IV-02-Meigo

Proton Beam Window Assembly (PBW Assy)

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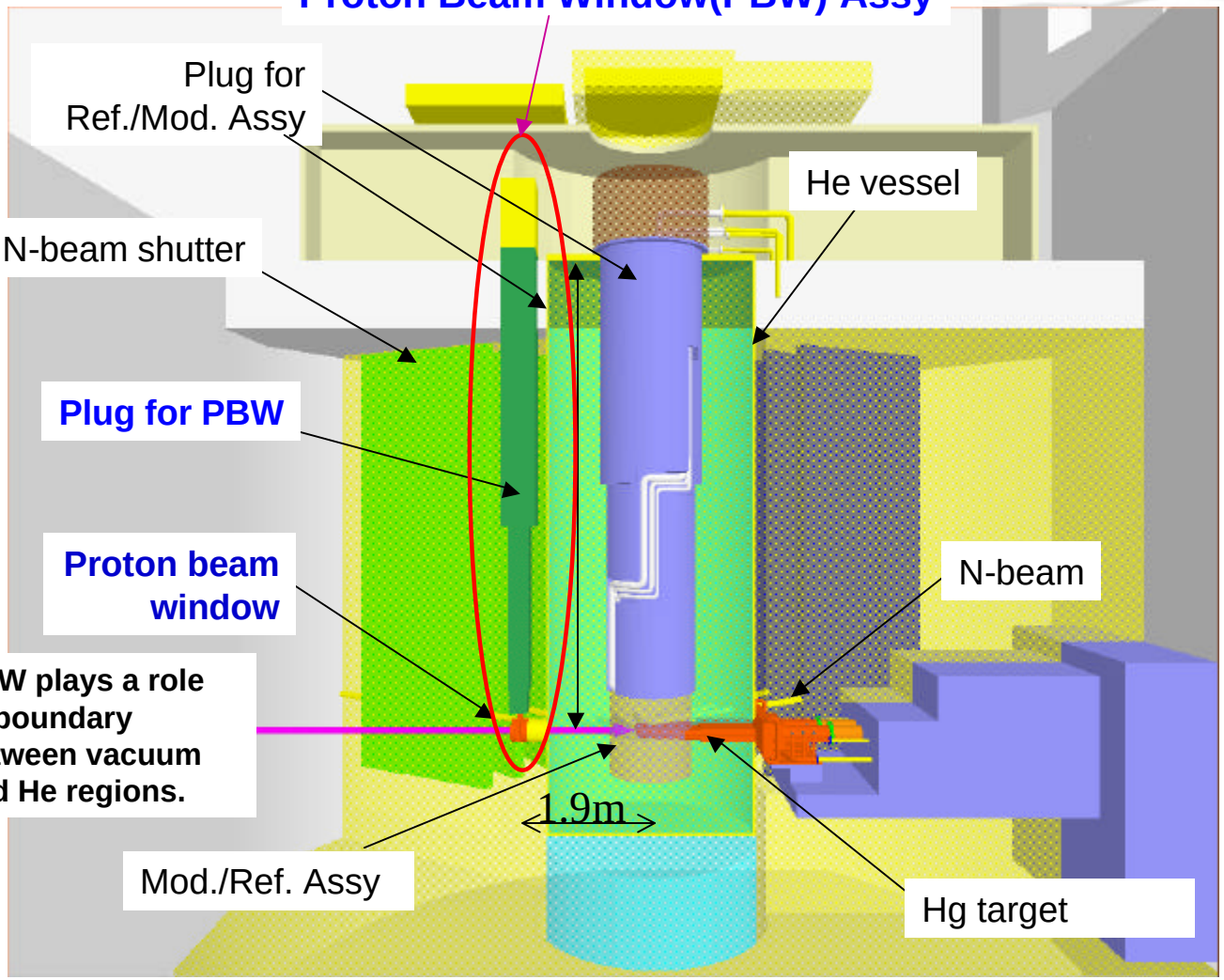
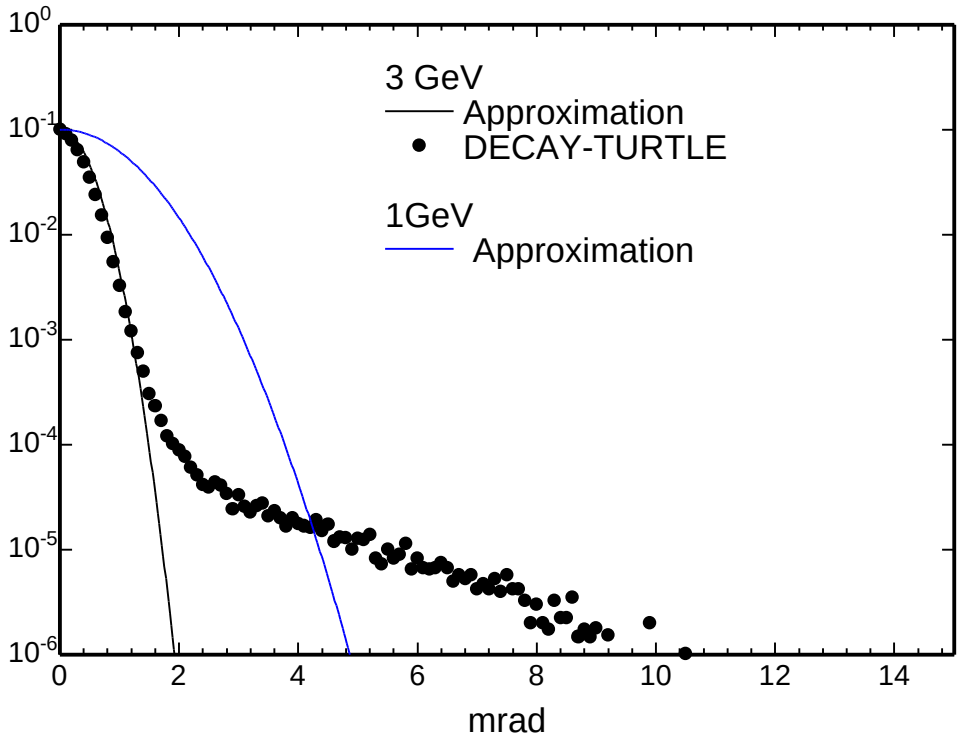
Outline

- Design of PBW
  - Philosophy
- Analysis for thermal hydraulic and stress
  - Temperature and stress
- Shielding plug
- Beam monitor and other equipments
- Maintenance scenarios

Overview of target station



Effect on beam by window



Cause blow up of primary beam, which is injected to reflector.
Blow up diminish as increase of energy.

Concept of PBW

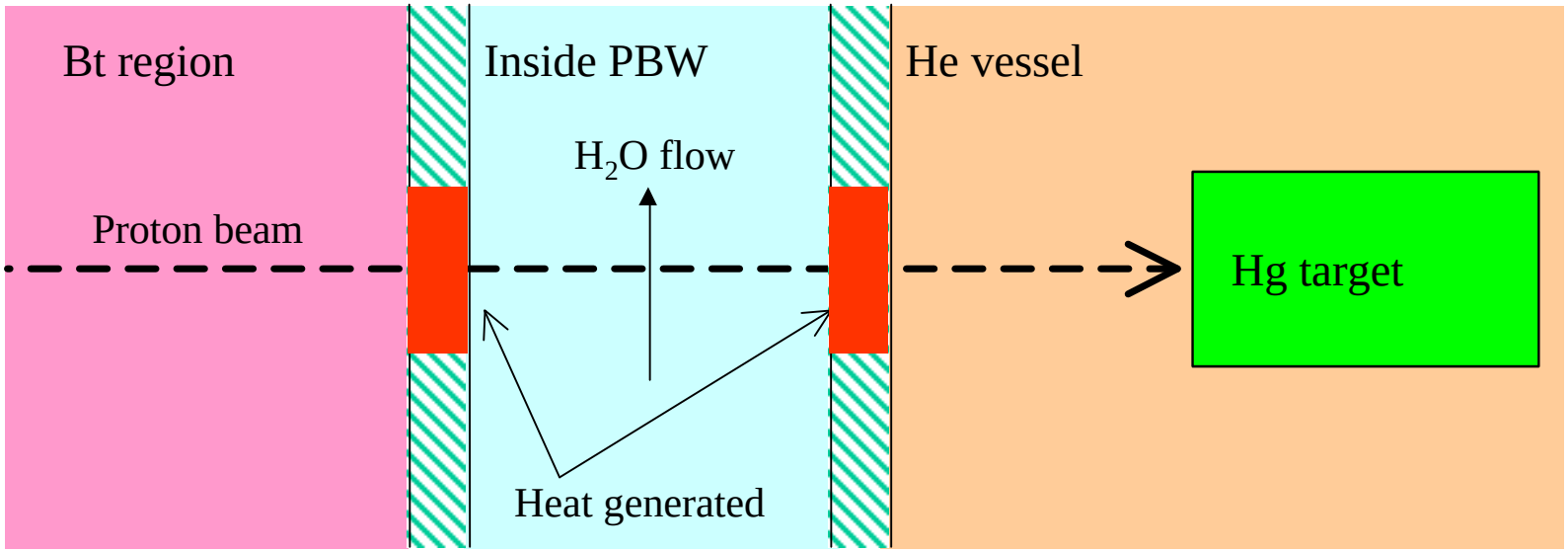
Design condition

- BT region : High vacuum (10^{-4} Pa)
- He vessel region : He atom. (0.3 MPa)
- Coolant region : H_20 ～ 1 MPa
- High power beam : 1MW

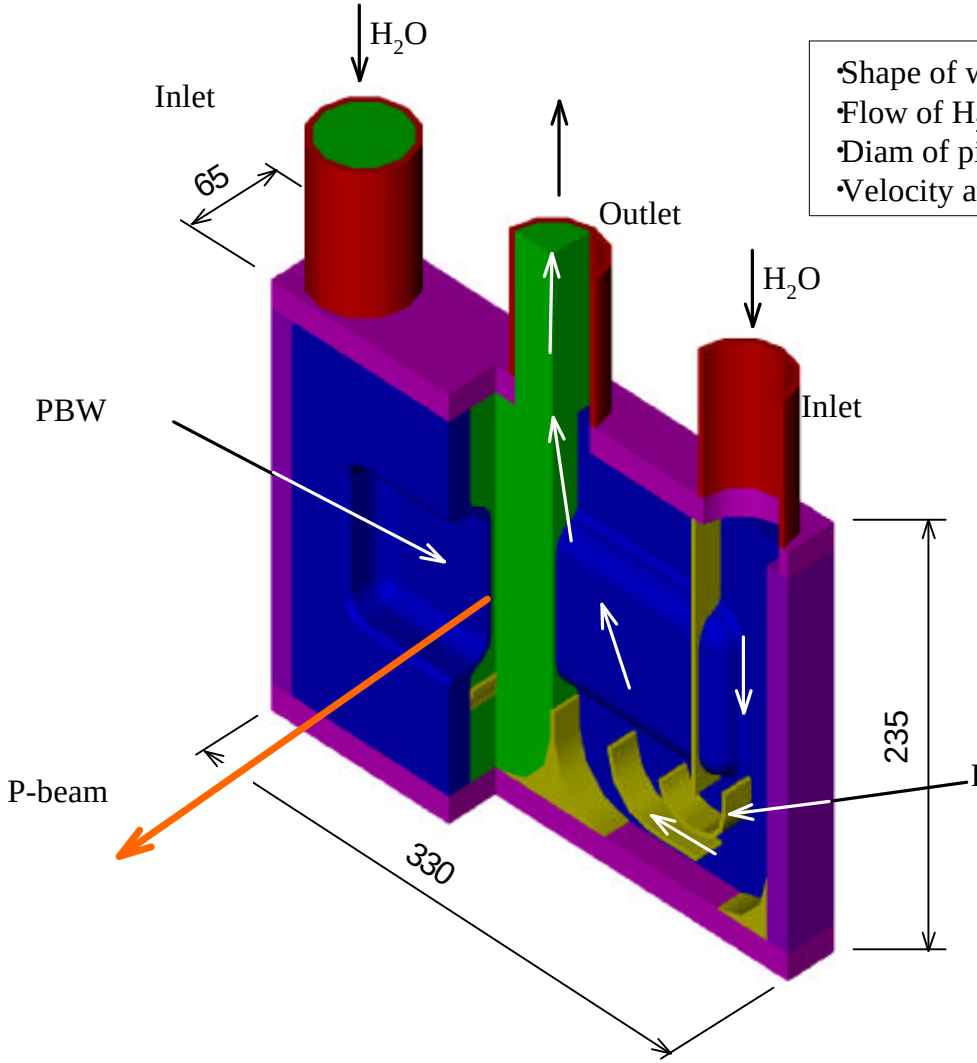
introduce → Pressure

→ Thermal stress

Evaluation is necessary.



