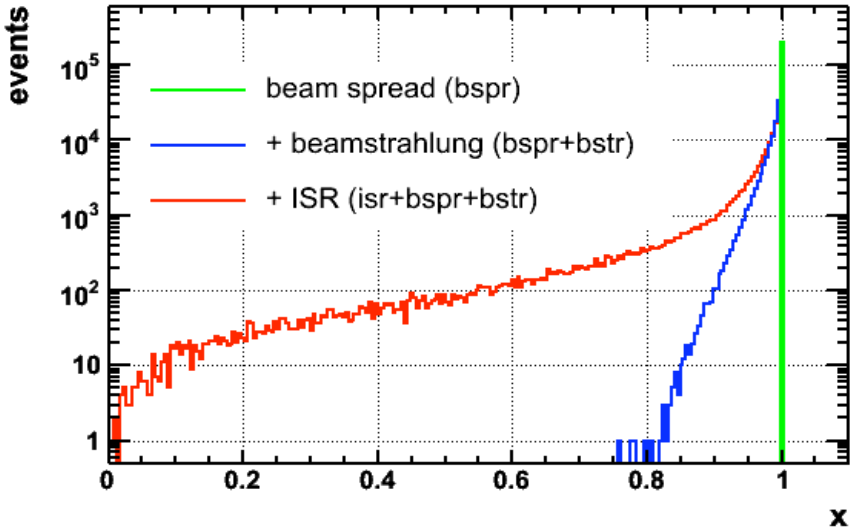
Beam-energy spectrometer

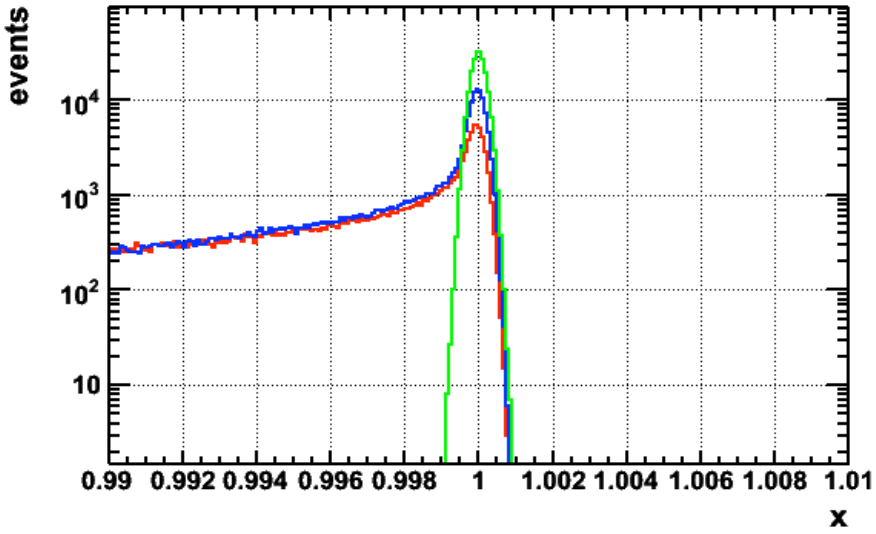
D. Ward, M. Thomson, M. Slater (Cambridge)
S. Boogert, G. Boorman (RHUL)
F. Gournaris, A. Liapine, B. Maiheu, D. Miller,
M. Wing (UCL)
and International Collaborators

- Introduction and motivation
- Work on nanoBPM at KEK
- Energy spectrometer in ESA at SLAC
- Chicane simulation
- Spectrometer BPM prototype
- Outlook

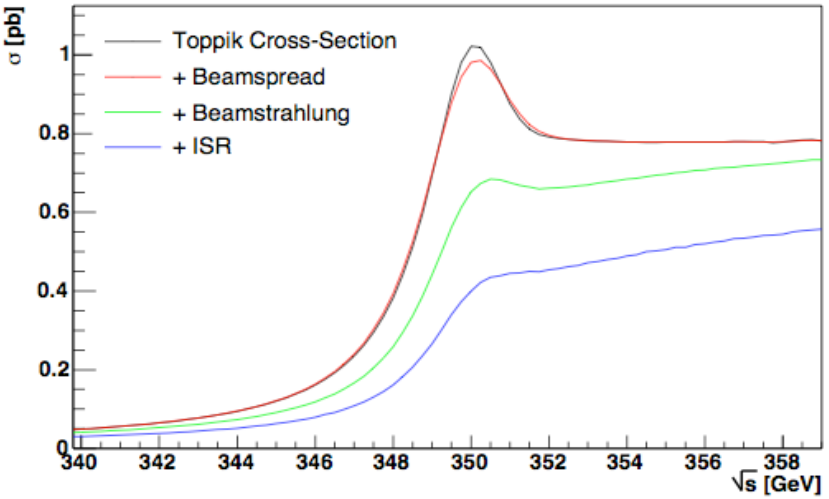
Introduction and motivation

Luminosity spectrum





Top quark mass scan



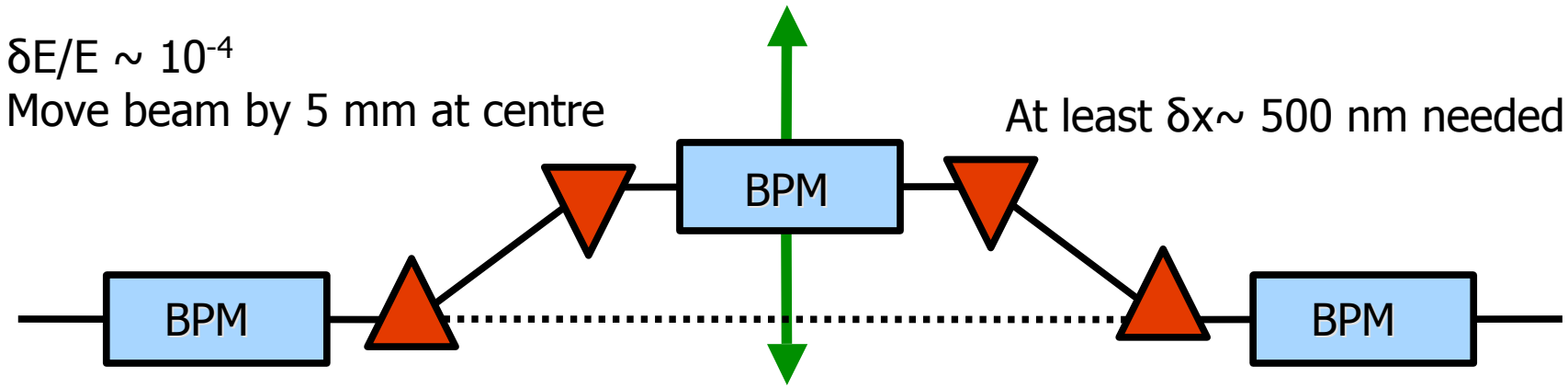
Uncertainty on beam energy measurement contributes directly to the uncertainty on the ILC physics output.

Need for:

- Energy measurement accuracy 10^{-4}
- Stability and ease of operation
- Minimal impact on data taking

