PoS PROCEEDINGS OF SCIENCE

ATLAS Physics Prospects for 2010-2011

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The ATLAS experiment is aimed at the exploitation of the full physics potential of LHC. Integrated luminosities of 50 pb^{-1} during 2010 and ~1 fb^{-1} during 2011 are expected. Physics prospects using these data samples are discussed within the context of the Standard Model, and Beyond the Standard Model.

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1 Speaker

1.Introduction

High Energy Physics steps into a new era with the start of proton-proton (pp) collisions at $\sqrt{s}$=7 TeV using the CERN Large Hadron Collider (LHC). The ATLAS experiment aims to exploit the full physics potential of LHC. The physics program of ATLAS covers almost all aspects of modern high energy physics. The precise cross-section measurement of known processes will reduce theoretical uncertainties. High luminosity will provide the possibility to study many rare Standard Model (SM) processes. The search for the Higgs-boson is major goal of the LHC experiments. At the same time searches will be carried out for particles predicted to exist by theories extending the SM (BSM – Beyond the Standard Model).

This paper is devoted to physics prospects for the ATLAS experiment with an integrated luminosity of 50 pb^{-1} expected in 2010 and ~1 fb^{-1} expected by the end of 2011.

2. Standard Model

2.1 WZ production

The *W* and *Z* bosons are produced at LHC with high cross-sections and are the most copious sources of high-p_T leptons. These two characteristics make them suitable for many purposes, from the very first stages of the data taking up to high luminosity scenarios. In particular lepton-pair decays of the *Z* allow to determine lepton trigger and reconstruction efficiencies using so-called Tag&Probe method, as well as energy scale, energy resolution and detector alignment. Since the high- p_T decay of the W and Z bosons in leptons has a very clean experimental signature, a measurement of the production cross-section is one the major benchmarks to have a detailed understanding of the known SM physics in new experimental conditions. In particular, a measurement of the lepton spectra from W decays provides information on the gluon structure function (PDF) at low-x and thus helps to improve the knowledge of PDFs. Recent *W* and *Z* boson measurements are presented in [1]

2.2 Top quark

The top quark completes the three generation structure of the SM. After QCD jets, and *W*/*Z* bosons, the production of top quarks is a dominant process in pp collisions at multi-TeV energies. Determinations of the top quark properties, for example its mass, spin, charge and couplings to fermions or bosons have been investigated at the Fermilab Tevatron [2], but the precision is still statistically limited for most of these measurements. The $t\bar{t}$ production cross-section at the LHC with $\sqrt{s}$=7 TeV is 20-25 times more than at the Tevatron. Thus $t\bar{t}$ data samples of ~25 K single-lepton and ~3 K di-lepton events are expected for each experiment using the 2011 data set. One of the first goals will be a determination of the top quark mass at the 1% level. This determination constitutes a crucial test of the electro-weak sector and places stringent constraints on its symmetry breaking mechanism, either in the SM or in a supersymmetric framework. The top quark spin properties, through W polarization and top spin correlation measurements at a precision better than 5% level, will also lead to a deep insight of the nature of the top quark couplings to fermions and to the mechanisms (SM or not) responsible for its production. Finally, a precise determination of the (electro-weak) single-top production cross-sections at a few percent precision level also constitutes a stringent test of the SM. These measurements offer a direct access to the CKM matrix element V_{tb} at the few percent level, as well as stringent tests of any departure to SM physics with sensitivity to anomalous couplings. Single-top analyses can also be a direct way to provide evidence for an extra charged Higgs boson. The top physics program for the ATLAS experiment is discussed in detail in [3]. Recent results for the top quark analysis are presented in [1].

3.B-physiscs

The B-physics program at the ATLAS experiment will evolve with the integrated luminosity and is described in detail in [3]. In the beginning of the LHC operation with an integrated luminosity below 10 pb^{-1}, ATLAS will concentrate on an understanding of the detector performance using well described *c*- and *b*-processes and measurements of production cross-sections for *D*-hadrons, *B*-hadrons, J/ψ, and Υ to test QCD predictions for *pp* collisions at $\sqrt{s}$=7 TeV. In 2011, when 1 fb^{-1} of data will be collected, a detailed study of the properties of the full family of *B*-hadrons (B, B_s, B_c, Λ_b) will be performed and the quarkonium polarization will be measured. With more statistics, rare decays (such as $B_s \rightarrow \mu^+\mu^-$) and BSM CP-violation in weak decays of the *B*-meson will be searched.

Recent results and prospects for the B-physics in the ATLAS experiment are described with more details in [4].

4. Searches for Higgs Boson

The Higgs mechanism is a proposed solution to the electroweak symmetry breaking mystery which predicts the existence of an undiscovered scalar particle in the SM, or five such in the Minimal Supersymmetric Standard Model (MSSM). Its discovery is one of the most important goals of the LHC physics program. The current experimental knowledge on the Higgs boson mass, the only free parameter in the theory, comes from direct searches at LEP, setting a lower limit of M_H > 114.4 GeV [5], direct searches at the Tevatron, excluding a SM Higgs boson in the mass range of 158 < M_H < 175 GeV, using the combined result from CDF and D∅[6], and the combination of precision measurement of electroweak observables, suggesting a relatively light Higgs boson (M_H < 157 GeV) [7].

The results, presented here and documented in [8], take into account all major backgrounds, use full simulation for both signal and background events and incorporate realistic systematic uncertainties. These results are used to extract the approximate ATLAS sensitivity to the Higgs boson, expressed in terms of expected 95% confidence level (CL) upper limits for 1 fb^{-1} of integrated luminosity assumed by the end of 2011, in selected representative channels. These are the SM channels $H \rightarrow WW$, $H \rightarrow ZZ \rightarrow 4l$ and $H \rightarrow \gamma\gamma$ and the MSSM channels $H/A \rightarrow \mu\mu$ and $H^+ \rightarrow \tau\nu/c\bar{s}$.

The results presented here are based on re-scaling the expectations from detailed analyses at 10 or 14 TeV using cross-section ratios or the PDF re-weighting to arrive at the 7 TeV projection.

