
- No miss clean work under pumping and venting ?
- Can we keep clean each components like screw ?
- Clean work has done smoothly ?

- 1. High quality local clean booth
- 2. Check component by high quality particle counter
- 3. Slow pumping & venting system
- 4. Reconsider & train clean work

Recent clean assembly work R&D in KEK (1)

- Local clean assembly work in KEK (ISO class 1)
- Slow pumping & venting system with vacuum particle monitor

local clean booth with laminar flow (E-XFEL)

How do we realize clean environment in local area & in accelerator tunnel for STF and ILC ?

Check the difference our old clean booth and ISO clean room 4

Clean booth was used in cERL assembly in 2012 (almost same as STF clean booth)

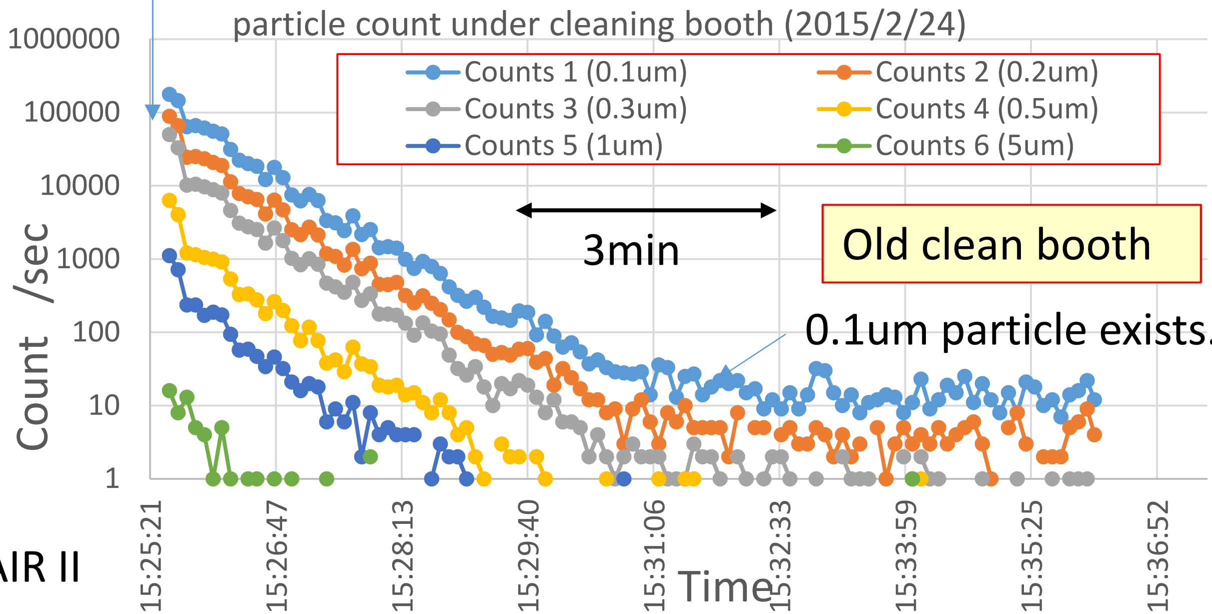
2mx2mx2.4m

Two HEPA filter set on roof

LASAIR II

HEPA power on

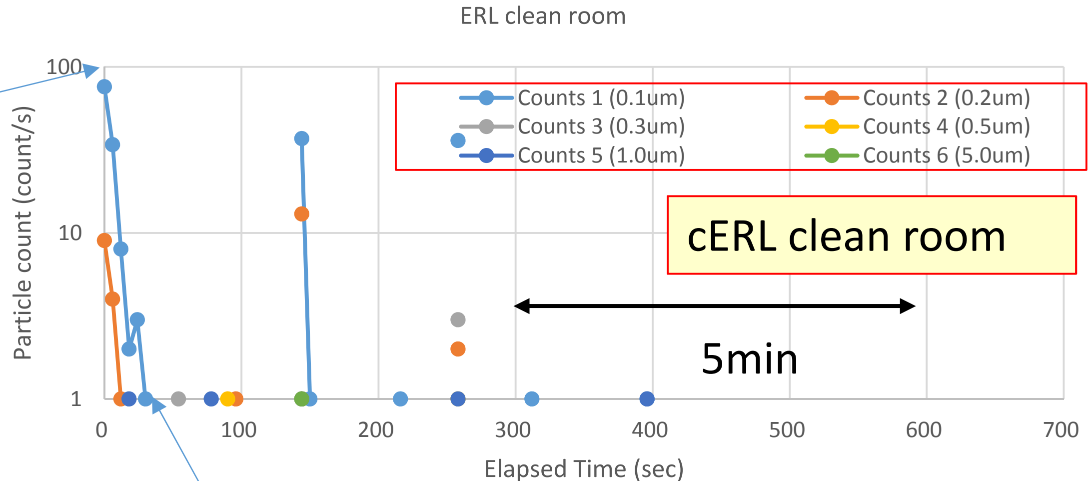
Measured by LASAIR II (0.1um)



Old clean booth

0.1um particle exists.

Hit grove.



cERL clean room

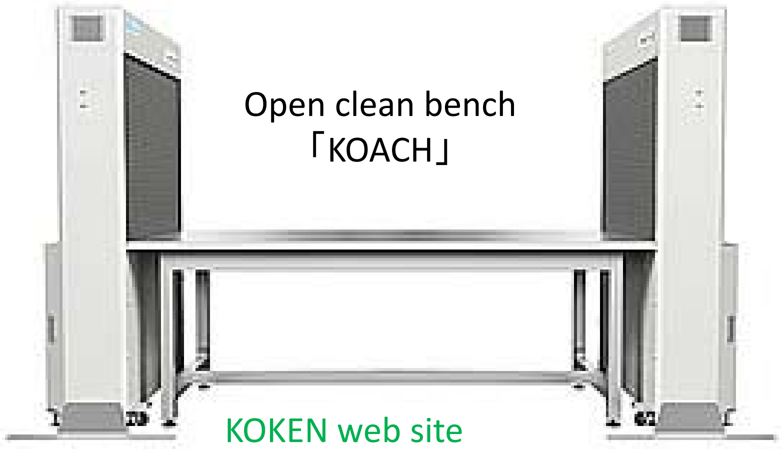
Particle of 0.1um level keeps 0 after 2o sec.

ISO 4 clean room : reduce 0 particle smoothly. (enough power to keep clean)

Old clean booth we cannot reduce to 0 particle in this room.

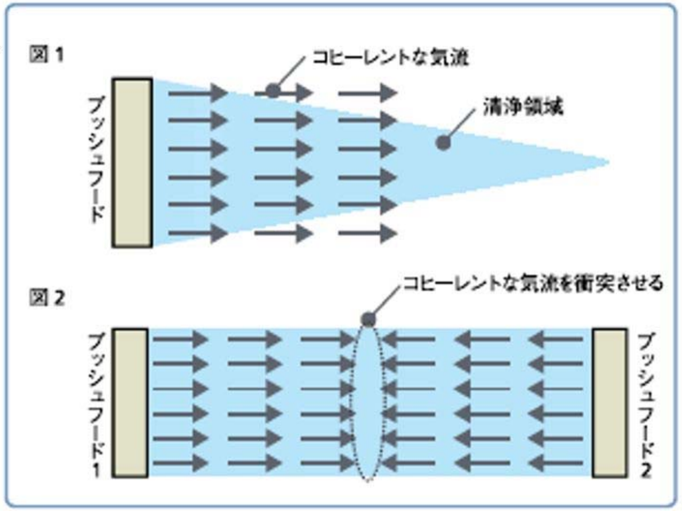
Need cleaner booth in STF

KOACH (ISO Class 1 open clean bench)



