BPM energy spectrometer

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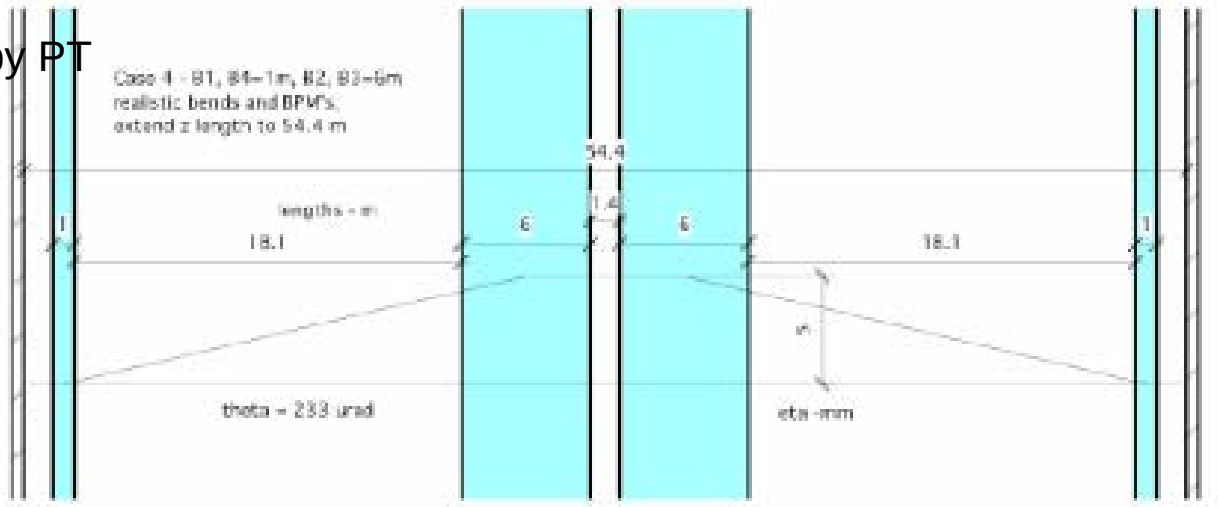
Overview

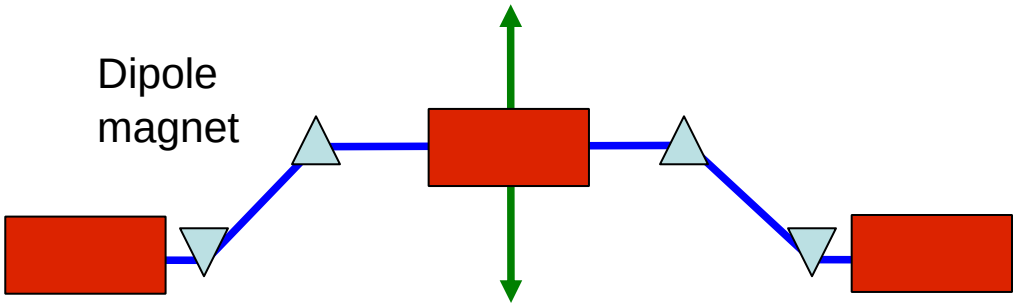
- Spectrometer essential diagnostic for ILC
  - 9 BPMs per spectrometer x 4 beam lines ~36 BPMs
  - Requirements different from Linac/BDS BPM requirements
  - Requires detailed design work now, for accelerator/detector CDR

- Talk outline
  - Spectrometer requirements
  - Spectrometer BPM requirements
  - Magnet questions
  - Other requirements
  - Quick overview of existing efforts
    - ATF nano BPMs
    - End station A chicane tests
  - Summary

Chicane spectrometer requirements

- Beam energy measurement requirement of 1 part in 10^4
- Assume chicane as proposed by PT and RA
  - 4 magnets
  - 5 mm maximum deflection
  - Bipolar operation
- Measurement time
  - Single bunch
  - Bunch train
  - 1 hour / 1 day
- Mode of operation effects 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?





