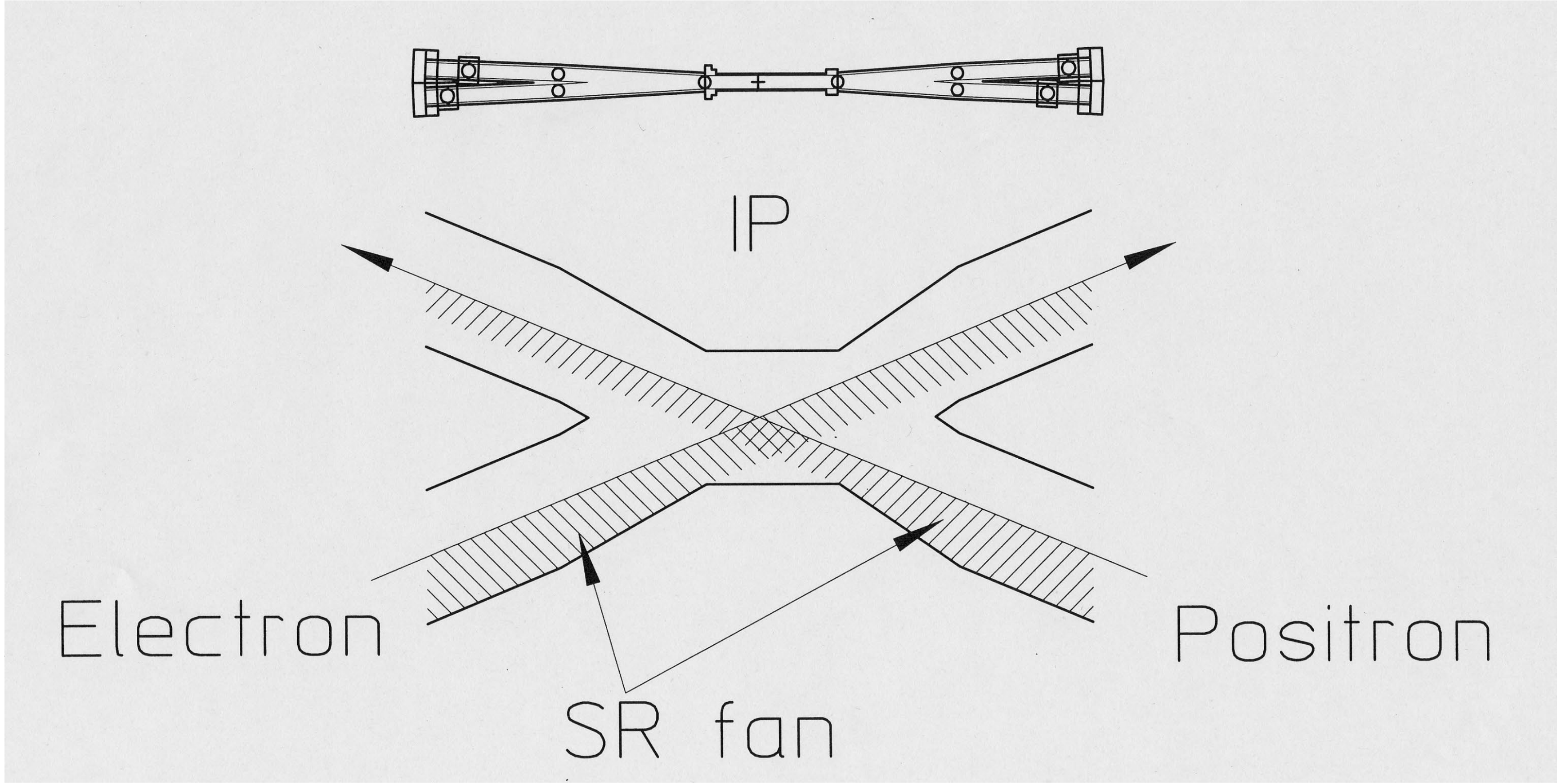
2023 Dec 7 slides

@B35F

Ken-ichi Kanazawa

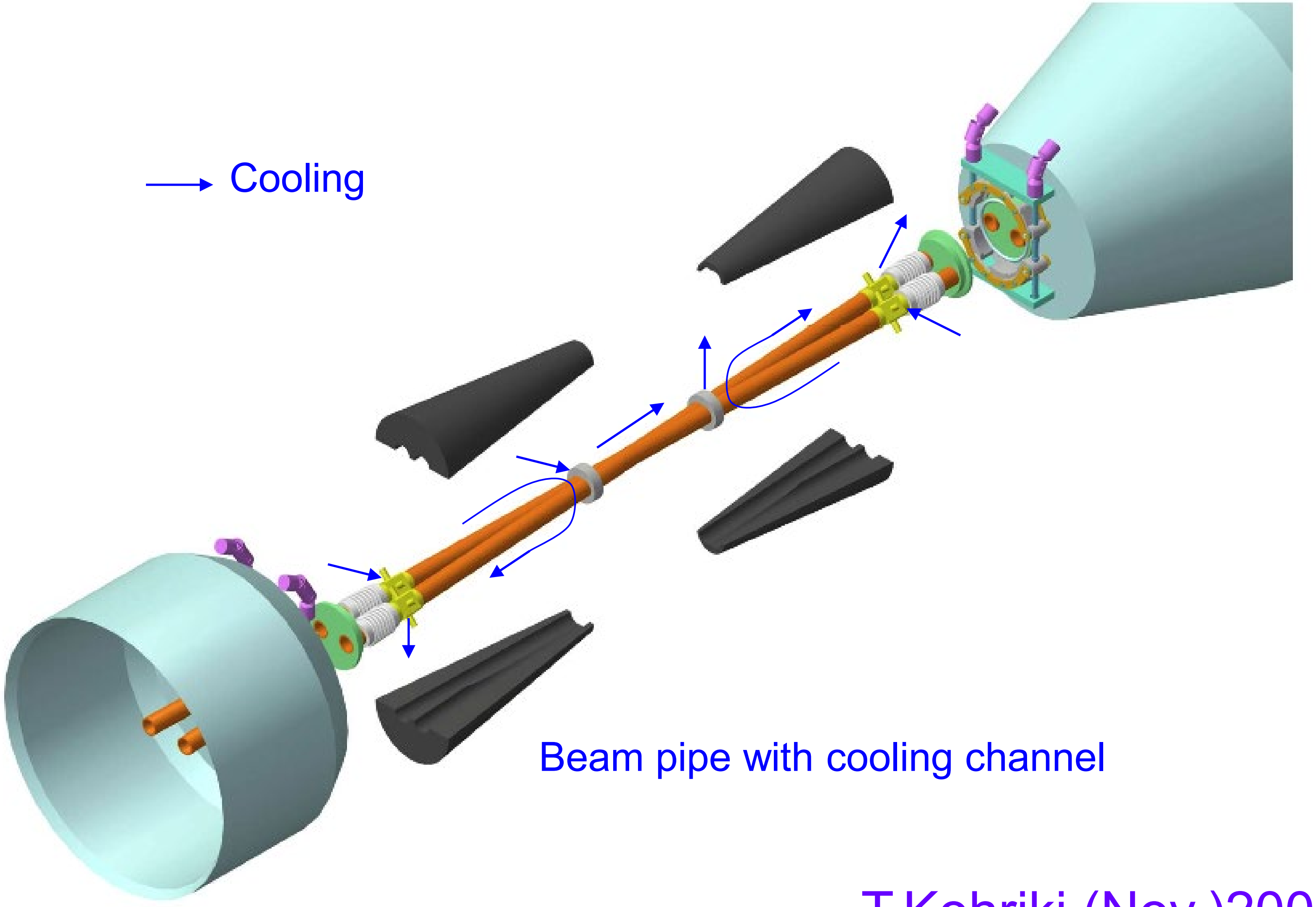
IP Chamber

The 15th KEKB ARC
15 February 2010



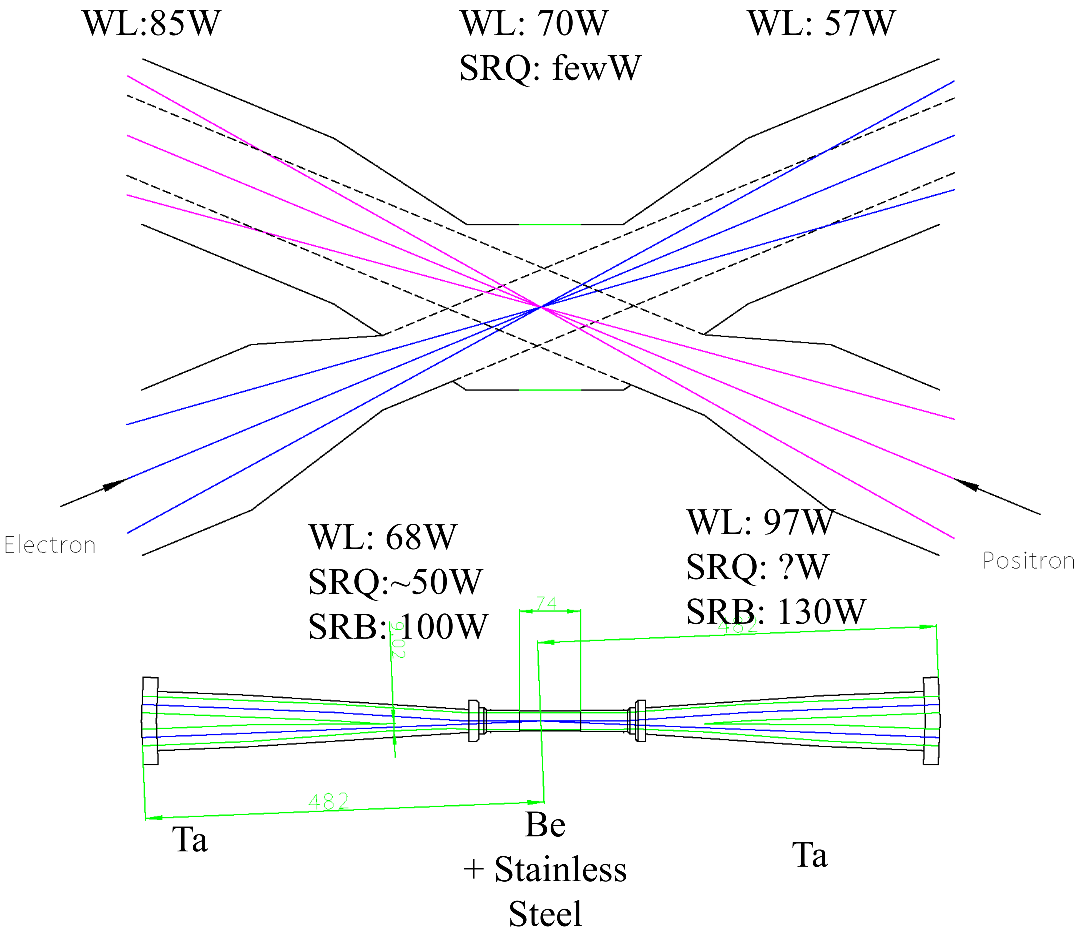
The polarity of the last bend is designed so that SR fan from the bend may not directly hit the central part of the IP chamber (in the 0^{th} approximation).

