Operational Experiences Tuning the ATF2 Final Focus Optics Towards Obtaining a 37 nano-meter Electron Beam IP Spot Size

Glen White, SLAC (on behalf of ATF2 collaboration)

May 26 2010
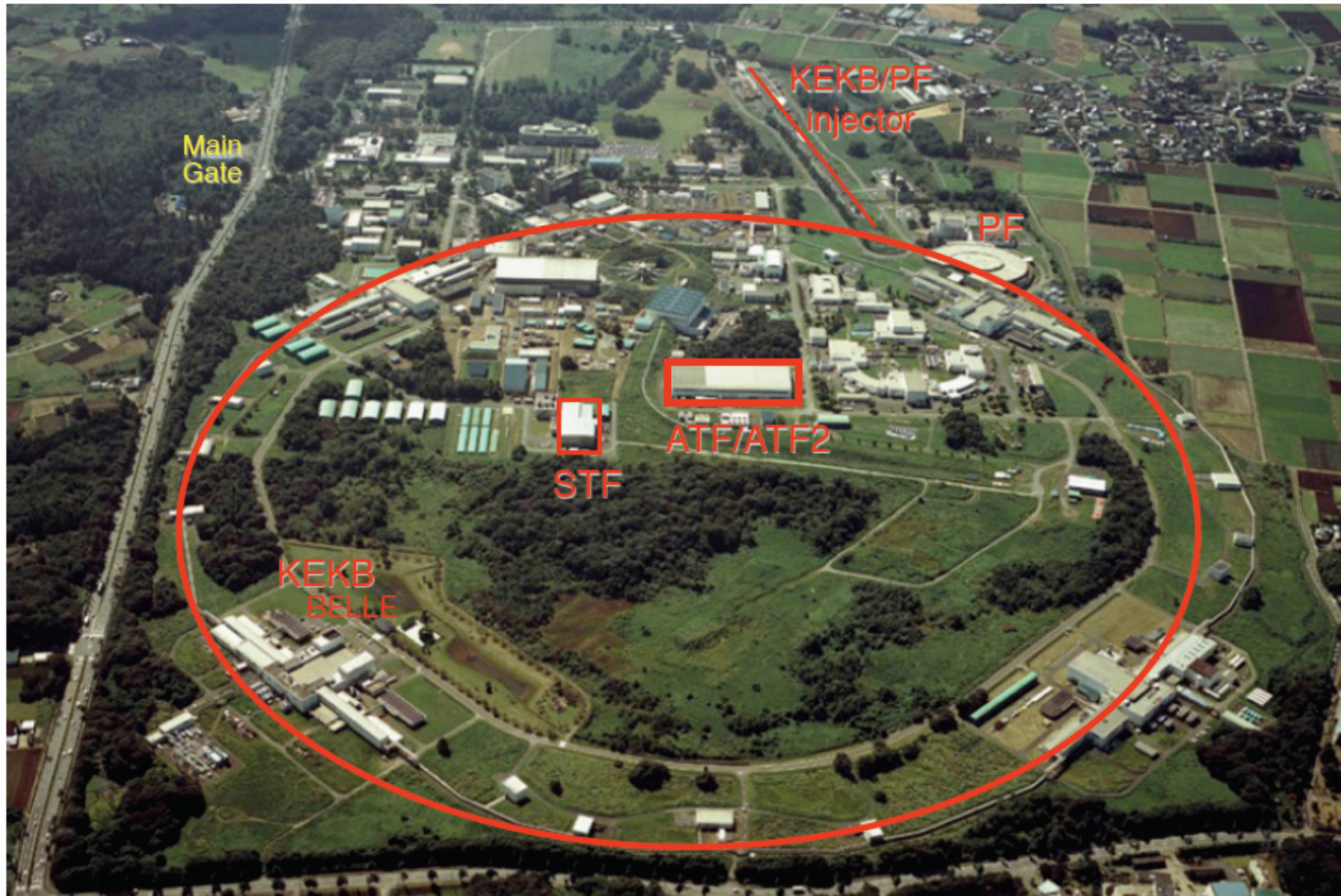
IPAC, Kyoto

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Overview

- The ATF2 test accelerator @ KEK, Tsukuba, Japan.
- ATF2 project goals and schedule
- ATF2 organisation and operation
- Tuning program
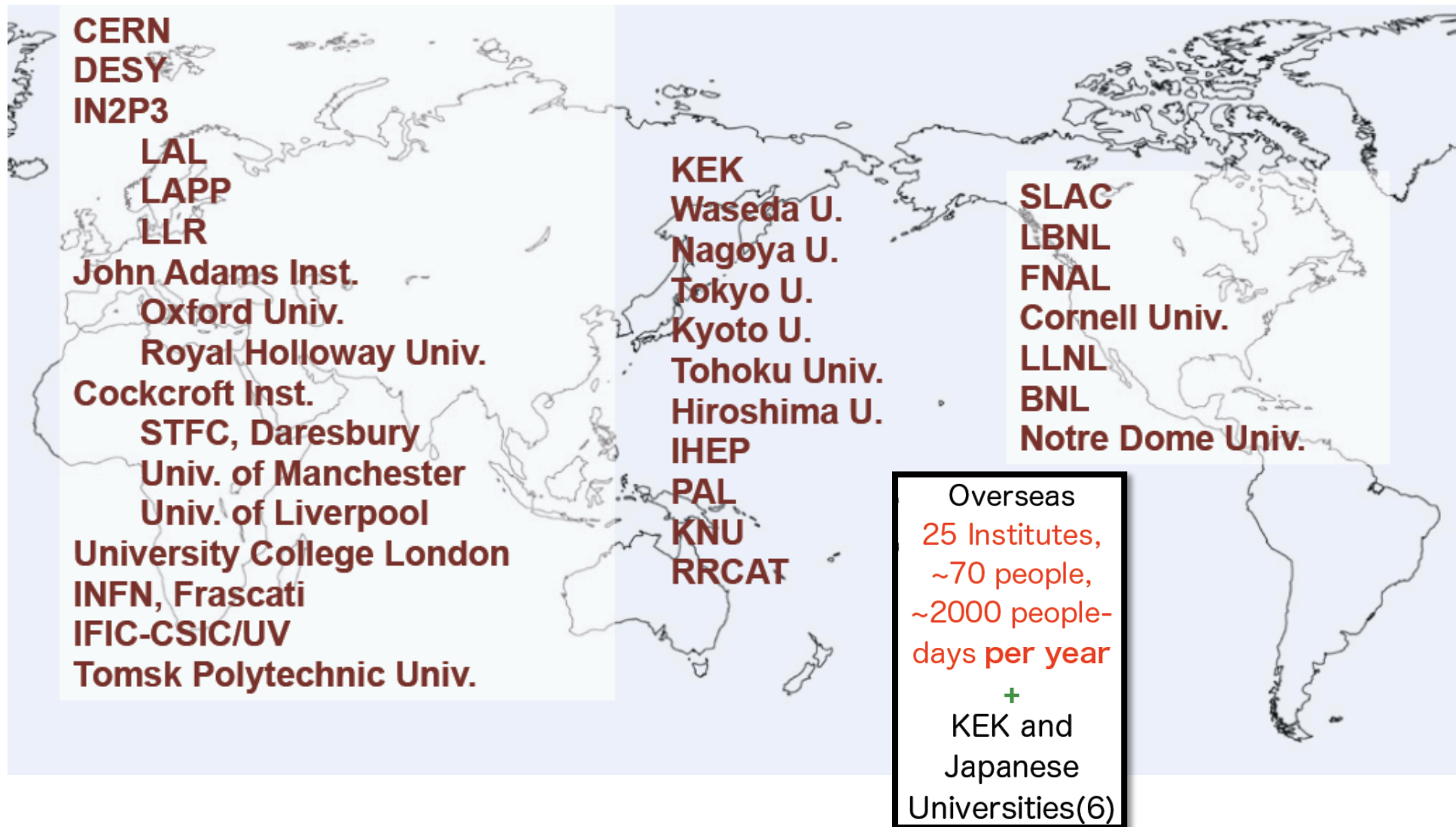- Recent results (last week)

