Brief report of nonlinear collimator study (The study is not yet finished, so this is a progress report.)

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S. Terui, B. Urbschat,

The 27th KEKB Accelerator Review Committee

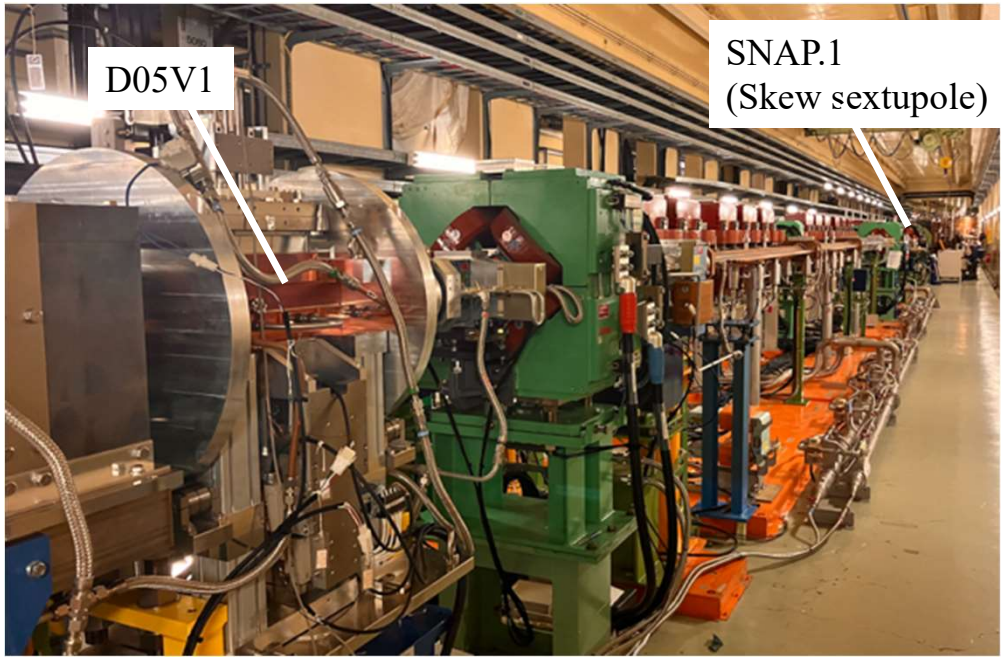
24th Mar. 2024

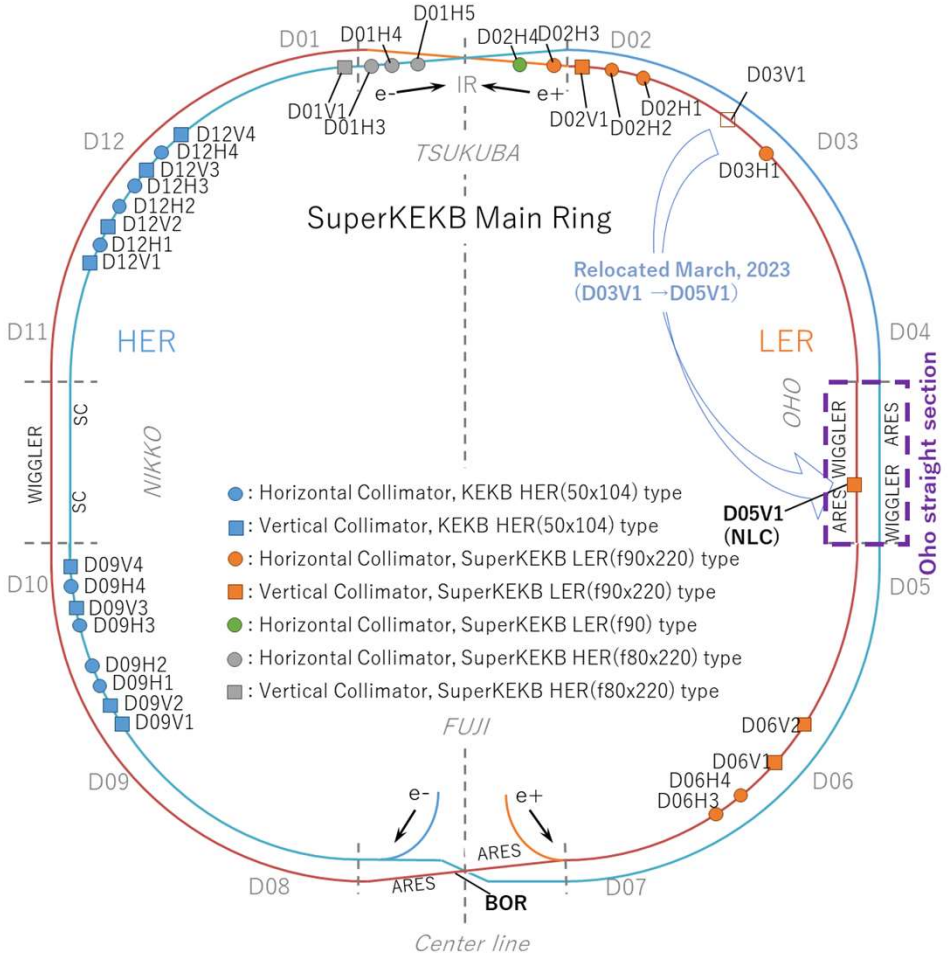
Outline

- Introduction
- Report of nonlinear collimator(NLC) study
- Summary

Photo of nonlinear collimator section at OHO

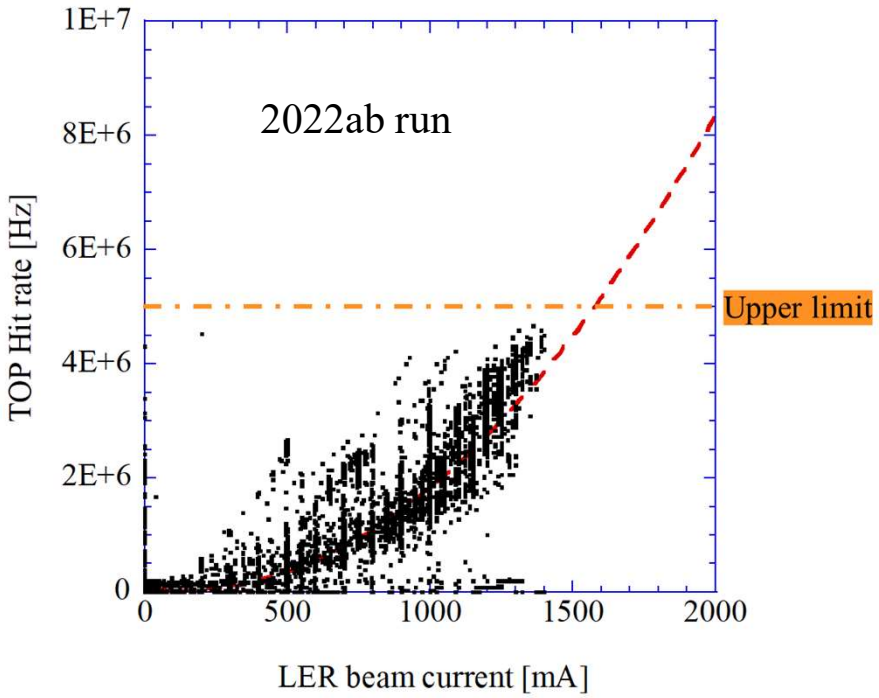
By T. Ishibashi

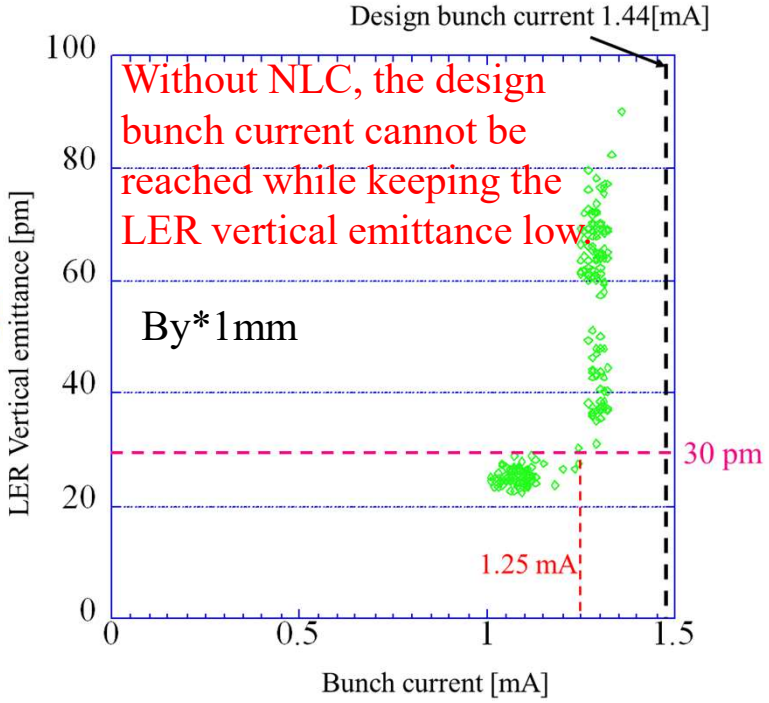




Introduction (Motivation of NLC installation)

- As the beam background noise (BG) is reaching its upper limit, further beam current increase requires a BG reduction.
- To increase the bunch current while avoiding LER vertical beam size blow-up, the impedance needs to be reduced.
- Use NLC as a countermeasure to sudden beam loss (not included in this presentation).