IP Chamber



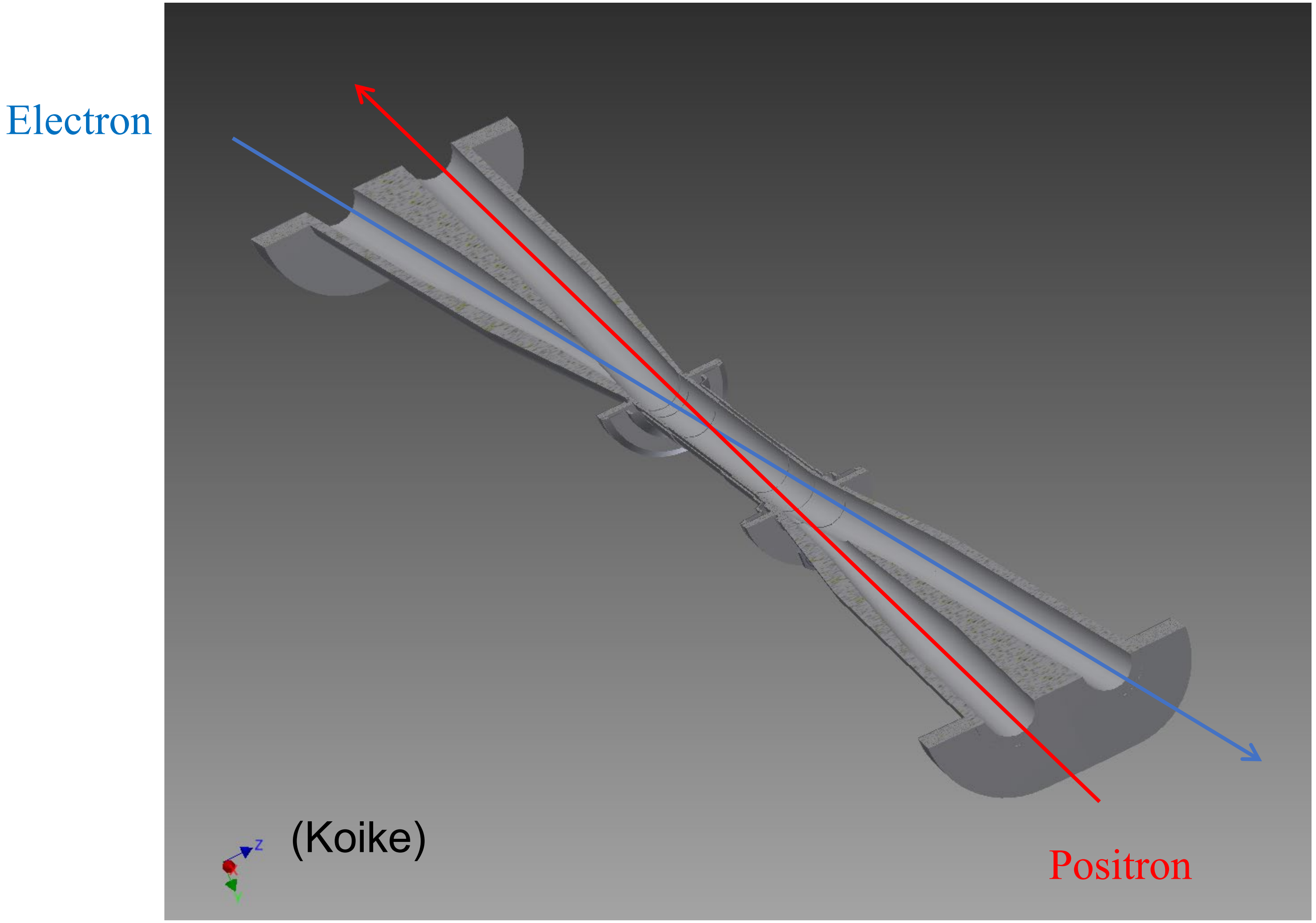
T.Kohriki (Nov.)2009

2. IP Chamber
Design features of the inner shape



- Minimize the creation and the trap of HOM.
- The pipe for incoming beam start from ID20 mm. Then ID is gradually reduced to about 9 mm to mask SR.
- The central part is a ID20mm straight pipe.
- The central part and the branch for out going beam constitute a bent pipe of ID20mm.
- The inner surface of a pipe for incoming beam has ridges to prevent scattered light from hitting the central part.
- All inner surface will be coated by 10~100μm thick Au.

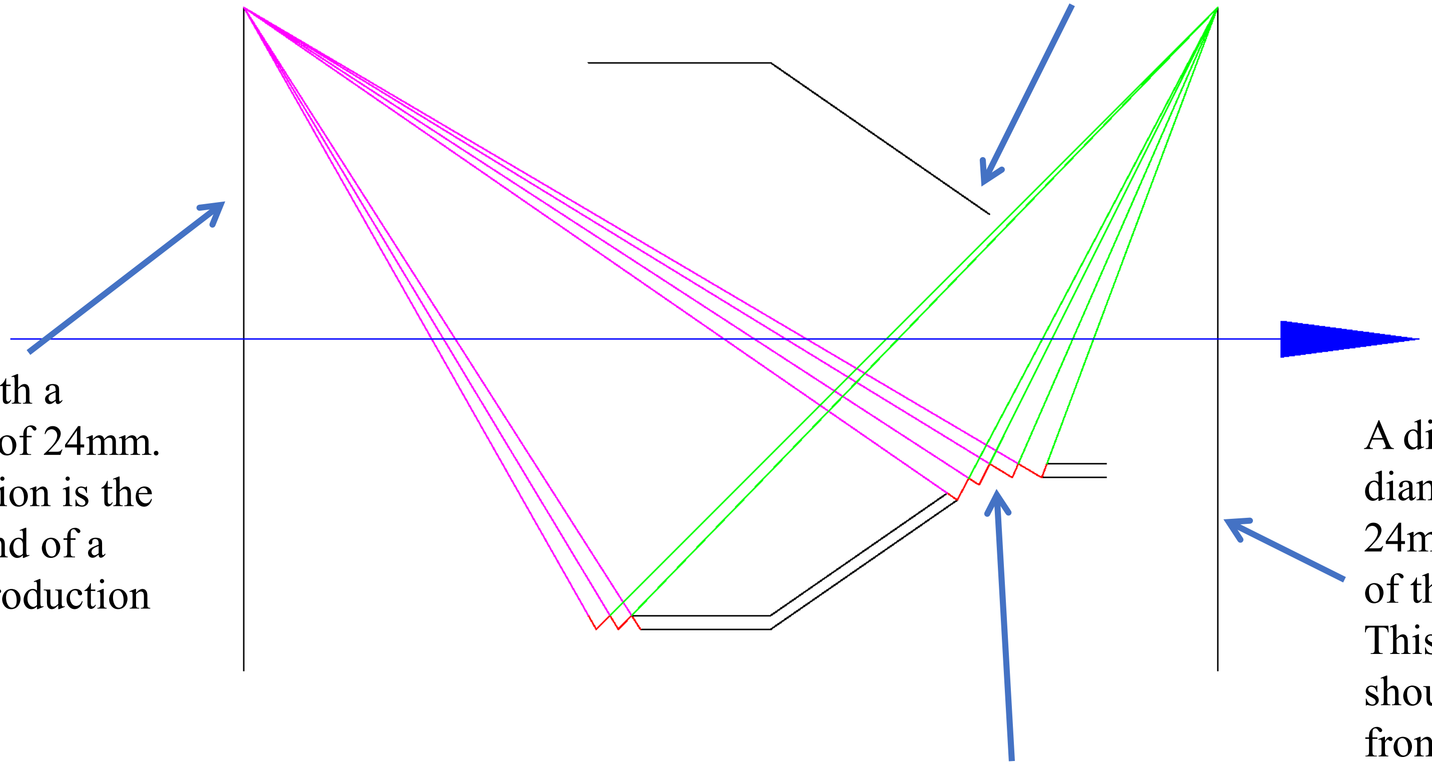
2. IP Chamber
Cut View



2. IP Chamber Ridge

Thin wall around here cannot has a ridge structure. However, scattered photons from this part enter the central pipe with a shallow angle and give no serious effect.

A disk with a diameter of 24mm. The position is the nearest end of a photon production region.

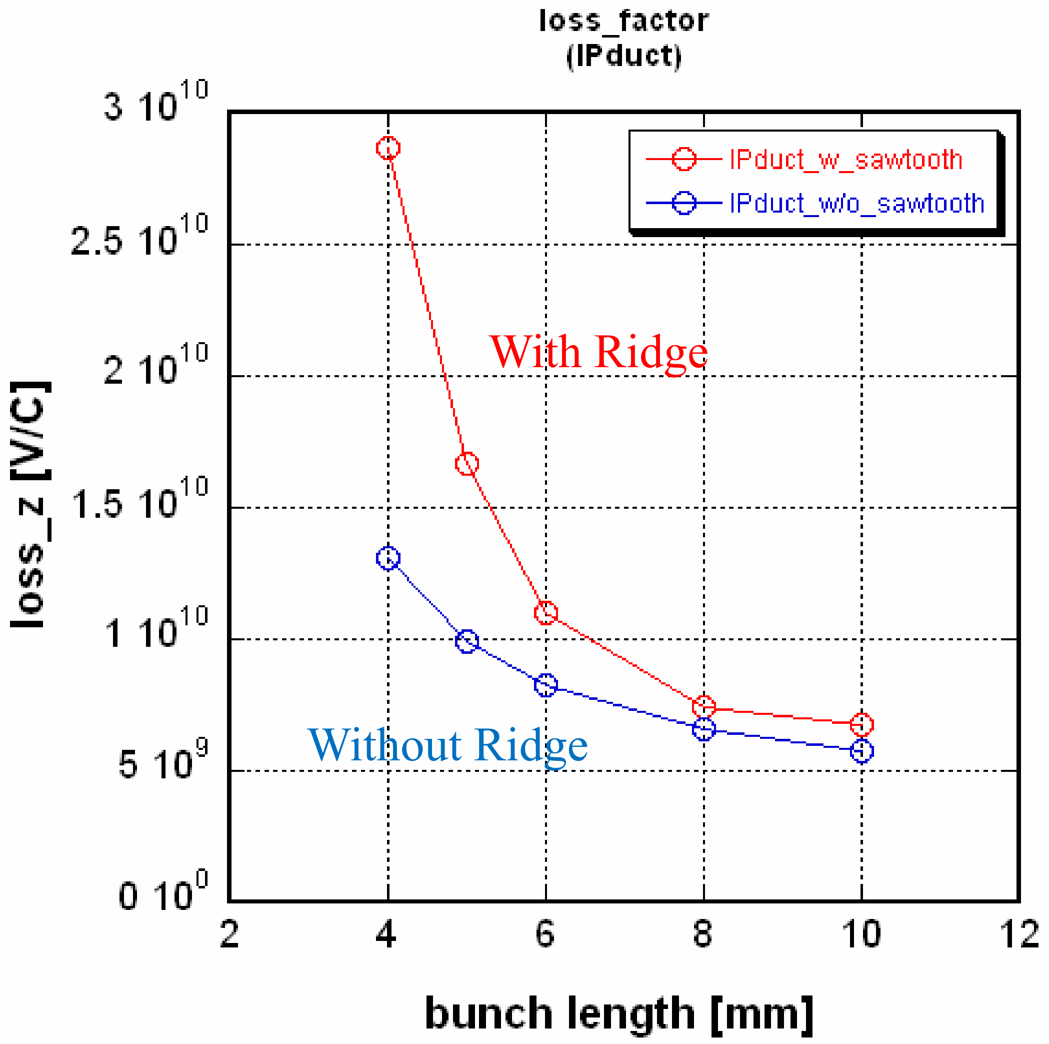


A disk with a diameter of 24mm in front of the Be pipe. This disk should be free from scattered photons.

The narrowest aperture must be a ridge, of course.

Only single scattering is taken into account. Test machining is in progress.

2. IP Chamber
Loss Factor (of HER beam)



(Shibata)

Loss factor [V/C]

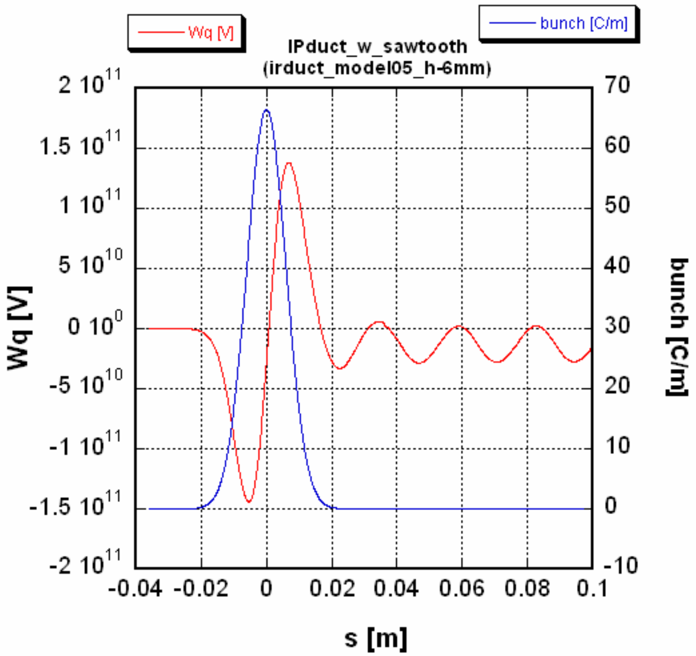
Bunch length [mm]	With Ridge	Without Ridge
3		
4	2.87E+10	1.31E+10
5	1.67E+10	9.92E+09
6	1.10E+10	8.28E+09
8	7.38E+09	6.62E+09
10	6.73E+09	5.78E+09

Power loss [W]
(current : 2.62 A, bunch spacing:4 ns)

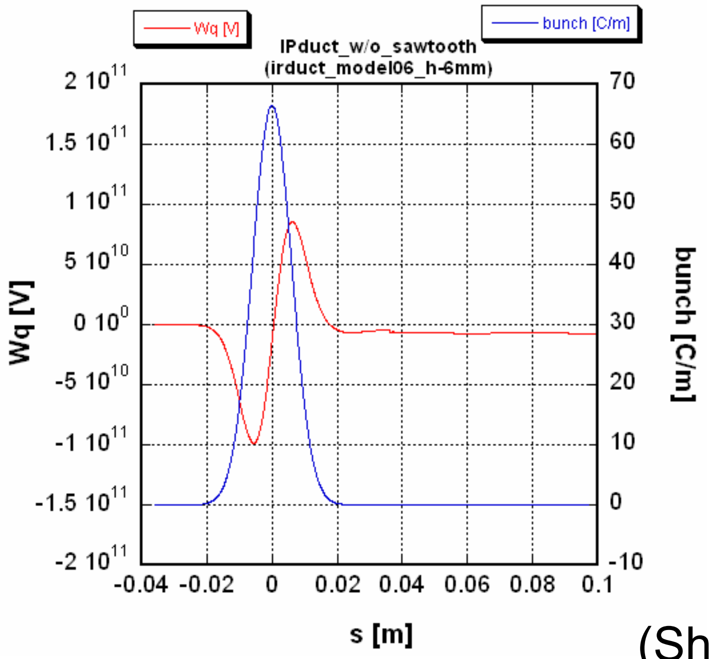
Bunch length [mm]	With Ridge	Without Ridge
3		
4	7.88E+02	3.60E+02
5	4.58E+02	2.72E+02
6	3.03E+02	2.27E+02
8	2.03E+02	1.82E+02
10	1.85E+02	1.59E+02

