Status of Emittance in ATF DR and EXT (Spring Run in 2009)

S.Kuroda(KEK)

- What's New in ATF Operation
- DR Emittance
  - Emittance tuning and measurement
  - Measured emittance
  - Data for check and comparison
- EXT Emittance
  - Measured emittance
- Summary and Discussion

ALCPG09/GDE meeting, Albuquerque, 2009

What's New in ATF Operation

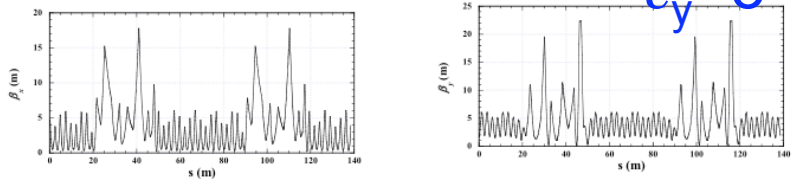
- Start with 'design optics' and optics correction(β beat correction)
- DR re-alignment in summer 2008
- Introduction of electric load for DR main bend.
- New QM7R.1 with larger bore radius
- …

- Off course, the biggest issue is the new ATF2 FF and EXT line.

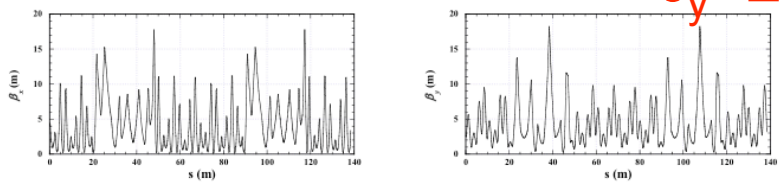
DR Optics

Optics mismatching ?

