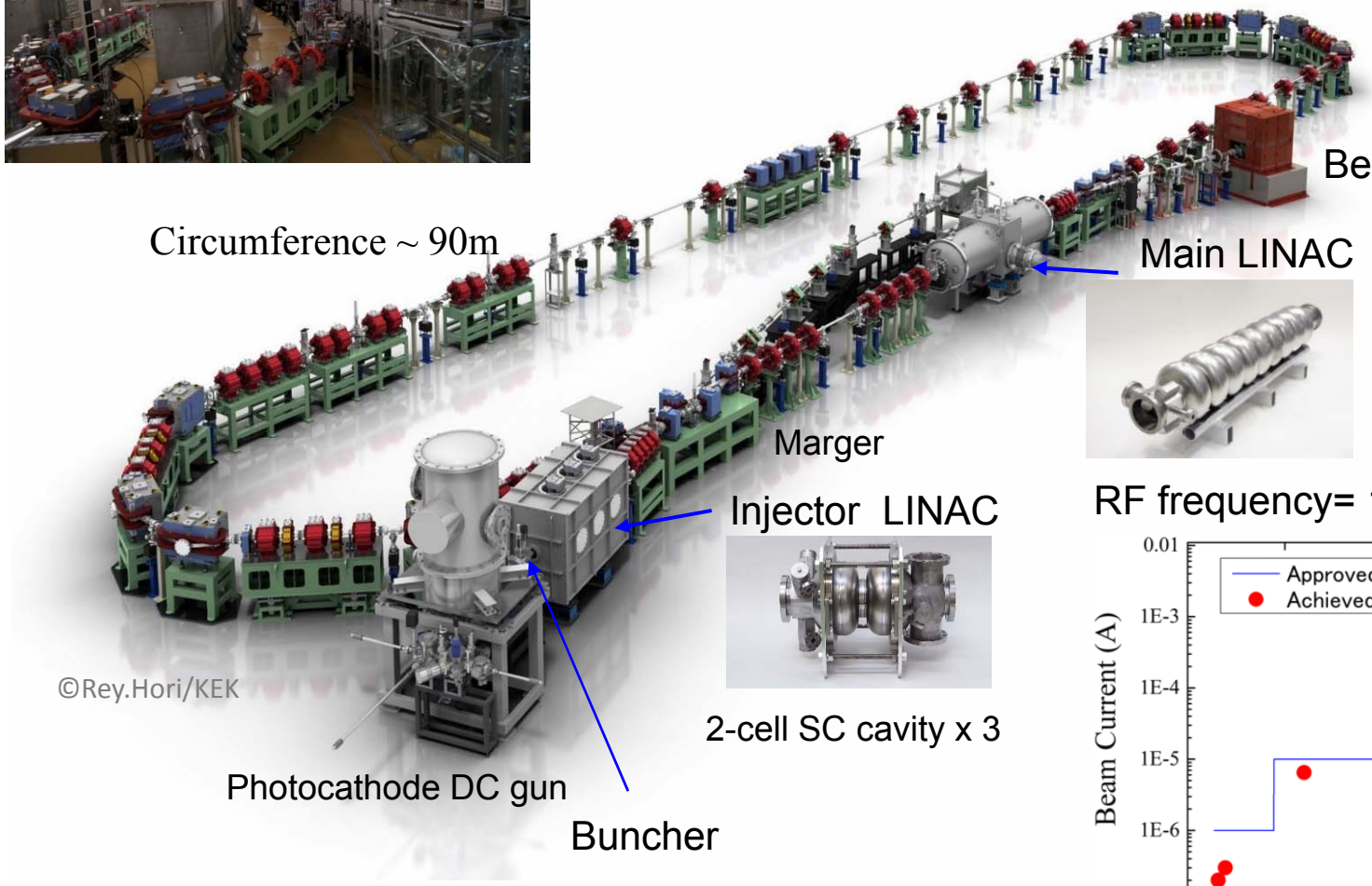
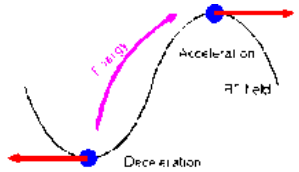
Application of NEG-coating chamber beside the SRF cryomodule in cERL at KEK

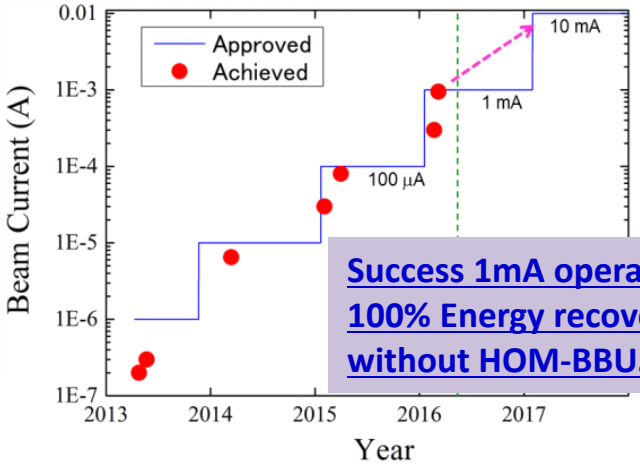
Compact ERL (**cERL**) has been constructed in 2013 at KEK to demonstrate energy recovery with low-emittance, high-current CW beams of more than 10 mA for future multi-GeV ERL & CW X-FEL.





9-cell SC cavity x 2

RF frequency= 1.3 GHz



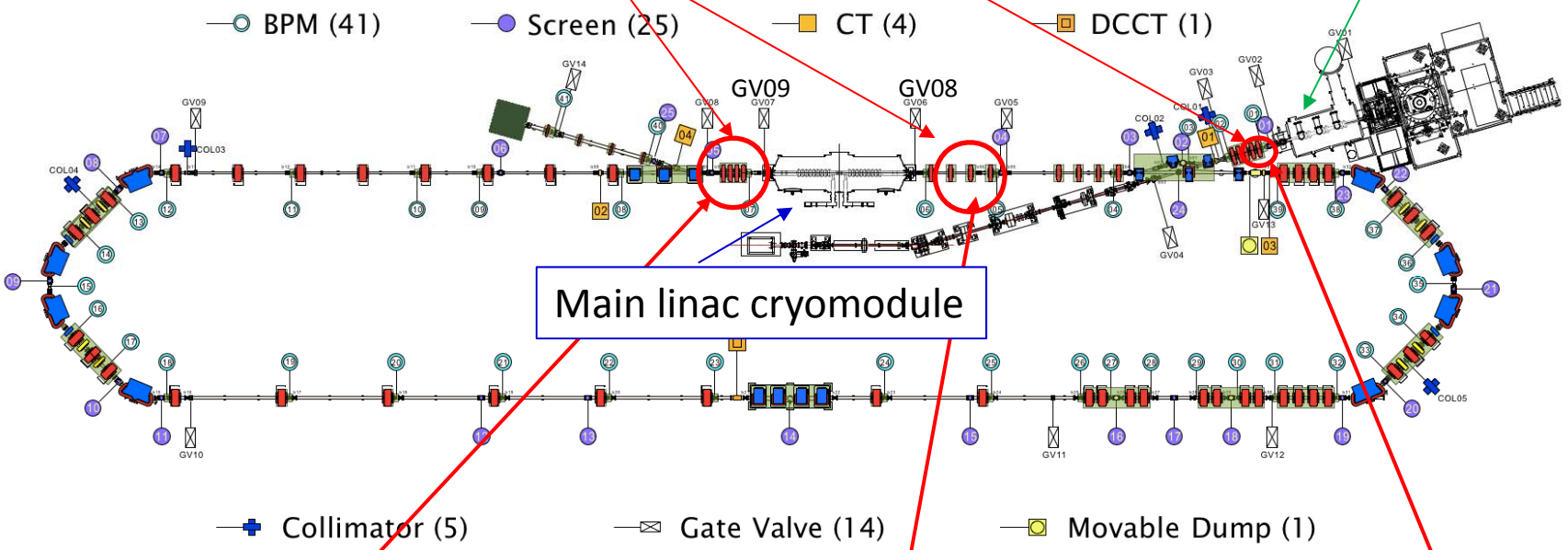
Success 1mA operation
100% Energy recovery
without HOM-BBU.