4.1The SM Higgs boson

At the LHC, a Higgs boson can be produced through gluon fusion ($gg \rightarrow H$), vector boson fusion ($qq \rightarrow qqH$) or associated production ($qq \rightarrow WH$ or ZH, $gg,qq \rightarrow ttH$). Depending on the Higgs boson mass, the decays to bb, $\tau\tau$, $\gamma\gamma$, WW and ZZ are important for experimental searches. The production cross-section and branching ratios as a function of the Higgs mass are shown in Figure 1.

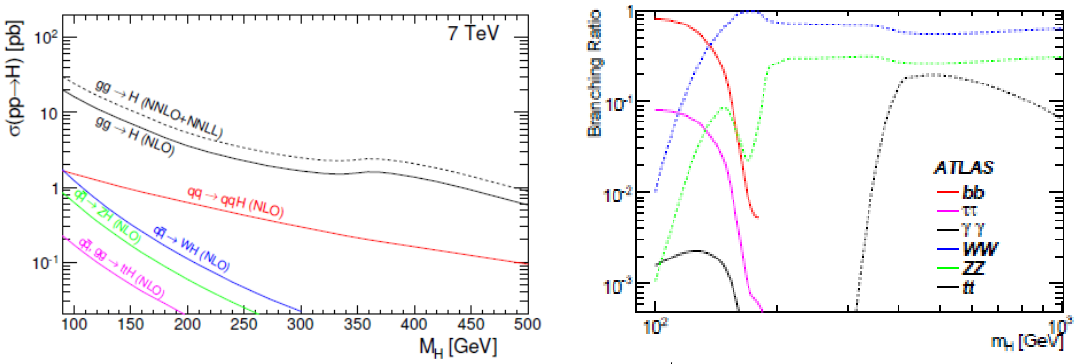

Figure 1: Higgs boson production cross-sections at the LHC at √s=7 TeV (left) and branching ratios (right) as a function of the Higgs mass.

4.1.1 $H \rightarrow WW \rightarrow l\nu l\nu$

ATLAS has investigated the $H \rightarrow WW$ channel in the different decay modes. Due to the spin correlation of the W-boson from the H, the background can be significantly reduced by requiring the presence of two leptons with a small transverse opening angle. In the case of the 2-jet analysis, cuts are made reflecting the characteristic vector boson fusion (VBF) topology (two forward jets with rapidity gap). The two neutrinos in the final state prohibit the reconstruction of a mass peak, so the transverse mass is reconstructed instead. Control regions are used to study the dominant backgrounds using data and to extrapolate them into the signal region. The estimated numbers of events in 1 fb^{-1} of data are shown for the leptonic decay mode in the Table 1. Figure 2 presents the expected 95% CL upper limits of the Higgs boson production for different integrated luminosities (left) and for 1 fb^{-1} with systematic uncertainties included (right).

M_H (GeV)	120	130	140	150	160	170	180	190	200
SM WW	26.3	35.4	43.8	50.1	55.2	58.5	60.6	61.7	62.4
top	4.9	6.7	9.1	11.6	14.0	16.3	17.2	17.9	18.2
W+jets	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Total background	36.8	47.7	58.5	67.3	74.8	80.4	83.4	85.2	86.2
Signal	4.1	10.4	18.5	26.3	39.5	35.4	26.2	16.8	11.0

Table 1: Estimated number of events for the signal and major backgrounds, using an integrated luminosity of 1 fb^{-1} for √s = 7 TeV after the full event selection in $H \rightarrow WW \rightarrow l\nu l\nu$

This channel is expected to have the earliest sensitivity for Higgs boson masses around 160 GeV.

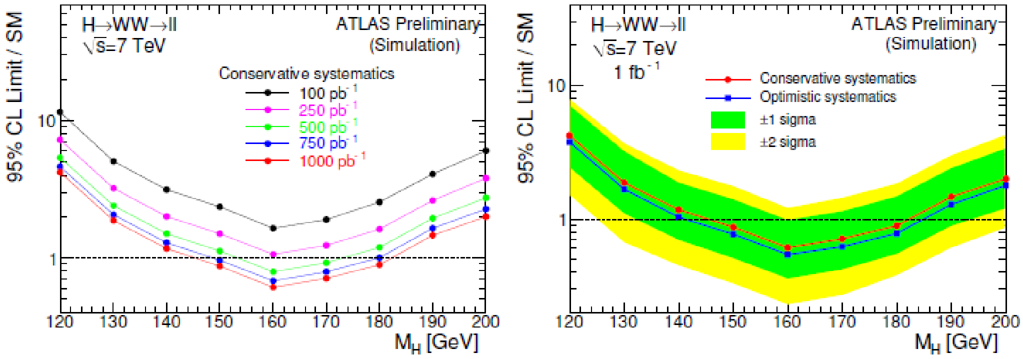

Figure 2: Expected 95% CL upper limits of the Higgs boson production cross-section normalised to the predicted SM cross-section. Left: for different integrated luminosity scenarios at √s = 7 TeV. Right: the green and yellow bands represent the range in which we expect the limit will lie, depending upon the data, normalised to the SM cross-section for an integrated luminosity of 1 fb^{-1}.

4.1.2 $H \to ZZ \to 4l$

The $H\to ZZ \to 4l$ channel is very promising, as it allows for a clear reconstructed mass peak superimposed on a smooth background. A wide range of masses can be covered. ATLAS has studied the $4e$, $2e2\mu$ and 4μ modes for $\sqrt{s}$ = 7 TeV. Two pairs of same flavour, opposite sign leptons are demanded from which the Z, and H masses are reconstructed. The background is further suppressed by requirements on the lepton isolation and impact parameter. The remaining backgrounds are estimated by making a fit on the sidebands. A mass resolution of ≈ 2-3 GeV can be obtained, while the discovery potential reaches up to very high Higgs masses. Table 2 shows the estimated number of events in the signal region for the signal and the major backgrounds using an integrated luminosity of 1 fb^{-1} for $\sqrt{s}$ = 7 TeV after the full event selection in $H \to ZZ \to 4l$ (the $4e$,$2e2\mu$ and the 4μ final states are summed). One can see that SM ZZ background dominates above 200 GeV.

