# Ion Instability observed in PLS revolver in-vacuum undulator

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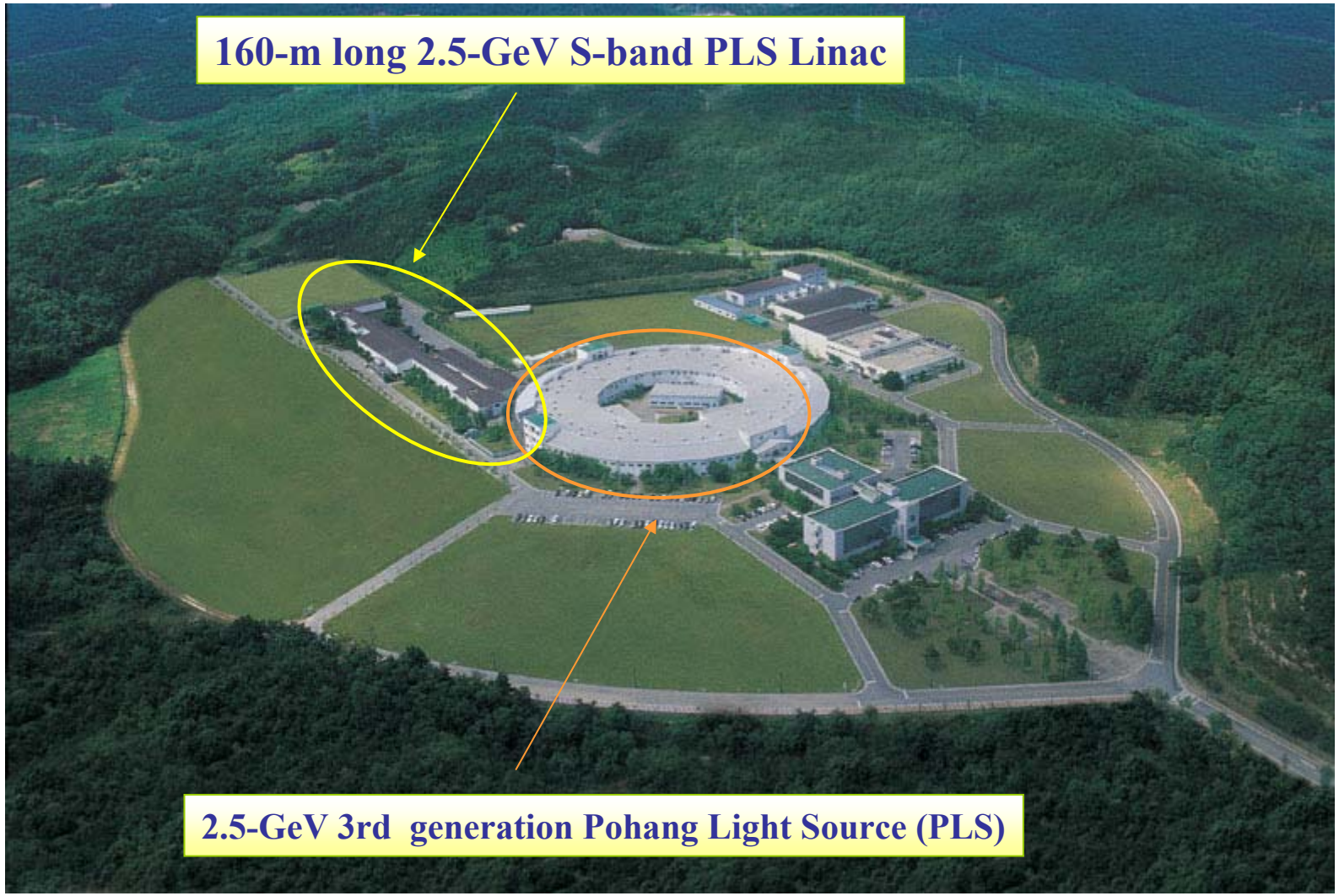




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# Introduction

1. Revolver Undulator: Revolver In-Vacuum X-ray UNdulator (RIVXUN). The minimum gap of the Revolver is 5 mm.
2. The observed ion instability was caused by vacuum degradation in the Revolver when the Revolver gap was closed down below 6.4 mm: Fast Beam Ion Instability (FBII)
3. Beam loss occurred due to the reduced physical aperture at the Revolver
4. Ion instability was suppressed by orbit adjustment around the revolver.


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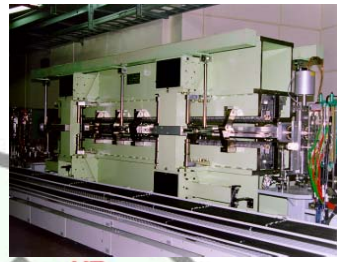
# Current ID Status of PLS

**Revolver In-Vacuum X-ray UNdulator**






MPW14

## 26 Beamlines (20 BM + 6 ID)

***6 IDs installed in the ring.***

- In-vacuum Undulator (1)
- Out-vacuum Undulator (3)
- Out-vacuum Wiggler (2)



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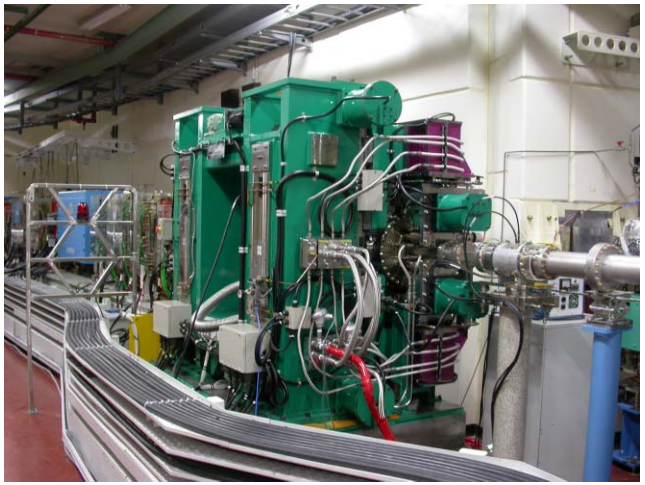
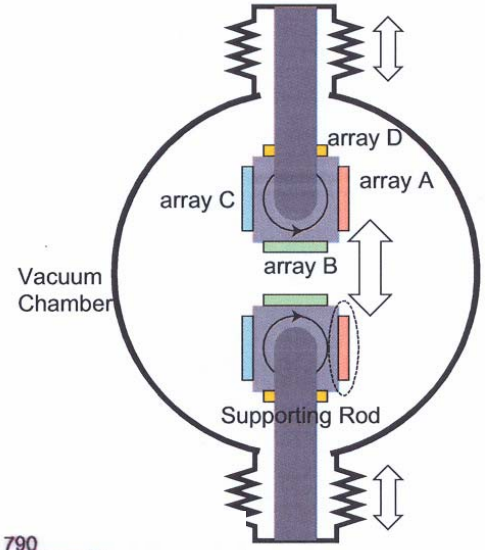
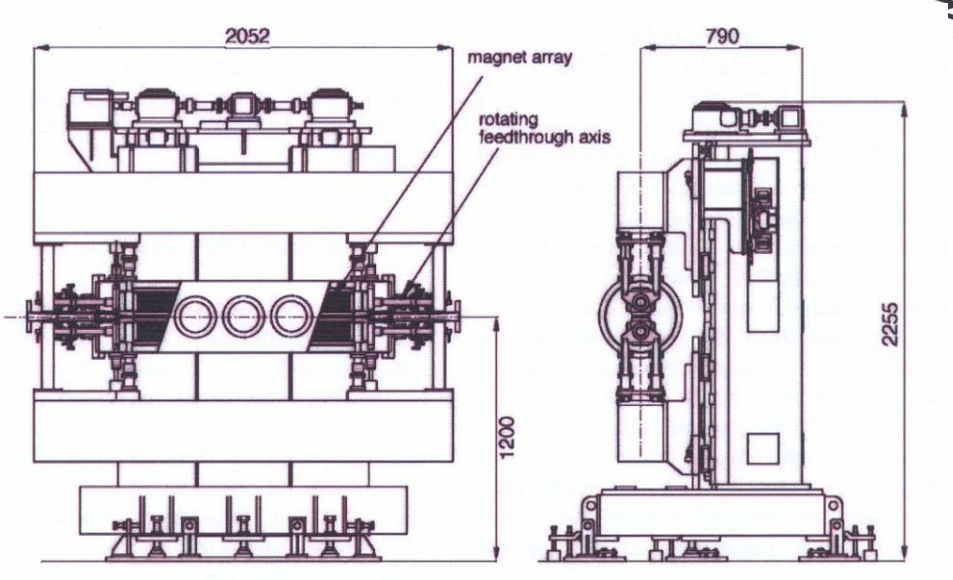
# RIVXUN: Revolver In-Vacuum X-ray UNdulator






