Run 2c BPM Development Update

L. Stant

AWAKE BI meeting, 26 November 2024

Recap of Requirements

Protons:

- Improve resolution from 70 µm to 20 µm.

Electrons:

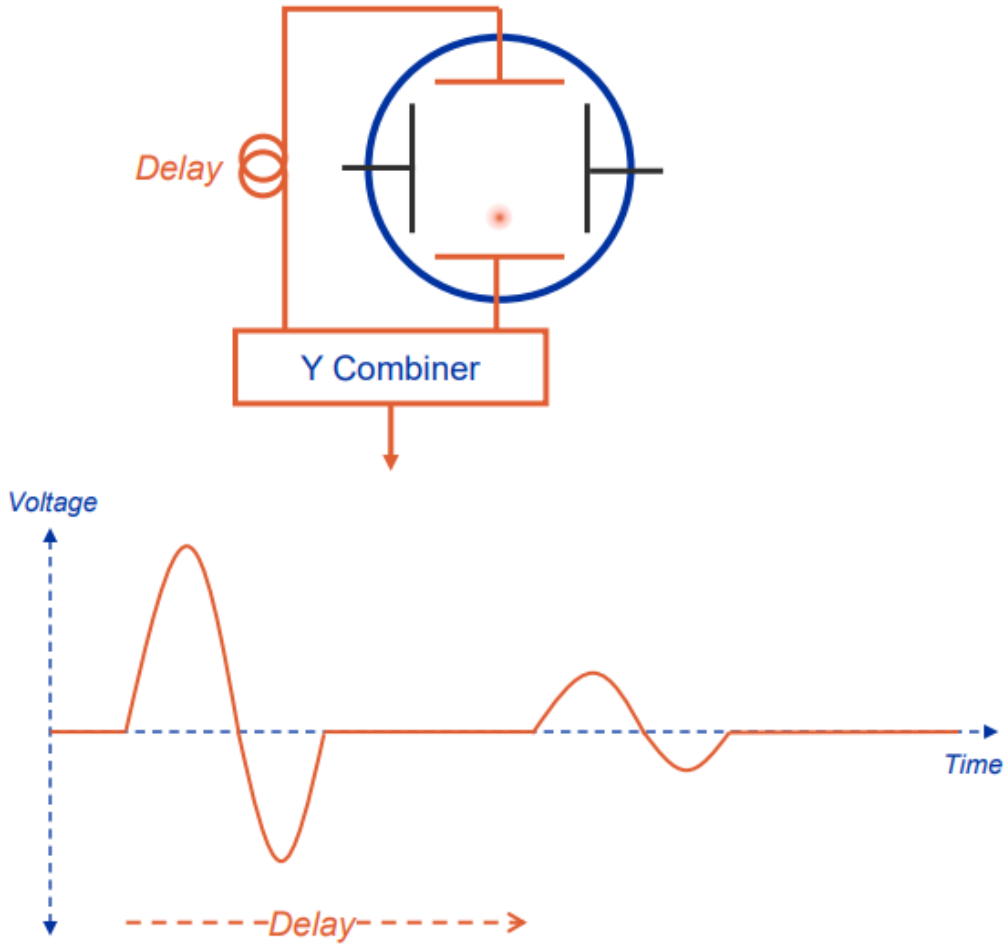
- Additional 9+3 BPMs (7+2 of 40mm pickup, 2+1 of 60mm pickup).
- Replace existing TRIUMF electronics so CERN can maintain.
- Preserve existing resolution of 10 µm (15 µm for 60mm pickup).

Both:

- Share all software and as much hardware as possible with HL-LHC.

