R&D of the High Frequency and ChDR BPMs

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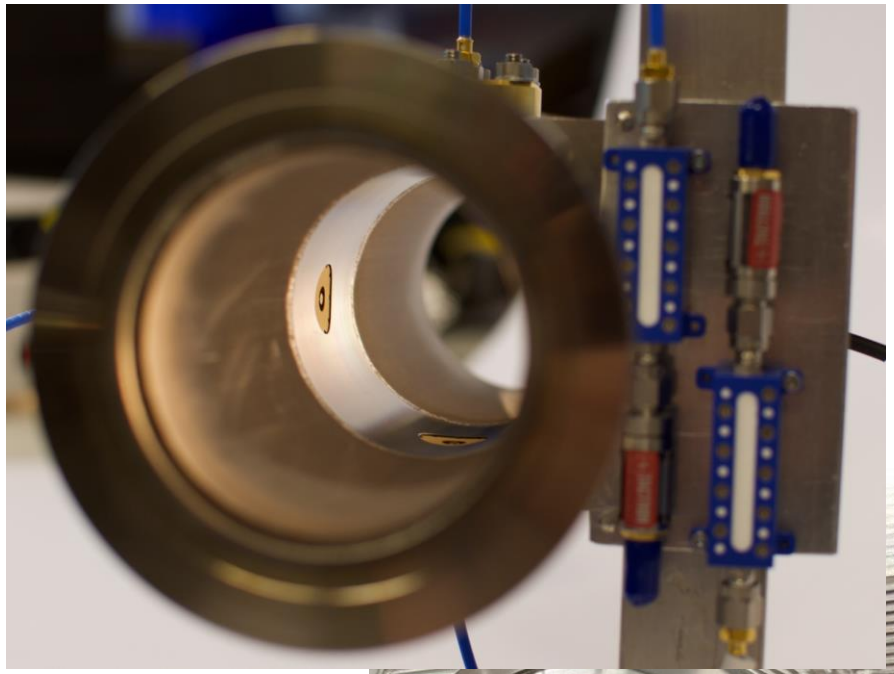
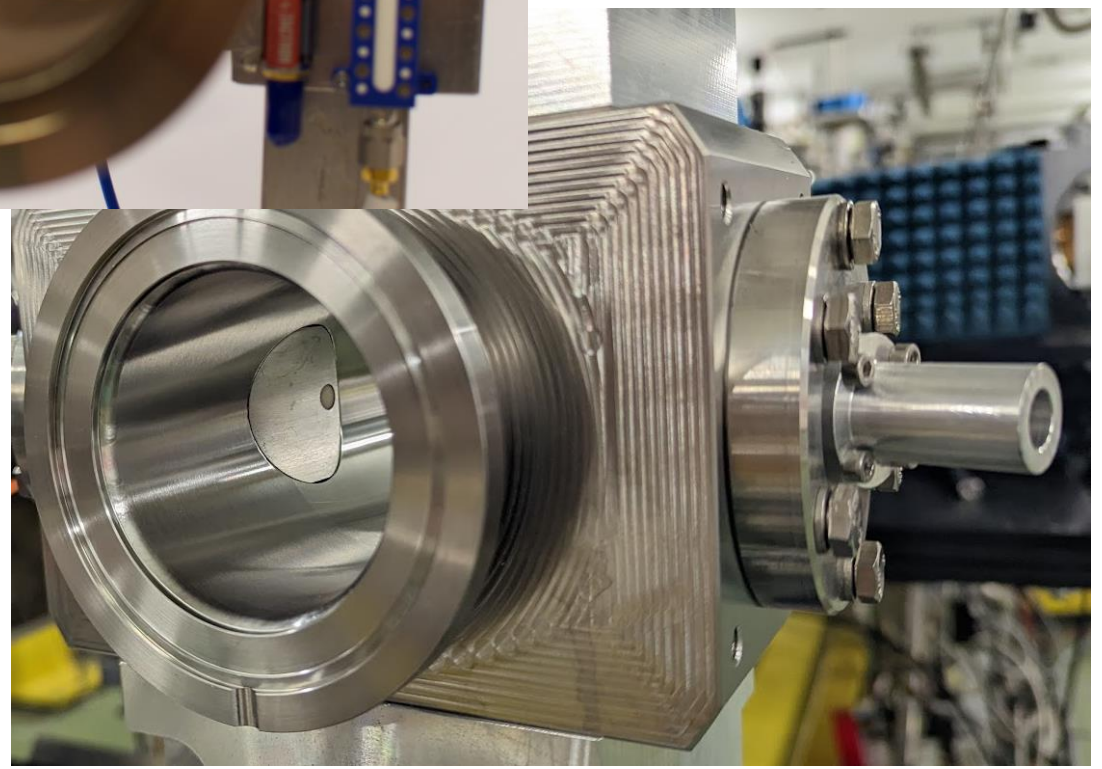
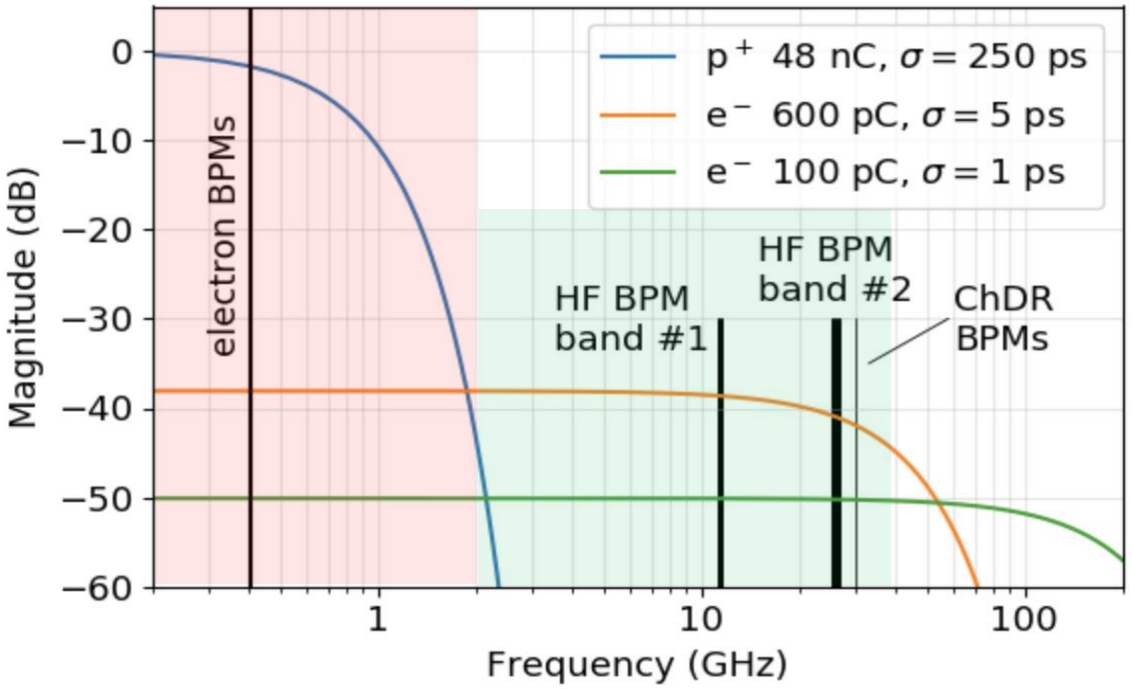
Outline

- Status of the ChDR BPMs
- 40GHz Button BPMs
- Outlook to Run 2b





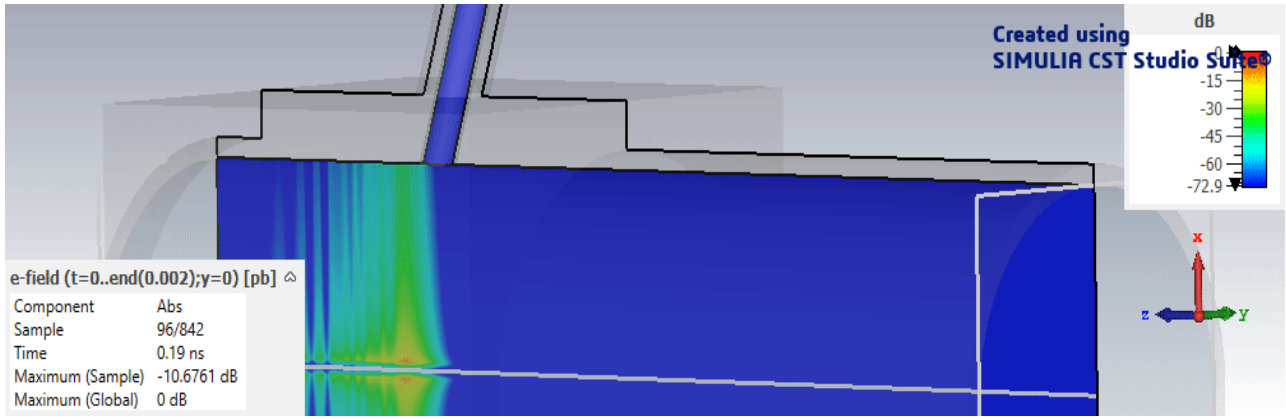
Measuring electron position in the common beamline



