IR/Background Issues of Super B-factory

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1. Introduction

Detector-IR Issues of Super-KEKB

1. ×3 increase of LER bunch current (0.66→1.95mA)
   ×2 decrease of bunch length (6→ 3 mm)
   → $3^2 2^{3/2} = 25\times$ **heating of the IP beampipe.**

2. Shorter Touschek lifetime.
   Possibly larger vacuum pressure.
   → **Larger particle background/Amp.**

3. Stronger synchrotron radiation.
   → **SR heating and SR background at the IP beampipe.**

4. Possibly larger crossing angle.
   → **More diffcult for SR and particle background masks.**

5. Smaller β_y^*
   → **final quads closer to IP (space constraint)**

6. More injection time
   → **Injection background.**

IR design for Super-KEKB

- Reduce particle background.
- Reduce SR background.
- Reduce HOM heating, image-current heating.
- Better cooling.
- (Mechanical strength - FEA).

Good vertexing resoution:
Only practical way is to reduce the beampipe radius
→ Assume r=1cm.

2. Particle Background

Some design guidelines

- Massive masks around the inner vertex detectors.

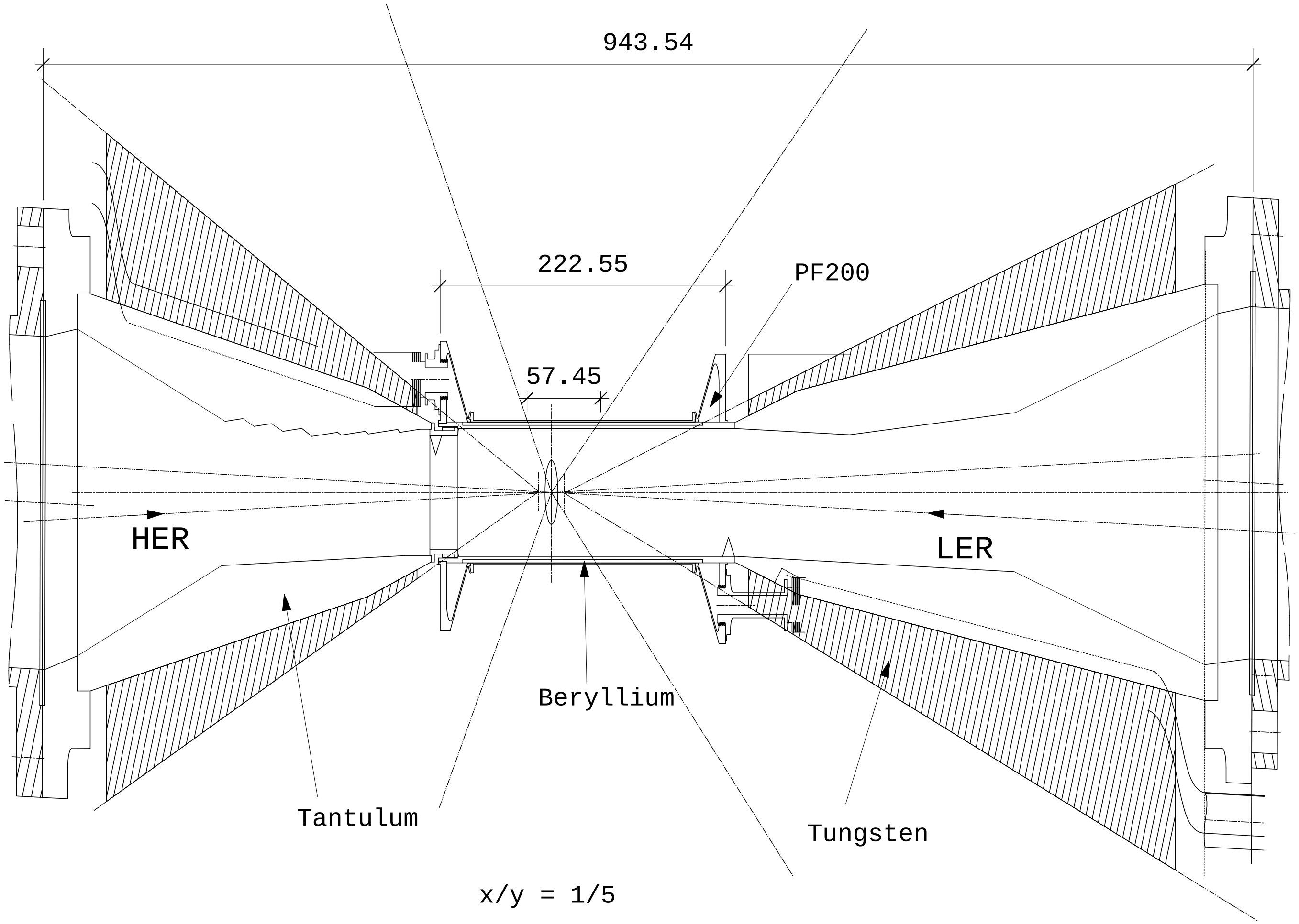
  1. At least ~10cm of path for particles hitting the mask.
     → r=1cm cylindrical tunnel on each side of IP along the incoming beam.
     The length limitted by crossing angle and the beam-stay-clear. (difficult for larger corssing angle)

