LCABD WP 4.2 - Spectrometer and BPM Studies

- Motivation
- BPM and Electronics Development
- BPM Simulation
- Update on NanoBPM Progress
- Update on ESA Progress
- Future Plans

The Collaboration

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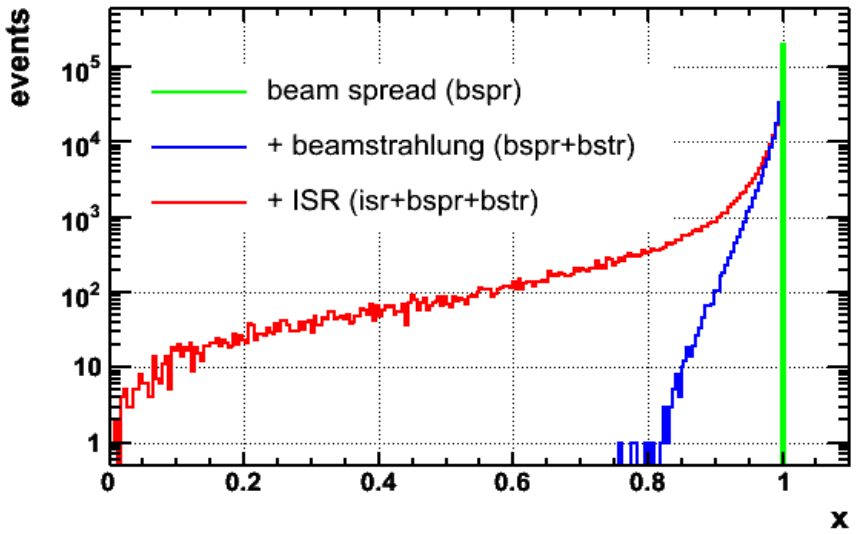
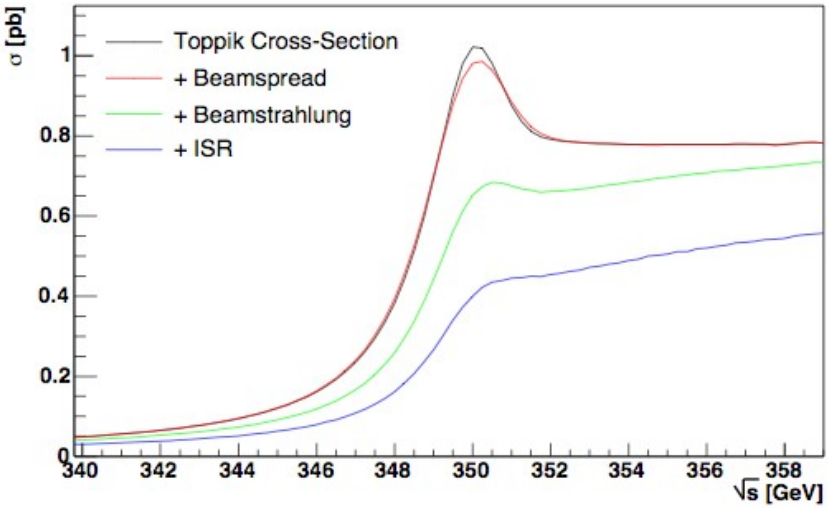
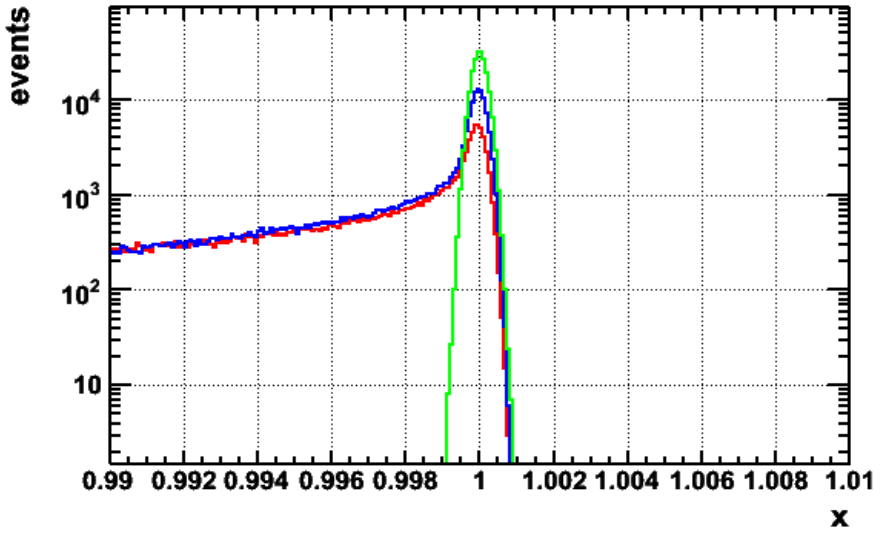
Motivation - Physics Case





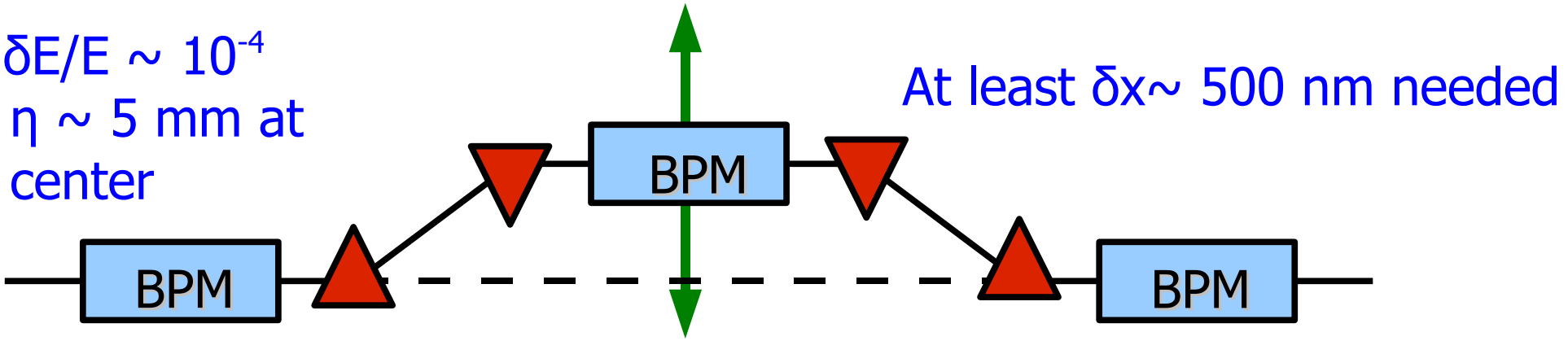


- *Uncertainty on beam energy measurement contributes directly to the uncertainty on the ILC physics output...*
- *Need for:*
  - *Energy measurement accuracy 10^{-4}*
  - *Stability and ease of operation*
  - *Minimal impact on physics data taking*

