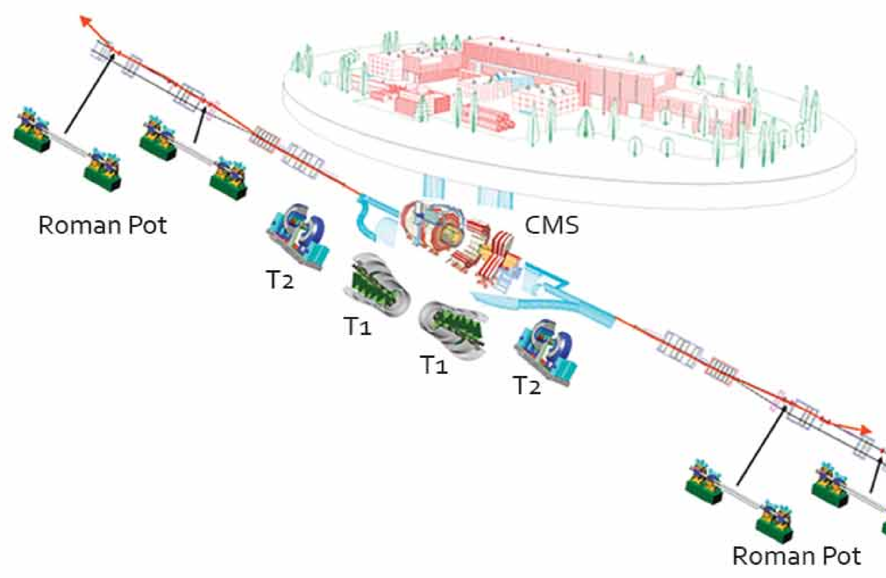
RF Optimization of the New TOTEM Roman Pot

Nicola Minafra, on behalf of the TOTEM Collaboration



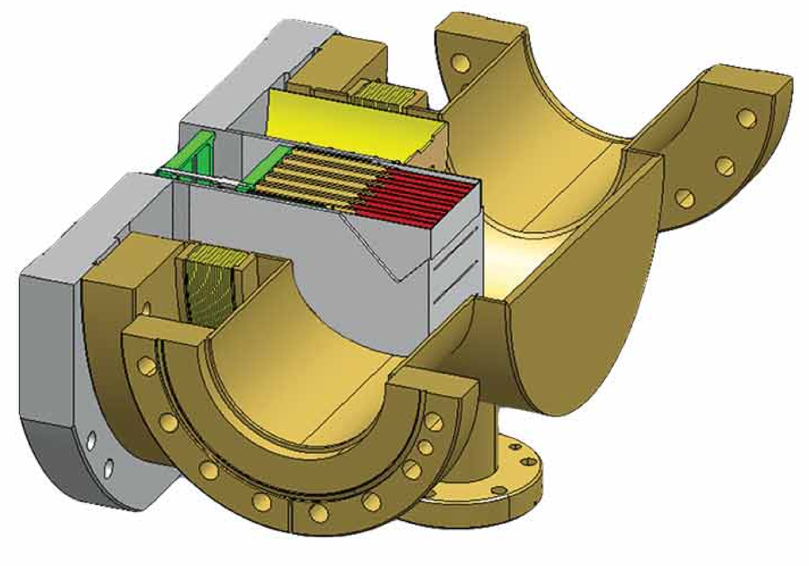
The TOTEM experiment

The TOTEM experiment was designed to measure the total proton-proton cross section and to study elastic and diffractive scattering at the LHC energy. In order to achieve a 2 % precision for the total cross-section using the Optical Theorem, one needs to be very close to the outgoing beam; this is done using Roman Pots.

