Strip Printed Circuit Board - PCB validation and properties for CMS iRPC during Phase 2 Upgrade

G. Garde[1], C. Combaret[1], M. Gouzevitch[1], I. Laktineh[1], C. Uribe Estrada[2], A. Albouy[1],

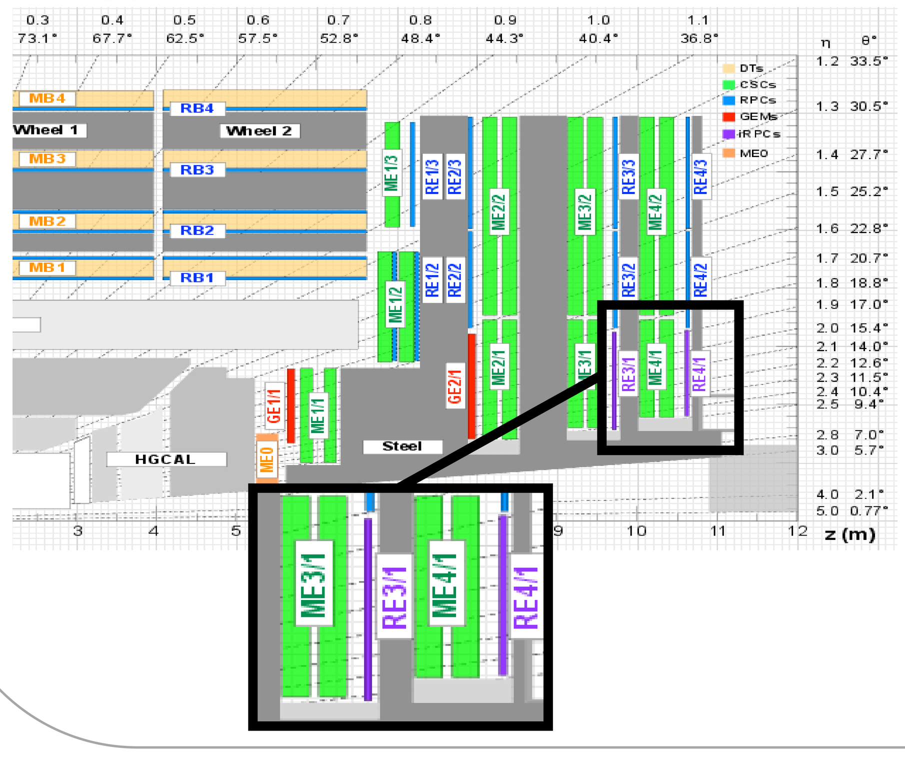
on behalf of CMS RPC group

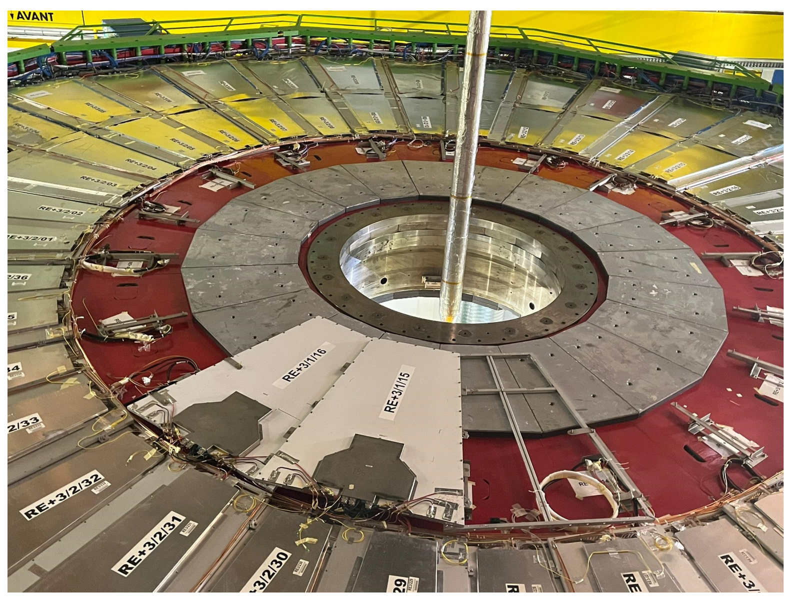
[1]Institut de Physique des 2 Infinis de Lyon (IP2I), Villeurbanne, France