calculated from setting Dec. 10, 1999 ε_y=5~10pm



calculated from setting May 16, 2008 ε_y=20~30pm

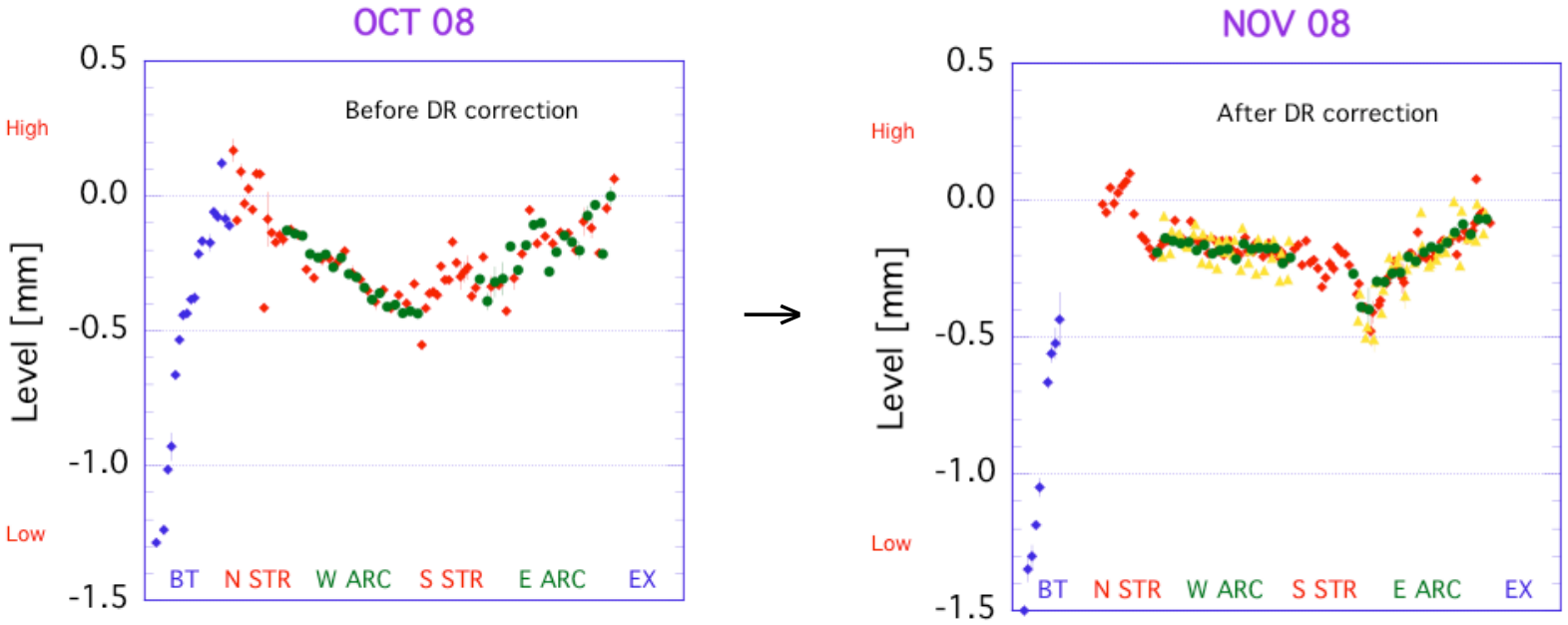


Kubo pointed out that the optics distortion is the one of the source of large emittance in DR.

Kubo, Special ATF2 Project Meeting,KNU,2008

- 'design optics' was made in 2007
  - Re-matching
  - Tune adjustment to measured tune
- DR commissioning has started with 'design optics' in Nov. 2008.

DR Re-Alignment in Summer Shutdown 2008



M.Takano

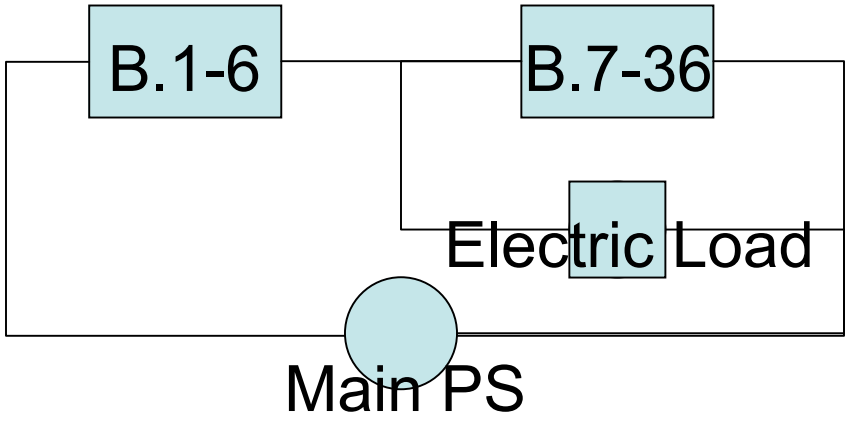
Alignment done for

V position: All around the ring

H position: Straight section

Electric Load for DR Main Bend

- 36 B magnets in DR
- 6 of them were productions of different maker from the others, and the field characteristics is slightly different.
- Correction has been done by trim coil, but it does not seem enough. The trim current <8A due to heat-up of the coil(the coil is air-cooled).
- Introduction of electric load is expected to improve the DR orbit, …
- I_{EL}<13A, by power dissipation.



DR Emittance

- We have measured ε_y of 5-10pm in 1999. But since then we hardly measured such low emittance because the other R&D have been majority of the ATF study.
- Typical emittance measured in 2008 was 20-30pm.
- These days, some experiments require low emittance in DR.
  - For ATF2 σ_y*=70nm, ε_y=24pm is needed.
  - For ATF2 σ_y*=35nm, ε_y=12pm is needed.
  - For study of fast ion instability, ε_y<10pm is needed.
  - For ILC DR study, goal emittance is ε_y=2pm.

- Goal of DR Study Group: to reproduce as small emittance as 5-10pm, and then challenge to lower emittance such as 2pm.