Permanent magnet structure is a revolving type with four arrays, which provides 4 different undulator periods of 10, 15, 20, and 24 mm.

| Array | Undulator Period [mm] | Number of period |
|---|---|---|
| C, c | 10 | 101 |
| B, b | 15 | 67 |
| A, a | 20 | 50 |
| D, d | 24 | 42 |

Undulator magnet length is 1.2 meter

***Magnet material*** : **Nd2Fe14B**

***designed at Spring-8***

**Kitamura et al. NIMA 467, 110 (2001)**



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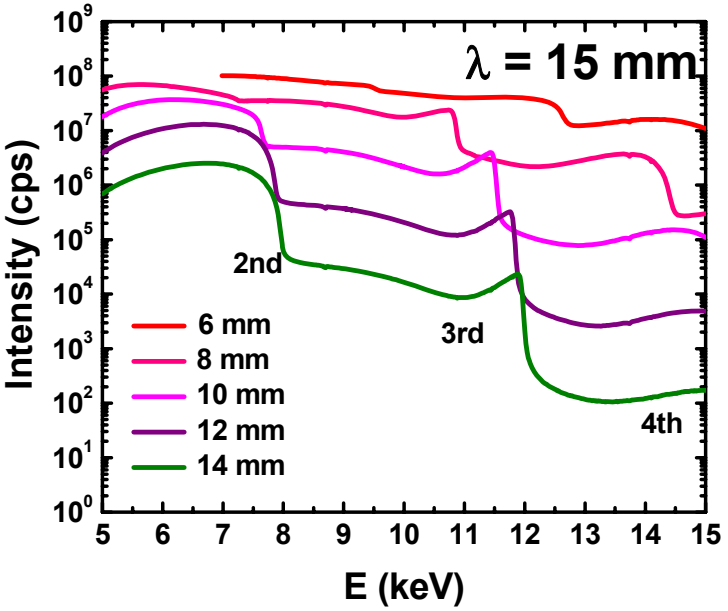
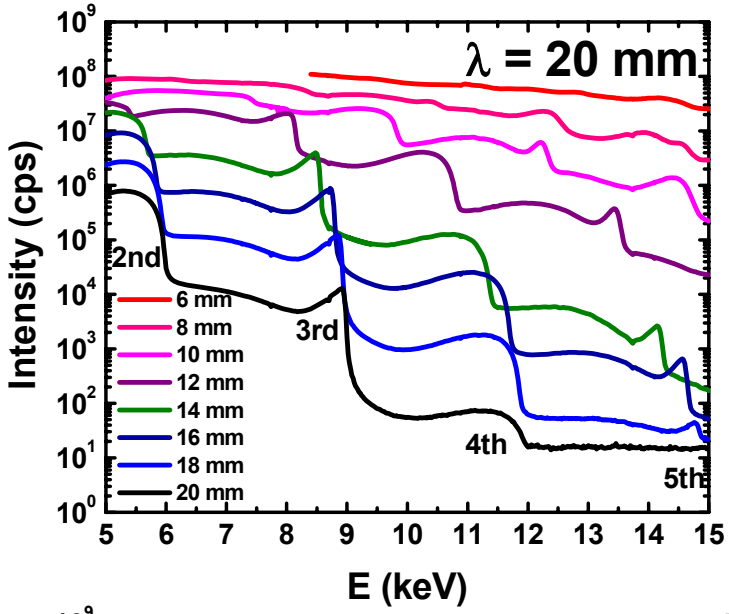
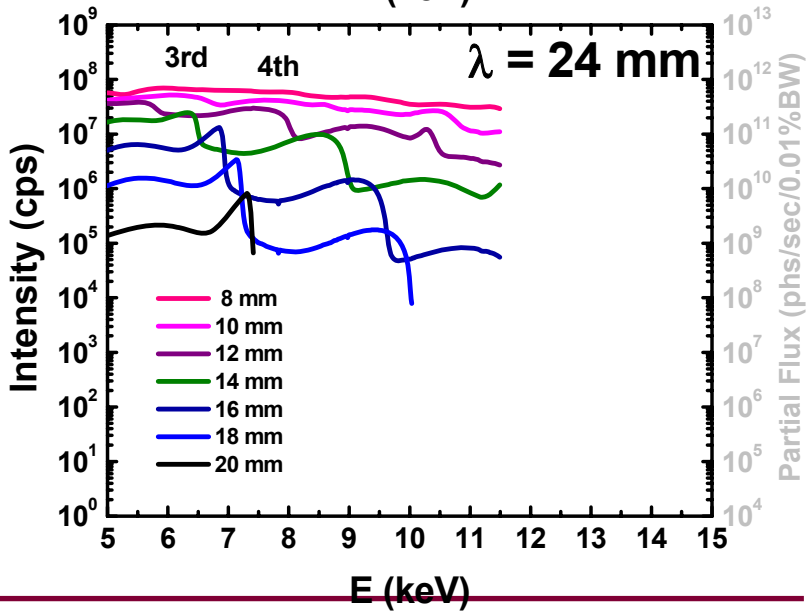
# Spectrum Measurement




## 3rd Harmonics

9 keV < E < 12 keV : λ = 15 mm
7 keV < E < 9 keV : λ = 20 mm
E < 7 keV : λ = 24 mm





