Status of Vacuum System and near future plan

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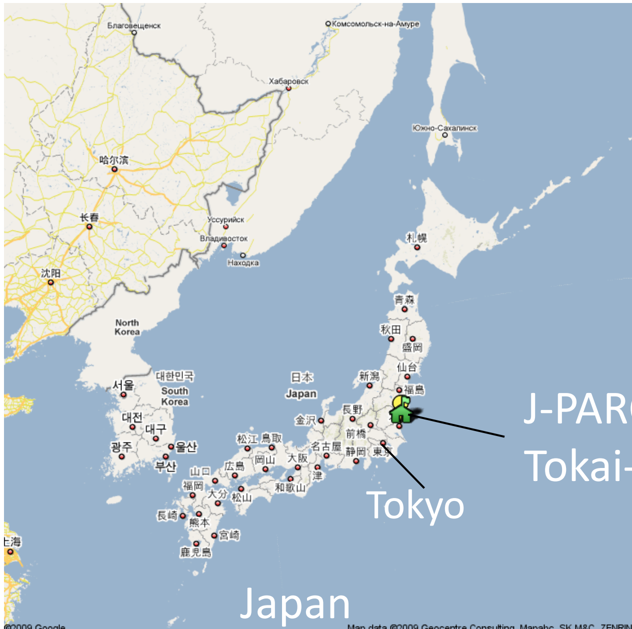


J-PARC RCS(rapid cycling synchrotron) design: Beam power 1MW= 3GeV, 8.3×10^{13} protons, 25Hz

Challenge to vacuum components

Small residual radio activity: Titanium ducts & bellows

N.Ogiwara, Vacuum 84(2010)

Resistance to radiation: TMP with high radioactive resistance

Suppression of eddy current & low impedance : Ceramic ducts with RF shield *M. Kinsho, Vacuum 81(2007)*

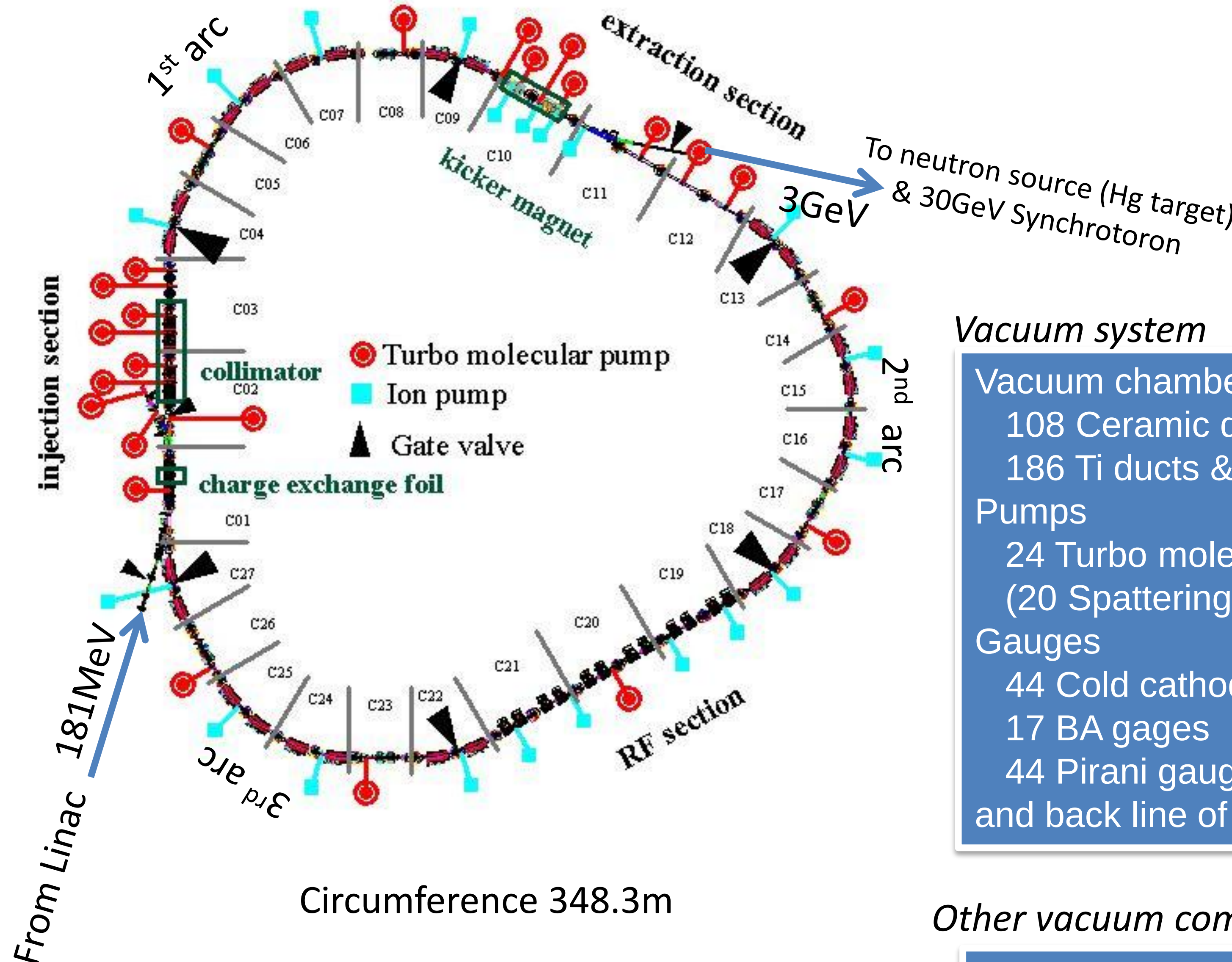
Components with low outgassing : Ferrite cores of kicker magnet

