CERN-RRB-2009-120

13 October 2009

The Status of TOTEM

Progress Summary Report for the October 2009 RRB

The TOTEM Collaboration

1. Introduction

Since the last RRB in April 2009 the installation and commissioning of the TOTEM detectors have been continuing successfully. All of the Roman Pot stations at 220 m on both sides of IP5 are equipped with silicon detectors. The complete T2 telescope is installed in both CMS forward regions.

Two quarters of the T1 telescope have been assembled, cabled, and are running in the test beam. Some optimizations are still in progress and a final test in the SPS beam is foreseen for October 2009. After an evaluation of the test beam data, one side of the T1 telescope could be installed requiring access to the CMS forward region. The last two T1 quarters are being assembled now.

The final data acquisition system (DAQ) is under test in IP5. The installed detectors are in the commissioning phase. This includes all related detector infrastructure, the Detector Control System (DCS), the various databases, as well as the connections to the LHC and CMS control rooms. Furthermore, the TOTEM control room is now equipped with monitor systems and DCS controls.

Using Monte-Carlo simulations, the offline software is now being optimized for data analysis. This includes alignment software, simulations of trigger responses, event displays, database exchanges, understanding of the machine optics etc. We envisage taking data from the beginning of the colliding beams, and we hope to get physics results soon after the calibration of our detectors.

2. The Roman Pots

The production of the Detector Packages (DPs) for the Roman Pot stations at 220m strictly followed the schedule presented in the April 2009 RRB. Since April, the second set of five DPs has been produced, assembled, tested and commissioned on surface with cosmic rays or muon beams in the TOTEM test beam facility in SPS/H8. With the first set of five DPs installed in the sector 56 in April and the second set installed in sector 45 in August, both stations at 220m are now complete. Figure 1 shows the picture of the recently equipped Roman Pot Station at 220m in sector 45.

