**GUT inspired SO(5) x U(1) x SU(3) gauge-Higgs unification**

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**gauge-Higgs unification**

\[ A_M = (A_\mu, A_y) \]

4D gauge field

Higgs field

The Higgs boson is protected by the gauge symmetry

- massless at the tree level
- massive at the loop level

\[ e^{i\theta_R} = \text{exp} \left( i g \int \text{d}y \langle A_y \rangle \right) \]

Higgs VEV appears as a Wilson-line phase

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**Matter fields**

**gauge-Higgs Grand unification**

In the bulk

\[ \Psi_{32} = \left( \begin{array}{c} \Psi_{16} \\ \Psi_{16}' \end{array} \right) \]

\[ \Psi_{16} = \left( \begin{array}{cccc} \nu & \nu_L & \nu_R & e_L \\ e & e_e & e_e' & e_L \\ \bar{e} & \bar{e}_L & \bar{e}_L & \bar{e}_L \\ d_j & d_j & d_j & d_j \\ d_j & d_j & d_j & d_j \end{array} \right) \]

\[ \Psi_{11} = \left( \begin{array}{cccc} \bar{N} & E \Psi_{16} \end{array} \right) \]

\[ \Psi_{32}' = \Psi_F \]

On the UV brane

\[ \Phi_{32} = \text{scalar} \]

\[ \chi = \left( \begin{array}{c} \eta \end{array} \right) \]

Majorana fermion

**quark & lepton masses**

<table>
<thead>
<tr>
<th>Particle</th>
<th>Mass (TeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$u, u'$</td>
<td>$m_u$</td>
</tr>
<tr>
<td>$c, c'$</td>
<td>$m_c$</td>
</tr>
<tr>
<td>$d, d', D^{\pm}$</td>
<td>$m_d$</td>
</tr>
<tr>
<td>$\nu, \nu', \eta$</td>
<td>$m_\nu$</td>
</tr>
</tbody>
</table>

brane masses are necessary to obtain mass difference between $u$-quark and $d$-quark and the small deviation of the $W$-coupling

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**Future work**

- Calculation of the effective potential
- $m_d > m_u$ is not realised yet
- Flavor physics
- Neutrino physics
- Dark matter constraints
- KK bottom search

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**References**


Furui, Hosotani and Yamatsu, 6 papers

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**SO(5) branching rules**

| $(\nu, \nu)$ | $1.996 \times 10^{-3}$ | $6.5 \times 10^{-3}$ | $6.8 \times 10^{-3}$ | $8.38 \times 10^{-3}$ |
| $(\nu, \nu)$ | $1 \times 10^{-3}$ | $2.1 \times 10^{-3}$ | $8.38 \times 10^{-3}$ |
| $(\nu, \nu)$ | $-1.096 \times 10^{-3}$ | $1.5 \times 10^{-3}$ | $-1.838 \times 10^{-3}$ |
| $(\nu, \nu)$ | $0.839 \times 10^{-3}$ | $0.5 \times 10^{-3}$ | $4.7 \times 10^{-3}$ |
| $(\nu, \nu)$ | $-0.839 \times 10^{-3}$ | $1.2 \times 10^{-3}$ | $7.74 \times 10^{-3}$ |
| $(\nu, \nu)$ | $0.703 \times 10^{-3}$ | $3.9 \times 10^{-3}$ | $24 \times 10^{-3}$ |
| $(\nu, \nu)$ | $-0.703 \times 10^{-3}$ | $8.8 \times 10^{-3}$ | $-6 \times 10^{-3}$ |