BPM-Based Energy Spectrometer

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UC Berkeley/LBNL

For T474/T491 Collaborations

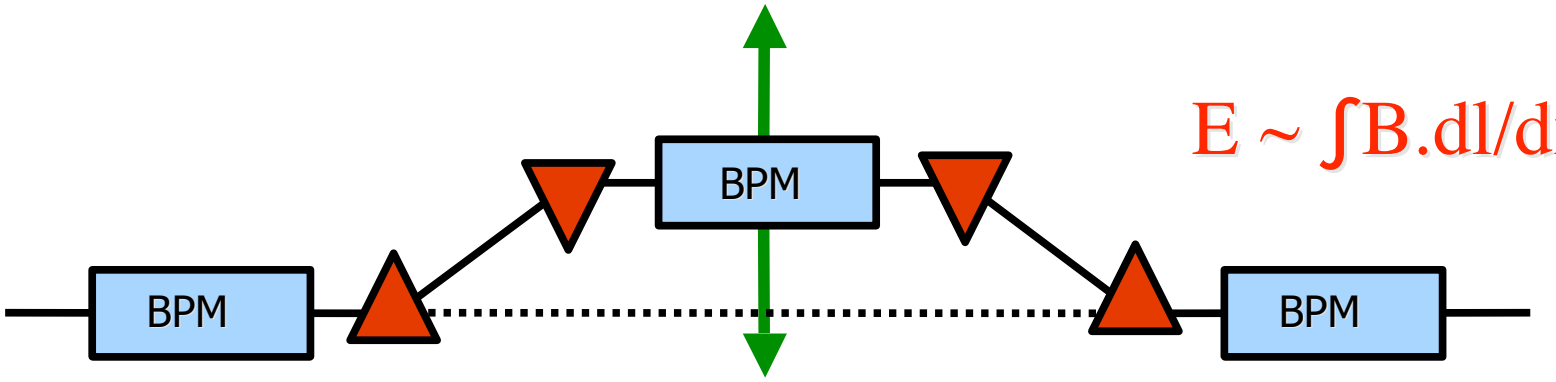
UCB/LBNL, Cambridge, Dubna, DESY/Zeuthen, UCL, Notre Dame , RHUL, SLAC

GDE/BDS

October 23, 2007

Upstream ILC Energy Spectrometer

- Precision measurement : $\sigma(E)/E \sim 10^{-4}$
- 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

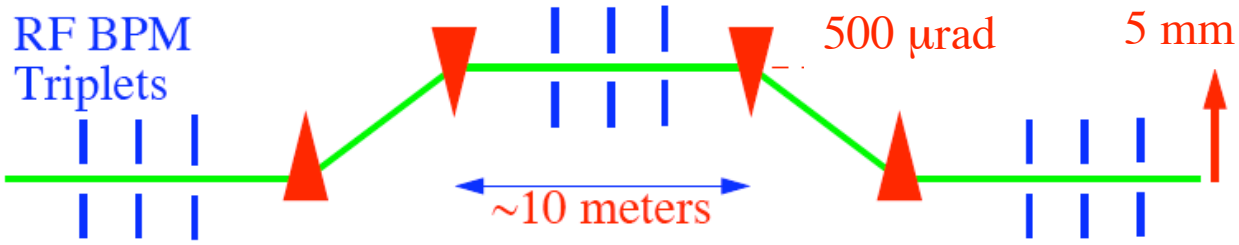


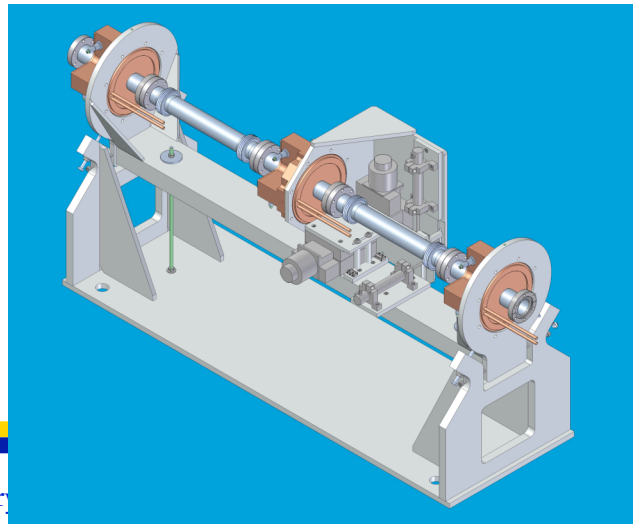
$$E \sim \int B.dl/dx$$

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

Energy Spectrometer Prototype in ESA

- T474/T491 experiments at SLAC End Station A
  - Build a prototype spectrometer with 10^{-4} stability
    - ☞ 250 nm position stability, ~1 μm resolution
    - ☞ Precisely measured and monitored magnetic fields
    - ☞ Precision measurement of physical positions
  - Also test linac BPM prototypes
  - Test beams at SLAC End Station A in 2006-2008

