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Modified Radar Signal

Supersymmetry Quantum Mechanics

Highlights

Vorticity Distribution Function

Mass of Schrodinger Equations

Discovering Thoughts, Inventing Future

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Target Distance Direct Determination from QPSK Mapped OFDM Modified Radar Signal

By A.A.Hakhoumian
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Abstract- Time shift of the target reflected signal in radar system can be calculated directly from modified QPSK mapped OFDM signal. It makes possible to determine target distance from radar station. When time shift respecting to phase delay depends on OFDM subcarrier number, modified OFDM signal prevents that dependence and lets system to decide the phase delay directly from QPSK-OFDM signal rotation angle of constellation points. Additionally, proposed system requires low computing resources as the entire calculation process could be done during a single OFDM symbol.

Keywords: OFDM, radar, constellation, signal processing, QPSK, time shift, target distance.

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Keywords: OFDM, radar, constellation, signal processing, QPSK, time shift, target distance.

I. Introduction

OFDM signals are in focusfor radar applications due to high time bandwidth product[1, 2]. One of the main applications occurring during utilization of OFDM signals in radar systems is the signal processing which detect target parameters - distance and velocity. One of proposed method based on solving of matrix equations or 2D Fourier transform need high computing resources [3,4].

Previously it was presented new method based on QPSK-OFDM signal constellation processing which make possible to detect Doppler shift and accordingly target velocity [5]. Unfortunately that method couldn't be done directly, without solving target distance detection. It is presented below a new method again based on constellation processing which let to calculate target distance and make previous presented method more reliable and applicable.

II. Calculation Scheme of Time Delay from Modified OFDM Radar Signal

Target distance estimation in radar system is calculation of time, during which transmitted signal travel to the target and back to the receiver.

$$\tau = \frac{2D}{c} \tag{1}$$

where D-target distance, c speed of light.

Therefore target distance measurement is the same as timing offset estimation.

Let's consider the effect of timing offset on the OFDM signal constellation which is the representation of a signal modulated by digital modulation scheme, such as 4-QAM or in particularly QPSK.

For a set of N modulated orthogonal subcarriers f_n the transmitted signal can be represented as

$$S_t(t) = \frac{1}{N}\sum_{n=0}^{N-1} \dot{F}_n \exp\{j2\pi f_n t\} \tag{2}$$

where $\dot{F}_n$ are modulated symbols. For QPSK modulation modulated symbols will be

$$\dot{F}_n = \exp\{j(2k+1)\}, k = 0,1,2,3 \tag{3}$$

Consequently transmitted OFDM signal symbols points in constellation will have correspondent positions:$\varphi_1 = \frac{\pi}{4}, \varphi_2 = \frac{3\pi}{4}, \varphi_3 = \frac{5\pi}{4}, \varphi_4 = \frac{7\pi}{4}$(Fig.1).

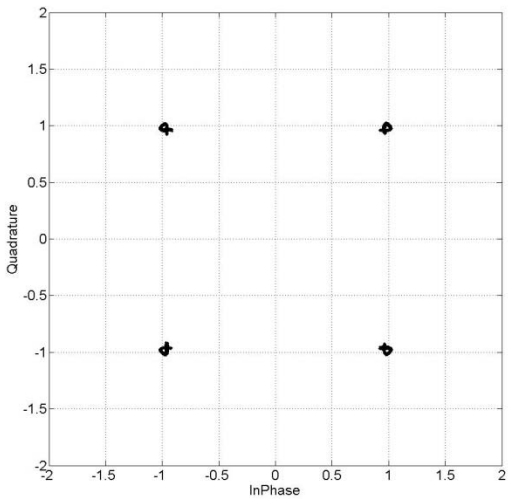


Figure 1 : OFDM transmitted signal constellation.

In communication systems phase difference of each two neighboring symbols could be $0, \frac{\pi}{2}, \pi, \frac{3\pi}{2}$. In such applications when it is necessary to solve time offset, this initial phase difference between each consecutive symbols must be prevented. One of the ways of preventing that initial shift is raising phase to the 4^{th} power [6].

Taking into account only time delay effect from target the received echo signal $S_r(t)$ will be time shifted version of the transmitted signal.

$$S_r(t) = S_t(t-\tau) \tag{4}$$

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So the received modulation symbols can be represented as

$$\dot{R_n} = \dot{F_n}\exp\{-j2\pi f_n \tau\} \quad (5)$$

As the phase of received symbol depended on subcarrier number, so with a large amount of subcarriers OFDM received symbols in constellation I/Q plane will spread all over plane in an interval $[0,2\pi]$(Fig.2).

To prevent this spreaded constellation, which doesn't give any opportunity to decide phase delay, we can simply take a divison of each consequitive symbols and make a new set of Q_k symbols.

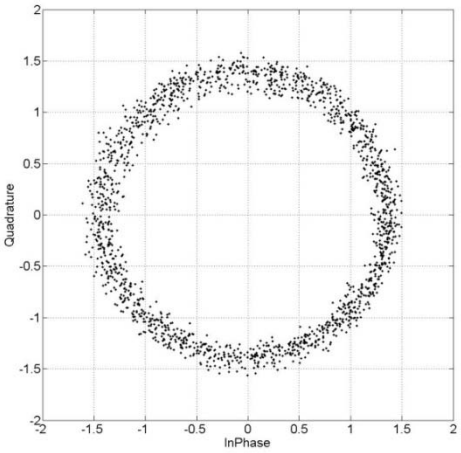


Figure 2 : OFDM received signal constellation consisting time delay.

$$Q_k = \frac{\dot{R_{n+1}}}{\dot{R_n}} = \frac{\dot{F_{n+1}}}{\dot{F_n}}\exp(-j2\pi f_{n+1}\tau + j2\pi f_n \tau) \quad (6)$$

where $k = 1,2,\dots,N-1$. As we stated before, OFDM stransmitted signal symbols can get phase values $\frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}$ and $\frac{7\pi}{4}$, it is obvious that

$$\frac{\dot{F_{n+1}}}{\dot{F_n}} = \exp\left(\mu\frac{\pi}{2}\right) \quad (7)$$

$\mu = 0,1,2,3$.From (6) and (7) new modified OFDM signal can be represented as

$$Q_k = \exp\left(\mu\frac{\pi}{2}\right)\exp(-j2\pi\Delta f\tau) \quad (8)$$

where $\Delta f = f_{n+1} - f_n$ is subcarrier spacing. Expression (8) shows that time delay is independent from subcarrier number. That's mean that it is the same on all modified OFDM symbols anymore and it can be easily calculated.

$$\Delta\varphi = 360 \cdot \Delta f\tau \quad (9)$$

Fig. 3.a shows modified QPSK transmitted signal constellation while in Fig 3.b it is received modified OFDM signal constellation.

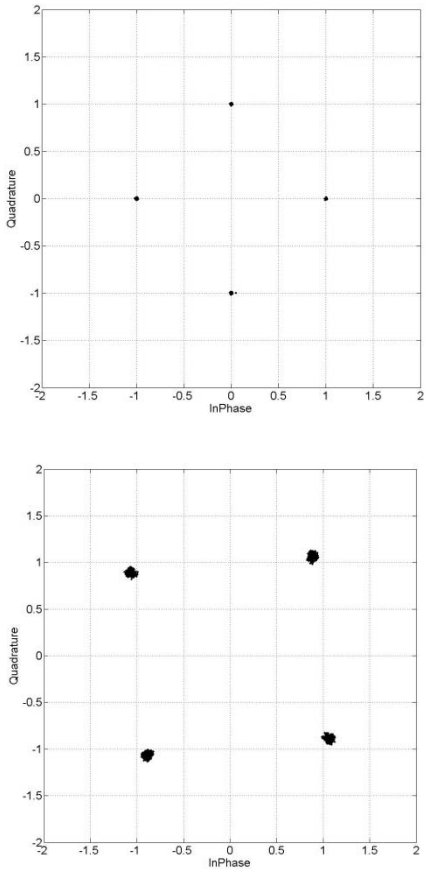


Figure 3 : (a) Modified OFDM transmitted signal constellation, (b) modified OFDM received signal constellation.

III. Distorted QPSK Mapped OFDM Radar Signal Time Delay Expected Value Calculation

In Fig. 3.b we can brightly see that even in all new modified OFDM symbols phase delay had the same impact, however there is still some distortion around the constellation poles. To prevent this distortion and calculate rotated angle more accurately, we simply have to extract an expected value of that rotated symbols (Fig. 4).

Simulations were done in Matlab environment with such parameterization: the carrier frequency $f_c = 24GHz$, OFDM symbol $T = 11\mu s$, guard interval $T_G = 1.375\mu s$. During the simulation our system generated a target with randomly selected actual distance $R_{act} = 248.1m$. Then from modified OFDM received signal we calculate rotated angle Fig 4. We get $\Delta\varphi_{meas} \approx 50.2^{\circ}$and consequently from (9) and (1) we get measured distance of the target from radar station $R_{meas} = 230m$. For absolute error we get

$$E_{\tau,abs} = |R_{act} - R_{means}| = 18.1m \quad (10)$$

And therefore relative percent error will be

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$$E_{\tau,rel,\%} = \frac{E_{\tau,abs}}{R_{act}} \cdot 100\% \approx 7\% \qquad (11)$$

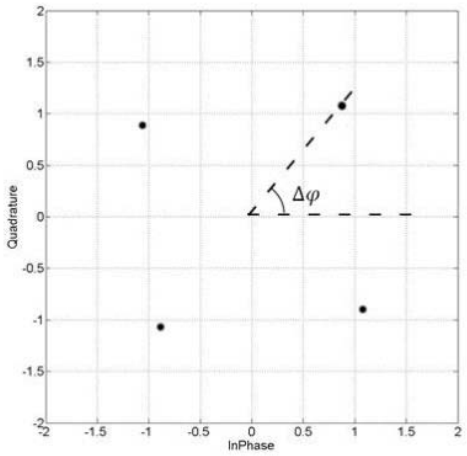


Figure 4 : The constellation of the modified OFDM received Q symbols estimated expected value.

IV. Conclusion

QPSK mapped OFDM modified signal processing let to solve target distance detection problem. Calculation process needs low computing resources because all processing could be done during one OFDM symbol.

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Some Exact Solutions of Non-Newtonian Fluid in Porous Medium with hall Effect Having Prescribed Vorticity Distribution Function

By Manoj Kumar
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Abstract- Two dimensional motion of an incompressible second grade fluid in a porous medium with Hall effects has been considered. Exact solutions are obtained via inverse method when vorticity distribution is proportional to stream function ψ, perturbed by a quadratic term.

Keywords: non-newtonian fluid, porous medium, hall effect, mhd, steady flow.

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Some Exact Solutions of Non-Newtonian Fluid in Porous Medium with hall Effect Having Prescribed Vorticity Distribution Function

Manoj Kumar

Abstract- **Two dimensional motion of an incompressible second grade fluid in a porous medium with Hall effects has been considered. Exact solutions are obtained via inverse method when vorticity distribution is proportional to stream function ψ, perturbed by a quadratic term.**

Keywords: non-newtonian fluid, porous medium, hall effect, mhd, steady flow.

I. Introduction

The study of magneto hydrodynamic (MHD) fluid flows has been a subject of great interest because of their applications in widespread fields like magneto hydrodynamic generators, designing cooling systems with liquid metals, geothermal energy extraction, handling of biological fluids, flow of nuclear fuel slurries, electromagnetic propulsion and flow of blood. A number of researchers (Noreen Sher Akbar, S. Nadeem, R. Ul Haq and Z. H. Khan[1], Manoj Kumar and C.Thakur[2]) worked on some interesting problems in these directions.

But the above studies cannot be implemented in the case of ionized gases because in ionized gases (where the density is low and the magnetic field is strong), there is a conductivity normal to the free spiraling of electrons and ions about the magnetic lines of force before suffering collisions; also, a current is induced in a direction normal to both electric and magnetic fields. This is what we call the Hall Effects. This study has interesting features in problems of MHD generators, Hall accelerators and flight magneto hydrodynamics. N. Ahmad and K. Kr. Das[3], R. K. Deka[4], M.A.M. Abdeen et.al.[5], Haider Zaman et.al.[6] discussed the Hall effects in different situations.

The flows of non-newtonian fluid through porous media have gained a lot of importance in recent years. The flow through porous medium has lot of applications in engineering and science such as groundwater hydrology, petroleum engineering, reservoir engineering, chemical reactors, agricultural irrigation and drainage and recovery of crude oil from the pores of reservoir rocks.

Navier-Stokes equations are inherently non-linear partial differential equations has non general solution and only a small number of exact solutions have been found because the nonlinear inertial terms do not disappear automatically. Exact solutions are very important not only because they are solutions of some fundamental flows but also they serve as accuracy checks for experimental, numerical and asymptotic methods. So in order to perform this task one adopt transformations, inverse or semi-inverse method for the reformulation of equations in solvable form. Some researchers have used hodograph transformation[7,8] in order to linearize the system of governing equations and got some exact solutions. Some authors have used inverse method where some a priory condition is assumed about the flow variables and have found some exact solutions. This method has been extensively used by many researchers for the first grade fluid such as Chandna[9], M. Jamil et.al.[10,11] and others. In case of second grade fluid T. Hayat et.al.[12] applied this method to find some exact solutions. Benharbit and Siddiqui[13] used this method to study steady and unsteady second grade fluid flow by taking vorticity function of the form $\nabla^2\psi = k(\psi - Uy)$. Islam, Mohyuddin and Zhou[14] taking the same form of vorticity function studied the non-newtonian fluid in porous medium with Hall Effect. Further this method was also used by Chandna and Ukpong[15], A.M. Siddiqui et.al.[16], B.Singh and C. Thakur[17], Rana Khalid Naeem[18] , Manoj Kumar et.al.[19] in the study of second grade fluid flow.

In this paper we have studied second grade electrically conducting fluid flow in porous media with Hall Effect. The equations are modeled and solved by assuming the vorticity function proportional to the stream function perturbed by a quadratic stream $B(Cx+Dy+Ey^2)$. We have also found exact solution for finitely conducting steady and unsteady fluid flow.

II. Basic Flow Equation

The basic equations governing the motion of second grade electrically electrically conducting fluid flow in porous media with Hall Effect are given by :

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \qquad (1)$$

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$$\frac{\partial p^*}{\partial x}+\rho\left[\frac{\partial u}{\partial t}-v\omega\right]=\left(\mu+\alpha_1\frac{\partial}{\partial t}\right)\nabla^2 u-\frac{1}{K}\left(\mu+\alpha_1\frac{\partial}{\partial t}\right)u-\alpha_1 v\nabla^2\omega-\frac{\sigma B_0{}^2}{1+\varphi^2}(u-\varphi v), \quad (2)$$

$$\frac{\partial p^*}{\partial y}+\rho\left[\frac{\partial v}{\partial t}+u\omega\right]=\left(\mu+\alpha_1\frac{\partial}{\partial t}\right)\nabla^2 v-\frac{1}{K}\left(\mu+\alpha_1\frac{\partial}{\partial t}\right)v+\alpha_1 u\nabla^2\omega-\frac{\sigma B_0{}^2}{1+\varphi^2}(v+\varphi u), \quad (3)$$

where u=u(x, y, t), v=v(x, y, t) are the velocity components, p*=p*(x, y, t) is the pressure field, μ is the viscosity of the fluid, α_1 is the normal stress moduli, K is the permeability, $\varphi = \sigma B_0/en_e$ is the Hall parameter, σ is the electrical field conductivity, B_0 is the magnetic field, e is the electric charge and n_e is the number density of electrons.

