IL NUOVO CIMENTO Vol. 33 C, N. 6 Novembre-Dicembre 2010
DOI 10.1393/ncc/i2011-10742-0

Colloquia: IFAE 2010

Status of TOTEM

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(ricevuto l'8 Ottobre 2010; pubblicato online il 18 Gennaio 2011)

Summary. — The status of the TOTEM experiment is described as well as the prospects for the measurements in the 2010 runs. The primary goal of TOTEM is the measurement of the total p-p cross section, using a method independent of the luminosity. A final accuracy of 1% is expected with dedicated $\beta^* = 1540\,\mathrm{m}$ runs (5% resolution with $\beta^* = 90\,\mathrm{m}$, more easily achievable in the early runs). TOTEM has installed the T2 telescope and fully equipped Roman Pots in the 220 m stations during the last winter shutdown and is taking the first p-p collision data with these detectors. T1 is finalizing the commissioning on beam and will be ready for the first opportunity of installation. During 2010 the collaboration will carry on a full commissioning of all detectors and will start a physics program compatible with the low β^* optics provided by the machine.

PACS 13.85.-t – Hadron-induced high- and super-high-energy interactions (energy > 10 GeV).
PACS 29.20.db – Storage rings and colliders.
PACS 29.40.-n – Radiation detectors.

1. – Introduction

The TOTEM experiment at the LHC will measure [1, 2] the total cross section with $\sim 1\%$ uncertainty, by using the luminosity independent method, which requires simultaneous measurements of elastic p-p scattering down to the four-momentum transfer squared $-t \sim 10^{-3}\,\mathrm{GeV}^2$ and of the inelastic p-p interaction rate with an extended acceptance in the forward region. The extrapolation of the present data to the LHC energy together with the existing cosmic ray data give a typical uncertainty of $\pm 15\%$ on the total cross section. TOTEM will also measure the elastic p-p scattering up to $-t \sim 10\,\mathrm{GeV}^2$ and will study soft diffraction.

Moreover, in collaboration with CMS, it will be possible to study jets, W's and heavy-flavour production in single-diffractive (SD) and double-Pomeron-exchange (DPE)

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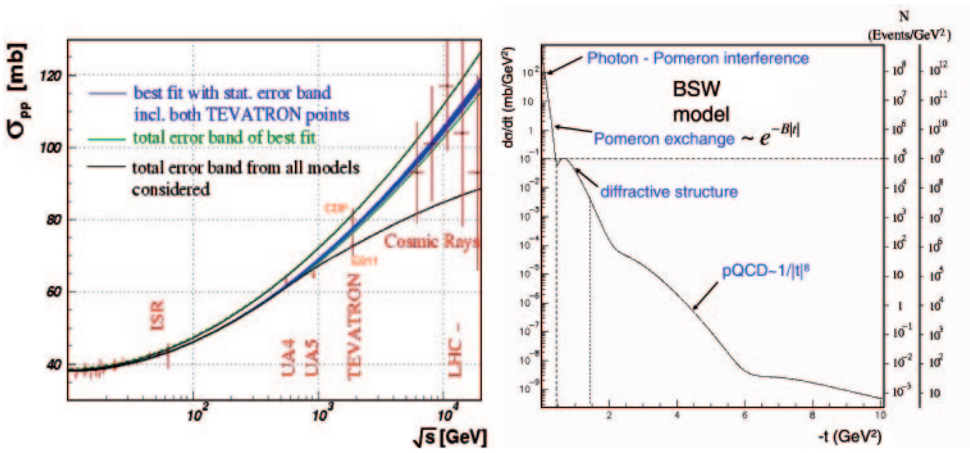

Fig. 1. – Left: COMPETE predictions for total p-p cross section with PS, ISR, SPS, Tevatron and cosmic ray data. Right: elastic p-p cross section as predicted by the BSW model; the two columns on the right side show the number of events expected after 1 day running at 10^{28} and $10^{32}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ luminosity.

events, measure particle and energy flow in the forward direction and study central exclusive particle production and low-x physics.

The TOTEM experiment is designed to measure σ_{tot} with an accuracy sufficient to discriminate between the current model predictions for the LHC energy ranging between 90 and 130 mb (see fig. 1 for COMPETE [3] fits). Using the optical theorem the total cross section can be written as

$$\sigma_{tot} = \frac{16\pi}{(1+\rho^2)} \frac{(\mathrm{d}N_{el}/\mathrm{d}t)_{t=0}}{(N_{el}+N_{inel})},$$

where N_{el} and N_{inel} are, respectively, the elastic and inelastic rate.

