BPM-Based Energy Spectrometer

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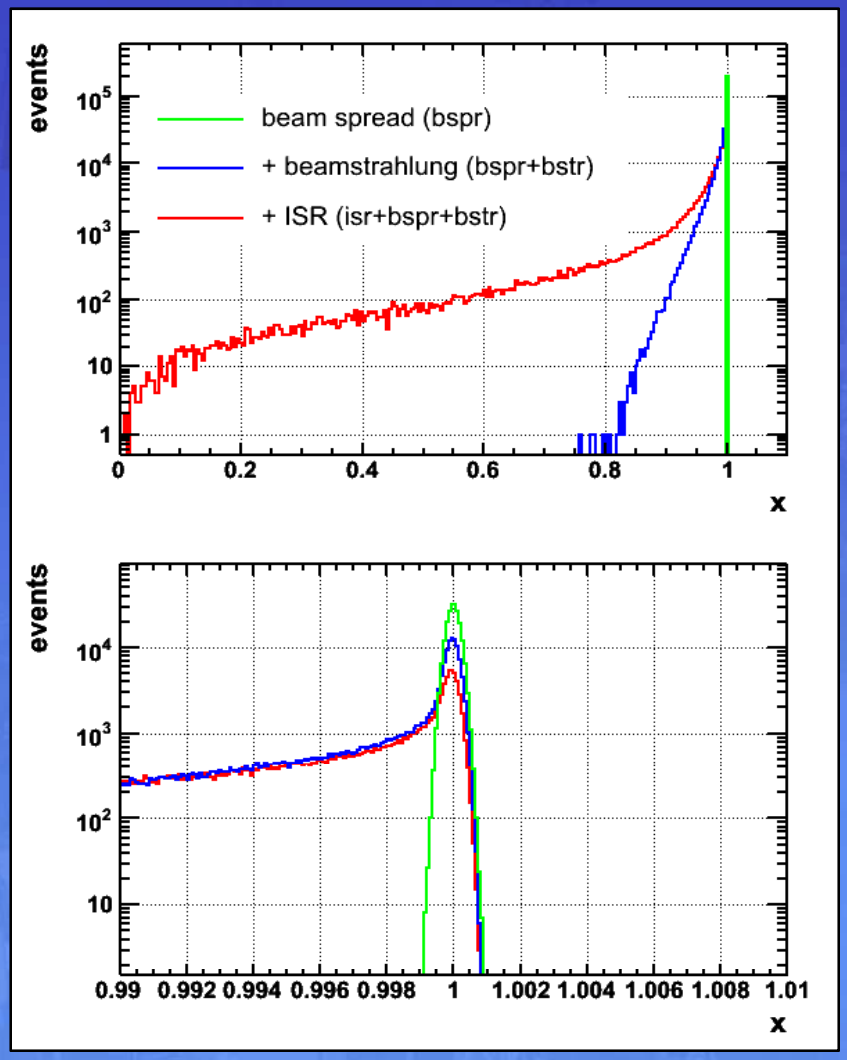
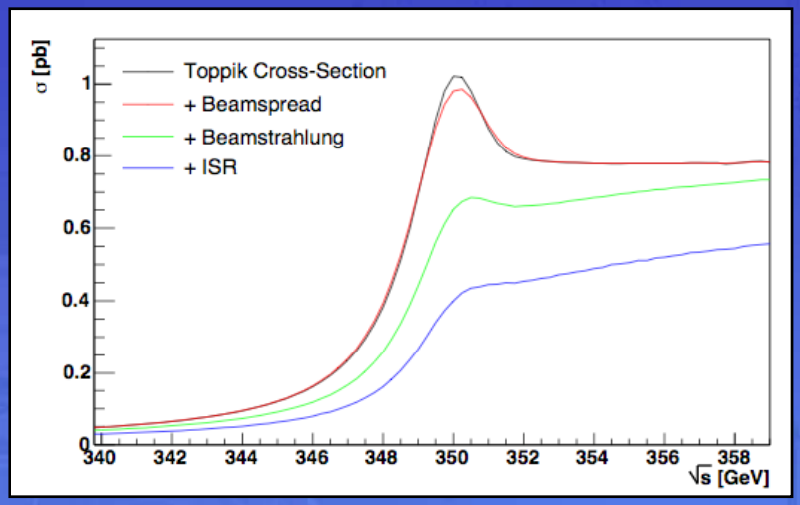
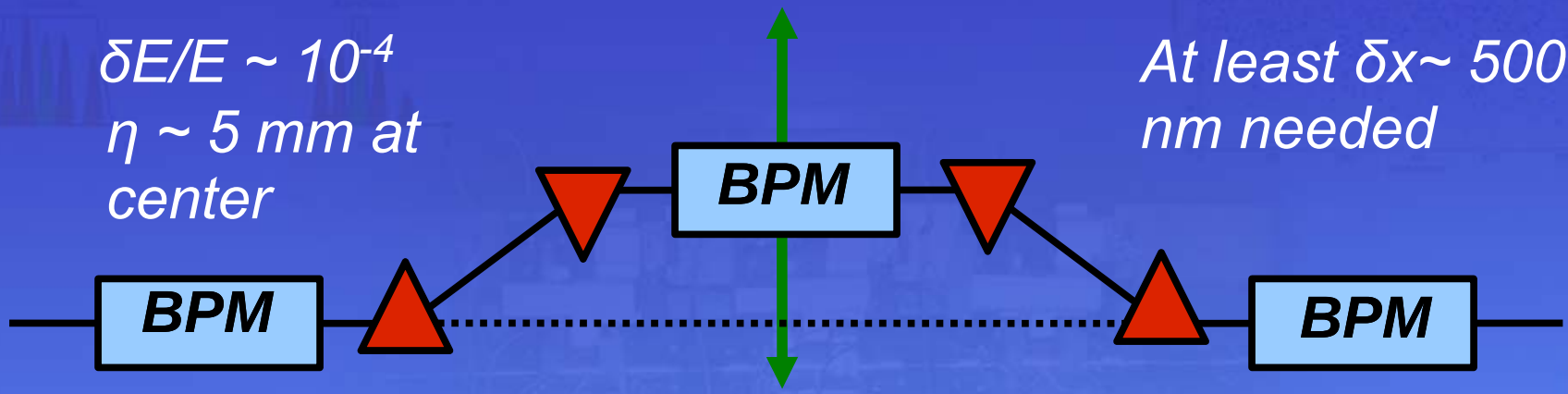
Physics and spectrometer