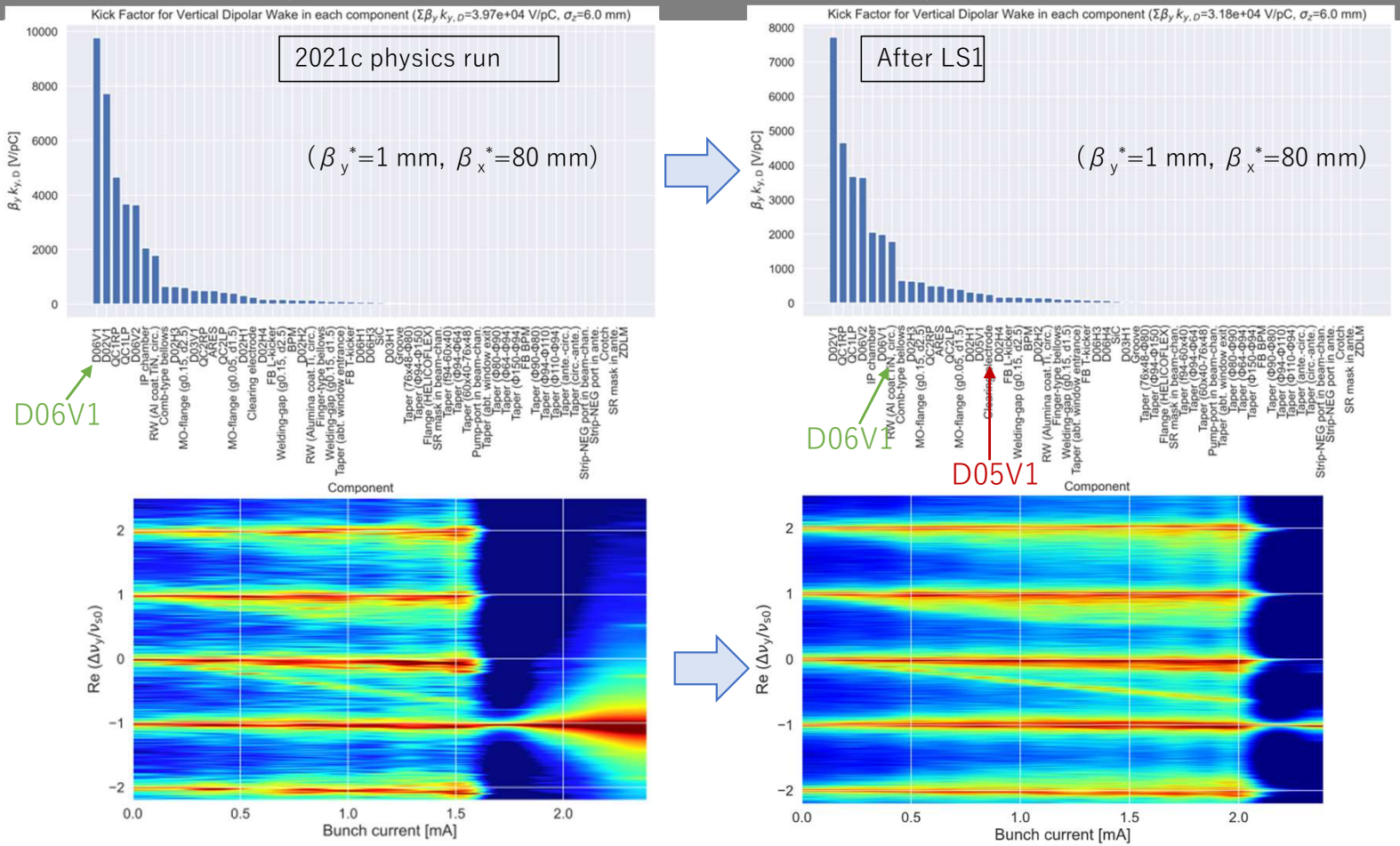


One of the causes of this beam size blow-up is impedance.

More information on this beam size blow-up can be found in Ref (Study for -1 Mode Instability in SuperKEKB Low Energy Ring by Ohmi-san).

Introduction (Motivation of NLC installation)

By T. Ishibashi



- It is estimated that the D05V1, with a half-aperture of about 4-5 mm and β_y=4.05 m, can have comparable background performance to the D06V1.

→ If D05V1 could be used instead of D06V1, the vertical impedance of the ring could be reduced.

- $\Sigma\beta_y k_y$ decreases from 3.97×10^4 to 3.18×10^4 V/pC. The TMCI threshold increases from ~1.8 mA to ~2.1 mA.
- If it turns out that the D05V1 will completely replace the D06V1 in the next commissioning, there is a possibility that we will remove the D06V1 from the LER in the future, in which case further impedance reduction could be expected.

- A pair of skew sextupoles are used for betatron collimation in the vertical plane.
- The phase advance between the paired skew sextupoles is set to π in both planes.
- The vertical kick by a skew sextupole is expressed as $\frac{K_s}{2}(y^2 - x^2)$

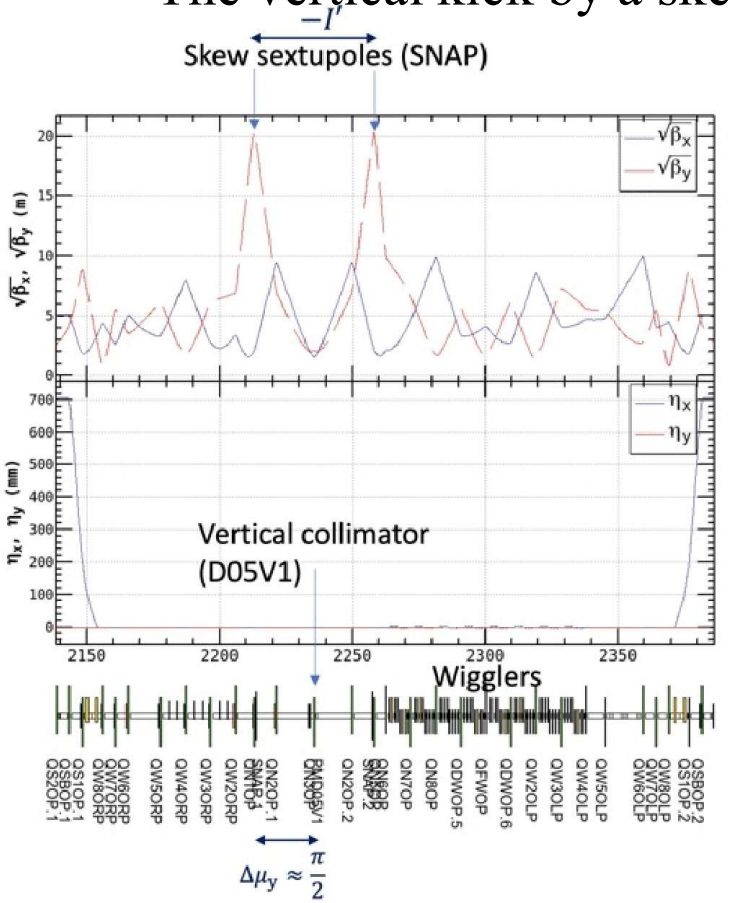
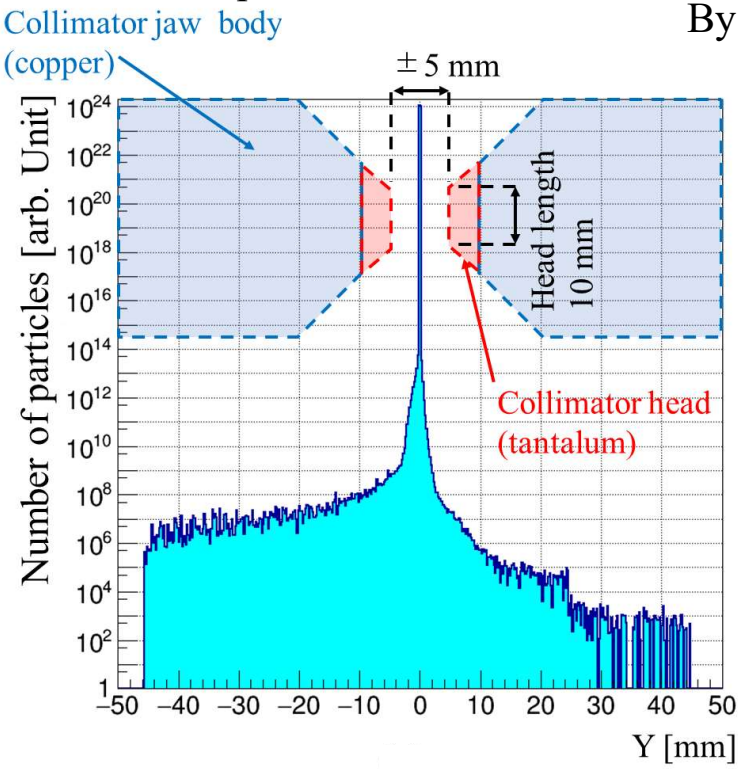