Good laminar flow

【水平式の送風による清浄領域を上から見たイメージ図】

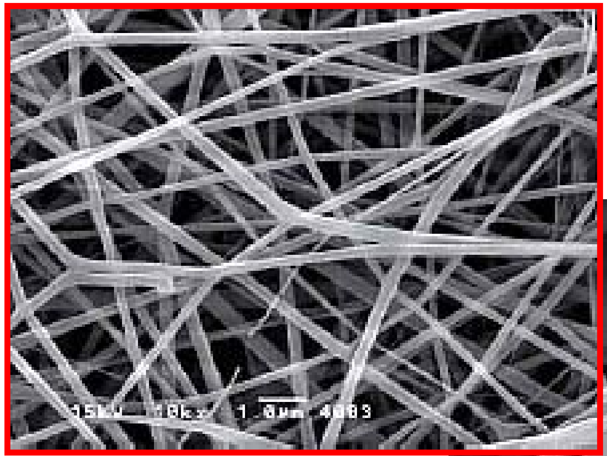


Keep clean

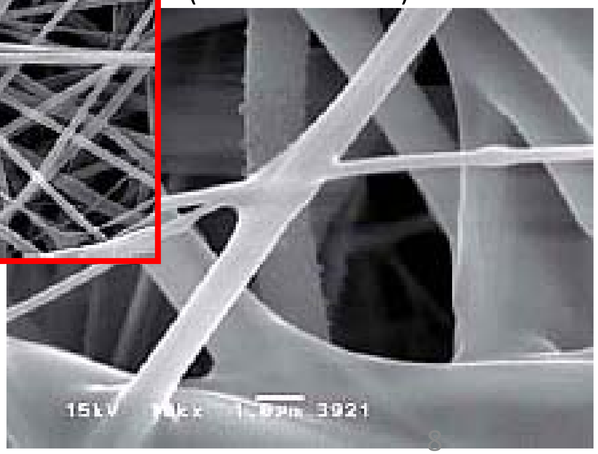
(×10,000)

FERENA

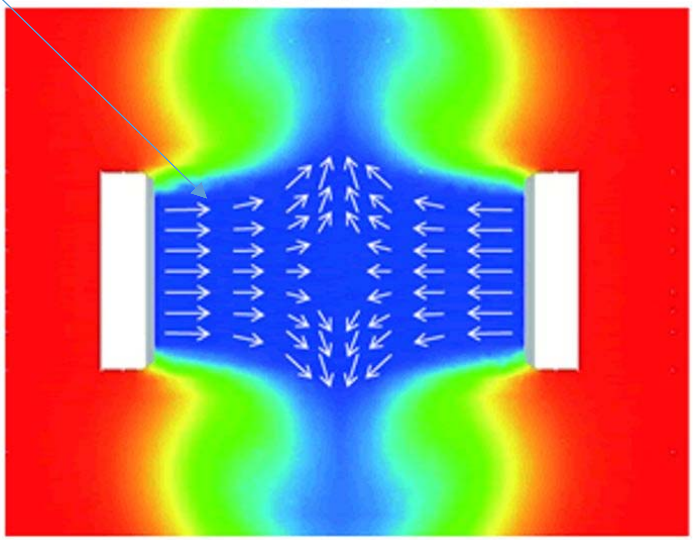
(nano fiber filter)



ULPA



【気流シミュレーション図】



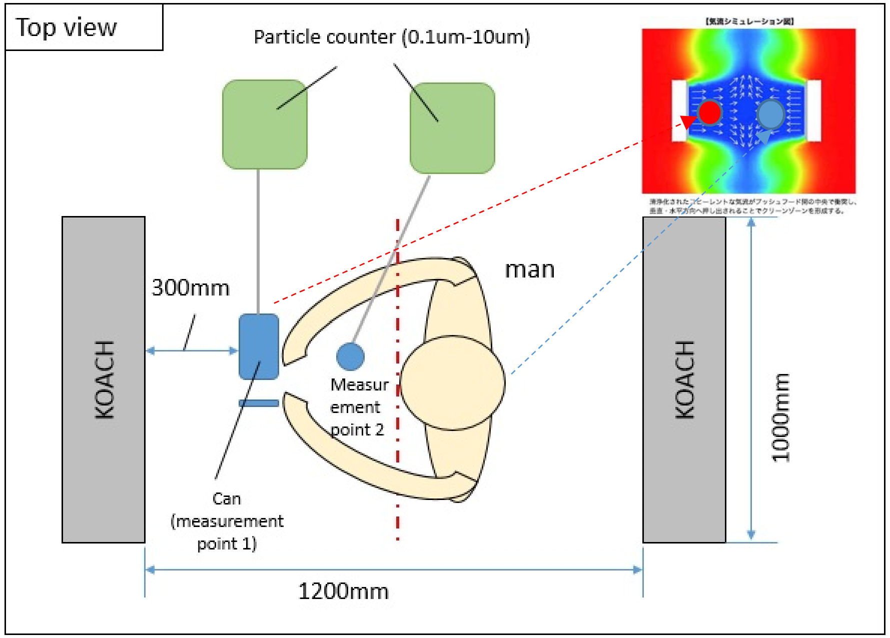
清浄化されたコヒーレントな気流がプッシュフード間の中央で衝突し、垂直・水平方向へ押し出されることでクリーンゾーンを形成する。

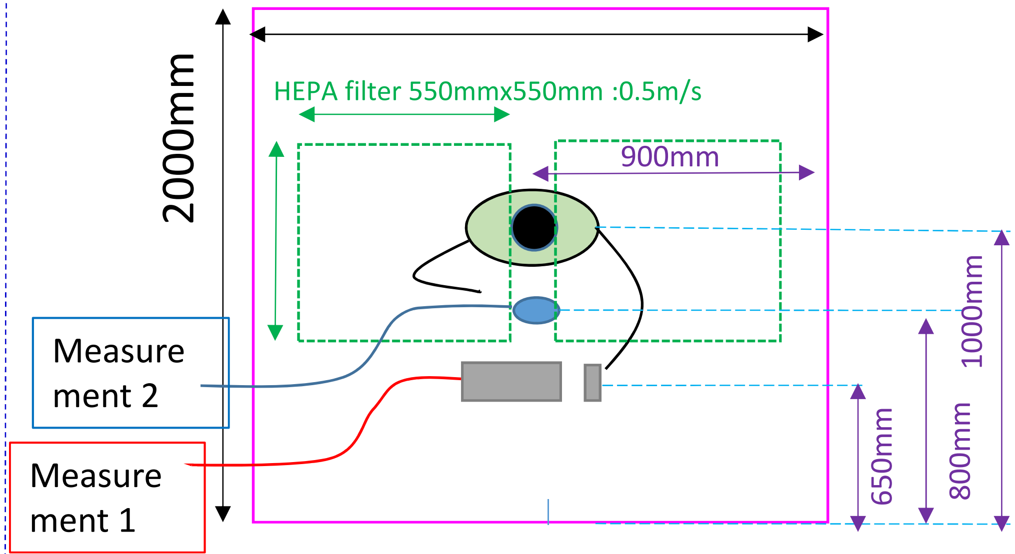
Realize ISO class 1 clean environment in local area

