

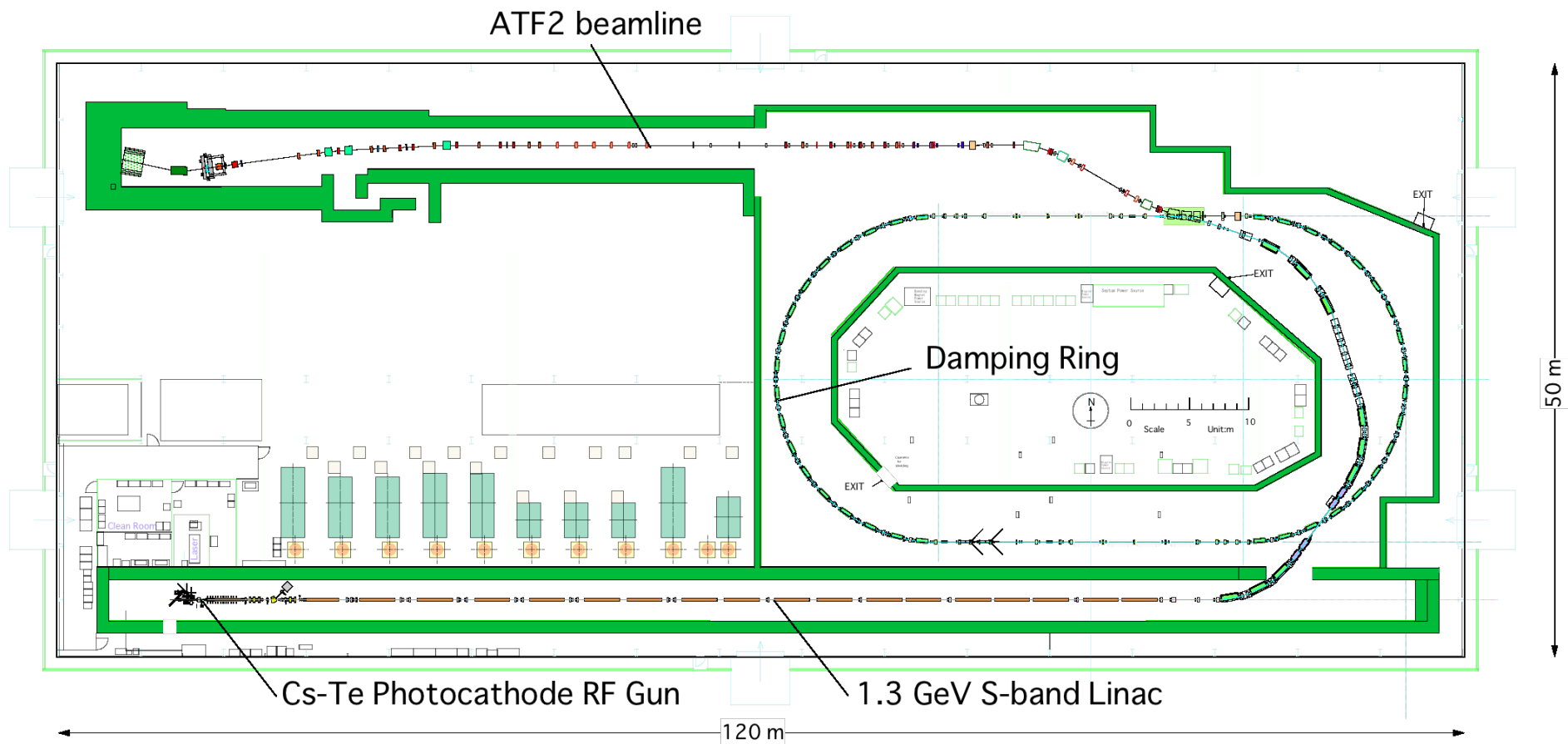
# Experimental Studies of fast ion instability in the ATF damping ring

- History
- Recent Emittance Recovery/Measurement
- Improvements/Upgrades of monitors
- R&D plans/schedule

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LER2010, Jan. 13th, 2010, CERN(WebEx)

# KEK Accelerator Test Facility (ATF)



# Beam Monitors in ATF-DR

**Screen Monitor**  
-Energy Spread- **One Path**



**Laser Wire**  
-Emittance meas.-  
bunch by bunch  
Exposure ~15 min.

**Superposition of multi-turn**

**Multi-bunch beam**  
1~20 bunch/train  
2.8 ns spacing  
 $\sim 2 \times 10^{10}$  electrons/bunch

**Turn-by-turn Monitor**  
-position meas.-  
bunch by bunch

**One Path & multi-turn**

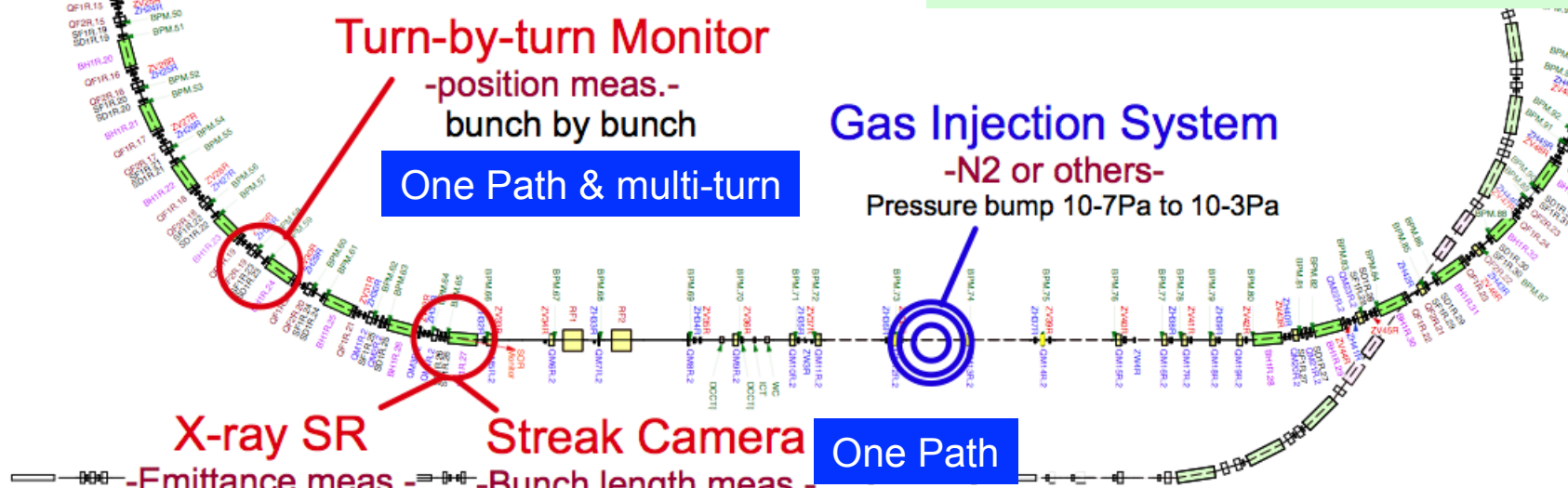
**Gas Injection System**  
-N<sub>2</sub> or others-  
Pressure bump 10<sup>-7</sup>Pa to 10<sup>-3</sup>Pa

