RHUL instrumentation and Simulation

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John Adams Institute at Royal Holloway
(on behalf of : G. Blair, A. Bosco, G. Boorman, A. Lyapin)

Friday 18-19th May 2011
SuperB Mini-workshop
Jesus College, Oxford, UK

Talk introduction

- RHUL diagnostics capability cover most requirements of lepton machines
  - Beam position monitors (cavity, strip-line, button), electronics (RF & digital) and processing (digital algorithms and controls)
  - Emittance measurement (laser-wires, OTR screens, ODR)
  - Bunch length (Coherent diffraction radiation CDR)
- Simulation
  - Mixed accelerator and particle physics (background and IR region) using BDSIM
  - Lattice design and optimisation (standard and in-house codes)
  - Electromagnetic (Gdfidl @ RHUL farm, SLAC ACD codes @ NERSC)

ATF2 facility

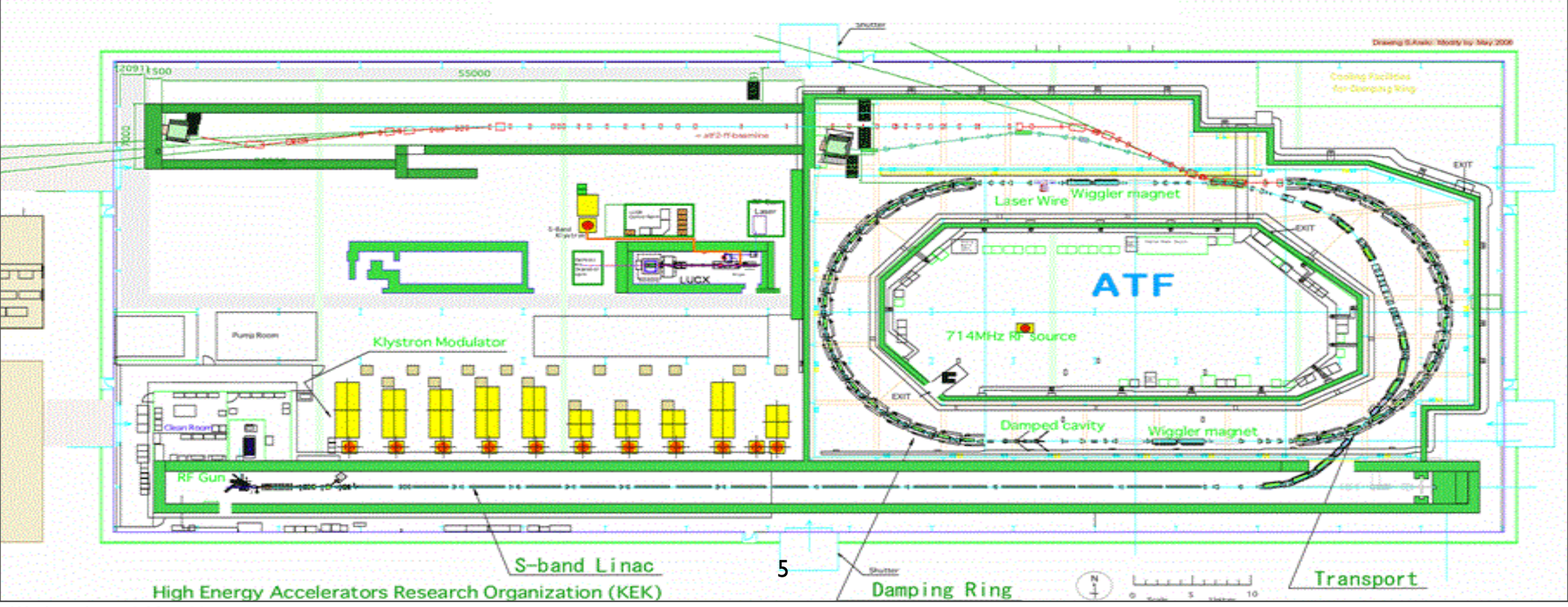
- ILC/CLIC test facility
  - Large number of installed advanced diagnostics
  - ATF damping ring (XSR size monitor, cavity laser-wire)
- ATF/ATF2 facility
  - Extension to the ATF damping ring
  - Main test facility for ILC/CLIC like beam delivery system
  - Goal 1 : Vertical beam size of 35 nm
  - Goal 2 : Stabilise beam vertically to few nm

Instrumentation at ATF2

- 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
- Straightness, alignment monitoring (Notre Dame/JAI@RHUL/KEK)

Accelerator Test Facility (ATF)

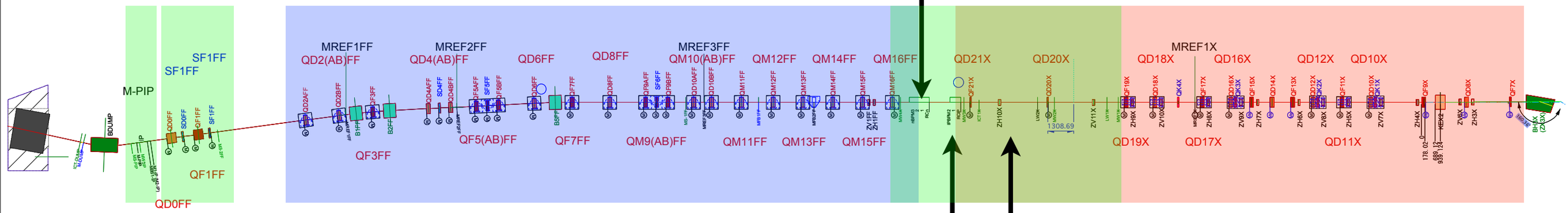
- Photo-injector gun
- S-band 1.28 GeV linac
- ~400 m length radiation ramping storage ring (X-ray and laser-wire emittance)
- Low emittance extraction and transport to ATF2



ATF2 Overview (instrumentation)

IP region
(4 BPMs, IPBSM)

BPM test area
(high-Q, low-Q, tilt)



S-band BPMs
(movers)

C-band BPMs (movers)

LW

WS/OTR

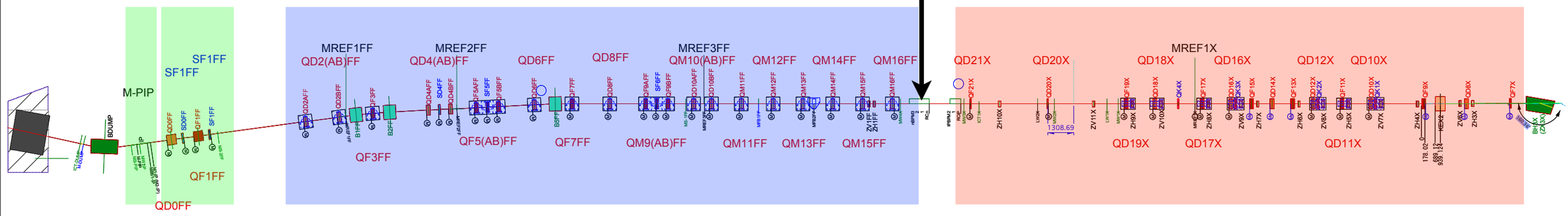
Strip line/Cavity BPMs
(rigid)

- 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

IP region
(4 BPMs)

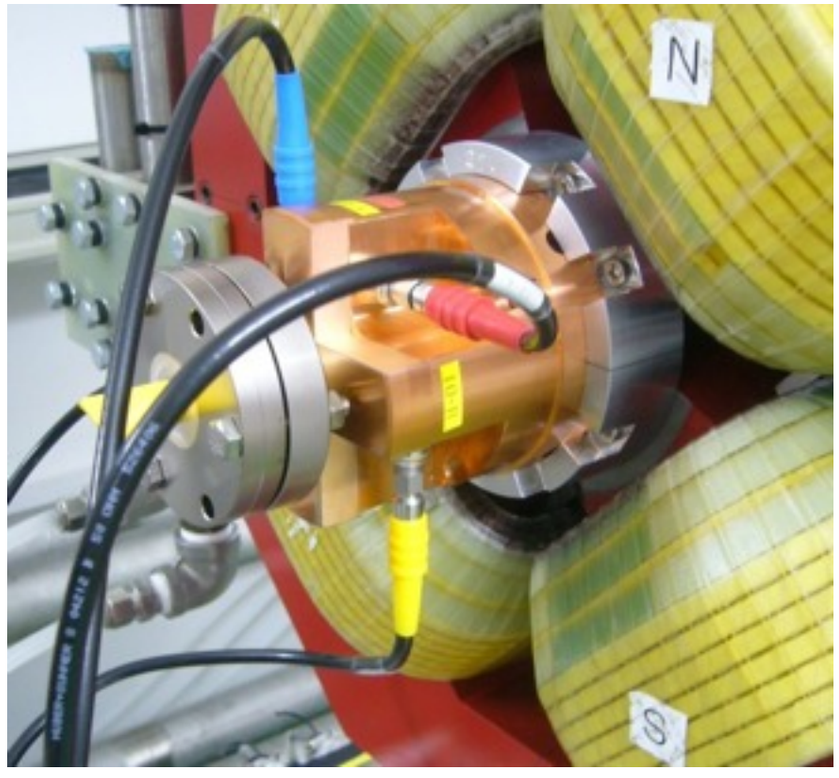
BPM test area
(high-Q, low-Q, tilt)



S-band BPMs
(movers)

C-band BPMs (movers)

