LCABD WP 4.2 – Spectrometer and BPM Studies

- *Motivation*
- *Final Results from 2006*
- *Upgrades for 2007*
- *Conclusions*

The Collaboration

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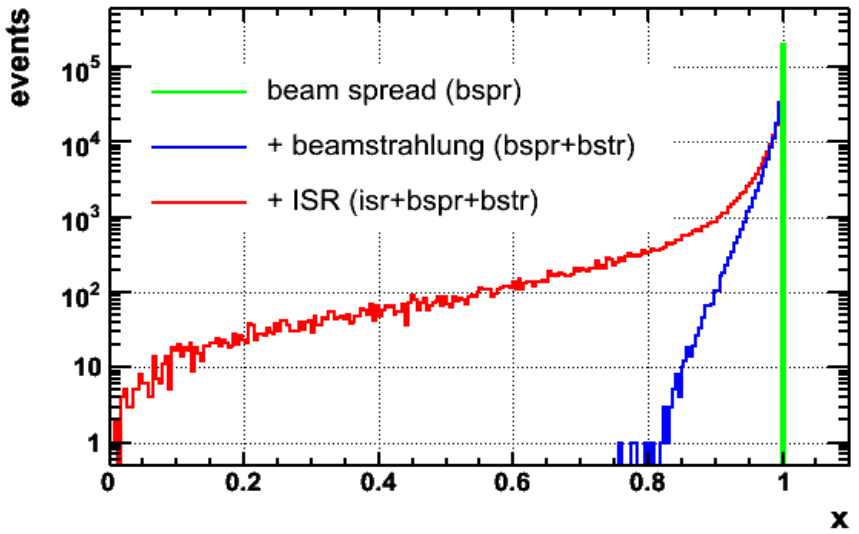
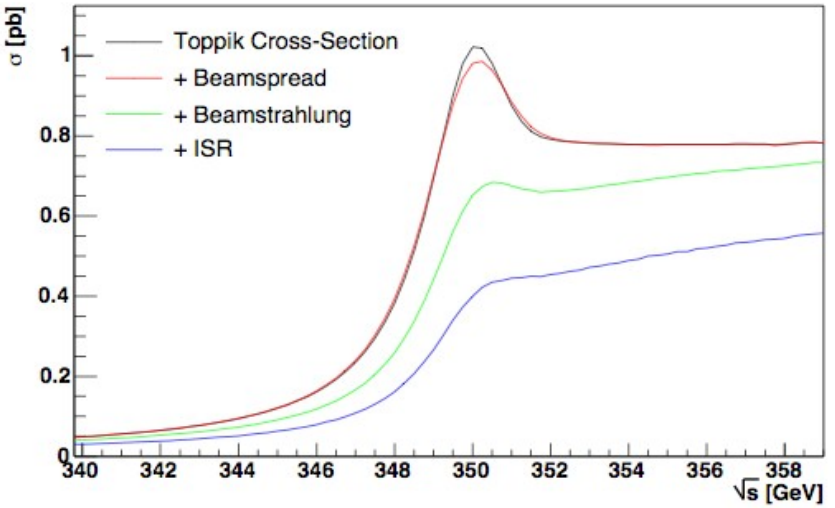
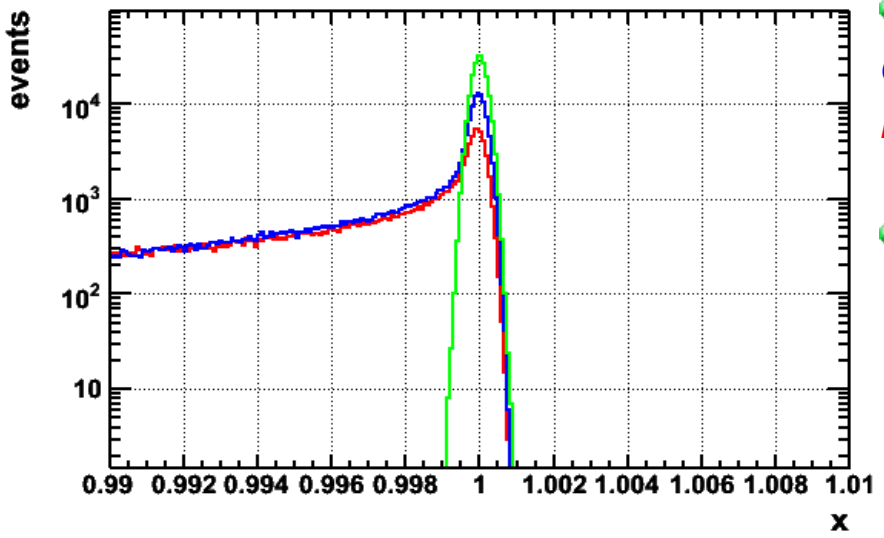
Motivation – Physics Case





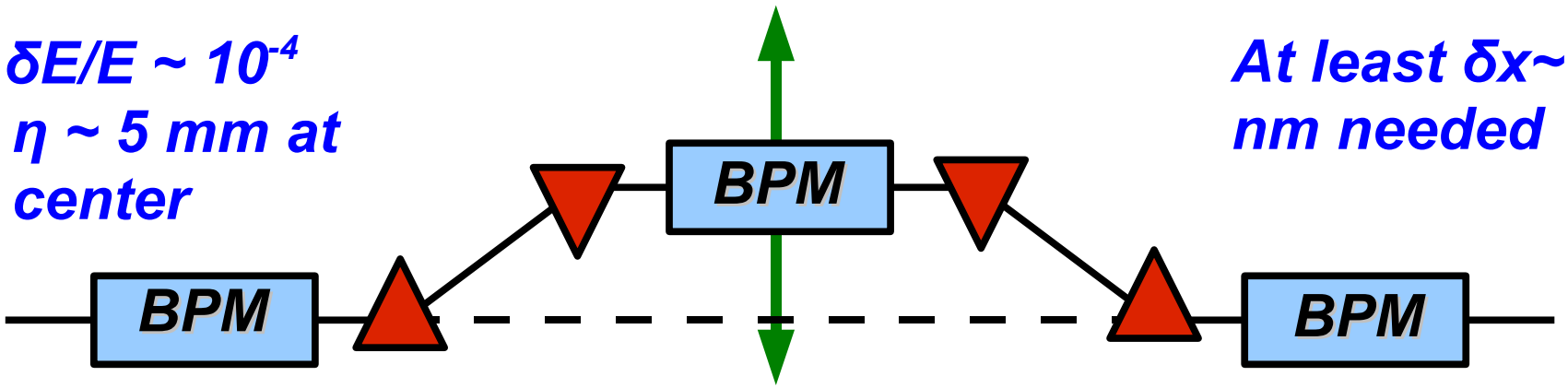


- ***Uncertainty on beam energy measurement contributes directly to the uncertainty on the ILC physics output...***
- ***Need for:***
  - ***Energy measurement accuracy 10^{-4}***
  - ***Stability and ease of operation***
  - ***Minimal impact on physics data taking***

