14 Physics overview

14.1 Introduction

The ATLAS physics programme has been already discussed in several documents, the most comprehensive ones being the Letter of Intent [14-1] and the Technical Proposal [14-2]. The goals which have been defined there and which have guided the detector optimisation procedure remain essentially the same, the most important one being measurements that will lead to an understanding of the mechanism of electroweak symmetry breaking.

The high energy and luminosity of the LHC offers a large range of physics opportunities, from the precise measurement of the properties of known objects to the exploration of the high energy frontier. The need to accommodate the very large spectrum of possible physics signatures has guided the optimisation of the detector design. The desire to probe the origin of the electroweak scale leads to a major focus on the Higgs boson; ATLAS must be sensitive to it over the full range of allowed masses. Other important goals are searches for other phenomena possibly related to the symmetry breaking, such as particles predicted by supersymmetry or technicolour theories, as well as new gauge bosons and evidence for composite quarks and leptons. The investigation of *CP* violation in *B* decays and the precision measurements of *W* and top-quark masses and triple gauge boson couplings will also be important components of the ATLAS physics programme.

As discussed in the previous volume, and as also will be illustrated several times throughout this one, excellent performance of the detector is needed to achieve these physics goals.

- The various Higgs boson searches, which resent some of the most challenging signatures, were used as benchmark processes for the setting of parameters that describe the detector performance. High-resolution measurements of electrons, photons and muons, excellent secondary vertex detection for τ–leptons and *b*-quarks, high-resolution calorimetry for jets and missing transverse energy (E_T^{miss}) are essential to explore the full range of possible Higgs boson masses.
- Searches for SUSY set the benchmarks on the hermeticity and E_T^{miss} capability of the detector, as well as on *b*-tagging at high luminosity.
- Searches for new heavy gauge bosons provided benchmark requirements for high-resolution lepton measurements and charge identification in the p_T range as large as a few TeV.
- Signatures characteristic for quark compositeness set the requirements for the measurement of very high-p_T jets.
- The precision measurements of the *W* and top-quark masses, gauge boson couplings, *CP* violation and the determination of the Cabibbo-Kobayashi-Maskawa unitarity triangle yielded benchmarks that address the need to precisely control the energy scale for jets and leptons, determine precisely secondary vertices, reconstruct fully final states with relatively low-p_T particles and trigger on low-p_T leptons.

14.2 Theoretical picture

The Standard Model (SM) [14-3] is a very successful description of the interactions of the components of matter at the smallest scales (10^{-18} m) and highest energies (~200 GeV) accessible to current experiments. It is a quantum field theory which describes the interaction of spin-1/2 point-like fermions, whose interactions are mediated by spin-1 gauge bosons. The bosons are a consequence of local gauge invariance applied to the fermion fields and are a manifestation of the symmetry group of the theory, *i.e.* SU(3)xSU(2)xU(1) [14-3] [14-4].

The fundamental fermions are leptons and quarks. The left-handed states are doublets under the SU(2) group, while the right-handed states are singlets. There are three generations of fermions, each generation identical except for mass: the origin of this structure, and the breaking of generational symmetry (flavour symmetry), remain a mystery. There are three leptons with electric charge -1, the electron (e), muon (μ) and tau lepton (τ) and three electrically neutral leptons, the neutrinos ν_e, ν_μ and ν_τ. Similarly, there are three quarks with electric charge 2/3, up (u), charm (c) and top (t), and three with electric charge -1/3, down (d), strange (s) and bottom (b). The quarks are triplets under the SU(3) group and thus carry an additional 'charge', referred to as colour. There is mixing between the three generations of quarks, which is parametrised by the Cabibbo-Kobayashi-Maskawa (CKM) [14-5] matrix whose origin is not explained by the Standard Model.

