HZB BESSY II Light Source

Plans for an Upgrade of BPMs and Orbit Feedbacks in BESSY II

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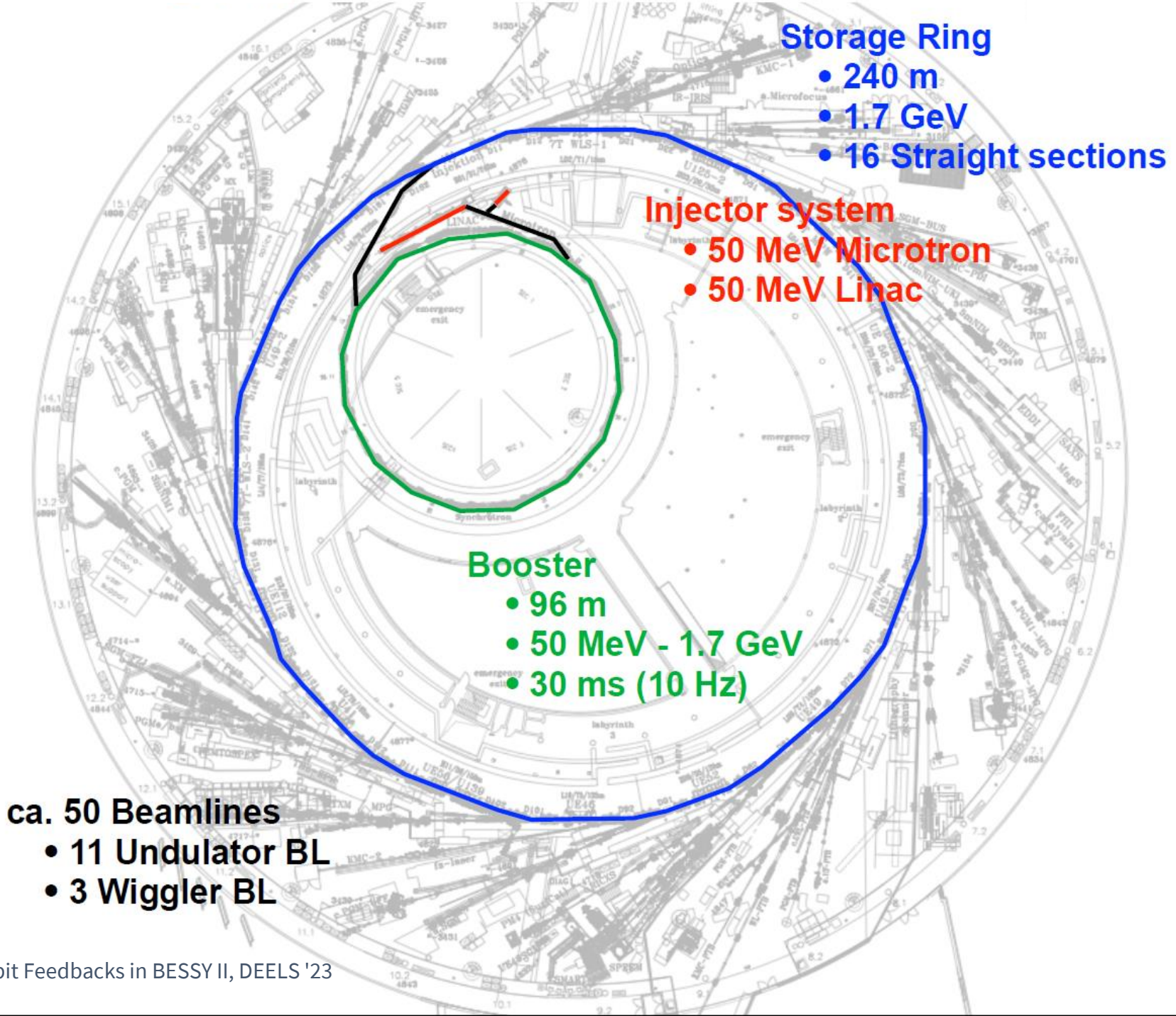
Can we go a bit faster?

BESSY II

In operation
since 1998
$\epsilon_x = 5$ nm rad
$\epsilon_y \approx 50$ pm rad



Why upgrade?

