Missing energy commissioning in CMS and prospects for supersymmetry searches with 1 fb^{-1}

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Supersymmetry may give rise to striking events that could be discovered early in LHC running. We discuss the prospects of discovery of search strategies based on the generic event signatures of high jet multiplicity and large missing transverse momentum. An important aspect of such searches is the commissioning of search variables with the first LHC data which we present in detail.

1 Introduction

The CMS detector [1] has nearly 4π solid angle coverage and is able to detect most species of particles produced in proton-proton (pp) collisions up to $|\eta| \approx 5$. Exceptions are neutrinos and hypothetical weakly interacting particles, which escape from the detector without leaving a trace. Their presence can still be inferred from the *missing transverse momentum* ($\vec{\not{E}}_T$), defined as the apparent imbalance of the component of the momentum in the plane perpendicular to the beam direction, and its magnitude is referred to as *missing transverse energy* ($\not{E}_T$).

$\not{E}_T$ is one of the most important variables for discriminating leptonic decays of W bosons from background events which do not contain neutrinos, such as QCD jet and Drell-Yan events. $\not{E}_T$ is also an important variable in any search for new particles that are weakly interacting or quasi-stable. Many beyond-the-standard-model scenarios, including Supersymmetry, predict events containing large $\not{E}_T$.

2 $\not{E}_T$ commissioning with early CMS data

$\not{E}_T$ is generally calculated as the magnitude of the negative vector sum of the momentum transverse to the beam axis of all final-state particles reconstructed in the detector. The most traditional and common algorithm uses energies deposited in calorimeter towers and assumes massless objects based on energies measured in the tower and angles defined by a vector from the reconstructed primary vertex of the event to the tower. CMS has implemented three types of algorithms to reconstruct $\not{E}_T$: (i) $\not{E}_T$ based on calorimeter energies (*Calo* $\not{E}_T$) [2], using the tower geometry of the hadron calorimeter, (ii) $\not{E}_T$ calculated by replacing the calorimeter tower energies matched to charged hadrons with their corresponding charged-track momenta (track-corrected $\not{E}_T$ or *Tc* $\not{E}_T$) [3], (iii) $\not{E}_T$ calculated using a complete particle-flow technique (*Pf* $\not{E}_T$) [4].

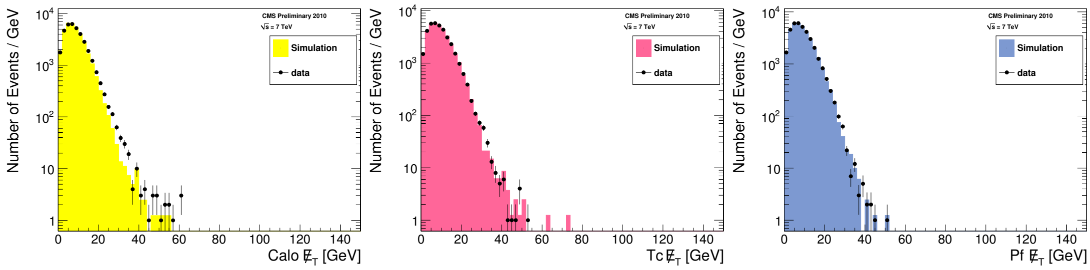

Figure 1: *Calo* $\not\!\!E_T$, *Tc* $\not\!\!E_T$ and *Pf* $\not\!\!E_T$ in a selection with two jets.