KOACH

Test of particle measurement in both condition

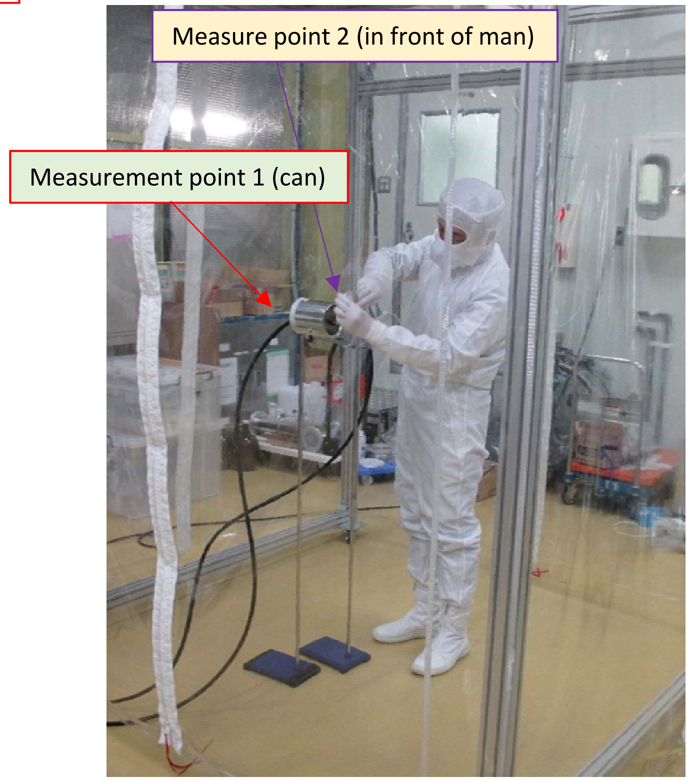
Old Clean booth in KEK



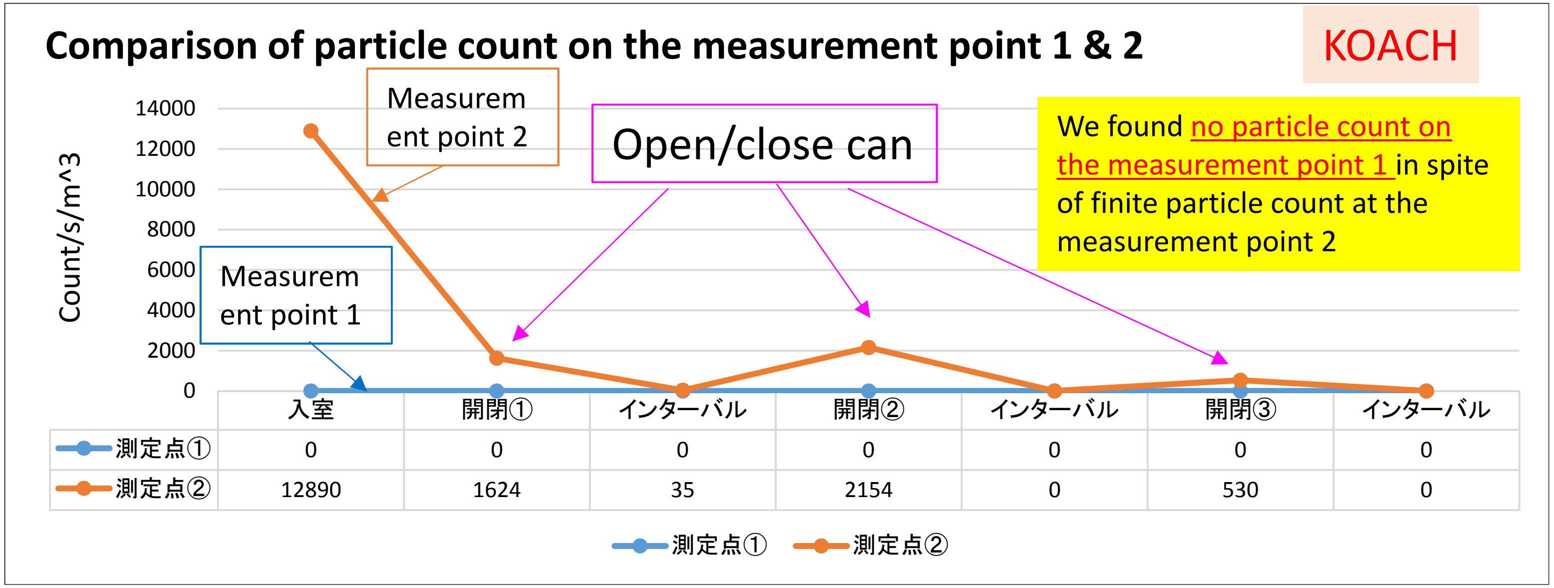


Measurement point 1 (in can)

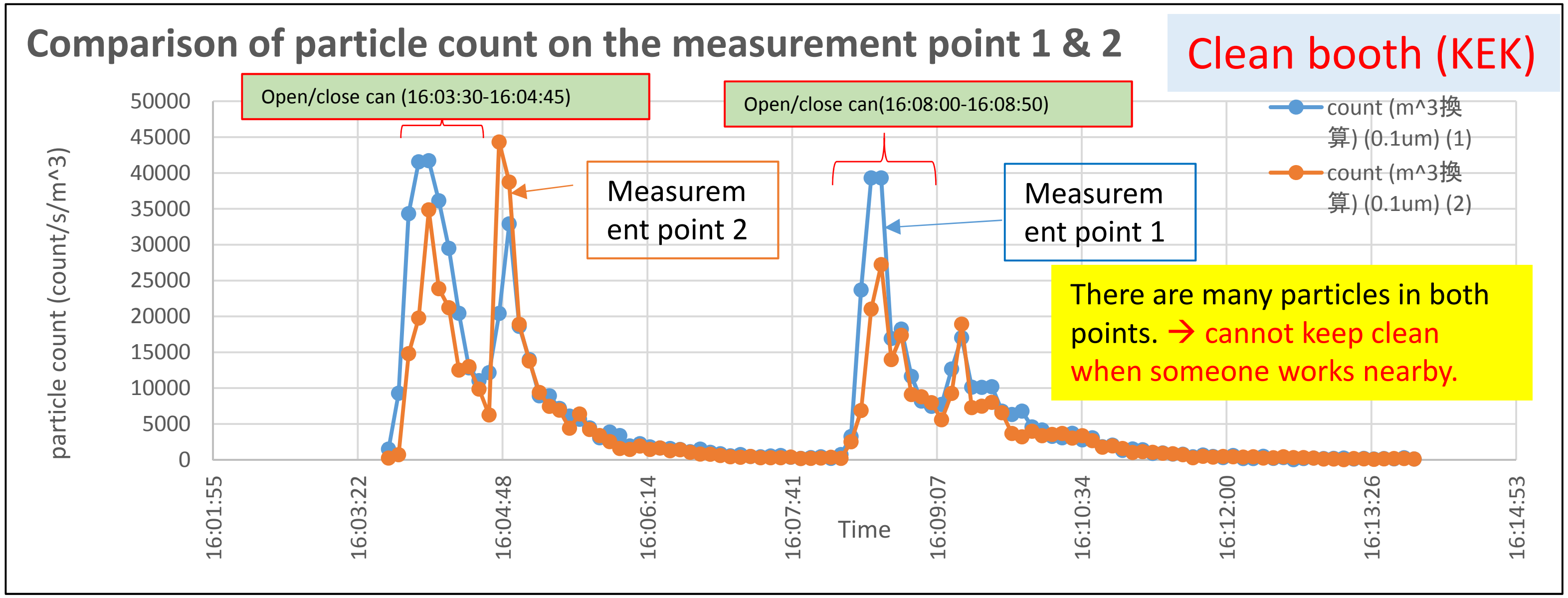
Measurement point 2



Comparison results of particle counts of both clean bench



	入室	開閉①	インターバル	開閉②	インターバル	開閉③	インターバル
測定点①	0	0	0	0	0	0	0
測定点②	12890	1624	35	2154	0	530	0



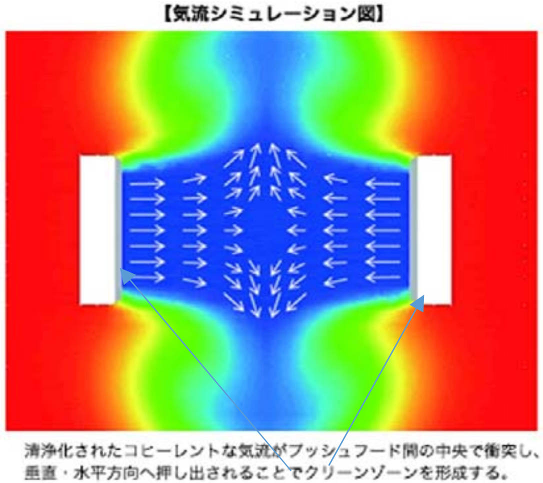
KOACH make local clean environment even though the man work in the clean bench.

Application by using KOACH in beam line to make clean environment (cERL beam line)

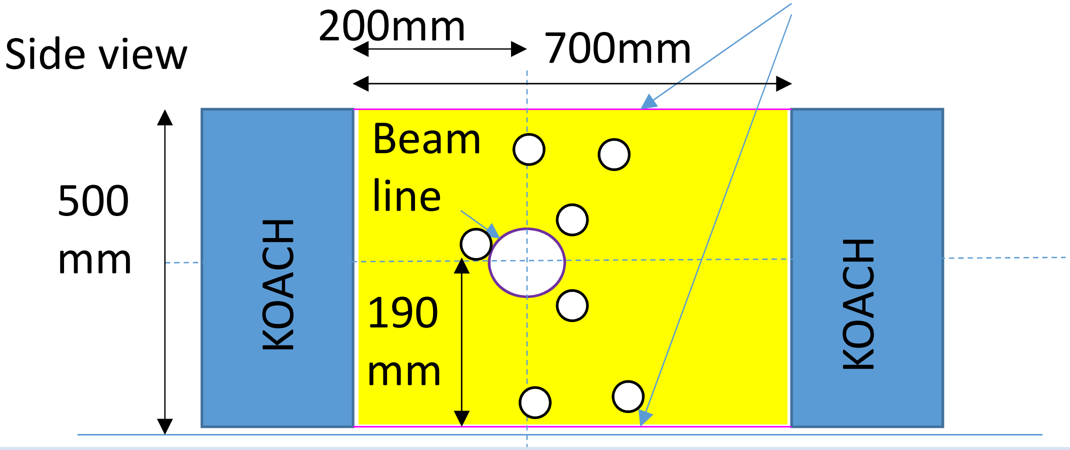
H. Sakai, et. al. "Improvement for clean assembly work about superconducting RF cavity & cryomodule to suppress field emission " ,Proc. of 14th annual workshop of Particle Accelerator Society of Japan, TUP051, Sapporo, Japan (2017)

