Institute of High Energy Physics
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# Beam background study of BEPCII, simulation and experiment

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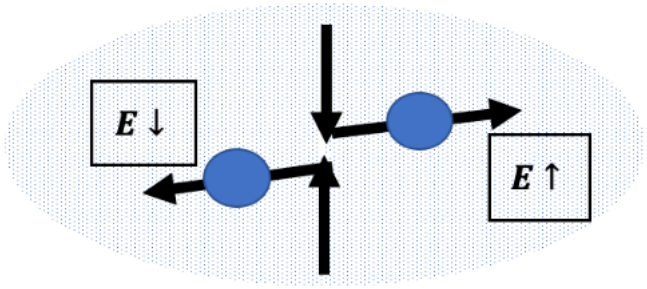
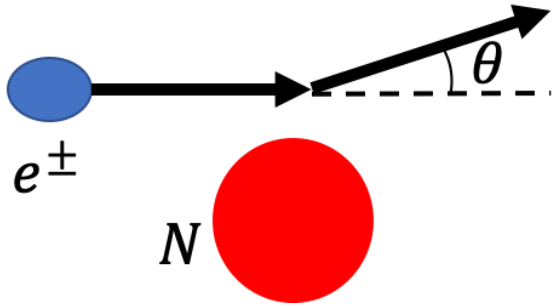
# Beam Background Sources of BEPCII

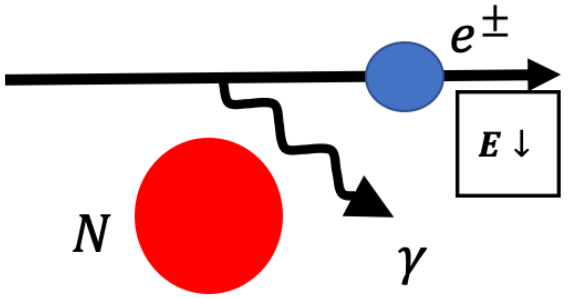
- **Touschek effect:**
  - Scattering among particles in a same bunch.
  - Generation rate ∝ $N_{bunch}$, beam size$^{-1}$, beam energy$^{-3}$



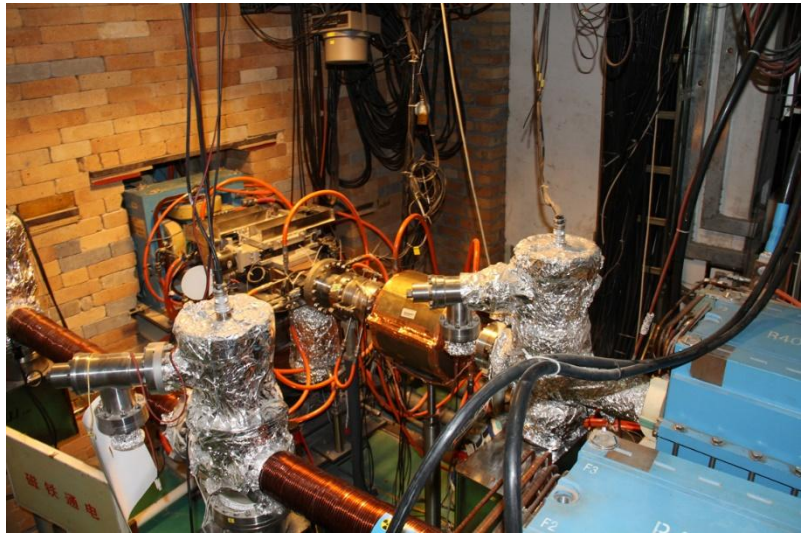

- **Beam-gas effect:**
  - Interactions between the particles of the beam and the residual gas molecules in the vacuum chamber, including Coulomb scattering and Bremsstrahlung scattering.
  - Generation rate ∝ pressure

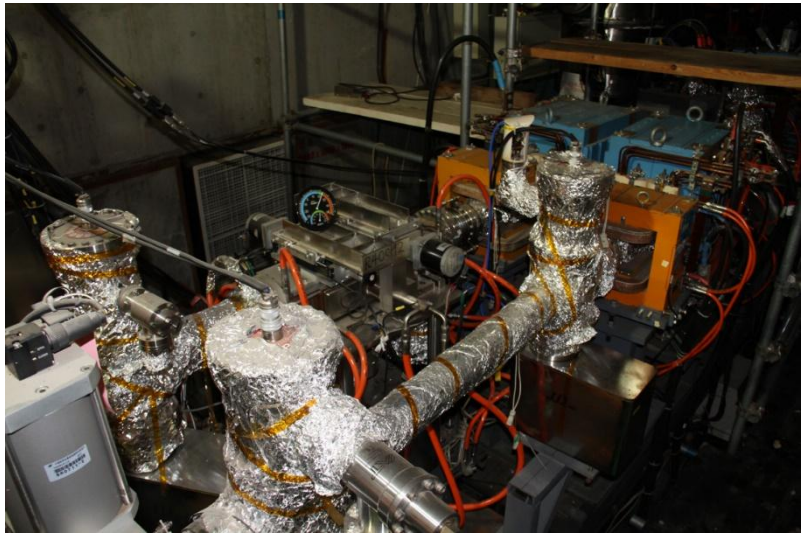


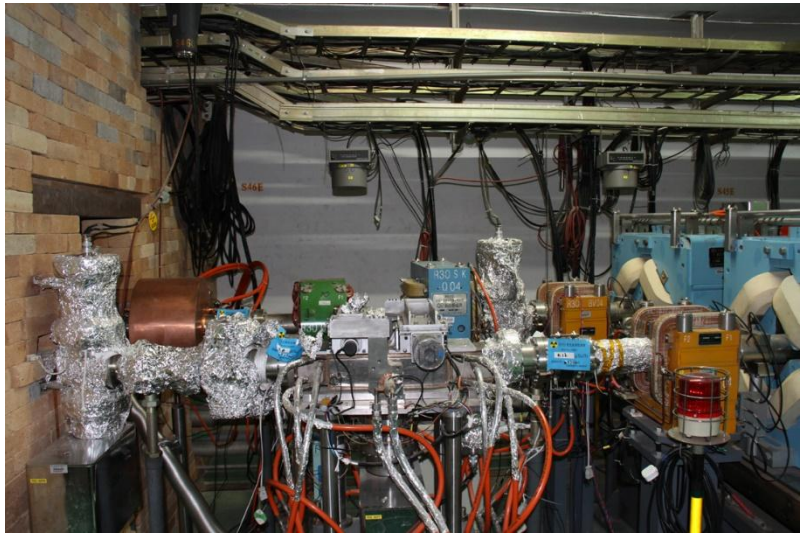

- Injection effect:
  - Caused by injected particles with a large amplitude of oscillations due to injection kicker errors;
  - High and instantaneous



