Using Tau Polarization for Charged Higgs Boson and SUSY searches at LHC

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The polarization can be easily measured at LHC in the 1-prong hadronic decay channel by measuring what fraction of the -jet momentum is carried by the charged track. A simple cut requiring this fraction to be > 0.8 retains most of the P = +1 -jet signal while suppressing the P = -1 -jet background and practically eliminating the fake background. This can be utilized to extract the charged Higgs signal. It can also be utilized to extract the SUSY signal in the stau NLSP region, and in particular the stau co-annihilation region.

1. Introduction

It is easy to measure polarization $P$ as it is expected in the kinematic distribution of its decay products. Moreover, the best channel for measuring polarization is also the best channel for identification, i.e., the 1-prong hadronic decay channel. In particular, a simple kinematic cut, requiring the single charged prong to carry > 80% of the hadronic -jet momentum retains most of the P = +1 -jet signal while suppressing the P = -1 -jet background and practically eliminating the fake background from standard hadronic jets. Interestingly, the most important channel for charged Higgs boson search at LHC is its decay channel, $H \rightarrow \tau_R \tau_R$, giving $P = +1$. Similarly a very important part of the parameter space of the minimal supergravity (mSUGRA) model has $\tilde{\tau}$ as the lightest superparticle, while the next to the lightest one is a stau(\tilde{\tau}_1) with a dominant $\tau \tau$ component. In this case one expects the supersymmetric(SUSY) signal at LHC to contain a $P = +1$ from the cascade decay of squarks and gluinos via $\tilde{\tau}_1 \rightarrow \tau_R \tilde{\tau}_2$. In both cases one can use the above kinematic cut to enhance the $P = +1$ signal over the $P = -1$ background as well as the fake background.

The paper is organized as follows. In section 2 we summarise the formalism of polarization in the 1-prong hadronic decay channel and discuss how the above mentioned kinematic cut retains most of the detectable $P = +1$ -jet signal while suppressing the $P = -1$ -jet as well as the fake -jet backgrounds. Section 3 briefly introduces the SUSY search program at LHC via SUSY as well as SUSY Higgs (and in particular $H^0$) signals. In section 4, we describe the most important $H^0$ signal, in both $m_H < m_\tilde{\tau}$ and $m_H > m_\tilde{\tau}$ regions, which contains a hard $H^0$ with $P = +1$ from the above mentioned $H$ decay. In section 5 we show Monte Carlo simulations using the above kinematic cut for extraction of the $H$ signal at LHC for both the $m_H < m_\tilde{\tau}$ and $m_H > m_\tilde{\tau}$ regions. In the latter case we also brie y discuss a corresponding kinematic cut for extracting the $m_H$ signal in the 3-prong hadronic decay channel of $H$. In section 6 we briefly describe the SUSY signal coming from the above mentioned cascade decay process. We also emphasise a very important part of the SUSY parameter space, called the stau co-annihilation region, where the signal contains a soft $H$ with $P = +1$. In section 7 we show the use of the kinematic cut for extracting the SUSY signal at LHC in the 1-prong hadronic $H^0$ decay channel, with particular emphasis on the stau co-annihilation region.

2. Polarization

The best channel for $P$ polarization is its 1-prong hadronic decay channel, accounting for 50% of its decay width. Over 90% of this comes from

$$P = (12.5\%); \; (26\%); \; (75\%);$$

where the branching fraction for $H$ and include the small $K$ contributions, which have identical polarization effects [1]. The CM angular distributions of

\begin{align}
\end{align}
decayed into and vector meson \( \nu(=v_1) \) is simply given in terms of its polarization as

\[
\frac{1}{2} \frac{d}{d \cos \theta} = \frac{1}{2} \left(1 + \frac{m_v^2}{m_\nu^2} \right) (1 - \cos \theta)
\]

and

\[
\frac{1}{2} \frac{d}{d \cos \theta} = \frac{1}{2} \left(1 + \frac{m_v^2}{m_\nu^2} \right) (1 - \cos \theta)
\]

