

# IR chamber upgrade

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

# 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.

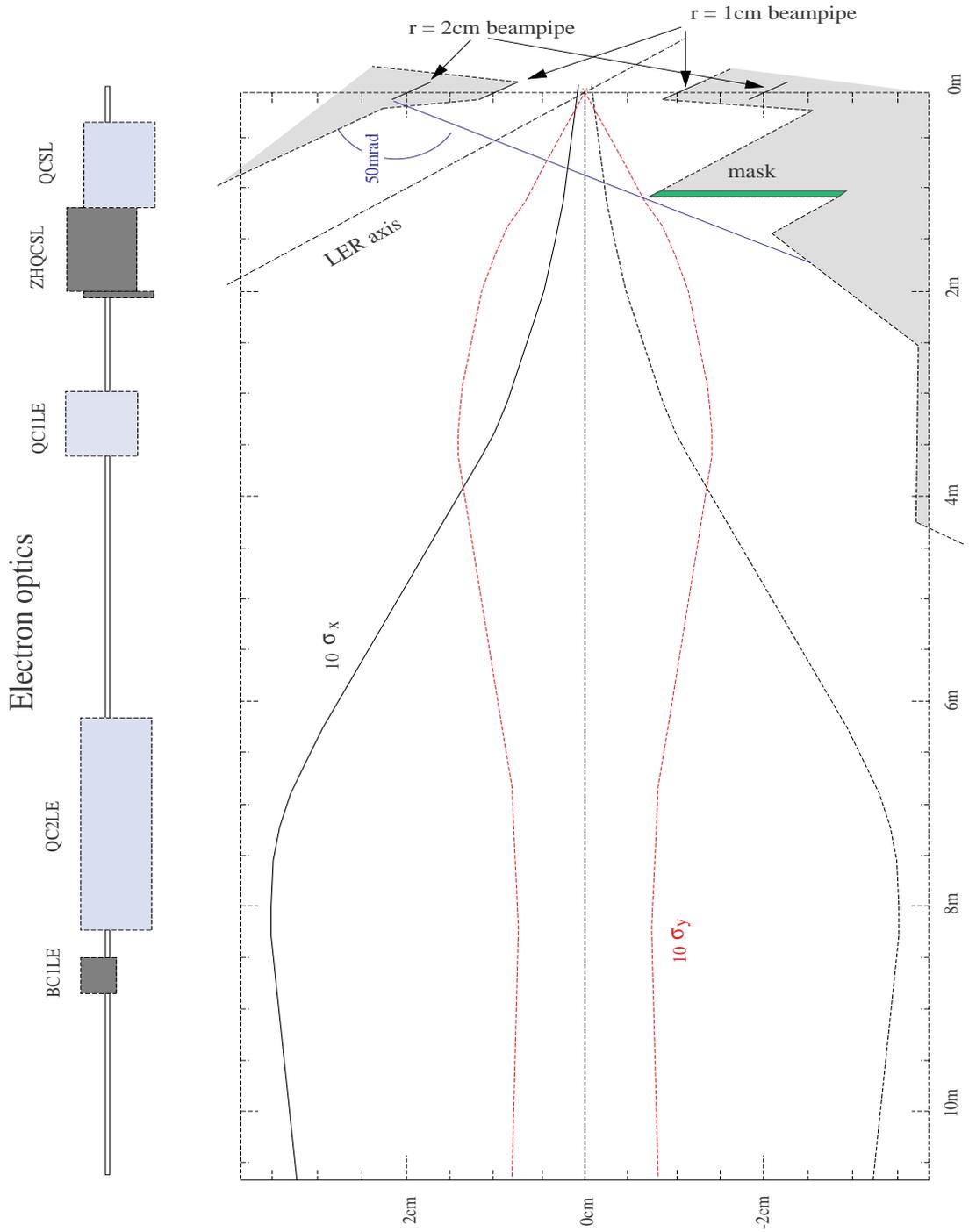
(From QCSR)

High-pulseheight component of SVD.

CDC leakage current.