J. Kamiya, J. Vac. Soc. Jpn(2007)

: Cu block of beam collimator

K. Yamamoto, Phys. Rev. ST-AB 11(2008)

RCS Vacuum System



Vacuum system

Vacuum chambers
- 108 Ceramic ducts
- 186 Ti ducts & bellows

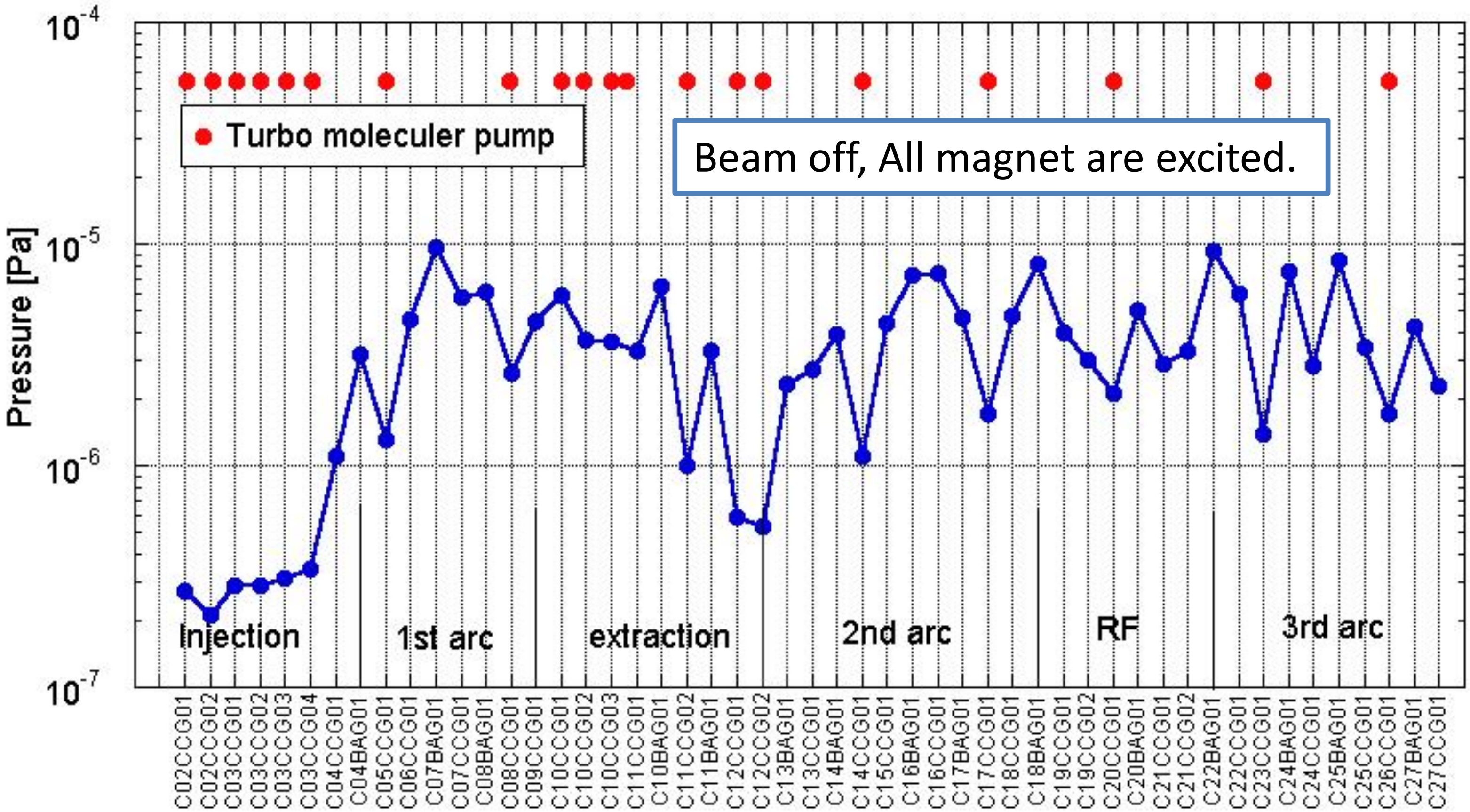
Pumps
- 24 Turbo molecular pumps
- (20 Spattering ion pumps)

Gauges
- 44 Cold cathode gages
- 17 BA gages
- 44 Pirani gauges (beam line and back line of TMP)

Other vacuum components

Collimators
Kicker magnet
Charge exchange foil …..

Vacuum Performance ~static pressure distribution



Pressure of less than 10^{-5} Pa is stably maintained.

Source of Dynamical pressure change in high intensity accelerator

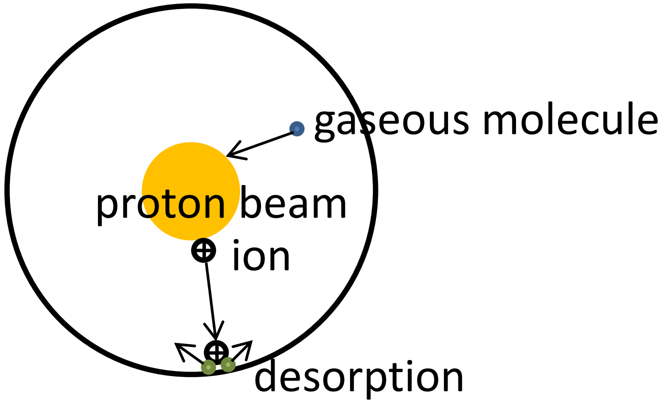
~Mechanism is similar to plasma-surface interactions in nuclear fusion machines.

