

# Joint beam study coherent tune shift

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**KEK / J-PARC**

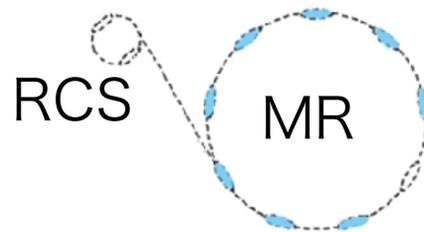
US-Japan meeting on Accelerators and Beam Equipment  
for High-Intensity Neutrino Beams

Accelerator Session

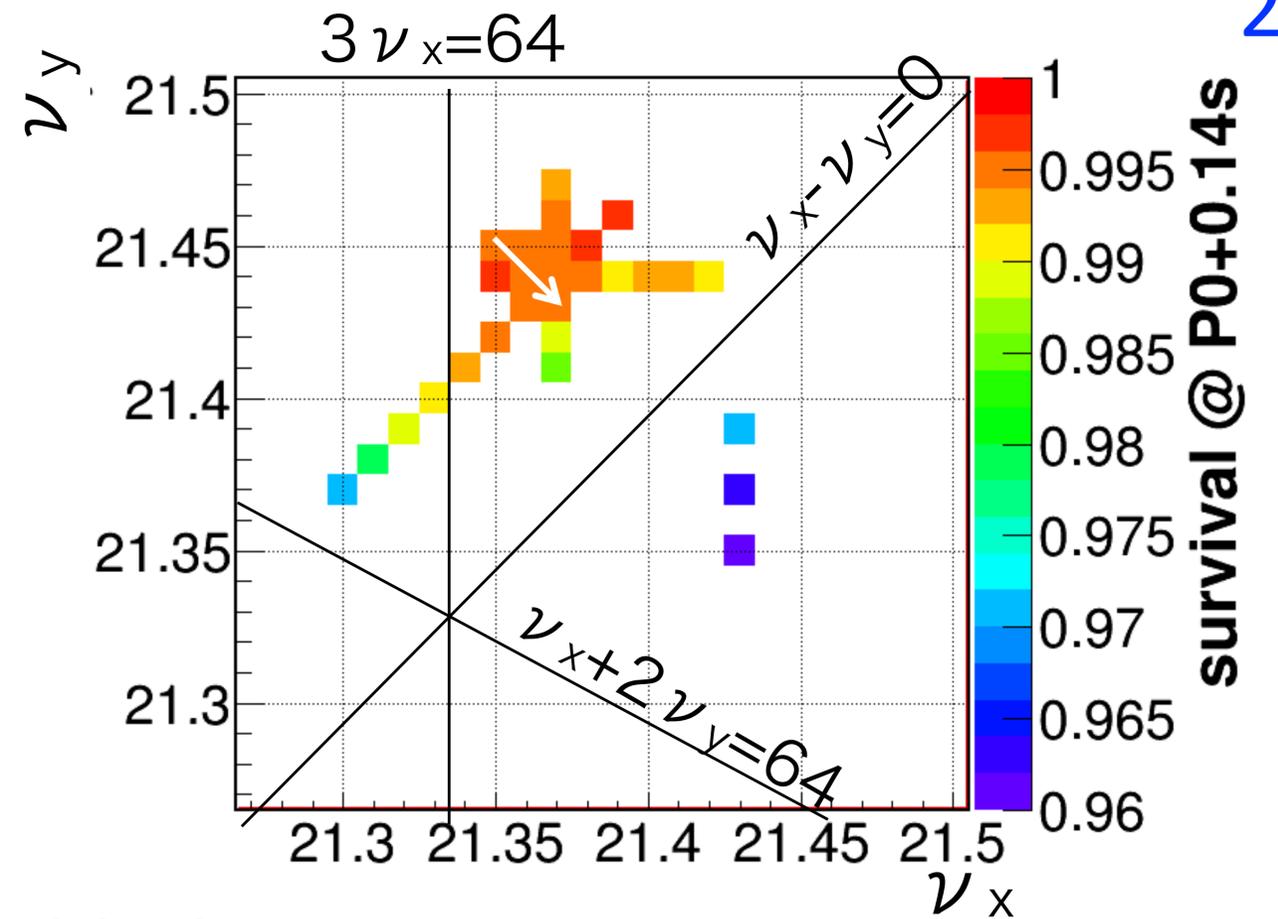
**21 Mar 2019**

# Motivation : tune shift correction at J-PARC MR for higher beam intensity

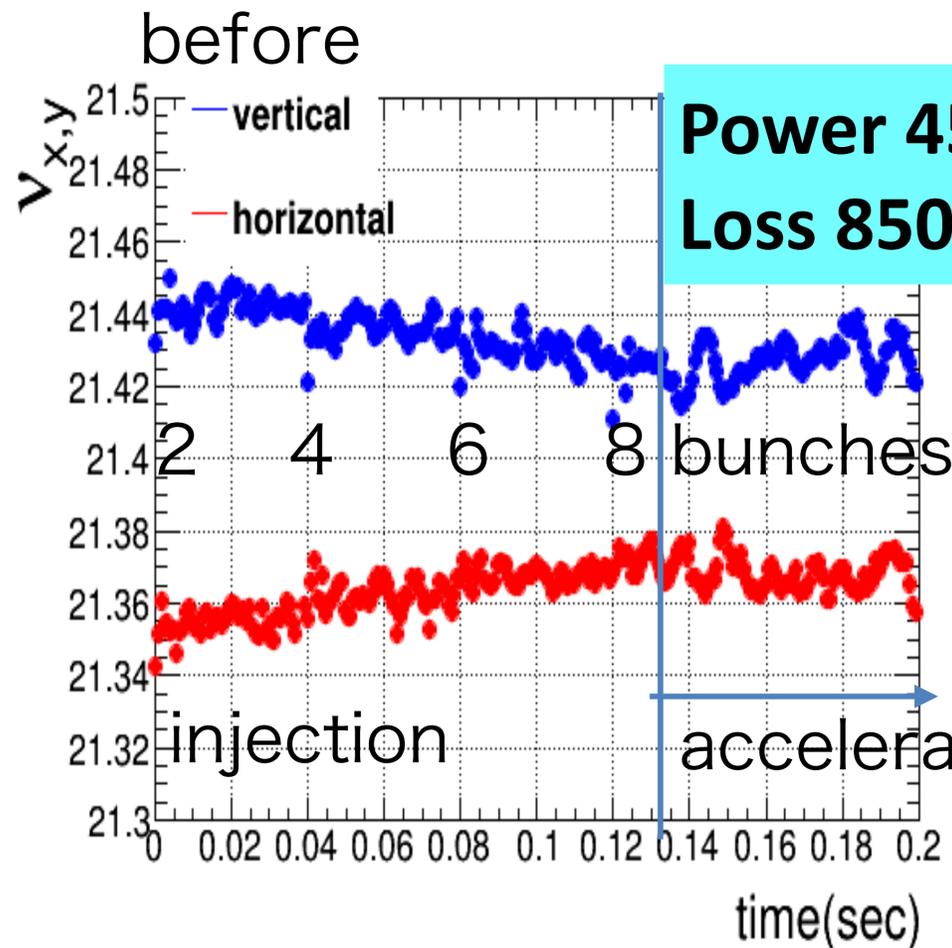
bunch train tune shift correction is one of necessary element for higher beam power.