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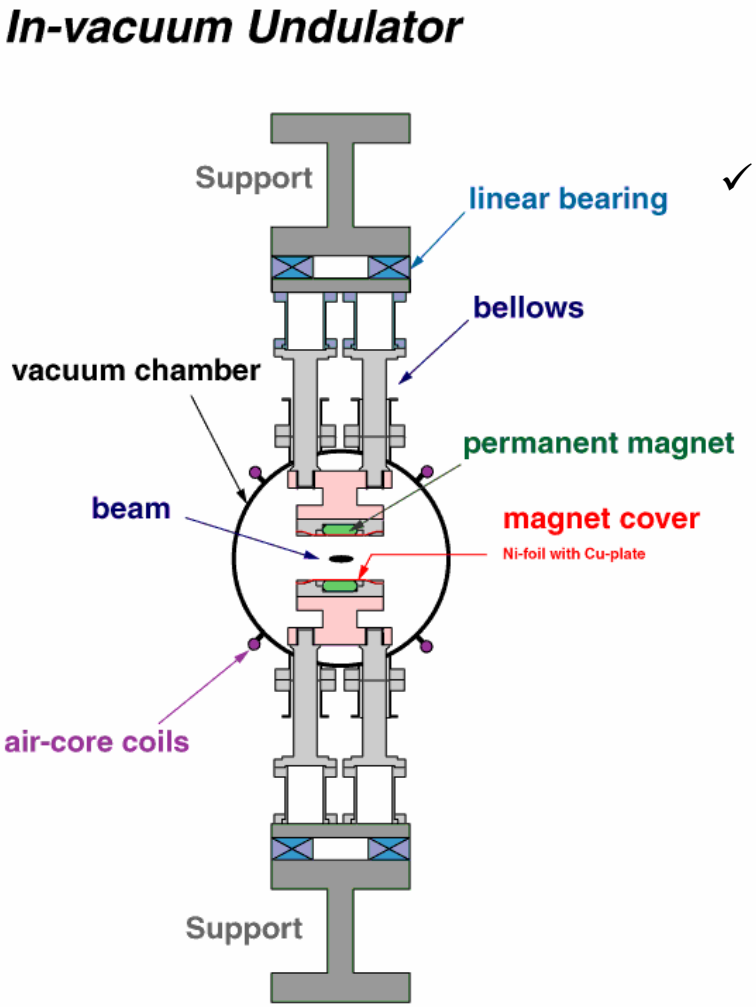
# Gas Desorption by Photons




- ✓ To reduce the resistive wall impedance, the permanent magnet array is covered with a **50 μm-thick Cu sheet coated with 50 μm-thick Ni**.
- ✓ The bakeout temperature for
  the vacuum chamber: 200°C
  the magnet arrays: 125°C
- ✓ Synchrotron radiation should be blocked by photon stops
- ✓ Gas desorption by stray photons
  - Photon desorption
  - Electron-stimulated desorption
- ✓ Pre-cleaning by stray photons: Aging process

| | Out-vacuum | In-vacuum |
|---|---|---|
| Aging by stray photons | Enough : Continuous | Not enough: Intermittent |
| Gas desorption by photons | weak | strong |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# FBII experiments at PLS in1998

M. Kwon et al., **Phys. Rev. E 57, 6016 (1998)**

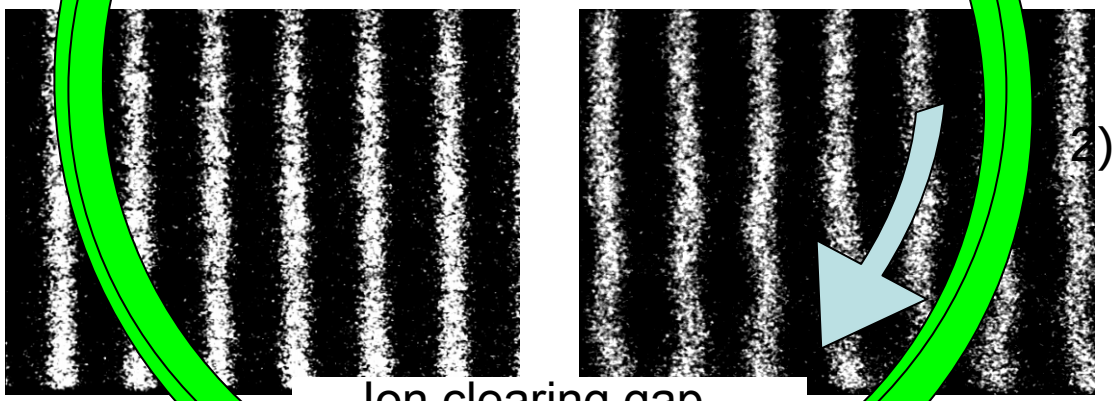
J. Y. Huang et al., **Phys. Rev. Lett. 81, 4388 (1998)**

Electron bunch train

Instability was excited by Helium gas injection at one place

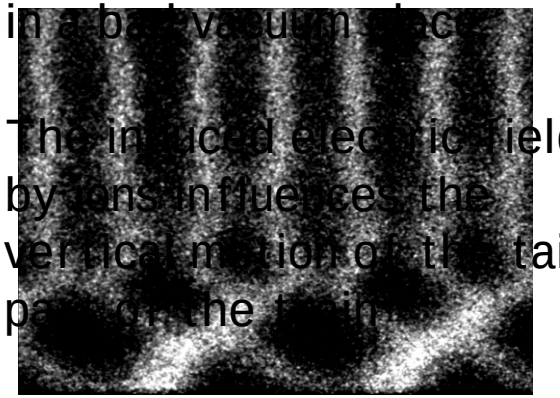
1) The head part of the Electron bunch train ionizes the gas molecules in a bad vacuum chamber

2) The induced electric field by ions influences the vertical motion of the tail part of the train




Ion clearing gap

Gas molecules in a bad vacuum



3.34 nTorr Helium



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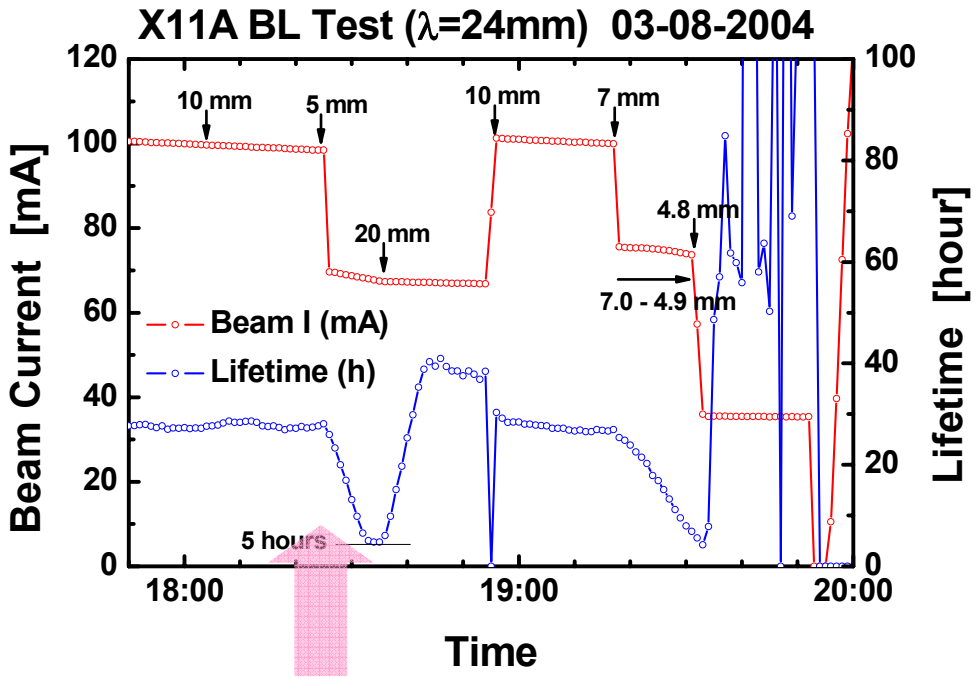
# Ion Instability during the revolver gap change

1. Above gap 7mm, no instability and no lifetime change
2. Below gap 6.4mm, transverse ion instability appeared and then beam loss occurred.




