ATF2 Instrumentation

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(also on behalf of the ATF2 international collaboration)

EuCARD 2nd Annual meeting, WP9 Highlight talk
Friday 10-13th May 2011
CNRS, Paris, France

Talk introduction

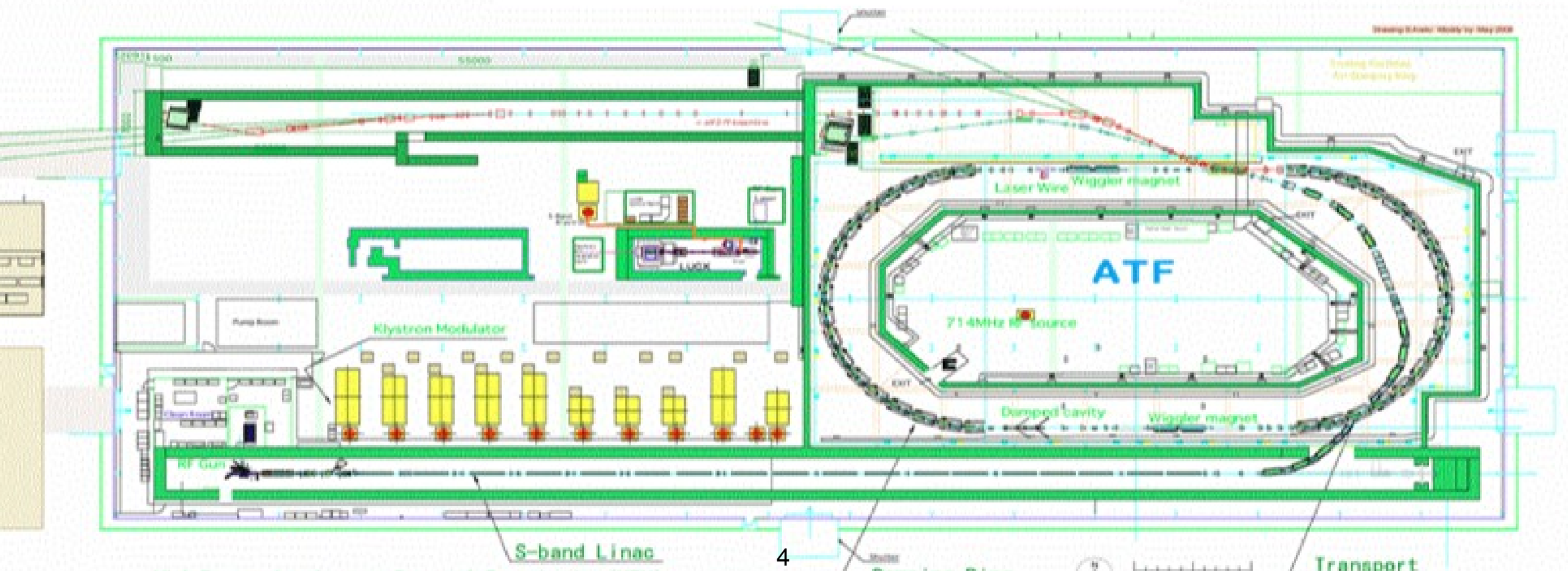
- ATF/ATF2 facility
  - Extension to the ATF damping ring
  - Main test facility for ILC/CLIC like beam delivery system
  - Goal 1 : Vertical beam size of 35 nm
  - Goal 2 : Stabilise beam vertically to few nm
- Diagnostic instrumentation
  - ATF2 is extremely dense with novel/performant diagnostics systems
  - WP9.4 funding activities : Feedback on nanosecond timescales (9.3.?), laser-wire transverse emittance monitoring (9.4.3), cavity beam position monitors (9.4.2)

Instrumentation at ATF2 (WP9)

- Cavity Beam position monitor systems (KEK/SLAC/JAI) ~40, 50 nm BPMs
- Interaction point beam size monitor (KEK/Tokyo) Aim to measure 35 nm beam size
- Optical transition radiation monitor (KEK/SLAC/IFIC)
- Micron scale optical transition radiation (KEK/JAI @ RHUL)
- Laser wire system (JAI@RHUL/Oxford) Aim 1um beam size measurement
- Feedback on nanosecond time scales Digital feedback on 300 nm timescale
- Background monitoring (LLR)
- Interaction point BPMs,
  - High Q (KEK/KNU)
  - Low Q (KEK/KNU)
- Tilt monitor (Tohoku university) Rotated monopole cavity

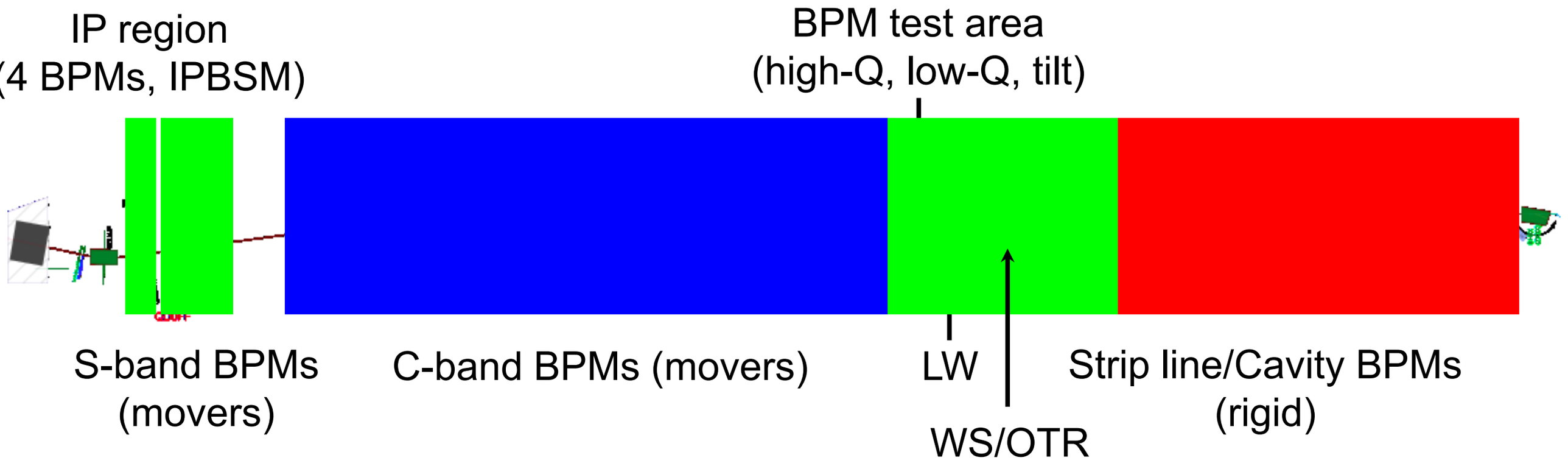
Accelerator Test Facility (ATF)

- Photo-injector gun
- S-band 1.28 GeV linac
- ~400 m length radiation ramping storage ring (X-ray and laser-wire emittance)
- Low emittance extraction and transport to ATF2



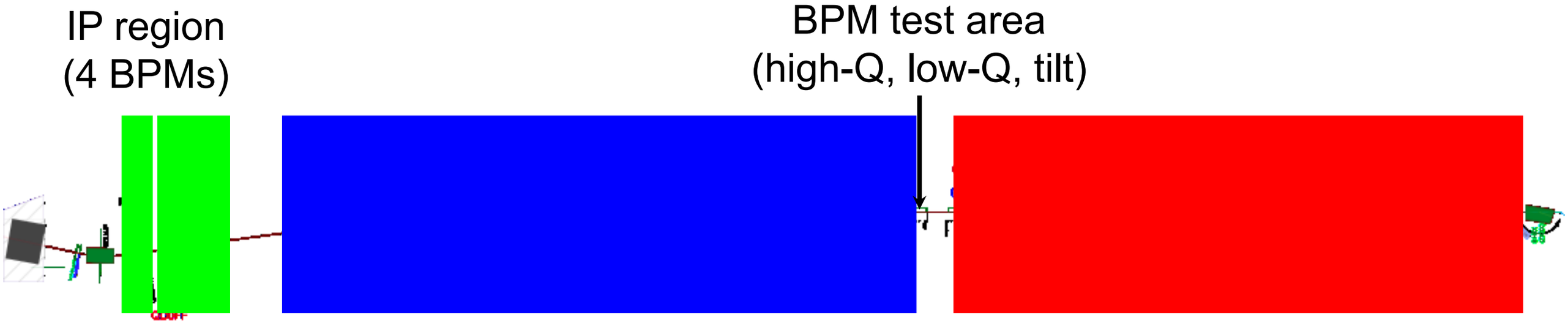
High Energy Accelerators Research Organization (KEK)

ATF2 Overview (instrumentation)

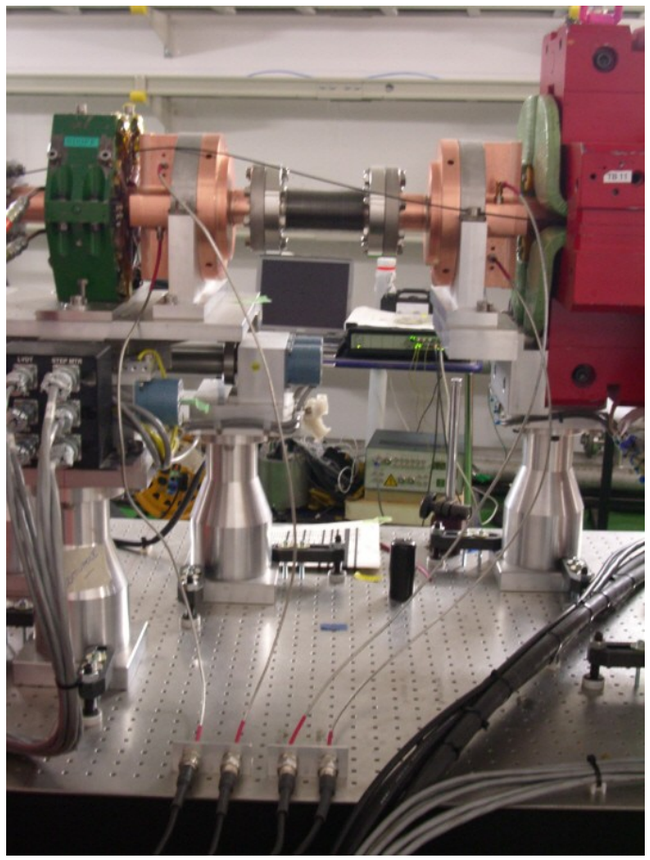


- Very dense with instrumentation
  - 2 independent emittance diagnostic systems (3 axis wires scanners : projected emittance, OTR : full emittance)
  - 2 independent interaction point systems (BPMs, IPBSM)
  - 41 Cavity beam position monitors (almost every quadrupole)
  - Test areas for development

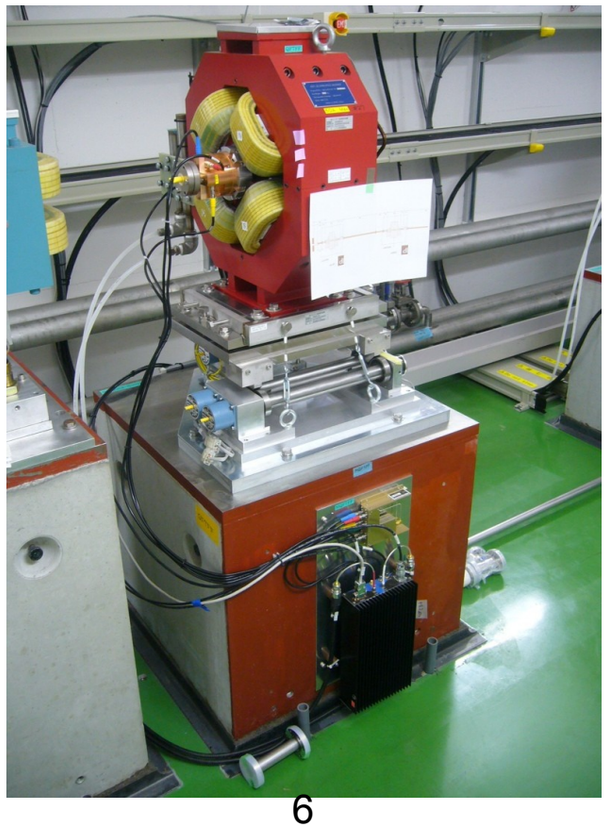
Cavity position monitor system



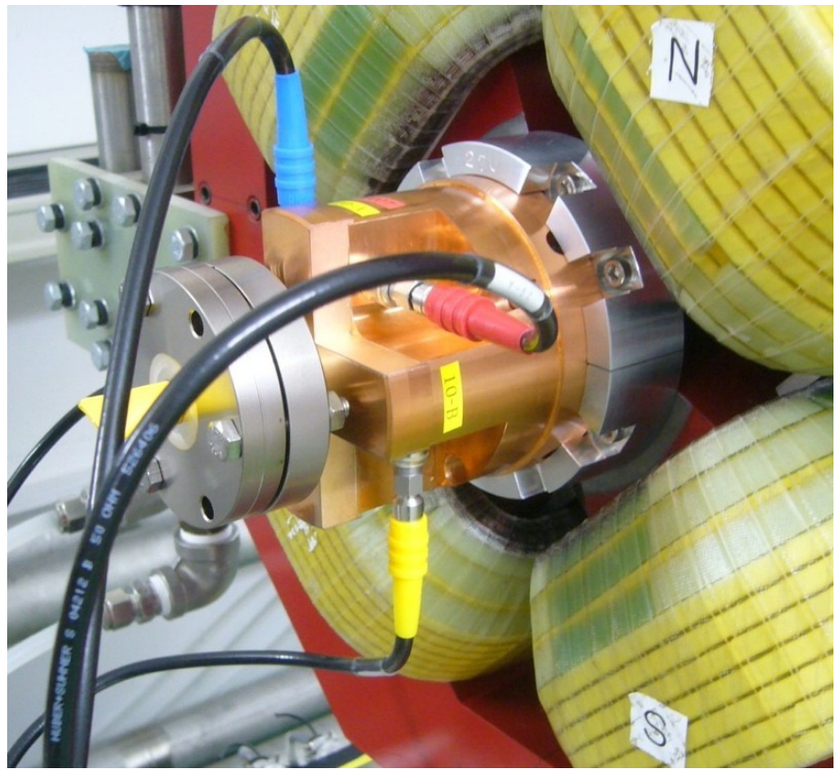
S-band BPMs (movers)



