# Report of ATF2 2012
# For Goal 1 (small beam size)

2013.01.24

K. Kubo

# ATF2 Oct. – Dec. 2012

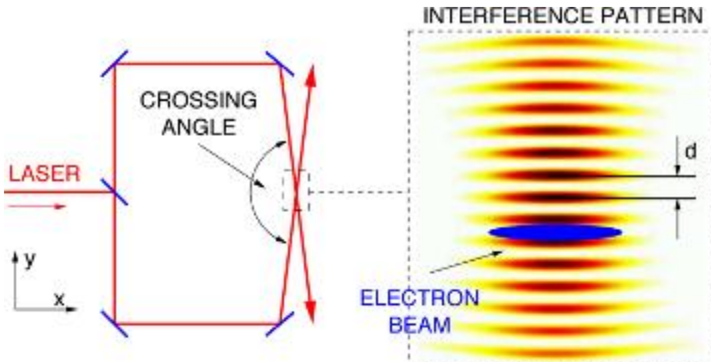
Goal in 2012

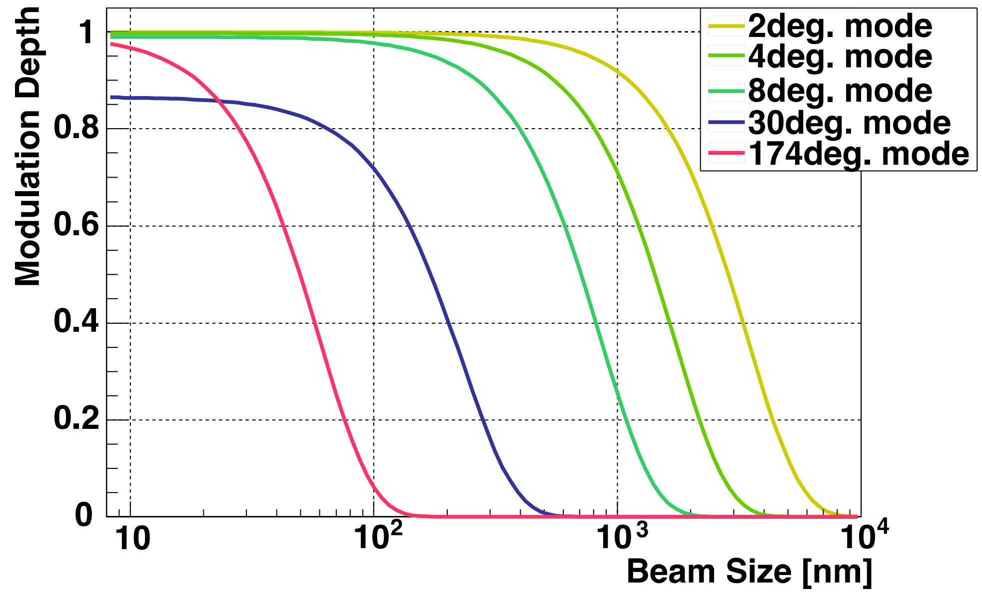
- Confirm < 70 nm beam size
  - This meant, clear observation of modulation with 174 deg mode of Shintake-monitor.
- Try to observe smaller beam size
  - If not ＜40 nm,  investigate the reason

Result

- Observed modulation of Shintake-monitor corresponding to about 70 nm beam size.
  - Bunch population about $10^9$
  - Estimation of errors is still under study.
- Beam size strongly depended on beam intensity

# IPBSM (IP Beam Size Monitor, Shintake-monitor)
# Crossing angle and modulation vs. beam size




Modulation

$$\equiv \frac{\text{peak} - \text{bottom}}{\text{peak} + \text{bottom}}$$

| | 174° | 30° | 8° | 2° |
|---|---|---|---|---|
| Fringe pitch | 266 nm | 1.03μm | 3.81μm | 15.2μm |
| Minimum | **25 nm** | 100 nm | 360 nm | - |
| Maximum | **100 nm** | 360 nm | - | 6 μm |

3 crossing angle modes.

Beam tuning with smaller angle -> Increase angle

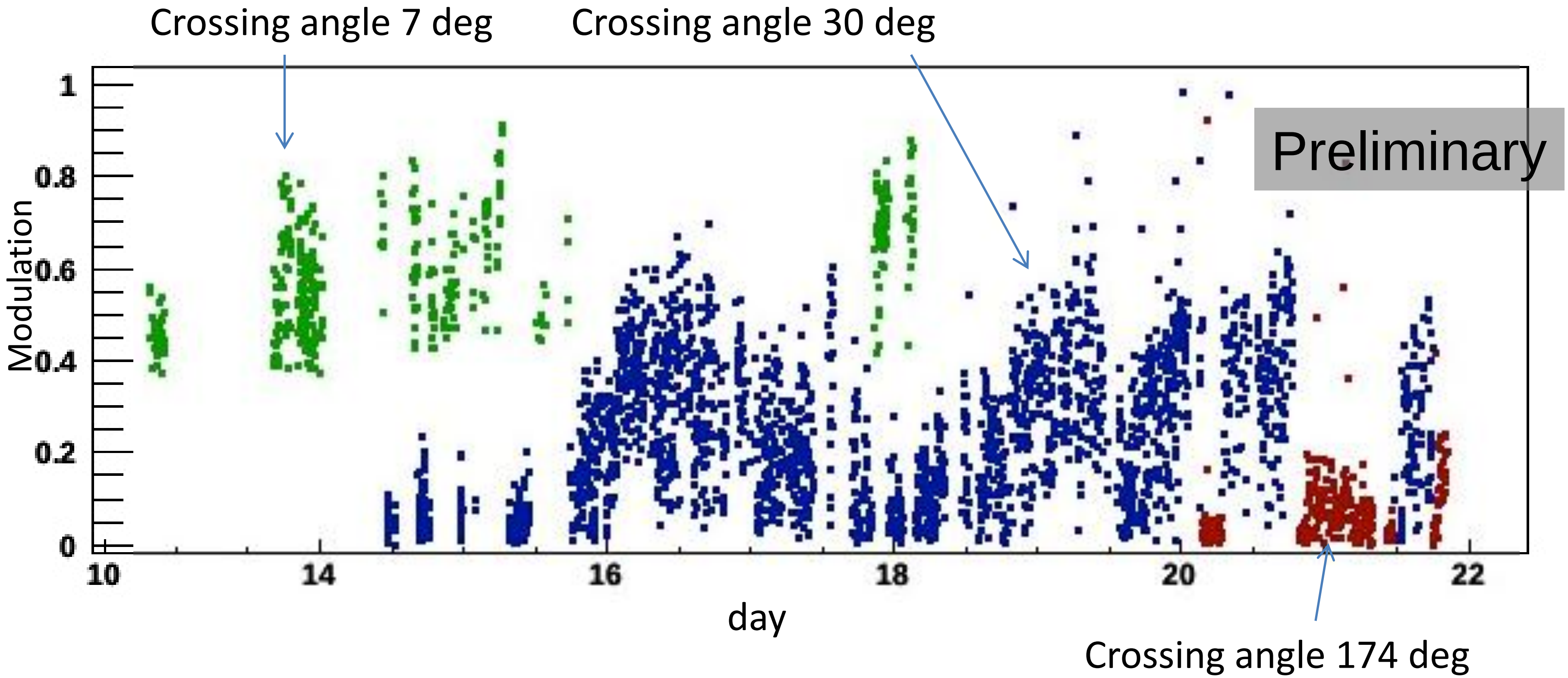
# Last 24 hours in Dec. Run

- After tuning with IPBSM crossing angle 30 deg mode, switch to 174 deg mode.
- Observed clear modulation. (modulation 0.2 – 0.3)
- Observed clear modulation for 7 hours continuously.
- Tried to tune beam for smaller beam size (larger modulation), but could not have effective tuning.
- Lost modulation during the tuning. Go back to 30 deg mode and re-tuned beam. Then, switch to 174 deg mode again.
- Observed clear modulation for 2 hours continuously, till the end of the run.

This showed:

- Stability in several hours
- Effectiveness of method of small crossing angle to large angle
- Limited modulation with 174 deg mode (about 0.3)