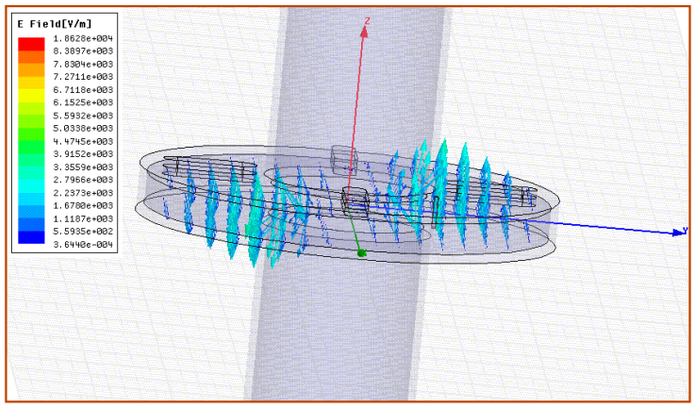
Strip line/Cavity BPMs
(rigid)



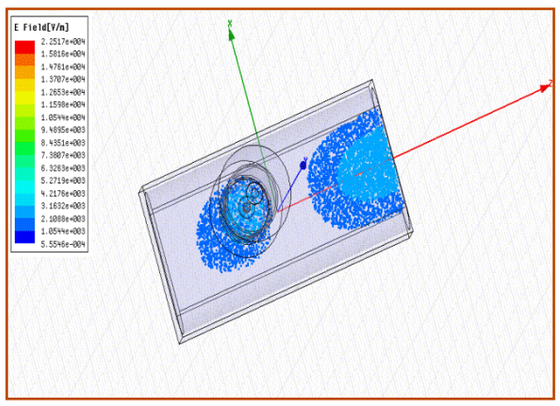
Cavity BPMs in one slide

S. Boogert & A. Lyapin

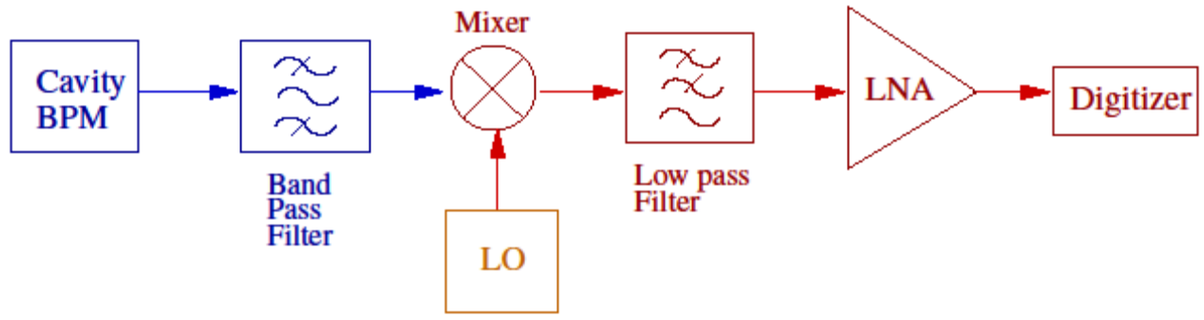
Dipole cavity, signal proportional to q*p



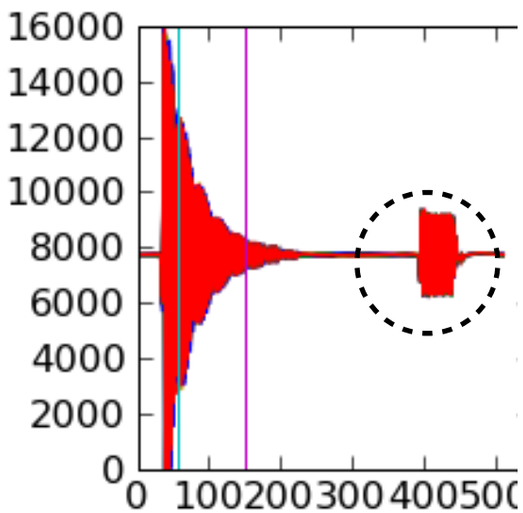
Dipole mode selective waveguide couplers