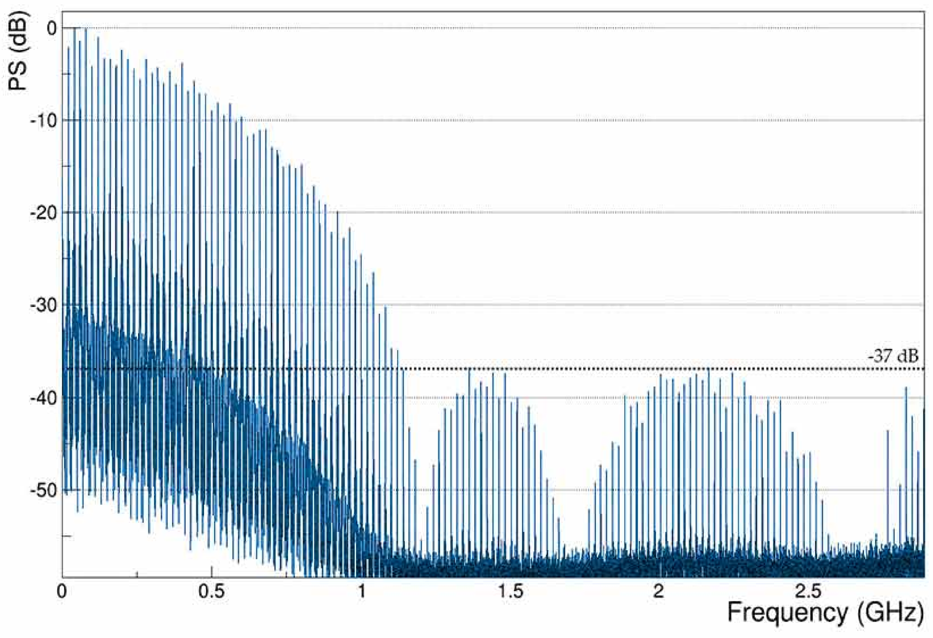
$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \frac{\left.\frac{dN_{el}}{dt}\right|_{t=0}}{N_{el} + N_{inel}}$$

However, in the LHC Phase 1, an increase of the temperature of the Roman Pots was observed both in the ALFA and TOTEM.

After the LS1, the LHC beam current will increase and the equipments that can interact with the beam need to be optimized; moreover, new detectors for the TOTEM upgrade program require an elongation of the Roman Pot along the beam direction.



TOTEM Horizontal Roman Pot



LHC power spectrum

When the beam is passing through a cavity, part of its energy is dissipated on its walls, hence producing heat. The amount of heat produced depends on the cha-racteristics of the cavity and of the beam power spectrum: in the LHC the heat is produced mainly by resonances below ~1.2 GHz.

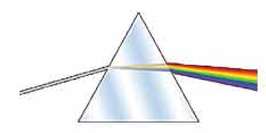
$$P_{loss} = 2\, I^2 \sum_{p=0}^{\infty} P.S.(p\, M' f_{rev})\, \Re[Z_{long}(p\, M' f_{rev})]$$

