Energy Spectrometer for the ILC

Alexey Lyapin

University College London

BPM energy spectrometer collaboration

UCL: Filimon Gournarnis, Alexey Lyapin, Matthew Wing

Cambridge: Mark Slater, David Ward

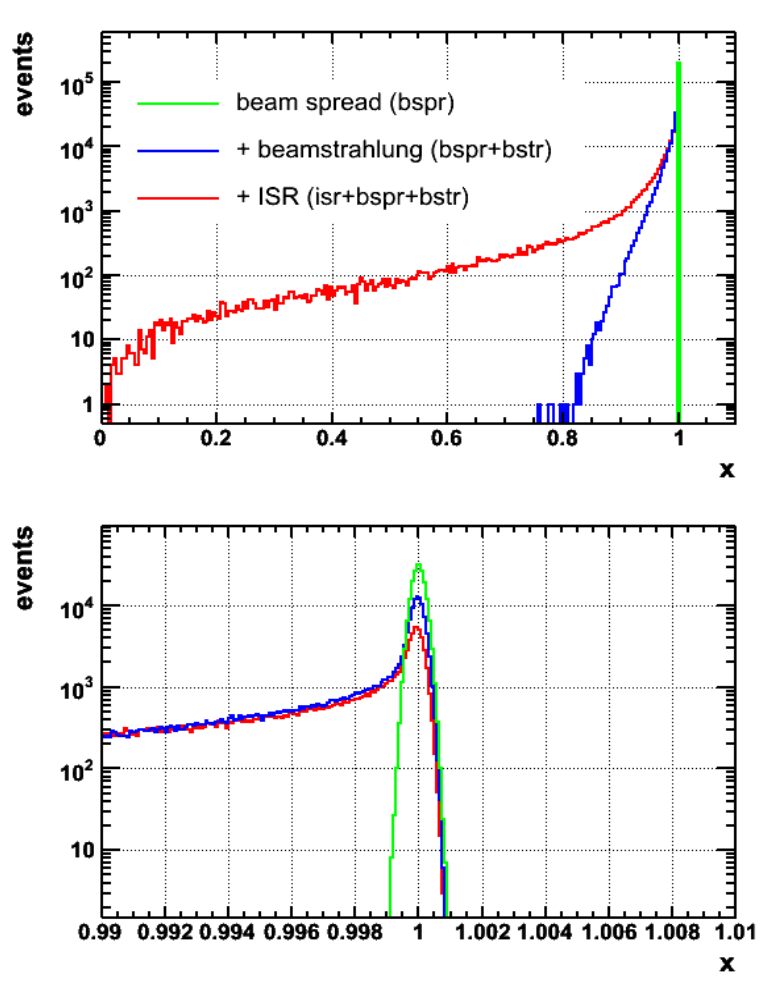
RHUL: Stewart Boogert

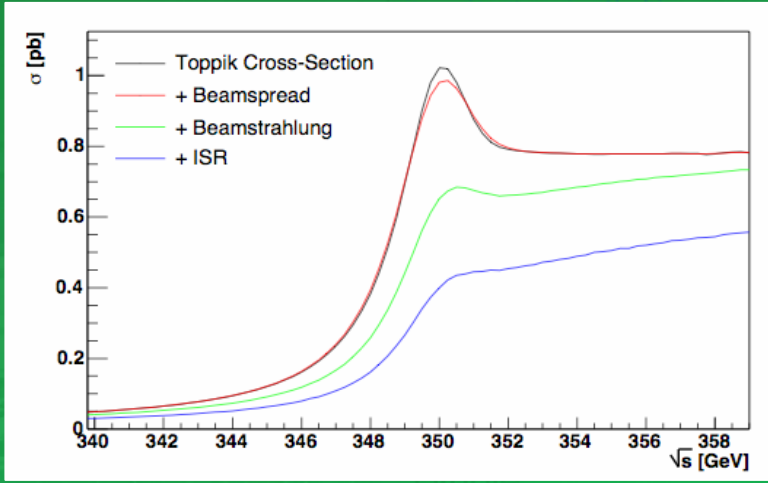
DESY-Zeuthen: Heinz-Jeurgen Schreiber, Michele Viti

JINR (Dubna): Viktor Duginov, Nikolay Morozov

In collaboration with SLAC, KEK, UC Berkley, LLNL, BINP…

Luminosity spectrum

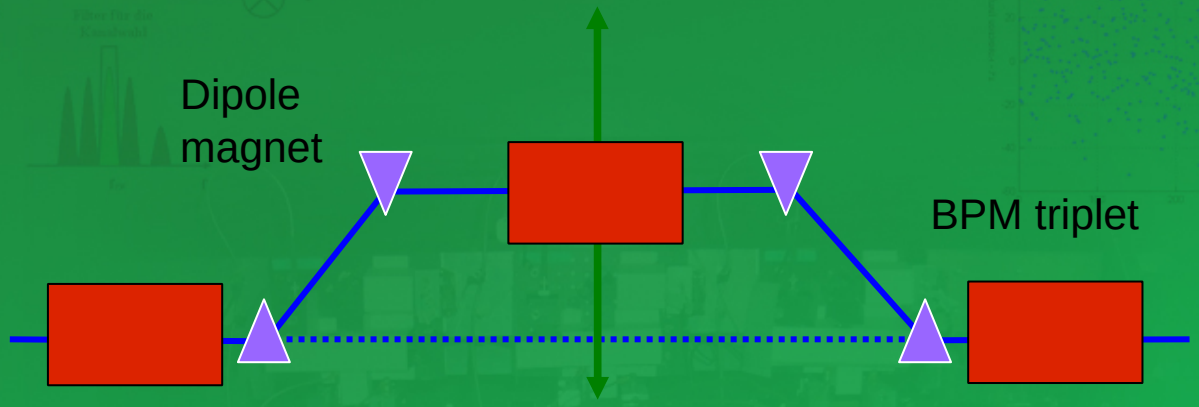




Precision threshold scan measurements:

- Energy loss effects have to be taken into account
- Absolute beam energy measurement of 1 part in 10^4
- Spectrometers up- and downstream

BPM spectrometer requirements



- Chicane
  - 4 magnets
  - 5 mm maximum deflection
  - Bipolar operation
- Measurement time
  - Single bunch
  - Bunch train
  - 1 hour / 1 day

- Mode of operation affects BPM design
  - Operation of chicane (frequency of ramping)
  - Frequent return to low energy?
  - Essential design beam energies
    - 50, 175, 250 & 500 GeV
  - Move BPMs to null dipole signal
- Single bunch information useful for machine operation?

