Family Unification using higher dimensional theory

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Y.G, Y.Kawamura and T.Miura, Phys.Rev.**D88**,055016 (2013)

Y.G and Y.Kawamura, Phys. Lett. B **752**, 252 (2016)

motivation

Origin of family → Unification of matter particles for SM

Unification of three families

↓

Appear many extra particles

↳ Extra fermions do not want to appear in the low energy scale (EW scale)

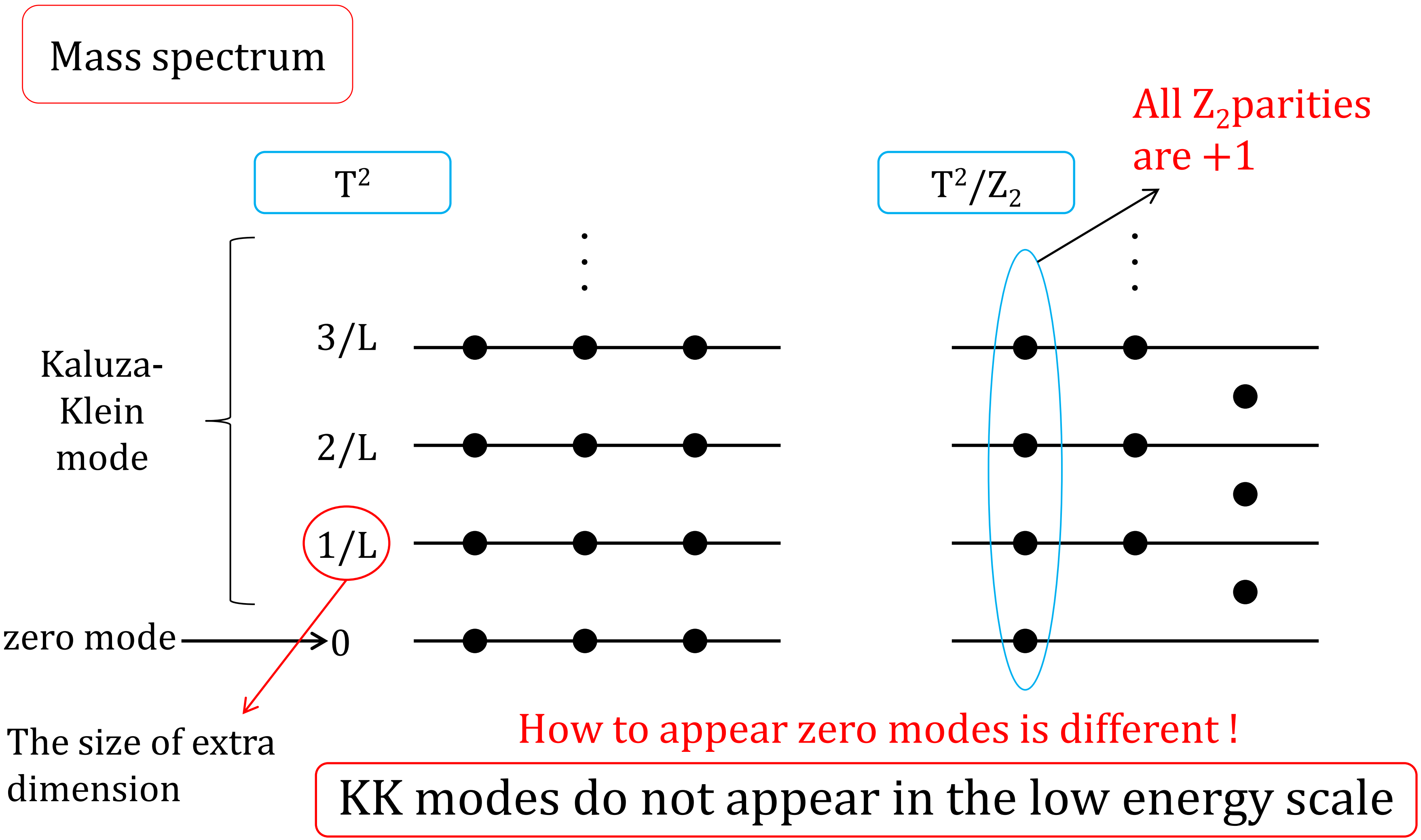
Ex) $E_8 \supset E_6 \times SU(3)$

$$\mathbf{248} = (\mathbf{78}, \mathbf{1}) \oplus (\mathbf{1}, \mathbf{8}) \oplus (\mathbf{27}, \mathbf{3}) \oplus (\overline{\mathbf{27}}, \overline{\mathbf{3}})$$

