PROCEEDINGS OF SCIENCE

Searches with early data at CMS

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This paper presents an overview of prospects for searches for new physics beyond the Standard Model with early data of the CMS experiment, at the Large Hadron Collider of CERN. The results presented here are based on Monte Carlo simulations of the CMS detector, assuming 10-100 pb^{-1} of collected integrated luminosity and proton-proton collisions at $\sqrt{s} = 7$ TeV. A selection of benchmark analyses feasible with early data is discussed, including searches for new physics in the di-jet and lepton-jet channels, the description of techniques to identify the production of heavy long-lived charged particles, and the searches for Supersymmetry in the all-hadronic and like-sign dilepton channels.

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1. Introduction

This paper presents a brief overview of prospects for searches for new physics, beyond the Standard Model (SM) of fundamental interactions, feasible with early data of the CMS experiment [1], at the Large Hadron Collider (LHC) of CERN. The results presented at the conference, and here summarized, are based on a detailed Monte Carlo (MC) simulation of the CMS detector, assuming order of 10-100 pb^{-1} of recorded integrated luminosity and proton-proton collisions with a center-of-mass energy of $\sqrt{s} = 7$ TeV. The estimates of the physics reach at 7 TeV are based on extrapolations from existing studies at higher energies ($\sqrt{s} = 10$ TeV or 14 TeV), by applying simple scaling of cross sections for signal and backgrounds as described at [2]. A selection of several benchmark analyses with different experimental signatures is discussed in the following sections. Some of these analyses have been recently performed with early 7 TeV data and they are currently under approval process within the CMS collaboration.

2. Di-jet channel

Several theoretical models predict the existence of new high mass resonances decaying to two jets. Even if the energy of the LHC is not sufficient to directly produce these new particles, the new physics might still appear as a quark contact interaction, and the LHC experiments should be able to identify its signature by looking at di-jet events. We discuss here the CMS analysis [3] of the di-jet ratio [1] used to identify the presence of contact interactions. The most sensitive search for contact interactions at the Tevatron gives an exclusion at 95% C.L. on the contact interaction scale of $\Lambda^+ < 2.4$ TeV [4]. Figure 1 (Left), illustrates the sensitivity of this measurement to contact interactions for different values of Λ^+ for a scenario at $\sqrt{s} = 14$ TeV. Recent studies suggest that it should be possible to exclude at 95% C.L. contact interactions with scale of $\Lambda^+ = 3$ TeV with only a few pb^{-1} of 7 TeV data.

3. Heavy long-lived charged particles and stopped R-Hadrons

Some models of new physics predicts the existence of exotic particles that are heavy (mass of hundreds of GeV/c^2), long-lived (enough to decay outside of the detector) and charged [5]. Heavy long-lived particles with hadronic nature, such as gluinos or stops, hadronizes in flight, forming meta-stable bounded states with quarks and gluons (so called R-Hadrons).

Such particles can be distinguished from SM particles by exploiting their unique signature: a low velocity ($\beta = p/E < 1$) associated with a high momentum (few hundreds of GeV/c). Two offline methods are used to measure β [6]: β_{DT} is derived from the time delay of the arrival of the particle at the muon chambers, while β_{Tk} is obtained from the dE/dx measured in the silicon tracker. The dE/dx measurement have been commissioned with low energy hadrons using early collision data, as described at [7]. The analysis results show that gluino and stop with mass of about 500 GeV/c^2, and 350 GeV/c^2, respectively, can be excluded at 95% C.L. with 100 pb^{-1} of data at 7 TeV (see Figure 1, Right).

[1] The di-jet ratio is an effective angular variable defined as $N(|\eta| < 0.7) \,/\, N(0.7 < |\eta| < 1.3)$, where N is the number of di-jet events with both jets satisfying the pseudo-rapidity requirements in parenthesis.

R-Hadrons lose energy via electromagnetic and nuclear interactions while traveling inside the CMS detector. For low-β R-hadrons, this energy loss is sufficient to bring a significant fraction of the produced particles to rest inside the CMS detector volume (in particular in the hadronic calorimeter HCAL). These "stopped" R-hadrons will decay seconds, day, or weeks later (accordingly with the "unknown" lifetime). These decays will be out-of-time with respect to LHC collisions and may well occur at times when there are no collisions (e.g. beam gaps) or when there is no beam in the LHC machine (e.g. inter-fill period).