Motivation - Beam Based Energy Measurement

- *WP 4.2 Mission Statement:*

Study and design magnetic chicane for beam energy measurement using BPMs for a future linear collider



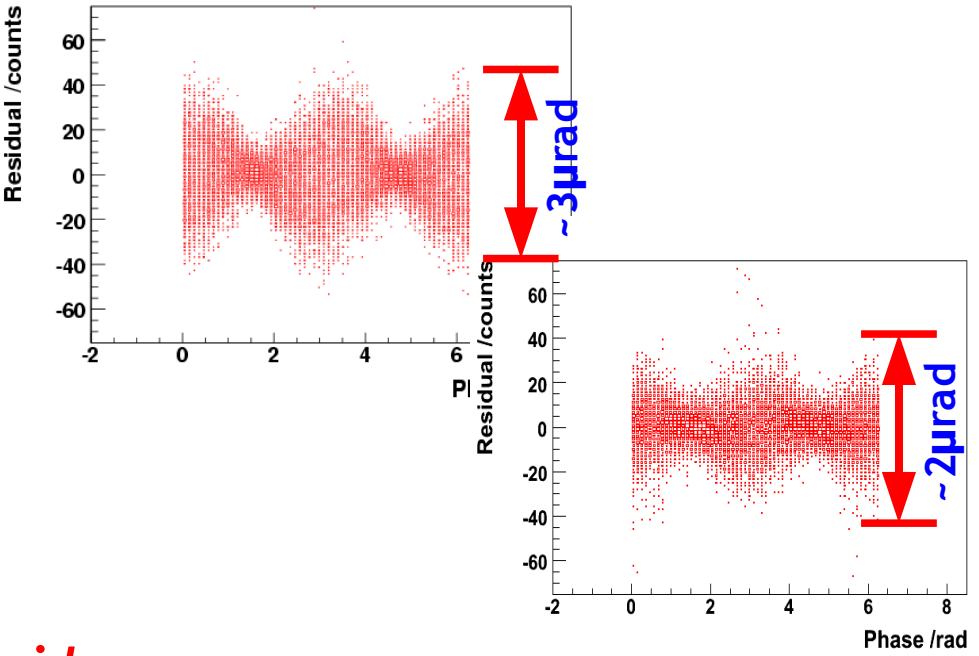
- *NanoBPM at ATF: test resolution, try different analysis methods, BPM stability tests, multibunch operation, advanced electronics techniques, inclination of beam in BPMs*

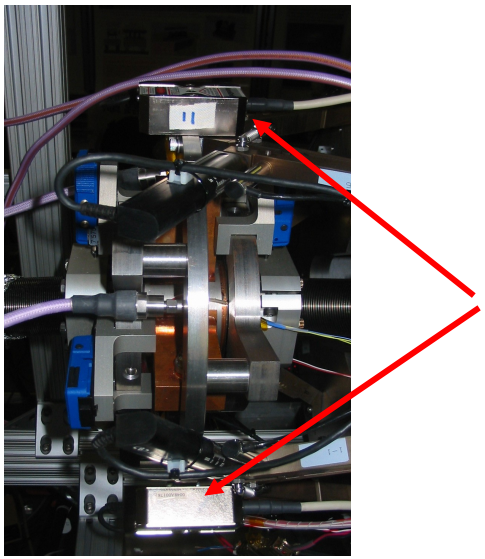
- *ESA at ATF: test stability and operational issues with a full implementation of 4 magnet chicane and 3 BPM stations*

NanoBPM Update - Hardware Improvements

Locking Box

- Built by Bob Meller (Cornell)
- Provides the LO signals for the electronics
- This phase locks all the electronics to the master 714MHz signal
- A reduction of a factor of 1.5 in phase noise was found



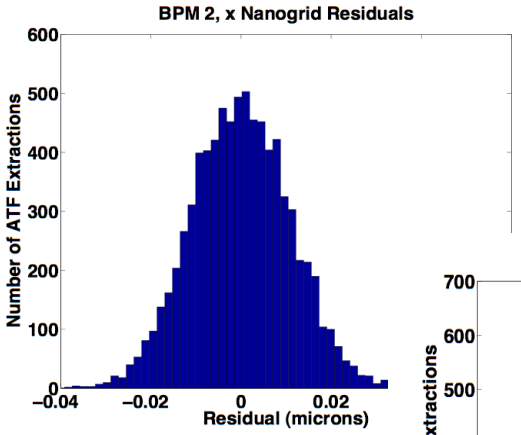


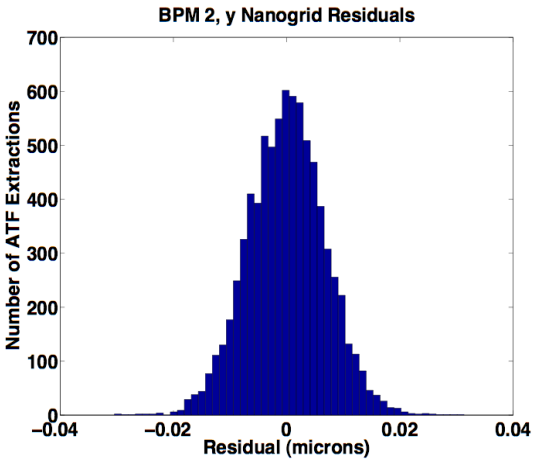
Nanogrid Sensor Heads

Nanogrids

- Very precise monitoring of BPM positions relative to the frame
- Allowed a measurement of the rigid body motion of the structure
- This gives a significant contribution to the achievable resolution (~5nm)

NanoBPM Update - Results





Rigid Body Motion

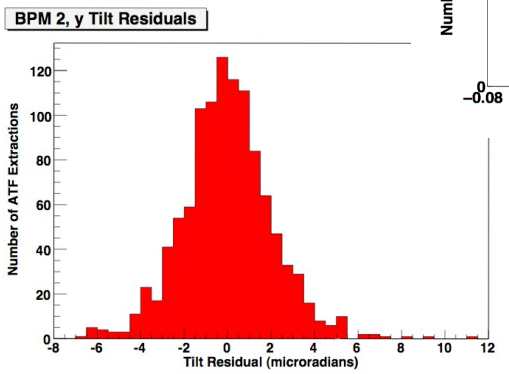
➔ *By using a similar regression technique used to find the resolution, the rigid body motion could be measured:*