ATF2 @ KEK

ATF International Collaboration

Organisation

- Day-day operations by KEK staff
- International partners direct contribution to ATF2
  - design, simulation, hardware, controls, tuning software, tuning shifts
- Much use of remote collaboration tools for offsite collaborators
  - Webex for weekly meetings
  - Wiki for documentation, data logging, file sharing etc
  - Webcam's / skype etc for remote participation in shifts
- Regular meetings to discuss progress on key topics
  - Tuning task force
  - Beam stabilisation task force
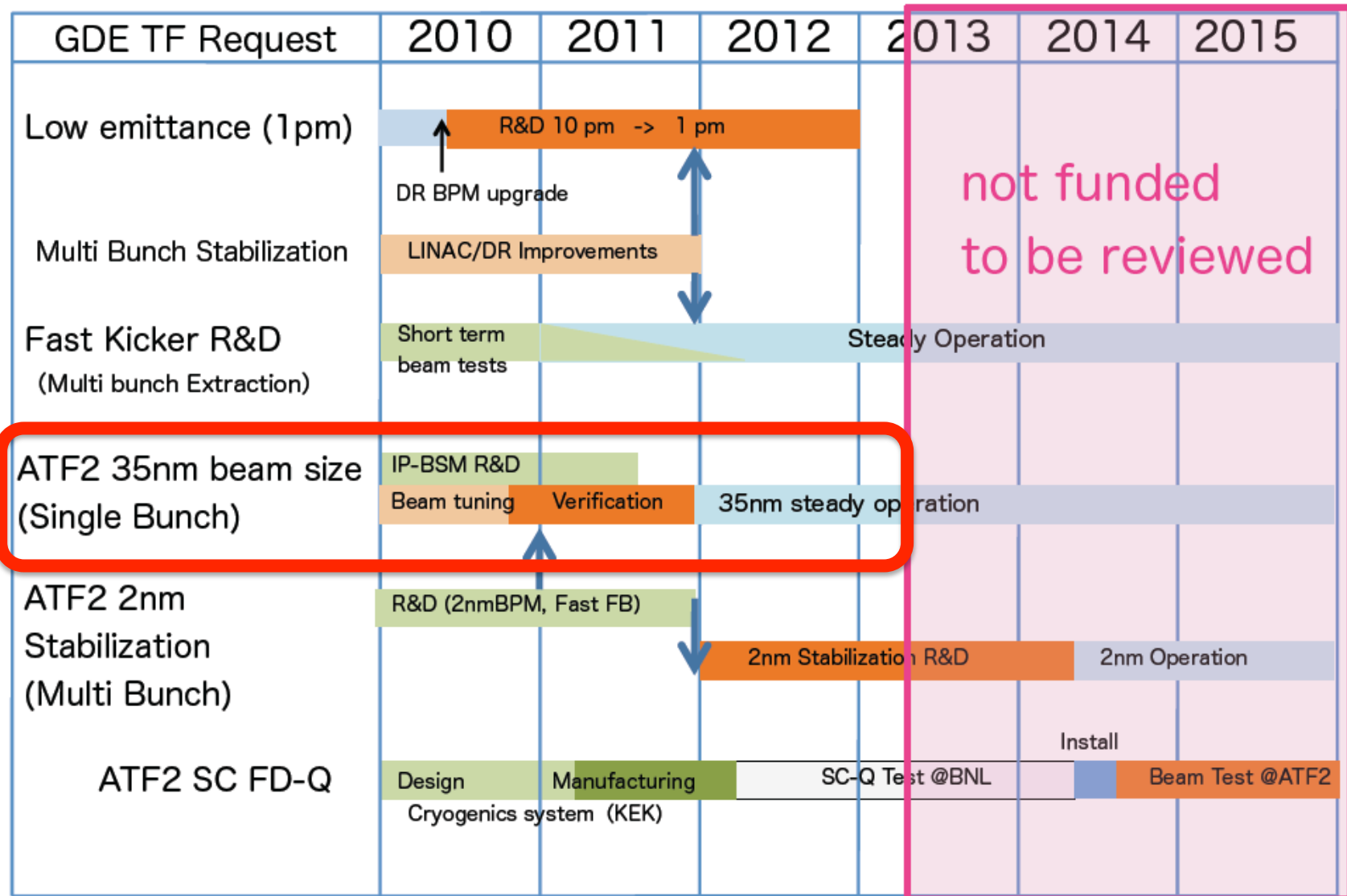 - Weekly run report meetings

ATF2 Project Goals

- Experimental verification of the ILC FFS scheme
  - Development of beam tuning procedures
  - Goal A: focus vertical spot at IP to ~37nm (single bunch)
  - Goal B: maintain IP vertical position with few-nm precision (multi-bunch)
- Development of ILC instrumentation
  - BPMs, movers, Fast feedback (FONT), Laserwire,
  - beam size monitor, HA-PS, fast pulser, SC-FD etc.
  - *See talk by N. Terunuma this afternoon*
- Education of young generation for future linear colliders
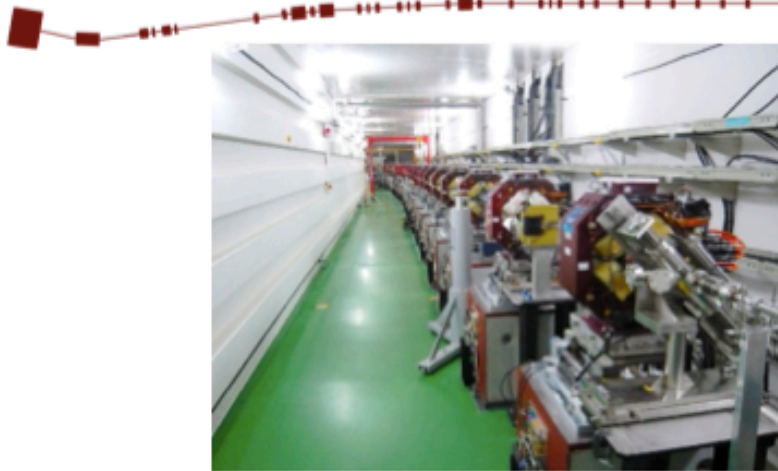 - Active participation of graduate students and post-docs.

