SEARCH FOR SUPERSYMMETRY USING FINAL STATES WITH MUONS, JETS, AND MISSING TRANSVERSE MOMENTUM WITH THE CMS DETECTOR IN $\sqrt{s} = 7\,TeV$ pp COLLISIONS

***S. T. Lukyanenko*[1], *T. V. Obikhod*[2*]**

[1]*National Science Center "Kharkov Institute of Physics and Technology", 61108, Kharkov, Ukraine;*

[2]*Institute for Nuclear Research National Academy of Sciences of Ukraine, 03068, Kiev, Ukraine*

(Received April 6, 2015)

The results of search for superparticles in final states with jets, muons and missing transverse energy are presented. The study is based on a data obtained in proton-proton collisions at $\sqrt{s}$ = 7 TeV. They correspond to 4.36 fb^{-1} of integrated luminosity collected with the CMS detector in 2011. mSUGRA/MSSM model built in generator PYTHIA6 was used for SUSY signal modeling. Two selection criteria for searching SUSY- manifesting were used. Background from Standard Model processes was estimated using the MADGRAPH and POWHEG generators. It is shown that with confidence level 95% the data are found to be in agreement with Standard Model expectations and new physics effects are not observed in ranges E_T^{miss} >200 GeV and M_{eff}^{inc} >600 GeV.

PACS: 11.25.-w, 12.60.Jv, 02.10.Ws

1. INTRODUCTION

The most powerful particle accelerator Large Hadron Collider (LHC) allows scientists to reproduce the conditions after the Big Bang through their recreating by colliding proton beams. The essential parts of the LHC project are four huge detectors (ATLAS, CMS, ALICE, LHCb) and the Worldwide LHC Computing Grid (WLCG). Researchers expect not only to confirm known experiments and theories but also to discover new particles and to test the theories for understanding the origin of the Universe.

ATLAS and CMS are two general-purpose detectors at the LHC for investigation a wide range of physics in high-energy collisions including the search for the properties of the discovered Higgs boson, supersymmetric paricles and the evidence for dark matter in the Universe.

Through many experiments, the Standard Model has become established as a well-tested physics theory. The theory incorporates only three out of the four fundamental forces, omitting gravity. Last but not least is a particle called the Higgs boson, an essential component of the Standard Model discovered in 2012. Even though the Standard Model is the best description of the subatomic world, it does not explain the complete picture. There are also important issues that it does not answer, such as the nature of the dark matter, or the matter/antimatter problem, the three generations of quarks and leptons with such a different mass scale, etc. So, the Standard Model is perhaps only a part of a bigger picture that includes new physics. New information from experiments at the LHC will possibly help us to find more of these missing pieces. Currently there are experimental data that may turn out to be a signal of new physics beyond Standard Model:

• LHCb has now analysed the ratio of the number of decays containing muons, to those containing electrons from proton-proton collisions on the LHC and found that B mesons decay to muons about 25% less than they decay to electrons [1];

• the Higgs boson production in association with a top-quark pair represents the excess, which is equivalent to a 2-standard-deviation above the SM [2].

Basing on all of the above, it is clear that currently a priority activity for the largest collaborations at CERN is a search for new hypothetical particles and possible effects indicating deviations from the Standard Model.

The aim of our experimental work is the search for effects of new physics within the supersymmetry theory (SUSY), which is one of the best studied theories beyond the SM. Such a symmetry predicts the existence of supersymmetric particles, abbreviated as sparticles, such as sleptons, squarks, neutralinos, gluinos and charginos . Due to the supersymmetry breaking, the sparticles are much heavier than their ordinary counterparts [3].

