Ideas on high resolution BPMs and wakefields

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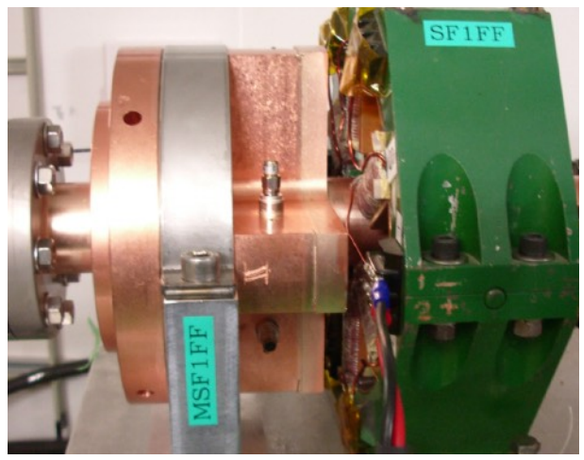
First, a recap on CBPMs

- C-band (6426 MHz) copper cavity BPM system, tuners for X-coupling minimisation, capacitive adapters, 2a = 20 mm, cavities produced by PAL
- Beam pipe continues into respective magnet, rigid mounting, calibrations using magnet movers or “dogleg” bumps
- PCB electronics by SLAC, most units have 20 dB attenuation at the front (direct contribution into NF)
- Off-the-shelf Struck 14 bit, 125 MS/s digitisers
- Digital processing, calibration, scripting etc by RHUL
- The system has been working with very little maintenance since ~2010, 24/7, any problems usually arise from start/stop
- Best resolution ~20-30 nm (no att), typical ~200-300 nm (with att), degradation to ~1-3 um when reaching 1 mm offset (with att) — designed for 100 nm resolution, +/- 100 um range
- ~1/3 of cavities have been removed to reduce wakefields
- Larger ~40 mm aperture S-band cavities in the IP region

abandoned due to mechanical errors



Current issues

- Phase drifts due to temperature changes, mainly due to machine on/off cycle, degrade calibrations — calibration lifetime shorter than desired

- Calibrations take a long time, mainly due to ageing hardware (noisy readings from resistive motion encoders)

- Many cavities operate in saturation — reduced resolution, not possible to use signal subtraction for multiple bunches

- Wakefields — ATF magnets are not necessarily operated at 0 offset (?), so even where BBA offsets are small, wakefields may still be produced + position jitter -> “dynamic” wakes. Still many “hidden” WF sources (aperture steps, bellows)

Temp/Phase drift

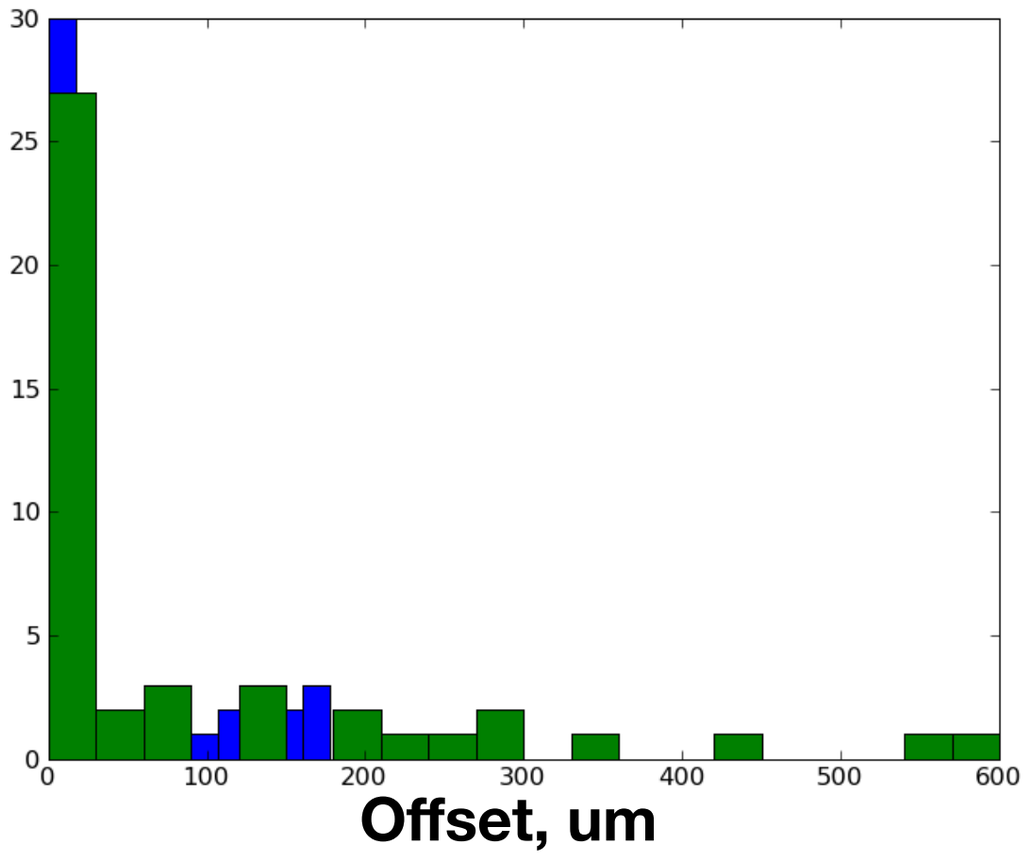
- Temperature stabilisation of cavities — keep at ~40 degC (example — old BINP design had integrated heaters)
    - Additional hardware, aircon load, but simple
- FFT-based algorithm for compensation of frequency, phase and arrival time drifts
    - Advanced algorithm, but completely in SW
- Short pulse injection into cavities (instead of CW burst into electronics) for referencing frequency offsets
    - Emulate the beam with additional HW, but is not at all as easy as it sounds