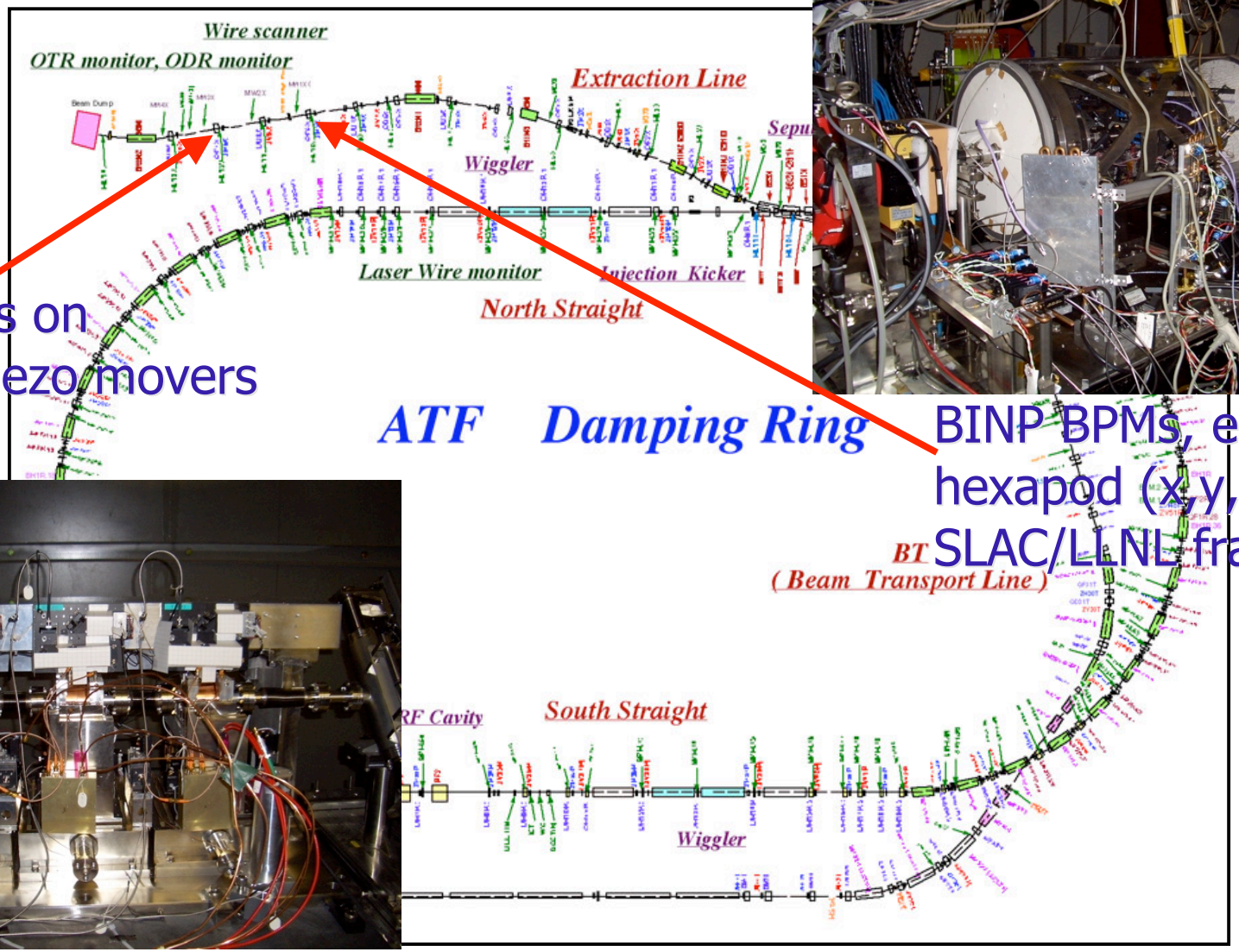
BPM Spectrometry

Study and design magnetic chicane for beam energy measurement using BPMs



- NanoBPM @ ATF (KEK): test resolution, try different analysis methods, BPM stability tests, multi-bunch operation, inclination of beam in BPMs, etc.
  - Spectrometer aspects of BPMs can be tested
- T474/491 @ ESA (SLAC): test stability and operational issues with a full implementation of 4 magnet chicane and 3 BPM stations.
  - Test of real chicane prototype

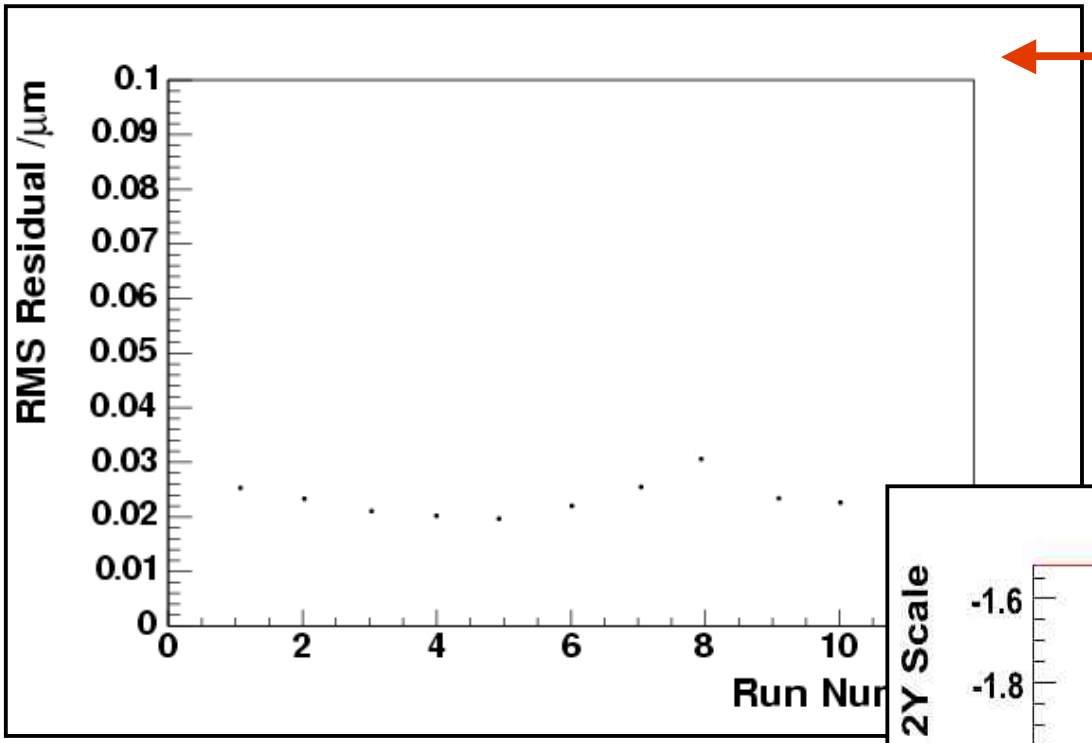
nanoBPM at ATF



KEK BPMs on flexure piezo movers (x,y)

BINP BPMs, each on hexapod (x,y,x',y') in SLAC/LLNL frame

ATF results: resolution and inclination



Resolution:

Precise calibration using movers and cross-calibration using corrector magnets

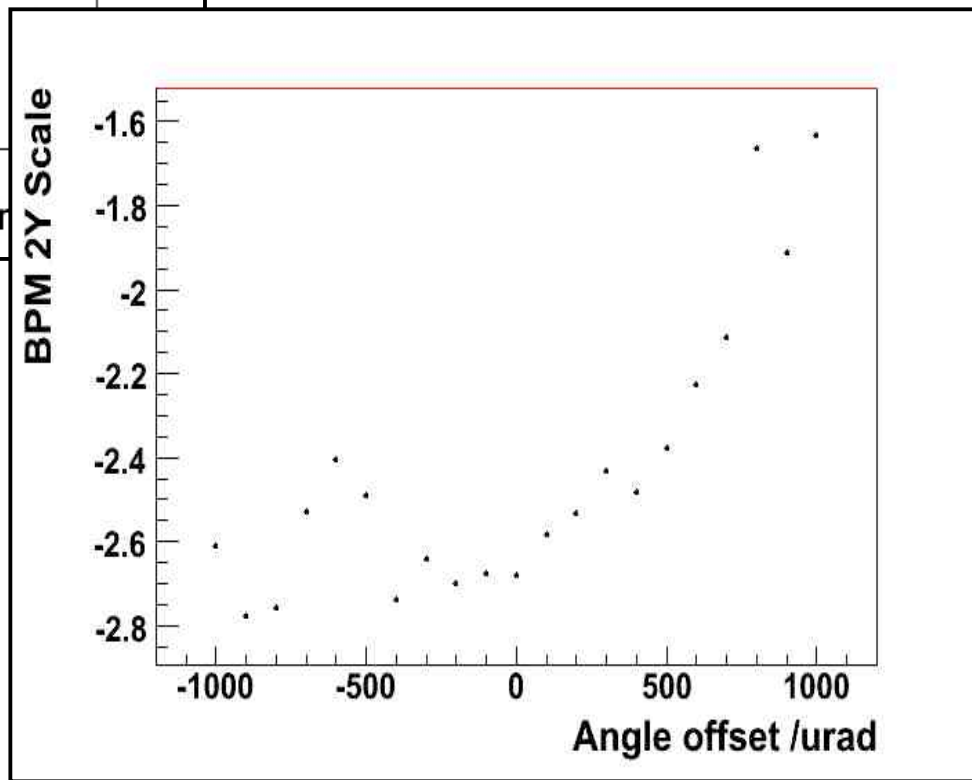
• Best resolution ~ 15 nm

Beam inclination:

Important for 3 or 4 magnet chicane

No significant change in resolution but clear change in calibration constants

➜Further investigation

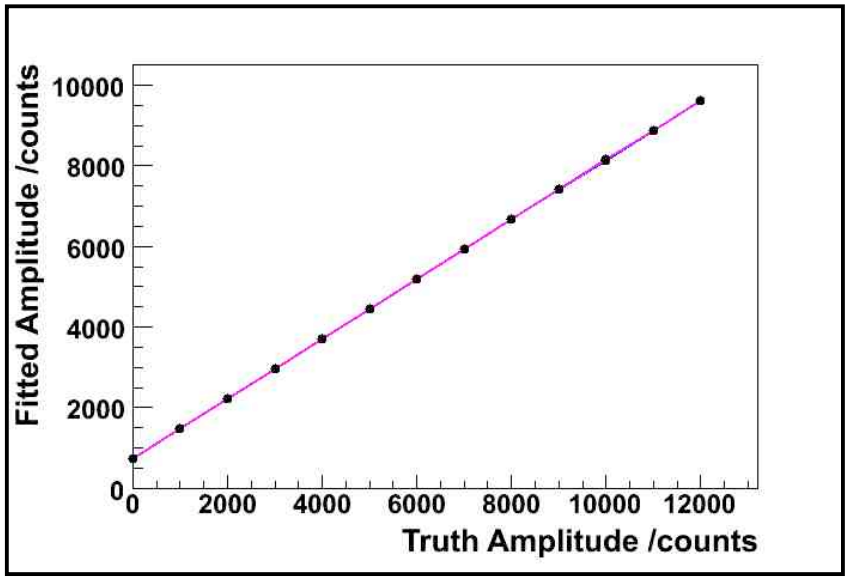


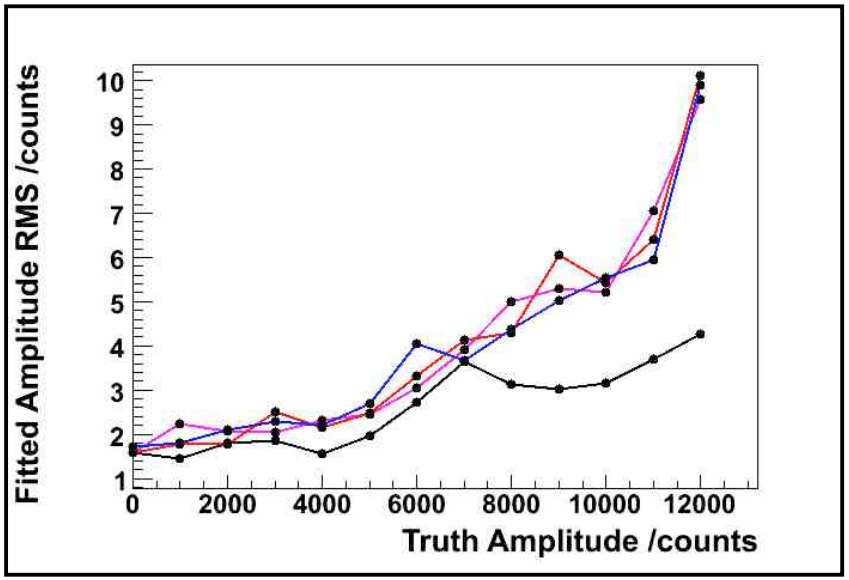
ATF results: multi-bunch studies

Cavity BPMs must work with ILC bunch train - can we measure the energy of individual bunches?

ATF has a bunch train of 3 bunches (150 ns)

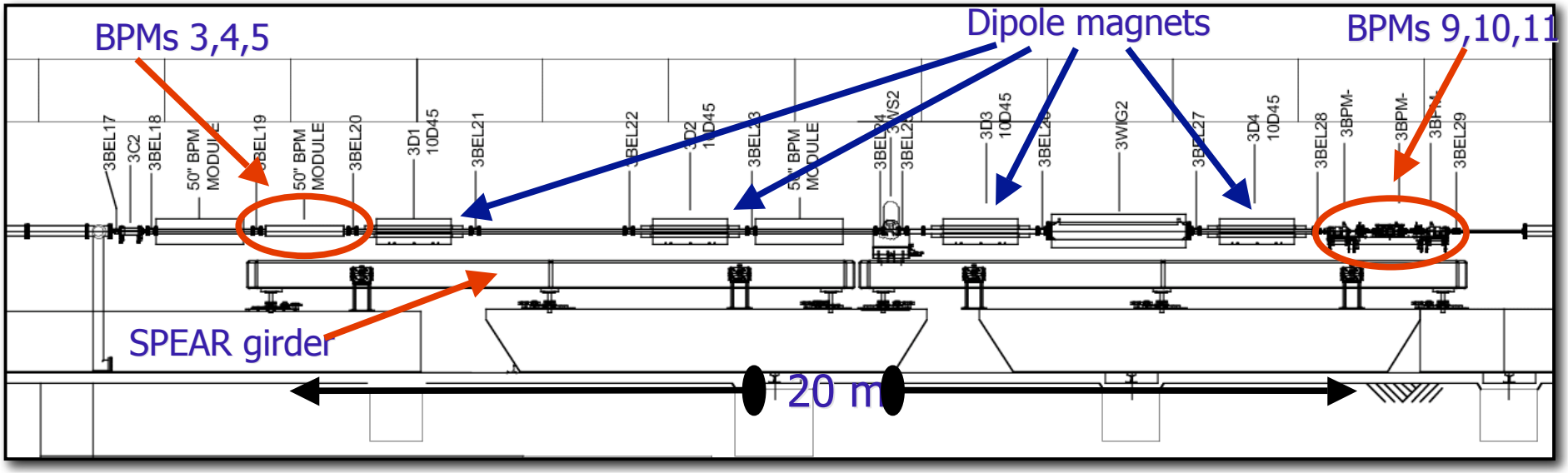
Simulation:





More to come and data as well

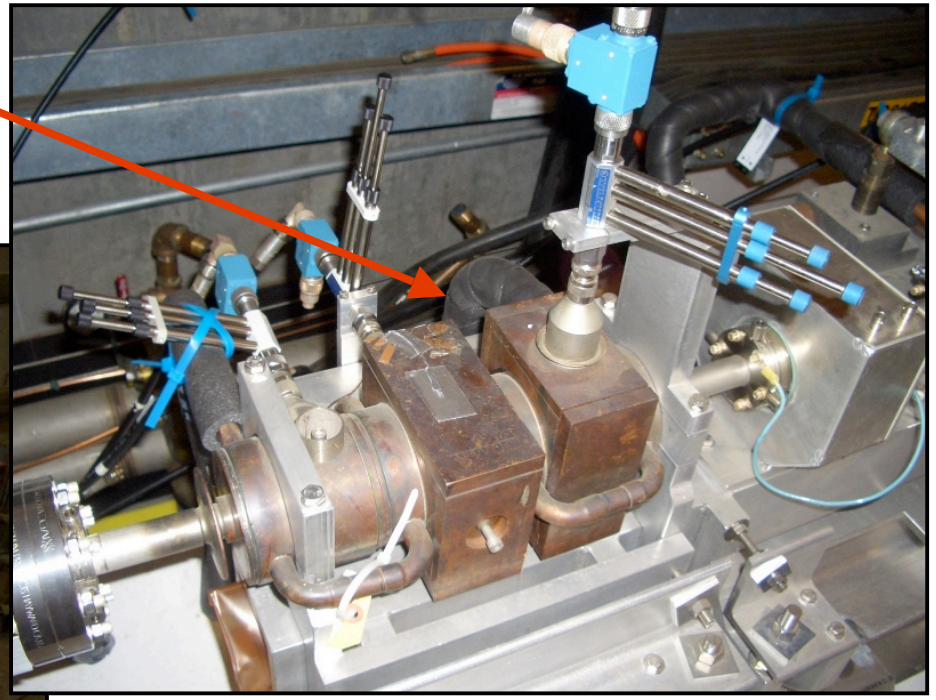
T474/T491 at ESA

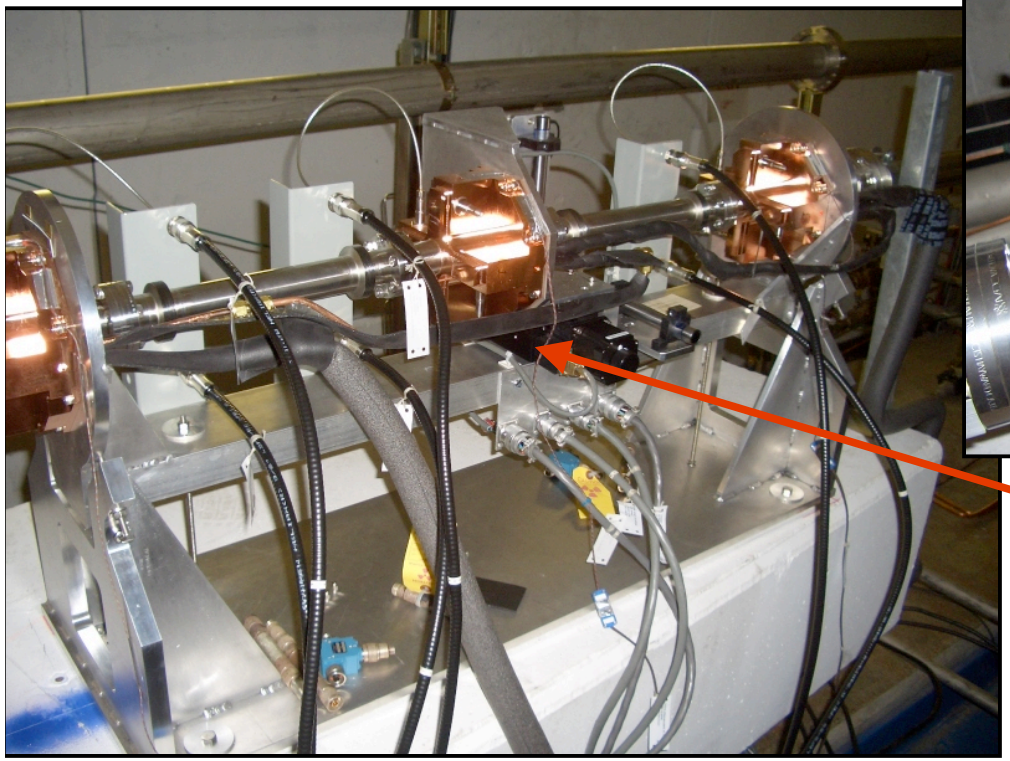


- January 2006 test run (4 days): commissioning BPMs 31,32 and 1,2 upstream
- April 2006 run (2 weeks):
  - o Commissioning new ILC prototype linac BPMs (3,4,5) where 4 is on a (x,y) mover system
  - o Commissioning old SLAC BPMs (9,10,11)
  - o Digitisation/signal processing optimisation
- July 2006 run (2 weeks):
  - o Commisioning Zygo interferometer system (3,4,5) + BPM24 upstream
  - o Further optimisation of hardware
  - o Stability data taking with 10 BPMs, frequent calibrations

ESA BPM set-up

Old SLAC rectangular cavities
- 2.856 Ghz, high Q ~ 3000
- 20 mm aperture

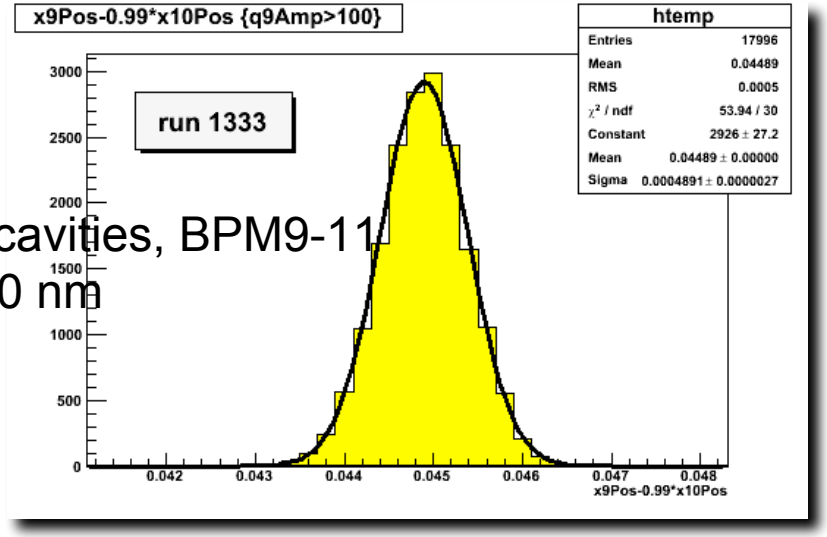




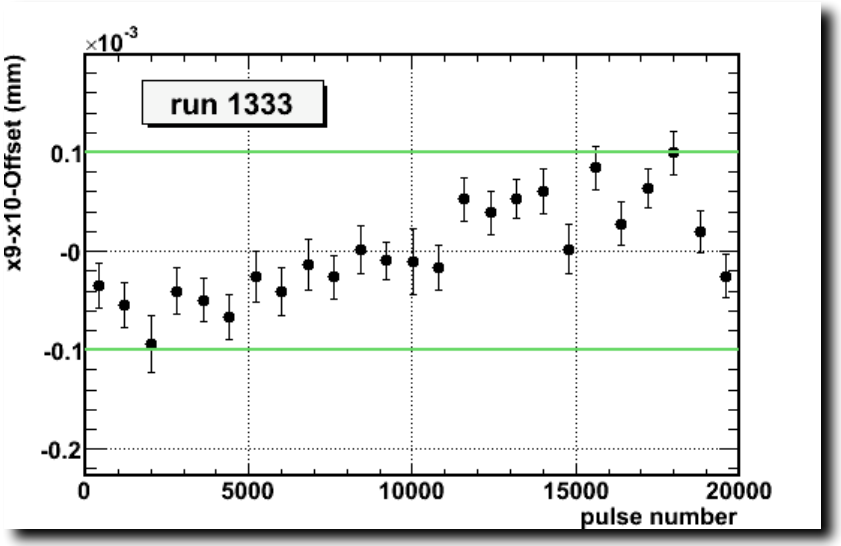
Adolphsen and Li cold LINAC prototype cavities
- 2.859 GHz, low Q ~ 500
- 36 mm aperture

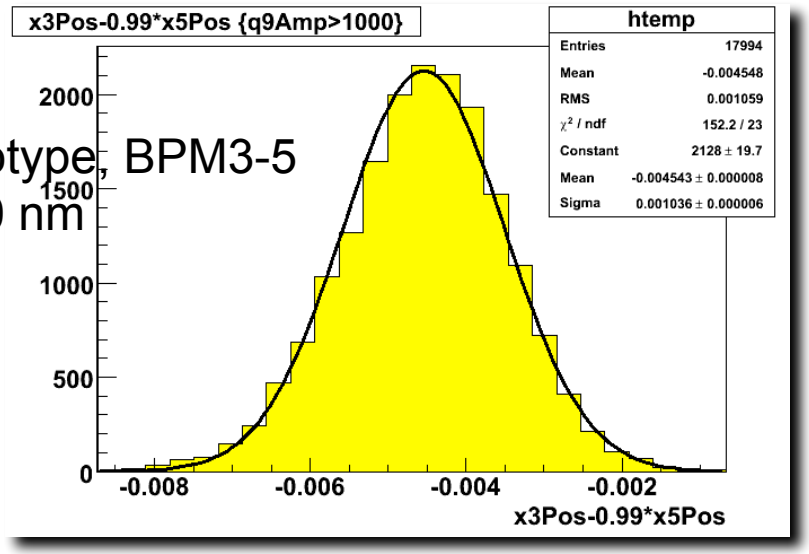
Properties under investigation, improving calibration routine

