IR chamber upgarde

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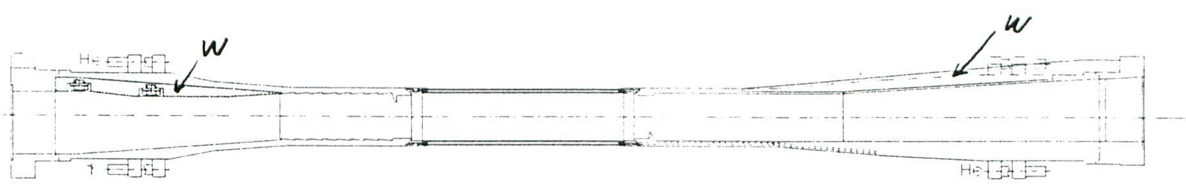
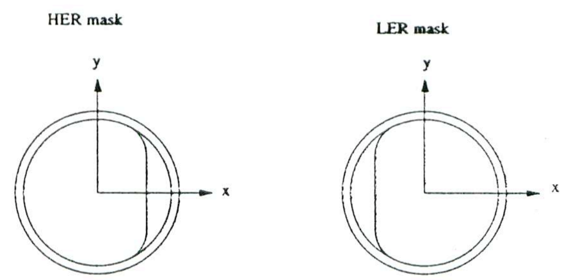
KEK-B Review
February 24, 2001

1. Beam backgrounds
2. Heat management
3. Mechanical design

Versions of SVD1.x IR beampipe





All $r = 2$ cm, Be: He cooled, Cone: Water-cooled.

verision	Period	comment
SVD1.0	6/99→8/99	no gold on Be SVD: rad-soft chip (200 kRad)
SVD1.2	10/99→7/00	20 μm gold outside Be SVD: rad-soft chip (200 kRad)
SVD1.5	10/00→	10 μm gold inside Be W masks enlarged SVD: rad-tolerant chip (1MRad, mostly)

IR Beampipe Design

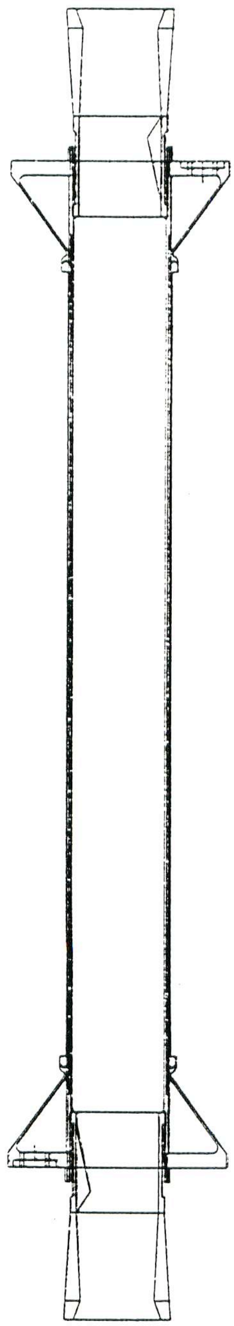
Default design has been decided:

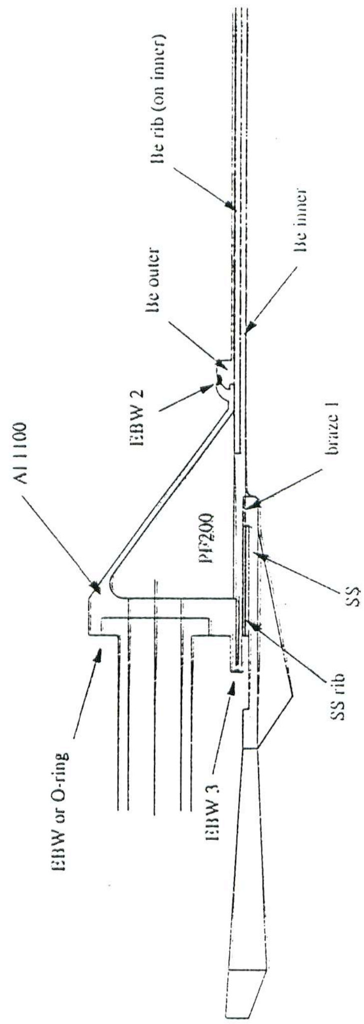
1. Be section
   - The design has been finalized at the last SVD upgrade review.
   - PF200 liquid cooling.
2. Cone section
   - Tantalum vacuum pipe.
   - Tungsten outer masks.
   - Water cooling.
3. Two sections joined by SuS transition.

Ta-SuS joining/vacuum tests starting at IHI.

