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THE TOTEM DETECTORS

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To determine the total pp cross section in a luminosity independent way at the LHC, the TOTEM experiment will use two tracking telescopes in the forward region $3.2 \leq \eta \leq 6.5$ and two sets of Roman Pot stations symmetrically placed with respect to the interaction region IP5. This allows the simultaneous determination of the inelastic and elastic rates. This paper will give an overview of the TOTEM detectors and their experimental possibilities.

1 Introduction

The Totem Experiment will measure the total pp cross-section and study elastic scattering and diffractive dissociation at LHC [1,2]. The experimental apparatus is placed symmetrically with respect to the Interaction Point 5 (IP5) and the CMS experiment. Two tracking telescopes, T1 and T2, will measure the inelastic interactions in the forward region covering an adequate acceptance over a rapidity interval of $3.2 \leq \eta \leq 6.5$. The measurement of $\mathrm{d}\sigma_{el}/\mathrm{dt}$ down to $-t = 10^{-3}\,\mathrm{GeV}^2$ is accomplished by silicon detectors placed in Roman Pots located at 147 m and 220 m from IP5. The beam of the LHC being rather thin, with a $10\,\sigma$ envelope of about 1 mm, the detectors in the Roman Pot must have a very small dead zone at the mechanical edge facing the beam. In the following paragraphs the single detectors will be described.

2 The Telescopes T1 and T2

The T1 and T2 telescopes will be employed to trigger and partially reconstruct inelastic events. Together they must provide a fully inclusive trigger for diffractive events and enable the reconstruction of the vertex of an event to disentangle beam-beam events from background. Both Telescopes are made of two arms symmetrically placed with the respect of the IP5. In T1 each arm will be installed in the End Caps of the CMS Magnet and will be composed of 5 planes of Cathode Strip Chambers [3] as shown in Fig. 1, with 6 chambers per plane. The orientation of the strips and the wire is given in Fig. 1. While for the 1-level trigger only the anode wires will be employed to recognise the primary tracks, for the tracking each point is given by 3 measurements (the two cathode strips and the anode wire) to resolve multiple events. To improve pattern recognition the planes will be staggered by 3 mm.

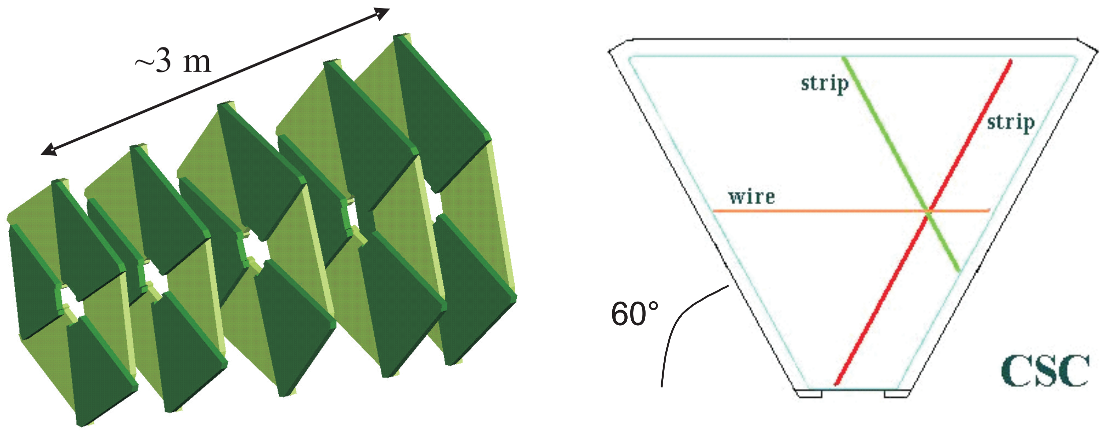


Figure 1: Drawing of a single arm of the CSC (left) and orientation of the wires and the strips in each chamber (right).

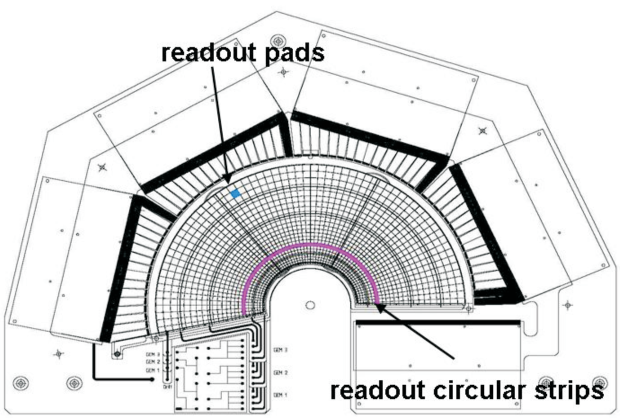


Figure 2: The TOTEM GEM prototype

Four large size prototypes were built and successfully tested in the 2004 at the fixed target SPS beam line X5 at CERN.

