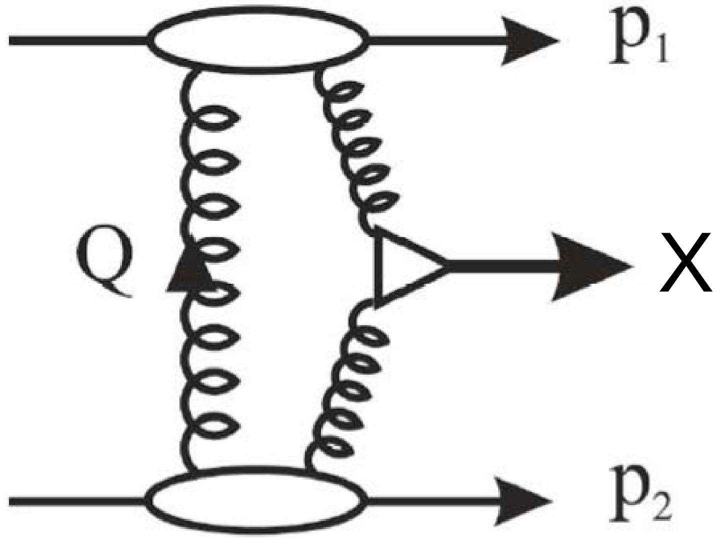
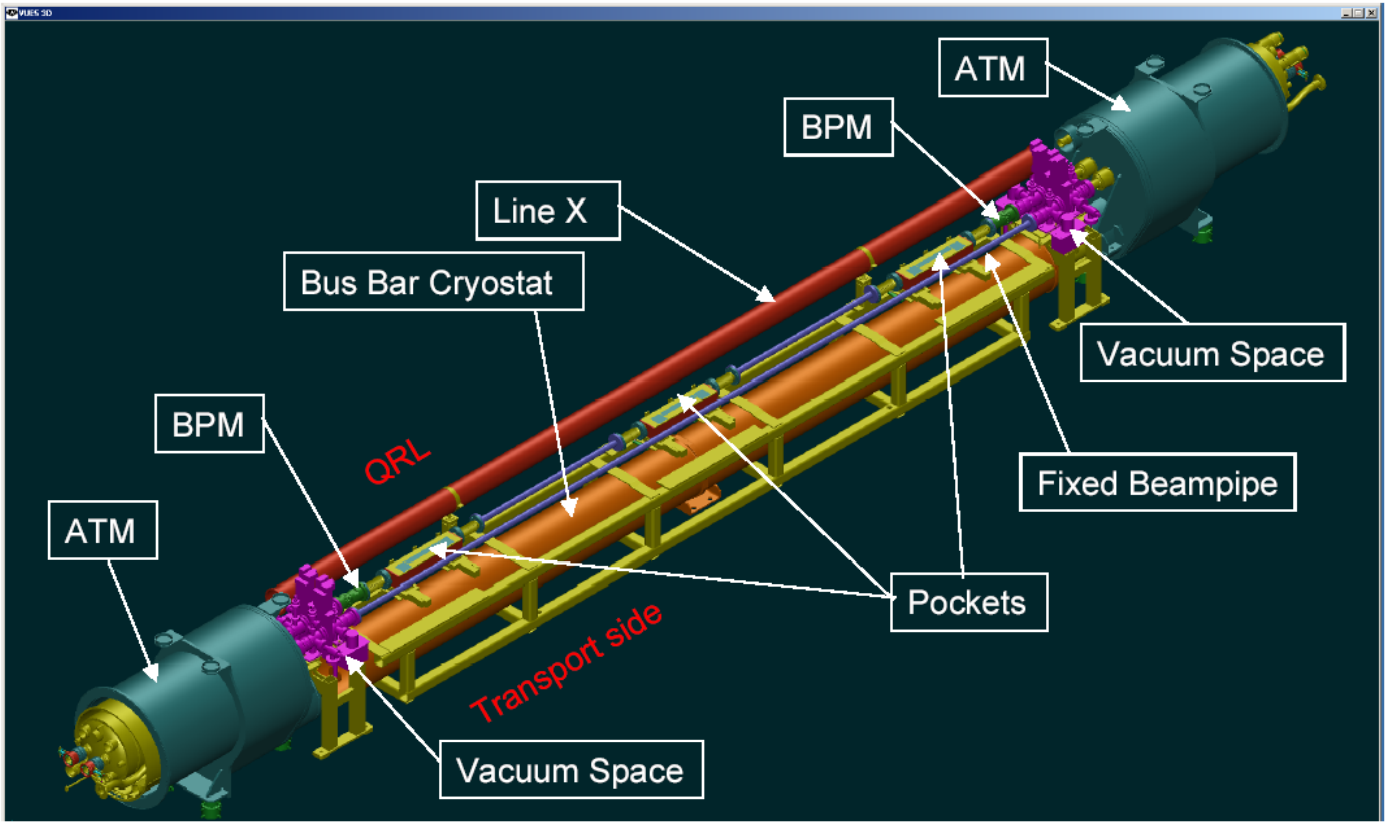
FP420