  2. Integrated design of the heavy mask and SVD support/EFC.

- Systematic covering of upstream beampipes with heavy masks.

- Movable mask placements. Beta phase: not just wrt IP also other weak spots.

  Steer the beam loss away from IR.



Possible r=1cm IP beampipe design
(Respecting the EFC fiducial)

MC Simulation of particle background (Karim Trabelsi) (KEKB)

1. GEANT simulation to QC2.
2. Scatterings from the entire ring. (1 turn)

Uncertainties:

1. Vacuum pressure where the beam passes.
   (what is it now, and what will it be?)
2. Unsimulated elements (calbles, trays...).
3. Multi-turn effects (Touscheck in particular).
4. Showers upstreams of QC2.
   (e.g. the beams entering QC2 just outside b.p.)
5. Gradual beamloss due to 'unstable' beams.

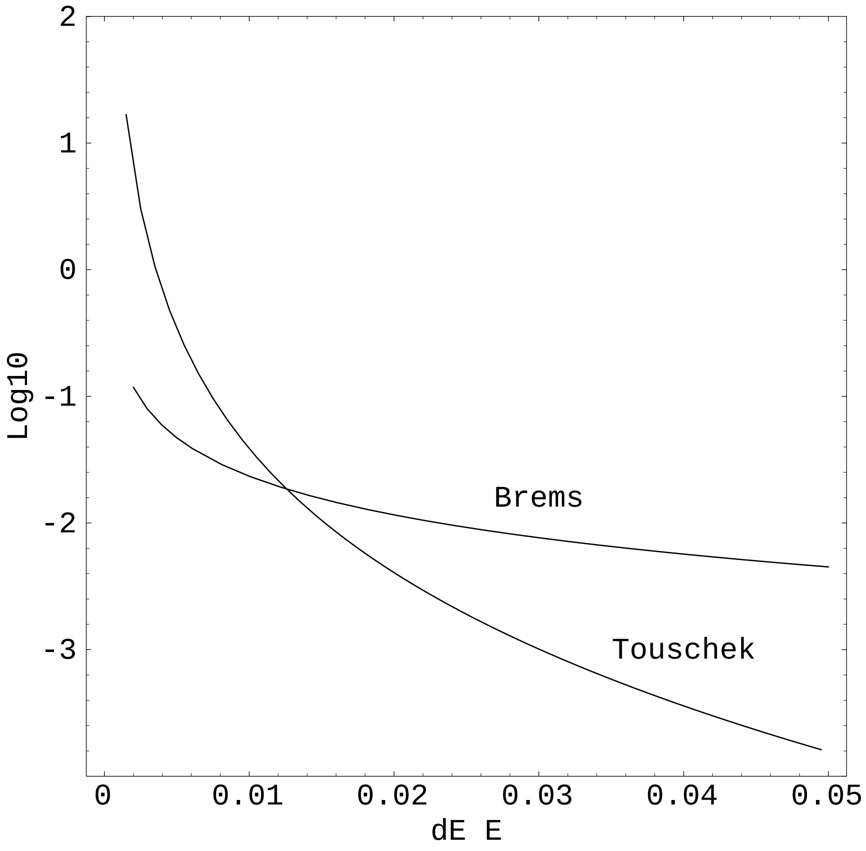
MC Simulation Results (Karim Trabelsi)
(KEKB)