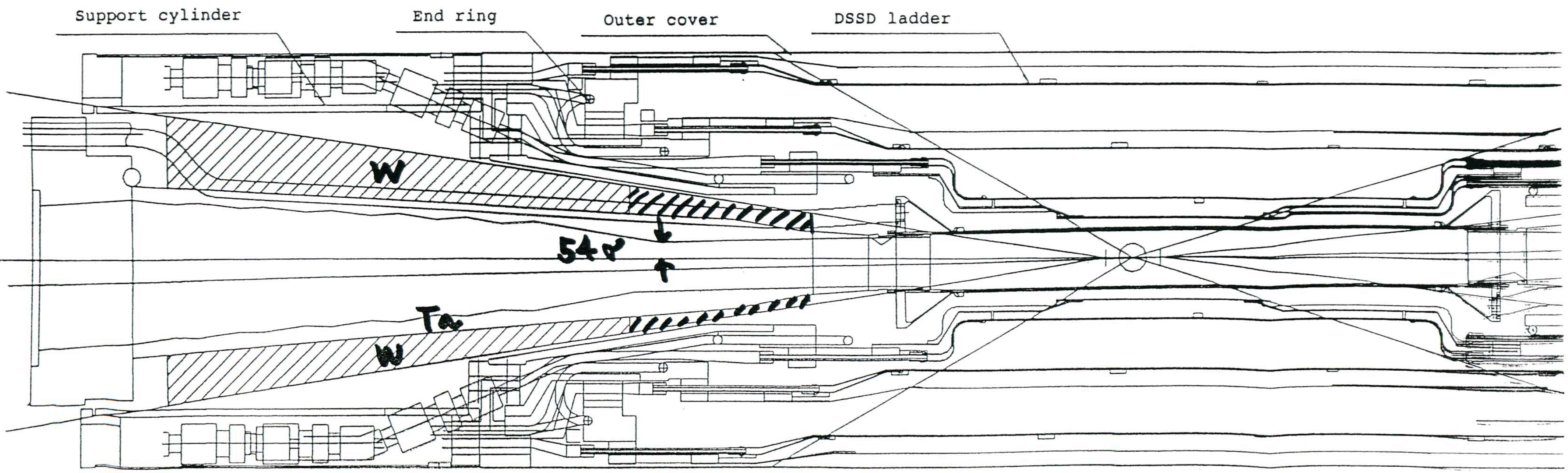
The quote for the entire beampipe system has been issued. Budget is tight, but not out of question.

SVD2.0 Be Beampipe

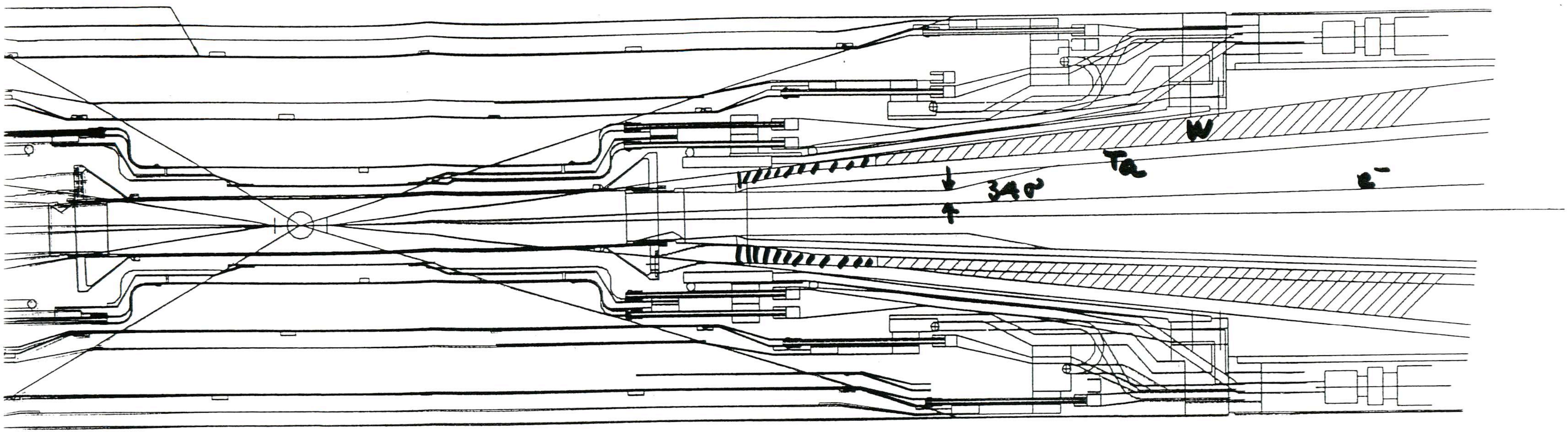




- r = 1cm (1.5cm)
- Liquid cooled (PF200)
- Au 10μ inside
  Au 250μ outside (except fiducial)