- Detect off-momentum protons at 420m from the interaction point, due to e.g. diffractive events in ATLAS/CMS
  - "X" can be for example a Higgs boson
- How far p_1 and p_2 are from the beam tells us how much momentum they lost, i.e. the mass of the central system.
  - The better we can measure distance(proton-beam), the better we can measure X's mass



FP420

Integration of the moving beampipe and detectors



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CRC
Louvain-la-Neuve

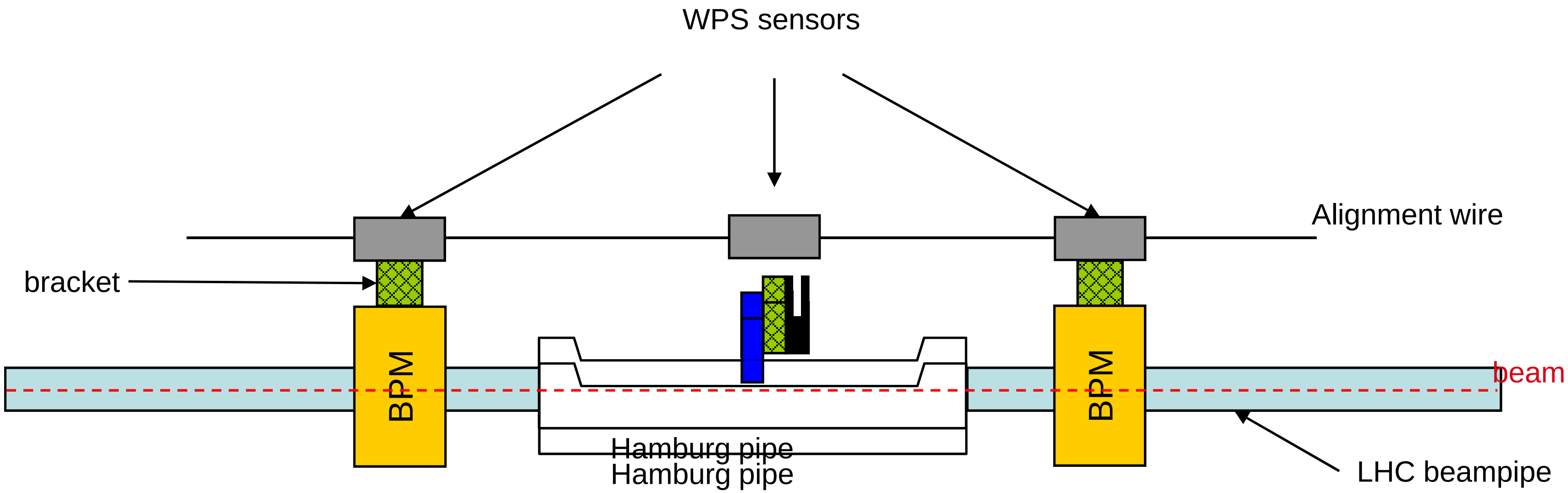
FP420 Alignment

- Alignment requirements:
  - Can probably align offline with tracks but want real-time alignment too:
    - Safety when moving detectors into working position
    - redundancy
  - Intrinsic energy spread of beam $\Rightarrow$ ~50μ position uncertainty
  - Want ~10μ alignment accuracy beam $\Leftrightarrow$ detectors

