Status of the Cherenkov and High Frequency BPMs

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AWAKE Collaboration Meeting

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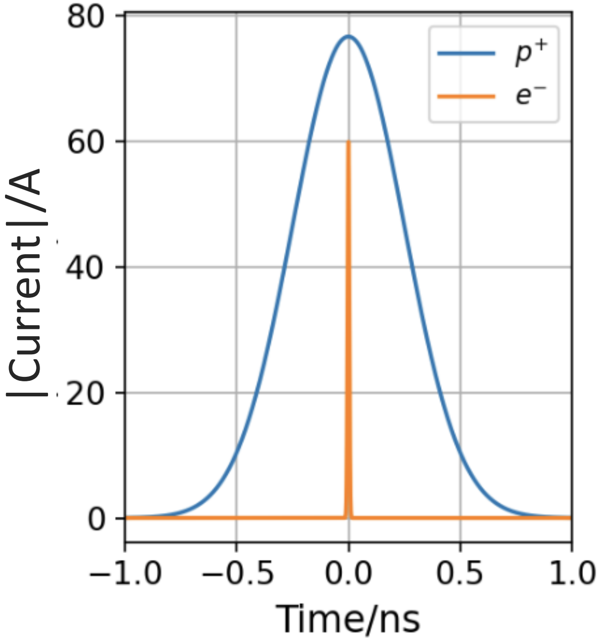
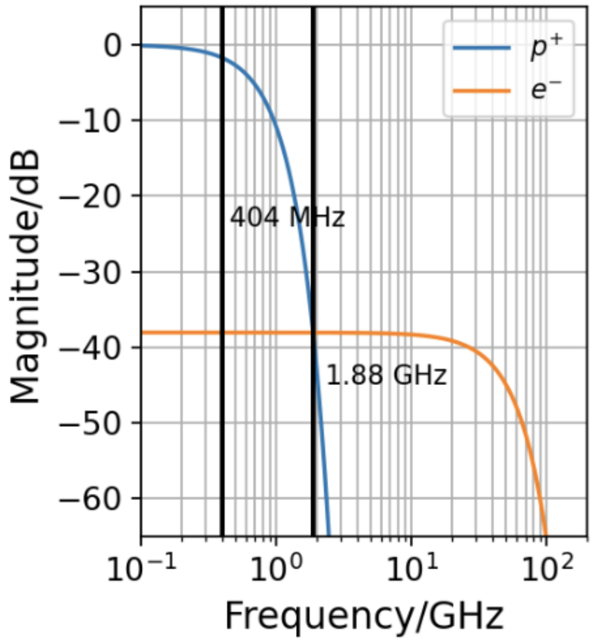
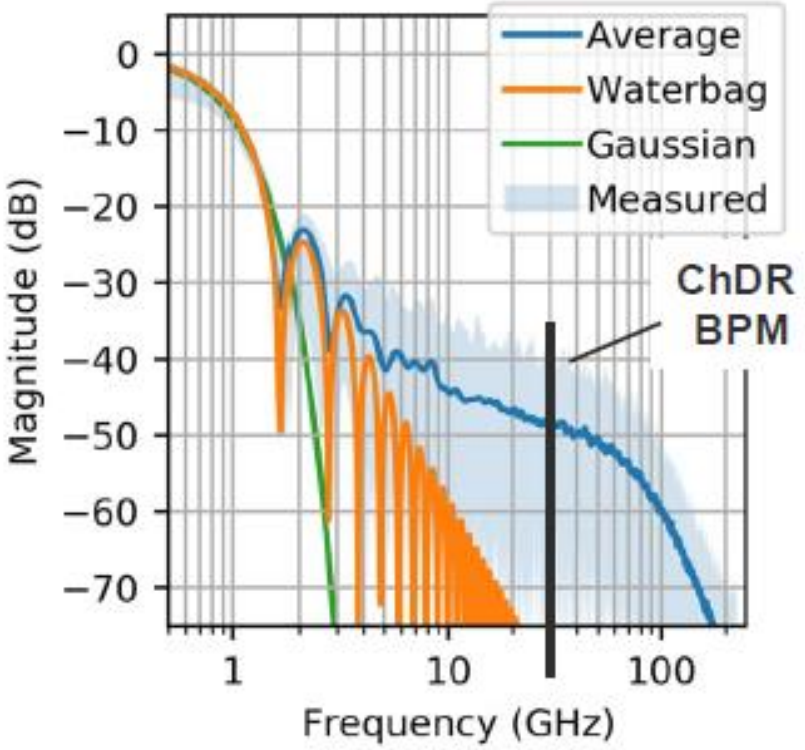
Measuring electron position in the common beamline

- Proton bunches are longer(~250ps) than the electron bunch (~1-5ps)
- At 404 MHz signal dominated by protons
- Current stripline BPMs unable to measure beam position when protons are present





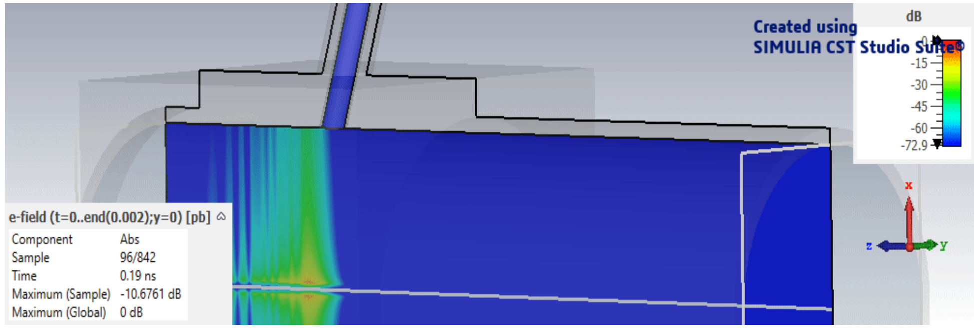
- Non-Guassian beams as found in AWAKE could extend to tens of GHz



