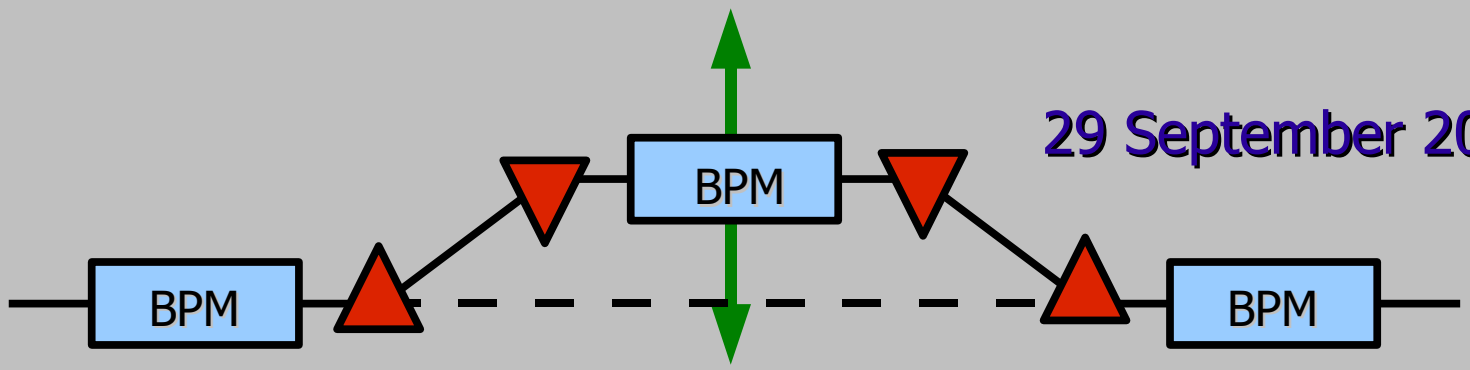
BPM Energy Spectrometry for the International Linear Collider

Bino Maiheu
for Alex, Stew, Fil, Steve, Matthew & David

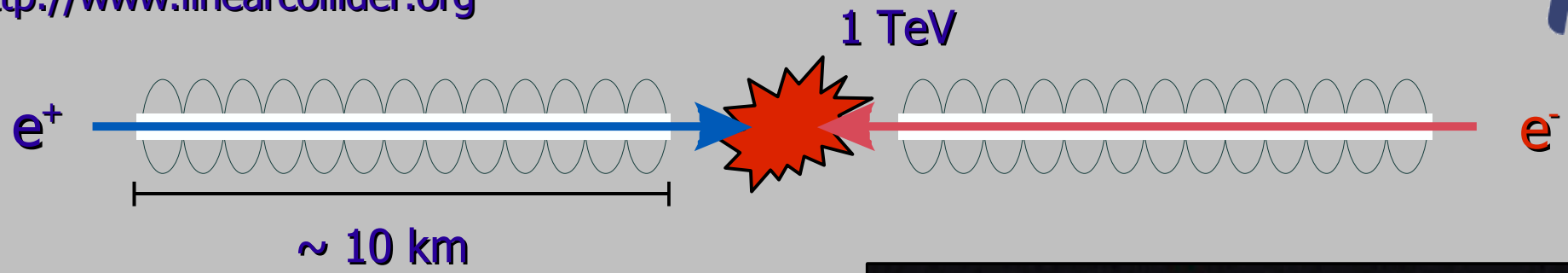
UCL – HEP group meeting



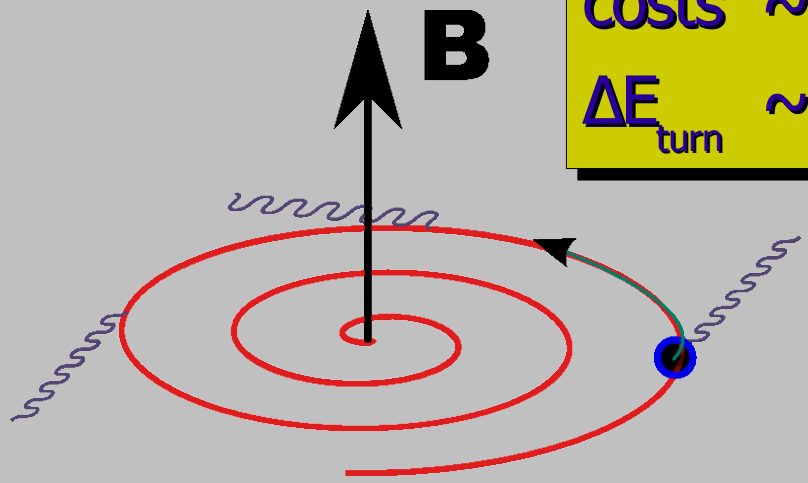
29 September 2006

What is the *international linear collider* ?

http://www.linearcollider.org

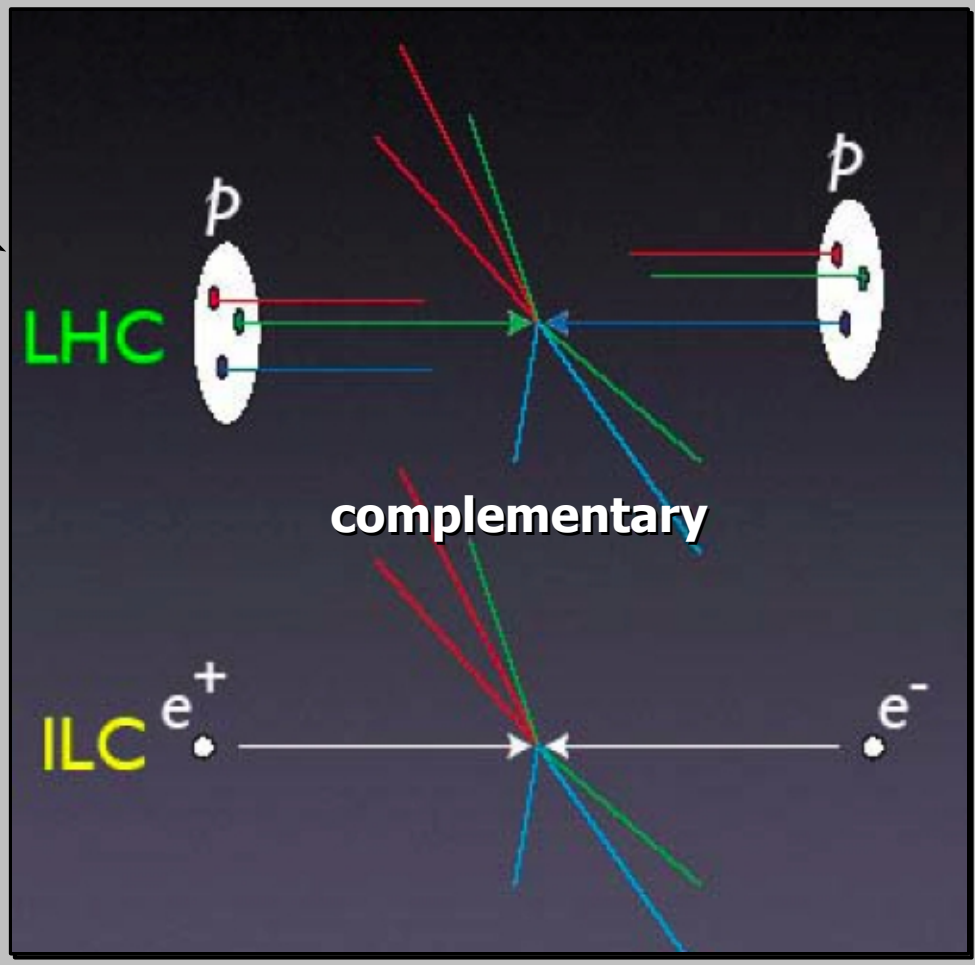


- Proposed ~30 km long linear e^+e^- collider
- CM energy up to 1 TeV
- International... obviously ☺
- targeted completion around 2020