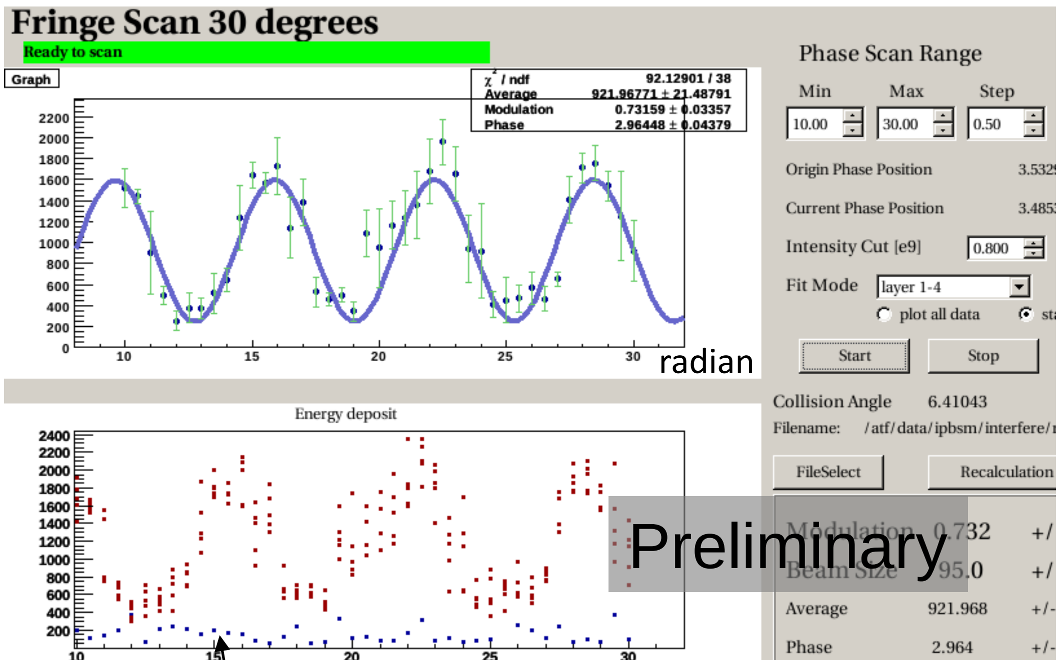
# Fringe scan history, Dec. 12-21




All fringe scans, including multi-knob scans

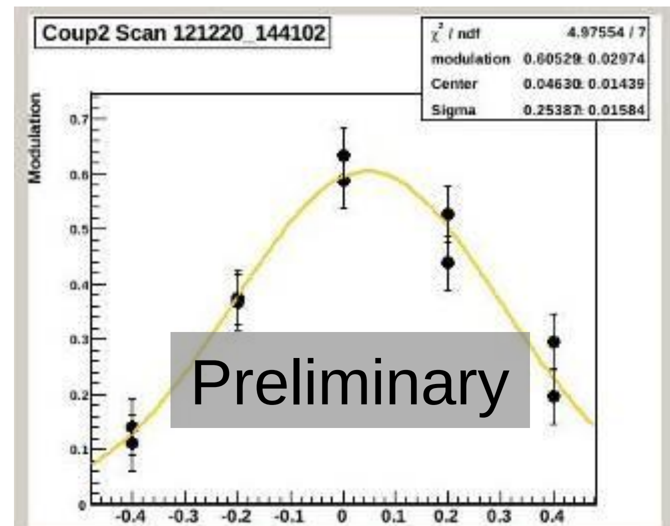
# Example of 30 deg mode measurement

Fringe scan

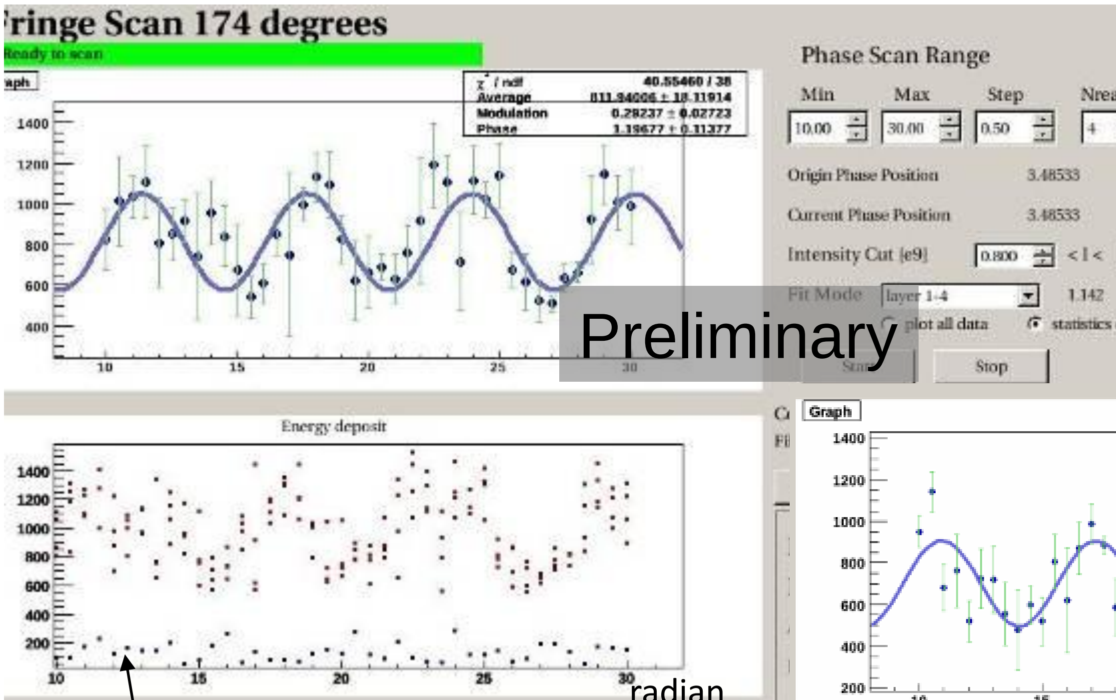



background (laser off)

