

Results of the recent eBPM measurements with electron and proton beams

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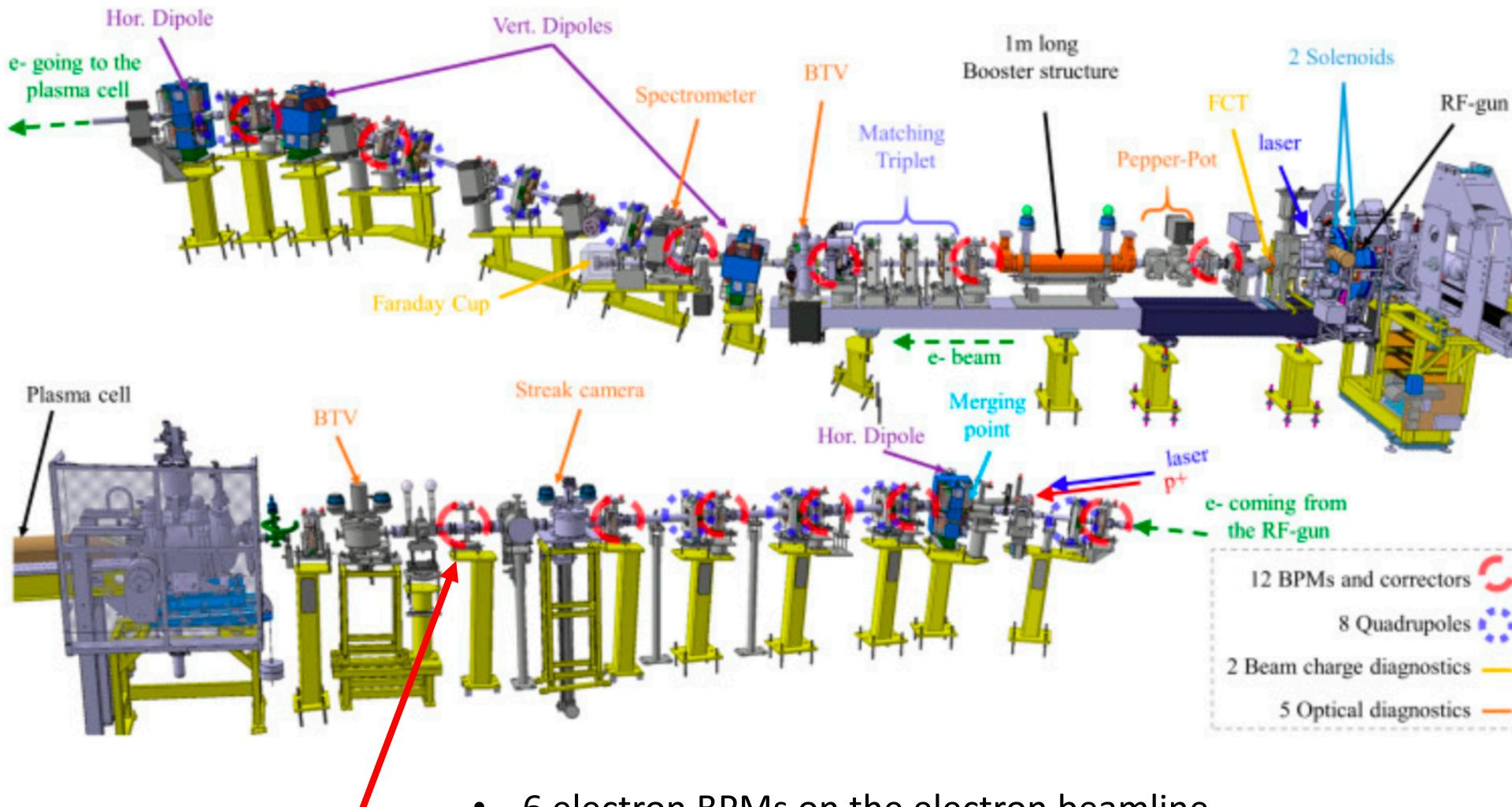


AWAKE instrumentation meeting
12 December 2018

Outline

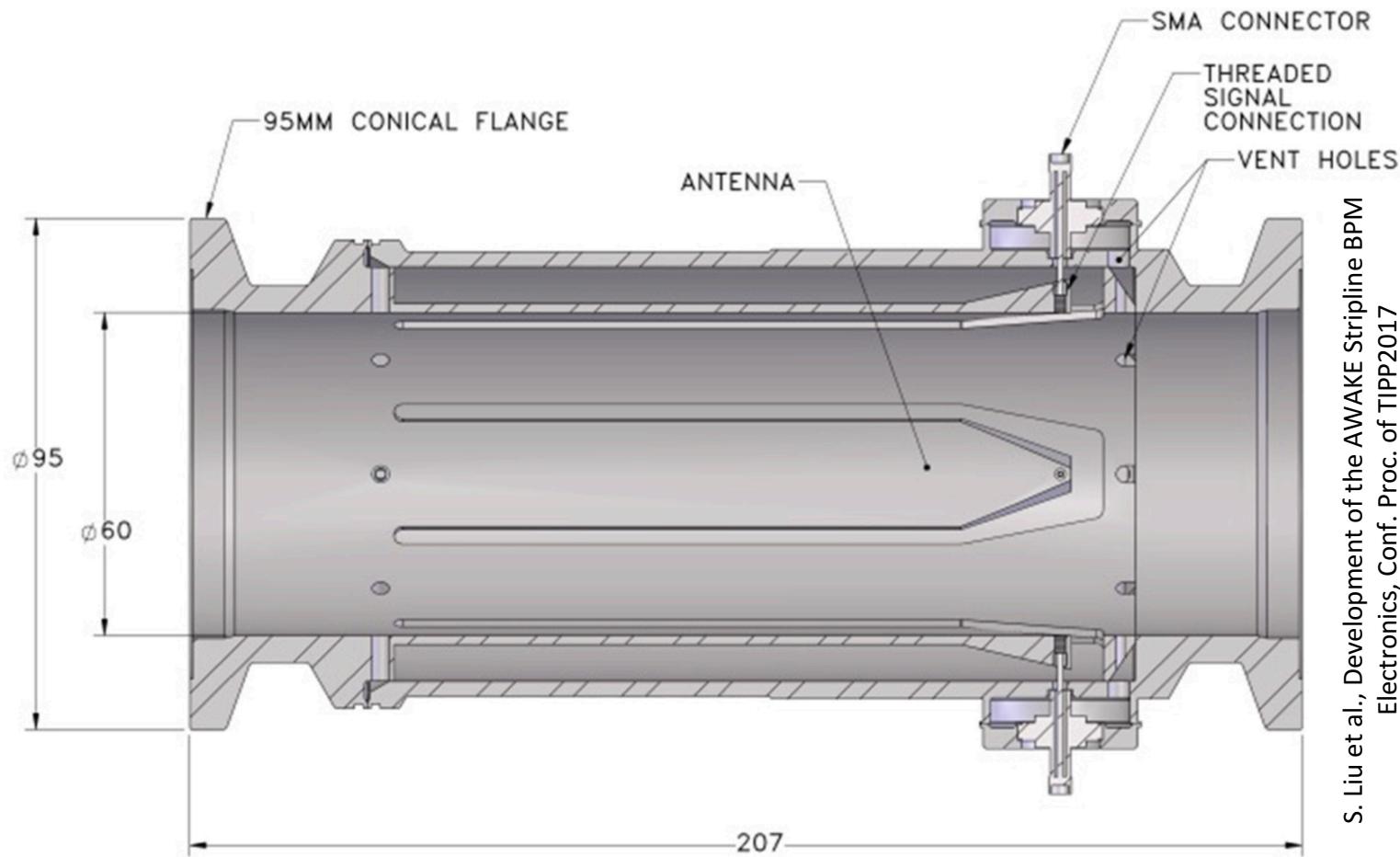
- Present setup
- The ideal case
 - Beam spectrum for AWAKE gaussian beams
 - Ideal stripline pickup
- The real world
 - Proton beam
 - Electron beam
 - Electron and proton beam
- Conclusions and what comes next

