IP Chamber for Belle SVD2

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— Outline —

1) SVD Upgrade
2) Beam-induced backgrounds
3) Stress analysis
4) Beam-pipe heating
5) Cooling system for the Be pipe
6) Schedule

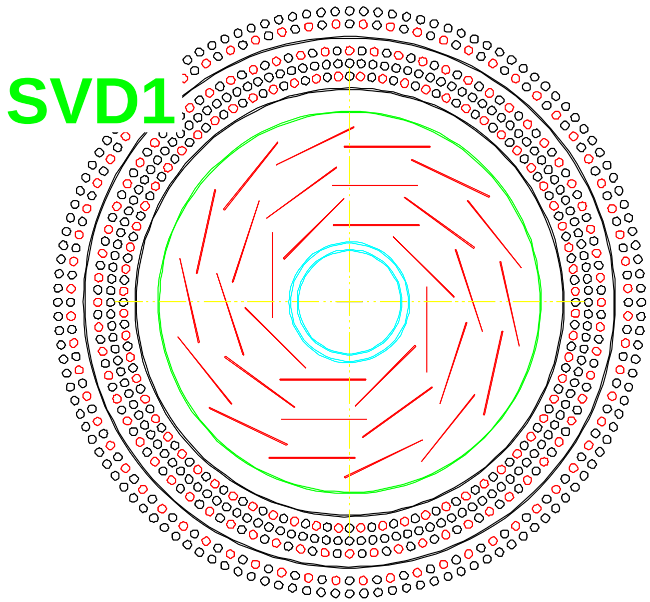
KEKB Review Meeting

Feb. 11, 2003

Silicon Vertex Detector (SVD) Upgrade

$\ll$ In current use $\gg$

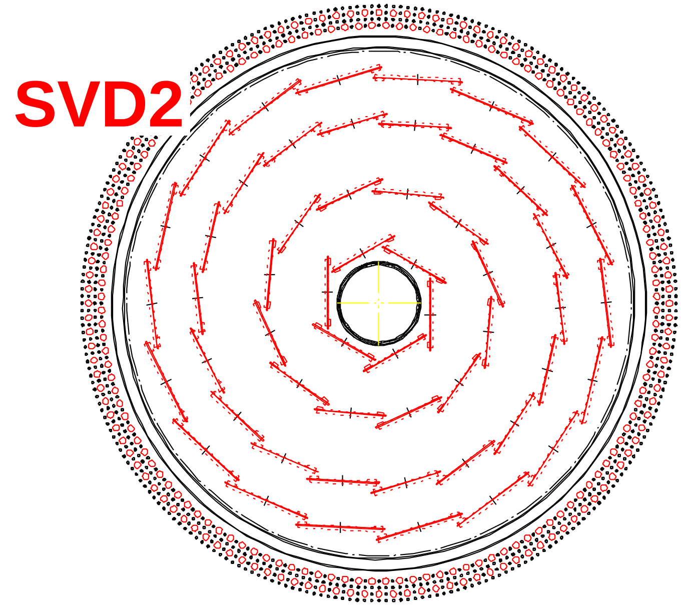
- Radiation hardness (VA1): ~ 1 MRad
- Pin-hole problem
- etc.



- $\mathrm{R(layer1)} = 3.0\,$cm
- 3 layers

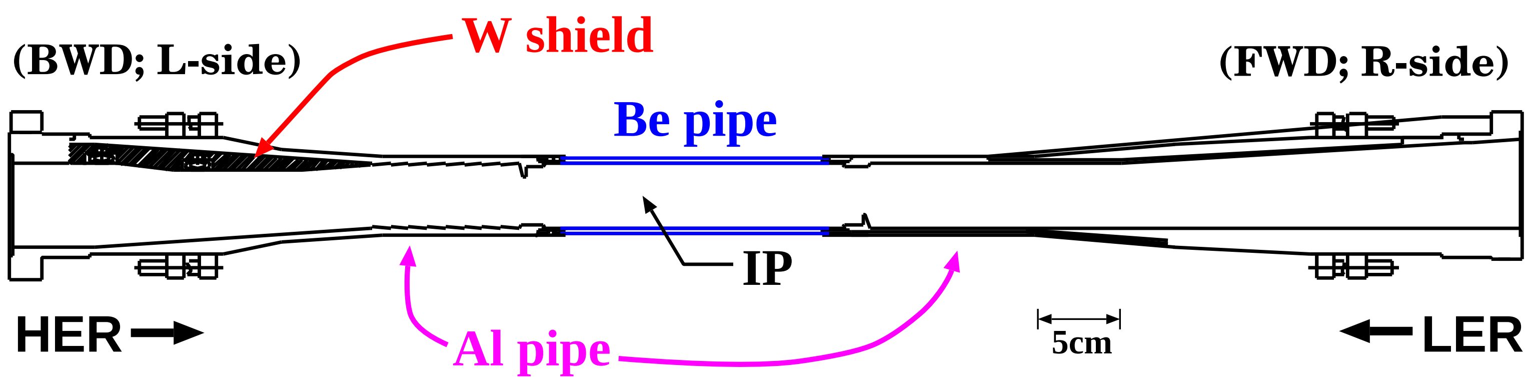
$\ll$ Installed in the summer of 2003 $\gg$