ESA results: resolution and stability

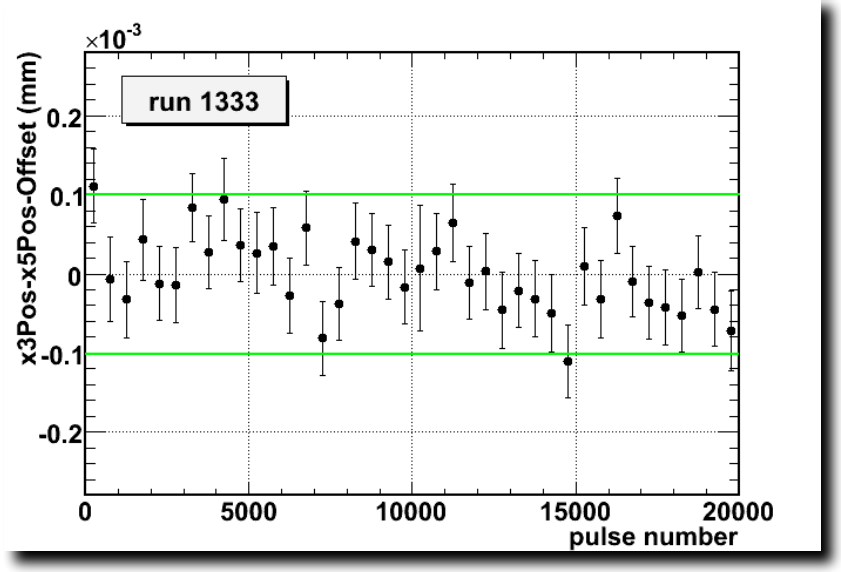


old cavities, BPM9-11
~350 nm





prototype, BPM3-5
~700 nm

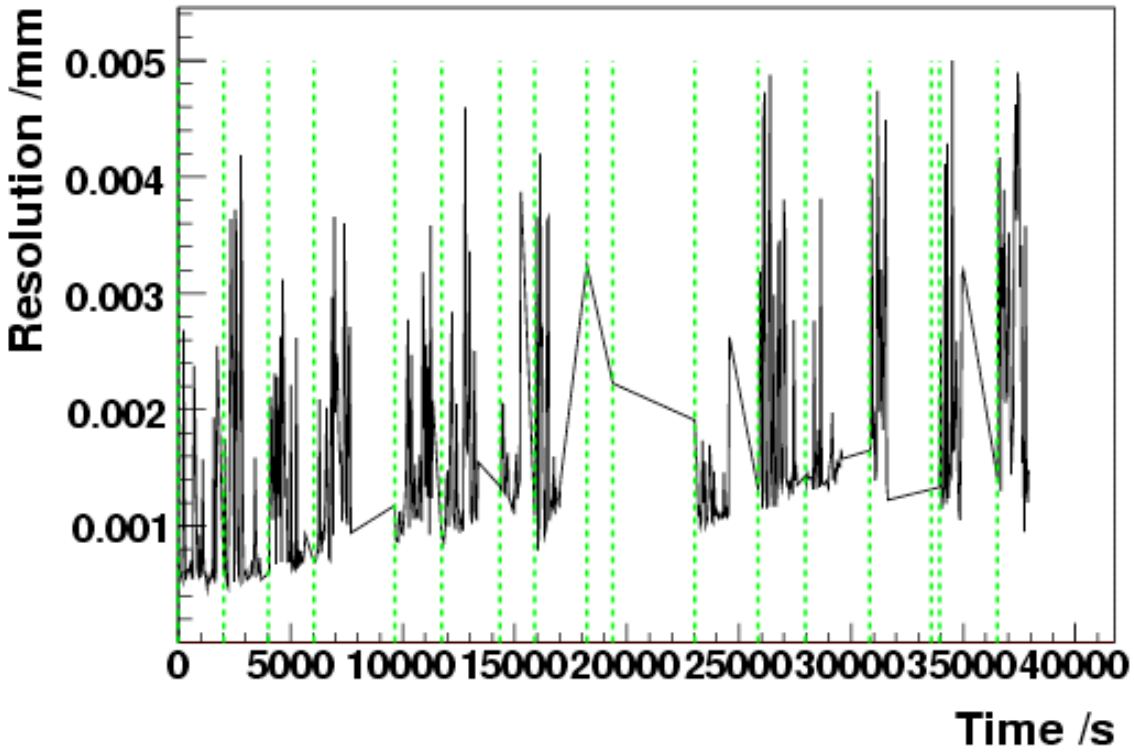


~30 mins.

ESA results, resolution drift

Resolution of BPM 11-10 in groups of 500 events

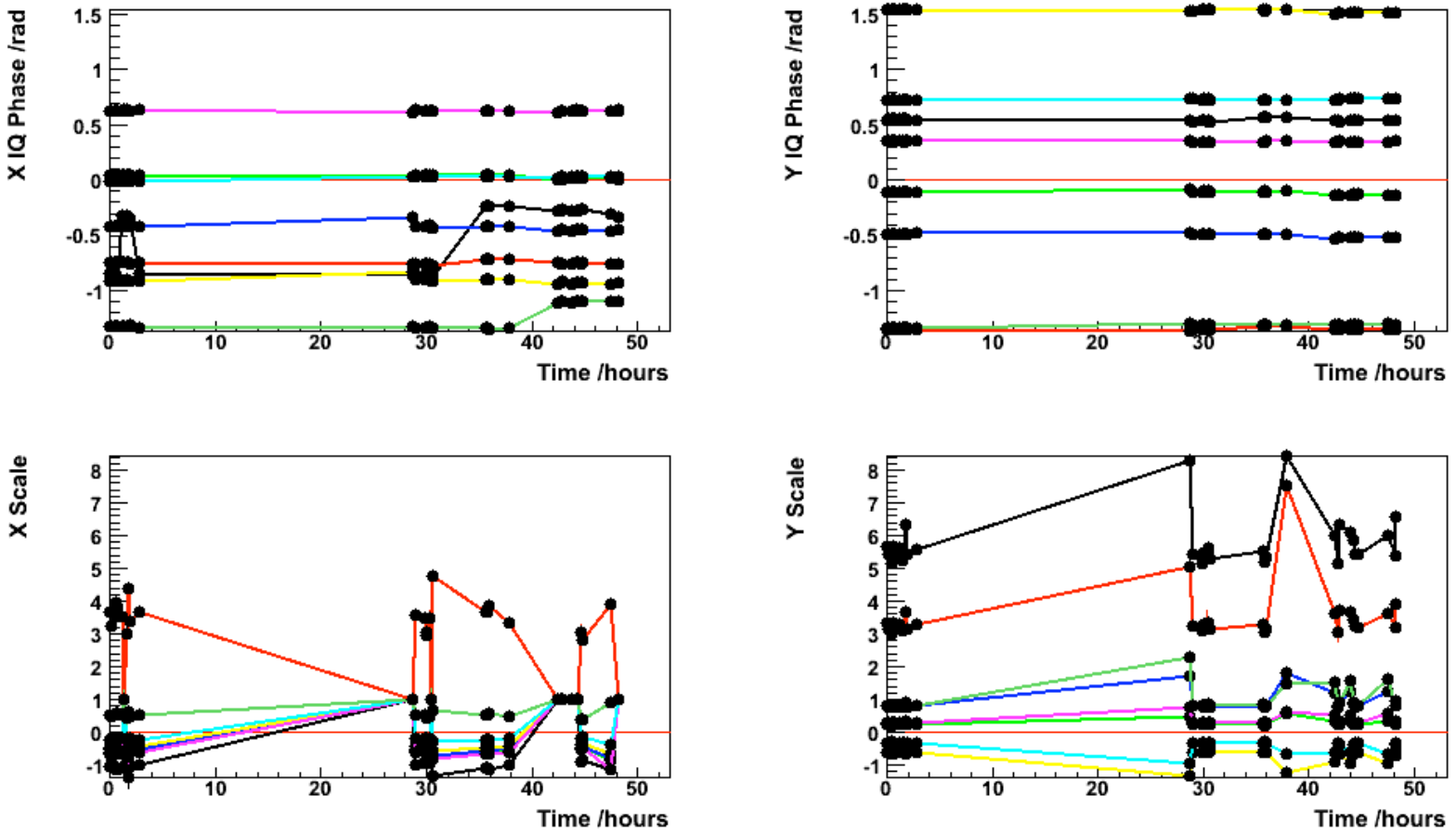
- 11 hour period
- Gradual degradation when using same calibration constants
- Cause of drift: frequency drift, electronic gain fluctuation, …?



Planned electronics gain monitoring system will aid understanding

ESA results: calibration stability

Stability of position and IQ phases: phase varies by ~0.6% and scale by ~2%



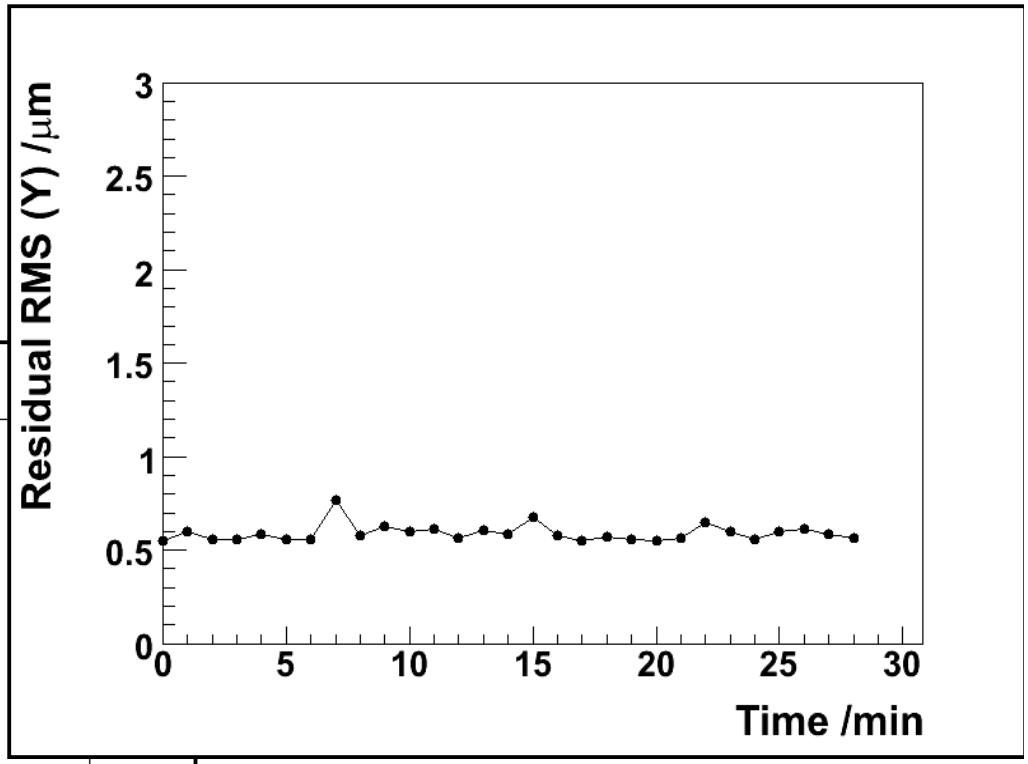
Systematic effects under investigation: gain drifts, frequency drifts, …