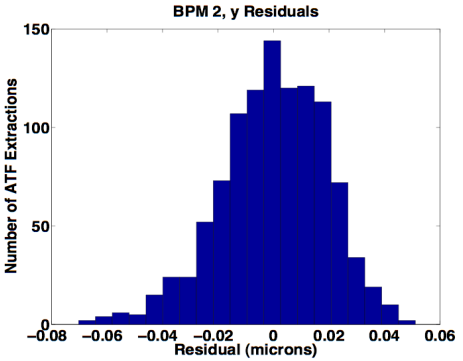
< 8.4 nm x
< 4.8 nm y

Resolution Results

➔ *Best resolution recorded so far was during April '06:*
- ➔ Position: 15.6nm
- ➔ Tilt: 2.1μrad

➔ *From simulation work, electronic, thermal and vibrational noise not dominant. Work in progress…*



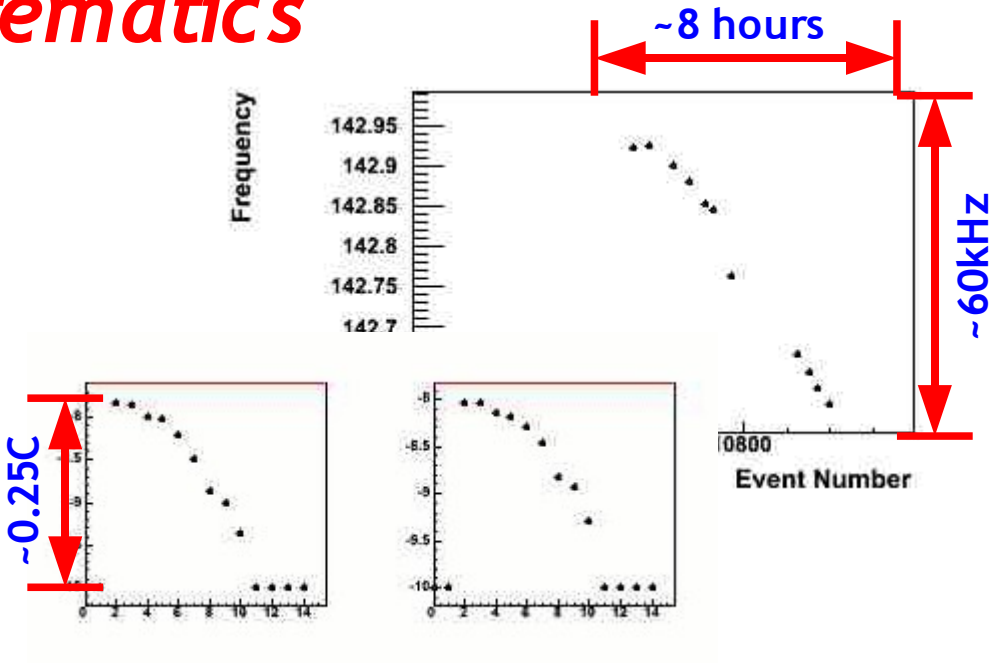


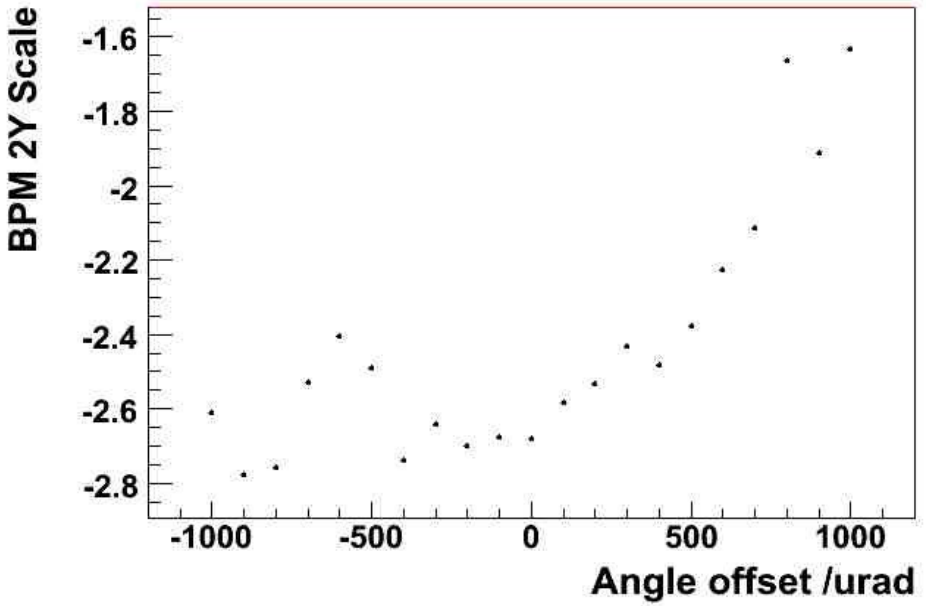
NanoBPM Update - Systematics

Temperature

- Frequency changes over the course of 8 hours have been correlated with temperature changes of the BPMs

- The change seen is in reasonable agreement with that predicted from thermal expansion arguments