[2]Benemerita Universidad Autonoma de Puebla, Puebla, Mexico

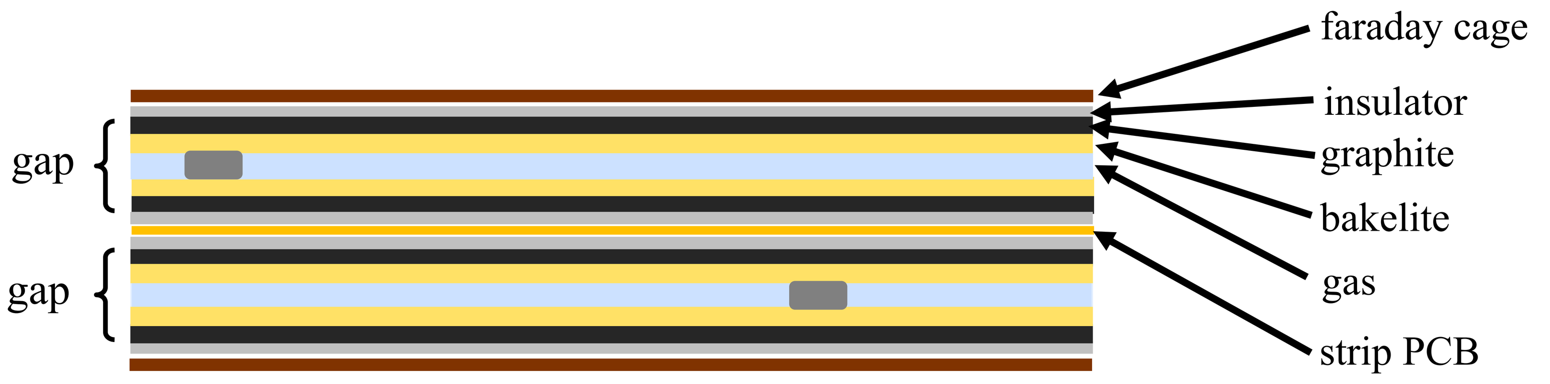
1 - Motivations

During the LHC to High Luminosity-LHC (HL-LHC) phase, the instantaneous luminosity in the CMS experiment is expected to increase up to a maximum of $5-7\times10^{34}$ cm^{-2} s^{-1} which is 5 times higher than LHC nominal luminosity. To cope with the increased particle flux, the CMS collaboration has proposed the installation of new detectors, improved RPC (iRPC), in RE3 / 1 and RE4 / 1 regions [1]. The iRPC allows a 2D reconstruction and high accuracy in absolute time [2].

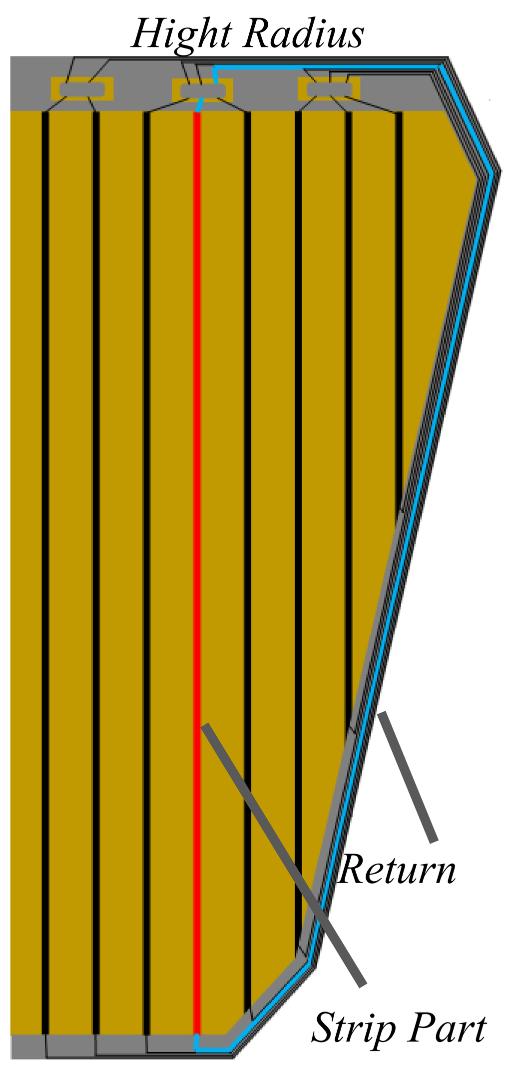




2 - The iRPC Chamber and PCB



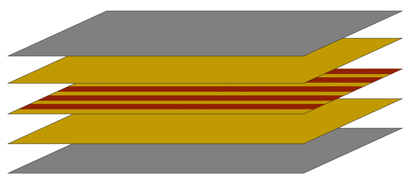
Double-gap iRPC detectors. The electron avalanche inside the gap generated by the transition of high energy particles induces a signal on the strip PCB. This signal is transferred in two directions along the strip and collected by the Front end Board (FEB).