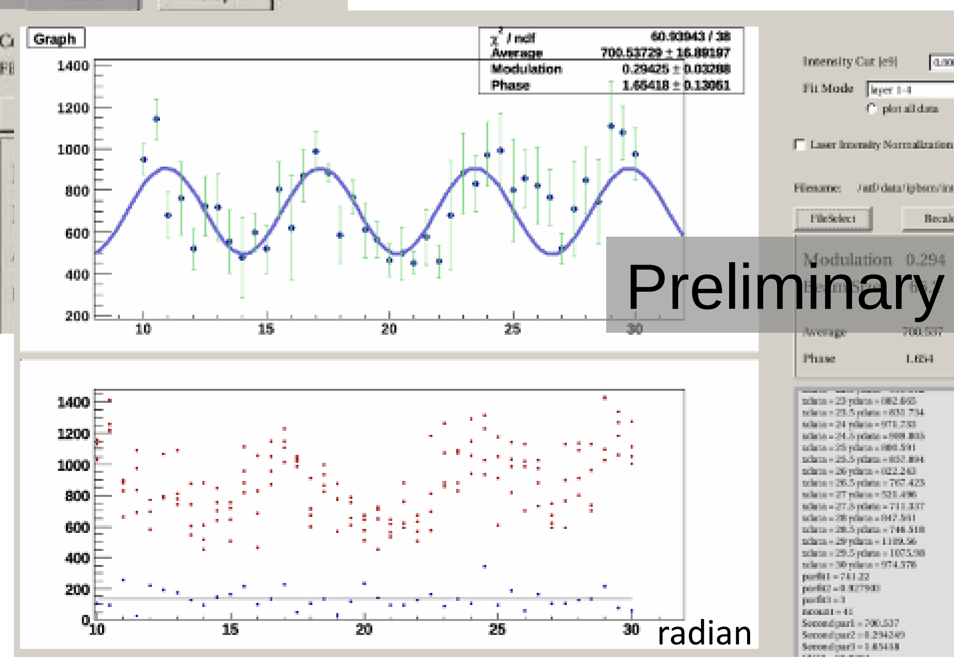
ビーム調整ノブのスキャンの例



# Example of 174 deg mode measurement



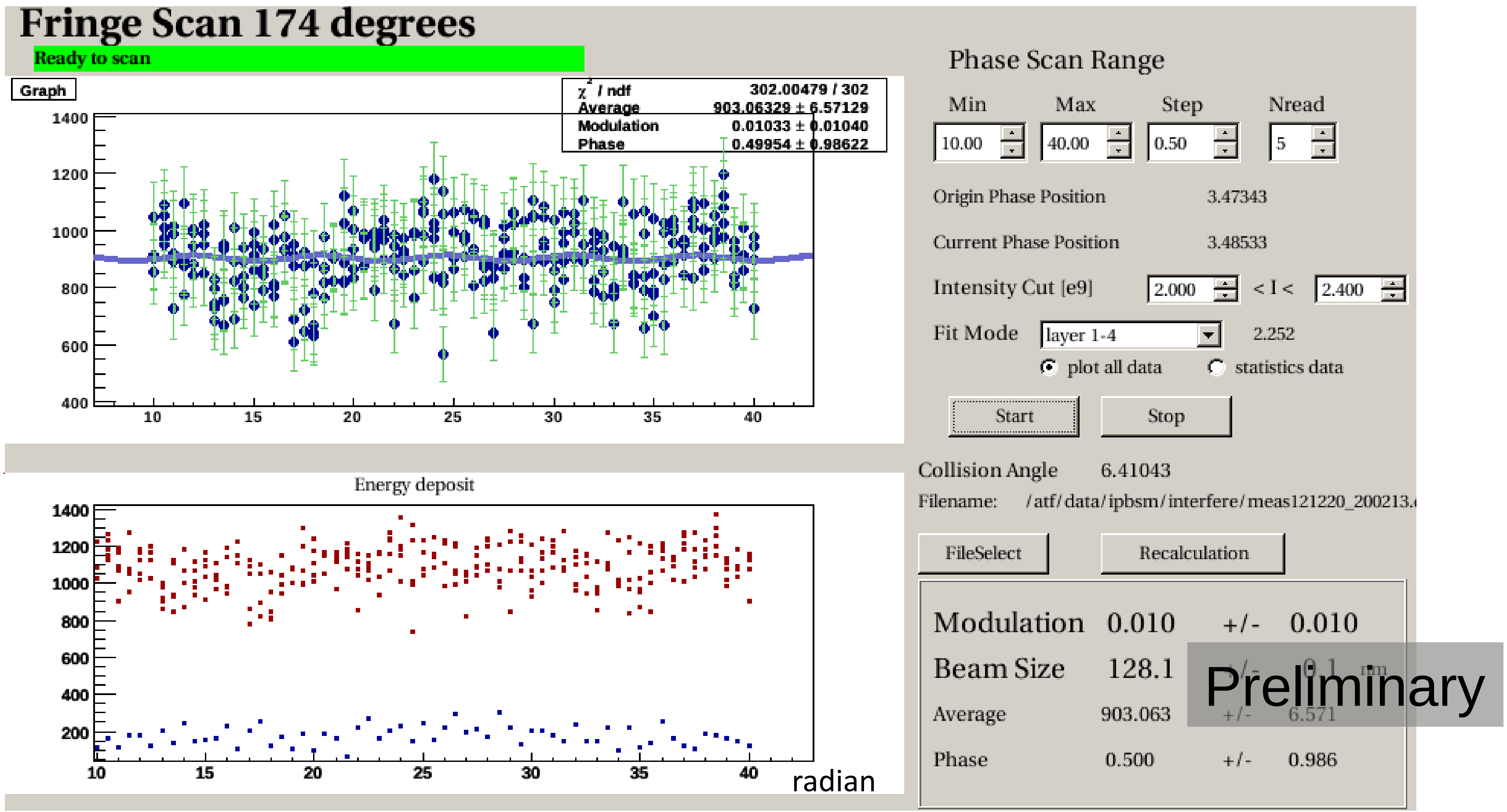

0.8e9 < N < 1.2e9



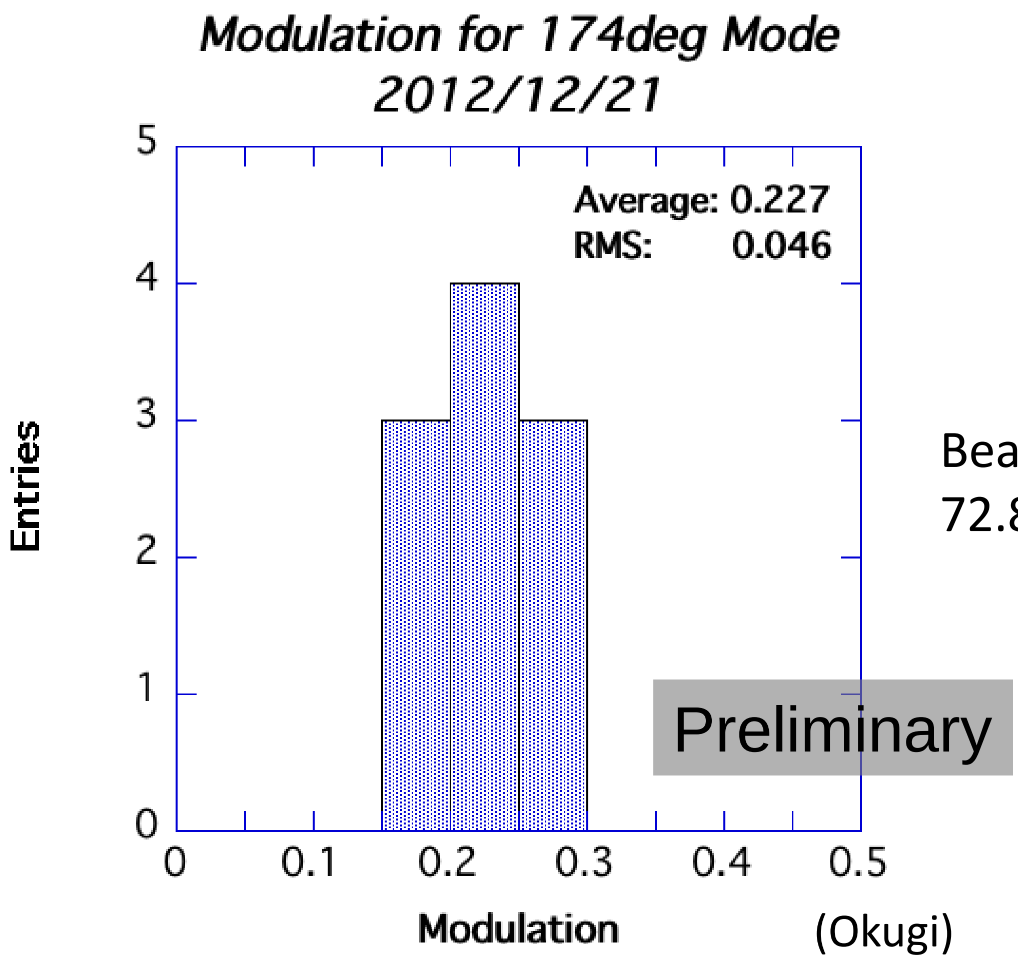

background (laser off)

Modulation corresponds to about 70 nm beam size.

# Example of 174 deg mode measurement (No modulation)



# Summary of 10 measurements with 174 deg mode




Beam size
72.8+5.4-4.7nm

(Okugi)

# Clear modulation observed with 174 deg mode of Shintake-monitor

- Modulation about 0.2 – 0.3, beam size about 70 nm. Reliable error estimation has not been done yet.
- Could be observed only for very small bunch population (1 – 2E9)
  - Beam size rapidly increased with bunch intensity
  - Operation and measurement with lower intensity beam is difficult .
- Performance and stability of the beam size monitor could be confirmed.
  - But, for small crossing angle, modulation was significantly smaller than theoretical maximum.
  - Stability of the laser system is still to be improved.
- Strong intensity dependence is serious problem. Need to understand. Need to mitigate it, if possible.
  - Study possible impact to ILC BDS design.

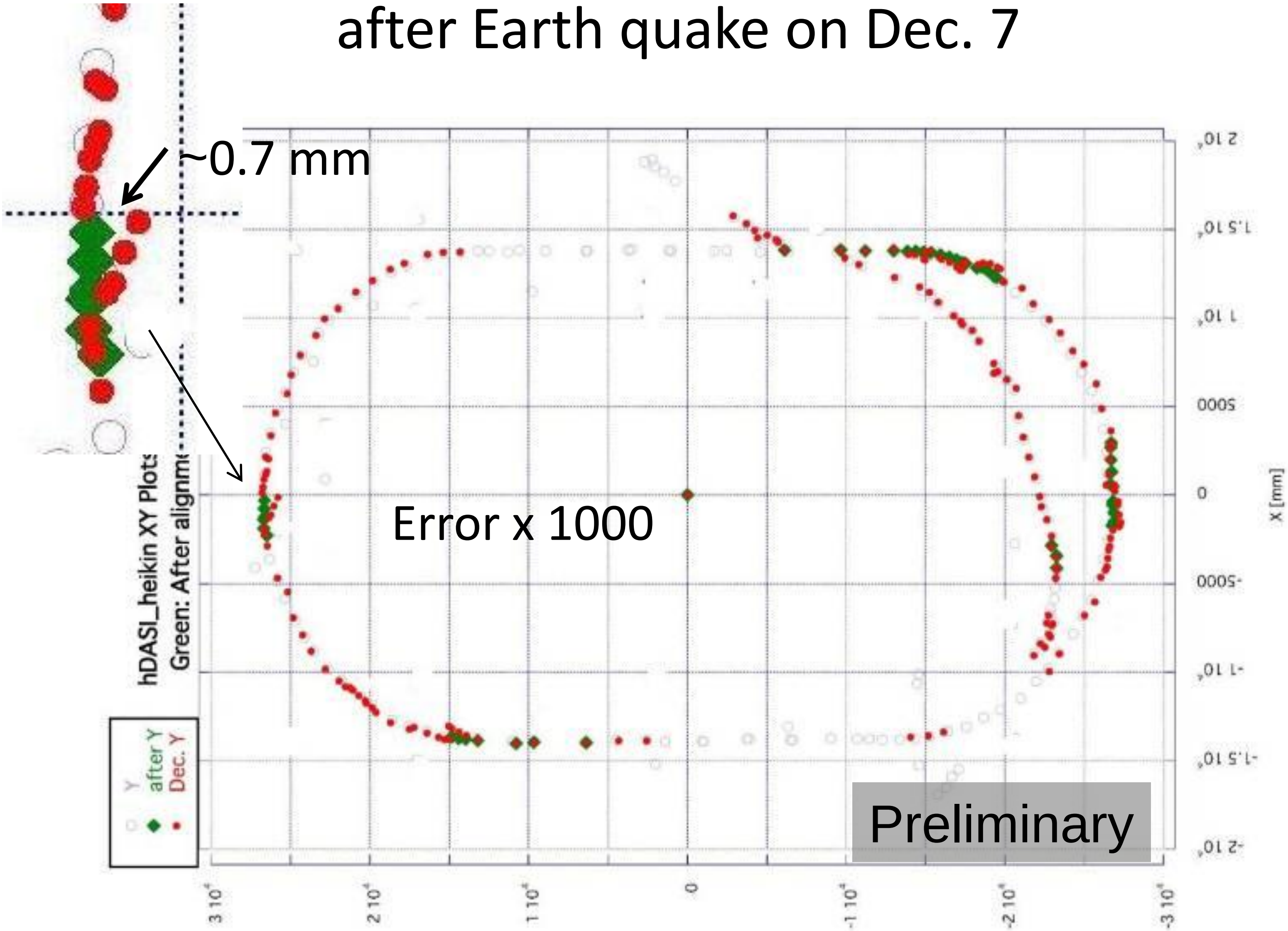
# Brief History of Autumn Run

- Oct. 15-19, 22-27
  - Recovery from summer shutdown, commissioning of new system (3 Hz operation etc.)
  - Confirm large modulation (about ~0.9) with 7 deg angle mode of IPBSM
  - Lost 1 day due to magnet power supply trouble

- Nov. 5-9, 12-16
  - Confirm clear modulation with 30 deg angle mode of IPBSM
  - Lost 1 week due to Linac RF modulator trouble

- Nov. 26-30, Dec. 3-7, 10-21
  - Confirm clear modulation with 174 deg angle mode of IPBSM
  - Earth quake on Dec. 7. DR alignment check and correction.

