BPM Energy spectrometry, status & future plans at ESA in SLAC

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Yerevan Collaboration Meeting
23-27 October 2006

Outline

- Principles of BPM based energy measurement
- T474/T491 (T474-X) in the End Station A at SLAC
  - BPM systems deployed and commissioned
  - Automated BPM calibration
  - Some systematics, resolution, stability and variations
  - Interferometer
- Our own spectrometer BPM prototype
- Simulation & modeling work
- Future plans

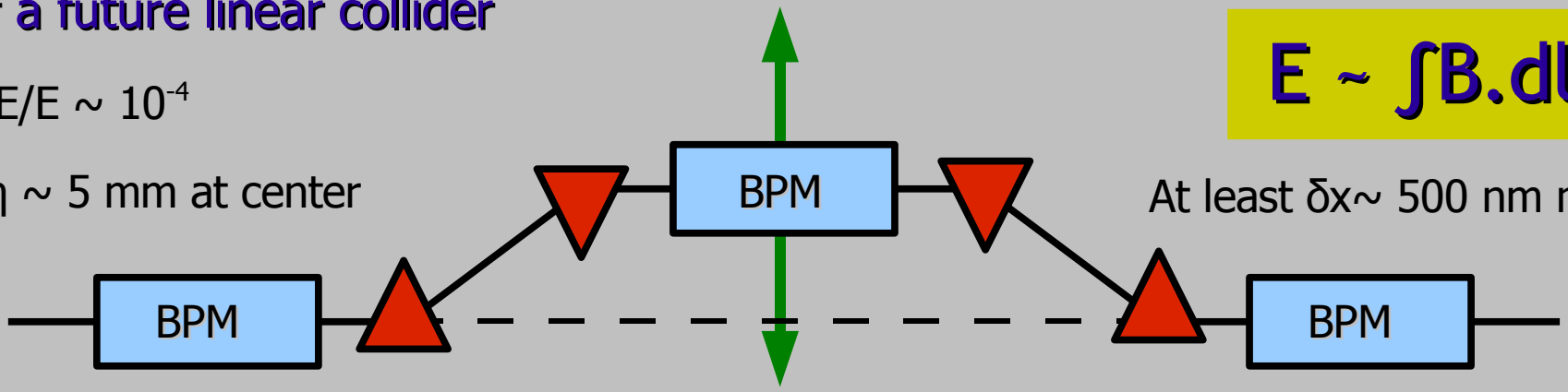
BPM based beam energy measurement

Study & design magnetic chicane for beam energy measurement using BPMs for a future linear collider

$\delta E/E \sim 10^{-4}$

$\eta \sim 5$ mm at center

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



At least $\delta x \sim 500$ nm needed

NanoBPM@ATF : test resolution, try different analysis methods, BPM stability tests, multi bunch operation, advanced electronics techniques, inclination of beam in BPMs.

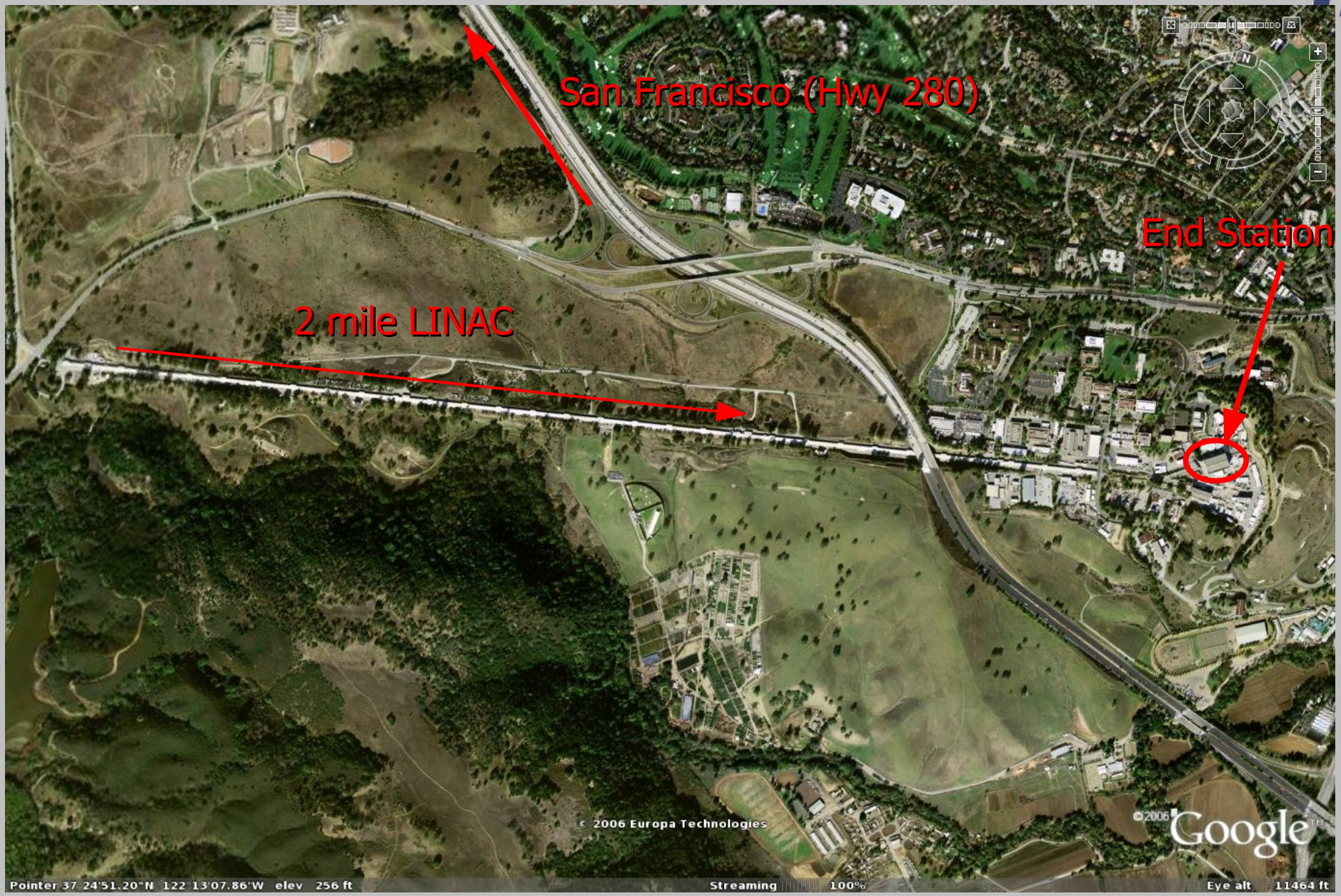
-> spectrometer aspects of BPMs can be tested

ESA@SLAC : test stability and operational issues with a full implementation of 4 magnet chicane and 3 BPM stations

-> test of chicane prototype

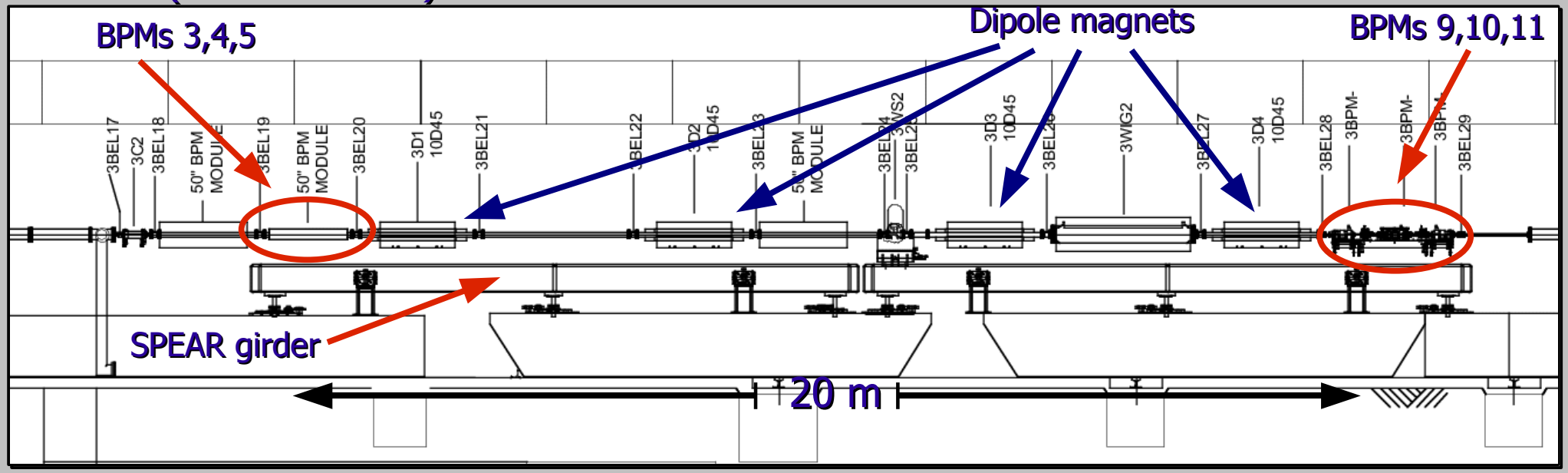
- capable of producing ILC-type bunch
- good test bed for systematic studies : vary energy spread, bunch length, beam halo, optics etc...