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

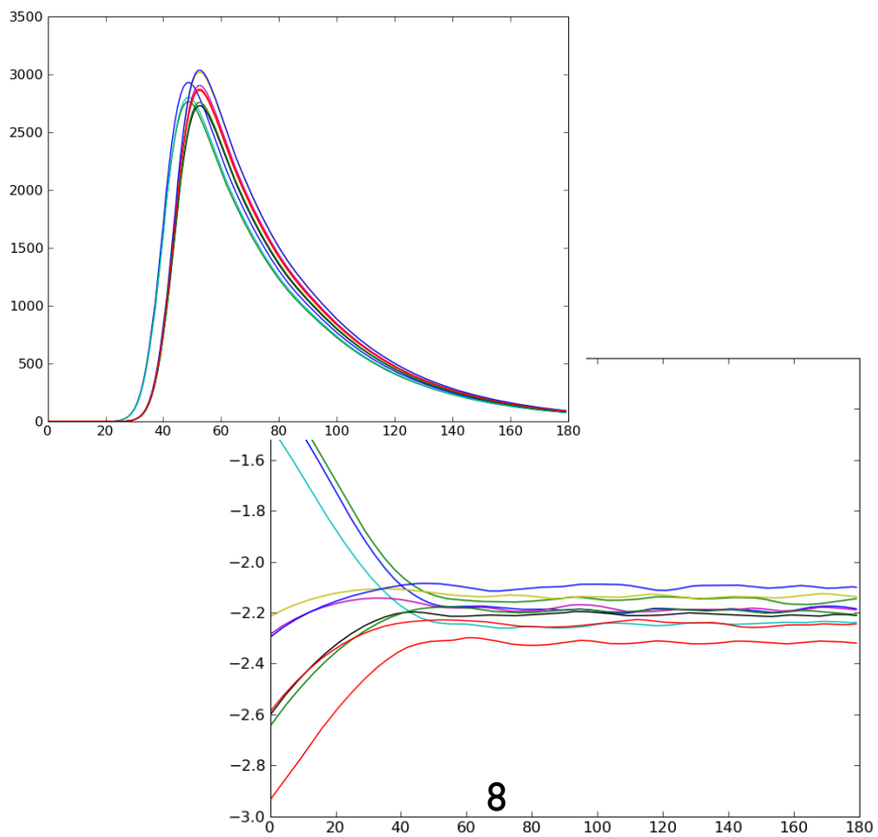


Digitised signal
Decaying exponential

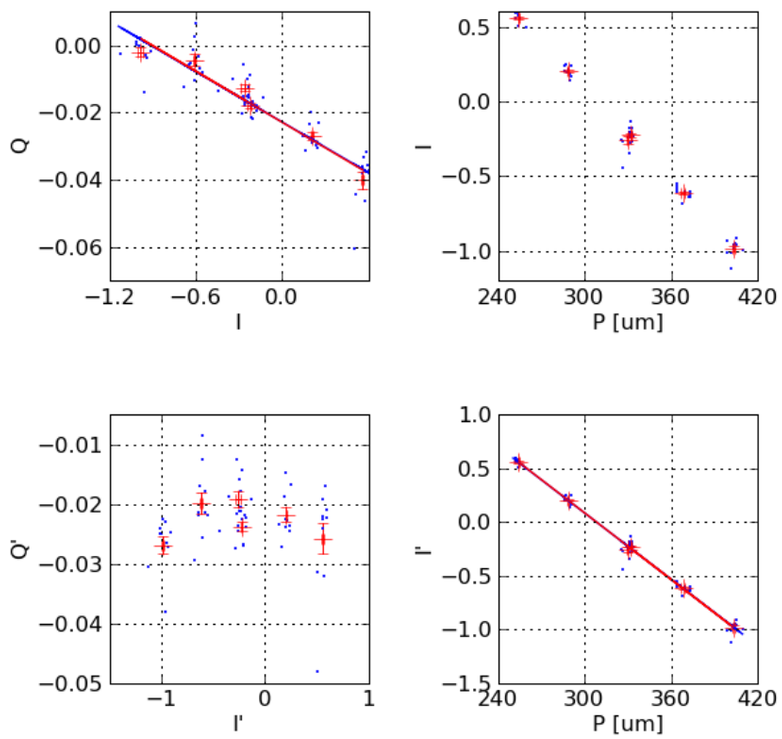


Calibration signal

Digitally mix to baseband

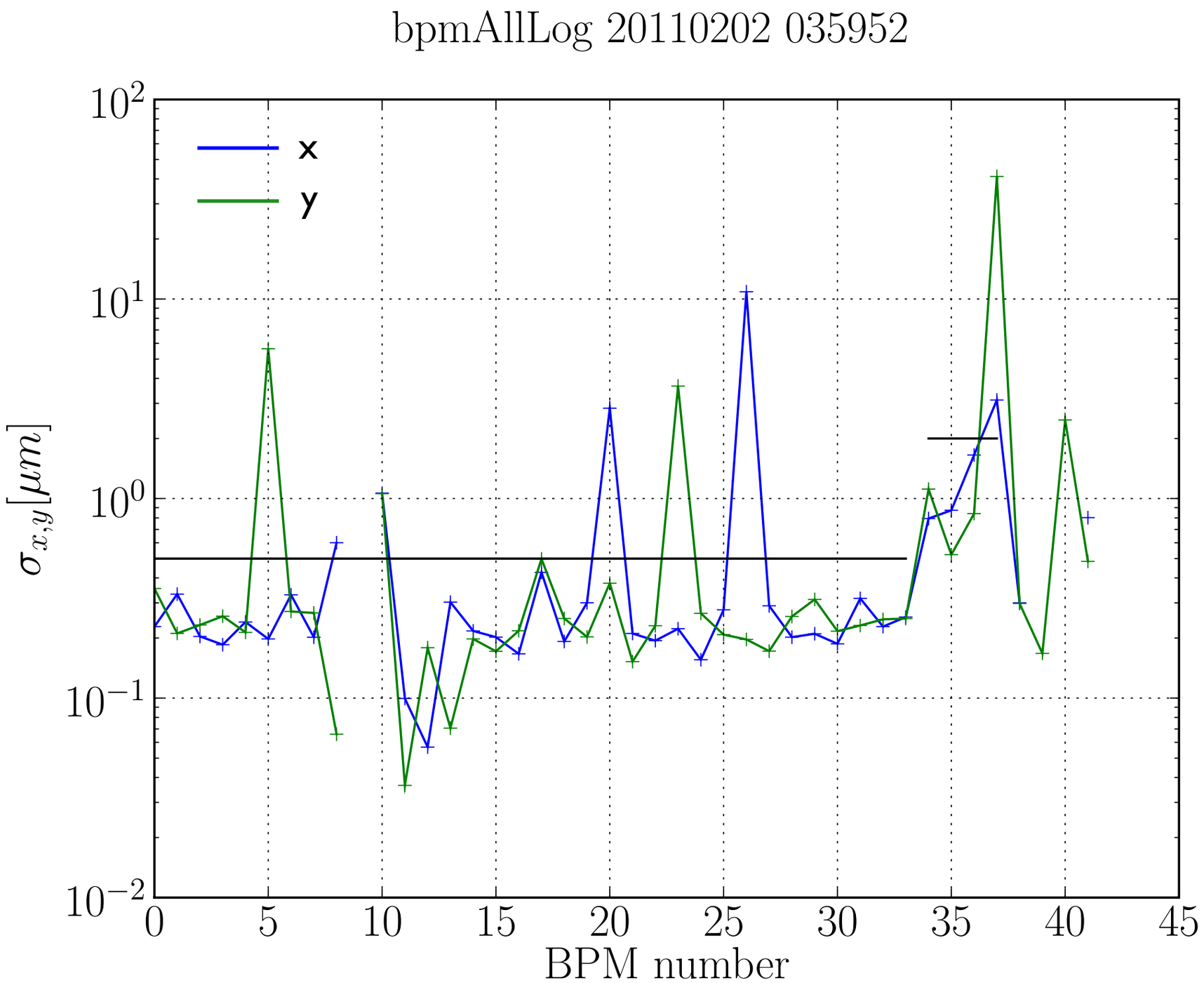


Calibration, move BPM (quad mover) or bump beam



BPM Resolution (2011-02-02)

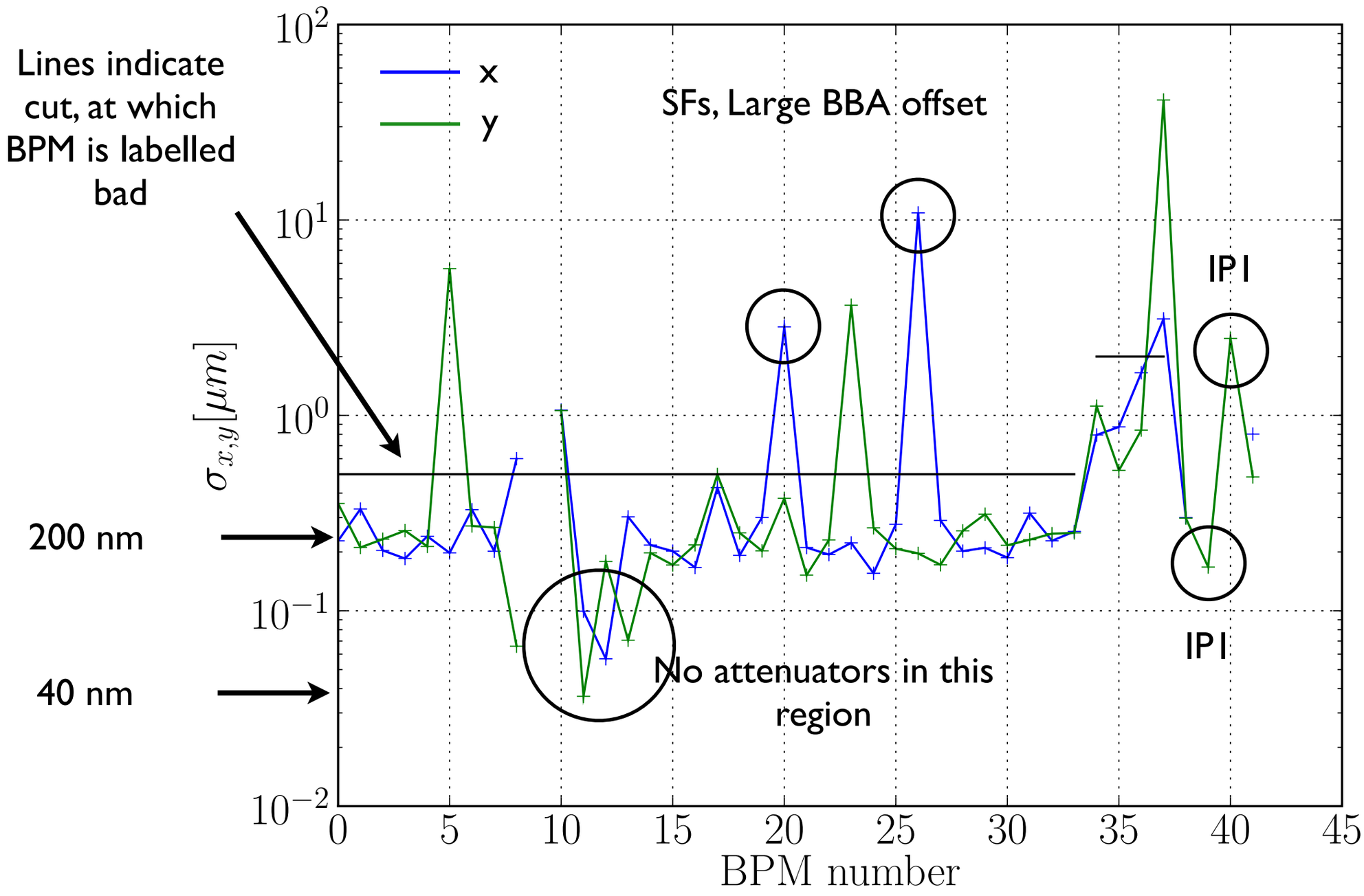
S. Boogert & A. Lyapin



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

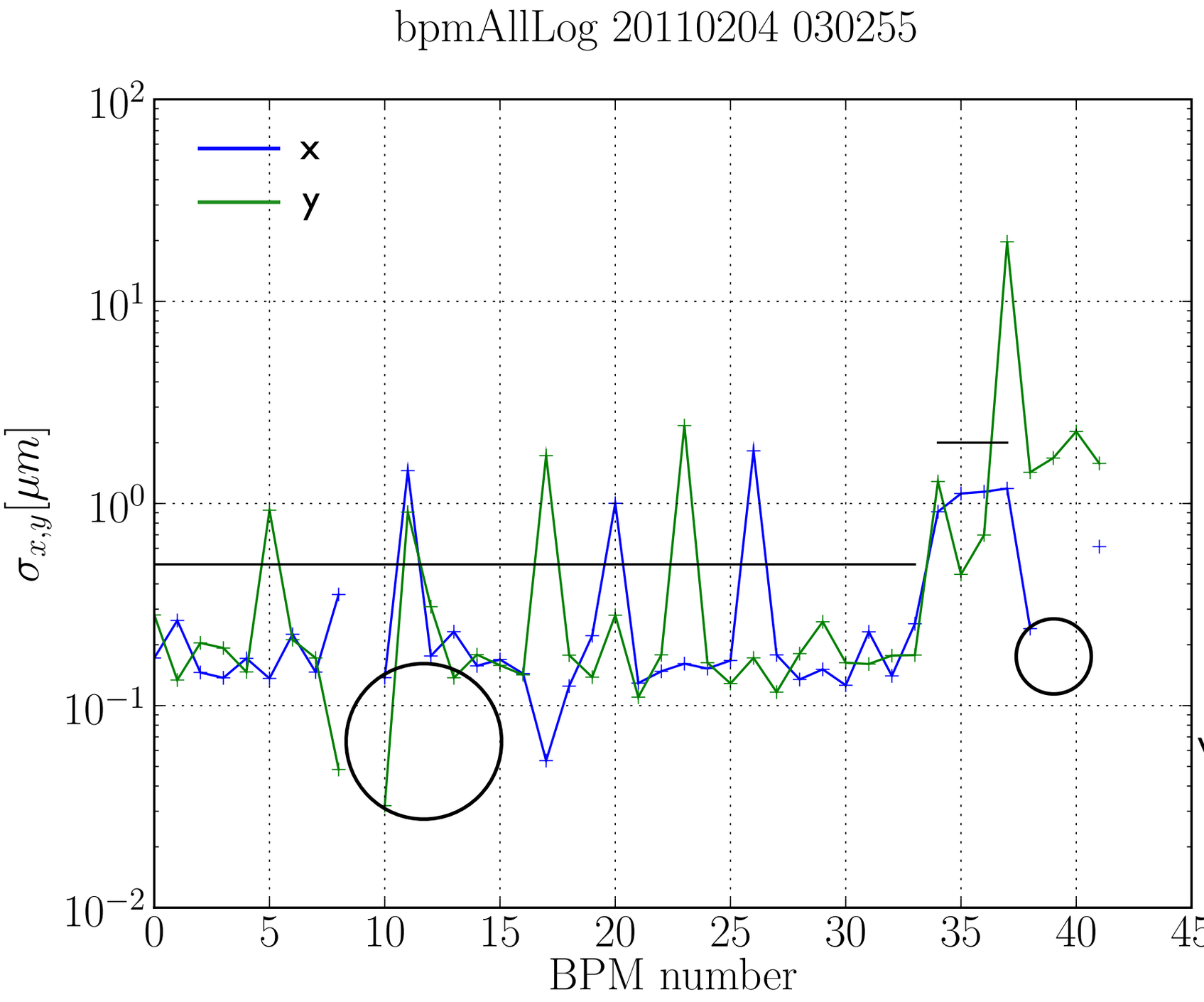
BPM Resolution (2011-02-02)