# Damping ring alignment check and correction after Earth quake on Dec. 7



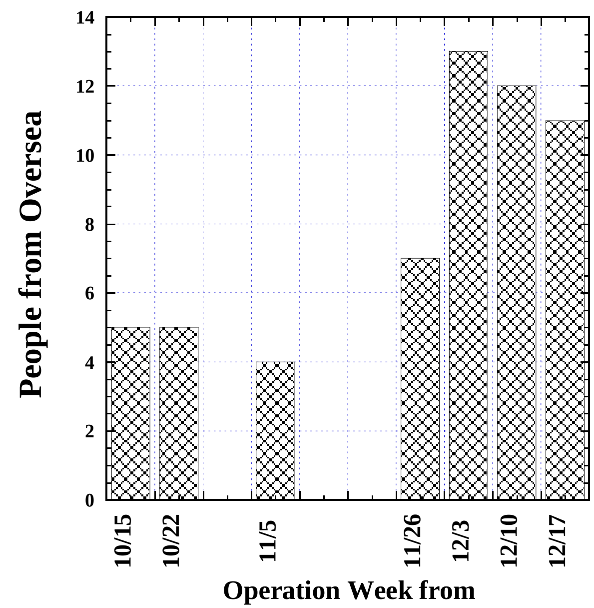

(S. Araki)

# Members from oversea

## ATF2 Visitors Schedule for Oct.-Dec. 2012

Put your name and schedule. (You are welcome to improve the format by editting this page.)

| Name | Oct. 15 | Oct. 22 | Oct. 29 | Nov. 5 | Nov. 12 | Nov.19 | Nov. 26 | Dec. 3 | Dec. 10 | Dec. 17 |
|---|---|---|---|---|---|---|---|---|---|---|
| Test Example | no | 23~26 | no | 7~ | ~15 | no | 29~ | yes | ~12 | ? |
| SLAC | | | | | | | | | | |
| G. White | 15-19 | 23-26 | no | no | no | no | 26-30 | 3-7 | 10-14 | 17-21 |
| M. Woodley | no | no | yes | yes | yes | no | yes | yes | yes | yes |
| J. Nelson | no | no | no | no | no | no | 30~ | yes | yes | ~21 |
| E. Marin | no | no | no | no | no | no | 26~ | yes | ~14 | no |
| CERN | | | | | | | | | | |
| J. Pfingstner | no | no | no | no | no | no | yes | yes | yes | yes |
| Yves Renier | | | | | | | no | yes | yes | yes |
| Hector Garcia Morales | no | no | no | no | no | no | no | yes | yes | yes |
| IFIC | | | | | | | | | | |
| J. Resta-Lopez | no | no | no | no | no | no | yes | yes | no | no |
| J. Alabau | no | no | no | no | no | no | yes | yes | no | no |
| Oxford U. (FONT) | | | | | | | | | | |
| Young Im Kim | yes | yes | no | yes | yes | yes | yes | yes | yes | yes |
| Davis | yes | yes | | no | yes | | no | no | yes | yes |
| Blaskovic | yes | yes | | no | cancelled | | no | yes | yes | no |
| Burrows | yes | | | | | | | | | |
| Christian | | yes | | | | | | | | |
| KNU | | | | | | | | | | |
| Siwon Jang | no | no | 31~ | yes | yes | no | no | no | ? | ? |
| RHUL | | | | | | | | | | |
| S. T. Boogert (RHUL) | no | no | no | no | no | no | no | no | yes | yes |
| J. Snuverink (RHUL) | no | no | no | yes | no | no | no | yes | yes | yes |
| Oxford JAI (EXTLW) | | | | | | | | | | |
| L. Corner | no | no | no | no | no | no | no | yes | yes | yes |



# Sift for ATF2 study

Assigned "Study leader" and "sub leaders"
(Many joined to not-assigned shifts)

Example: table for the last week

| | 1:00 – 9:00 | 9:00 – 17:00 | 17:00 – 25:00 |
|---|---|---|---|
| 12/10 Mo | --- | --- | *Kubo* |
| 12/11 Tu | Kuroda + A | White + B | *Okugi* + C |
| 12/12 Wd | Woodley + D | *Tauchi* + E | Kuroda + A |
| 12/13 Th | Kubo + B | *Okugi* + C | Tauchi + D |
| 12/14 Fr | White + E | Terunuma + A | Woodley + B |
| 12/15 Sa | Kuroda + C | Terunuma + D | White + E |
| 12/16 Su | Kubo + A | Tauchi + B | Woodley + C |
| 12/17Mo | Okugi + D | White + E | *Terunuma* + A |
| 12/18 Tu | *Kuroda* + B | Tauchi+ C | Okugi + D |
| 12/19 Wd | Woodley + E | *Kubo* + A | White+ B |
| 12/20 Th | *Okugi* + C | Kuroda + D | Kubo + E |
| 12/21 Fr | White+ A | *Tauchi* + B | |

Name: Study/Tuning leader ( *Italic: shift leader (for safety)*)

A-D: Study/Tuning sub-leaders

The assignments are not strict and you may join any shifts.

A: J. Nelson, E. Marin, L. Corner

B: Y. Renier, H. Garcia Morales

C: S. Boogerd, J. Snuverink,m

D: Y-I Kim, N. Blaskovic, Davis

E: J. Pfingstner, Akagi, Tanaka

# Daily meeting

S. Araki

# Reduction of multi-pole field, and beam study

Hardware works for reducing multi-pole field (before the last 4-weeks run)

- Replace QF1FF (the $2^{nd}$ last quadrupole magnet to IP)
  - Old one had large multi-pole field
  - From SLAC (PEPII), Large aperture and small multi-pole field.
- Remove two S-band Cavity BPMs attached to the last two quadrupole magnets (QD0 and QF1)
  - Feed-through made of Kovar

Beam Experiment

- Used 6 skew sextupole magnets in beam size tuning
  - If they were effective, it would be a evidence of some unexpected multi-pole field errors.
  - We observed some effect but cannot have clear conclusion yet. (see next next slides)

QF1 replaced

Cavity BPM removed

# *The effect of skew quadrupole field of SD4FF*

***Simulation***

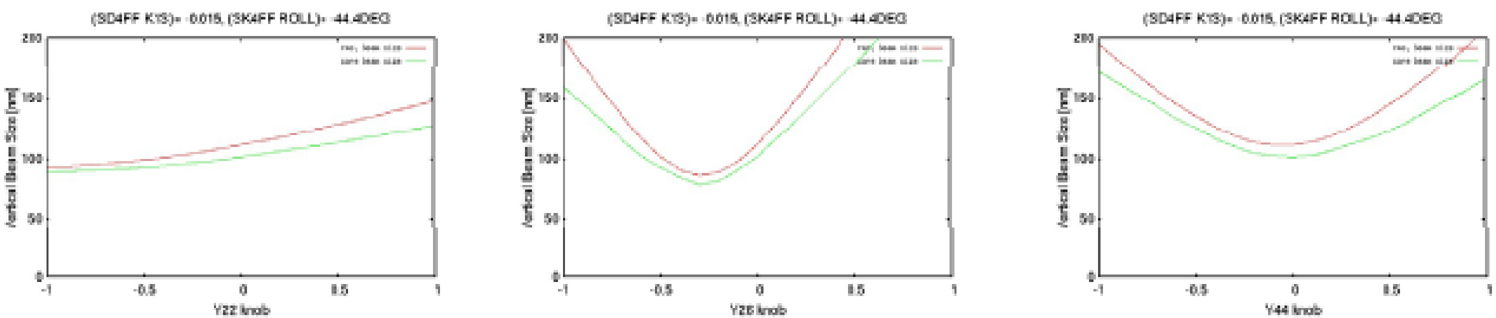
*-Put K1S=-0.015 at SD4FF*

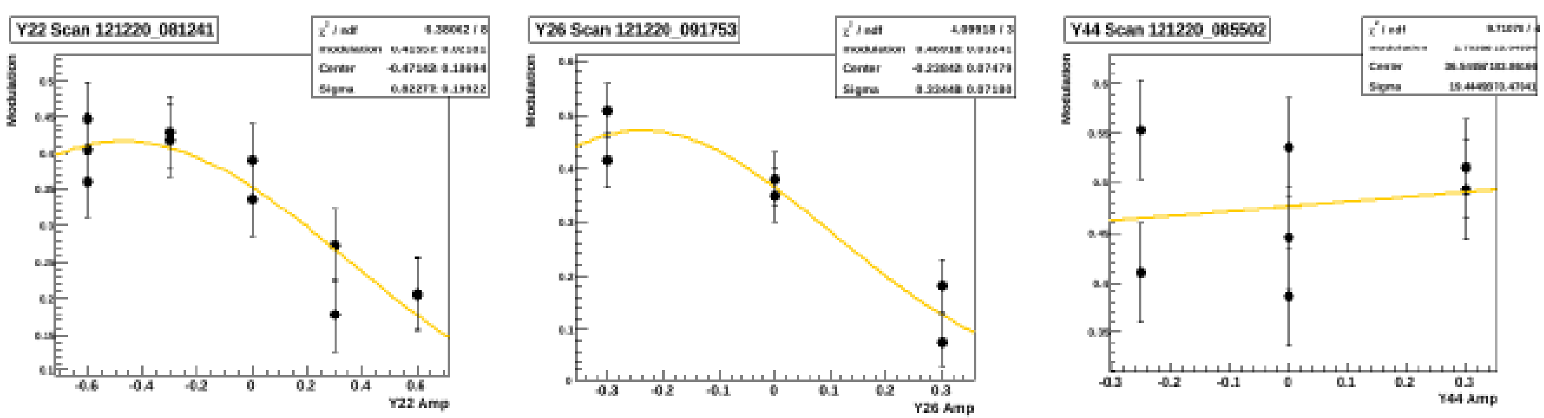
*-Rotate the SK4FF by -44.4 deg.*

*-Optimize the linear knobs (Ay, Ey, Coup2)*

*-Evaluate the nonlinear knob response*

Experiment may be explained by
Errors of Sextupole magnet
and rotation of Skew Quadrupole magnet