The Minimal Supersymmetric Standard Model (MSSM) is one of the best candidates for physics beyond the Standard Model . It is characterized by five free parameters of mSUGRA model [4]: m_0 – the uni-

*Corresponding author E-mail address: obikhod@kinr.kiev.ua

versal mass of the scalars (sleptons, squarks, Higgs bosons) at the Grand Unification scale, $m_{1/2}$ – the universal mass of the gauginos and higgsinos at the Grand Unification scale, A_0 – the universal trilinear coupling, tanβ – the ratio of the vacuum expectation values of the two Higgs doublets, sign(μ) – the sign of the higgsino mass parameter. The paper presents the results of searching for SUSY signal, described by such model with certain values of parameters.

First searches for the production of SUSY particles at the Large Hadron Collider (LHC) corresponded to a total integrated luminosity of 35 pb^{-1} with jets and significant missing transverse energy [5, 6, 7] in final states. More recent publications [8] are based on a 20.3 fb^{-1} dataset of $\sqrt{s}$ = 8 TeV proton-proton collisions in final states with jets and missing transverse momentum.

SUSY particles, the squarks $\tilde{q}$ and gluinos $\tilde{g}$ are expected to be produced via the strong interaction at the TeV energy scale. Their decays via cascades ending with the lightest supersymmetric particle (LSP) produce experimental signatures leading to final states containing multi-jets, charged leptons and large missing transverse momentum (undetected neutralino and possibly leptons).

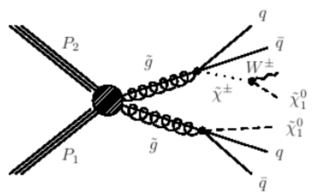
Taking into account the large number of possible final states after the decay of a SUSY particle, we have tried to summarize their contributions with an appropriate choice of kinematical constraints for registration of possible signal. The article does not suggest an original approach in such studies and does not propose a new method of data analysis. It is not contradict earlier researches (see above) and, actually, presents the tests of our algorithms. These algorithms can be used for processing and analysis of future CMS data.

2. DATA AND EVENT SELECTION

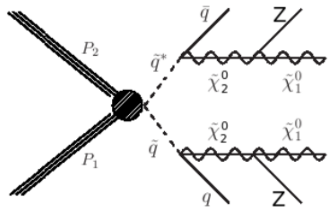
SUSY particles, the squarks ($\tilde{q}$) and gluinos ($\tilde{g}$) are mainly produced, with large probability, via direct production of $\tilde{g}\tilde{g}$, $\tilde{q}\tilde{g}$ or $\tilde{q}\tilde{q}$ pairs. Squarks typically generate at least one jet in their decays, while gluinos typically generate at least two jets. Processes with $\tilde{q}\tilde{q}$, $\tilde{q}\tilde{g}$ and $\tilde{g}\tilde{g}$ in intermediate states therefore lead to events containing at least two, three or four jets, respectively. Using a data obtained in pp collisions at $\sqrt{s}$ = 7 TeV, we perform the search for massive SUSY particles that decay to the muons, jets and neutralinos. Two of many possible processes of superparticle decays are presented in Fig.1.

We used the data sample collected during 2011 by the Compact Muon Solenoid (CMS) - a multipurpose detector described in detail in [9].

Searches in final states with many jets, leptons, and large missing transverse energy in final states are sensitive to a wide range of new models, including SUSY. Such searches were performed in [10].



a



b

Fig.1. *Processes of superparticle decay after pp collisions: a) decay of gluinos; b) decay of squarks*

We begin the search for the superparticle signatures with four hard jets, two high-energetic isolated muons and large E_T^{miss}. The analysis uses a muon sample of CMS experimental data $/DoubleMu/Run2011*PromptReco*/AOD$ containing in each event at least two muons with transverse momentum p_T^{μ} above 200 MeV in the pseudorapidity range $|\eta^{\mu}| < 2.7$. The pseudorapidity η is defined as $\eta = -\ln[\tan(\theta/2)]$, where θ is the polar angle with respect to the beam axis.

