Nady Bakhet

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PhD Thesis Title

Search for BSM Physics at the Hadron Colliders Using Artificial Neural Networks and Monte Carlo Simulation Techniques.

Supervisors

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National Research Nuclear University
Moscow Engineering Physics Institute - Russia

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Cairo University

M. Sc. Thesis Title

Phenomenology of B-L Model at the LHC Using Monte Carlo Simulation Techniques

In this presentation I will present some results of

Phenomenology of B-L Model

at the LHC

Using Monte Carlo Simulation Techniques

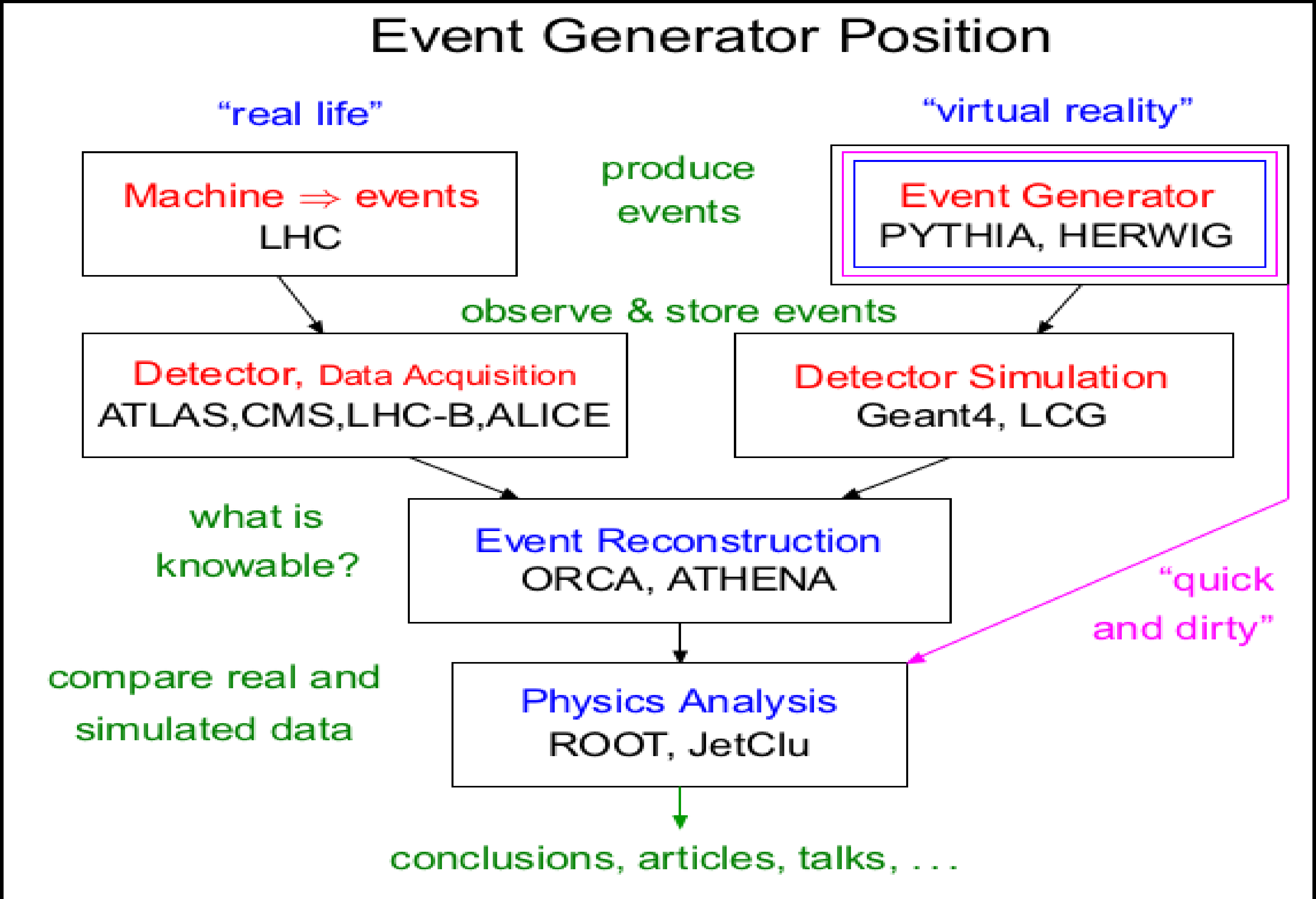
Contents

Introduction

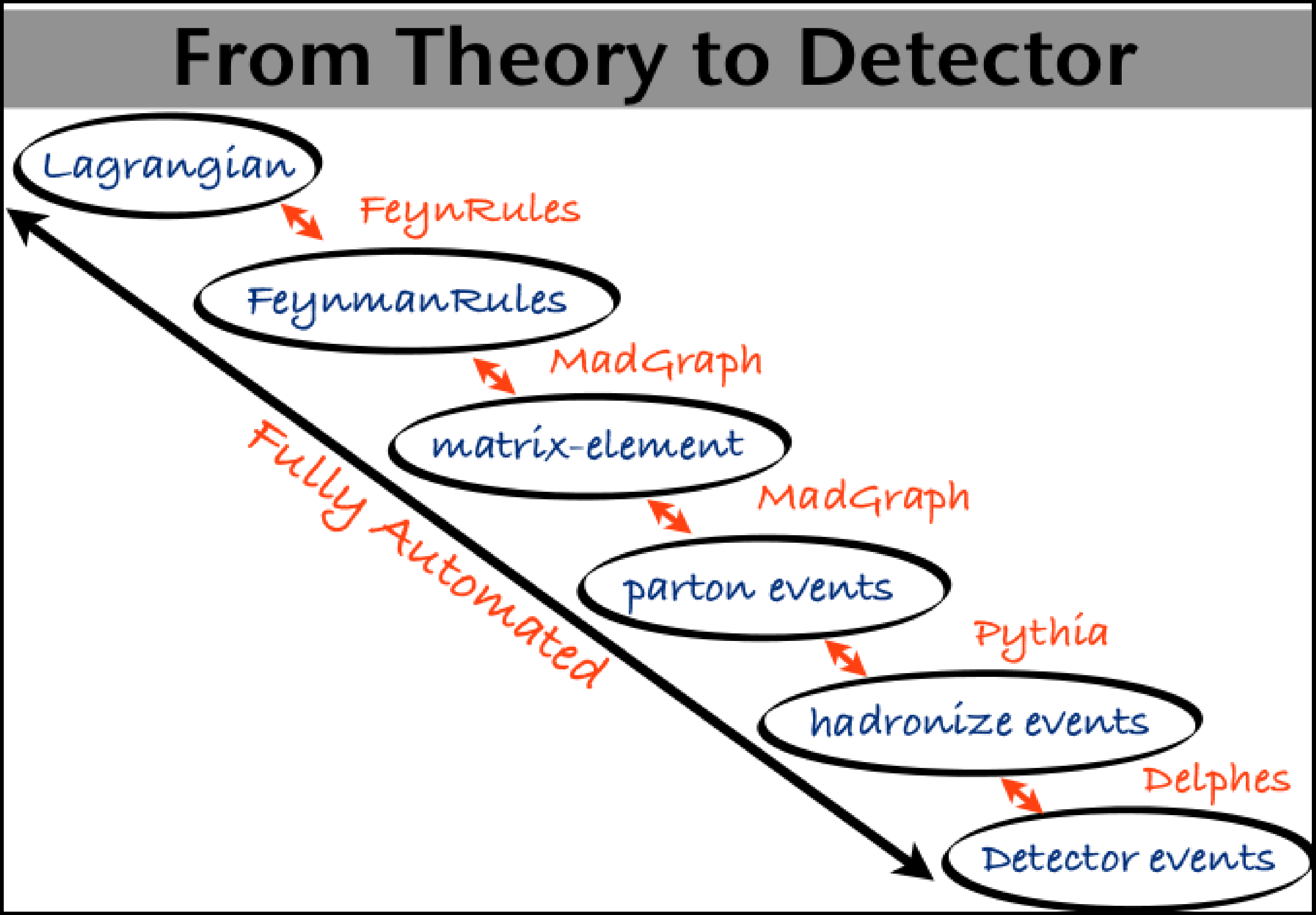
To simulate B-L model I used the programs:

- **FeyRules**
- **MadGraph5 /MadEvent**
- **CalcHep**
- **Pythia8**
- **Root**
- **PAW (Physics Analysis Workstation)**

Introduction



Introduction



Why We Need an Extension for Standard Model of Paeticles Physics ?

Introduction

The Standard Model of Particle Physics

1- Neutrino mass.
2- The existence of dark matter.
3- The observed matter-antimatter asymmetry
……

Form the previous reasons :
Many of its extensions that have been proposed to cure its flaws.

Introduction

Extensions of the Standard Models

There are many models as an extension for SM and are tested by LHC from these models

1- B-L Model → My M. Sc. Thesis (Z', H2,heavy neutrino)

2- Left-Right symmetry Model — W', H^{++} , Z'

3-Two Higgs Doublet Higgs Model — My PhD Thesis

5-Fourth generation Model — t', b'

B-L Model extension of SM

Baryon number minus ***L***epton number model

B-L model

B-L model is one of many extensions of the standard model which predicts the existence of three new physics states at LHC new neutral massive gauge boson Zprime , Heavy Neutrino and new scalar gauge boson Higgs rather than SM Higgs boson.

Example : Beta Decay:

$$\begin{array}{lcccccccc} & n & \rightarrow & p & + & e^- & + & \overline{\nu}_e \\ L: & 0 & = & 0 & + & 1 & - & 1 \end{array}$$

Violations of the lepton number conservation laws

Example : Louis Michel Decay

$$\begin{array}{lccccccccc} & \mu^- & \longrightarrow & e^- & + & \nu_e & + & \overline{\nu}_\mu \\ L: & 1 & = & 1 & + & 1 & - & 1 \\ L_e: & 0 & \neq & 1 & + & 1 & + & 0 \\ L_\mu: & 1 & \neq & 0 & + & 0 & - & 1 \end{array}$$

If the lepton number non conservation then :

The quantum number *B* − *L* is much more likely to work and is seen in different models such as the B-L Model .

***B* − *L* is the difference between the baryon number (*B*) and the lepton number (*L*).**

If *B* − *L* exists as a symmetry, it gives heavy neutrinos and neutral gauage boson Zprime and new Higgs

Example :

$$p \rightarrow e^{+} + \pi^{0}$$

proton (*B* = 1; *L* = 0) → pion (*B* = 0, *L* = 0) + positron (*B* = 0; *L* = −1)

B-L : 1 = 0 + 1

B-L model is a proposal model as an extension for SM based on the gauge group $G_{B-L} = SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)_{B-L}$ where the invariance of the Lagrangian under this gauge symmetry implies the existence of a new gauge boson (beyond the SM ones) and the spontaneous symmetry breaking in this model provides a natural explanation for the presence of three right-handed neutrinos in addition to an extra gauge boson and a new scalar Higgs. Therefore, it can lead to very interesting phenomenological different from the SM results which can be tested at the LHC .

B-L quantum number for different particles

particle	B-L charge
l	-1
q	1/3
e_R	-1
ν_R	-1

RESULTS

Simulation of B-L model at LHC

Part 1	**Gauge Sector**	**Heavy Boson**
Part 2	**Fermion Sector**	**Heavy neutrino**
Part 3	**Scalar Sector**	**Heavy Higgs**

In current work we used the data produced from Monte Carlo program for proton-proton collision at LHC for different CM energy to simulated the production and decay the three particles of B-L model at Large Hadron Collider calculated :

