IP-BSM
2-bunch operation

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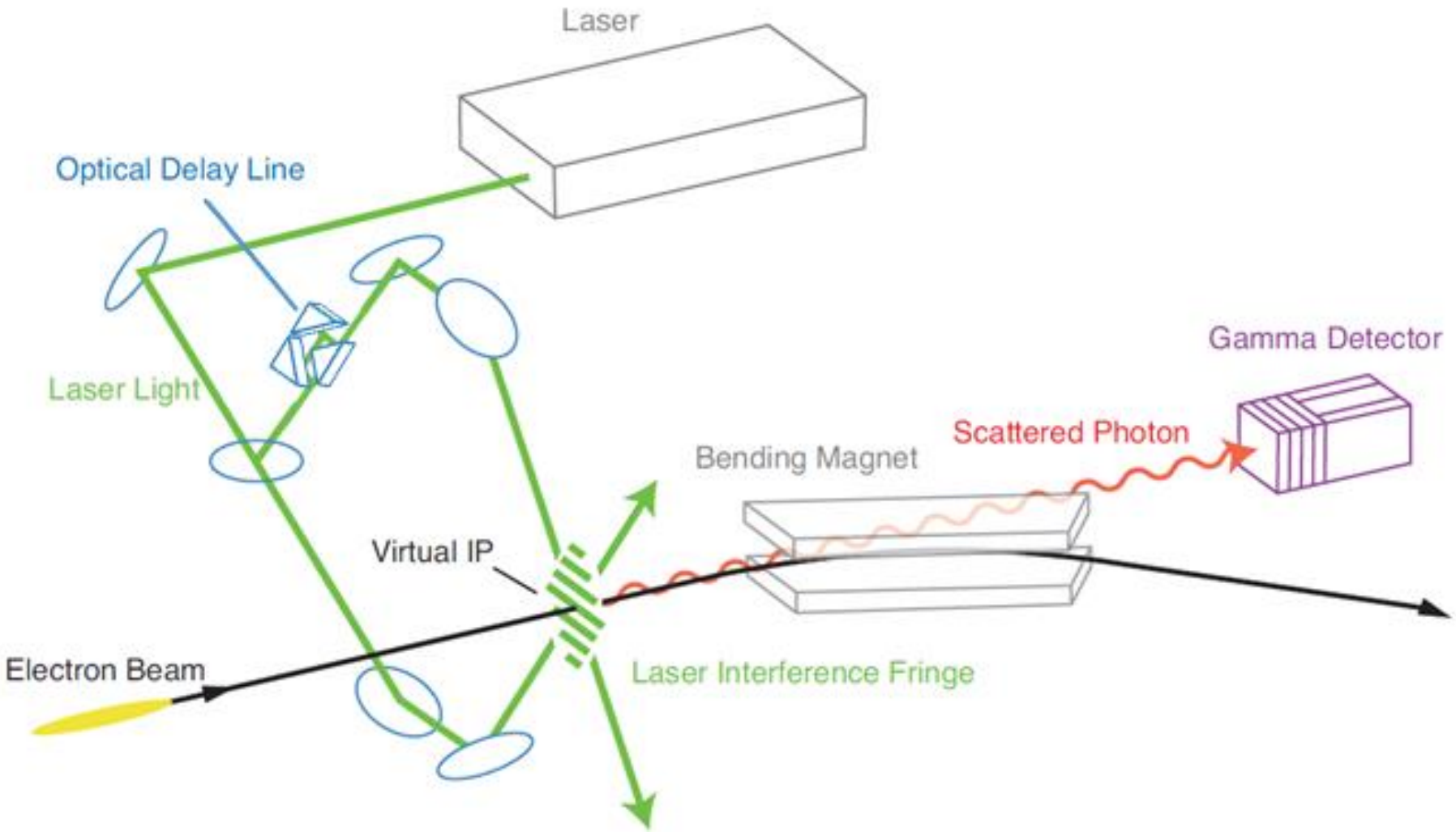
Outline

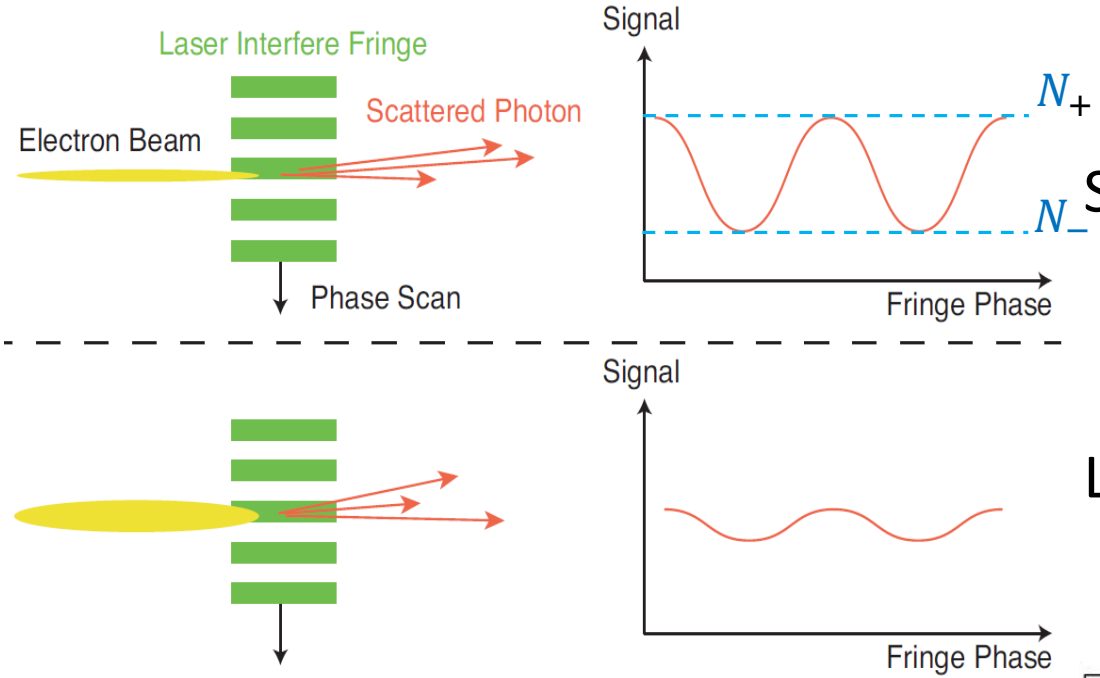
- Introduction
- IPBSM measurement with FONT upstream feedback
  - Study with jitter generation by steering magnets
  - Beam intensity dependence study
- Summary