Protons stronger below 2 GHz

Electrons stronger above 2 GHz

- Cherenkov-Diffraction Radiation is a type of polarisation radiation that is generated when a charged particle beam passes in close proximity to a dielectric
- Highly directional, emitted at the Cherenkov angle 71° in alumina

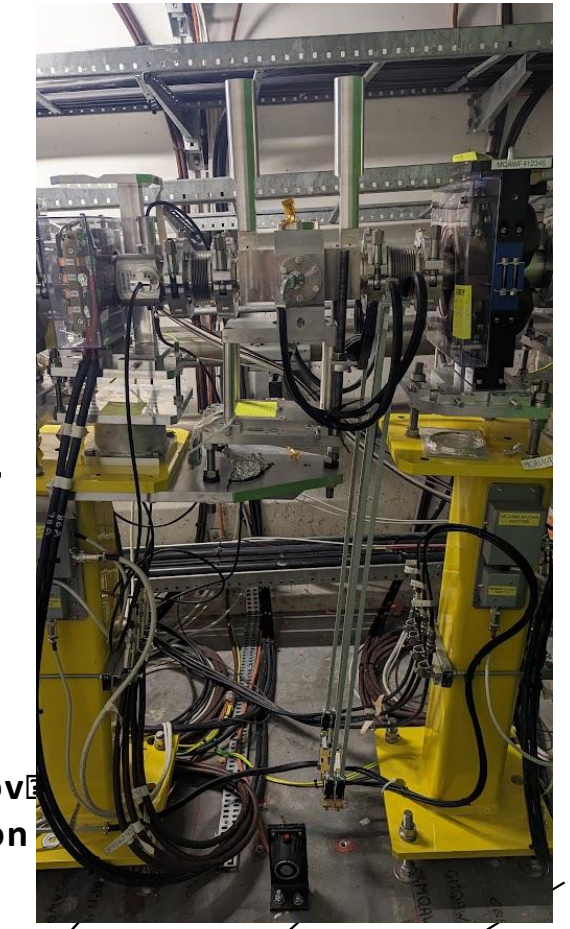


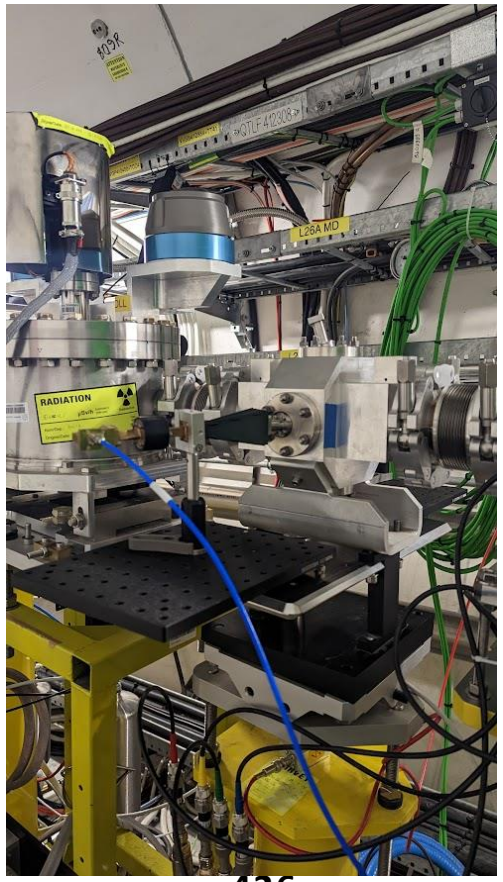
Need for a system performing the detection at sufficiently **high frequencies**

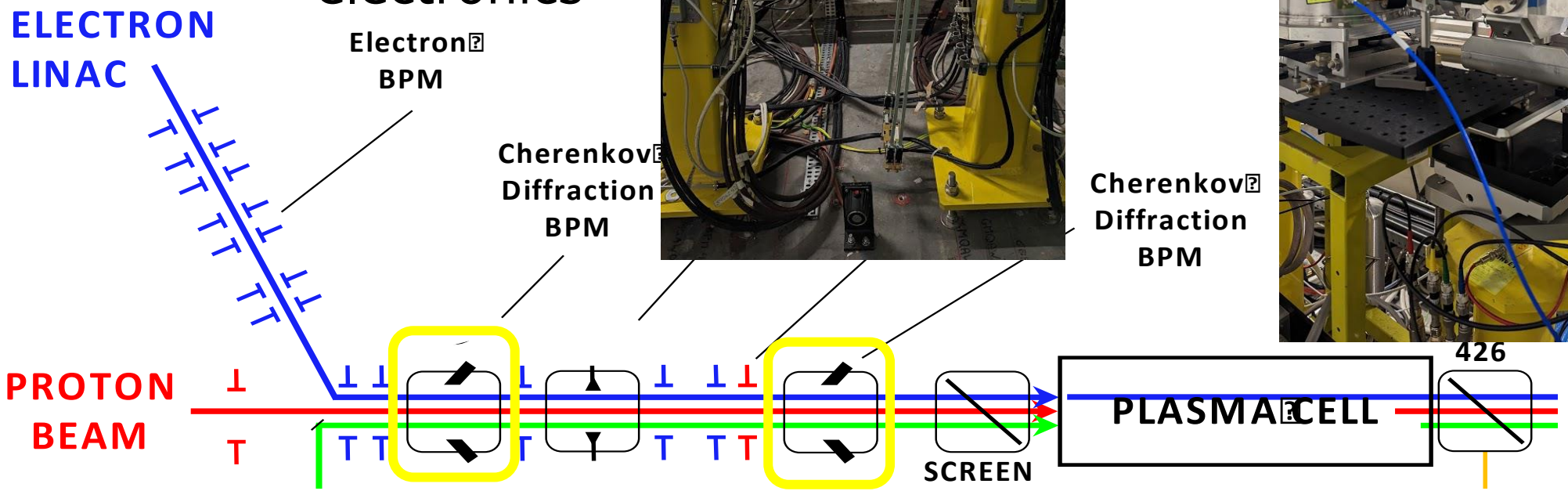
From simulation: 6.4 %/mm position sensitivity
Linear region ±5 mm
Image current model 6.7 %/mm

Current AWAKE Setup

- 2 x ChDR BPMs Installed in AWAKE
  - 1 installed with TRIUMF electronics
  - 1 installed with 2 mounted optical boards on either side