C-band BPMs (movers)

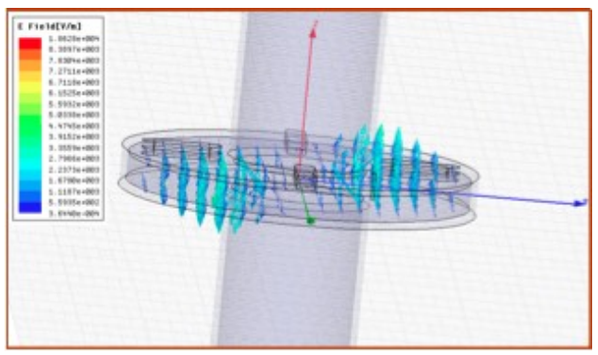


Strip line/Cavity BPMs (rigid)

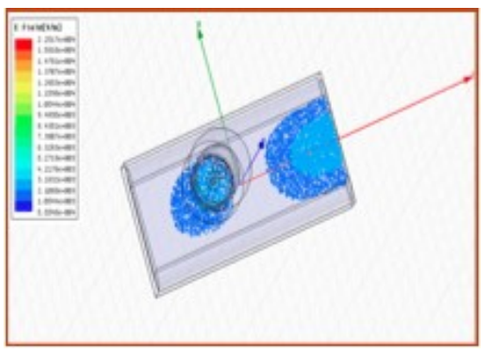


Cavity BPMs in one slide

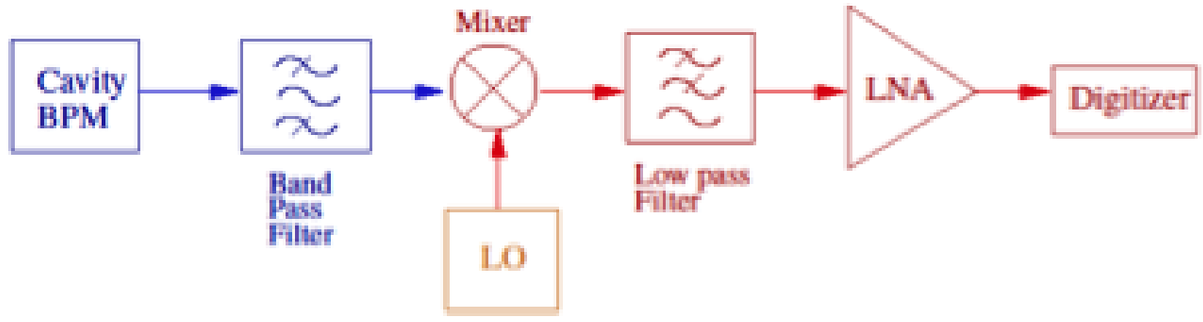
Dipole cavity, signal proportional to q*p



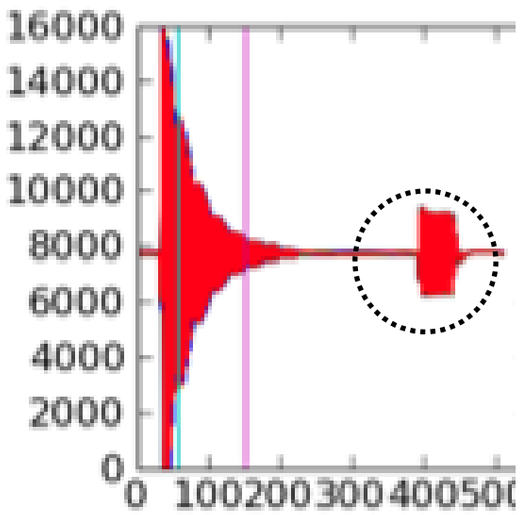
Dipole mode selective waveguide couplers



