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Beam background simulations for the CEPC and the experience from BEPCII

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On behalf of the beam background team

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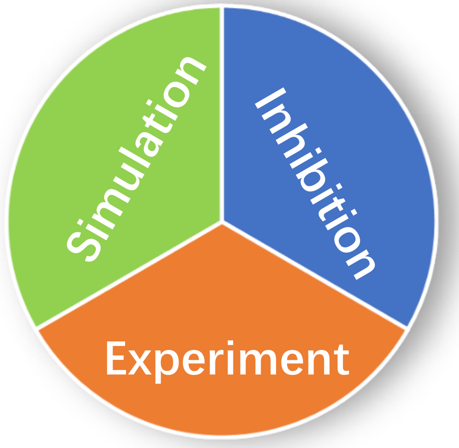
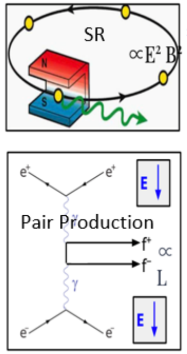


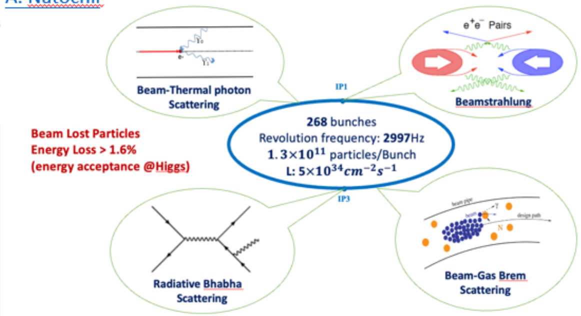
Background Source at CEPC

- Single Beam
  - Touschek Scattering
  - Beam Gas Scattering(Elastic/inelastic)
  - Beam Thermal Photon Scattering
  - Synchrotron Radiation
- Luminosity Related
  - Bremsstrahlung
  - Radiative Bhabha Scattering
- Injection

A. Natochii

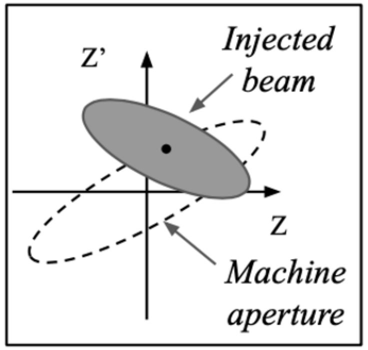


Photon BG



Beam Loss BG

A. Natochii



Injection BG

Background	Generation	Tracking	Detector Simu.
Synchrotron Radiation	BDSim	BDSim/Geant4	Mokka/CEPCSW/FLUKA
Bremsstrahlung/Pair Production	Guinea-Pig++	SAD	
Beam-Thermal Photon	PyBTH[Ref]		
Beam-Gas Bremsstrahlung	PyBGB[Ref]		
Touschek/Beam-Gas Coulomb	BGC in SAD		
Radiative Bhabha	BBBREM		

- One Beam Simulated
- Simulate each background separately
- Whole-Ring generation for single beam BGs
- Multi-turn tracking(50 turns)
  - Using built-in LOSSMAP
  - SR emitting/RF on
  - Radtaper on
  - No detector solenoid yet

- The generators and accelerator software used for CEPC beam background simulation are consistent with those used for BEPCII beam background simulation. The software for accelerator design is also consistent.
- More simulations and experiments based on BEPCII can help understand the background and narrow the differences between data and simulation.