# Movable Collimators of BEPCII

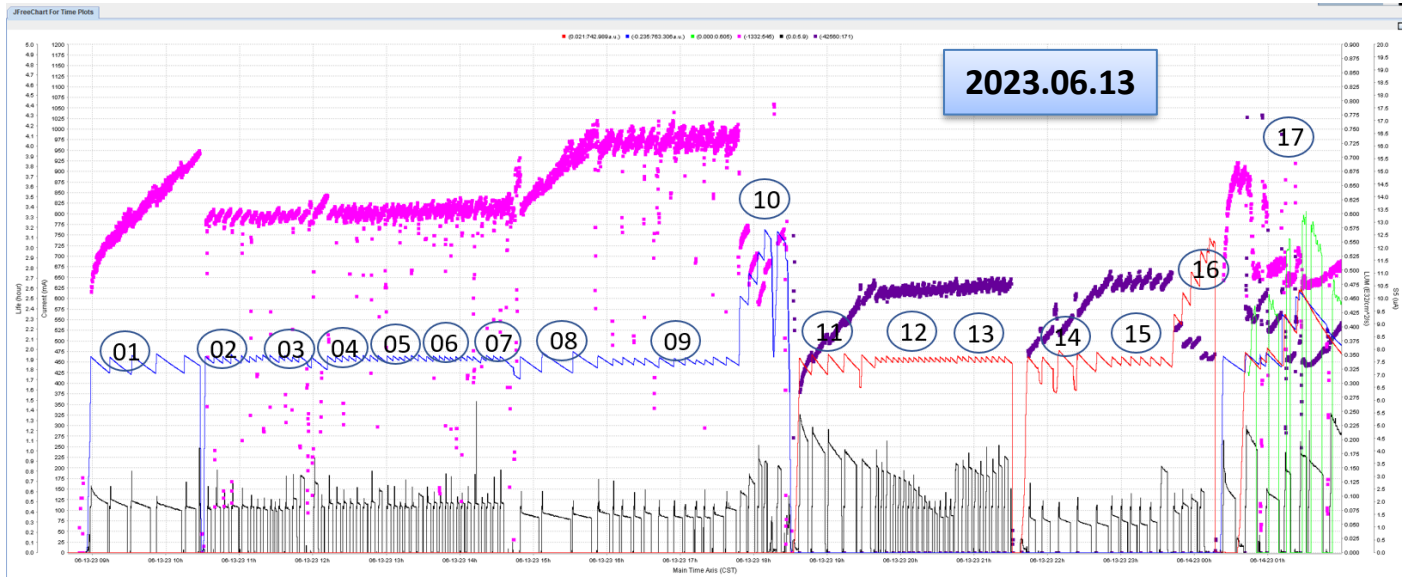


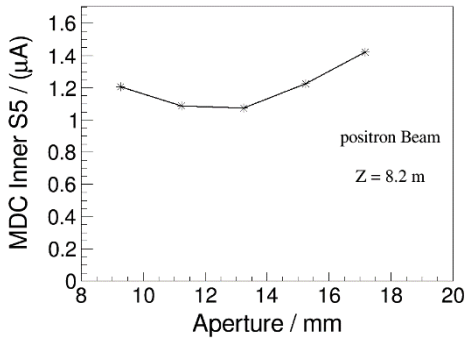


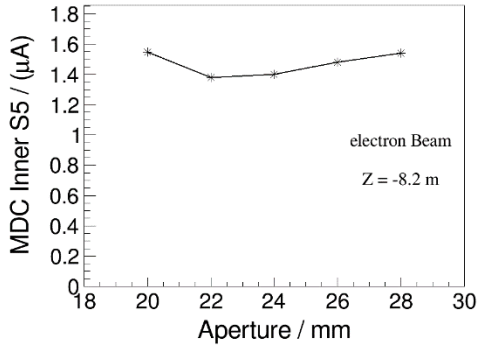


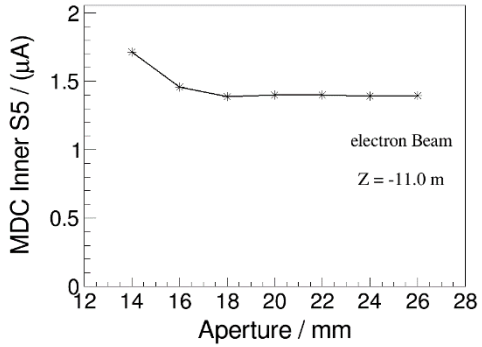
- Three horizontal movable collimators (8.2m and 11m upstream from the IP and 11m downstream from the IP) in the electron ring;
- A horizontal movable collimator (8.2m upstream from the IP) in the positron ring;

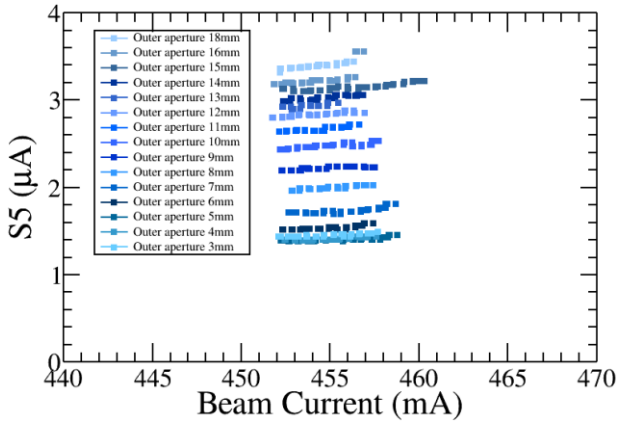
# Movable Collimator experiment in BEPCII

