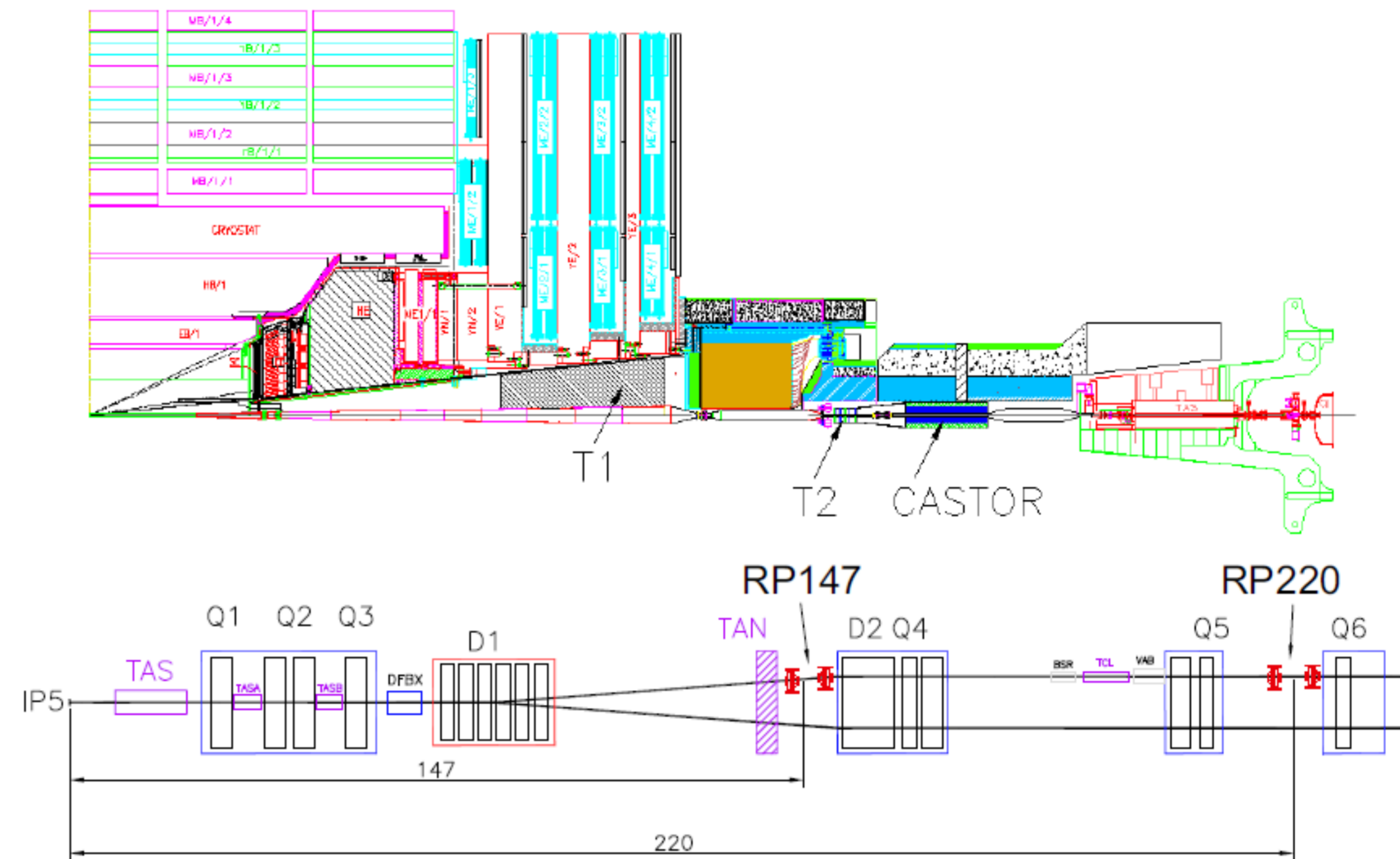