- Radiation hardness (VA1): > 20 MRad
- Improvemtns on the electronics
- Inprovemtns on the DAQ
- etc.

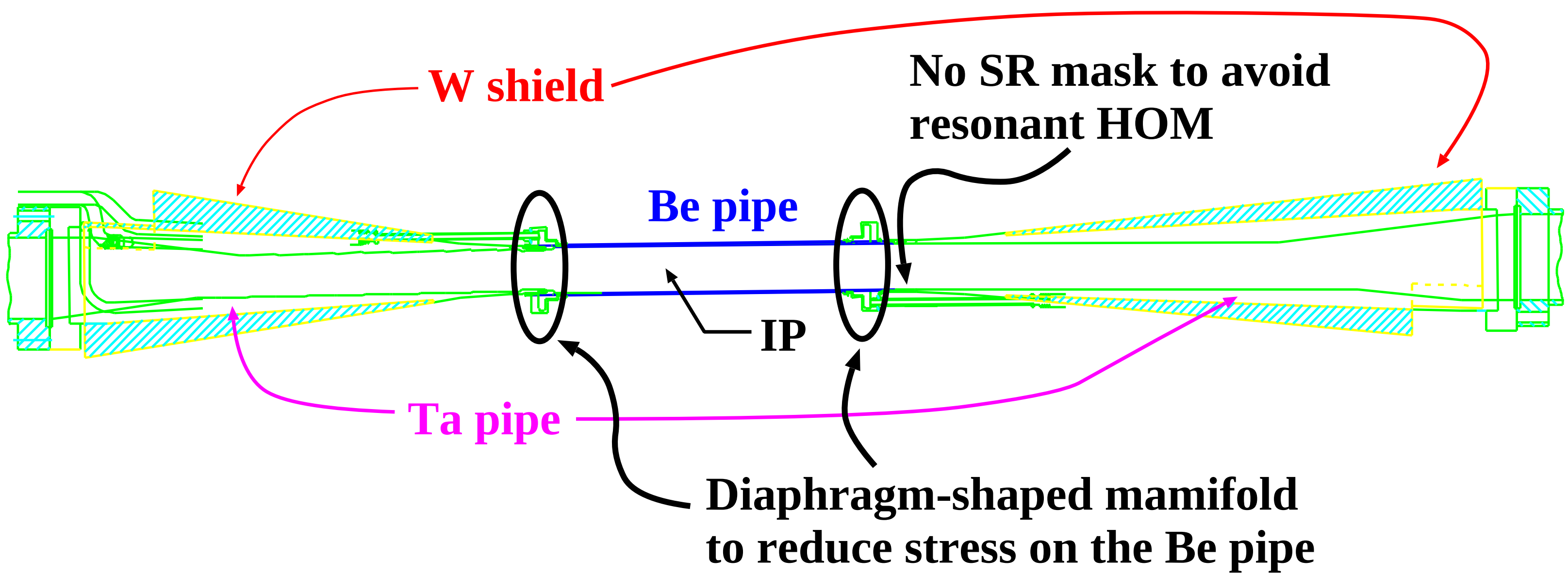


- $\mathrm{R(layer1)} = 2.0\,$cm
- 4 layers
  - **Better vertex resolution** $(\propto 1/\mathrm{R})$
  - **Higher tracking efficiency**

IP Chamber for SVD1 ($r \sim 2.0$ cm)



IP Chamber for SVD2 ($r \sim 1.5$ cm)



