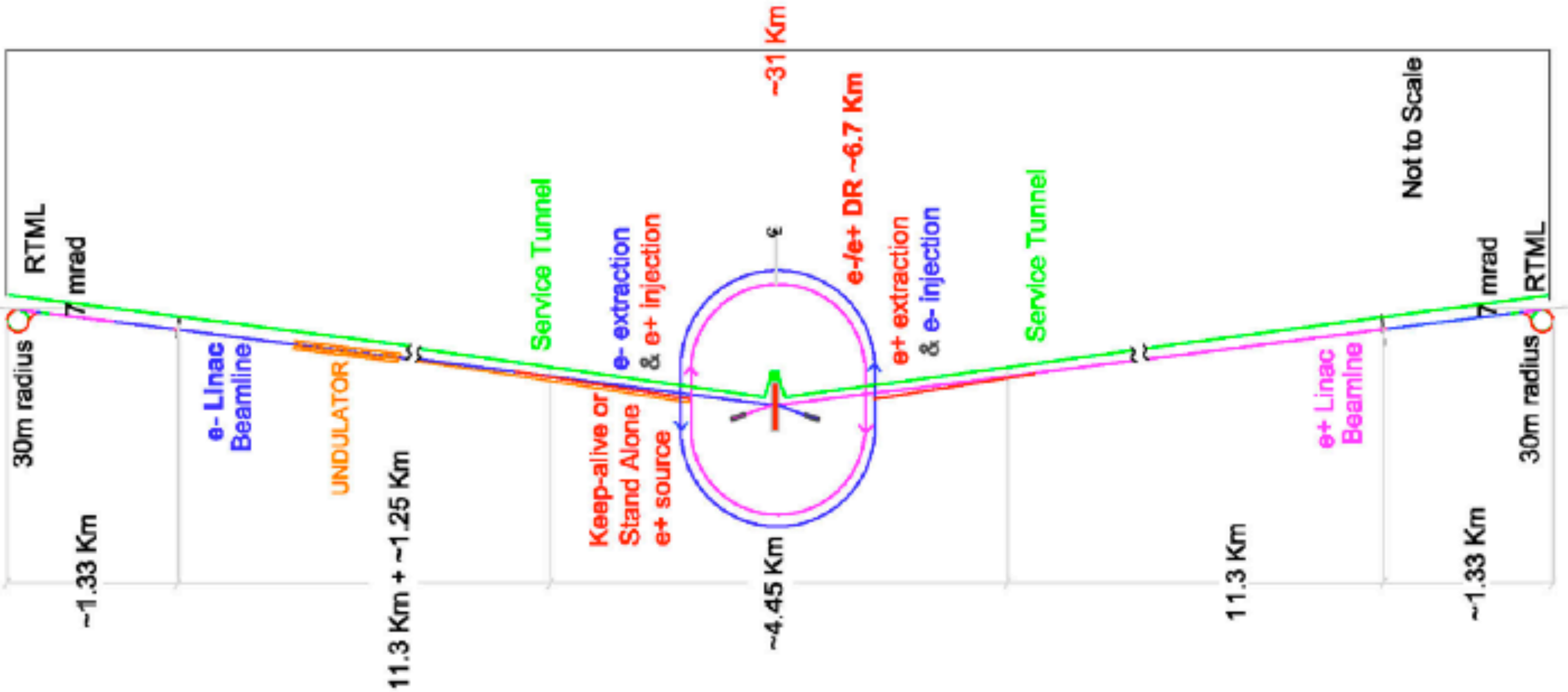
IR and backgrounds of ILC and Super KEKB

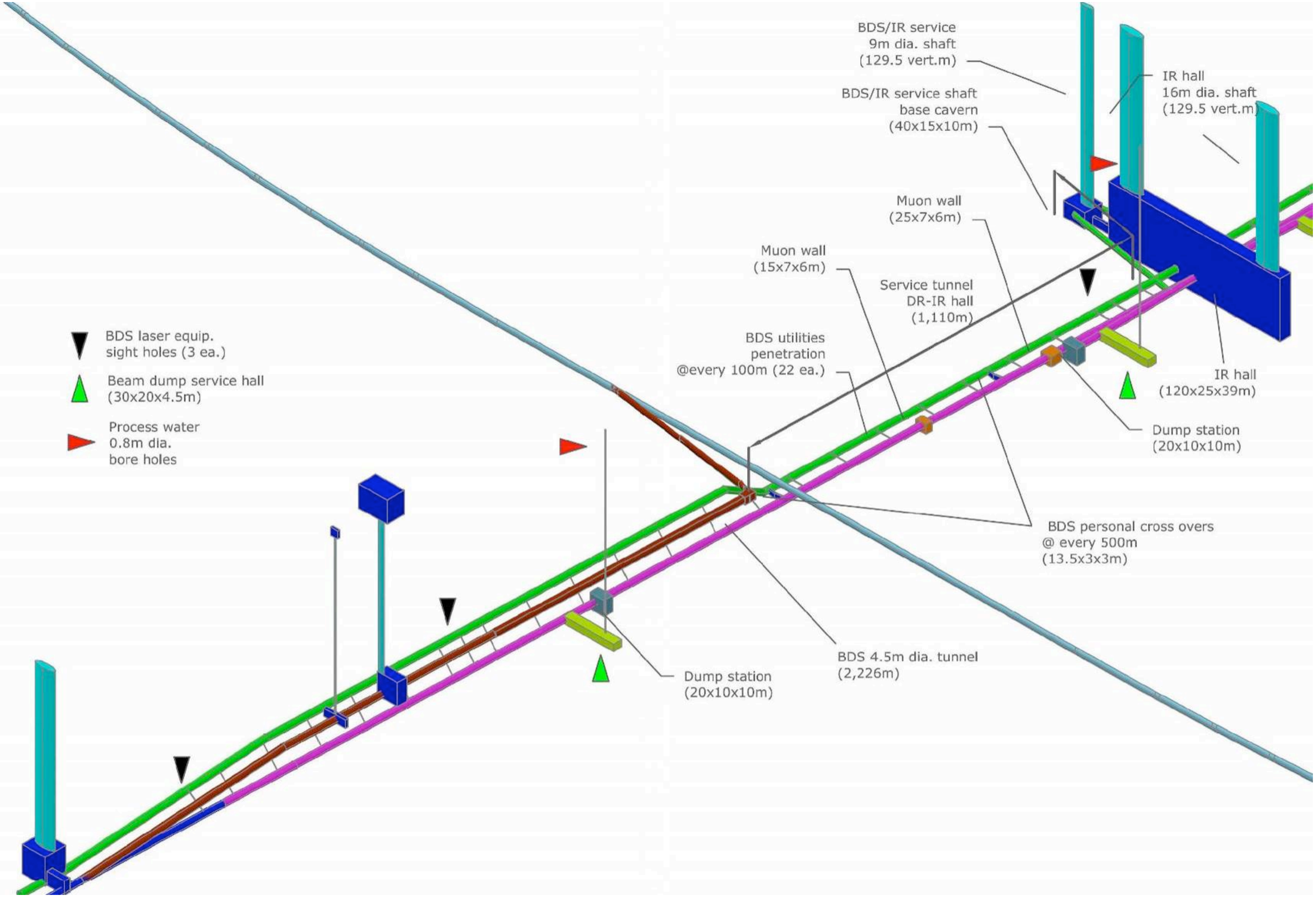
BEPCII background mini workshop
IHEP, March 10, 2008