Beam current: $I = M\, e\, N_B\, f_{rev}$

LHC revolution frequency

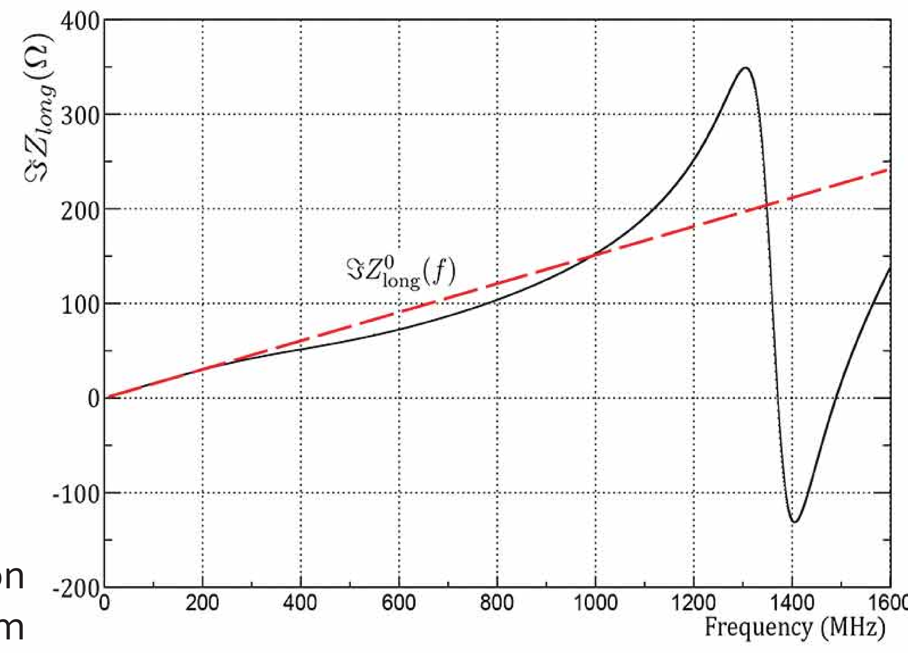
Number of buckets

LHC Power Spectrum



$$\frac{Z_{long}}{n} \stackrel{\text{def}}{=} \lim_{f\to 0} f_{rev} \frac{dZ_{\parallel}}{df}$$

The Effective Longitudinal Impedance is an indication of the dispersion through the cavity. If $\frac{\Im[Z_{long}]}{n} = 0$ the longitudinal shape of the beam remains the same.