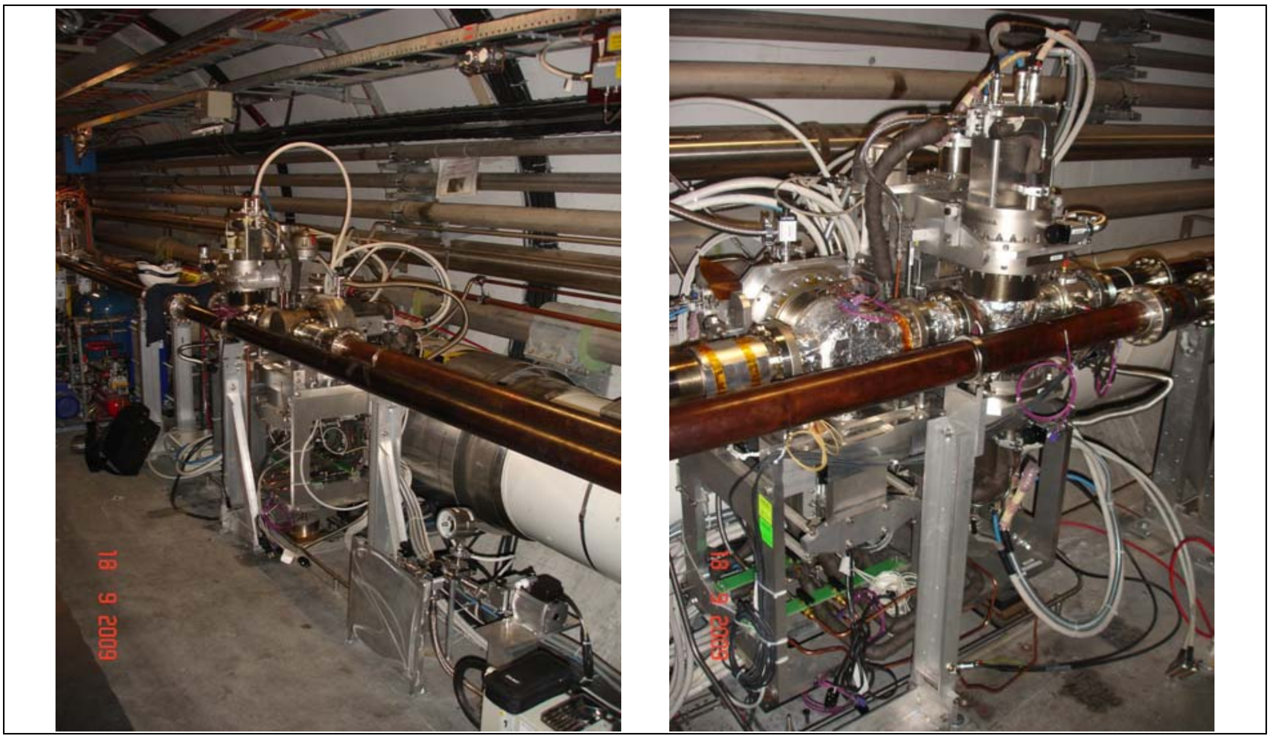

Figure 1: Roman Pot Station at 220m in sector 45, far unit (left) and near unit (right).

To make the commissioning of the Roman Pots and their detectors possible, the related infrastructure was installed and tested. The vacuum and cooling lines were checked, as well as the electrical cabling and the optical fibers. All pots are now connected to all services. To ensure a permanent secondary vacuum in the pots, an additional safety system has been added locally on both stations to prevent vacuum losses due to pump failures.

All the environmental sensors (temperature, pressure, radiation) for the completed stations are accessible via DCS and their data are continuously stored in the DCS database. The cooling has been operated successfully on the loops serving the two stations. In Figure 2, a plot of the temperatures in the six detector packages of the two 220m stations illustrates a recent cooling exercise.

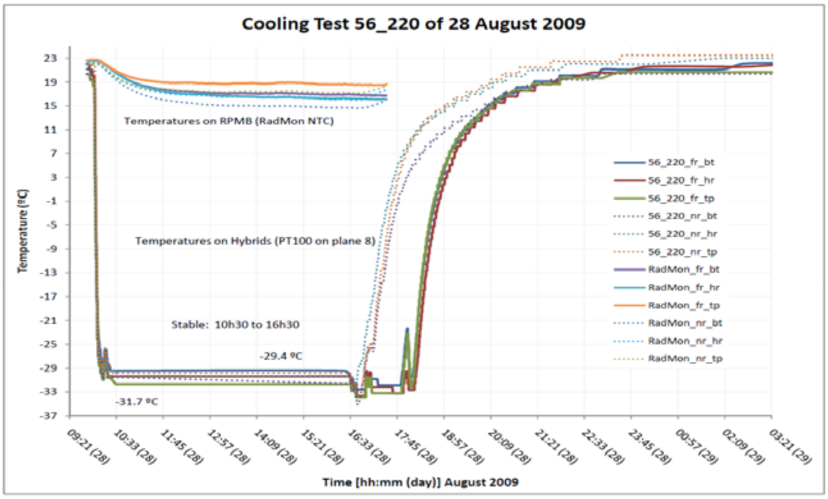

Figure 2: Temperature in the six DPs of the station at 220m, sector 56, at the level of the motherboard (Temperatures on RPMB) and on the hybrids.

With the cooling system available and fully functional, we have started the first tests on the control and the readout of the front-end electronics. The control loop has been successfully tested on both Roman Pot stations. The LV has been turned on for the read-out electronics in sector 56 and the data retrieved from the VFAT front-end chips showed the correct format. The same tests are now ongoing in sector 45. In parallel, the HV system is being commissioned: the control and monitoring are fully included in the DCS and the connectivity has been thoroughly checked. At the end of this phase, the noise behaviour of these detectors will be measured and compared with the performance recorded previously in the tests in H8.

The motorization of all Roman Pots and its control have been extensively tested in situ. The LVDT position measurement system has been calibrated for all pots by means of micrometers and laser trackers. Recently, the RP movement control system has been integrated with the LHC collimation system and the machine control in the CCC. Commissioning and tests of the combined system are currently in progress. The logic of the beam interlock based on the RP positions has been approved by the Machine Protection Panel. It is being implemented in the programmable TOTEM interlock circuit board and will then be tested together with the other LHC beam interlocks.