2. IP Chamber
Longitudinal Wake Potential (of HER beam)

With Ridges



No Ridges Bunch length = 6 mm

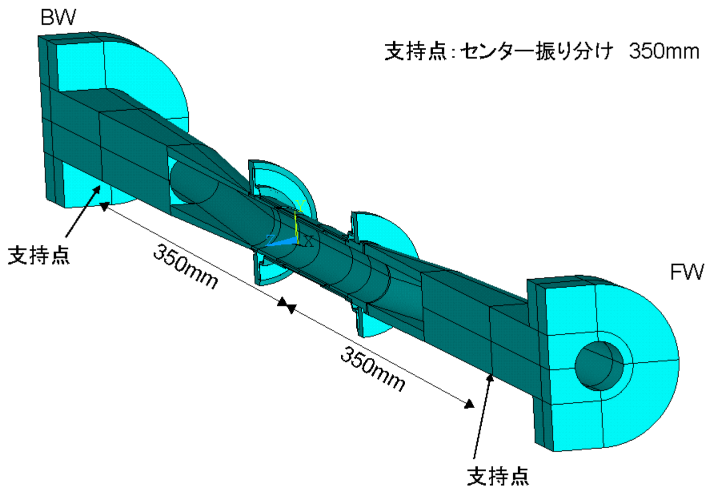


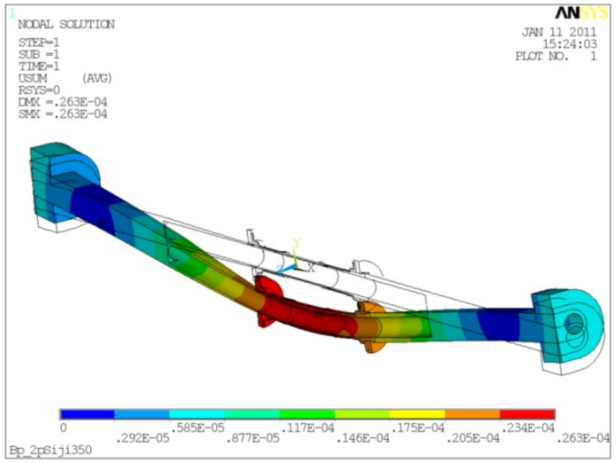
(Shibata)

With a ridge structure, a long oscillating wake appears. The effect of this wake is now under study.
The estimation of the transverse impedance is also to be done.

2. IP Chamber Stress Analysis

(Koike)





変位：Max 0.026mm

Results of stress analysis of the IP chamber

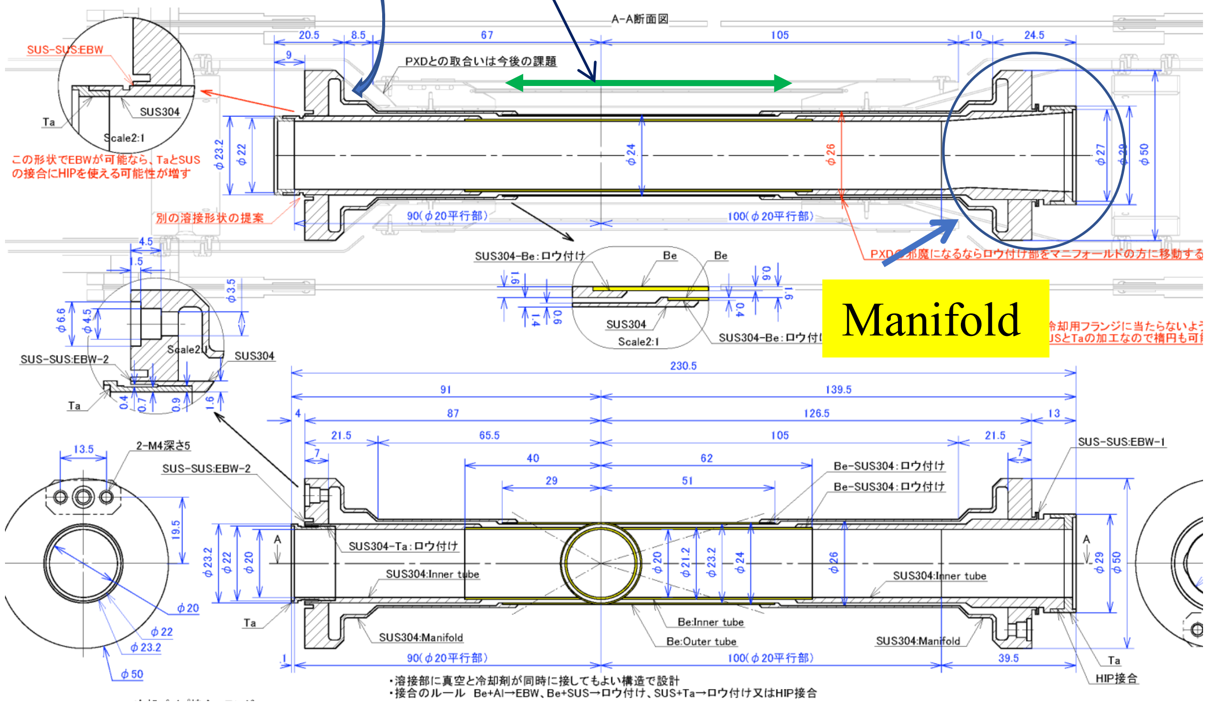
- Even if the chamber is horizontally supported at one end , the maximum stress in the Be part (157 MPa) is less than its yield strength (245 MPa). (It doesn't break!)
- If the chamber is supported at both ends, the central part bend down 0.44 mm, and the stress in the Be tube is 39 MPa.
- If the chamber is supported at the proper position of the Y-shaped part, the central part bend down only 0.026 mm (above picture), and the stress of Be pipe becomes as small as 3.5 MPa.

Therefore, though IP chamber has a delicate built structure, it is not so weak as to require a help of a special supporting tool in handling.

1. IP Chamber Central Part

Diaphragm to absorb the change of the length of Be pipes.

Be double tube

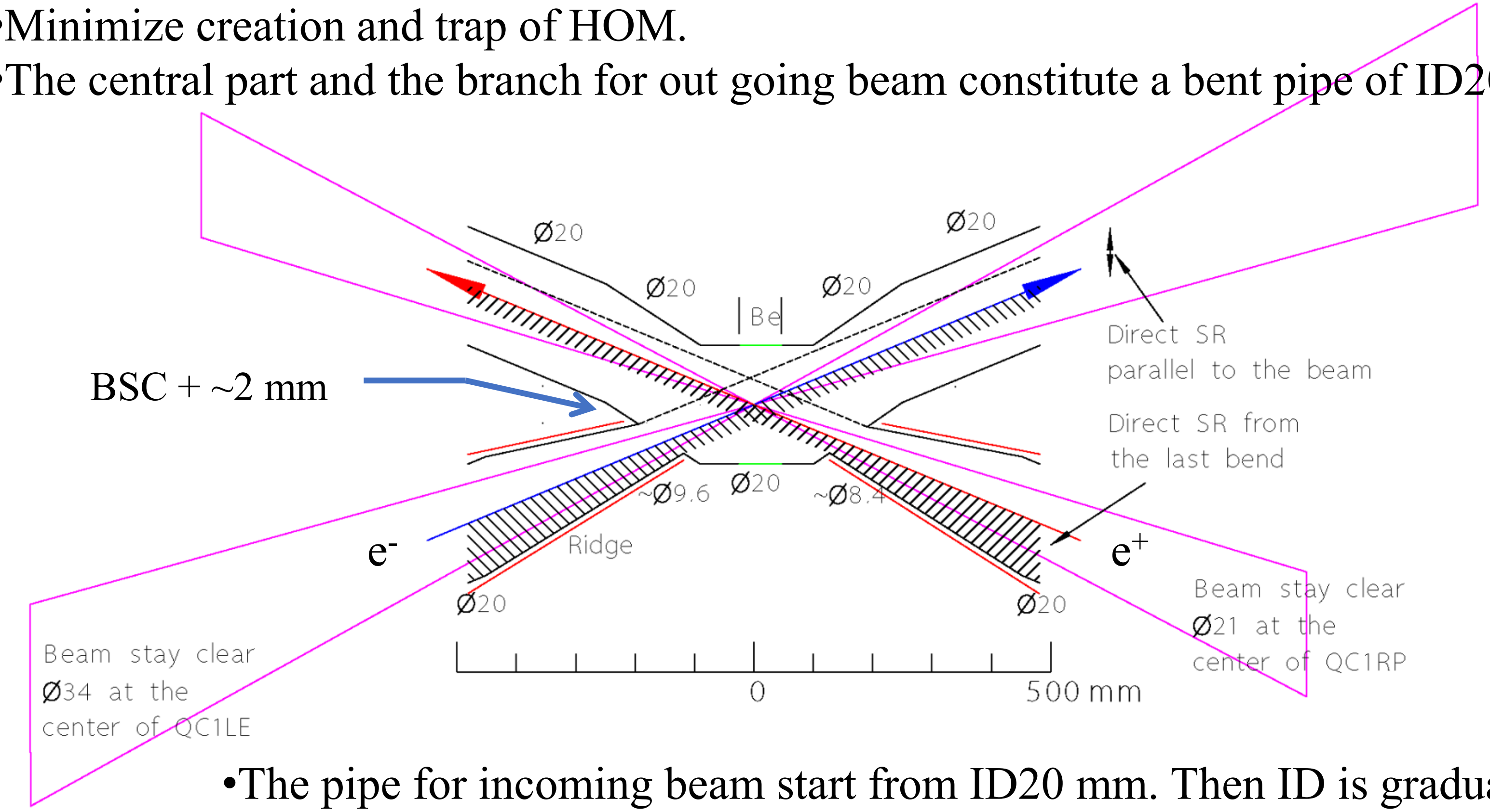


(Kohriki)

- The central part of the central part is a Be double tube. The gap is a space for a coolant.
- The coolant is paraffin. The flow of paraffin can absorb a heat of ~270W for a temperature rise of 10℃. (Estimated heat load from the beam is less than 100W.)
- In this design, it is permitted to put a weld seam between paraffin and vacuum.
- At first, the manifolds at the end of a Be pipe is designed to be made of stainless steel. The material is changed to Ti according to the result of stress analysis.