M_H(GeV)	120	130	140	150	165	170	180	190
SM ZZ	0.090	0.094	0.083	0.089	0.121	0.147	0.376	0.981
top & Z+jets	0.005	0.004	0.005	0.004	0.005	0.005	0.003	0.003
Total background	0.095	0.098	0.088	0.093	0.126	0.152	0.379	0.984
Signal	0.105	0.319	0.595	0.713	0.185	0.192	0.458	1.49
M_H(GeV)	200	220	240	260	300	400	500	600
SM ZZ	1.29	1.18	0.92	0.89	0.72	0.48	0.49	0.39
Signal	1.60	1.46	1.25	1.08	0.88	0.67	0.29	0.13

Table 2: Estimated number of events in the signal region for the signal and the major backgrounds using an integrated luminosity of 1 fb^{-1} for $\sqrt{s}$ = 7 TeV after the full event selection in $H \to ZZ \to 4l$.

The expected exclusion limits on the SM production cross-section times branching ratio in the decay channel $H \to ZZ \to 4l$ are presented in Figure 3 as a function of the Higgs boson mass. The results are presented in terms of the expected exclusion limit on the cross-section times branching ratio, divided by the corresponding SM prediction. If the result is less than one at some mass, then the probability of correctly excluding a non-existent SM Higgs is 95%. The limit shown in Figure 3 is strictly valid only in the context of the SM. For large Higgs boson masses, the natural width predicted by the SM is larger than the experimental resolution, and a truly model-independent treatment would take into account the fact that other models might

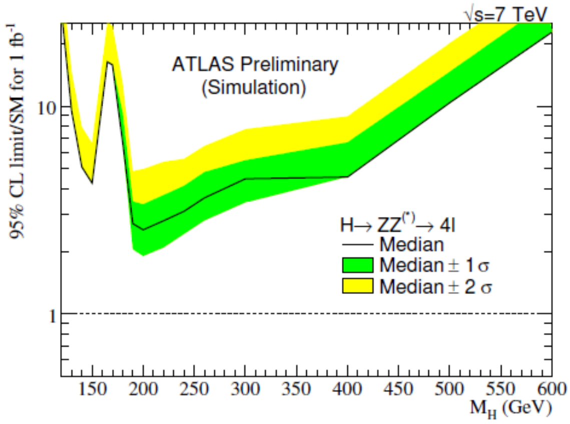

Figure 3: Expected 95% CL upper limits on the Standard Model Higgs boson production in the $H \to ZZ \to 4l$ channel as a function of the Higgs mass, for the $\sqrt{s}$ = 7 TeV. The bands indicate the range in which we expect the limit will lie, depending upon the data. These limits were obtained with the *CLS* method used in LEP and Tevatron experiments[9].

have a Higgs boson with a natural width different from the SM value. With an integrated luminosity of 1 fb^{-1} at 7 TeV the SM Higgs boson cannot be excluded at the quoted confidence level for any mass value in the $H \to ZZ \to 4l$ channel alone. The analysis is most sensitive for a SM Higgs mass of about 200 GeV where an upper bound in the cross-section times branching ratio of 2.5 × (σ_H × BR($H \to 4l$)) is expected. The systematic uncertainties are found to have a small effect on the exclusion reach, which is predominantly affected by the statistical fluctuations on the number of observed background events.

4.1.3 $H \to \gamma\gamma$

Despite its small branching ratio, the decay of the Higgs boson to two γ's is an important channel, as it allows for a clear mass peak to be reconstructed. ATLAS has performed both an inclusive analysis, and as well is studying diphotons in association with 1 or 2 jets. It was shown that a good mass resolution ($\sigma_m/m \approx 1.2\%$) can be obtained (see Figure 4). Powerful γ identification is required to reduce the backgrounds from jets faking γs and this is achieved by making use of shower shape and track isolation requirements, while γ conversions can be efficiently reconstructed by combining information from the electromagnetic calorimeter and the tracker. That is important as almost 50% of photons are converted in the Inner Detector.

The expected numbers of signal and background events with 1 fb^{-1} of data are summarised in Table 3. For the associated production processes with no available Monte Carlo (MC) samples, the expected numbers of events are extrapolated using the process cross-section at a given mass and an efficiency correction factor estimated from VBF events. To further validate the procedure these numbers are compared to a simple rescaling of those obtained at 10 TeV and are found to be consistent.

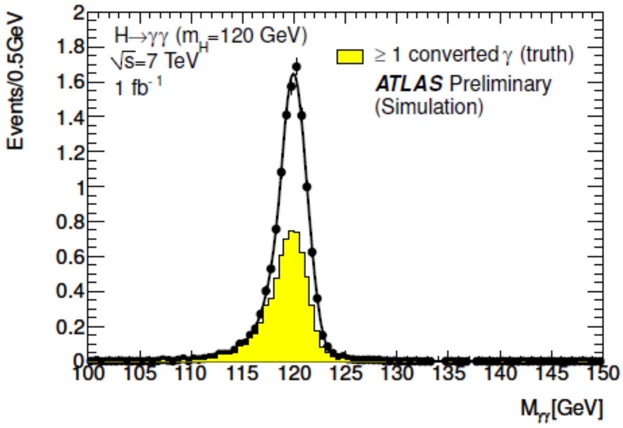

Figure 4: Invariant mass of the two candidate photons from MC samples simulating the production of a Higgs boson with m_H = 120 GeV through all production channels, normalised to an integrated luminosity of 1 fb^{-1} at $\sqrt{s}$ = 7 TeV. Also shown is the distribution when at least one photon is converted according to the Monte Carlo truth.

M_H (GeV)	110	115	120	130	140
$\gamma\gamma$	5540	5540	5540	5540	5540
γj	2500	2500	2500	2500	2500
jj	360	360	360	360	360
Drell Yan	90	90	90	90	90
Total background	8490	8490	8490	8490	8490
Signal	12.6	12.8	13.0	12.0	9.2

Table 3: Number of signal ($H\rightarrow\gamma\gamma$) and background events expected for an integrated luminosity of 1 fb^{-1} for $\sqrt{s}$ = 7 TeV. For the backgrounds, the number of events is estimated in the mass window 100< m_H < 150 GeV.