ESA at SLAC (GoogleEarth)



T474/T491 - ESA@SLAC

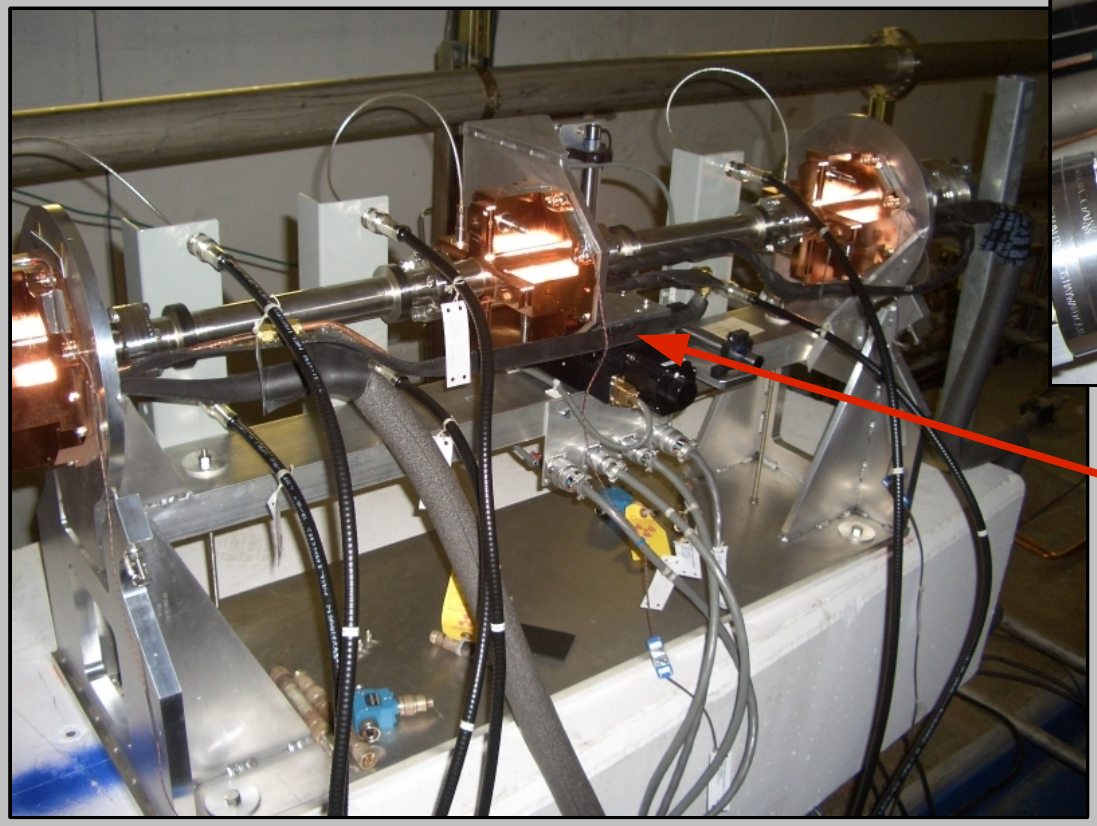
Collaboration with LBNL (Y. Kolomensky et al.), SLAC (M. Woods et al.) and Notre Dame (M. Hildreth et al.)

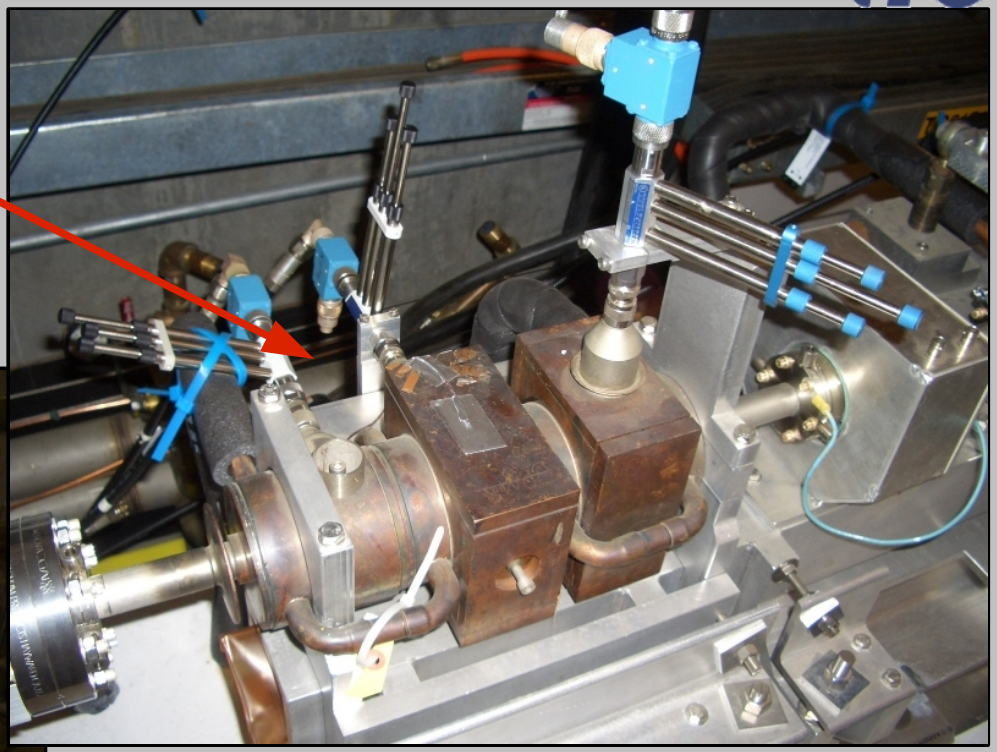


- January test run 2006 (4 days) : Commissioning of BPMs 31,32 and 1,2 upstream
- April run 2006 (2 weeks) :
  - Commissioning of new ILC prototype linac triplet (BPM 3,4,5), where BPM4 on x,y mover system
  - Commissioning of old SLAC BPMs (9,10,11)
  - Digitisation/signal processing optimization
- July run 2006 (2 weeks) :
  - Commissioning of Zygo interferometer system (BPMs 3,4,5) + energy BPM24 upstream
  - Further optimisation of hardware (down mixing)
  - Stability data taking with 10 BPMs, frequent calibrations

BPM systems used in ESA

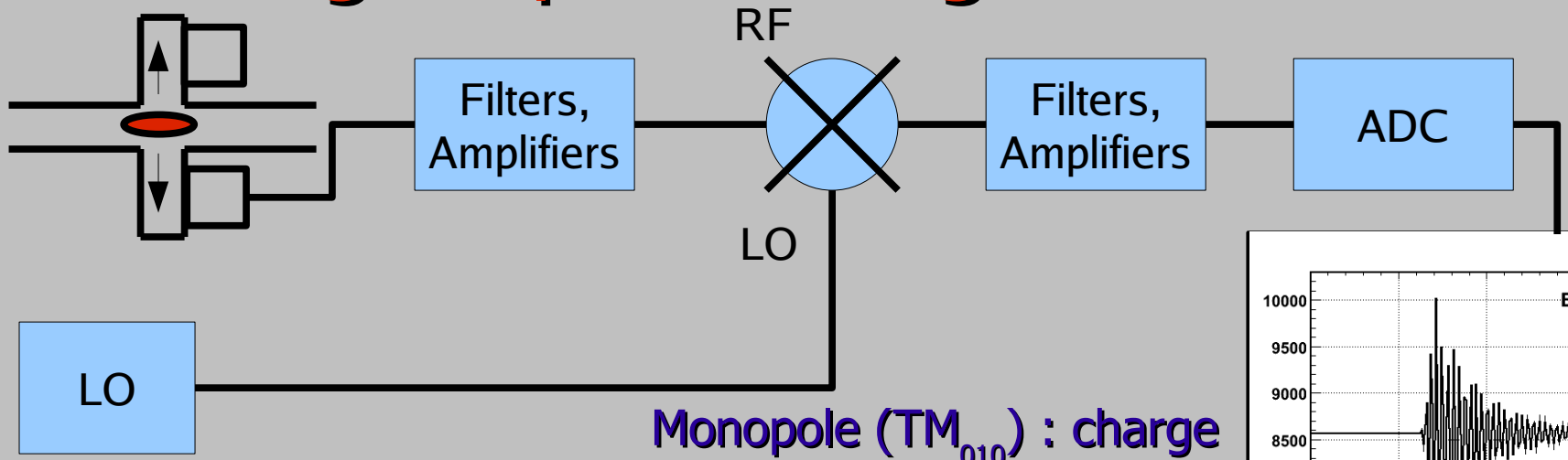
- Rectangular cavities
  - x and y separated
- 2.856 GHz, high Q ~ 3000
- 20 mm aperture (0.8 “)

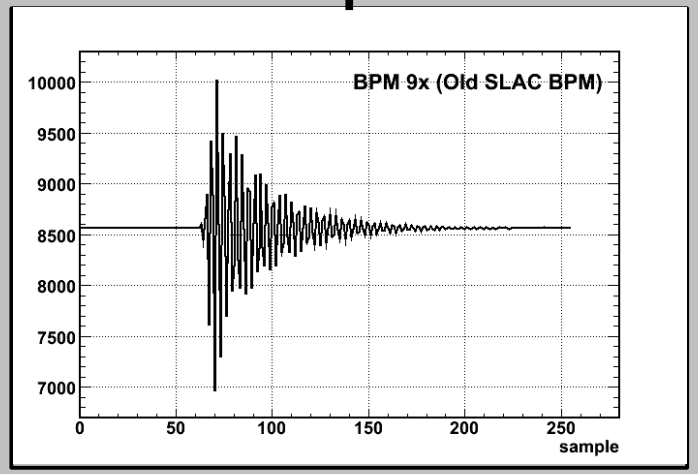




- C. Adolphsen, Z. Li
- ILC cold linac prototype cavities
- 36 mm aperture, 2.859 GHz
- low Q (~ 500)
- good monopole suppression