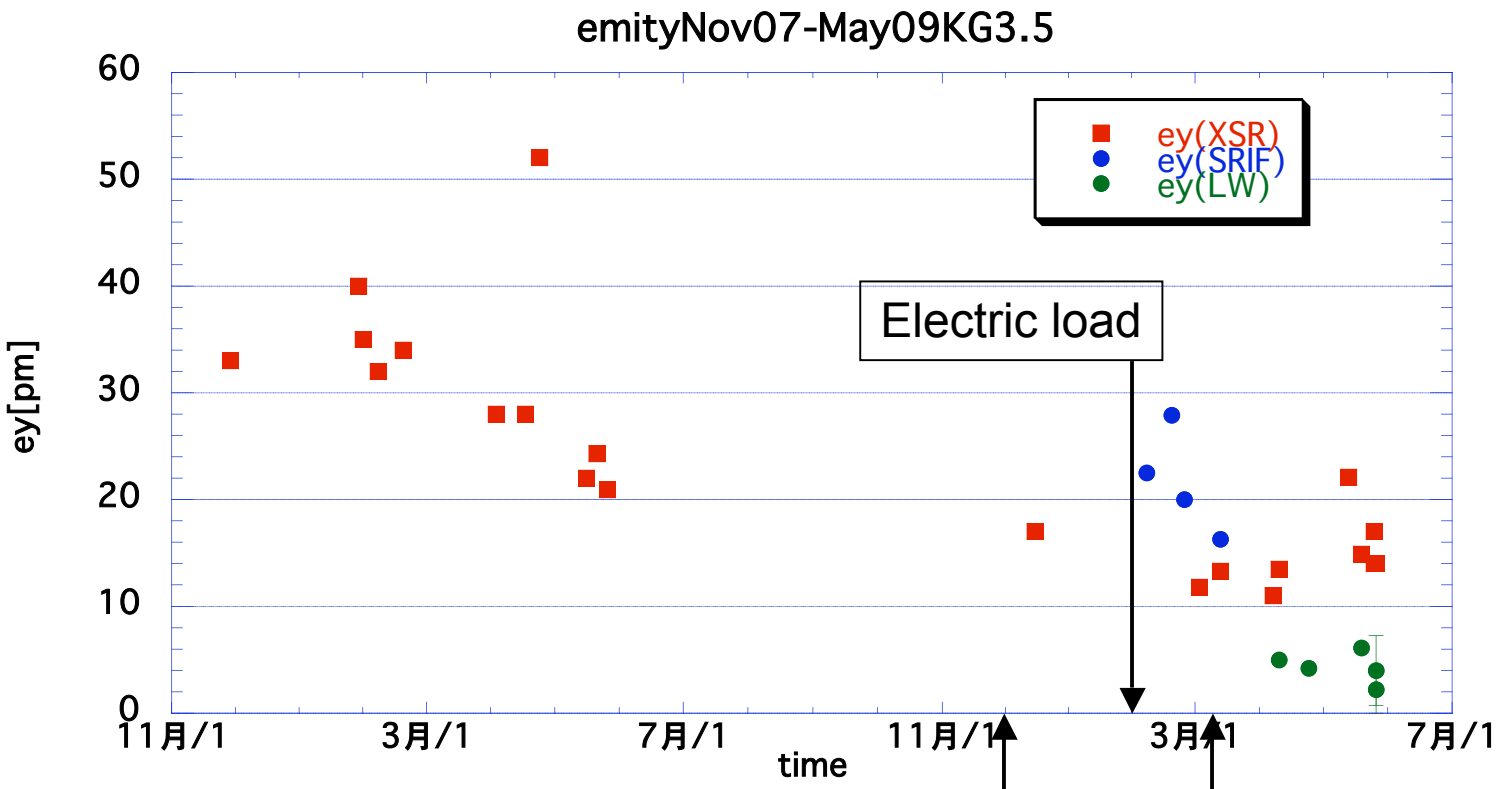
DR Emittance Tuning

- β beat correction
  - Using QM trim, new QM7, IHEP Q trim and QF1&2(for tune adjustment)
- Orbit correction
  - Using correctors for several settings of the Bend trim and electric load
- Dispersion correction
  - η_x in straight section is corrected by QM trim
  - η_y is corrected by correctors
- Coupling correction
  - ONLINE correction: Correction of vertical leakage of the horizontal kicks by a couple of horizontal correctors.
  - OFFLINE correction: The same as ONLINE correction but using data by all the horizontal corrector in the arc.
  - Correction is done by Skew Q winding trim coil of SX.