Need for a system performing the detection at sufficiently **high frequencies**

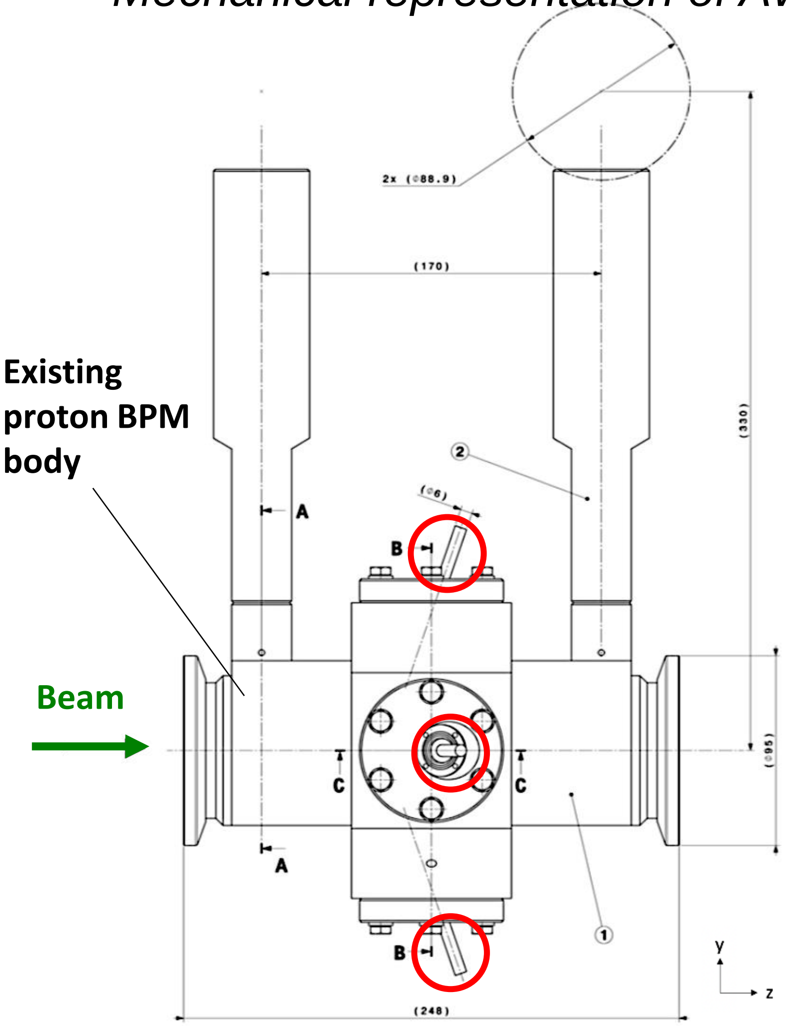
BPM Types for consideration - ChDR

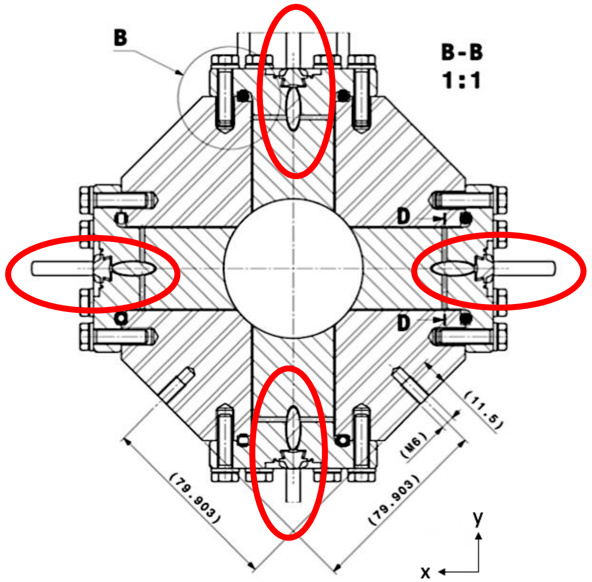
- **⌀6 mm, 86 mm long alumina rods** angled at the Cherenkov angle (71°), 9.6 GHz cut-off
- Respects the geometry of existing pBPM body



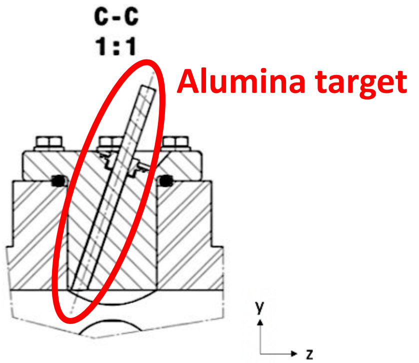
Example CST simulation with cylindrical Alumina radiator

Mechanical representation of AWAKE ChDR BPM





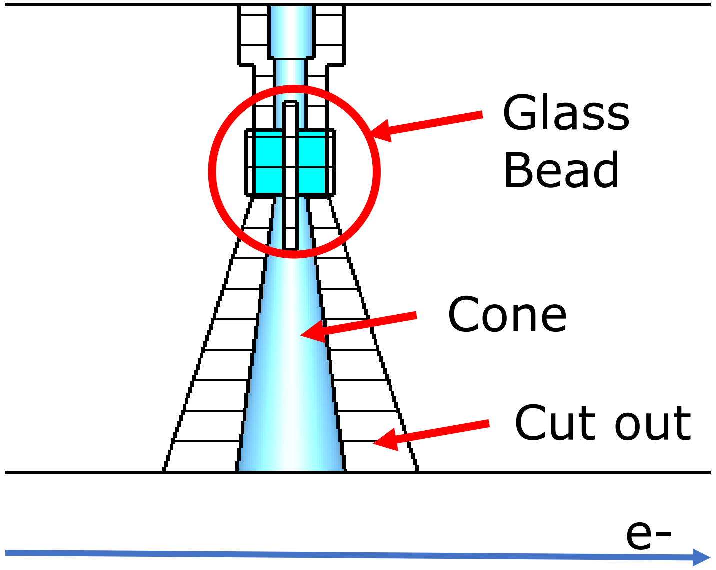
2+2 symmetric arrangement of ChDR targets



BPM Types for consideration – High Frequency

- Conical shaped High Frequency button BPM
- One design in literature working up to 40 GHz cutoff frequancy

See A. Angelovski et al., Phys. Rev. ST Accel. Beams **15**, 112803 (2012)



Comparison to LHC-type Button BPM

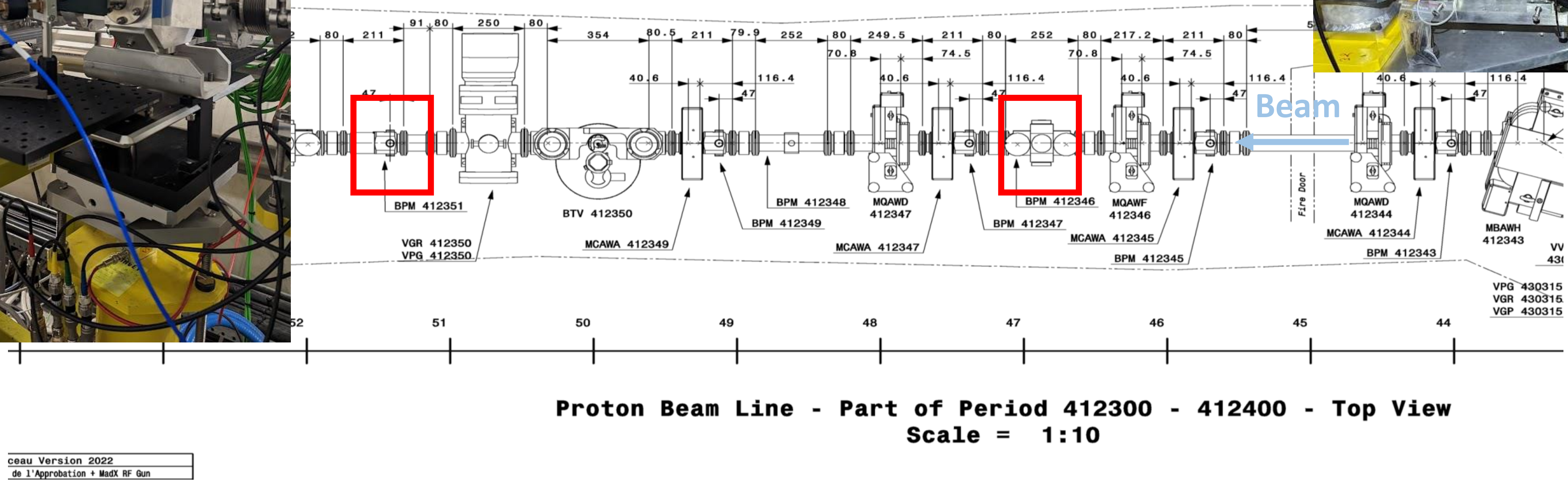
ChDR BPMs in the AWAKE beamline

- One BPM installed with 2 mounted optical boards on either side for higher frequency broadband testing