While the overall status of the Roman Pots at 220m is approaching the readiness for the start of the LHC, the production of the hybrids for the 147m stations is continuing with the objective to assemble first the four DPs for the “vertical” pots. It is intended to install these assemblies before the 3.5 TeV physics starts.

3. The T1 CSC Telescope

The T1 telescope will be installed inside the end-caps of CMS, in the region between the beam pipe and the inner envelope of the flux return yoke, between 7.5 m and 10.5 m on both sides of the interaction point, thus covering the pseudo-rapidity range $3.1 \leq \eta \leq 4.7$. Since the last RRB in April 2009, considerable progress can be reported about the construction and tests of the T1 Cathode Strip Chambers (CSCs). The assembly of all CSCs (60 chambers + 10 spares, in 10 different shapes) at PNPI in Russia is finished, and all chambers have been tested for HV, gas tightness and gain uniformity immediately after production and again after delivery at CERN.

The front-end electronics include three types of custom boards for anode and cathode read-out (70 AFECs and 180 CFECs, respectively) and the data concentration/transmission boards

(40 ROC). All boards, including spares, have been produced and tested. As a result, the design of the AFECs has been improved in order to eliminate a minor cross-talk effect observed on the first version of the boards. On the ROCs, a number of faulty chips from a defective lot have been substituted after a set of thorough acceptance tests on the boards.

One telescope arm has been assembled on its support structures in the lab, equipped with all services, and then moved to the H8 test beam line in the North Area (Fig. 3) for a full system test and commissioning. Few runs have been taken in two very short periods of parasitic data taking in September. A Cu target positioned in the pion beam line has been used in order to illuminate the whole telescope with similar conditions as later at the LHC. Already during the first runs in August, many tracks have been reconstructed and observed to be pointing to the target or to a metal support structure in front of the telescope (Figs. 4, 5). Another period of data taking on the test beam, as primary user, is scheduled for October 15-19.

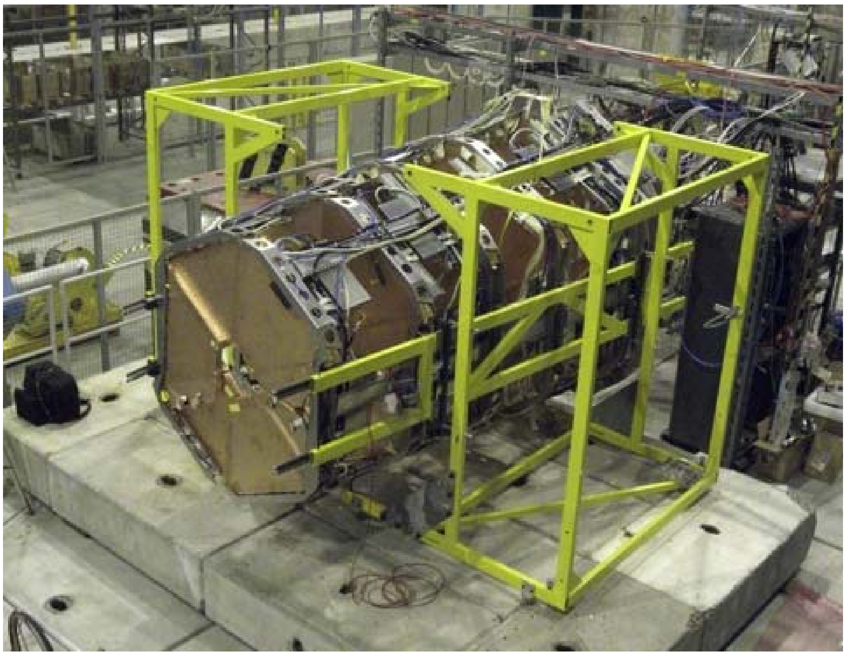

Figure 3: One arm of the T1 telescope assembled and set up for data taking on the test beam line in the North Area.