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

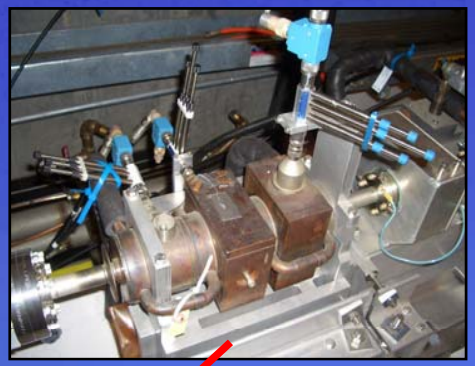
BPM based spectrometer

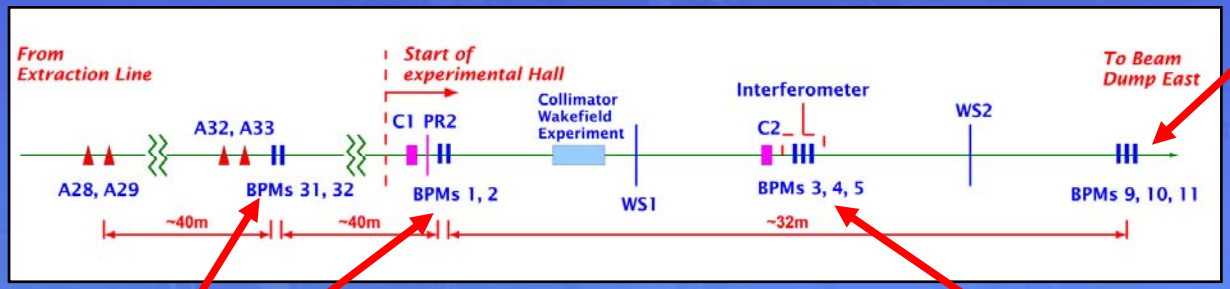


- Accuracy of the energy measurement = accuracy of BPMs + accuracy of BdL + many other things
- NanoBPM at ATF: test resolution, try different analysis methods, BPM stability tests, multibunch operation, advanced electronics techniques, inclination of beam in BPMs
- ESA at ATF: test stability of BPMs and of a full implementation of 4 magnet chicane and 3 BPM stations + investigate operational issues

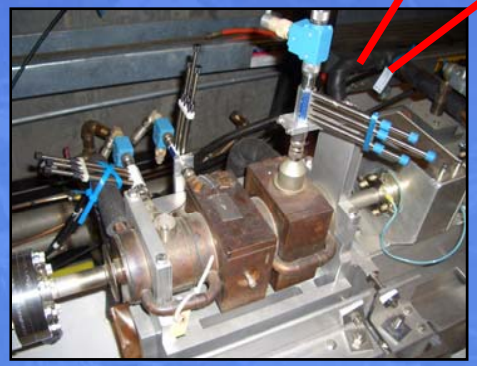
ESA – BPM and spectrometer study

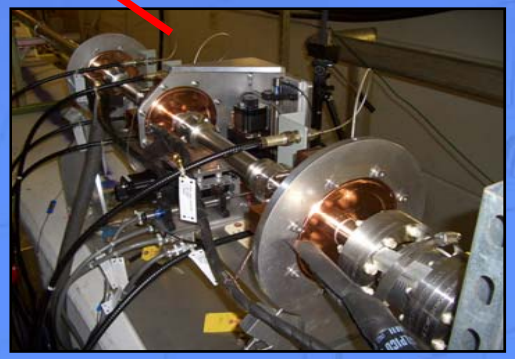
- Tests with a unique high energy beam (28.5 GeV, $2 \cdot 10^{10}$ particles per bunch)
- Analysis of the data taken in 2006 is now complete, a NIM paper has been accepted for publication
- A lot has been learned from this data:
  - BPM stability measurements
  - Algorithm optimisation
  - Calibration optimisation
  - Dominant systematics
- More data taken in 2007, including full spectrometer data, is being analysed
- Planning one more run in June 2008



