Beam background and collimator experiment at BESIII/BEPCII

BIN WANG[1], HAOYU SHI[1], HUANGCHAO SHI[2], YUPENG PEI[3]

1 INSTITUTE OF HIGH ENERGY PHYSICS

2 ZHEJIANG UNIVERSITY

3 UNIVERSITY OF SCIENCE AND TECHNOLOGY OF CHINA

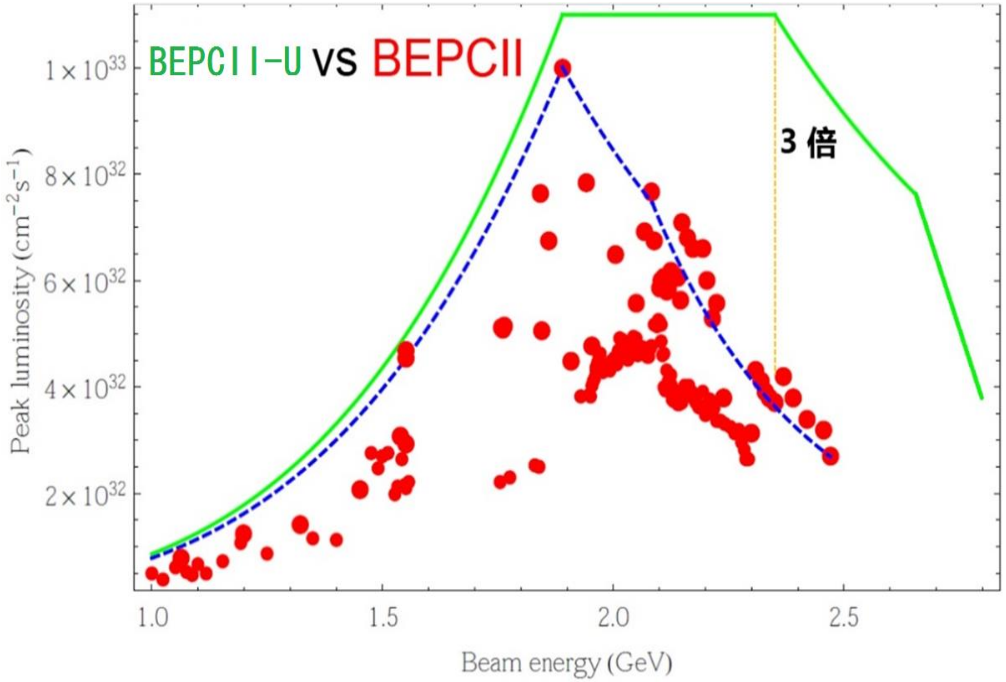
2023.08.18

Content

- Introduction
- Beam background experiment and simulation in 2021
- Movable collimator experiment in 2023
- Simulation of beam background at BEPCII/BESIII
- Summary and next to do

Introduction of BEPCII-U

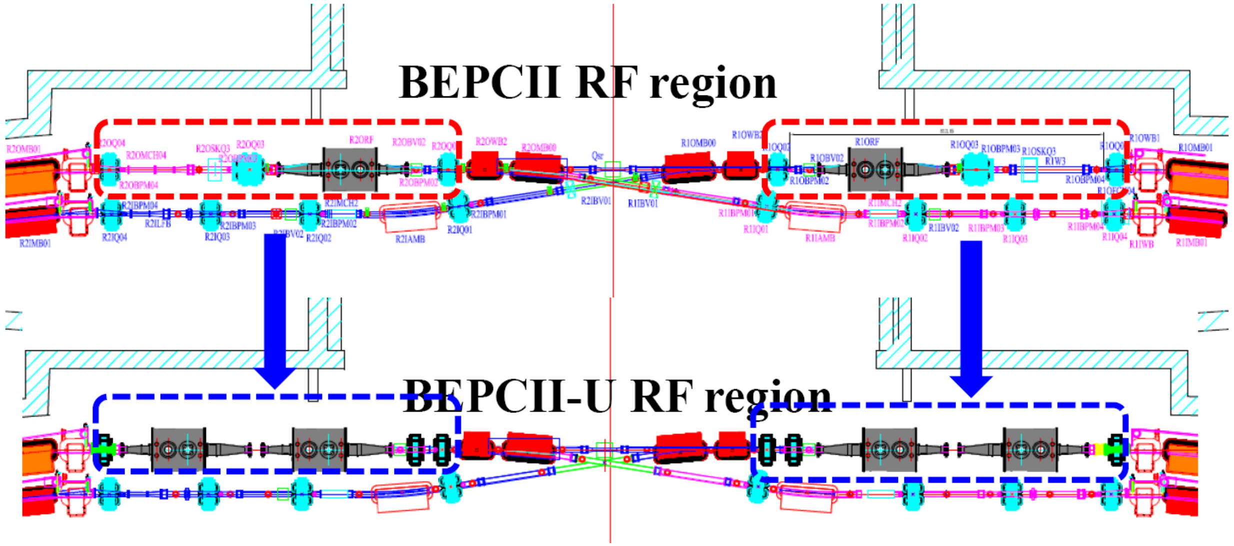
Beam Energy：2.35GeV	BEPCII	BEPCII-U
Lum [$10^{32}cm^{-2}s^{-1}$]	**3.5**	**11**
β_y^* [cm]	**1.5**	**1.3**
Bunch Current [mA]	7.1	7.5
Bunch Num	56	120
SR Power [kW]	**110**	**250**
$\xi_{y,\mathrm{lum}}$	**0.029**	**0.036**
Emittance [nmrad]	147	152
Coupling [%]	**0.53**	**0.35**
Bucket Height	0.0069	0.011
$\sigma_{z,0}$ [cm]	1.54	1.04
σ_z [cm]	**1.69**	**1.3**
RF Voltage	**1&1.6 MV**	**2&3.3 MV**