G. M. McRACKEN, P.E. SCOTT, Nuclear Fusion, Vol.19, No.7(1979)

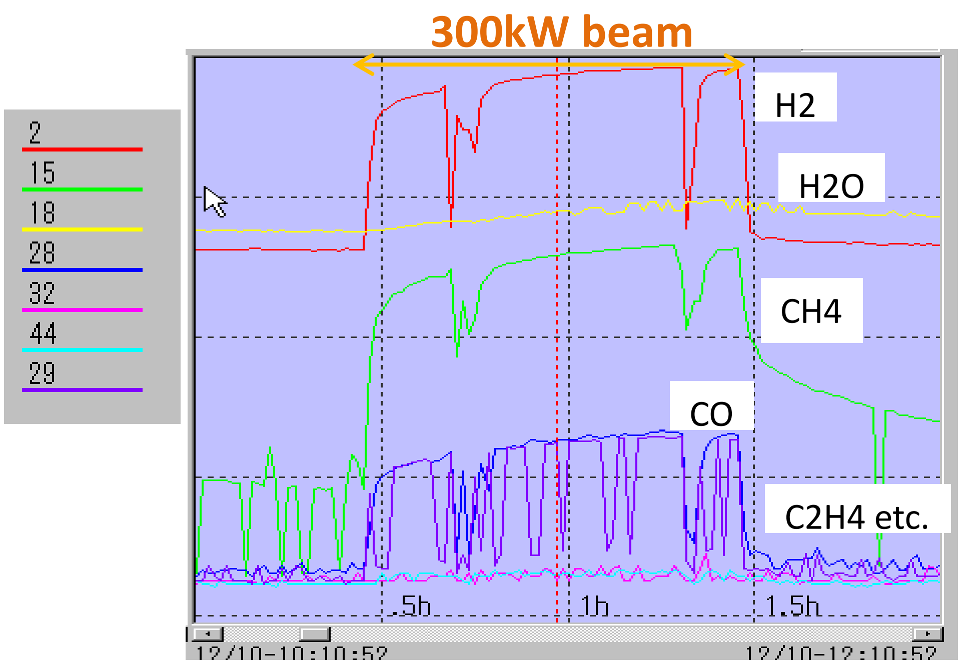
1) Thermal desorption of gas adsorbed on the vacuum walls
2) Desorption due to bombardment by ions, electrons, and photons
3) Chemical reactions which release gaseous contaminants such as H_2O and CH_4.

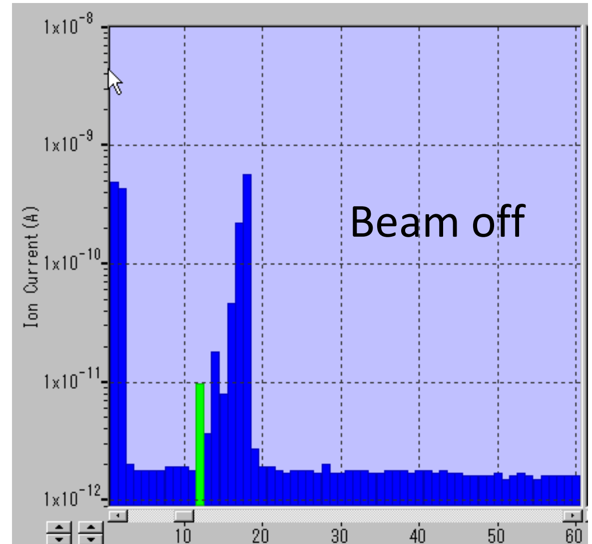
We are seeing the combination of those interactions.

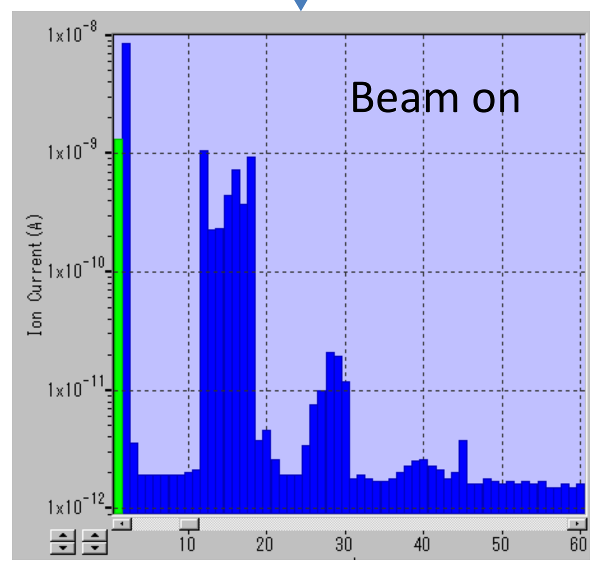
Dynamic Pressure in RCS (2) ~ gas analysis