In equations (2) – (3), the vorticity and the modified pressure are given respectively as

$$\omega=\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}, \quad (4)$$

$$p^*=\frac{\rho}{2}|\mathbf{v}|^2+p-\alpha_1\left[u\nabla^2 u+v\nabla^2 v+\frac{1}{4}|A_1|^2\right], \quad (5)$$

where,

$$|A_1|^2=4\left(\frac{\partial u}{\partial x}\right)^2+4\left(\frac{\partial v}{\partial y}\right)^2+2\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)^2 \quad (6)$$

These systems of equations have three unknowns u, v, and p. Once the velocity field is determined, the pressure field (5) can be found by integrating equations (2) and (3). The continuity equation (1) implies the existence of stream function ψ (x, y, t) such that

$$u=\frac{\partial\psi}{\partial y}, \quad v=-\frac{\partial\psi}{\partial x}. \quad (7)$$

Using integrability condition $\partial^2 p^*/\partial x\partial y = \partial^2 p^*/\partial y\partial x$, equation (2) and (3) reduces to

$$\rho\left[\frac{\partial}{\partial t}\left(\nabla^2\psi\right)-\left\{\psi,\nabla^2\psi\right\}\right]=\left(\mu+\alpha_1\frac{\partial}{\partial t}\right)\nabla^4\psi-\frac{1}{K}\left(\mu+\alpha_1\frac{\partial}{\partial t}\right)\nabla^2\psi-\alpha_1\left\{\psi,\nabla^4\psi\right\}-\frac{\sigma B_0^2}{1+\varphi^2}\nabla^2\psi. \quad (8)$$

In equation (8) if $K\to\infty$, and neglecting the Hall effects, we obtain the Benharbit and Siddiqui [13] case. If $K\to\infty$, $\alpha_1=0$, and neglecting Hall effects in equation (8), we recover the viscous case equations of Hui[20].

III. Exact Solutions

We shall investigate fluid motion for which vorticity distribution is proportional to the stream function perturbed by the quadratic term in x and y as given by

$$\nabla^2\psi=A\left[\psi-B\left(Cx+Dy+Ey^2\right)\right], \quad (9)$$

where A,B,C,D and E are constants but A≠0.The special case of A= 0 corresponds to an irrotational flow.

Introducing this value equation (8) reduces to

$$A\left(\rho-\alpha_1 A-\frac{\alpha_1}{K}\right)\psi_t+\rho BA\left\{(D+2Ey)\psi_x-\psi_y C\right\}-\alpha_1 A^2 B\left\{(D+2Ey)\psi_x-C\psi_y\right\}=$$

$$\mu A^2\left\{\psi-B\left(Cx+Dy+Ey^2\right)-\frac{2BE}{A}\right\}-\frac{\sigma B_0^2}{1+\varphi^2}A\left[\psi-B\left(Cx+Dy+Ey^2\right)\right]-\frac{\mu A}{K}\left\{\psi-B\left(Cx+Dy+Ey^2\right)\right\}$$

Letting $\Psi=\psi-B\left(Cx+Dy+Dy^2\right)$, the equation reduces to

$$A\left(\rho-\alpha_1 A-\frac{\alpha_1}{K}\right)\Psi_t+\left(\rho BA-\alpha_1 A^2 B\right)\left\{(D+2Ey)\Psi_x-C\Psi_y\right\}=\mu A^2\left\{\Psi-\frac{2BE}{A}\right\}-\frac{\mu A}{K}\Psi-\frac{\sigma B_0^2}{1+\varphi^2}A\Psi \quad (10)$$

Also,

$$\nabla^2\Psi=A\Psi-2BE. \quad (11)$$

In equation (10) if B=0, α_1=0 & K→∞ and neglecting the Hall effects we obtain the Taylor [20] case. If α_1=0, D=E=0, K→∞ and in the case of Hall effects equation (10) reduces to Hui[21] case. Also if K→∞ and neglecting the Hall effects we obtain the Benharbit and Siddiqui [13] case. Putting D=E=0, we reproduce the S. Islam et.al.[14] case.

Dividing equation (10) by A, we have

$$\left(\rho-\alpha_1 A-\frac{\alpha_1}{K}\right)\Psi_t+\left(\rho B-\alpha_1 AB\right)\left\{(D+2Ey)\Psi_x-C\Psi_y\right\}=\delta\left(\Psi-\frac{2\mu BE}{\delta}\right), \quad (12)$$

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where,

$$\delta = \left\{ \frac{\mu(1+\varphi^2)(KA-1) - \sigma B_0^2 K}{K(1+\varphi^2)} \right\}. \quad (13)$$

a) Creeping Flow

For creeping flow, we have from equation (12),

$$\delta\left(\Psi - \frac{2\mu BE}{\delta}\right) = 0.$$

Since $\delta \neq 0$, we must have $\Psi = \frac{2\mu BE}{\delta}$.

Hence, $\psi = B(Cx + Dy + Ey^2) + \frac{2\mu BE}{\delta}$. (14)

The stream function (14) gives the exact solutions

u = B(D+2Ey),

v = -BC,

$$p = p_0 - \frac{\rho}{2}B^2(C^2+D^2) - 2\alpha_1 B^2 E^2 + B\left[2\rho BCE - \frac{\mu D}{K} - \frac{\sigma B_0^2}{1+\varphi^2}(D+\varphi C)\right]x - 2BE\left[\frac{\mu}{K} + \frac{\sigma B_0^2}{1+\varphi^2}\right]xy + B\left[\frac{\mu C}{K} - \frac{\sigma B_0^2}{1+\varphi^2}(\varphi D - C)\right]y - BE\left[\frac{\sigma B_0^2}{1+\varphi^2}\varphi\right]y^2.$$

b) Steady Flow

For steady flow we have $\Psi_t = 0$, so the system of equations (12) and (11) can be written as

$$(\rho B - \alpha_1 AB)\{(D+2Ey)\Psi_x - C\Psi_y\} = \delta\left(\Psi - \frac{2\mu BE}{\delta}\right), \quad (15)$$

& $$\nabla^2\Psi = A\Psi - 2BE, \quad (16)$$

We now introduce the following co-ordinate transformations

$$\Psi = \psi - B(Cx + Dy + Ey^2)$$

$$\xi = Cx + Dy + Ey^2$$

$$\eta = y$$

Equation (15) and (16) respectively reduces to

$$(\rho - \alpha_1 A)BC\Psi_\eta = \delta\left(\Psi - \frac{2\mu BE}{\delta}\right), \quad (17)$$

$$\{C^2 + (D+2E\eta)^2\}\Psi_{\xi\xi} + 2(D+2E\eta)\Psi_{\xi\eta} + 2E\Psi_\xi + \Psi_{\eta\eta} = \delta\left(\Psi - \frac{2\mu BE}{\delta}\right). \quad (18)$$

Case I :

One of the solution of equation (17), when, $(\rho - \alpha_1 A) = 0$, is

$$\Psi = \frac{2\mu BE}{\delta}.$$

Hence, $\psi = B(Cx + Dy + Ey^2) + \frac{2\mu BE}{\delta}$.

The stream function gives the exact solutions

u = B(D+2Ey),

v = -BC,

$$p = p_0 - \frac{\rho}{2}B^2(C^2+D^2) - 2\alpha_1 B^2 E^2 + B\left[2\rho BCE - \frac{\mu D}{K} - \frac{\sigma B_0^2}{1+\varphi^2}(D+\varphi C)\right]x - 2BE\left[\frac{\mu}{K} + \frac{\sigma B_0^2}{1+\varphi^2}\right]xy + B\left[\frac{\mu C}{K} - \frac{\sigma B_0^2}{1+\varphi^2}(\varphi D - C)\right]y - BE\left[\frac{\sigma B_0^2}{1+\varphi^2}\varphi\right]y^2.$$

Case II :

When $(\rho - \alpha_1 A) \neq 0$, solving equation (17) (By variable separable method) we get

$$\Psi = \frac{2\mu BE}{\delta} + g(\xi)e^{\lambda\eta}, \quad (19)$$

where, $\lambda = \left\{ \frac{\mu(1+\varphi^2)(KA-1) - \sigma B_0^2 K}{K(1+\varphi^2)(\rho - \alpha_1 A)BC} \right\}$. (20)

To find g(ξ), we substitute equation (19) in to equation (18) and get

$$e^{\lambda\eta}\left[\{C^2 + (D+2E\eta)^2\}g''(\xi) + \{2\lambda(D+2E\eta) + 2E\}g'(\xi) + (\lambda^2 - \delta)g(\xi)\right] = 0. \quad (21)$$

Since ξ, η are independent variables, we must have two cases $E = 0$, $g'(\xi) = 0$.

Case IIa: In this case $E = 0$ and equation (21) becomes

$$(C^2 + D^2)g''(\xi) + 2\lambda Dg'(\xi) + (\lambda^2 - \delta)g(\xi) = 0 \quad (22)$$

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The solution of (22) combined with equation (19) and also using $\Psi = \psi - B\left(Cx + Dy + Ey^2\right)$, $\xi = Cx + Dy + Ey^2$, $\eta = y$ and taking $E = 0$, we obtain the stream function as :

$$\psi(x,y) = B(Cx+Dy) + A_1 e^{m_1(Cx+Dy)+\lambda y} + A_2 e^{m_2(Cx+Dy)+\lambda y} \text{ for } M > 0, \quad (23.1)$$

$$= B(Cx+Dy) + (B_1 + B_2(Cx+Dy))e^{m_3(Cx+Dy)+\lambda y} \text{ for } M = 0, \quad (23.2)$$

$$= B(Cx+Dy) + C_1 e^{\alpha(Cx+Dy)+\lambda y}\cos(\beta(Cx+Dy)+C_2) \text{ for } M < 0, \quad (23.3)$$

where,

$$M = \lambda^2 D^2 - (C^2+D^2)(\lambda^2 - \delta^2),$$

$$m_1 = \frac{-\lambda D + \sqrt{M}}{(C^2+D^2)}, m_2 = \frac{-\lambda D - \sqrt{M}}{(C^2+D^2)}, m_3 = \frac{-\lambda D}{(C^2+D^2)},$$

$$\alpha = \frac{-\lambda D}{(C^2+D^2)}, \beta = \frac{\sqrt{M}}{(C^2+D^2)}.$$

A_1, A_2, B_1, B_2, C_1 and C_2 are arbitrary constants.

It is noted that the results of S. Islam et.al. (2008) can be recovered as special case by taking C=0 and appropriately choosing the value of constants in the present result.

The exact solution given by equation (23.1) when $M > 0$

$$u = \left[BD + A_1(m_1 D + \lambda)e^{m_1 Cx + (m_1 D + \lambda)y} + A_2(m_2 D + \lambda)e^{m_2 Cx + (m_2 D + \lambda)y}\right] \quad (24.1)$$

$$v = -\left[BC + A_1 m_1 C e^{m_1 Cx + (m_1 D + \lambda)y} + A_2 m_2 C e^{m_2 Cx + (m_2 D + \lambda)y}\right]. \quad (24.2)$$

The exact solution given by equation (23.2) when $M = 0$

$$u = \left[BD + B_2 D e^{m_3 Cx + (m_3 D + \lambda)y} + \{B_1 + B_2(Cx+Dy)\}(m_3 D + \lambda)e^{m_2 Cx + (m_2 D + \lambda)y}\right]. \quad (25.1)$$

$$v = -\left[BC + B_2 C e^{m_3 Cx + (m_3 D + \lambda)y} + \{B_1 + B_2(Cx+Dy)\}m_3 C e^{m_2 Cx + (m_2 D + \lambda)y}\right] \quad (25.2)$$

And equation (23.3) gives the exact solution for $M < 0$

$$u = \left[BD + C_1(\alpha D + \lambda)e^{\alpha Cx + (\alpha D + \lambda)y}\cos(\beta(Cx+Dy)+C_2) + C_1\beta e^{\alpha Cx + (\alpha D + \lambda)y}\sin(\beta(Cx+Dy)+C_2)\right]. \quad (26.1)$$

$$v = -\left[BC + C_1\alpha C e^{\alpha Cx + (\alpha D + \lambda)y}\cos(\beta(Cx+Dy)+C_2) - C_1\beta e^{\alpha Cx + (\alpha D + \lambda)y}\sin(\beta(Cx+Dy)+C_2)\right]. \quad (26.2)$$

In all the above cases p can be calculated by putting the value of u and v in equation (5).

Case IIb: In this case we take $g'(\xi) = 0$, which implies $g(\xi) = a_\circ$, where $a_\circ \neq 0$ is an arbitrary constant and $\delta = \lambda^2$, using this in equation (19), $\Psi = \psi - B\left(Cx + Dy + Ey^2\right)$ and $\eta = y$ we get stream function $\psi = \frac{2\mu BE}{\lambda^2} + B\left(Cx + Dy + Ey^2\right) + a_0 e^{\lambda}$, (27)

Hence, we get the exact solution as:

$$u = \left[B(D + 2Ey) + a_0 \lambda e^{\lambda y}\right],$$

$$v = -BC, \quad (28)$$

Also p can be calculated by putting the value of u and v in equation (5).

Discussion

Solution (23.1) represents a uniform flow in (x, y) plane, in the region $y > 0$, perturbed by a part which grows and decays exponentially as y increases if $\lambda \rangle 0$ and $\lambda \langle 0$, respectively. The reverse holds true for the region $y < 0$, and the flow is exponential in x and y in both cases. The solution (23.2) can be used to describe, in $y > 0$, a uniform flow plus a different type of perturbation which again grows and decays as y increases in the same as in (23.2). Solution (23.3) represents a uniform flow with a perturbation part which is periodic in x and y and grows and decays exponentially as y increases, respectively, when $\lambda \rangle 0$ and $\lambda \langle 0$ for the region $y > 0$. A similar description can be given for a flow in $y < 0$.

c) Unsteady Flow

By rewriting equation (12) in the form

$$\frac{\partial \Psi}{\partial t} + U_1\left\{(D + 2Ey)\frac{\partial \Psi}{\partial x} - C\frac{\partial \Psi}{\partial y}\right\} = \gamma\left(\Psi - \frac{2\mu BE}{\delta}\right), \quad (29)$$

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where,

$$\gamma = \left\{ \frac{\mu\left(1+\varphi^2\right)\left(KA-1\right)-\sigma B_0^2 K}{K\left(1+\varphi^2\right)\left(\rho-\alpha_1 A-\alpha_1/K\right)} \right\},$$

$$U_1 = \frac{\left(\rho B-\alpha_1 AB\right)}{\left(\rho-\alpha_1 A-\alpha_1/K\right)} \quad . \qquad (30)$$

Solving equation (29) by variable separable method we get

$$\Psi = F(X,Y)e^{\gamma t} + \frac{2\mu BE}{\delta}, \qquad (31)$$

where F(X, Y) is an unknown function to be determined and

$$X = x - U_1(D+2Ey)t,$$
$$Y = y + U_1 Ct. \qquad (32)$$

Putting the value of Ψ in equation (16)

$$\nabla^2\left[F(X,Y)e^{\gamma t}+\frac{2\mu BE}{\delta}\right] = A\left[F(X,Y)e^{\gamma t}+\frac{2\mu BE}{\delta}\right]-2BE,$$

$$F_{XX}+F_{YY} = AF(X,Y)+2EB\left(\frac{\mu A}{\rho}-1\right)e^{-\gamma t}. \qquad (33)$$

Plane wave solution of Helmholtz equation (33) exist in the form

$$F(X,Y) = g(\xi), \xi = X\cos\theta + Y\sin\theta, -\pi \le \theta \le \pi \qquad (34)$$

Using equation (34) in equation (33) we obtain

$$g''(\xi) - Ag(\xi) = 2EB\left(\frac{\mu A}{\delta}-1\right)e^{-\gamma t} \quad . \qquad (35)$$

Following cases arises:

Case I: When A=0

$$g(\xi) = -2EBe^{-\gamma t}\frac{\xi^2}{2} + C_1\xi + C_2 \ , \qquad (36)$$

where C_1 and C_2 are arbitrary constants depending on θ.