S. Boogert & A. Lyapin



BPM Resolution (2011-02-04)

S. Boogert & A. Lyapin



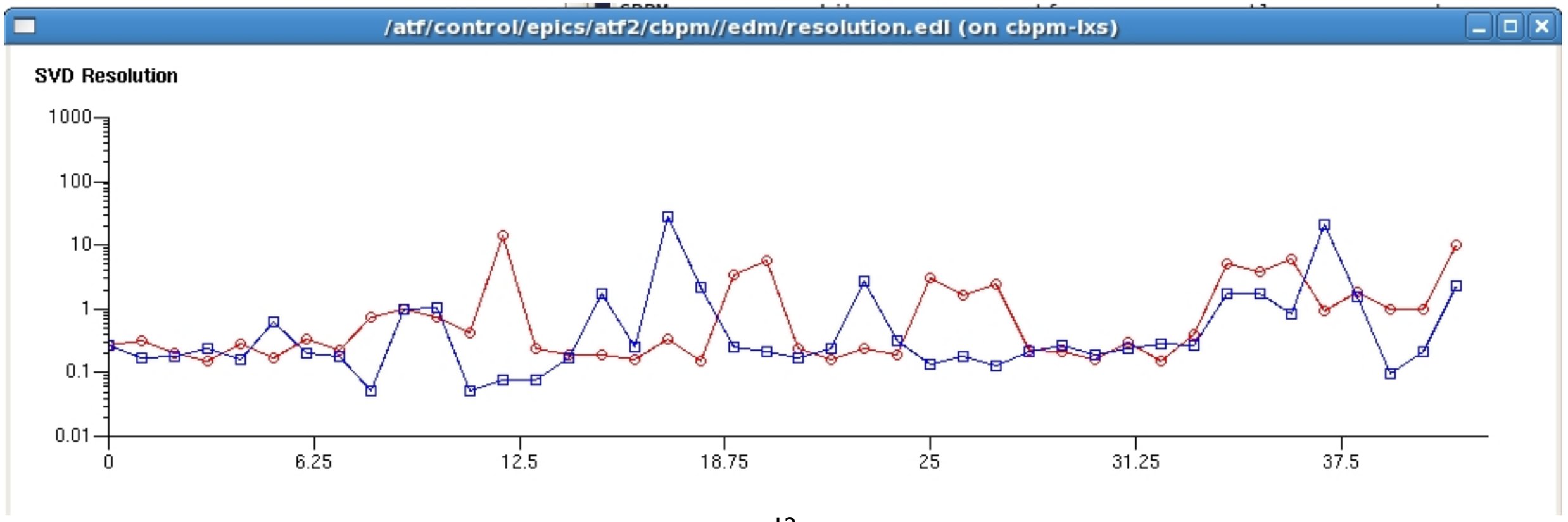
Pattern similar days later but some degradation of high resolution BPMs

High resolution BPMs were where the circles are

Online resolution

S. Boogert, A. Lyapin, F. Cullinan

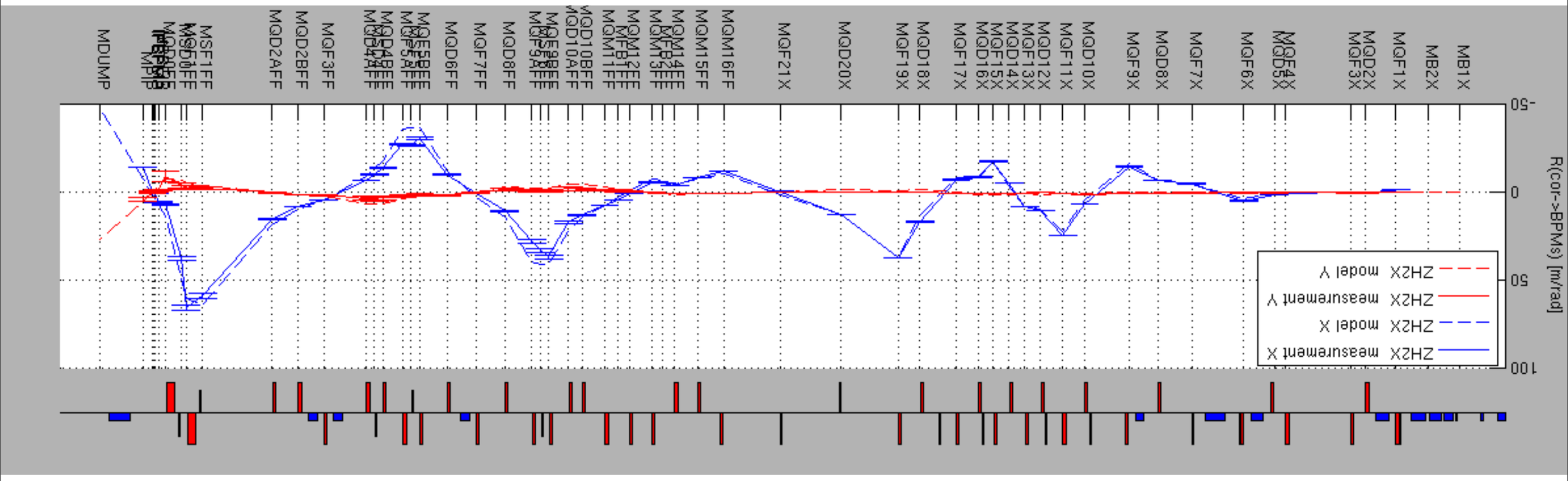
- Cavity BPMs in test accelerator is complex
  - Saturation, alignment (resolution beam position dependent)
- Online analysis complete
  - Resolution, beam jitter, calibration
  - Cavity BPMs are non-constant resolution devices



Beam optics verification

ATF2 tuning group

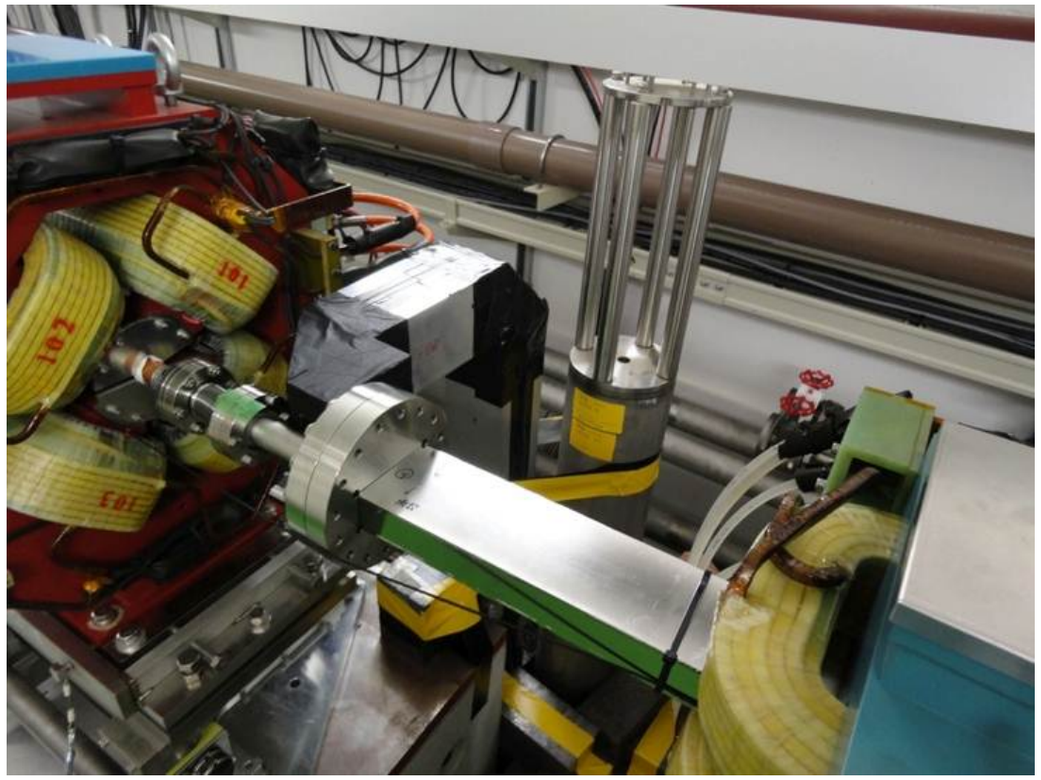
- Routinely use cavity BPM system of optics verification, beam based alignment, jitter studies.
  - Use single upstream corrector and compare model prediction (Lucretia) vs BPM response
  - Complex lattice reproduced faithfully (including coupling)
  - Study use of high resolution BPMs