Obsolete design used parallel plates window



- Shape of window : Parallel plates of 200 mm × 60 mm
- Flow of H_2O : 2～3m/s
- Diam of pipe : 51 mm
- Velocity at window : 10m/s

This model requires thick window.

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Increase undesirable beam scattering.
We ceased to use this model

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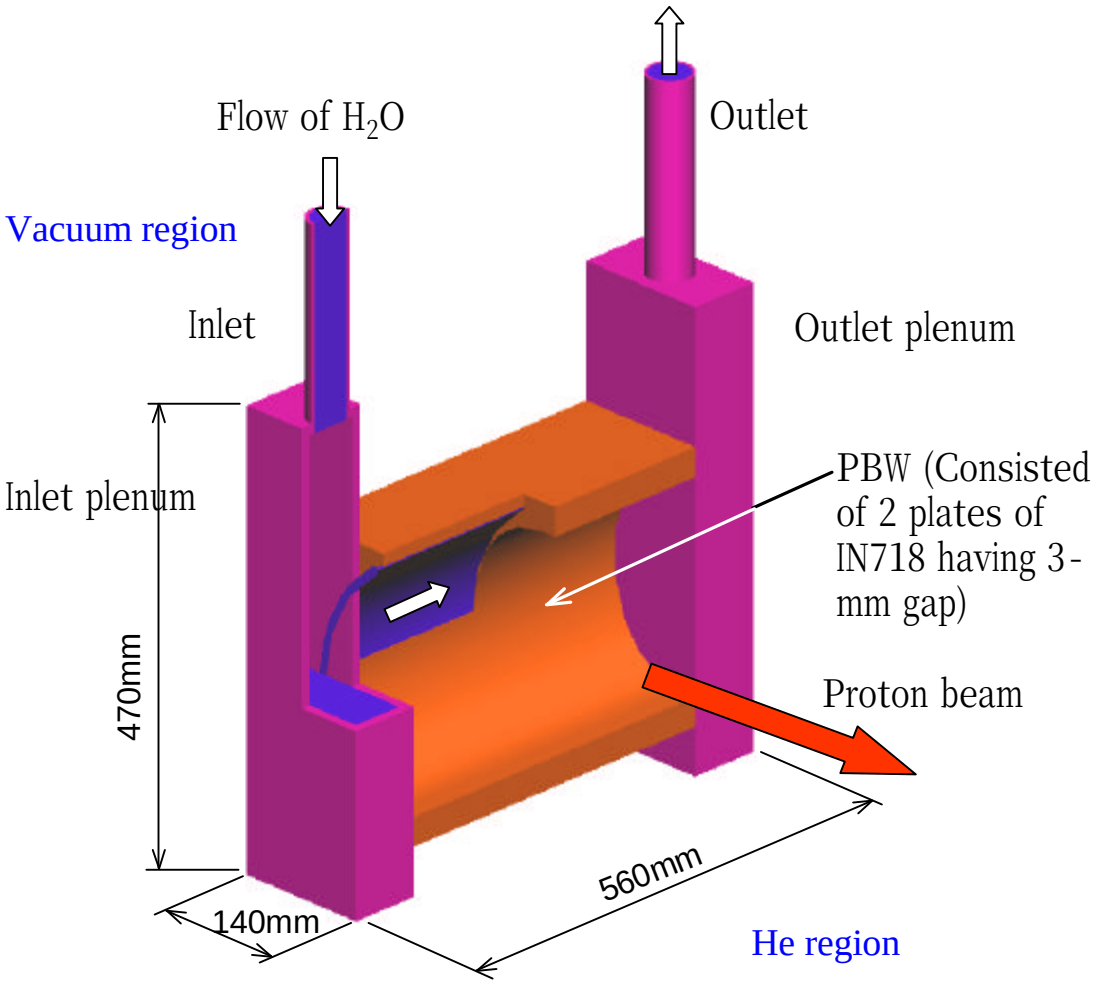
A new model with
Curved surface has been
designed.

New PBW design with curved surface



(Dimension)
Width and height is given by the proton beam size. Window consists of curved surface similar as cut away shape of cylinder. It consists of two plates. Between the gap of plates, H_2O flows.

(Material)
Considering high strength for stress, we determined to use INCONEL 718 as PBW. Except PBW, SS will be used.

(Flow channel)
In vertical direction, water comes in and out via 28.4mmϕ pipe. At PBW, it flows in horizontal direction.

Design and analysis flow

Following is given
- H_2O pressure ～1MPa

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Analysis of internal stress caused by H_2O flow