Ion bombardment ~one of the process of dynamic pressure change

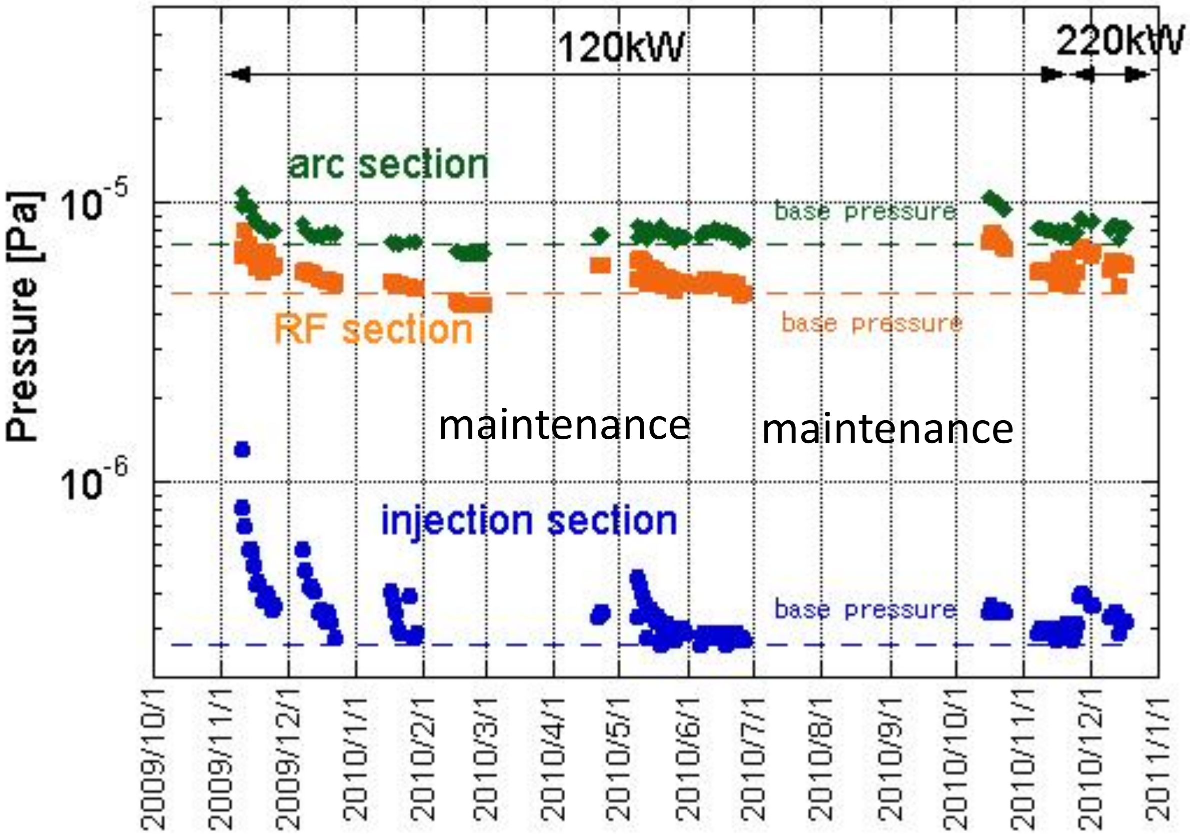




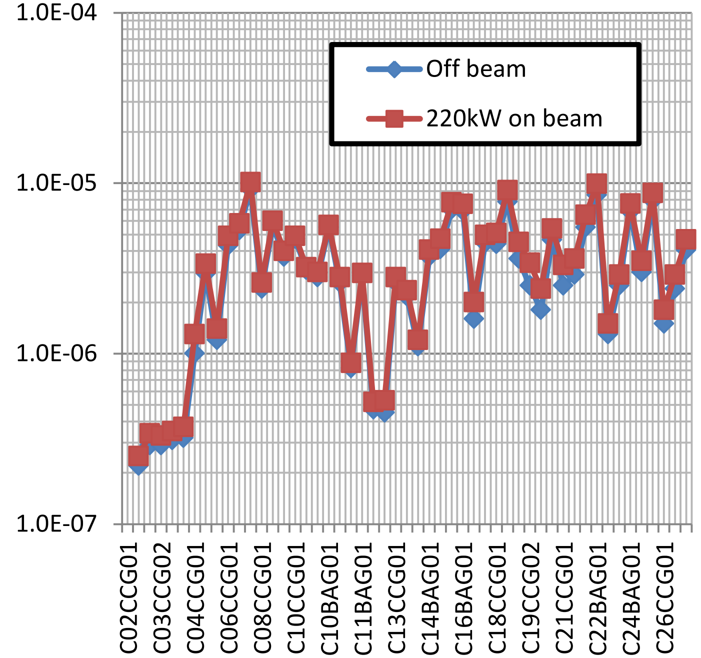


Especially in the beam operation just after a maintenance, we see the large pressure increase.

Dynamic Pressure in RCS (2)~ conditioning effect



Pressure history (on beam)



Pressure distribution after long beam operation.

There is a conditioning effect by the beam during a continuous beam operation.
There is no pressure increase after long term beam operation.
-> After molecules on the surface are desorbed by the particle hit, a clean surface is obtained.

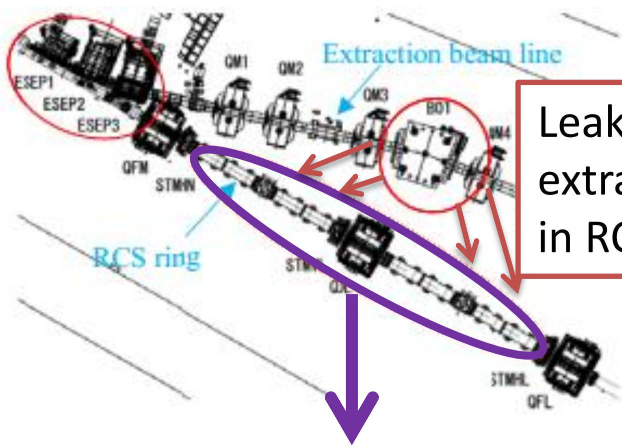
For higher power beam? No one knows. We will see.