Image of Skew sextupole kick

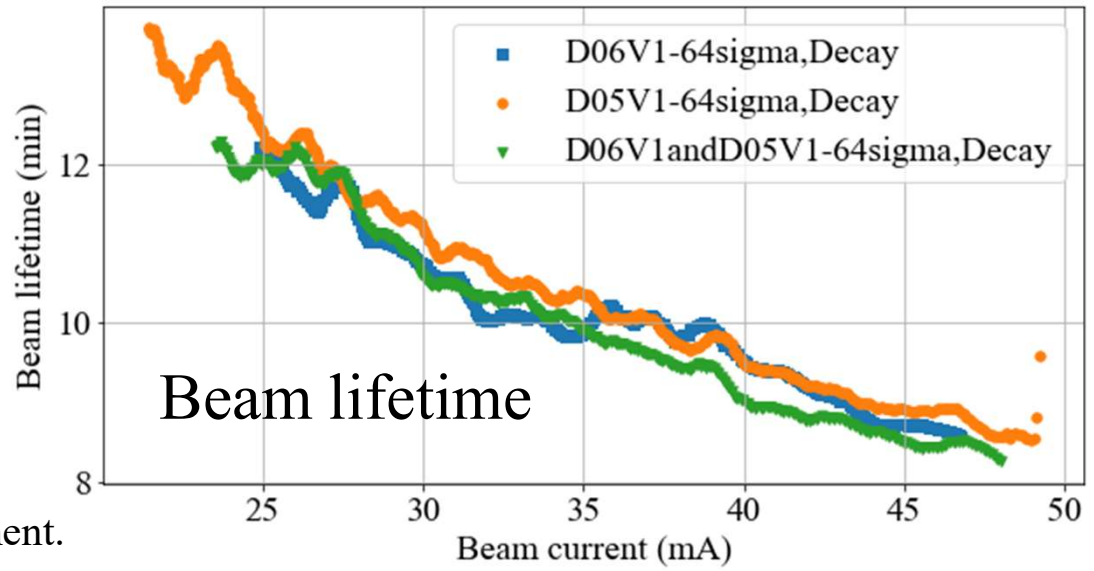
By A. Natochii



The studies performed on 8 Mar. and 14 Mar. checked whether D05V1 (NLC) would be a substitute for D06V1, which had been very much relied upon until previous runs.

By*1mm, crab waist=0
Assumption: Bunch length=6 mm, V emittance = 20 pm

Under the conditions described below, the lifetime was almost the same.



This table shows the collimator gap at the time of measurement.

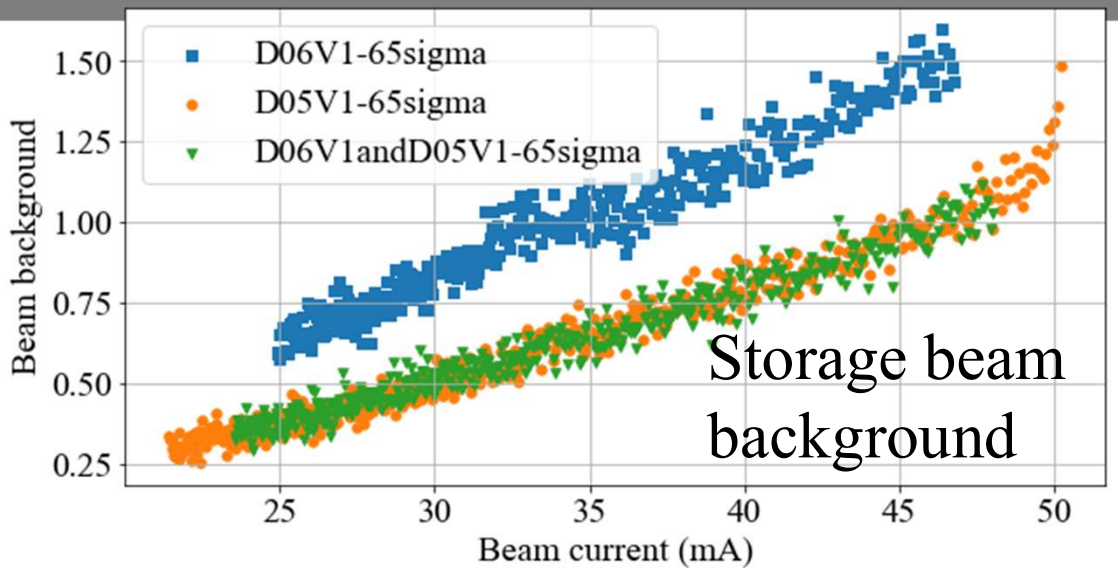
14 Mar. Name	Time	Beam current	# of bunch	D06V1 gap	D06V2 gap	D05V1 gap	D02V1 gap	D06V1 σ	D06V2 σ	D05V1 σ	D02V1 σ
D06V1-64σ	21:11:50	50	94	2.375	8	14	1.1	64	394	128	71
D06V1D05V1-64σ	21:26:40	50	94	2.375	8	3.5	1.1	64	394	64	71
D05V1-64σ	21:41:00	50	94	8	8	3.5	1.1	218	394	64	71

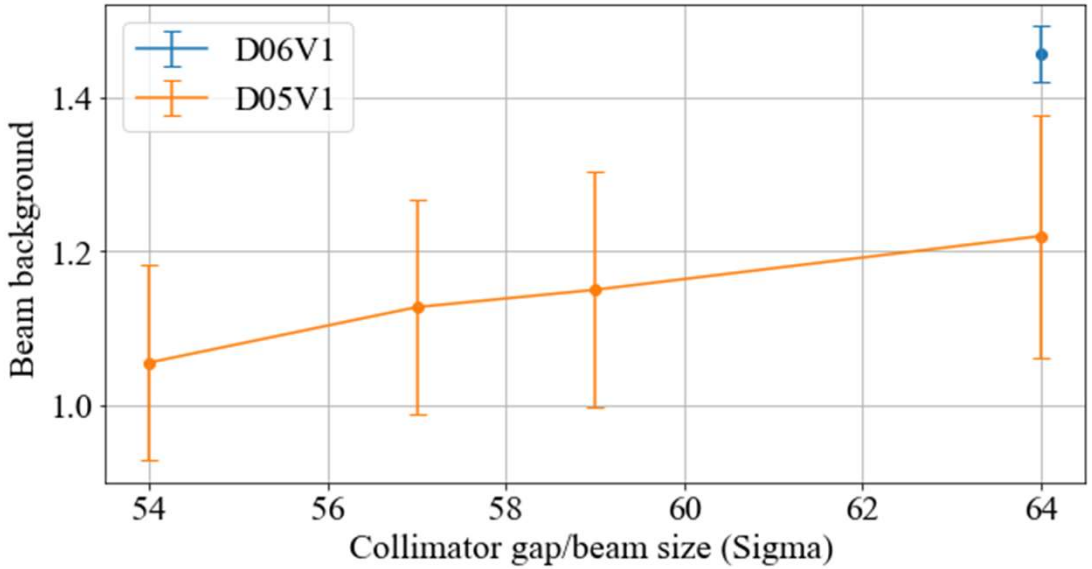
Storage beam background:

*D05V1 is more capable of storage BG reduction than D06V1.

