Test Facilities

CESRTA

ATF

ATF2

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PAC Review, PAL, Korea, Nov.2.2009

Critical Items of Risk Mitigation

- Damping Rings
  - **Ultra-low emittance → ATF, CESRTA**
  - **Fast kicker → ATF**
  - **Fast ion instability → ATF**
  - **Electron cloud → CESRTA**
- Beam Delivery System
  - **Final Focus System integration → ATF2**
    - Small spot
    - Bunch stabilization
    - Final quads

ILC Damping Rings

	RDR	SB2009
Circumference	6476 m	3238 m
Number of bunches	2625	1312
Harmonic number	14042	7021
Bunch population	2×10^{10}	2×10^{10}
Average current	400 mA	400mA
Extracted (normalised) emittance $\gamma\varepsilon_x \times \gamma\varepsilon_y$	8 μm × 20 nm	8 μm × 17 nm?
Bunch length (rms)	9mm	6 mm
Bunch distance	6.16ns	6.16ns
Kicker repetition freq.	2.7MHz	1.4MHz
Total length of wigglers	216m	78m

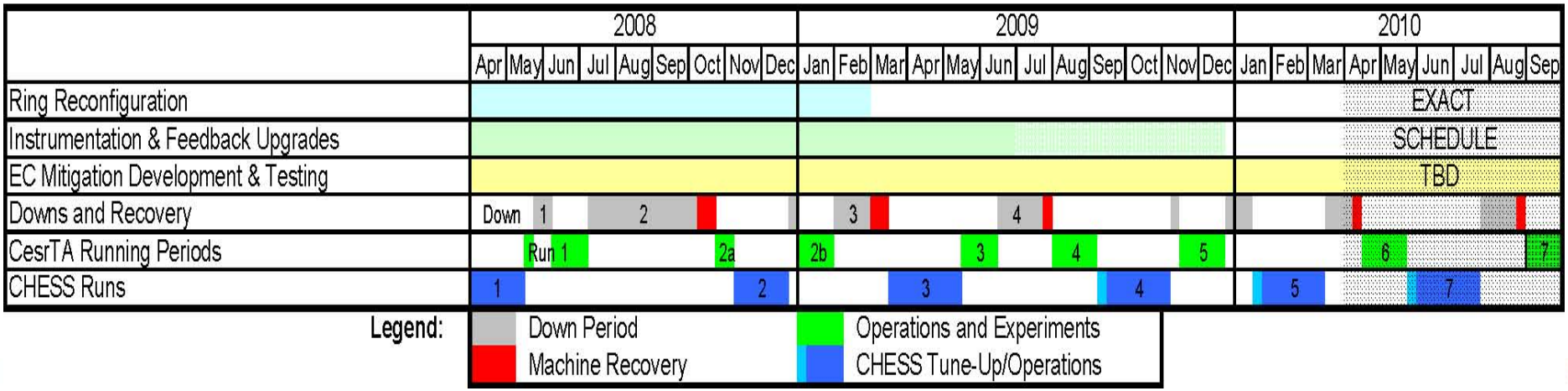
CESR-TA

- Electron cloud is one of the highest risk factor for ILC
- Study at CESR started last year
  - **Evolution of electron clouds under various cloud-mitigation techniques**
    - chamber coatings (TiN, alpha carbon)
    - clearing electrodes
    - grooved chambers

    can be monitored in various magnetic fields: drift, dipole, quadrupole, wiggler
- World-wide collaboration
  - **Not only for ILC (KEKB, CLIC, etc)**
- 2 Runs (#3,#4) since Vancouver PAC

Run#3

- May 12→Jun.16
- Major Activities
  - **Instrumentation Commissioning**
  - **BPM system**
  - **xBSM - including first single-pass measurements**
  - **4ns Feedback (DIMTEL)**
- L3 EC Hardware
  - **SLAC Chicane and EC chambers commissioned**
- Mitigation Studies
- CesrTA 5 GeV Optics



Upgrade during Down#4

- June 16-July 23
- xBSM upgrade - Electron line deployment
- New EC vacuum chambers
  - Wiggler chamber with groove mitigation (CU-KEK-LBNL-SLAC)
  - Upgraded RFA detectors (in wiggler, Q15E/W chambers and quadrupole chamber)
  - Diagnostic quadrupole chamber for L3 experimental region
  - Amorphous Carbon chamber (CERN) in Q15W experimental section
  - Grooved chamber with TiN coating in L3 Chicane (SLAC)
- EC solenoid windings on ~80% of CESR drift region
- **Almost all reconfiguration works finished**

Run #4

- Aug.31-Sep.8
- Electron Cloud Build-up & Mitigation
  - **Tests of new EC-mitigating vacuum chambers**
    - Wiggler chamber with grooves (CU-KEK-LBNL-SLAC)
    - Amorphous carbon coated chamber (CERN)
    - Grooved dipole chamber (SLAC)
    - Diagnostic quadrupole chamber
- Beam Size Monitors
- High energy x-ray coded aperture optics (4-5 GeV) tested for x-ray beam size monitor
  - **Commissioning of electron beam x-ray line underway**
  - **Upgraded vertical polarizer and interferometer setups for visible light beam size monitors**
  - **Bunch-by-bunch single-pass beam size measurements for EC instability studies**
- Ring Optics Commissioning
- Low Emittance Tuning
  - **Digital BPM System commissioning (4ns bunch spacing)**

Run #5 Planning

- Nov.17 – Dec. 23
- Short down preceding the run
  - **Install new diagnostic chambers**
    - Q15 TiN on Al chamber for tests in CESR Arcs
    - Quadrupole chamber with mitigation
  - **Install supporting hardware**
    - Additional TE Wave pickups to allow horizontal and vertical polarization measurements in L3. Also, dedicate pickups in chicane for local (resonance) measurements
- Nov: focus on establishing machine conditions and commission new instrumentation
- Dec: Focused experimental period
  - **Particular focus on low emittance tuning and beam dynamics studies**

2010 Schedule

- Remaining runs
  - **Run#6 (early spring)**
  - **Run#7 (~Sept.2010, final run)**
- Major tests
  - **Wiggler with clearing electrode**
  - **NEG test in L3 Experimental Region**
  - **Emittance dilution at ultra-low emittance**
- Reflect EC study to ILC DR design

Possible Extension of the Program

- Submitting a proposal to the NSF for continued accelerator R&D funding for 2011- 2013 (somewhat smaller scale than now)
- NSF Site-Visit to Cornell scheduled for December 2-3, 2009

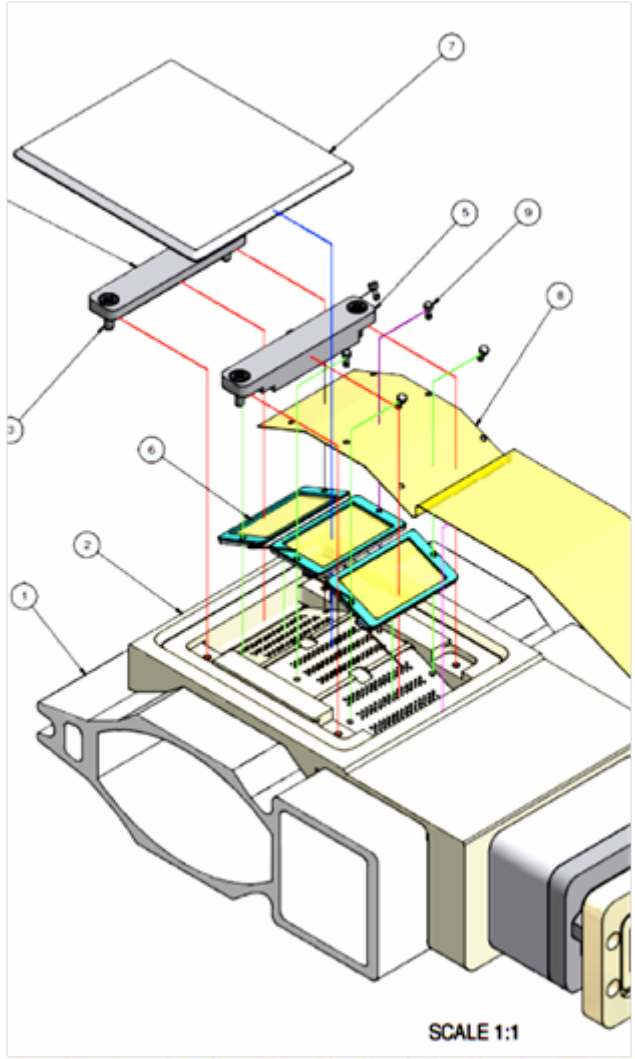
Comparison with Simulation

- CESRTA does not exactly reproduce ILC DR parameters
  - **e.g., ε_x ~ 40nm @5GeV (1nm in RDR)**