where \( L, T \) denote the longitudinal and transverse polarization states of the vector meson. The fraction \( x \) of the laboratory momentum carried by its decay meson, i.e., the visible \(-\)jet, is related to the angle \( \theta \) via

\[
x = \frac{1}{2} (1 + \cos \theta) + \frac{m_\nu^2}{2m_\nu^2} (1 - \cos \theta);
\]

in the collinear approximation \( p = m \). It is clear from Eqs. 4 and 5 that the relatively hard part of the signal \( p = +1 \) \(-jet\) comes from the \( v_L \) and \( a_1L \) contributions, while for the background \( p = -1 \) \(-jet\) it comes from the \( v_T \) and \( a_1T \) contributions. Note that this is the important part that would pass the \( p_T \) threshold for detecting \(-jets\).

One can similarly understand the above feature from angular momentum conservation. For \( R(\nu L) \)

\[
\nu L = 0 \quad \text{it favors forward (backward) emission of } \nu L \text{ or longitudinal vector meson, while it is the other way around for transverse vector meson emission, } \nu T(\nu L) \approx \nu T(\nu L).
\]

\( v_T = 0 \): A faster boost back to the laboratory frame becomes the leading particle, giving a hard \(-jet\).

Now the \( T \) and \( a_1T \) decays favor equal sharing of the momentum among the decay pions, while the \( L \) and \( a_1L \) decays favor unequal sharing, where the charged pion carries either very little or most of the \(-jet \) momentum. Thus plotted as a function of the \( \nu \) momentum fraction carried by the charged pion,

\[
R = \frac{\nu \text{ jet}}{p \text{ jet}}
\]

the longitudinal and \( a_1 \) contributions peak at very low \( R \) \( 0.2 \text{ or } 0.8 \), while the transverse contributions peak in the middle \( 0.5 \). This is shown in Fig. 1 [3]. Note that the \( -jet \) would appear as a delta function at \( R = 1 \) in this case. The low \( R \) peaks of the longitudinal and \( a_1 \) contributions are not detectable because of the minimum \( p_T \) requirement on the charged track for \(-identication\). The \( R > 0.2 \) contribution would appear as a delta function at \( R = 1 \) in this case. The low \( R \) peaks of the longitudinal and \( a_1 \) contributions are not detectable because of the minimum \( p_T \) requirement on the charged track for \(-identication\). Now moving the \( R \) cut from 0.2 to 0.8 cuts out the transverse and \( a_1 \) peaks, while retaining the detectable longitudinal peak along with the single contribution. Thanks to the complex entanglement of these two sets of contributions, one can effectively suppress the form while retaining most of the latter by a simple cut on the ratio

\[
R > 0.8;
\]

Thus one can suppress the hard part of the \(-jet\) background \( p = -1 \) while retaining most of it for the detectable signal \( p = +1 \), even without separating the different meson contributions from one another [3]. This is a simple but very powerful result particularly for hadron colliders, where one cannot isolate the different meson contributions to the \(-jet\) in [4].

The result holds equally well for a more exact simulation of the \(-jet\) including the nonresonant contributions. It should be noted here that the simple polarization cut suppresses not only the \( p = 1 \) \(-jet\) background, but also the fake \(-jet\) background from combinatoric jets. This is particularly important for \(-jets\) with low \( p_T \) threshold of 15-20 GeV, as we shall need for SUSY search in the stau co-annihilation region in section 7. Imposing this cut reduces the faking efficiency of hadronic jets from 5-10% level to about 0.2%. The reason is that a combinatoric jet can fake an 1-prong \(-jet\) by a rare fluctuation, while all but one of the constituent particles (mostly pions) are neutral. Then requiring the single charged particle to carry a more than 80% of the total jet energy requires a second fluctuation, which is even rarer.