- One BPM connected to TRIUMF electronics
- Logged on NXCALS as of Oct 23

ChDR BPM

ChDR BPM



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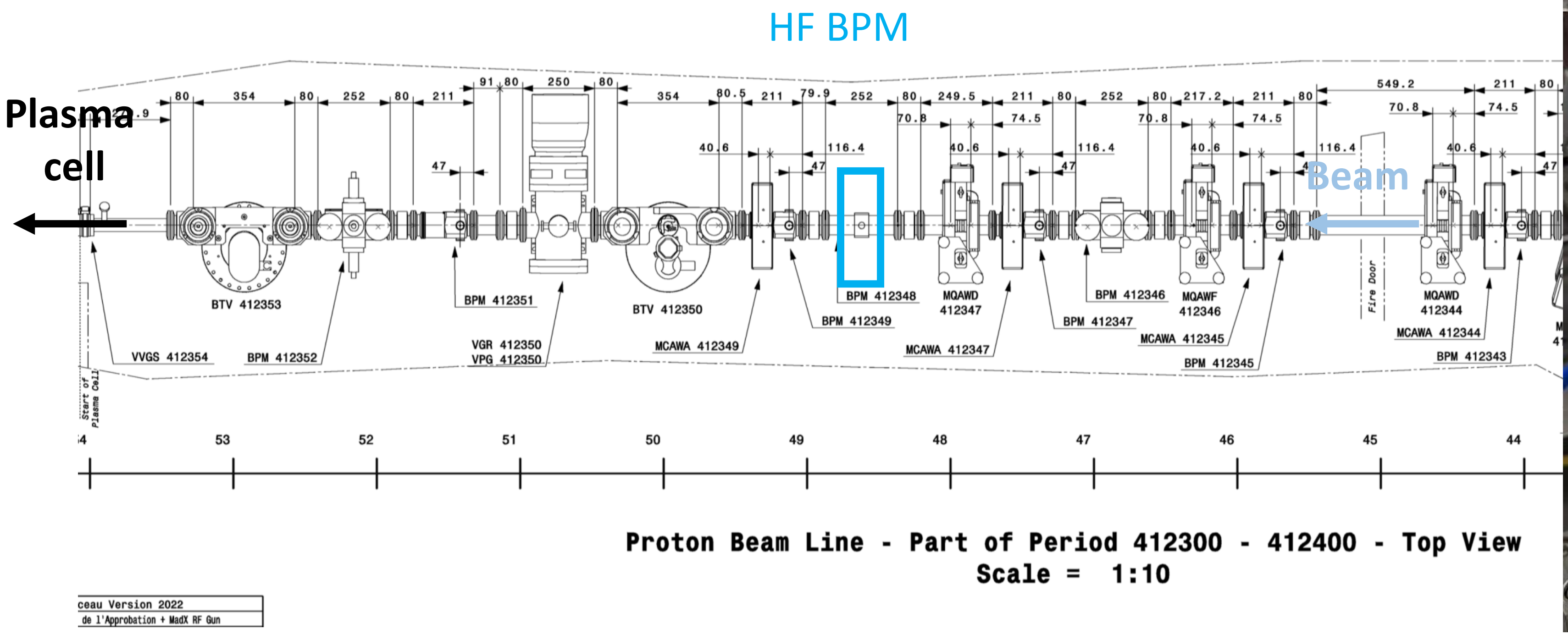
High Frequency button based BPM

- One HF BPM installed between the ChDR BPMs
- 2 symmetrical planes



Proton Studies

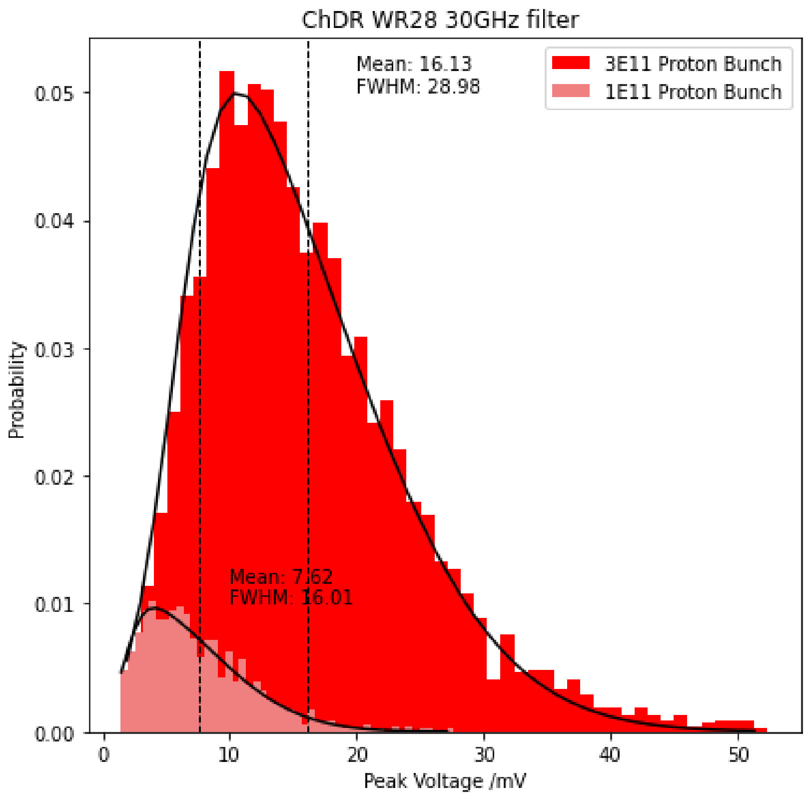
- Determining the signal contribution from the Protons for both the ChDR BPM and HF BPM in different frequency regimes

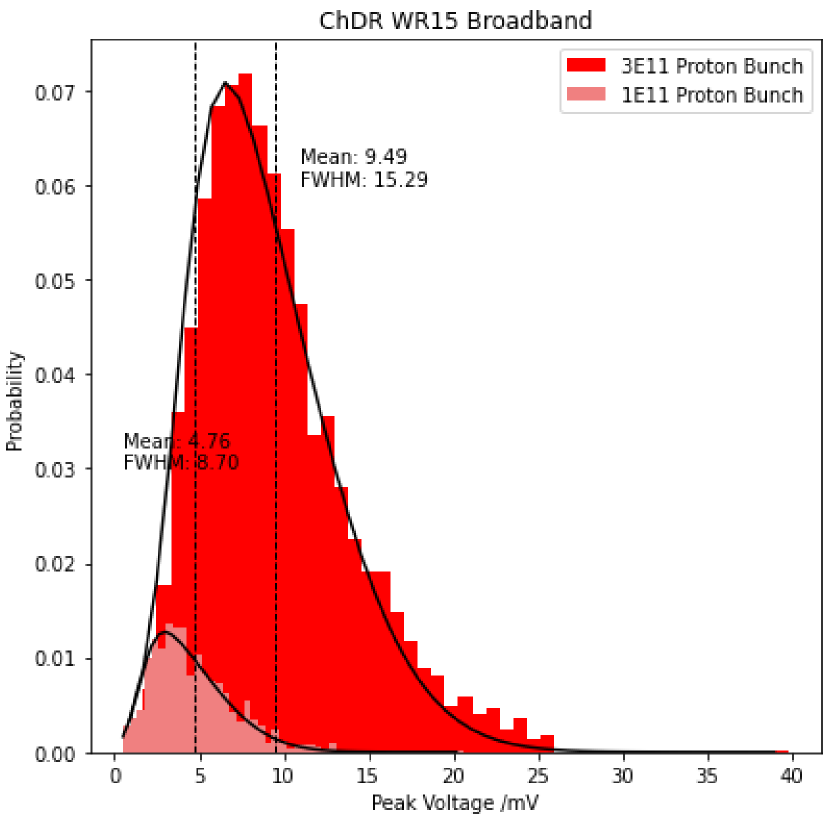
- ChDR ranges tested: WR28(26.6-40GHz), WR15(50-75GHz), WR10(75-110GHz), Filtered WR28(30GHz-40GHz)