Using the methods of the PAT (Physical Analysis Toolkit) package [11], implemented in the CMS software package (CMSSW) [12], and WLCG infrastructure [13], we got a sample of preselected events. This sample meets the criteria of high-level muon trigger HLT_Mu13_Mu8 (at least two muons with $p_T^{\mu} > 13$ and $p_T^{\mu} > 8$ GeV) and corresponds to integrated luminosity $L_{int} = 4.36$ fb^{-1}. It was recorded on the disk storage of KIPT CMS Tier-2 Center ($T2\_UA\_KIPT$) and used for the final analysis. Events are required to have at least two opposite sign isolated "signal" muons with p_T^{μ} above 10 GeV, $|\eta^{\mu}| < 2.4$, and the leading muon must have $p_T^{\mu} > 20$ GeV; at least four hadron "signal" jets with a transverse momentum $p_T^{jet} > 30$ GeV, $|\eta^{jet}| < 2.5$; missing transverse momentum E_T^{miss} must exeed 100 GeV and must satisfy restriction $E_T^{miss}/M_{eff} > 0.2$, where the effective mass M_{eff} is the scalar sum of p_T^{jet} of four leading jets and E_T^{miss} is absolute value of the vector sum of the transverse momentums of the all reconstructed physical objects. The last criterion allows us to suppress the background caused by incorrectly reconstructed hadronic jets more efficiently.

Two event distributions will be analyzed using the main observables E_T^{miss} and inclusive effective mass M_{eff}^{inc}. Quantity M_{eff}^{inc} is defined in terms of the scalar sum of p_T^{jet} of all "signal" jets, the p_T^{μ} of all "signal" muons and missing transverse energy, E_T^{miss}:

$$M_{eff}^{inc} = \sum_{i=1}^{N_{lep}} p_{T,i}^{\mu} + \sum_{j=1}^{N_{jet}} p_{T,j}^{jet} + E_T^{miss} \; .$$

These selection criteria choose two high-energetic muons, four hard jets and two LSPs mainly in processes $pp \to \tilde{q}\tilde{q} + X \to q\bar{q} + ZZ + \tilde{\chi}_1^0\tilde{\chi}_1^0 + X$ and $pp \to \tilde{q}\tilde{q}^* + X \to q^{'}\bar{q} + WZ + \tilde{\chi}_1^0\tilde{\chi}_1^0 + X$, where $\tilde{q}$ is squark, $\tilde{q}^*$ - antisquark, $\bar{q}$ - antiquark. The main criterion for manifestation of SUSY particles is a certain excess of events in the distribution of M_{eff}^{inc} or E_T^{miss} compared to the Standard Model predictions. The excess, if it exists, must occur at sufficiently large values M_{eff}^{inc} and E_T^{miss} and is directly connected with the large masses of the superpartners. The signal estimation is based on Monte Carlo samples generated by PYTHIA6 [14] and reconstructed with taking into account the CMS detector response. The SUSY signal in the mSUGRA/MSSM model is defined for m_0 = 500 GeV, $m_{1/2}$ = 300 GeV, A_0 = - 300 GeV, tan $\beta = 10$, sign$(\mu) > 0$.

Contamination of the signal region due to background from the following Standard Model processes is estimated:

- Di-boson (WW, WZ, ZZ boson pairs) + jets production events generated using the MADGRAPH generator [15];
- $t\bar{t}$ + jets and tW + jets production estimated using the MADGRAPH and POWHEG [16] correspondingly;
- Z+jets production generated using the MADGRAPH generator.

POWHEG background simulation results include the real and virtual next-to-leading-order (NLO) corrections. The MADGRAPH gives an opportunity to consider in tree approximation the processes leading to 5 jets. All Monte-Carlo results for the distribution of events presented in the paper are rescaled taking into account the static factor

$$K = \sigma_{theor}^{tot} / \sigma_{gen}^{tot}$$

(σ_{gen}^{tot} - cross section calculated by the events generator and σ_{theor}^{tot} - cross section including higher-order corrections to leading process), and an integrated luminosity of 4.36 fb^{-1}.