*The better collimation performance of D05V1 compared to D06V1 is expected. NLC is much closer to the IP than D06V1, so scattered particles between D06V1 and D05V1 can now be stopped by D05V1 before they hit the IR.

*The storage BG was also observed to decrease when the D05V1 gap was closed.





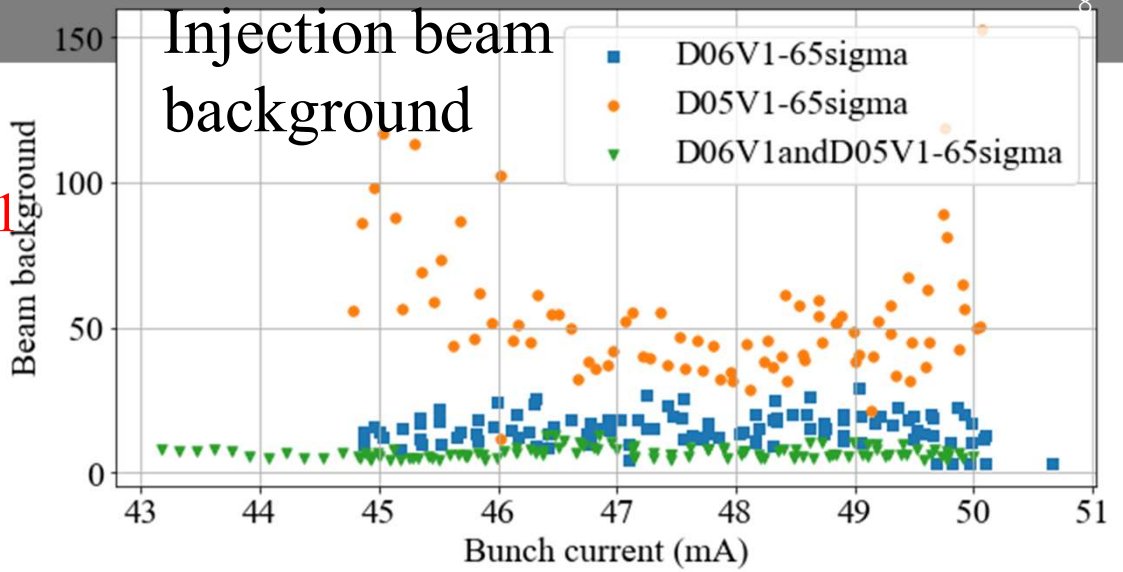
Injection beam background:

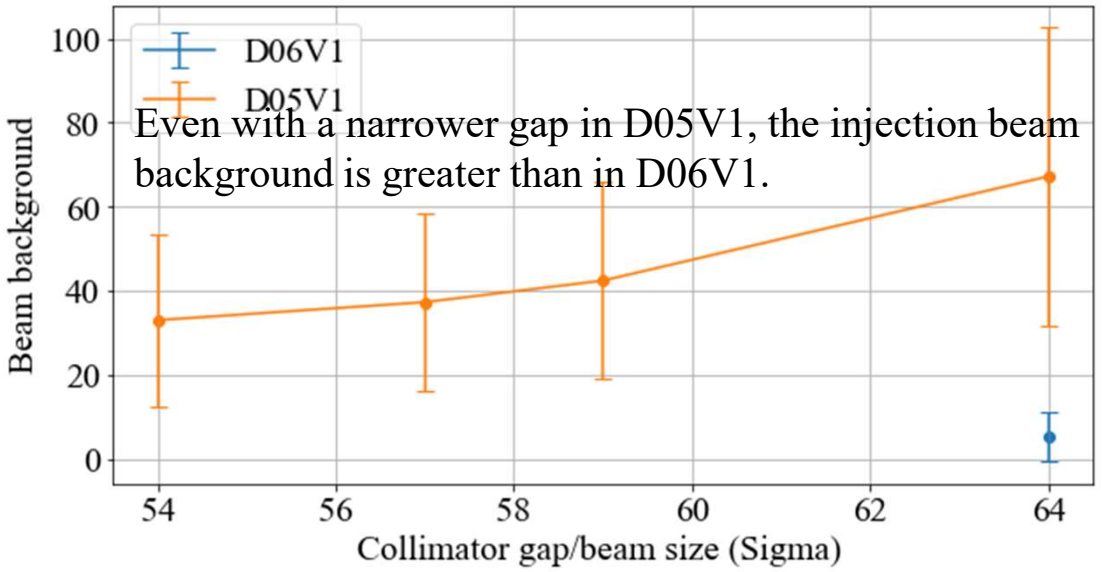
*The injection BG reduction capability of D05V1 is significantly less than that of D06V1. When both D06V1 and D05V1 are used, the injection BG reduction capability is higher than that of D06V1 alone.

Vertical kick $= \frac{K_s}{2}(y^2 - x^2)$

We expect that D05V1 is less effective for injection BG reduction because of this term.

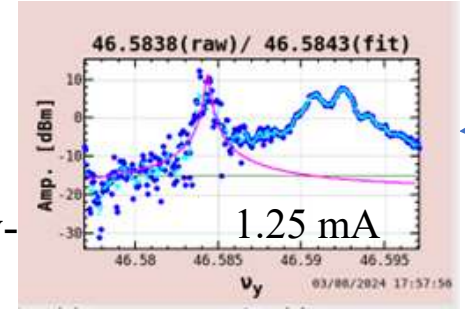
This countermeasure is presented in the summary.

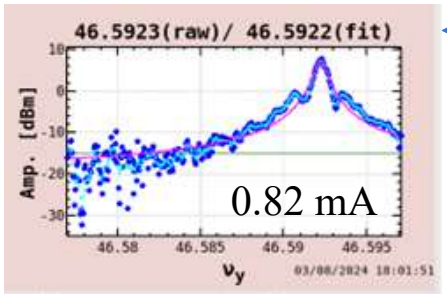




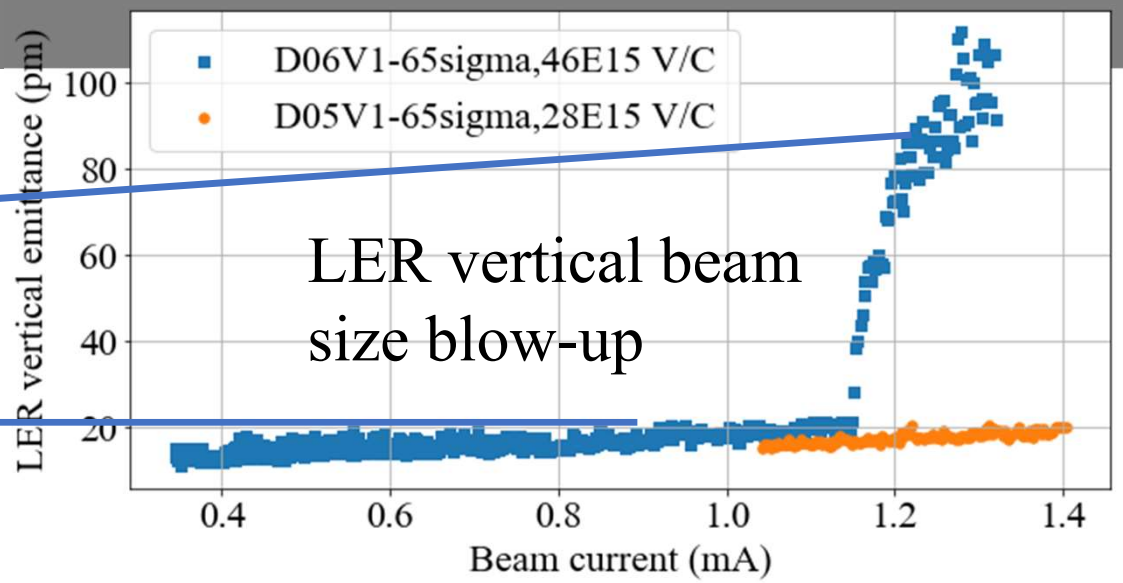
Report of nonlinear collimator(NLC) study