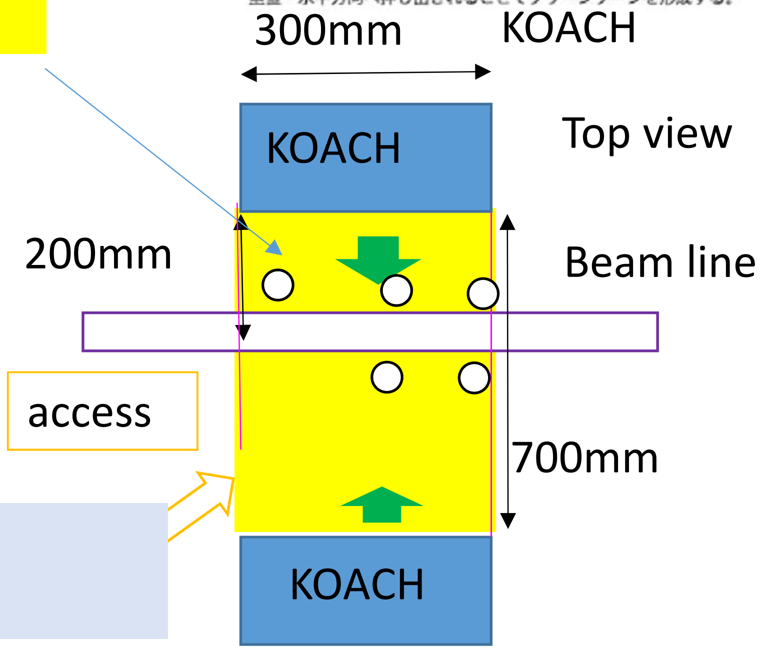
KOACH make open clean environment with ISO class 1.
Push-push laminar flow make clean.

KOACH set in cERL beam line to demonstrate clean environment in accelerator.



Yellow area will be set clean area





Results: all 0 count with 0.3um level of open circle.
This KOACH can apply as new local clean booth to STF

Recent clean assembly work R&D in KEK (2)

- Local clean assembly work in KEK (ISO class 1)
- Slow pumping & venting system with vacuum particle monitor

slow pumping & venting system (Euro-XFEL)

How do we suppress the particle contamination during pumping & venting ?
→ Need to check particle movement during pumping & venting and control pumping/venting speed

Slow pumping & venting system in 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)

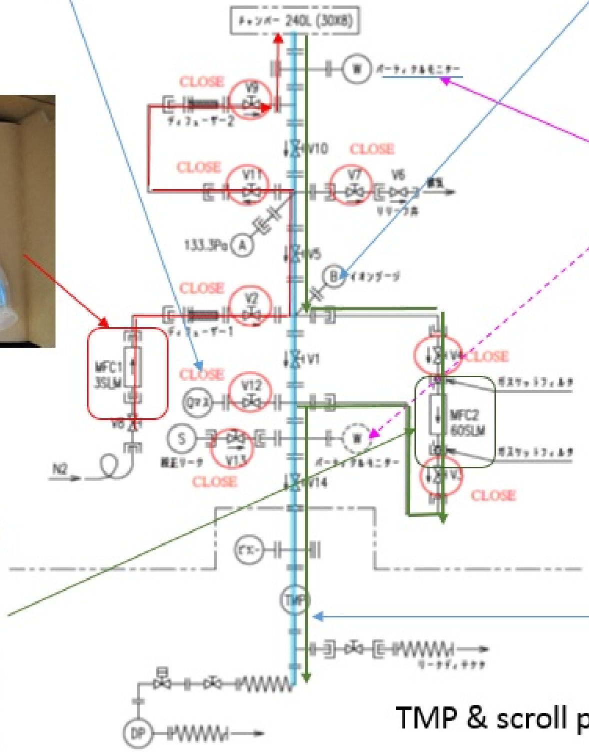
RGA

Slow pumping & venting system block diagram(setup)

Mass flow (for slow venting)

Mass flow (for slow pumping)

SRF cavity



Ion gauge

Vacuum particle sensor

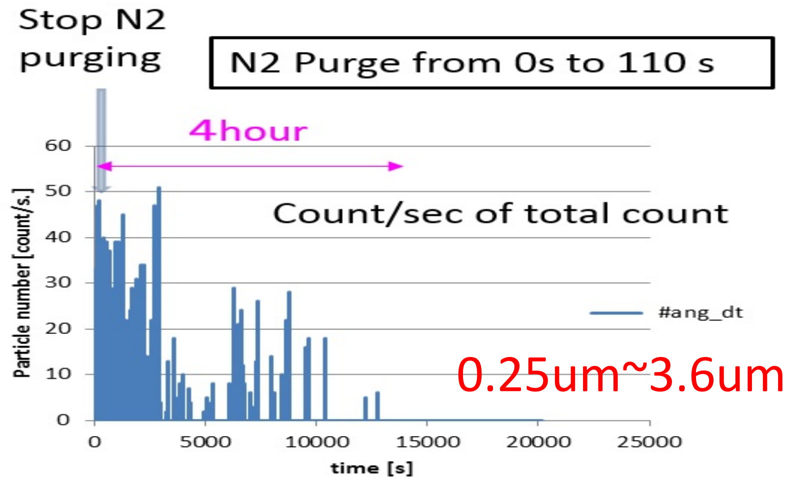
TMP & scroll pump

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.