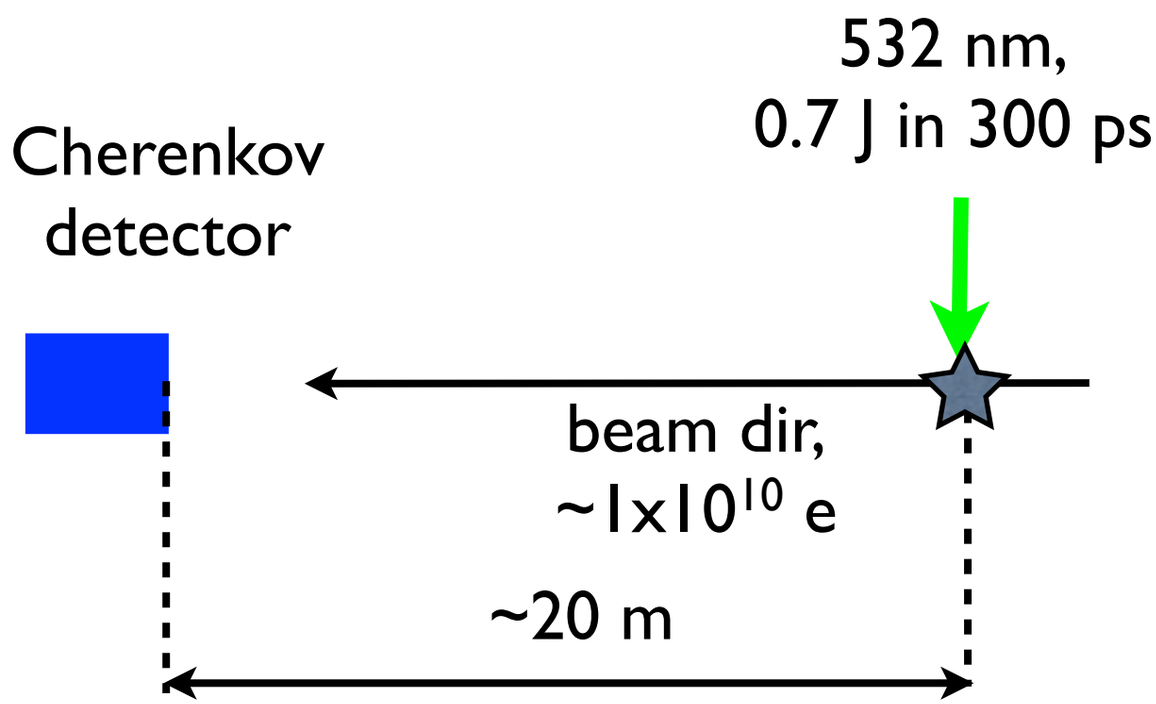


Laser-wire

John Adams (RHUL/Oxford)

- Two systems
  - ATF2 : Aim to reach 1 um beam size measurement
  - PETRA3 : Ring system, fast scanning
- ATF2
  - Custom lens near diffraction limit focusing
  - 4 um already published
  - Need to extract Compton photon signal over 20 m at 1.56 Hz



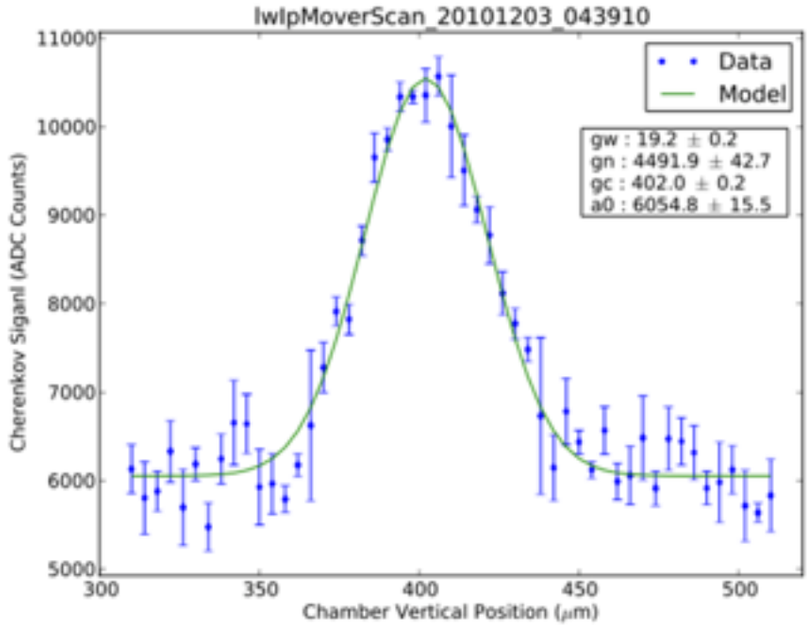


Laser-wire (ATF2 results)

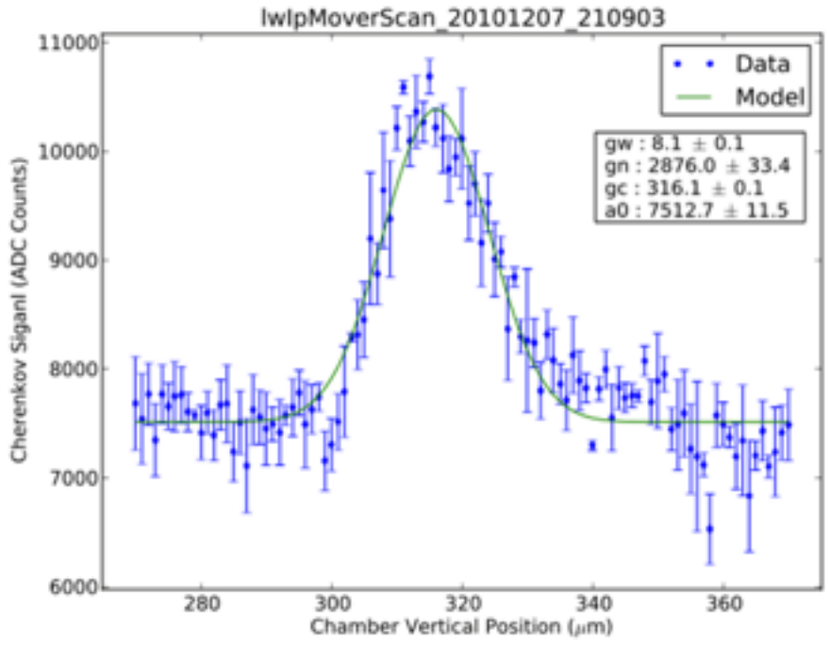
John Adams (RHUL/Oxford)