Beam-induced Backgrounds

We have studied:

[1] Particle background on HER and LER

- Beam-gas scatterings in the entire ring (Bremsstrahlung $+$ Coulomb)
- Beam-chamber interactions around IP (up to QC2's)
- Touschek effect

[2] Background from the Synchrotron Radiation (SR) of HER

(1) *Soft* SR radiated from the HER beam in the straight section

– $E_{crit} \lesssim$ a few keV

(2) *Hard* SR $(\leftarrow$ backscattering $\leftarrow$ QCSR$)$

– $E_{crit} \sim$ 20 keV

[1] Particle-background simulation

(done by Karim Trabelsi)

- KEKB lattice model & Materials around IP
  $\longrightarrow$ GEANT+TURTLE simulation

- Data/MC comparison on the SVD1-layer1 dose

	Simulation [kRad/yr] Brems+Coul	Touschek	Total	**Measurement** [kRad/yr]
HER	40.5	—	40.5	24
LER	35.2(23.3)	56.5(6.5)	91.7(29.8)	82

(The numbers in () with no contribution from scatterings on materials outside the vacuum chamber.)

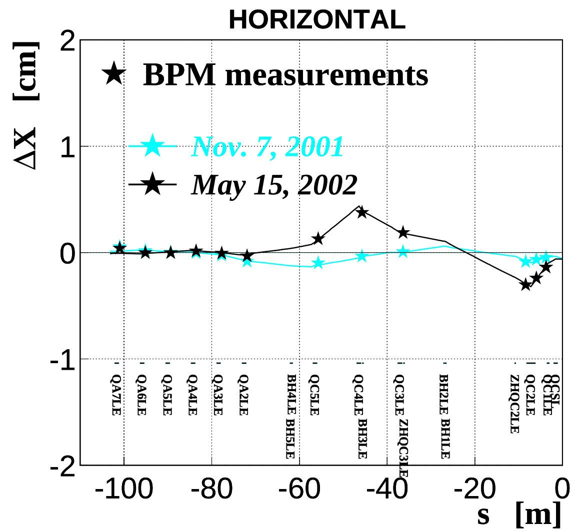
The simulation can reproduce the measurement within a factor of a few.

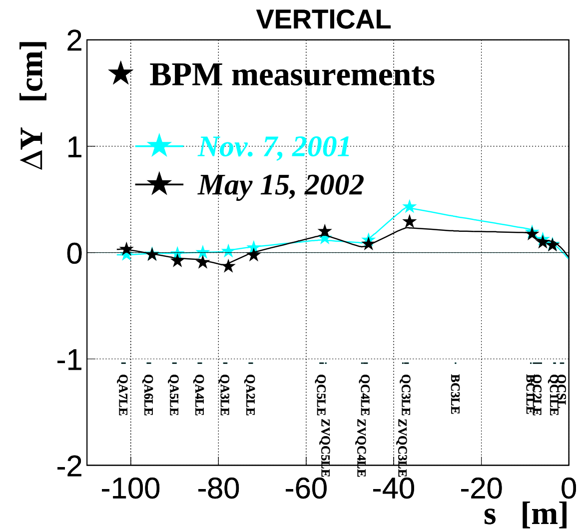
Dose calculation for SVD2 (r=1.5 cm)

	Dose [kRad/yr]		
	Layer1	Layler2	Layler3
HER Brems	12.5	3.0	1.9
HER Coul	13.4	3.9	3.5
LER Brems	13.1(9.0)	3.4(2.0)	1.6(0.6)
LER Coul	14.0	1.4	1.0
Touschek	28.8(9.0)	6.7(1.3)	9.7(0.9)
Sum	**82**(58)	18(12)	18(8)

The expected dose is much less than the radiation hardness of SVD2 (>20 MRad).

[2]-(1) Dose Estimation for the Soft SR





- **Based on the two orbits**

  on Nov. 7 (2001) and May 15 (2002)

- **Beam parameters**
  - $\epsilon_X = 24$ nm, $\epsilon_Y/\epsilon_X = 3$ %
  - $\beta^*_X/\beta^*_Y = 63/0.7$ cm
  - $\bar{X}^{(inj)}_{\rm offset} = 10$ mm, $\sigma^{(inj)}_X = 0.9$ mm (in injections)

(SR photons generated from each magnet)

- **EGS4**
  - Improved on low-energy photons (L-edge X-rays) at KEK
  - Photons traced down to 1 keV
  - Electrons traced down to 20 keV
  - Exact geometry of the beam-pipe from the drawing

SVD2 SR Dose

for the Physics-run Orbit on 2001.11.07

(BP-geometry cut is applied.)

