Opening up baryon number violating operators

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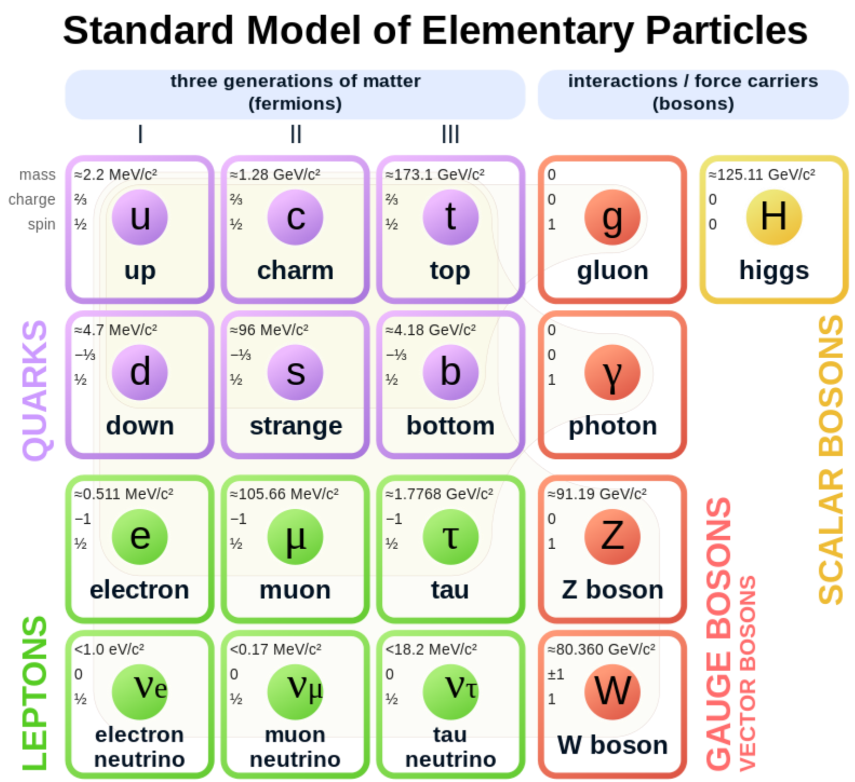
Baryon number violation

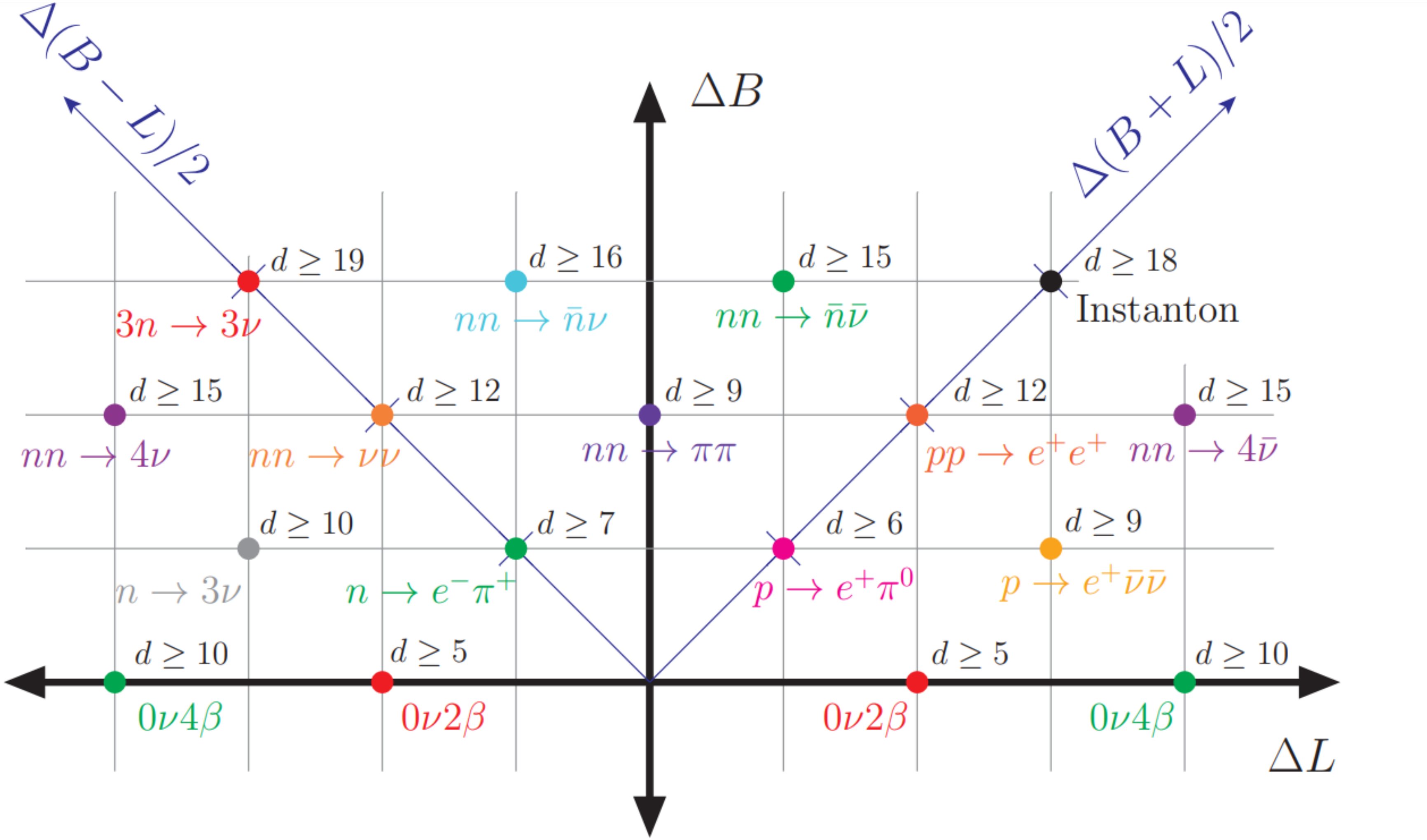


We can assign $U(1)_B$ charge 1/3 to baryons

- Baryon and lepton number violation is sensitive to $d \gg 6$, unlike any other experiment.
- Use SMEFT to describe:

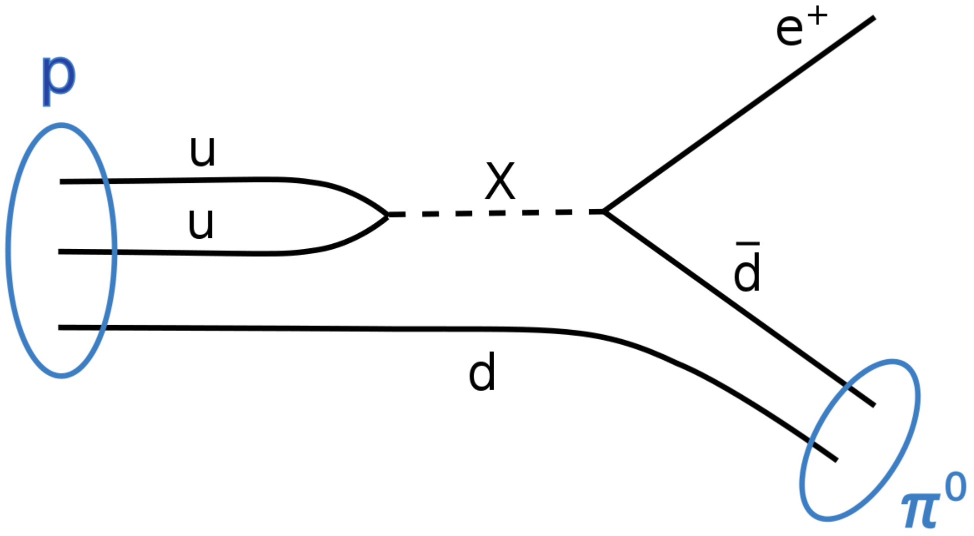
$$\mathcal{L} = \mathcal{L}_{SM} + \sum_{d=5} \frac{\sum_i C_i \mathcal{O}_i}{\Lambda^{d-4}}$$