⇩

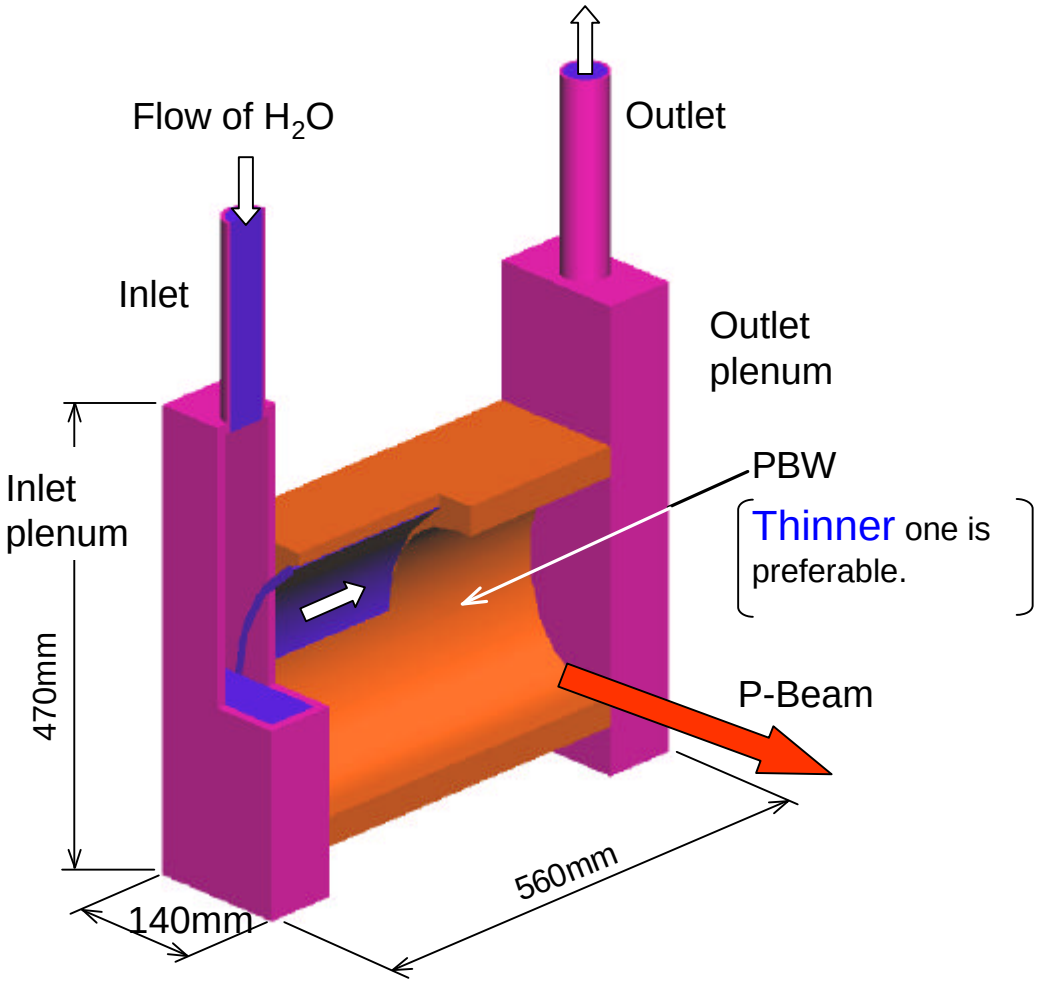
Heat deposition analysis

⇩

Analysis
- Thermal stress
- Thermal hydraulics

⇩

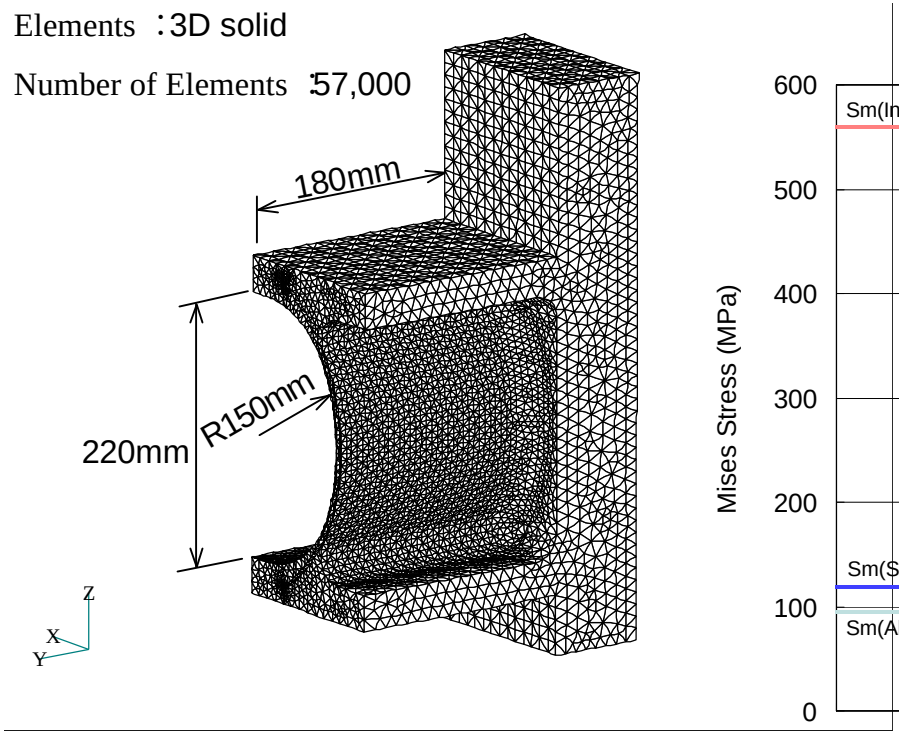
Finally determined structure

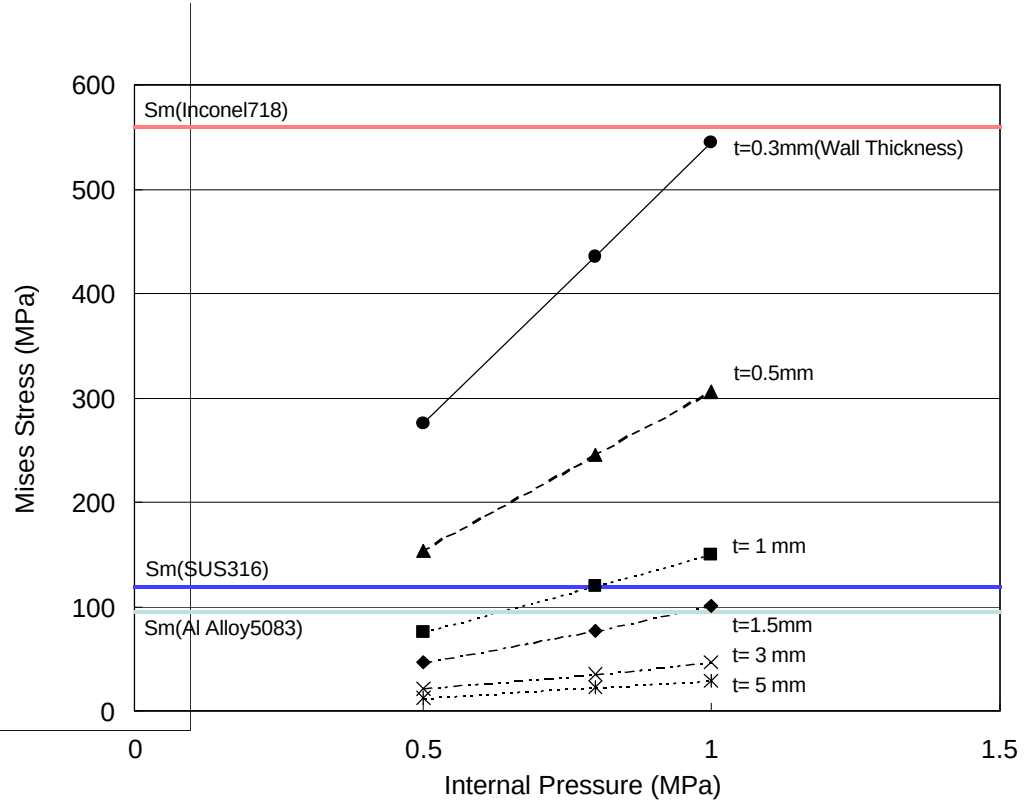


Evaluation of stress due to internal pressure

Elements ：3D solid

Number of Elements ：57,000



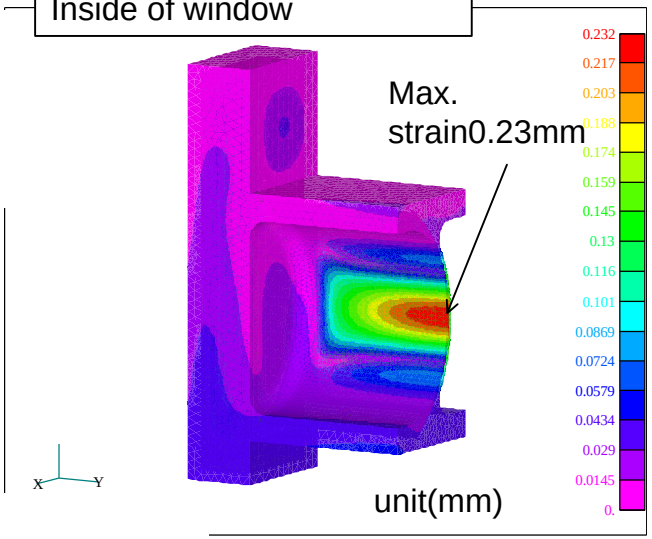


- 0.5 mm thickness for IN718 is satisfied for the stress.
- However, 1.5mm of the thickness seems to be the thinnest as for manufacturing with IN718.

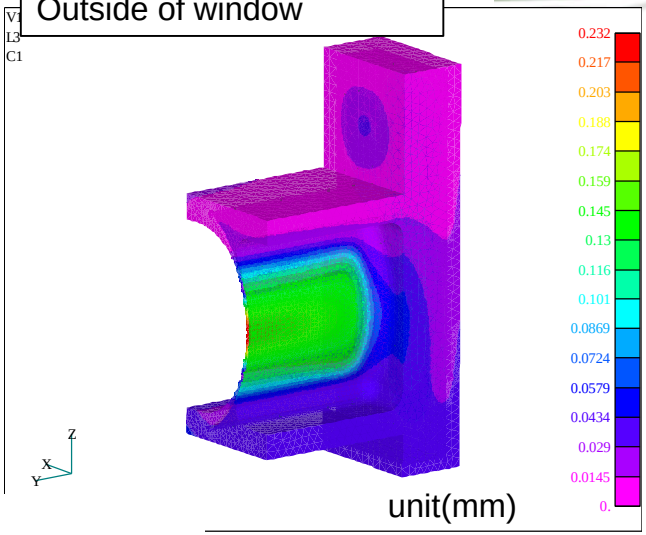
Analysis of stress due to H_2O flow

for thickness: 1.5mm, pressure: 1MPa

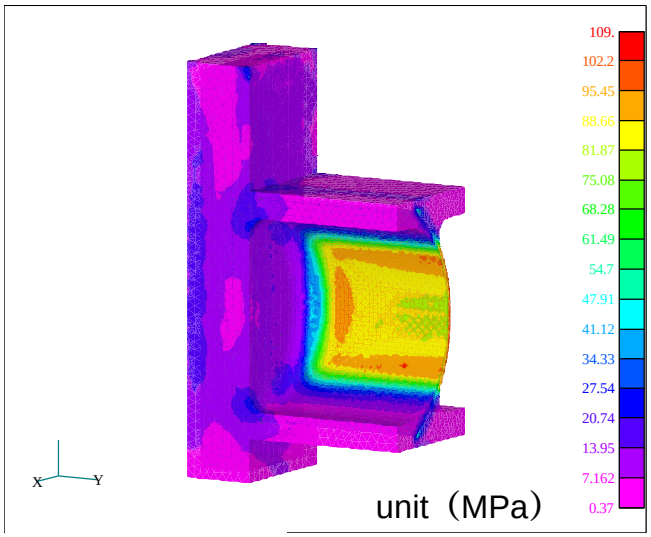
Inside of window

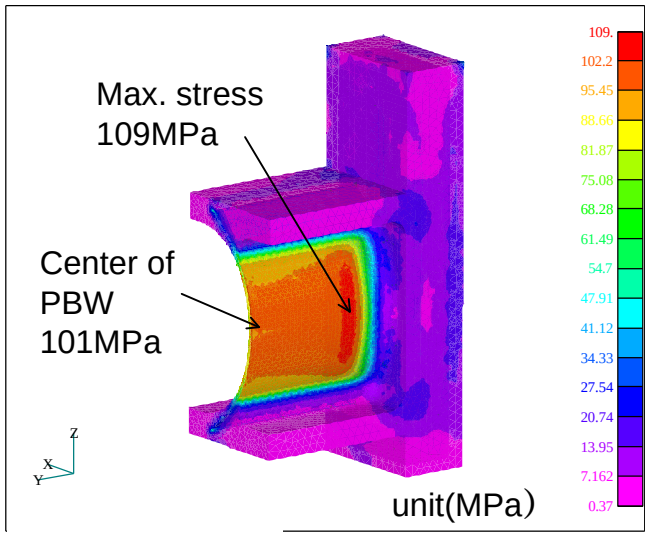


Outside of window



Strain and stress due to pressure of water is acceptable for IN718.





Thickness of win-dow is determined as 1.5 mm.

Distribution of heat deposition

- Up to now, real distribution of proton beam can not be estimated. Assumptions are made.
- Heat deposition is given by Decay-TURTLE and NMTC/JAM.

・Uniform distribution in phase space(likely to be real)