PCBs are composed of 48 strips, connected to 3 ERNI connectors. The two ends of the strips are connected. The position of the induced signal is known by the strip number, and the time difference for the electric signal to reach the end of both ends of the strip, given the velocity v of the signal propagation. Each strip is composed of a «strip» part, in red, and a «return line» part, in blue. The PCB and the chamber were designed for an impedance Z=50 Ω all along the signal extraction chain. The design of such strip PCB implies a careful matching of the impedance at each connection:

FEB ⟷ Strip ⟷ Return line ⟷ FEB.

To be able to retrace particle tracks throw the iRPC detector, the velocity of the electric signal must be known and must be the same from one PCB to another.



Return strip part layers

Strip part layers

The differences between the «strip» and «return line» are their composition and the width of the strips.

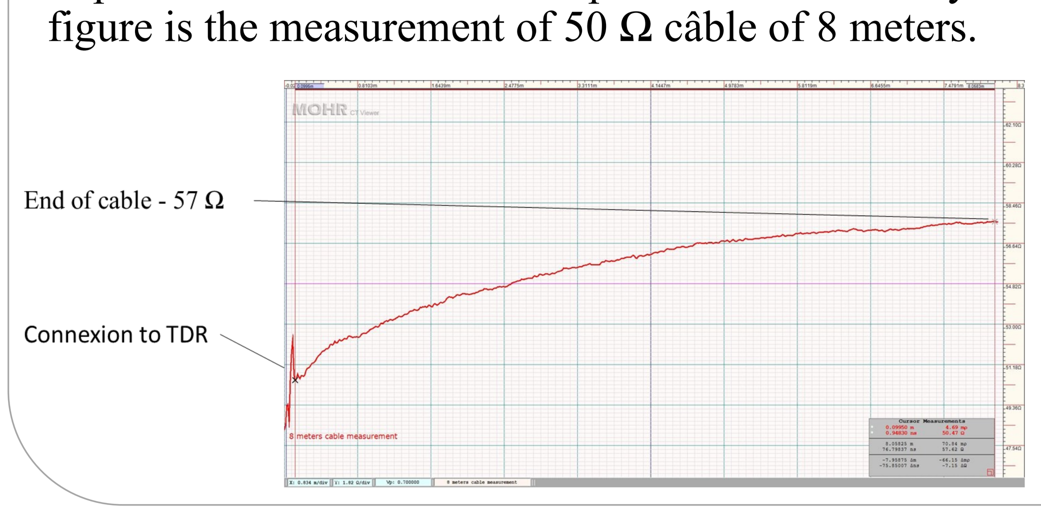
The «strip» part is composed of copper strips of 30 µm thick - in red - separated and set between two layers of insulator EM888 of 300 µm thick - in brown (similar to FR4, but with higher density and lower high-frequency signal attenuation during the propagation). The «return line» part is composed of copper strips of smaller width, and two layers of copper - in grey - connected to the ground.

The impedance of the strip is a function of its dimensions, the type of insulator used, and its distance to the ground layer. For the « strip part », the ground layer is the faraday cage of the chamber. Therefore, the impedance of the «return line» is defined by the PCB design. The impedance of the « strip » part will depend on chamber design.

PCBs are produced by «ELVIA Printed Circuit Board» company.

3 - Time Domain Reflectometer (TDR)

A Time Domain Reflectometer (TDR) – Mohr CT100 – is used to investigate strip impedance. It is important to know that the impedance measures by the TDR are affected by a deviation, The left figure is the measurement of 50 Ω câble of 8 meters.



The first peak corresponds to the connection between TDR and cable. At the start of the measurement, the value measured is 50 Ω - the impedance of the câble. Then, the impedance increases up to the value of 57 Ω .