Three families of SM particles

It may be solved by using higher dimensional theory with Orbifold as extra dimension

Orbifold breaking mechanism



- Boundary conditions decide Z_2 parities and the symmetry breaking pattern.

Our study

We study the possibility of family unification on the basis of SU(N) gauge theory on $M^4 \times (T^2/Z_M)$ (M=2,3,4,6) using orbifold breaking mechanism.

We investigate whether or not three families are derived from a single massless Dirac fermion with a higher-dimensional representation of SU(N) for two patterns of symmetry breaking.

$$SU(N) \to SU(5) \times SU(p_2) \times \cdots \times SU(p_n) \times U(1)^{n-m-1}$$

$$SU(N) \to SU(3) \times SU(2) \times SU(p_3) \times \cdots \times SU(p_n) \times U(1)^{n-m-1}$$

Orbifold family unification

$$SU(N) \to SU(5) \times SU(p_2) \times \cdots \times SU(p_n) \times U(1)^{n-m+1}$$

	T^2/Z_2	T^2/Z_3	T^2/Z_4	T^2/Z_6
$SU(8)$	-	[8,3]:24 [8,4]:12	[8,3]:14 [8,4]:16	[8,3]:28 [8,4]:20
$SU(9)$	[9,3]:192	[9,3]:182 [9,4]:348	[9,3]:142 [9,4]:32	[9,3]:512 [9,4]:800
$SU(10)$	-	[10,3]:852 [10,4]:1308 [10,5]:48	[10,3]:160 [10,4]:92	[10,3]:2484 [10,4]:2654 [10,5]:1532
$SU(11)$	[11,3]:768 [11,4]:768	[11,3]:1608 [11,4]:1716 [11,5]:1794	[11,3]:456 [11,4]:436 [11,5]:186	[11,3]:6530 [11,4]:6768 [11,5]:5540
$SU(12)$	[12,3]:1104	[12,3]:2214 [12,4]:1020	[12,3]:748 [12,4]:676 [12,5]:534 [12,6]:632	[12,3]:17084 [12,4]:13692 [12,5]:10498 [12,6]:13188

Rep. of SU(N)

# of model

$$SU(N) \to SU(3) \times SU(2) \times SU(p_3) \times \cdots \times SU(p_n) \times U(1)^{n-m+1}$$

	T^2/Z_2	T^2/Z_3	T^2/Z_4	T^2/Z_6
$SU(8)$	-	-	-	-
$SU(9)$	[9,3]:32	-	[9,3]:8	[9,3]:8 [9,4]:32
$SU(10)$	-	-	-	[10,3]:80 [10,4]:108
$SU(11)$	[11,3]:80 [11,4]:80	[11,4]:80	[11,3]:20 [11,4]:20	[11,3]:84 [11,4]:144 [11,5]:156
$SU(12)$	[12,3]:120	[12,3]:80	[12,4]:88 [12,6]:240	[12,3]:392 [12,4]:120 [12,5]:72 [12,6]:552
$SU(13)$	[13,3]:144	-	[13,4]:40	[13,3]:712 [13,4]:88 [13,5]:140 [13,6]:200

Summary

- By choosing appropriate boundary conditions and intrinsic Z_M element (parity) for a 6D Dirac fermion, We have obtained enormous number of models with three families of the SM multiplet.
- It would offer a hint to explore the family structure in our models.
- But, we do not lead whether or not those models successfully achieve the realistic fermion mass and generation mixing.

Thank you for attention !