1. IP Chamber
Design features

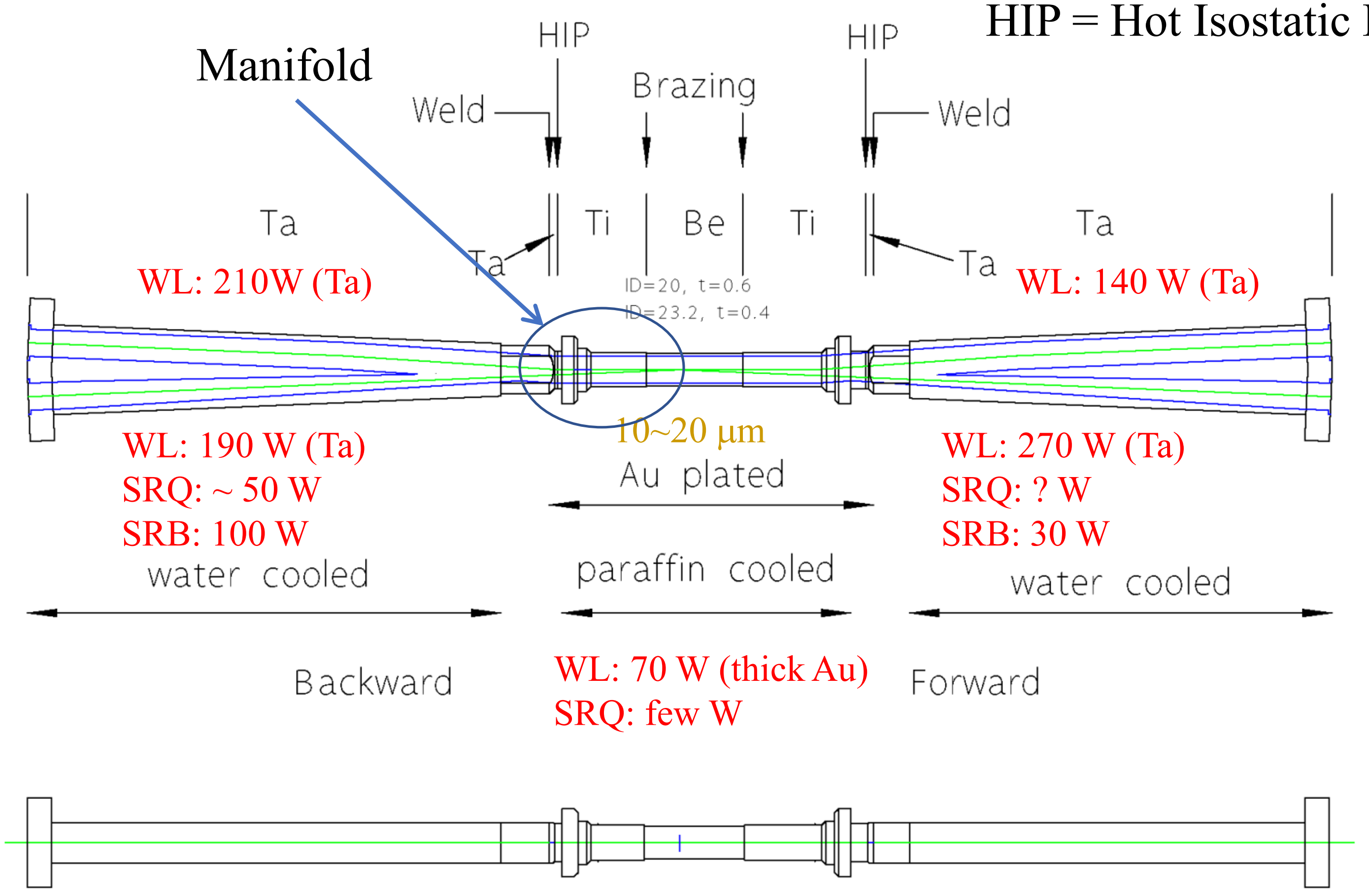
- Minimize creation and trap of HOM.
- The central part and the branch for out going beam constitute a bent pipe of ID20mm.



- The pipe for incoming beam start from ID20 mm. Then ID is gradually reduced to about 9 mm to stop direct SR. Now the taper is longer than before.
- The inner surface of a pipe for incoming beam has ridges to prevent scattered light from hitting the central Be part.

1. IP Chamber
Fabrication issues

HIP = Hot Isostatic Pressing



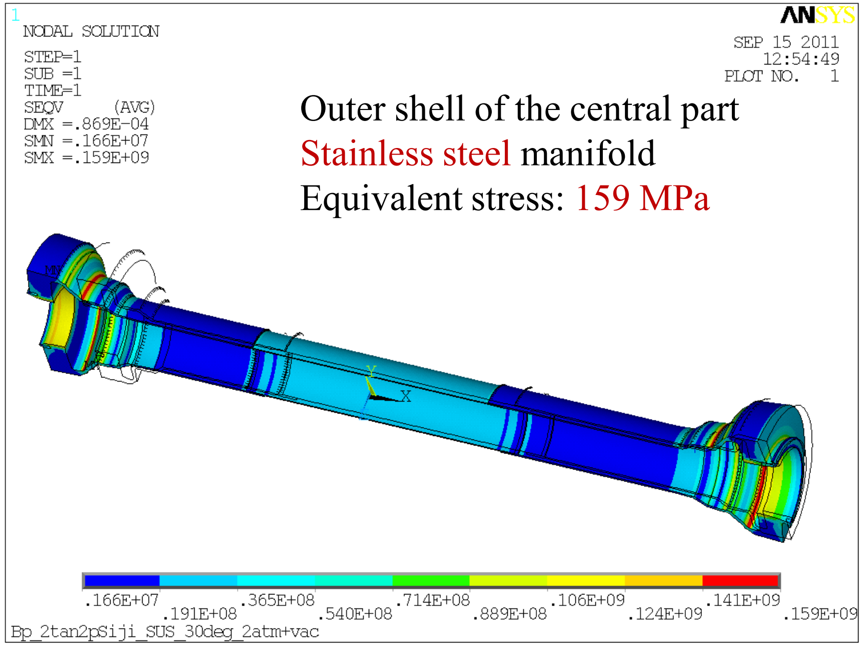
- A test for Be-Ti brazing and Ti-Ta HIP is now undergoing.

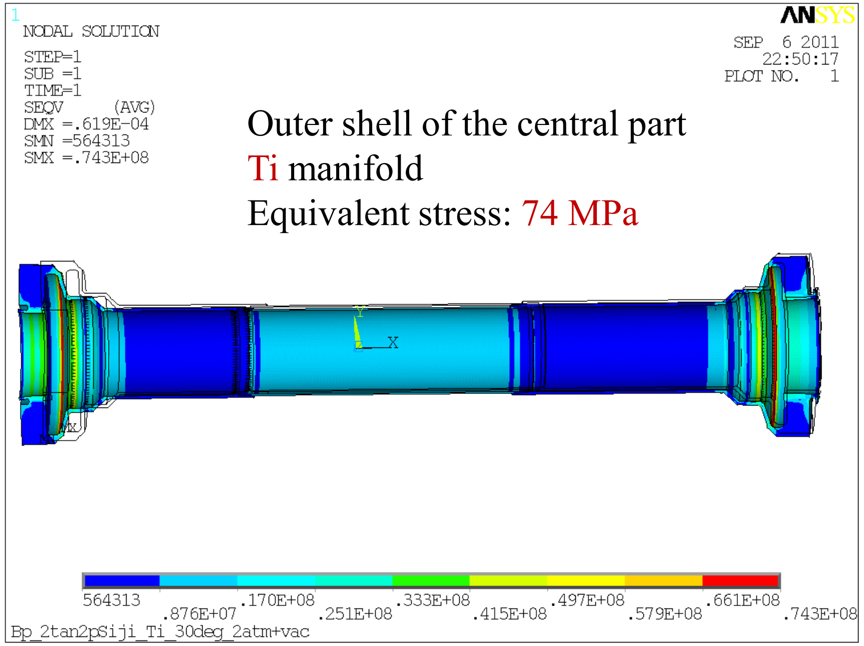
- Ti is adopted for the manifold instead of stainless steel to reduce the stress (the following slides).

Thin (1~2 mm) Au coat to reduce ohmic power loss on Ti and Ta is an option.

1. IP Chamber Stress analysis

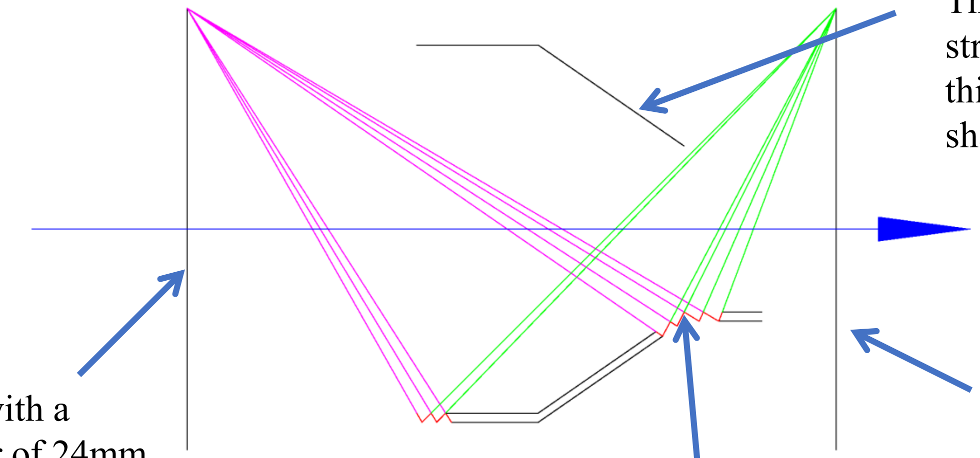
(Koike)





- Under the temperature difference of 30°C between the inner and the outer Be pipe causes an equivalent stress of 159 MPa in a stainless steel manifold, which is about 80% of the yield strength of stainless steel (206 MPa).
- Therefore Ti is adopted instead of stainless steel for the manifold. The equivalent stress for Ti under the same condition is 74 MPa while the yield strength of Ti is 170 MPa.

1. IP Chamber
Ridge shape (original idea)



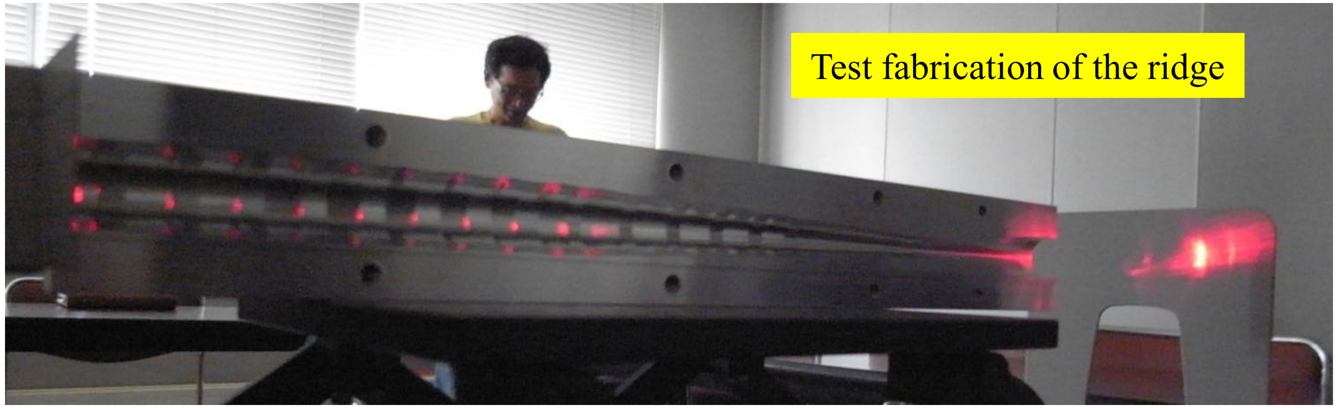
Thin wall around here cannot has a ridge structure. However, scattered photons from this part enter the central pipe with a shallow angle and give no serious effect.

A disk with a diameter of 24mm in front of the Be pipe.
This disk should be free from scattered photons.

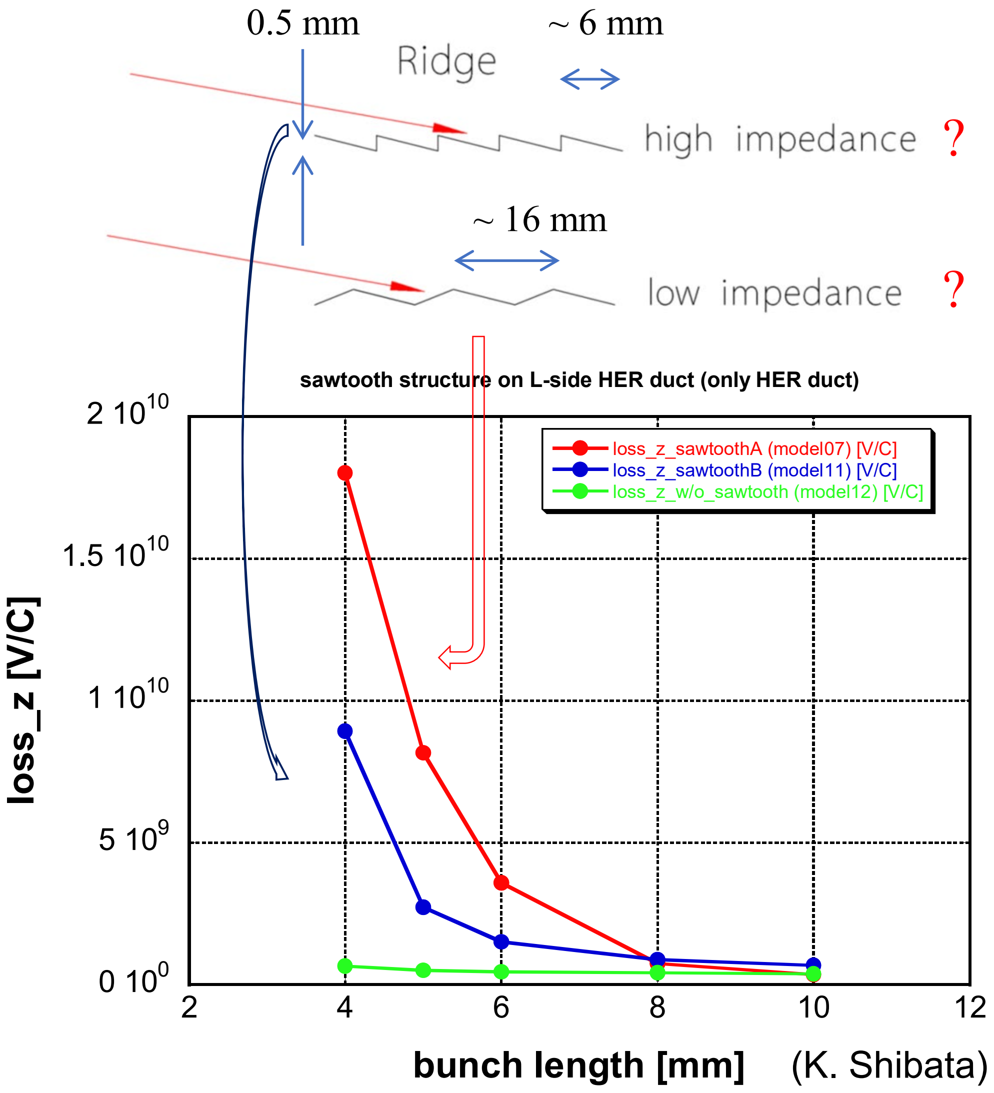
A disk with a diameter of 24mm. The position is the nearest end of a photon production region.