BNV landscape

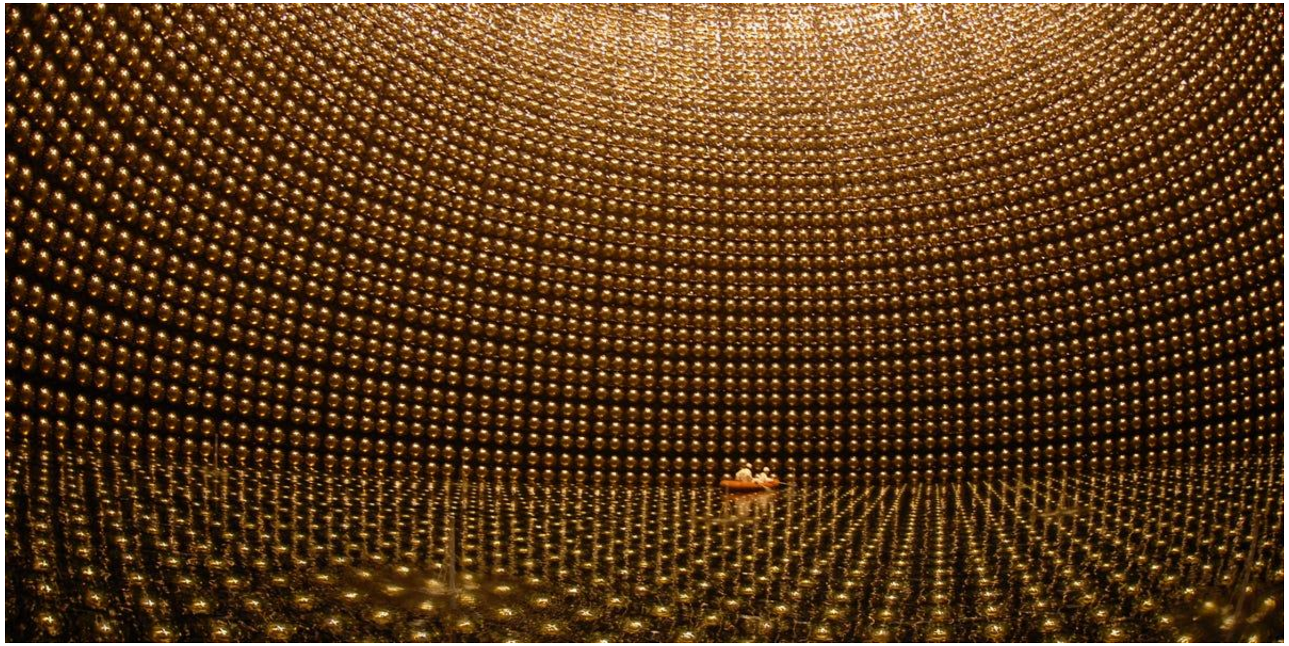


[J. Heeck, V. Takhistov (arXiv:1910.07647)]

Example: Proton decay



Super-Kamiokande.



$$\frac{uude}{\Lambda^2} \rightarrow \Gamma(p \rightarrow e^+\pi^0) \sim \frac{m_p^5}{\Lambda^4} \sim \frac{1}{10^{34}\ years}\left(\frac{10^{15}GeV}{\Lambda}\right)^4$$

$\tau(p \rightarrow e^+\pi^0) > 10^{34}$ yr.

Generate operators

$$O^{(1)}_{abcd} = (\bar{d}^C_{\alpha aR} u_{\beta bR})(\bar{q}^C_{i\gamma cL} l_{jdL})\epsilon_{\alpha\beta\gamma}\epsilon_{ij}, \quad (1)$$

$$O^{(2)}_{abcd} = (\bar{q}^C_{i\alpha aL} q_{j\beta bL})(\bar{u}^C_{\gamma cR} l_{dR})\epsilon_{\alpha\beta\gamma}\epsilon_{ij}, \quad (2)$$

$$O^{(3)}_{abcd} = (\bar{q}^C_{i\alpha aL} q_{j\beta bL})(\bar{q}^C_{k\gamma cL} l_{ldL})\epsilon_{\alpha\beta\gamma}\epsilon_{ij}\epsilon_{kl}, \quad (3)$$

$$O^{(4)}_{abcd} = (\bar{q}^C_{i\alpha aL} q_{j\beta bL})(\bar{q}^C_{k\gamma cL} l_{ldL})\epsilon_{\alpha\beta\gamma} \times(\vec{\tau}\epsilon)_{ij}\cdot(\vec{\tau}\epsilon)_{kl}, \quad (4)$$

$$O^{(5)}_{abcd} = (\bar{d}^C_{\alpha aR} u_{\beta bR})(\bar{u}^C_{\gamma cR} l_{dR})\epsilon_{\alpha\beta\gamma}, \quad (5)$$

$$O^{(6)}_{abcd} = (\bar{u}^C_{\alpha aR} u_{\beta bR})(\bar{d}^C_{\gamma cR} l_{dR})\epsilon_{\alpha\beta\gamma}. \quad (6)$$

[Weinberg, 1979]

Linearly independent operators (including right-handed neutrinos).

$$\mathcal{O}^1_{6\,abcd} \equiv \epsilon^{\alpha\beta\gamma}\epsilon_{ij}(\overline{d}^C_{a,\alpha} u_{b,\beta})(\overline{Q}^C_{i,c,\gamma} L_{j,d}),$$

$$\mathcal{O}^2_{6\,abcd} \equiv \epsilon^{\alpha\beta\gamma}\epsilon_{ij}(\overline{Q}^C_{i,a,\alpha} Q_{j,b,\beta})(\overline{u}^C_{c,\gamma} \ell_d),$$

$$\mathcal{O}^3_{6\,abcd} \equiv \epsilon^{\alpha\beta\gamma}\epsilon_{il}\epsilon_{jk}(\overline{Q}^C_{i,a,\alpha} Q_{j,b,\beta})(\overline{Q}^C_{k,c,\gamma} L_{l,d}),$$

$$\mathcal{O}^4_{6\,abcd} \equiv \epsilon^{\alpha\beta\gamma}(\overline{d}^C_{a,\alpha} u_{b,\beta})(\overline{u}^C_{c,\gamma} \ell_d),$$

$$\mathcal{O}^5_{6\,abcd} \equiv \epsilon^{\alpha\beta\gamma}\epsilon_{ij}(\overline{Q}^C_{i,a,\alpha} Q_{j,b,\beta})(\overline{d}^C_{c,\gamma} \nu_d),$$

$$\mathcal{O}^6_{6\,abcd} \equiv \epsilon^{\alpha\beta\gamma}(\overline{d}^C_{a,\alpha} u_{b,\beta})(\overline{d}^C_{c,\gamma} \nu_d),$$

[Weinberg, 1979]

[Beltran, Cepedello, Hirsch (arXiv:2306.12578)]

Generate operators

field	chirality	generations	$SU(3)_C \times SU(2)_L \times U(1)_Y$ representation
Q	left	3	$(\mathbf{3}, \mathbf{2}, \frac{1}{6})$
u	right	3	$(\mathbf{3}, \mathbf{1}, \frac{2}{3})$
d	right	3	$(\mathbf{3}, \mathbf{1}, -\frac{1}{3})$
L	left	3	$(\mathbf{1}, \mathbf{2}, -\frac{1}{2})$
ℓ	right	3	$(\mathbf{1}, \mathbf{1}, -1)$
ν	right	3	$(\mathbf{1}, \mathbf{1}, 0)$
H	scalar	1	$(\mathbf{1}, \mathbf{2}, \frac{1}{2})$

SYM2INT

https://renatofonseca.net/sym2int

Dim 6 $\mathcal{O}_6^1 \equiv duQL, \quad \mathcal{O}_6^2 \equiv QQu\ell, \quad \mathcal{O}_6^3 \equiv QQQL, \quad \mathcal{O}_6^4 \equiv duu\ell, \quad \mathcal{O}_6^5 \equiv QQd\nu, \quad \mathcal{O}_6^6 \equiv dud\nu.$

Dim 7 $\mathcal{O}_7^1 \equiv QQd\bar{L}\bar{H}, \quad \mathcal{O}_7^2 \equiv ddQ\bar{e}\bar{H}, \quad \mathcal{O}_7^3 \equiv ddu\bar{L}\bar{H}, \quad \mathcal{O}_7^4 \equiv ddd\bar{L}H\,,$
$\mathcal{O}_7^5 \equiv duQ\bar{\nu}\bar{H}, \quad \mathcal{O}_7^6 \equiv QQQ\bar{\nu}\bar{H}, \quad \mathcal{O}_7^7 \equiv ddQ\bar{\nu}H\,.$

Dim 8 $\mathcal{O}_8^1 \equiv uuQL\bar{H}\bar{H}, \quad \mathcal{O}_8^2 \equiv udue\bar{H}H\,, \quad \mathcal{O}_8^3 \equiv udQL\bar{H}H\,, \quad \mathcal{O}_8^4 \equiv QQue\bar{H}H\,, \mathcal{O}_8^5 \equiv QQQL\bar{H}H\,,$
$\mathcal{O}_8^6 \equiv ddQLHH\,, \quad \mathcal{O}_8^7 \equiv QQdeHH\,, \quad \mathcal{O}_8^8 \equiv QQu\nu\bar{H}\bar{H}\,, \quad \mathcal{O}_8^9 \equiv udd\nu\bar{H}H\,, \quad \mathcal{O}_8^{10} \equiv QQd\nu\bar{H}H\,.$

Dim 9 $\mathcal{O}^1_{9,\,(1,3)} \equiv uuQLLL$ + 61 more operators

Dim 10 $\mathcal{O}^1_{10,\,(1,1)} \equiv \bar{d}ddQQLH$ + 111 more operators

Dim 11 $\mathcal{O}^1_{11,\,(1,-1)} \equiv \bar{H}\bar{e}\bar{d}dddH$ + 130 more operators