**Beam loss occurred as well as lifetime decreased rapidly**
**~ 5 Hours Electron Beam Lifetime @ 5 mm Undulator Gap !**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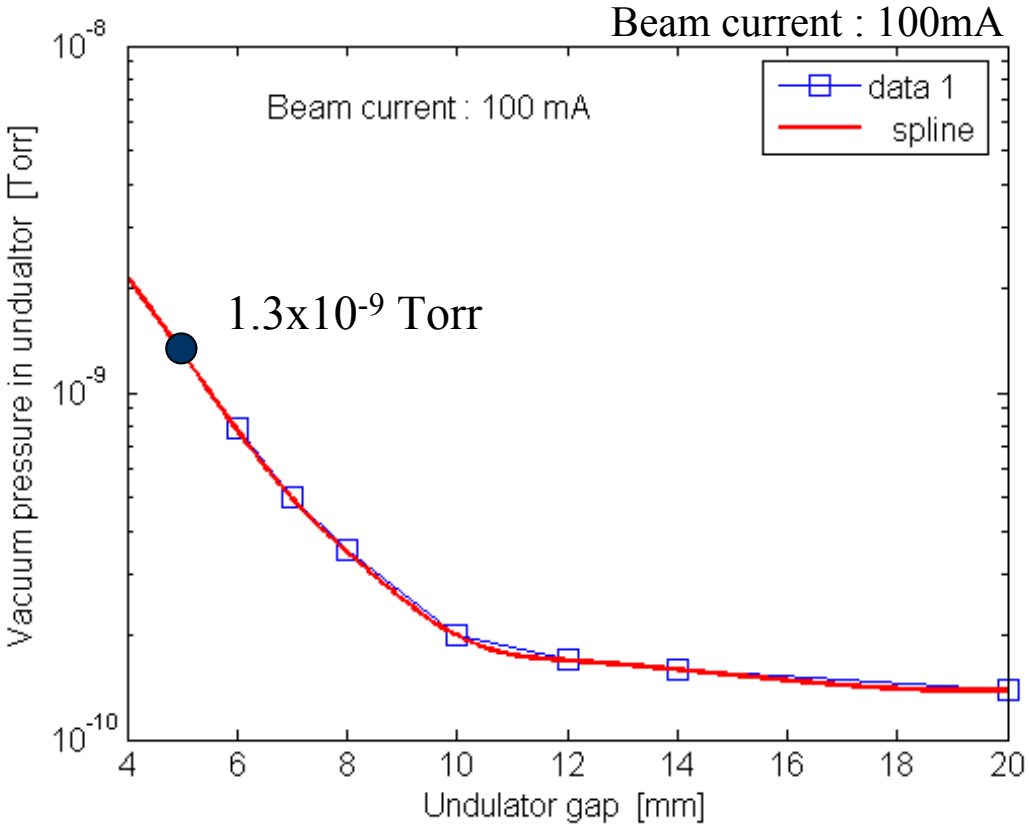
# Ion Instability: Measured vacuum pressure in Revolver

1. The Revolver vacuum pressure increased by 10 times when the gap was changed from 20mm to 6mm.
2. **This high vacuum pressure gives rise to FBII**




Average vacuum pressure in the ring:
$5.0 \times 10^{-10}$ Torr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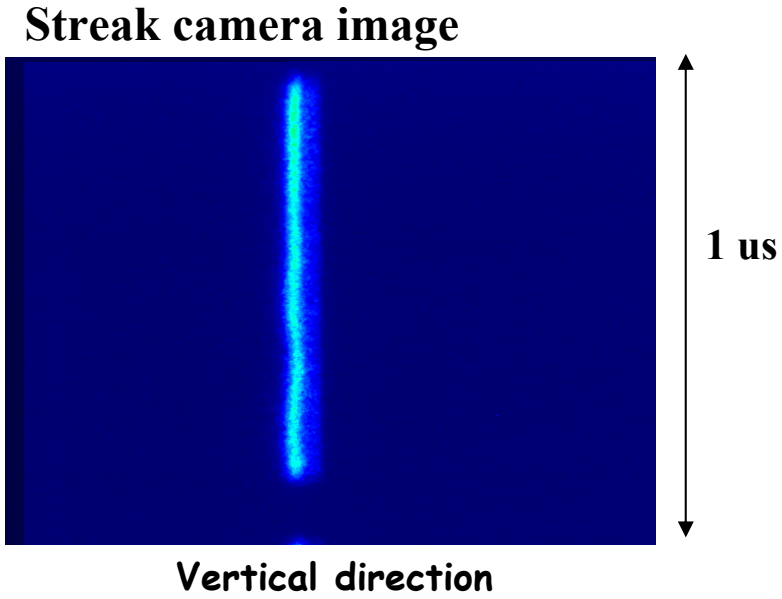
# Ion Instability: FBII

1. Streak camera IMAGES shows that this ion instability is Fast Beam Ion Instability: the tail part of a long bunch train oscillates vertically.

2. There was no appreciable difference at the different fill patterns.




**The tail part of the bunch train is oscillating vertically.**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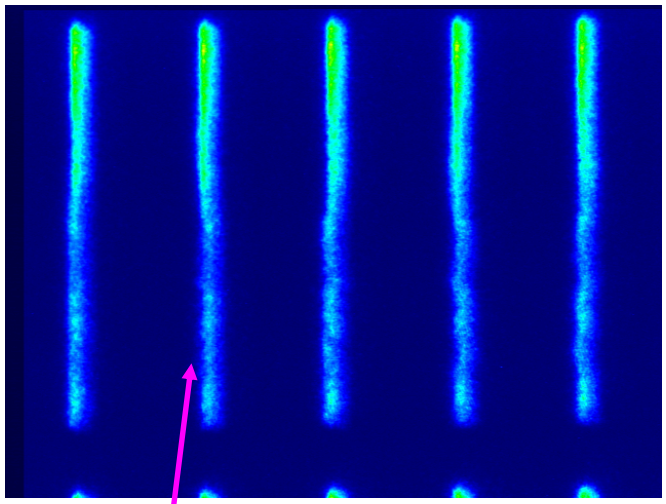
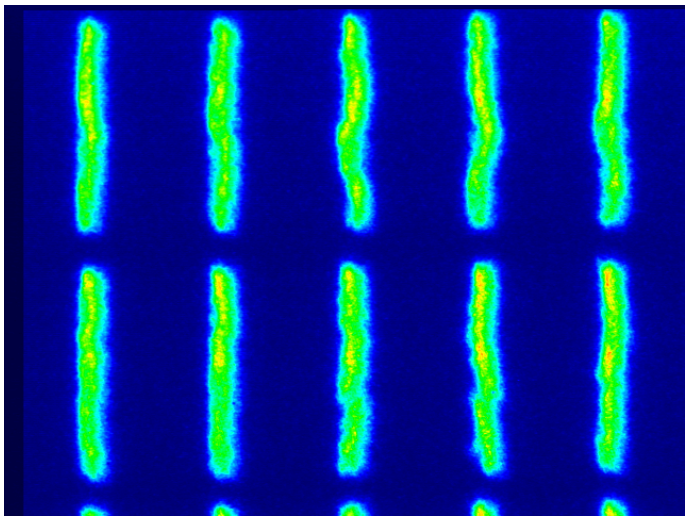
# Bunch Trains