Motivation – Beam Based Energy Measurement

- *WP 4.2 Goals:*

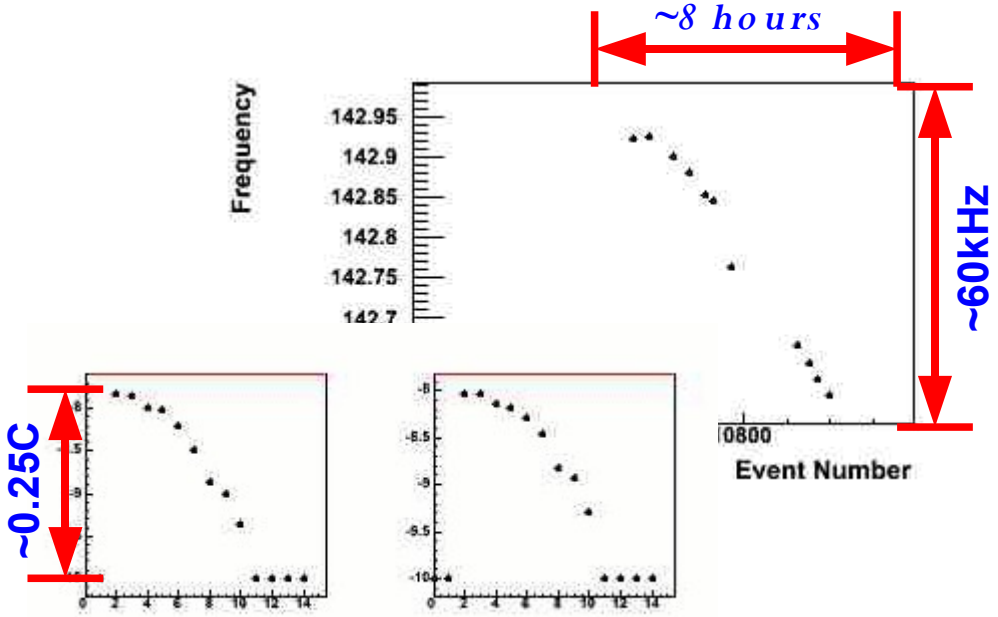
Study and design magnetic chicane for beam energy measurement using BPMs for a future linear collider



- *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 – Results

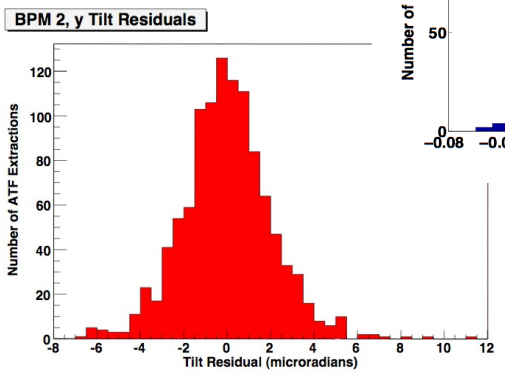


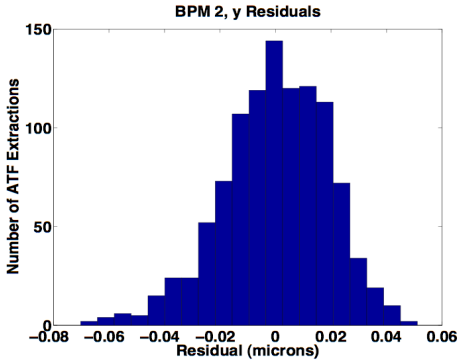
Temperature

- 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

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.