Z' boson , Heavy Higgs , Heavy Neutrino

1- The production Cross Section of the particl

2-Branching Ratios for every decay channel

3- Detection the Signal of the particle

B-L model at LHC

Part 1

Gauge Sector

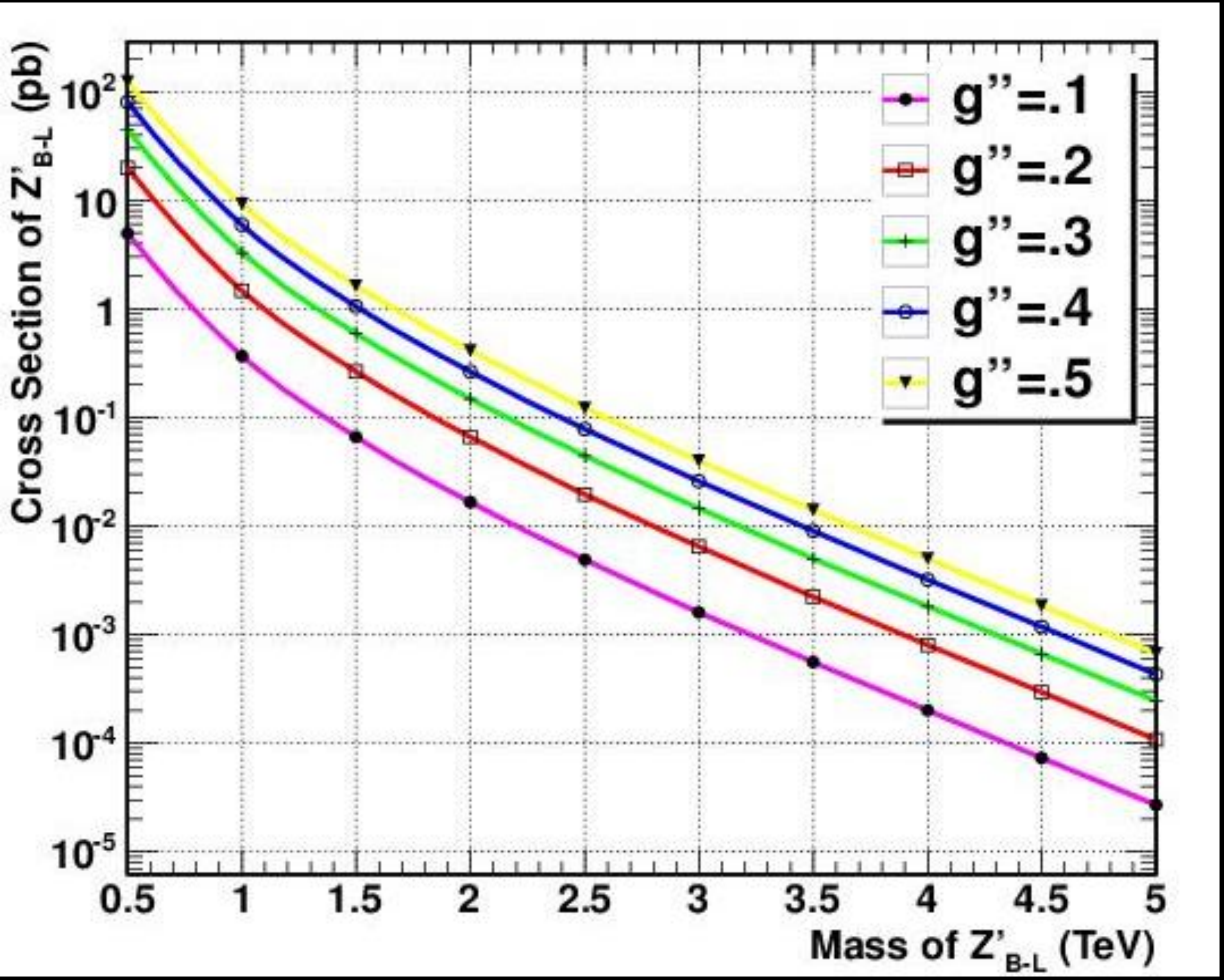
New Heavy Neutral Gauge Boson

Open Journal of Microphysics
Vol.3 No.2 (2013),9 pages
DOI: 10.4236/ojm.2013.32007

arXiv:1206.4533

Production Cross Section

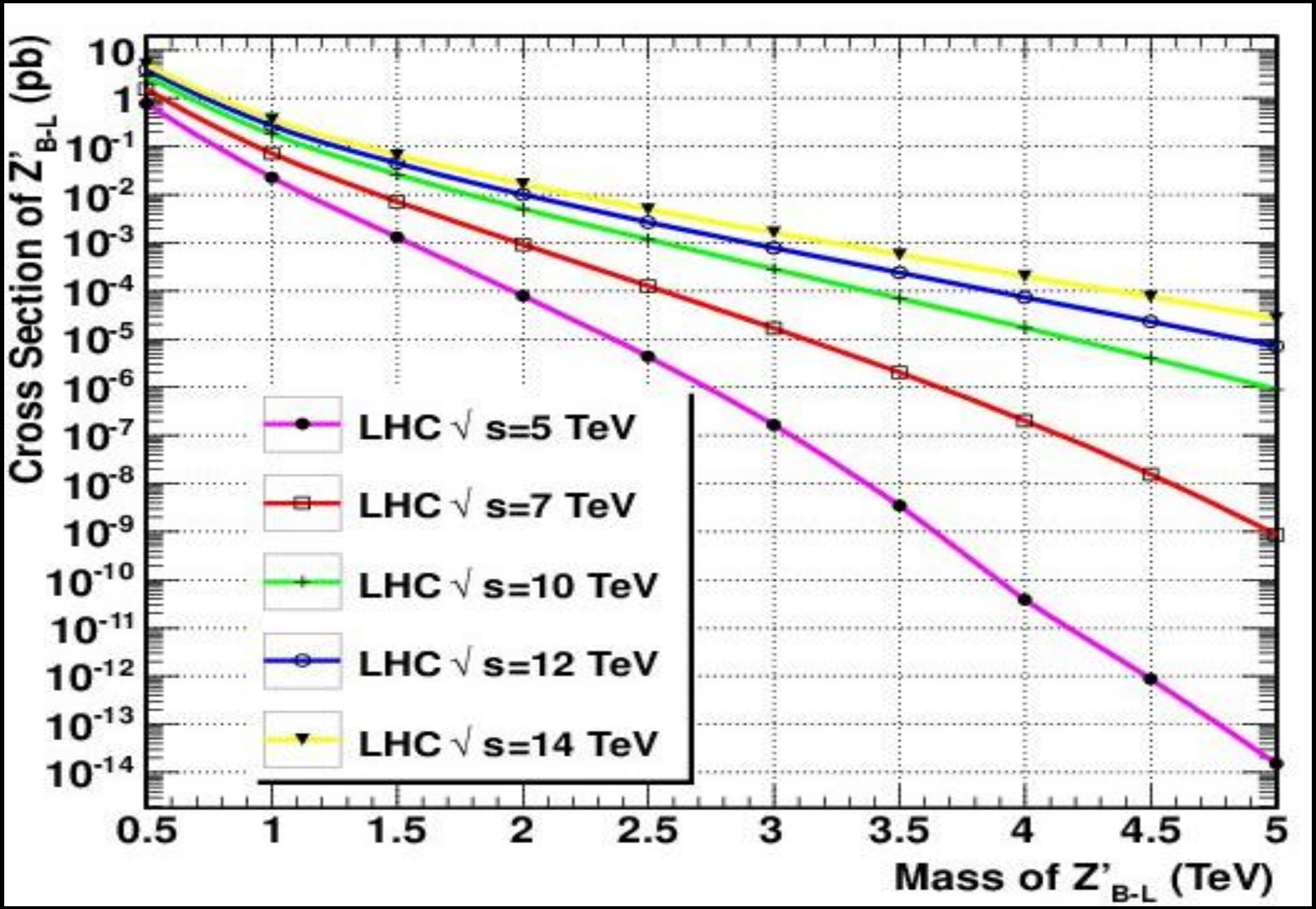
Cross section of Z' as a function of its mass for various g" values at fixed CM energy of LHC=14 TeV



experimental constraint from CDF experiment

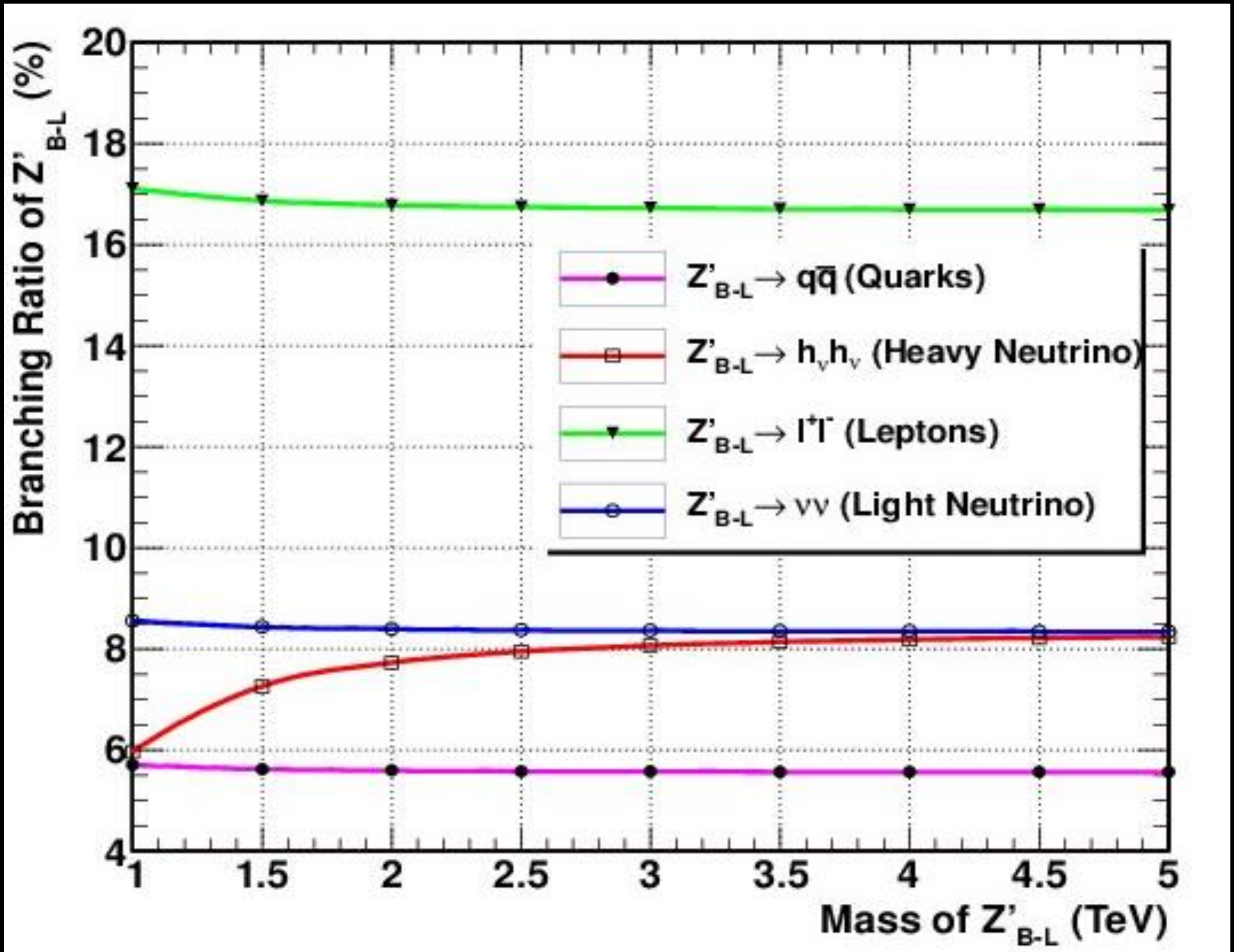
$$\frac{Z'}{g''} > 6\,TeV$$

Cross section of Z' as a function of its mass for various energies of LHC at √s = 5, 7, 10, 12, 14 TeV at fixed value of g” =0.2



