The simulation of the TOTEM inelastic telescopes in OSCAR

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Abstract

The simulation of the TOTEM inelastic telescopes T1 and T2 has been implemented in the CMS framework for the simulation OSCAR, which is based on the Geant4 toolkit. The note describes the software packages which manage the detector simulation and which contain the geometry description. The simulation has been tested calculating the charged particle fluxes in both detectors.

Contents

1 Introduction

This note is intended to describe the simulation of the TOTEM inelastic telescopes (T1 and T2), inside the CMS software framework for the simulation (OSCAR[1]).

The choice of the TOTEM collaboration of implementing the code for the simulation inside OSCAR has been driven by a few practical considerations. In fact, the joint CMS/TOTEM physics programme and the co-existence of the detectors of both exepriments in the same location naturally led to the choice of having also common software tools.

This note wants both to describe the technicalities of this implementation and to show some results that have been obtained as a test of the code.

In section 2, a general overview of OSCAR and of the TOTEM code implementation is given, forwarding the reader to much more detailed descriptions of the framework, which can be found inside dedicated CMS papers.

In sections 3 a detailed description of the detector geometry used in the simulation is given.

In section 4 the package used to analyze the output of the simulation is described in details while some results are shown in section 5.

2 Software framework

OSCAR, which stands for Object oriented Simulation for CMS Analysis and Reconstruction, is a Geant4[2] based framework which is used by the CMS collaboration to perform a full simulation of its detectors. In OSCAR, the Geant4 simulation recieves the event information either by an external file, generated by any event generator (Pythia, Herwig, etc.), or by an internal particle gun managed by the user. OSCAR output is a set of objects, called hits, which are created any time a particle goes through a detector sensitive region.

The geometry of the detectors is described by means of XML documents which must follow a specific grammar, defined in standard XML schema files; a description of the information contained in the geometry can be found in section 3.

OSCAR has two logical layers: subsystems and packages (which are located inside the subsystems). Each package produces a single shared library dedicated to an aspect of the detector and which is linked and executed at run time.

Two subsystems are of particular interest for the TOTEM code: TotemSim and TotemTest.

TotemSim contains two different packages:

- TotemNumberingScheme: this package describes the algorithm which provides a biunique association between a number (UnitID) and any detector part:

- T1 right: from 110000 to 132000;
- T1 left: from 210000 to 232000;
- T2 right: from 1401 to 1420;
- T2 left: from 2401 to 2420;

- TotemSD: it contains the methods which select the hits, store the hit information and create the hit list (see the Appendix for a detailed description of the variables contained in a hit object).

TotemTest is part of OscarApplication and contains the methods to retrieve the stored hits and save them into a ROOT[3] tree.

For OSCAR a hit is a set of information which is retrieved from the simulation program any time a particle goes through a detector part which has been declared as sensitive inside the geometry. In the package TotemSD, the user can set any kind of selection rule in order to store only the hits which generate a signal in the detector. For T1 and T2, only the hits generated by charged particles which lose energy in the detector are stored in the hit list.

3 T1 and T2 geometry

3.1 Geometry description

The geometry of the detectors (dimensions, materials, position) is described inside XML files, whose syntax in defined in [4]. The XML files with the description of T1 and T2 have been published inside the Forward package in the CMS Geometry repository. More in details, the space volumes inside CMS where the two TOTEM telescopes are positioned are defined inside forward.xml, and the descriptions of T1 and T2 elements are written inside totemt1.xml and totemt2.xml.

Each XML file is divided into three main sections. The first one, the so-called Solid section, describes the dimensions of all the detectors costituents and provides them names; the second one, the so-calles Logical section, describes the materials and the hierachical relations among different parts of the detectors; the third one, the so-called Position section, describes the positions of all the detectors, creates duplicates of identical detectors and set translations and rotations of the elements.

The beampipe is described in the file beampipe.xml which is stored in the CMS/CMSGeometry directory, while a very schematic description of the ion pump in front of T2 is described separately inside ionpump.xml.

The T1 and T2 parts in which the signal is generated (sensitive regions) are listed in TotemsensGem.xml: any particle going through a sensitive region generates a hit.