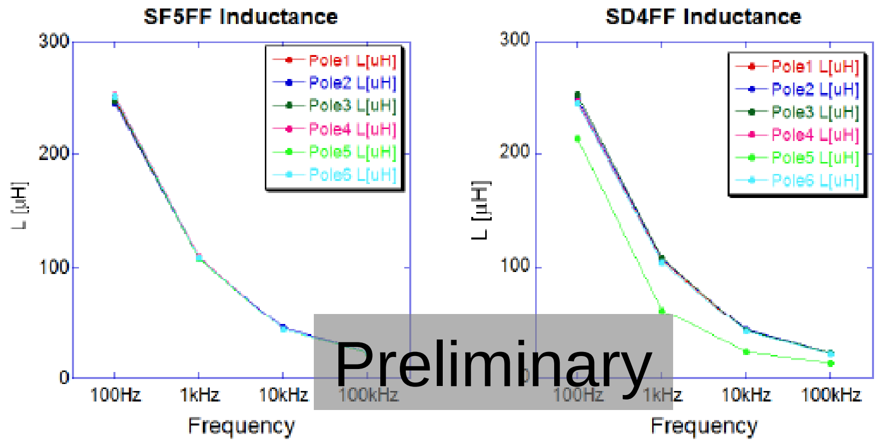




*Same response to the measurement*

(T. Okugi)

# Problem of sextupole magnet found in Jan.

- Impedance of each pole coil of sextupole magnets were recently measured and problem found with one magnet (SD4FF). (by T.Okugi)
  - Impedance of one pole is significantly small compare with other five. (short)
  - Caused skew qudrupole field and multi-pole field errors.
- May explain observations. (Need more study for conclusion)




- We have no spare sextupole magnet now.
  - Exchange SD4FF(strong) and SF5FF(weak) for now.
  - Replace it later, ASAP.

# Beam size depend on bunch intensity

Possible reason

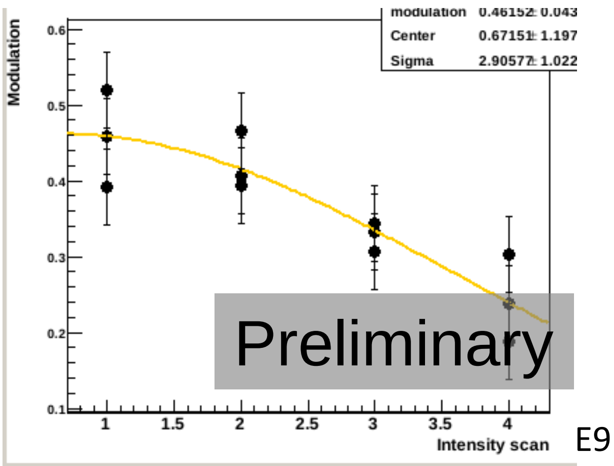
- Wakefield is mostly suspected. (In large beta region)
  - Cavity-BPM
  - Bellows, Vacuum port, etc.
  - Resistive wall of narrow beam pipe region.

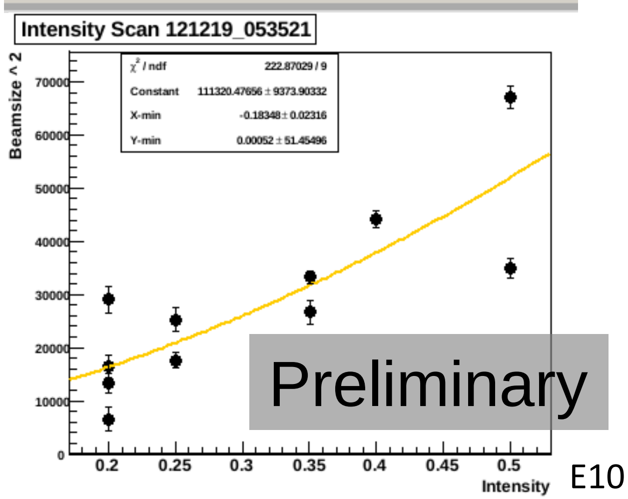
- Intra-beam scattering + Non-linear magnetic field cannot be excluded
  - Intra-beam scattering → energy spread, horizontal emittance increase
  - → Non-linear magnetic fields increase vertical beam size

Need more study.

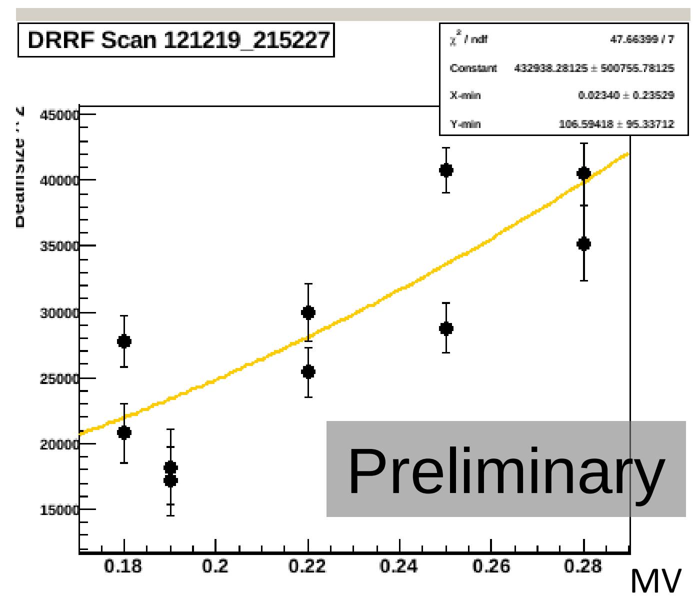
# IP beam size Intensity dependence

Modulation (beam size) vs.
bunch intensity.
IPBSM 30 deg




Beam size vs.
DR RF voltage (bunch length)
IPBSM 30 deg

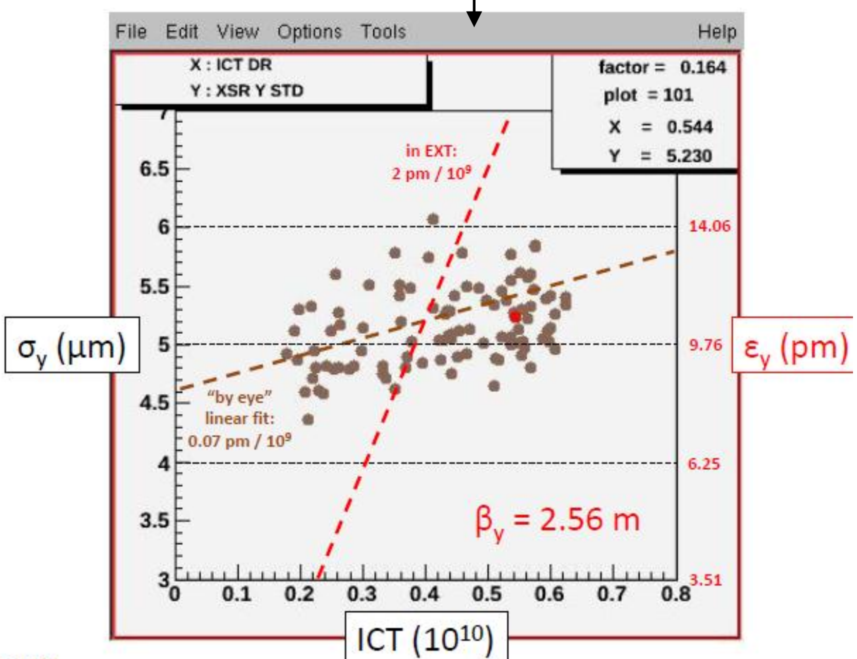



Depend on line density,
not only total charge.
Longer bunch → Less wake
Less intrabeam scatt.

