TOTEM: EARLY DIFFRACTIVE PHYSICS AT THE LHC†

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This report describes the physics plans of the TOTEM LHC experiment. The topics include measurement of the total pp cross section with a 1% precision, elastic pp scattering in the momentum transfer squared range $10^{-3} < |t| < 10$ GeV^2, and soft and hard diffractive phenomena including inclusive and exclusive Double Pomeron Exchange.

1. Introduction

The TOTEM experiment is located at the Large Hadron Collider (LHC) Interaction Point (IP) 5, sharing this location with CMS. The physics goals of this approved experiment include measuring the pp total cross section, elastic pp scattering in the momentum transfer squared range of $10^{-3} < |t| = (p\theta)^2 < 10$ GeV^2, and a variety of forward physics including diffractive phenomena, together with CMS, with high cross sections. The measurement of leading particles and particle and energy flows in the forward direction will not be discussed here [1].

1.1. *Detector Components*

TOTEM is planning (see Fig. 1 in [1]) to insert additional detectors at each end of CMS: Roman Pot (RP) detectors at 147 and 220 m (with a later option at 180 m), a T2 telescope at 13.5 m and a T1 Telescope at 10.5 m from IP5.

The concept of the RP proton detectors is that one wants to detect small scattering angles (~ a few mrad) $\theta^*_{min} = K\sqrt{(\varepsilon/\beta^*)}$ with a beam divergence $\sigma(\theta^*) = \sqrt{(\varepsilon/\beta^*)} \sim 0.3$ μrad. Hence one wants large values of β*. However, the luminosity L α 1/β* means small β* is preferred. As a result, TOTEM requests a range of β* values (0.5-1540 m), although this talk will concentrate [2] on β* = 1540 and 90 m. At 220 m, the proton momentum loss, $\xi = \Delta p/p$, is reconstructed

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with RPs with $0.02 < \xi < 0.2$. A single RP unit consists of a vertical pot and a horizontal pot mounted as close as possible to each other, with a similar pair ~4 m away (see Fig.1). Leading protons can be detected down to distances of $10\sigma_{beam} + d$ (with $\sigma_{beam} \approx 80$ μm), requiring "edgeless" detectors that are efficient up to the physical edge to minimize "d". Currently there are two techniques being pursued. The "active edges or Planar/3D" version provides 5-10 μm, while the planar technology Current Termination Structure has achieved a 40-50 μm dead region.

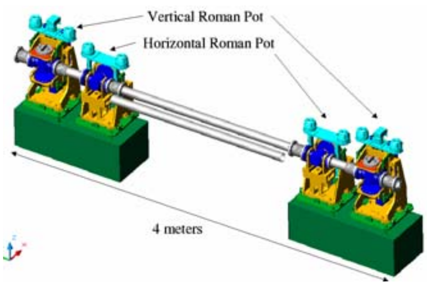

Figure 1. Schematic plan view of the TOTEM Roman Pot unit.

TOTEM's T2 GEM telescope covers the $5.3 < \eta < 6.5$ range and consists of 10 $\frac{1}{2}$-planes and has digital readout pads and analog readout circular strips (Fig. 2, left). The T1 telescope consists of Cathode Strip Chambers covering the range $3.1 < \eta < 4.7$. T1 consists of 5 planes with measurements of 3 coordinates per plane, with 3° rotation and overlap between adjacent planes (Fig. 2, right).

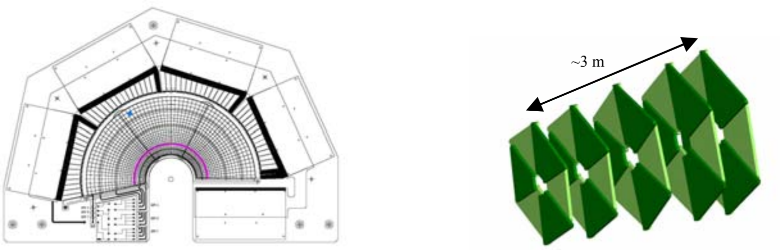

Figure 2. Schematic views of the TOTEM T2 (left) GEM and T1 (right) Cathode Strip Chamber detectors.

2. *Forward Physics at the LHC*

Different running scenarios provide access to different kinematic regions of phase space. Table 1 shows a few possible running scenarios, as currently being discussed by TOTEM, and the different physics that can be reached with each scenario. Plans include a reduced number of bunches (43 and 156) to avoid interactions downstream. The new optics with $\beta^* = 90$ m is designed to optimize diffractive proton detection at $L = 10^{30-31}$ in the "warm" region at 200 m. For this optics, $|t_{min}| = 3\times10^{-2}$ GeV^2, ~65% of all diffractive protons are seen and the ξ determination has a precision of a few $\times10^{-4}$. This configuration is expected to be easier to achieve than that with higher β* (which needs a special injection) and can be obtained by un-squeezing from the 18 m injection optics.

