Institute of High Energy Physics
Chinese Academy of Sciences

BEPCII/BEPCII-U本底研究

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ON BEHALF OF THE BEAM BACKGROUND SYSTEM

INSTITUTE OF HIGH ENERGY PHYSICS

2023.12.16

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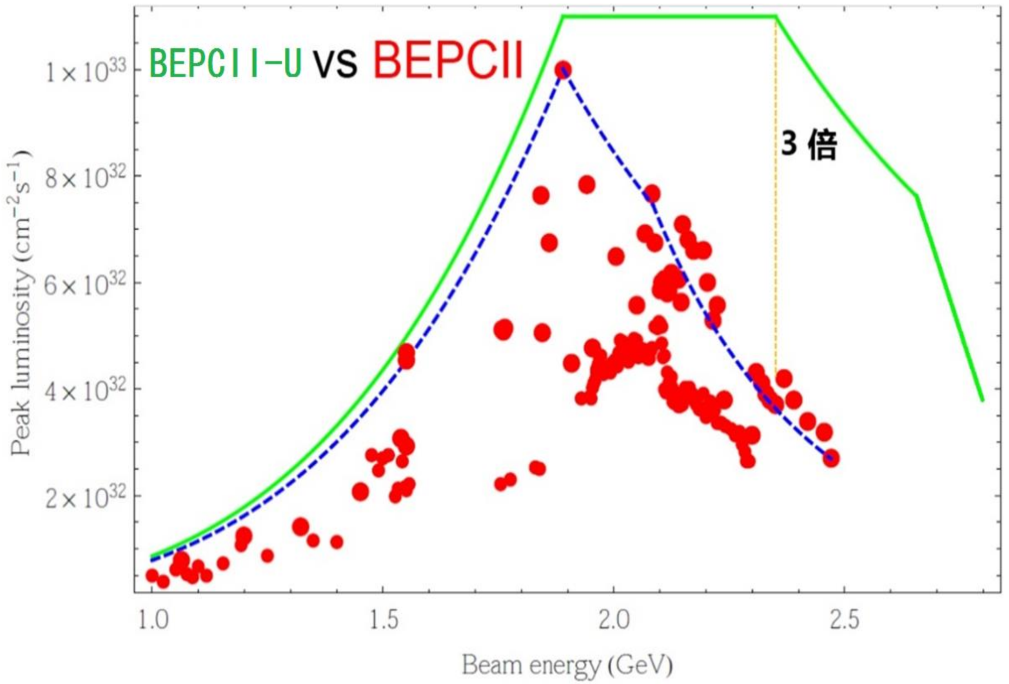
- Introduction
  - Introduction of BEPCII-U
  - Beam background sources in BEPCII/BEPCII-U
- Beam-related background experiment in BEPCII
- Beam background simulation at BEPCII/BESIII
- Summary and next to do

Introduction of BEPCII-U

	BEPCII	BEPCII-U
luminostiy $[10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$ @2.35GeV	3.5	11
β_y^* [cm]	1.5	1.35
Beam current[mA]	400	900
SR Power [kW]	110	250
$\xi_{y,\mathrm{lum}}$	0.029	0.033
emittance[nmrad]	147	152
couple [%]	0.53	0.35
Bucket Height	0.0069	0.011
$\sigma_{z,0}$ [cm]	1.54	1.07
σ_z [cm]	1.69	1.22
Rf voltage	1.6MV	3.3MV



- 2024 .7-12, Shut down for hardware dismantling and installation
- 2025-2028, Operation at 2.3~2.5GeV, prepare for energy upgrade
- 2028.6-9, Energy upgrade to 2.8GeV
- 2028.9~2030, Operation at 2.5~2.8GeV

Introduction of BEPCII-U

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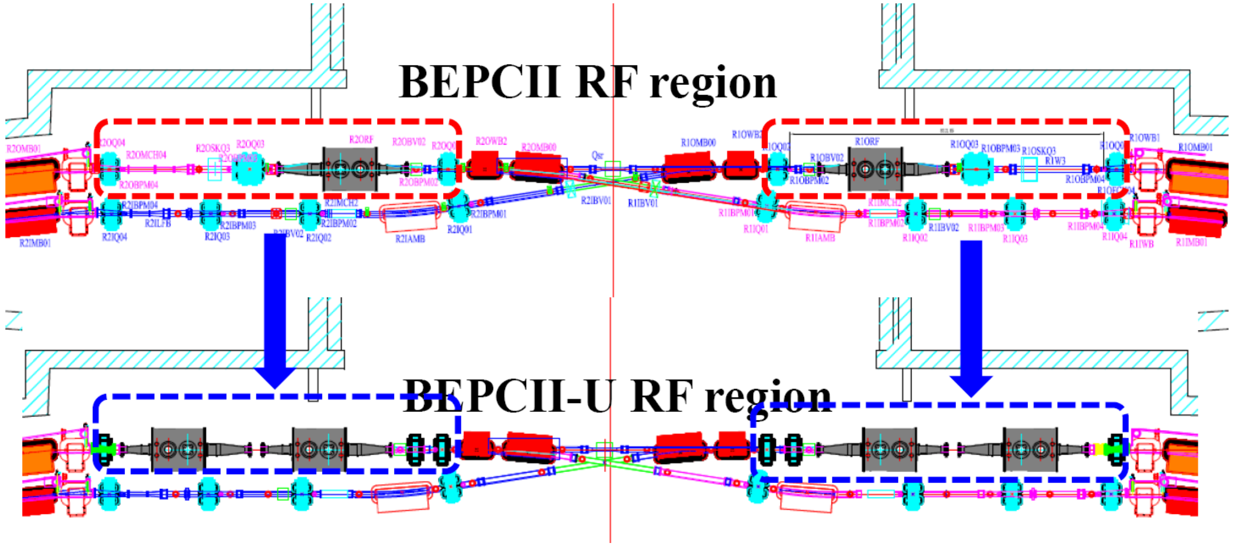
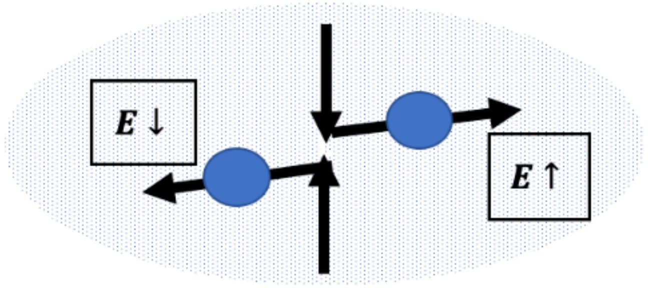


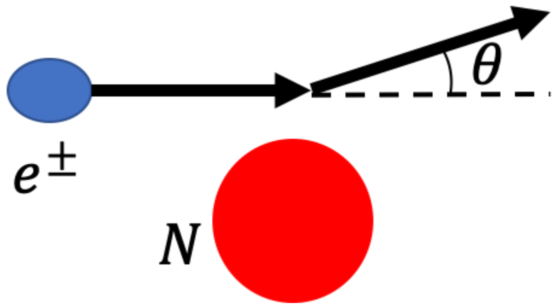
- 1 existing and 1 additional RF cavity per ring.
- The survey will be kept exactly the same as BEPCII.