Figure 5 shows the signal and background contributions to the expected di-photon invariant mass distribution for an integrated luminosity of 1 fb^{-1}. The signal contribution is enhanced by a factor 10 for the purpose of illustration (left plot). The 95% CL exclusion limit, normalised to the expected SM cross-section, is shown as a function of the Higgs mass in Figure 5 (right).

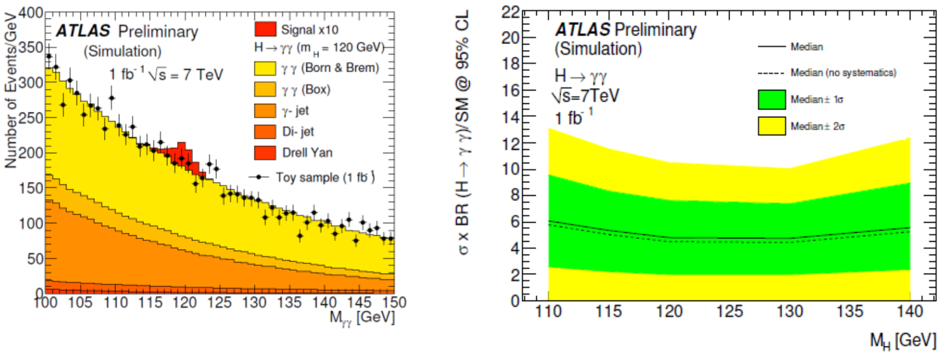

Figure 5: The expected di-photon invariant mass distribution at $\sqrt{s}$ = 7 TeV for an integrated luminosity of 1 fb^{-1}(left). The signal contribution is enhanced by a factor 10. The 95% CL exclusion limit, normalized to the expected SM cross-section, is shown as a function of the Higgs mass for an integrated luminosity of 1 fb^{-1} (right).

As seen from Figure 5 (right), 95% CL exclusion at the level of 4.5 times the SM cross-section can be achieved with an integrated luminosity of 1 fb^{-1} for $H \to \gamma\gamma$ in the Higgs mass range 120 – 130 GeV.

4.1.4 Combination of $H \to WW, ZZ, \gamma\gamma$

Three SM Higgs boson decay modes are considered in this combination: $H \to WW \to l\nu l\nu$, $H \to ZZ \to 4l$, and $H \to \gamma\gamma$, described above. The expected upper bound on the Higgs boson production cross-section after collecting 1 fb^{-1} of integrated luminosity in 7 TeV collisions with the ATLAS detector is shown in Figure 6. The limit is normalised to the NLO prediction of the SM cross-section. The green and yellow bands represent the range in which we expect the limit will lie, depending upon the data. Only the $H \to WW \to ll\nu\nu$, $H \to ZZ \to 4l$ and $H \to \gamma\gamma$ channels are included in this limit.

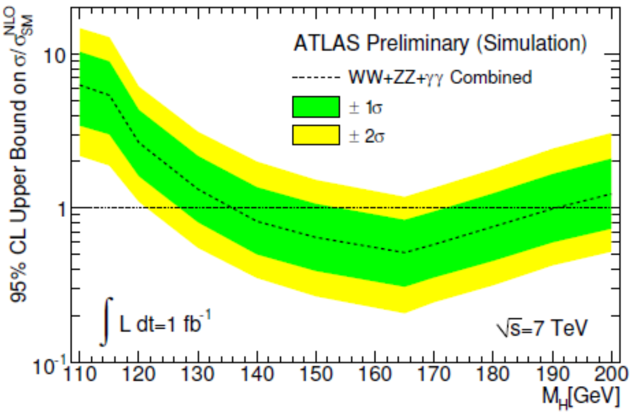

Figure 6: Expected 95% CL upper limits on the Standard Model Higgs boson production in the combination of the $H \to WW \to ll\nu\nu$, $H \to ZZ \to 4l$ and $H \to \gamma\gamma$ channels as a function of the Higgs mass, for 7 TeV centre-of-mass energy. The bands indicate the range in which we expect the limit will lie, depending upon the data.

At the luminosity and centre-of-mass energy used, a SM Higgs boson with a mass between 135 and 188 GeV can be excluded at 95% CL. This mass range is largely determined by the $H \to WW$ channel. However, for masses above 200 GeV the limit is based exclusively on $H \to 4l$ and is as shown in Figure 6. In the low mass region, the limit could still be improved by including other channels such as $H \to bb$ and $H \to \tau\tau$; and in the high mass region an improvement can be obtained by including the $H \to ZZ \to llbb$ and $H \to ZZ \to ll\nu\nu$ channels. This excluded region will be an important new constraint on the Higgs sector. Sensitivity improvement can also be expected using more sophisticated analysis techniques.

4.2 MSSM Higgs bosons

In the MSSM, the Higgs sector consists of two Higgs doublets (as opposed to one in the SM) which leads to five physical Higgs bosons ($h, H, A, H^{\pm}$). At tree level, this Higgs sector can be described using only two parameters, conventionally m_A and $\tan\beta$. The discovery potential for both neutral and charged Higgs bosons has been evaluated in the m_h^{max} scenario [10] of the MSSM.

For the neutral Higgs bosons of the MSSM, the dominant production modes are gluon fusion and associated production with *b*-quarks. Decays to third generation fermions are enhanced with respect to the SM, while decays to vector bosons are suppressed (h, H) or completely absent (A). The $h/H/A \rightarrow \mu\mu$ decay has been studied by ATLAS for $\sqrt{s}$ = 14 TeV in both the 0 b-tag (*i.e.* gluon-fusion production) and the ≥1 b-tag (associated production) channels [3]. Then results have been extrapolated to the $\sqrt{s}$ = 7 TeV. The dominant backgrounds are estimated using sidebands and control samples (*e.g.* using the *ee* channel to get a signal-free control region). The results of this study are presented in Figure 7.