The details of the T1 geometry are those published in the TOTEM TDR[5]. Each arm of the T2 detector is described as a set of twenty GEM detectors, ten upper and ten lower, covering a $\Delta\phi = 192°$ wide region, bounded by two concentrical circles with radius 35 mm and 148 mm. The twenty detectors have an azimuthal overlap of 12° and are equally spaced in a region surrounding the beam pipe at a distance from the interaction point between 13.57 m and 13.97 m. A sketch of the two telescopes, taken from the simulation viewer, is shown in Fig.1.
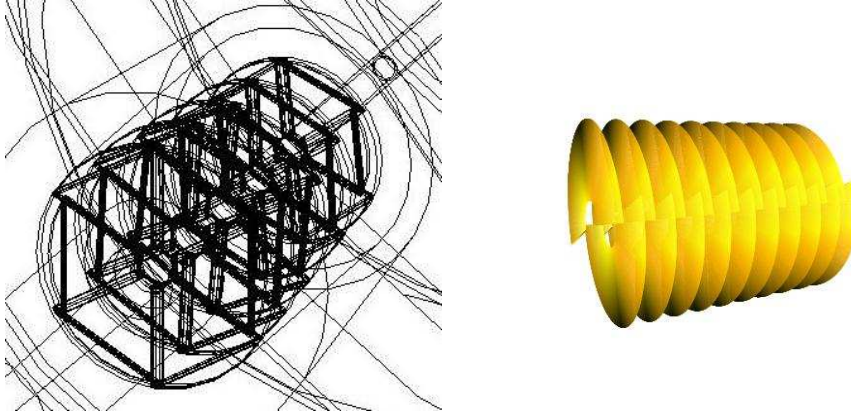

Figure 1: T1 (left) and T2 (right).

3.2 Geometric acceptance

The geometric acceptance of the telescopes has been verified measuring the efficiency in the detection of straight tracks at different angles; for T1 a track is detected with 3 hit planes over 5, while for T2 it was asked 4 over 10. The angular coverage of T1 is not homogenous in the azimuthal coordinate ϕ; four different values of ϕ have been considered in the study in order to show the behaviuor of the efficiency for a quarter of T1. The results are shown in Fig.2. The geometric acceptance has been measured assuming that a track can be reconstructed in T1 or T2 if at least three planes have been hit.

4 Test package

TotemTest package has been created inside the OscarApplication container. Its aim is to provide a test executable which runs OSCAR and stores the hit collections from T1 and T2 in a ROOT tree. The executable, named TotemGem,
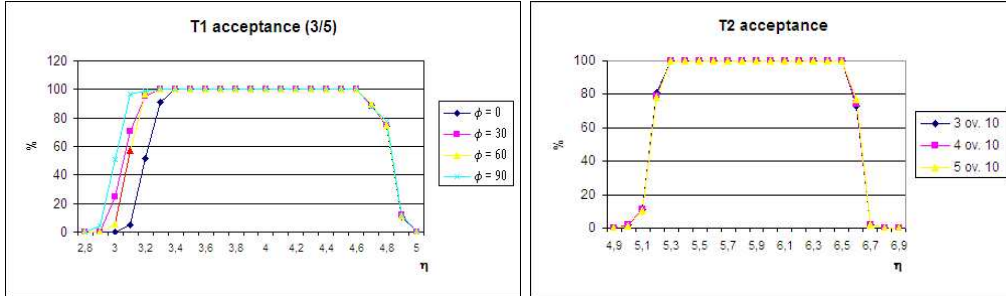
Figure 2: T1 (left) and T2 (right) geometric acceptance. T1: as expected, because of the trapezoidal shape of the CSCs, the acceptance behavior is different for a different ϕ. T2: the acceptance is shown requiring that at least 3, 4 or 5 over 10 planes are hit; the difference is small, due to the very low angle of the tracks hitting T2.

retrieves the hit collections from the simulation and saves the hits in a ROOT tree in the file TotemHits.root. The program can be run from the TotemTest/test directory, provided that the run time environment has been properly set up. The XML files with the description of the detectors to be included in the simulation are listed in OSCARconfiguration.xml, while the OSCAR set up is specified in the file .orcarc or oscarRC, depending on the running version of OSCAR.

5 Charged flux

The hits stored in the ROOT tree have been analyzed in order to test the simulation technicalities and to perform more detailed studies. This note is not intended to give an overview of all the studies done with the T1 and T2 simulation, therefore I will report here only an example, showing the charged particle fluxes through the detectors.