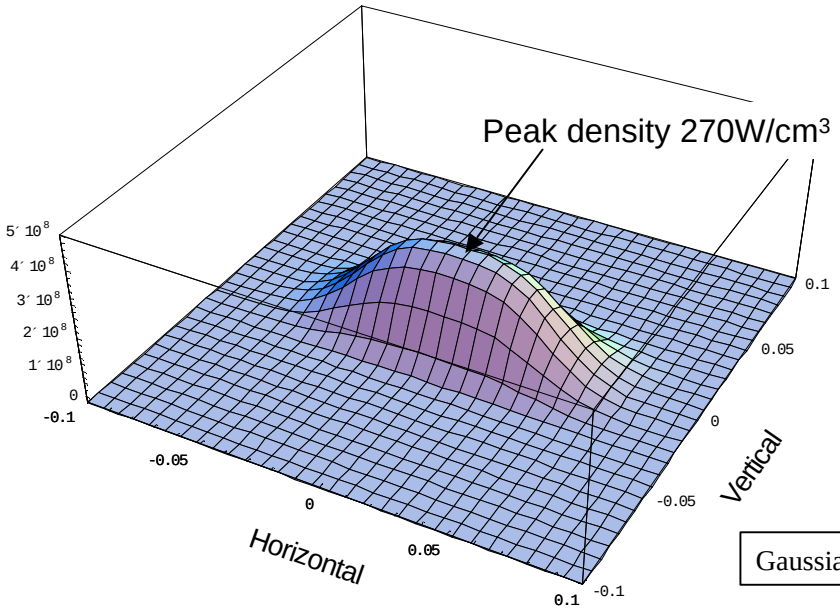
Uniform dist. in 81 πmm mrad

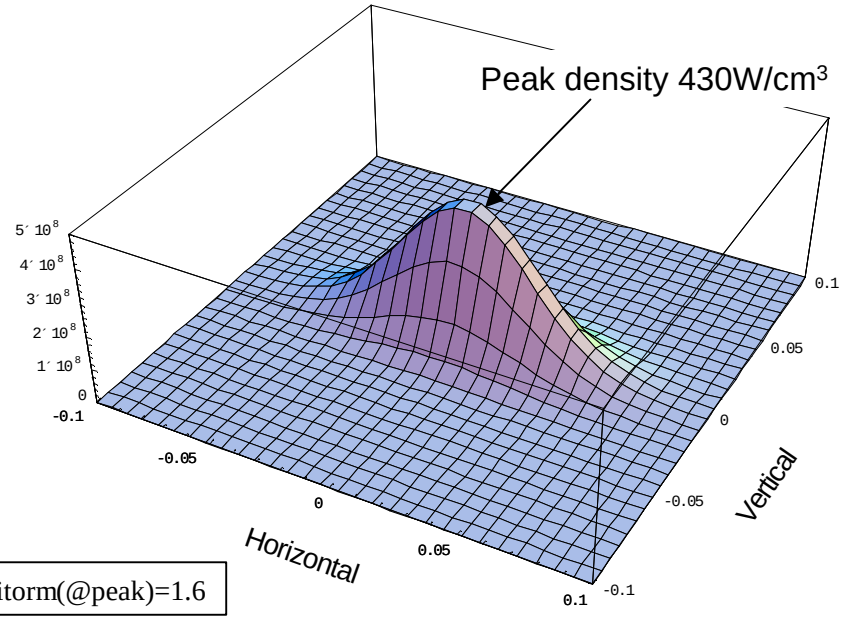
Total heat 1.17kW × 1.1 = 1.26Kw/1.5mm

・Gaussian distribution in phase space

4σ = 81 πmm mrad

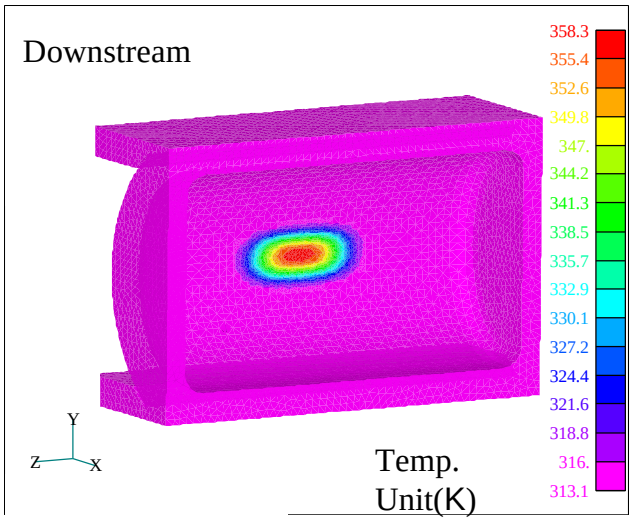
Total heat 1.17kW × 1.1 = 1.26Kw/1.5mm

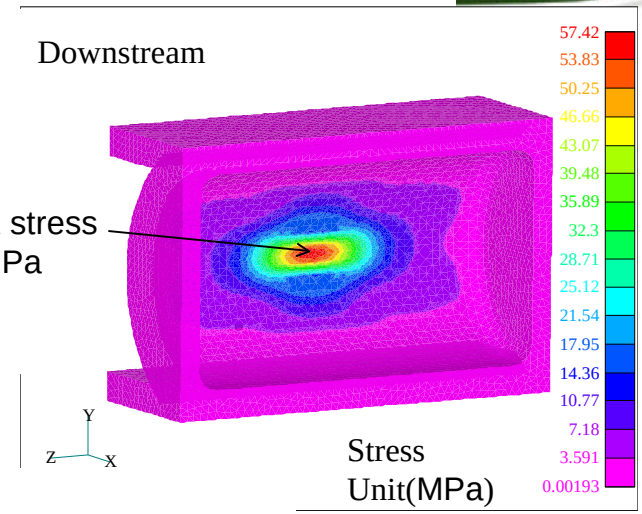


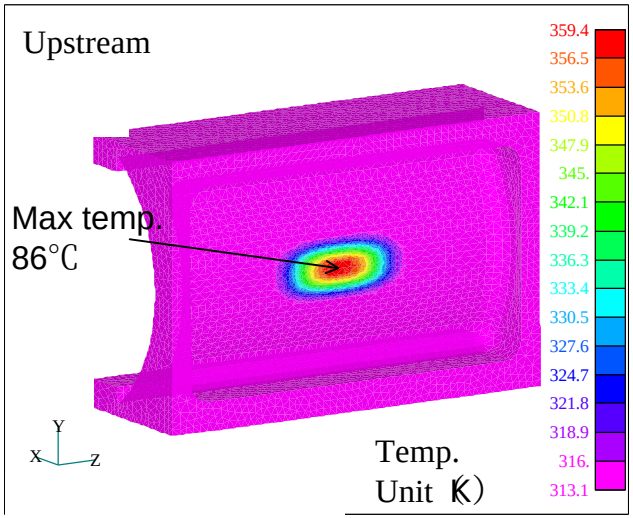


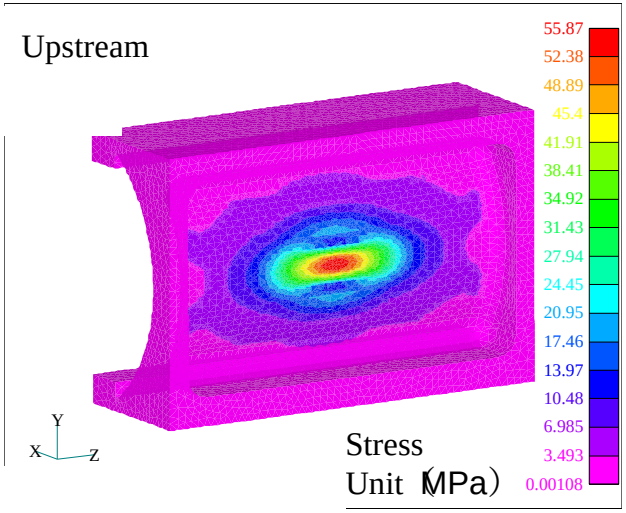
Gaussian/Unitorm(@peak)=1.6

Results of temperature and thermal stress for uniform dist. in phase space



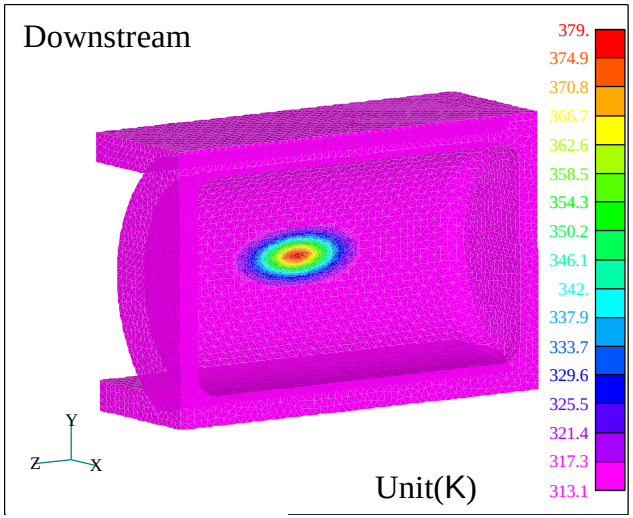


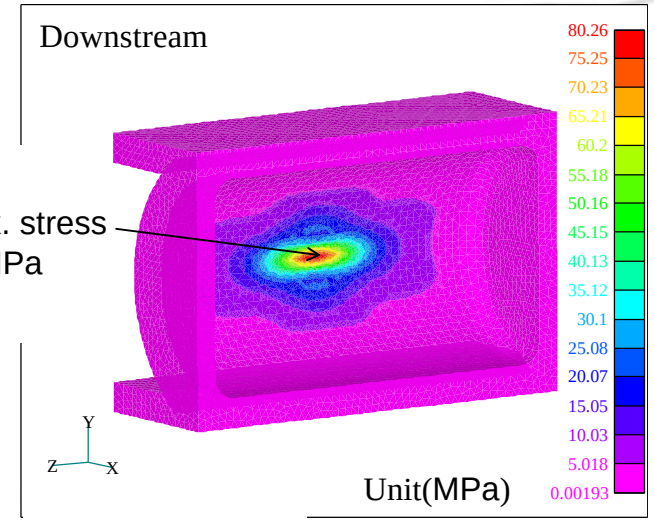


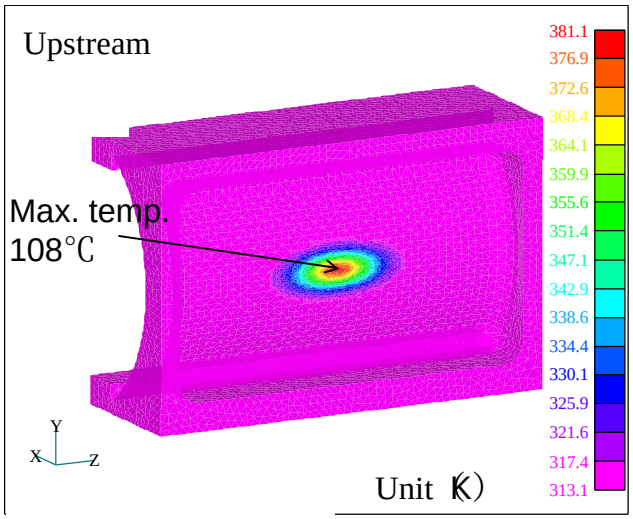


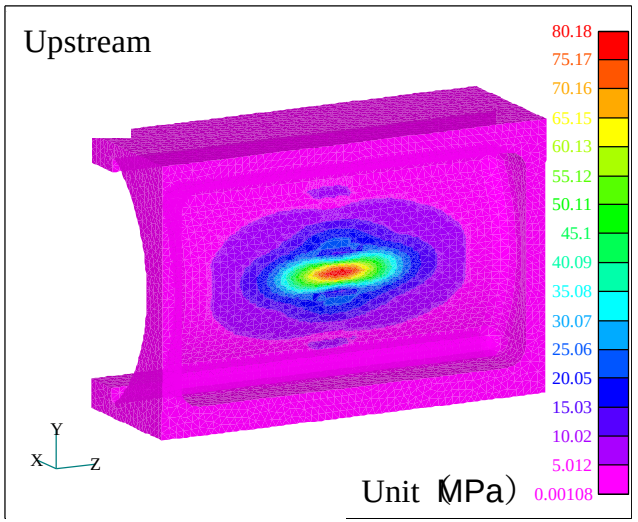
For uniform case, temp. and stress are acceptable for IN-718.

Results of temperature and thermal stress for Gaussian dist. in phase space







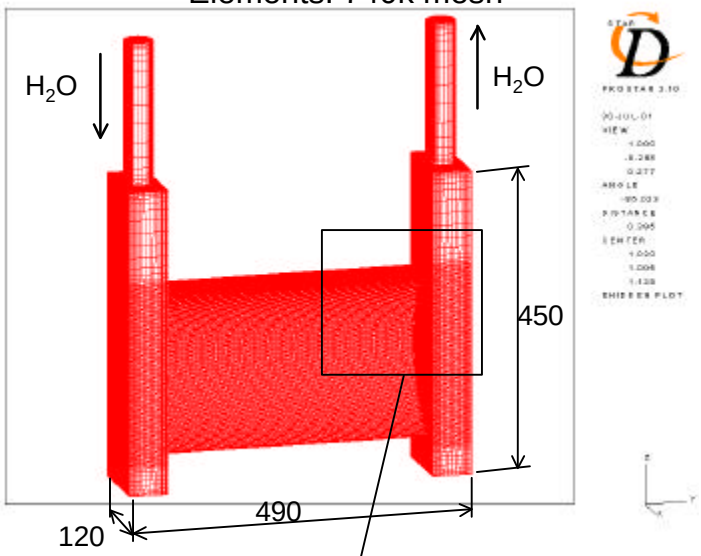


For Gaussian case, temp. and stress are acceptable for IN-718 as well.