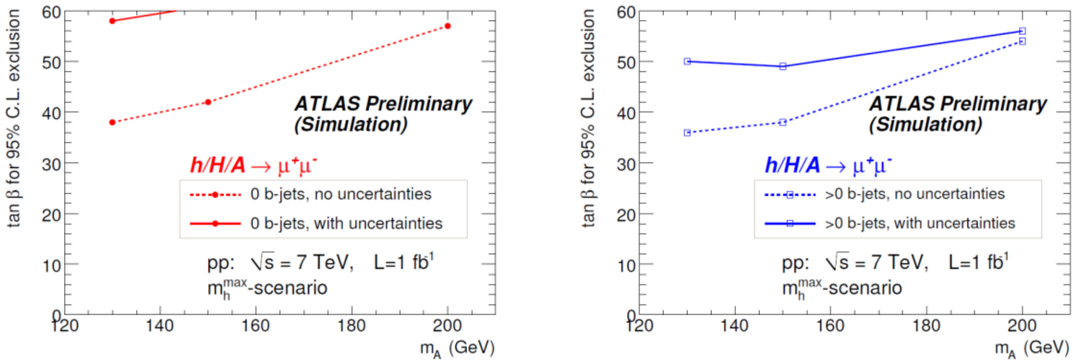

Figure 7: The tanβ values needed for an exclusion of the neutral MSSM Higgs bosons shown as a function of the Higgs boson mass m_A, separately for the analysis mode with 0 *b*-jet (left) and analysis mode with at least one *b*-jet (right). An integrated luminosity of 1 fb^{-1} and $\sqrt{s}$ = 7 TeV are assumed. Dashed lines represent the results assuming zero uncertainty on the signal and background, while the full lines correspond to the results with both signal and background uncertainty taken into account.

The charged Higgs bosons are primarily produced in top quark decays if $m_{H^{\pm}} < m_t$, else in gg/gb-fusion. For tanβ < 1, the branching ratio $BR(H^+ \rightarrow cs)$ may reach 40% for $m_{H^+} \approx 130$ GeV. For tanβ > 1, $H^+ \rightarrow \tau^+\nu$ dominates the other decays and for tanβ > 3, $BR(H^+ \rightarrow \tau^+\nu)$ exceeds 90%.

The expected upper limits for 1 fb^{-1} of data are presented in Figure 8.

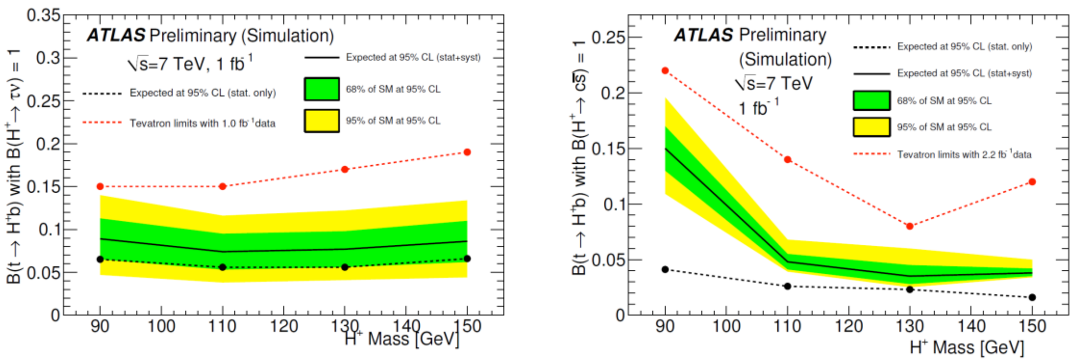

Figure 8: Expected 95% CL upper limits in early data (with L = 1 fb^{-1} at $\sqrt{s}$ = 7 TeV) versus the charged Higgs boson mass assuming $BR(H^+ \rightarrow \tau^+\nu)$ = 1 (left) or $BR(H^+ \rightarrow cs)$ = 1 (right). The green and yellow bands correspond to the range in which we expect the limit will lie, depending upon the data.

4.2 Conclusions

The estimated ATLAS sensitivities to Higgs bosons in selected channels at $\sqrt{s}$ = 7 TeV and an integrated luminosity of 1 fb^{-1} are presented. These results were obtained by extrapolating from those at $\sqrt{s}$=10 TeV in the three SM channels $H \rightarrow WW$, $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^{(*)}$, and for the MSSM modes $A/H/h \rightarrow \mu^+\mu^-$ and $H^+ \rightarrow c\bar{s}/\tau^+\nu$. The theoretical and detector-related systematic uncertainties for the signal and background processes have been taken into account. Data-driven methods are employed to estimate most of the background contributions in the signal region.

The combined analysis of these SM channels, $H \rightarrow WW \rightarrow ll\nu\nu$, $H \rightarrow ZZ \rightarrow 4l$ and $H \rightarrow \gamma\gamma$, should allow a SM Higgs boson with a mass between 135 and 188 GeV to be excluded at 95% confidence level. This mass range is largely determined by the $H \rightarrow WW \rightarrow ll\nu\nu$ channel. The limit for masses above 200 GeV is based exclusively on $H \rightarrow 4l$ channel. The expected upper bound will be an important new constraint on the Higgs sector.

For the MSSM charged Higgs, two channels have been considered, namely $H^+ \rightarrow c\bar{s}$ in semi-leptonic $t\bar{t}$ events and $H^+ \rightarrow \tau^+\nu$ in di-lepton $t\bar{t}$ events. For both searches, the 95% CL upper limits were estimated by scaling the results obtained from detailed full simulation analysis at 10 TeV. The ATLAS experiment is likely to improve substantially on the current limits at the Tevatron experiments [11].

The ATLAS sensitivity for the neutral MSSM Higgs boson search in the di-muon decay channel has been estimated to allow exclusion of tanβ values above 50, for Higgs boson masses between 130 and about 150 GeV. This is not as sensitive as the current Tevatron limits [12]. However, the search in the $A/H/h \rightarrow \mu^+\mu^-$ decay channel can be used to improve the sensitivity reached in the $A/H/h \rightarrow \tau^+\tau^-$ channel.

It should be pointed out that the current analyses have all used simple, cut-based techniques. For a dataset of the size of O(1) fb^{-1}, we should be in a position to deploy advanced analysis techniques which will likely improve the sensitivity significantly. There are also many channels which are not included in this note. However, a 5σ discovery of a Higgs boson is unlikely in this energy/luminosity scenario.