3. SUSY and SUSY Higgs searches at LHC

The minimal supersymmetric standard model (MSSM), has been the most popular extension of the standard model (SM) for four reasons. It provides (1) a natural solution to the hierarchy problem of the
electroweak symmetry breaking (EW SB) scale of the SM, (2) a natural (radiative) mechanism for EW SB, (3) a natural candidate for the dark matter of the universe in terms of the lightest superparticle (LSP), and (4) the coupling of the gauge couplings at the grand unification (GUT) scale. Therefore, there is a great deal of current interest in probing this model at LHC. This is based on a two-prong search strategy. On the one hand, we are looking for the signal of supersymmetric (SU SY) particle production at LHC. On the other hand, we are also looking for the signal of the extended Higgs boson sector of the MSSM and, in particular, the charged Higgs boson (H). We shall see below that the channel plays a very important role for both SUSY and the H signals and one can use the above-mentioned polarization effect in extracting both these signals at LHC.

4. H Signal

As mentioned above, the MSSM contains two Higgs doublets H_u and H_d, the ratio of whose vevs is denoted by tan β. The two com plex doublets correspond to 8 degrees of freedom, 3 of which are absorbed as Goldstone bosons to give massless and longitudinal components to the W and Z bosons. This leaves 5 physical states: two neutral scalars h and H, a pseudo scalar A, and a pair of charged Higgs bosons

H = H_u \cos \beta + H_d \sin \beta. \tag{6}

While it may be hard to distinguish any of these neutral Higgs bosons from that of the SM, the H pair carry the distinctive hallmark of the MSSM: hence the H search plays a very important role in probing the SUSY Higgs sector [2]. All the tree level mass and couplings of the MSSM Higgs bosons are given in terms of tan β and any one of their mass, usually taken to be m_A. It is simply related to m_H via,

m_H^2 = m_A^2 + m_H^2. \tag{7}

The most important H couplings are

H: tH(c) = \frac{g}{2M_W} (m_{t(c)} \cot \beta + m_{b(s)} \tan \beta); \tag{8}

A sum ing the H → tH coupling to remain perturbative up to the GUT scale implies \tan \beta < m_t = m_b.

For m_H < m_t, Eq. (8) implies large branching fractions for

t! H \tag{9}
decay at the two ends of the above range, tan \beta \leq 1 and tan \beta \geq \tan \beta < 50, driven by m_t and m_b, respectively. But there is a huge dip in the intermediate region around

\tan \beta = m_t = m_b; \tag{10}

which is overwhelmed by the SM decay t! hW. Eq. (8) also implies that the dominant decay mode for this H over the theoretically favored region of tan β > 1 is,

H !→ r; P = +1 \tag{11}

where the polarization follows simply from angular momentum conservation, requiring the to be right handed. It implies the opposite polarization for the SM process

W !→ r; P = 1 \tag{12}

since the is now required to be left-handed. One can use the opposite polarizations to distinguish the H signal from the SM background [2,3]. In particular, one can use the kinematic cut, mentioned in the introduction, to enhance the signal/background ratio and extend the H search at LHC over the intermediate range [10], which would not be possible otherwise [3].

For m_H > m_t, the dominant production process at LHC is the LO process

gg! th + hc; \tag{13}

The dominant decay channel is H !→ tH, which has unfortunately a very large QCD background. By far the most viable signal comes from the second-largest decay channel [11], which has a branching fraction of ≈ 10% in the intermediate to large tan β (10) region. The largest background comes from the production, followed by the decay of one of the top quarks into the SM channel [12]. One can again exploit the opposite polarizations to enhance the signal/background ratio and extend the H search to several hundreds of GeV for tan β > 10 [5, 6, 11]. This will be discussed in detail in the next section.