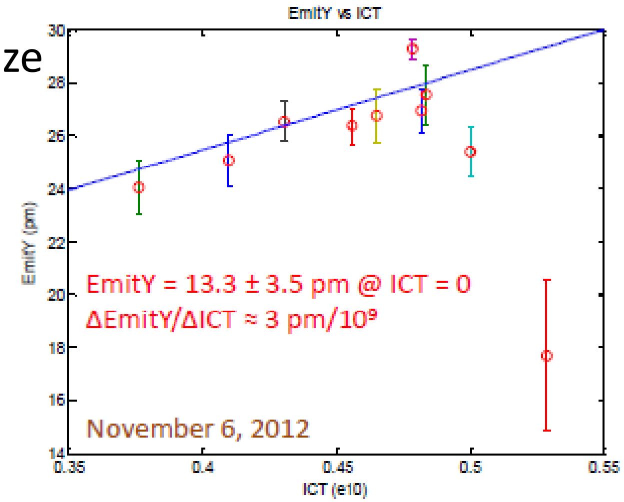
# Emittance upstream of FF  Intensity dependence

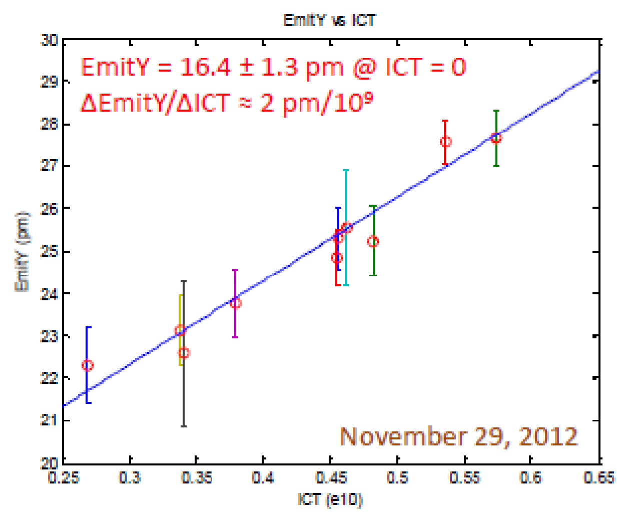
In EXT line, 2-3 pm/1E9
Problem, but much smaller than IP size

In Damping Ring, <0.1 pm/1E9
(intra-beam scattering)




6, 2012




by Marc Woodley

# Reduction and study of Wakefield

- Removed possible wake sources in large beta region, as possible.
- (Re-)Calculate Wakefield
- Put Cavity BPM (C-band reference cavity) on a mover (Wakefield generation, compensation)
  - Beam size vs. Cavity offset
    - Apparent dependence much stronger than calculation
  - Beam orbit vs. Cavity offset
    - Almost consistent.

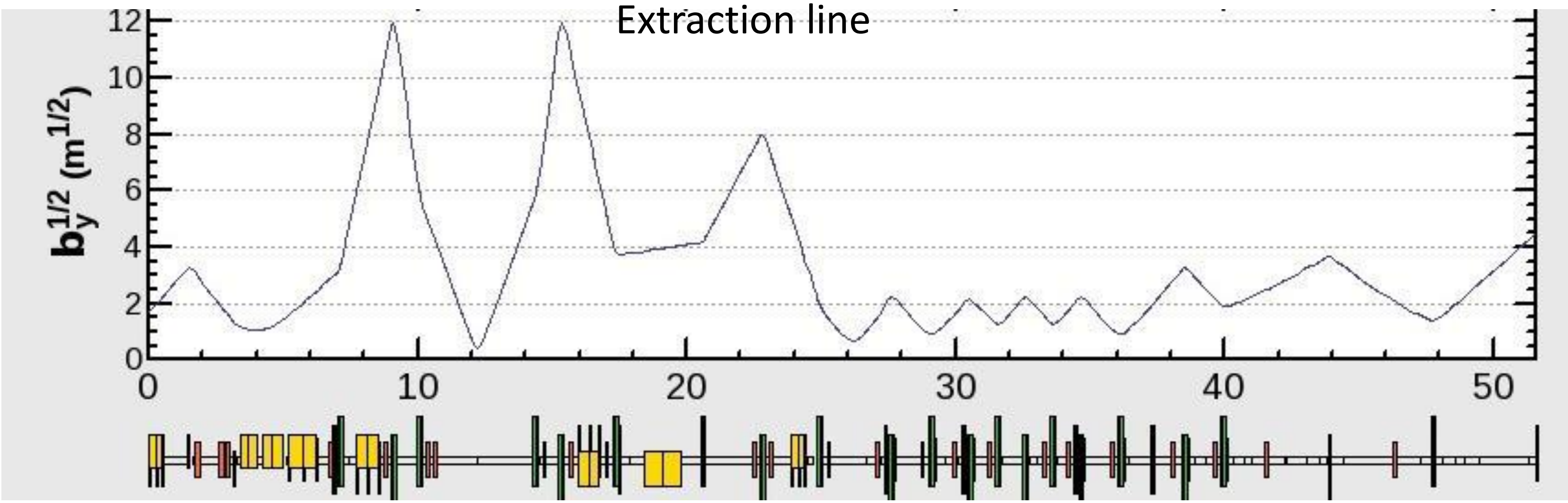
# Removed possible wake sources in large beta region

Replace Vacuum ports by more symmetric ones. (T to +)

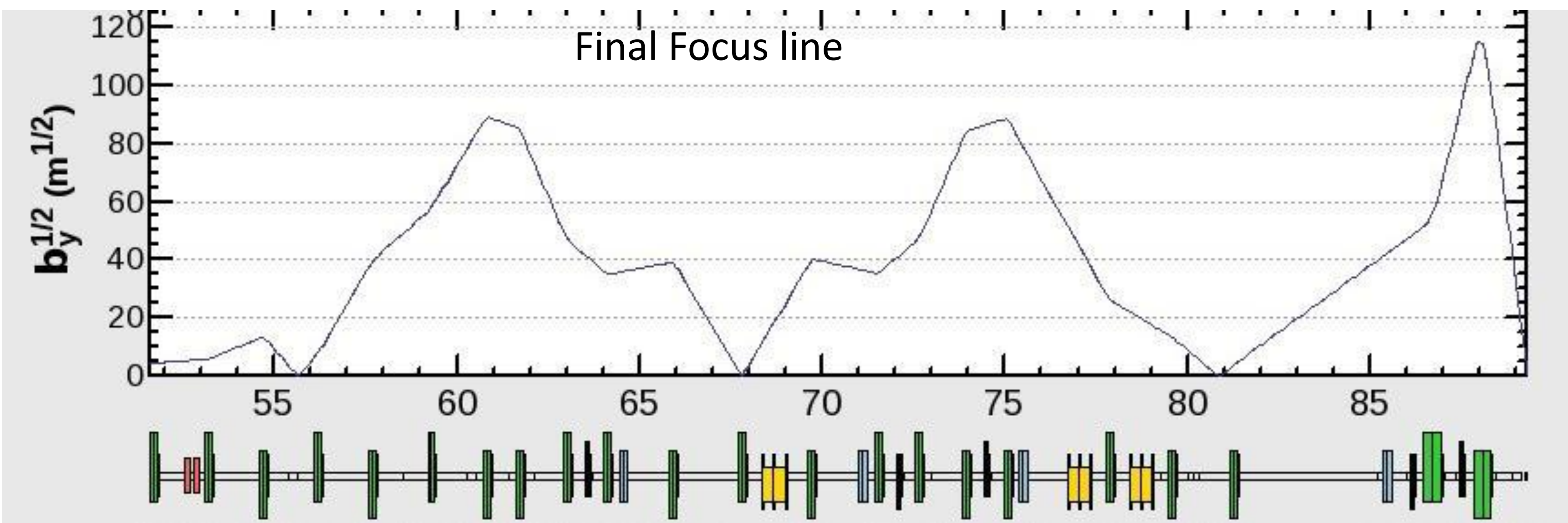
Remove 3 C-band reference cavities (not used)

Move Gate Valve and S-band Reference cavity from High beta region to lower beta region

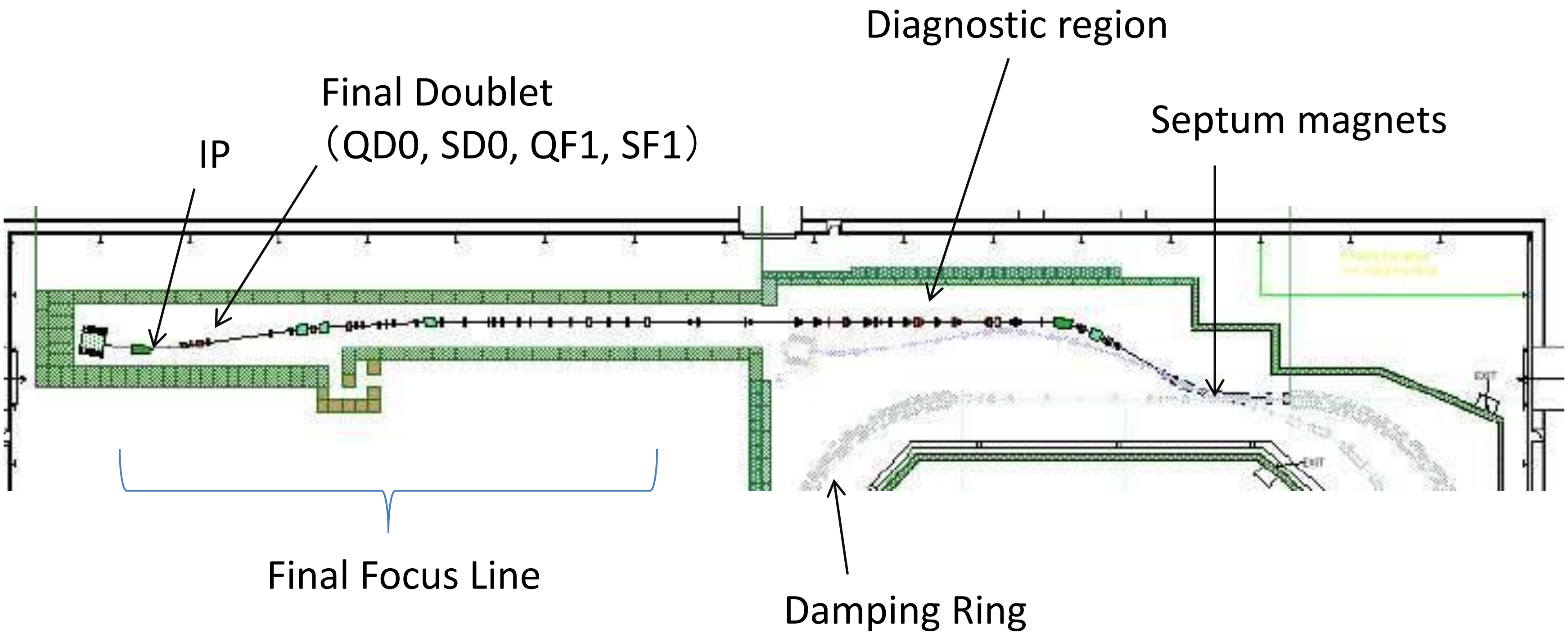
Sqrt(beta-y)