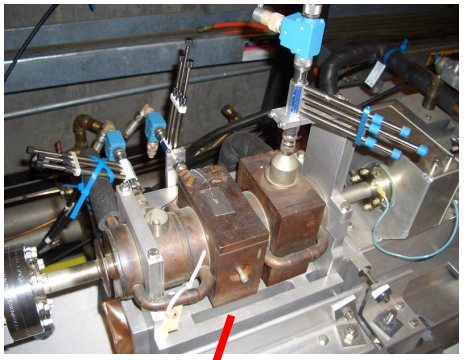


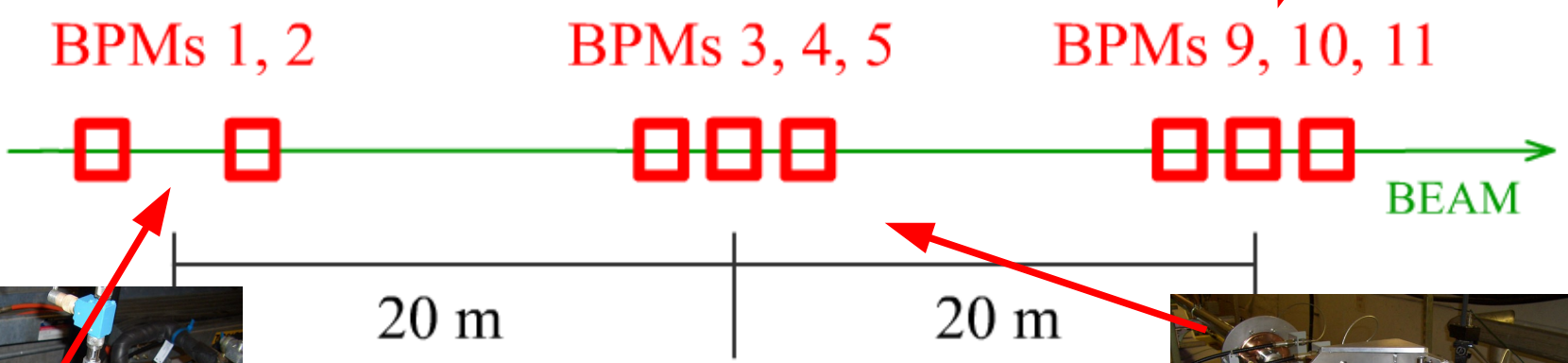


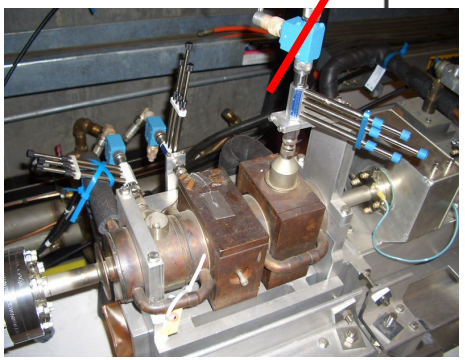
Now published in NIM: A578:1-22,2007

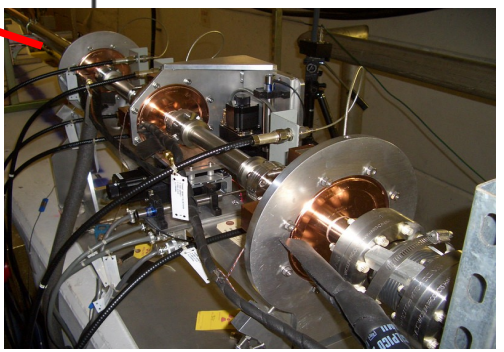
ESA 2006 (T474) Update

- *Final analysis of the data taken in 2006 is almost complete*
- *A lot has been learned from this data:*
  - *Algorithm optimisation*
  - *Calibration optimisation*
  - *Dominant Systematics*
  - *Required hardware upgrades*





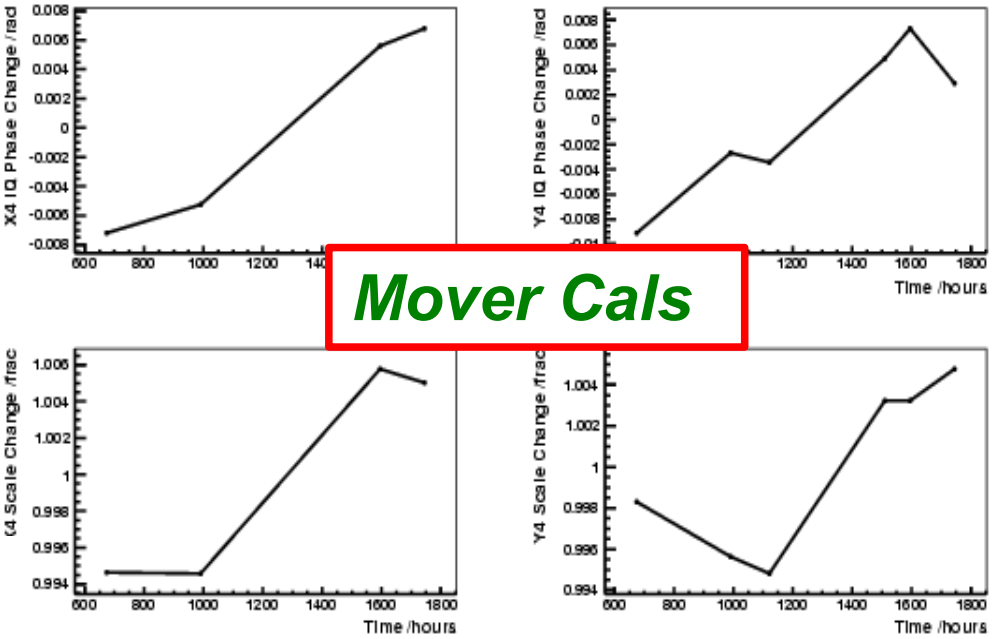




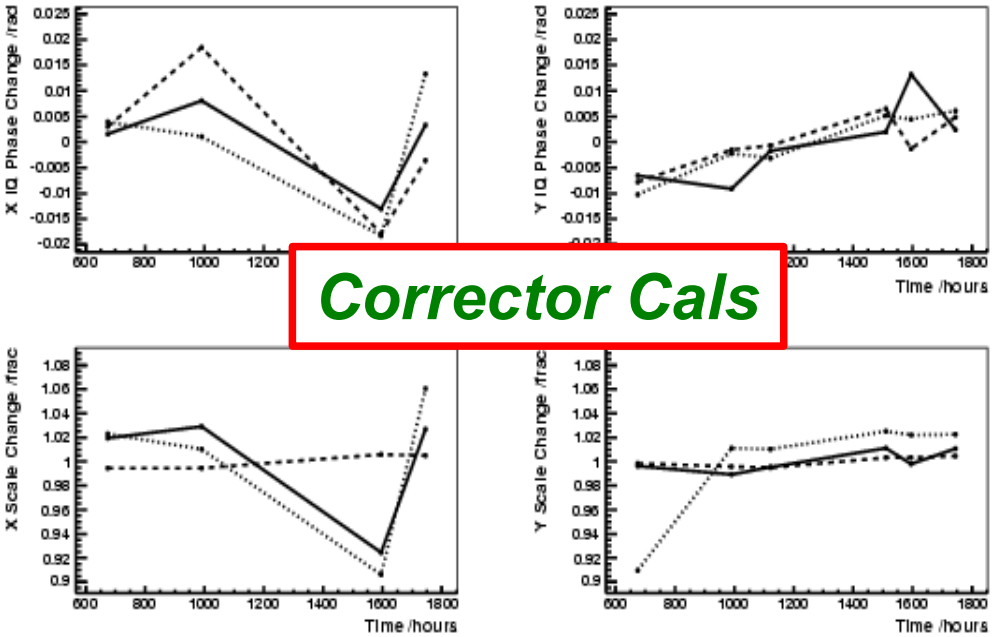
ESA 2006 (T474) Results – Calibration Stability

- *Two types of calibration were used*
  - *Corrector – enables calibration of all BPMs*
  - *Mover – Accurate steps and can use outer BPMs to remove beam jitter*

- *More accurate calibrations could be found by using the mover calibration for one BPM to correct the those of the others*