DR Emittance Measurement

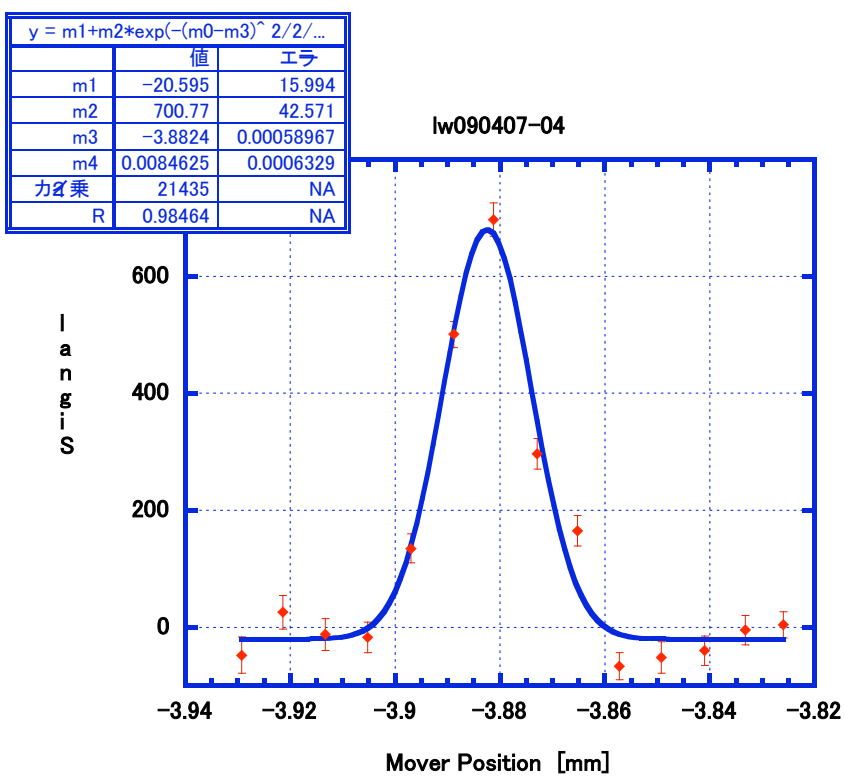
- Beam size measurement
  - SR Interferometer
    - Quick measurement, 5ms
    - Minimum beam size can be measured is ~5-6um
    - Suffering from mechanical vibration
  - XSR monitor
    - Quick measurement, 20ms→50Hz oscillation?
    - Minimum beam size can be measured is ~5-6um
    - Less mechanical vibration but still.
  - Laser wire
    - A few ten minutes requires for measurement
    - ‘design’ laser waist size is 6.5um→going to higher mode, beam size of 1um can be measured.
- Beta function measurement
  - Fitting β of Qs nearby which were obtained from tune slope.