Support cylinder
End ring
Outer cover
DSSD ladder
W
54°
Ta
W

DSSD ladder



Synchrotron Radiation

Two Sources of SR Backgrounds

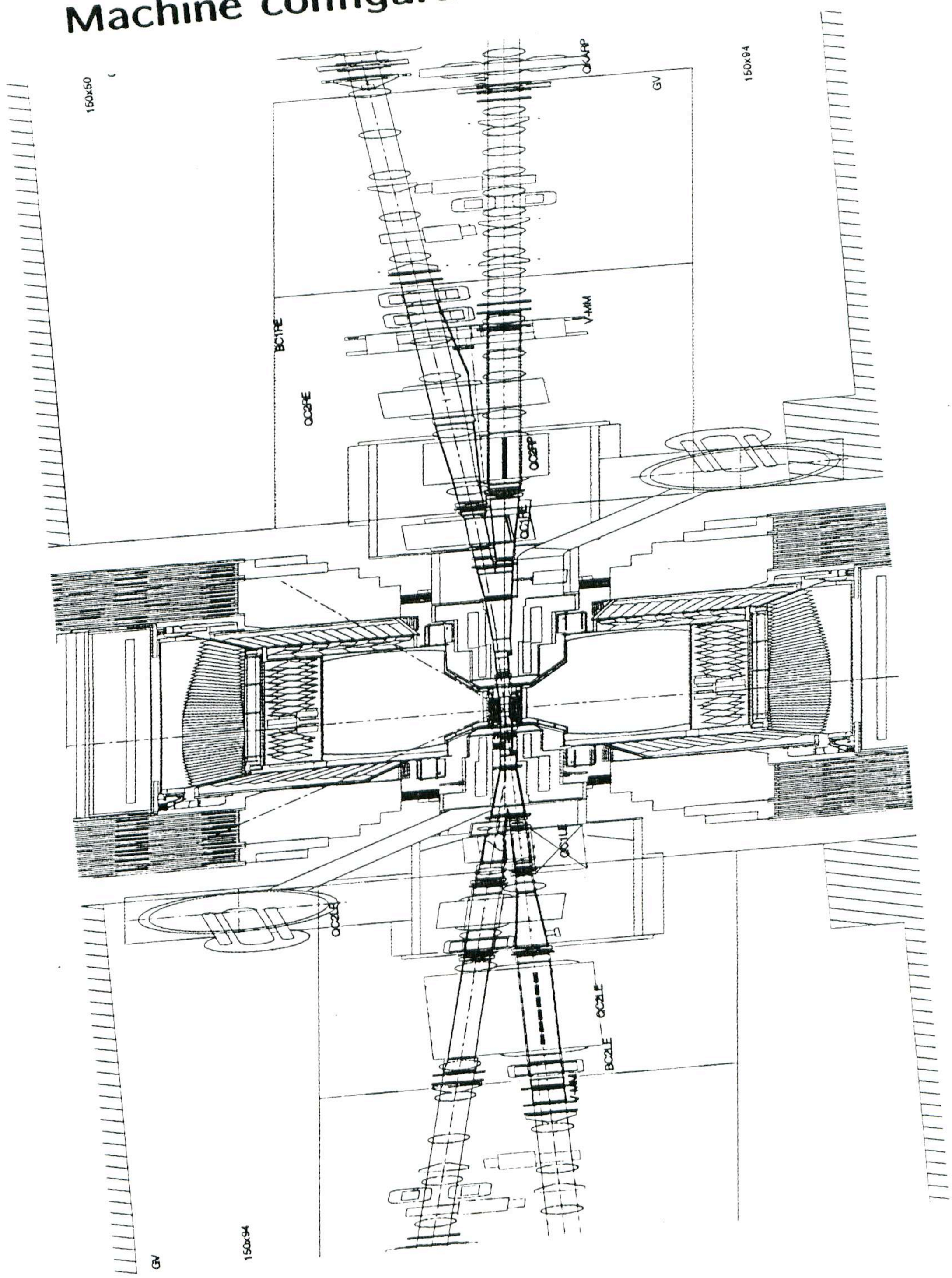
- **'Soft' SR background**

  SR photons from HER upstream.
  (Quads, Steering)
  Caused gain loss of SVD1.0.

- **'Hard' SR background**

  Backscattering from downstream HER.
  (From QCSR)
  High-pulseheight component of SVD.
  CDC leakage current.

Machine configuration near Belle



SVD2.0 Design for 'Soft' SR

Pursue $r = 1$cm possibility.

- Tilt 11mrad w.r.t. Belle axis.
  - Smaller masks → less HOM.
    3mm high masks (HER and LER).
  - Be section and cones on axis.
- Sawteeth on HER side (varying angle).
  Surface scattering → tip scattering.
  ∼ 1/50 dose reduction.
- Masks away from fiducial region.
  ∼ 1/10 backscattering dose per 5cm.
  (300μm Au foil)

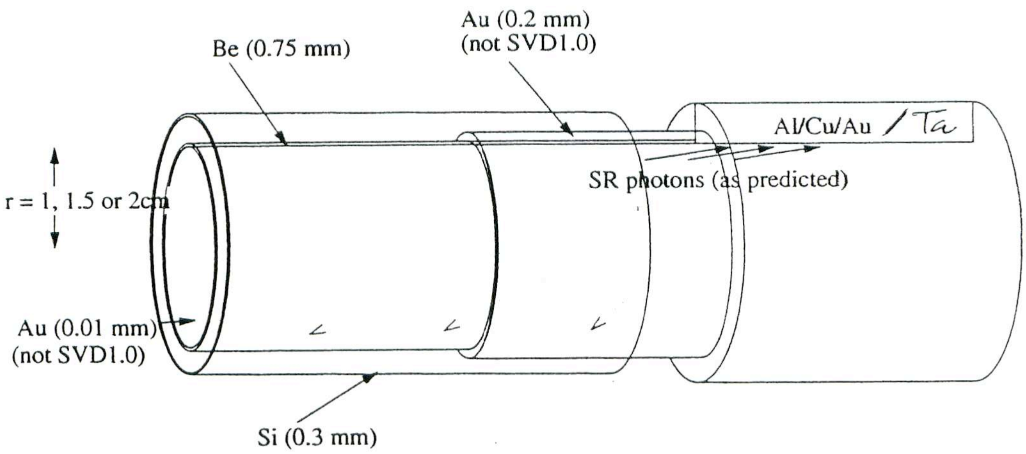
Total dose ∼ 0.01kRad/yr

(dominated by {HER-mask tip-scattering from QC2)
{LER-side Ta surface backscattering? (QC2).