The narrowest aperture must be a ridge, of course.

Only single scattering is taken into account.



1. IP Chamber
Consideration on ridge shape



Low risk for multiply scattered photon to escape forward

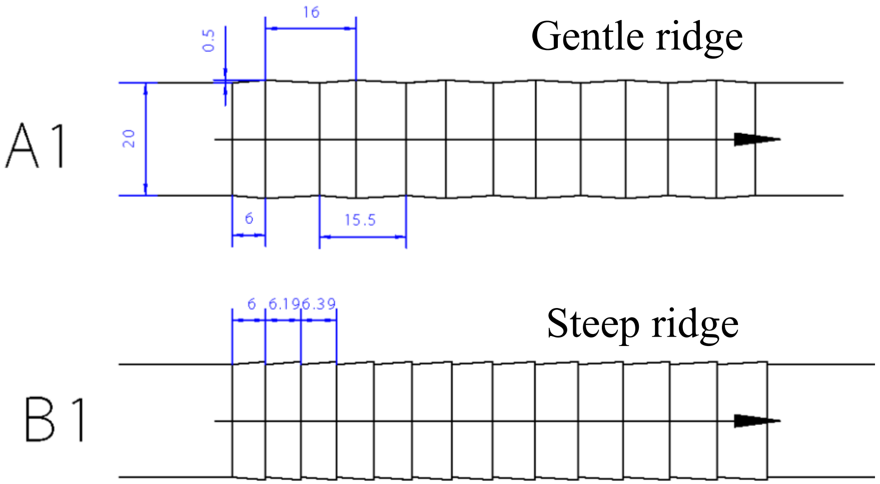
Risk for multiply scattered photon to escape forward

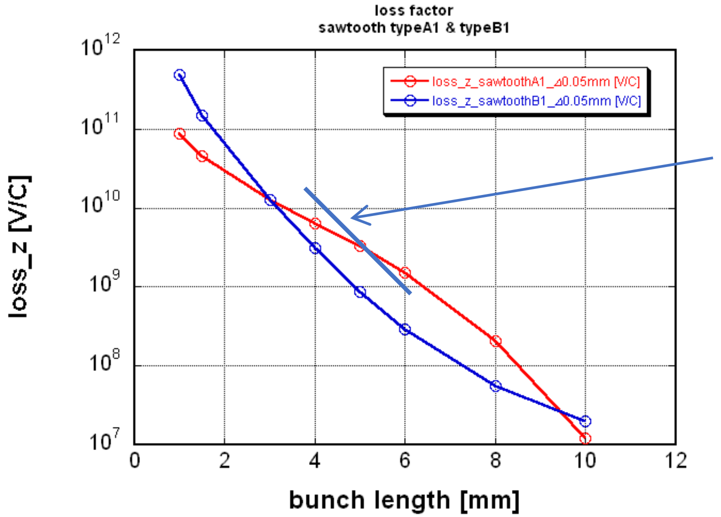
Against intuition, the loss factor of the shape with a vertical face is lower. The shape of ridges will be changed to similar one shown in the upper figure.

The contribution of the tip scattering on the top of a ridge is experimentally studied by Z. Murakami and S. Tanaka. Its effect in SR shielding is not serious.

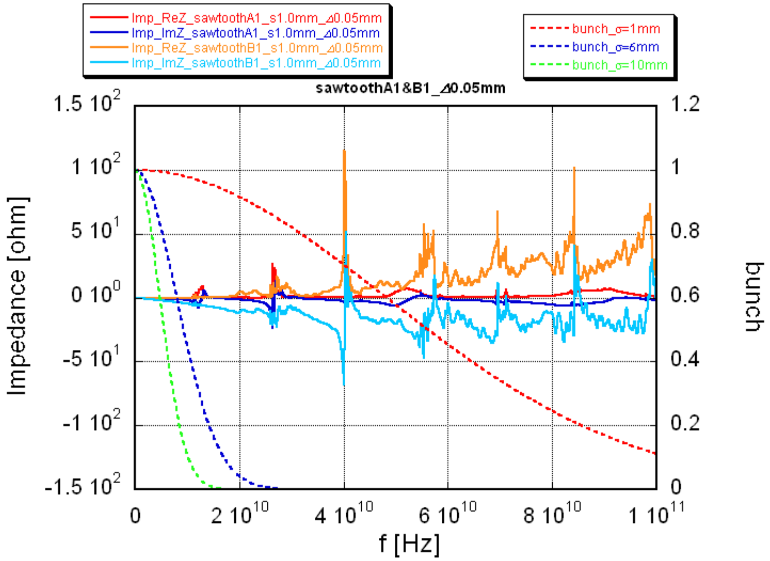
IP Chamber

Are steep ridges permissible?





New ridge



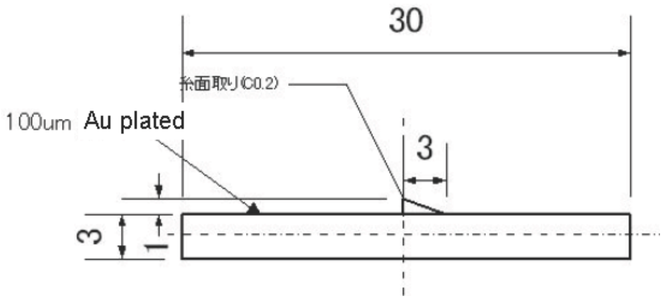
Since the height of the ridge is only 0.5 mm, structures of impedance due to the sharpness of ridges appears in higher frequencies than a 6mm bunch spectrum.

Steep ridges are OK.

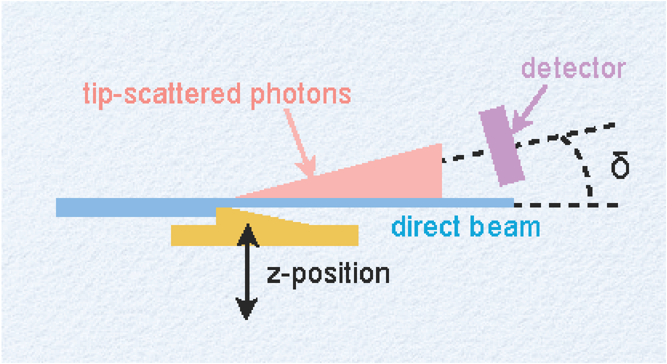
(K. Shibata, Y.H. Chin)

IP Chamber

Tip scattering on a ridge



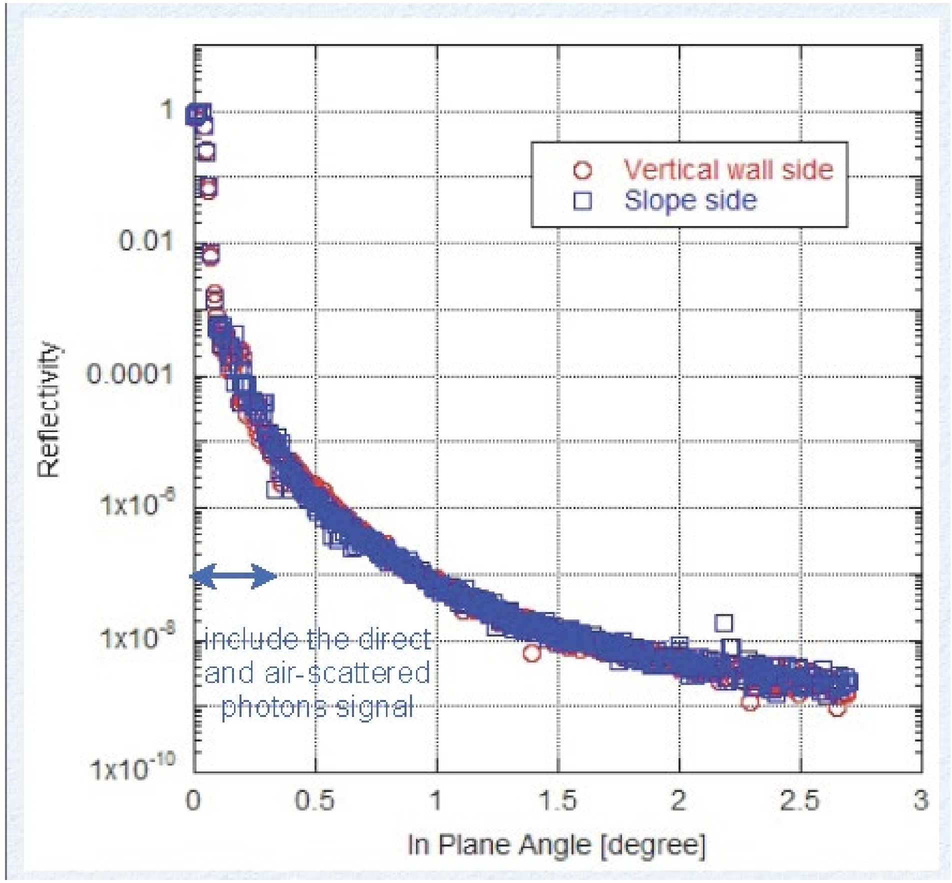
Ta sample



Set up

CHESS (Cornell Univ.) G2 beam line
Photon energy : 9 keV
Slit : 2 mm (H) by 0.05 mm (V)
Detector angular resolution : 0.2 degree (FWHM)

T. Ishibashi, et al



Ratio of the scattered photon. The slope of the taper inside the pipe is 1.23 degree.

Pressure Estimation

The 15th KEKB ARC
15 February 2010

	A	B	C	
Length	1.14	0.5	1.12	m
Radius	0.01	0.015	0.03	m
Conductance (C_X)	1.08×10^{-3}	8.29×10^{-3}	2.96×10^{-2}	$m^3 s^{-1}$
Photon load	1.84×10^{18}	2.60×10^{18}	3.03×10^{18}	Photons s^{-1}
Gas load (Q_X)	$7.45 \times 10^{-3} \eta$	$1.05 \times 10^{-2} \eta$	$1.23 \times 10^{-2} \eta$	Pa m^3 s^{-1}

η: Photo-desorption Coefficient

Simplified model for the incoming positron line

P_0 : Pressure at the pump (pumping speed $= S$)

$$P_0 = \frac{\sum_{X=A,B,C} Q_X}{S} = 1.01\eta \quad [\text{Pa}] \quad (S = 0.03\ \text{m}^3 s^{-1})$$

$$P_{IP} = P_0 + \frac{1}{2} \sum_{X=A,B,C} \frac{Q_X}{C_X} + \frac{Q_A + Q_B}{C_C} + \frac{Q_A}{C_B} = P_0 + 5.8\eta \quad [\text{Pa}]$$

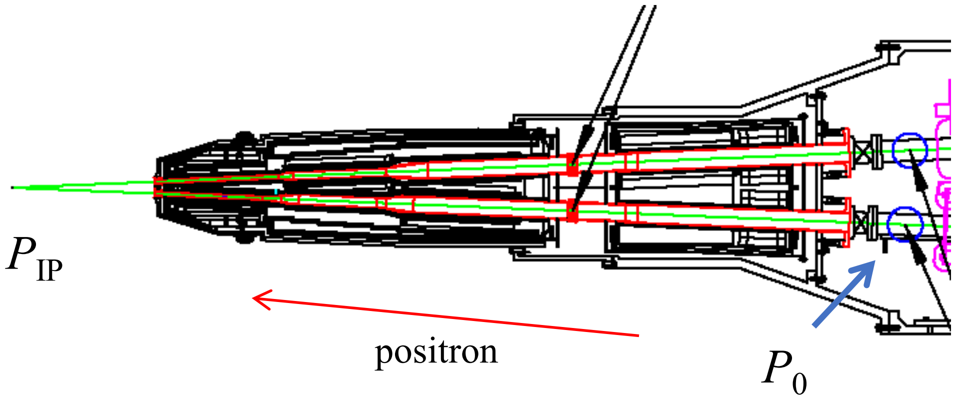
$$\eta = 10^{-5} \quad (\text{after} \sim 10^{24}\ \text{photons m}^{-1})$$

See slide 22

$$\rightarrow P_0 = 1.0 \times 10^{-5} \quad [\text{Pa}], \quad P_{IP} = 6.8 \times 10^{-5} \quad [\text{Pa}]$$

Small conductance and limited space for pumping result in a high pressure around IP. However according to the background study using a pressure bump in the present KEKB, these pressures seem to be acceptable.

