Notes for ILD Beam Pipe
(Technical Aspect)

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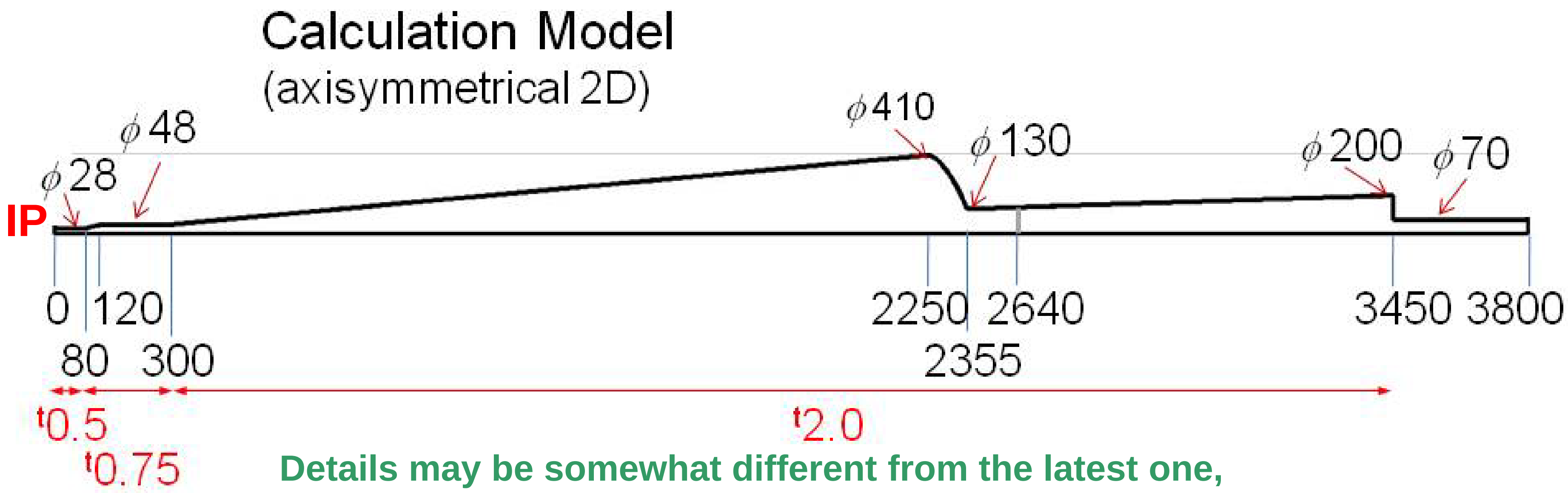
- Parasitic loss
- Vacuum pressure profile
- Some comments for beam pipe

- Here presented are some calculations and brief notes on
  - **Parasitic loss**
  - **Vacuum pressure profile**

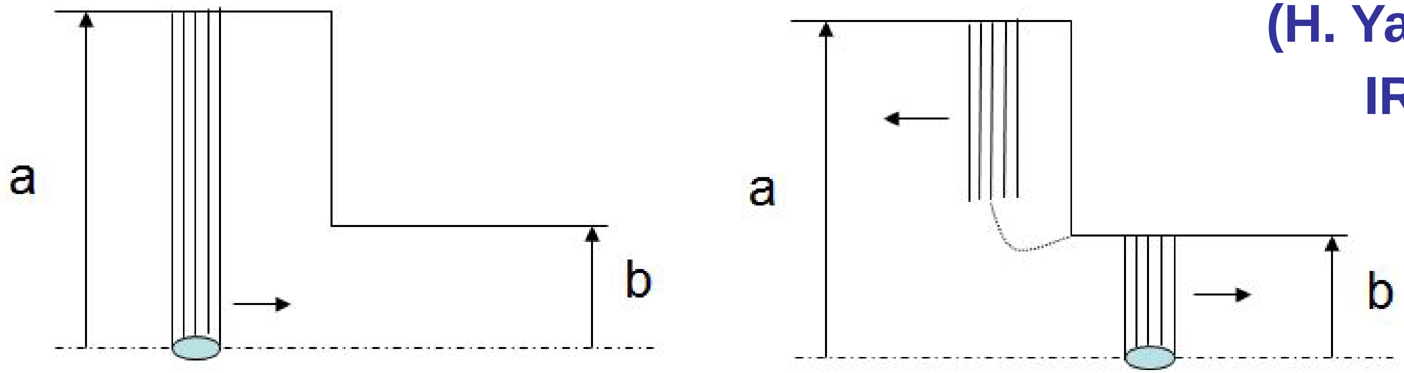
  for the beryllium ILD beam pipe.



