CERN/LHCC 2006-001
CMS TDR 8.1
02 February 2006

CMS Physics

Technical Design Report

Volume I:

Detector Performance and Software

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Acknowledgments

We wish to acknowledge the extraordinary effort from a large fraction of the CMS Collaboration in producing this Technical Design Report on the preparation for physics analysis at the LHC. Subprojects in all areas were involved (Detector, PRS, Software, and Computing) in order to produce the large Monte Carlo simulation samples needed, to develop the software to analyze those samples, to perform the studies reported in this Report, and to write and review our findings.

For their constructive comments and guidance, we would like to thank our CMS internal reviewers.

We also would like to thank our LHCC referees.

For their patience in meeting sometimes impossible demands, we wish to thank the CMS Secretariat: Kirsti Aspola, Madeleine Azeglio, Nadejda Bogolioubova, Dorothée Denise, Dawn Hudson, Guy Martin and Marie-Claude Pelloux.

We also would like to thank George Alverson and Lucas Taylor for their invaluable technical assistance in the preparation of this manuscript.

Finally, we wish to thank the CMS management for their strong support and encouragement.

ISBN 92-9083-268-1
ISBN 978-92-9083-268-3

Also available at: `http://cmsdoc.cern.ch/cms/cpt/tdr/`

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Executive Summary

The Large Hadron Collider will provide extraordinary opportunities in particle physics based on its unprecedented collision energy and luminosity when it begins operation in 2007. The principal aim of this Technical Design Report is to present the strategy of CMS to explore the rich physics programme offered by the LHC: Volume 1 covering the operational procedures and reconstruction tools necessary to perform physics at the LHC, and Volume 2 demonstrating the physics capability of the CMS experiment based on this foundation.

In the first volume we highlight the final detector configuration as it will appear shortly after LHC start-up, including new detectors in the forward regions and for determining the beam luminosity. Results on the performance of the CMS detectors as obtained from detailed simulations are presented for realistic operating conditions, and validated where possible against test-beam or cosmic-ray data. Schemes to synchronize, calibrate, align, and monitor the detectors before, during and after LHC start-up are also given. Reconstruction algorithms developed to perform measurements of muons, electrons, photons, jets, taus, heavy-flavour quarks and the missing transverse energy using these detector subsystems are described. The performance of the reconstruction algorithms is determined from detailed simulations for realistic operating conditions, but techniques to measure the performance from LHC data are described as well. Parameterizations of the performance have been derived to facilitate faster simulations for some of the physics studies described in Volume 2. Included in this first volume are descriptions of the software components needed to implement all of the above, covering simulation, reconstruction, calibration and alignment, monitoring, and visualization.

The second volume covers the capability of the CMS experiment to address physics at the LHC. The prime goals of CMS are to explore physics at the TeV scale and to study the mechanism of electroweak symmetry breaking—through the discovery of the Higgs particle or otherwise. To carry out this task, CMS must be prepared to search for new particles, such as the Higgs boson or supersymmetric partners of the Standard Model particles, from the start-up of the LHC since new physics at the TeV scale may manifest itself with modest data samples of the order of 1 fb^{-1} or less. The experience of the Cosmic Data Challenge plays a crucial role in the preparation of CMS experiment, whereby calibration, alignment and reconstruction procedures are tested and made ready in advance of the LHC pilot and first physics runs. Lessons drawn from this test are described in this volume. Also described in Volume 2 is the online selection strategy of CMS as well as the analysis model and the data flow.

The tools that have been prepared in Volume 1 are applied in Volume 2 to study in great detail and with all the methodology of performing an analysis on CMS data specific benchmark processes upon which to gauge the performance of CMS. These processes cover several Higgs boson decay channels, the production and decay of new particles such as Z' and supersymmetric particles, B_s production and processes in heavy ion collisions. The simulation of these benchmark processes includes subtle effects such as possible detector miscalibration and misalignment. Besides these benchmark processes, the physics reach of CMS is studied for a large number of signatures arising in the Standard Model and also in theories beyond the Standard Model for integrated luminosities of 10 fb^{-1} up to the asymptotic value of 300 fb^{-1}. The Standard Model processes include QCD, B-physics, diffraction, detailed studies of the top quark properties, and electroweak physics topics such as the W and Z^0 boson properties. The production and decay of the Higgs particle is studied for all observable channels, and the precision with which the Higgs boson properties can be derived is determined. About ten different supersymmetry benchmark points are analysed, and methods to extract e.g. the sparticle masses are tested. Furthermore, the discovery reach for a plethora of alternative models for new physics is explored, notably extra dimensions, new vector boson high mass states, little Higgs models, technicolour and others.

In summary, the content of these two volumes is meant to serve as a comprehensive reference for new CMS collaborators. It provides an entry point to the documentation of the standard simulation, reconstruction, and analysis tools and provides a measure of the expected detector performance and physics reach as we head into the LHC era.

Structure of Volume 1

Chapter 1, the Introduction, describes the context of this document.

Chapter 2 describes the software foundation being prepared for LHC data-taking, including the underlying framework, simulation tools, reconstruction, calibration, alignment, monitoring, and visualization of data.

Chapters 3–6 describe the design, operation and performance of the muon detectors, electromagnetic and hadron calorimeters, and inner tracking detectors.

Chapter 7 describes the design, operation and performance of detectors in the forward regions.

Chapter 8 describes techniques to measure the luminosity and the design, operation and performance of associated detectors.

Chapters 9–12 describe the reconstruction algorithms designed to measure muons, electrons, photons, jets, missing transverse energy, taus, and heavy-flavour quarks.