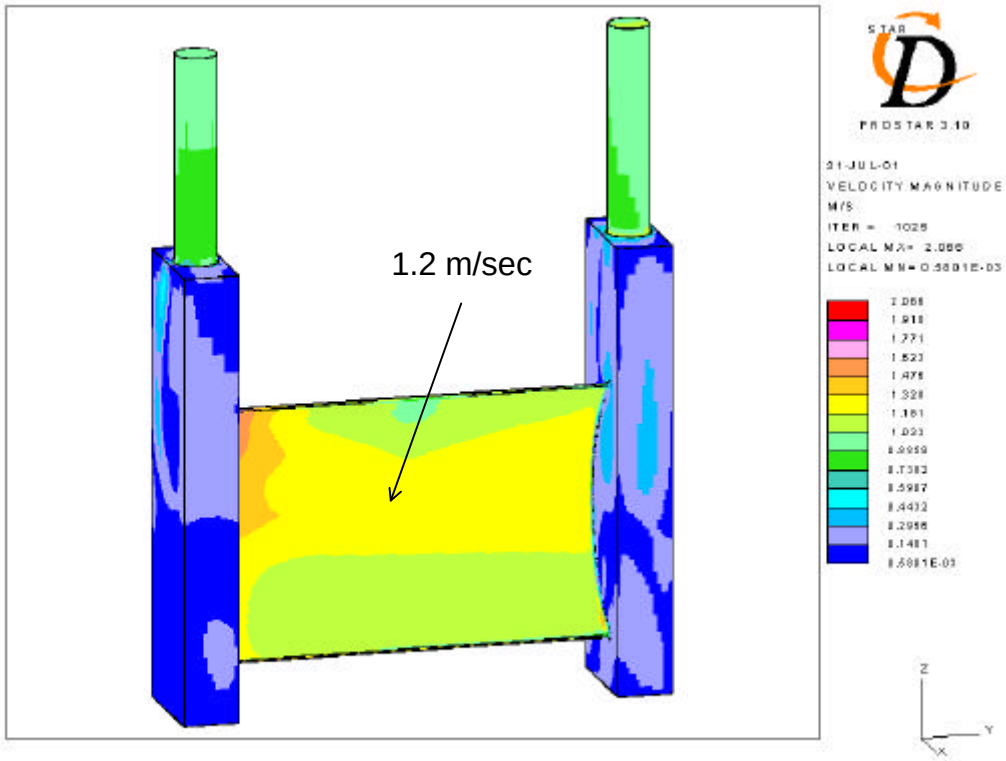
The present PBW is feasible.

Analysis flow distribution of H_2O

Elements: 740k mesh

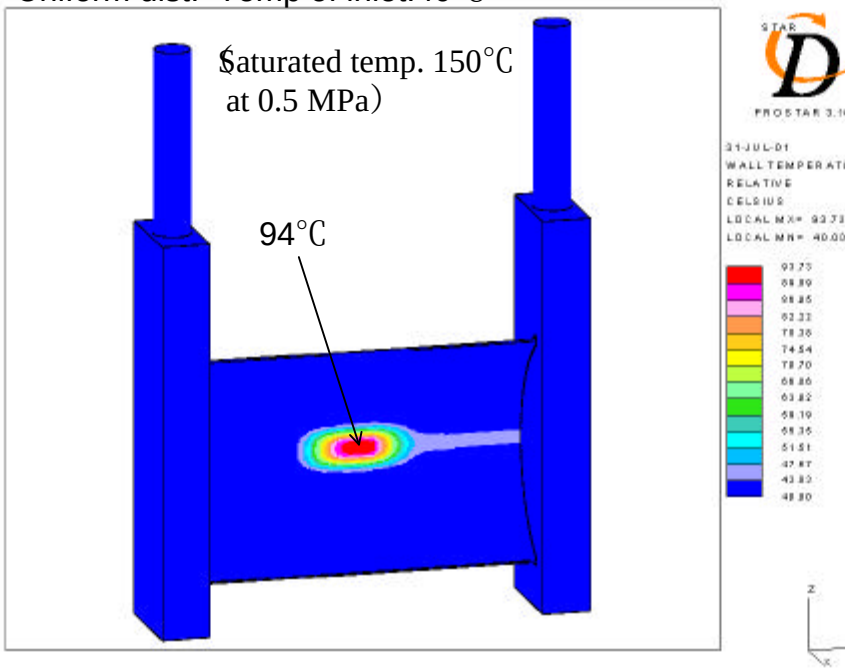


Velocity at inlet：1 m/sec　(4.8 m^3/hr)

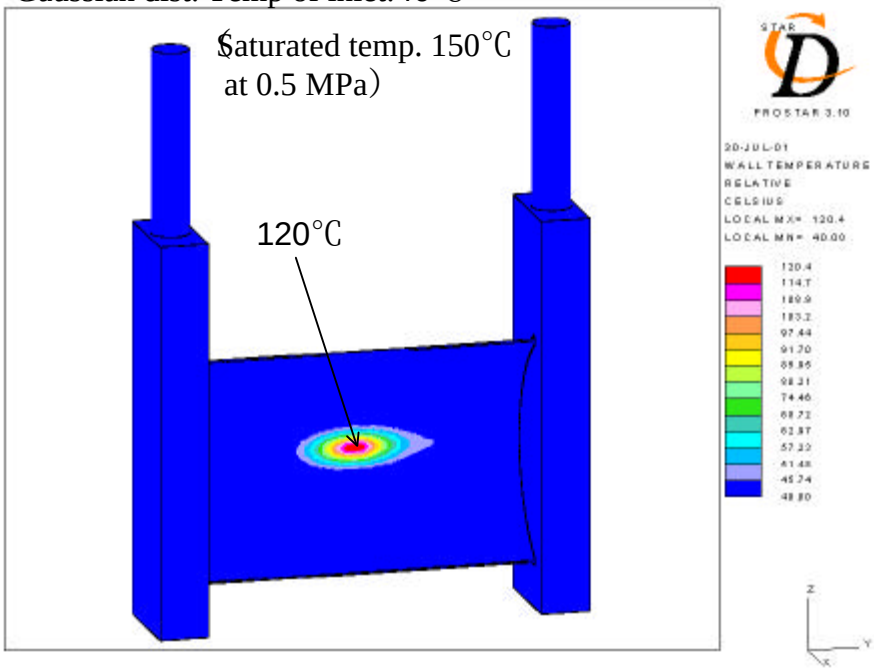


Result of wall temperature by thermal hydraulics analysis

Uniform dist. Temp of inlet:40℃

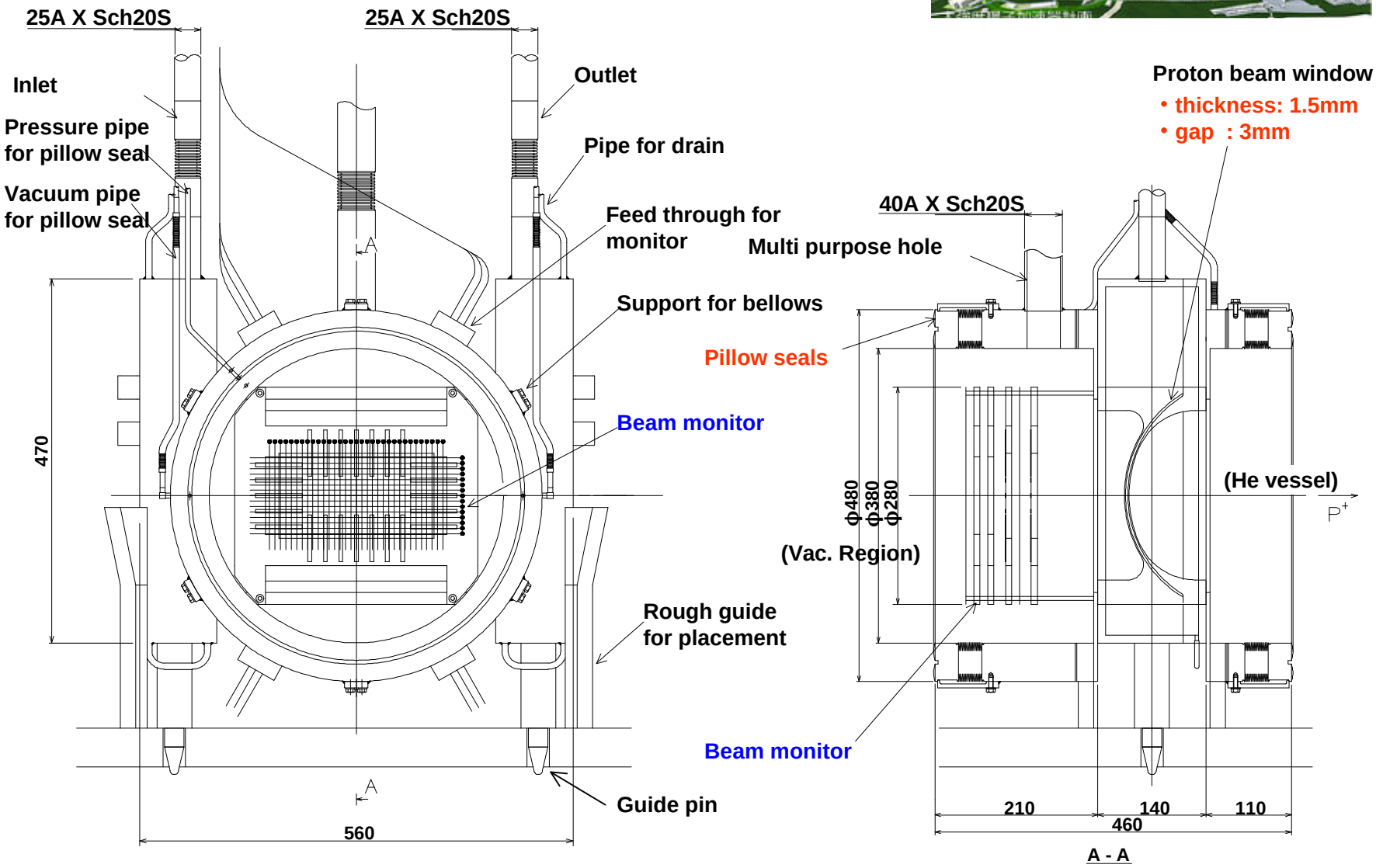


Gaussian dist. Temp of inlet:40℃



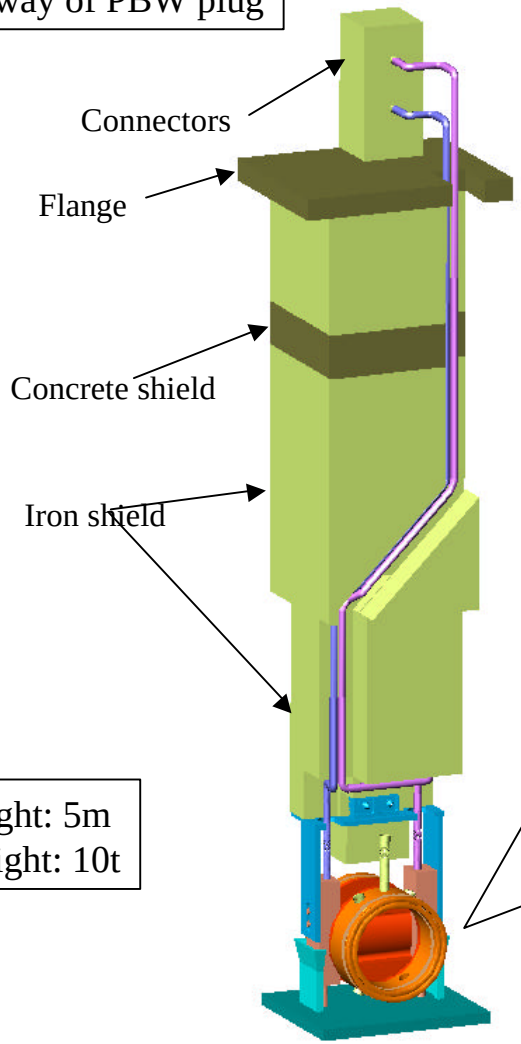
Temperature of wall is acceptable.