Details may be somewhat different from the latest one, but these small differences will have little impact on the results.

1. Parasitic loss

- Any steps in a beam pipe result in the energy loss of passing bunches.



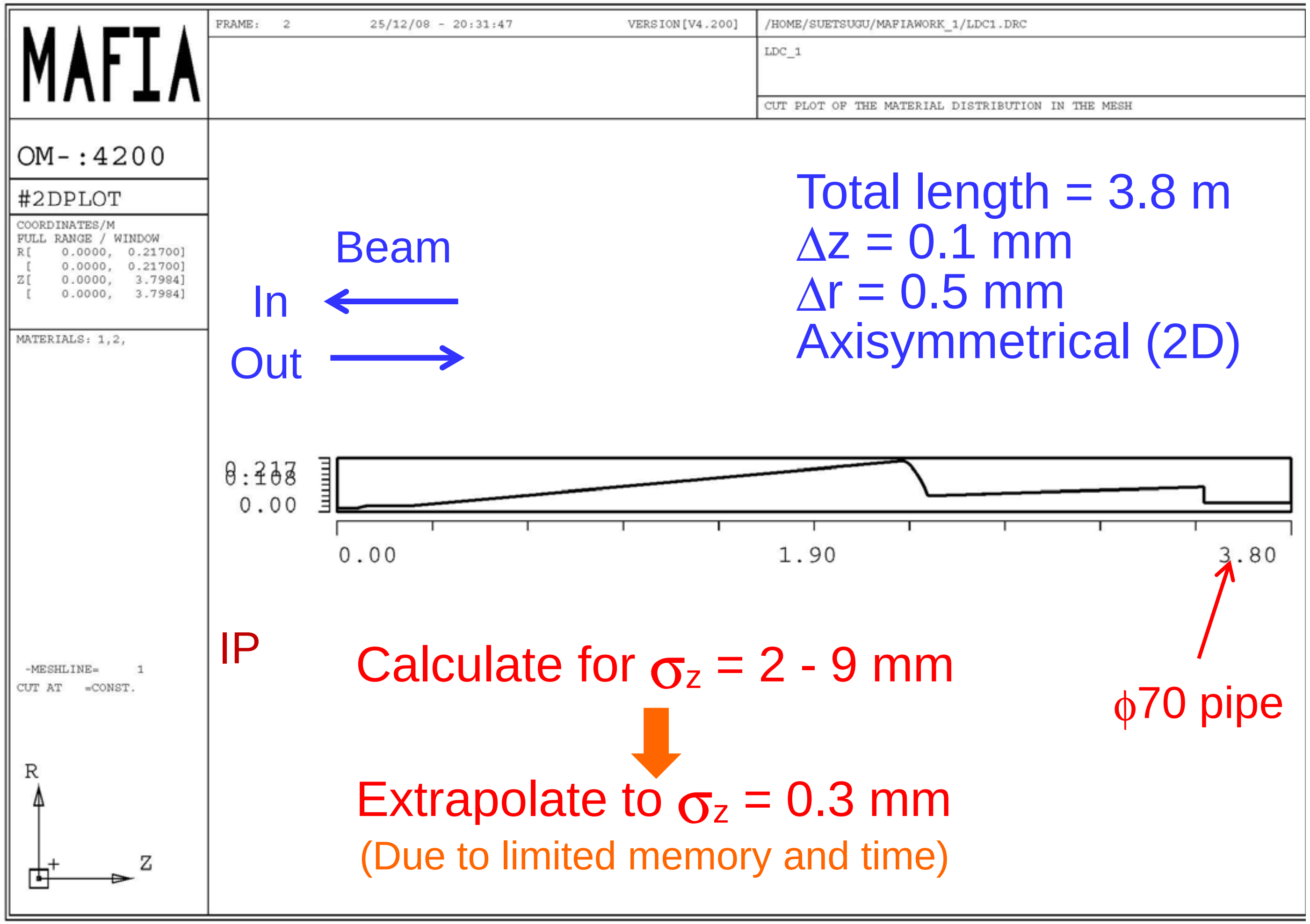
(H. Yamamoto) IRENG07

Ex. EM energy bounced back = HOM loss (Parasitic loss)