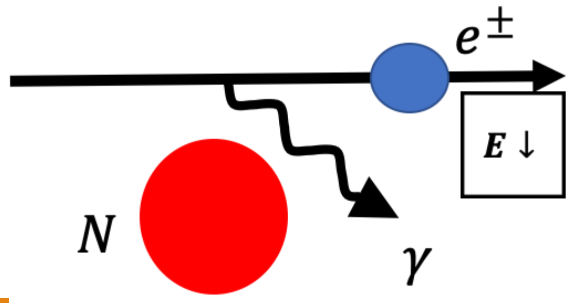
Beam background sources in BEPCII

- **Touschek effect:**
  - Scattering among particles in a same bunch.
  - Generation rate ∝ N_{bunch}, beam size^{-1}, beam energy^{-3}



- **Beam-gas effect:**
  - Interactions between the particles of the beam and the residual gas molecules in the vacuum chamber, including Coulomb scattering and Bremsstrahlung scattering.
  - Generation rate ∝ pressure





- Injection effect:
  - Caused by injected particles with a large amplitude of oscillations due to injection kicker errors;
  - High and instantaneous

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Beam background experiment in BEPCII

- Measure the Touschek background and beam-gas background separately.

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

- $\boldsymbol{O_{SB}}$ 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.

- The constant background is measured without any beam in the storage ring.

- The Touschek and beam–gas backgrounds can be separated by using different **bunch currents,** where the nominal beam current is set to 450 mA.

- To study the correlation between vacuum pressure and beam current, we fix the bunch current (6 mA) and increase the bunch number.

Beam background experiment in BEPCII

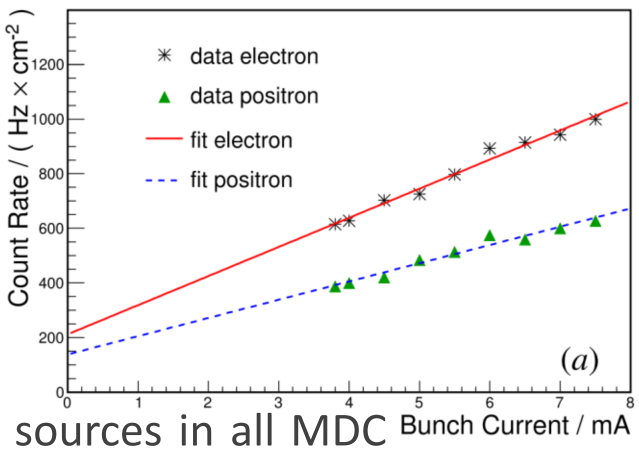
Touschek background: Parameters setting for bunch number scan

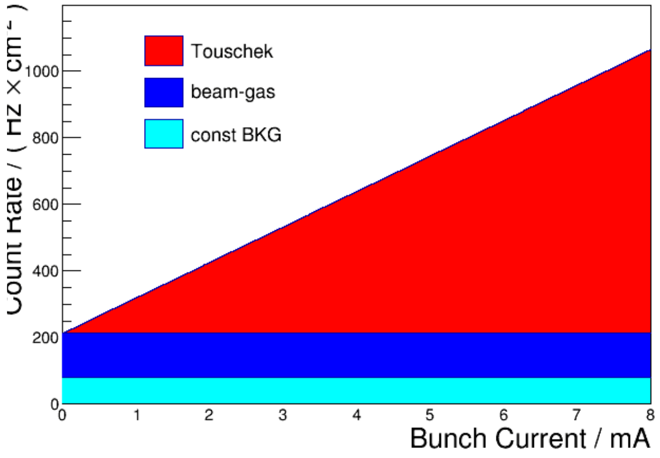
N bunch	118	113	100	90	82	69	64	60	56
I_b/mA	3.8	4.0	4.5	5.0	5.5	6.5	7.0	7.5	8.0

Beam-gas background: fixed bunch current to 6 mA and scan bunch number from 15 to 90.

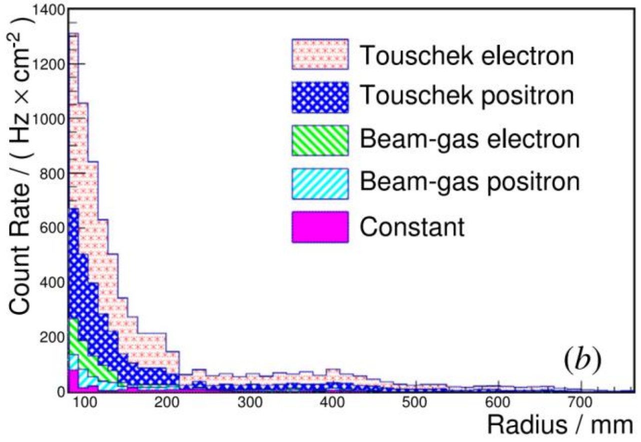
Beam background experiment in BEPCII

- Touschek fit: $O_{ob} = k \cdot I_b + b_{gas} + b_{const}$
- Constant: b_{const} from cosmic ray experiment
- Beam-gas: $b_{fit} - b_{const}$





- 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.



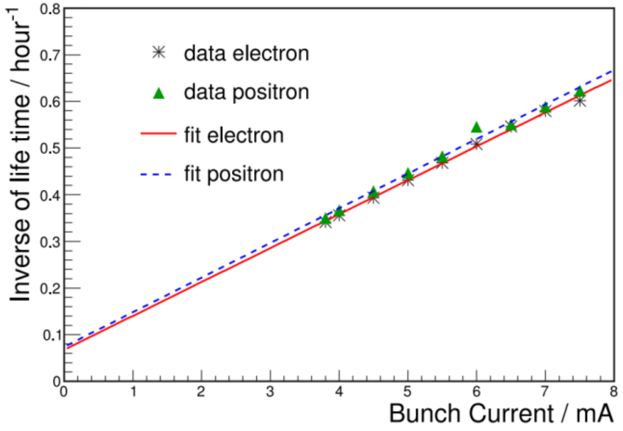
Beam background experiment in BEPCII

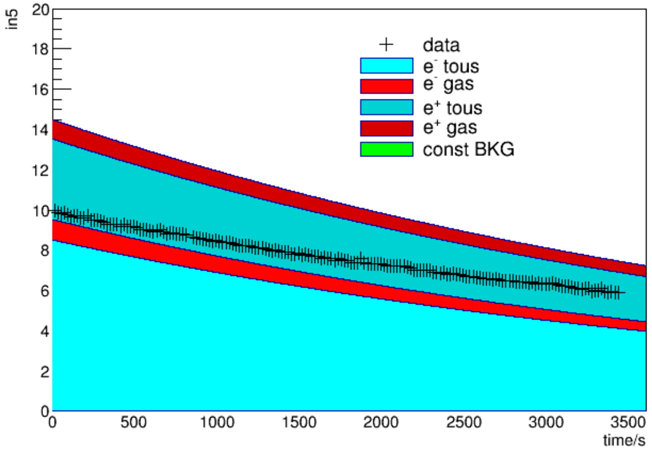
$$\frac{1}{\tau} = \frac{1}{\tau_{\text{tous}}} + \frac{1}{\tau_{\text{gas}}} = k_{\text{tous}} \cdot I_b + k_{\text{gas}} \cdot P,$$

- The lifetimes at bunch current of 6 mA are 2.29 (2.25) h as Touschek lifetime and 14.80 (13.52) h as beam–gas lifetime for the electron (positron) beam.