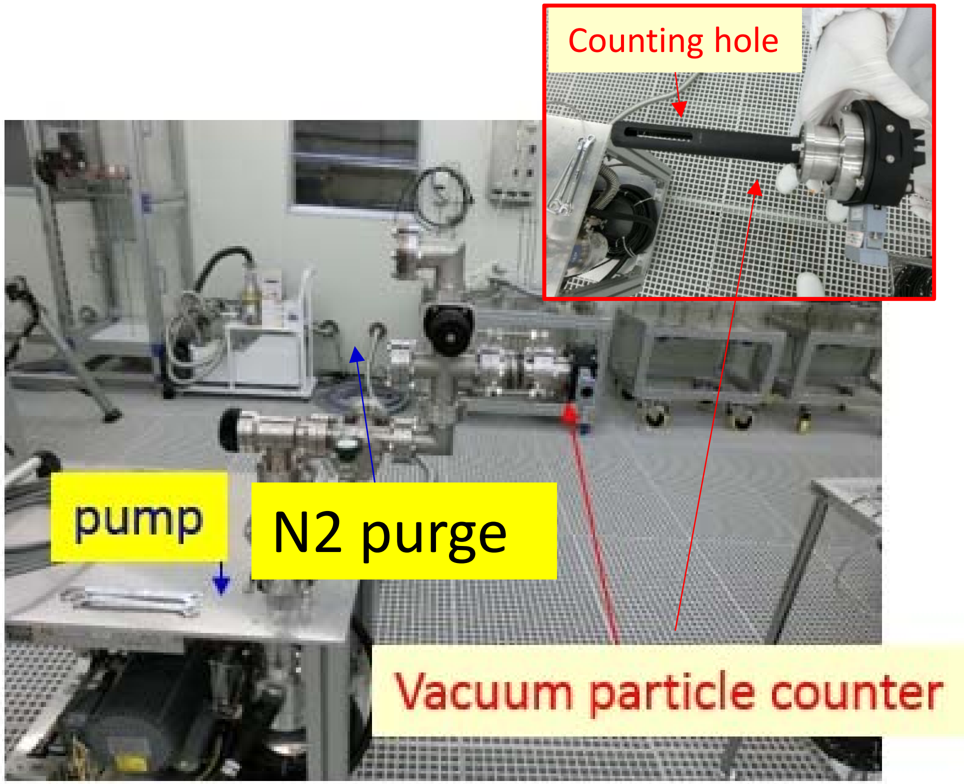
Test of vacuum particle sensor

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

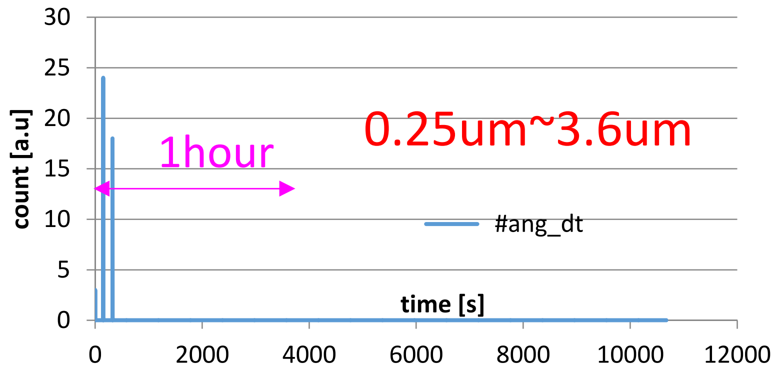


Setup of vacuum particle sensor

Particle measurement results after purging N2 with/without filter



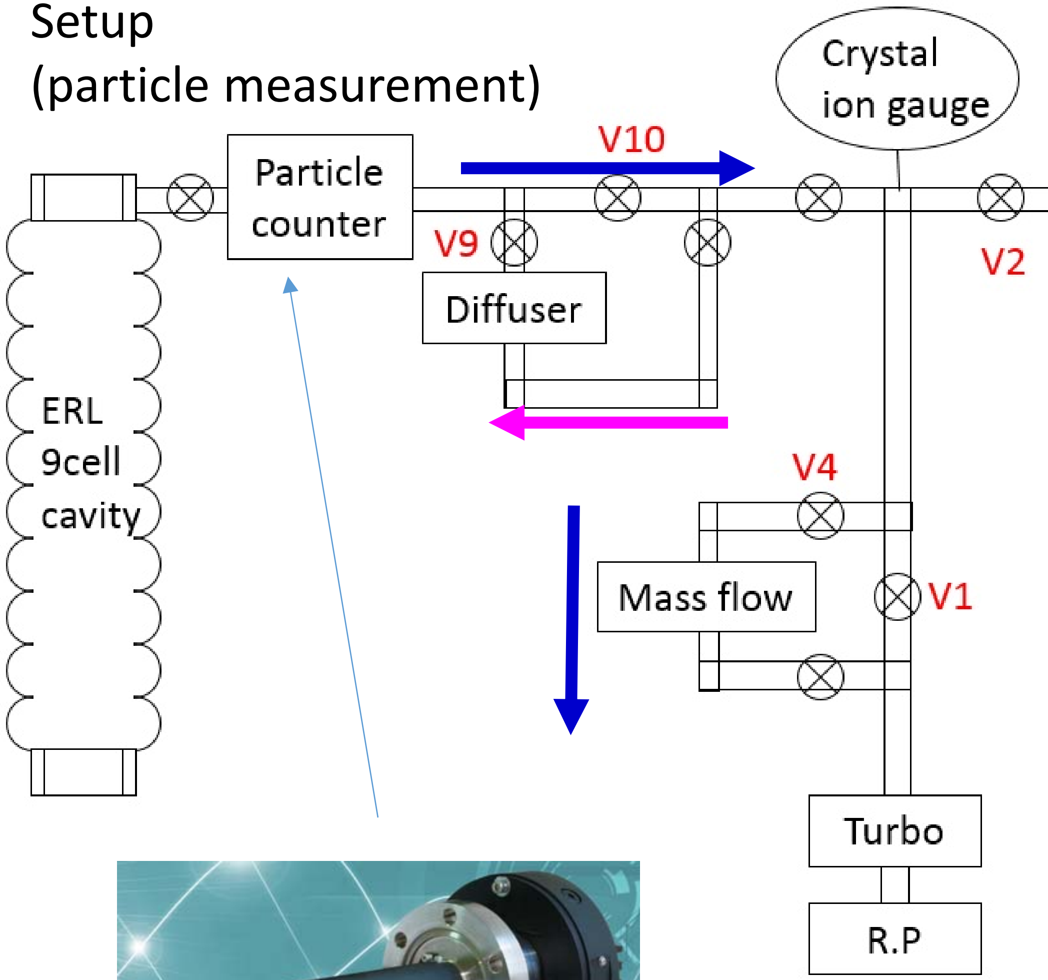
Particle was smaller than w/o filter case. Filter works to reduce particle contamination. But we saw the particle count during N2 purging both with and without filter of 5L/min flow



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

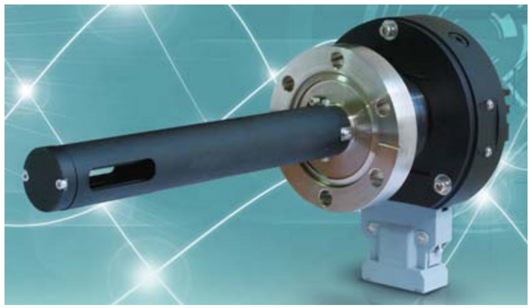
Test of slow pumping & venting system by using SRF cavity

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

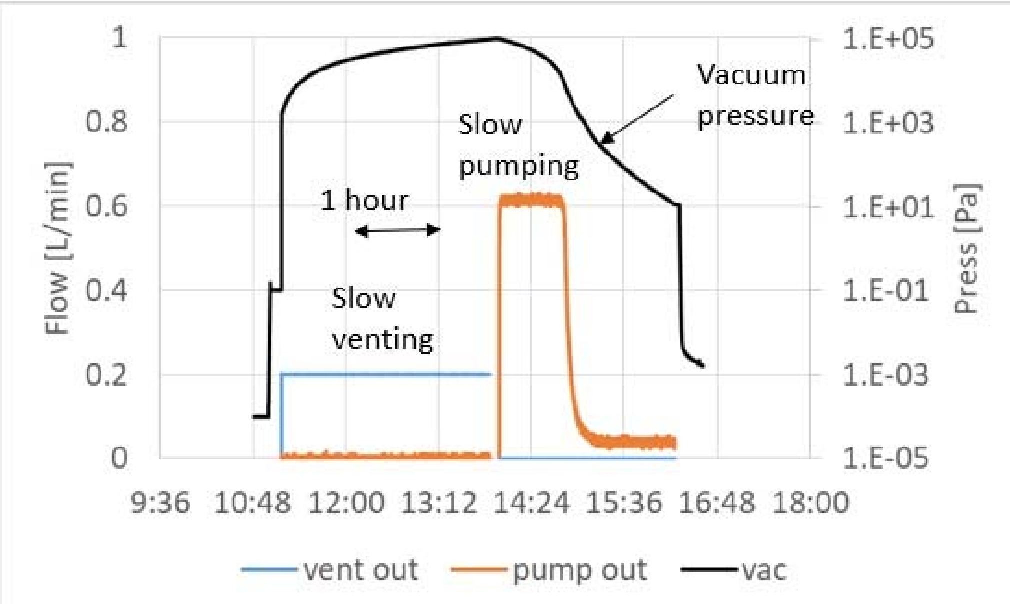


Vacuum particle sensor

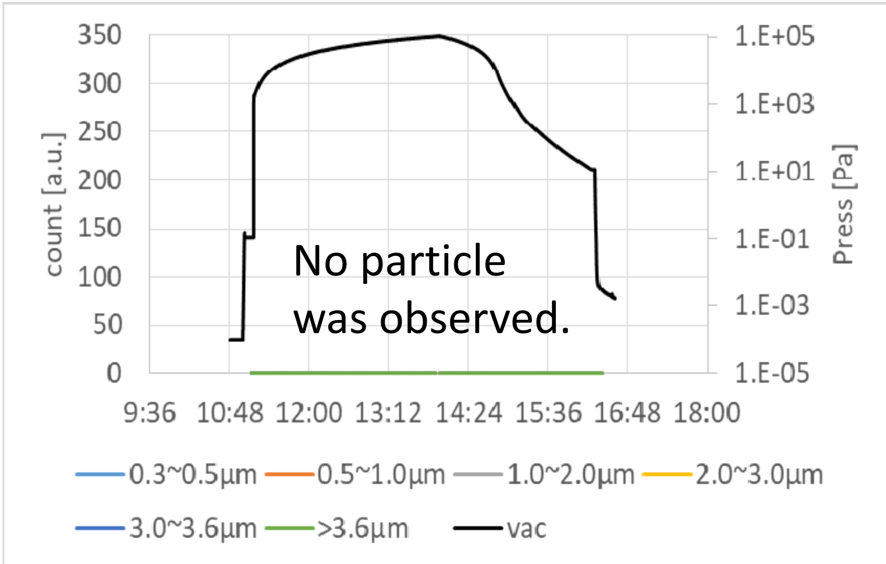
Flow of both lines were controlled by mass flow controller.