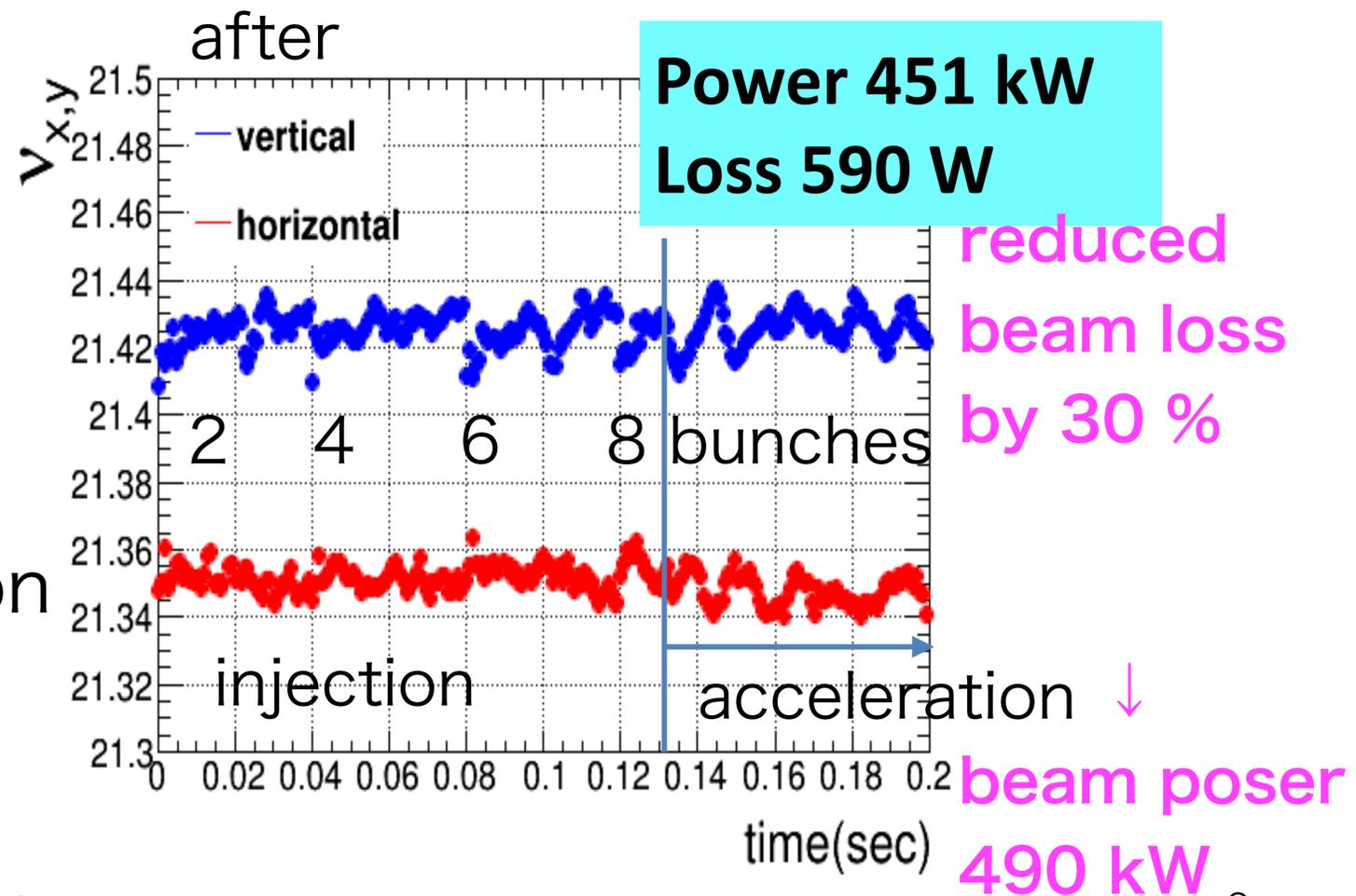
2 bunches x 4 times injections



2017 Dec.



correction



collaborated with MR monitor, beam comm. and magnet groups

# Motivation : current status

Estimations on the effects from beam impedance for tune shift are necessary.

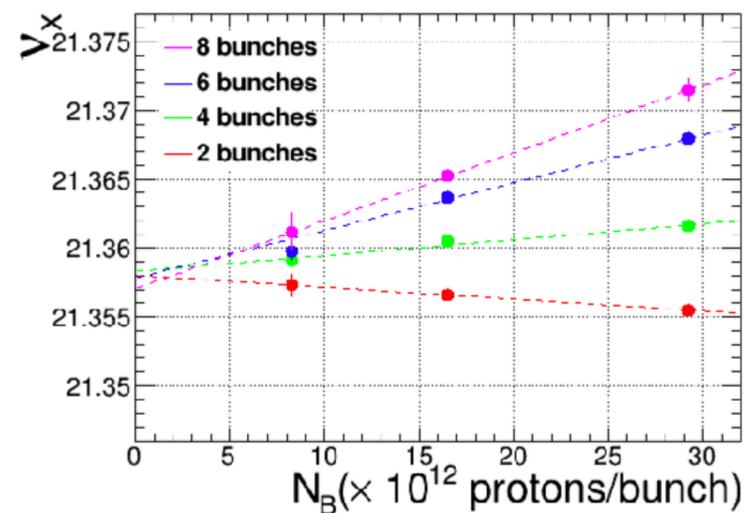
- intensity, number of bunches and bunching factor dependences
- difference of single bunch and multi bunches of tune shifts

- Simplified models based on main transverse-impedance sources : space charge and resistive wall
- It explains qualitatively the origin of bunch-train tune shift.

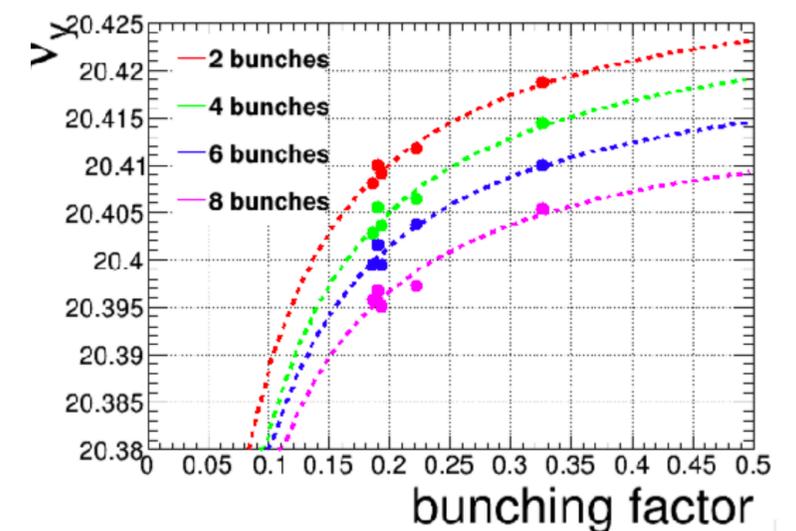
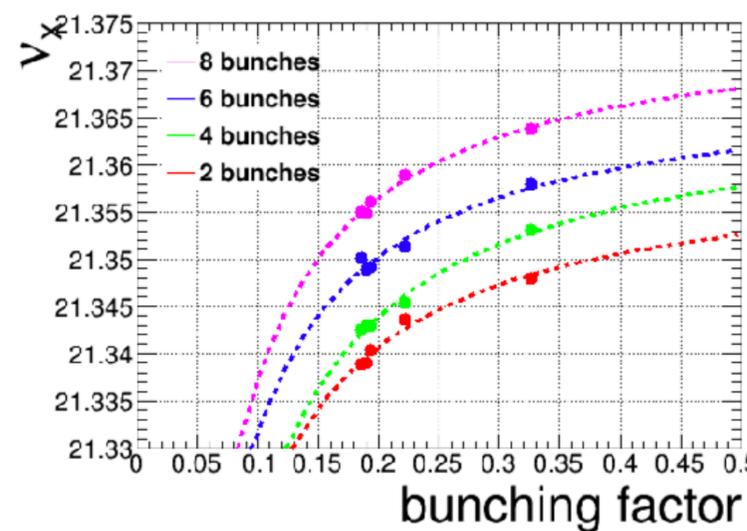
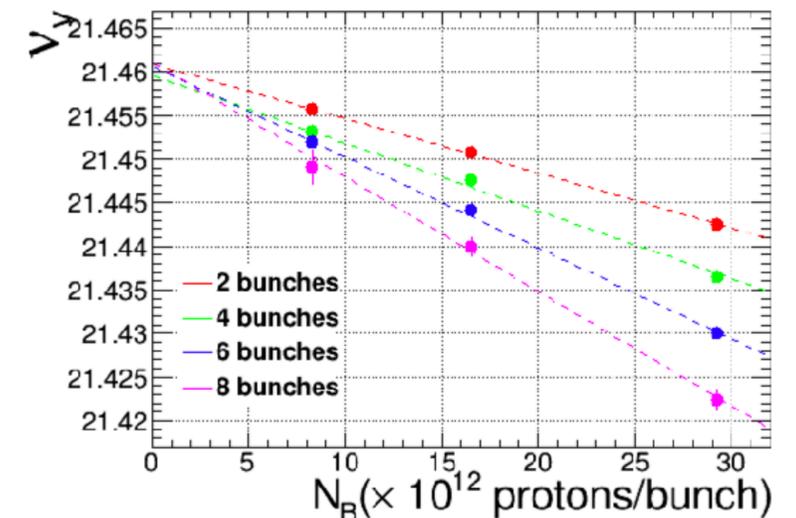
Lastlett (B.Ng)

