CERN PS Booster transverse damper: 10 kHz – 200 MHz radiation tolerant amplifier for capacitive PU signal conditioning

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Abstract After connection to the LINAC4, the beam intensity in the PS Booster is expected to double and thus, an upgrade of the head electronics of the transverse feedback BPM is necessary. In order to cover the beam spectrum for an effective transverse damping, the pickup (PU) signal should have a large bandwidth on both the low and high frequency sides. Furthermore, in order to extend the natural low frequency cut-off from 6 MHz (50 Ω load) down to the required 10 kHz, with no modification of the existing PUs, a high impedance signal treatment is required. The electronic parts should withstand the radiation dose received during at least a year of service. This constraint implies the installation of the amplifier at a remote location. A solution was found inspired by the technique of oscilloscopes' high impedance probes that mitigates the effect of transmission line mismatch using a lossy coaxial cable with an appropriate passive circuitry. A new large bandwidth, radiation tolerant amplifier has been designed. The system requirements, the analysis, the measurements with the present PUs, the design of the amplifier and the experimental results are described in this contribution.

Pickup

Fig. 1: PU Frequency response

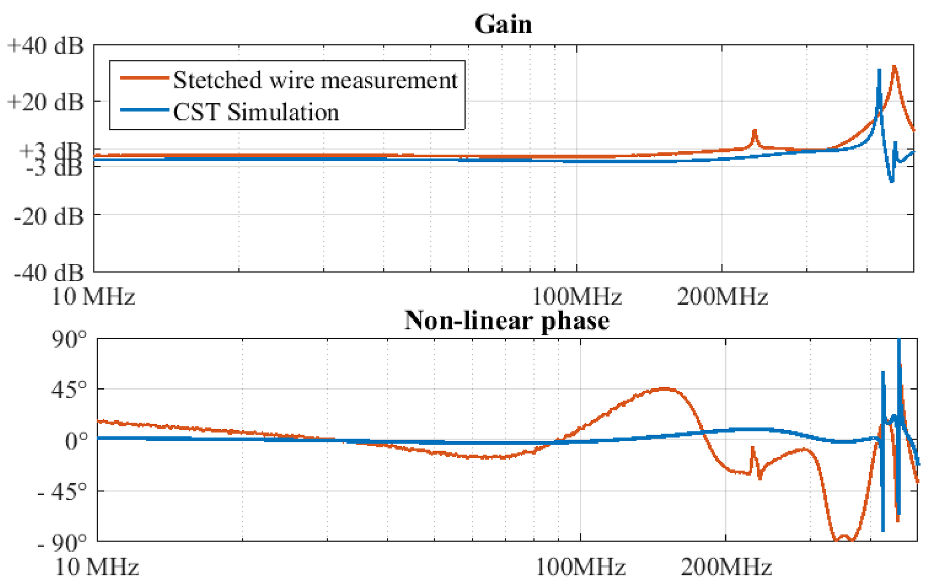


Fig.2: PU Signal amplitude

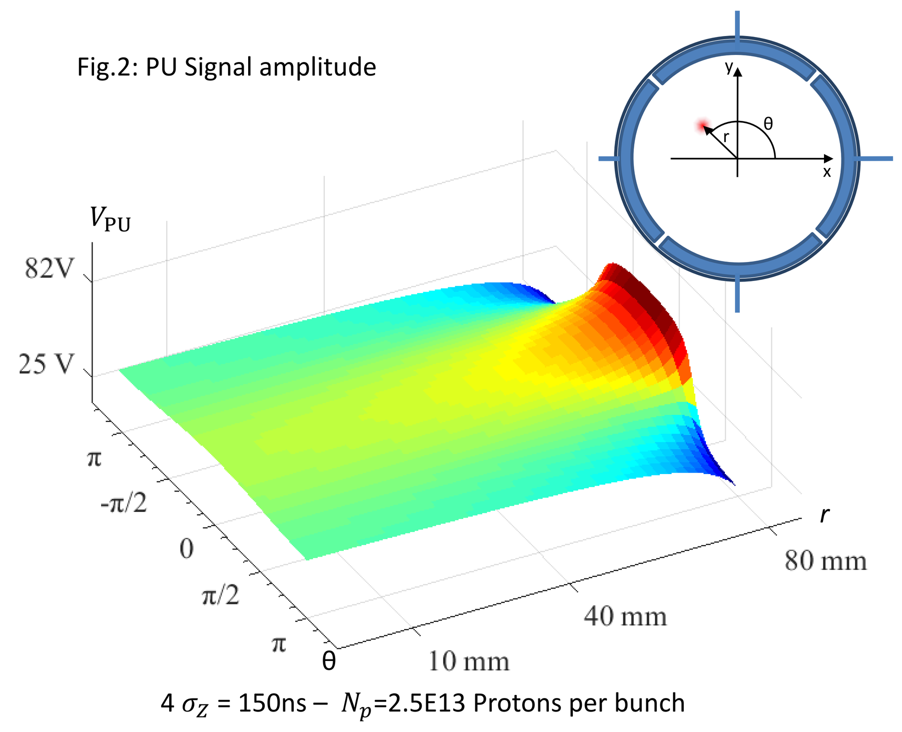
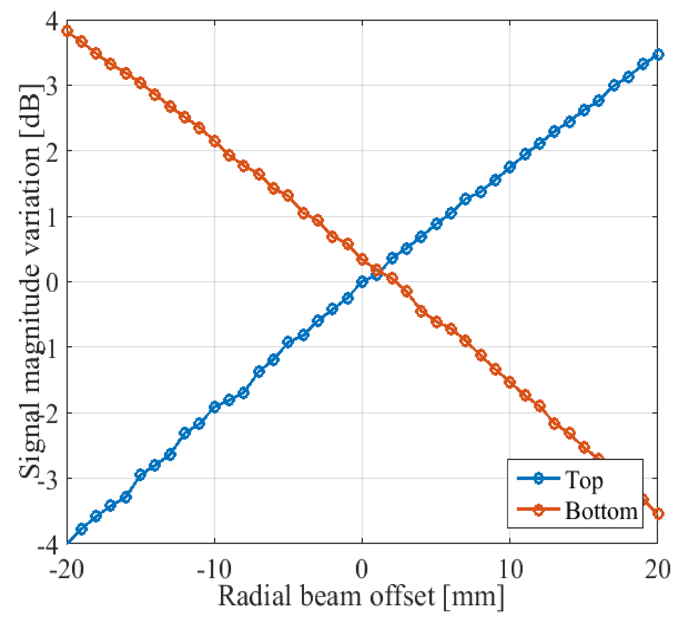


Fig. 3: PU Sensitivity



Bandwidth (± 3 dB):	200 MHz
Sensitivity	≈ 0.2 dB/mm
Mechanical offset	1.2 mm
Signal amplitude with a centred beam (4σ=150 ns, 2.5E13 Protons per bunch)	≈ 25 Vpp

Table 1: PU characteristic

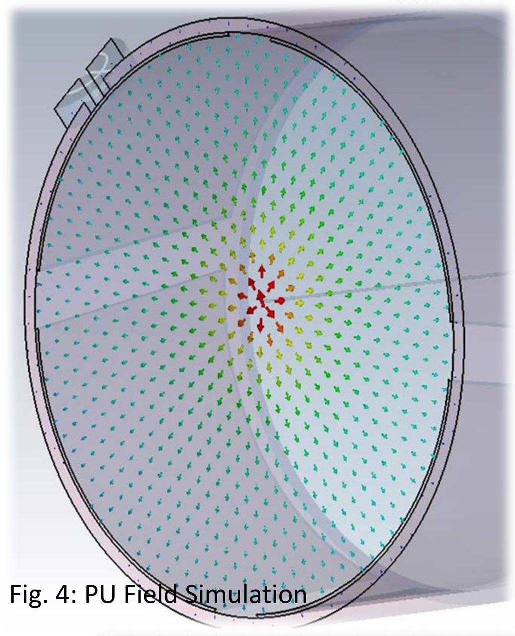


Fig. 4: PU Field Simulation

Fig. 5: Stretched wire measurements

The frequency response of the pickup has been measured reproducing the electromagnetic transverse field generated by the beam trough the stretched wire technique. A conductive wire is placed inside the pick-up along the direction of the beam, and it is exited with a sine-wave sweep, generating a TEM wave travelling in the beam pipe. The induced signal is taken from the PU plate.

