The TOTEM experiment has been designed to measure the total proton-proton cross section and to study elastic and diffractive scattering at the LHC energy. The measurement requires detecting protons at distances as small as 1 mm from the beam center. TOTEM uses Roman Pots (RP), special beam pipe insertions, to move silicon detectors close to the beams to detect particles very near the beam axis. In the first period of running of the LHC no problems were detected with retracted Roman Pots and during insertions in special runs, however, during close insertions to highest intensity beam, impedance heating has been observed. After the Long Shutdown 1 (LS1) the LHC beam current will increase and the equipment that can interact with the beam needed to be optimized.

THE IMPEDANCE PROBLEM

A charged beam perturbs its surroundings, creating an electromagnetic field (wake field) that affects other charged particles. In presence of a cavity, the perturbation can last for a long time, even after the passage of the beam.

In the following images are shown subsequent instants of a simulation of the electric field inside a simple cavity.

The RF measurements at the proton station show a cavity on the beam depends on the impedance of the cavity and on the power spectrum of the LHC beam.

OPTIMIZATION OF THE ROMAN POT

Before the LS1 all TOTEM RP installed in the LHC were box shaped. These RPs have a considerable amount of empty space between the detector housing and the vacuum flange that resonates at low frequency (~500 MHz). This lead to the introduction of planes of ferroite on the sides of the RP.

The simple solution of having a detector housing that uses all the available space would be ideal; however, the RP needs to be safely inserted and retracted and mechanical constraints and tolerances have to be considered.

The final design, has a 2.5 mm gap around the detector housing to guarantee a safe movement and has a small ferroite ring to damp the resonances due to this gap.

Following the same strategy, a RF shield has been developed to optimize the impedance of the box RP (Shielded RP) without a complete replacement of the existing RPs.

The shield is made of a thin layer of copper and stainless steel, some holes on its side and bottom guarantee enough ventilation.

The RF performances of the optimized design are undoubtedly better than the old box RP. As shown in the figures on the right, the new RP behaves better both when the RP is retracted in garage position at 40 mm and when is inserted close to the beam.

TEST BENCH MEASUREMENTS

Tests to check the validity of the simulations were performed on a prototype of the new RP stations: the tests consisted of studying the cavity with a probe or using one or two thin wires to simulate the presence of the beam.

In particular, one of the tests is done positioning a thin wire at the center of the beam pipe. A current pulse traveling through the wire perturbs the cavity in a way similar to a bunch of charged particles.

While the electromagnetic behavior of the cavity is perturbed by the presence of the wire, adapting the same models used to optimize the impedance, it is possible to simulate the behavior of the device under test and to compare the measured transmission coefficient, $S_{21}$, with the simulated one. These tests represent an important milestone to ensure that the numerical model are accurate and that the details not implemented in the models (soldering, imperfections, etc.) have a negligible impact on the results.

The TOTEM Collaboration has designed, realized and tested a new Cylindrical Roman Pot and a new RF shield has been proposed and realized to improve the RF behavior of the old RP model without requiring a complete redesign. The new designs were simulated using CST Particle Studio and RF bench measurements were performed on the prototypes showing good agreement with the simulations.

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