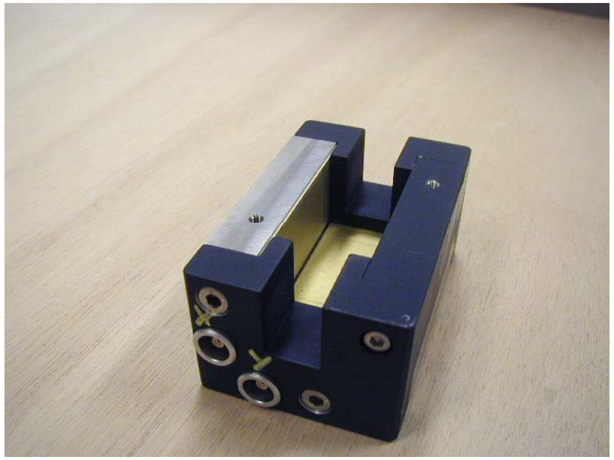
FP420 Alignment

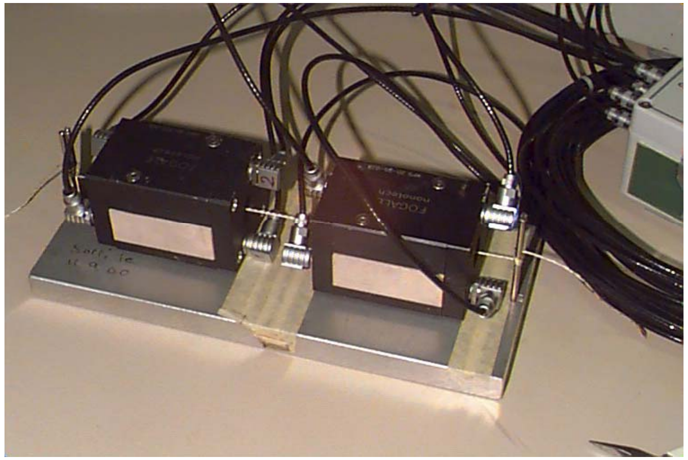
Considering system(s) based on BPMs & Wire Positioning

- BPMs on fixed beampipe?
- BPMs on moving beampipe?
- Both?

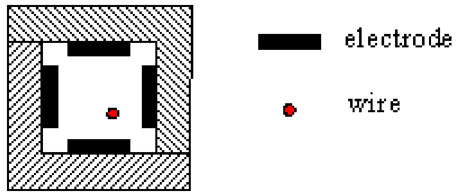


Wire Positioning Sensors





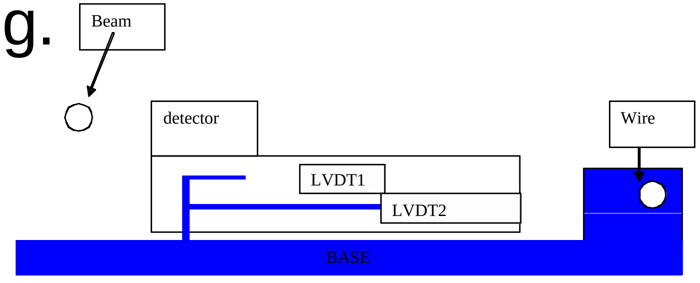
- WPS sensors use a capacitive measurement technique along 2 perpendicular axes.
- On each axis the wire lies between 2 electrodes
- Proven resolution ~0.1μ in e.g. LEP alignment (1cm^2 sensors)



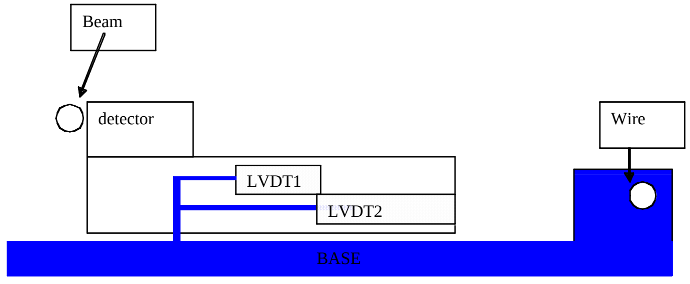
The Moving Bit

Need to relate detector position to alignment wire, while allowing detector to move freely

- Various types of precision displacement measurement devices available “off the shelf”, e.g.
  - Potentiometers, LVDTs
    - Rad-hard examples accurate to ~0.25%-0.5% full scale, e.g.:
      - »5 cm stroke: ±75µ accuracy
      - »1.5 mm stroke: ±3.75µ accuracy
    - Could combine the two? (B.Winter)
  - Optical displacement measurement devices:
    - more accurate (±1µ possible)
    - rad-hardness not clear