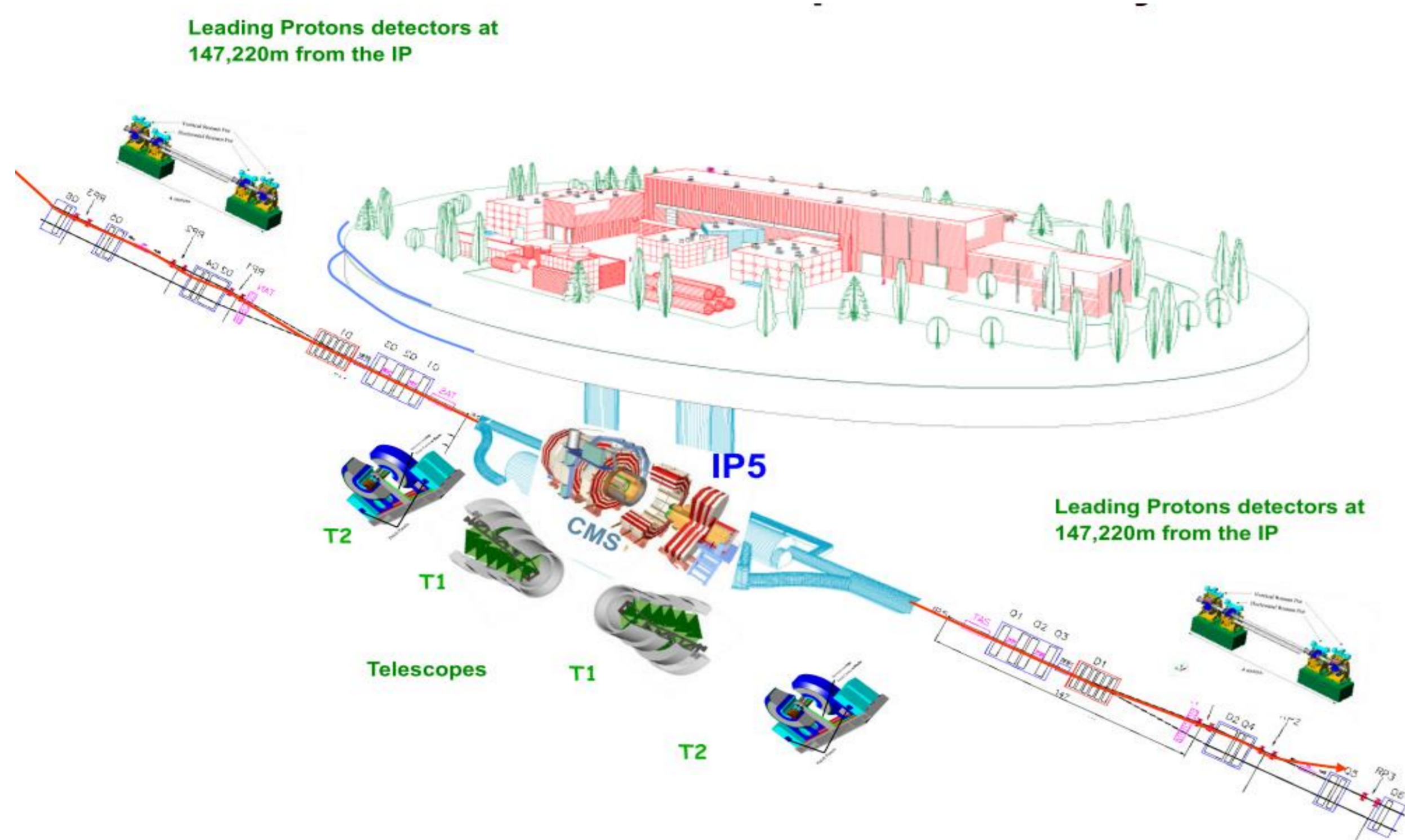