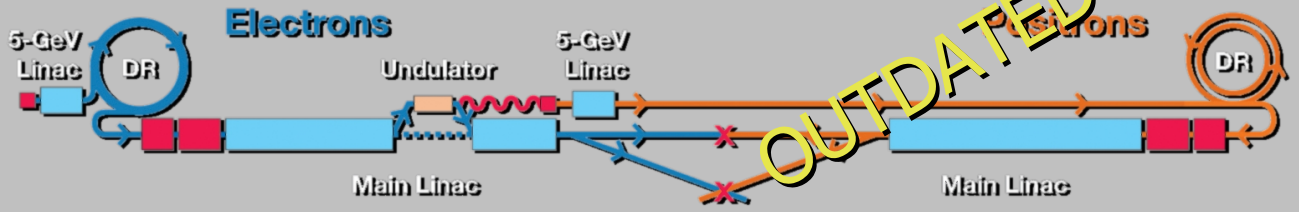
$$\text{costs} \sim P_{RF}$$

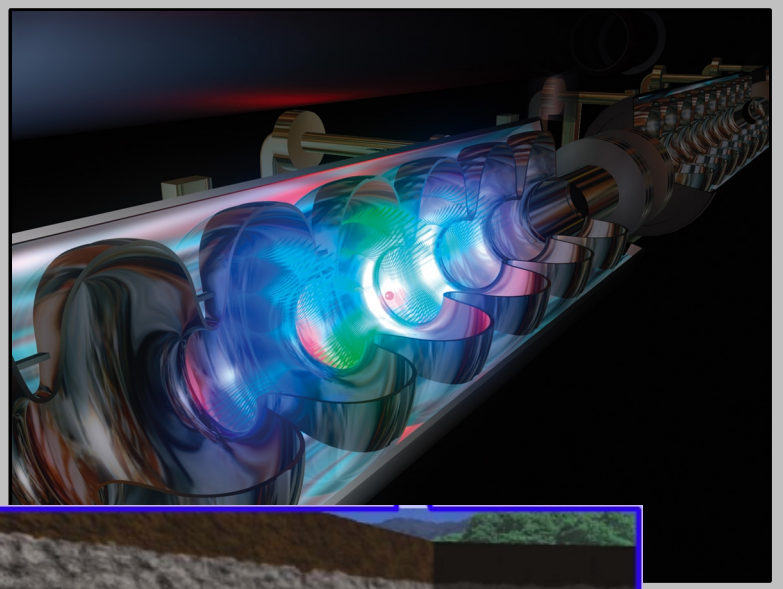
$$\Delta E_{turn} \sim E^4 / \rho^2$$



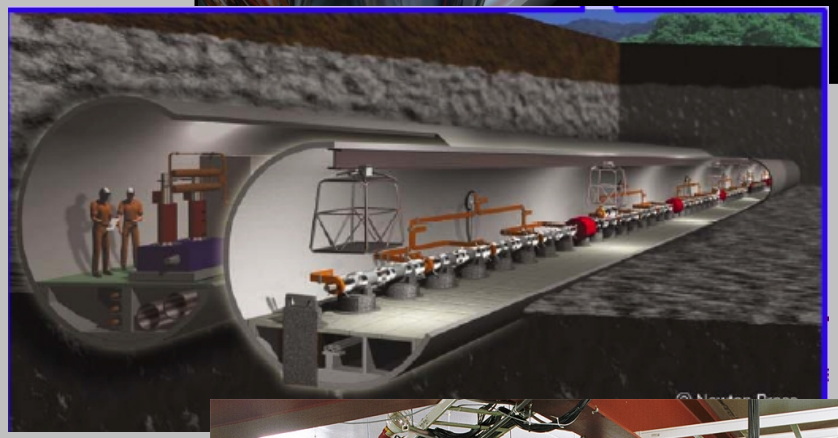
However... we're not 2020 yet...

ILC layout & challenges





- Accelerating gradient ~ 35-40 MeV/m
- Damping rings, sources, final focus
  - Lumi ~ f_{rep} / $\sigma_x \sigma_y$
  - f_{rep} = 40 kHz (LEP), = 5 Hz (ILC)
  - -> beam size ~ 1000 times smaller
  - Test facilities !!
- Civil engineering, ...

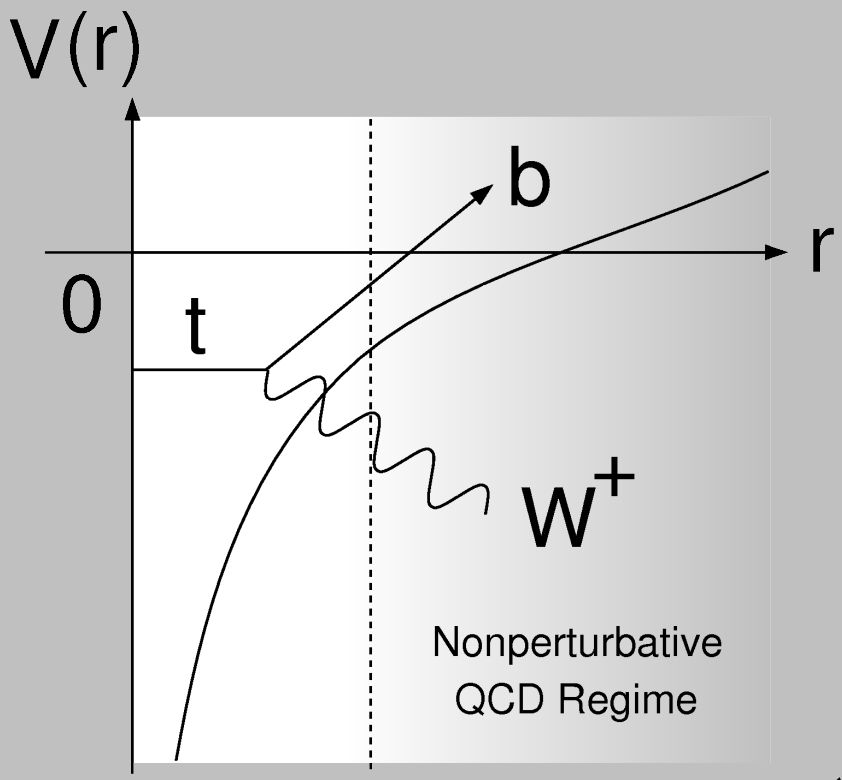


- Beam Delivery System : you only get 1 go !!!
  - UK has leading role
  - Beam energy measurement

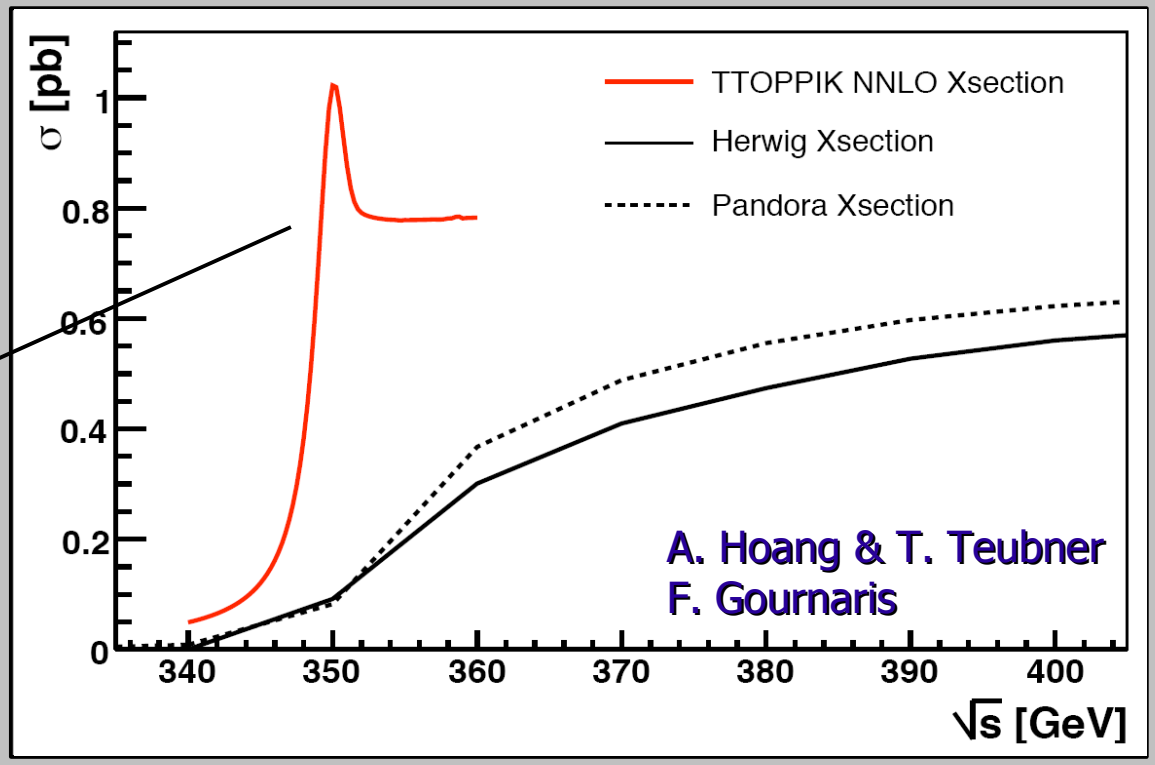
- High quality physics need accuracy (see later)
- No averaging over bunches possible
- Min. impact on the beam and physics datataking