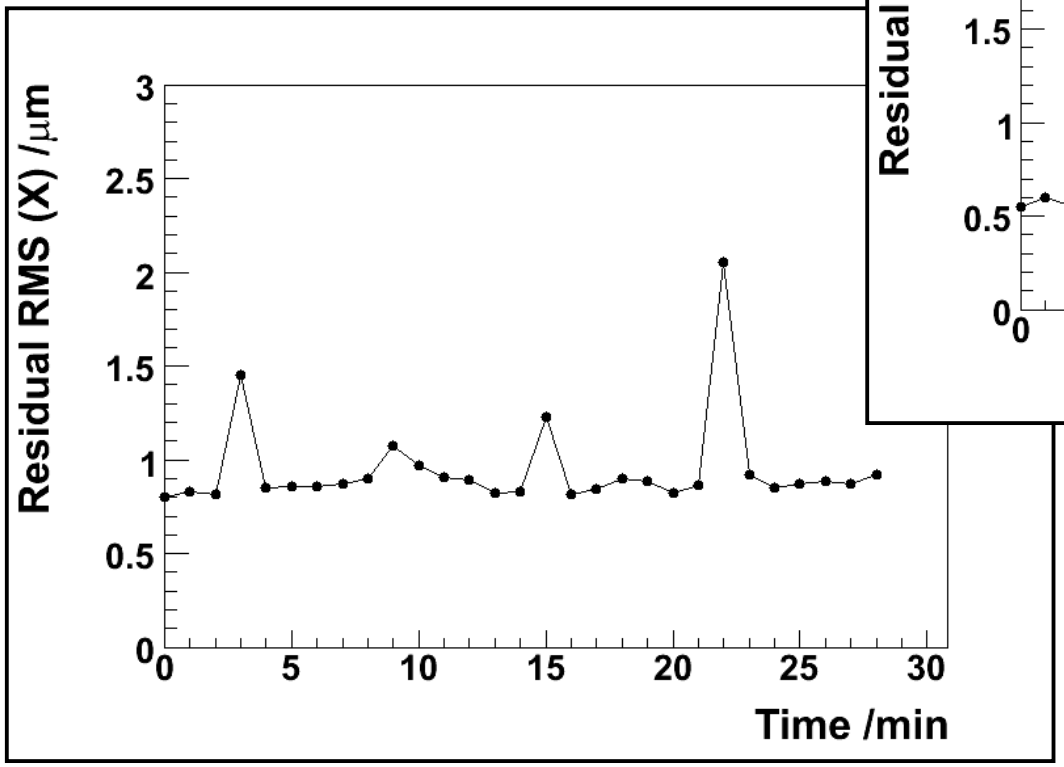
Linking stations over whole trajectory

How well do we know the entire orbit in the end station?

Upstream and BPM 9, 10 and 11 positions regressed to BPM 3, 4 or 5

RMS ~ 800 nm in x and ~600 nm in y

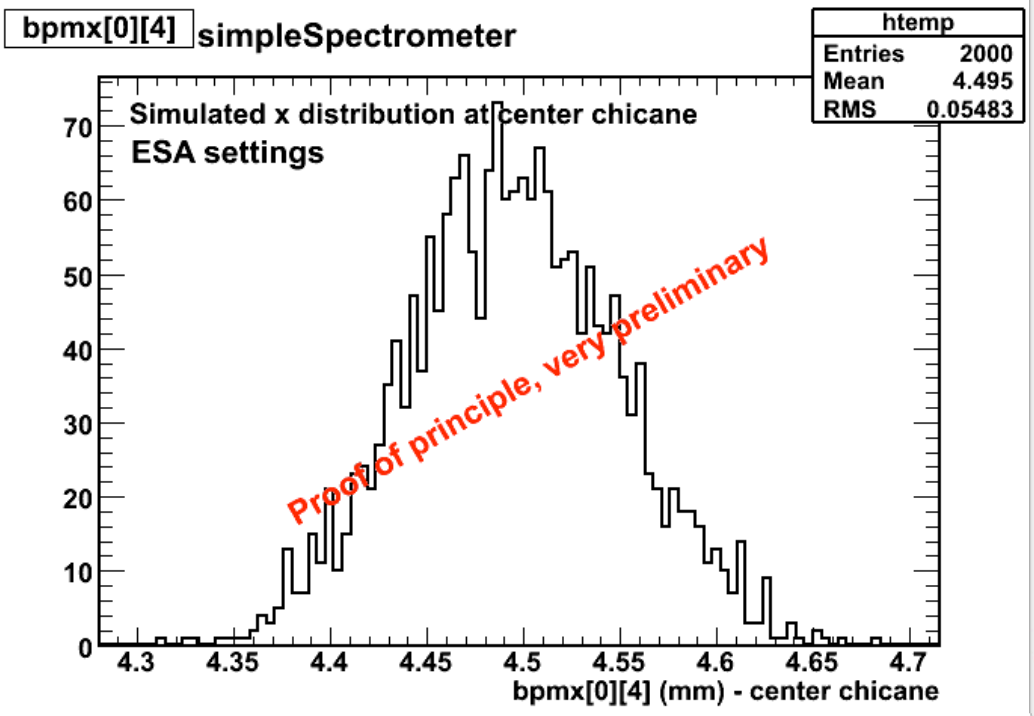


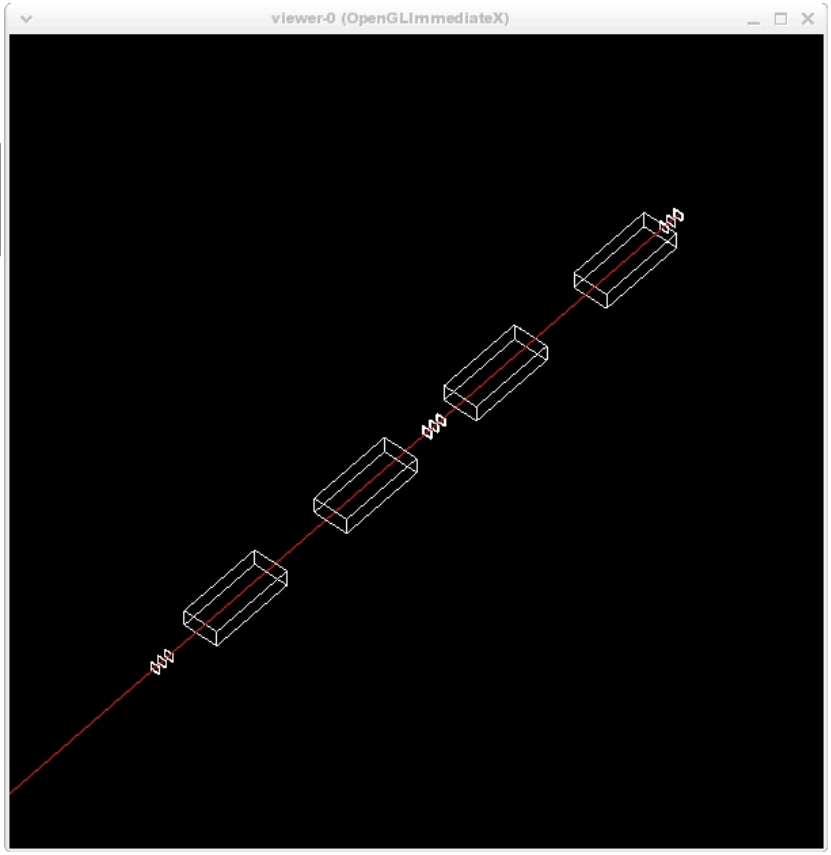


Long-term study in progress

Spectrometer simulation

- Developed a simulation in Geant 4 for the spectrometer chicane
  - Load field maps (parabolic interpolation) as well as uniform fields
  - XML input file to setup layout (dipoles and BPMs), e.g. 3 or 4 magnet chicane, beam parameters, etc..
  - Writes out root file with positions in the defined BPMs.
- Status
  - Main part finished, accuracy check in progress
  - Add some Geant 4 physics processes