One train

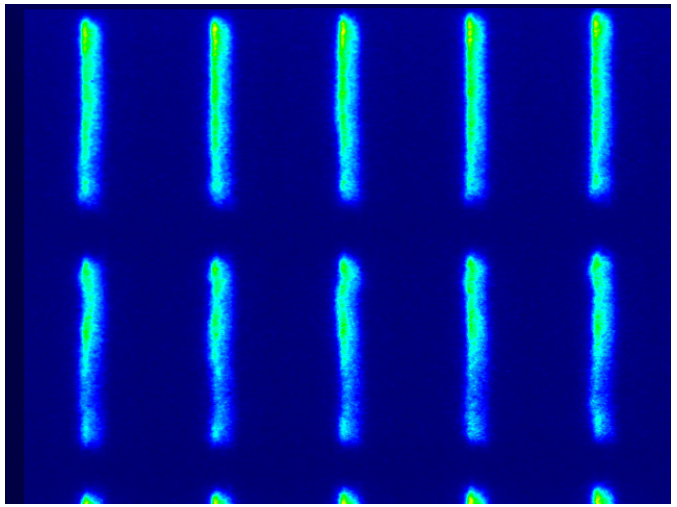



1 us

two trains Before beam loss



After beam loss



Beam loss is mostly at the tail



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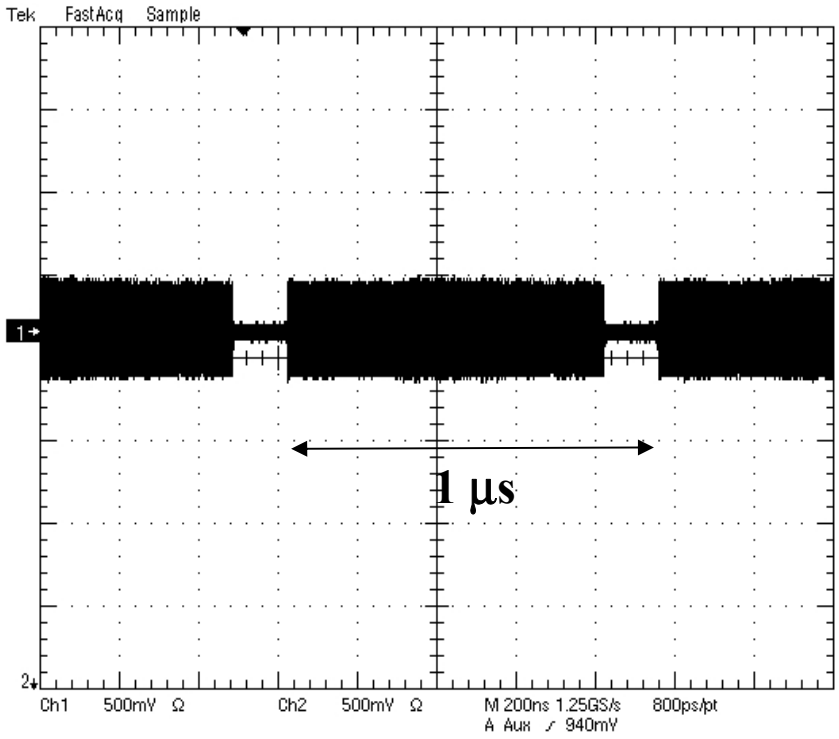
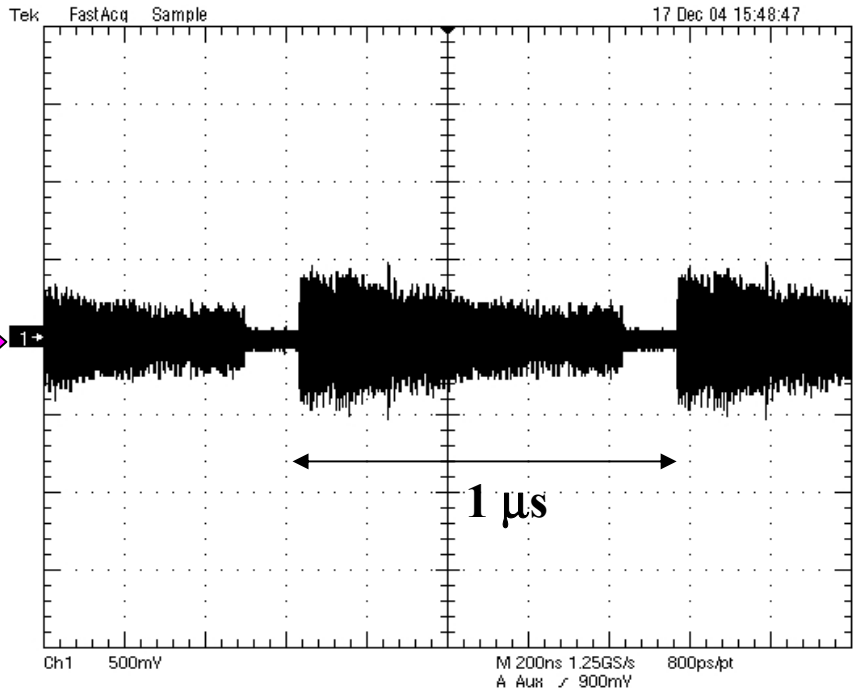
# Ion Instability: **Bunch Current**

Before the instability




After the ion instability




- ✓ The bunch current of long bunch train was scraped off to a triangular shape.
- ✓ The vertical beam size seems to be linearly growing along the bunch train as FBII grows.
- ✓ The physical aperture of the storage ring reduced to the Revolver gap.



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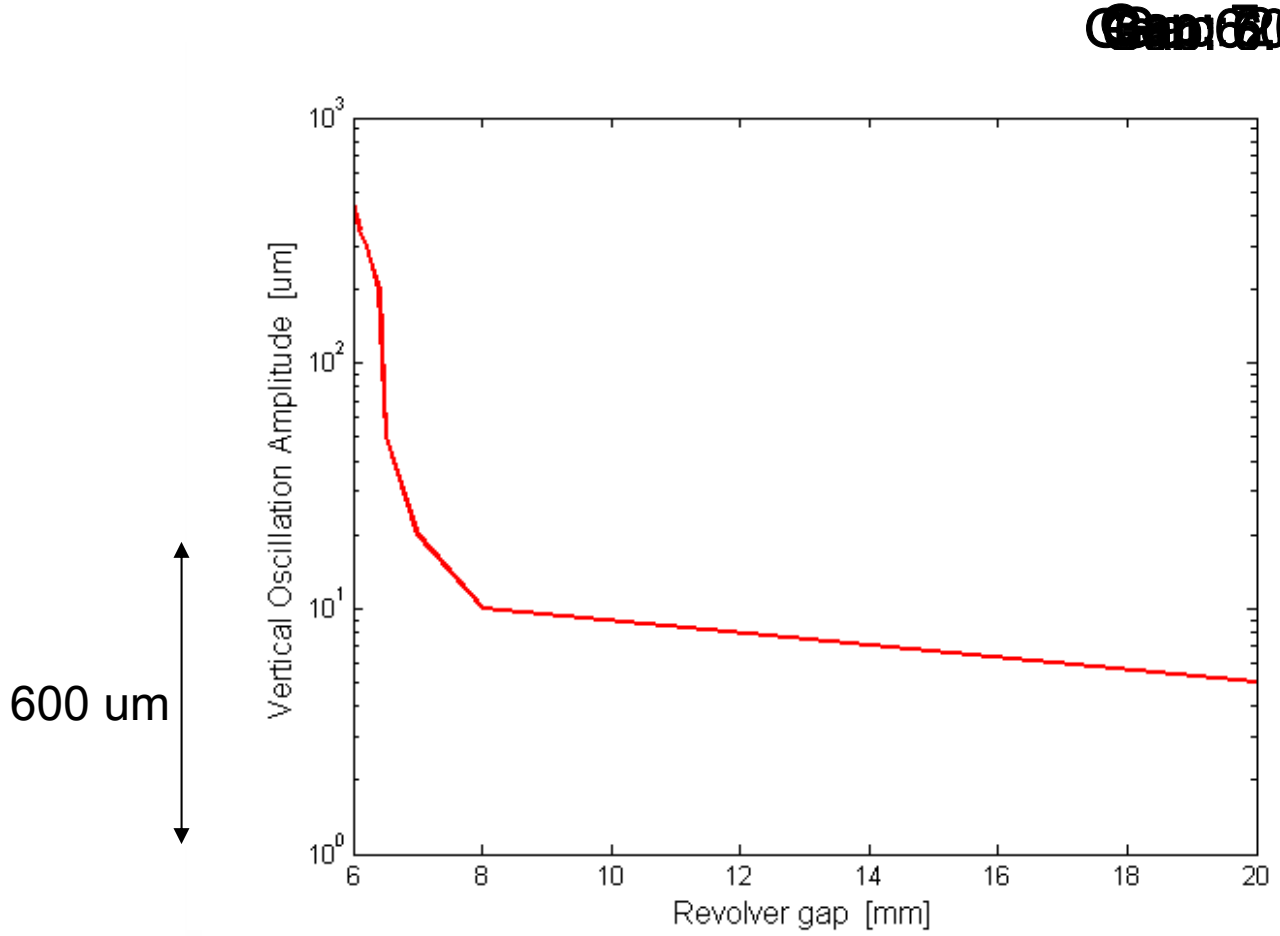
# Measurement of Beam Oscillation with turn by turn DBPM