- 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

$$\sigma_V = 19.2 \pm 0.2 \mu m$$



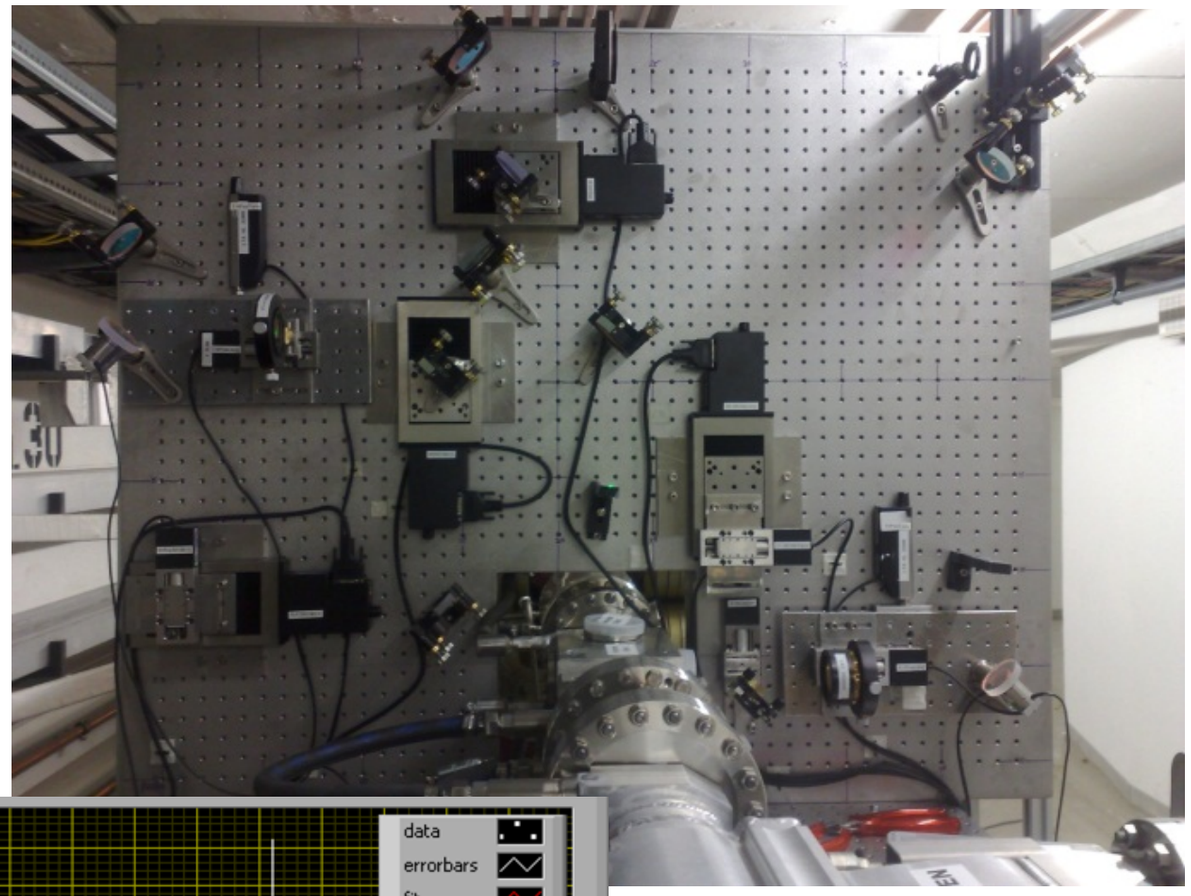
$$\sigma_V = 8.1 \pm 0.1 \mu m$$

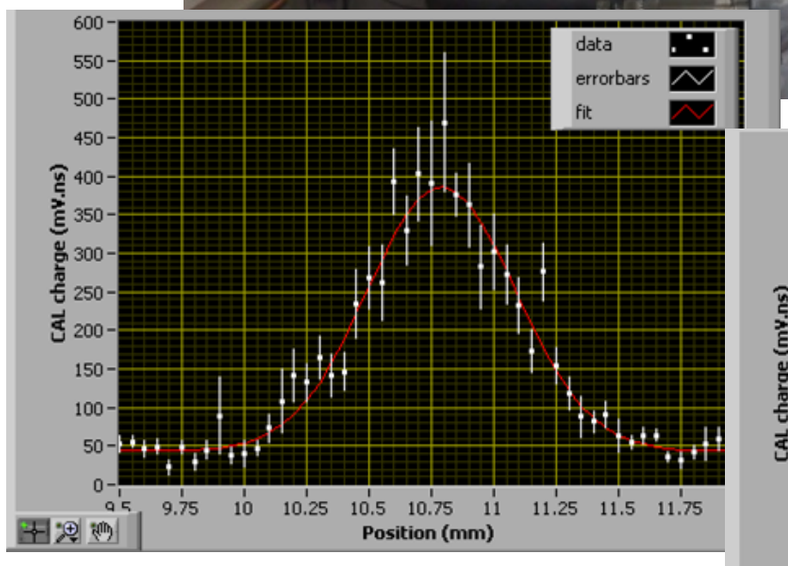


PETRAIII

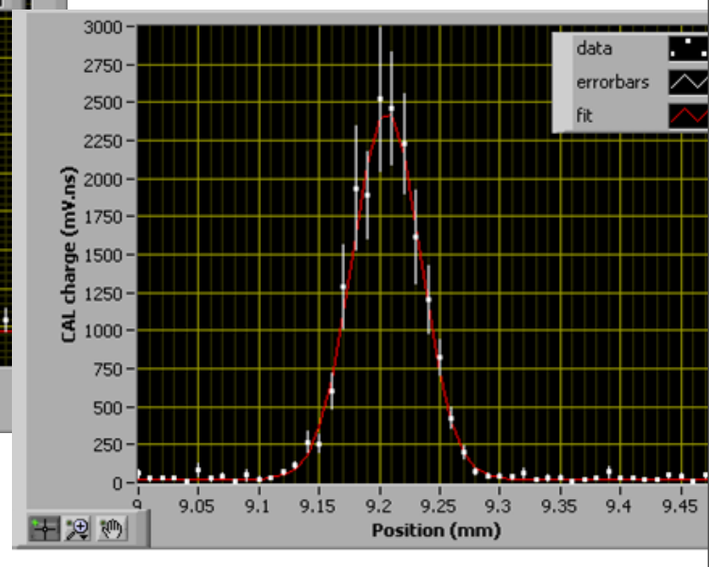
A. Bosco

- Vertical two dimensional system
- Two scanning systems
  - Piezo driven mirror
  - Translation stage
- Fast scanning (120 kHz)
  - Electro-optic fast scanner developed
  - Also high rep-rate laser
    - Mode locked seed
    - Fibre amplification





$$\sigma_H = 0.298 \pm 0.001 mm$$



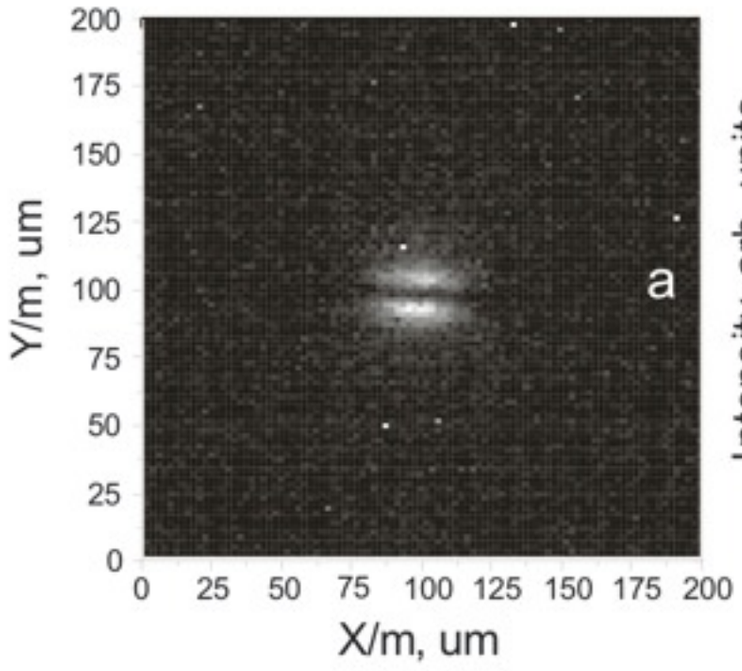
$$\sigma_V = 0.028 \pm 0.001 mm$$

Transition and diffraction Radn

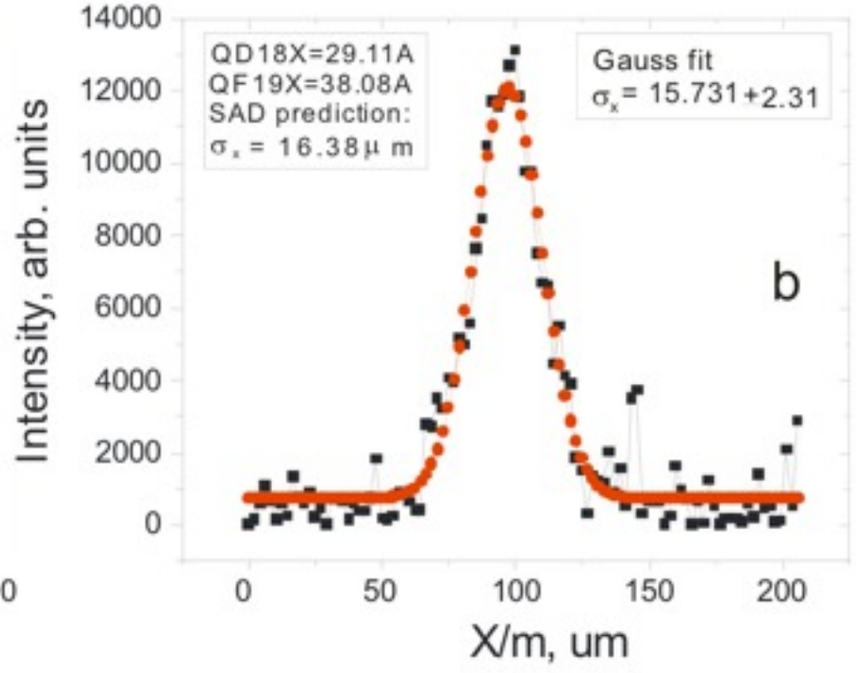
P. Karataev

- Transverse and longitudinal diagnostics systems
  - Micrometre OTR system installed along with ATF2 laser-wire
  - Coherent diffraction radiation (CDR) monitor at CLIC Test Facility CTF3
- ATF2 example below
  - Note vertical double peaked structure