5. Polarization in the H Search

A parton level Monte Carlo simulation of the H signal in the m_H < m_t region [3] showed that using the polarization cuts [5] enhances the signal/background ratio substantially and makes it possible to extend the H search at LHC over m_H of the intermediate tan β region [10]. This has been confirmed now by more exact simulations with particle level event generators. Fig.2
shows the H discovery contours at LHC using this polarization cut \cite{7}. The vertical contour on left shows H discovery contour via t\arrow HB decay. The middle dip in the middle shows the remaining gap in this intermediate region.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{The 5 H boson discovery contours of the ATLAS experiment at LHC from t\arrow HB \arrow \pi H (vertical); gb \arrow HB \arrow \pi H (middle horizontal) and gb \arrow HB \arrow \pi H \arrow jet channel \cite{7}.}
\end{figure}

For \(m_H > m_t\), the signal comes from \cite{13} and \cite{14}, while the background comes from \(t\bar{t}\) production, followed by the decay of one top into H. To start with the background is over two orders of magnitude larger than the signal, but the signal has a harder jet. Thus a \(p_T^{\text{jet}} > 100\) GeV cut in proves the signal/background ratio. Fig.3 shows the \(R(X^0)\) distribution of the resulting signal and background. One can see that increasing the \(R\) cut from 0.2 to 0.8 suppresses the background substantially while retaining most of the detectable(R > 0.2) signal events. The remaining signal and background can be separated by looking at their distributions in the transverse mass of the jet with the missing \(p_T\), coming from the accompanying jet.

Fig.4 shows these distributions from a recent simulation \cite{8} using PYTHIA Monte Carlo event generation \cite{8}, interfaced with TAUOLA \cite{9} for handling decay. One can clearly separate the H signal from the W background and also measure the H mass using this plot.

Finally, one can also use the polarization effect in the 3-prong hadronic decay channel,

\begin{equation}
\sigma = \frac{1}{\sin^2 \theta} \frac{1}{\cos^2 \phi} \frac{1}{\cos^2 \phi} \frac{1}{\cos^2 \phi} \frac{1}{\cos^2 \phi}
\end{equation}

with no neutrals. This has a branching fraction of 10\%, which accounts for 2/3rd of inclusive 3-prong decay (including neutrals). Excluding neutrals explicitly eliminates the fake \arrow jet background from com-m on hadronic jets. About 3/4 of the branching fraction for eq.14 comes from \(a_1\). The model can improve fraction R of this channel is equivalent to the \(m_\text{cm} \ll m_\text{jet} \) contribution carried by the unlike sign pion in \(a_1\) channel. Thus one sees from Fig.1 that one can retain the \(a_{1\perp}\) peak while suppressing \(a_{1\parallel}\) by restricting this m energy fraction to < 0.2, which is accessible in this case. This will suppress the hard \arrow jet background events from \(P = 0\) while retaining them for \(P = 1\) signal. This simple result holds even after the inclusion of the non-resonant contribution.

Fig.5 shows the H discovery contours of LHC using 1-prong and (1+3)-prong channels \cite{8}. One sees a modest improvement of the discovery reach by including the 3-prong channel. Note also that the 1-prong H discovery contour for 100 fb \(^{-1}\) is not consistent with that of Fig.2 for the ultimate 300 fb \(^{-1}\) at LHC.

6. SUSY signal

We shall concentrate in the mSUGRA model as a simple and well motivated parametrization of the MSSM. This is described by four and half parameters.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{The LHC cross section for a 300 GeV H signal at \(\tan \beta = 40\) shown along with the tt background in the 1-prong \arrow jet channel, as function of the \arrow jet \(m_\text{cm} \ll m_\text{jet} \) fraction \(X^0(R)\) carried by the charged pion \cite{4}.}
\end{figure}
A very important scale appears in representing the Higgs mass limit from LEP \cite{1}. The sign of the first three representing the common gaugino and Higgsino mass scales is fixed by the radiative EW SB condition described below. All the weak scale superparticle masses are given in terms of these parameters by the renormalization group evolution (RGE). In particular the gaugino masses evolve like the corresponding gauge couplings. Thus

\[ M_1 = ( g_1 m_{\text{1-2}}', 0 \), \]

\[ M_2 = ( g_2 m_{\text{1-2}}', 0 \), \]

represent the bino $\tilde{B}$ and wino $\tilde{W}_3$ masses respectively. A very important weak scale scalar mass, appearing in the radiative EW SB condition, is