Simple single sideband down-converter
IF~25 MHz, 100 MHz digitisation

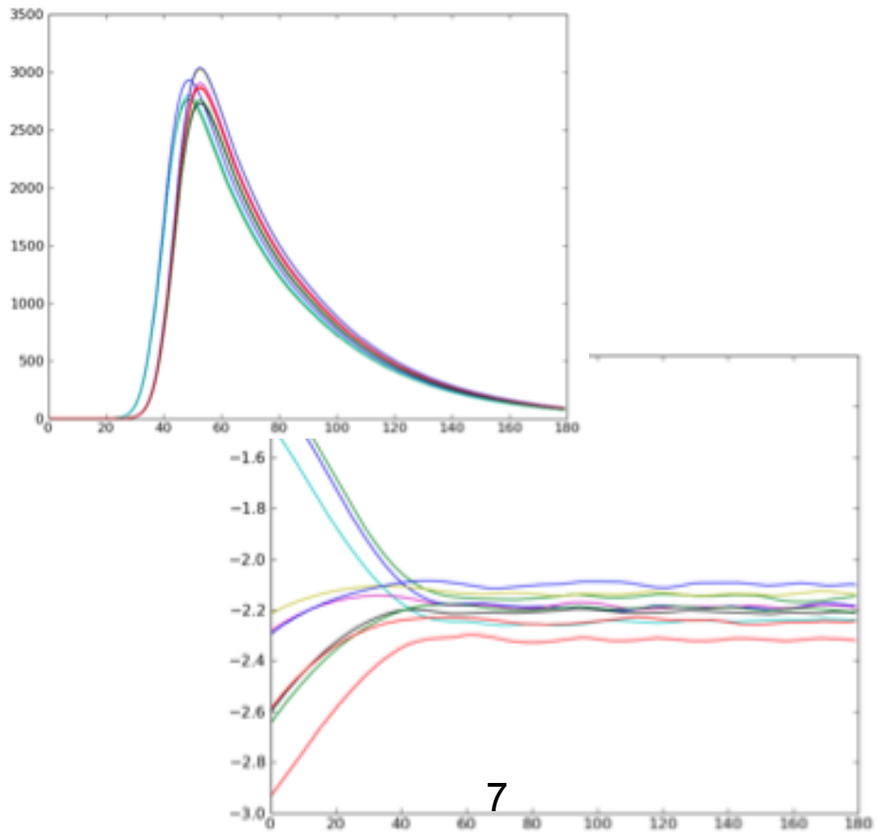


Digitised signal
Decaying exponential

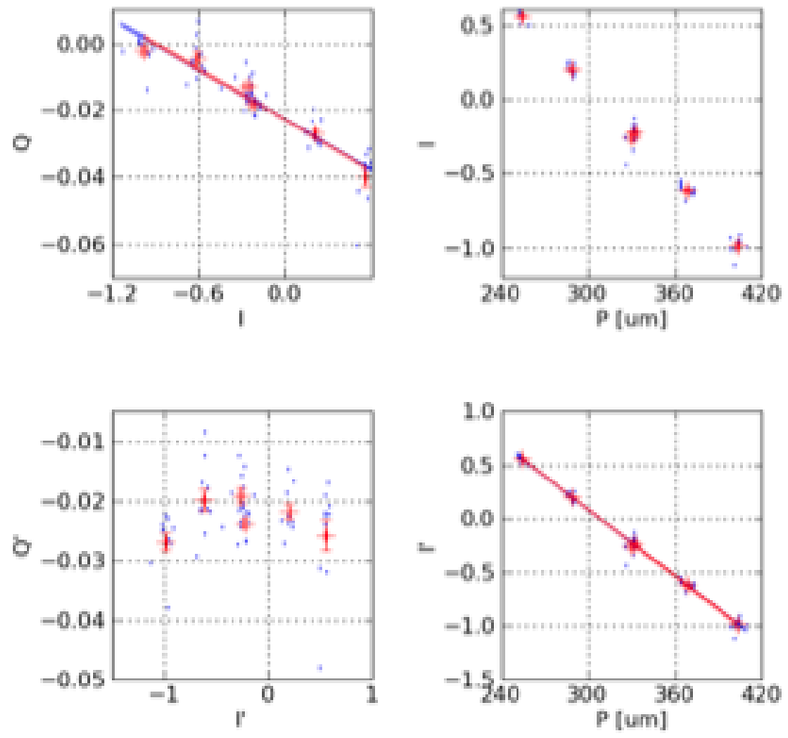


Calibration signal

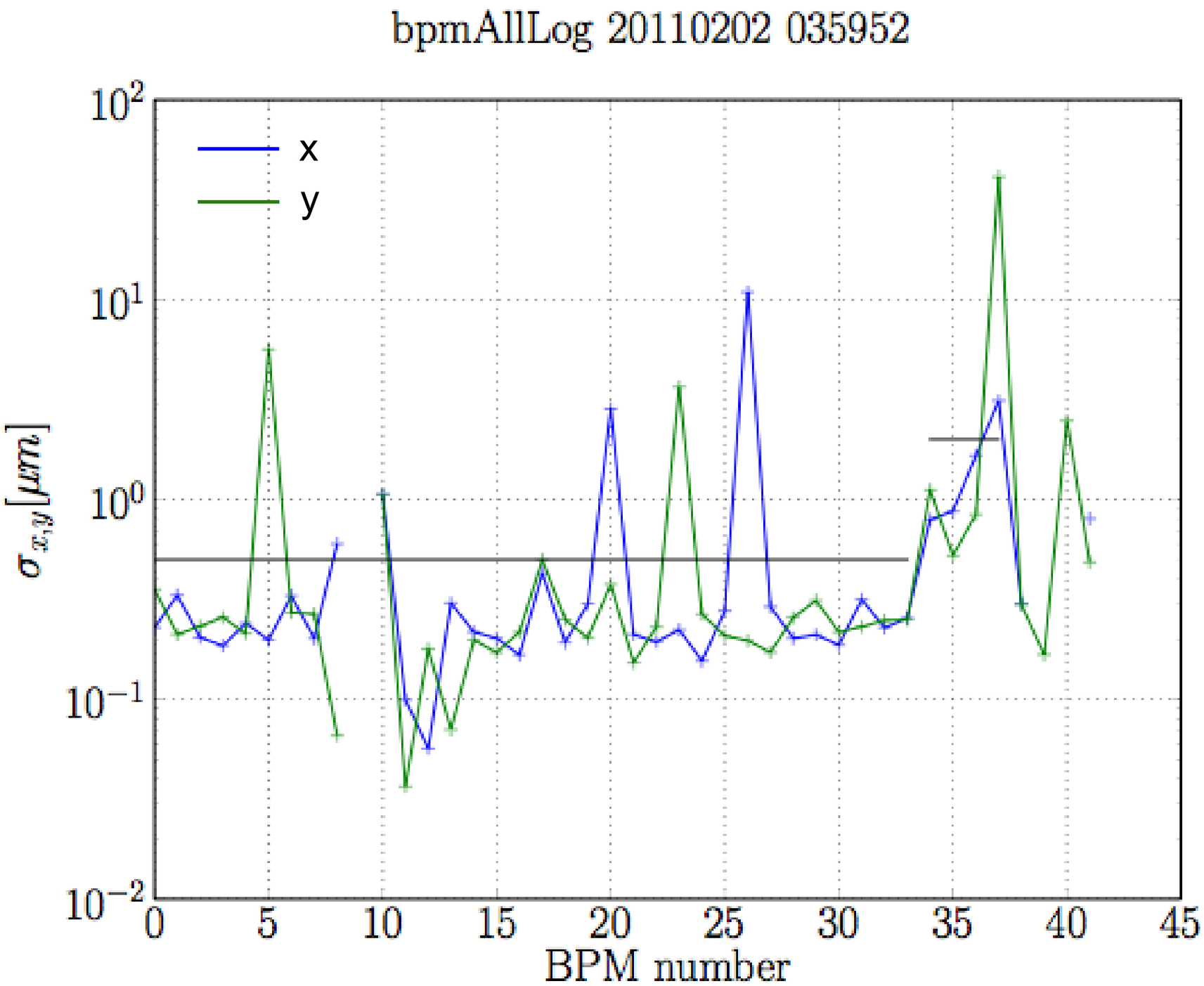
Digitally mix to baseband



Calibration, move BPM (quad mover) or bump beam

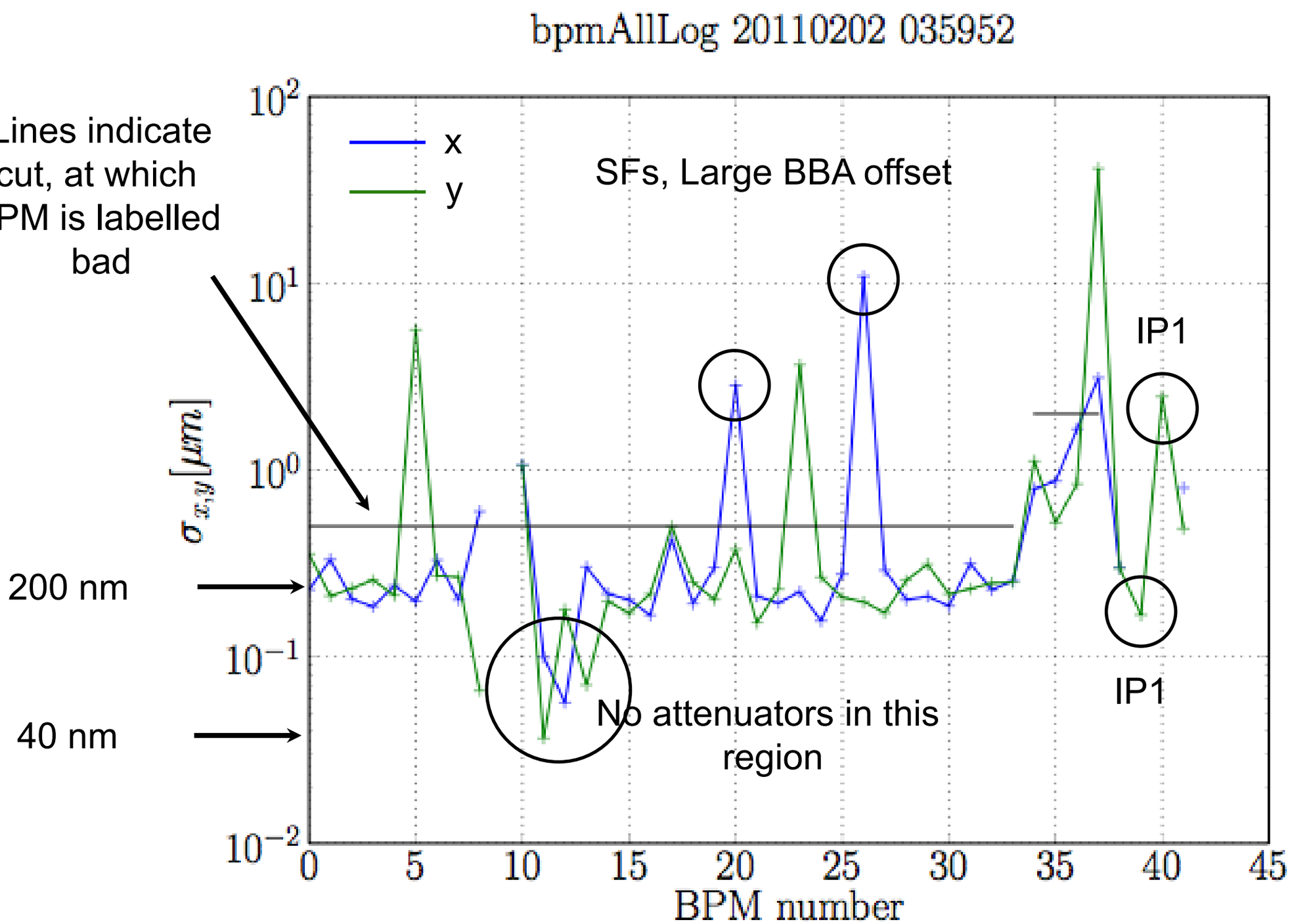


BPM Resolution (2011-02-02)

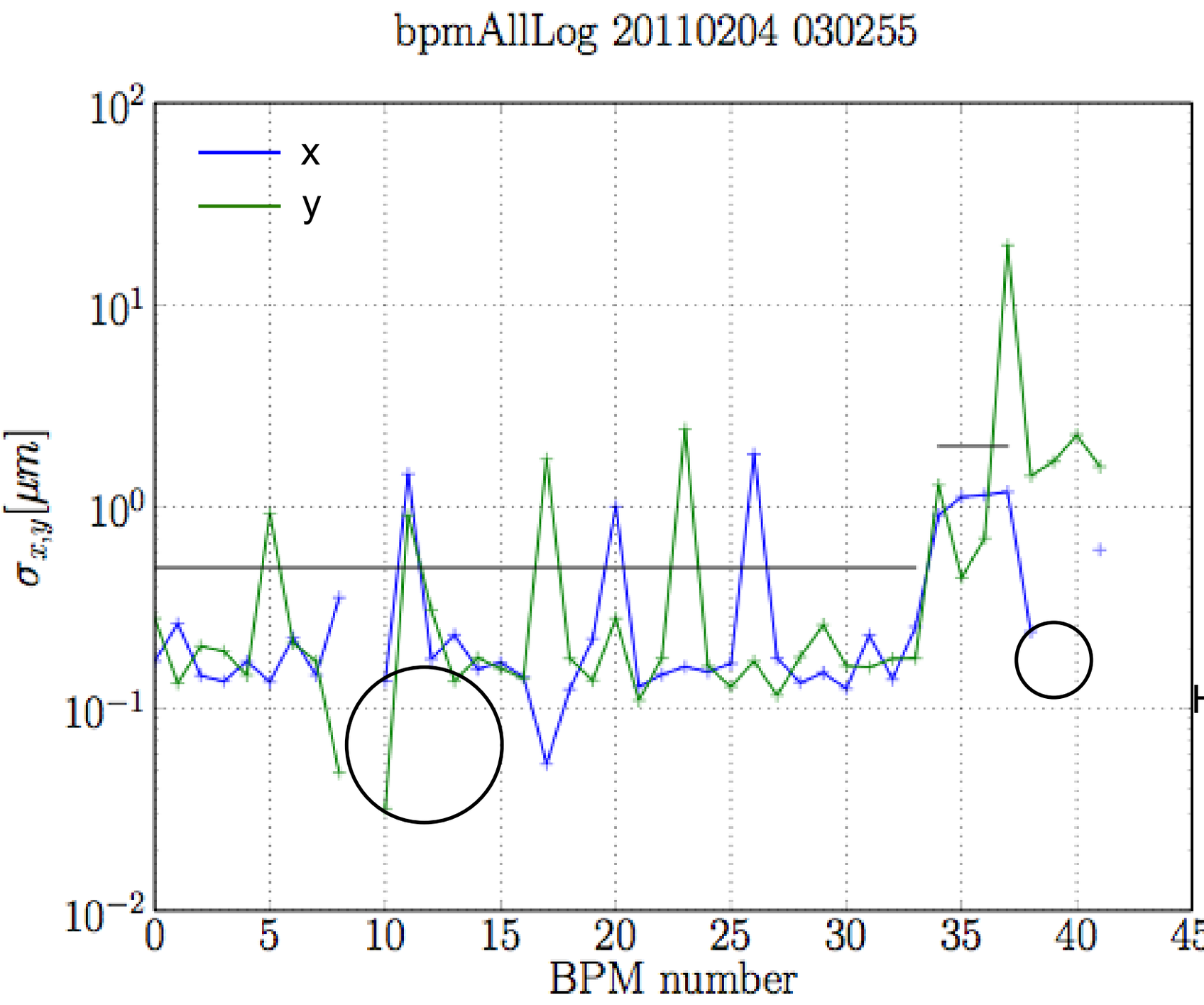


- ATF beam jitter 20% of beam size
  - ~ 10s micron
- Use PCA/MIA/SVD to determine position correlation between BPMs, based on 500 pulses

BPM Resolution (2011-02-02)



BPM Resolution (2011-02-04)

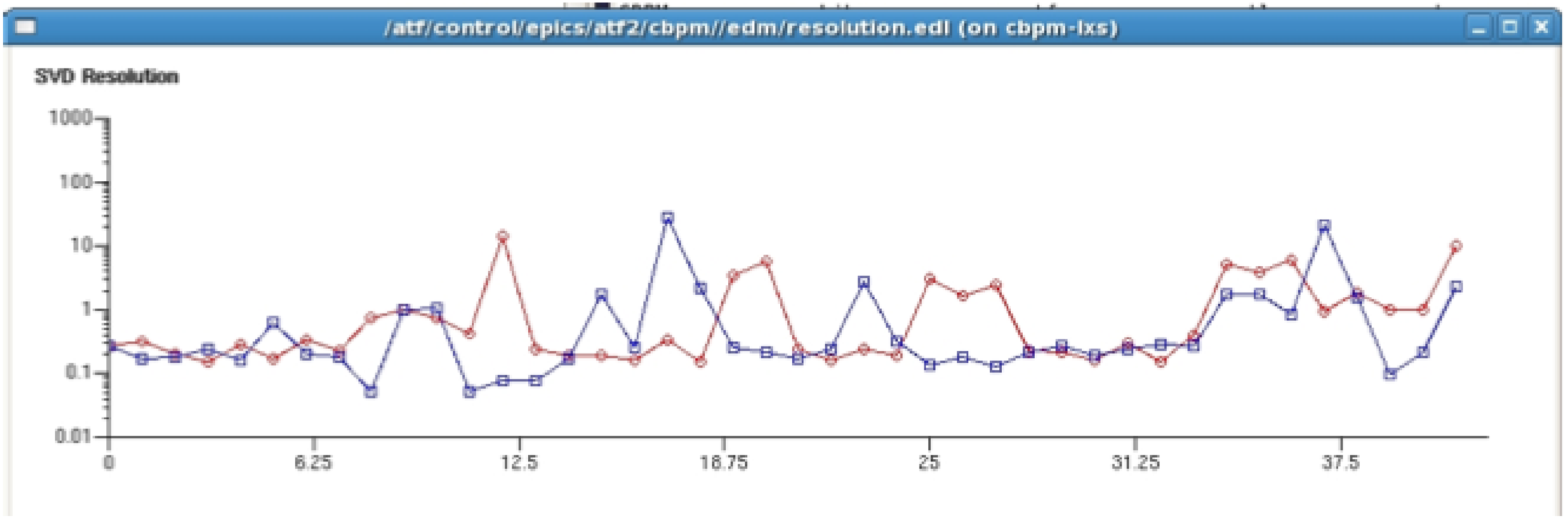


Pattern similar days later but some degradation of high resolution BPMs

High resolution BPMs were where the circles are

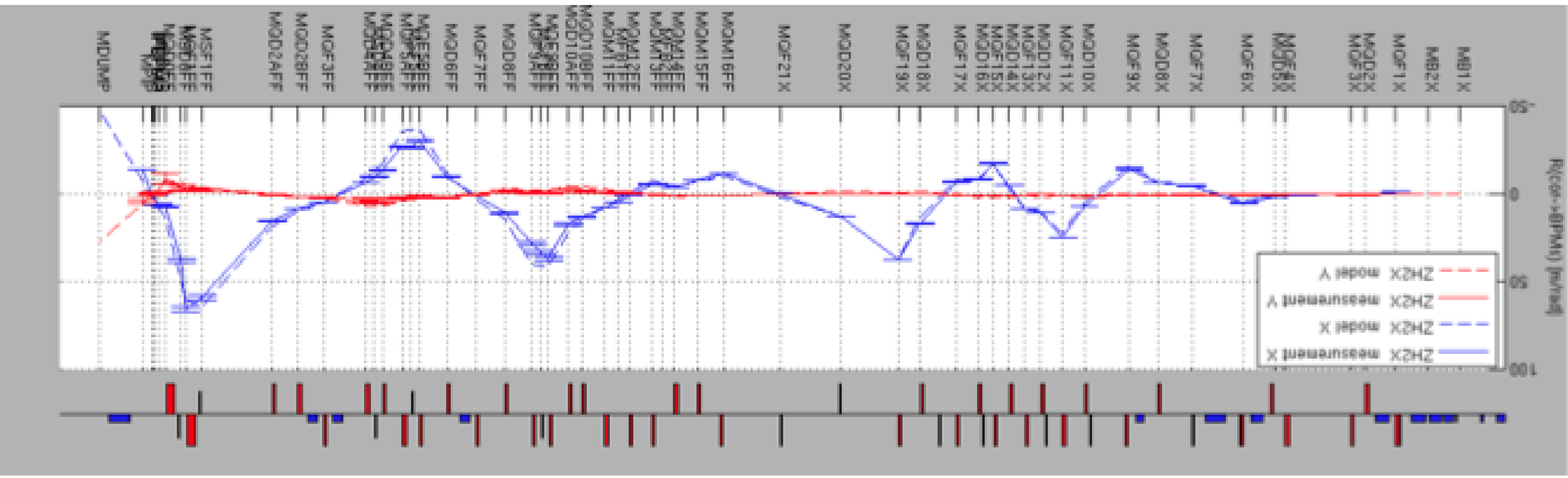
Online resolution

- Cavity BPMs in test accelerator is complex
  - Saturation, alignment (resolution beam position dependent)
- Online analysis complete
  - Resolution, beam jitter, calibration
  - Cavity BPMs are non-constant resolution devices



