Beam jitters

Mar. 14, 2018

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Outline

1. Introduction
2. Investigation of beam jitter source
   – Dependence on flux concentrator, solenoid, bridge coil, pulsed magnet, and chicane.
   – Charge dependence.
   – Correlation between beam position before and after the target.
   – Positron beam, that does not pass though the target hole.
   – Dispersion leak dependence.
3. Conclusion

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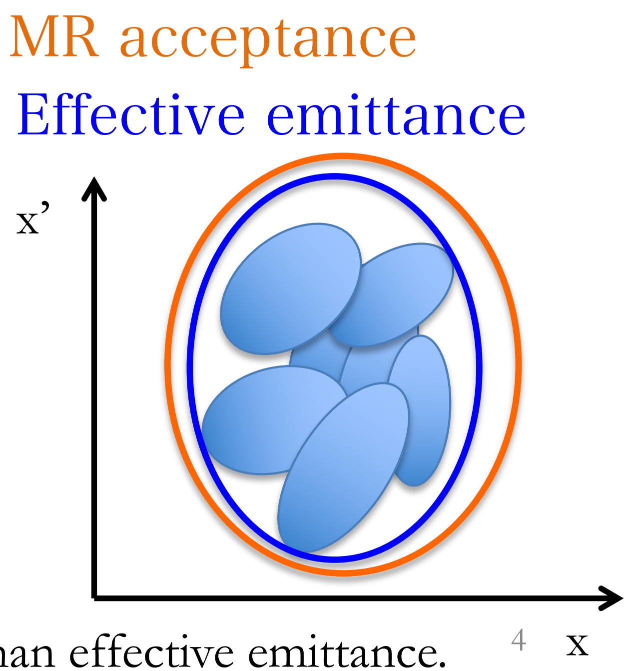
Requirement to LINAC for SuperKEKB

- Low emittance & high charged beam transportation is required for SuperKEKB.
- Transported beam to MR must be stable to the extent that the beam can be injected inside MR acceptance.
- SuperKEKB requirement must be satisfied for emittance including jitter emittance, called as effective emittance.
- In phase 3, 40/20 nor. emittance under 4 nC is required.

SuperKEKB requirement for electron

	H/V nor. emittance (μm)	Charge (nC)	Energy spread (σ)
Phase 2	150/150	1	0.1%
Phase 3	40/20	4	0.07%



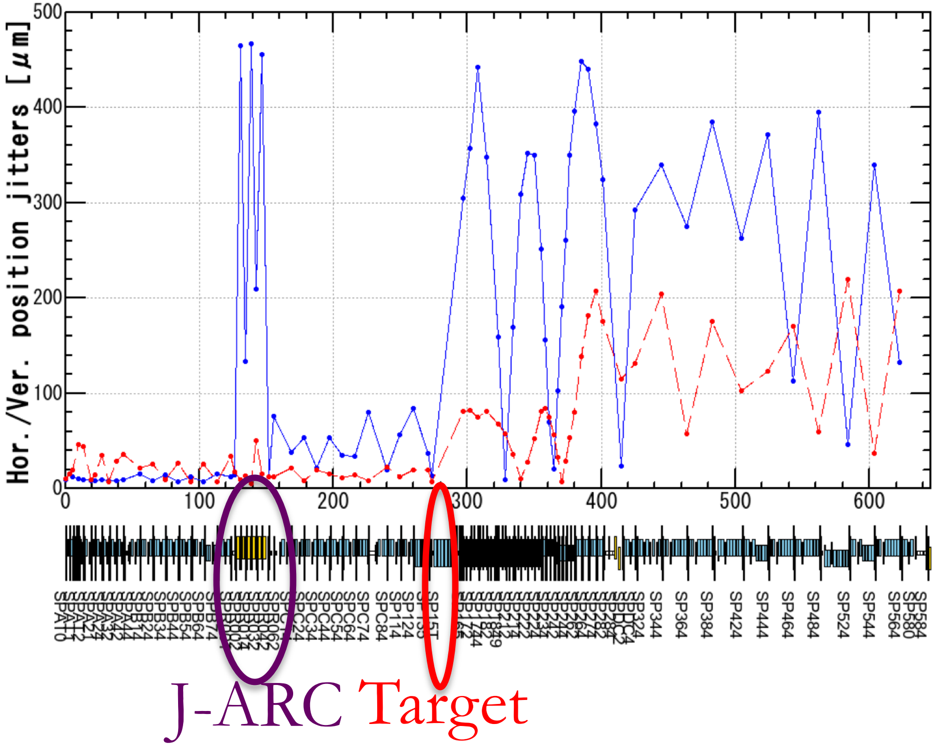
Effective emittance have to be less than effective emittance.

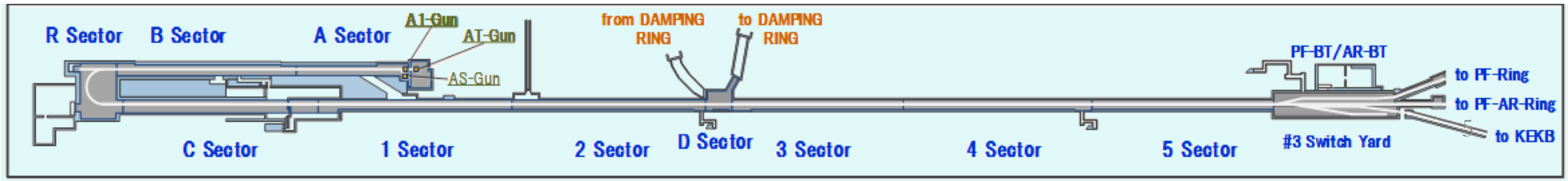
Measured beam position jitter (thermionic gun)

- **After J-ARC section, horizontal position jitter is enlarged because position jitter is proportional to both dispersion and energy jitter.**
- **After target hole, hor. and ver. position jitters are enlarged.**

Thermionic gun

- 1 nC.
- BPM resolution ~ 10 μm.
- $\eta_{\text{J-ARC}} \sim 0.8$ m
  $\rightarrow \Delta P_{\text{J-ARC}}/P_0 \sim 0.06\%$.
- 1000 shot data
- Dec. 2017



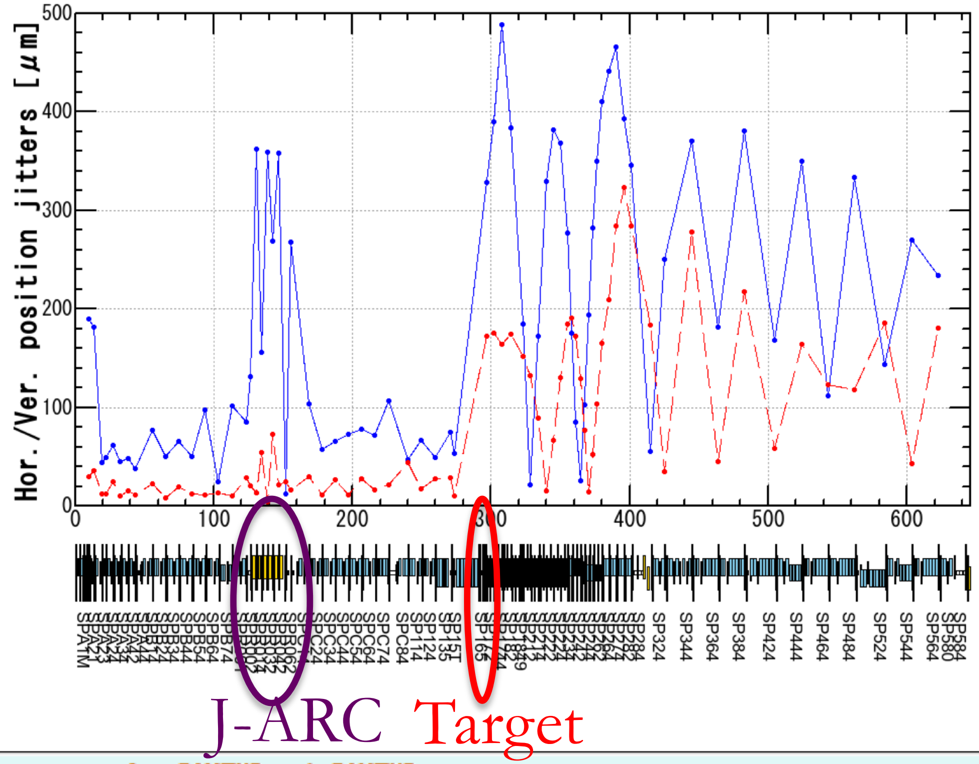


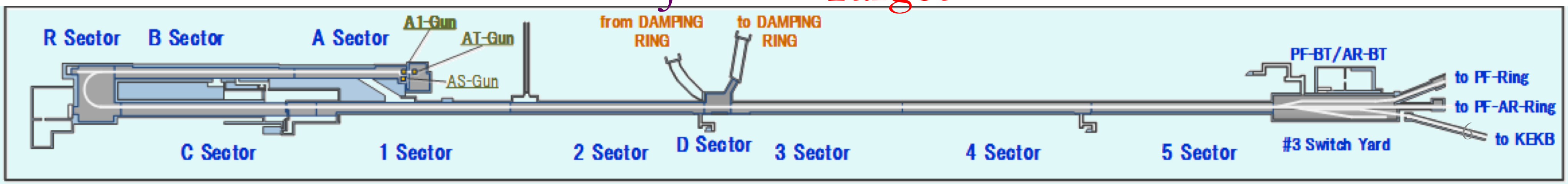
Measured beam position jitter (RF gun)

- **After target hole, hor. and ver. position jitters are enlarged.**
- **This behavior is similar to that of thermionic gun.**

RF gun

- 1 nC.
- $\eta_{J\text{-}ARC} \sim 0.8$ m
  $\rightarrow \Delta P_{J\text{-}ARC}/P_0 \sim 0.05\%$.
- 1000 shot data
- Dec. 2017