3. RESULTS

Application of the above criteria for the selection of events leads to poor statistics for the signal (~ 3 events over the entire range of M_{eff}^{inc} or E_T^{miss}).

Therefore, a natural step is to loosen the kinematic constraints on the selection of SUSY events. We add a signature containing the final states with one muon, which corresponds, for example, to process $pp \to \tilde{q}\tilde{q} + X \to q^{'}\bar{q}^{'} + WW + \tilde{\chi}_1^0\tilde{\chi}_1^0 + X$ and further reduce the threshold for p_T of leading muon. As a result, we have the following set of constraints:

$$\left.\begin{array}{c} \text{at least one isolated signal muon} \\ p_T^{\mu} > 10 \text{ GeV}, \; |\eta^{\mu}| < 2.4; \\ \text{at least four hadron "signal" jets} \\ p_T^{jet} > 30 \text{ GeV}, \; |\eta^{jet}| < 2.5; \\ E_T^{miss} > 100 \text{ GeV}; \\ E_T^{miss}/M_{eff} > 0.2. \end{array}\right\} \qquad (1)$$

The event distributions over E_T^{miss} and M_{eff}^{inc} for CMS experimental data are shown in Fig.2. Expectation for the mSUGRA/MSSM model and the contribution of the main background processes are also shown.

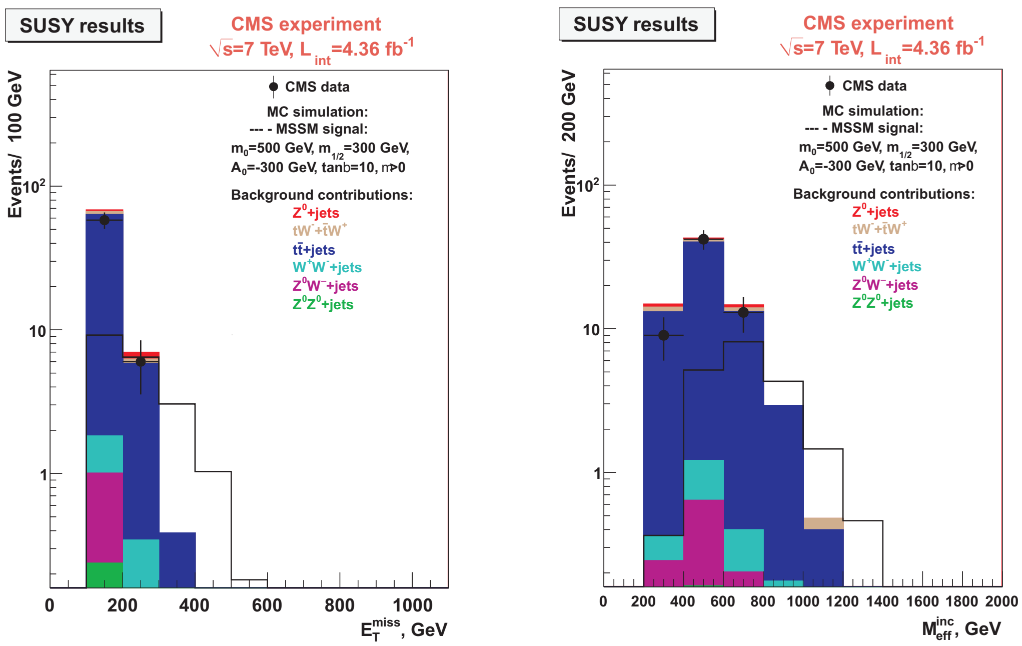


Fig.2. The event distributions over E_T^{miss} and M_{eff}^{inc} satisfying selection criteria (1) are shown (only statistical errors are shown)

Experimental data are qualitatively in agreement with the Standard Model expectations. Quantitative contributions of separate sources of the background for various ranges in E_T^{miss} and M_{eff}^{inc} are presented in Table 1. Contribution of the expected signal as well as the yield of real data is shown too. All quantities presented in this table are obtained with taking into account only statistical errors. Then, for trigger HLT_Mu13_Mu8 that is used here, it can be assumed that the contribution of background W + jets will be very small.