Particle measurement results

Flow ratio and pressure under Slow pumping & venting



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

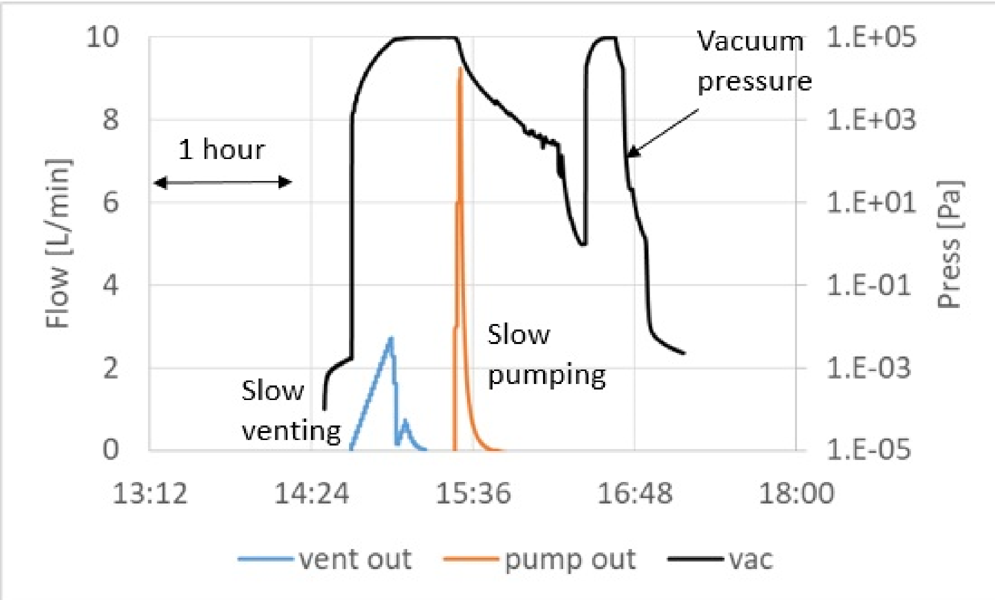


- <u>Realize 0.2 l/min slow pumping & venting</u>
- <u>No particle of 0.3 um size was observe during slow pumping & venting.</u>

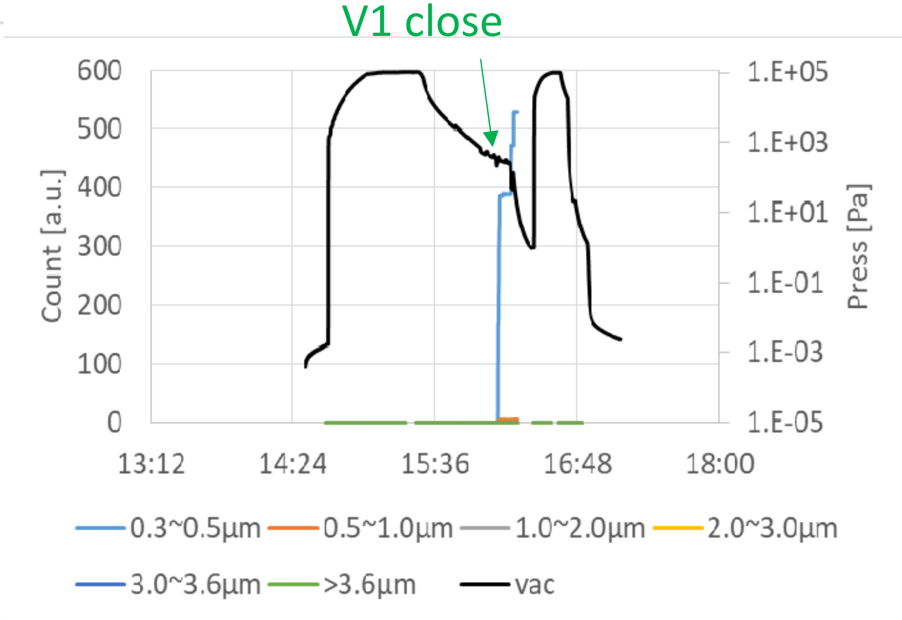
<u>→ make good laminar flow in pumping line and in the cavity and particulate in the flow line did not move and come into the cavity.</u>

Particle measurement results (faster case)

Flow ratio and pressure under Slow pumping & venting



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



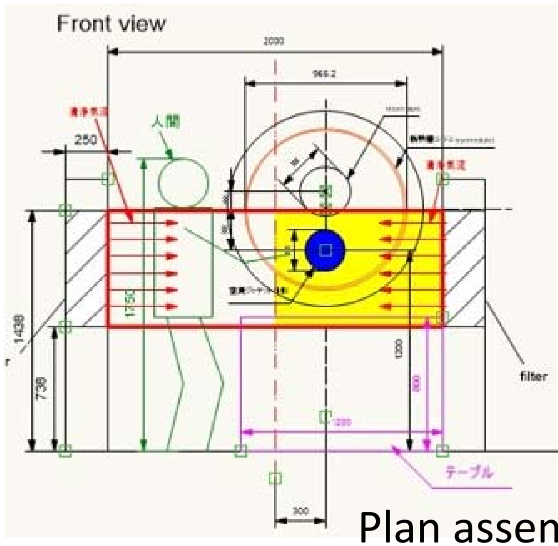
- No particle of 0.3 um size was during slow pumping & venting of a few l/min speed.
- But during changing from the slow pumping to normal pumping by closing V1 valve. We found the particulate. Valve made particulate and need control closing/opening speed not to make particulate.

speed	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.

Summary & future plan

- Local clean booth by using KOACH make cleaner local environment around beam line if we optimize the local bench configuration
- Slow pumping & venting system works well. Slow closing/opening valve is important.
- In this fiscal year, we are trying clean assembly work by using STF cryomodule for the replacement of clean bellows between the GV section in cryomodule.
- And check the cavity performance after opening GV for beam test of STF cryomodule.



Plan assembly at STF

Acknowlegments

Yasuchika Yamamoto, Eiji Kako, Kensei Umemori, Taro Konomi, Takafumi Okada
& All STF members
Takashi Nogami & all cERL members
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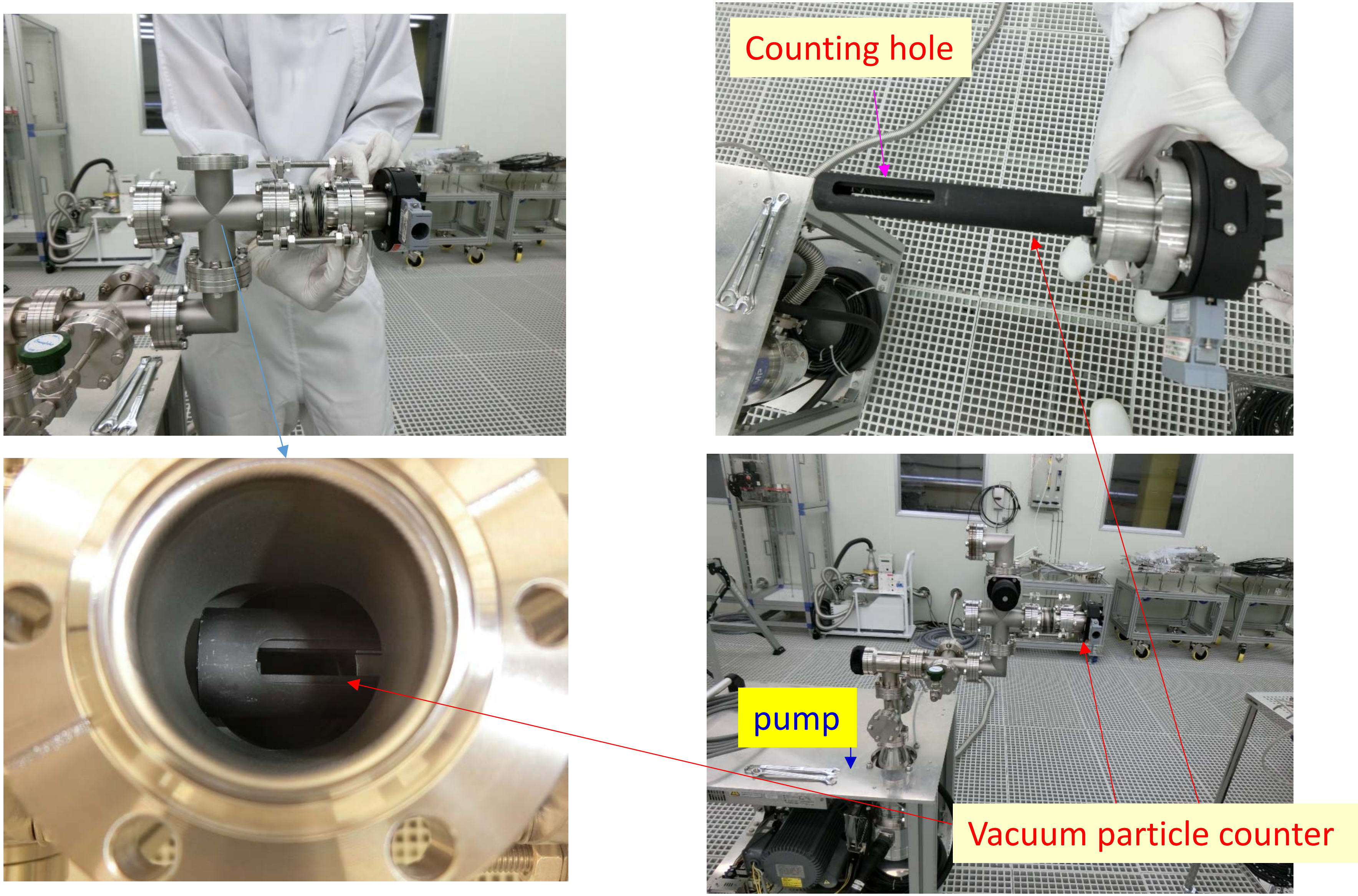
Hirokazu Okada of K-vac
Naomi Sasaki , Ichiro Mine of Fujikin company
Kazuhiro Iimura of R-dec company
Hiroyuki Asada, Keiji Toriyama, Izumi Hattori of Wexx company