Present setup



- 6 electron BPMs on the electron beamline
- 6 electron BPMs on the common beamline
- BPM51 was tested (the closest to the plasma cell)

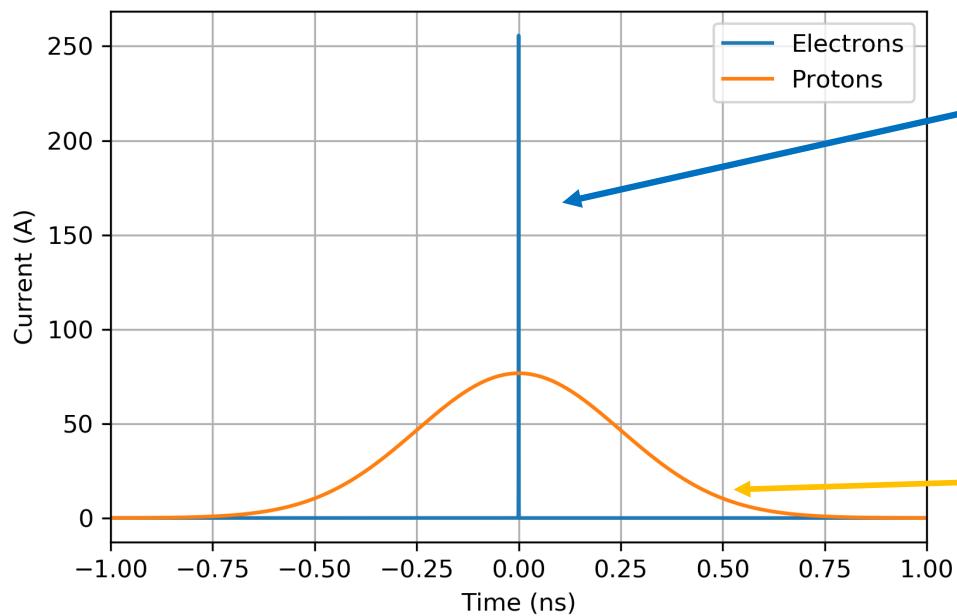
AWAKE eBPM design



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

The ideal world

Example p⁺ and e⁻ beams



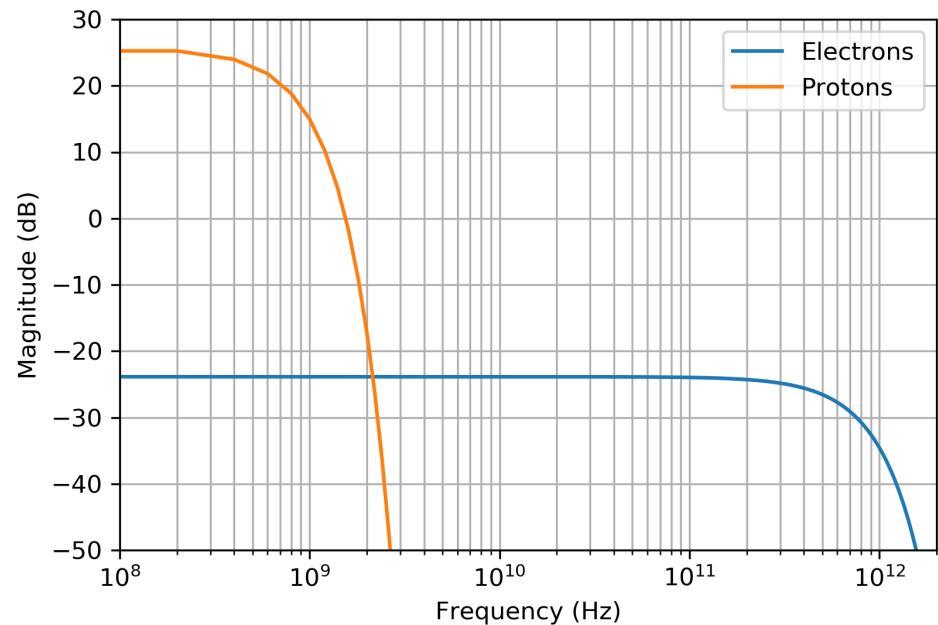
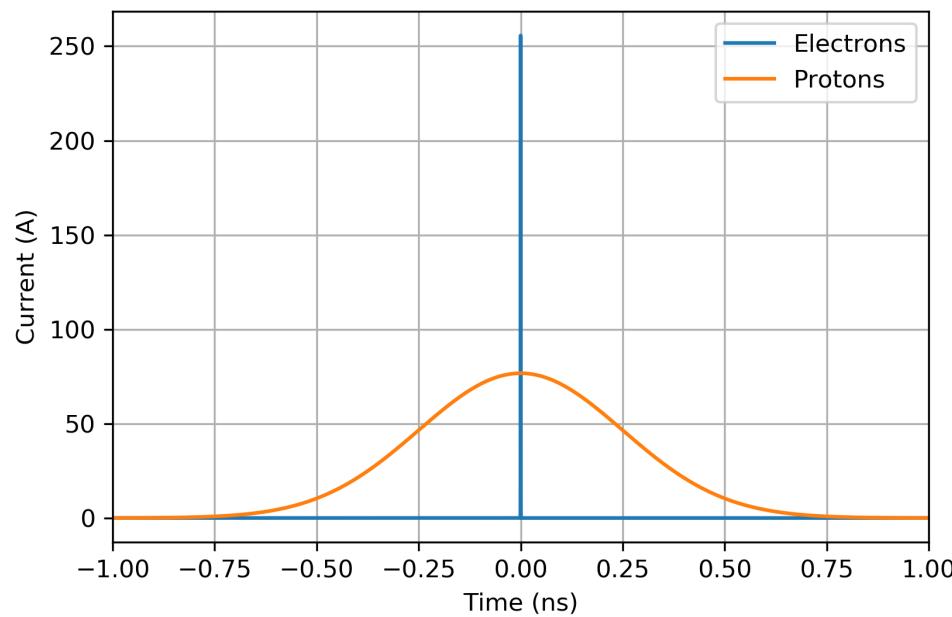
Electron drive bunch:

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

Proton drive bunch:

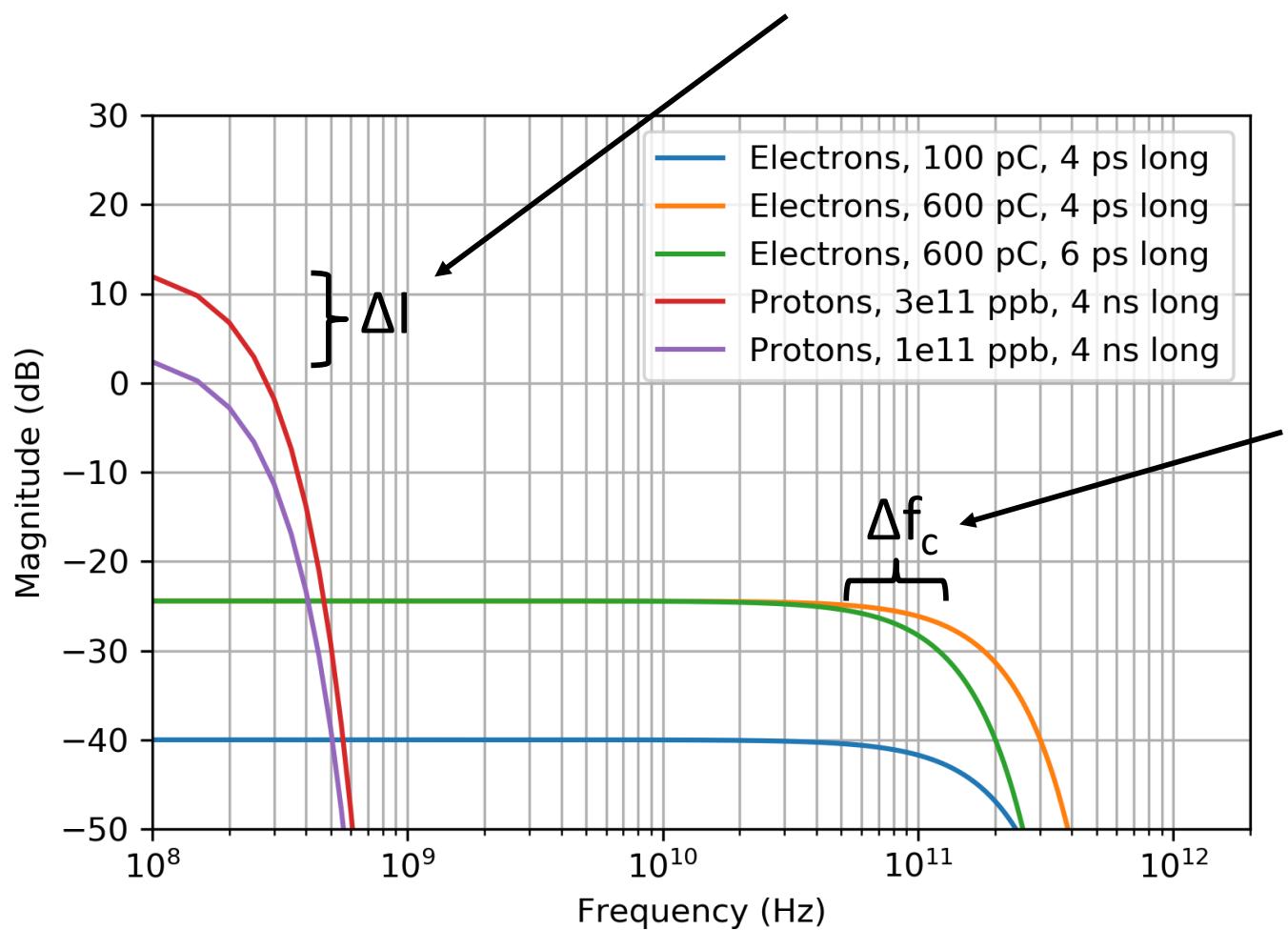
- 3e11 ppb
- 1 ns bunch length (4σ)