$$\Delta\nu_{\text{coh}}^{H,V} = -\frac{Nr_oR}{\pi\nu_{H,V}\gamma} \left( \frac{\xi_1^{H,V}}{\beta^2 B_f h^2} + \frac{\epsilon_2^{H,V}}{g^2} F - \frac{\xi_1^{H,V} (1/B_f - 1)}{h^2} - \frac{\xi_1^{H,V} - \epsilon_1^{H,V}}{h^2} \right)$$

horizontal



vertical



dots : measured, dashed lines : fitted



# Joint beam study at FNAL RR

- 19 March 2019
- Rob Ainsworth, Aine Kobayashi and Kenichirou Satou
- **Recycler Ring**

(Thank you very much for arranging this opportunity, zKiyomi, Bob, FNAL peoples and US-Japan collaboration.)

[Studied menu]

- intensity, number of bunches and bunch length dependences : done last year for horizontal direction
- **intensity dependences**
- **number of batches dependences**
- **batch spacing dependences**

# Intensity dependence

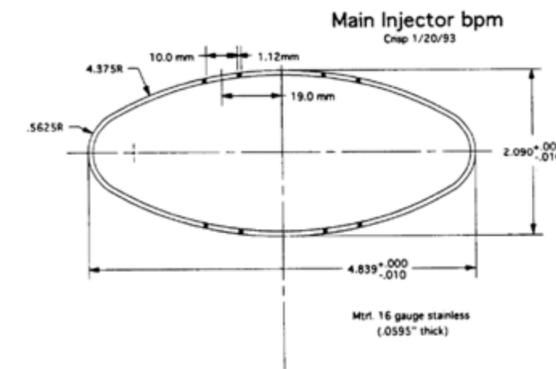
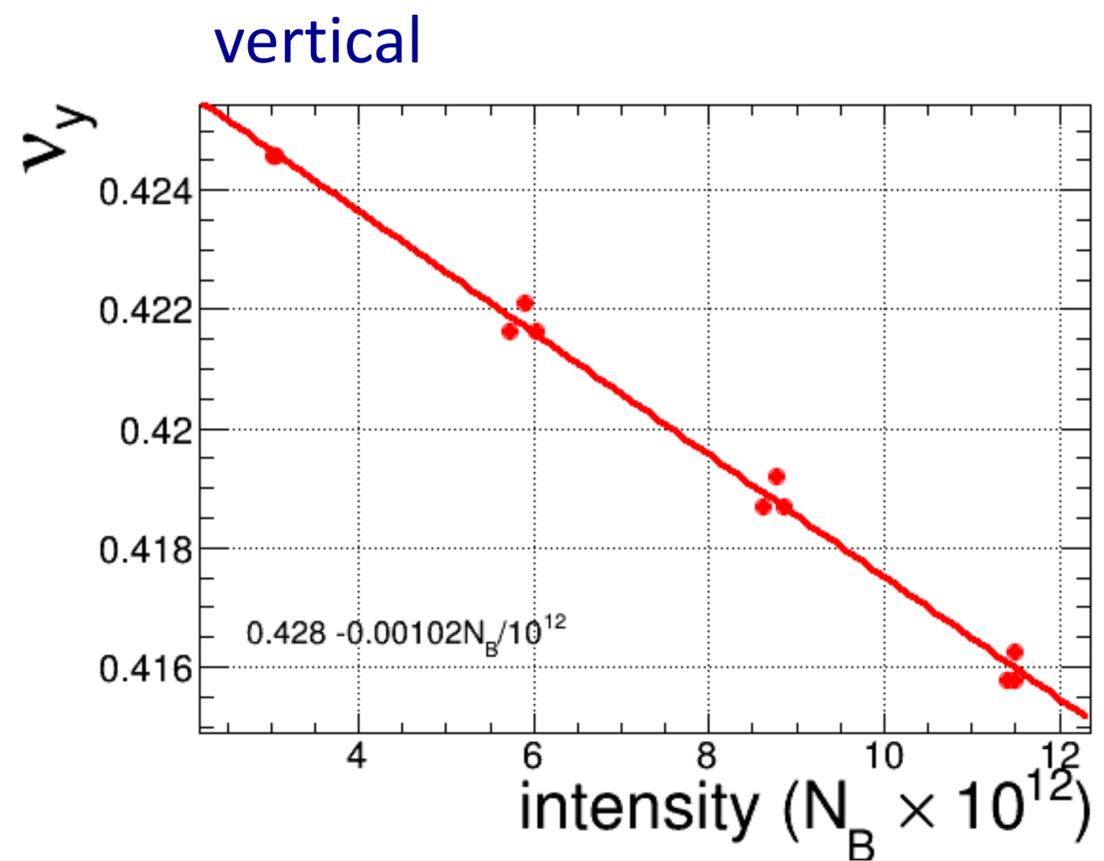
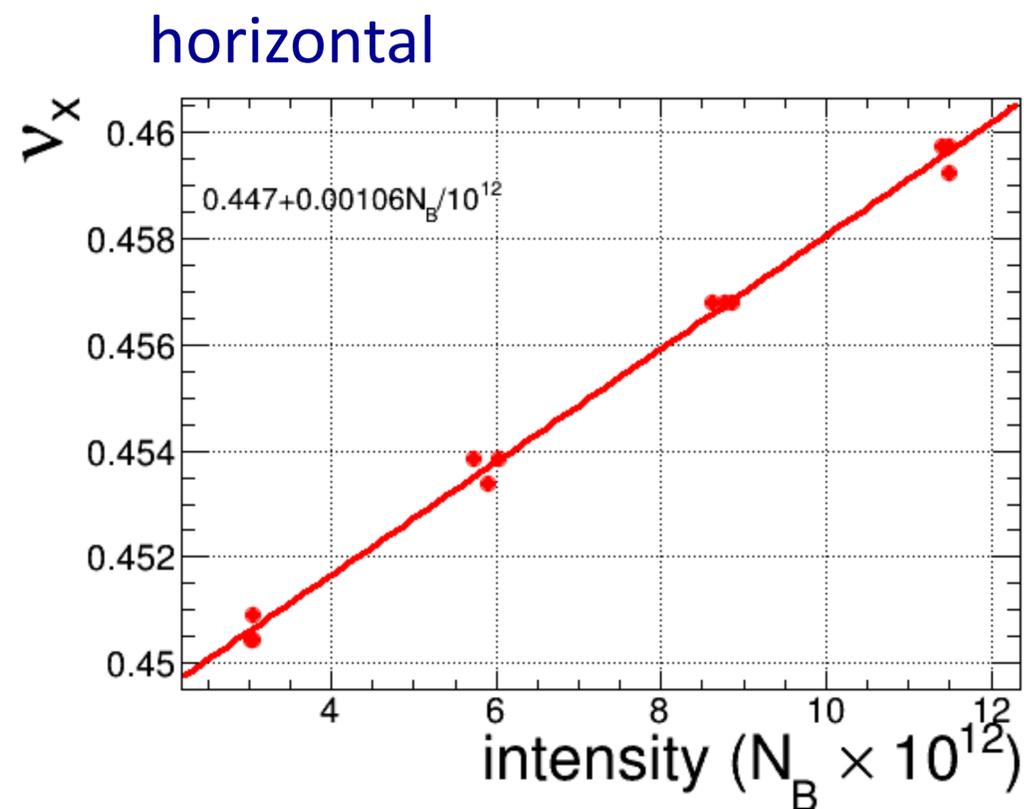
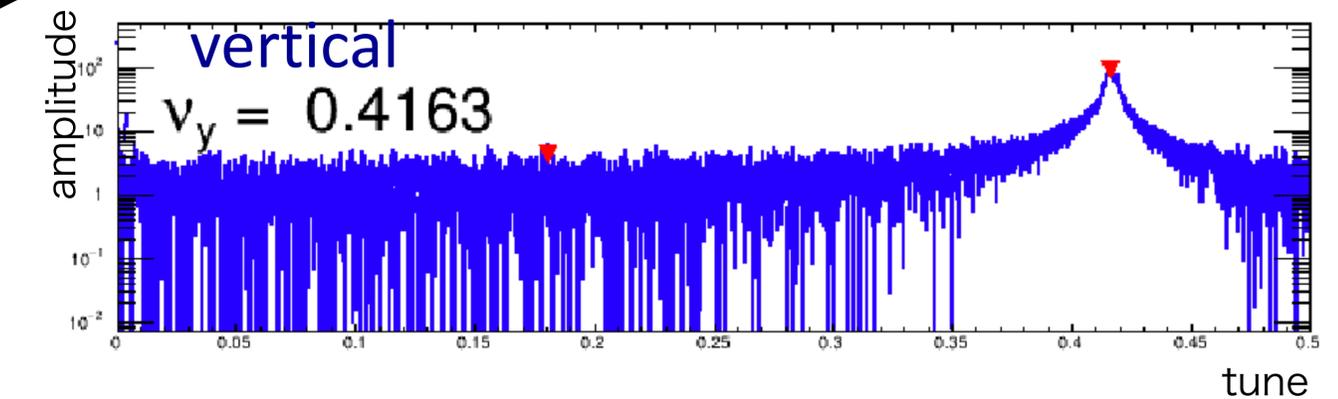
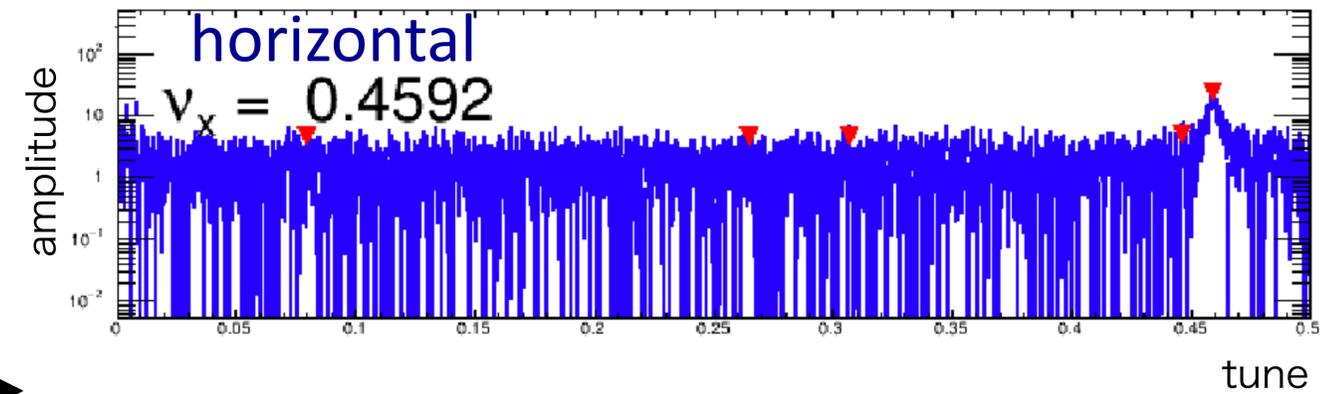
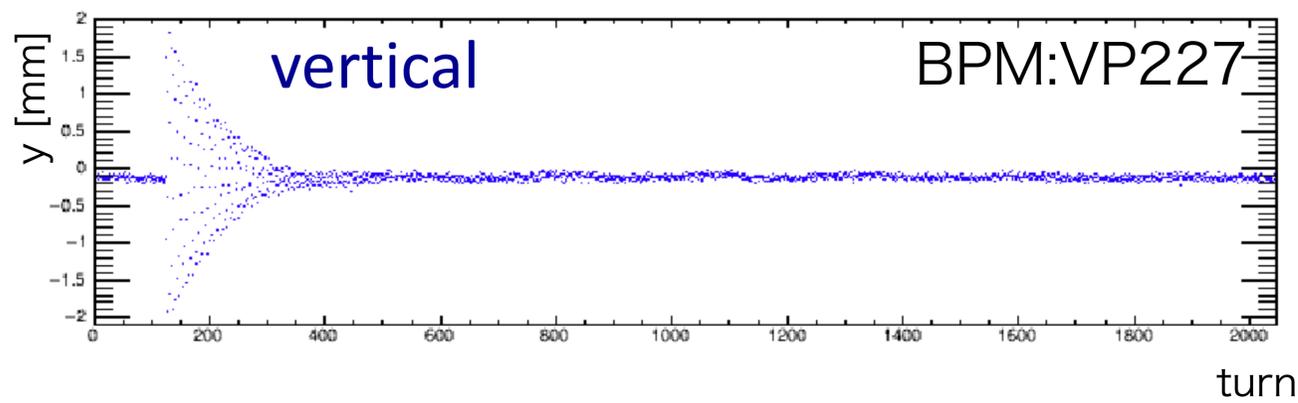
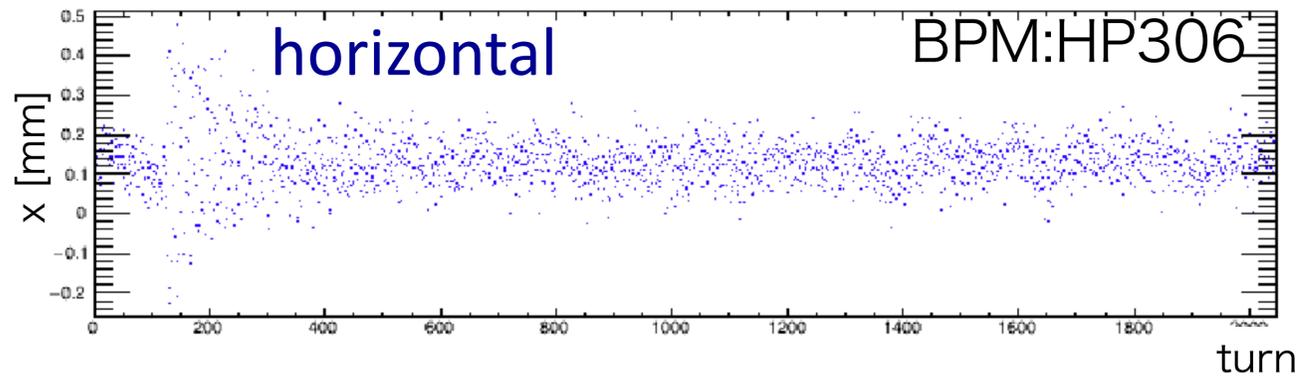
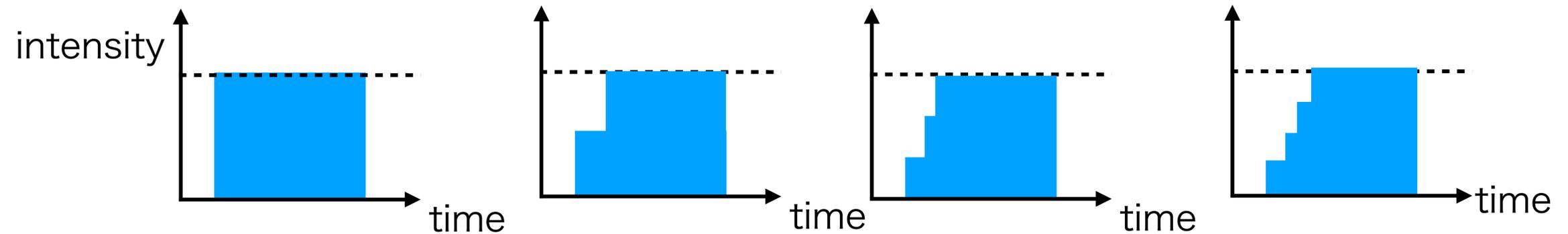