Beam optics verification

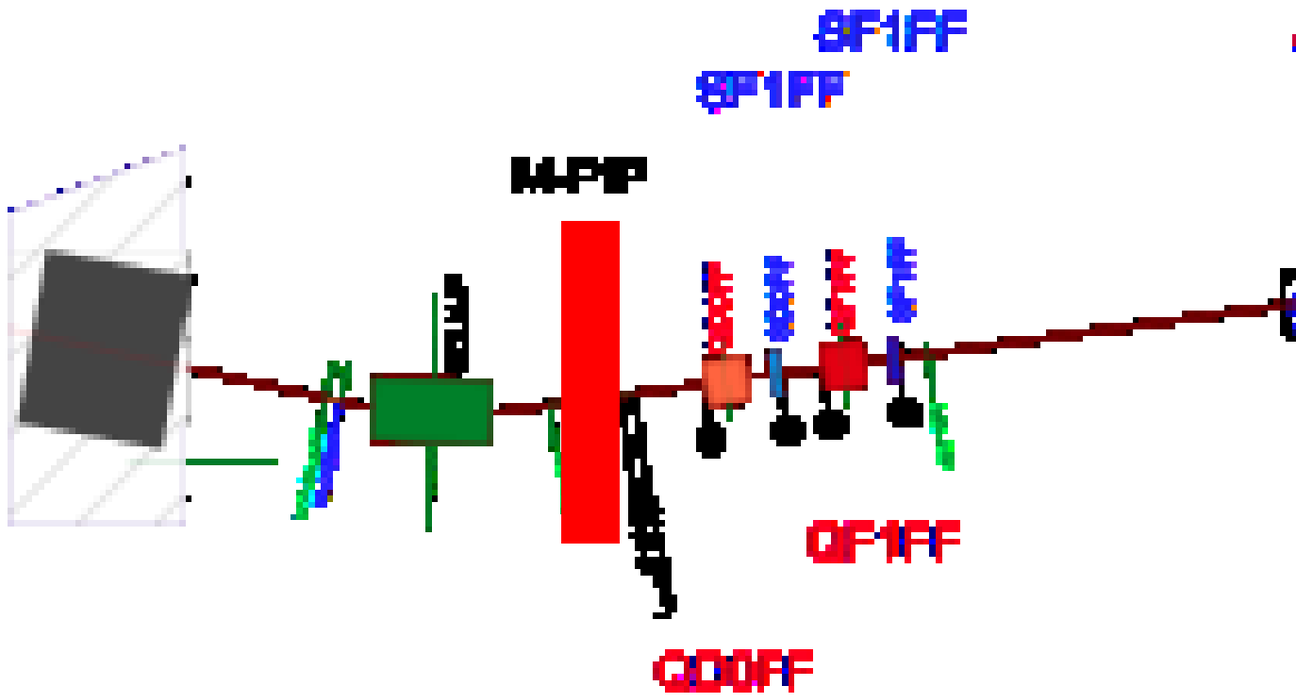
- Routinely use cavity BPM system of optics verification, beam based alignment, jitter studies.
  - Use single upstream corrector and compare model prediction (Lucretia) vs BPM response
  - Complex lattice reproduced faithfully (including coupling)

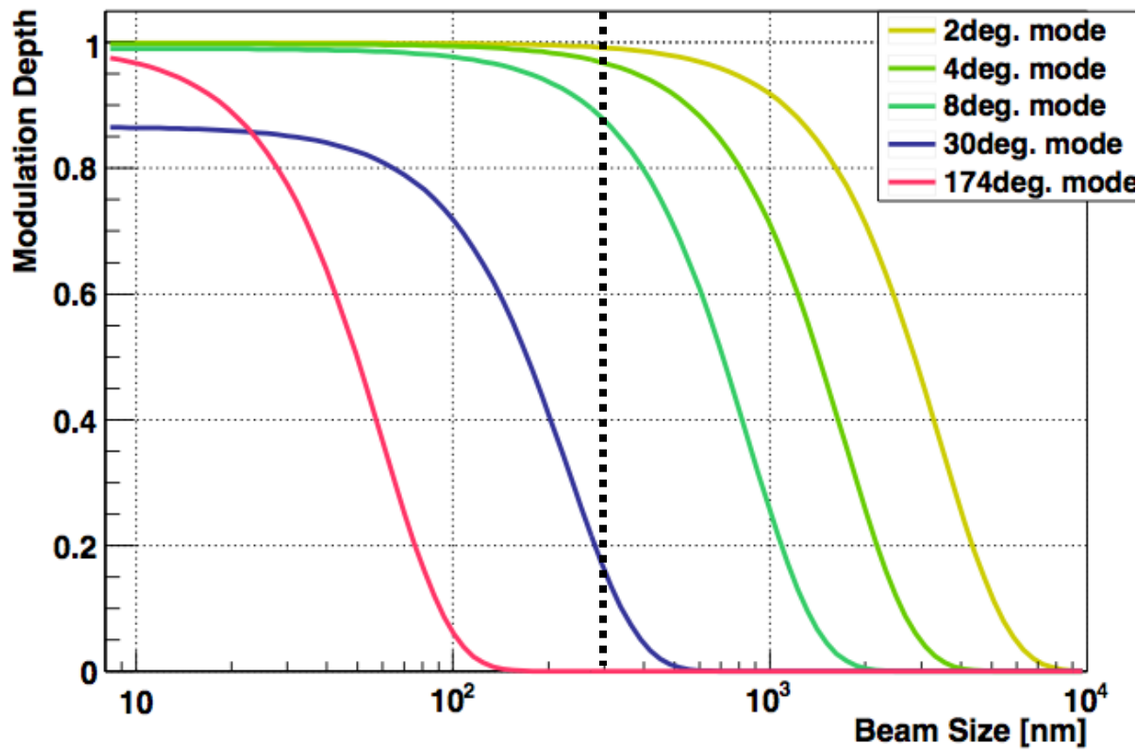


Interaction point beam size (IPBPM)

U. of Tokyo

- Laser interference system
  - 5 different laser beam angular separations
  - Observe modulation of Compton rate
- Problems...
  - Backgrounds in detector
  - Mode switching
  - Laser power/timing ... (ok always an issue)





IPBSM : 2-8 degree mode

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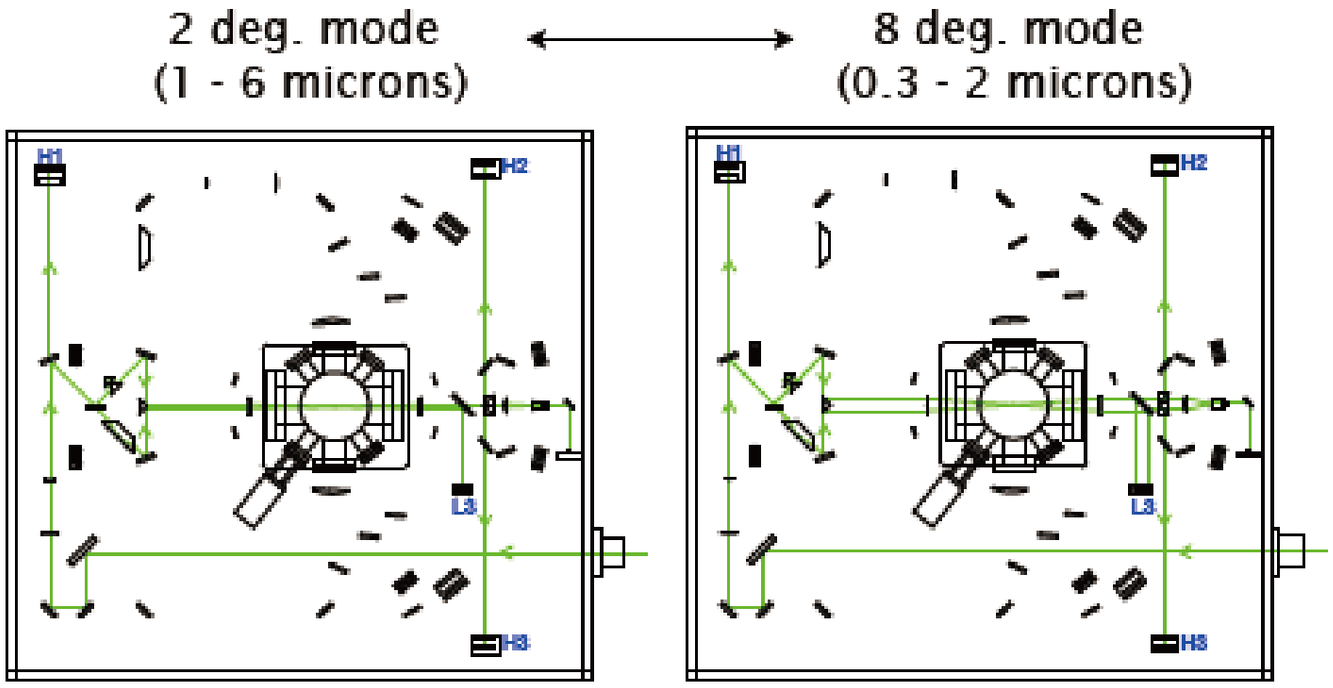
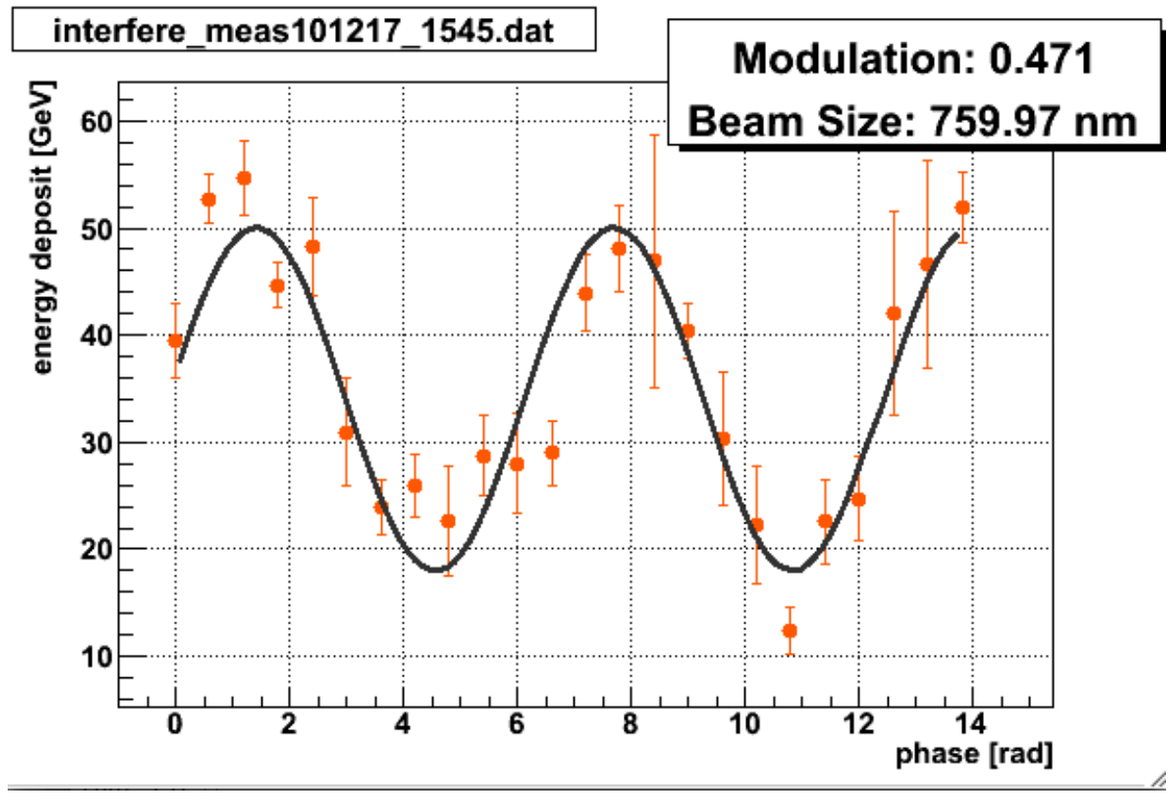