Development of the vacuum component

1. Vacuum chamber and bellows of magnetic material with high permeability

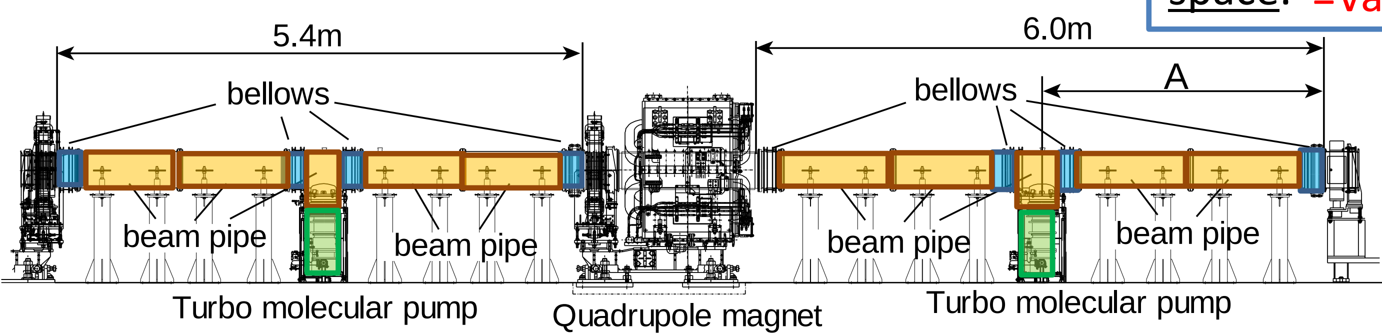
2. In-situ bake out for kicker magnets

1. Magnetic field shielding by vacuum chambers of magnetic material



Leakage field from a magnet in the extraction line distort the beam orbit in RCS.

Most effective way to shield such field is to cover the beam by the magnetic materials at the <u>nearest space</u>. =Vacuum wall



Beam ducts | Bellows | Turbo molecular pumps → These components are made of magnetic alloys.

Request from beam commissioning group

Magnetic field in the area (~10gauss) must be 1/10 at beam position.

➡ Beam ducts, bellows, turbo molecular pumps of magnetic materials.

Selection of magnetic alloy

□SUS430(ferritic stainless steel):

○Ready availability: easy

△magnetic permeability (μ):   500~1000

Enough field shielding characteristic with a thickness of more than 10mm

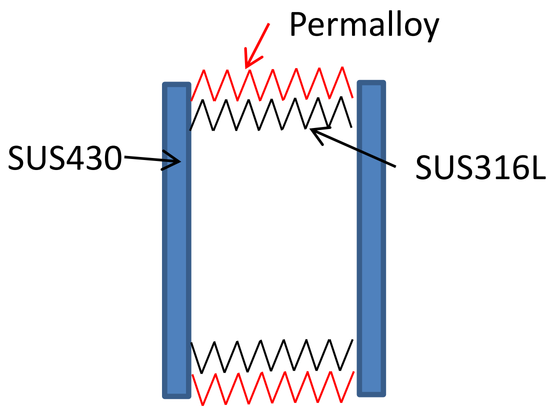
-> Enable for flanges(t30mm) and outer case of TMP (t10~20mm)

□Permalloy (Ni base alloy with very high permeability)

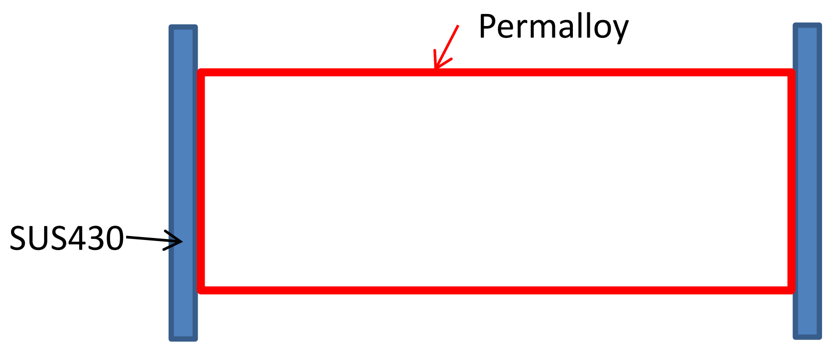
○ magnetic permeability (μ): >10000

△ Ready availability: difficult especially for thick alloy

-> Enable for bellows (t0.2mm) and ducts (t3mm)



