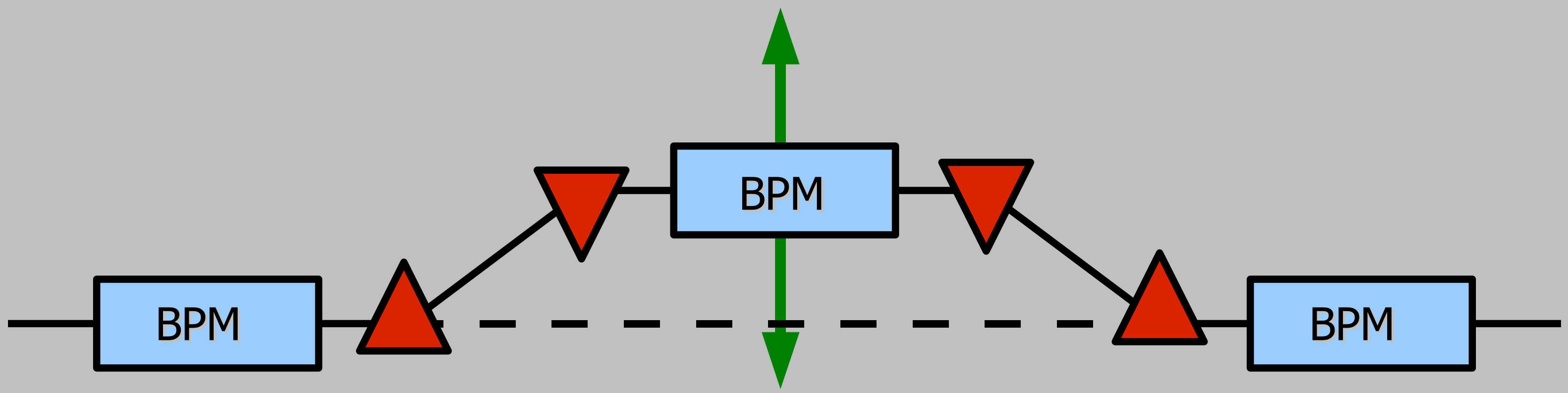
Progress report for the energy spectrometer test experiment at ESA at SLAC



Bino Maiheu
on behalf of the T474/T491 collaboration

LCWS 2007, DESY Hamburg

Outline

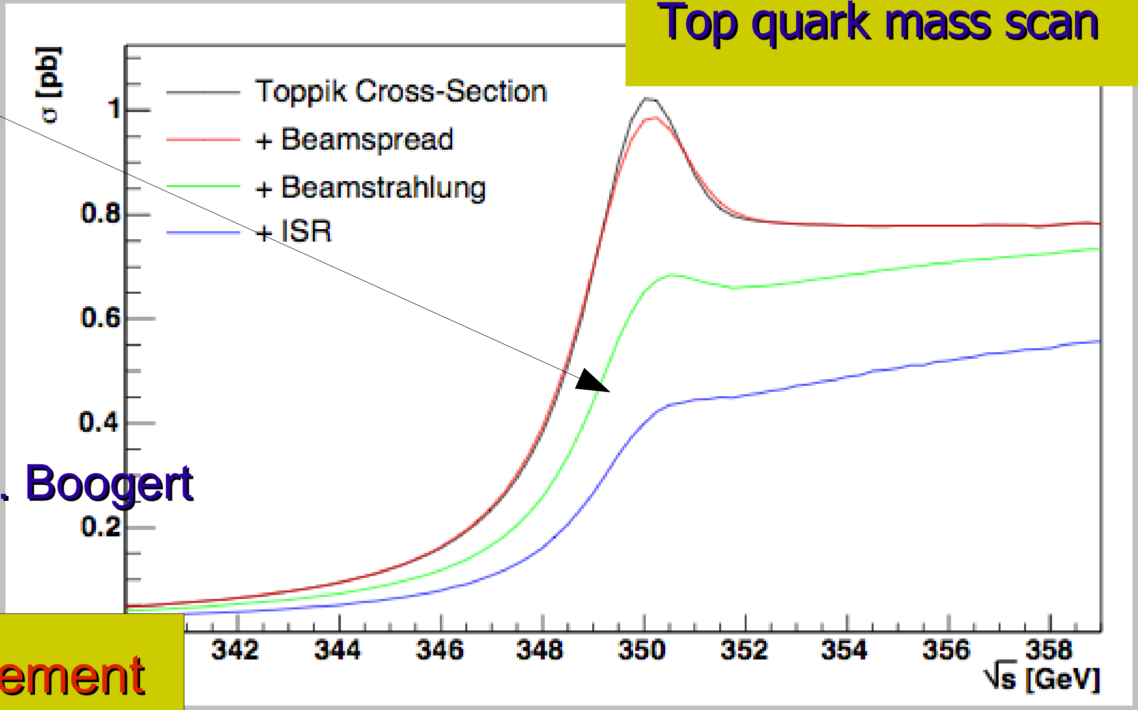
- Physics motivation
- Building an energy spectrometer based upon high resolution cavity BPMs
- The ESA test facility at SLAC, T474/T491, experimental setup
- Putting in the chicane, beam line modifications, progress since VLCWS '06
- Progress on results and data analysis, understanding systematics
- Outlook

Physics motivation, project aim

- Precision physics, constrain SM parameters, eg. top threshold properties
- Constrain/exclude SUSY scenarios

- Impact of beam energy on measurements, luminosity spectrum dL/dE

Top quark mass scan

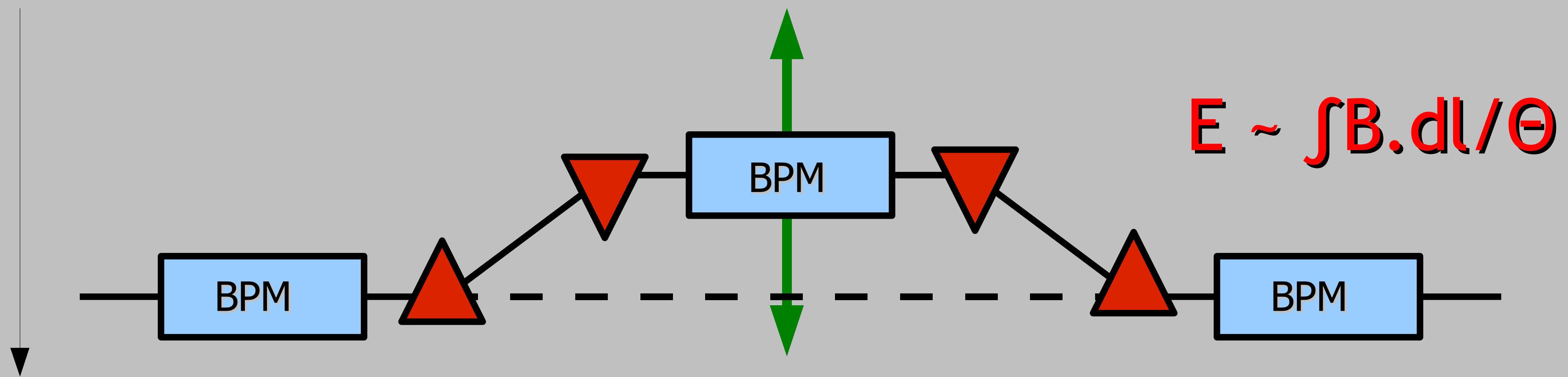


See e.g. talks of F. Gournaris and S. Boogert in top QCD session...

