SUSY PHYSICS WITH ATLAS

S. N. KARPOV

on behalf of the ATLAS Collaboration

Joint Institute for Nuclear Research
Dubna, 141980, Russia
E-mail: karpovsn@jinr.ru

The main Monte Carlo predictions of the expected SUSY signal are presented for the 10 TeV collision energy of the LHC machine. Performance, effectiveness, energy resolution and other characteristics of the ATLAS detector were obtained with the first data. Preliminary estimations of main sources of the Standard Model background for the several SUSY processes are presented too.

1 Introduction

The ATLAS is one of two large general-purpose detectors at the Large Hadron Collider (LHC). About 2900 scientists and 1000 students from 173 institutes and 37 countries are involved in the ATLAS Collaboration.

Detection of the Higgs boson and search for new physics beyond the Standard Model (SM) are among the main tasks of experiments at the LHC and ATLAS. One of major candidates for extension of the Standard Model is Supersymmetry (SUSY) [1]. Direct exclusion limits on masses of supersymmetric particles (squarks – $\tilde{q}$ and gluino – $\tilde{g}$) are obtained by the CDF and D∅ Collaborations at the Tevatron. These masses should be not less than 400 GeV [2, 3]. Some indirect restrictions on SUSY parameters can be obtained also from existing data of various experiments: precise measurements of electroweak observed values (m_W, m_t, etc.), B-physics and cold dark matter. Some of similar predictions in framework of the SM and Minimal Supersymmetry Model (MSSM) are given in Ref. [4]. General conclusion of this analysis is that SUSY can be discovered with high probability at the LHC at the collision energy $\sqrt{s} = 7$ TeV and integrated luminosity $L \sim 1fb^{-1}$. Many other predictions of various Supersymmetry models exist for the LHC. We cannot enumerate all them here.

2 SUSY with LHC

Large cross section of the $\tilde{q}\tilde{q}, \tilde{g}\tilde{g}, \tilde{q}\tilde{g}$ pairs production is predicted for the LHC energy (both 7 and 14 TeV), because the supersymmetric particles are strongly interacting ones. Therefore, if SUSY exist at the TeV scale, then it should be found rather "quickly" at the LHC. Super-particles have high masses (≥400 GeV) and the rather long cascade decay up to the lightest supersymmetric particle (LSP), which is stable under condition of R-parity conservation. The neutral LSP is unobservable directly in any detector and can be traced only by energy imbalance in transverse direction. In result, final state will include many jets with high transverse momentum (p_T), leptons (if any) with high p_T and large Missing Transverse Energy (E_T^{miss}).

3 Predictions for ATLAS

Researches are performed mainly within framework of the MSSM with breaking of symmetry by means of supergravity (mSUGRA model [5]) under condition of R-parity conservation. Use of mSUGRA reduces number of free parameters of the theory to five. Grid and set of benchmark points in parameters space of the mSUGRA are used in MC predictions. With the early LHC data the inclusive search for squark/gluino is preferable. These E_T^{miss}-based searches require multi-object events with high p_T and large E_T^{miss}. Furthermore, searches of the slow massive long-lived particles and the stopped "semi-stable" particles (gluino) are in progress. Such particles are feature of many SUSY models and other BSM scenarios. Study of all above processes is performed mainly by "cut-based" method.

The LHC team plans to provide integrated luminosity about 100 pb^{-1} to end of this year and $\sim 1fb^{-1}$ to end of 2011. In result, about 5-6 events for processes of the gluino/squark production with mass equal 450 GeV can be expected in ATLAS at end of this year [6]. Next year this amount could be 10 time higher. Most probably, this year ATLAS will be sensitive to the gluino/squark masses comparable or better than Tevatron data. Next year ATLAS will be sensitive to the masses at level 600-700 GeV or discover production of the supersymmetric particles.

Number of events expected for signal and background at 200 pb^{-1} and 10 TeV for a range of various final states is shown on Fig. 1 [7]. Signal was generated in the SU4 mSUGRA benchmark point. It is belonging to "bulk region" in parameters space, which is located near to the Tevatron restriction region.