- Parasitic loss: *P*
  - ***P* = *k* x *q* x *I***
  - ***k*: loss factor, *q*: charge and I: beam current**

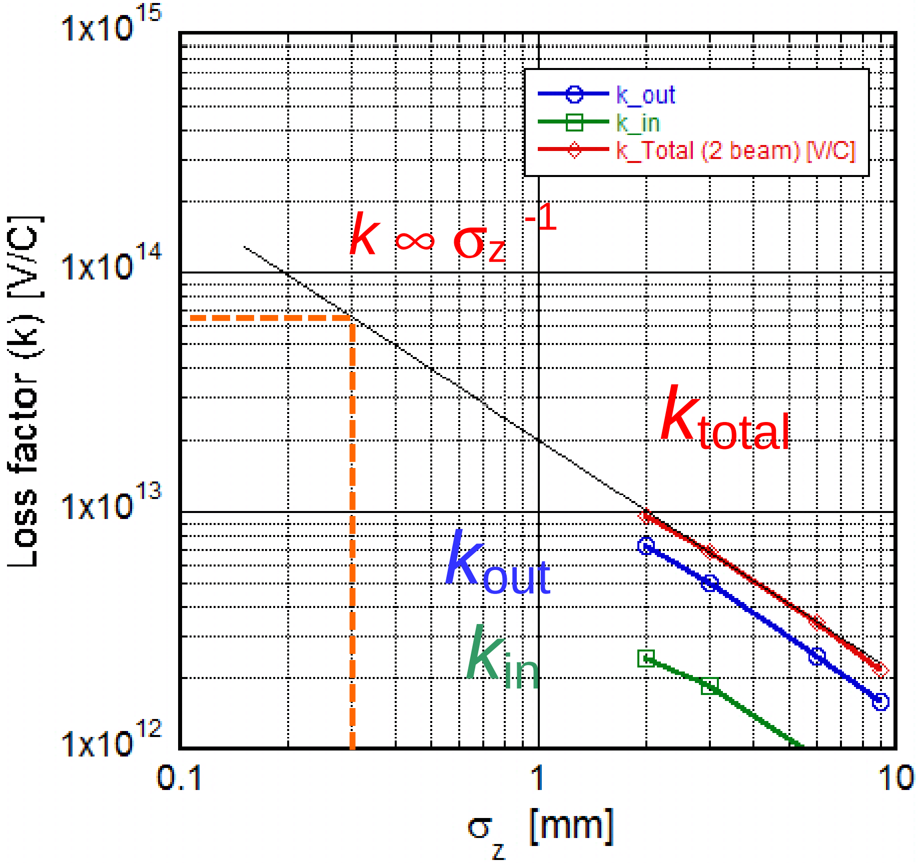
1. Parasitic loss

- Calculation of the loss factor (*k*) using MAFIA



1. Parasitic loss

- Results



k_{total} (two beams) 6~7x10^{13} V/C @ σ_z = 0.3 mm

If q = 3.2 nC, N_b = 6600 bunch, and f_r = 5Hz : I = 8.6x10^{-5} A (Low P option)

$\therefore P = kqI$ = 20~24W (one side)

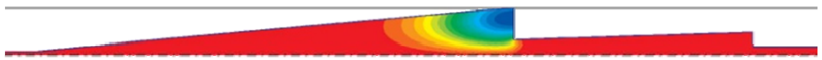
Same to that presented in TILC08

k_{in} and k_{out} is different, since the apertures at both ends are different.