- Roughly consistent with SRSIM
  (Stu Henderson's code that replaces EGS)
- All SR from LER found to be negligible.
  (Low E_c)

SR dose simulation

Method



1. SRGEN (by S. Henderson)
   Twiss parameters → beam profile.
   Steps through magnetic field.
   Numerically integrates the power spectrum on a given surface.
2. EGS4
   Photons to 1 keV, Electrons to 20 keV.
   KEK improvements (L-edge X-rays etc.)

SVD2.0 Design for 'Hard' SR

HER offset $\sim 4.3cm$ in QCSR on exit

$$\longrightarrow \begin{array}{l} E_c = 38 \text{ keV} \\ \text{Power} = 25 \text{ kW/A} \end{array}$$

Dumped on a beampipe surface that has direct line of sight to IR beampipe.

'SR dump' beampipe: Al $\rightarrow$ Cu ($\times 1/10$) (1999 Fall)
SVD1.5: $\sim$ 10kRad expected by simulation.

SVD2.0

- Use Ta for the cone section. (absorb QCSR 40 keV X-rays)
- LER side mask made of SS (not Al). Blocks backscattered X-rays for $E_\gamma < 100keV$.
- 11mrad tilt.

$\rightarrow$ 'Hard' SR should be negligible.

Particle Background

Simulation

- TURTLE simulation
  - The entire ring, up to one whole turn.
  - Bremsstrahlung and Coulomb scattering on CO at 1 nTorr.
- GEANT simulation
  - Full detector simulation.
  - Up to QC2 on both sides
    (8.3 m HER side, 6.5 m LER side)
  - Magnetic fields of Quads and soleinoids in the GEANT simulation.

Single-Beam Background

Dec 2000

	current	pressure	CO press.	dose
HER	0.4A	0.45 nTorr	0.81 nTorr	7 kRad/yr
LER	0.5A	0.53 nTorr	0.95 nTorr	15 kRad/yr

Normalizing this to the design beam currents and at 1nTorr of CO,

	current	CO press.	dose
HER	1.1A	1 nTorr	24 kRad/yr
LER	2.6A	1 nTorr	82 kRad/yr

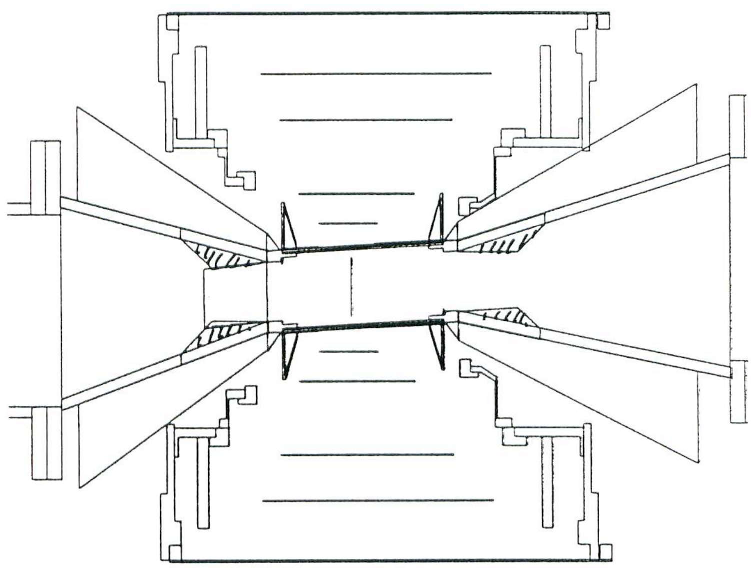
The MC expectation to be compared is

	current	CO press.	dose
HER	1.1A	1 nTorr	9.4 kRad/yr
LER	2.6A	1 nTorr	40.4 kRad/yr

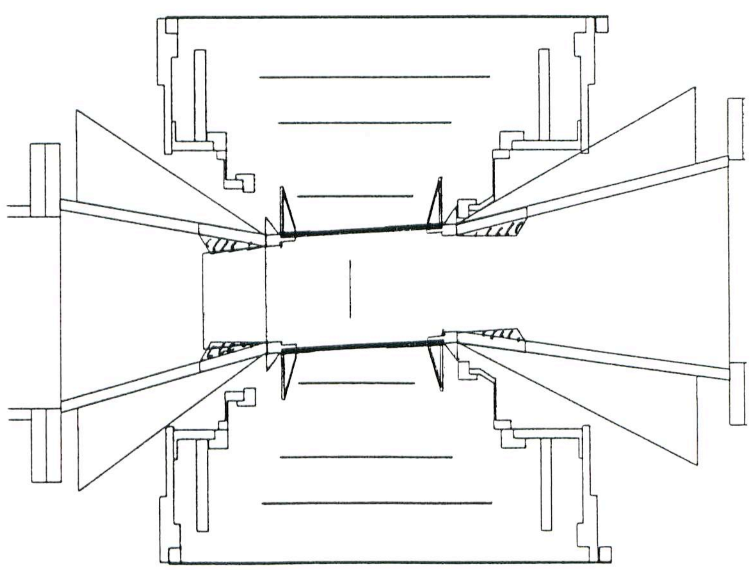
Namely, the agreement between data and MC is within a factor of a few.

