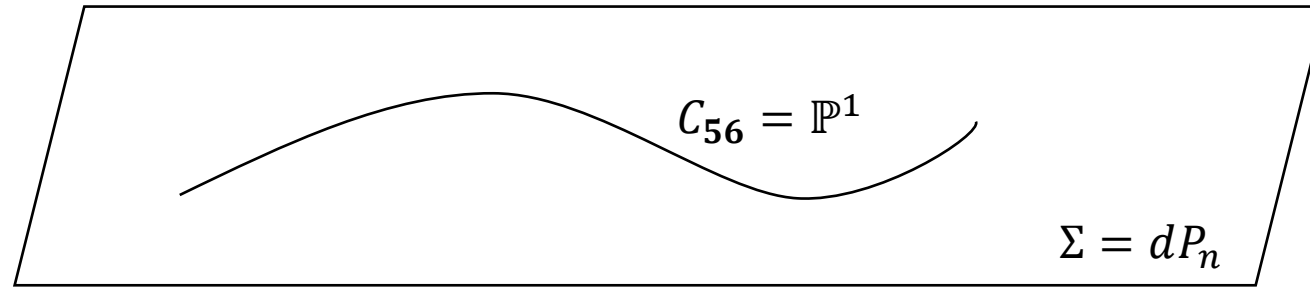


# Towards natural and realistic $E_7$ GUTs in F-theory

Shing Yan Li, MIT

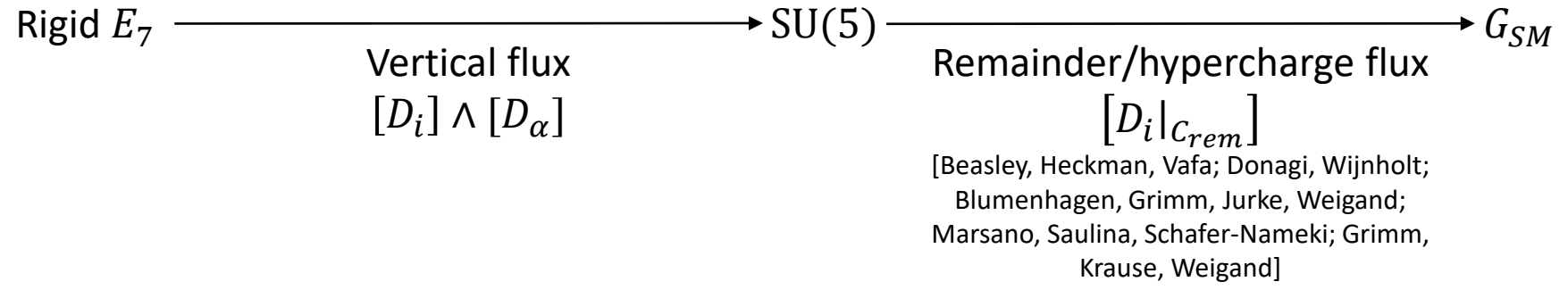
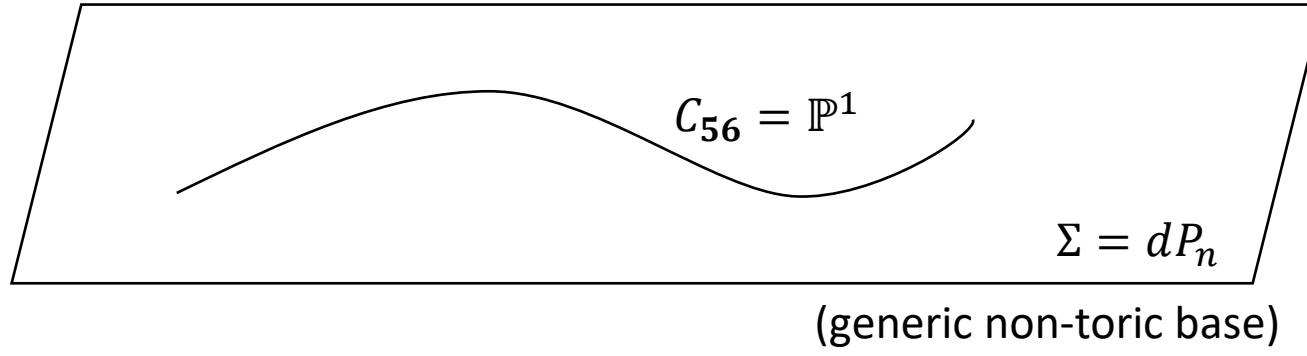
Based on 2112.03947, 2207.14319, and 2307.xxxxx