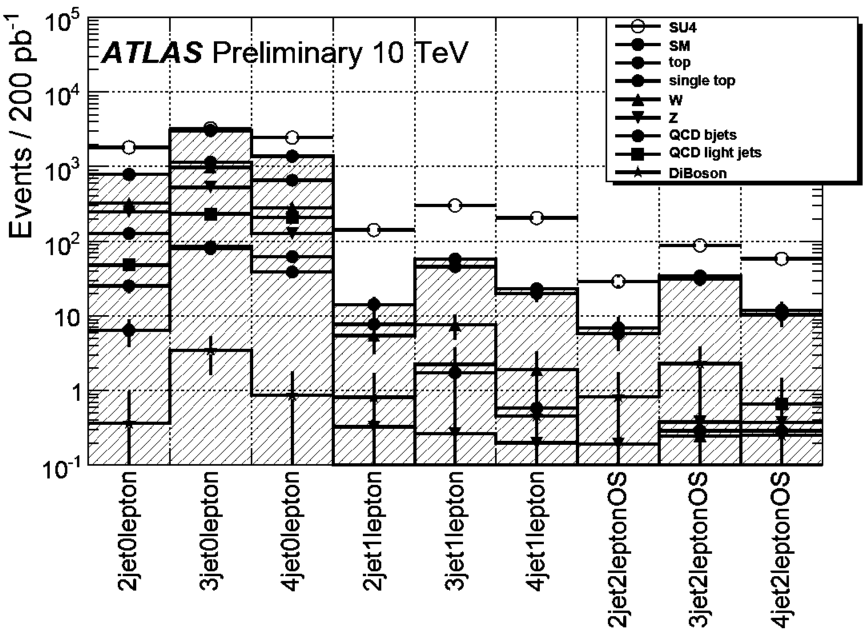

Figure 1: The MC predictions for SUSY and main backgrounds for a range of various final states for the integrated luminosity L = 200 pb^{-1} at the 10 TeV collision energy.

The inclusive jets + E_T^{miss} channels (first three bins) are statistically more rich. But the lepton + jets + E_T^{miss} channels (next three bins) can be preferable for early data, because signal is more clear and the signal/background ratio is better. The same one can say about last three channels with two leptons in final state. But statistics is even less in this case.

The ATLAS discovery potential for SUSY search at 5σ level with grid using is presented on Fig. 2 [7]. Analysis was performed at $\sqrt{s}$ = 10 TeV and L = 200 pb^{-1}. These results assume conservative uncertainties in the SM background (20% for electroweak and top, 50% for QCD). Squark/gluino with masses up to 600-700 GeV could be discovered in 0-lepton and 1-lepton mode. It is about 1.5 times greater than Tevatron restrictions. Preliminary predictions for 1 fb^{-1} at 7 TeV are very similar to above ones.

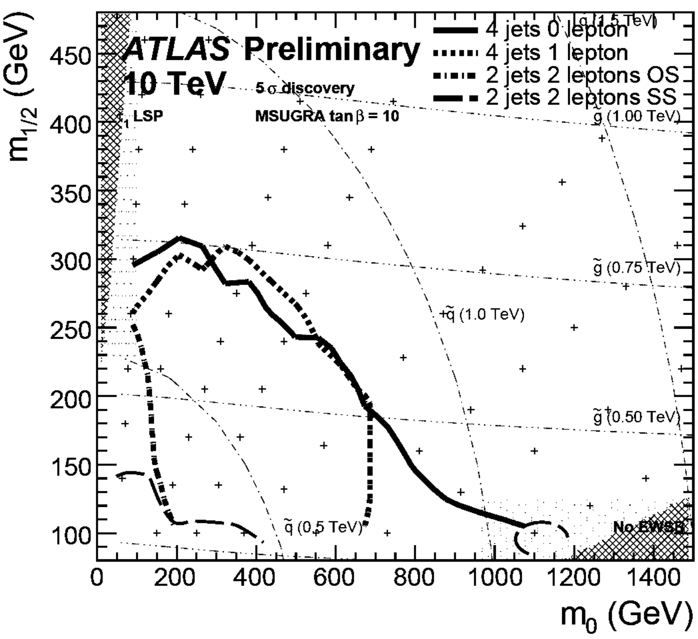

Figure 2: The ATLAS discovery potential for the SUSY search at 5σ level obtained with grid in the mSUGRA parameters space.