SVD2.0 geometries

r=1cm



r=1.5cm



Inner masks : 1/2 ~ 1/3 reduction
of SVD lyr 1 dose.

Particle Background Simulations

Unit = kRad/yr (1yr = 10^7 sec)
(1.1A/2.6A, 1nTorr CO)

SVD1.4

	$L1$	$L2$	$L3$
$r(cm)$	3.0	4.6	6.1
HER Brem	5.1 ± 0.6	2.3 ± 0.2	1.8 ± 0.2
HER Coul	4.3 ± 0.7	2.6 ± 0.5	0.9 ± 0.2
LER Brem	5.4 ± 1.2	2.2 ± 0.5	1.2 ± 0.2
LER Coul	35.0 ± 3.2	16.8 ± 1.5	8.4 ± 0.7
Sum	49.8	23.9	12.3

SVD2.0 $r = 1cm$

	$L1$	$L2$	$L3$	$L4$
$r(cm)$	1.5	2.2	4.5	6.0
HER Brem	13.9 ± 1.4	9.4 ± 0.8	4.3 ± 0.3	3.8 ± 0.3
HER Coul	9.0 ± 2.2	5.1 ± 1.1	2.6 ± 0.4	2.2 ± 0.3
LER Brem	4.7 ± 1.6	5.4 ± 1.5	1.8 ± 0.4	1.7 ± 0.6
LER Coul	96.1 ± 13.8	66.3 ± 6.9	22.5 ± 3.1	16.6 ± 1.6
Sum	123.7	86.2	31.2	24.3

SVD2.0 $r = 1.5cm$

	$L1$	$L2$	$L3$	$L4$
$r(cm)$	1.5	2.2	4.5	6.0
HER Brem		10.2 ± 0.9	4.6 ± 0.3	3.8 ± 0.3
HER Coul		3.0 ± 0.7	1.4 ± 0.3	2.4 ± 0.4
LER Brem		7.7 ± 2.4	3.2 ± 0.7	2.6 ± 1.3
LER Coul		85.0 ± 13.3	25.8 ± 2.4	13.8 ± 1.2
Sum		105.9	35.0	22.6

IR Beampipe Heating Sources

1. Synchrotron Radiation
   In some cases,
   - $\sim$3.5 W on the HER mask,
     $\rightarrow$ 6 K rise at the tip.
   - $\sim$ 10 W on Ta pipe (forward side).

   Manageable.

2. Image current
   (μ: permeability, σ: conductivity)

   $$\text{Heat } U(W) \propto n_b Q_b^2 \sqrt{\frac{\mu}{\sigma_z^3 \sigma}} \cdot \frac{L}{r}$$

   SVD2.0 (r=1cm):
   $\rightarrow$ 25 W total on Be section.
   $\rightarrow$ 30 W at a SS piece (5 W with Au coating)
   $\rightarrow$ 70 W at a Ta pipe (28 W with Au coating)
   Au coating on SS and Ta (r=1cm section).

3. HOM

HOM Heating Simulation

1. MAFIA
   Non-cylindrical geometry. CPU intensive.
   HOM of a mask is determined by
   the area of mask aperture.

2. ABCI
   Cylindrical geometries only.
   Estimates trapped modes → heating.

Heat generated on the Beryllium section.
(P_{heat}: estimated by ABCI)

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

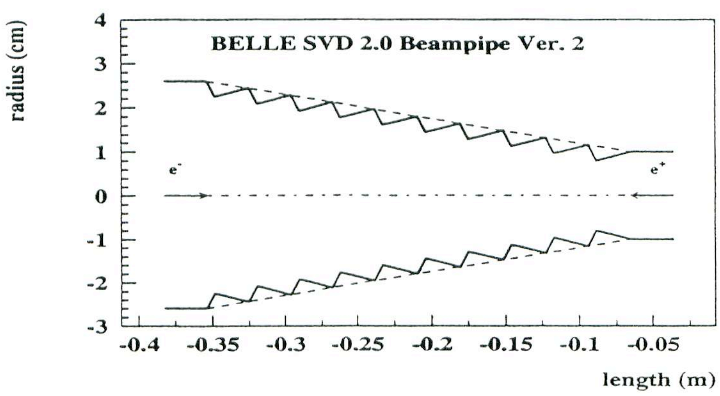
ABCI estimate works reasonably well.

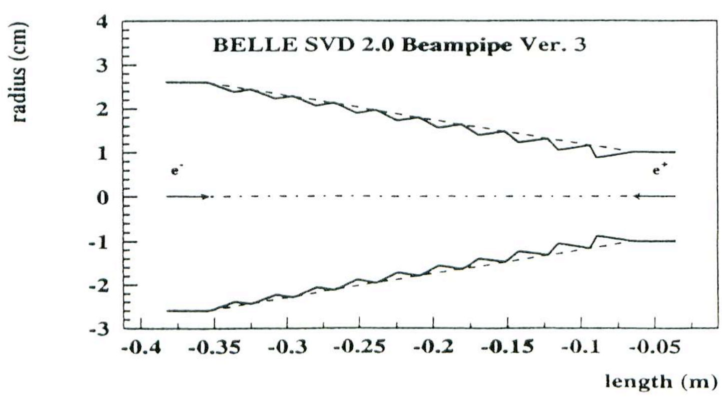
HOM Heating by Sawteeth

ABCI estimates

$I = 2.6A$, $dt_{bunch} = $ 2ns, $\sigma_z = $ 4mm (LER dominated)

	P_{HOM} (W)	P_{heat} (W,trapped)
Fixed angle	5550	740
Varying angles	1860	38





HOM Heating Estimate of SVD1.2 and 2.0

HOM loss and trapped modes (heating)
for entire IR beampipe:

measurement	P_{HOM} (W)	P_{heat} (W)
SVD1.2	6800	300
SVD2.0*	2560	68

*×1/2 for the final SVD2.0 design with large inner particle mask.