**X-ray SR**  
-Emittance meas.-  
Exposure ~20 msec.

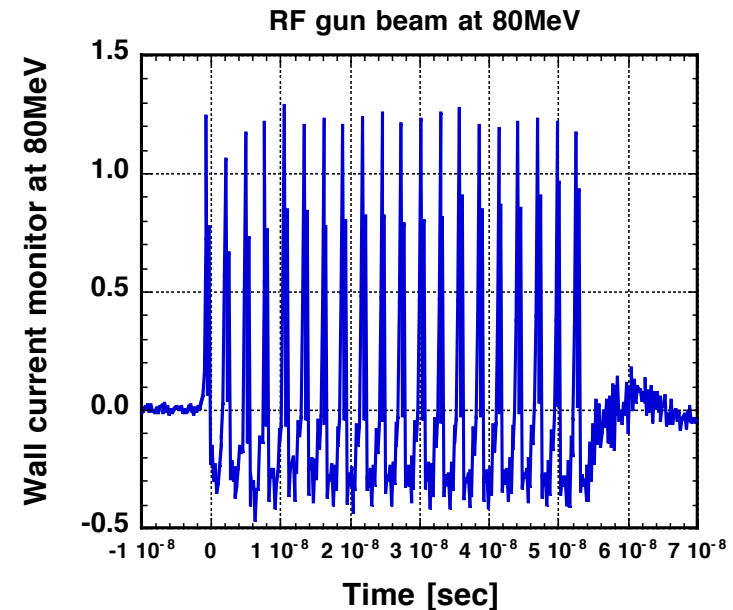
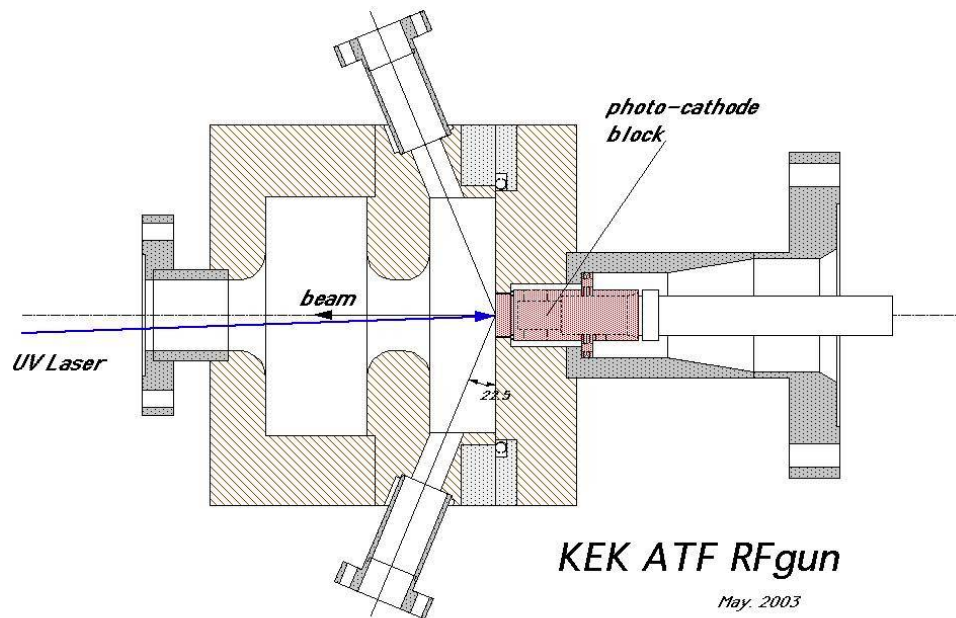
**Streak Camera**  
-Bunch length meas.-  
Bunch by bunch

**One Path**

**Superposition of multi-turn**



# Multi-bunch electron beam structure



*Number of bunches from the RF Gun is controlled by changing the Laser pulse structure.*

**Linac: 1.3 GeV, 1.56 Hz,  $\sim 2 \times 10^{10}$  electrons / bunch**

**1 ~ 20 bunches/pulse(train) with 2.8ns spacing by 357MHz laser  
and**

**1 ~ 10 bunches/pulse(train) with 5.6ns spacing by 178.5MHz laser  
for Fast Kicker R&D, will be available in October 2009.**

# Brief History of Vertical Emittance in the ATF damping ring

## **Concentrated on the generation of the low emittance multi-bunch beam (1996~2004)**

2003: Confirmed 4pm emittance for single bunch  
and found emittance blowup for multi bunch

## **Beam monitor developments (2004~2007)**

Cavity BPM (resolution: C-band 17nm, IP-BPM 9nm)

Laser wire, Intra-train feedback, XSR, ...

did not fully care the low emittance then found the emittance was 30pm or more

## **Emittance recovery under the ATF2 construction (2007~2009)**

~2008: ATF2 construction

2009: recovered as less than 10pm

## **Low emittance beam (2010~)**

DR BPM upgrade for 1pm emittance

Low emittance beam for ATF2, Fast ion study, ...