bellow

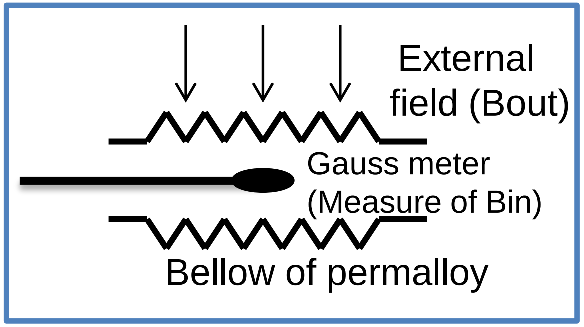


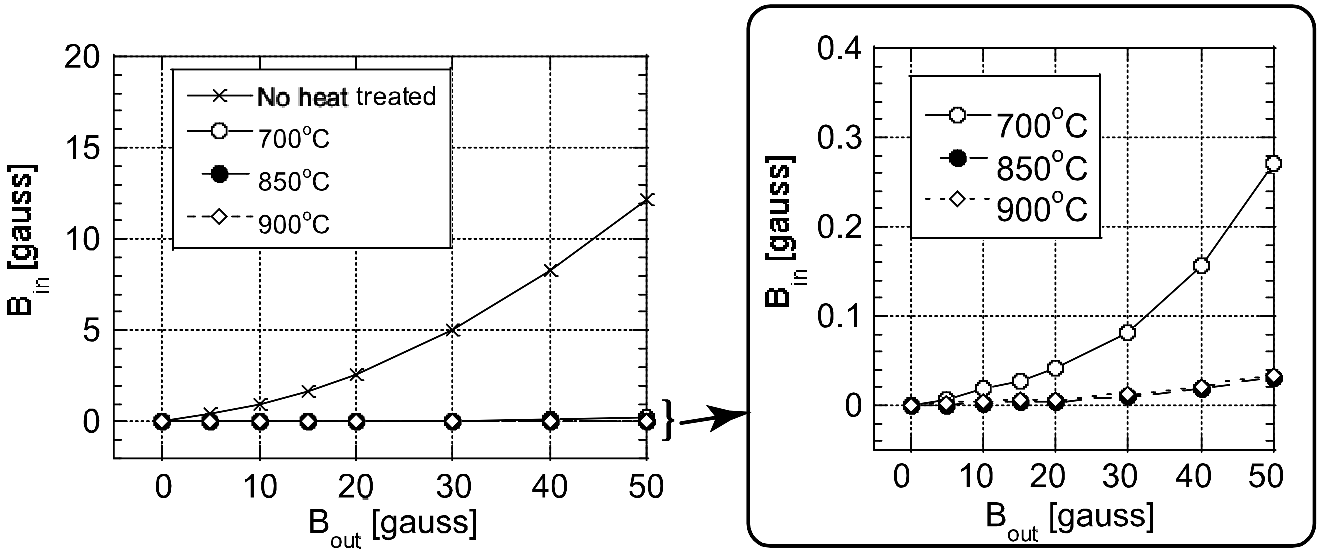
Beam duct

Conditions for magnetic annealing

Mechanical stress = Decrease of magnetic permeability
→ Magnetic annealing(=heat treatment) is necessary after cutting, bending, pressing etc..

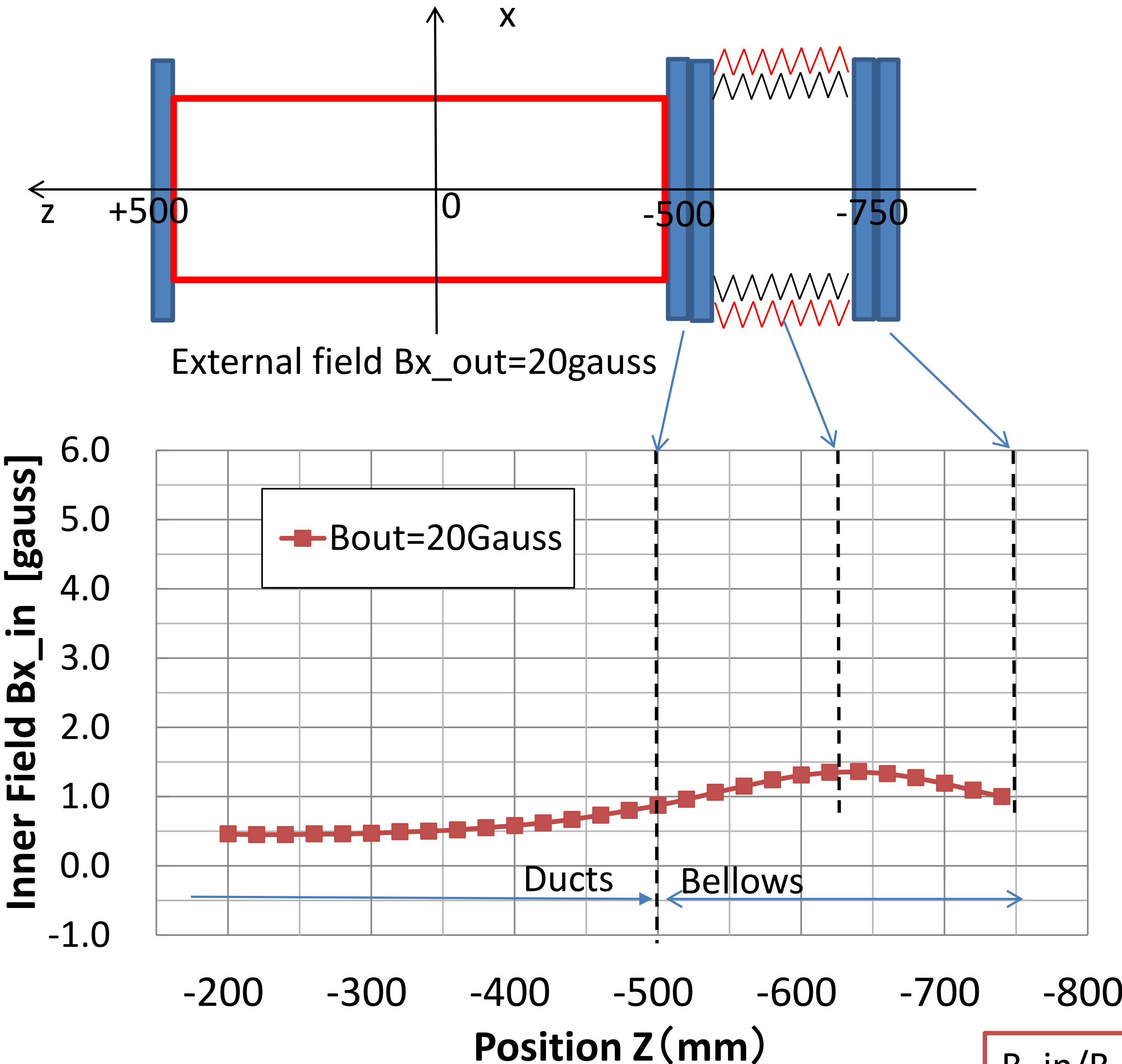
Dependence of magnetic shielding characteristic on annealing temperature





Good shielding characteristic for the annealing temperature with more than 850 degC(10H).

