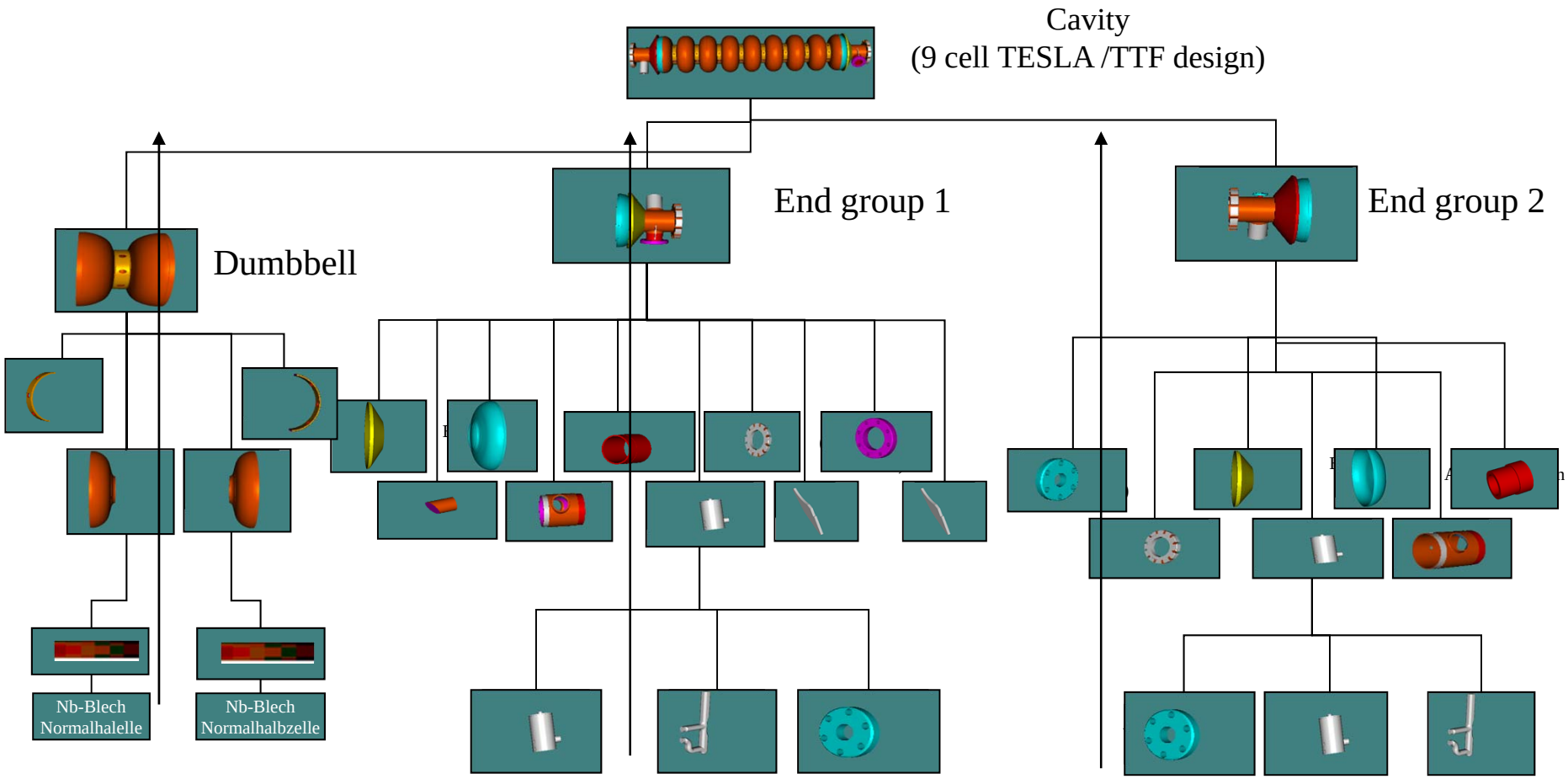
# 5. Fabrication of SRF Niobium Cavity

- **Deep Drawing**
- **Trimming**
- **Machining Error**
- **Beam tube fabrication**
- **EBW**

# Overview on cavity fabrication

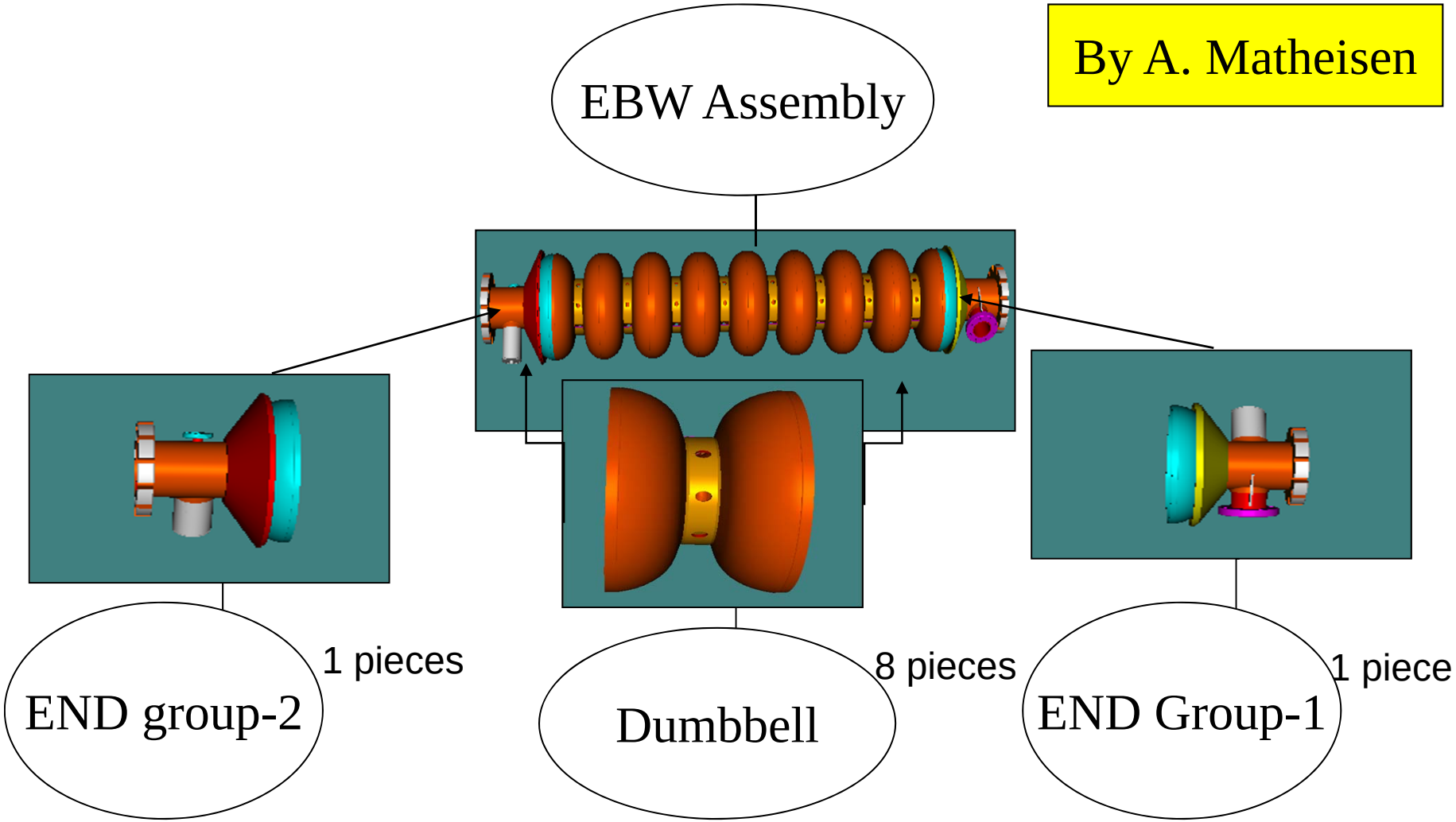



**Cavity fabrication and preparation sequences**
**for the TESLA / TTF cavities at DESY**

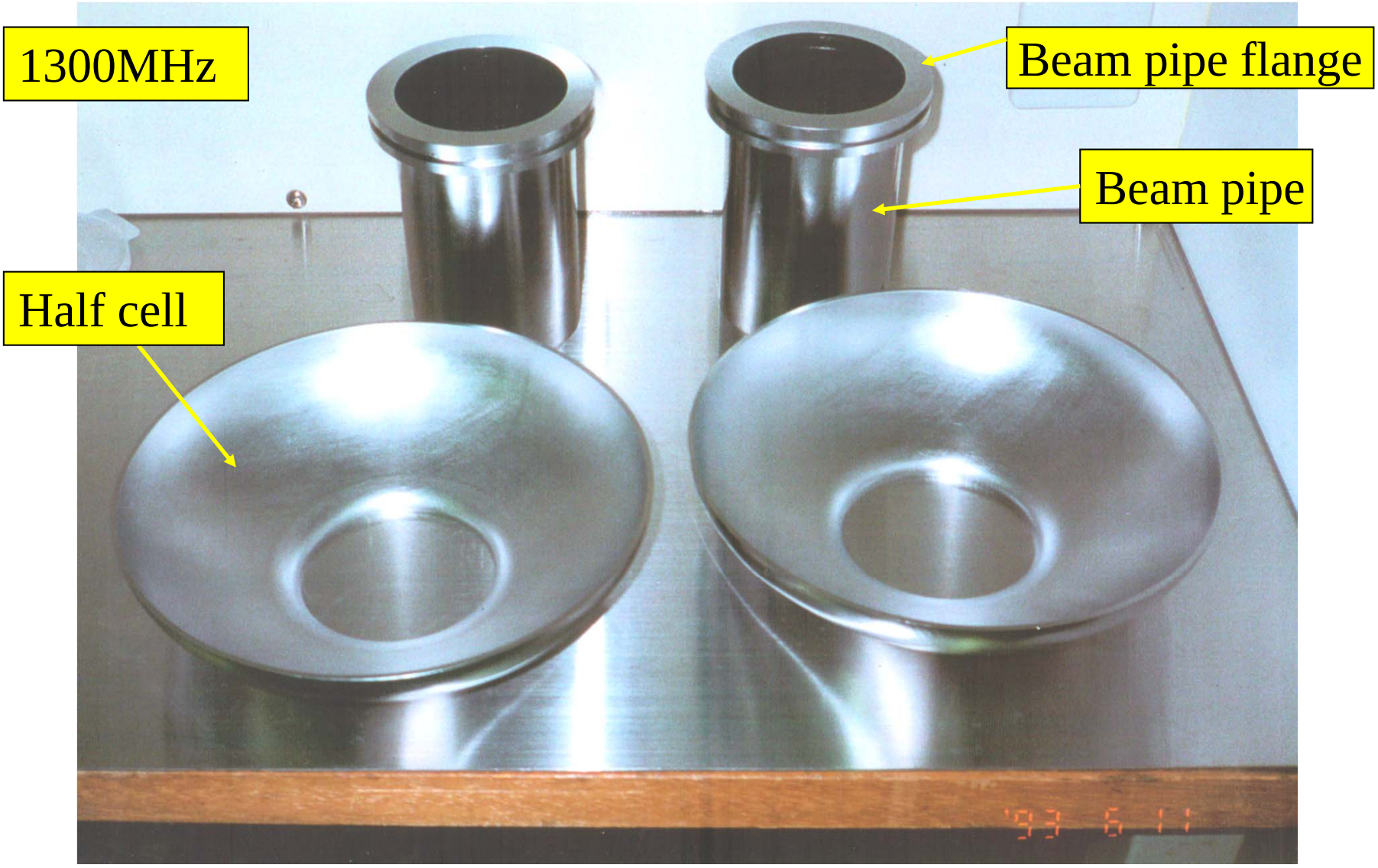
**1st ILC workshop at KEK Tsukuba Japan**
**A.Matheisen**
**for DESY and the TESLA Collaboration**