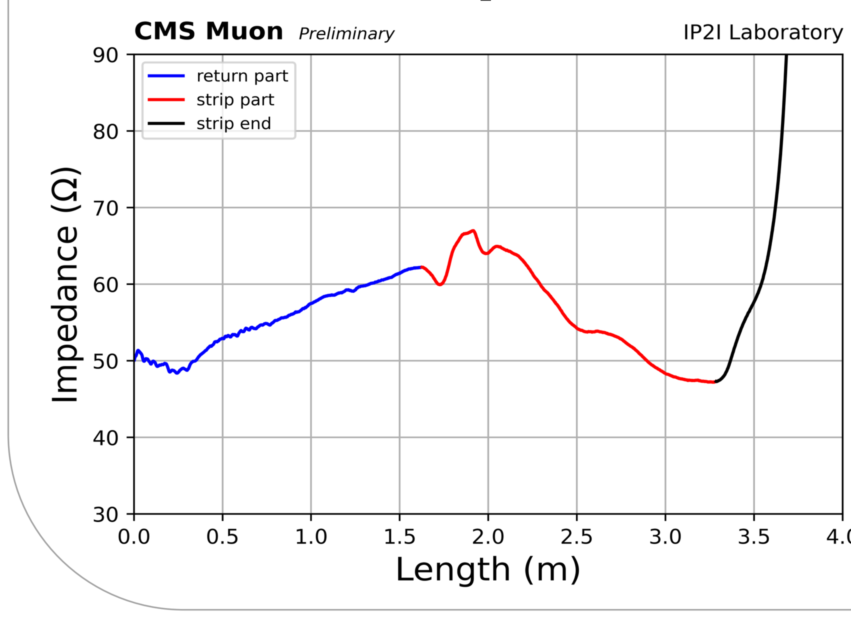
The plot shows the deviation of impedance measured by TDR along the strip.

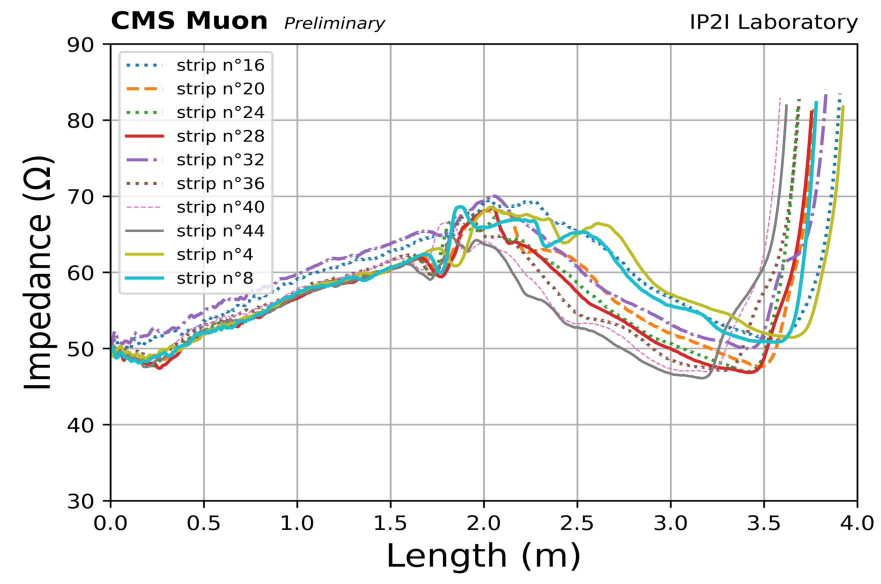
References

1.CMS Collaboration, "The Phase-2 Upgrade of the CMS Muon Detectors," CERN-LHCC-2017-012, CMS-TDR-016,(2017).
2.K. Shchablo,I. Laktineh,M. Gouzevitch,C. Combaret,L. Mirabito, Performance of the CMS RPC upgrade using 2D fast timing readout system , Performance of the CMS RPC upgrade using 2D fast timing readout system, Elsevier, 1 April 2020

4 - PCB impedance

To investigate PCB impedance continuity strips, TDR has been used. These figures have been obtained by connecting the TDR to the «return line» part of strips. The left plot represents the impedance evolution through the different parts of the strips. The right figure shows the uniformity of impedance of « return parts ». The differences from strip to strip is due to TDR drift. By connecting the TDR to the «strip part», the impedance is for all ~53 Ω. The impedance of the FEB would be adapted to match 53 Ω.