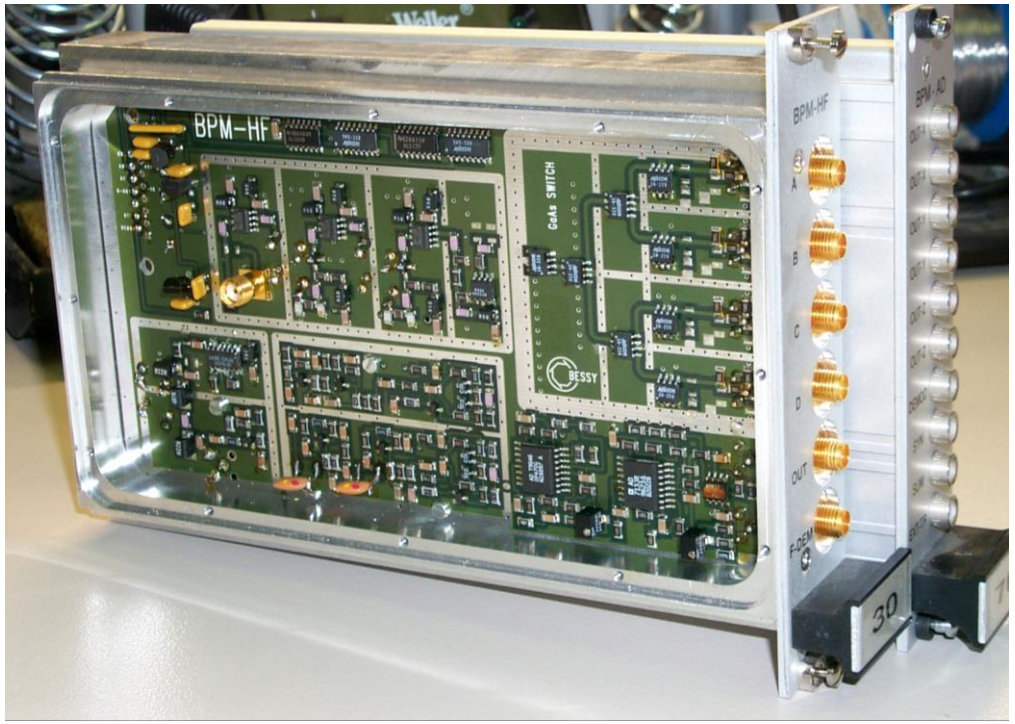
- Old BPMs:
  - Failures increasing, spares low, no parts for spares
  - Analogue only, low bandwidth, no TbT
  - Digitisation in VME, PV update rate 0.5Hz
- Old SOFB:
  - EPICS based, running at 0.5Hz, sending PV updates to corrector PSU
- Old FOFB:
  - 6.6 ms latency, running at 150 Hz, corrects up to 20 Hz

What challenges?

- **Paradigm change:**
  - Tradition: BPMs are Diagnostics, digitisation and feedback are Controls
  - Modern Digital BPMs cover traditional Diagnostics and Controls
- **Allow cell-by-cell BPM upgrade and decouple upgrades of orbit feedback:**
  - Need operation in hybrid configuration of old and new BPMs
  - Need stages of upgrade on SOFB and FOFB
- **Reusability:**
  - Operating two machines, buildup and commissioning of a third
  - Need solution that can be re-used

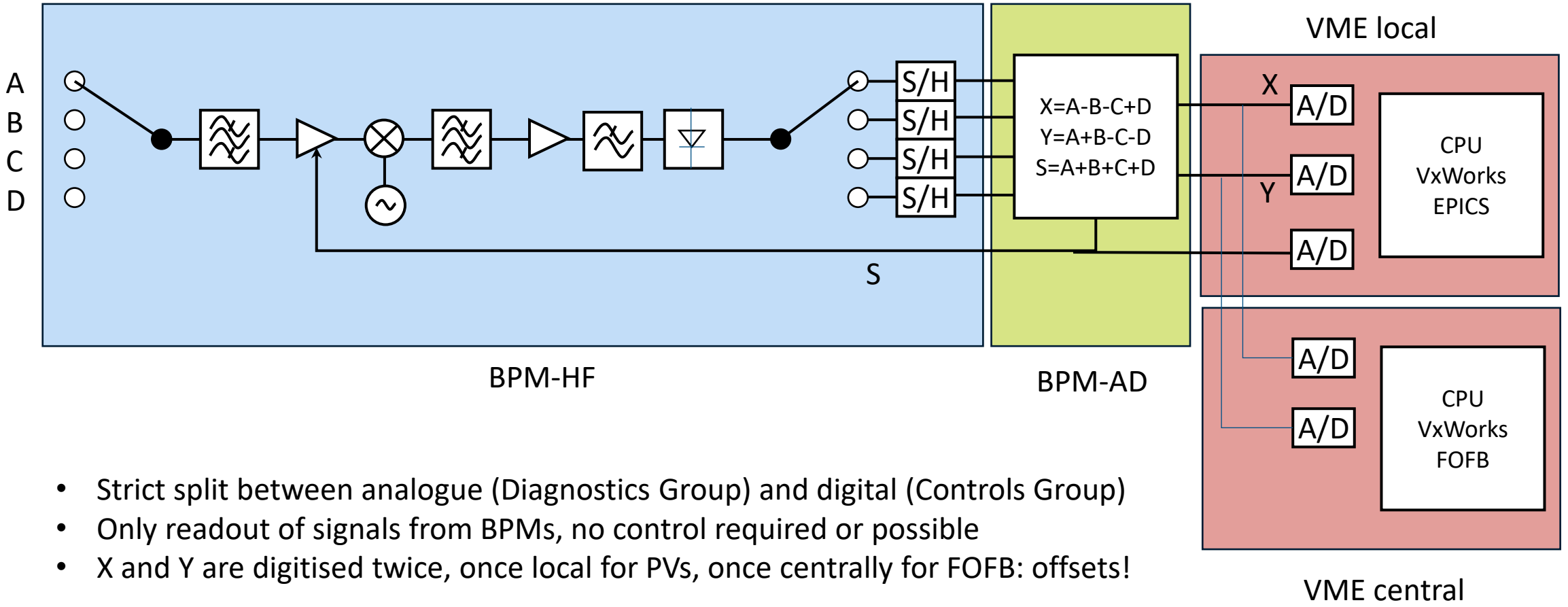
EXISTING BPM ELECTRONICS

- **Original BESSY II BPMs:**
  - Use single channel multiplexing
  - Analogue processing of X,Y and S
  - Rudimentary „first turn“ capabilities:
    - Shots with multiplexer stopped in one position
    - Selection of one BPM through external multipler
    - Digitisation of cells in one crate with fast digitisers
    - No longer in use