\[ 2 + M_{\tilde{g}}^2 = \frac{\tan^2 \beta}{\tan^2 \beta - 1}, M_{\tilde{H}^0}^2 ; \tag{17} \]

where the last equality holds at $\tan \beta > 5$, favored by the Higgs mass limit from LEP \cite{1}. The sign of $M_{\tilde{H}^0}^2$, turning negative by RGE triggers EW SB, as required by \cite{17}. The RHS is related to the GUT scale parameters by the RGE,

\[ M_{\tilde{H}^0} = C_1 ( i \gamma_5 \tan \beta \tilde{m}_{\text{1-2}}^2 + C_2 ( i \gamma_5 \tan \beta \tilde{m}_{\text{1-2}}^2 ) \tilde{m}_{\text{1-2}}^2 ) . \tag{18} \]

The tiny coefficient of $m_{\tilde{g}}^2$ results from an almost exact cancellation of the GUT scale parameter by a negative top yukawa ($y_t$) contribution. We see from eq. (16-18) that apart from a narrow strip of $m_{\tilde{g}}^2 > 0$, the m SUGRA parameter space satisfies the mass hierarchy

\[ M_1 < M_2 < \ldots \]

Thus the lighter neutralinos and charginos are dominated by the gaugino components $\tilde{\chi}_1^- \tilde{B}^0; \tilde{\chi}_2^- \tilde{W}_3^0; \tilde{\chi}_3^- \tilde{W}_3^0; \tilde{\chi}_4^- \tilde{W}_3^0$; while the heavier ones are dominated by the higgsinos. The lightest neutralino $\tilde{\chi}_1^0$ is the LSP. The lightest stau is the right-handed sleptons, getting only the U(1) gauge contributions to the RGE, i.e.

\[ m_{\tilde{\tau}}^2 = m_A^2 + 0.15 m_{\text{1-2}}^2 \]

The Yukawa coupling contribution drives the $\tilde{\chi}_1$ mass still lower. Moreover, the mixing between the $\tilde{\chi}_{1,2}$ states, represented by the off-diagonal term,

\[ m_{\tilde{L}R}^2 = m_A + \tan \beta \]

drives the lighter mass eigenvalues further down. Thus the lighter stau mass eigenstate,

\[ \chi_1 = \chi_1 \sin \beta + \chi_2 \cos \beta ; \]

Figure 4. The number of events are shown against transverse mass for signal and background for 1-prong decay channel of $\mu$-jets. These are subject to $p_T > 100$ GeV, $R > 0.8$ and $B_T > 100$ GeV. The masses of charged Higgs are 300 GeV and 600 GeV and $\tan \beta = 40$. \cite{6}.

Figure 5. The 5 H discovery contours at LHC shown for integrated luminosities of 30 fb$^{-1}$ (solid) and 100 fb$^{-1}$ (dashed) for $H^0$, with 1 and 3 prong hadronic decay of [6].
is predicted to be the lightest fermion. Moreover, one sees from eq. (25) and (26) that $\gamma$ is predicted to be the next to lightest superparticle (NLSP) over half of the parameter space

$$m_0 < m_{1/2}.$$  \hspace{1cm} (24)

Thanks to the modest $\gamma$ component in eq. (23), a large part of the SUSY cascade decay signal at LHC proceeds via

$$\gamma \rightarrow \bar{\gamma} \rightarrow \bar{\gamma} + \text{soft}.$$  \hspace{1cm} (25)

$$\gamma \rightarrow \bar{\gamma} \rightarrow \bar{\gamma} + \text{soft}.$$  \hspace{1cm} (26)

The dominance of the $\gamma$ component in $\gamma$ implies that the polarization $P' = 1$.

while $P = 1$. We shall see in the next section that the polarization effect can be utilized to extract the SUSY signal containing a positively polarized $P = 1$.