Lyr1 doses

(kRad/yr=10^7s) for (1nTorr CO, 1.1A/2.6A)				
Version	Data	SVD1.4	SVD2.0	SVD2.0
r(b.p.)	2cm	2cm	1cm	1.5cm
r(lyr1)	3cm	3cm	1.5cm	2.2cm
HER Brem		6	28	13
HER Coul		35	35	13
HER sum	24	41	63	26
LER Brem		20(9)	67(63)	13(9)
LER Coul		15	52	14
LER Touschek		57(7)	474(464)	29(9)
LER sum	82	92(31)	593(579)	56(32)
Total	106	133(72)	655(641)	82(58)

( ): ignore bkg from just outside beampipe at QC2.

Touschek effect generates energy shift just like Brems.
(but + and - dE symmetrically)
Much sharper peak near dE/E∼0 than Brems.



MC Simulation of Particle Background
(KEKB)

1. The data-MC agreement is reasonable.

2. Touschek bkg now may not be large if the component entering QC2 just outside b.p. is not important.

3. Touschek bkg will be huge for r=1cm.

4. Bkg for r=1.5cm is much better than that for r=1cm.
   → SVD2.0 upgrade will be r=1.5cm.

Extrapolation to Super-KEKB
Without actually simulating, that is.

Assume that the vaccuum pressure will stay the same.
(true??)

Beam current $\sim \times 4$, Lifetime $\sim \times 1/3$.

1. Conservative:

   Scale with (beam current)/(lifetime).
   $\sim 4 \times 3 = 12$ times larger bkg

   Actually, luminosity lifetime may have less contribution to bkg than beam-gas or Touscheck lifetime.

2. Optimistic:

   Scale with (beam current).
   ~ 4 times larger bkg.

   Assumes that efforts to reduce background are effective.
   (better IR masks, placements of movable masks etc.)

Super-KEKB Particle Background

Lyr1 doses

(MRad/yr=10^7s) for (1nTorr CO, 3A/10A)				
	Conservative		Optimistic	
r(b.p.)	1cm	1.5cm	1cm	1.5cm
HER sum	0.5	0.2	0.2	0.1
LER sum	6.8	0.6	2.3	0.2
Total	7.3	0.8	2.5	0.3

- Radiation tolerence of SVD is OK up to >10 MRad.
- Occupancy will be of order unity for r=1cm. (even for the optimistic case) → pixel detector.
- The r=0.5 version will be fine.
- Can we use r=1cm? The key is Touschek!

MC comparison of r=1cm vs r=1.5cm (KEKB)

(Karim Trabelsi)

SVD2.0 r=1cm

r	L1 1.5 cm	L2 2.2 cm	L3 4.25 cm	L4 6.15 cm
HER Brem	27.5	18.7	5.7	3.3
HER Coul	35.1	21.7	6.5	4.2
LER Brem	67.2(62.8)	38.2(36.9)	9.4(8.9)	4.2(3.1)
LER Coul	51.5	18.2	7.2	2.1
LER Touschek	474(464)	245(239)	57(52)	23(18)
Sum	655(641)	361(335)	86(82)	37(31)