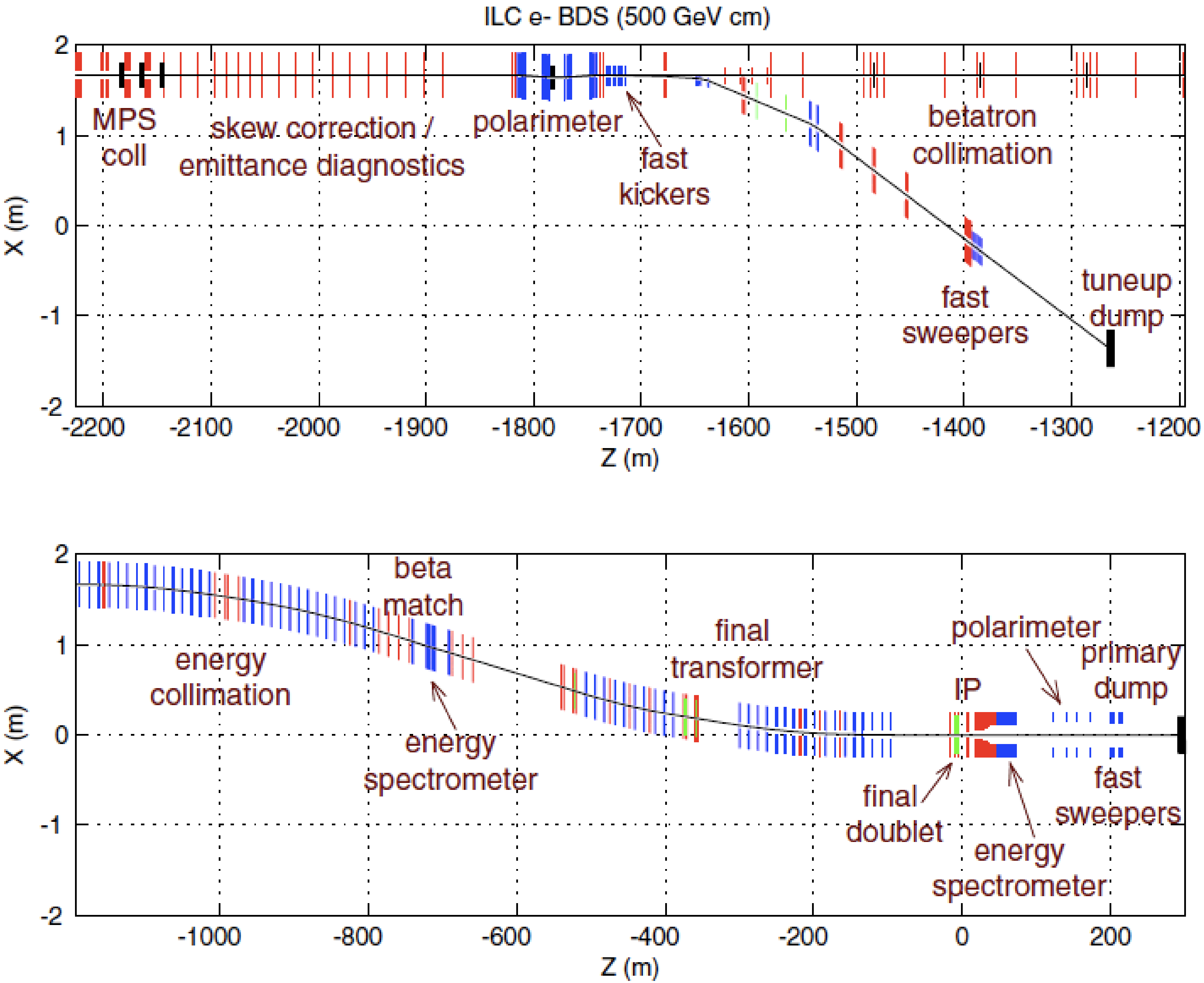
Hitoshi Yamamoto

ILC configuration

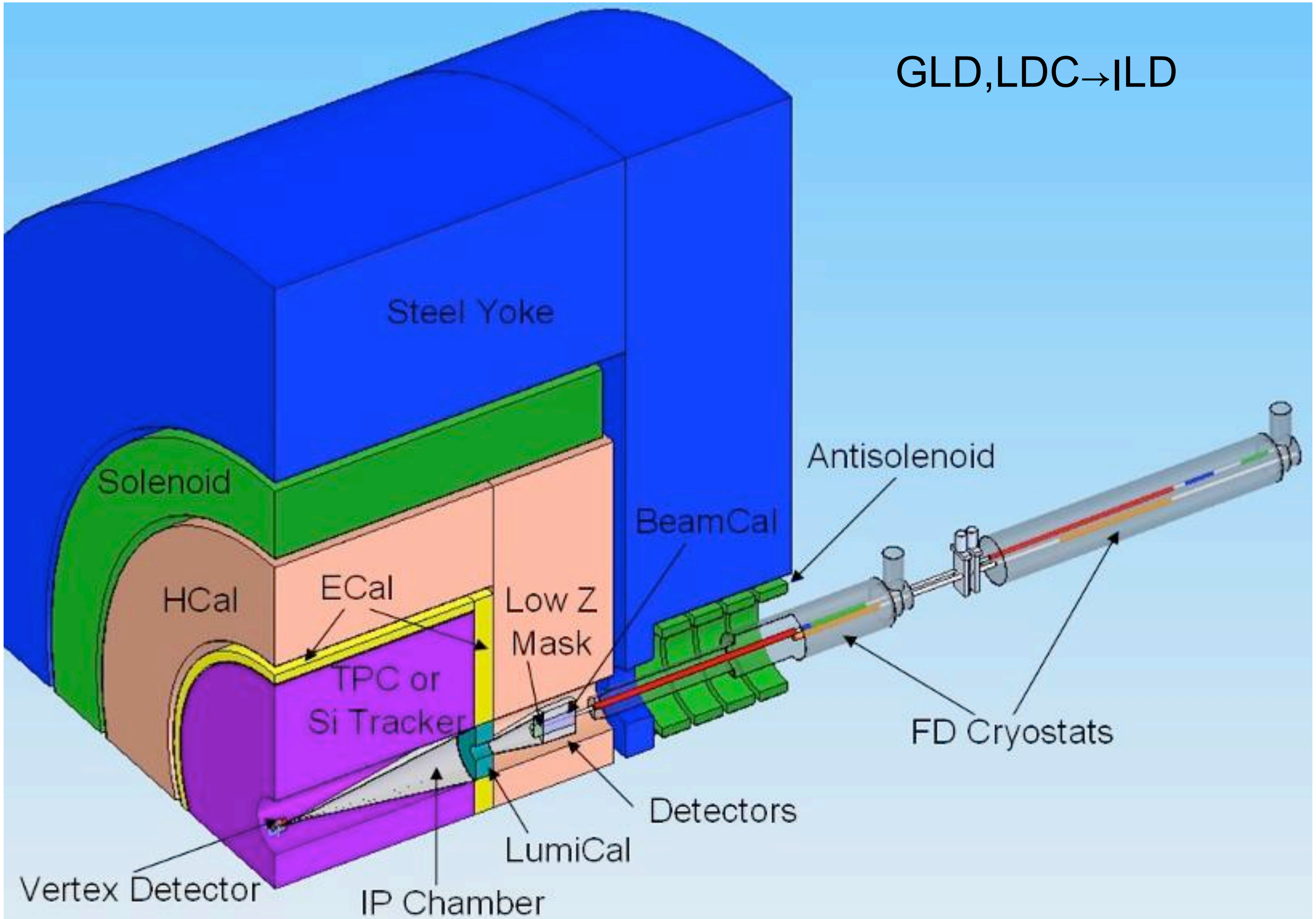
500 GeV CM
14mrad crossing angle
3000 bunches/train, 1ms/train
5 trains/sec




BDS/IR service
9m dia. shaft
(129.5 vert.m)
IR hall
16m dia. shaft
(129.5 vert.m)
BDS/IR service shaft
base cavern
(40x15x10m)
Muon wall
(25x7x6m)
Muon wall
(15x7x6m)
Service tunnel
DR-IR hall
(1,110m)
BDS utilities
penetration
@every 100m (22 ea.)
BDS laser equip.
sight holes (3 ea.)
Beam dump service hall
(30x20x4.5m)
Process water
0.8m dia.
bore holes
IR hall
(120x25x39m)
Dump station
(20x10x10m)
BDS personal cross overs
@ every 500m
(13.5x3x3m)
BDS 4.5m dia. tunnel
(2,226m)
Dump station
(20x10x10m)


ILC e- BDS (500 GeV cm)
MPS coll
skew correction / emittance diagnostics
polarimeter
fast kickers
betatron collimation
fast sweepers
tuneup dump
X (m)
Z (m)
2
1
0
-1
-2
-2200
-2100
-2000
-1900
-1800
-1700
-1600
-1500
-1400
-1300
-1200
beta match
energy collimation
energy spectrometer
final transformer
polarimeter
primary dump
IP
final doublet
fast sweepers
energy spectrometer
-1000
-800
-600
-400
-200
0
200

IR design of typical ILC detector (SiD, GLD, LDC, 4th)



HOM loss

- Loss factor k :

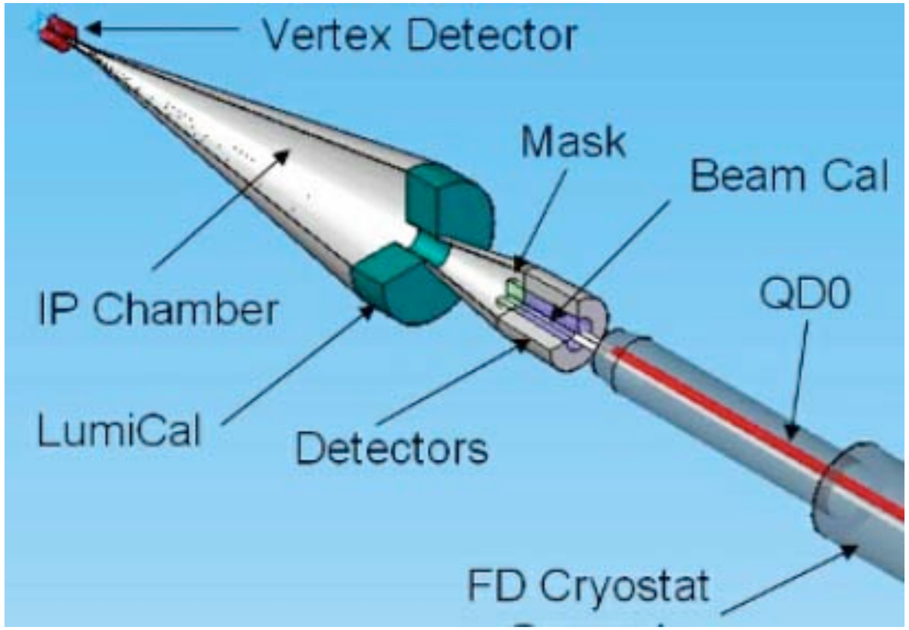
$$\Delta E = kq^2 \quad \rightarrow \quad k = \frac{\log \frac{b}{a}}{4\pi^{3/2}\varepsilon_0\sigma_Z} \quad (V/C)$$

- HOM loss by an iris of a=1cm to b=10cm

$$P = n_{\text{bunch}} n_{\text{train}} kq^2 = 2820 \quad 5kq^2$$
$$= 5.6W$$

- This is to turn to heat somewhere

HOM loss



- Two beams & FCAL/BCAL

5.6 x 2 x 2 ~ 22.4 W

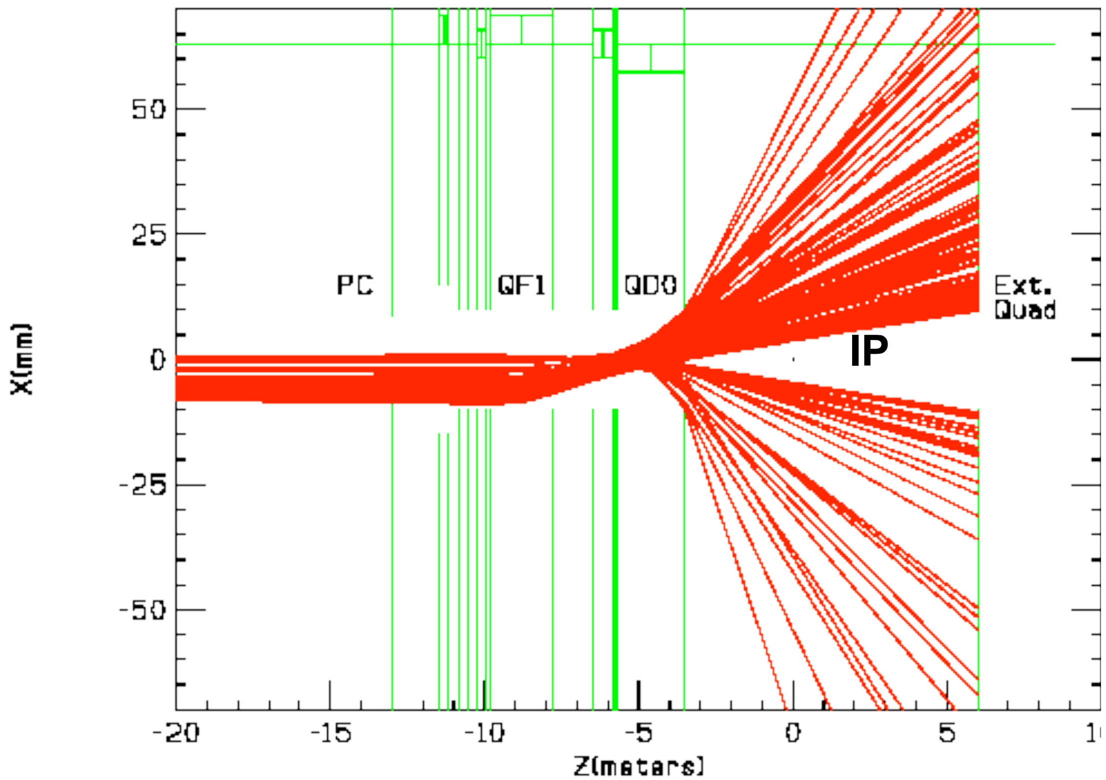
Beam-gas background

Beam-Gas Bremsstrahlung Electrons Hitting Beyond the Final Doublet

Cut: Outside 10 mm at entrance to 1st extraction line quad

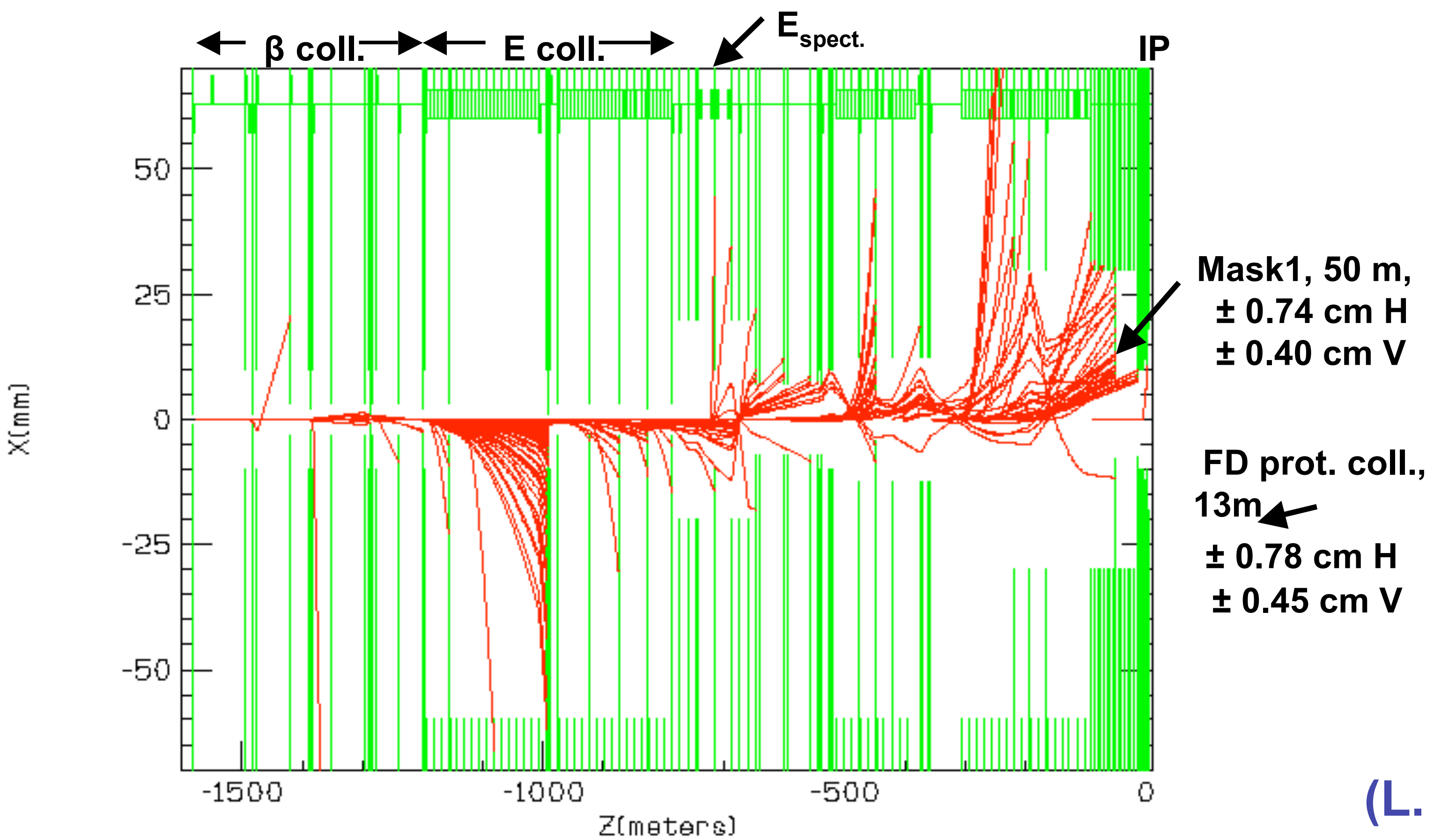
Average Energy = 100 GeV

Origin is inside 200 m from the IP



(L. Keller)

Loss pts. of 150 random beam-gas brem. trajectories in the BDS using LP TURTLE



(L. Keller)

Summary of Hits/bunch and Hits/160 bunches (TPC) – both beams, 10 nTorr

Hits/bunch   Hits/160 bunches (TPC)