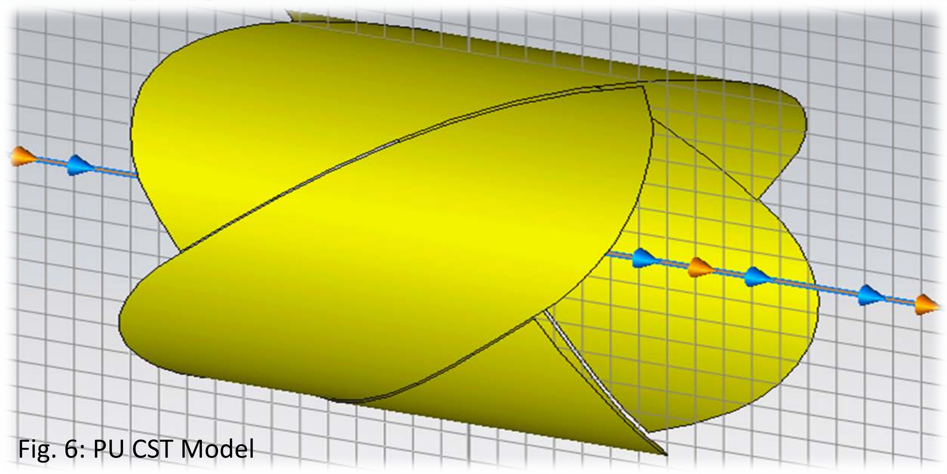


Fig. 6: PU CST Model

Proton kinetic energy, E_k	160 MeV → 2 GeV
Velocity factor, β	0.533 → 0.948
Revolution frequency, f_{rev}	1 MHz → 1.8 MHz
Maximum protons per bunch, N_p	$2.5 \cdot 10^{13}$ppb
Minimum bunch length, 4σ	≈ 150 ns

Table 2: PS Booster parameters

Radiations and mechanical constraints

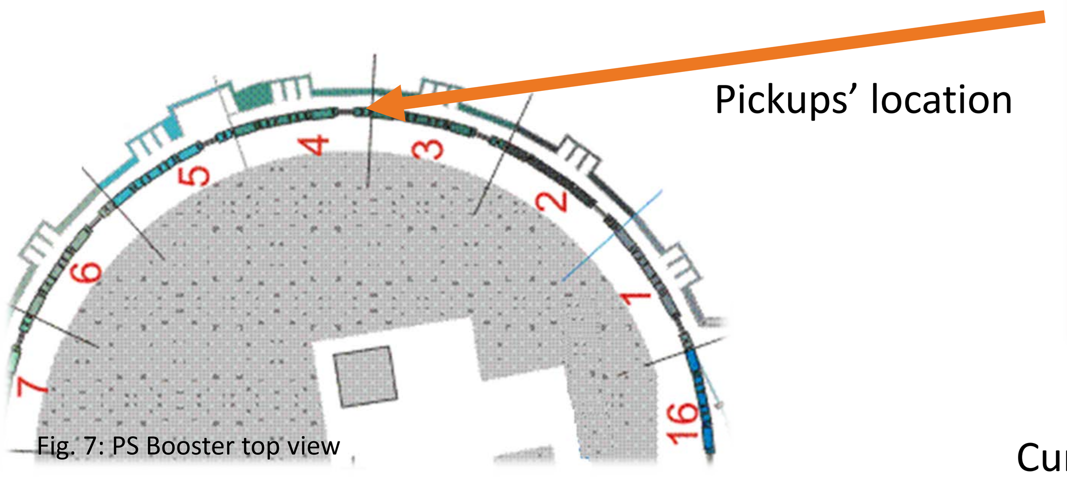
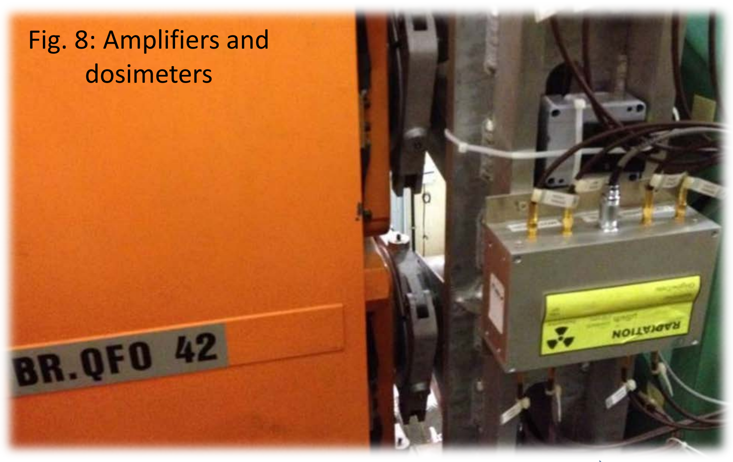