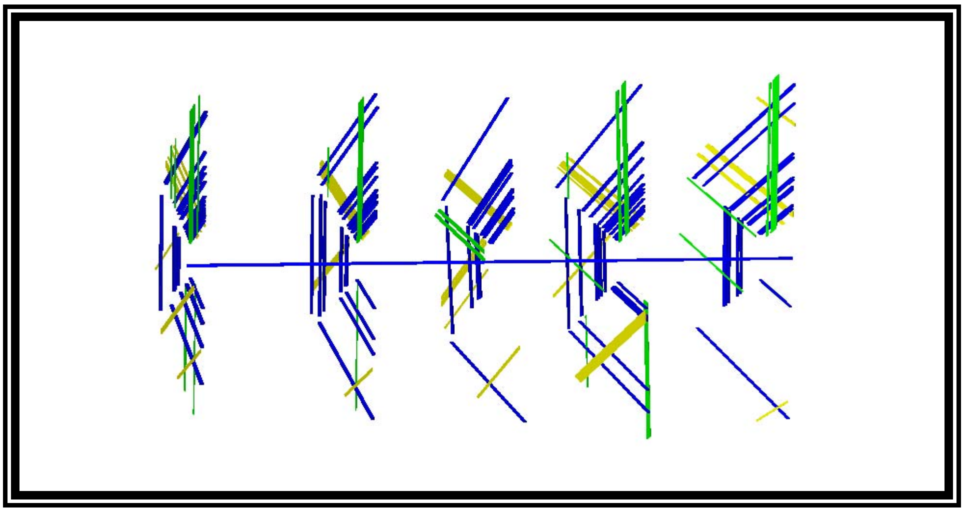

Figure 4: CSC hits from an event recorded during T1 beam tests in August: wires are shown in blue, strips on the two cathode sides in yellow and green.

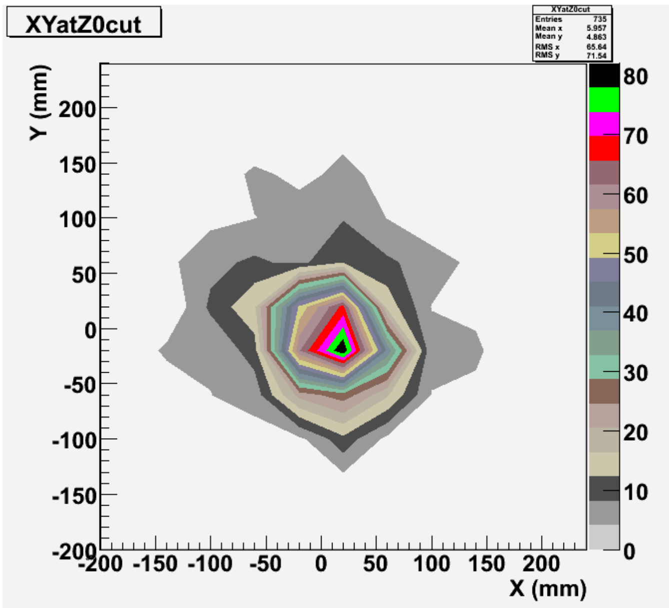

Figure 5: Distribution of the intersection of tracks reconstructed in the T1 telescope with the plane z = 0 where z is the beam axis. z=0 is the nominal position of the Cu target.

During the test period, a few VFATs were found to be damaged as a consequence of occasional discharges in some chambers. In order to prevent future damages to the read-out chips, an additional protection stage has been designed and tested. Insertion of this stage does not require a new AFEC production and is estimated to require about 1.5 months for the installation on all boards. Furthermore, two chambers (out of 41) causing repeated HV trips during the test period have now been fixed.

The “basket” support structures for the two remaining half-arms are now assembled. CSC mounting and cabling will proceed as soon as the corresponding AFECs have been modified and soldered.

A new, completely re-designed, support structure for the telescopes inside CMS has been produced. Welding to YE2 of the bracket-adapter set has been completed for one telescope and needs to be done for the second. A truss insertion and alignment procedure has been thoroughly discussed with CMS and a dedicated installation tool built. A first mounting test of the truss on the support blocks in YE2 was successfully carried out in June.