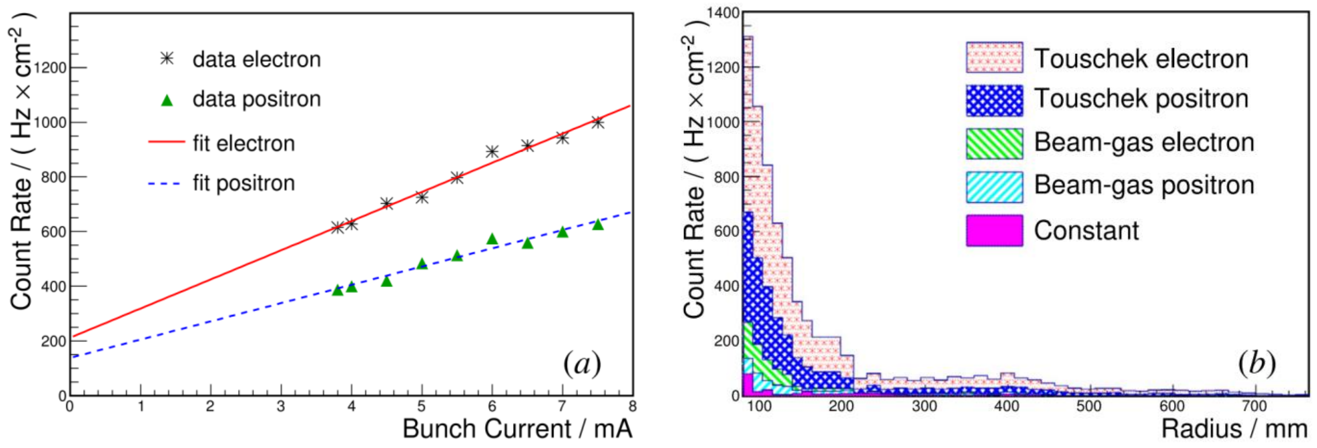
Recent beam background workshop

The 2023 Particle Collider Beam Background Workshop was held to discuss the current progress and future research plans in beam background studies.

Progress of beam background experiment

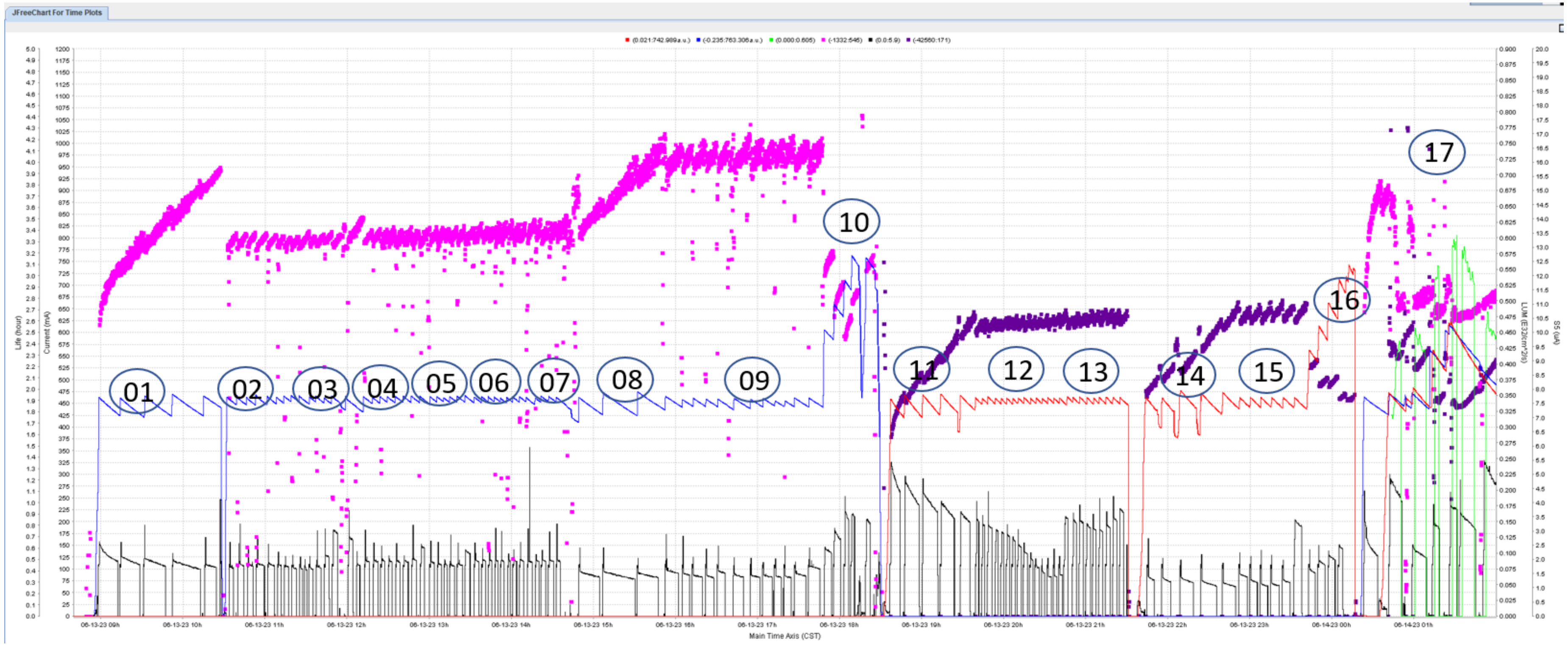
$$O_{\rm SB} = S_{\rm tous} \cdot \frac{I_t \cdot I_b}{\sigma_x \sigma_y \sigma_z} + S_{\rm gas} \cdot I_t \cdot P(I_t) + S_{\rm const},$$

$\boldsymbol{O_{SB}}$ is the total single beam background rate that can be represented by count rate of the MDC, $\boldsymbol{I_t = n_{bunch} \times I_b}$, and $\boldsymbol{P(I_t)}$ is vacuum pressure.