BPMs in the spectrometer

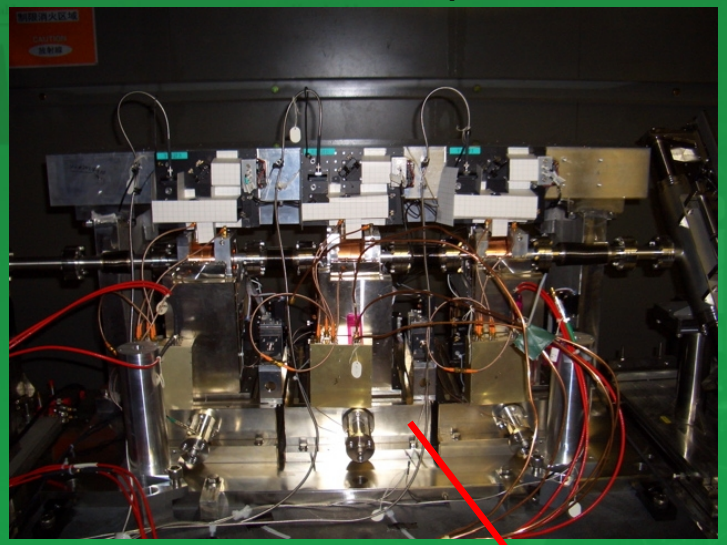
- Essential part of diagnostic
  - 9 BPMs per spectrometer x 4 beam lines ~36 BPMs
  - Requirements different from Linac BPM requirements
  - Requires detailed design work now

Spectrometer BPM requirements

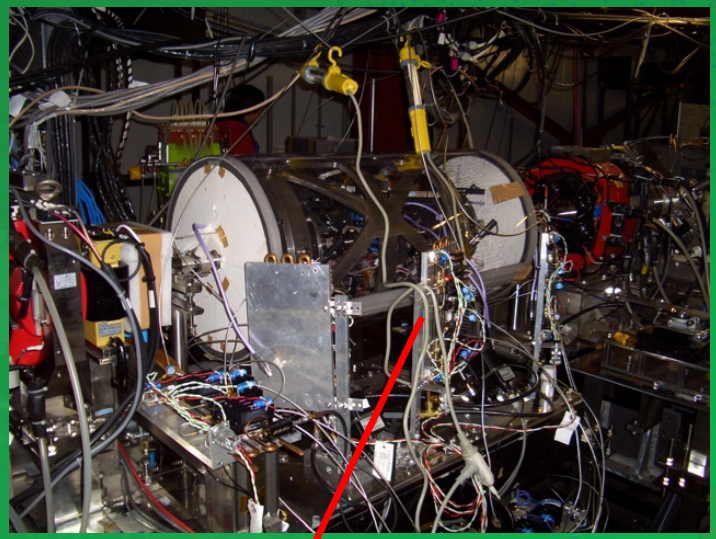
- Spectrometer BPM will probably set the most stringent requirements on BPM design
  - Aperture
  - **Resolution**
  - Dynamic range (1000:1)
  - **Stability (intrinsic and electronics)**
  - Accuracy
  - Calibration
  - Backgrounds
- Existing BPM designs are far from optimal for an energy spectrometer
  - Button and strip-line not seriously considered
  - ATF/ATF2 - aperture
  - Reentrant resolution/stability?
  - Generic pill box cavity
- Machine
  - Bunch angle, position & charge jitter
  - Aperture
- Spectrometer
  - Movement range
    - Stray fields
    - Emittance dilution
- BPM
  - Resolution already achieved (See ATF results)
  - Scaling of resolution as function of cavity size
  - Design for stability (monopole rejection)