Hit Location	GEANT3 Beam-gas brem (charged)	TURTLE Beam-gas brem (charged)		TURTLE Beam-gas brem (photons)		TURTLE Coulomb (charged)	
	Hits	Hits	<E>	Hits	<E>	Hits	<E>
FD Prot. Coll. (13 m) |x| > 0.74 cm |y| > 0.45 cm Origin 0-800m from IP	0.22 35	0.17 27	235 GeV	0.056 9.0	~50 GeV	0.009 1.4	250 GeV
Inside F.D. (10 – 3.5 m) (QF1 to QD0) Origin 0-100m from IP	0.014 2.2	0.006 1.0	~100 GeV	0	-	0	-
IP region (± 3.5 m) (R > 1 cm at Z = 6.0 m) Origin 0-200m from IP	0.04 6.4	0.02 3.2	~100 GeV	0	-	0	-

GEANT3 simulations show that only hits in the IP region (± 3.5 m) cause problems for the vertex detector

(L. Keller)

Vacuum requirement near IP

Electro-production of hadrons in gas near the IP (± 3.5 m)

σ_{tot} ~ 2 mb => ~ $5x10^{-5}$/BX @ 10 nT

Lumonosity bkg.: gamma-gamma at L_{max} ~ 0.5/BX

Therefore the near-IR pressure requirement is not determined by the beam-gas background rates

(L. Keller)

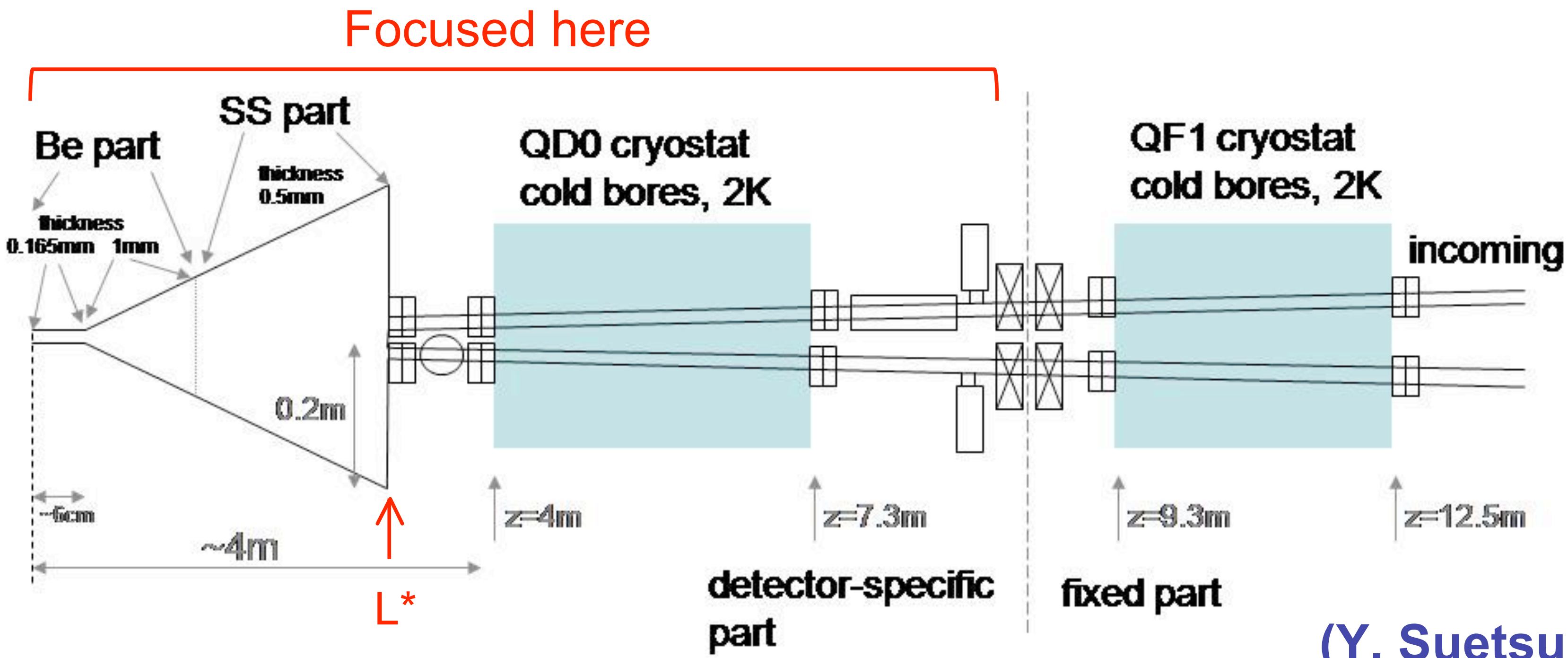
Vacuum requirement summary

1. Within 200m of IP, the pressure spec is 1nTorr.

2. Within 200m-800m, the pressure spec is 10nTorr.

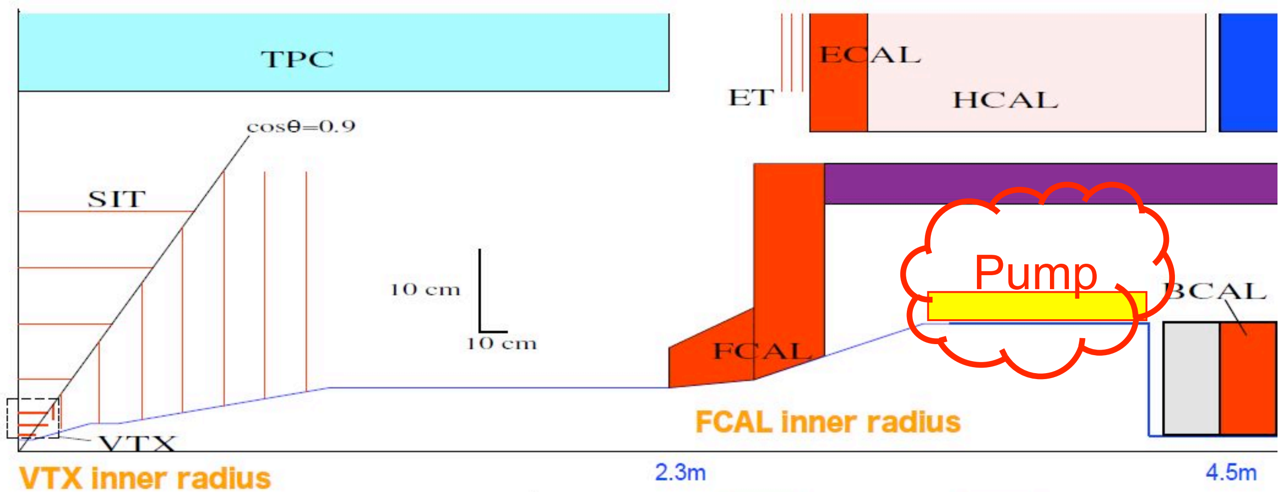
3. Between QD0 (±4m), the pressure spec can be more than 1nTorr (luminosity background dominates)

Vacuum pumping near IP



(Y. Suetsugu)

• GLD NEG pump location

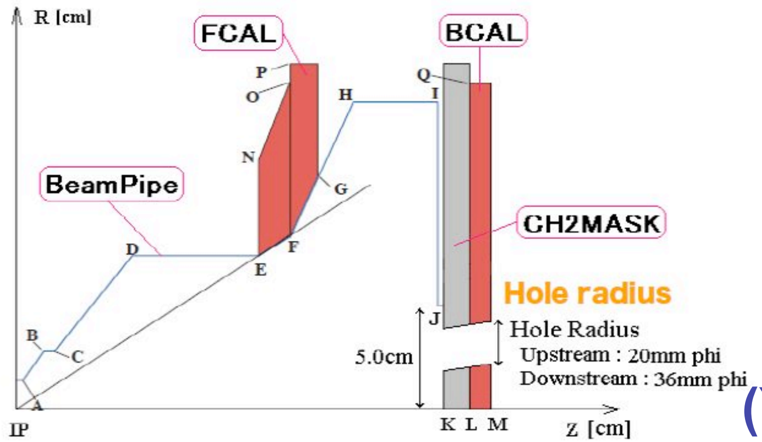


IR Optimization

FCAL inner radius for TPC background hits.

Hole radius of extraction to decrease backscattering.

Radius of beam pipe @VTX



(Y. Suetsugu)

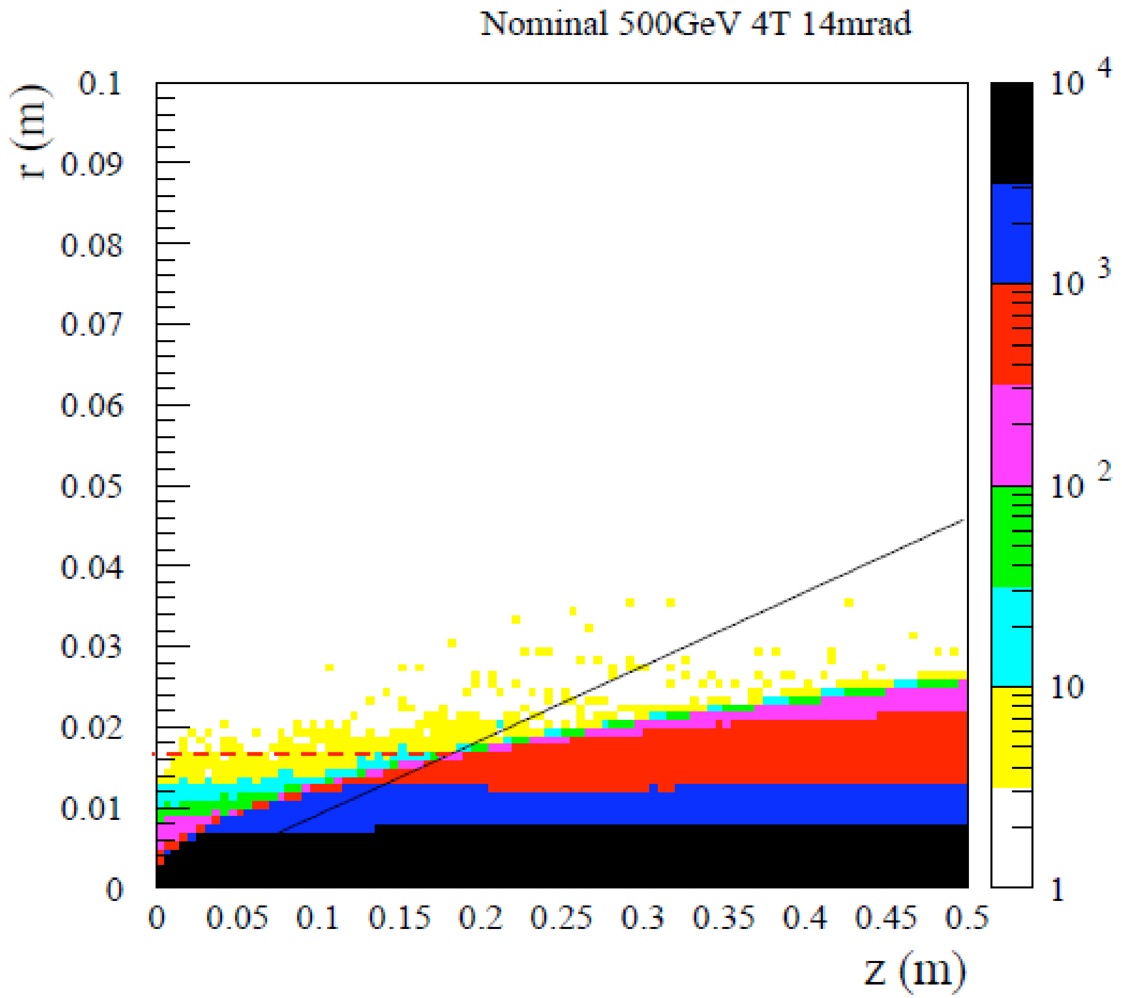
Vacuum pumping

- Pumping scheme at z < L* (Cone) depends on the required pressure;
  - For P >10 nTorr, (probably acceptable)
    - No baking and no pump are OK
  - For 10 nTorr > P >1 nTorr, (acceptable)
    - No baking is OK, but some pumps are required
  - For P < 1 nTorr, (overkill)
    - NEG coating and baking are required.