Importance of energy measurement

Introducing... Filimon, our one leg in "proper" physics :-) ...



- Study of top quark important for standard model / SUSY constraints
- Top quark : large decay width -> pQCD
- ILC = top quark factory, QCD precision tests
- Top pair production cross section : TOPPIK



Filimon is developing MC generator for top quark production

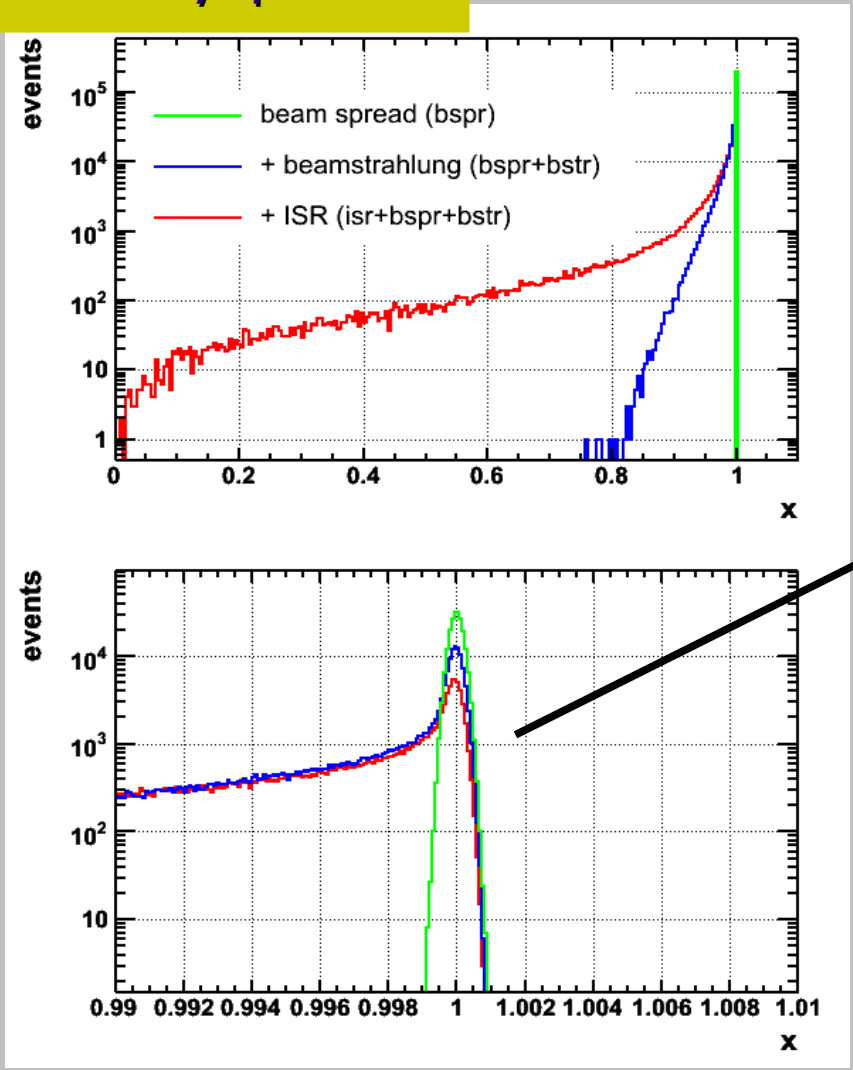
- based upon TOPPIK
- some "voodoo" to improve speed
- ILC workshops Vancouver & Valencia

However... not full story...

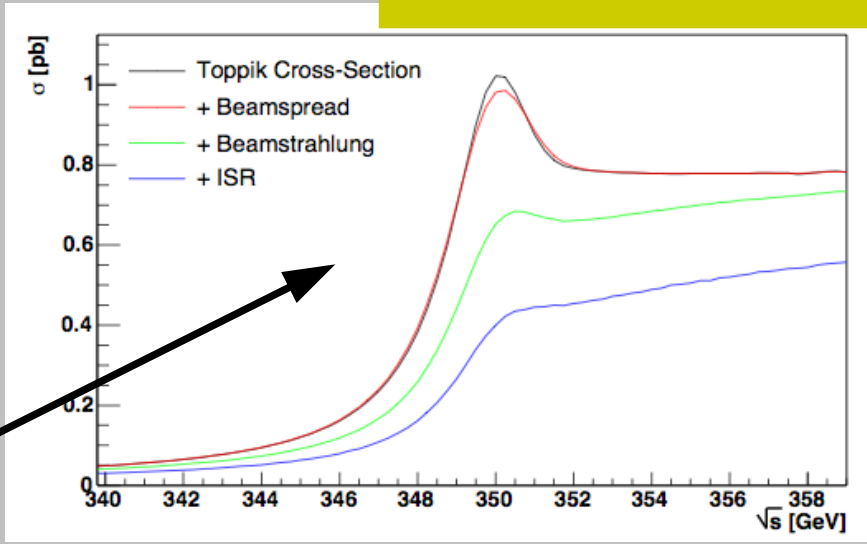
Influence of beam energy...

GDE stresses importance of link between accelerator physics & particle physics

Luminosity spectrum



Top quark mass scan



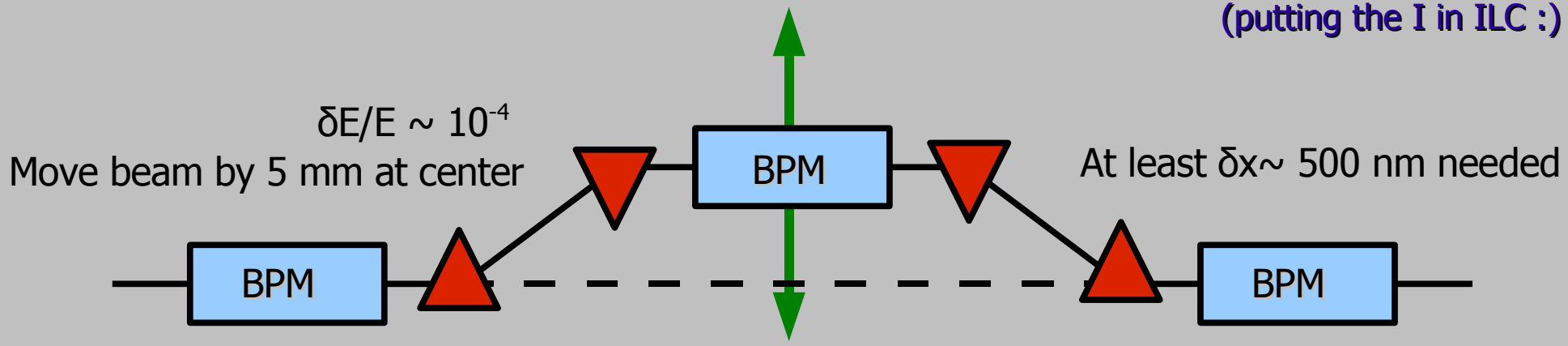
Uncertainty on beam energy measurement contributes directly to the uncertainty on the ILC physics output...