Table 1. Possible Running Scenarios for Diffractive Physics for TOTEM.

Scenario =	1 Low |t| elastic, σ_{tot}, min bias Soft diffraction	2 Diffraction	3 Large |t| elastic	4 Hard diffraction Large |t| elastic (under study)
β* [m]	1540	1540	18	90
N of bunches	43	156	2808	156
N part./bunch ($x10^{11}$)	0.3	0.6 – 1.15	1.15	1.15
Half cross.angle [μrad]	0	0	160	0
Peak Luminosity [cm^{-2} s^{-1}]	$1.6x10^{28}$	$2.4x10^{29}$	$3.6x10^{32}$	$2x10^{30}$

2.1. *Total cross section and Luminosity monitor*

TOTEM plans to measure the pp total cross section with the luminosity-independent method using the Optical Theorem and expects to measure the total rate (N_{el} +N_{inel}) with a precision of 0.8%. Extrapolating the elastic cross section to t=0 will be systematics dominated with a precision of 0.5% (the statistical error is 0.07% after 1 day of running). Using the COMPETE [3] estimate for ρ = Re f(0)/Im f(0) yields a precision of 0.2% and an overall precision on σ_{tot} of 1%.

Current models predict between 90 and 130 mb [1] for the pp total cross section at the LHC and the COMPETE prediction [3] is 111.5±1.2+4.1-2.1 mb.

2.2. *Elastic pp scattering*

The pp elastic differential cross section will be measured as a function of |t|. The low |t| region can be accessed in Scenario #1 for $|t| < 1.5$ GeV^2. Under Scenario #3, the elastic pp differential cross section will be determined out to $|t| < 8$ GeV^2.

2.3. *Diffractive Physics*

To fully study the many diffractive processes, CMS/TOTEM expects to be the largest acceptance detector ever built at a hadron collider. The rapidity coverage for TOTEM+CMS extends from ±7.5 in η and 90% (65%) of all diffractive protons are detected for β* = 1540 (90) m. For β* = 1540 m, 10^7 minimum bias events, including all diffractive processes, can be collected in a one-day run. Figure 3 (left) shows the various hard diffractive final states that can be detected involving jets in CMS and protons in TOTEM. For the inclusive DPE process, CMS/TOTEM can reach masses of the X system up to $M_X = \sqrt{(\xi_1\xi_2 s)} \leq 1.4$ TeV when both protons are detected (see Fig. 3, right). The cross section for pp → pXp is 1 mb with an acceptance of 27.8%. This process can also provide a clean gluon-gluon to X final state due to the exchange of color-singlets (Pomerons). TOTEM+CMS will perform a threshold scan for New Physics and study the central DPE production for which X is a single state [4, 5]. Tagging with two protons yields excellent mass resolution (~GeV), irrespective of the decay products. Proton tagging may well lead to a discovery channel at the LHC.

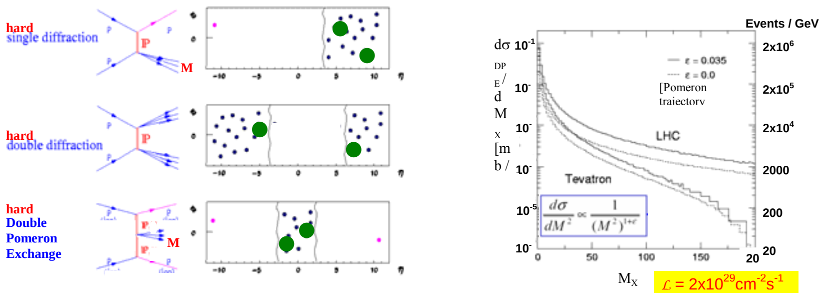

Figure 3. (Left) schematic representation of different hard diffractive final states, the green dots represent jets; (right) distribution of masses M_X produced in the DPE process pp→ pXp.

3. *Summary*

TOTEM will make a wide range of diffractive measurements at different luminosities. The total pp cross section can be determined with a precision of 1%; elastic scattering can be measured in the range $10^{-3} < |t| < 8$ GeV^2; and there will be studies of soft and hard diffractive physics. Currently, TOTEM and CMS are writing a Technical Design Report for common diffractive physics.

3.1. *Acknowledgments*

I thank my TOTEM colleagues, M. Deile, V. Avati and K. Eggert for their help.

References

1. See Figures in my talk in the Plenary session at this conference.
2. For β*=0.5 m, see M. Ruspa's talk in a Parallel session at this conference.
3. J. Cudell et al., *Phys. Rev. Lett.* **89**, 201801 (2002).
4. See M. Ruspa's talk in a Parallel session at this conference.
5. See B. Cox's talk in a Parallel session at this conference.