- Focus on the physics above charmed baryon threshold, the beam energy is 2.1 – 2.8 GeV.

Introduction of BEPCII-U

Beam Energy：2.35GeV	BEPCII	BEPCII-U
Lum [$10^{32}cm^{-2}s^{-1}$]	**3.5**	**11**
β_y^* [cm]	**1.5**	**1.3**
Bunch Current [mA]	7.1	7.5
Bunch Num	56	120
SR Power [kW]	**110**	**250**
$\xi_{y,\mathrm{lum}}$	**0.029**	**0.036**
Emittance [nmrad]	147	152
Coupling [%]	**0.53**	**0.35**
Bucket Height	0.0069	0.011
$\sigma_{z,0}$ [cm]	1.54	1.04
σ_z [cm]	**1.69**	**1.3**
RF Voltage	**1&1.6 MV**	**2&3.3 MV**



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

Beam background experiment in BEPCII

Beam Energy：2.35GeV	BEPCII	BEPCII-U
Lum [$10^{32}cm^{-2}s^{-1}$]	**3.5**	**11**
β_y^* [cm]	**1.5**	**1.3**
Bunch Current [mA]	7.1	7.5
Bunch Num	56	120
SR Power [kW]	**110**	**250**
$\xi_{y,\mathrm{lum}}$	**0.029**	**0.036**
Emittance [nmrad]	147	152
Coupling [%]	**0.53**	**0.35**
Bucket Height	0.0069	0.011
$\sigma_{z,0}$ [cm]	1.54	1.04
σ_z [cm]	**1.69**	**1.3**
RF Voltage	**1&1.6 MV**	**2&3.3 MV**

- The beam related beam background and collimator experiments are studied in the beginning of BEPCII running, the collimators effectively decrease the beam background.
- Due to the more stable and well beam parameters and machine situation, these collimators were opened Since 2012. There are some quick tests to these movable collimators in the decade, while the beam background and the vacuum pressure are increased when the collimators closed.
- The higher beam current and smaller beam size result in the higher beam background, so the study of beam background and collimator are necessary.

Beam background results in 2021

- First beam background experiment in recent years.
- Plan to measure the Touschek background and beam-gas background separately.
- Compare the experimental results with the simulation results to optimize the background simulation program.