Introduction

Setup of IPBSM



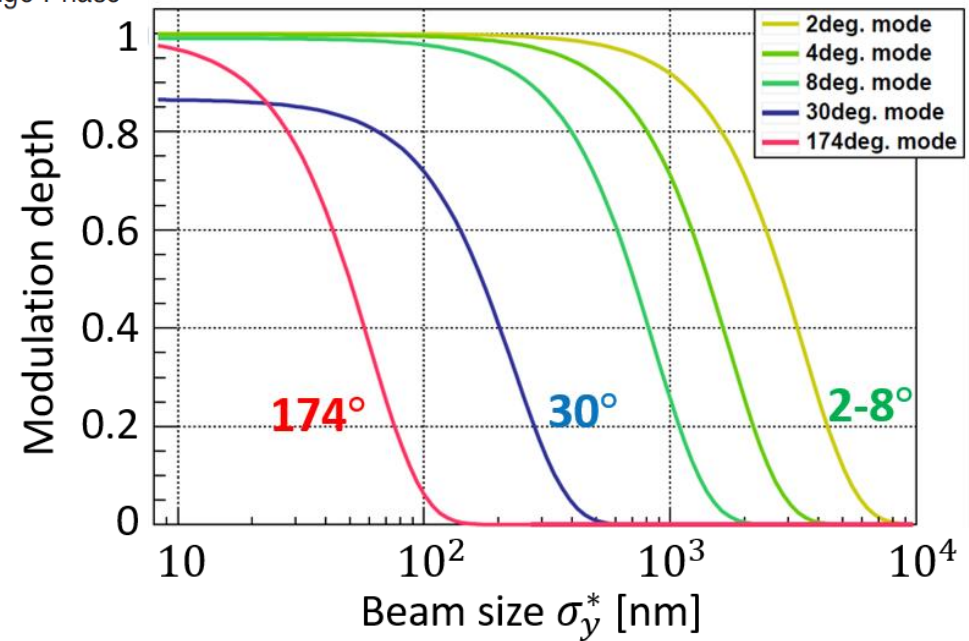
Concept of IPBSM



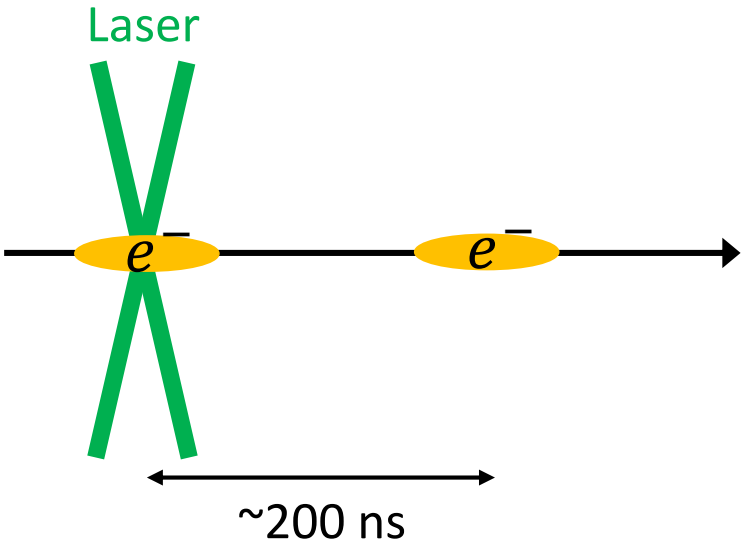
Small beam size ⇒ large M

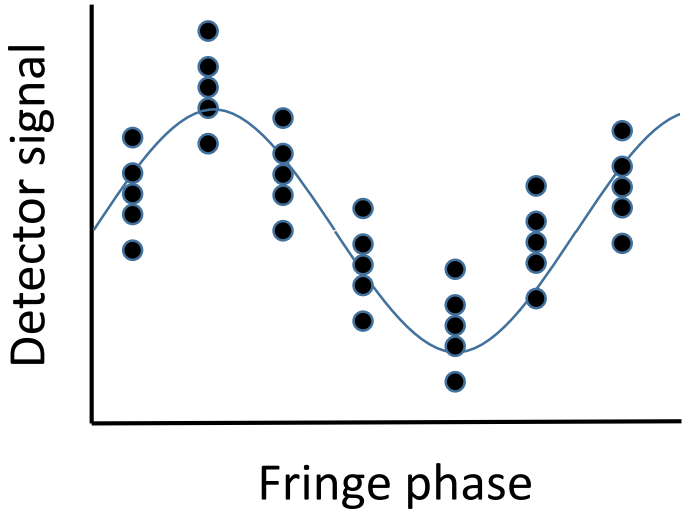
Large beam size ⇒ small M

Modulation depth $M = \frac{N_+ - N_-}{N_+ + N_-}$



2nd bunch IPBSM measurement





- Timing of the IPBSM laser is matched to 2nd bunch timing
- Beam size measurement is done by measuring 100-200 pulses
- It is not possible to measure the beam size of 1st&2nd bunch at the same time

IPBSM measurement with FONT upstream feedback

Aim

- Aim:
  - To observe the IP vertical beam orbit stabilization by FONT upstream feedback, using IPBSM
- At 2-bunch beam operation, using FONT upstream feedback, beam orbit jitter of 2nd bunch at the IP should decrease
- This effect should be observed using IPBSM as a decrease in observed beam size

Measurements

1. Study of IP beam orbit stabilization using FONT upstream feedback, with jitter generation by steering magnets

2. Study of beam intensity dependence of IPBSM Modulation, with FONT upstream feedback

1. Study with jitter generation by steering magnets

Jitter generation using steering magnets

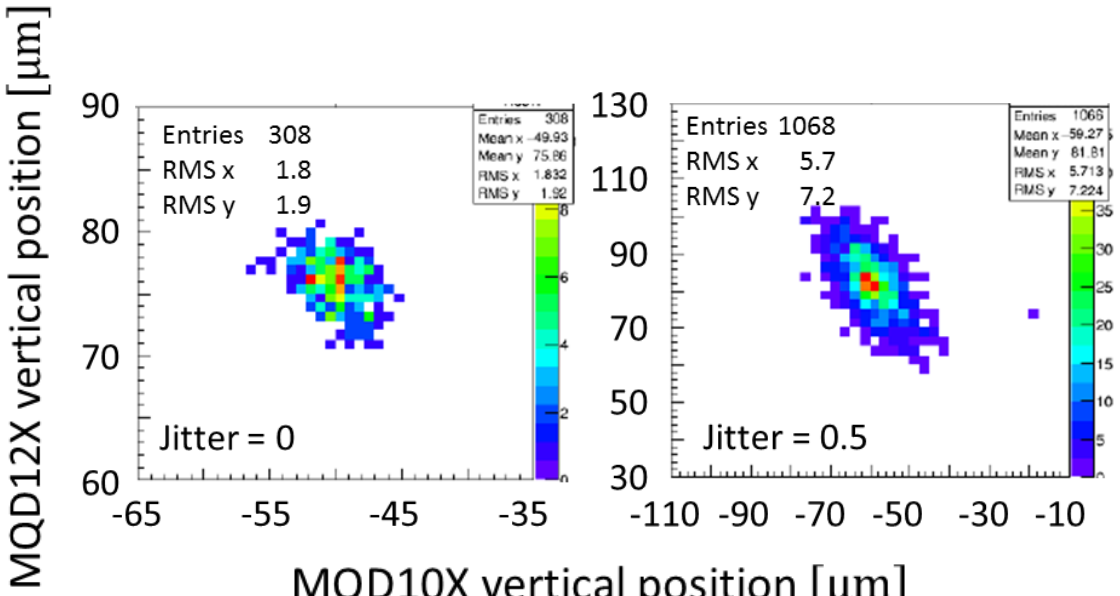
- To avoid beam size growth by wake field, IPBSM measurement should be done at low beam intensity