Example p⁺ and e⁻ beams



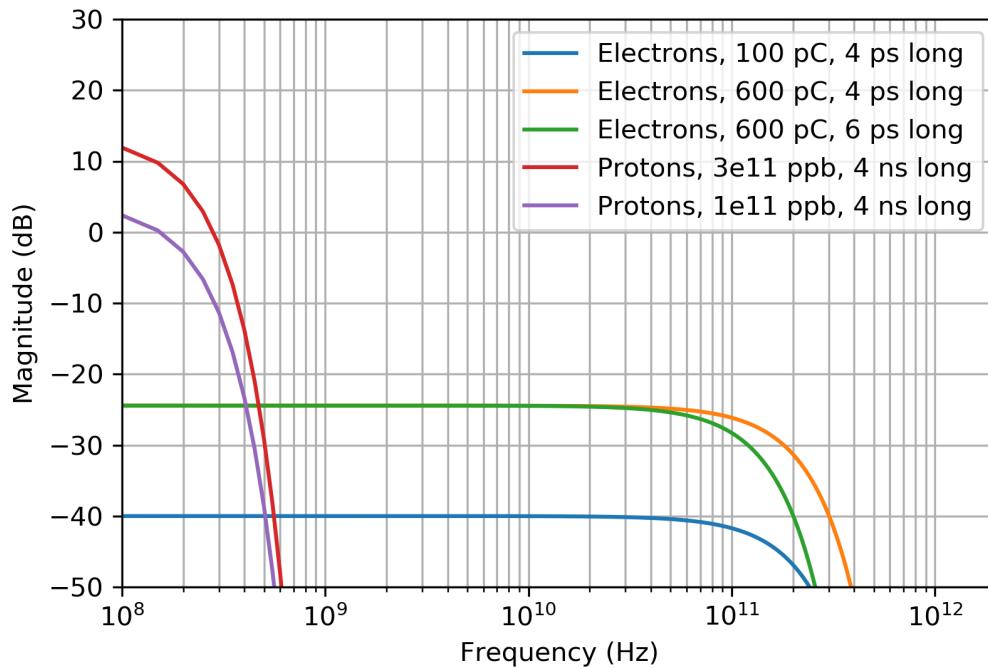
Sensibility to beam parameters

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



Cutoff frequency on
the **bunch length**

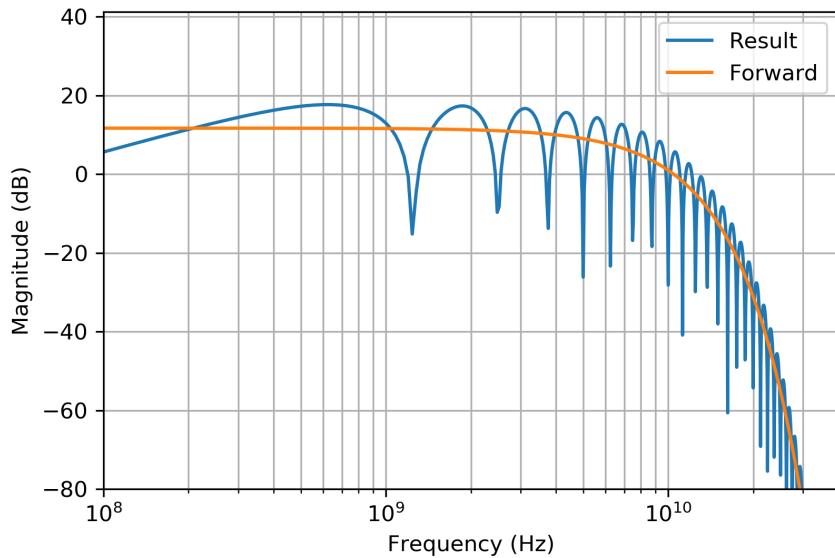
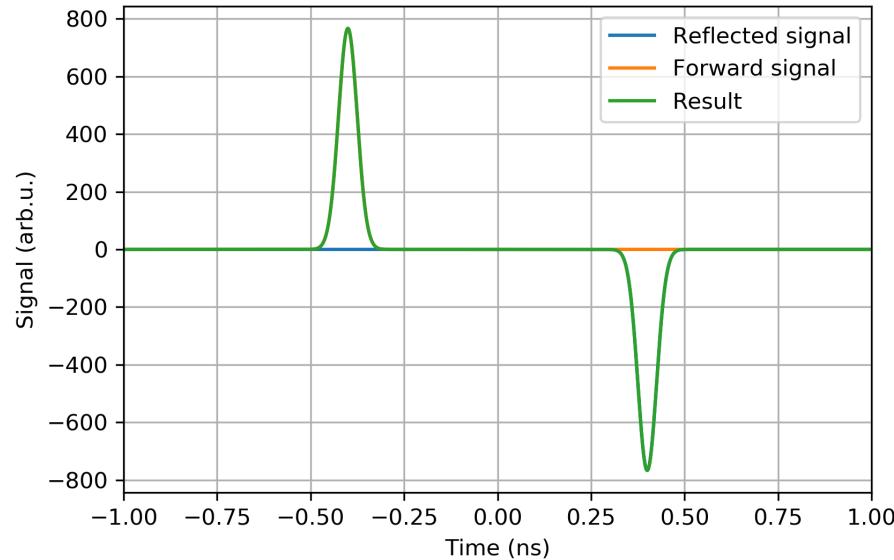
Sensibility to beam parameters



Using more realistic parameters:

- The **proton** spectrum drops considerably after 500 MHz
- The **electron** spectrum stays almost constant for tens of GHz
- **Ideal beams** assumption
- Large dependence on the beam parameters

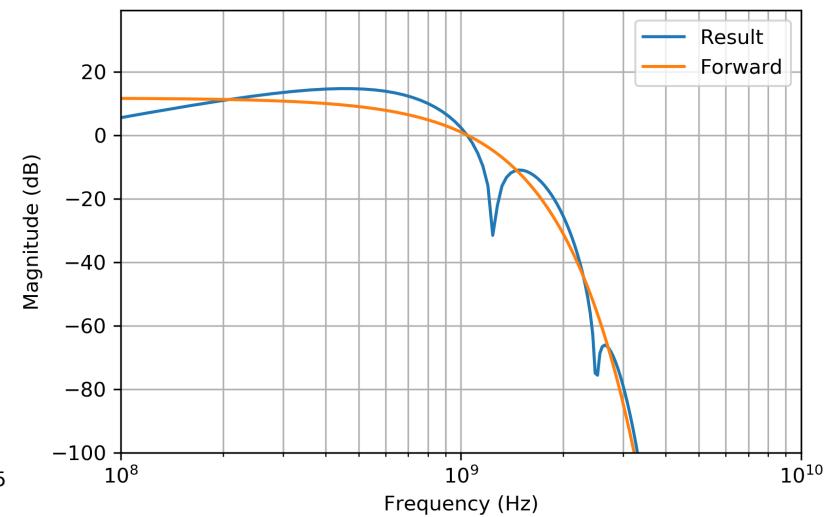
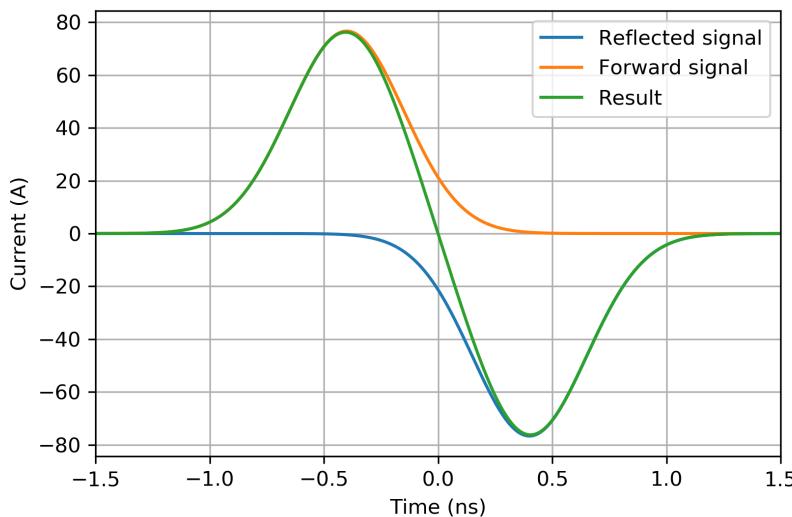
Ideal stripline pickup response