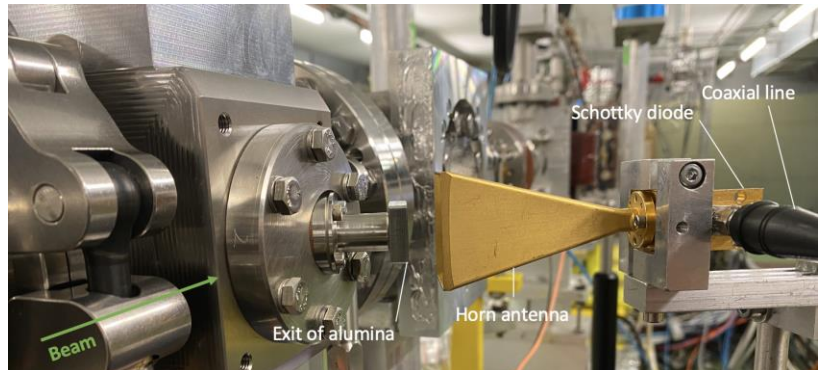




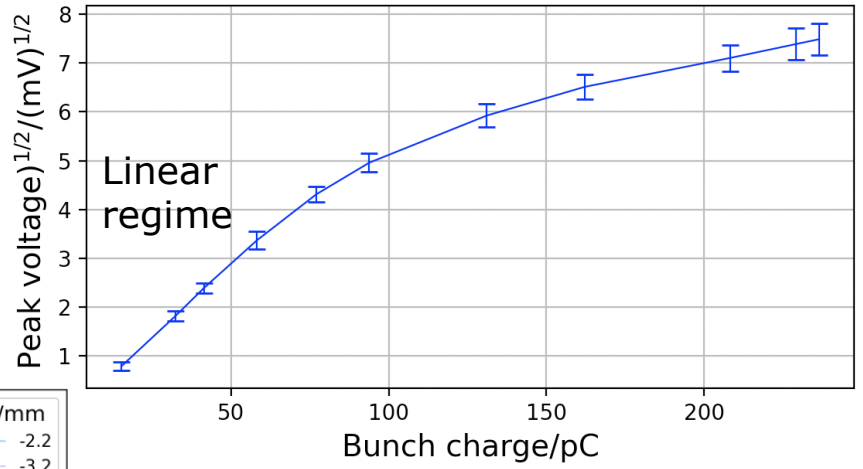


Summary of results from CLEAR testing in 2022

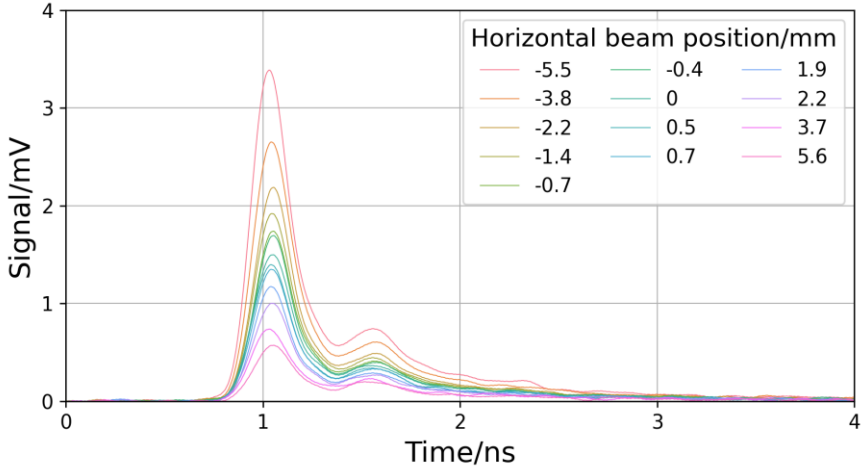
- Three different frequency ranges tested at CLEAR, 26.5 – 40 GHz, 50 – 75 GHz and 75 – 110 GHz
- Set-up was horn antenna, Schottky diode detector, coax to scope outside of tunnel

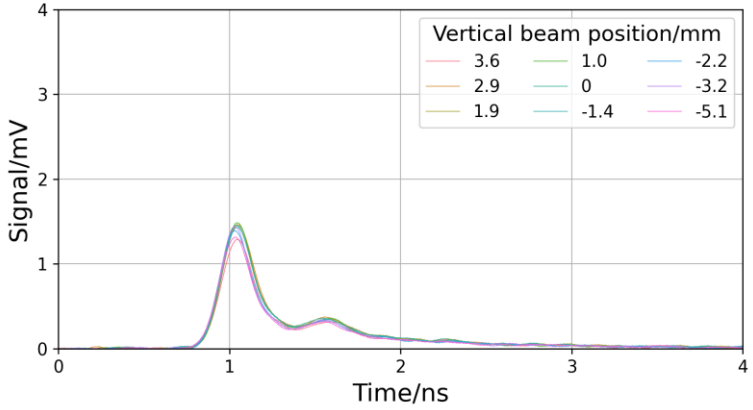


- Charge scan to get response of diodes, tried to operate in the linear regime where input voltage of diode is proportional to the bunch charge



- Beam position scans in horizontal and vertical e.g. below are signals from one arm when beam position is scanned in each plane for WR15 (50-75 GHz).





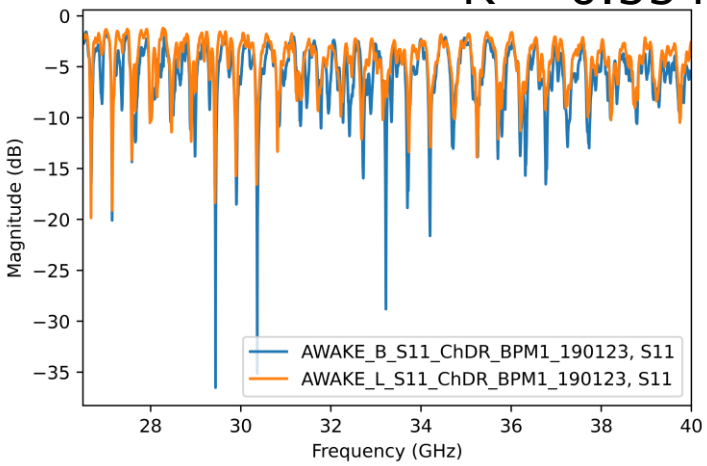
Slide provided by C.Pakuza

Preparation for Run 2b

- ChDR buttons measured with a VNA up to 44GHz and matched according to most similar reflection coefficients
- 8 swaps were made in total including those from CLEAR
- Copper shields installed in the bellows on either side of the downstream BPM