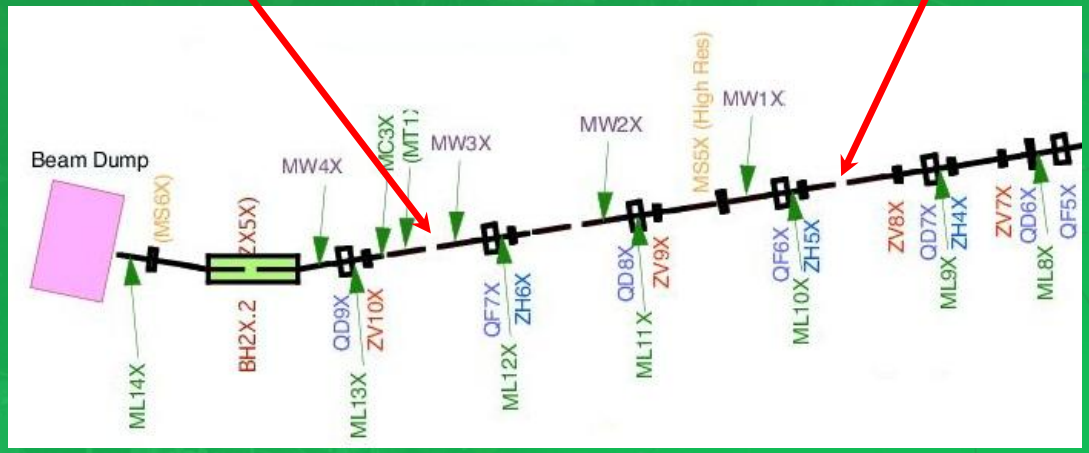
NanoBPM collaboration at ATF

KEK BPMs on flexure piezo movers



BINP BPMs in SLAC/LLNL frame

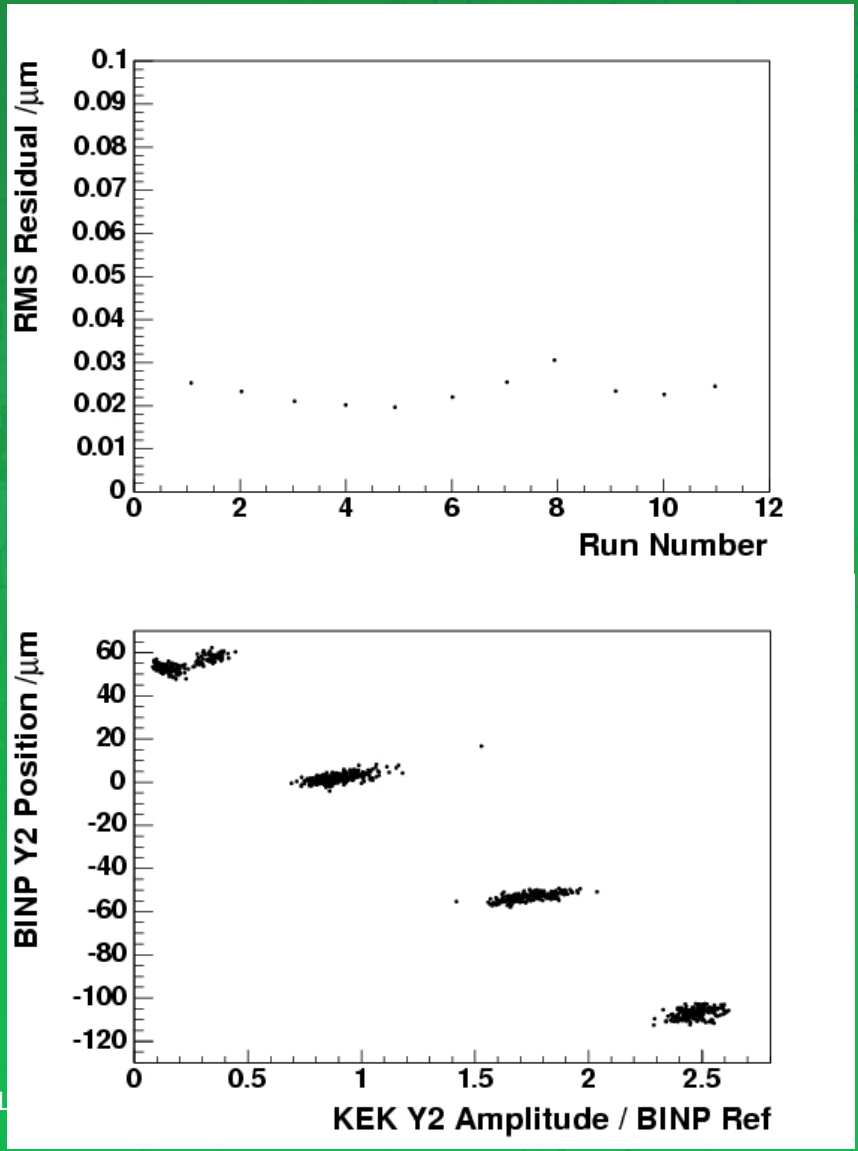




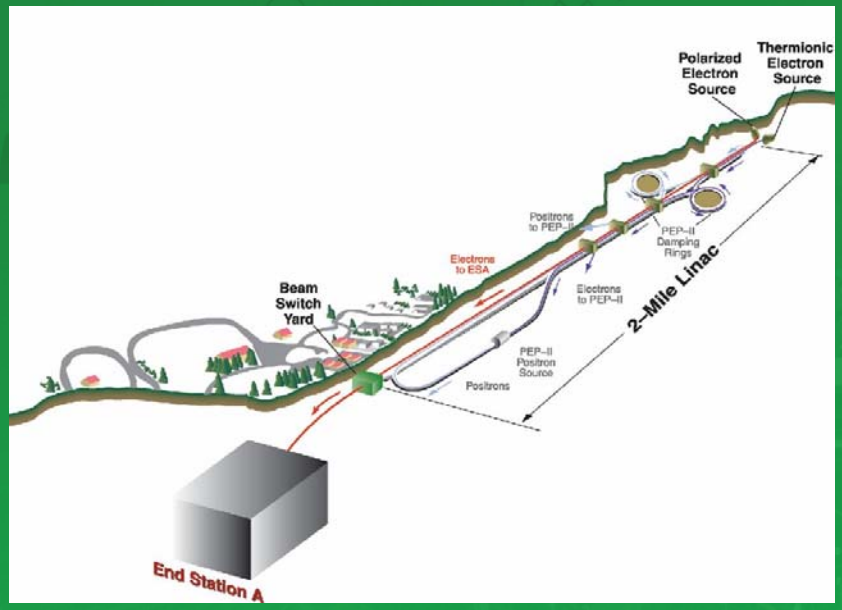
- Experiment to test the best BPM resolution among with the other BPM properties, systematics and stability

Results from ATF

- April 2006 data
  - Fitting algorithm
  - Calibration using hexapod movers
  - Resolution for the best runs ~ 18 nm
  - Short and long term drifts less than 100 nm
  - LO sources locking improved
  - KEK BPMs coupling to the reference cavity fixed
  - Cross-calibration with corrector magnets