    (ε_x ~ 2.5nm @2.08GeV)
- Comparison with simulation is essential
- Major measurement items for comparison
  - **RFA (Retarded Field Analyzer)**
  - **TE Wave measurements**
  - **Tune-shift**

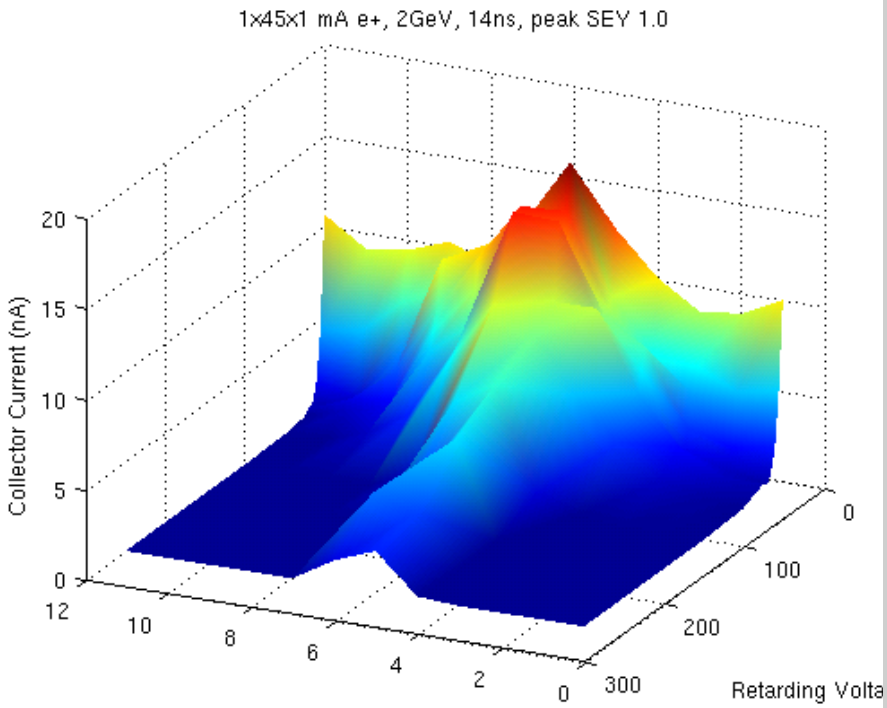
RFA

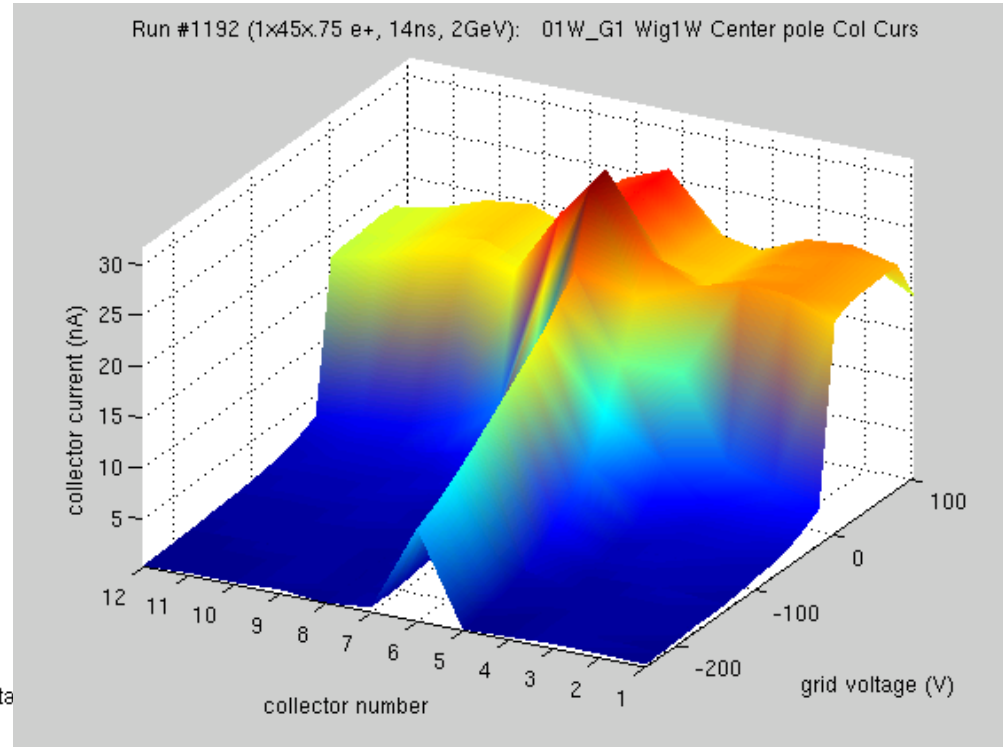
- Measure the energy spectrum of the time-average cloud current density hitting the chamber wall
- Can be placed in drifts, dipoles, quadrupoles, wigglers
- However, it influences the behavior of electrons
- → need modelling
- → include into simulations



Example: RFA in Wigglers

- Done with wiggler (pole center) RFA model in ECLOUD
  - **Performs analytic calculation when macroparticle hits in the RFA region**
  - **Assumes macroparticles don't move between beam pipe holes**
  - **Includes SEY on the retarding grid**
  - **Produces results similar to data**



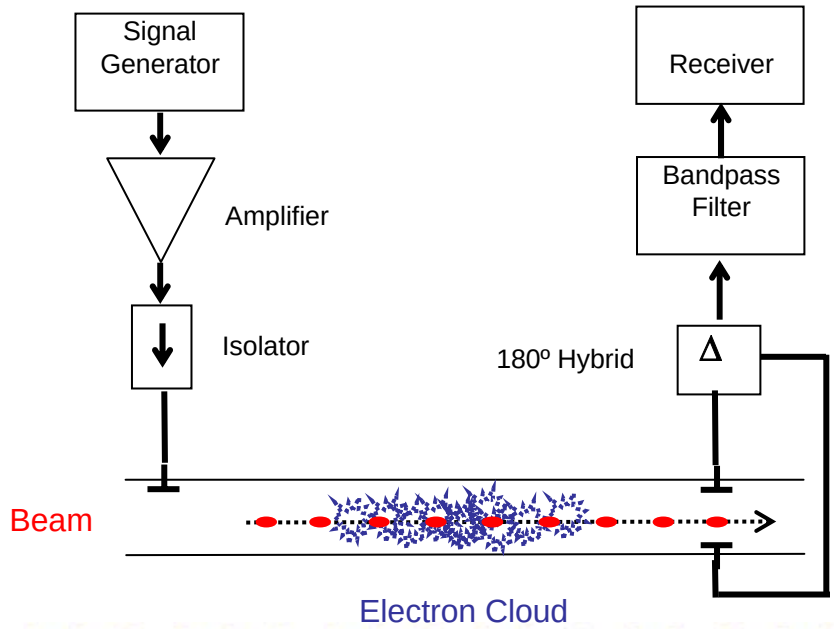


TE Wave Measurement

- Electron cloud changes the wave number of EM wave propagating along chamber
- Beam gaps create phase shift modulation → frequency sideband
- Sideband intensity related to cloud density

