Proposal for Interferometer Monitoring of IP Steering Feedback BPMs

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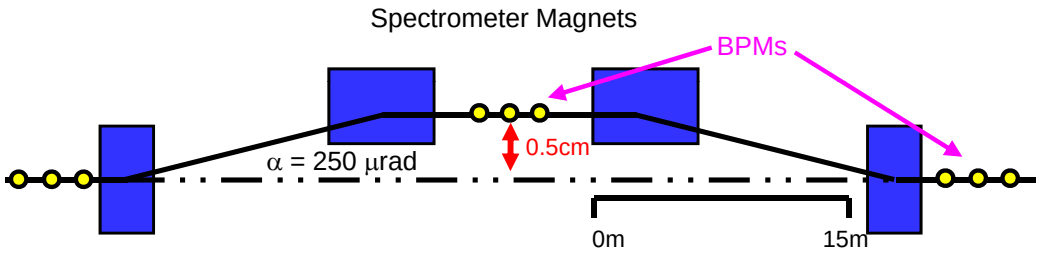
Starting Points: Energy Spectrometry

- "LEP-style" BPM-based Spectrometer
  - The only technique we could think of that gives required resolution while doing ~nothing to the beam
    - very simple:

$$\theta = \frac{ec}{p}\int B \cdot d\ell$$



- Considerations:
  - Constrained by allowed emittance growth from SR
  - Constrained by available real estate in BDS, overall size
    - These constraints determine needed BPM resolution/stability
  - Other issues drive systematic errors, diagnostics

  ⇒ Complicated dependence on design parameters, options

  - Must be robust, invisible to luminosity

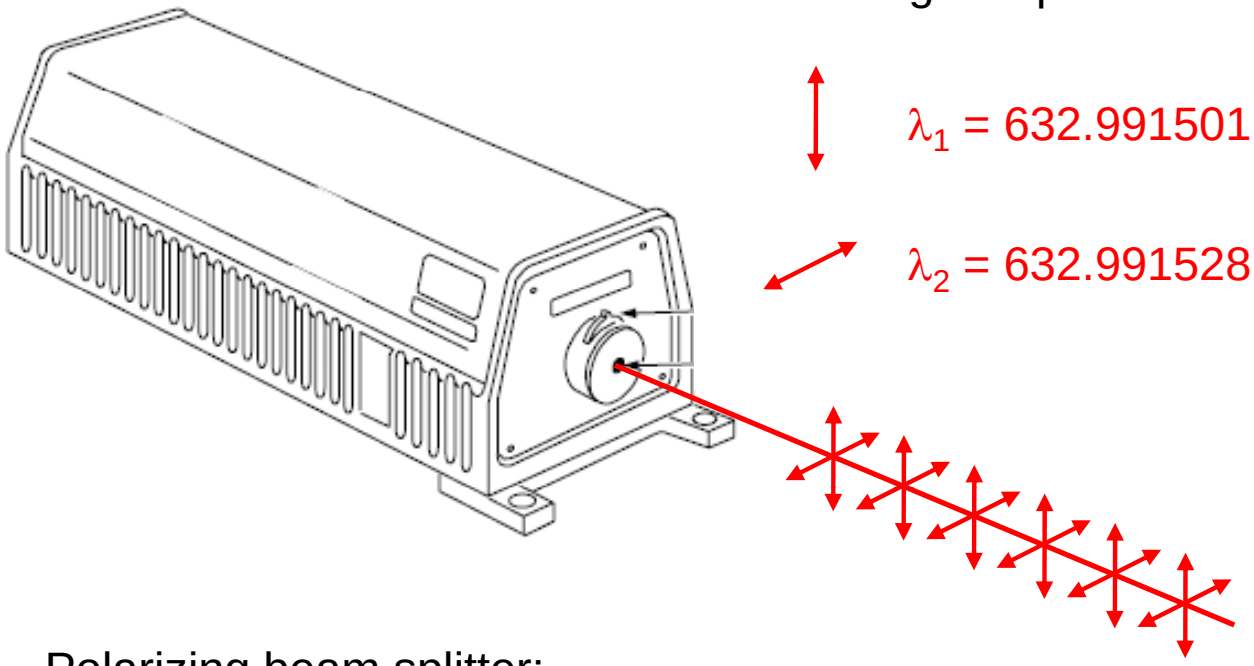
Goals and Constraints

- $\delta E/E < 10^{-4}$ desired (so, 0.5 μm on 5mm)
  - convolution of BPM resolution, Magnetic measurements, BPM mechanical and electrical stability
    - measurements dominated by stability systematics at this point in development

- Overall Goal: <100nm Resolution $\oplus$ Stability over ~hours
  - Factor of 10 better than current "strawman" design
  - would allow bunch-to-bunch measurements
  - if achievable, loosens many constraints, opens many options
    - e.g., shorter chicane, smaller bends, bunch-by-bunch *E*, smaller pickup motion $\Rightarrow$ smaller pickup aperture, etc.

$\Rightarrow$ Driver toward interferometer techniques for monitoring

Zygo Interferometer



orthogonal polarizations:

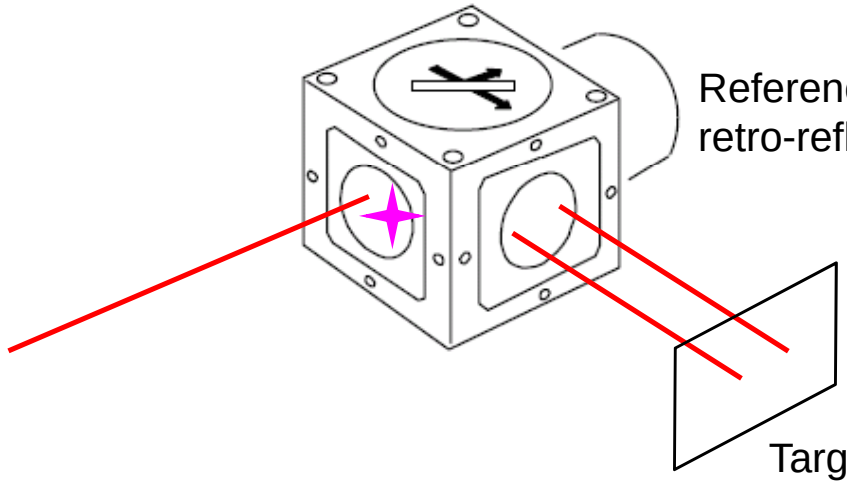
λ_1 = 632.991501 nm

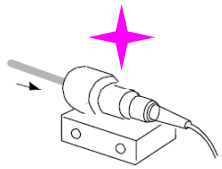
λ_2 = 632.991528 nm

Resolution:

- Displacement:
  - 0.31 nm/count
- Sensitivity:
  - velocity: ±5.1 m/s
  - length: ±21.2 m
  - DAQ rate: 33 MHz

Polarizing beam splitter:

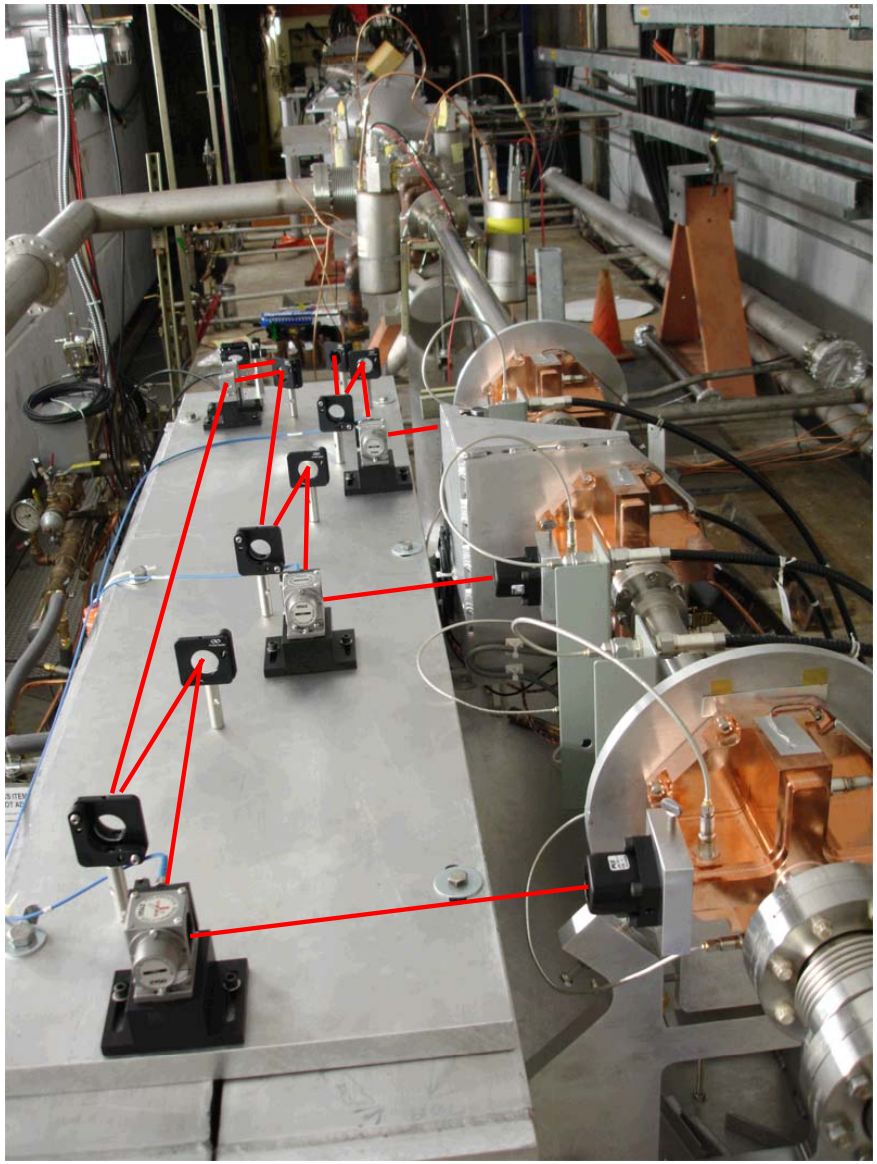




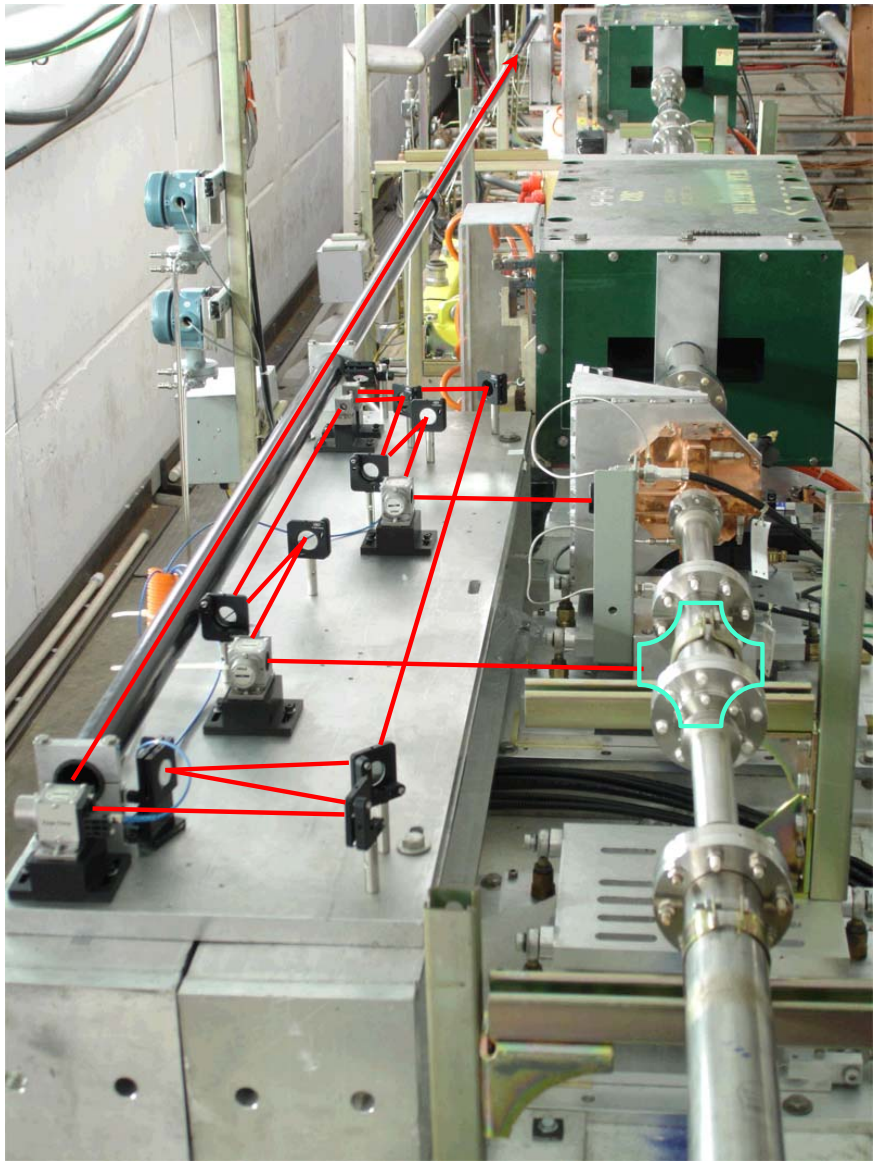
Light is recombined on a fiber optic pickup. Zygo electronics measures displacement by phase shift between two frequencies. Also uses doppler shift to get velocity.