Mover Cals

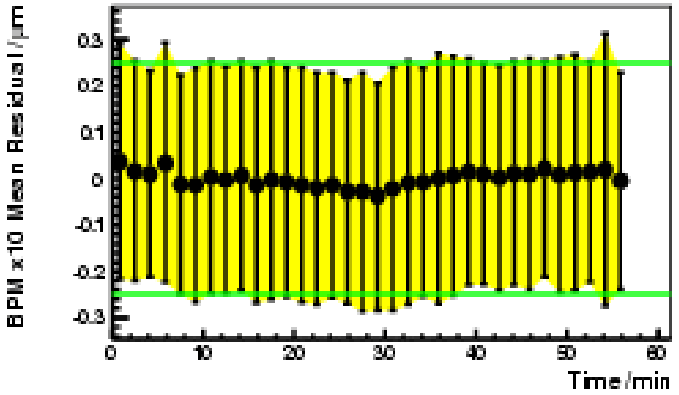


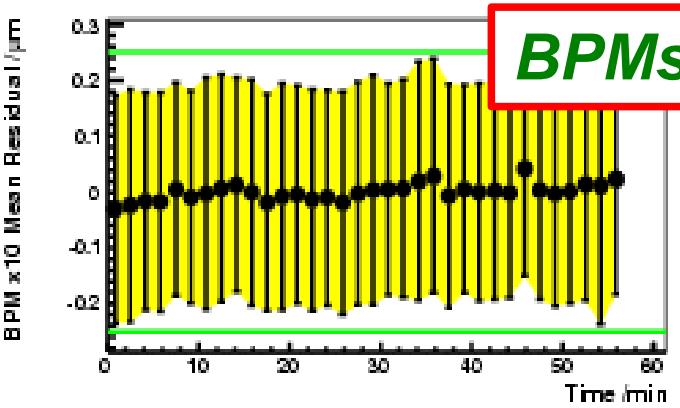
Corrector Cals

- *Over a 20 hour period, the variation in calibration constants were found to be:*
  - *Frequency: ~5kHz*
  - *IQ Phase: 0.01 rad*
  - *Scale: ~1%*

- *Given a typical offset of ~200 μm, this was predicted to have the following effect*
  - *Precision: ~150nm*
  - *Accuracy: ~2-10μm*

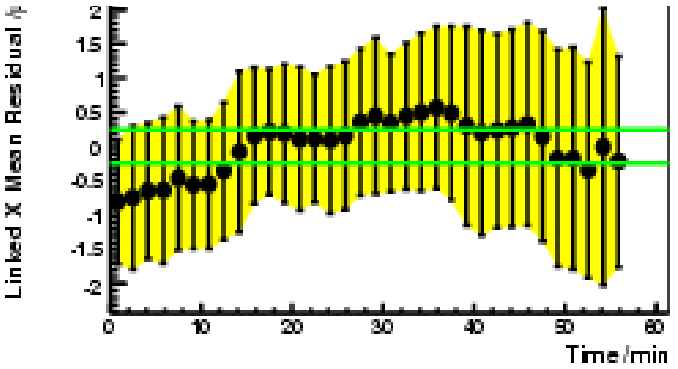
ESA 2006 (T474) Results – Short Term Precision Stability

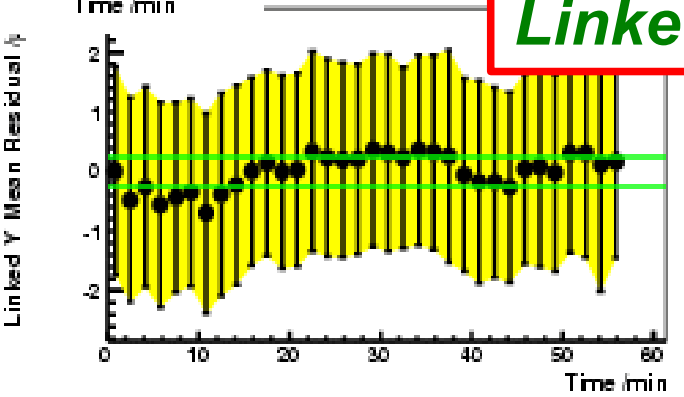




BPMs 9-11

Linked





NOTE:

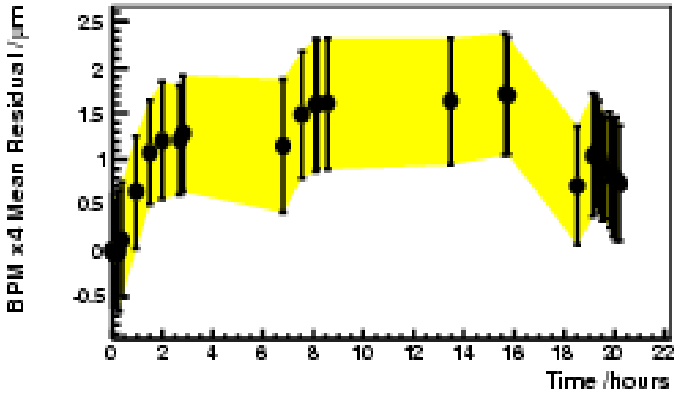
- All values in µm
- `Linked' refers to predicting the position at BPM 3 using BPMs 1-2 and 9-11

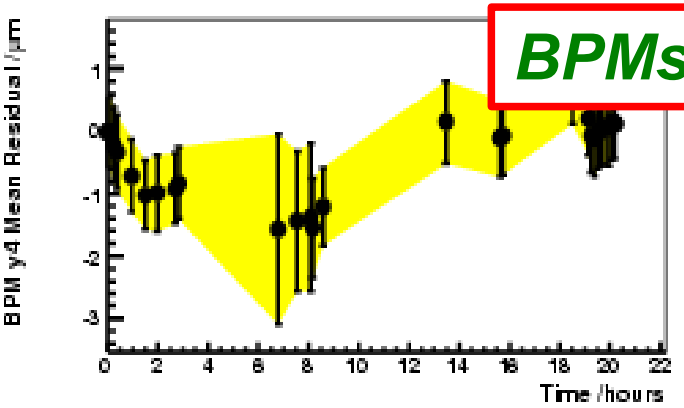
BPM	Precision (X)	Precision (Y)
1,2	0.93	2.01
3, 4, 5	0.56	0.47
9, 10, 11	0.21	0.17
Linked	0.77 (*)	1.20 (*)

BPM	Stability (X)	Stability (Y)
1,2	4	3
3, 4, 5	0.5	0.25
9, 10, 11	0.1	0.1
Linked	1.5	1.5