A combination of (36) with (34) gives

.

This relation with (32),(31) and $\Psi = \psi - B\left(Cx+Dy+Ey^2\right)$ gives stream function as

$$\psi = -EB\xi^2 + \left(C_1\xi + C_2\right)e^{\gamma t} + \frac{2\mu BE}{\delta} + B\left(Cx+Dy+Ey^2\right), \qquad (37)$$

where,

$$\xi = \left\{x - U_1\left(D+2Ey\right)t\right\}\cos\theta + \left\{y+U_1 Ct\right\}\sin\theta \ ,$$

$$\gamma = \frac{-\mu\left(1+\varphi^2\right)-\sigma B_0^2 K}{K\left(1+\varphi^2\right)\left(\rho-\alpha_1/K\right)},$$

$$U_1 = \frac{\rho B}{\left(\rho-\alpha_1/K\right)}.$$

Hence we get exact solutions as

$$u = -2EB\xi\left(-U_1 2Et\cos\theta+\sin\theta\right)+C_1\left(-U_1 2Et\cos\theta+\sin\theta\right)+B\left(D+2Ey\right),$$

$$v = -2EB\xi\cos\theta - C_1 e^{\gamma t}\cos\theta - BC.$$

P can be calculated by putting the value of u and v in equation (5).

Case II: If $A = \Omega^2 \rangle 0$ then solution of equation (35) is

$$g(\xi) = D_1 e^{\Omega\xi} + D_2 e^{-\Omega\xi} + 2EB\left(\Omega^2-1\right)e^{-\gamma t}\left(\frac{\xi^2}{2}-\frac{\Omega^2\xi^4}{24}\right), \qquad (38)$$

where D_1 and D_2 are arbitrary constants depending on θ.

Combining (38) with equation (34)

$$F(X,Y) = D_1 e^{\Omega\xi} + D_2 e^{-\Omega\xi} + 2EB\left(\Omega^2-1\right)e^{-\gamma t}\left(\frac{\xi^2}{2}-\frac{\Omega^2\xi^4}{24}\right).$$

Putting this value in (31) and using $\Psi = \psi - B\left(Cx+Dy+Ey^2\right)$ we get stream function as

$$\psi = \left(D_1 e^{\Omega\xi} + D_2 e^{-\Omega\xi}\right)e^{\gamma t} + \frac{1}{12\delta}EB\left(\Omega^2-1\right)\left(12\xi^2-\Omega^2\xi^4\right)+\frac{2\mu BE}{}+B\left(Cx+Dy+Ey^2\right),$$

where,

$$\xi = \left\{x - U_1\left(D+2Ey\right)t\right\}\cos\theta + \left\{y+U_1 Ct\right\}\sin\theta,$$

$$\gamma = \frac{\mu\left(1+\varphi^2\right)\left(K\Omega^2-1\right)-\sigma B_0^2 K}{K\left(1+\varphi^2\right)\left(\rho-\alpha_1\Omega^2-\alpha_1/K\right)},$$

$$U_1 = \frac{\rho B - \alpha_1\Omega^2 B}{\left(\rho-\alpha_1\Omega^2-\alpha_1/K\right)}.$$

Hence we get velocity components as

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$$u=\left(D_1e^{\Omega\xi}-D_2e^{-\Omega\xi}\right)e^{\gamma t}\Omega\left(-U_1 2Et\cos\theta+\sin\theta\right)+\frac{1}{12}EB\left(\Omega^2-1\right)\left(24\xi-4\Omega^2\xi^3\right)\left(-U_1 2Et\cos\theta+\sin\theta\right)+B\left(D+2Ey\right)$$

$$v=-\left(D_1e^{\Omega\xi}-D_2e^{-\Omega\xi}\right)e^{\gamma t}\Omega\cos\theta-\frac{1}{12}EB\left(\Omega^2-1\right)\left(24\xi-4\Omega^2\xi^3\right)\cos\theta-BC.$$

Also p can be calculated using equation (5).

Case III: If $A=-\Omega^2\langle 0$, then the general function for $g(\xi)$ is

$$g(\xi)=B_1\cos\Omega\left(\xi+B_2(\theta)\right)+\left(\frac{\xi^2}{2}+\frac{\Omega^2\xi^4}{24}\right)2EB\left(-\Omega^2-1\right)e^{-\gamma t}, \tag{39}$$

where B_1 and B_2 are arbitrary constants depending on the parameter θ.

Combining equation (39) with equation (34) we get

$$F(X,Y)=B_1\cos\Omega\left(\xi+B_2(\theta)\right)+\left(\frac{\xi^2}{2}+\frac{\Omega^2\xi^4}{24}\right)2EB\left(-\Omega^2-1\right)e^{-\gamma t}$$

Putting this value in equation (31) and using $\Psi=\psi-B\left(Cx+Dy+Ey^2\right)$ we get stream function as

$$\psi=\left\{B_1\cos\Omega\left(\xi+B_2(\theta)\right)\right\}e^{\gamma t}+\frac{1}{12\delta}EB\left(12\xi^2+\Omega^2\xi^4\right)\left(-\Omega^2-1\right)+\frac{2\mu BE}{}+B\left(Cx+Dy+Ey^2\right),$$

where,

$$\xi=\left\{x-U_1\left(D+2Ey\right)t\right\}\cos\theta+\left\{y+U_1Ct\right\}\sin\theta,$$

$$\gamma=\frac{\mu\left(1+\varphi^2\right)\left(-K\Omega^2-1\right)-\sigma B_0^2K}{K\left(1+\varphi^2\right)\left(\rho+\alpha_1\Omega^2-\alpha_1/K\right)},$$

$$U_1=\frac{\rho B+\alpha_1\Omega^2B}{\left(\rho+\alpha_1\Omega^2-\alpha_1/K\right)}.$$

Hence we get exact solutions as

$$u=-\Omega\sin\theta\left\{B_1\cos\Omega\left(\xi+B_2(\theta)\right\}e^{\gamma t}+\frac{1}{12}EB\left(24\xi+4\Omega^2\xi^3\right)\left(-\Omega^2-1\right)\left(-U_{12}Et\cos\theta+\sin\theta\right)+B\left(D+2Ey\right),$$

$$v=-\Omega\cos\theta\left\{B_1\cos\Omega\left(\xi+B_2(\theta)\right)\right\}e^{\gamma t}-\frac{1}{12}EB\left(24\xi+4\Omega^2\xi^3\right)\left(-\Omega^2-1\right)\cos\theta+BC$$

P can be calculated by putting the values of u and v in equation (5).

IV. Conclusion

In this paper we have found the exact solutions of the governing equations of incompressible second grade fluid in a porous medium with the Hall currents under the assumption that vorticity distribution is proportional to the stream function perturbed by a quadratic term. We recovered the solutions of Benharbit and Siddiqui[13], Hui[21] and Islam, Mohyuddin and Zhou[14] in limiting cases if the corresponding conditions are applied. Our solutions are compatible in a limiting case with those of Benharbit and Siddiqui, Hui and Islam et.al. Expressions for streamlines, velocity components and pressure fields are defined in each case. Our solutions are more general and several results of various authors can be recovered in a limiting case.

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Search for Four-Charged Lepton from Decay Doubly-Charged Higgs Pair Production at the Hadron Colliders

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Keywords: LHC, tevatron, left-right model, doubly charged higgs, monte carlo simulation.

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Search for Four-Charged Lepton from Decay Doubly-Charged Higgs Pair Production at the Hadron Colliders

Nady Bakhet [α], Maxim Yu. Khlopov [σ] & Tarek Hussein [ρ]

Abstract- The Left-Right symmetry Model (LRSM) is an extension of the Standard Model based on the gauge symmetry group SU(3)C × SU(2)L × SU(2)R × U(1)B-L predicts by existence new particles like doubly-charged Higgs boson, W' new charged boson, Z' new neutral boson and heavy neutrinos. In this work we present an analysis for production four-charged lepton in final state produced via decaying a pair of doubly-charged Higgs boson in the context of LRSM by using Monte Carlo simulation Techniques at both the Large Hadron Collider (proton-proton collisions) and the Fermilab Tevatron Collider (proton-antiproton collisions). In this analysis we assume that the branching ratio of decay channels of left-handed or right-handed doubly-charged Higgs boson BR ($H^{\pm\pm} \to \ell^{\pm}\ell^{\pm} = 100\%, \ell = e^{\pm}, \mu^{\pm}, \tau^{\pm}$). We carry out a Monte Carlo study of the (Left or Right) doubly charged Higgs pair production and decay to four-charged lepton via the process $pp(\bar{p}) \to H^{\pm\pm}H^{\pm\pm} \to \ell^{\pm}\ell^{\pm}\ell^{\pm}\ell^{\pm}$, $\ell = e^{\pm}, \mu^{\pm}, \tau^{\pm}$. From Monte Carlo simulation level the doubly-charged Higgs may be found at the LHC or at the Tevatron in the mass range up to 800 GeV.

Keywords: LHC, tevatron, left-right model, doubly charged higgs, monte carlo simulation.

I. Introduction

Doubly-charged Higgs bosons $H^{\pm\pm}$ appear in several extensions beyond the Standard Model, in particular, in Left-Right Symmetric Model (LRSM) [1], in Higgs triplet models [2] and in Little-Higgs models [3]. In addition to the neutral Higgs boson, single charged and doubly-charged Higgs bosons are part of Higgs triplet. Both Higgs bosons may be reconstructed giving two like-charge pairs of leptons with similar invariant mass. Left-Right Symmetric Model predicts the appearance of a left- and a right-handed Higgs triplet both with hypercharge $|Y| = 2$. In this work we search for doubly-charged Higgs bosons decaying to pairs of electrons and/or muons. Pairs of isolated, high transverse momentum leptons with the same electric charge ($e^{\pm}e^{\pm}, \mu^{\pm}\mu^{\pm}, e^{\pm}\mu^{\pm}$) are selected, and their invariant mass distribution is searched for a narrow resonance. We use Monte Carlo (MC) event generator PYTHIA8 [4] for the simulation of signal and background processes either to generate a given hard interaction at leading order (LO), or for the simulation of showering and hadronization. Also we use MADGRAPH5 [5] to generate diboson and Drell–Yan events. The LRSM predicts dominant decay modes to like-charge lepton pairs $H^{\pm\pm} \to \ell^{\pm}\ell^{\pm}$. Pairs of doubly-charged Higgs bosons can be produced through the Drell-Yan process $(\bar{P}) \to \gamma^*/Z \to H^{--}H^{++}$. The observation of a doubly-charged scalar particle would establish the type II seesaw mechanism as the most promising framework for generating neutrino masses. The minimal type II seesaw model [6] is realized with an additional scalar field that is a triplet under SU(2)L and carries U(1)Y hypercharge Y = 2. The triplet contains a doubly-charged component $H^{\pm\pm}$, a singly-charged component $H^{\pm\pm}$ and a neutral component H^0. The masses of doubly-charged Higgs bosons are constrained depending on the branching ratio into these leptonic final states. A $H^{\pm\pm}$ particle can also occur as a singlet as proposed in the Zee-Babu model [7], where it is postulated for the purpose of generating Majorana neutrino masses. Assuming pair production, coupling to left-handed fermions, and a branching ratio of 100% for each final state.

II. The Results

The process $pp(\bar{p}) \to H^{++}H^{--} \to \ell_{\alpha}^{+}\ell_{\beta}^{+}\ell_{\lambda}^{-}\ell_{\delta}^{-}$ is simulated using PYTHIA8 [8] event generator for Left-Right Symmetric model new particle $H^{\pm\pm}$. In order to obtain the full signal cross-section, a cut which PYTHIA applies by default on the transverse momentum P_T of the lepton. Left-handed and Right-handed states are distinguished through their decays into left-handed or right-handed leptons. The cross section also depends on the hypercharge Y of the $H^{\pm\pm}$ boson.

a) Production Cross Section of $H^{\pm\pm}$ at the LHC and the Tevatron

Figure (1-a) shows the production cross section of doubley-charged Higgs boson pair production and both of H^{++} and H^{--} decay to $e^{+}e^{+}$ and $e^{-}e^{-}$ respectively. In this simulation we off all decay channel of $H^{\pm\pm}$, only decays to $e^{+}e^{+}$ and $e^{-}e^{-}$ means BR ($H^{\pm\pm} \to e^{\pm}e^{\pm}$) = 1 and we calculate the production and decay of doubly charge Higgs boson (Right-handed and Left handed) at center of mass energies of the

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Large Hadron Collider (proton-proton collision) $\sqrt{s}$ = 7,8,10 and 12 TeV in addition to the production and decay at the Tevatron (proton- antiproton collision) $\sqrt{s}$ = 1.96 TeV, the mass values range here form 200 GeV to 1 TeV . From the Figure we see that the value of production decrease with increase the mass value at both the LHC and the Tevatron for right handed and left-handed doubly charged Higgs boson also the value of cross section at the Tevatron is small than at the LHC which increases with increasing the center of mass energy from 7 TeV to 12 TeV. In order to select events from well-measured collisions, the events are preselected by requiring at least two final-state light leptons, with pT > 30 GeV. If pairs of light leptons with invariant mass less than 12 GeV are reconstructed, neither of the particles is considered in the subsequent steps of the analysis. In Figures (1, b-c) show the production cross section of doubly-charged Higgs boson and decay to $e^{\pm}e^{\pm}, \mu^{\pm}\mu^{\pm}$ *and* $e^{\pm}\mu^{\pm}$ respectively, here the center of mass energy for the LHC is 14 TeV and at the Tevatron is 1.96 TeV we calculated for left-handed and right-handed doubly-charged Higgs boson in Left-Right Symmetric Model .