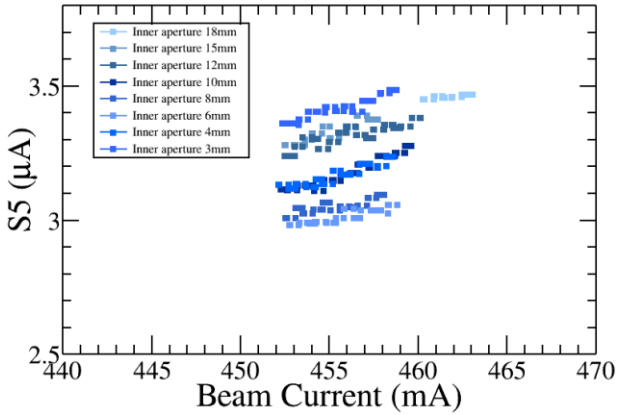


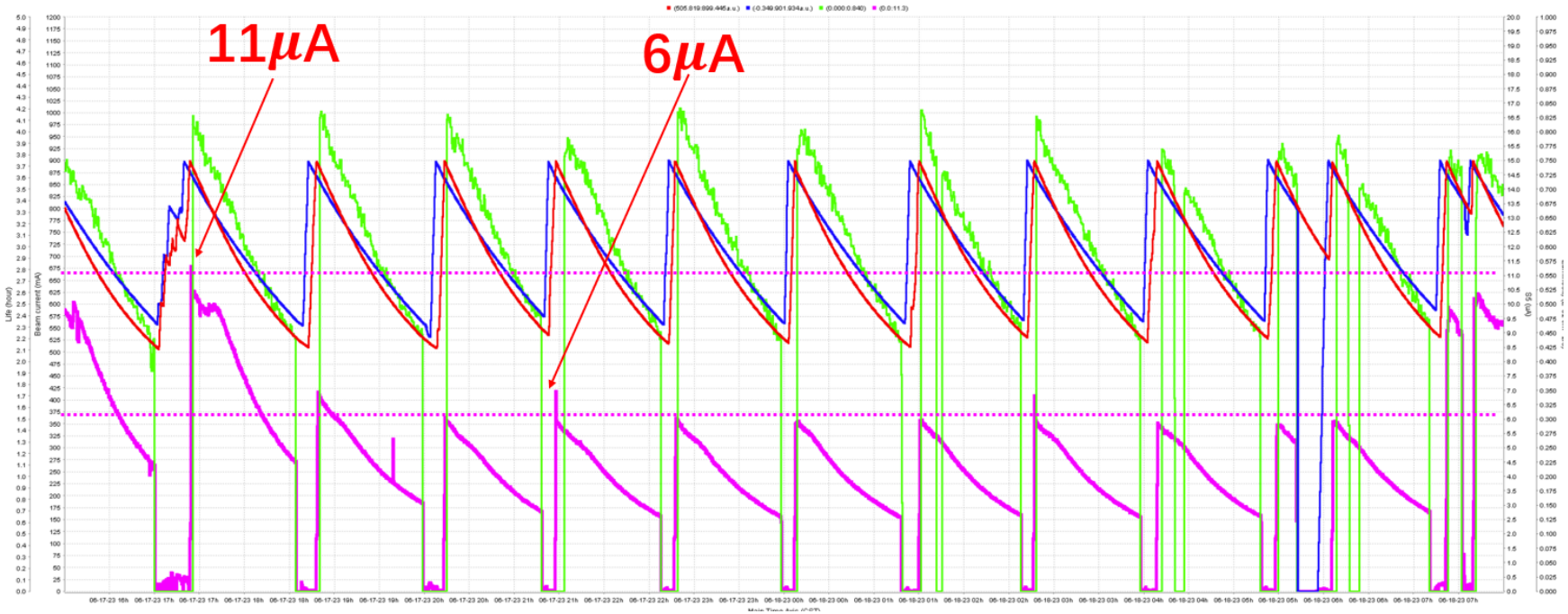



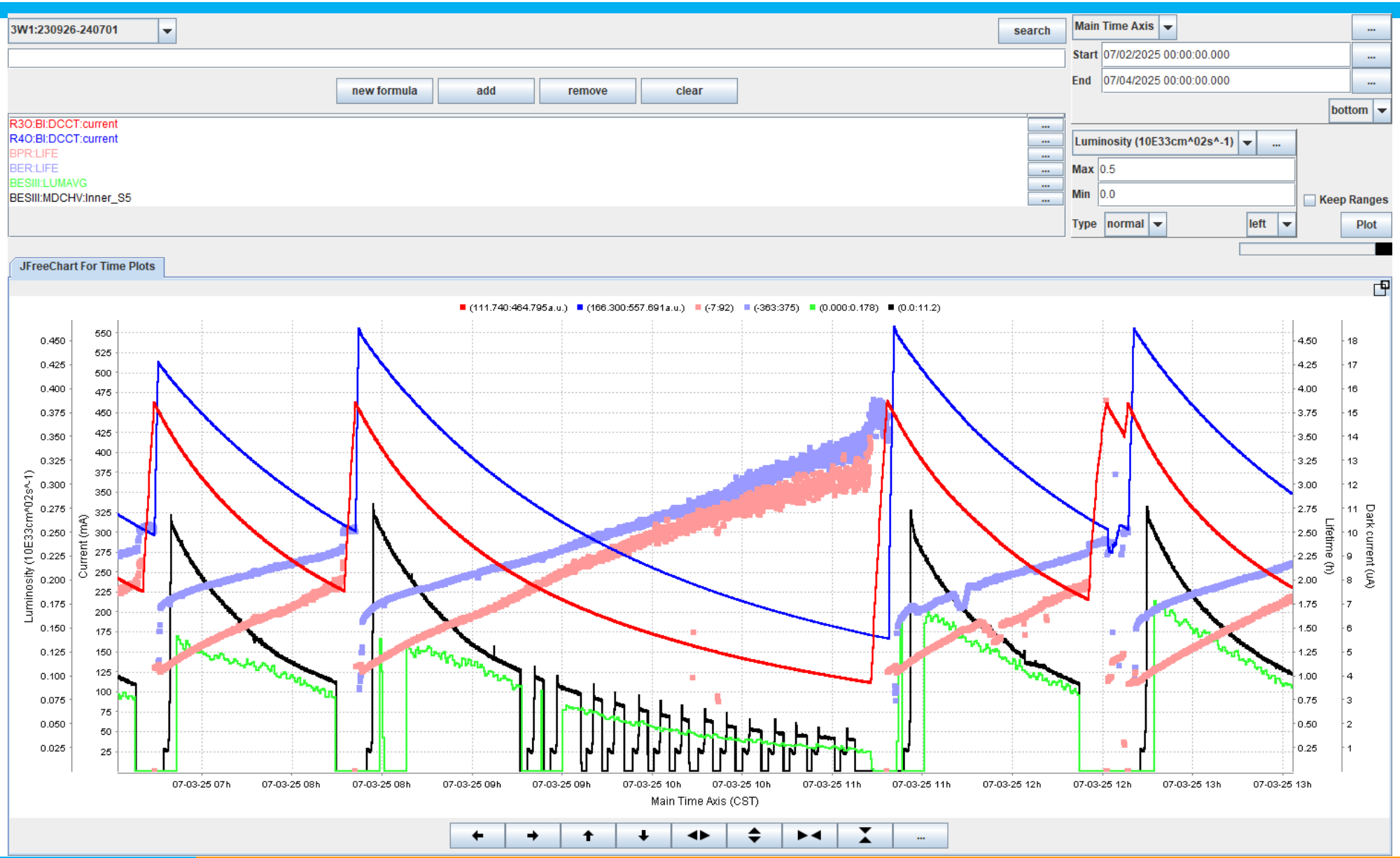

- 17 items of movable collimator experiments are conducted in the movable collimator。
- The best aperture settings of movable collimators with respect to the minimum beam background are selected for further experiments.