- A separate experiment of main background components at BEPCII has been carried out at BEPCII.
- The fit to the count rate in the first layer of the MDC with respect to the bunch current for both electron and positron beam.
- The accumulated count rate of separate background sources in all MDC layers when bunch current is 6 mA. The Touschek background is dominant in all layers and the beam–gas background occupies a small portion, especially in the outer layers.
- The background at first layer of MDC is composed of 75.1% Touschek, 15.4% beam-gas, and 9.5% constant background.

Movable Collimator experiment



电子环的束流本底实验

① 基准值实验;
② -8.2m处的挡块外挡板孔径扫描
③ -8.2m处的挡块内挡板孔径扫描
④ -11m处的挡块外挡板孔径扫描
⑤ -11m处的挡块内挡板孔径扫描
⑥ +8.2m处的挡块外挡板孔径扫描
⑦ +8.2m处的挡块内挡板孔径扫描
⑧ 挡块最佳位置的基准值实验
⑨ 挡块孔径与暗电流的实验数据采集
⑩ 升流实验

正电子环的束流本底实验

⑪ 基准值实验
⑫ -8.2m处的挡块外挡板孔径扫描
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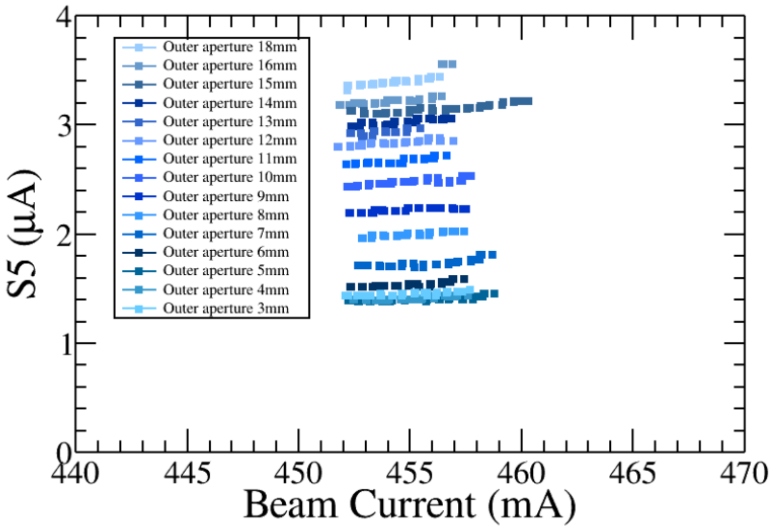
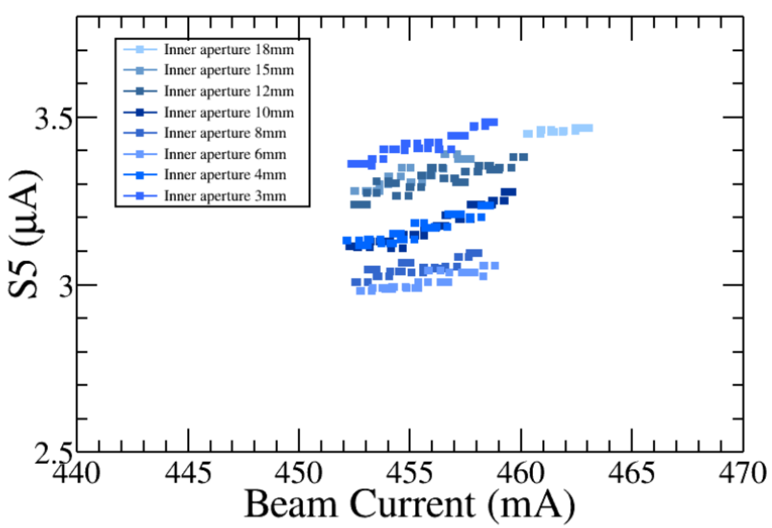
⑮ 挡块孔径与暗电流的实验数据采集
⑯ 升流实验
⑰ 挡块处在最佳位置的对撞取数实验

17 items of movable collimator experiments are conducted in 2023: Baseline beam background experiment (01 and 11). Scan the aperture of collimators for finding a best settings (02-07, 12-13). Baseline beam background experiment with best settings of movable collimators (08, 14). Data taking with different aperture settings (09, 15). Beam background experiment with different beam current (10, 16).