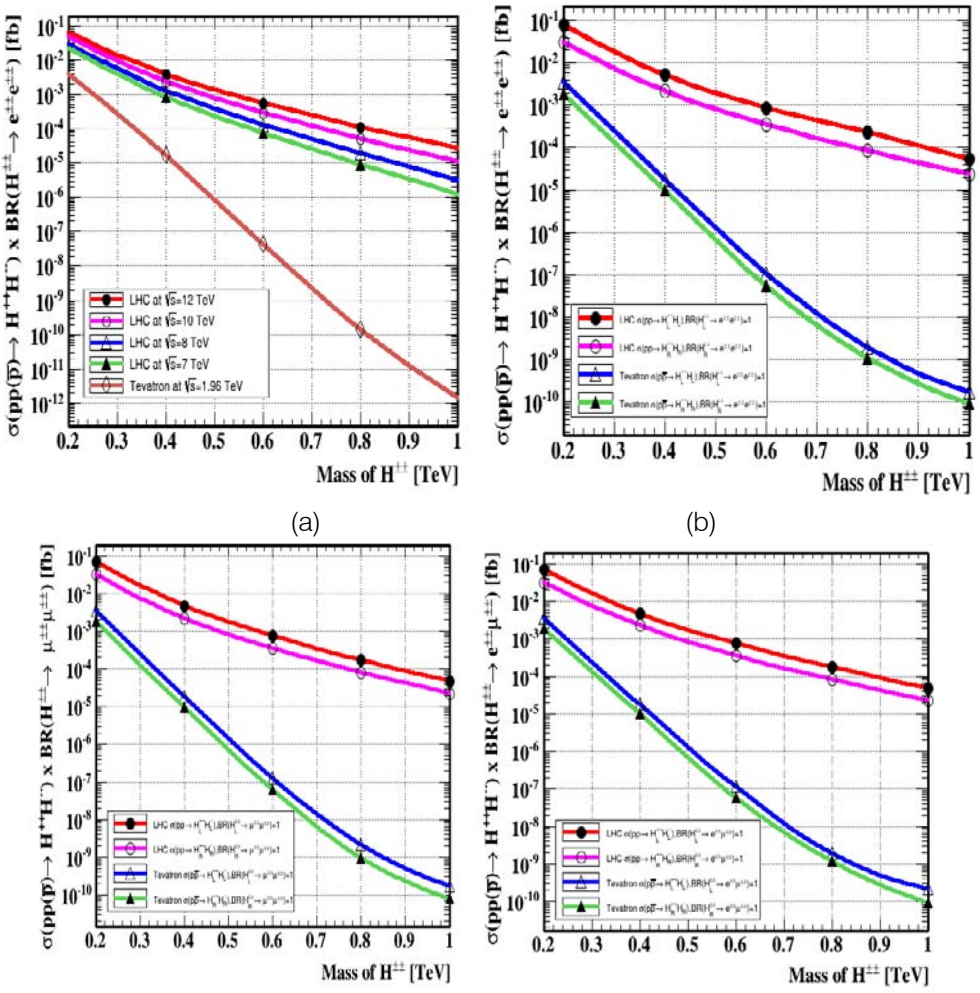


Figure 1 : The production cross section times branching ratio for pair production of $H_L^{\pm\pm}$ or $H_R^{\pm\pm}$ bosons at the LHC and the Tevatron decays to (a) $e^{\pm}e^{\pm}$ at the LHC energies 7,8,10 and 12 TeV and (b) $e^{\pm}e^{\pm}$ (c) $\mu^{\pm}\mu^{\pm}$ (d) $e^{\pm}\mu^{\pm}$ at 14 TeV (in the Left-Right Symmetric Model using Pythia8 and MadGraph5).

The main production mechanisms of $H^{\pm\pm}$ bosons at hadron colliders are pair roduction via an s-channel Z boson or photon exchange and associated production with a $H^{\pm\pm}$ boson via a W-boson exchange but in our work we study the production of $H^{\pm\pm}$ in concept of Left-Right Symmetric Model (LRSM) .

At D0 detector at the Fermilab Tevatron Collider. In the absence of an excess above the standard model background, lower mass limits M($H_L^{\pm\pm}$) >150 GeV/c2 and M($H_R^{\pm\pm}$) >127 GeV/c2. For left-handed and right-handed doubly-charged Higgs bosons assuming a 100% branching ratio into leptons BR($H^{\pm\pm} \rightarrow \ell^{\pm}\ell^{\pm} = 100\%, \ell = e^{\pm}, \mu^{\pm}, \tau^{\pm}$).

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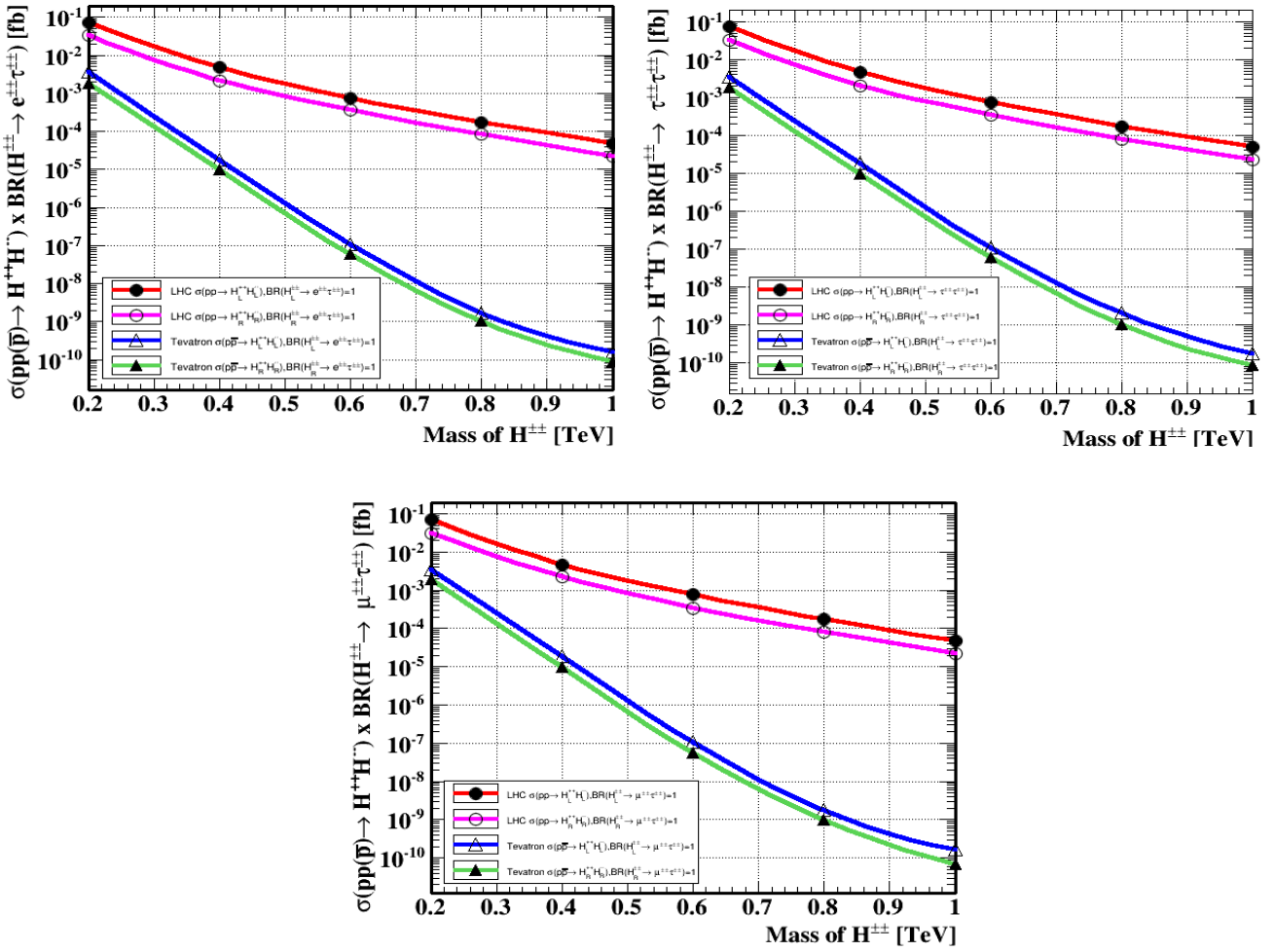


Figure 2 : The production cross section times branching ratio for pair production of $H_L^{\pm\pm}$ or $H_R^{\pm\pm}$ bosons at the LHC and the Tevatron decays to (a) $e^{\pm}\tau^{\pm}$ (b) $\mu^{\pm}e^{\pm}$ (c) $\tau^{\pm}\tau^{\pm}$ at $\sqrt{s} = 14$ TeV (in the Left-Right Symmetric Model using Pythia8 and MadGraph5).

b) Decay Width of $H^{\pm\pm}$

Doubly-charged Higgs bosons can couple to either left-handed or right-handed fermions. In Left-Right Symmetric Model, the two cases are distinguished and denoted $H_L^{\pm\pm}$ and $H_R^{\pm\pm}$. The $H^{\pm\pm}$ boson may decay to a pair of like-sign leptons whose invariant mass is consistent with the mass of M($H^{\pm\pm}$). The partial decay width to leptons is given by:

$$\Gamma(H^{\pm\pm} \to \ell^{\pm}\ell^{\pm}) = k\frac{h_{\ell\ell'}^2}{16\pi}m(H^{\pm\pm})$$

Where k = 2 if both leptons have the same flavour ($\ell = \ell'$) and k = 1 if they have a different flavor. The factor $h_{\ell\ell'}$ is the coupling parameter.

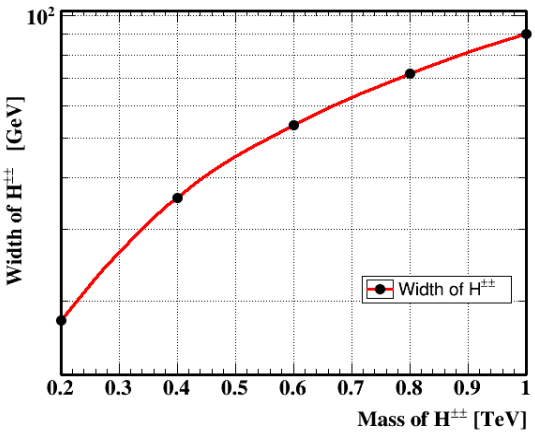


Figure 3 : Decay Width of $H^{\pm\pm}$ bosons as a function of $H^{\pm\pm}$ mass values (in the Left-Right Symmetric Model using Pythia8 and MadGraph5).

The electron identification uses a cut-based approach in order to reject jets misidentified as electrons, or electrons originating from photon

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conversions. In addition, electrons are required to have pT $>$ 20 GeV and$|\eta| < 2.5$. For Muon candidates are required to have pT $>$ 5 GeV and$|\eta| < 2.4$. Isolation of the final state leptons plays a key role in suppressing the SM backgrounds.

c) Branching Ratios of $H^{\pm\pm}$

The mass limits obtained for the $H^{\pm\pm}$ bosons depend on the ranching ratio (BR) assumed. The most stringent limits were set by the CMS Collaboration [9], masses below 382 GeV, 391 GeV, and 395 GeV for, $e^{\pm}e^{\pm}, \mu^{\pm}\mu^{\pm}$ *and* $e^{\pm}\mu^{\pm}$ final states, respectively, assuming left-handed couplings and a 100% branching ratio to each final state. In current work a search for a $H^{\pm\pm}$ boson decaying to pairs of electrons or muons or taus with the same electric charge $H^{\pm\pm} \rightarrow e^{\pm}e^{\pm}$, $H^{\pm\pm} \rightarrow \mu^{\pm}\mu^{\pm}$ and $H^{\pm\pm} \rightarrow \tau^{\pm}\tau^{\pm}$ is 12% but for electrons and muons and taus is 22% . Also the branching fraction of doubly-charged Higgs boson decay to W boson is small as shown in Figure (4)

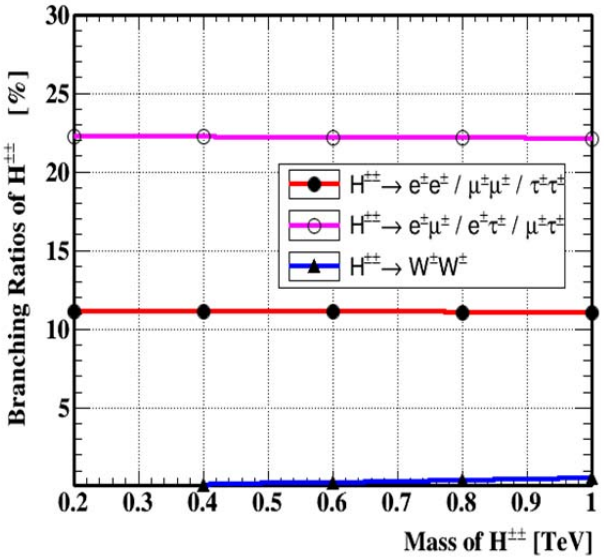


Figure 4 : Branching Ratios of $H^{\pm\pm}$ bosons as a function of $H^{\pm\pm}$ mass values (in the Left-Right Symmetric Model using Pythia8 and MadGraph5).

d) Dilepton Invariant Mass Distributions

Figure (5) shows the invariant mass distributions for the two leptons in final state produced from $H^{\pm\pm}$ bosons decay for different values of $H^{\pm\pm}$ masses at the LHC $\sqrt{s}$=14 TeV for $e^{\pm}e^{\pm}, \mu^{\pm}\mu^{\pm}$ *and* $e^{\pm}\mu^{\pm}$. The invariant mass of the lepton pair must be larger than 15 GeV, and for $e^{\pm}e^{\pm}$ the region close to the Z-boson mass (70 GeV $<$ m($e^{\pm}e^{\pm}$) $<$ 110 GeV) is excluded due to a large background from $Z \rightarrow e^{\pm}e^{\pm}$ events with an electron charge misidentification, as described below. The first limits on the $H_L^{\pm\pm}$ mass were derived based on the measurements done at PEP and PETRA experiments [11]. Next, the $H^{\pm\pm}$ was searched for at the MARK II detector at SLAC [12], the H1 detector at HERA [13] and the LEP experiments [14].

As we mentioned before the pair production cross section for left-handed doubly charged Higgs bosons for 200 GeV $<$ M($H^{\pm\pm}$) $<$ 800 GeV is larger than that for the right-handed states due to different couplings to the intermediate Z boson [10]. Leptons must have a transverse momentum above 30 GeV, in pairs where the higher transverse momentum lepton is an electron, it is required to have pT $>$ 25 GeV. All pairs of electrons or muons with the same electric charge are considered, so more than one lepton pair may be reconstructed per event.

In our search we look for an excess of events in one or more flavor combinations of same-sign lepton pairs coming from the decays $H^{\pm\pm} \rightarrow \ell^{\pm}\ell'^{\pm}$ so the final states containing four charged leptons are considered. From the dilepton events to test the presence of a $H_L^{\pm\pm}$ boson at LHC and Tevatron through resonance search technique $M(\ell^{\pm}\ell^{\pm})$ analysis. By using PYTHIA8 we note 4 peaks correspond to four different values of $H_L^{\pm\pm}$ mass 200,400,600 and 800 GeV. The most important experimental signature of the $H^{\pm\pm}$ is the presence of two like-charge leptons in the final state, with a resonant structure in their invariant mass spectrum. In this final state the background from SM processes is expected to be very small. For the four-lepton final state from $H^{++}H^{--}$ pair production, both Higgs bosons may be reconstructed, giving two like-charge pairs of leptons with similar invariant mass.

