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Supersymmetry searches at LHC

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Summary. — In this paper, a brief overview of the principal strategies for Supersymmetry searches with both ATLAS and CMS detectors at LHC is presented. Particular attention will be devoted to the techniques to estimate the principal SM backgrounds using real data and to the discovery potential in the mSUGRA scenario.

PACS `11.30.Pb` – Supersymmetry.
PACS `12.60.Jv` – Supersymmetric models.
PACS `14.80.Ly` – Supersymmetric partners of known particles.
PACS `04.65.+e` – Supergravity.

1. – Generalties on supersymmetry

One of the main purposes of LHC is the search for physics beyond the Standard Model (SM). In this framework, Supersymmetry (SUSY) is one of the most popular and credited candidates to extend the SM [1]. It introduces a new symmetry that for each SM boson predicts a fermionic super-partner and vice versa. Following this symmetry, one has: scalar fermions (called sleptons and squarks) and gauginos (called Winos, Binos, Zinos, photinos and gluinos). The Higgs sector is composed by five Higgs bosons and their four fermionic partners called Higgsinos (two neutral and two charged). In the R-parity (quantum number that has value $+1$ or -1, respectively, for SM and SUSY particles) conserving models, the lightest SUSY particle called LSP (Lightest Supersymmetric Particle) provides a suitable candidate for Dark Matter because it is stable, neutral and weakly interacting. The final number of free parameters needed for the MSSM (Minimal Supersymmetric Standard Model) is then 105. Because of this large number of free parameters, more constrained frameworks are often used at LHC in order to develop analysis strategies. In this paper the focus will be on strategies for mSUGRA scenario.

The mSUGRA model [2] depends on only five independent parameters to describe SUSY sector: the common gaugino mass $m_{1/2}$, the common scalar mass m_0, the common trilinear gauge coupling A_0 at some high unification scale, the ratio of the vacuum expectation values of the two Higgs doublets $\tan\beta$ and the sign of the Higgsino mixing parameter μ. The top mass can be treated like a sixth independent parameter because it strongly affects the value of physical quantities. All the analyses in this paper are performed in this framework with the addition of the R-parity conservation. In order to perform detailed studies of the SUSY discovery potential, specific sets of values of the mSUGRA space parameters have been chosen [3, 4] taking into account the constraints arising from experimental data (direct searches on Higgs and SUSY at LEP, precision tests at B-factories), theoretical reasons (request of electroweak symmetry breaking mechanism) and cosmological data (compatibility of abundance of cold Dark Matter in the Universe with relic density of lightest neutralinos) [5].

2. – Data-driven estimation methods

To claim a discovery of SUSY, one needs a very good knowledge both of SM background events and detector performances. In this section I will briefly show some examples of the estimation of the SM backgrounds for SUSY analysis starting from data. The most important variable to distinguish SUSY from SM is missing energy in the orthogonal plane with respect to the beam direction (called transverse missing energy E^T_{miss}), because the LSP escapes the detection. Hence one must estimate very carefully the contribution to missing energy coming from SM events. In particular the transverse missing energy is defined as $E^T_{\text{miss}} = \sqrt{(P^X_{\text{miss}})^2 + (P^Y_{\text{miss}})^2}$, where P^X_{miss} and P^Y_{miss} are, respectively, the missing energy in the X and Y directions in the transverse plane.

The main SM contributions to E^T_{miss} come from QCD events (characterised by a small amount of E^T_{miss}, but also very sensible to the performances of the detector itself that can introduce "fake" missing energy signals), from $Z \to \nu\nu$ events (due to neutrinos presence) and from semileptonic W and top decays that involve neutrinos. For each of these SM backgrounds, several techniques to estimate their contribution to E^T_{miss} have been developed by ATLAS and CMS based both on Monte Carlo and on data.

An example of them is the technique used to estimate the contribution of $Z \to \nu\nu$ events. Applying the same cuts as the analysis, one starts to reconstruct the $Z \to ee$ decay, then one computes the energy in the transverse plane for the two reconstructed electrons and substitutes it with the transverse missing energy. A rescaling is then needed to take into account of several factors: the different branching ratios between the two channels, the efficiency in selecting and reconstructing the electrons and the acceptance of the detector (the electrons cannot be reconstructed in the whole solid angle while neutrinos can be produced in all directions). The E^T_{miss} distribution obtained in this way represents the estimation of the $Z \to \nu\nu$ contribution to the missing energy.