Assuming 1/3 is deposited on Beryllium section,
Heat(Beryllium) = 100 W for SVD1.2

For SVD2.0 also, assume 100W on the Beryllium section, and 100W on each cone.
+ 50 W on each SS section.

Stress analysis of SVD1.2

IHI analysis: He cooling close to allowed stress limit:
(100W on Beryllium section)

item	value	Stress (kgf/mm^2)
T (Al-Be joint)	15 K	1.29
dT(Be inner-outer)	14.6 K	1.01
dT(Al-Be)	5 K	0.81
Self weight + press.	-	0.51
Total		3.51
Allowed limit*		3.9

* 1.5 times 0.2% elongation yield point.

Verified by FEA analysis of Marc Rosen.

Be Beampipe Coolant Selection

IHI analysis: He cooling close to allowed stress limit

Water cooling: used by CLEO/BaBar
but corrosion risk
(sulfide, chroride, etc.)

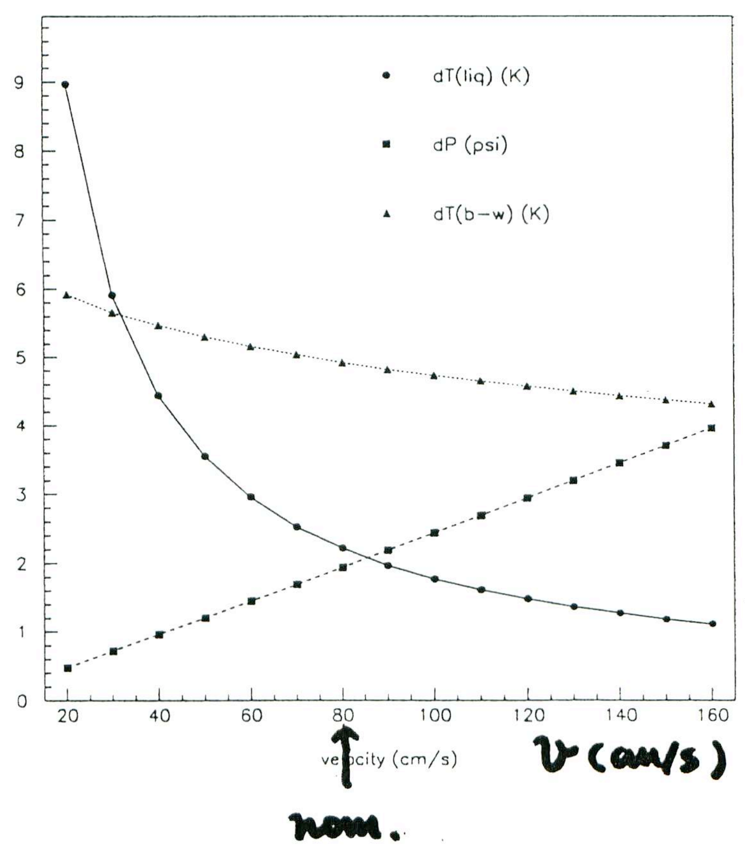
PF200 widely used by CLEO including Be beampipe
well tested on bare Be
(no need to coat)

	water	PF200
density (g/cc)	1.0	0.78
viscosity (g/cm·s)	0.010	0.019
th.cond. (W/cm·K)	0.0062	0.0016
sp. heat (J/g·K)	4.2	2.3