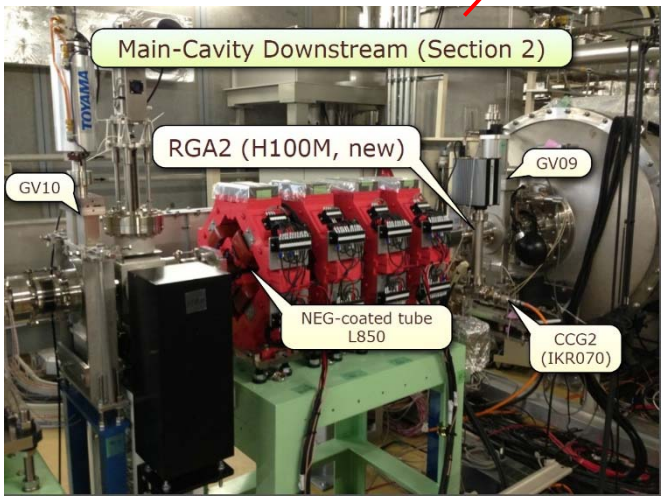
Hiroshi Sakai (KEK)

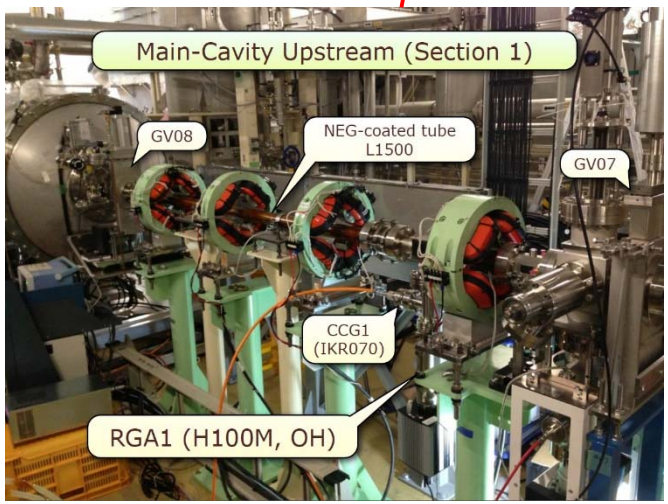
Our design of warm section in cERL at KEK
(position of NEG coated chamber)

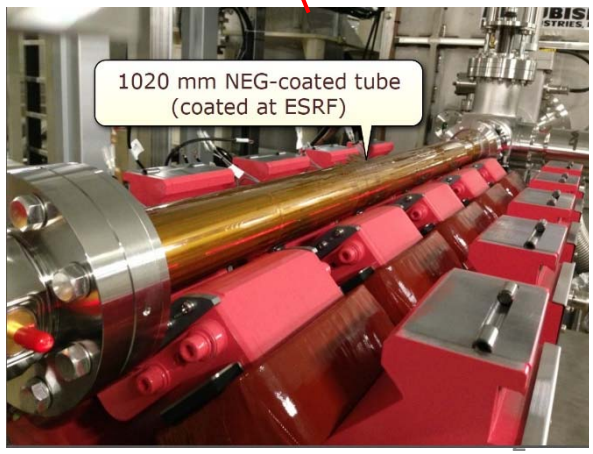
Three NEG-coated chambers (50ϕ) are installed beside the cryomodules

Injector cryomodule









Current status of our cryomodule performance with NEG-coated chamber

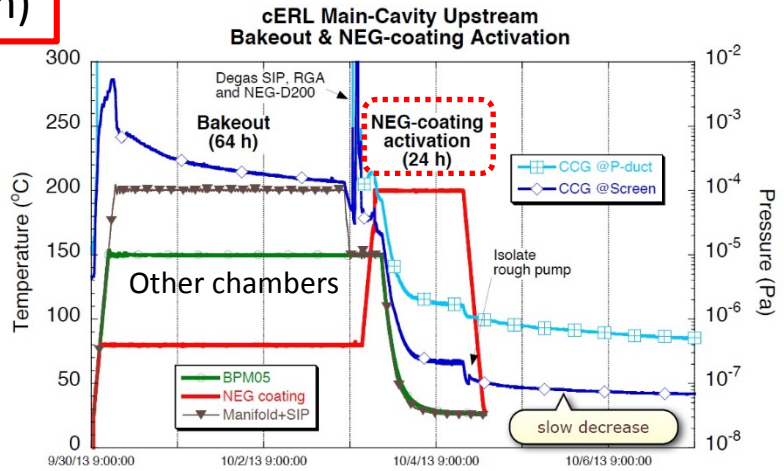
- Purpose: reduce outgassing beside the cryomodule by NEG-coated chamber.
- NEG with 1 um thickness coated by ESRF inside the SUS316L beampipe
- We cleaned inside the NEG-coated chamber by ionized-Ar gas through a ion gun before connected beamline until the count of the particle (>0.3um level) will be zero (it took about 10 minutes.) in a local clean boose. (see below picture). No water rinse was applied to NEG-coated chamber during installation to the beam line.
- 24 h activation with 200 °C to NEG-coated chamber improve vacuum level from ~10^{-6} Pa level to 6x10^{-8} Pa. Especially, Hydrogen was reduced to H_2 (after)/H_2 (before) ~ 1/550 by RGA measurement. NEG-coated chamber works well
- After activation and open the GV of cryomodule, first we did not see the degradation for a week. No particle contamination would be found in a week. But after two-month cERL beam operation we saw the degradation of cavity performance of both cavities. Unfortunately, we did not identify that the degradation come from the NEG-coated chamber or not because of the lack of the particle monitor inside the vacuum chamber.
- We need to investigate that NEG-coated chamber produce particle or not for a long time operation.