The proton-proton cross sections measured by TOTEM at LHC

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The TOTEM experiment layout is shown along with the position of the inelastic telescopes and Roman Pot stations. The two inelastic telescopes consists of two arms located symmetrically on both sides of the LHC interaction point 5 (IP5). The pseudorapidity coverage of the two telescopes allows the detection of 95% of the inelastic events, including events with diffractive mass down to 3.6 GeV.



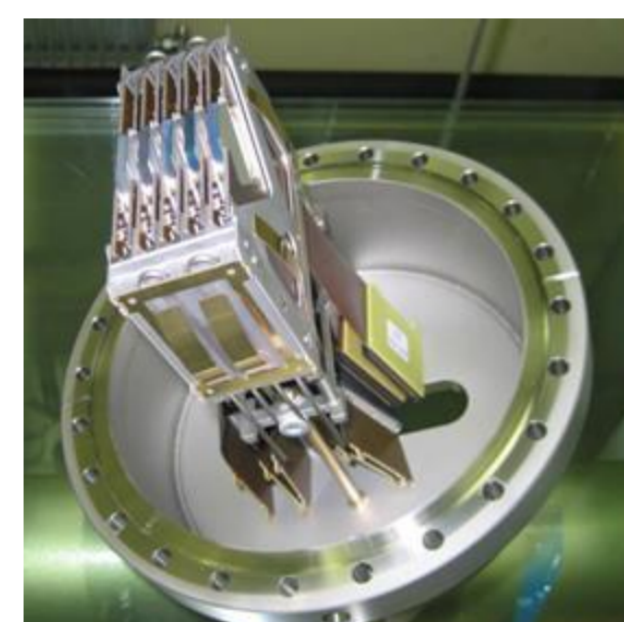
The TOTEM Collaboration measured the total pp cross-section at the energy of $\sqrt{s} = 7$ TeV and 8 TeV, using a luminosity, L, independent method and validating it by comparing several approaches to determine the total cross-sections. The total cross-section can be obtained via the optical theorem that combines the total inelastic rate N_{inel} and the total nuclear elastic rate N_{el} with its extrapolation to $t=0$, $dN_{el}/dt|_{t=0}$.

$$\sigma_{TOT} = \frac{16\pi}{1+\rho^2} \left(\frac{dN_{el}/dt}{N_{el} + N_{inel}} \right)_{t=0}$$

where ρ is the ratio of the real to imaginary part of the hadronic scattering amplitude at $t=0$. The method requires the simultaneous measurements of the inelastic and elastic rates, as well as the extrapolation of the latter in the invisible region down to $|t|=0$. This is achieved with the experimental set-up of TOTEM which can detect charged particles produced in inelastic pp collisions, using the inelastic telescopes T1 and T2, and elastically scattered protons at very small angles, using the Roman Pot. The optical theorem can be used also to derive the total and fully inclusive inelastic pp cross-sections, from the measurement of the elastic scattering ones:

$$\sigma_{TOT}^2 = \frac{16\pi}{1+\rho^2} \frac{d\sigma_{el}}{dt} \Big|_{t=0}, \sigma_{inel} = \sigma_{tot} - \sigma_{el}$$

To access to the smaller $|t|$ -value region, the colliding beams must have a beam divergence of not more than a few micro-radians. This can be obtained by either increasing the betatron value, β^* , or by reducing the beam emittance, ϵ (beam divergence = ϵ / β^*). With a dedicated beam optics configuration ($\beta^* = 90$ m), TOTEM extended the measurement to $|t|$ -values as low as 5×10^{-3} GeV², measuring the differential elastic cross-section over a wide range of t . This made the extrapolation of the differential cross-section to the optical point at $t=0$ possible and enabled, for the first time at the LHC, the determination of the elastic scattering cross-section as well as the total cross-section via the optical theorem.