# FII study on 2007/3/13-14 (1)

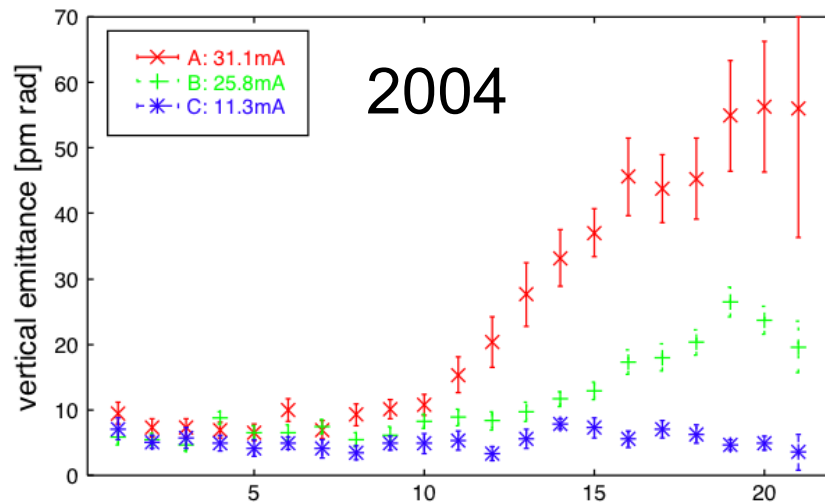
## Vertical emittance of 20 bunches in ATF DR

Table 2: vacuum pressure in 2004

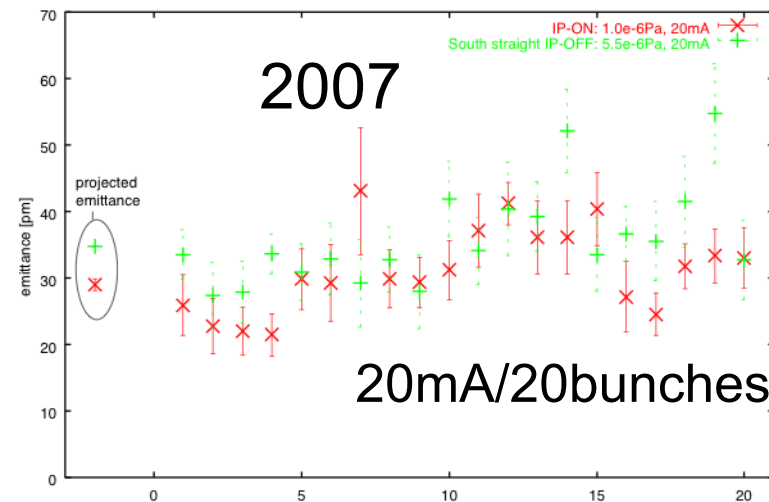
| ion pump status | 11mA                    | 26mA                    | 31mA                    |
|-----------------|-------------------------|-------------------------|-------------------------|
| normal          | $4.0 \times 10^{-6}$ Pa | $6.0 \times 10^{-6}$ Pa | $6.5 \times 10^{-6}$ Pa |

Table 1: vacuum pressure in the measurements

| ion pump status                  | 5mA                     | 10mA                    | 20mA                    |
|----------------------------------|-------------------------|-------------------------|-------------------------|
| normal                           | $4.6 \times 10^{-7}$ Pa | $5.9 \times 10^{-7}$ Pa | $1.0 \times 10^{-6}$ Pa |
| south straight OFF               | $2.0 \times 10^{-6}$ Pa | $2.7 \times 10^{-6}$ Pa | $5.5 \times 10^{-6}$ Pa |
| both arcs and south straight OFF | $3.4 \times 10^{-6}$ Pa | $5.2 \times 10^{-6}$ Pa |                         |



Single bunch was less than 10pm.



Bunches in front are already bigger.  
 Single bunch is also bigger.

# FII study on 2007/3/13-14(2)

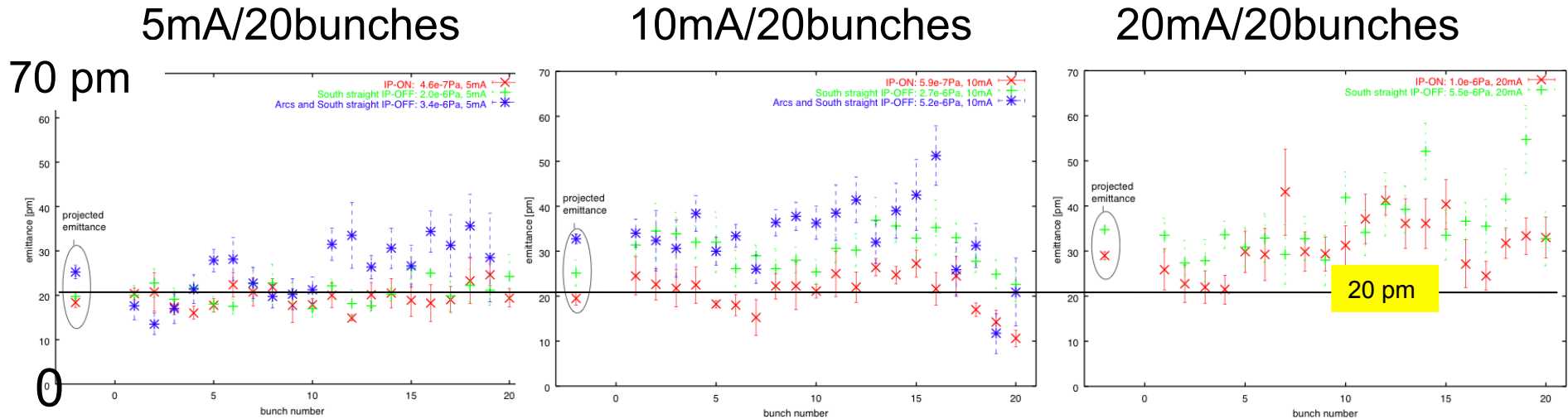


Figure 7: emittance of multi-bunch beam at 5mA/20bunches

Figure 8: emittance of multi-bunch beam at 10mA/20bunches

Figure 9: emittance of multi-bunch beam at 20mA/20bunches

We measured emittance of each bunch in a 20-bunch beam in the DR with a laser-wire monitor. **No clear emittance blow-up** along a train was observed up to 20mA/train.