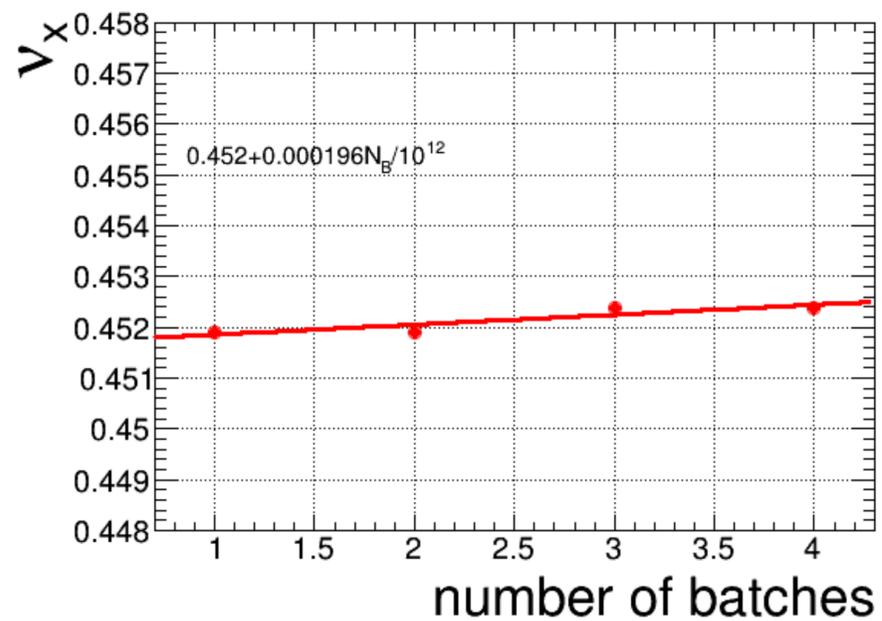
Figure 1: Geometry of Main Injector Beampipe and Beam Position Monitor.



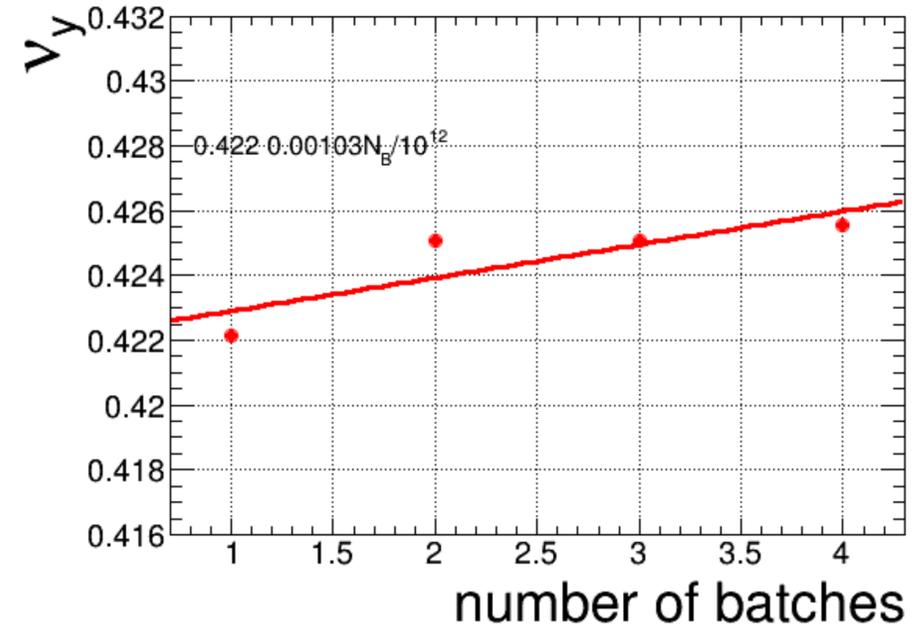
# Number of batches dependence at constant intensity



horizontal



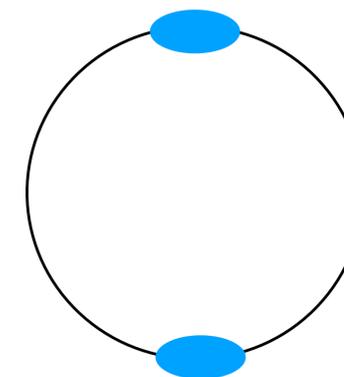
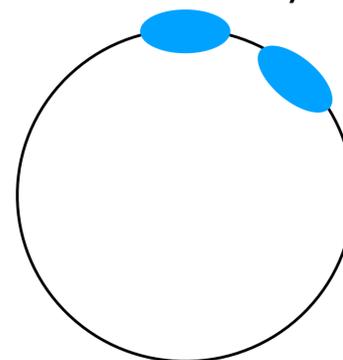
vertical



consistent within the error (need to normalise intensity)