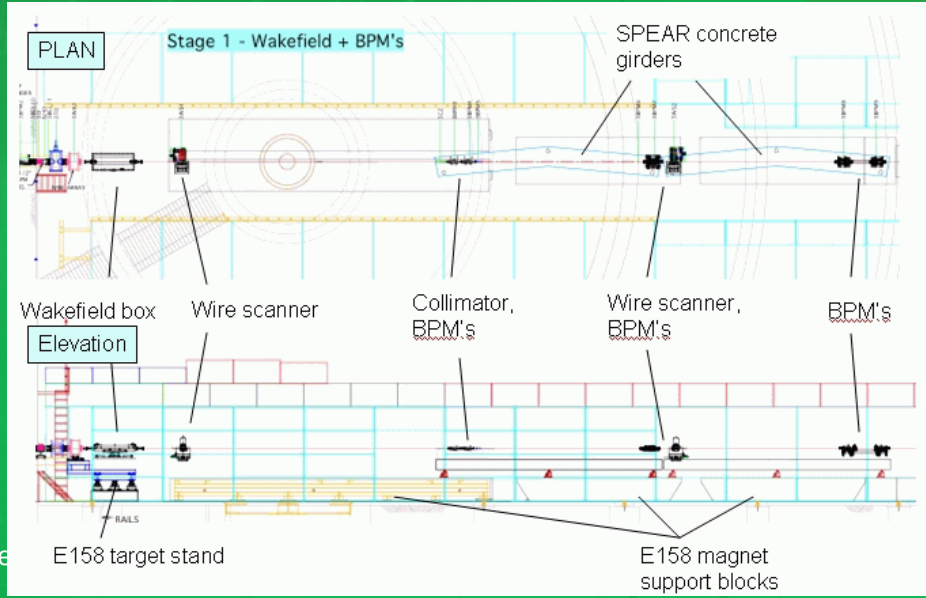


SLAC ESA spectrometer activities

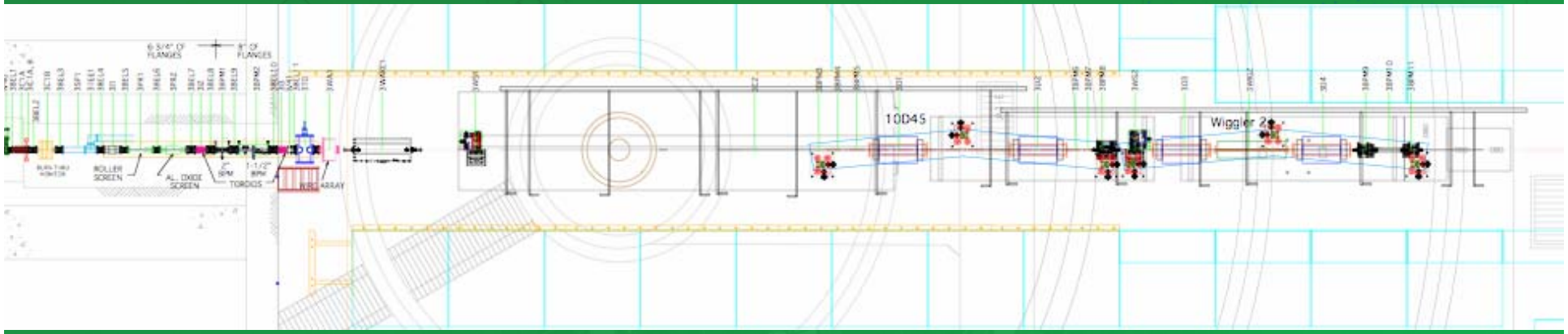


- One of the primary tests is a 4-magnet chicane spectrometer
- High energy beam test
- Commissioning run in Jan 2006 to test the BPMs and electronics, other diagnostics installed
- Preliminary old (not nano-) cavity BPM resolution with the new electronics ~1μm

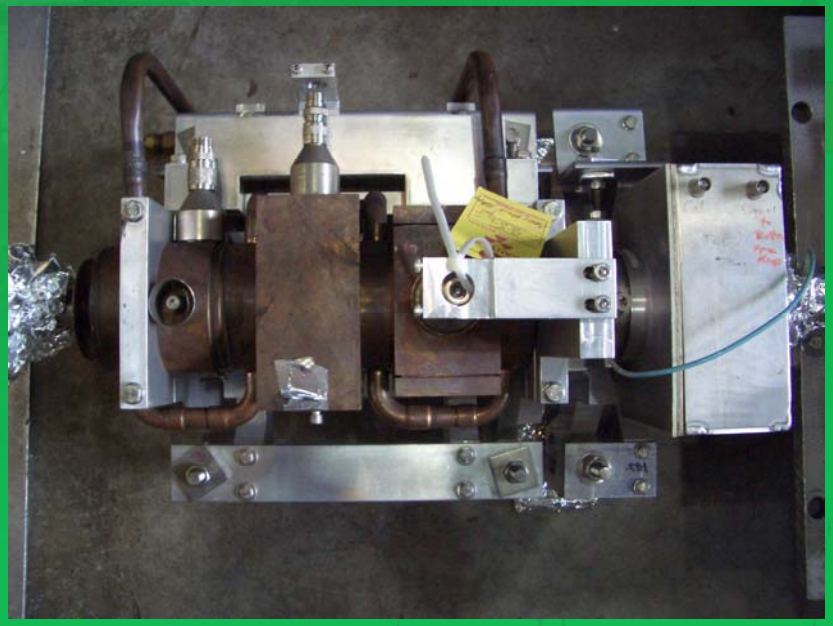
- Two more runs next year with magnets installed
- Planning to add/replace BPMs around 2007 with higher resolution ones now designed in UCL