Table 1. *Expected (Total+Signal) and observed (Data) number of events satisfying selection criteria (1) for different ranges in E_T^{miss} and M_{eff}^{inc}*

	ZZ+jets	ZW+jets	WW+jets	$t\bar{t}$+jets	tW+jets	Z+jets	Total	Signal	Data
E_T^{miss} >100 GeV M_{eff}^{inc} > 200 GeV	0.3±0.0	0.9±0.1	1.1±0.1	67.2±4.8	3.5±0.5	2.6±1.0	75.5±0.6	20.0±0.5	64±8
E_T^{miss} >200 GeV	0.1 ± 0.0	0.1±0.0	0.2±0.1	5.8±1.4	0.4±0.2	0.7±0.5	7.4±0.1	10.8±0.4	6±2.5
M_{eff}^{inc} > 600 GeV	0.1±0.0	0.2±0.0	0.4±0.1	15.8±2.3	0.9±0.3	0.7±0.5	18.1±0.3	14.5±0.4	13±3.6

Using the Bayesian method [17] the upper limits on signal strength R (the ratio the number of observed signal events to the number of expected signal events) has been calculated with the confidence level CL=95%. Quantities presented in Table 2 indicate the absence with CL=95% of any effects of new physics described by the selected model (except for case where R< 2.47 ± 0.04). The signal significance is defined from simulated data as S/$\sqrt{B}$, where S is the number of signal events and B is the number of background events. Along with taking into account the statistical errors, for calculating the upper limits we used the systematical errors as well. The maximum systematical errors are considered for signal and background separately (30% - signal, 60% - background). They are taken from studies of article [18].

Table 2. *Left to right: signal significance for the various ranges in E_T^{miss} and M_{eff}^{inc}. The third column shows the 95% CL upper limits on the observed signal strength R, calculated with the statistical errors. The last column shows the 95% CL upper limits on the observed signal strength R, taking into account the total uncertainties (see text)*

	$S/\sqrt{B}$	R < $R^{up}_{staterr}$	R< R^{up}_{toterr}
E_T^{miss} >100 GeV, M_{eff}^{inc} > 200 GeV	2.3	R< 0.65 ± 0.01	R< 2.47 ± 0.04
E_T^{miss} >200 GeV	4	R< 0.57 ± 0.01	R< 0.88 ± 0.02
M_{eff}^{inc} > 600 GeV	3.4	R< 0.46 ± 0.01	R< 0.91 ± 0.02