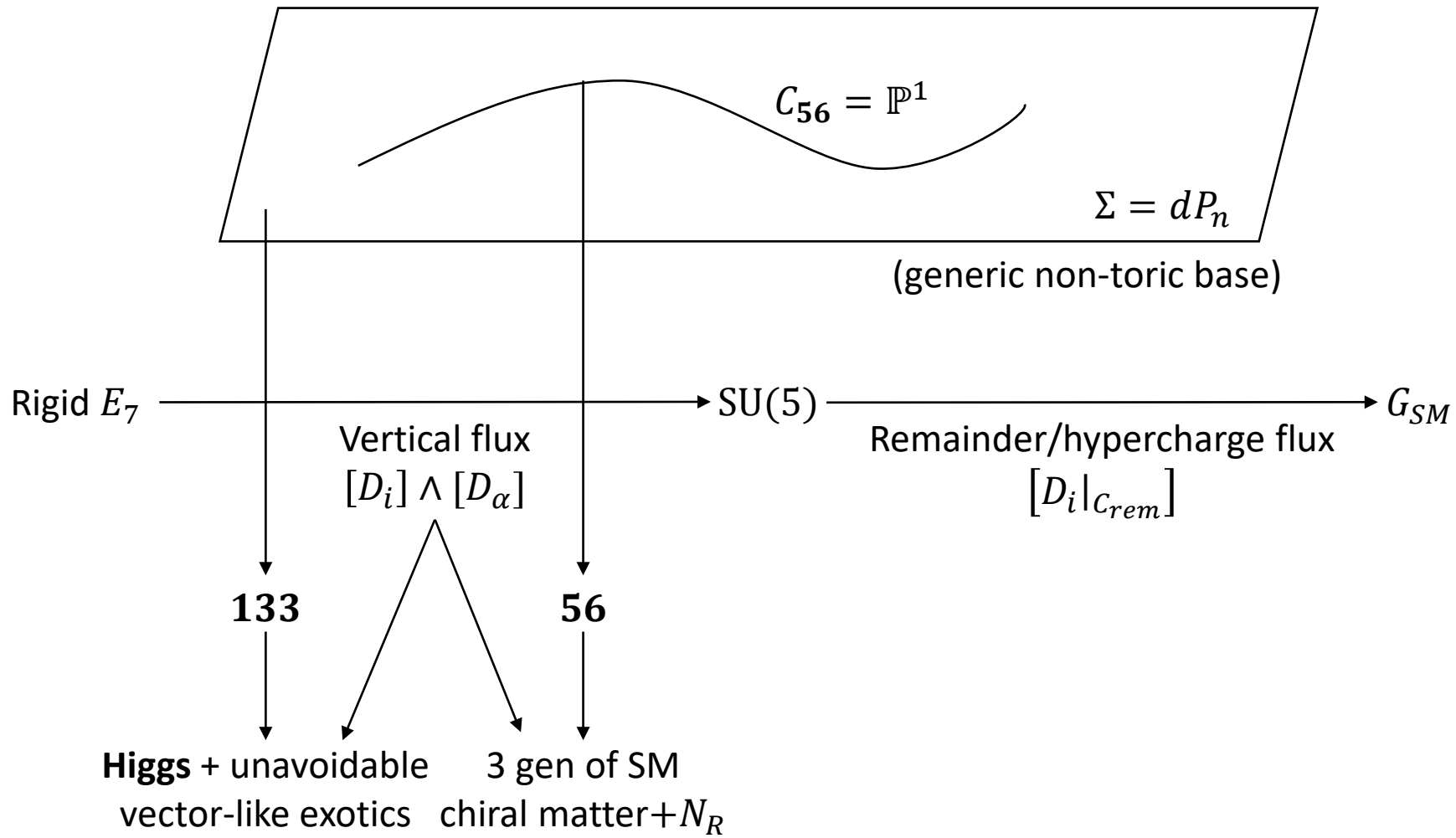
with Washington Taylor



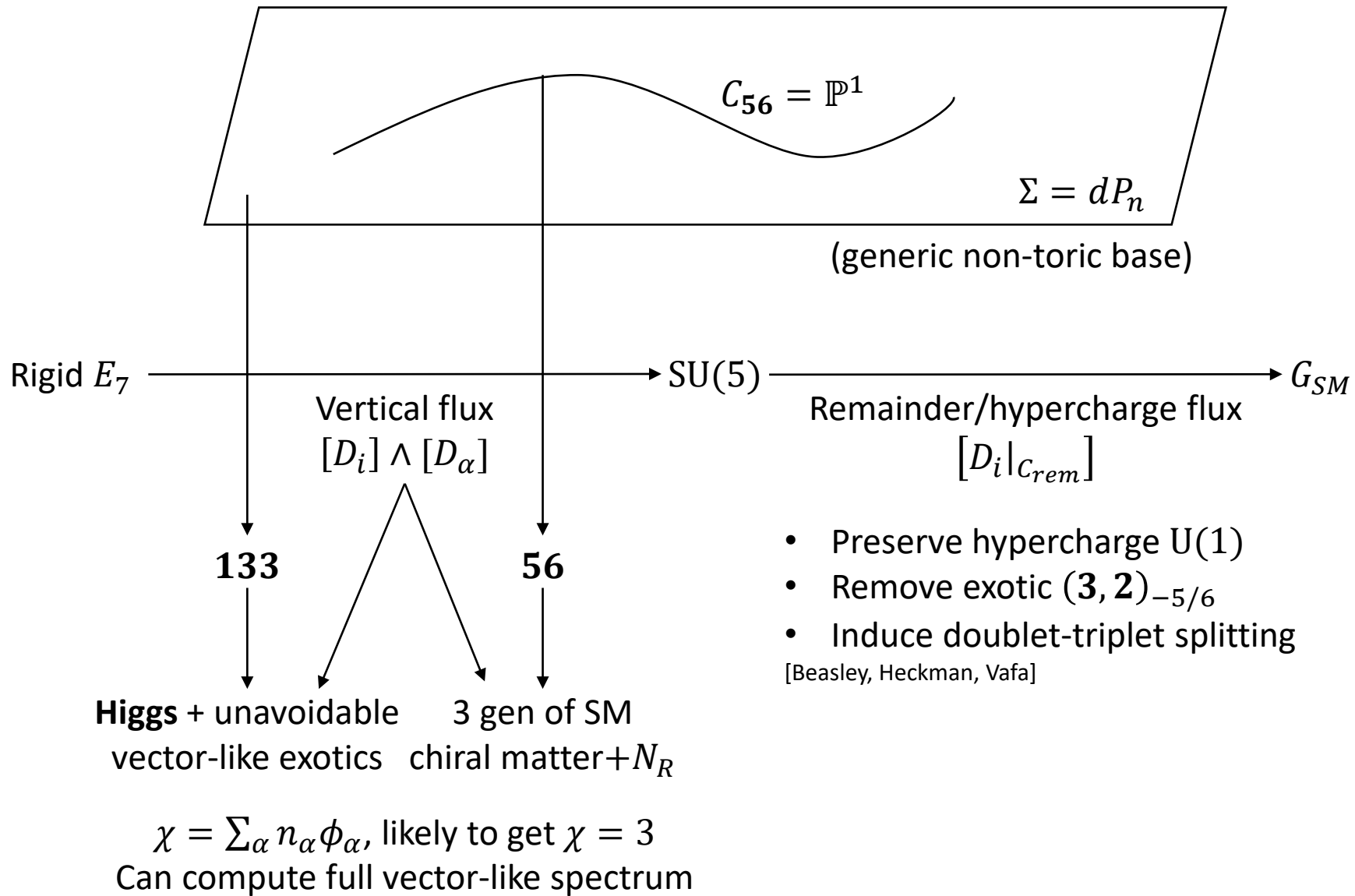
Rigid  $E_7$