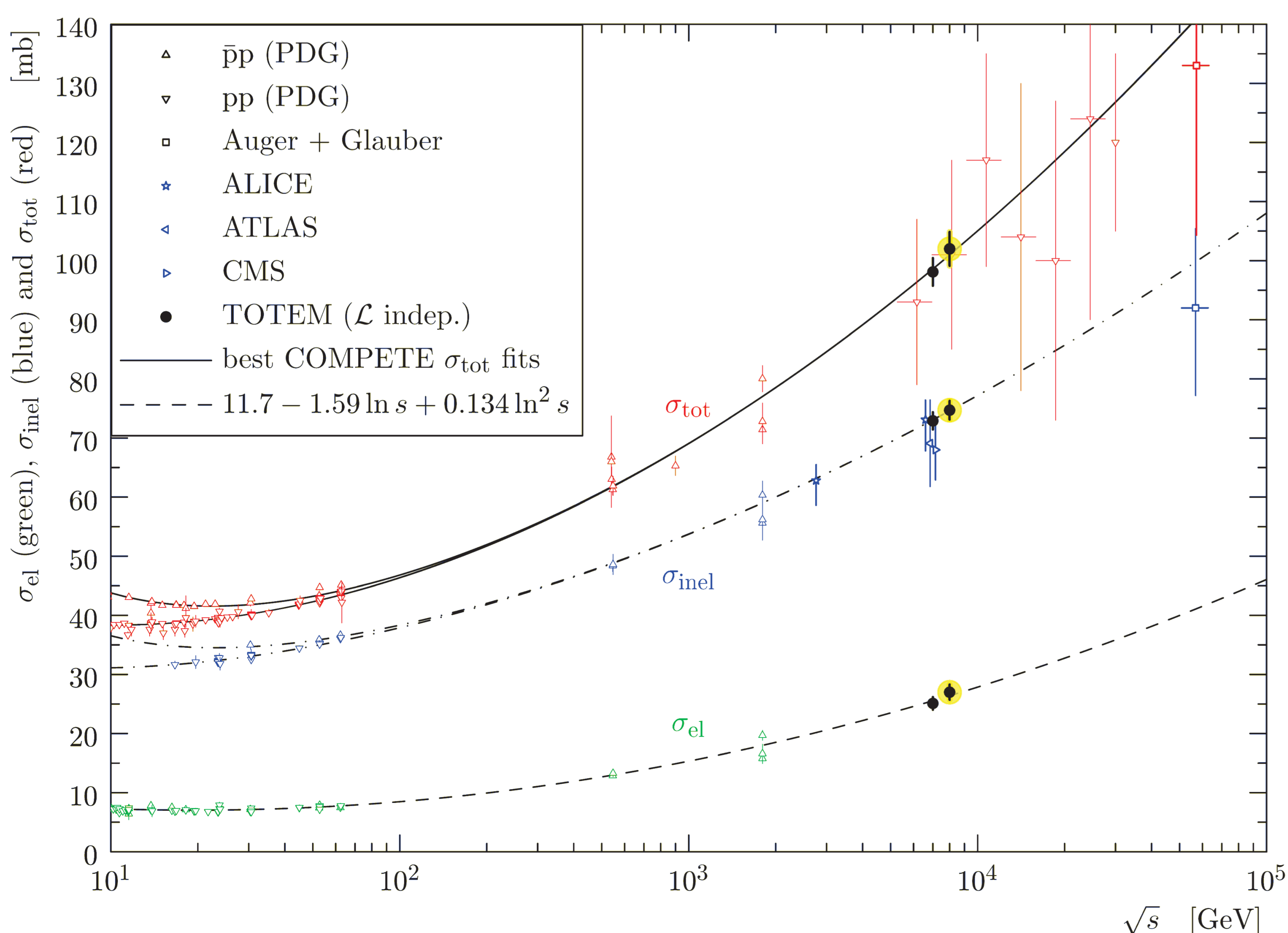
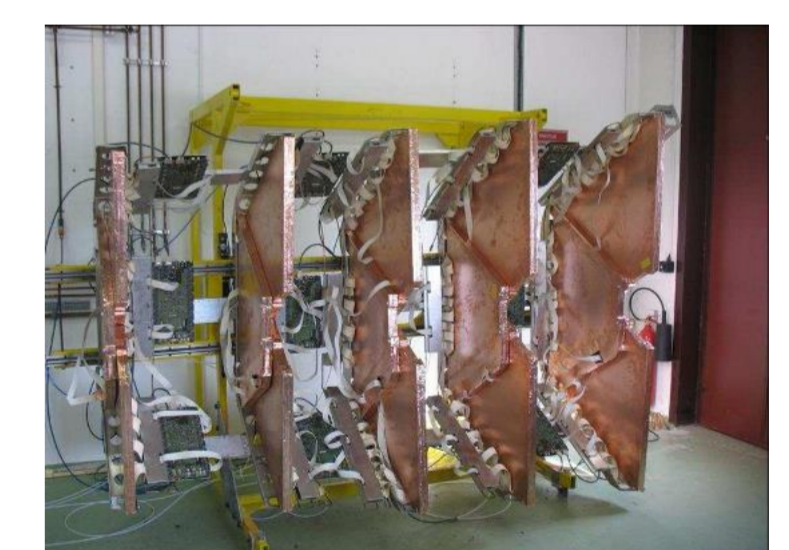
The Roman Pot (RP) stations, used for these measurements, are located symmetrically on either side of the IP5 at distances of 215 and 220 m from it. Each station is composed of two units (near and far) separated by a distance of about 5 m. A unit consists of 3 RPs, two approaching the outgoing beam vertically, from the top and the bottom, and one horizontally. Each RP is equipped with a stack of 10 silicon strip detectors, designed with the specific objective of reducing the insensitive area at the edge facing the beam to only a few tens of micrometers.