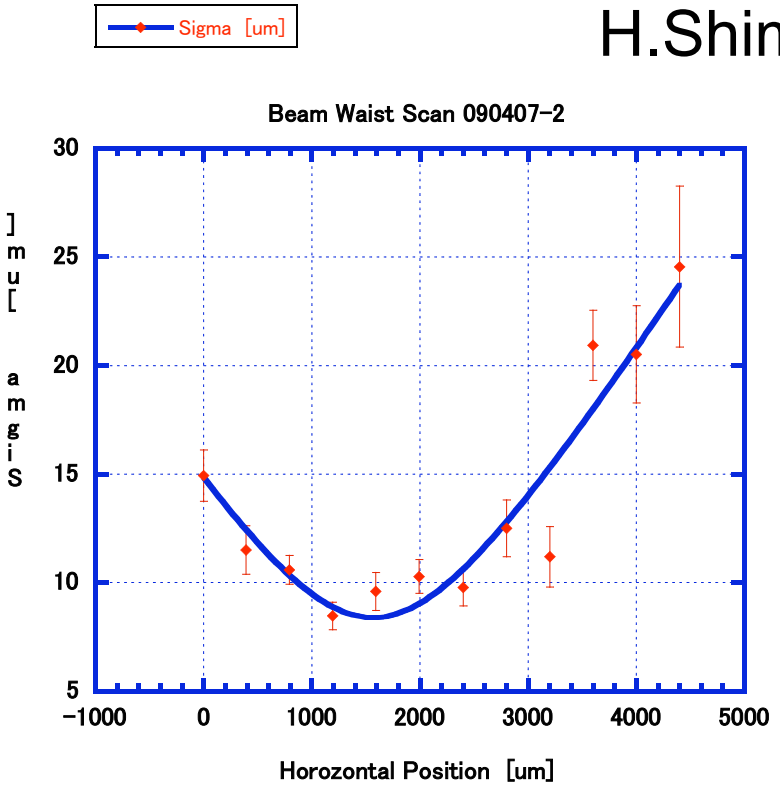
Measured DR Emittance



Laser Wire Measurement

H.Shimizu





Minimum size measured=8.46um
Measured Laser waist=5.96um
→ e beam size=~6um

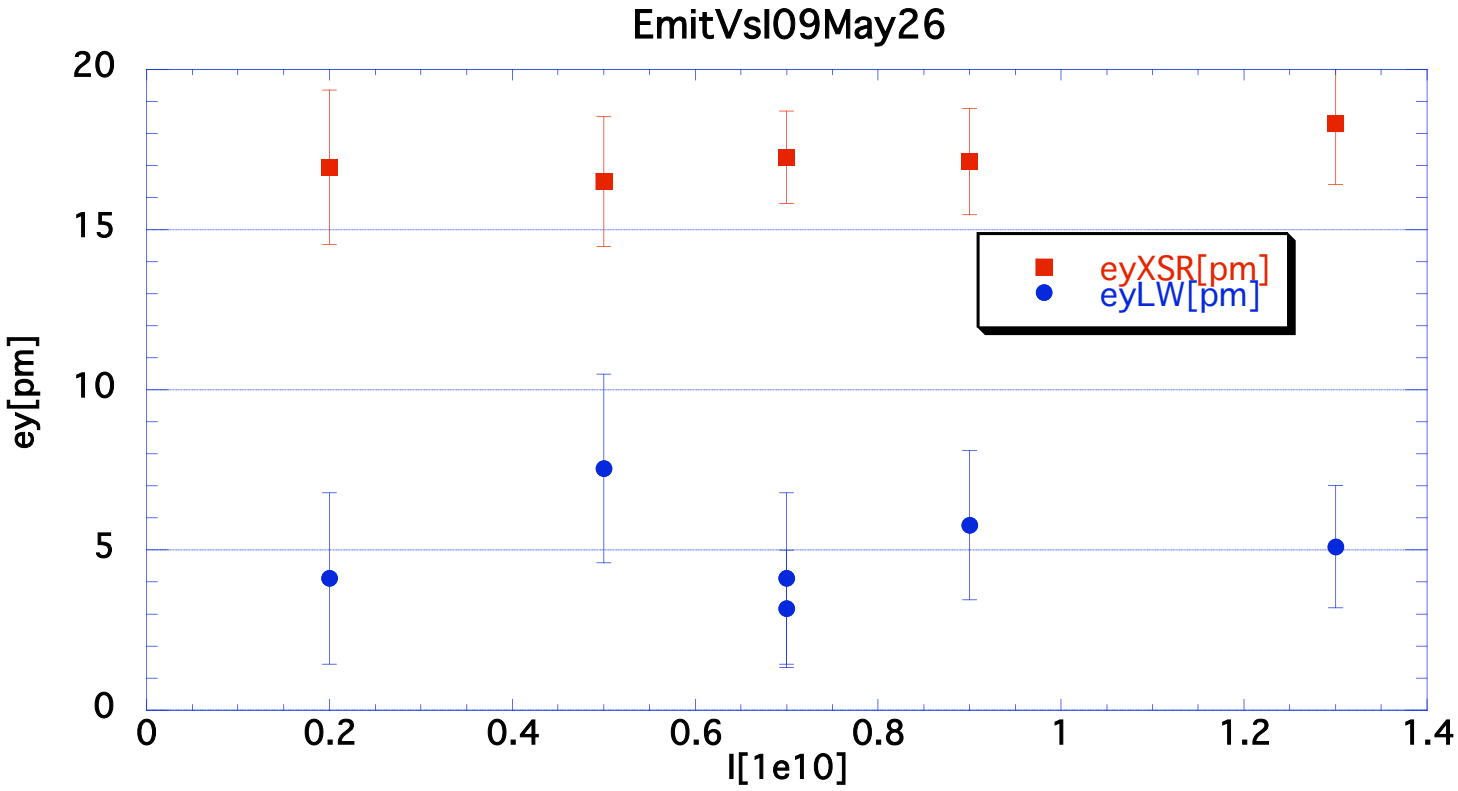
Scanning in horizontal position
Fitting with

$$\sigma^2_{\text{Obs.}} = \sigma_e^2 + \sigma^2_{\text{LW}} = \sigma_e^2 + \frac{\lambda}{4\pi} z_0 \left\{ 1 + \frac{(z-c)^2}{z_0^2} \right\}$$

