CMS Conference Report

13 April 2006

Standard Model Physics at CMS

Presented at *Lake Louise Winter Institut*, Lake Louise, February 2006

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Abstract

The LHC will provide proton-proton collisions at energies of about 14 TeV and at luminosity up to 10^{34} cm^{-2}s^{-1}. It will be possible to observe new physics but also to have precise measurements of Standard Model phenomena. The perspectives for top quark physics, electro-weak physics, gauge boson couplings and B physics with CMS are briefly discussed here. With the high rate and energy, new processes from the Standard Model, as for example single top, will become visible.

1 Introduction

The LHC is expected to provide proton-proton collisions at a centre-of-mass of 14 TeV, at an instantaneous luminosity ranging from 2×10^{33} cm^{-2}s^{-1} (low luminosity phase) to 10^{34} cm^{-2}s^{-1} (high luminosity phase). This frontier machine will open a new window on physics beyond the Standard Model. At the same time many improved measurements of Standard Model physics can be performed. In this short report some of these measurements are briefly reviewed and the sensitivity expected with the CMS detector [1] are discussed. Most of the results presented here are currently being updated in preparation of the Physics TDR volume II [2].

2 Top Quark Physics

The top quark mass is a fundamental Standard Model parameter. It allows to constraint the Standard Model Higgs mass through electroweak radiative corrections. The $t\bar{t}$ production is a major background for a lot of processes beyond Standard Model. At LHC, top quarks are mainly produced in pairs via gluons fusion (90%) and quark annihilation (10%). A top quark will decay immediately in almost 100% of cases in $W^{\pm}b$. According to the decay of the Ws, selection of $t\bar{t}$ pairs can be classified as fully hadronic (both W decay hadronically, 46%), semileptonic (one W decays leptonically, the second decays hadronically, 29%) and dileptonic (both W decay leptonically).

2.1 Top Quark Mass

Two methods to compute the top mass have been developed so far at CMS. The first one presented here uses the semileptonic decay events. The lepton is used for the selection of events, while the mass is computed using the second top which is decaying hadronically. This analysis selects 3000 signal events for a integrated luminosity of 10fb^{-1} with a background level of 5% [3] shown on figure 1. The typical systematic error, mainly coming from the uncertainty on the jet energy scale, is less than 0.9 GeV. The second method uses also semileptonic decay events but requires also that the b-hadron from the same side of the $W \rightarrow l\nu$, decays via a J/Ψ [4]. The top mass is then computed using the linear relation between the maximum of the distribution of invariant mass of the lepton and J/Ψ as shown on figure 1. This method needs a lot of statistics but the systematic error on the top mass is reduced as it is independant of the jet energy scale. With 100fb^{-1} of integrated luminosity, 1000 signal events are expected and systematic errors on the top mass could be less than 1 GeV.

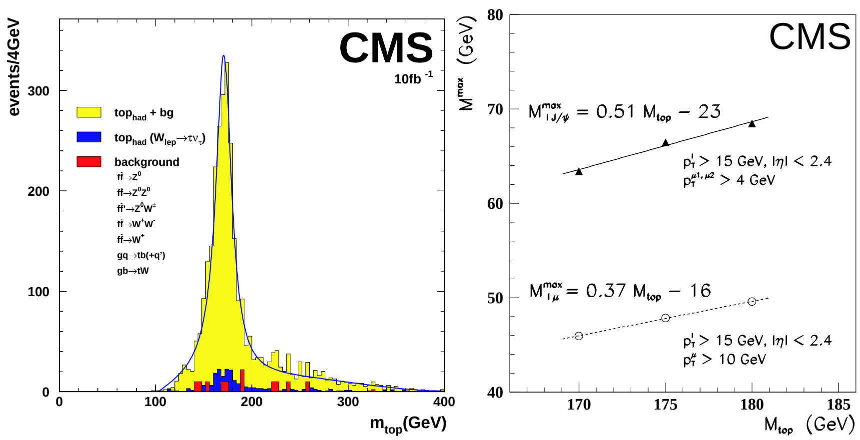

Figure 1: Left plot: Top Mass reconstructed in semileptonic events for 10fb^{-1} of integrated luminosity. Right Plot: Linear relation between Top Mass and maximum of invariant mass distribution of lepton J/Ψ system.

2.2 Spin correlation and W polarization in top pairs

Others properties of the top quark can be studied with the CMS detector. The top quark is decaying before hadronization so leptons coming from the W decay retain the information on the spin of the top quark. Looking at dileptonic decay of $t\bar{t}$ events, ones can use the differential angular distribution and measure the asymmetry of same sign spin and opposite sign spin. With 30 fb^{-1} of integrated luminosity, a statistical error on the asymmetry of 0.035 is expected as well as a systematic error of 0.028 [3].

The structure of the weak current allows the W boson to be longitudinally polarized in semileptonic decay. The differential angular distribution of the lepton is described as a function of left-handed component, longitudinal polarization and right-handed one. In the Standard Model the right-handed polarization must be zero. A statistical uncertainty of 0.023 and a systematic uncertainty of 0.022 on the longitudinal polarization can be obtained [3].

2.3 Single Top

The top quark can be produced individually with a lower cross section than the pair production. This process is predicted in Standard Model but not yet observed. It can be used for a direct mesurement of $|V_{tb}|$. This channel is also very sentitive to physics beyond Standard Model. A preliminary selection has been proposed to allow the observation of this process [5].

