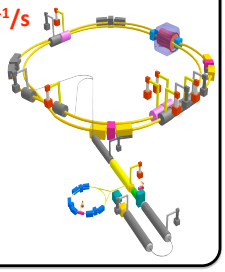
Beam Background Simulation for SuperKEKB/Belle-II

Hiroshi Nakano, Hitoshi Yamamoto
Hiroyuki Nakayama, Yoshiyuki Ohnishi,
Ken-ichi Kanazawa
Andreas Moll, Christian Kiesling,
Martin Ritter, Susanne Koblitz

Abstract The Belle experiment is now being upgraded to the Belle II experiment designed for a 40 times higher luminosity. Such a high luminosity is realized by the SuperKEKB collider where beam-induced background rates are expected to be much higher than those of KEKB. This poses a serious challenge for the design of the machine-detector interface. We have thus carried out a GEANT4-based beam background simulation for Touschek effect. We describe the method of generating background particles and present the result of simulation.

1 SuperKEKB / Belle II

In order to search new physics,
KEKB will be upgraded to SuperKEKB.
Design luminosity : 21 nb^{-1}/s → **800 nb^{-1}/s**
(σ_{BB} ~ 1nb @ 10.58GeV)



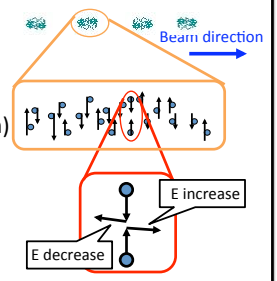
SuperKEKB parameters

	LER e^+	HER e^-
Energy [GeV]	4.0	7.0
Current [A]	3.6	2.6
emittance x [nm] / y [pm]	3.2 / 8.64	4.3 / 13.3
Beam size at IP x [um] / y [nm]	10 / 48	10 / 63
Touschek life [s]	~600	~600

2 Touschek scattering

Scattering process

1) Collision within a bunch
2) Transverse momentum (betatron oscillation)
→ Longitudinal momentum.
3) Beam energy changes



Scattering rate

We suppose that
scattering rate is proportional to $\frac{1}{\sqrt{\beta_x(s)\beta_y(s)}}$

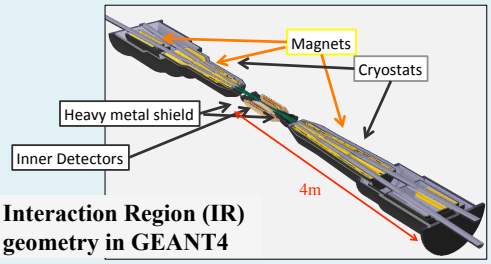
$\beta_{x,y}(s)$: horizontal / vertical beta function

3 Simulation

A. Moll
M. Ritter
S. Koblitz
H. Nakayama
H. Nakano

For generation and tracking, SAD [1] and TURTLE [2] were used.

Once scattered particles reach close to the interaction region (s = -4m ~ +4m), detector responses are simulated by GEANT4.



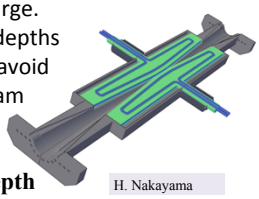
Interaction Region (IR) geometry in GEANT4

4 Movable collimators

Scattered particles deviate its orbit at bending magnet.

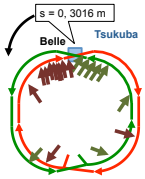
To stop scattered particles before they reach the IR, we set movable collimators where horizontal beta or dispersion is large.

Collimator depths are chosen to avoid decreasing beam lifetime.



Position & Depth H. Nakayama

Horizontal collimation from both inner and outer sides.
Most of them are placed just before IP.



LER collimators	
s[m]	depth[mm]
956.17	12.34
1710.94	12.31
2463.72	12.34
2813.88	12.28
2872.80	12.98
2927.91	16.70
2947.61	17.60
2998.47	12.34

HER collimators	
s[m]	depth [mm]
2057.56	8.97
1302.98	8.97
549.89	8.97
202.34	8.97
156.64	8.97
126.67	12.53
91.16	14.35
74.55	14.35
48.35	6.21
34.15	6.21
17.7	10.82

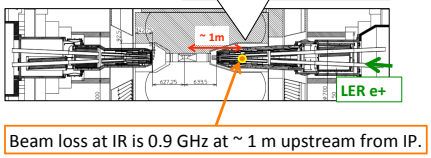
5 Loss rate in IR

Simulation with SAD Y. Ohnishi
LER : Loss rate & position were simulated.
The result was used for pixel detector simulation.

Simulation with TURTLE H. Nakano
LER : Agree with SAD result.
HER : Much smaller than LER's one.

Both simulation result shows
Collimators just before the IR are effective to reduce loss rate in IR.

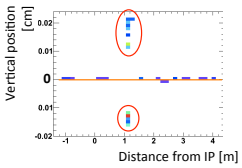
LER Touschek result



Beam loss at IR is 0.9 GHz at ~ 1 m upstream from IP.

Scattered particles are mainly lost vertically.

Vertical collimators might further reduce BG, but we suffer from transverse mode coupling instability

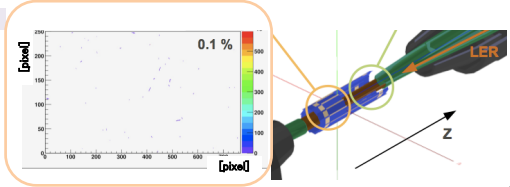


6 BG impact on detector (PXD)

Analysis of the pixel detector hit A. Moll

Averaged occupancy is 0.18 %.

Pixel detector requirement
(less than 2-3 %) was achieved.



Summary

- Touschek BG at SuperKEKB is estimated.
- Touschek rate in IR can be reduced down to ~1 GHz thanks to collimators.
- Innermost pixel detector at Belle-II can be operated under simulated Touschek BG.
- Neutron rate generated by the Touschek background are also tolerable for the detector.

reference
SAD[1] http://acc-physics.kek.jp/SAD/
TURTLE[2] http://www.slac.stanford.edu/pubs/slacreports/slac-r-246.html

nakano@epx.phys.tohoku.ac.jp