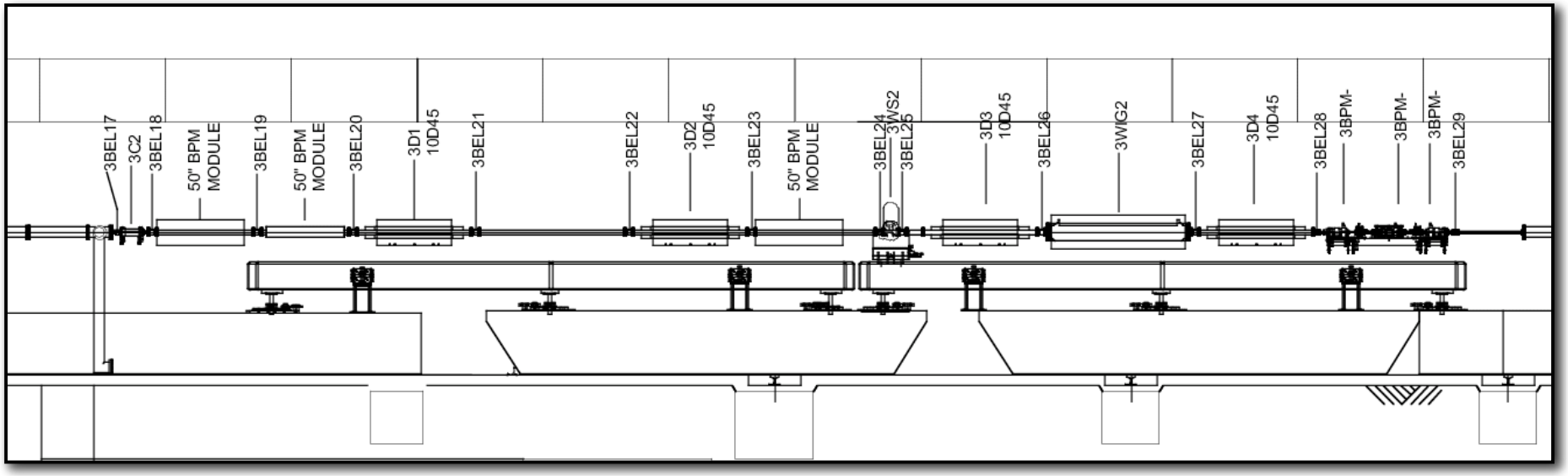




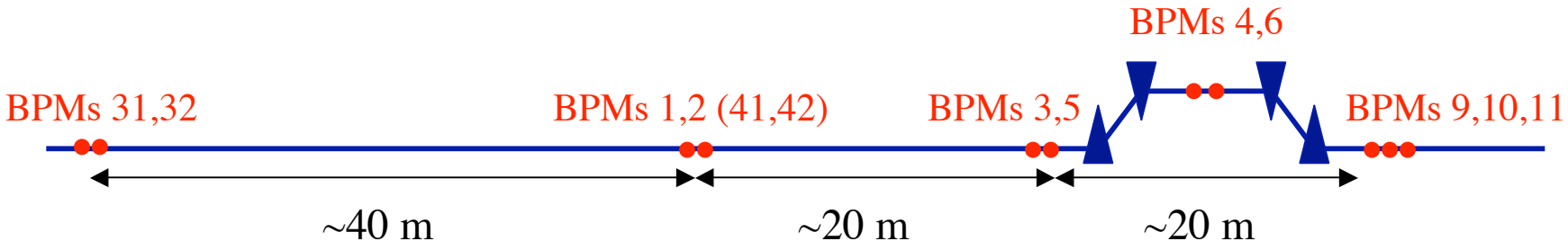
ESA Layout

Comparable repetition rate, bunch charge, energy spread as ILC
Systematics: ability to vary bunch length, energy, charge
Position feedback system

- Build an energy spectrometer prototype, using a 4 magnet chicane
  - 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 ~ 250 nm



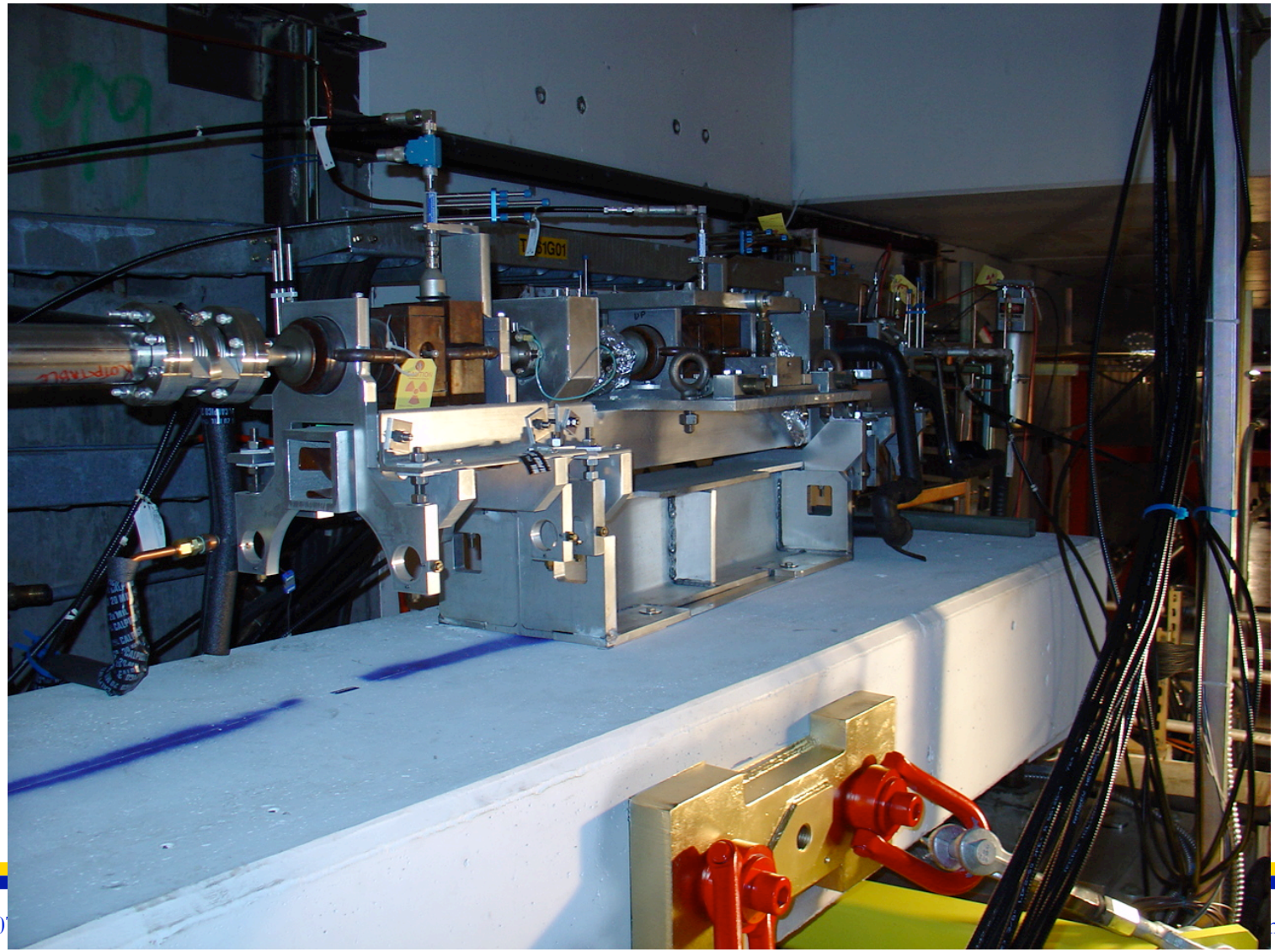
ESA BPM Configuration



- 13 BPM stations, S-band
  - 12, 24, 31,32 (A-line),1,2 (ESA alcove): ALine-style stations
    - ☞ Each with X,Y,Q cavities, 2-3” ID
    - ☞ A-line BPMs for trajectory and energy reference/cross check
  - 9,10,11: SLAC linac-style stations
    - ☞ Each with X,Y,Q cavities, 0.8” ID, Q~3000
  - 3,4,5: ILC linac-style cavities
    - ☞ New SLAC design (C.Adolphsen et al.), 36 mm ID, Q~500
  - 6: new UK design

ILC Linac Prototypes

BPMs 9,10,11 (E158 ASSET structure)



Spectrometer

T474/T491 Collaborations

UC Berkeley/LBNL, Cambridge, DESY/Zeuthen, Dubna, UCL, Notre Dame, RHUL, SLAC
PI's: M. Hildreth (Notre Dame), Yu. Kolomensky (Berkeley) and S. Boogert (RHUL)

FY06 running :

January run : test setup (4 days)

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 :

- 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

July run :

- commissioning of second energy BPM
- cal tone system and new processors with remotely controllable attenuation

Planned FY08 operations

New Spectrometer BPM Prototype

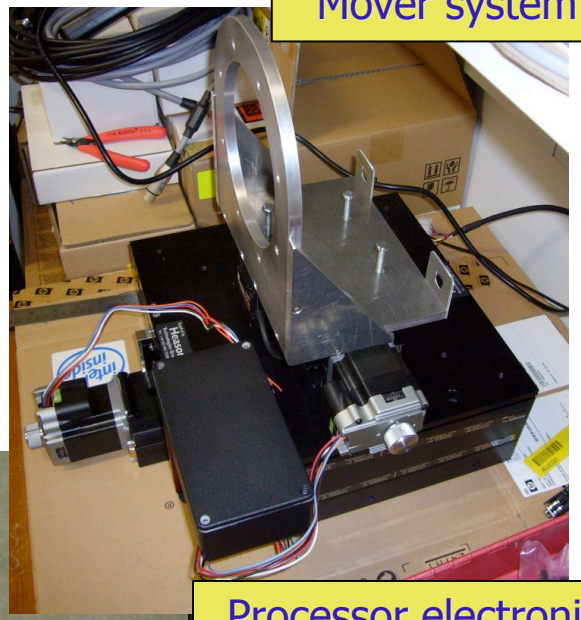
Optimized design : A. Lyapin/UCL :