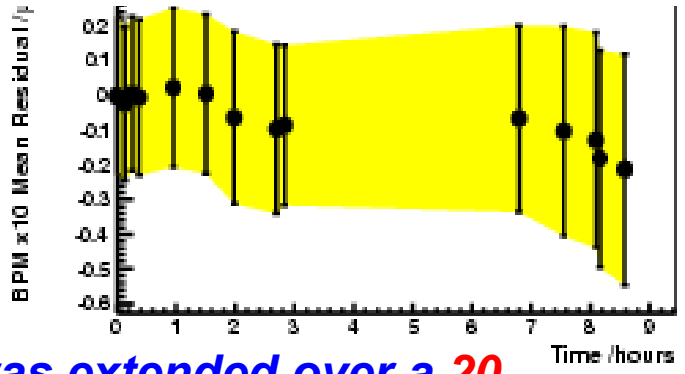
* Geometric Factor not removed

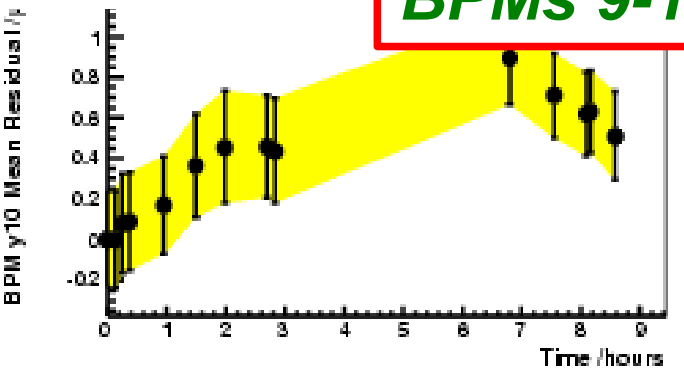
ESA 2006 (T474) Results – Long Term Precision Stability





BPMs 3-5





BPMs 9-11

NOTE:

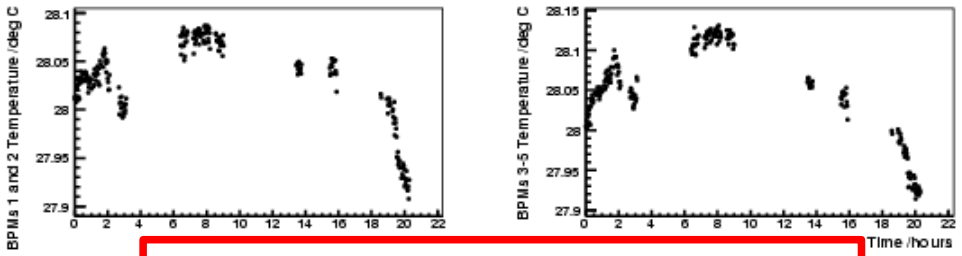
- *All values in µm*
- *`Linked' refers to predicting the position at BPM 3 using BPMs 1-2 and 9-11*

- ***The stability test was extended over a 20 hour period***
- ***BPMs 1 and 2 were limited by the thermal stability of the electronics***
- ***BPM 11 had a significant shift in frequency and a consequent change in calibration after 8 hours***

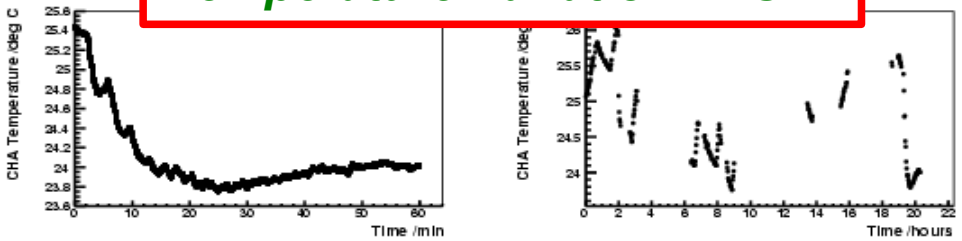
BPM	Stability (X)	Stability (Y)
1,2	10	10
3, 4, 5	1.5	2
9, 10, 11	0.1 (*)	0.1 (*)
Linked	20	15

** Results from only 8 hours rather than 20 hours*

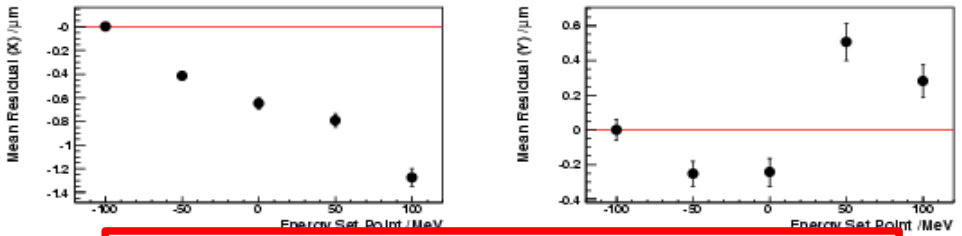
ESA 2006 (T474) Results – Systematics



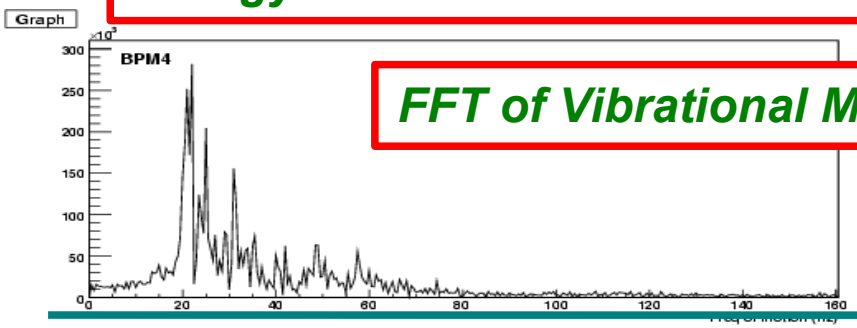
Temperature Variation - ESA



Temperature Variation – CHA



Energy Variation vs. BPM Offset



FFT of Vibrational Motion

- *Several systematic sources were investigated*
  - *Temperature*
  - *Magnetic Field*
  - *Vibrational Motion*
  - *Charge*
  - *Offset*
- *Temperature was found to be limiting the stability for most BPMs due to a change in calibration*
- *The Earth's field was found to produce an offset of 1.2 μm with a change in energy of 200 MeV*
- *Vibrational Motion was found to dominate the precision of BPM 4*
- *There was some slight dependence of the residuals on position and charge*