Dim 12 $\mathcal{O}^1_{12,\,(1,-3)} \equiv \bar{L}\bar{L}\bar{e}\bar{u}dddd$ + 479 more operators

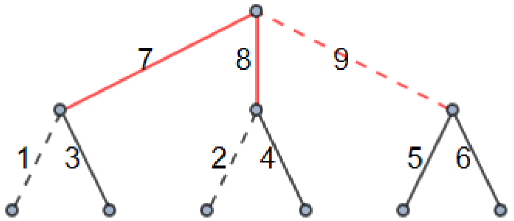
Dim 13 $\mathcal{O}^1_{13,\,(1,3)} \equiv \bar{d}QQQQLLLH$ + 781 more operators

Dim 14 $\mathcal{O}^1_{14,\,(1,5)} \equiv uuQLLLLLHH$ + 983 more operators

Dim 15 $\mathcal{O}^1_{15,\,(3,1)} \equiv ddQQQQQQL$ + 2626 more operators

Generate topologies

- To obtain topologies, we use FeynArts Mathematica package to generate all possible diagrams and removed topologically same ones. (https://feynarts.de)

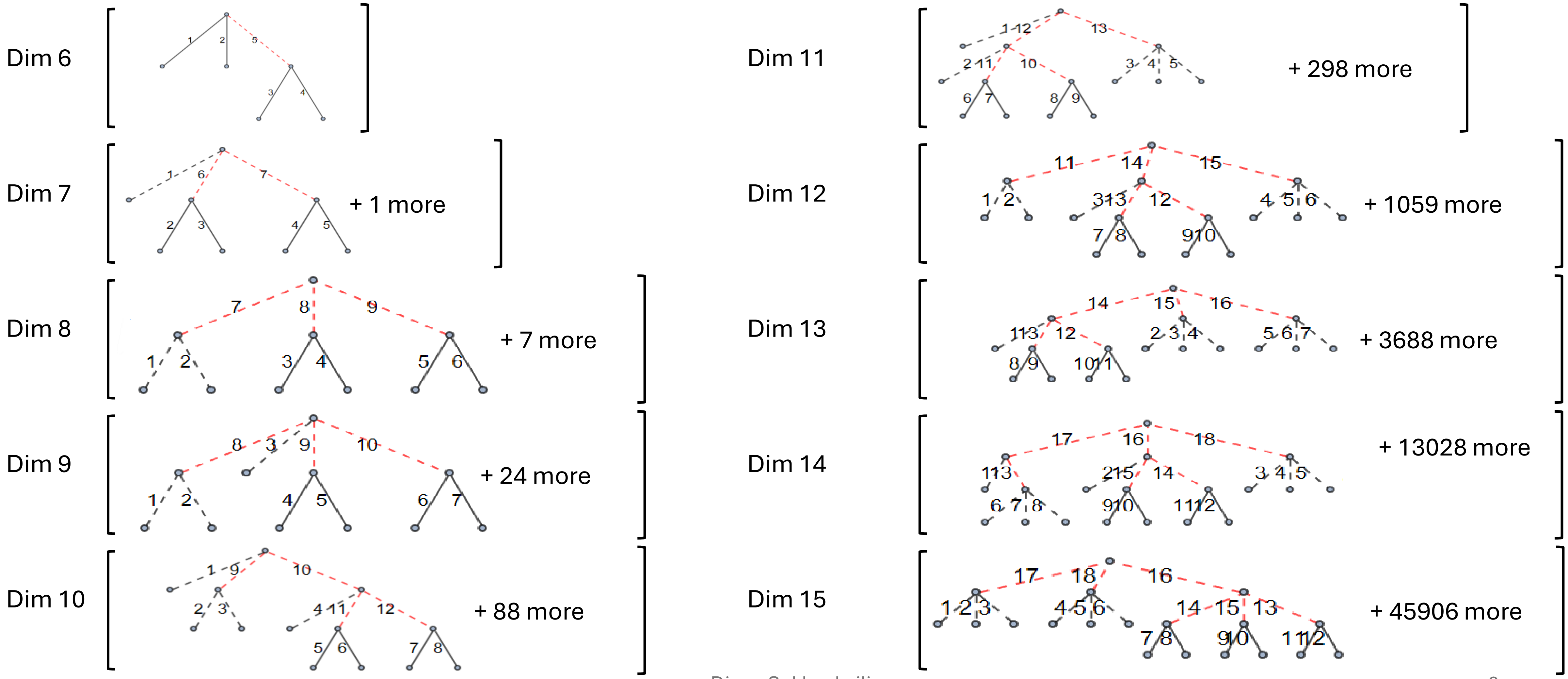
{ 

, {S, S, F, F, F, F, Fermion, Fermion, Boson}, {{1, 3, 7}, {2, 4, 8}, {5, 6, 9}, {7, 8, 9}}},

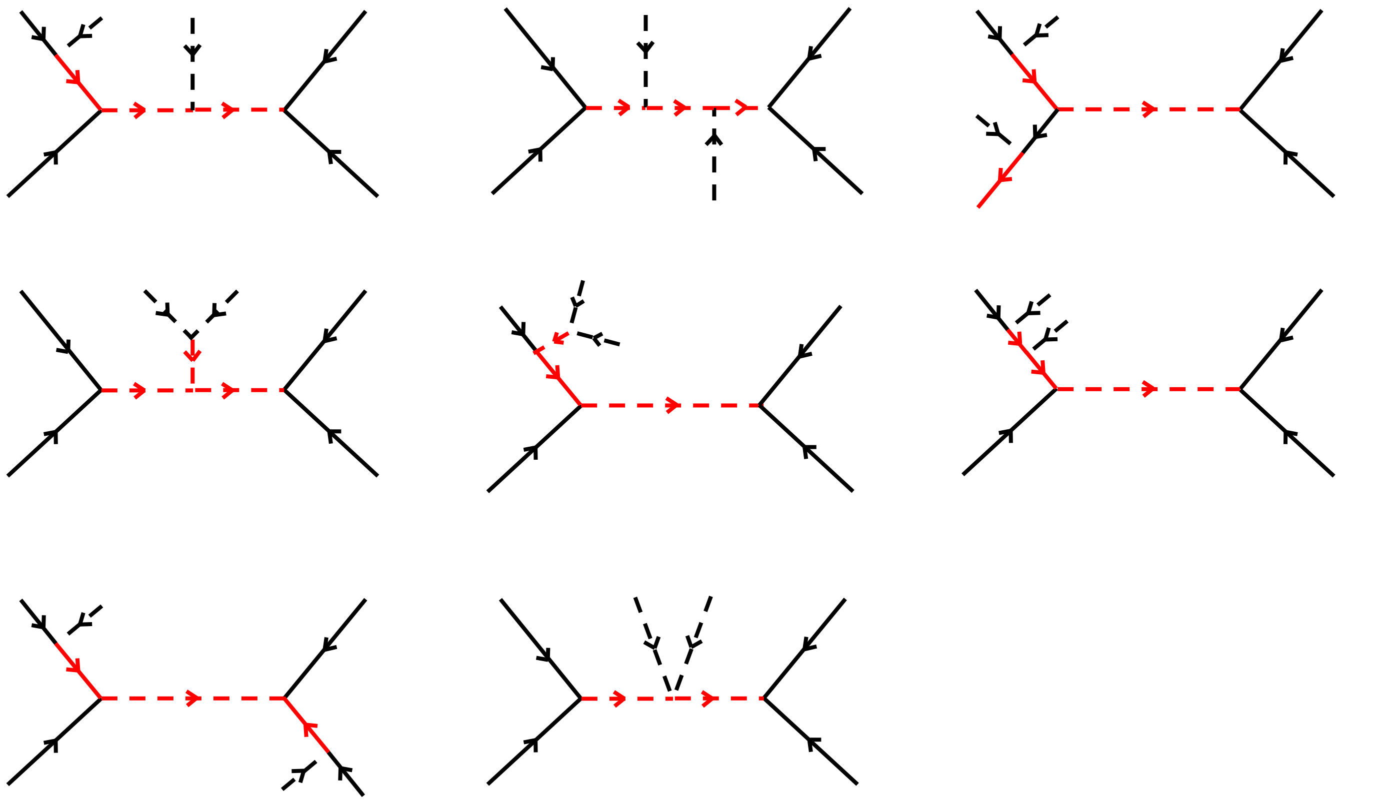
Topologies

SM Boson - - - - - - New Boson - - - - - -

SM Fermion ——— New Fermion ———



Example (Dimension 8)