- At low beam intensity (e.g. $1 \times 10^9/\mathrm{pulse}$), the resolutions of FONT stripline BPMs increase to $\sim$ 1-2 μm
  - At these BPMs, $\sigma_y \sim 6\mu\mathrm{m}$ and vertical jitter is $\sim 2\ \mu\mathrm{m}$
  - Effect of orbit stabilization may not be clear

- 2 steering magnets are used to generate large vertical orbit jitter, so that the effect of orbit stabilization will be clear

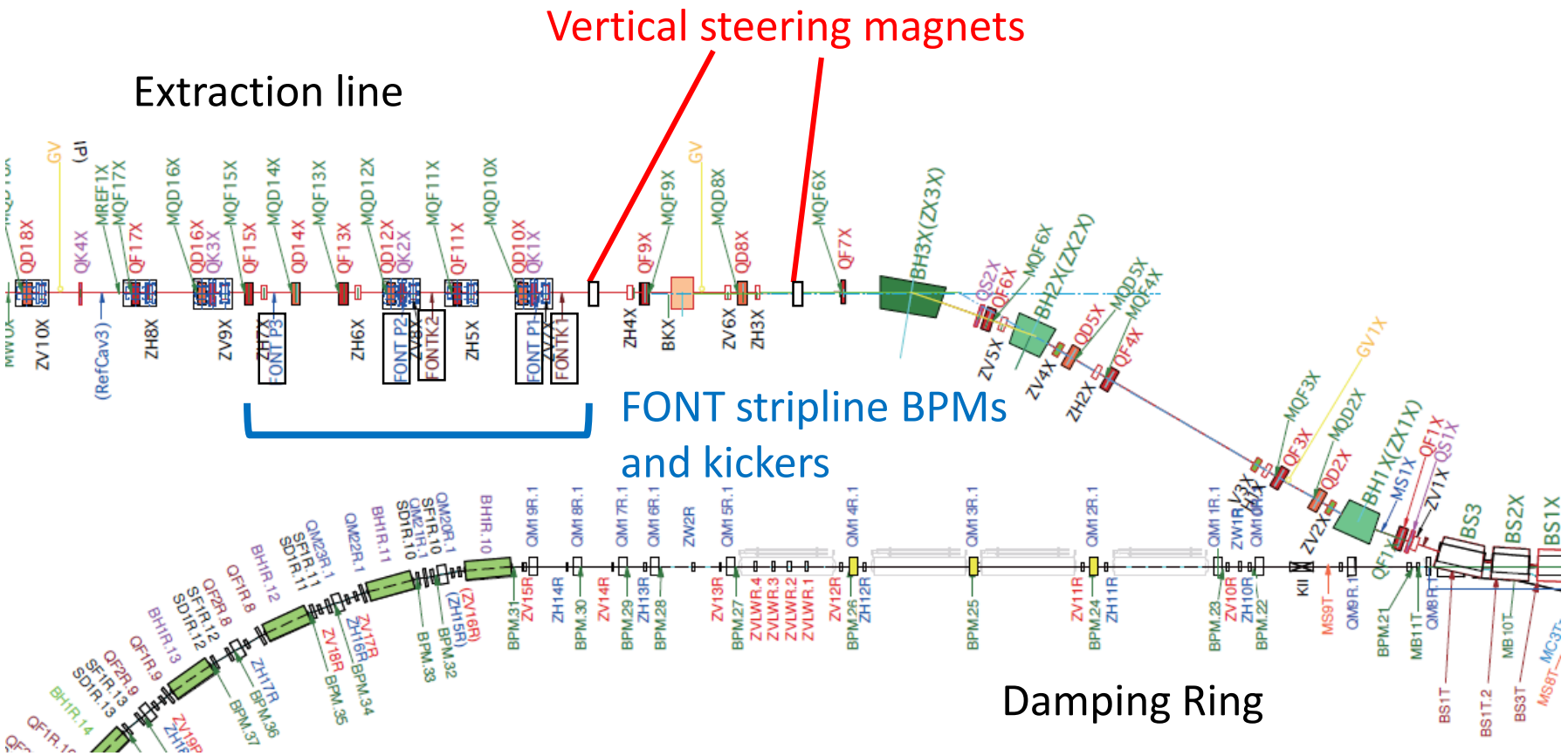
Jitter generation using steering magnets

- 2 air-core steering magnets are installed in the extraction line
  - Vertical phase is $\sim 90°$ apart
- Currents which follow Gaussian distributions are applied
  - ZVFB1X: $I_1 \sim N(I_{1,0}, \sigma_1)$
  - ZVFB2X: $I_2 \sim N(I_{2,0}, \sigma_2)$
- Values of σ are scaled to change the magnitude of jitter
  - $\sigma_1 = 0.20 * J$ [A]
  - $\sigma_2 = 0.50 * J$ [A]



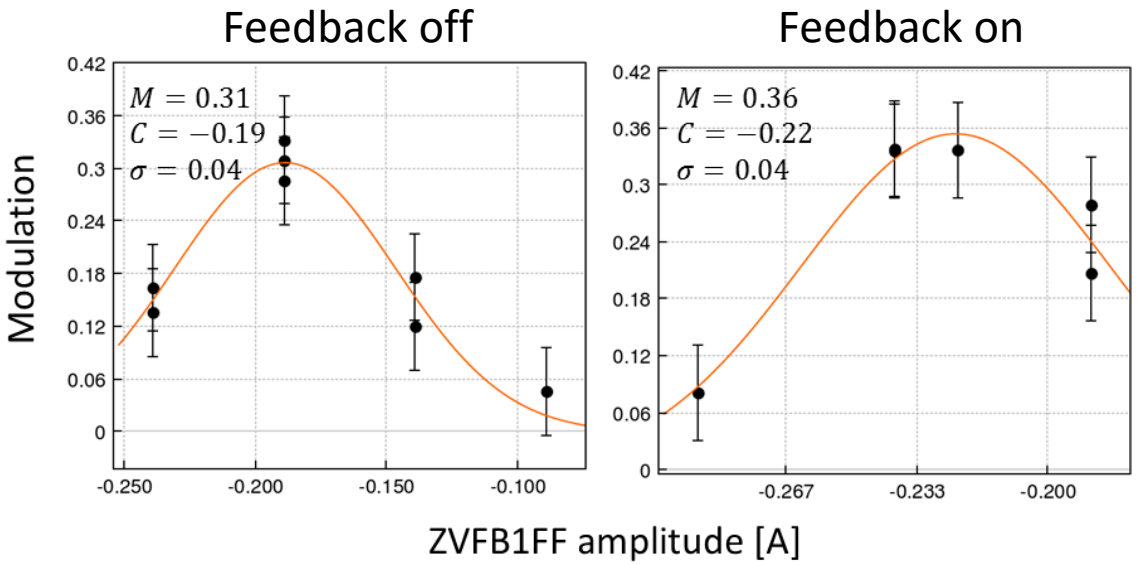
(plots by Okugi-san)