SLAC Installations

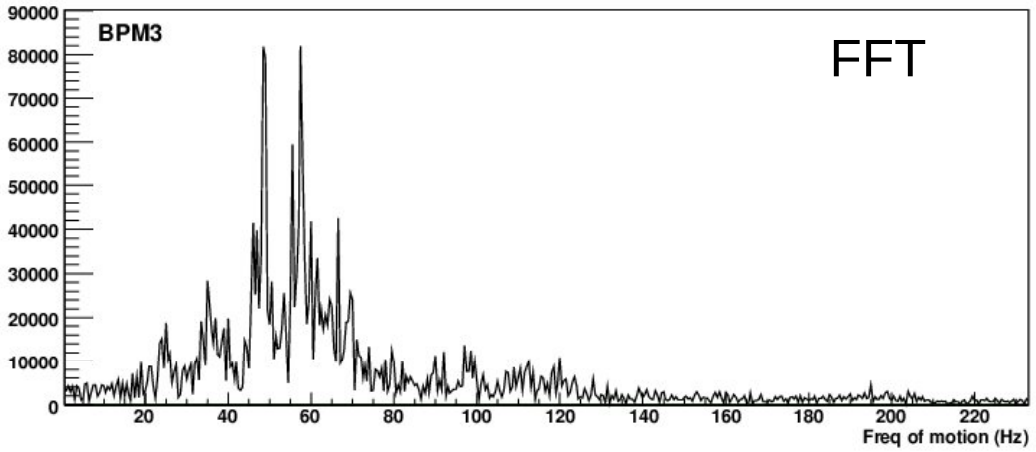
- 2006 single BPM station

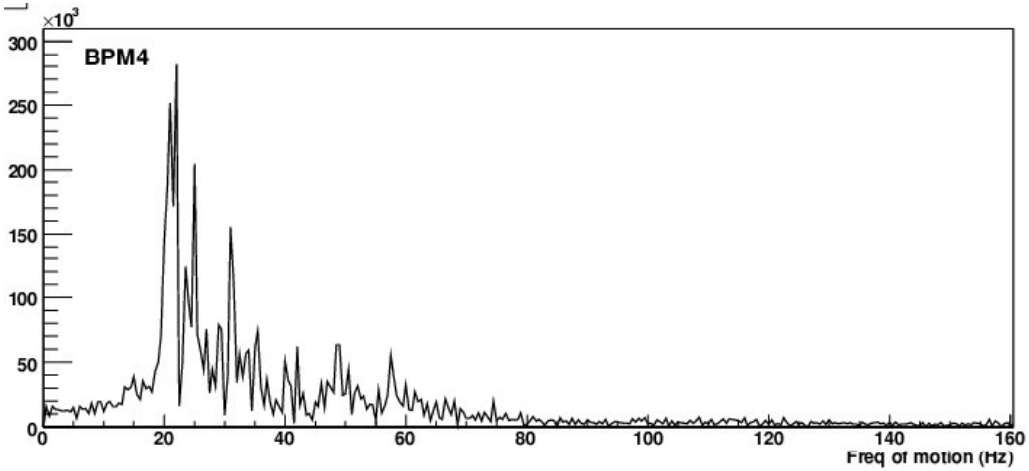


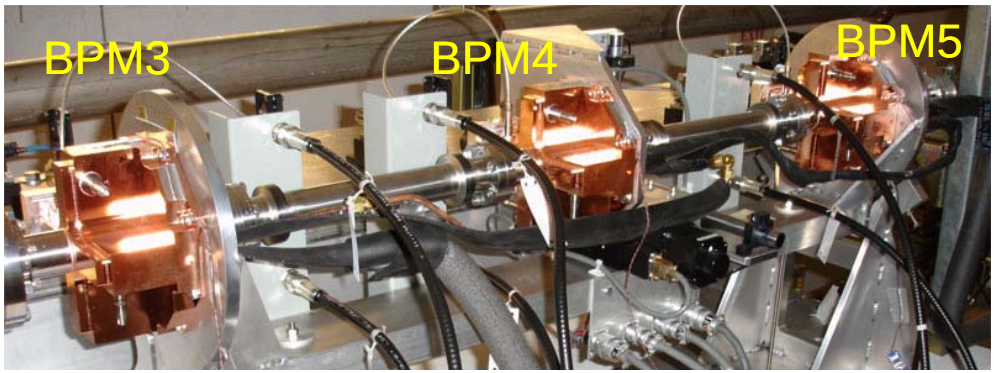
- 2007 link two BPM stations

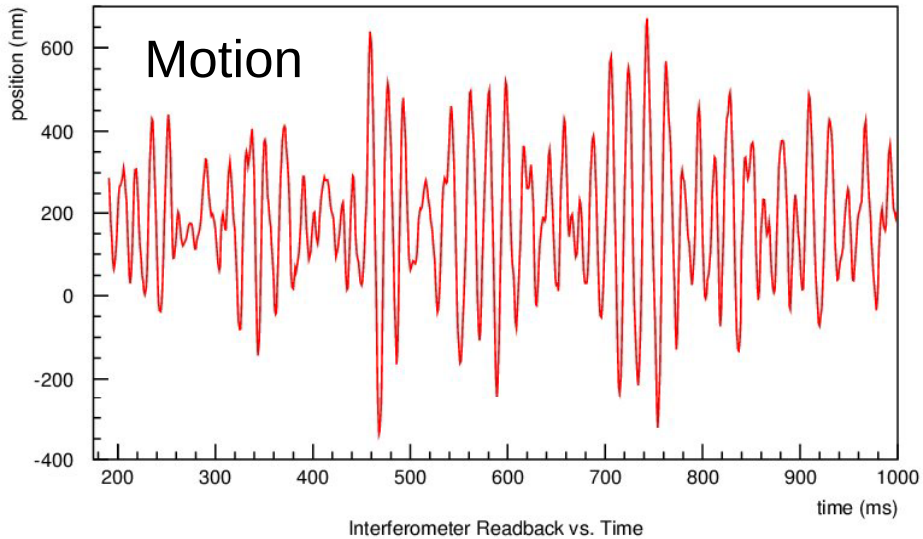


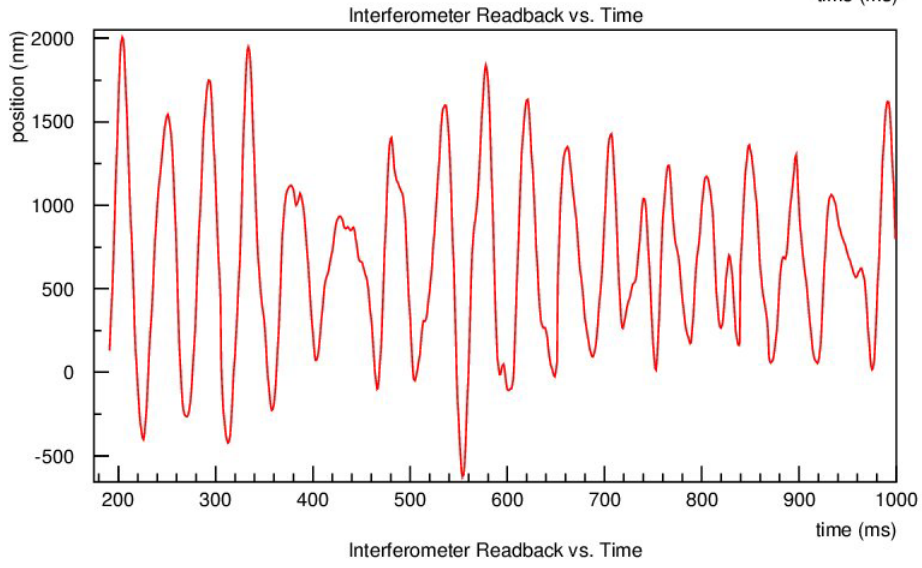
Data from SLAC (2006)











- LOTS of motion due to flimsy girder design. Vibration excited by water pumps. Measured resolution of BPM5 ~700nm.