$$\mathcal{O}_8^1 \equiv uuQL\bar{H}\bar{H},$$
$$\mathcal{O}_8^2 \equiv udue\bar{H}H\,,$$
$$\mathcal{O}_8^3 \equiv udQL\bar{H}H\,,$$
$$\mathcal{O}_8^4 \equiv QQue\bar{H}H\,,$$
$$\mathcal{O}_8^5 \equiv QQQL\bar{H}H\,,$$
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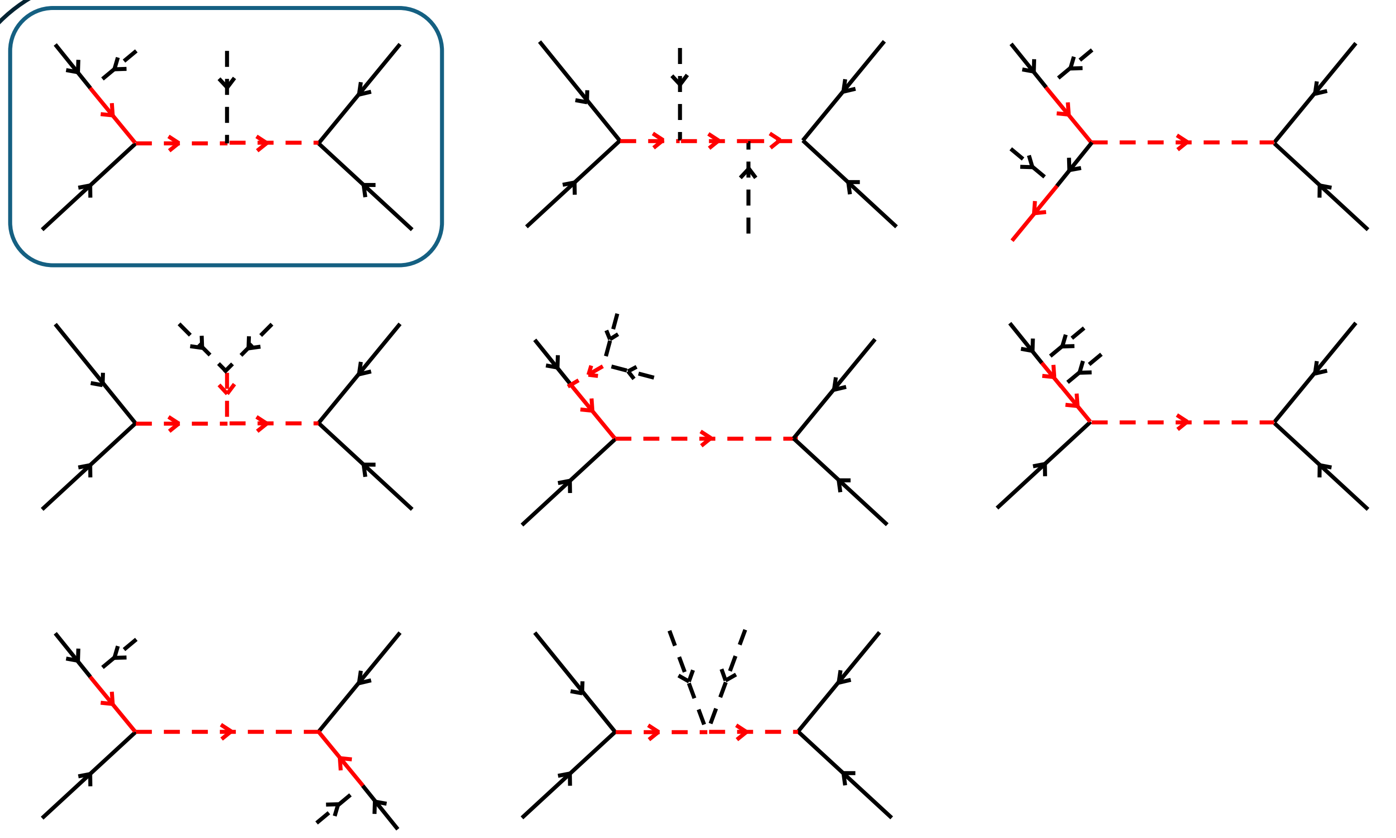
Example (Dimension 8)



$\mathcal{O}_8^1 \equiv uuQL\bar{H}\bar{H}\,,$

$\mathcal{O}_8^2 \equiv udue\bar{H}H\,,$

$\mathcal{O}_8^3 \equiv udQL\bar{H}H\,,$

$\mathcal{O}_8^4 \equiv QQue\bar{H}H\,,$

$\mathcal{O}_8^5 \equiv QQQL\bar{H}H\,,$

$\mathcal{O}_8^6 \equiv ddQLHH\,,$

$\mathcal{O}_8^7 \equiv QQdeHH\,,$

$\mathcal{O}_8^8 \equiv QQu\nu\bar{H}\bar{H}\,,$

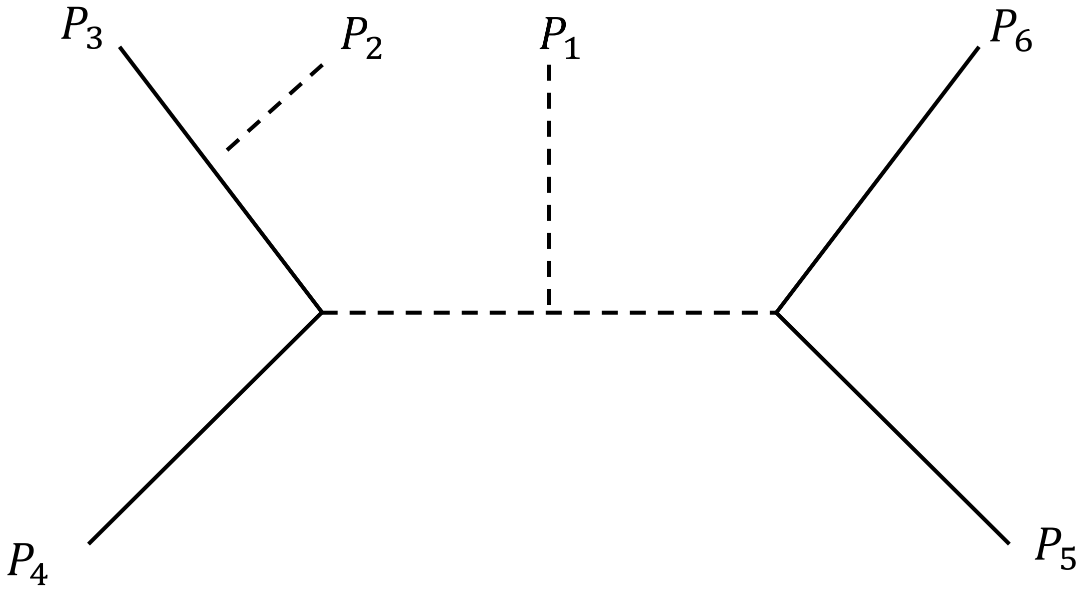
$\mathcal{O}_8^9 \equiv udd\nu\bar{H}H\,,$