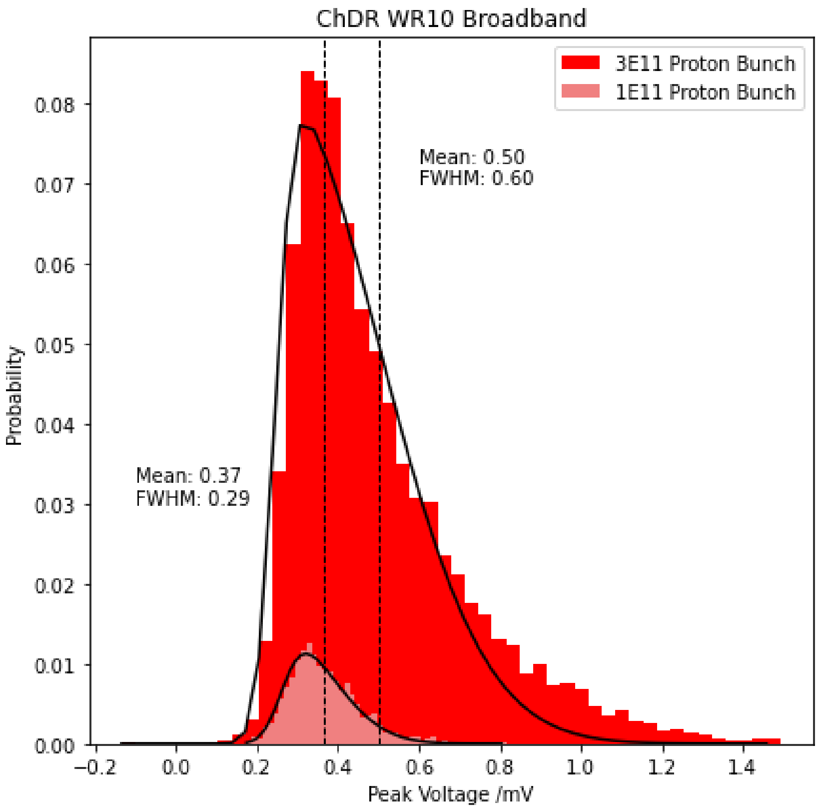
- HF ranges: 26GHz Filter, through 40GHz Diode detector (Coaxial)

Example setup for the ChDR BPM

Proton Studies

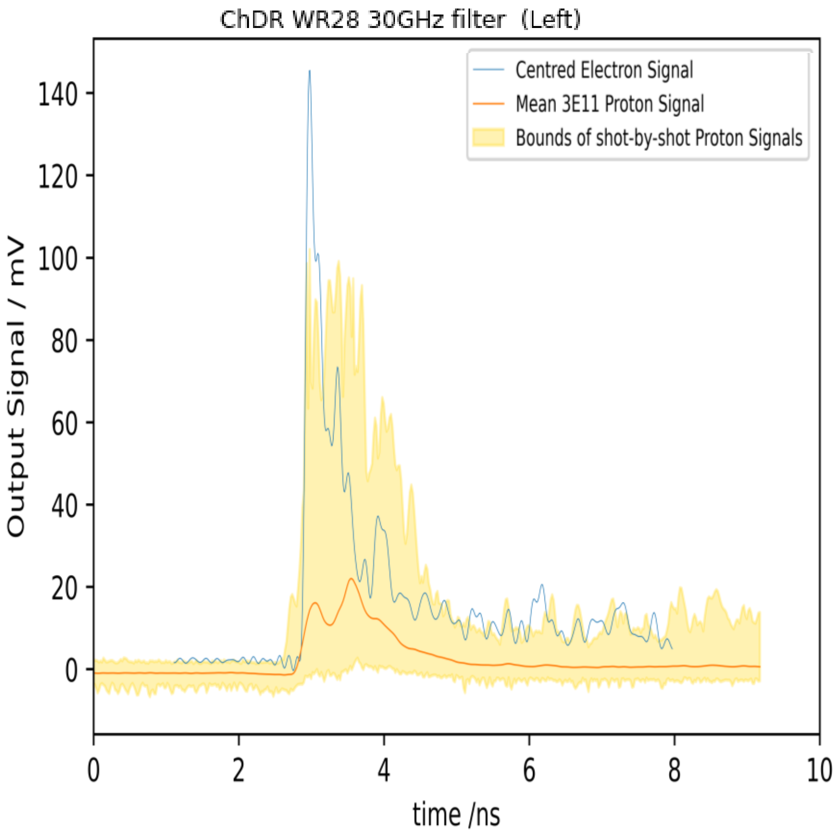




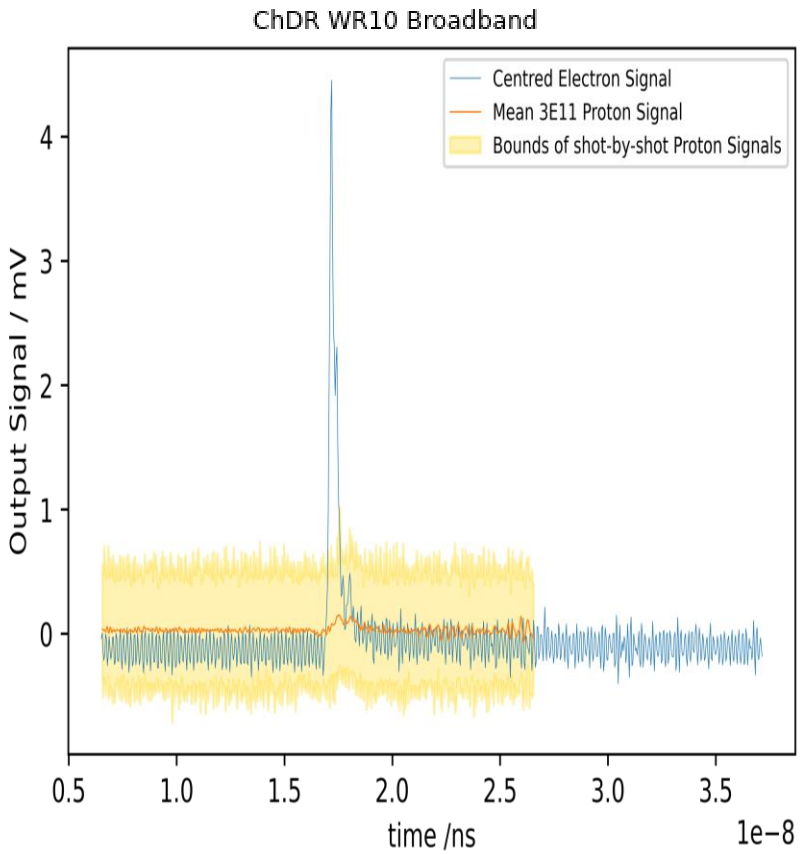


- For each Proton shot over 5000 shots, the Proton signal was recorded on a 8GHz Oscilloscope
- For both 1E11 and 3E11 protons