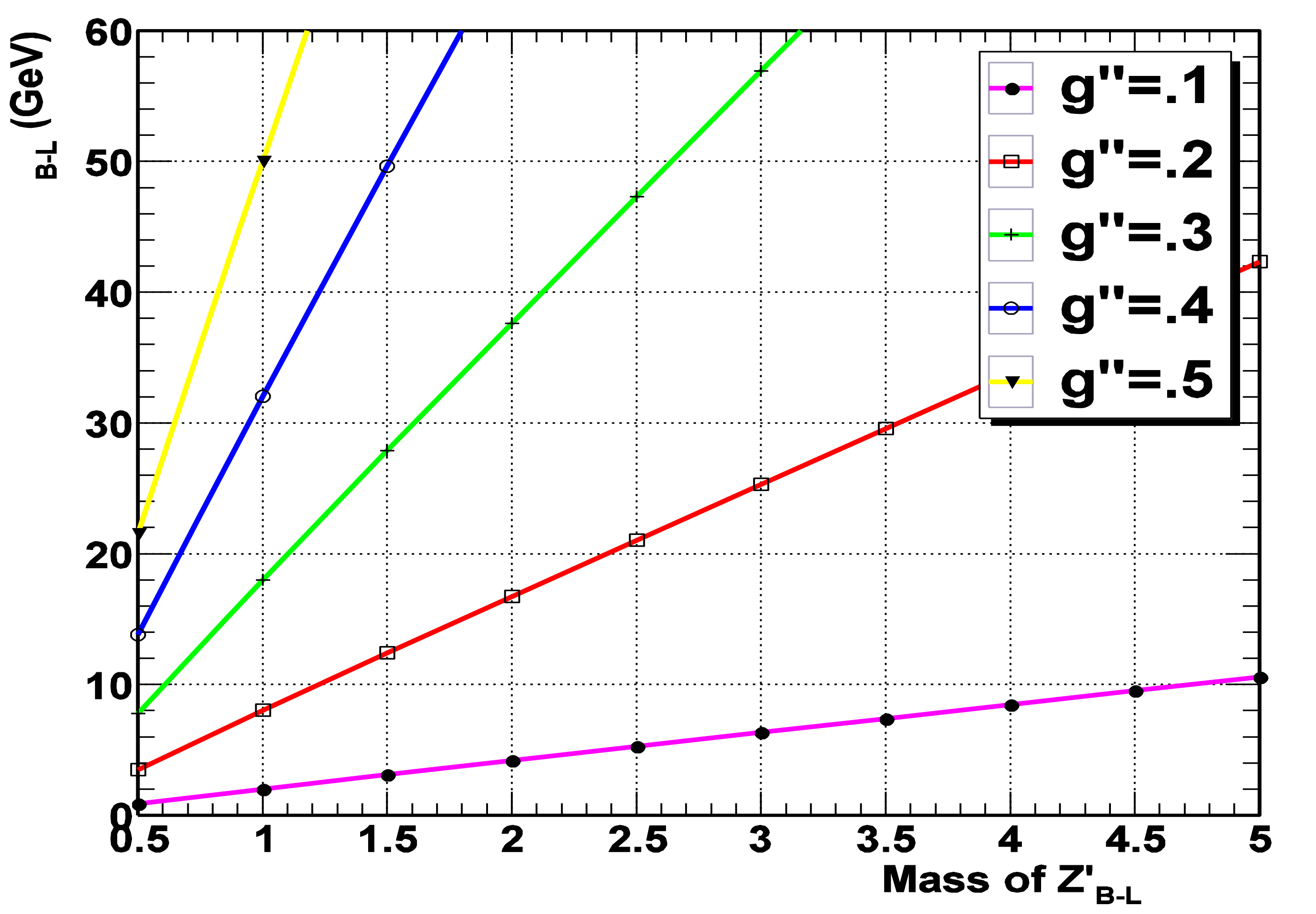
Branching Ratios

Branching ratios for Z' as a function of its mass



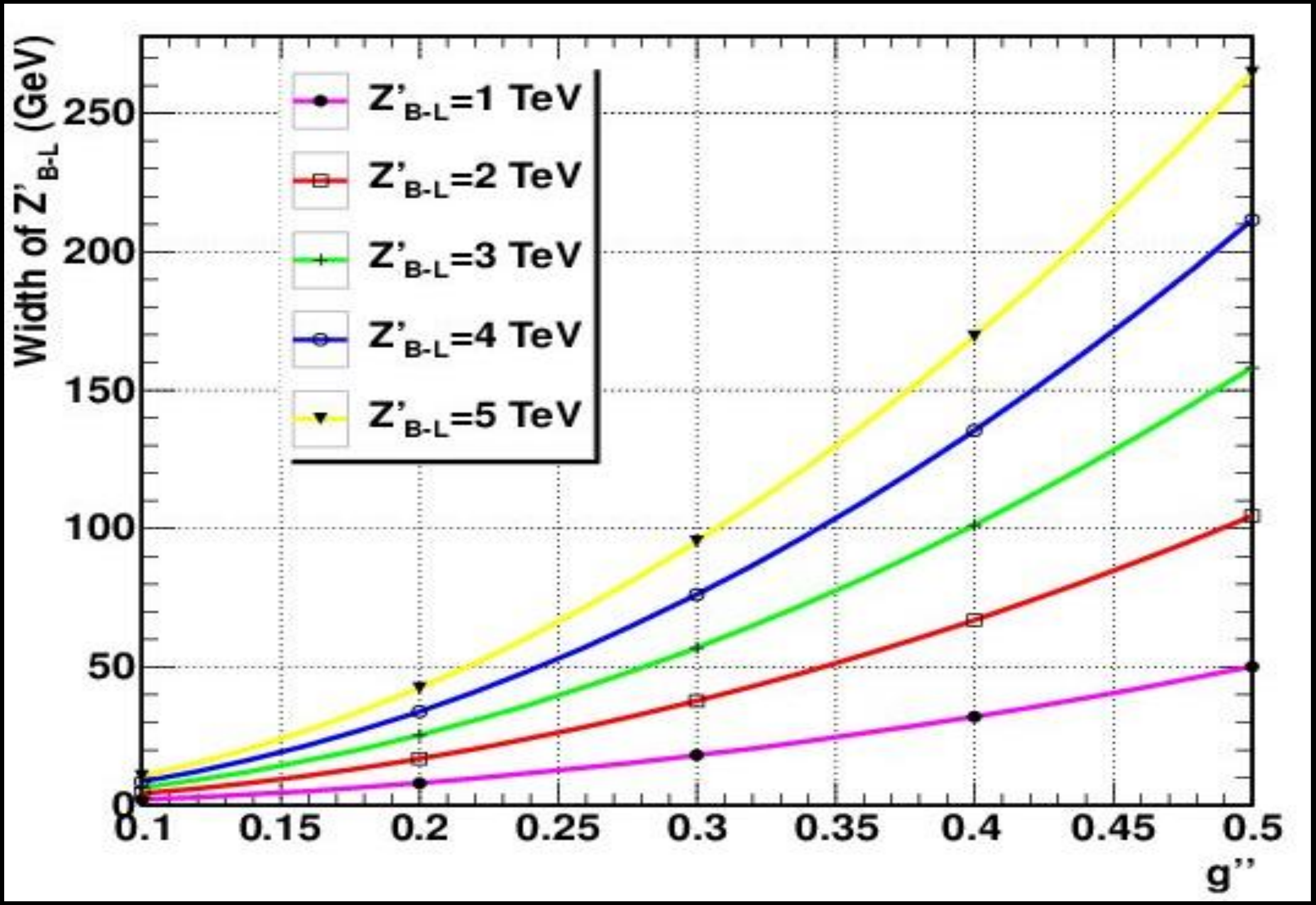
Total Width of Z'

Total Width for Z' as a function of its mass for fixed values of g”



Total Width of Z'

Total Width for Z' as a function of g'' for fixed values of mass of Z'



Detection of Z' signal at LHC

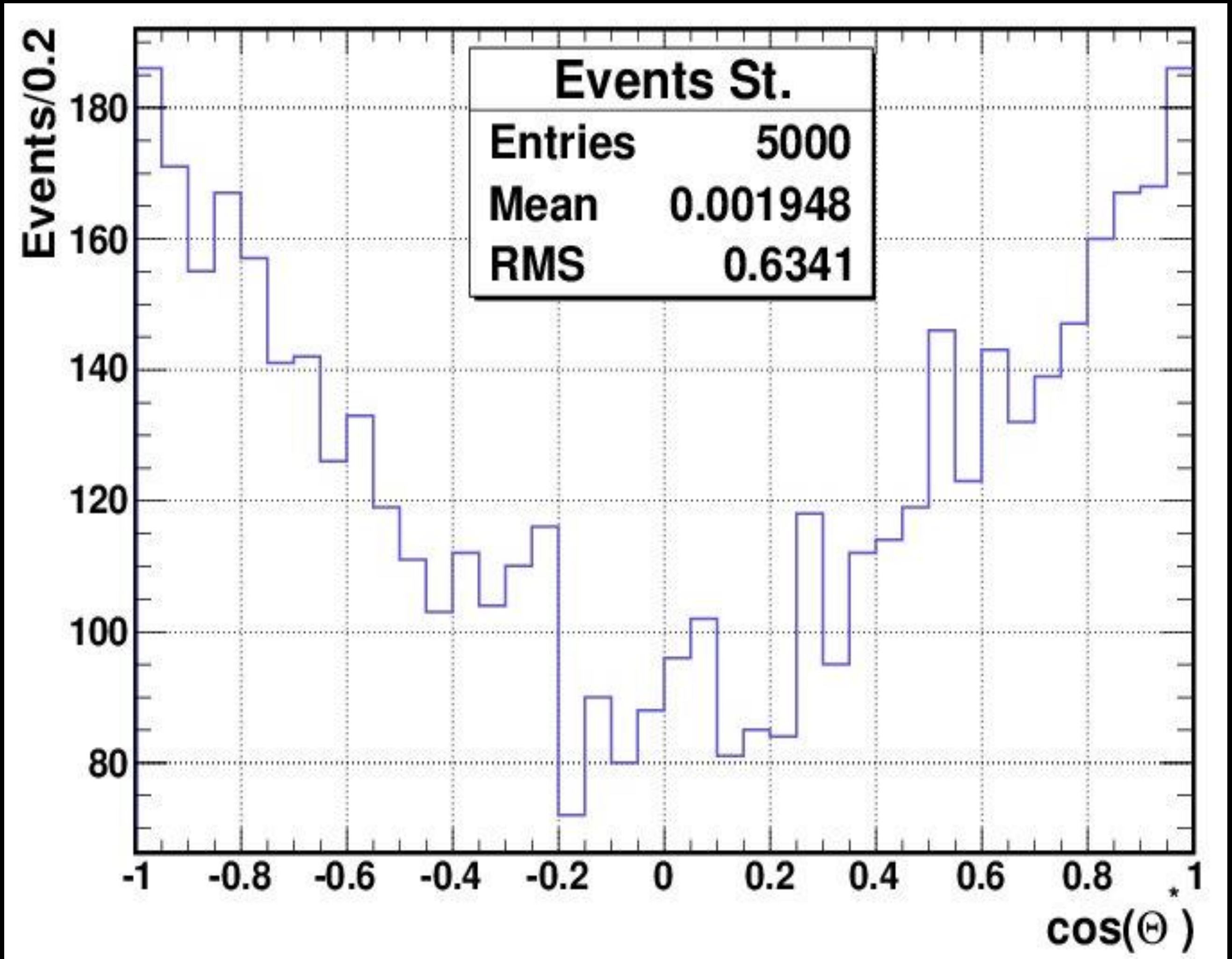
1 Dielectron Angular Distribution

The angular distribution of the dilepton events can also be used to test the presence

$$Z' \rightarrow e^+ + e^-$$

So we will use the dielectron angular distribution cos (θ) where θ is the angle in the dielectron rest reference frame between the electron and the incident incoming quark.

Angular distribution of dielectron of Z' boson decay where forward electrons have cos(θ) > 0 and backward electrons have cos(θ) < 0



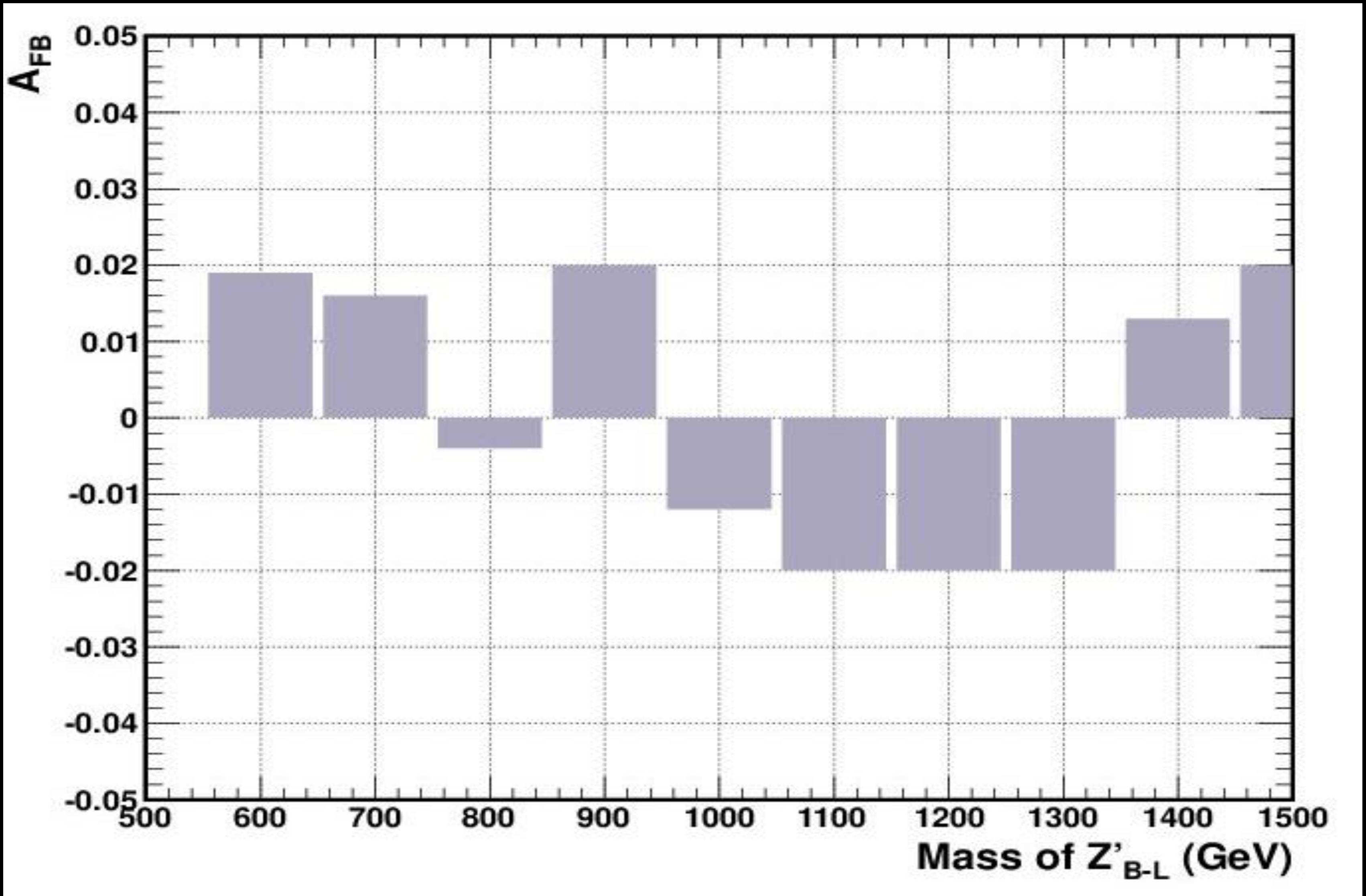
2 Dielectron Asymmetry A_{FB}

$$A_{FB} = \frac{N_f - N_b}{N_f + N_b}$$

the general form of the asymmetry

mass (GeV)	Forward Electrons N_F $\cos(\theta) > 0$	Backward Electrons N_B $\cos(\theta) < 0$	Asymmetry A_{FB}
1500	1531	1469	0.020
1400	1520	1480	0.013
1300	1470	1530	– 0.02
1200	1470	1530	– 0.02
1100	1470	1530	– 0.02
1000	1482	1518	– 0.02
900	1531	1469	0.020
800	1498	1510	– 0.004
700	1524	1476	0.016
600	1529	1471	0.019
500	1500	1500	0.000