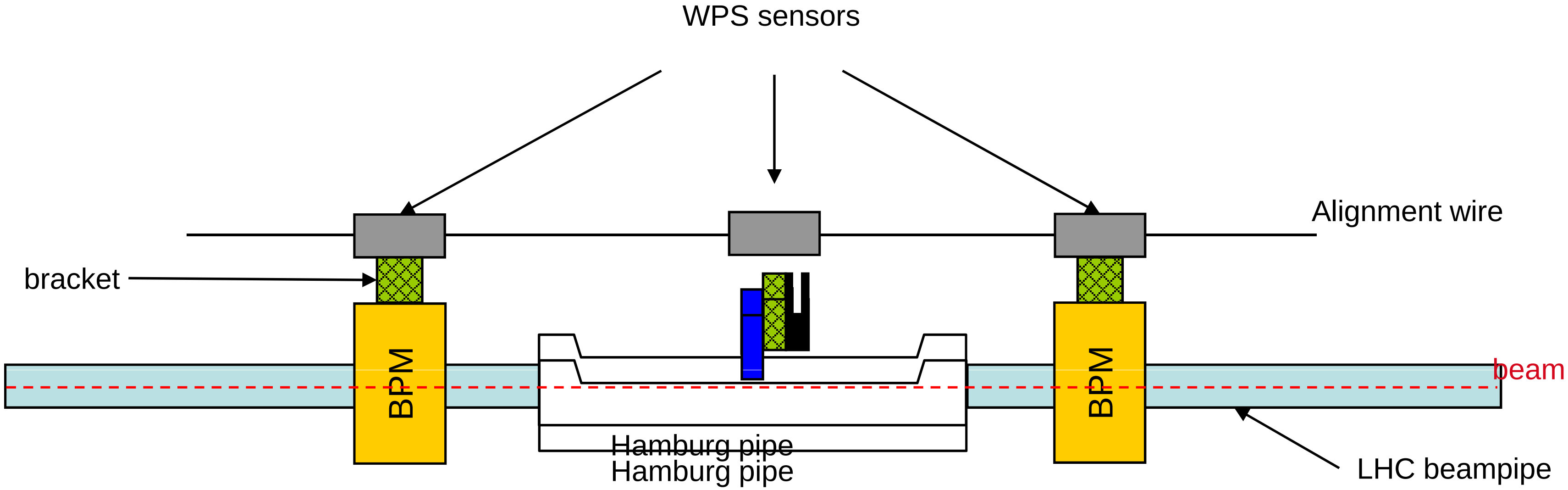


Garage position: long-stroke, low-accuracy LVDT



Running position: short-stroke, high-accuracy LVDT takes over

FP420 Alignment



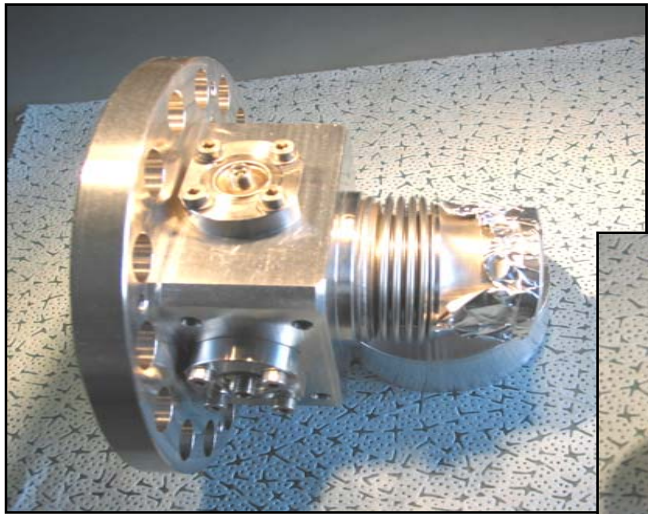
Overall accuracy of ~10μ challenging: tolerances of individual components add up quickly!

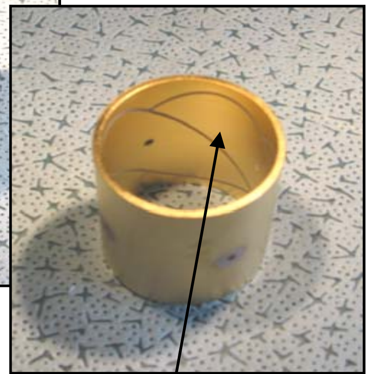
- WPS sensors: known to be accurate to < 1μ
- Mechanics: <10μ tolerances possible but not easy!
- Complicated by the moving bit
- BPMs: need micron-scale accuracy and resolution