All services on the ‘–’ side of CMS are ready; high voltage and low voltage modules are installed in the counting room and on the platform. Piping and cabling work for the ‘+’ side on YE3 is still needed and requires suitable access.

4. <u>The T2 GEM Telescope</u>

The installation of the four T2 quarters in their final positions in IP5 has been completed in May 2009, in compliance with the CMS schedule. Each quarter consists of 10 semi-circular gaseous electron multiplier (GEM) detectors, installed in the forward shielding of CMS between the vacuum chamber and the inner shielding of the HF calorimeter (Fig.6).

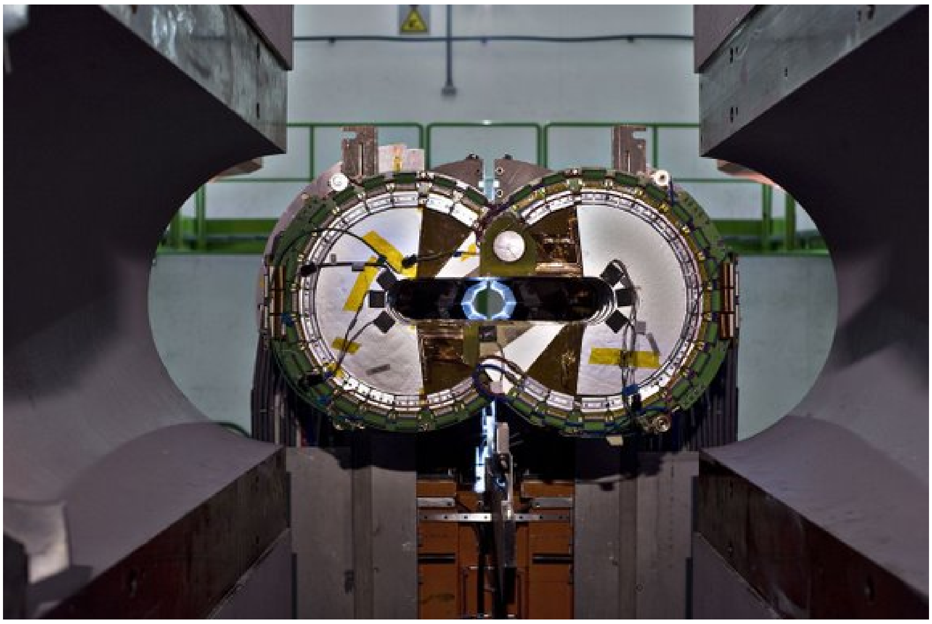

Figure 6: A view of one T2 arm, with the HF shielding open.

Each quarter has been systematically tested in the SPS beam line H8, where also cabling and shielding were optimized with respect to noise reduction. The tests at the TOTEMINO facility on the H8 line have been performed with cosmic rays due to the absence of beam in the first half of 2009. Efficiencies above 98% in the track reconstruction have been obtained by each T2 quarter (Fig. 7).