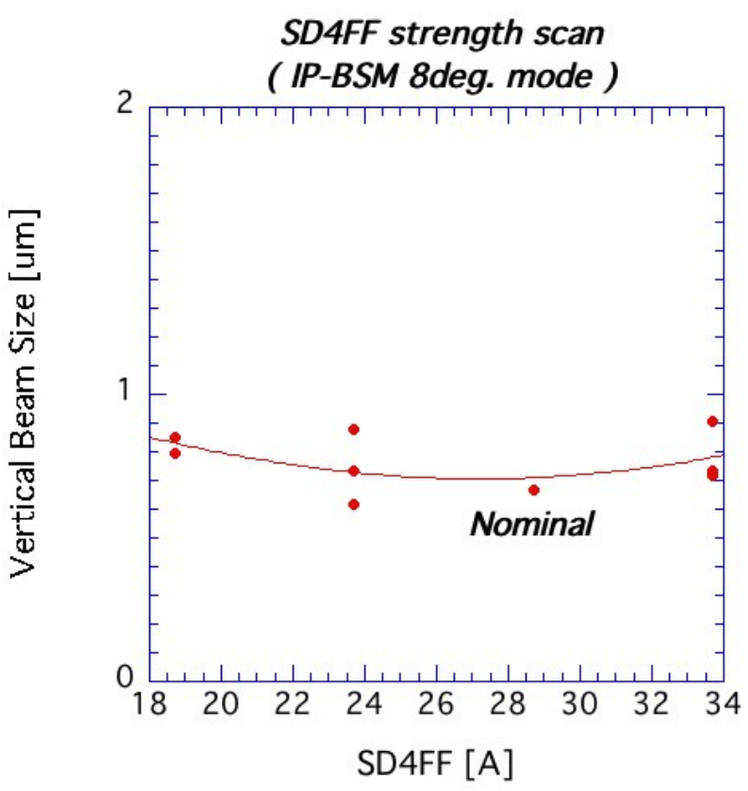


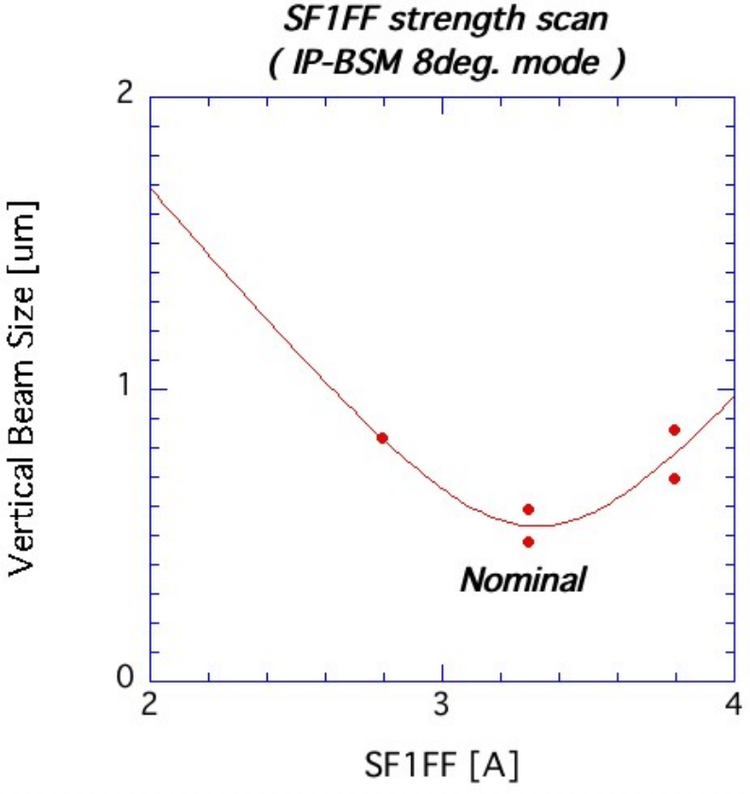
- Compton signal modulation clearly observed
- Multi-knob scans conducted
- Optimise vertical beam size down to ~300-400 nm

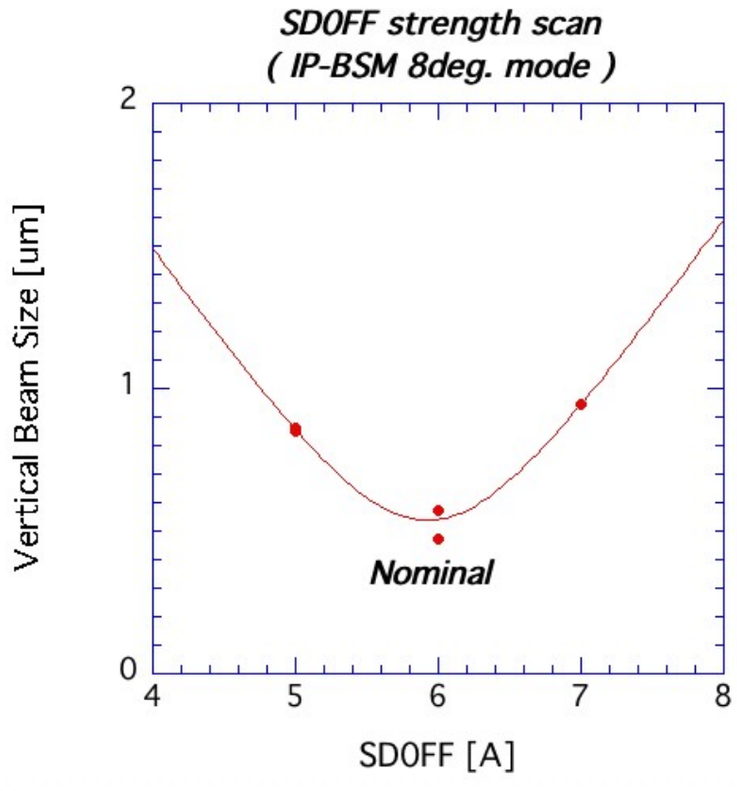
Optics scans with IPBSM

KEK

- Sextupole strength scans, to check the chromaticity correction
- SD4FF, SF1FF, SD0FF
- Minimum measured ~300 nm





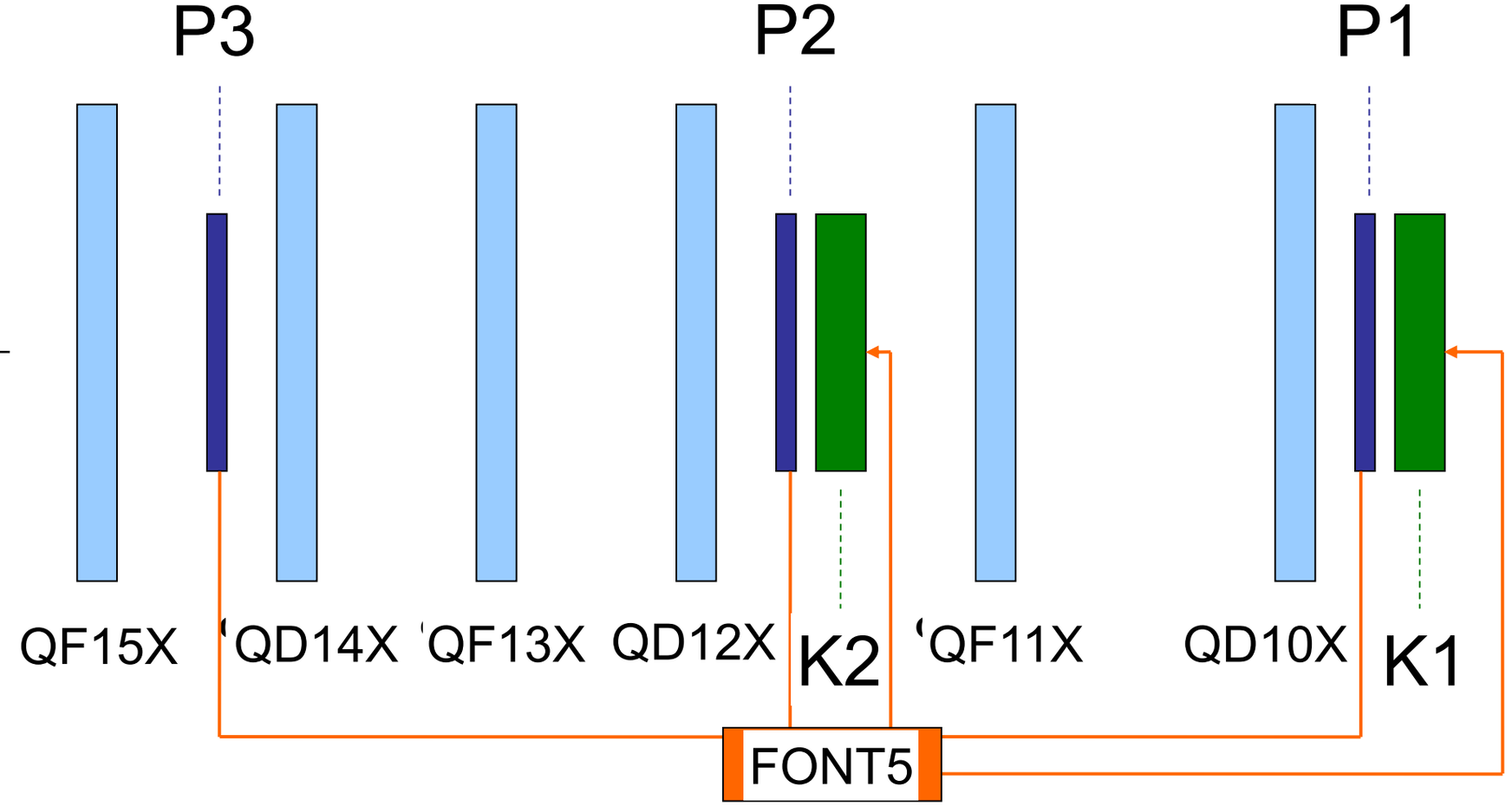


FONT

Oxford JAI

3 bunches, with 150 ns separation

P1,2,3 Strip line BPMs
K1,2 Strip line kickers

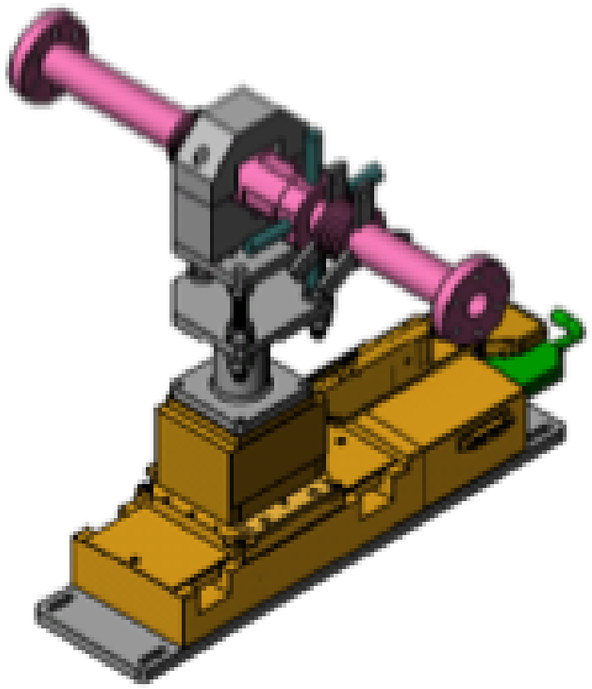


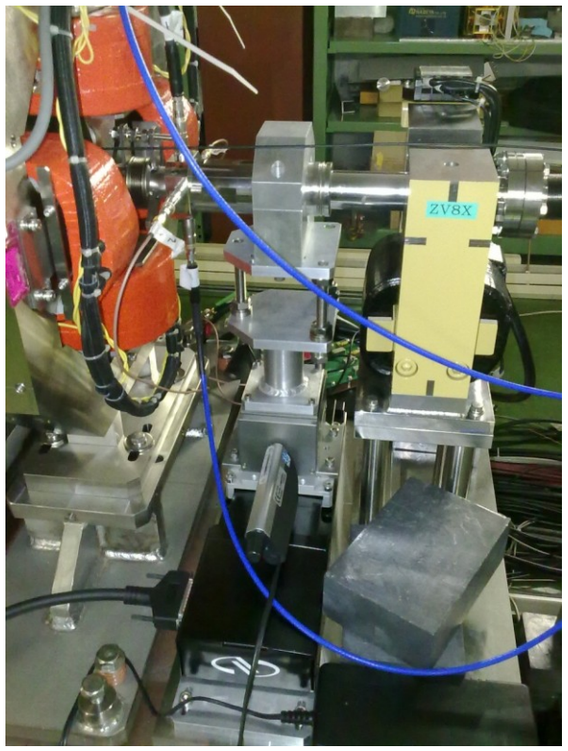
P2 → K1 (‘position’)
P3 → K2 (‘angle’)
P3 → K1
P2 → K2

