



CONSTRAINTS ON NEW PHYSICS PARTICLES

Zhijie Zhao

zhao@physik.uni-siegen.de

February 9, 2026

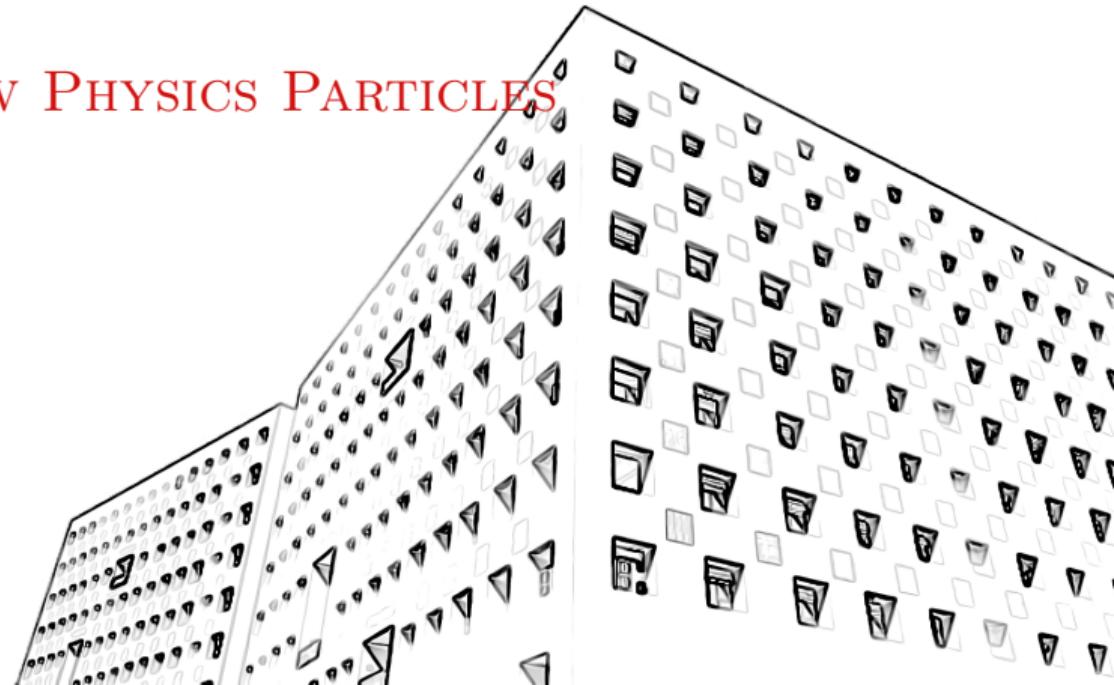




Table of Contents

1 Vector-Like Lepton

► Vector-Like Lepton

► Long-Lived Charged Lepton

► W' , Z'

► H^\pm

► $H^{\pm\pm}$



Vector-Like Lepton

1 Vector-Like Lepton

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

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



Vector-Like Lepton

1 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 $\tau' \rightarrow \tau a_\tau$? (arXiv:2304.08509)

1 Vector-Like Lepton

- 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 μ^\pm .



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

1 Vector-Like Lepton

The complex scalar can be written as

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

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

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



Table of Contents

2 Long-Lived Charged Lepton

► Vector-Like Lepton

► Long-Lived Charged Lepton

► W' , Z'

► H^\pm

► $H^{\pm\pm}$



Long-Lived Charged Lepton

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
$\tau'^+ \tau'^-$	$\tau' \rightarrow \tau \tilde{G}$	200 – 560 GeV	2502.06694



Table of Contents

3 W' , Z'

- ▶ Vector-Like Lepton
- ▶ Long-Lived Charged Lepton
- ▶ W' , Z'
- ▶ H^\pm
- ▶ $H^{\pm\pm}$



W' , Z'
3 W' , Z'

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

Process	Decay	Constraint	ArXiv Number
$pp \rightarrow W'$	$W' \rightarrow \ell\nu$	$0.15 - 7$ TeV	1906.05609, 2202.06075
$pp \rightarrow Z'$	$Z' \rightarrow \ell\ell$	$0 - 5$ TeV	1903.06248, 2103.02708
$pp \rightarrow W'/Z'$	$V' \rightarrow WH/WZ/ff$	$0 - 5.5$ TeV	2601.12583



Table of Contents

4 H^\pm

- ▶ Vector-Like Lepton
- ▶ Long-Lived Charged Lepton
- ▶ W' , Z'
- ▶ H^\pm
- ▶ $H^{\pm\pm}$



$$H^\pm$$

$$_4 H^\pm$$

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

Process	Decay	Constraint	ArXiv Number
$pp \rightarrow H^\pm jj$	$H^\pm \rightarrow WZ$	$0.2 - 1.5$ TeV	2407.10798
$pp \rightarrow H^\pm$	$H^\pm \rightarrow W\gamma$	$0.3 - 2.0$ TeV	2406.05737
$t \rightarrow H^\pm b$	$H^\pm \rightarrow Wa, a \rightarrow \mu\mu$	$120 - 160$ GeV	2304.14247
$t \rightarrow H^\pm b$	$H^\pm \rightarrow cb$	$60 - 160$ GeV	2302.11739
$pp \rightarrow tbH^\pm$	$H^\pm \rightarrow tb$	$200-2000$ GeV	2102.10076
$pp \rightarrow tbH^\pm$	$H^\pm \rightarrow Wh$	$230-3000$ GeV	2411.03969
$pp \rightarrow WbH^\pm b$	$H^\pm \rightarrow \tau\nu_\tau$	$80-3000$ GeV	2412.17584



Table of Contents

5 $H^{\pm\pm}$

- ▶ Vector-Like Lepton
- ▶ Long-Lived Charged Lepton
- ▶ W' , Z'
- ▶ H^\pm
- ▶ $H^{\pm\pm}$



$$H^{\pm\pm} \\ 5 \ H^{\pm\pm}$$

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

Process	Decay	Constraint	ArXiv Number
$pp \rightarrow H^{\pm\pm} jj$	$H^{\pm\pm} \rightarrow W^\pm W^\pm$	$0.2 - 1.5$ TeV	2407.10798
$pp \rightarrow H^{++} H^{--}$	$H^{\pm\pm} \rightarrow \ell\ell$	$0 - 1.08$ TeV	2211.07505



Q&A

*Thank you for listening!
Your feedback will be highly appreciated!*