Results of the recent eBPM measurements with electron and proton beams

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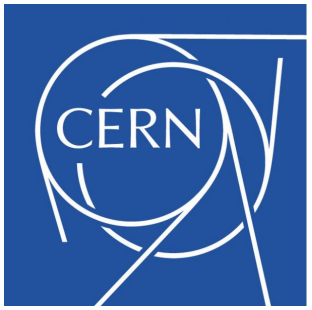


AWAKE instrumentation meeting

12 December 2018

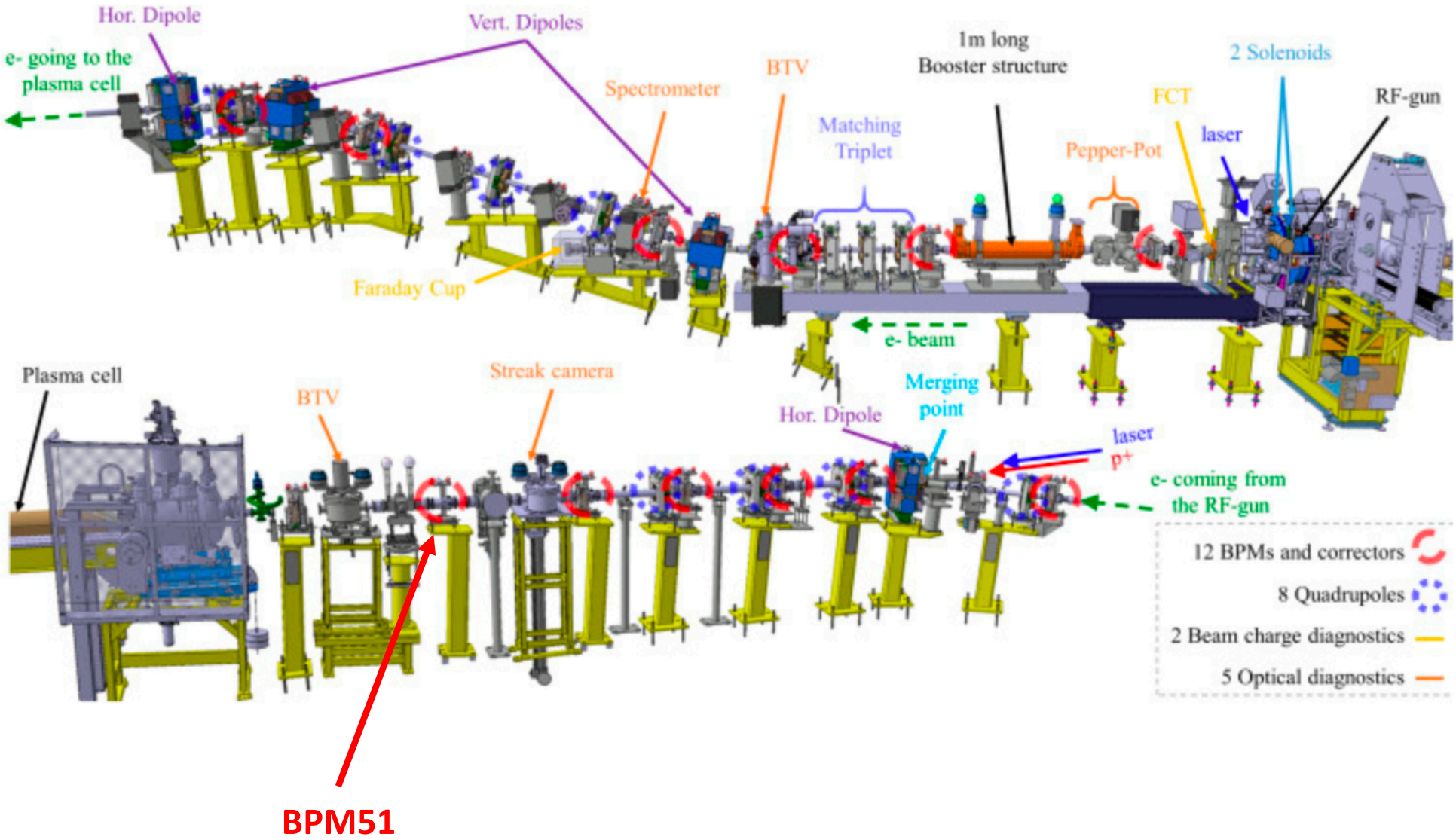
Outline

- Present setup
- The ideal case
  - Beam spectrum for AWAKE gaussian beams
  - Ideal stripline pickup
- The real world
  - Proton beam
  - Electron beam
  - Electron and proton beam
- Conclusions and what comes next

Present setup

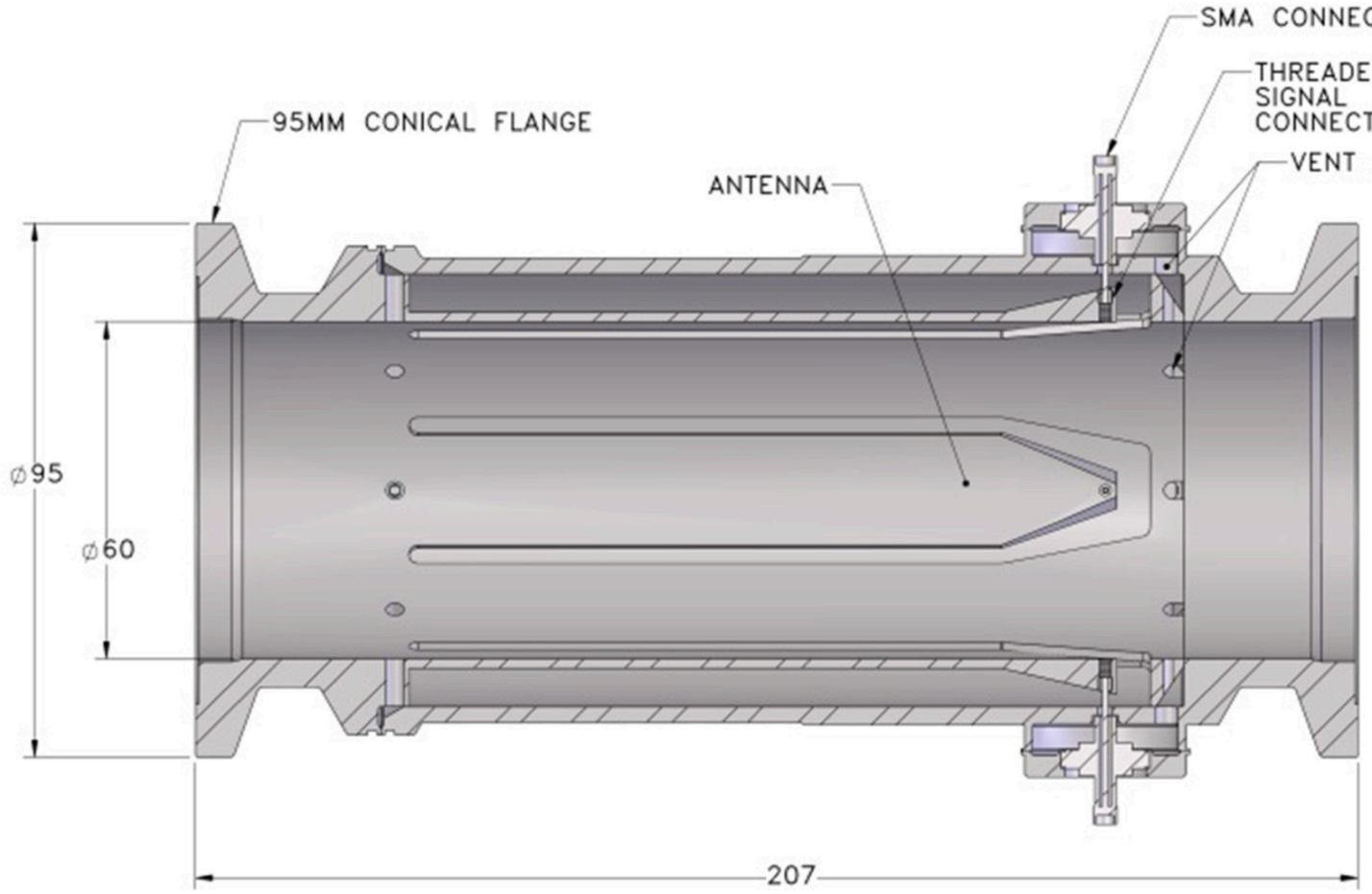
- The electron BPM system installed at AWAKE was developed at TRIUMF and used at CERN for the operation
- 12 eBPM installed in the beamline
  - 7 eBPM in the electron beamline
  - 5 eBPM in the common beamline
- BPM51 was tested. It is the last upstream the plasma cell