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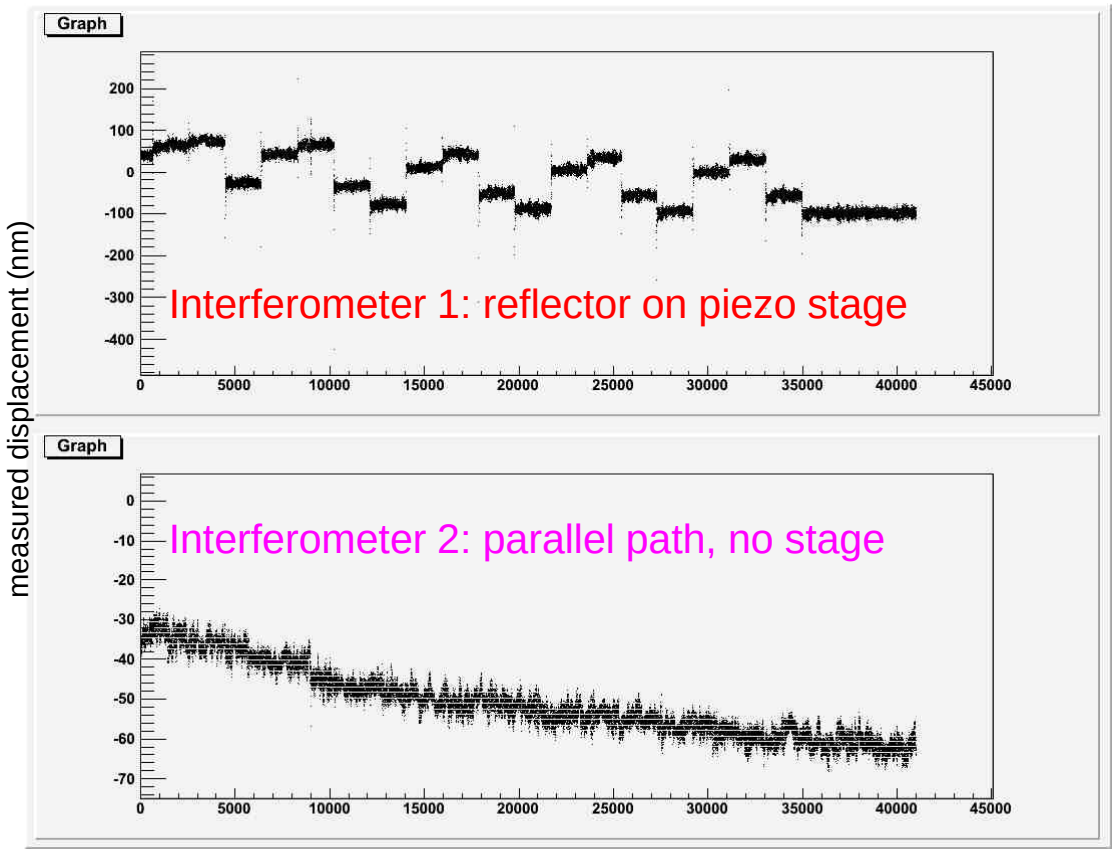
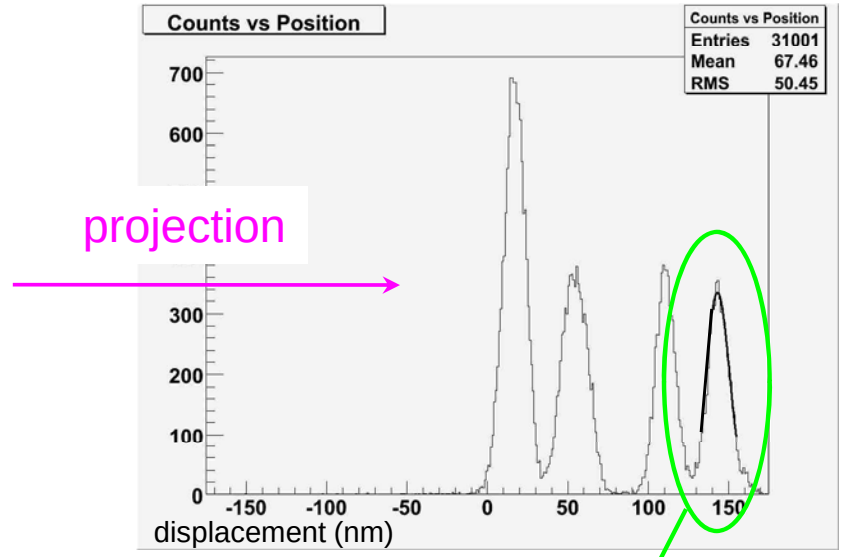
SLAC Data 2007

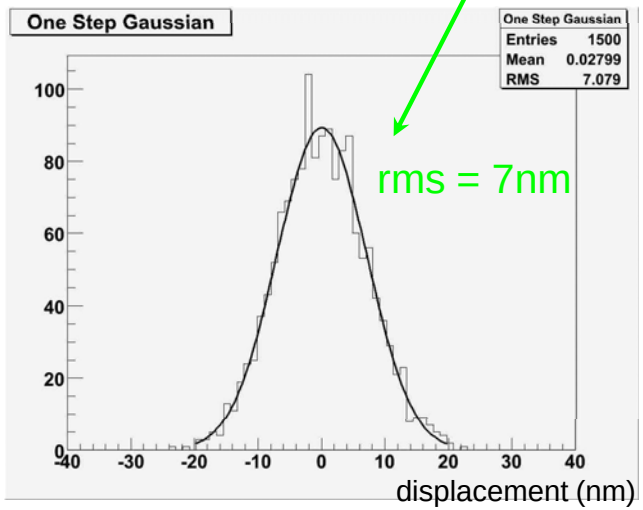
- Interferometer readout moved close in time to beam crossing (July run). Within ~few ms.
  - Should allow correction for BPM motion
  - analysis underway (slowed by dispersion of personnel)
- New UK BPM7 had more vibration than BPM4 in 2006
  - Traced back to cooling water manifold
  - efforts were underway to put in vibration isolation
    - couldn't test them because the run was cancelled
- Long arm to upstream BPM (March Run) had very large motion
  - clearly temperature related
  - analysis underway (again) to characterize
  - used this to deliver laser upstream for local vibration studies