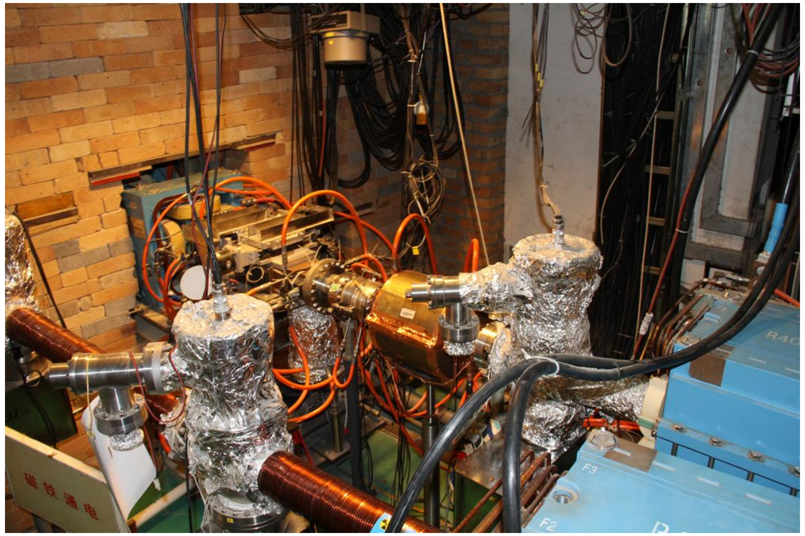
- Based on above empirical formula of the single beam, we add the positron and electron beam backgrounds to the constant background and compare with the collision beam background.

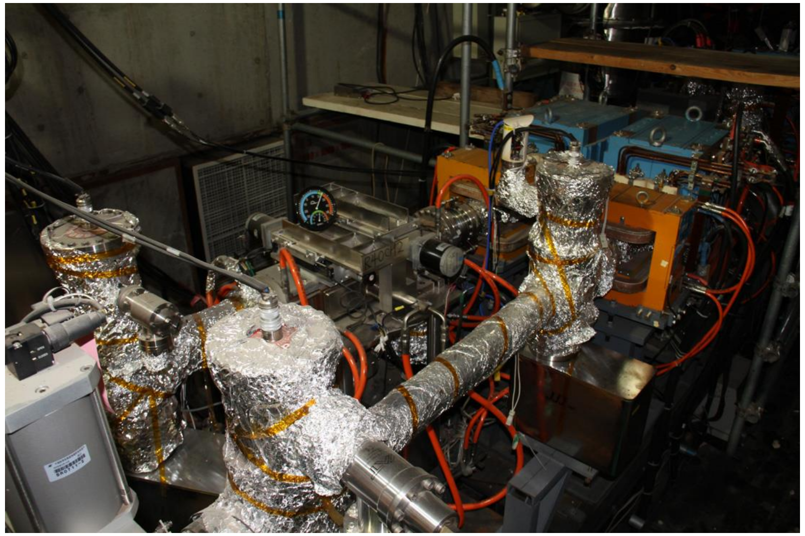
- One potential explanation is that the blowup effect reduces the Touschek background, resulting in a total collision background that is lower than the sum of the individual beam backgrounds.

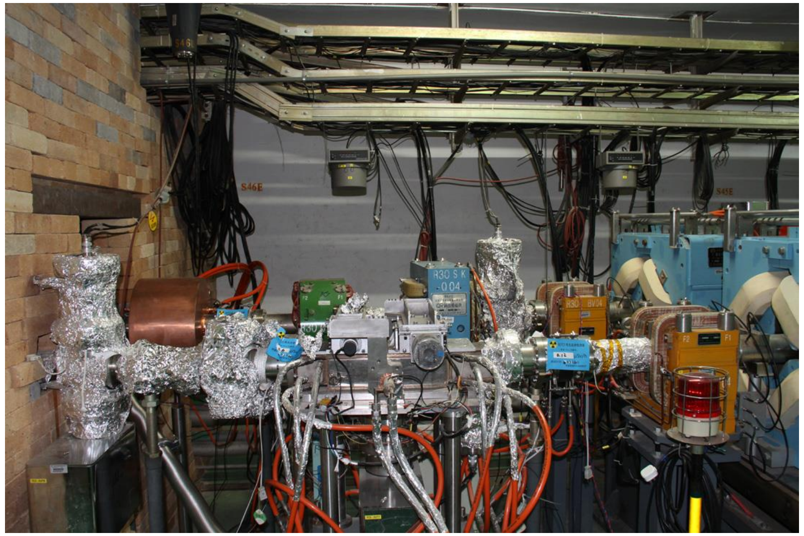


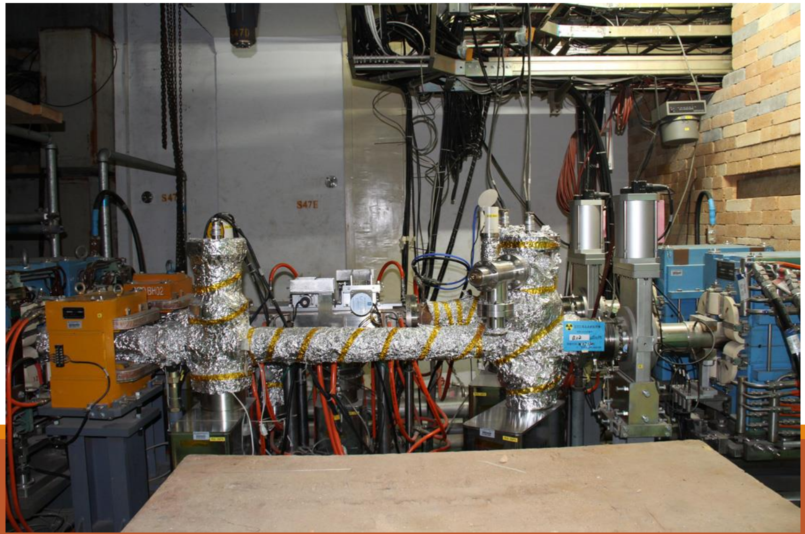


Movable Collimator experiment in BEPCII





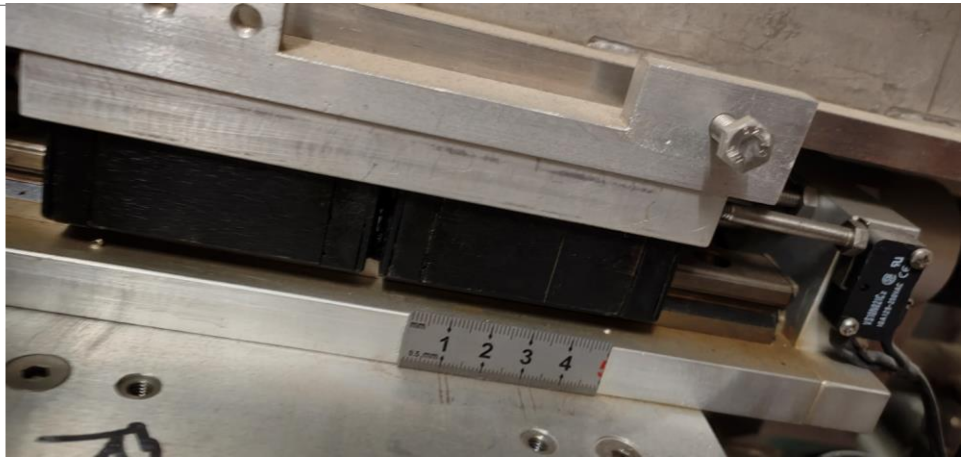




- Three horizontal movable collimators (8.2m and 11m upstream from the IP and 11m downstream from the IP) in the electron ring;
- A horizontal movable collimator (8.2m upstream from the IP) in the positron ring;