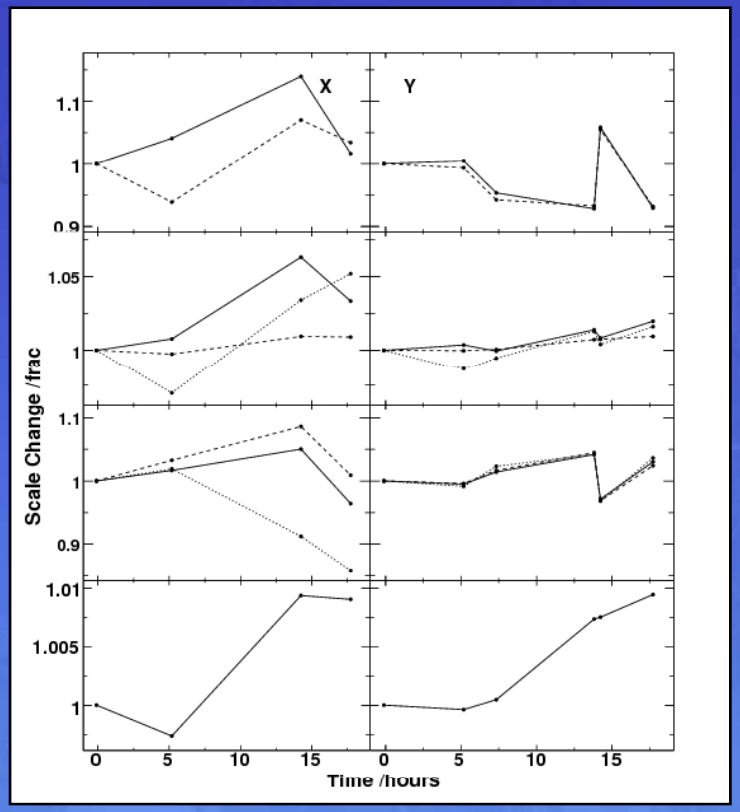


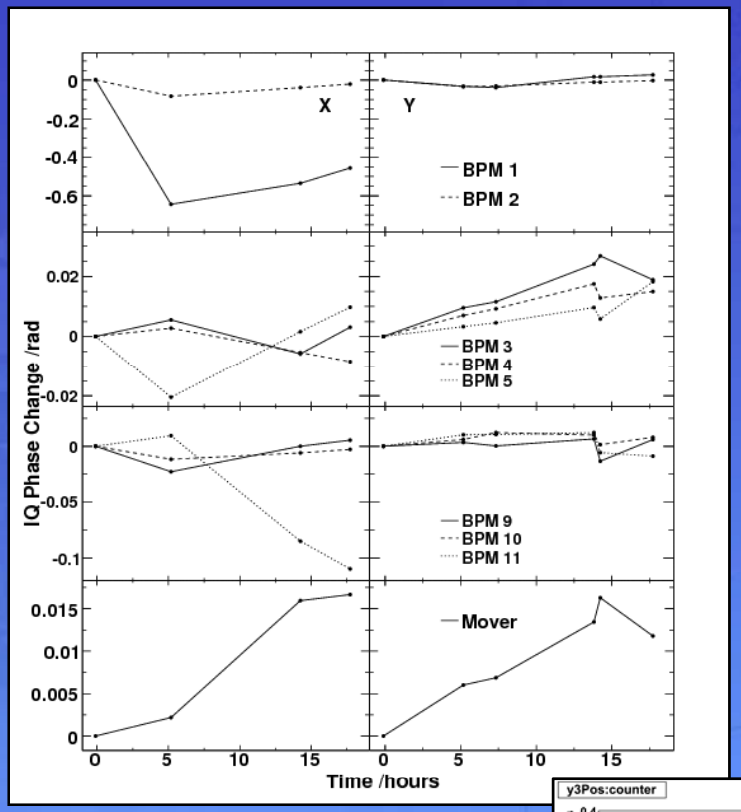
ESA beamline as in 2006

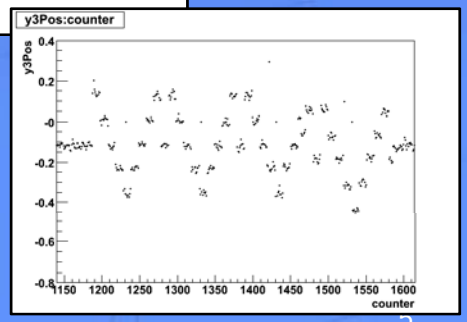




Calibration stability

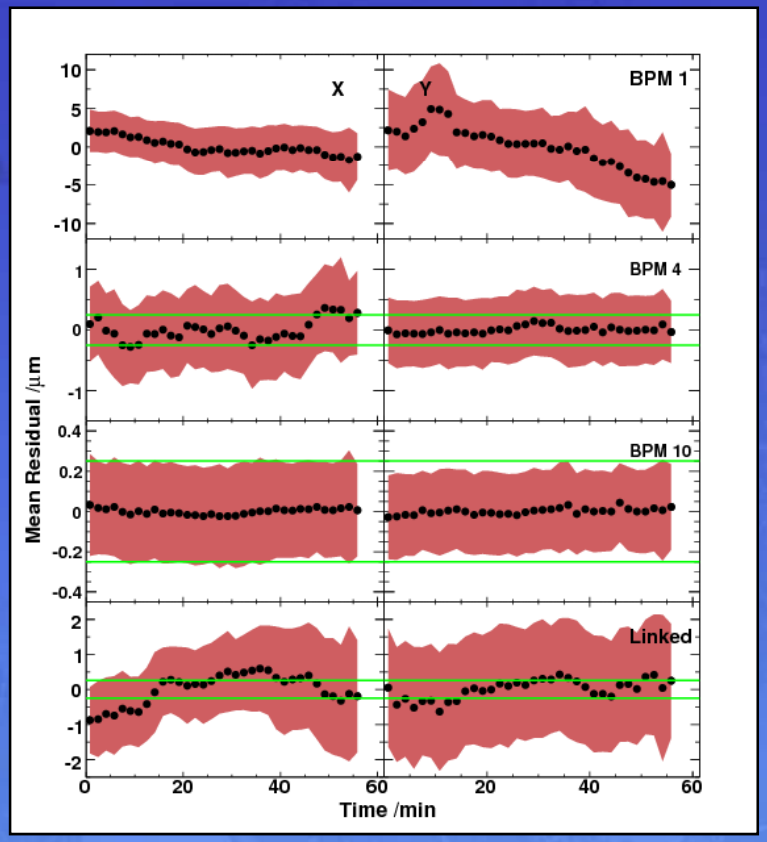


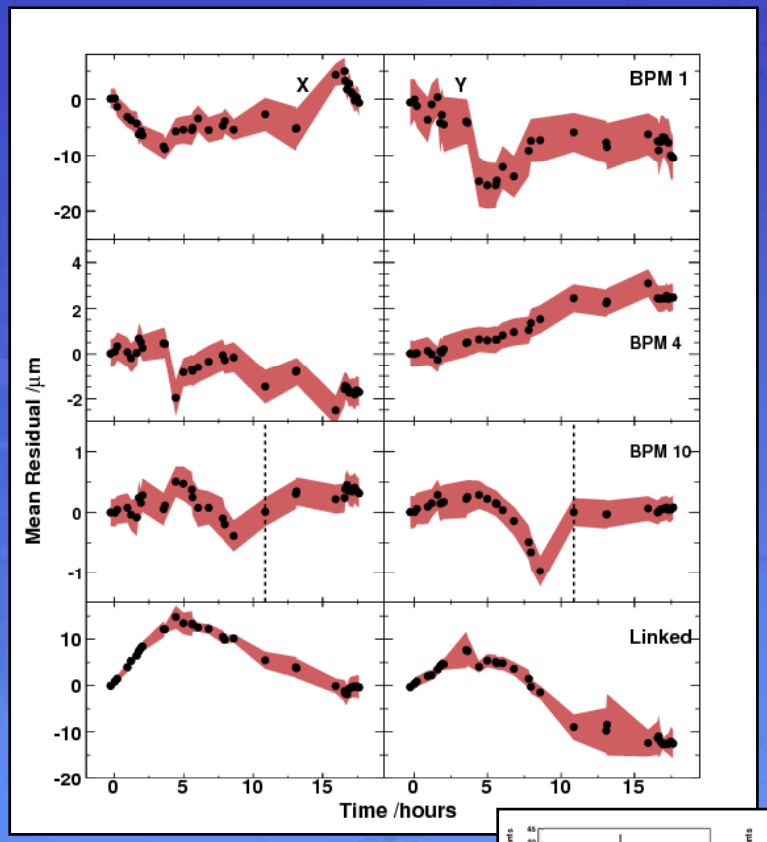


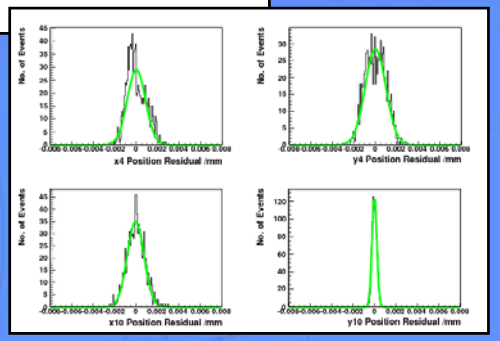


- studied changes of calibration coefficients in time
- results from calibrations obtained with help of corrector magnets, refined with a mover calibration (only one BPM on the mover!)