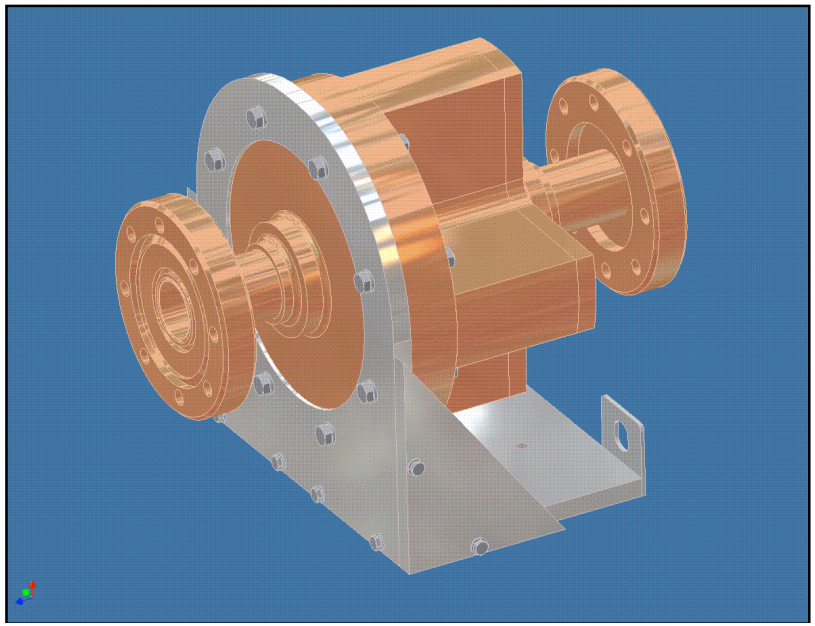
Spectrometer-specific BPM

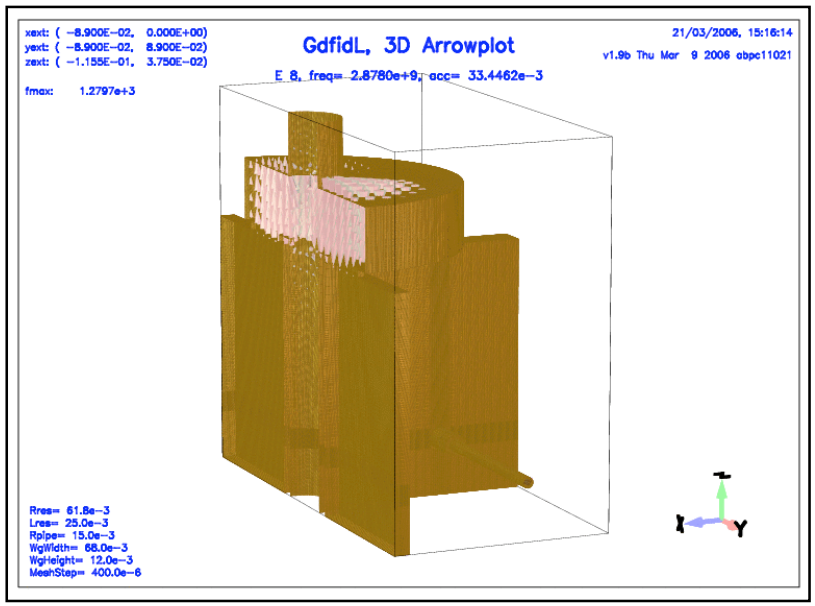
Existing BPM designs are not optimal for an energy spectrometer

- aperture (machine protection)
- resolution, stability
- monopole rejection
- coupling → decay time

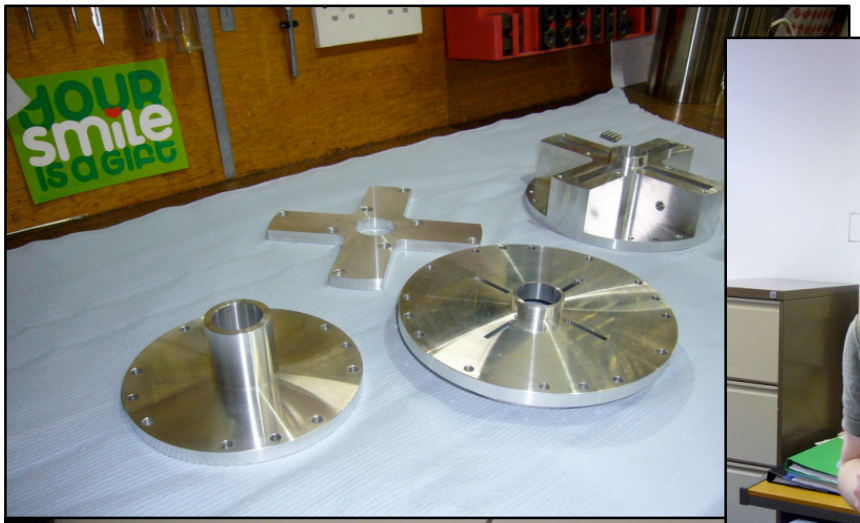
Take know-how gained from collaboration work and design a BPM suitable for an energy spectrometer.

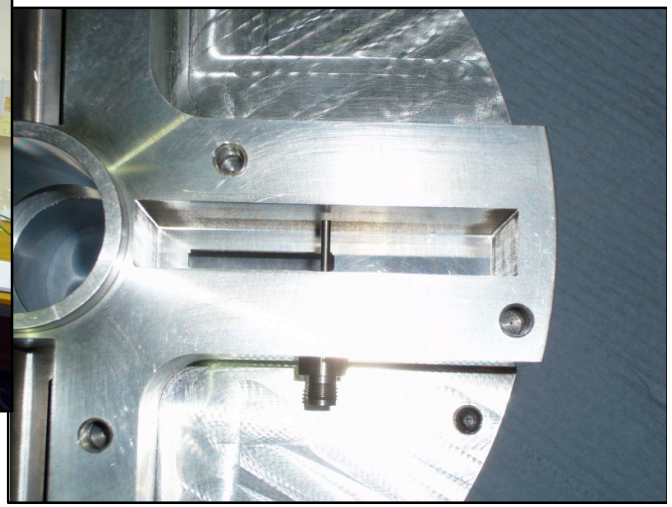
- Al model and Cu vacuum prototype
- 30 mm aperture, 2.878 GHz
- theoretical resolution ~ 11.2 nm