NEG coated chamber (0.85m)

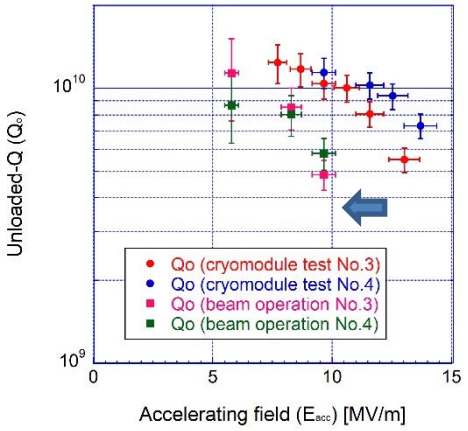
Main linac cryomodule

Assembly done in local clean boose

Temperature/vacuum trend

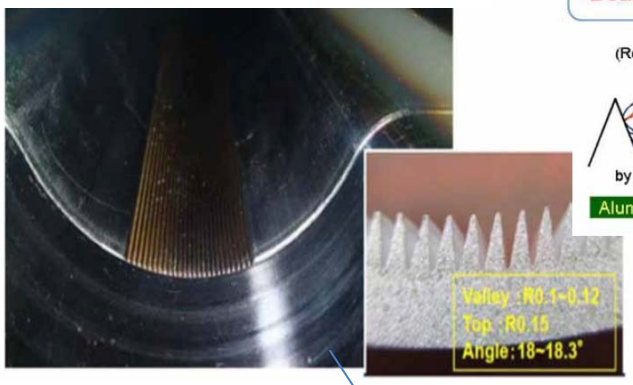


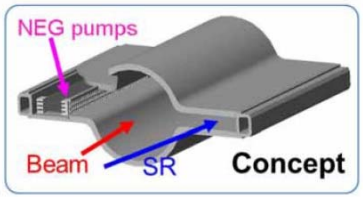
Cavity performance Before/after 2 month beam operation

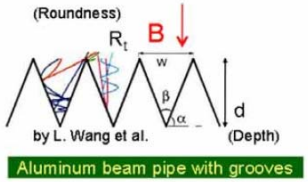


Did NEG make some particulate ?

Old NEG (St707 type)
case is yes at Super KEK-B operation



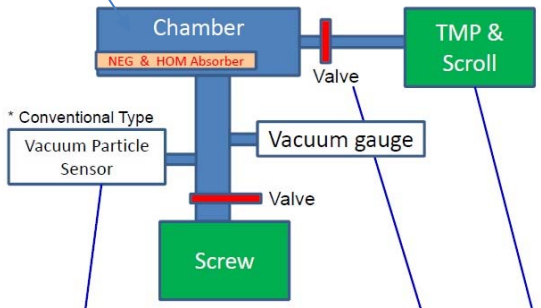




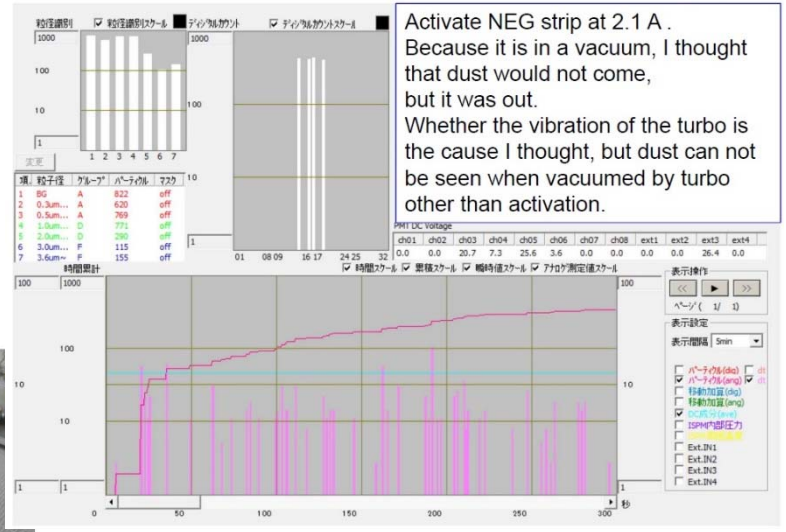
Aluminum beam pipe with grooves

Beam Abort with Pressure Burst occurred frequently in Phase-1 operation (2016) of Super KEKB LER (4.0 GeV positron ring).
When Knocker is operated, in beam pipe with groove structure, Pressure Burst occurred 100%(17/17) , and the beam was aborted.
Many particles composed of V and Zr which are components of NEG were observed.
→ Performed dust evaluation of NEG.

Test by using vacuum particle sensor in a clean room



Particle count during NEG strip activation



Activate NEG strip at 2.1 A .
Because it is in a vacuum, I thought that dust would not come,
but it was out.
Whether the vibration of the turbo is the cause I thought, but dust can not be seen when vacuumed by turbo other than activation.

Dust was made during activation of NEG

We will plan to verify the dust production during activation of NEG-coated chamber by using vacuum particle sensor

Backup slide

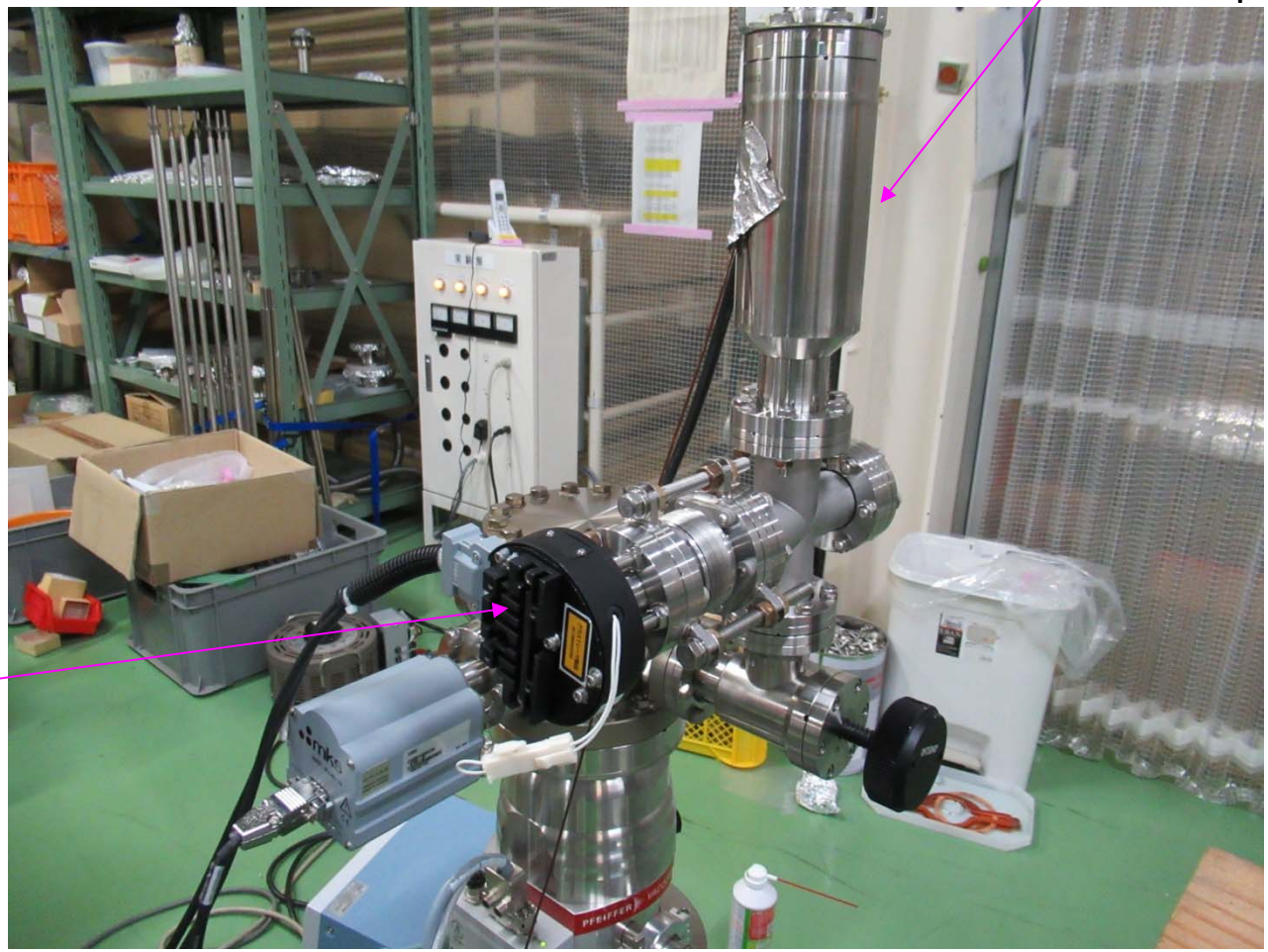
New NEG(ZAO) under testing with vacuum particle sensor