- calibration seems to be affected by changes of the beam incline
- working on faster corrector calibrations + putting more BPMs on movers for a cross-calibration

BPM stability

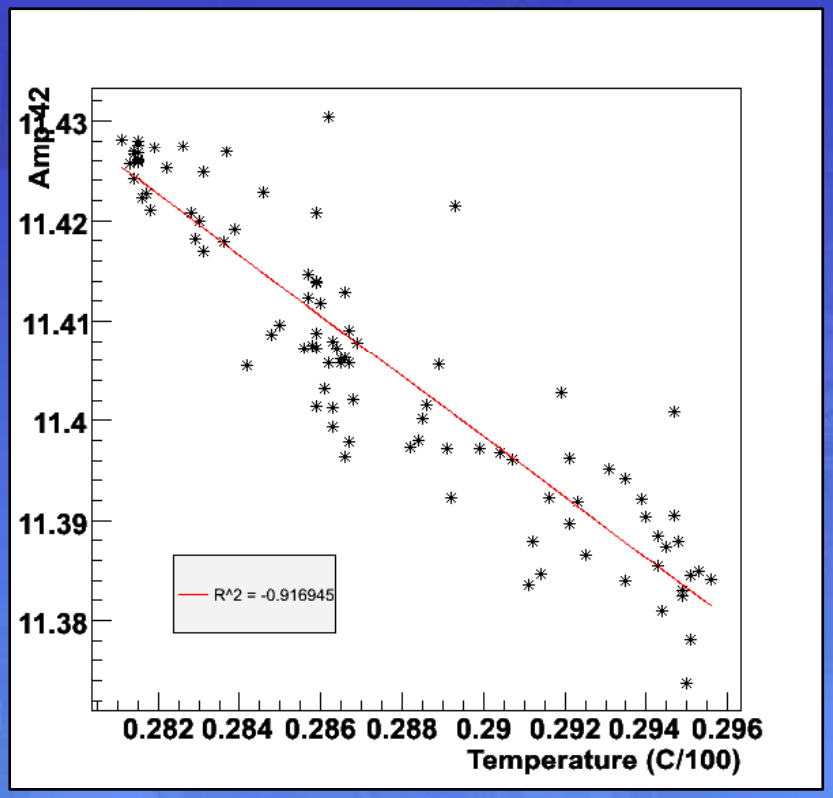






- um level resolutions obtained for all BPMs
- short-term drifts at um level
- long-term drifts at a few um level
- gain variations – the main suspect to cause the drifts
- need to monitor gains in-situ