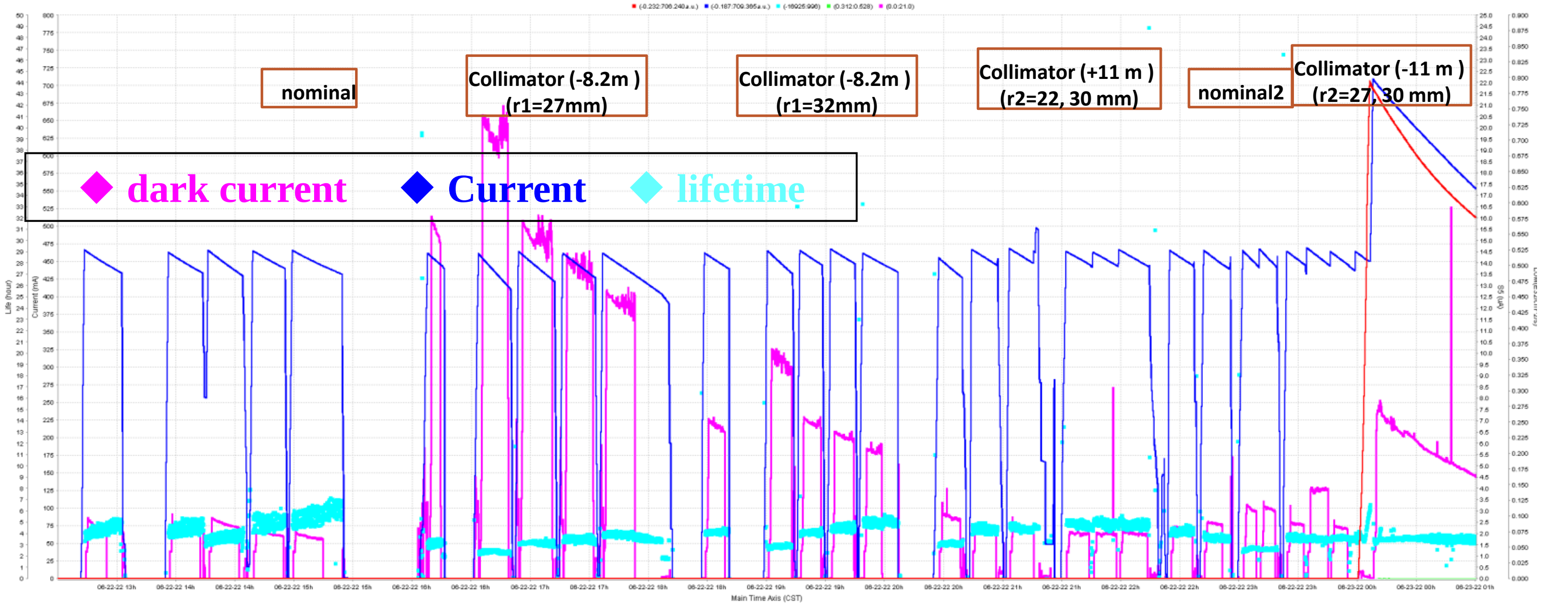
Movable Collimator experiment in BEPCII

- The collimator has two independent jaws, which can be adjusted from 3mm to 21mm, the half aperture can be changed between 40 mm and 22 mm.
- The simulation results indicate that the collimator located upstream from IP significantly affects the beam background, while the collimators positioned downstream from the IP do not have a noticeable impact.



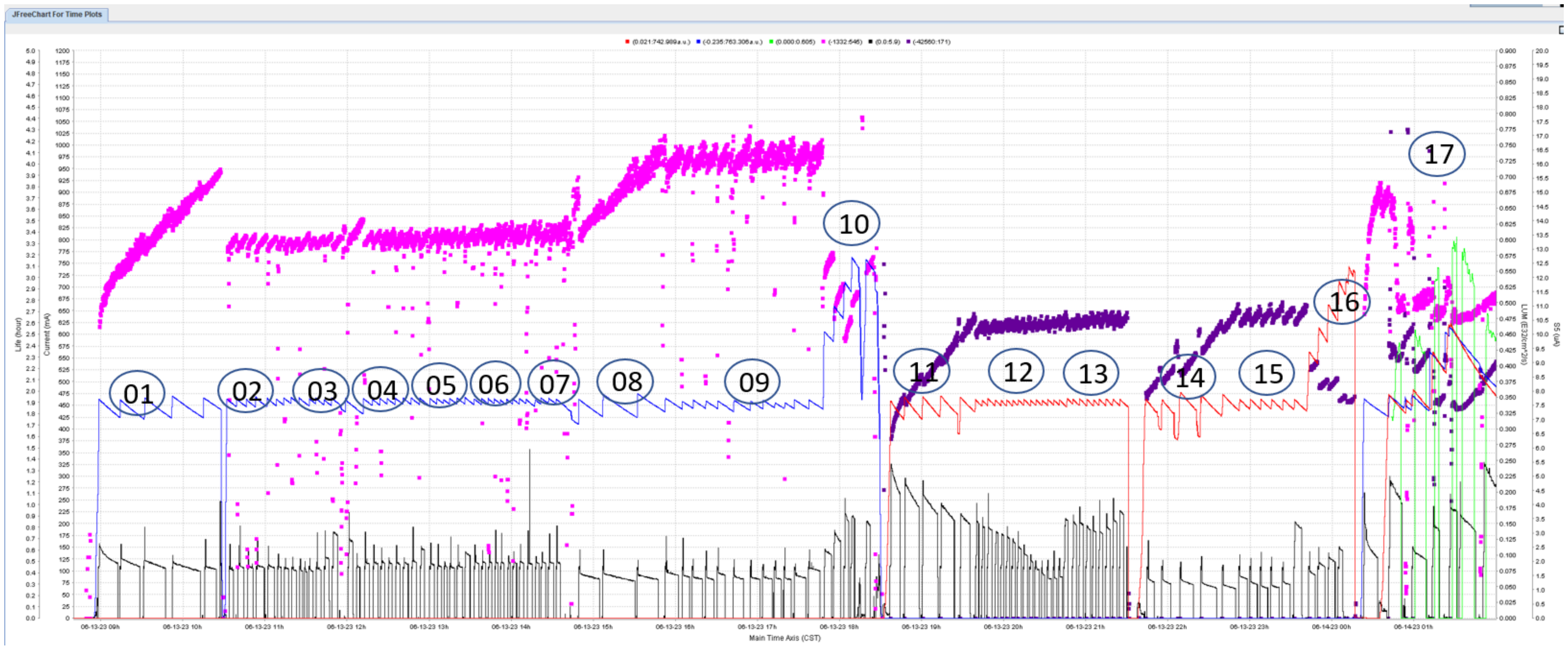
Movable Collimator experiment in BEPCII

- The nominal beam current is 450 mA. Four bunch number (60, 75, 82, and 90) is selected.
- Changing the aperture of movable collimator located at -8.2 m from 35 mm to 32 mm (27 mm), the beam background increased more than four times. The injection is failed if the aperture is decreased to 22 mm.
- Adjusting the apertures of the other two movable collimators did not noticeably affect the beam background.