BPM-HF and BPM-AD, mid 1990s in-house design and build

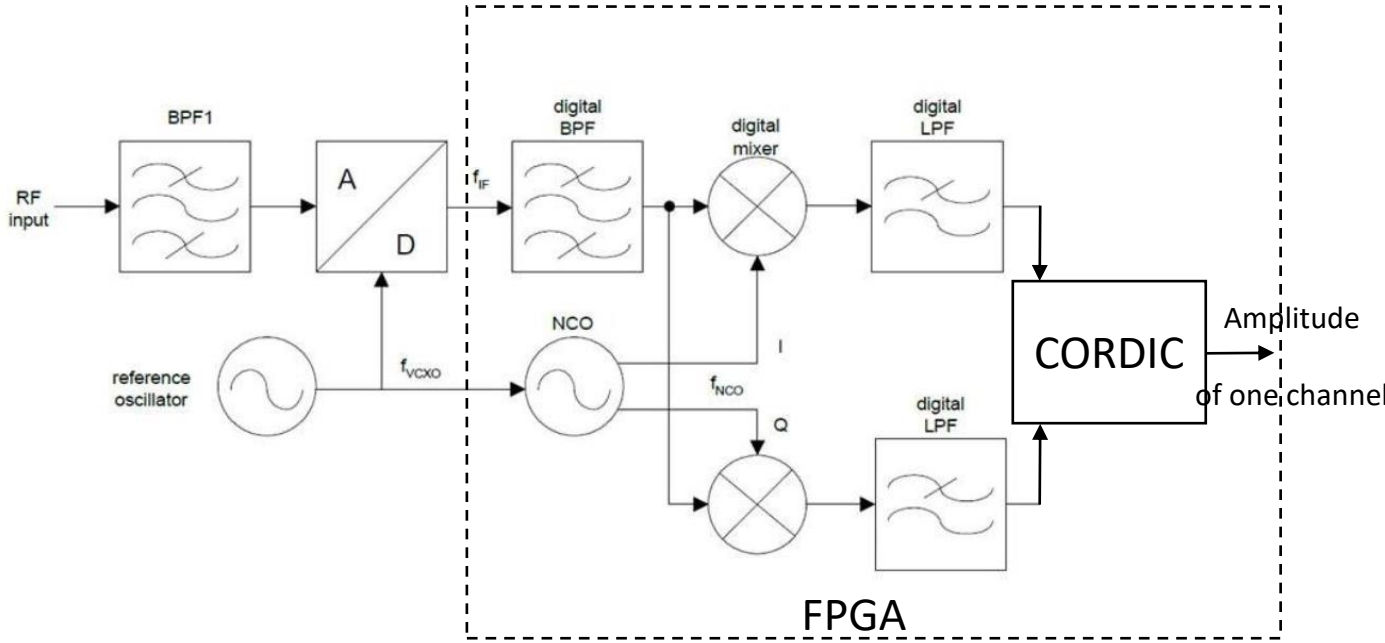
MULTIPLEXING APPROACH IN EXISTING BPM ELECTRONICS



- Strict split between analogue (Diagnostics Group) and digital (Controls Group)
- Only readout of signals from BPMs, no control required or possible
- X and Y are digitised twice, once local for PVs, once centrally for FOFB: offsets!