PBW Assy around beam line



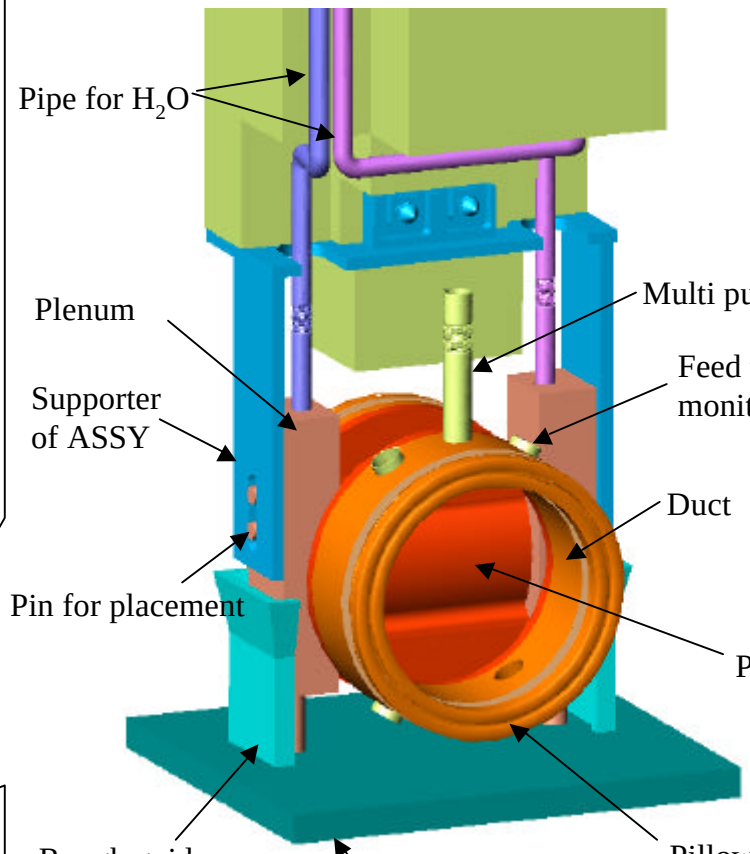
Structure of PBW Assy

Cut away of PBW plug

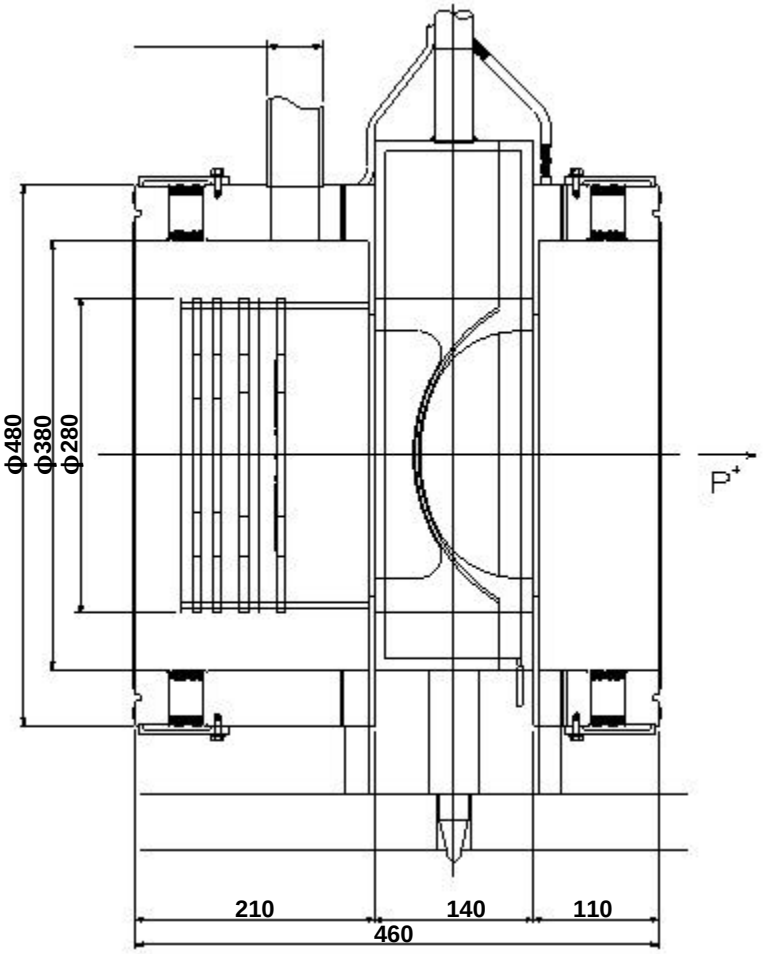


Height: 5m
Weight: 10t

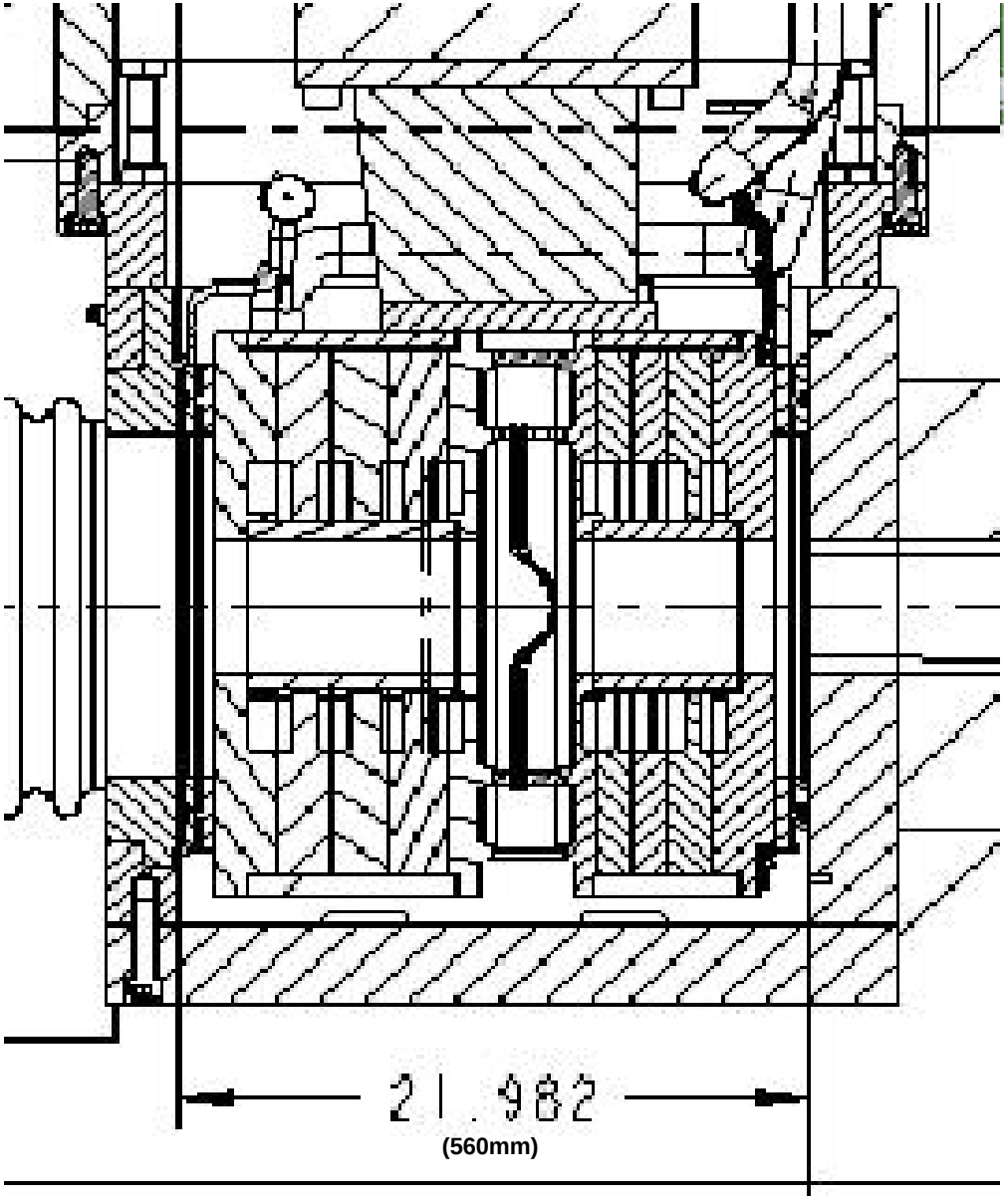
PBW



Comparison with SNS-PBW
(same scale and same beam direction)



Present

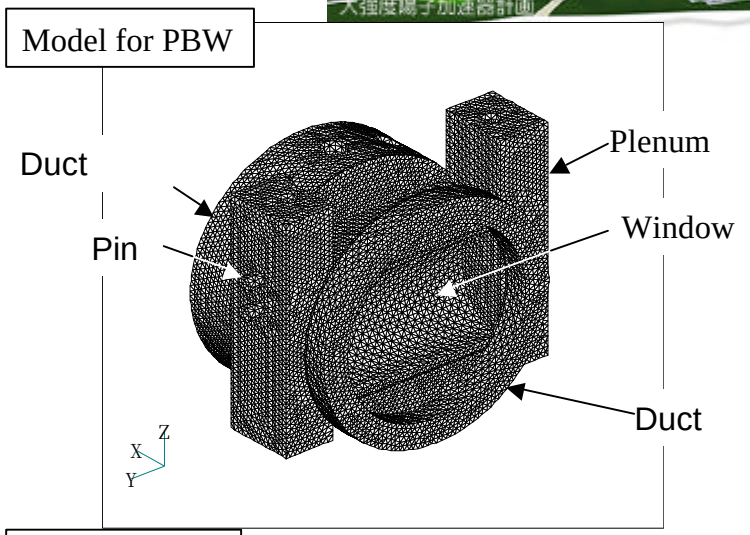


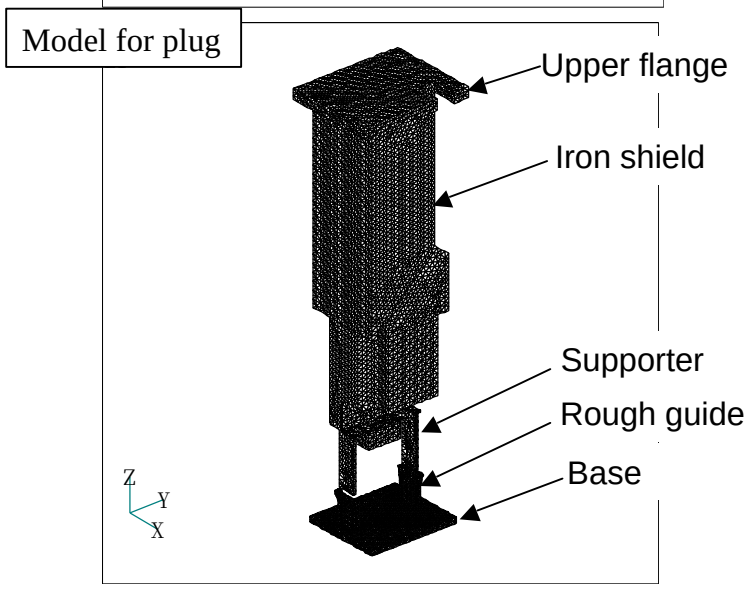
Distribution of temperature for assembly