Changing the aperture of collimators can suddenly but no dramatically increase the vacuum pressure and decrease the lifetime of beam. While the vacuum pressure and lifetime will recovered in a few seconds. It indicates that more detailed collimator experiments can be conducted in the next beam background experiment.

Movable Collimator experiment in BEPCII



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
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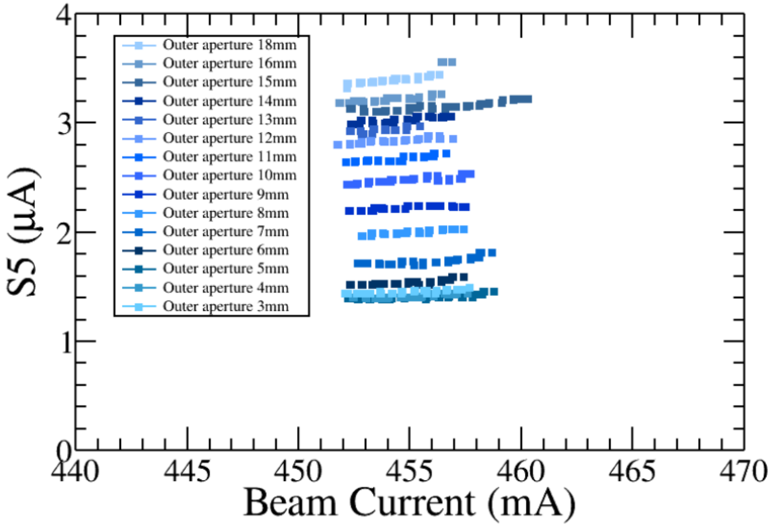
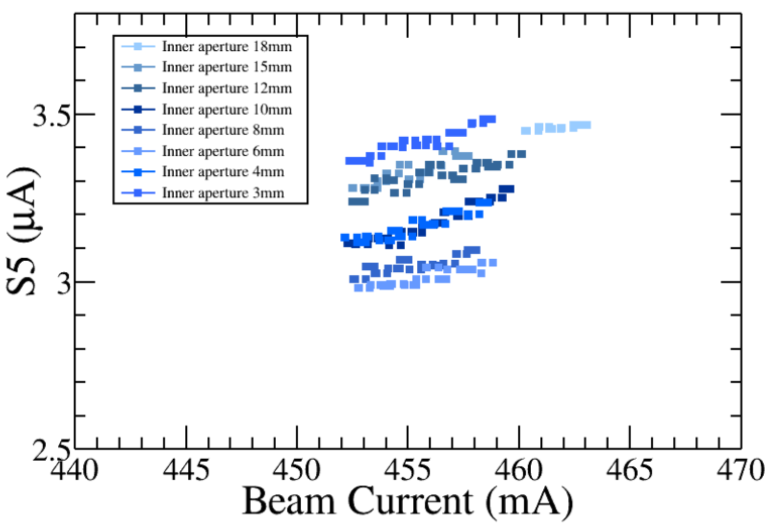
⑯ 升流实验
⑰ 挡块处在最佳位置的对撞取数实验

17 items of movable collimator experiments are conducted in the movable collimator: 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).

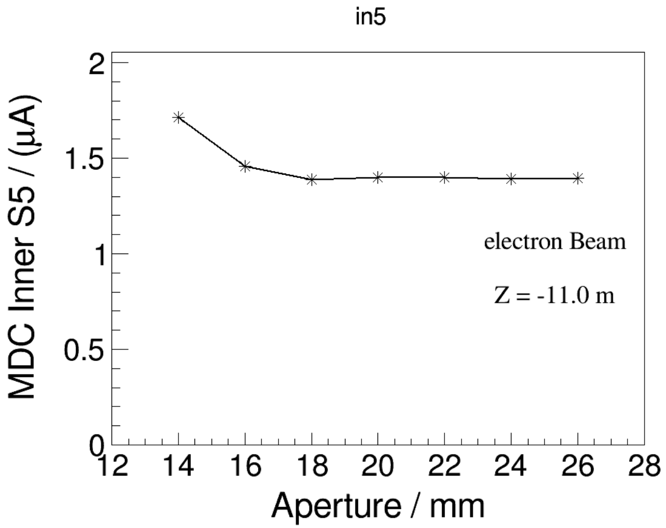
Movable Collimator experiment in BEPCII

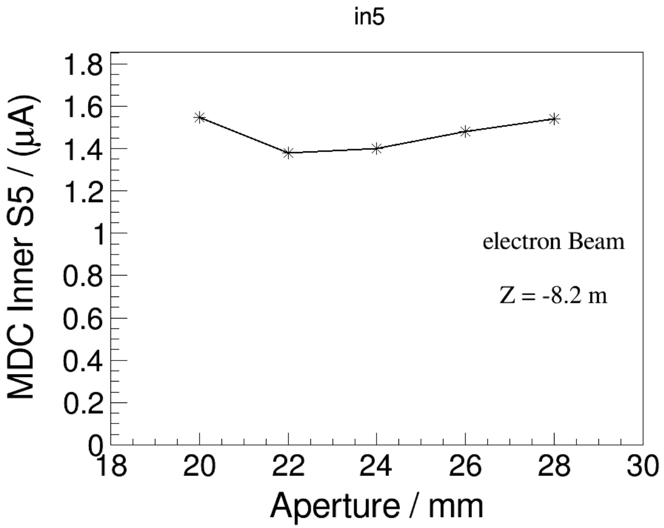


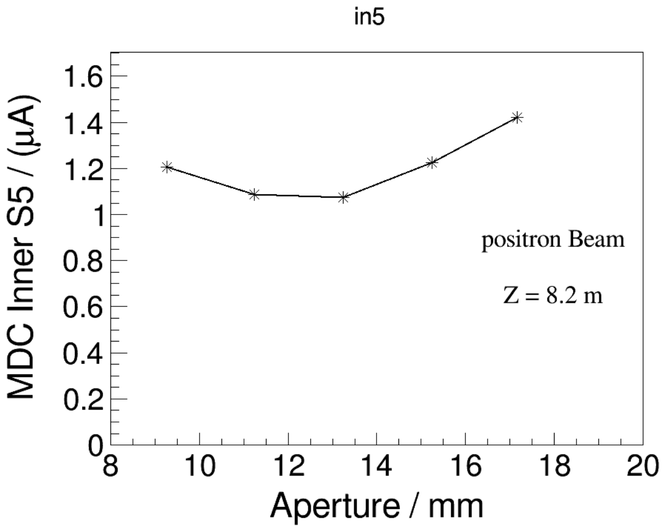


- Scanning the aperture of four movable collimators to find a best aperture settings, the scan result of positron ring.
- Changing the apertures of the collimators downstream from IP is no significantly affect the beam background, while the other three collimators obviously affect the beam background, 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 in BEPCII