BPM Spectrometry

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

Study & design magnetic chicane for beam energy measurement using Beam Position Monitors (BPMs)

Royal Holloway University London: S. Boogert
Cambridge : M. Slater, M. Thomson and D. Ward
University College London: F. Gournaris, A. Lyapin, B. Maiheu, S. Malton, D. Miller and M. Wing
(putting the I in ILC :)



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

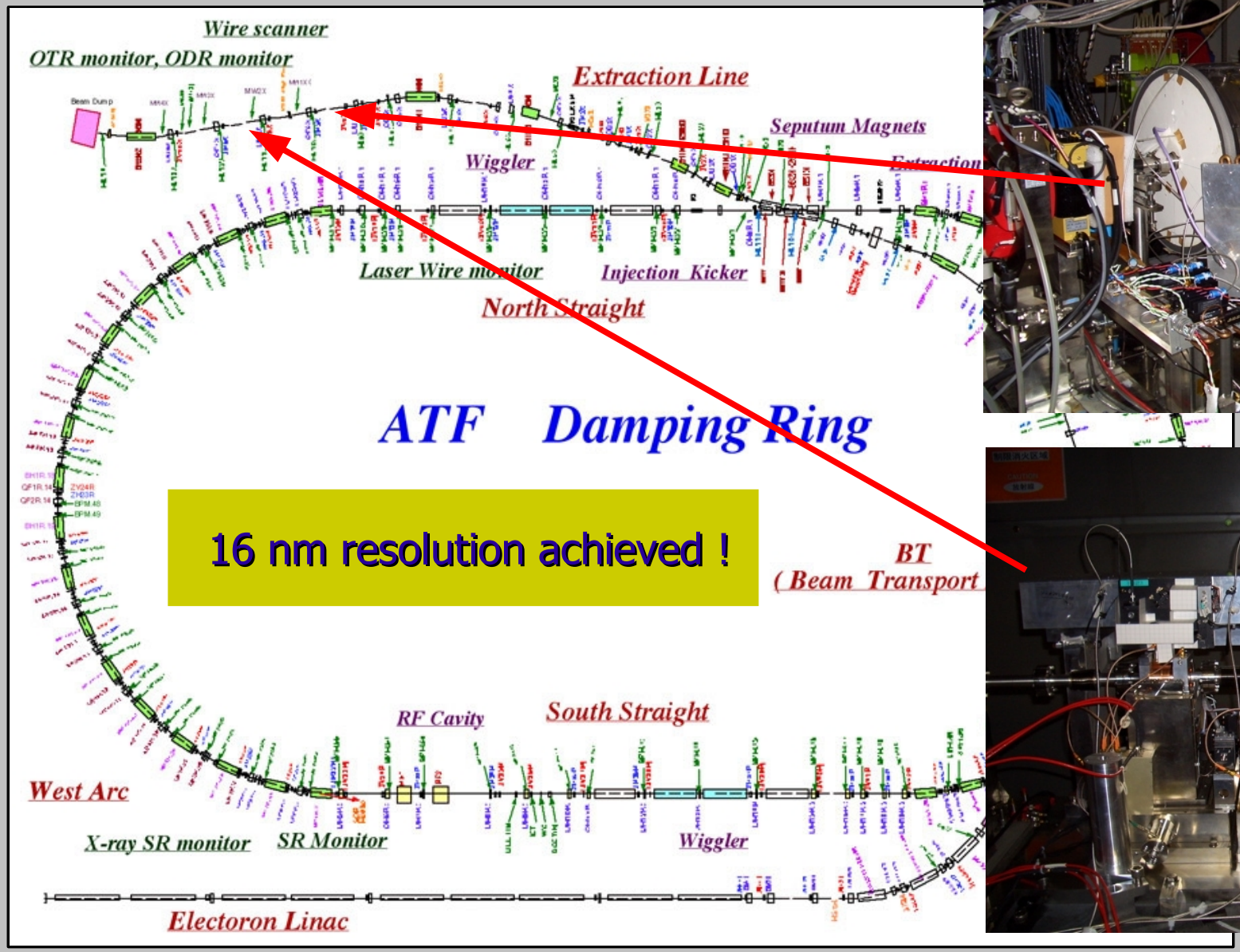
-> spectrometer aspects of BPMs can be tested

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

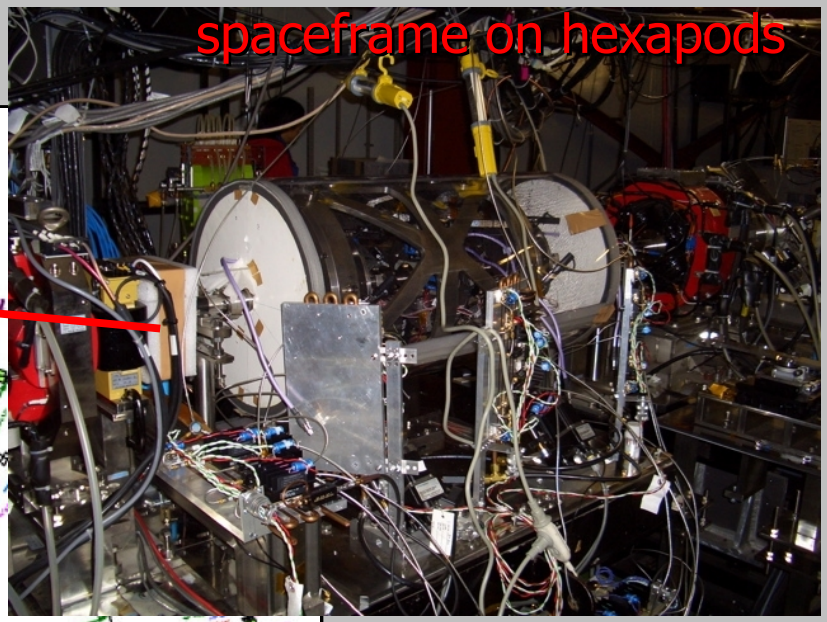
-> test of real chicane prototype

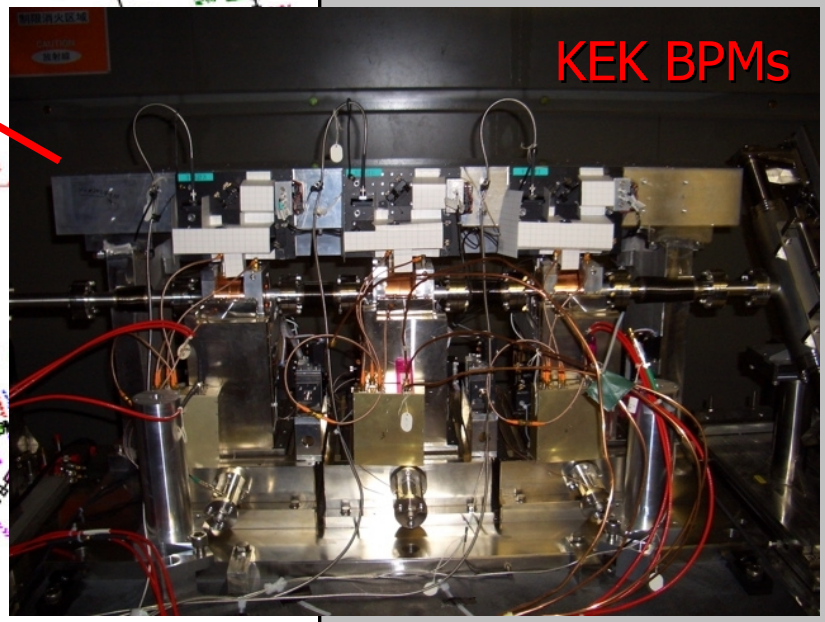
NanoBPM at ATF (KEK)