A very important part of the above-mentioned parameter space is the stau co-annihilation region \[11\], where the $F$ LSP co-annihilates with a nearly degenerate $\gamma$, $\sim \gamma$, to give a cosmologically compatible relic density \[12\]. The mass degeneracy $m_\gamma = m_\tilde{\tau}$ is required to hold to 5%, since the freeze-out target temperature is 5% of the LSP mass. Because of this mass degeneracy, the co-annihilation lepton com ing from eqs. (25, 26) is rather soft. We shall see in the next section how the polarization effect can be utilized to extract the soft signal and also to measure the tiny mass difference between the co-annihilating particles.

7. polarization in SUSY search:

The polarization coming from the $\gamma$ decay of eqs. (25, 26) is given in the collinear approximation by \[13\]

$$P = \frac{\Phi R}{\Phi R + \Phi L} = \frac{\cos^2 \theta_W}{\cos^2 \theta_W + \sin^2 \theta_W}.$$  \hspace{1cm} (28)

$$a_{11}^R = \frac{2g}{2m_0} N_{11} \tan \theta_W \sin \theta_W, \hspace{1cm} \frac{2m_0}{2m_0} N_{13} \cos \theta_W,$$

$$a_{11}^L = \frac{2g}{2m_0} N_{12} + N_{11} \tan \theta_W \cos \theta_W, \hspace{1cm} \frac{2m_0}{2m_0} N_{13} \sin \theta_W + \text{soft.}$$

where the 1st and 2nd subscript of $a_{ij}$ refer to $\gamma$ and $\gamma'$, and

$$\sim \gamma = N_{11}^w + N_{12}^w N_{3} + N_{13}^w H_d + N_{14}^w H_u,$$  \hspace{1cm} (29)

gives the com position of LSP. Thus the dominant term is $a_{11}' \sim N_{11}^w \tan \theta_W \sin \theta_W \cos \theta_W$, as it is $P = 1$. In fact, in the mSUGRA model there is a cancellation between the subdominant term $s$, so that one gets $P > 0.9$ throughout the allowed parameter space \[14\]. Moreover, in the $\gamma$ NLSP region of eq. (24) $P > 0.9$, so that one can approximate $P$ to $P = 1$. The polarization of the $\sim \gamma$ from eq. (25) is obtained from eq. (26) by replacing $a_{11}^R$ by $a_{11}^L$. The dominant contribution comes from $a_{11}' \sim N_{12}^w \cos \theta_W$, as it is $P = 1$.

There is a similar cancellation of the subdominant contributions, leading to $P < 0.95$ in the $\gamma$ NLSP region. Thus one can safely approximate $P = 1$.

Figure 6. BR ($W_1 \rightarrow \gamma \gamma$) is shown as contour plots (dashed lines) in $m_0$ and $m_{1/2}$ plane for $A_0 = 0$, tan $\beta = 30$ and positive $\mu$. The kinematic boundaries (dotted lines) are shown for $W_1 \rightarrow Z_1$ and $W_1 \rightarrow \gamma \gamma$ decay. The entire region to the right of the boundary (dot-dashed line) corresponds to $P > 0.9$. The excluded region on the right is due to the $\gamma$ being the LSP while that on the left is due to the LEP constraint $m_{W_1} > 102$ GeV \[14\]. Note that here $W_1$ and $Z_1$ correspond to $\gamma$ and $\gamma'$ in the text.

shows that $P$ is $> 0.9$ for $\gamma'$ and $\gamma$ decay throughout the mSUGRA parameter space \[14\]. It also shows that the branching fraction of the decay \[25\] is large over the $\sim \gamma$ NLSP region of eq. (24), so that one expects a large part of the SUSY signal in the $B_\gamma$ channel to contain a jet with $P = 1$. Fig. 7 shows the R distribution
of this \( P = +1 \) \(-\text{jet} \) at LHC [13]. For comparison the \( R \) distributions are also shown for \( P = 0 \) and \(-1 \) for this \(-\text{jet} \). Thus one can test the SUSY model or check the com position of \( \gamma \) \((-1) \) by \( m \) ensuring this distribution.