5. SUSY

Supersymmetry (SUSY) is one of the theoretically favoured candidates for BSM physics. The main motivation is to protect the Higgs boson mass from quadratically diverging radiative corrections, in a theory where the SM is valid only up to a high scale Λ. The proposed solution postulates the invariance of the theory under a symmetry which transforms fermions into bosons and vice-versa. The basic prediction of SUSY is thus the existence for each SM a corresponding sparticle with spin different by half a unit. SUSY partner particles would have the same quantum numbers and masses as the SM particles. However, since no superpartner has been observed to date, SUSY must be broken. A common approach to the phenomenological study of SUSY is to assume the minimal possible particle content, and to parametrise the SUSY-breaking Lagrangian as the sum of all the terms which do not reintroduce quadratic divergences into the theory. The simplest model thus obtained is called MSSM and is characterised by a large number of parameters (~100). In order to warrant the conservation of baryonic and leptonic quantum numbers, a new multiplicative quantum number, *R*-parity, is introduced, which is 1 for particles and -1 for the SUSY partners. The consequences of *R*-parity conservation would be that sparticles must be produced in pairs, and that each will decay to the lightest SUSY particle (LSP) which must be stable. Cosmological arguments suggest that stable LSPs should be weakly interacting and so would escape direct detection at ATLAS, resulting in the characteristic feature expected for SUSY events – an imbalance of the transverse energy measured in the detector, abbreviated here as MET. The associated signatures will provide sensitivity to a large class of models.

The SUSY has to be broken to make the sparticles very massive. In models such as minimal supergravity (mSUGRA) [13], it is assumed that gravity acts as a messenger interaction to communicate the SUSY breaking in a “hidden sector” to the “visible sector” of MSSM. With the soft breaking terms, there are a total of 105 new parameters added in the MSSM compared to the SM, rendering this theory not very predictive. With some additional constraints and assumptions in the mSUGRA model, there are just a total of five free parameters to determine the phenomenology: m_0 (scalar masses), $m_{1/2}$ (gaugino mass), A_0 (soft trilinear coupling constant), tanβ (ratio of the vacuum expectation values of the two Higgs) and the sign of μ.(Higgsino mass parameter) This means the theory has a large predictive power and can be easily tested at ATLAS. A set of points based on the principle that the predicted cosmological relic density of neutralinos should be consisted with the observed density of cold dark matter. To reproduce the observed relic density the model parameters must result in a spectrum which ensures efficient annihilation of neutralinos in the early universe. For mSUGRA this is possible only in restricted regions of parameter space where annihilation is enhanced. The closest to the Tevatron limit [14] such point is so-called SU4 benchmark point with m_0 = 200 GeV, $m_{1/2}$ = 160 GeV, $A_0 = -400$ GeV, tanβ = 10 and $\mu > 0$.

The strategy for SUSY searches is described in [3].The 0-lepton search mode is most promising for an integrated luminosity of 1 fb^{-1} as a fully hadronic decay of the SUSY particles has the highest cross-section. The SUSY group of the ATLAS experiment has performed a study with two, three and four jets in the final state [15]. The four jets signature has the best discovery potential due to highest background suppression. Figure 9 presents the discovery

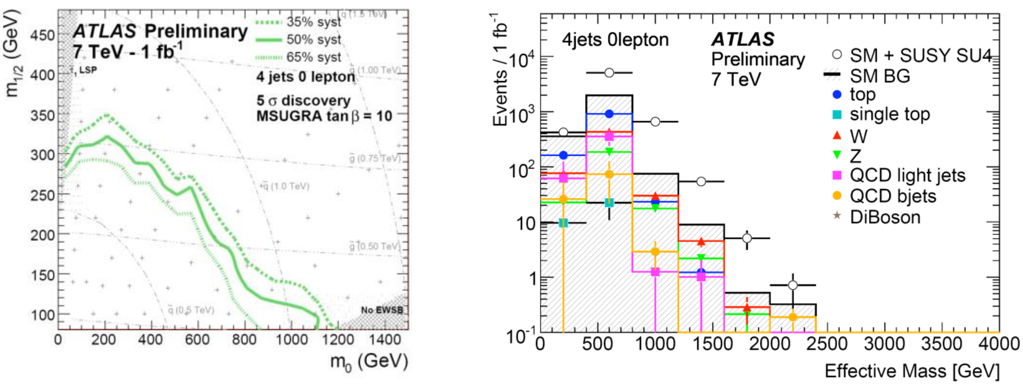

Figure 9: The 5σ discovery potential for an integrated luminosity of 1 fb^{-1} as a function of m_0 and $m_{1/2}$ for tanβ = 10 (left) and the effective mass distribution for the SU4 benchmark point (right) using the (4 jets and no-lepton) channel.

potential in the mSUGRA for the (MET + 4 jets + 0 lepton) channel using 1 fb^{-1} of data (left), and the effective mass distribution for SM backgrounds and the SUSY signal at the SU4 benchmark point.

The results of the early SUSY searches in the ATLAS experiment are presented in [16]. The distribution of the MET after pre-selection and effective mass distribution after selection for events in the four-jet-channel are shown in Figure 10 for an integrated luminosity of 70 nb^{-1}. It is noted that the SU4 signal is multiplied by 10 on these plots. This figure demonstrates that the QCD shape after pre-selection is well described by MC and agrees with the data.

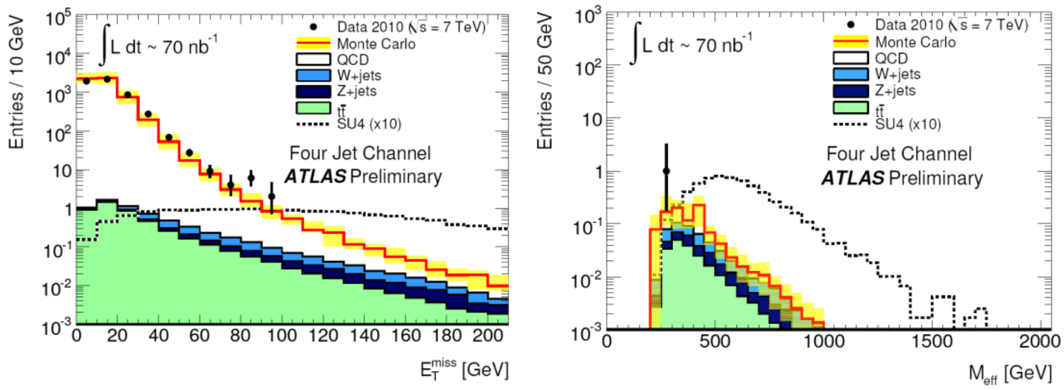

Figure 10: Distributions of the missing transverse momentum from the ATLAS experiment after pre-selection (left) and effective mass after final selection (right) for events in the four-jet channel for an integrated luminosity of 70 nb^{-1}.