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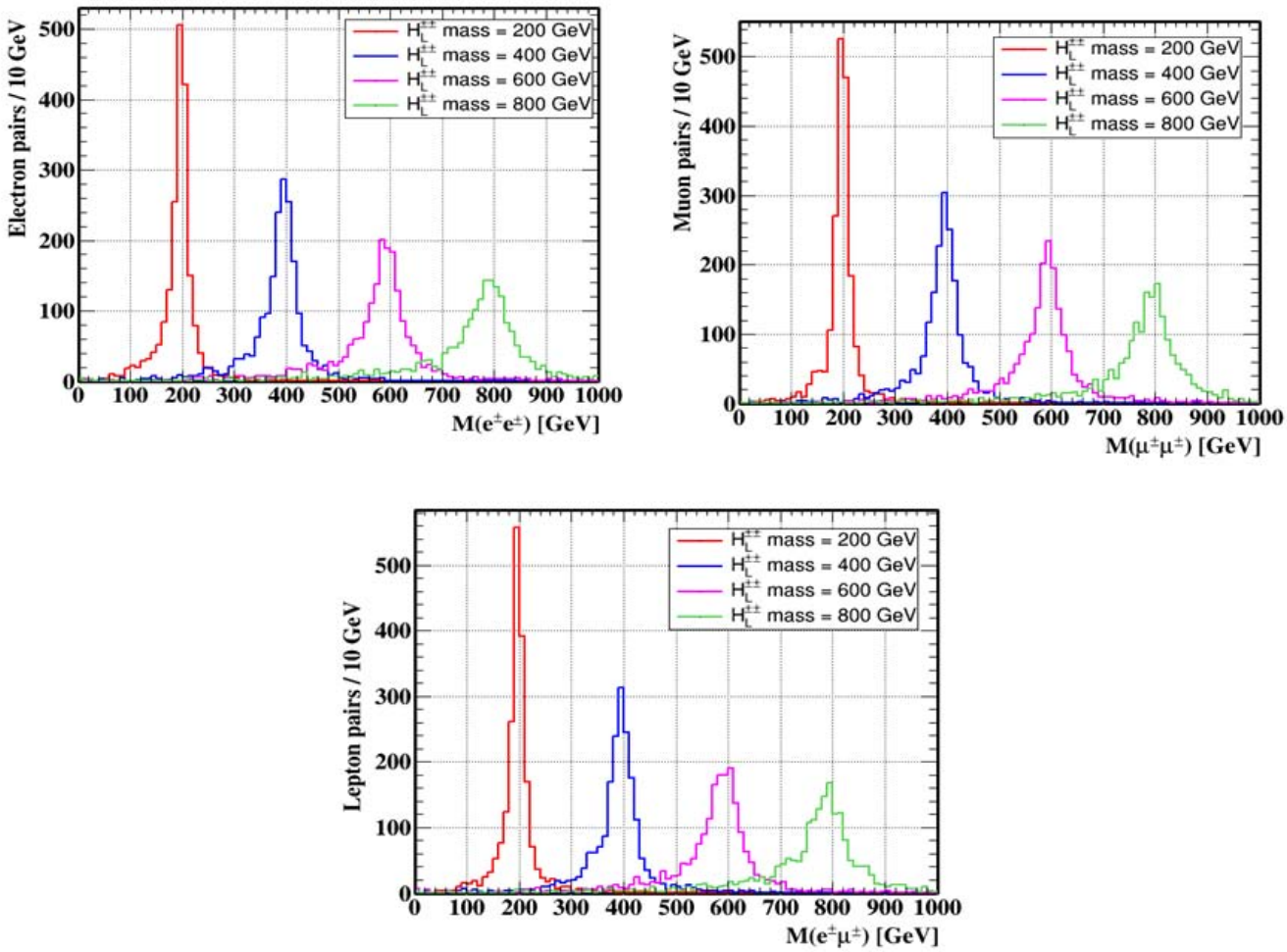


Figure 5 : Invariant mass distributions for two leptons in final state produced from $H_L^{\pm\pm}$ bosons decay for different values of $H_L^{\pm\pm}$ mass at the LHC $\sqrt{S}$=14 TeV (a) $e^{\pm}e^{\pm}$ (b) $\mu^{\pm}\mu$, (c) $e^{\pm}\mu^{\pm}$ (in the Left-Right Symmetric Model using Pythia8 and MadGraph5).

Experiments at the CERN LEP collider have searched for pair production of doubly charged Higgs bosons in $e^{\pm}e^{\pm}$ interactions. Mass limits for decays into muons of $M(H_L^{\pm\pm})$ >100.5 GeV/c2 and $M(H_R^{\pm\pm})$ >100.1 GeV/c2 were obtained by the OPAL collaboration [24], and a limit of M($H_{L(R)}^{\pm\pm}$) > 99.4 GeV/c2 by the L3 collaboration [25]. Similar limits were set for decays into electrons and τ-leptons [26]. Previous searches for $H^{\pm\pm}$ have been performed by the LEP collaborations in $e^{\pm}e^{\pm}$ collisions and by the D0 [27] and CDF [28] collaborations at the Tevatron $p\bar{p}$ collider.

e) Leptons Angular Distributions

Figure (6) shows the angular distribution of four leptons in final state of produced from the decay of pair doubly-charged Higgs boson events which act as forward and backward events for interaction. The angular distribution can also be used to test the presence of $H_L^{\pm\pm}$ boson at the LHC and the Tevatron, we see from the figure that there is a symmetry around value for different values of masses for $H_L^{\pm\pm}$.

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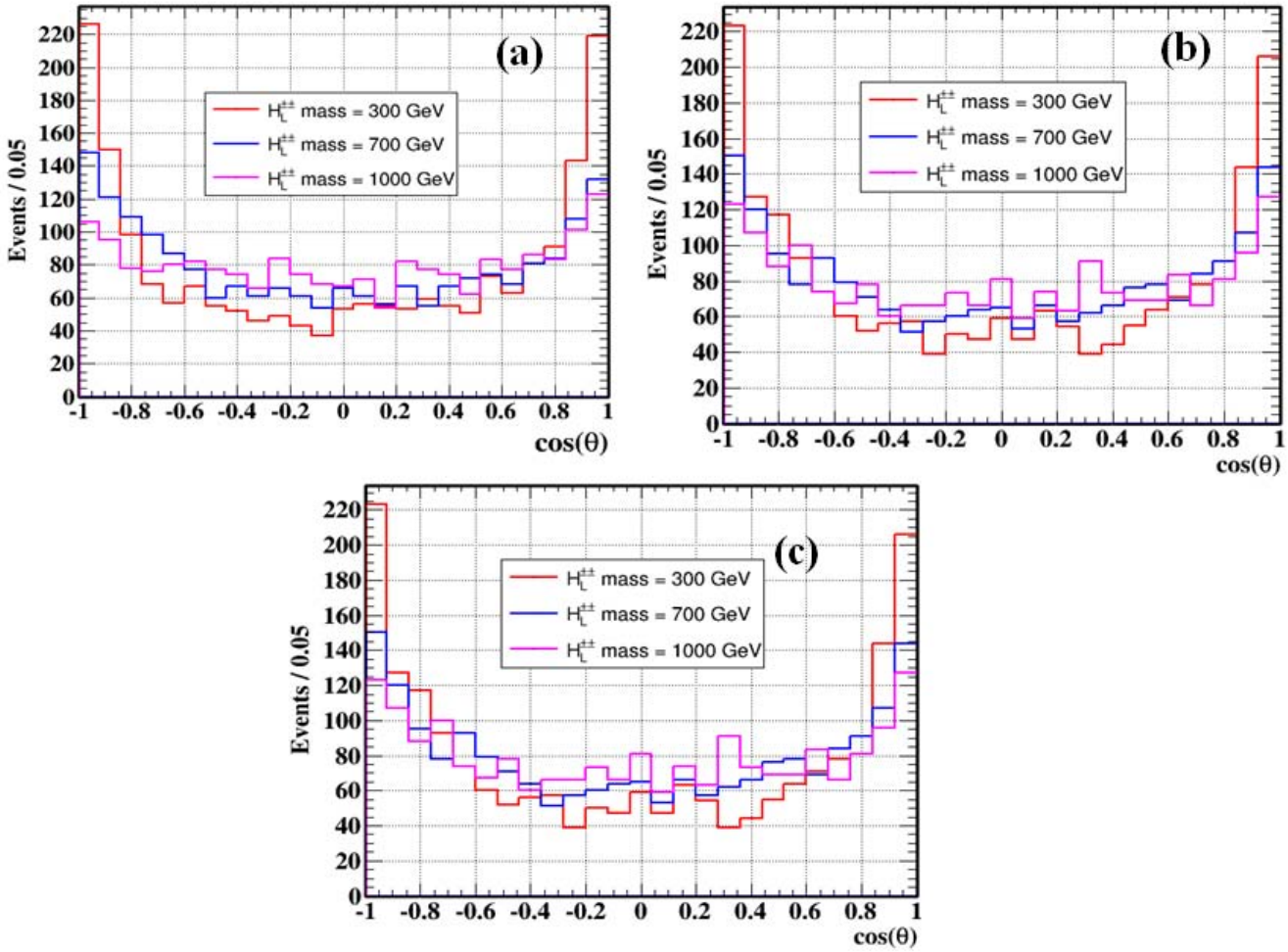
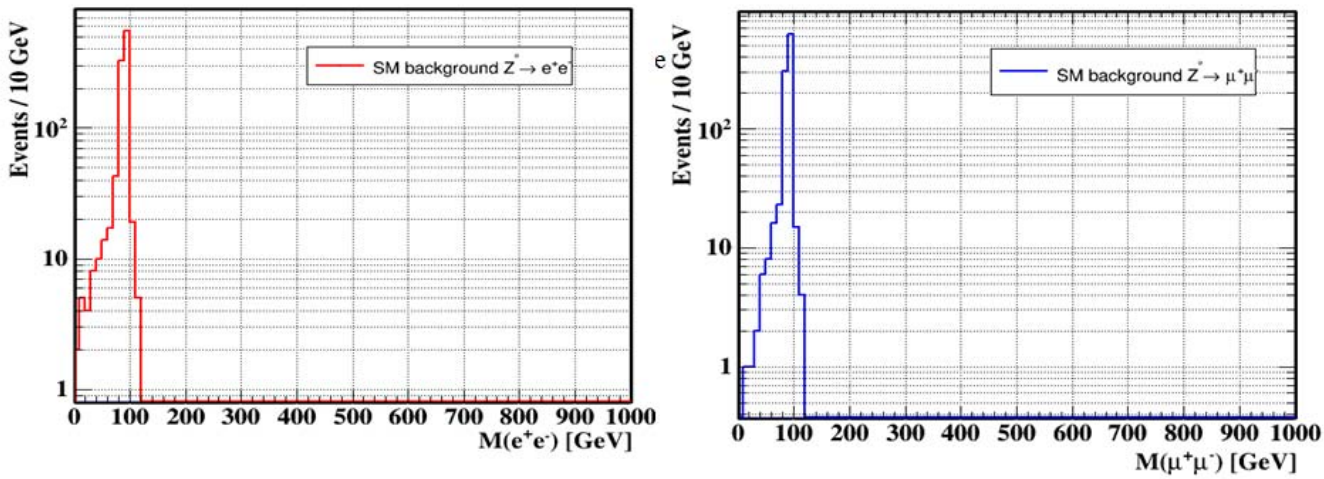


Figure 6 : Angular distribution (forward and backward) of leptons in the final state produced from doubly charged Higgs decay for M($H_L^{\pm\pm}$) =300,700 and 1000 GeV at the LHC $\sqrt{s}$=14 TeV (a) $e^{\pm}e^{\pm}$ (b) $\mu^{\pm}\mu^{\pm}$ (c) $e^{\pm}\mu^{\pm}$ (in the Left-Right Symmetric Model using Pythia8 and MadGraph5).

f) Standard Model Background

The dominant SM background comes from Zo decay. Figure (7) shows the generated $e^{\pm}e^{\pm}$, $\mu^{\pm}\mu^{\pm}$ *and* $e^{\pm}\mu^{\pm}$ events for a reconstructed mass of 300 GeV for SM Zo. We note that there is a peak centered around 100 GeV. According to the SM this peak corresponds to the production of a Zo with a mass of 91.188 GeV. This process



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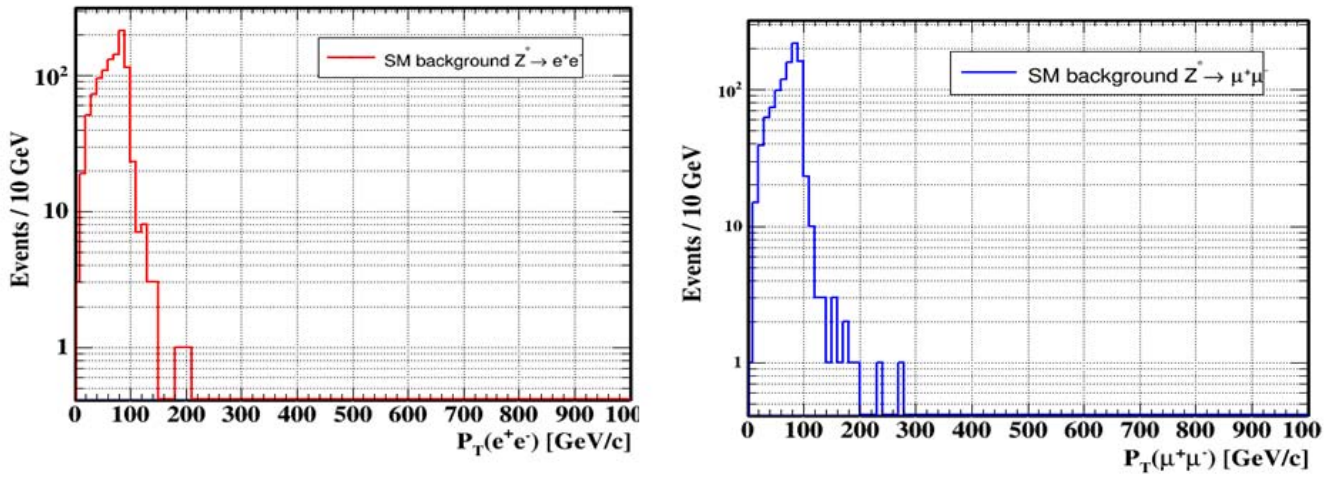


Figure 7 : The Drell-Yan process background – the invariant mass of electrons and muons (Top) produced from Z° boson and the transverse momentum for electrons and muons (Bottom) (in the Left-Right Symmetric Model using Pythia8 and MadGraph5).