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?
    - Cross coupling
- 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)

Magnet requirements/questions

- Factors which influence magnet design
  - Ramping strategy
  - Ability to continuously monitor field
- SC/Warm
  - Which type of magnet would provide the most stable, uniform field?
  - Which would be quicker to ramp?
  - Which is easier to map?
- Magnet imperfections
  - Could effect luminosity
  - Fringe fields
- Must start dialogue with magnet designers
  - Bret Parker present here …

Background/Halo

- LEP spectrometer had problems
  - Possible source was SR
- Effect of halo on BPM position measurement
  - Message from BPM experts, cavities just monitor the centroid
  - Clear this does not contribute to luminosity but might pull energy measurement

- Background in the region of spectrometer
  - Main source in spectrometer?
    - Energy collimation
    - Betatron collimation region
    - SR from local bends
- Need simulation of nearby accelerator
  - BDSim or variants
  - Second order question, more basic issues need to be addressed first

Operation problems questions

- Mainly associated with ramping whilst trying to provide luminosity

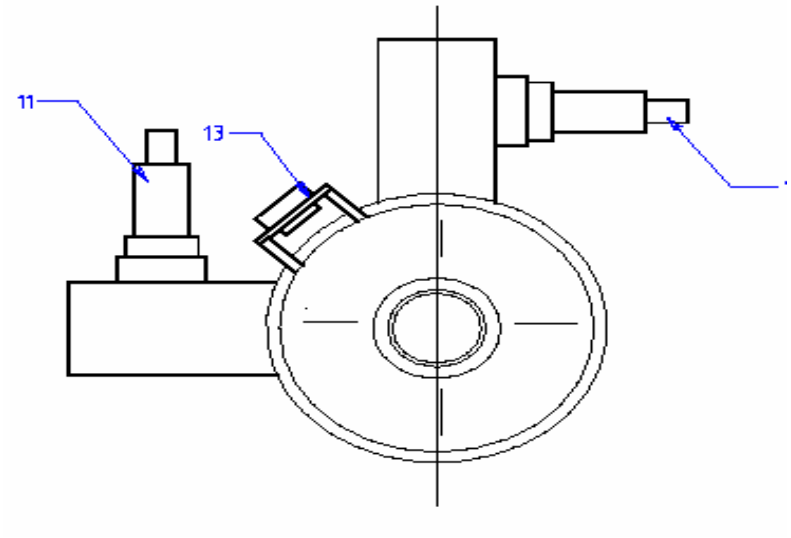
- Orbit effects
  - Kicker and feedforward when ramping to remove beam orbit changes from spectrometer chicane
- Optical effects (simplistic)
  - What is there are focusing/defocusing effects at different chicane magnet settings
  - Possible to remove this too, tweaking down stream quads etc

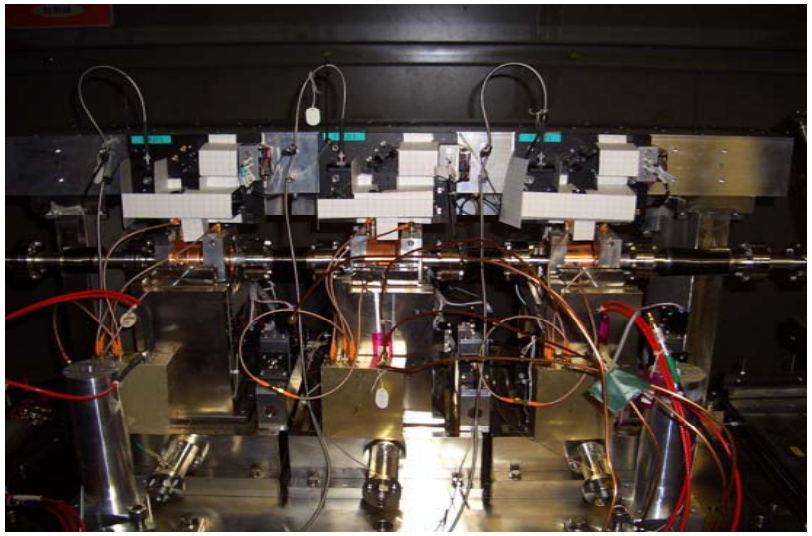
- ESA tests can be used to try and answer some of these questions

Other requirements

- BPM position monitoring
  - Need to know BPM position to better than BPM stability
  - Large travel range ±5mm
- Mechanical stability, BPM and triplet movers
  - Good to be able to move all BPMs and triplets together
  - See LLNL space frame
- Dipole field monitoring
  - How to monitor integrated B.dl?
  - Low fields (for Z calibration) in dipole
- Careful monitoring of environmental conditions
  - Temperature
  - Electronics gain
    - Calibration tones
  - Stray fields
  - Ground stability/motion