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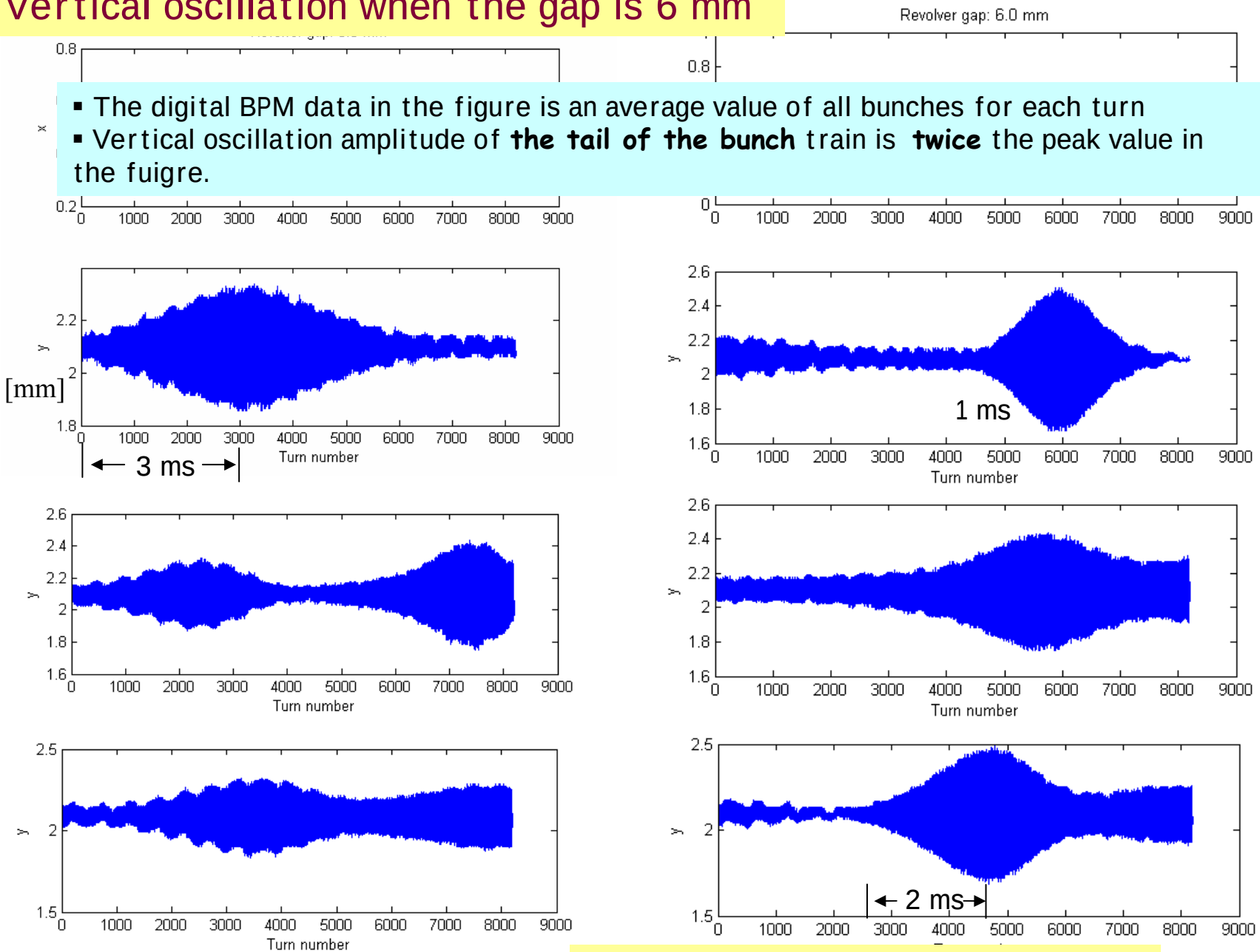
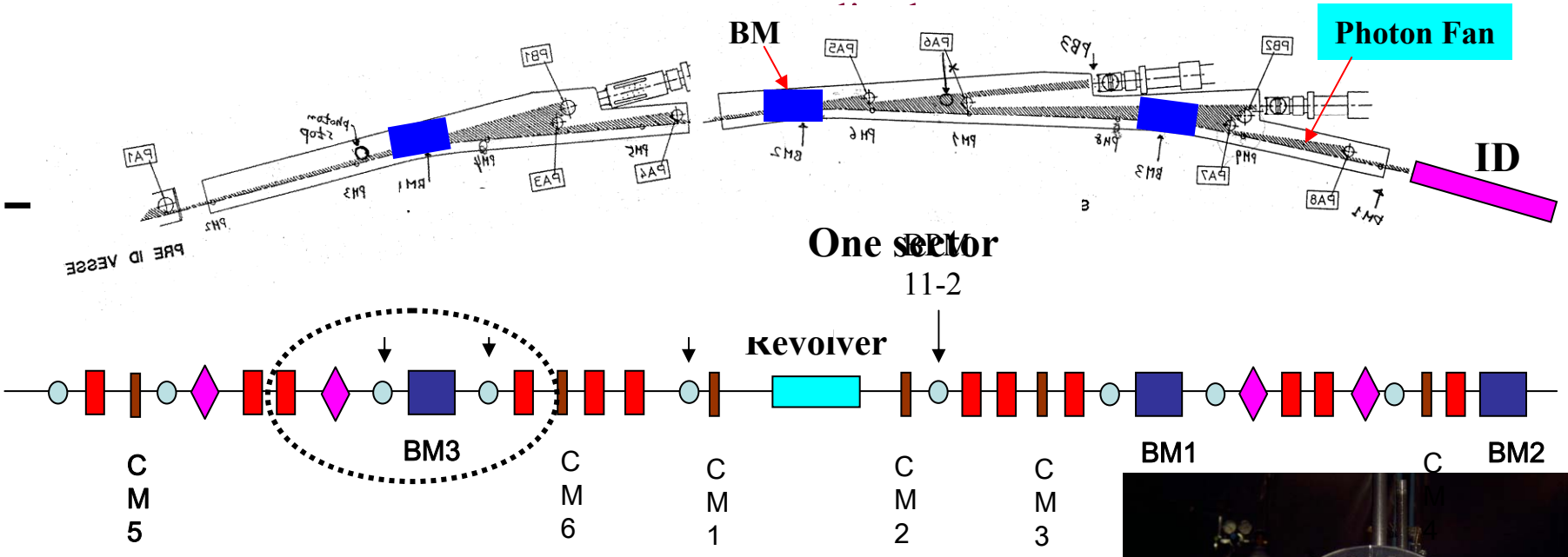
# Vertical oscillation when the gap is 6 mm

- The digital BPM data in the figure is an average value of all bunches for each turn
- Vertical oscillation amplitude of **the tail of the bunch** train is **twice** the peak value in the fuigre.