ESA 2006 (T474) – Conclusions

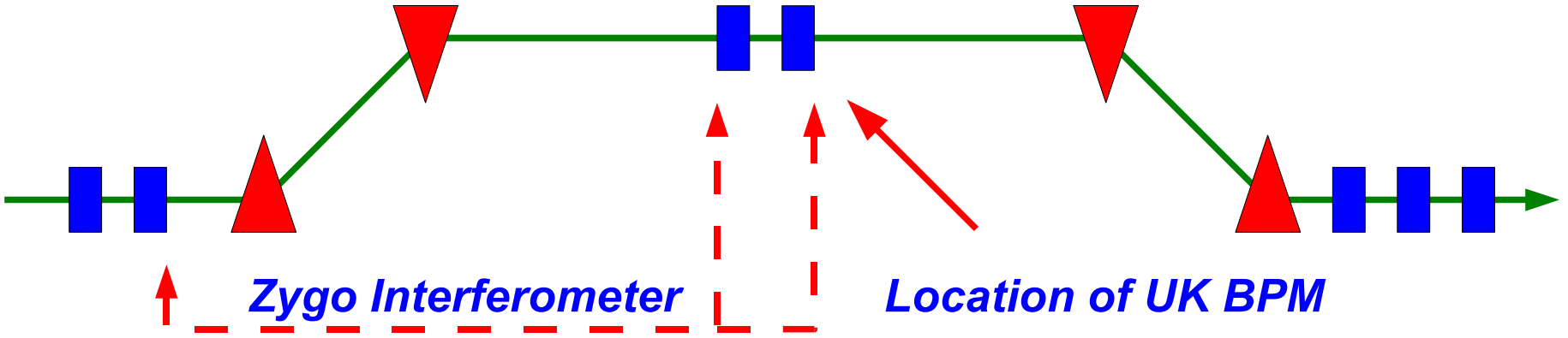
- The algorithms and systems used during 2006 running have been optimised to achieve the best precision and stability of the BPMs
- Precision of 250nm or better has been achieved and maintained for several BPMs over a minimum of 1 hour and a maximum of 8 hours
- Limitations on these results was found to be due to
  - Electronic Noise
  - Vibrational Motion
  - Temperature Induced Calibration Changes
- All analysis for this paper has been completed using the `home-grown' libbpm library and has proved this code is ready for deployment in both online and offline systems
- A NIM paper is in its third (and hopefully final) draft
- Submission planned for end of September/beginning of October

ESA 2007 (T491) – Progress in 2007

- *A number of upgrades were carried out at ESA preceding this years running*

- *These included*
  - *UK BPM, Mover and electronics*
  - *Calibration Tone*
  - *Calibration routine using Helmholtz Coils*

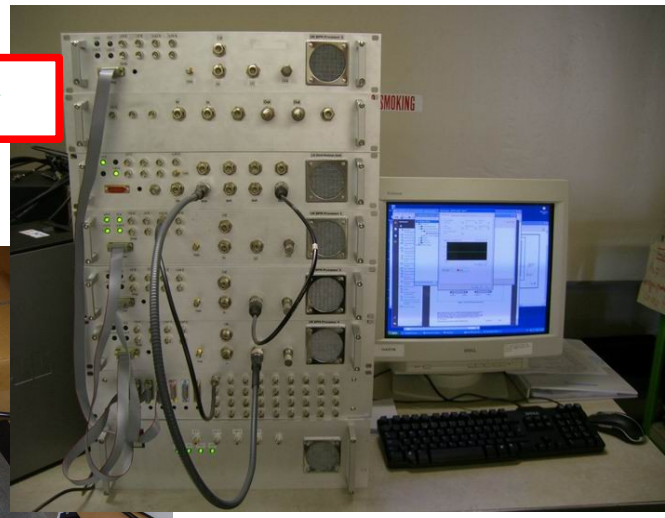
- *The major part of the upgrade was the installation of the four dipole magnets that formed a working spectrometer prototype*

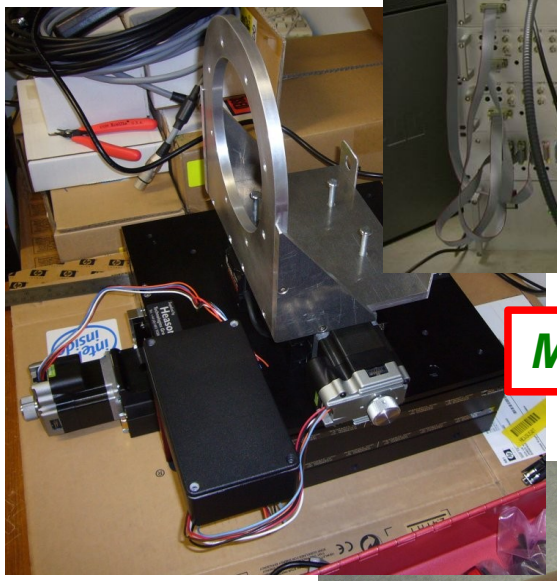


ESA 2007 (T491) – UK Hardware

- An entire BPM system including mover and electronics has been designed and built by the group
- Installation of the electronics was performed in early 2007 with the BPM and mover installed in time for the July run
- The electronics were tested on BPMs already present (9-11) and comparable precisions were found as with the SLAC electronics (~150nm)
- The mover and read back system was tested using the interferometer and was shown to work to a high degree of accuracy
- The BPM showed considerable cross-talk due to manufacturing problems
- A precision of 1.5 – 2 μm was achieved.
- See Bino's talk for more info on the UK equipment and future plans...