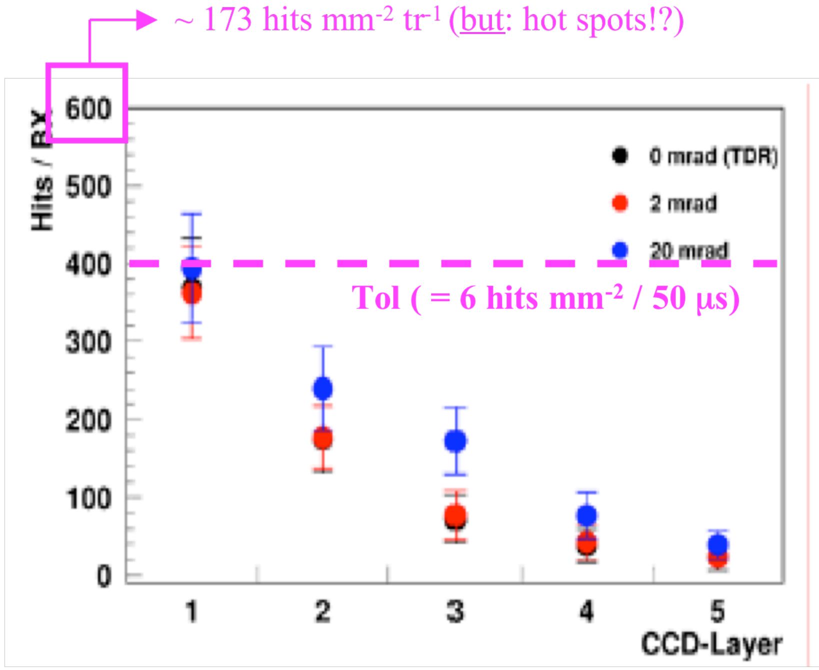
- Other room temperature region needs pumps (distributed or lumped pumps or NEG coating)

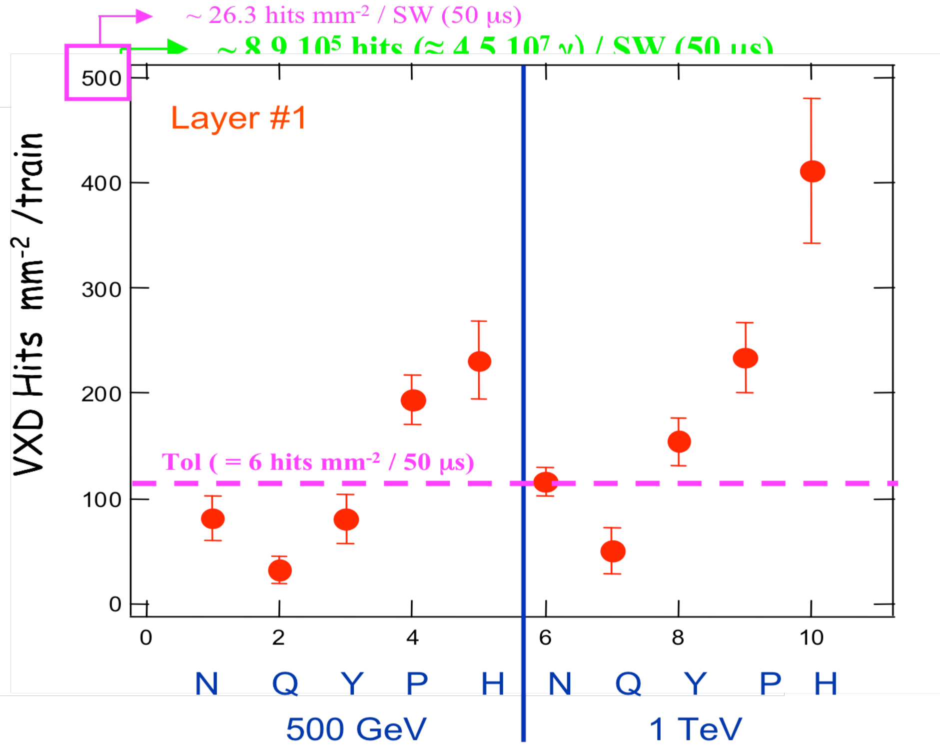
e+e- Pair background

Vertex detector needs to stay out of the dense area.
Dominates the background in vertexing.



Pair background in CCD



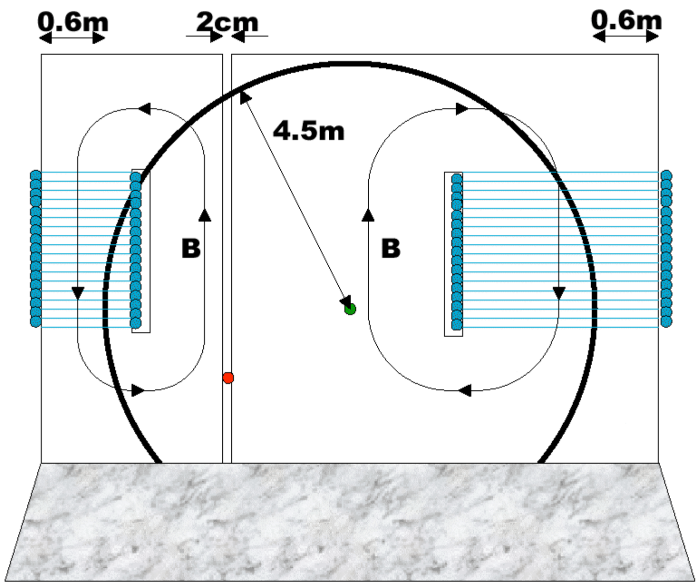


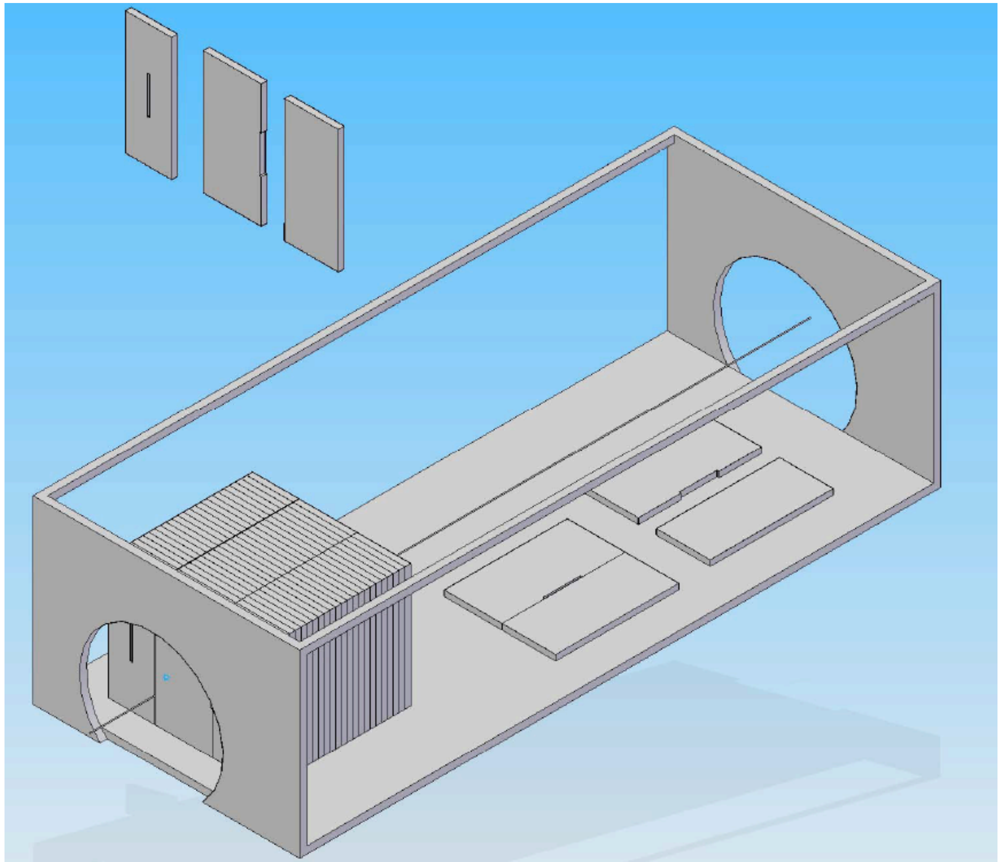
Readout every 50μs
Or fine-pixel needed

N: nominal beam params

Muon Spoiler

Toroid magnets
5m thick, 1.5 Tesla
Estimated muons: a few/TPC sweep
Upgradable to 18m
Additional 9m optional