$$k^2 = \frac{\omega^2 - \omega_c^2 - \omega_p^2}{c^2}$$

Plasma frequency : contains cloud information



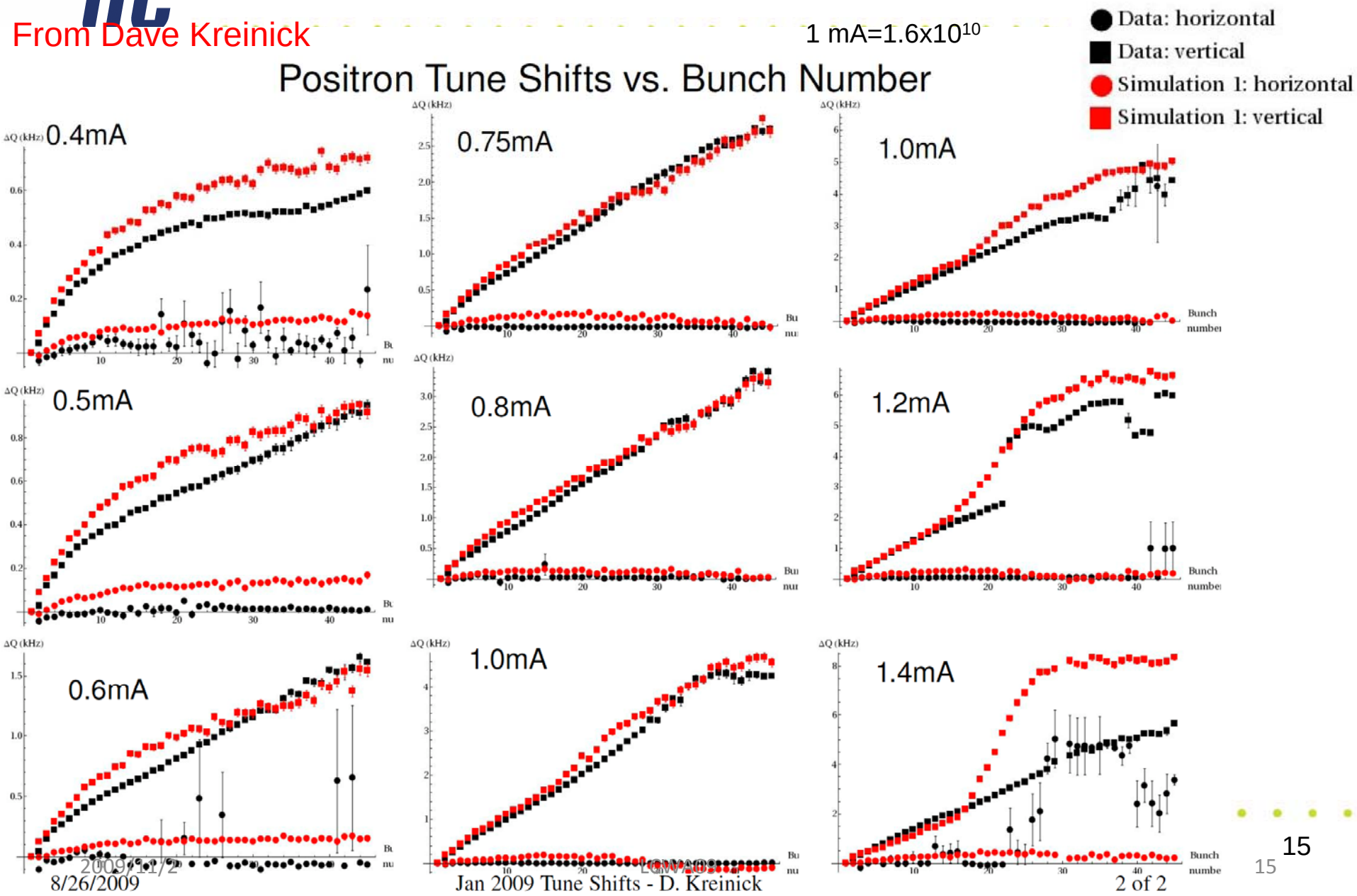
Bunch Tune Shift

- Electron cloud brings about bunch-by-bunch betatron tune shift
- Good probe of the electron cloud density
- Integration over the ring (not a local measurement of the cloud density)
  - **Need a model of entire ring**

Tune Shift Example

From Dave Kreinick

1 mA=1.6×10^{10}



EC Mitigation Methods

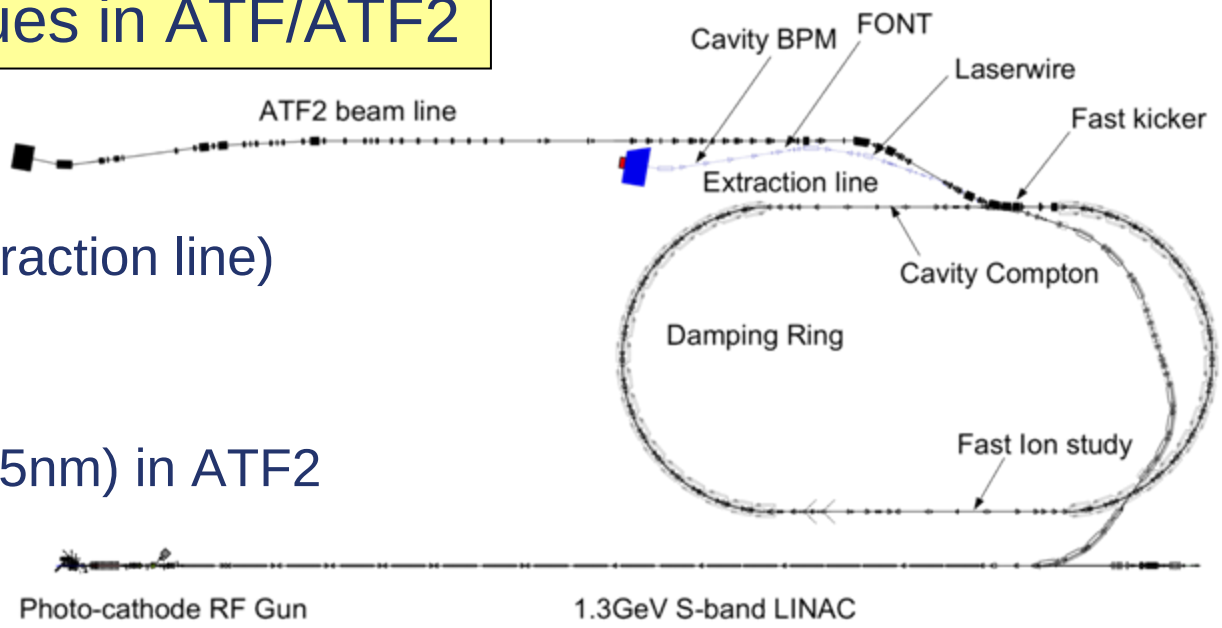
- Various EC mitigation methods compared
- Tentative conclusion
  - **Drift space**
    - TiN and carbon coating better than aluminum (but only slightly than copper)
  - **Dipole**
    - TiN coating is very effective compared to Al
    - TiN coated grooves are even better
  - **Wiggler**
    - Groove is the most effective
    - clearing electrode in a wiggler also planned

ATF

- Built in 1993 as prototype of JLC-DR, international MoU in 2005
- Achieved ~4pm vertical emittance emittance
- Continue to be a good test bench for ILC-DR
- Extended with ATF2 for R&D of final focus system
  - **International project from the beginning**

Highest Priority Issues in ATF/ATF2

- Emittance (Ring, Extraction line)
- Fast kicker
- Fast ion instability
- Small beam size (~35nm) in ATF2