The SU(2)xU(1) symmetry group (which describes the so-called electroweak interaction) is spontaneously broken by the existence of a (postulated) Higgs field with non-zero expectation value [14-6]. This leads to the emergence of massive vector bosons, the W and Z, which mediate the weak interaction, while the photon of electromagnetism remains massless. One physical degree of freedom remains in the Higgs sector, which should manifest as a neutral scalar boson H^0, which is presently unobserved. The SU(3) group describes the strong interaction (quantum chromodynamics or QCD) [14-4]. Eight vector gluons mediate this interaction. They carry colour charges themselves, and are thus self-interacting. This implies that the QCD coupling α_s is small for large momentum transfers but large for small momentum transfers, and leads to the confinement of quarks inside colour-neutral hadrons. Attempting to free a quark produces a jet of hadrons through production of quark-antiquark pairs and gluons.

The success of the SM of strong, weak and electromagnetic interactions has drawn increased attention to its limitations. In its simplest version, the model has 19 parameters, the three coupling constants of the gauge theory SU(3)xSU(2)xU(1), three lepton and six quark masses, the mass of the Z boson which sets the scale of weak interactions, and the four parameters which describe the rotation from the weak to the mass eigenstates of the charge -1/3 quarks (CKM matrix). All of these parameters are known with varying errors. Of the two remaining parameters, a *CP*-violating parameter associated with the strong interactions must be very small. The last parameter is associated with the mechanism responsible for the breakdown of electroweak SU(2)xU(1) to $U(1)_{em}$. This can be taken as the mass of the, as yet undiscovered, Higgs boson. The couplings of the Higgs boson are determined once its mass is given.

The gauge theory part of the SM has been well tested, but there is no direct evidence either for or against the simple Higgs mechanism for electroweak symmetry breaking. All masses are tied to the mass scale of the Higgs sector. Although within the model there is no guidance about the Higgs mass itself, some constraints can be delivered from the perturbative calculations within the model requiring the Higgs couplings to remain finite and positive up to an energy scale Λ [14-7]. Such calculations exists at the two-loop level for both lower and upper Higgs mass bounds. With present experimental results on the SM parameters, if the Higgs mass is in the range 160 to 170 GeV [14-8] then the renormalisation-group behaviour of the Standard Model is perturbative and well behaved up to Planck scale $\Lambda_{Pl} \sim 10^{19}$ GeV. For smaller or larger values of m_H new physics must set in below Λ_{Pl}.

As its mass increases, the self couplings and the couplings to the W and Z bosons grow [14-9]. This feature has a very important consequence. Either the Higgs boson must have a mass less than about 800 GeV, or the dynamics of WW and ZZ interactions with centre-of-mass energies of order 1 TeV will reveal new structure. It is this simple argument that sets the energy scale that must be reached to guarantee that an experiment will be able to provide information on the nature of electroweak symmetry breaking.

The presence of a single elementary scalar boson is unsatisfactory to many theorists. If the theory is part of some more fundamental theory, which has some other larger mass scale (such as the scale of grand unification or the Planck scale), there is a serious 'fine tuning' or naturalness problem. Radiative corrections to the Higgs boson mass result in a value that is driven to the larger scale unless some delicate cancellation is engineered ($(m_0^2 - m_1^2) \sim m_W^2$ where m_0 and m_1 are order 10^{15} GeV or larger). There are two ways out of this problem which involve new physics on the scale of 1 TeV. New strong dynamics could enter that provides the scale of m_W, or new particles could appear so that the larger scale is still possible, but the divergences are cancelled on a much smaller scale. In any of the options, Standard Model, new dynamics or cancellations, the energy scale is the same; something must be discovered at the TeV scale.

Supersymmetry [14-10] is an appealing concept for which there is so far no experimental evidence. It offers the only presently known mechanism for incorporating gravity into the quantum theory of particle interactions and provides an elegant cancellation mechanism for the divergences, provided that at the electroweak scale the theory is supersymmetric. The successes of the Standard Model (such as precision electroweak predictions) are retained, while avoiding any fine tuning of the Higgs mass. Some supersymmetric models allow for the unification of gauge couplings at a high scale and a consequent reduction of the number of arbitrary parameters.