**One of the reason may be the bigger vertical emittance compared with the data taken in 2004.**

# Emittance Works for ATF DR

## Hardware issue

Re-alignment of DR magnets in summer shutdown  
Beam size monitor improvement → following slides

## Beam tuning method

### $\beta$ beat correction

Correction with QM18R.1&QM15R.2 trim.

### Dispersion correction

$\eta_x$  in straight section is corrected by QM trim

$\eta_y$  is corrected by correctors

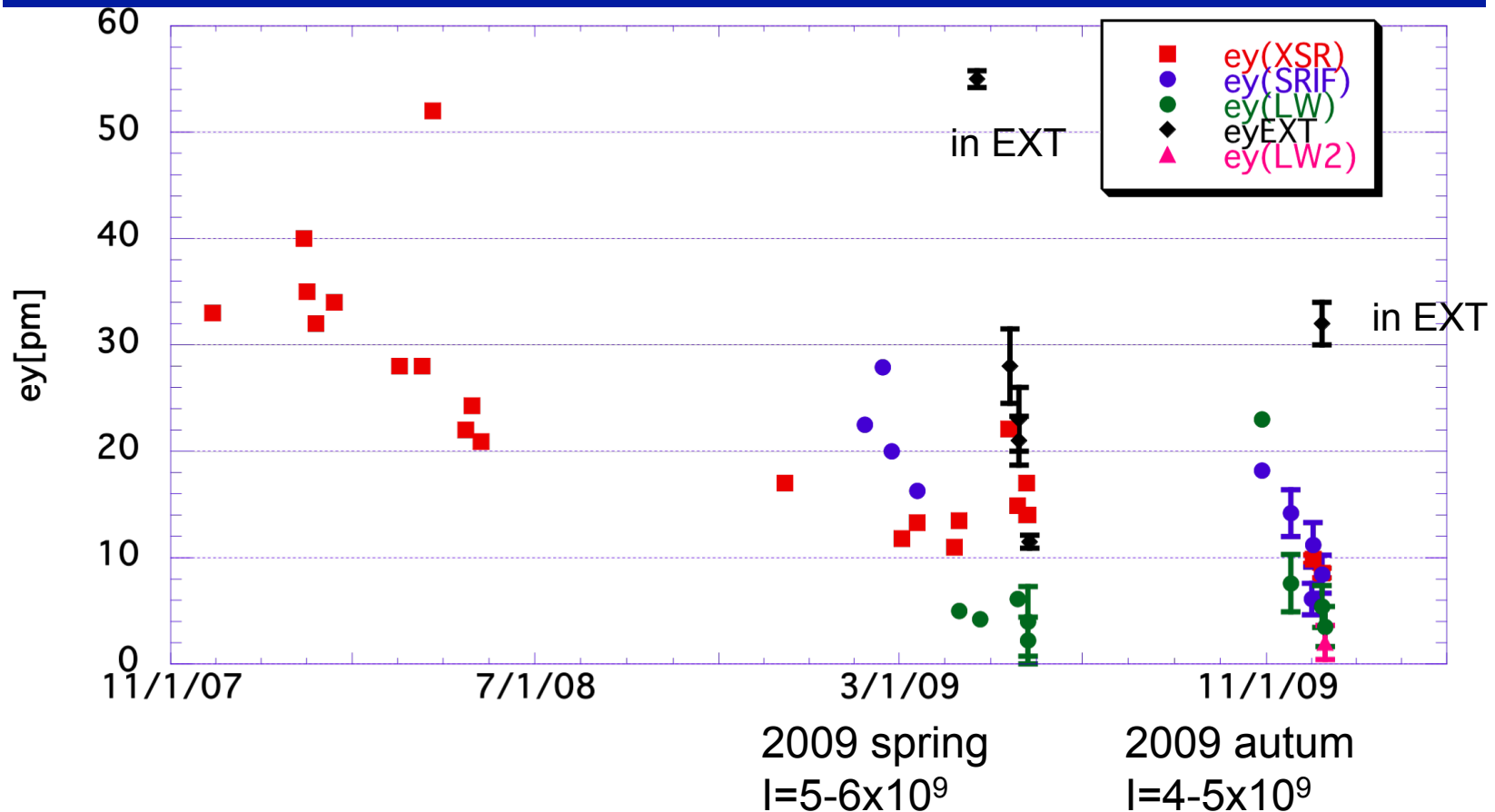
### Coupling correction

Correction of vertical leakage of the horizontal kicks by a couple of horizontal correctors.

Correction is done by Skew Q winding trim coil of SX.