LER Pilot bunch vertical spectrum



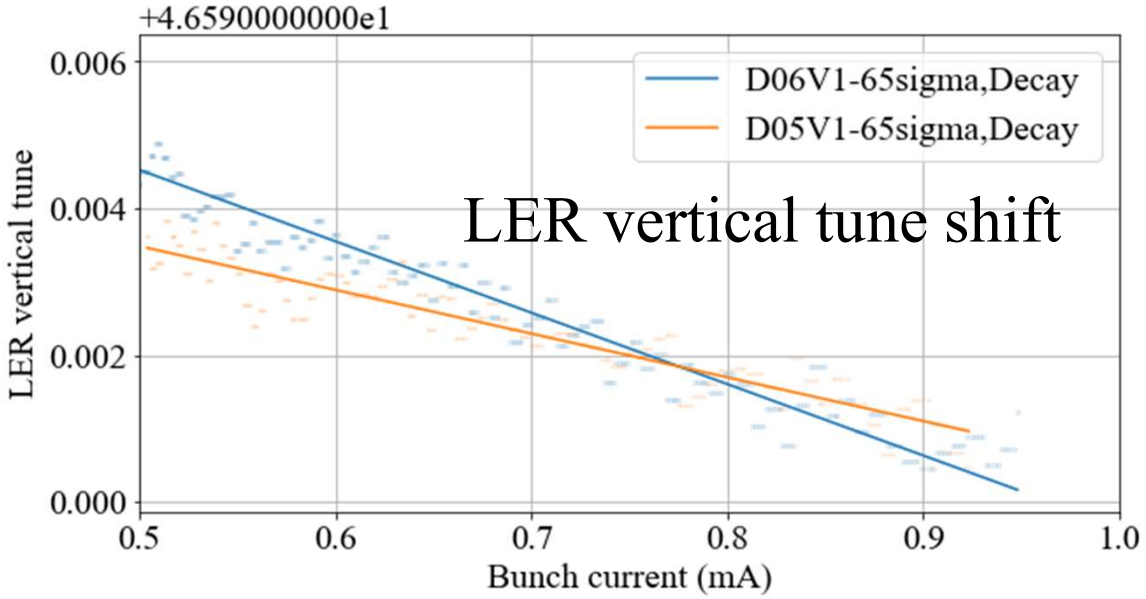


No vertical beam size blow-up was observed in the design bunch current when D05V1 was used in its narrowest setting.



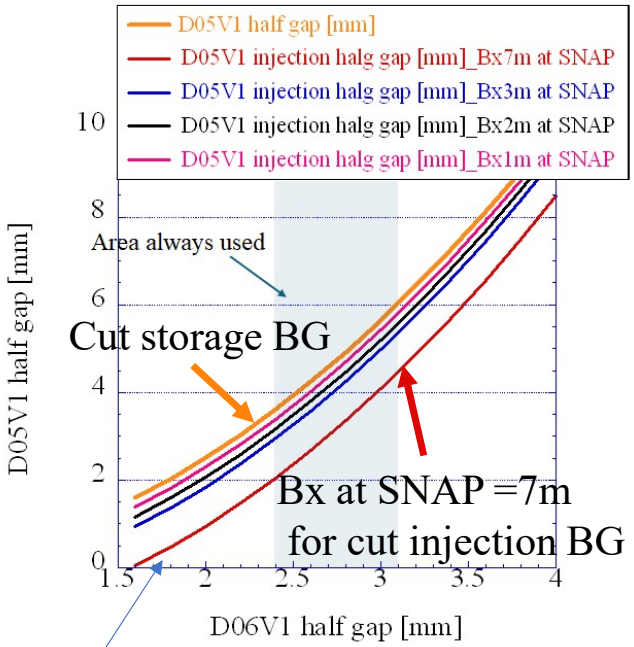
Mea_D06V1-65sigma(46E15 V/C)=0.0097 /mA
Cal_D06V1-65sigma(46E15 V/C)=0.0092 /mA
Mea_D05V1-65sigma(28E15 V/C)= 0.0059 /mA
Cal_D05V1-65sigma(28E15 V/C)=0.0055 /mA

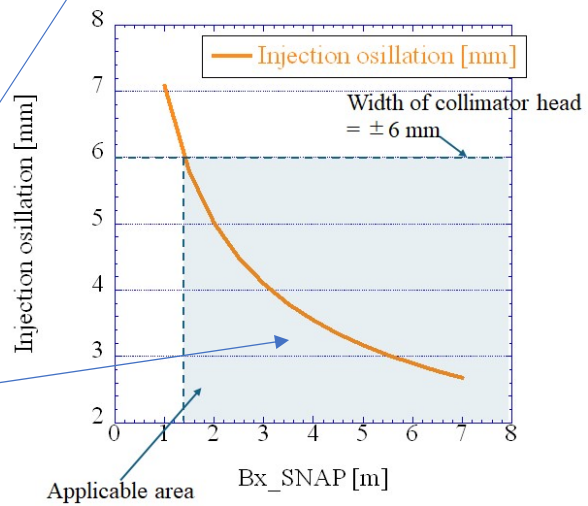
Vertical tune shift was nearly consistent in measurement and calculation.



Summary

- The motivation for the installation of the NLC and the concept of the NLC were briefly explained.
- D05V1 is more capable of storage BG reduction than D06V1.
- The injection BG reduction capability of D05V1 is significantly less than that of D06V1.(Funakoshi-san suggested to optics group that the βx at the SNAP location could be smaller.)
- Experiments confirmed that D05V1 has a smaller impedance than D06V1.





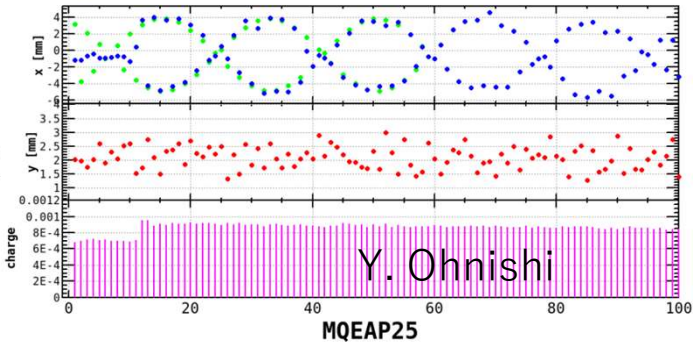
***Currently, the Bx at SNAP is 7m. We can see that to cut the injection BG at this time, the gap of cut injection BG needs to be smaller than the gap of cut of the storage BG.**
***Due to the collimator head width constraints, at the next opportunity we plan to do a study with optics with a Bx = 2m at SNAP.**