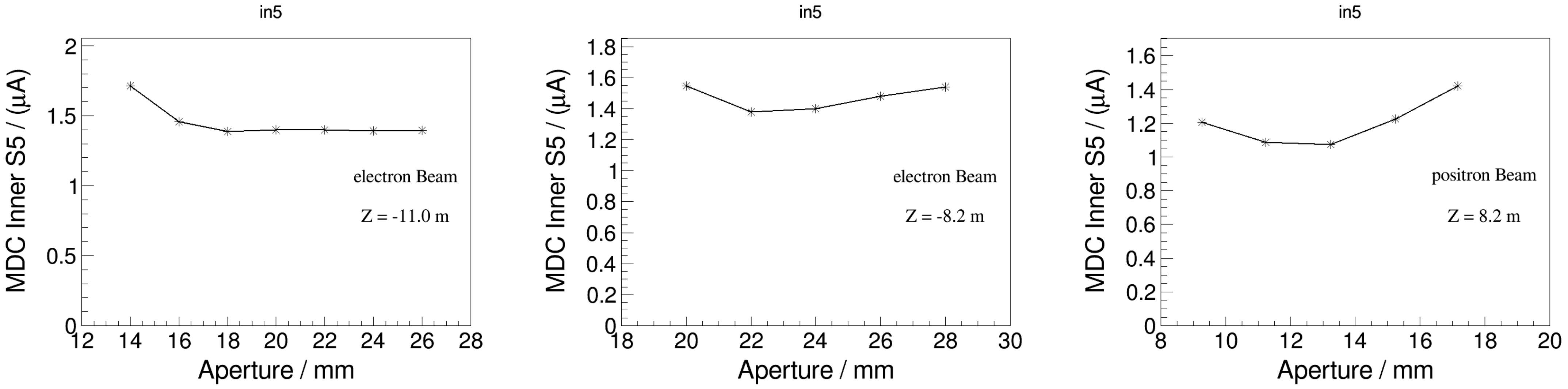
Movable Collimator experiment





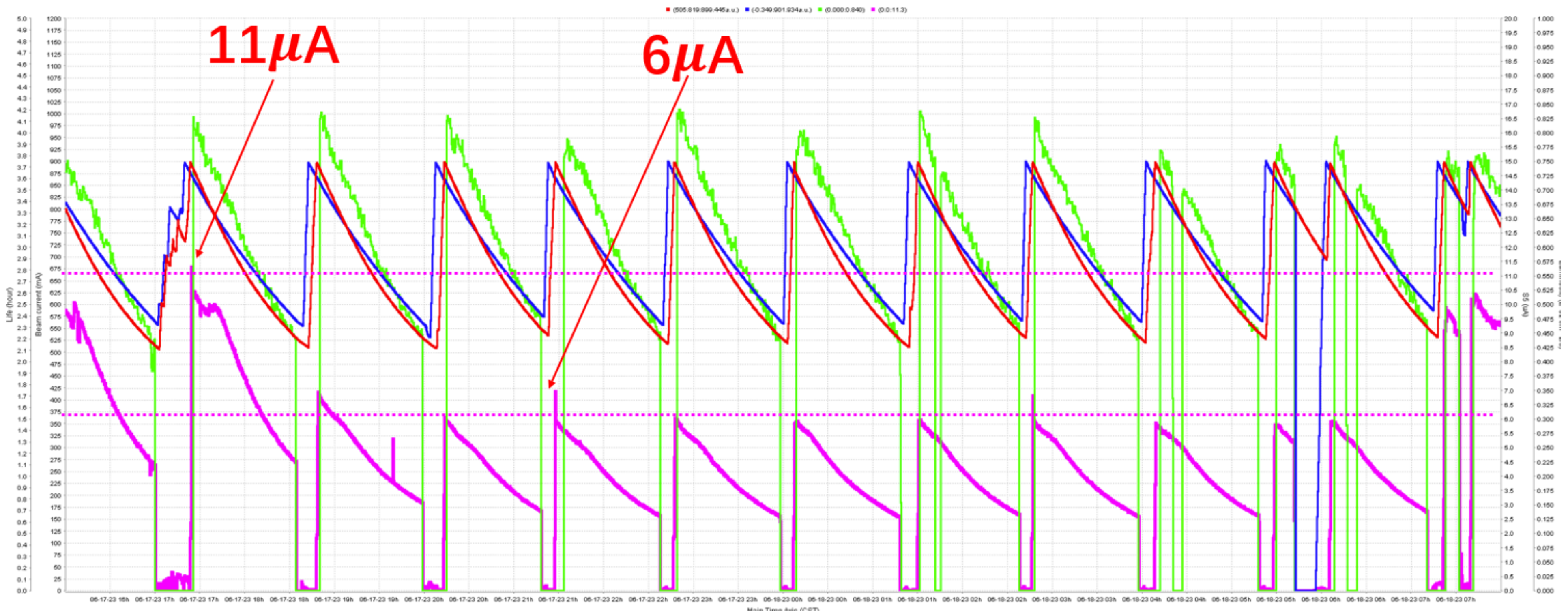
- Scanning the aperture of four movable collimators to find a best aperture settings, the scan result of positron ring.
- Changing the apertures of the collimators downstream from IP is no significantly affect the beam background, while the other three collimators obviously affect the beam background, especially the collimators at 8.2 m upstream from IP for both electron and positron ring.
- **The best aperture settings** of movable collimators with respect to the minimum beam background are selected for further experiments.