# Movable Collimator experiment in BEPCII



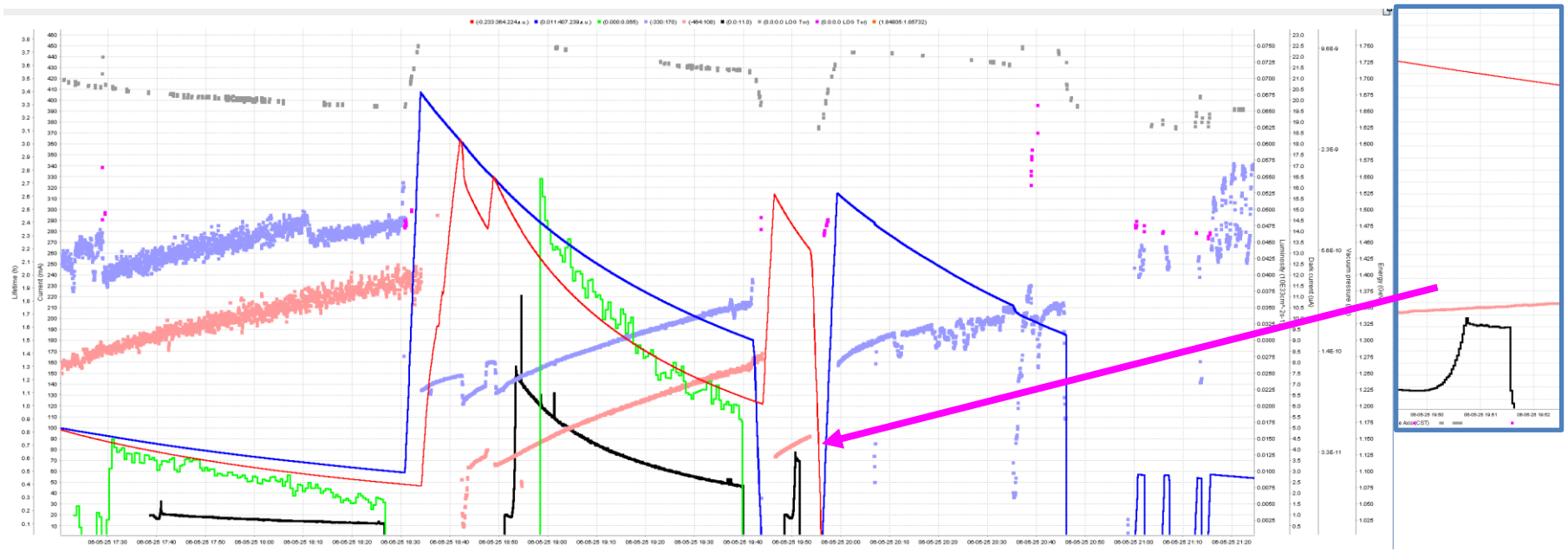

An additional data taking with the best setting of these movable collimators is performed, the dark current is decreased from 11$\mu$A to 6 $\mu$ A (about 40%) with 900mA beam current and the beam lifetime and peak luminosity are no obviously changed. The obvious mitigation of beam background will play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

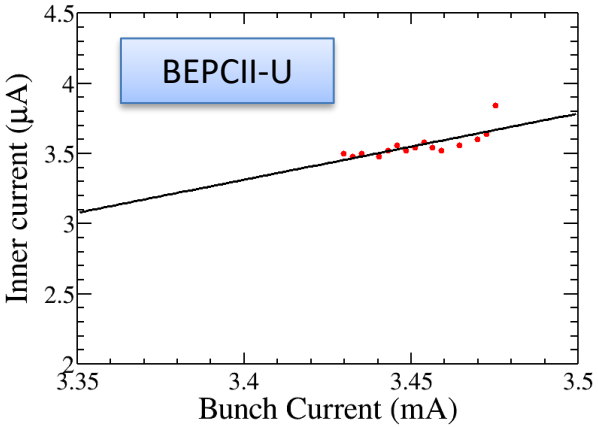
# Beam Background experiment of BEPCII upgrades