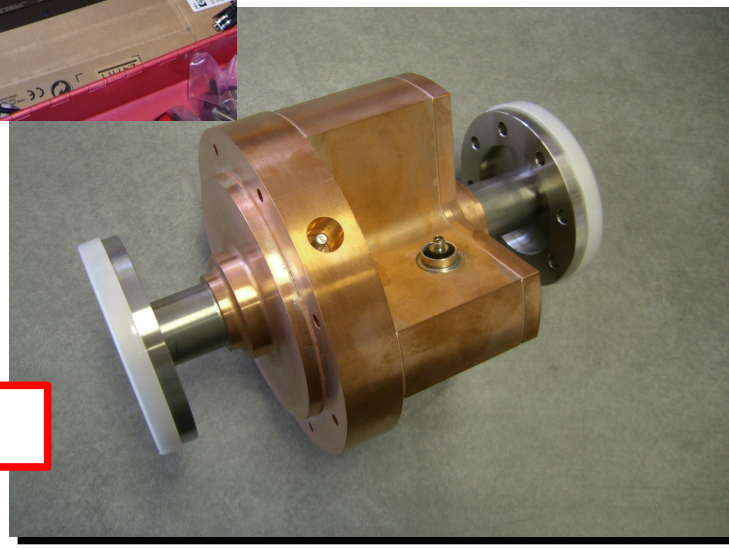
Electronics





Mover

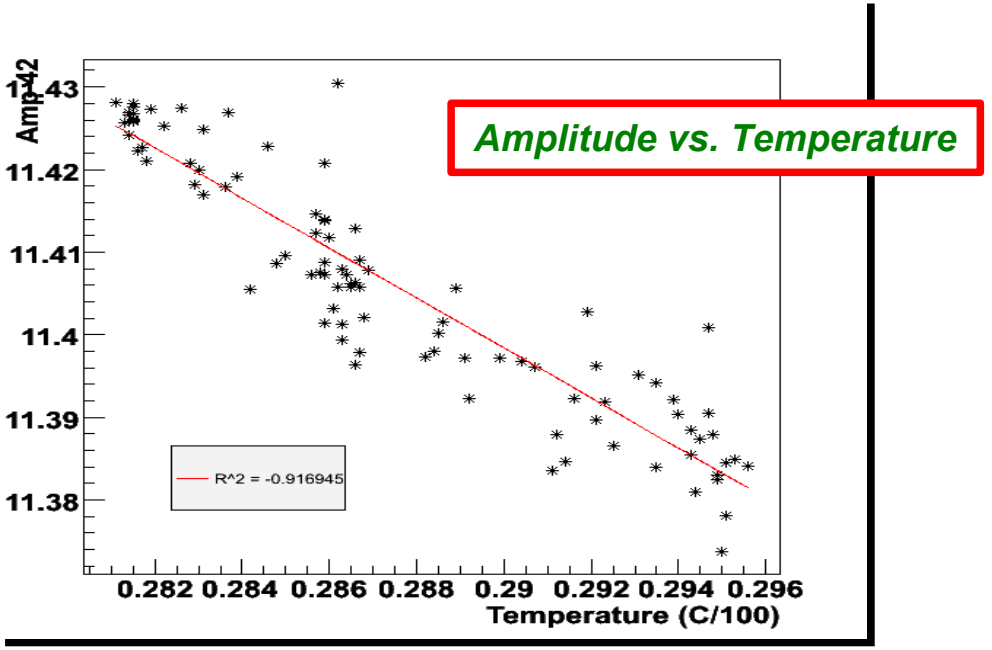
BPM

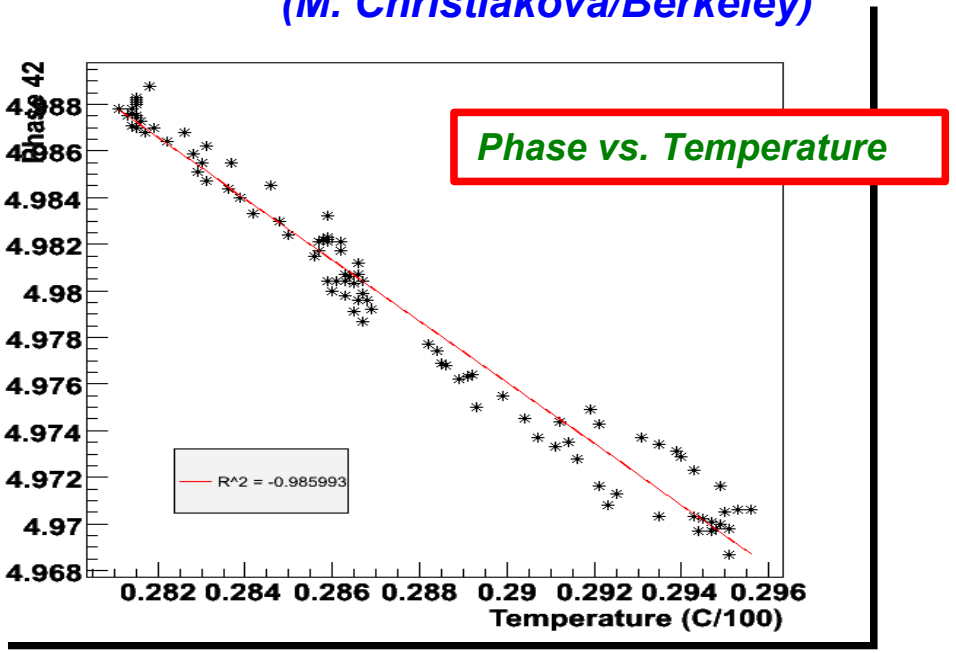


ESA 2007 (T491) – Calibration Tone

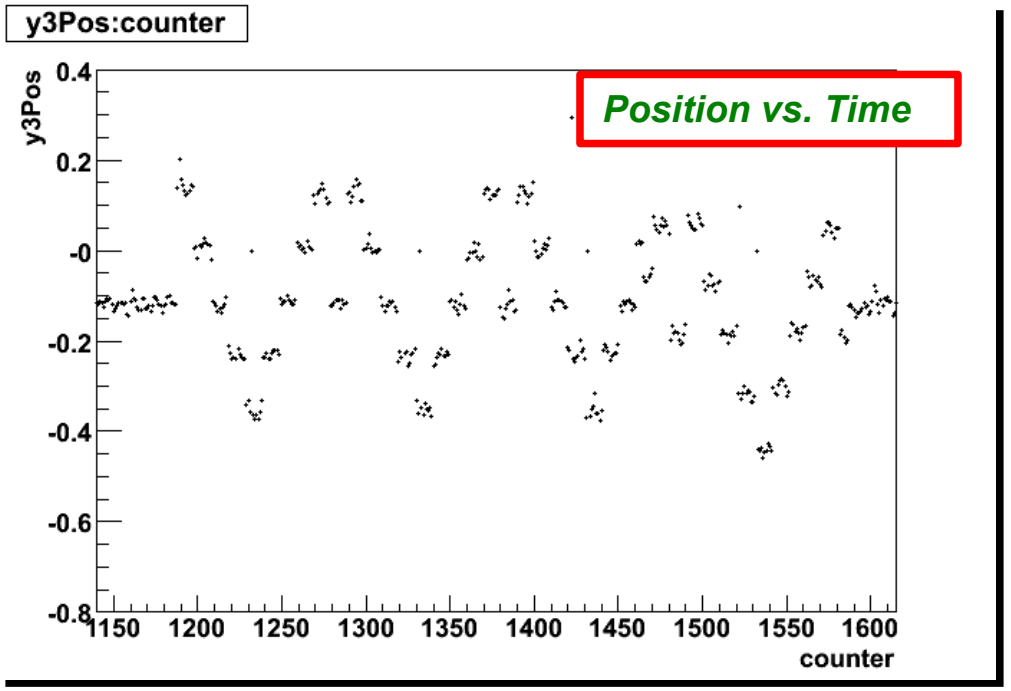
- The installed UK BPM electronics also included a CW calibration tone that could be used to check gain and phase variation
- The signal was split to go through the electronics of all the BPMs
- Using the 0.1 Hz trigger supplied by the SLAC control system, `online' calibration drifts could be corrected
- Initial (offline) checks have been made showing the variation of gain and phase with temperature