$\mathcal{O}_8^{10} \equiv QQd\nu\bar{H}H\,.$

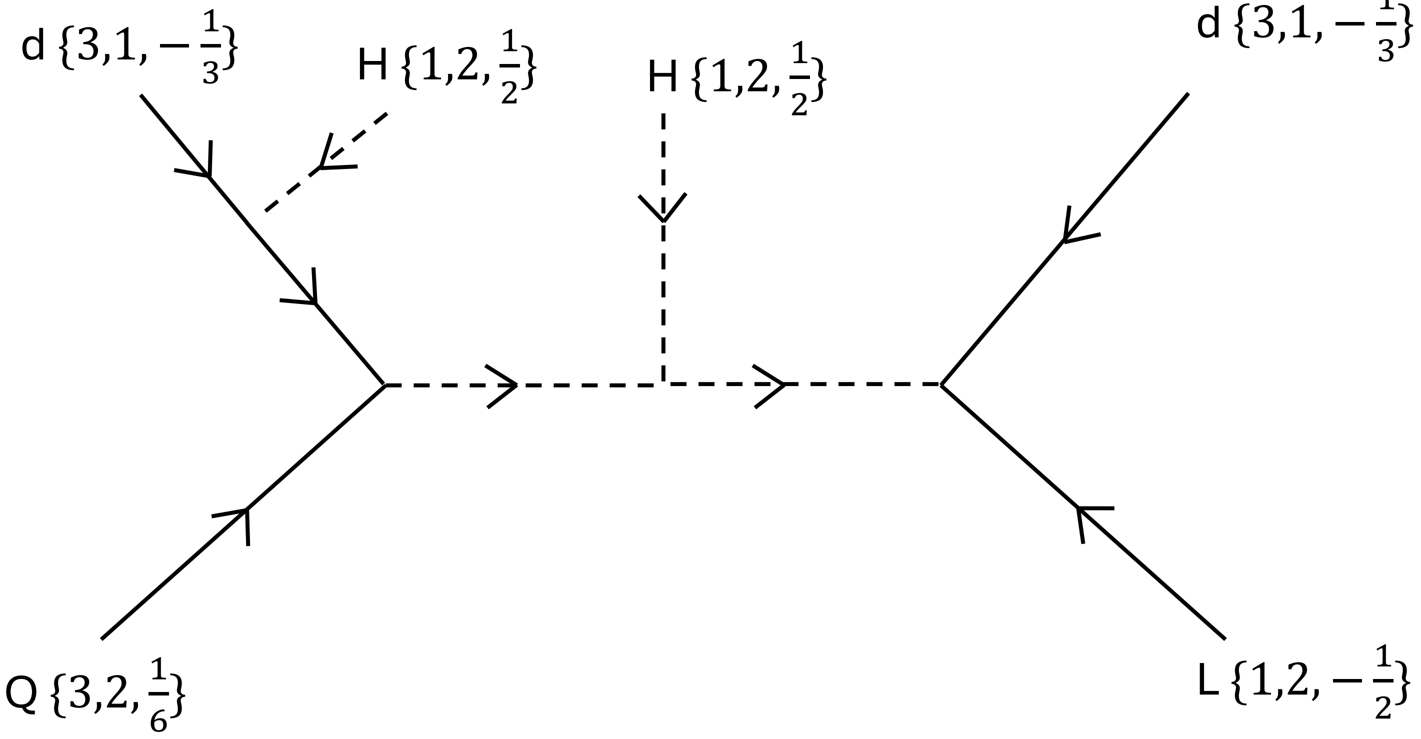
Possible permutations

Operator: ddLQHH

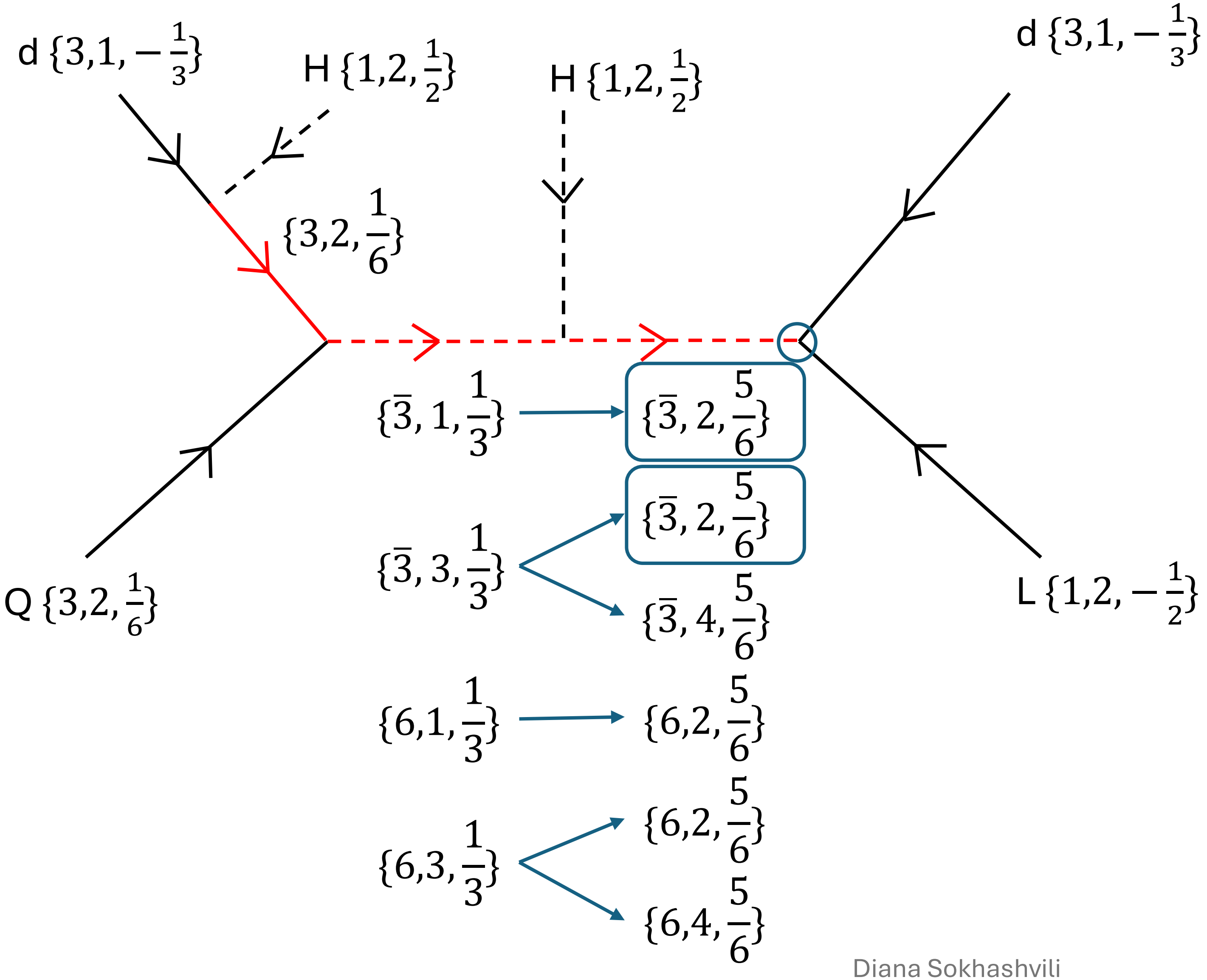
{{H H d d L Q}, {H H d d Q L} ,{H H d L d Q}, {H H d L Q d}, {H H d Q d L}, {H H d Q L d},
{H H L d d Q} ,{H H L d Q d} ,{H H L Q d d} ,{H H Q d d L}, {H H Qd L d}, {H H Q L d d}}