End station A programe

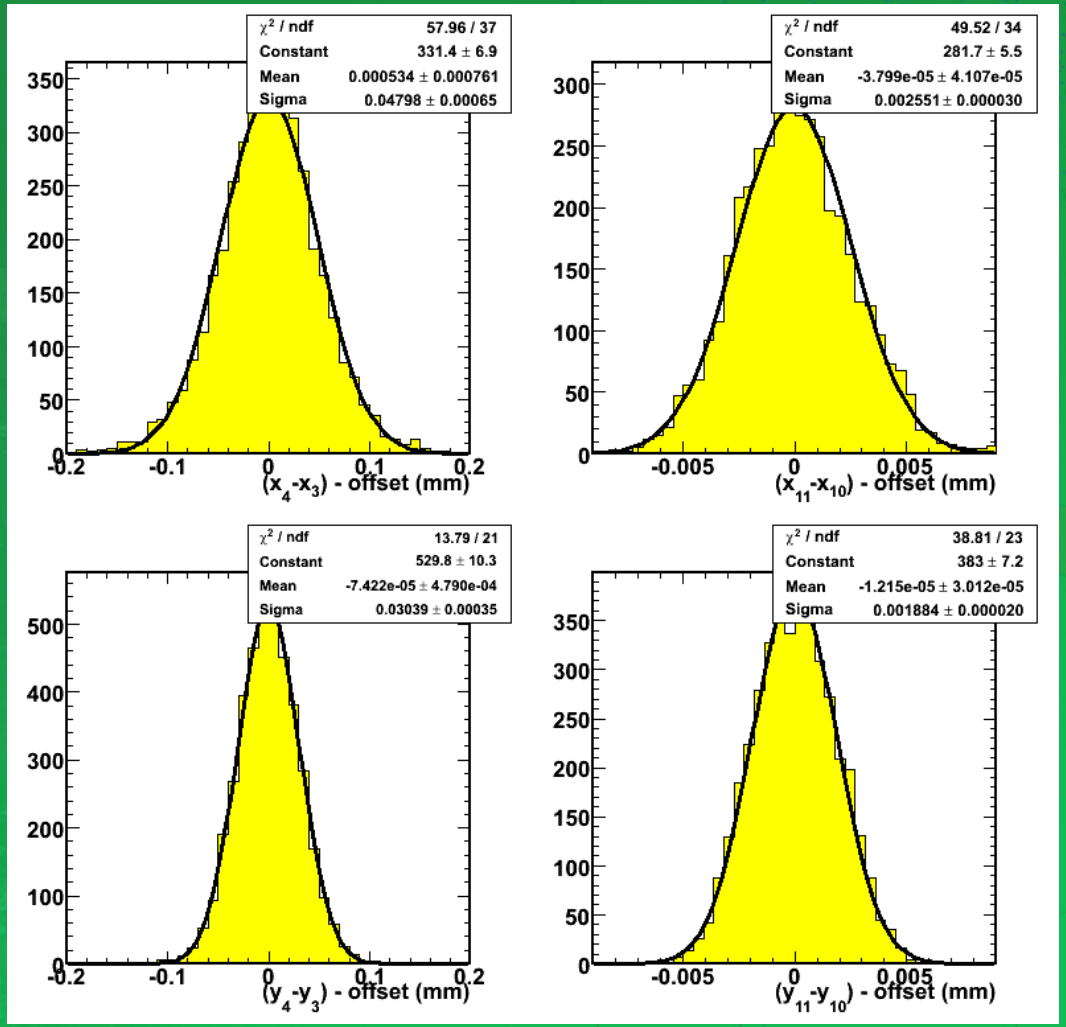


- Plans to test chicane ideas at ESA
  - Using old SLAC cavities
  - Test of chicane ideas and identification of possible problems
  - Test system of other general ILC and spectrometer specific BPM designs
  - New RF electronics
    - Resolution ~1μm
- First tests in January and April 2006, chicane tests in 2007…

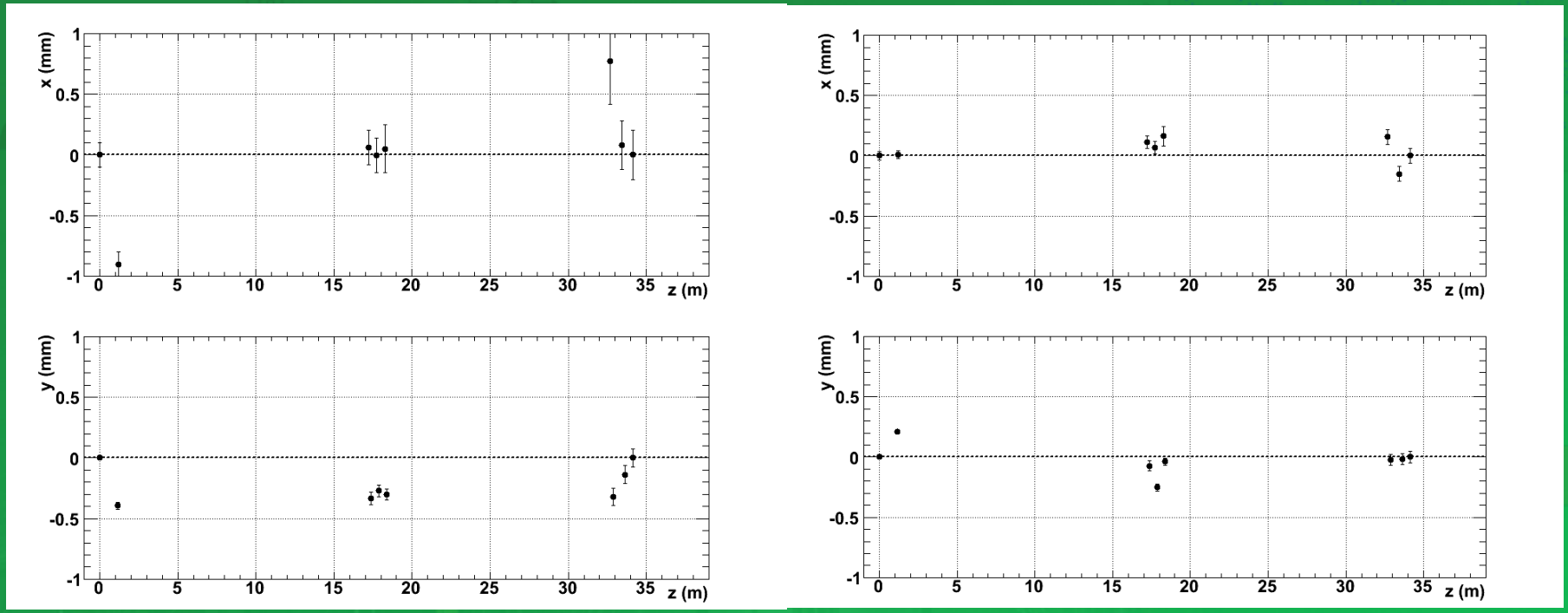


Results from ESA

- Commissioned 2 BPM triplets, including the new Linac BPMs
- Resolution data
  - Resolutions of <1μm were achieved
  - Dynamic range +/- 1 mm
  - Resolution of the Linac BPMs still worse (few μm), should improve significantly with the analysis tuned to the different decay rate/bandwidth