New NEG (ZAO@SAES) is good candidate to make cleaner vacuum environment

"Operation of a high gradient superconductive radio frequency cavity with a NEG pump"
G. Ciovati et al. Nuclear Instrument and Methods in Physics Research A 842 (2017) 92-95

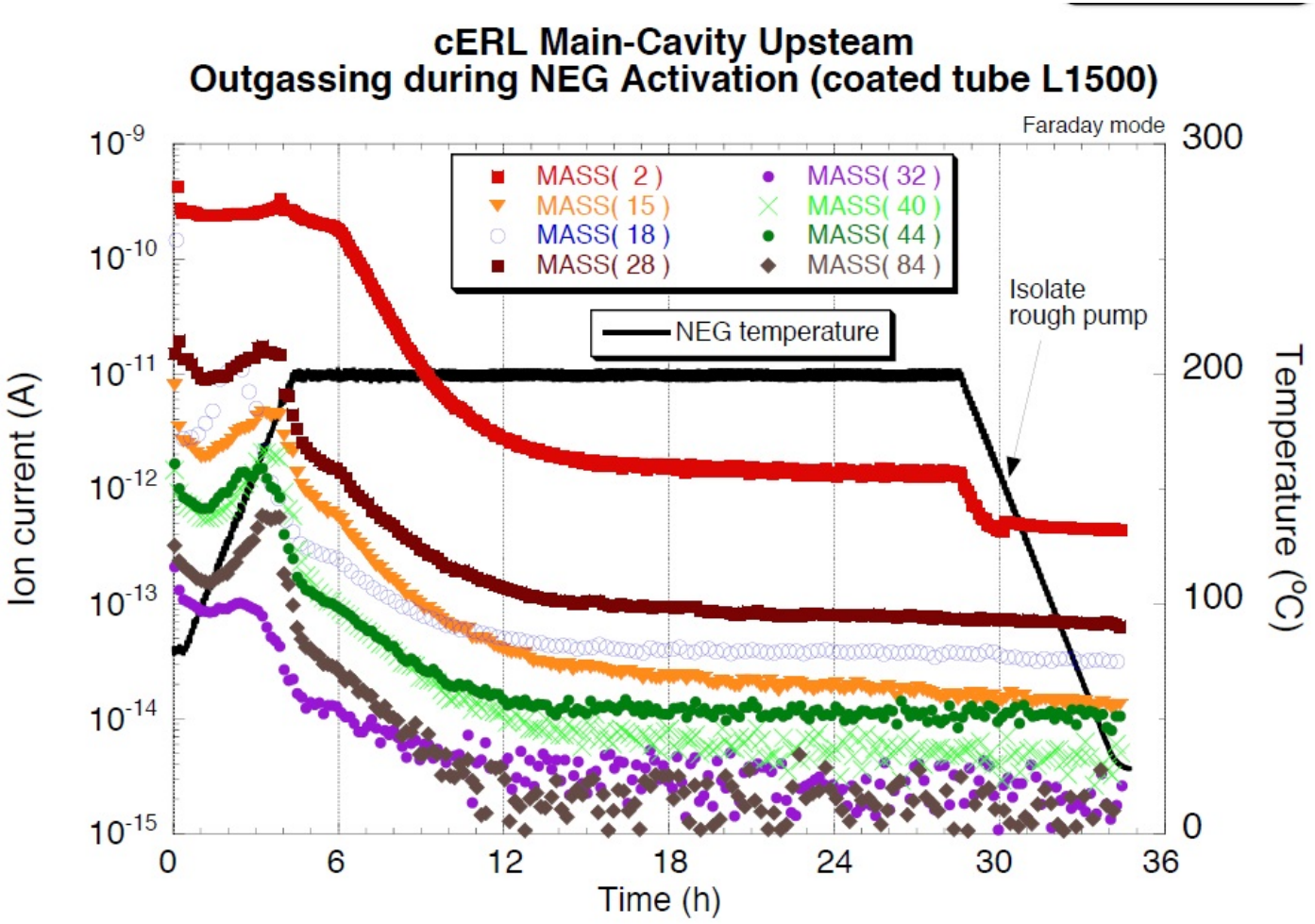
ZAO NEG pump

Vacuum particle sensor (Wexx)



Now under testing of new NEG pump of ZAO with a vacuum particle sensor

(RGA trend before/after activation)



Comact ERL (cERL) in KEK for Energy recovery Linac

Circumference ~ 90m

Compact ERL (**cERL**) has been constructed as a test facility of a 3-GeV ERL future plan.