For the online selection of these events, the CMS experiment developed a dedicated calorimeter trigger. The observation of such decays in a form of an isolated jet in HCAL, in what should be a quiet detector (save for the occasional cosmic ray or noise from calorimeters), would be an unambiguous discovery of new physics [8]. Figure 2 (Left) shows that few weeks of data taking at 7 TeV, with an instantaneous luminosity of 10^{32} cm^{-2}s^{-1}, will be sufficient to discover a long-lived gluino of 300 GeV/c^2 over a large range of lifetimes.

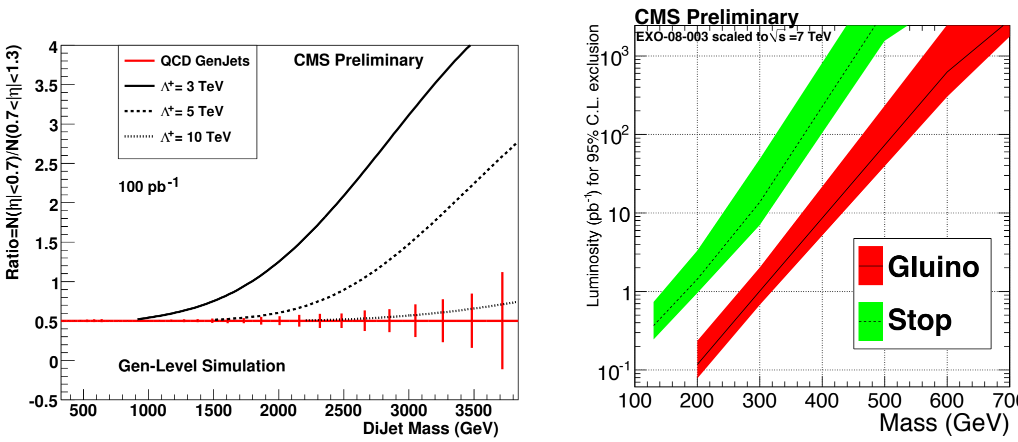

Figure 1: Left: Di-jet ratio as a function of di-jet mass in presence of contact interactions at different energy scales Λ^+, and for QCD multi-jet background at $\sqrt{s} = 14$ TeV. Right: 95% C.L. limit for HSCP searches at 7 TeV. Tracker-only analysis (i.e. $\beta_{\rm Tk}$ measurement) is used. Current lower limit of stop mass is around 250 GeV [9]

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4. Lepton-jet channel

The experimentally observed symmetry between families of leptons and quarks in the SM has motivated the search for leptoquarks (LQ), hypothetical bosons carrying both quark and lepton quantum numbers that decay in a lepton and a quark. The pair production of first (second) generation scalar LQ has been studied in CMS [10], in the final state with 2 high p_T electrons (muons) and 2 high p_T jets. Figure 2 (Right) shows the CMS exclusion reach for the first generation LQ analysis with 100 pb^{-1} at $\sqrt{s} = 7$ TeV and the current Tevatron limit.

5. Supersymmetry

CMS will perform a broad range of searches for supersymmetric (SUSY) particles. The initial