Present setup



S. Liu et al., The installation and commissioning of the AWAKE stripline BPM, Conf. Proc. of IBIC 2018

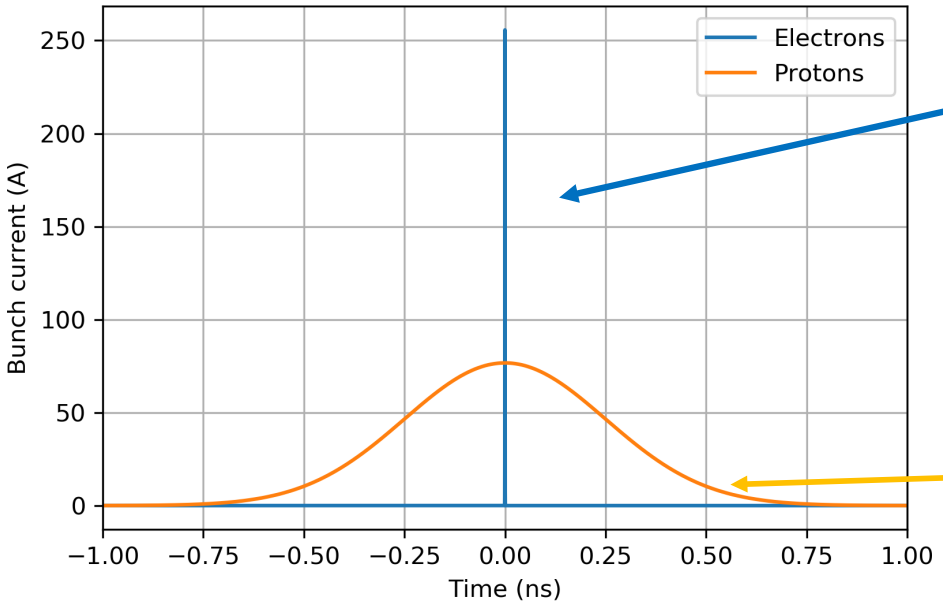
AWAKE eBPM design



S. Liu et al., Development of the AWAKE Stripline BPM Electronics, Conf. Proc. of TIPP2017

The ideal world

Example p^+ and e^- beams



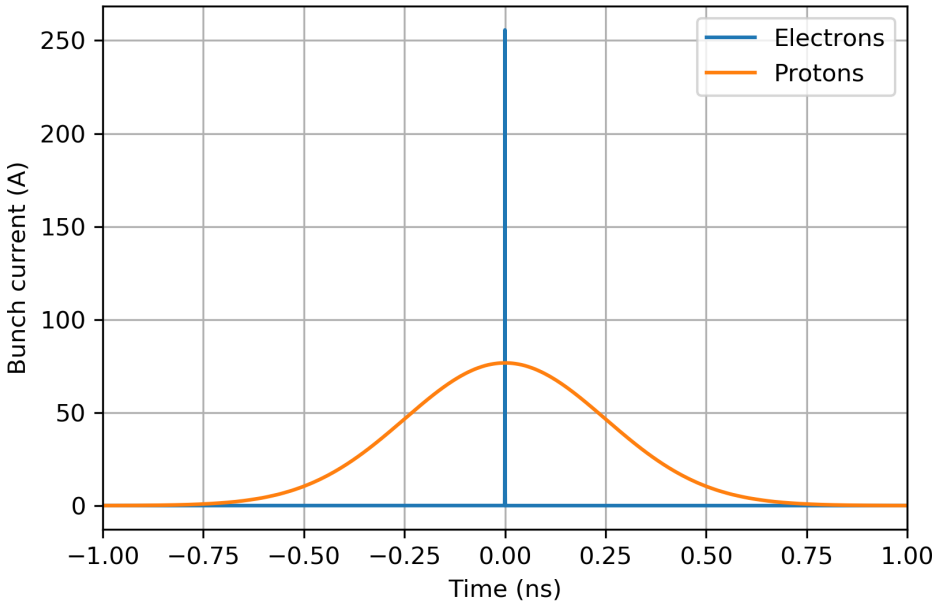
Electron drive bunch:

- 1e9 electrons (~160 pC)
- 1 ps bunch length (4σ)

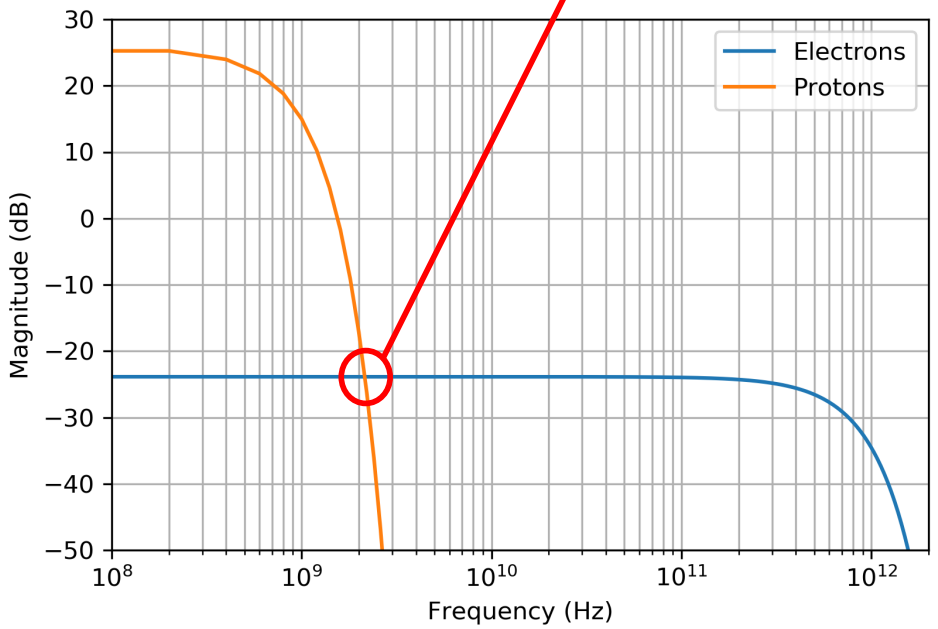
Proton drive bunch:

- 3e11 ppb
- 1 ns bunch length (4σ)