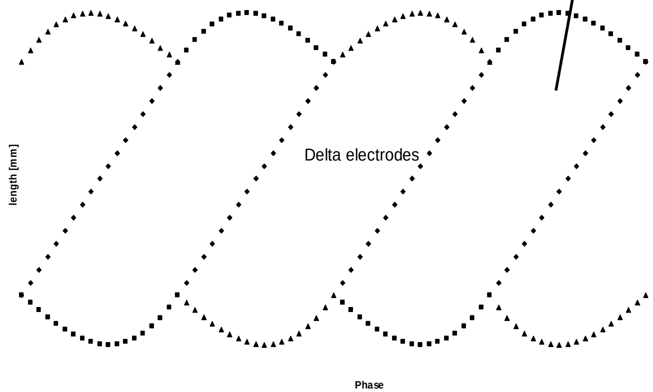
Beam Position Monitors

Have done some work with electrostatic BPMs (borrowed - thanks Lars). These are CLIC-injection-line prototypes:

- Approximately same diameter as LHC beampipe.
- Measure intensity-normalised difference between signals on opposing electrodes (Δ/Σ)
  - Sinusoidally-shaped electrodes maximise linearity of response
- BPM characteristics (e.g. diameter, capacitance) tuned to beam characteristics
  - Would need to understand if/how they would need modification for LHC beam