FONT summary

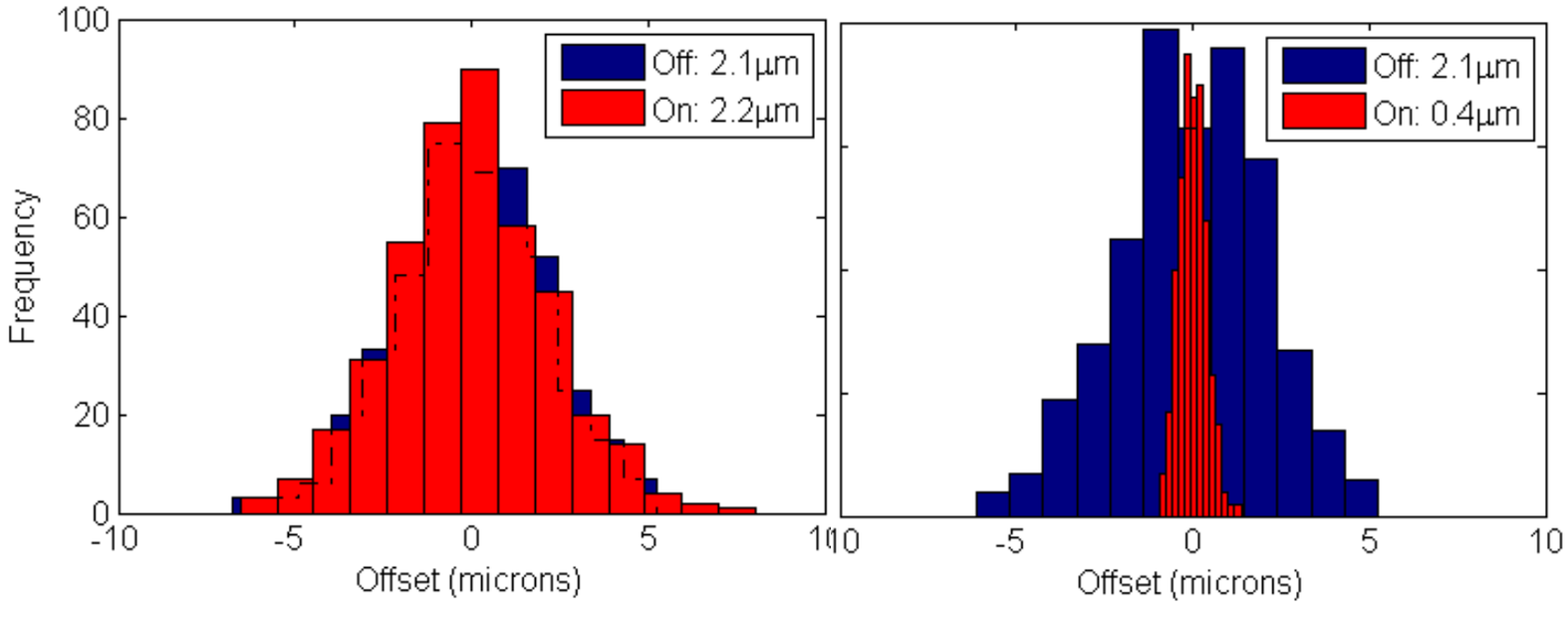
Oxford JAI

- Improvements to FONT5 board
- Latency 44 ns (irreducible)
- Electronics 87 ns
- BPM mover calibration
- Investigation of bunch to bunch correlations





Bunch 1 **Bunch 2**

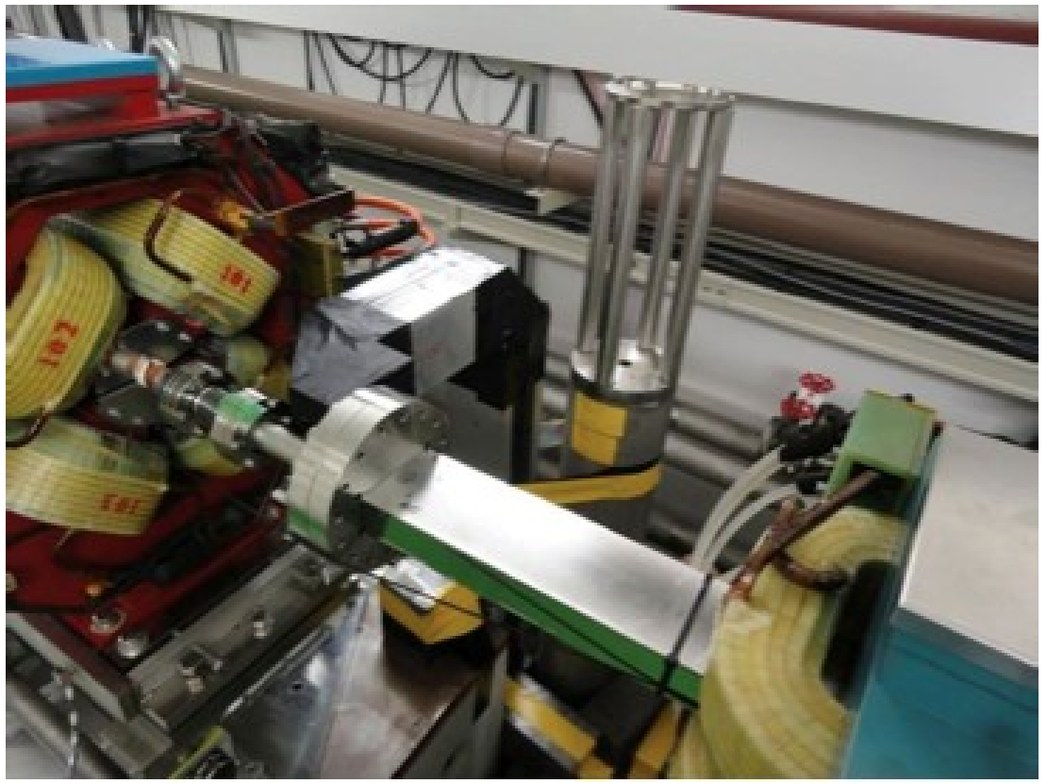


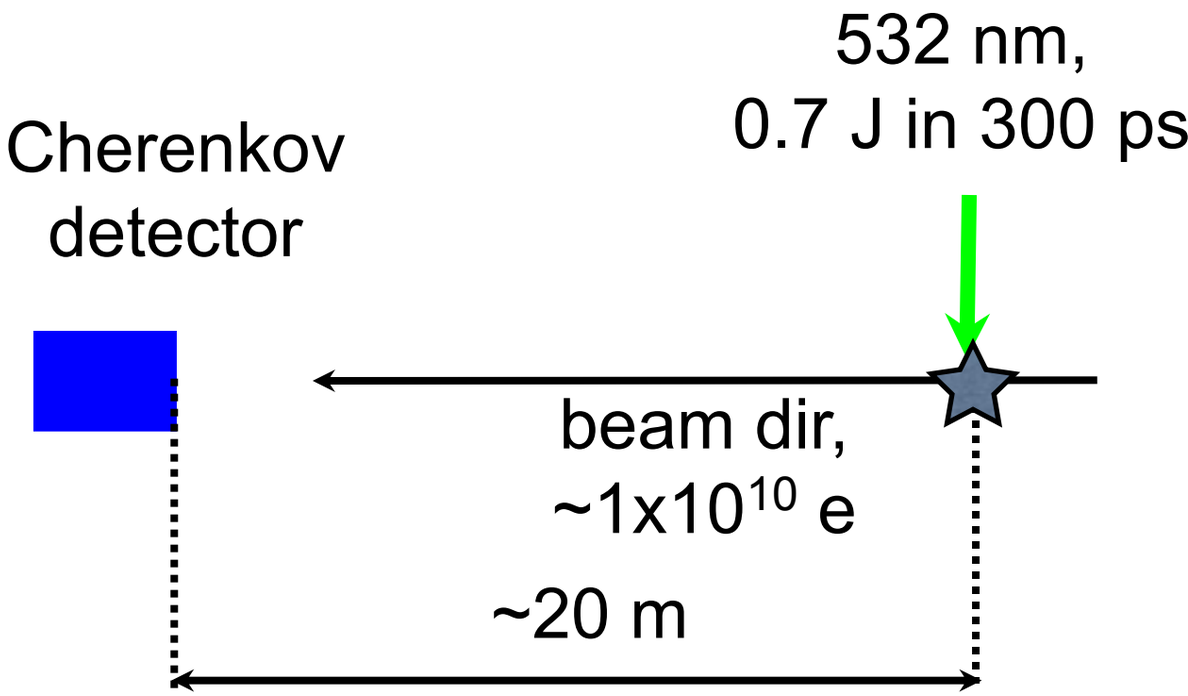
2.1um → 0.4 um

Laser-wire

John Adams (RHUL/Oxford)

- Aim to reach 1 um beam size measurement
  - 4 um already published
- EuCARD plan
  - Integrate with optics modelling and BPMs
- Need to extract Compton photon signal over 20 m at 1.56 Hz
  - Small exit window in special flange



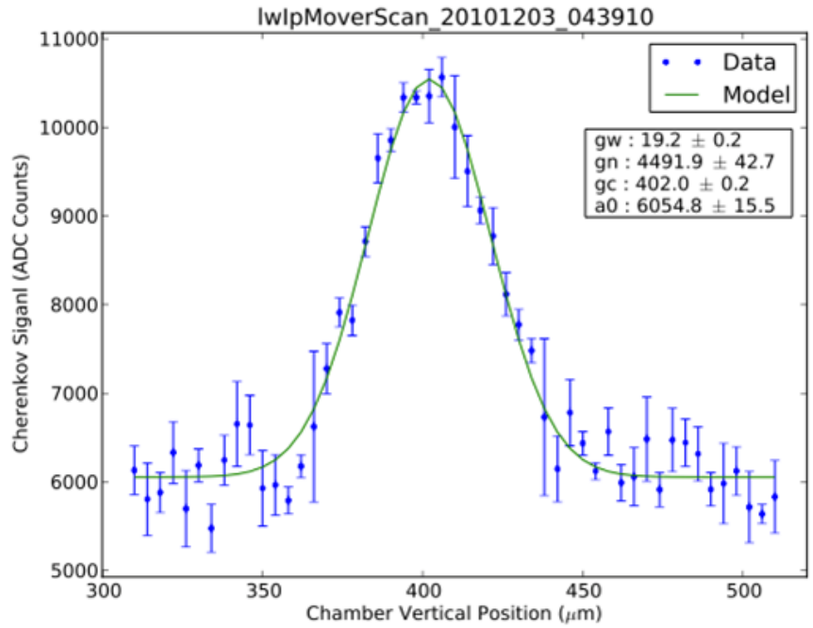


Laser-wire

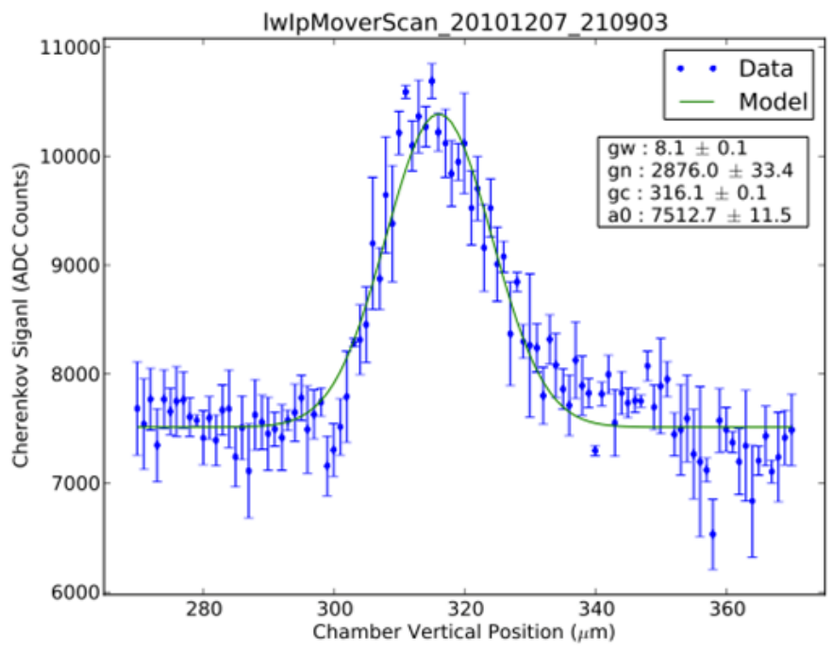
John Adams (RHUL/Oxford)

- Difficult commissioning due to ~25m Compton transport
- Fixed using alignment laser and 2 wire scanners in drift around LWIP
- Best results thus far ~8 micron
- Synchronised with cavity BPM system