ATF Schedule

GDE TF Request	2010	2011	2012	2013	2014	2015
Low emittance (1pm)		R&D 10 pm -> 1 pm				
	DR BPM upgrade					
Multi Bunch Stabilization	LINAC/DR Improvements					
Fast Kicker R&D (Multi bunch Extraction)	Short term beam tests		Steady Operation			
ATF2 35nm beam size (Single Bunch)	IP-BSM R&D					
	Beam tuning	Verification	35nm steady operation			
ATF2 2nm Stabilization (Multi Bunch)	R&D (2nmBPM, Fast FB)		2nm Stabilization R&D		2nm Operation	
ATF2 SC FD-Q	Design	Manufacturing	SC-Q Test @BNL	Install	Beam Test @ATF2	
	Cryogenics system (KEK)					

not funded
to be reviewed

ATF2 Facility Layout

ATF2 beam line (Jan.2009~)

Previous EXT line (~Jun.2008)

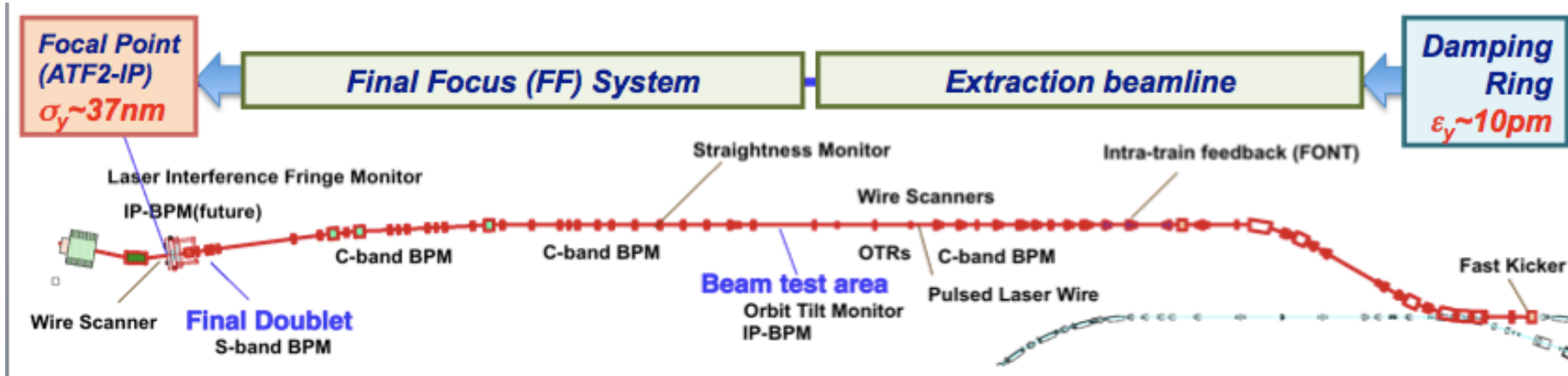Photo-cathode RF gun
(electron source)
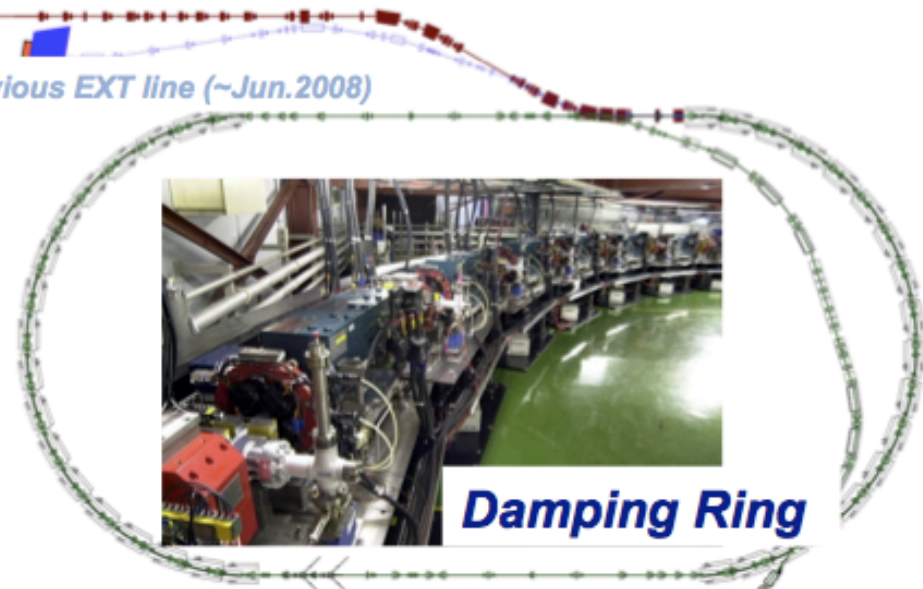
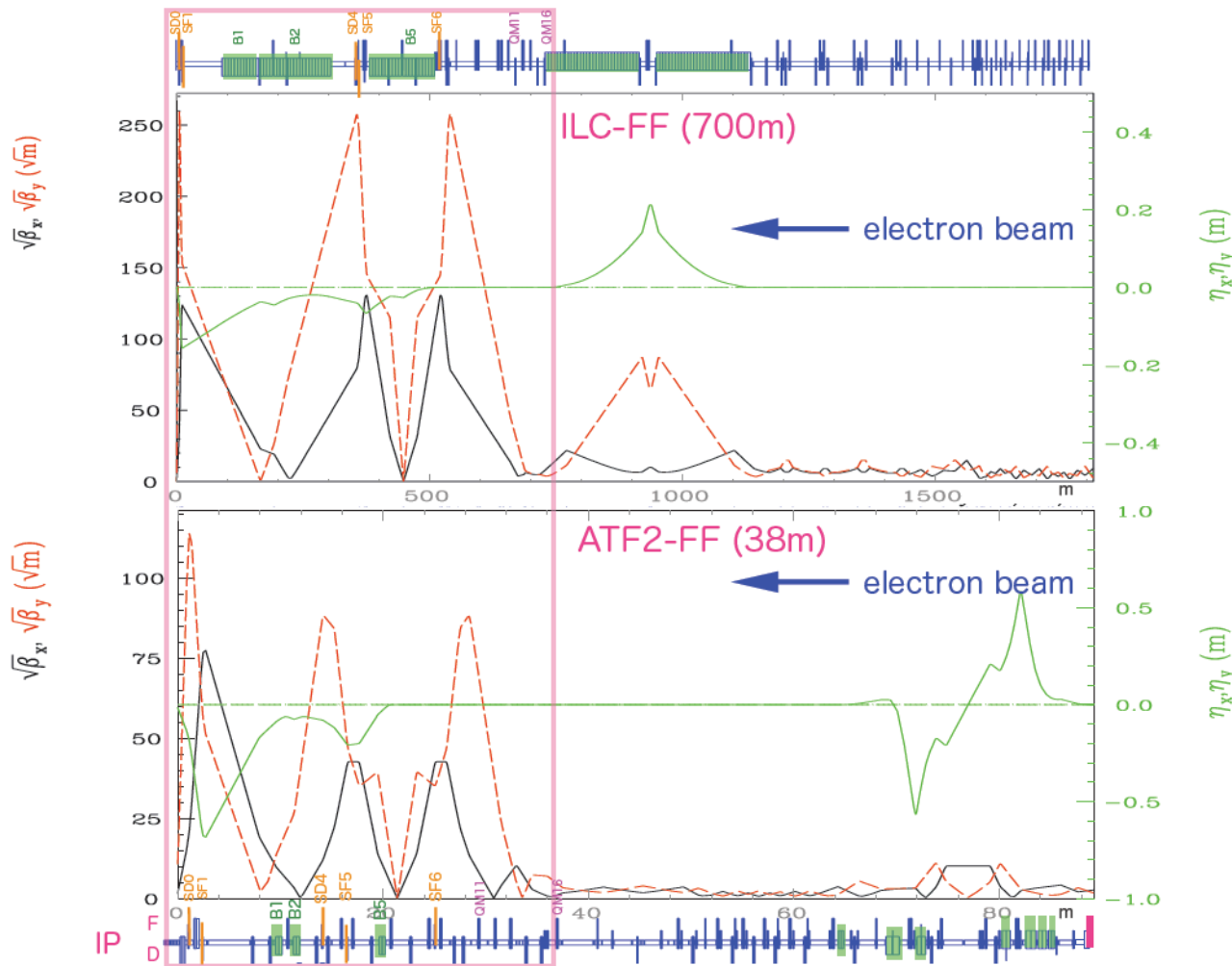Damping Ring
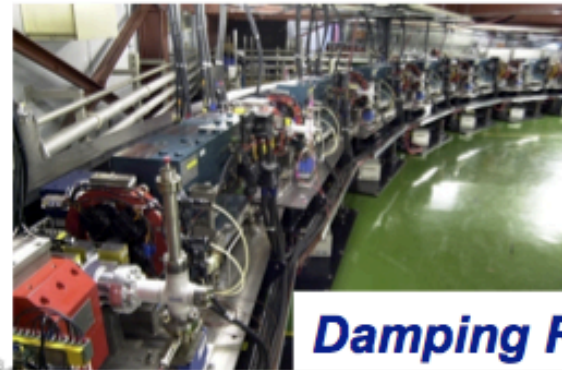
ATF2 Facility Layout