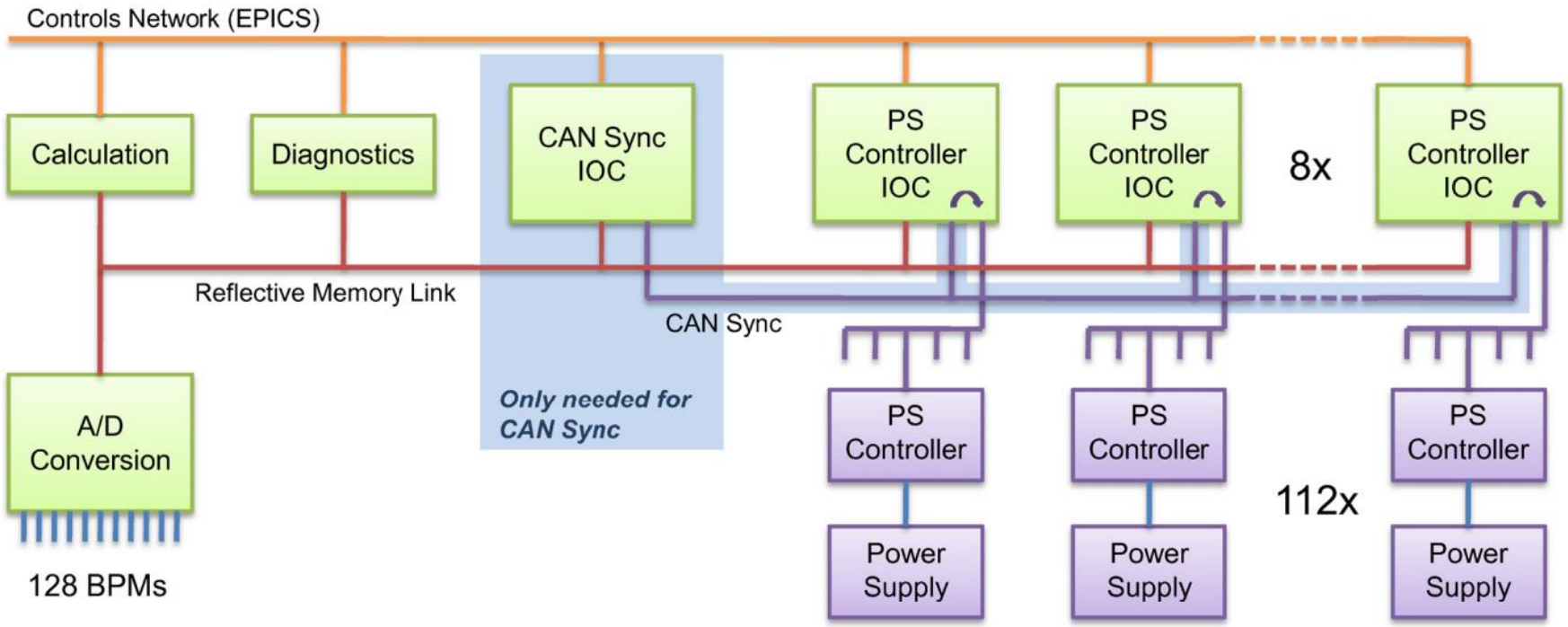
NEW BPMS: LIBERA SPARK

- 4 channel 117 MS/s ADC (undersampling RF!)
- Zynq FPGA realises DSP and high level control including EPICS connection
- Highly integrated:
  - In: buttons (6), trigger and clock ref (7)
  - Out: EPICS (4) and FA data on GBE (1)
  - Data rates:
    - ADC, turn-by-turn: on demand
    - 10 kHz, 10 Hz: streaming
- 50 units already installed in BESSY II injector
  - Will serve as testbed for FA collection
- New for HZB: **optional external reference oscillator and extra programmable attenuation at the input**



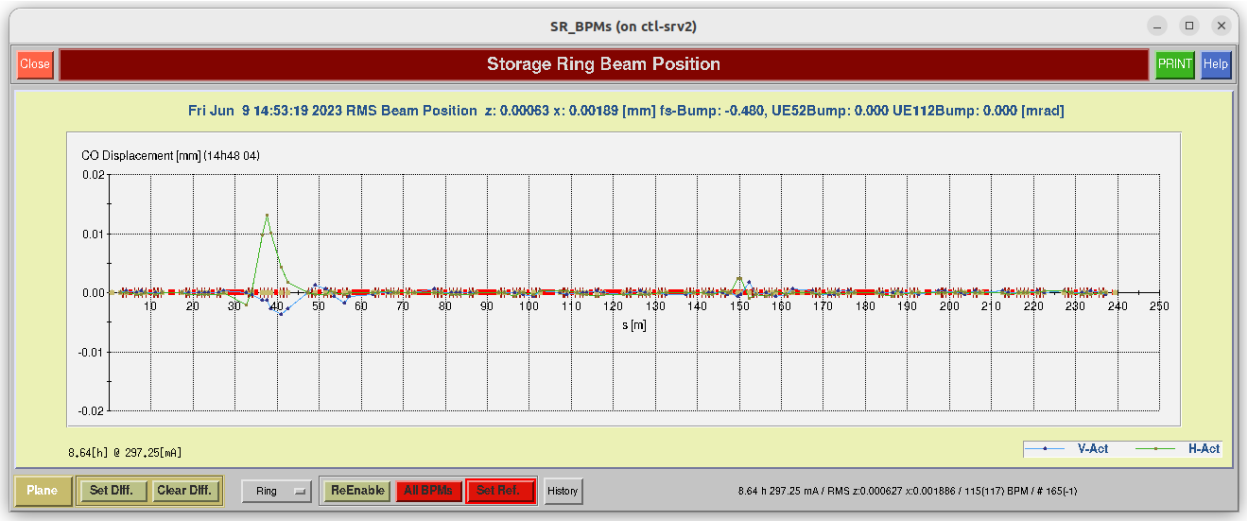
EXISTING FAST ORBIT FEEDBACK

- In operation since 2012
- Runs at 150 Hz (could do 600Hz) update rate
- Uses reflective memory to distribute BPM data and corrector data
- Bottleneck is large latency in CAN bus (>3ms)