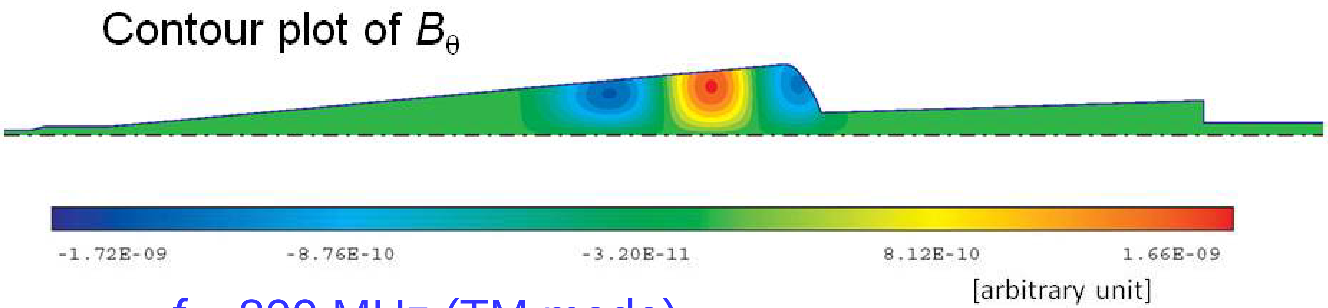
1. Parasitic loss

- Dissipation of power
  - **ILD Beam Pipe : a cavity structure**
  - **Some low frequency modes are trapped in the beam pipe. (~10 %?, S. Pei et al., IRENG07)**

f = 582 MHz

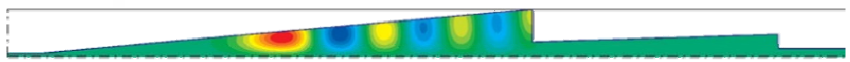


Example of B_θ



f = 800 MHz (TM mode)

f = 1.1 GHz

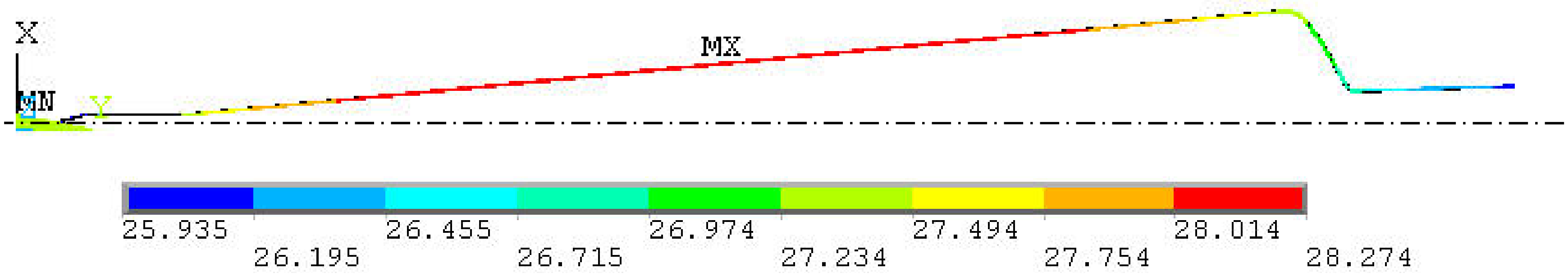


The power will be dissipated at the big cone section.

1. Parasitic loss

- Expected temperature
  - **Assumption: Cooling by natural laminar air flow**
    - α = 5 $Wm^{-2}K^{-1}$, λ (beryllium) = 210 $Wm^{-1}K^{-1}$, 25 °C
    - All Power is dissipated in the big cone part, P = 17 Wm^{-2}

(*Area* = 1.4 m^2)



Temperature rise ~ 3 °C.
No cooling water. Air blow will be sufficient.

2. Vacuum pressure profile

- In order to evaluate the vacuum pressure profile,
  - **Gas desorption rate of beryllium**
  - **Pumping speed**
  - **Required pressure**

  are required.

- For the gas desorption rate, however, we have no value for beryllium at present.
  - **The values without baking, since a baking (150~200 °C) is hardly possible.**
  - **After a proper surface cleaning.**

2. Vacuum pressure profile

- Here used are the data for aluminum, as the first approximation.
  - **Thermal gas desorption rate without baking:**
    - After 10 hours evacuation:

      CO: 2 x10^{-7} Pa $m^3s^{-1}m^{-2}$ (~ 2 x10^{-10} Torr / $s^{-1}cm^{-2}$)

      H_2: 2 x10^{-6} Pa $m^3s^{-1}m^{-2}$ (~ 2 x10^{-9} Torr / $s^{-1}cm^{-2}$)
    - After 100 hours evaculation (after 4 days)