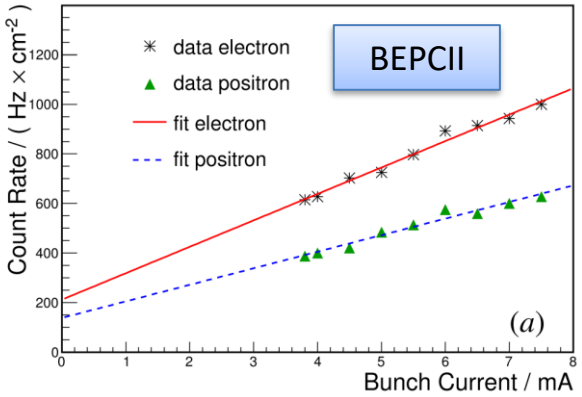


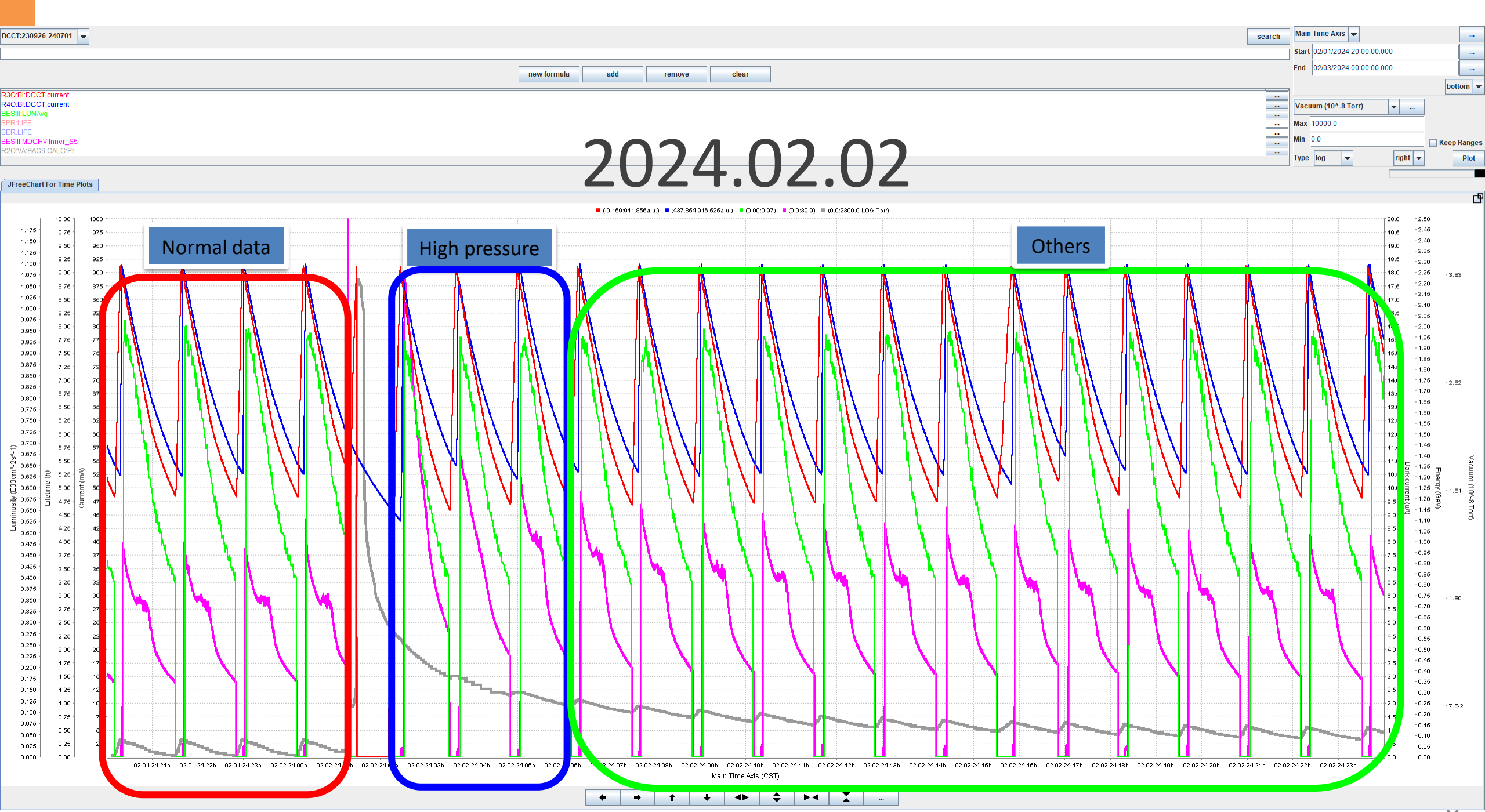
# Beam background and vacuum degree

- 2025.06.05 Single beam data analysis: The fitting results showed that the main components were indeed from the background of the beam (more than 80% of the beam).



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Main Time Axis
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R3O:BI:DCCT:current
R4O:BI:DCCT:current
BESIII:LUMAvg
BPR:LIFE
BER:LIFE
BESIII:MDCHV:Inner_S5
R2O:VA:BAG6:CALC:Pr
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Max 10000.0
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Keep Ranges
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JFreeChart For Time Plots
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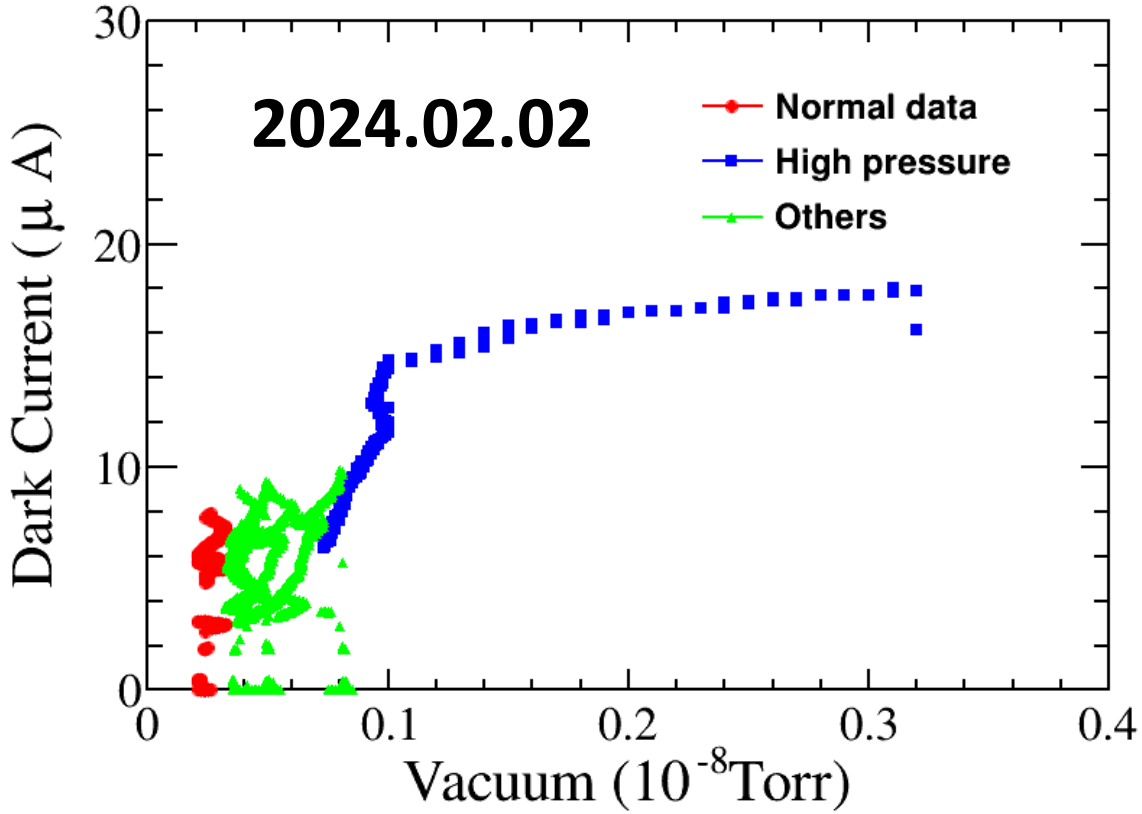
(437.854:916.525a.u.)
(0.00:0.97)
(0.0:39.9)
(0.0:2300.0 LOG Torr)
Normal data
High pressure
Others
Luminosity (E33cm^-2s^-1)
Lifetime (h)
Current (mA)
Dark current (uA)
Energy (GeV)
Vacuum (10^-8 Torr)
Main Time Axis (CST)

# Beam background and vacuum degree

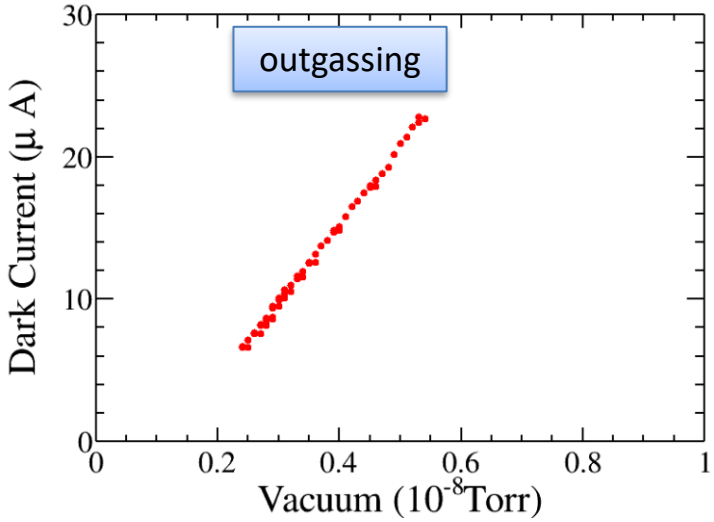
- The background dark current during normal operation is less than 10mA, and the gas pressure is about **0.5 × $10^{-9}$ Torr**.
- During the slow recovery of the vacuum, when the gas pressure exceeds $10^{-9}$ Torr, the background dark current generally exceeds 15 μA, which is almost close to the threshold of the detector.
- As the vacuum continues to recover, the machine running tends to be stable, and the background dark current is slightly higher than the background dark current during normal operation.