Collaboration with LBNL, LLNL, SLAC, KEK

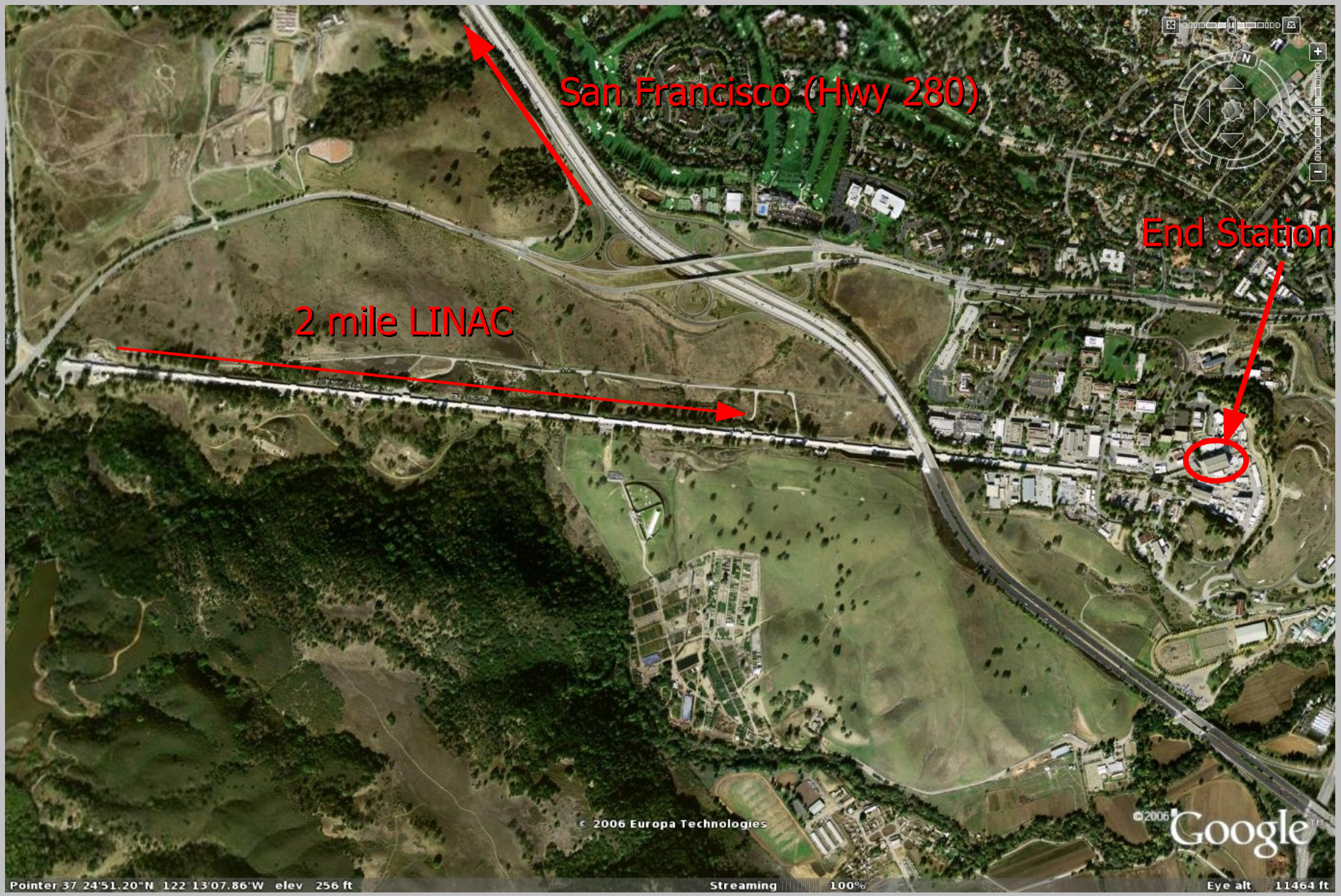


BINP BPMs in LLNL/SLAC spaceframe on hexapods



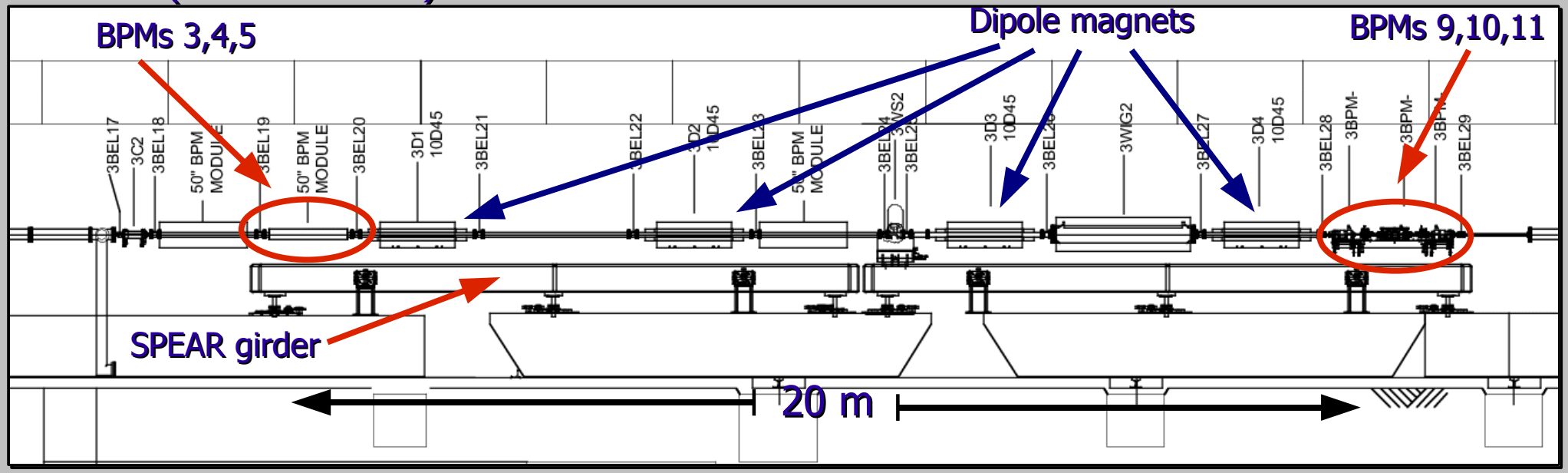


ESA at SLAC (as seen by GoogleEarth)