Technical Performance

- Bench tests of interferometer resolution
  - 30 cm path length, in air



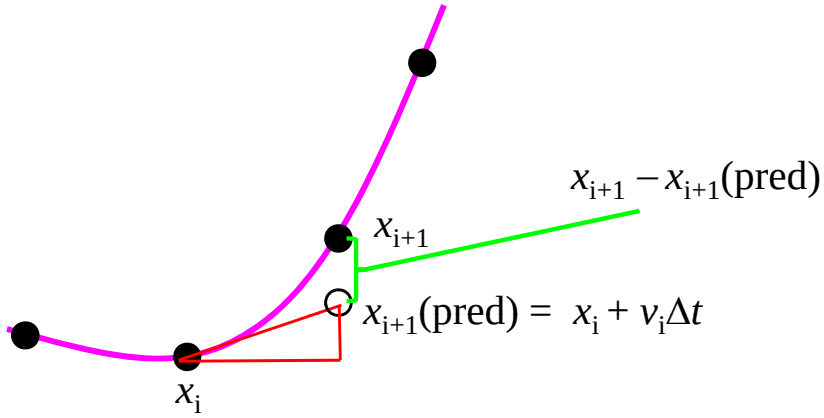


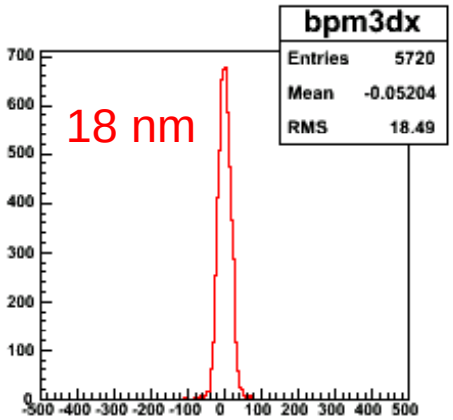


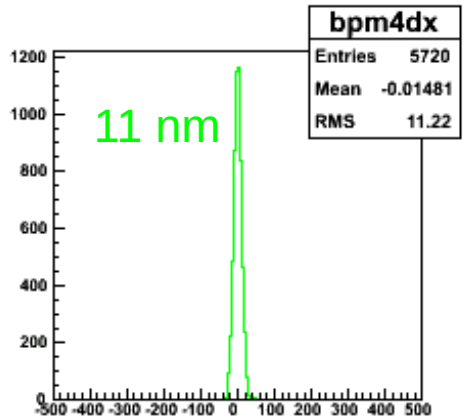
single measurement resolution < 10nm

Vibration Correction

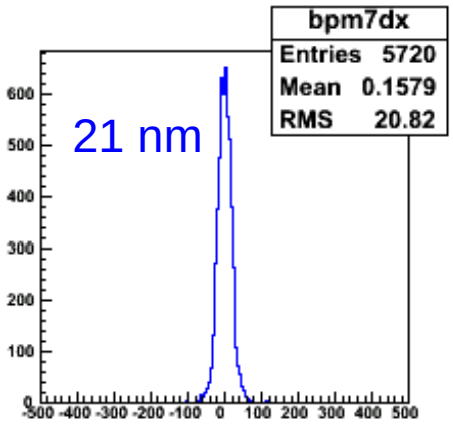
- Tests on End Station A data
  - Use measured position, velocity of BPM from interferometer to predict future motion







prediction residual (nm)



★ "Correction" of vibration possible down to approximately interferometer resolution, even with huge relative motion

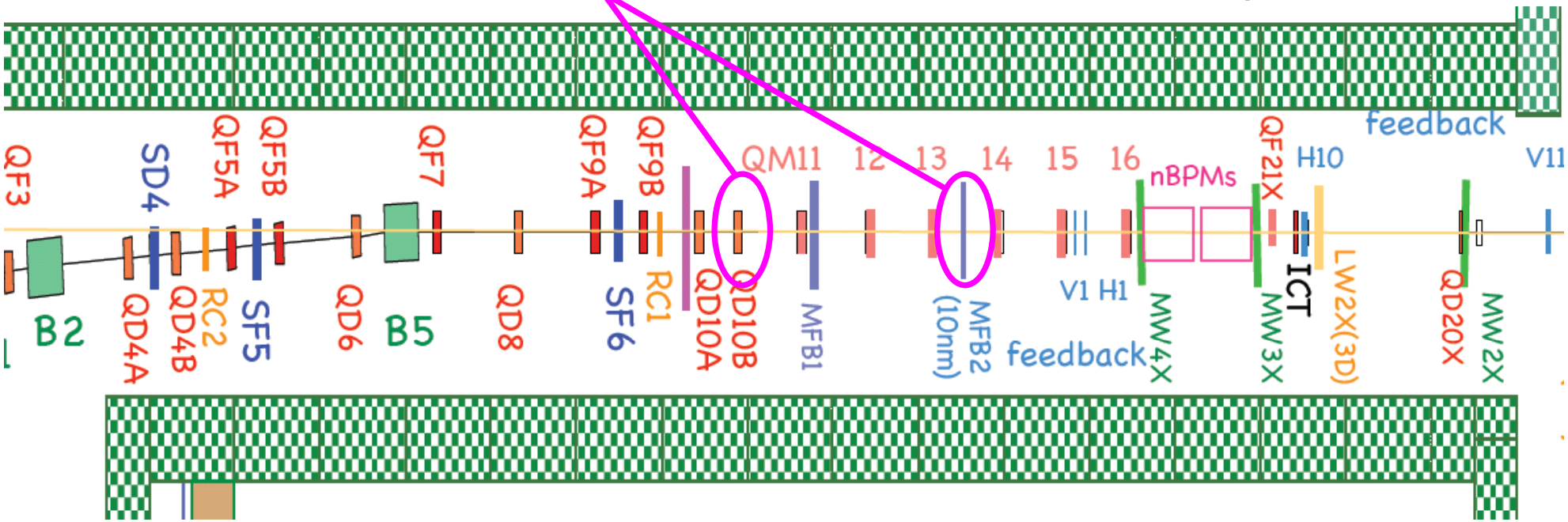
(waiting for analysis results to show this)

Peak-to-peak BPM motion ranges from 1-3 *microns*

High-amplitude motion is at low frequencies

Proposal for ATF2 Installation

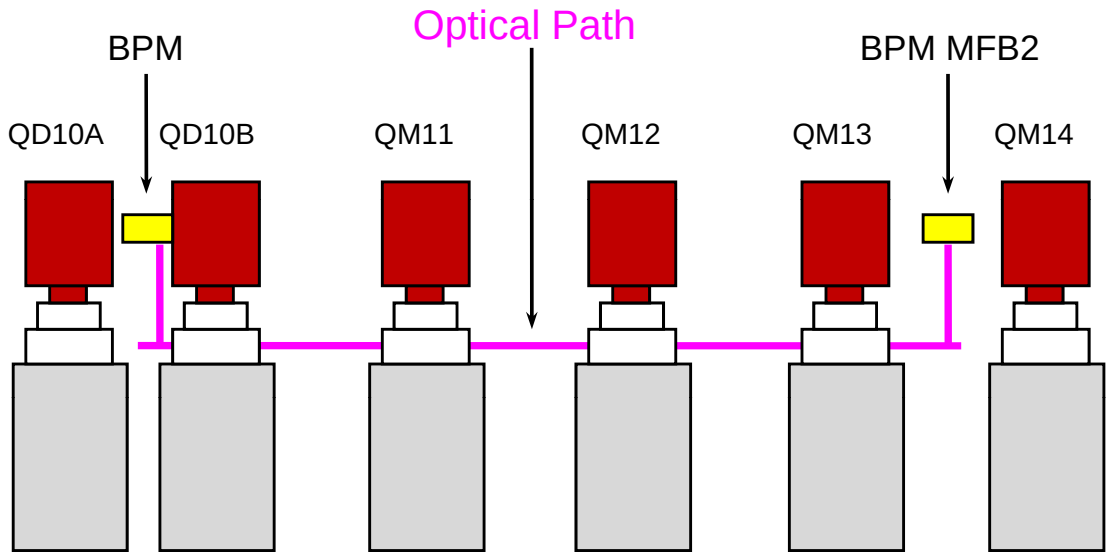
- Straightness monitor can be used to provide position measurements of BPMs used in the vertical IP steering feedback:



- Currently, the plan is for BPM MFB2 to be on a dedicated stand, not bolted to a quad
  - no means of monitoring mechanical drift/vibration
- Can use interferometer system to measure relative heights of both BPMs, eventually feed back to steering correction

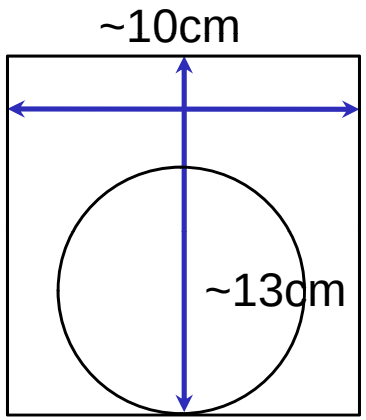
Proposed Layout

- Straightness monitor can define a line referenced to the support blocks of the quads
  - measure independent vertical displacements of BPMs relative to this horizontal line:



  - Simultaneously monitor stability of straight line

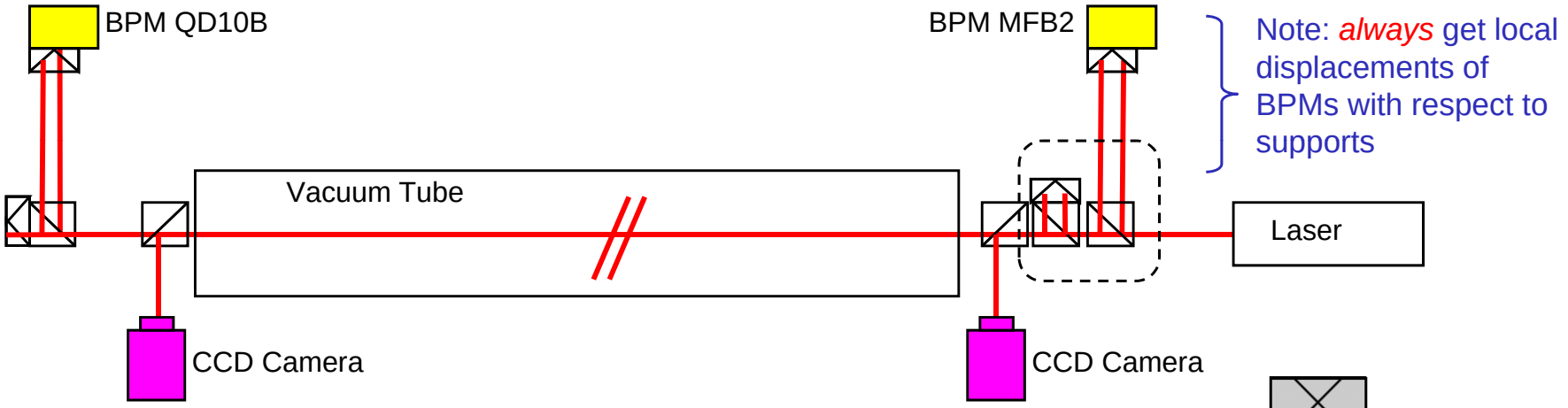
stay-clear under quads

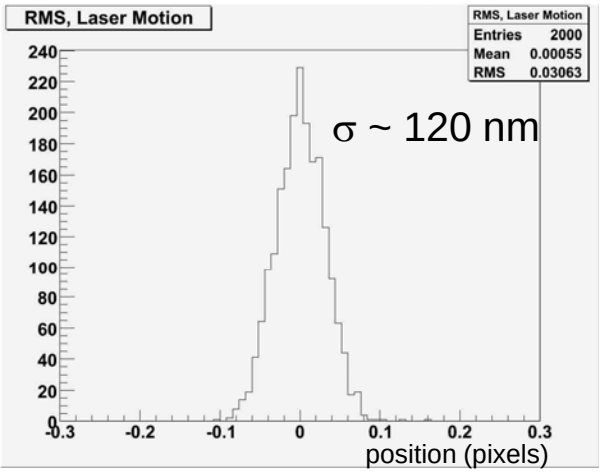


plenty of room for a ~8cm diameter light pipe

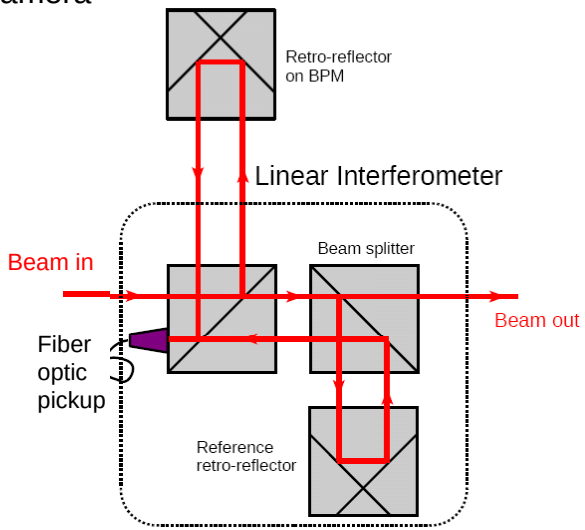
Proposed layout: more detail

- Straightness monitor consists of two measurement arms on BPMs plus straight-ahead beam monitored by two CCD cameras
  - vacuum tube necessary for stability against temperature and pressure variations
  - initially, all optical elements in air (option for vacuum tubes later)

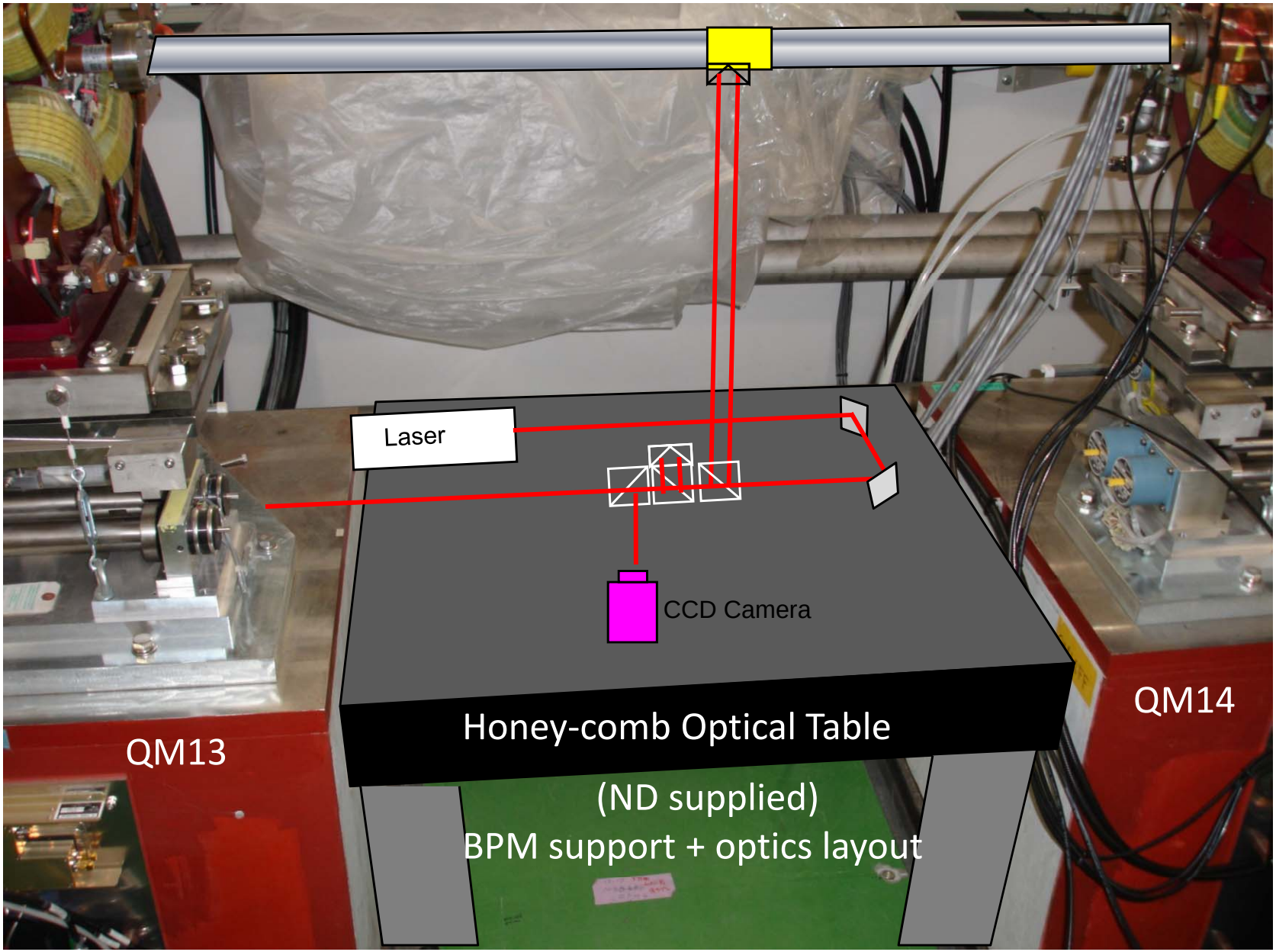




CCD cameras: 2 MP, 70 fps. Intensity-weighted centroid algorithm. Single-image resolution < 200 nm