- Common (10%-20%?) in F-theory landscape
- Independent of moduli





$\chi = \sum_\alpha n_\alpha \phi_\alpha$ , likely to get  $\chi = 3$   
 Can compute full vector-like spectrum



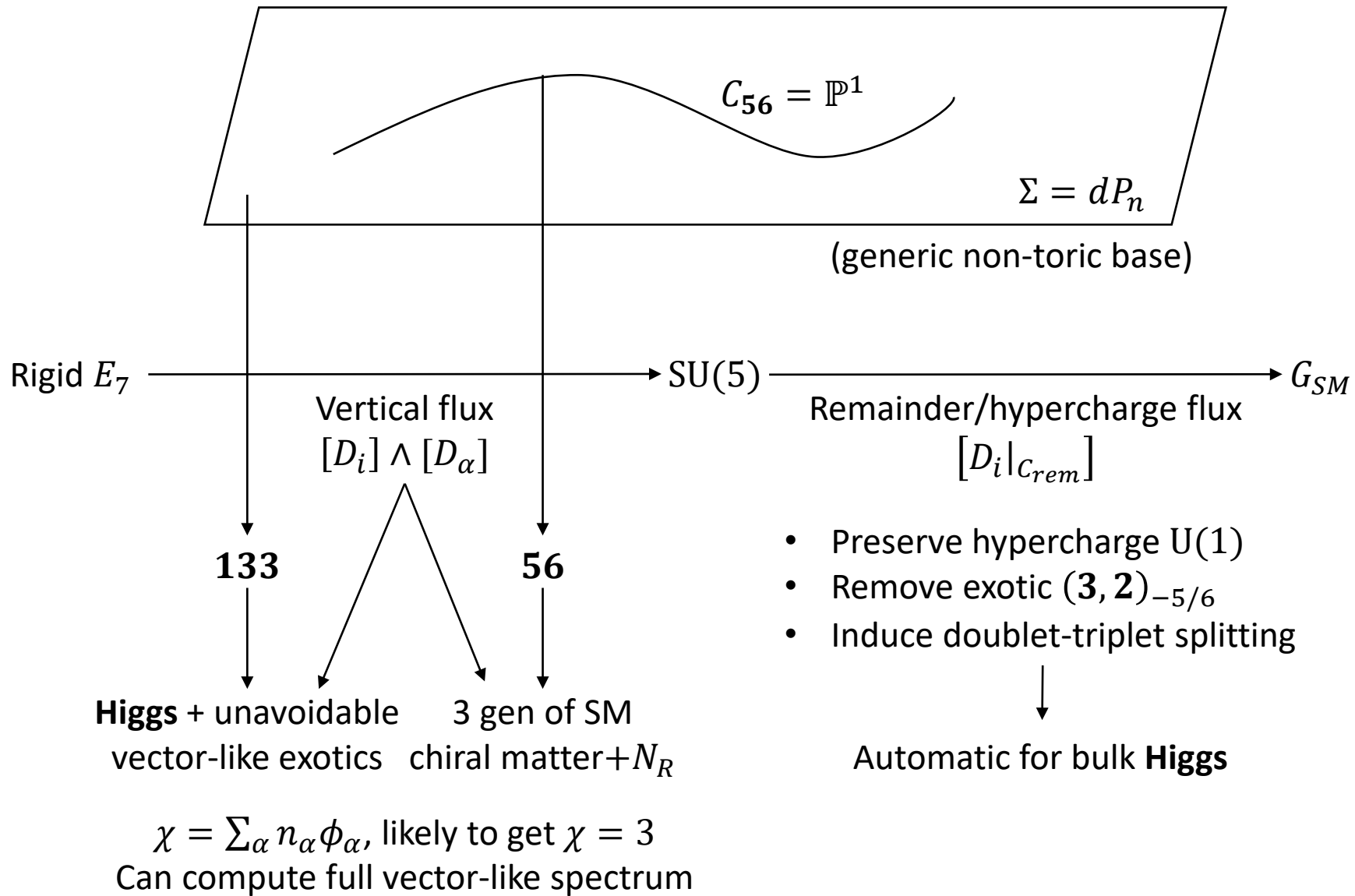
# Removing exotic $(\mathbf{3}, \mathbf{2})_{-5/6}$