This design permits to measure the proton distance from the beam center, in both coordinates perpendicular to the beam, with a precision of about 11 μ m. The movement and the alignment of all pots are monitored with a precision better than 20 μ m based on track reconstruction and external alignment tools. The large lever arm between the near and the far units allows the determination of the track angle in both projections with a precision of about 5 μ rad.



The T2 telescope is based on gas electron multiplier (GEM) chambers and located at ± 13.5 m from IP5 and covers the pseudorapidity range $5.3 \leq \eta \leq 6.5$.

T1 telescope is based on cathode strip chambers (CSC) placed at a distance of 9 m from IP5 and covers the pseudorapidity range $3.1 \leq \eta \leq 4.7$.



Taking maximum advantage from the possibility of measuring elastic and inelastic rates, it was possible to perform completely different estimation of the inelastic, elastic and total cross-sections, comparing all the results for better understanding of the systematic uncertainties and double checks.

By extrapolating the differential elastic cross-section to the optical point $|t|=0$ and using the optical theorem, the total and inelastic cross-sections were also derived.

While from the direct measurement of the inelastic rates the inelastic cross-section was determined and compared with the one deduced from the difference between the total and the elastic cross section.

In this way, leveraging the advantage of two measurements and the special run conditions, it was possible to extract a wealth of informations from the data, like:

- luminosity-independent cross-sections,
- luminosity determination,
- ρ -independent cross-sections,
- luminosity and ρ -independent cross-section ratios,
- ρ constraints.

	L independent at $\sqrt{s} = 7$ TeV	L independent at $\sqrt{s} = 8$ TeV
$\sigma_{TOT}(mb)$	98.0 ± 2.5	101.7 ± 2.9
$\sigma_{inel}(mb)$	72.9 ± 1.5	74.7 ± 1.7
$\sigma_{el}(mb)$	25.1 ± 1.1	27.1 ± 1.4

Summary of the measured cross-sections using a luminosity, L, independent method. The full systematic uncertainty is reported for each measurements. For the ρ parameter value the COMPETE preferred-model extrapolation of 0.141 ± 0.007 was chosen.

Successful measurements with larger betatron values, like β^* of 1000 m, have been done and data analysis is in progress.