A few thousands minimum bias, single and double diffractive events have been generated with Pythia 6.158[6] and used as input for OSCAR. Analyzing these events it has been possible to measure the charged particle flux through T1 and T2. The fluxes at the TOTEM nominal luminosity $L = 10^{28} cm^{-2} s^{-1}$ are shown in Fig.3; for T2 the main contribution is due to low energy electrons generated by secondary interactions in the material between T2 and the interaction point (Fig.4).
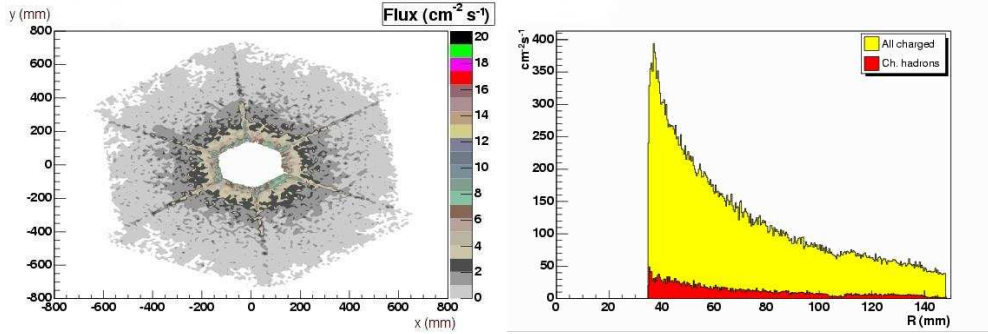
Figure 3: Charged flux for T1 (left) and T2 (right) at $L = 10^{28}$ cm^{-2} s^{-1}.
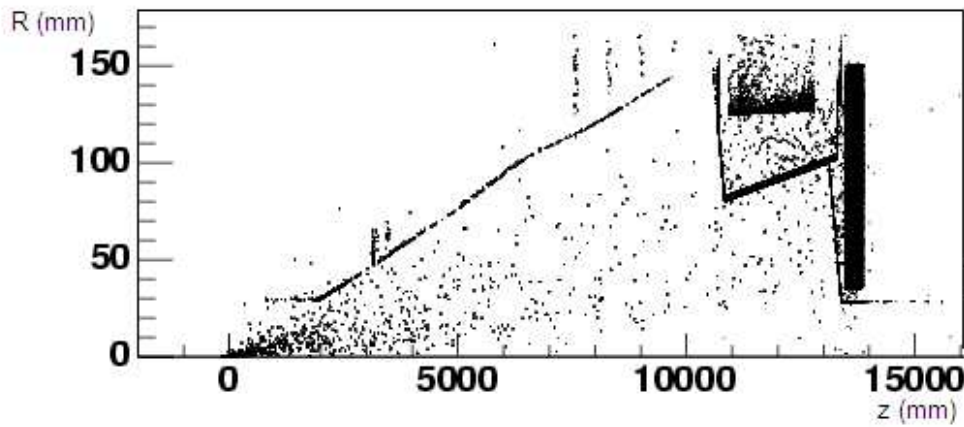

Figure 4: A section of T2 and the points where the charged particles hitting T2 are generated. The beampipe and the CMS HF are clearly visible.

6 Conclusion

The T1 and T2 detectors of TOTEM have been fully implemented in the framework for the simulation OSCAR developed by CMS. The whole software machinery has been proved to be working properly and an estimation of the charged flux in the detectors at the TOTEM nominal luminosity has been calculated.

7 Appendix

7.1 Hit object

The hit object contains the following variables:

- Event: event number

- x,y,z: absolute coordinates of the hit (z is the coordinate parallel to the beam axis)

- vx,vy,vz: absolute coordinate of the point where the particle hitting the detector was generated

- PABS: absolute momentum of the particle

- ELoss: energy lost by the particle in the detector

- ParentID: each particle has an its own identification number; this is the ID number of the particle from which the particle hitting the detector was originated (it is 0 for the primary particles)

- TrackID: particle identification number

- Ptype: particle type, using the PDG standard numbering scheme[7] (e.g. 13 corresponds to μ^-, 22 to a γ)

- UnitID: identification number of the part of the detector hit by the particle (the association of the detector part with a number is done in the TotemNumberingScheme package)

References

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