Dielectron asymmetry distribution for forward and backward electrons for various values of Z'



3

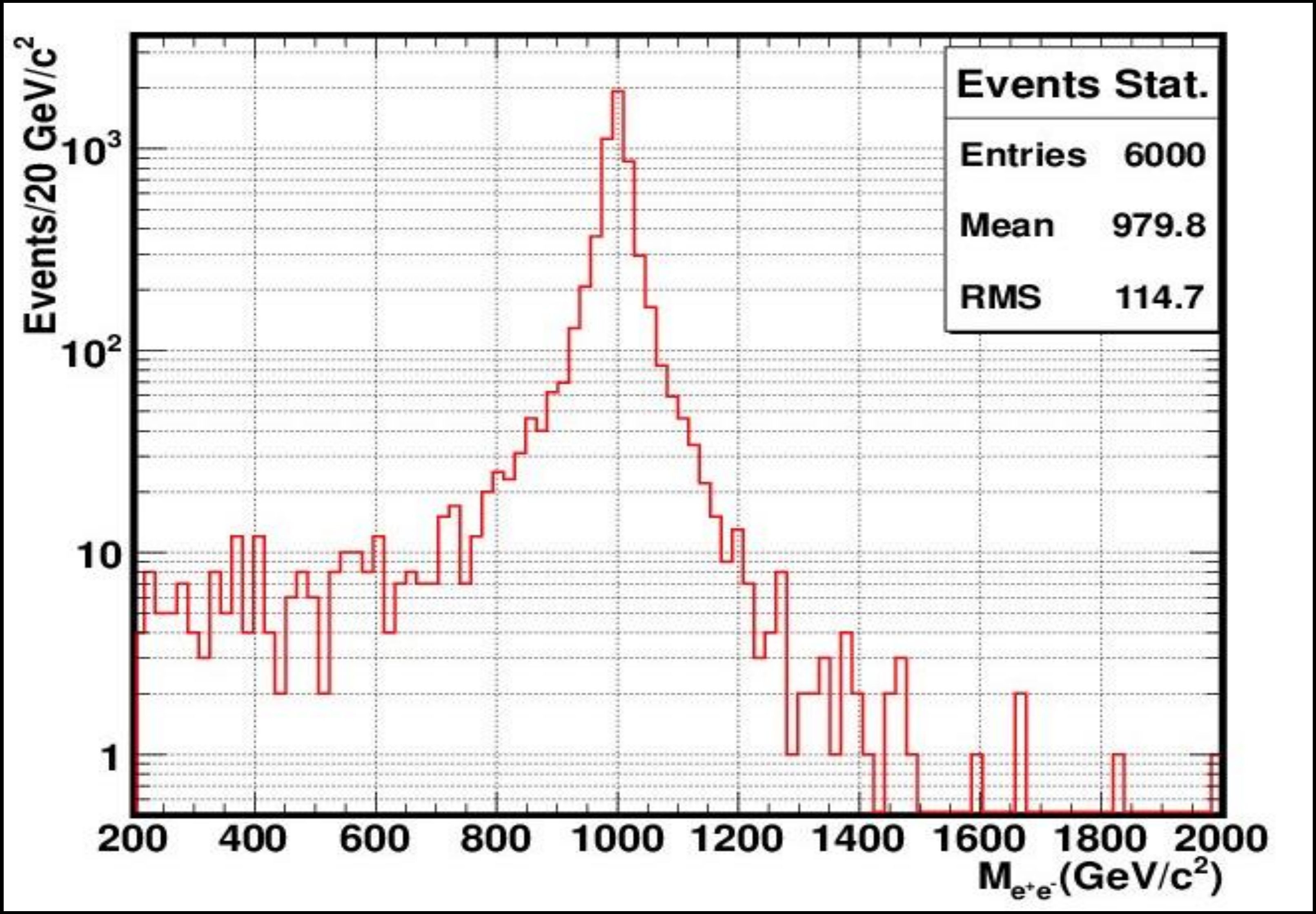
Dielectron Invariant Mass

we used the dilepton invariant mass $M_{e^+e^-}$

from the dilepton events to test the presence of a

boson at LHC

$$Z' \rightarrow e^+ + e^-$$



The reconstruction for Z' mass from produced dilectron invariant masses

B-L Model at the LHC

Part 2

Fermion Sector

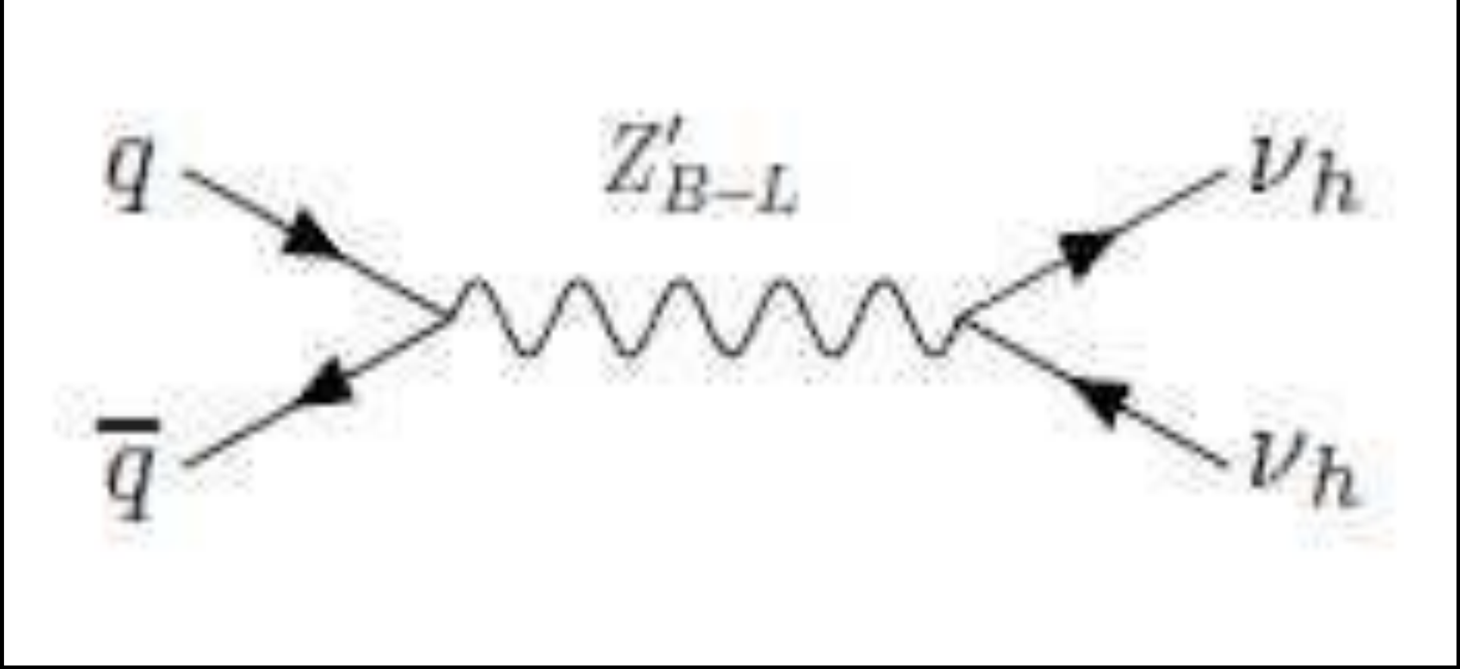
Heavy Neutrino

Open Journal of Microphysics
Vol.3 No.1(2013), Article ID:28227,6 pages
DOI:10.4236/ojm.2013.31003
arXiv:1206.4534

Production Cross Sections

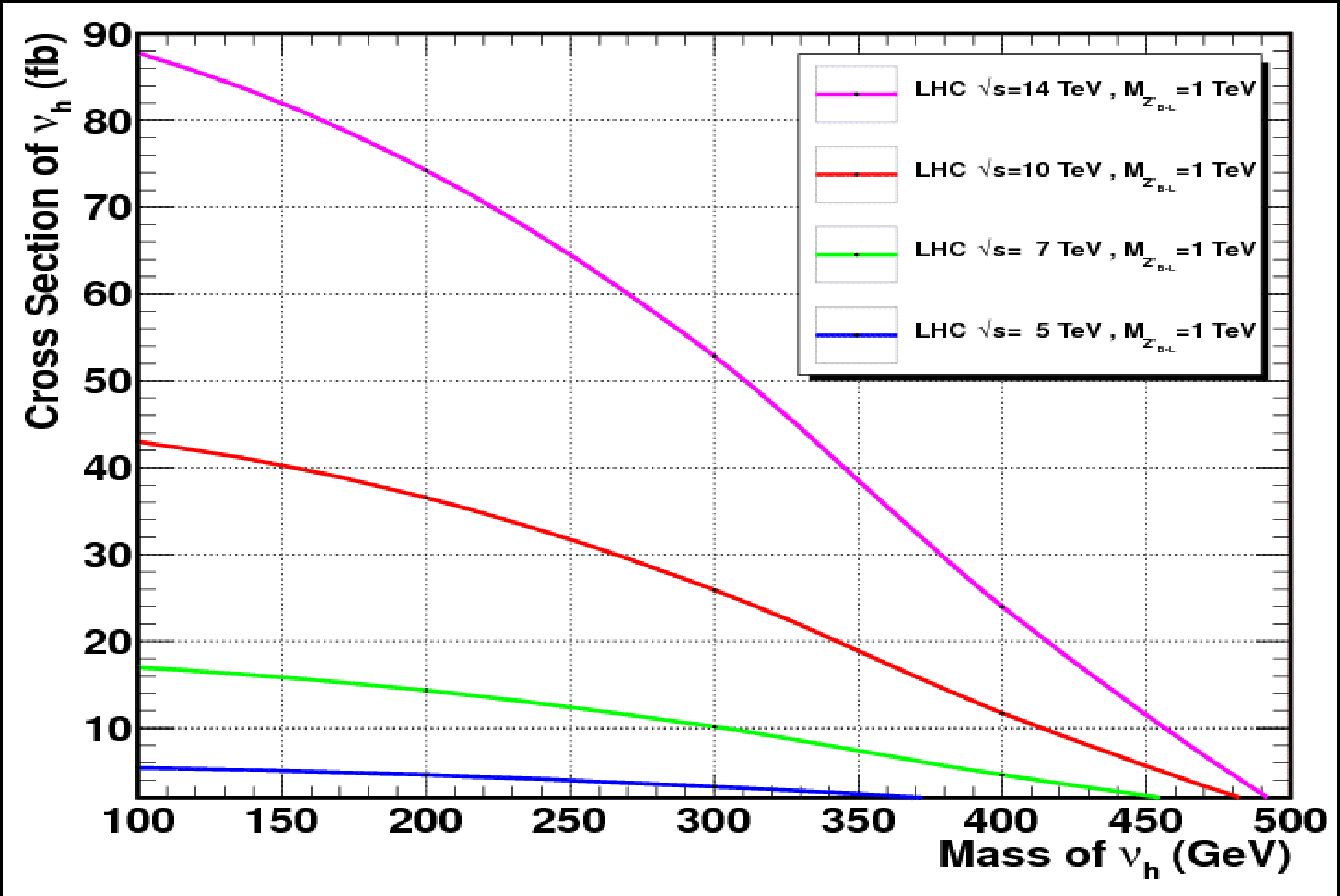
B-L model predicts by existence 3 heavy neutrinos one per generation at LHC via the decay of Z' gauge boson