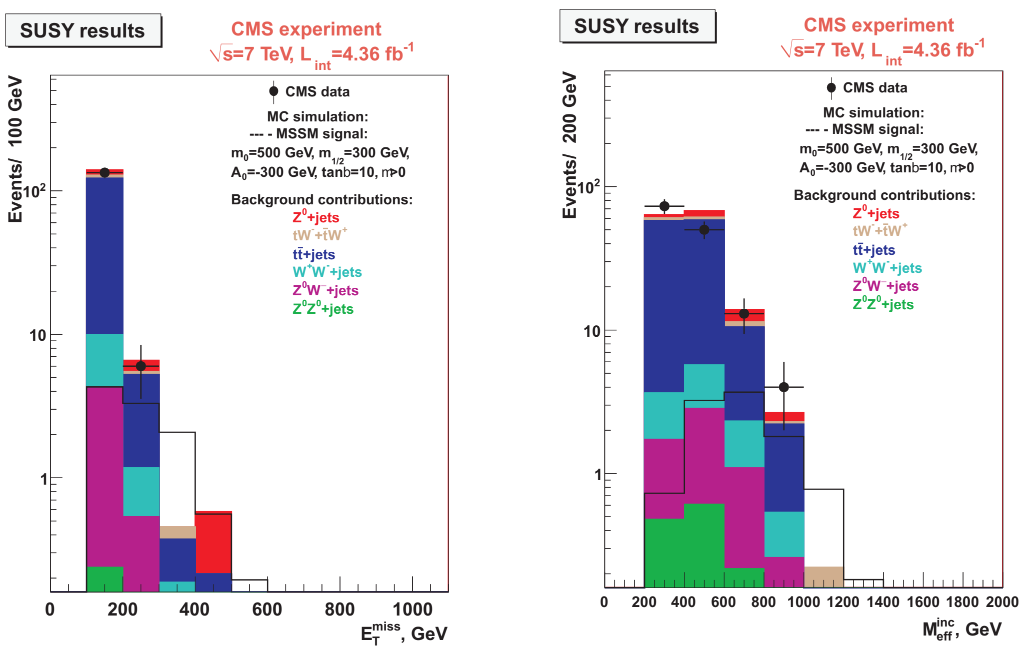


Fig.3. *The event distributions over E_T^{miss} and M_{eff}^{inc} satisfying selection criteria (2) are shown (only statistical errors are shown)*

Note that we are not bound in our consideration to any particular SUSY process. We are interested in the total contribution of the group of processes, selected by the relevant criteria. Therefore, it makes sense to calculate CL for a group of processes, which, in addition to those already discussed, will include also formation of three hard jets and $\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0$. The cuts in this case are as follows:

$$\left.\begin{array}{c}\text{at least two isolated opposite-sign "signal" muons}\\ p_T^{\mu} > 10\text{ GeV}, |\eta^{\mu}| < 2.4\\ \text{including one leading muon with } p_T^{\mu} > 20\text{ GeV};\\ \text{at least two hadron "signal" jets}\\ p_T^{jet} > 30\text{ GeV}, |\eta^{jet}| < 2.5;\\ E_T^{miss} > 100\text{ GeV};\\ E_T^{miss}/M'_{eff} > 0.2.\end{array}\right\} \quad (2)$$

Here M'_{eff} is the scalar sum of p_T^{jet} of two leading jets. The result of their application is shown in Fig.3.

Quantitative contributions of separate sources of the background for various ranges in E_T^{miss} and M_{eff}^{inc} are presented in Table 3. Contribution of the expected signal as well as yield of real data is shown too. All quantities presented in this table are obtained with taking into account only statistical errors.

Table 3. *Expected (Total + Signal) and observed (Data) number of events satisfying selection criteria (2) for different ranges in E_T^{miss} and M_{eff}^{inc}*

	ZZ+jets	ZW+jets	WW+jets	$t\bar{t}$+jets	tW+jets	Z+jets	Total	Signal	Data
E_T^{miss} >100 GeV M_{eff}^{inc} > 200 GeV	1.4±0.0	4.7±0.1	6.4±0.3	116.7±4.7	6.4±0.7	13.2±2.2	148.7±0.3	10.5±0.5	140±11.8
E_T^{miss} >200 GeV	0.3±0.0	0.6±0.1	0.7±0.1	4.5±0.9	0.3±0.2	1.5±0.7	7.9±0.1	6.2±0.4	6±2.5
M_{eff}^{inc} > 600 GeV	0.3±0.0	1.2±0.1	1.6±0.2	9.9±1.4	1.1±0.3	2.9±1.0	16.9±0.1	6.5±0.4	17±4.1

Despite the increase in the number of analyzed SUSY-processes, the increase in the signal did not occur. Furthermore, the signal became smaller compared to selection criteria 1. The main reasons for this are, firstly, the smaller number of signal events with two "good" (satisfying the CMS identification criteria) muons, and secondly, small relative probability of weak boson decay to leptons. At the same time, criteria (2) suppress the background to about the same degree of criteria (1) do. The restriction on the existence of the SUSY signals turn out to be less stringent (see Table 4).