SVD2.0 r=1.5cm

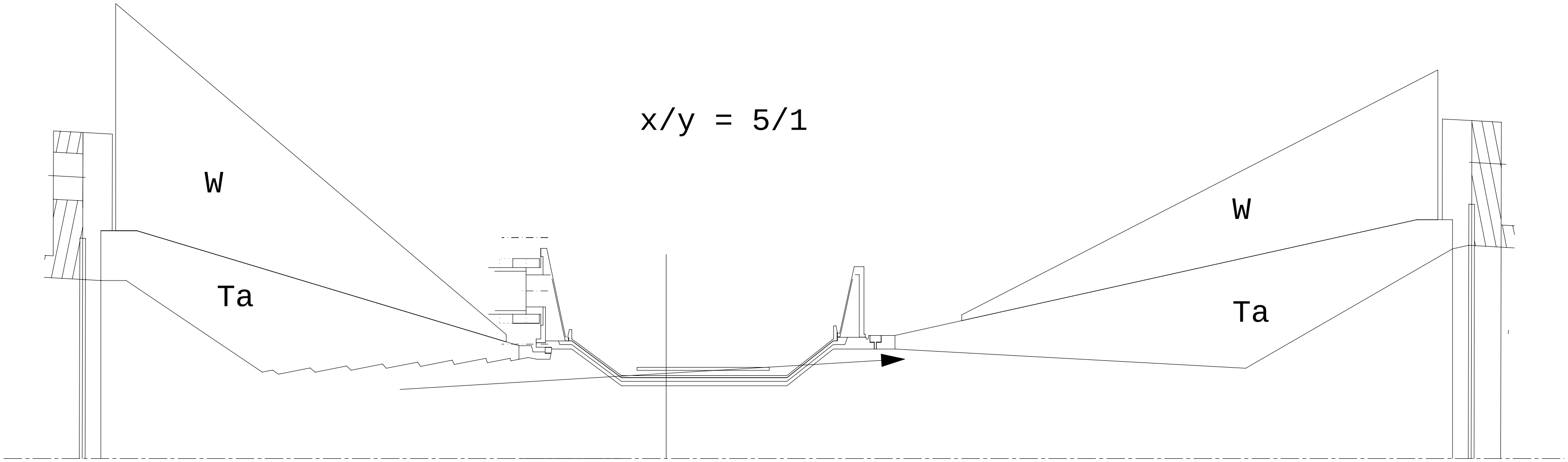
HER Brem		12.5	3.0	1.9
HER Coul		13.4	3.9	3.5
LER Brem		13.1(9.0)	3.4(2.0)	1.6(0.6)
LER Coul		14.0	1.4	1.0
LER Touschek		28.8(9.0)	6.7(1.3)	9.7(0.9)
Sum		82(58)	18(12)	18(8)

Bkg for r=1cm is much larger than for r=1.5cm at the same radius.
And that is due to Touschek hitting the mask at small r.

Possible improvement: Suka-suka design

Use the particle masks for r=1.5cm.
Make the r=1cm b.p. with light material (Be).

Preliminary: x1/2 reduction of bkg.



To be worked out: SR protections.

Can the pixel detector be put inside the beampipe?

1. Needs to be electrically shielded

   Au coated thin Be?

2. Image heat = 500W, HOM heat = 1000W

   Needs to be actively cooled.

3. Needs water coolant ($\sim$0.5mm thick channel).

   Back to the current design.

3. Synchrotron Radiation Background

- Incoming HER beam.

1. Sawteeth for outer-x wall.
   Surface scatt. → tip scatt. ($\sim 1/100$)

2. Use left-side SR mask
   3mm high for 22mRad crossing.
   (if 30mRad, it should be higher → HOM!)

3. Will be dominated by QC1 SR backscattered from the right-side particle mask (Simulation).

   5 kRad/yr (yoff = 0mm at QC1)
   670 kRad/yr (yoff = 3mm at QC1)
   needs software orbit tracking. → Real-time alarm.

- Incoming LER beam.

  Lower E_c, lower power than HER.
  → in general no severe problems.

  1. No masks (outer-x).
     In order to reduce HOM resonances.
  2. From Q's, weak bends and steerings:
     → Online orbit tracking alarm just in case.