Extraction line
$b_y^{1/2}$ ($m^{1/2}$)
12
10
8
6
4
2
0
0
10
20
30
40
50

Final Focus line
$b_y^{1/2}$ ($m^{1/2}$)
120
100
80
60
40
20
0
55
60
65
70
75
80
85

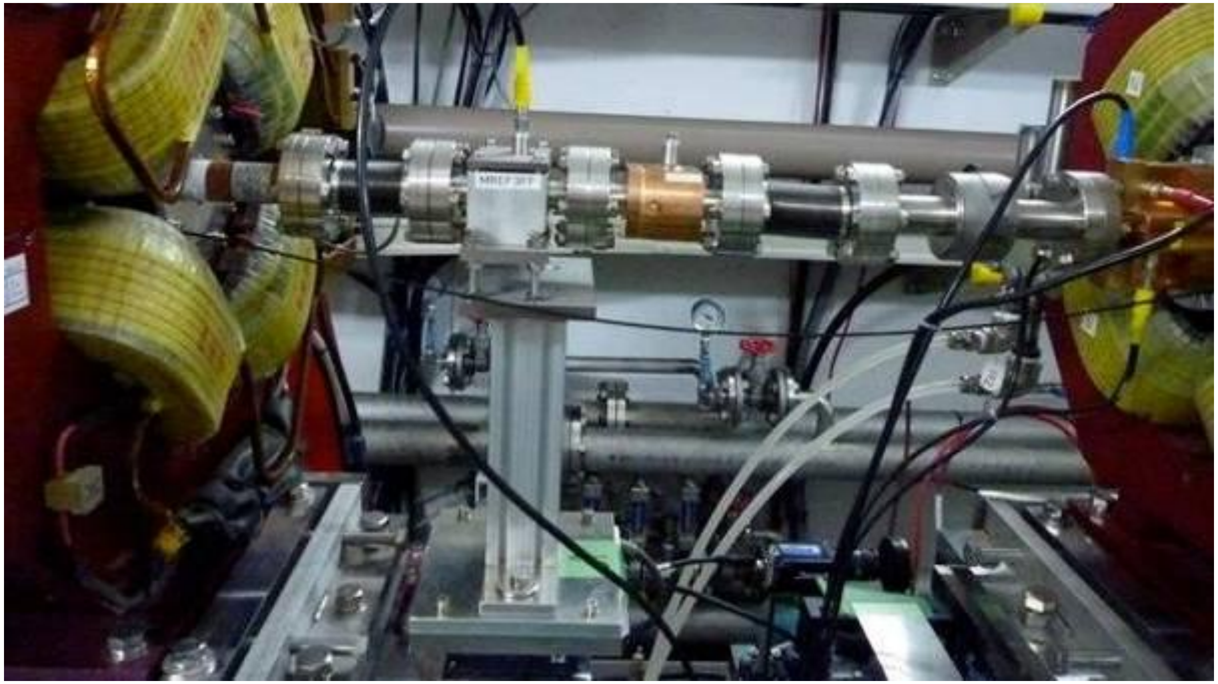


Diagnostic region
Final Doublet
（QD0, SD0, QF1, SF1）
Septum magnets
IP
Final Focus Line
Damping Ring

# C-band Reference cavities on a mover

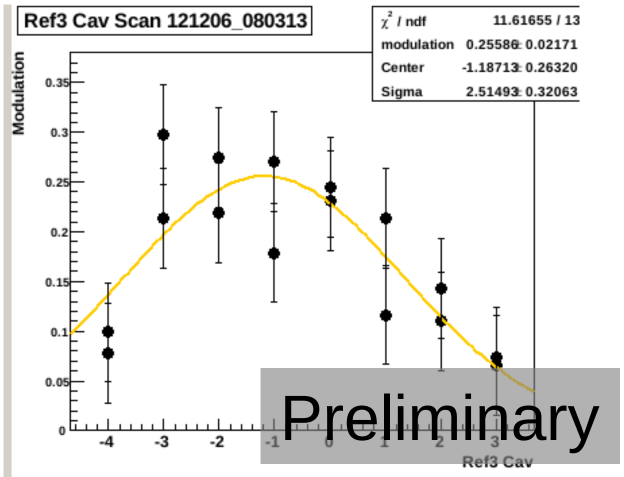
For studying effect of Cavity BPM wakefield

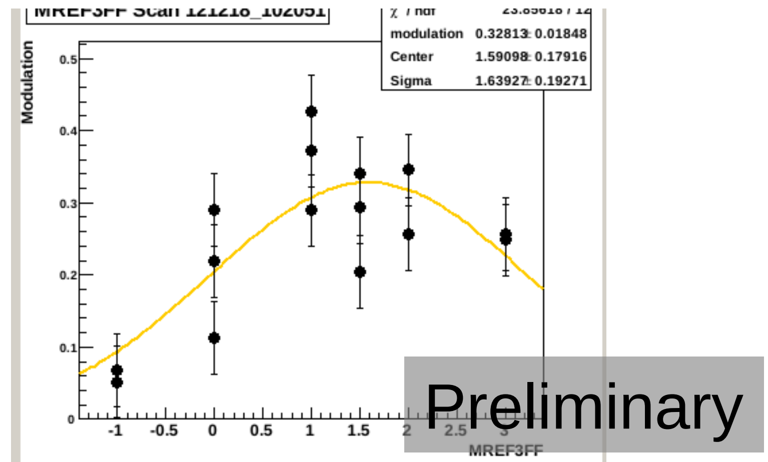
May compensate wakefield of other locations



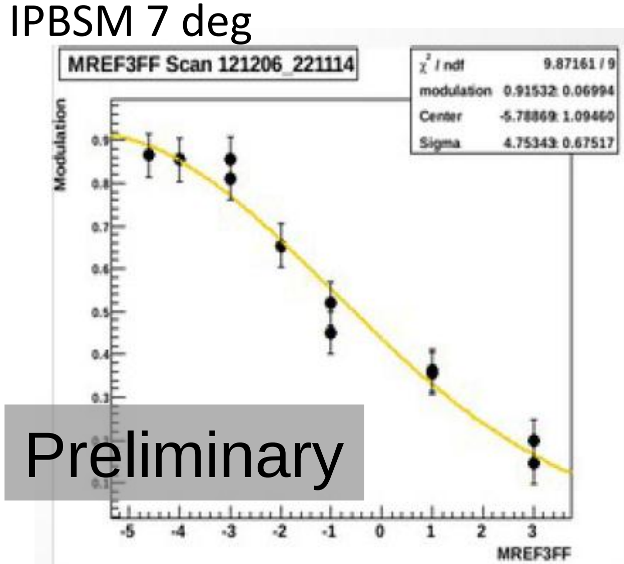
# Study using C-band Reference cavities on a mover

Example Beam size measurement: Modulation vs. cavity position, IPBSM 30 deg




IPBSM 7 deg

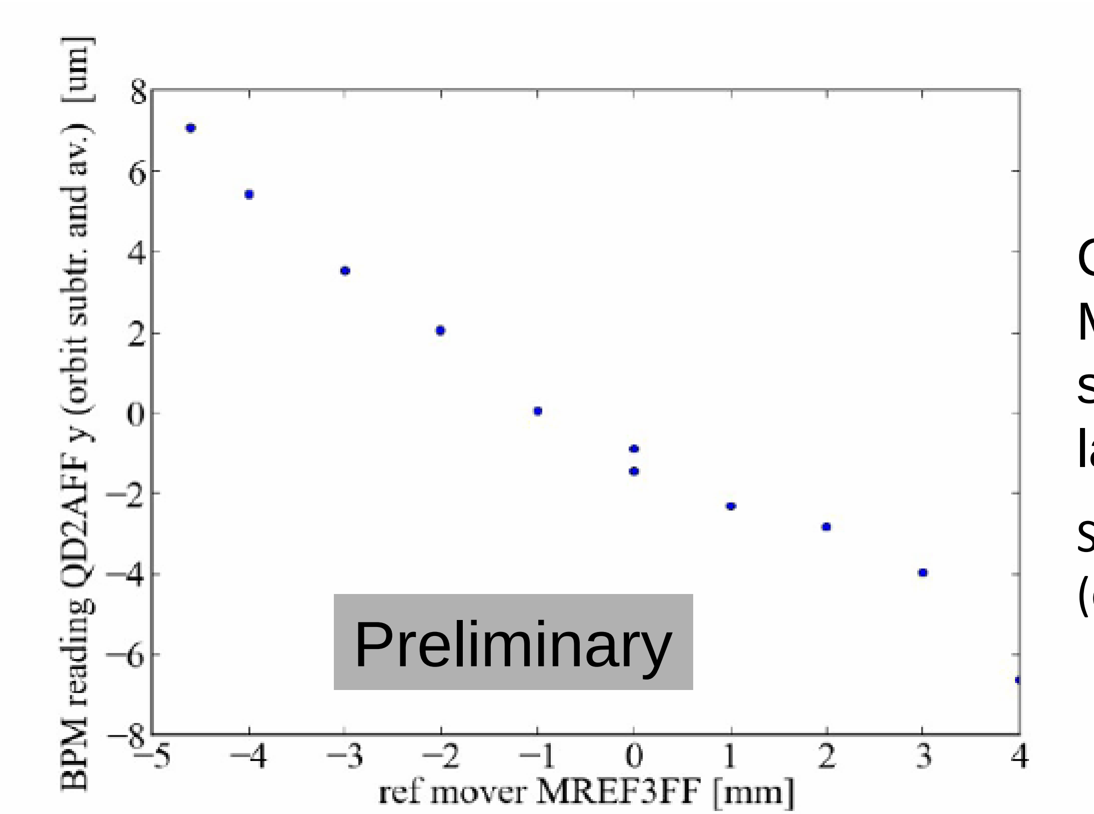



Very strong dependence.
Inconsistent with calculation including only wakefield of cavity BPMs.