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

Proposed ILC energy spectrometer

- Precision measurement : dE/E 10^{-4}
- Minimal impact on beam itself : allowed emittance growth from SR
- Limited space budget in BDS ~ 60 m
- Minimal impact on physics data taking for e.g. calibration runs

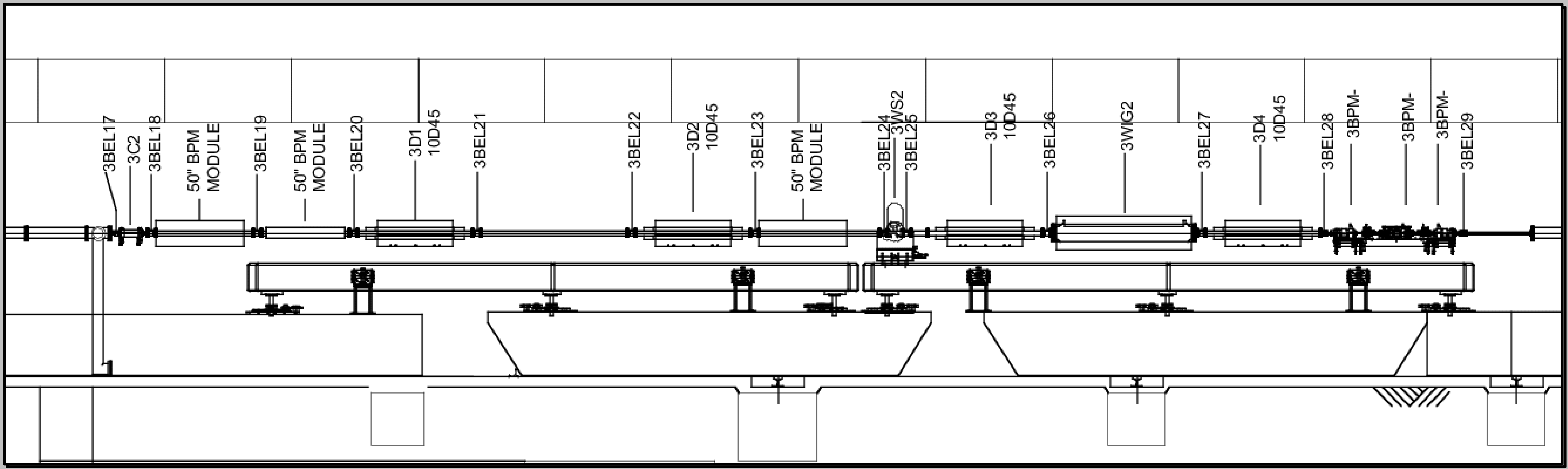


- Magnetic chicane with high resolution beam position monitors : cavity BPMs
- Max 5 mm dispersion at center chicane : determines resolution
- Emittance growth determines chicane layout
- Diagnostics needed:
  - Gain drifts : temperature
  - Mechanical stability : interferometer
  - Magnetic fields ($\int B.dl$) : NMR, Hall, fluxgate magnetometers

T474 test experiment at ESA, SLAC

ESA comparable repetition rate, bunch charge, energy spread as ILC
Possibility to vary bunch length, energy, charge
Easy steering with feedback system

- Build an energy spectrometer prototype, using a 4 magnet chicane
- Goal is to demonstrate the stability of this type of energy measurement at 10^{-4} level, and investigate how such a magnetic chicane can be operated most efficiently at the ILC
  - Operate at ~5 mm η_x at center chicane as in current ILC design
  - Need < 1 µm resolution on position measurement (BPM)
  - With position measurement stability over multiple hours of ~ 100 nm



T474/T491 collaboration, running

Institutes involved

SLAC, UC Berkeley/LBNL, Notre Dame, Dubna, DESY/Zeuthen, RHUL, UCL, Cambridge

PI's

M. Hildreth (Notre Dame), Y. Kolomensky (Berkeley) and S. Boogert (RHUL)

FY06 running :

January run : test run (4 days), commissioning of steering BPMs

April run :

- commissioning of RF cavity BPMs outside of chicane (old & new)
- optimization of digitization and processing

July run :

- commissioning of interferometer system on ILC linac prototype BPMs
- commissioning of energy BPM at high dispersion
- stability data taking with 10 BPMs, frequent calibrations

FY07 running :

March run :

- commissioning of second energy BPM
- installation and commissioning of magnetic chicane : first chicane data !
- relocation of BPM/interferometer to center of chicane,
- cal tone system and new processors with remotely controllable attenuation

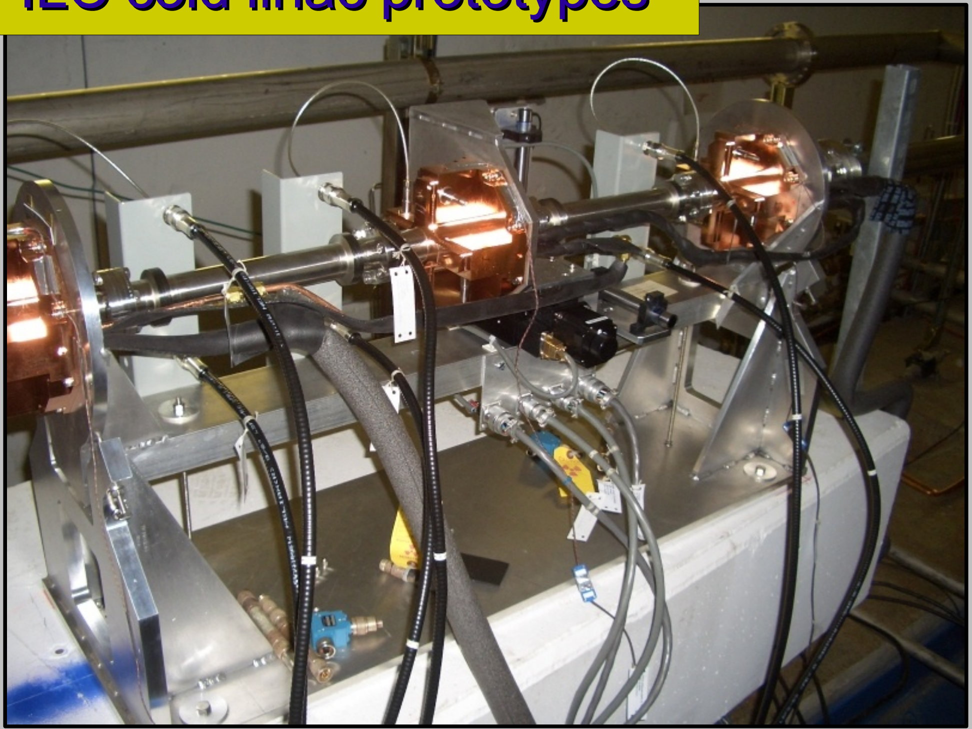
Planned July run

Different BPM systems used

- ILC linac prototype cavities
- 36 mm aperture, 2.859 GHz
- low Q (~ 500)
- good monopole suppression
- x/y polarizations in same cavity
- Middle BPM on x/y mover system
- Referenced to downstream Q

- Rectangular cavities, Q, x and y
- Polarizations separated
- 2.856 GHz, high Q ~ 3000
- 20 mm aperture (0.8 ")

ILC cold linac prototypes



SLAC cavities

New spectrometer BPM prototype

Optimized design : A. Lyapin/UCL :

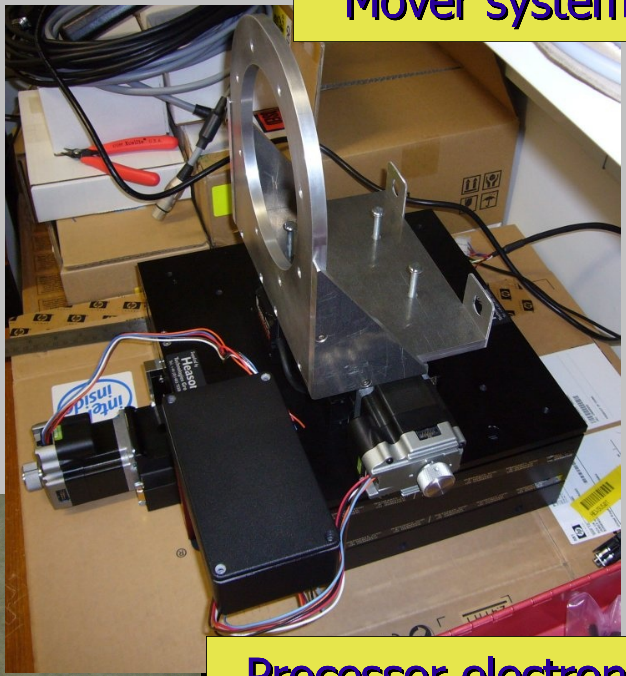
- high resolution : ~ 100 – 200 nm
- aperture
- monopole suppression
- own reference cavity