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.

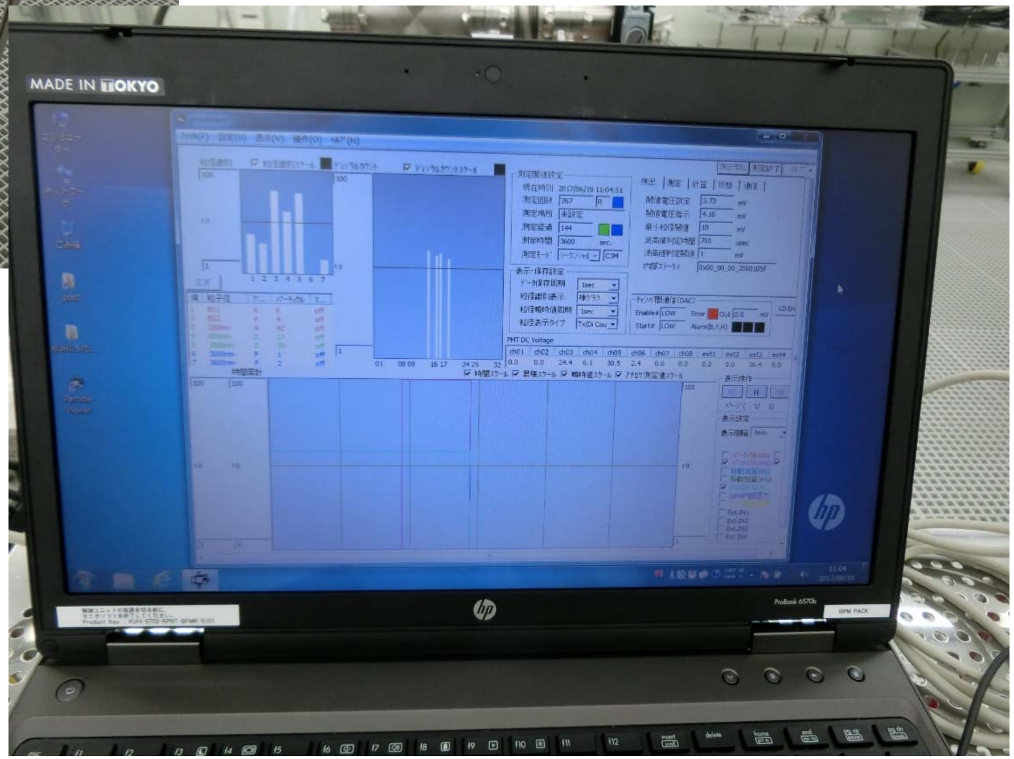


Position of the open area of vacuum particle counter in chamber

Final setup

Measurement setup in clean room

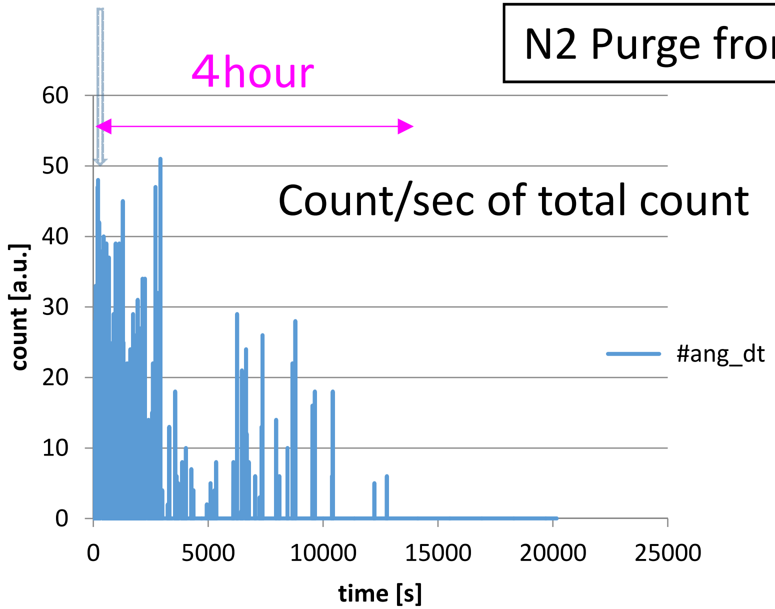
All PC and controller and cable was cleaned in clean room



Measurement of particle in N2 purge

Stop N2 purging

N2 Purge from 0s to 110 s

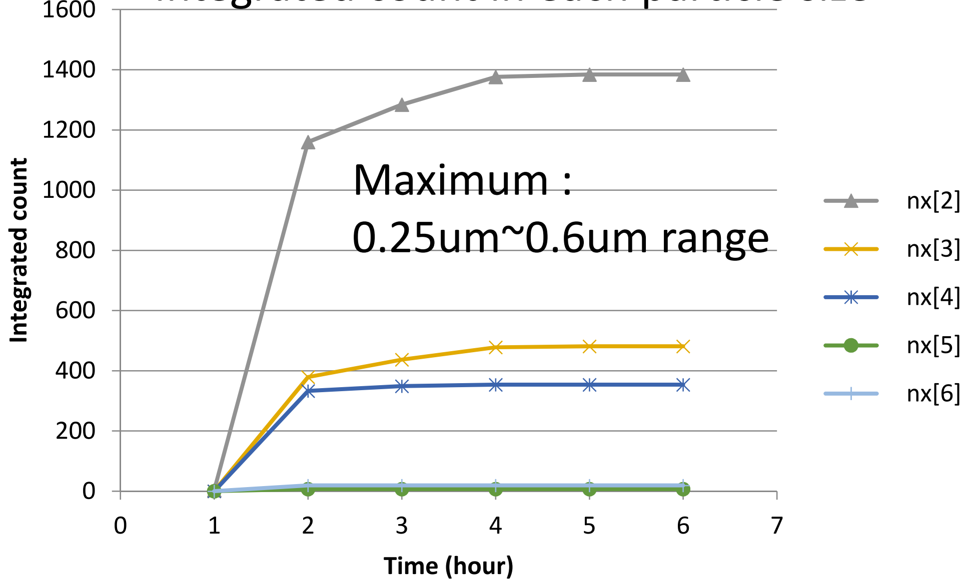


We saw many particles after purging N2 gas w/o filter.
Many particle come into and stay in vacuum during 4 hours.