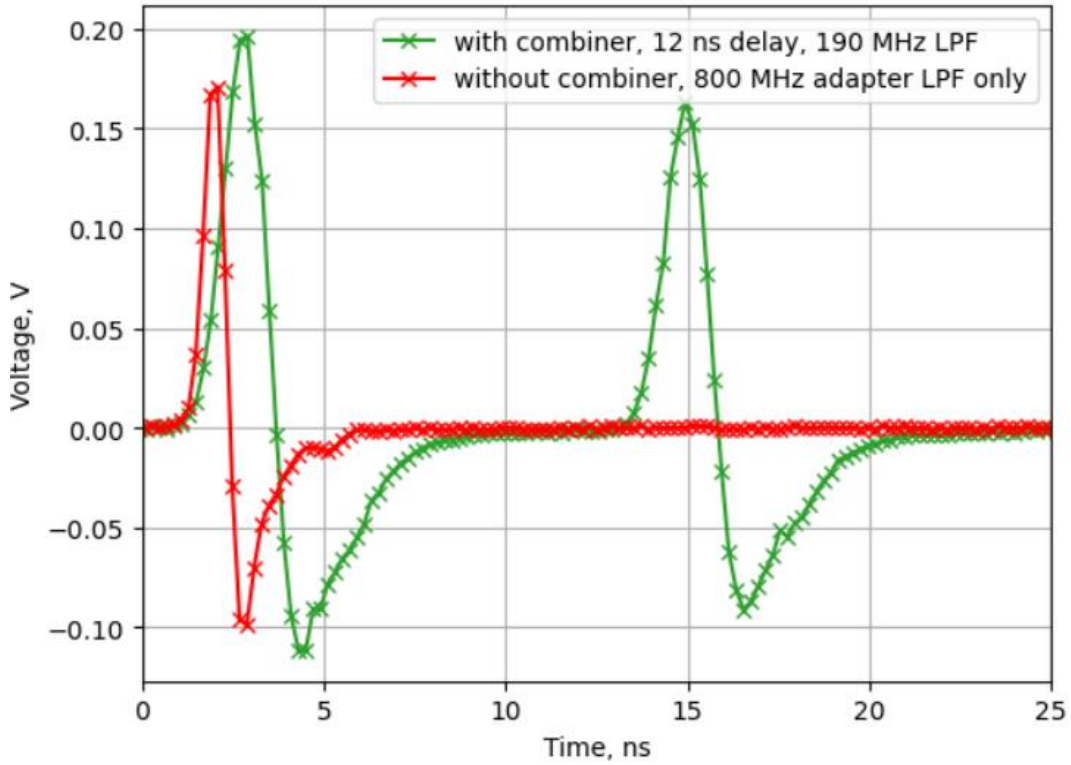
Desired Architecture - Multiplexing

- Time multiplexing our pulsed signals is beneficial:
  1. Reduced channel count – less electronics to procure and maintain.
  2. Systematic error in cabling, front-end electronics and digitizer largely eliminated as both signals normalised to their sum.



Proton BPM Status

- Measurements using prototype lowpass filtering front-end show that the 15 µm required resolution will be achievable using unmodified HL-LHC electronics.
- These agreed well with simulations and lab tests of the front-end.
- Next steps involve designing local multiplex cabling (delay and combiner) with mounting.

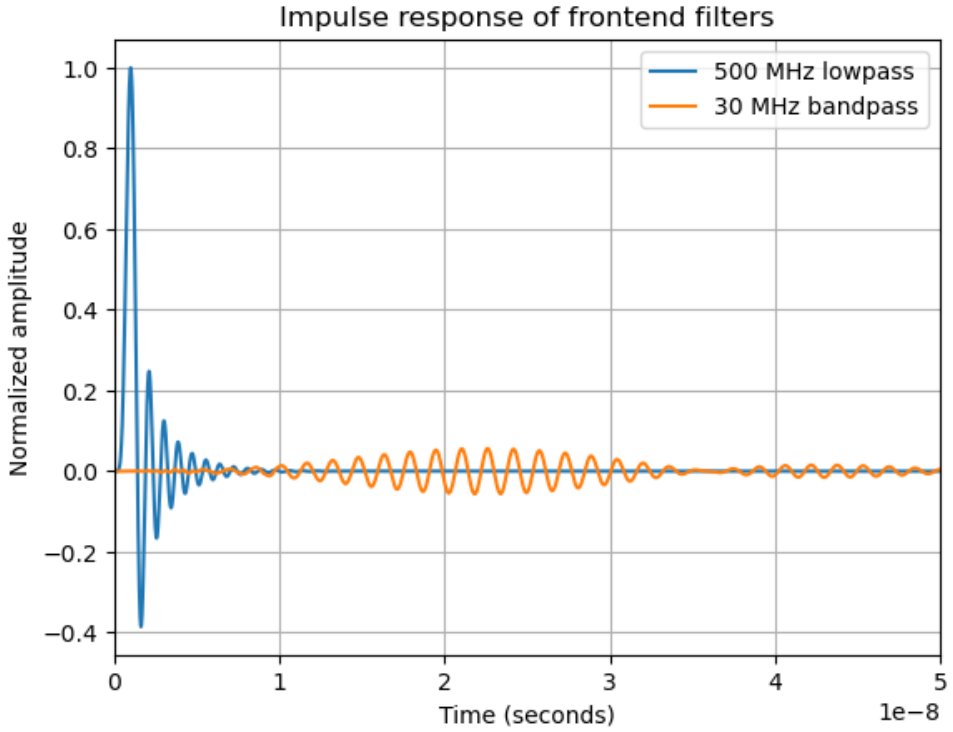


Electron BPM Status – Beam Specification

- **To confirm the beam specification:**
  - **18 MeV**
    - Unchanged from Run 2b.
    - 100 pC to 600 pC charge.
    - 4 ps bunch length (RMS?).
    - Repetition rate of 10 Hz.
  - **150 MeV**
    - 100 pC to 200 pC.
    - 0.2 ps to 0.4 ps bunch length (RMS?).
    - Repetition rate of 10 Hz.