$19.2 \pm 0.2 \mu m$



$8.1 \pm 0.1 \mu m$



Summary

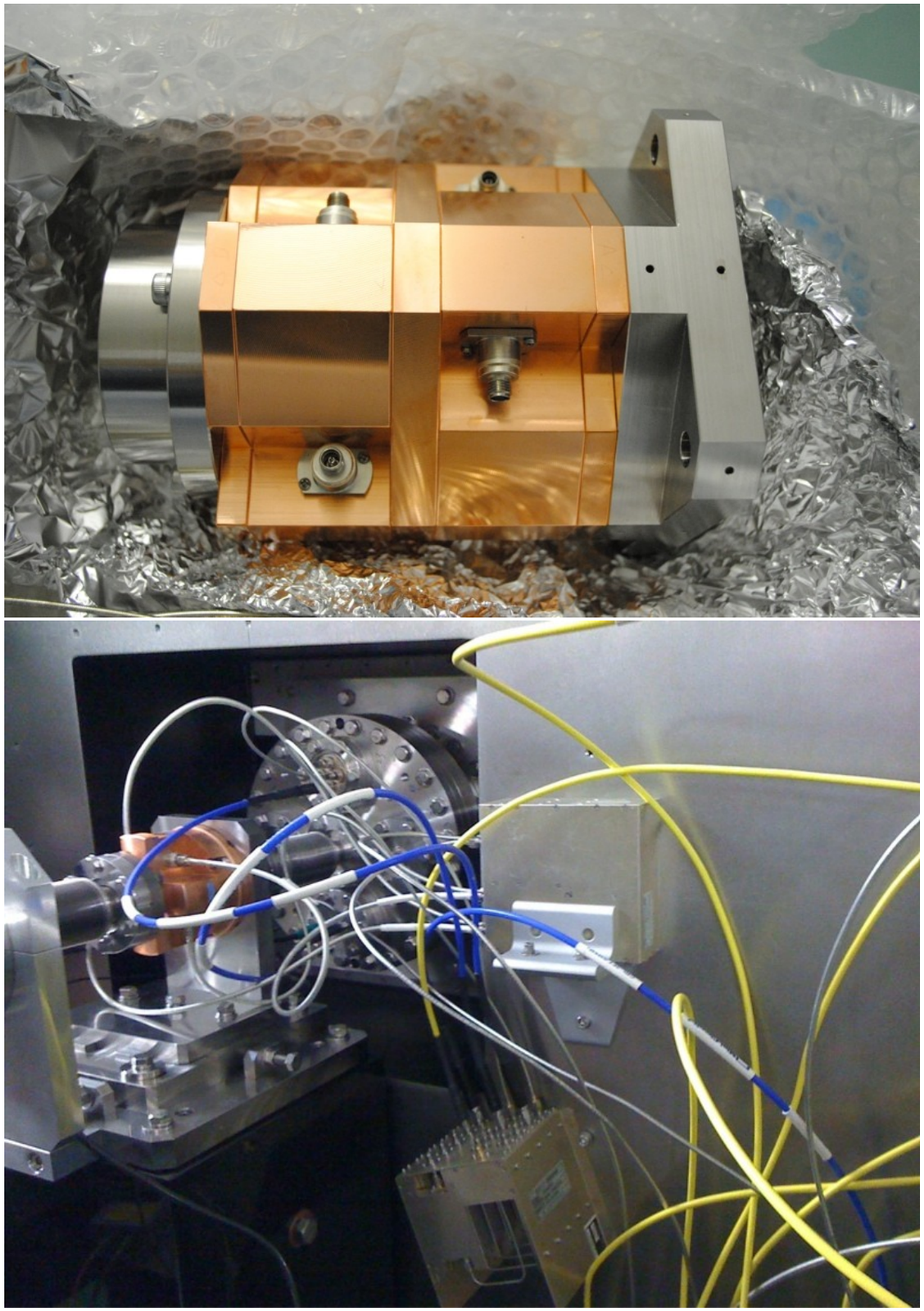
- Cavity BPM system performing well resolution 200 (20 dB) and 50 (no attenuators) nm
  - Typical numbers reproducible over weeks
- Best resolution recorded 27 nm (high charge and well aligned)
- Re-commissioned laser-wire system, aim to reach 1 micrometer will use BPM data to constrain laser-electron collision
- IPBSM used by tuning operators but problems using 30 degree mode to tune beam down to goal
- Other diagnostics development proceeding well (not discussed in this talk)
- Difficult times for ATF/ATF2 firstly because of a modulator fire and more importantly the recent earthquake. Try to restart some beam operation this month.

Back up slides

- High resolution IPBPMs
- More information of IPBSM
- Emittance measurement
- IPBPM Performance
- Tuning

IP region BPM installation

T. Smith/YI Kim/Y Honda

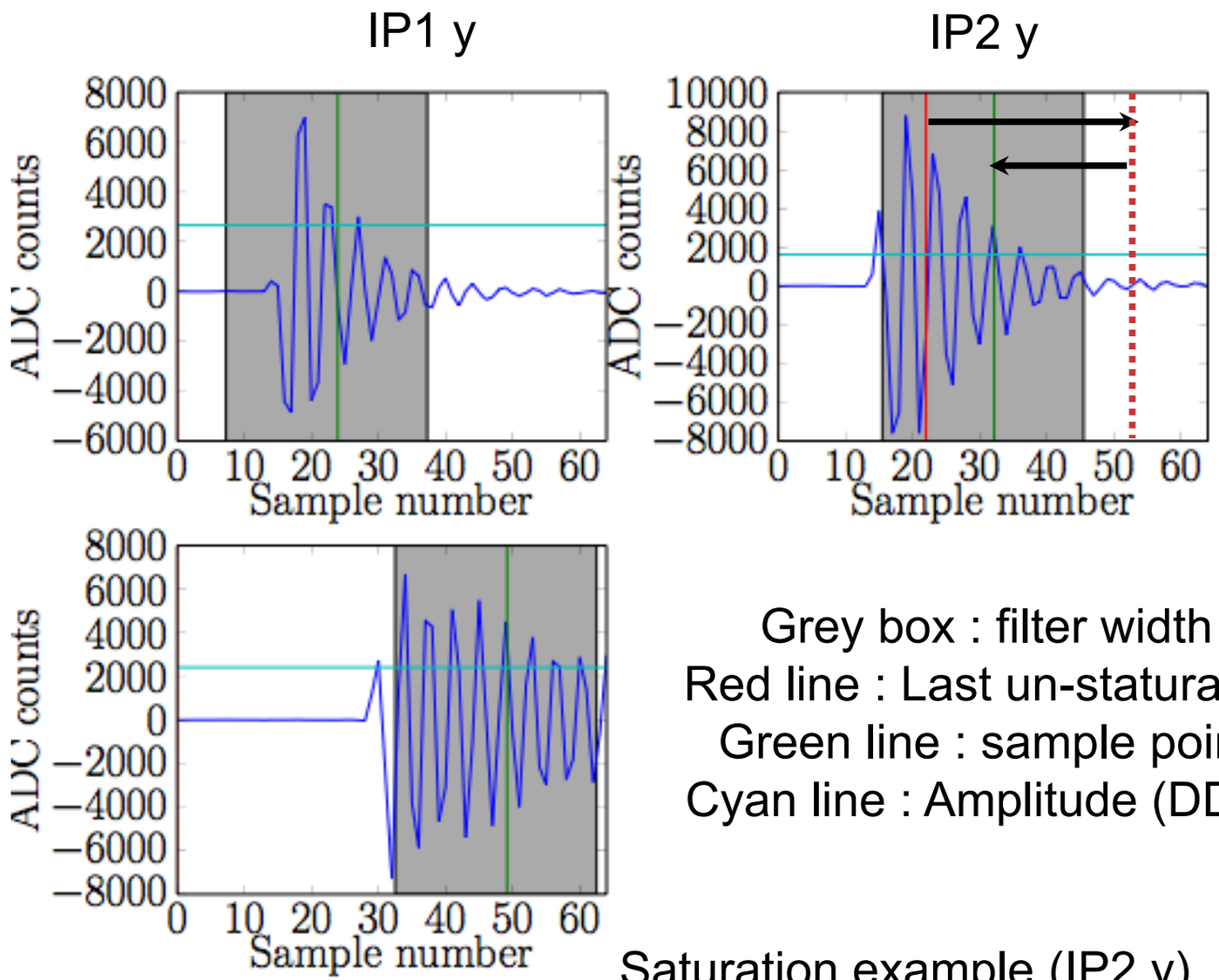


- Honda-san installed
  - 2 BPM, IPBPM block
- T. Smith installed
  - Mixdown electronics
  - 5.7 GHz source for x
- New SLAC 16 bit, 120 MHz digiziters
  - Excellent linearity
  - Low noise

IPBPM waveform processing

Boogert/Lyapin/Kim/Cullinan

- Filter width of 0.03, so 33 samples
- IPBPM decay time ~10 samples
- Increase filter to 0.1 and recalibrate
- More important with saturation (see IP2 y)



Reference

Grey box : filter width
Red line : Last un-staturated
Green line : sample point
Cyan line : Amplitude (DDC)

Saturation example (IP2 y). Nominal sample point (green) disturbed by saturation so sample at new point 1/BW later (red-dashed) extrapolate back (green)

Emittance measurement

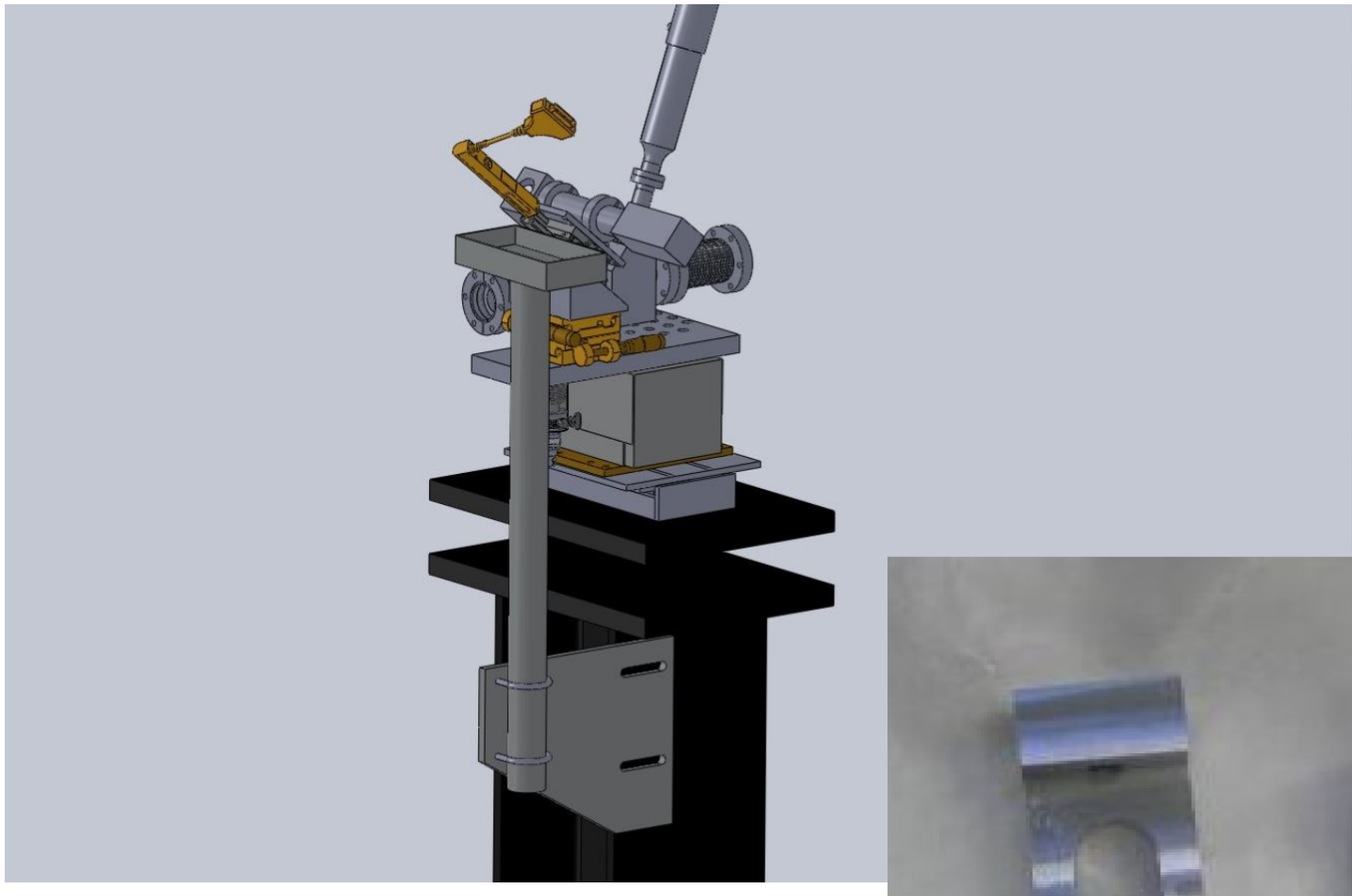
SLAC/IFIC

- Wire scanners
  - From old ATF extraction line
  - Relatively slow and projected measurement (coupling etc)
- Installed new multi OTR system (SLAC/IFIC)
  - Fast measurement
  - Can extract full emittance and coupling in few minutes