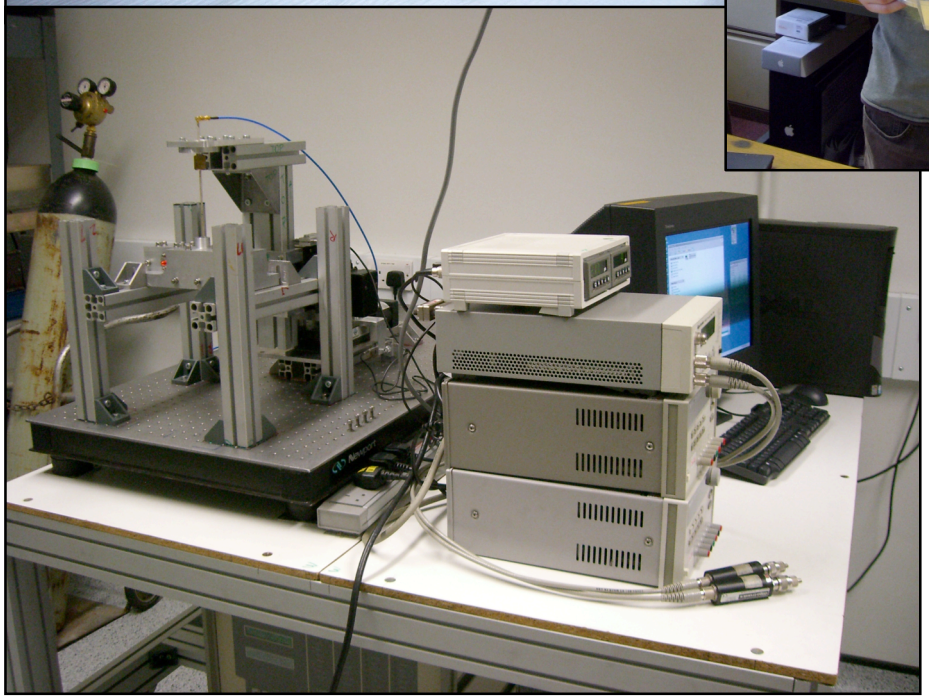




Aluminium model





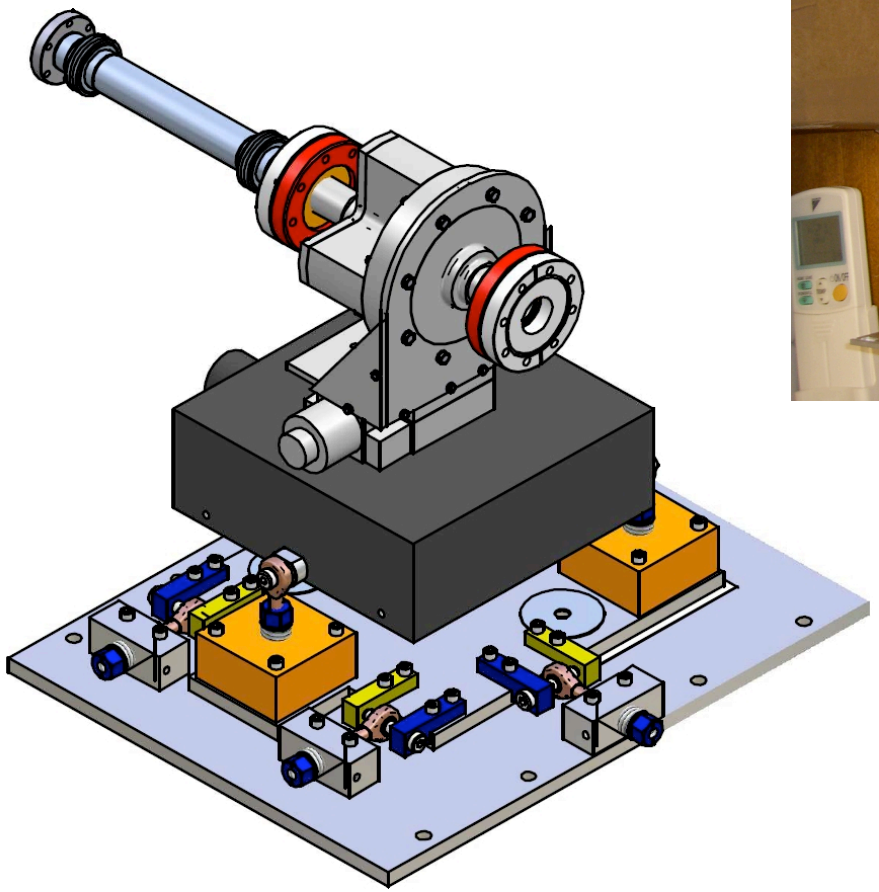


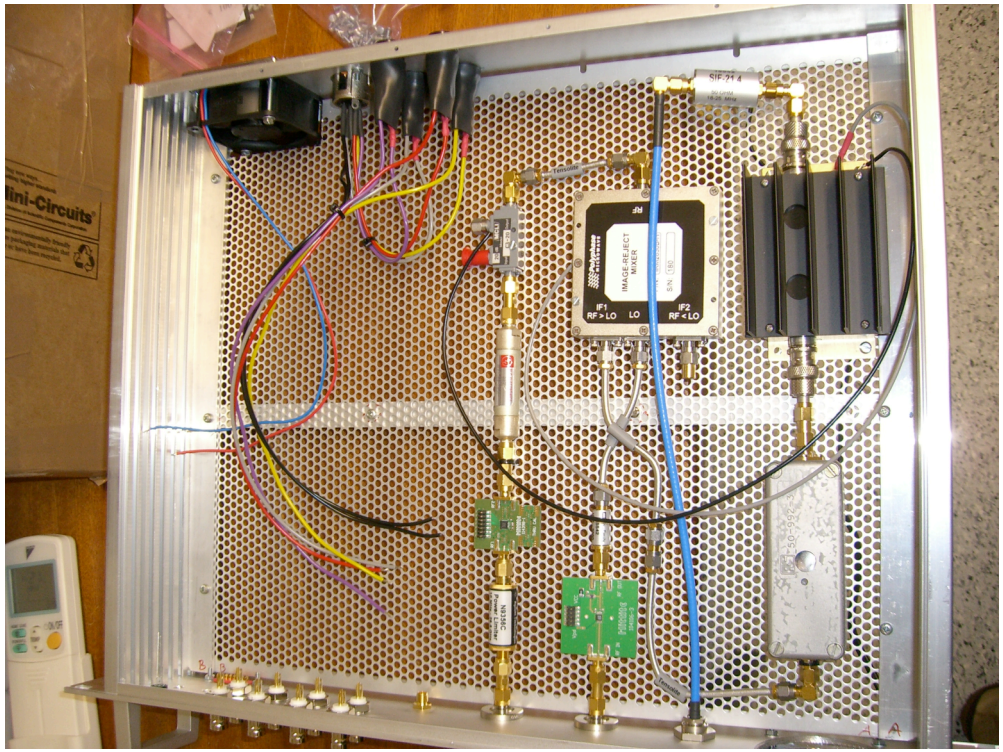
Measurements ongoing in labs in RHUL and UCL

Hardware

Mover system

- Horizontal stage: 2” travel range, 15 μm
- Vertical stage: 5 mm travel range, 10 μm accuracy



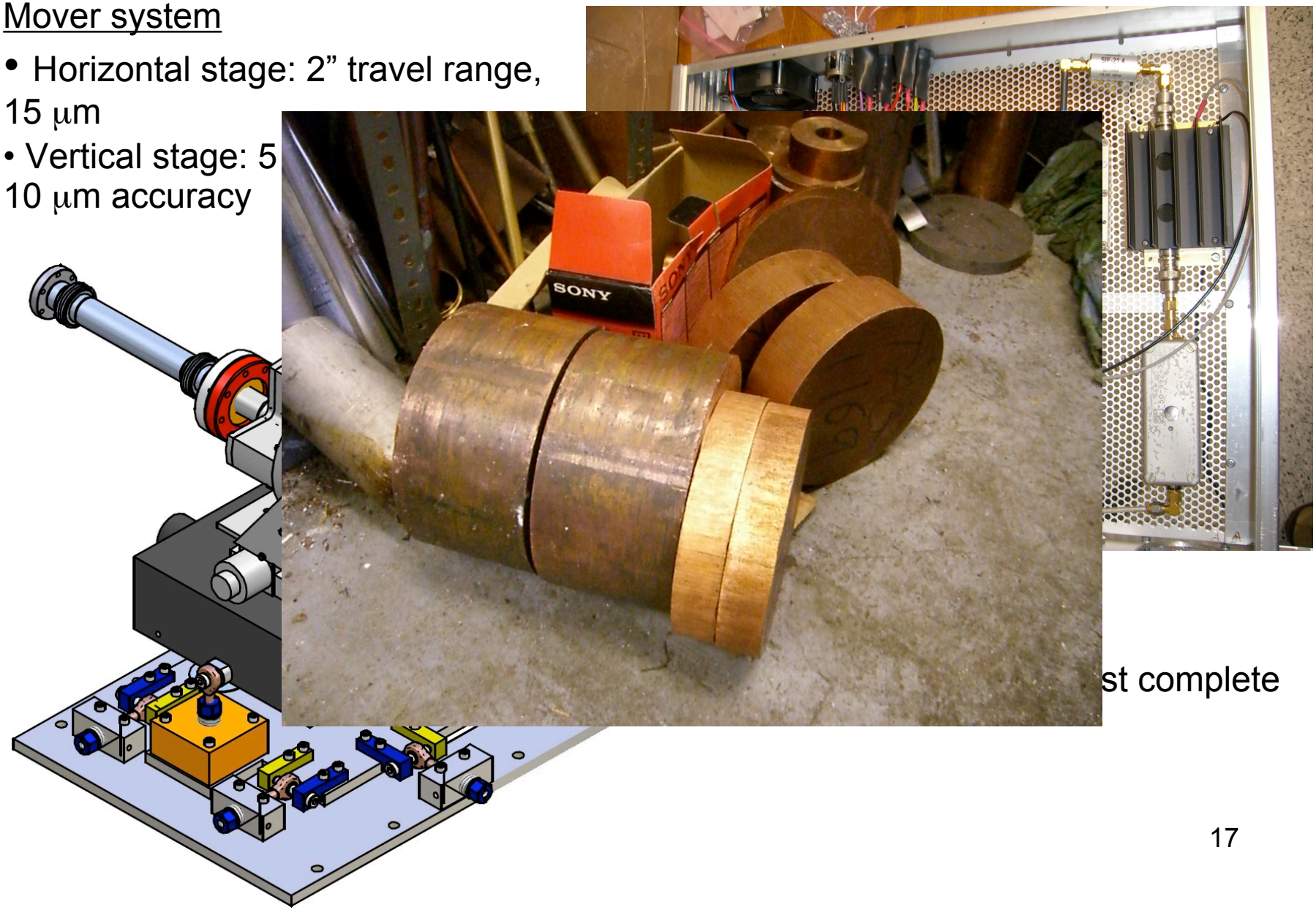


Electronics box almost complete

Hardware

Mover system

- Horizontal stage: 2” travel range, 15 μm
- Vertical stage: 5 10 μm accuracy



st complete

Summary and Outlook

- Work at KEK providing vital information on BPM performance and issues relevant to spectrometer.
- Test-beam running (and simulation) underway at ESA in SLAC to understand the spectrometer set-up
- Development of BPM specific to Spectrometer needs in progress

- Further stability, multi-bunch and tilt studies to be performed at KEK
- For 2007 at ESA
  - Install magnets to form chicane
  - Install and commission Spectrometer-specific BPM prototype with mover and electronics.
  - Link BPM stations with interferometer
  - Assess issues with running a Spectrometer system
- Further development of simulation and impact on physics.