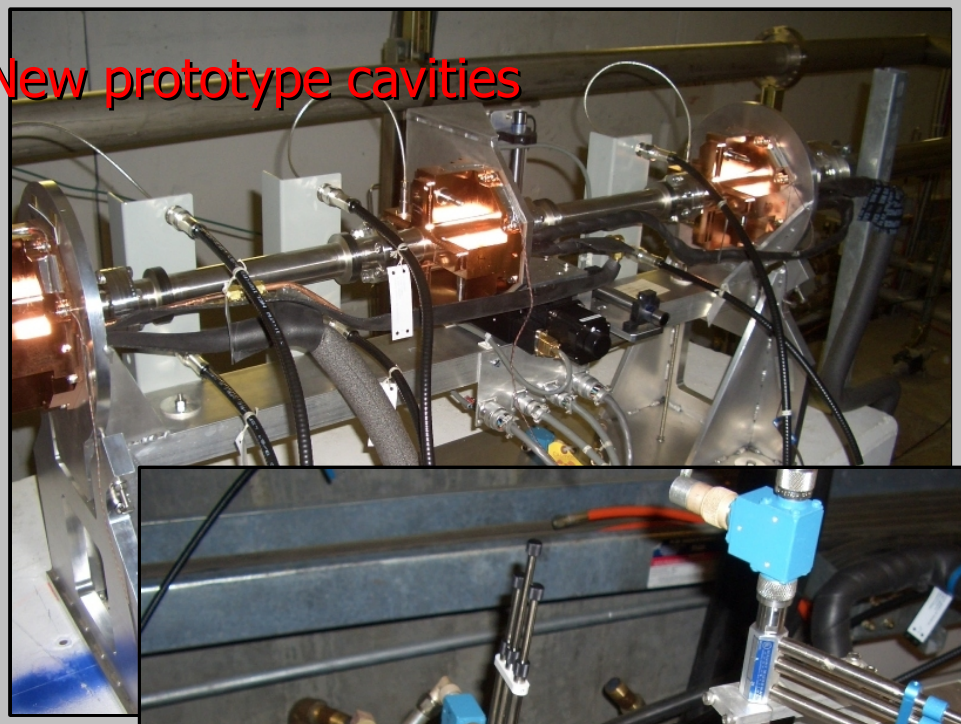
T474/T491 - ESA@SLAC

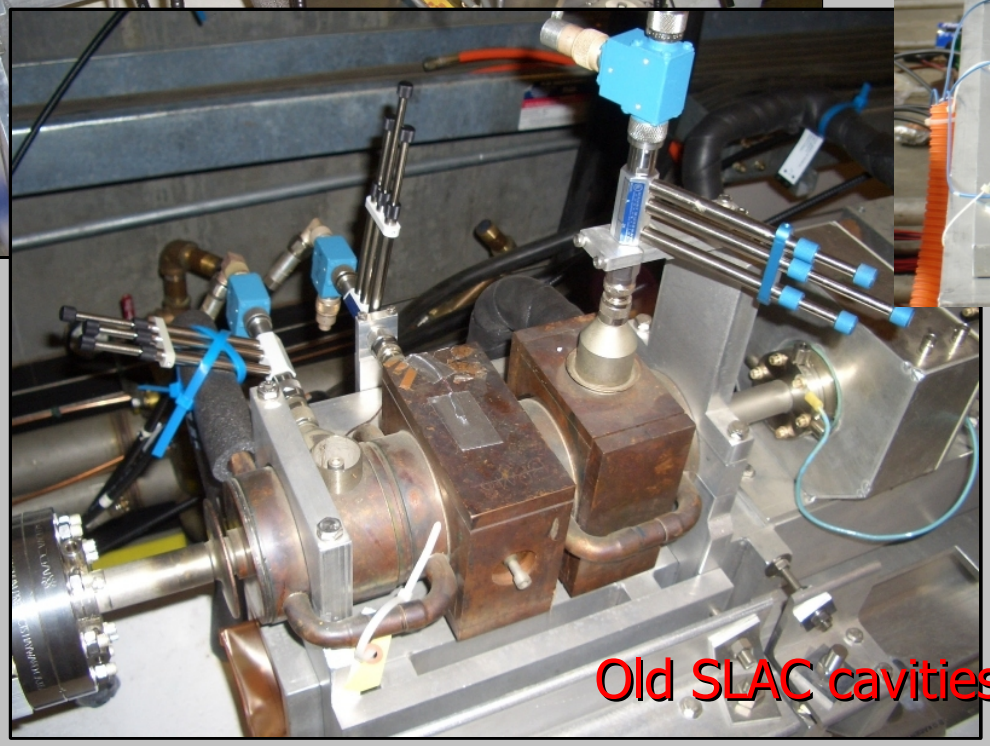
Collaboration with LBNL (Y. Kolomensky et al.), SLAC (M. Woods et al.) and Notre Dame (M. Hildreth et al.)



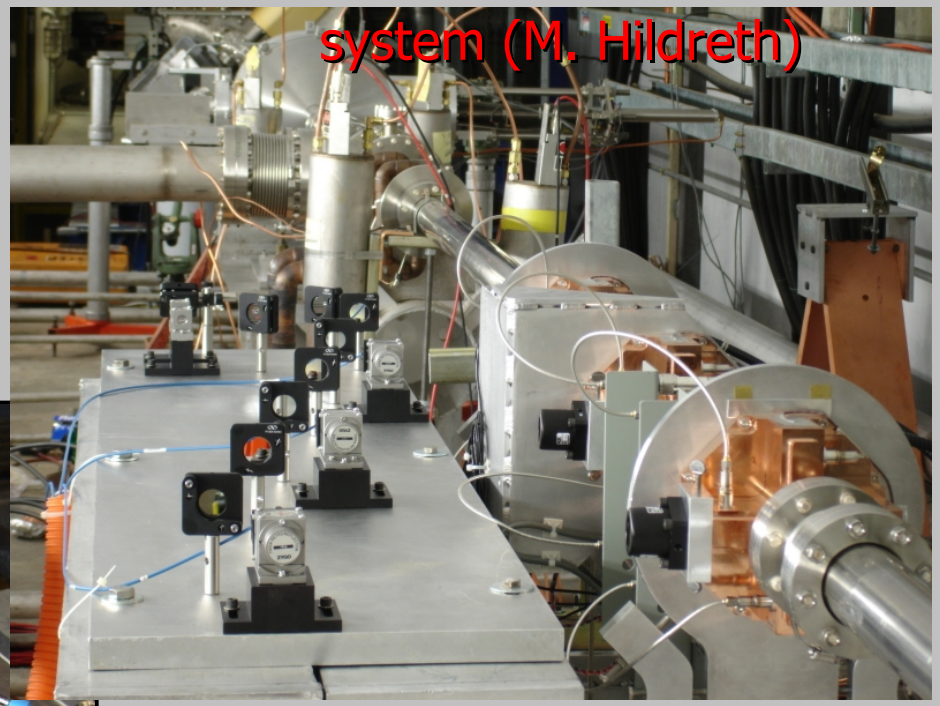
- January test run 2006 (4 days) : Commissioning of BPMs 31,32 and 1,2 upstream
- April run 2006 (2 weeks) :
  - Commissioning of new cold linac prototype triplet (BPM 3,4,5), where BPM4 on x,y mover system
  - Commissioning of old SLAC BPMs (9,10,11)
  - Digitisation/signal processing optimization
-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