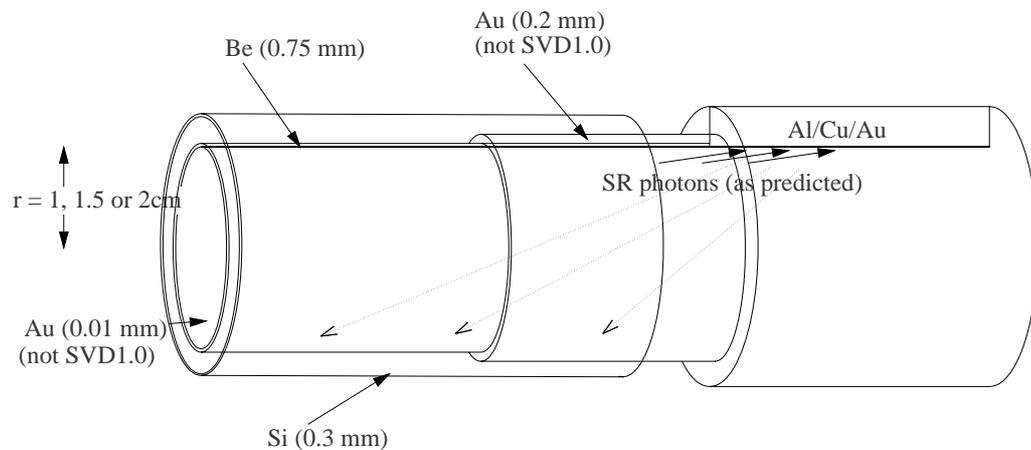


# HER side optics near IR



# SR dose simulation

## Method



### 1. SRGEN (by S. Henderson)

Twiss parameters  $\rightarrow$  beam profile.

Steps through magnetic field.

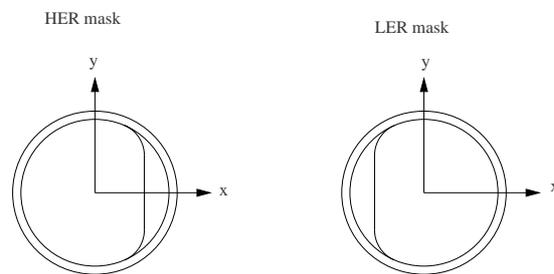
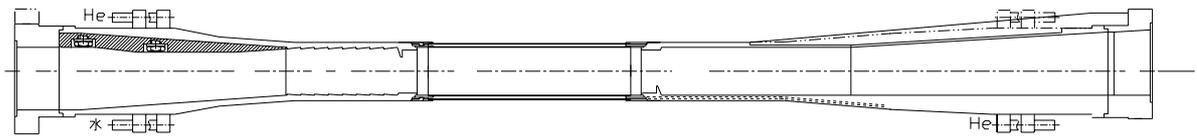
Numerically integrates the power spectrum on a given surface.

### 2. EGS4

Photons to 1 keV, Electrons to 20 keV.

KEK improvements (L-edge X-rays etc.)

## Versions of SVD1.x IR beampipe



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

version	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 $\mu$ m gold outside Be SVD: rad-soft chip (200 kRad)
SVD1.5	10/00→	10 $\mu$ m gold inside Be W masks enlarged SVD: rad-tolerant chip (1MRad, mostly)

## Possible Sources that damaged SVD1.0

(dose estimation: SRGEN + EGS)

1. QC2 ~ 50 kRad/10days

It could hit anywhere on the HER mask depending on steering.

2. BC3 ~ 300 kRad/10days

BC3 SR Could hit IR if not blocked by  $z = 1.1\text{m}$  mask.

3. QC1 ~ 500 kRad/10days

If y offset of QC2 causes SR hit on IR, QC1 should also hit.

These are in the right ball park to explain the SVD1.0 damage.