# Grouping of fabrication process

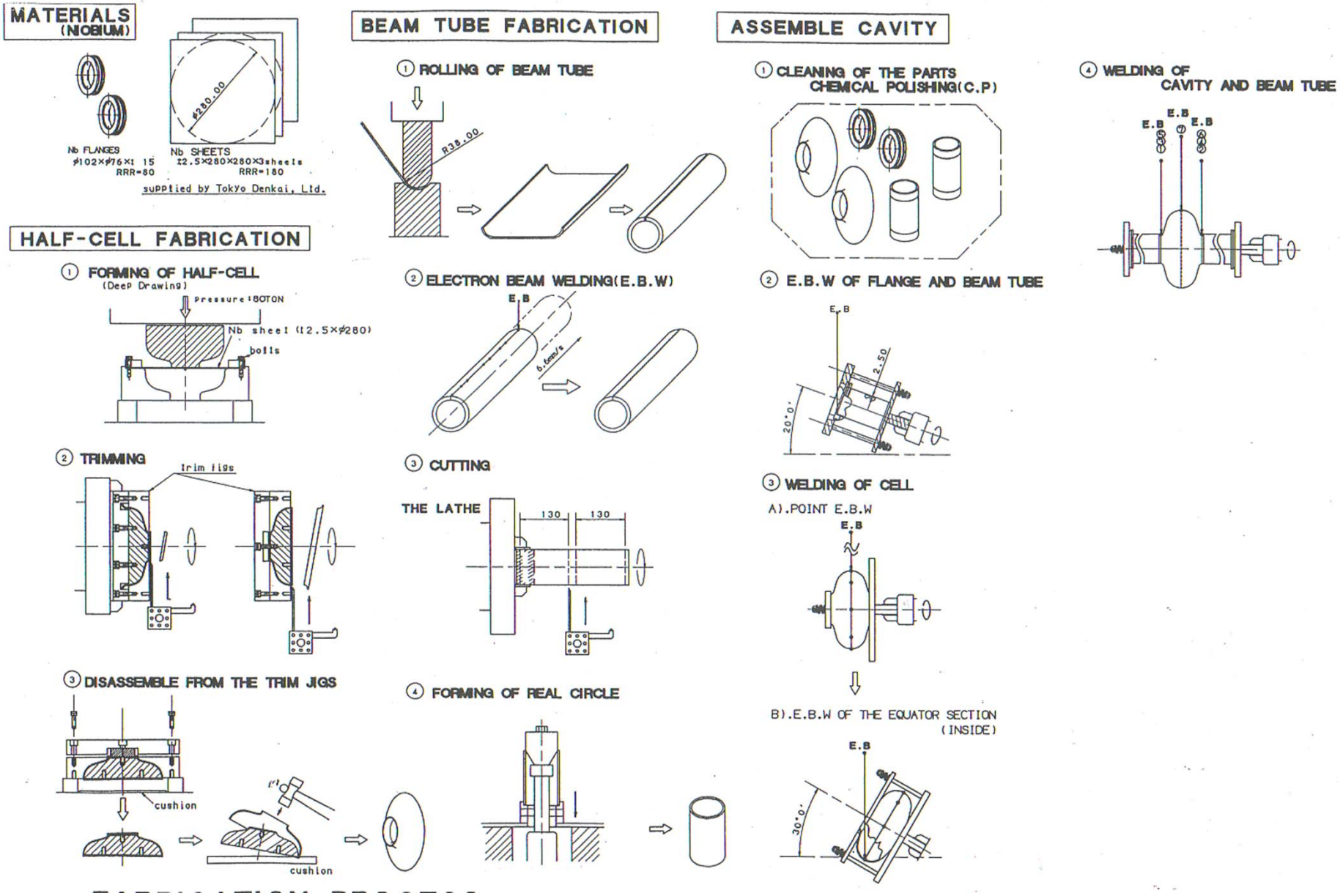
By A. Matheisen



# Half Cells



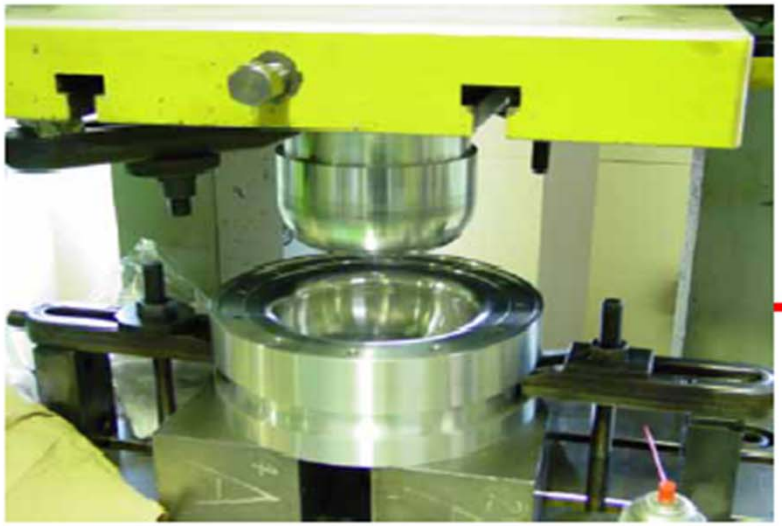
# Fabrication Flow:現状



# KEK in-house experience with 9-cell cavity (Ichiro 9-cell)

## Fabrication of half cell

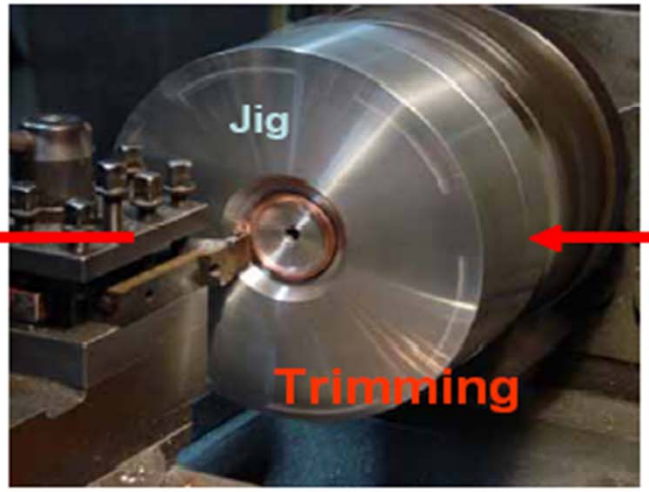
Pressing Nb plate



56 half-cells were pressed in a few hours

21 February 2005

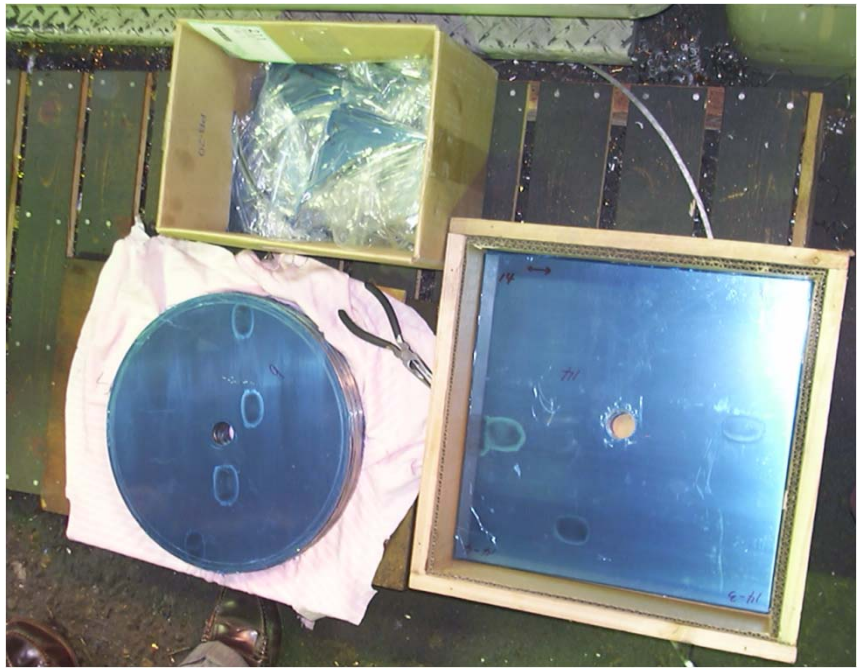
After pressing




After trimming

# Niobium Materials

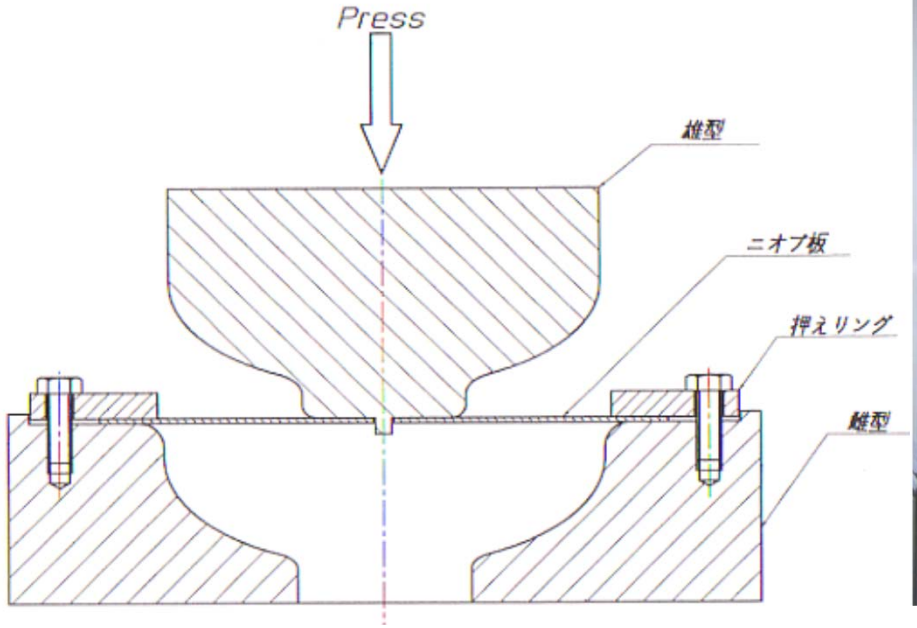
Nb material cutting



# Dies for Deep Drawing

# Deep Drawing

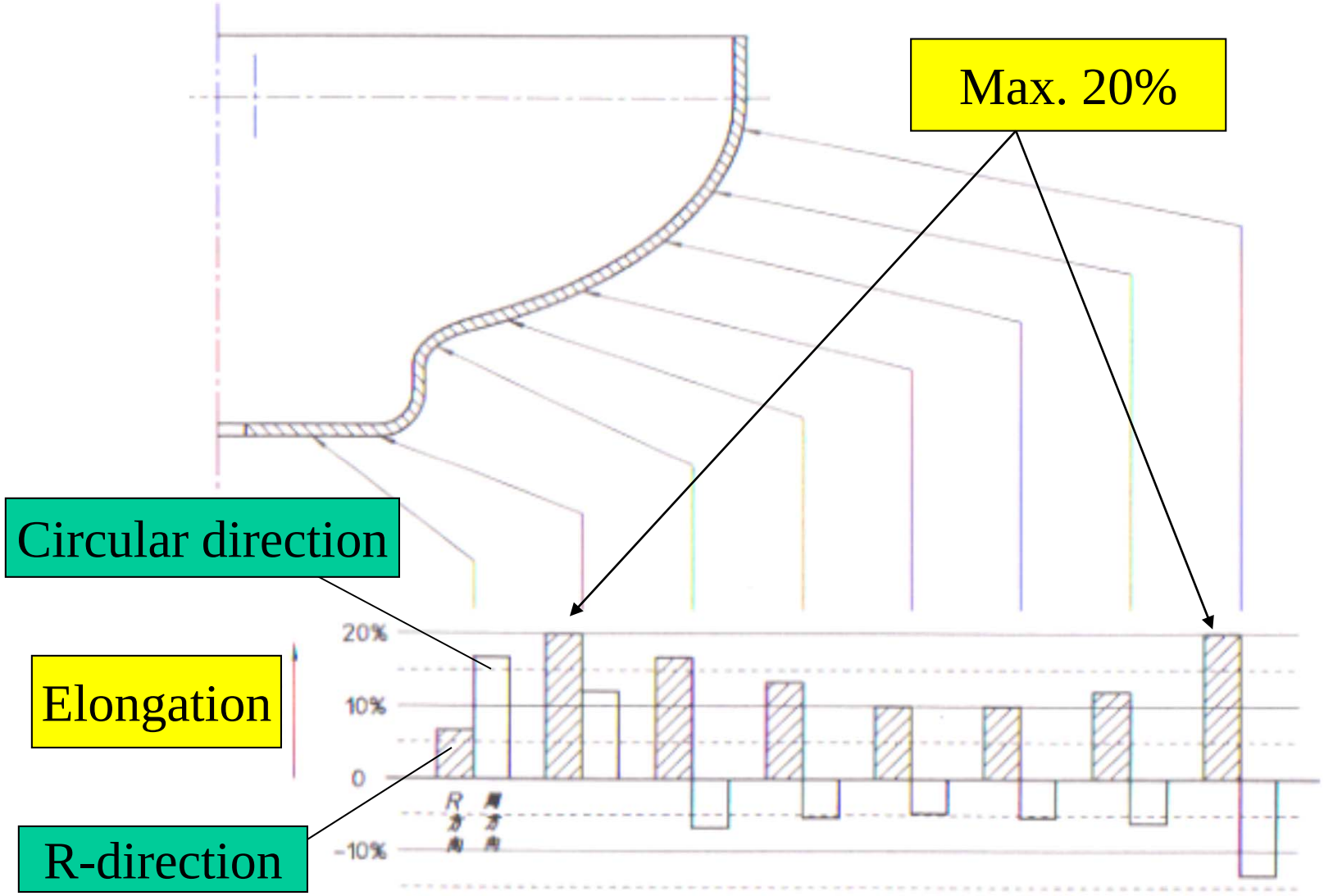
80 t プレスfor 2.5t Nb half cell (1300MHz)