Placement


Vertical steering magnets
Extraction line
FONT stripline BPMs and kickers
Damping Ring

Procedure

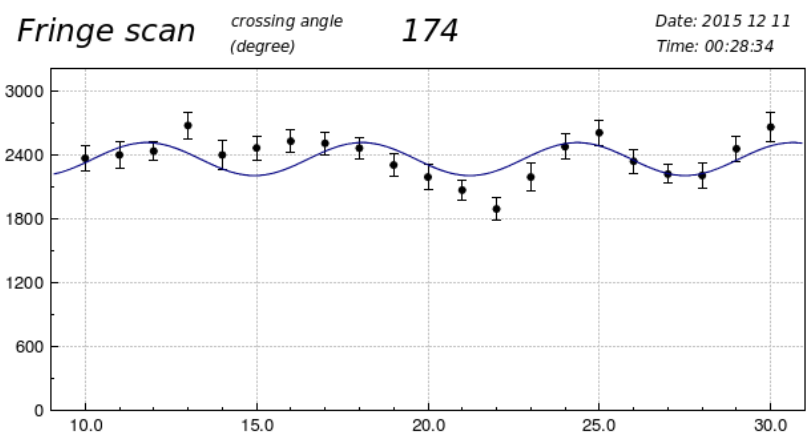
- ZVFB1FF amplitude tuning was done, before doing measurements with feedback on/off
  - ZVFB1FF: vertical steering magnet in the FF
  - This is because the center value of the vertical beam position may change, using FONT feedback
- Thus, the condition of measurements with feedback on/off is not completely the same



IPBSM 174 deg mode measurement

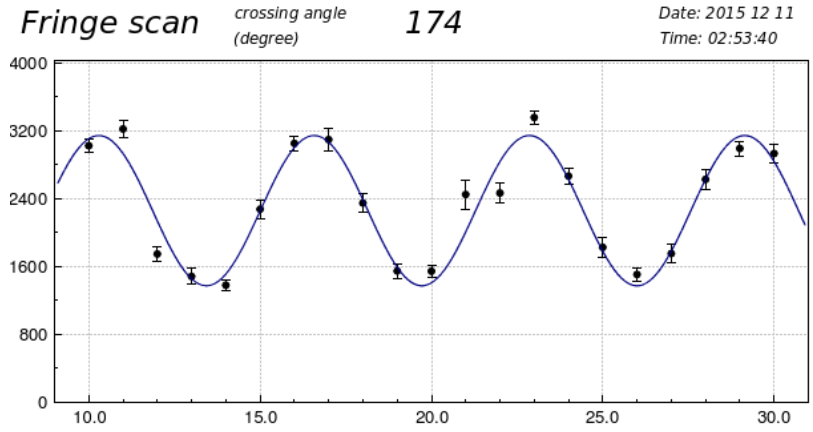
Cherenkov detector signal [CH]

Feedback off



Modulation: 0.066 +/- 0.014
Beam Size: 98.8 + 4.4 -3.6 nm
Average: 2362.332 +/- 24.554
Phase: 0.774 +/- 0.230
Chi2/ndf: 4.0072e+01 / 18

Feedback on



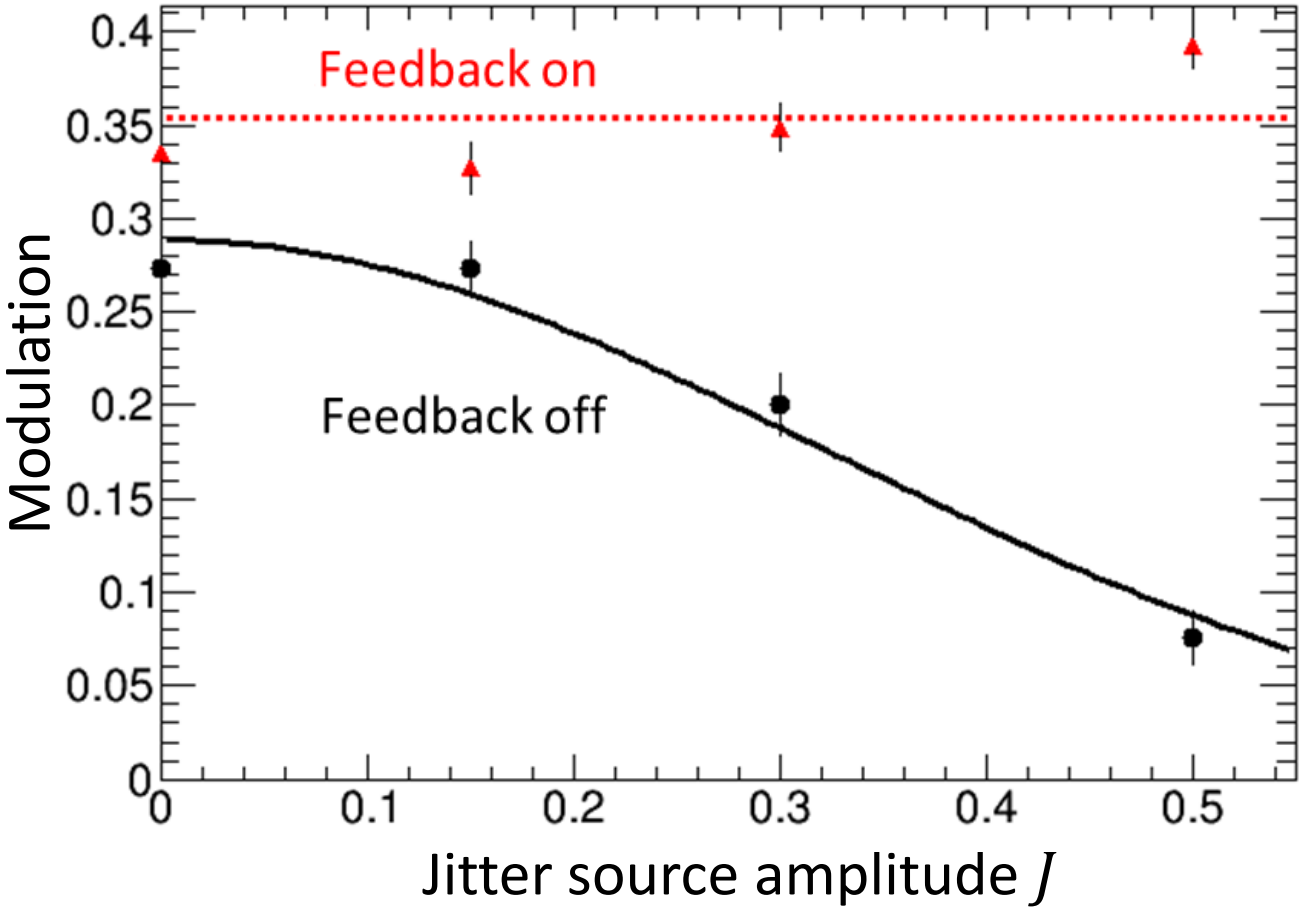
Modulation: 0.392 +/- 0.012
Beam Size: 57.9 + 0.9 -0.9 nm
Average: 2258.345 +/- 20.174
Phase: 2.274 +/- 0.037
Chi2/ndf: 6.9504e+01 / 18