e beam size=6.41±1.07um

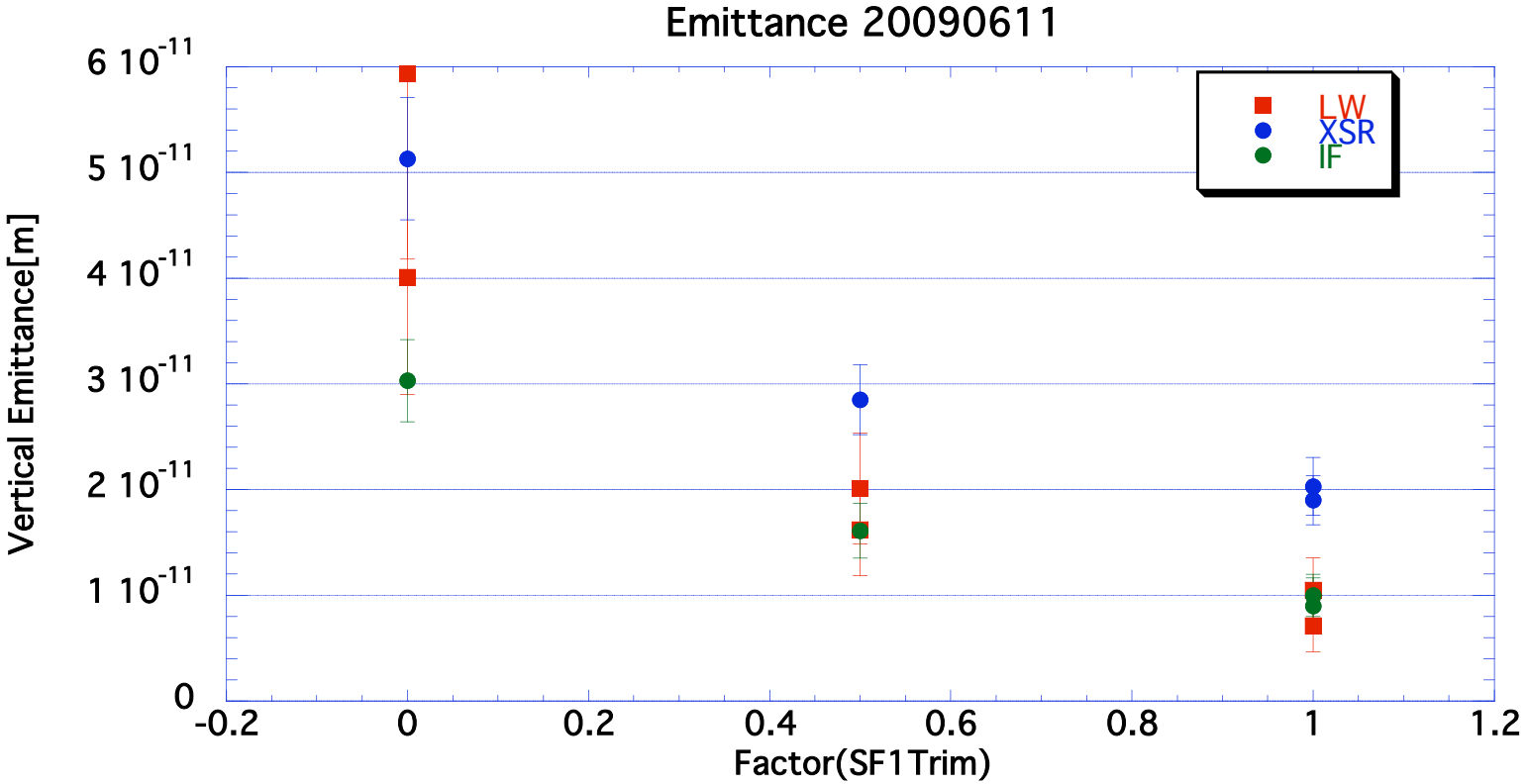
Assuming β_y~5m, ε_y=~7pm

Beam Current Dependence of DR Emittance



No significant current dependence could be seen.
There must be intra-beam scattering effect
→ emittance already smaller than measurement limit?