BPM signal processing in a nutshell



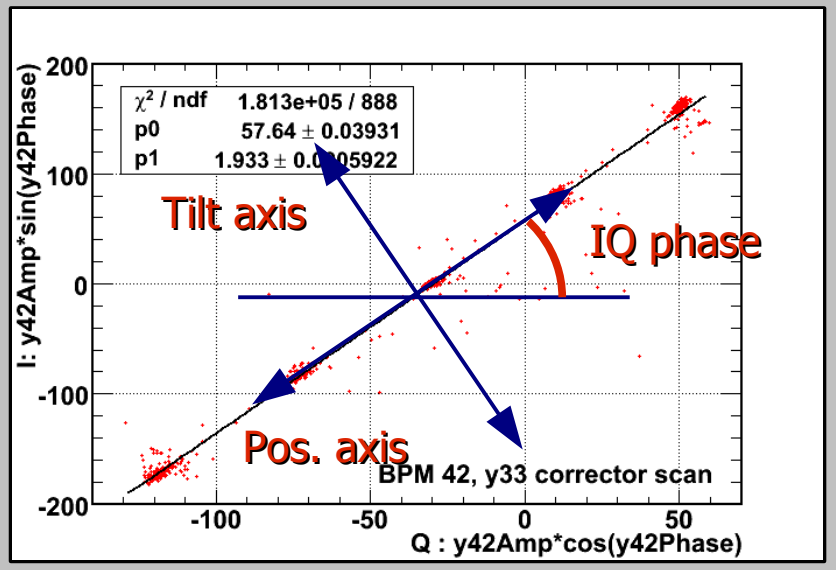


Monopole (TM_{010}) : charge

Dipole (TM_{110}) : charge + offset + tilt

Determine Amplitude & Phase

- Fit waveform : $V = V_0 + A\, e^{-\Gamma(t-t0)} \sin[\omega(t-t_0) + \varphi]$
- Digital Down Conversion (DDC) :
  - Multiply waveform with $e^{i\omega t}$
  - Filter out 2ω component
  - Sample waveform at fixed t0Ref -> A, φ



Disentangle charge, offset and tilt :

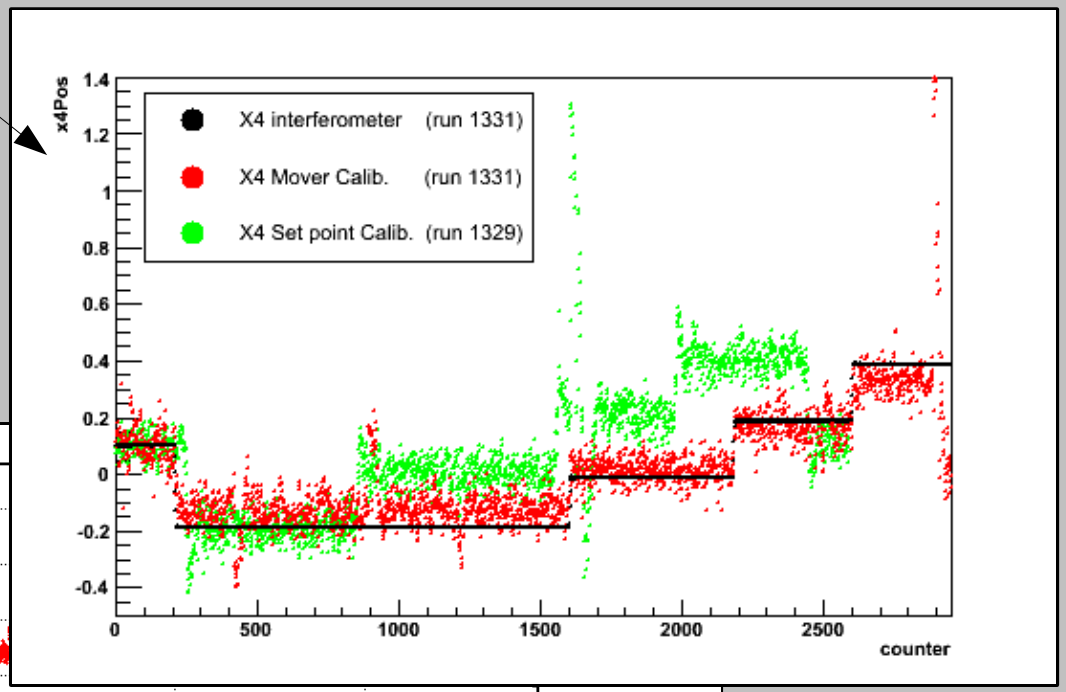
Normalise signal to Ref (Q) Cavity

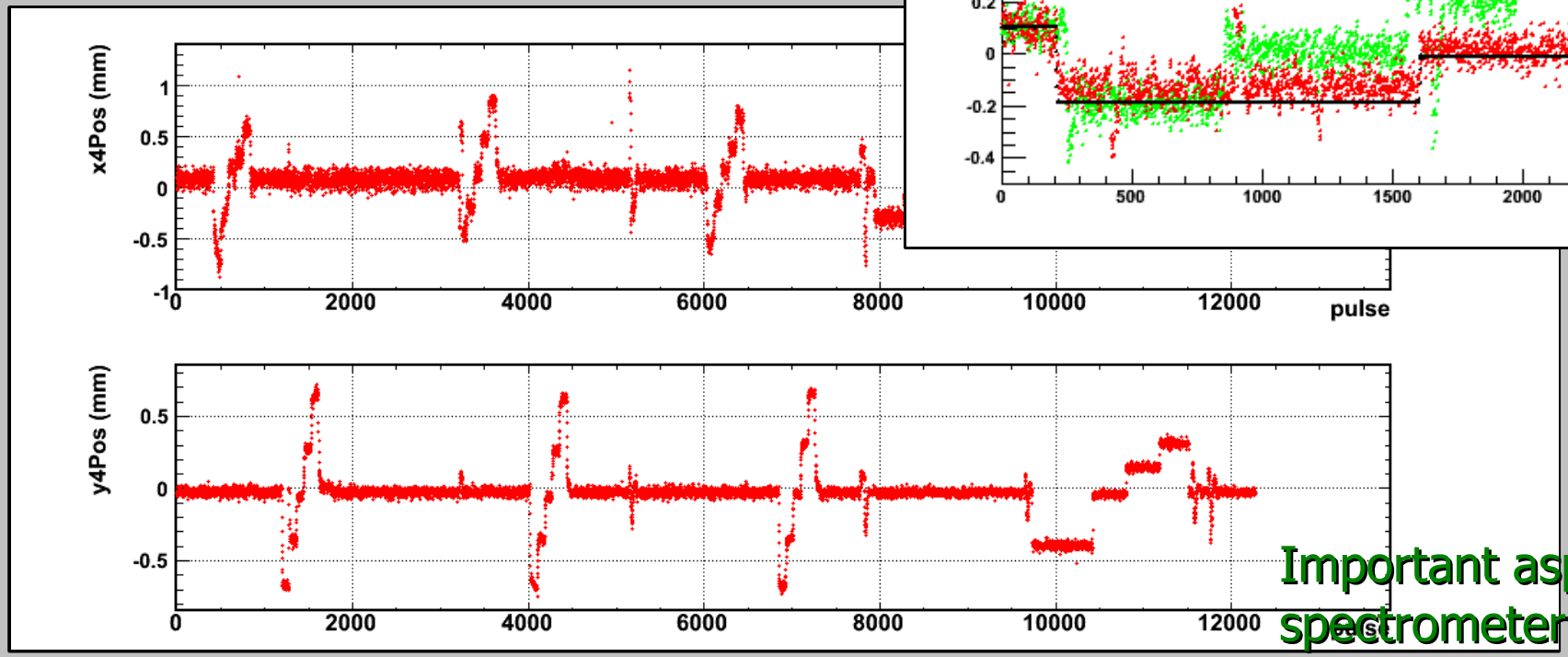
Tilt has π/2 phase difference to position

Automatic calibration

Corrector scans / set point calibration... lot of manual work needed

- Automatic setting of correctors with/without feedback
- Followed by mover scan on BPM4
- Set voltage level for each step in ADC
- Still need to implement automatic processing