Phase [rad]

Jitter = 0.5
Beam intensity = 1×10^9 /pulse
30 data points are taken for each phase
Bar = standard deviation of 30 points

Jitter source amplitude dependence

Bar = fit error



Standard deviation= 0.03

$M = M_0 \exp\left(-2k_y^2 \sigma_{\Delta y}^2\right)$

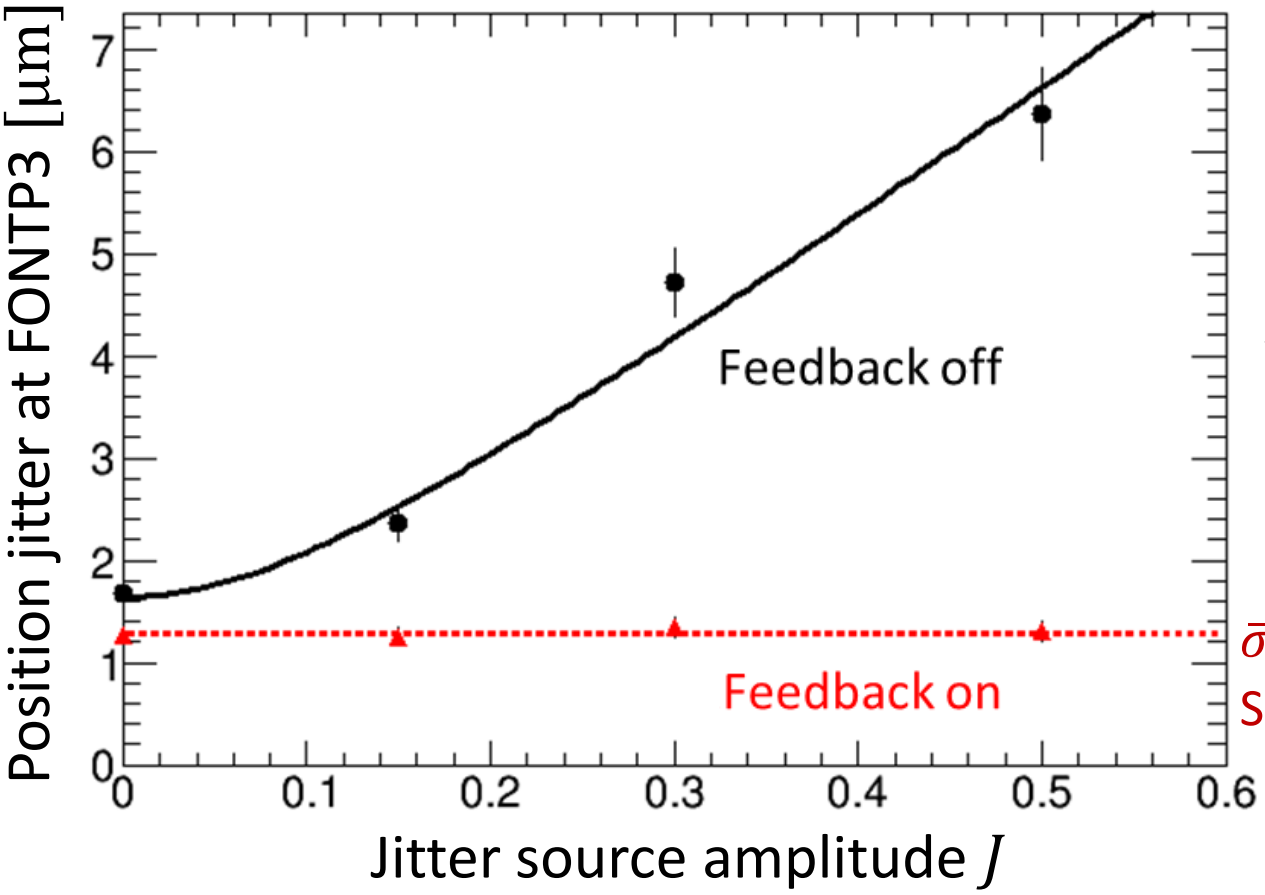
$\sigma_{\Delta y}/J = 131$ nm

$\chi^2/N_{dof} = 3.4/2$

(k_y ~IPBSM laser wavelength)

Position jitter at FONTP3

Bar $= jitter/\sqrt{2(100-1)}$



$\sigma'_{\Delta y} = \sqrt{\sigma^2_{\Delta y,0} + \sigma^2_{\Delta y}}$

$\sigma_{\Delta y}/J = 12.8$ μm

$\sigma_{\Delta y,0} = 1.6$ μm

$\chi^2/N_{dof} = 4.0/2$

$\bar{\sigma}_{\Delta y} = 1.3$ μm

Standard deviation = 0.04 μm

Rough assumption of jitter at IP

- Fit results:
  - $\sigma_{\Delta y,\mathrm{IP}}/J \quad = 131\ \mathrm{nm}$ at IP
  - $\sigma_{\Delta y,\mathrm{FONTP3}}/J \ = 12.8\ \mu\mathrm{m}$ at FONTP3

- Assuming that jitters at IP and extraction line scale, i.e. $\sigma_{\Delta y,\mathrm{IP}} \propto \sigma_{\Delta y,\mathrm{FONTP3}}$,
  - $\sigma_{\Delta y,\mathrm{FONTP3}} = 1.6\ \mu\mathrm{m}$ when $J = 0$
  - $\sigma_{\Delta y,\mathrm{IP}} \sim \sigma_{\Delta y,\mathrm{FONTP3}} * \frac{131\ \mathrm{nm}}{12.8\ \mu\mathrm{m}}$
    $= 16\ \mathrm{nm}$ when $J = 0$