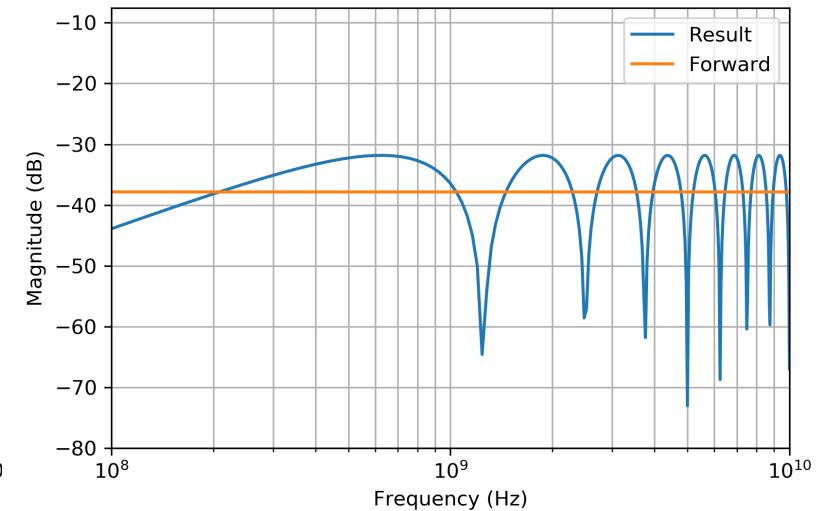
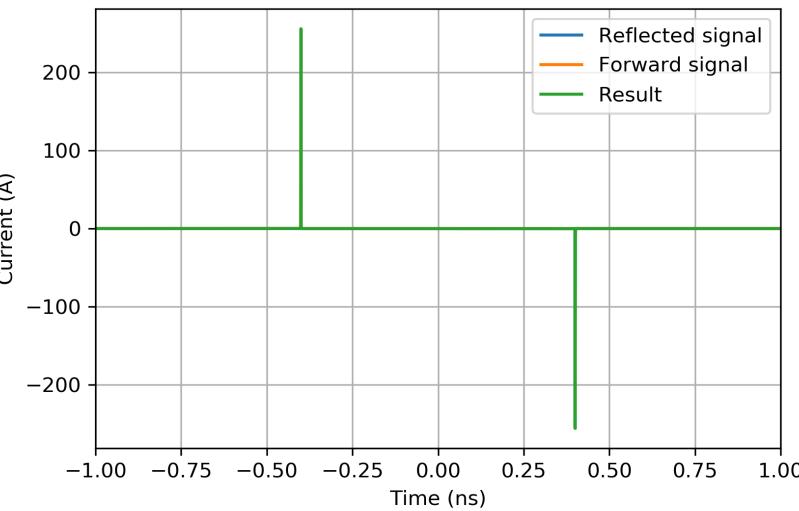
- When the bunch overcomes and runs away from the pickup, the reflected signal builds up
- The distance between the two peaks is $2L_{\text{stripline}}/c$. In our case it is ~ 800 ps for 120 mm electrodes
- In frequency domain the ideal beam response is convoluted with the pickup response

Ideal stripline pickup response

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

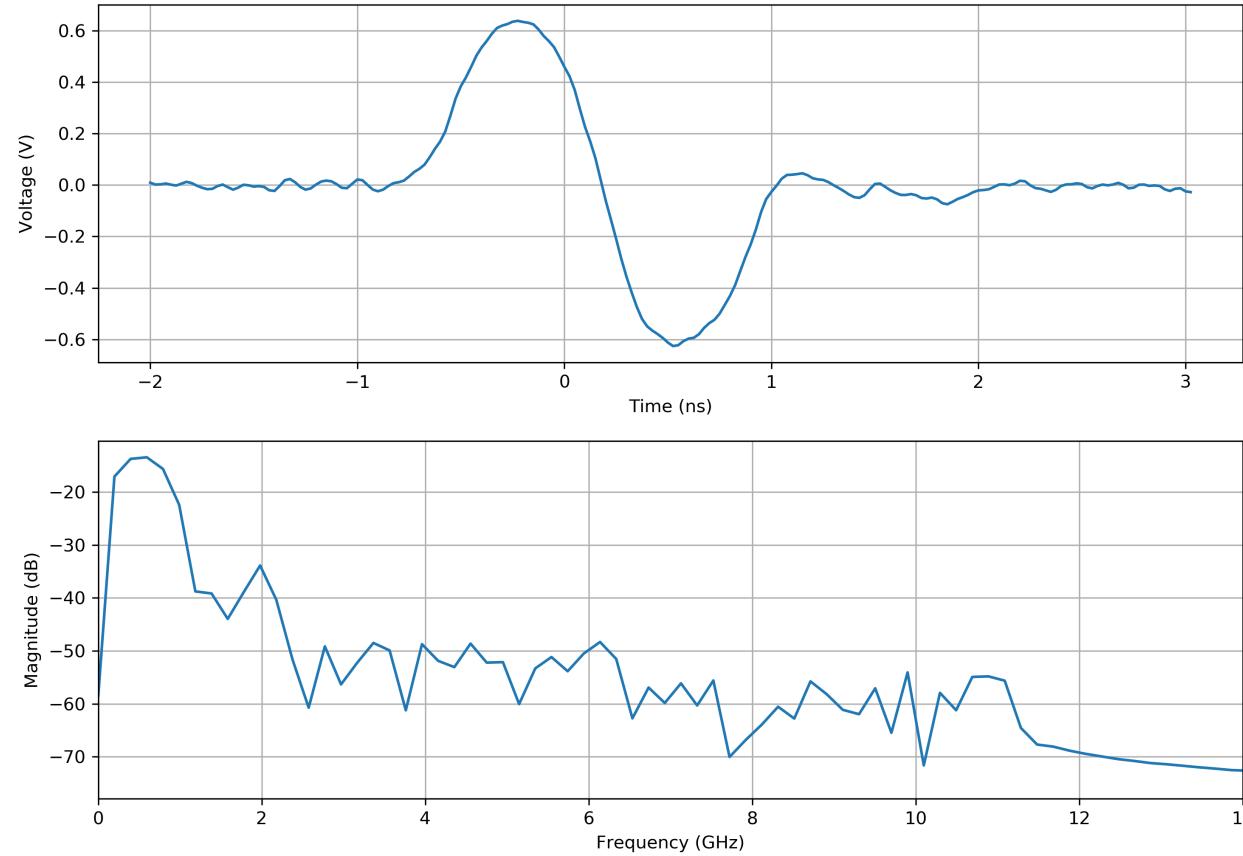


e⁻-like beam:
1e9 ppb
4 ps (4σ length)