EXISTING SLOW ORBIT FEEDBACK

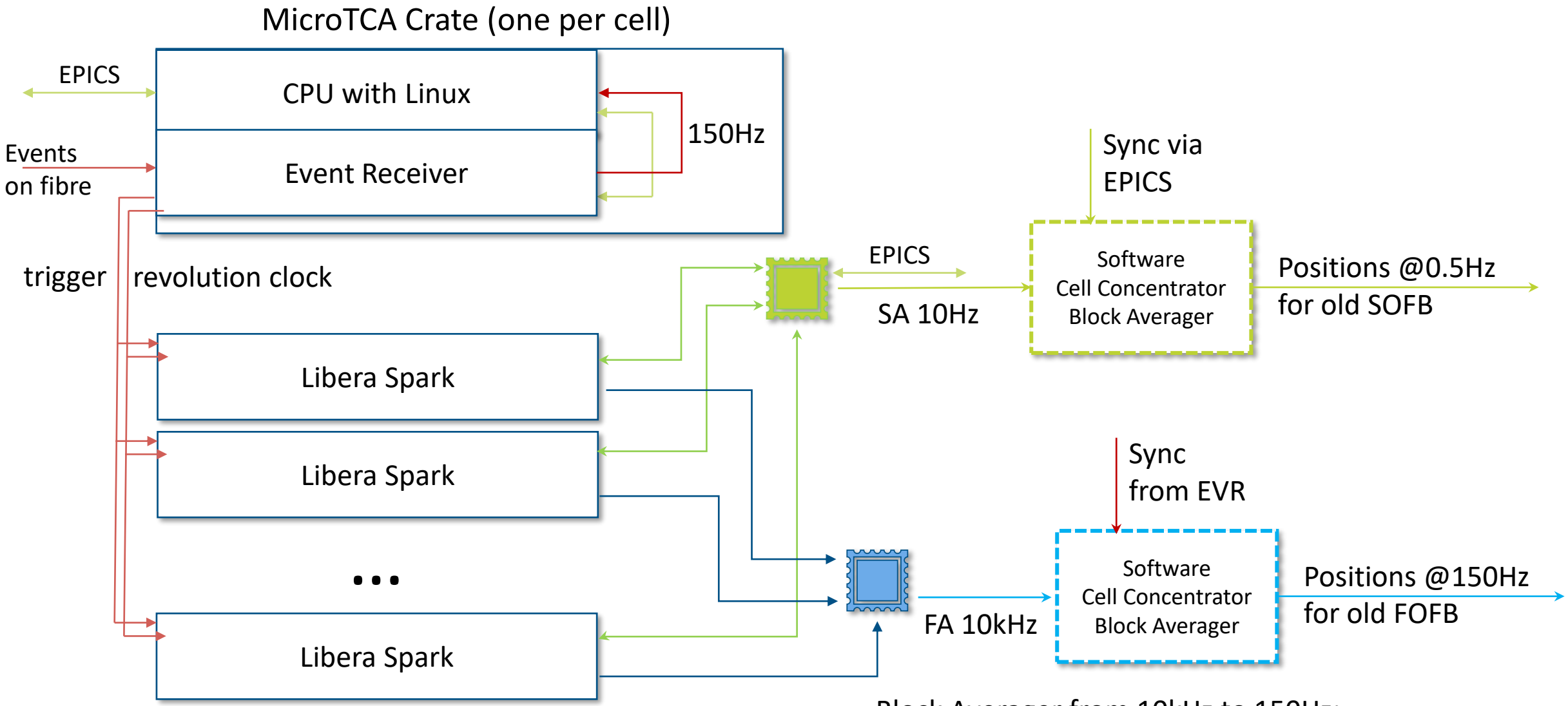
- In operation since dawn of BESSY II
- Monolithic Tcl/Tk tool:
  - Measurement of Orbit Response (inkl. dispersion)
  - Application of individual corrections
  - Continuous correction at 0.5 Hz
  - Display of orbit
- Allows individual disabling of BPMs and correctors
- Allows setting deviations to target orbit
- Interfaces solely via PVs to BPMs and corrector PSUs
- Used during maintenance
- Setting up initial good orbit



Upgrade in three Stages

1. Install new BPMs cell by cell
   - Operate SOFB (0.5Hz) and FOFB (150Hz) with hybrid BPM population
   - Need to produce relevant data at original rates and in sync
2. Replace old SOFB with new Python routine
   - Headless server, communicates with users solely through EPICS
   - Will also be able to communicate with new FOFB
3. Replace old FOFB with new routine using FA data at full rate
   - Transfer to compuational node through GBE and 10 GBE
   - GBE Receiver for cell corrector values produces DAC values for PSU

STAGE 1: TIMING OF NEW BPMS AND HYBRID ORBIT FEEDBACK



Block Averager from 10kHz to 150Hz:

- Software in MTCA CPU
- Firmware in Libera Spark

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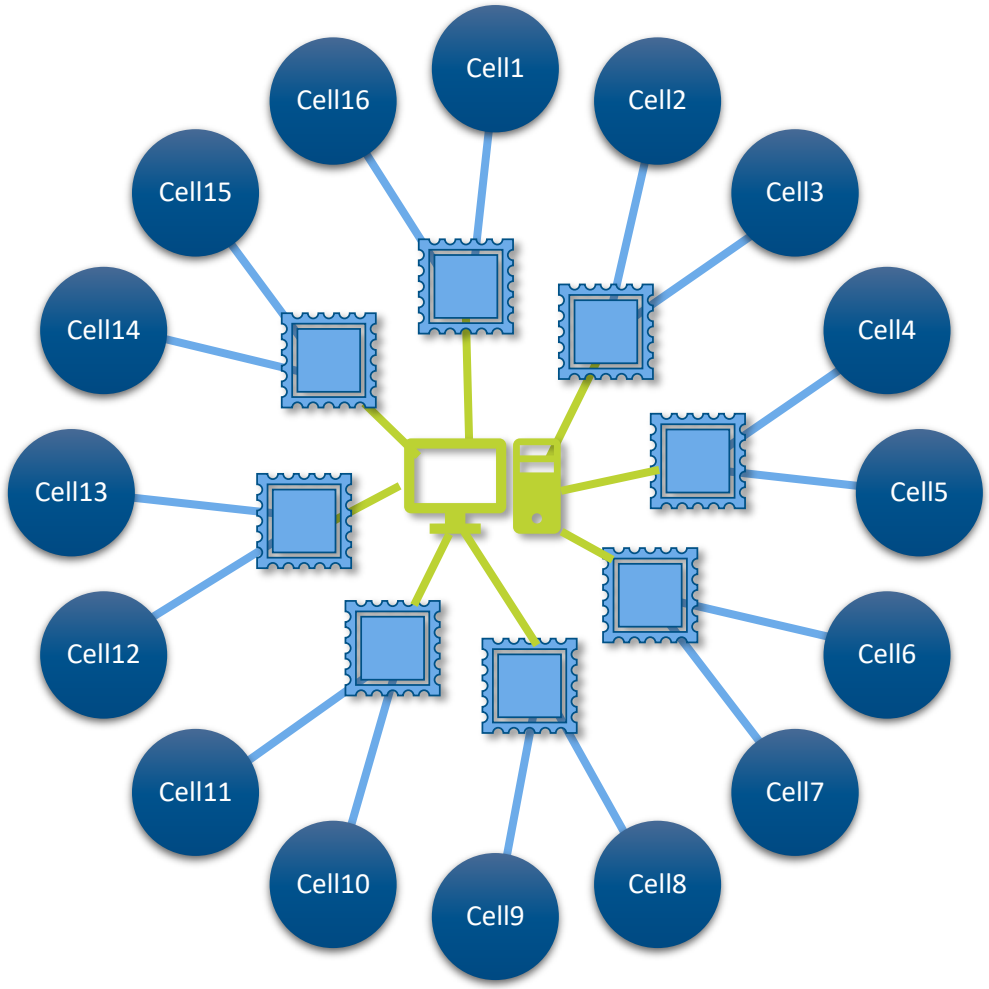
STAGE 3: ORBIT FEEDBACK PERFORMANCE MAXIMISE BANDWIDTH / MINIMISE LATENCY

- Two main parameters influence all feedbacks:
  - Compound low pass bandwidth
  - Roundtrip latency
- Bandwidth needs to be maximised
  - Bandwidth of PSU
  - Bandwidth of magnet/vessel
- Latency needs to be minimised
  - Increase in sample speed leads to lower group delay in BPM filter
  - Reduce transport latencies by using high speed protocols
  - Transmit and receive with low latency
  - Compute with low latency