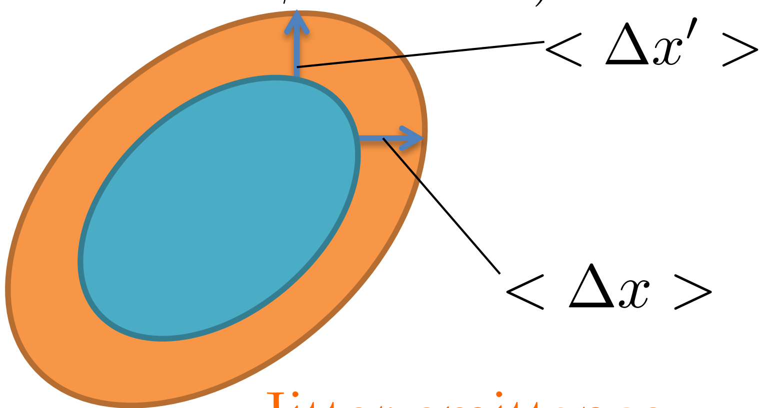
Jitter emittance (1)

- Effective emittance = Nominal emittance + Jitter emittance
- If beam position and transfer matrix between two BPMs is identified, we can derive beam angle. Using the position and angle, effective emittance is derived by

$$\epsilon_{eff} = \sqrt{< (x + \Delta x)^2 >< (x' + \Delta x')^2 > - < (x + \Delta x)(x' + \Delta x') >^2}.$$

If beam jitter is independent of particle motion,

$$\begin{aligned}\epsilon_{eff} &= \sqrt{\epsilon_0^2 + \epsilon_{jitter}^2 + \epsilon_0(\gamma < \Delta x^2 > + 2\alpha < \Delta x \Delta x' > + \beta < \Delta x^2 >)} \\ &= \sqrt{\epsilon_0^2 + \epsilon_{jitter}^2 + 2\epsilon_0 \epsilon_{jitter}} \\ &= \epsilon_0 + \epsilon_{jitter},\end{aligned}$$



$$\epsilon_0 = \sqrt{< x^2 >< x'^2 > - < x x' >^2},$$

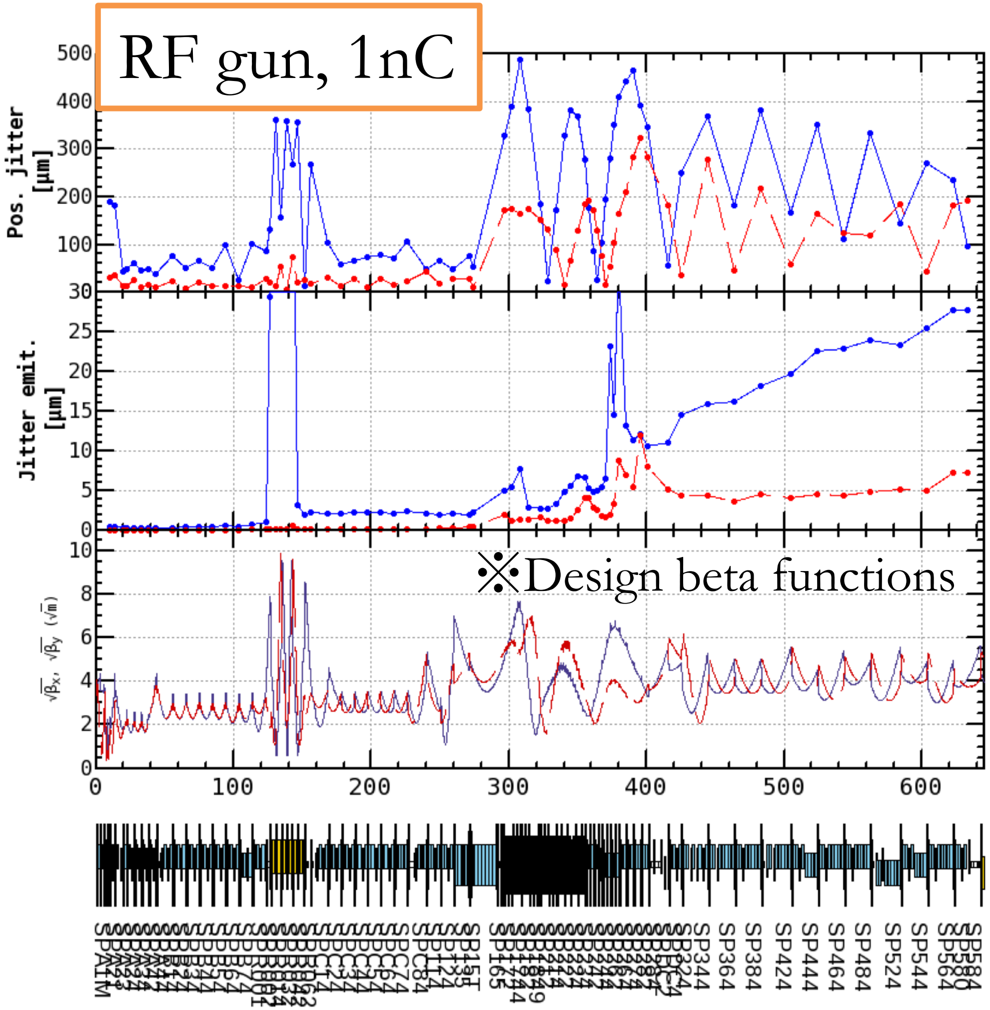
$$\epsilon_{jitter} = \sqrt{< \Delta x^2 >< \Delta x'^2 > - < \Delta x \Delta x' >^2}.$$

Jitter emittance

Nominal emittance

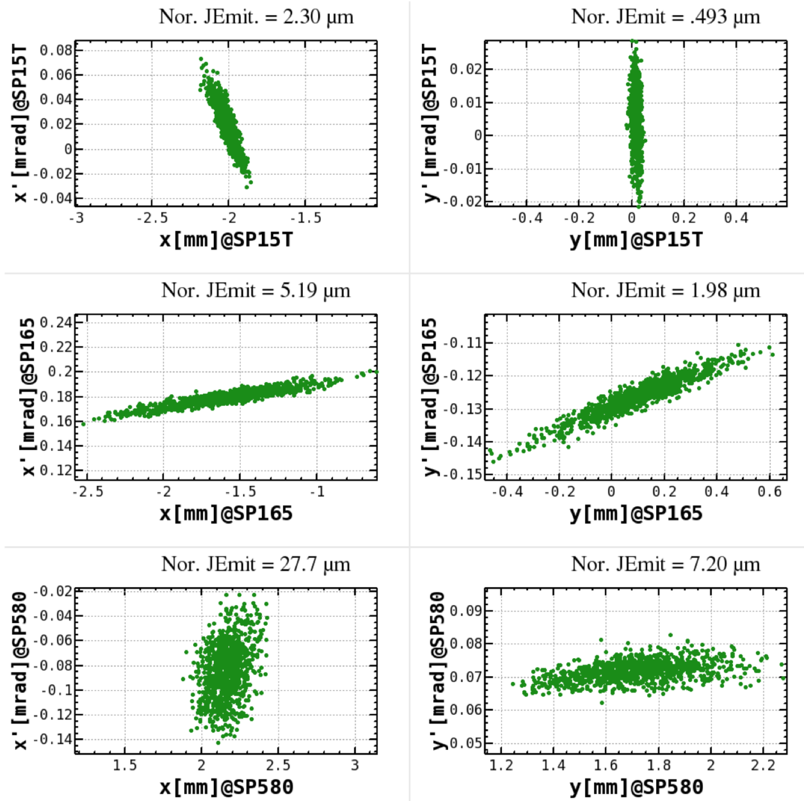
Jitter emittance (2)

- **Jitter emittance remarkably increases after the target.**
- **This jitter emittance strongly affect the effective emittance.**



	Phase 3 requirement to effective emit.
εx	40 μm
εy	20 μm

	jitter emit.
εx	27.7 μm
εy	7.2 μm



※phase space plot is not scaled by gamma factor.

- What is the jitter source?
- Does effective emittance satisfy the SuperKEKB requirement?

- Unfortunately, jitter source is not clear for now. This presentation is progress report.

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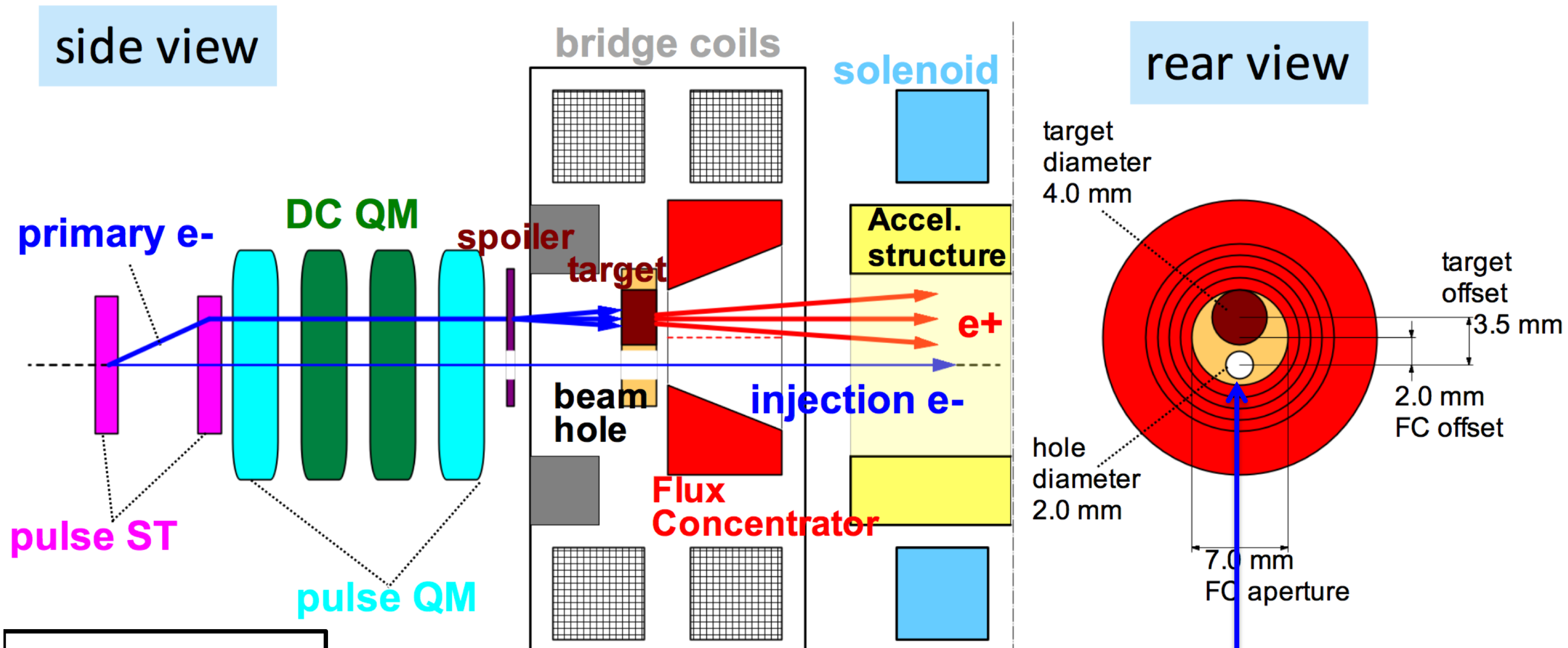
Positron generation target

- As jitter source, components around target is suspected.
- Schematic layout of component around target.