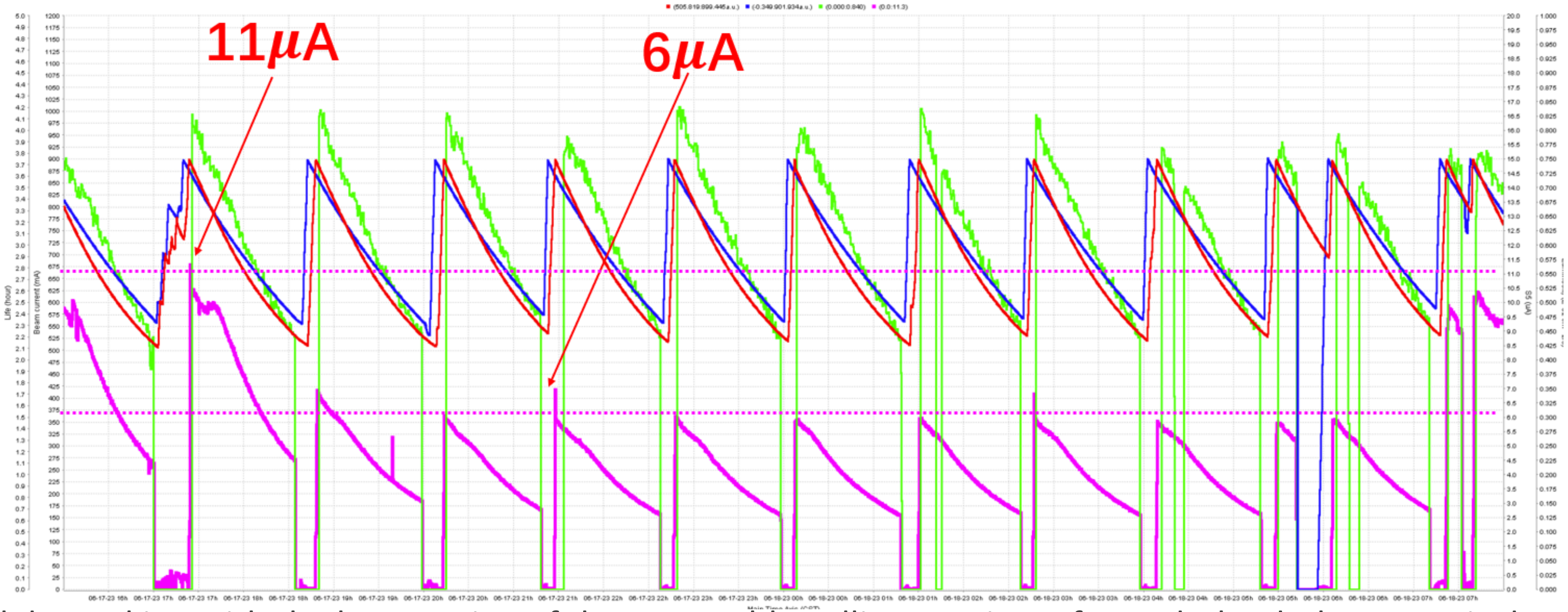






- Symmetry scanning the aperture of four movable collimators **under the best aperture settings**.
- A clear minimum dark current corresponding to the best aperture settings is observed.
- Collect these experimental data sets with different aperture settings for further analysis and validating the simulation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

Movable Collimator experiment in BEPCII



- 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.

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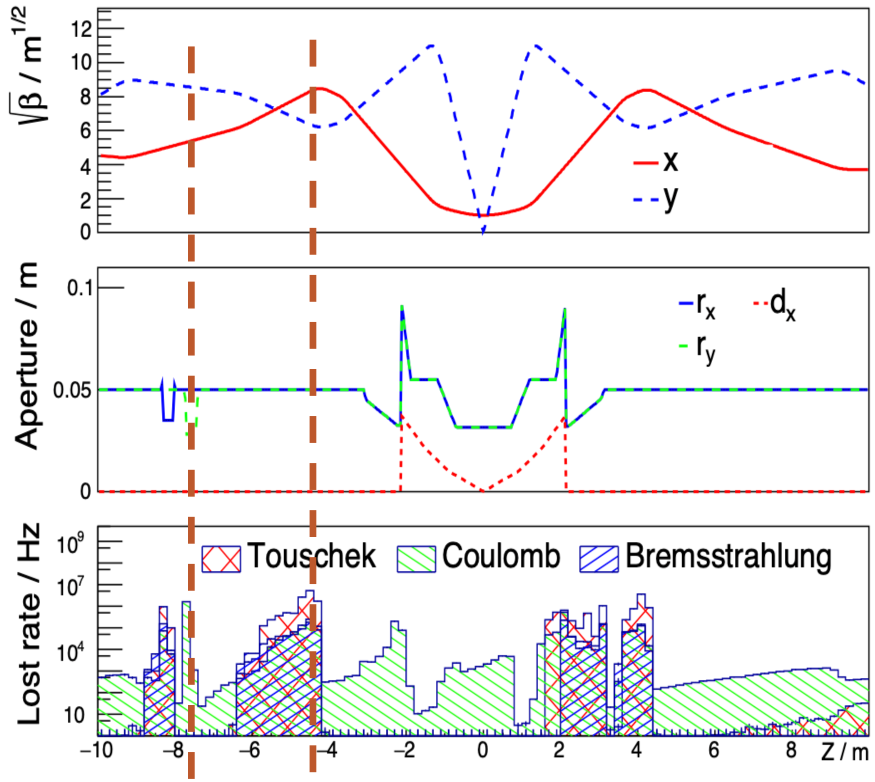
Beam background simulation at BEPCII/BESIII

- Generator: SAD for tracking the particles in the accelerator, and Gearnt4 for calculating the MDI interactions and the detector.
- The Touschek and beam–gas background are generated through sampling with the cross section.
- The BEPCII lattice is sliced to improve the accuracy of generator and that of tracking, and the background particles are generated and tracked in the middle of each slice in SAD.
- The residual gas is assumed as a mixed gas of 80% hydrogen and 20% Carbon-Oxide with the same pressure in the total ring.



Beam background simulation at BEPCII/BESIII

- MDI geometry: Based on Geant4-based software framework of the BESIII Offline Software System (BOSS), which includes all subdetectors. The elements of the MDI are added to the framework.