      CO: 2 x10^{-8} Pa $m^3s^{-1}m^{-2}$ (~ 2 x10^{-11} Torr / $s^{-1}cm^{-2}$)

      H_2: 2 x10^{-7} Pa $m^3s^{-1}m^{-2}$ (~ 2 x10^{-10} Torr / $s^{-1}cm^{-2}$)
    - About 20 times larger than those after baking (O. Malyshev, IRENG07)
  - **Uniform gas desorption in the beam pipe**

2. Vacuum pressure profile

- Pumps
  - **NEG strip (ST707[SAES Getters]), or Cylindrical sputter ion pump**
  - **Aligned at the circumference of pipe**

To a small ion pump (and rough pumps)

4m NEG strip in total

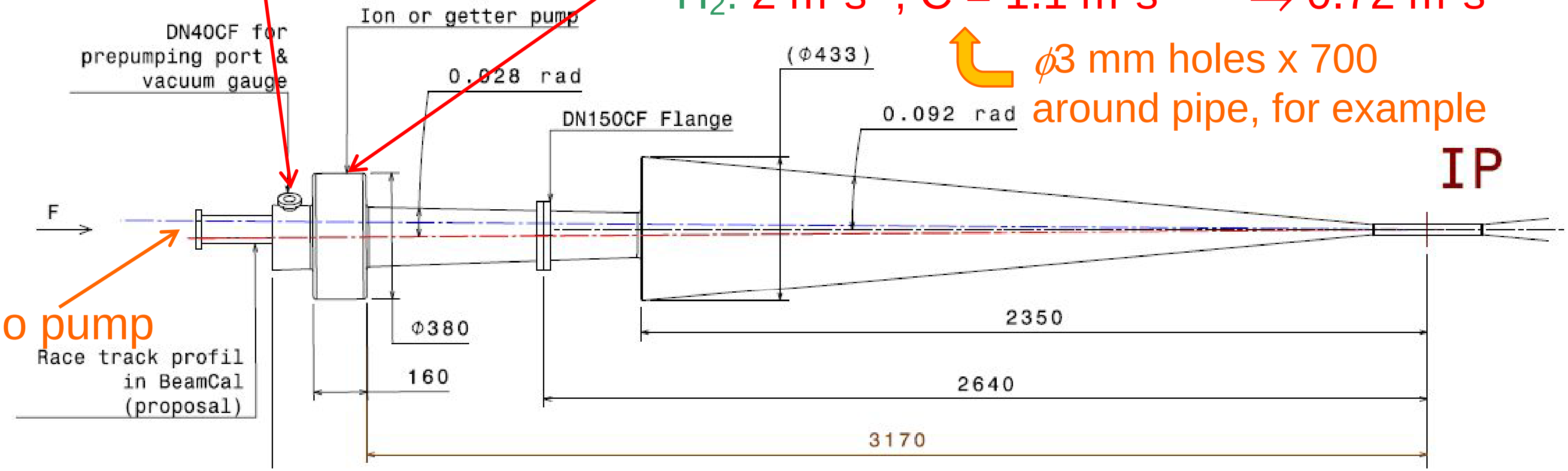
CO: 0.2 m^3s^{-1}, C = 0.3 m^3s^{-1} $\rightarrow$ 0.12 m^3s^{-1}

H_2: 2 m^3s^{-1}, C = 1.1 m^3s^{-1} $\rightarrow$ 0.72 m^3s^{-1}

S_{eff} =

ϕ3 mm holes x 700 around pipe, for example

No pump



2. Vacuum pressure profile

- Required pressure (in IRENG07)

Conclusions

1. At 10 nTorr within the IP region there are 0.02–0.04 hits/bunch (3-6 hits TPC) at an average energy of about 100 GeV/hit originating inside 200 m from the IP. Some of these cause intolerable background in the vertex detector, so to reduce this background to less than 1% per bunch crossing, the pressure specification inside 200 m from the IP is 1 nTorr.

2. At 10 nTorr, on the FD protection collimator 13 m from the IP, there are 0.21 charged hits (33 hits TPC) at an average charged energy of about 240 GeV/hit and 0.06 photon hits/bunch (9 hits TPC) at an average photon energy of about 50 GeV/hit originating inside 800 m from the IP. This leads to a conservative pressure specification of 10 nTorr in the BDS from 200 to 800 m.