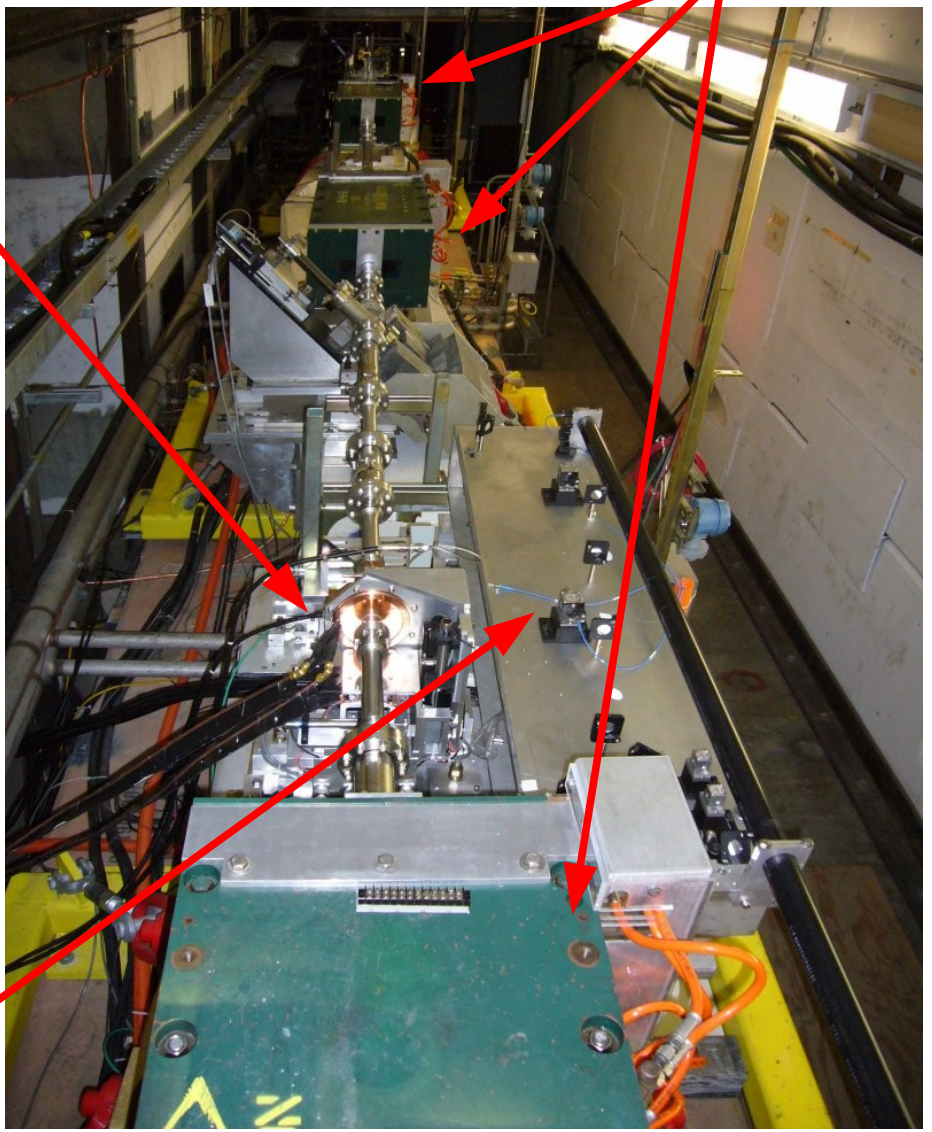
BPM Tilt

- The dependence of the calibration on BPM tilt was investigated

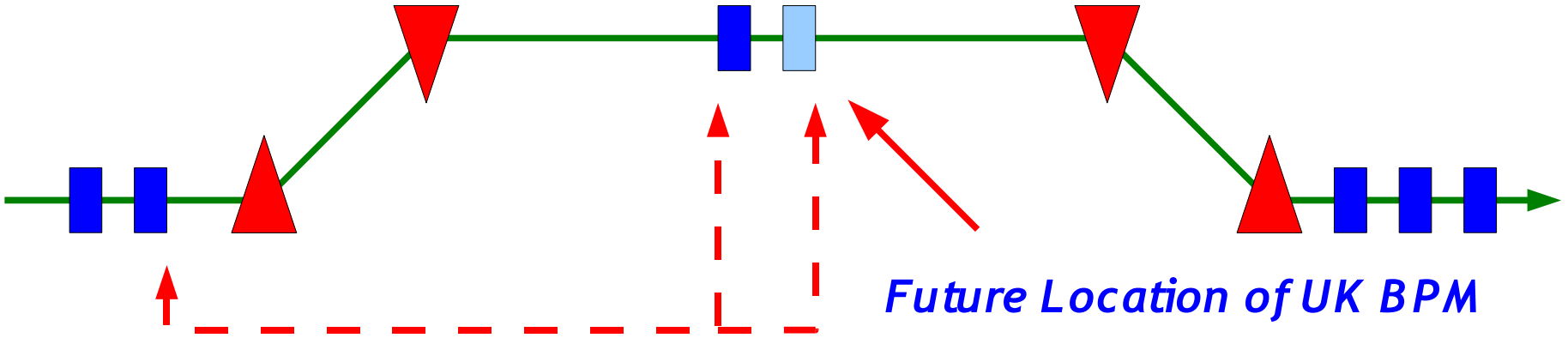
- A significant dependence of the scale factor was found, the source of which is still under investigation

ESA Update - April Run

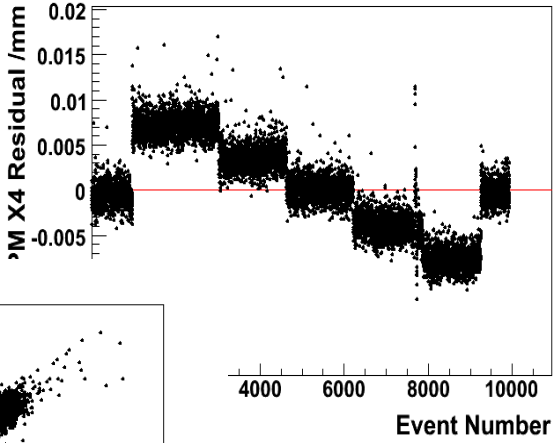
- There were a large number of hardware updates for the April Run:
  - Installed and tested the full spectrometer chicane
  - Commissioned an additional energy BPM at high dispersion
  - Relocated interferometer
  - Commissioned the UK electronics
  - Developed a new calibration scheme using Helmholtz coils rather than correctors