developed by UCL/RHUL/MSSL

mechanically rigid mover system

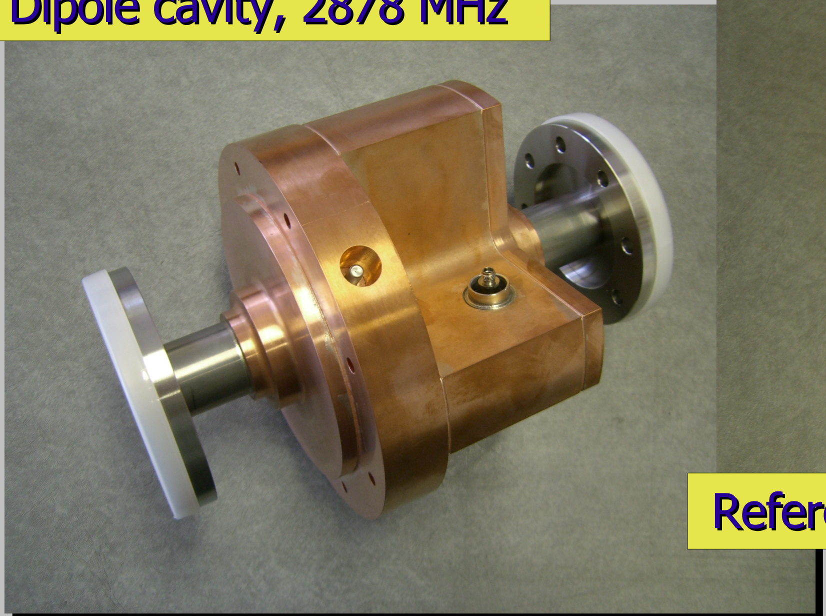
installation planned in July

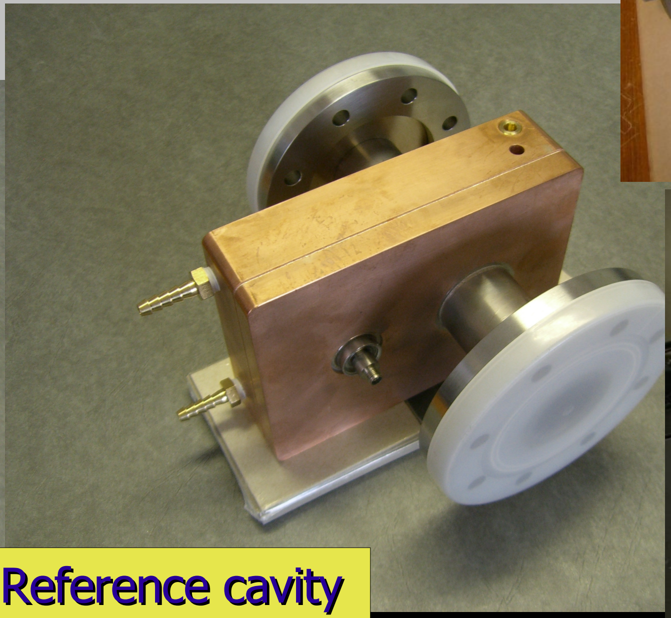
Mover system



Use SLC MDL 2856
Digitize at 22 MHz

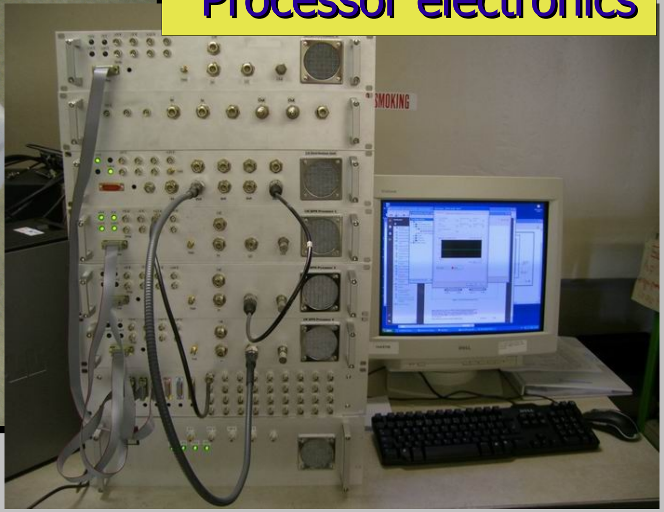
Dipole cavity, 2878 MHz





Reference cavity

Processor electronics

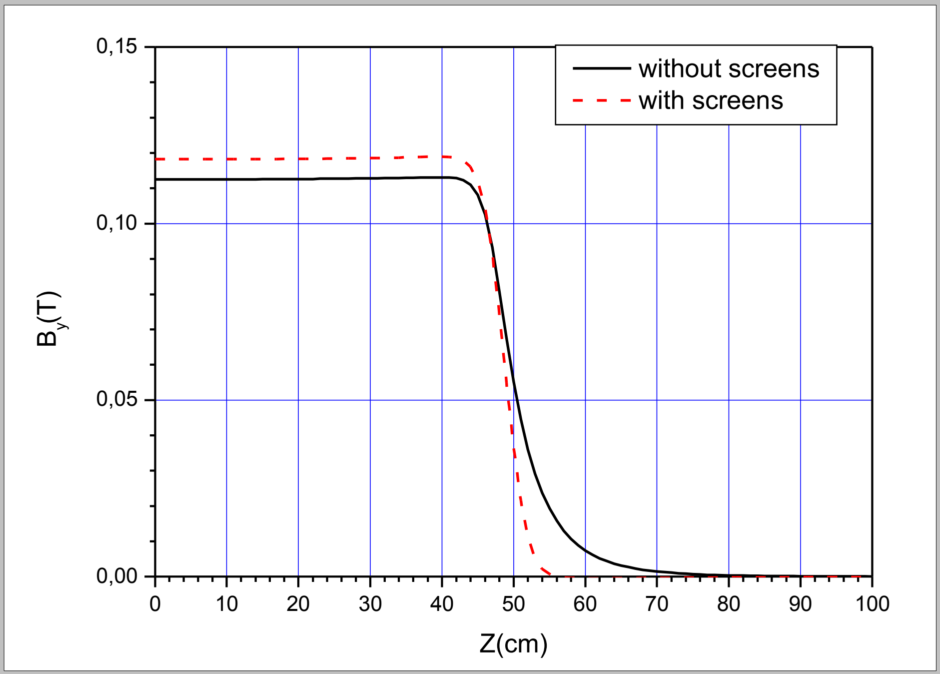


Magnetic measurements

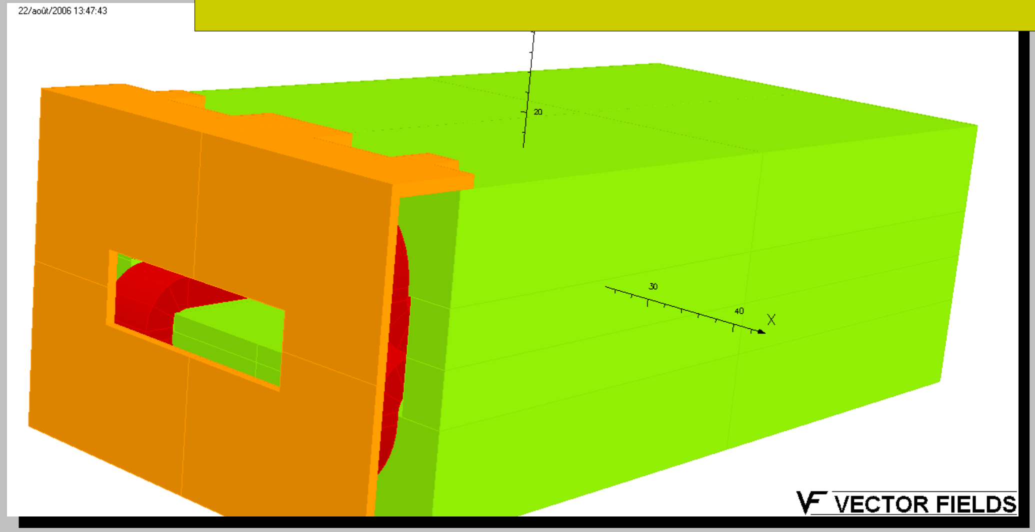
Simulation of magnets carried out by N. Morozov (Dubna)
prepare for measurements in SLAC testlab (SLAC/Dubna/Zeuthen)

Main simulation results :

- magnetic field integral 10^{-4} uniformity region is ±15 mm
- region for possible NMR probe use determined (X*Z= ±7*±40 cm)
- relative contribution of the fringe field to the total field integral is 22%
- maximal level of the magnetic field in return yoke is no more 0.4 T
- temperature factor for the magnetic field integral is $6.1\times10^{-5}\times1/C°$
- Screens to reduce fringe fields



Model simulation using “Vector Fields”