1. Modeling (3D solid) (See the right fig.)
 (1)PBW
  Window, Plenum and Pillow seal
 (2)Plug
  Flange, Shield, Supporter, Base and Guide

2. Placement
 ・Fixed by the pin located plenum
 ・Upper flange and base

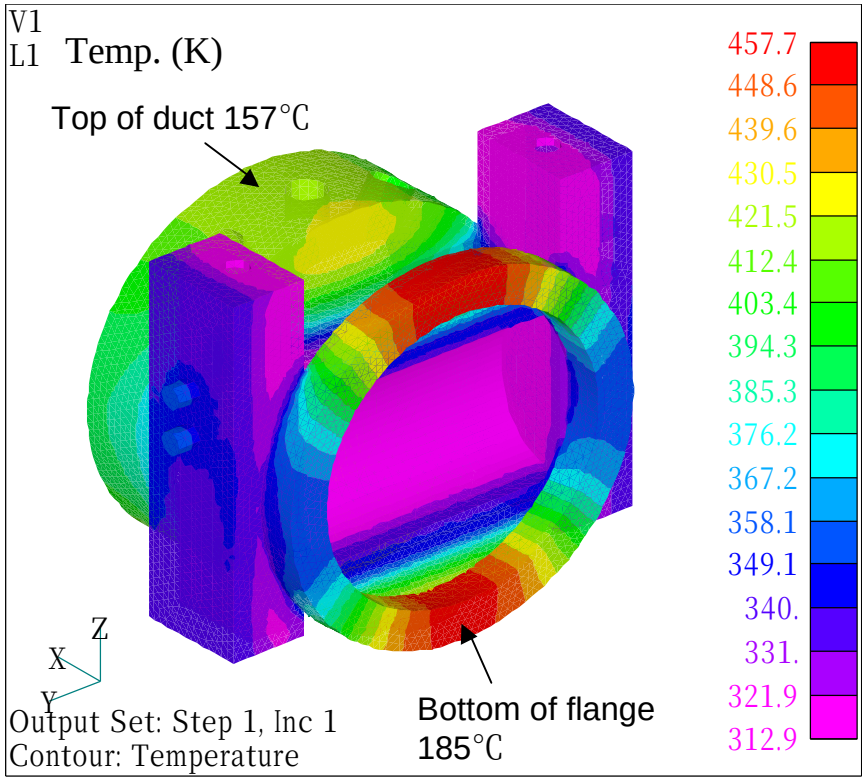
3. Analysis condition
 (1)Density of heat deposition
  a. Window and Plenum ・・・0.3 W/cc (const)
  b. Duct at upstream ・・・0.02～0.06W/cc
  c. Duct at downstream ・・・0.06～0.14W/cc
  d. Plug ・・・0.0001～0.01W/cc
  e. Mount, Rough guide ・・・0.002～0.01W/cc
 (2)Heat transfer coefficient
  a. Heat transfer for water cooling (for 40℃)
   Window 9 kW/m^{2}K, Plenum 1 kW/m^{2}K
  b. Air ambient (natural convection heat transfer)
   On surface of Duct, Plug and Base
    5 W/m^{2}K, Temp. 40℃
  c. Vacuum region
   Heat transfer insulated on vacuumed area
   and He area



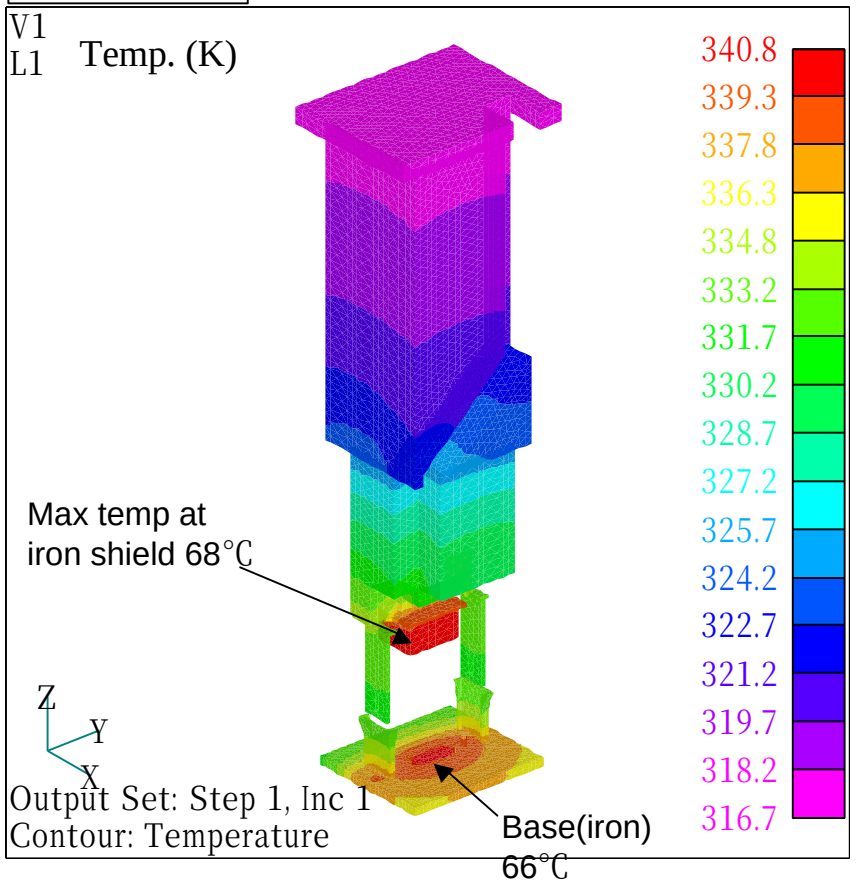


Results of temperature distribution

Beam window



Plug etc.



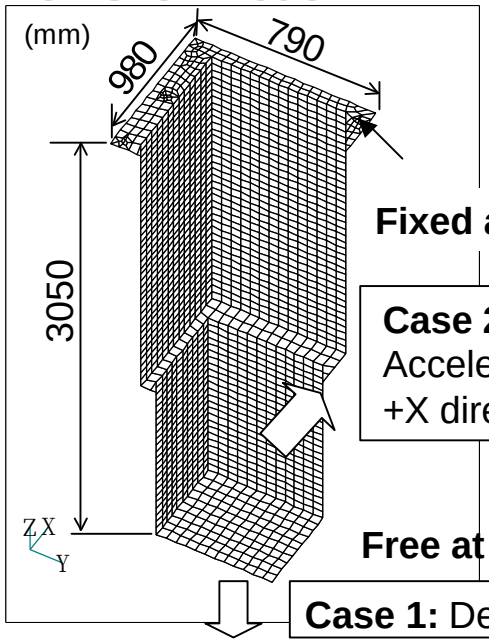
Lower than 185°C →Allowable for SS316

Lower than 68°C →Allowable for iron

Earthquake resistance analysis for plug

Plug material : iron
(E=198GPa, ρ =80MN/m³)
Allowable stress : 100MPa
Inside iron shield : 10 tons

3D shell model



Fixed at the upper end

Case 2
Acceleration in
+X direction(0.4G)

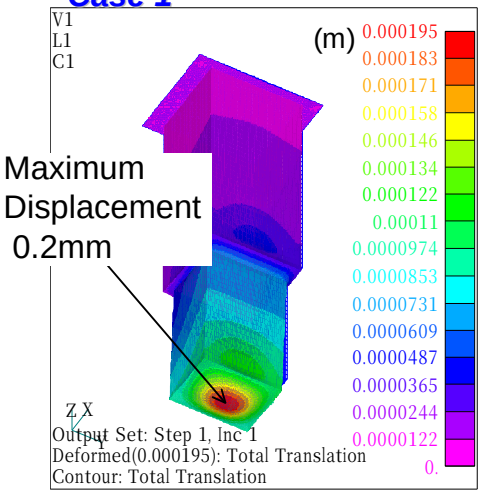
Free at the bottom end

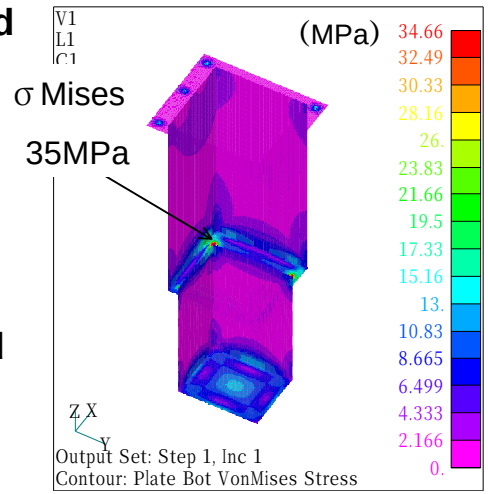
Case 1: Dead Load (1G)

Next step : Analyses under constraint by steady rests at the bottom end.