Conceptual orbit feedback loop

STAGE 3: FOFB ON PRIVATE NETWORK

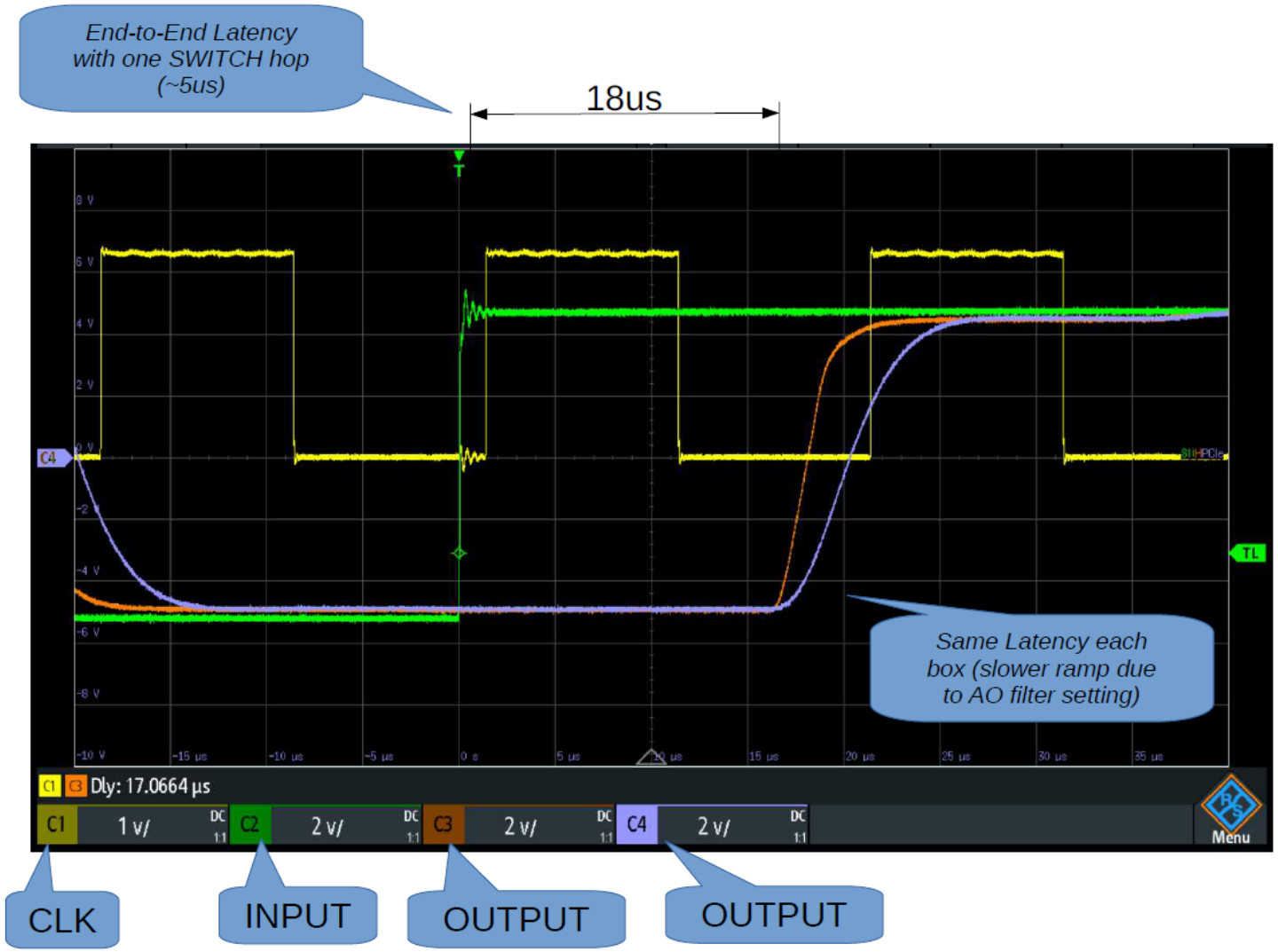
- 7-8 BPMs in each cell
- BPMs produce packets synchronously at 10 kHz
- Packet size is 512 bits
- Switch will receive data from 14-16 BPMs and forward on 10 GBE
- Central node use 10 GBE switch to collect
- Central node computes orbit correction
- Corrector set points sent out as broadcast packet
- Broadcast received in one FPGA per cell
- Forwarded through DAC to corrector PSU