Final Focus System (FFS)
- Scale test of ILC FFS optics

Extraction Line (EXT)
- Extract beam from DR
- Correct for coupling and dispersion errors
- Correctly match beam into final focus system.

Scale Test of ILC FFS Optics

- Scaled design of ILC local-chromaticity correction style optics.
- Same chromaticity as ILC optics.
- At lower beam energy, this corresponds to goal ~37nm IP vertical beam waist.

Typical DR Parameters
$\varepsilon_x / \varepsilon_y$ = 1.3nm / 8-10pm
E = 1.282 GeV
ATF2 IP parameters
β_x / β_y = 4cm / 0.1mm
σ_x / σ_y = 6um / 37nm
Rep. Rate = 1.56 Hz

ATF2 Operations

- Initial commissioning started Dec 2008
- 2009 Operations based on "R&D" mode
  - ~50% of shifts allocated to ATF2 commissioning tasks
  - 2-3 weeks operations per month Jan-Jun Oct-Dec
  - Concentrate on isolated hardware and software commissioning items (e.g. cavity BPM system)
  - Test of individual tuning tasks (e.g. correction of EXT dispersion, coupling).
- First "continuous operations" run in May 2010
  - Last week, one dedicated week just for ATF2 tuning
 - First merging of full EXT and FFS tuning procedures

High-Level Controls for Commissioning and Tuning

- Main system used = VSYSTEM + SAD online model
  - Mainstay for accelerator operations, tested, maintained and stable.
- Alternate system developed based on EPICS+ Matlab + Lucretia beam dynamics code: ATF2 "flight-simulator"
  - Portable for offsite code development and testing
  - Same software runs either in production or simulation mode using simulation mode of low-level EPICS controls.
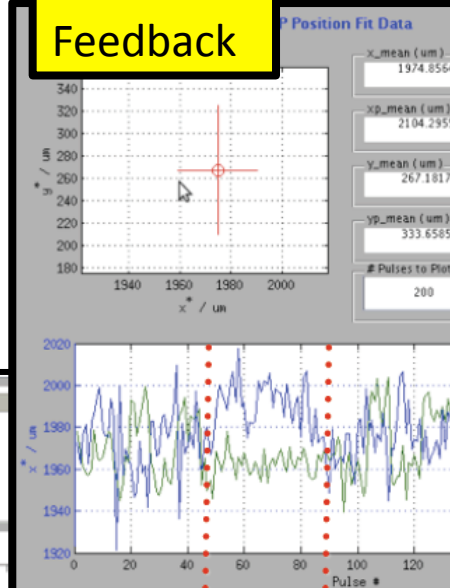 - Can interface to other code through tcp/ip socket layer or EPICS DB interface.