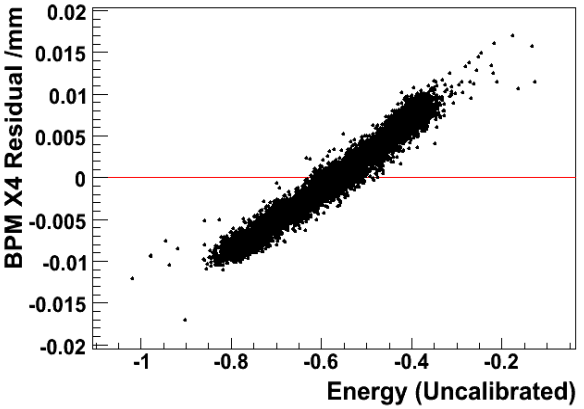


ESA Update - Initial Spectrometer Results



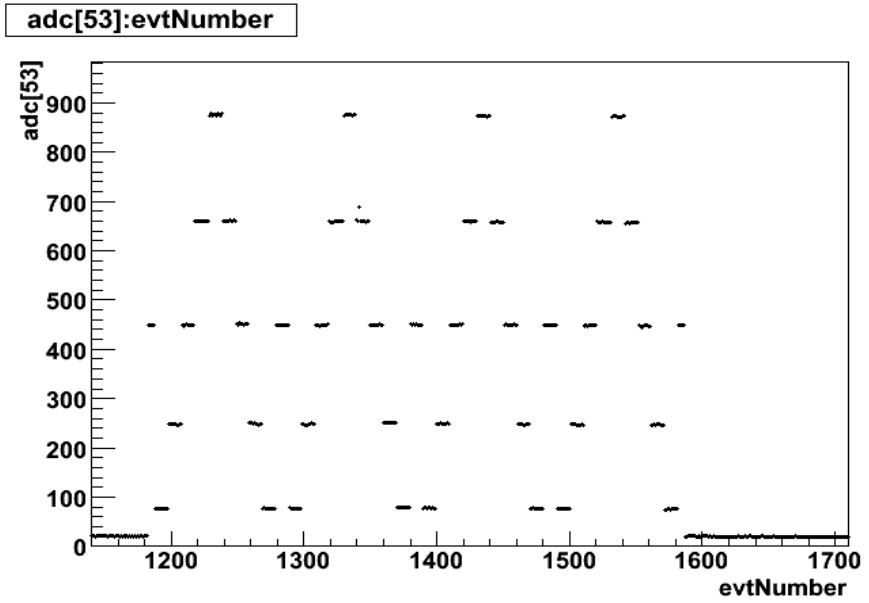
- A lot of spectrometer data was taken during April
- A maximum dispersion of ~5mm was recorded
- The mover for the mid-chicane BPM was used to track the beam and these moves could be accurately recorded using the Zygo
- Varying the energy at the nominal magnet setting produced clear steps that could be correlated with the energy BPMs

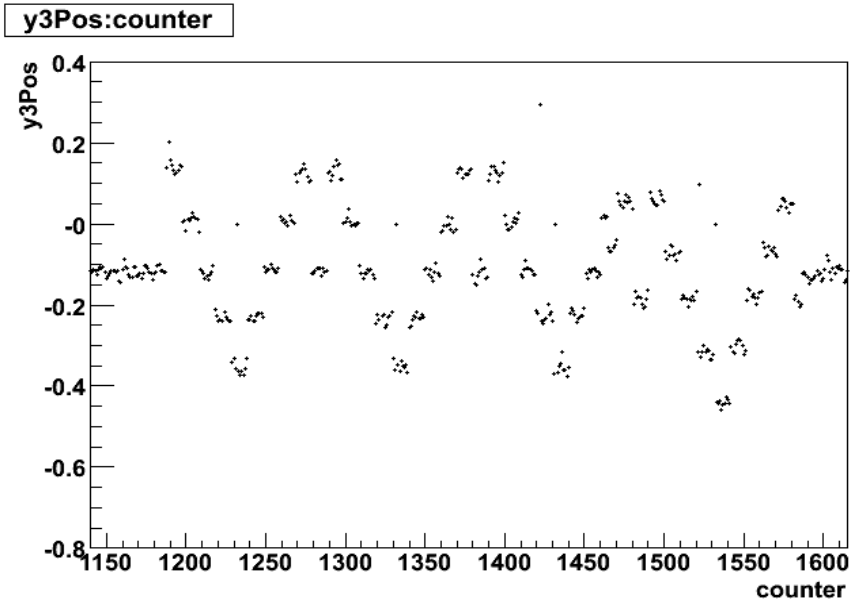




ESA Update - Improved Calibrations

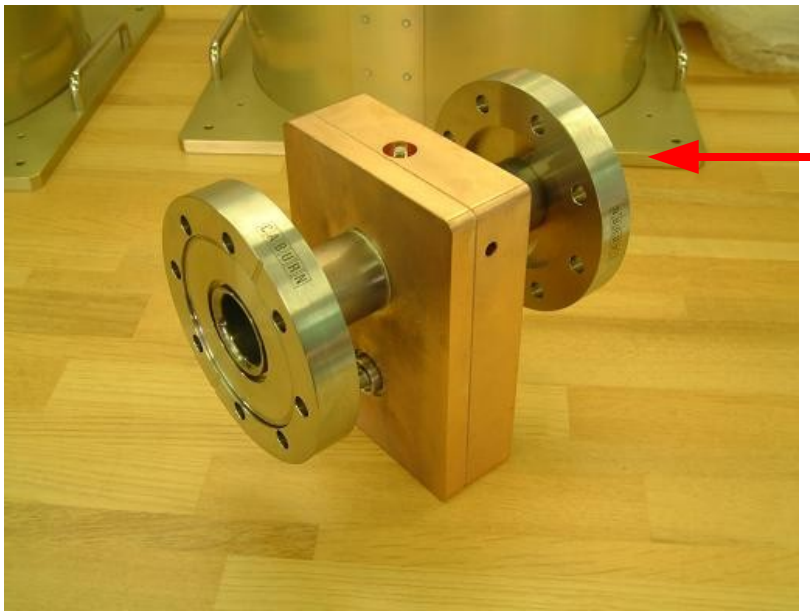
- In order to improve the stability of the calibrations at ESA, a set of helmholtz coils were commissioned
- This had the following advantages over the correctors used previously:
  - Fast - The required field is reached within a machine cycle
  - Dithering - This speed allowed fast dithering to be used
  - Averaging Slopes - Slopes are averaged instead of Set Points
- Additionally, calibration schemes now record their set points in an ADC which allow steps to found automatically
- A set of automatic calibration scripts to speed up the calibration process have now been developed