9-cell SC cavity x 2

RF frequency= 1.3 GHz

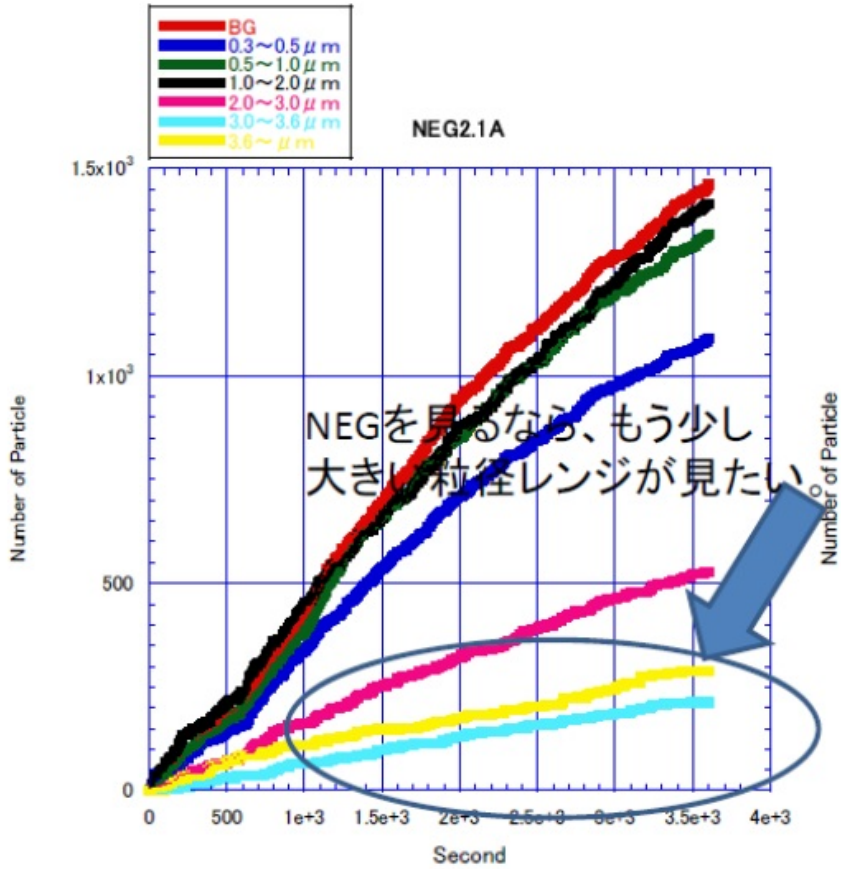
2-cell SC cavity x 3

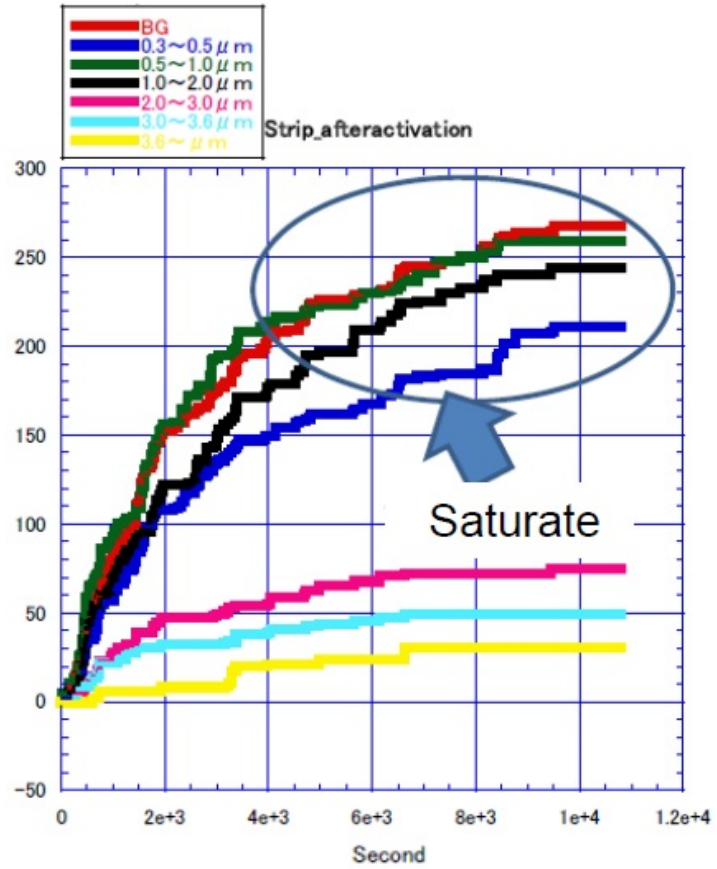
- Construction was started in 2009
- The commissioning has been started from Dec. 2013.

Design parameters of the cERL

Nominal beam energy	35 MeV
Nominal Injector energy	5 MeV
Beam current	10 mA (initial goal) 100mA (final)
Normalized emittance	0.1 – 1 mm·mrad
Bunch length	1-3ps (usual) 100fs (short bunch)