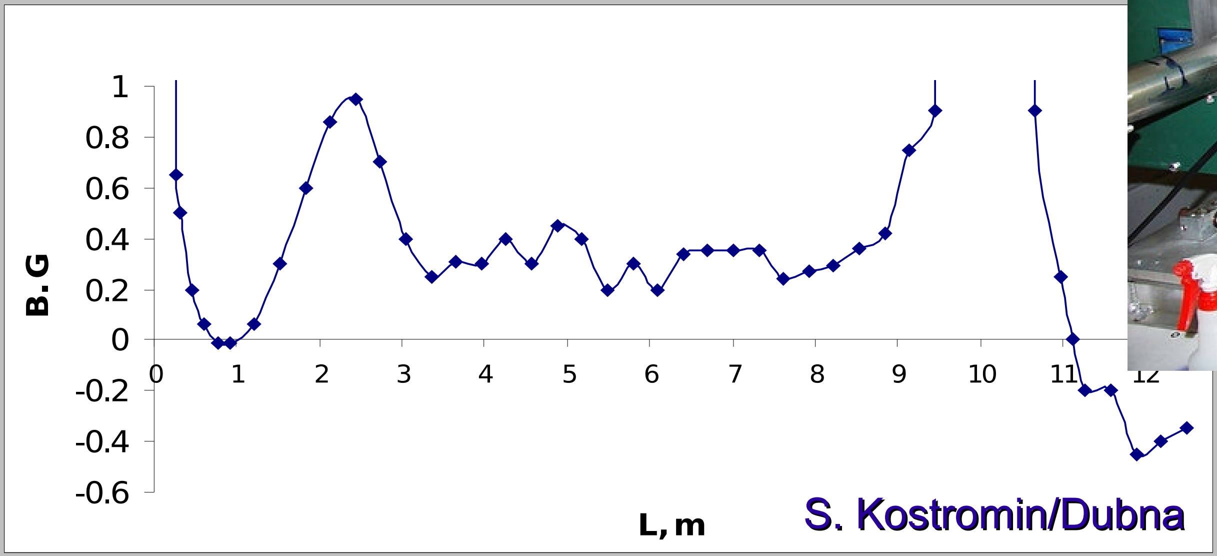
N. Morozov/Dubna

Magnetic measurements

Results of magnetic measurements in SLAC lab, Nov. '06 (SLAC/Dubna/Zeuthen)

- Magnetic field integral RMS stability : 60 ppm (near working point – 150 A)
- Bdl relative RMS stability : ~ 100 ppm (both at 150 A and 200 A)
- measured temperature factor for the magnetic field integral is $5.7\ 10^{-5}$ 1/C°
  in a good agreement with estimated one from magnetic field simulations $6.1\ 10^{-5}$ 1/C°
- ∫B.dl value (~ 0.117 T.m when I ~ 150 A) is in agreement with simulations : 0.118 T.m
- Analytical dependence of ∫B.dl vs. Current obtained in the vicinity of the working point
  ∫B.dl = $0.7813\ 10^{-3}$ x Current

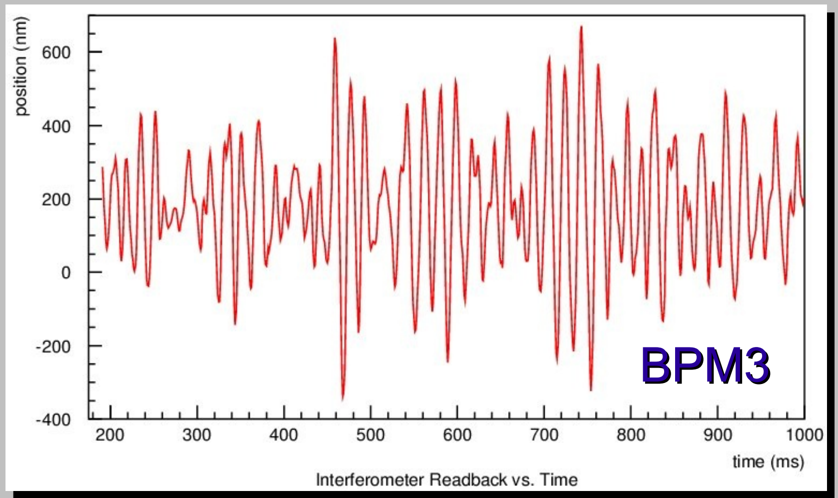
Residual magnetic field along full chicane length (vertical component)

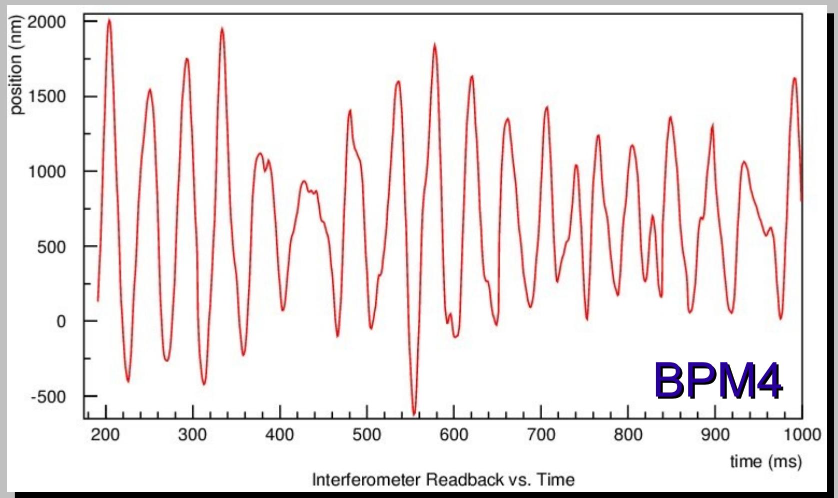


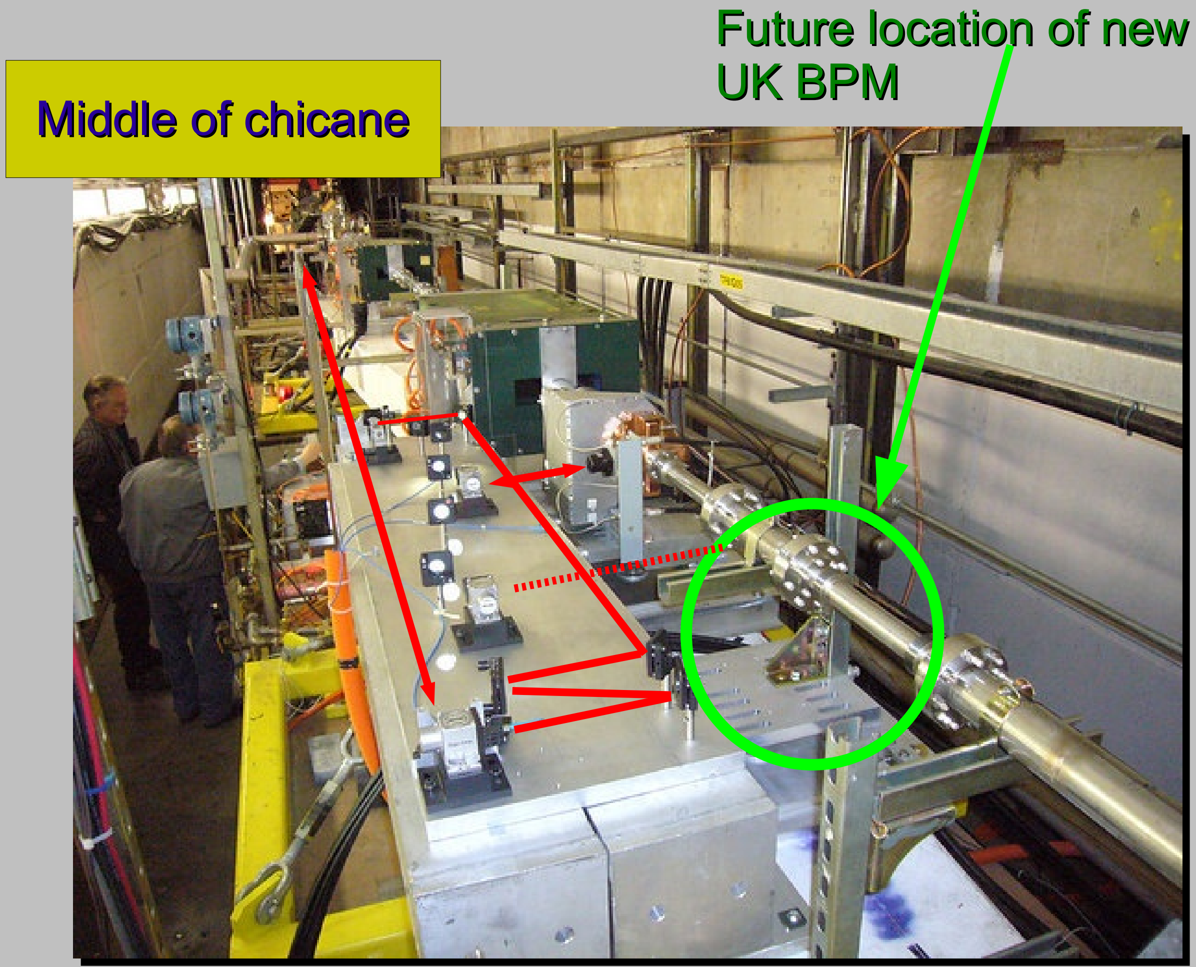
Magnets in beam line

Interferometer

- Sub-nm resolution, installation itself is stable over 1 hour within 30 nm with fixed mirrors
- Relocated for march '07 run (previously on ILC cold linac prototype triplet)
- Now monitor center of chicane + one head left for new UK BPM
- 1 BPM in front of chicane, send laser beam down long pipe