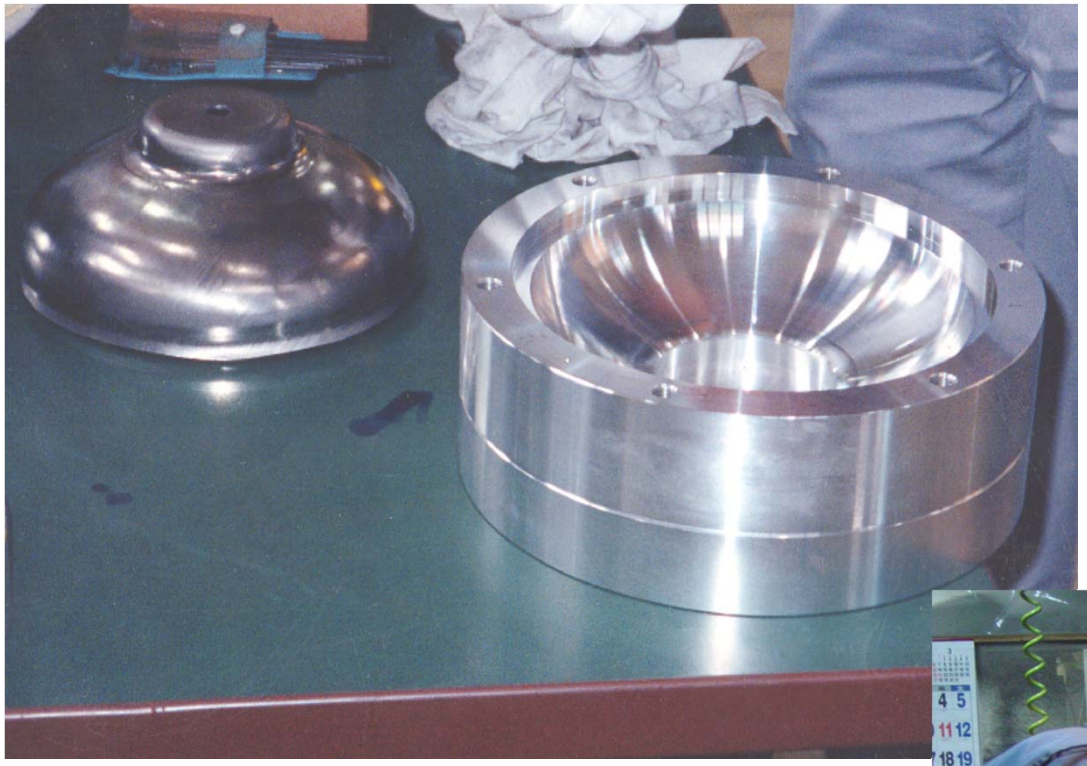

# Deep Drawing

菊池製作所

# Local Elongation



# Trimming

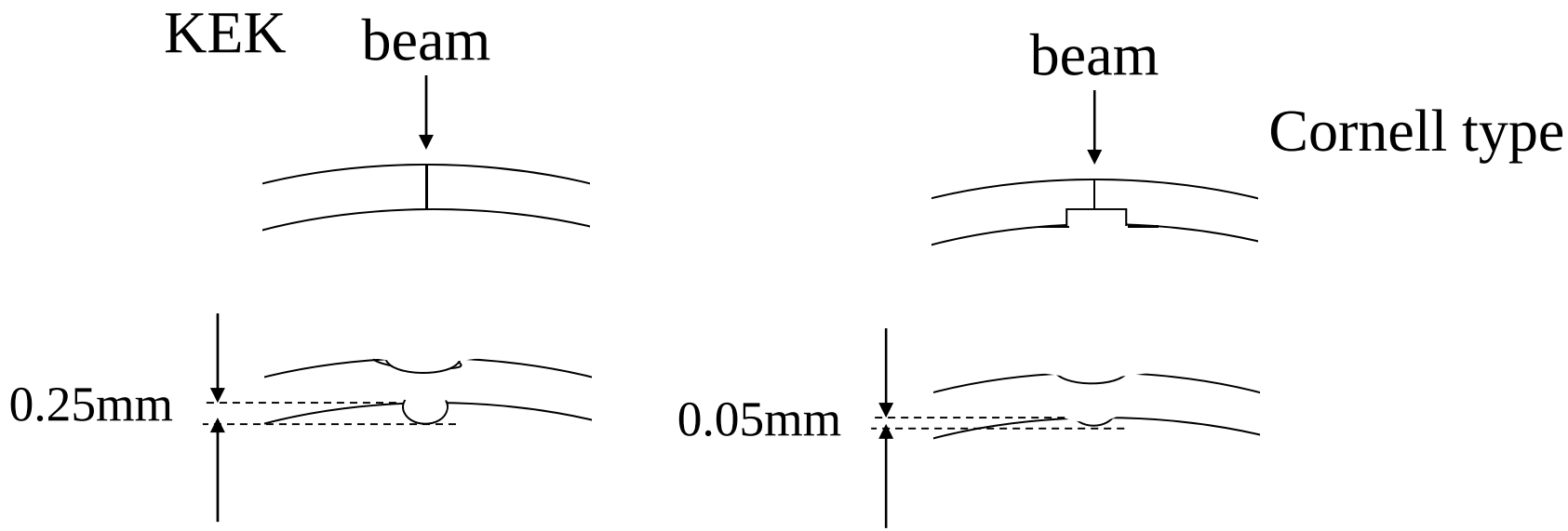


石塚製作所

11-13/May/2011
K.Saito

# Improved Trimming Shape

So far, KEK takes CBP 100-200μm to make smooth the equator EBW seam. It is time consuming process.

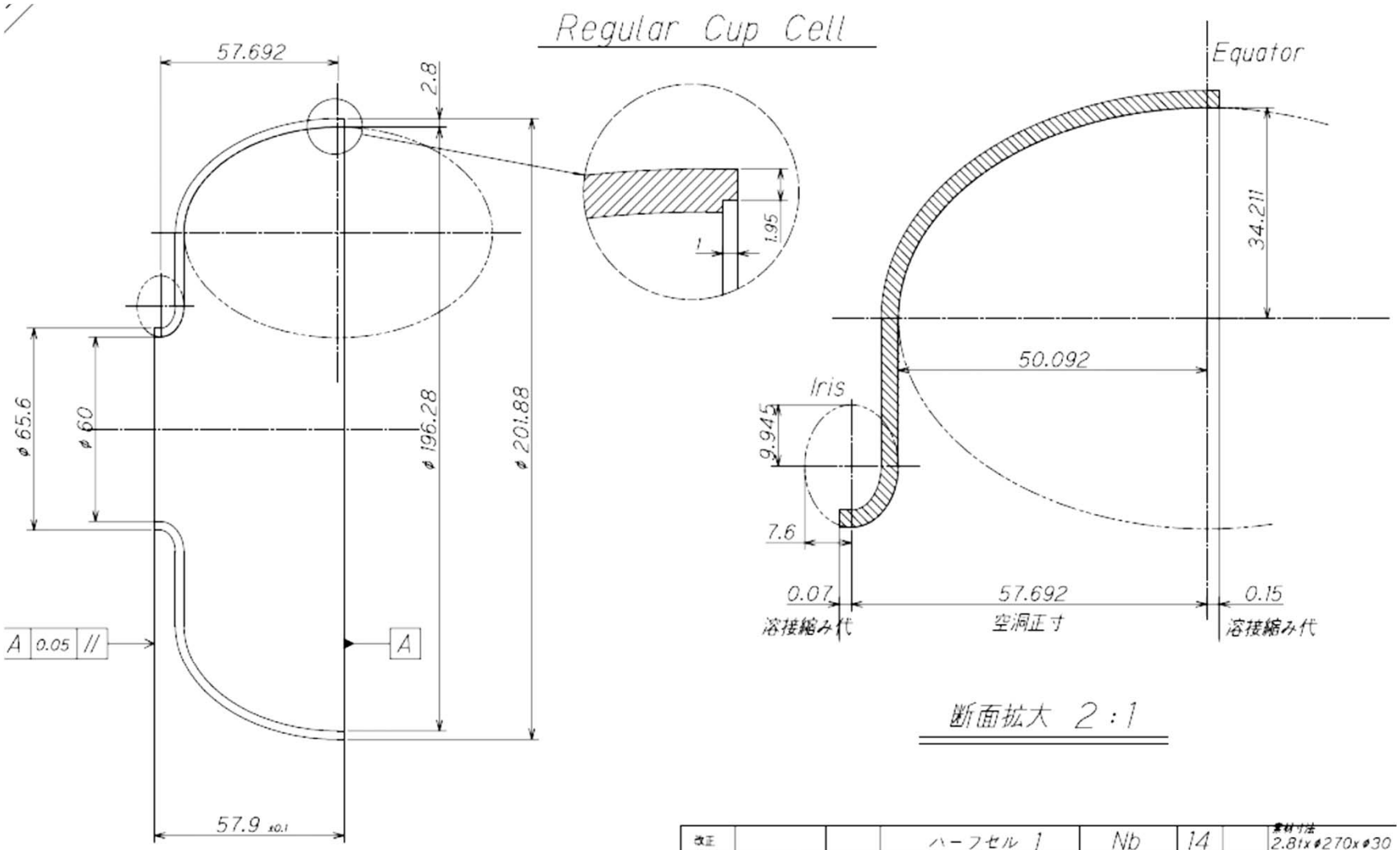



Needed CBP ~10 times

Maybe CBP only twice!?

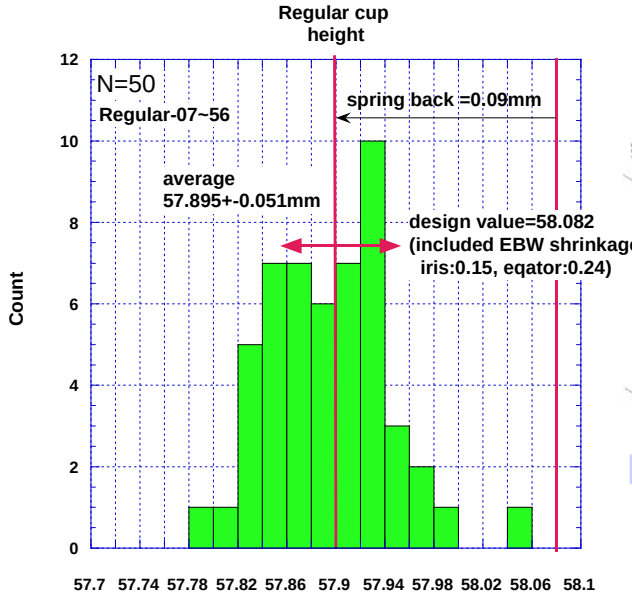
Cornell trimming shape is so useful to smooth the EBW seam. KEK has successfully reconfirmed the trimming shape with single cell cavities. We will test CBP soon.