- High resolution : ~ 100 – 200 nm
- Large aperture
- Monopole suppression
- Additional reference cavity

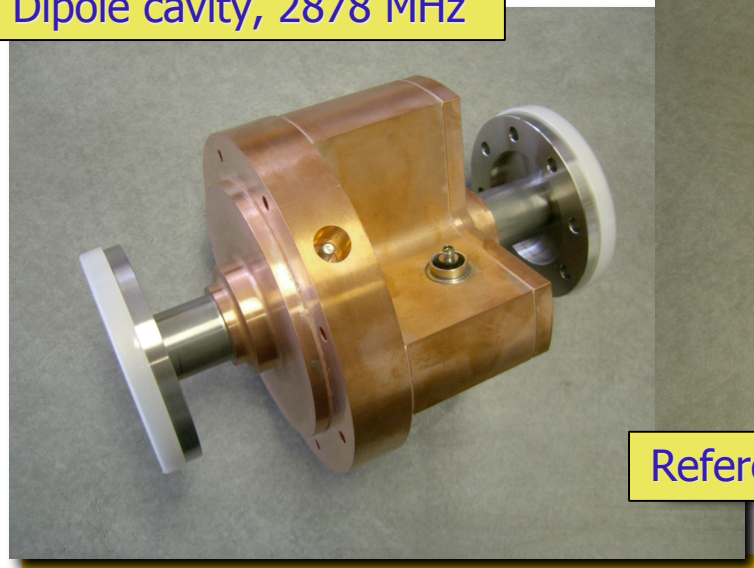
developed by UCL/RHUL

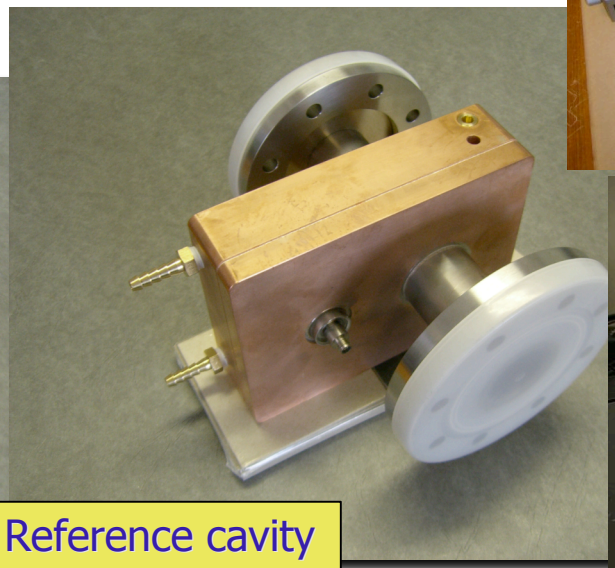
Use SLC MDL 2856
Digitize at 22 MHz

Mover system



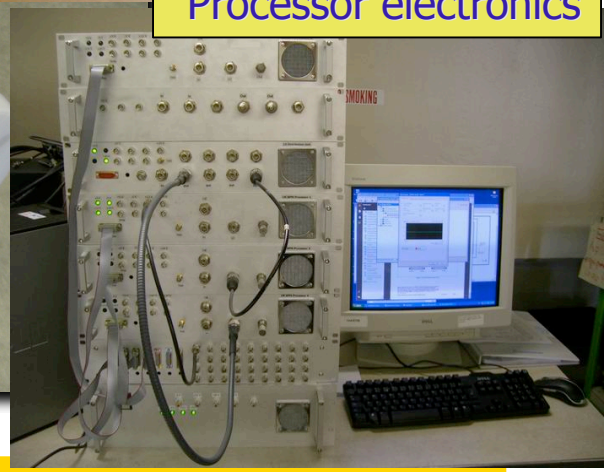
Dipole cavity, 2878 MHz





Reference cavity

Processor electronics

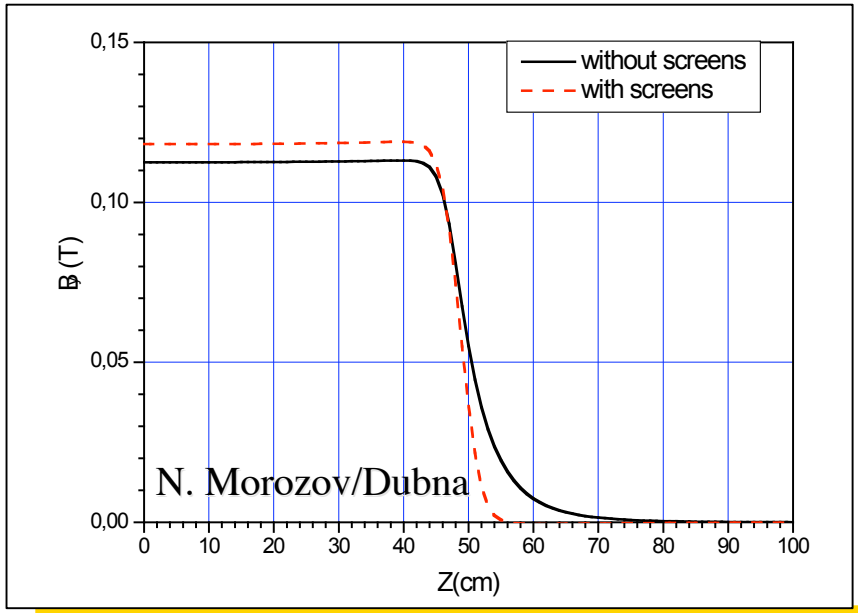


Magnetic Fields

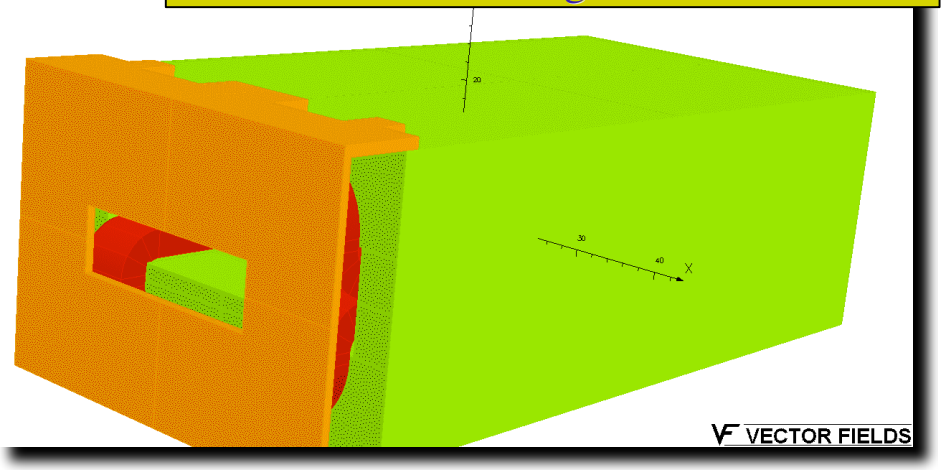
Simulation of magnets carried out by N. Morozov (Dubna)
prepare for measurements in SLAC testlab (SLAC/Dubna/Zeuthen)

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



SLAC 15D6 beamline magnets
Model simulation using "Vector Fields"