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

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

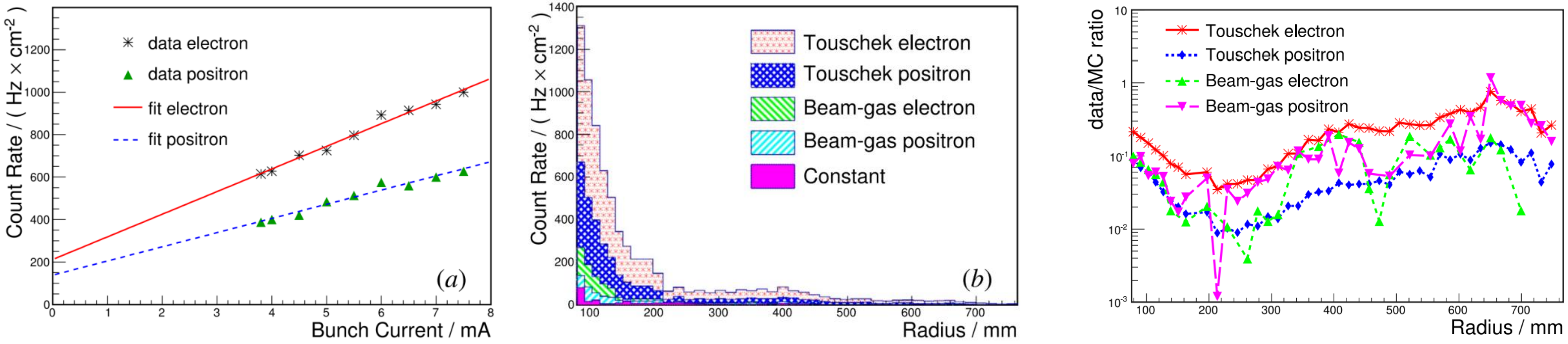
Beam background results in 2021

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 2021

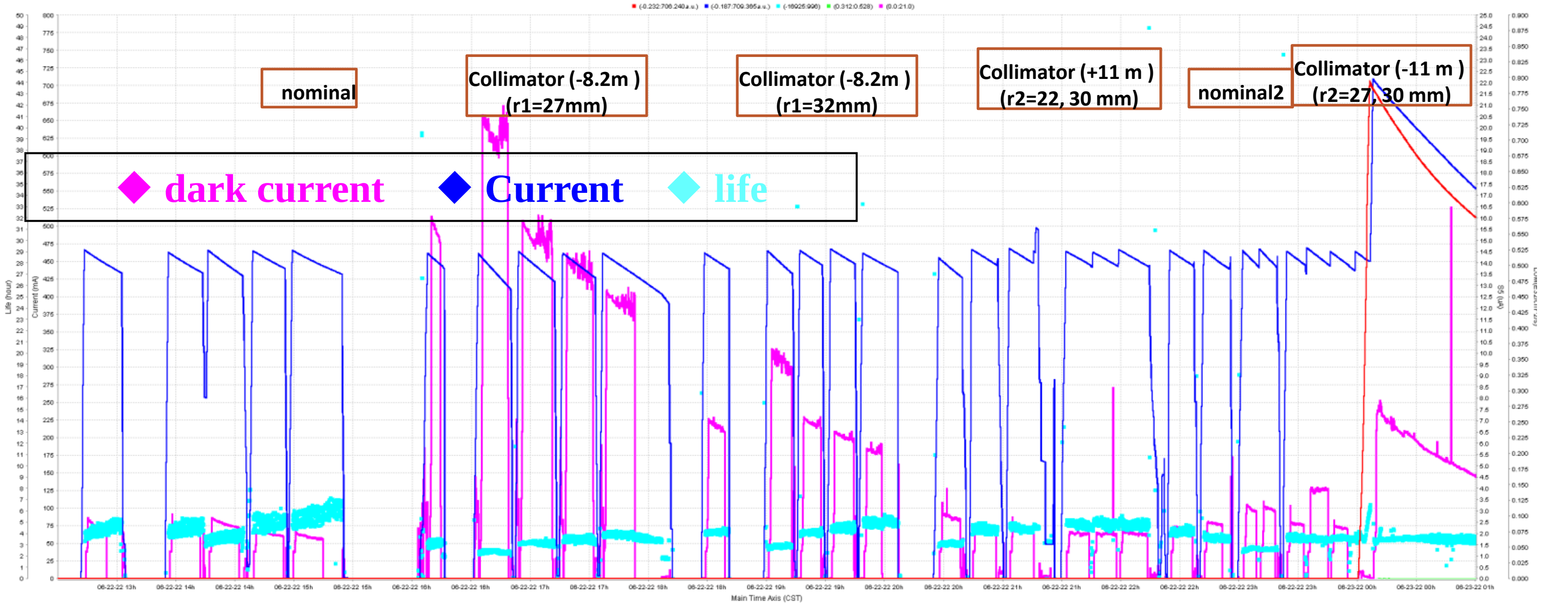


- The fit to the count rate in the first layer of the MDC with respect to the bunch current for both electron and positron beam.
- The accumulated count rate of separate background sources in all MDC layers when bunch current is 6 mA.
- The Touschek background is dominant in all layers and the beam–gas 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.
- Both simulating and experimental results show that the Touschek background is dominant in all layers. However, the magnitude of simulating Touschek background is larger than that in the experiment by one to two orders.