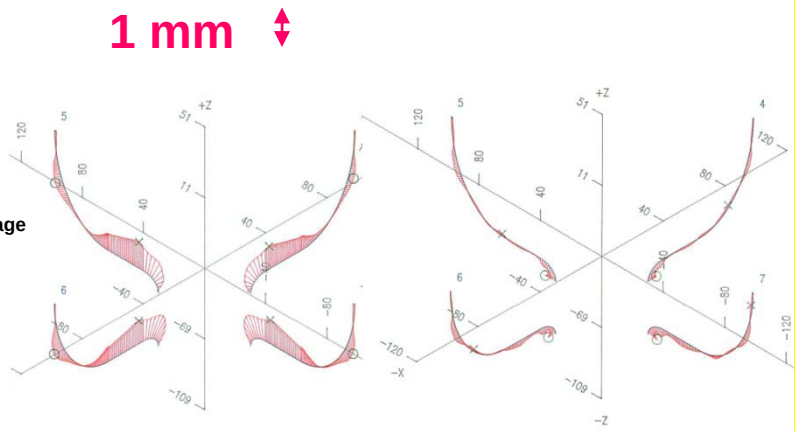
# Improved Trimming Shape



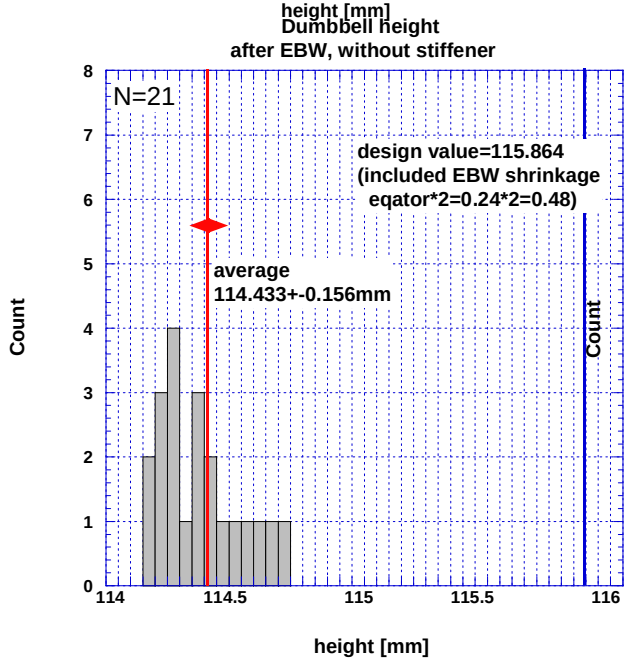

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 改正 | | | ハーフセル 1 | | Nb | 14 | | 素材寸法 2.8t×ø270×ø30 |
| 改正2 | 2006-11-29 | 番号 | 名称 | | 材質 | 1台 | 合計 | 備考 |
| 改正1 | 2006-8-9 | | | | | 数量 | | |
| B付け | | 設計 | 製図 | 検査 | 承認 | 尺度 | 図名 | 高電界9連超伝導空洞 |
| 2005-1-24 | | 両角 斉藤 | 井上 | | | 1: | | |
| 〒305-0801 茨城県つくば市大穂 1-1 高エネルギー加速器研究機構 機械工学センター | | | | | | | 図番 | 04L03-50-001 Rev |

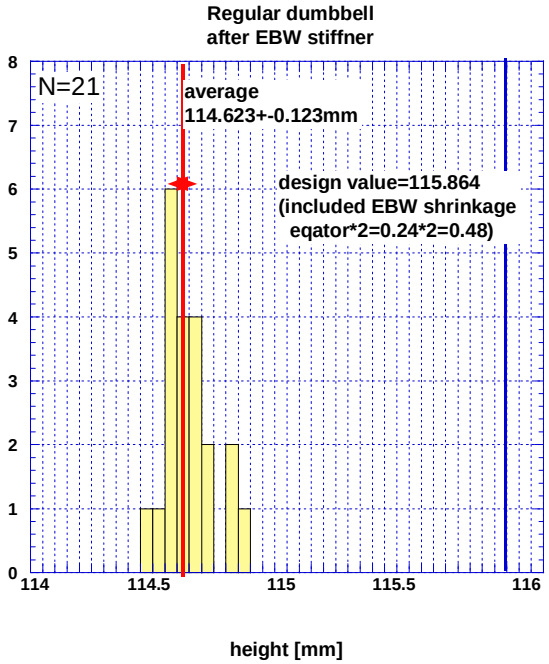
# Dimensional measurement

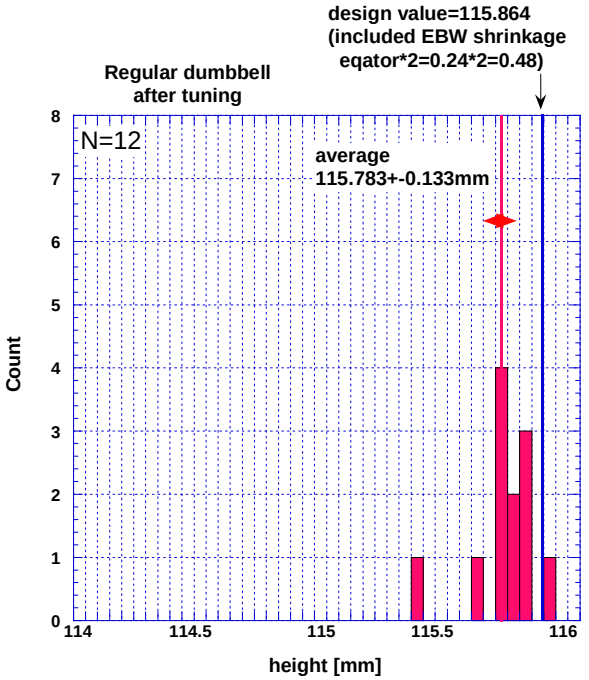



**Machining error: 50μm**
**Half cell spring back:90μm**
**EBW shrinkage**
**0.42 ± 0.13mm @ equator**
**0.15 ± 0.04mm @ iris**
**Dumbbell fabrication error ~80μm after tuning**
**9-cell length error: 0.7~0.1mm**



