The RPC of the inelastic trigger of TOTEM  
(status report)

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Abstract. The inelastic detector of TOTEM will be triggered by Resistive Plate Chambers (RPC). We describe the RPC prototypes and the results of the first tests made on a test beam at CERN and also the electronics trigger scheme.

1 Introduction

The purpose of the inelastic detector of TOTEM [1] is to measure the inelastic rate, an information which is needed for the measurement of the total cross section at the LHC with the luminosity independent method. The inelastic detector has two components.

- Telescopes of wire chambers with cathode strip read-out (CSC) [2] for reconstructing charged particles tracks and extrapolating to the collision point in order to disentangle beam-beam events from background.
- Resistive plate chambers (RPC) for triggering.

The system, symmetric on both sides of the crossing region, covers the nominal pseudorapidity interval from about 3 up to about 7 units and, for practical reasons, is subdivided into two telescopes, T1 and T2.

For each telescopes two RPC chambers are foreseen, one in front and one behind the CSC planes. Each chamber is practically made of two monogap planes, electronically “ORed” in the trigger logics, in order to increase the efficiency.

The read-out of the RPC is with pads having projective geometry with respect to the crossing point. Each plane of T1 is subdivided into four quadrants while a plane of T2 is made of two semicircular sectors.

The purpose of the trigger system is to make a rough geometrical selection on the interaction region by means of the projective geometry and to disentangle beam-out tracks from beam-in background tracks by exploiting the good time resolution of the RPC.

It could also be used as a fast veto for the elastic trigger.
2 The prototype RPC

The prototype RPC detectors were made by the firm General Tecnica in Italy following the "standard" construction procedure adopted by the other experiments at the LHC (ATLAS and CMS).

Each chamber plane has a monogap structure with 2 mm gap width. Spacers were glued between the electrodes in order to keep the gap width constant. They are placed on a grid at the distance of 10 cm.

The chambers were assembled following the usual procedure developed at General Tecnica. They were sandwiched in between two rigid foam plates having external aluminium foil put to ground.

The HV connection was on the side opposite to the pad plane. The surface resistivity was $(1.1-1.2) \times 10^{10}$ Ohm cm.

For the prototypes the pad read-out has a simple geometrical structure with pads of square shape. The pads were equipped with the front-end electronics adopted by CMS [3]. The size of the prototype detectors is close to the final design.

- **T1 sector**: $R_{\text{int}} = 15$ cm, $R_{\text{out}} = 95$ cm, pad size 4 cm x 4 cm
- **T2 sector**: $R_{\text{int}} = 5$ cm, $R_{\text{out}} = 20$ cm, pad size 2 cm x 2 cm

Pictures of the T1 and of the T2 sectors are shown in Fig.1,2,3 and Fig.4,5 respectively.

![Figure 1: Picture of two quadrants of the T1 prototype.](image)
Figure 2: Picture of a T1 quadrant and of the read-out printed board with pad structure.

Figure 3: Picture of a T1 quadrant, of the read-out printed board with pad structure and one of the foam plates before assembling.
Figure 4: Picture of the T2 prototype.

Figure 5: Picture of the T2 prototype and of the read-out printed board with pad structure.
3 Test beam set-up

After preliminary tests in Rome with cosmic rays the prototype chambers were installed on the test beam X5 in the West Area at CERN. A small 10 cm x 10 cm RPC test chamber, equipped with 4 cm x 4 cm pad read-out was also installed on the beam line. A telescope of three scintillation counters was used for triggering. The beam spot was usually defined by an additional scintillator of dimensions 3 cm x 3 cm. The intensity of the pion beam could be adjusted by means of the collimators up to a maximum of about $10^6$ particles/s. The beam spot was of the order of one cm$^2$. By closing the beam shutter a muon beam was obtained with typical intensity of $10^3$ particles/s over an area of about 10 cm$^2$. This muon beam was very useful for low intensity setting up. In fact the flux of the muon beam was similar to that which is expected at the LHC in the region of T2 for the luminosity of $10^{28}$cm$^{-2}$s$^{-1}$.

Pictures of the set-up are shown in Fig.6,7 and 8.

