1 Spin determination at colliders

Lepton colliders

Spin measurements in electron colliders are studied in Feng–Peskin+ [1], Battaglia–Datta+ [5], Bhattacharyya–Dey+ [4], Bhattacherjee–Kundu [8], Riemann [7], and more.

LHC, q–l–l chain

- Barr [2] considers SUSY $\tilde{q} \to \tilde{\chi}_2^0 \to \tilde{l} \to \tilde{\chi}_1^0$ cascade decay to find jet–lepton angular correlation. NLO correction is found in Horsky–Kramer+ [22]. As applications,
  - Smillie–Webber [6] and Datta–Kong–Matchev [9] to discriminate SUSY and UED by the method (the power is not very strong); the former mentions the production cross section can be used as a criterion; the latter utilizes the second KK mode production.
  - Goto–Kawagoe–Nojiri [3] to study L–R mixing of sleptons.
  - Choi–Drees+ [23] to study whether the gaugino is Majorana or Dirac.
  - Hisano–Nojiri–Sreethawong [28] to determine electroweakino hierarchy.
  - Gedalia–Lee–Perez [29], with third-generation initial squark, to discriminate SUSY/UED.
- Alves–Eboli–Plehn [13] provides a technique to assert $\tilde{g}$ is Majorana fermion, based on the chain $\tilde{g} \to \tilde{b}(\tilde{b}^*) \to \tilde{\chi}_2^0 \to \tilde{l} \to \tilde{\chi}_1^0$, where we can determine whether $\tilde{b}$ or $\tilde{b}^*$ is produced by measuring the daughter b.
- Wang–Yavin [16] is for chargino/neutralino spin determination in $\tilde{q} \to qW\tilde{\chi}$ decay channel. It especially provides for $X \to Y \to Z$-chain with $p_1 p_2 Z$ final states

$$\frac{\mathrm{d}\Gamma}{\mathrm{d}t_{12}} = a_0 + \cdots + a_{2s}(t_{12})^{2s} \qquad \text{where} \quad t_{12} = (p_1 + p_2)^2. \tag{1}$$

  This channel was studied later in Smillie [17].
- Kilic–Wang–Yavin [18] extended the work to scenarios in which primary and intermediate particles with any spins.
- A general framework for the spin determination in $D \to Cq \to Bql \to Aqll$ chain is found in Athanasiou–Lester+ [14] (and Athanasiou–Lester+ [15]) with plenty of analytic formulae. More practical analyses are found in Burns–Kong+ [24].

LHC, other chains

- Barr [11] focuses on $\tilde{l}\tilde{l}^*$ DY production (short-lived) to discriminate SUSY/UED. They propose a variable $\tanh(\eta_{l^+} - \eta_{l^-})/2$, which is boost-invariant and thus can be useful.
- Alwall–Rainwater–Plehn [20] considers $\tilde{W}^+\tilde{W}^+jj$ VBF production, mediated by Majorana neutralino, and detemines the spin of $\tilde{W}^+$ (long-lived) by m_{jj} of the forward jets.
- Alves–Eboli [19] is the same analysis for $\tilde{b}\tilde{b}^*$ DY production.
- Csaki–Heinonen–Perelstein [21] uses m_{jj} distribution of $\tilde{g} \to jj\tilde{\chi}_1^0$ process to discriminate SUSY/UED.
- Ehrenfeld–Freitas+ [30] uses chains with γ, i.e., $\tilde{\chi}_2^0 \to \tilde{l} \to \tilde{\chi}_1^0 \to \tilde{G}$ $(ll\gamma)$ and $\tilde{q} \to \tilde{\chi}_1^0 \to \tilde{G}$ $(q\gamma)$ to discriminate spins, but the power is not significant.
- Kim [32] discusses mass and spin measurement in $\tilde{q}_\mathrm{L} \to qZ(\to ll)\tilde{\chi}_1^0$ chain, where intermediate $\tilde{\chi}_2^0$ can be polarized which results in the angular distribution of Z.

LHC, indirect spin measurement

- Datta–Kane–Toharia [10] focuses on same-sign di-lepton events and utilizes its cross section for SUSY/UED discrimination.
- Meade–Reece [12] discusses t' pair-production, where t' is a particle decaying into t + missing, and its mass and spin determination. The mass is determined by cross section in a two-fold way (lower for scalar, higher for fermion), and then, as an indirect spin determination, the angular distribution *in the lab frame* is utilized to distinguish the two-fold. A detector simulation is considered in Hallenbeck–Perelstein+ [27].
- Kane–Petrov+ [31] discusses crosssection-based spin measurement in colored pair production.

Others

- Alves–Eboli+ [25] determines the spin of a resonance V^+ in $pp \to V^+jj$ (VBF) $\to WZjj$ process, possible in Higgsless models, where $\cos\theta^*_{ll}$ is utilized.
- Graesser–Shelton [26] collects possible correlations in b–τ, b–l, and τ–l, including possible mixings, but merely theoretical calculation.

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