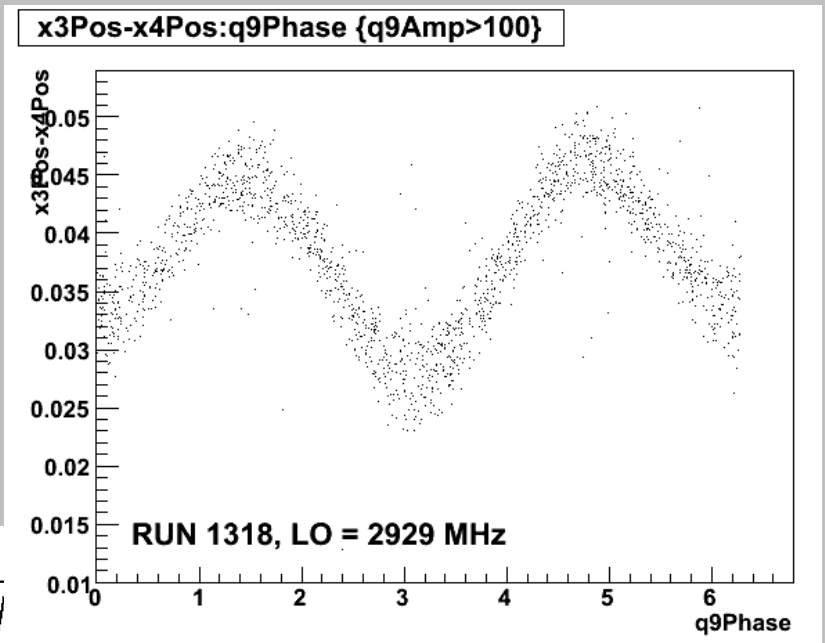


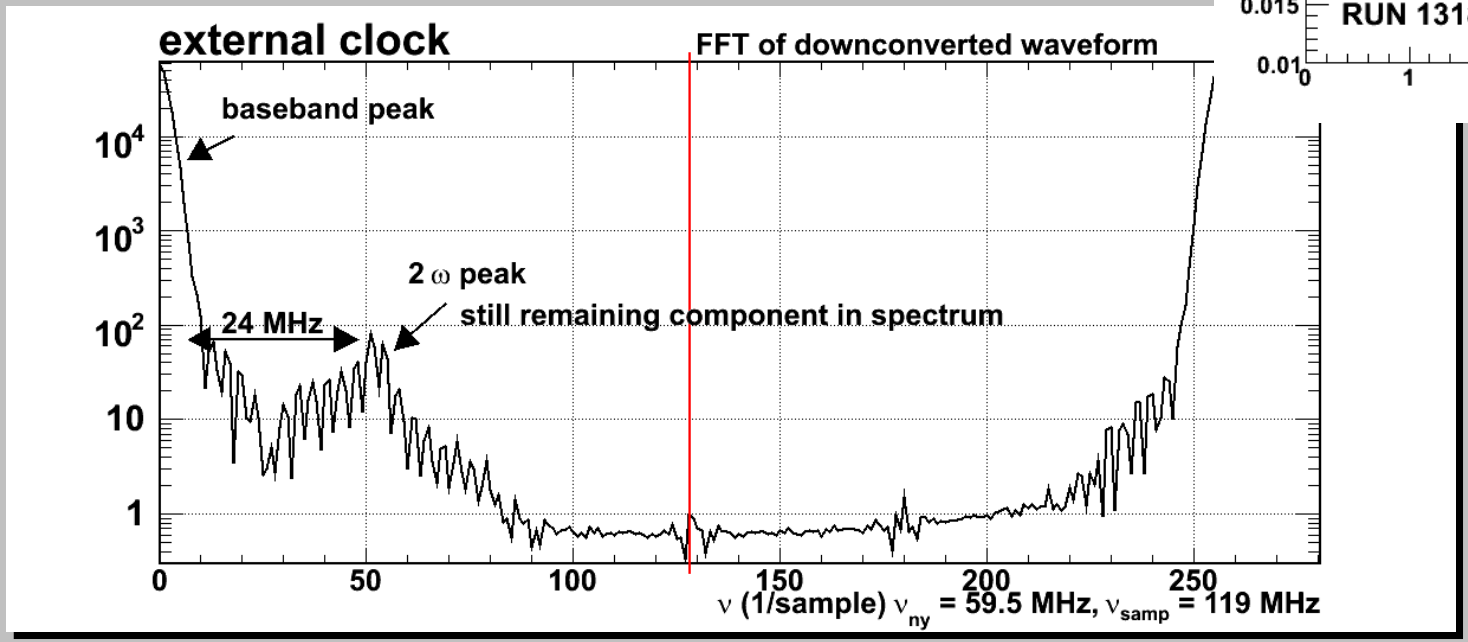
Important aspect of future spectrometer operation !

Phase systematics

Resolution data from April run showed strong Q phase dependence

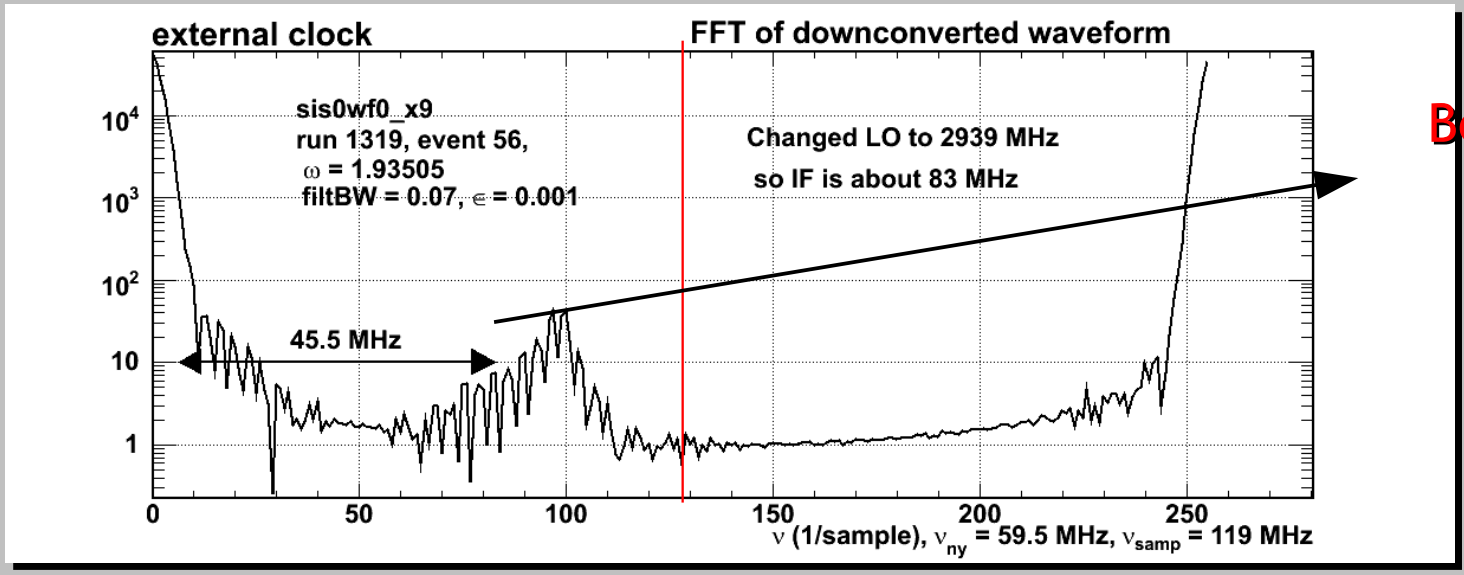
Problem traced back to non-perfect filtering of 2ω peak +
separation between sampling and downmixed frequencies (reflection from upper nyquist band)