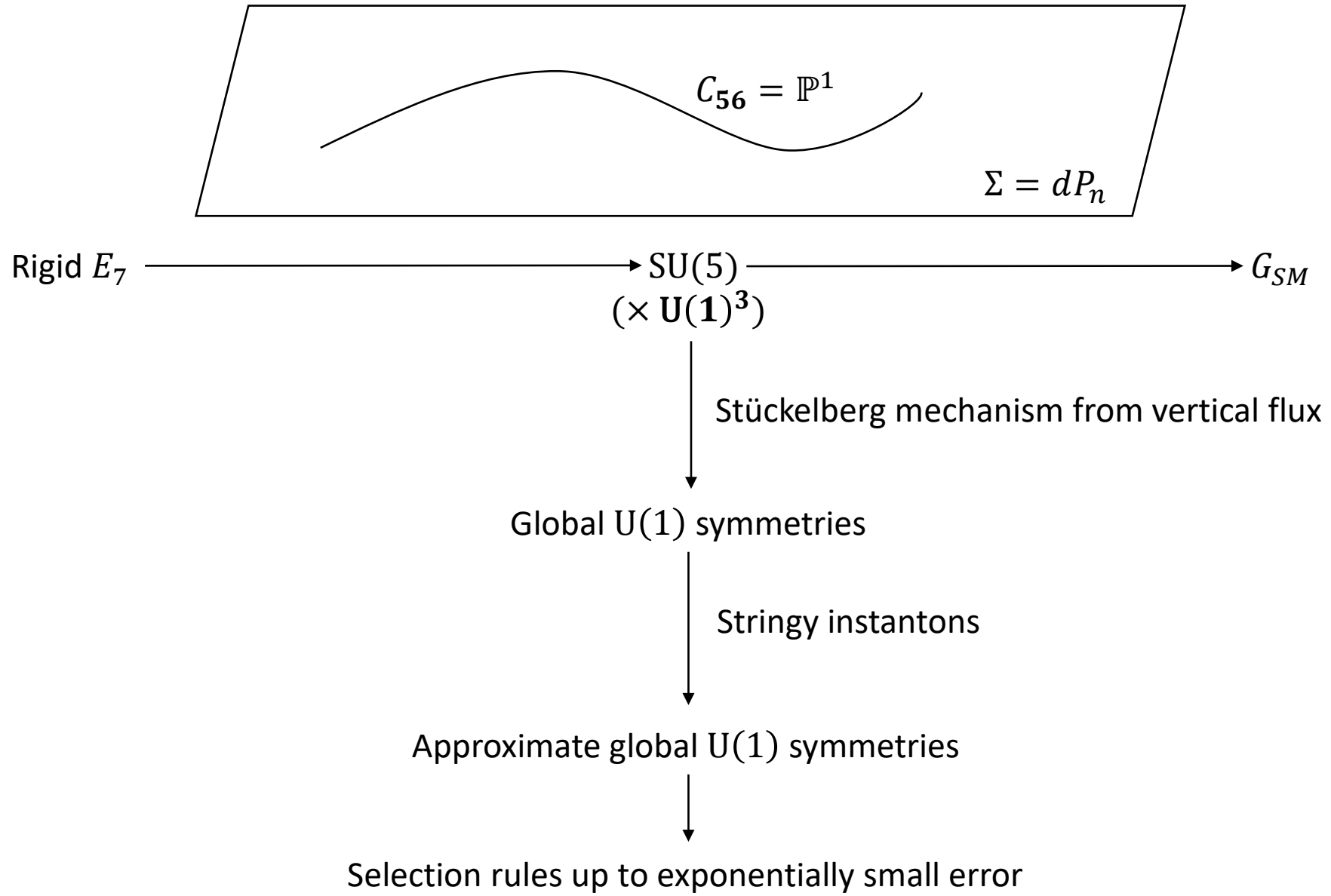
- Achieved by manifestly integer hypercharge flux with minimal tadpole