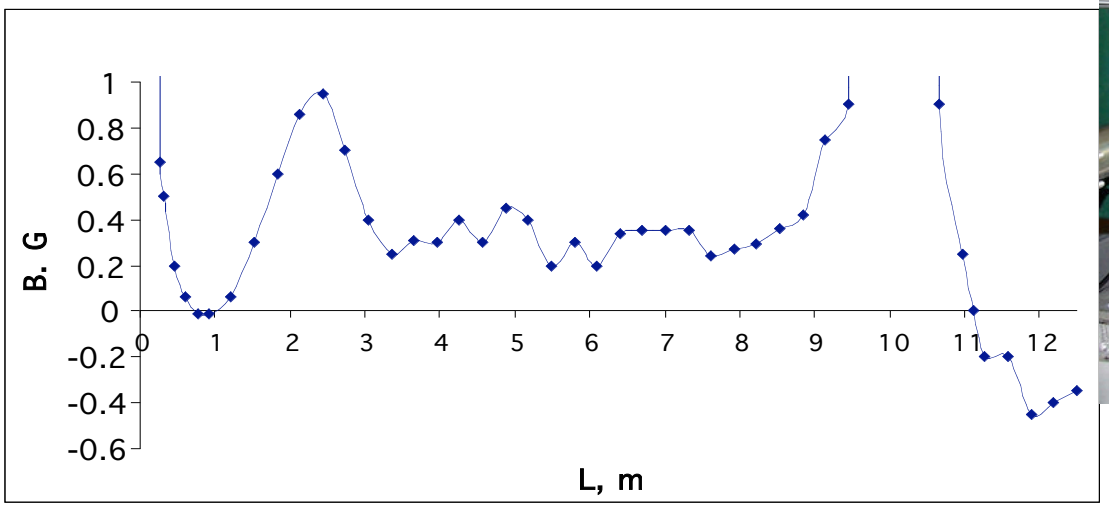


Magnetic Measurements

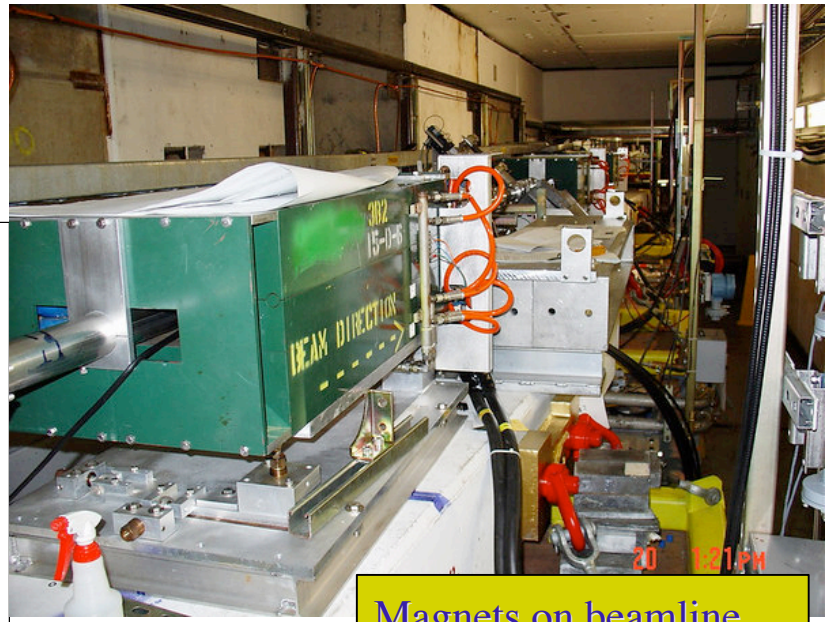
Results of magnetic measurements in SLAC lab, Nov. '06 (SLAC/Dubna/Zeuthen)

- 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 $5.7\ 10^{-5}$/C°
  in a good agreement with estimated one from magnetic field simulations $6.1\ 10^{-5}$/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)



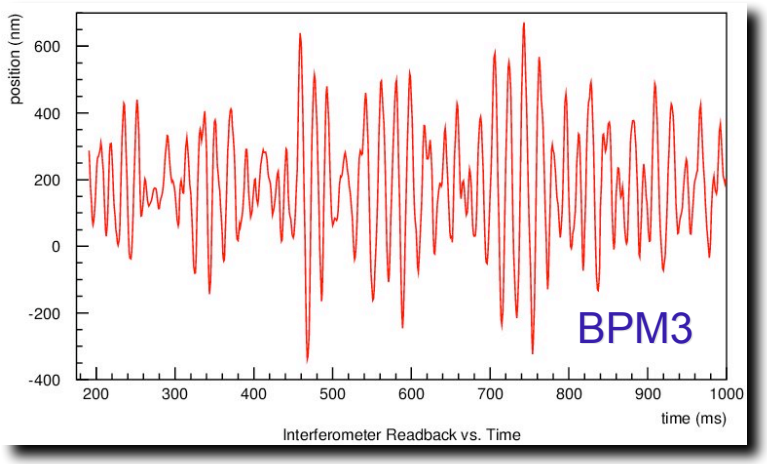
S. Kostromin/Dubna

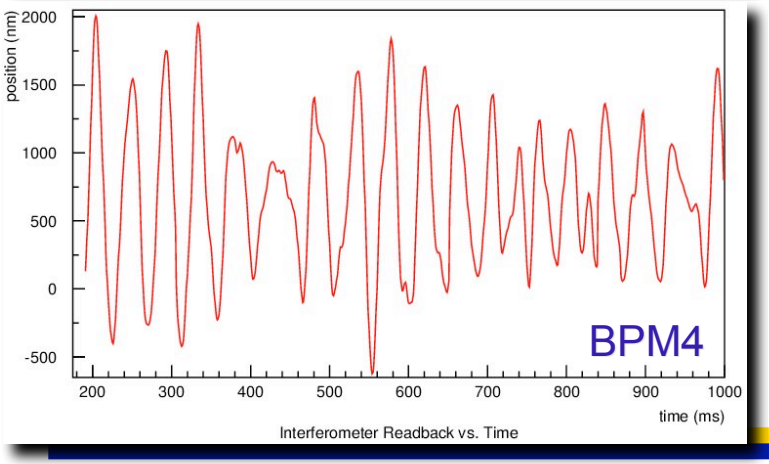


Magnets on beamline

Mechanical Stability: Interferometer

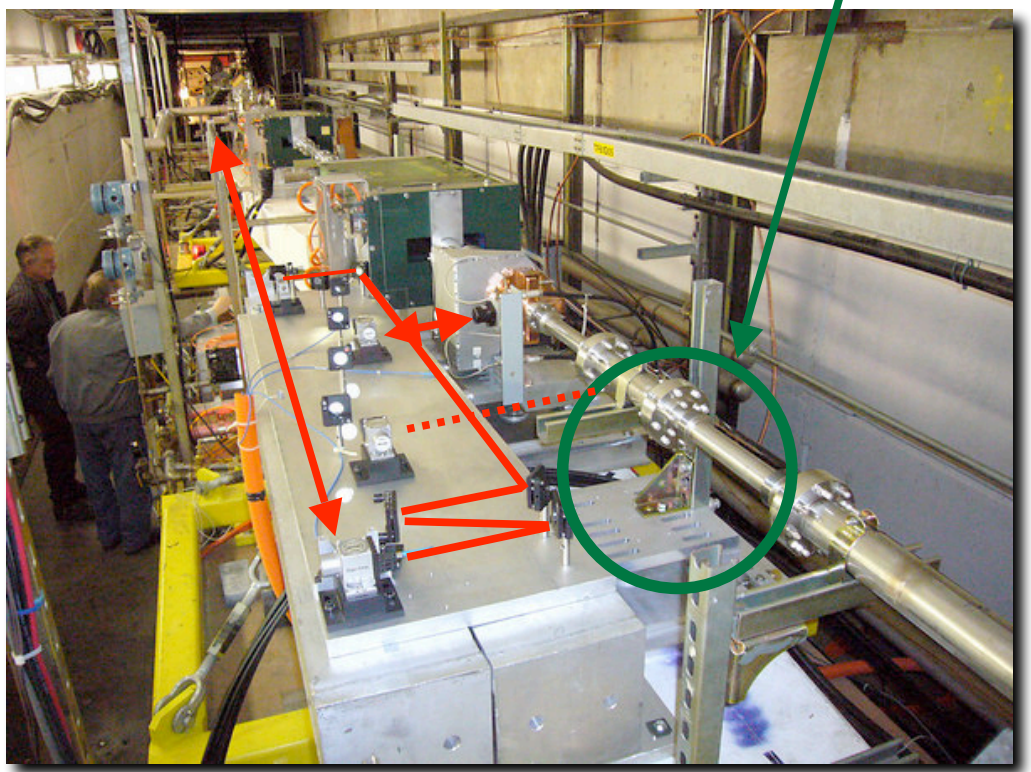
- Sub-nm resolution, installation itself is stable over 1 hour within 30 nm with fixed mirrors
- Monitor offset front to center of chicane
- Single laser, send laser beam down long pipe