- Outgoing HER at QCSR.

  Large offset (∼4cm) → $E_c \sim$ 40keV, 100kW.
  Backscattering from the SR dump (now 8m away)

  1. If no mask: Expect 60 kRad/yr.
     → Move the Cu absorber further away.
  2. With a mask: bkg small.
     One has to avoid HOM resonances.
     (risky but possible - next slide)

4. Beampipe heating and cooling

Image current heating.

$$P_{\mathrm{image}}(W) = \frac{\Gamma(\frac{3}{4})}{4\sqrt{2}\pi^2}\sqrt{\frac{c\,\mu}{\sigma}}\,\frac{I^2 b_{sp}}{\sigma_z^{3/2}}\,\frac{L}{r}$$

L, r, b_{sp}, σ_z in m.
σ: conductivity ($1/\Omega m$).
μ: permeability
($4\pi 10^7 N/A^2$ for non-permeable metals)

- Power $\propto \sigma_z^{-3/2}$.
  Smaller bunch length → more heating.

- Power $\propto 1/r$.
  Smaller radius → more heating.

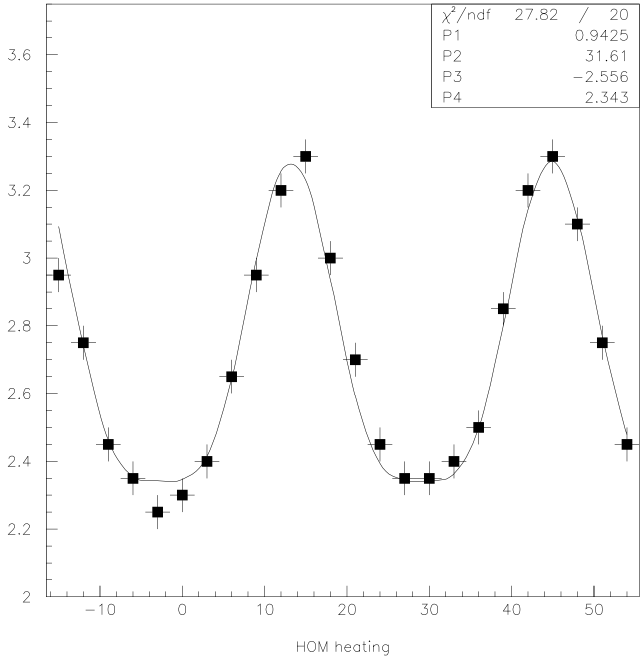
HOM heating: assume twice the image-current heating.
(true?)

Resonant HOM

1. **Simmulation can predict dangerous modes:**

e^+/e^- **RF phase-shift machine study.**

Be beampipe temp
vs.
RF phase difference



Period = 31.61±0.2° (TM011: 31.54° expected)

2. **Avoid high-Q resonances:**

$L = 10cm$, $r = 1cm$. Gold coated.

188cc/s of water (11ℓ/s) through 0.5mm gap channel.
(δP=9.4psi)

	Super BaBar	Super KEKB
I: (A) (LER/HER)	20/7	10/3
b_{sp}:bunch sep. (m)	0.6	0.6
σ_z: bunch length (mm)	1.3	3
δ: skin depth (μm)	0.46	0.7
P_{image} (kW) (LER/HER)	3.4/0.4	0.24/0.02
P_{tot} (kW)	11.4	0.78
ΔT (K), outer Be	7.6	0.5
ΔT (K), inner Be	29.6	2.0

OK for Super-KEKB. (a smaller flow would be fine)
Not out-of-question even for Super-BaBar.

Summary

- Particle background is probably OK for r=1.5cm, worrisome for r=1cm.

  Pixel detector will probably be needed.

- Touschek is the main problem for r=1cm.

  Beam loss away from IR.
  Better masking.

- SR background is probably OK.

  Reduce the HER backscattering from downstream dump.
  (Remove SR mask → no HOM resonance.)

- IR beampipe heating is probably OK.

  Water cooling.