TOTEM needs to run with special running conditions ($\beta^* = 1540\,\mathrm{m}$ and luminosity $\mathcal{L} \approx 10^{28}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$). The β value at the interaction point requires zero crossing-angle, due to the increased beam size (proportional to β), and then a reduced number of bunches which is compatible with the LHC injection scheme. Almost half of the total cross section at the LHC is predicted to come from elastic scattering, single, double and central diffractive processes. With the TOTEM acceptance extending up to the pseudorapidities of 6.5, and with the efficient proton detection capabilities close to the LHC beams, the diffractively excited states with masses higher than $10\,\mathrm{GeV}/c^2$ are will be measured by the experiment. The precise luminosity independent measurement of the total cross section requires the measurement of $\mathrm{d}\sigma_{el}/\mathrm{d}t$ down to $-t \sim 10^{-3}\,\mathrm{GeV}^2$, which corresponds to a proton scattering angle of $5\,\mu$rad, and the extrapolation of $\mathrm{d}\sigma_{el}/\mathrm{d}t$ to the optical point ($t = 0$). The leading proton will be detected by silicon detectors placed inside movable sections of the vacuum pipe (Roman Pots), located symmetrically with respect to the interaction point (IP) (fig. 2). In order to measure the inelastic rate, two separate forward telescopes will be installed on both sides, with a rapidity coverage of $3.1 < |\eta| < 6.5$ (fig. 3). With these additional detectors, a fully inclusive trigger, also for single diffraction, can be provided with an expected uncertainty on the inelastic rate of the order of 1%, after corrections.

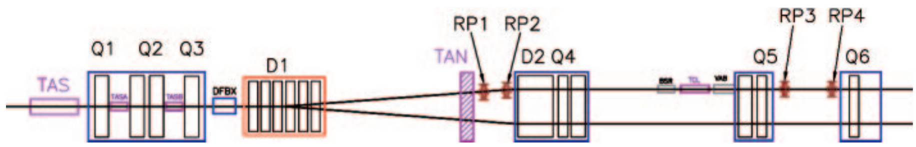

Fig. 2. – The LHC beam line with the Roman Pots at 147 and 220 m.

2. – The experimental apparatus: description and present status

The TOTEM experiment uses precision silicon microstrip detectors inserted in Roman Pots, movable sections of vacuum chamber (fig. 4), installed in the machine tunnel, at 147 and 220 m from the IP, to measure the elastically and diffractively scattered protons close to the beam direction. Each Roman Pot station consists of 2 units with a distance of 4 (for 220 m station) and 1.5 m (for 147 m station). Each unit consists of 3 Roman Pots, 1 horizontal and 2 vertical (top and bottom). The lever arm among different units allows local track reconstruction and a fast trigger selection based on track angle. In order to measure the elastic scattering to the smallest $|t|$ values, the detectors should be active as close to their physical edge as possible. In particular the detectors will have to be efficient up to a few tens of microns to their edge. These are planar silicon detectors with a current terminating structure, which consists in replacing the commonly used voltage terminating guard rings (usually 0.5–1 mm wide) with a 50 μm wide structure of rings which strongly reduces the influence of the current generated at the detector edge on the active detector volume [4].

The detectors inside the 220 m stations have been installed in 2009, while those at 147 m are being tested and will be installed during the technical shutdown at the end of 2010. During 2009, the installed Roman Pots were allowed to enter the beampipe only in dedicated (non-physics) runs approaching the beam down to $4\sigma_{beam}$, which corresponds to ~ 4.4 mm. In the last months a delicate work of movement calibration was carried on in collaboration with the machine. Nonetheless the Roman Pots are still kept in garage position during the physics runs, in order to avoid any possible risk of twisting the beams for the other experiments. It is expected that the Roman Pots will be allowed to enter the beam before the end of 2010.

The telescopes for the detection of the inelastic events have a good trigger capability, provide tracking with a good angular resolution and allow the measurement of the trigger

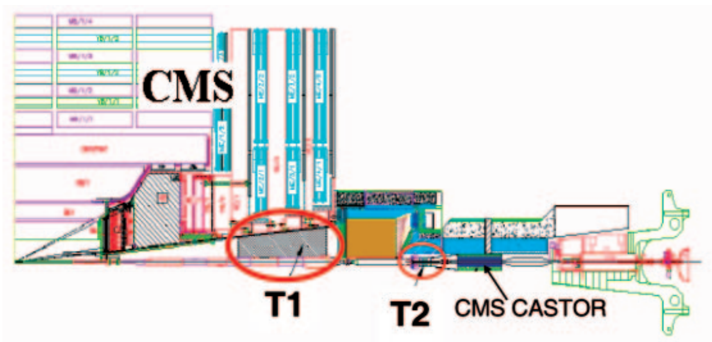

Fig. 3. – The TOTEM detectors T1 and T2 installed in the CMS forward region.

