Bell nonlocality and collider studies

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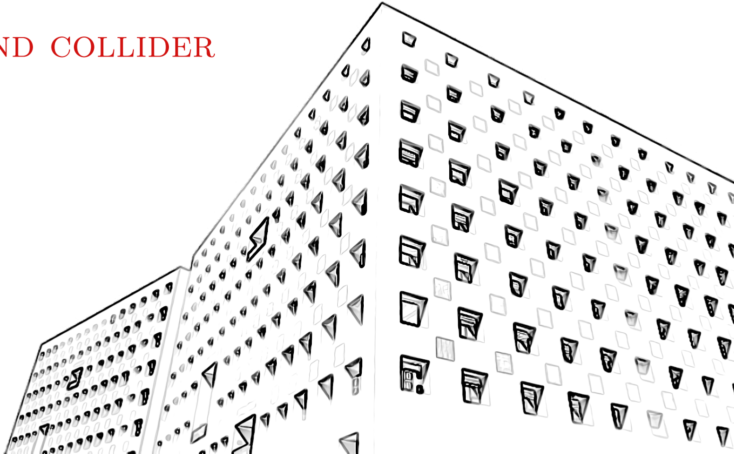

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Table: Current experimental limits ($E_{cm} = 13$ TeV, $\mathcal{L} = 140$ fb^{-1}) on VLL.

Process	Decay	Constraint (VLL)	Arxiv
$\tau'^{+}\tau'^{-}$	$\tau' \to \tau a_\tau \to \tau\gamma\gamma$	$0 - 700$ GeV	2503.16699
$e'^{+}e'^{-}, e'N, NN$	$e' \to Z(H)e, N \to W\ell$	$0 - 1220$ GeV	2411.07143
$\mu'^{+}\mu'^{-}, \mu'N, NN$	$\mu' \to Z(H)\mu, N \to W\ell$	$0 - 1270$ GeV	2411.07143

Vector-Like Lepton

VLLs are non-chiral, which means that their left- and right-handed components have same gauge charges. The motivations of VLL:

- Hierarchy problem
- Muon $g-2$
- Dark matter
- Vacuum stability
- Flavor and mass hierarchy

Why $\tau' \to \tau a_\tau$? (arXiv:2304.08509)

- This model is renormalizable and includes only two new fields: a Dirac fermion $\mathcal{E}$ and a complex scalar ϕ.
- The a_τ is long-lived particle, which leads to deposits in the muon systems.
- Violation of lepton universality from pion decays gives strong limits on the mixing of VLL with $e^\pm$ and $\mu^\pm$.

Why $\tau' \to \tau a_\tau$? (arXiv:2304.08509)

The complex scalar can be written as

$$\phi = \left(v_\phi + \frac{1}{\sqrt{2}}\varphi \right) e^{i a_\tau / (\sqrt{2} v_\phi)}$$

v_ϕ is the vacuum expectation value, which can be much larger than the mass of a_τ. φ_τ is a CP-even scalar with mass of the order of v_ϕ. The most general Yukawa couplings can be written as

$$- \begin{pmatrix} \bar{e}^3_L & \bar{\mathcal{E}}_L \end{pmatrix} \begin{pmatrix} y_3 \left(v_H + \frac{h^0}{\sqrt{2}} \right) & 0 \\ m_o + \frac{y_o e^{i\beta_o}}{\sqrt{2}} (\varphi_\tau + i a_\tau) & m_{\mathcal{E}} + \frac{y_{\mathcal{E}} e^{i\beta_{\mathcal{E}}}}{\sqrt{2}} (\varphi_\tau + i a_\tau) \end{pmatrix} \begin{pmatrix} e^3_R \\ \mathcal{E}_R \end{pmatrix} + \text{h.c.}$$

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2 Long-Lived Charged Lepton

Table: Current experimental limits ($E_{cm} = 13$ TeV, $\mathcal{L} = 140$ fb^{-1}) on Long-lived charged Lepton.

Process	Decay	Constraint (LLP)	Arxiv
$\tau'^{+}\tau'^{-}$	$\tau' \to \tau \tilde{G}$	$200 - 560$ GeV	2502.06694

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W', Z'

3 W', Z'

Table: Current most stringent experimental limits ($E_{cm} = 13$ TeV, $\mathcal{L} = 139$ fb^{-1})

Particle	Channel	Constraint	ArXiv Number
W'	$W' \to \ell\nu$	$0.15 - 7$ TeV	1906.05609, 2202.06075
Z'	$Z' \to \ell\ell$	$0 - 5$ TeV	1903.06248, 2103.02708

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$H^{\pm}$

4 $H^{\pm}$

Table: Current most stringent experimental limits ($E_{cm} = 13$ TeV, $\mathcal{L} = 139$ fb^{-1})

Process	Decay	Constraint	ArXiv Number
$pp \to H^{\pm}jj$	$H^{\pm} \to WZ$	$0.2 - 1.5$ TeV	2407.10798
$pp \to H^{\pm}$	$H^{\pm} \to W\gamma$	$0.3 - 2.0$ TeV	2406.05737
$t \to H^{\pm}b$	$H^{\pm} \to Wa, a \to \mu\mu$	$120 - 160$ GeV	2304.14247
$t \to H^{\pm}b$	$H^{\pm} \to cb$	$60 - 160$ GeV	2302.11739

Q&A

Thank you for listening!

Your feedback will be highly appreciated!