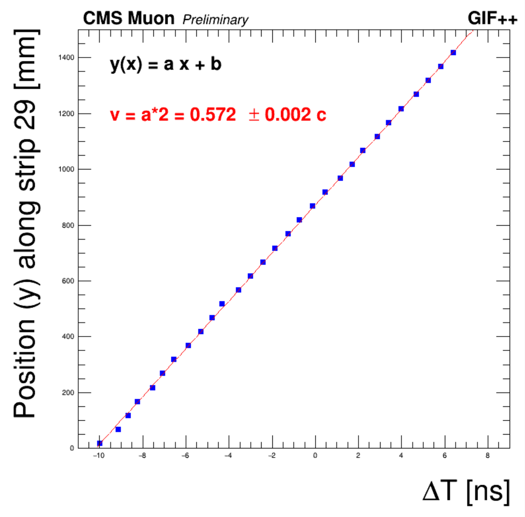


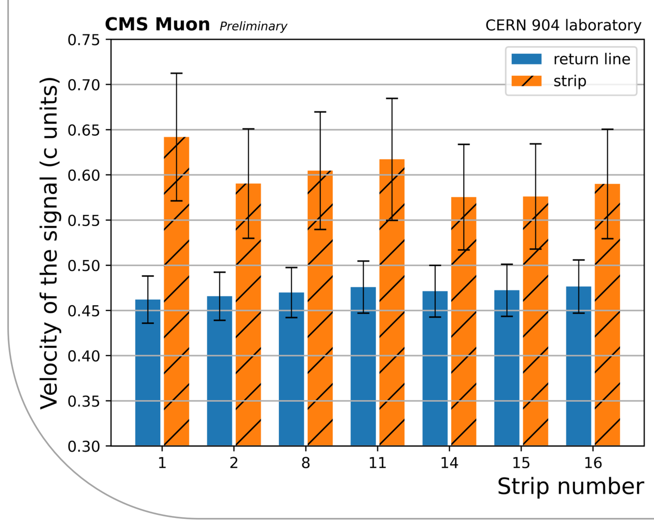


5 - Signal velocity

The two different parts of each strip - «return line » and «strip» have different geometries. It induces a difference in velocity of propagation, V_{strip} = 0.572c, and $V_{return\ strip}$ = 0,47c - where c is the speed of light in vacuum.

The figure on the right plot is obtained using ^{60}Co radiation source and FEB on a real chamber The curve represents the position of the source along the strip function of the time difference between the signal on the «return line» and «strip» part. The velocity of propagation of the «return line» is calculated as the time travel of the injection of a signal from one end to the other knowing V_{strip} part = 0.572c.