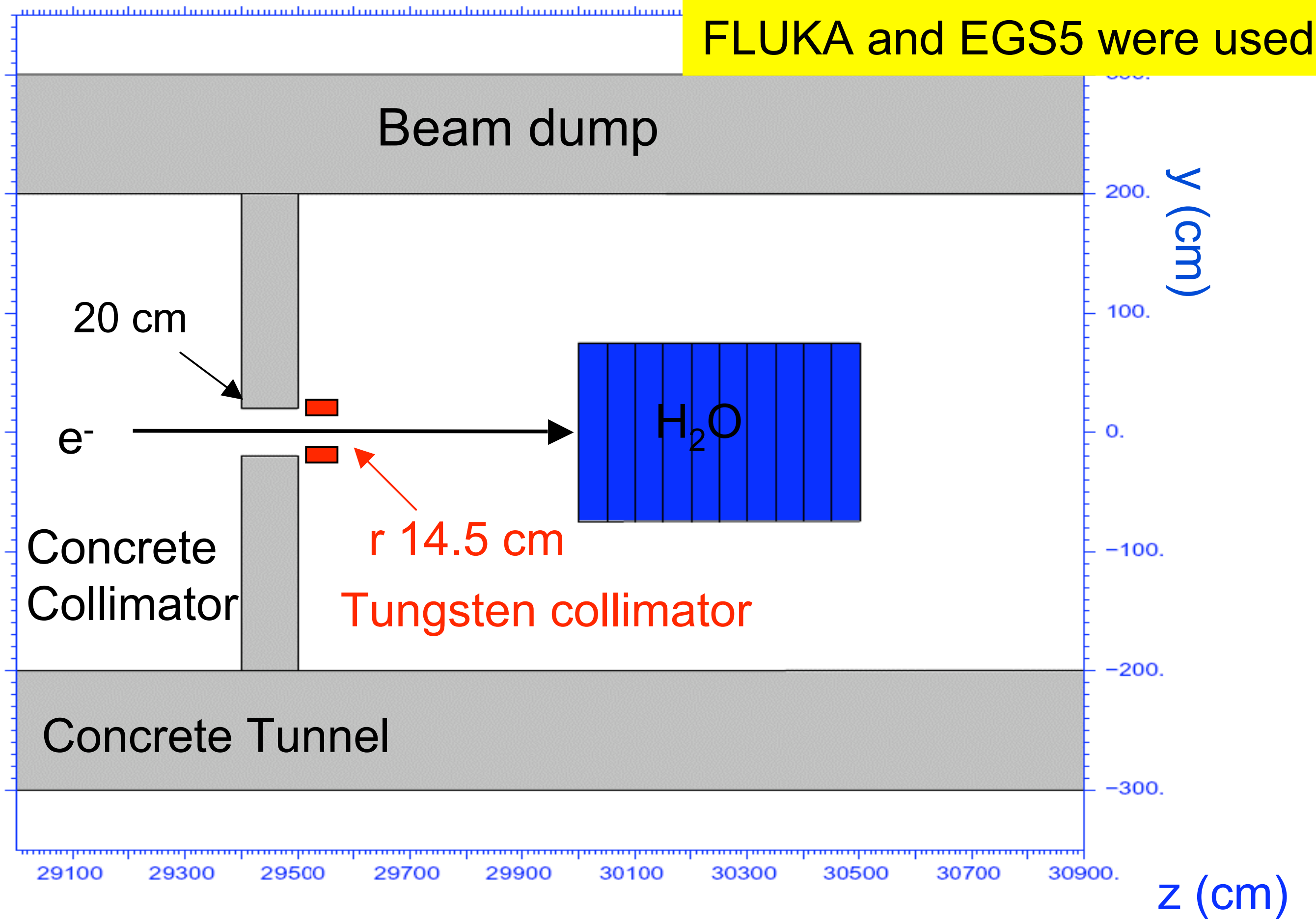




Neutron backgrounds

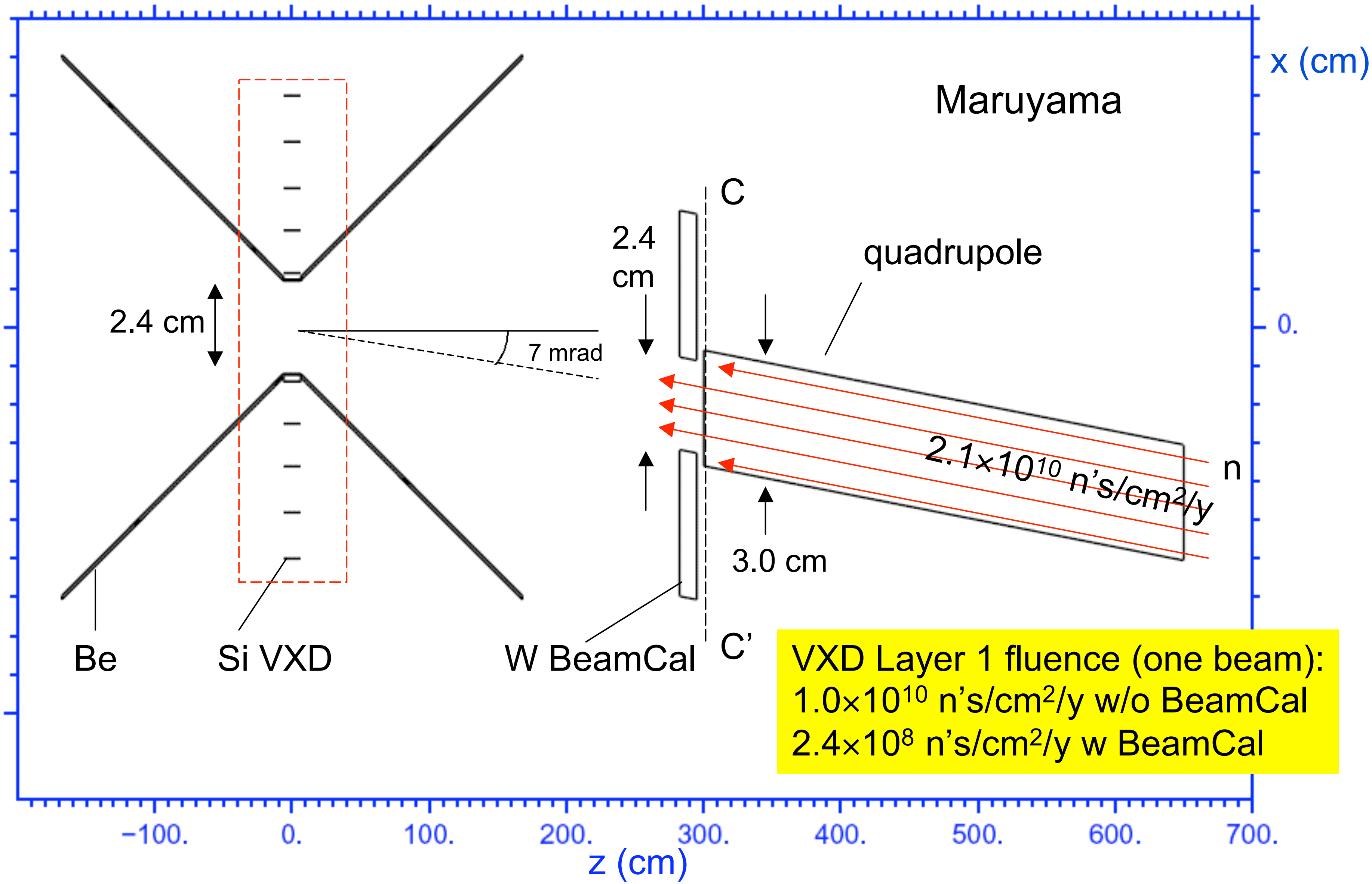
- The IP has a direct line-of-sight from the beam dump.
- Neutrons and photons produced at cosθ ~ -1 will reach the IP, and no shielding is possible.
- What is the IP flux?

FLUKA was used for neutrons.
FLUKA and EGS5 were used for photons.



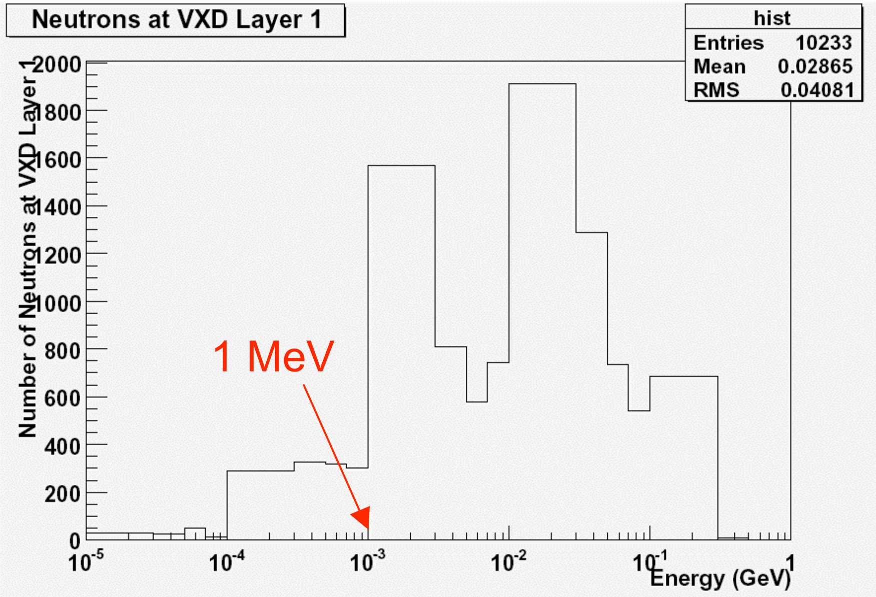
Maruyama

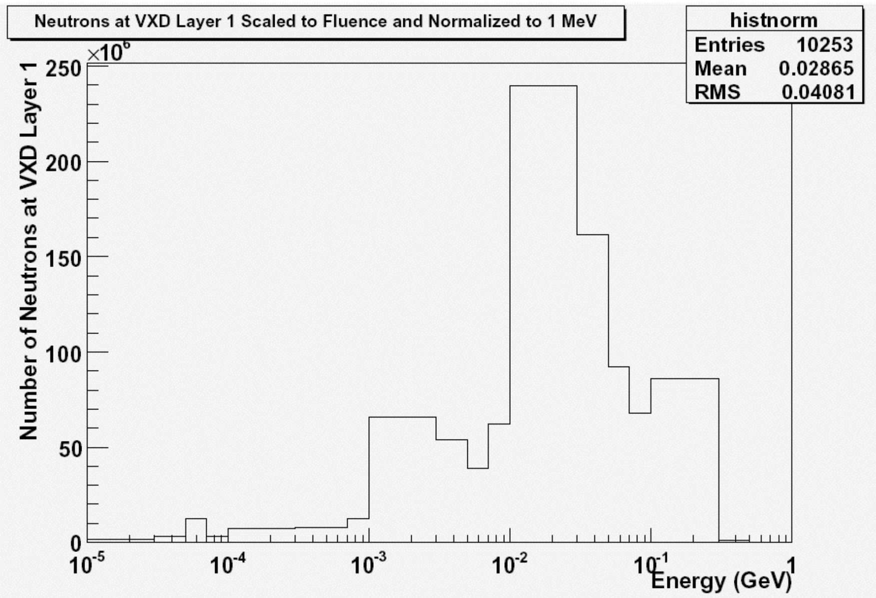
SiD Vertex Detector



Maruyama

1 MeV Neutron Equivalent Fluence





- However, the amount of displacement damage done to CCD Si detector by neutrons is a function of neutron energy
- When relative damage to Si is considered, normalized to 1 MeV, the fluence is: 5.3×10^8 n/cm^2/year
- When e^+ beam is considered also, value is doubled to 1.1×10^9 n/cm^2/year
- A value of 10^{10} n/cm^2 would damage the CCD Si detector by this measure

WHITE SANDS FAST BURST REACTOR

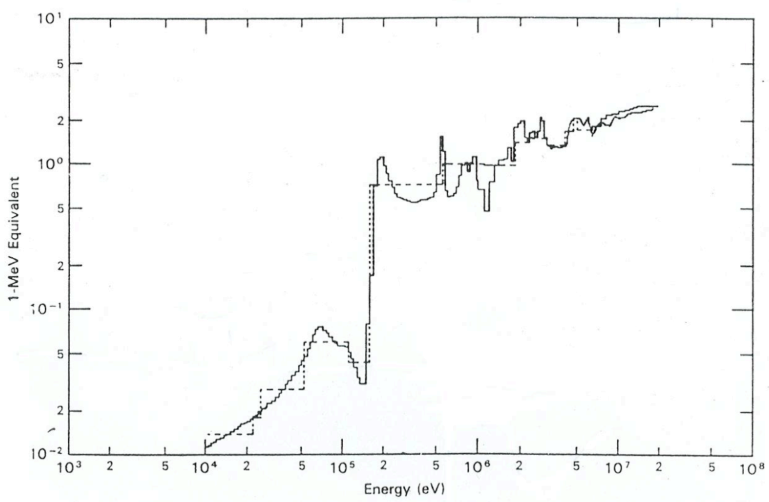


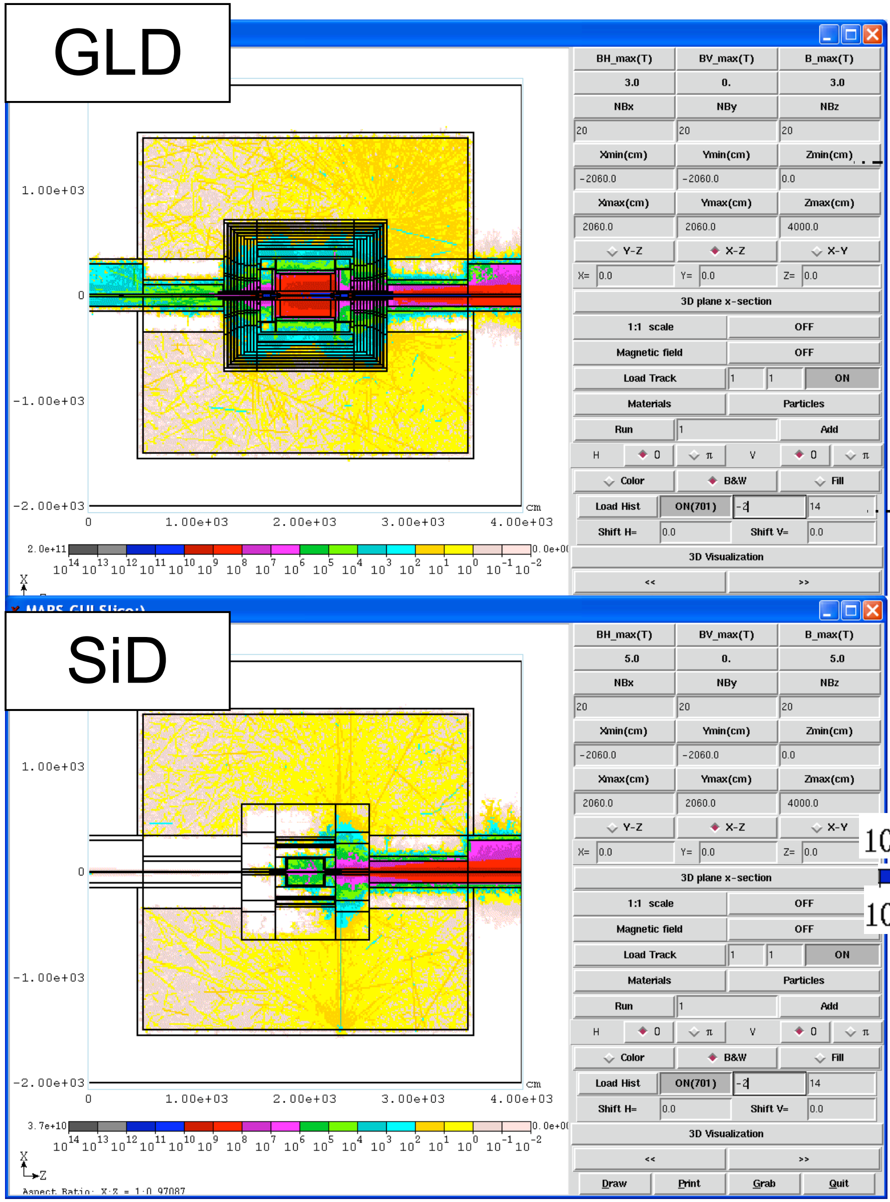
Fig. 3. Silicon displacement kerma as a function of energy. The fine-group histogram is the tabulated kerma values from Ref. 13. The broader group histogram is the function used in this work.

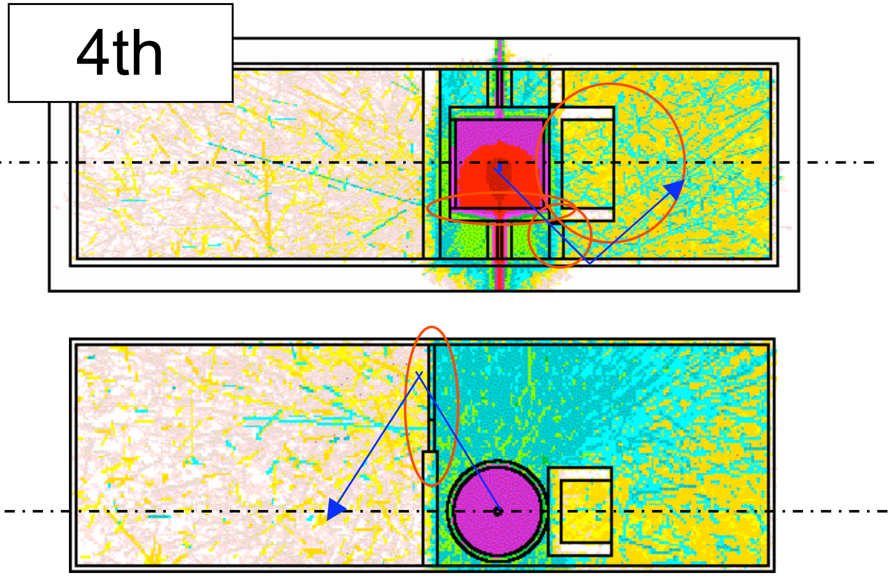
T. M. Flanders and M. H. Sparks, *Nuclear Science and Engineering*, 103, 265, 1989.