Putting together all the estimation techniques, the overall uncertainties on QCD and W/Z/top backgrounds estimation are estimated to be, respectively, 50% and 20%, for an integrated luminosity of $1\,\text{fb}^{-1}$.

3. – Results

Starting from the results of the "data driven" SM background estimation techniques mentioned earlier, the most promising way to discover SUSY is the jets$+E_T^{\text{miss}}+n$ leptons (with $n = 0, 1, 2, 3$) channel. It has been widely studied by both ATLAS and CMS, and the discovery potential for an integrated luminosity of $1\,\text{fb}^{-1}$ in the $(m_0, m_{1/2})$ mSUGRA plane is shown in fig. 1. The two experiments show a similar discovery potential, covering the allowed region of mSUGRA plane until $M_{\tilde{q}} \approx 1.2\,\text{TeV}$ and $M_{\tilde{g}} \approx 700\,\text{GeV}$.

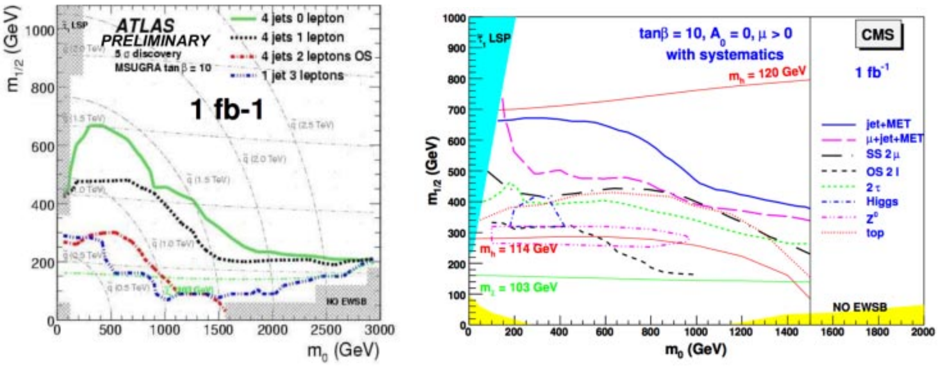

Fig. 1. – 5σ discovery potential including systematics for ATLAS (left) and CMS (right) in the $(m_0, m_{1/2})$ plane for mSUGRA models with $\tan\beta = 10$, $\mu > 0$ and $A_0 = 0$ assuming $1\,\text{fb}^{-1}$ integrated luminosity. Left plot: ATLAS discovery potential in the channels 4 jets + $E^T_{\text{miss}} + n$ leptons ($0l$ channel (solid curve), $1l$ channel (dashed curve), $2l$ OS channel (*i.e.* Opposite Sign) dash-dotted curve) and in the 1jet + 3 leptons channel (dotted curve). The gray regions are excluded because no ElectroWeak Symmetry Breaking is foreseen (low $m_{1/2}$ region) or because the lightest neutralino is not the LSP (low m_0 region). Right plot: CMS discovery potential in various channels: jets + E^T_{miss} + $0l$ channel (solid curve), jets + E^T_{miss} + 1 muon channel (long-dashed curve), jets + E^T_{miss} + 2 SS (same sign) muons channel (dash-dotted curve) and jets + E^T_{miss} + 2 OS (opposite sign) leptons channel (short-dashed curve). Discovery potential in other channels using taus, Higgs, Z and top is also shown.

The "golden channel" for both the experiments is jets + E^T_{miss} channel (with lepton veto), followed by the 1 lepton (only μ for CMS) and the 2 opposite and same sign leptons channels. Other signatures involving taus, Higgs, Z and top have been also studied by both experiments obtaining a lower discovery potential, as the right plot in fig. 1 shows for CMS.

Even if the 1 lepton and the 2 leptons channels have a lower discovery potential, they strongly suppress QCD background (difficult to estimate with early data) requiring at least one lepton (e, μ) and then they give a cleaner signature very useful for an early discovery.

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