Supersymmetric models postulate the existence of superpartners for all the presently observed particles: bosonic superpartners of fermions (squarks and sleptons), and fermionic superpartners of bosons (gluinos and gauginos). There are also multiple Higgs bosons: h, H, A and $H^{\pm}$. There is thus a large spectrum of presently unobserved particles, whose exact masses, couplings and decay chains are calculable in the theory given certain parameters. Unfortunately these parameters are unknown. Nonetheless, if supersymmetry is to have anything to do with electroweak symmetry breaking, the masses should be in the region below or order of 1 TeV.

An example of the strong coupling scenario is 'technicolour' for models based on dynamical symmetry breaking [14-11]. Again, if the dynamics is to have anything to do with electroweak symmetry breaking we would expect new states in the region below 1 TeV; most models predict a large spectrum of such states. An elegant implementation of this appealing idea is lacking. However, all models predict structure in the WW scattering amplitude at around 1 TeV centre-of-mass energy.

There are also other possibilities for new physics that are not necessarily related to the scale of electroweak symmetry breaking. There could be new neutral or charged gauge bosons with mass larger than the Z and W; there could be new quarks, charged leptons or massive neutrinos, or quarks and leptons could turn out not to be elementary objects. While we have no definitive expectations for the masses of these objects, the LHC experiments must be able to search for them over the available energy range.

Results on precision measurements within the Standard Model, as well as limits on new physics, from present experiments are presented, case by case, in the relevant chapter of this volume.

14.3 Challenges of new physics

This volume presents examples of the physics programme which should be possible with the ATLAS detector. The channels studied in previous documents [14-1][14-2] are re-examined and many new strategies proposed.

In the initial phase at low luminosity, the experiment will function as a factory for QCD processes, heavy flavour and gauge bosons production. This will allow a large number of precision measurements in the early stages of the experiment.

A large variety of QCD related processes will be studied. These measurements are of importance as studies of QCD 'per se' in a new energy regime with high statistics. Of particular interest will be jet and photon physics, open charm and beauty production and gauge bosons production. A study of diffractive processes will present significant experimental challenges itself, given the limited angular coverage of the ATLAS detector. Several aspects of diffractive production of jets, gauge bosons, heavy flavour partons will be nevertheless studied in detail. LHC will extend the exploration of the hard partonic processes to large energy scales (of few hundred GeV^2), while reaching small fractional momentum of the proton being carried by a scattered partons (of 10^{-5}). Precise constraints on the partonic distribution functions will be derived from measurements of Drell-Yan production, of W and Z bosons production, of production of direct photons and high-p_T jets, heavy flavours and gauge boson pairs. Deviation from the theoretical predictions for QCD processes themselves might indicate the onset of new physics, such as compositeness. Measurement and understanding of these QCD processes will be essential as they form the dominant background searches for new phenomena.

Even at low luminosity, LHC is a beauty factory with 10^{12} $b\bar{b}$ expected per year. The available statistics will be limited only by the rate at which data can be recorded. The proposed B-physics programme is therefore very wide. Specific B-physics topics include the search for and measurement of CP violation, of B_s^0 mixing and of rare decays. ATLAS can perform competitive high-accuracy measurements of B_s^0 mixing, covering the statistically preferred range of the Standard Model predictions. Rare B mesons such as B_c will be copiously produced at LHC. The study of B-baryon decay dynamics and spectroscopy of rare B hadrons will be also carried out.

LHC has a great potential for performing high precision top physics measurements with about eight million $t\bar{t}$ pairs expected to be produced for an integrated luminosity of 10 fb^{-1}. It would allow not only for the precise measurements of the top-quark mass (with a precision of ~2 GeV) but also for the detailed study of properties of the top-quark itself. The single top production should be observable and the high statistics will allow searches for many rare top decays. The precise knowledge of the top-quark mass places strong constraints on the mass of the Standard Model Higgs boson, while a detailed study of its properties may reveal as well new physics.