## SVD2.0 Design for 'Soft' SR

Pursue  $r = 1\text{cm}$  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.  
(300 $\mu\text{m}$  Au foil)

Total dose ~ 0.01kRad/yr

(dominated by HER-mask tip-scattering from QC2)

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

## SVD2.0 Design for 'Hard' SR

HER offset  $\sim 4.3\text{cm}$  in QCSR on exit

$$E_c = 38 \text{ keV}$$

→

$$\text{Power} = 25 \text{ kW/A}$$

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:  $\sim 10\text{kRad}$  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  $E_\gamma < 100\text{keV}$ .
- 11mrad tilt.  
→ 'Hard' SR should be negligible.

## SR during injection

2min injection/90 min physics run

HER $\gg$ LER again  
(QC1 dominates)

### 1. Fast component

Motion of bunch center

-  $\tau_{\text{dump}} \sim 1\text{ms}$  (feed back)

- Injected beam:  $x_{\text{off}} = 5\text{mm}$ ,  $x' = 0$ .

$$\sim \epsilon_x = 3 \times 10^{-7}\text{m}, \epsilon_y \sim 0.1\epsilon_x$$

- Kicker kicks existing bunches.

(1/5 of bunches every 20ms)

Assumed to have the same amplitude as the newly injected beam.

→ 0.1 kRad/yr

### 2. Slow component

Injection Emittance decays to normal.

-  $\tau_{\text{dump}} \sim 40\text{ms}$ .

$$\epsilon_x = 8 \times 10^{-8}, \epsilon_y = 0.5\epsilon_x.$$

(normal:  $\epsilon_x = 1.8 \times 10^{-8}$ ,  $\epsilon_y = 0.04\epsilon_x$ )

→ less dose than the fast component

## Offset Limits

Set limits (for machine people to follow)  
on offsets at QC1,2

Slopes are fixed from the offsets by

$$x'(s) = -\frac{\alpha(s)}{\beta(s)}x(s)$$

This assumes that the betatron phase advance is small in the region of quads and that the beam goes through the IP.

Good rule of thumb:

Do not exceed 3mm offsets in  $x$  or  $y$  at QC1,2.

# 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,

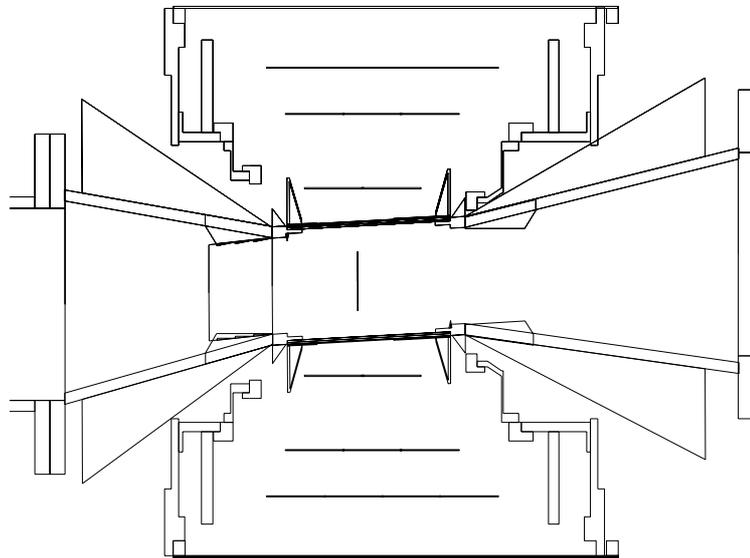
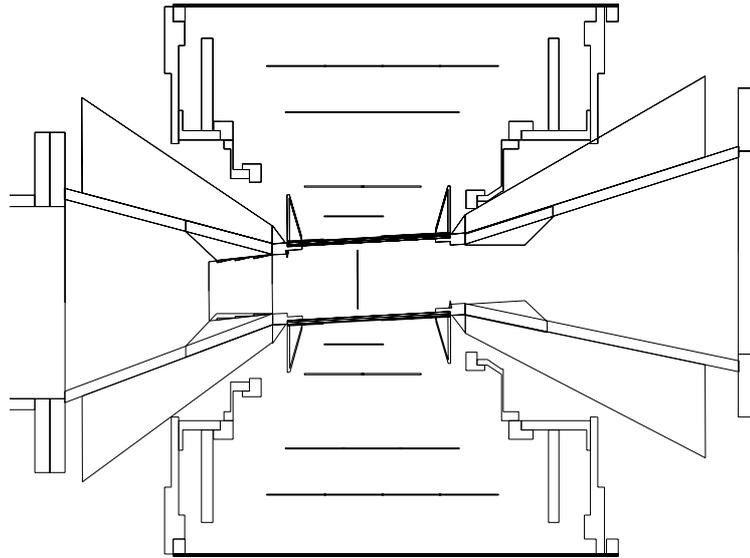
	current	CO press.	dose
HER	1.1A	1 nTorr	24 kRad/yr
LER	2.6A	1 nTorr	82 kRad/yr