3. From a particle background standpoint, within the IP region between the QD0 quadrupoles, the pressure can be greater than 1 nTorr since luminosity backgrounds will be dominant in this region.

$P \geq 1\text{x}10^{-7}$ Pa is OK.
But, what is the upper limit?

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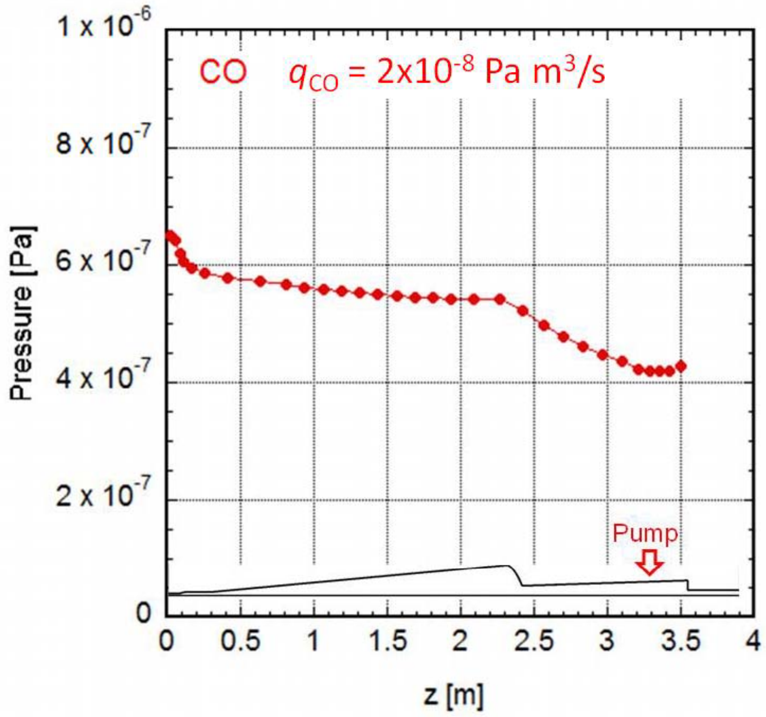
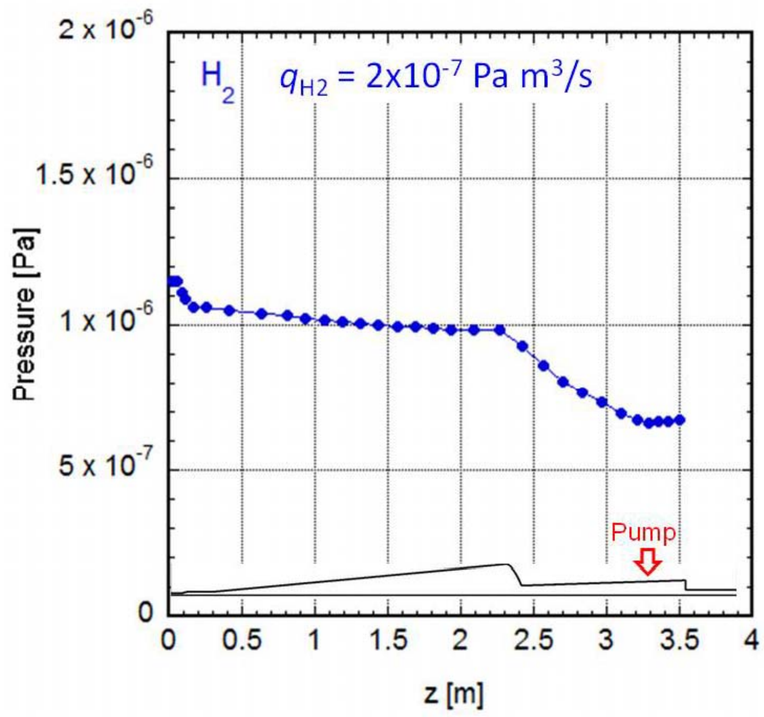
(L. Keller)

(1 nTorr = $1\text{x}10^{-7}$ Pa)

- Results





P ~ 1×10^{-6} Pa for H_2. Is it OK?
To achieve P ~ 10^{-7} Pa, lower gas desorption rate and/or higher pumping speed are required.