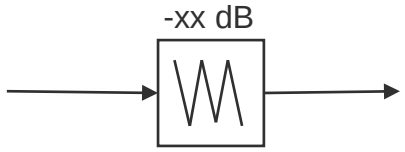
Electron BPM Status – Challenges

- Considering the same HL-LHC frontend, electron bunches are very short and give a much weaker signal than the protons.
- Existing TRIUMF system uses a bandpass “ringing” filter to provide more samples to the 100 Msps digitizer.
- HL-LHC frontend uses lowpass filtering, but we have *much* faster sampling (5 Gsps).
- If lowpass works, the pulses are short enough to time multiplex pickups. This provides systematic error and cable drift correction per plane.

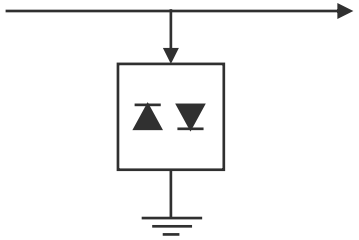


Electron BPM Status – Challenges

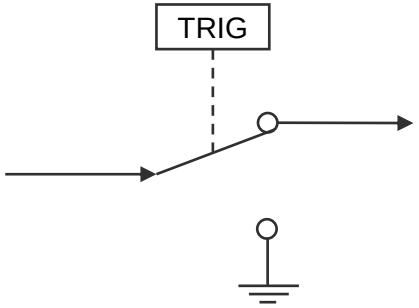
- But <100 ms after our last electron bunch, with a high gain frontend configuration, a proton will arrive and provide 500 times the amplitude.
- The existing system uses heavy attenuation to reduce the proton signal below damage threshold for the electronics.
- We will need to either do the same (degrading performance) or implement a method to bypass the receiver when the proton bunch arrives.