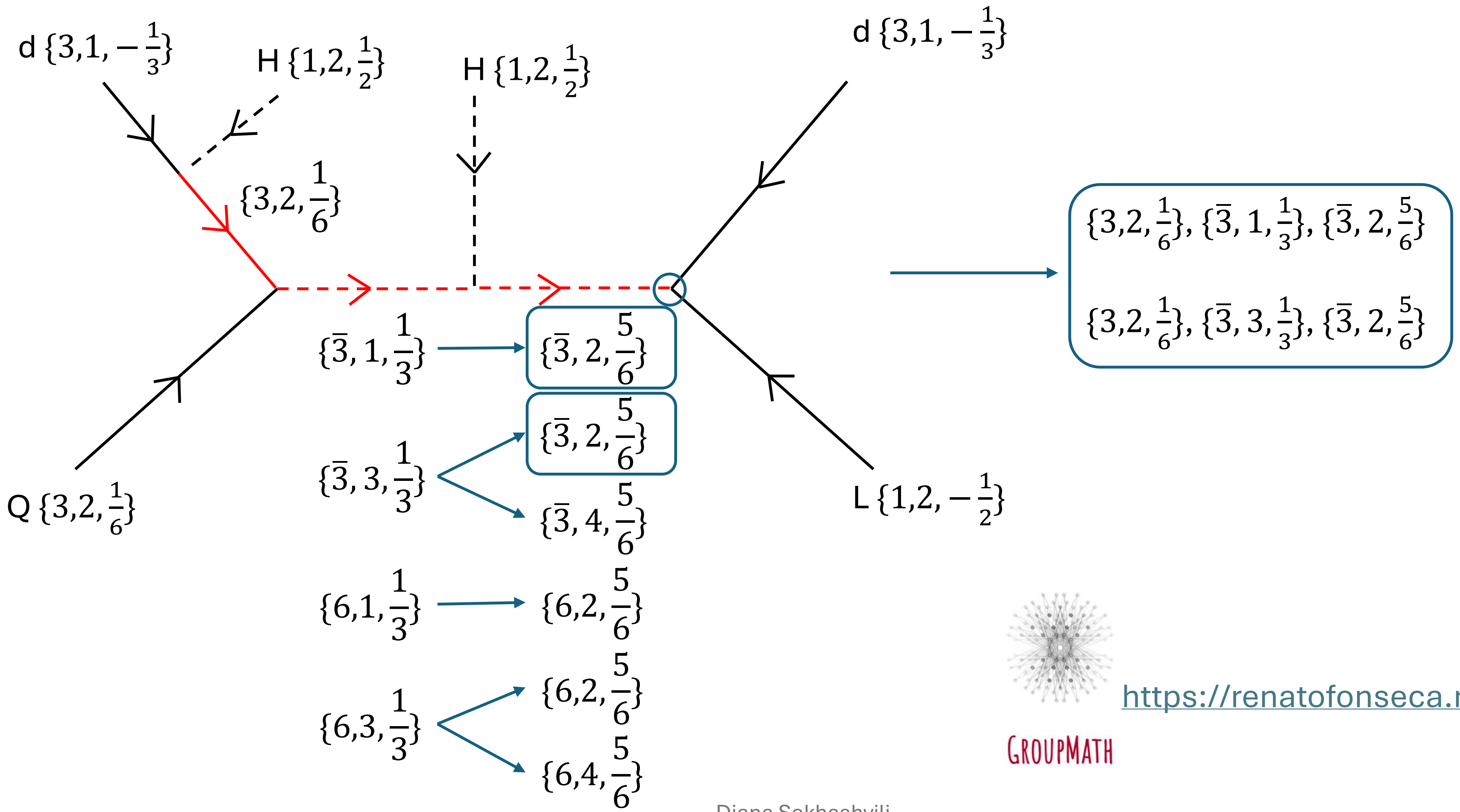
Internal particles



Internal particles



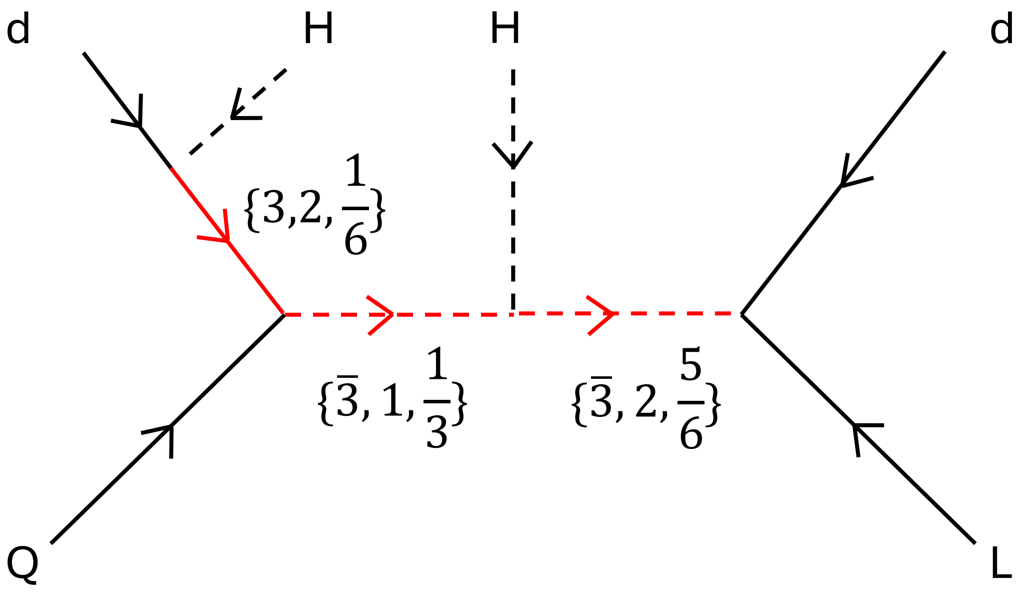
Internal particles



GroupMath

https://renatofonseca.net/groupmath

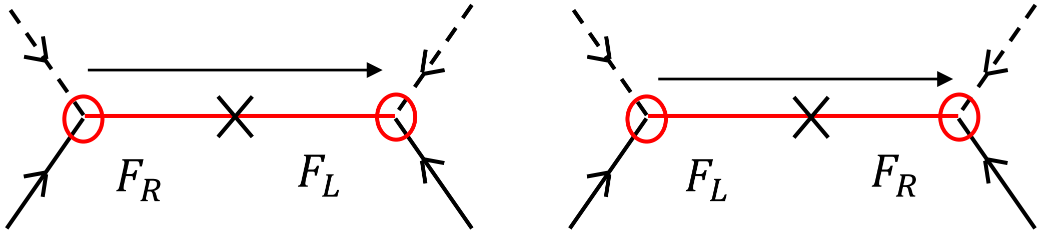
Internal particles



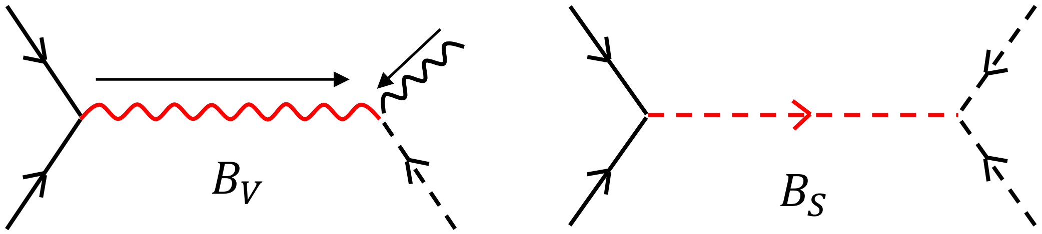
$\{3,2,\frac{1}{6}\}, \{\bar{3},1,\frac{1}{3}\}, \{\bar{3},2,\frac{5}{6}\}$

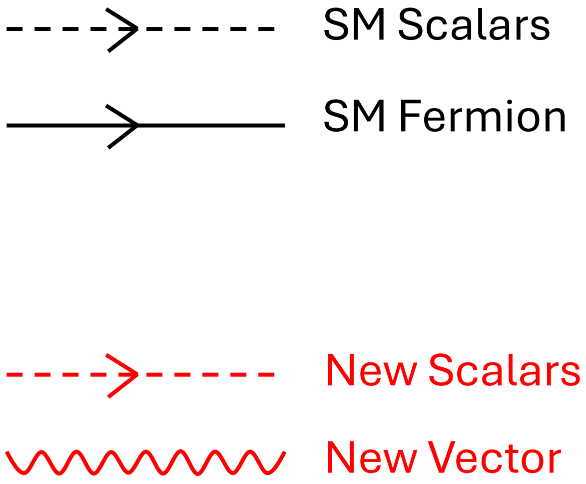
Lorentz group (SU2×SU2)

- For internal fermions we need to make sure that chirality is flipped to ensure that this fermions are massive.

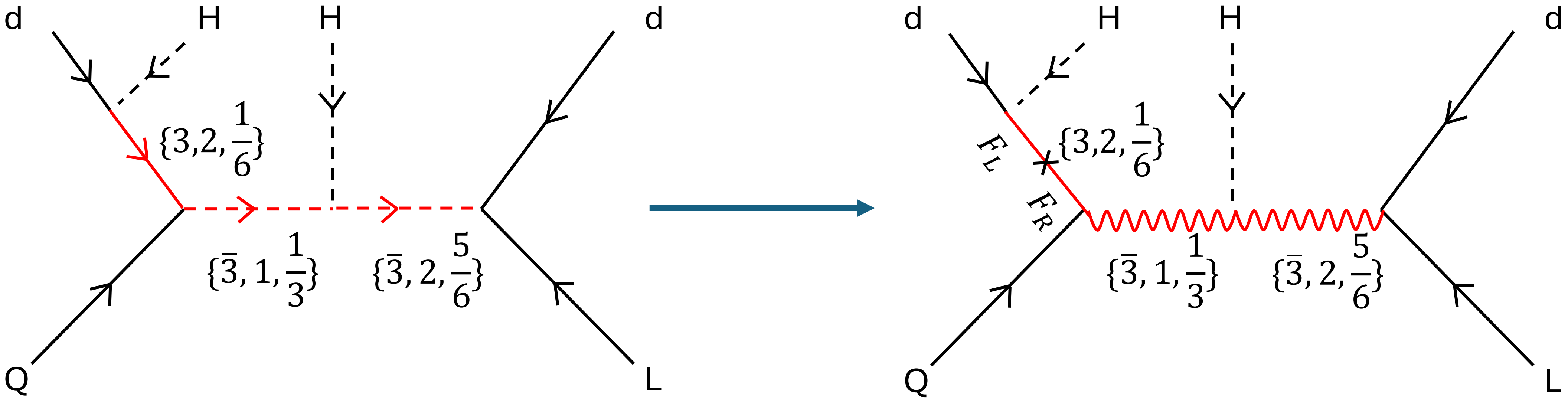


- For internal bosons we determine whether they are vector or scalar.





Internal particles



$\{3,2,\frac{1}{6}\}, \{\bar{3},1,\frac{1}{3}\}, \{\bar{3},2,\frac{5}{6}\}$

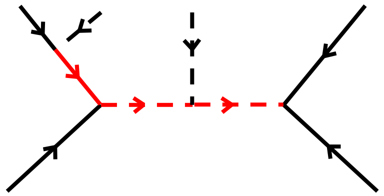
$\left\{3,2,\frac{1}{6}\right\}_F, \left\{\bar{3},1,\frac{1}{3}\right\}_V, \left\{\bar{3},2,\frac{5}{6}\right\}_V$

SYM2INT https://renatofonseca.net/sym2int

Permuting fields around topology

Operator: ddLQHH

Topology:



$\{\{\{H, H, d, Q, L, d, \{F, \{3, 2, \frac{1}{6}\}\}, \{V, \{\bar{3}, 3, \frac{1}{3}\}\}, \{V, \{\bar{3}, 2, \frac{5}{6}\}\}\}\}, \{\{H, H, d, Q, L, d, \{F, \{3, 2, \frac{1}{6}\}\}, \{V, \{\bar{3}, 1, \frac{1}{3}\}\}, \{V, \{\bar{3}, 2, \frac{5}{6}\}\}\}\},$

$\{\{H, H, d, L, Q, d, \{F, \{3, 2, \frac{1}{6}\}\}, \{V, \{3, 3, -\frac{1}{3}\}\}, \{V, \{3, 2, \frac{1}{6}\}\}\}\}, \{\{H, H, d, L, Q, d, \{F, \{3, 2, \frac{1}{6}\}\}, \{V, \{3, 1, -\frac{1}{3}\}\}, \{V, \{3, 2, \frac{1}{6}\}\}\}\},$

$\{\{H, H, d, d, Q, L, \{F, \{3, 2, \frac{1}{6}\}\}, \{S, \{\bar{3}, 2, -\frac{1}{6}\}\}, \{S, \{\bar{3}, 1, \frac{1}{3}\}\}\}\}, \{\{H, H, d, d, Q, L, \{F, \{3, 2, \frac{1}{6}\}\}, \{S, \{\bar{3}, 2, -\frac{1}{6}\}\}, \{S, \{\bar{3}, 3, \frac{1}{3}\}\}\}\},$