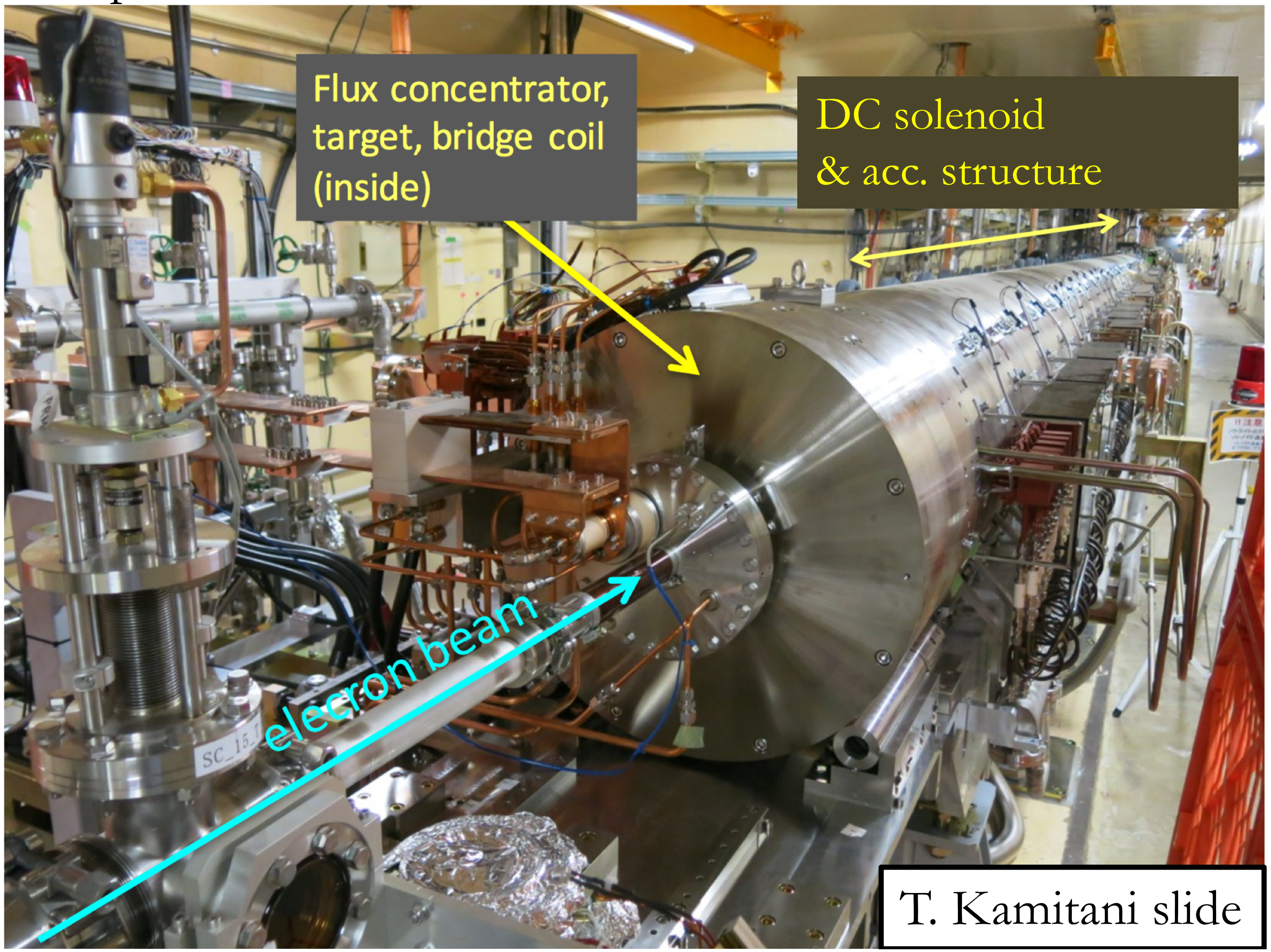
T. Kamitani slide

Target hole for electron beam

- Electron beam straightly pass through the positron generation target hole, which diameter is 2 mm.

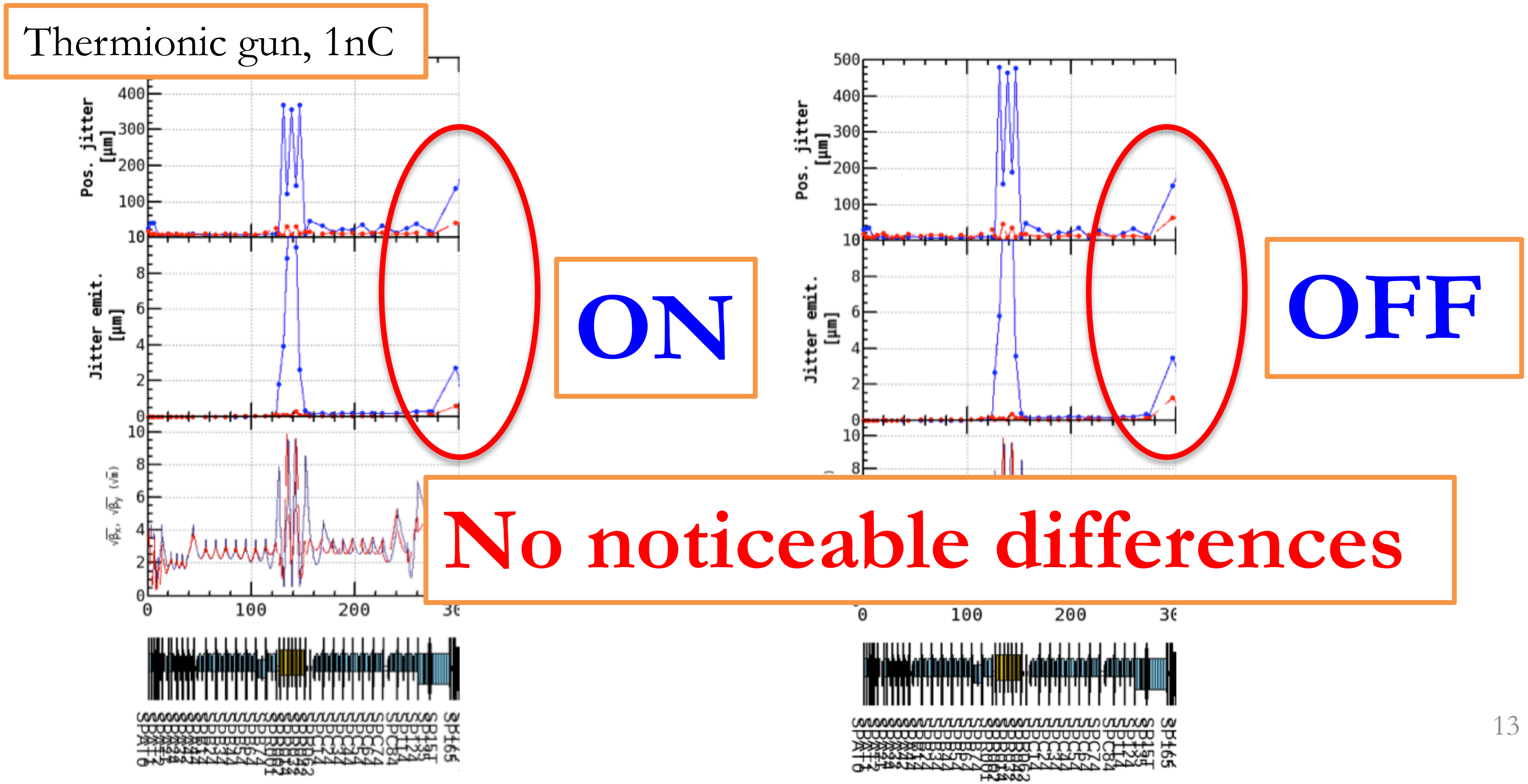
Configuration around the target

- Electron come from upstream and pass through FC, target, bridge coil, and DC solenoid.
- After the DC solenoid, chicane for dump electron beam, that is generated together with positron beam.