3. Notes on beryllium beam pipe

- Vacuum pressure:
  - In order to evaluate the vacuum pressure more practically, a measurement of thermal gas desorption rate from beryllium is required.
  - Experiments to measure it using a test chamber is necessary.
    - Residual gas
    - How about a baking with low temperature?.
    - Surface treatment
  - New pumping port should be prepared at the big cone region depending on the result.
  - It also depends on the upper limit of the pressure.

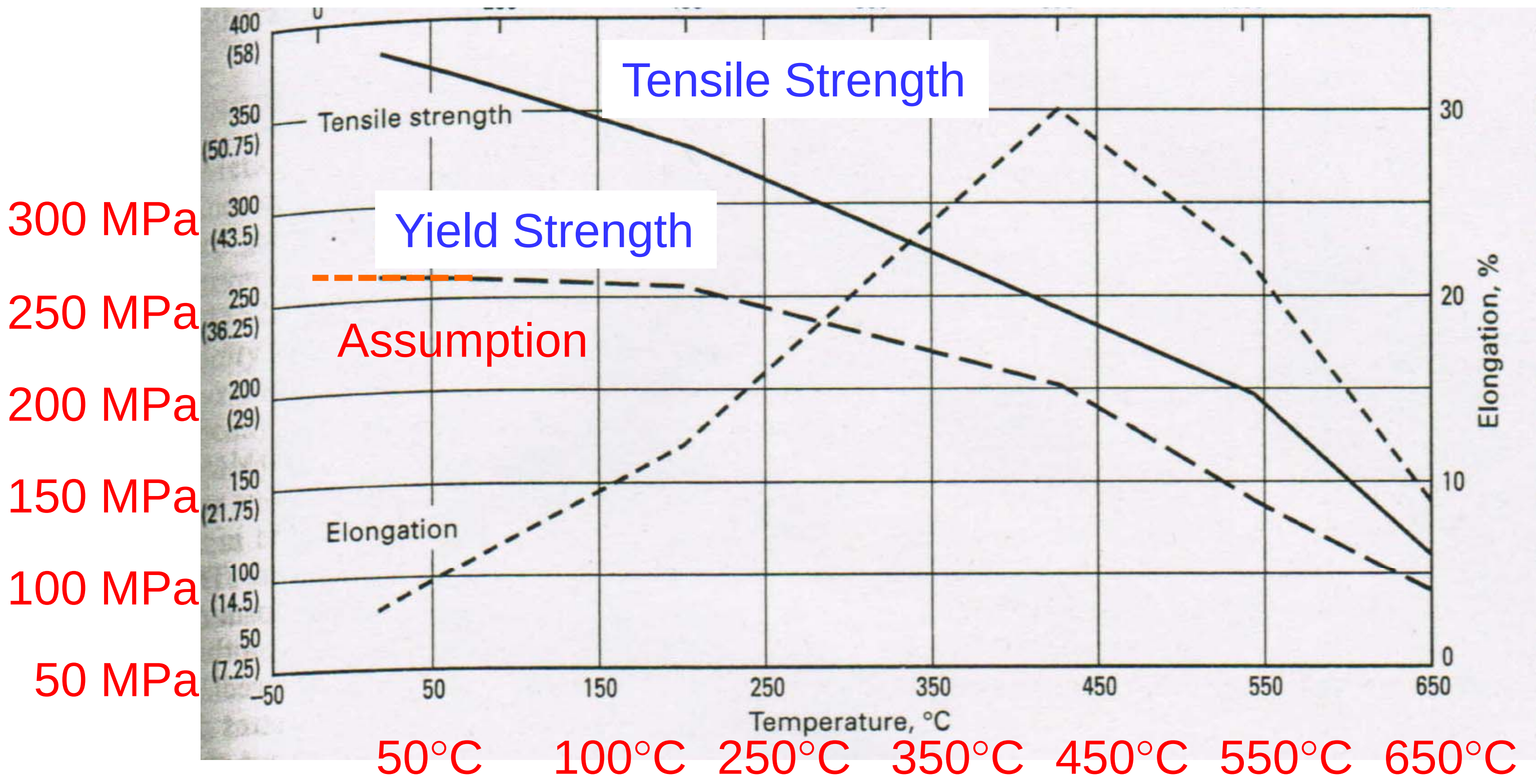
  - Checking of other sources of the gas desorption, such as photons, electros and ions may be necessary