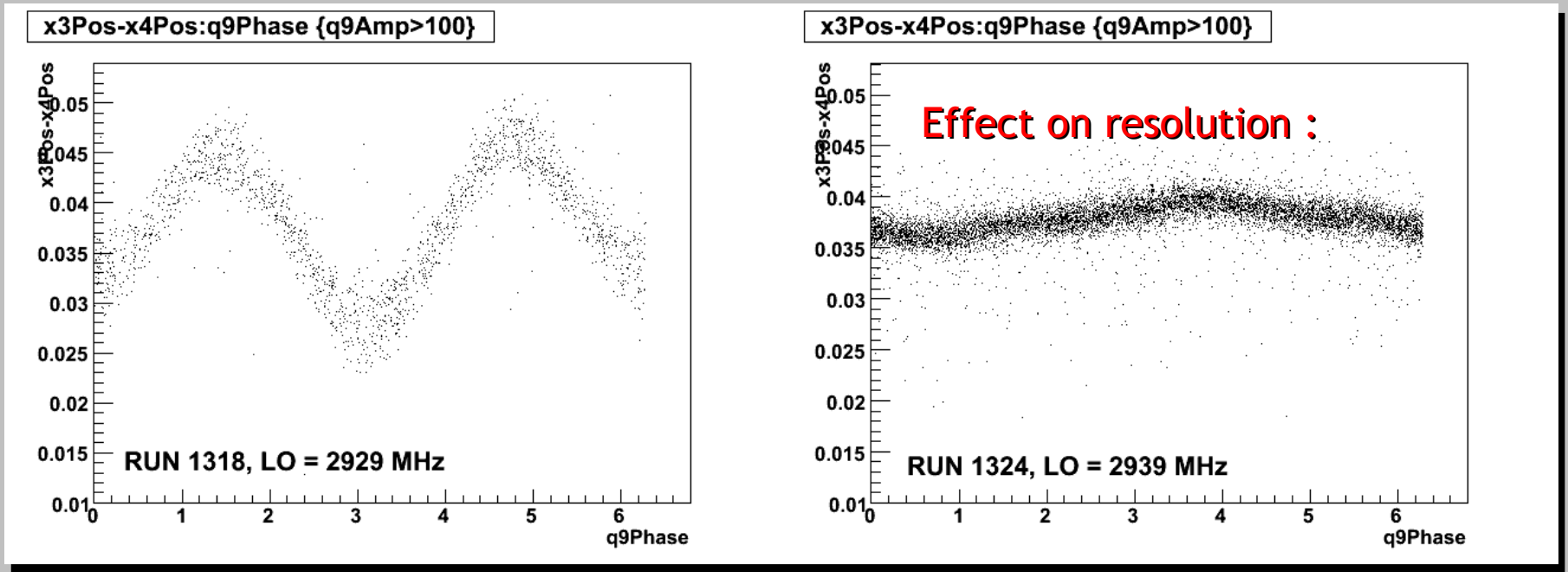


Hardware solution : encrease LO by 10 MHz

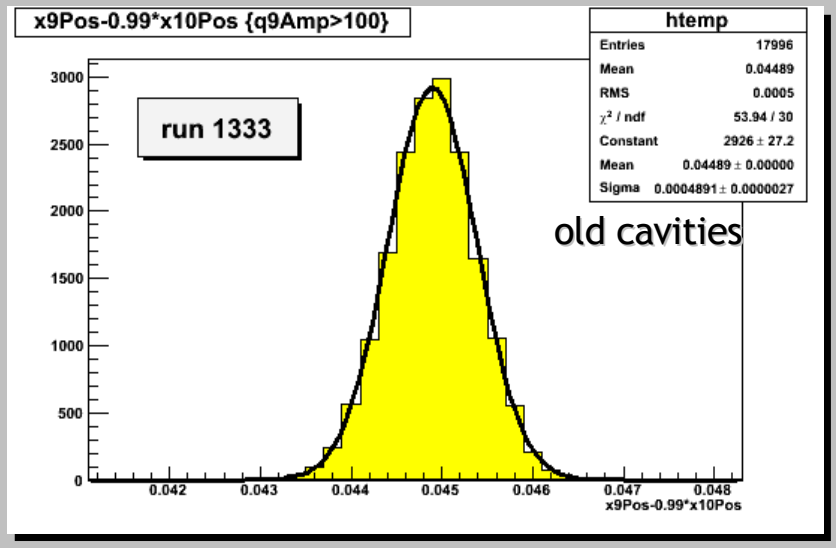
Phase systematics, new LO frequency

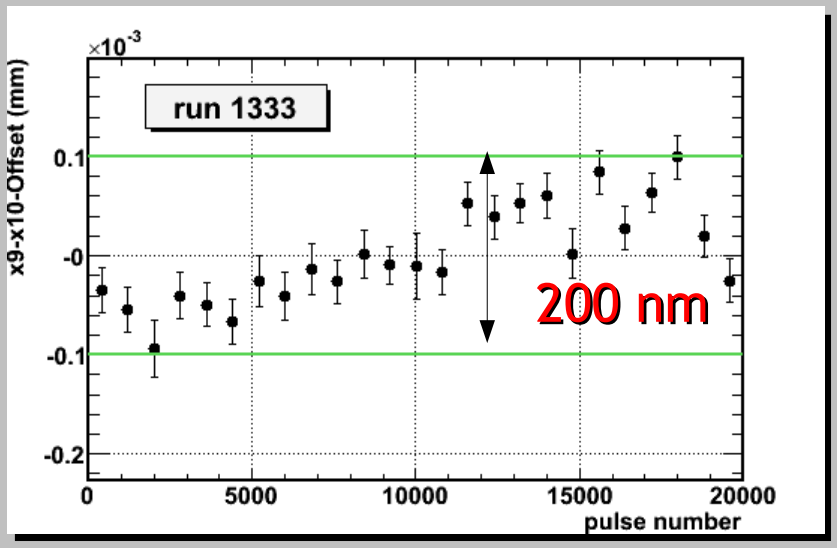


Better separated !



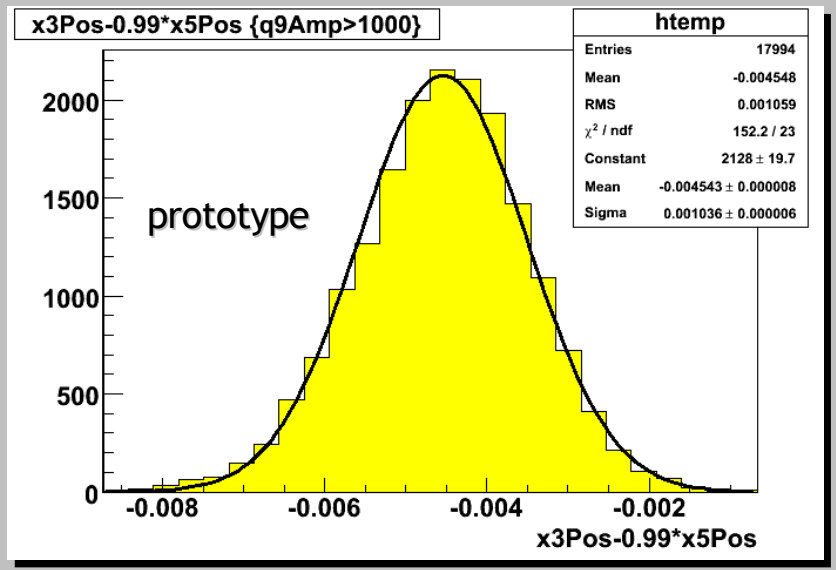
ESA Resolution & stability

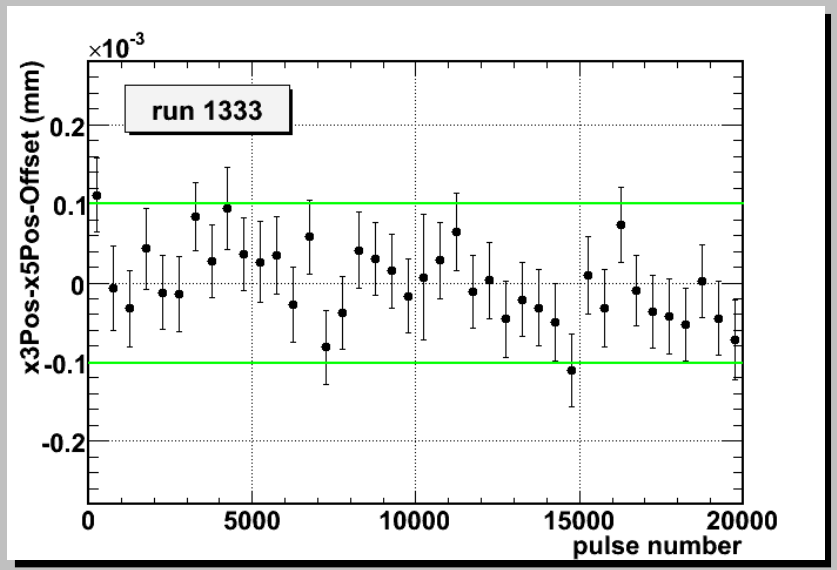




Resolution : BPM 3-5: ~ 700 nm in x, BPM 9-11: ~350 nm in x

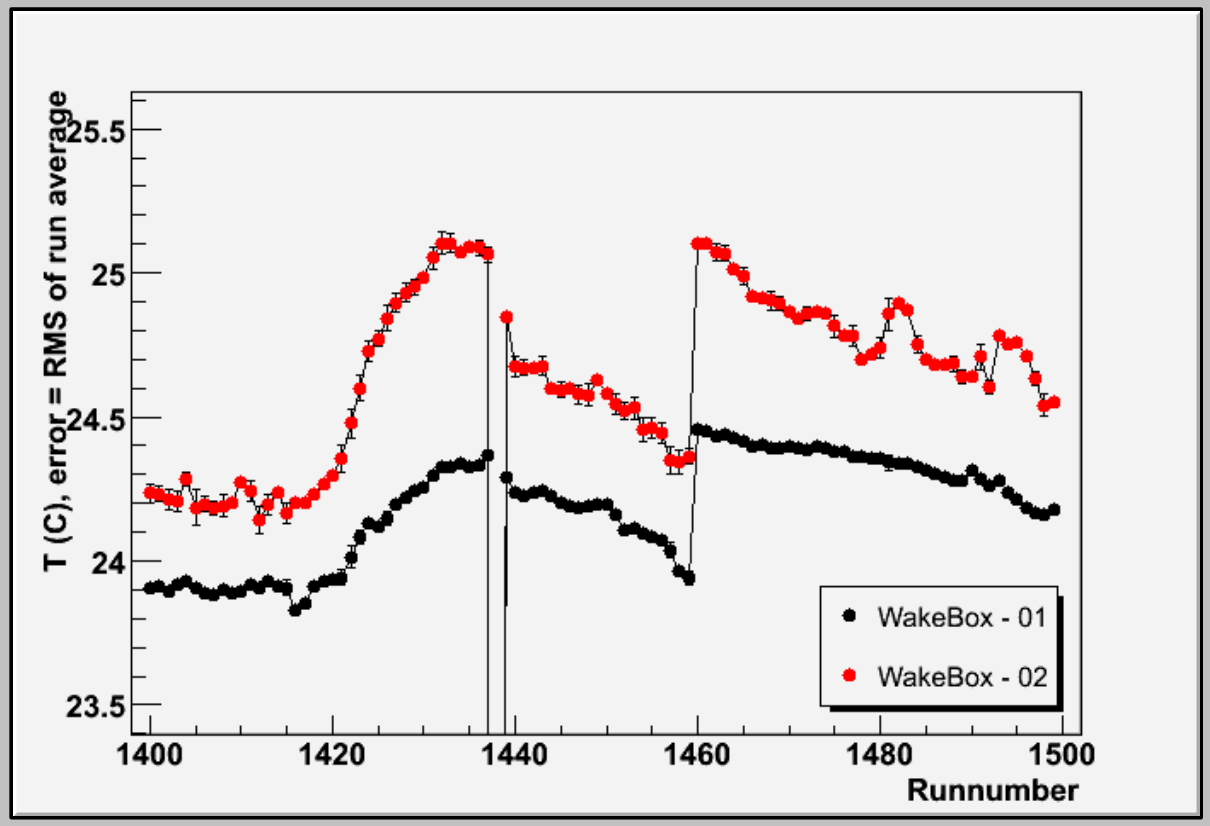
20k pulses ~ 30 min





Some long term stability results

In a flash :)