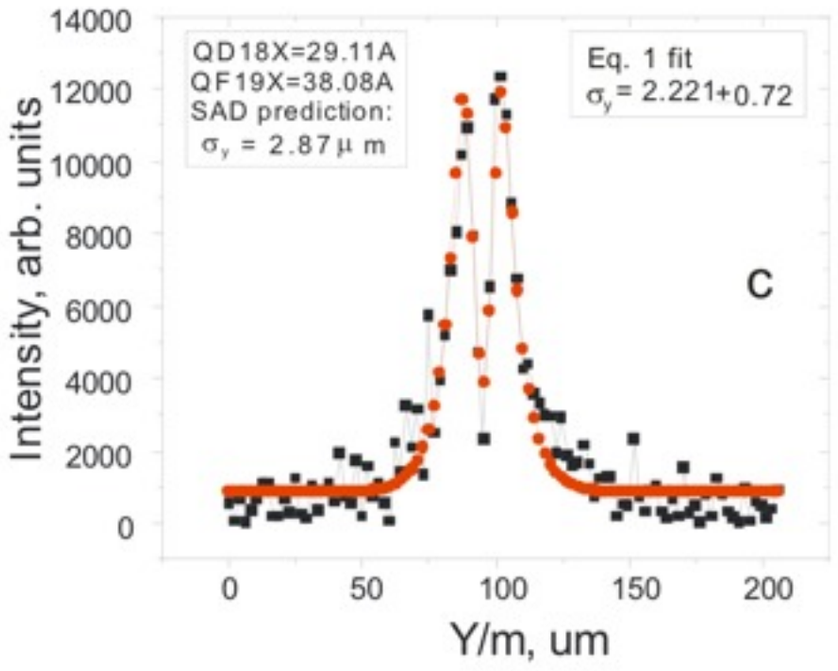
CCD image



H-projection



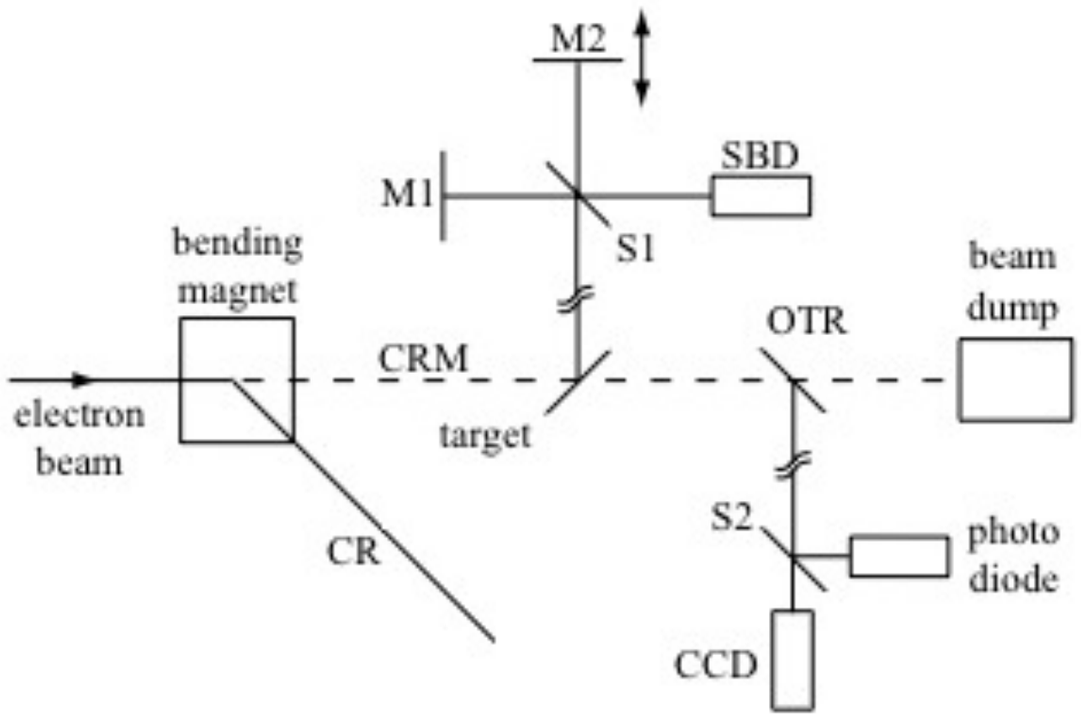
V-projection

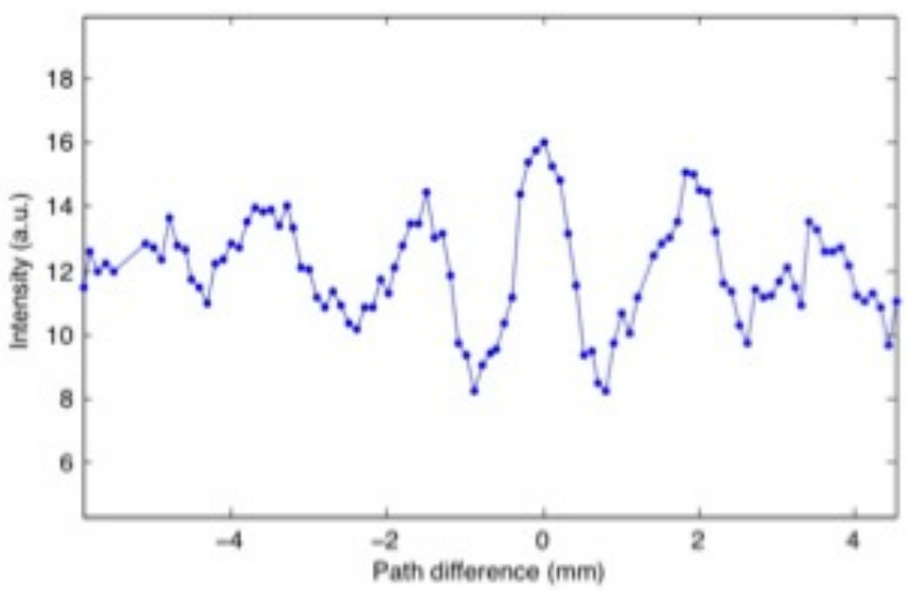


CDR at CTF3

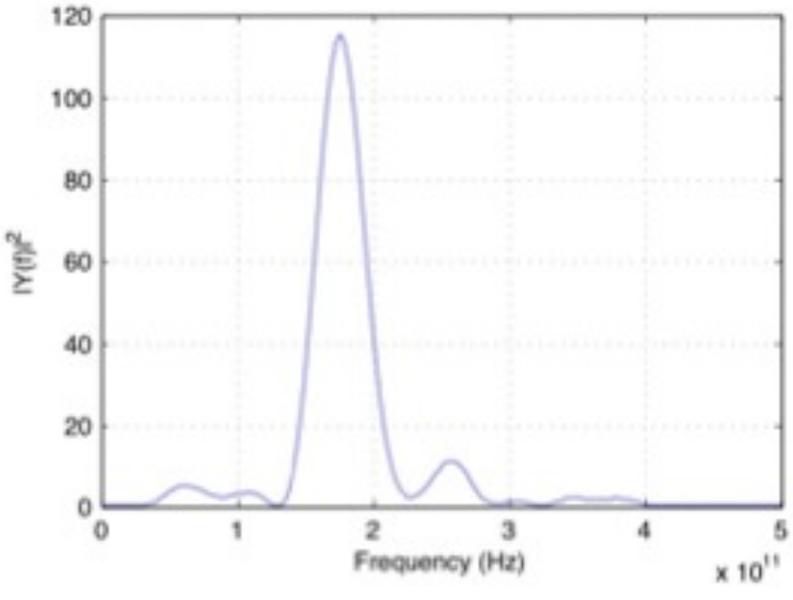
P. Karataev

- Measure CDR from CTF3 (drive beam)
  - Setup in dump line
  - Information extracted using interferometer setup
  - Aim to extract bunch longitudinal profile





(b) Interferogram



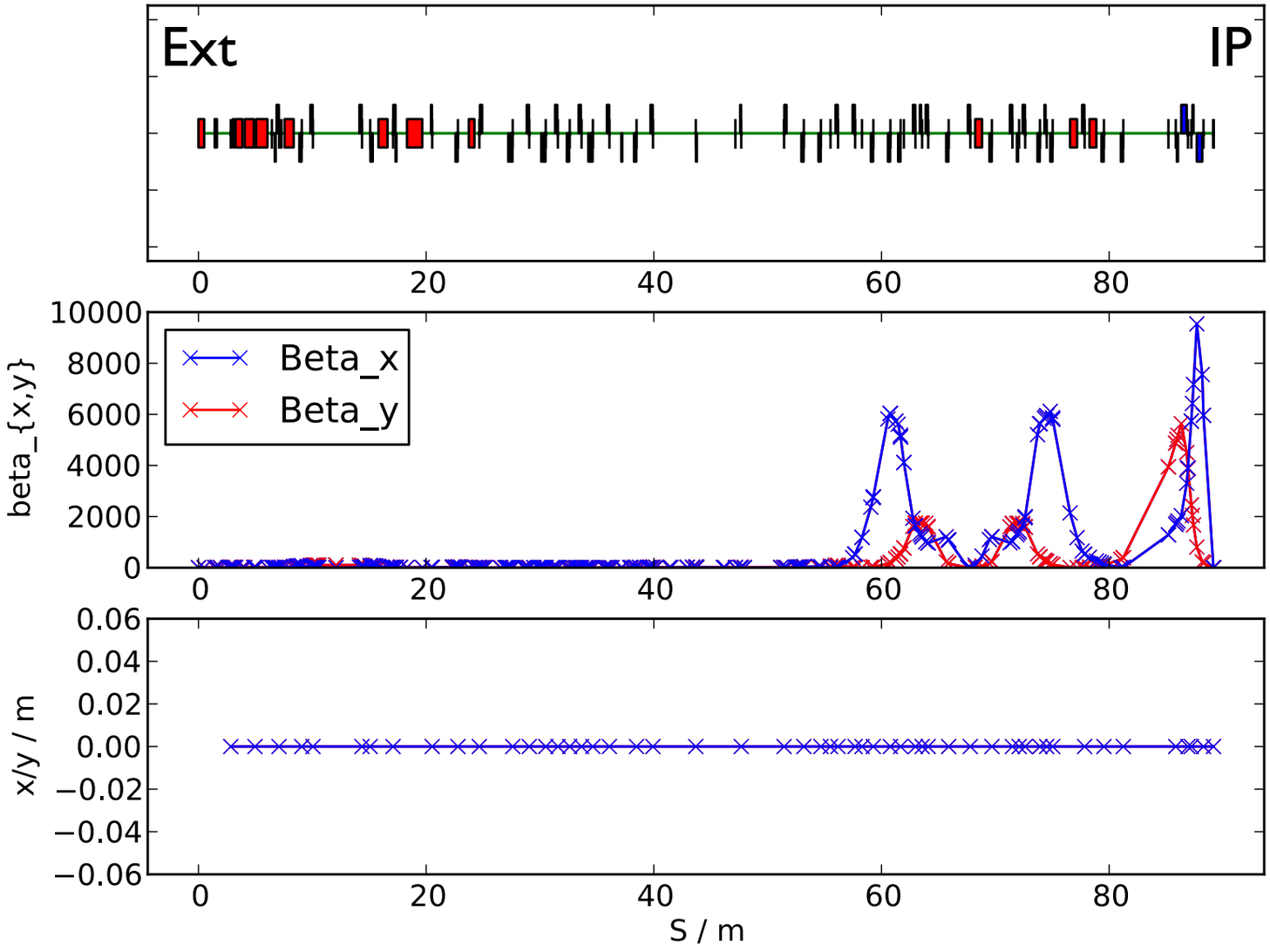
(c) Spectrum

Simulation

S. Boogert

- Complete suite of simulation codes
  - Normal machine codes (MADX, PLACET, etc etc)
    - Extensions for diagnostics (LW, BPMs, FBs)
    - Interfaces to EPICS for simulated control
  - Electro-magnetic
  - Backgrounds and PP