Example p^+ and e^- beams

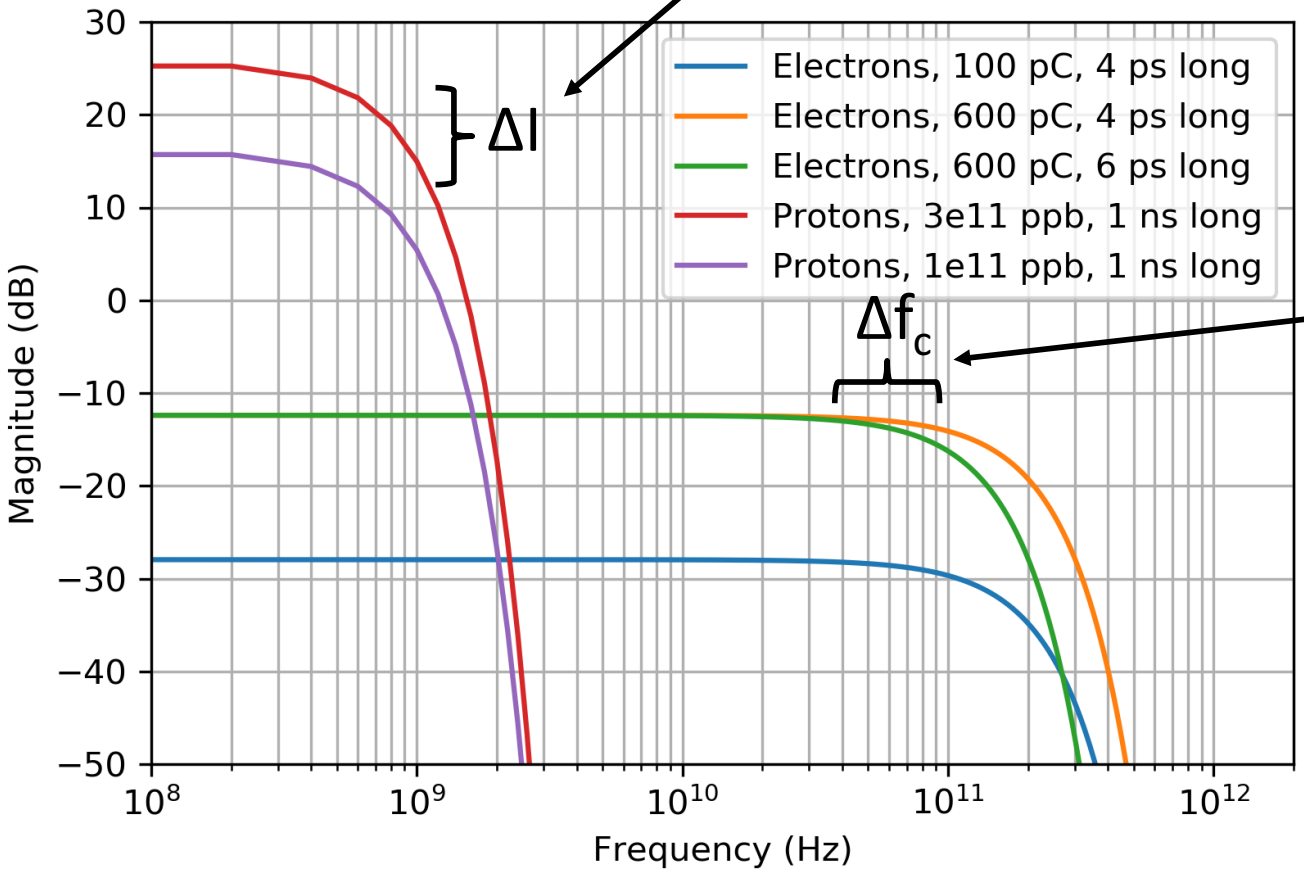


Same magnitude
at ~2 GHz



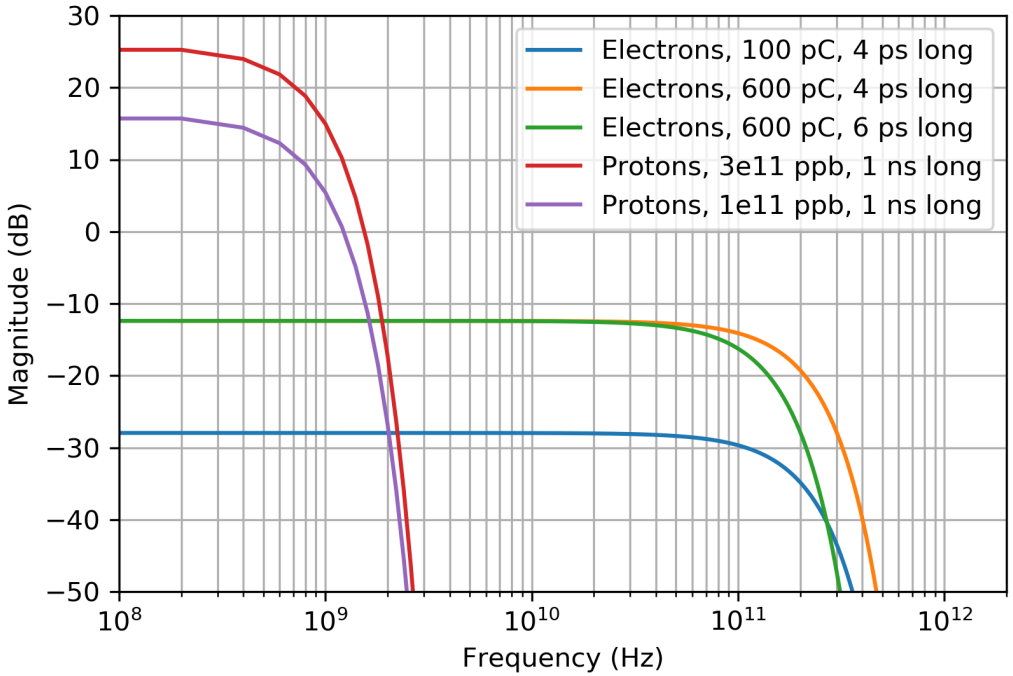
Sensibility to beam parameters

The maximum magnitude depends on the **bunch charge**



Cutoff frequency on the **bunch length**

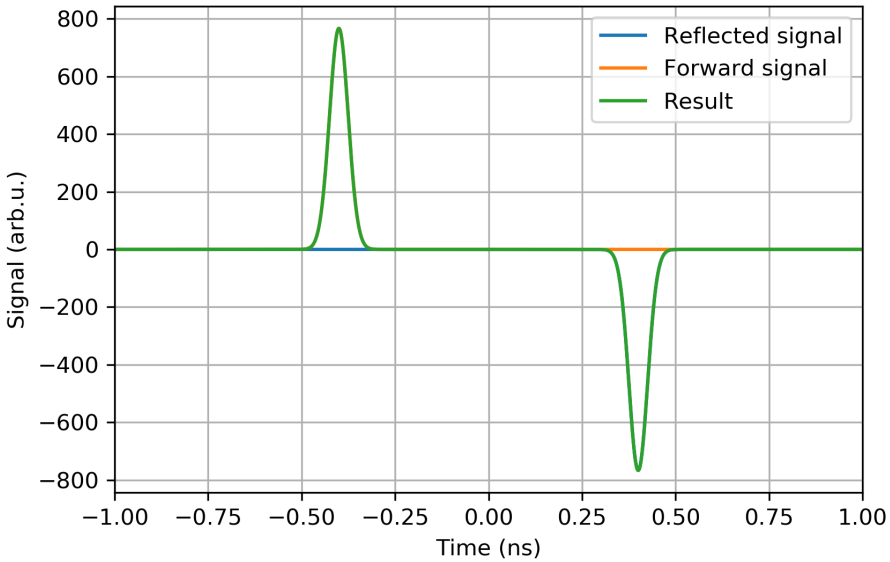
Sensibility to beam parametres

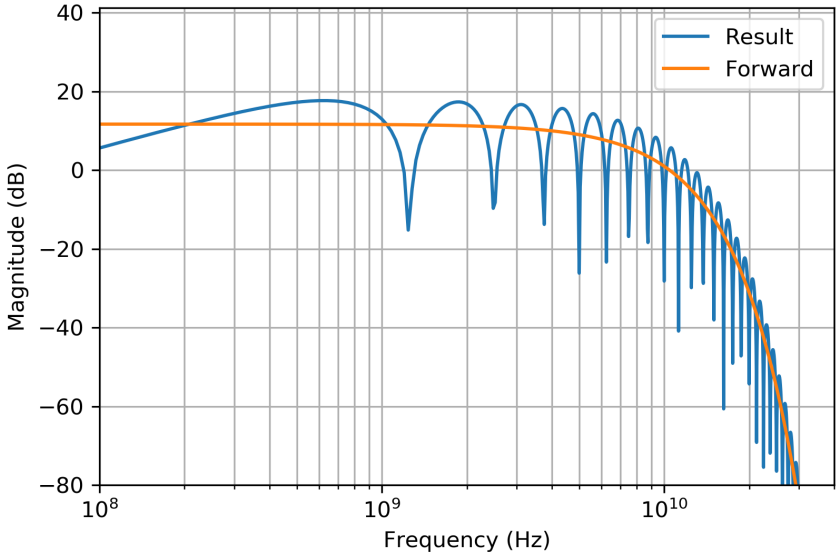


Using more realistic parameters:

- The **proton** spectrum drops considerably after 1 GHz
- The **electron** spectrum stays almost constant for tens of GHz
- **Ideal beams** assumption
- Large dependence on the beam parameters

Ideal stripline pickup response

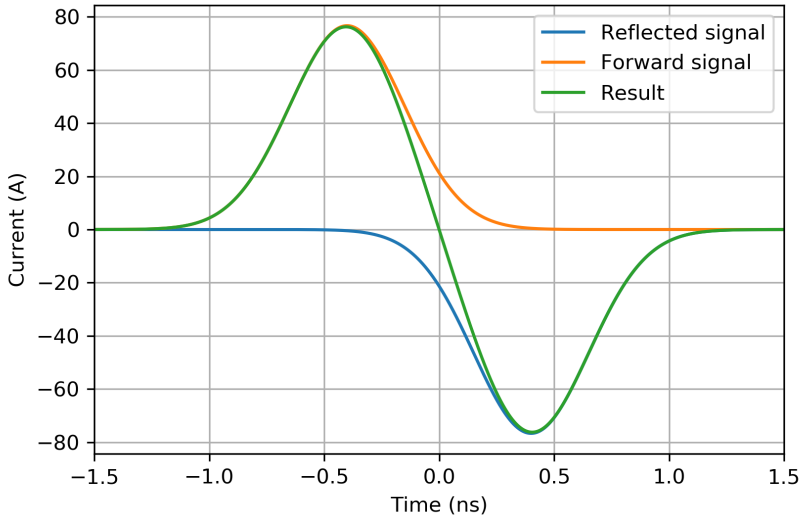


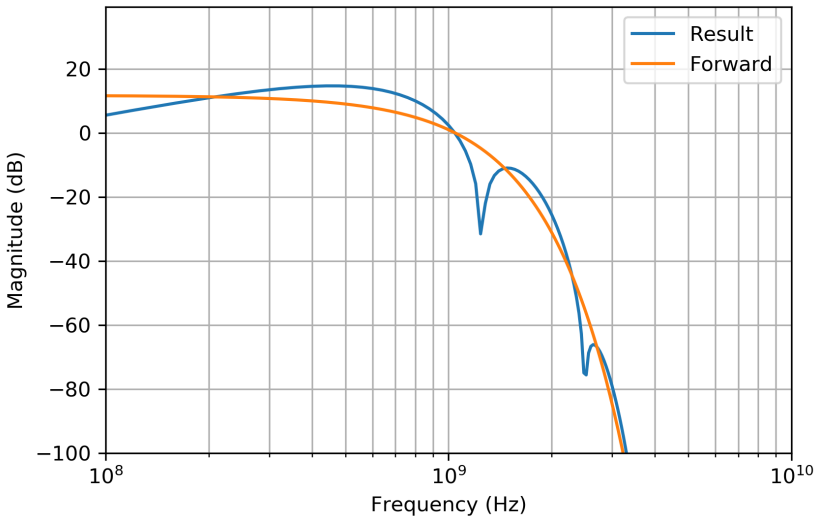


- When the bunch overcomes and runs away from the pickup, the reflected signal builds up
- The distance between the two peaks is $2L_{stripline}/c$. In our case it is ~800 ps for 120 mm electrodes
- In frequency domain the **ideal** beam response is convoluted with the **ideal** pickup response

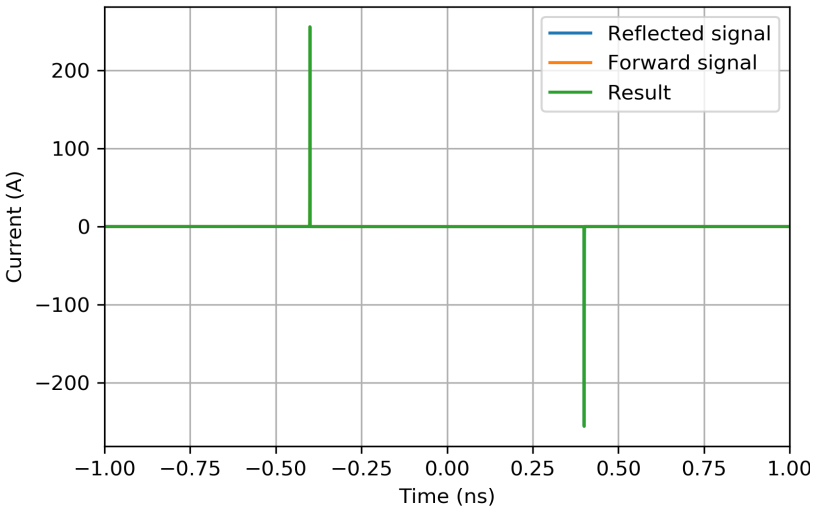
Ideal stripline pickup response

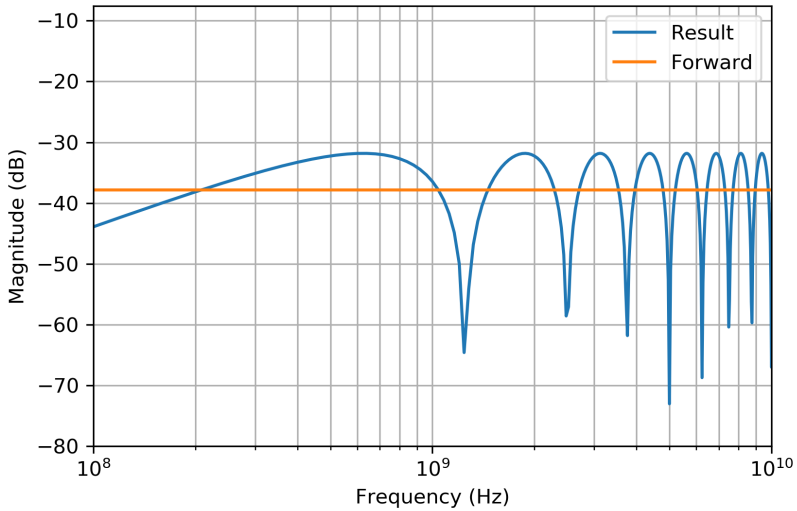
p⁺-like beam:
3e11 ppb
1 ns (4σ length)





e⁻-like beam:
1e9 ppb
4 ps (4σ length)