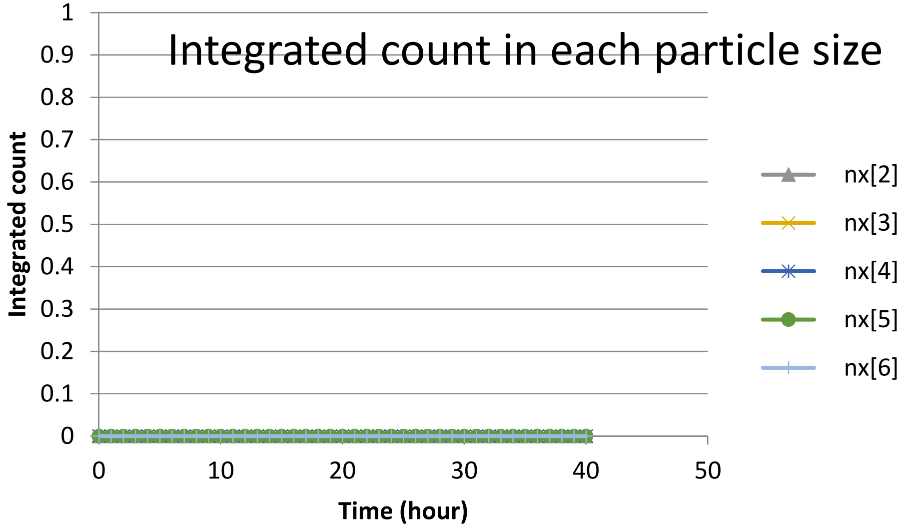
Particle range

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



Pumping (not slow) after purging N2

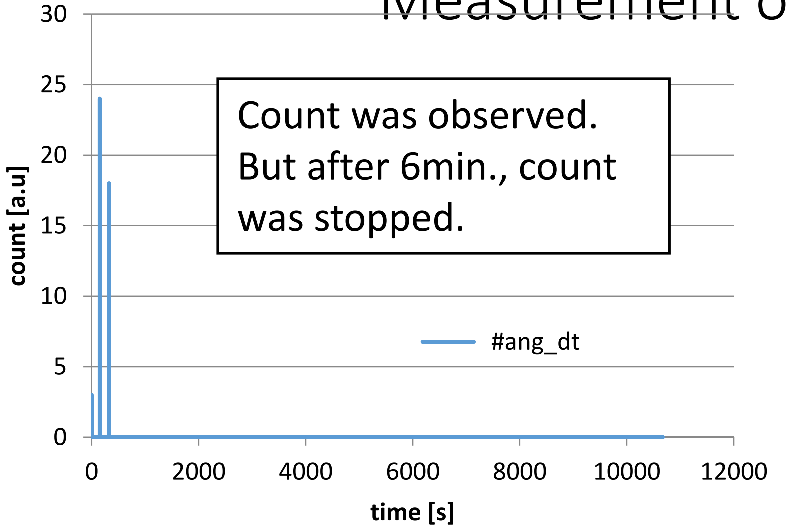


- Scroll ON
- start measurement
- TMP on

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

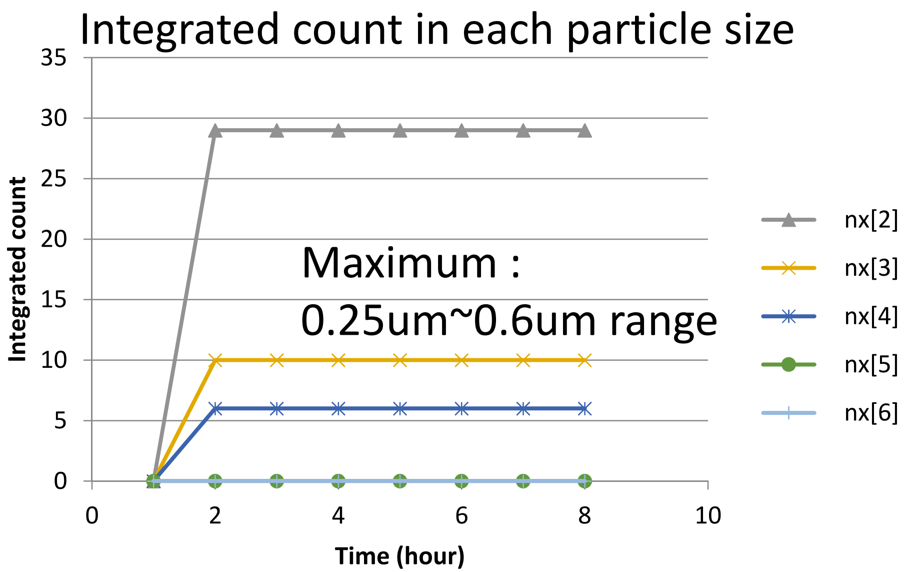


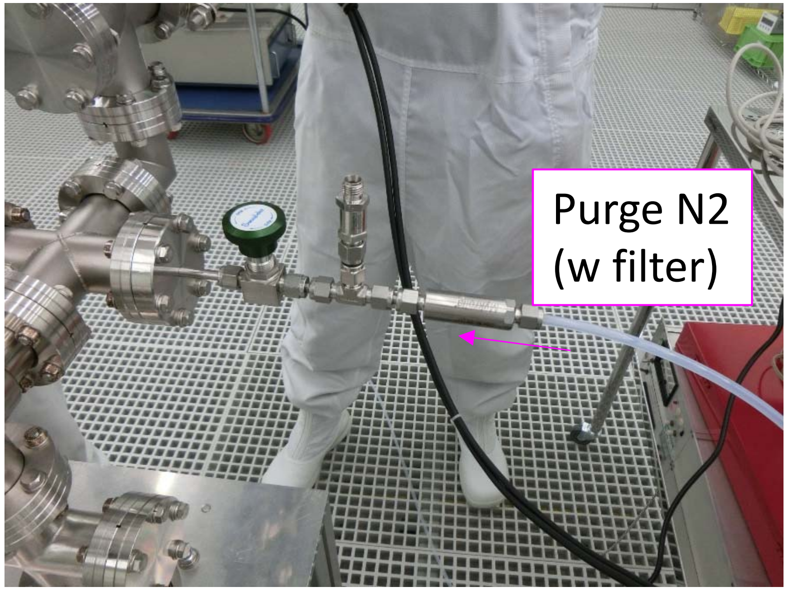
N2 flow: 5 L/min
N2 stop after
1min.

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.



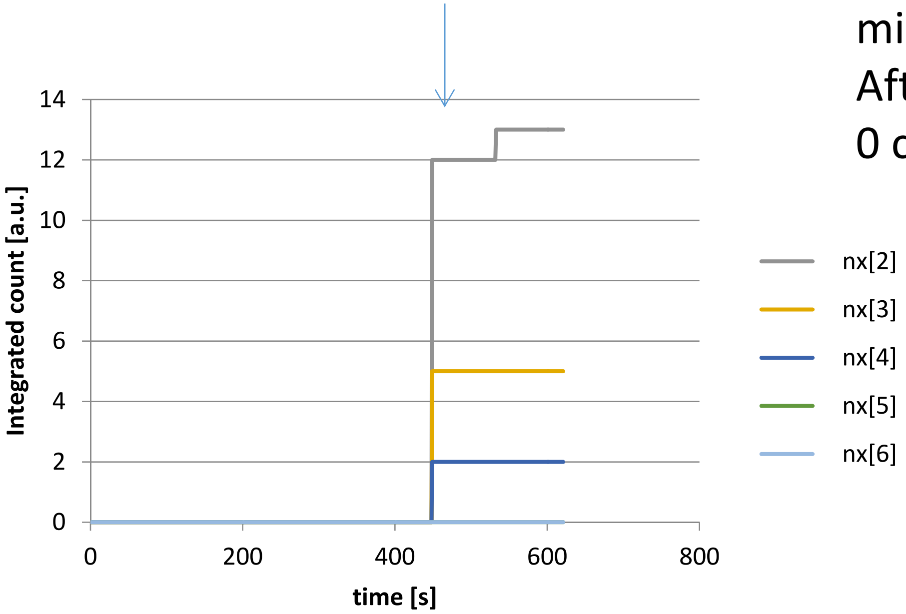


Anyway, we saw the particle count during N2 purging both with and without filter of 5L/min flow

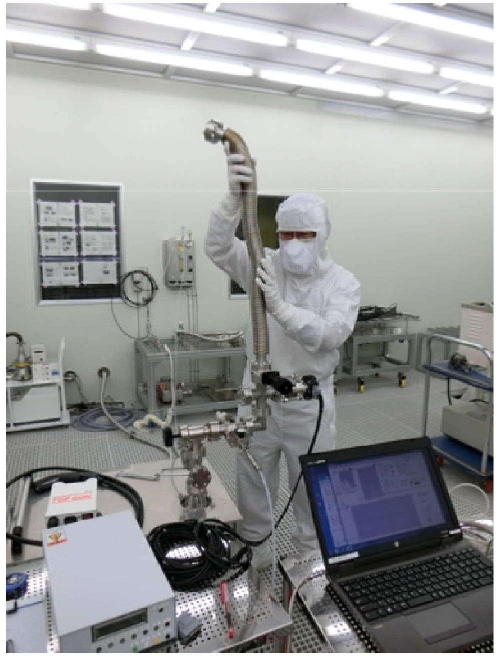
Venting is more dangerous than pumping. More slow pumping speed and optimization are needed to make slow pumping system.

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~