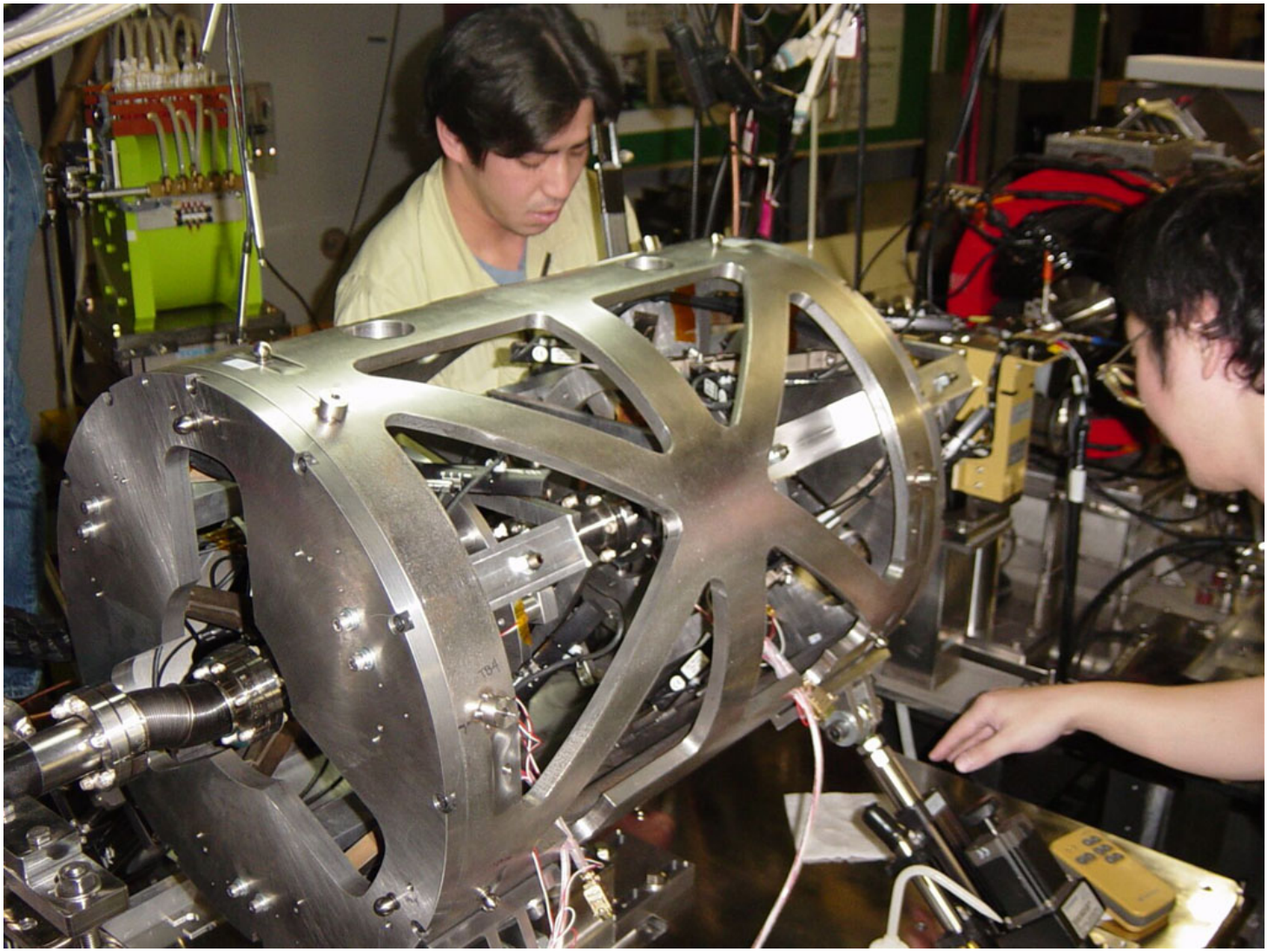
ATF NanoBPM programme





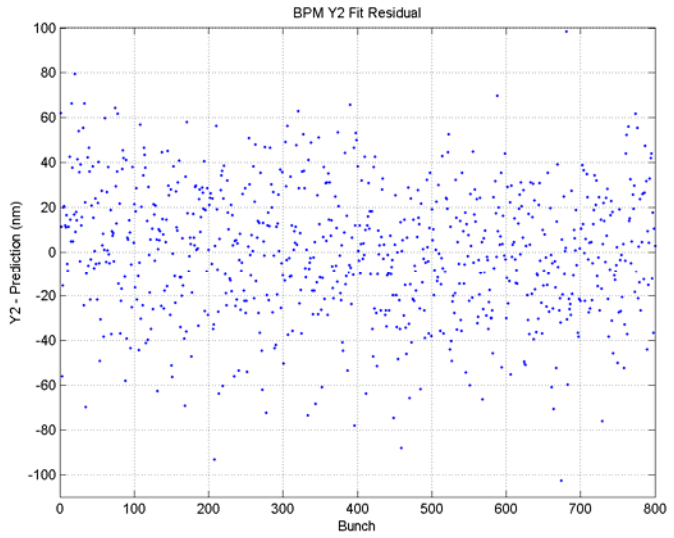
- BINP BPMs (V. Vogel et al)
  - ~2cm diameter
  - Dipole selective waveguide couplers
  - 2 stage down-mixs electronics
- Triplet installed in the ATF extraction line
  - Mechanically stable LLNL “space-frame”
  - Ability to move each BPM
  - Whole triplet together
- Triplet of ATF cavities installed down stream of BINP BPMs
  - Performance not as good
  - Cross coupling
  - Monopole mode rejection