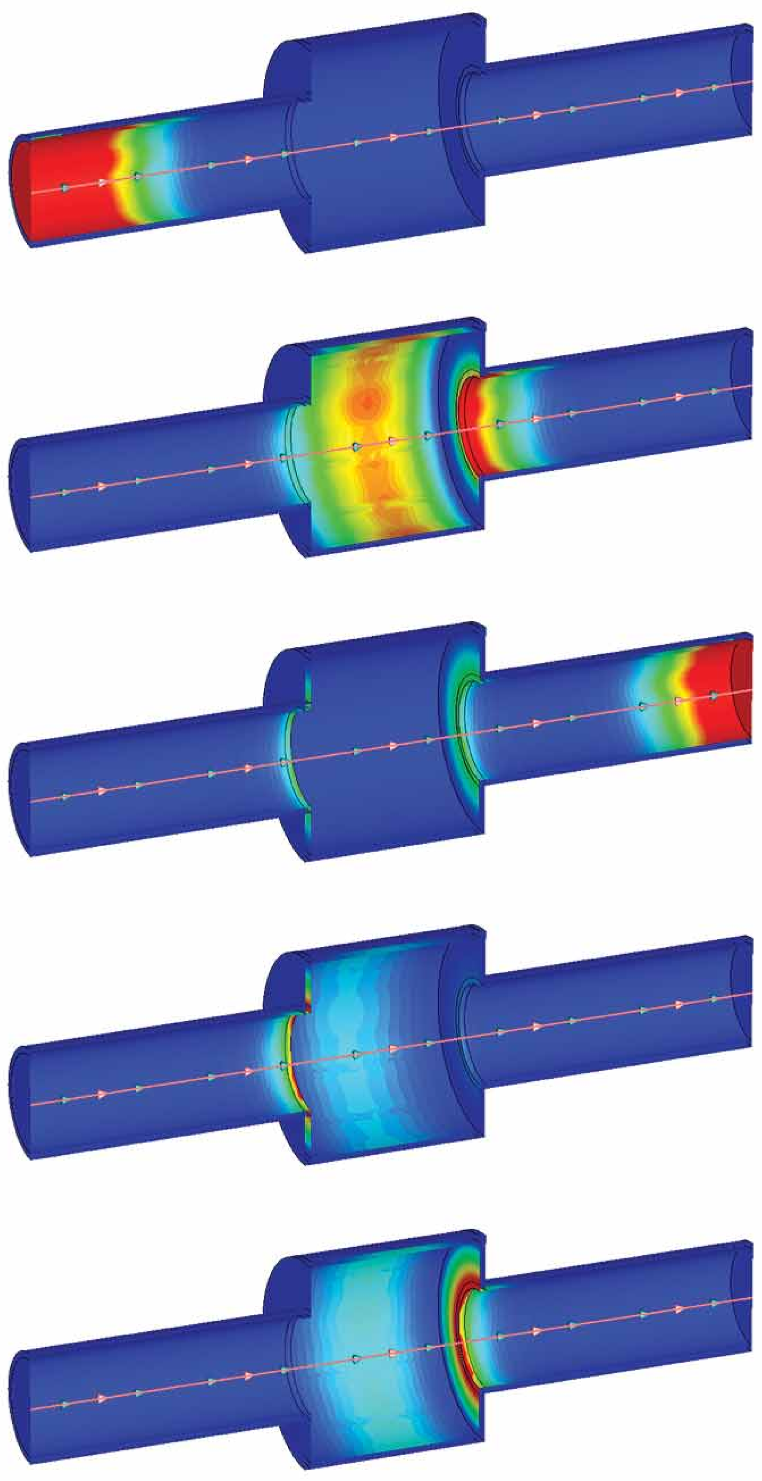


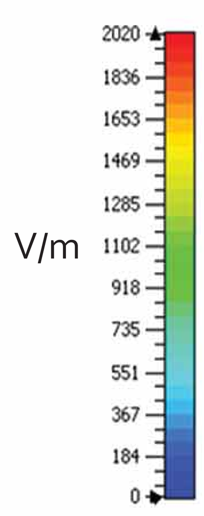
Effective Longitudinal Impedance

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 long, even after the passage of the beam.

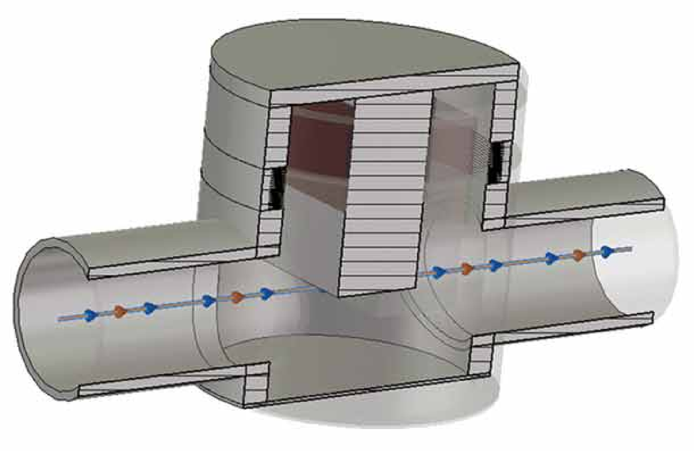
In the following images are shown subsequent instants of a simulation of the electric field inside a simple cavity.



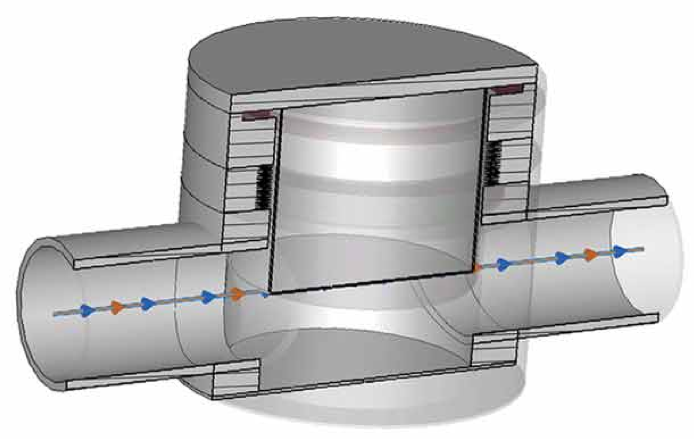


When the beam is outside the region shown in the pictures, inside the cavity an electric field is still present.

The energy released is then dissipated on the wall of the cavity, in form of heat, and it will introduce instabilities when the beams enters again the cavity, i.e. following bunches.



Current design of the Roman Pot



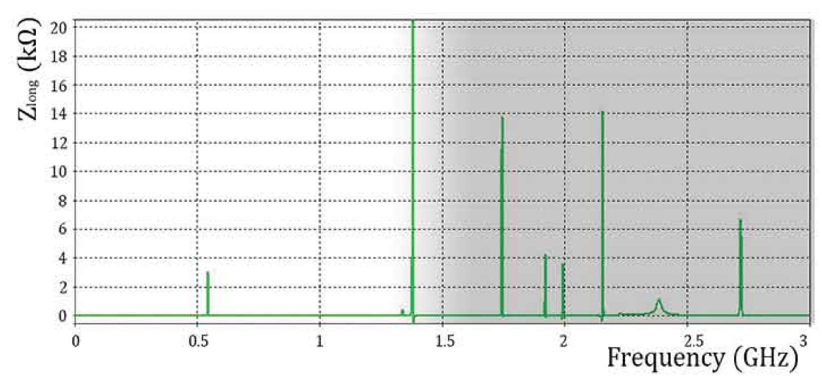
Cylindrical design of the Roman Pot

A low-frequency resonance is the main responsible for the heat produced; it is caused by the empty space between the detector housing and the cylindrical flange.