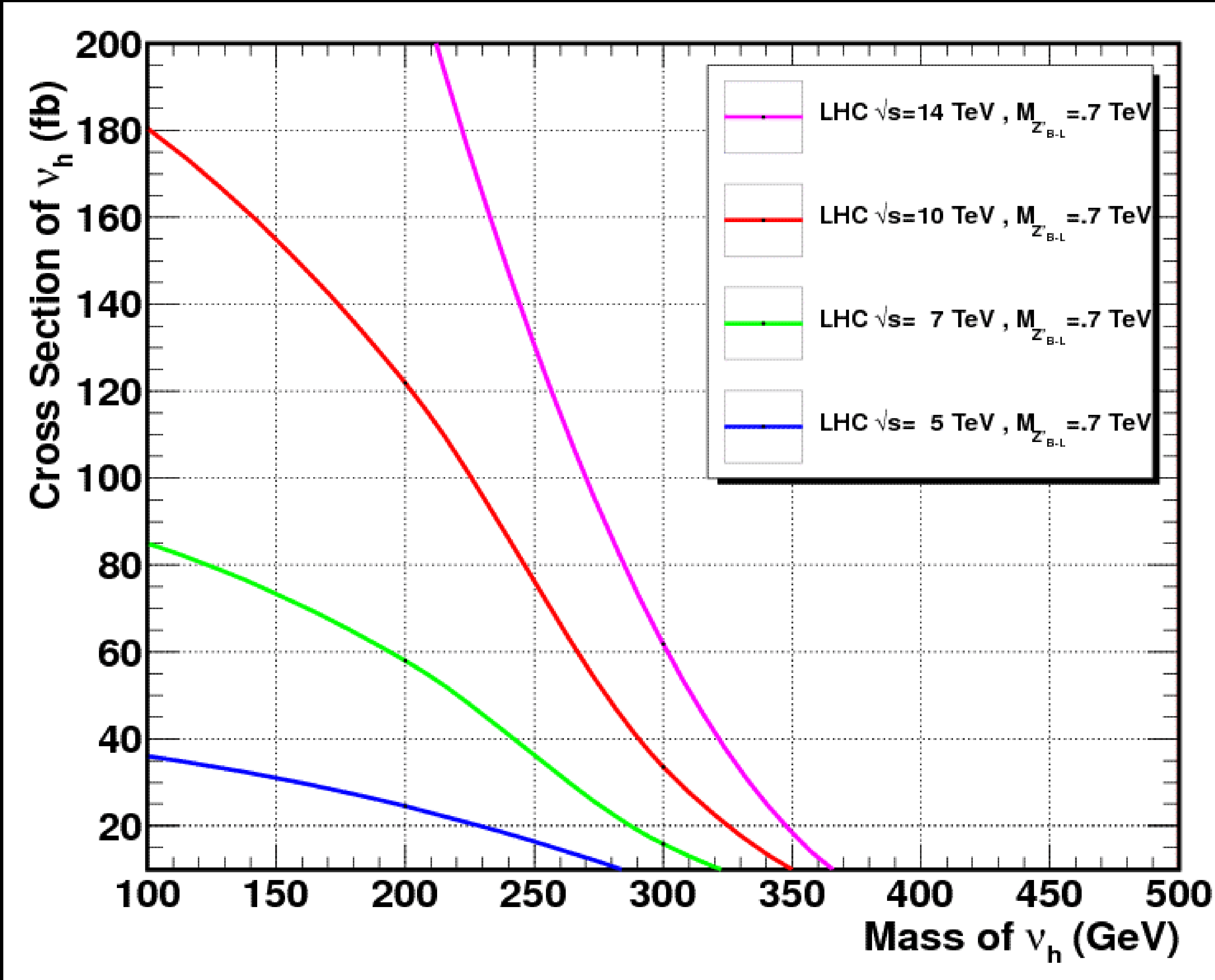
$$pp \rightarrow Z' \rightarrow \nu_h \, \nu_h$$



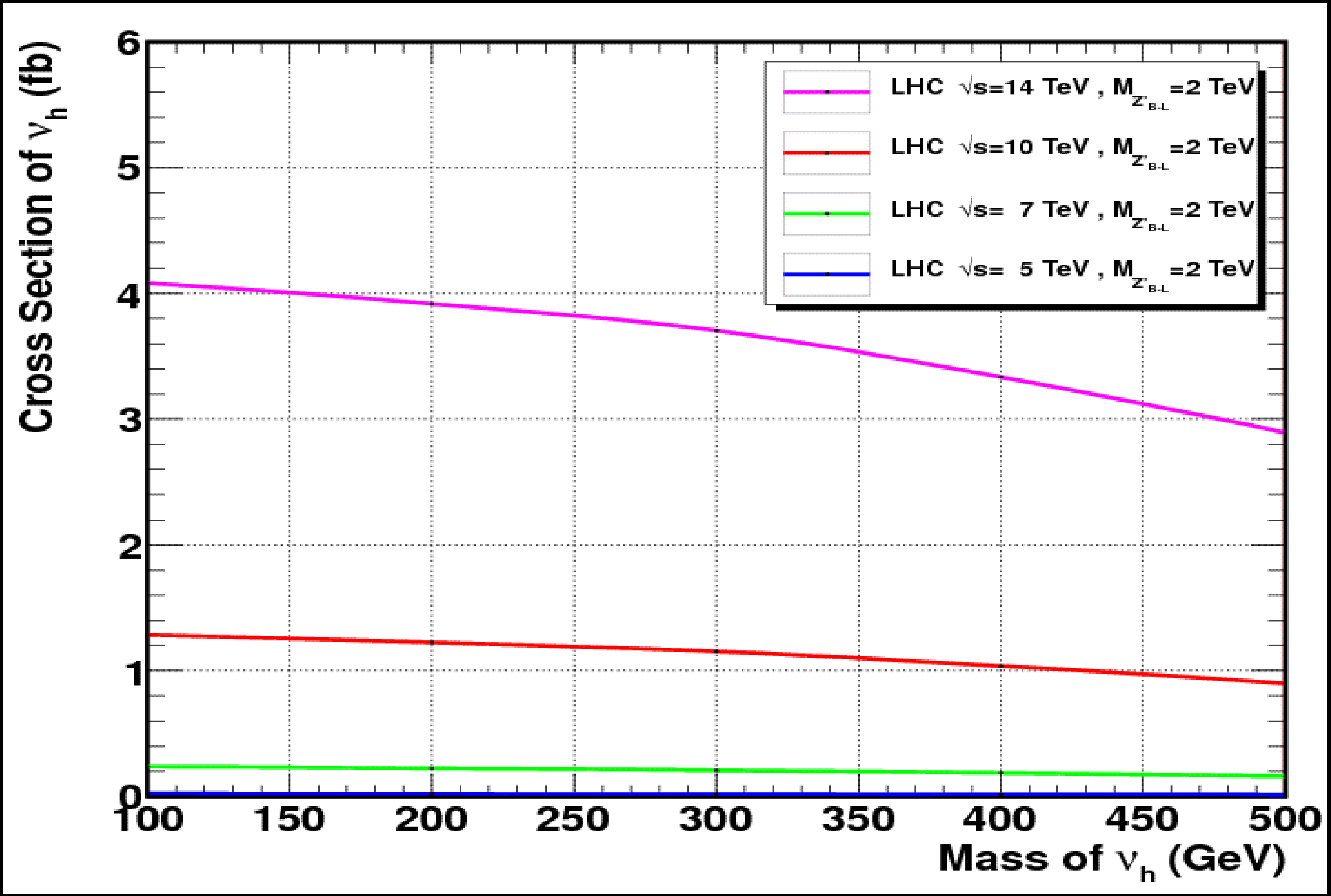
Feynman diagram for Heavy Neutrino pair production

Heavy neutrino pair production cross sections at the LHC for √s = 5,7,10 and 14 TeV and Z' mass 1 TeV

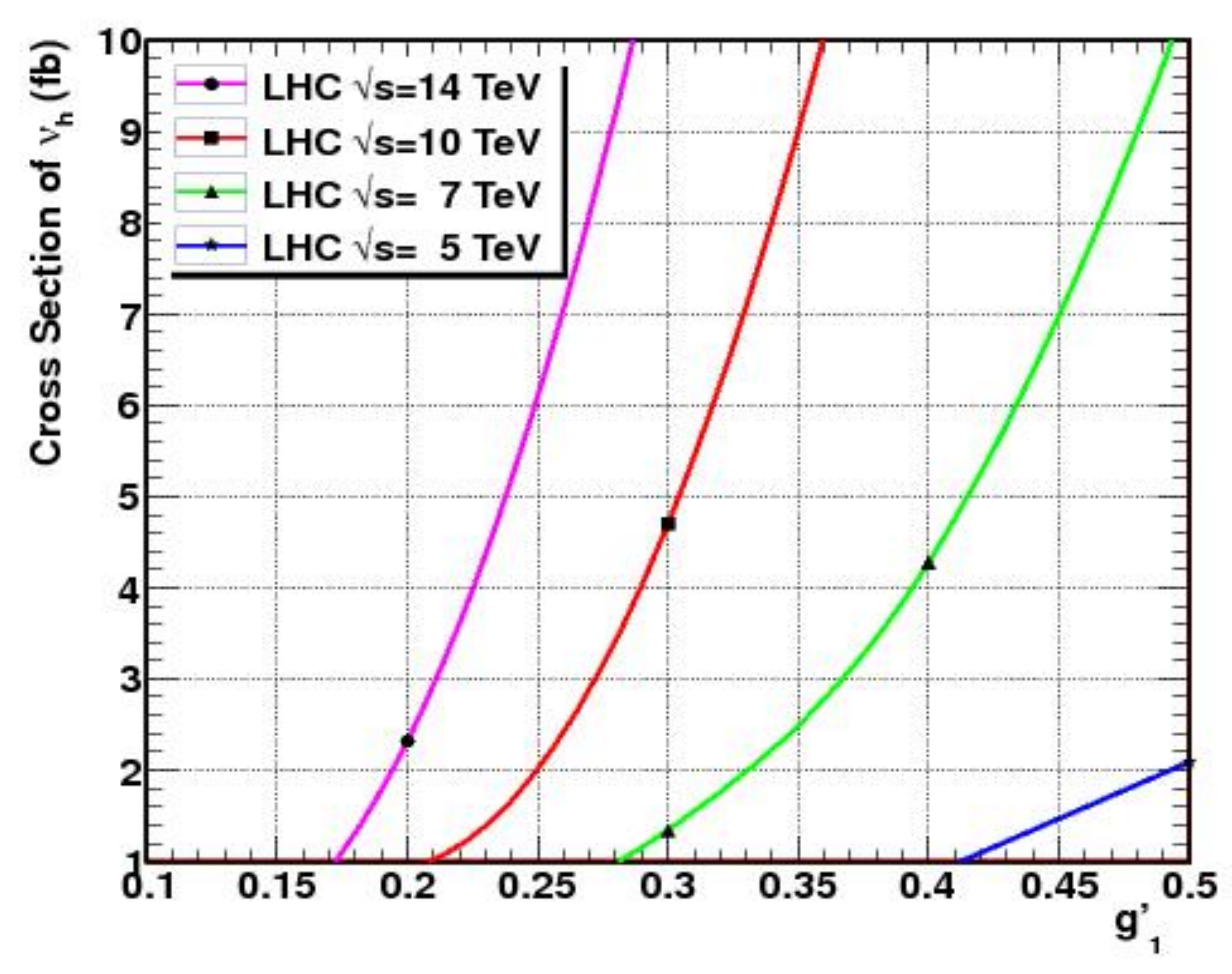




Cross Section of ν_h (fb)
Mass of ν_h (GeV)
LHC $\sqrt{s}$=14 TeV , $M_{Z'_{B-L}}$ =.7 TeV
LHC $\sqrt{s}$=10 TeV , $M_{Z'_{B-L}}$ =.7 TeV
LHC $\sqrt{s}$= 7 TeV , $M_{Z'_{B-L}}$ =.7 TeV
LHC $\sqrt{s}$= 5 TeV , $M_{Z'_{B-L}}$ =.7 TeV
200
180
160
140
120
100
80
60
40
20
100
150
200
250
300
350
400
450
500



Cross Section of ν_h (fb)
Mass of ν_h (GeV)
LHC √s=14 TeV , $M_{Z'_{B-L}}$ =2 TeV
LHC √s=10 TeV , $M_{Z'_{B-L}}$ =2 TeV
LHC √s= 7 TeV , $M_{Z'_{B-L}}$ =2 TeV
LHC √s= 5 TeV , $M_{Z'_{B-L}}$ =2 TeV
0
1
2
3
4
5
6
100
150
200
250
300
350
400
450
500



Cross Section of ν_h (fb)
LHC √s=14 TeV
LHC √s=10 TeV
LHC √s= 7 TeV
LHC √s= 5 TeV
10
9
8
7
6
5
4
3
2
1
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
g'_1