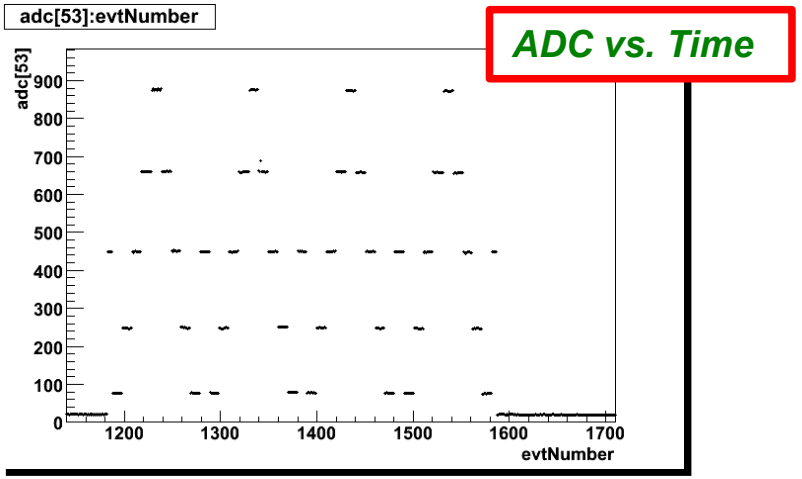
(M. Christiakova/Berkeley)





ESA 2007 (T491) – Helmholtz Calibration

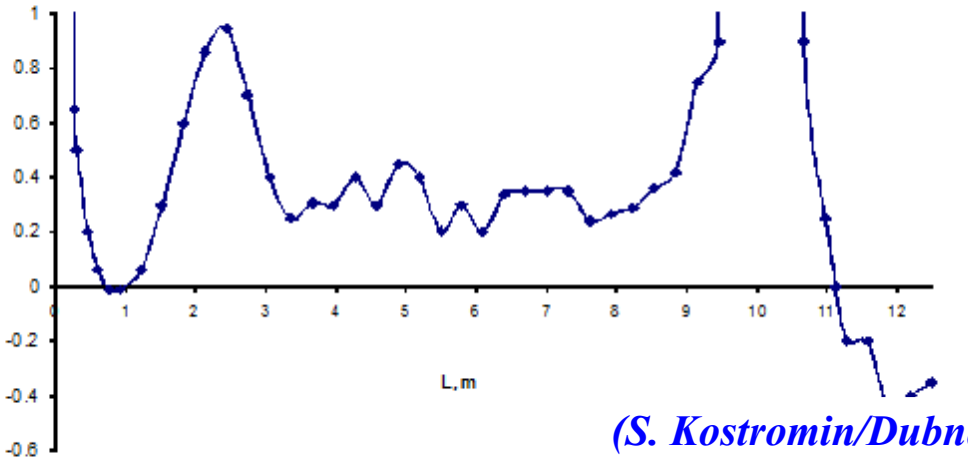




- *Calibrating using the upstream steel correctors was found to be inaccurate due to drifts in the beam position during a cal step*
- *Another method was implemented that involved using helmholtz coils*
- *These could reach the desired field strength almost instantly and therefore a dithering calibration could be used*
- *Instead of averaging over 50-100 events in each step, the scale was determined for a cal consisting of 5 events per step*
- *The scales were then averaged over several cals resulting in an improvement of scale variation from 40% to 5-10%*
- *ADC values were set indicating the position in the cal cycle allowing automation of the calibration*

ESA Update – Initial Spectrometer Results

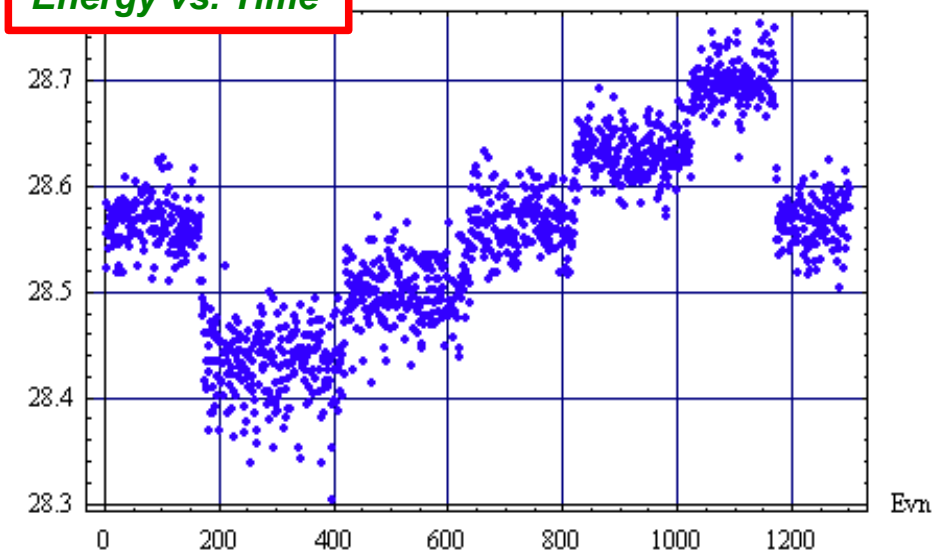
Residual Field vs. Chicane Length (vertical)



(S. Kostromin/Dubna)

- The magnets were profiled in Nov. 06
  - Field Integral RMS Stability: 60ppm
  - Bdl relative RMS Stability: 100ppm
- The beam energy was changed and the central BPMs moved to follow the deflection
- Step were clearly seen and could be correlated with the upstream `Energy BPM'
- Current energy resolution: ~10 MeV

Energy vs. Time



LCABD WP 4.2 – Conclusions

- *The work completed in 2006 at both ATF and ESA has been written up and has either been or will be published. In summary, we have demonstrated:*
  - *15.6nm position resolution within a triplet*
  - *~800nm position resolution across a 40m beamline*
  - *Stability within a triplet of a few hundred nm over 1-8 hours*
  - *An understanding of the systematic issues dominating the BPMs*

- *In 2007, the following was achieved at ESA:*
  - *Installation and commissioning of UK BPM, Mover and Electronics*
  - *Improved calibration scheme*
  - *Introduction of a calibration tone to improve on results from 2006*
  - *Installation and operation of a full spectrometer chicane*

- *Now on to LCABD2...*