Results from ESA

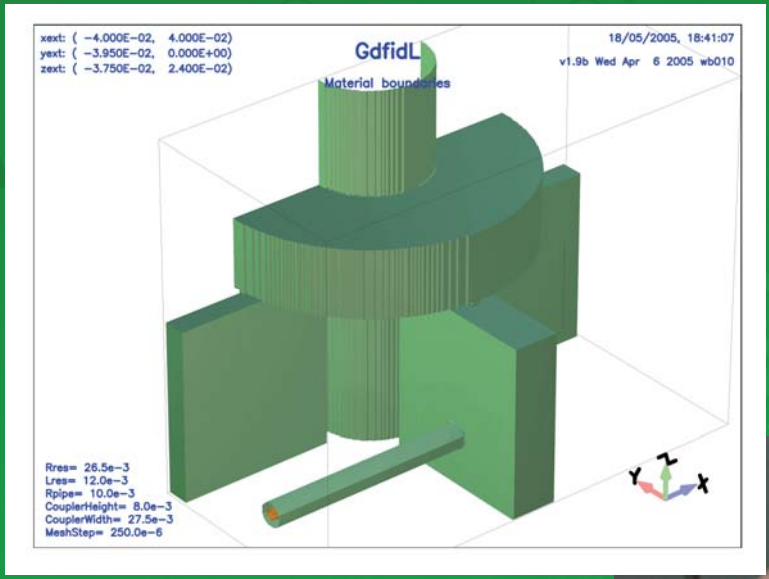


- BPM alignment
  - 3 sets aligned within +/- 200 μm
  - Distance between sets ~20 m

Need optimized BPM design

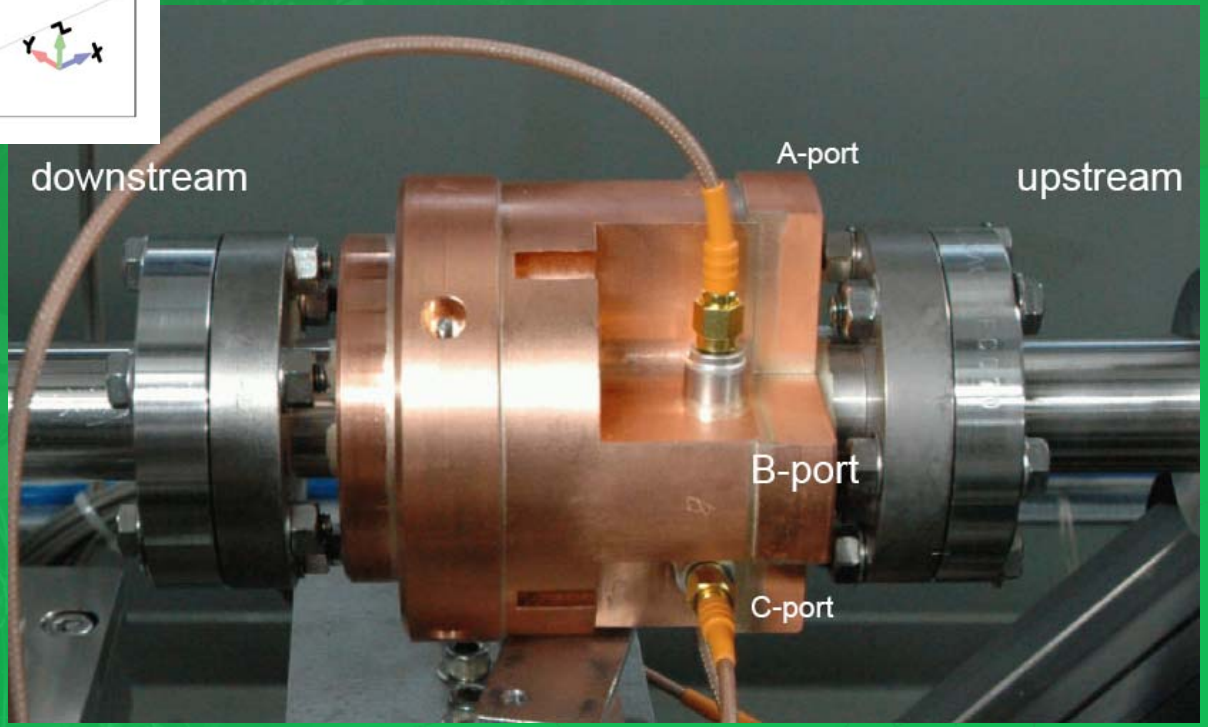
- Cavity BPMs, no alternative yet
  - Positive experience with ATF/ATF2 cavities
  - Need a bigger aperture for machine protection
  - Scale ATF2 design to a lower frequency