2. Vacuum around IR
Rough estimation of pressure



Thermal only

$P_0 = 2\times10^{-7}$ Pa

$P_{IP} = 8\times10^{-7}$ Pa

Photon-desorption dominant

$P_0 = 2\times\eta$ Pa

$P_{IP} = 11\times\eta$ Pa

η : photo-desorption coefficient

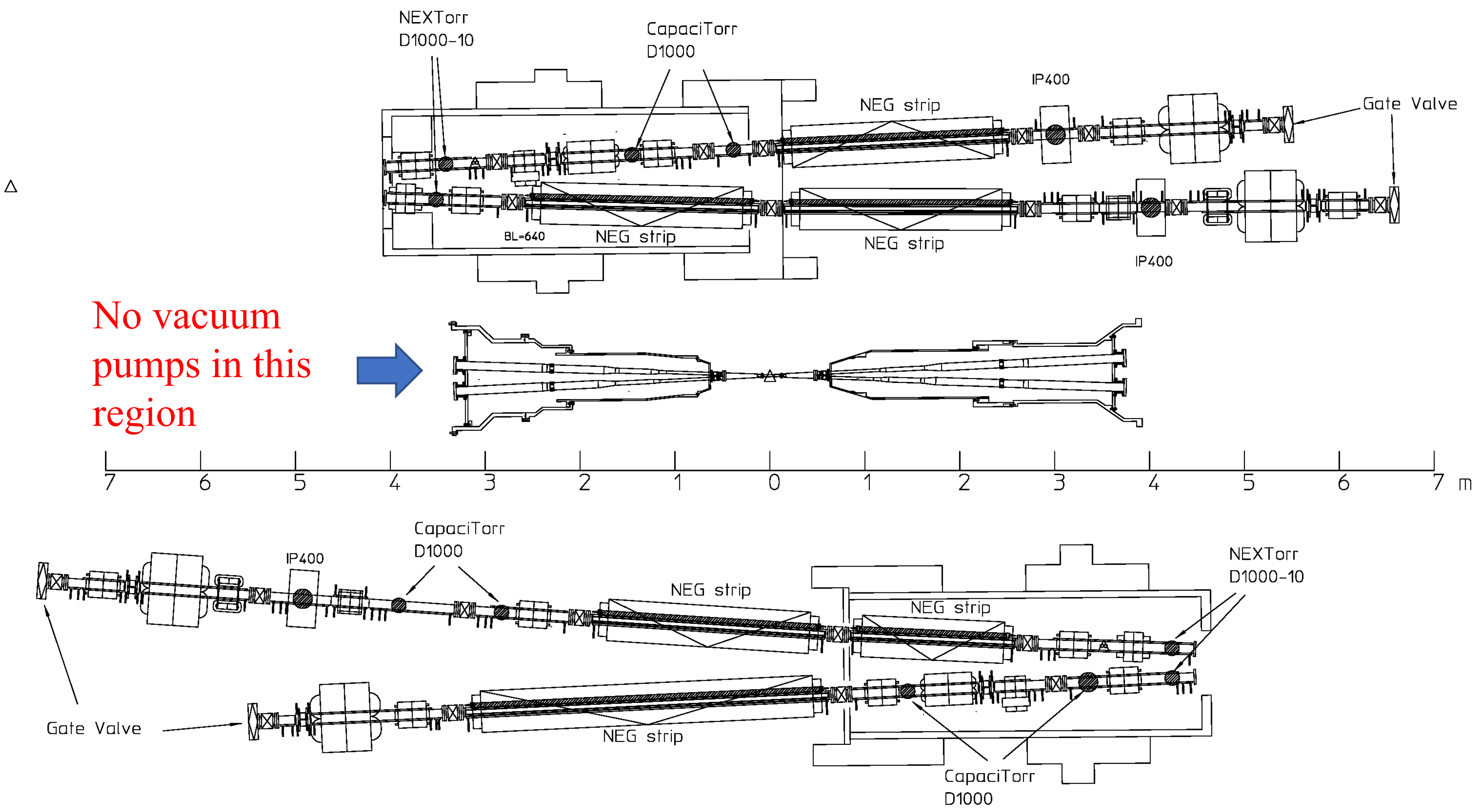
Example: Incoming positron line
Assumptions:

- The equation for a long tube gives good estimation for a short tube
- At IP pressure is maximum
- P_0 is determined by the total outgassing of the cryostat beam pipe and the pumping speed there (50 l/s).
- The thermal outgassing rate is 1×10^{-11} Torr*l*/s/cm^2 (1.33×10^{-8} Pa m^3/s/m^2).

The difference between P_0 and P_{IP} is determined by the local outgassing and the conductance of the beam pipe. It doesn't depend on the pumping speed outside the cryostat.

Vacuum system of IR

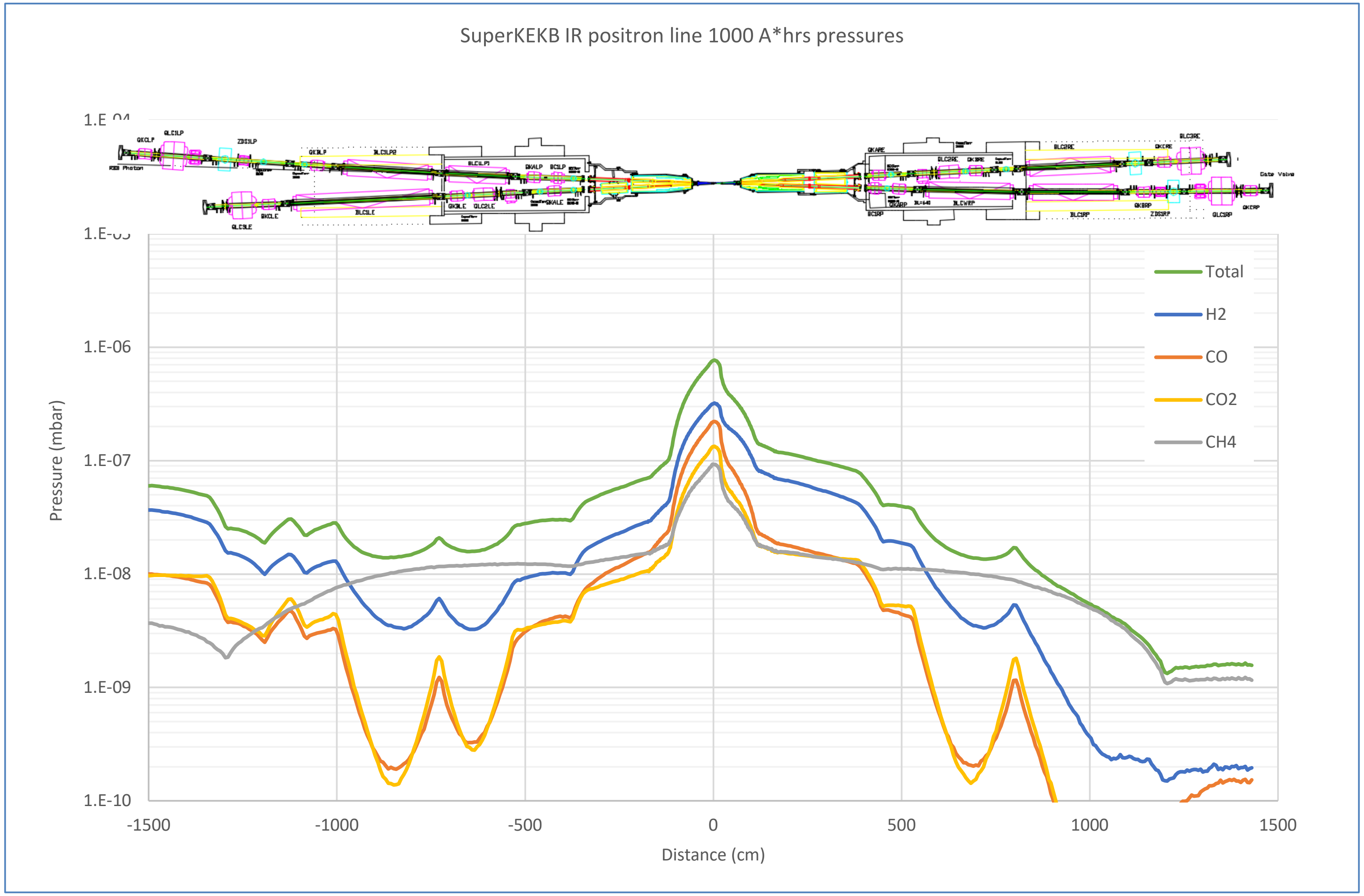
The 21th KEKB ARC
13-15 June 2016



The 21th KEKB ARC
13-15 June 2016

Issues relating to IR vacuum

Pressure distribution



Thanks to J. Carter (ANL), M. Ady, R. Kersevan, and P. Chiggiato (CERN)

R&D

Fabrication issue

- Cleared
  - Stress analysis
    - For the temperature difference between the two tubes at the center.
    - Changing support position of beam pipe
  - Fabrication test
    - Precise machining of Be pipes
    - NC machining of ridges
    - Be-Ti brazing
    - Ti-Ta HIP
    - EBW near by HIP
    - Pulsed sputter coating of Cu inside 2 cm Al pipe and its uniformity check
- To be done (in preparation)
  - Stress analysis
    - Check the strength under dynamic force
  - Fabrication test
    - Au coating on Ti pipe
    - Effect of EBW on the coating
    - Simulation welding between inner and outer Ti pipe

Scientific issue

- Background simulation
- Understanding tip-scattering of photon on a ridge

Superkekb mechanical assembly at IR

Workshop on the mechanical optimization of the FCC-ee MDI

30 Jan – 9 Feb, 2018, CERN

Ken-ichi Kanazawa

KEK Accelerator Laboratory

IP chamber R&D

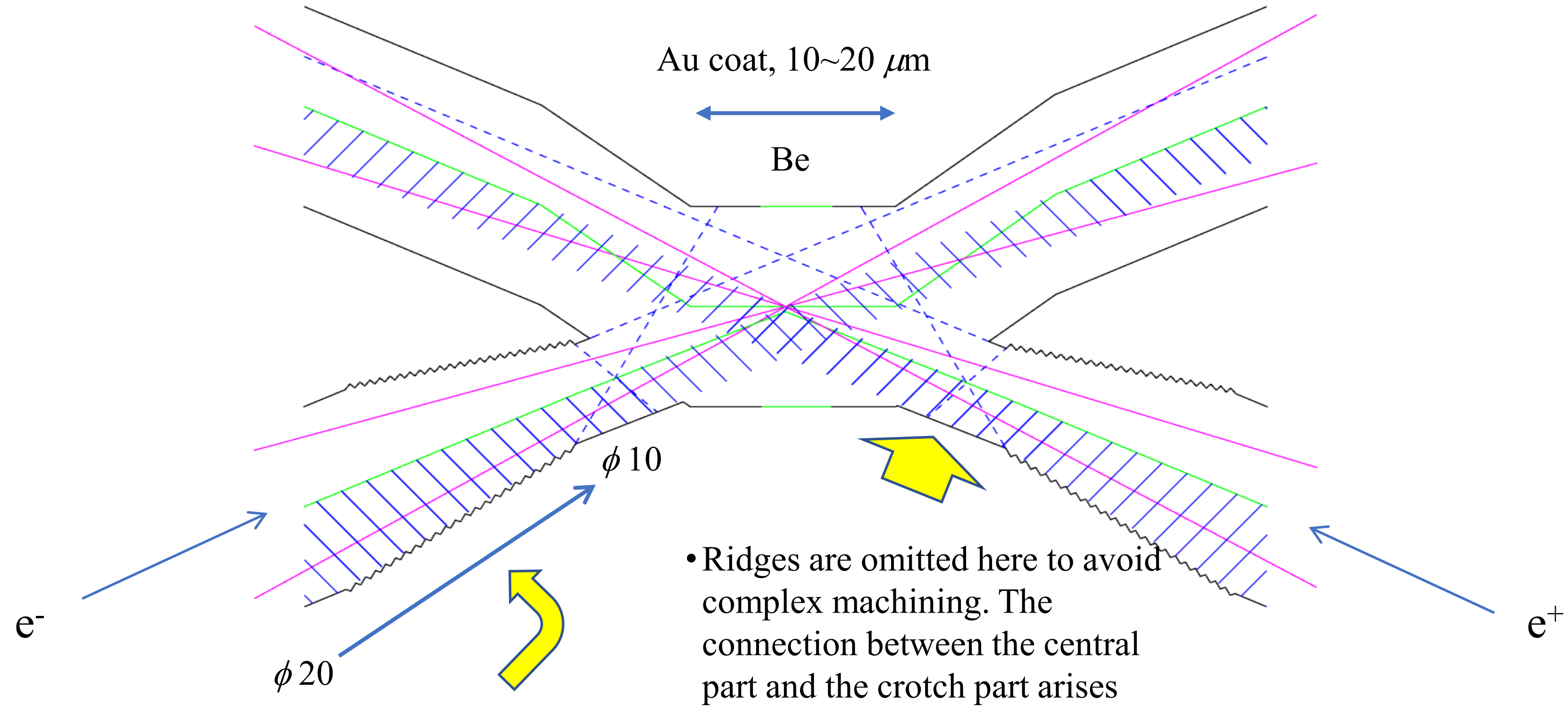
- Related works performed for the design and production of IP chamber
  - Cooling test of the central part using a dummy model
  - Mechanical analysis
  - Impedance estimation
  - Measurement of tip-scattering of photon on a ridge
  - Photon-induced desorption measurement of Au coat, Cu, and Ta
  - Estimation of SR background inside chamber
  - DC sputter coating test
  - HIP and welding test under various conditions

Ref.