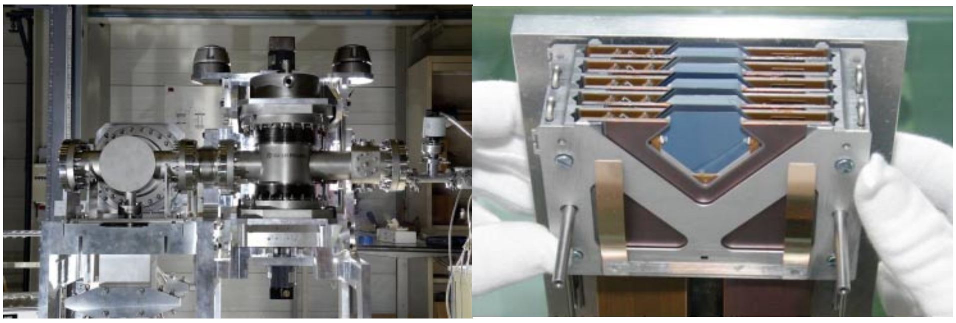

Fig. 4. – Left: horizontal and vertical Roman Pots. Right: mounted silicon detectors.

efficiency. To discriminate beam-beam from beam-gas events, the telescopes will identify the primary interaction vertex with an accuracy at the level of a cm in the transverse plane by reconstructing a few tracks from each side of the interaction point; the knowledge of the full event is not needed.

The T1 telescope (fig. 5) is made of 5 planes of 6 trapezoidal Cathode Strip Chambers (CSC) [5] and will be placed in the CMS end-caps in the rapidity range $3.1 < |\eta| < 4.7$ with a 2π azimuthal coverage. It provides a spatial resolution of $\sim 1\,\mathrm{mm}$. T2 (fig. 5) is made of 20 half circular sectors of triple-GEM [6] (Gas Electron Multiplier) detectors mounted back-to-back and which provides a spatial resolution of $\sim 100\,\mu\mathrm{m}$ in the radial direction; it is placed in the shielding behind the CMS Hadronic Forward (HF) calorimeter to extend the coverage at larger η. The T2 telescope covers with good efficiency the range $5.3 < |\eta| < 6.5$.

T2 telescope has been installed in 2009 and is currently taking data. Even if the detector has not yet completed its commissioning phase, the preliminary results for what concerns alignment, trigger capabilities and track and vertex reconstruction are encouraging.

T1 telescope is fully equipped. One T1 arm has been commissioned in muon and pion beams at the SPS test lines and is ready for the installation. The other arm is currently being tested at CERN. The tests have shown good detector performances in terms of efficiency, noise, track and also vertex reconstruction (a Cu target has been used to provide interactions with the high-energy pion beam). The full detector will be

Fig. 5. – Left: Half T1 ready for the installation. Right: Half T2 during the installation.

commissioned on beam and ready for the installation within the summer. Since T1 is to be installed inside CMS endcaps, a detailed scheduling of the installation procedure is being prepared by TOTEM and CMS, in order to have everything ready for the next LHC shutdown.

3. – Physics during 2010

Year 2010 will be mainly dedicated to finalize the commissioning of the detectors. Moreover, due to the fact that not all TOTEM detectors are installed and only low β^* optics are foreseen for the LHC, the physics program will be quite limited. After the commissioning phase, the first measurements will be devoted to background studies, multipllicity measurement and possibly to Monte Carlo tuning. Once the Roman Pots are in, they will be able to measure elastic scattering at high t and Double Pomeron Exchange events at very high masses of the diffractive system ($M \gtrsim 1\,\mathrm{TeV}$).

4. – Conclusions

In the very moment the LHC provides the first p-p collisions part of the TOTEM experiment (T2 telescope and Roman Pots 220 m) are installed and taking data. Year 2010 is a challenging one for the collaboration, since all its detectors will finalize the commissioning and the installed ones will possibly start physics measurements. Moreover, to carry on its physics program, it is of the utmost importance for TOTEM to install as soon as possible T1 and Roman Pots at 147 m.

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