$$G_4^{rem} = \left[ 2D_1 + 4D_2 + 6D_3 + 4D_4 + 2D_5 + D_6 + 3D_7 \Big|_{C_{rem}} \right]$$

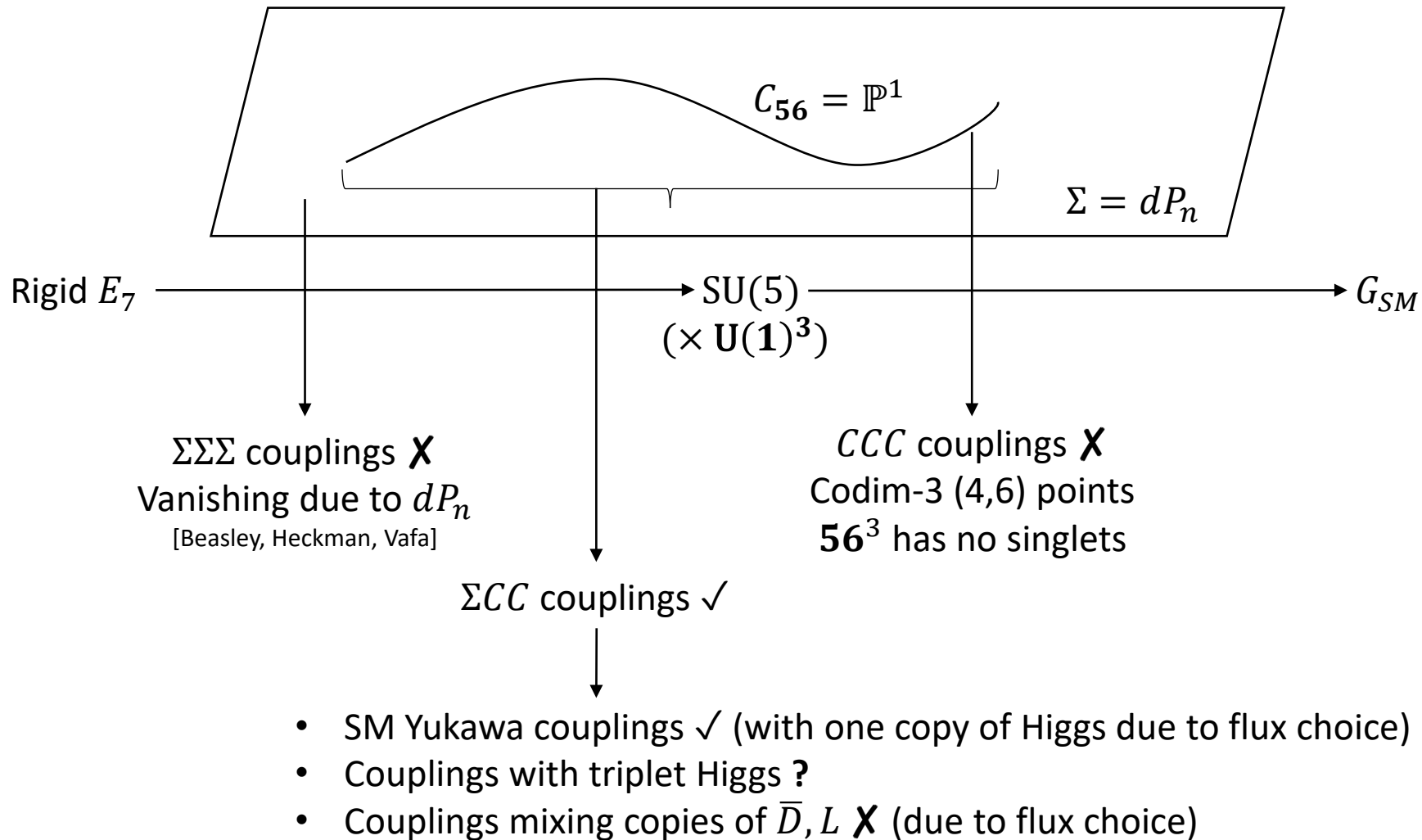
with  $C_{rem}^2 = -2$  e.g.  $e_i - e_j$  in  $dP_n$