	Watt ($E_\gamma > 10$ keV)	E_{crit} [keV]	θ_{kick} [mrad]	**Dose [kRad/yr]**
BC1LE	1.1E−03	1.5	-0.47	< 0.24
ZHQC2	8.0E−04	1.3	$+0.38$	< 0.26
QC2LE	7.0E−05	1.1	—	< 0.08
$\cdots$	$<$ 1.0E−08			

SVD2 SR Dose

for the Physics-run Orbit on 2002.05.15

(BP-geometry cut is applied.)

	Watt ($E_\gamma > 10$ keV)	E_{crit} [keV]	θ_{kick} [mrad]	**Dose [kRad/yr]**
QC4LE	8.9E-04	1.0	—	2.1 ± 0.3 (BOTTOM)
BC1LE	3.1E-05	1.3	-0.40	< 0.02
ZHQC2	7.9E-06	1.0	$+0.30$	< 0.005
QC2LE	4.7E-06	1.1	—	< 0.008
QC1LE	1.9E-06	3.7	—	< 0.001
$\cdots$	< 1.4E-08			

SVD2 SR Dose for the Injection based on the Orbit on 2001.11.07

(BP-geometry cut is applied.)

	Watt ($E_\gamma > 10$ keV)	E_{crit} [keV]	θ_{kick} [mrad]	**Dose [kRad/yr]**
QC1LE	17.1	5.6	—	0.86 ± 0.07 (TOP) 1.46 ± 0.10 (BOTTOM)
QC2LE	1.8	2.4	—	0.022 ± 0.002 (TOP) 0.023 ± 0.002 (BOTTOM)
QA2LE	5.0E−02	—	—	—
QA3LE	4.0E−02	—	—	—
QA7LE	1.7E−02	—	—	—
QA4LE	1.6E−02	—	—	—
QA6LE	1.4E−02	—	—	—
BC1LE	1.1E−02	1.5	—	—
$\cdots$	$<$ 6.0E−03			

SVD2 SR Dose for the Injection based on the Orbit on 2002.05.15

(BP-geometry cut is applied.)

	Watt ($E_\gamma > 10$ keV)	E_{crit} [keV]	θ_{kick} [mrad]	**Dose [kRad/yr]**
QC1LE	17.3	5.7	—	0.84 ± 0.07 (TOP) 1.56 ± 0.10 (BOTTOM)
QC2LE	1.8	2.4	—	0.016 ± 0.003 (TOP) 0.027 ± 0.004 (BOTTOM)
QA2LE	5.2E−02	—	—	—
QA3LE	4.8E−02	—	—	—
QA7LE	2.2E−02	—	—	—
QA4LE	1.9E−02	—	—	—
QA6LE	1.7E−02	—	—	—
$\cdots$	< 7.0E−03			

Dose from the soft SR in the SVD2 layer1 is expected to be

- $\lesssim 1\,\mathrm{kRad}/\mathrm{yr}$ in physics runs
- $\sim 1\,\mathrm{kRad}/\mathrm{yr}$ in injections

which are much less than the SVD2 radiation hardness:

- > 10 MRad on the silicon sensors (DSSD)
- > 20 MRad on the readout chips (VA1)

[2]-(2) Dose Estimation for the Hard SR

(QCSR $\longrightarrow$ backscattering $\longrightarrow$ IP chamber)

(done by H. Yamamoto)