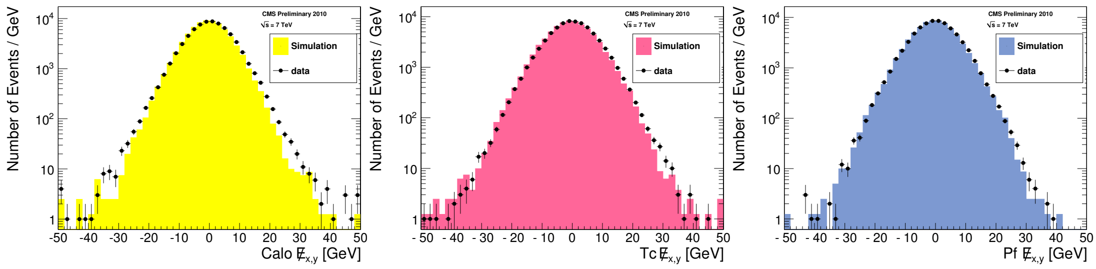

Figure 2: *Calo* $\not\!\!E_{x,y}$, *Tc* $\not\!\!E_{x,y}$ and *Pf* $\not\!\!E_{x,y}$ in a selection with two jets.

The data sets used for studies were collected since the end of March 2010 and correspond to an integrated luminosity of 272 μb^{-1}. The data samples were collected by the minimum-bias trigger and the dijet-selection requires two jets in the central rapidity range $|\eta| < 3$ passing the jet ID cuts and $p_T > 20$ or 10 GeV for the first and second hardest jet [5].

In Fig. 1 and Fig. 2 we show the $\not\!\!E_T$ and $\not\!\!E_{x,y}$ distributions for the three algorithms and note the good general agreement with simulation. The Monte Carlo distribution for Calo $\not\!\!E_T$ in Fig. 1 is somewhat narrower, consistent with the under-estimation of the $\not\!\!E_T$ resolution in the simulation [5]. The distributions in Fig. 2 have two entries per event; one for the x component and the other for the y component. As expected, they are roughly symmetric with respect to zero, and general agreement is observed between data and Monte Carlo distributions, although the data distributions are slightly wider, indicating worse $\not\!\!E_T$ resolution. This observed difference is primarily attributed to the imperfect response in the HCAL barrel and endcap regions. There is also a slight asymmetry in the $\not\!\!E_{x,y}$ distributions which is partially due to the non-uniform noise contributions in the ECAL endcap in the azimuthal angle.

3 Prospects for SUSY searches

The phenomenology of mSUGRA models [6, 7] has been studied extensively in the literature, partly because these models have the attractive feature that they can be specified by just four parameters and a sign:

$$m_0, m_{1/2}, \tan\beta, A_0, \text{sign}(\mu) \tag{1}$$

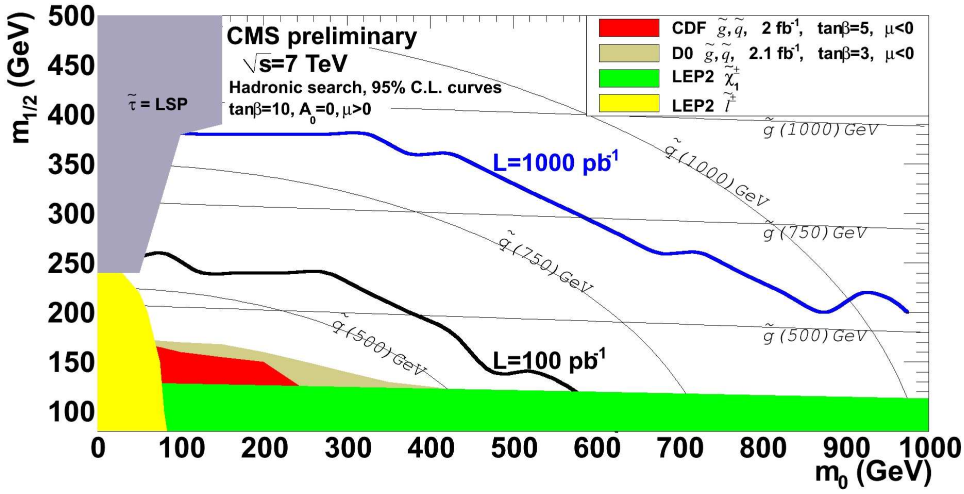

Figure 3: Estimated 95% C.L. exclusion limits for the all-hadronic SUSY search, expressed in mSUGRA parameter space.