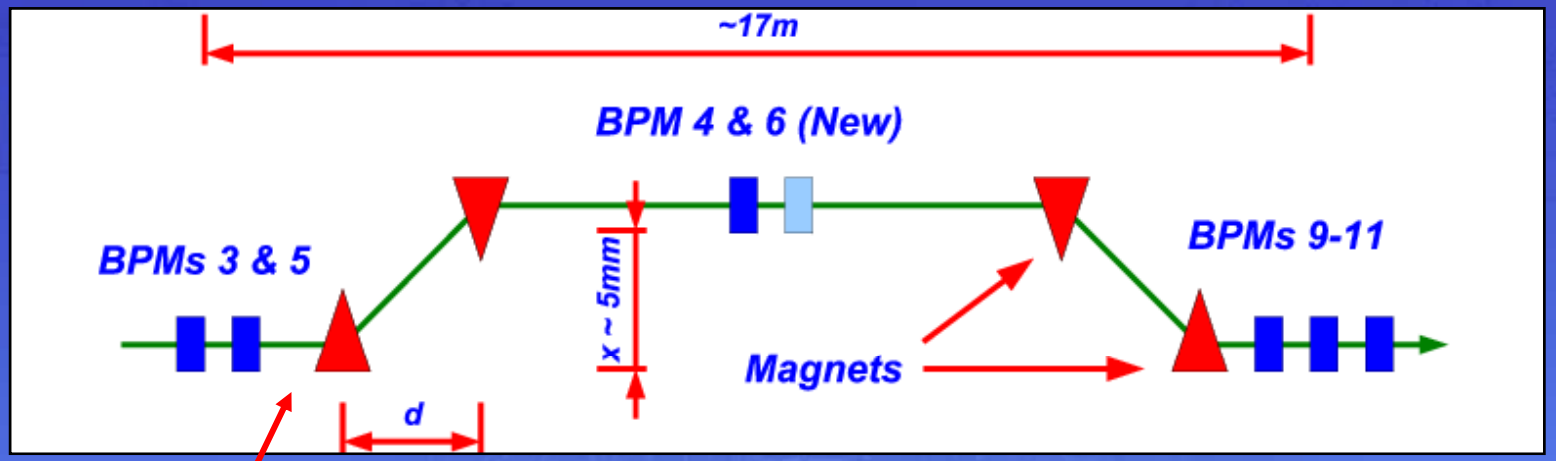
Gain monitoring system



- Essential component for understanding drifts etc
- Feed electronics with constant level CW signal and monitor changes when the beam is not present
- Developed in UK in collaboration with LBNL
- Preliminary studies indicate temperature correlated drifts

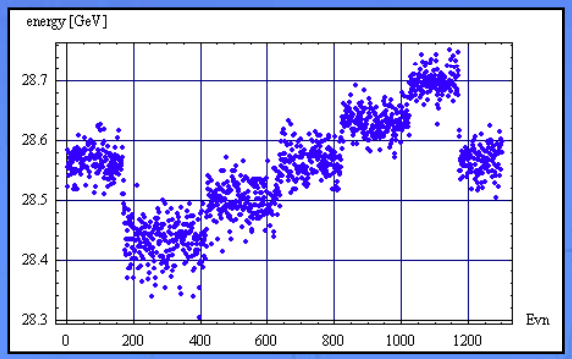
- Planning to extend the system to all BPM channels for the last run in June this year