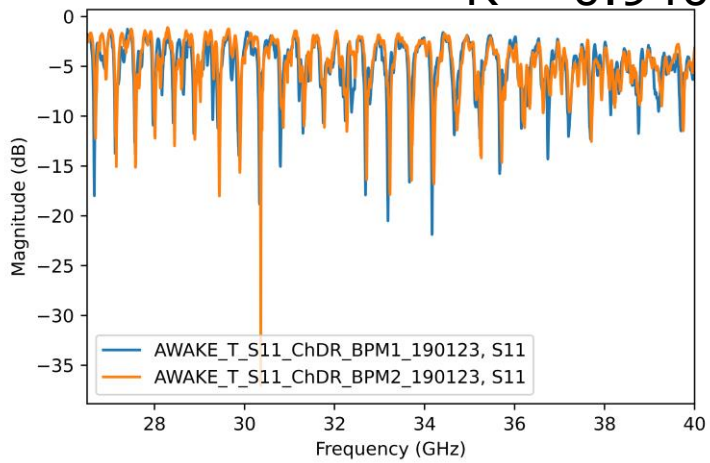
Before Matching

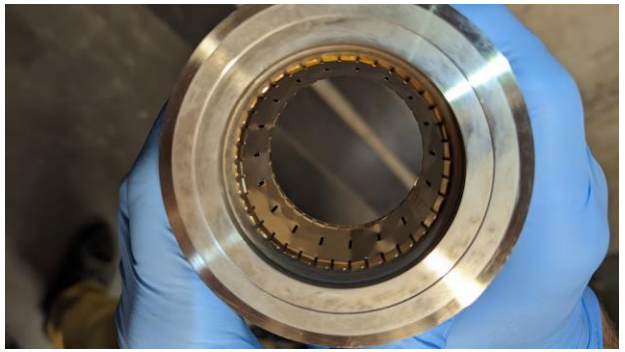
R = 0.554



After Matching

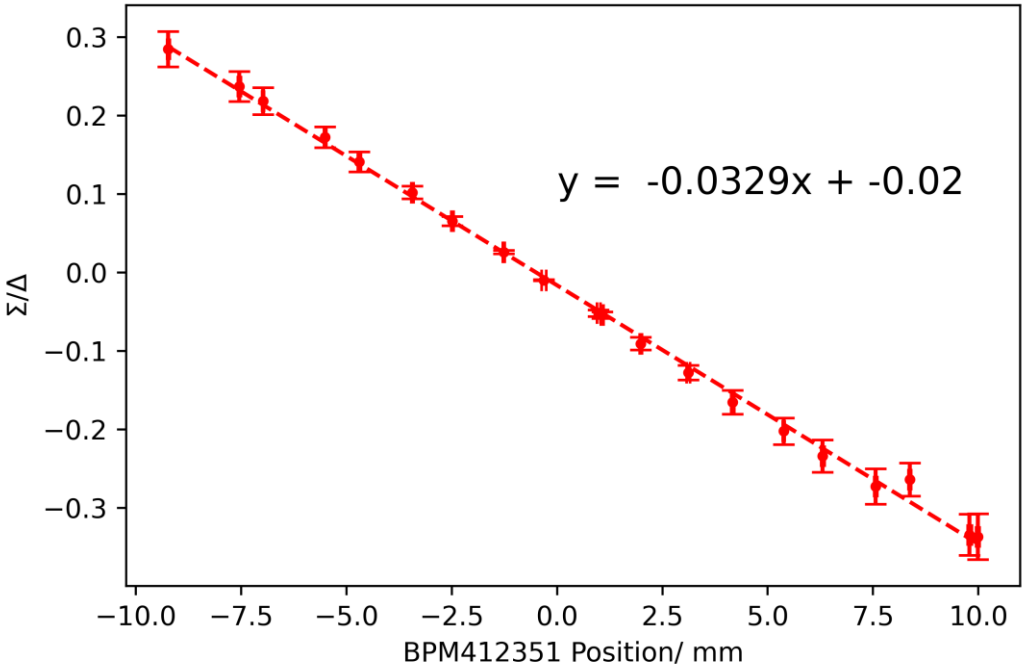
R = 0.940

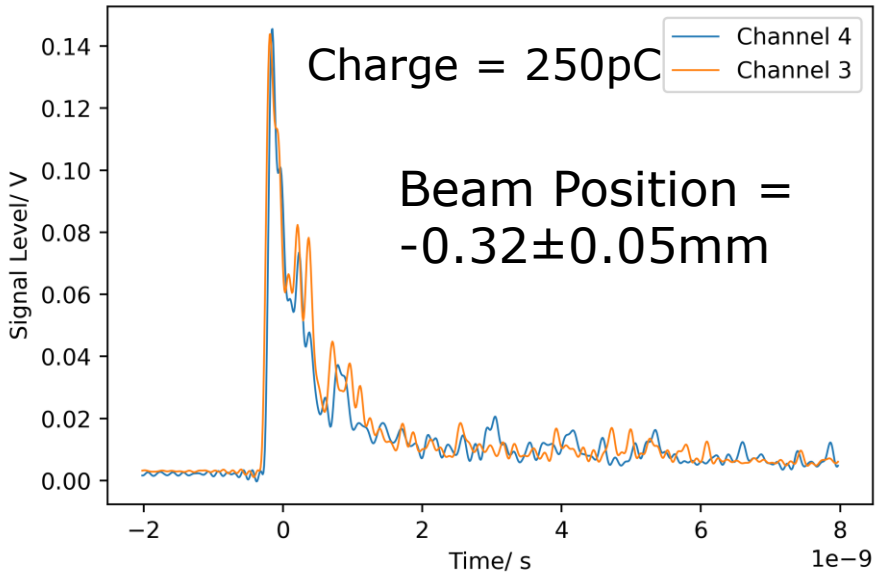




Recent results from the ChDR BPMs

- Recent studies conducted in AWAKE with a symmetrical WR28 setup
- Acquisition via 8GHz oscilloscope





First peak shows nicely symmetrical intensity and shape

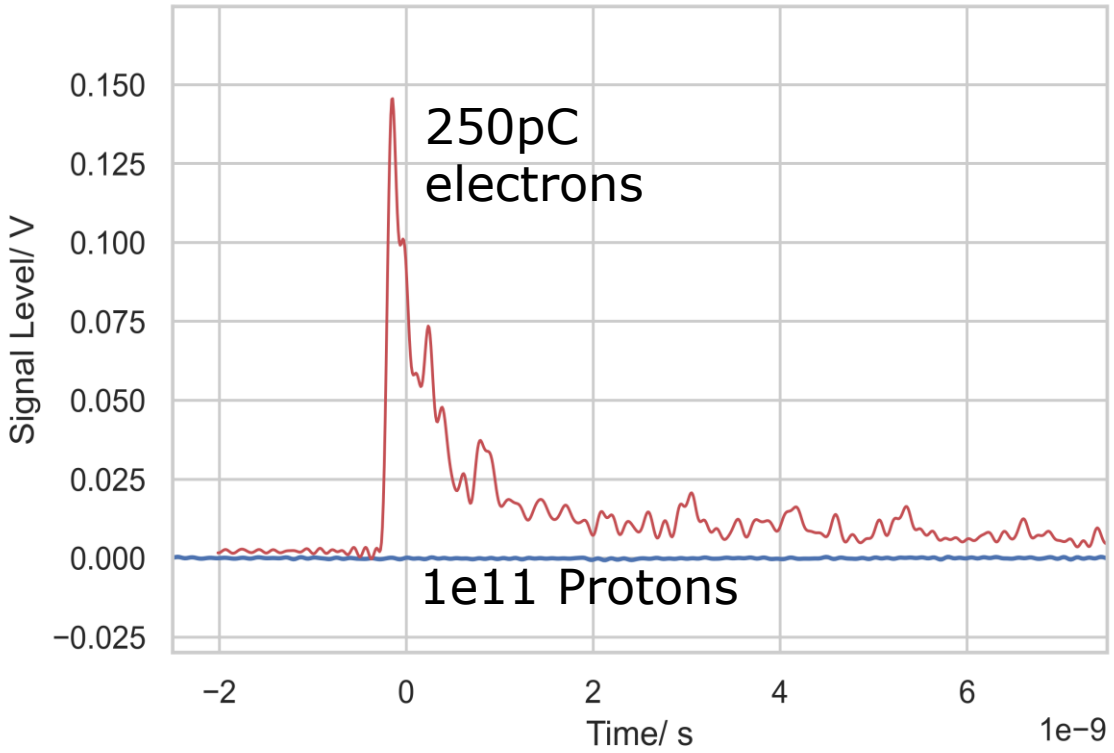
Trailing peaks have a larger waveform asymmetry

Position sensitivity results from the 21/04/23
Horizontal position scan
20-40GHz Frequency band

- Non-linearities of the detector diode still need to be taken into account

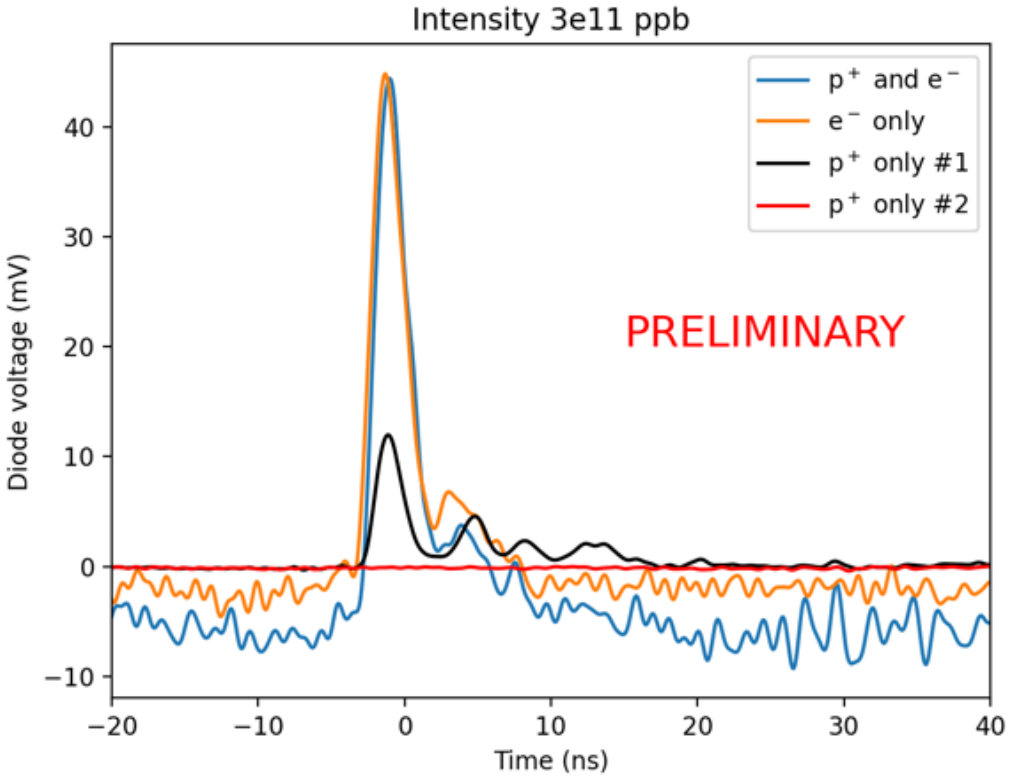
Proton sensitivity

62 proton shots recorded on the 13/04/23



- Very small signal from protons of order of 0.6mV
- <1% Signal measured from electrons