Measurement Method Comparison in Big Emittance Case

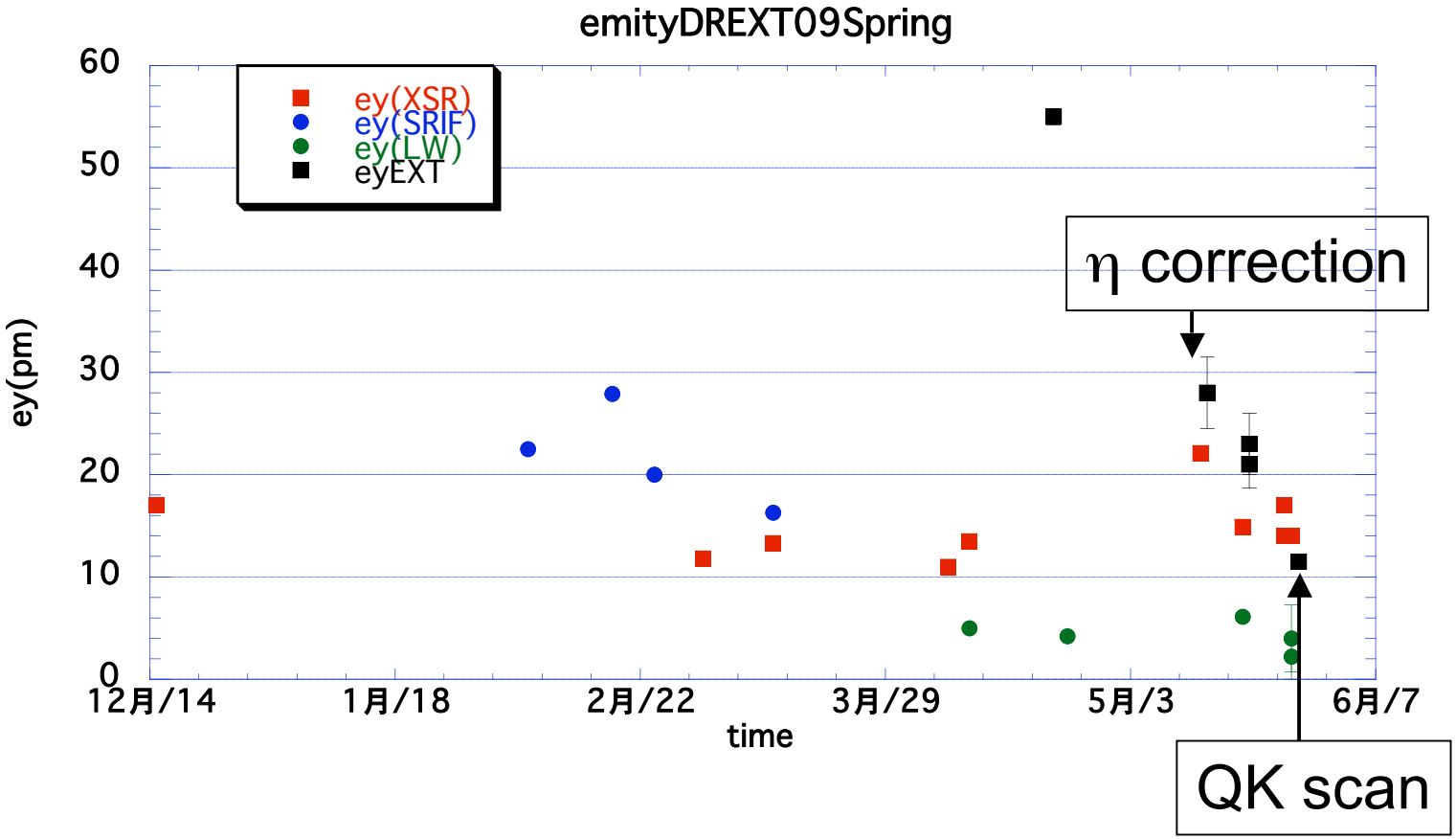


- Change skew Q strength(Factor=1(normal correction) ↔ Factor=0(no correction))
- Discrepancy seems to begin at Factor>0.5. When ε_y=20pm measured by XSR, σ_y=7.7um with β_y=3m. σ_y=7.7um is already beyond the XSR measurement limit?
- At Factor=0, all the measurement agree within error bars, but the error bar is very big.
- IF measurement result is very close to LW one. IF setup was tuned up well by an expert(T.Mitsuhashi) before the measurement.