ESA – spectrometer studies

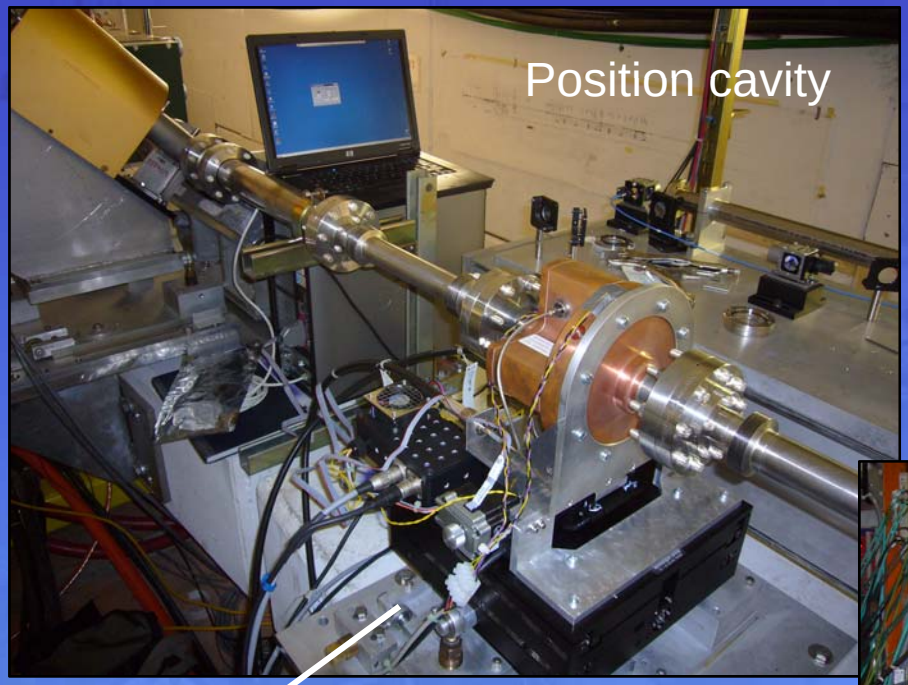


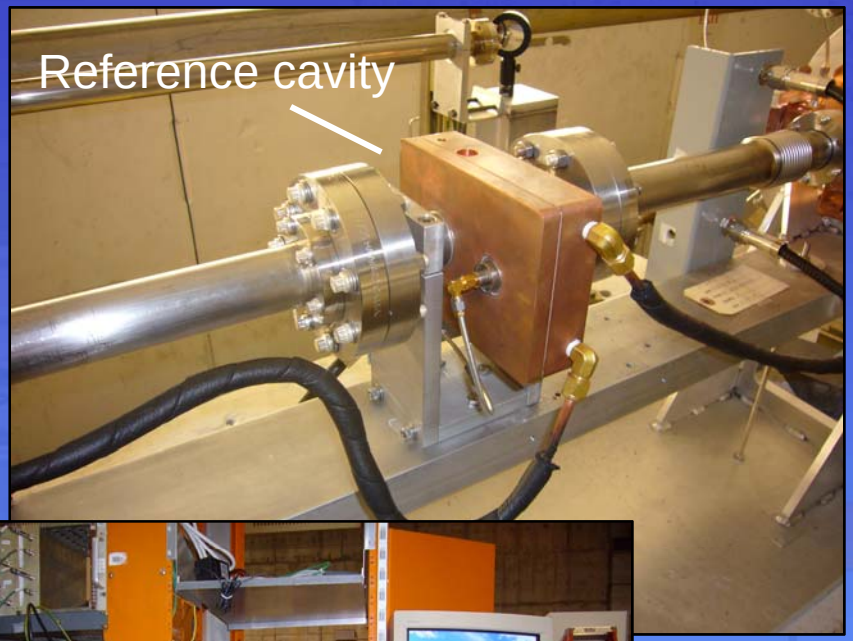
- Full spectrometer tests to demonstrate (relative) precision and get some operational experience
- Some data has already been taken in 2007, analysis in progress

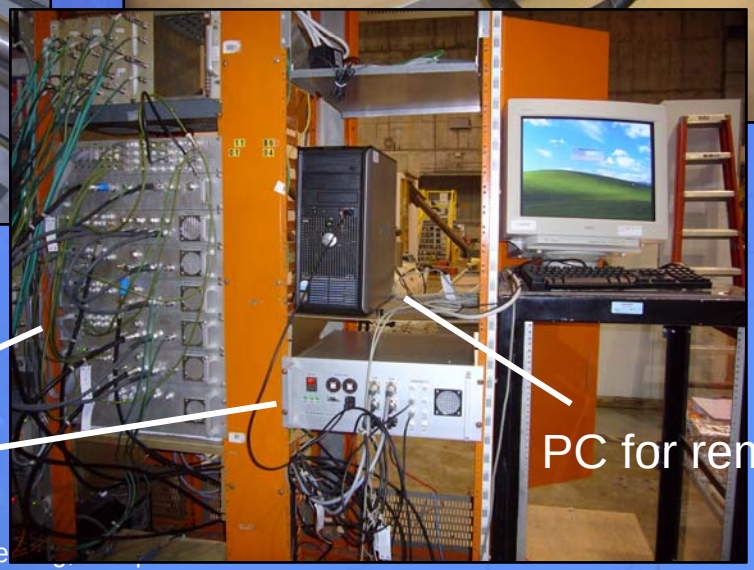
- Energy scan as seen by the spectrometer



BPM prototype in ESA beamline

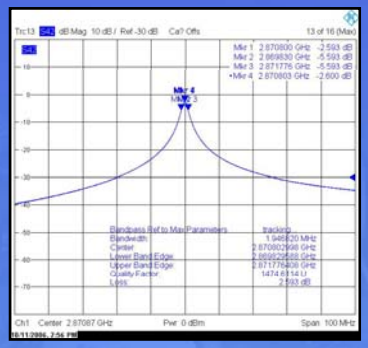




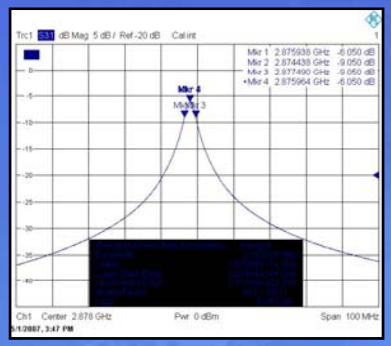


Prototype cavity

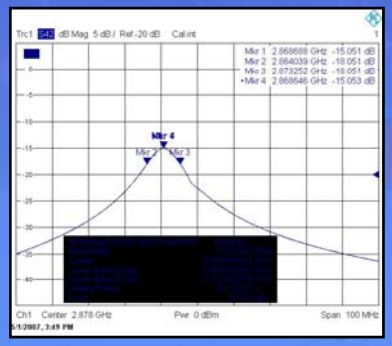
- The first brazed prototype hasn't been that successful
- Gaps between parts were left, reducing the Q-value, changing the frequency, introducing a high x-y coupling
- Brazed a few test pieces, which looked much better, were planning another prototype
- Work stopped because of the funding situation...