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



## Particle Background Simulations

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

SVD1.4				
$r(cm)$	$L1$	$L2$	$L3$	
$r(cm)$	3.0	4.6	6.1	
HER Brem	$5.1 \pm 0.6$	$2.3 \pm 0.2$	$1.8 \pm 0.2$	
HER Coul	$4.3 \pm 0.7$	$2.6 \pm 0.5$	$0.9 \pm 0.2$	
LER Brem	$5.4 \pm 1.2$	$2.2 \pm 0.5$	$1.2 \pm 0.2$	
LER Coul	$35.0 \pm 3.2$	$16.8 \pm 1.5$	$8.4 \pm 0.7$	
Sum	49.8	23.9	12.3	
SVD2.0 $r = 1cm$				
$r(cm)$	$L1$	$L2$	$L3$	$L4$
$r(cm)$	1.5	2.2	4.5	6.0
HER Brem	$13.9 \pm 1.4$	$9.4 \pm 0.8$	$4.3 \pm 0.3$	$3.8 \pm 0.3$
HER Coul	$9.0 \pm 2.2$	$5.1 \pm 1.1$	$2.6 \pm 0.4$	$2.2 \pm 0.3$
LER Brem	$4.7 \pm 1.6$	$5.4 \pm 1.5$	$1.8 \pm 0.4$	$1.7 \pm 0.6$
LER Coul	$96.1 \pm 13.8$	$66.3 \pm 6.9$	$22.5 \pm 3.1$	$16.6 \pm 1.6$
Sum	123.7	86.2	31.2	24.3
SVD2.0 $r = 1.5cm$				
$r(cm)$	$L1$	$L2$	$L3$	$L4$
$r(cm)$	1.5	2.2	4.5	6.0
HER Brem	$10.2 \pm 0.9$	$4.6 \pm 0.3$	$3.8 \pm 0.3$	
HER Coul	$3.0 \pm 0.7$	$1.4 \pm 0.3$	$2.4 \pm 0.4$	
LER Brem	$7.7 \pm 2.4$	$3.2 \pm 0.7$	$2.6 \pm 1.3$	
LER Coul	$85.0 \pm 13.3$	$25.8 \pm 2.4$	$13.8 \pm 1.2$	
Sum	105.9	35.0	22.6	

## Particle Background Summary

1. SVD Ly1 dose: MC and DATA agree within a factor of 2-3 for both LER and HER .
2. Z scattering location: MC and DATA agreement is reasonable.
3. Phi distribution: MC and DATA agreement is reasonable.
4. About 1/2 of LER background is probably due to Touschek effect. (intra-beam scattering, tail blowup)
5. Innermost SVD layer dose is 2.5 times higher for SVD2.0 with  $r=1\text{cm}$  compared to SVD1.4 with  $r=2\text{cm}$ . (for the same pressure and beam current).
6. The dose for the 2nd layer of  $r=1\text{cm}$  version and innermost layer of  $r=1.5\text{cm}$  are comparable (optimization?)
7. CDC rates/current will go up for SVD2.0  $r=1\text{cm}$ , but needs more study.

## IR Beampipe Heating Sources

### 1. Synchrotron Radiation

In some cases,

- $\sim 3.5$  W on the HER mask,  
→ 6 K rise at the tip.
- $\sim 10$  W on Ta pipe (forward side).

Manageable.