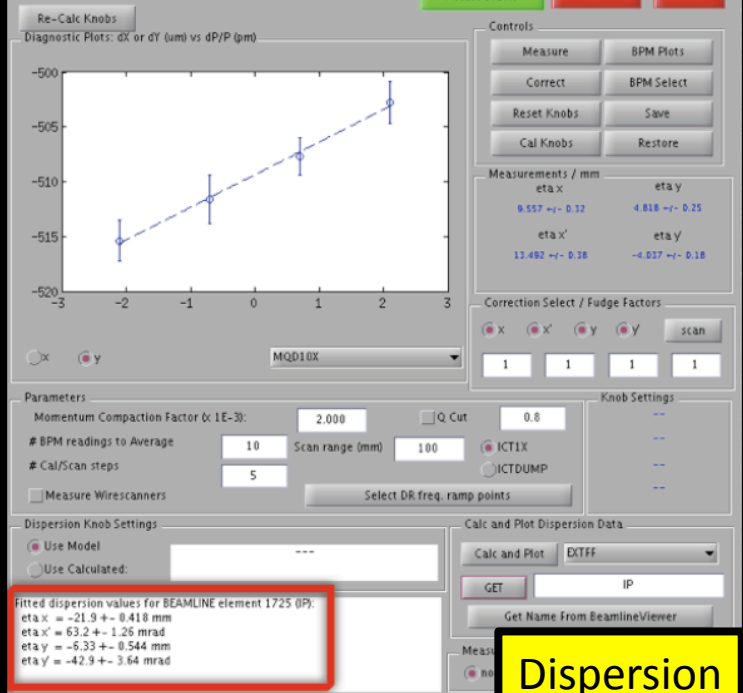# Example Flight Simulator Tuning Tools
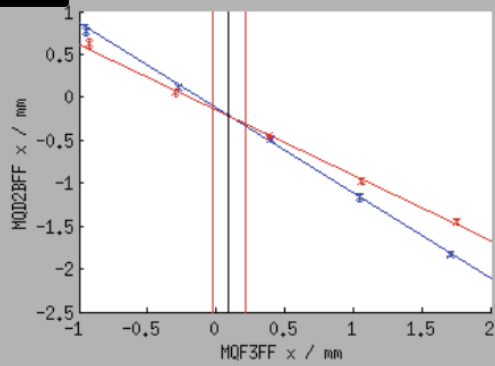
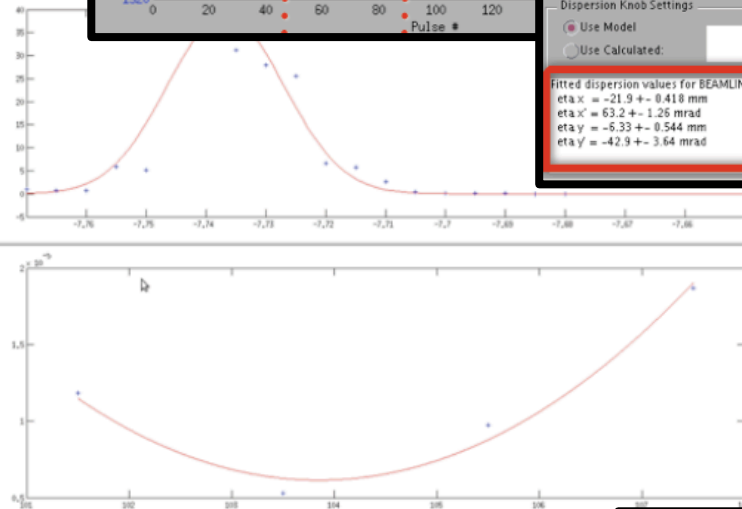# Tuning Procedure (week May 17 – 21)

- DR tuning
  - COD, dispersion, coupling, E match …
- EXT + FFS steering, setup
  - Cav. BPM cal, BBA, steering, background reduction
- EXT tuning
  - Dispersion, coupling correction.
  - Matching into FFS
- FFS tuning
  - Check match conditions at IP
  - "Coarse" IP matching (beta, alpha, dispersion)
    - e.g. "Irwin Knobs", MAD/SAD rematching
  - Fine tuning of IP aberrations with "multiknobs" and IPBSM "Shintake Monitor".
    - Waist, dispersion, coupling, sensitive second-order terms.
    - Sextupole mover-based multiknobs, FD roll scans, EXT skew-quad scans…

ATF2 Optics

- Difficulty in tuning (length of tuning time, probability of tuning close to design IP spot size) is related to the magnitude of chromaticity in the final focus optics.
- Currently running with 10 x nominal beta functions at IP (40cm / 1mm).
  - Min vertical beam size with this configuration @ 12pm emittance is ~110nm.
- Background levels at IPBSM become larger at lower IP beta sizes (with increasing beam divergence).
  - Last week, tested with ~0.5mm vertical beta and beam size measurements still possible.