The setup in the End Station



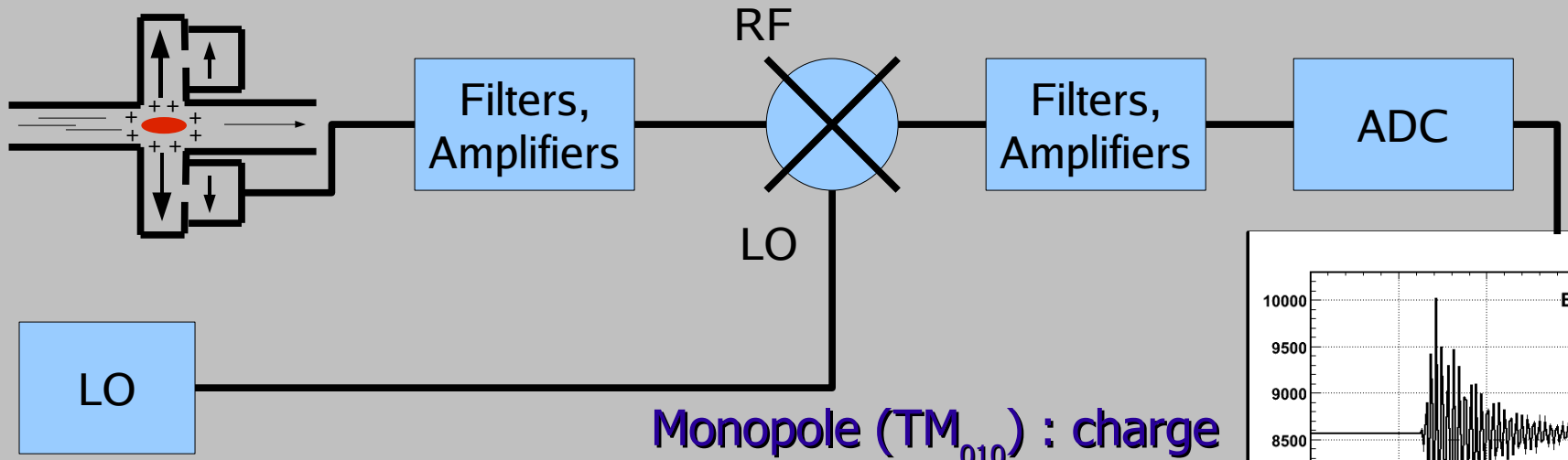


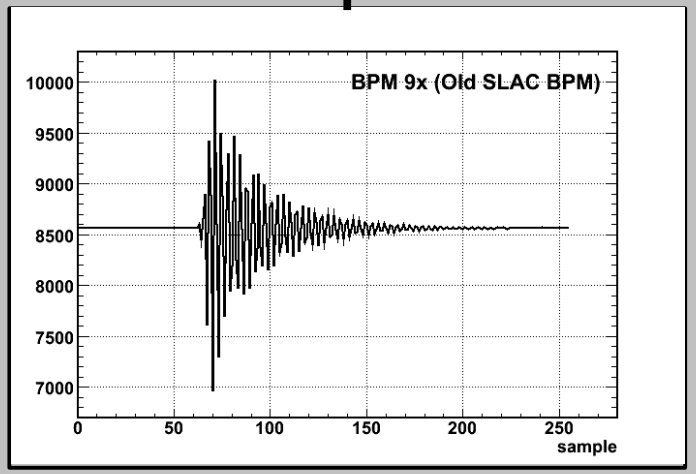
Notre Dame Interferometer system (M. Hildreth)



- ~ 700 nm in new cold LINAC prototype cavities, designed by Z. Li & C. Adolphsen
- ~ 350 nm in old SLAC cavities
- Systematics under investigation
- Improving calibration routine

How do these BPMs work... nutshell-ish ?





Monopole (TM_{010}) : charge

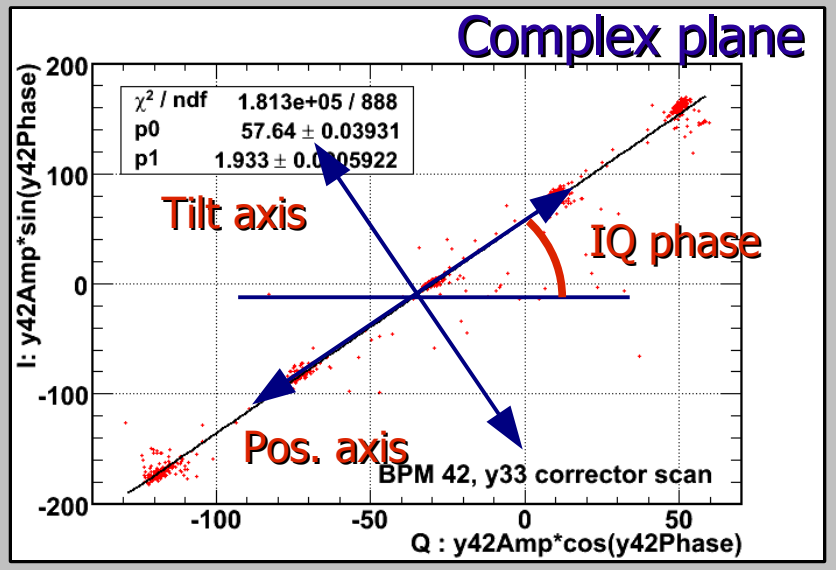
Dipole (TM_{110}) : charge + offset + tilt

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 -> A, φ

Disentangle charge, offset and tilt :

1. Normalize signal to Ref (Q) Cavity
2. IQ rotation (π/2 tilt phase difference)
3. Calibrate



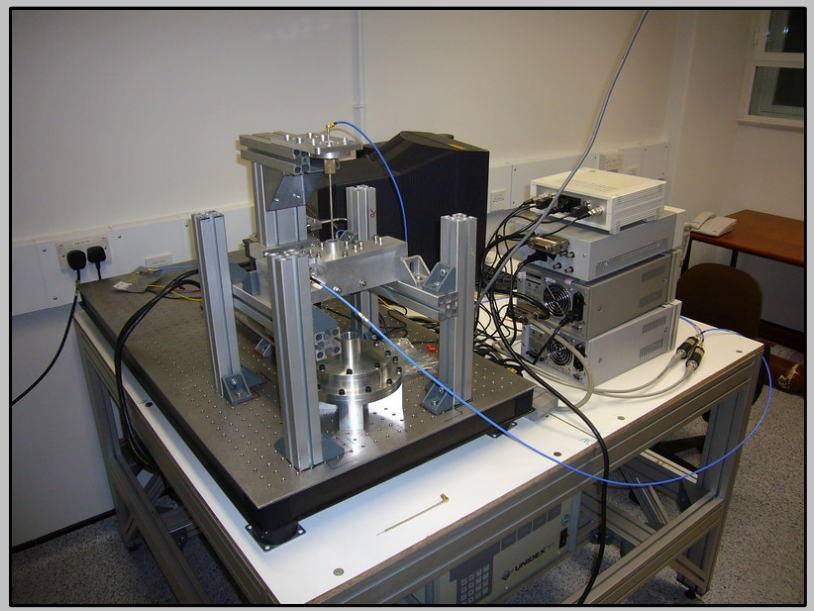
Our own spectrometer BPM prototype

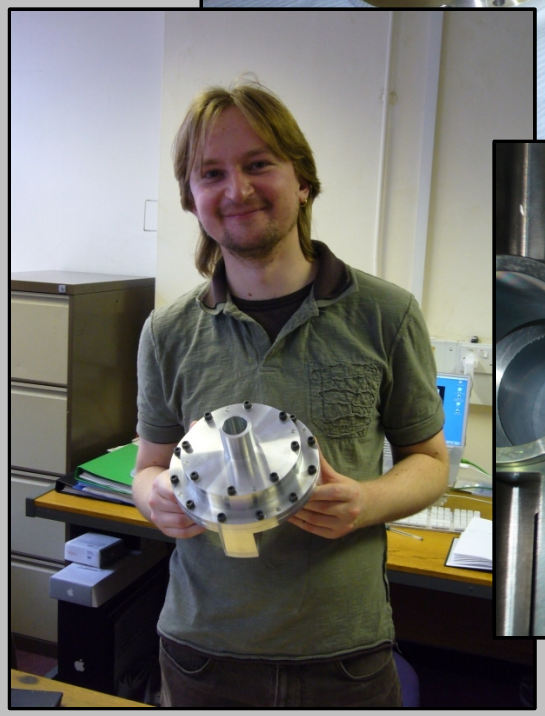
Existing BPM designs not optimal for an energy spectrometer

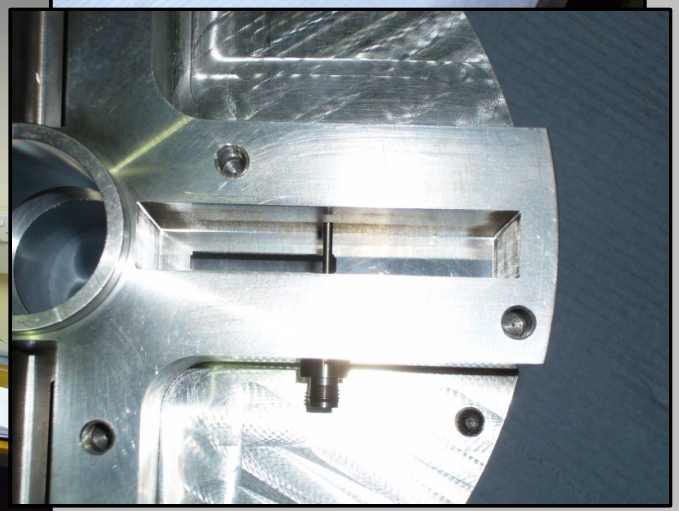
- aperture (machine protection, resolution)
- resolution, stability
- monopole rejection
- coupling -> decay time (multi bunch)

