TOTEM forward measurements: leading proton acceptance

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Abstract
We report about the acceptance of forward leading protons in Roman Pot stations placed along the LHC beam line. The TOTEM stations plus additional detectors at 420 m from the interaction point have been considered using the low–β^* optics V6.5 for LHC physics runs.

1 Introduction

The TOTEM very forward detectors consist of telescopes of "Roman Pots" (RP) placed symmetrically on both sides of the interaction region IP5. The RP stations will be placed at 147 m and 220 m from IP5: each station is composed of two units separated by 2.5–4 m and each unit is equipped with two vertical and one horizontal silicon detector package. For more details on the TOTEM RPs, please refer to [1]. The possibility to add a detector in the cryogenic sections of the LHC is under investigation, therefore, we have included one more RP station at 420 m in these acceptance studies. This work is an update, due to the release of a new LHC optics, of previous studies done by the TOTEM Collaboration [2].

1.1 Low β^* optics acceptance study

The transverse displacement $(x(s), y(s))$[1] of a scattered leading proton (with momentum loss $\xi = \Delta P/P < 0$) at distance s from the interaction point (IP) is determined by tracking the proton through the accelerator lattice using the MAD-X program [3].

The new optics version 6.5 for the standard LHC physics runs is used. Notable changes (at IP5) from the previous versions are :

- β^* = 0.55 m (previously 0.5 m)
- Beam offset in the horizontal plane = 0.5 mm (previously zero)
- Horizontal crossing angle = 142 μrad (previously 150 μrad)

The protons at the IP are generated with flat distributions in the azimuthal angle ϕ, in Log($-\xi$) and in Log($-t$) in the kinematically allowed region of the ξ–t plane, i.e. for physical values of the scattering angle of the proton. The Mandelstam variable t is defined as $t = (p_{\text{orig}} - p_{\text{scatt}})^2$, where $p_{\text{orig(scatt)}}$ is the four-momentum of the incoming (scattered) proton. The scattering angle of the proton is physical when $t \geq t_0(\xi)$, where $t_0(\xi)$ is given by

$$t_0\left(\xi\right) = 2\left(P_{\text{orig}}^2 + m_p^2\right)\left[\sqrt{1 + \left(P_{\text{orig}}^2\left[\xi^2 + 2\xi\right]\right) / \left(P_{\text{orig}}^2 + m_p^2\right)} - 1\right] - 2\xi P_{\text{orig}}^2 . \quad (1)$$

In Eq. 1, P_{orig} is the momentum of the incoming proton and m_p is the proton mass.

The transverse vertex position and the scattering angle at the IP are smeared assuming Gaussian distributions with widths given by the transverse beam size (16 μm) and the beam divergence (30 μrad).

[1]The reference system (x,y,s) defines the reference orbit in the accelerator; the s-axis is tangent to the orbit and positive in the beam direction; the two other axes are perpendicular to the reference orbit. The x-axis (horizontal, bending plane) is negative toward the center of the ring.

To determine the acceptance of a RP station, the minimum distance of a detector to the beam and constraints imposed by the beam pipe or beam screen size are considered.

The minimum distance of detector approach to the beam is proportional to the beam size:

$$x(y)_{min} = 10{\sigma_{x(y)}}^{beam} + c\,, \tag{2}$$

where c is a constant that takes into account the distance from the edge of the sensitive detector area to the bottom of the RP window ($\sim$ 0.5 mm). For the nominal transverse beam emittance ϵ = 3.75 $\mu\mathrm{m}\cdot\mathrm{rad}$ typical values of the horizontal detector distance are $\sim$1 mm (at 220 m) and $\sim$4 mm (at 420 m). In the results shown later, the detector shape has not been included. The beam pipe apertures can be found in the LHC–LAYOUT Database [4].

1.2 Results

Figures 1–3 show the acceptance in Log($-\xi$), Log($-t$) for the RP stations at 220 and 420 m for the clockwise ("beam1") and counter–clockwise ("beam2") circulating beam.

One should note that these results refer to non-physical distributions in the variables ξ and t in order to have good statistics in each interval and describe all possible processes. To use these results in a general simulation program, the ϕ dependence has to be taken into account, since it is not negligible in many kinematical configurations. More detailed analysis such as detector alignment samples, collimator effects, etc. can be found in [5].

These results have been included in FAMOS (FAst MOntecarlo Simulation of the CMS detector) by M. Tasevsky ("Diffractive Higgs production", these proceedings) and they have been used in the CMS/TOTEM studies on triggering a diffractively produced light Higgs boson with the CMS Level-1 trigger ("Diffractive Higgs: CMS/TOTEM Level-1 Trigger Studies", these proceedings).

References

[1] The TOTEM collaboration, TOTEM Technical Design Report, **CERN-LHCC-2004-002 TOTEM-TDR-001** (2004).

[2] The TOTEM collaboration, Status Report to the LHCC (`http://www.cern.ch/totem`) (2002);
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[3] The MAD-X Program, Methodical Accelerator Design, `http://www.cern.ch/mad`.

[4] LHC Layout, `http://lhclayout.web.cern.ch/lhclayout/`.