Particle count during NEG strip activation & after activation

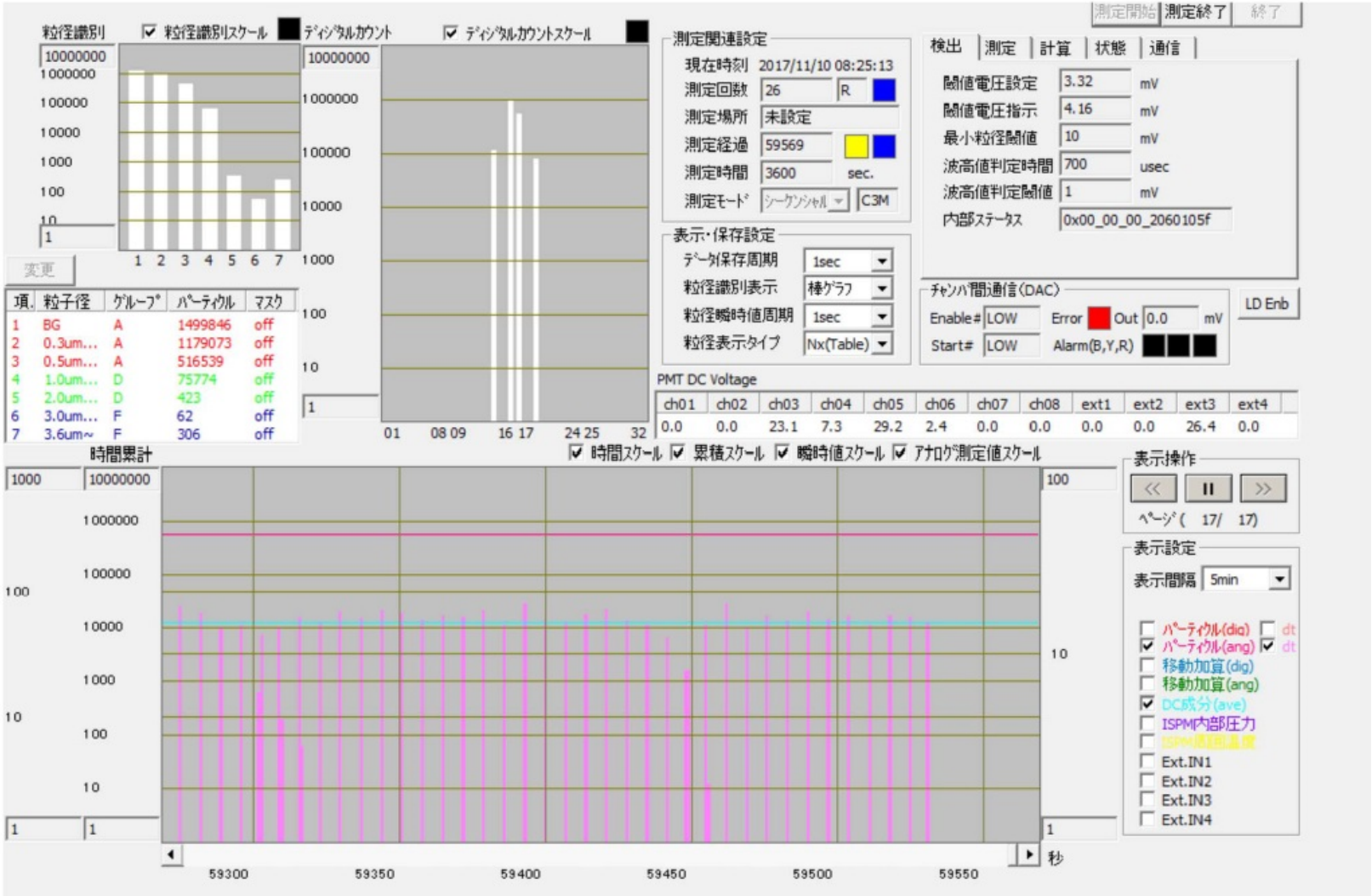




Dust during NEG activation
at 2.1 A

NEG pumping
after activation was over

Particle count during Knocker operation

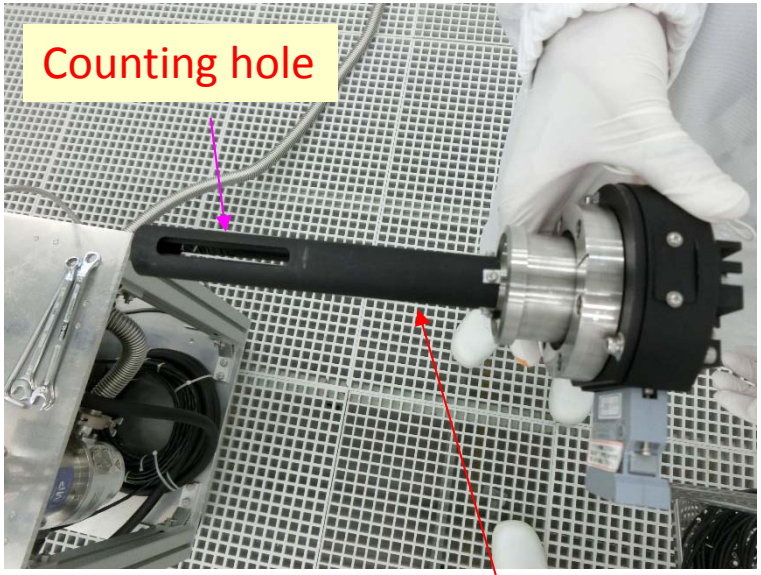


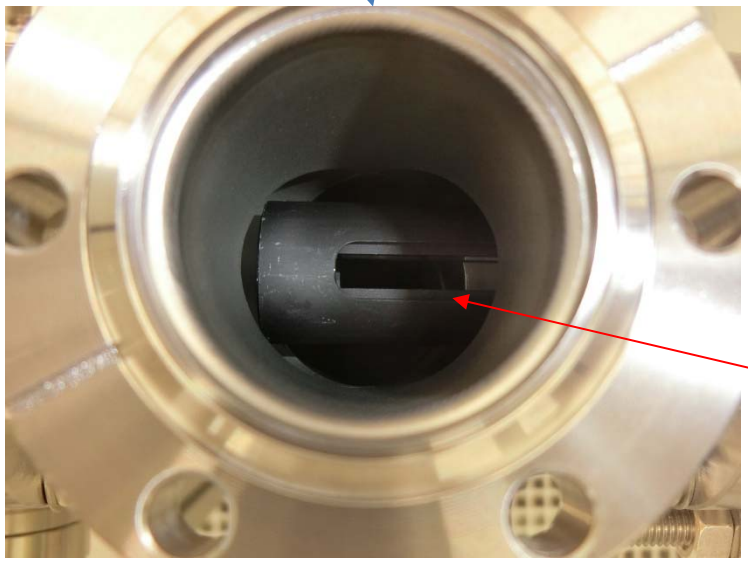
Simple setup of vacuum particle sensor

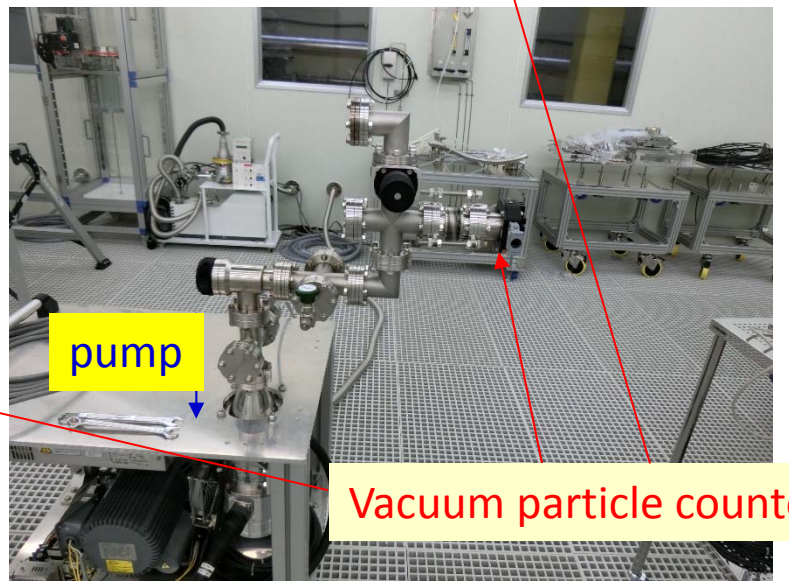
All chambers except for monitor and gate valve are rinsed by high pressure water. All components are assembled in ISO class 4.

Particle monitor & setup.

Blowed by ion gun before setting.