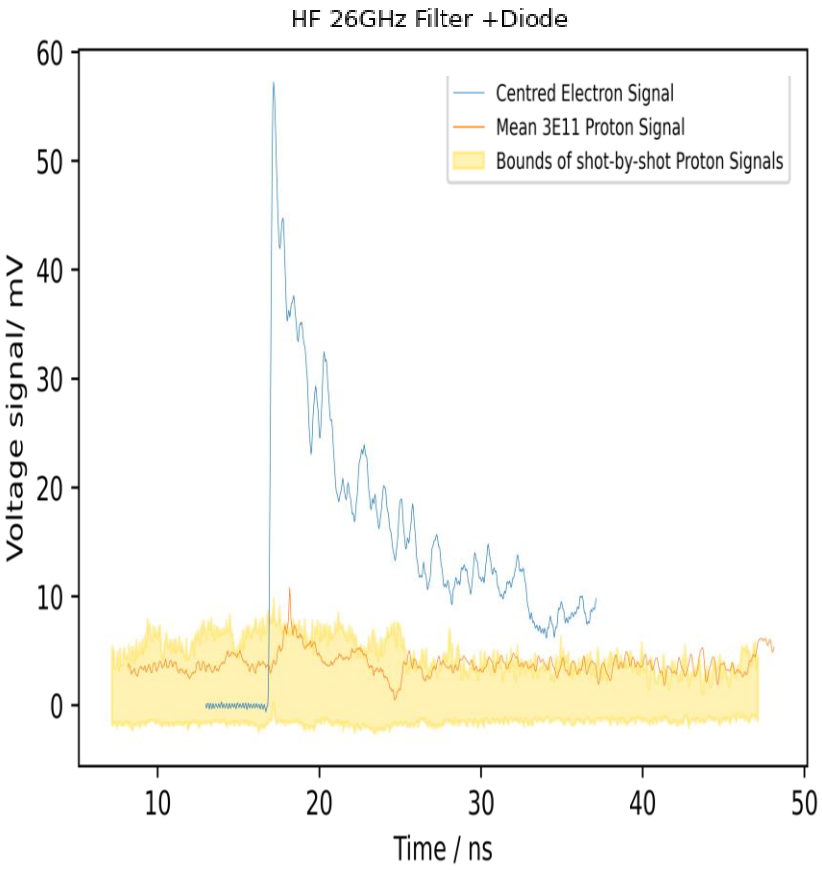
Proton Studies



- Up to 70% of 300pC electron signal



- Up to 3% of 300pC electron signal

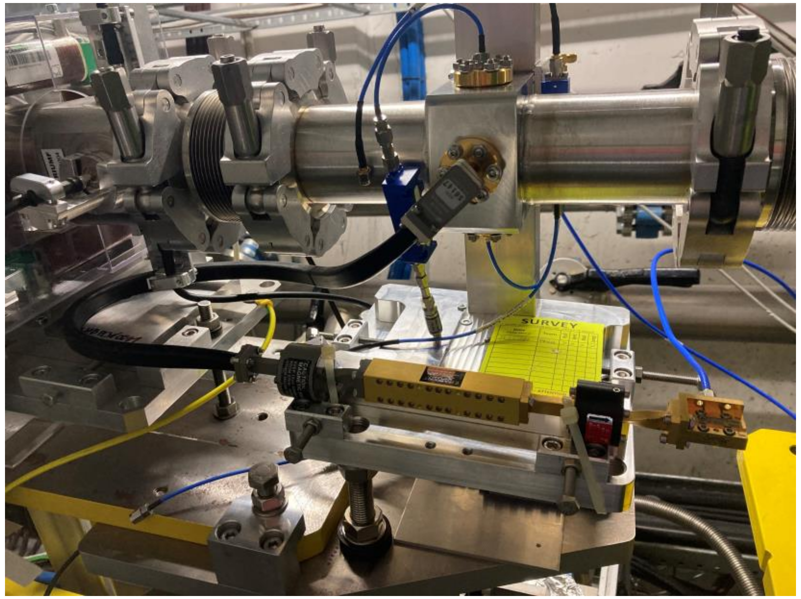


- Up to 15% of 300pC electron signal

Proton and Electron Studies

The Ka-Band read-out arms are identical and pass a frequency range ~20...32 GHz, given by the low-pass filter and the WR28 dimensions. At the end there is a Ka-Band diode detector.

The ChDR radiator is connected through a quarter wavelength - transformer to the WR28 read-out arm, the HF-button utilizes a R281B coaxial-to-WG adapter
and a flexible WR28 waveguide.

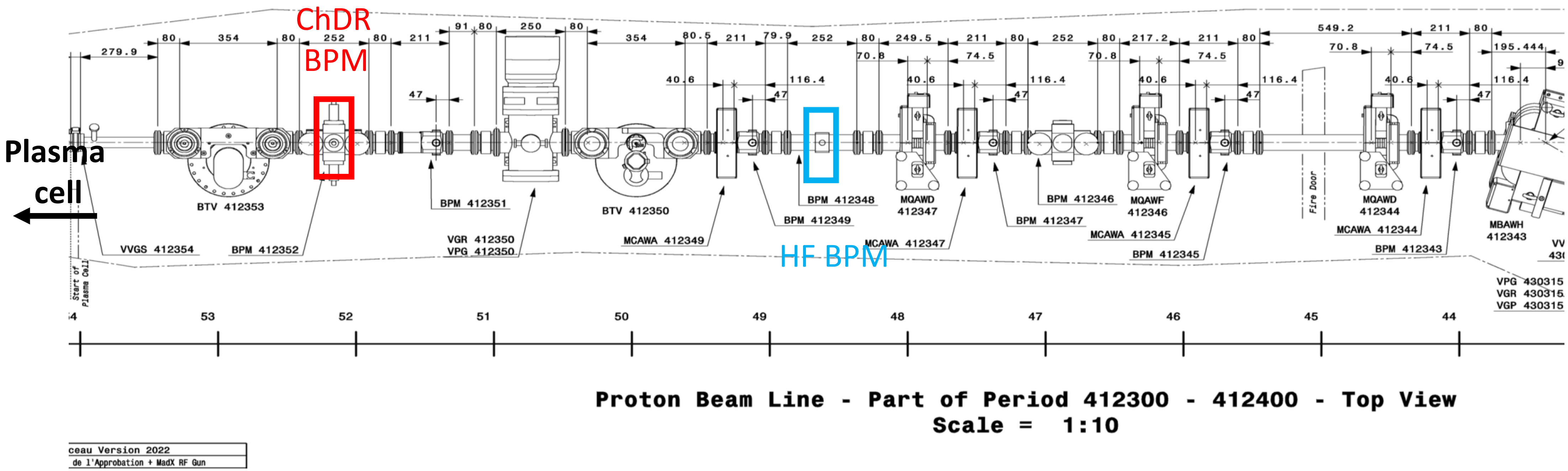


Single arm read-out only

Proton and Electron Studies

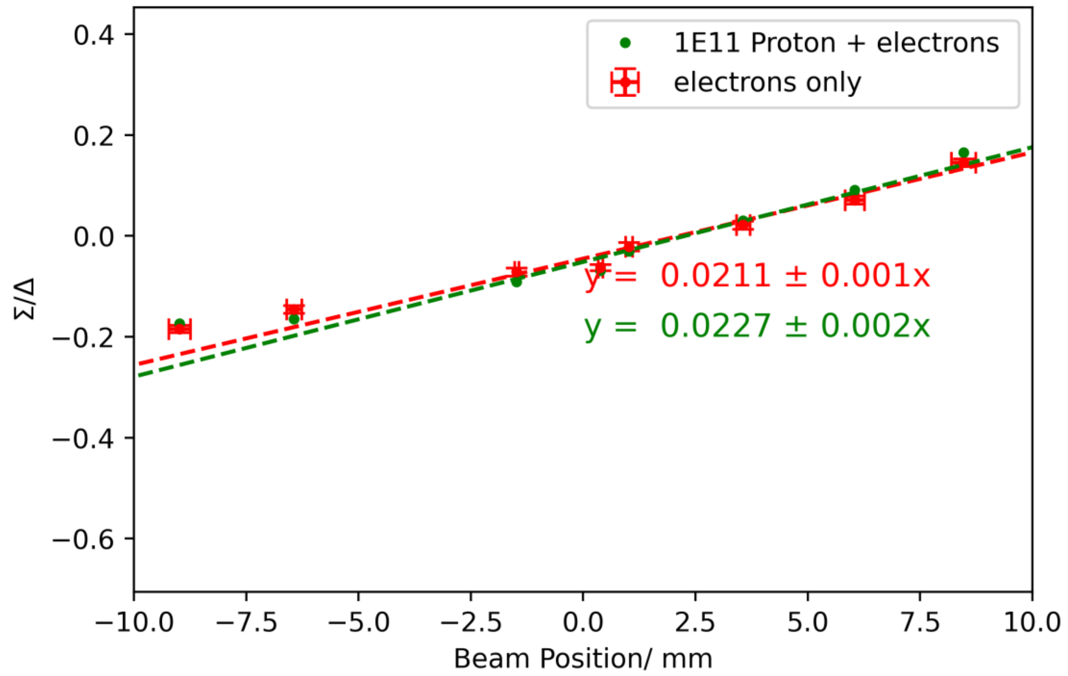
Only the horizontal planes of the 2 BPMs under investigation

- ➢ Quadrupoles 45,47 turned off
- ➢ Correctors 47,49 turned off
- ➢ Steering the beam on MCAWA412345 in the horizontal plane