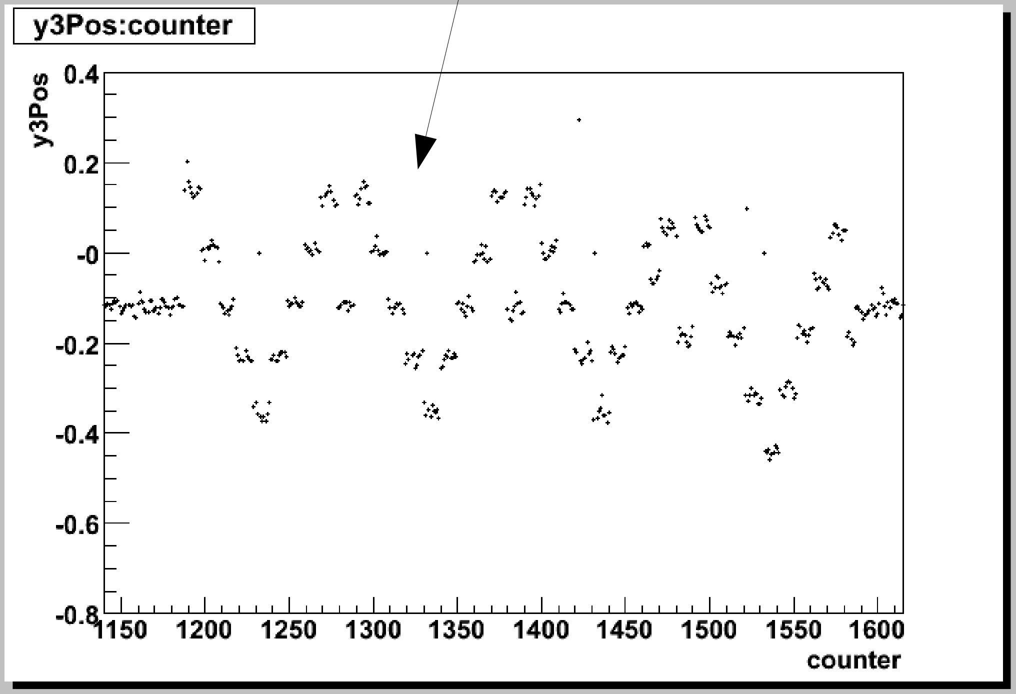


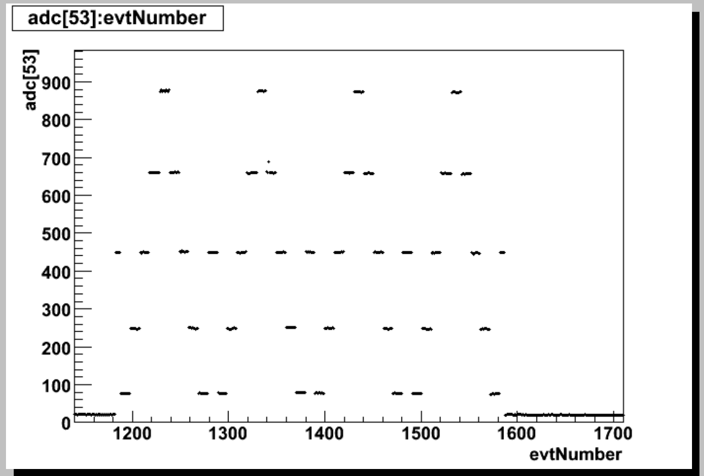


Stability results, FY06 running

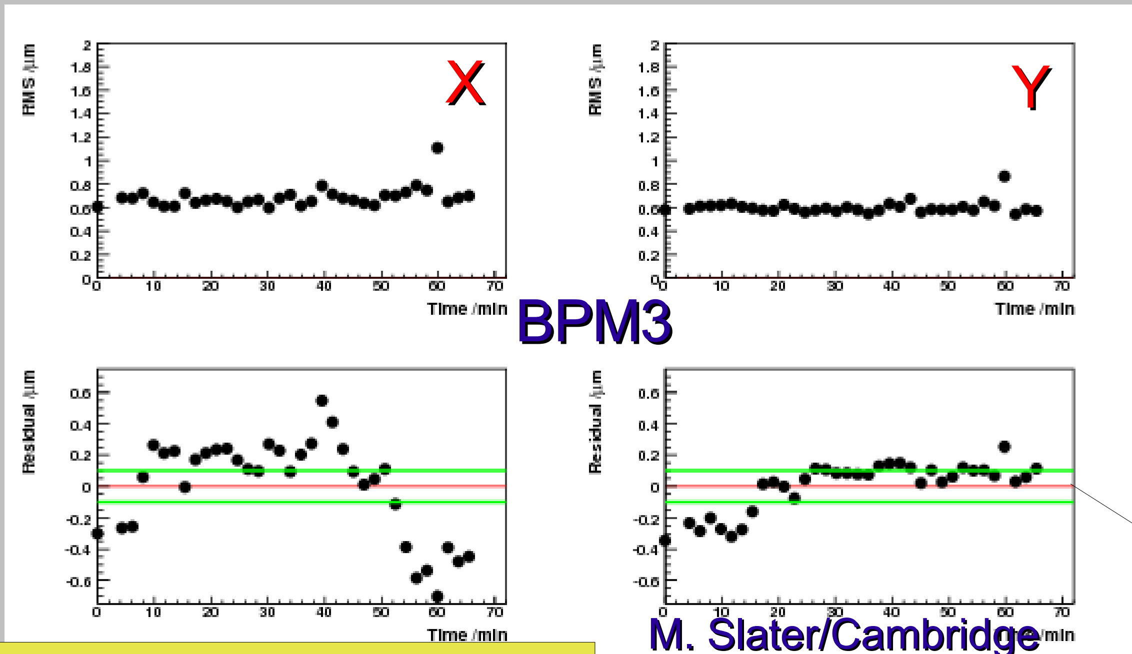
Paper "Commissioning of Spectrometer BPMs in End Station A" in the make
In depth analysis of 48 hour stability data taking with frequent calibrations

- Variation in ω and γ over 48 hours found negligible (~ 2 nm)
  justifies use fixed ω and γ in algorithm which extracts amplitude and phase
- Calibration with beam (corrector scans) induce quite large variations in
  IQ phase and scales : no feedback, beam jitter
  mover calibrations + think of clever calibration scheme (helmholtz coils)
  - Commissioned during march '07 run
  - Fast pulse per pulse beam motion
  - Less sensitive to beam jitter/drifts
  - Average scales and IQ phases
  - Automation : write status into ADC





Stability results, FY06 running

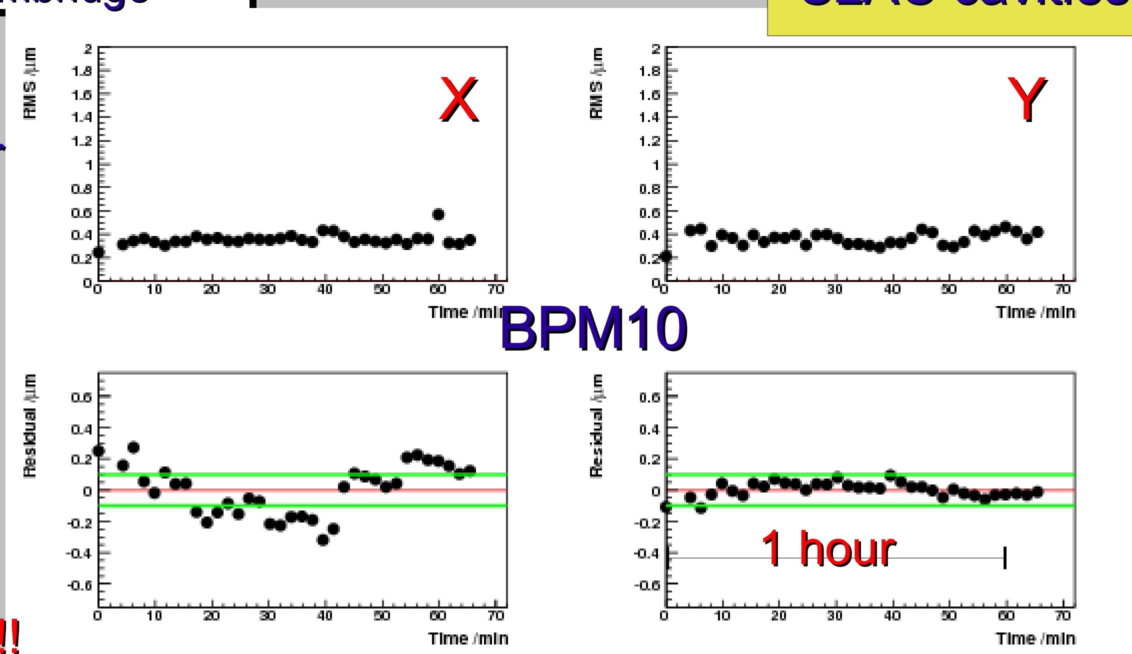


ILC cold linac prototype

- Using SVD algorithm to predict position from spectator BPMs
- Resolution given by RMS of residual
- Stability given by drift of residual
- Typical good Resolution :
  ~ 700 nm for ILC cavities
  ~ 300 nm for SLAC cavities