3 Gauge Boson Couplings

Measurements of vector boson couplings via the cross-section measurements is a test the non-Abelian nature of the Standard Model gauge theory. New physics can appear in anomalous gauge boson couplings. Studies were made in the $W\gamma$ channel [6] and in the $Z\gamma$ channel [7] and limits on the couplings can be set assuming 100 fb^{-1}. The transverse momentum spectrum of the photon is sensitive to anomalous couplings, as shown on figure 2.

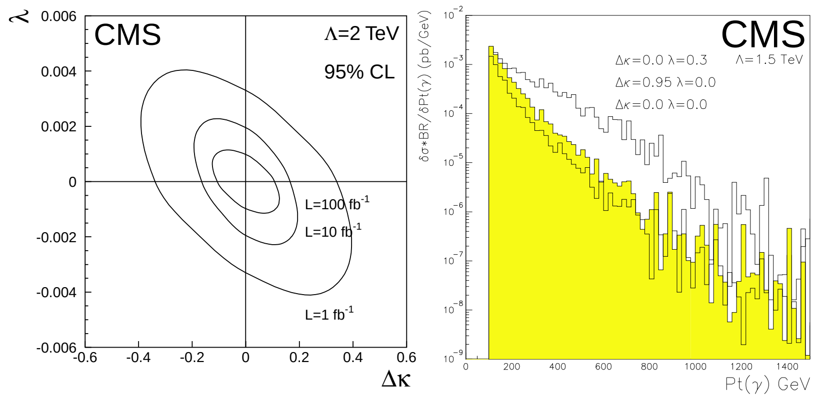

Figure 2: Left plot: 95% confidence level on the couplings $\lambda, \Delta\kappa$ for differents luminosity with a scale $\Lambda = 2$ TeV. Right Plot: Transverse momentum of photon produced in association with a Z-boson. Anomalous coupling will increase the number of events seen at high transverse momentum.

4 Drell-Yan production of lepton pairs

The Drell-Yan process $pp \to l^+l^- + X$ and its forward-backward asymmetry is shown in figure 3. In this measurement, new physics can appear [8]. Also, the higher center of mass energy allows the production of dilepton masses greater than 1 TeV: new particles beyond the Standard Model can show up in this distribution (fig 3).

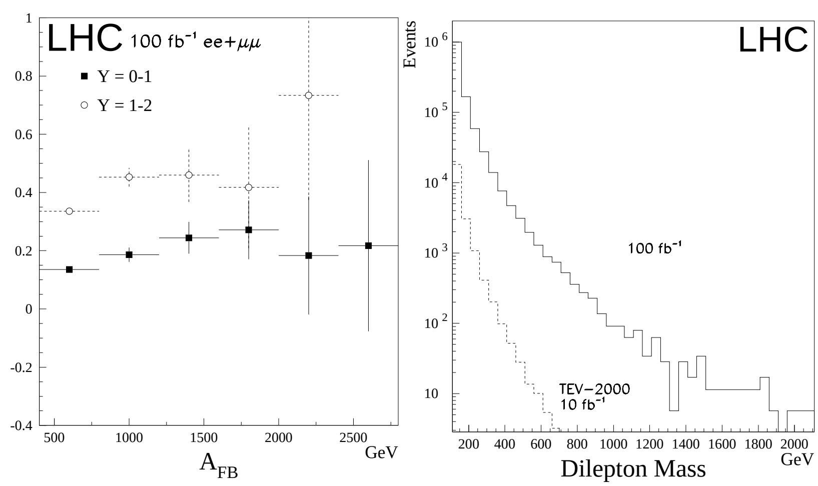

Figure 3: Left plot: Forward-backward asymmetry measurement. Right Plot: Invariant mass of dileptons.

5 B-Physics: $B_s \to \mu^+\mu^-$

The CMS detector has a rich potential for B-Physics because of its precise tracking and vertexing. It is possible to study CP violation, to look for rare decays, study B-lifetime, B_c mesons etc.

The process $B_s \to \mu^+\mu^-$ is highly suppressed in the Standard Model with a branching ratio of $(3.42 \pm 0.54) \times 10^{-9}$ and any deviation is a potential signature for new physics. After 3 years of low luminosity(30 fb^{-1}) a 4σ evidence [9] is possible.

6 Conclusion

Examples of possible Standard Model physics studies have been given. Using the CMS detector the mass of the top could be measured with a systematic error less than 1 GeV, improving the constraint on the Standard Model Higgs mass. Spin correlation in $t\bar{t}$ will be studied and a systematic error on the spin asymmetry lower than 0.03 will be obtained with 30 fb^{-1}. W polarisation in $t\bar{t}$ events will be measured with a precision better than 0.023. Triple Gauge Boson Coupling will be constrainted to the percent level. The Drell-Yan process will allow to measure its forward-backward asymmetry and to study high dilepton masses. The B-physics program is rich and even a low rate process as $B_s \to \mu^+\mu^-$ will reach a significance of 4σ after 3 years of running at low luminosity.

Acknowledgments

Many thanks to the organizers for the wonderful conference and to all CMS colleagues who provided inputs to this presentation.

References

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