Let us conclude by briefly discussing the use of polarization in probing the stau co-annihilation region at LHC, corresponding to \( m = m_{\tilde{\chi}^0_1} \) [15]. This is one of the very few regions of mSUGRA parameter space compatible with the cosmological constraint of the dark matter relic density, and the only one which is also compatible with the muon magnetic moment anomaly [16]. It corresponds to a narrow strip adjacent to the lower boundary of Fig. 6, which can be totally covered at LHC. Therefore, the stau co-annihilation region is a region of special interest to the SUSY search program at LHC. In particular one is looking for a distinctive signature, which will identify the SUSY signal at LHC to this region and also enables us to ensure the tiny mass difference between the co-annihilating particles, \( M = m_{\tilde{\chi}^0_1} - m_{\tilde{\chi}^0_2} \). Such a distinctive signature is provided by the presence of a soft \( (P = +1) \) \(-\text{jet} \) from the \( \gamma \) ! \( \frac{1}{2} \) decay of eqs. [25,26] in the canonical ultraleptonic SUSY signal. Fig. 8 [15] shows the \( p_T \) distributions of this soft \( (P = +1) \) \(-\text{jet} \) signal along with the \( (P = 1) \) \(-\text{jet} \) background coming mainly from the \( \frac{1}{2} \) decay of eq. (28) and \( W \) decay. It also shows a significant fake background from the accompanying hadronic jets in these events. Fig. 9 shows that the \( R > 0.8 \) cut of eq. (29) efficiently suppresses the \( (P = 1) \) \(-\text{jet} \) background to a little over half the signal size and practically eliminates the fake background.

A distinctive signal with a very steep slope is clearly sticking above the background at the low \( p_T \) end. One can use this slope to extract the signal from the background jets at 3 \( \ell \) level with a 10 fb \(^{-1} \) luminosity run of LHC, going up to 10 \( \ell \) with a luminosity of 100 fb \(^{-1} \). Moreover, one can estimate \( M \) to an accuracy of 50% at the 1.5 \( \ell \) level with 10 fb \(^{-1} \), going up to 5 \( \ell \) with 100 fb \(^{-1} \) luminosity [15].

8. Summary

The polarization can be easily measured at LHC in its 1-prong hadronic decay channel by \( m \) measuring what fraction of the hadronic \(-\text{jet} \) momentum is carried by the charged prong. A simple cut requiring this fraction to be > 0.8 retains most of the detectable \( P = +1 \) \(-\text{jet} \) events, while e effectively suppressing the \( P = -1 \) \(-\text{jet} \) events and practically eliminating the fake \(-\text{jet} \) events. \( W \) e show with the help of Monte Carlo simulations that this cut can be e effectively used for (1) \( \tilde{\chi} \) \( \tilde{\chi} \) \( \tilde{\chi} \) \( \tilde{\chi} \) \( \tilde{\chi} \) \( \tilde{\chi} \) \( \tilde{\chi} \) boson and (2) SUSY searches at LHC. (1) The most important channel for the \( \tilde{\chi} \) signal at LHC contains a \( P = +1 \) \(-\text{jet} \) from \( \tilde{\chi} \) ! \( \frac{1}{2} \) decay. The above polarization cut can e effectively suppress the \( P = 1 \) \(-\text{jet} \) background from \( W \) decay, while retaining most of the detectable signal \( P = +1 \) \(-\text{jet} \) events. So it can be used to extract the \( \tilde{\chi} \) signal at LHC. (2) Over half the mSUGRA parameter space the NLSP is \( \gamma \), which is dominated by the right-handed component, while the
LSP (L) is dominantly bino. In this region a large part of the SUSY cascade decay is predicted to proceed via $\sim !$, giving a $P = +1$ --jet along with the canonical BB$_1$ + jets. One can use the above polarization cut to extract this SUSY signal. A very important part of this region is the co-annihilation region, corresponding to $m_\chi \sim m$. So the $P = +1$ --jet signal is expected to be soft in this region. However, one can use this polarization cut to extract this signal from the $P = 1$ --jet and fake --jet backgrounds, and also to measure the small mass difference between the co-annihilating superparticles.

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