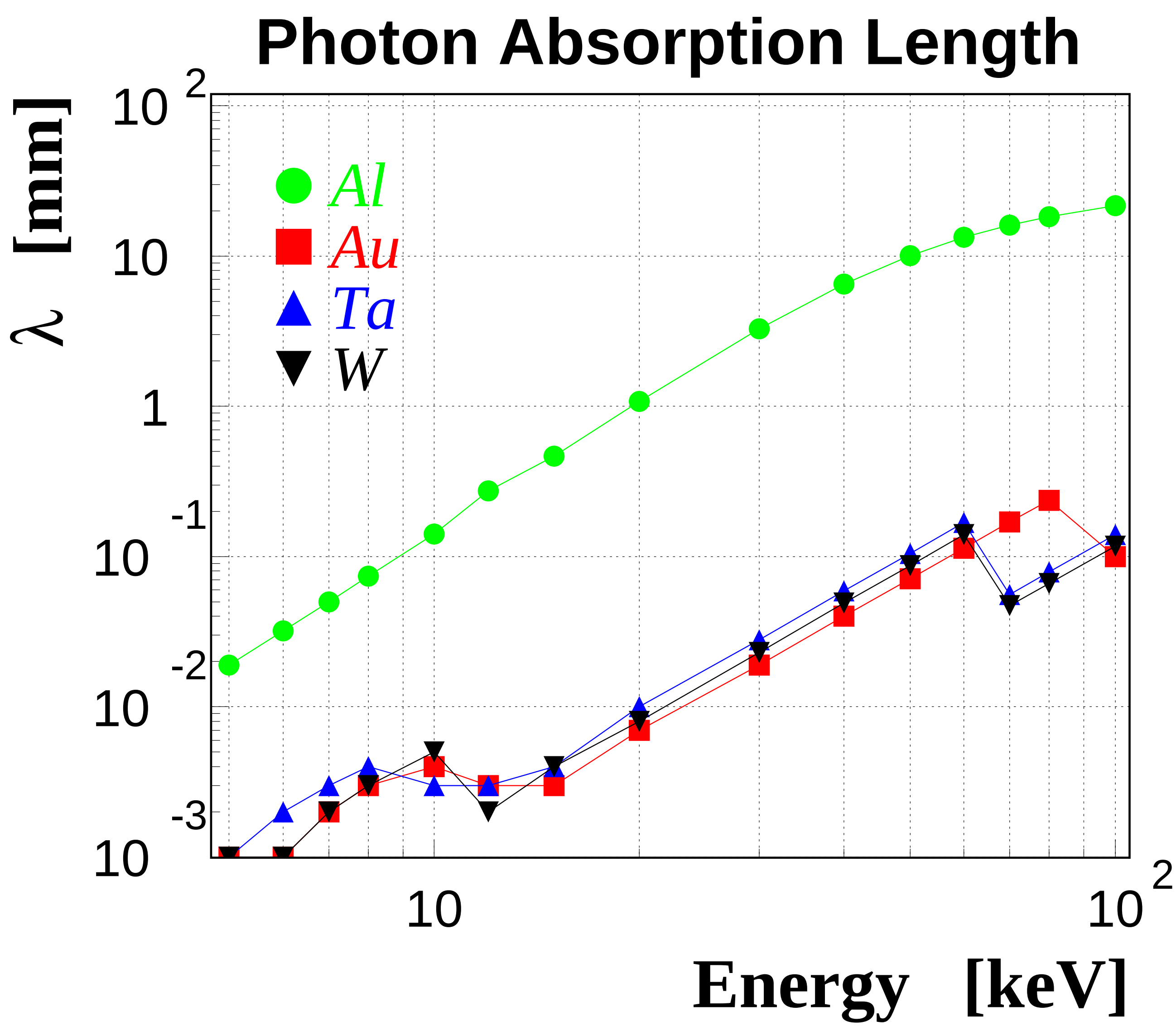
➠ **No SR mask** in FWD (R-side)
to avoid possible resonant-HOM heatings

- Simulation can predict dangerous modes.
- However, the required fabrication accuracy is close to the limit.
- We chose to remove the SR mask.

➠ **Heavy metals** $(Ta,\, W)$ in the taper section

$\boxed{\sim 20\,\mathrm{kRad}/\mathrm{yr}}$

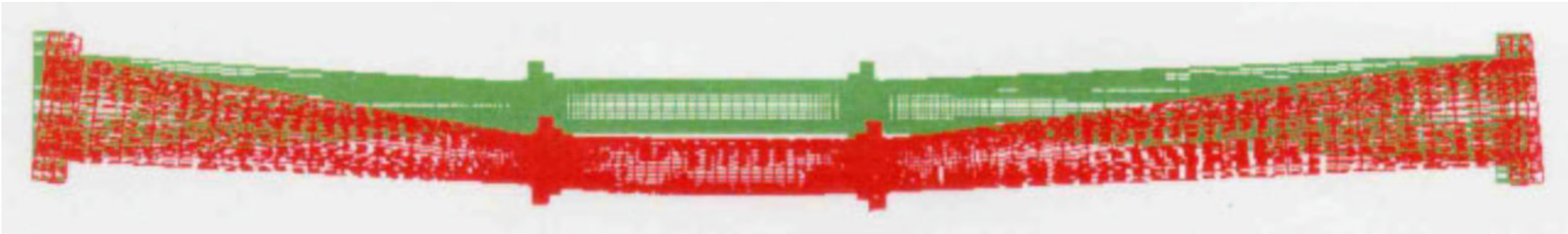
(much less than the radiation hardness of SVD2)