- Collimator settings:

表 3　08-09 年电子环调束运行中实际安装使用的水平挡块位置和孔径

	最小孔径位置	半孔径
R4OCH02*	对撞点上游约 8.2m，靠近 R4OBPM03	26mm
R4OCH08	对撞点上游约 27m，与 R4OQ08 位置重合	31mm
R4OCH14	对撞点上游约 46.8m，与 R4OQ14 位置重合	26 mm
R3ICH08	对撞点下游约 27.5m，直线节 D3I33 中	30mm

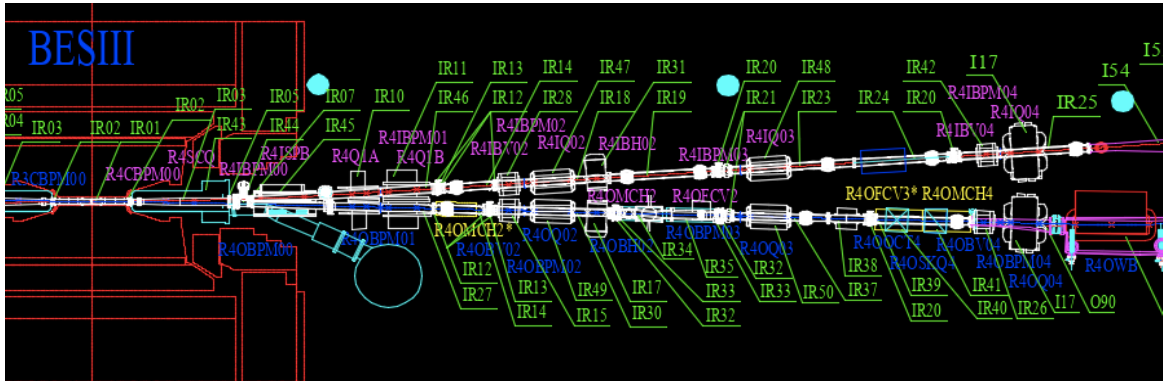
表 4　08-09 年电子环调束运行中实际安装使用的垂直挡块位置和孔径

	最小孔径位置	半孔径
R4OCV02	对撞点上游约 7.6m，靠近 R4OBH02	28mm
R4OCV15	对撞点上游约 50.1m，靠近 K3	15mm
R4OCV16	对撞点上游约 64.8m，与 R4OSKQ16 位置重合	14mm
R3ICV09	对撞点下游约 28.5m，直线节 D3I33 中	15mm

表 5　09 年电子环新（改）装水平挡块位置和孔径

	最小孔径位置	半孔径
R4OCH02*	对撞点上游约 8.2m，靠近 R4OBPM03	19mm
R4OCH04*	对撞点上游约 11m，靠近 R4OQ03	19mm
R3ICH04*	对撞点下游约 11m，靠近 R3IQ03	26mm

注：带*表示为水平活动挡块



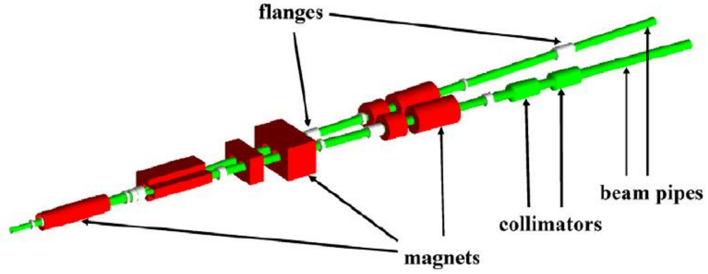
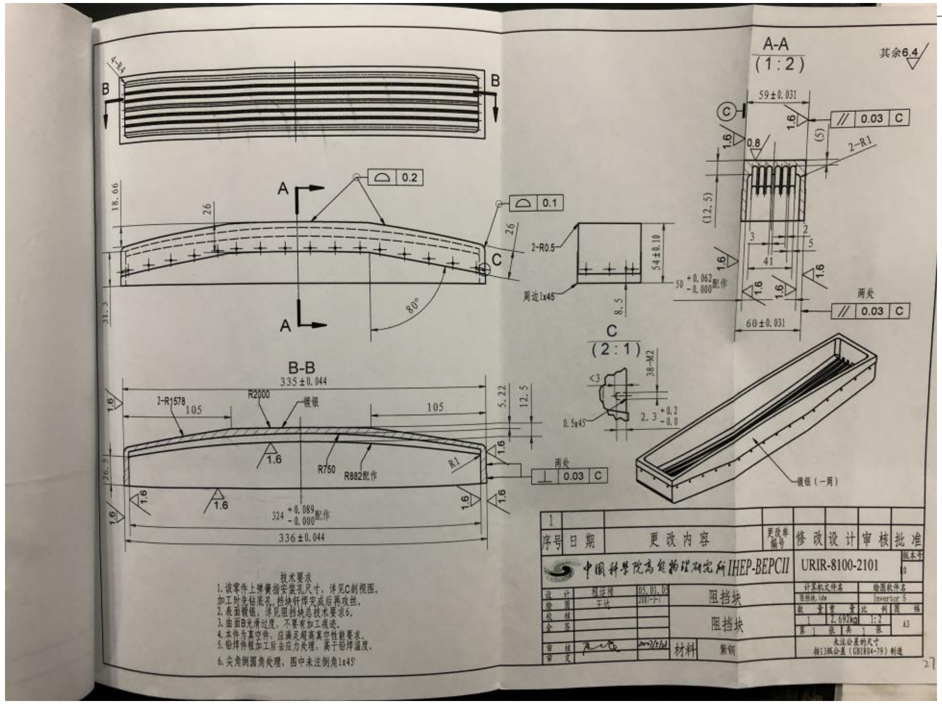
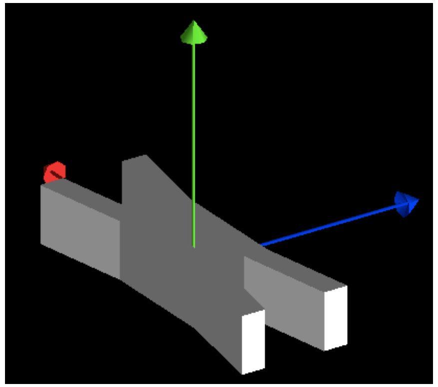
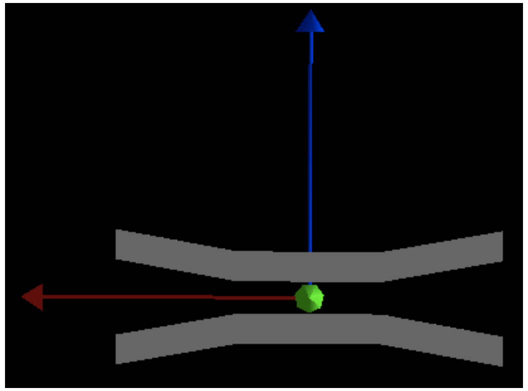


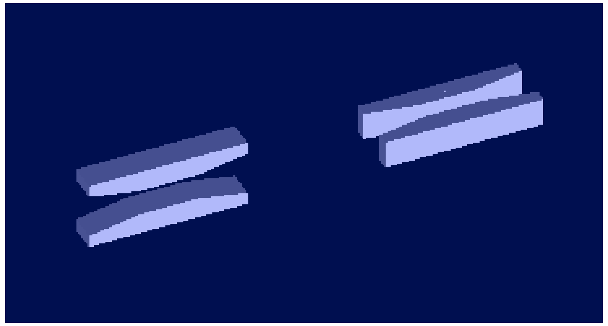
Fig. 3. Geometry of the MDI elements within 10 m of the IP, including beam pipes, magnets, collimators and flanges. The collimators OCH02 and OCV02 are enveloped by the upstream beam pipe.