### 2. Image current

( $\mu$ : permeability,  $\sigma$ : conductivity)

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

SVD2.0 ( $r=1\text{cm}$ ):

- 25 W total on Be section.
  - 30 W at a SS piece (5 W with Au coating)
  - 70 W at a Ta pipe (28 W with Au coating)
- Au coating on SS and Ta ( $r=1\text{cm}$  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

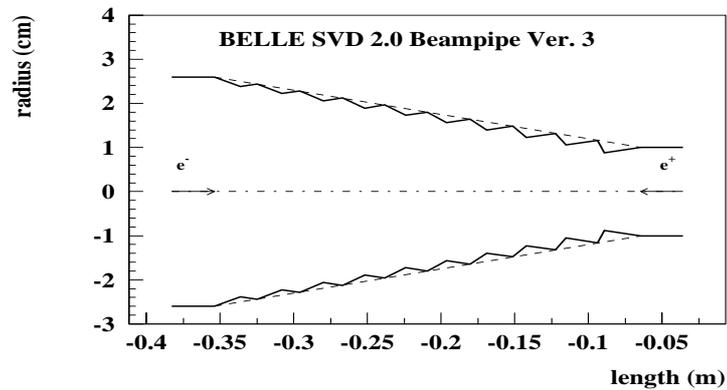
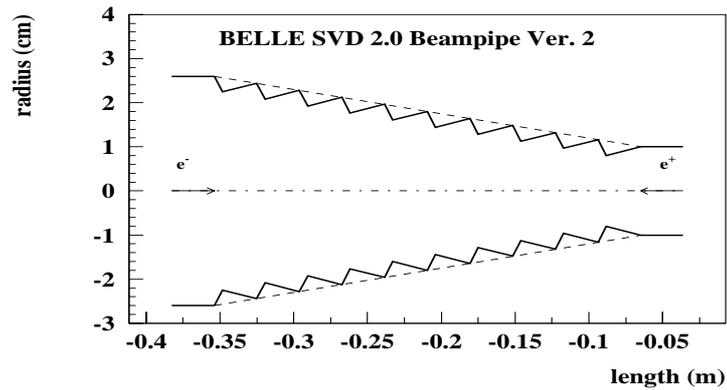
ABCI estimate works reasonably well.

# 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

\* $\times 1/2$  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 <sup>2</sup> )
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

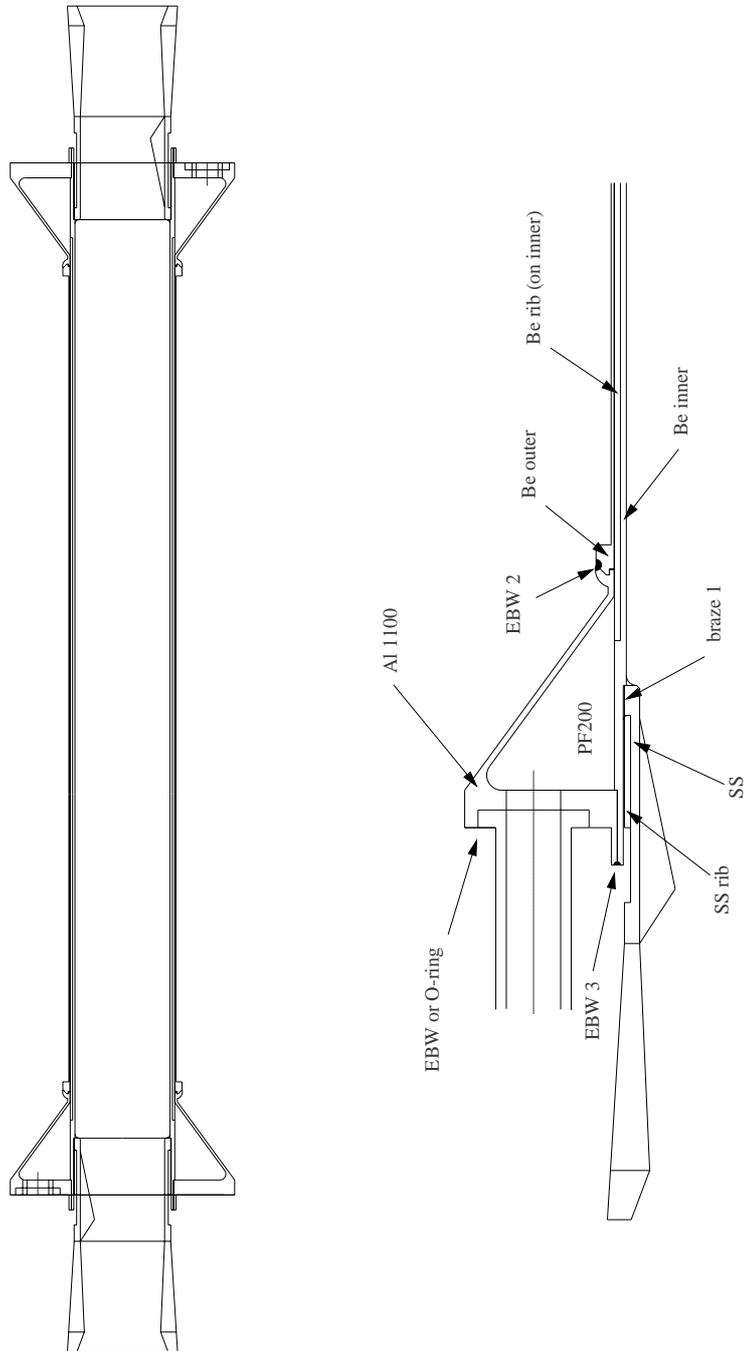
Water cooling: used by CLEO/BaBar  
but corrosion risk  
(sulfide, chloride, etc.)