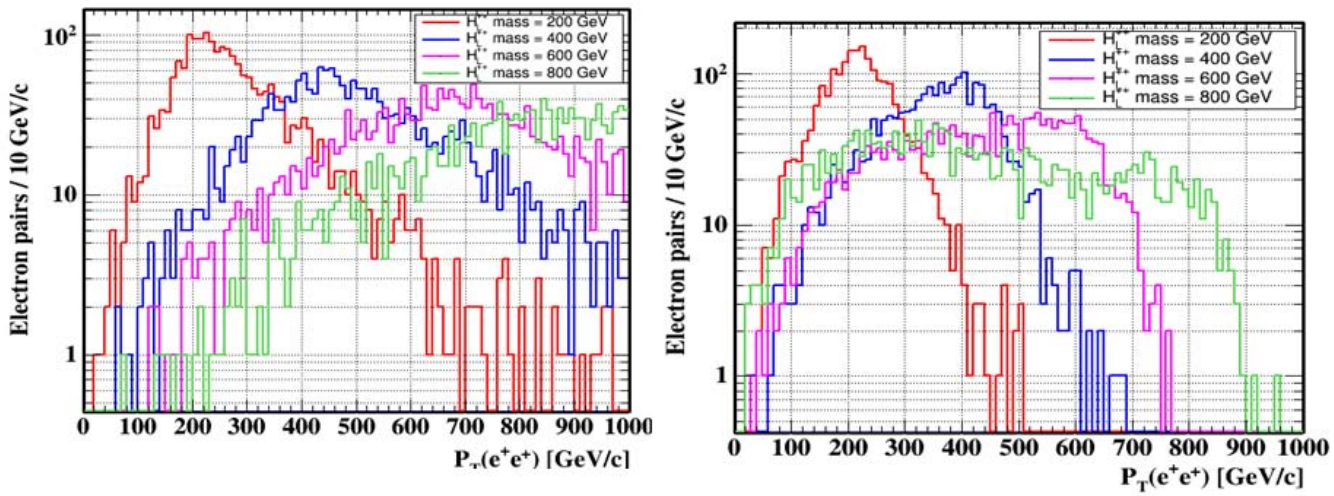
SM backgrounds in this search come from like-sign lepton pairs is WZ production, and smaller sources include ZZ, like-sign WW, $t\bar{t}W$, and $t\bar{t}Z$production. The $H^{\pm\pm}$ process is simulated using PYTHIA8 [16] to estimate the acceptance and efficiency for reconstructing $H^{\pm\pm}$ bosons with masses between 200 GeV and 800 GeV. The latest results are from the Tevatron and ATLAS [17–19] experiments, which set lower limits on the $H^{\pm\pm}$ mass between 112 and 355 GeV, depending on assumptions regarding $H^{\pm\pm}$ branching fractions. In all previous searches, only the pair-production mechanism, and only a small fraction of the possible final state combinations, were considered. The addition of associated production and all possible final states significantly improves the sensitivity and reach of this analysis.

The kinematic properties of $H_L^{\pm\pm}$ and $H_R^{\pm\pm}$ bosons are identical only their cross sections differ. In this article the results of a search for a doubly-charged Higgs boson at the LHC and the Tevatron using Monte Carlo simulation Techniques experiments are presented the pair-production process $pp(\bar{p}) \rightarrow H^{++}H^{--} \rightarrow \ell_\alpha^+\ell_\beta^+\ell_\lambda^-\ell_\delta^-$ [20, 21] and the associated production process $pp(\bar{p}) \rightarrow H^{++}H^{--} \rightarrow \ell_\alpha^+\ell_\beta^+\ell_\lambda^-\nu_\delta$ [22, 23] are studied.

g) Transverse Momentum Distributions

The transverse-momentum PT distributions and rapidity of the $H_L^{\pm\pm}$ boson provide new information about the dynamics of proton collisions at high energies and the PT spectrum provides a better understanding of the underlying collision process at low transverse momentum.

Figure (8) shows the transverse momentum PT distributions of different combination of electron and muon in final state in invariant mass region 200 < $M_{e^+e^-}$< 800 GeV produced from $H_L^{\pm\pm}$ decay. The results are obtained using PYTHIA8 of proton-proton collisions at a center-of-mass energy of 14 TeV at LHC. The distributions are measured over the ranges $|\eta| <$ 2.5.



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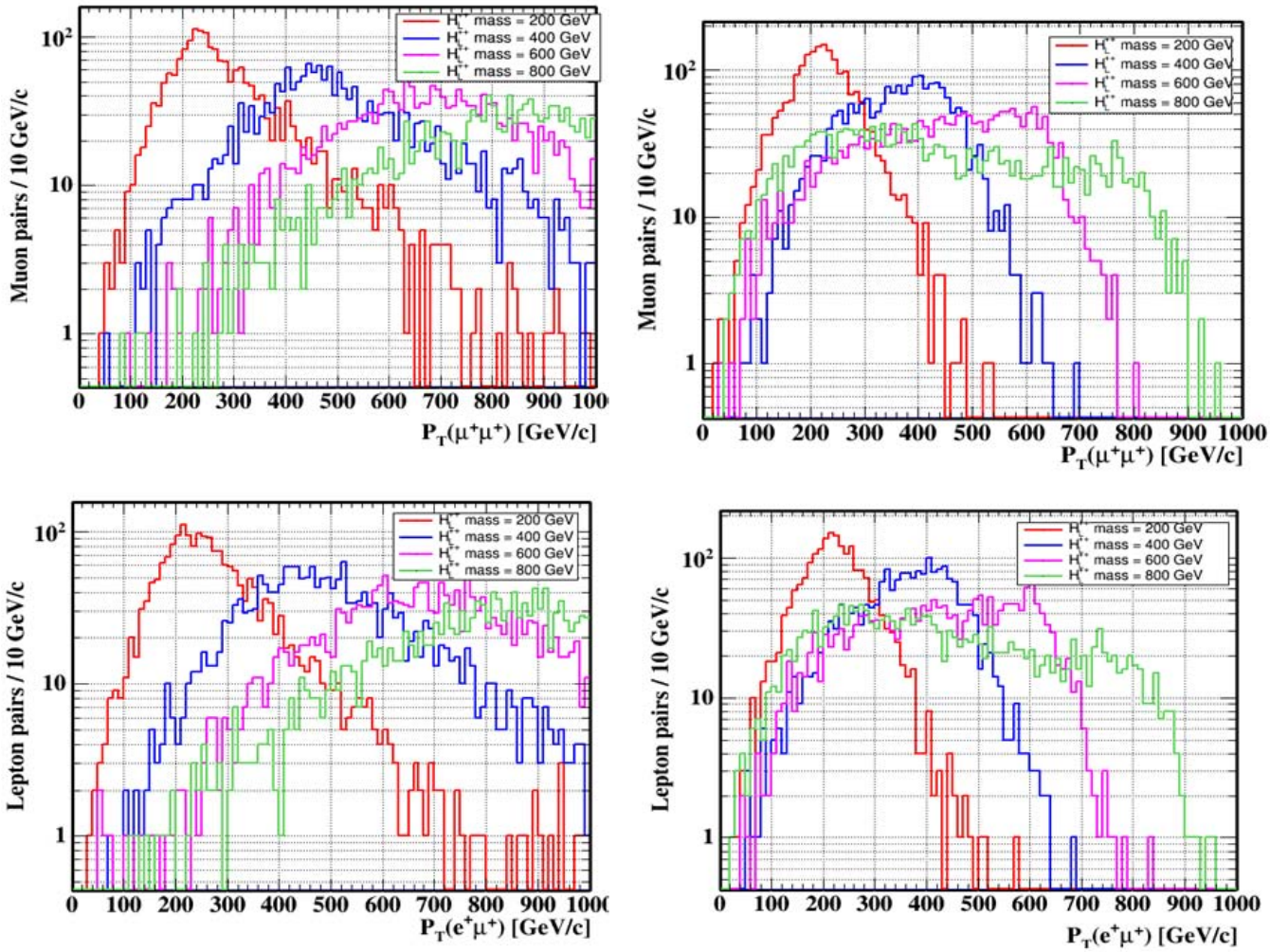


Figure 8 : Transverse momentum distributions of $e^{\pm}e^{\pm}$, $\mu^{\pm}\mu^{\pm}$ *and* $e^{\pm}\mu^{\pm}$ for different values of $H_L^{\pm\pm}$ mass at the LHC $\sqrt{s}$=14 TeV (Left column) and at the Tevatron $\sqrt{s}$=1.96 TeV (Right column)

For the $e^{\pm}e^{\pm}$, $\mu^{\pm}\mu^{\pm}$ *and* $e^{\pm}\mu^{\pm}$ channels in Figure (5) assuming a branching ratio to the given lepton flavour of 100% assuming that the sum of the branching fractions of the $H^{\pm\pm}$ to all lepton flavour combinations is 100%. The dominant background in this analysis arises from electroweak processes where real high pT muons are created from W or Z boson decays as well as non-isolated muons originating from jets. The SM backgrounds and signal processes are generated with Pythia8 [29].

The signal final state consists of four charged leptons. Two like-sign leptons originate from the $H^{\pm\pm}$ decay and are expected to be visible in the detector in most cases. A search for a doubly-charged Higgs boson in proton-proton and proton-antiproton collisions are presented. The search is performed using events with three or more isolated charged leptons of any flavor. The $H^{\pm\pm}$ particle carries double electric charge, and decays to same-sign lepton pairs $\ell^{\pm}\ell'^{\pm}$. The relevant Production cross sections, calculated following are presented in Figures 1 and 2. $H^{\pm\pm}$ is assumed to decay in 100% of the cases in turn in each of the possible lepton combinations $ee, \mu\mu, \tau\tau, e\mu, e\tau, \mu\tau$

h) Transverse Energy Distributions

Figure (9) show the transverse energy of different combination of leptons produced from the decay of for different values of $H_L^{\pm\pm}$ masses at the LHC $\sqrt{s}$ =14 TeV (Left column) and at the Tevatron $\sqrt{s}$ =1.96 TeV (Right column). We see that there are four peaks for every mass value of $H_L^{\pm\pm}$. Transverse energy is defined as $E_T = E\sin(\theta)$

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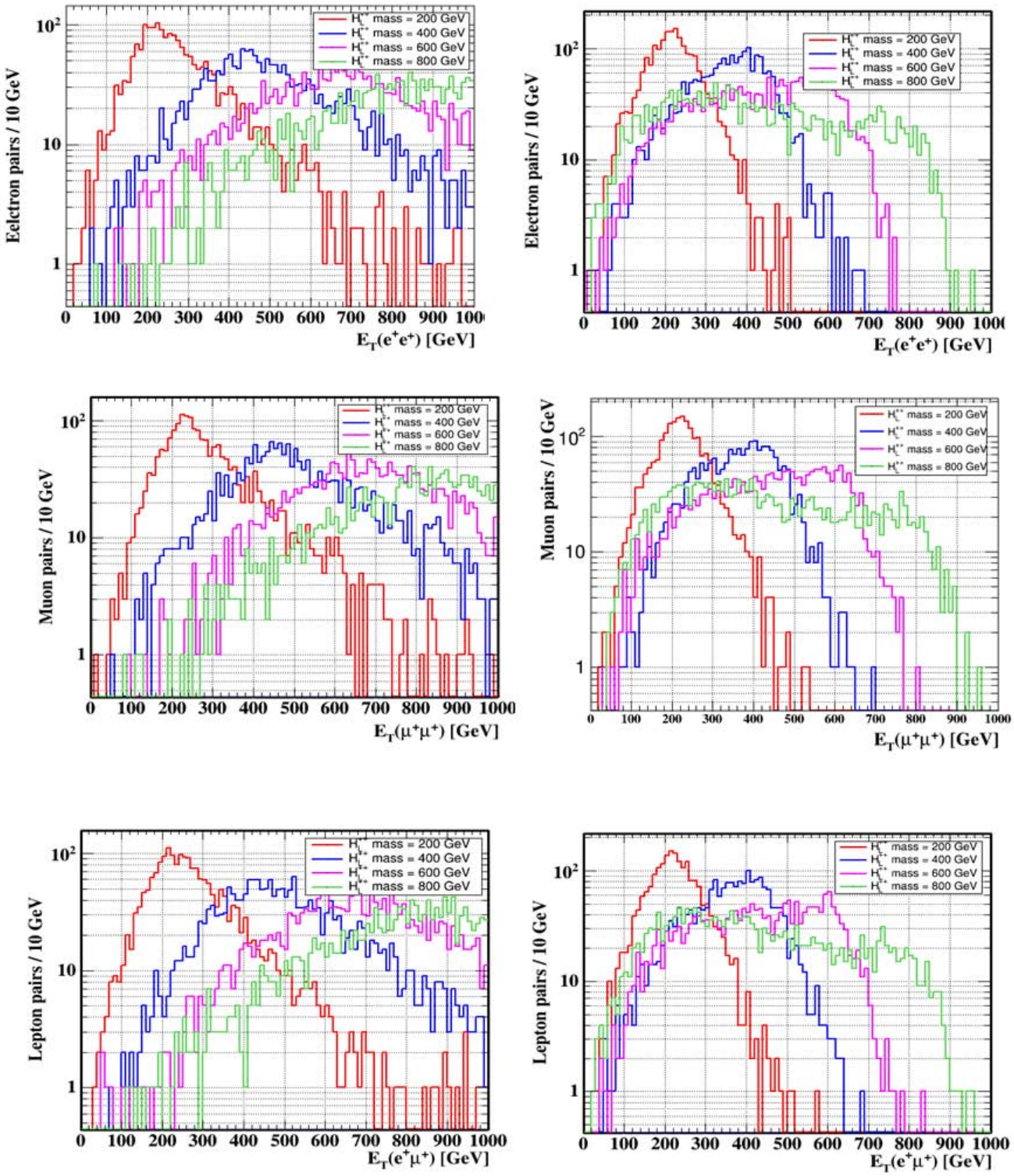


Figure 9 : Transverse Energy distributions of $e^{\pm}e^{\pm}$, $\mu^{\pm}\mu^{\pm}$ *and* $e^{\pm}\mu^{\pm}$ for different values of $H_L^{\pm\pm}$ mass at the LHC $\sqrt{s}$ =14 TeV (Left column) and at the Tevatron $\sqrt{s}$ =1.96 TeV (Right column).

i) Pseudorapidity Distributions

The selected electrons must be in the central or in the forward regions of $|\eta| < 2.5$ then we choose the two highest-energy electron or muons where η is the pseudo rapidity of emitted electrons which describes the angle of a particle relative to beam axis.

$$\eta = -\ln\left[\frac{\theta}{2}\right]$$

θ is the angle between the particle momentum vector P and the beam axis see figure.