Photon Absorption Length
λ [mm]
10 2
10
1
10 -1
10 -2
10 -3
Al
Au
Ta
W
10
10 2
Energy [keV]

Stress Analysis

- The heavy-metal shield leads to a large amount of stress in the joint section.
- The final design has been checked by IHI using FEA.



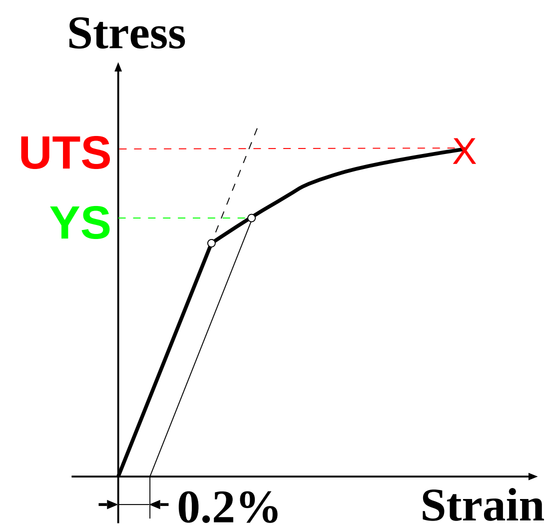
Finite-Element Analysis (FEA)

- ⇛ Based on the 3-dimensional SOLID model with an approximation:
  - Cylindrically symmetric around the beam axis
- ⇛ Single support at the flange
- ⇛ Inside: vacuum, the cooling gap: $2\,\mathrm{kgf}/\mathrm{cm}^2$, outside: $1\,\mathrm{atm}$
- ⇛ (calculated stress) $\times$ 1.15 for earthquakes
- ⇛ Static analysis
- ⇛ Definition of the permissible amount of stress:

$$\boxed{\min\left(\frac{1}{4}\times\mathbf{UTS}\,,\ \frac{2}{3}\times\mathbf{YS}\right)}$$

UTS: Ultimate Tensile Stress

YS: Yield Stress



Results

[1] Displacement (max.)

- 0.628 mm with the single support at the flange
- ~ 0.1 mm with the fixed support on the flange