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

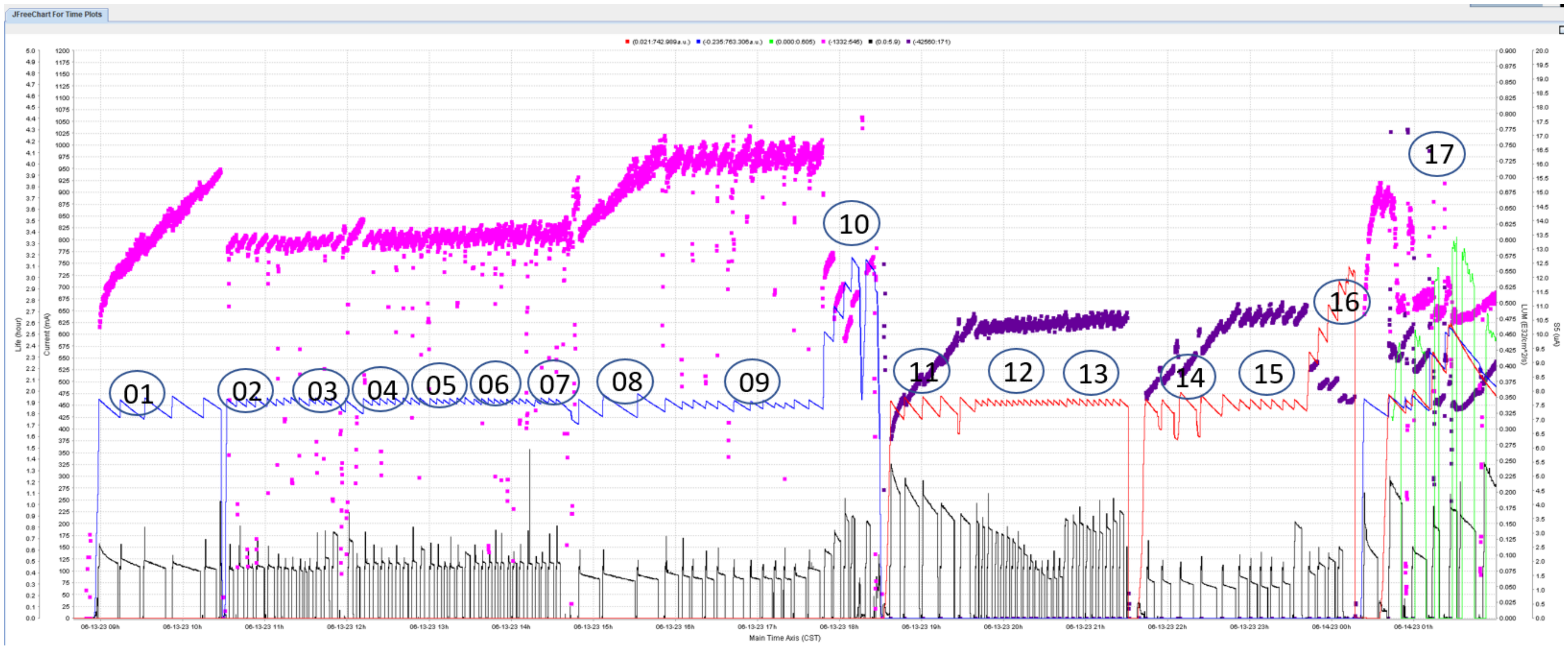
Movable Collimator experiment in 2022

- 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 2023



电子环的束流本底实验

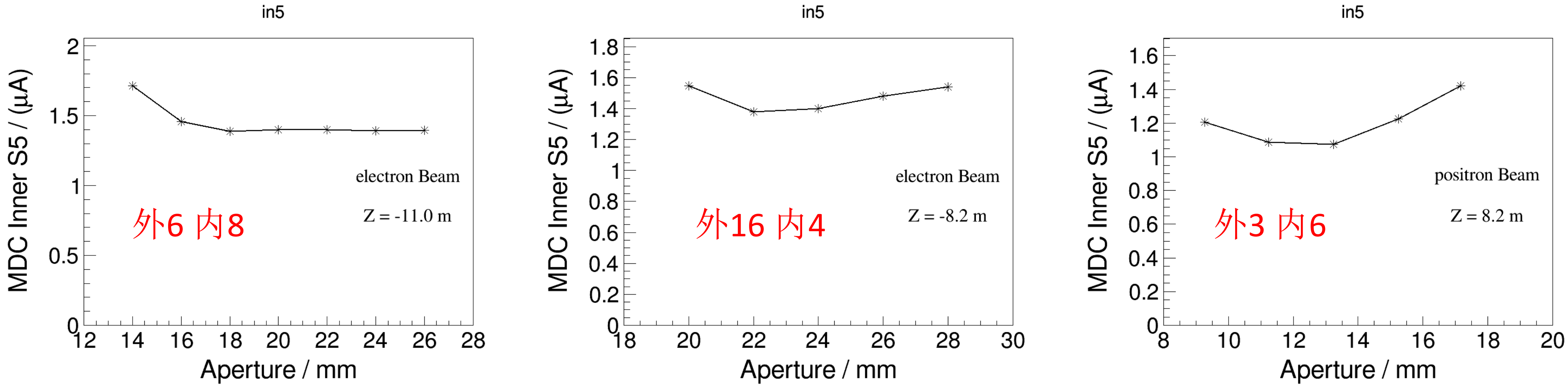
① 基准值实验;
② -8.2m处的挡块外挡板孔径扫描
③ -8.2m处的挡块内挡板孔径扫描
④ -11m处的挡块外挡板孔径扫描
⑤ -11m处的挡块内挡板孔径扫描
⑥ +8.2m处的挡块外挡板孔径扫描
⑦ +8.2m处的挡块内挡板孔径扫描
⑧ 挡块最佳位置的基准值实验
⑨ 挡块孔径与暗电流的实验数据采集
⑩ 升流实验