Extracted Emittance

(DR emit_y = 10pm)

```
sigt    sigd    sigw    sig
------- ------- ------- -------
13.63    5.31    2.50    12.30
10.47    4.57    2.50     9.08
23.07    9.20    2.50    21.00
 8.97    3.89    2.50     7.68
10.30    3.00    2.50     9.53
```
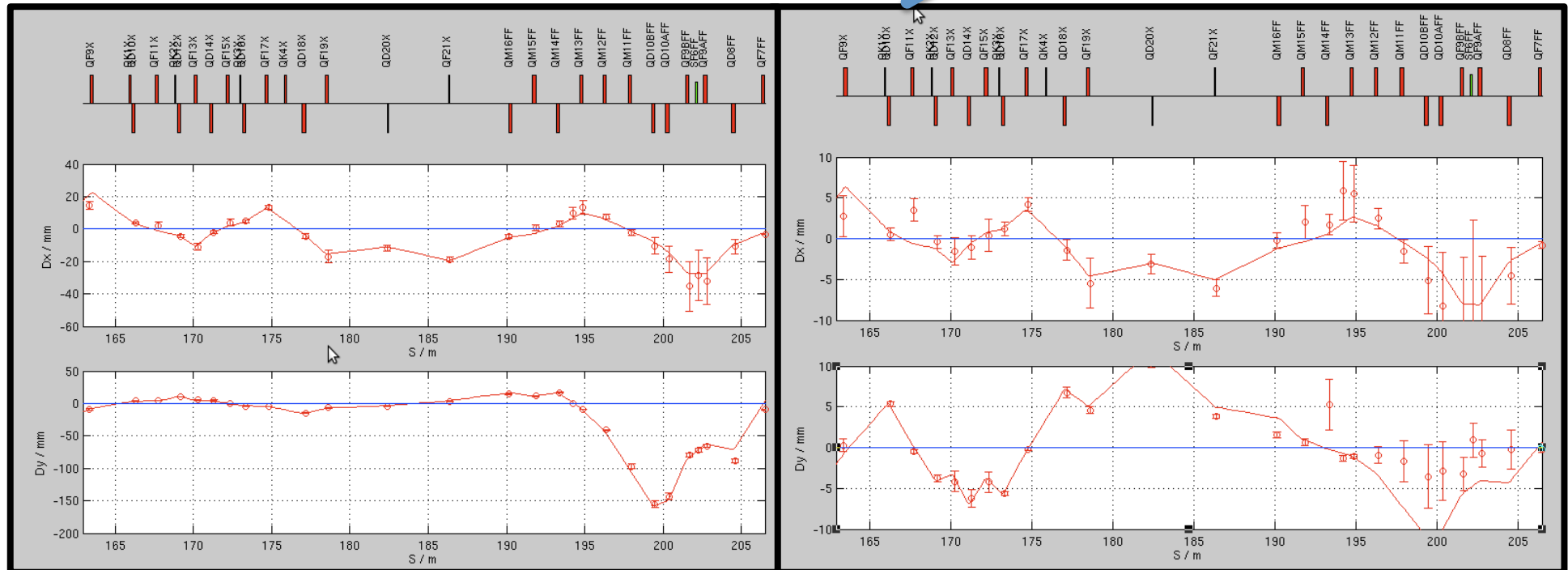
Vertical emittance parameters at MW0X

```
energy     =     1.2817          GeV
emit       =    11.7381 +-    2.2922 pm
emitn      =    29.4427 +-    5.7495 nm
emitn*bmag =    42.2019 +-    1.9205 nm
bmag       =     1.4334 +-    0.2490     ( 1.0000)
bmag_cos   =     0.0448 +-    0.0000     ( 0.0000)
bmag_sin   =    -0.7150 +-    0.0000     ( 0.0000)
beta       =    12.6951 +-    2.0753 m   ( 8.4774)
alpha      =     3.5809 +-    0.4296     ( 3.0756)
chisq/N    =     7.9155
```
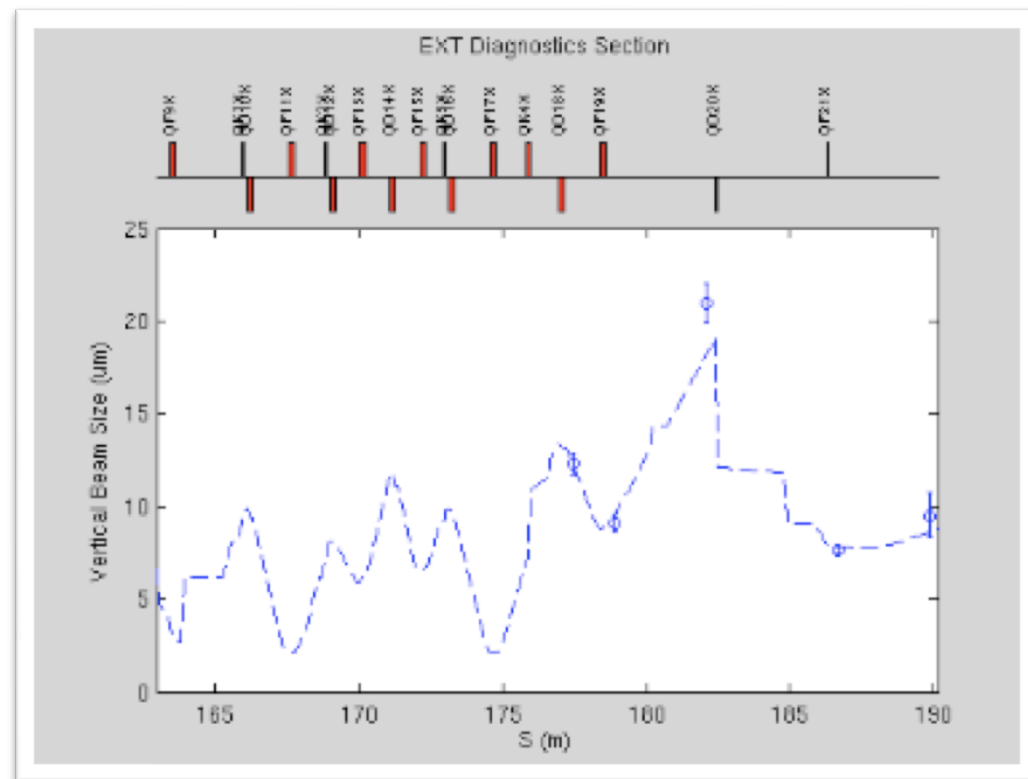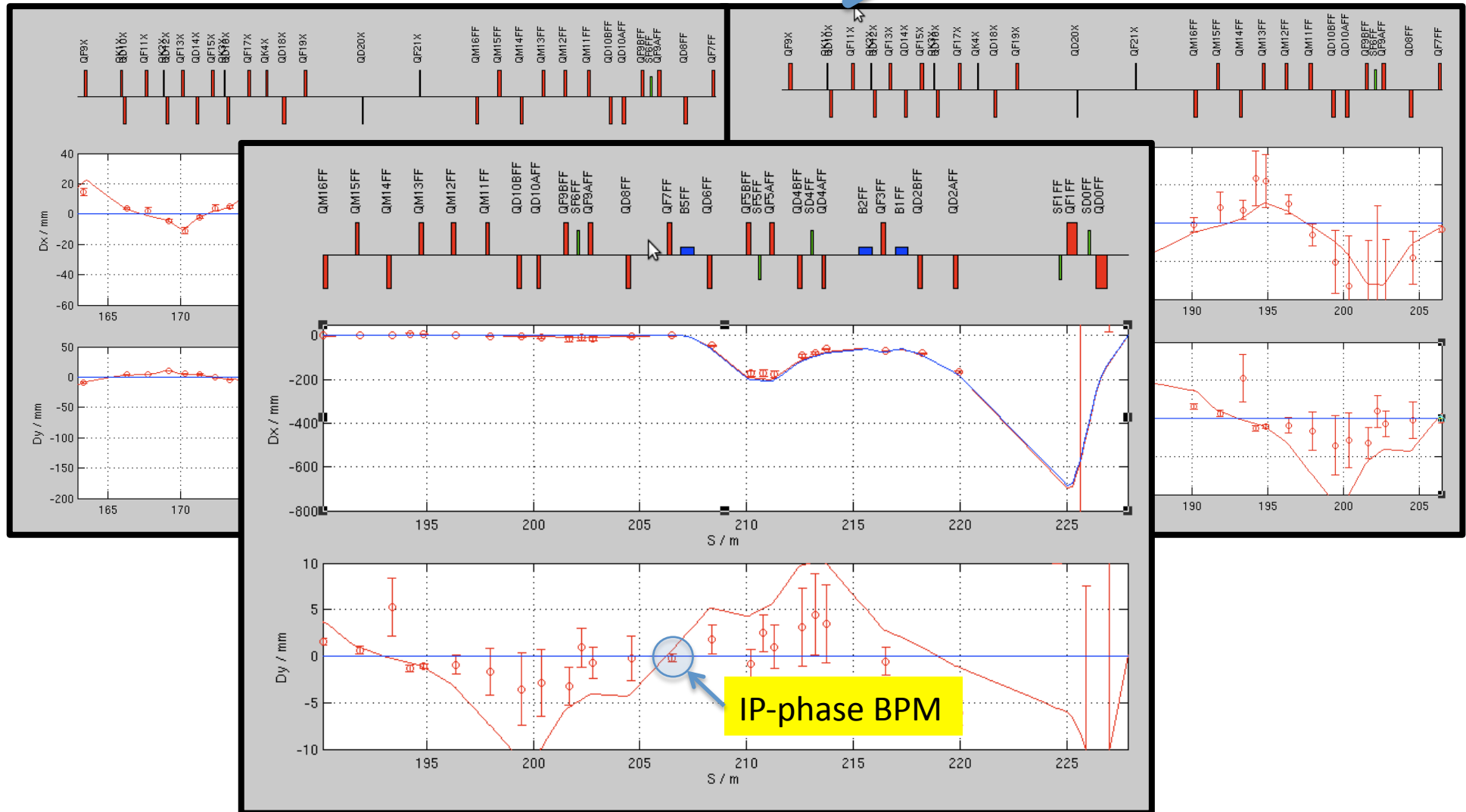
EXT Dispersion Correction