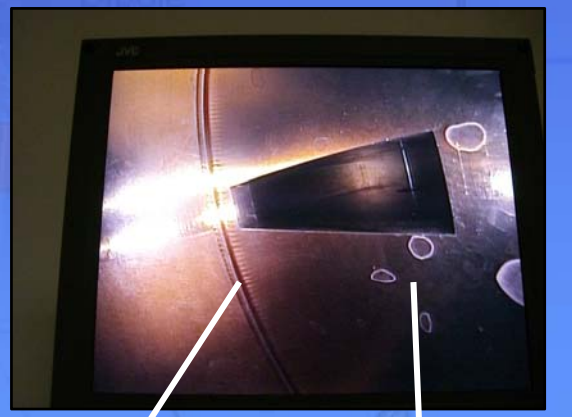
- Al prototype transmission: Q_L = 1470



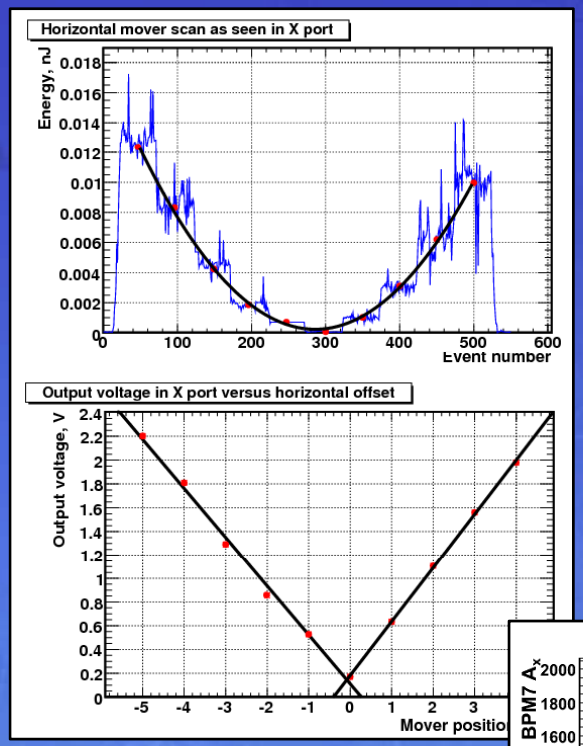
- Cu prototype, "good" channel transmission: Q_L = 950



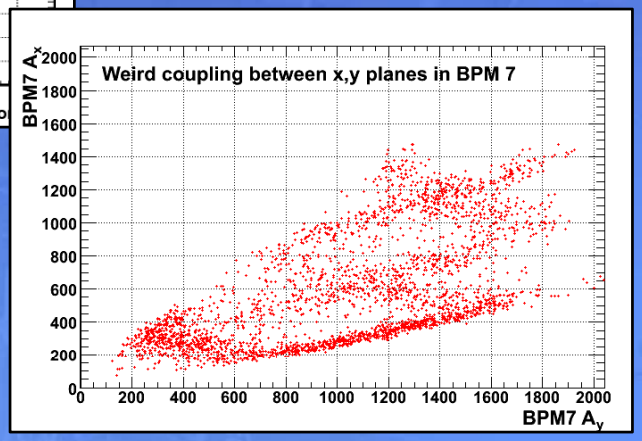
- Cu prototype, "bad" channel transmission: Q_L = 300

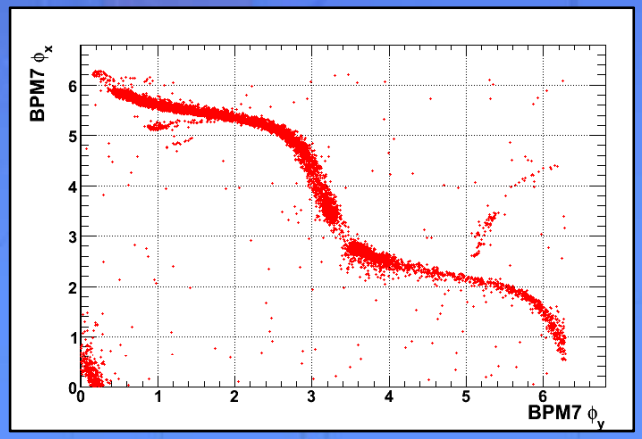


Beam test results



- Sensitivity measured close to expected: ~0.45 V/mm/nC vs. 0.7 V/mm/nC
- Non-trivial dependence of the signal on the offset in both x and y has been observed
- Have some 2D mover scan data, still analysing

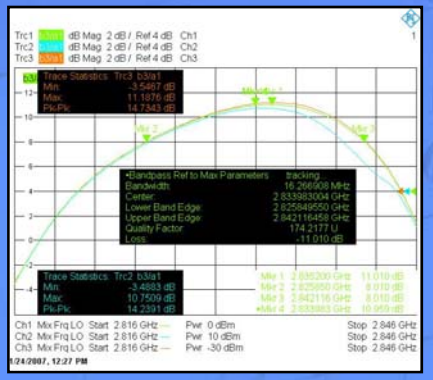




BPM electronics

- Simple mixer down-conversion electronics
- Some advanced features such as remote control of attenuation and LO amplification, monitoring voltages, potentially also switches control
- Concentrate on simplicity and high performance
- Tests at SLAC indicated 200 nm resolution
- IF part recently revised for better suppression of out-of-band signals
- Final filtering moved to digital processing for better flexibility
- Integrated PCB version can be made with some more engineering

- Not will be used for ESA experiment anymore...
- But, 10 modules will be installed in ATF2 for the final focus QBPMs with a dedicated gain monitoring system, so
- Can do some stability studies at ATF!

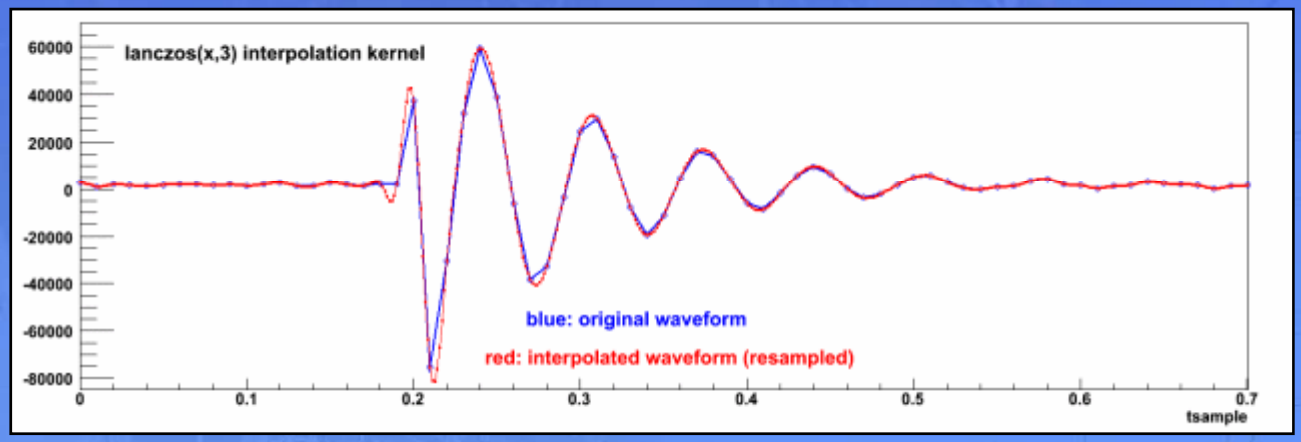


Digital signal processing

- *libbpm* – core library, containing basic BPM signal processing, simulation and other useful functions, plain C