[5] V. Avati and K. Österberg, "Acceptance calculations methods for low–β^* optics", **TOTEM Internal Note 05-2 (`http://www.cern.ch/totem`)** (2005).

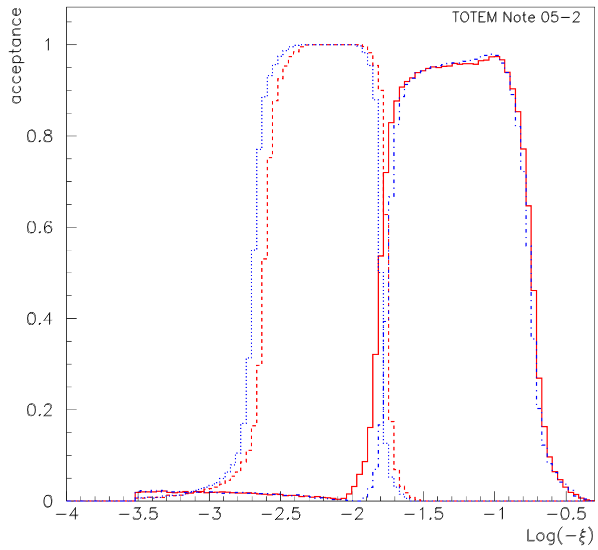

Fig. 1: Log($-\xi$) acceptance for: beam1 station at 220 m (solid-red) and 420 m (dashed-red) and beam2 station at 220 m (dashed-dotted-blue) and 420 m (dotted-blue).

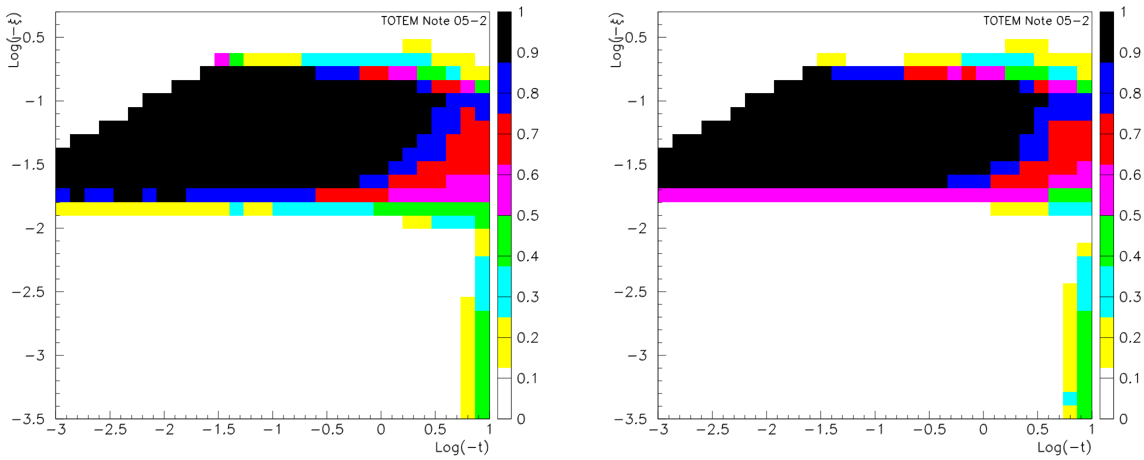

Fig. 2: Log($-\xi$) vs Log($-t$) acceptance for beam1 (left) and beam2 (right) stations at 220 m.

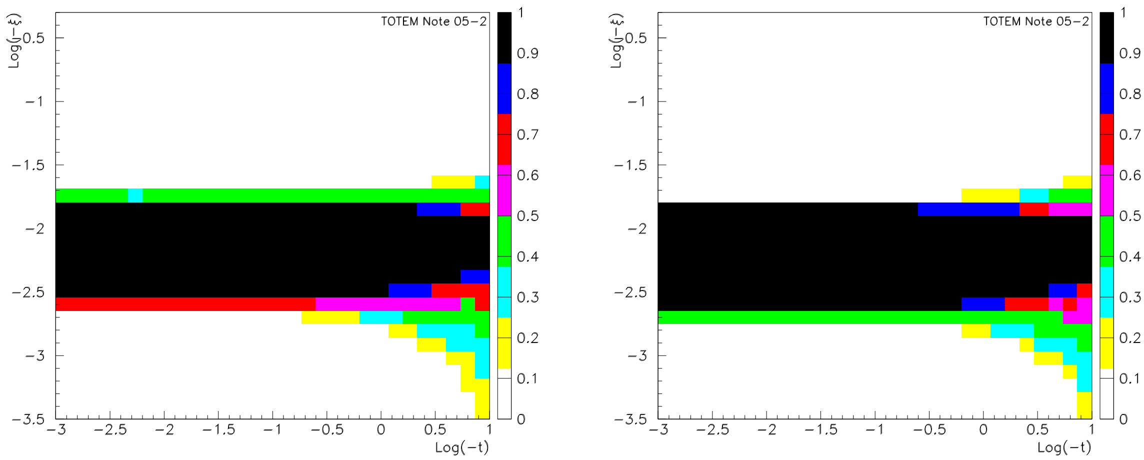

Fig. 3: Log($-\xi$) vs Log($-t$) acceptance for beam1 (left) and beam2 (right) stations at 420 m.