ATLAS will start to extend the Tevatron limit with 10 pb^{-1} of data. The discovery potential for the SU4 benchmark point will be reached with 0.5 fb^{-1} of the integrated luminosity which can be achieved by the end of 2010.

6. Exotics

The SM of particle physics has been able to predict or describe, within errors, almost all measurements performed within its domain. However, several fundamental questions remain unresolved. Its mechanism for electroweak symmetry breaking has not been experimentally confirmed. The model parameters still lack a theoretical explanation. Although the SM of the strong and electroweak interactions describes particle physics at energies attainable so far, the model is not a complete theory. For example, it does not explain the number of lepton and quark generations nor their mass hierarchy, and many constants in the model are unconstrained. There are indications, therefore, that the SM is not a fundamental theory, but a good approximation of nature at the energy ranges that have been so far accessible to experiment. Thus, the search for the BSM physics is an important part of the ATLAS physics program.

The ATLAS Exotics program includes a study of signatures for discovering non-supersymmetric physics beyond the SM with the ATLAS detector at the CERN. This program covers a wide variety of signatures and models, from Little Higgs [17] to Extra Dimensions [18], Compositeness [19], etc. Here we will discuss two of them.

6.1 Heavy Gauge bosons

Some of the theories proposed to address the above shortcomings contain gauge symmetries that can be spontaneously broken, and that correspond to additional gauge bosons; in particular, any charged, spin 1 gauge boson which is not included in the SM is called a *W'*, and a neutral, spin non-SM gauge boson is customarily denoted as *Z'*.

The DØ experiment at Fermilab has published the present direct search lower limit for the *W*' boson mass [20] as $m_{W'}$ > 1 TeV at 95% CL. CDF has published the current limit on the mass of a *Z*' boson as $m_{Z'}$> 1 TeV [21].

The decay $Z' \rightarrow l^+l^-$ provides a simple and clean signature of two oppositely charged, same flavor high p_T leptons. The invariant mass of the two leptons can be used very effectively to discover the resonance over a rapidly falling background at high masses. The decay $W' \rightarrow l\nu$ provides a rather clean signature consisting of a single high-energy lepton and large missing transverse energy due to the undetected neutrino. Analysis details, i.e. main background, selection criteria etc. can be found in [3].

Figure 11 represents simulated spectra of the signal and main backgrounds for the di-lepton channel (left) and for the lepton plus MET channel (right) after final selections [22].

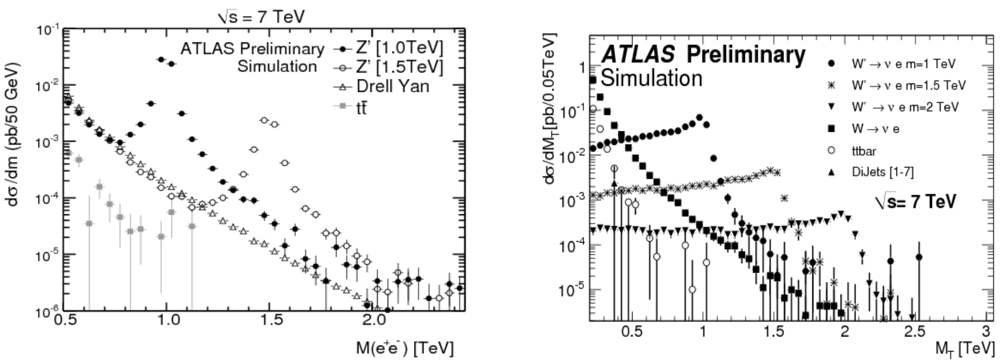

Figure 11: Dilepton invariant mass spectra after all cuts for the di-electon channel (left) and for electron + M_T^{miss} (right).

The expected integrated luminosity required to exclude heavy gauge boson as a function of its mass is presented in Figure 12 for *Z*' (left) and *W*' (right). Summarizing results presented in [20], scenario for searches of the *W*' and *Z*' can be:

- 10 pb^{-1}: exclusion of the *W*' up to M(*W*') = 1 TeV;
- 20 pb^{-1}: discovery of the *W*' at M(*W*') = 1 TeV;
- 50 pb^{-1}: exclusion of the *W*' up to M(*W*') = 1.5 TeV, and of the *Z*' up to M(*Z*') = 1 TeV;
- 100 pb^{-1}: discovery of the *W*' up to M(*W*') = 1.5 TeV, and of the *Z*' up to M(*Z*') = 1 TeV;
- 300 pb^{-1}:exclusion of the *Z*' up to M(*Z*') = 1.5 TeV;
- 1 fb^{-1}: discovery of the *W*' up to M(*W*') = 2 TeV, and of the *Z*' up to M(*Z*') = 1.5 TeV.

First results of the $W' \rightarrow l\nu$ search [23] are presented in Figure 13 using 300 nb^{-1} of data: the transverse mass spectra after all selections (left) and the 95% CL upper limit of the *W*' production obtained with data (right) are shown.

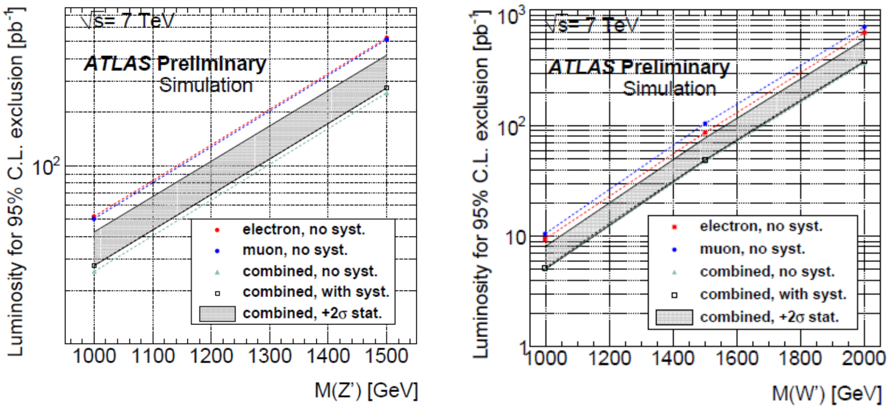

Figure 12: Integrated luminosity expected to allow a 95% CL exclusion of the *Z*' model(left), and of the *W*' production cross section (right), assuming the same branching ratio for all leptons.