Back up

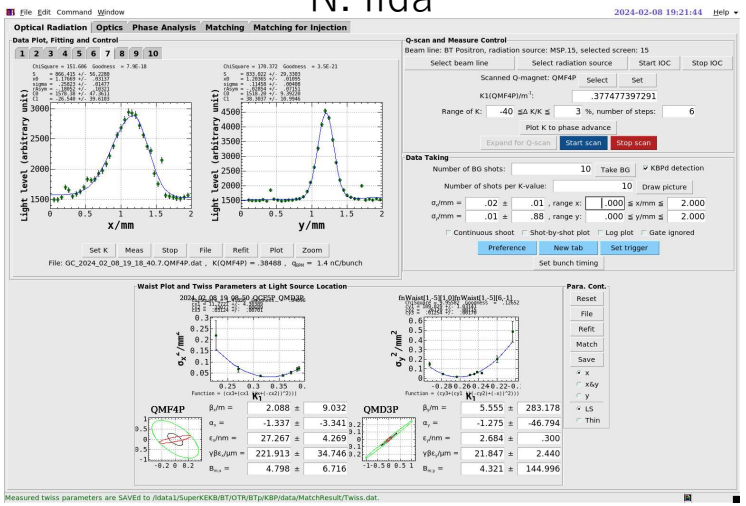
Y. Funakoshi

2Jx of injectin

- Dipole oscillation
  - 2Jx = 7.84 x 10^-7 m

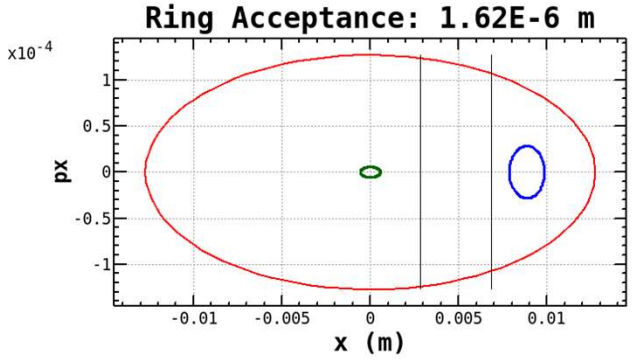


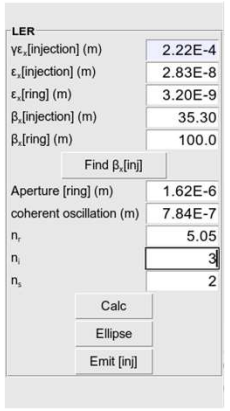
N. Iida



- Beam emittance of injecting beam
  - $\gamma\varepsilon_x$ = 222±35 mm
    -> ε_x = 2.83 x 10^-8 m

- Ring acceptance
  - 2Jx = 1.62 x 10^-6 m (with $3\sigma_{x,inj}$)
    -> 2Jx = 2 x 10^-6 m (with some margin)

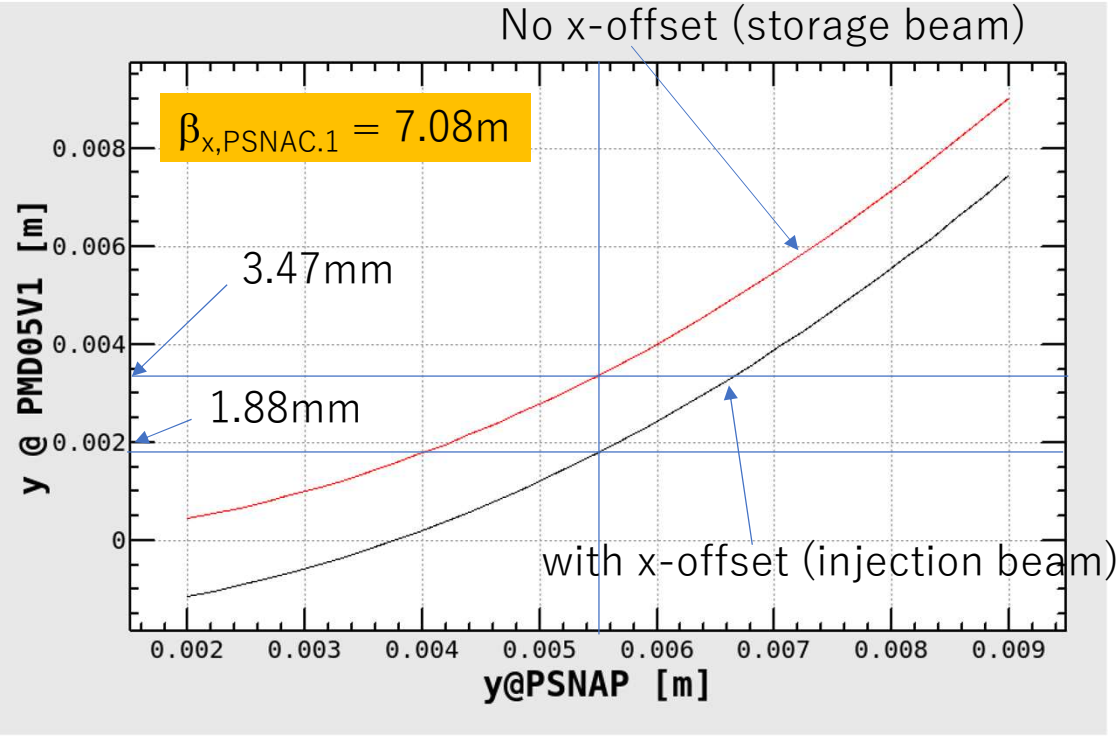


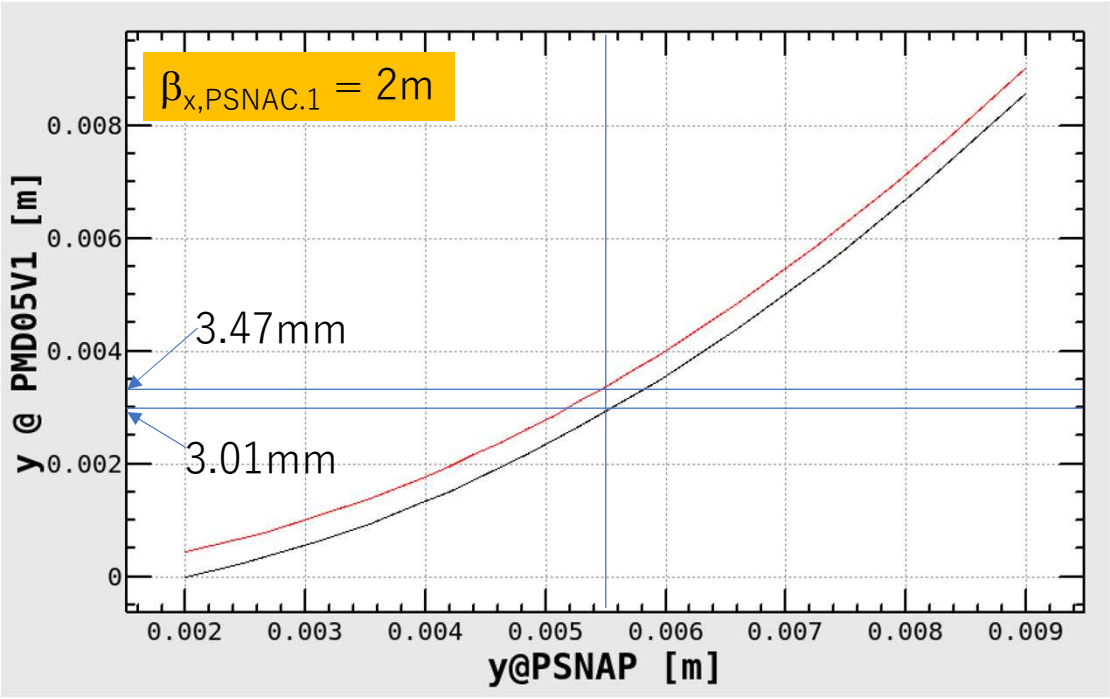


Y. Funakoshi

Collimation for storage and injecting beams

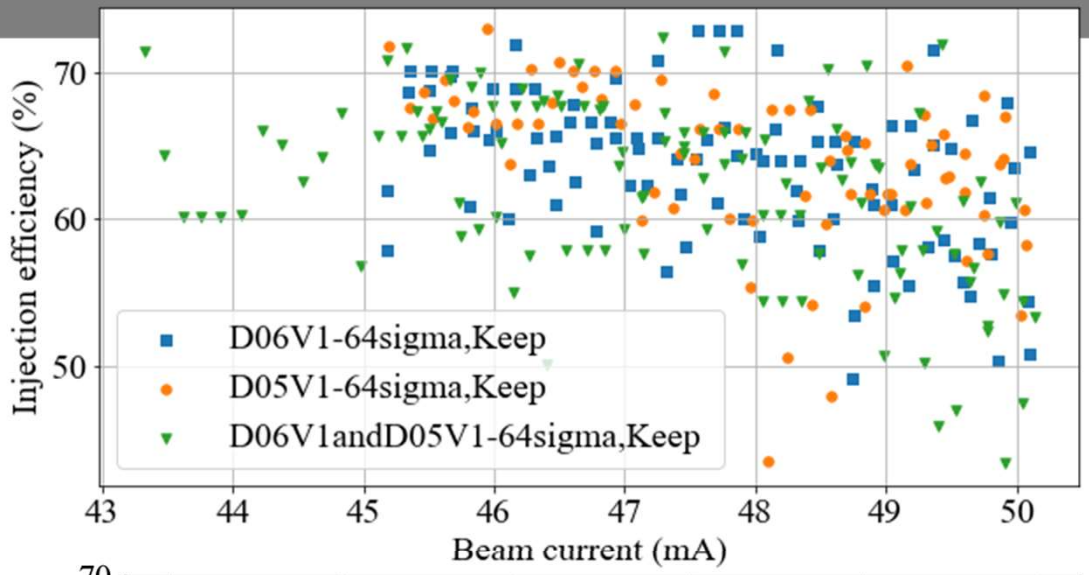
2Jx (injection acceptance) = **2 x 10^-6 m**