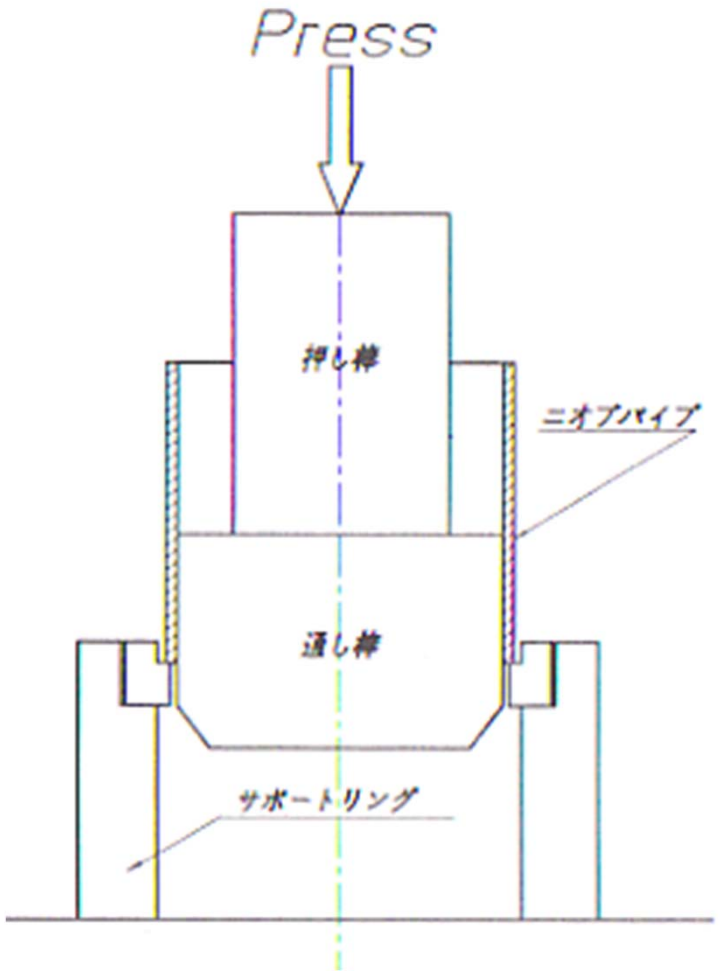



# Rolling of Beam Pipes : 厚肉パイプの場合

Nb肉厚: 4t ~ 6t

11-13/May/2011
K.Saito

# 芯だし




# Rounding

After EBW

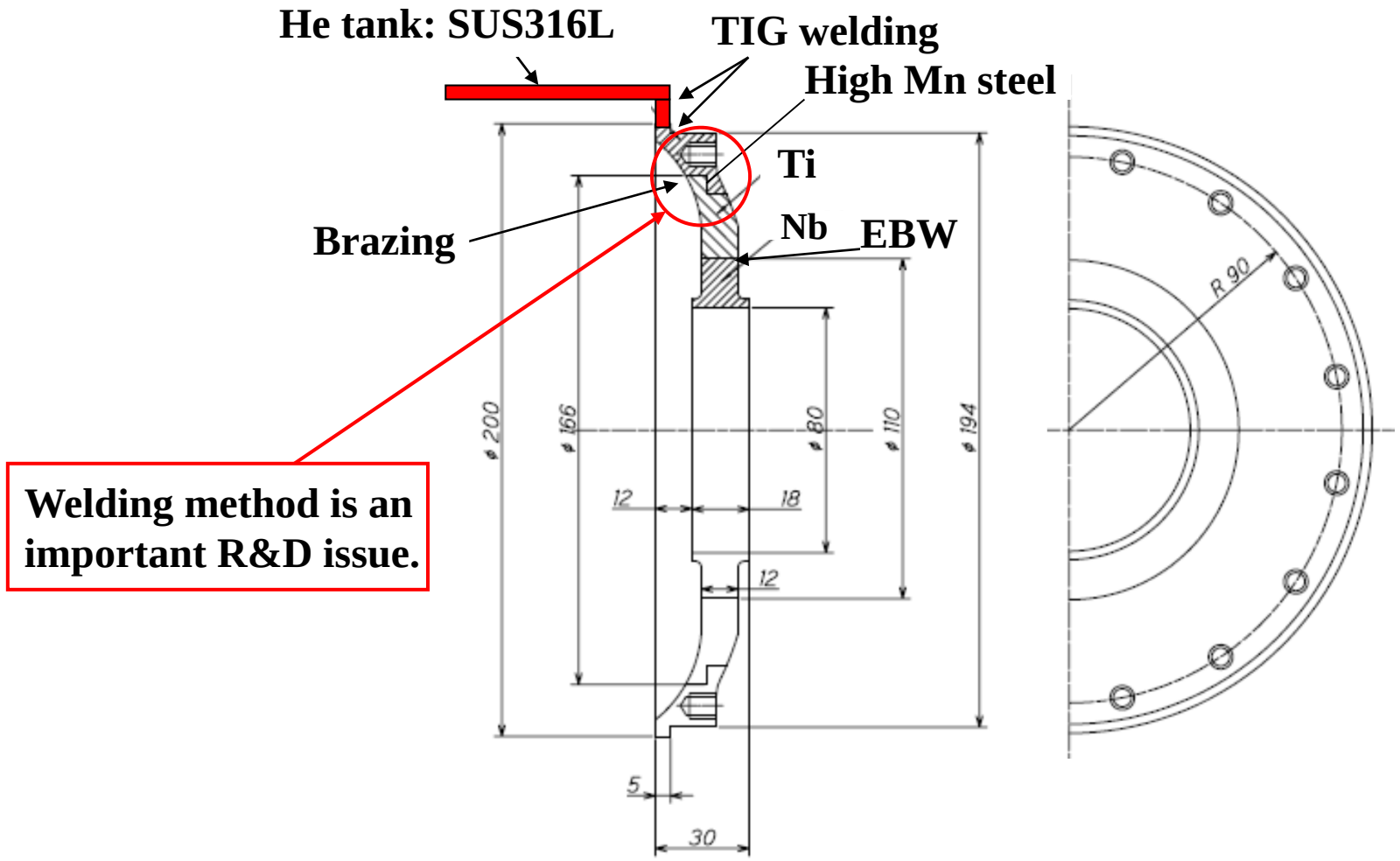
11-13/May/2011
K.Saito

# Completed Niobium Tubes

# HOM Couplers before EBW

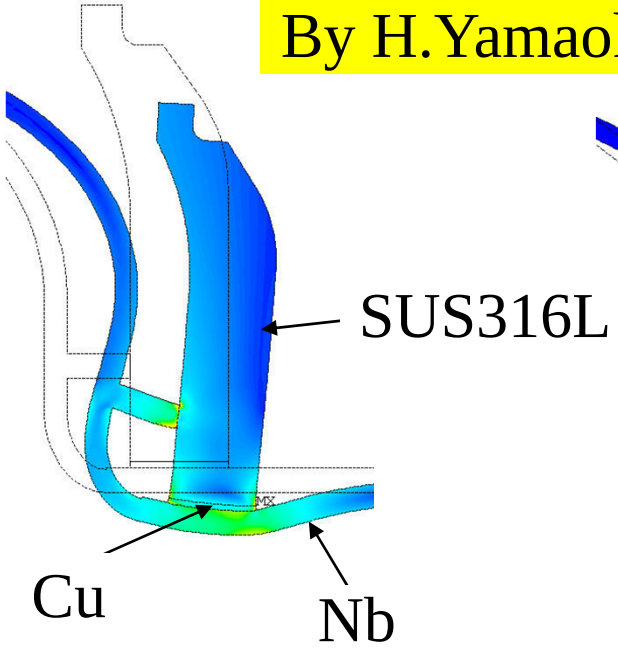
# Parts for END Group

# Design of new END base plate

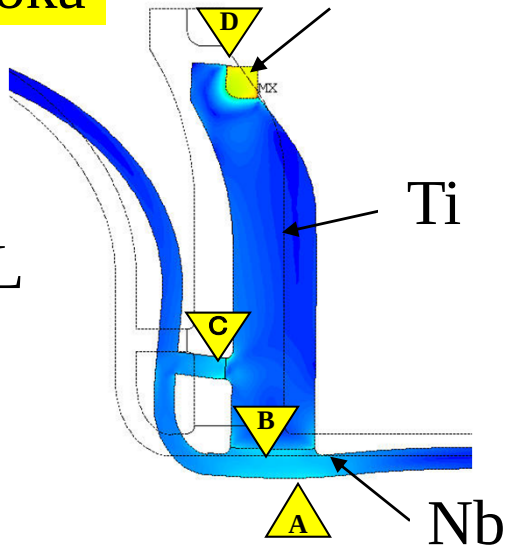


# Cure for the thermal stress at the base plate

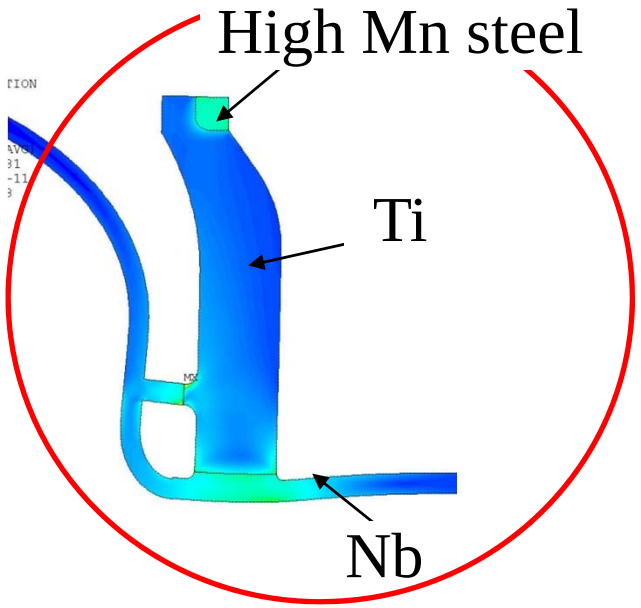
By H.Yamaoka




**Nb/Cu/SUS316L**




**Nb/Ti+SUS316L**




**Nb/Ti+High Mn steel**

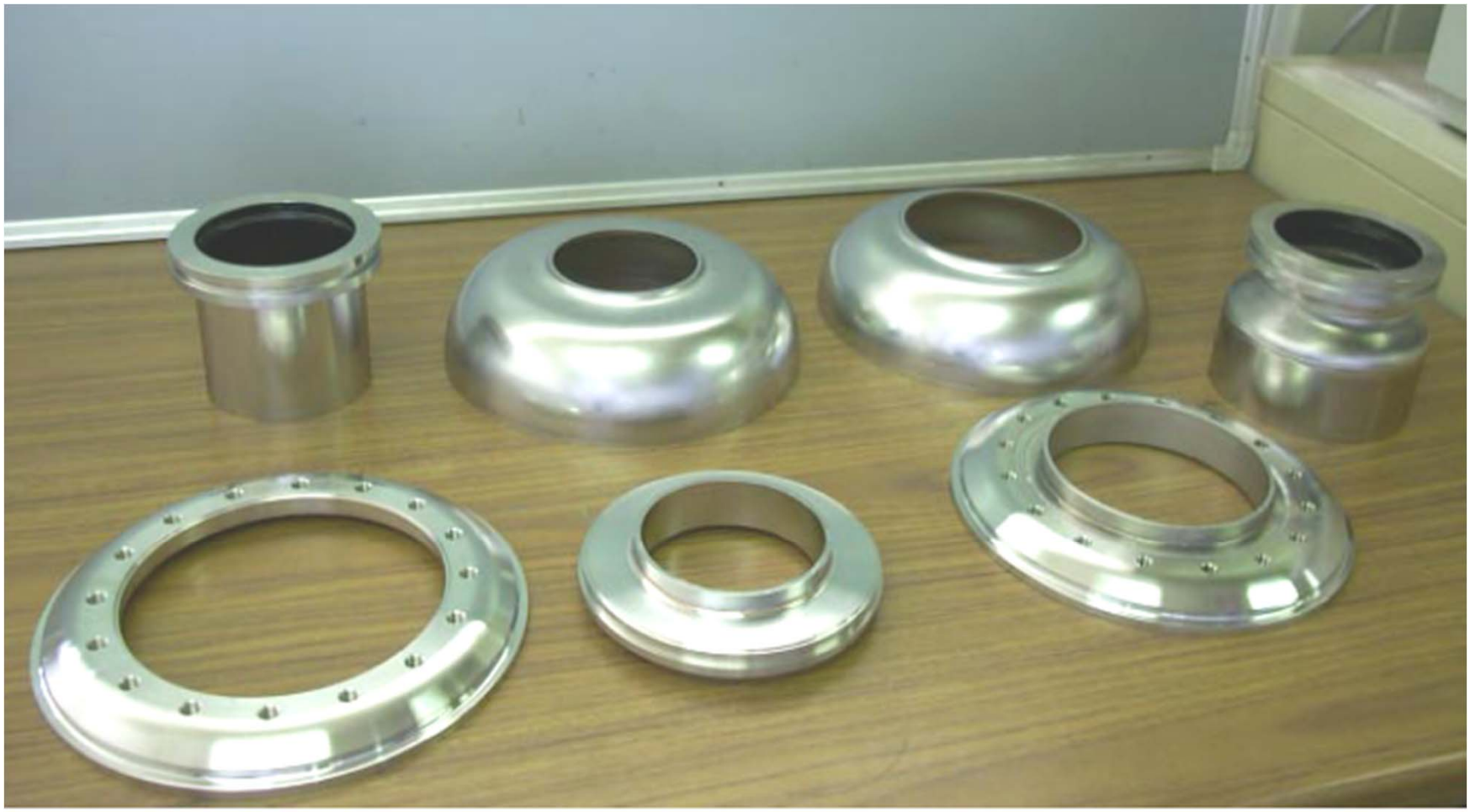
## Stress concentration

| | A [MPa] | B [MPa] | C [MPa] | D [MPa] |
|---|---|---|---|---|
| Nb/Cu/SUS316L | 250 | 500 | 500 | |
| Nb/Ti/SUS316L | 100 | 100 | 200 | 470 |
| Nb/Ti/High Mn Steel | 100 | 100 | 200 | 80 |

## Thermal expansion coefficient

| | $\alpha = \frac{\int_{77K}^{300K} \alpha(T)dT}{300-77}$ [E-6/K] |
|---|---|
| SUS316L | 16.0 |
| Cu | 17.0 |
| High Mn steel | 9.8 |
| Ti | 8.4 |
| Nb | 5.0 |