4 The first ATLAS data at 7 TeV

First collisions at $\sqrt{s} = 7$ TeV were obtained at the LHC on 30 March, 2010. Since that moment up to now (8 July) the integrated luminosity is $L = 101\ nb^{-1}$ with stable beam delivered by the LHC. Absolute luminosity is known today to about 20% (due to uncertainties of MC-based cross-sections and acceptance of luminosity detectors). One can expect to achieve soon $\leq 10\%$. In the same period ATLAS has collected $L = 90\ nb^{-1}$. The data recorded with all ATLAS subdetectors at nominal voltage correspond to $L = 87\ nb^{-1}$. The peak stable luminosity now is $1.1 \cdot 10^{30}\ cm^{-2}s^{-1}$.

The early ATLAS data are used first of all to calibrate and understand the detector. It is very hard and important work and many good results are already obtained. We present only one small example – calculation of the missing transverse energy. E_T^{miss} is crucial variable to search for SUSY-like events. But E_T^{miss} is very sensitive to any detector problems, calorimeter performance (noise, coherent noise, dead cells, miscalibrations, cracks, etc.), cosmic muons and beam-related backgrounds.

E_T^{miss} distribution obtained with the "Minimum Bias" collision data after standard data quality restrictions is shown on Fig. 3 by dark histogram.

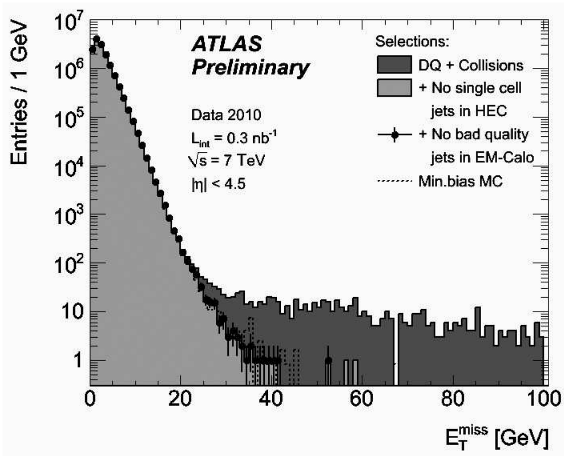

Figure 3: E_T^{miss} distribution before and after the data cleaning.

One can see unacceptable tail at high E_T^{miss}. Distribution comes to good agreement with Monte Carlo after data cleaning with exclusion of events, which contain "bad jets". Event fraction removed by additional cleaning cuts is only 10^{-4}. Jet quality is determined on the basis of several variables of the Hadronic Endcap Calorimeter (HEC) (light histogram – after cuts) and Electromagnetic Calorimeter (EM-Calo) (dots on Fig. 3).

5 Summary

The ATLAS data are used now to calibrate and understand the detector. These first data demonstrate that the performance of the detector and the quality of the reconstruction and simulation software are close to nominal. Now the focus is moved from performance and calibrations to more and more precise physics measurements.

The LHC operating at $\sqrt{s} = 7$ TeV and integrated luminosity of 100 pb^{-1} can provide data sufficient for the ATLAS detector calibrations and for early standard physics analysis. It can probably provide New Physics results also (SUSY, BSM ...).

In other words, the physics reach (including SUSY) will be competitive with the Tevatron in 2010 (at $L \sim 100\ pb^{-1}$), but will be superior for "New Physics" with integrated luminosity 1 fb^{-1} (in 2011).

Acknowledgements

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The ATLAS detector design and construction has taken about fifteen years, and our thoughts are with all our colleagues who sadly could not see its final realization.

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