Overall structure for FOFB 2.0 at BESSY II has 16 cells with 7-8 BPMs each

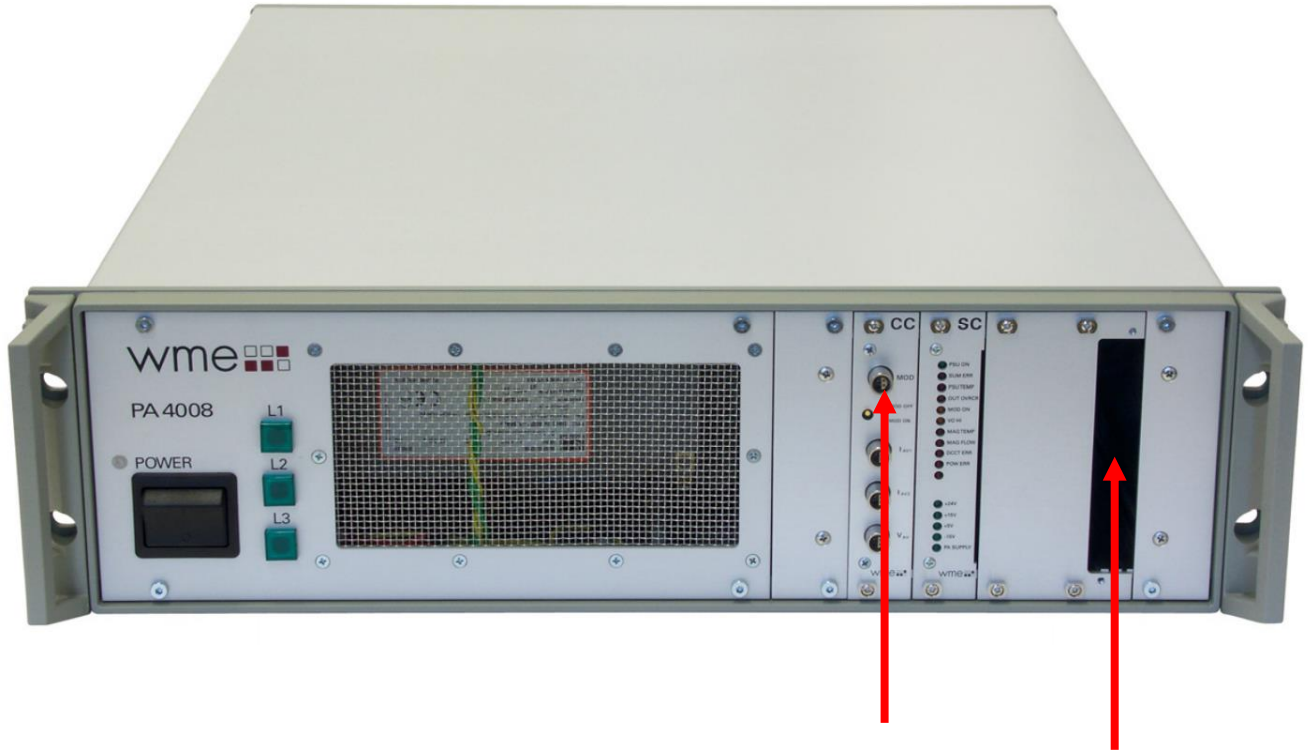
NETWORK TO DAC PROTOTYPE

- Potential supplier demonstrated ADC->FPGA->UDP->FPGA->DAC
- Whole setup achieved <20 µs latency
- No jitter in transmitter/receiver
- Minimal jitter in switch, rarely long delays
- Firmware will be modified to receive one large broadcast packet per time slot and apply only relevant values to DACs



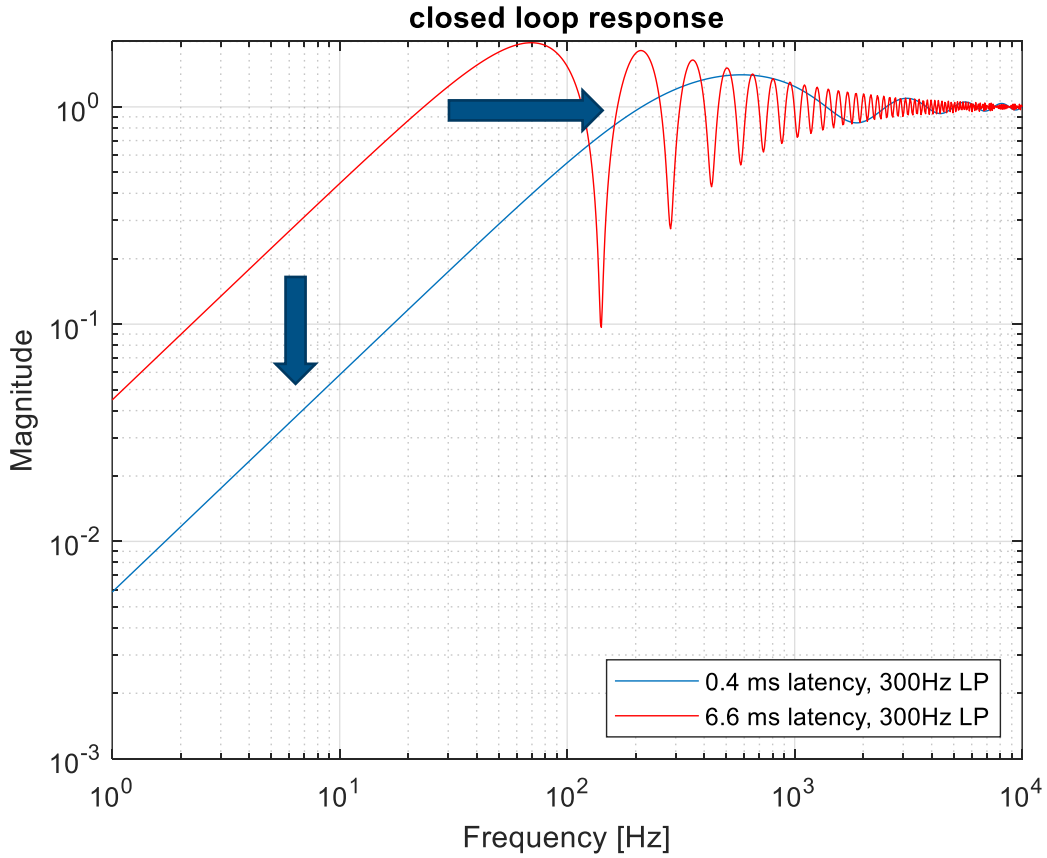
CORRECTOR POWER SUPPLY WITH FAST ANALOGUE INPUT

- Will keep power supplies, magnets and vessel
- Use analogue differential input for fast correction
- CAN-bus used in the past will remain
  - Use for status readback
  - Use for SOFB and FOFB starting points
  - Both values are internally added
- Good EMI immunity in tests
  - With floating differential output from DAC



ESTIMATED FOFB PERFORMANCE AT STAGE 3

- Existing corrector PSU, magnets and vessel
- Conservative estimate 300 Hz LP
- Existing feedback has latency of 6.6 ms
  - 1.6 ms in BPMs (multiplexing)
  - 2 ms in calculation and global transport
  - 3 ms in application of corrector values through CAN-bus
- Latency estimate
  - FA filter with 0.2 ms @ 10 kHz sample rate
  - Calculation and transport in 0.1 ms
  - Distribution of corrector values in 0.1 ms



Simulation using Internal Model Controller: closed loop response of existing and future orbit feedback shows >8 times improvement of disturbance suppression

Summary

Old BPMs in BESSY II will be exchanged for Libera Spark

Upgrade will happen cell-by-cell

Appropriate data will be produced at rates and format of old cells

Network-DAC to provide low latency interface to existing PSU

Ultimately, improve 0dB crossover from 20 Hz to 200 Hz

Thank you for your attention!

Questions?