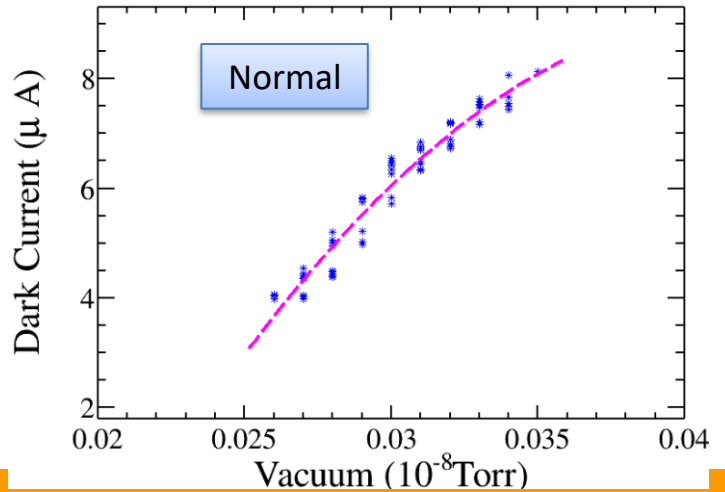


# Beam background and vacuum degree

- During the stable operation of the high flow strength + movable collimators in last year, we extracted the operation data before and after vacuum chamber outgassing for analysis.
- For the background dark current during sudden outgassing, due to the small time window of outgassing and recovery, **the dark current has an obvious linear relationship with the gas pressure** when the change of beam current is ignored.

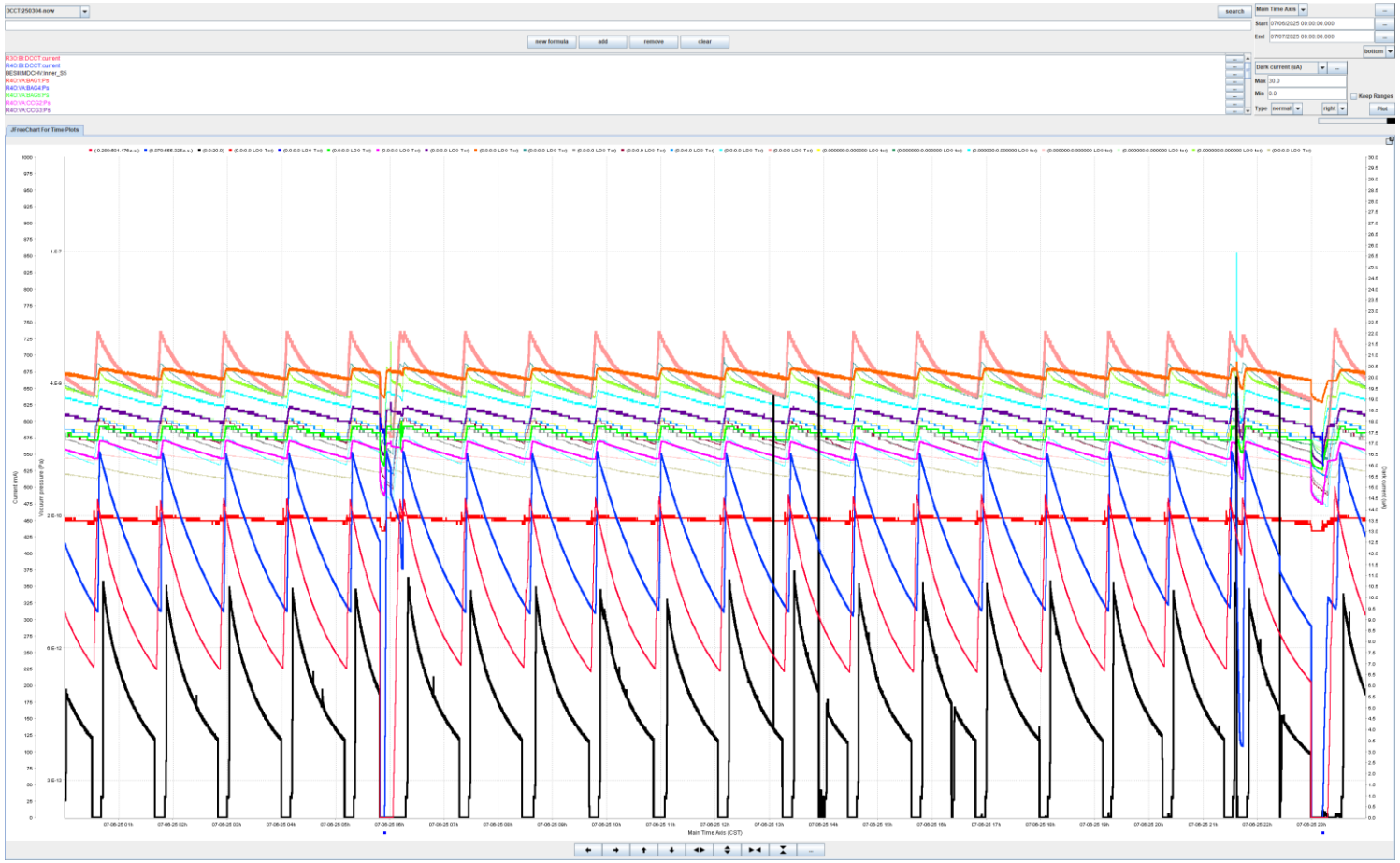
$$O_{\mathrm{SB}} = S_{\mathrm{tous}} \cdot \frac{I_t \cdot I_b}{\sigma_x \sigma_y \sigma_z} + S_{\mathrm{gas}} \cdot I_t \cdot P(I_t) + S_{\mathrm{const}},$$