# Study using C-band Reference cavities on a mover

Example: Read of BMP downstream vs. cavity position

N～6e9




Jochem Snuverink, etc. 20121207 ATF operation meeting

Calc. with offset 1 mm

↓

Calc.： ~1 micron/mm
Meas.： ~1 micron/mm for small offset, but larger for large offset

Suggested non-linear mode wake (quadrupole wake)

(Reports in last Dec. was wrong.)

# Strong intensity dependence

Strong intensity dependence is really caused by wakefield?

If so,

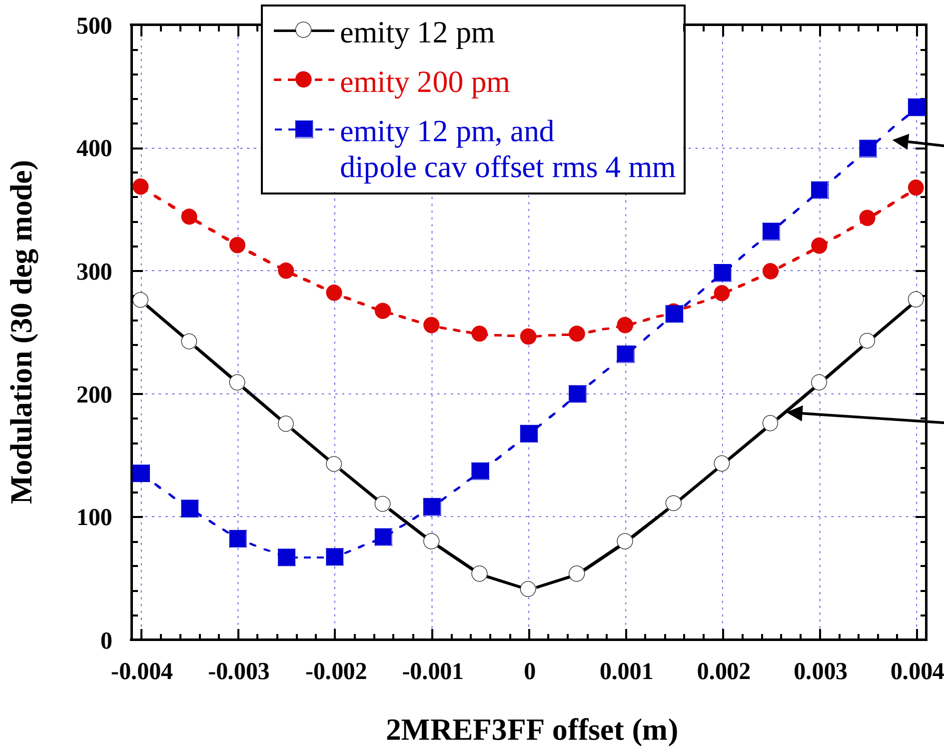
- Which part of beam line?
- Wakefield mitigation
  - Modify beam pipe and structures ? (shields, tapers, etc.)
  - Re-align Cavity BPM ?
  - Remove some cavity BPMs ?
  - Develop and try tuning methods considering wakefield effect
- Look impact to ILC BDS design.

Other reasons?

- Intrabeam-scattering → non-linear field ??? So strong???

# Large beam size Cannot be explained by only cavity BPM wake -1

Should have been almost compensated by reference cavity wake, by scanning the position.



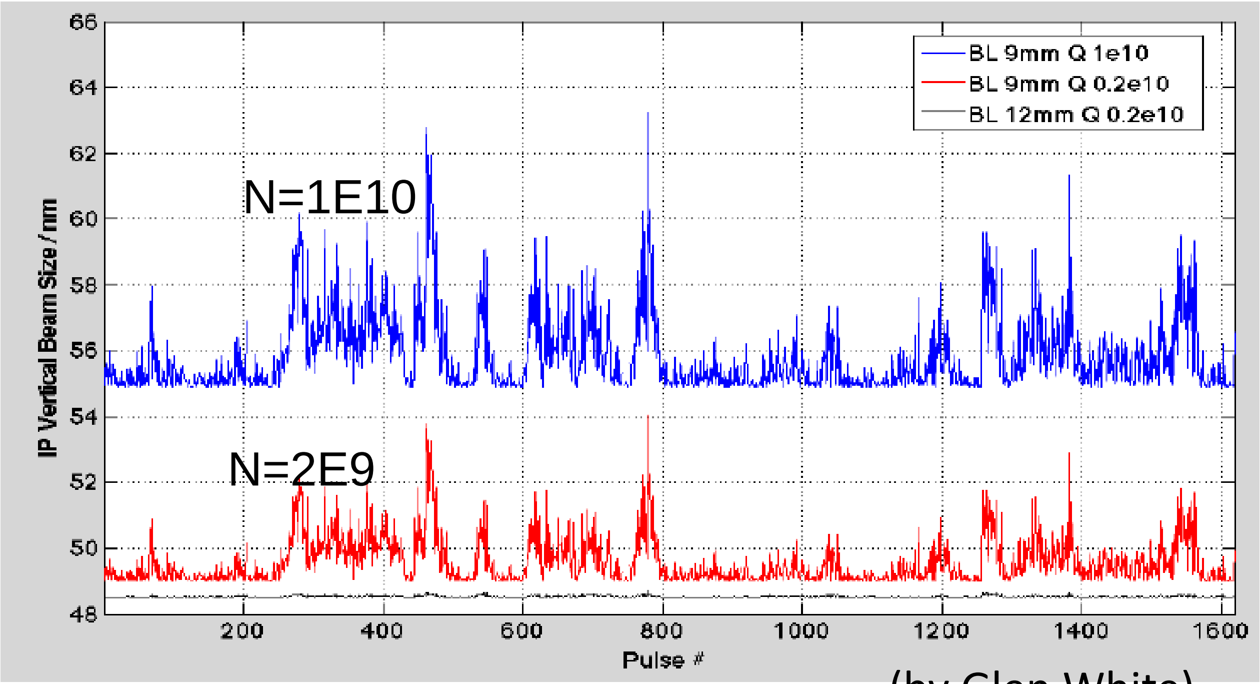

Simulation
Beam size at IP vs. reference cavity position with other cavity BPM wake

Beam size at IP vs. reference cavity position without other source

# Large beam size Cannot be explained by only cavity BPM wake -2

Simulation
Setting beam-cavity BPM offset based on BPM Reading Log in December.
Assume twice strong wake of calculated.

## IP Beam Size from Cavity Wakes




(by Glen White)

# Rough comparison of Effect of Wakefield

Proportional to

- 1/E_beam
- 1/σ' (angular divergence)
- offset of beam center – wake source center
  - Assume constant (misalignment) or,
  - Assume proportional to beam size (beam jitter)
- Length and/or Number of wake source
  - Number of Q magnets, or
  - Beam line length for resistive wall (??? sqrt ???)

Depend on bunch length

- Cavity BPM (W_ILCBDS ~ W_ATF x 0.3 ~ W_ILCRTML x 0.3) (?)
- Resistive wall ~ 1/(bunch length) (?)

# Rough comparison of Effect of Wakefield

$(\Delta\varepsilon/\varepsilon)/(\Delta\varepsilon/\varepsilon)ATF$

| Wake Source | Error | ILC BDS | ILC RTML (return line) |
|---|---|---|---|
| Same wake source at every quadrupole magnet | Misalignment | 0.06 | 5 |
| | Beam jitter | 0.009 | 0.3 |
| Resistive wall, same aperture, and same material | Misalignment | 30 | 20 |
| | Beam jitter | 0.8 | 0.4 |

# Summary

- IPBSM modulation was confirmed, about 70 nm beam size
  - Only at low intensity (N~1E9)
- Confirmed performance of IPBSM
  - Stability and reproducibility were clearly improved after modification in summer shutdown.
  - Stability of laser is still to be improved
- Beam size strongly depend on beam intensity
  - Suspect wakefield.
  - May be other reasons. Need more study.
  - Need to study impact to ILC BDS design. (No conclusion yet.)
- Multi-pole field error studied
  - Problem of one sextupole magnet was found. Exchange → replace.
- Many people joined from overseas and contribute the progress. International collaboration worked.