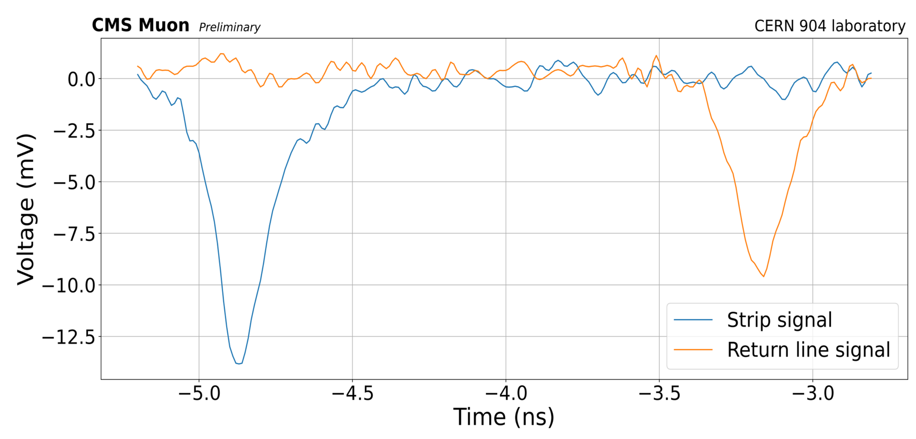


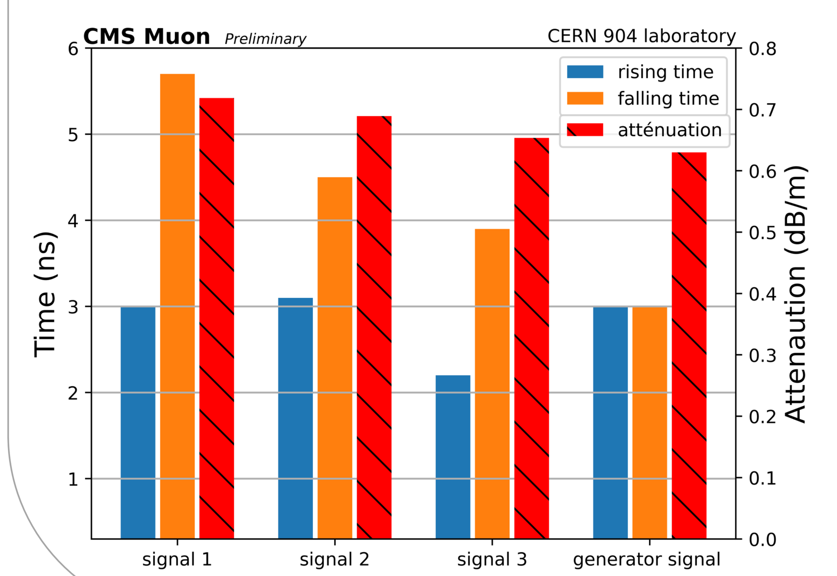


The result on the left has been obtained by injecting a signal into a PCB, using a capacitor. The signal was injected at the change between the strip and the return part. The velocity of propagation is calculated by measuring the travel time. The measurement uncertainty is due to the deformation of the signal by the induction. These results confirm the values obtained previously with ^{60}Co radiation source .

6 - Signal attenuation

In the right figure, signals, coming from an iRPC chamber have been measured with an oscilloscope. The orange - which has passed throw the return strip - is more attenuated than the blue - coming from the strip part.

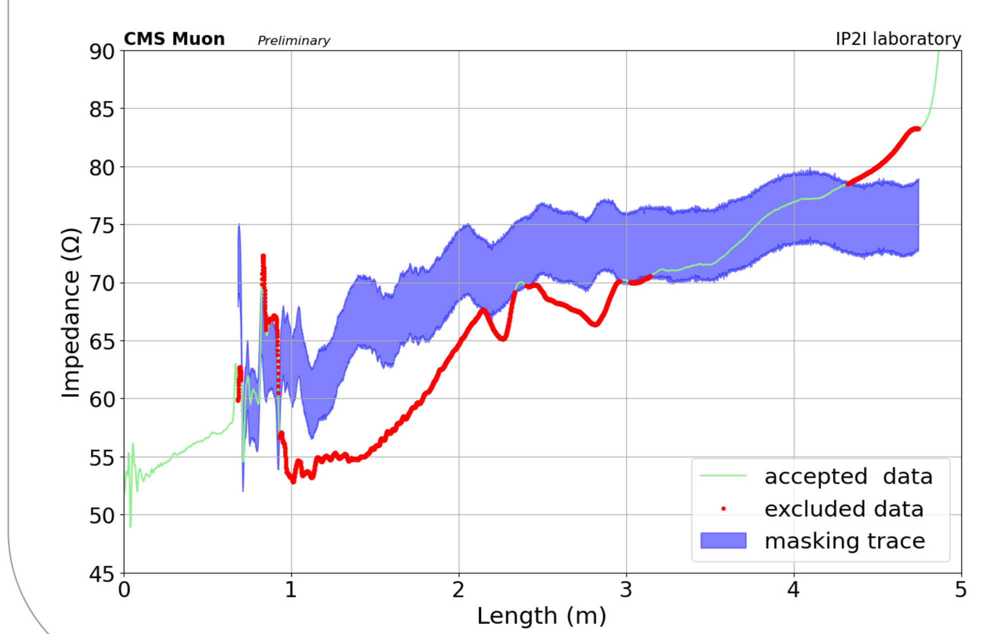




In the left figure, signals 1, 2, and 3 have been measured on the iRPC chamber with an oscilloscope. The «generator signal» has been induced in iRPC chamber with a signal generator on the strip part and measured with an oscilloscope at the end of the return part. The attenuation measured on the induced signal is of the same order of magnitude as real iRPC signals. Attenuation measures within the strip can be achieved by injecting a signal.

7 - Mass production Quality Control

For the iRPC project, 160 PCB will be produced. Each strip of each PCB will be tested to check that its impedance and propagation speed correspond to the expected values. For this purpose, the quality control implemented is a "mask test".



The curve on the left is from Quality Control (QC) in IP2I RPC laboratory. The impedance of the strip tested (green) is expected to be within the tolerance envelope (blue), otherwise (red curve) the PCB is rejected.

This test allows to control the speed of propagation of the electrical signal, a deviation from the expected values will appear by a drift of the curve.

Conclusion

Impedance and propagation velocity measurements are used to validate the integration of PCBs in iRPC chambers. Quality control is ready to verify the validation of the PCBs for the production phase.