ATF2 QBPMs

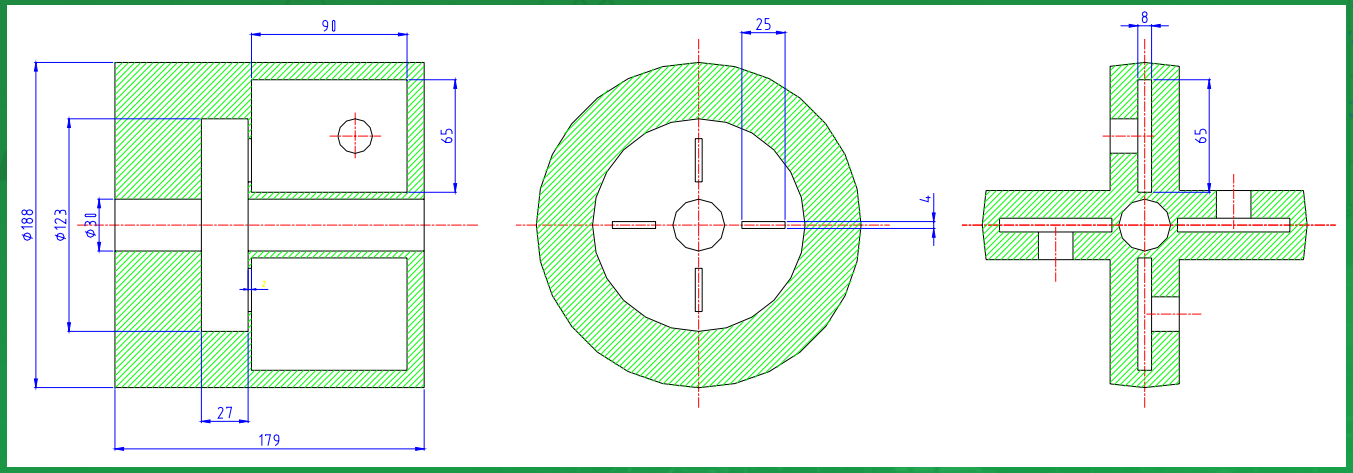


- Electrical design done by UCL
- Several prototypes successfully tested
- Good performance observed
- At least 40 dB isolation between x and y channels measured after tuning
- Successful tests with dedicated electronics

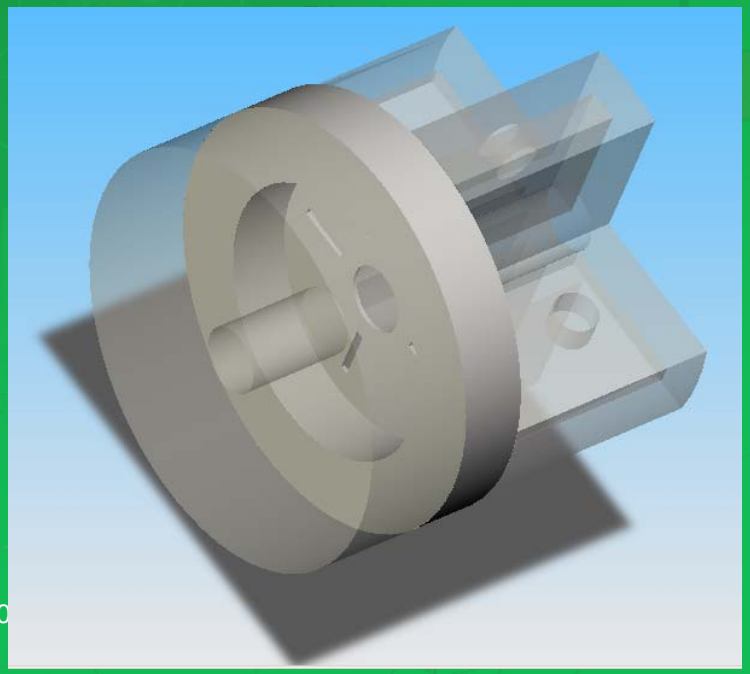
- First nanoBPM for serial production! (~30 units to be produced for ATF2)