The real world

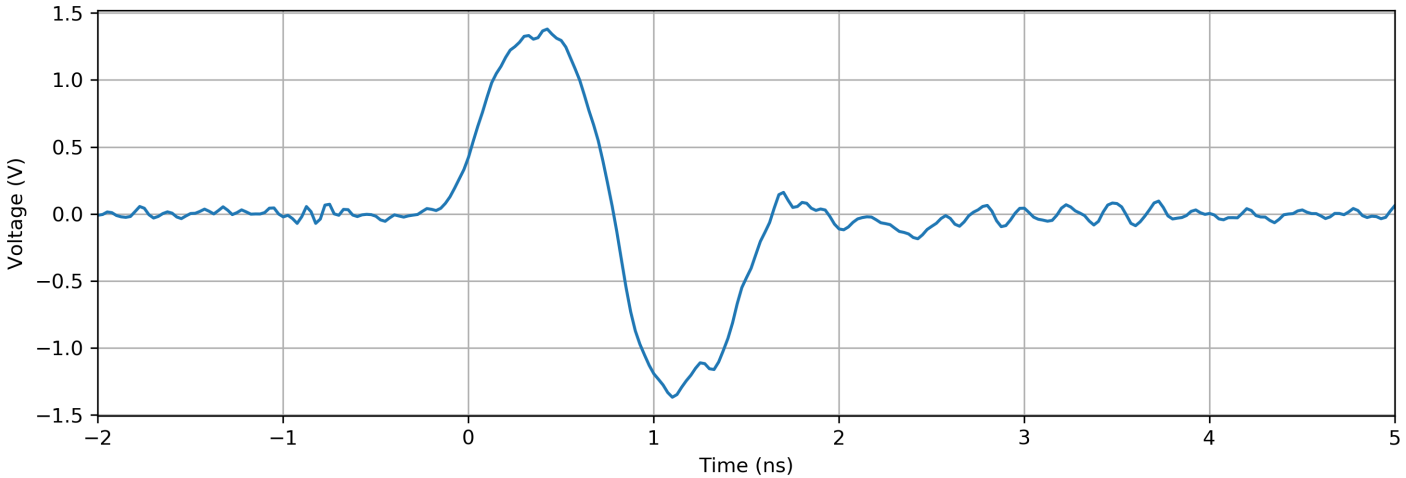
eBPM measurements

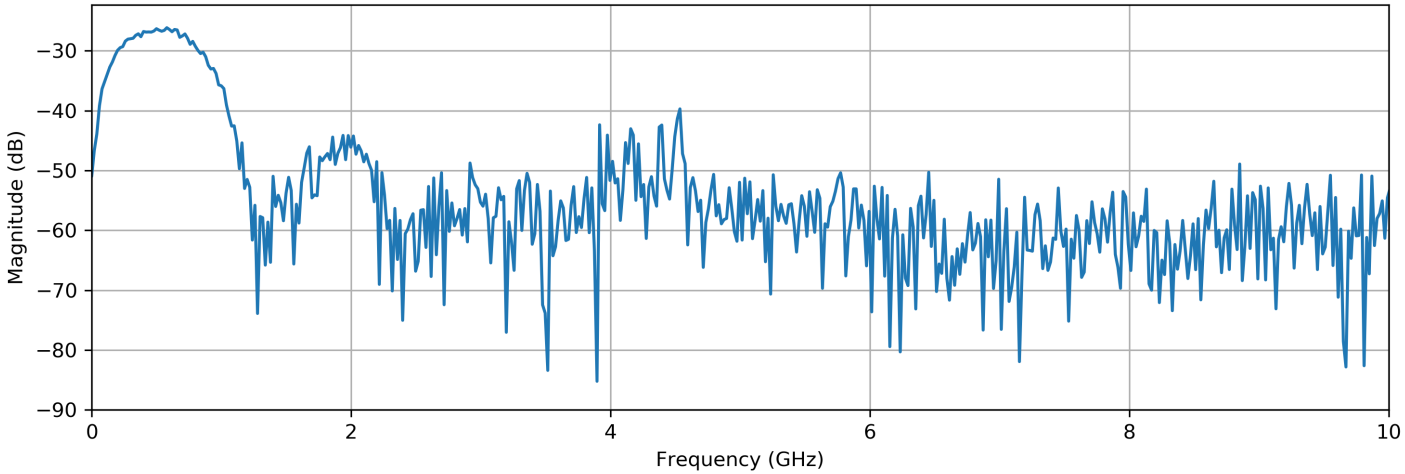
- Two plates of BPM51 were disconnected from the electronics and connected to a Lecroy SDA18000 oscilloscope.

	Single channel	Dual channel (CH1 – CH2)
Bandwidth	18 GHz	12 GHz – 6 GHz
Sampling rate	60 MSa/s	40 MSa/s – 20 Msa/s
Resolution	8 bits	8 bits

- The signals were attenuated to protect the scope from the proton signal
- All the measurement are single shot (no averaging)
- The measurements results are presented for discussions. Drawing final conclusions requires a more broad work, including simulations.

Proton beam measurements



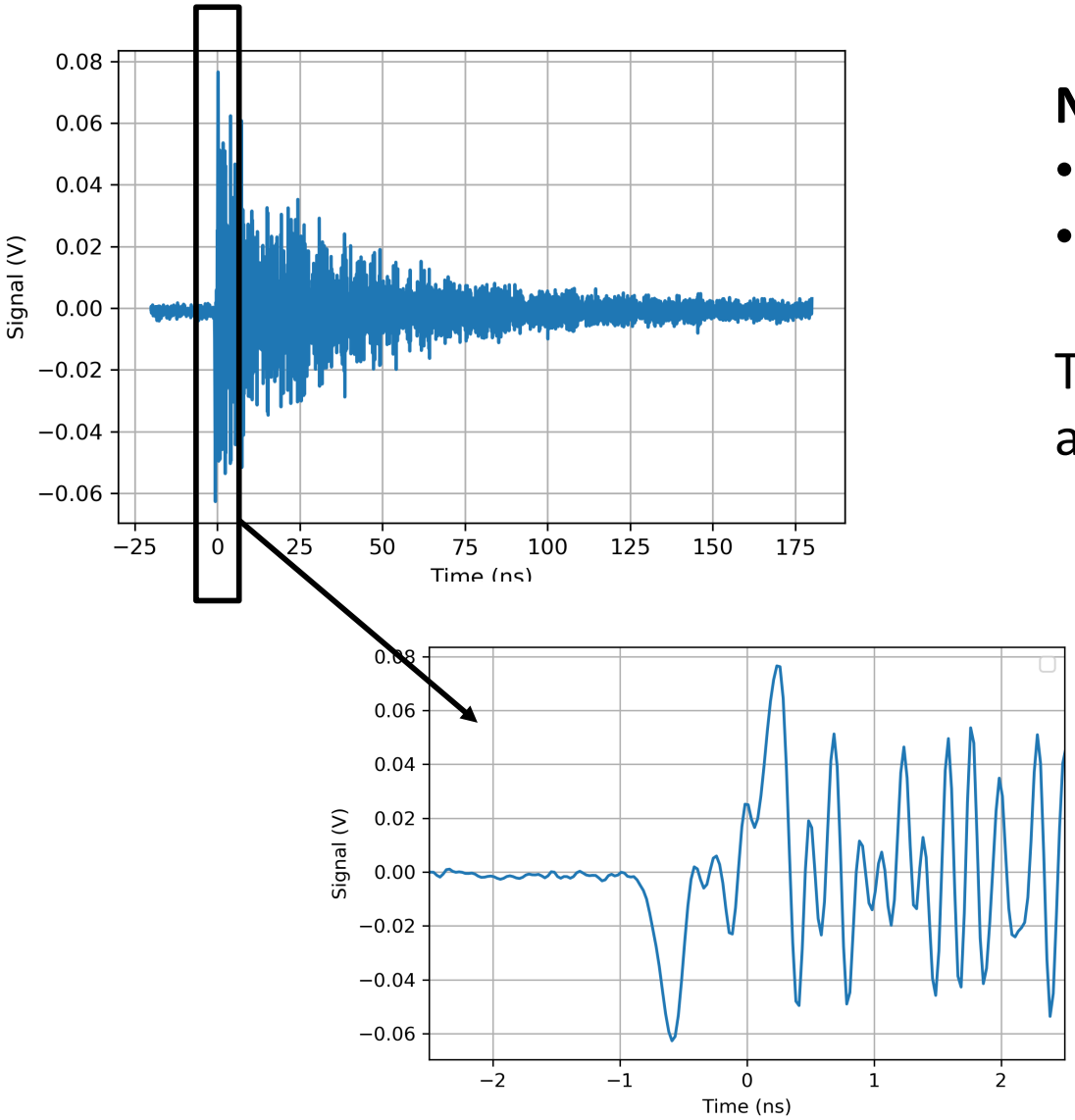


Proton beam:

- 2e11 ppb
- 1 ns bunch length (4σ)