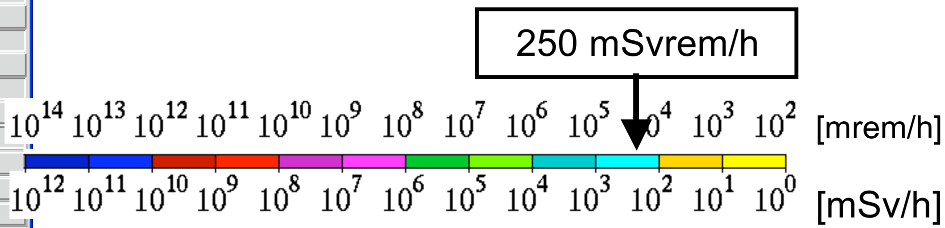
Neutron Backgrounds

- 1-MeV neutron equivalent fluence from the beam dump is estimated to be 1.1×10^{9} n's/cm^{2}/year at the SiD VXD detector.
- Neutron fluence by the pairs is 0.9×10^{9}
- The total 1-MeV neutron equivalent fluence is 2×10^{9} n's/cm^{2}/year.
- Photon backscattering from the dump is negligible.

Shielding of detectors







Can be self-shielded except for '4th'

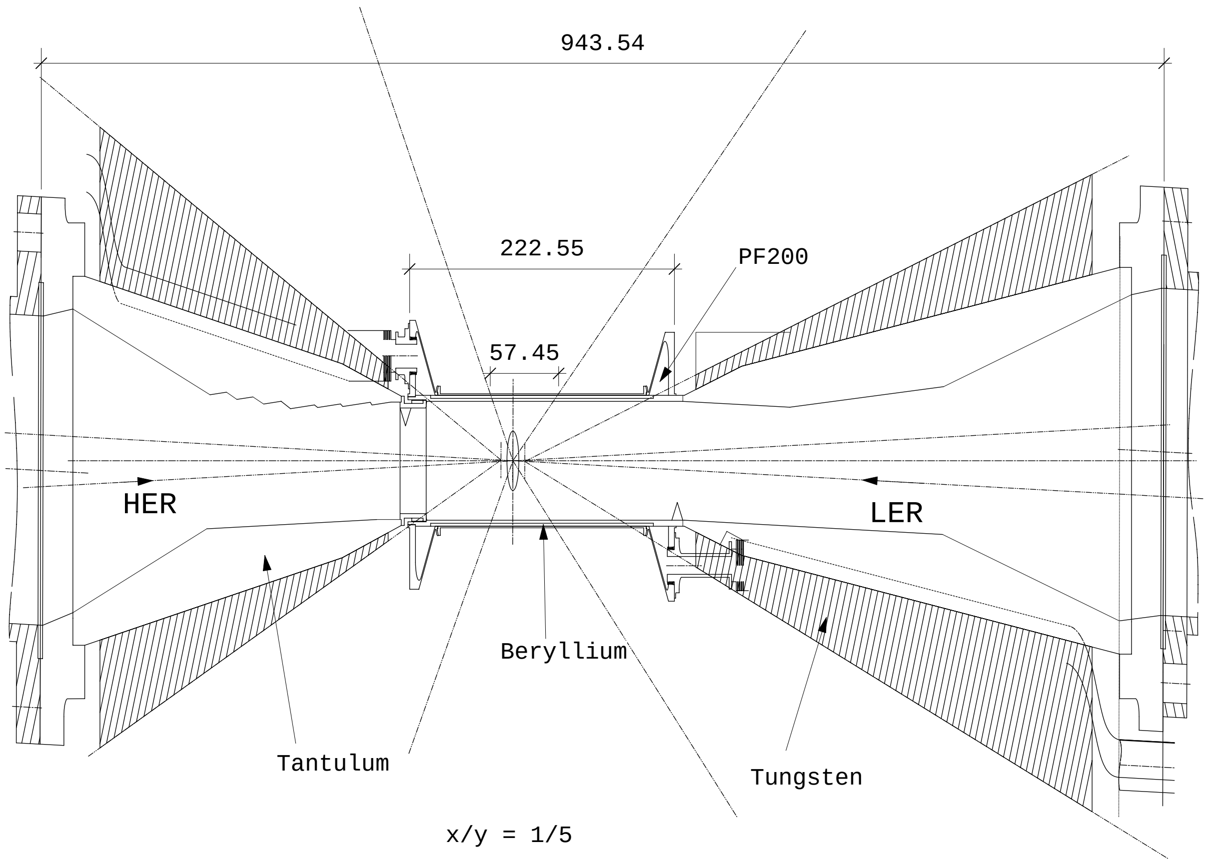
Super KEKB backgrounds

Machine Parameters of KEKB and Super-KEKB

	KEKB (now) LER$^+$/HER$^-$	Super-KEKB LER$^-$/HER$^+$
energy(GeV)	3.5/8	3.5/8
nbunch	1223/1223	5018/5018
$I_{\rm beam}$(A)	1.41/1.06	9.4/4.1
$I_{\rm bunch}$(mA)	1.14/0.86	1.87/0.82
ϵ_x(nm)	18/24	24/24
ϵ_y/ϵ_x	0.055/0.041	0.01/0.01
β_x^*(cm)	59/63	15/15
β_y^*(mm)	6/7	3/3
σ_z(mm)	5.6/5.6	3/3
xing(mRad)	22	30
L(10^{33}/cm^{2}s)	10.6	500

Super-KEKB: More currents by more bunches,
Smaller beta*s, shorter bunches.

SuperKEKB beampipe baseline: SVD2.0 $r = 1.0$cm design. (fall-back design : $r = 1.5$cm)



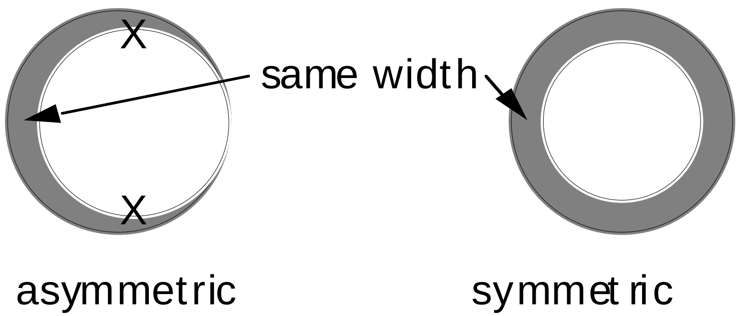
No LER-side mask → no resonant cavity.

SuperKEKB Synchrotron Radiation Background

Incoming HER beam (LER dose will be small)

- Use the program SRW (written by T. Abe).
- Dominant source is QC1.
- For the same mask shape as SVD2.0 (asymmetric crescent shape), Dose $\sim$ 200 kRad/yr.

  More than half is due to photons sneaking though the half-width regions (top and bottom).
  $\longrightarrow$ try symmetric circular mask.



- Symmetric circular mask.
  Dose $\sim$ 80 kRad/yr (T. Abe, confirmed by O. Tajima).
  (mostly backward inside)

  Further optimization should be possible.

  Is HOM OK?

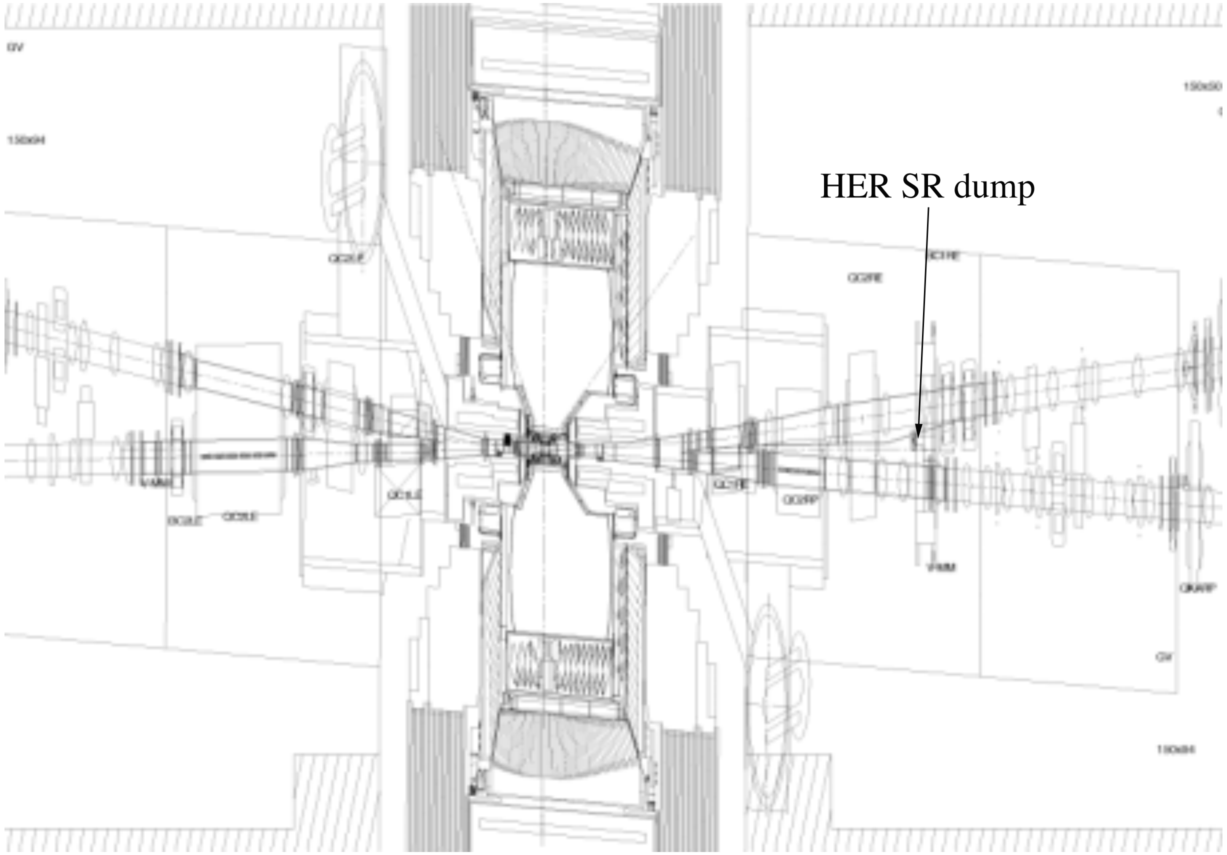
- HOM estimation (S. Stanic)
  Symmetric mask design : k = 0.29 V/pC
  (Ref.) SVD1.5 : k = 0.5 V/pC
  $\longrightarrow$ HOM loss is OK.

$$\text{HOM loss}(W) = \frac{I(A)^2 k(V/C)}{c(m/s)/b_{sp}(m)}$$

  Also there is no resonant cavity.
  (heat deposit small)

- Large orbit dependence seen.
  $\longrightarrow$ needs real-time orbit tracking (T. Abe)

Outgoing HER Backscattering



Large offset (∼4cm) at QCSR → $E_c \sim$ 40keV, 100kW.

Outgoing HER Backscattering

- No LER-side mask.

  For SVD 2.0, expect 20-30 kRad/yr of dose.
  (Estimated by H.Y. using EGS)

  Preliminarily confirmed by O. Tajima using GEANT4.
  (23 kRad/yr)

- For SuperKEKB, Expect ~60 kRad/yr.
  → Move the Cu absorber further away,
  or, use heavier metal as surface?

- With a LER-side mask: bkg small.
  But one has to avoid HOM resonances.
  Reduces flexibility for machine operation.
  → the default is not to use the LER-side mask.