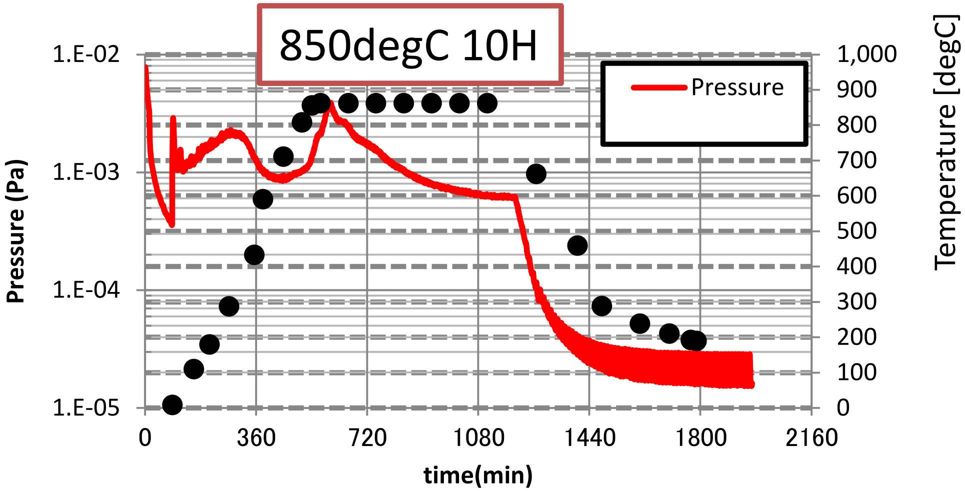
Magnetic field shielding



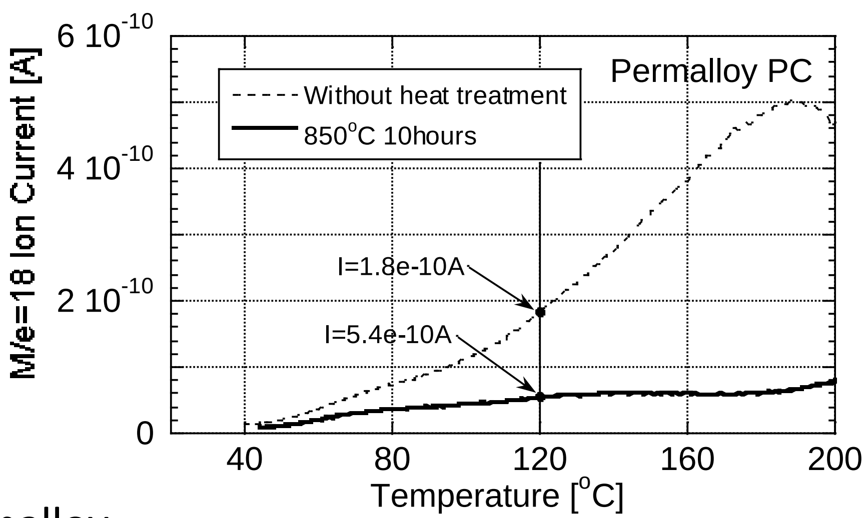
B_in/B_out<1/10 is achieved.

Vacuum fire

If we work annealing in good vacuum, it can combine with vacuum fire.



TDS spectrum(H2O)



Outgassing rate of permalloy

Before vacuum fire: 1.e-8 Pam/s → After vacuum fire: 3.e-9Pam/s

2. In-situ bake out for kicker magnets

Kicker : Outgassing from ferrite cores

= Water is a main component due to the porosity of ferrites.

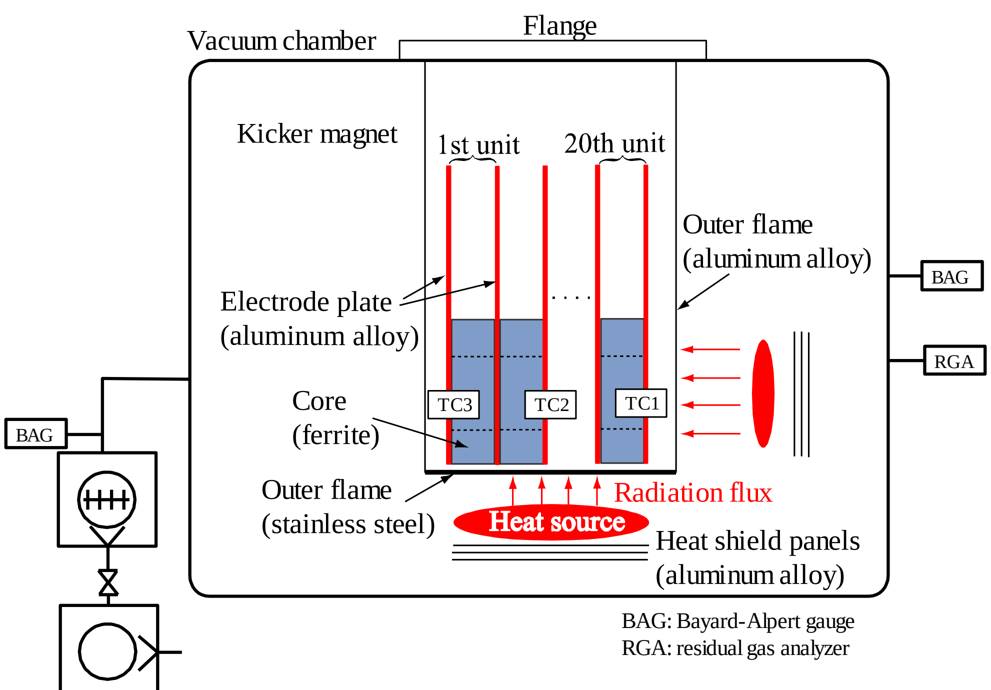
The usual way= bake-out the whole vacuum chamber