Dependence on flux concentrator, solenoid, bridge coil, pulsed magnet, and chicane

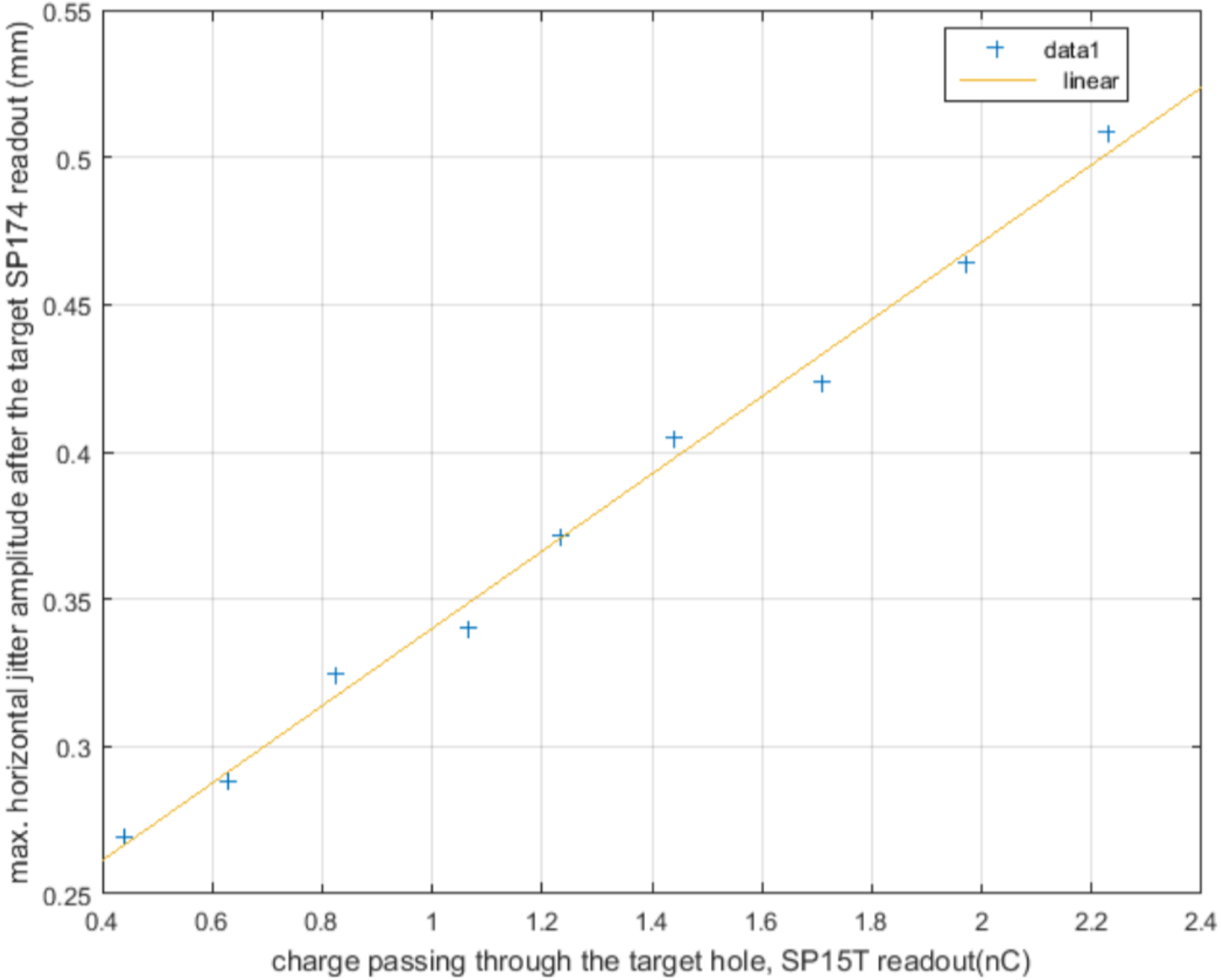
- We check whether these components are sources of jitter or not by turn off these components between BPMs before and after target.



Charge dependence

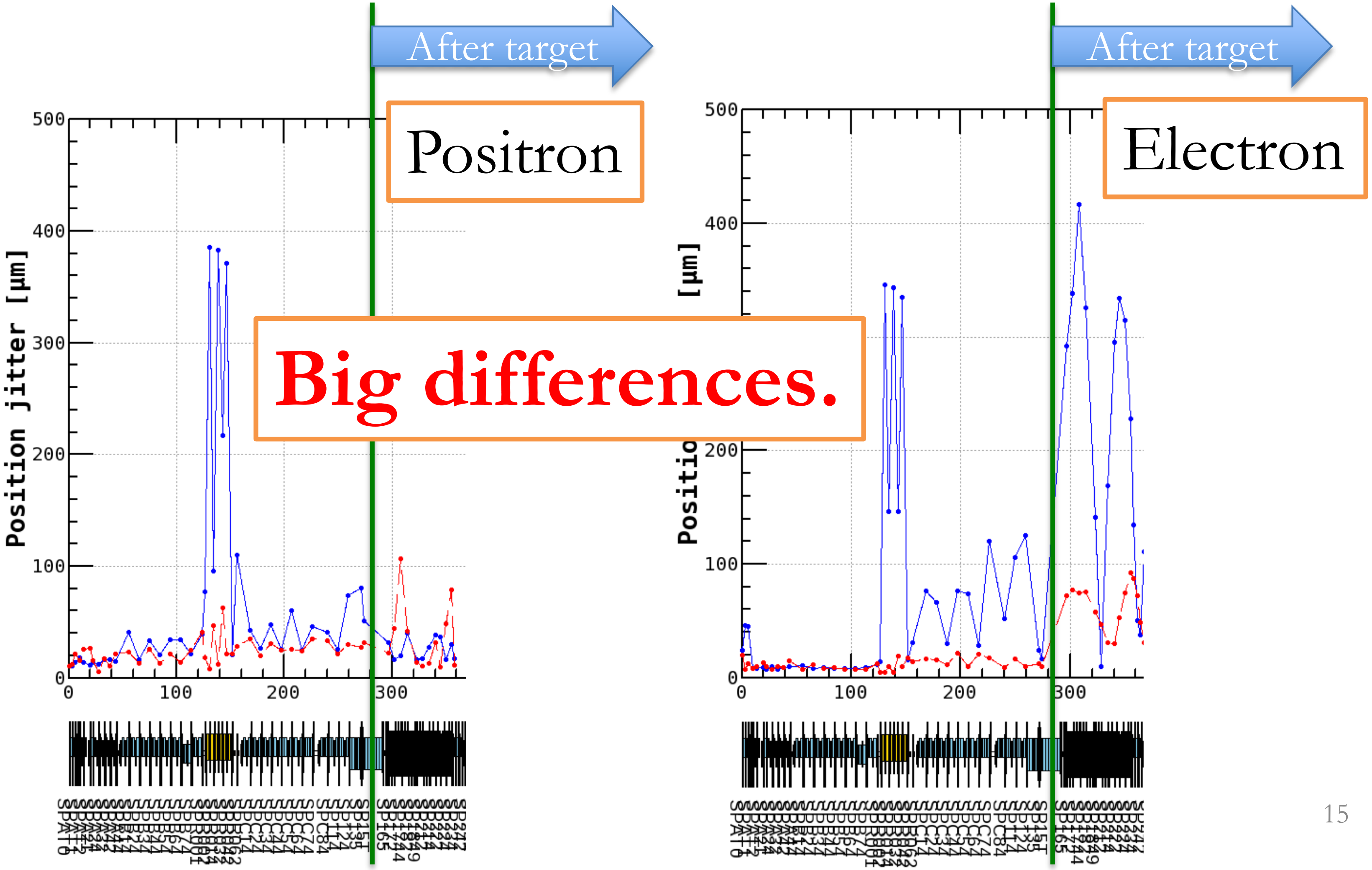
- Maximum horizontal jitter amplitude as a function of charge.
- Linear charge dependence can be seen.

S. Ogur



Positron beam, that does not pass though the target hole

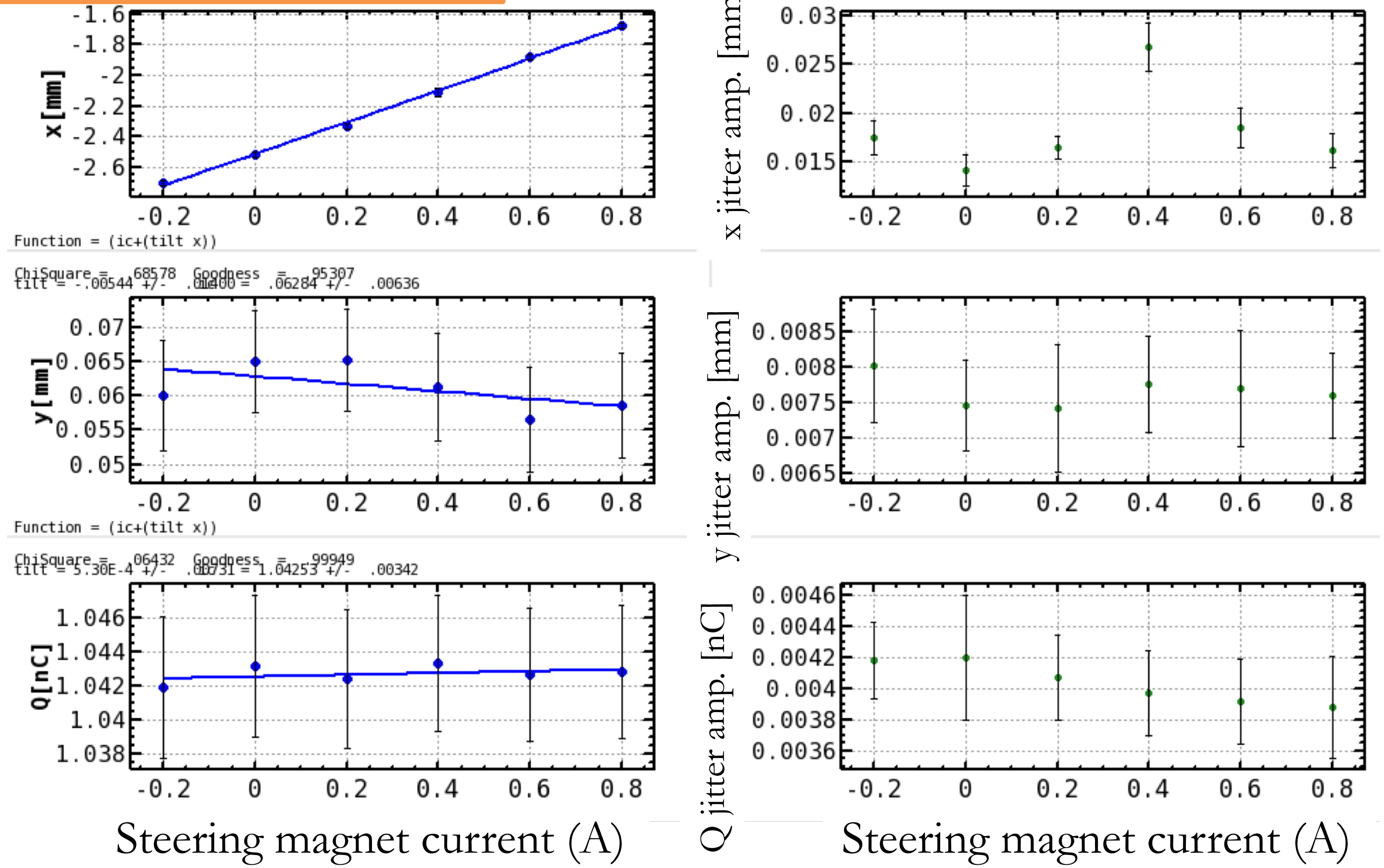
- Difference of positron beam (hits the target) and electron beam (through the target hole).
- **It seems that target hole enhance beam position jitter remarkably. Wake field effect is suspected.**



Correlation between beam position before and after the target (1)

- To find the wake field effect, beam position pass through the target hole was changed by steering magnet.