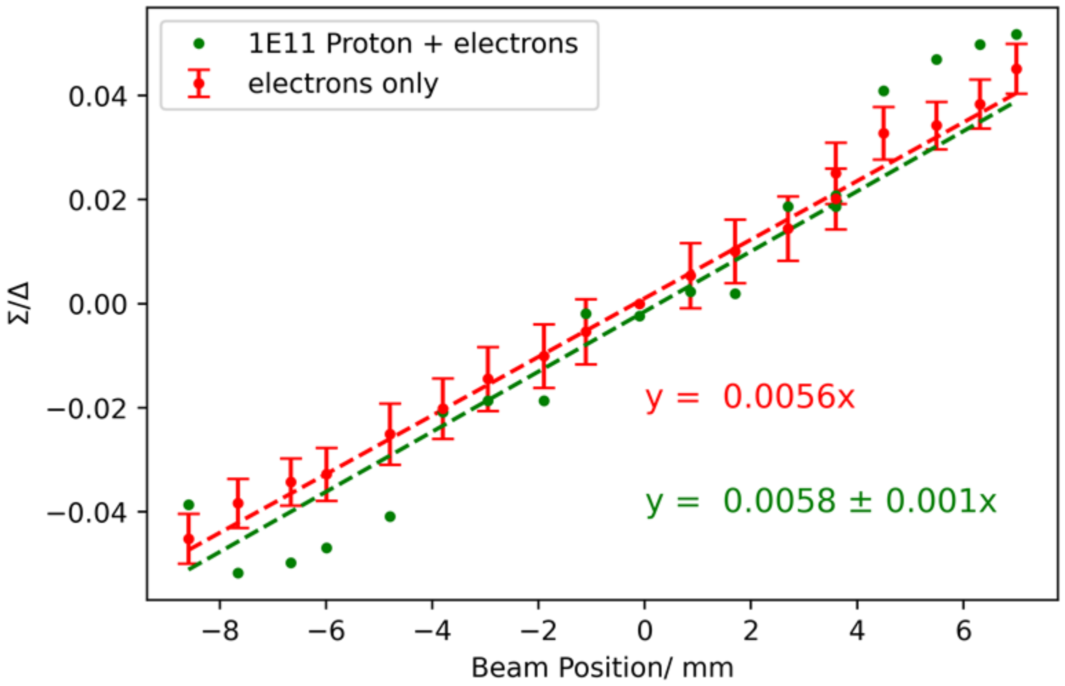


Electron Position scan with Low Intensity Protons

ChDR BPM



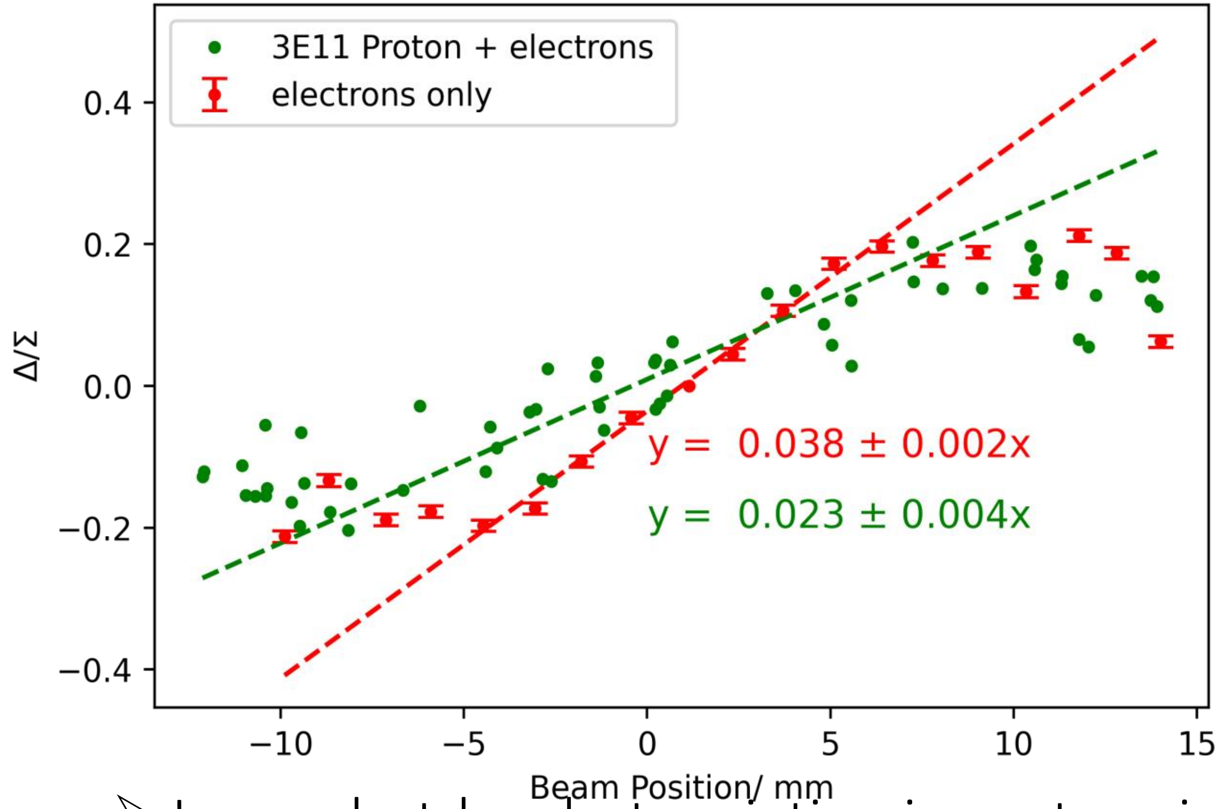
HF BPM



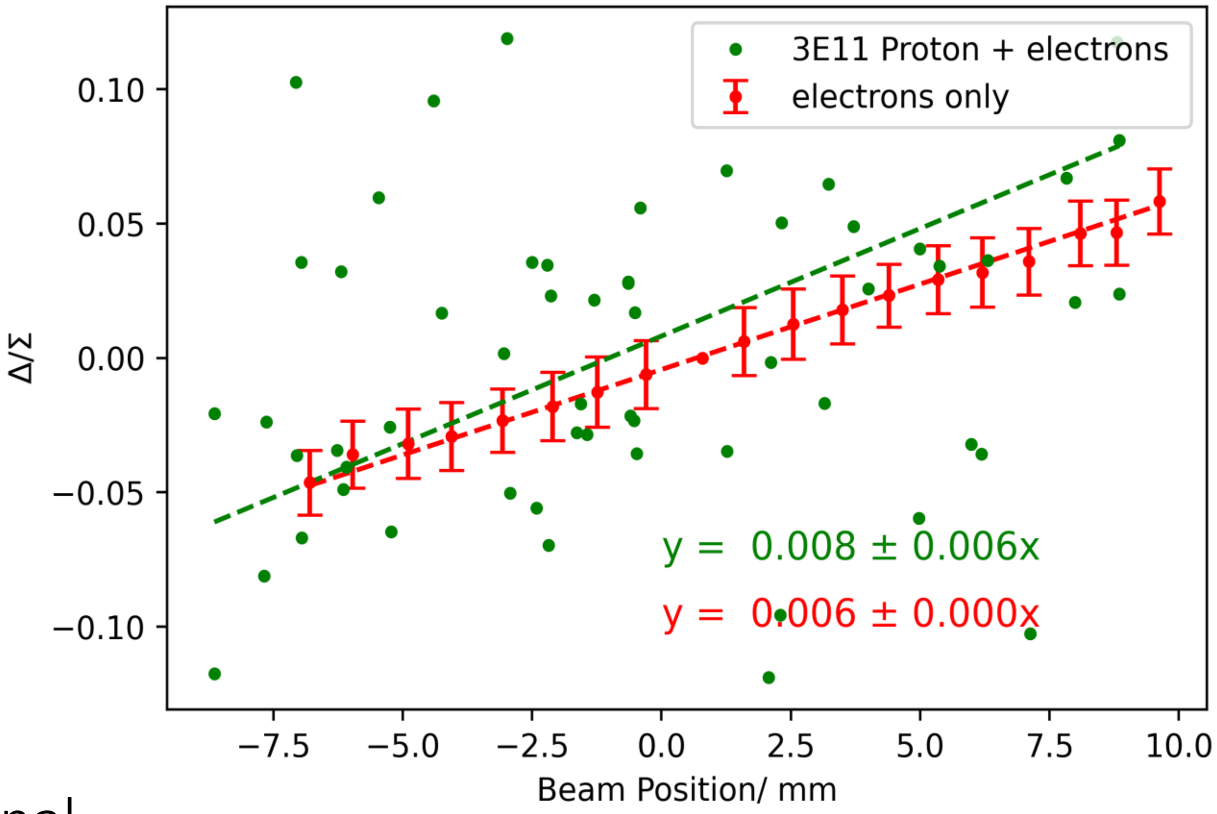
- Sensitivity is consistent between electrons, and Protons + electrons over ~ 10mm at 1e11 bunch intensities