- Dispersion propogation to IP corrected <1mm x/y
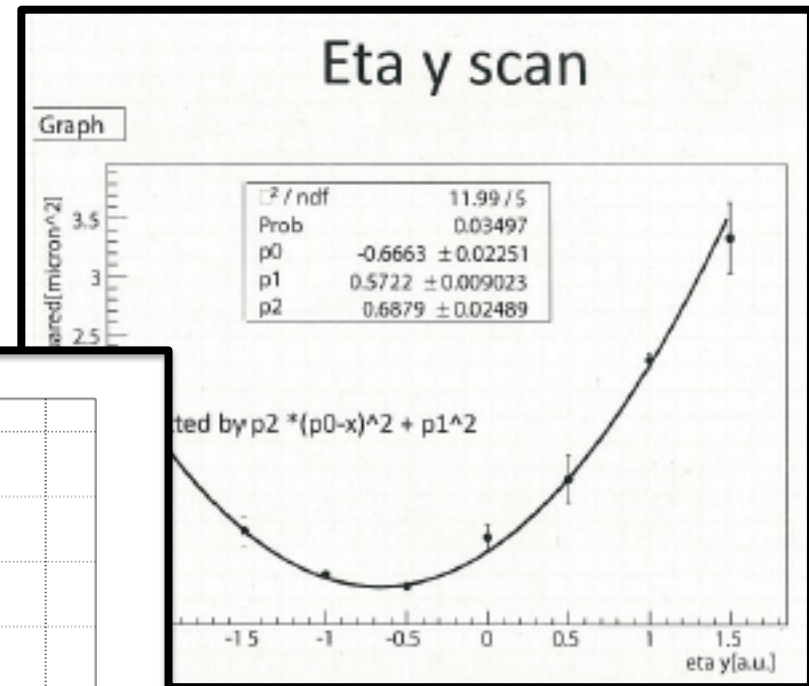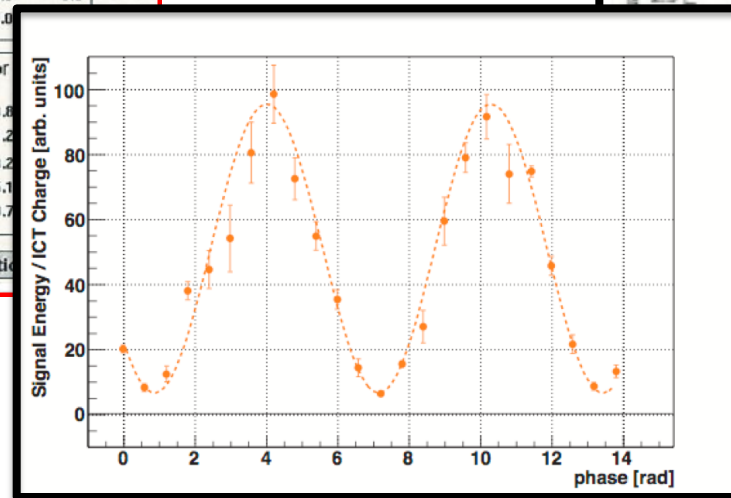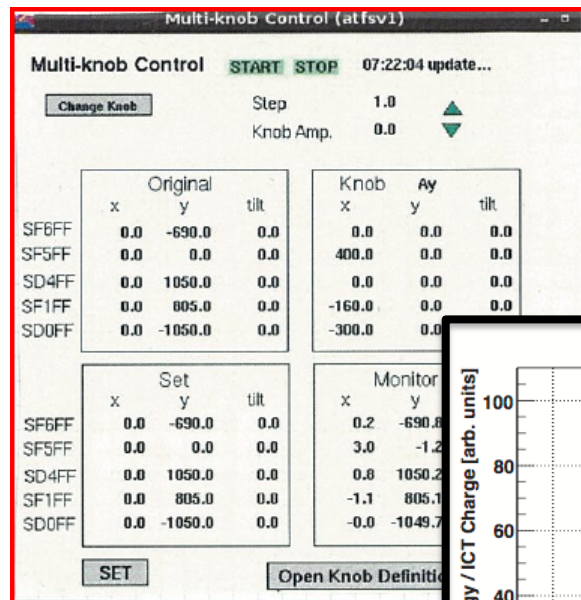- Residual vertical dispersion fine-tuned with FFS Sextupole multiknobs