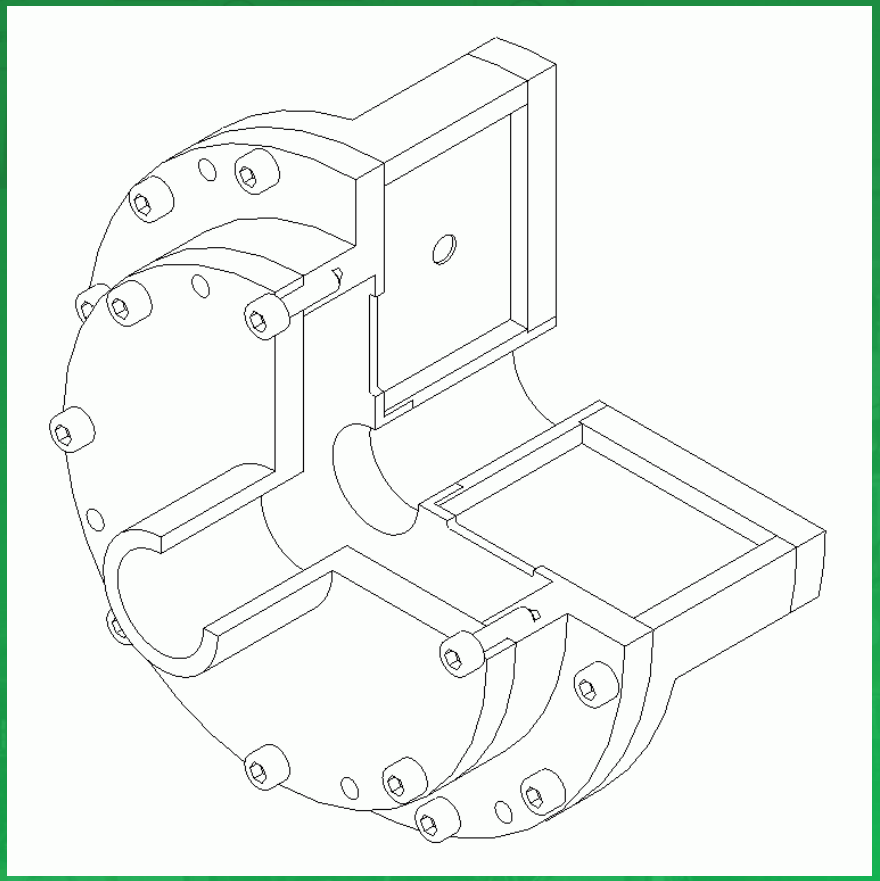
2.8 GHz cavity design in progress

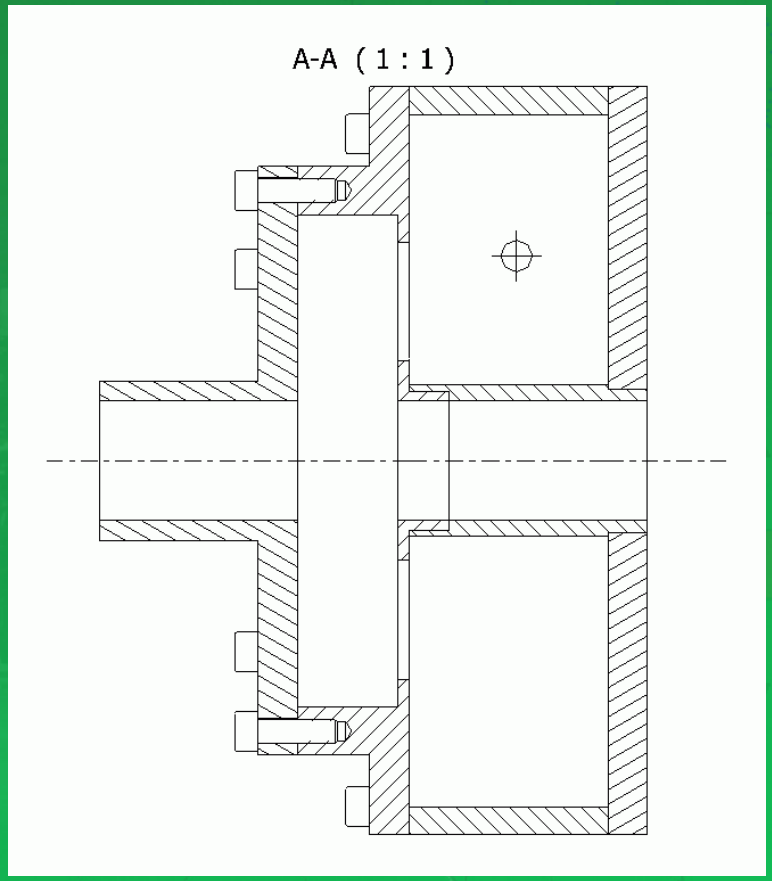


- Robustness vs. high sensitivity and compactness optimum
- Tuning to 2876 MHz
- Reduced Q to keep the decay time small
- Use nanoBPM analysis – keep similar processed signal properties
- Almost the same sensitivity as for BPMs in nanoBPM experiment at ATF beam, expect a resolution < 100 nm
- Planning to test in ESA



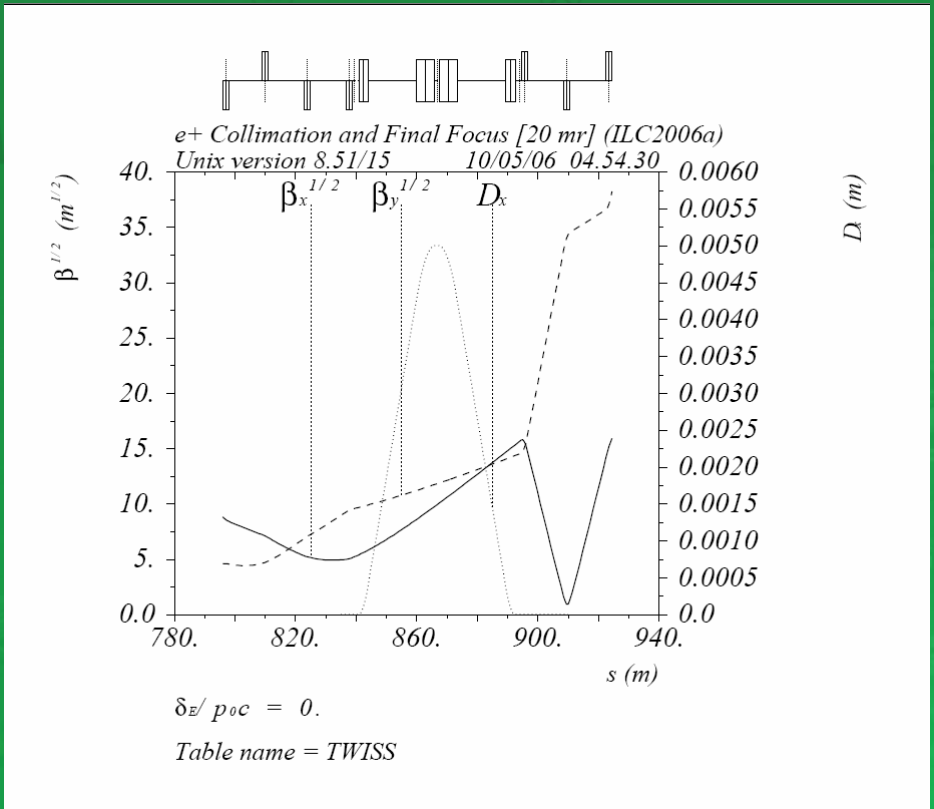
Prototype Al model





- Planning to do cold tests before producing a vacuum prototype, a model is being produced in UCL workshop
- Going to introduce an asymmetry (one slot will be off axis), also reduced the waveguide length in order to see the monopole mode coupling; this should allow us to set reasonable tolerances, benchmark the simulation code, and choose a reasonable waveguide length

ILC spectrometer



Spectrometer analysis:

- Started with a simulation of systematic effects in the spectrometer chicane
- Backgrounds simulation
- Improving existing analysis of the impact of the spectrometer chicane on the beam (energy bandwidth etc)
- Joined the efforts with all European institutions involved