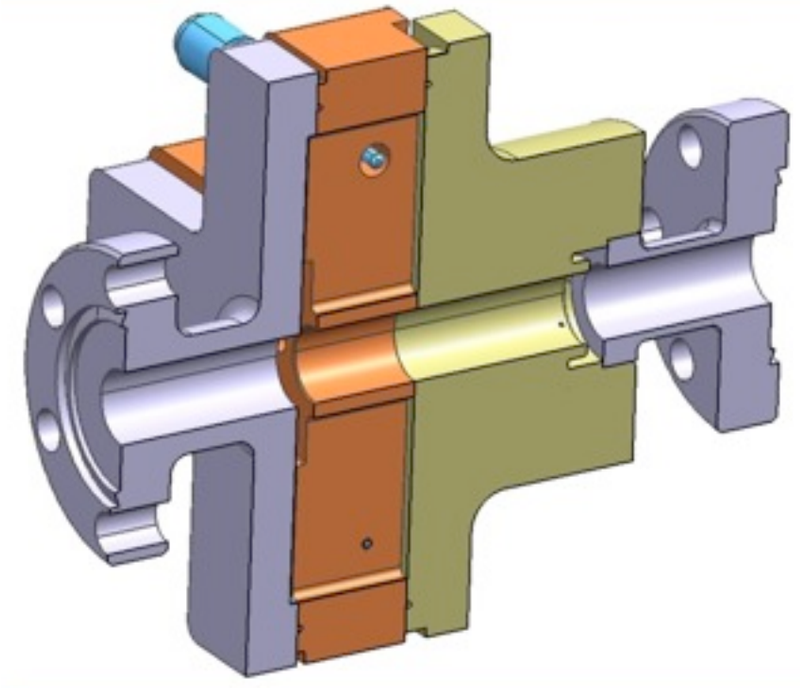
ATF2 example : from extraction of ATF to final focus. Full BPM (SL and Cavity) simulation and EPICS interface for control and tuning

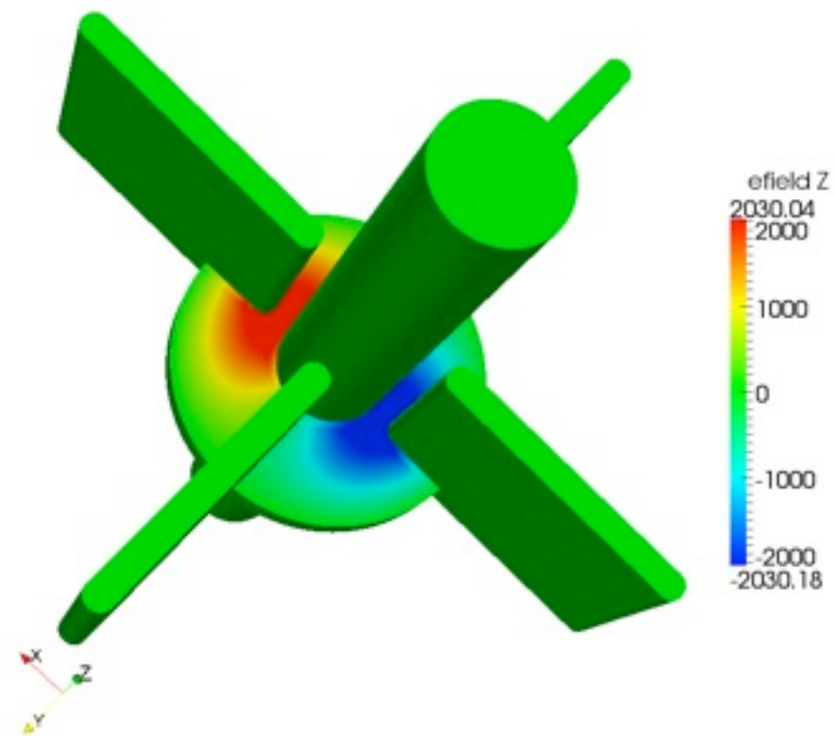


Electromagnetic simulation

A. Lyapin

- Facilities
  - 120 core, farm running Gdfidl
  - Access to NERSC and SLAC ACD EM codes
- Application examples
  - Wakefields and impedences
  - RF diagnostics, example simulation of FNAL CLIC BPM design



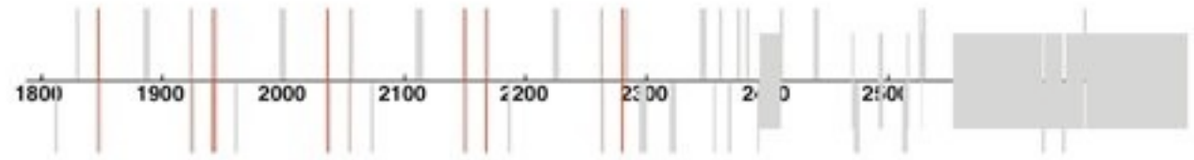


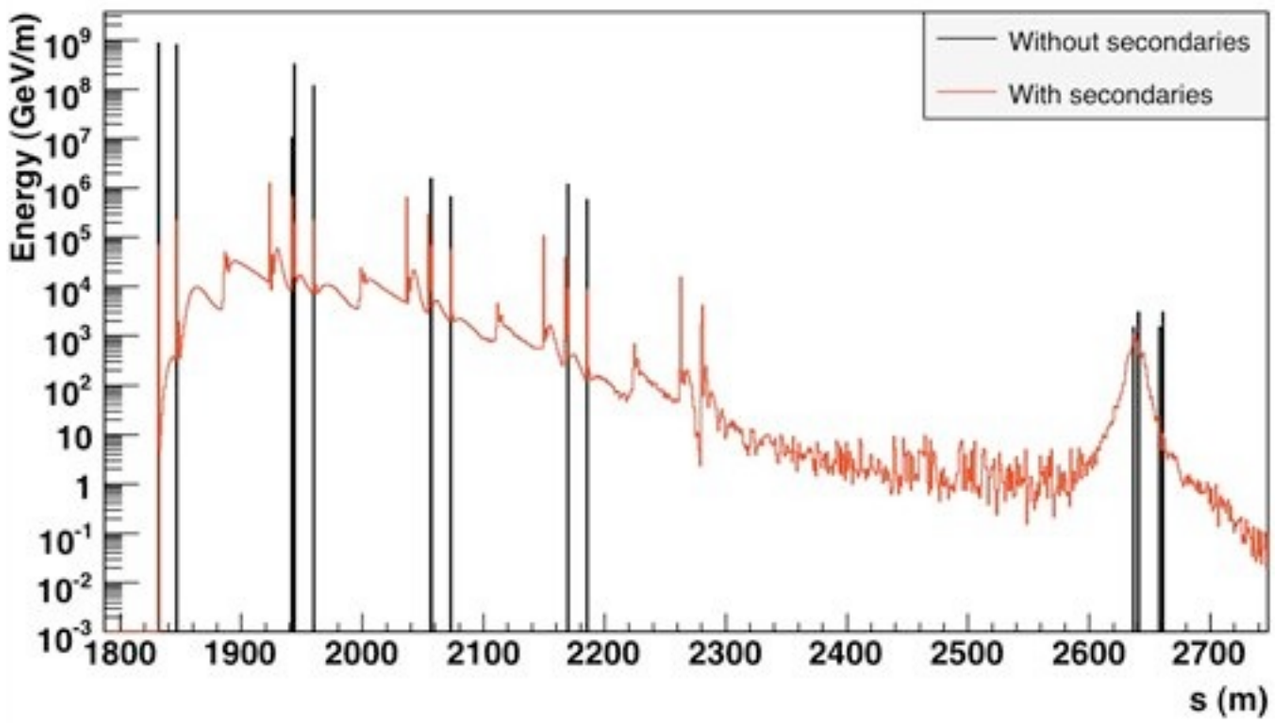
Beam delivery simulation

G. Blair

- BSDIM
  - Geant4 combined with fast accelerator like tracking
- Applications
  - Interaction region
  - Background and halo studies
  - Collimation and beam loss
- Currently used for
  - LHC collimation/IR
  - ILC/CLIC beam delivery

CLIC BDS example : halo generation, via collimation, secondard production and inclusion of wakefields (from PLACET)





Summary

- Large number of lepton machine diagnostics developed at Royal Holloway
  - Full life cycle of diagnostics, design, prototype, implementation, installation, routine operation and upgrade
  - Some developments applicable to SuperB, emittance measurement and BPM systems
- Many diagnostics systems not discussed, ultra high resolution BPMS, beam tilt monitors, phase monitors, digital controls
- Present here today A. Bosco (emittance measurement) and myself (everything else) for more discussion on possible joint areas of interest