Location of new UK BPM

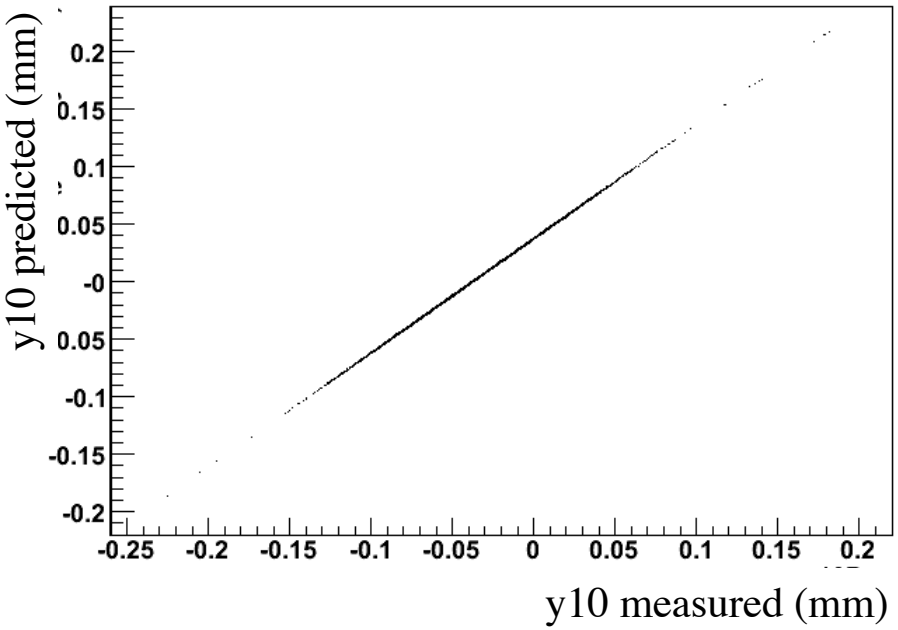
Middle of chicane



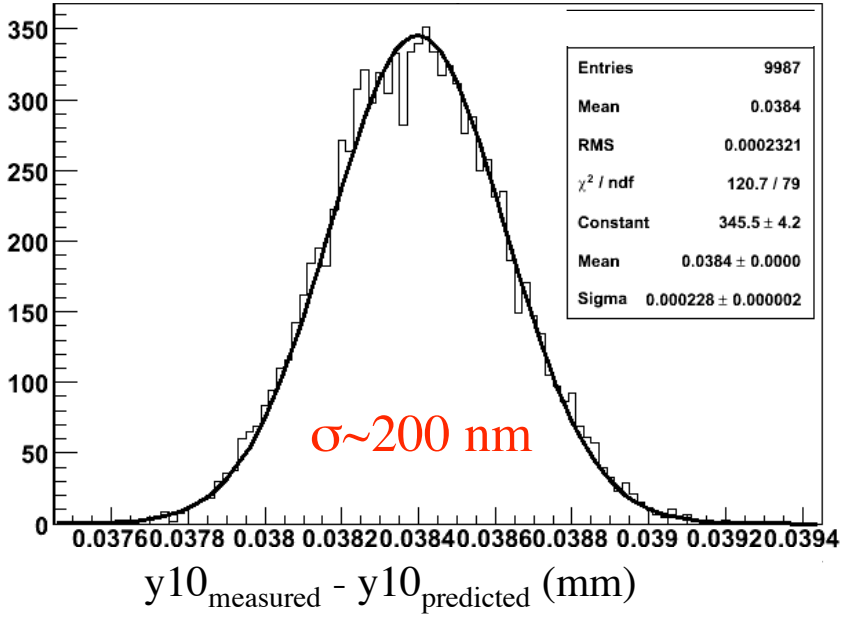
Current Status

- Adequate resolution
  - S-band, 200-600 nm resolution over ~1 mm dynamic range
  - Better than 500 nm resolution for linac BPM prototypes

y10 predicted vs measured position



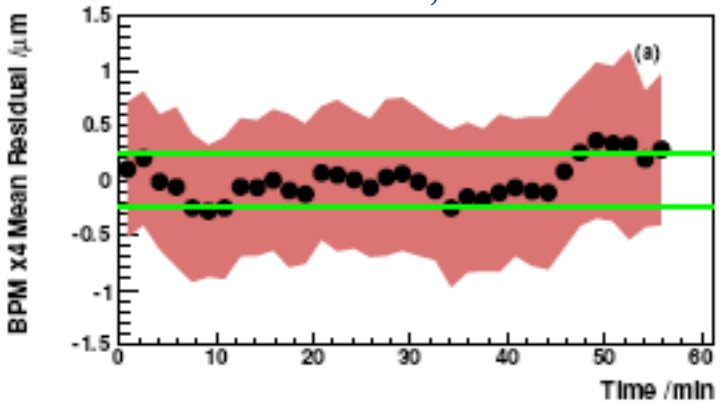
y10 resolution



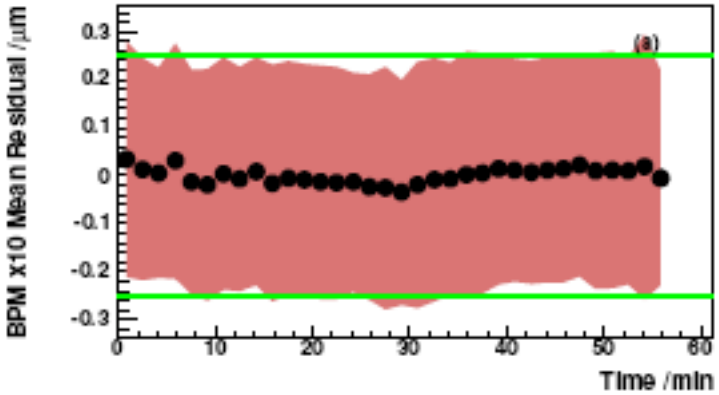
ESA Status (cont.)