Electron Position scan with High Intensity Protons

ChDR BPM

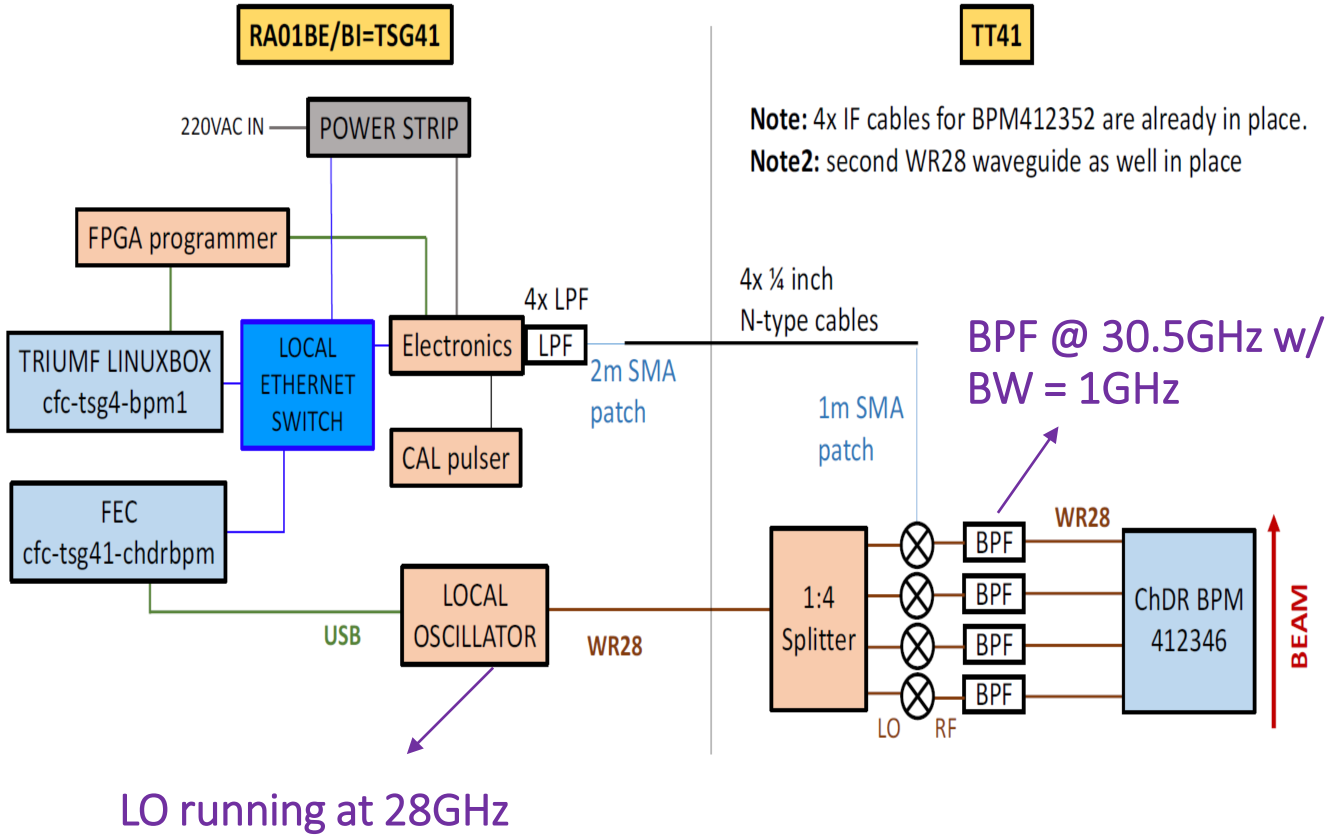


HF BPM



- Large shot-by-shot variation in proton signal
- Position sensitivity has deteriorated at high proton bunch intensities

TRIUMF commissioning + installation



Current Status

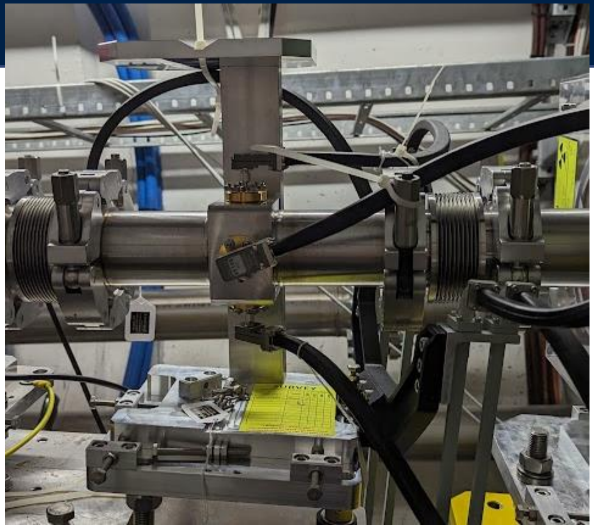
- First TRIUMF installation in 2022
- Minimal beam tests completed, no further investigation until October 2023
- Digitiser characterised and commissioned with help from TRIUMF personnel

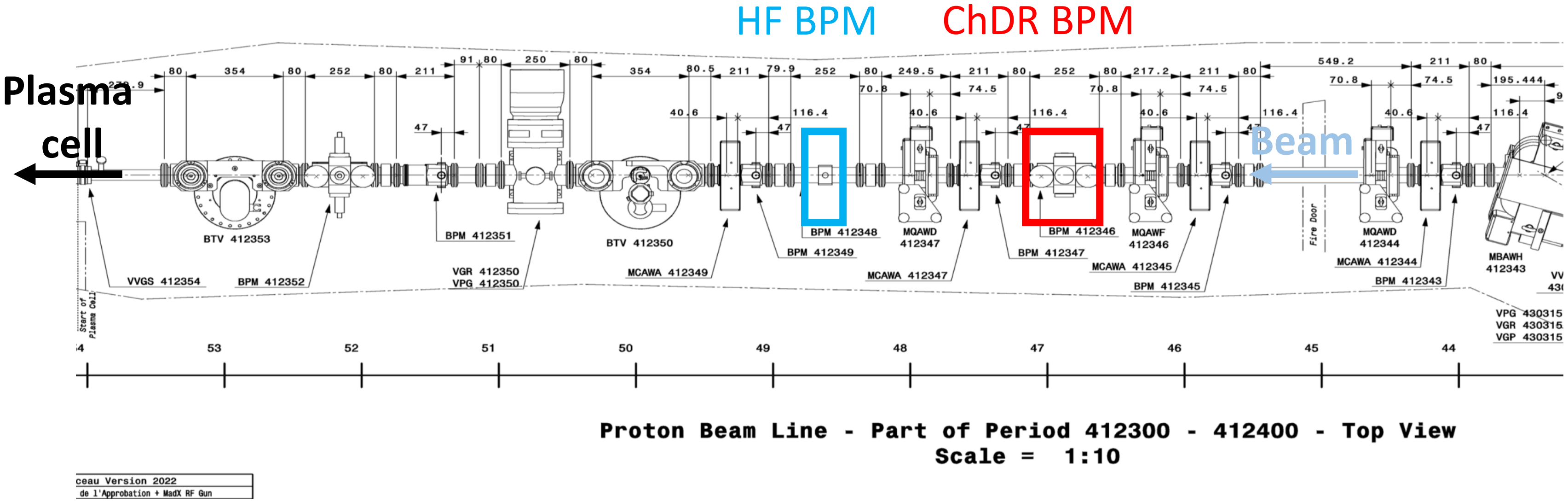
- Installation and connection of additional digitizer and LO from TRIUMF on 28 September
- Calibration of WGs, mixers, in-line filters and cables with CW source on 5 October
- Calibration/commissioning of new digitizer less trivial – black box, requires some time to understand the system and get it operational/publishing data on FESA