Attenuation



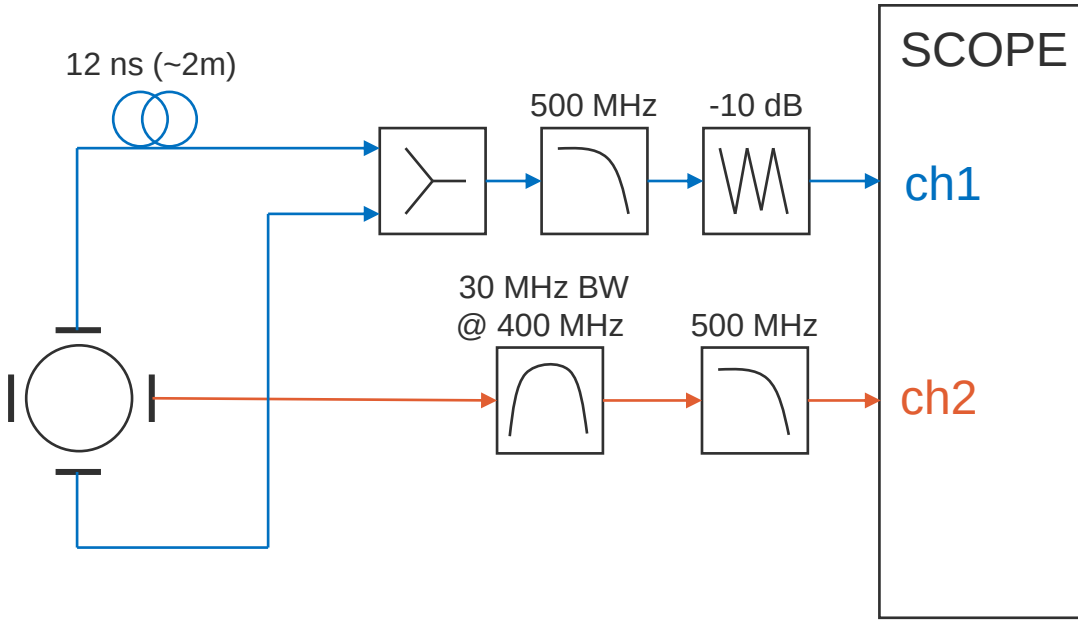
Diode Limiter



Fast Switch

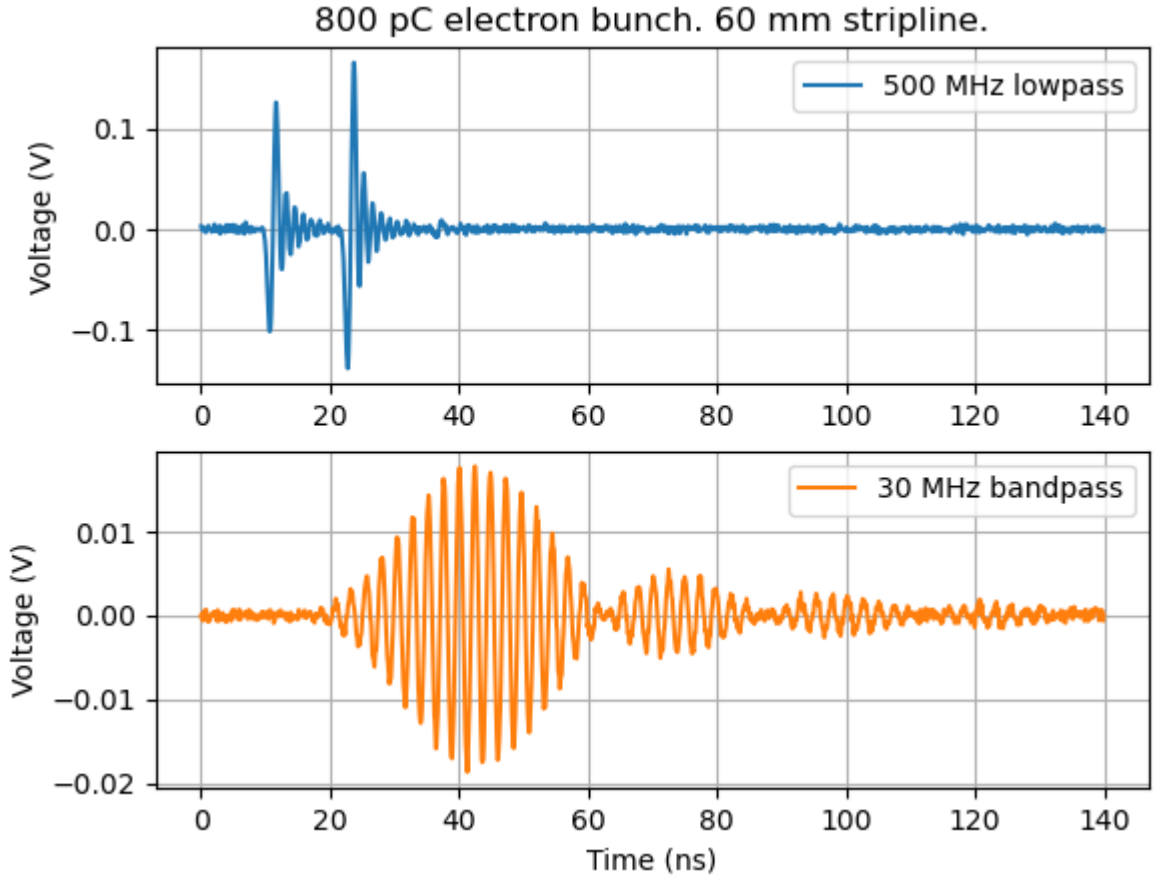
Electron BPM Status – Measurements

- Tested filter options with fast scope in AWAKE during October.
- Lowpass included a multiplex setup to demonstrate feasibility with real signal levels.



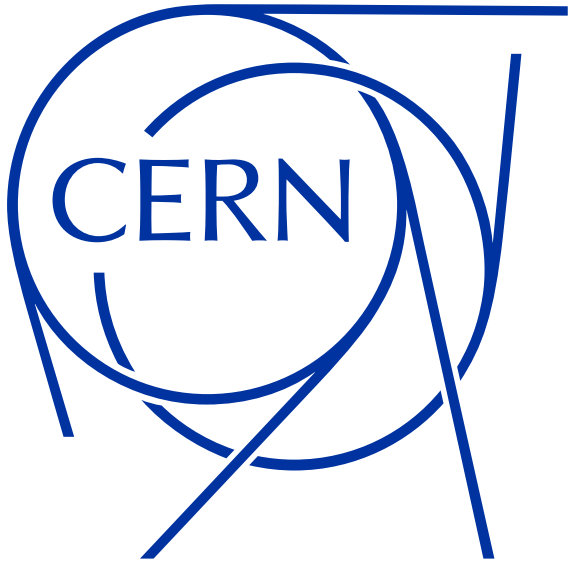
Electron BPM Status – Measurements

- Tested filter options with fast scope in AWAKE during October.
- Lowpass included a multiplex setup to demonstrate feasibility with real signal levels.
- Bandpass cannot work with combiner. Ringing would require around a hundred metres of delay cable, degrading the signal.
- These measurements suggest that using planned HL LHC electronics, we can meet the spec using lowpass and multiplexing.
- Further analysis required; more measurements next year would be useful to check against thermal noise predictions.



Electron BPM Status – Next Steps

- Finish design report with all information and results to date.
- Complete analysis of electron bunch measurements.
- Decide on filtering method, or more measurements if required.
- Test technique for limiting proton signals during run next year.
- Design cable and combiner mount for proton BPM multiplexing.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