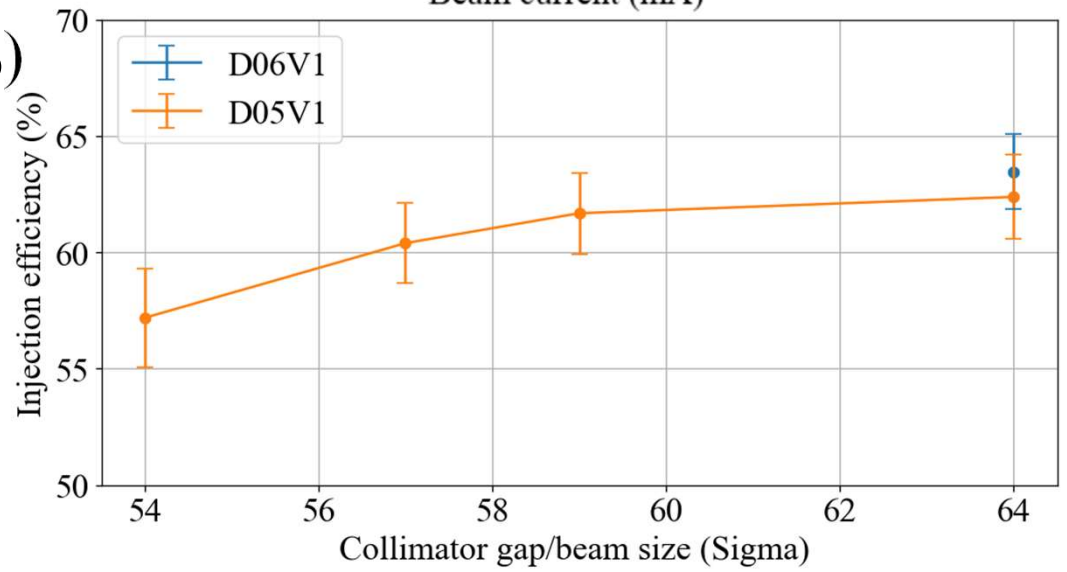




Injection efficiency :
*The injection efficiency is almost the same when D06V1 is 64σ and when D05V1 is 64σ.
* A slight decrease in injection efficiency was observed when D05V1 was lower than 57σ.

Injection efficiency (%)



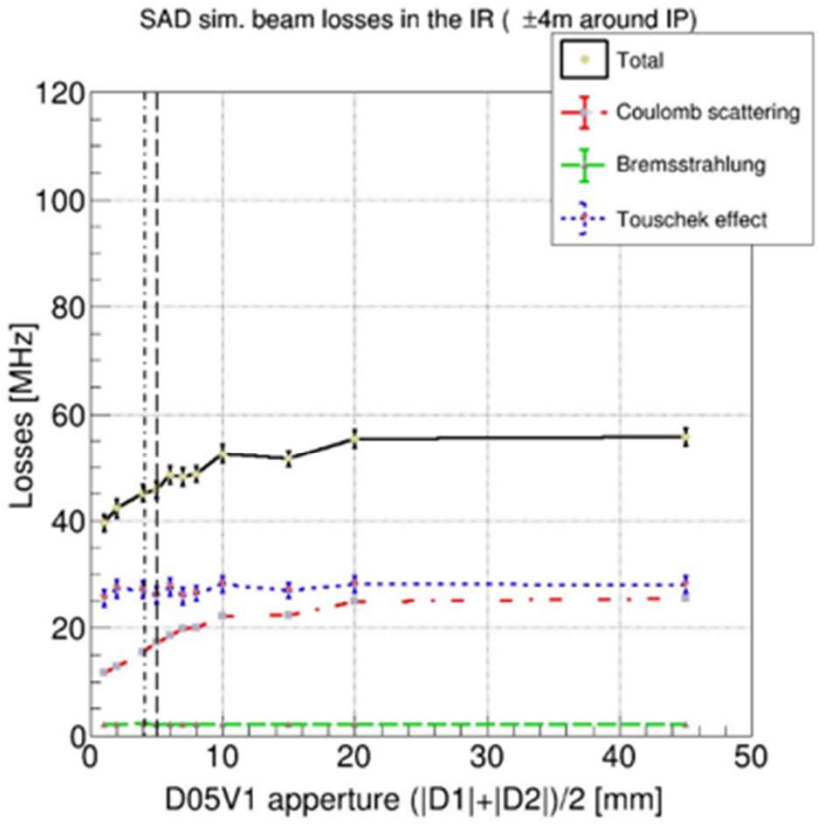


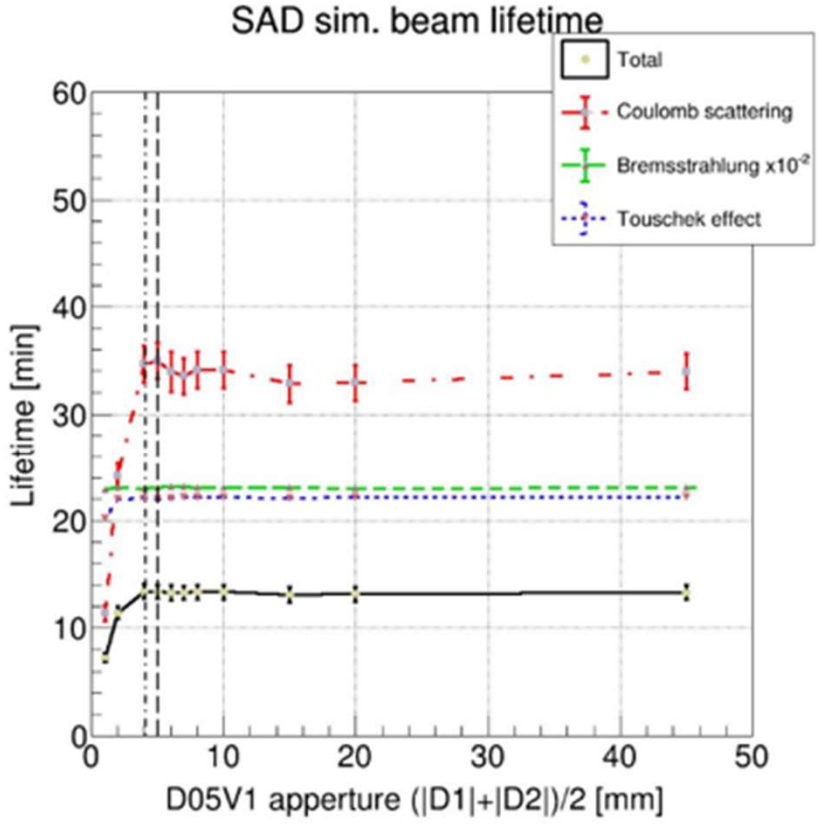
[A. Natochii]