Heavy Neutrino Decays

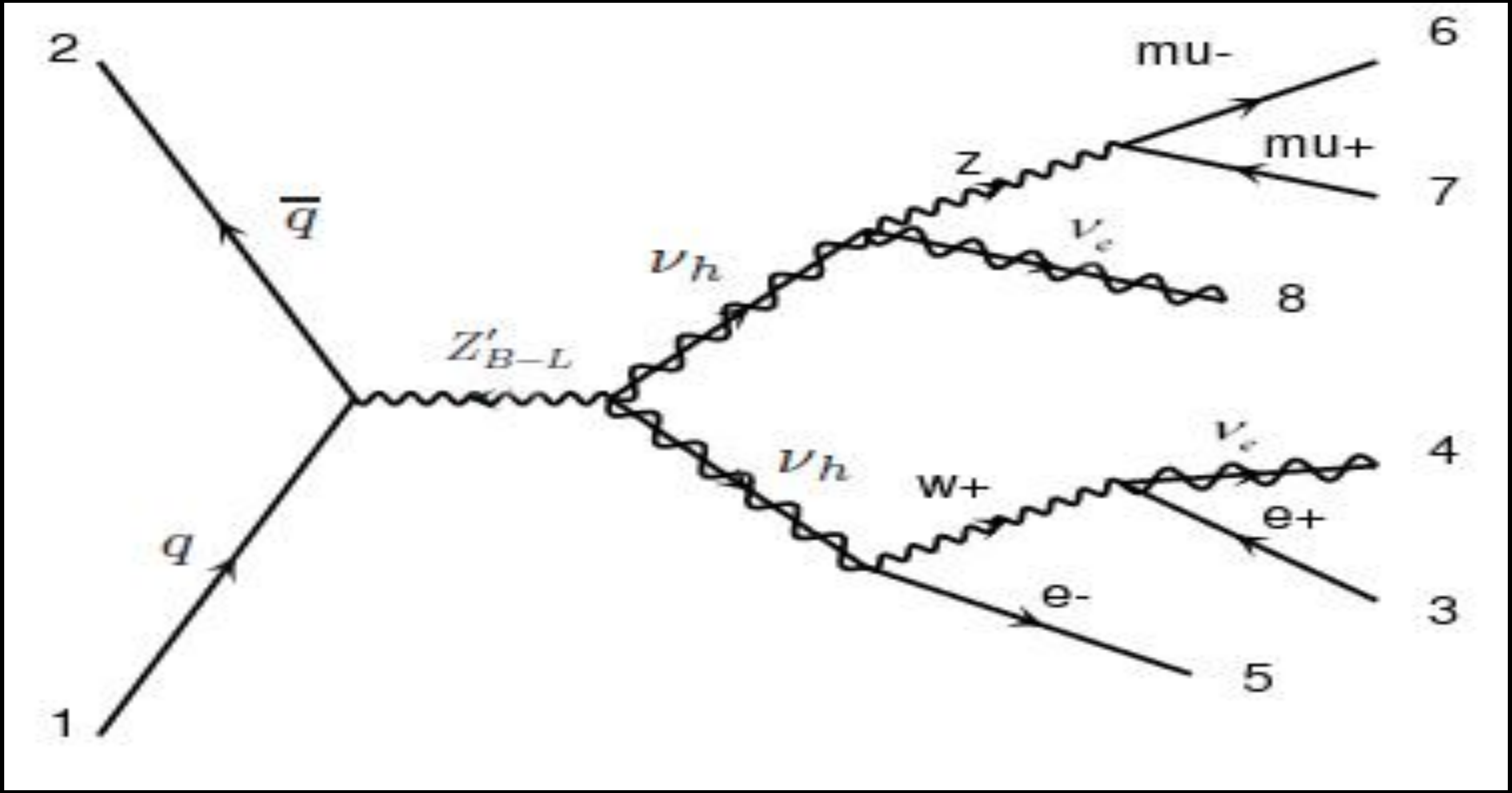
The detection of the signal coming from the pair production of the heavy neutrinos in the B-L model at LHC will be through very clean signal for four charged leptons in the final states and missing energy due to the associated neutrinos .

The first heavy neutrino dominant decay is to a W^+ boson and a charged lepton here is e^+

The second heavy neutrino decays to Z boson and a light neutrino.

Feynman diagram for heavy neutrino pair production and its decay in B-L model

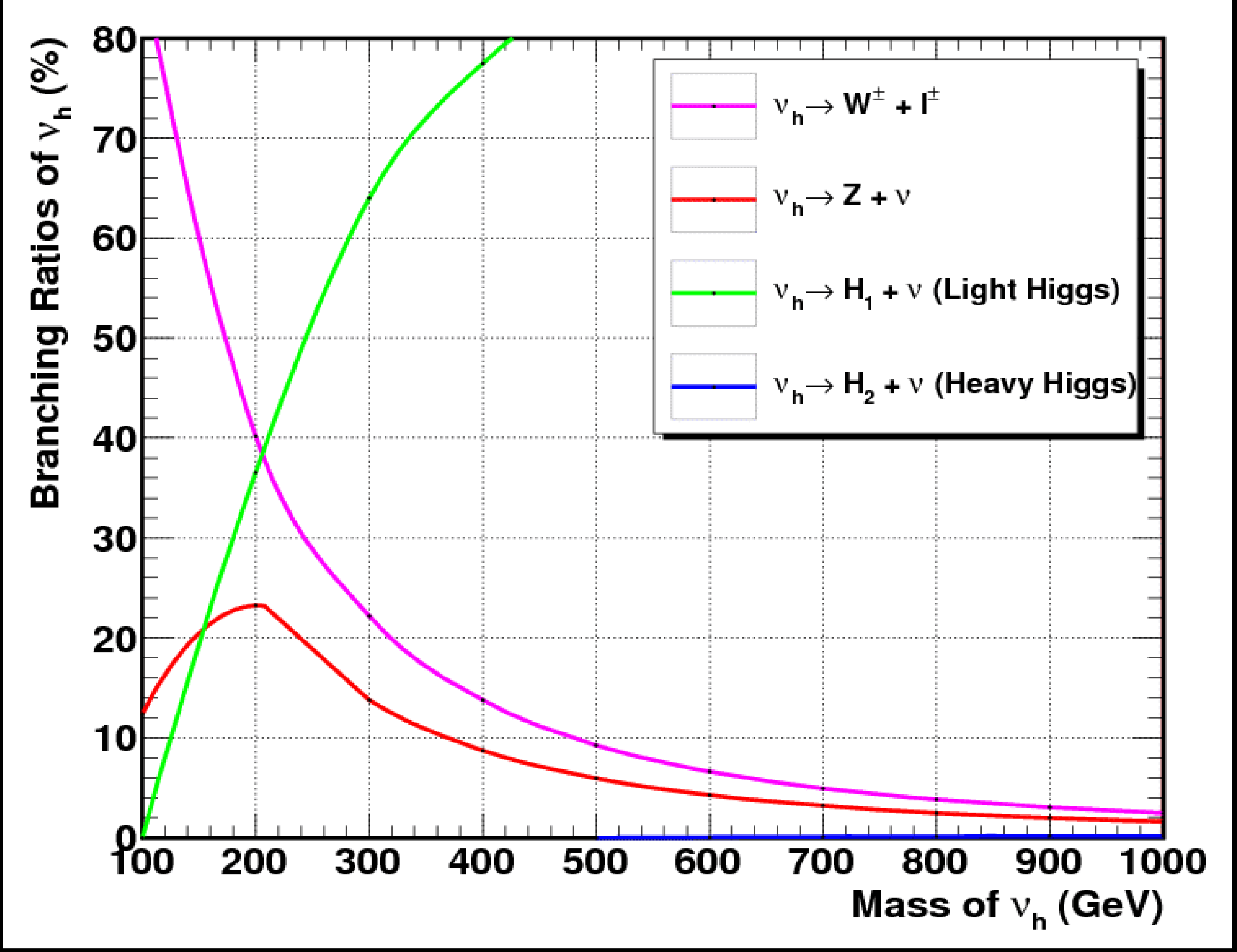
pp→ Z' → $\nu_h \nu_h$ → μ- μ+ e- e+ + missing Energy



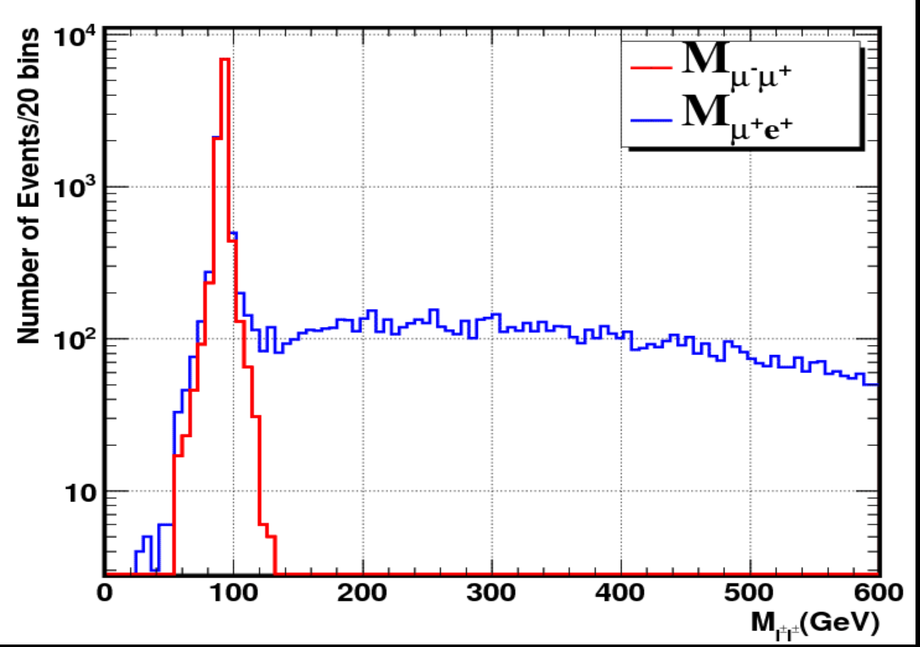
Branching Ratios

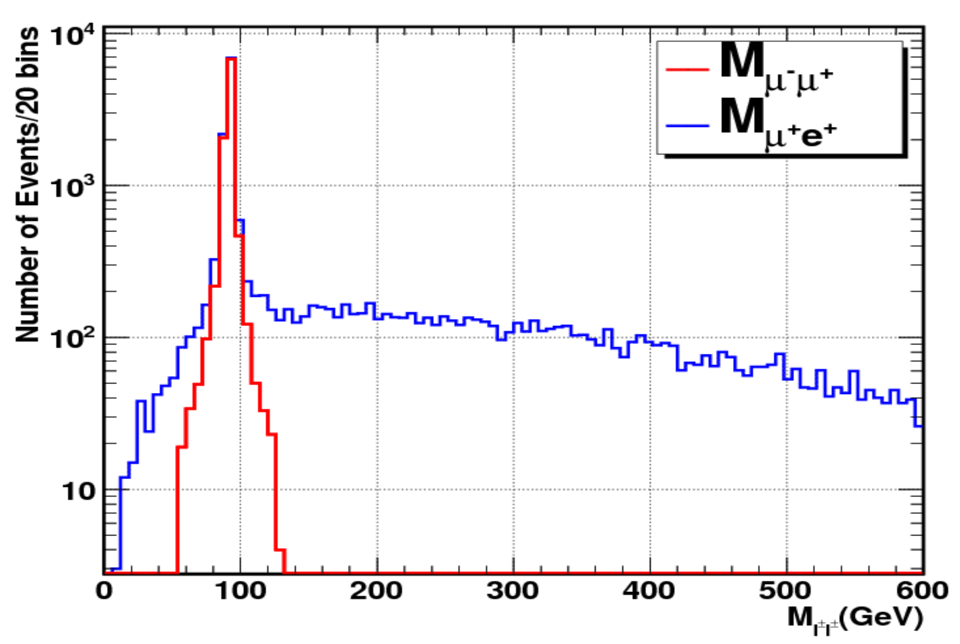
Heavy neutrino has 4 decay channels

$$\nu_h \rightarrow W^{\pm} + l^{\pm}$$
$$\nu_h \rightarrow Z + \nu$$
$$\nu_h \rightarrow H_1 + \nu$$
$$\nu_h \rightarrow H_2 + \nu$$



The branching ratios for the different decay channels versus different heavy neutrino masses. B-L model includes H1 SM-like Higgs boson and H2 heavy Higgs boson. One can notice from this figure that the ratio of the decay channel BR ($v_h \rightarrow W\pm + l\pm$) is the highest ratio in comparison with the other decay channels.