- Position stability of O(100 nm) achieved over short distance scales
  - 250 nm over spectrometer length, ~40 mins
  - Mainly caused by temperature drifts
    - ☞ Calibrate out with external tone

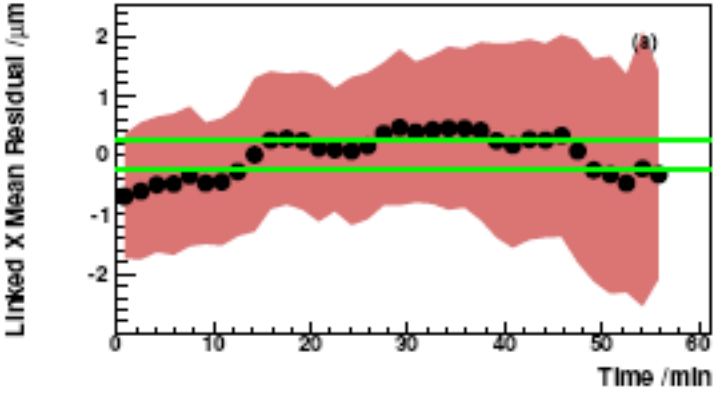
ILC Linac BPM, ~1m arm

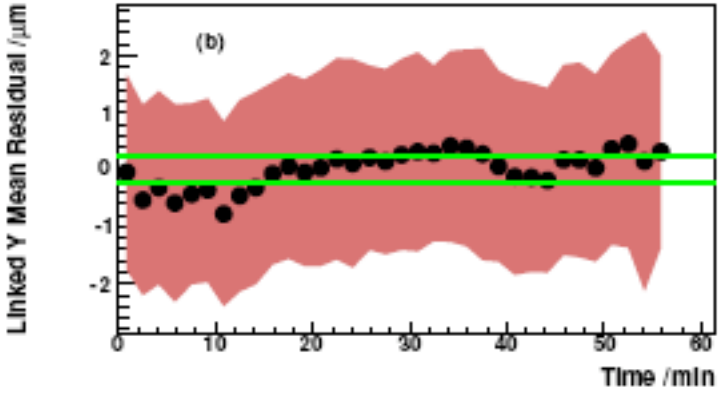


ILC Linac BPM, ~1m arm

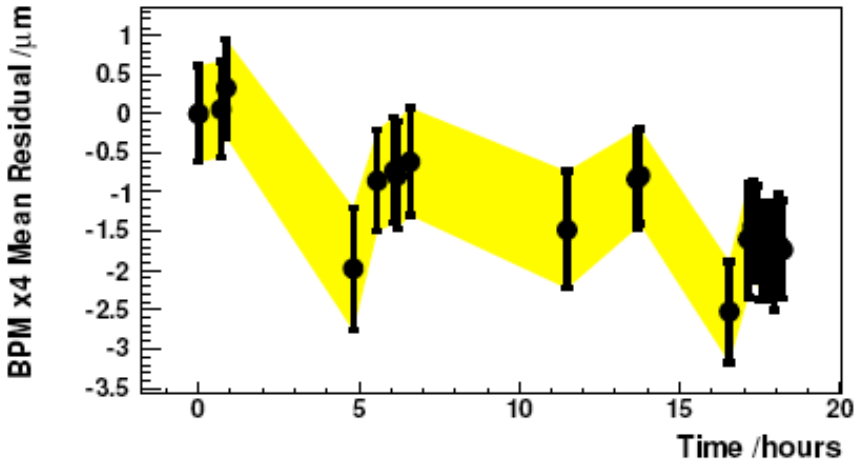


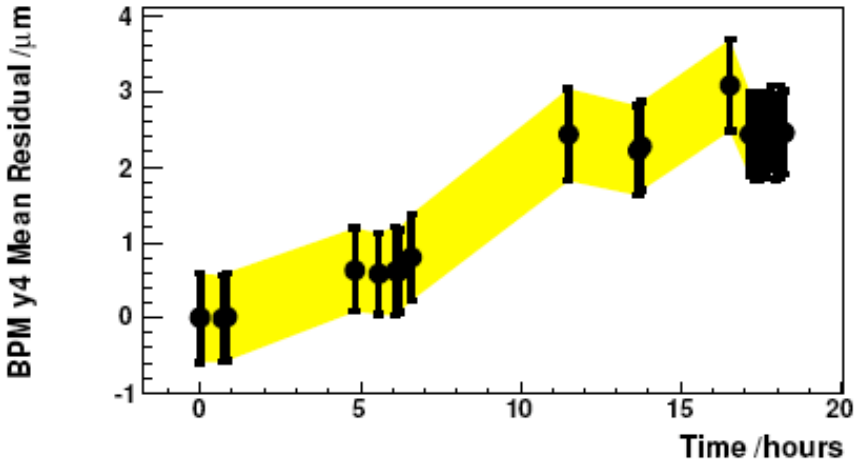
"Linked" BPM residual over 40m





Long-Term Stability



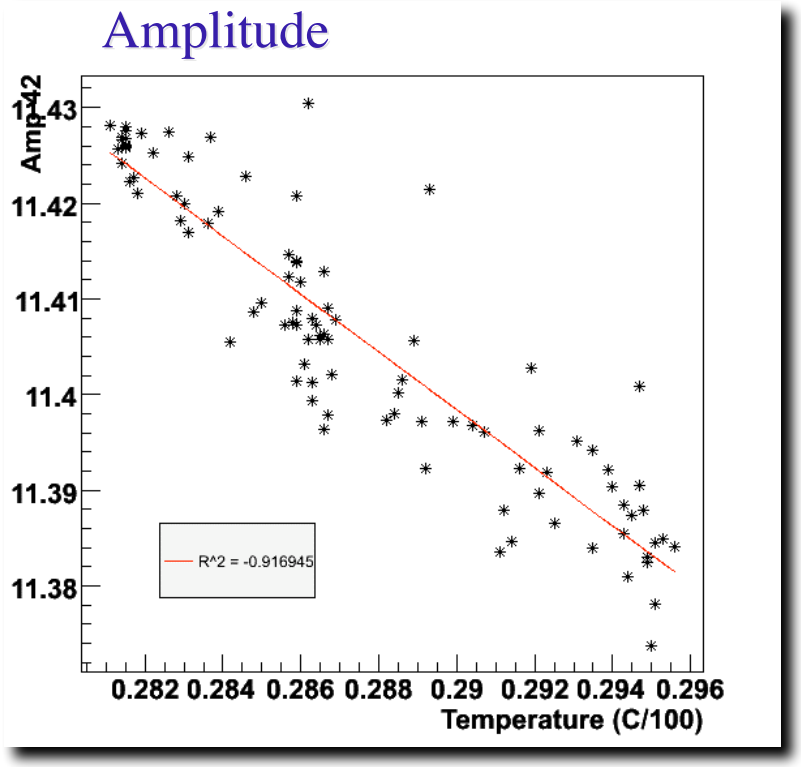


- No intermediate calibrations applied
  - Sizable drifts
    - ☞ Orbit stability
    - ☞ Environmental effects (still to be taken out)