# DR Emittance Summary (single bunch)

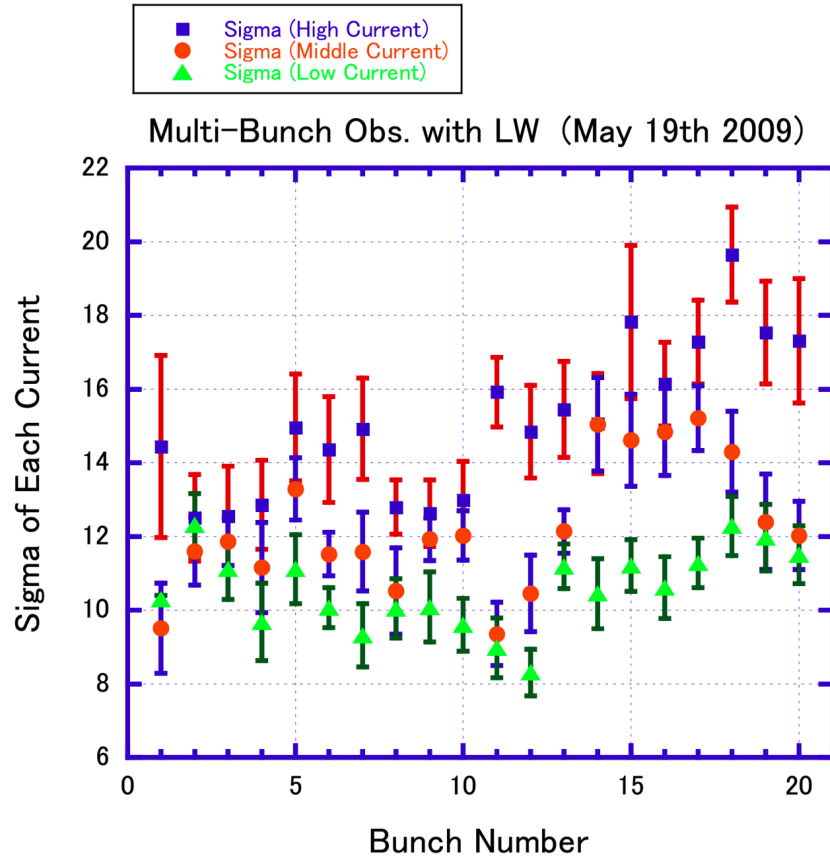


Measured vertical emittance (2009 Dec)

XSR=8.56±0.46 pm, IF=8.43±1.79 pm,

LW<sub>00</sub> =3.50±1.78 pm, LW<sub>01</sub>=2.00±1.61pm ← under the poor laser intensity

# multi-bunch beam size, 2009may19



$0.4 \times 10^{10}/\text{bunch}$

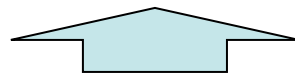
Multi-bunch was not well tuned.

$0.3 \times 10^{10}/\text{bunch}$

$0.1 \times 10^{10}/\text{bunch}$

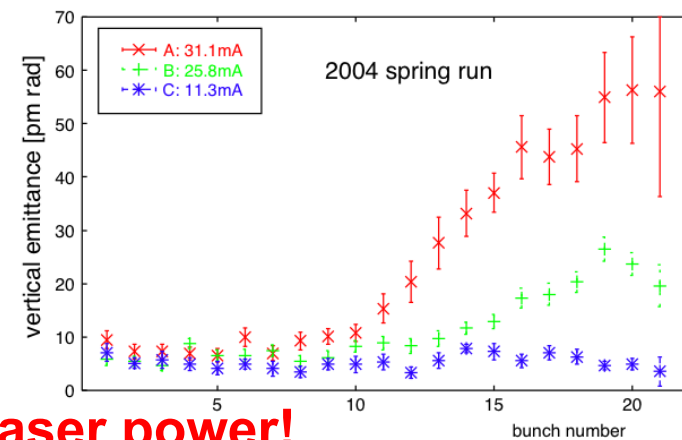
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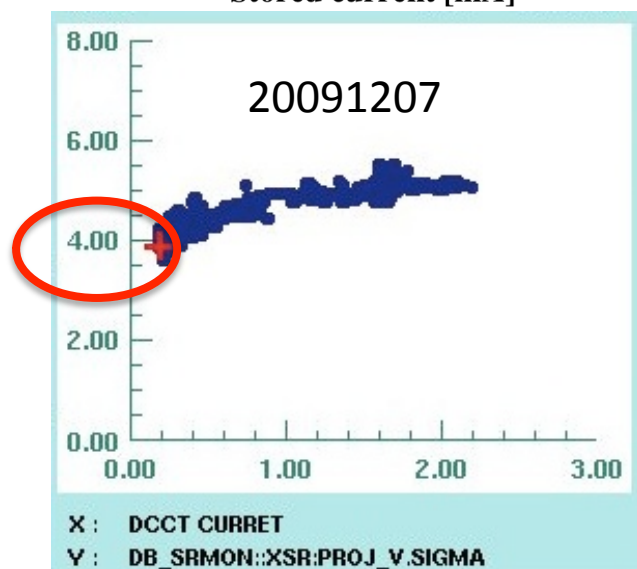
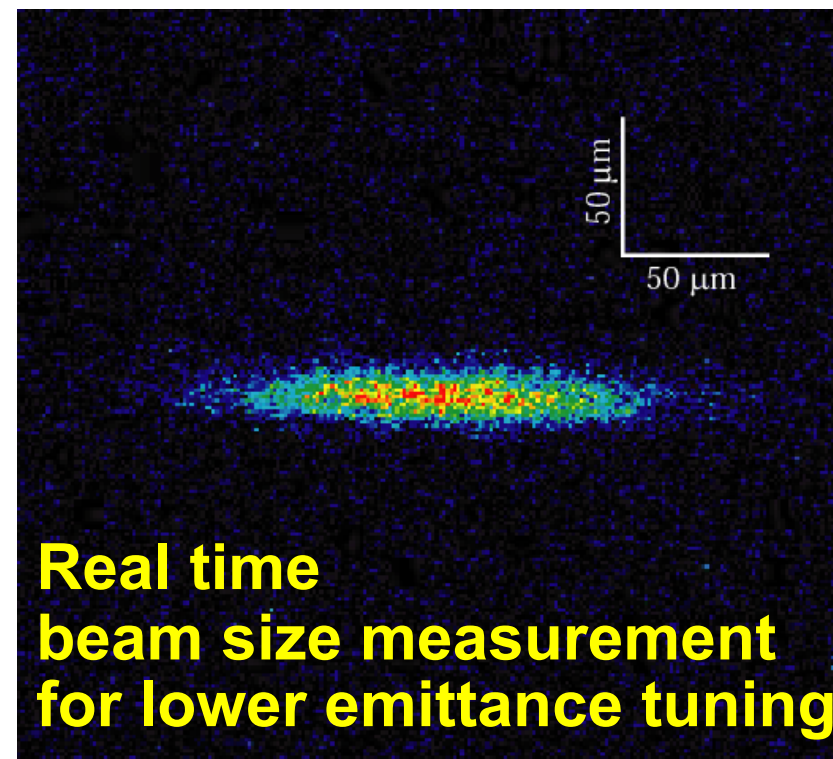
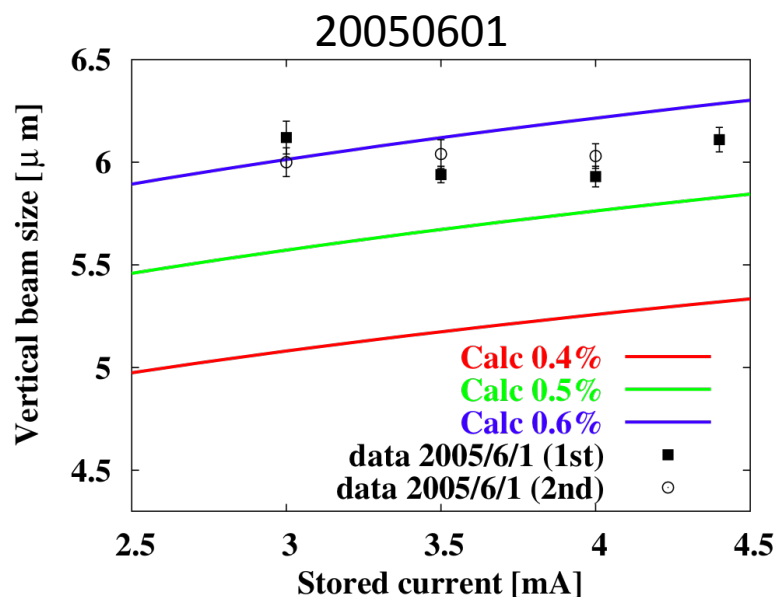