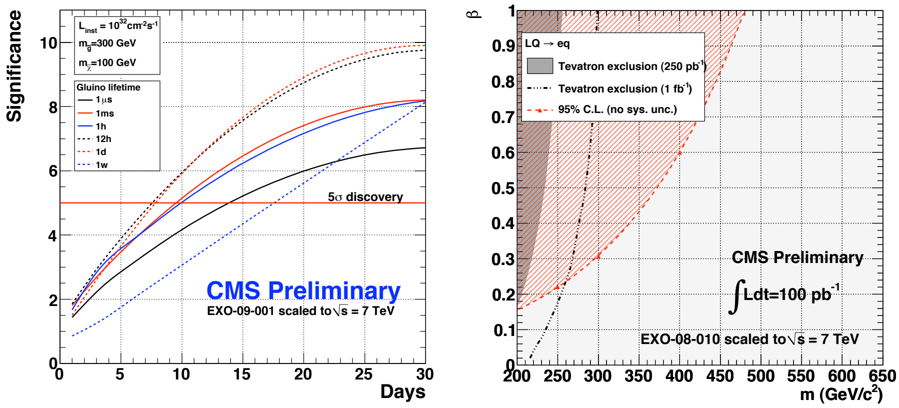

Figure 2: Left: The discovery potential for a long-lived 300 GeV/c^2 heavy gluino stopping in the CMS calorimeter in a 7 TeV run at an instantaneous luminosity of 10^{32} cm^{-2}s^{-1} as a function of the data-taking duration. Right: The 95% C.L.limit for first generation leptoquarks in the $eejj$ channel as a function of their branching fraction into electron and quark for 100 pb^{-1} of data at 7 TeV. Similar reach is obtained in the $\mu\mu jj$ channel.

searches will be performed in a variety of inclusive final states involving jets, leptons, photons and missing transverse energy. Background will be determined using data-driven methods whenever possible, with multiple methods for crosschecks.

Theorist have noted that the models commonly adopted for use as benchmarks, such as mSUGRA, do not span the full range of reasonable phenomenological patterns for which experiments should search. As a consequence, it is important to design searches that are as generic as possible. Nevertheless, the sensitivity of the analyses for 100 pb^{-1} and 1 fb^{-1} at 7 TeV [2] is presented in Figure 3 , for both all-hadronic and like-sign dilepton signatures, using a scan over mSUGRA parameters, since it allows direct comparison with existing results from Tevatron and LEP experiments.

6. Conclusions

At the time of the conference (April 2010), the LHC delivered a fraction of nb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV. The current expectation is to collect order of 100 nb^{-1} of data by the middle of July, just before the ICHEP summer conference. This amount of integrated luminosity is not sufficient to improve the existing constrains on new physics set by other experiments; anyway, for some of the analyses presented here, this “turning point” could already be reached with 1 - 10 pb^{-1} of data.

The LHC is expected to deliver approximately 100 pb^{-1} of integrated luminosity between the end of 2010 and the beginning of 2011, and 1 fb^{-1} by the end of 2011. This large 7 TeV dataset will allow to set stringent limits on many exotic theoretical models, and, if Nature is kind to us, to even observe the first evidence of new physics beyond the SM.

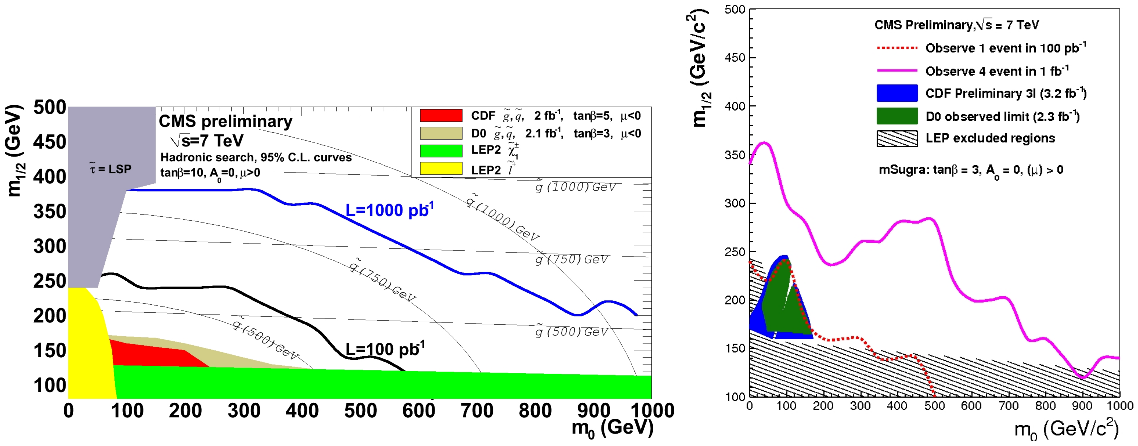

Figure 3: Left: Estimated 95% C.L. exclusion limits for the all-hadronic SUSY search, expressed in mSUGRA parameter space. Right: Estimated 95% C.L. exclusion limits for the like-sign dilepton SUSY search, expressed in mSUGRA parameter space. The expected standard model background at 100 pb^{-1} (1 fb^{-1}) is0.4 (4.0) events; an observed yield of 1 event (4 events) is assumed for the purpose of setting these exclusion limits.

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