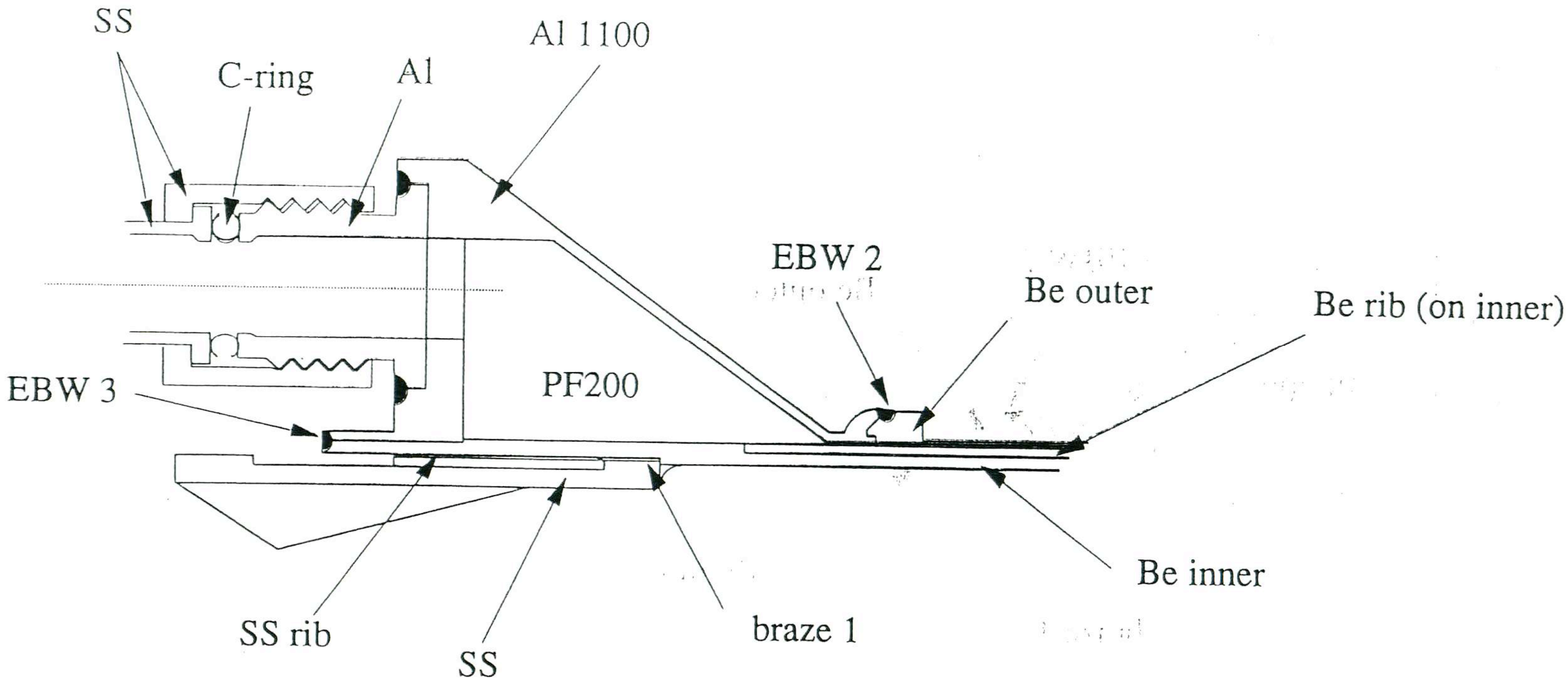
Still, avoid direct liquid-to-vacuum braze.

Be Beampipe

- Inner cylinder 0.5mm thick.
- Outer cylinder 0.25mm thick.
- Gap for PF200 0.5mm.
- 6 ribs
- One inlet, one outlet.
- To be facbricated by Brush-Wellman.

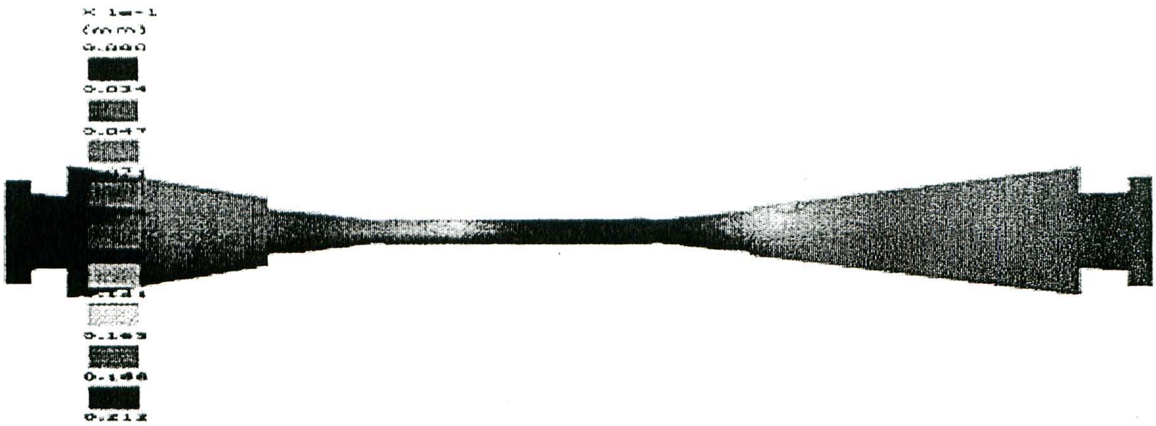


Temp rise of inner Be: ~ 1/5 of He cooling.