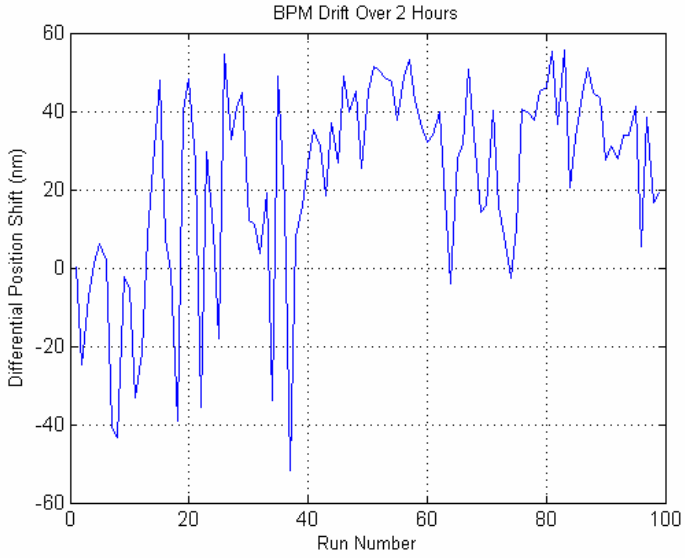
LLNL Spaceframe and BPMs



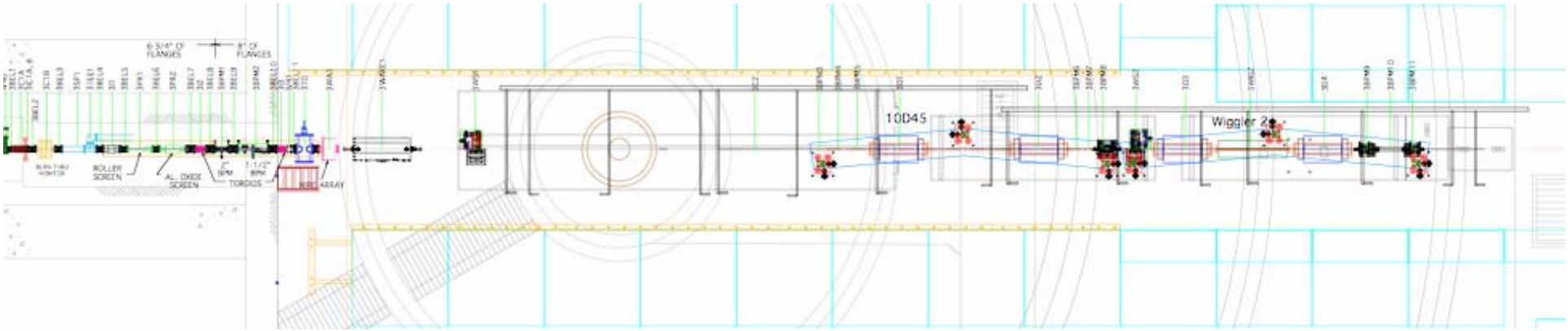
Recent nano BPM results

- Resolution and stability measurements from BINP cavities
- Resolution
  - Long run 800 events ~ 10 minutes
  - **σ ~ 24 nm**
  - Resolution for spectrometer achieved
- Stability
  - Measured drift over 2 hours
  - First 100 events used for calibration
  - Drift <120 nm peak to peak
  - RMS drift **~40nm** over 2 hours
  - Stability already seems promising