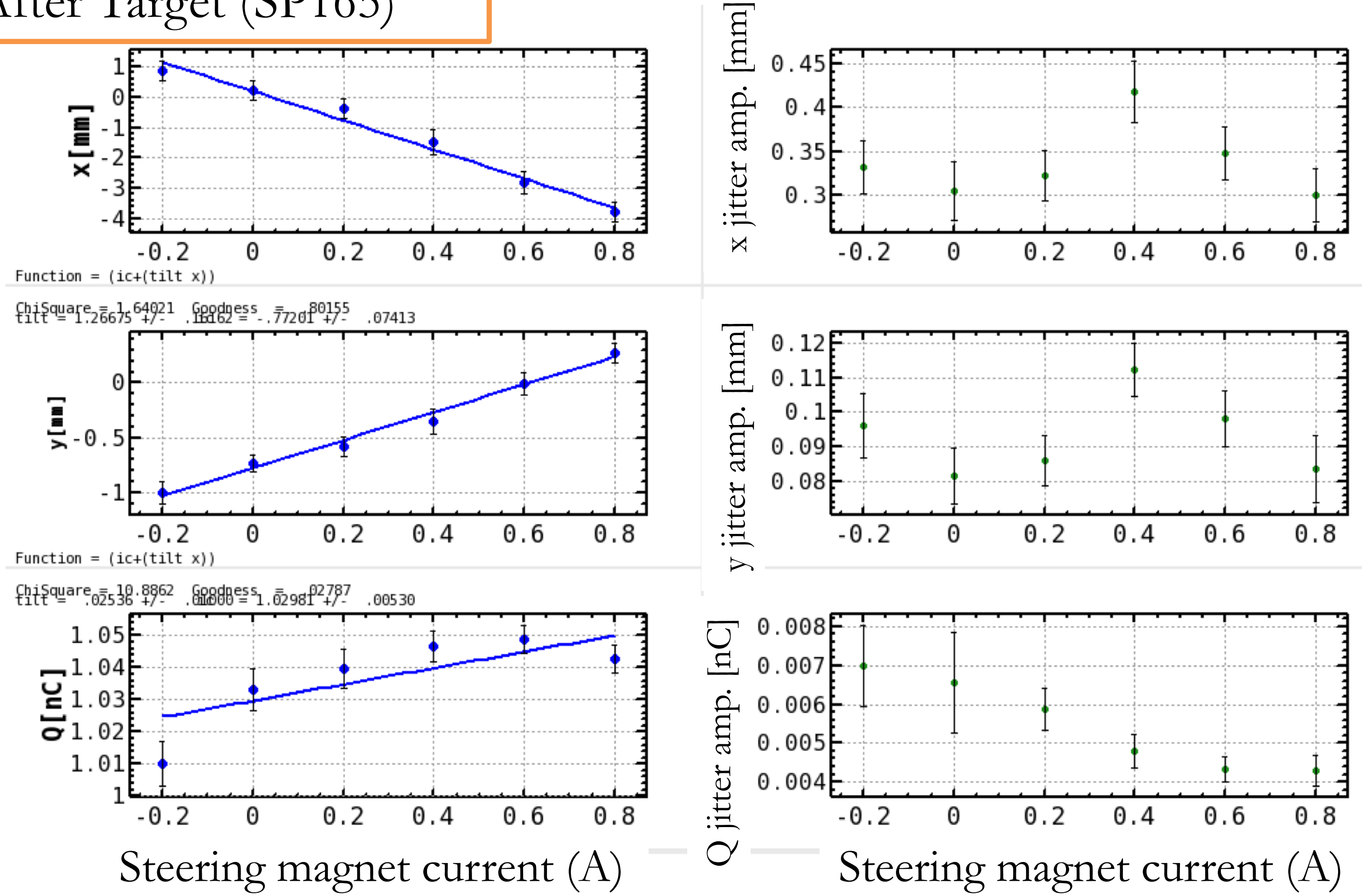
Before Target (SP15T)



Correlation between beam position before and after the target (2)

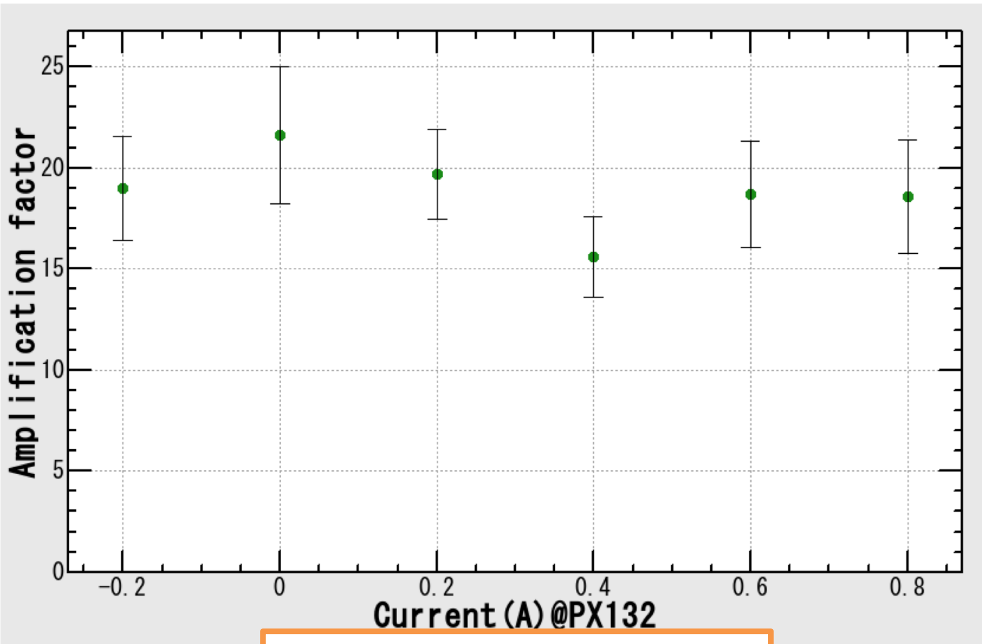
- It seems that there is not remarkable difference between beam position jitter amplitude and steering magnet current.

After Target (SP165)

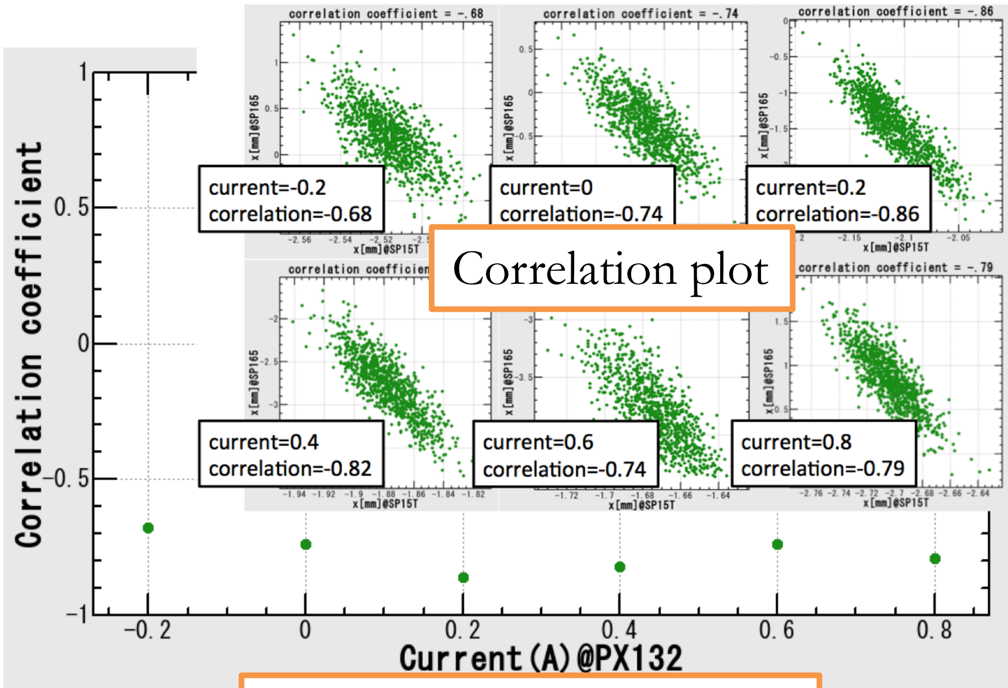


Amplification factor and correlation coefficients

- From the beam position before and after target, amplification factor and correlation coefficients are derived.
- It seems that beam jitter dependence on beam position pass through the target is small.
- Wake effect is not found from this result.