$\{\{H, H, Q, d, L, d, \{F, \{3, 3, \frac{2}{3}\}\}, \{V, \{\bar{3}, 3, \frac{1}{3}\}\}, \{V, \{\bar{3}, 2, \frac{5}{6}\}\}\}\}, \{\{H, H, Q, d, L, d, \{F, \{3, 1, \frac{2}{3}\}\}, \{V, \{\bar{3}, 1, \frac{1}{3}\}\}, \{V, \{\bar{3}, 2, \frac{5}{6}\}\}\}\},$

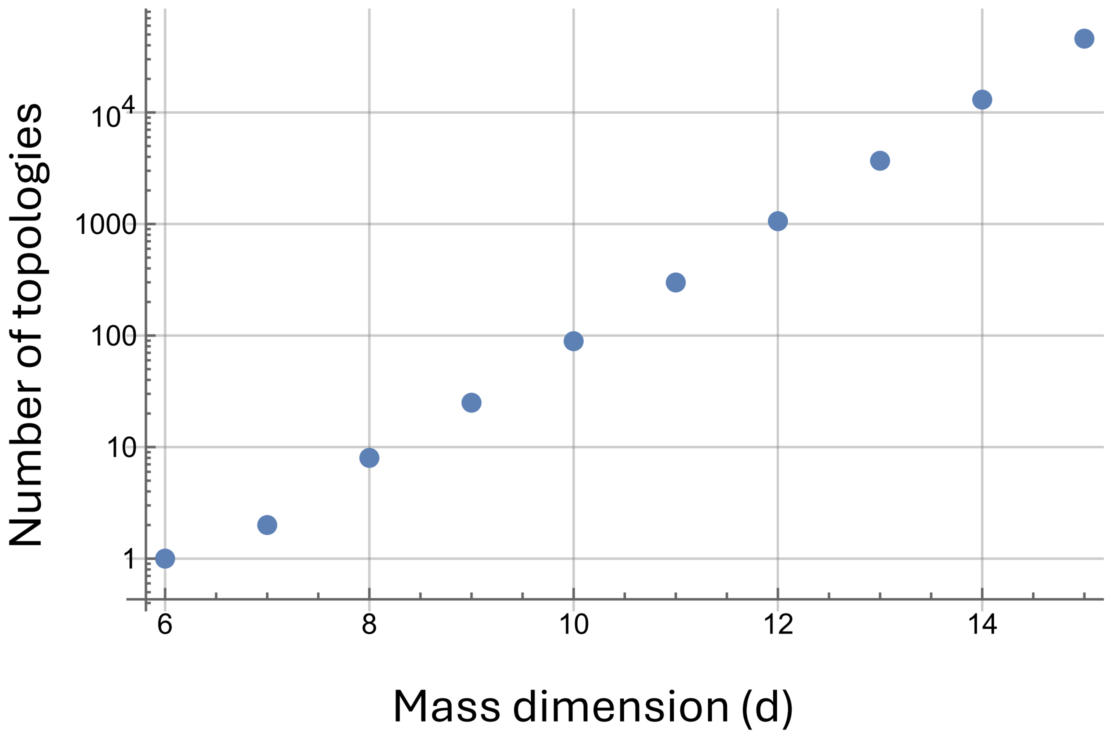
$\{\{H, H, Q, L, d, d, \{F, \{3, 3, \frac{2}{3}\}\}, \{S, \{3, 2, \frac{1}{6}\}\}, \{S, \{3, 1, \frac{2}{3}\}\}\}\}, \{\{H, H, Q, L, d, d, \{F, \{3, 1, \frac{2}{3}\}\}, \{S, \{3, 2, \frac{1}{6}\}\}, \{S, \{3, 1, \frac{2}{3}\}\}\}\},$

$\{\{H, H, L, d, Q, d, \{F, \{1, 3, 0\}\}, \{V, \{3, 3, -\frac{1}{3}\}\}, \{V, \{3, 2, \frac{1}{6}\}\}\}\}, \{\{H, H, L, d, Q, d, \{F, \{1, 1, 0\}\}, \{V, \{3, 1, -\frac{1}{3}\}\}, \{V, \{3, 2, \frac{1}{6}\}\}\}\},$

$\{\{H, H, L, Q, d, d, \{F, \{1, 3, 0\}\}, \{S, \{3, 2, \frac{1}{6}\}\}, \{S, \{3, 1, \frac{2}{3}\}\}\}\}, \{\{H, H, L, Q, d, d, \{F, \{1, 1, 0\}\}, \{S, \{3, 2, \frac{1}{6}\}\}, \{S, \{3, 1, \frac{2}{3}\}\}\}\}\}$

Number of operators and topologies

Number of topologies VS Mass dim



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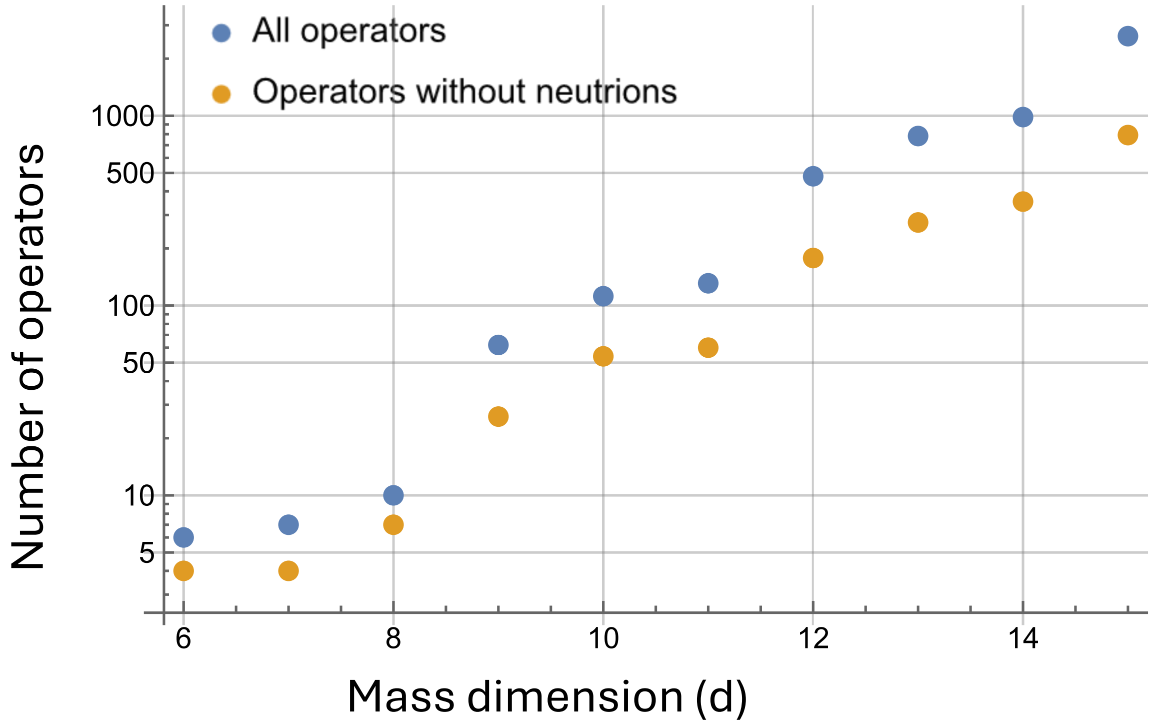