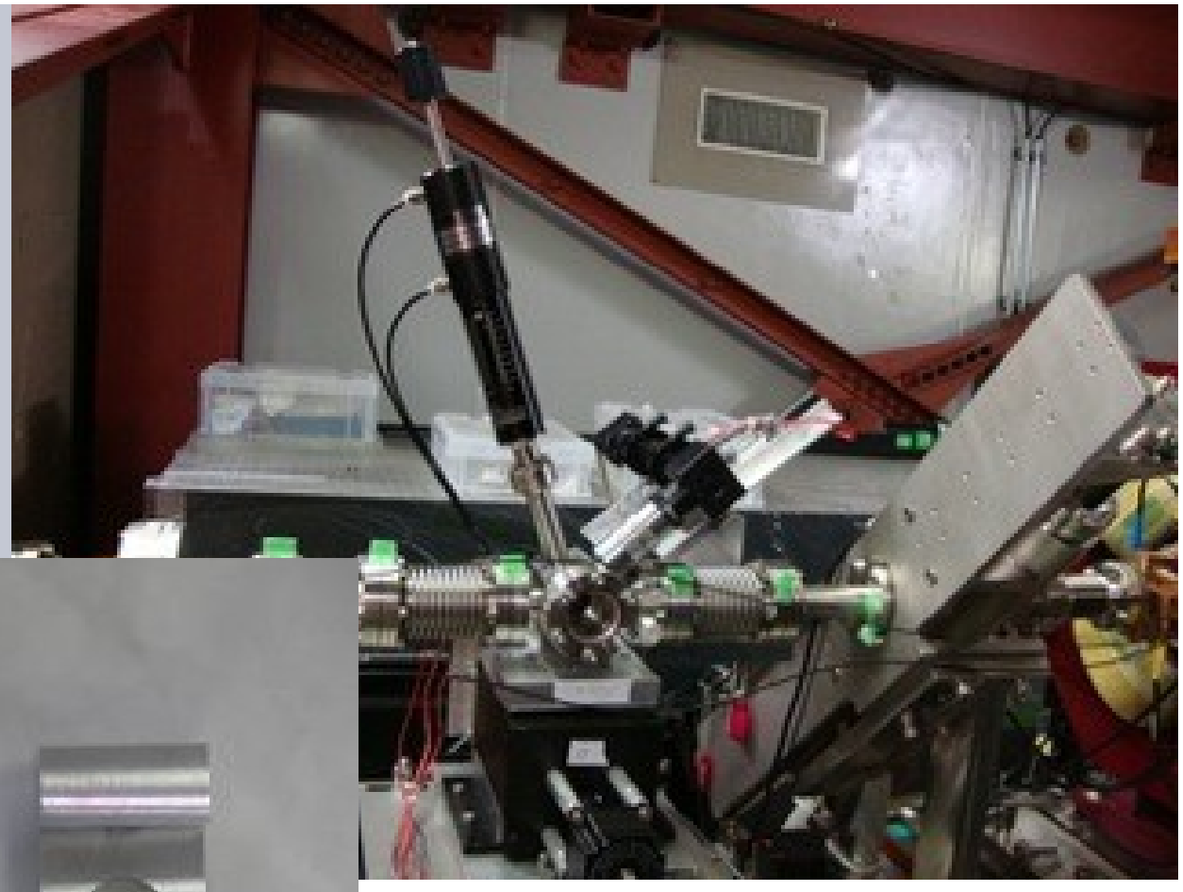
OTR station

SLAC/IFIC

Mechanical design



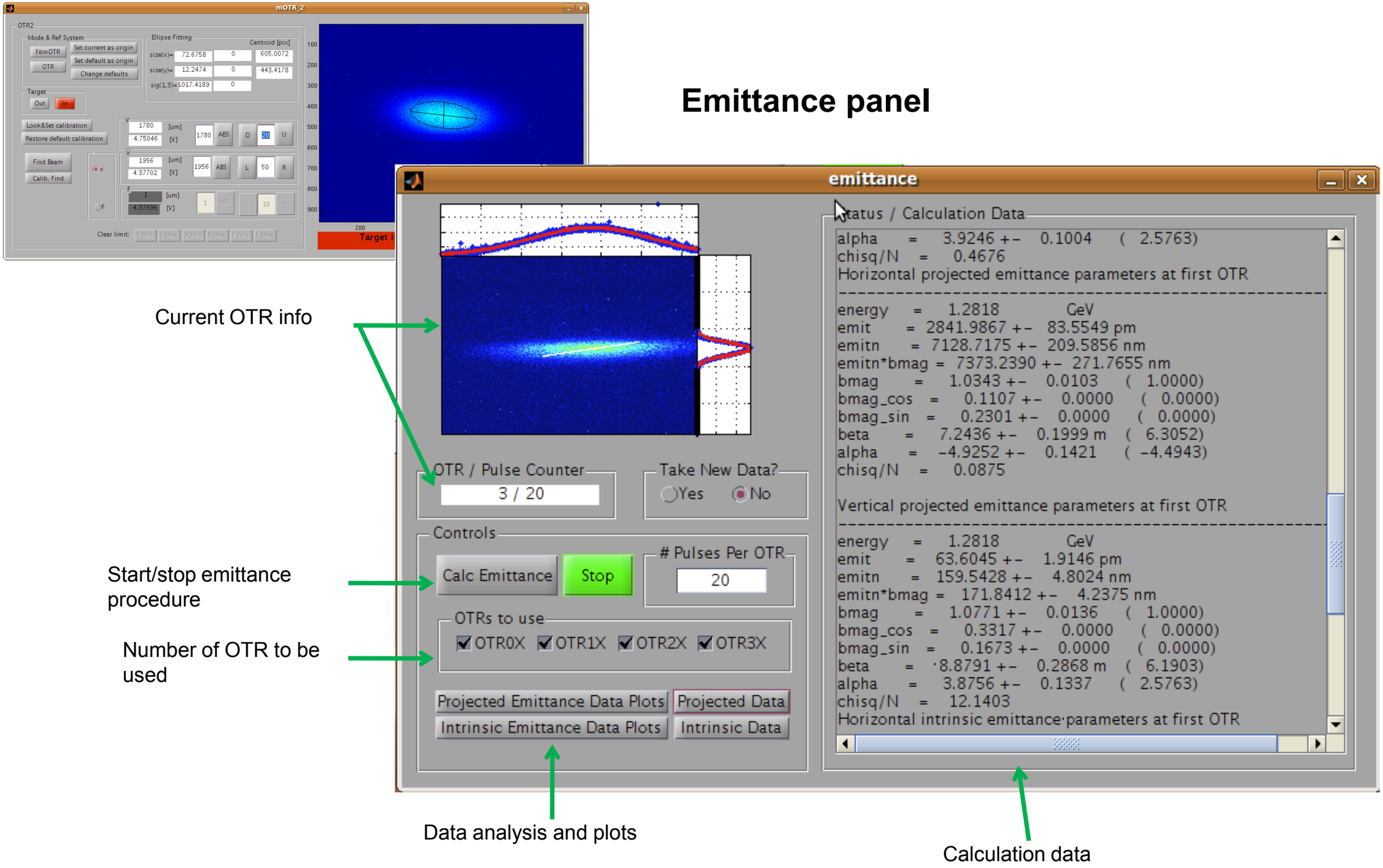
Installed on beam-line



New targets

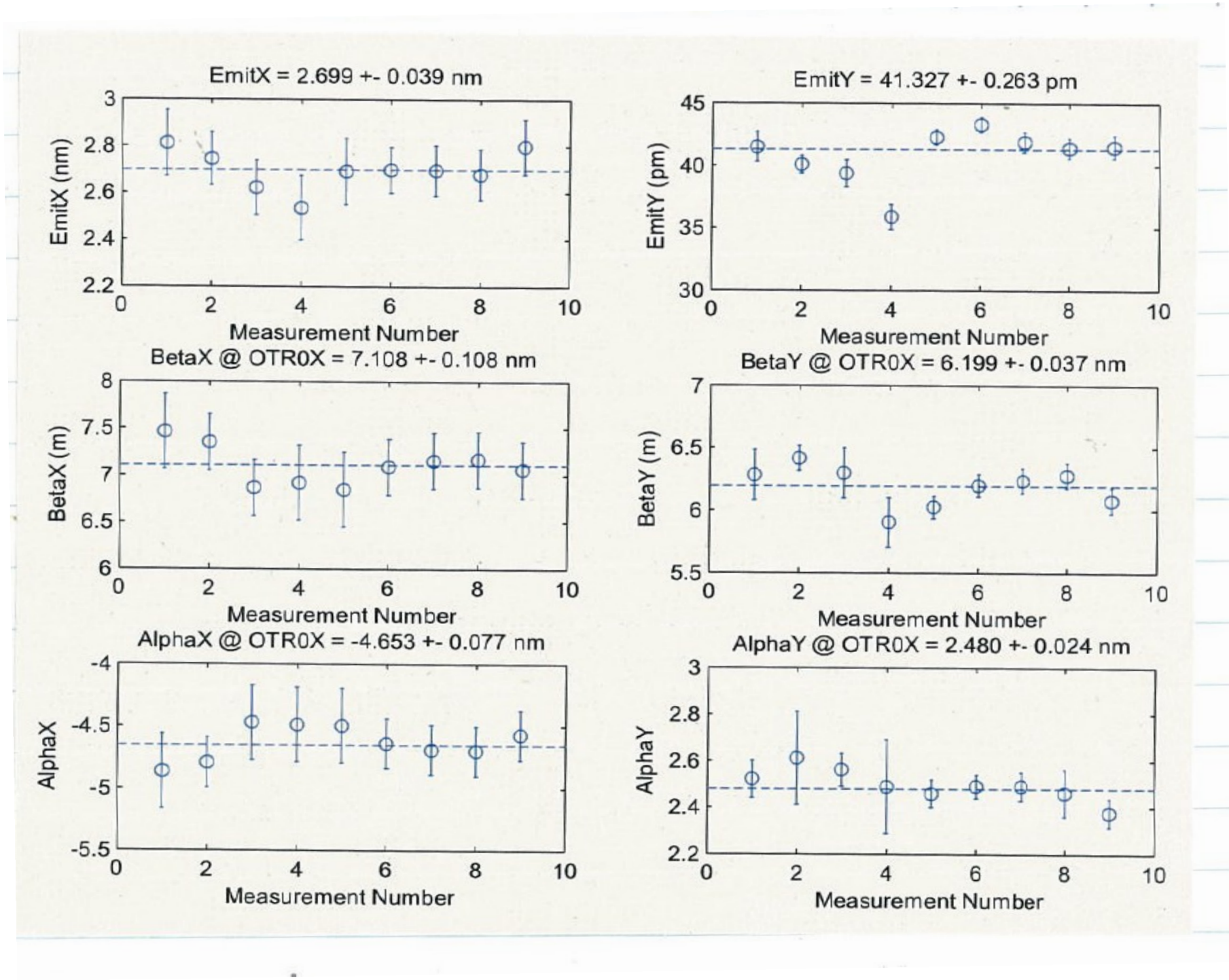
Beam measurement

SLAC/IFIC



Emittance measurement stability

G. White



30 degree mode

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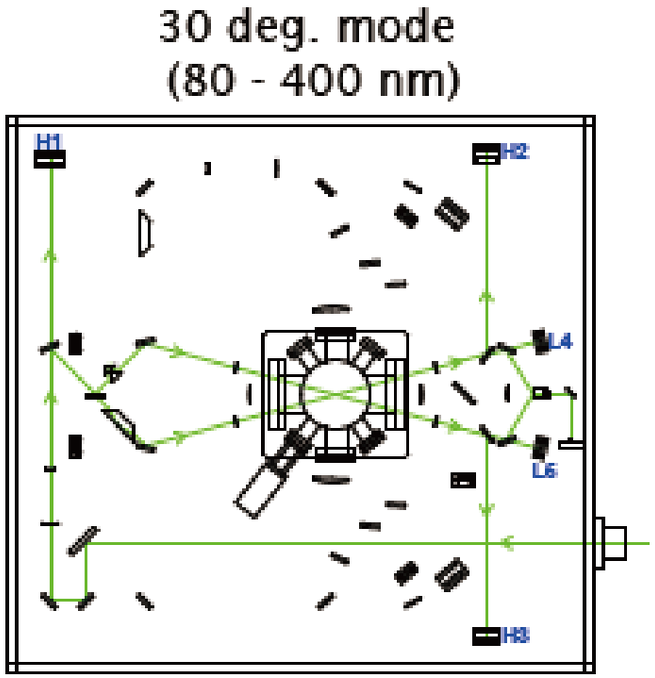

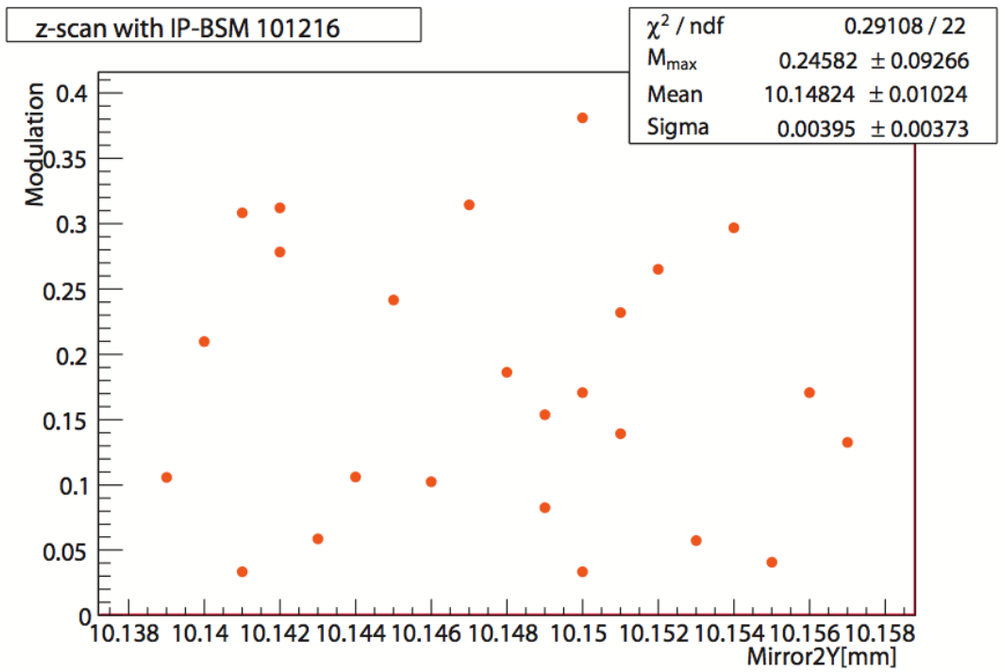

- Signal not observed in 30 degree mode
  - Backgrounds, other drifts
  - Collision geometry
  - Beam size itself