Amplification factor



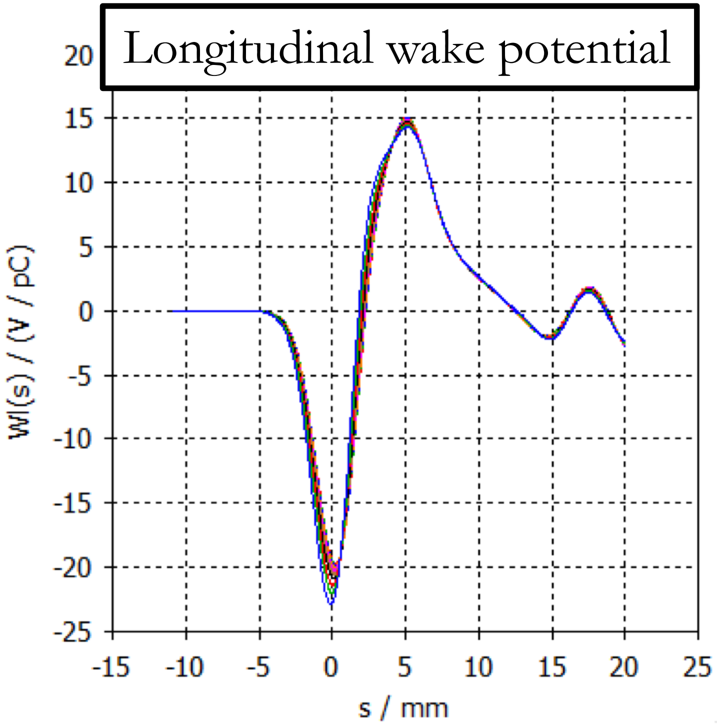
Correlation coefficients

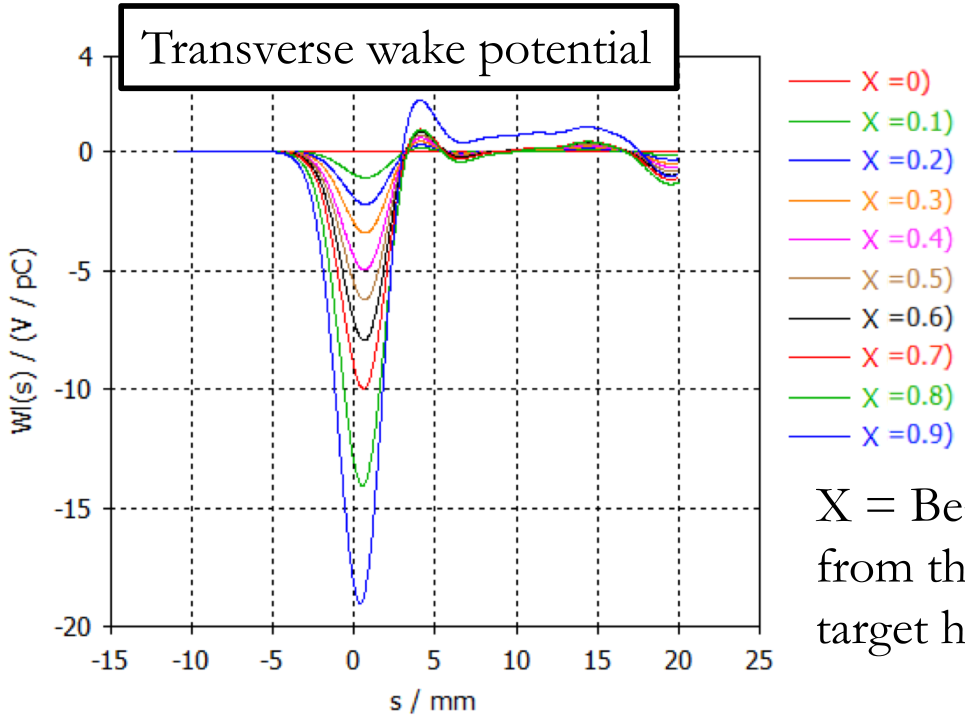
No noticeable differences.

Simulation analysis

Wake potential in the target hole.

- In order to reveal beam jitter problem, simulation analysis is also performing.
- Though target hole size is small (φ2 mm), higher order wake field affect beam.
- Color variation shows difference of beam position from the center of target hole.
- This simulation is performed by CST studio.
- Longitudinal wake has little position dependence. While, transverse wake increase nonlinearly.
- K. Oide, K. Yokoya, and A. Novokhatski help to analyze beam jitter problem induced by wake field.



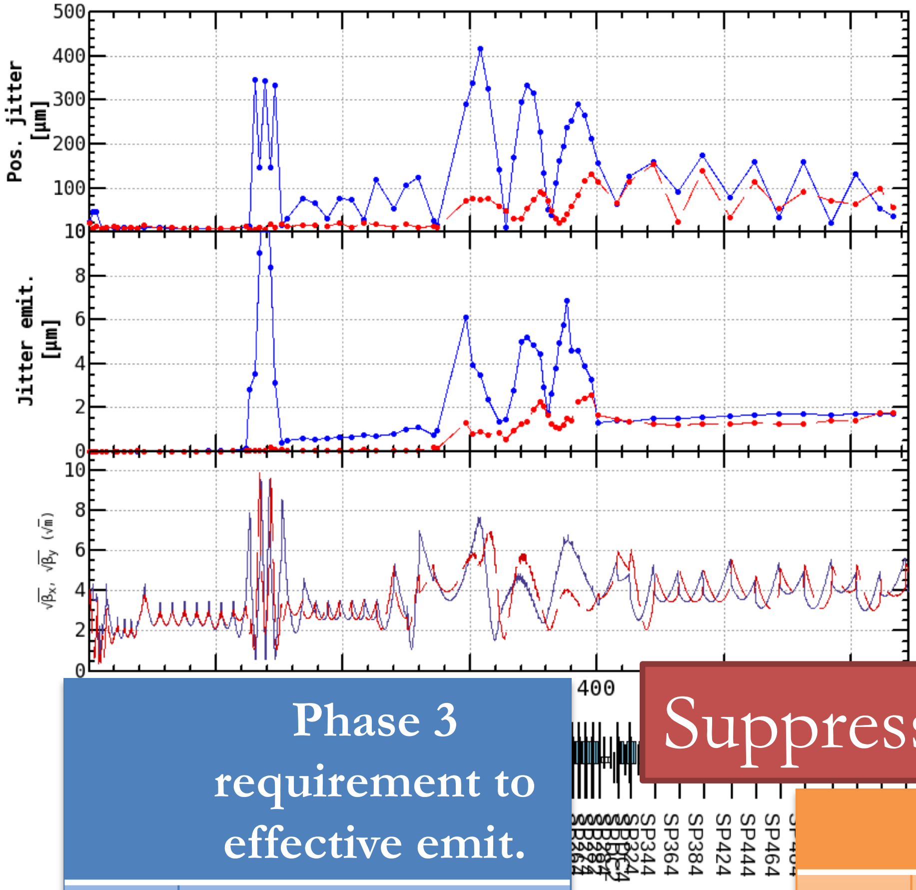


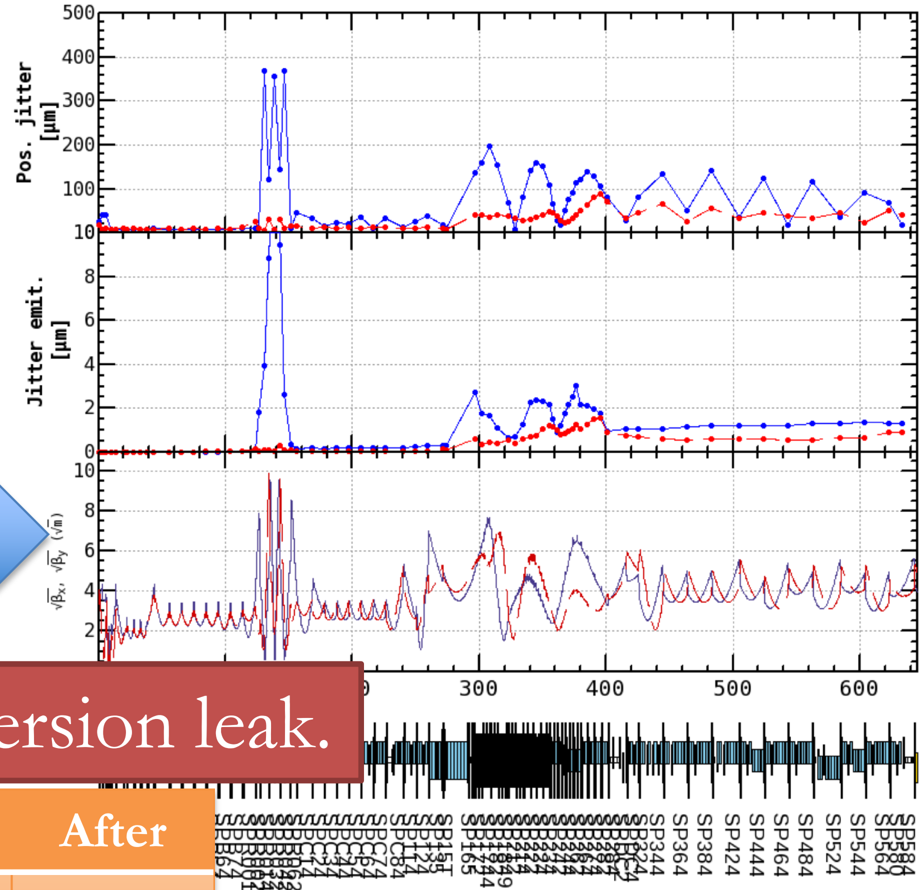
X = Beam position from the center of target hole.

Dispersion leak (thermionic gun)

- **By dispersion leak suppression, jitter emittance is reduced.**

1nC





Suppress dispersion leak.

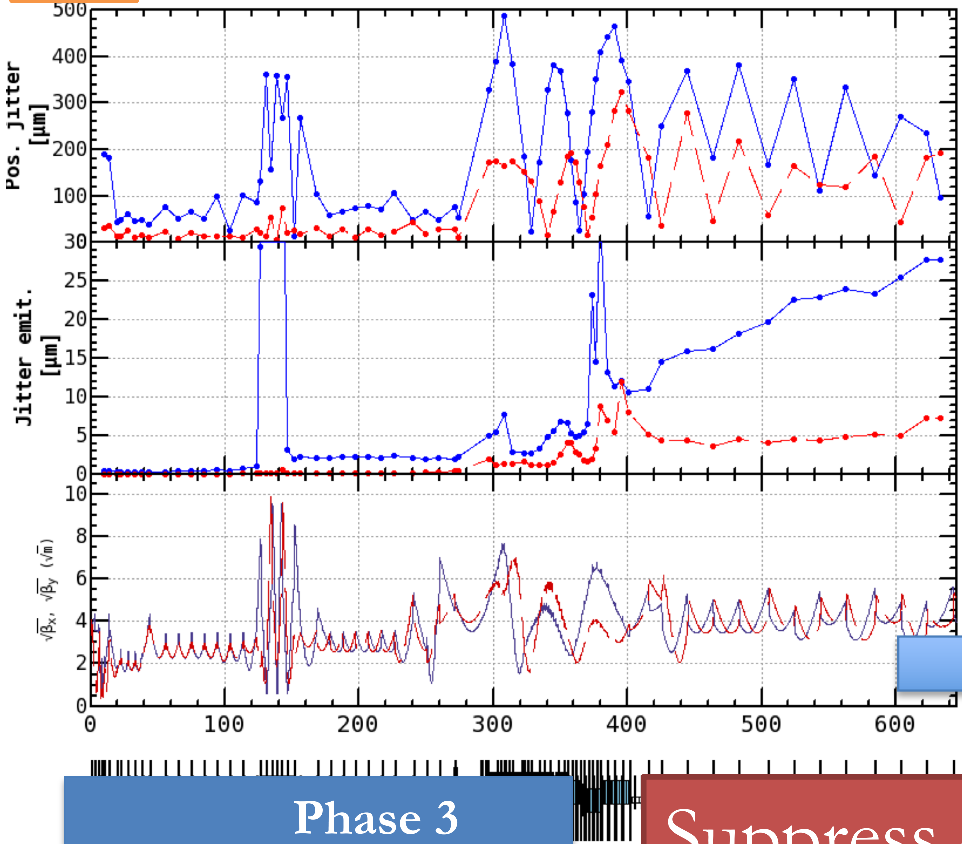
Phase 3 requirement to effective emit.	
εx	40 μm
εy	20 μm