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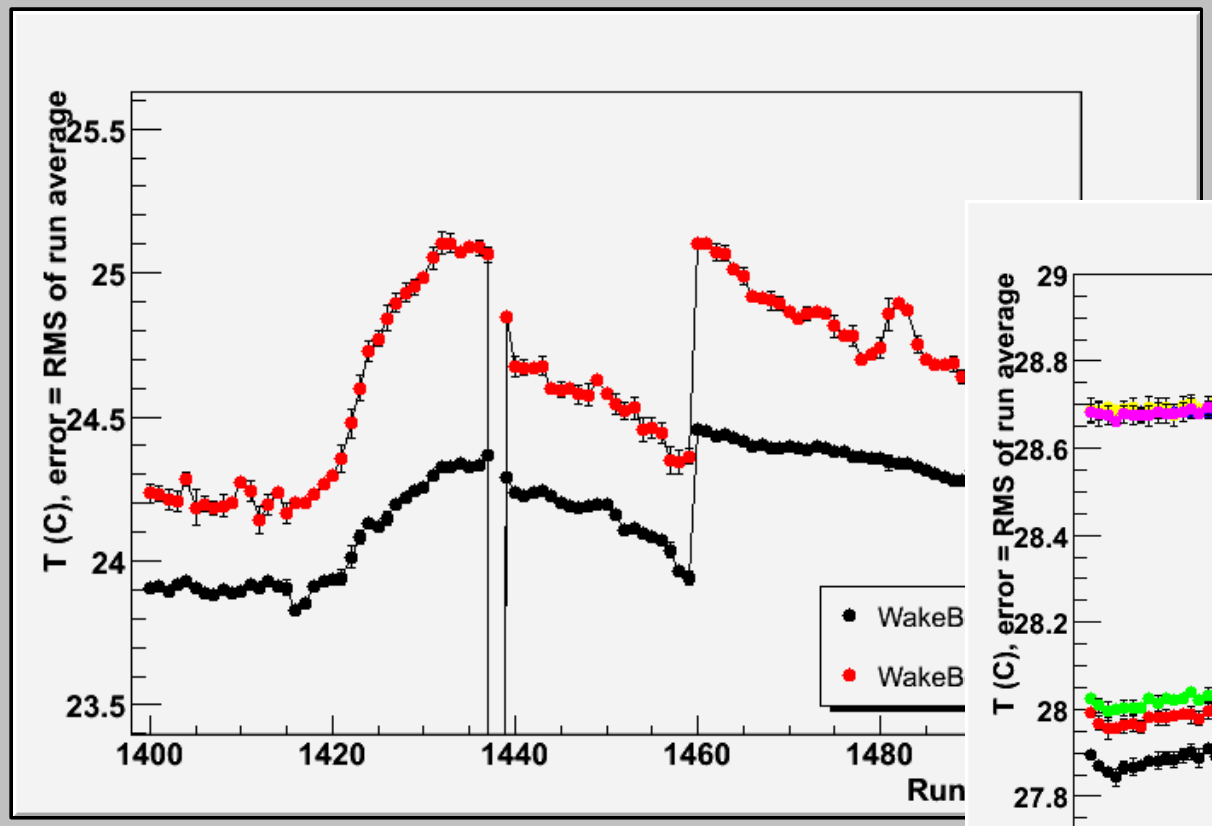

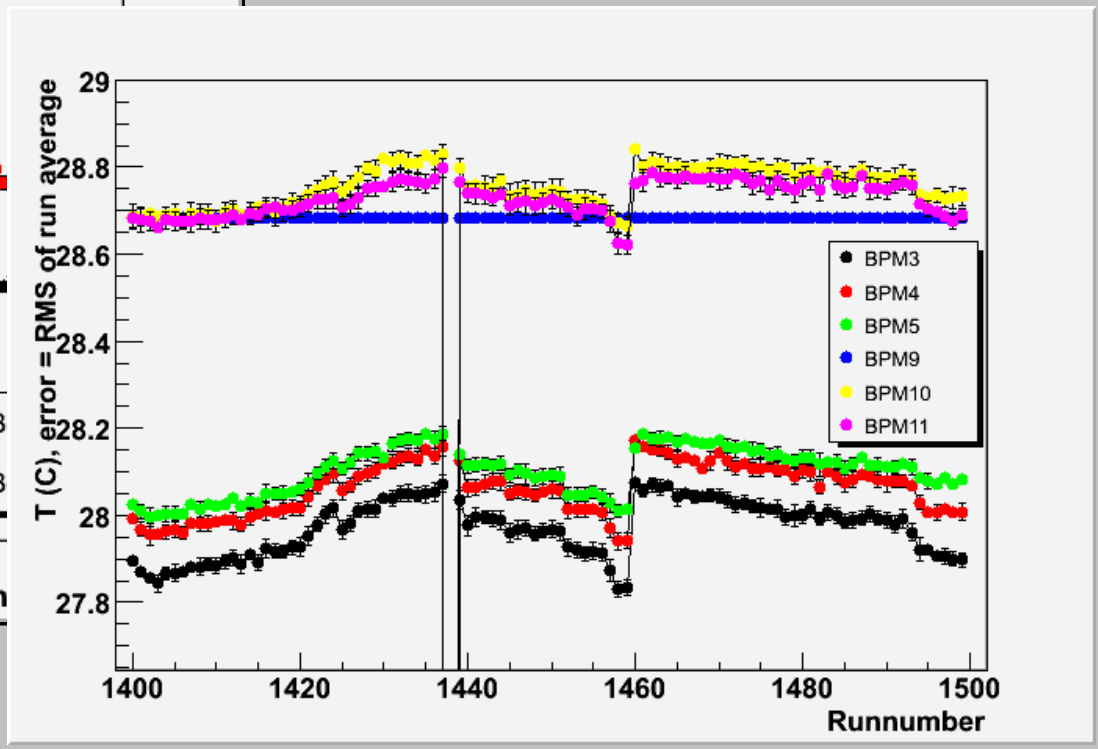

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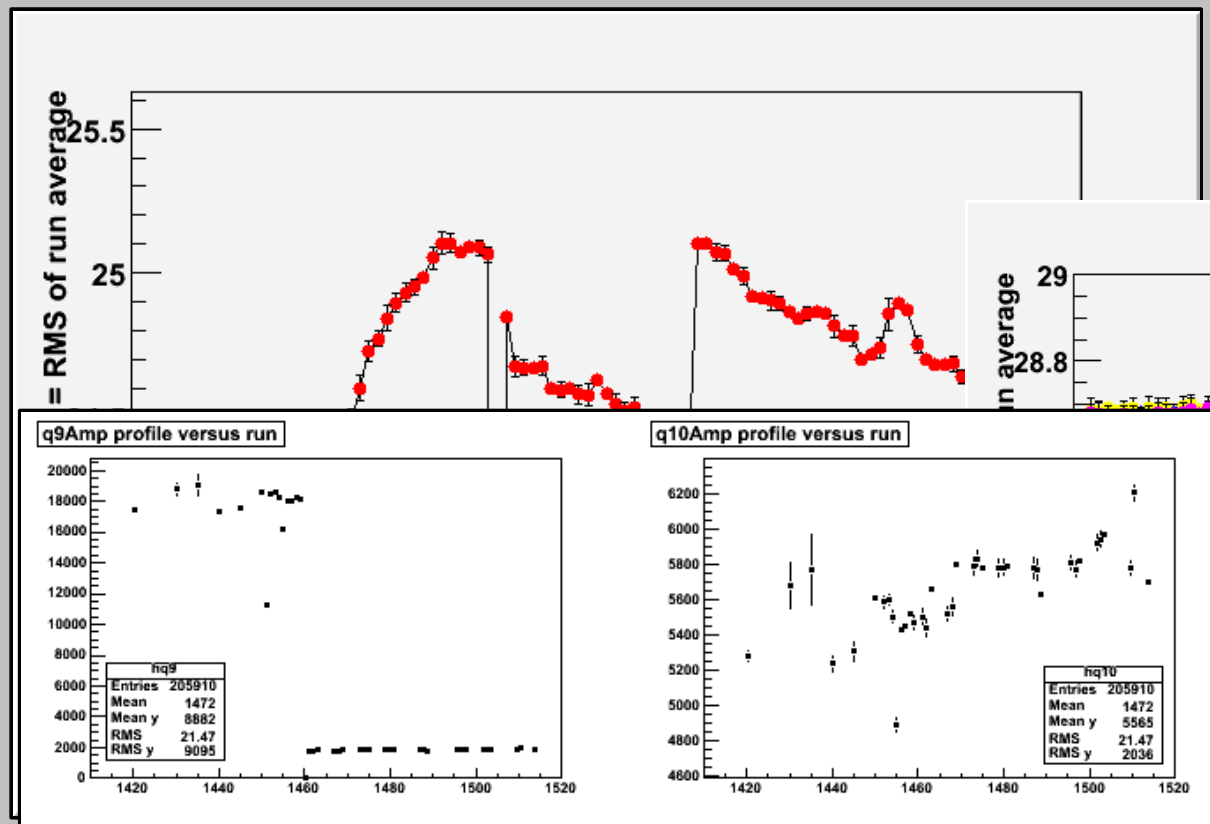
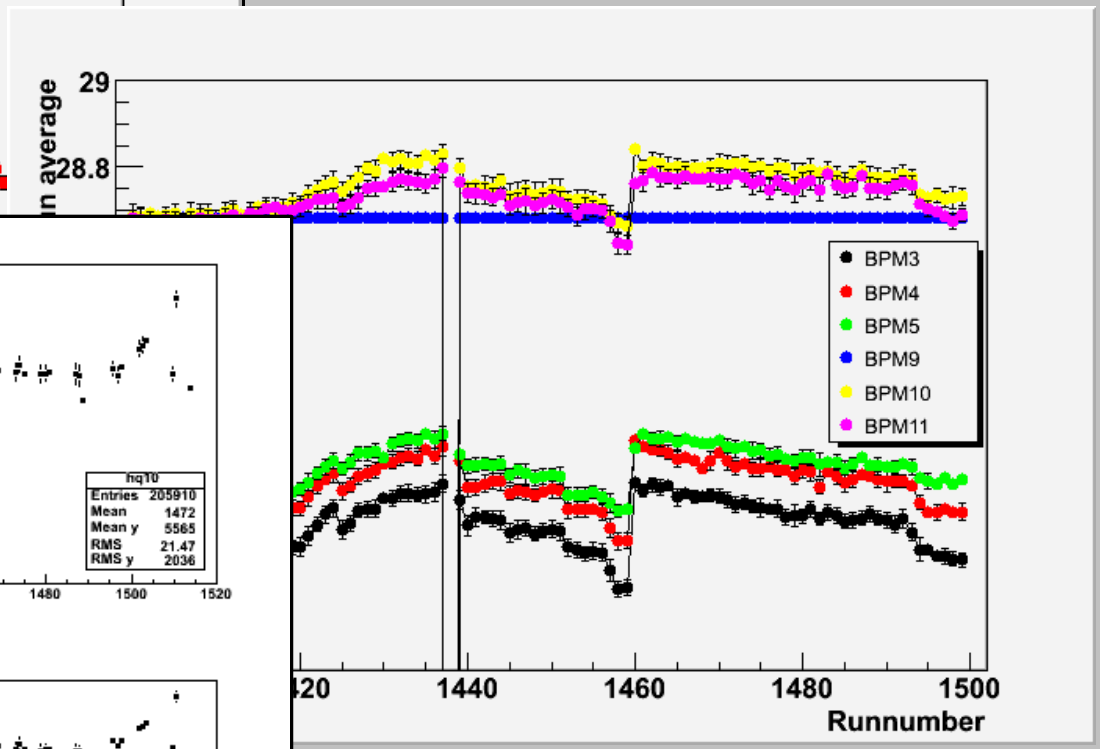