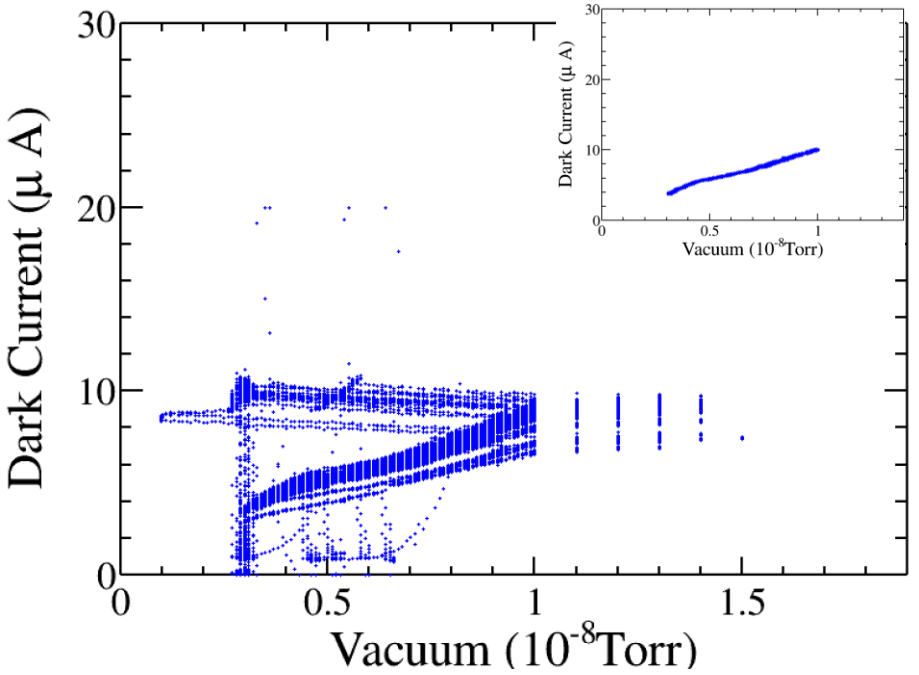


# Beam background and vacuum degree

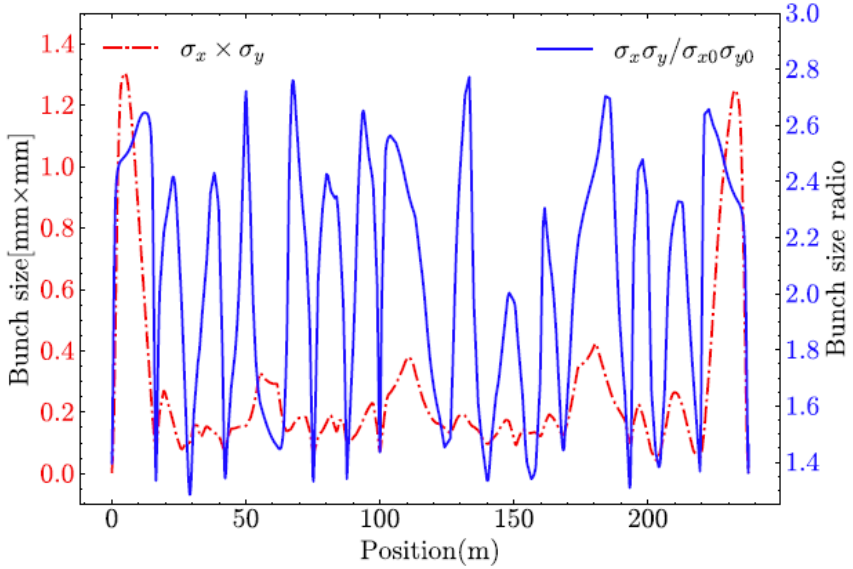
- During the stable operation of BEPCII-U, the gas pressure is generally one order of magnitude higher than that of last year's stable operation at BEPCII. According to the significant linear relationship between the dark current and the gas pressure, **we considered that the current dark current is dominated by the beam gas background.**

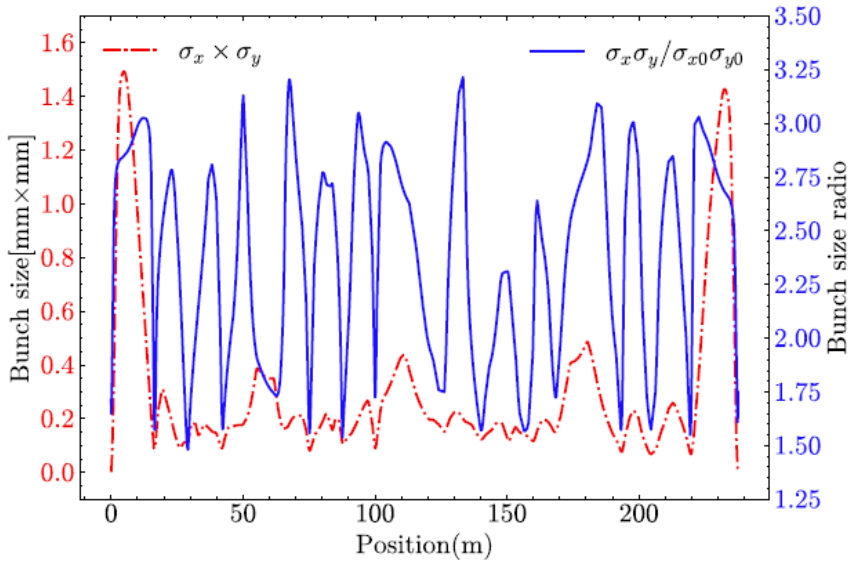




# Beam background simulation with beam-beam effect

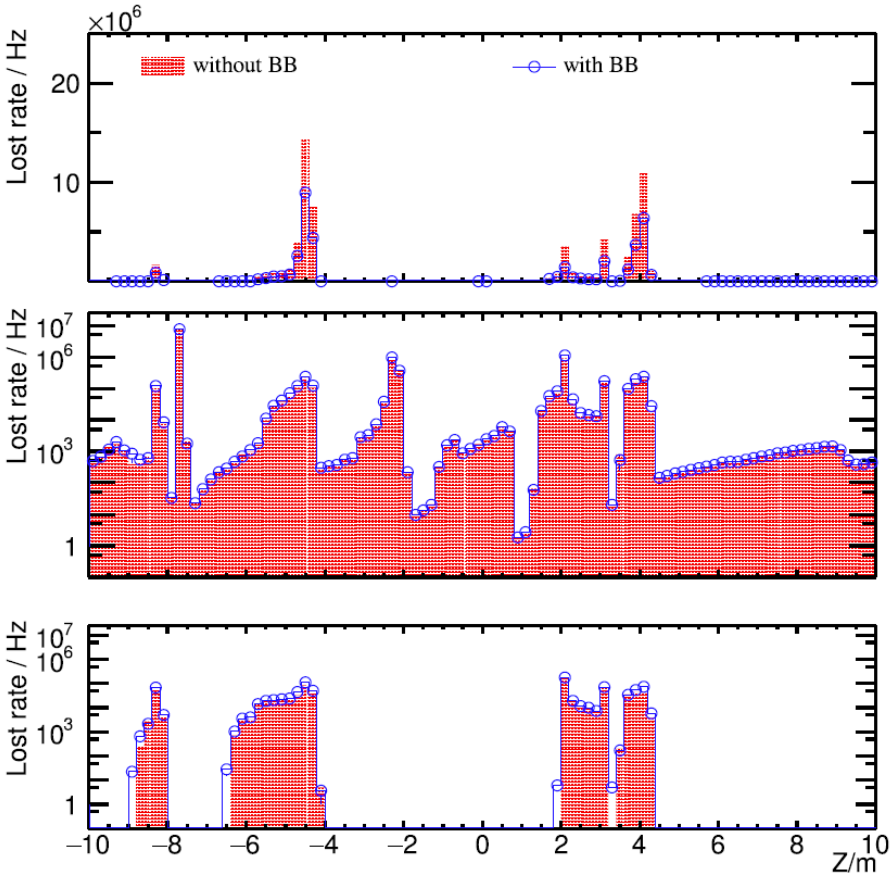
- The beam-beam interaction can change the beam distribution, especially at the interaction point, which is a critical factor influencing the cross section of Touschek scattering.
- The product of transverse bunch sizes (σx ×σy ) would increase by a factor of 1.5~3.0 compared to that without collision, which is mainly contributed by the blowup of the horizontal bunch size.