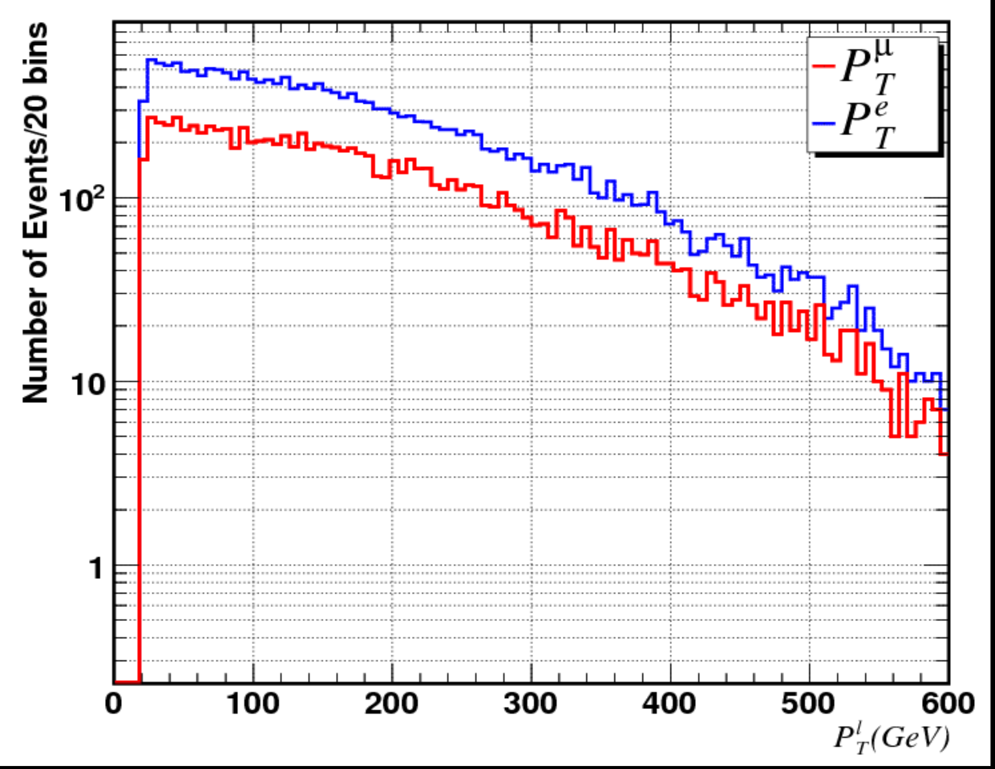




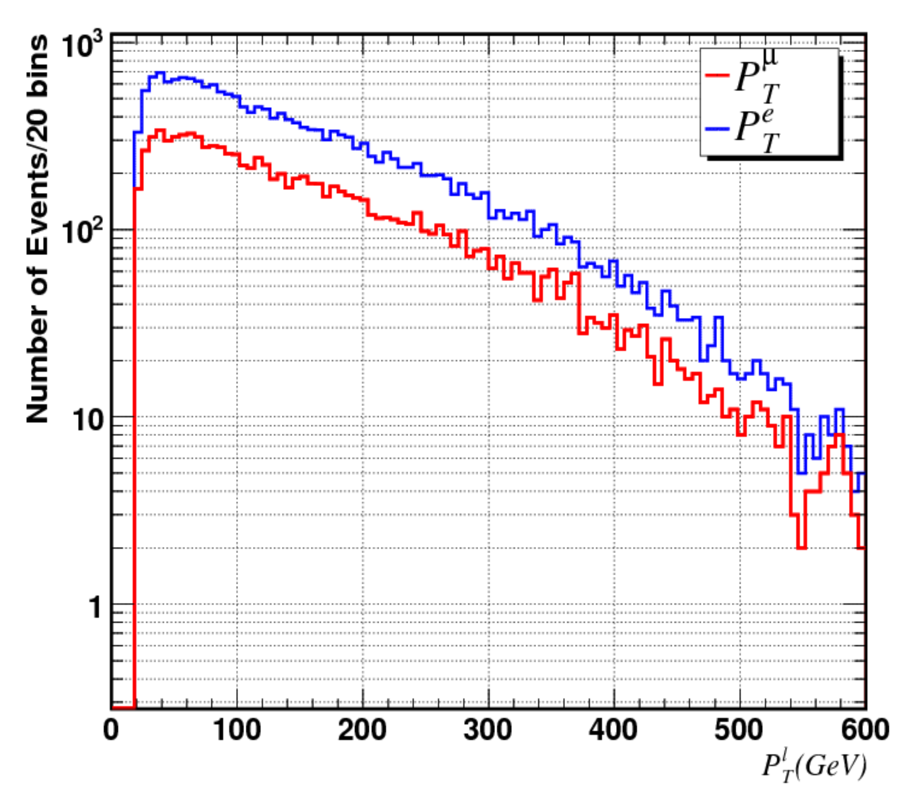
A

B

Distribution of the invariant mass of the charged lepton pairs in the final state (a) for heavy neutrino mass = 200 GeV and (b) for heavy neutrino mass = 400 GeV for LHC √s = 14 TeV CM energy, Z' mass = 1.5 TeV and g'' = 0.2

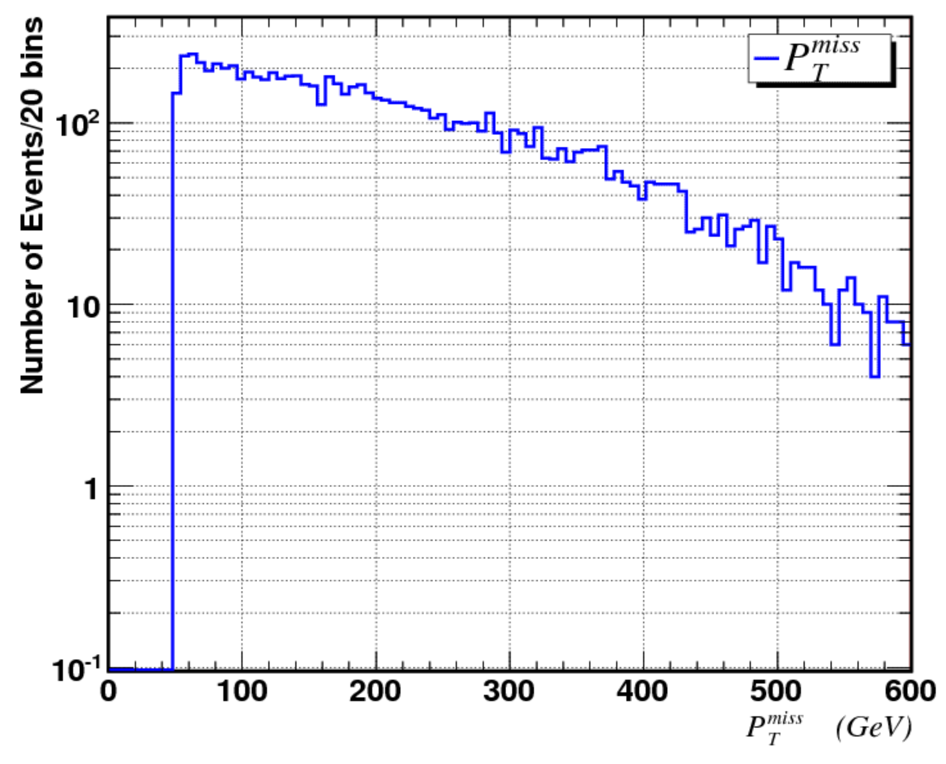


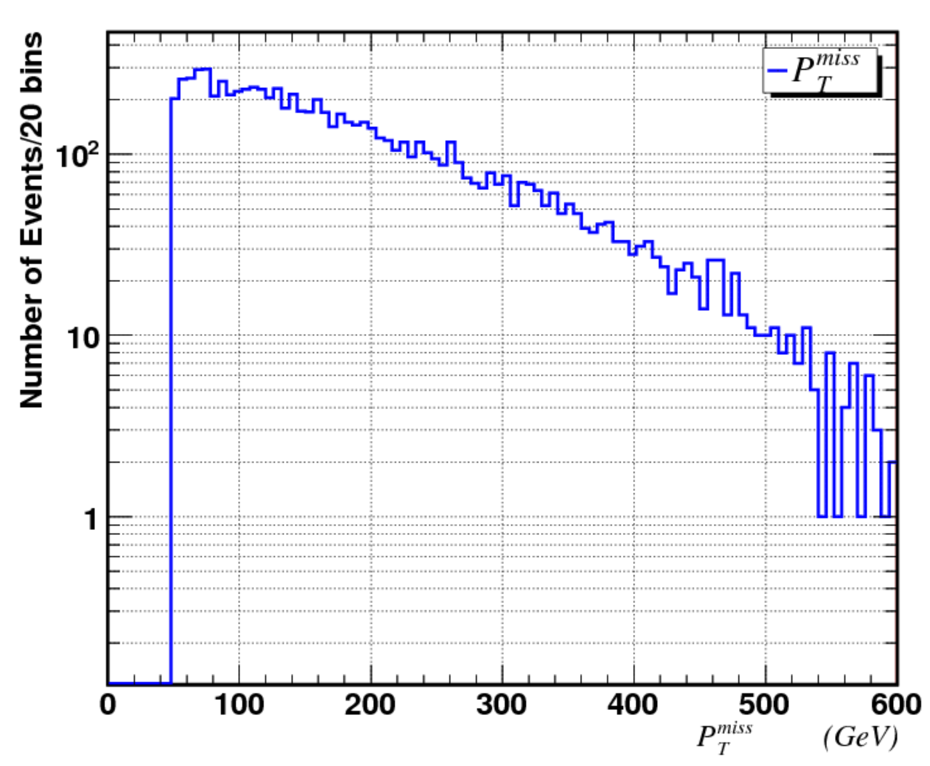
A



B

Distribution of transverse momentum for the e different charged leptons in the final state (a) for heavy neutrino mass = 200 GeV and (b) for heavy neutrino mass = 400 GeV for LHC √s = 14 TeV CM energy, Z' mass = 1.5 TeV and g'' = 0.2.





A

B

Distribution of the missing transverse momentum, for the 4l + signal : (a) for heavy neutrino mass = 200 GeV and (b) for heavy neutrino mass = 400 GeV for LHC √s = 14 TeV CM energy, ma ass = 1.5 TeV and g'' = 0.2 .

B-L model at the LHC

Part 3

Scalar Sector

Heavy Higgs

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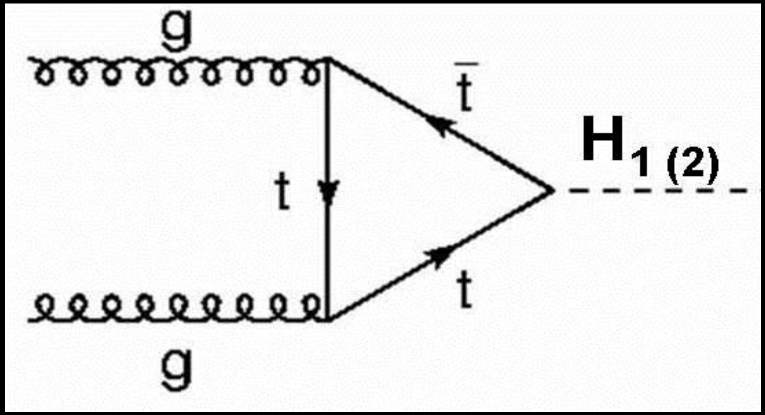
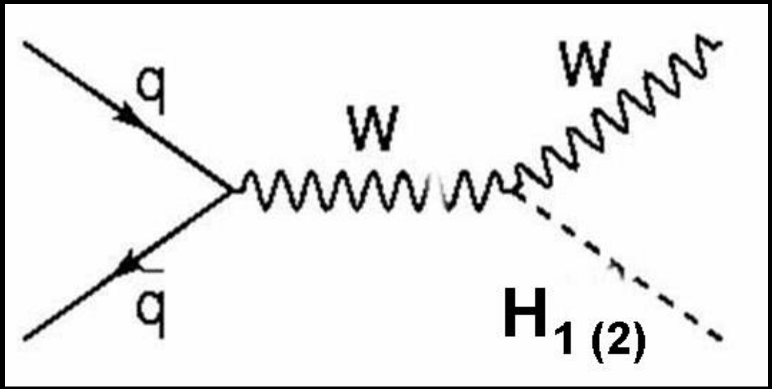
Doi:10.4236/ojm.2013.33016