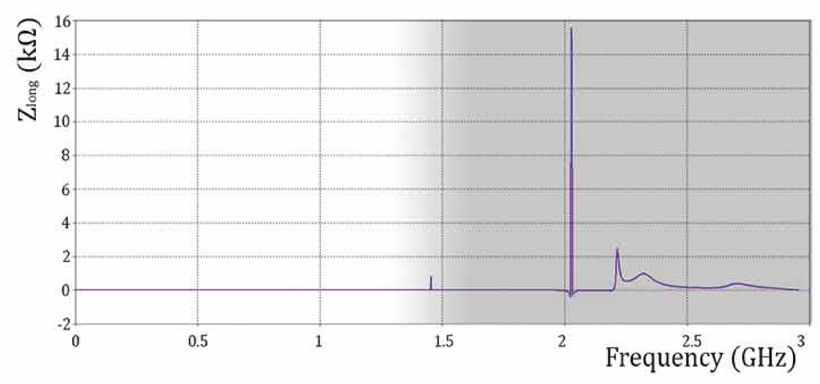
In the current design, the resonance is damped using some ferrite; however, in the first stage of the RF studies, ferrite materials have been excluded, to facilitate the design of a new optimized geometry of the vacuum chamber.

In order to reduce the volume of the cavity and, at the same time, increase the space available for the detector, a cylindrical Roman Pot design was simulated.

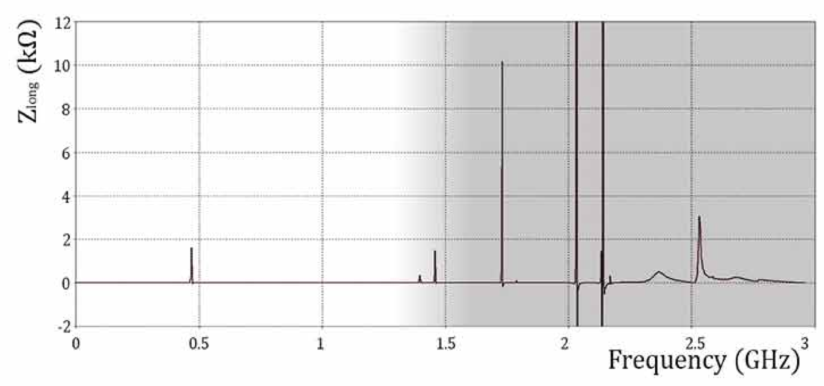
As shown in the images on the right, the low frequency resonance (~500MHz) completely disappears for a cylindrical Roman Pot that fills the empty space with the vacuum chamber.



Simulated Z_{long} of the box shaped RP without ferrite



Simulated Z_{long} of the cylindrical RP without ferrite and with zero gap between the detector housing and the flange