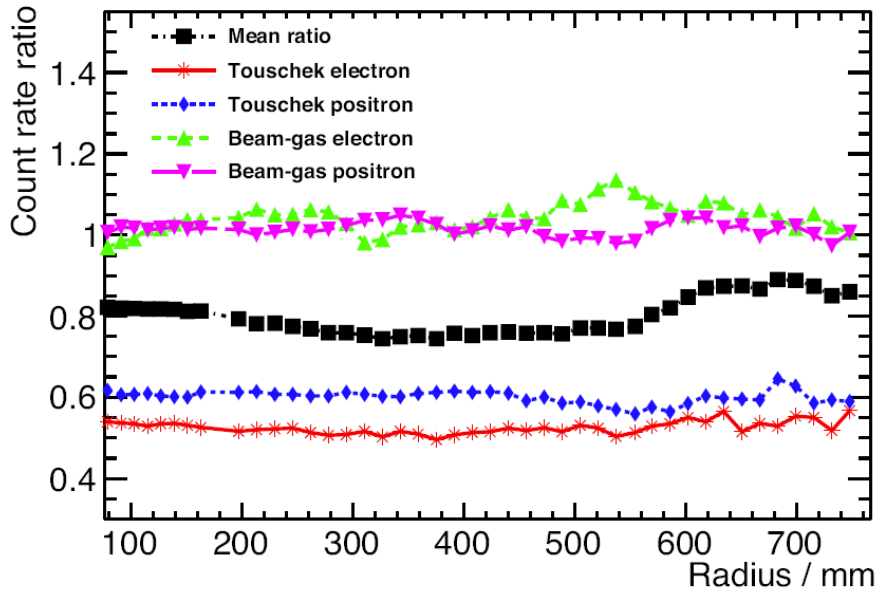
# Beam background simulation with beam-beam effect

- To provide a baseline comparison, simulations with and without considering the beam–beam effect are performed.
- The loss rate due to the Touschek effect is notably reduced when beam–beam interactions are considered, while the background contribution from the beam–gas effect remains essentially unchanged.



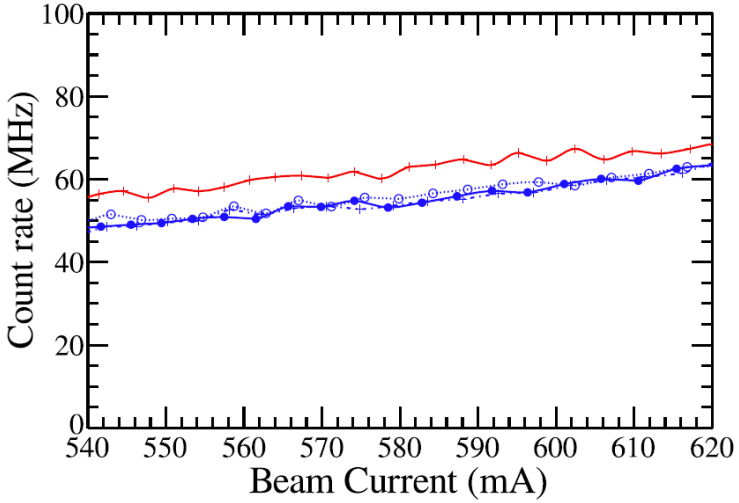
# Beam background simulation with beam-beam effect

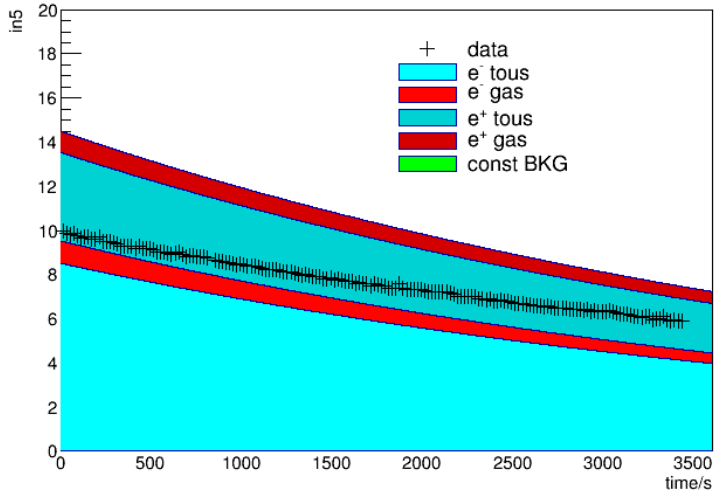
- Check the count rate comparison in simulations between with and without beam–beam effect.
- The beam–gas background remains relatively stable with beam–beam effect, while there is a clear decrease exceeding 30% in the Touschek background. The overall background is reduced by (20±5)%.



# Beam background simulation with beam-beam effect

- Beam background without beam–beam effect was measured by separating the electron beam and positron beam in vertical direction at the IP. Beam background in three neighbor runs with normal collision are used to do a baseline comparison.
- The beam background without collision exhibits an increase in the range of 10% to 15% over the background during the regular collision operation.
- Compared with the beam background data collected in 2021, the data/mc distribution is also support the result of beam background simulation.




Bin Wang*, Z. Y. Li et al., Radiat Detect Technol Methods 8, 1505–1510 (2024).

# Summary

- In the BEPCII phase, the collimators with proper aperture settings effectively decrease (~40% decrease@900 mA) the beam background..
- In the BEPCII upgrades, the current beam background is mainly beam-gas background, and the movable collimators cannot effectively reduce it.
- By controlling the vacuum degree is controlled at about $5 \times 10^{-9}$ Torr and with Touschek background dominating, the movable collimator will reduce the beam background.
- Beam background with beam-beam effect leads to a decrease in the beam background by approximately 20%, which is consistent with the trend of experimental observation.

# Thank you for your attention!