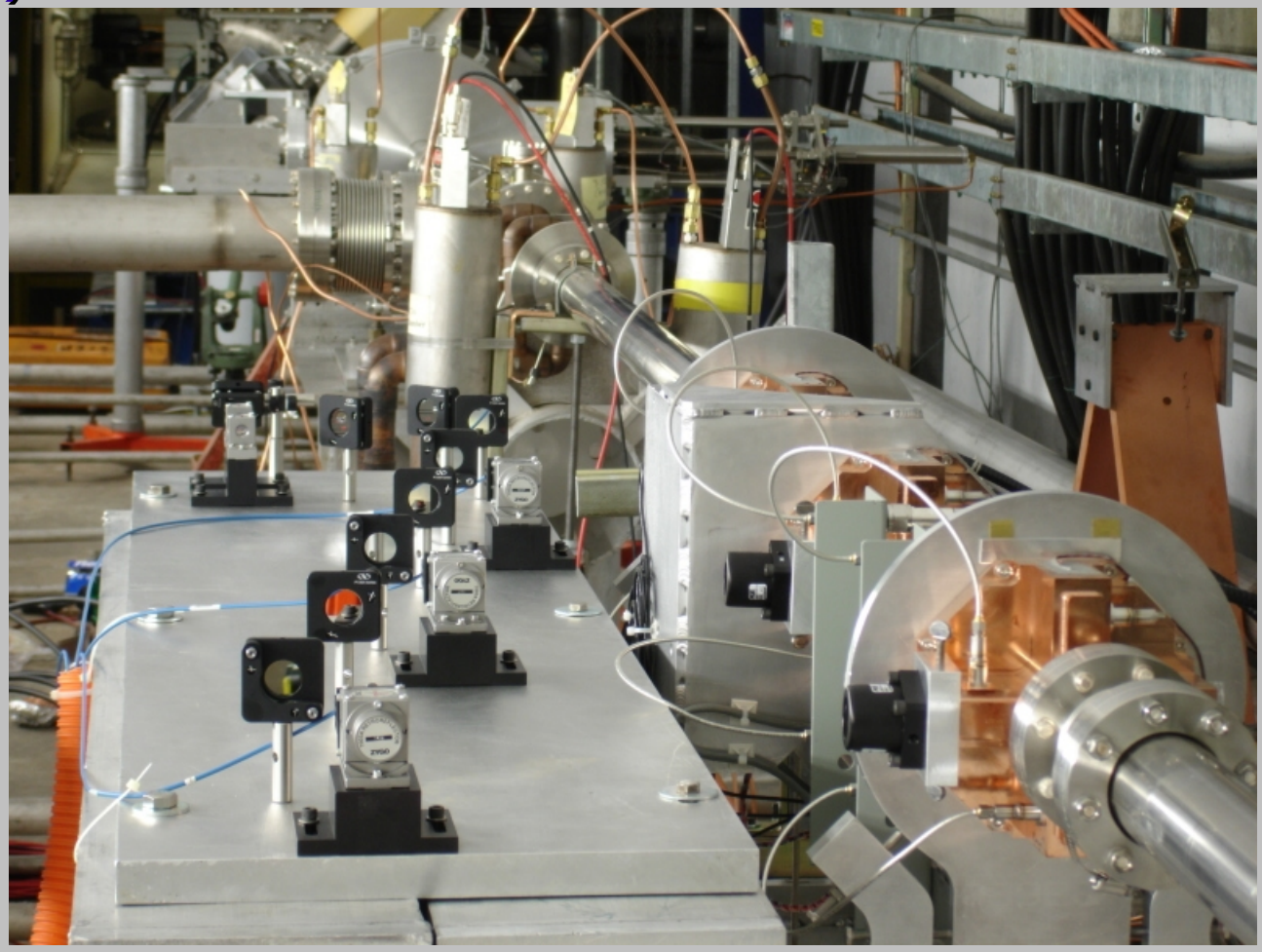


Need more work !
Seeing some interesting effects, understand electronics better !

Interferometer

M. Hildreth, M. Albrecht (Notre Dame)

- commissioned during July run
- sub nm resolution
- stability of < 30 nm (1 hr) with fixed mirror
- plan to link BPM stations



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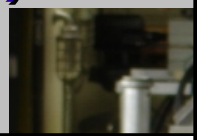
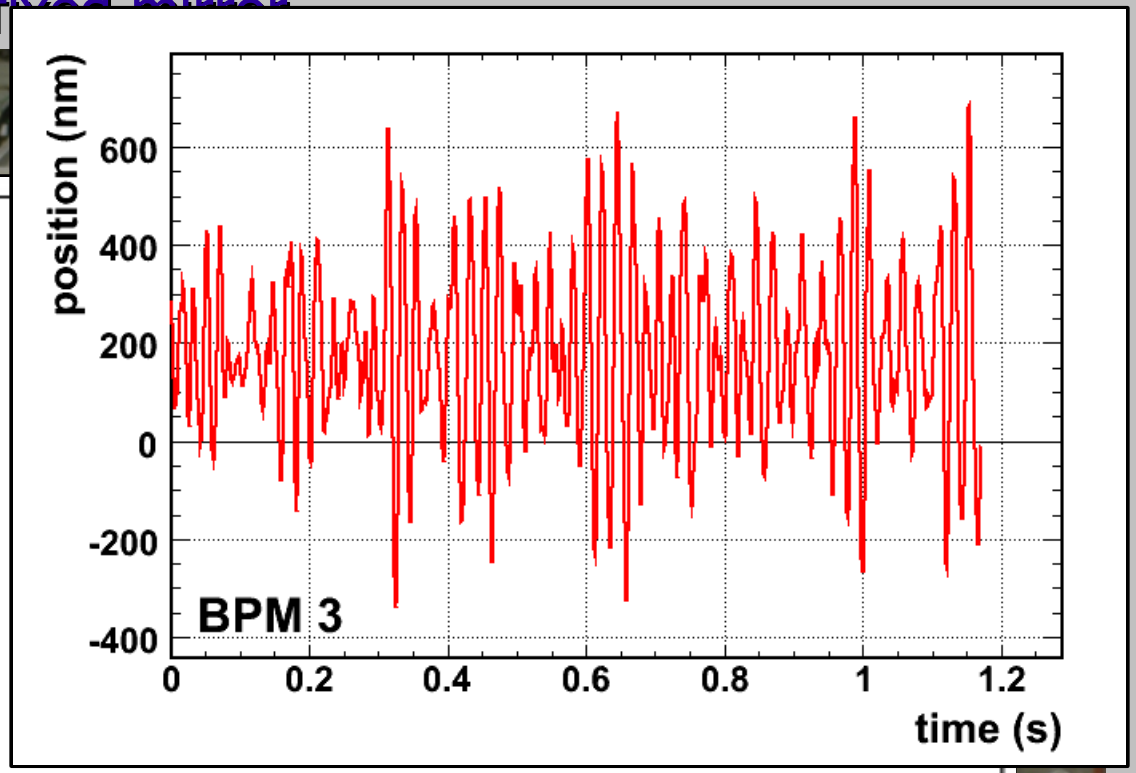
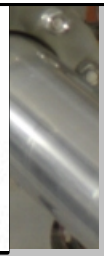