Position of the open area of vacuum particle counter in chamber

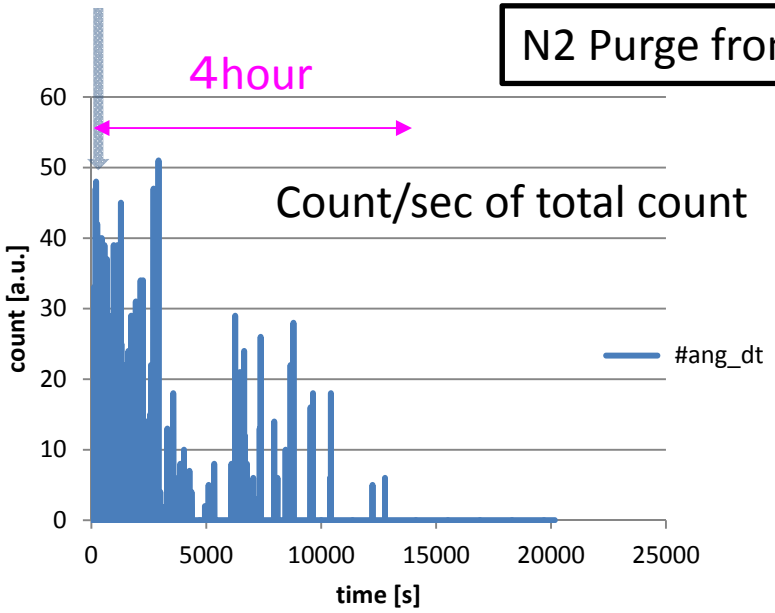
Final setup

Stop N2 purging

Measurement of particle in N2 purge

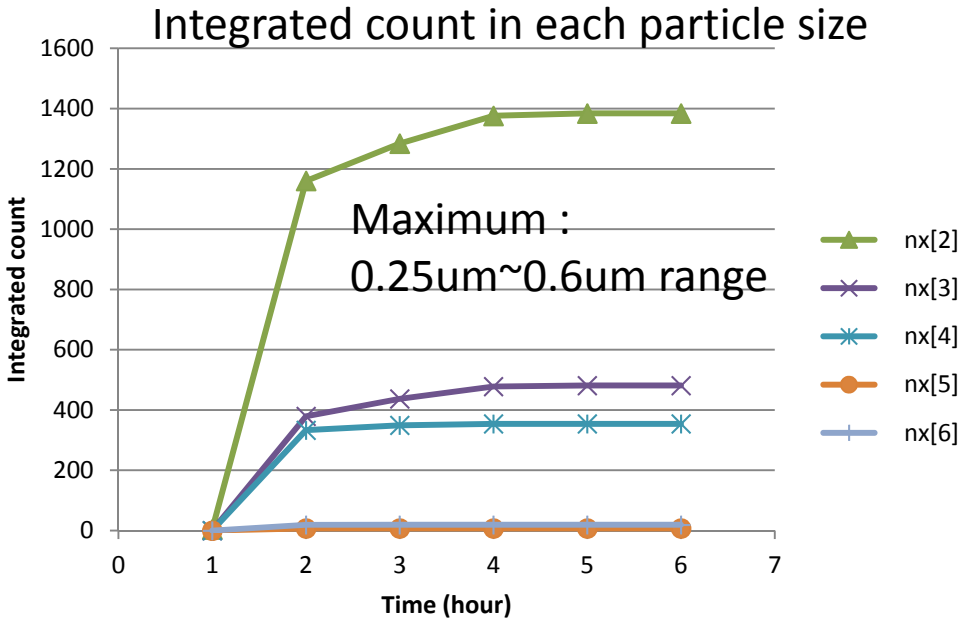
We saw many particles after purging N2 gas w/o filter.
Many particle come into and stay in vacuum during 4 hours.