$\longrightarrow$ Acceptable for the SVD2 mechanical structure

[2] Proper frequency

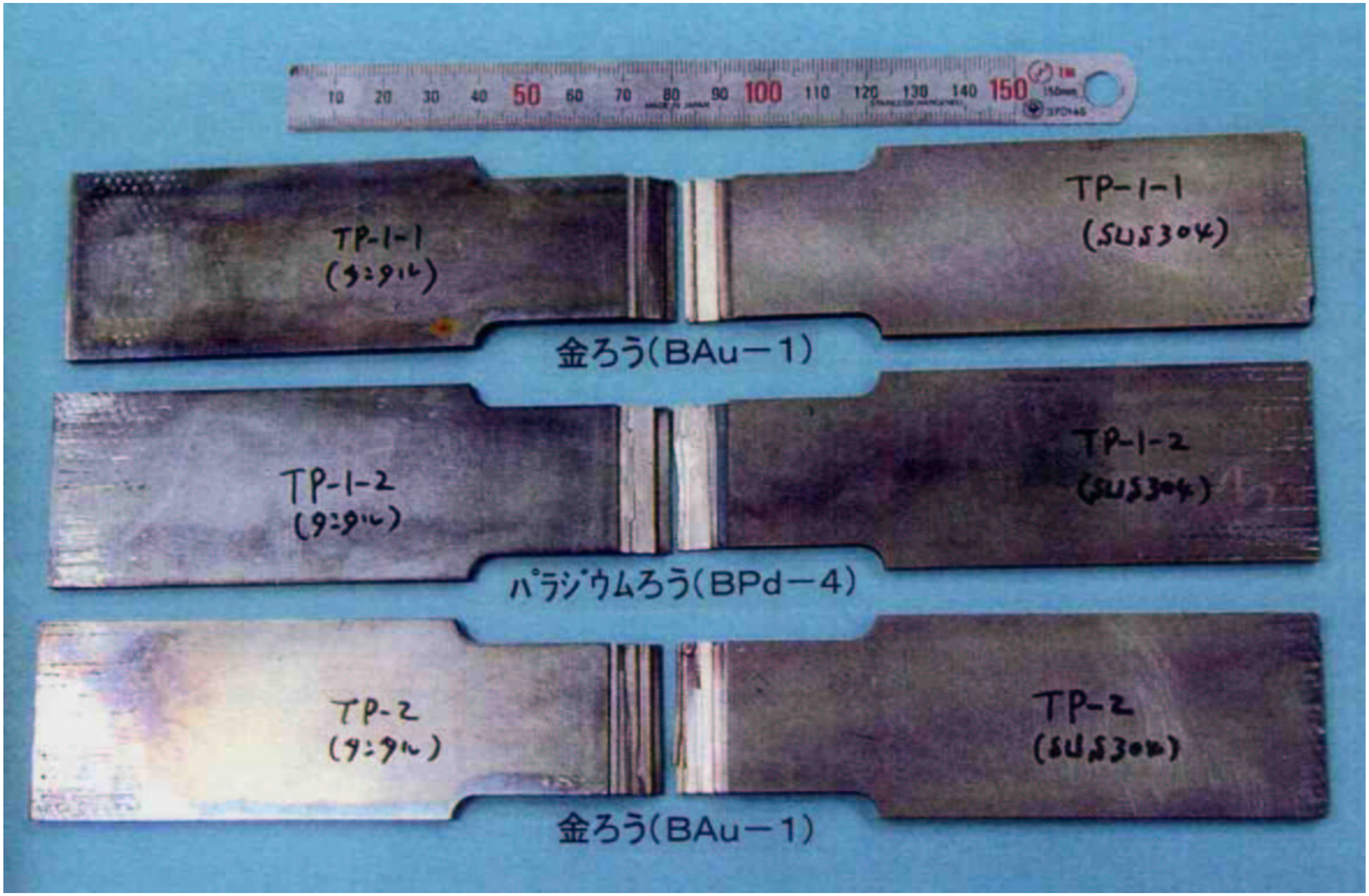
- 29.8 Hz with the single support at the flange
- ~ 70 Hz with the fixed support on the flange

$\longrightarrow$ Rigid structure (> 20 Hz)
$\longrightarrow$ No dynamic analysis needed for earthquakes

[3] Stress

Section	**Stress** (max) [$\mathrm{kgf/mm^2}$]	$\times$ 1.15	**Permissible limit** [$\mathrm{kgf/mm^2}$]	**Judgment**
Inner Be (FWD)	7.69	8.84	12.4	**OK**
(BWD)	7.39	8.50	12.4	**OK**
Al (FWD)	2.12	2.44	2.5	**OK**
(BWD)	1.88	2.16	2.5	**OK**
Ta (FWD)	2.01	2.31	10.5	**OK**
(BWD)	3.36	3.86	10.5	**OK**
Ta welding (FWD)	2.01	2.31	2.58	**OK**
(BWD)	2.36	2.71	3.87	**OK**
Ta-SUS brazing (FWD)	0.70	0.81	–	**(OK)***
(BWD)	0.74	0.85	–	**(OK)***
SUS-Be brazing (FWD)	0.88	1.01	–	**(OK)***
(BWD)	0.74	0.85	–	**(OK)***
Al-Be(out) welding (FWD)	1.12	1.29	1.88	**OK**
(BWD)	1.05	1.21	1.88	**OK**
Al-Be(in) welding (FWD)	1.42	1.63	1.88	**OK**
(BWD)	0.83	0.95	1.88	**OK**

* Estimated using the data of the tensile tests



The final design has stress under the limit all over the chamber.