# Batch space dependence

81 bunches/1 batch

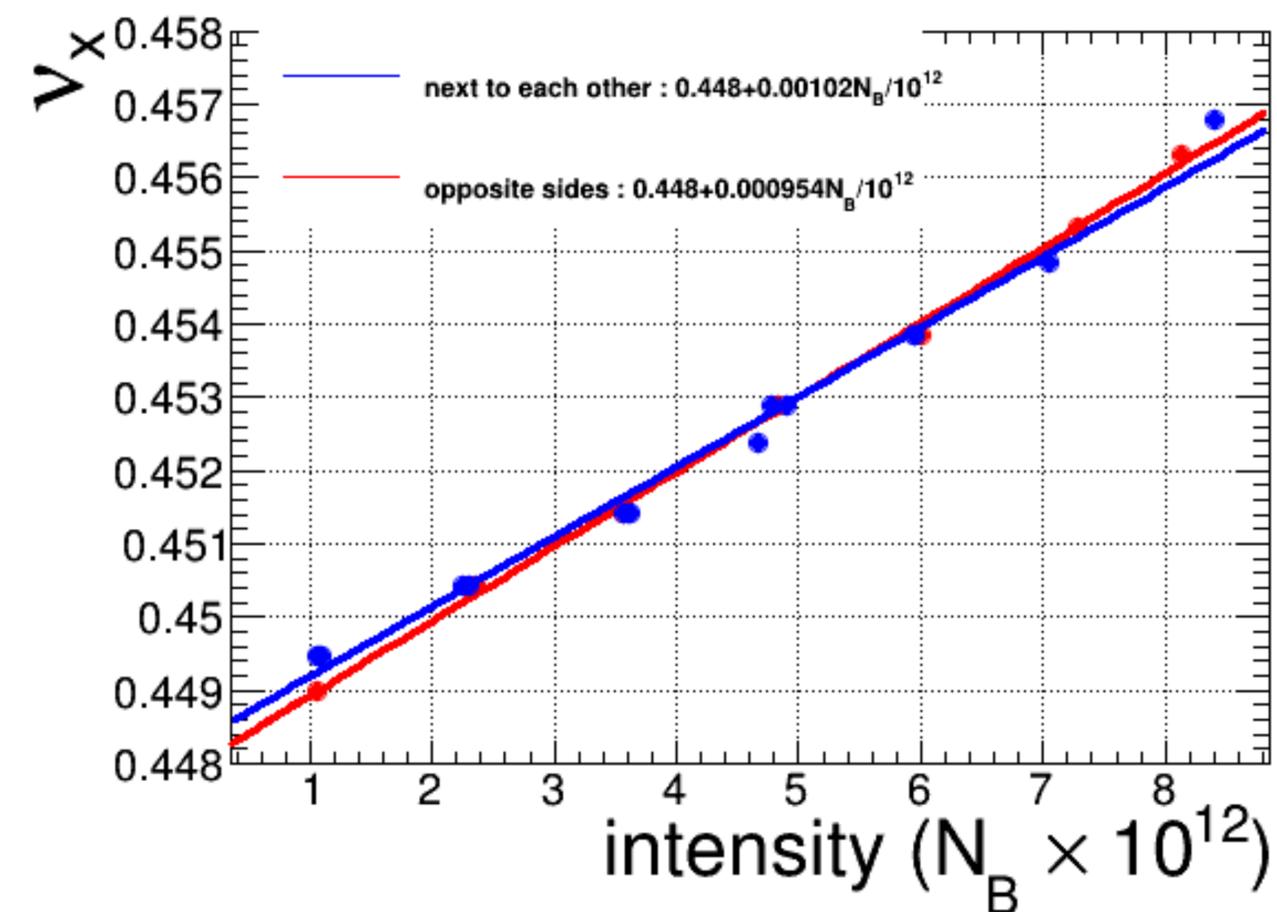


2 batches

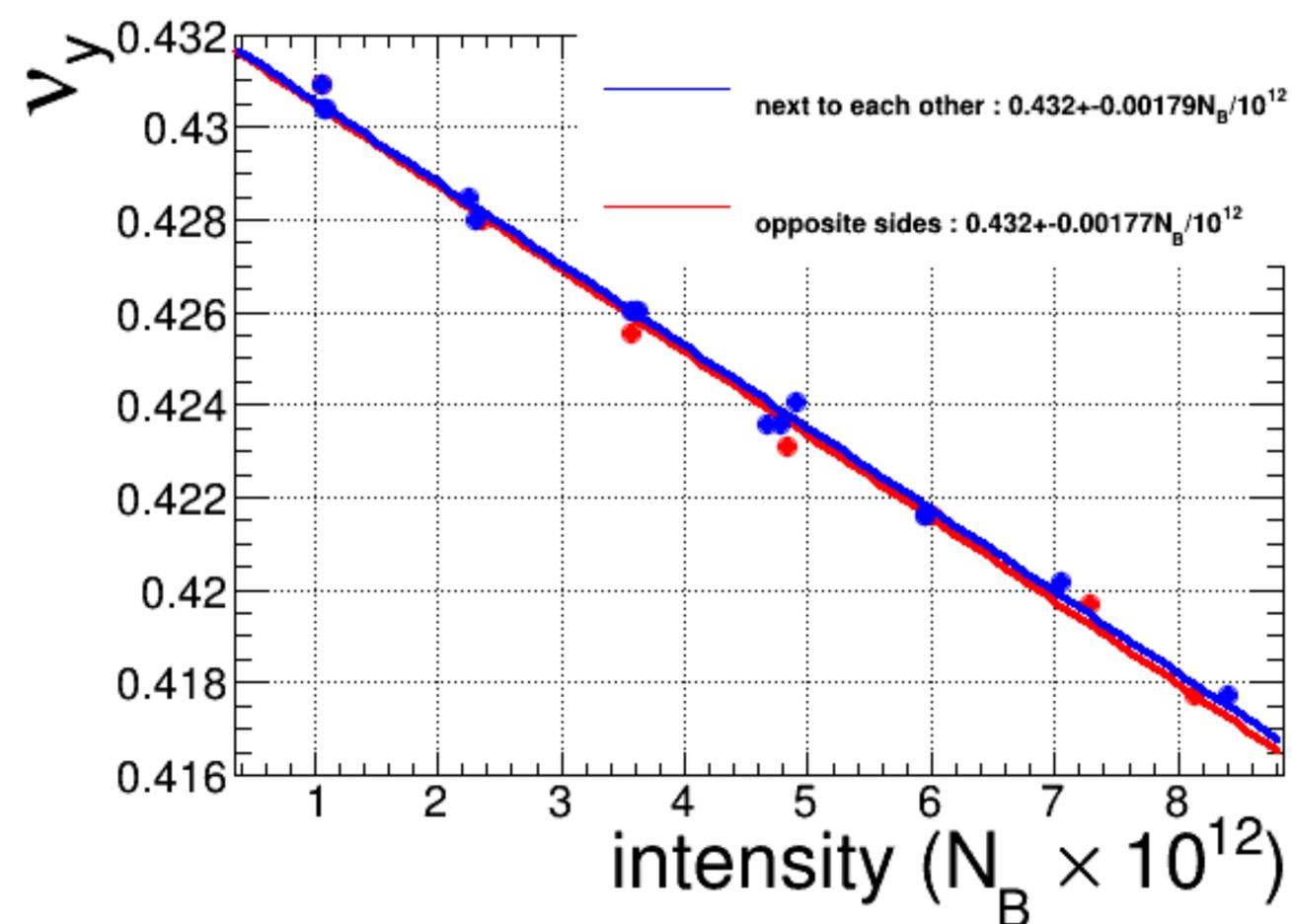
— next to each other

— opposite sides

horizontal

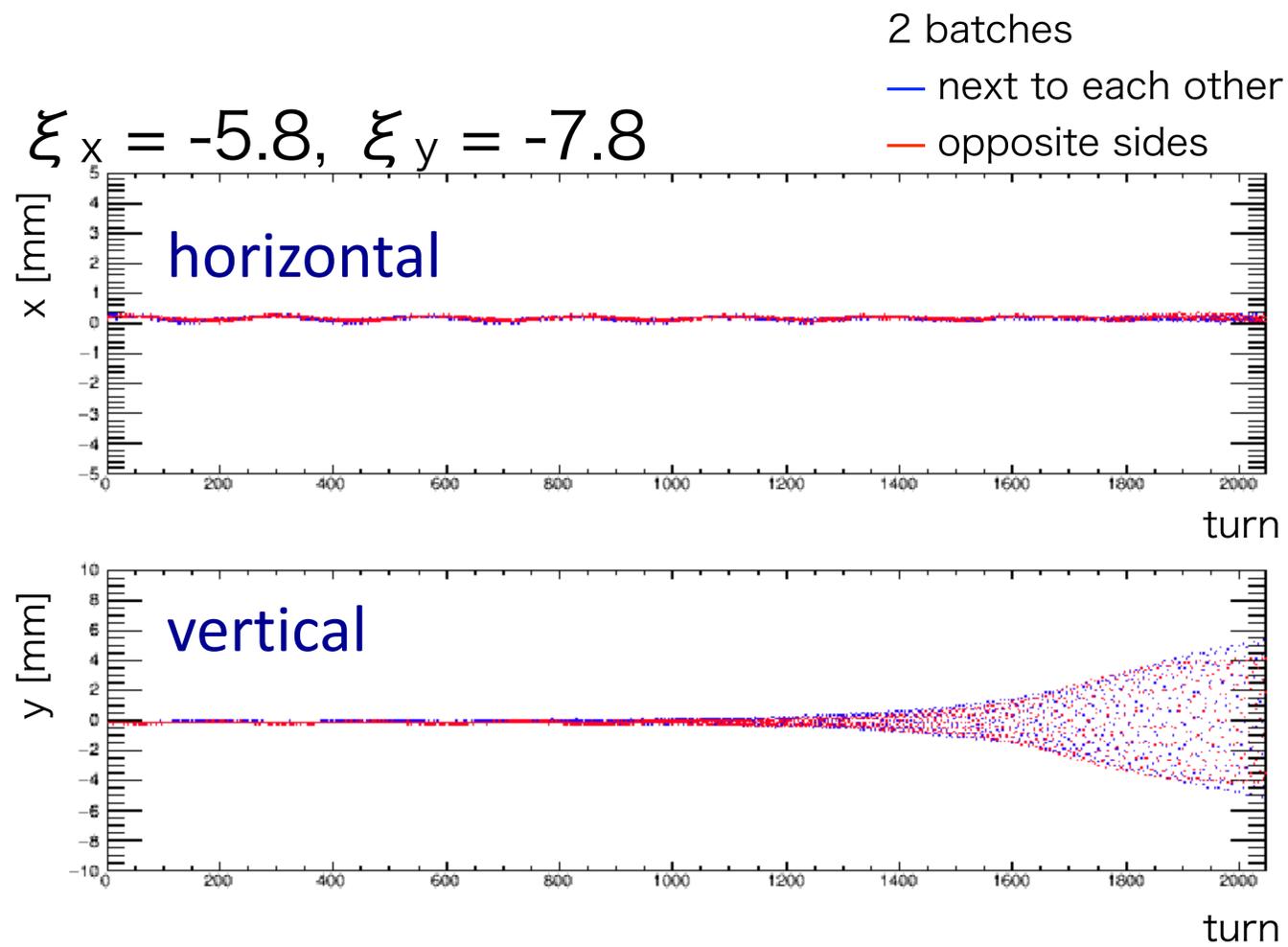
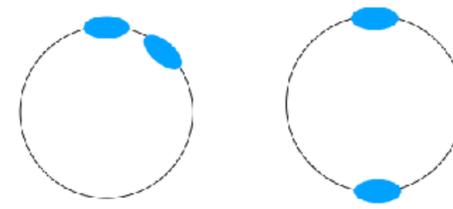