$$\frac{1}{2} \int G_4^{rem} \wedge G_4^{rem} = 4$$









$$56 \rightarrow Q + \bar{U} + \bar{E} + 3 \times (\bar{D} + L + N_R) + h.c.$$

$$133 \rightarrow H_u + T_u + 3 \times (H_d + T_d) + \dots + h.c.$$

Choose vertical flux such that only one copy is present

# Proton decay

- Dimension-4 proton decay (R-parity violation)

$$W \supset \alpha_1 QL\bar{D} + \alpha_2 LL\bar{E} + \alpha_3 \bar{D}\bar{D}\bar{U}$$

- *CCC* couplings are absent
- $\therefore$  No dimension-4 proton decay (possible tiny violation from flux breaking?)

# Proton decay

- Dimension-5 proton decay :  $\frac{1}{M} QQQ L$  ?

$$W \supset \lambda_1 T_u Q Q + \lambda_2 T_d Q L + \underbrace{M T_u T_d}_{\substack{\uparrow \\ \text{Violate } U(1)^3}}$$

- $T_u$  and  $T_d$  do not have opposite  $U(1)^3$  charges

# Proton decay

- Dimension-5 proton decay :  $\frac{m}{M^2} QQQ L \checkmark$  ( $m \ll M$ )

$$W \supset \lambda_1 T_u Q Q + \lambda_2 T_d Q L + M T_u T'_d + M T_d T'_u + m T_u T_d + m T'_u T'_d$$

- **Inert**  $T'_u$  and  $T'_d$
- $\therefore$  Dimension-5 proton decay is exponentially suppressed

# Higgs sector

$$W \supset MH_u H'_d + MH_d H'_u + mH_u H_d + mH_u' H_d'$$

- $\mu$ -problem remains unsolved
- Gauge coupling unification at  $10^{16}$  GeV, but...

$H_u, H_d$

Chiral matter

$H'_u, H'_d$  + unknown **inert** fields with **TeV** masses

GUT multiplets

# An explicit global construction

$$\begin{array}{c} \mathbb{P}^1 \\ \downarrow \\ \text{Base } B = \text{hypersurface in } \mathbb{P}^1, \text{ gauge divisor } \Sigma = dP_6 \\ A = \downarrow \\ \sigma = dP_2 \end{array}$$

$$\text{Normal bundles: } N_\sigma = -h, N_A = -4\sigma - 3E_1$$

Flux $\phi$	1	2	3	4	5	6	7
$\sigma$	0	0	0	0	0	1	0
$E_1$	-3	-6	-9	-15/2	-5	-7/2	-9/2
$E_2$	0	0	0	0	2	1	0
$F$	3	6	9	15/2	3	-1/2	9/2
$r$	2	4	6	4	2	1	3

$$\text{Total tadpole} = 36 < 49 = \chi/24$$

Many realistic features arise naturally from  $E_7$ !

Computations of masses and couplings?

Moduli stabilization?

SUSY breaking?