Spectrometer BPM prototype

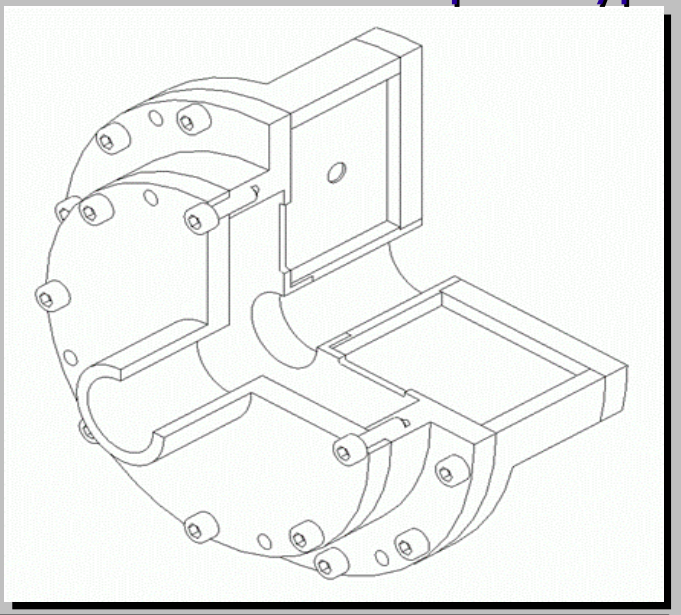
Existing BPM designs not optimal for an energy spectrometer

- aperture (machine protection, resolution)
- resolution, stability
- monopole rejection (electric center stability)
- coupling -> decay time (multi bunch)

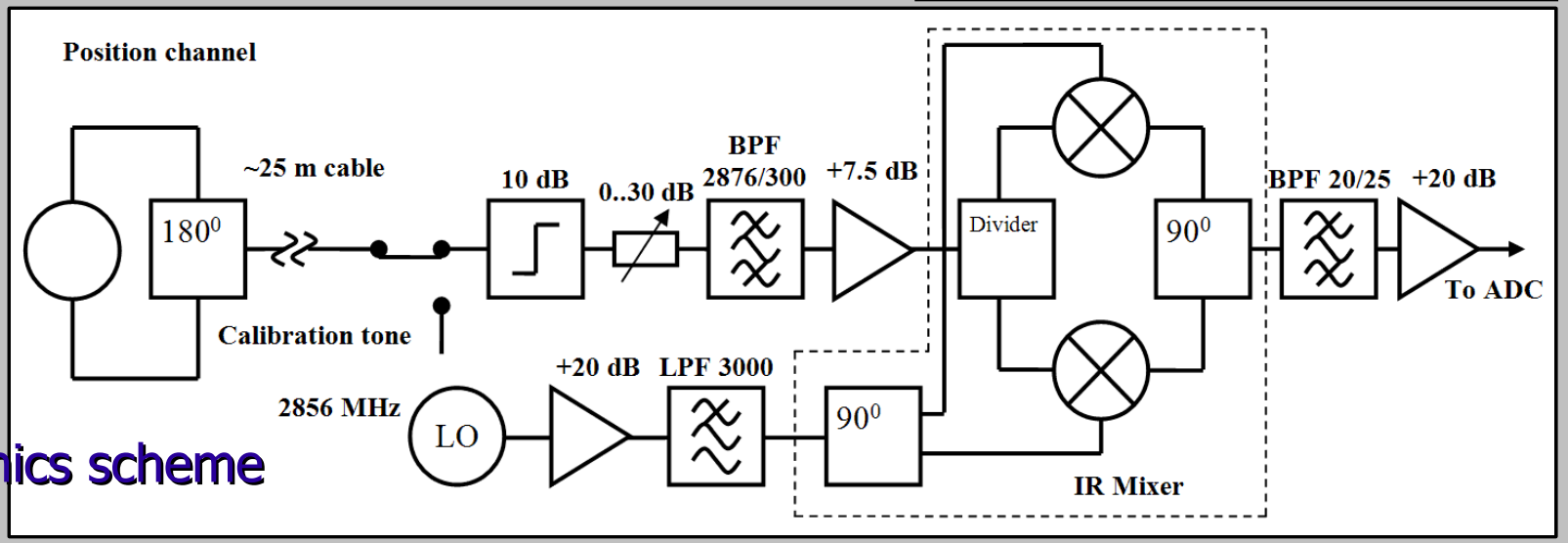
Designed new prototype (A. Lyapin)

- 30 mm aperture, 2.878 GHz, 1.3 MHz bandwidth
- theoretical resolution ~ 11.2 nm
- Al prototype by UCL workshop, Cu vacuum beam prototype by Mullard Space Science Lab (MSSL)

Al prototype



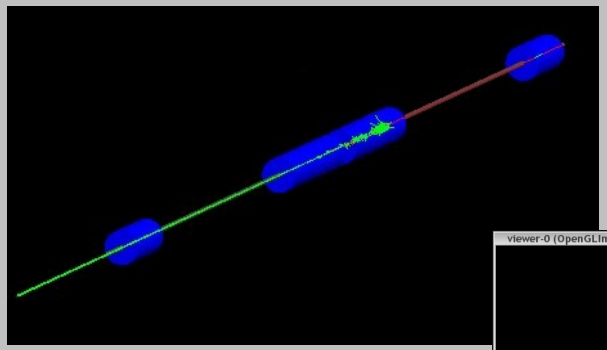
Proposed electronics scheme

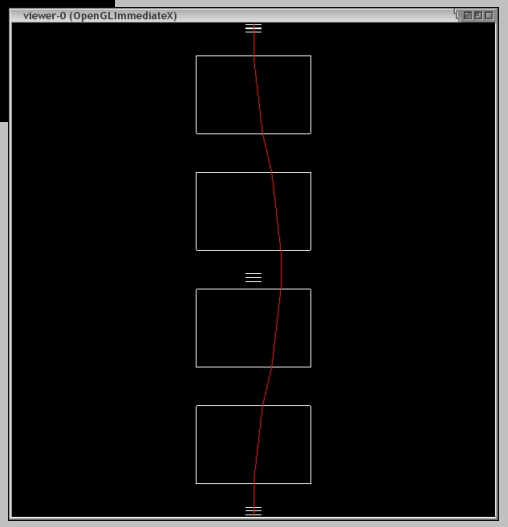


Aluminium prototype for new BPM

Al prototype is done & ready for measurements at UCL & RHUL

Chicane simulation

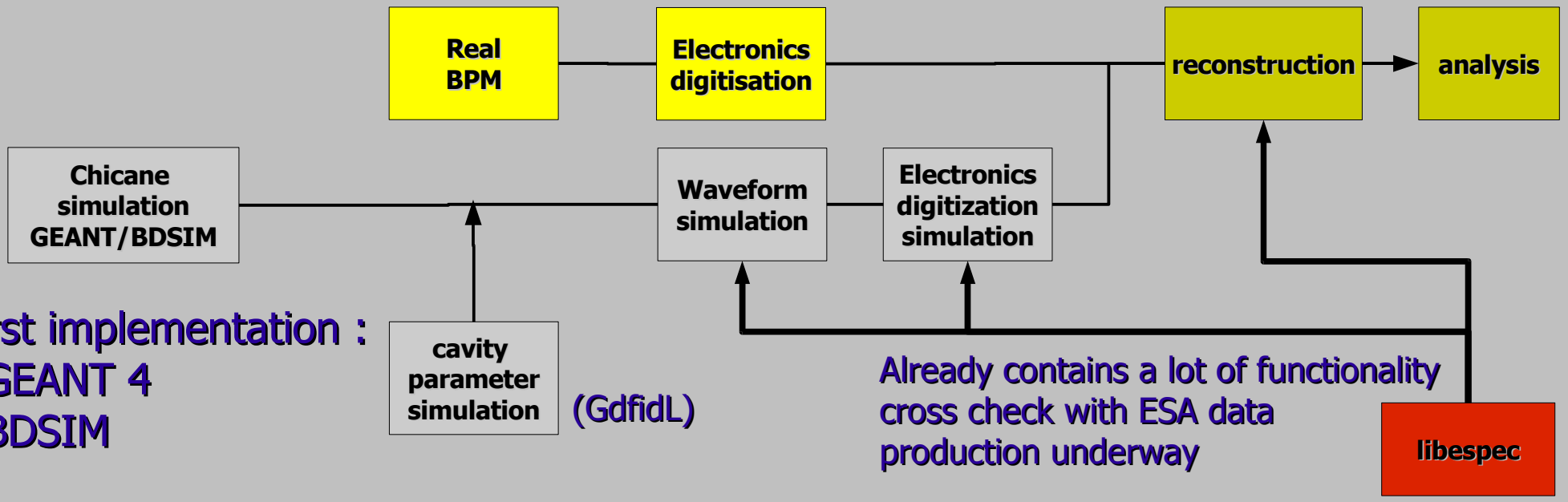




Currently most simulation work just generates "sampled waveforms"

Developing core library for full simulation :

- Uses physical units (easily portable between e.g. KEK & SLAC)
- Portability between platforms, e.g. import into LabVIEW
- Simulation of electronics : loss, non linearity, digitization
- Contains analysis routines as well -> simulation & real data analysis based upon idential set of routines



First implementation :

- GEANT 4
- BDSIM

Closing remarks & future plans

Plans for ESA :

- Install 4 magnets in beam line (Jan. '07)
- Install & commission new spectrometer BPM prototype
  complete with temperature readout and x,y mover system
- Commission constant calibration tone system to monitor gain drifts
  in electronics
- Link BPM stations with interferometer system (M. Hildreth)