where m_0 is the common mass of the scalars at the supersymmetric GUT scale, $m_{1/2}$ is the common gaugino mass, A_0 is the common soft trilinear SUSY breaking parameter, $\tan\beta \equiv v_u/v_d$ is the ratio of the two Higgs vacuum expectation values, and sign(μ) is the sign of Higgsino mass parameter. For the CMS sensitivity scans, we have chosen $A_0 = 0$, $\tan\beta = 3$ or 10, and sign(μ) to be positive. With these parameters fixed, the sensitivity curves are displayed in the plane of $m_{1/2}$ vs. m_0 in Fig. 3. The sensitivity curves are based on the expected signal yield, which is a function of position in mSUGRA parameter space (due to variation in both the cross section and in the efficiency), and the expected background (and its uncertainty), which is only a function of the cuts. No attempt was made to optimize the selection cuts as a function of position in mSUGRA space.

Figure 3 shows the 95% C.L. upper limit contours [8] for the all-hadronic search at two values of the integrated luminosity, 100 pb^{-1} and 1 fb^{-1}, for $\tan\beta = 10$ at $\sqrt{s} = 7$ TeV. Some aspects of this plot require care in interpretation. The exclusion regions for the CDF [9] measurement are defined for $\tan\beta = 5$, while those from D0 [10] are defined for $\tan\beta = 3$. These Tevatron searches are both based on jets + missing transverse momentum signatures using approximately 2 fb^{-1}. The LEP exclusion regions are based on searches for sleptons and charginos [11]. Preliminary CMS studies of the hadronic channel indicate that its sensitivity is only weakly dependent on the value of $\tan\beta$.

Figure 4 shows the 95% C.L. upper limit contours for the like-sign dilepton search, combining the $\mu^\pm\mu^\pm$, $\mu^\pm e^\pm$ and $e^\pm e^\pm$ channels. For comparison, we show the exclusion region from recent CDF and D0 trilepton analyses [12, 13]. Both CMS and Tevatron analyses assumed $\tan\beta = 3$ in evaluating the sensitivity curves. The peaks in the sensitivity curve at low $m_{1/2}$ and for $m_{1/2}$ 450 GeV reflect the rate of production of like-sign dileptons in mSUGRA models.

These results indicate that in the 7 TeV run, CMS should have sensitivity to regions of SUSY (mSUGRA) parameter space beyond the current Tevatron limits. Both of the channels discussed here (all-hadronic and like-sign dileptons) should be able to yield interesting sensitivities well before 1 fb^{-1}.

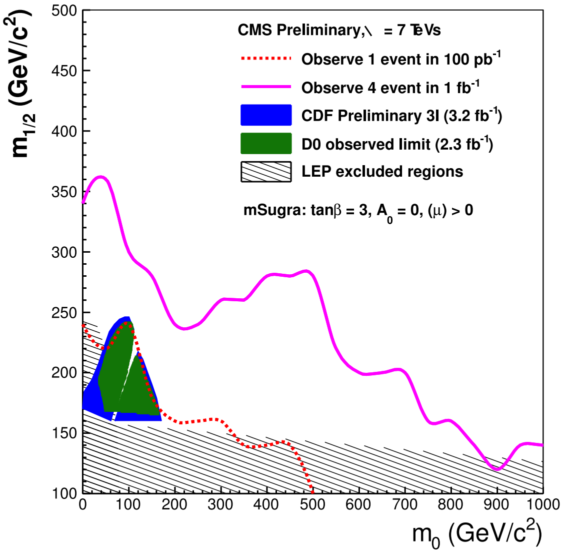

Figure 4: Estimated 95% C.L. exclusion limits for the like-sign dilepton SUSY search, expressed in mSUGRA parameter space. The expected background from the standard model at 100 pb^{-1} (1 fb^{-1}) is 0.4 (4.0) events; we have assumed an observed yield of 1 event (4 events) for the purpose of setting these exclusion limits.

References

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