The real world

Proton beam measurements

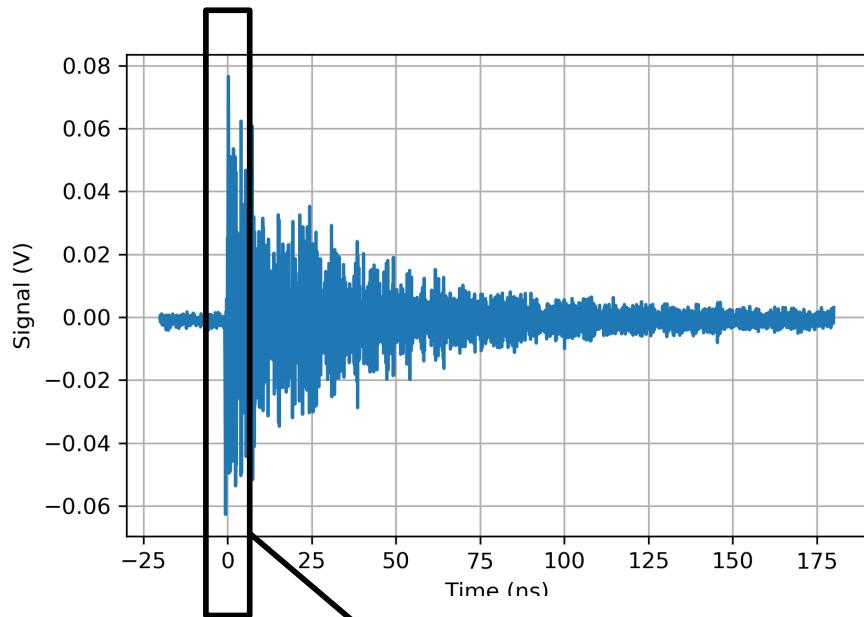


Proton beam:

- $2\text{e}11$ ppb
- 4 ns bunch length (4σ)

Most of the signal below the GHz

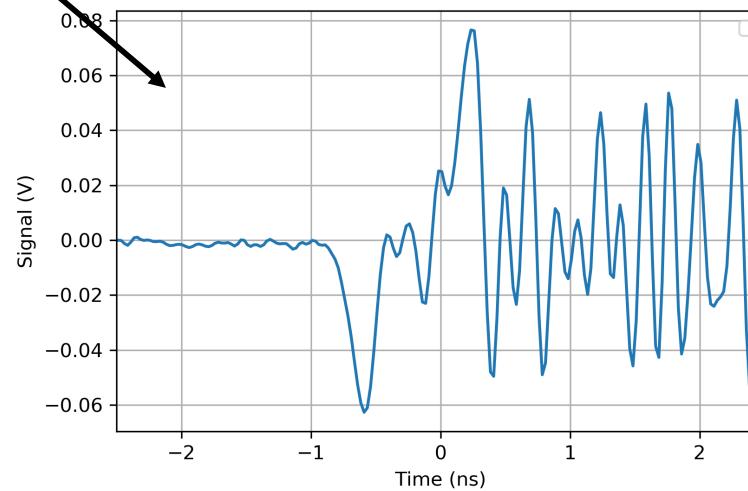
Electron beam measurements



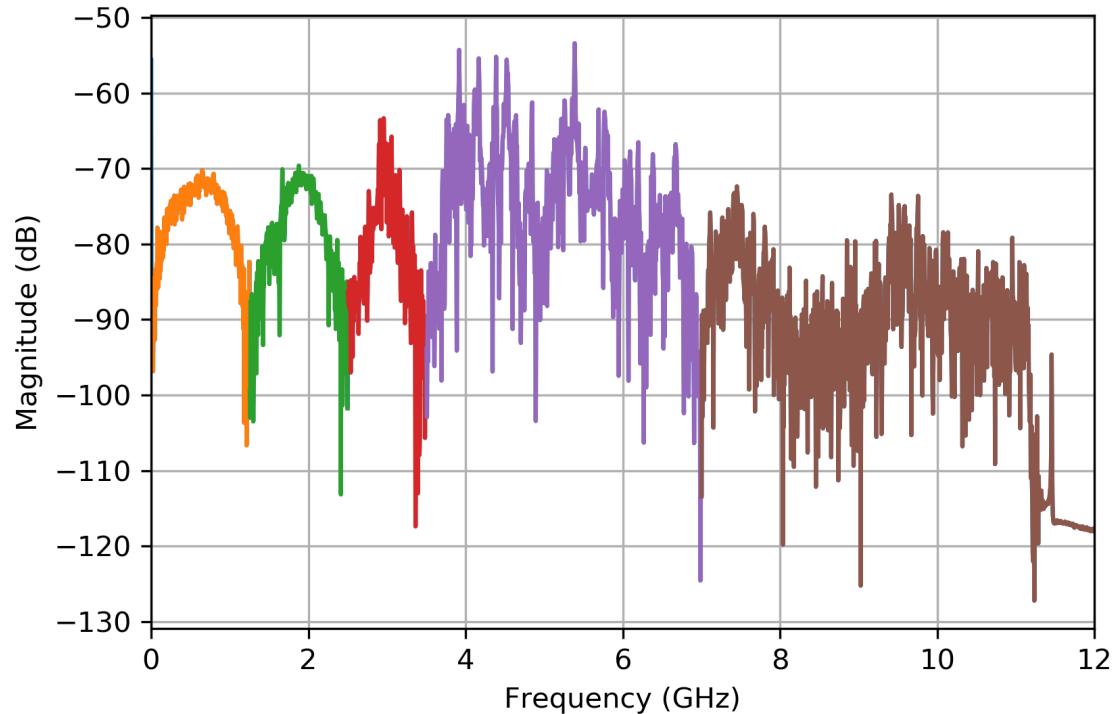
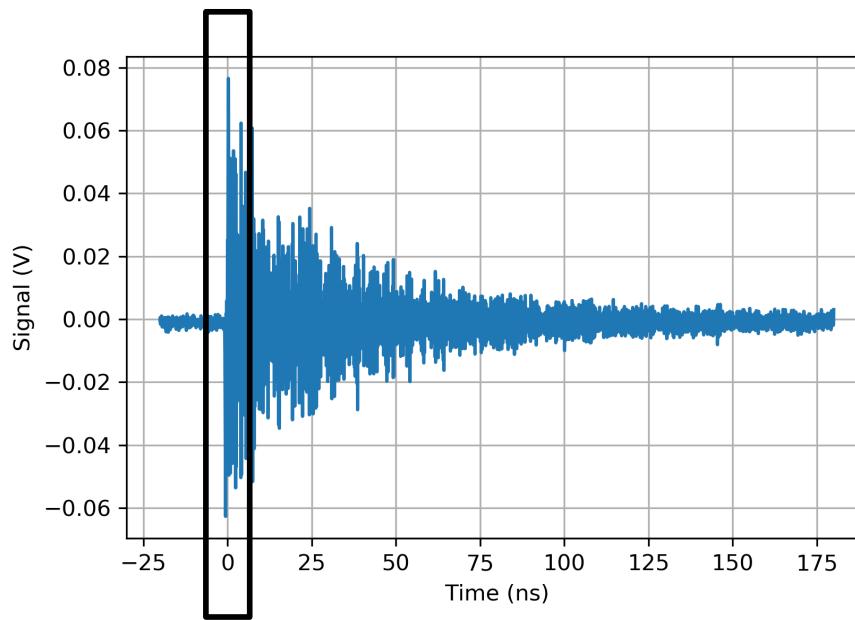
Nominal electron beam:

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

The signal is visible, but followed by a lot of noise



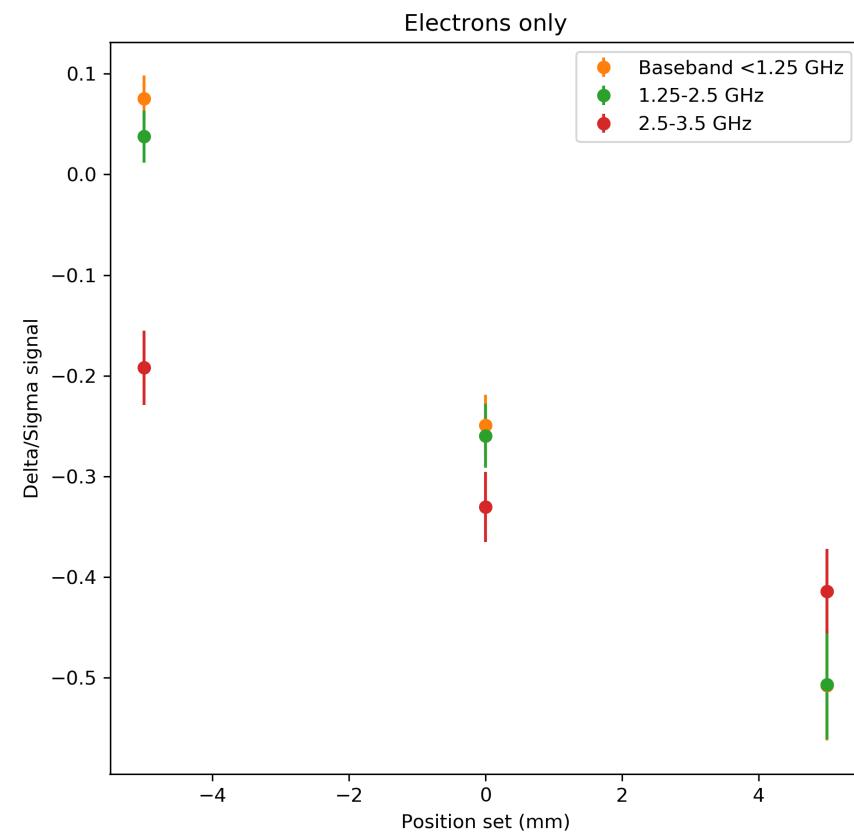
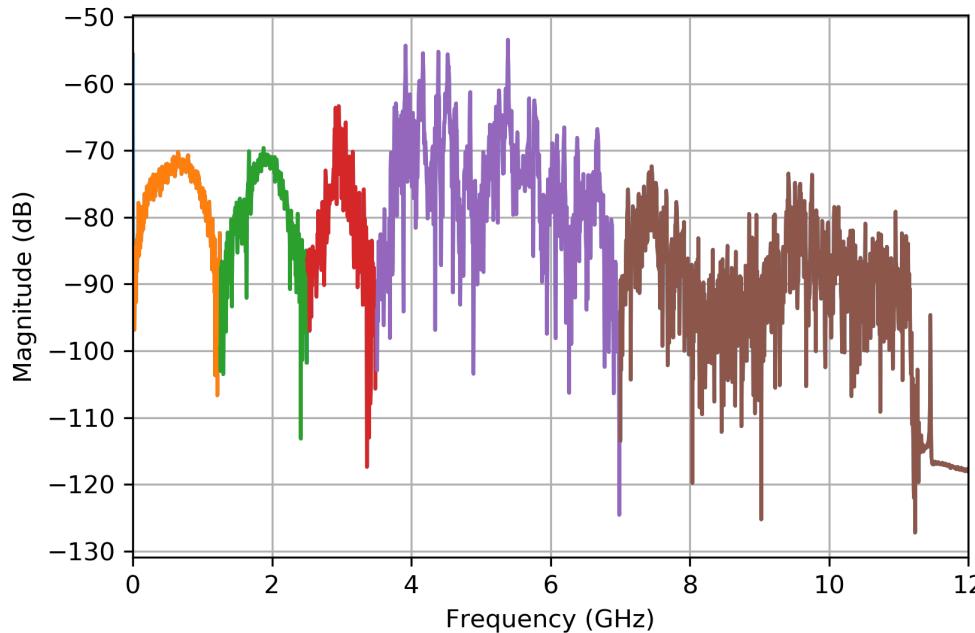
Electron beam measurements