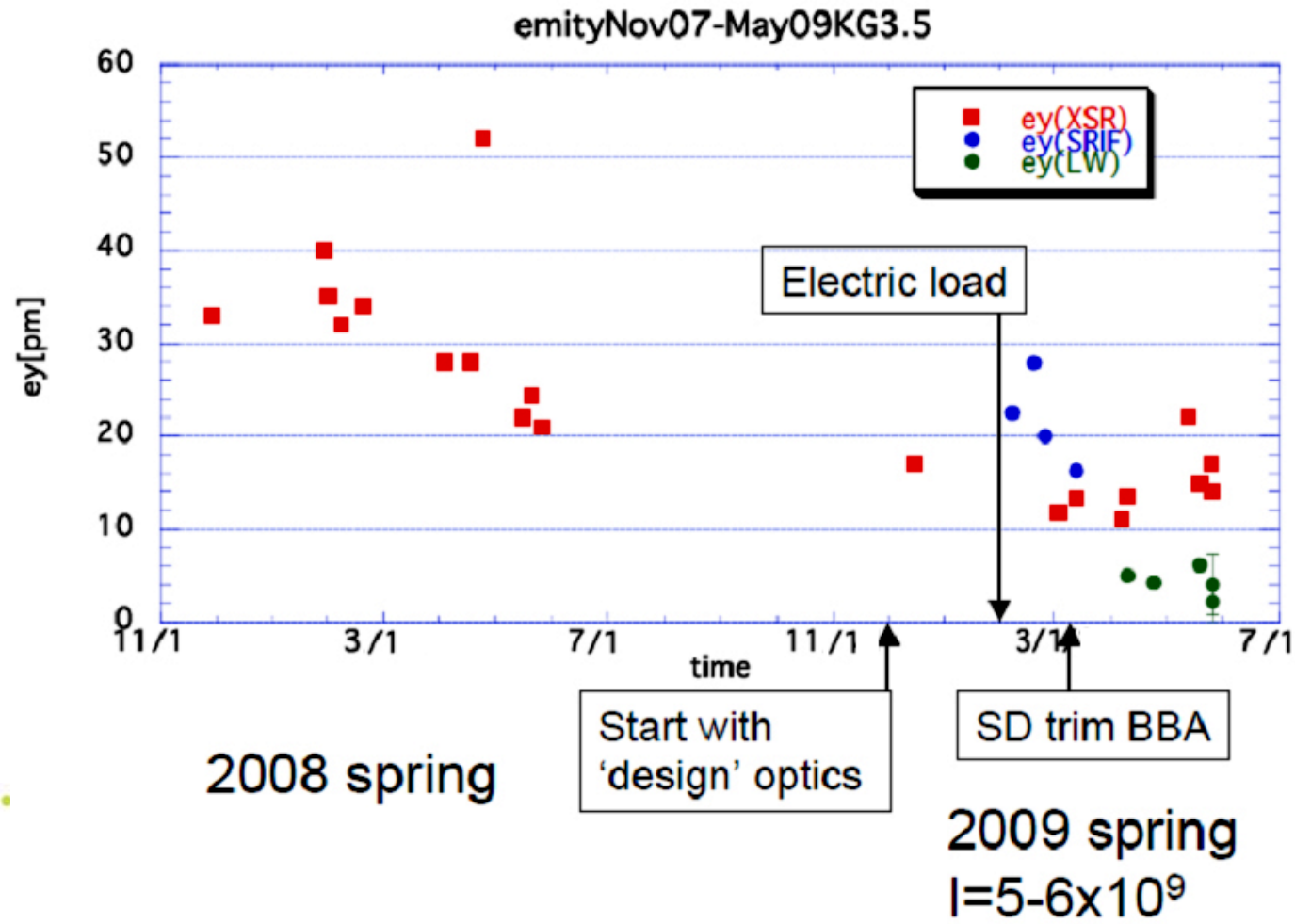


Emittance in ATF

- Reached the world smallest emittance ε_y= ~4pm in 2003
- No strong motivation to improve the emittance since then
- ε_y = 20~30pm in early 2008
- Now a better emittance is required
  - **ATF2 goal σy^*=35nm is based on ε_y = 12pm**
  - **ε_y < 10pm needed for fast ion study**
  - **ILC DR demands ε_y = 2pm**
- Efforts of emittance improvement since 2008
  - **Re-alignment**
  - **BPM upgrade done for 20BPMs, eventually all 96BPMs**
  - **Corrections**
    - Dispersion correction, Coupling correction, β beat correction using Q trim
- Emittance measurement systems
  - **SR Interferometer**
    - Fast (~5ms), ~5-6 μm can be measured, mechanical vibration
  - **XSR monitor**
    - ~20ms, ~5-6 μm can be measured
  - **Laser wire**
    - Slow (a few 10's of minutes), Design 6.5 μm but ~1 μm by higher mode

Measured DR Emittance

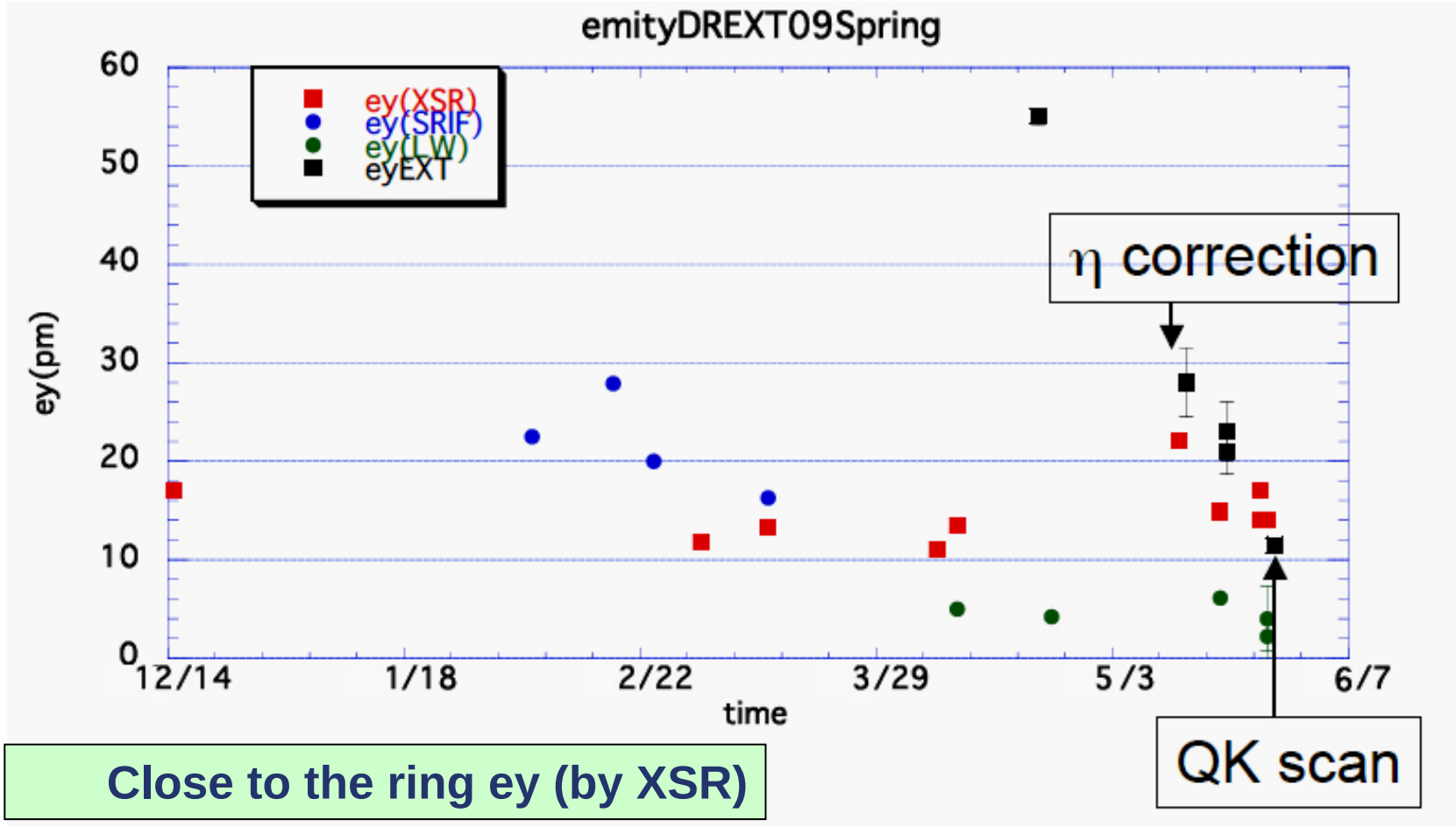
- ε_y= ~12pm by XSR monitor
- Laser wire gives smaller emittance by about factor 2 (need to reduce the waist size by higher mode)