2. Beam intensity dependence study

Measurement

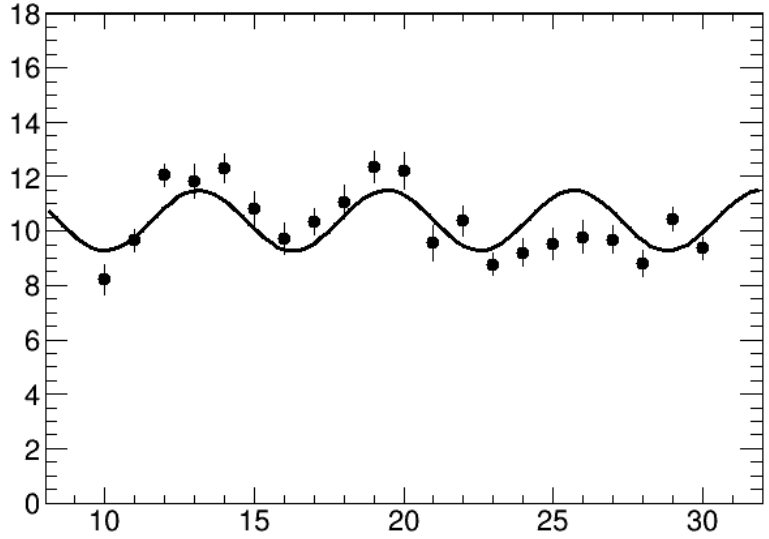
- There is no jitter generation using steering magnets

- Beam intensity was changed, then IPBSM measurement was done
  - The resolutions of FONT stripline BPMs are expected to decrease
  - Beam size is expected to increase

- Tuning
  - Before measurements with feedback off, extraction kicker amplitude tuning was done
  - Before measurements with feedback on, ZVFB1FF amplitude tuning was done

IPBSM 174 deg mode measurement

Feedback off

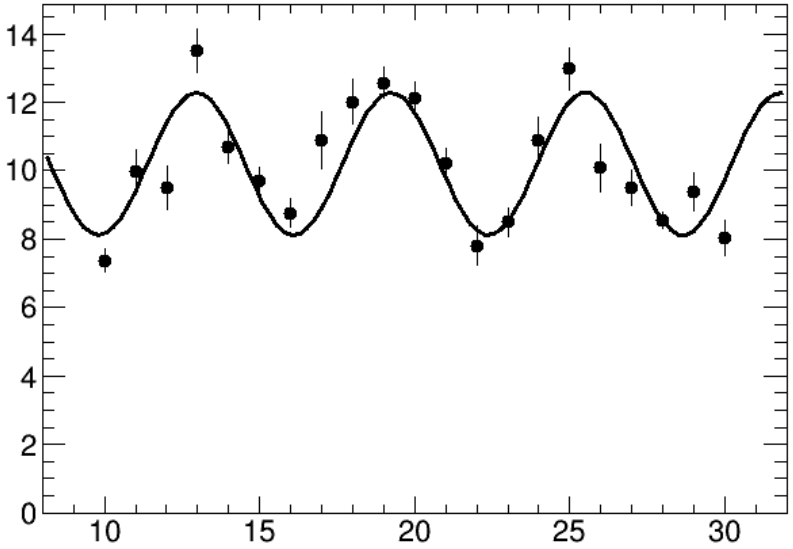


$M = 0.11 \pm 0.02$

$\sigma_y^* = 89.0$ nm

$\chi^2/N_{dof} = 71/18$

Feedback on



Phase [rad]