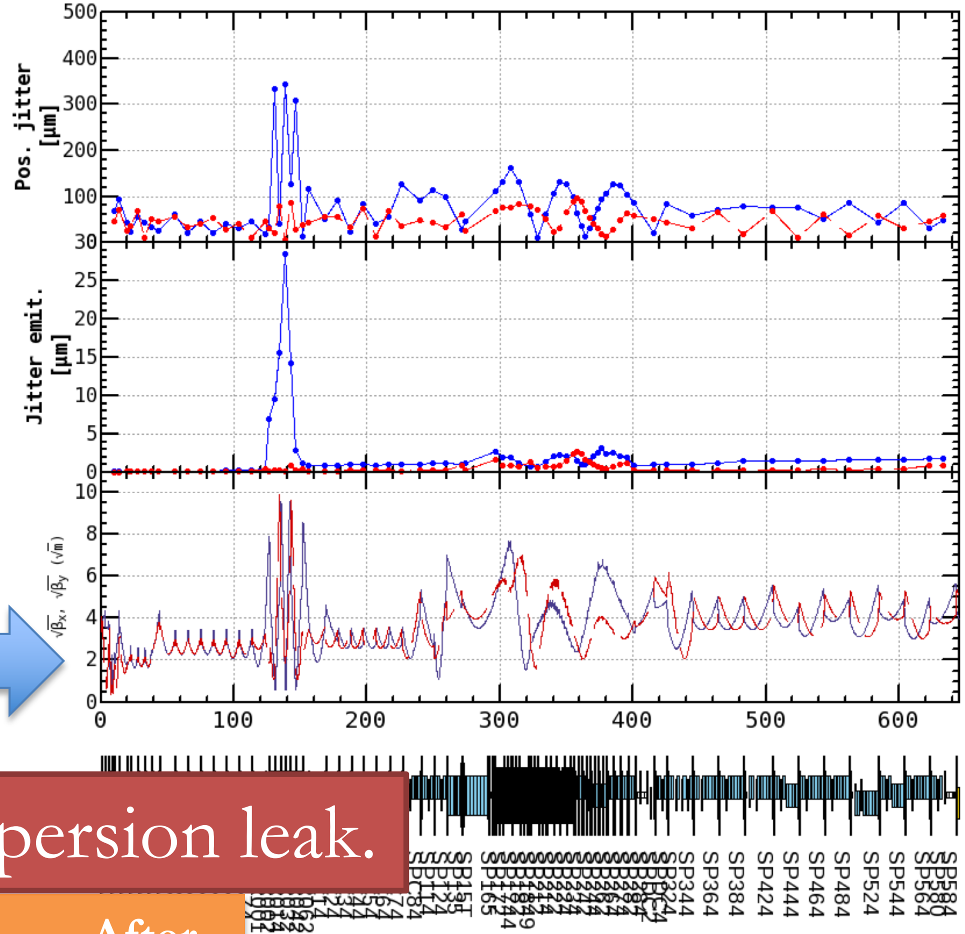
	Before	**After**
εx	1.8 μm	**1.3 μm**
εy	1.8 μm	**0.9 μm**

Dispersion leak (RF gun)

- **Jitter emittance is reduced to same level as thermionic gun.**

1nC





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	Before	After
εx	27.7 μm	**1.8 μm**
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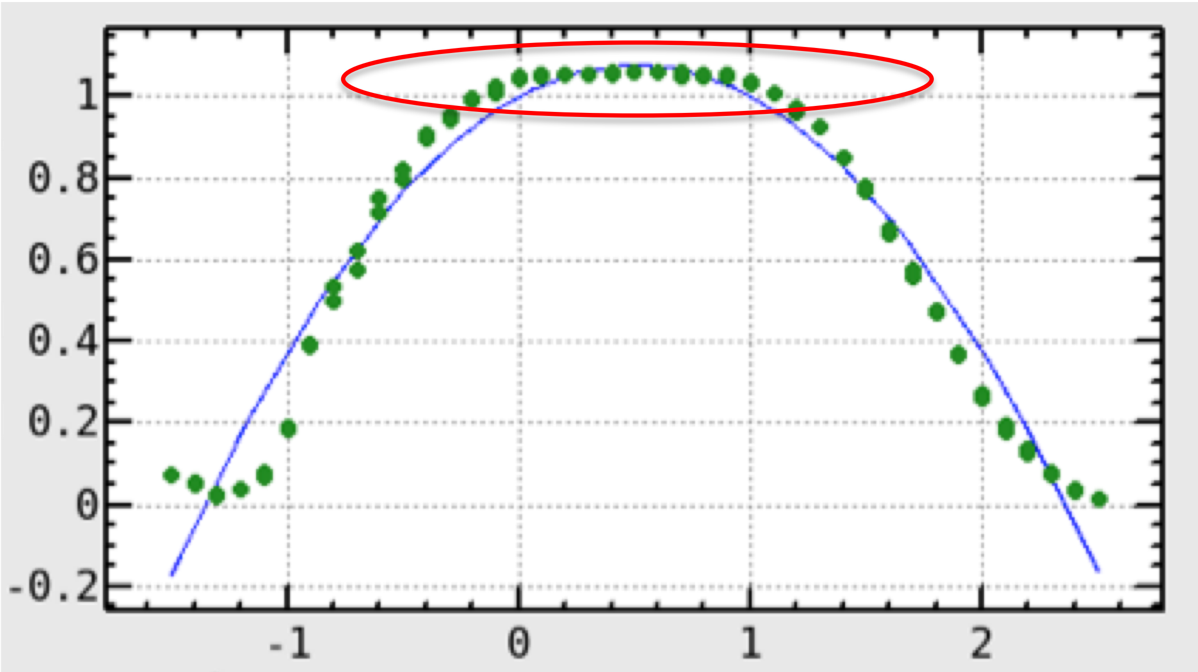
Conclusion

- Jitter emittance enhanced by the target hole.
- By dispersion leak suppression, jitter emittance is reduced.
- In phase 2, beam jitter is not problem. Under 1 nC beam operation, the jitter emittance is small even for phase 3.
- In phase 3, SuperKEKB requirement of beam charge is 4 nC. We have to check whether jitter emittance under the 4 nC beam is small or not with respect to phase 3 target emittance.

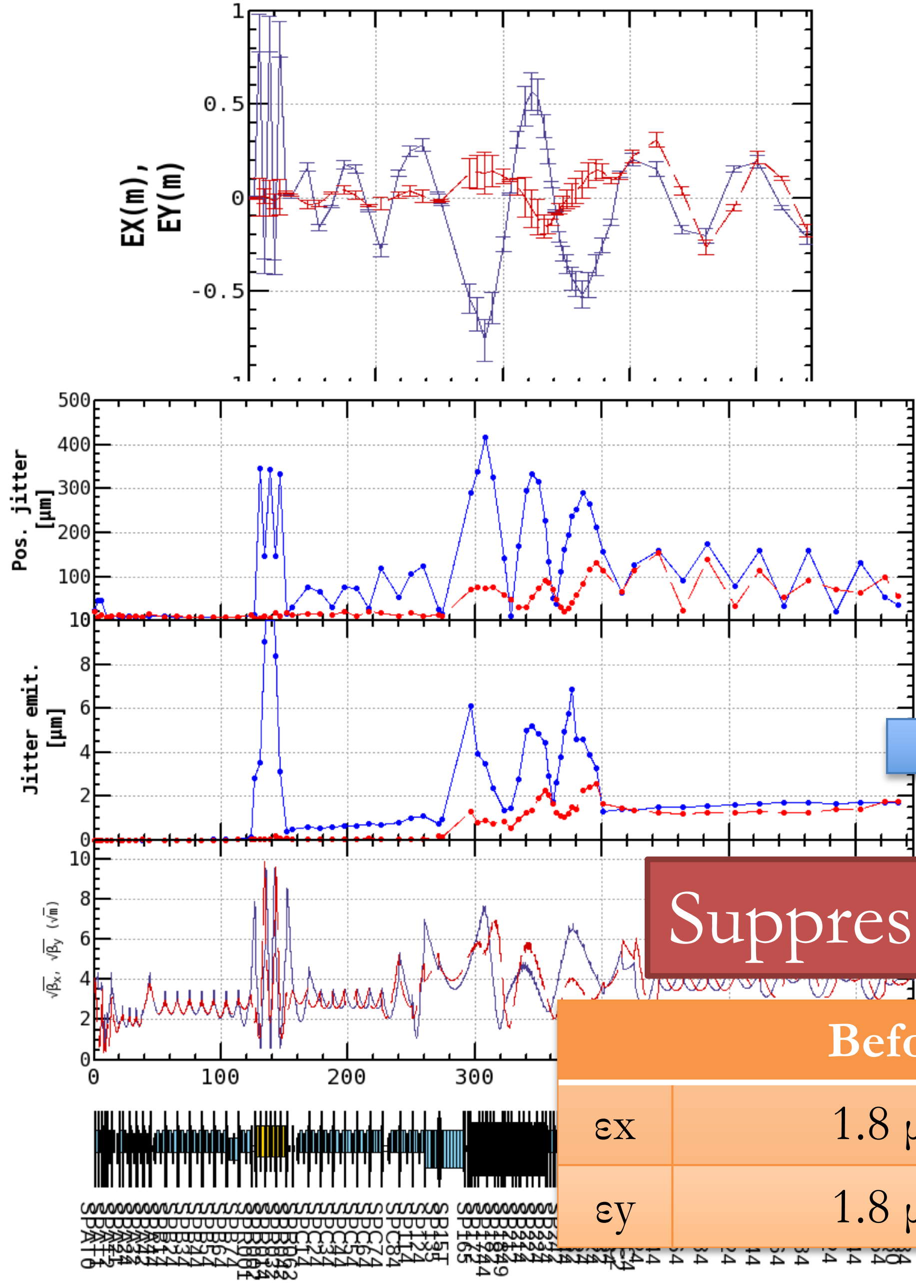
Thank you for your attention.