Extracted Emittance

- Extracted emittance > ring emittance
  - **One of the possible reasons: non-linear effect by QM7R due to off-center orbit**
  - **→ replaced with larger magnet**
- Measurement
  - **5 wire scanners (10μmϕ tungsten)**
- Corrections
  - **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**

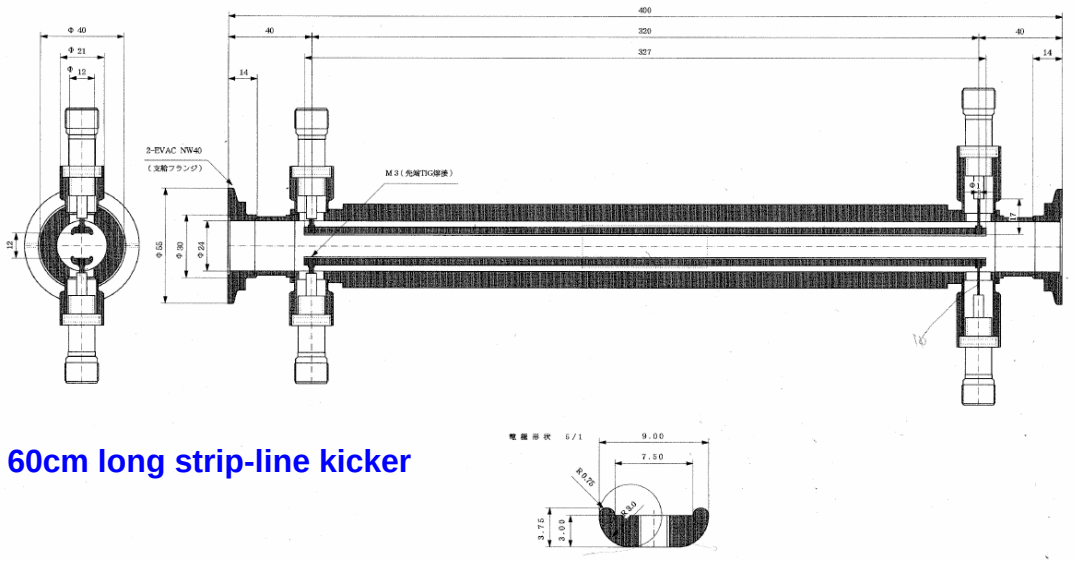
Measured Extraction Line Emittance



Close to the ring ey (by XSR)

Fast Kicker Development

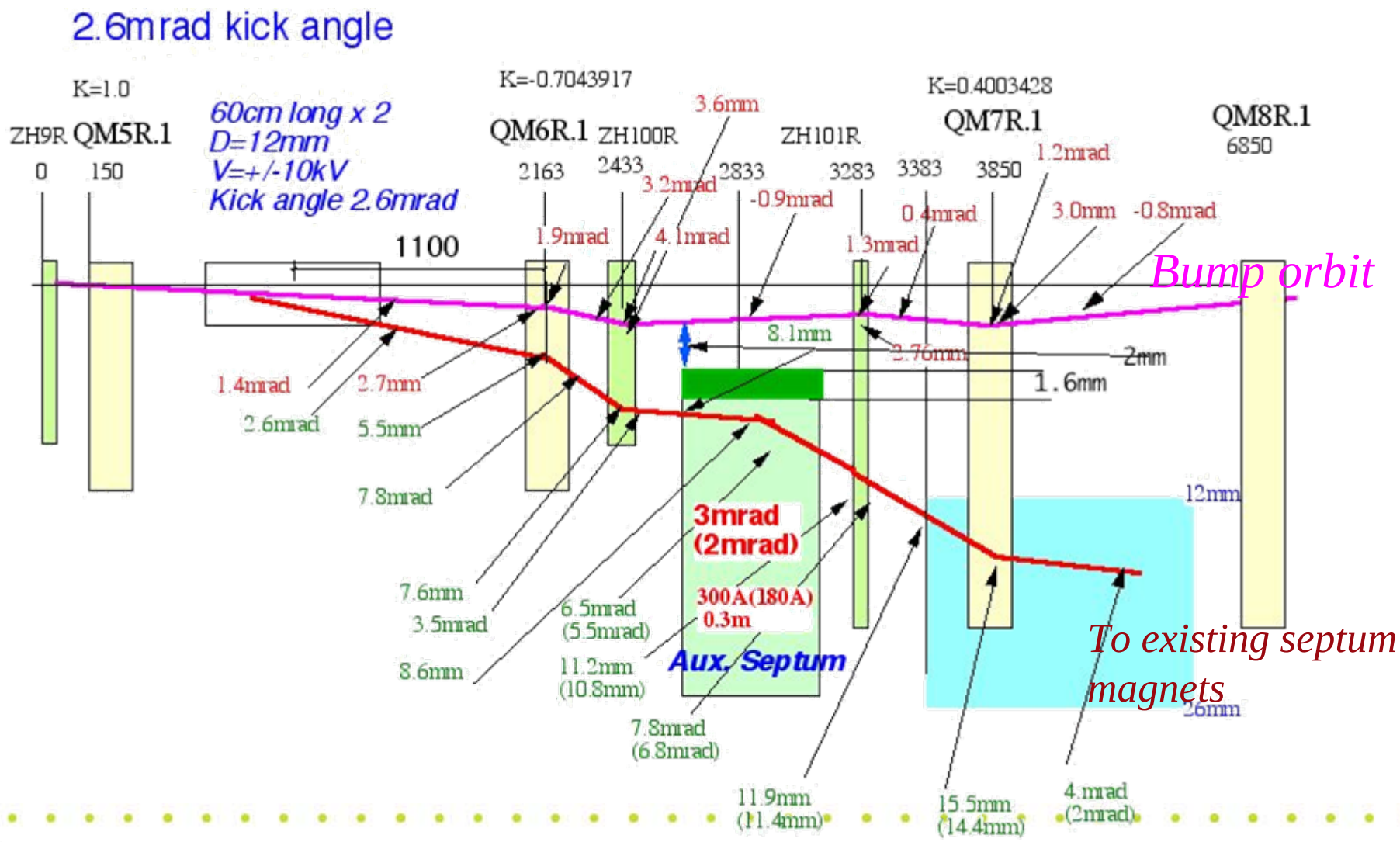
- Kicker with rise/fall time 3~6ns needed
- Use combination of fast pulser and stripline



60cm long strip-line kicker

- Pulsers
  - **FID (commercial) pulser confirmed to give < 3ns already in 2006**
  - **SLAC/LLNL pulser (based on Mosfet technology)**
  - **SLAC/DTI pulser (based on DSRD (drift step recovery diode) technology)**