3. Notes on beryllium beam pipe

- Mechanical properties
  - Beryllium may be the best material for IP pipe.
  - However, note that beryllium oxide has a high toxicity, especially to the lung, as is well known.
  - Welding of beryllium by TiG or electron beam (EB) is usually avoided, and the vacuum brazing has been widely used.
  - Even if TiG or EB was used, the thermal conductivity of beryllium is high, only a half of Cu, and the melting point is high, 1280°C. So, some portion of beryllium will be heated up during the welding.
  - Thus the beam pipe is likely to experience a high temperature, 800–900 °C, during the brazing or welding process (although restricted range).

3. Notes on beryllium beam pipe

– **Beryllium pipe can be annealed, and the mechanical strength will weaken.**
– **Structural analysis should take it into account.**



3. Notes on beryllium beam pipe

- Manufacturing of beryllium pipe
  - **The method of joining beryllium should be considered carefully.**
    - Any measures to enforce the structural strength will be required if vacuum brazing is adopted.
  - **The cutting and welding of beryllium requires careful consideration. The manufacturer that can treat beryllium should be limited.→ Cost.**
  - **Don’t we need bellows near to the collision point?**
    - Small bellows is enough to avoid mechanical shock to IP

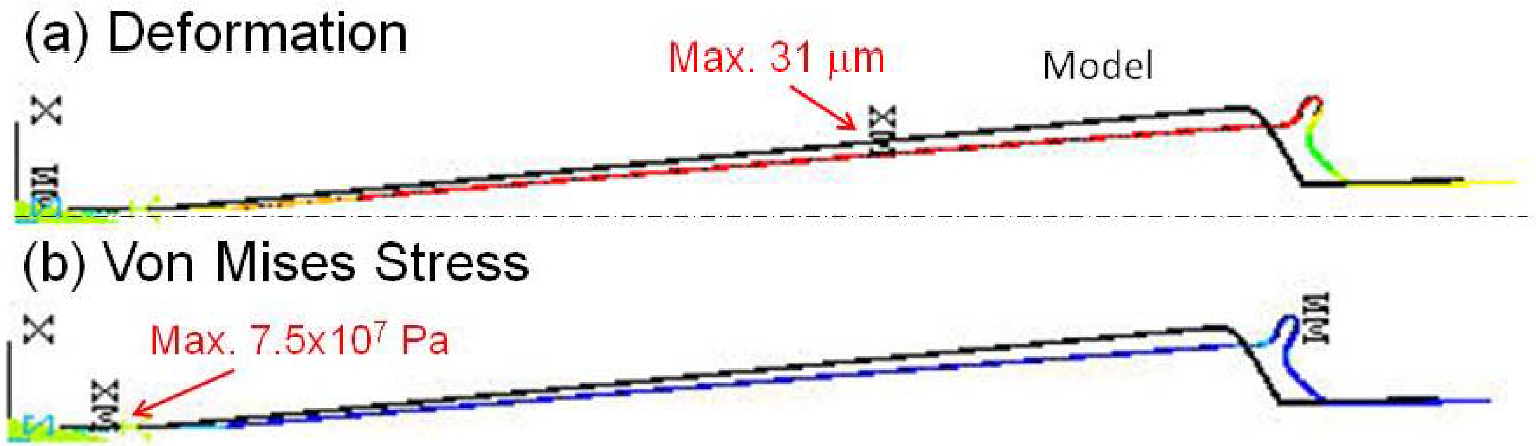
Summary

- Parasitic loss and vacuum pressure profile was estimated for the present beryllium beam pipe.
- Power loss is 20-24 W, and not so large.
- Many ambiguity are in the vacuum pressure evaluation.
- Measurement using a test chamber is highly required.
- Structural strength should be evaluated considering the thermal history and welding methods.

Ref: Structural strength

- Deformation and stress: only for double check
  - **Studied in detail by M. Anduze et al., including buckling.**
  - **Material: Beryllium**
  - **Load: Atmospheric pressure (1.013×10^5 Pa)**

Total length = 3.8 m
$E = 7.056 \times 10^{10}$ N/m^2
$\nu = 0.3$
Axisymmetrical (2D)



Similar results were obtained for the deformation and stress.
Reinforcement by discs seems good if more thin wall is required.