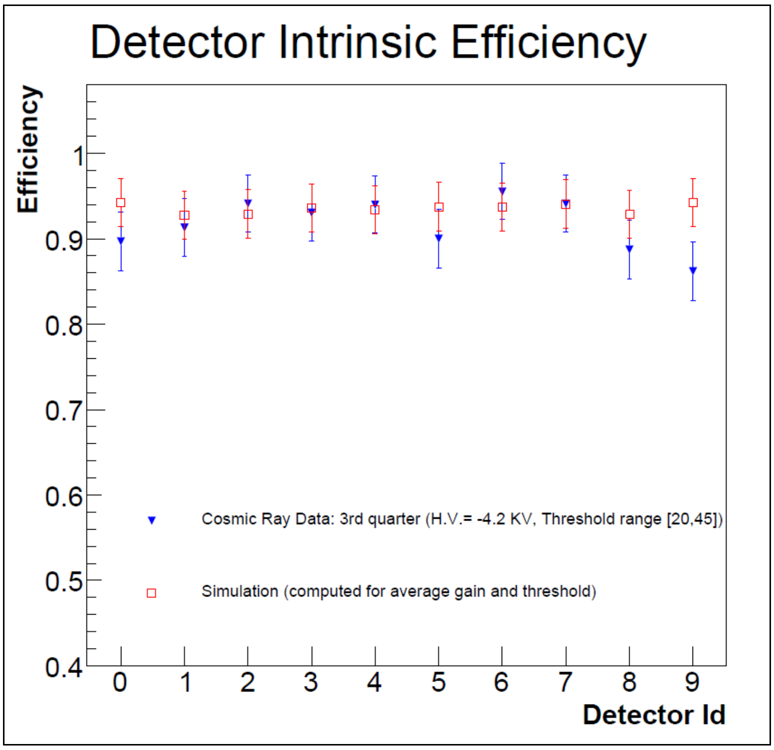

Figure 7: Efficiency of the individual GEM detector planes resulting in an overall track efficiency > 98%.

After installation in IP5, the insertion inside the HF calorimeter went smoothly (Fig. 8), without any mechanical interference with other CMS components. All services (HV/LV cables, gas, cooling) have been connected and tested. The cooling pumps, shared with Castor and T1, have been screened, due to some interference between their three-phase motors and the strong CMS magnetic fringe field of CMS, and have then been successfully tested during the CMS CRAFT test. The commissioning phase started in June and all GEM chambers have been kept at the nominal HV value for a long period of time. Electronics have been verified, control loops have been closed and responded correctly, and all components could be seen and programmed resulting in a correct data transmission and read-out. The final integration and commissioning into the DCS system is ongoing with all sensors and cables installed and the most significant ones correctly read out.

The T2 telescope will be operational and ready for data taking at the LHC start.

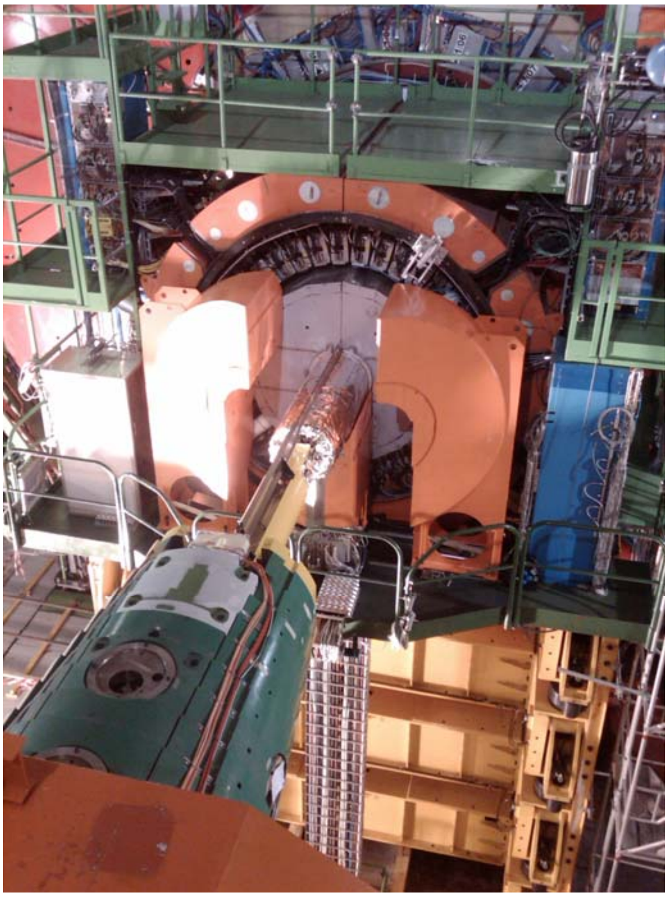

Figure 8: Forward platform with Castor, illustrating the environment of T2.