One of the challenges to the LHC experiments will be whether the precision of the W-mass measurement can be improved. Given the 300 million single W events expected in one year of data taking, the expected statistical uncertainty will be about 2 MeV. The very ambitious goal for both theory and experiment is to reduce the individual sources of systematic errors to less than 10 MeV, which would allow for the measurement of the W mass with precision of better than 20 MeV. This would ensure that the precision of the W mass is not the dominant source of errors in testing radiative corrections in the SM prediction for the Higgs mass.

The large rate of gauge boson pair production at the LHC enables ATLAS to provide critical tests of the triple gauge-boson couplings. The gauge cancellations predicted by the Standard Model will be studied and measurements of possible anomalous couplings made. These probe underlying non-standard physics. The most sensitive variables to compare with Standard Model predictions are the transverse momentum spectra of high-p_T photons or reconstructed Z bosons.

If the Higgs boson is not discovered before LHC begins operation, the searches for it and its possible supersymmetric extensions in the Minimal Supersymmetric Standard Model (MSSM) will be a main focus of activity. Search strategies presented here explore a variety of possible signatures, being accessible already at low luminosity or only at design luminosity. Although the cleanest one would lead to reconstruction of narrow mass peaks in the photonic or leptonic decay channels, very promising are the signatures which lead to multi-jet or multi-τ final states. In several cases signal-to-background ratios much smaller than one are expected, and in most cases detection of the Higgs boson will provide an experimental challenge. Nevertheless, the ATLAS experiment alone will cover the full mass range up to 1 TeV for the SM Higgs and also the full parameter space for the MSSM Higgs scenarios. It has also a large potential for searches in alternative scenarios.

Discovering SUSY at the LHC will be straightforward if it exists at the electroweak scale. Copious production of squarks and gluinos can be expected, since the cross-section should be as large as a few pb for squarks and gluinos as heavy as 1 TeV. Their cascade decays would lead to a variety of signatures involving multi-jets, leptons, photons, heavy flavours and missing energy. In several models, discussed in detail in this volume, the precision measurement of the masses of SUSY particles and the determination of the model parameters will be possible. The main challenge would be therefore not to discover SUSY itself, but to reveal its nature and determine the underlying SUSY model.

Other searches beyond the Standard Model have been also investigated. Throughout this volume are presented strategies for searching for technicolour signals, excited quarks, leptoquarks, new gauge bosons, right-handed neutrinos and monopoles. Given the large number of detailed models published in this field, the task of evaluating each of them is beyond the scope of this document. Rather an exploratory point of view is taken, examples are used and in some cases a detailed study is performed.

14.4 Simulation of physics signals and backgrounds

In the process of evaluation of the physics potential of the ATLAS experiment, Monte Carlo event generators were used to simulate multiparticle production in physics processes appearing in the *pp* collisions. Detailed or parametrised simulation of the detector response to this multiparticle stream was then used to evaluate the possible observability of the signal.

In the full detector simulation, described in Section 2.2, the detailed geometry of the detector is implemented and the interactions of particles with the material of the detector are modelled. Results from full-simulation studies have been described in Chapters 3-10 for several crucial benchmark signatures and physics processes, *e.g.* mass resolutions, acceptances and identification efficiencies for $H \to \gamma\gamma$, $H \to ZZ^* \to 4l$, $H \to b\bar{b}$, $H \to \tau\tau$ decays, E_T^{miss} resolution, *b*-jet and τ-jet identification capability.

However, in most of the cases presented in this volume, evaluation of the expected signals and backgrounds has been done with the fast simulation described in Section 2.5. This simulation includes, in a parametrised way, the main aspects related to the detector response: jet reconstruction in the calorimeters, momentum / energy smearing for leptons and photons, reconstruction of missing transverse energy and charged particles. It is tuned to reproduce as well as possible the expected ATLAS performance, and this tuning has been verified with several benchmark processes as described in Section 2.5.

The fast simulation was used very extensively for estimating the expected backgrounds from physics processes. Such approach was particularly useful for channels requiring large event samples, which one could not process with the much more time-consuming full simulation. Many of these studies are presented in this volume, *e.g.* for Higgs searches in Chapter 19, where, in some cases, both irreducible and reducible backgrounds required simulations of several million events.