Purpose Built Cavity

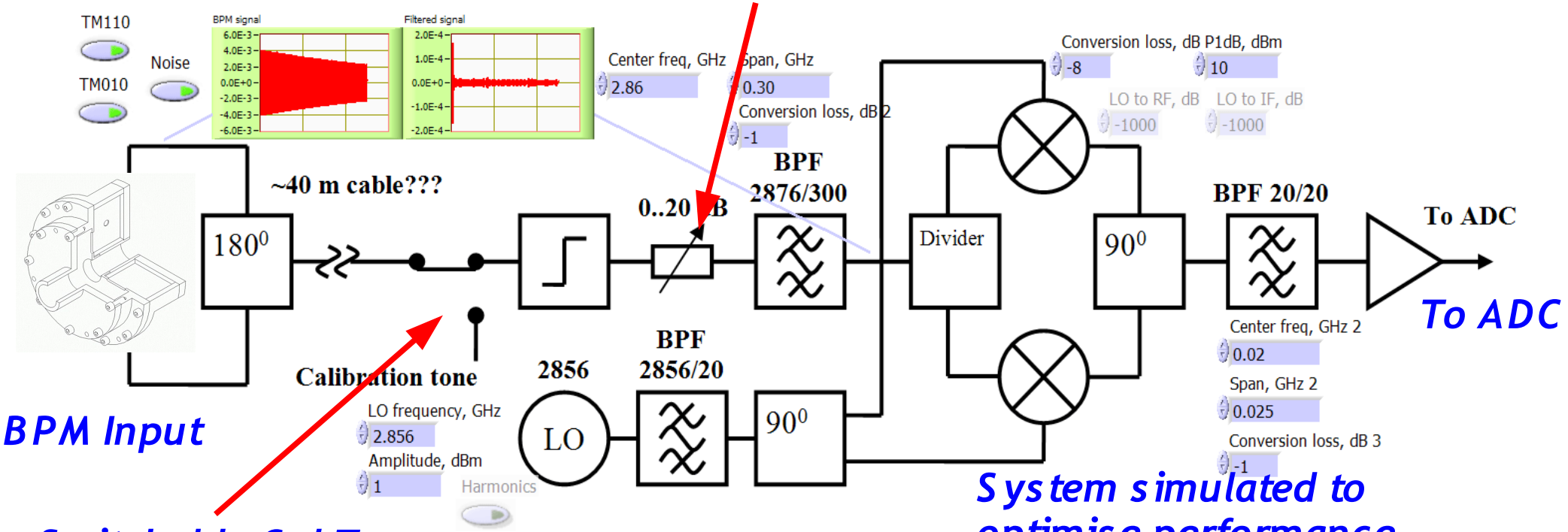
- New S-band cavity designed specifically for the Spectrometer by Alexey (2.88 GHz, Qext ~2000, t = 250ns, s ~10-20nm)
- Attempted to combine advantages of existing designs:
  - Monopole suppression
  - Decay time optimised for analysis
  - Tunable
  - Low X-Y coupling
- Testing of the Aluminium prototype has been successfully completed
- Final copper prototype now complete and ready for installation at ESA



Reference

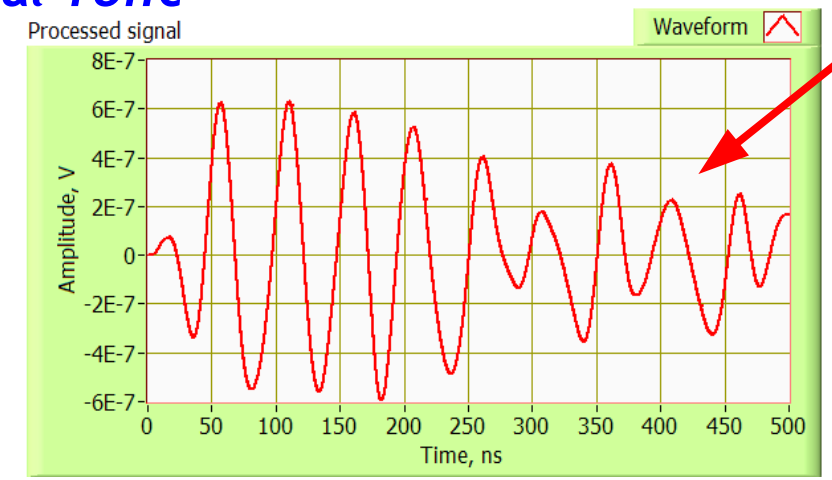
Dipole

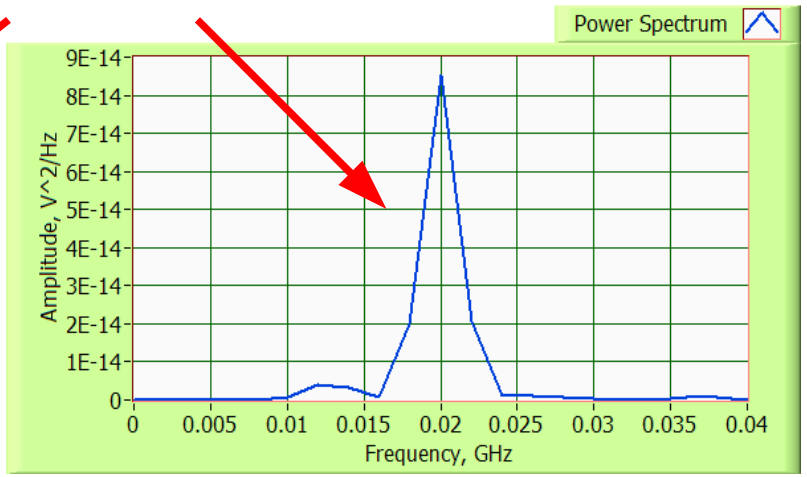
Electronics



Simulation parameters
N of points: 50000
Smpl freq, GHz: 100

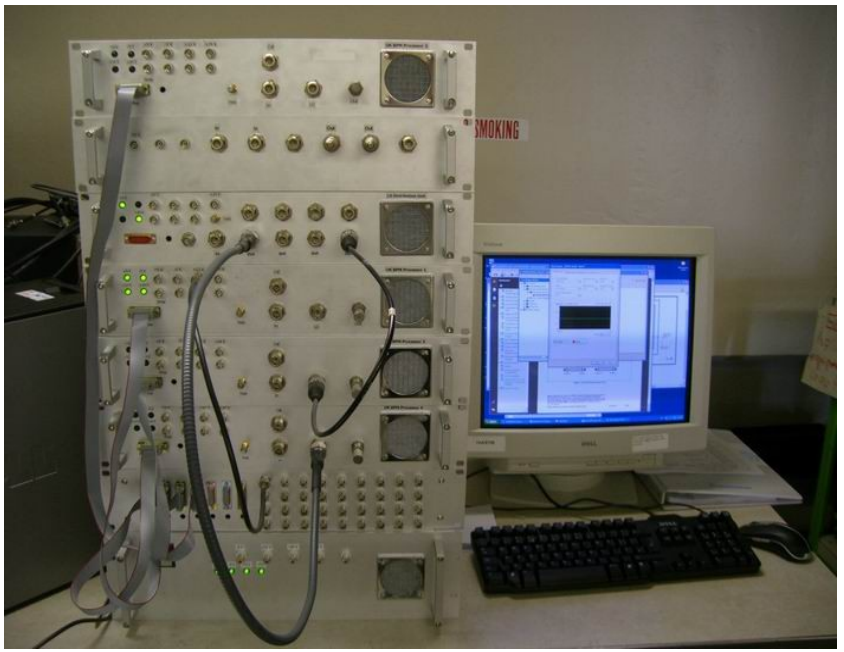
Beam parameters
Charge, nC: 1
Offset, mm: 2E-5