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
⑬ -8.2m处的挡块内挡板孔径扫描
⑭ 挡块最佳位置的基准值实验
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

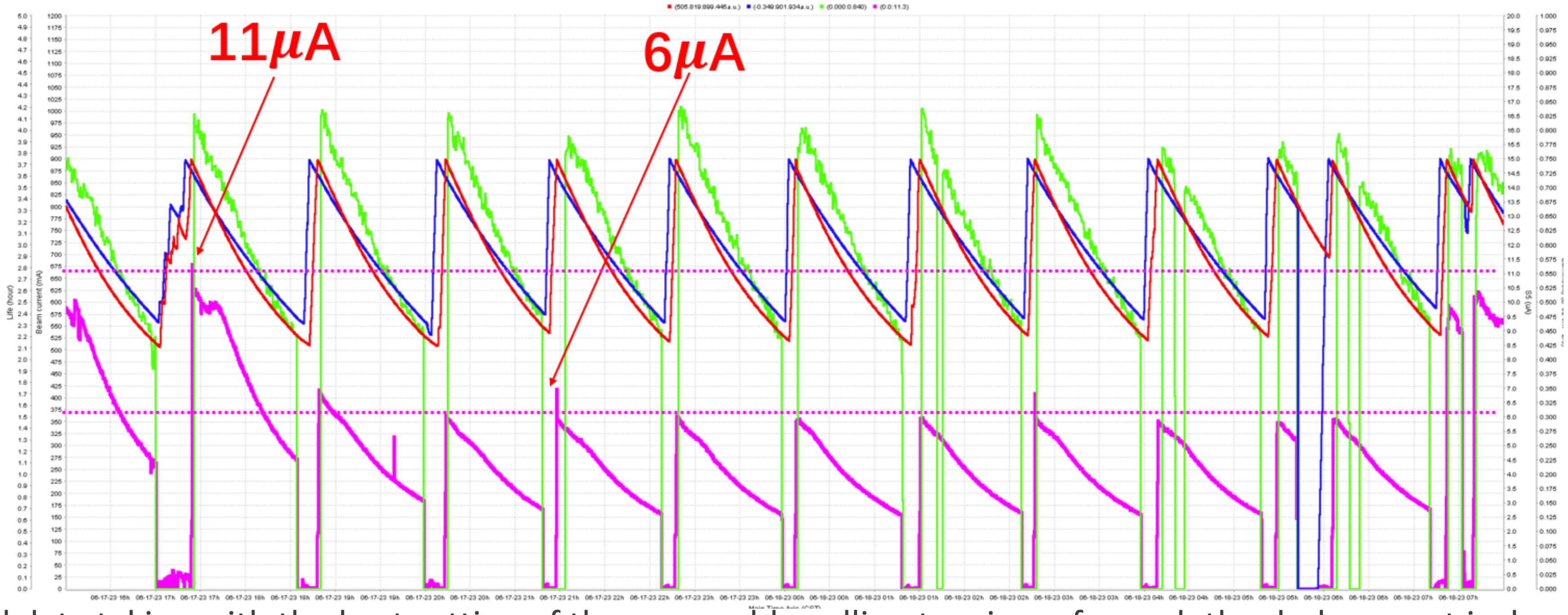
17 items of movable collimator experiments are conducted in 2023: Baseline beam background experiment (01 and 11). Scan the aperture of collimators for finding a best settings (02-07, 12-13). Baseline beam background experiment with best settings of movable collimators (08, 14). Data taking with different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

Movable Collimator experiment in 2023



- Scanning the aperture of four movable collimators is performed.
- 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 2023



- 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.

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 collimators with proper aperture settings effectively 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.