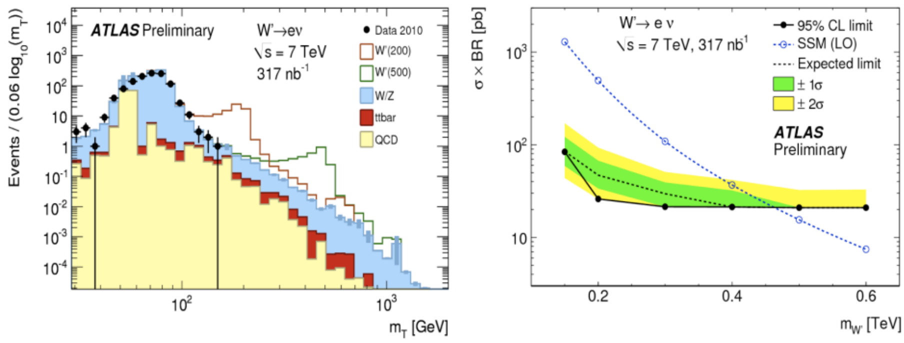

Figure 13: Transverse mass spectrum after all selections (left) and 95% CL upper limit of the *W*' boson production cross-section observed with 317 nb^{-1} of the integrated luminosity (right).

6.2 Dijet resonance

Two-jet (dijet) events in high-energy *pp* collisions are usually described in the SM by applying QCD to the scattering of beam-constituent quarks and gluons. Several extensions beyond the SM predict new heavy particles accessible at LHC energies that decay into two energetic partons. Such new states may include an excited composite quark q^*, exemplifying quark substructure, an axigluon predicted by chiral colour models, a flavour-universal colour-octet coloron, or a colour-octet techni-ρ meson predicted by models of extended technicolour and top-colour-assisted Technicolor.

Particularly sensitive to such new objects is the dijet invariant mass observable, defined as

$$m^{jj} \equiv \sqrt{\left(E^{j_1} + E^{j_2}\right)^2 - \left(\vec{p}^{j_1} + \vec{p}^{j_2}\right)^2}, \qquad (1)$$

where *E* and *p* are the jet energy and momentum, respectively. Several experiments have examined m_{jj} distributions in search of new resonances; recently, using 1.13 fb^{-1} of $p\bar{p}$ collision data at the Fermilab Tevatron collider have excluded the existence of excited quarks q^* with mass $260 < m_{q^*} < 870$ GeV [24].

Figure 14 shows results from a dijet resonance search using an integrated luminosity of 315 nb^{-1}. In the left plot, the dijet mass distribution is fitted using a binned background distribution described by equation (1). The predicted q^* signals for excited-quark masses of 500, 800, and 1200 GeV are overlaid, and the bin-by-bin significance of the (data-background) difference is shown. The right plot shows the 95% C.L. upper limit on σA, where A is a signal acceptance, as a function of dijet resonance mass (black filled circles). The black dotted curve shows the expected 95% C.L. upper limit, and the light and dark yellow shaded bands represent the 68% and 95% credibility intervals of the expected limit, respectively. The dashed curves represent excited-quark σA predictions for different MC tunes, each using a different PDF set. It is the first LHC result to surpass the world's best limit [25].

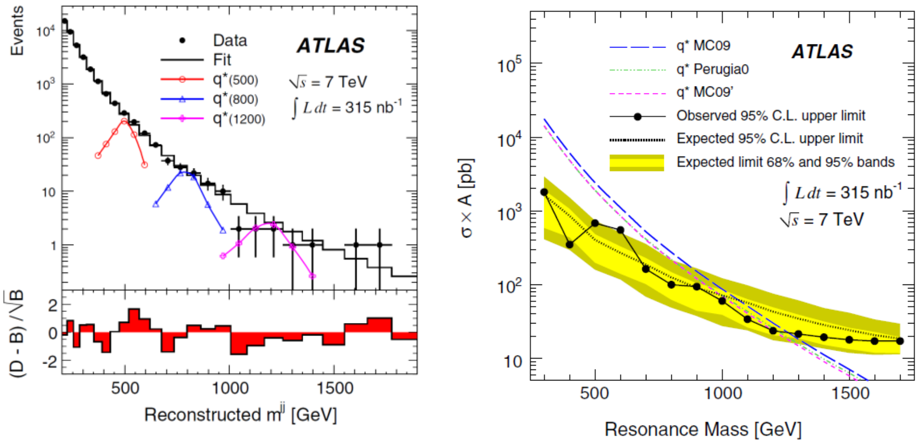

Figure 14: The data dijet mass distribution (filled points) fitted using a binned background distribution described by equation (1) (histogram) is shown on the left plot. The predicted q^* signals for excited-quark masses of 500, 800, and 1200 GeV are over-laid. The 95% CL upper limit on the exited-quark production cross-section is shown as a function of dijet resonance mass (right)

7. Conclusions

The ATLAS experiment is exploring uncharted territory at the TeV scale. Recent data [25] extends limits on New Physics in the dijet channel beyond previous experiments, using an integrated luminosity of 300 nb^{-1}. Using more data, an accurate measurement of the expected W charge asymmetry; exclusive measurements of $W+n$ and $Z+n$ jet cross-sections; a measurement of the $t\bar{t}$ and "single-top" cross-sections; precision measurement of the *t*-quark mass; and many measurements in B-physics will be performed. Using 1 fb^{-1} of data, a SM Higgs boson with a mass between 135 and 188 GeV can be excluded at 95% confidence level. Exotics and SUSY searches can extend recent limits on new particles an integrated luminosity of a few 10 nb^{-1}.

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