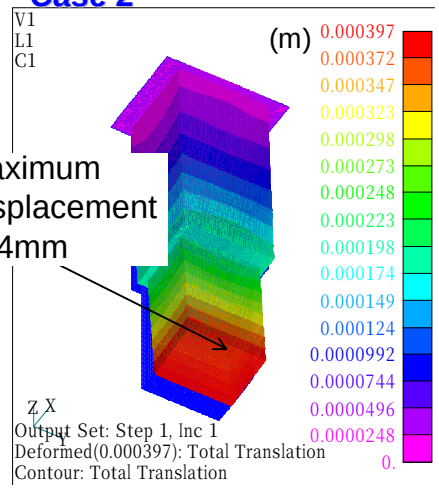
- Analytical Results -

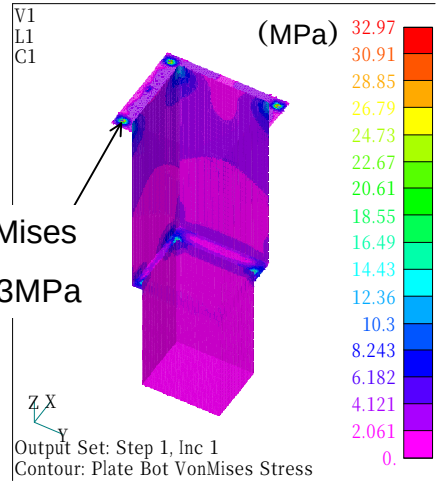
Case 1





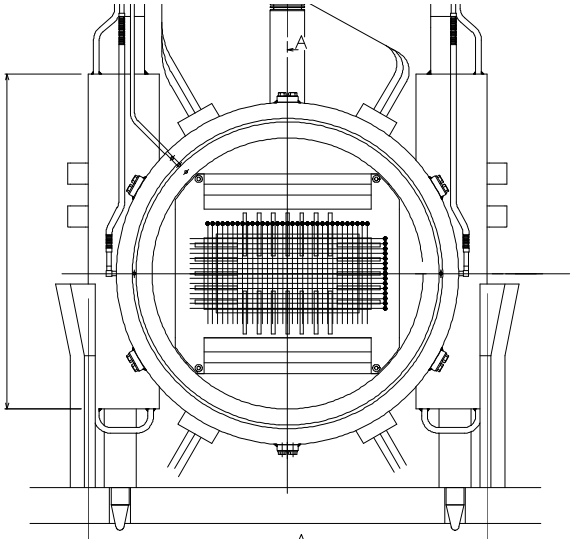
Case 2

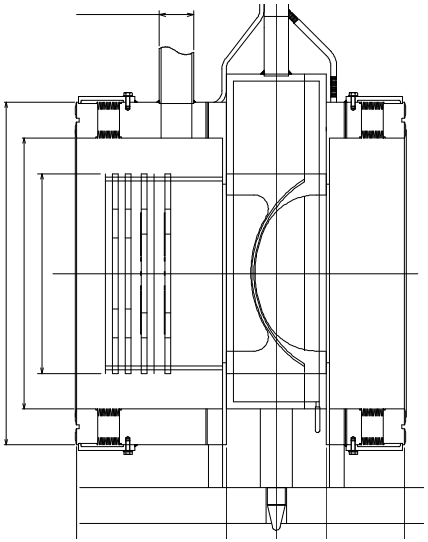




Max. stress is smaller than the allowable stress

Beam Monitor





Difficulty of replacement

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Long lived monitors

SiC wire

R&D will be started.

Beam profile monitor(PM)

(Position, Distribution)

Multi Wire Profile Monitor

W+Au (ϕ 30 μm) :SEC-PM1

SiC (ϕ 150 μm) :SEC-PM2

Beam halo monitor(HM)

(Halo hits reflector and shield)

Thermocouple :TC-HM

Heat deposited on metal plates(eg. Cu) is read.

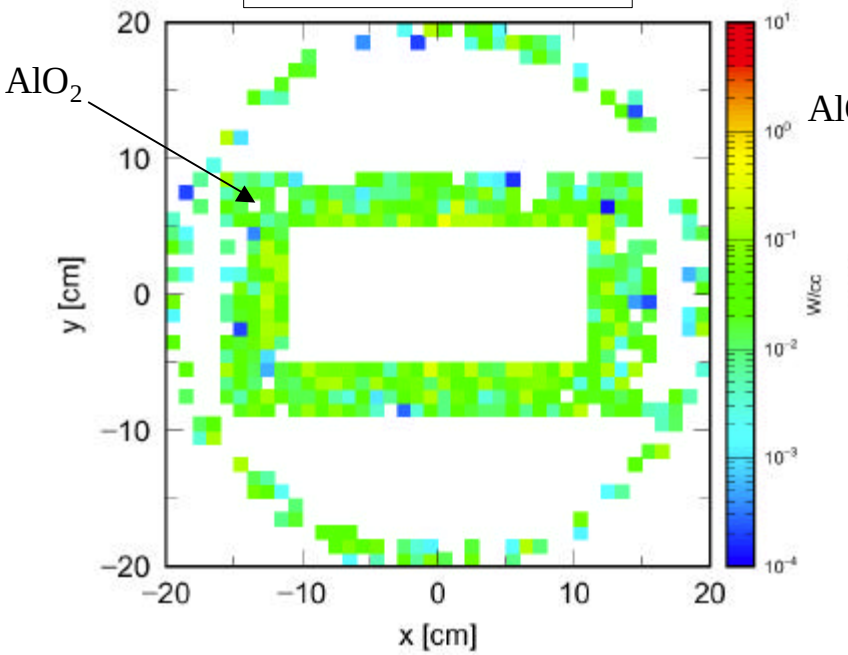
Secondary-emission :SEC-HM

Mineral insulator cables made of MgO_2 will be used.

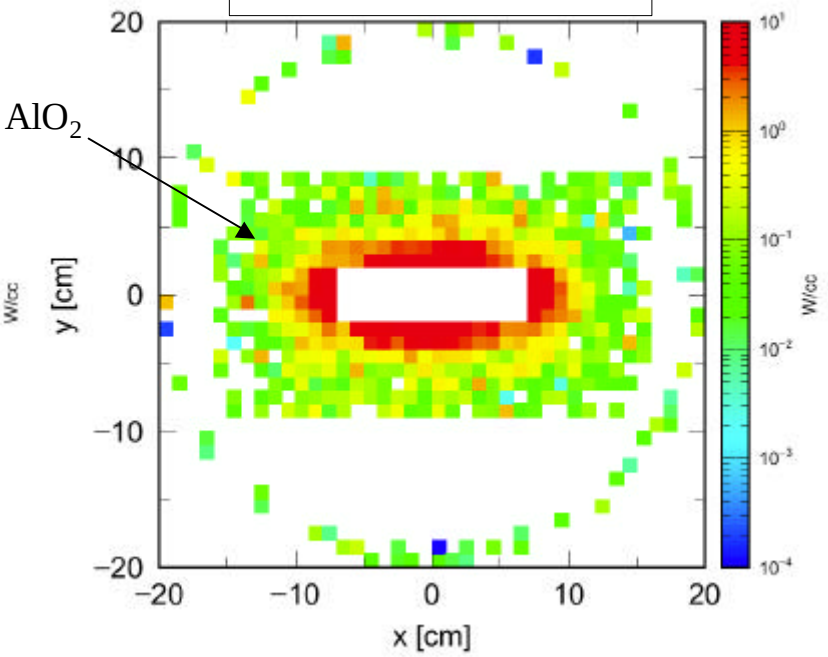
Heat deposition on beam monitor

Wires and T/C of monitors are mounted on AlO_2 plates(8mm t).

On profile monitor



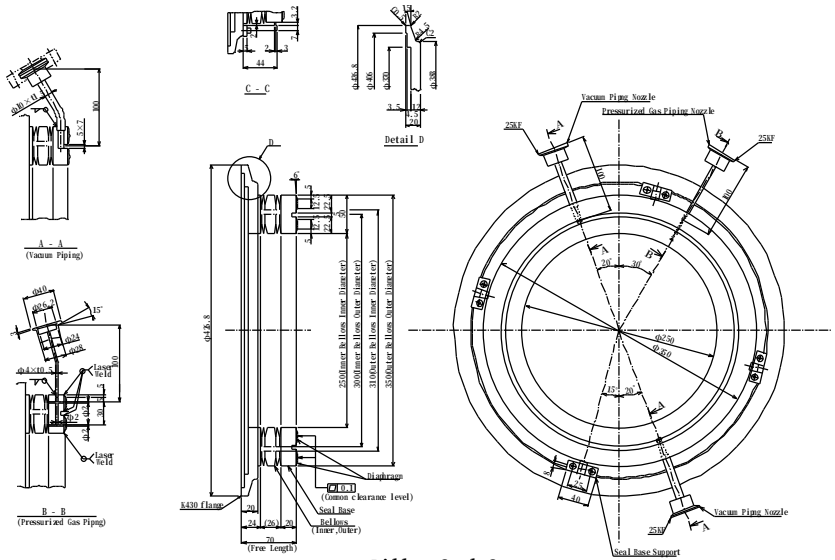
On halo monitor



Temp. will be raised up to 200℃.
However, power of beam will significantly smaller than 1 MW in 1st phase. We need redundant system for case of low power.

Pillow seal

Pillow seal used in KEK N-Hall



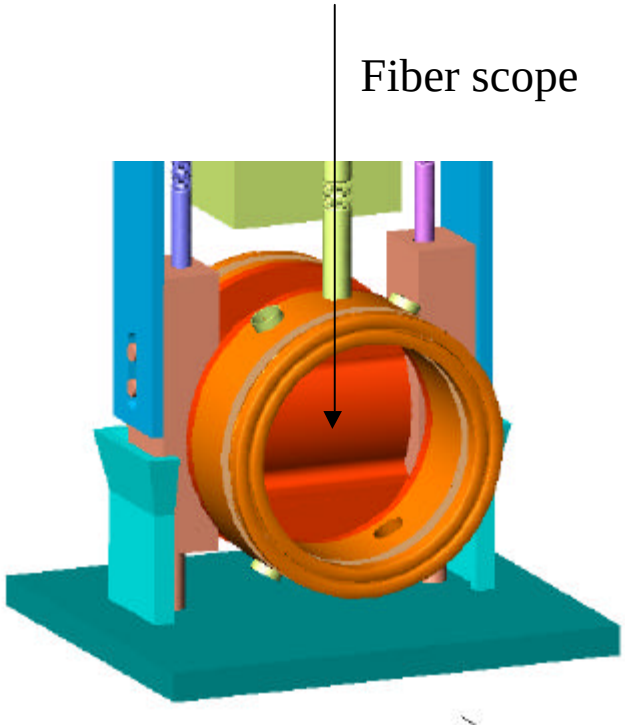
Pillow Seal Structure

By pillow seal
- Coupled with vacuum and He duct
- Compensated thermal expansion

Already pillow seal has been used in KEK, PSI. Although some modification will be necessary, it is feasible.

Maintenance scenarios

Life time: PBW is given 5 DPA/y. It will be used longer than 1 year.
Is it enough by the estimation of DPA? (Nobody knows)
How should we determine life time before plugged out? → PIE is reliable.
Make sure by the inspection, which is possible by fiber scope fed through multi-purpose hole.



Trigger for Fast Closing Valve (FCV), which is placed in case of rupture of window, will be ahead of multi-purpose hole.

Maintenance scenarios(Cond.)

Scenario of PBW replacement :

1) During long shutdown, waiting for radiation cooling of radiation. (2～3days)

2) Surrounded by cask, old Assy is removed with remote handing tech.
   Transferred to cooling area (Basement floor of MLF).
   Used plug can be employed again after several years(>10 y).

3) Replaced new Assy by remote handing.

In case of replacement, position of new Assy is determined by
◯ Insert new Assy
   Hole for PBW Assy gives rough position (<20 mm).
◯ Led by rough guide (～5 mm)
◯ Course position determined by guide pin (～1 mm)

Summary

A Proton Beam Window (PBW) with curved surface is designed.
Window: IN-718 (1.5mm-t) x2, Water: 1 MPa

Analyses were performed
1) Stress by internal pressure due to water
2) Thermal stress and temperature
3) Earthquake resistance for plug
It is found that the present PBW is feasible.

PBW is assembled with
1) Pillow seal
2) Beam monitor
3) Hole for inspection
PBW Assy : Height 5m, Weight 10 t
Procurement of Mark-I will start this December.

For the confirmation of design, other devices such as T/C on the duct should be equipped. These data will help design for next generation of PBW Assy.