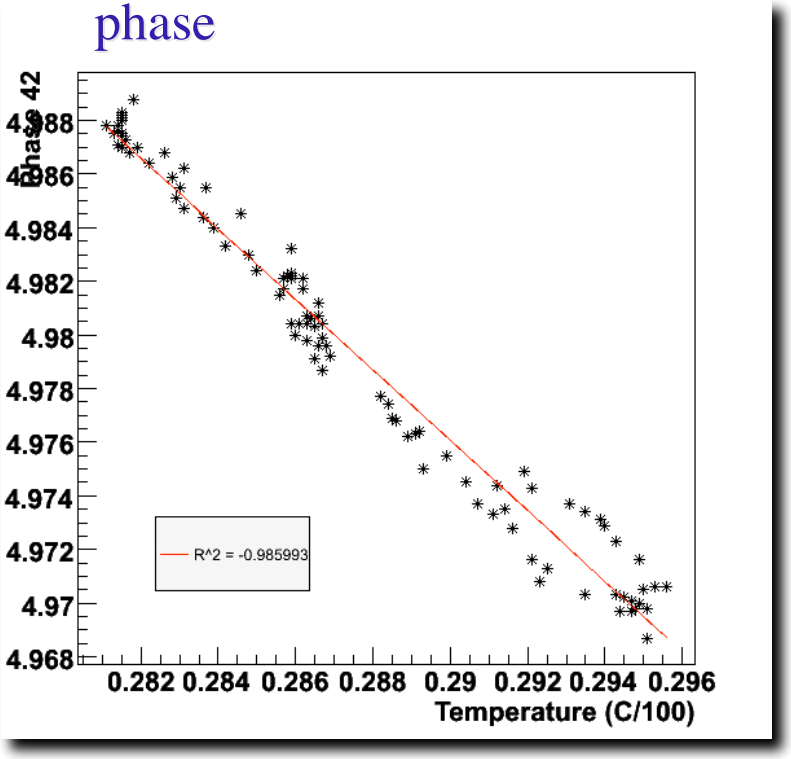
Gain Stabilization

Send triggered CW tone to electronics to monitor gain / phase drifts (UCL/RHUL/UCB)
Observe variation correlated with temperature
Entire chicane equipped with gain calibrators in July 07: data being analyzed

Amplitude



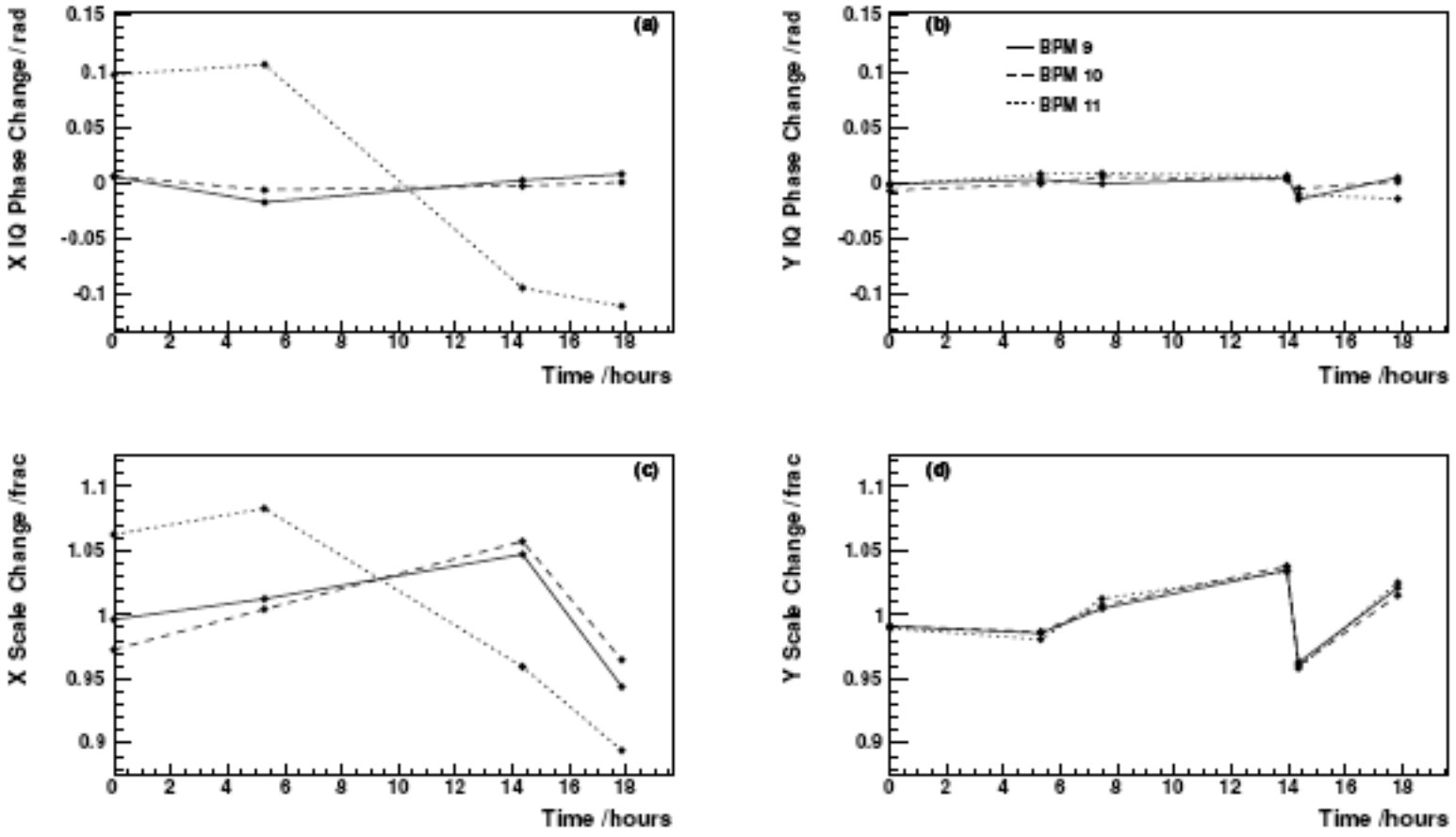
phase



M.Chistiakova/Berkeley

Temperature drifts in counting house are significantly larger than ESA; have now moved all electronics into ESA

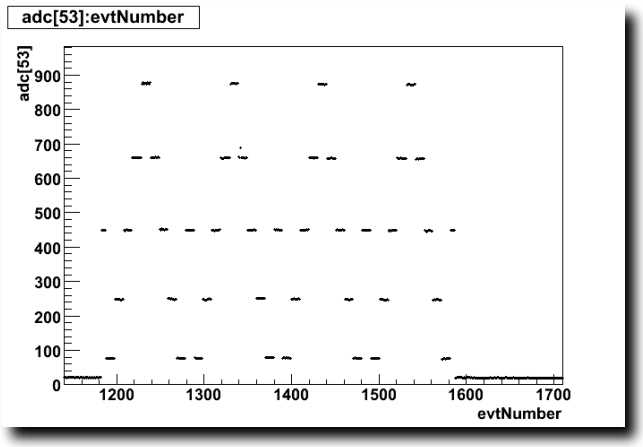
Issues: Position Calibration

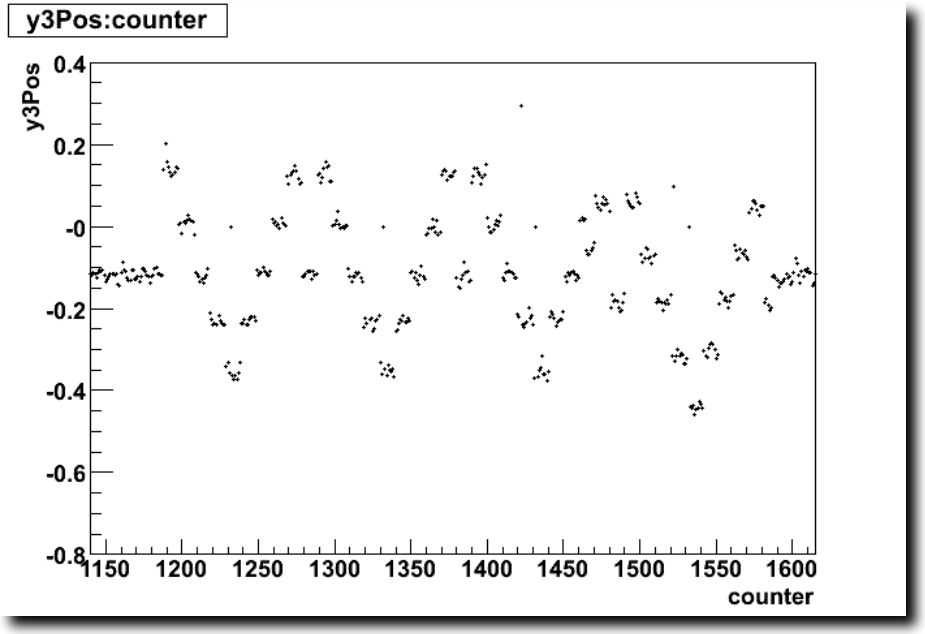


Apparent calibration constant drifts: issues with corrector calibrations
Need at least a pair of BPMs on movers (to be installed before FY08 run)