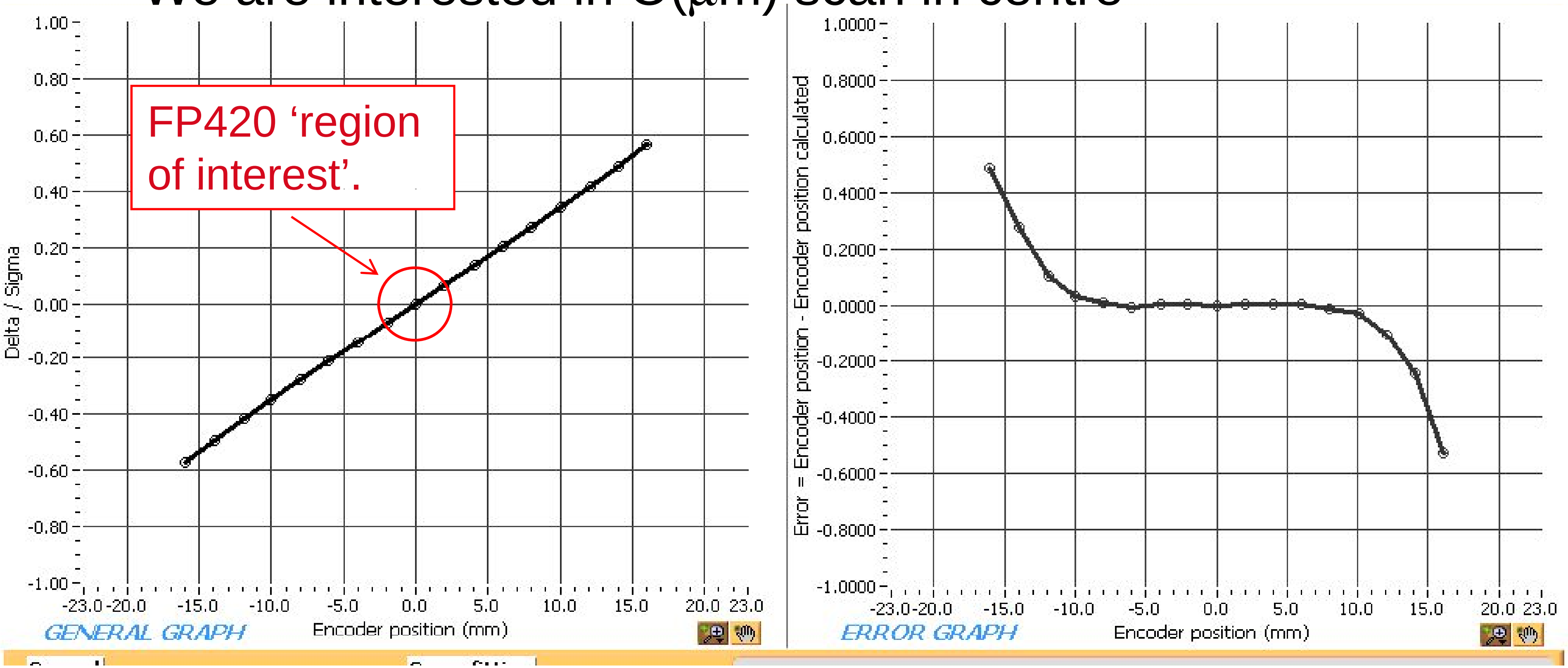






BPM Resolution

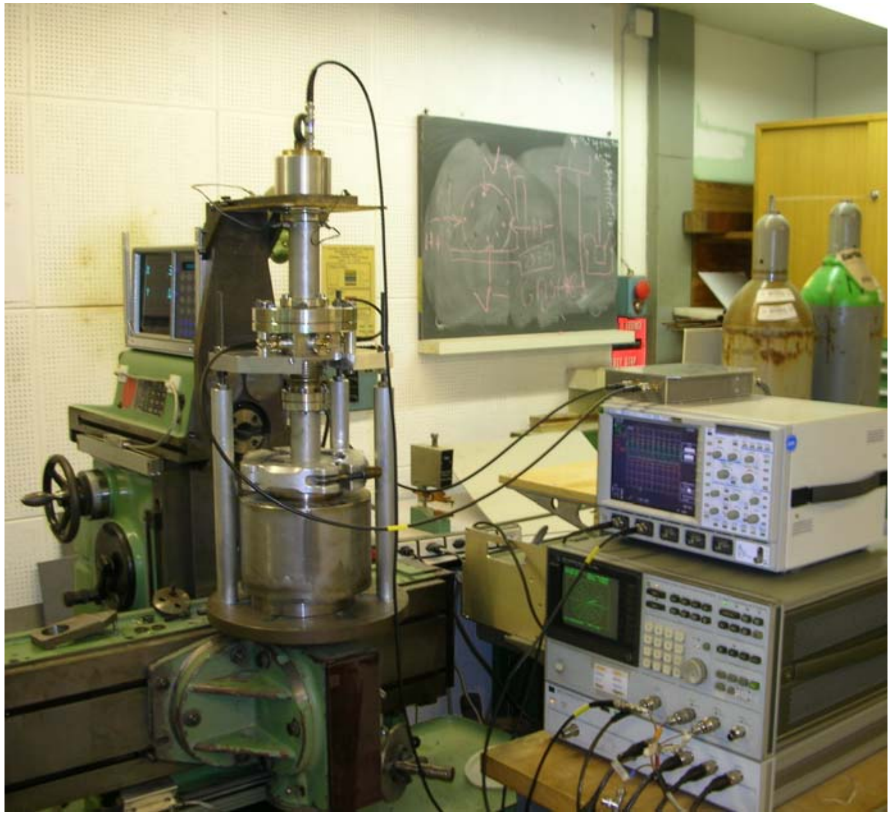
- Previous work (Lars Soby et.al): scanned across ~whole aperture in 2mm steps (see plots below)
- We are interested in O(μm) scan in centre



First try at measuring BPM "Fine Resolution"

June '06, CERN: re-assembled setup used for original measurements:

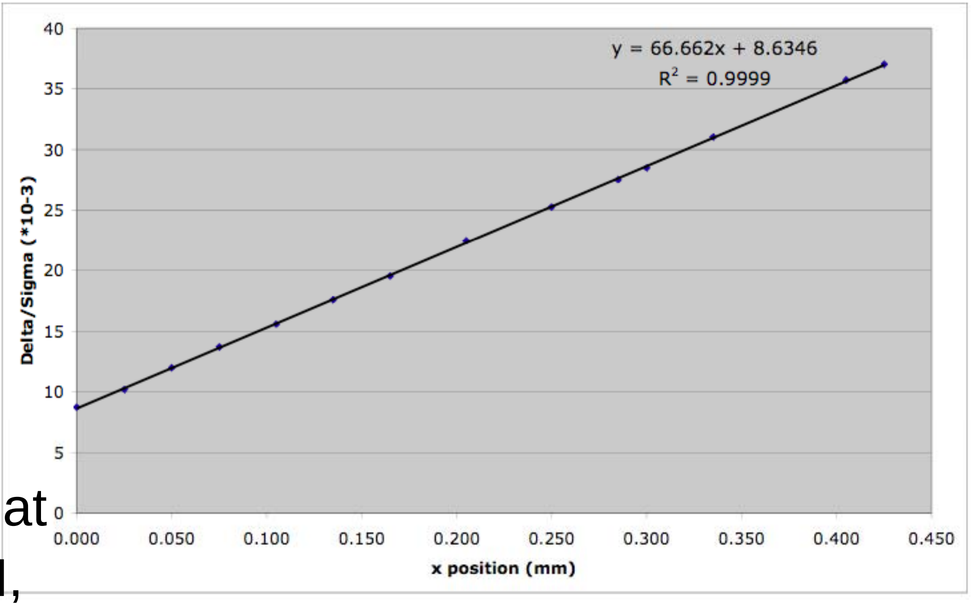
- BPM mounted vertically, x and y positions controlled by lathe, 5μ steps possible (but difficult)
- Wire ("beam") through BPM, attached to weight in oil bath
- Two BPM electrodes terminated, other two read out through amplifier
- Network Analyser provided sine wave on wire, calculated Δ/Σ and displayed it as amplitude & phase
  - no attempt to realistically simulate LHC beam