Movable Collimator experiment



- Symmetry scanning the aperture of four movable collimators **under the best aperture settings**.
- A clear minimum dark current corresponding to the best aperture settings is observed.
- Collect these experimental data sets with different aperture settings for further analysis and validating the simulation prediction.

Movable Collimator experiment



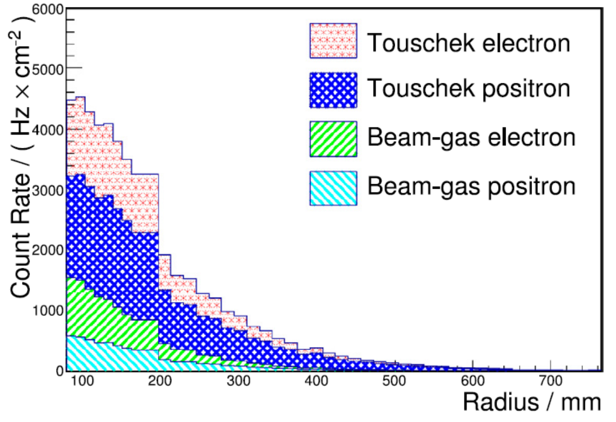
➨ An additional data taking with the best setting of these movable collimators is performed, the dark current is decreased from 11μA to 6 μ A (about 40%) with 900mA beam current and the beam lifetime and peak luminosity are no obviously changed. The obvious mitigation of beam background will play an important role of the future data taking of BEPCII and the evaluation of the beam background of the BEPCII upgrade.

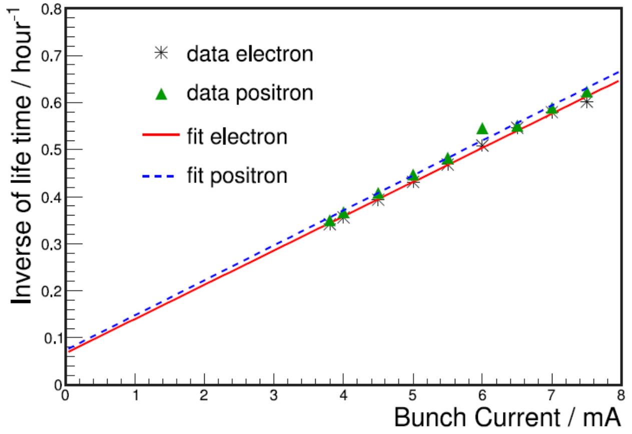
Beam background simulation at BEPCII/BESIII

- Multiple iterations of the background simulation program have been upgraded.
- The rate of loss and count rate of positrons are both higher than those of electron by about 50%, which is consistent with those in experiments.
- Both simulating and experimental results show that the Touschek background is dominant in all layers.
- The generation rate of beam background simulation by the scale factor calculated by the beam lifetime.

$$\frac{1}{\tau} = \frac{1}{\tau_{\text{tous}}} + \frac{1}{\tau_{\text{gas}}} = k_{\text{tous}} \cdot I_b + k_{\text{gas}} \cdot P,$$