Growth time of instability : 1 – 3 ms
Transverse damping time of PLS: 8 ms

# Instability suppression:
## Synchrotron radiation from the upstream dipole magnet




2. A fixed gap photon mask with a vertical aperture of 8 mm was installed in front of the Revolver, but no appreciable change.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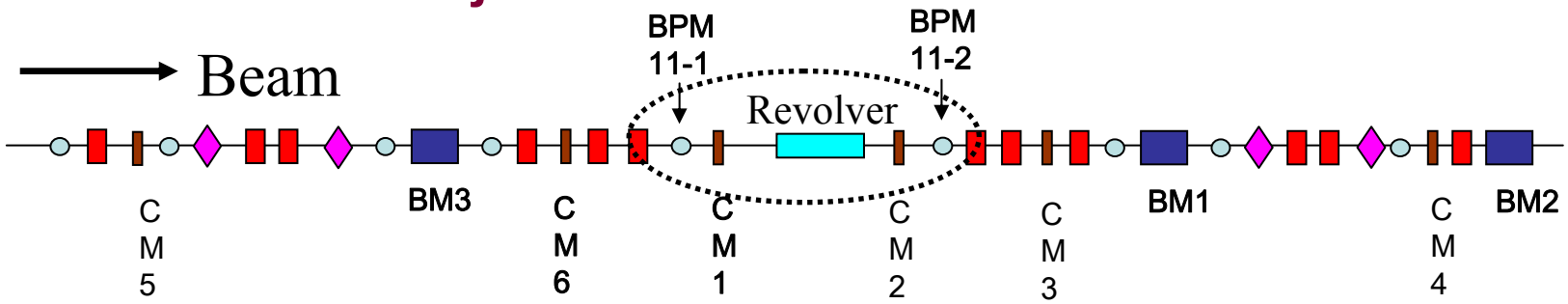
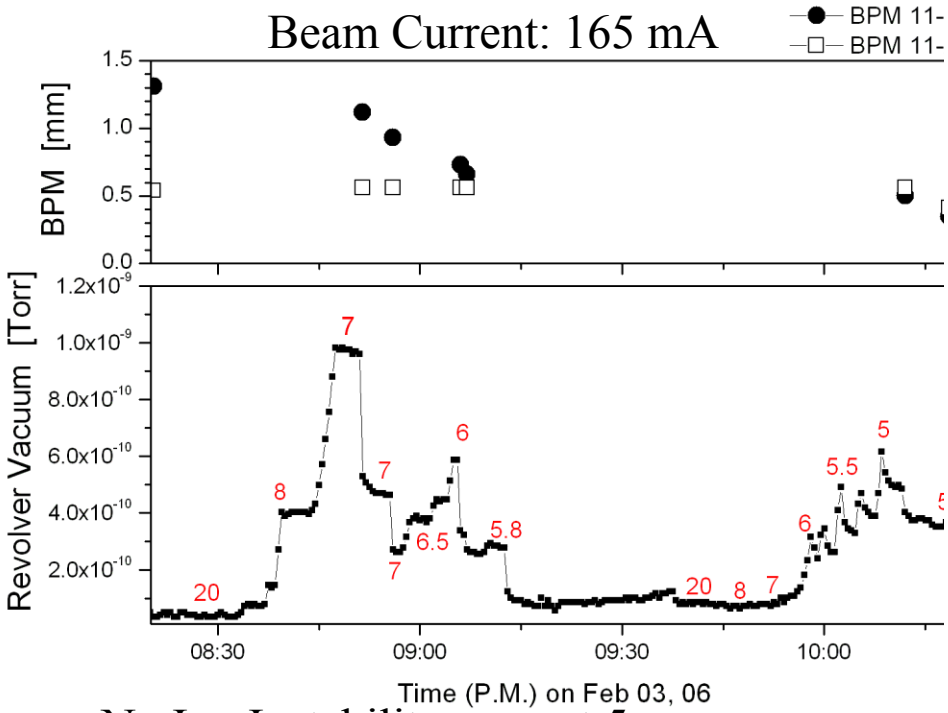
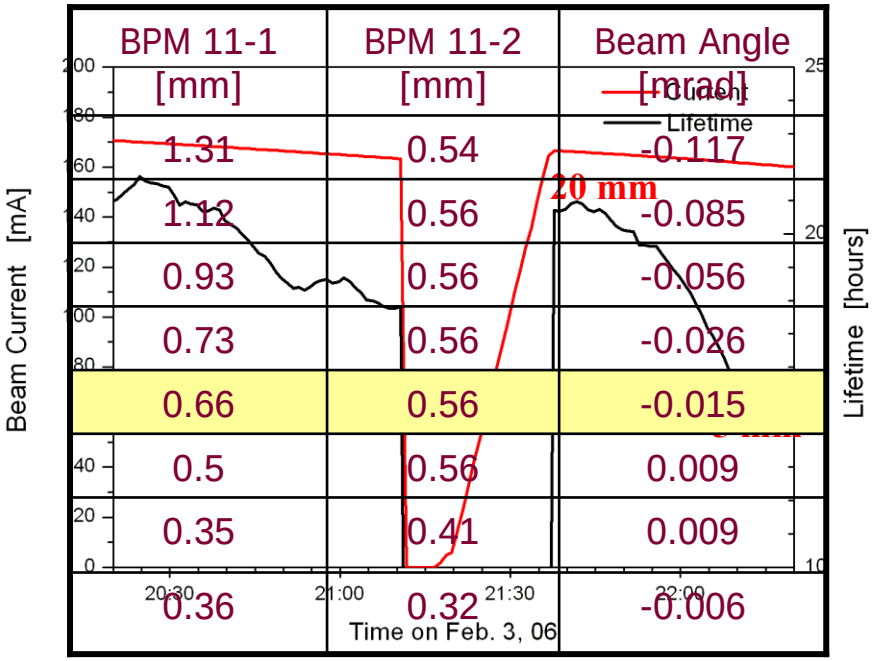
# Instability suppression: orbit adjustment around the Revolver




No Ion Instability even at 5 mm,
No beam loss !