We observed a beam-size growth of 50%.  
It becomes clear than the result of 2007.

Increase the beam intensity as done in 2004!  
and Improve the LW measurement. **Higher Laser power!**



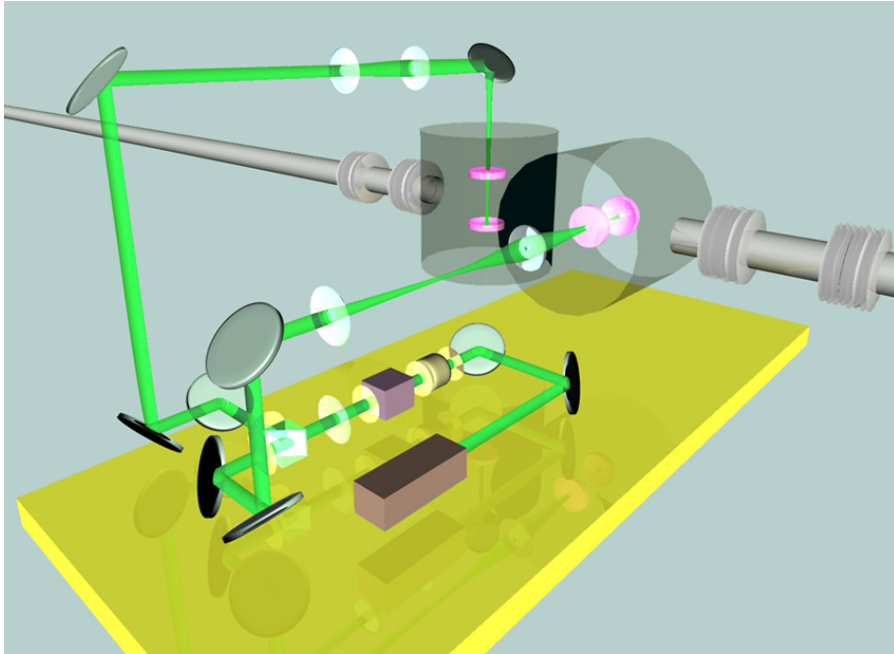
# Performance of XSR monitor



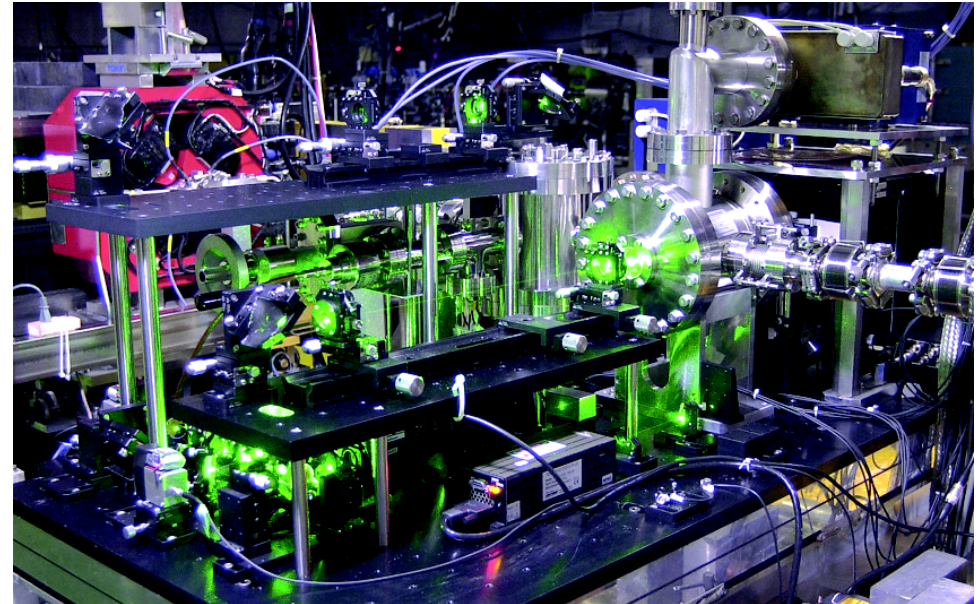
1. Used as a real time monitor for DR beam tuning.
2. Measured image is a superposition of the multi bunches during 20 ms.