![Figure 6: The TOTEM test beam set-up. A sector of T1 is shown on the beam line.](image)

We used the "standard" gas mixture for the RPC on avalanche mode which is mainly based R134A, tetrafluoromethane ($C_2H_2F_4$), with addition of isobutane ($C_4H_{10}$) and sulfur hexafluorine ($SF_6$) at the nominal fractions of 3% and 0.5% respectively. Only simple glass flowmeters were available during this test and therefore the absolute fractions could be somewhat different from the nominal reading. Care was taken, however, to keep the mixture well stable in the period of test.

For the read-out a standard VME system with scalers, pattern unit, TDC and charge integrating ADC was used.
Figure 7: Test beam set-up. The T1 sector is shown.

Figure 8: Test beam set-up: trigger counters and the RPC small test chamber.
4 Results of the tests

The efficiency plateau for the T1 sector is shown in Fig.9. The dependence of the

![Graph](image1)

Figure 9: The efficiency plateau of the T1 sector.

efficiency plateau on the value of the threshold of the front-end electronics is shown in
Fig.10. The value of 110 mV corresponds to an integrated charge of about 0.1 pC.

![Graph](image2)

Figure 10: The efficiency plateau as a function of the threshold setting of the front-end electronics.

The time resolution of the RPC was measured by recording the time-of-flight between a pad of the T1 sector and a pad of the small test chamber. The TDC time
spectrum is shown in Fig.11. The r.m.s. value of the distribution of the time difference is 0.93 ns. This implies a time resolution of each chamber of $0.93/\sqrt{2} = 0.66$ ns.

![Graph](image1.png)

**Figure 11**: Time of flight between the T1 sector and the small test chamber.

By modifying the setting of the collimators it was possible to change the particle flux on a single pad and measure the efficiency plateau as a function of the flux. The results are shown in Fig.12.

![Graph](image2.png)

**Figure 12**: Measurement of the efficiency as a function of the particle flux.
It is clear that our RPC chambers can easily tolerate a flux up to about 1 kHz/cm² with negligible loss of efficiency because each chamber will actually result from the OR of two planes. This result can be compared to the expected rate from beam-beam collisions.

The nominal luminosity for the high-β runs devoted to the measurement of the total cross section is $10^{28}$ cm$^{-2}$ s$^{-1}$. For this luminosity, the calculated flux of charged particles from beam-beam interactions [4] is below 5 particles/(cm$^2$ s) for T1 and below 50 particles/(cm$^2$ s) in the region of T2, as shown in Fig.13.

We may then conclude that the RPC chambers foreseen for the inelastic trigger should operate safely. A substantial level of background may be easily tolerated and also a larger value of the luminosity.

![Diagram](image)

Figure 13: The expected particle flux in T1 and T2 from beam-beam collisions at the luminosity of $10^{28}$ cm$^{-2}$ s$^{-1}$.

Some loss of efficiency is expected when particles hit the chamber in a position at the border line between pads. The effect was studied by having the beam spot on different position with respect to the pads. The beam spot was defined by the 3 cm x 3 cm scintillator. The results are shown in Fig.14.
Figure 14: Measurement of the mean efficiency for different positions of the beam spot with respect to the structure of the pads.

5 The trigger scheme

The final pad structure of T1 and T2 will not be rectangular as in the prototype. We shall use a r-phi structure designed, however, in such a way as to keep the pad area approximately constant (about 5 cm x 5 cm) for T1, as shown in Fig.15. This ensures that the signal is almost of the same magnitudes for the different pads.

The T2 pad size will be smaller, about 2 cm x 2 cm as in the prototype but with similar r-phi geometry.

The two monogap planes of each chamber are set in OR, pad by pad, in order to increase the efficiency. A coincidence is then made of the front and back chambers as shown in Fig.16.

The scheme is conceived to allow flexibility in the sense that a single physical pad of the front chamber can be set in coincidence with a “logic pad” of the back chamber obtained by “ORing” a few adjacent “physical” pads.
Figure 15: Sketch of the final pad structure of T1 with a r-phi geometry designed to keep the pad area practically constant.

Figure 16: Scheme of the trigger logics. The coincidence of the front and back chambers is made after the OR of the two planes.
6 Conclusions

The prototype RPC chambers of TOTEM were found to operate correctly and reliably in the way which is expected for detectors of this kind and of this size. The time resolution is good and sufficient for the needs of the inelastic trigger of TOTEM.
The rate dependence of the efficiency is as expected for these detectors and implies a substantial margin of safety at the luminosity of the total cross section runs of TOTEM.

References