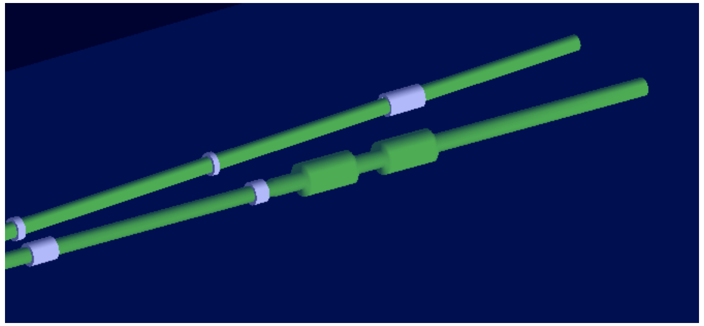
Movable Collimator simulation



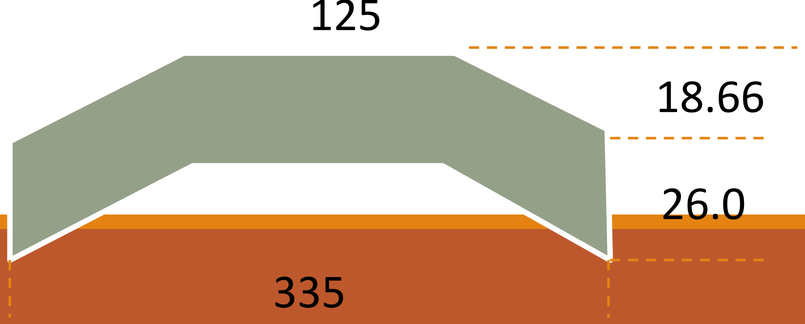








m=2.692kg, V=306cm^3,S~51cm^2

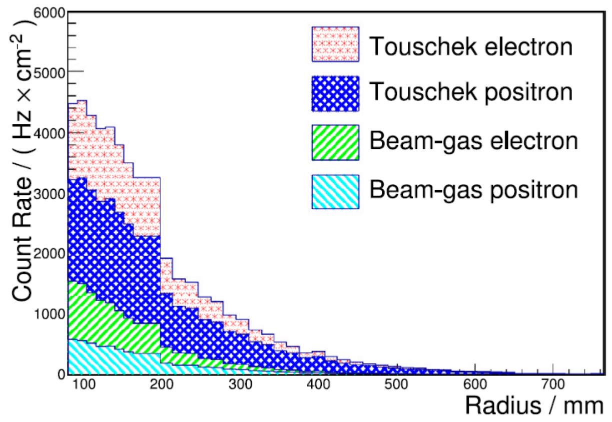


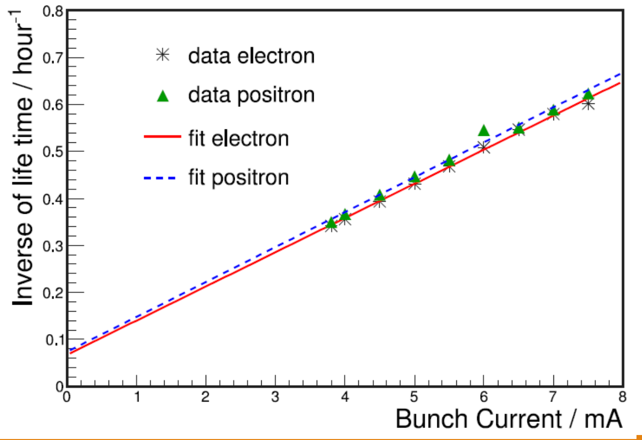
Beam background simulation at BEPCII/BESIII

- 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.

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

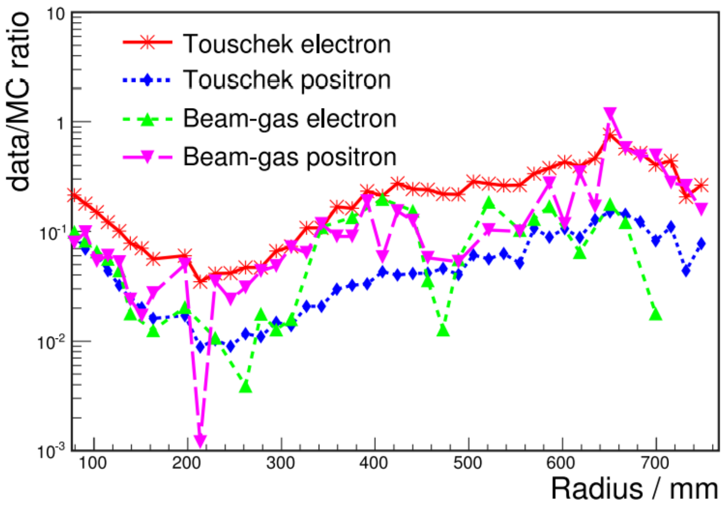
	τ (h) experiment	τ (h) simulation	Scale factor
Touschek e^-	2.29	11.00	4.8
Touschek e^+	2.25	11.81	5.2
Beam-gas e^-	14.80	37.26	2.5
Beam-gas e^+	13.52	37.26	2.8





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.



H.C. Shi*, B. Wang*, H.Y. Shi et al., Nuclear Inst. and Methods in Physics Research, A 1050 (2023) 168174

Summary

- The beam background simulation and experiment are studied in recent three years.
- The Touschek background is dominant in the beam-related background for **both experimental and simulation results**.
- By comparing the beam parameters of BEPCII and BEPCII-U, it is anticipated that the beam-related background in BEPCII-U will be approximately **three times** higher than the current level, the Inhibition by collimators is necessary during the upgrade.
- The collimators with proper aperture settings **effectively decrease (40% decrease)** the beam background in the recent data taking, where the beam current is **up to 900 mA**.
- Further analysis of the recent experimental data is ongoing.

To do list

- Data analysis for operational data sets.
  - Extract the operational data for those runs with poor vacuum pressure.
  - Analyzing the operational data from the past 5-10 years.
- Beam background simulation optimization:
  - Optimizing the BEPCII lattice.
  - Optimizing the MDI simulation, collimator simulation, and so on.
- International collaboration, especially for SuperKEKB staff.
- Funding: We are applying a special funding focus on the beam background study.

我们的束流本底研究与国际水平相比还有较大差距，模拟结果显示我们需要加倍努力。我们的束流本底团队将持续深入开展研究工作。

Mini-Workshop on BEPCII Background

March 10-12, 2008, IHEP, Beijing

15年

2023年粒子对撞机束流本底研讨会

2023年12月15-17日, 浙江大学, 杭州

https://indico.ihep.ac.cn/event/257/timetable/#all.detailed

遥远的目标，需要脚踏实地的前行；艰难的事业，需要不懈的努力。

THANK YOU

即使天公不作美，诸位仍旧参与讨论，非常感谢大家的支持!