Duration of calibrations

- Switch to 3-step calibrations
    - Implications to precision may need evaluation, harder to monitor quality, but a very easy solution
- Put CBPMs for critical magnets on smaller fast movers
    - Depending on quantities, may result in a substantial cost, mechanical difficulties

Offset/saturation

- Is the issue systematic (offset required by optics) or the orbit needs to be improved
    - Again, movers for critical cavities typically operating with substantial offsets — *changes with optics,* or
    - Additional correctors for “flatter” orbit
- Use higher resolution and/or higher speed digitisers for CBPMs
- Introduce remotely controlled attenuators



Wakefields

- Reduce offsets

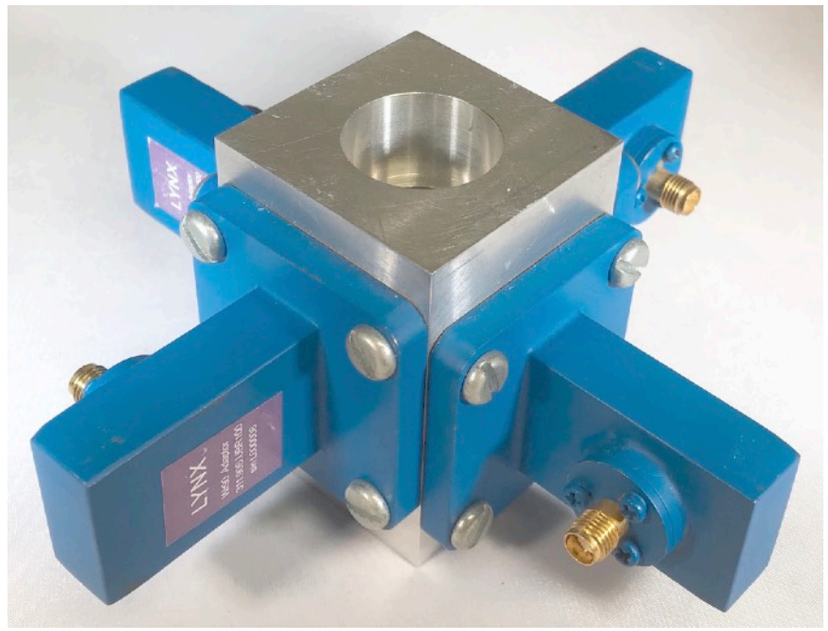
- Redesign to suit the 24 mm aperture, reduce the cavity gap as have overhead in sensitivity

    - Costs are high: £50-100k for prototyping, then £10k/cavity, even for 10 cavities that’s easily £200k, and only for parts

- At the same cost, it may be possible to get low wakefield Waveguide BPMs

Waveguide BPMs

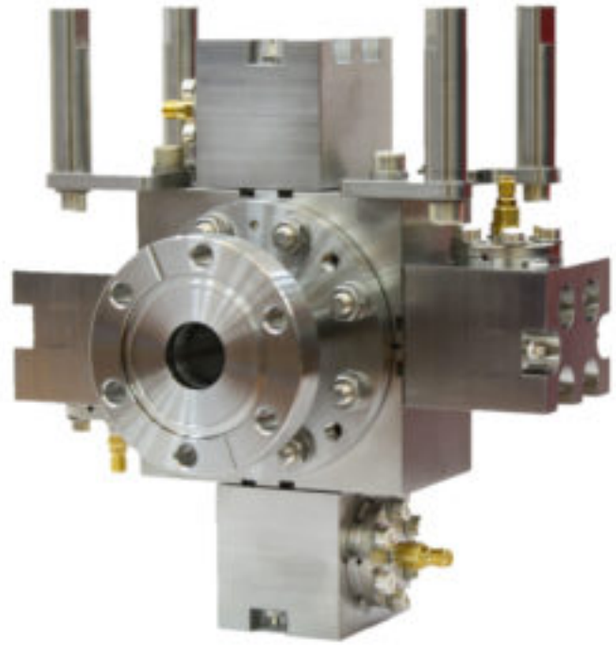
- Much easier to design for any aperture, but the sensitivity degrades as 1/a
- Include a small aperture step (~2 mm)
- No resonance, no frequency drifts
- Operationally very much like CBPMs, but more compact
- Signals, however, very different: broadband, short pulses
  - Suitable for very fast feedbacks -> FONT synergy
  - Not easy to process using traditional RF methods
- Work ongoing to design and build a small (8 mm) aperture prototype
- Could potentially be tried as an alternative for ATF3, but a redesign is required



Industry involvement

- FMB-Oxford (UK) and Instrumentation Technologies (Slovenia) now offer a complete off-the-shelf CBPM system

- 20 mm aperture cavities remotely resembling ATF design + rack mount boxes with front-ends, digitisers and FPGA/SoC with built-in EPICS interface



- First commercial delivery in 2021, but commissioning may take longer

- Would be interesting to try and characterise as a candidate for ILC in ATF environment

Final remarks

- The solution is likely to be a mixture of some of the above (and perhaps other ideas?)

- IP BPMs not reviewed — another critical area

- Integration with other systems critical (e.g. feedbacks)

- Some things can be tried in simulation, some in the existing ATF2 beamline

- Getting any resources would be hard at this stage, but small pots may be found to support for example travel or single prototypes