K. Kanazawa, The 18th KEKB Accelerator Review Committee, KEK, 4-6 March 2013,

K. Kanazawa, 7th Belle PAC, 10 -11 March 2013, KEK

On Synchrotron Radiation

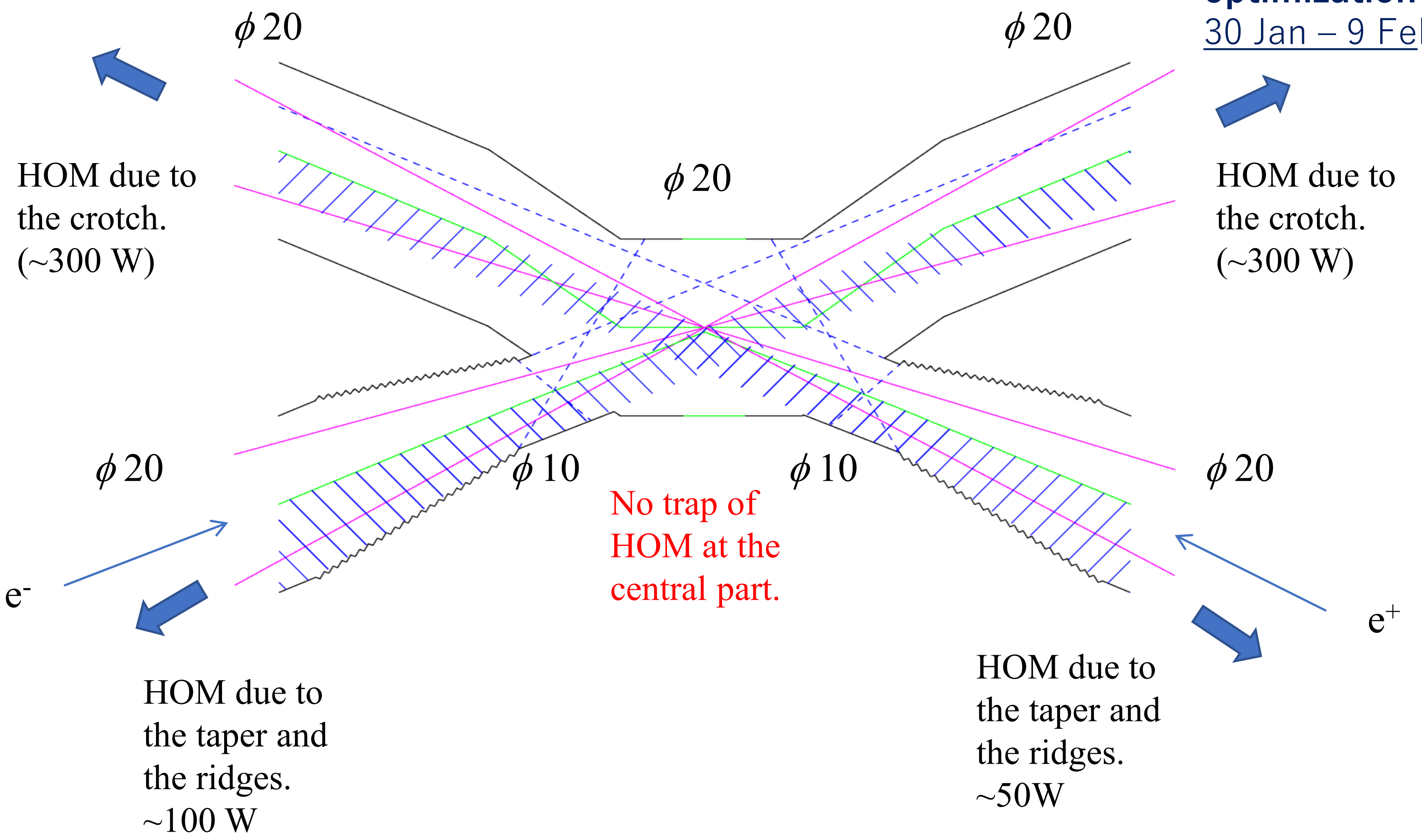


Taper: to reduce the number of photons entering into the central part
+
Ridges: to keep the direction of scattered photons away from Be

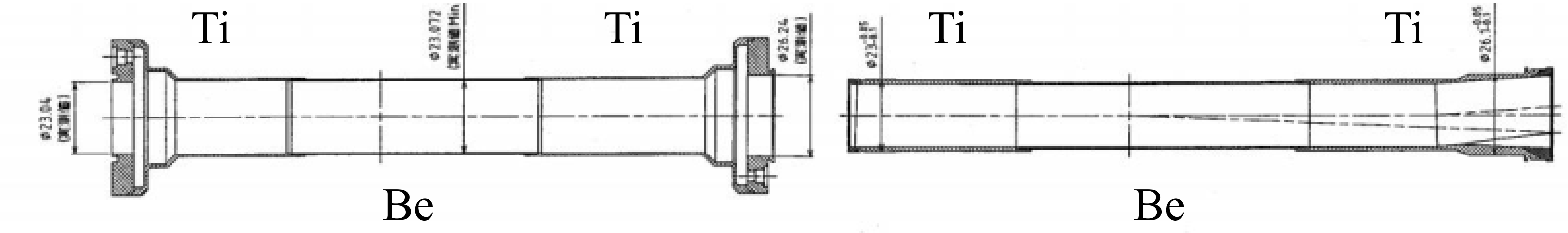
- Ridges are omitted here to avoid complex machining. The connection between the central part and the crotch part arises here.
- Instead, this part is slightly bent downward (in the drawing) to avoid the direct hit of SR from the last bend. At present, simulation shows no serious scattered photons from this part.

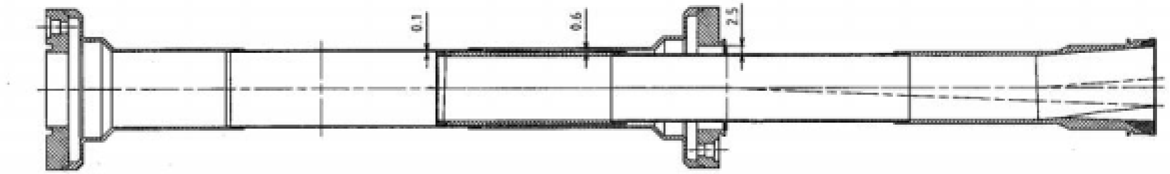
On Beam Induced Electro-magnetic Field (or HOM)

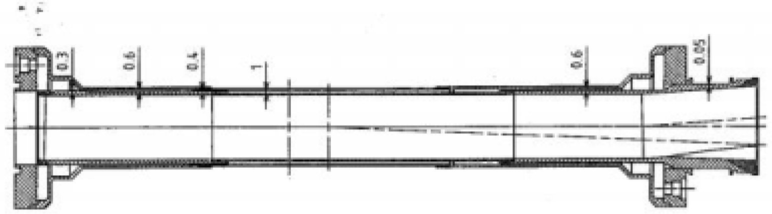
Workshop on the mechanical optimization of the FCC-ee MDI
30 Jan – 9 Feb, 2018, CERN

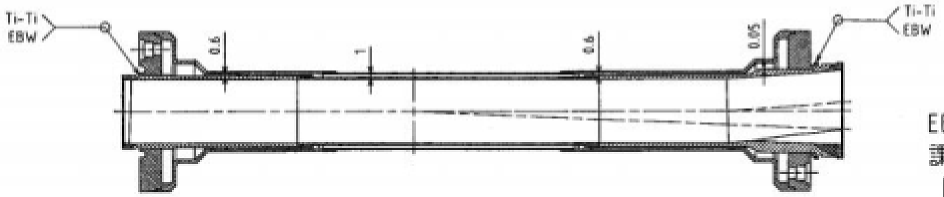


Central part of IP chamber









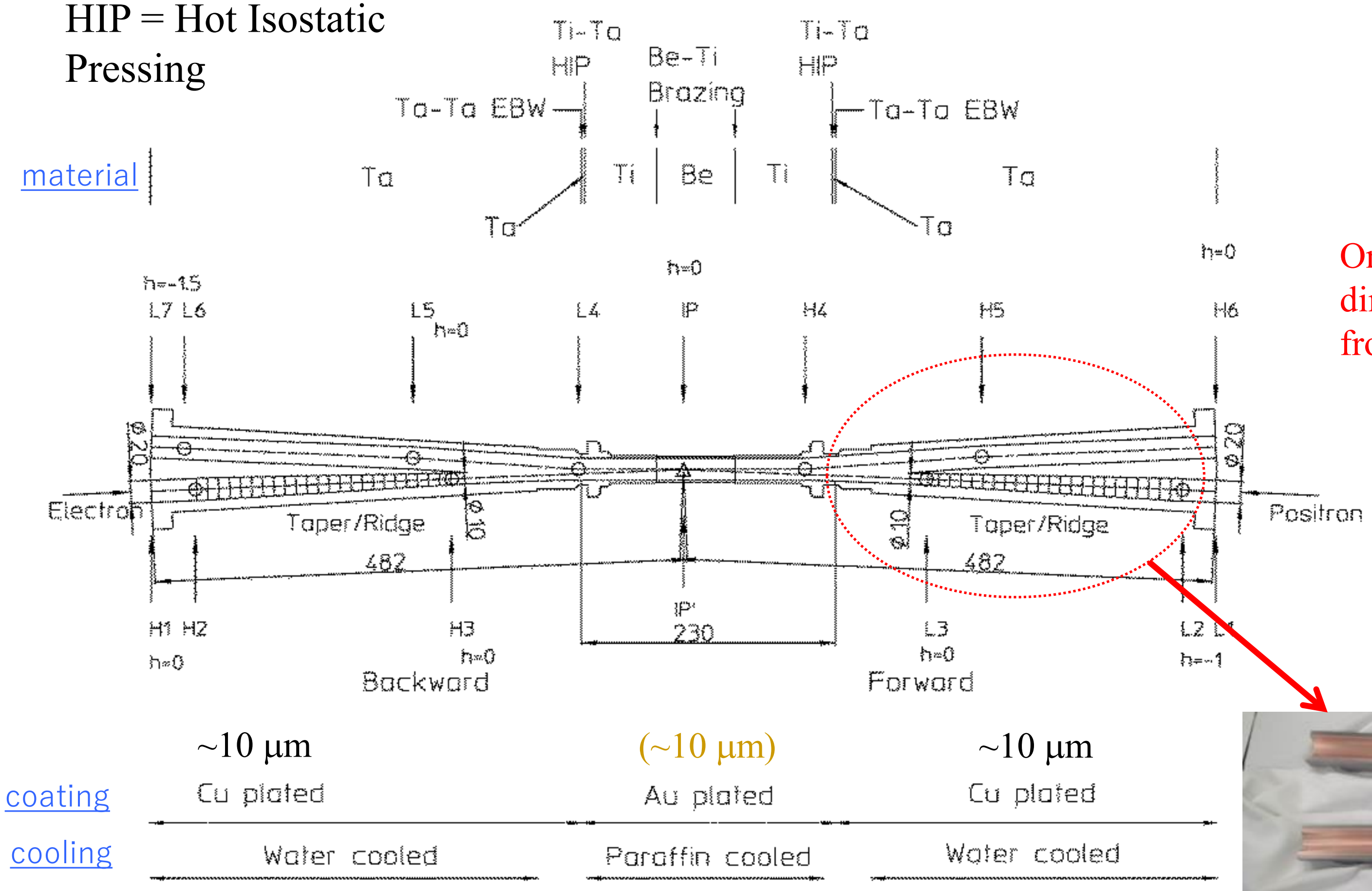
- The central straight part consists of double tube. Paraffin runs between them.
    - Outer Be: 0.4 mm thick
    - Inner Be: 0.6 mm thick
    - Gap: 1 mm
- The connection between double tubes is done by Ti-Ti EBW.