# END half cells and He Vessel base plate



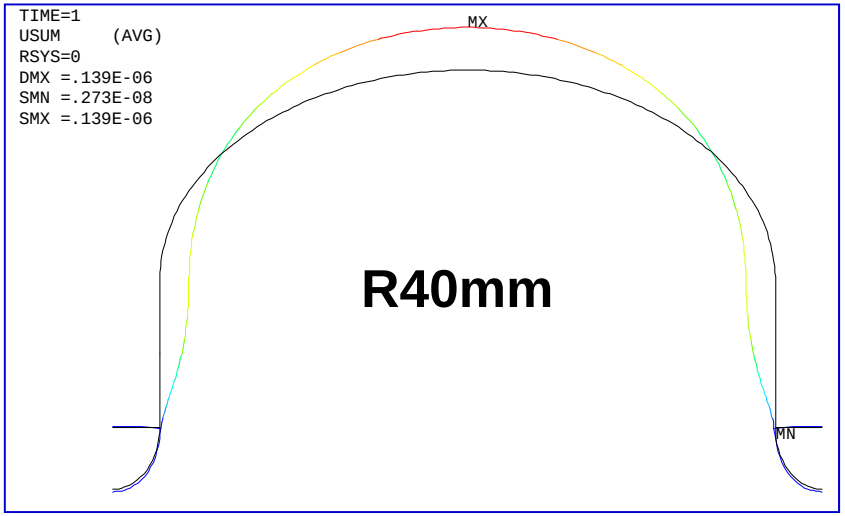
# EBW of END Group

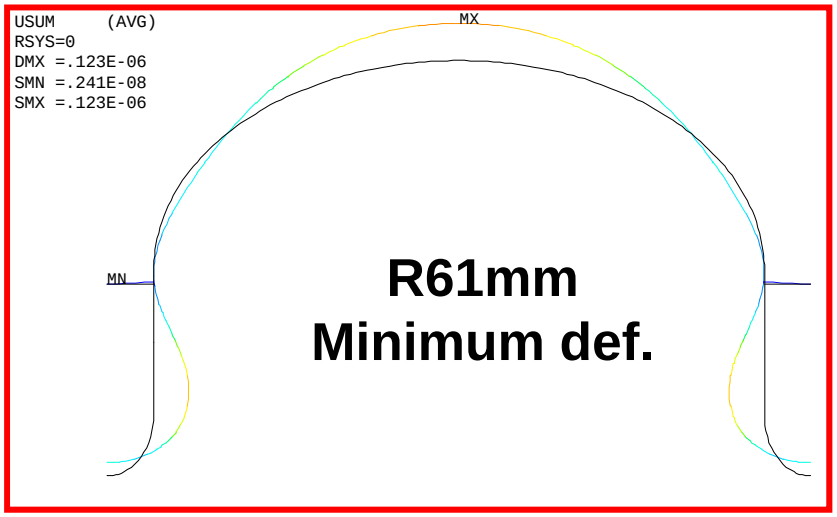
**SFC**

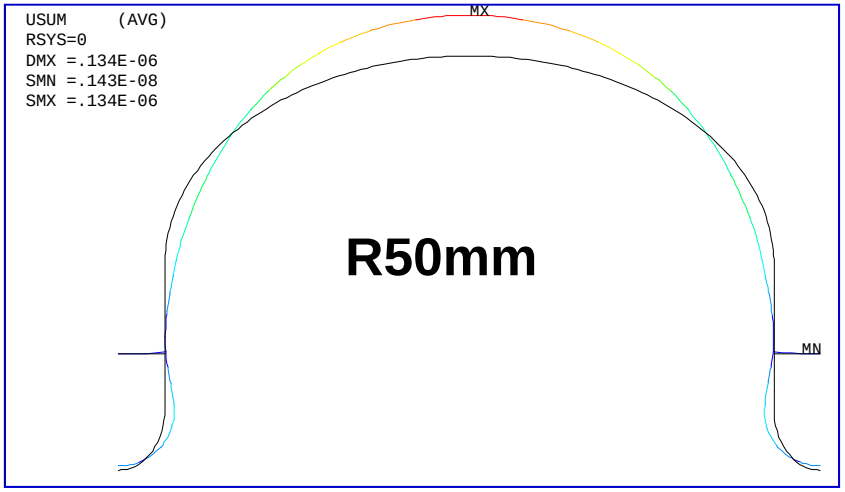

# Optimum location for stiffener ring against Lorentz detuning

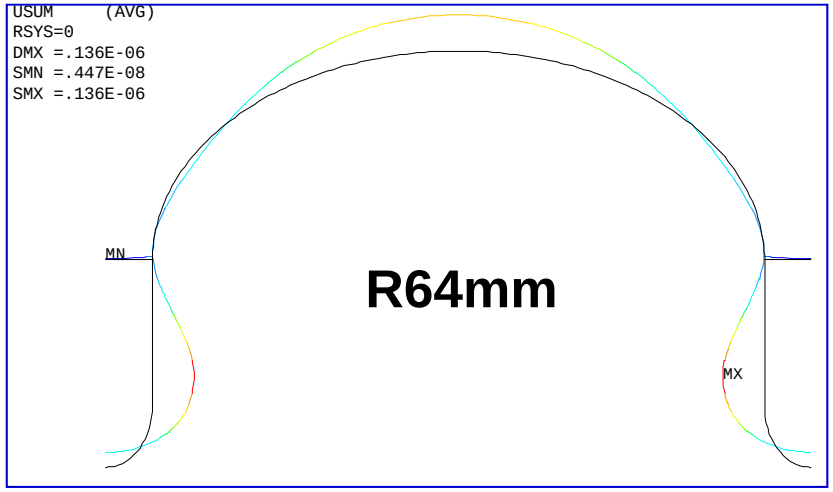
Eacc=38MV/m

**by H.Yamaoka**



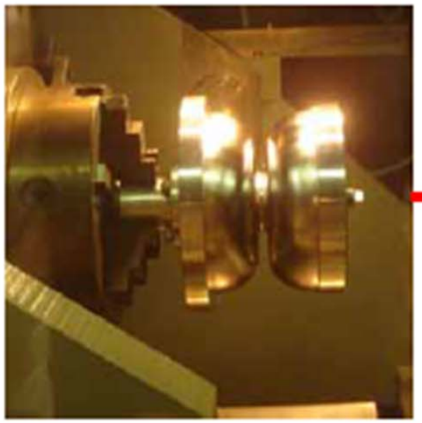



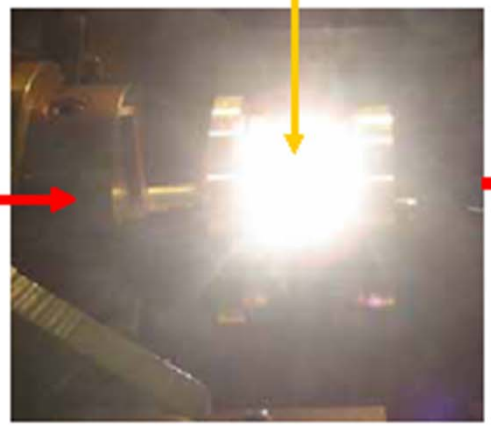


**(Unit: m)**

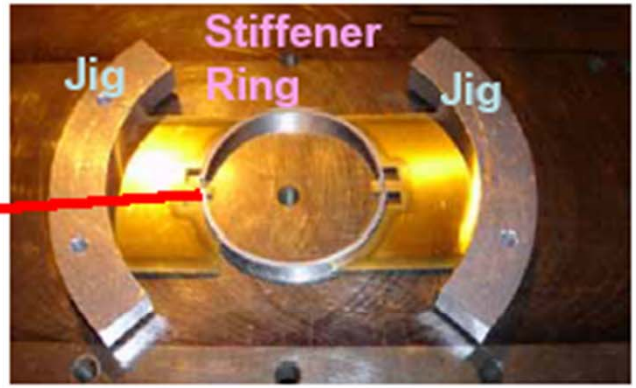
# Fabrication of Dumbbell with stiffener

Electron Beam Welding (EBW)
In KUROKI corporation

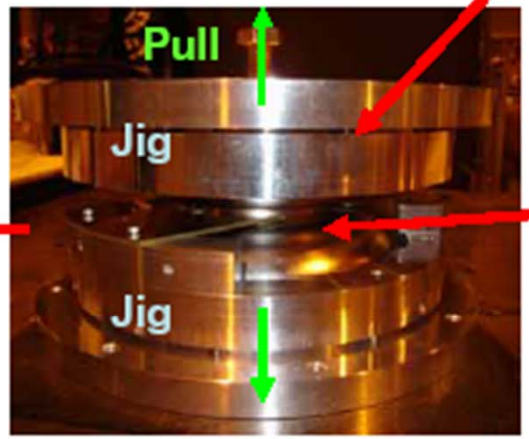





Dumbbell


Insert stiffener-ring into the iris part of dumbbell.

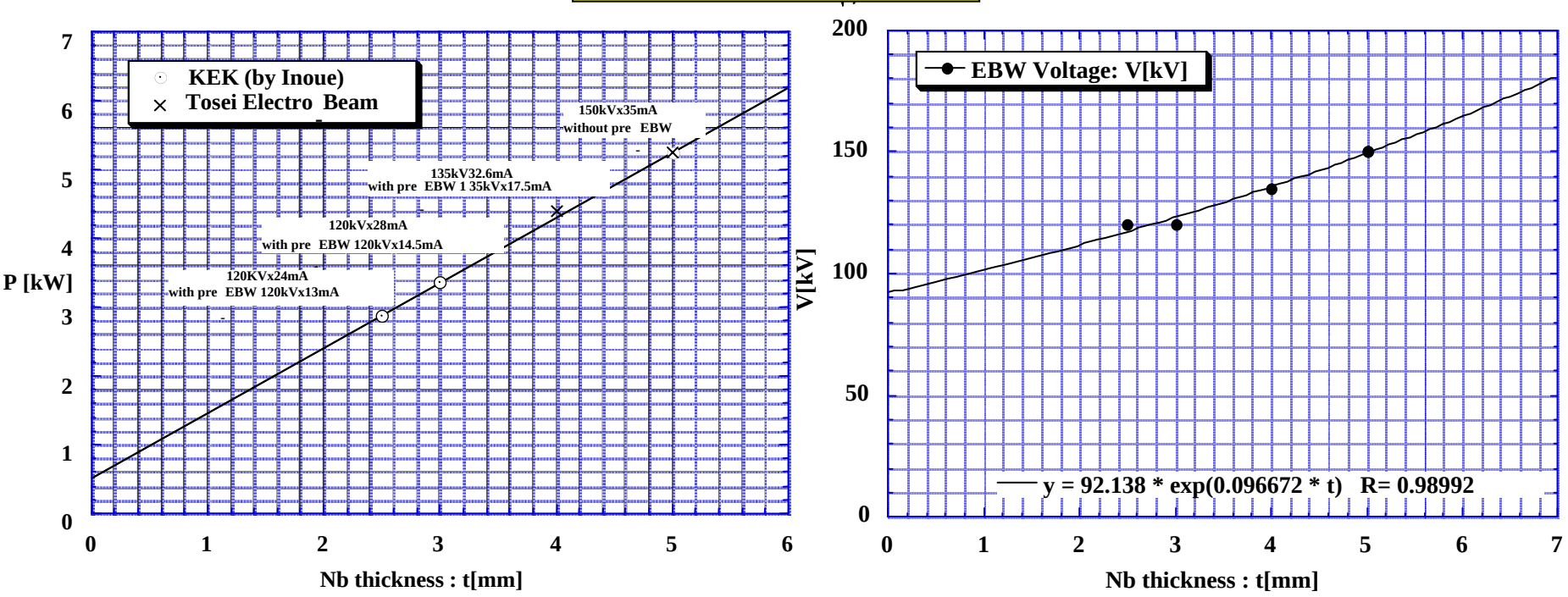



Pull and extend dumbbells to insert stiffener-ring.
=> EBW (dumbbell + ring)


Dumbbell with stiffener-ring after EBW.

# EBW Conditions with NEC Machine : High Voltage Type

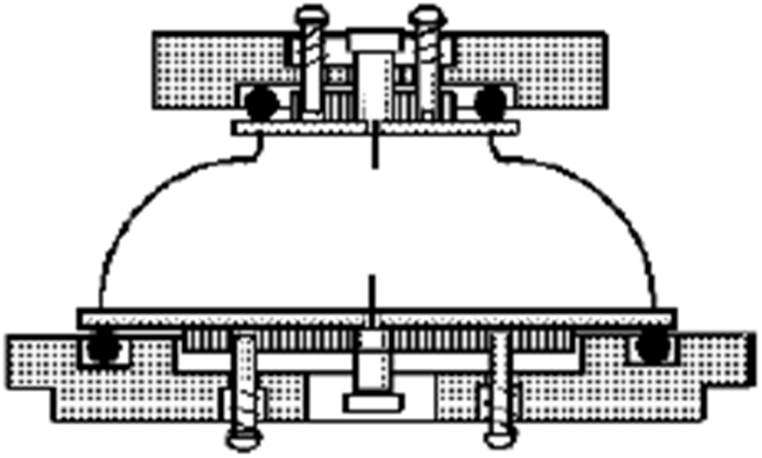
KEK Data



# Dumbbells and END Cups

**PAL**

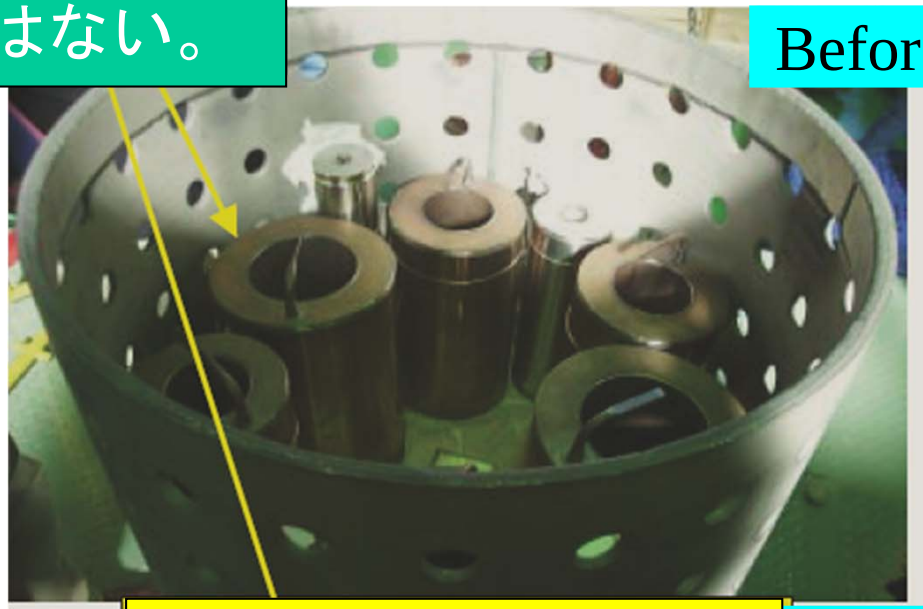
# Example of inspection (Frequency check) @ DESY



