D6 Family Symmetry and Cold Dark Matter at LHC

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Points

1) construct the predictive mass matrix in the lepton sector
   → a family symmetry based on D6 sym. mainly
2) discuss the CDM candidates in a non-SUSY extension of the S.M.
   → the specific radiative seesaw mechanism
The main steps to construct the various radiative seesaw mechanism

1) introduce some Higgses that don't have VEVs in addition to the S.M. Higgs

2) impose a $\mathbb{Z}_2$ sym. corresponding to the R-parity sym. in SUSY.
Ma model

Recently, a new type model along these lines of thought was proposed.

This model, that has a \( n \) and an \( \eta \), is the most economic mechanism!

Based on this idea, I promoted the study.
Textures and Predictions

$M_e = \begin{pmatrix} -m_2 & m_2 & m_5 \\ m_2 & m_2 & m_5 \\ m_4 & m_4 & 0 \end{pmatrix}$

 charged–lepton sector

$M_\nu = \begin{pmatrix} 2(\rho_2)^2 & 0 & 0 \\ 0 & 2(\rho_2)^2 & 2\rho_2\rho_4 \\ 0 & 2\rho_2\rho_4 & 2(\rho_4)^2 + (\rho_3)^2 e^{2i\phi} \end{pmatrix}$

neutrino sector

The number of parameters

real part ... 6
imaginary part ... 1

hep-ph/0302196; J. Kubo, Mondragon...
Predictions

- inverted hierarchy \( (m_{\nu 1}, m_{\nu 2} > m_{\nu 3}) \)

- \( |U_{e3}| \approx 0.0034 < 0.2 \)

- \( m_{\nu 2,\text{min}} = f(\tan \theta_{\text{sol}}, \Delta m_{32}^2, \Delta m_{12}^2, \Phi = 0) \)
  \[ = 0.038 \sim 0.067 \text{eV} \]

- \( <m_{\text{ee}} >_{\text{min}} \approx \Delta m_{23}^2 / \sin 2\theta_{\text{sol}}(\Phi = 0) \)
  \[ = 0.034 \sim 0.069 \text{eV} \]
CDMs
In this case, the right-handed neutrino can be a good CDM candidate.

※ for the flavor symmetry, right-handed neutrino $n$ means the D6 singlet $\eta_s$ and the D6 doublet $\eta_1, \eta_2$. 

- $\eta$ is a particle that does not fly, unlike CDM. It forms a loop with $n_1, n_s$ and $\eta_1, \eta_2$, which fly together. There are 6 types in total.
It is more natural that the D6 right-handed neutrino ns remains as a fermionic CDM candidates!

Otherwise we have to impose a fine tuning for the $n_1$ masses.
As we can see from the following Yukawa matrix, almost all the charged extra Higgs η couples to the eL and the ns.

\[ Y^S \simeq \begin{pmatrix} 0 & 0 & h_3 \\ 0 & 0 & \sqrt{2} \epsilon_e h_3 \\ 0 & 0 & 0 \end{pmatrix}, \quad (\sqrt{2} \epsilon_e = m_e/m_\mu \simeq \sqrt{2} \sin \theta_{13} \simeq 0.0048). \]
the dominant decay mode
CDM analysis from the cosmology

Here, we would like to investigate whether or not the ns can be a good CDM candidate.

In this model, the ns is annihilated mostly into the above pairs.
We can compute the relativistic cross section, and we can obtain the following figure!
Ms versus ms for the various $h_3$.

$\Omega_d h^2 = 0.12$

$|h_3| = 1.0$

$0.7$

$1.3$

$1.5$

$m_s \sim 750 \text{GeV}$
$\Omega dh = 0.12 \quad |h_3| < 1.5$

$B(\mu \rightarrow e, \gamma)$ constraint $< 1.2 \times 10^{-11}$.
Conclusions

- We could construct the predictive model for the neutrino sector radiatively.

- From the $\mu \rightarrow e, \gamma$ and cosmological analyses, if the CDM is fermionic, and we could single out the ns ($D6$ singlet right-handed neutrino) as the best cold dark matter candidate.
• We also find that an extra Higgs with a mass between 300 GeV and 750 GeV decays mostly into an electron (or a positron) with a large missing energy, where the missing energy is carried out by the CDM candidate. This will be a clean signal at LHC.