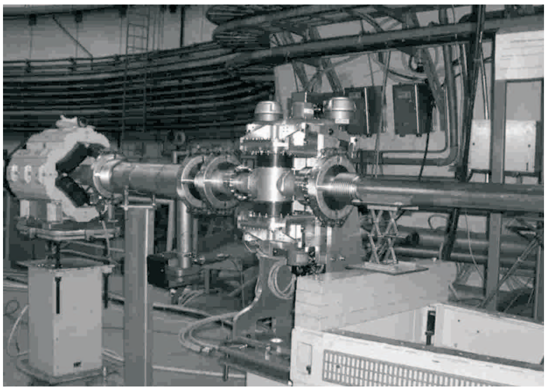
The T2 telescope will be made of Gas Electron Multipliers (GEM) [4]. GEMs are gas-filled detectors that have the advantageous decoupling of the charge amplification structure from the charge collection and readout structure. Furthermore, they combine good spatial resolution with very high rate capability and a good resistance to radiation. The T2 telescope will be placed 13.5 m away from the IP5 and the GEMs employed will have an almost semicircular shape, with an inner radius matching the beam pipe. Each arm of T2 will have a set of 10 aligned detector planes mounted on each side of the vacuum pipe. To avoid efficiency losses the angular coverage of each half plane is more than 180°. The GEM readout board has two separate layers with different patterns: one with 256 concentric rings, 80 μm wide and with a pitch of 400 μm, providing the radial coordinates of traversing tracks with a good precision, and the other with a matrix of 1536 pads varying in size from $2 \times 2\,\text{mm}^2$ to $7 \times 7\,\text{mm}^2$ used for triggering. An illustration of the GEM is shown in Fig 2. Like the T1 chambers, also the full size prototype GEM for T2 has been successfully tested in 2004 at the X5 beam line.

With a resolution of $\sigma_x = 0.36$ mm and $\sigma_y = 0.62$ mm for T1 and a resolution of $\sigma_R \cong 115$ mm and $\sigma_\phi \cong 16$ mrad for T2, Montecarlo studies have shown the capability of reconstructing primary vertices well inside the beampipe with a resolution in the radial coordinate of $\sigma_{R_v} \cong 3$ mm within ± 5 cm from the IP5 along the beam axis [2]. This vertex resolution is sufficient to discriminate beam-beam events from beam-gas background.

3 The Roman Pots

The Roman Pots are special beam insertions which allow to bring the detectors very close to the beam without interfering with the primary vacuum of the machine. Each RP station is made of two units separated by 4 m and equipped with one horizontal and two vertical pots. Given the challenging constraints of the LHC machine, such as high beam energy, Ultra High Vacuum and the required physics performance of TOTEM, which needs to have active detectors at ~1 mm from the 7 TeV beam, a special design has been developed [5]. A main issue has been the welding technology employed for the thin window that separates the vacua of the machine and the Roman Pot, still minimizing the distance of the detector from the beam, with a thickness and a planarity of less than 200 μm and 100 μm respectively. The first prototype of Roman Pot units with only the vertical pots has been successfully tested in the SPS ring with coasting beam in 2004 [6] (see Fig. 3 (left)). The construction of a final prototype is expected for the end of 2005.

Edgeless Detectors To detect leading protons in the Roman Pots two different types of silicon detectors have been chosen. Both technologies respond to the crucial requirement of a very small insensitive volume at their physical edges to be fully efficient at ~1 mm from the beam. These edgeless silicon detectors are respectively called Planar Edgeless Detectors with Current Terminating Structure (CTS) [7] and 3D/Planar Edgeless Detectors with Active Edges [8]. In the Planar Edgeless Detector the CTS occupies the first 50 μm from the cut edge, after which the sensitive volume starts. In this case, the voltage applied to bias the device has to be applied also across the die cut via an implanted ring that runs along its physical edge. This external ring, called the current terminating ring, collects all the surface current from the cut avoiding its diffusion into the sensitive volume. A schematics of the CTS is shown in Fig. 3 (right). Several test beams have shown that these devices start to be sensitive right after the CTS [7]. Moreover, studies on samples irradiated up to 10^{14} "n"/cm^2 have shown that up to such fluences the radiation hardness of Edgeless Planar detectors is equal to the standard planar detectors [9]. The 3D/Planar Edgeless Detector instead exploits a new detector fabrication technique producing active edges by depositing doped polysilicon across the die cut. With this approach it has been shown in several measurements and test beams that the device is sensitive within 10 μm from the physical edge [8].



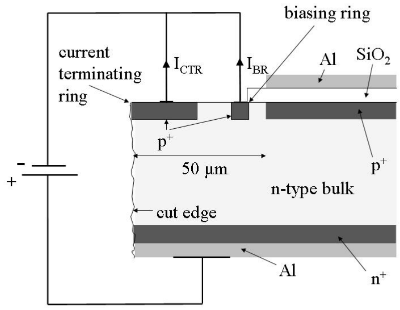


Figure 3: Roman Pot test in the SPS beam in October 2004 (left) and cross-section of the CTS and its biasing scheme (right).

4 Conclusions

The TOTEM Collaboration has gained experience in installing and operating the detector systems in different testbeams. The final Roman Pot prototype will be ready by the end of 2005 and the installation in the LHC tunnel will take place in the Summer 2006. Both technologies of forward proton detectors (Planar Edgeless & 3D/Planar) have been chosen. Their full production and test will take place in 2006. The T1 telescope is ready for production. An integration test in CMS is foreseen for Sept. 2005. The T2 telescope is also ready for production: a pre-series of 5 final detectors in 2005, full production in 2006.

References

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