14.4.1 Event generators

There are several available Monte Carlo event generators for *pp* collisions, the most exhaustive ones, with respect to available physics processes and complexity in modelling hadronic interactions, being: HERWIG [14-14], ISAJET[14-12] and PYTHIA[14-13]. Each of these simulates a hadronic final state corresponding to some particular model of the underlying physics. The details of the implementation of the physics are different in each of these generators, however the underlying philosophy of the generators is the same.

- The basic process is a parton interaction involving a quark or gluon from each of the incoming protons. Elementary particles in the final state, such as quarks, gluons or $W/Z/\gamma$-bosons, emerge from the interaction. The fundamental process is calculated in perturbative QCD, and the initial momentum of the quarks or gluons is given by structure functions.
- Additional QCD (gluon) radiation takes place from the quarks and gluons that participate in the basic scattering process. These parton showers are based on the expansions around the soft and collinear limits and can be ascribed to either the initial or final state. The algorithm used by HERWIG includes some effects due to quantum interference and generally produces better agreement with the data when detailed jet properties are studied. The showering continues down to some low energy cut-off. For some particular cases the matrix element calculations involving higher-order QCD processes are used. The events that have more energy in the parton process have more showering, and consequently more jet activity.
- The collection of quarks and gluons must then be hadronised into mesons and baryons. This is done differently in each of the event generators, but is described by a set of (fragmentation) parameters that must be adjusted to agree with experimental results. HERWIG looks for colour singlet collections of quarks and gluons with low invariant mass and groups them together; this set then turns into hadrons. PYTHIA splits gluons into quark-antiquark pairs and turns the resulting set of colour singlet quark-antiquark pairs into hadrons via a string model. ISAJET simply fragments each quark independently paying no attention to the colour flow. In ISAJET the underlying event that arises from the re-

maining beam fragments must be added. The other generators tie these fragments back into the partonic system in order to neutralise the colour.

Matrix elements are likely to provide a better description of the main character of the events, *i.e.* the topology of well separated jets, while parton showers should be better at describing the internal structure of these jets.

The above model(s) describe events where there is a hard-scattering of the incoming partons; either a heavy particle is produced or the outgoing partons have large transverse momentum. While these are the processes that are of most interest, the dominant cross-section at the LHC consists of events with no hard scattering. There is little detailed theoretical understanding of these minimum-bias events and the event generators must rely on data at current energies. These minimum-bias events are important at LHC, particularly at design luminosity, as they overlap interesting hard-scattering events such as the production of new particles. The generators use a different approach in this case. ISAJET uses a pomeron model that has some theoretical basis. HERWIG uses a parametrisation of data mainly from the CERN $p\bar{p}$ Collider. PYTHIA uses a mini-jet model where the jet cross-section is used at very low transverse momenta, *i.e* the hard scattering process is extrapolated until it saturates the total cross-section. Whenever relevant, ATLAS has used the PYTHIA approach with dedicated modifications that agree with present data from Tevatron [14-17]. The multiplicity in minimum-bias events predicted by this approach is larger than that predicted by ISAJET or HERWIG (see Chapter 15), hence issues associated with pile-up are treated conservatively.

The generators differ in the extent to which non-standard physics processes are included. The most complete implementation of the Standard Model processes are available in PYTHIA, while ISAJET has the most complete implementation of SUSY scenarios.

In the physics evaluation presented in this volume, the Standard Model physics and Higgs searches were mostly simulated with PYTHIA. ISAJET was used extensively for the supersymmetry studies but some analyses have been done also with the supersymmetric extension of PYTHIA [14-23]. HERWIG has been used for some of the QCD studies. The model of the hadronic interactions implemented in the physics generator has a direct impact on physical observables such as jet multiplicity, their average transverse momentum, internal structure of the jets and their heavy flavour content. That was one of the reasons why, whenever possible, PYTHIA was used enabling a consistent set of signal and background simulations to be generated.