Beam-pipe Heating

caused by

(1) **Synchrotron Radiation**

In some cases,

- $\sim$ 3.5 W on the SR mask ($\rightarrow$ 6 K rise at the tip)
- $\sim$ 10 W on the Ta pipe

(2) **Image current**

Heat: $U(W) \propto n_b Q_b^2 \sqrt{\frac{\mu}{\sigma_z^3 \sigma}} \cdot \frac{L}{r}$ (μ: permeability, σ: conductivity)

In case of SVD2,

- 25 W in the Be section
- 47 W on the Ta pipe
- SUS piece is hidden.

(3) **HOM** (dominant)

($\rightarrow$ next page)

HOM Heating (incoherent)

simulated with

- **MAFIA**
  - Non-cylindrical geometries
  - More CPU time
- **ABCI**
  - Cylindrical geometries only
  - Used in the estimation of the trapped modes ($\rightarrow$ heating)

$\ll$ **Heat generated in the Be section** $\gg$

	current	n_b	P_{meas}	P_{heat}
BEAST	e^+ 300 mA	648	7 W	8 W
BEAST	e^- 350 mA	921	10 W	8 W
SVD1.2	e^+ 450 mA	1146	10.5 W	11 W

(P_{heat}: estimated with ABCI)

$\longrightarrow$ ABCI simulation works well.

$\ll$ HOM loss and heating in the entire IP chamber $\gg$

	$P_{HOM}(W)$	$P_{heat}(W)$
SVD1.2	6800	300
SVD2 (fixed angle)	6250	770
SVD2 (varying angle)	2560	68

$\boxed{\textbf{Heat(SVD2)}/\textbf{Heat(SVD1)} \sim \textbf{1}/\textbf{5}}$

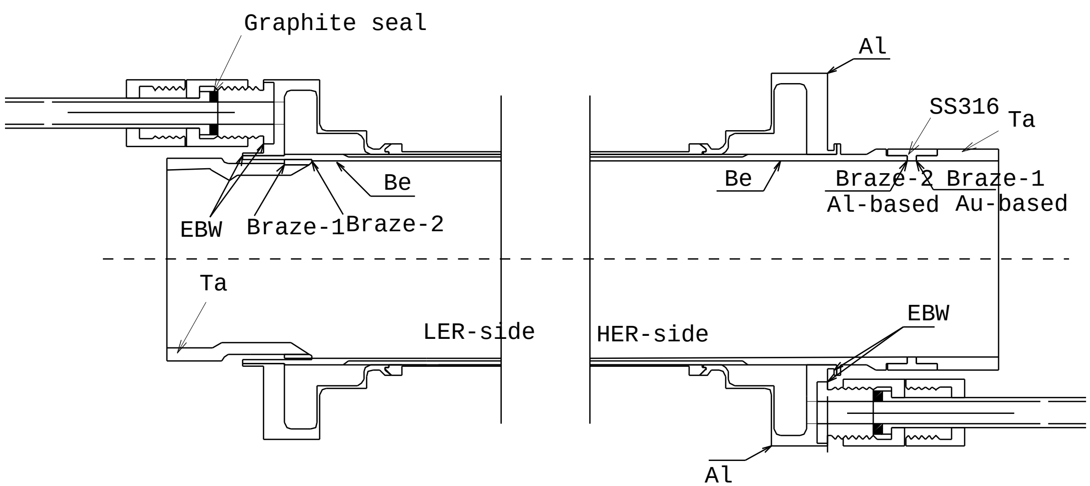
due to the smoother inner surface of the SVD2 IP chamber

The SVD2 cooling system was designed for

- 100 W in the Be section
- 100 W in the FWD Ta cone
- 100 W in the BWD Ta cone

Cooling System for the Be pipe

- Liquid coolant: *normal paraffin*
  (He cooling close to the allowed stress limit)
  - Chemically equivalent to PF200 (C_nH_{2n+2}) which has been used by CLEO for 3 years
  - Flows in the gap of the double-wall Be cylinder (0.5 mm)
  - Corrosion test has been performed using a Be rod over 6 months.
- The enough **cooling power** has been confirmed using the simulation and the mockup.
- The enough **flow rate** has been confirmed using the **genuine** beam-pipe.
  - $\sim 2\,l/$min (should be $> 1\,l/$min)



Schedule

In 2003,

(1) **Feb. 17 $\sim$ 28**: Installation of the IP chamber into SVD2

(2) **Mar. $\sim$ Jun.**: System test & alignment using cosmic ray

(3) **Jul. 1 $\sim$ Oct.**: Summer shutdown
$\longrightarrow$ Installation of SVD2 into the Belle detector