EBW(Ti-Ti)
課題
・Inner tubeがOuter tubeに挿入できるようにろう付の精度を上げると共に寸法公差の見直し。
・EBW施工時にベリリウムに負荷が加わらない治具の検討。

BEAST II installation

IP chamber: Design feature

HIP = Hot Isostatic Pressing

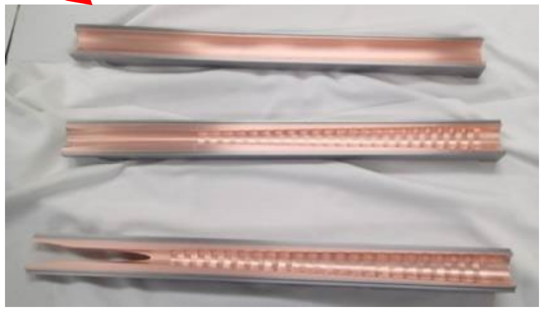


Beam space design with minimum trap of HOM at the central part.

ID of the beam passage ≤ QCS beam pipe (HOM propagates away.)
HOM is trapped at a merging volume of two passages.

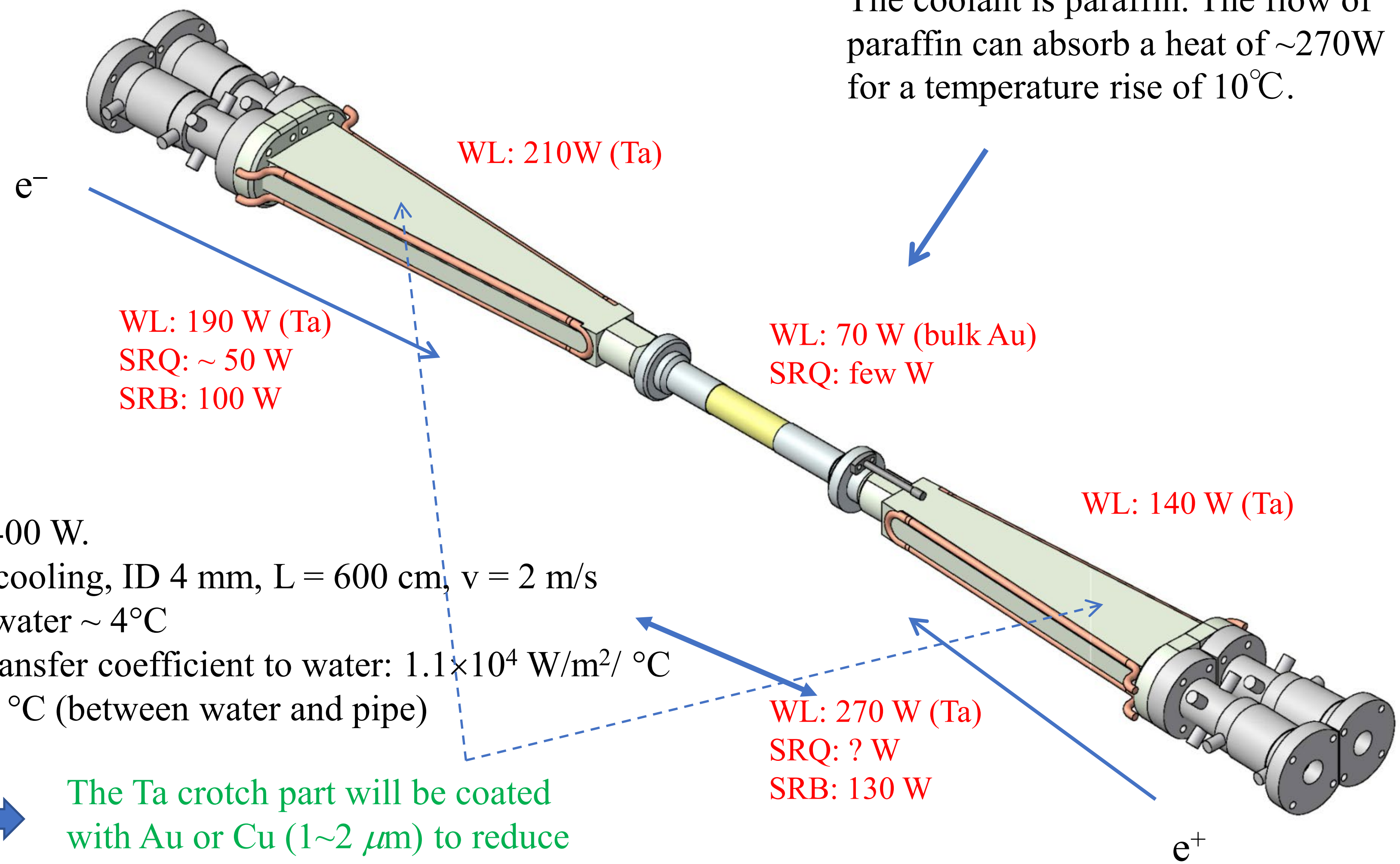
Only taper parts are exposed to direct synchrotron radiation from the last bend.

Taper: to reduce the number of photons entering into the central part
Ridges: to keep the direction of scattered photons away from Be



On Heat load

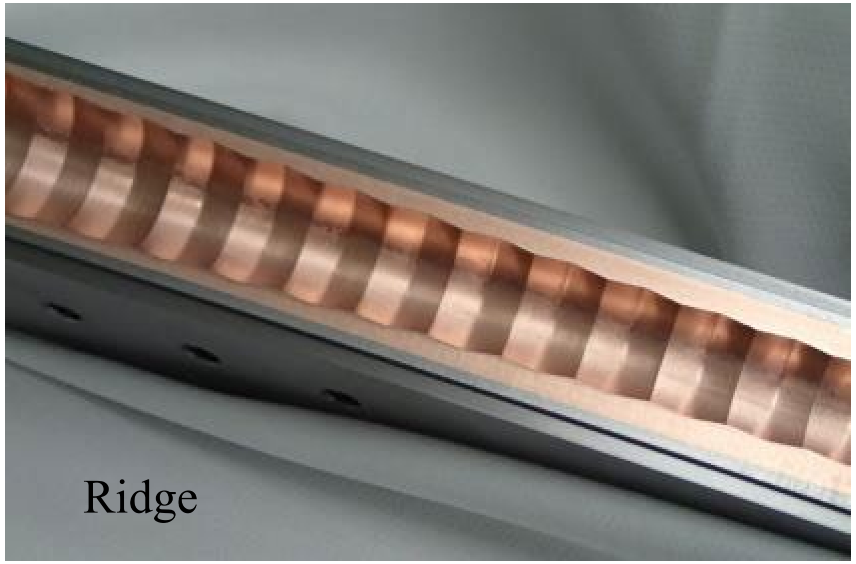
The coolant is paraffin. The flow of paraffin can absorb a heat of ~270W for a temperature rise of 10℃.

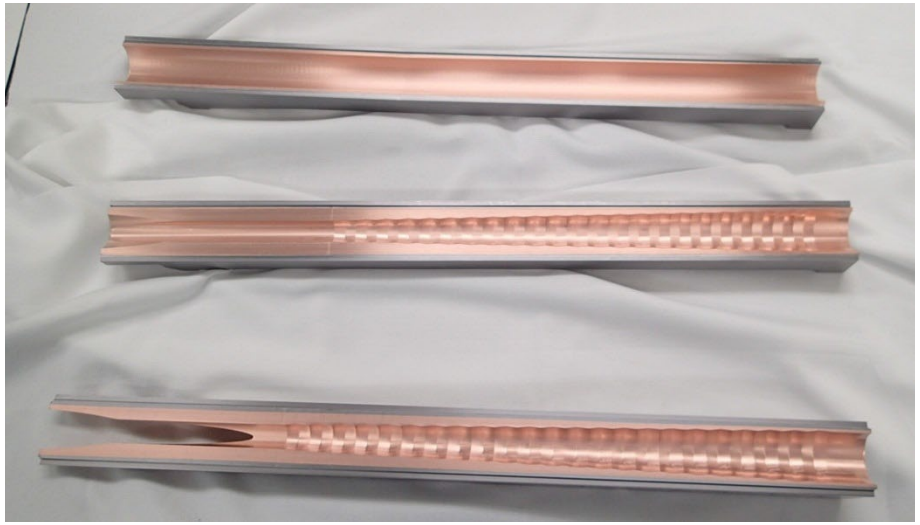


Heat: 400 W.
Water cooling, ID 4 mm, L = 600 cm, v = 2 m/s
ΔT of water ~ 4°C
Heat transfer coefficient to water: 1.1×10^4 W/m²/ °C
ΔT ~ 5 °C (between water and pipe)

The Ta crotch part will be coated with Au or Cu (1~2 μm) to reduce the wall loss.

IP chamber (Ta part manufacturing)



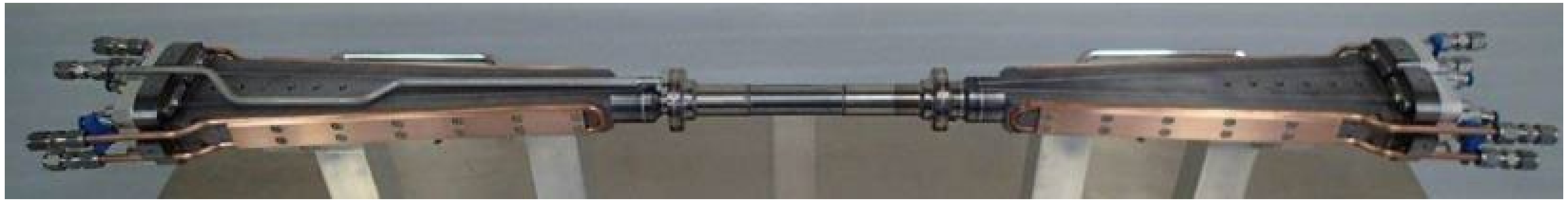


End flange

Metal Technology Co., Ltd

Phase 2 hardware

IP chamber



- The central straight part consists of double tube. Paraffin runs between them.
  - Outer Be: 0.4 mm thick
  - Inner Be: 0.6 mm thick
  - Gap: 1 mm

The IP chamber for Phase 2 is completed. The IP chamber for Phase 3 is needed before September 2017 when the assembly of VXD starts. Therefore, without feedback from Phase 2 experiences, the next chamber for Phase 3 must be fabricated.

SuperKEKB IPチェンバー（＋QCSダクト）の設計

１．衝突店回りの真空系

・衝突点の圧力はビームへの影響を考える限り他より一桁か二桁悪くてもよいとされるが、これはビーム寿命への影響に限った話で、ビーム・ガスによる測定器へのバックグラウンドを考えると、きちんと許容圧力を評価した方がよいかもしれない。

・ガス源と真空ポンプ

通常衝突点に近い変更電磁石からの放射光による動的ガス放出がガス源になる

真空ポンプのスペースを確保するのは難しい。NEG（コーティング）を用いるときは活性化の方法と手順をよく考える。

・熱源とその対応

通常衝突点に近い変更電磁石からの放射光が第一の熱源になる。ダクトの水冷が必要。二股部などに起因するHOMによる発熱が気になるが、HOMをトラップしなければ問題ない。

・QCSダクト

ビームパイプをクライオスタットと機械的に一体にするかどうかの決断が必要

２．IPチェンバー
１）いろいろな留意点
・有限交差角への対応はKEKBまでの経験をもとに設計・製作された。（KEKBまではIPチェンバーはBelleが製作した）
・衝突点付近は物質量の少ない直線パイプである。パイプの径と長さは、測定したい物理から決まるが、ビームが有限角度で交差しているので、直線部の両端ではビームが壁に接近する（水平方向のアパーチャーが片側狭くなる。）
・中央の直線部は高力さんが設計した。
・直線部の外側は二本のパイプになる。衝突点以外での衝突を避けるため、二つのビームの共有スペースに同時に4つ以上のバンチが存在することがないようにする。
・IPチェンバーの外を含めパイプの径を決めるときは、HOMを極力トラップしないというKEKB以来の原則に従っている。差部に少し広い空間が出来るが、体積は最小にする。衝突点から遠ざかるにつれてパイプの内径を大きくする。
ベータ関数の振る舞いには沿っていないので、ビームサイズで測ると最終収束磁石部分が小さくなる。
・HOMのトラップは覚悟で、HOMアブソーバーも含めて設計する考えもある。（PEPII）
・放射光を直接中央直線部（付近）にあてない。最終ベンドの向きが重要
・（一回）散乱した放射光をベリリウムパイプにあてない。リッジの形状。リッジ先端による放射光の散乱試験（石橋、コーネル）

２）形状の特徴
・入射パイプをテーパーで絞っている。放射光マスクの代わり。
・斜面で反射する放射光の散乱方向を制限するためにリッジを設ける。
・二つのパイプの交差部の空間は、それぞれのパイプのもとの内部空間の共通部分とし、それを広げる構造は避ける。
・HOMはチェンバー出口のパイプを伝わって出る。

３）不満足な点
・中央の直線部と両側の二股部の接続を（電子ビーム）溶接で行った。このような方法では接合部の構造を工夫しないと真直度を出すのは難しい。
・中央部のロー付けや、全体の電子ビームでの接合を縦置きで行うことを提案したが、採用されなかった。
ただし、中央部のロー付けは縦置きにするとベリリウムの片方にとっては都合がいいが、他方にとっては上下逆になる。
・二股部の肉厚と冷却構造を十分に時間をかけて検討すべきであった。