vertical

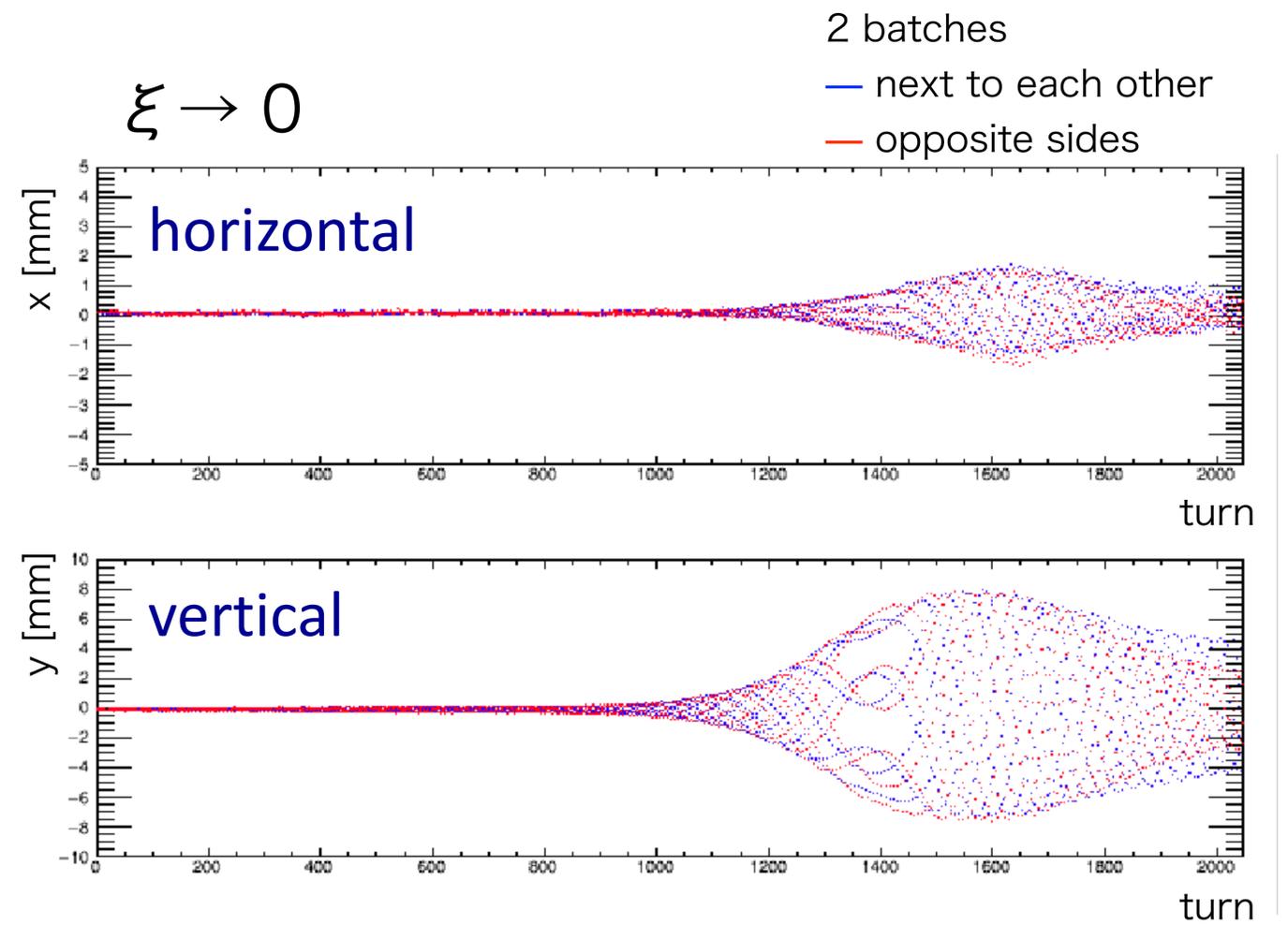


Consistent with two filling patterns.

# Imaginary part of the tune shift growth rate measurement



$8.2 \times 10^{12}$  ppp



$8.1 \times 10^{12}$  ppp

Consistent with two filling patterns for both achromaticity settings.

## Summary

- For higher beam intensity, understanding of tune shift mechanism is necessary.
- For make a comparison between data and models, we had joint beam study at FNAL RR.
- Intensity dependences and number of batches dependences of tune shifts were observed for both horizontal and vertical directions.
- No apparent difference was observed in tune slope with different batch distances.

## To do

- Precise analysis of data and compare models.
- Investigate on the impact of the wake length for other batches.

backups

## **Tune shift study in J-PARC MR**

[Collaborators]

Aine Kobayashi, Takeshi Toyama, Yoichi Sato, Susumu Igarashi, Testushi Shimogawa, Fumihiko Tamura, Yasuyuki Sugiyama and Masahito Yoshii

[Acknowledgements]

Yong Ho Chin, Kazuhito Ohmi, Yasuhiro Shobuda, Kenichirou Satou, Hironori Kuboki, Jumpei Takano and all MR members

JSPS KAKENHI Grant-in-Aid for Specially promoted Research, JP16H06288

## **Tune shift study in FNAL RR**

[Collaborators]

Aine Kobayashi, Robert Ainsworth

[Acknowledgements]

Kiyomi Seiya, Kenichirou Satou and US-Japan collaboration

US-Japan budget

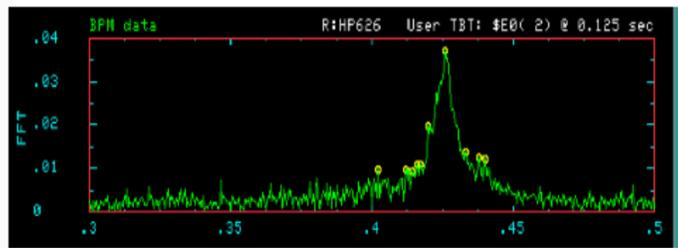
# Last year

FNAL RR

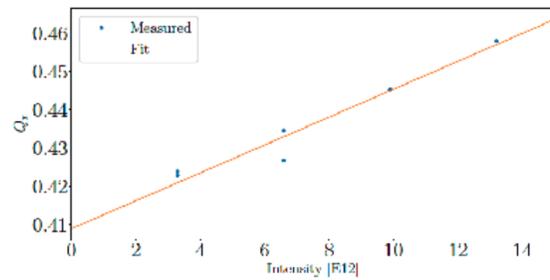
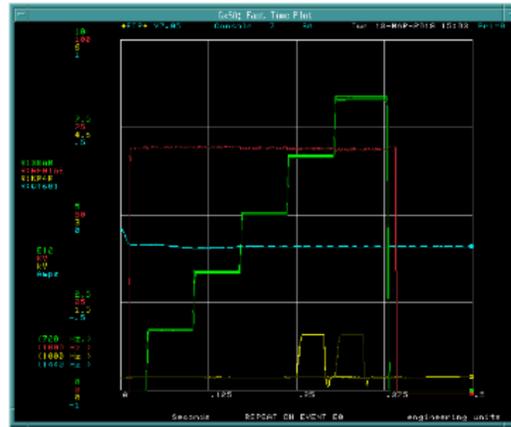
## Impedance and BPM related measurements