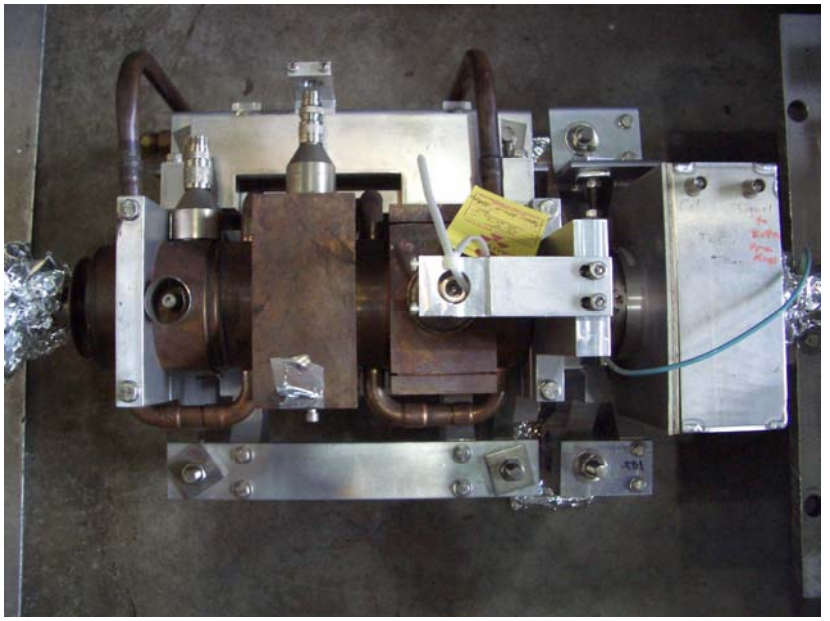




End station A programe



- 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 specificBPM designs
  - New RF electronics
    - Resolution <1μm
- First tests in November 2005, Chicane tests 2006…



Snowmass 2nd week work/discussions

- Spectrometer
  - Single bunch resolution
  - Bunch train resolution
- Machine
  - Range of possible
    - Aperture
    - Position, angle, charge jitter
- Spectrometer-machine interaction
  - Chicane operation
  - Magnet ramping
  - Possible loss of luminosity?

- BPMs
  - Resolution
    - 100 nm to 1 μm
  - Dynamic range
    - 100 μm to 1mm
  - Stability (thermal, etc)
    - Common mode rejection
    - Mechanical symmetry
    - 200 nm (to 2 μm) many hours/days
  - Cavity Q
    - Implications for single bunch measurement
    - Is it possible to extract single bunch information with large Q
    - Tests at ESA and ATF to verify this
  - Other
    - Reference cavities
    - Mechanics/size

My design (to stimulate discussion)

- PT + RA Chicane
  - ~18m drift from analyzing bends
  - ~2m drift for BPMs
  - Pre/mid/post chicane triplets in LLNL type structures
- BPMs
  - Cylindrical cavities (scaled from existing cylindrical designs)
    - ~4-7 cm diameter (GG2?)
    - Resolution ~50-100nm
- BPM stability/alignment
  - Oxford STAFF stability monitoring system
- Magnets
  - Warm (quicker to ramp?)
  - Integrated magnetic field probes

Summary

- Still more questions than answers here at Snowmass!
- Spectrometer geometry/layout
  - Is the existing design optimal? (Z to 1TeV running?)
- Accelerator
  - Is the existing chicane acceptable for the machine?
    - Sets limits on dipole magnet requirements (quadrapole, sextapole contributions)
  - More specific information on the beam at chicane location
- BPM
  - Resolution ~100nm, stability ~200nm quite possible
  - Scale existing cavity designs for spectrometer
  - High gain electronics and readout readily available
- Operation
  - Calibration with Z running
    - Frequency. How long can the calibration with Z be maintained
    - Systematic effects using ~50GeV calibration up at 500 GeV?
  - Magnet ramping
- Magnets
  - Must begin discussion with magnet designers