PhD Research Project

Search for New Physics in hadronic final states at $\sqrt{s} = 13$ TeV with the ATLAS experiment at LHC

PhD Candidate: Giuliano Gustavino
Tutor: Prof. Stefano Giagu

Università degli Studi di Roma "La Sapienza"
Dottorato di Fisica, XXIX Ciclo
January 19, 2015

Introduction

The Large Hadron Collider (LHC) at CERN is a proton-proton collider in operation since 2010. It reached a center-of-mass energy of 8 TeV, the highest energy ever reached in particle collisions, and a bunch crossing frequency of 20 MHz. The data collected during the Run1 (2010-2012) took to discovery announcement of the Higgs boson in July of 2012 by the ATLAS and CMS collaborations and lead to the assignment the Physics Nobel Prize to Peter Higgs e Francois Englert. After a long shutdown (2012-2015) the LHC is currently being upgraded to resume operations in 2015 at a center of mass energy of 13 TeV and at a higher collision rate (it will reach a bunch crossing frequency of 40 MHz). For the Run2 (2015-2017) LHC is expected to collect a statistics of about 100 fb^{-1} in the end of the 2017 (5 times the total luminosity collected during the Run1) and it will give the opportunity to search New Physics in an unexplored energy range to the particle physics.

Motivations

The high performance calorimeter system providing near hermetic coverage in the pseudorapidity range $|\eta| < 4.9$, enables ATLAS to perform reliable jet measurements.

The dijet final state is one of the most relevant in a hadronic collider to the search for new exotic resonances and contact interactions. The two jets emerging from the collision may be reconstructed to determine the two-jet (dijet) invariant mass, m_{jj}, and the scattering angular distribution with respect to the colliding beams of protons.. The dominant Quantum Chromodynamics (QCD) interactions for this high-p_{T} scattering regime are t-

channel processes, leading to angular distributions that peak at small scattering angles. Different classes of new phenomena are expected to modify dijet mass distribution and the dijet angular distributions as a function of m_{jj}, creating either a deviation from the QCD prediction above some threshold or an excess of events localised in mass (often referred to as a "bump" or "resonance"). To perform the angular analysis the χ variable that uses the rapidities of the two jets, is used in several m_{jj} bins and its distributions predicted by QCD are relatively flat compared to those produced by new phenomena. In particular, many NP signals are more isotropic than QCD, causing them to peak at low values of χ. Searching for "resonances" or "bumps" in the mass and angular distributions at the new energy that LHC can reach from 2015, this can claim a discovery or, in a pessimistic point of view, can constraint different theoretical models such like quark contact interactions in compositness theory and models that provide colour octet scalars, excited quarks, heavy W bosons, quantum black holes etc.

Looking the final states with only a jet+MET (Missing Transverse Energy) it is possible to use a model-independent treatment of the production of Dark Matter (DM) particles at the LHC in which the Dark Matter particles are pair-produced and the events are tagged by the initial emission of a gluon. Particle DM is a well-established paradigm to explain a range of astrophysical measurements. Since none of the known SM particles are adequate DM candidates, the existence of a new particle is supposed, with properties suitable to explain the astrophysical measurements. One class of particle candidates of interest for searches at the LHC consists of weakly interacting massive particles (WIMPs). These are expected to couple to SM particles through a generic weak interaction, which could be the known weak interaction of the SM or a new type of interaction. Because WIMPs do not interact with the detector material, their production leads to signatures with missing transverse momentum (p_{miss}), the magnitude of which is called E_{miss}. Monojet final states have been studied in the context of searches for supersymmetry (gravitinos), large extra spatial dimensions (LED) aiming to provide a solution to the mass hierarchy problem and in which graviton modes may escape detection and can be produced in association with an energetic jet, and the search for WIMPs particles as DM.

Ph.D Project Plan

The last results at $\sqrt{s} = 8$ TeV in dijet [2], [3] and monojet [4] final states are in agreement with the SM predictions but the last two years of my PhD will coincide with the start of Run2 at LHC, therefore will be possible to study the first data at the energy of 13 TeV. During this period I will involved in the exotic group of the ATLAS experiment in the search for New Physics in the hadronic final states. The timescale in which the several final states will be sensitive to NP depends on the luminosity profile that will reach LHC. The dijet analysis will be sensitive to the Physics beyond the SM with the first fb^{-1}, while the monojet one will be sensitive with an integrated luminosity of ~ 5 fb^{-1}. My first task will consist in the learning of the experimental technics relative to the jet detections, then the work will be involved in the study of the preliminary sensitivity, the event selections that will be adapted to the new data collection at 13 TeV and the implementation of the systematic uncertainties. Finally my thesis will conclude with the first results with the first data collected in the Run2 and their interpretations in the several theoretical models.

References

[1] The ATLAS Collaboration, *Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC*, arXiv:1207.7214.

[2] The ATLAS Collaboration, *Search for New Phenomena in Dijet Mass and Angular Distributions using 4.8 fb^{-1} of pp Collisions at $\sqrt{s} = 7$ TeV collected by the ATLAS Detector*, ATL-COM-PHYS-2012-801

[3] The ATLAS Collaboration, *Search for new phenomena in the dijet mass distribution using pp collision data at $\sqrt{s} = 8$ TeV with the ATLAS detector*, arXiv:1407.1376

[4] The ATLAS Collaboration, *Search for New Phenomena in monojet plus Missing Transverse Momentum Final States using 10 fb^{-1} of pp Collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector at the LHC*, ATLAS-CONF-2012-147