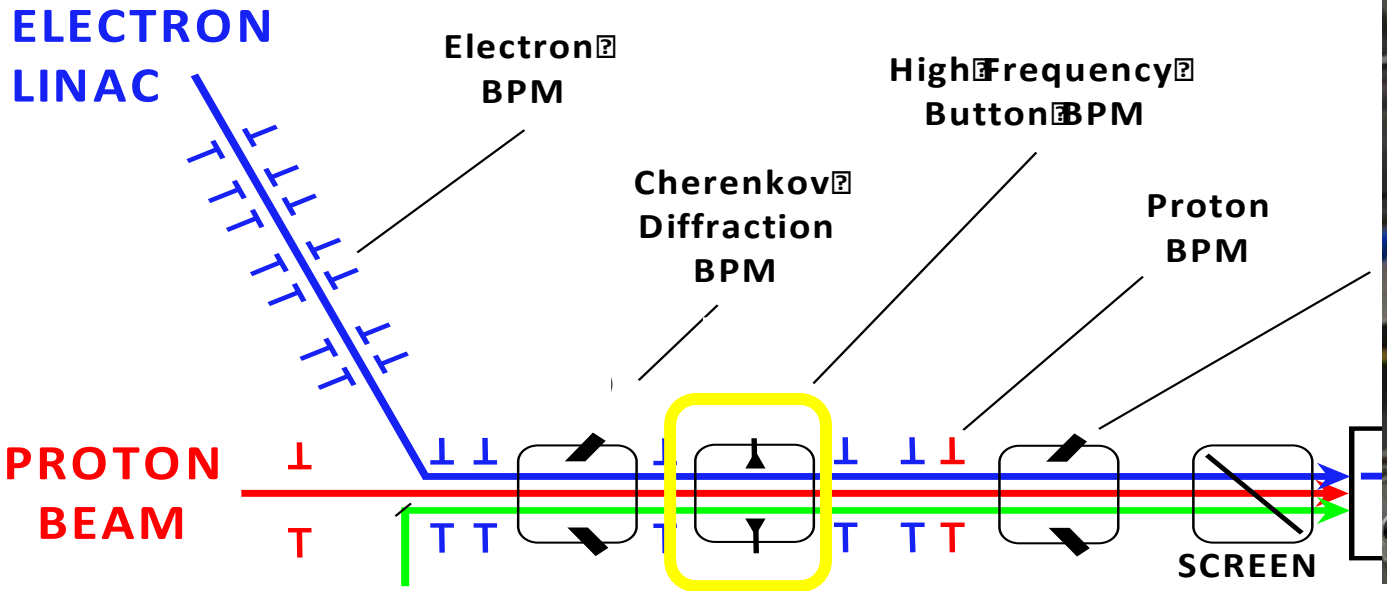
- However previous testing shows significant signal from more intense 3e11 protons
- Need a thorough statistical study at these higher intensities over all considered frequency bands

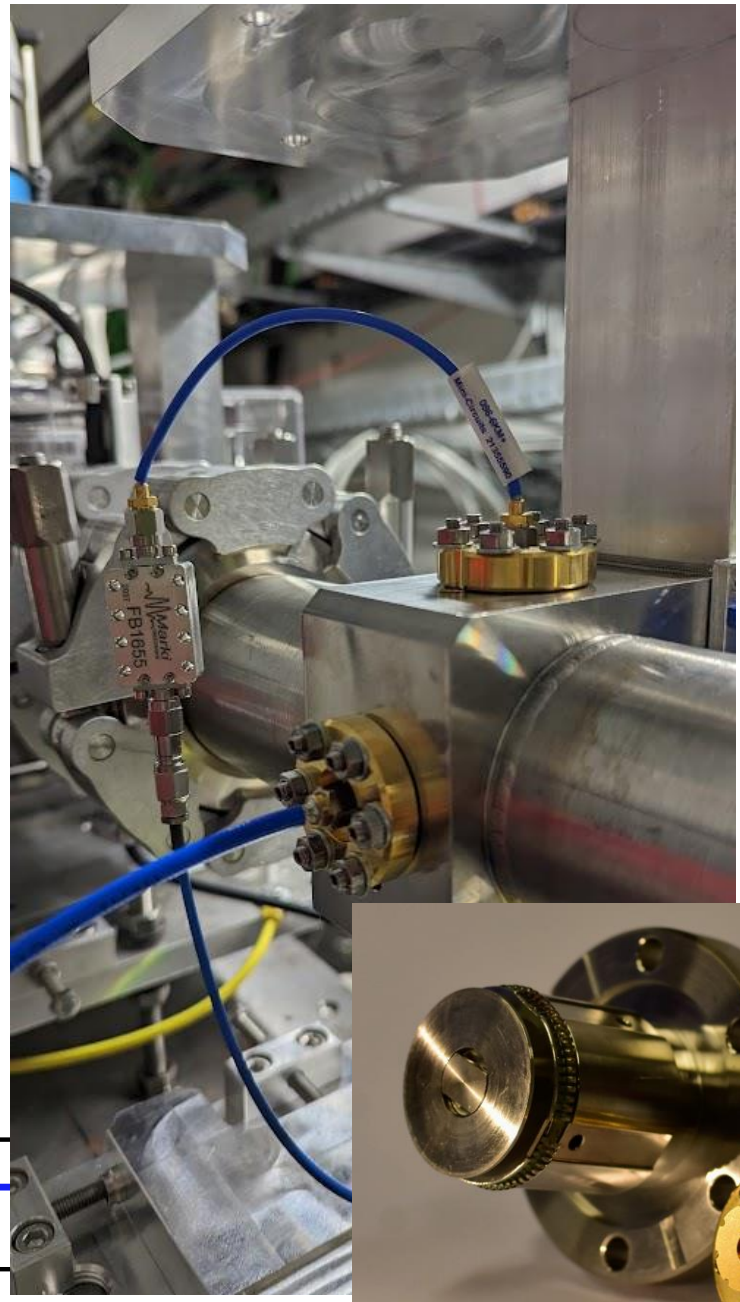


E.Senes

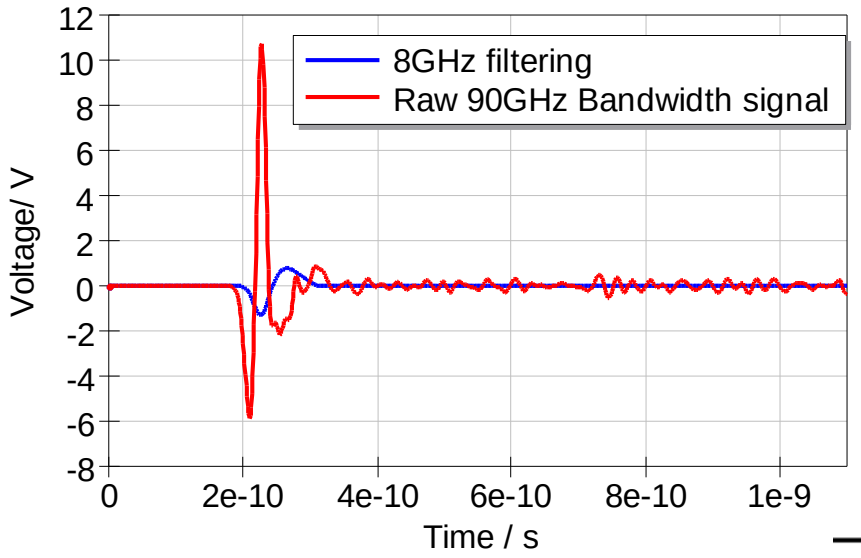
High Frequency Button BPMs

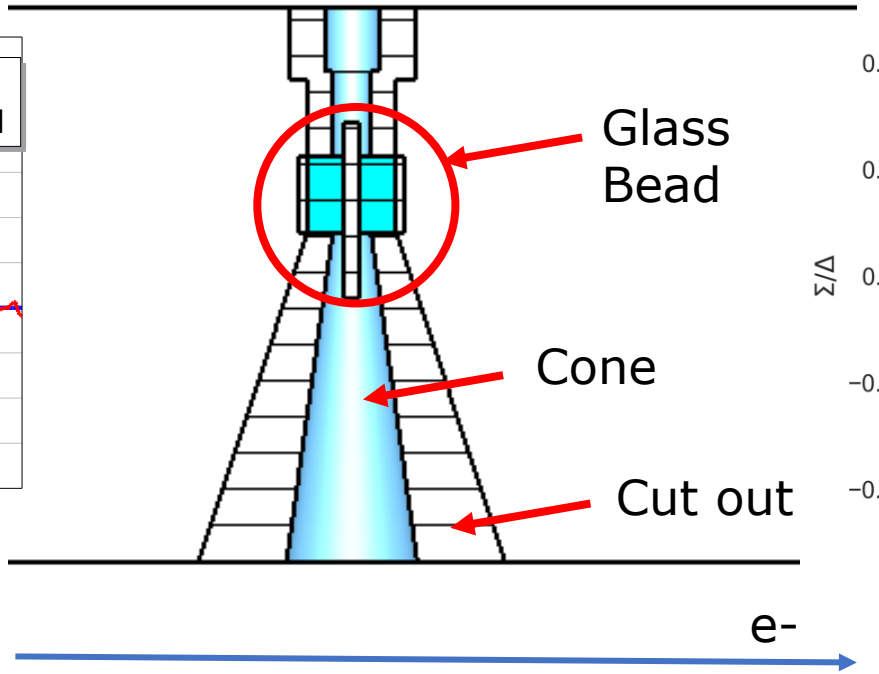
- One design in literature working up to 40 GHz
  See A. Angelovski et al., Phys. Rev. ST Accel. Beams **15**, 112803 (2012)
- First tests April-May 2022
- **Concluded that a systematic comparative performance study to be performed,** to understand if they suit better the AWAKE needs than ChDR buttons