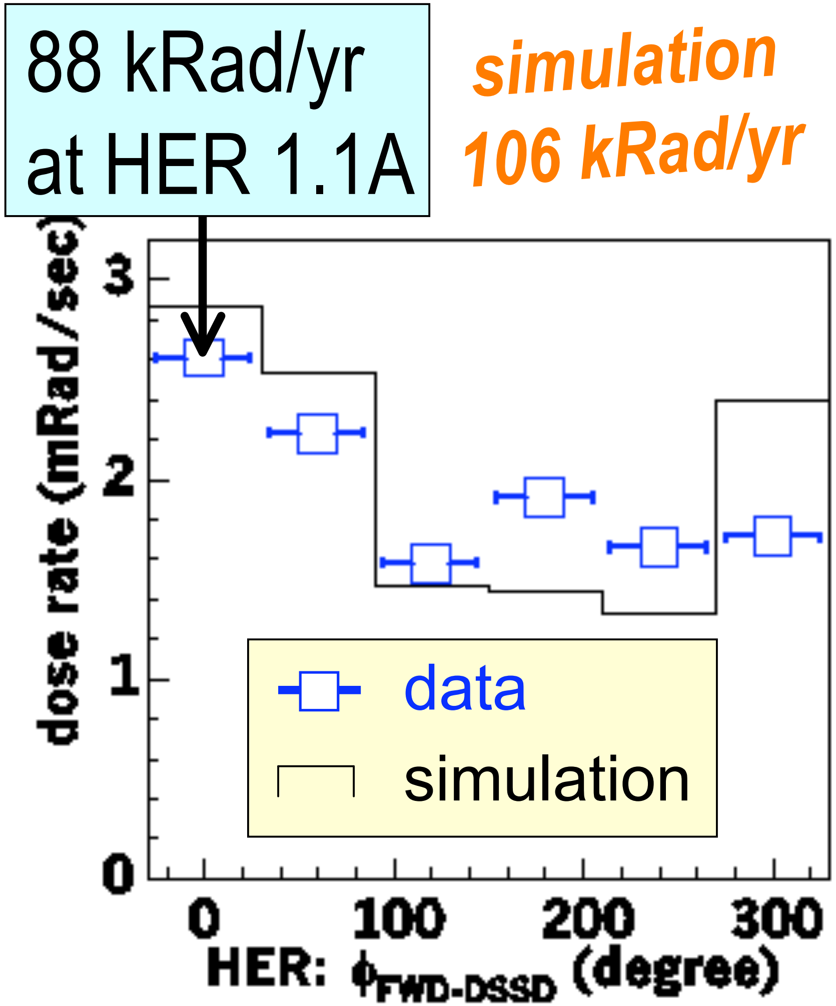
MC Simulation Results (Karim Trabelsi)
(KEKB)

Lyr1 doses

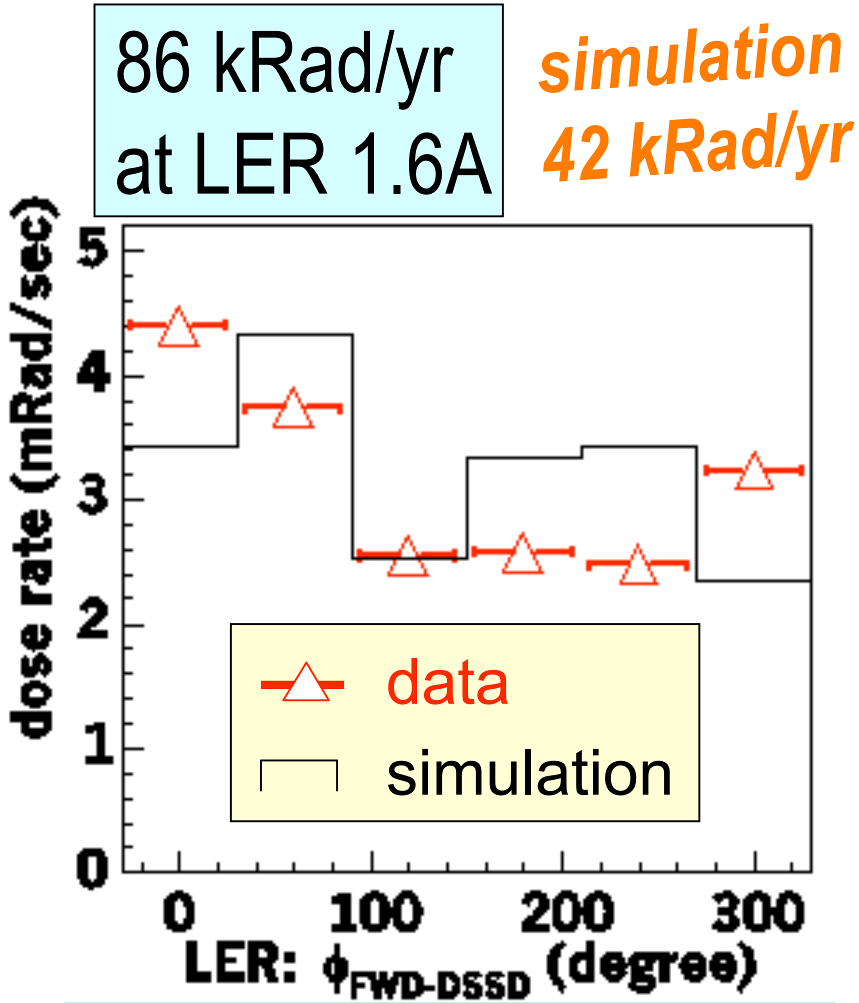
(kRad/yr=10^7s) for (1nTorr CO, 1.1A/2.6A)				
Version	Data	SVD1.4	SVD2.0	SVD2.0
r(b.p.)	2cm	2cm	1cm	1.5cm
r(lyr1)	3cm	3cm	1.5cm	2.2cm
HER Brem		6	28	13
HER Coul		35	35	13
HER sum	24	41	63	26
LER Brem		20(9)	67(63)	13(9)
LER Coul		15	52	14
LER Touschek		57(7)	474(464)	29(9)
LER sum	82	92(31)	593(579)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

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

Azimu. angle dist. of Shower particles



HER single beam 0.8 A



LER single beam 1.5 A

SuperKEKB Particle Background

MC Simulation by K. Trabelsi

- LER only now.
  (LER optics only is available at this time)
- Use ± 11 mrad crosing angle (for quick answer).
- Use SVD2.0 $r = 1$ cm design (to begin with).
- Whole one turn simulation by TURTLE.
  (multi-turn effects not simulated)
- GEANT simulation upto/including QC2's.
- Vacuum = 1 nTorr of CO.
  (needs a good pumping)
- Physics run only (no injections).

MC Simulation Results (Preliminary)

Coulomb scattering

SVD layer	dose (kRad/yr)
Lyr 1	1655 ± 229
Lyr 2	374 ± 57
Lyr 3	107 ± 18
Lyr 4	61 ± 9

(1yr = 10^7 s)

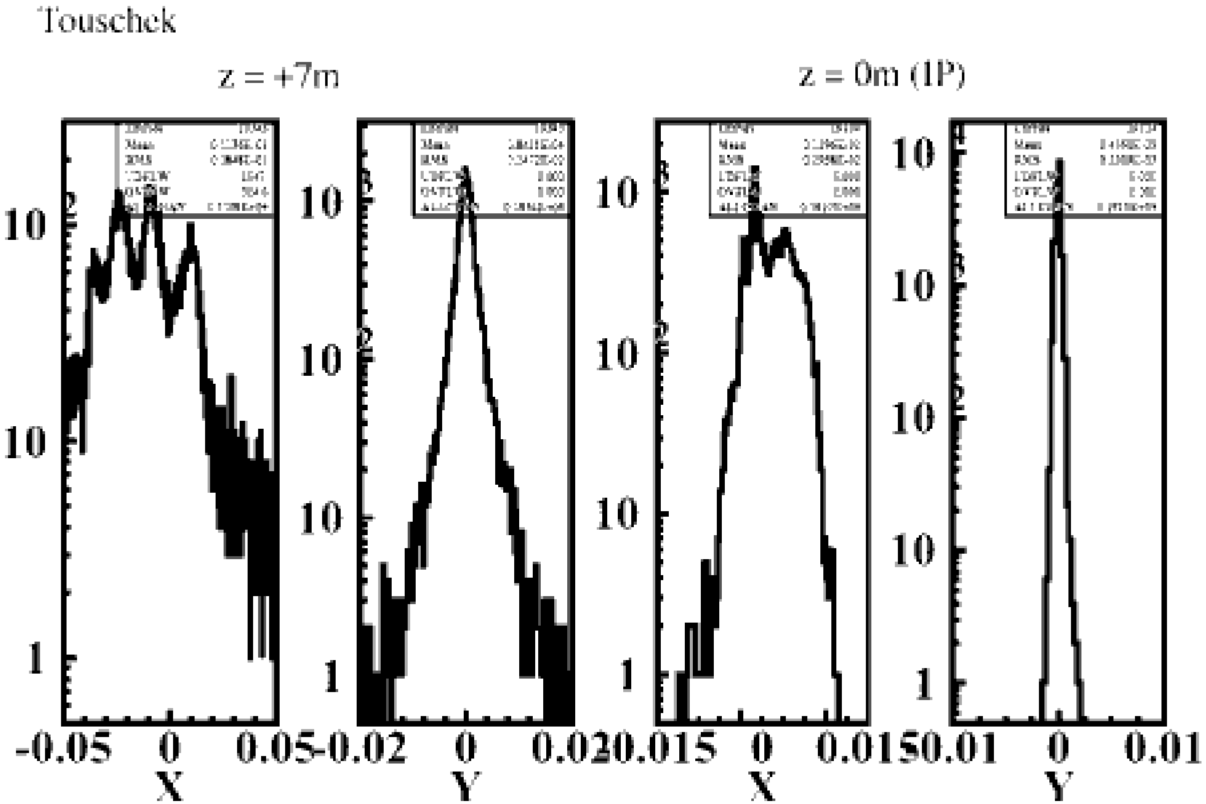
Mostly due to beam particles hitting at around QCSR.

Uniform in ϕ (Coulomb)

Brems. and Touschek $\sim$ 0. (!!)
(preliminary, but let us hope it is true)

Touschek Transverse Profiles

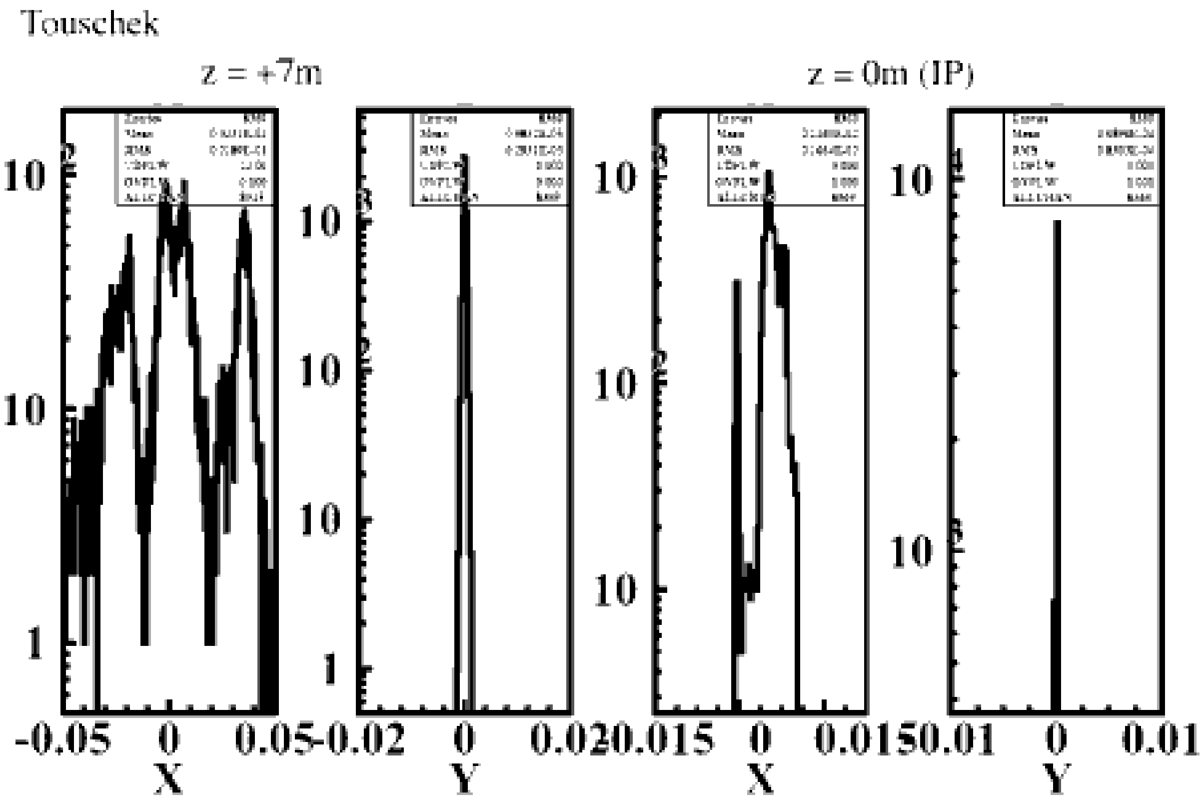
KEKB design



There are many particles with $x < 5cm$ at $z = +7m$, which creates a large dose.