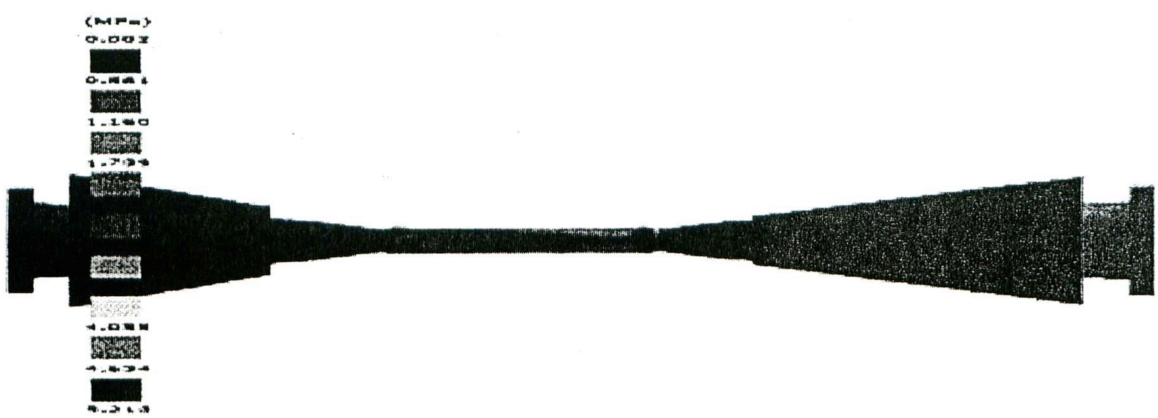

SS
C-ring
Al
Al 1100
EBW 2
Be outer
Be rib (on inner)
EBW 3
PF200
Be inner
SS rib
SS
braze 1

FEA analysis

Sag test: Simple support at ends.

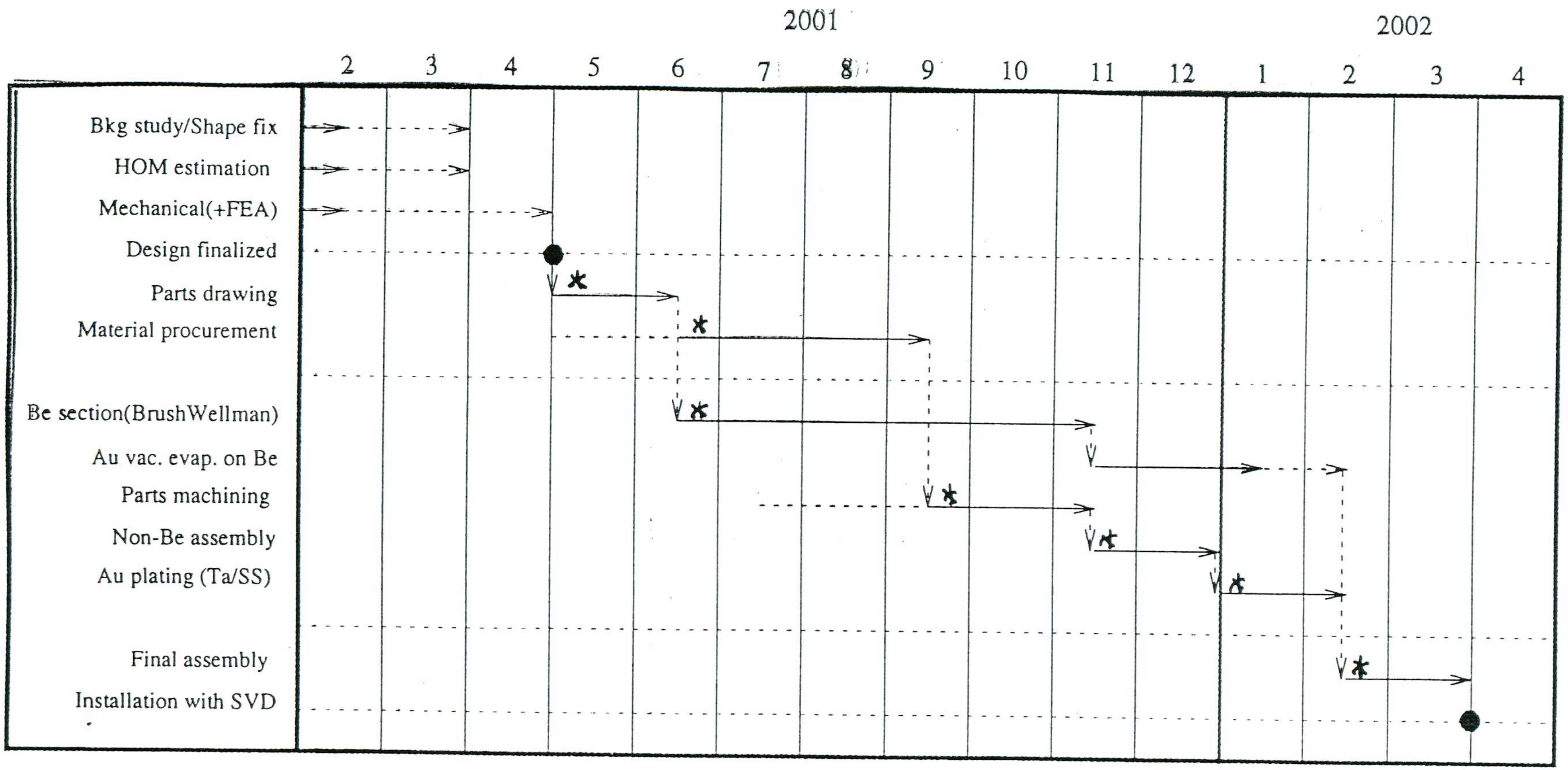


0.02mm max



2 MPa max ($\sim$ 6% yield point)

- Cantilevering deflects 1cm at the other end, and exceeds yield limit.
- Thermal stress OK (in particular at the SS tube)



* Approved by IHI, BW.

To do list

- Particle background
  - CDC dose/rate study and optimization
  - r=1.5 cm optimization
  - Touschek effect simulation
- Final machanical design
- HOM resonance study
- Establish assembly procedure that avoids cantilevering of the IR beampipe.