BPM “Fine” Resolution

June 2006 (at CERN): Measured Δ/Σ in small (10-20μ) steps, near centre of BPM:

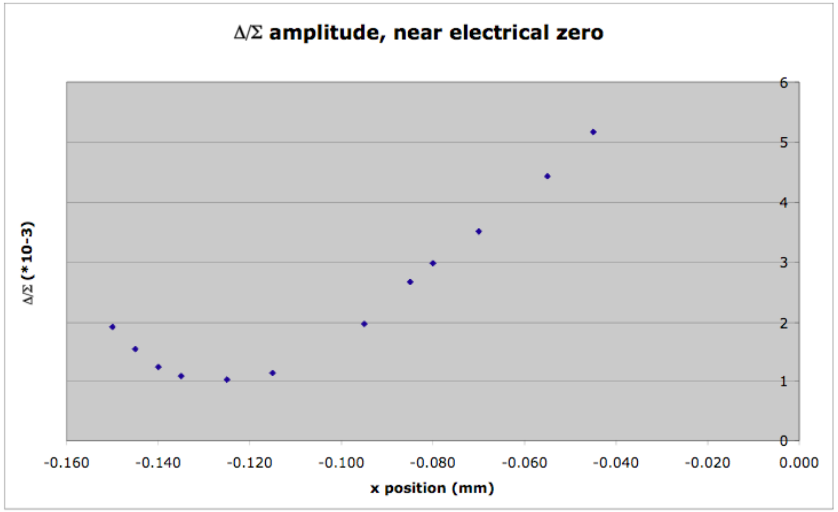
- Amplitude measurement near centre of BPM:
  - Linear
  - Measurement error d(Δ/Σ)~ 0.02 E-3
  - Reproducible
- However, there were problems at electrical zero (~centre) of BPM, possibly due to common-mode noise…

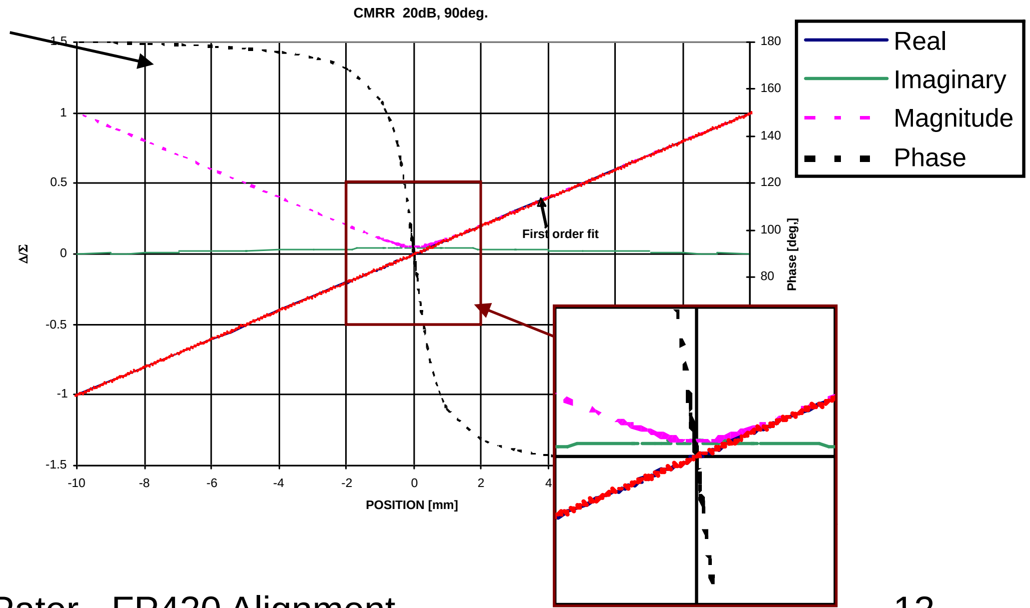


Common-mode noise on BPM ?