Fig. 7: PS Booster top view

Fig. 8: Amplifiers and dosimeters



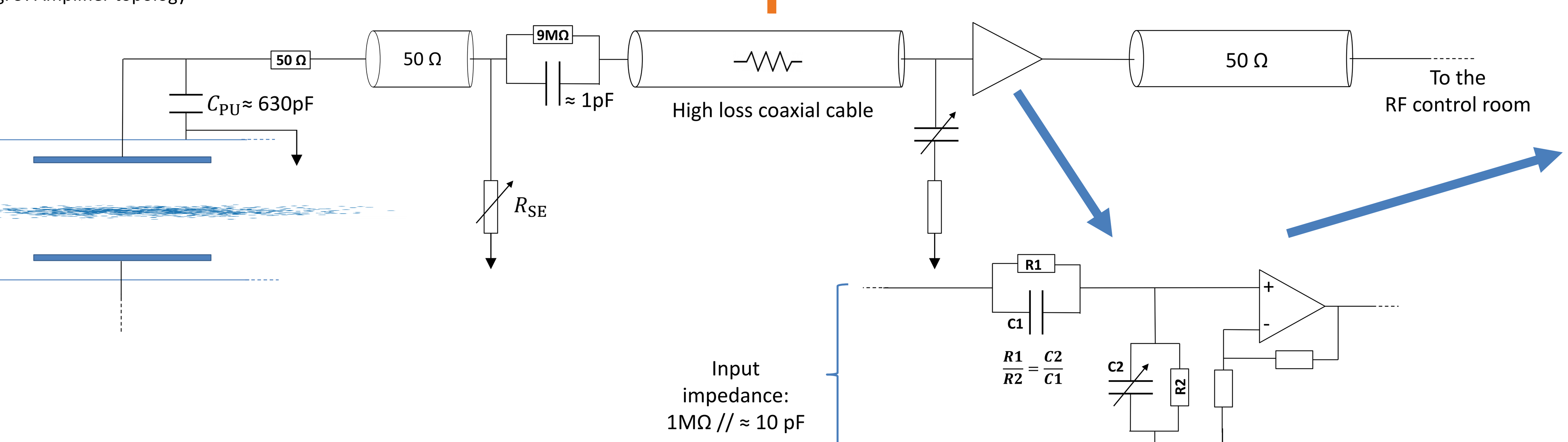
In order to extend the electronics lifetime, it was chosen to place it at a reasonable distance from the beam pipe as it is the main source of harmful radiation. The dose decreases exponentially with the distance. At the selected amplifiers location, the radiation dose has been measured with the present accelerated beam.

3.5 Gy/year
Current average annual dose

7 Gy/year
Average annual dose after LINAC4 connection

Head amplifier

Fig. 9: Amplifier topology



R	210 Ω/m
L	0.6 μH/m
C	33 pF/m

Table 3: High loss cable characteristics

Bandwidth (-3dB)	10KHz - 200MHz
Input signal range	±40 V
Input impedance	1 MΩ // 10 pF
TID dose	>> 40 Gy (4 kRad)