Faster BPM Calibration

- Fast dither with helmholtz coils
- Commissioned during march '07 run
- Less sensitive to beam jitter/drifts
- Produces average scales and IQ phases
- Automation : synchronize with DAQ

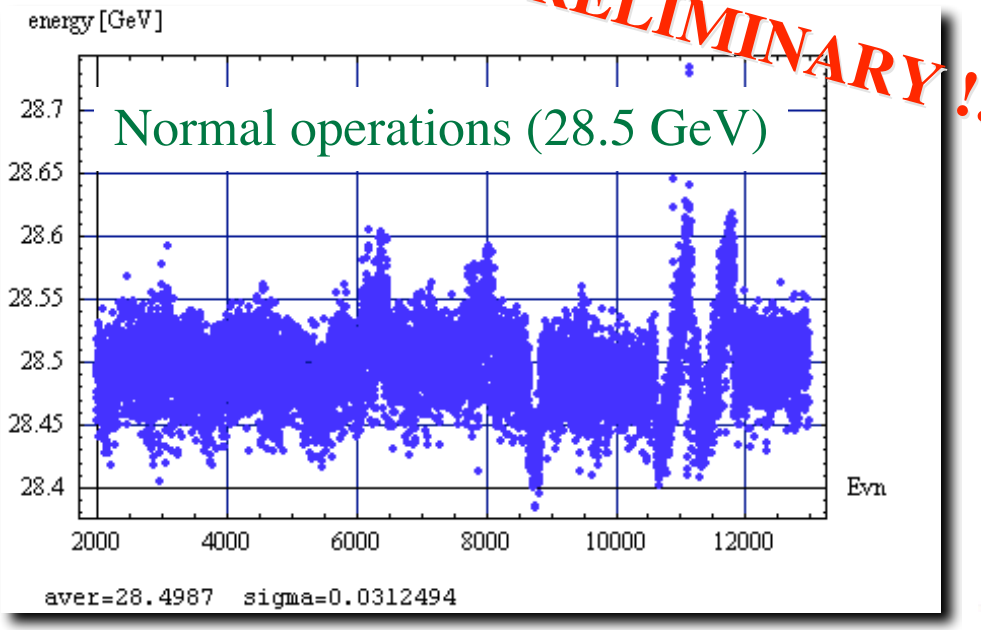




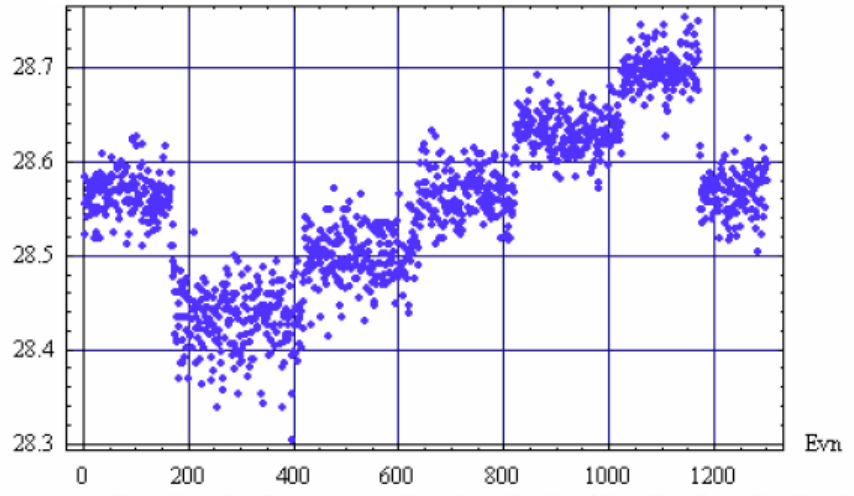
Preliminary Spectrometer Results

- 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...

PRELIMINARY !!



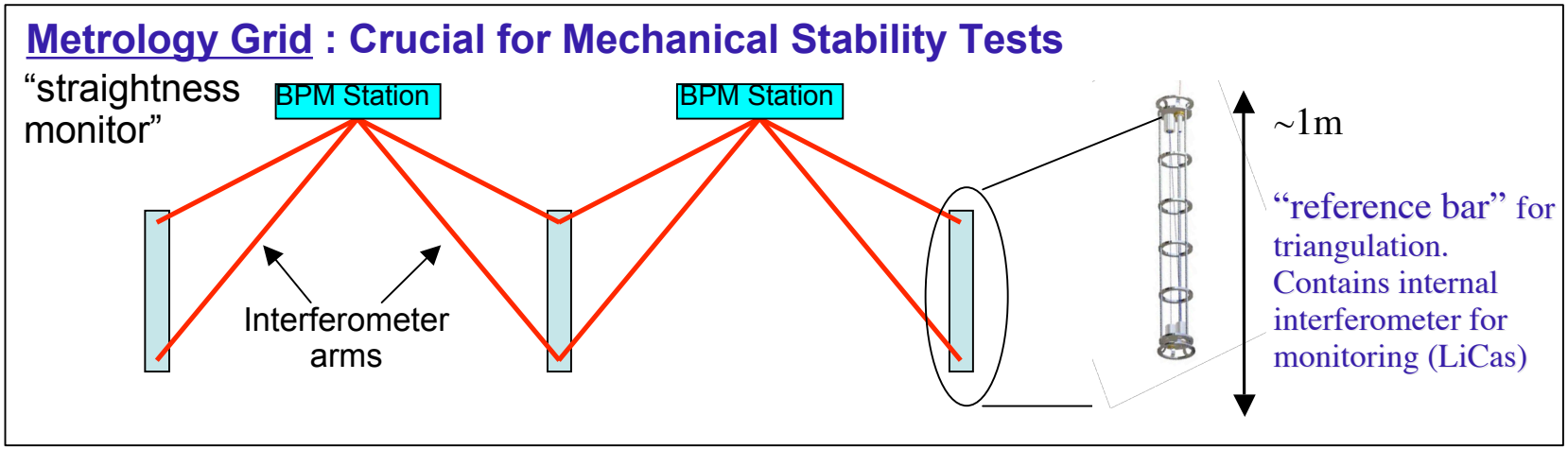
Energy calibration ± 100 MeV



S. Kostromin/Dubna

Outlook

- Planned FY08 run
  - New/improved BPM prototype (UCL), movers on at least 2 BPMs
  - Well-debugged calibration, monitoring; full chicane operation
  - Reduce vibrations
  - Correlate to synch stripe measurements (T475, see E.Torrence's talk) :
- Hope to install metrology grid (M. Hildreth et al.)
  - Understanding mechanical stability over entire spectrometer



- Publications in preparation (NIM)
- Full analysis in progress