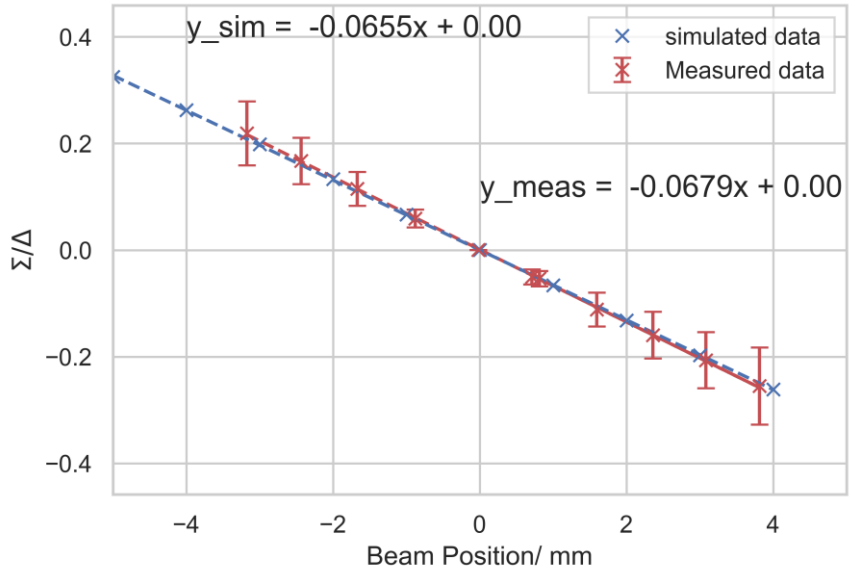




Characterisation of the HF BPMs







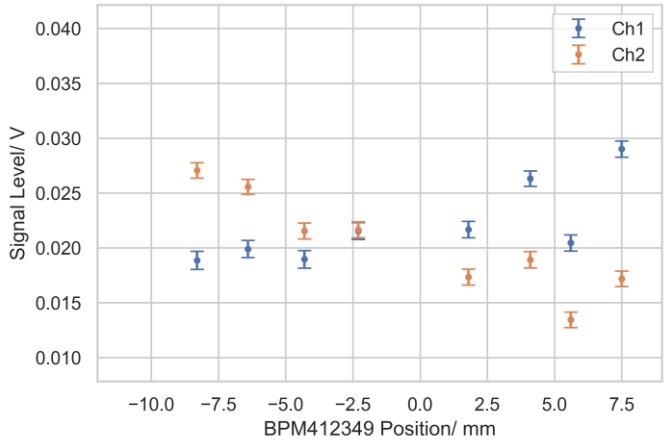
- Filtering at 8GHz reduces the expected signal to 10% of the full signal
- We also loose a lot of information about what happens at these higher frequencies

- Still some discrepancy between the Simulation and button measurements taken in the lab.
- A work in progress... A lot more work to be done to fully characterise the buttons

- Position sensitivity expected from a 320pC electron beam
- Measured data using direct coaxial connection to 8GHz scope

Recent results from the HF BPMs Dec 22 data

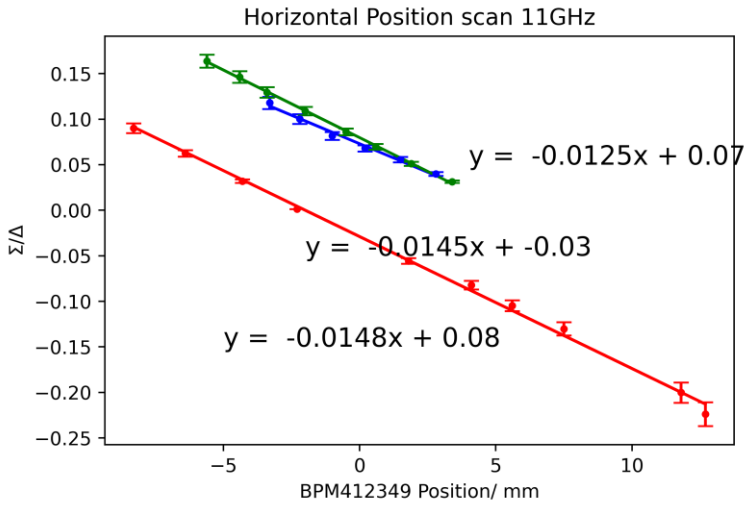
Horizontal position scan



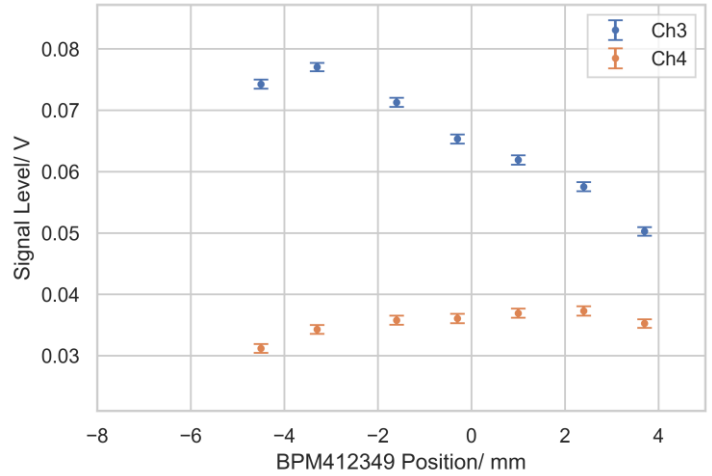
Electron Charge = 550pC

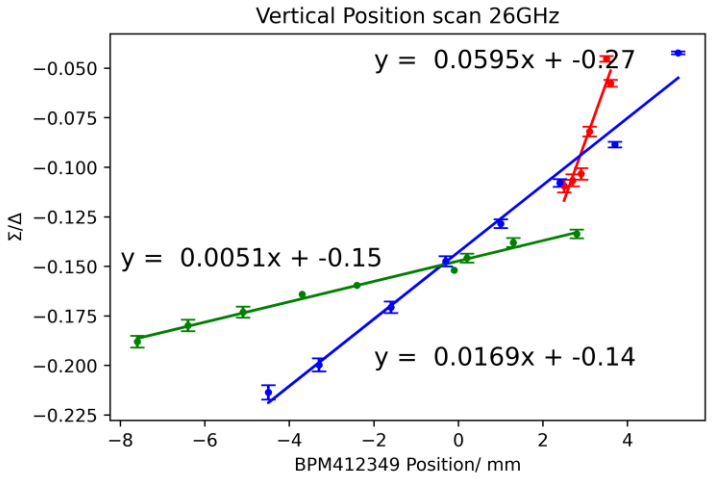
Device	Plane	Detection band
HF-BPM	x	11.375 ± 0.250 GHz
HF-BPM	y	26.25 ± 0.900 GHz

- 3 scans of each horizontal and vertical on the same day
- Acquisition through filter -> diode -> 1GHz Oscilloscope
- Horizontal scan with the 11GHz readout has fairly consistent position sensitivity between each scan ~ 1.4%/mm
- Poor consistency in the 26GHz scans, may be due to a fault in Channel 4 but more investigation/ repeat scans needed