Beam Extraction Orbit
by using Strip-line Kicker & pulse bump



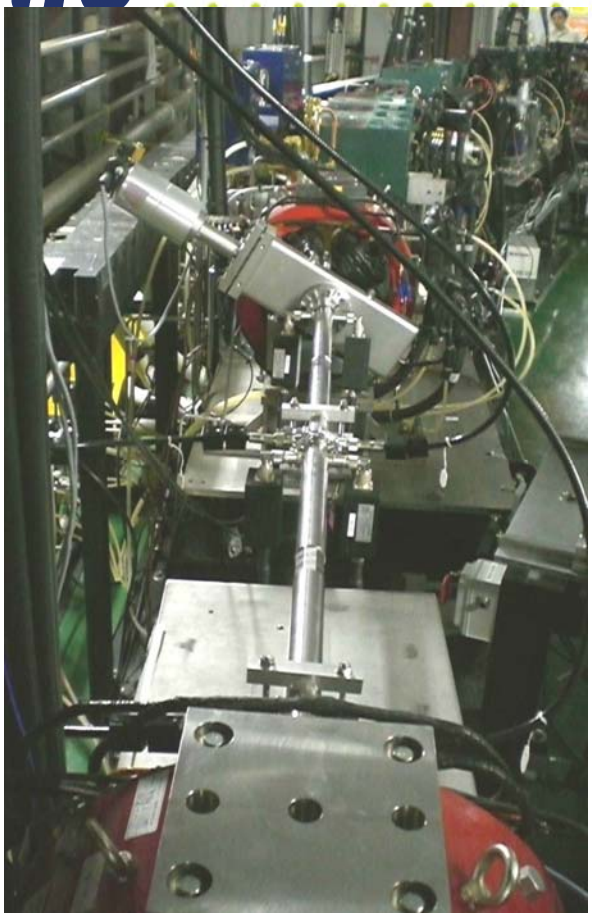
Extraction Experiments (1)

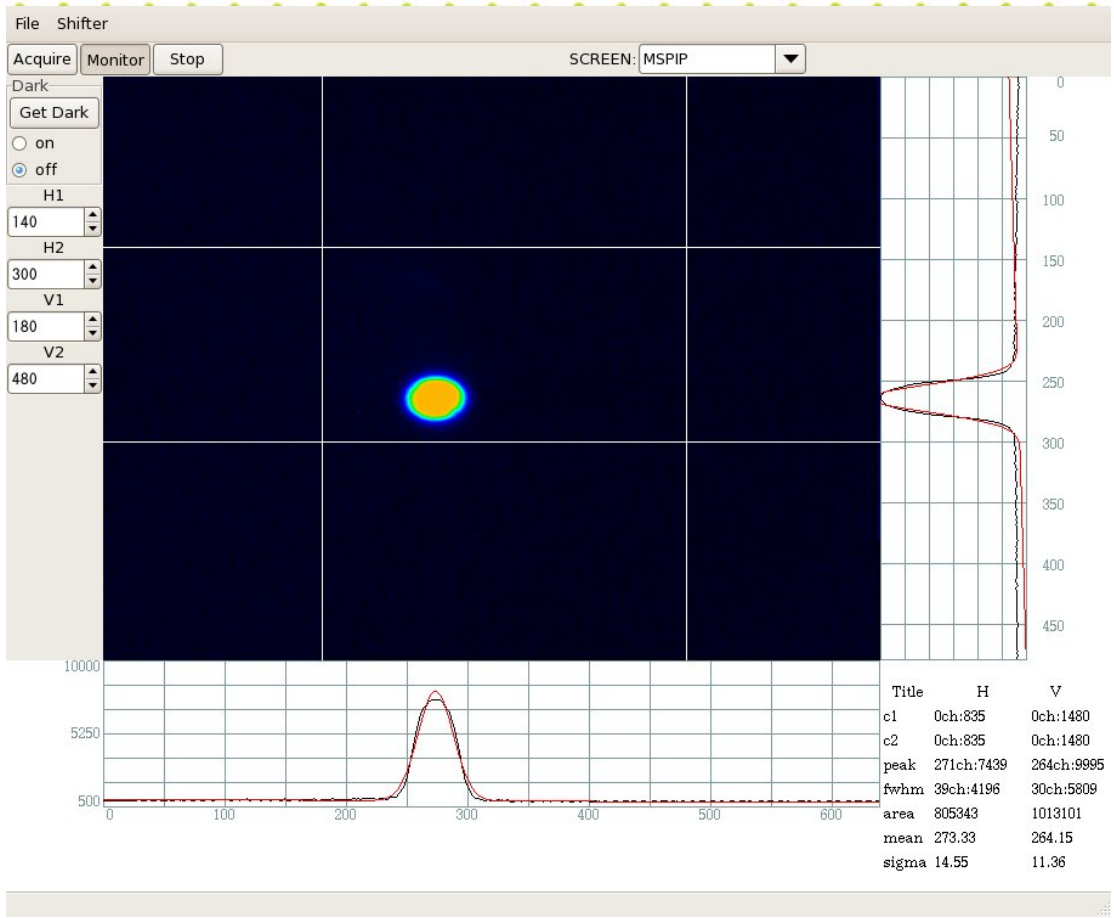
- Jan.2009
  - **FID and LLNL pulsers broke down after ~1hr experiment**
  - **The radiation level at the pulser location turned out to be to high**
  - **Pulsers repaired in April**
  - **Moved outside the shield**
- Jun.2009
  - **Bump orbit confirmed**
  - **FID pulser worked without trouble**
  - **But the beam could not be extracted**
  - **Kick angle (~2mrad) insufficient by 20-30%**
  - **Fabrication error of the stripline electrode-- fixed**
  - **FID replaced for higher power (~3.6mrad)**

Extraction Experiments (2)

- Oct.2009 (next pages)
  - **Succeeded in single bunch extraction on Oct.23**
  - **Multi-bunch extraction succeeded in Oct.28**
- Next experiment
  - **Scheduled in Jan.2010**
  - **Stabilization of timing jitter**

Beam Extraction succeeded from DR to ATF2 by using Fast Kicker (Oct.23)