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

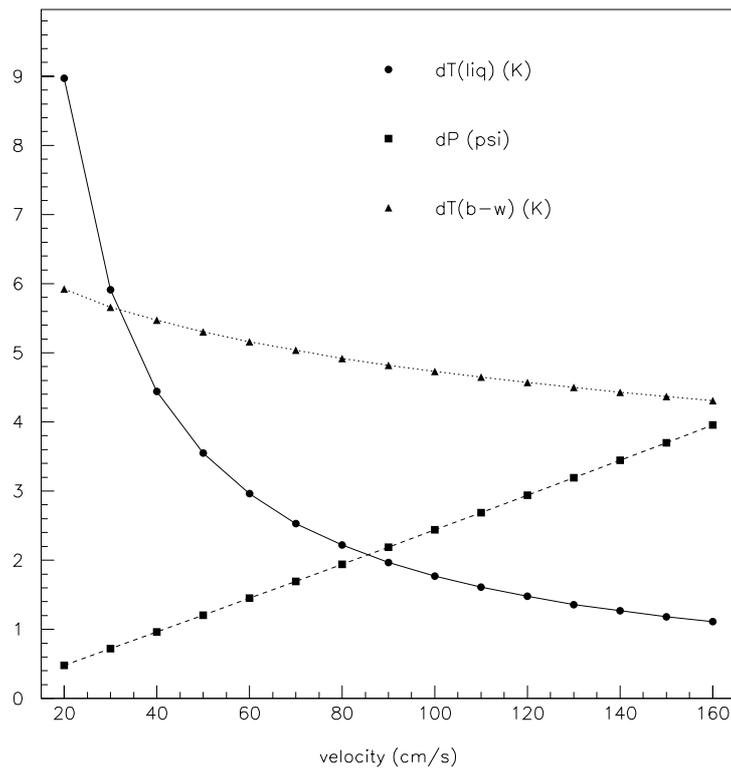
Still, avoid direct liquid-to-vacuum braze.

# SVD2.0 Be Beampipe



## 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:  $\sim 1/5$  of He cooling.

## Al Model Flow/Cooling Test

- $r=1.5\text{cm}$  mockup was built with Al.  
Same gap thickness (0.5mm), same number of ribs (6),  $\sim$  same length as the real Be beampipe.
- Pressure drop is as calculated (at 0.5 l/s):  
Measured: 0.04 atm  
Calculated: 0.037 atm
- Temperatures are also as expected.  
Flow is uniform in azimuth.