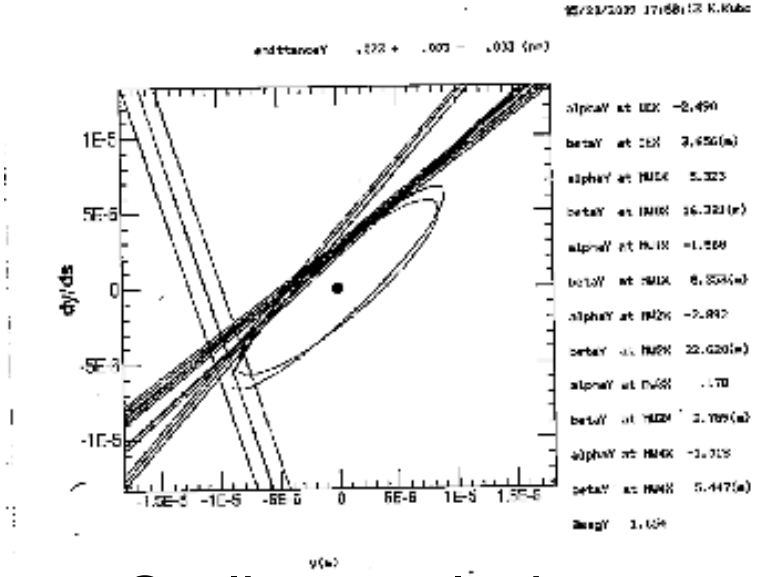
EXT Emittance

- EXT ε_y >DR ε_y (~2008)
  - One of the ε growth source: QM7R of which the beam passes through off-center. Non-linear field effect of QM7R was really observed, but there might be other sources.
  - $\rightarrow$ QM7R was replaced with large bore magnet.
- Measurement
  - Beam size measurement with 5 wire scanners
    - 10mmϕ tungsten wire
  - Analysis: 2D
    - 1. On-line program with ε>0 (K.Kubo)
    - 2. Linear fit of σ_{ij} (M.Woodley)
- η/coupling correction is very important for the measurement.
  - η_y correction: with 2 skew Qs placed at non-zero η_x section
  - Coupling correction: with 4 skew Qs just upstream of WS section

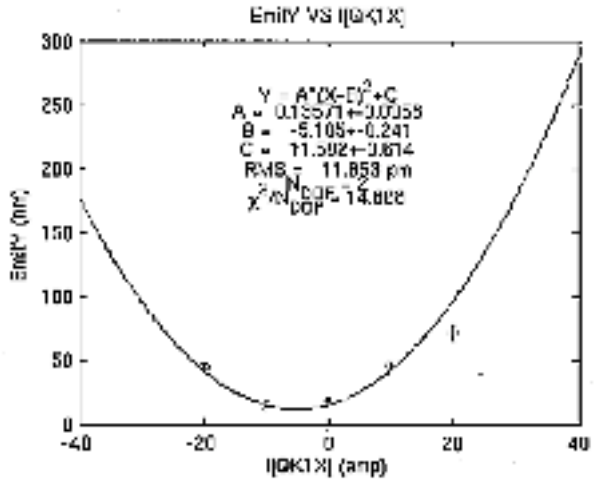
Measured EXT Emittance



Measured EXT Emittance(cont.)



On-line analysis



QK1X scan

Vertical EXT Emittance Measurement
May 20, 2009

sigt	sigd	sigw	sig
24.00	12.90	2.50	20.09
17.40	8.24	2.50	15.12
22.70	10.38	2.50	20.03
9.20	0.01	2.50	8.85
13.20	7.34	2.50	10.69

Vertical emittance parameters at MW0X

energy	=	1.2857		GeV	
emit	=	20.8442 +-	2.2679	pm	
beta	=	18.6659 +-	2.7592	m	(9.2710)
alpha	=	6.2569 +-	0.9955		(3.1872)
bmag	=	1.2614			
chisq/N	=	7.3364			

Propagated vertical spot sizes

MW0X =	19.7 um	(20.1 +-	1.0)
MW1X =	13.7 um	(15.1 +-	1.0)
MW2X =	21.2 um	(20.0 +-	1.0)
MW3X =	6.7 um	(8.9 +-	1.0)
MW4X =	11.2 um	(10.7 +-	1.0)

Vertical wire-to-wire phase advance

MW0X =	0.0 deg
MW1X =	7.6 deg
MW2X =	13.4 deg
MW3X =	41.3 deg
MW4X =	62.3 deg

Cal. by M.Woodley

Summary and Discussion

- DR emittance
  - The vertical emittance of ATFDR is ~12pm(by XSR monitor).
  - Measurement errors
    - 10% for both of beam size(by XSR) and β measurement statistically. Then the error of measured emittance is ~14%.
  - Need to check minimum σ_y measurable by XSR.
    - When we measured ε_y=12pm, σ_y=~6um and β_y=~3m. If the 50Hz oscillation is σ_{50Hz}=~4um which was observed in 2007, ε_y=~6.6pm?
  - For much smaller emittance:
    - BPM upgrade
    - Full ORM analysis will improve the emittance?
    - Need reliable monitor(e.g. LW w higher order mode)
- EXT emittance
  - Measured emittance was quite close to the one by DR XSR. But if the emittance is smaller in DR, there is still ε growth in EXT.
  - For more accurate/precise measurement
    - η correction: combination with orbit bump(K.Kubo)
    - Coupling correction: data analysis is on going
  - Energy spread measurement?