Touschek Transverse Profiles (preliminary)

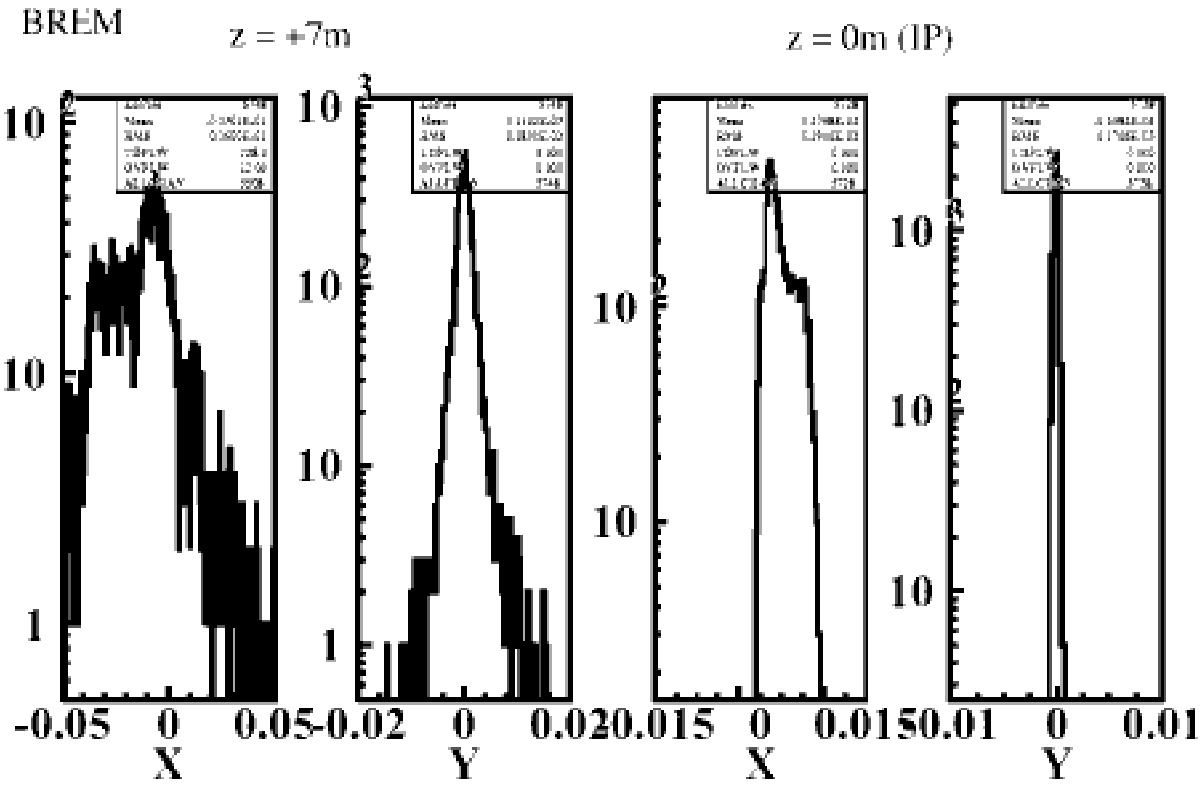
SuperKEKB



Not much outside of $x = \pm 5cm$ **at** $z = +7m$**.**

Brems. Transverse Profiles

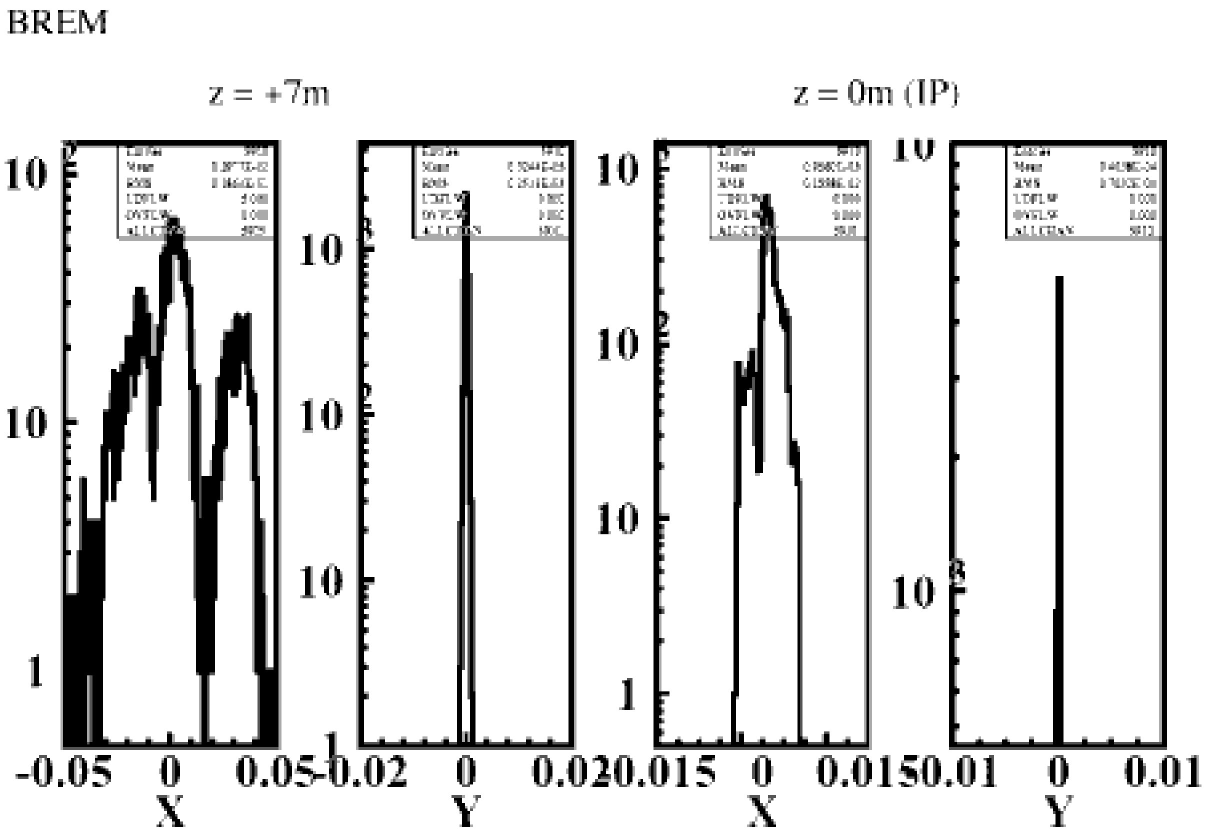
KEKB design



There are some for $x < 5$cm at $z = 7m$.

Brems. Transverse Profiles (preliminary)

SuperKEKB

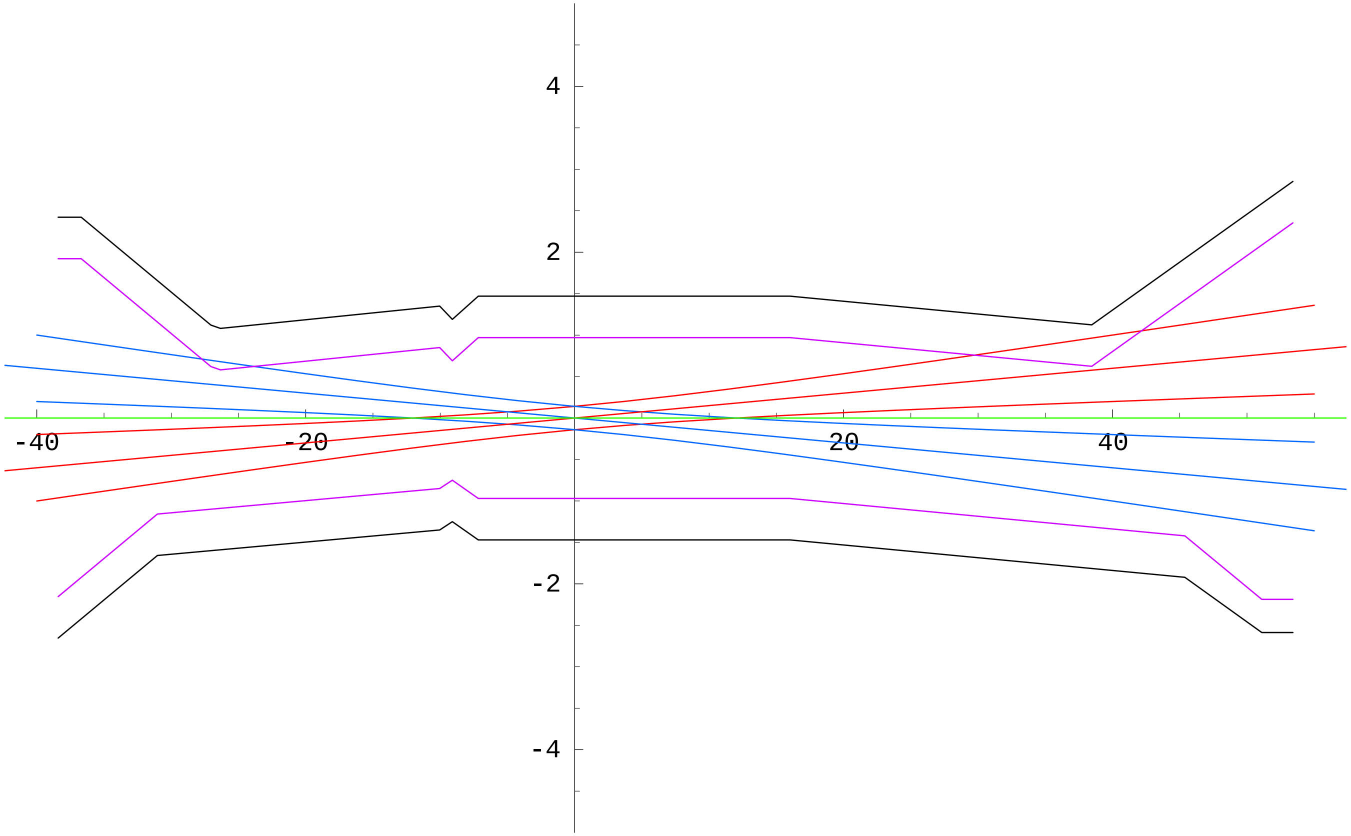


Not much outside $x = \pm 5$cm at $z = 7m$.

Effect of 30mrad crossing angle

Simulation was for 22mrad crossing angle.

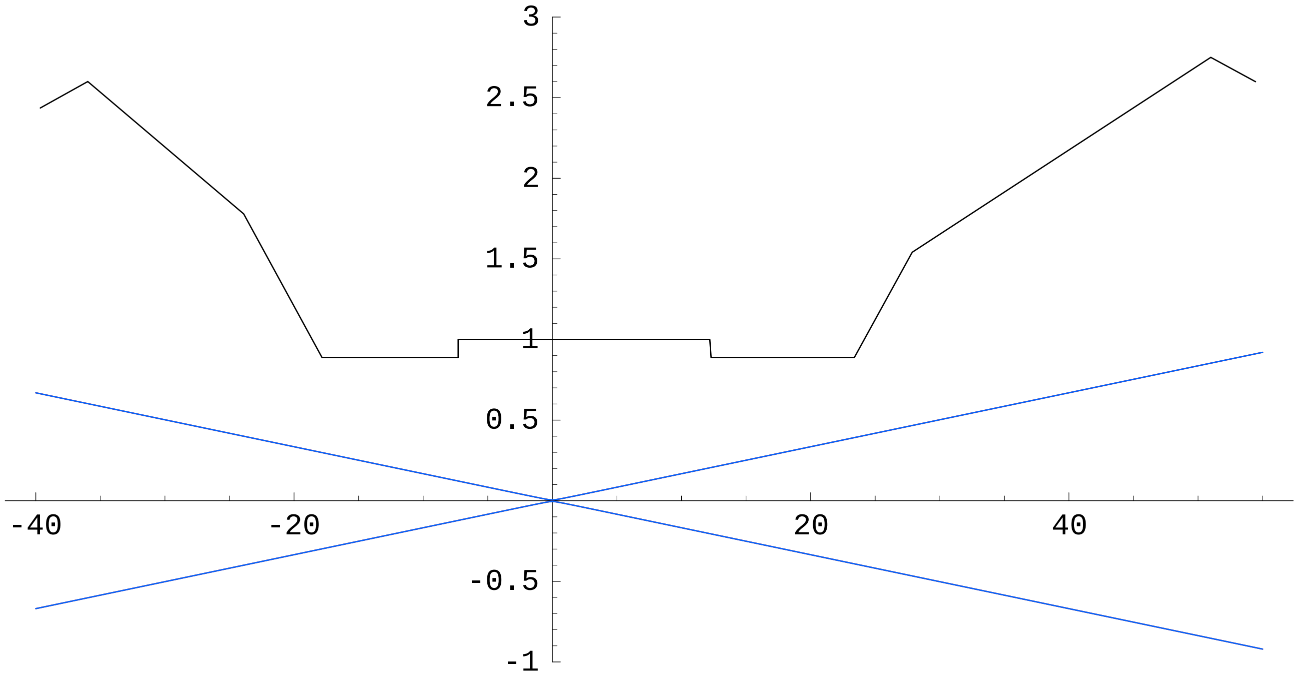
Super-KEKB $r_{\mathrm{beampipe}} = 1.5$cm, 1cm
Horizontal beam-stay-clear (20σ)



Larger cuts may be needed at the mask corners.
(redesign of mask $\longrightarrow$ reevaluation of bkg)

Crossing angle (22→30mrad) and beam-stay-clear in y

Super-KEKB $r = 1$cm.
$\epsilon_y/\epsilon_x = 0.065$ (0.01 for the newest design)
Vertical beam-stay-clear (20σ)



No problem in y.

To be done:

- Further optimization of SR background.
  Protect against possible orbit shifts.

- CDC simulation for the HER SR backscattering.

- Further particle background simulation for LER.
  (confirm the small Brems. and Touschek backgrounds)

- Particle background simulation for HER.

- Simulate injection.

- Mask design/optimization for 30mrad crossing angle.
  (including the design with $r = 1$cm beampipe
  with $r = 1.5$cm version mask.)

- Study mechanical support system.
  Attach SVD directly to the beampipe.