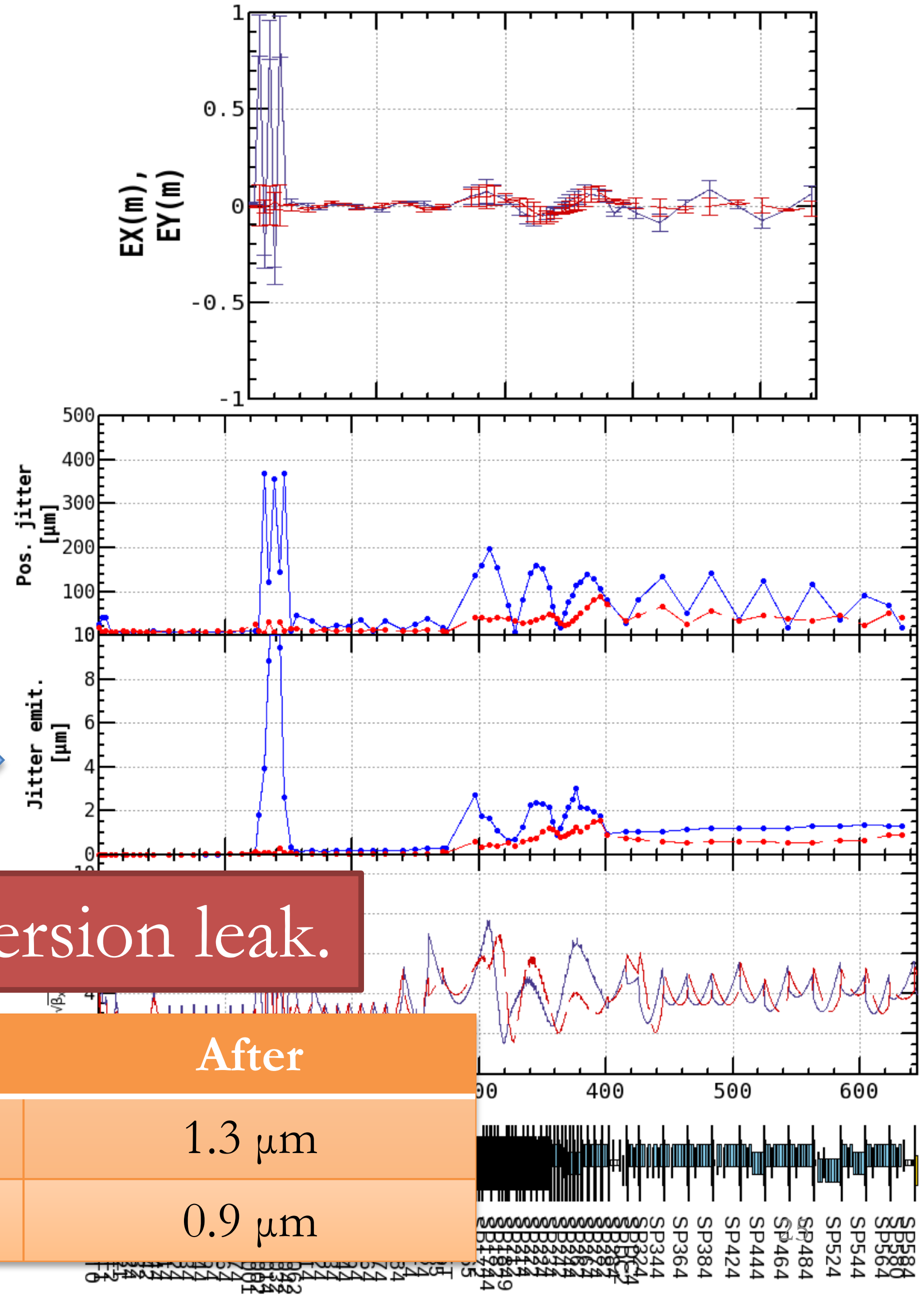
- During the data acquisition, only lossless beams are considered. Charge dependence is small.



Current of steering magnet.

Dispersion leak (thermionic gun)





Suppress dispersion leak.

	Before	After
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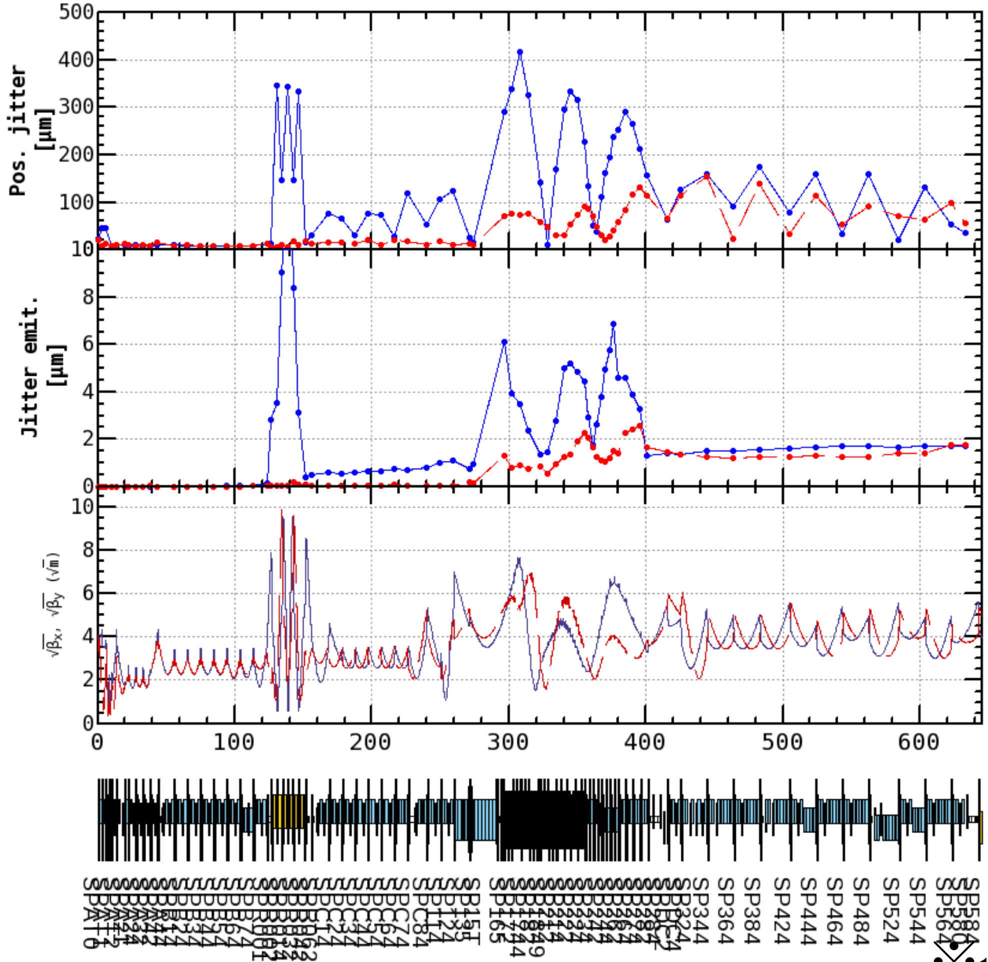
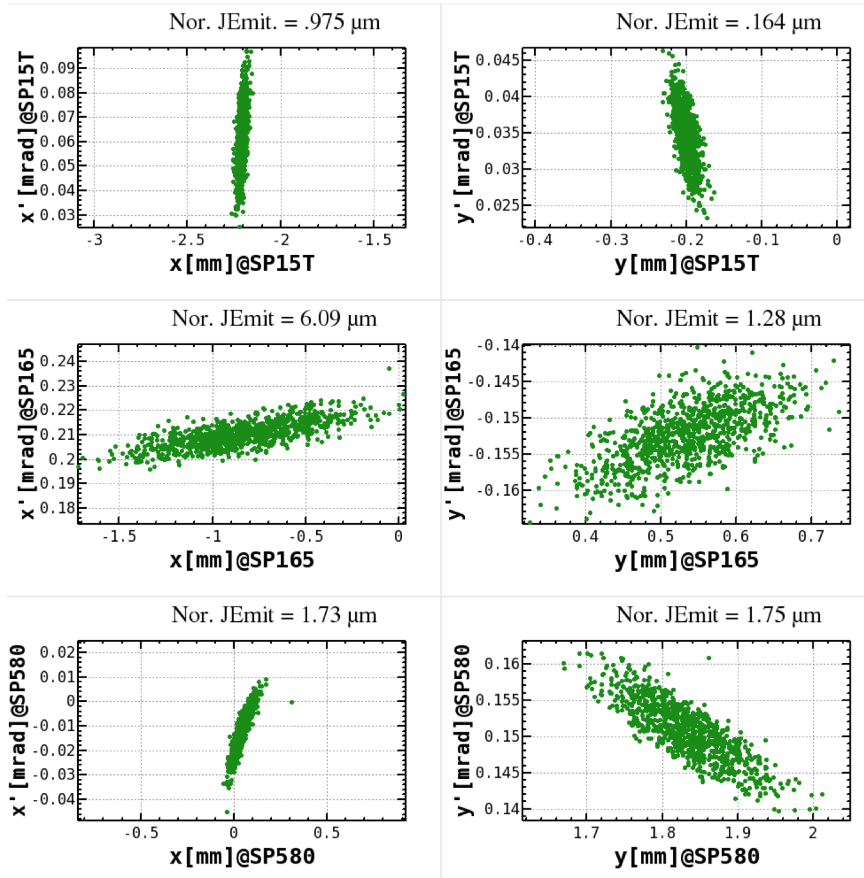
Thermionic gun 1nC





※phase space plot is not scaled by gamma factor.

- If all of the linac quadrupole magnet readout is used for simulation, beta functions diverge. This is because initial beta function do not match real one.
- In jitter emittance calculation, magnetic readout is used.