Most of the signal below the GHz

Electron beam measurements

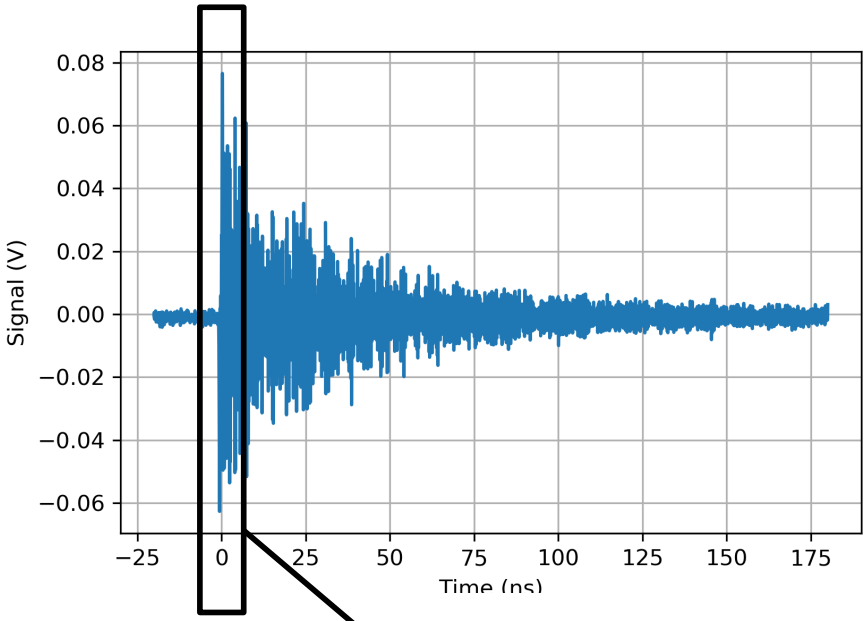


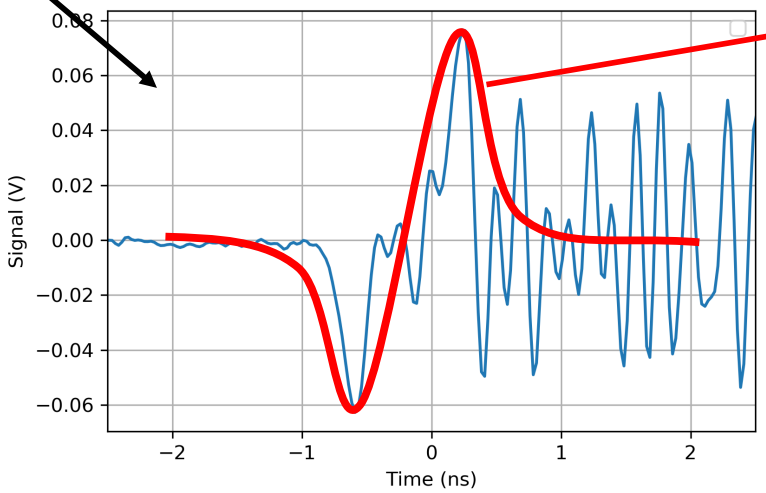
Nominal electron beam:

- 600 pC bunch charge
- 4-6 ps bunch length (4σ)

The signal is visible, but followed by a resonance around 4-5 GHz

Electron beam measurements





Nominal electron beam:

- 600 pC bunch charge
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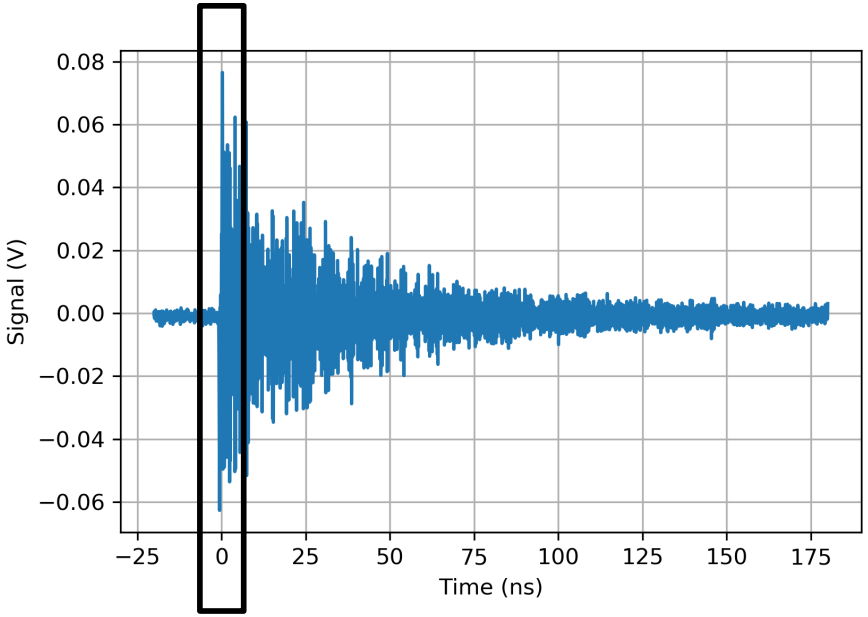
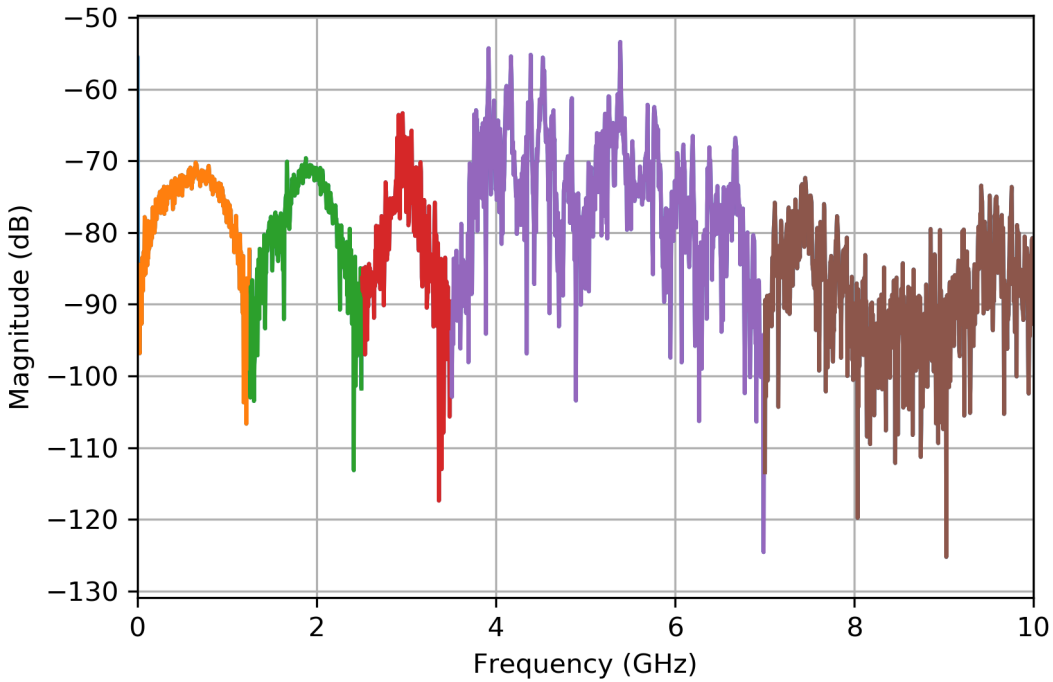
Electron bunch signal