arXiv:1304.6676

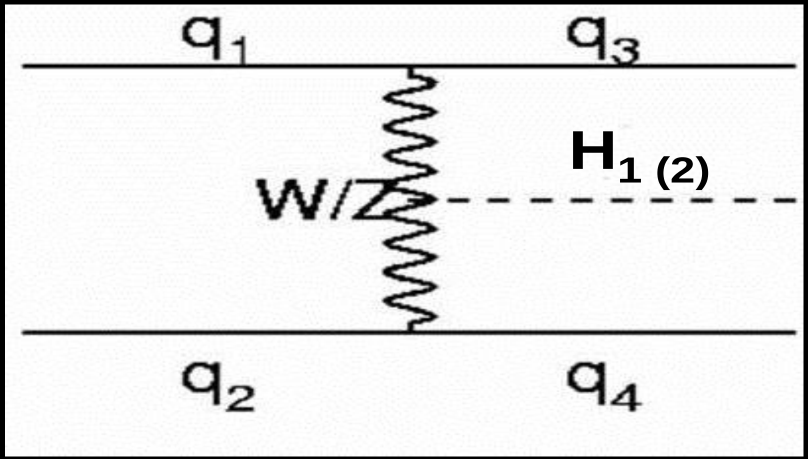
Production of Heavy Higgs



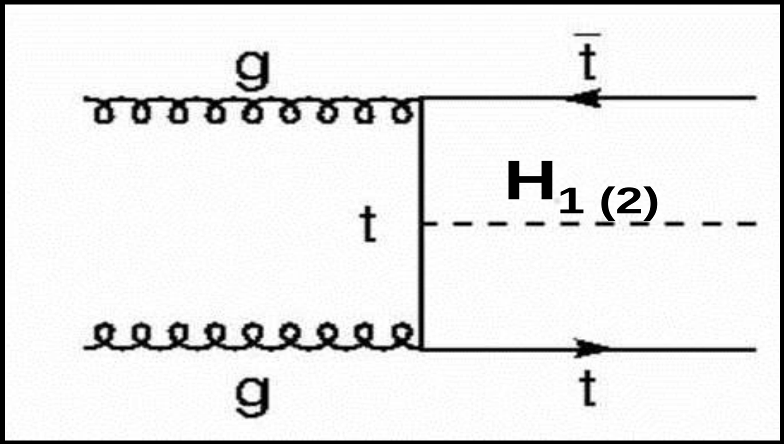
Gluon-Gluon fusion



associative production with W



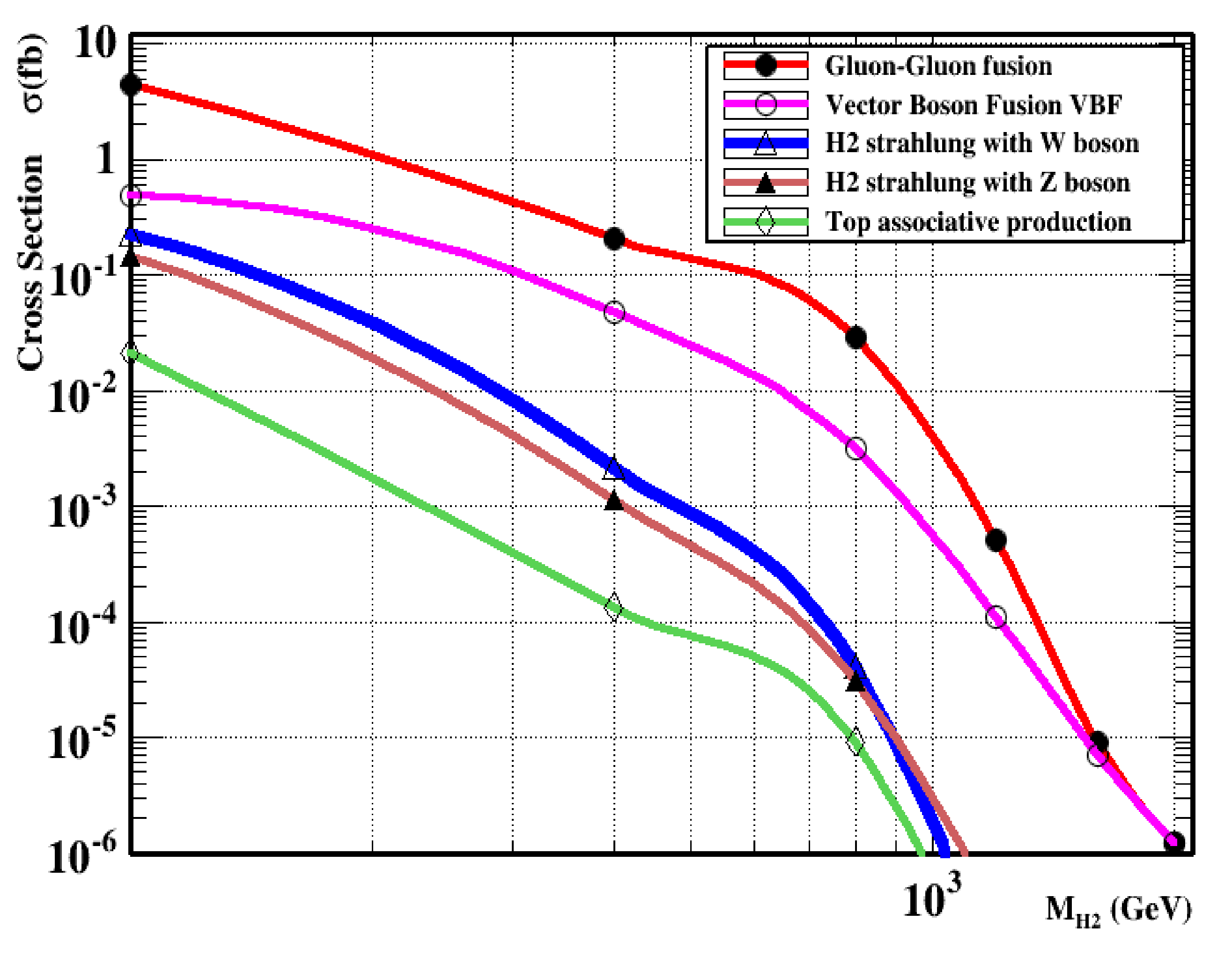
Vector boson fusion



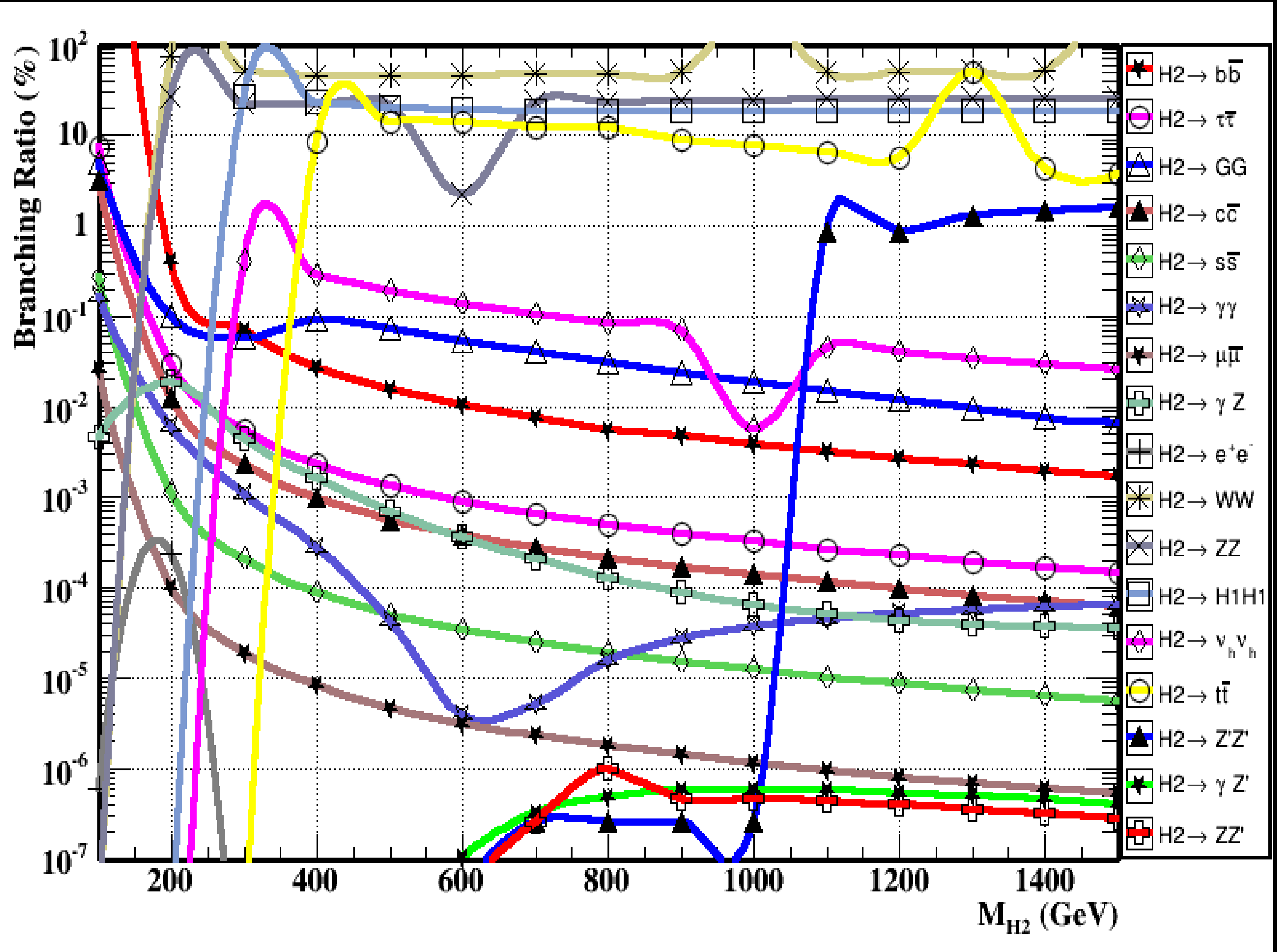
associative production with a top pair

Production Cross Section

Production Cross-sections at the LHC in the B − L model for heavy Higgs boson H_2 at $\sqrt{s}$ = 7 TeV



Branching Ratios of heavy Higgs



shows the branching ratios of all two body decay channels of the heavy Higgs boson H2 for a range of mass 100 GeV to 1500 GeV. In this case we have a new decay channel for the heavy Higgs in B-L model where it can decay into a pair of new Z′ boson and this channel is not in the SM. one can also consider this as a new feature of the B-L model at LHC where the new gauge boson can decay to a pair of heavy neutrino and every one of them can decay into 2 leptons

The other standard decay channels of the heavy Higgs decaying into W boson pairs is always dominant when it is kinematically open. Before that the decay into bottom quarks is the dominant decay channel, and the Higgs boson decays into pairs of photons.

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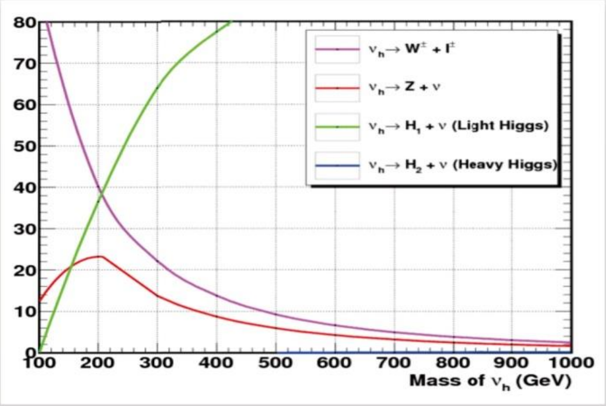
Scientific Research

Open Journal of Microphysics



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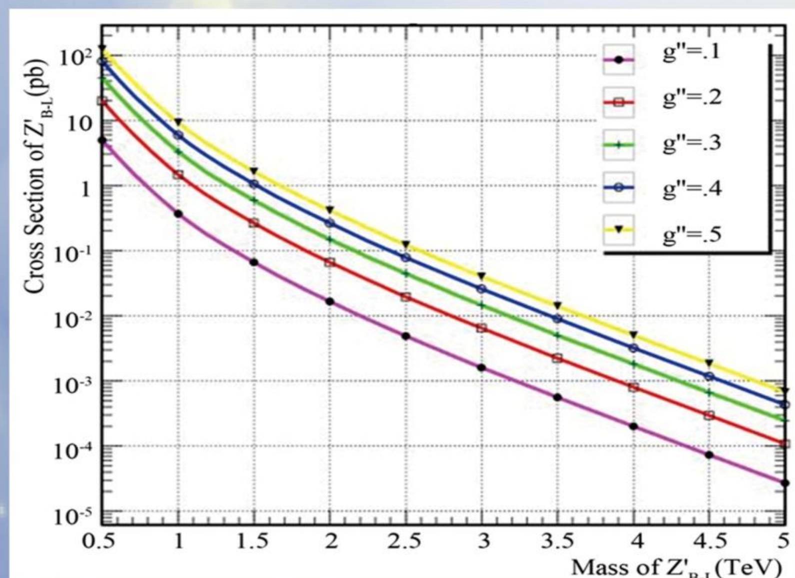
Scientific Research

Open Journal of Microphysics



ISSN: 2162-2450

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In this book, we simulated B-L model at Large Hadron Collider by using Monte Carlo simulation software. B-L model is one of many scenarios proposed to add an extension of the Standard Model of particle physics. These scenarios or models try to find a solution for many problems where the Standard Model can not solve it like dark matter, neutrino oscillation. B-L model predicts the existence of three new particles at the LHC. They are new neutral massive gauge boson, three heavy neutrinos (Right-Handed) and new heavy Higgs boson which is different from than Higgs of SM. We simulated these new particles at the LHC using Monte Carlo simulation programs and predict that the three particles may be found at the LHC particular new neutral massive gauge boson Z' and it has a mass in the range 1TeV to 1.5TeV. Also the particle Higgs-Like which was discovered in 2012 at the LHC may be the Higgs of B-L model of this book and is not of the SM. Finally we predict the existence three heavy neutrinos which are different from the light neutrino of the Standard Model.

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Bakhet, Mansour

Nady Bakhet
Hesham Mansour

New Neutral Heavy Particles at the LHC's CMS by MonteCarlo Simulation

LAP LAMBERT Academic Publishing

Baryon number

In particle physics, the baryon number is conserved

$$B = \frac{1}{3}[N(q) - N(\overline{q})]$$

where $N(q)$ is the number of quarks

$N(\overline{q})$ is the number of antiquarks.

Baryons a baryon number of +1,

Mesons a baryon number of 0

Antibaryons a baryon Number of −1.

Particles without any quarks have a baryon number of zero as : Leptons , Bosons

Lepton number

The lepton number is the number of leptons minus the number of antileptons.

$$L = N_l - N_{\bar{l}}$$

All leptons have +1.

Antileptons −1

Non-leptonic particles 0.

Lepton number preserved in interactions

THANKS