Table 4. *Left to right: signal significance for the various ranges in E_T^{miss} and M_{eff}^{inc}. The third column shows the 95% CL upper limits on the observed signal strength R, calculated with the statistical errors. The last column shows the 95% CL upper limits on the observed signal strength R, taking into account the total uncertainties (see text)*

	$S/\sqrt{B}$	R<$R_{staterr}^{up}$	R<R_{toterr}^{up}
E_T^{miss} >100 GeV, M_{eff}^{inc} > 200 GeV	0.9	R< 1.94 ± 0.02	R< 10.15 ± 0.25
E_T^{miss} >200 GeV	2.2	R< 0.99 ± 0.02	R< 1.44 ± 0.03
M_{eff}^{inc} > 600 GeV	1.6	R< 1.58 ± 0.01	R< 2.72 ± 0.04

4. CONCLUSIONS

We performed a search for superparticles in events with either one or two muons, two or more jets, and large missing transverse energy using 4.36 fb^{-1} of $\sqrt{s}$ = 7 TeV CMS data. The event distributions over M_{eff}^{inc} and E_T^{miss} are presented for two sets of selection criteria. For different ranges in E_T^{miss} and M_{eff}^{inc} we defined the upper limits on observed signal strength R with confidence level CL=95%. In case of the selection criteria (1), the estimations with the statistical and the maximum systematic error (up to 30% for signal and 60% for background) give the upper limit values 0.88 and 0.91 for E_T^{miss} >200 GeV and M_{eff}^{inc} >600 GeV, respectively. This confirms with the confidence level 95% the conclusion about the absence of SUSY signal for E_T^{miss} >200 GeV and M_{eff}^{inc} >600 GeV. No excess of events over the expected SM background was observed in experimental CMS data. The proposed method allows us to search for superparticles within different theoretical models, as well as at higher LHC energies.

References

1. LHCb collaboration. Rare decays at the LHCb experiment // e-print arXiv:1410.2411 [hep-ex].
2. The CMS Collaboration. Search for the associated production of the Higgs boson with a top-quark pair // e-print arXiv:1408.1682 [hep-ex] (2014).
3. H.E. Haber. Introductory Low-Energy Supersymmetry// e-print arXiv: hep-ph/9306207, (1993).
4. J.J. Heckman, and C. Vafa. F-theory, GUTs, and the weak scale // e-print arXiv:0809.1098 [hep-th].
5. ATLAS Collaboration. Search for supersymmetry using final states with one lepton, jets, and missing transverse momentum with the ATLAS detector in $\sqrt{s}$ = 7 TeV pp // e-print arXiv:1102.2357v1 [hep-ex] (2011), submitted to Phys. Rev. Lett.
6. ATLAS Collaboration. Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in $\sqrt{s}$ = 7 TeV proton-proton collisions // e-print arXiv:1102.5290v1 [hep-ex] (2011), submitted to Phys. Lett.
7. CMS Collaboration. Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy // e-print

arXiv:1101.1628 [hep-ex] (2011), submitted to Phys. Lett.

8. Marija Marjanovic, for the ATLAS Collaboration. Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum using 20.3 fb^{-1} of $\sqrt{s}$=8 TeV proton-proton collision data // e-print arXiv:1408.5857 [hep-ex].

9. CMS Collaboration. The CMS experiment at the CERN LHC // *JINST* 3 (2008) S 08004.

10. ATLAS Collaboration. Search for supersymmetry using final states with one lepton, jets, and missing transverse momentum with the ATLAS detector in $\sqrt{s} = 7$ TeV pp // e-print arXiv:1102.2357 [hep-ex].