$M = 0.20 \pm 0.01$

$\sigma_y^* = 75.9$ nm

$\chi^2/N_{dof} = 65/18$

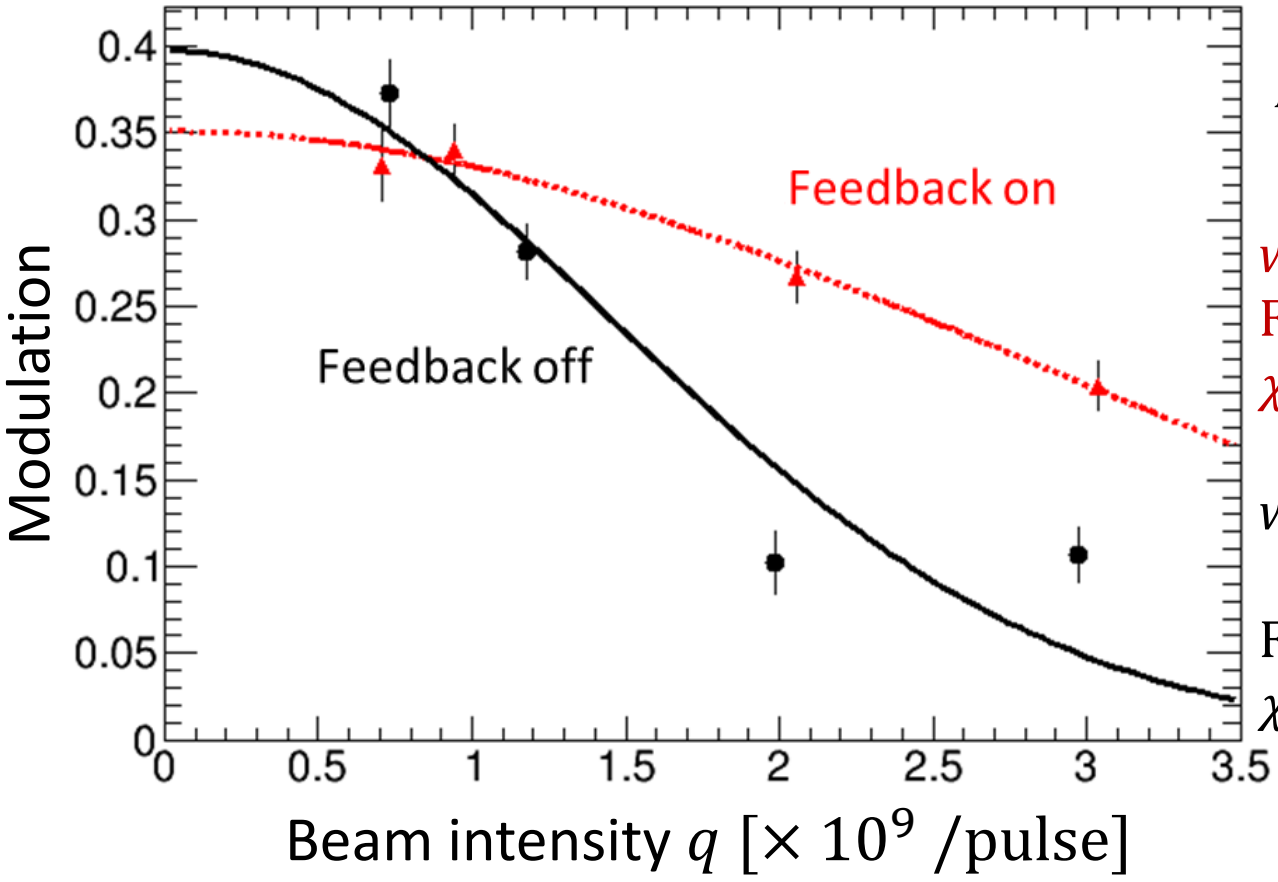
Beam intensity = 3×10^9 /pulse

20 data points are taken for each phase

Bar = standard deviation of 20 points

Beam intensity dependence

Bar = fit error

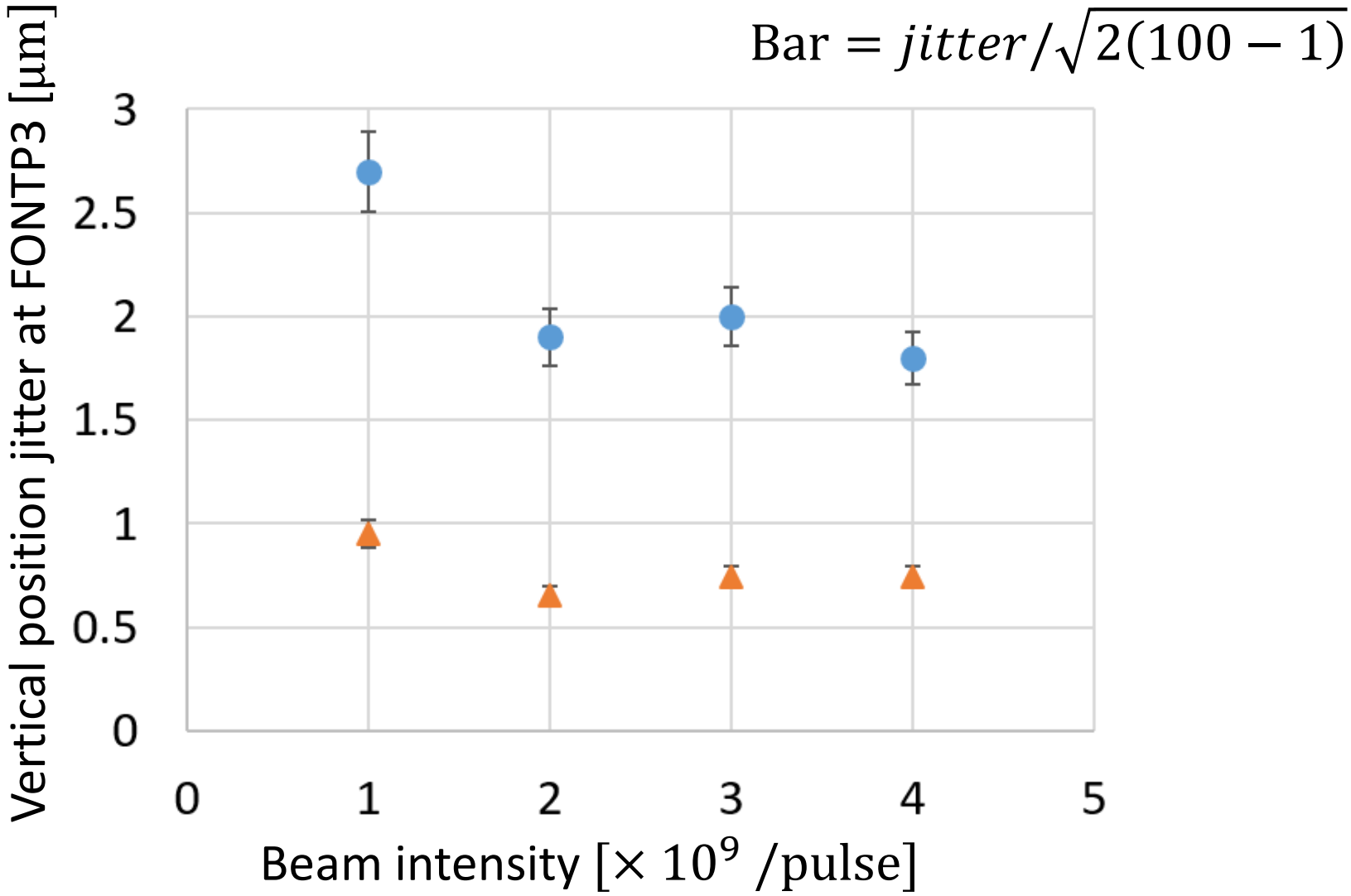


$$M = M_0 \exp\left[-2\left(k_y w q\right)^2\right]$$

$w = 92$ nm/nC (15 nm/1e9)
Fit error $= 7$ nm/nC
$\chi^2/N_{dof} = 0.65/2$

$w = 18 \times 10$ nm/nC
(29 nm/1e9)
Fit error $= 10$ nm/nC
$\chi^2/N_{dof} = 24/2$