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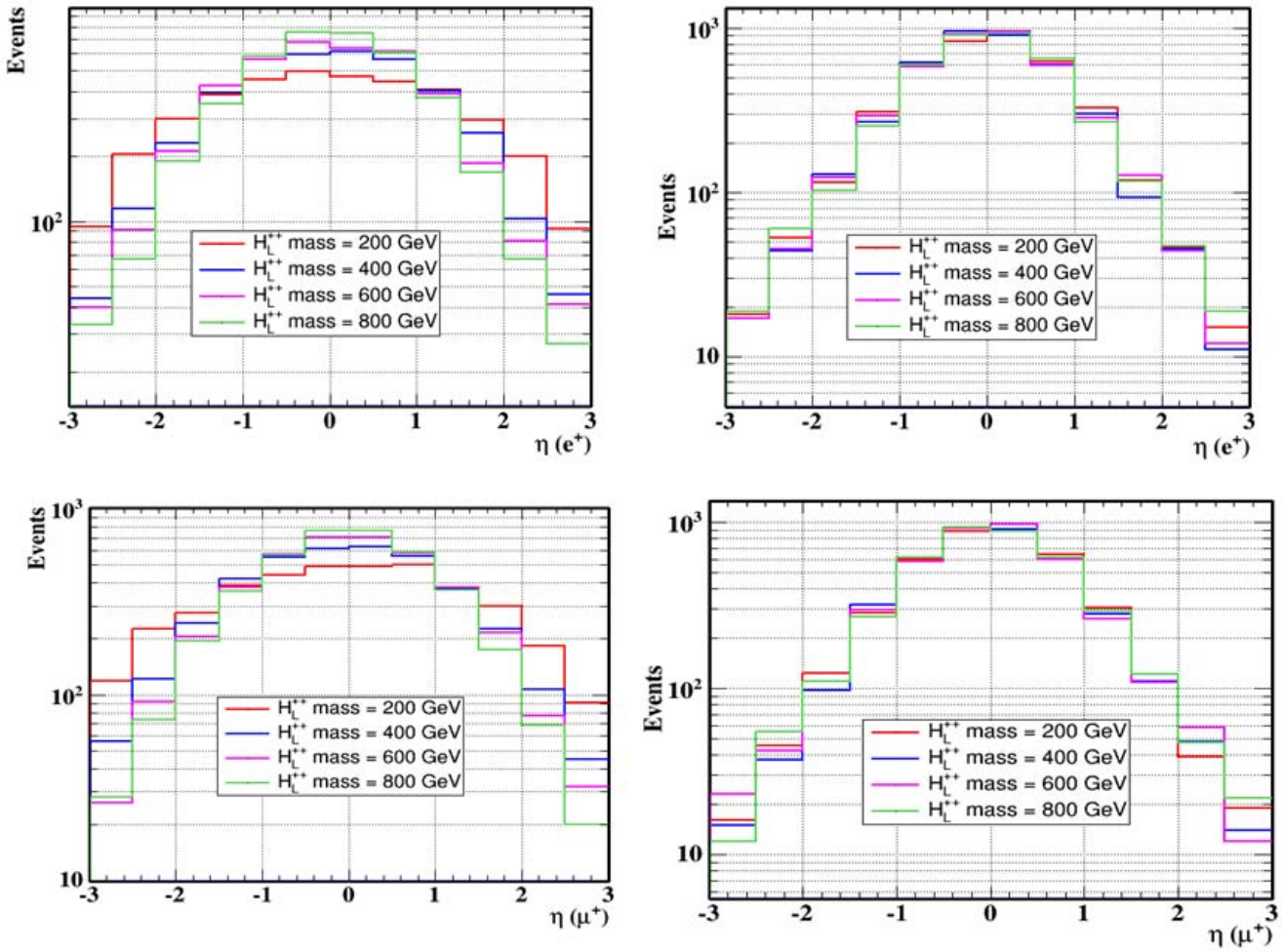


Figure 10 : Pseudorapidity distributions of Electrons and Muons for different values of $H_L^{\pm\pm}$ mass at the LHC $\sqrt{s}$= =14 TeV (Left column) and at the Tevatron $\sqrt{s}$=1.96 TeV (Right column)

j) Rapidity Distribution

The Rapidity y is a measure of where a lepton is located in space and is defined as:

$$y = \frac{1}{2} \ln \frac{(E + P_T)}{(E - P_T)}$$

where E is the energy of the H^{++} candidate and PT is its longitudinal momentum along the anticlockwise beam axis (the z axis of the detector). The y and PT of H^{++} are determined from the leptons momenta.. The distributions are corrected for signal acceptance and efficiency and for the effects of detector resolution and electromagnetic final-state radiation (FSR) using an unfolding technique based on the inversion of a response matrix. The final result takes into account the bin width and is normalized by the measured total cross section.

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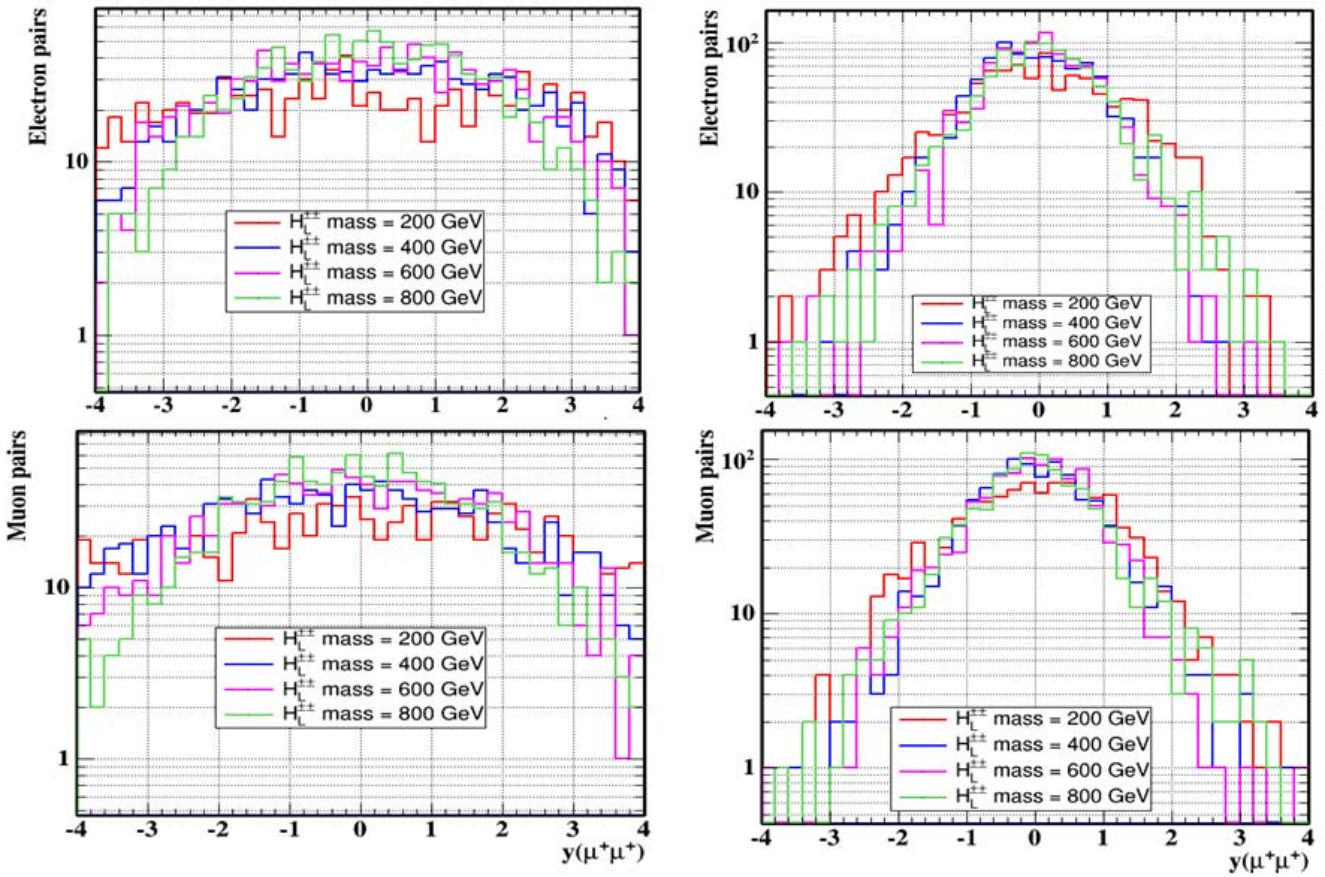


Figure 11 : Rapidity distributions of Electrons and Muons for different values of $H_L^{\pm\pm}$ mass at the LHC $\sqrt{s}$ =14 TeV (Left column) and at the Tevatron $\sqrt{s}$ =1.96 TeV (Right column)

III. Conclusion

In this work we have analyzed doubly-charged Higgs pair production at the Tevatron and the LHC using Monte Carlo event generators Pythia8 and also by MadGraph5. The doubly-charged Higgs boson can be decayed to $e^{\pm}e^{\pm}, \mu^{\pm}\mu^{\pm}$ *or* $e^{\pm}\mu^{\pm}$ so we can search for four charged leptons in final state produced from doubly-charged Higgs boson pair via the process$pp(\bar{p}) \rightarrow H^{\pm\pm}H^{\pm\pm} \rightarrow \ell^{\pm}\ell^{\pm}\ell^{\pm}\ell^{\pm}$, $\ell = e^{\pm}, \mu^{\pm}$. We serarched for a narrow resonance peak in the dilepton mass distribution produced from $H^{\pm\pm}$ decay. Also we calculated the production Cross section of doubly charged Higgs boson pair at the LHC and at the Tevatron for left-hand $H_L^{\pm\pm}$ and right-hand $H_R^{\pm\pm}$. We found that the production cross section depends on the mass of the $H^{\pm\pm}$ boson in the final state. We calculated different dynamics distributions for the different combination of leptons in the final states assuming pair production couplings to left handed leptons, and a branching ratio of 100% BR($H^{\pm\pm} \rightarrow \ell^{\pm}\ell^{\pm} = 1, \ell = e^{\pm}, \mu^{\pm}$). for each final state. Finally, the doubly charged Higgs may be found at the LHC or at the Tevatron in the mass range up to 800 GeV.

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Supersymmetry Quantum Mechanics and Exact Solutions of the Effective Mass of Schrodinger Equations with Rosen-Morse Potential

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Abstract- In quantum mechanics a localized attractive potential typically supports a (possibly infinite) set of bound states, characterized by a discrete spectrum of allowed energies, together with a continuum of scattering states, characterized (in one dimension) by energy-dependent phase shift. The Morse potential named after physicist Philip M.Morse, is a convenient model for the potential energy of a diatomic molecule. It is a better approximation for the vibrational structure of the molecule than the quantum harmonic oscillator because it explicitly includes the effects of bond breaking such as the existence of unbound states. It also accounts for the anharmonicity of real bonds and the non-zero transition probability for overtone and combination bands. The Morse potential can also be used to model other interactions such as the interaction between an atom and a surface. We here make the case that the trigonometric Rosen-Morse potential is exactly soluble in terms of a family of real orthogonal polynomials and present the solutions. and analytical solutions of the Klein-Gordon equation for the Rosen-Morse potential with equal scalar and vector potentials are studied in this paper.

Keywords: *supersymmetry, morse-rosen potential, eckart potential, schrodinger eqation.*

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Supersymmetry Quantum Mechanics and Exact Solutions of the Effective Mass of Schrodinger Equations with Rosen-Morse Potential

R.Amiri [α] & M.Tavakkoli [σ]

Abstract- In quantum mechanics a localized attractive potential typically supports a (possibly infinite) set of bound states, characterized by a discrete spectrum of allowed energies, together with a continuum of scattering states, characterized (in one dimension) by energy-dependent phase shift. The Morse potential named after physicist Philip M.Morse, is a convenient model for the potential energy of a diatomic molecule. It is a better approximation for the vibrational structure of the molecule than the quantum harmonic oscillator because it explicitly includes the effects of bond breaking such as the existence of unbound states. It also accounts for the anharmonicity of real bonds and the non-zero transition probability for overtone and combination bands. The Morse potential can also be used to model other interactions such as the interaction between an atom and a surface. We here make the case that the trigonometric Rosen-Morse potential is exactly soluble in terms of a family of real orthogonal polynomials and present the solutions. and analytical solutions of the Klein-Gordon equation for the Rosen-Morse potential with equal scalar and vector potentials are studied in this paper.

Keywords: supersymmetry, morse-rosen potential, eckart potential, schrodinger eqation.
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I. Introduction

The supersymmetric quantum mechanics manages a family of exactly soluble potentials, one of them being the trigonometric Rosen-Morse potential. As long as this potential is obtained from the Eckart potential by complexification of the argument and one of the constants,also its solutions have been concluded rfom those of the Eckart potential by same procedure.

Supersymmetric quantum mechanics was originally proposed by Witten as a simple learning ground for the basic concepts of supersymmetric quantum field theories but soon after it evolved to a research field on its own rights. Supersymmetric quantum mechanics starts with the factorization of one-dimensional Hamiltonians,

$$H(y) = -\frac{\hbar^2}{2m}\frac{d^2}{dy^2} + V(y) \qquad (1)$$

According to $H(y) = A^+(y)A^-(y) + \mathcal{E}$ with $A^{\pm}(y) = (\pm\frac{\hbar}{\sqrt{2m}}\frac{d}{dy} + U(y))$ Where *U(y)* is the superpotential [1-3]. supersymmetry is arguably the most attractive mechanism to stabilize the hierarchy between the fundamental scale (e.g. the Planck scale $M_* \sim 10^{18}$ *GeV)* and the electroweak scale ($M_w \sim 100GeV$). However, superpartners of the standard model particles have not been observed up to energies of order *Mw*, so supersymmetry must be broken at or above the weak scale.The phenomenology of supersymmetry depends crucially on the mechanism of supersymmetry breaking and the way that supersymmetry breaking is communicated to the observable sector. The supersymmetric quantum mechanics manages a family of exactly soluble potentials, one of them being the trigonometric Rosen-Morse potential .we make the point that the trigonometric Rosen-Morse potential is of possible interest to quark physics in so far as it captures the essentials of the QCD quark-gluon dynamics [4-6].

II. The Morse Potential Energy Function

Exact solutions of the effective mass of schrodonger equations for the mentioned potentials are interesting in the fields of material science and condense matter physics. There are various methods for exact solutions to energy eigenvalues and corresponding wave function [7,8].

We can quite write the schrodinger equation in three dimensions for a diatomic molecule with the mass of nuclei m_1 and m_2 as the following form:

$$\left(-\frac{\hbar^2}{2\mu}\nabla^2 + V(r)\right)\psi_{nlm}(r,\theta,\varphi) = E\psi_{nlm}(r,\theta,\varphi) \qquad (2)$$

Where $\hbar$, μ , $V(r)$ and E are Planck's constant, reduced mass, spherical potential and eigenvalue energy of a quantum system. The radial part of the wave function $R_{nl}(r)$ is defined by relation of $\psi_{nlm}(r,\theta,\varphi) = \frac{R_{nl}(r)}{r} Y_{lm}(\theta,\varphi)$ In that case, the radial schrodinger equation is written by,

$$\frac{d^2R_{nl}(r)}{dr^2} + 2\big(E - V_{eff}\big)R_{nl}(r) = 0 \qquad (3)$$

Where we simply suppose that $\hbar = \mu = 1$ and V_{eff} equal the Rosen-Morse potential plus centrifugal term [8,9].