11. https://twiki.cern.ch/twiki/bin/view/CMSPublic/WorkBookPAT

12. http://cms-sw.github.io/index.html

13. http://wlcg.web.cern.ch/

14. T. Sjostrand, S. Mrenna and P. Skands. PYTHIA 6.4 Physics and Manual // *JHEP*. 2006, 05, p.1-26.

15. Johan Alwall, Pavel Demin, Simon de Visscher, et al. MadGraph/MadEvent v4: The New Web Generation // *JHEP* 0709:028, 2007, e-print arXiv:0706.2334.

16. Emanuele Re. Single-top Wt-channel production matched with parton showers using the POWHEG method // *Eur.Phys.J.* 2011, C71:1547, e-print arXiv:1009.2450.

17. J. Beringer et al. (Particle Data Group) // *Phys. Rev.* 2012, D8, p. 386-401.

18. CMS Collaboration. Search for new physics in events with opposite-sign leptons, jets, and missing transverse energy in pp collisions at sqrt(s) = 7 TeV // *Phys. Lett.* 2013, B 718, 815 - 840, e-print arXiv:1206.3949.

ПОИСКИ СУПЕРСИММЕТРИИ С МЮОНАМИ, СТРУЯМИ И ПОТЕРЯННОЙ ПОПЕРЕЧНОЙ ЭНЕРГИЕЙ В КОНЕЧНОМ СОСТОЯНИИ С ПОМОЩЬЮ CMS ДЕТЕКТОРА ПРИ ЭНЕРГИИ $\sqrt{s} = 7$ ТэВ В pp - СТОЛКНОВЕНИЯХ

С.Т. Лукьяненко, Т.В. Обиход

Представлены результаты поиска суперчастиц с мюонами, струями и потерянной поперечной энергией в конечном состоянии. Изучение основано на данных, полученных в протон-протонных столкновениях при энергии $\sqrt{s} = 7$ ТэВ и соответствующих интегральной светимости $4.36\,fb^{-1}$, накопленной CMS детектором в 2011 году. Для моделирования SUSY сигнала использовалась модель $mSUGRA/MSSM$, встроенная в пакет $PYTHIA6$. Рассматривалось два критерия отбора для поиска SUSY событий. С помощью генераторов $MADGRAPH$ и $POWHEG$ были оценены фоны, обусловленные процессами Стандартной Модели. Показано, что с уровнем доверия 95% полученные результаты находятся в согласии с предсказаниями Стандартной Модели и в пределах $E_T^{miss} > 200$ и $M_{eff}^{inc} > 600$ эффекты новой физики не наблюдаютя.

ПОШУКИ СУПЕРСИМЕТРІЇ ІЗ МЮОНАМИ, СТРУМЕНЯМИ І ВТРАЧЕНОЮ ПОПЕРЕЧНОЮ ЕНЕРГІЄЮ В КІНЦЕВОМУ СТАНІ ЗА ДОПОМОГОЮ CMS ДЕТЕКТОРА ПРИ ЕНЕРГІЇ $\sqrt{s} = 7$ ТеВ У pp - ЗІТКНЕННЯХ

С.Т. Лук'яненко, Т.В. Обіход

Наведено результати пошуку суперчастинок із мюонами, струменями і втраченою поперечною енергією в кінцевому стані. Вивчення ґрунтується на даних, отриманих при протон-протонних зіткненнях при енергії $\sqrt{s} = 7$ ТеВ , що відповідають інтегрованій світимості $4.36\,fb^{-1}$, накопиченій CMS детектором у 2011 році. Для моделювання SUSY сигналу використовувалась модель $mSUGRA/MSSM$, вбудована в пакет $PYTHIA6$. Розглядалось два критерії відбору для пошуку SUSY подій. За допомогою генераторів $MADGRAPH$ і POWHEG були оцінені фони, обумовлені процесами Стандартної Моделі. Показано, що з рівнем довіри 95% отримані результати знаходяться у відповідності із передбаченнями Стандартної Моделі і в межах $E_T^{miss} > 200$ і $M_{eff}^{inc} > 600$ ефекти нової фізики не спостерігаються.