Table 4: Amplifier characteristics

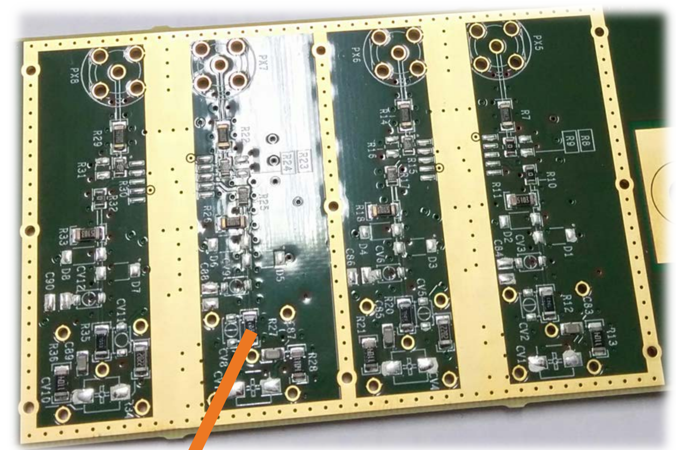


Fig. 13: PCB detail

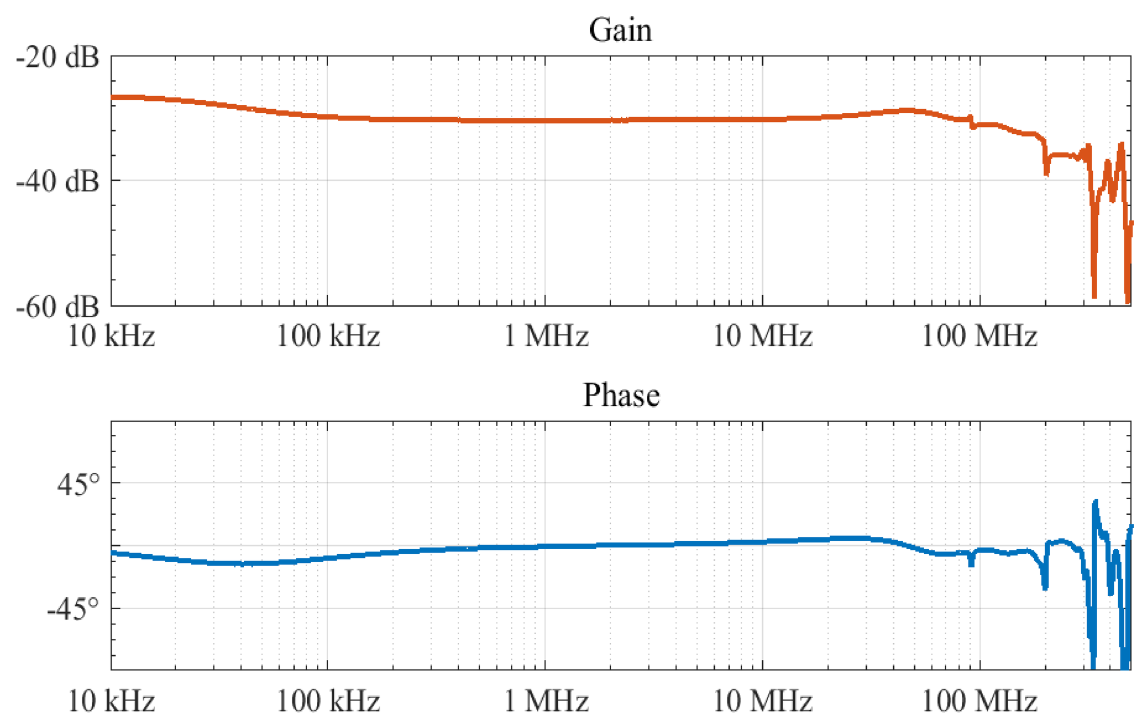


Fig. 10: Amplifier frequency response

As the Head amplifier ends up being distant from the PU connector, a transmission line needs to connect both parts. To match the load impedance requirements from the PU perspective, the line must present a high impedance at low frequencies.

A lossless coaxial cable terminated with a high unmatched impedance would cause standing waves. To keep a good signal integrity it was chosen to benefit from the design used in oscilloscope probes. This technique is using a high loss coaxial line and a passive network on both ends that allow to cover a very large bandwidth with a high perceived impedance.