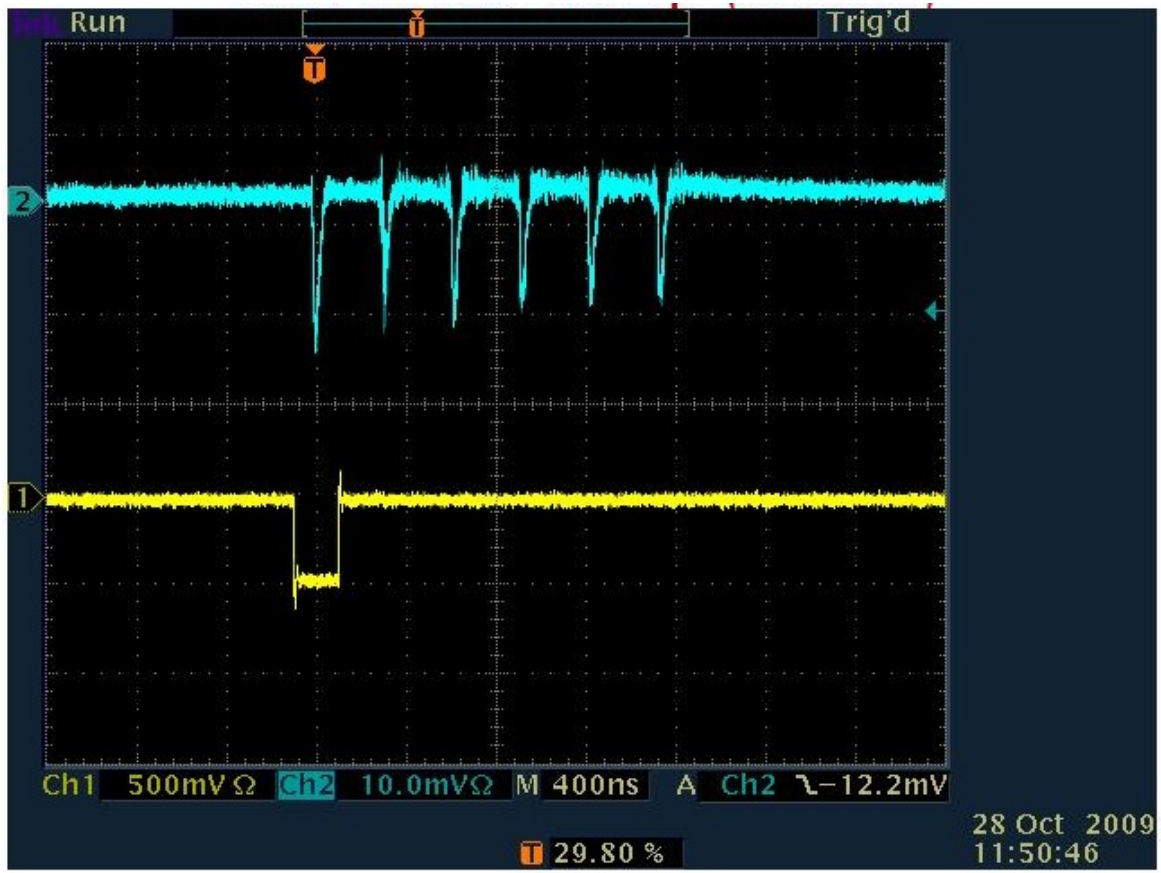




The left side picture shows the proto-type of the fast kicker installed in the DR of ATF-KEK. The beam is extracted by using the fast kicker, the right picture shows the beam profile at the end of the ATF2 beam line.

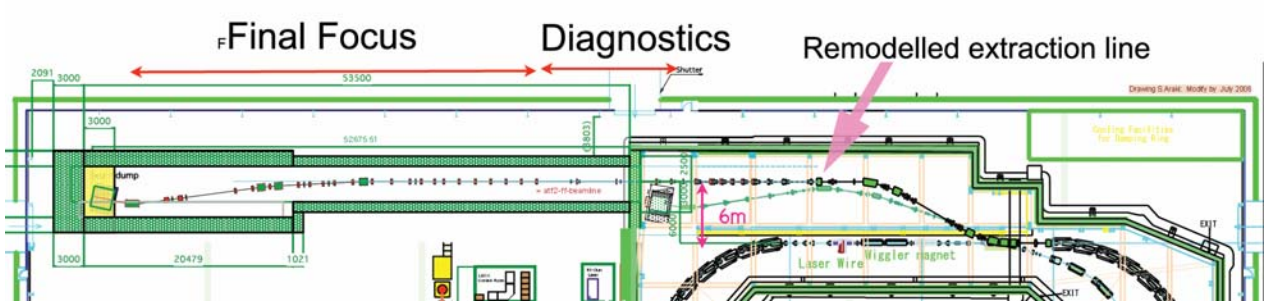
First Multi-bunch Extraction Oct.28

- Bunch interval 5.6ns
- Kicker excitation interval 308ns
- Upper line: bunch charge measured in the extraction line
- Hor: 400ns/div
- Ver: 0.2nC/div



ATF2

- Miniature of ILC Final Focus
  - **Same optics system as ILC**
  - **Tolerances similar to ILC**
  - **International project**
    - Funding
    - Manpower
    - >100 people from >25 institutes

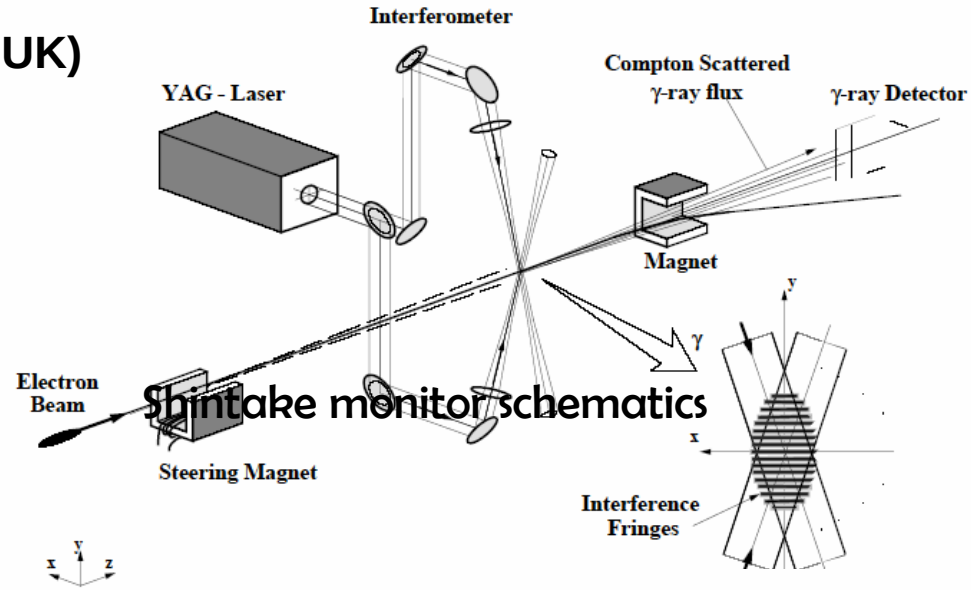


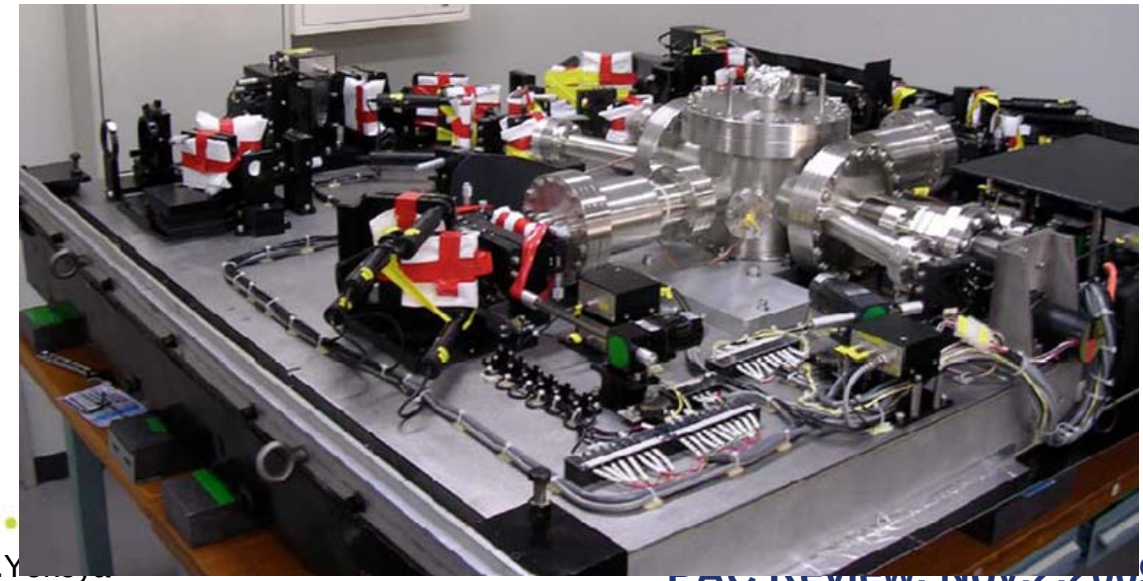
- Goals
  - **1st step: Beam size < 35nm (by 2010)**
    - IP BSM (beamsize monitor) needed
  - **2nd step: Stability of the beam centroid < 2nm (by 2012)**
    - IP BPM (beam position monitor) (<2nm) needed
    - IP feedback system
    - ILC format beam from ATF
- **Construction started in 2005 and completed in December 2008**