- tune shift measurements
  - number of bunches dependence
  - bunch length dependence
- COD rms measurements

intensity :  $\sim 8 \times 10^{12}$  ppp  
81 x 5 batch injection with pinger



horizontal tune at each intensity  $\rightarrow$   
(integer : 25)  
(vertical measurement did not work well)

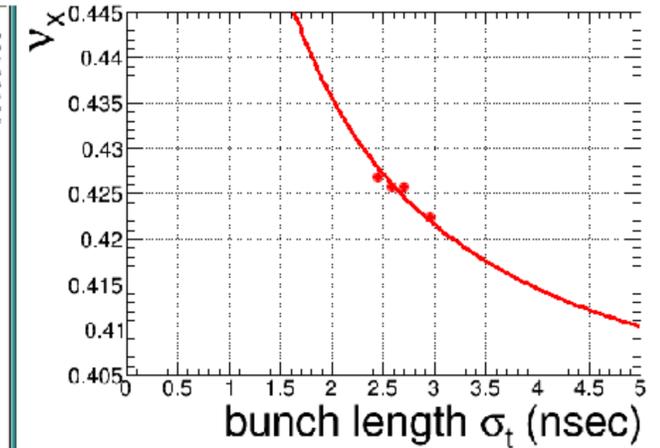
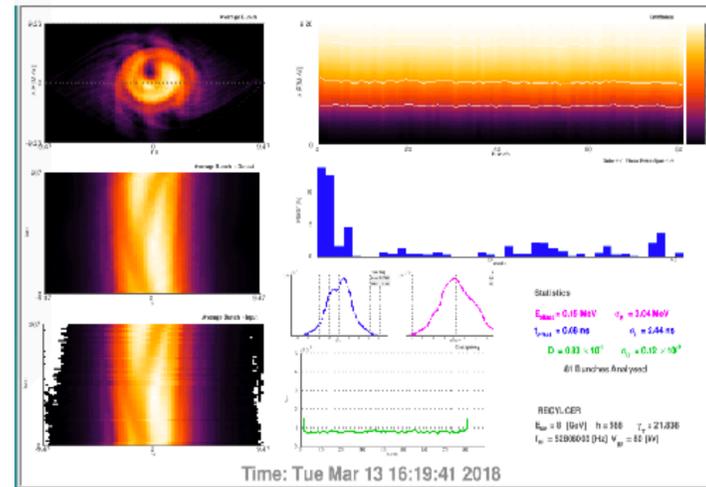


FNAL RR

## bunch length dependence

adjusted bunch length with tomography by changing the RF voltage

bunch length  $\propto$  bunching factor $^{-1}$



FNAL MI

FERMILAB-CONF-12-179-AD

## 6 BATCH INJECTION AND SLIPPED BEAM TUNE MEASUREMENTS IN FERMILAB'S MAIN INJECTOR

D. J. Scott, D. Capista, I. Kourbanis, K. Seiya, M.-J. Yan, Fermilab, Batavia, IL, 60510, U.S.A.

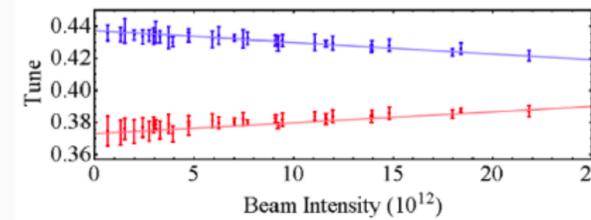


Figure 10: Expected tune vs total beam intensity (line) compared to measured tune (points) for horizontal (red) and vertical (Blue) planes.

FNAL Main Injector

[arXiv:1301.7442 \[physics.acc-ph\]](https://arxiv.org/abs/1301.7442)

Submitted on 30 Jan 2013

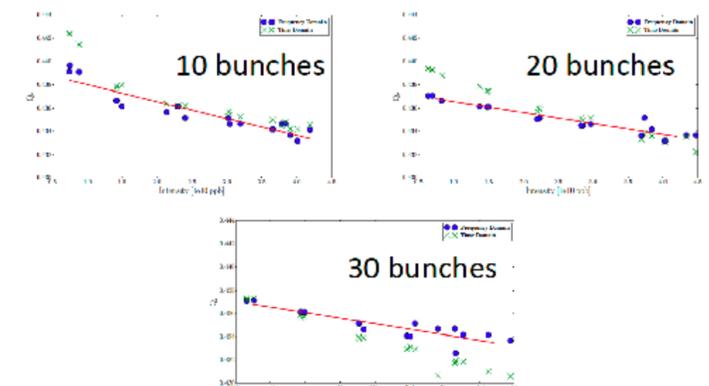
FNAL RR

## Recycler

Transverse Impedance Measurement of Recycler

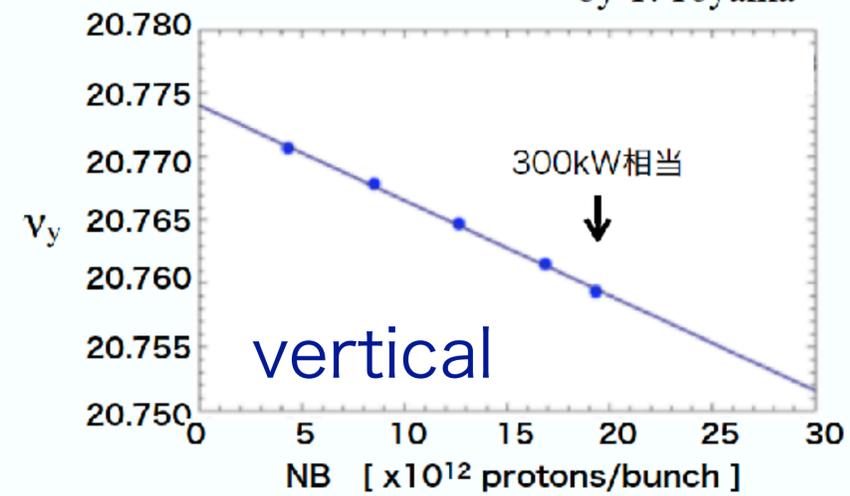
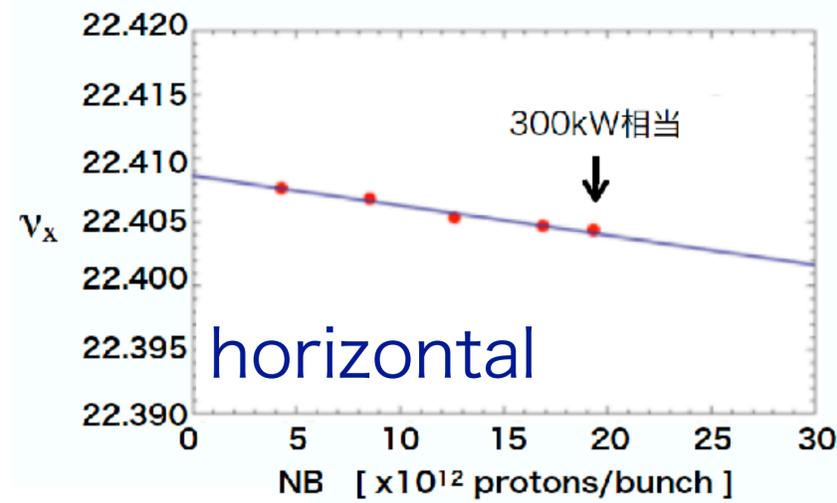
Rob Ainsworth

March 2, 2018



### Single bunch event measurements (2015/12/24)

by T. Toyama



### Multi bunch event measurements (2017/11/30)

by A. Kobayashi et al.