+/- 100 nm

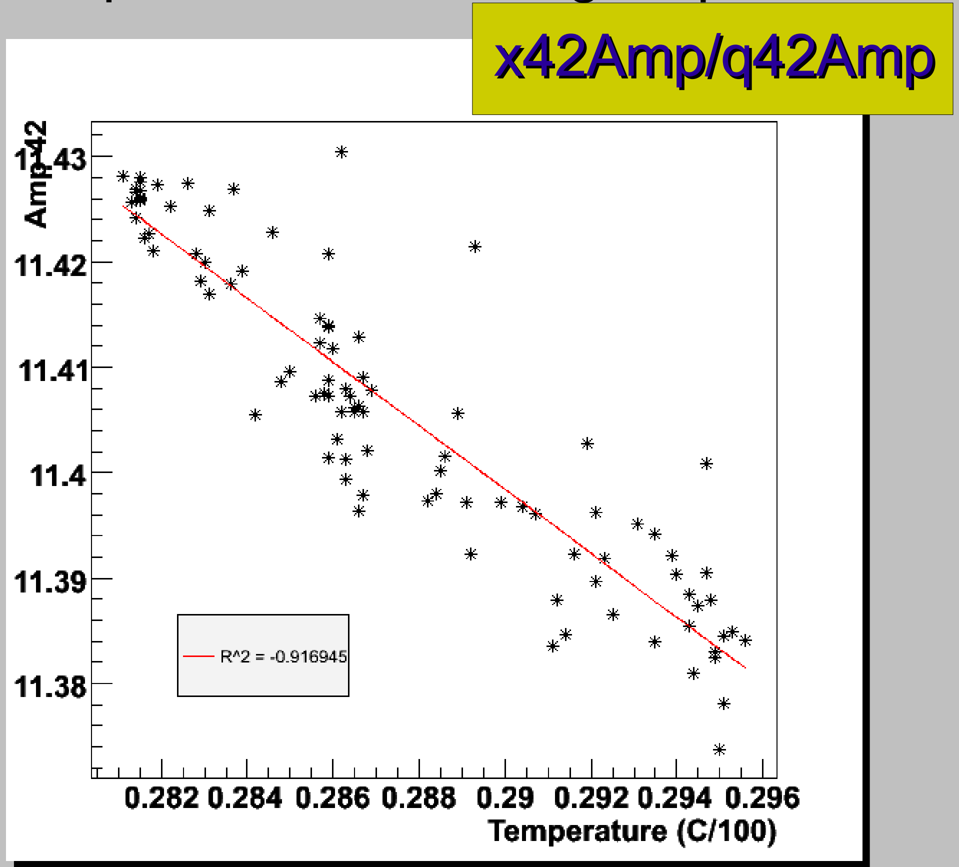
SLAC cavities

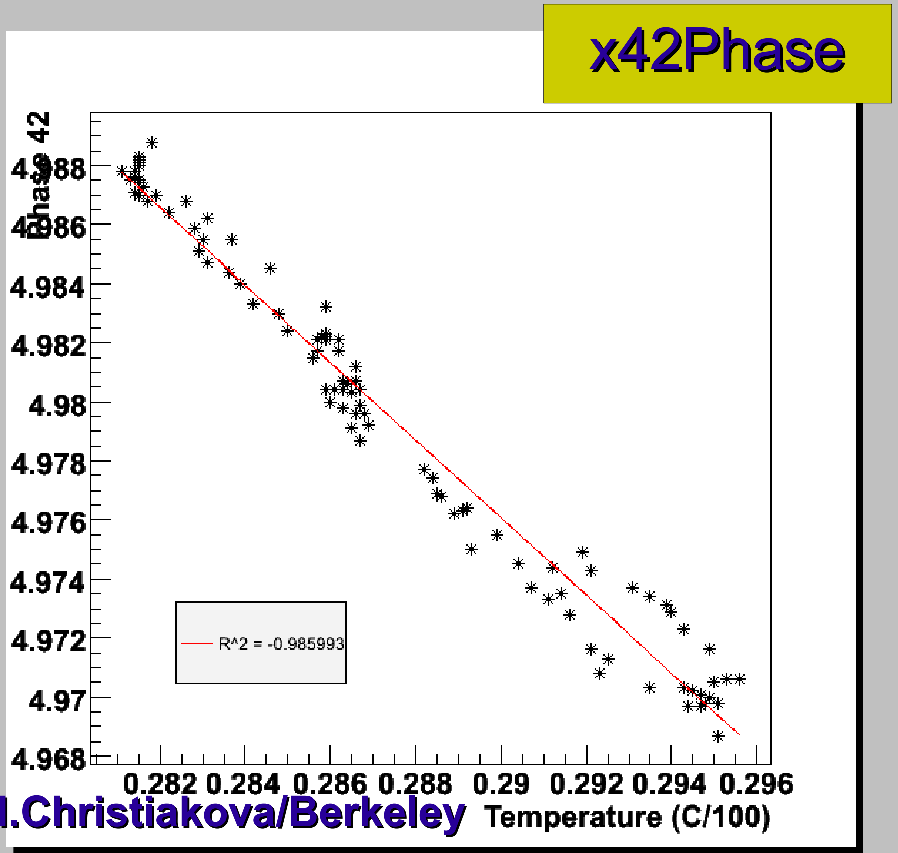


- Drifts can be seen over course of 1 hour
  - no gain monitoring available yet
  - correlate with temperature
- Long term drifts : clearly degradation of resolution
- Orbit stability shows to be +/- 1 µm over the course of an hour and RMS on the level of 1 µm
- Need to understand systematics way better : calibration tone, more analysis !!!

Calibration tone data, March '07 run

Send triggered CW tone down electronics and monitor gain / phase drifts
UCL/RHUL/UC Berkeley
Correlate with temperature
Calibration tone test runs March '06 (e.g. BPM 41/42)
Temperature monitoring on processors