Vertical position scan





Outlook

May Proton run

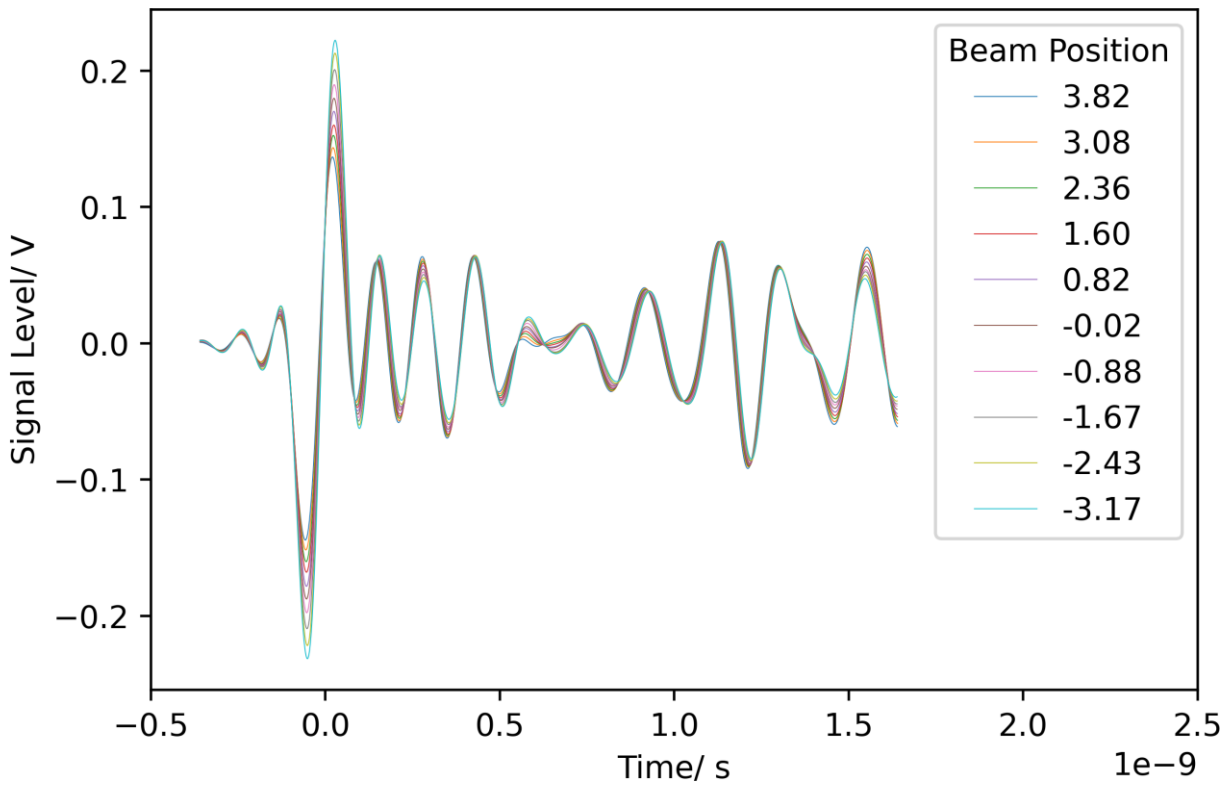
- Parasitic broadband waveform measurements at different frequency bands:
  - Ka Band 26.5 - 40 GHz
  - V Band 50 - 75 GHz
  - W Band 75 – 110 GHz
- Need to find frequency band where contribution of proton signal is within noise levels
- Additional narrowband measurements at 30 GHz
- Comparison with narrowband measurements from HF BPM

Testing with Electrons

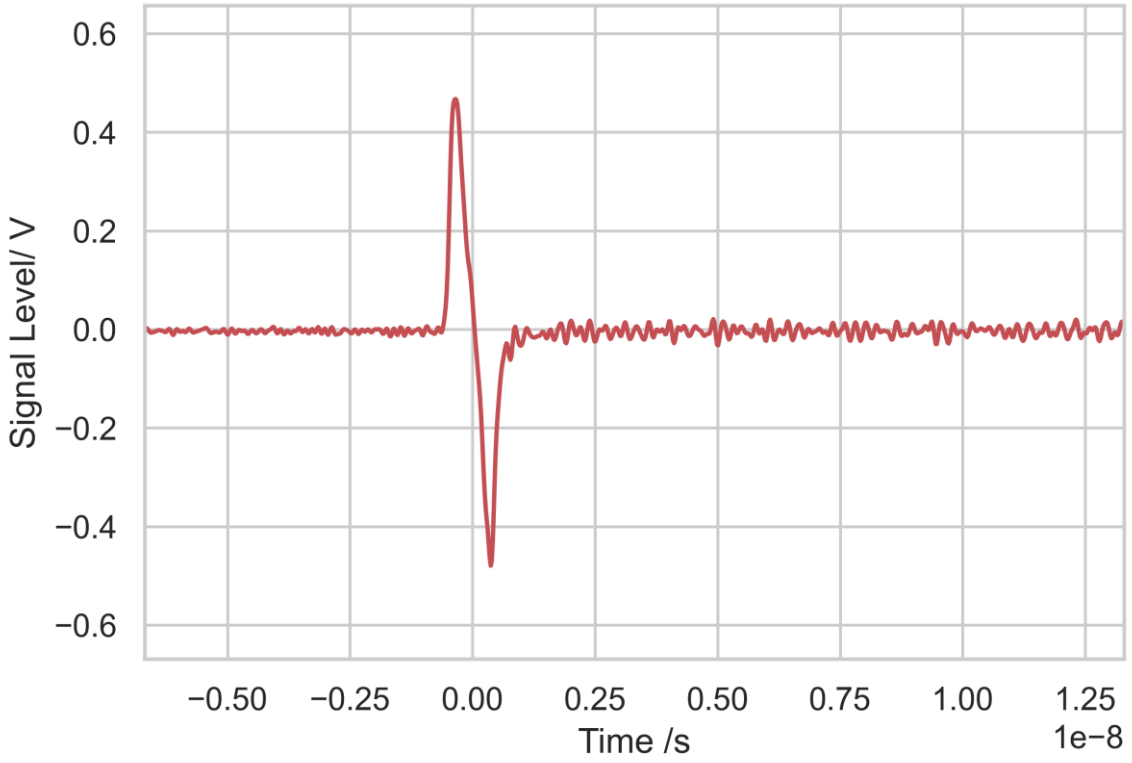
- hor./vert. scans of the ChDR BPM in a **broadband regime**
- **Impact scan** with logging of ChDR and HF, with the same frequency regime and similar setups.
- Further statistical study of Signal Voltage output with Protons + Electrons.
- After finding optimal setup with previous tests, request for dedicated beamtime to allow enough time for statistically significant impact parameter scans.
- Last TRIUMF module on its way to CERN – Possible installation and calibration before the beginning of the August run to allow for full comparison of all BPMs with the same readout system

Thank you!

Extra slides



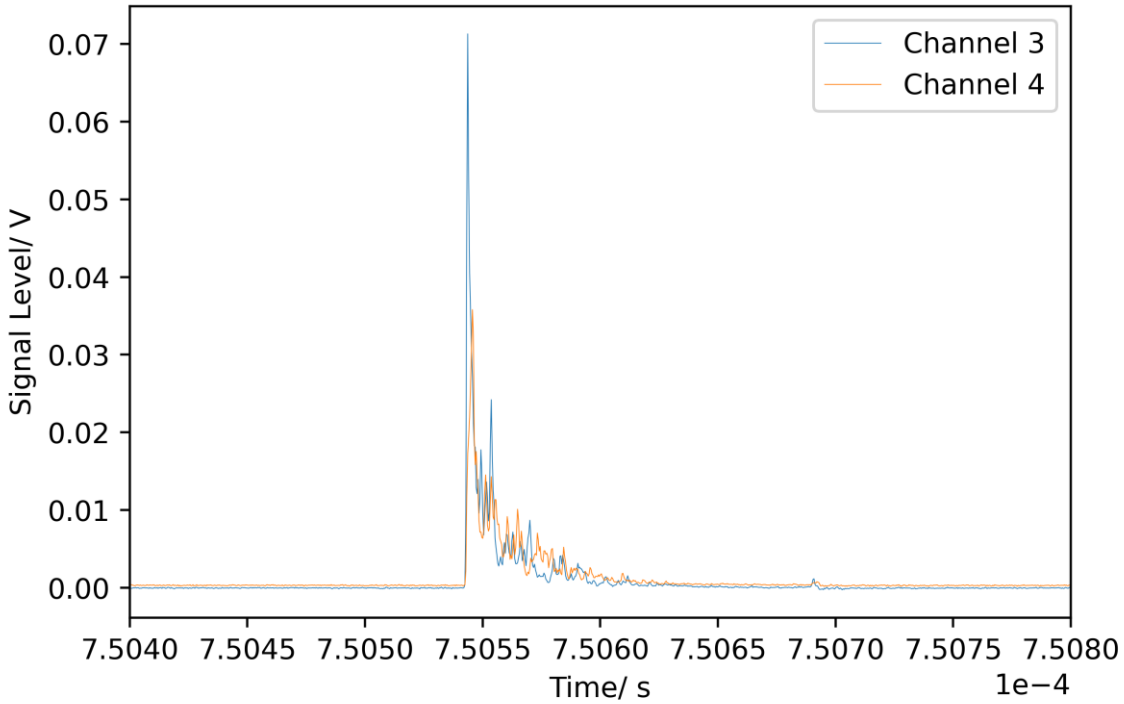
- 320pC electrons 8GHz direct coaxial connection HF BPMs