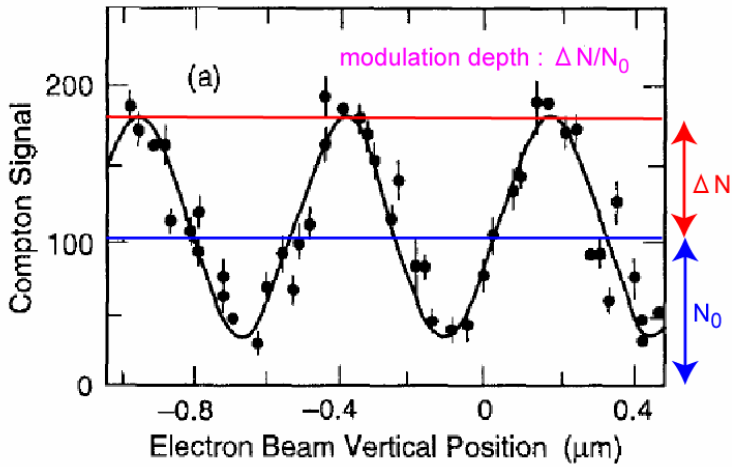
IP Beam Size monitor (BSM)

(Tokyo U./KEK, SLAC, UK)

- Improvement FFTB BSM
  - 1064nm=>532nm
  - dynamic range:
    35nm up to a few μm
  - phase scanning mode





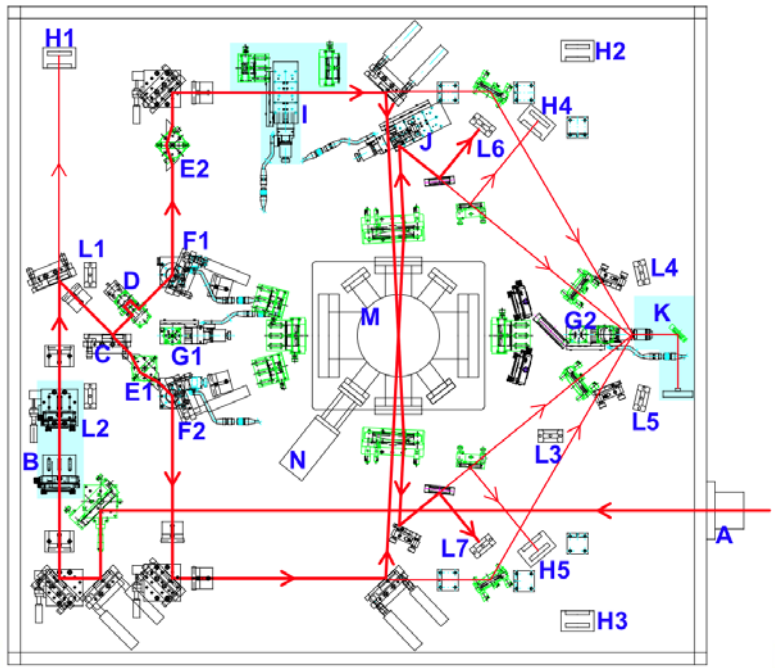


FFTB sample : σ_y = 70 nm

Commissioning of IPBSM

- First test: Jan-Feb 2009
- Laser Wire mode
  - **0.2~0.5x10^{10} electrons**
  - **Laser size < 20μm**
  - **Expected beam size ~10μm**
  - **photons O(1000)/bunch**
- Obtained convolution size ~50μm

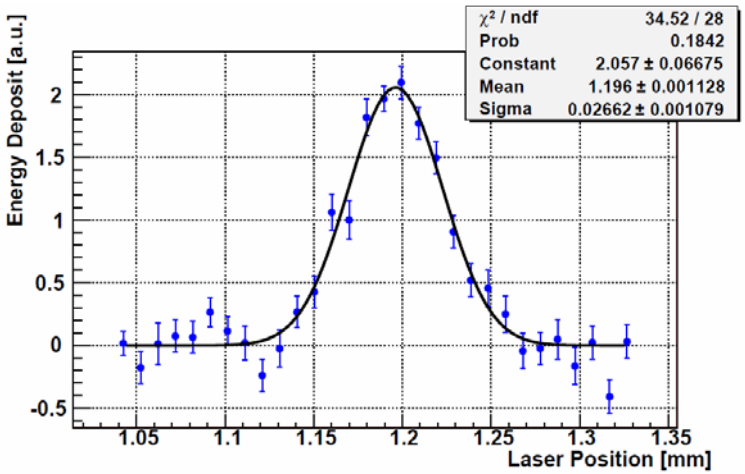
Interference mode		
4 steps of crossing angle		
2deg	1400~	nm
8deg	360~1400	nm
30deg	100~360	nm
174deg	25~100	nm (below)



Result by End of May

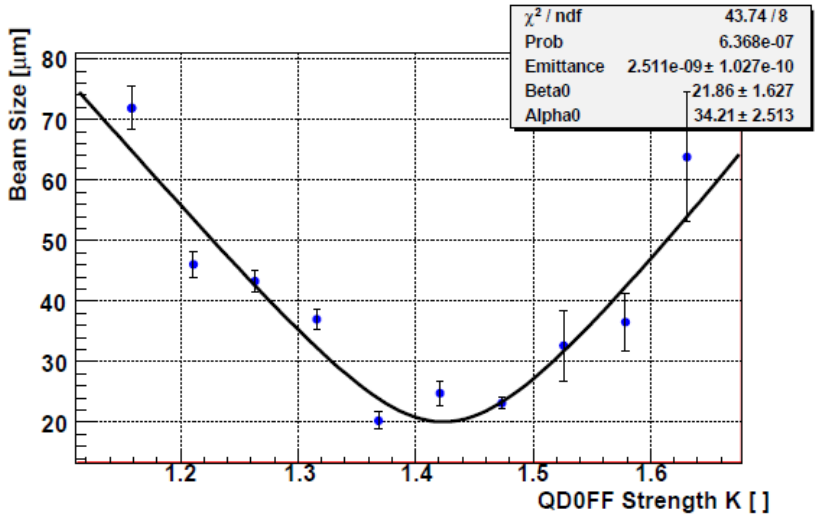
- Horizontal beam size measurement by laserwire
  - **laser size at the IP : σ_L=10-15 um**
- Q-scan at the IP was performed by laserwire mode

Horizontal beam size measurement



Example: σ = 26.6 um

Q-scan of horizontal beam size



emittance from fitting ε_x = 2.5 nm (σ_L=10 um)

ε_x = 2.0 nm (σ_L=15 um)

Upgrade during Summer Shutdown

- Improve signal resolution
  - **Raise the laser power 400mJ → 1500mJ**
  - **Add collimator**
- Install the laser-beam adjustment device
- Speed up of DAQ
  - **Prepare the module for 3Hz repetition rate (Δf Ramp for dispersion correction)**

Other ILC Activities at ATF/ATF2

- FONT4: Bunch-by-bunch digital feedback system
- Monalisa: Monitor relative motion between final quads and IP-BSM
- Straightness monitor
- Cavity BPMs
- Pulsed Laser Wire
- XSR beam size monitor
- Positron generation by laser-Compton

ATF2 Future Plan

Plan to Jan.2010

- Continue fast extraction kicker R&D in Damping Ring
- Confirm large β^* optics ($\beta_{x,y}$=8,1cm) ➔ towards sub-μm σ_y
- First signal evidence in interference mode ➔ BSM σ_y measurement

  - New BSM hardware
  - Carbon wire scanner at IP with 5 μm diameter
  - Cavity BPM stability and reproducible calibrations
  - Strip-line BPM improved calibration & reproducibility
  - Efficient optical tuning strategy in extraction line ➔ IP spot

Plan for 2010-2012

- New strip-line BPM electronics
- Multi-OTR fast extraction line 4D phase space diagnostics
- Tilt monitor & IP-BPM R&D
- FONT
- Background study at and near IP as function of β^* and FD alignment

Summary

- CESRTA
  - **Almost all reconfiguration works finished**
  - **Great deal of data of EC growth obtained**
  - **Comparison with simulation showing great progress**
  - **Various EC mitigation techniques being compared**
  - **Choice for ILC DR expected soon**
- ATF/ATF2
  - **Extraction by fast kicker (multibunch) successful**
  - **ATF2 beamsize tuning in early stage. IPBSM will try interferometer mode soon**