# HIP装置

同じ物ではない。

HIP装置　金属技研（株）水戸営業所



Before

HIPにより脱気
引口パイプが完全に潰れている

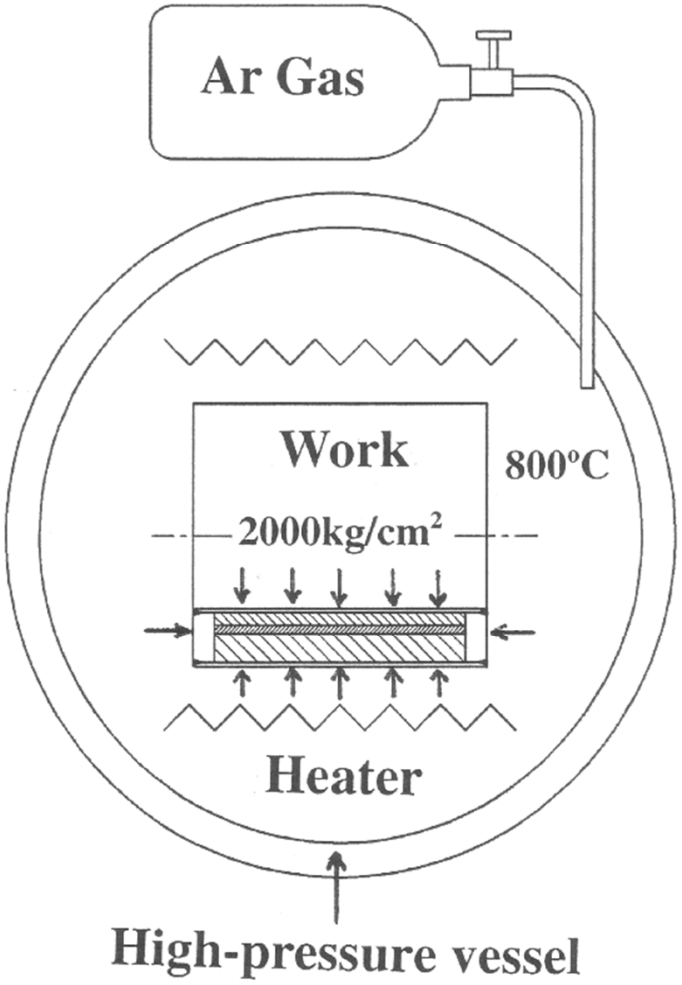
After

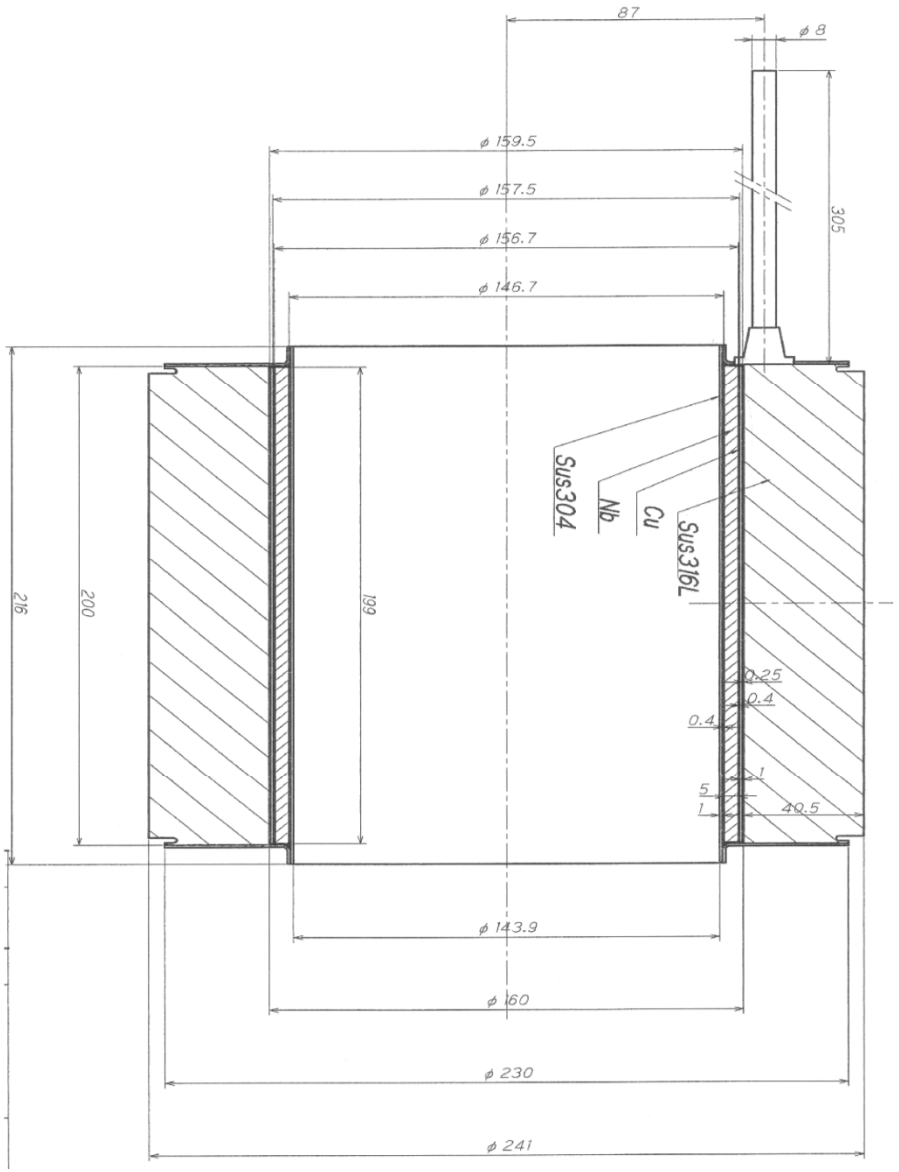
900$^{O}$C 2000kg/cm$^{2}$

# END Groups

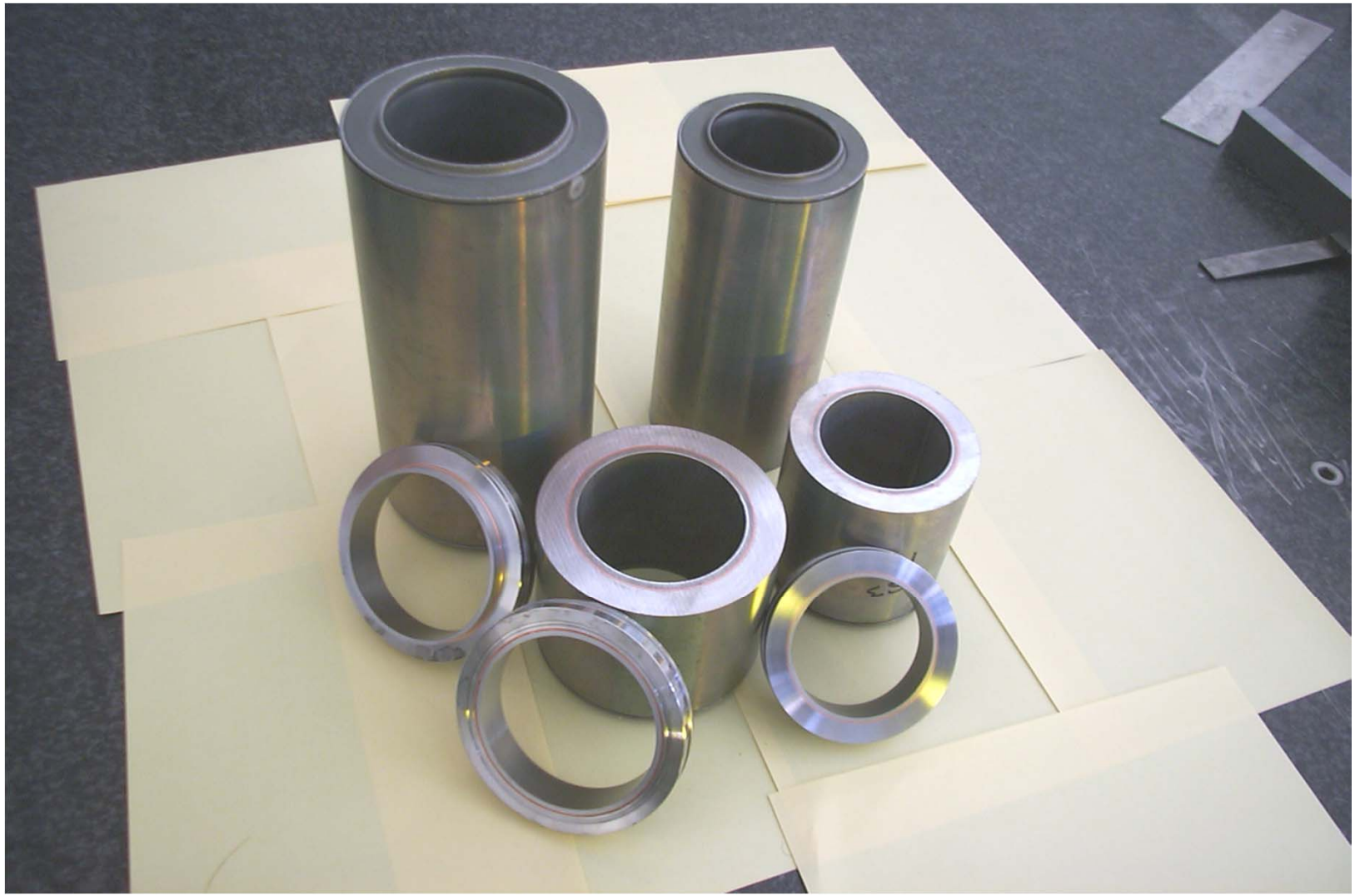
11-13/May/2011
K.Saito

# Nb/SUS bonding by HIP



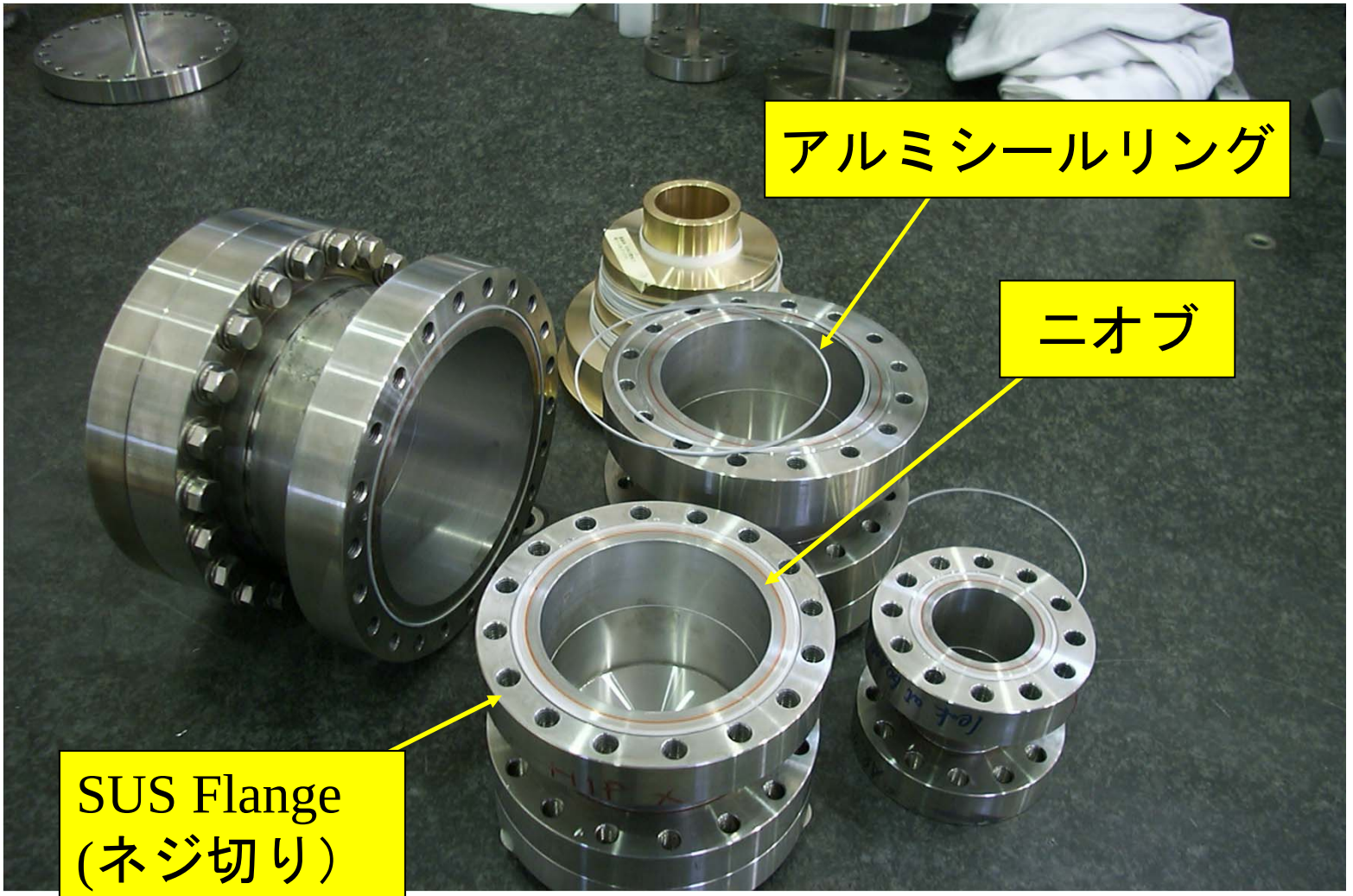



# HIP Bonding



# Beam Tubes and Flanges

# Aluminum Seal SUS Flanges

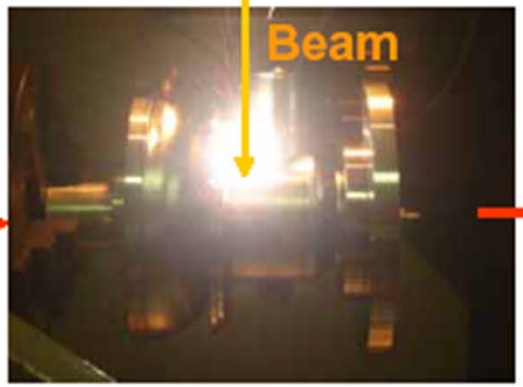


# EBW Assembly of Cavity

EBW of dumbbells

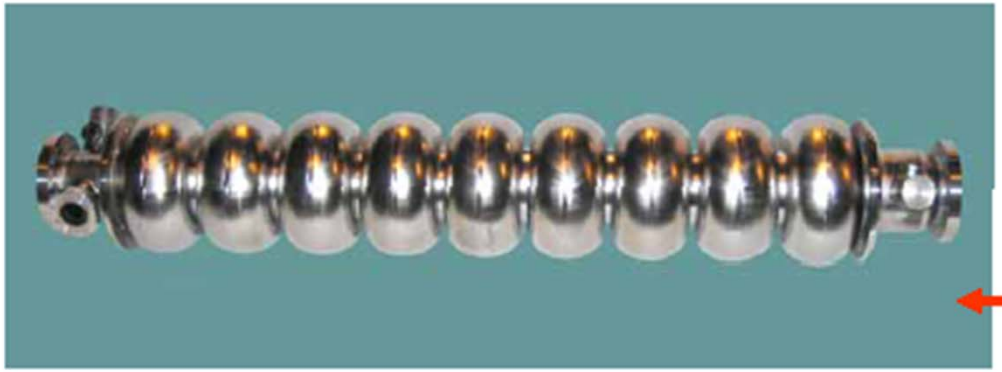
Beam

EBW of end-beam-pipe




End-beam-pipes with HOM and flanges


EBW of end-beam-pipes and cell-part



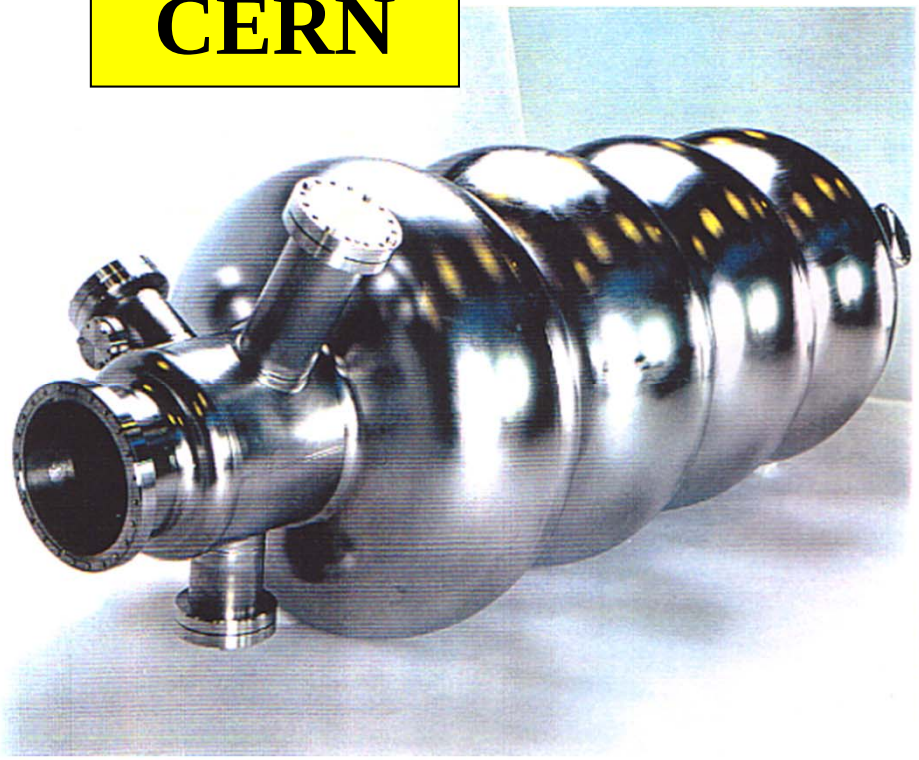
Four 9-cell ICHIRO high-gradient LL Cavities were successfully delivered to KEK ! (4 July 2005)

# Completed Ichiro 9-cell Cavity

黒木溶接工業（株）

# CERN 352MHz Cavity

**CERN**



LEP-II 352MHz

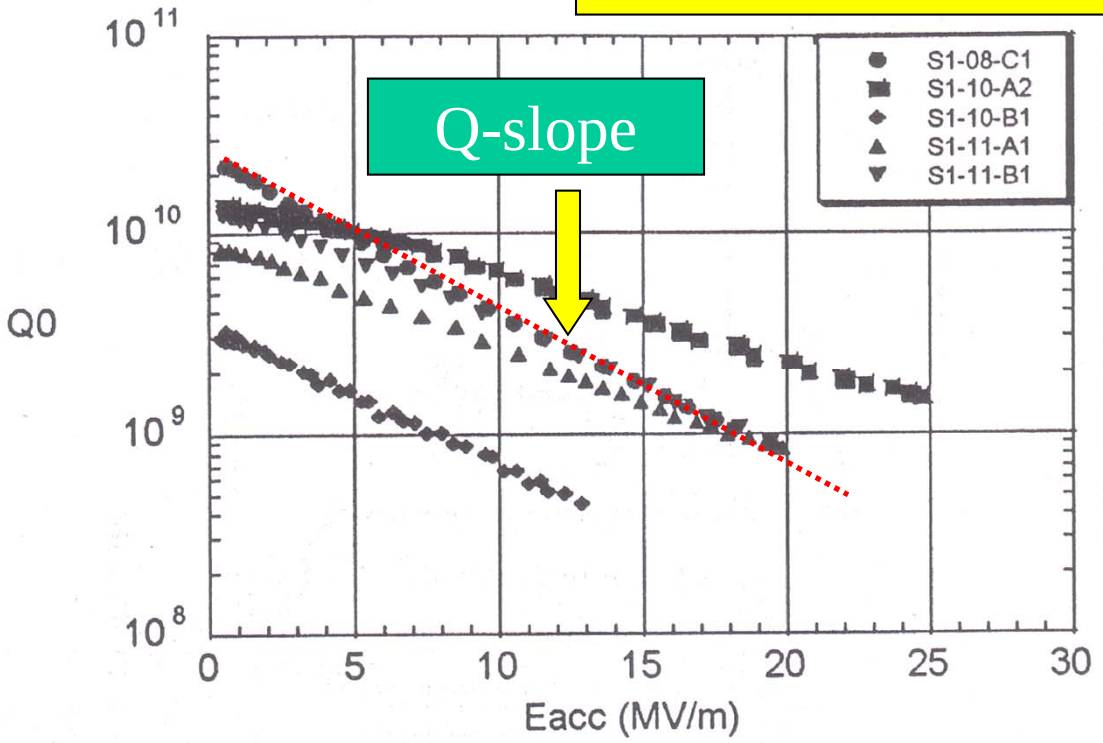
niobium bulk cavity

Copper half cell before Nb coating