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Exactly solvable 1-dimensional Schrodinger equations play an important role in quantum physics. The best known are the harmonic oscillator and the radial equation for the hydrogen atom, which are covered in every course of quantum mechanics.
The Morse potential energy function is o the form

$$V_{eff}(r) = D_e\left(1 - e^{-a(r-r_e)}\right)^2 \quad (4)$$

Here r is the distance between the atoms, r_e is the equilibrium bond distance, D_e is the well depth (defined relative to the dissociated atoms), and a controls the width of the potential) the smaller a is, the larger the well). The dissociation energy of the bond can be calculated by subtracting the zero point energy $E(0)$ from the depth of the well. The force constant of the bond can be found by Taylor expansion of $V(r)$ around $r = r_e$ to the second derivative of the potential energy function, from which it can be shown that the parameter, a, is

$$a = \sqrt{\frac{K_e}{2D_e}} \quad (5)$$

Where K_e is the force constant at the minimum of the well. Since the zero of potential energy is arbitrary, the equation for the Morse potential can be rewritten any number of ways by adding or subtracting a constant value. When it is used to mode the atom- surface interaction, the Morse potential is usually written in the form:

$$V_{eff}(r) - D_e = D_e\left(e^{-2a(r-r_e)} - 2e^{-a(r-r_e)}\right) \quad (6)$$

Where r is now the coordinate perpendicular to the surface. This form approaches zero at infinite r and $-D_e$ at its minimum. It clearly shows that the Morse potential is the combination of a short-range repulsion and a longer-range attractive tail.
The schrodinger equation

$$\left(-\partial_r^2 + V_{eff}(r) - \delta\right)\varphi(r) = 0 \quad (7)$$

Where

$$V_{eff}(r) = \frac{cosr}{sinr} + \left(\frac{\mu^2}{4} - \frac{1}{4}\right)\frac{1}{sin^2 r} \quad (8)$$

This potential is known as the Rosen-Morse potential, also the trigonometric Rosen-Morse potential. to write the stationary states on the Rosen-Morse potential, i.e. solution $\psi(v)$ and E(v) of the following schrodinger equation:

$$\left(-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial r^2} + V_{eff}(r)\right)\psi(v) = E(v)\psi(v) \quad (9)$$

It is convenient to introduce the new variables:

$$x = ar,\ \ x_e = ar_e,\ \ \lambda = \frac{\sqrt{2mD_e}}{a\hbar},\quad \mathcal{E}_v = \frac{2m}{a^2\hbar^2}E(v) \quad (10)$$

Then, the schrodinger equation takes the simple form:

$$\left(-\frac{\partial^2}{\partial x^2} + V_{eff}(x)\right)\psi_n(x) = \varepsilon_n\psi_n(x) \quad (11)$$

$$V_{eff}(x) = \lambda^2\left(e^{-2(x-x_e)} - 2e^{-(x-x_e)}\right) \quad (12)$$

Its eigenvalues and eigenstates can be written as:

$$\varepsilon_n = -(\lambda - n - \tfrac{1}{2})^2 \quad (13)$$

$$\psi_n(z) = N_n z^{\lambda-n-\frac{1}{2}} e^{-\frac{1}{2}z} L_n^{2\lambda-2n-1}(z) \quad (14)$$

Where $z = 2\lambda e^{-(x-x_e)}$. whereas the energy spacing between vibrational levels in the quantum harmonic oscillator is constant at $h\nu_O$, the energy between adjacent levels decreases with increasing v in the Rosen-Morse oscillator.

$$\frac{E_v}{hc} = \omega_e\left(v + \frac{1}{2}\right) - \omega_e\chi_e(v + \frac{1}{2})^2 \quad (15)$$

In which the constants ω_e and $\omega_e x_e$ can be directly related to the parameters for the Rosen-Morse potential. As is clear from dimensional analysis, for historical reasons the last equation uses spectroscopic notation in which we represents a wave number obeying $E = hc\omega$, and not an angular frequency given by $E = \hbar\omega$ [10-12].

figure 1: the Morse potential (dark) and harmonic oscillator potential (light) unlike the energy levels of the harmonic oscillator potential, which are evenly sapced by $\hbar\omega$, the Morse potential level spacing decreases as the energy approaches the dissociation energy. The dissociation energy D_e is larger than the true energy required for dissociation D_0 due to the zero point energy of the lowest (v=0) vibrational level.[12]

One of the main problems which are involved in many physical processes is the difference of energy state between ground state and first excited state for potential wells. Ground state wave energy E^1 and first excited state energy E^2, as a result:

$$E^1 = \frac{\int_{-\infty}^{+\infty}\varphi(x)(\delta H)\varphi(x)dx}{\int_{-\infty}^{+\infty}\varphi^2(x)dx} = \frac{\int_{-\infty}^{+\infty}\varphi(x)\left[\frac{\left[\psi_0^1(x_0)\right]^2}{I_1}\right]\delta(x-x_0)\varphi(x)dx}{\int_{-\infty}^{+\infty}\varphi^2(x)dx} + \frac{\int_{-\infty}^{+\infty}\varphi(x)\left[\frac{\left[\psi_0^1(-x_0)\right]^2}{I_1}\right]\delta(x+x_0)\varphi(x)dx}{\int_{-\infty}^{+\infty}\varphi^2(x)dx} =$$
$$\frac{1}{4}\left[\frac{1}{I_1} + \frac{1}{I_2}\right]\frac{1}{\int_{-\infty}^{+\infty}\varphi^2(x)dx} \quad (16)$$

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$$E^2 = -\{\int_{-\infty}^{-x_0} dx \left[\frac{E^1 \int_{-\infty}^{x} \varphi^2(x)dx}{\varphi(x)}\right]^2 + \int_{-x_0}^{+x_0} dx \left[\frac{E^1 \int_{-x_0}^{x} \varphi^2(x)dx}{\varphi(x)}\right]^2 + \int_{x_0}^{x} dx \left[\frac{E^1 \int_{x}^{\infty} \varphi^2(x)dx}{\varphi(x)}\right]^2\} \quad (17)$$

$$\Delta E = E^1 + E^2 \quad (18)$$

$$I_+ = \int_{nx_0}^{\infty} \left(\psi_0^1(y)\right)^2 dy, \qquad I_- = \int_{-\infty}^{-nx_0} \left(\psi_0^1(y)\right)^2 dy \quad (19)$$

III. The Shpe of the Trigonometric Rosen-Morse Potential

The study of exactly solvable potentials in quantum mechanics for years has received a lot of attention. For solvable models, the simplest generation technique is supersymmetric quantum mechanics, which is equivalent to the factorizatior method, the intertwining technique and the Darboux transformation method.it is well known that the spectrum of the generated Hamiltonian differs little from the initial one. This suggests a way to realize, in practice, the spectral design: (i) one starts from a potential having a spectrum close to the desired one. (ii) then, by appropriately moving creating or deleting a certain set of levels, and iterating the method as many times as needed to achieve the required spectrum, one will arrive at a Hamiltonian (or a set of Hamiltonians),which could model the situation under study [13].

We adopt the following form of the trigonometric Rosen-Morse potential

$$v(z) = -2bcotz + a(a+1)csc^2 z \quad (20)$$

With $a > -\frac{1}{2}$ and displayed in Fig.1. Here, $z = \frac{y}{d}$, $v(z) = V(zd)/(\frac{\hbar^2}{2md^2})$ and $\mathcal{E}_n = E_n/(\frac{\hbar^2}{2md^2})$, with y being the one-dimensional variable, d a properly chosen length scale, *V(y)* the potential in ordinary coordinate space, and E_n the energy level.

Our point here is that *v(z)* interpolates between the Coulomb - and the infinite wall potential going through an intermediary region of linear-*z*-and harmonic-oscillator-z^2 dependences. To see this it is quite instructive to expand the potential in a Taylor series which for appropriately small *z* takes the form of a coulomb like potential with a centrifugal barrier like term, provided by the $csc^2 z$ part,

$$v(z) \approx -\frac{2b}{z} + \frac{a(a+1)}{z^2}, \quad z << 1 \quad (21)$$

For $z < \frac{\pi}{2}$ we can the take Eq. (20) plus a linear like perturbation

$$\Delta v(z) = \frac{a(a+1)}{3} + \frac{2bz}{3} \quad (22)$$

[14-16]

The $\frac{1}{x^2}$ potential has no ground state, and the allowed energies are not quantized. Perhaps some potential are just plain illegal in quantum mechanics. It seems odd, though, that we never encounter such difficulties in classical mechanics.

Well, in the first place there are classical precursors. Moreover there do exist systems represented by a $\frac{1}{x^2}$ potential [17].

IV. The Rosen-Morse Potentia as Complexified Eckart Potential

Exactly solvable 1-dimensional schrodinger equation play an important role in quantum physics. The best known are the harmonic oscillator and the radial for the hydrogen atom, which are covered in every course of quantum mechanics. A number of other examples were discovered in the 30's of the last century [18].

Before proceeding further we first introduce a properly chosen length scale d and change variables in the one-dimensional equation

$$H(y) = -\frac{\hbar^2}{2m}\frac{d^2}{dy^2} + V(y) \quad (23)$$

To dimensionless ones according to

$$z = \frac{y}{d}, \; v(z) = \frac{V(dz)}{(\hbar^2/2md^2)}, \quad \epsilon_n = \frac{E_n}{(\hbar^2/2md^2)} \quad (24)$$

Next we employ the Eckart potential,

$$v(z) = -2bcothz + a(a-1)csch^2 z \quad (25)$$

Where $b > a^2$. The exact solutions to the Eckart potential read:

$$\psi_n(x) = c_n(x-1)^{(\beta_n - n - a)/2}(x+1)^{-(\beta_n + n + a)/2} P_n^{\beta_n - n - a, -(\beta_n + n + a)}(x)$$

$$x = \coth z\,, \qquad \beta_n = \frac{b}{n+a} \quad (26)$$

Here, $P_n^{(\beta_n - n - a, -(\beta_n + n + a))}(x)$ are the well known Jacobi polynomials with $n \leq (b^{1/2} - a)$ and c_n is a constant. Equation {26} equivalently rewrites to

$$\psi_n(x) = c_n(x^2-1)^{-(n+a)/2} e^{-\beta_n \; \text{arccoth}\; x} P_n^{(\beta_n - n - a\,, -(\beta_n + n + a))}(x) \quad (27)$$

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The corresponding energy value spectrum is determined by

$$\epsilon_n = -(n+a)^2 - \frac{b^2}{(n+a)^2} \quad (28)$$

Complexify the argument of the Eckart potential and one of its constants according to

$$z \to -iz\,,\ or\,,equivalently,\ x \to ix\,,\ b \to ib \quad (29)$$

Substitution of Eq.{29} into {25} results in

$$v(z) = -2bcot\ z + a(a-1)csc^2 z \quad (30)$$

Morse potential is concluded from Eq.{27} through complexification of b and x leading to

$$\psi_n(ix) = c_n((ix)^2 - 1)^{-(n+a)/2} e^{-\beta_n \ \text{arccoth}\ ix}\ P_n^{((i\beta_n - n - a),(i\beta_n + n + a))}(ix) \quad (31)$$

[19]

V. Spectrum and Wave Functions of the Trigonometric Rosen-Morse Potential

Solving schrodinger' equation for the trigonometric Rosen-Morse potential as obtained in Ref [20,21] All in all, the trigonometric Rosen-Morse potential and its real orthogonal polynomial solutions open new venues in the calculation of interesting observables in both supersymmetric quantum mechanics and particle spectroscopy [20,21].

The one- dimensional schrodinger equation with the trigonometric Rosen-Morse potential reads:

$$\frac{d^2}{dz^2}R_m(z) + (2bcotz - a(a+1)csc^2 z + \varepsilon_n)R_m(z) = 0 \quad (32)$$

Our pursued strategy in solving it will be to first reshape it to the particular case of a Sturm-Liouville equation {32} of the form

$$s(x)\frac{d^2}{dx^2}F_m(x) + \frac{1}{w(x)}\left(\frac{d}{dx}s(x)w(x)\right)\frac{d}{dx}F_m(x) + \lambda_m F_m(x) = 0 \quad (33)$$

And they try to solve it by means of the so called Rodrigues representation

$$F_m(x) = \frac{1}{K_m w(x)}\frac{d^m}{dx^m}(w(x)s(x)) \quad (34)$$

Where Km is the normalization constant. And

$$\lambda_m = -m(K_1\frac{d}{dx}F_1(x) + \frac{1}{2}(m-1)\frac{d^2}{dx^2}s(x) \quad (35)$$

[21].

VI. Conclusion

In this paper we have discussed on the solution of the schrodinger equation with Rosen-Morse potential. In that case we have written radial part of schrodinger equatin with centrifugal term. Helping the factorization method and comparing it with associated Jacobi differential equation, we have obtained energy eigenvalue and wave function. We also have considered two different cases such as s-wave and Eckart potential for the Rosen-Morse.

All in all the Rosen-Morse potential and its real orthogonal polynomial solutions open new venues in the calculation of interesting observables in both supersymmetric quantum mechanics and particle spectroscopy.

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Table 1 : Some Potentials and Relations [22-28].

potential	relation
Rosen-Morse	$V(r) = -V_1 sech^2 \alpha r + V_2 tanh \alpha r^*$
Woods-Saxon	$V(r) = -\frac{V_0}{1 + exp\left(\frac{r-R}{a}\right)}^{**}$
Eckart	$V(r) = -k\frac{coshr}{sinhr} + \left(\frac{\mu^2}{4} - \frac{1}{4}\right)\frac{1}{sinh^2 r}^{***}$
Poschl-Teller	$V(r) = \left(\alpha^2 - \frac{1}{4}\right)\frac{1}{4sin^2\frac{r}{2}} + \left(\beta^2 - \frac{1}{4}\right)\frac{1}{4cos^2\frac{r}{2}}^{****}$
Morse	$V(r) = D_e\left(1 - e^{-a(r-r_e)}\right)^{2*****}$
Manning-Rosen	$V(r) = -k\frac{sinhr}{coshr} - \left(\frac{\mu^2}{4} - \frac{1}{4}\right)\frac{1}{cosh^2 r}^{******}$
Hulthen	$V(r) = -\frac{z}{\alpha}\frac{exp\frac{-r}{\alpha}}{1 - exp\frac{-r}{\alpha}}^{*******}$

1. **Rosen-Morse,** In this relation V_1 and V_2 denotes the depth of the potential and a is the range of the potential.
2. **The Wood-Saxon potential,** is a mean field potential for the nucleons (protons and neutrons) inside the atomic nucleus, which is used to approximately describe the forces applied on each nucleon, in the shell model for the structure of the nucleus.in this potential V_0 (having dimension of energy) represents the potential well depth, a is a length representing the surface thichness of the nucleus, and $R = r_0 A^{\frac{1}{3}}$ is the nuclear radius where $r_0 = 1.25$ fm and A is the mass number.

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3. **Eckart,** This potential was proposed and solved by C.Eckart. A natural real domain for this potential is $]0,\infty[$
4. **Poschl-Teller,** This potential was proposed and solved by Poschl and Teller.A natural real domain for this potential is $]0,\pi[$.
5. **Morse,** In this potential r is the distance between the atoms, re is the equilibrium bond distance.
6. **Manning-Rosen,** This potential was proposed and solved by M.F.Manning and N.Rosen. A natural real domain for this potential is $]-\infty,\infty[$.
7. **Hulthen,** The Hulthen potential is a short - range potential which behaves like a Coulomb potential for small values for r and decreases exponentially for large values of r. in this potential a is the screening parameter and z is a constant which is identified with the atomic number when the potential is used for atomic phenomena.

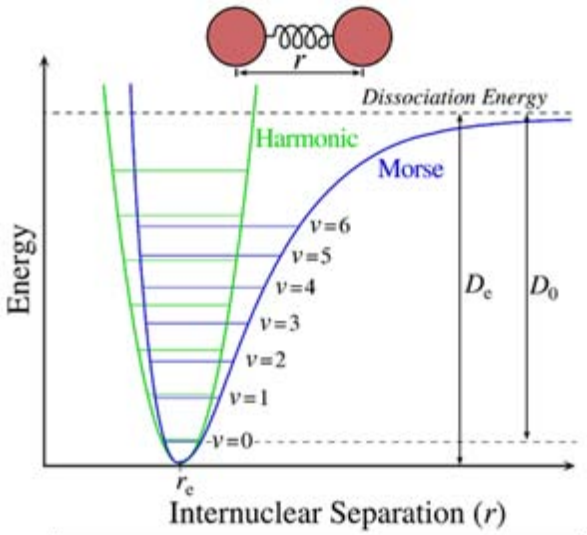


Figure 1: the Morse potential and harmonic oscillator potential

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References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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