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Searches for physics beyond the Standard Model at ATLAS☆

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Abstract

Results on searches for new phenomena in particle physics are presented using $p-p$ collision data collected with the ATLAS detector at the Large Hadron Collider at CERN. The data correspond to an integrated luminosity ranging from 31 to 236 pb^{-1} and have been collected during 2010 and up to May 2011. No signal of new phenomena was observed and limits were placed on the parameter space of various theoretical frameworks, e.g. supersymmetry and extra dimensions.

Keywords: ATLAS, SUSY, Exotics

1. Introduction

The Standard Model (SM) is a very successful model that describes nature with great precision. All particles and forces it describes (Figure 1) have been experimentally discovered, with the only exception being the Higgs boson, which still eludes detection. The yet undiscovered Higgs boson is not the only weak point of the SM. The SM does not provide information about some of its own properties; why there are 3 generations of particles, what determines the masses and mixings of the particles, or if there is a unified description of all forces. It also does not tell us anything about Dark Matter. All these pending questions are being tackled by various extensions of the SM, the most favorable of which are accessible at the Large Hadron Collider (LHC). Investigating this new parameter space is one of the reasons the LHC was built.

The LHC is a $p-p$ collider at 7 TeV center-of-mass energy. In 2011 it has been operating with a bunch spacing of 50 ns, and a very rapidly evolving bunch structure and initial peak luminosity; in June 2011 the LHC has been running with 1042 bunches per beam at a peak luminosity of 1.2×10^{33} $cm^{-2}s^{-1}$, resulting in approximately 6 $p-p$ collisions per bunch crossing. ATLAS [1] is a multipurpose detector placed in one of the two high-luminosity collision points of the LHC.

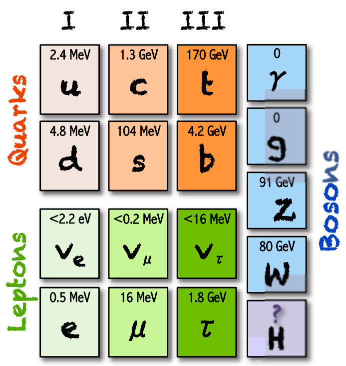

Figure 1: The particles and forces predicted by the SM. Why there are 3 generations of particles and what determines their masses and their mass hierarchy are among the most puzzling open questions.

ATLAS is built with a typical collider detector multilayer design. In its innermost part, it consists of layers of tracking devices. These devices are made of silicon pixel and strip detectors in the inner volume and transition radiation tubes in the outer part. They operate within a 2T solenoidal magnetic field. The tracker is surrounded by the calorimeters, used to identify and measure the energy of electrons, photons and jets. The calorimeters consist of electromagnetic and hadronic

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components. The electromagnetic calorimeter uses liquid Argon as sampling material, while the hadronic calorimeter uses scintillating tiles in the barrel region and liquid Argon in the end-caps. The overall shape of the ATLAS detector is defined by the muon chambers in the outermost part, which operate within a toroidal magnetic field of up to 4T.

The ATLAS detector was designed to have large acceptance and hermeticity, fast response and readout, and high granularity, to allow for large coverage, high rate of recorded events and very precise measurements [2]. Excellent particle identification, vertex reconstruction and calorimeter (jet and Missing Transverse Energy, E_T^{Miss}) resolution are crucial for both, precision measurements and Beyond the Standard Model (BSM) searches.

Out of the 20 MHz of the current LHC collision rate, only $\sim 300-400$ Hz are recorded from ATLAS for offline analysis. The rest of the events are rejected by the trigger system. Building trigger selections is one of the greatest challenges; the trigger has to select as many interesting events as possible for the diverse ATLAS physics program (precision measurements, and searches for Higgs, SUSY and exotics), as well as any unpredicted new phenomena.

In June 2011 the ATLAS experiment has collected $\sim$1 fb^{-1} of integrated luminosity (many factors larger than the 2010 dataset, $\sim$45 pb^{-1}) and analyzed up to 236 pb^{-1}.

In this document we present searches for new phenomena using data from the ATLAS detector collected up to May 2011. The presentation is organized in (i) searches for exotic phenomena, and (ii) searches for SuperSymmetry (SUSY).

2. Exotic Searches

2.1. Search for new heavy bosons

Various SM extensions predict the existence of heavy gauge bosons, denoted as $W'^{(\pm)}$ and Z' [3]. A benchmark model used for the description of these is the Sequential Standard Model (SSM) [4], where W' and Z' have the same fermionic couplings as the SM W and Z, and their widths scale linearly with their mass. Z' specifically exists within string theory inspired models as well [5].

Both W' and Z' are searched for using very clean signatures that only involve leptons and E_T^{Miss}, allowing for possible early discoveries. Z' is searched in two-electron or two-muon final state as a peak in the tail of the two-lepton mass (Figure 2). W' is searched in electron or muon plus E_T^{Miss} final state as a Jacobian edge in the tail of the lepton and E_T^{Miss} transverse mass[1].

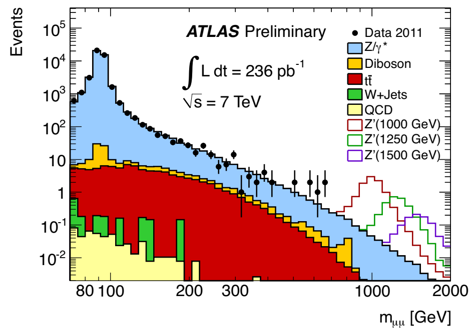

Figure 2: Two-muon invariant mass. The tail of the two-muon invariant mass is where a Z' would manifest itself as a peak. The background to the Z' signal comes primarily from the SM Z and the data is everywhere well described by the Monte Carlo predicted events.

A search for Z' in two-electron and two-muon final states using 167-236 pb^{-1} of data found no excess of events beyond the SM expectation and excluded at 95%C.L. the existence of the SSM Z' with mass less than 1.4 TeV [6]. The two-muon final state gives a handle to also search for $qq\mu\mu$ contact interaction. This interpretation lead to a 95% C.L. limit at the compositeness scale $\Lambda > 4.9$ TeV (4.5 TeV) for constructive (destructive) interference in the two-lepton isoscalar compositeness model [7].

Similarly, the W' boson was searched for in electron and muon plus E_T^{Miss} final states, and in absence of an observed new physics signal, a 95% C.L. exclusion was set within SSM of a mass below 1.7 TeV [8].

2.2. Search in di-jet final state

The production and properties of di-jet events in high energy collisions are well described by perturbative QCD and have been measured in ATLAS [9] showing good agreement between data and QCD expectations. This allows for detailed analyses searching for new physics in the di-jet final state, which could have additional contributions from either new massive particles, or new forces. There is a rich variety of new phenomena that could manifest themselves in di-jet spectra; compositeness: the possibility of quarks being made from more fundamental particles, thus existence of excited quarks, q^*, which could decay to a quark-gluon

[1] The transverse mass of a lepton ℓ and the E_T^{Miss} of the event is defined as $m_T = \sqrt{2 \cdot p_T^{\ell} \cdot E_T^{Miss} \cdot (1 - cos[\Delta\phi(\ell, E_T^{Miss})])}$.