(electropolished)

# Steeper Q-slope in Nb coated cavities

Saclay 1500MHz



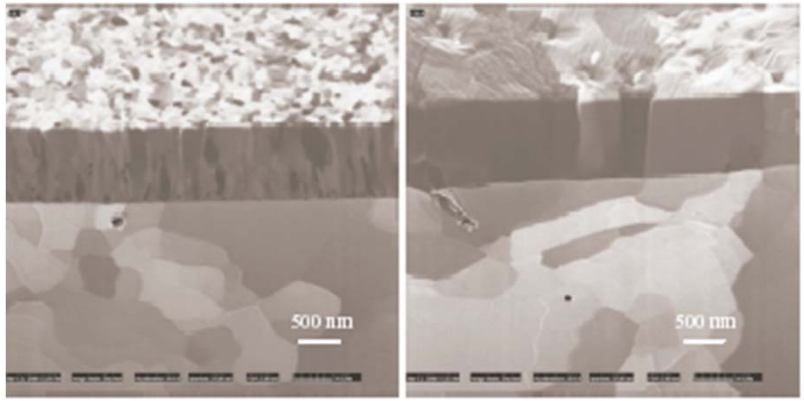



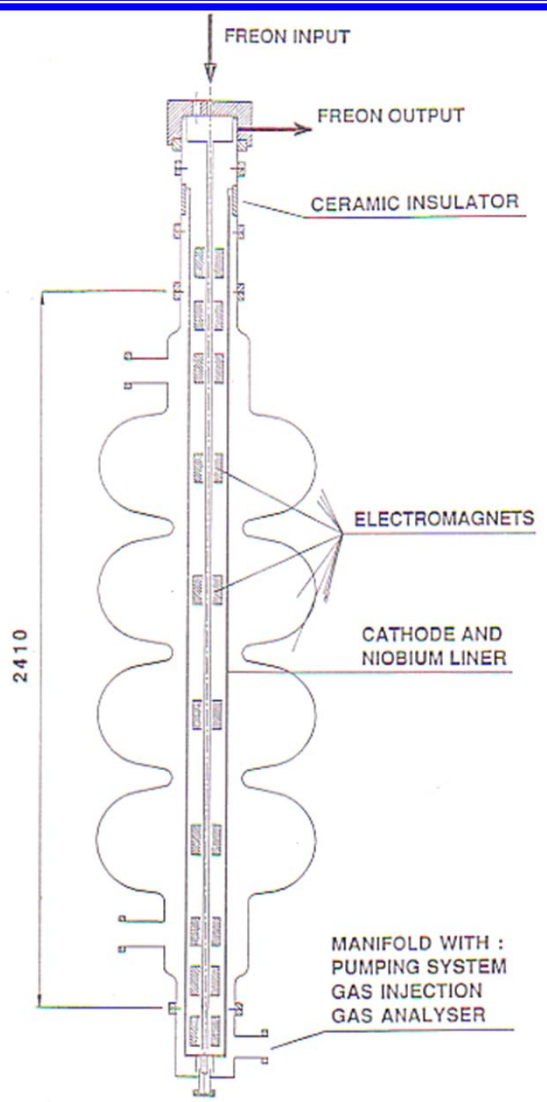

Figure 4: Cross sectional FIB images of niobium films on oxidised (left) and oxide-free (right) copper substrates

**Q-slopeの原因は、薄膜の細かなgrainにあると考えられている。**
**現在、問題解決の研究がなされているが、簡単ではなさそう。**
**TESLAのような高電界は、今の所この技術では期待出来ない。**

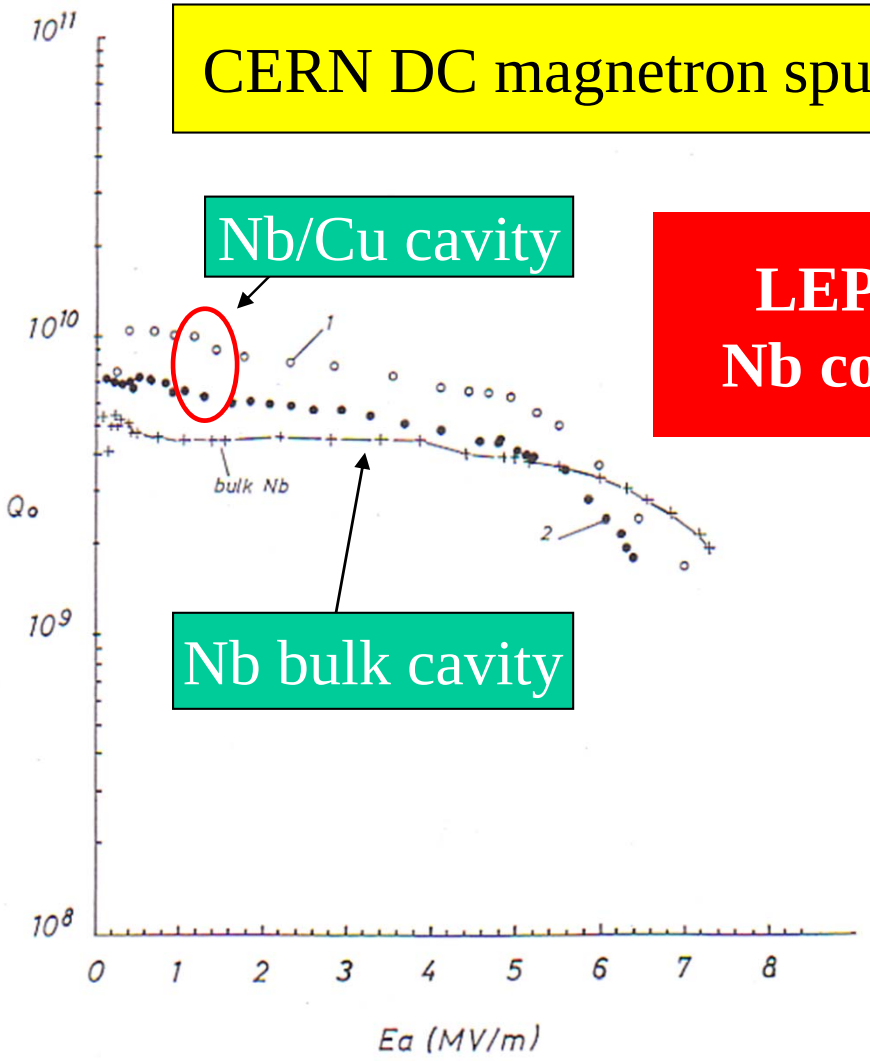
# Bonding Technology

| Bonding technology | 特徴 | 溶接性 Nb/Nb<br>Nb/other |
|---|---|---|
| Argon welding (ITG) | アルゴン中、簡単<br>厚肉okay | ？<br>NO |
| ロウ付け | 真空／水素中、煩雑<br>厚肉okay | NO<br>YES |
| EBW | 真空中、煩雑、<br>厚肉okay | YES<br>NO (except for Ti) |
| Hot isotatic pressing (HIP) | 高圧･高温中、煩雑 | YES<br>YES |
| レーザー溶接 | 大気/アルゴン中<br>簡単、低高率 | ？<br>？ |

# Nb Coating Method at CERN




CERN DC magnetron sputtering




**LEP-IIは全て**
**Nb coated cavity**

# 5. Summary

- ニオブ超伝導空洞の現状の製作技術を示した。
- 電子ビーム溶接以外は、板金加工を中心とする容易な技術の集合体である。
- 空洞製作自体は簡単である。