Take know-how gained from collaborating with others and design BPM of our own, suitable for energy spectrometer

- Al prototype by UCL workshop
- Cu vacuum beam MSSL

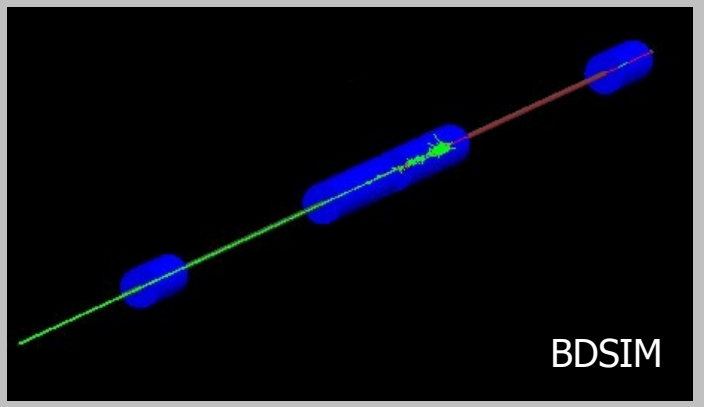




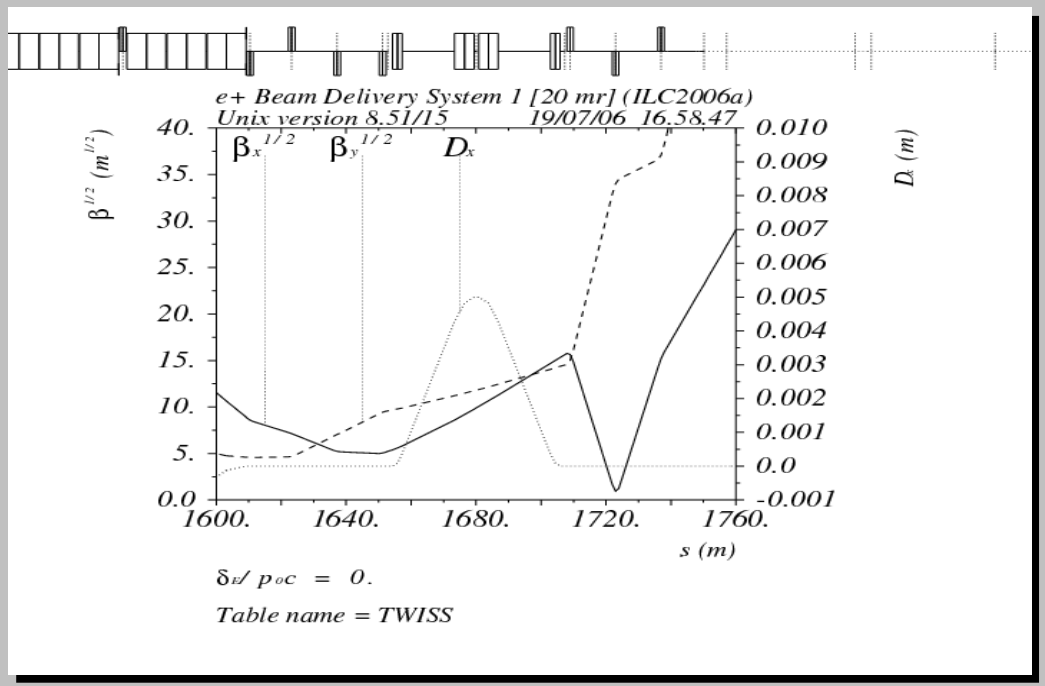


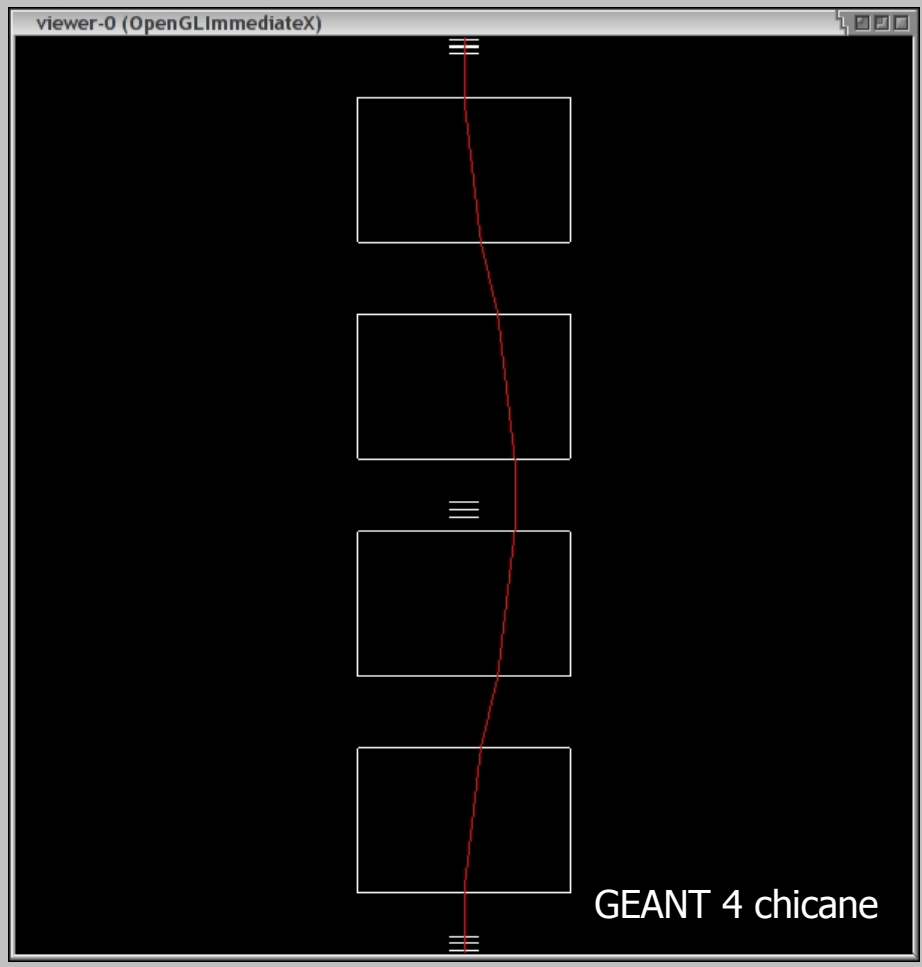
Spectrometer simulation

- Impact of the chicane on the optics of the beam ?
- Where does the synchrotron radiation go ?
- General opertional issues...
- Emittance growth, energy bandwidth of system ?
- ...



Simulation in GEANT4, BDSIM and MAD
Developing core, platform independent library for BPM analysis & simulation





Future plans

- Continue to develop Top Monte Carlo generator
- Further contributions to NanoBPM & ESA work : spectrometer related studies, data-analysis...
- Commission BPM vacuum prototype in January in ESA beam line and develop full triplet the coming years...
- Simulation work : full simulation of chicane, BPMs, digitization and analysis

- And in the end...

Go to GDE and say :

"Look guys, here's a 'little' spreadsheet with what you need for a BPM spectrometer, this is how you build it, these are the systematics involved and this is how it's measurements will impact the physics output of the ILC."

Possible PhD projects...

- Physics analysis
  - Other thresholds e.g. SUSY, W^+W^-, Higgs,...
  - Energy measurement essential for all of these !

- BPM spectrometer
  - UCL developing BPM triplet system
  - Plenty of opportunities : electronics, simulations, data-analysis, beam tests

- Linear Collider
  - Integration of spectrometer into beam delivery system
  - Exposure to advanced beam instrumentation
  - **Real** hardware experience

Accelerator being designed now, PhDs on this project can Significantly influence design & operation

Thank you :-)

http://www.hep.ucl.ac.uk/lc/
http://www.hep.ucl.ac.uk/~bino/T474/
http://www.hep.ucl.ac.uk/~liapine/
http://www.hep.ucl.ac.uk/~sboogert/