5. The Electronic system

With the completion of the installation of T2 and the Roman Pot stations at 220m, considerable progress was made on the overall electronics system. Cabling in the tunnel is now complete and commissioning has started. Additional cabling work and patch panels were necessary, e.g. to ensure better protection for the optical fibers as well as to increase the flexibility of the system. To meet latency requirements for future joint runs with CMS, significant progress was also made on propagating electrical trigger signals via copper cables from the 220m pots to the counting room. The required repeater modules have been successfully tested with the final cables in the tunnel, and their production has started. We are moving towards the final configuration in USC55, with readout boards, detector control, interlock and safety systems installed. Their connections to the TOTEM counting room are in progress.

We have yet to solve some important production problems with some printed circuit boards. Discussions with the manufacturer of the Roman Pot hybrids and the gas detector hybrids were successful, and we are confident that the needed hybrids will be produced on time, provided that a small production is re-launched now.

The situation with the HOST boards is more complicated. The first produced 15 boards showed deficiencies in the soldering, making these boards unreliable when used constantly in the experiment. The second production, out of which TOTEM received only 5 boards (the rest went to CMS), also exhibited failures. TOTEM and CMS are in negotiations with the manufacturing company (located in Israel) to obtain reliable boards as soon as possible.

6. Data Acquisition

The VME read-out crates dedicated to the Roman Pots and T2 have been installed in the underground counting room at IP5 to allow the interested groups to commission their detectors. Equivalent hardware for the T1 detector is available and will be installed as soon as needed.

One half of the storage system has been installed in order to cope with the needs during the commissioning phase. Additional storage will be added following the needs and the operations.

The DAQ group has made a large effort to boost the development of the firmware for the TOTFED VME board; a substantial increase in manpower has been possible both by shifting people from the DAQ and trigger groups and by hiring additional experts. The internal data flow has been completely revised and the VME protocol optimized in order to achieve the design goal of 1 kHz trigger rate. Prior to any development, a detailed requirement and specification document has been prepared. This effort will continue in the next months.

7. Offline Software and Computing

Like the previous version, the current TOTEM Offline Software Release (3.0) includes: the simulation (Geant4 + digitization) and the reconstruction (clustering, tracks) in all TOTEM detectors, the simulation of the Coincidence Chip, the simulation of the L1 trigger response, and a package for the forward proton transport in the LHC lattice.

The newly developed packages that are now implemented in the software chain are: alignment procedures, procedures to write/read the alignment constants from/to the offline database, event displays based on the FROG framework allowing the visualization of the detector geometries as well as any reconstructed objects (hit, track..), and access to a custom database, based on Oracle.

The corresponding access procedures have been developed in the software. The work is now focused on the applications that allow us to collect the information to be stored in the database, such as LHC measurements, DCS/DAQ settings, and beam and data taking conditions. Mapping and calibration are almost ready and the commissioning of the detectors has started. The Data Quality Monitor is completely integrated into the offline software to be used both online and offline. A collection of plots can be defined by the users to monitor the data from calibration to reconstruction.

A production of simulated data is currently ongoing, based on the new energy and optics foreseen at the LHC start-up. The simulated data will be used to test the software performance, improve the analysis tools, and to define the trigger strategy.

8. Physics

At the beginning, the LHC will run with beams of reduced energy (3.5 TeV) and number of bunches. Under these conditions, TOTEM will have the opportunity to make its first physics measurements covering large-|t| elastic scattering and high-mass central and single diffraction, as well as the measurement of inelastic rates and event topologies. At a later stage, as soon as it is feasible, TOTEM will request short dedicated runs with special beam optics ($\beta^* = 90$ m). This will allow us to measure the total cross-section with typically 5 % relative precision and to study soft diffraction at all diffractive masses.

In close collaboration with the offline software group, the physics group is preparing for the analysis of the TOTEM data. Over the last months, a strategy for a global alignment of the RP detectors has been worked out, using the RP data of elastic scattering events in conjunction with machine data, e.g. from the beam position monitors. Besides preparing for the physics analysis of the first data, we are also developing a trigger strategy for the first LHC runs, which includes a more detailed study of the first physics measurements in terms of expected precision and physics relevance. Using the event topology in T1 and T2, we developed a method for classifying inelastic events. In parallel, the group continues systematic comparisons of different event generators and models in view of preparing the interpretation of the first data.