Resonance pattern

Electron beam measurements

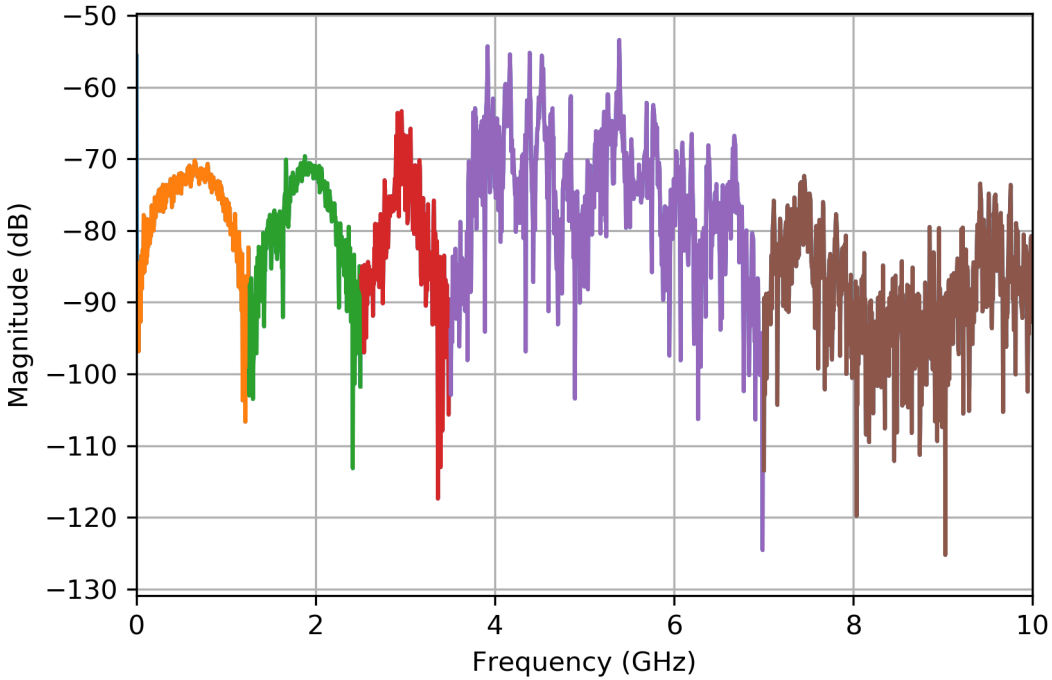


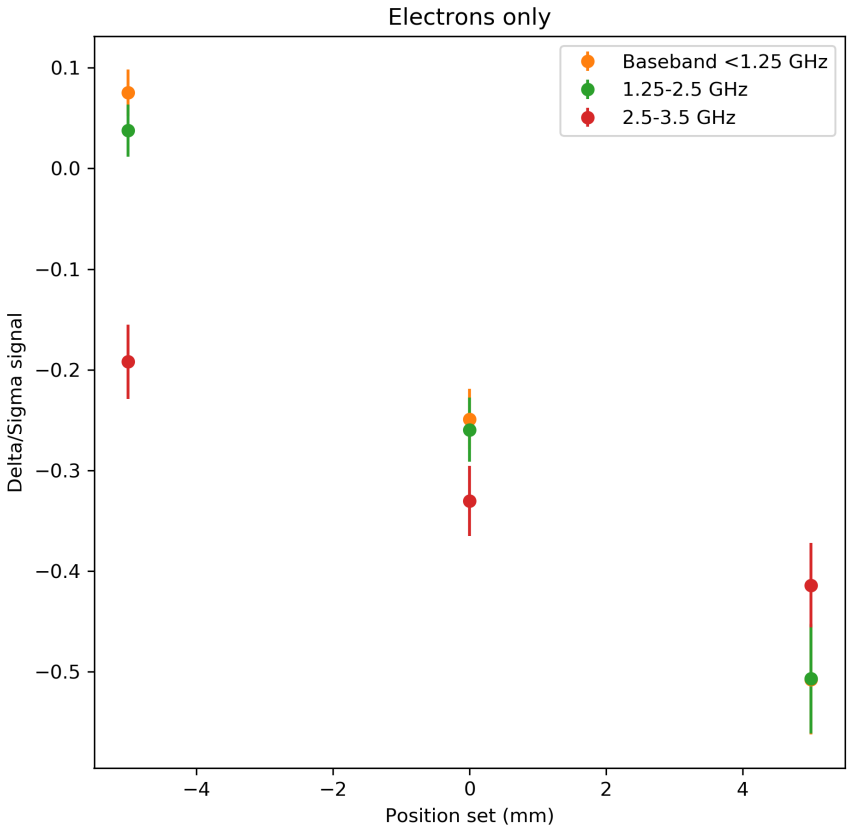


Nominal electron beam:

- As the beam component is constant up to 10s of GHz, the signal can be observed on the longer scale including the reflections
- The dips in the spectrum are compatible with the pickup length
- Three frequency intervals look interesting
  - **0 – 1.25 GHz**
  - **1.25 – 2.5 GHz**
  - **2.5 – 3.5 GHz**
- Above 3.5 GHz mostly noise