Lifetime decrease of 5 hours is due to the reduced physical aperture at the Revolver

Distance between BPM 11-1 and 11-2: 6.6 m



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# Causes of the vacuum degradation

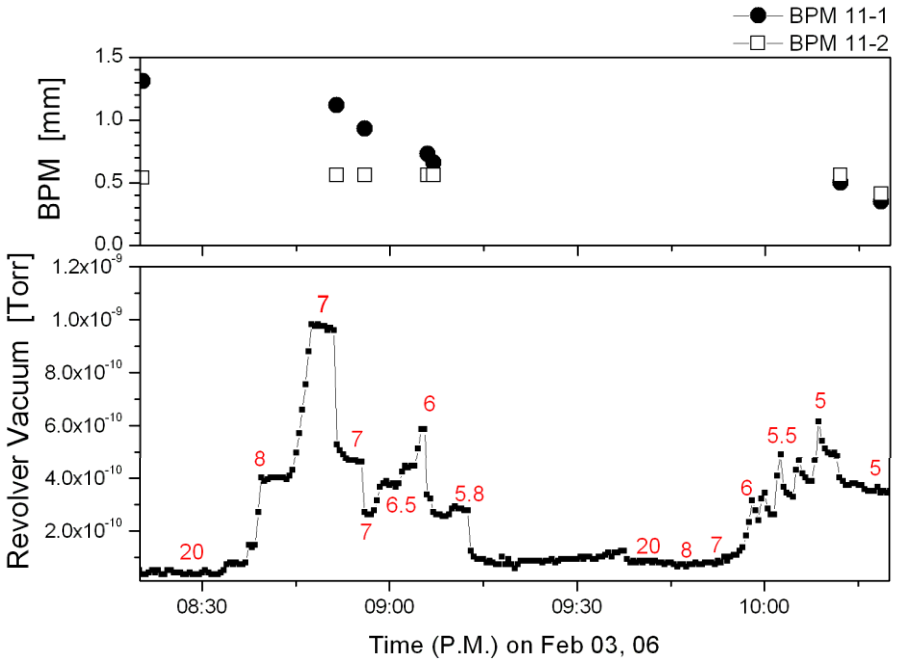
- Stary synchrotron radiation from the upstream dipole is not serious.
- Other sources may be dominant:

photon desorption →

- Synchrotron radiation from the Revolver itself, or

Heat source {

- Heat deposit in the flexible input / output transitions, or
- Resistive wall impedance in the permanent magnet array




As soon as the orbit was changed, the vacuum pressure rapidly dropped.

Time constant of the vacuum pressure change by orbit is very short.

This rapid change of vacuum pressure might be caused by photon desorption not by heat source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# Summary

1) Ion instability (FBII) was caused by vacuum degradation in the Revolver undulator when the gap was closed down below 6.4 mm.
2) Orbit optimization around the Revolver improved the vacuum pressure appreciably so that the ion instability disappeared.
3) Causes of the vacuum degradation
   - Synchrotron radiation from the upstream dipole is not serious.
   – Synchrotron radiation from the Revolver itself might be dominant.
1) Further Study to identify the causes of vacuum degradation is necessary.
   - Heat deposit in the flexible input / output transitions
   - Resistive wall impedance

Thank You For Your Attention!


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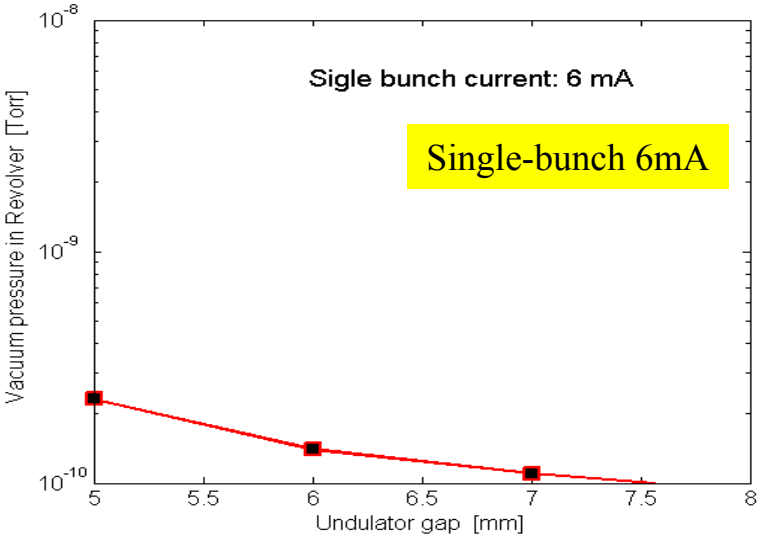
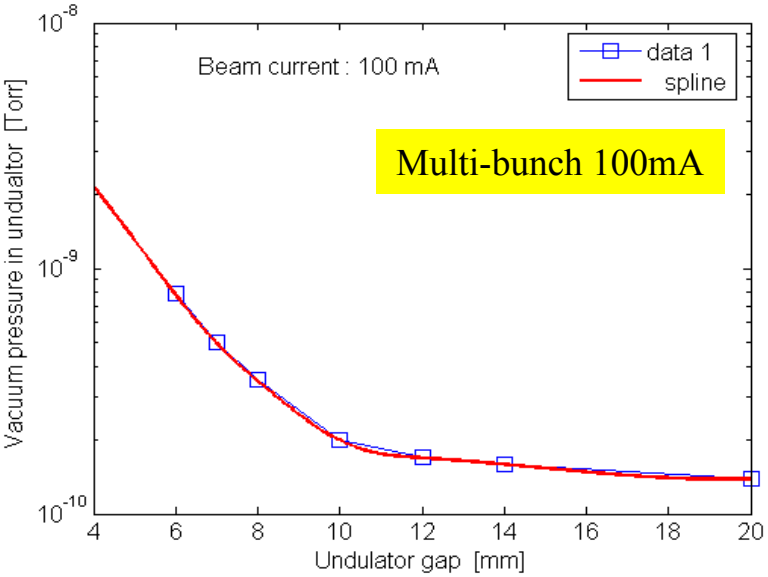
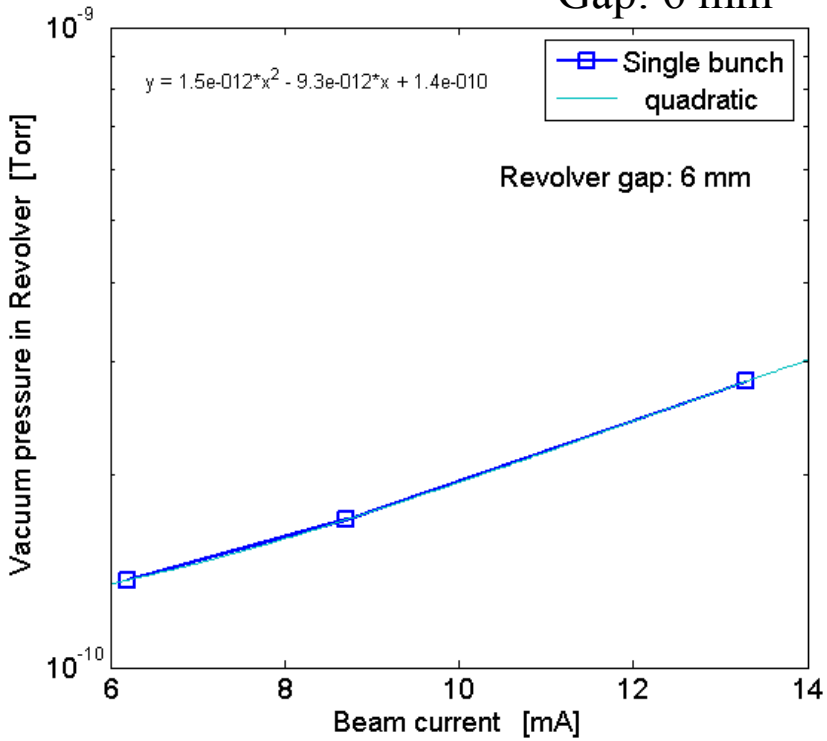
# Single bunch Test




Gap: 6 mm




Vacuum pressure with single-bunch
≈ Multi-bunch



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