New particles

Dimension 6	$\{\{0, 3\otimes 1\otimes -\frac{4}{3}\}, \{0, 3\otimes 1\otimes -\frac{1}{3}\}, \{0, 3\otimes 1\otimes \frac{2}{3}\}, \{0, 3\otimes 3\otimes -\frac{1}{3}\}, \{1, 3\otimes 2\otimes -\frac{5}{6}\}, \{1, 3\otimes 2\otimes \frac{1}{6}\}\}$
Dimension 7	$\{\{\frac{1}{2}, 1\otimes 1\otimes 0\}, \{\frac{1}{2}, 1\otimes 1\otimes 1\}, \{\frac{1}{2}, 1\otimes 2\otimes \frac{1}{2}\}, \{\frac{1}{2}, 1\otimes 3\otimes 0\}, \{\frac{1}{2}, 3\otimes 1\otimes -\frac{1}{3}\}, \{\frac{1}{2}, 3\otimes 1\otimes \frac{2}{3}\}, \{\frac{1}{2}, 3\otimes 2\otimes -\frac{5}{6}\}, \{\frac{1}{2}, 3\otimes 2\otimes \frac{1}{6}\}, \{\frac{1}{2}, 3\otimes 3\otimes -\frac{1}{3}\}, \{0, 3\otimes 2\otimes \frac{1}{6}\}, \{0, 3\otimes 2\otimes \frac{7}{6}\}, \{1, 3\otimes 1\otimes -\frac{1}{3}\}, \{1, 3\otimes 1\otimes \frac{2}{3}\}, \{1, 3\otimes 3\otimes \frac{2}{3}\}\}$
Dimension 8	$\{\{\frac{1}{2}, 1\otimes 2\otimes \frac{3}{2}\}, \{\frac{1}{2}, 1\otimes 3\otimes 1\}, \{\frac{1}{2}, 1\otimes 4\otimes \frac{1}{2}\}, \{\frac{1}{2}, 3\otimes 2\otimes \frac{7}{6}\}, \{\frac{1}{2}, 3\otimes 3\otimes \frac{2}{3}\}, \{\frac{1}{2}, 3\otimes 4\otimes \frac{1}{6}\}, \{0, 1\otimes 1\otimes 0\}, \{0, 1\otimes 3\otimes 0\}, \{0, 1\otimes 3\otimes 1\}, \{0, 3\otimes 2\otimes -\frac{11}{6}\}, \{0, 3\otimes 2\otimes -\frac{5}{6}\}, \{0, 3\otimes 4\otimes -\frac{5}{6}\}, \{0, 3\otimes 4\otimes \frac{1}{6}\}, \{1, 3\otimes 1\otimes -\frac{4}{3}\}, \{1, 3\otimes 3\otimes -\frac{4}{3}\}, \{1, 3\otimes 3\otimes -\frac{1}{3}\}\}$
Dimension 9	$\{\{\frac{1}{2}, 1\otimes 1\otimes 2\}, \{\frac{1}{2}, 6\otimes 1\otimes -\frac{4}{3}\}, \{\frac{1}{2}, 6\otimes 1\otimes -\frac{1}{3}\}, \{\frac{1}{2}, 6\otimes 1\otimes \frac{2}{3}\}, \{\frac{1}{2}, 6\otimes 2\otimes -\frac{5}{6}\}, \{\frac{1}{2}, 6\otimes 2\otimes \frac{1}{6}\}, \{\frac{1}{2}, 6\otimes 3\otimes -\frac{1}{3}\}, \{\frac{1}{2}, 3\otimes 1\otimes -\frac{4}{3}\}, \{\frac{1}{2}, 3\otimes 1\otimes \frac{5}{3}\}, \{\frac{1}{2}, 3\otimes 3\otimes -\frac{4}{3}\}, \{\frac{1}{2}, 3\otimes 4\otimes -\frac{5}{6}\}, \{\frac{1}{2}, 8\otimes 1\otimes 0\}, \{\frac{1}{2}, 8\otimes 1\otimes 1\}, \{\frac{1}{2}, 8\otimes 2\otimes \frac{1}{2}\}, \{\frac{1}{2}, 8\otimes 3\otimes 0\}, \{0, 1\otimes 1\otimes 1\}, \{0, 1\otimes 1\otimes 2\}, \{0, 1\otimes 2\otimes \frac{1}{2}\}, \{0, 1\otimes 2\otimes \frac{3}{2}\}, \{0, 1\otimes 4\otimes \frac{1}{2}\}, \{0, 1\otimes 4\otimes \frac{3}{2}\}, \{0, 6\otimes 1\otimes -\frac{4}{3}\}, \{0, 6\otimes 1\otimes -\frac{1}{3}\}, \{0, 6\otimes 1\otimes \frac{2}{3}\}, \{0, 6\otimes 3\otimes -\frac{1}{3}\}, \{0, 3\otimes 1\otimes \frac{5}{3}\}, \{0, 3\otimes 3\otimes \frac{2}{3}\}, \{0, 3\otimes 3\otimes \frac{5}{3}\}, \{0, 8\otimes 2\otimes \frac{1}{2}\}, \{1, 1\otimes 1\otimes 0\}, \{1, 1\otimes 1\otimes 1\}, \{1, 1\otimes 2\otimes \frac{1}{2}\}, \{1, 1\otimes 2\otimes \frac{3}{2}\}, \{1, 1\otimes 3\otimes 0\}, \{1, 6\otimes 2\otimes -\frac{5}{6}\}, \{1, 6\otimes 2\otimes \frac{1}{6}\}, \{1, 3\otimes 1\otimes \frac{5}{3}\}, \{1, 3\otimes 2\otimes \frac{7}{6}\}, \{1, 3\otimes 4\otimes \frac{1}{6}\}, \{1, 3\otimes 4\otimes \frac{7}{6}\}, \{1, 8\otimes 1\otimes 0\}, \{1, 8\otimes 1\otimes 1\}, \{1, 8\otimes 3\otimes 0\}\}$
Dimension 10	$\{\{\frac{1}{2}, 1\otimes 3\otimes 2\}, \{\frac{1}{2}, 1\otimes 4\otimes \frac{3}{2}\}, \{\frac{1}{2}, 1\otimes 5\otimes 0\}, \{\frac{1}{2}, 1\otimes 5\otimes 1\}, \{\frac{1}{2}, 6\otimes 1\otimes \frac{5}{3}\}, \{\frac{1}{2}, 6\otimes 2\otimes \frac{7}{6}\}, \{\frac{1}{2}, 6\otimes 3\otimes \frac{2}{3}\}, \{\frac{1}{2}, 6\otimes 4\otimes \frac{1}{6}\}, \{\frac{1}{2}, 3\otimes 1\otimes -\frac{7}{3}\}, \{\frac{1}{2}, 3\otimes 2\otimes -\frac{11}{6}\}, \{\frac{1}{2}, 3\otimes 3\otimes \frac{5}{3}\}, \{\frac{1}{2}, 3\otimes 4\otimes \frac{7}{6}\}, \{\frac{1}{2}, 3\otimes 5\otimes -\frac{1}{3}\}, \{\frac{1}{2}, 3\otimes 5\otimes \frac{2}{3}\}, \{\frac{1}{2}, 8\otimes 1\otimes 2\}, \{\frac{1}{2}, 8\otimes 2\otimes \frac{3}{2}\}, \{\frac{1}{2}, 8\otimes 3\otimes 1\}, \{\frac{1}{2}, 8\otimes 4\otimes \frac{1}{2}\}, \{0, 1\otimes 2\otimes \frac{5}{2}\}, \{0, 1\otimes 5\otimes 0\}, \{0, 6\otimes 2\otimes -\frac{11}{6}\}, \{0, 6\otimes 2\otimes -\frac{5}{6}\}, \{0, 6\otimes 2\otimes \frac{1}{6}\}, \{0, 6\otimes 2\otimes \frac{7}{6}\}, \{0, 6\otimes 4\otimes -\frac{5}{6}\}, \{0, 6\otimes 4\otimes \frac{1}{6}\}, \{0, 3\otimes 1\otimes -\frac{7}{3}\}, \{0, 3\otimes 3\otimes -\frac{7}{3}\}, \{0, 3\otimes 3\otimes -\frac{4}{3}\}, \{0, 3\otimes 5\otimes -\frac{4}{3}\}, \{0, 3\otimes 5\otimes -\frac{1}{3}\}, \{0, 3\otimes 5\otimes \frac{2}{3}\}, \{0, 8\otimes 1\otimes 0\}, \{0, 8\otimes 1\otimes 1\}, \{0, 8\otimes 3\otimes 0\}, \{0, 8\otimes 3\otimes 1\}, \{1, 1\otimes 1\otimes 2\}, \{1, 1\otimes 3\otimes 1\}, \{1, 1\otimes 3\otimes 2\}, \{1, 1\otimes 4\otimes \frac{1}{2}\}, \{1, 6\otimes 1\otimes -\frac{4}{3}\}, \{1, 6\otimes 1\otimes -\frac{1}{3}\}, \{1, 6\otimes 1\otimes \frac{2}{3}\}, \{1, 6\otimes 3\otimes -\frac{4}{3}\}, \{1, 6\otimes 3\otimes -\frac{1}{3}\}, \{1, 6\otimes 3\otimes \frac{2}{3}\}, \{1, 3\otimes 2\otimes -\frac{11}{6}\}, \{1, 3\otimes 2\otimes \frac{13}{6}\}, \{1, 3\otimes 4\otimes -\frac{11}{6}\}, \{1, 3\otimes 4\otimes -\frac{5}{6}\}, \{1, 8\otimes 2\otimes \frac{1}{2}\}, \{1, 8\otimes 2\otimes \frac{3}{2}\}, \{1, 8\otimes 4\otimes \frac{1}{2}\}\}$
⋮	⋮

$$\{\underbrace{0}_{\text{Spin}}, \underbrace{3\otimes 1\otimes \frac{2}{3}}_{\text{SU3×SU2×U1}}\}$$

Conclusion:

- Baryon number violation is uniquely sensitive to heavy new physics, probing mass dimensions $\gg 6$.
- We found all UV completions for operators up to d=15 in terms of scalars, fermions and vectors including right-handed neutrinos.
- Previously, only incomplete results up to dimension 9.
- Useful for model building and in the event of a discovery in Super-Kamiokande, Hyper-Kamiokande, JUNO or DUNE.
- Our method can be easily applied to other operators, for example violating lepton number, only limiting factor is presentation of actual results due to a number of solutions.

Thank You For Your Attention!

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