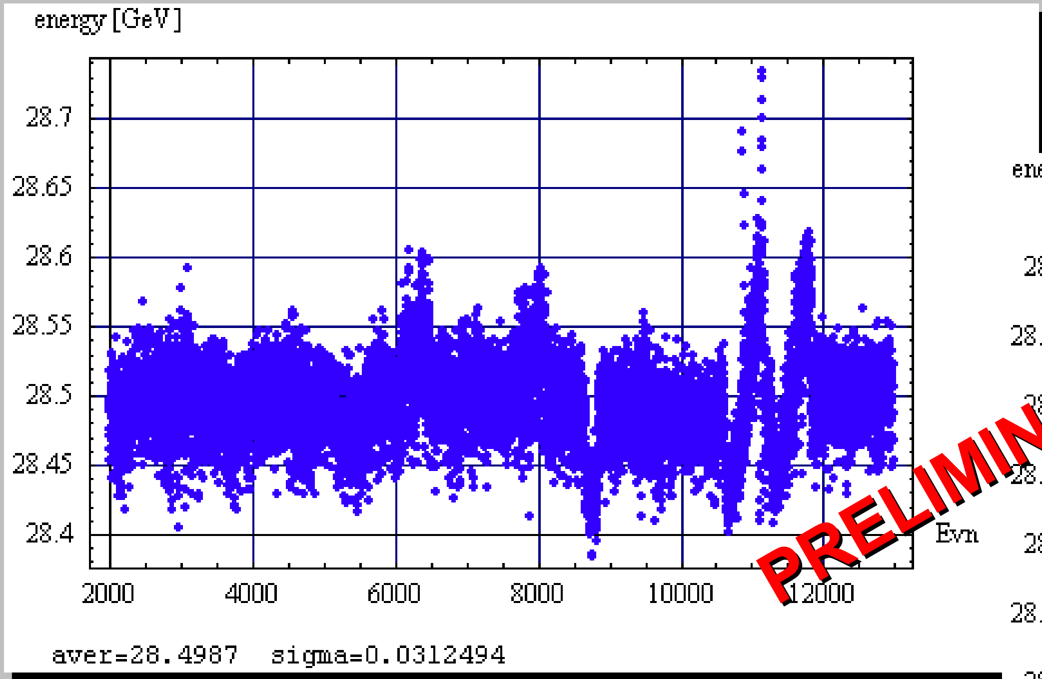
M.Christiakova/Berkeley

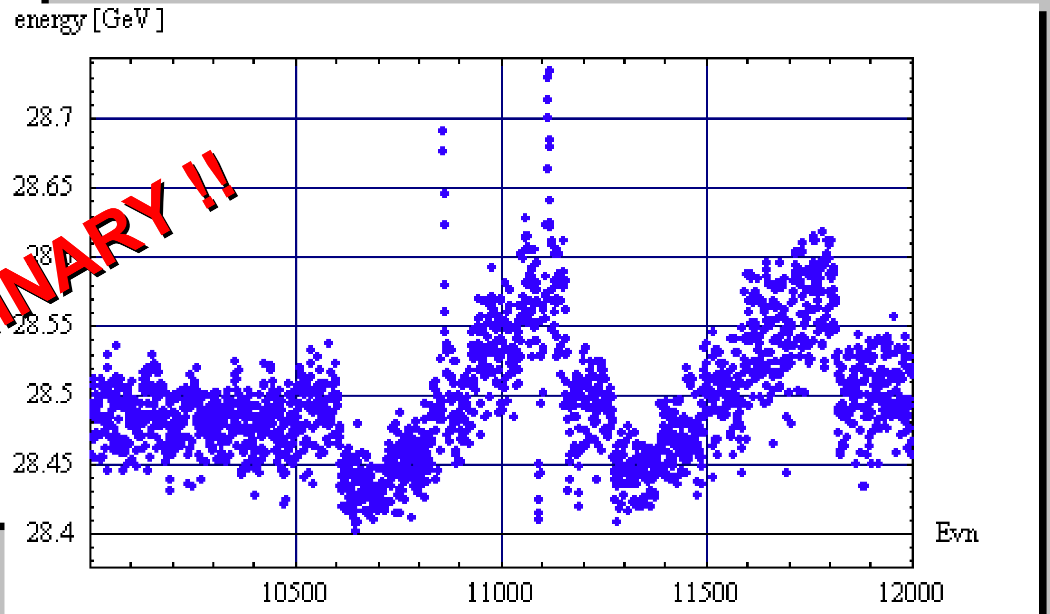
Clear correlation, phase seems fairly stable, need to analyze what effect this has on stability of energy measurements, data needed !

Preliminary spectrometer results

- Taking into account ∫B.dl and deflection at center of chicane, can compute correct beam energy
- Have to subtract incoming orbit in each event : prove we measure just energy !
- Further detailed analysis, spectrometer stability studies underway…

More and better data to come in July…



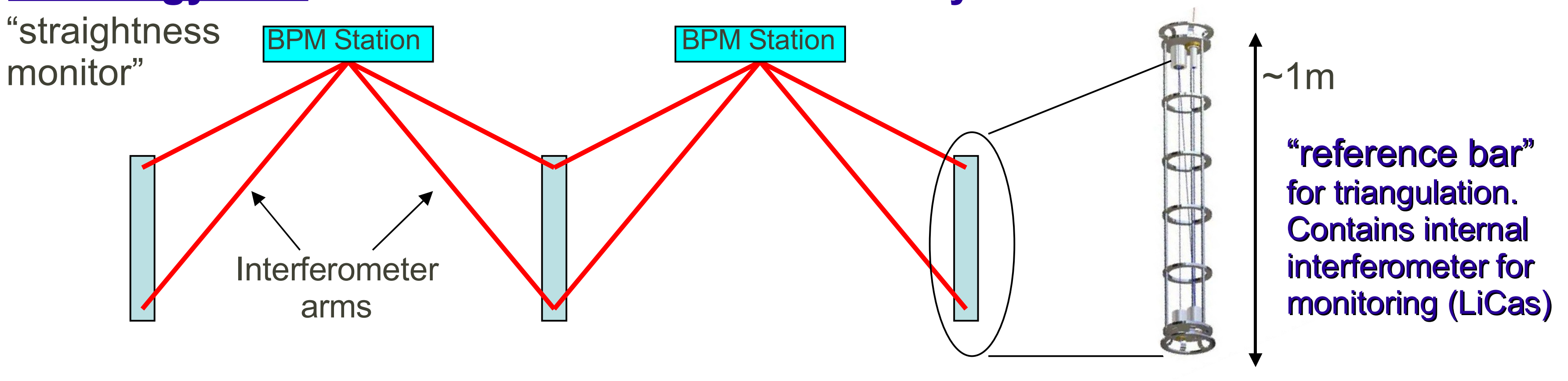


S. Kostromin/Dubna

Outlook

- Planned July run
  - Installation of new BPM prototype at center of chicane on mover system
  - Further data taking, full commissioning of calibration system
  - will be first good run with complete chicane up and running
  - also commissioning of synch stripe measurements (T475) :
    additional energy measurement systematics !
- Future plans to install metrology grid (M. Hildreth et al.)
  - Understanding mechanical stability

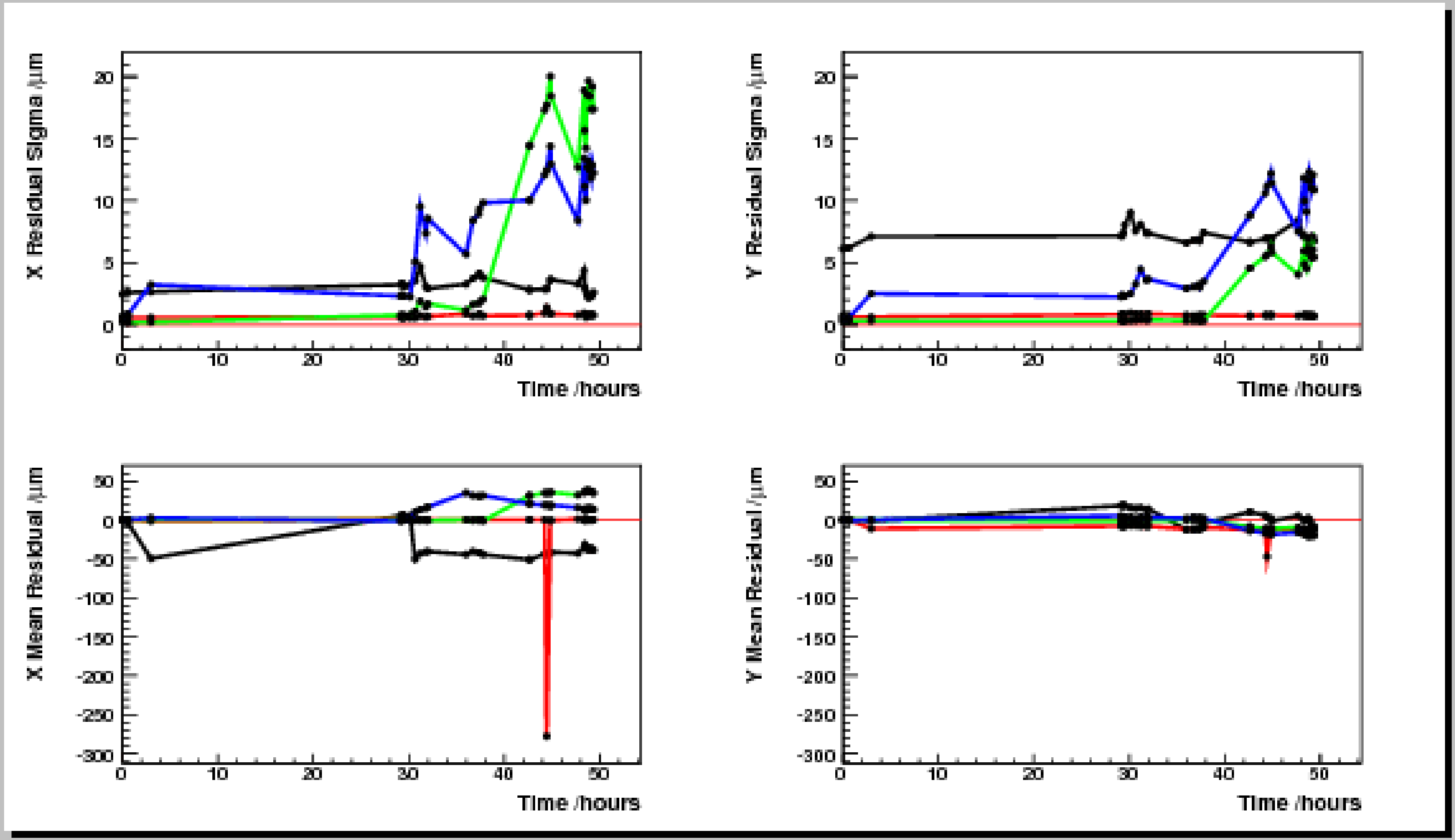
Metrology Grid : Crucial for Mechanical Stability Tests