Theoretical precision of the existing Monte Carlo generators is far from adequate for the challenging requirements of the LHC experiments. Despite the huge efforts which have been put into developing of physics generators for hadron colliders over the last years, the precision with which *e.g.* present data can be reproduced is not better than 10-30%, and in some cases is not better than a factor of two.

Table 14-1 shows a few examples of important signal and background processes with their predicted cross-sections, as used in the simulations discussed in this volume. If not explicitly stated otherwise, these are calculated using leading-order QCD as implemented in PYTHIA 5.7, using the CTEQ2L set of structure functions as the reference one. Whenever better or more appropriate calculations were available, the production cross-section from PYTHIA was suitably normalised, or a different Monte Carlo generator was used.

- The QCD multi-jet production is a dominant background for *e.g.* Higgs searches in the multi-jet final state. The production of events with three or more high-p_T jets is not well modelled by lowest-order di-jet processes convoluted with parton showers. To illustrate the large discrepancy between exact matrix element calculations and parton shower approaches in this case, Table 14-1 gives rates for one, three and four jet final states as given by the exact multi-parton matrix element NJETS Monte Carlo [14-15] and PYTHIA. On the other hand, heavy flavour content of jets is not modelled with the NJETS Monte Carlo. Simulation of four *b*-jet final states has been therefore only possible with the PYTHIA generator, which has the heavy flavour content of the partonic shower implemented.

- In the case of di-jet production in association with a *W* or *Z*, the VECBOS Monte Carlo [14-16], dedicated to this process, has been used. Exact matrix-element calculations were used also for estimating the expected cross-section in the case of $Wb\bar{b}$ [14-18] and $Zb\bar{b}$ [14-19] production. In the first case a modified version of HERWIG [14-18] was used, while in the second case the EUROJET Monte Carlo [14-21] was adopted.
- The leading order $t\bar{t}$ cross-section is quoted in Table 14-1 since it has been used for all the background studies to new physics. For the specific case of top physics studies in Chapter 18, a more accurate NLO calculation of 833 pb has been used, except for the case of single-top production, for which the NLO terms are not yet known.
- The total $b\bar{b}$ cross-section is also quoted in Table 14-1. For the *B*-physics studies, much more detailed work reported in Chapter 17 has shown that for high-p_T *b*-quark production, which can provide a Level-1 trigger with a high-p_T muon, the PYTHIA model as used by ATLAS [14-20] reproduces quite well the $b\bar{b}$ production as measured at the Tevatron [14-21] [14-22]. In this case, only a small fraction of the total cross-section quoted in Table 14-1 is relevant for physics, and many of the large theoretical uncertainties inherent to the calculations of the total $b\bar{b}$ production are very significantly reduced. A more detailed discussion of $b\bar{b}$ production at the LHC is discussed in Section 15.8.

The list above collects some relevant examples of the attempts which have been made to estimate as correctly as possible the expected production rates at the LHC. More details can be found in the specific Chapters of this volume discussing particular physics processes

Large uncertainties in the signal and background production cross-sections, due to missing higher-order corrections, structure function parametrisations, energy scale for the QCD evolution, as well as models used for full event generation, remain. In addition, despite the existence of many higher-order QCD correction (*K*-factor) calculations, not all processes of interest at the LHC have benefited from this theoretical effort. In most cases they have also not been embodied in the Monte Carlo generator, so that proper studies of their impact on the observed rates cannot be undertaken. Therefore, the present studies consistently and conservatively avoided the use of *K*-factors, resorting to Born-level predictions for both signal and backgrounds.

14.4.2 Signal observability

In the following sections, most of the results will be given for integrated luminosities of 30 fb^{-1} and 100 fb^{-1}, which are expected to be collected in three years of data taking at the initial (low) luminosity and one year of data taking at the design (high) luminosity respectively. The ultimate discovery potential is evaluated for an integrated luminosity of 300 fb^{-1}.