Electron beam measurements

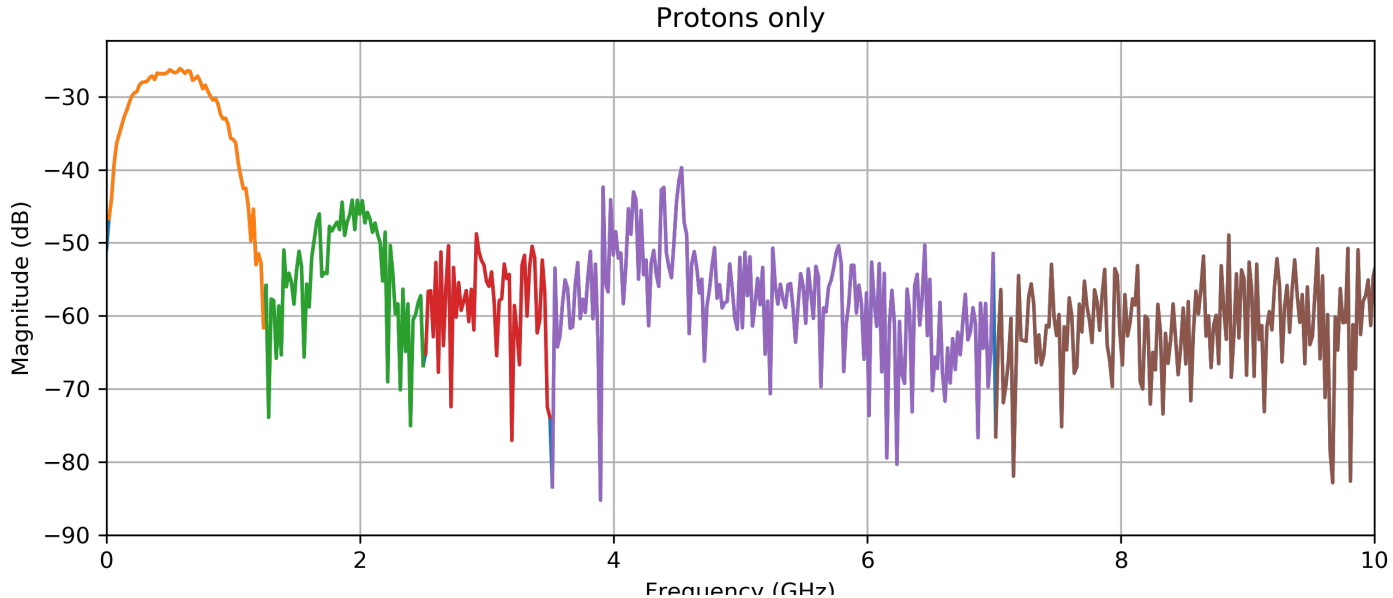


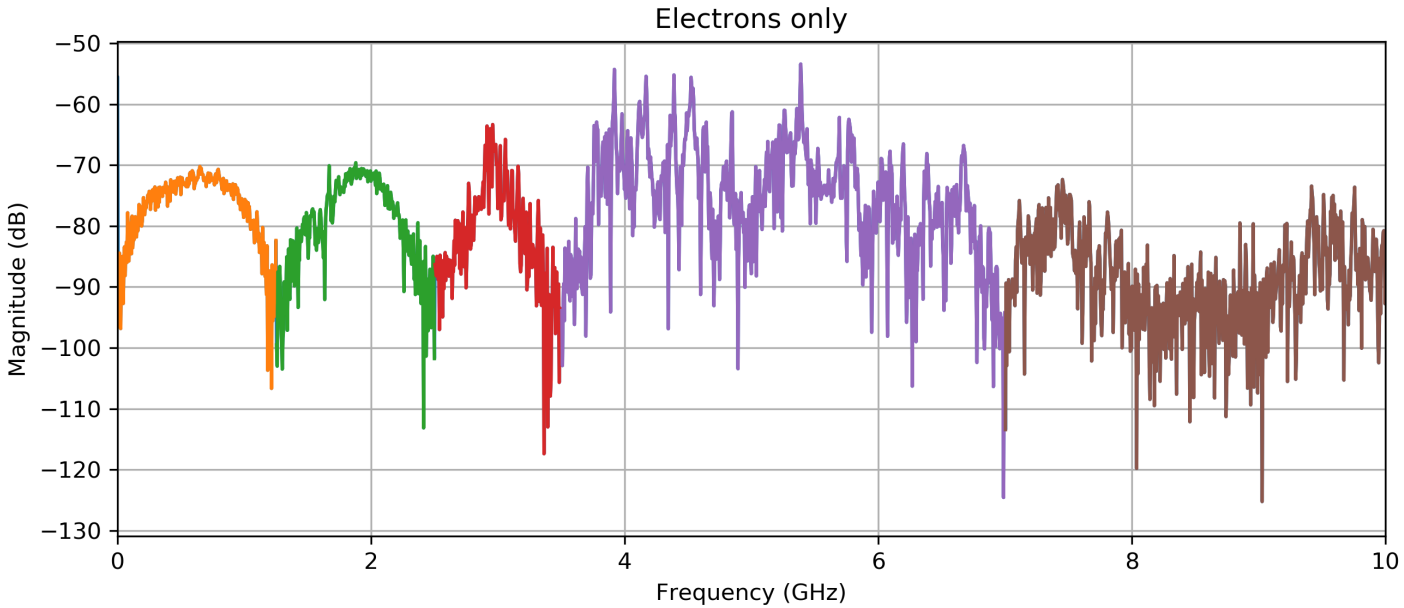


Electron beam steering:

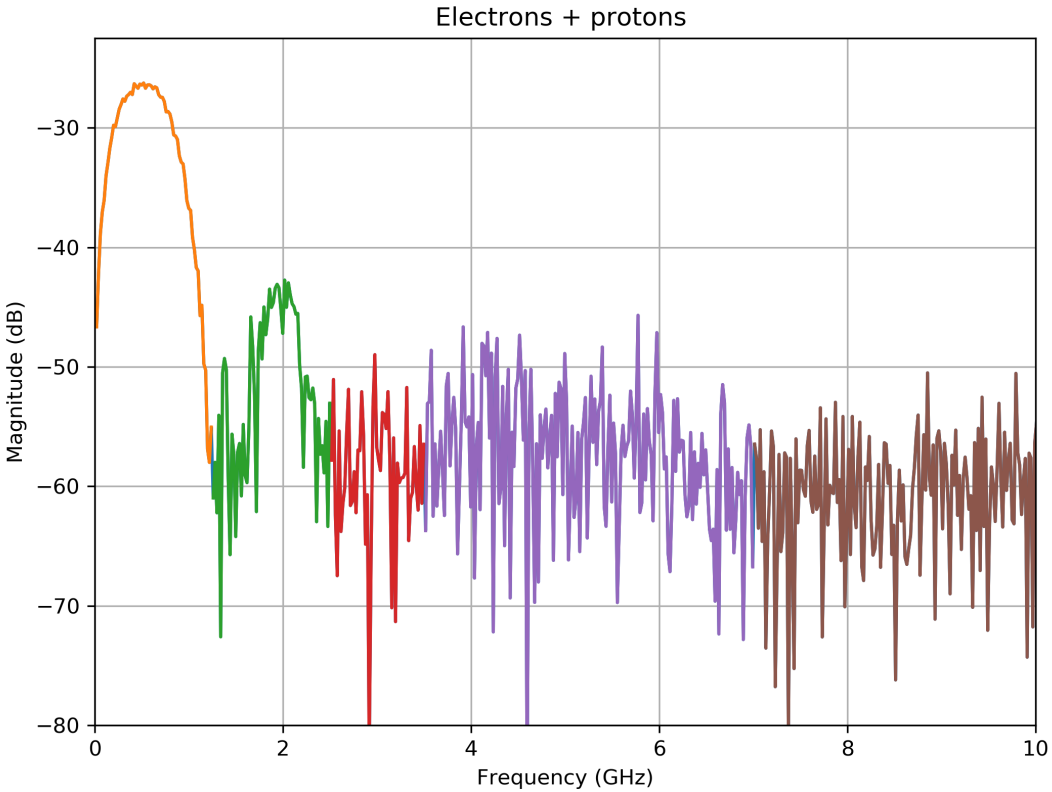
- The electron beam was steered via YASP in the +/- 5 mm range
- The first two frequency regions show clear dependency on the position of the Δ/Σ signal. The third one in a reduced scale.
- Above the 3.5 GHz the position information is lost

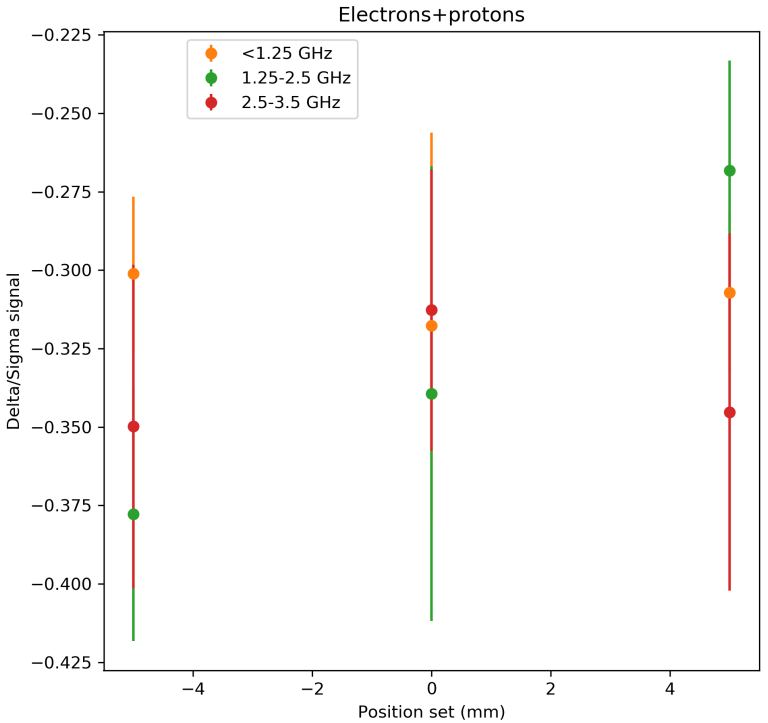
e^--p^+ spectra comparison





e^- and p^+ together





Electron beam steering with proton presence:

- The electron beam was steered via YASP in the +/- 5 mm range
- Proton beam stayed in the centre due to the reduced time
- In the orange region the signal of the protons dominates
- Some dependence in the green band
- Measurement limited by the dynamic range of the scope

Conclusions

- **The measurement** of the electron beam position in presence of the protons **is challenging**
  - It might be possible if the beams are different in bunch charge and length
  - The bigger the difference the smaller the bias of the protons on the measured electron position
  - The **bunch shape** plays an important role as it **changes the relative contribution of the two beams to the measurement**
- According to the measurements, the present system might be capable to measure the electron position in one of the higher frequency intervals before the noise
- The measurement in presence of protons is limited by the dynamic range of the oscilloscope
- **The input of AWAKE on the future beams parameters in run 2 is fundamental to design reliable diagnostic**

Future steps

- EM simulation of the pickup structure in order to possibly understand the source of the resonance at high frequency
- VNA measurements on a spare
- Brainstorm on further future design ideas
- Repeat the measurements using the new scope featuring 12 bits resolution. Only the electrons will be available, but the higher frequency bands will be accessible using the new instrument.