Monitor performance: (single bunch)  
Beam size measurement was limited  $\sim 6\mu\text{m}$  in past.  
**It was improved and could reach  $\sim 4\mu\text{m}$  in 2009, which is not yet limited by the monitor.**

# *Laser wire beam size monitor in DR*

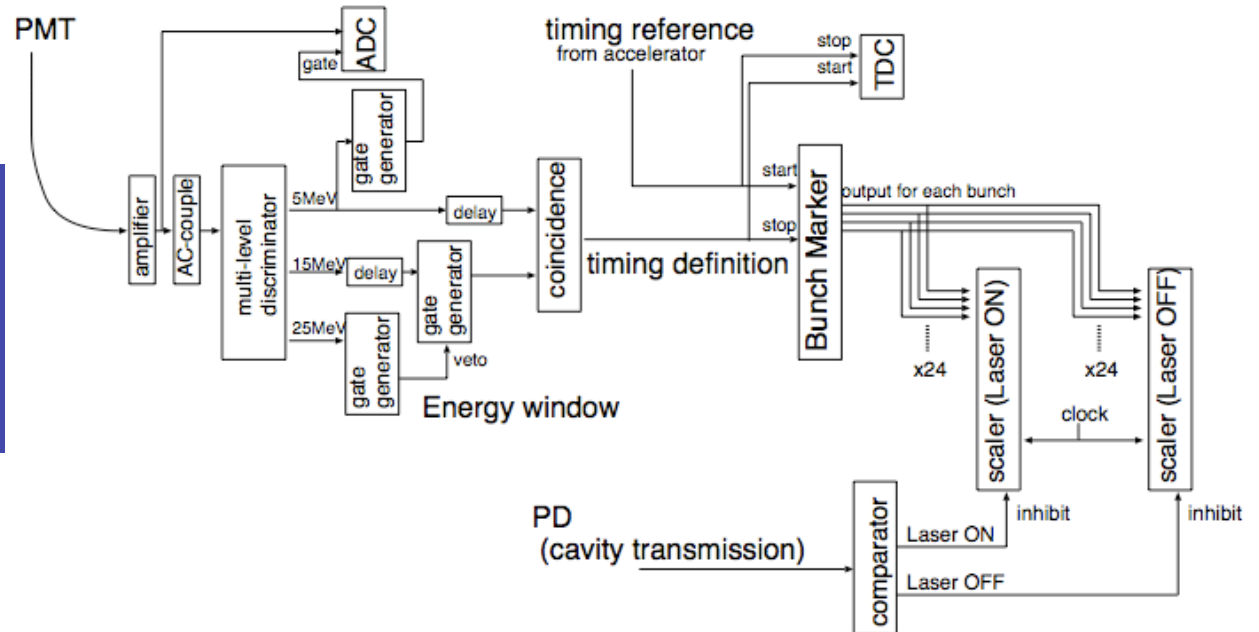


*300mW 532nm Solid-state Laser  
fed into optical cavity*

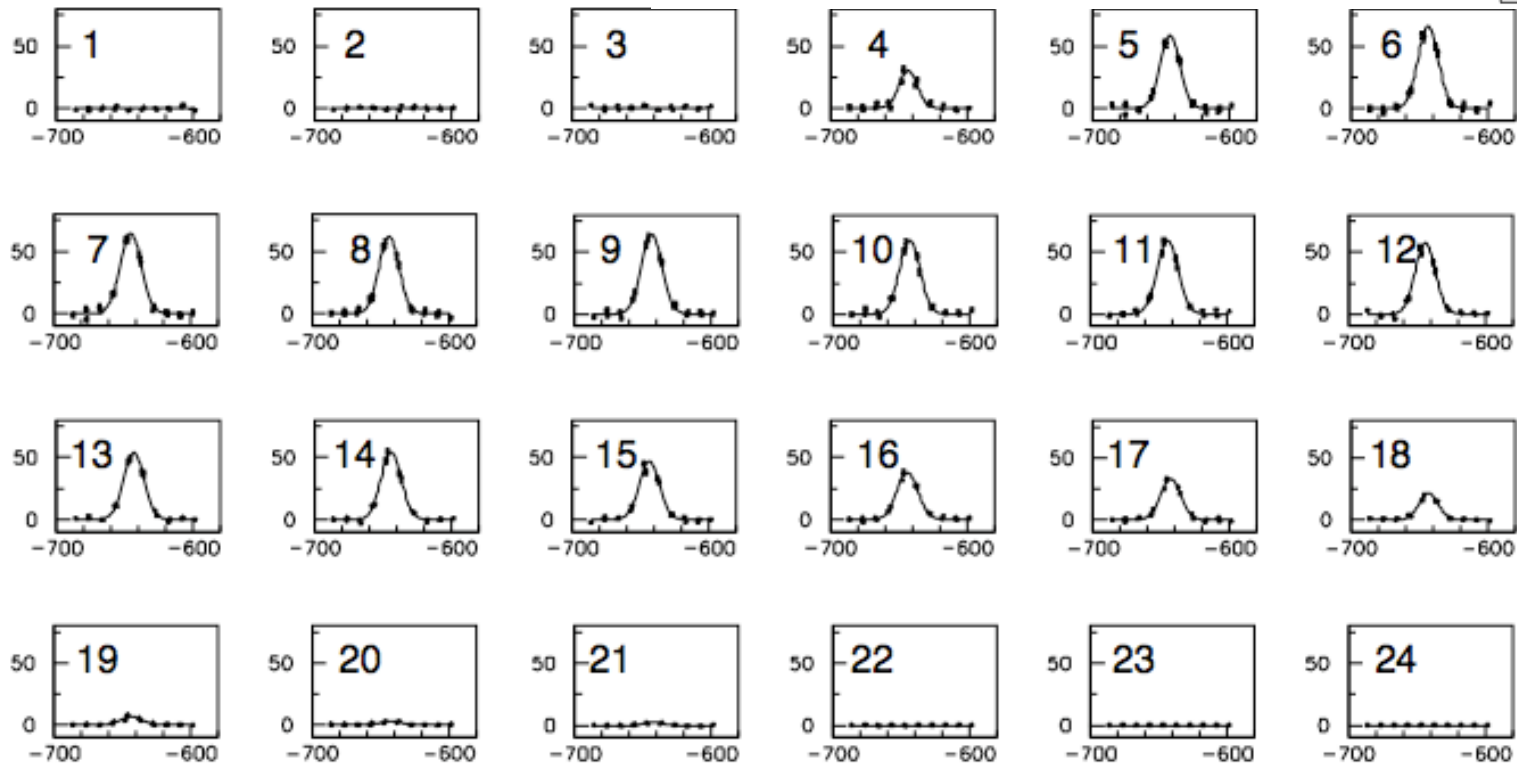


*14.7 $\mu$ m laser wire for X scan  
5.7 $\mu$ m for Y scan  
(whole scan: 15min for X,  
6min for Y)*

# LW: multi-bunch scanning



## Normal condition



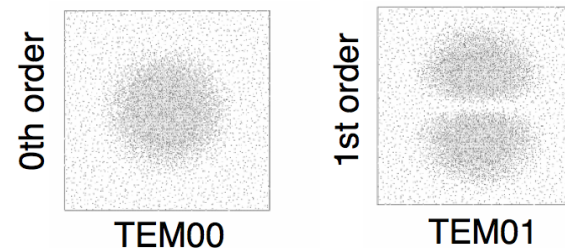
# Upgrading the Laser Wire system

## (1) Non-storage mode

- ▲ Past measurements were done by storage mode in DR. It means the dedicated beam time is necessary.
- Measurement under the non-storage mode was prepared for the parasitic measurement under the other R&D programs, ATF2, etc.
- ✗ Longer accumulation time is needed at present.

## (2) Higher order mode

- Smaller laser wire
- ✗ Lower laser intensity



## (3) Increase the laser intensity (x3 or more)

- New fiber laser is under testing.
- faster beam-size scanning (< a few min) and improve the measurements.



# About the Multi-bunch operation in ATF DR

- **Most of the R&Ds request a single-bunch beam**
  - As a result, ATF is usually optimized for a single bunch beam.
  - It does not well match for the multi bunch beam, especially for the injection to DR and storage. (due to the beam loading, etc.)
- **A few R&D programs request a multi-bunch beam.**
  - Fast Ion Study