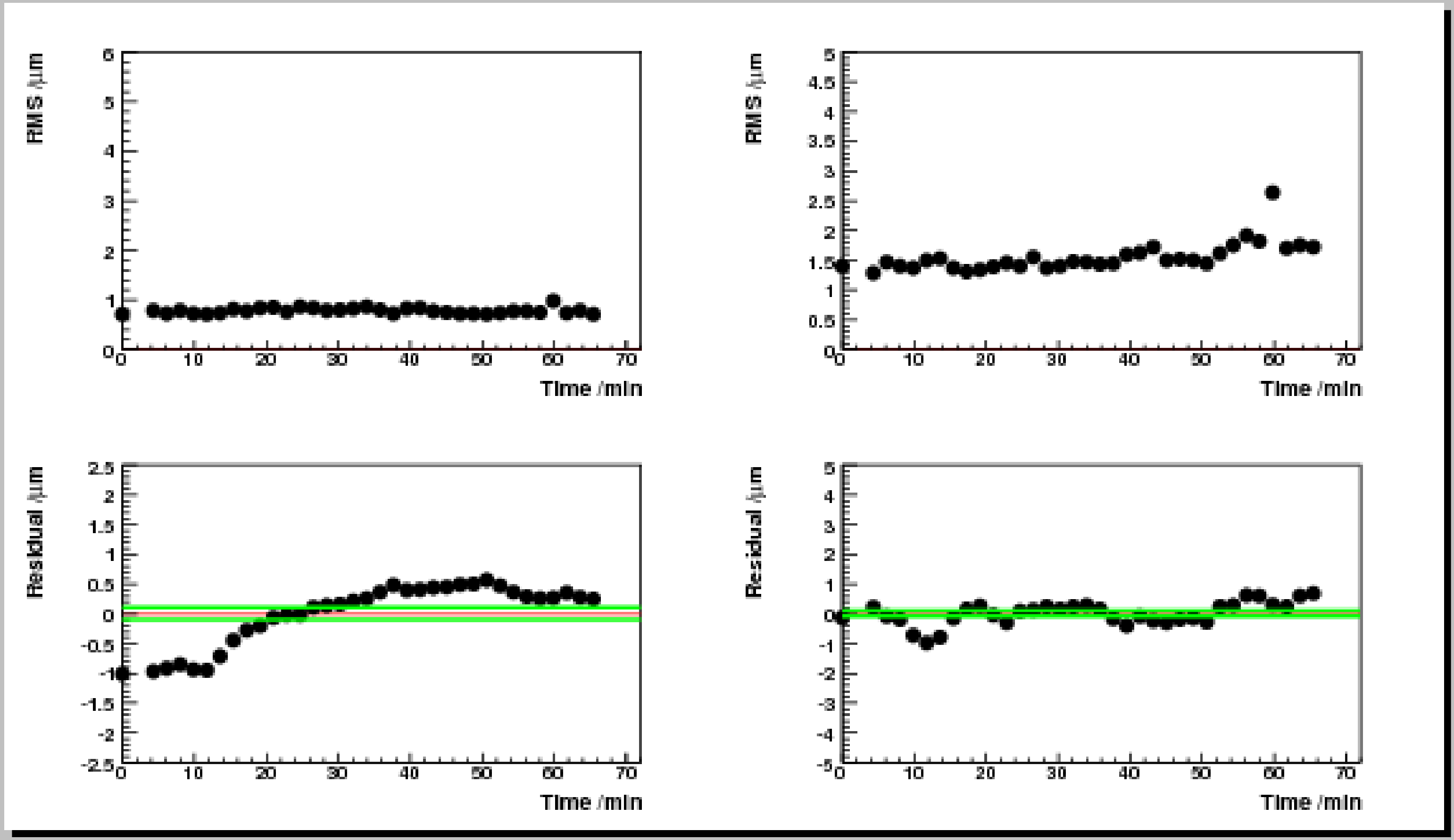
- Publications in pipeline
- More systematic understanding of complete system needed !

Backup Slides

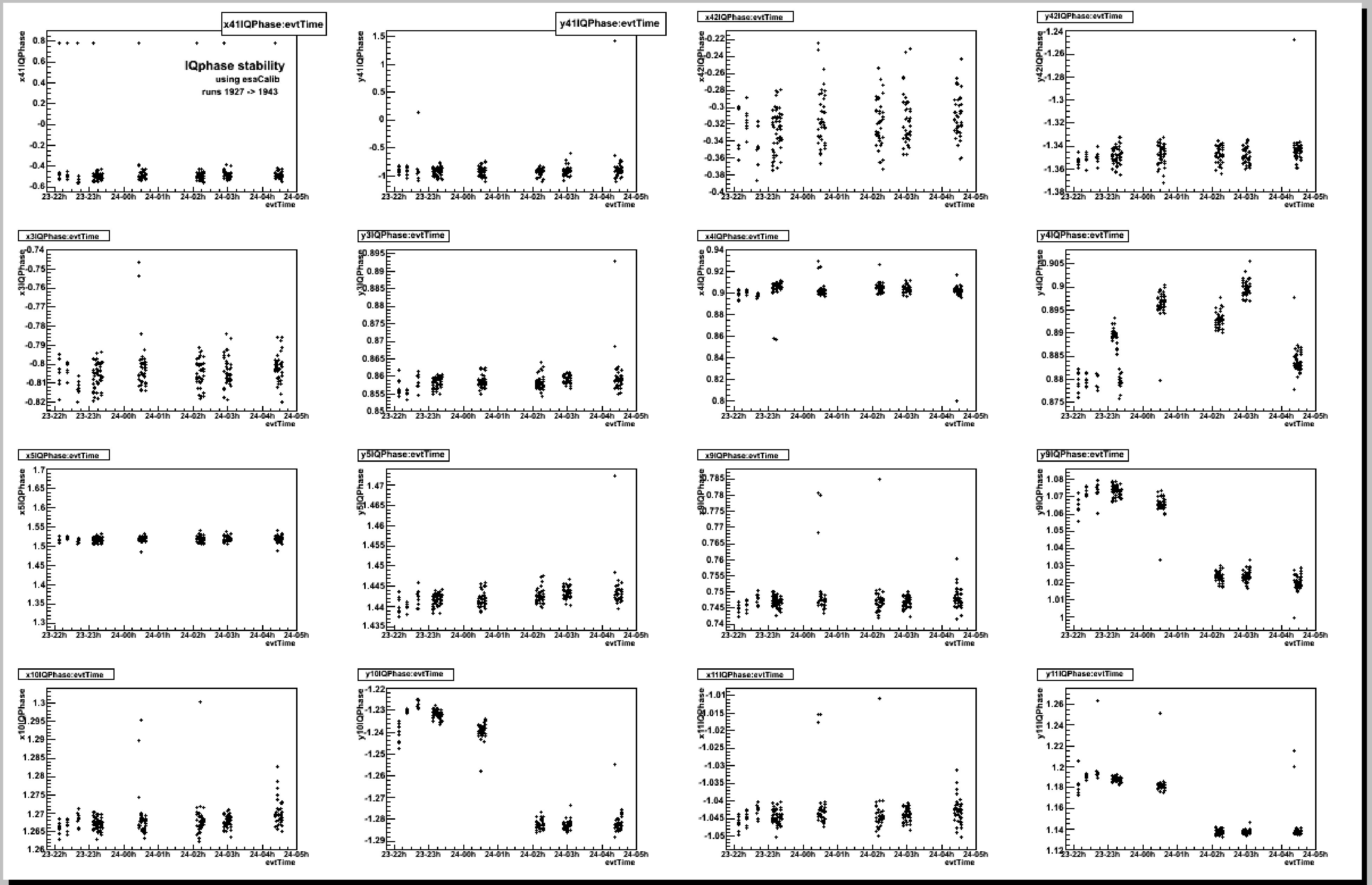
Stability/resolution over 48 hours



Linked resolution



Helmholtz calibration results



Helmholtz calibration results