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Proposal for processing Beam Position Monitors (BPMs) signals at the Front-End Test Stand (FETS) at Rutherford Appleton Laboratory (RAL)

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Abstract:
This document describes options and a preferred solution for obtaining beam position information at FETS. Each system is described and the advantages and disadvantages of each are discussed. This document assumes that space with be made available within the Medium Energy Bean Transport (MEBT) for a number of BPMs.

1. **FETS Beam-line:** *Add beam-line parameters & timing.*
2. **Beam Position Monitor:** There are four BPMs to be used between the RFQ and chopper, with one further BPM after the chopper. The BPMs are either shortened strip-line or capacitive button devices and intended to work at 324MHz. One option is to use strip-line BPMs which have been designed to work at LINAC4 at a frequency of 352MHz, and are currently being used at LINAC2 working at 202MHz. Information from CERN regarding the strip-line BPM design has not been forthcoming at the time of writing this document. Another option is to use a commercial capacitive button design, details of which are not yet known. A final option is to design a button or strip-line device from scratch. The amount of space available for BPMs is not known at the time of writing.
3. **Beam Position Determination:** The four electrode signals from each BPM need to be processed to obtain the sum and difference of the signal amplitudes from opposing pairs of electrodes. The beam position in each axis is proportional to the difference divided by the sum. The position of the beam is required to be known to 100µm or better and should be determined at intervals along the extent of the macro-bunch.
4. **BPM Signal Acquisition and Processing:** There are various options to convert BPM electrode signals to a beam position. The following sections describe a variety of acquisition and processing options.
    a. **Fast Oscilloscope:** Each BPM electrode signal can be digitized at around 2.5GS/s. A four channel oscilloscope is required for each BPM. Some high-end 'scopes run either Windows or Linux, and have the ability to run executables. The beam position determination can be performed onboard, and the results served via an EPICS IOC. The cost of one oscilloscope is around £7k, three more are required since one has been purchased already.

Tektronix DPO4034B (3off)	£6.9k (21k)	SW calculation on scope

    b. **RF Down-conversion:** This can be either a commercial unit (usually 4 BPM channels per unit) or a self-made system which uses either connectorised components or PCB-mounted active and passive components. Each BPM signal is mixed with a Local Oscillator (LO) and then low-pass filtered to produce an Intermediate Frequency (IF) of a few MHz. This IF signal is then digitized and the BPM position information extracted. A typical commercial unit would be Bergoz BPM-AFE, costing around £1.8k per BPM, but requires some additional mounting hardware and PSU. A self-made system using connectorised components would cost about £1k per BPM. A custom PCB would cost around £2-300 per BPM but take considerably longer to design and manufacture.

Bergoz BPM-AFE (4off)	£1.8k (£7.2k)	14 week lead-time ARO

Connectorised RF Elements	£4k total	2-4 weeks to design; test
PCB RF System	£1k total	6-8 weeks to design; test

c. **Digitizing and Processing:** The down-converted (IF) BPM signals must be digitized to enable software calculation of the beam position.

i. **Fast DAQ:** A fast DAQ card (few MS/s sample rate) can be situated within the PXI system and the BPM signals sampled. The data can be moved to the processor card where the BPM position can be determined.

PXI-6133 (2off)	£2.4k (£4.8k)	8 Ain(diff); 2.5MS/a; 14-bit
PXI-5105 (2off)	£5.3k (£10.6k)	8 Ain(SE); 60MS/s; 12-bit

ii. **FPGA and Digitizer:** A FlexRIO (FPGA) card with an attached 50MS/s simultaneously sampling digitizer can be situated within the PXI system. The FPGA can perform the sampling and the position determination before moving the results to the processor card.

PXI-7954R	£5.6k	FPGA LX110 128M RAM
PXI-5752R	£3.3k	32 Ain(diff); 50MS/s; 12-bit
VHDCI-VHDCI 1m cable	£300	Connect 5752 to breakout
SMB-2145	£500	16 channel Breakout
PXI-7952R	£3.4k	FPGA LX50 128MB RAM

(Only one of 7954R and 7952R required – it is likely 7952R is sufficient to do the processing required)

d. **Logarithmic Amplifier with Processing:** A LR-BPM card from Bergoz can perform the mixing and difference/sum calculation within the analogue domain. The output is a voltage proportional to the beam position which can then be digitized at a slower rate (two DAQ channels per BPM).

Bergoz LR-BPM (4off)	£3.4k (£13.6k)	Requires rack system (£1.5k)

5. **Fast BPM Signal Monitoring:** The BPM after the chopper will be monitored using a 20(40)GS/s oscilloscope to determine if any micro-pulses have been chopped. The signal from this BPM will only be viewed, not stored (yet). This scope is being supplied by ICL.s
6. **Ancillary Items:**

Items such as cables, connectors, PSU etc are not included. Cost is estimated at £500-£1k, depending upon cable routes.

7. **Conclusion:** A down-converted system with FPGA acquisition and processing is likely to be the most flexible, cheapest and quickest to produce, assuming that four BPMs are to be used. Depending when the BPM electronics is required, a test system using connectorised RF components (two BPM channels) could be developed and tested first, then a PCB solution produced. The Bergoz BPM-AFE is a reasonable solution if time is of the essence. The fast-scope option would require more investigation to determine if an executable can be developed and run on the scope (requires scope to have an accessible O/S). More accurate costs of the connectorised and PCB RF systems are being determined, but are within about 25%.