Position jitter at FONTP3

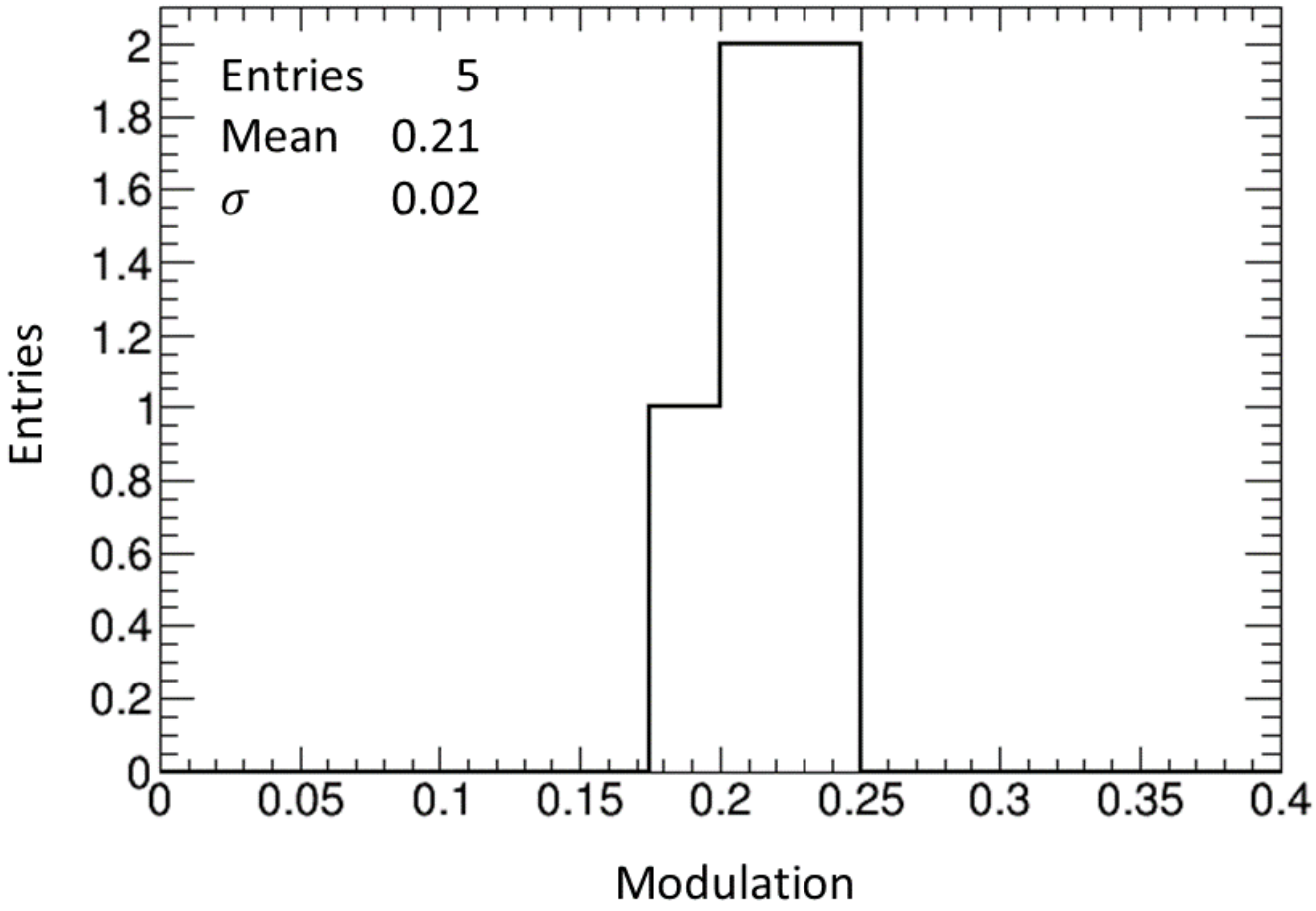


Summary

- As a study of IP beam orbit stabilization using FONT upstream feedback, 2 measurements were done:
  - Study with jitter generation by steering magnets
  - Study of beam intensity dependence
- Vertical beam orbit at the IP is stabilized by several 10s of nm
- Closer investigation is probably needed to verify the result of the beam intensity dependence of upstream feedback

Backup

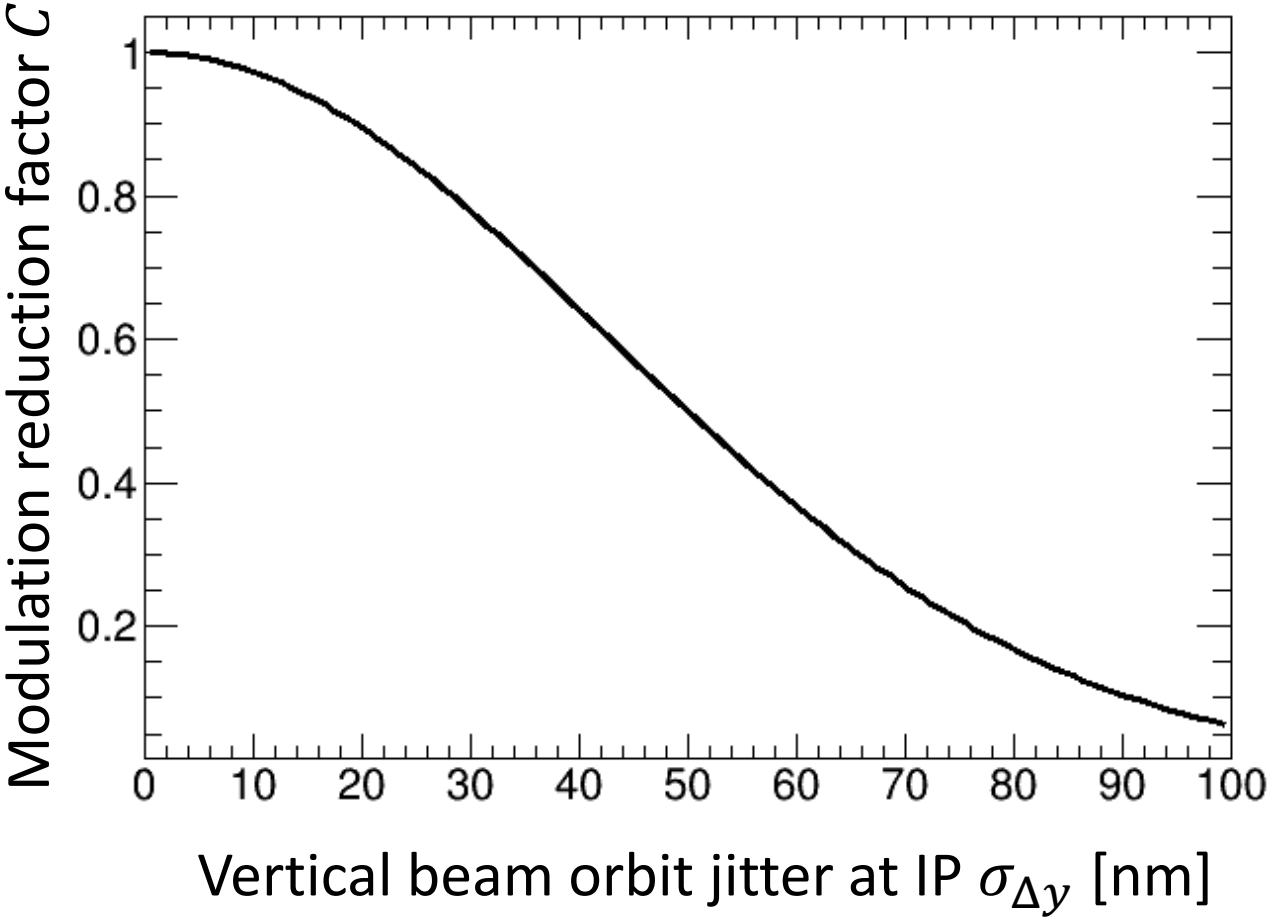
Result of consecutive measurements when jitter=0.3



Beam intensity = 1×10^9 /pulse

30 data points are taken for each phase

Calculation of Modulation reduction factor by vertical beam orbit jitter



$$M_{observed} = C \cdot M$$
$$C = \exp\left(-2k_y^2\sigma_{\Delta y}^2\right)$$

(k_y ~IPBSM laser wavelength)
(IPBSM 174 deg mode)