Electronics Testing

- Electronic rack units completed and shipped to SLAC late February in time for the last run
- Installation and testing completed over the course of the two week run
- Data taken both in parallel with current electronics (two x channels) and 'standalone' (3 y and a q channel)



- Initial results indicate a similar resolution achieved by the current electronics, despite not being designed for use on these BPMs (no monopole suppression + diff. freq.)
- A lot of calibration data was also taken to check the stability of the electronics
- Finally, the automatic calibration routine for the electronics was commissioned successfully (cal tone switched on at 0.1Hz)

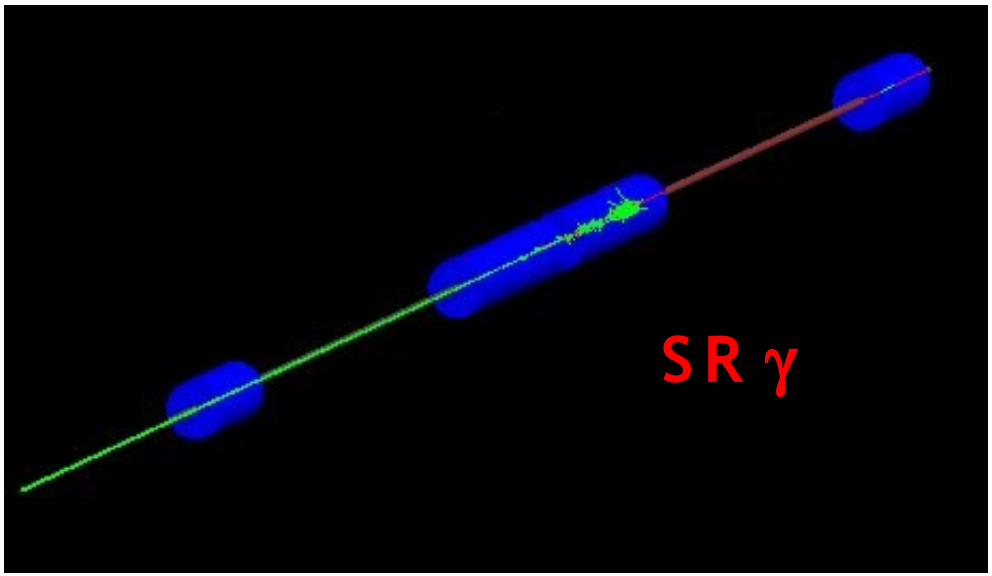
Simulation Work

- The ultimate aim is to build an entire simulation chain from beam orbit to energy measurement
- This will include the following `modules':
  - Spectrometer Simulation - including SR, backgrounds, etc.
  - RF simulation - To go from a hit location to a waveform at the ADC
  - Processing - Optimised versions of the processing algorithms used atm
  - Calibration - Optimised calibration routines
- The first pass of these software `modules' are already up and running:

http://cvs.hep.ucl.ac.uk/viewcvs/especSoft/?cvsroot=LC+Energy+Spectrometer

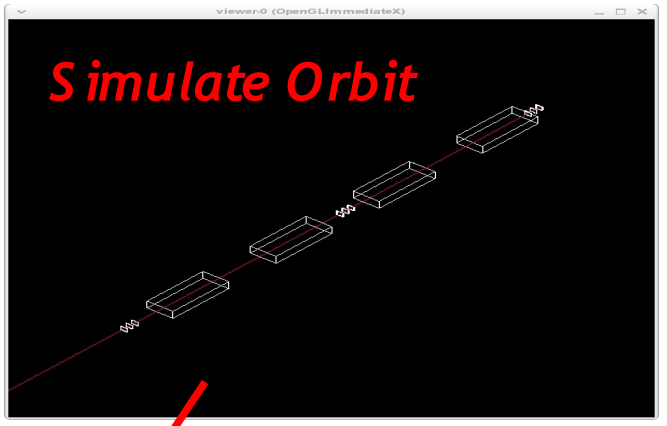
Spectrometer Simulation

- Based on GEANT4/BDSIM
- Will be used to study:
  - Synchrotron Radiation
  - Halo, Charge backgrounds
  - Magnet design and position

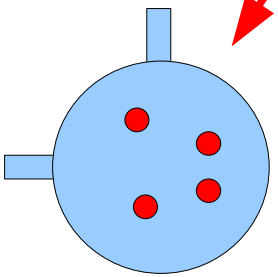


RF Simulation, Processing and Calibration

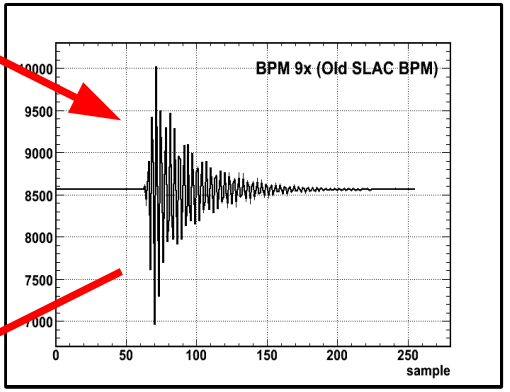
- Remaining components of the simulation chain are bundled together into one library called `libbpm'
- This is a library of C routines usable in most applications (ROOT, LabView, etc.)
- The RF component currently includes:
  - Mixers
  - Filters
  - Amplification (inc. non-linearity)
  - Digitisation
- The principle method of processing is the Digital Downconversion Algorithm:
  - Downconvert from the 25MHz IF to DC
  - Perform gaussian filtering
- Additional functions have also been implemented to perform
  - Waveform fitting
  - Fourier Transforms
  - Corrector Calibration
  - Mover Calibration
  - Resolution

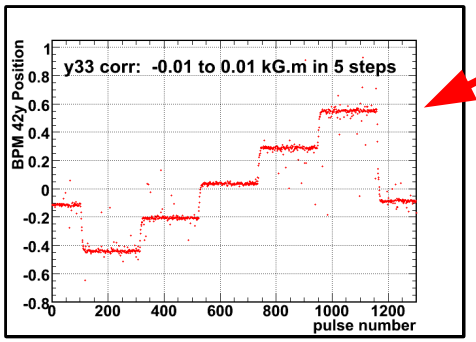


Generate hits



Generate waveforms





Process

The Future - Hardware

- The electronics, including the calibration tones, have all been commissioned and are ready for the new hardware

- Both reference and dipole BPMs are ready for mounting at the mid-chicane location in the ESA beamline