  - Compton  $\gamma$ -ray generation by Laser Cavity for pol-positron source
  - Multi-bunch extraction by Fast Kicker
  - Intra-train nano seconds feedback by FONT (near future)
- **Injection and storage of the intensity-flat multi-bunch beam**
  - We need a dedicated time for multi-bunch beam tuning before above R&Ds.
  - Multi-bunch beam is much sensitive to the environment issues at ATF, such as drift of the cooling water temperature in Linac.
  - Improvements are continued for the cooling water stability, RF compressor, etc.

# Plan of FII R&D

1. We need to arrange the time for MB operation.
  - Beam time assignment: ATF (50%) and ATF2 (50%)
  - ATF includes the R&Ds for ...
    - Low emittance, Cavity Compton, fast ion, fast kicker, ...
  - Once per week or two weeks for FII study seems to be fine.
2. Re-confirmation of the results in 2004 is first step.
  - check the consistency etc.
3. Measurement by changing the ionization condition
  - beam intensity, ion pump ON/OFF, Gas injection,...



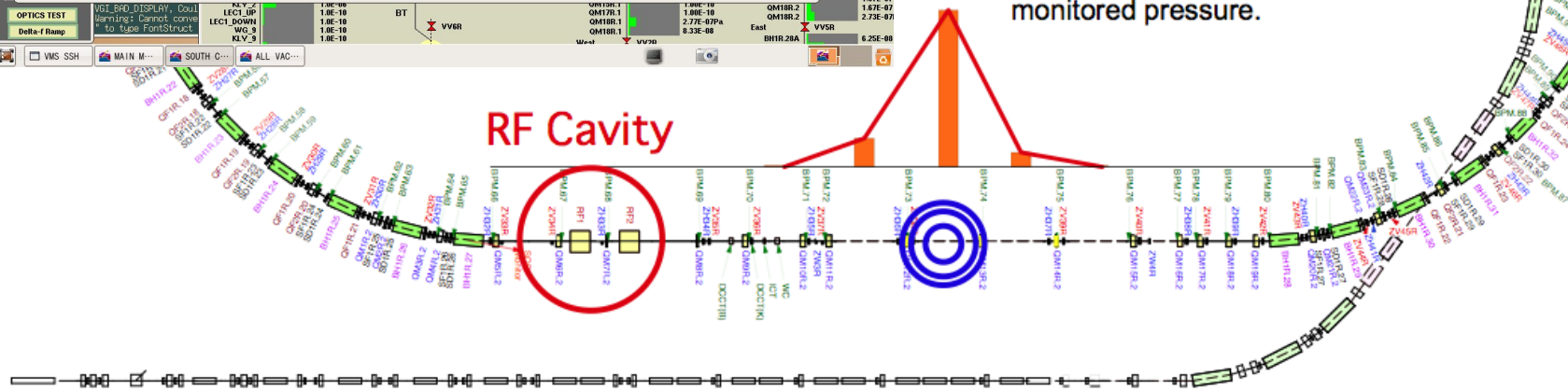
# Pressure bump at ATF-DR



**Gas Injection System**  
-N<sub>2</sub> or others-  
Pressure bump 10-7Pa to 10-3Pa

Scaled by  
monitored pressure.

**RF Cavity**



# Summary

- Vertical emittance in DR is almost recovered about less than 10 pm. It should be maintained for all studies.
- Fast ion study should be well scheduled with other ATF/ATF2 programs.
- Multi-bunch beam tuning should be well done just before the FII study.
- Local and remote participation for FII beam study is welcome.