BPM MFB2: layout schematic

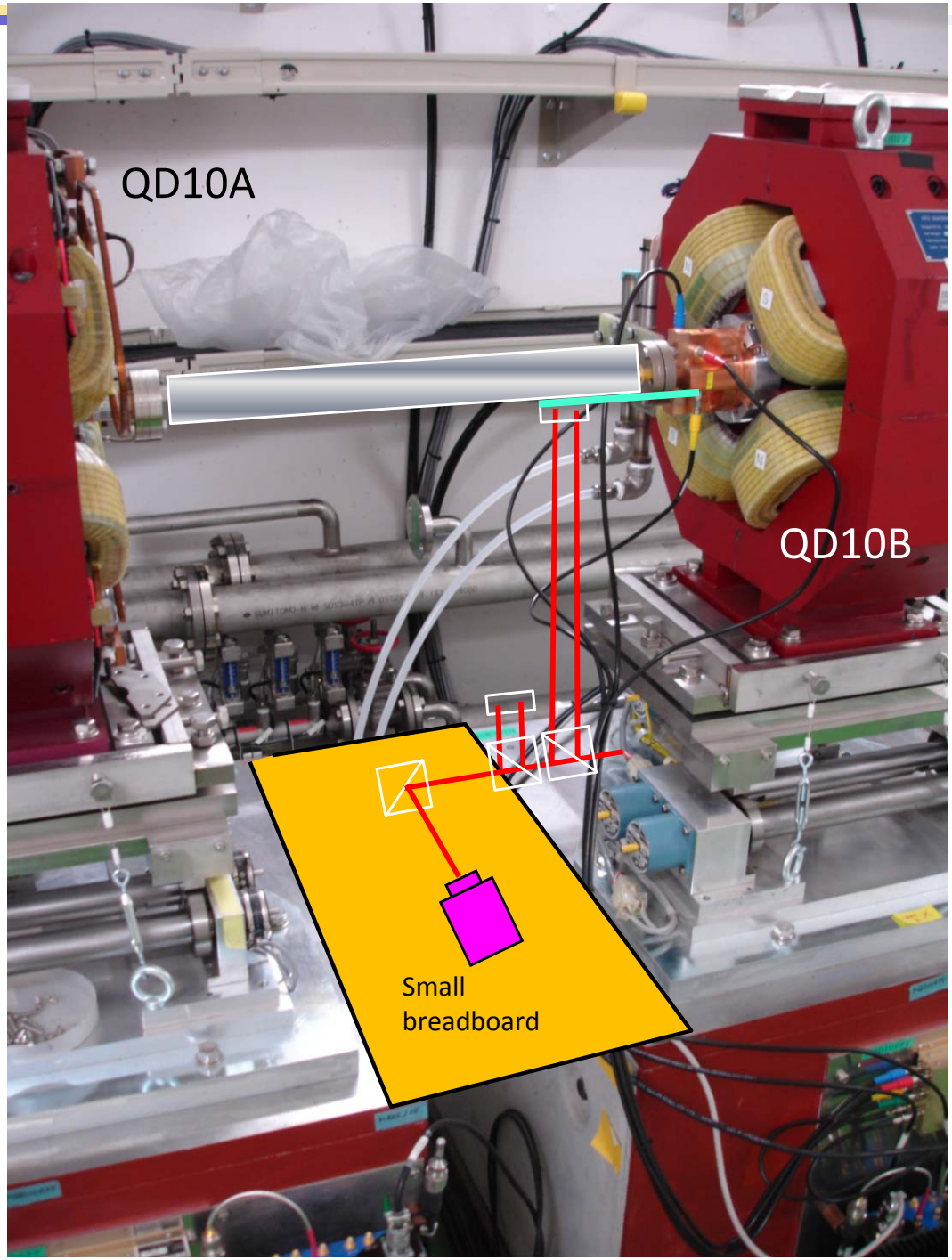


Proposal:

BPM support built on optical table (like the SLAC nano-bpm setup)

Is there already a support block there?

QD10B BPM: schematic

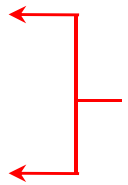


Integration into ATF2 Project

- Hardware:
  - All optics items, including support table and support breadboard, will be provided by Notre Dame
    - can have table delivered to KEK for BPM support
  - Will provide DAQ PC, Zygo electronics, and VME crate
  - Vacuum tube needs discussion
    - e.g., we can provide flanges with windows; tube?
      - must be assembled in small sections
- Installation schedule:
  - can do Summer ‘09 shutdown (have all hardware)
- Commissioning:
  - No beamtime needed
- Manpower:
  - Hildreth, undergraduates (2 or 3), one graduate student

Considerations/Details

- DAQ Infrastructure:
  - Hardware
    - VME crate & PCI-VME interface
    - Zygo VME board
    - Frame-grabber for cameras
    - 20m (or longer) cables & fibers to alcove