x huge heater capacity

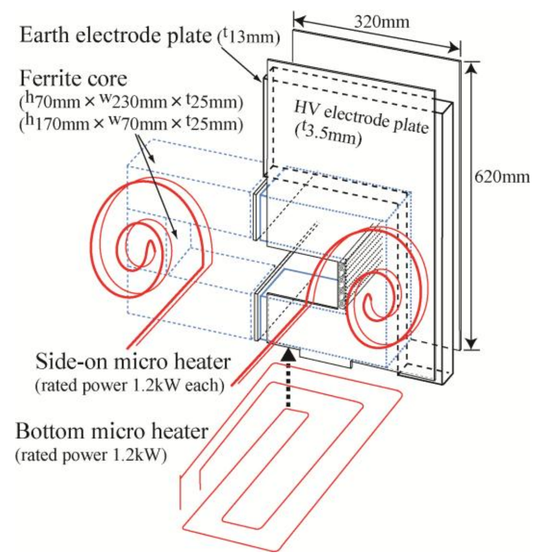
x heat expansion of the chamber (Critical to the accelerator, which have many components in small area.)

↓

Raise the temperature of the structure inside without heating the vacuum chamber.

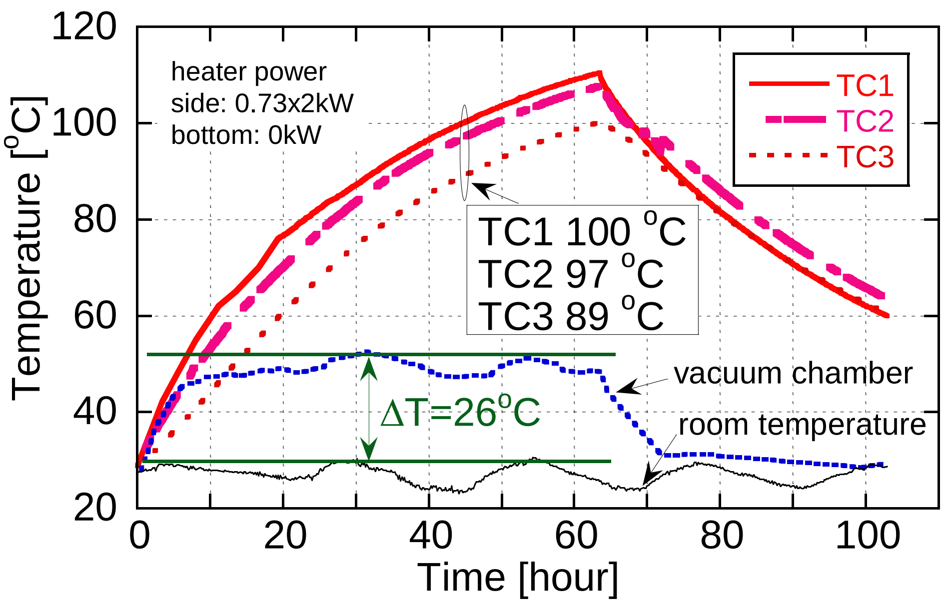


Concept of setup.

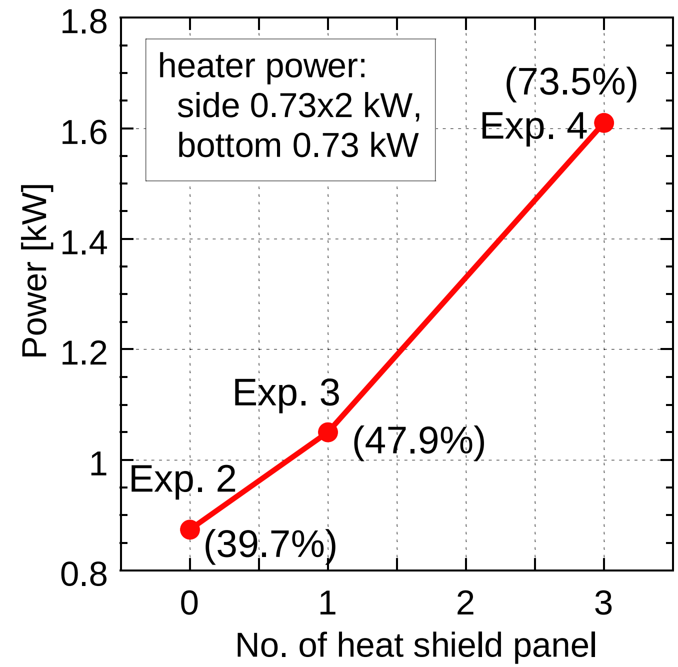


Relative position of kicker and heaters.

Temperature of ferrite cores due to the in-situ method



Temperature of ferrite cores and vacuum chamber.



Required heater power to reach a kicker temperature up to 100 °C.

Heater power at this measurement 1.6kW << Former heater power 10kW (heaters are put onto the outer surface.)

Install heaters directly into vacuum＋Heat shield panels to direct the radiated heat to kicker

= Effective and “eco” way for outgassing reduction!

Summery

Status of vacuum system

- Dynamical pressure change due to high power beam has been observed.
- After molecules on the surface are desorbed by several mechanisms, pressure is stable even during high power beam operation up to 200kW.
- What will happen in higher beam power?

Development of vacuum components

We are developing vacuum components such as

- Vacuum chambers and bellows of magnetic alloy with high permeability
- In-situ outgassing reduction method for kicker magnets

We desire the continuous collaboration about information exchange, development of vacuum components, and scientific research about accelerator vacuum.