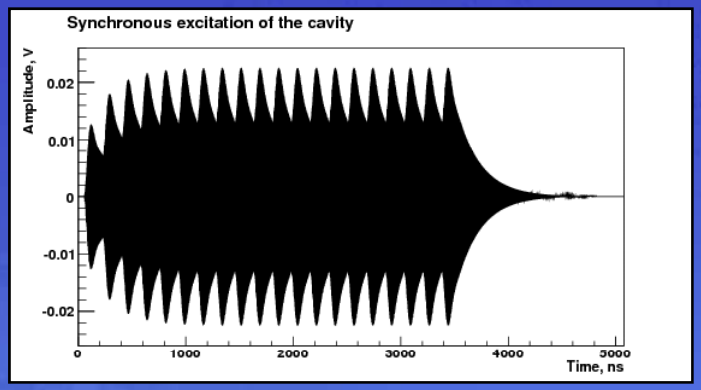
  http://www.hep.ucl.ac.uk/%7Ebino/libbpm/
- Various types of filtering, improved DDC and interpolation algorithms are examples of the latest additions
- *esaProcess* – BPM signal processing code, based on *libbpm*
- *esaProcess* has already been used to generate the results for the last NIM paper, and will be used for ATF2 BPM data processing

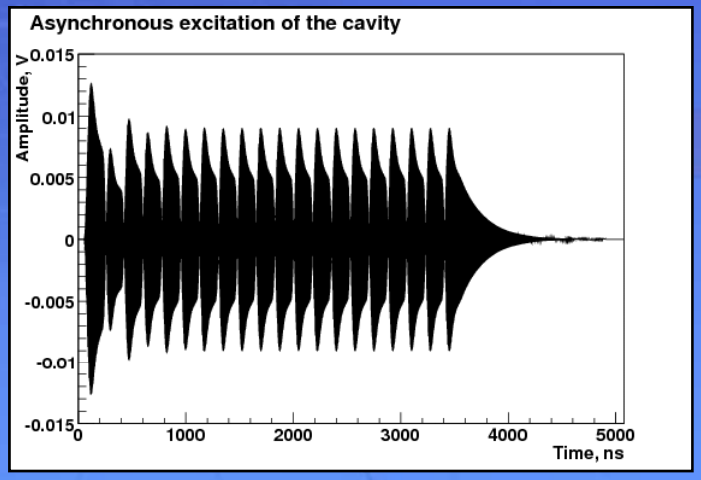
- Example – waveform interpolation:



Simulation work - ABSim

- Based on *libbpm*
- BPM simulation from first principles
- BPM responses for different modes are simulated applying resonator filters with corresponding parameters to a pulse
- Responses are then scaled taking into account current charge, position, etc and added together
- Multibunch operation is being implemented now
- xml interface
- Potential of integration with other simulation codes
- Drifts and other systematics are not yet implemented…






```
General simulation parameters -->
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<rf_setup nsamples="65535" samplefreq="41234.234" />
</simulation>
 <!-- Definition of the BPM system  -->
<bpm name="x3" spos=".5" xpos="-0.13" ypos="-0.19" pitch="0. "
yaw="0.785398e-3 " roll="0." polarisation="0" cavitylength="20.">
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value="-45."  /> <double  name="phase_shift"  value="45."  />
```

Simulation work – spectrometer

- Spectrometer simulation toolkit now available
- Basic spectrometer simulation and error propagation

http://www.hep.ucl.ac.uk/~bino/spectrometer/doc/

```
+++ Running over file with +B
Pulse 0, measured = 34.067, simulated = 34.0608 GeV, deltaE/E = 0.000182628
Pulse 1, measured = 28.1609, simulated = 28.1585 GeV, deltaE/E = 8.69246e-05
Pulse 2, measured = 32.1094, simulated = 32.1075 GeV, deltaE/E = 6.13955e-05
Pulse 3, measured = 23.2807, simulated = 23.2835 GeV, deltaE/E = -0.000116418
Pulse 4, measured = 26.3032, simulated = 26.3101 GeV, deltaE/E = -0.000260183
Pulse 5, measured = 27.686, simulated = 27.6815 GeV, deltaE/E = 0.000163069
+++ Running over file with -B
Pulse 0, measured = 34.0545, simulated = 34.0608 GeV, deltaE/E = -0.000183494
Pulse 1, measured = 28.156, simulated = 28.1585 GeV, deltaE/E = -8.82544e-05
Pulse 2, measured = 32.1054, simulated = 32.1075 GeV, deltaE/E = -6.2425e-05
Pulse 3, measured = 23.2861, simulated = 23.2835 GeV, deltaE/E = 0.0001145
Pulse 4, measured = 26.3169, simulated = 26.3101 GeV, deltaE/E = 0.000258791
Pulse 5, measured = 27.6769, simulated = 27.6815 GeV, deltaE/E = -0.000164404
```

Summary

- A lot has already been learned and one more ESA run is scheduled
- Data is available, some more is hopefully coming
- Some BPM stability issues understood and being addressed, efficiency of the correction for the gain drifts has to be demonstrated
- Tools are becoming available
- Data needs to be looked at!