In same PC, put in alcove

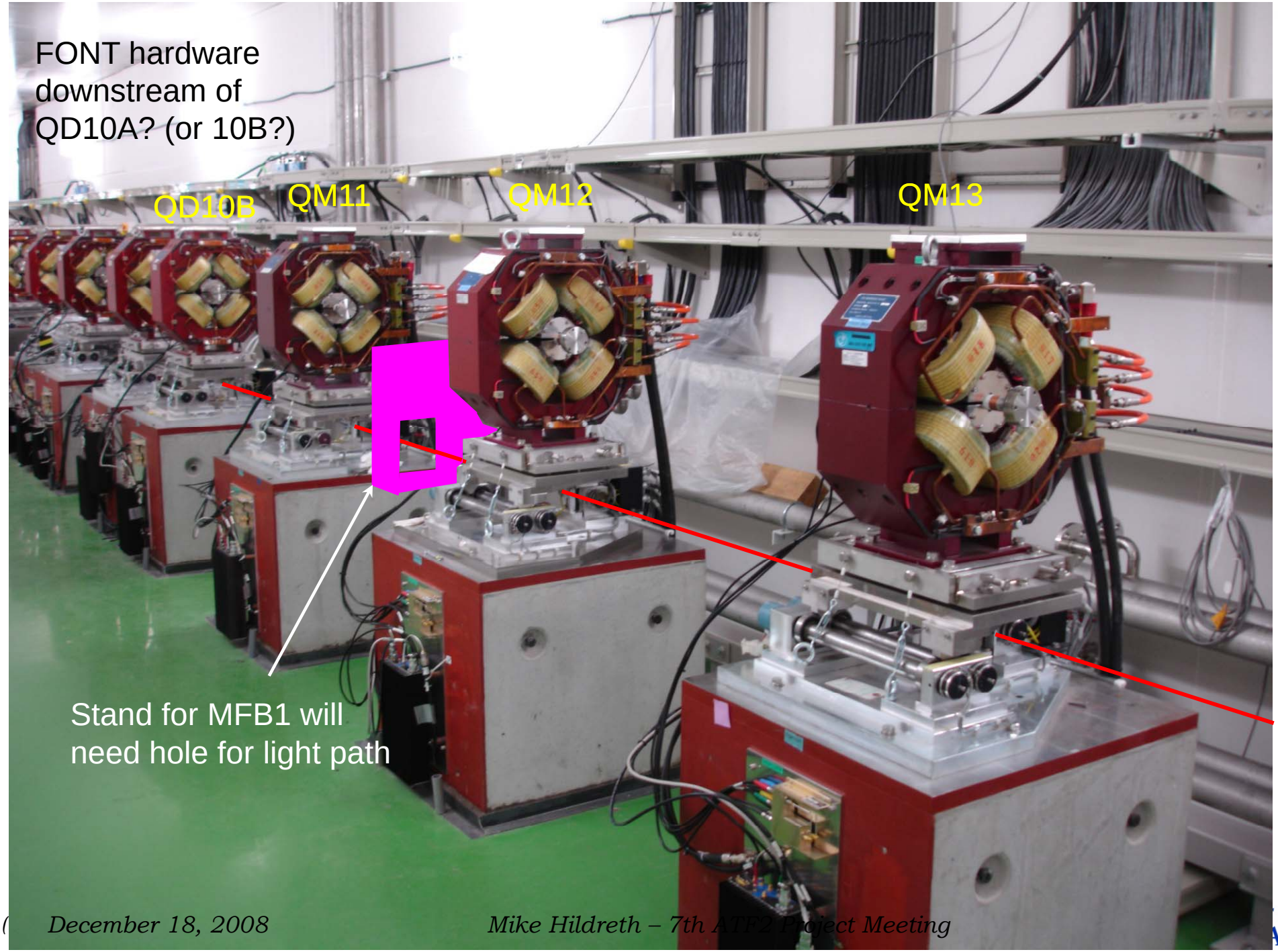
  - Software
    - LabView based DAQ on PC, can publish directly to EPICS
      - idea: FIFO of 1 ms interferometer readings for ATF DAQ
      - collaborate with Stew & Co. for software expertise

- Availability of optical hardware:
  - essentially all in-hand at ND already
    - was going to install at SLAC summer 2008…

Considerations/Details (ATF interface)

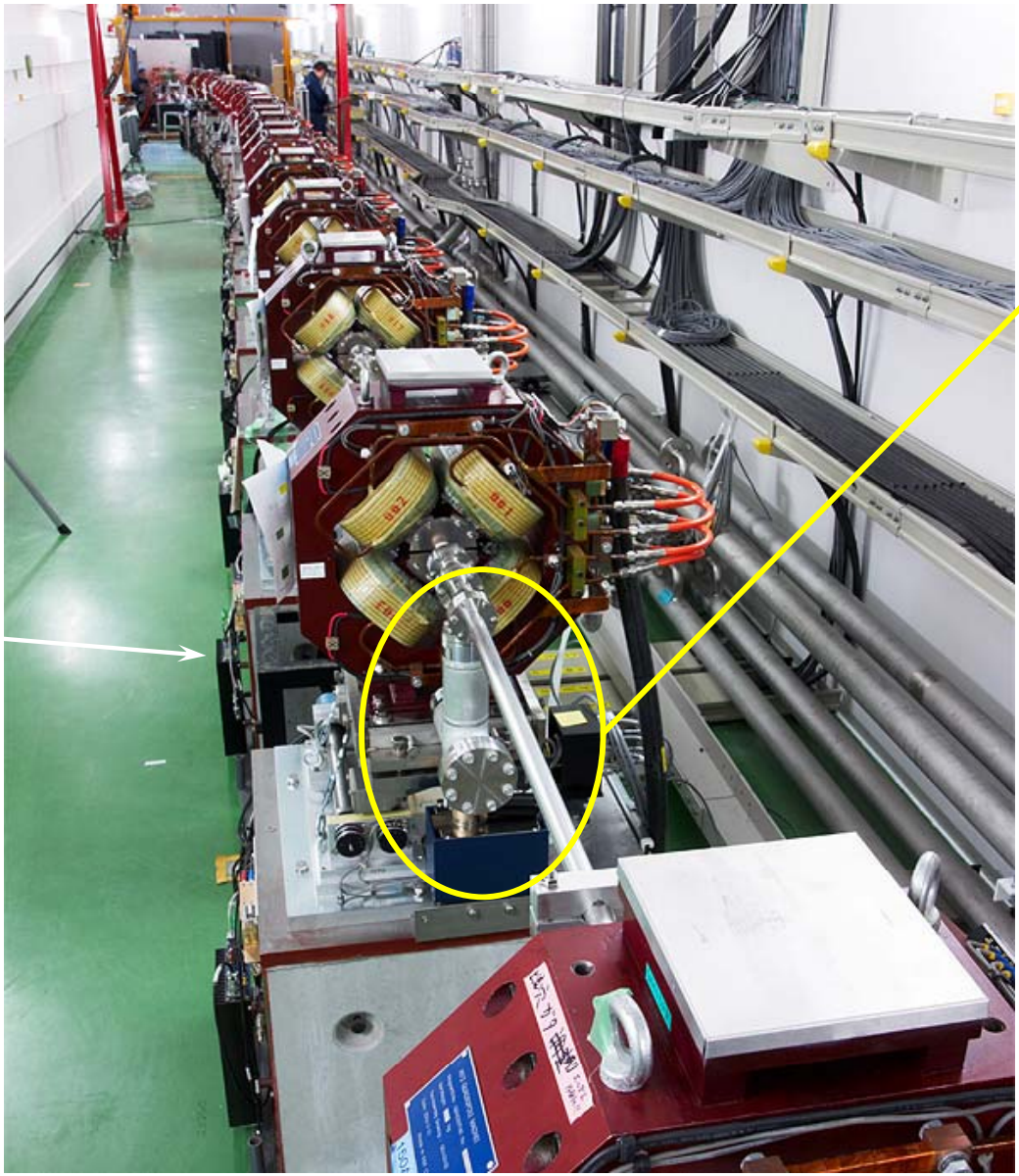
- Mechanical Issues:
  - Will need to collaborate on BPM MFB2 support structure
    - routing of optics to “see” bottom of BPM
      - retro-reflector mounting
    - consistent with rigid monolithic support
    - “optical table” specifications
  - Need some means of mounting retro-reflector on existing BPM QD10B
    - quad support plate blocks direct vertical optical path to bottom of BPM
      - some sort of cantilever? Some mechanical modifications or additions will be necessary
  - Shielding
    - cameras and laser need lead shielding
  - Services
    - electrical power for laser and cameras

Mechanical interference I:



Mechanical Interference II:

- Vacuum pumps in optical pathway?



support block?

This vacuum connection would block the proposed optical pathway. Happily, looks like it's upstream of QM14? Are there more pumps between here and QD10B?

Conclusions

- Straightness monitor installation would provide
  - direct measurement of any mechanical motion of BPMs used in IP vertical steering feedback
  - potential means of correcting feedback signals for residual BPM motion
    - future development
  - further development of long-baseline interferometric position monitoring for high-precision ILC applications
- Hardware/Software already exists
  - has run stably and with minimal intervention at SLAC
- No impact on ATF2 beamtime
- Exploits existing connections with UK BPM effort