TRIUMF configuration

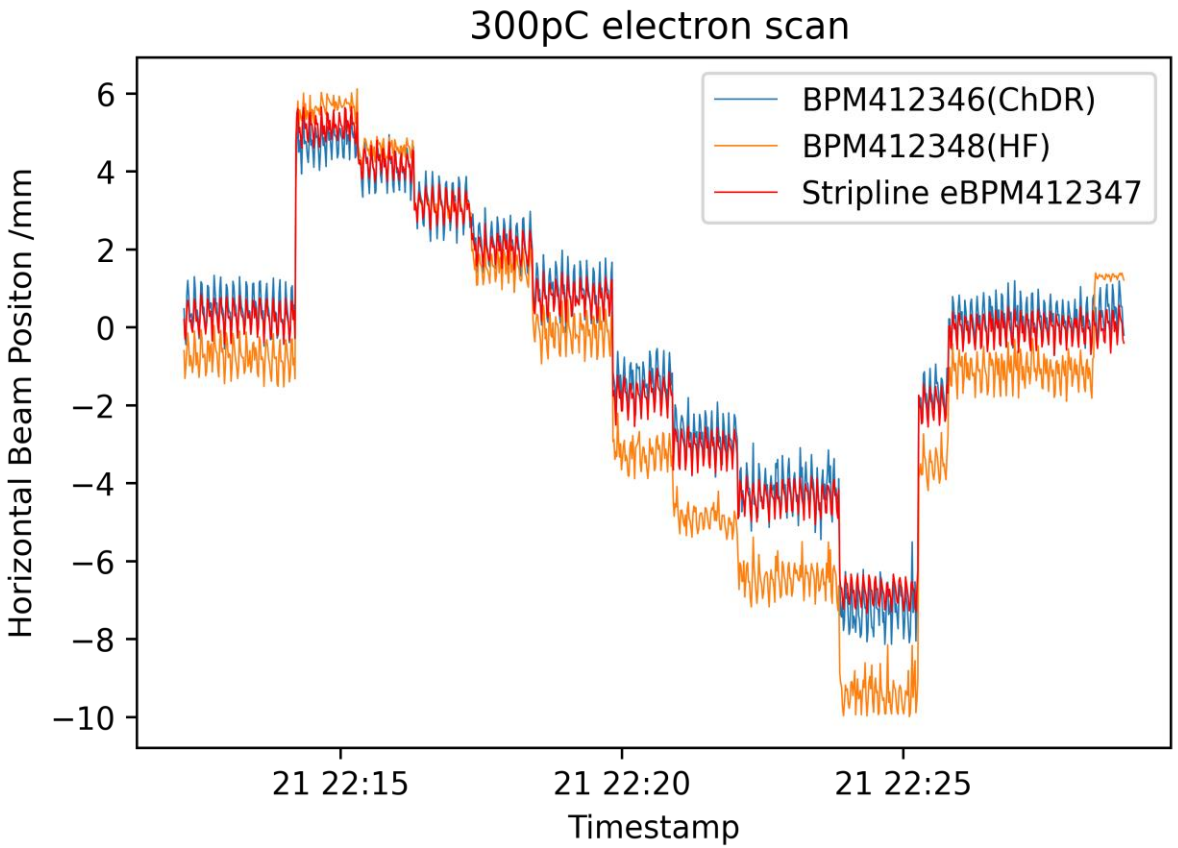
The upstream ChDR BPM and HF BPM

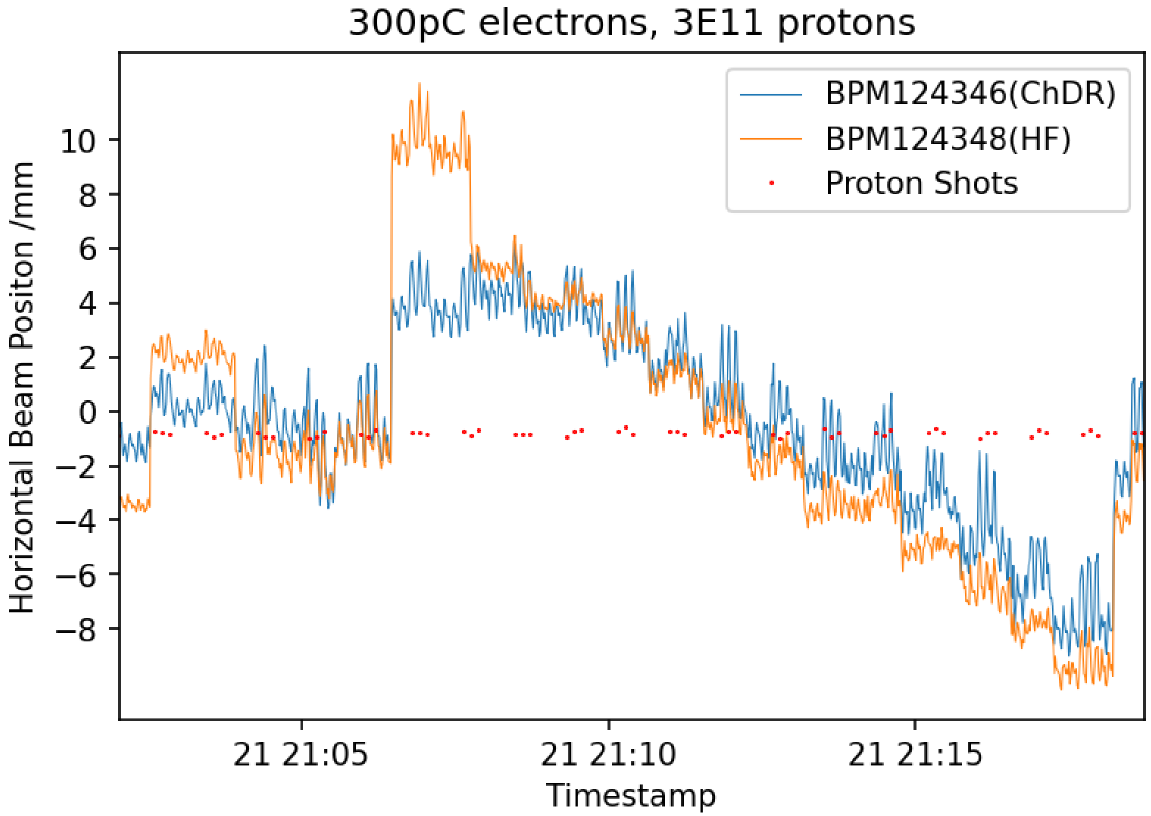
Only the horizontal planes of the 2 BPMs under investigation were connected to the original TRIUMF digitiser





TRIUMF Scans





- Nice agreement with current stripline eBPMs, but proton signal still appearing
- Linear relationship of BPM positions and gradient represents their respective distances to the corrector

Conclusions and Future Outlook

- Extensive testing of both BPM types over the course of this beam year
- Electron scans show we have very good sensitivity to the beam
- Proton studies indicate the spectrum of the proton bunch frequency content extends much higher than theorised
- Initial Proton and Electron tests show we have very good Proton discrimination at low proton bunch intensities

- Calibration of the second TRIUMF digiziter and connection of all channels of the ChDR and HF BPMs for complete horizontal and vertical position measurements
- With electrons: position scans with degaussed magnets, and comparison of performance e.g. resolution between stripline, ChDR and HF BPMs
- Electrons and protons: how well the ChDR BPM suppresses the proton bunch, again measurements of the resolution