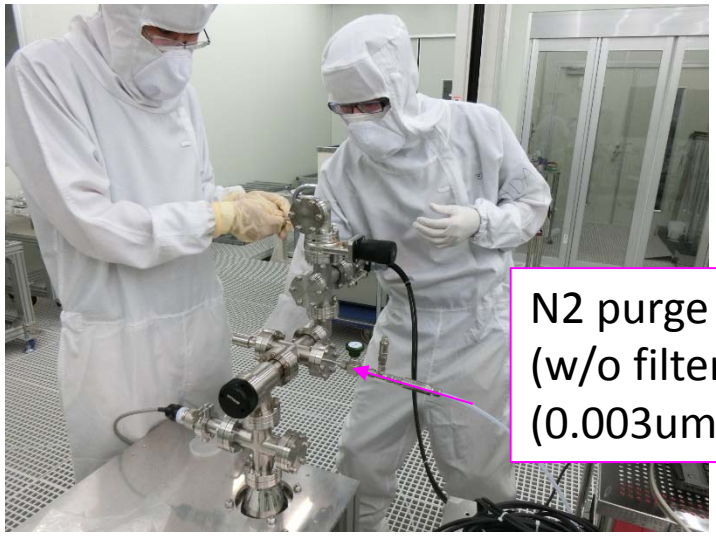
N2 Purge from 0s to 110 s



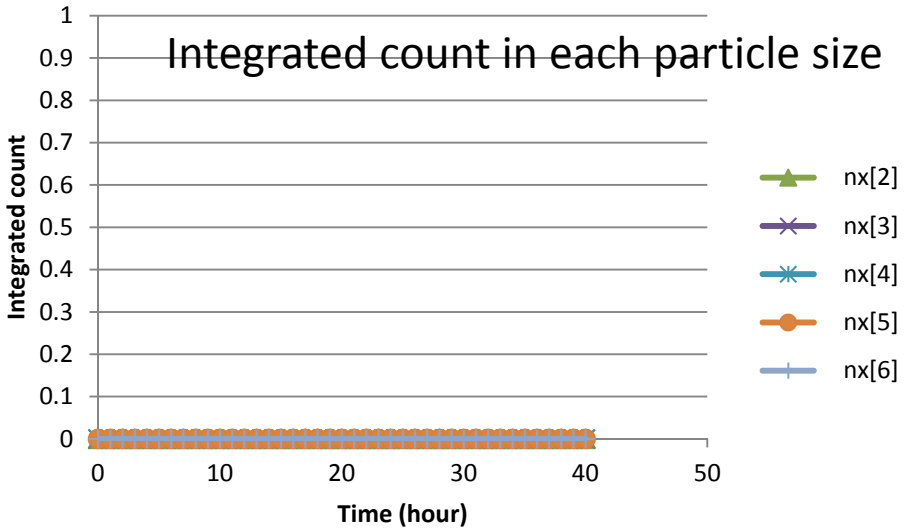
Particle range

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~





Pumping (not slow) after purging N2

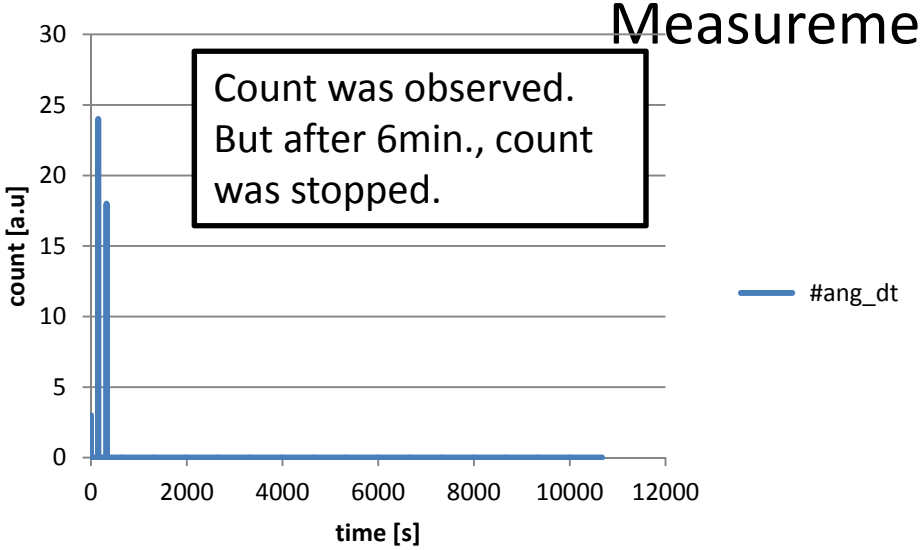


- Scroll ON
- start measurement
- TMP on

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

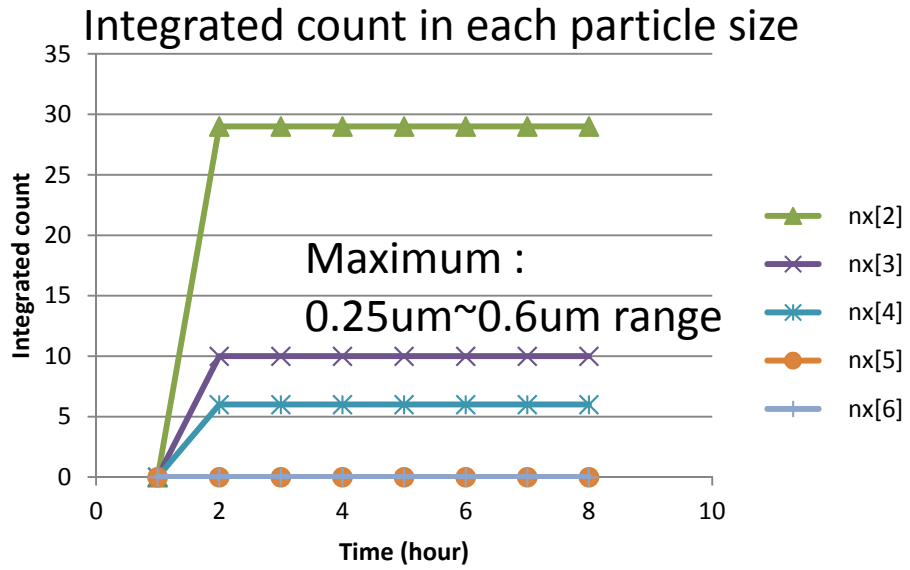


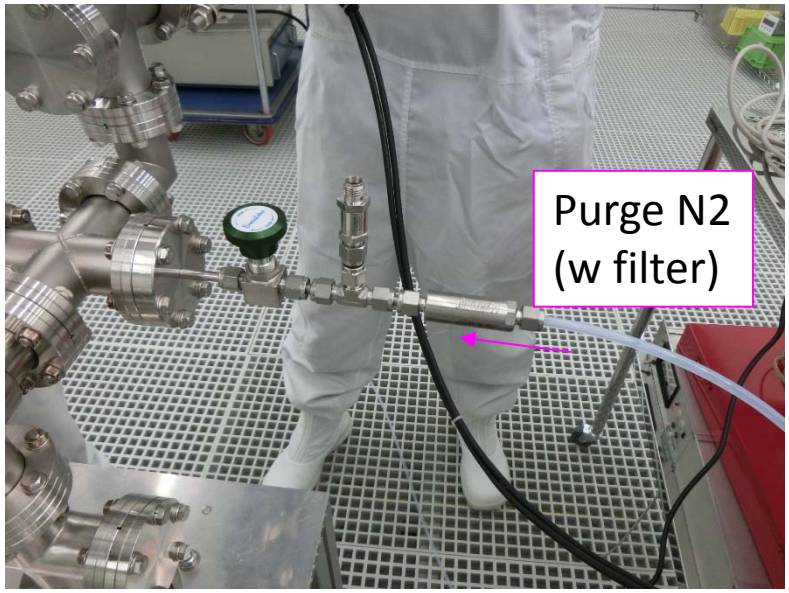
N2 flow: 5 L/min
N2 stop after 1min.

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.



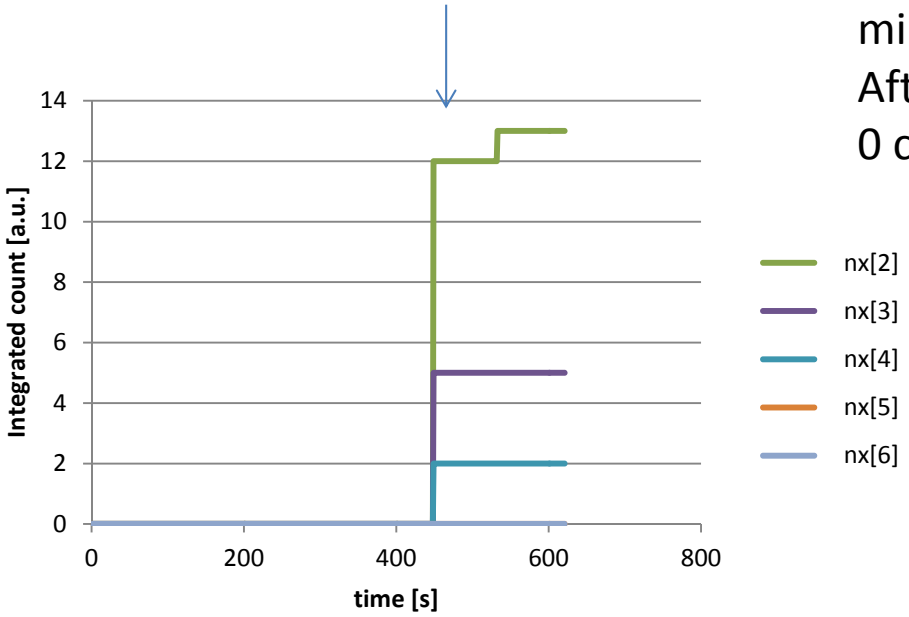


Anyway, we saw the particle count during N2 purging both with and without filter of 5L/min flow

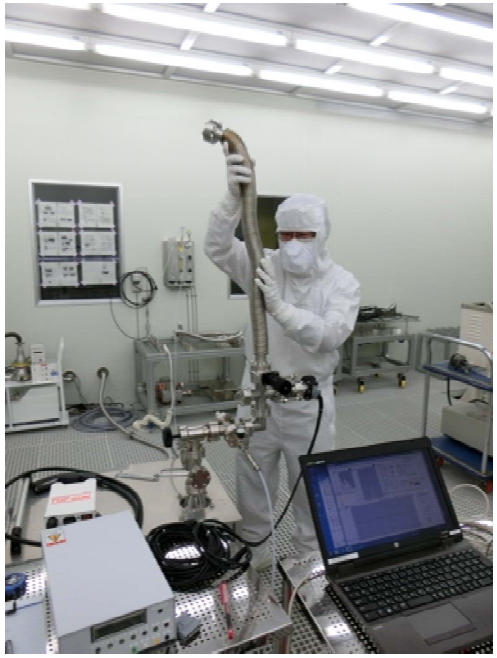
Venting is more dangerous than pumping. More slow pumping speed and optimization are needed to make slow pumping system.

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~