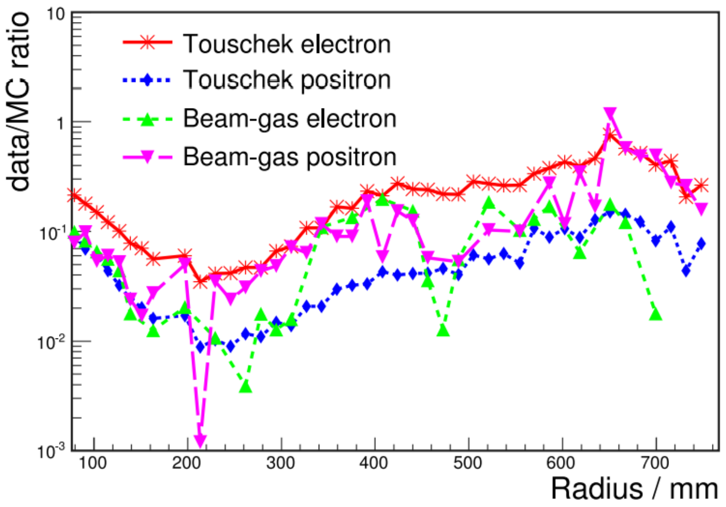
	τ (h) experiment	τ (h) simulation	Scale factor
Touschek e^-	2.29	11.00	4.8
Touschek e^+	2.25	11.81	5.2
Beam-gas e^-	14.80	37.26	2.5
Beam-gas e^+	13.52	37.26	2.8





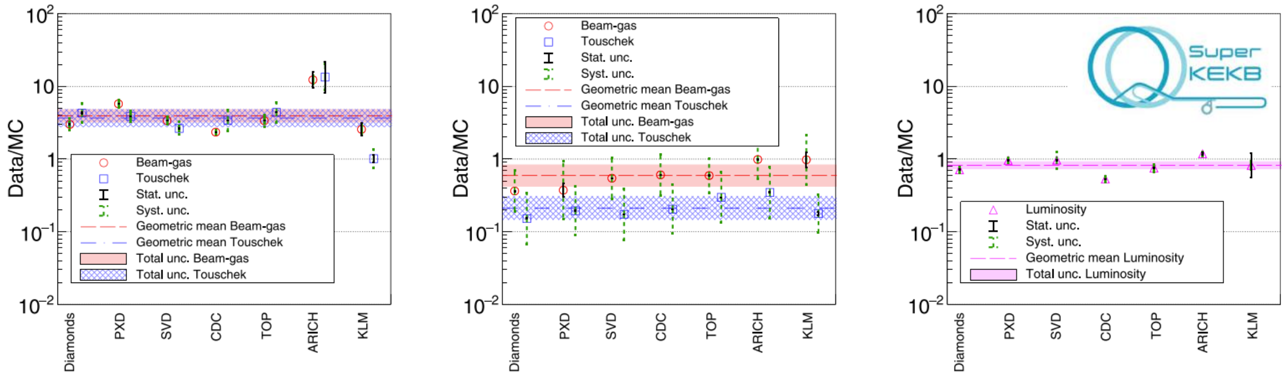
Beam background simulation at BEPCII/BESIII

- The rate of loss and count rate of positrons are both higher than those of electron by about 50%, which is consistent with those in experiments.
- Both simulating and experimental results show that the Touschek background is dominant in all layers.
- The generation rate of beam background simulation by the scale factor calculated by the beam lifetime.
- The magnitude of simulating Touschek background is larger than that in the experiment by one to two orders. The difference occurs mainly due to lattice, tracking, the MDI simulation, collimator simulation, and so on.



To do list

- Narrow the difference between experimental measurement and simulating prediction:
  - Simulation:
    - More detail model of detector
    - The Solenoid simulation
    - A more realistic lattice
    - Tip-scattering
  - Experiment:
    - Analyzing the operational data from the past 5-10 years.
    - Decrease the statistical fluctuation of beam gas calculation.
    - Manual adjust the beam orbit and measure the changes in the beam background.



(a) LER single-beam background. (b) HER single-beam background. (c) Luminosity background.

A. Natochii, T.E. Browder, L. Cao et al., Nuclear Inst. and Methods in Physics Research, A 1055 (2023) 168550

- More manpower for improving the detector simulation and analyzing of operational data.
- International cooperation, especially with SuperKEKB.

Thank you to all the experts for their support of the background work.