NLC aperture scan: 1800_nlc

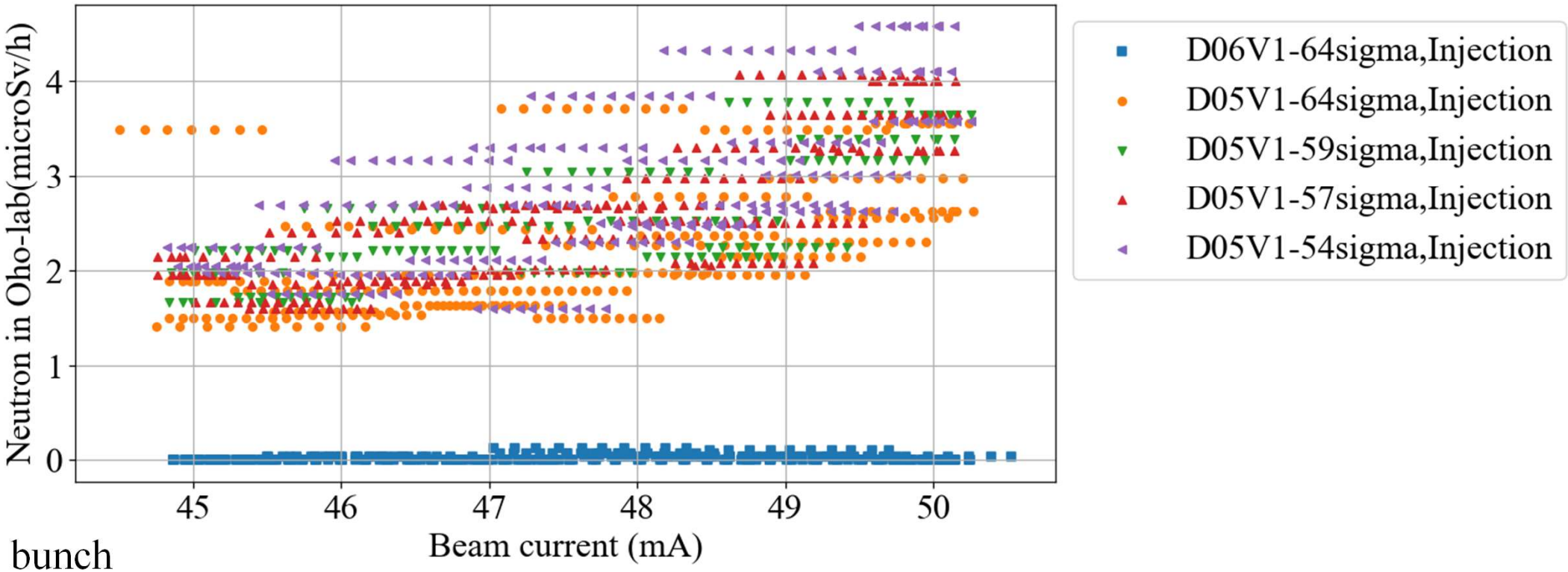
$I^{LER/HER}$ = 1.2/1.0 A, Nb = 1576, σ_z = 6 mm

Dec-20, 2021 (D06H4 same as was D06H1, w/o D03V1, w/o D06H1)

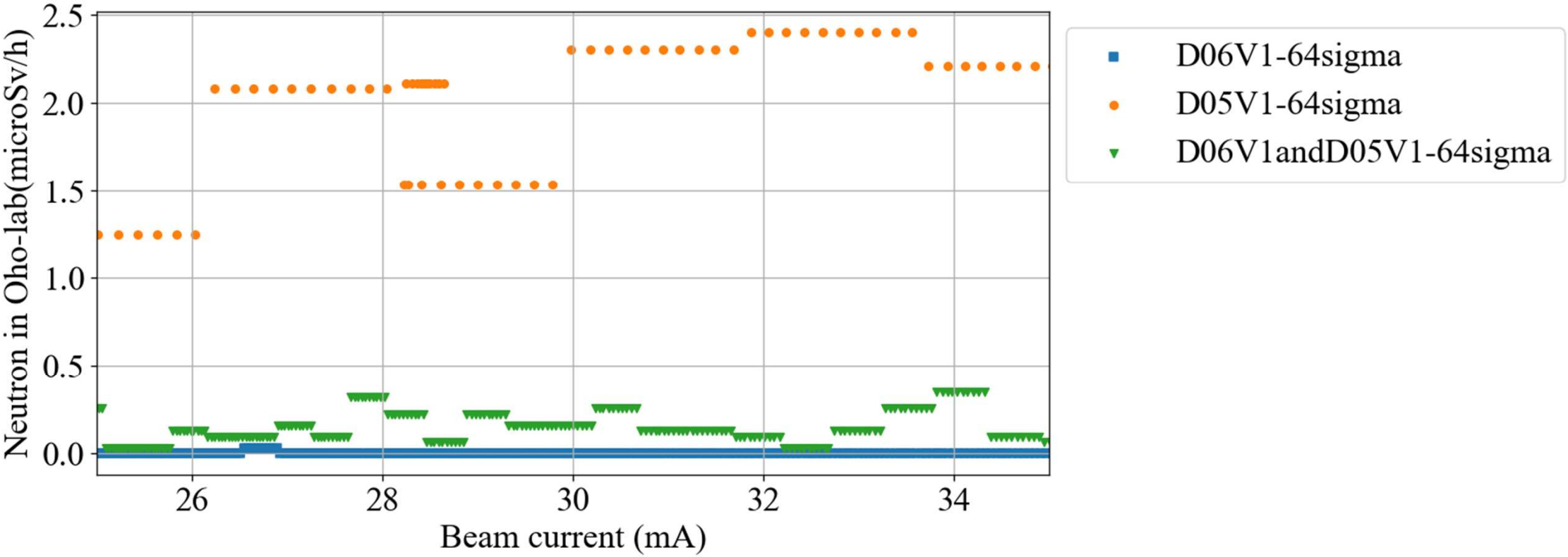


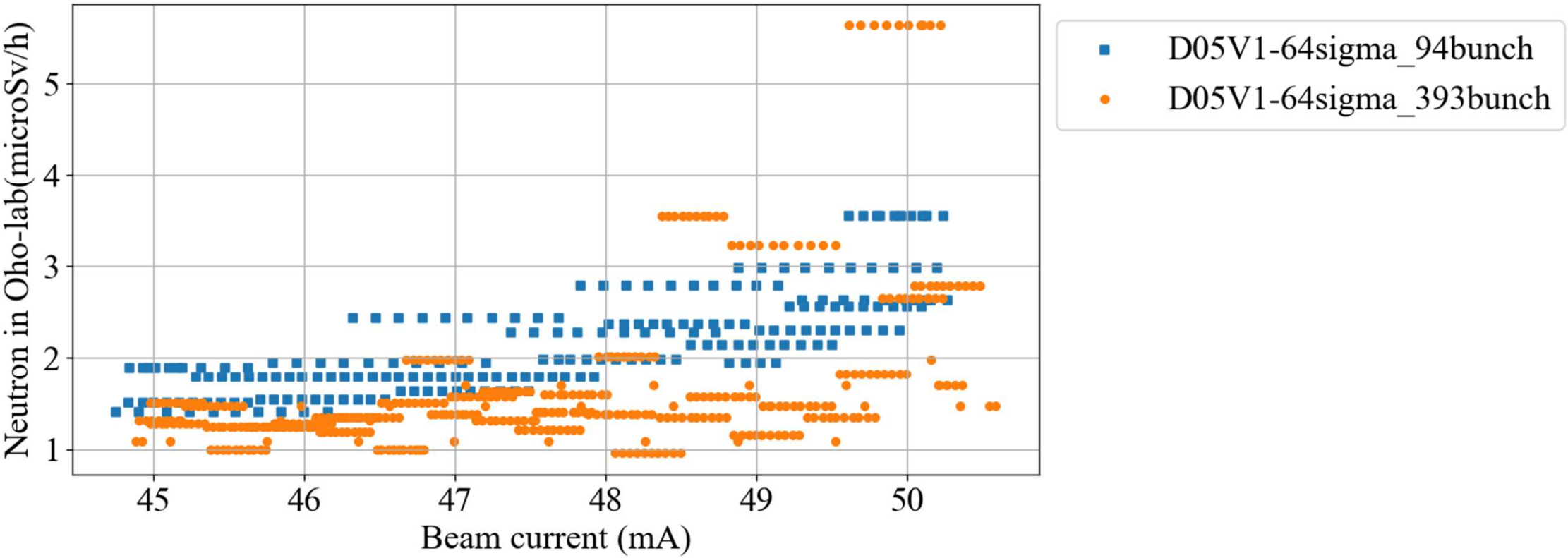


Report of nonlinear collimator(NLC) study



94 bunch
FC on
1 Hz
1 bunch injection


Neutron in Oho-lab(microSv/h)
2.5
2.0
1.5
1.0
0.5
0.0
26
28
30
32
34
Beam current (mA)
D06V1-64sigma
D05V1-64sigma
D06V1andD05V1-64sigma


Neutron in Oho-lab(microSv/h)
1
2
3
4
5
45
46
47
48
49
50
Beam current (mA)
D05V1-64sigma_94bunch
D05V1-64sigma_393bunch