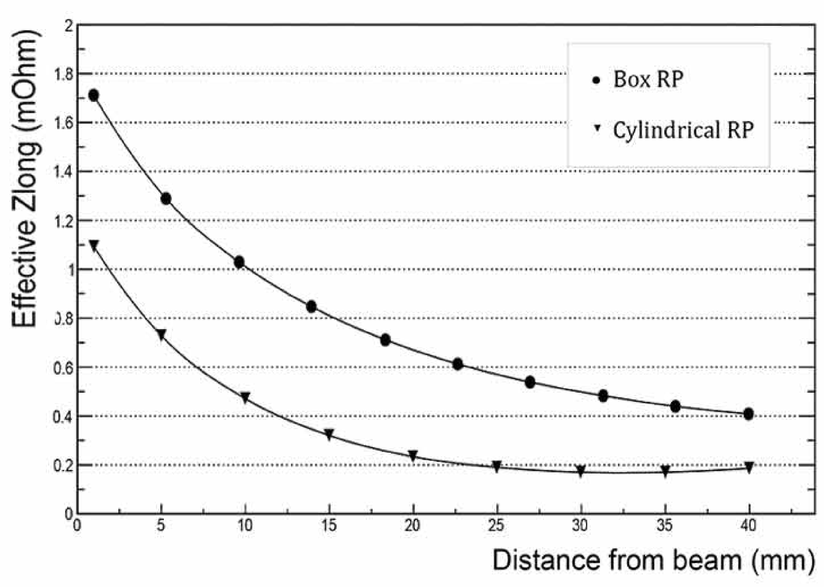


Simulated Z_{long} of the cylindrical RP without ferrite and with a realistical gap (2.5 mm) between the detector housing and the flange

However, the simulated design is not feasible as mechanical tolerances require some space to permit a safe insertion and extraction of the Roman Pot.

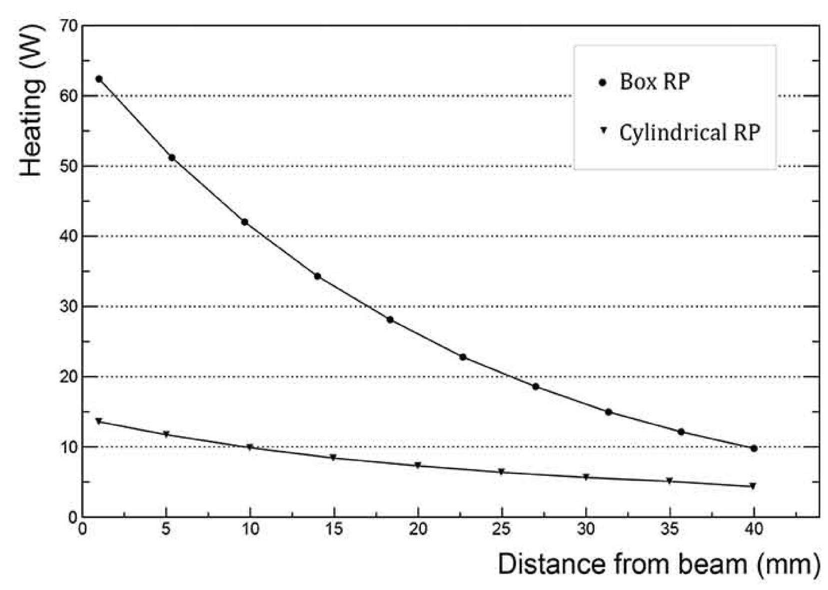
A low frequency resonance is present when foreseeing a gap of 2.5 mm between the movable detector housing and the fixed part of the vacuum chamber; however, its shunt impedance is lower.

So as to reduce the heat produced, the design and the geometry were further optimized with the integration of a cylindrical ferrite.



The final design was thoroughly studied and optimized; on the sides a comparison with the current Roman Pot.

Simulations show a fivefold reduction of the dissipated energy when the Roman Pot is inserted at 1 mm from the beam. Futher-more, the interaction with the beam is also considered: the Effective Longitudinal Im-pedance is reduced up to ~40%.



The final results of the simulations are shown in the table below:

	Distance from the beam [mm]	$\frac{\Im Z^0_{long}}{n}$ [mΩ]	fraction of $(\frac{\Im Z_{long}}{n})^{eff}_{LHC}$ (90 mΩ)	$\overline{\Im Z^{driving}_{trans}}$ [MΩ/m]	fraction of $\Im(Z_x)^{eff}_{LHC}$ (25 MΩ/m)	Heating [W]
Box RP	1	1.7	< 1.9%	0.15	< 0.6 %	62
	5	1.3	< 1.4%			52
	40 (garage)	0.41	< 0.45%			10
Cylindrical RP	1	1.1	< 1.2%	0.11	< 0.5 %	13
	5	0.73	< 0.81%			11
	40 (garage)	0.18	< 0.20%			4

This poster summarizes the work done by the TOTEM collaboration.
In particular I would like to thank M. Bozzo, M. Deile and D. Druzhkin, for their help and support while writing the reference note and B. Salvant, E. Metral and H. Burkhardt, from the BE-ABP group, for their supervision and for their interesting and masterful advices.
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