In most cases, the event selection for signal and background has been performed as it might be expected for off-line analysis. The foreseen trigger LVL1/LVL2 menus were used for the discussed channels. The possible irreducible and reducible backgrounds are extensively discussed. Given that the presently available tools for physics modelling have inherent uncertainties, analyses in most cases are straightforward; sophisticated statistical methods and very detailed optimisation of cuts are not applied.

Table 14-1 Leading order cross-sections for some typical processes at the LHC. Unless stated otherwise, these numbers have been obtained by using PYTHIA 5.7 with CTEQ2L structure functions.

Process	Cross-section	Comments
Inclusive H $m_H = 100$ GeV	27.8 pb	
WH with $W \to l\nu$ $m_H = 100$ GeV	0.40 pb	
$t\bar{t}H$ with one $W \to l\nu$ $m_H = 100$ GeV	0.39 pb	
Inclusive SUSY $m_{\tilde{g}}$, $m_{\tilde{q}}$ ~ 1 TeV	3.4 pb	ISAJET or PYTHIA
Inclusive $b\bar{b}$	500 μb	All di-jet processes used
Inclusive $t\bar{t}$ ($m_t = 175$ GeV)	590 pb	
Di-jet processes: 1 jet $p_T^j > 180$ GeV, $\|\eta\| < 3.2$	13 μb	PYTHIA
3 jets $p_T^j > 40$ GeV, $\|\eta\| < 3.2$	2.0 μb (0.7 μb)	NJETS (PYTHIA)
4 jets $p_T^j > 40$ GeV, $\|\eta\| < 3.2$	0.4 μb (0.1 μb)	NJETS (PYTHIA)
Inclusive W	140 nb	
Inclusive Z	43 nb	
Wjj with $W \to l\nu$ with 2 jets $p_T^j > 15$ GeV, $\|\eta\| < 3.2$	4640 pb	VECBOS
$Wb\bar{b}$ with $W \to l\nu$	69.3 pb	Matrix element [14-18]+ HERWIG
Zjj with $Z \to ll$ with 2 jets $p_T^j > 15$ GeV, $\|\eta\| < 3.2$	220 pb	VECBOS
$Zb\bar{b}$ with $Z \to ll$	36 pb	EUROJET + [14-19]
WW	71 pb	
WZ	26 pb	
$W\gamma$ with $W \to l\nu$ with $p_T^\gamma > 100$ GeV, $\|\eta\| < 2.5$	210 fb	

The observation of a given signal will be considered as possible if a significance of five standard deviations, defined according to the naive estimator $S/\sqrt{B}$, where *S (B)* is the expected number of signal (background) events, can be obtained. This includes the relevant systematic uncertainties. If the number of expected signal and background events is smaller than 25, Poisson statistics has been used to compute the equivalent Gaussian significance.

14.5 Outline

This volume reviews the potential of the ATLAS detector for the observability of a variety of physics processes, starting from the studies of hadronic physics, precision measurements in the Standard Model sector and *CP*-violation phenomena, continuing through the searches for the Higgs boson(s) and supersymmetry, and ending with a discussion of physics beyond the Standard Model.

The volume begins with a discussion of QCD processes (Chapter 15), which have the largest rate and represent the dominant background for new physics searches. Next is a discussion of the properties of the *W* and *Z* gauge bosons and how ATLAS can improve the precision measurements of the masses and couplings (Chapter 16). This is followed by a presentation of the *B*-physics programme; methods for the measurement of *CP* violation, mixing and rare decays are discussed (Chapter 17). Next, measurements related to the top quark and searches for other heavy quarks / leptons are described (Chapter 18). The Standard Model Higgs boson and its variants in the minimal supersymmetric model provide a benchmark for LHC physics; the large number of possible discovery channels are analysed in detail (Chapter 19). Physics beyond the Standard Model is the subject of the final two sections; the most popular extension to Supersymmetry is discussed in detail and many signatures that allow precise measurements in this sector are presented (Chapter 20). Finally, signatures for other extensions to the Standard Model, such as new gauge bosons and technicolour, are discussed (Chapter 21).

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