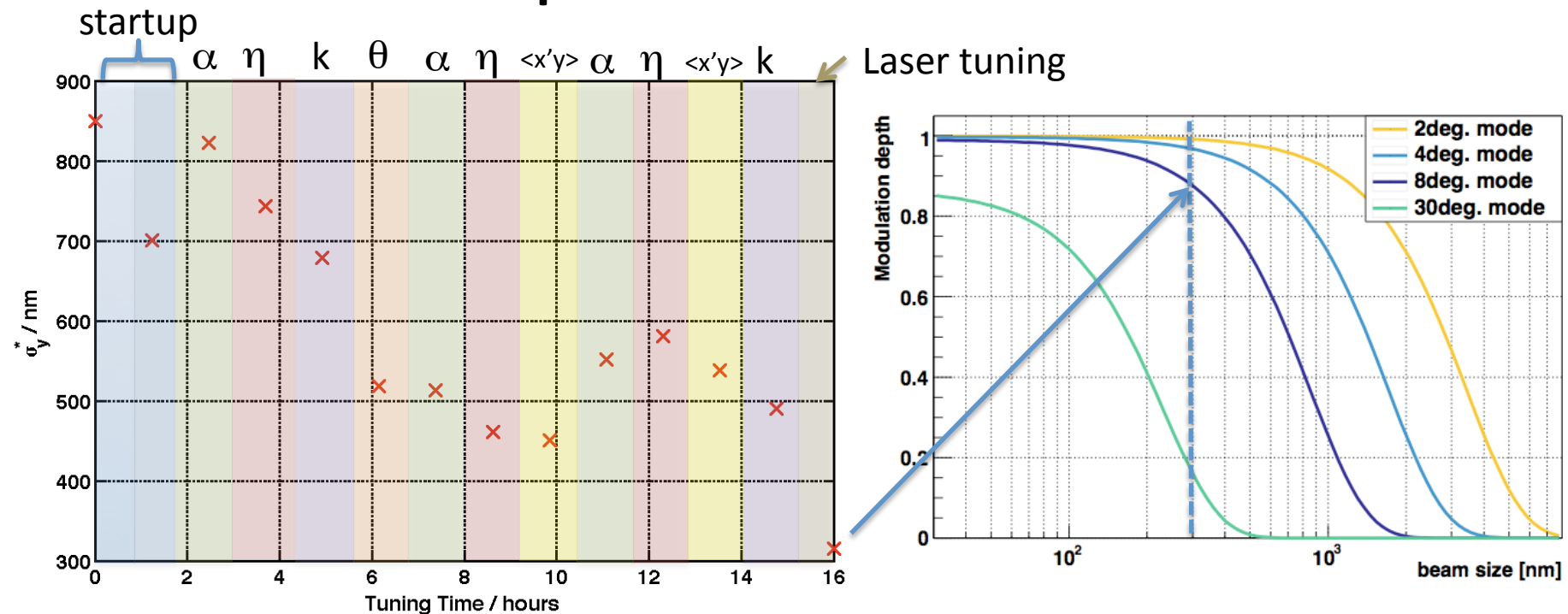# EXT Dispersion Correction

IP Tuning with FFS Sextupole Multiknobs

- Iterative use of various knobs to bring down IP spot size by scanning with IPBSM.
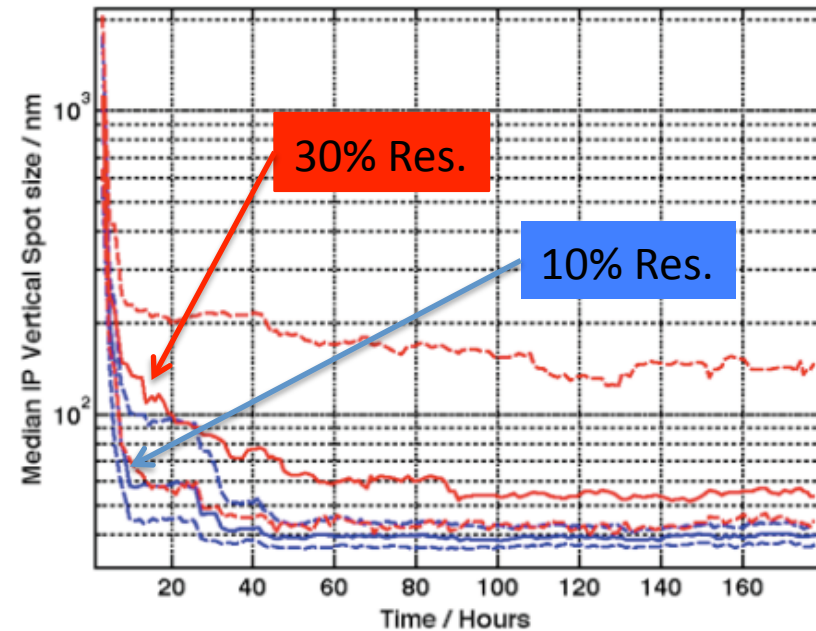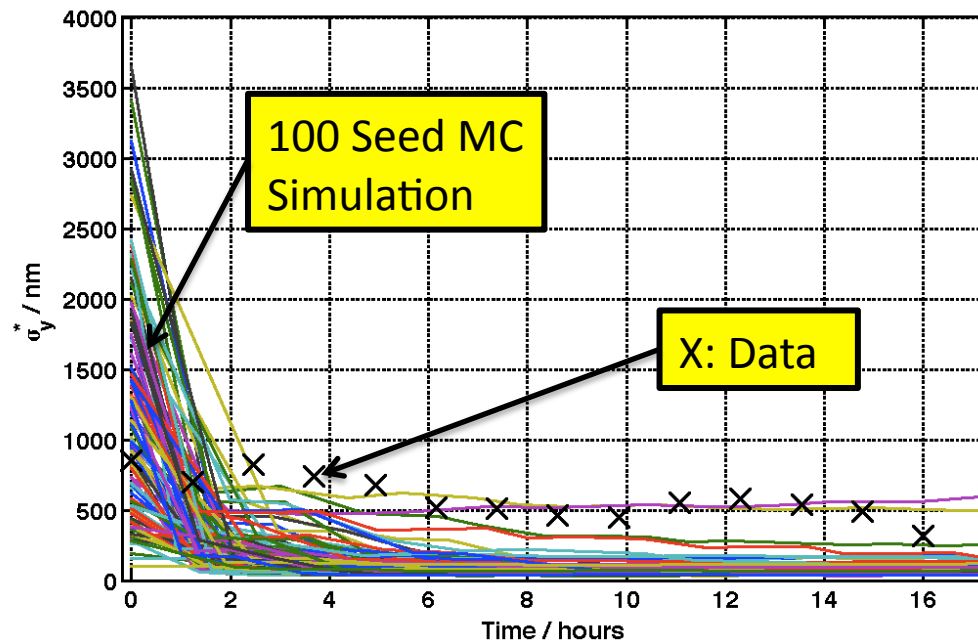
IP Tuning Results During Continuous Operations Week

- Tuning from initial setup of 850nm down to 300nm during 2 consecutive shifts last Thursday.

- Beam size cross-checked on IPBSM 8-degree & 30-degree mode.

- Trouble reducing beam size past 300nm in 30-degree mode as do not have the resolution to scan higher beam sizes.

Data vs. Simulation

- Initial tune up in mid-range expected from Monte Carlo simulations.
- Convergence time slower than simulated as tuning software not yet fully automated.
- This will be essential to be able to achieve goal beam size ~<1 operations week

Summary

- First dedicated attempt at tuning ATF2 beamline last week.
- 300nm vertical beam size at IP waist achieved.
- Now commissioned and checked all but 174-degree operation modes of IPBSM.
  - Intermediate mode between 8 and 30-degree may help with tuning efforts.
- Understanding next steps on way to 37nm
  - Many ideas on tuning knobs, need to understand performance limitations, relative merits etc
  - develop more automated applications
  - Test implementation of nominal optics and see if background levels tolerable.

- MOPE022 Development of Shintake Beam Size Monitor for *ATF2*
- MOPE023 Evaluation of Expected Performance of Shintake Beam Size Monitor for *ATF2*
- MOPE035 Development of Electronics for Beam Position Monitor at *ATF2* Interaction Point Region
- Multi Optical Transition Radiation System for *ATF2*
- MOPE070 Cavity Beam Position Monitor System for *ATF2*
- MOPE074 Development of a Fast, Single-pass, Micron-resolution Beam Position Monitor Signal Processor: Beam Test Results from *ATF2*
- MOPE100 The Straightness Monitor System at *ATF2*
- WEZMH02 Instrumentation for the *ATF2* Facility
- WEOCMH01 First Beam Test of the Tilt Monitor in the *ATF2* Beam Line
- WEPEB039 Simulation Study of Intra-train Feedback Systems for Nanometer Beam Stabilization at *ATF2*
- WEPEB044 Latest Beam Test Results from *ATF2* with the Font ILC Prototype Intra-train Beam Feedback Systems
- WEPE017 Beam Test Plan of Permanent Magnet Quadrupole LENS at *ATF2*
- WEPE041 A Superconducting Magnet Upgrade of the *ATF2* Final Focus
- THPD077 Linear Collider Test Facility: Twiss Parameter Analysis at the IP/Post-IP location of the *ATF2* beam line
- THPD080 Coupling Measurements in *ATF2* Extraction Line
- THPD096 Simulation of Multiknobs Correction at *ATF2*
- THPE020 Scenarios for the *ATF2* Ultra-Low Betas Proposal