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

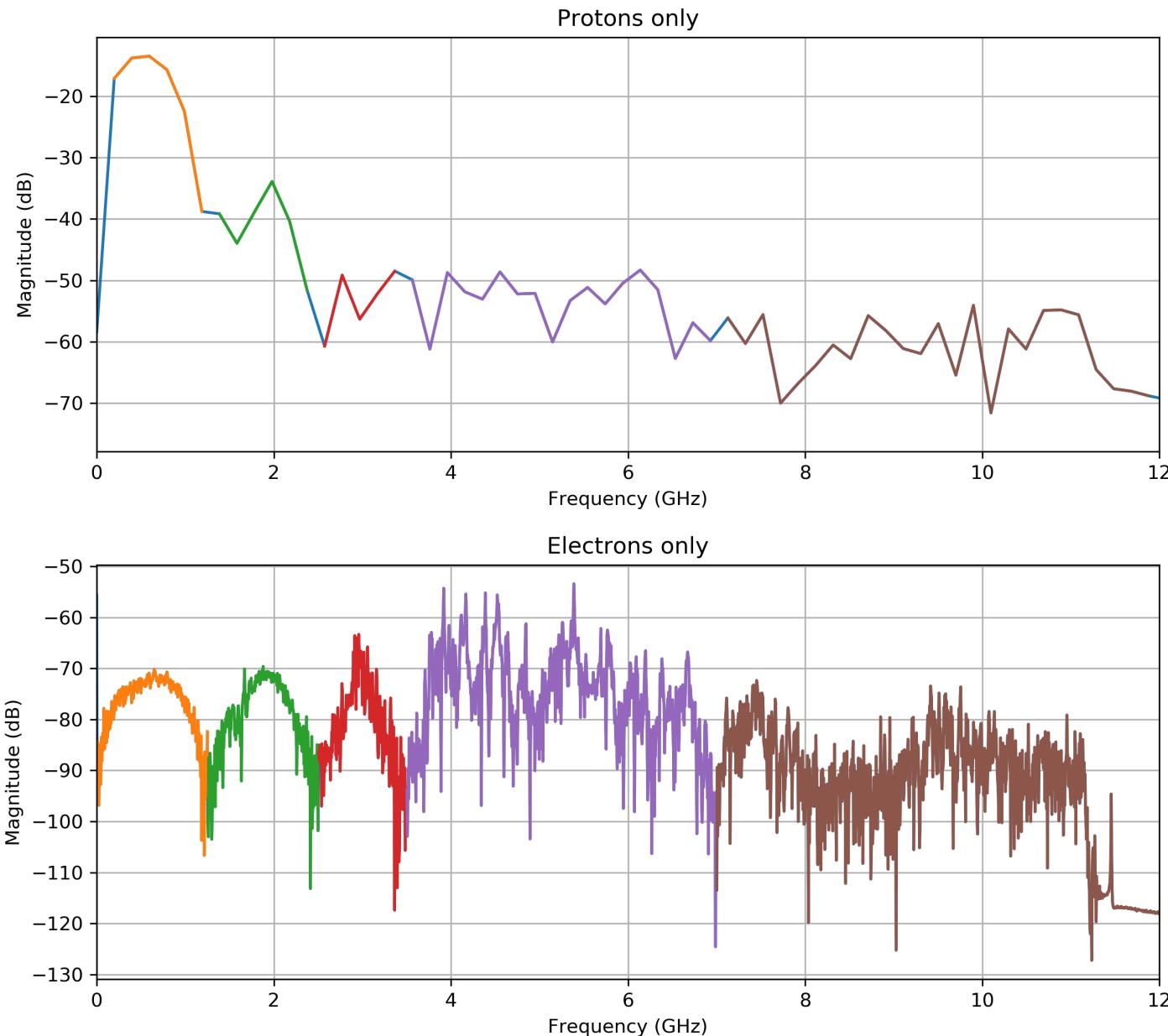
Electron beam measurements



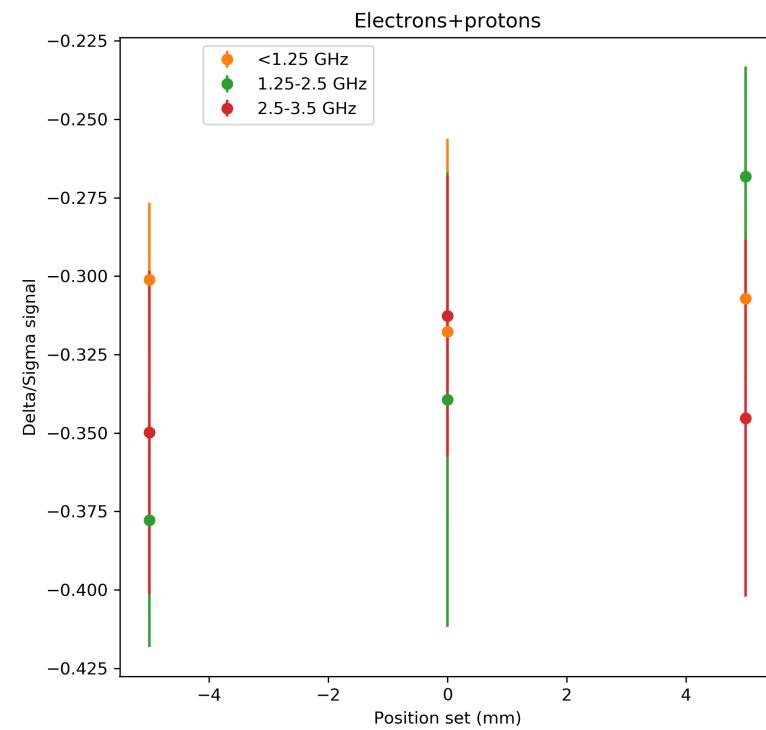
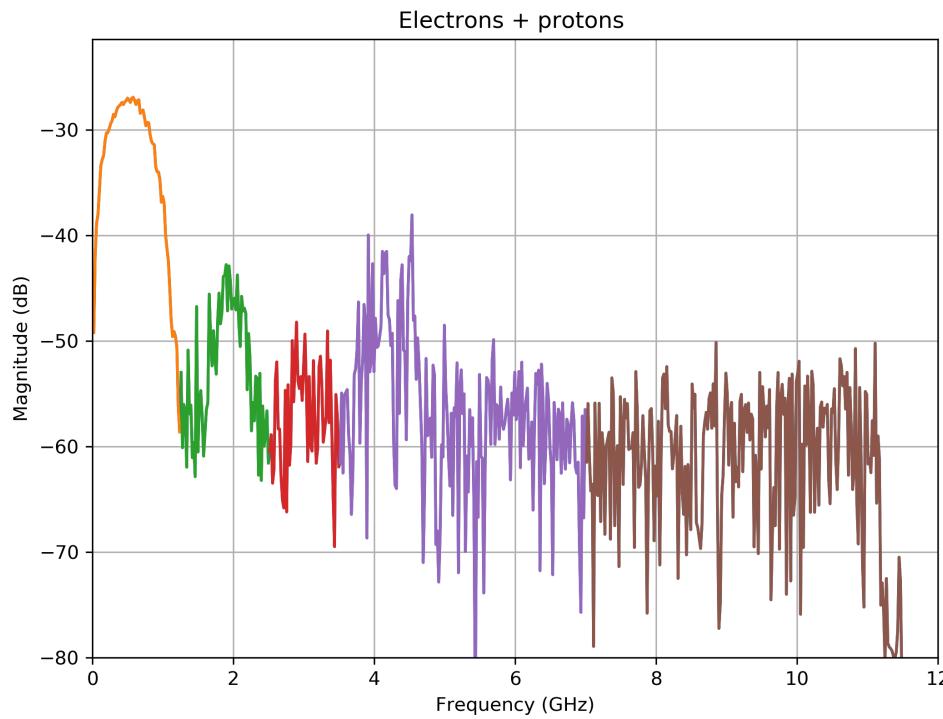
Electron beam steering:

- 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 is possible if the beams are different in bunch charge and length
 - The bigger the difference the smaller is 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 looks 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 noise at high frequency
- VNA measurements on a spare
- Brainstorm on further future design ideas