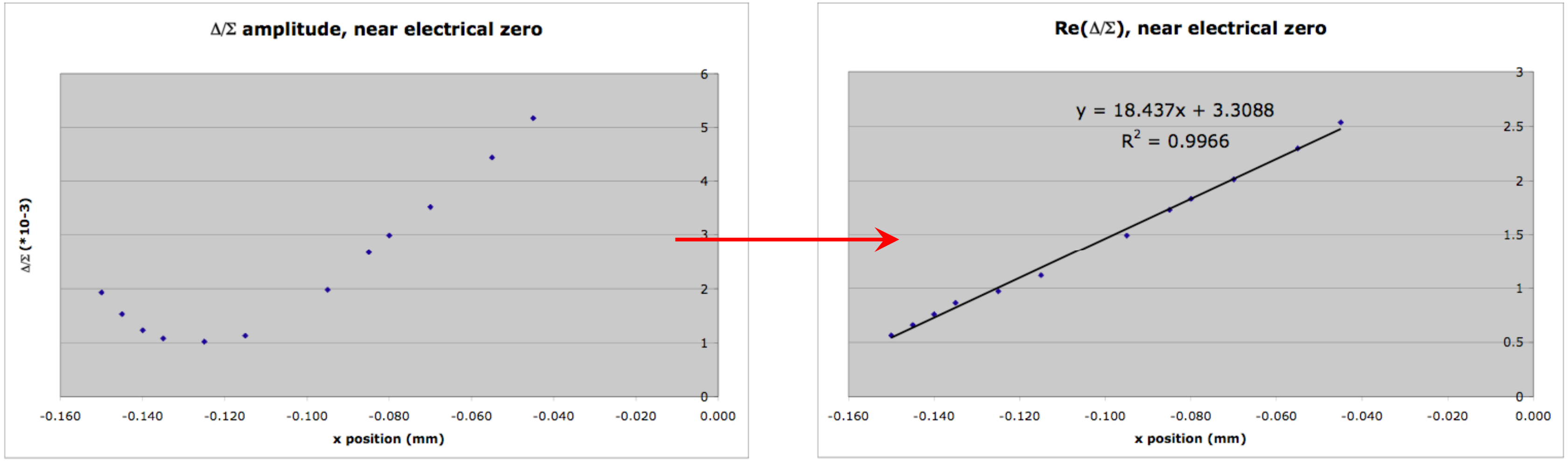
Near electrical zero (~centre) of BPM:

- Ideally: Δ/Σ amplitude should go to zero, phase should make a clean 180º flip. This didn't happen in my measurements.
- Simulations (L.Soby) show that this may be due to common-mode noise:
  - Figure to the lower right shows the influence of common-mode noise (90º out of phase with signal, worst-case scenario) on position calculation in an arbitrary pickup (simulation)
  - Can possibly be overcome by measuring the real part of the Δ/Σ signal (see next slide)
    - (although should make every effort to get rid of noise!)





Common-mode noise on BPM ? (2)



- Above right: plot real part of same data
- Linearity: not great but worst points about ~8 microns off the line (very simple line fit)
- This is worst part of BPM - much better just 10s of microns from electrical centre

FP420 Alignment Bench

- These BPMs are now at Manchester:
  - Horizontal setup:
    - “beam” wire stretched by hanging weight over pulley
  - BPM and one end of wire on micro-positioners
  - Sine wave on beam wire from pulse generator
  - No amplification of BPM signals
  - Read out with oscilloscope
- Data so far is not high quality but see similar trends as in earlier data
- Imminent improvements:
  - Bench to be replaced with damped optical table
  - Upgrade readout to LabView analysis of scope signals
  - Try pulses on wire to simulate LHC beam
  - Noise control?

BPM issues for FP420

- Are these electrostatic BPMs the best choice for us?
  - On LHC beampipe
  - On Hamburg (moving) beampipe
  - See next slide…
- Calibration
  - On-bench survey: relate beam-wire position, fiducials, electrical response
  - Is some in-situ calibration necessary? Possible?
- Readout
  - Do we want bunch-by-bunch averaging i.e. 2808 separate measurements?
    - Would make sense if bunches will occupy particular ‘regions’ of the beam cross-section. Not clear if this is so or not.
    - If we want this, the readout must be fast: < 25ns

BPMs for alignment

(Alex Lyapin - UCL)

Type of BPM	A few µm resolution?	Operation in a circular machine?	Linearity	Design/ fabrication time
Button/ Electrostatic	Should be possible	Yes	~½ of the beampipe	Moderate
Stripline	Reported at e^- machine	Yes	??? (~1/3 of the beam pipe)	Moderate
Low Q resonant/ waveguide	Reported at e^- machine	Possible	~1/3 of the beampipe	Extended
High Q resonant	20 nm reported at e^- machine	No	~1/3 of the beampipe	Moderate