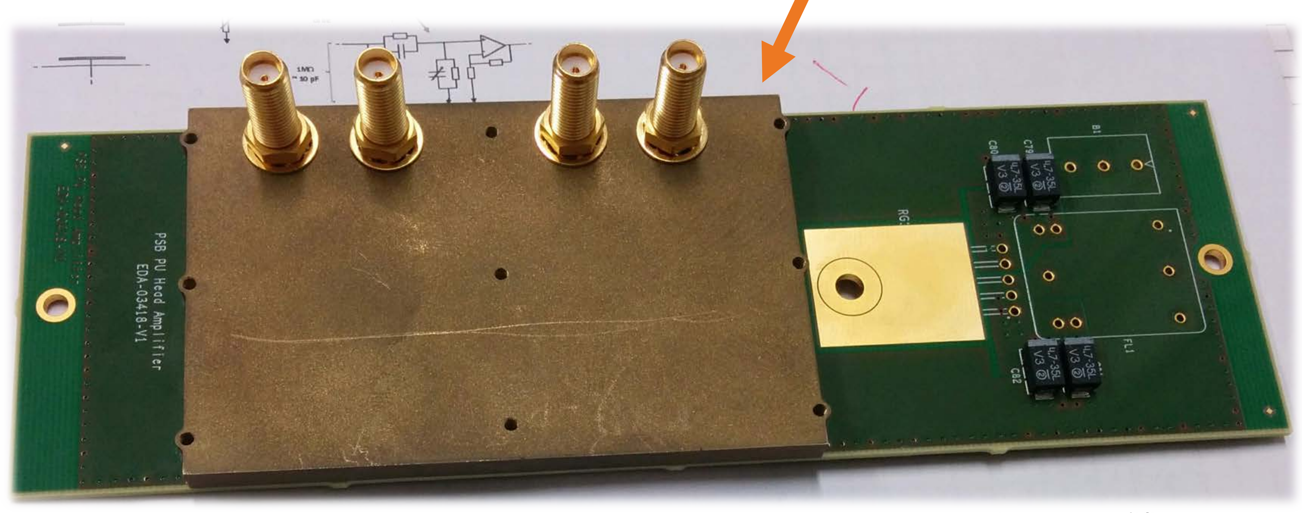


Fig. 11: Amplifiers top view

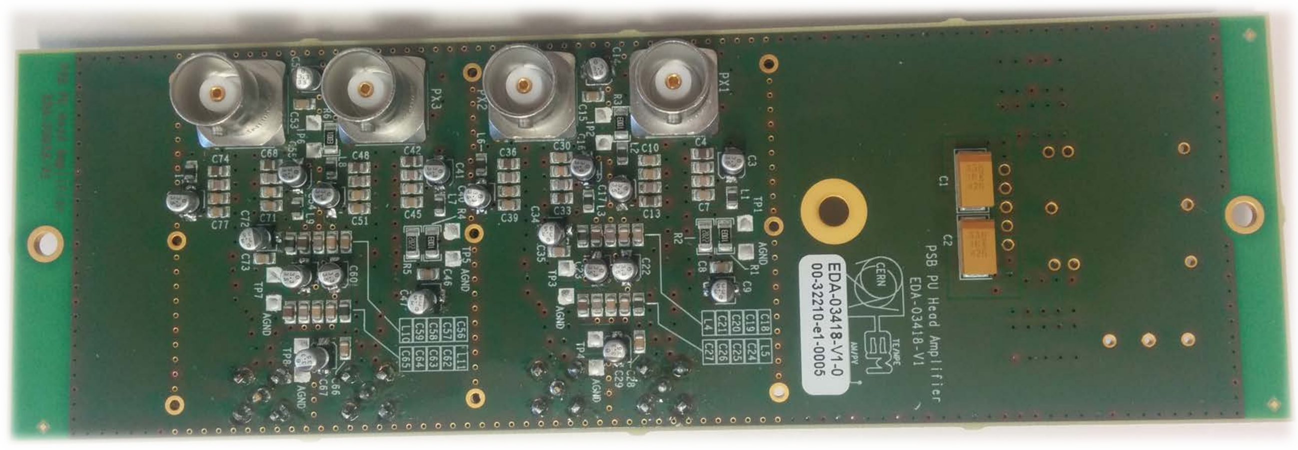


Fig. 12: Amplifiers bottom view

Conclusion

A head amplifier setup has been designed to measure the beam position in the CERN PSB even when loaded with the maximum beam intensity expected after the PSB connection to LINAC 4. Its bandwidth extends from 10 kHz to 200 MHz thanks, at the low frequency end, to a passive probe setup as used in commercial oscilloscopes, and on the high frequency side, to high frequency commercial operational amplifiers. The distance from PU to amplifier allowed by the high impedance probe allows for the reduction of radiation doses. Selected radiation hardening components should further extend the circuit lifetime.

To be done:

- Final validation of the components
- Installation in the machine for the long tests
- Final version of the PCB
- Installation in the machine and replacement of the old amplifiers

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