- A mover has also been ordered and should arrive in time for the next run at ESA

The Future - Software

- A new EPICS based control system is being developed for the new hardware to allow remote access to:
  - BPM output
  - Attenuation control
  - Mover control
  - Temperature readback

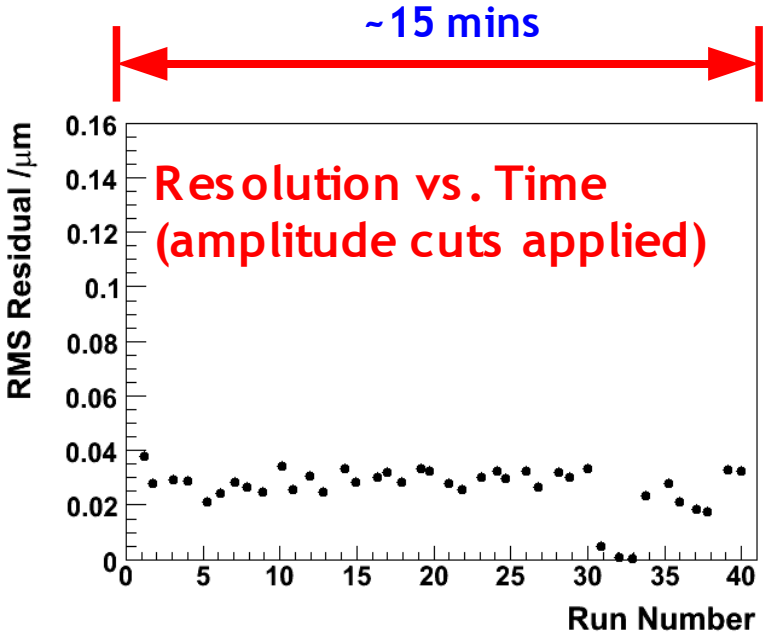
- The libbpm code library will be central to this system

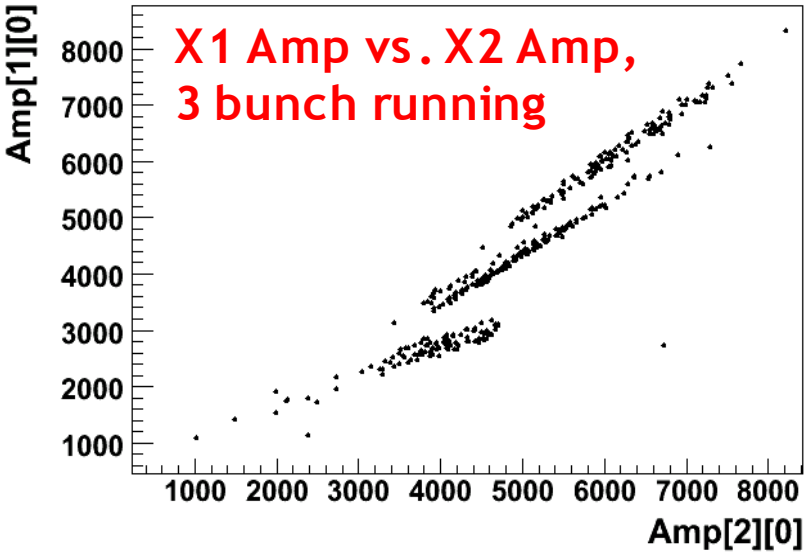
The Future - NanoBPM

- A large amount of data was taken during the last run in December

- Several analysis tasks are planned:
  - Resolution Stability
  - Calibration Stability
  - Gain variation of the electronics
  - Multibunch

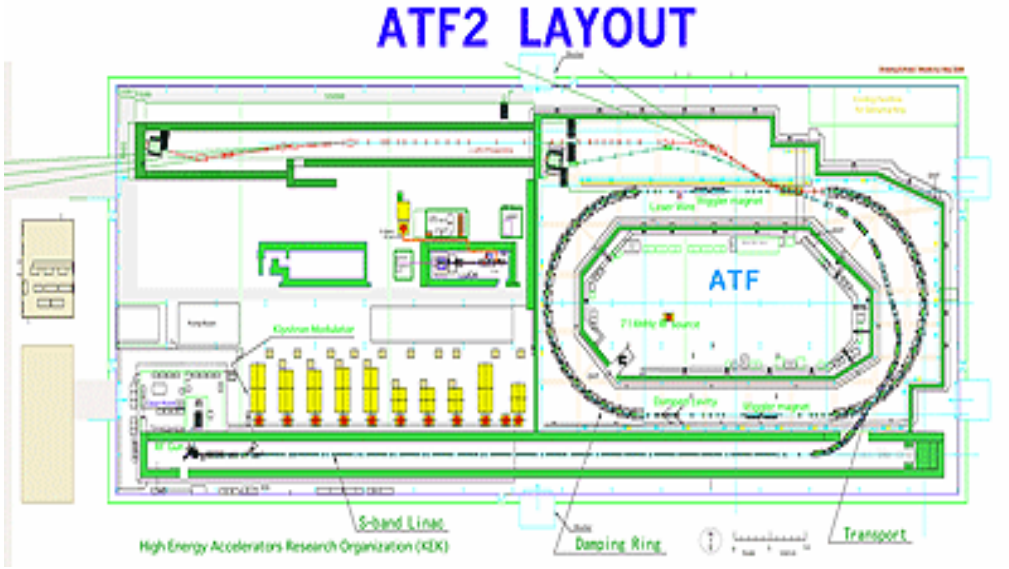
- Preliminary results are becoming available...





The Future - ATF2

- We are now involved in the BPM systems to be used in ATF2
- The BPMs have already been designed and shown to work well already
- We are in the process of designing the BPM control system, again, based on EPICS and the libbpm library



The Future - ESA

- This July, we will hopefully install our own mover system and BPM at the mid-chicane location
- This will allow more accurate orbit determination through the chicane
- Resolution and Stability of both the spectrometer BPM and electronics as well as the chicane as a whole with then be possible

LCABD WP 4.2 - Conclusions

- We have made a lot of progress in the last 6-12 months in all areas
- This is a (very!) brief overview of where we currently stand:
  - BPM Design and Fabrication - Full prototype ready
  - Electronics - Commissioned and ready for use
  - Control Systems - Two systems in development (ESA & ATF2)
  - Simulation - From spectrometer through to analysis
  - Consolidated Analysis code - A complete simulation and processing library is now available
  - NanoBPM - 15.6nm resolution, systematics and multibunch
  - ESA - Commissioned the chicane and seengood initial energy dependence
- We hope to continue this success for as long as possible!