- 1e11 protons direct coaxial connection HF BPMs

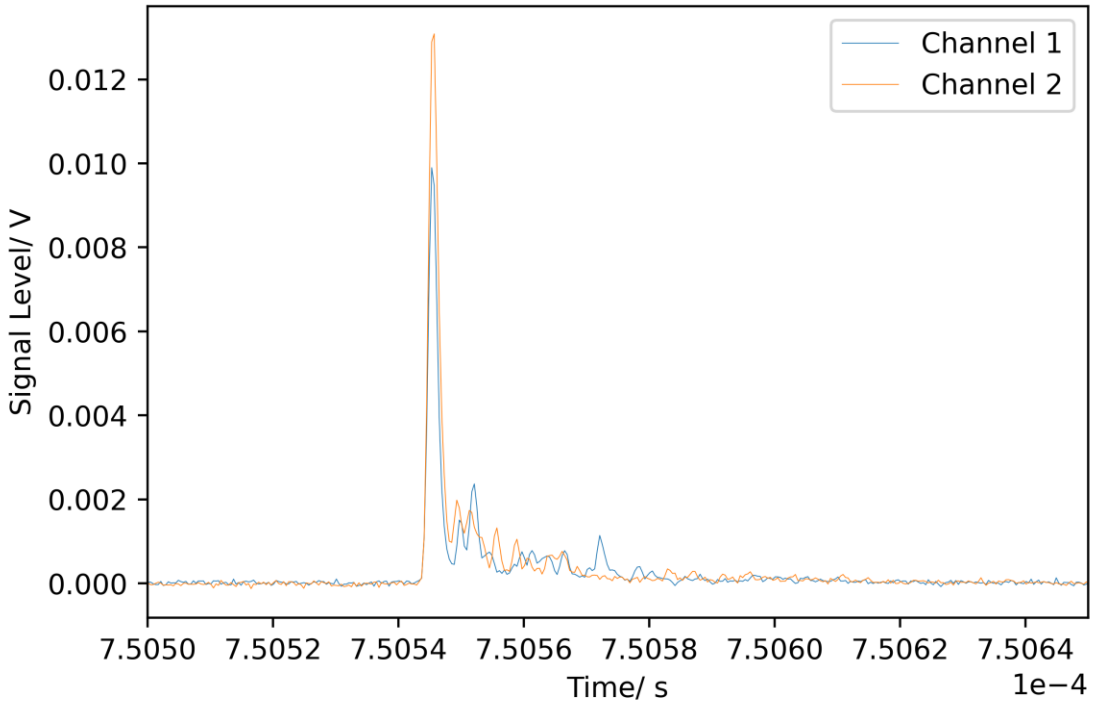
26GHz Channels example Waveforms

-0.3mm



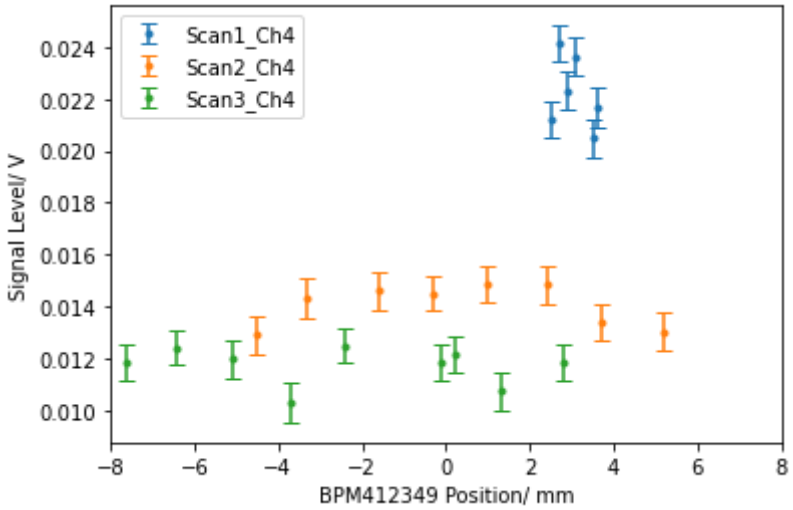
11GHz Channels example Waveforms

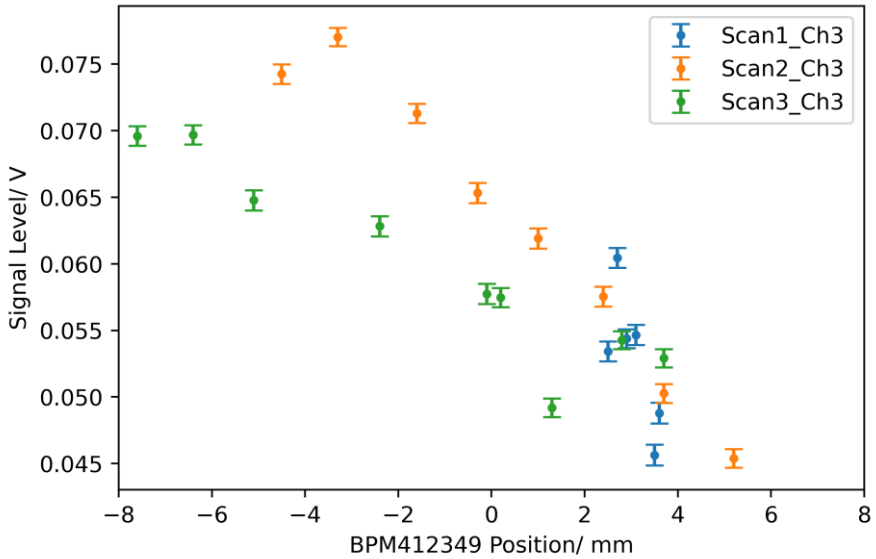
0.2mm



Vertical position scan on HF buttons- 26GHz

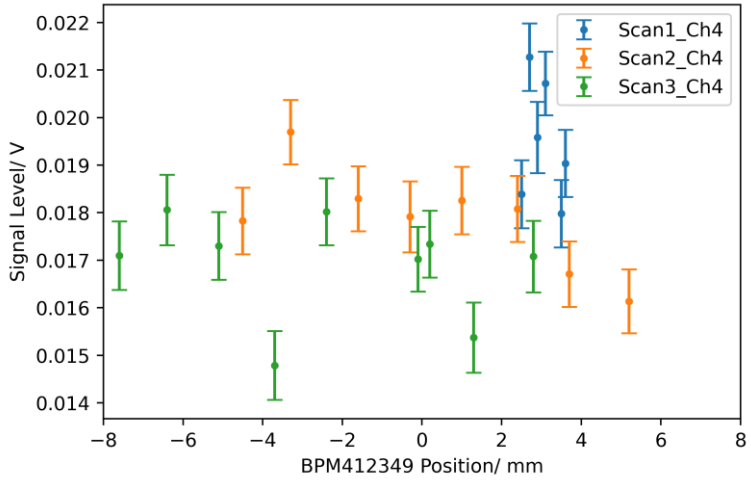
Channel 1

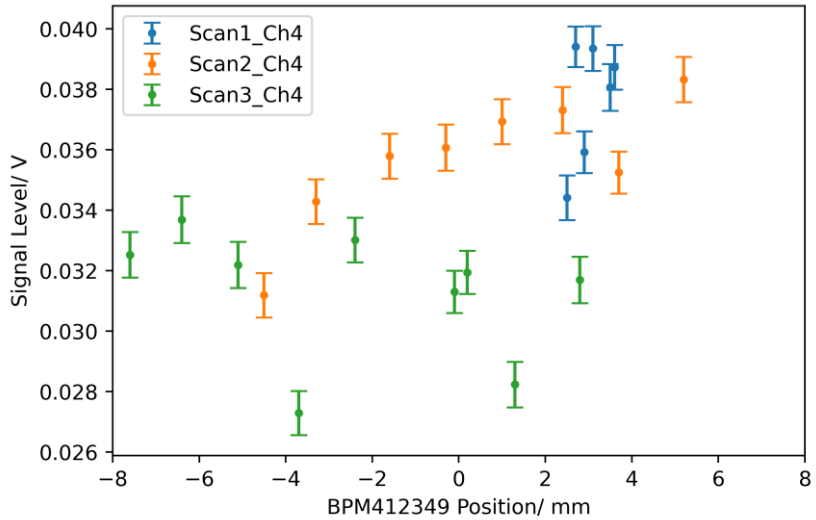




Channel 2

Channel 2





Channel 4

Horizontal position scan on HF buttons- 11GHz