Protecting baryon number violating operators

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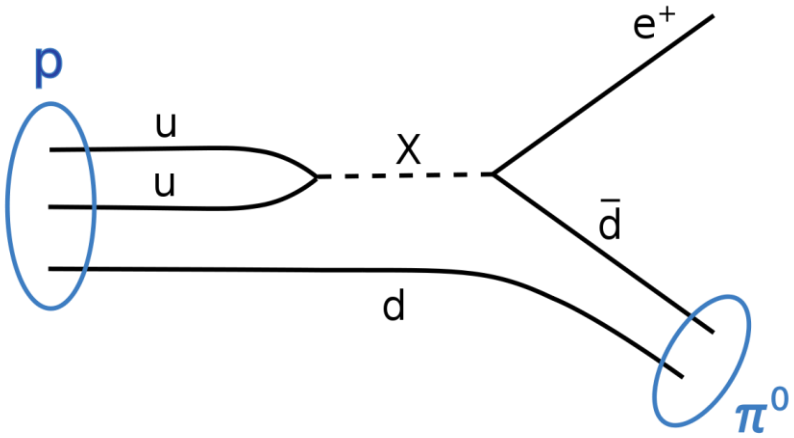
Collaborators: Julian Heeck

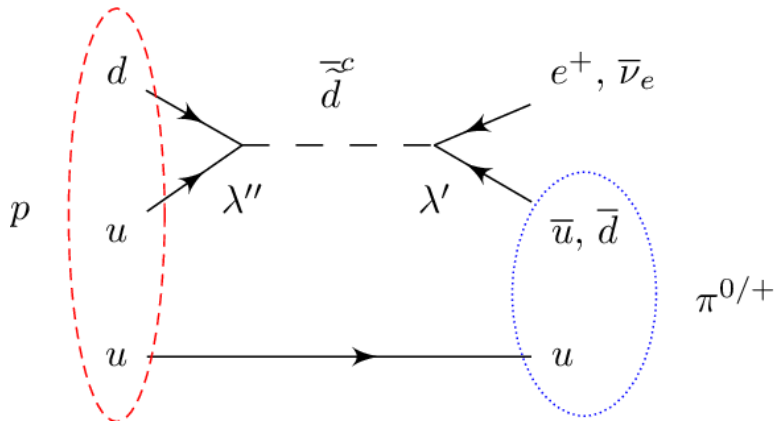
Why baryon number violation is important

Grand Unified Theories (GUTs)



- GUTs, which can unify the fundamental forces of nature, predict that the proton can decay into lighter particles.

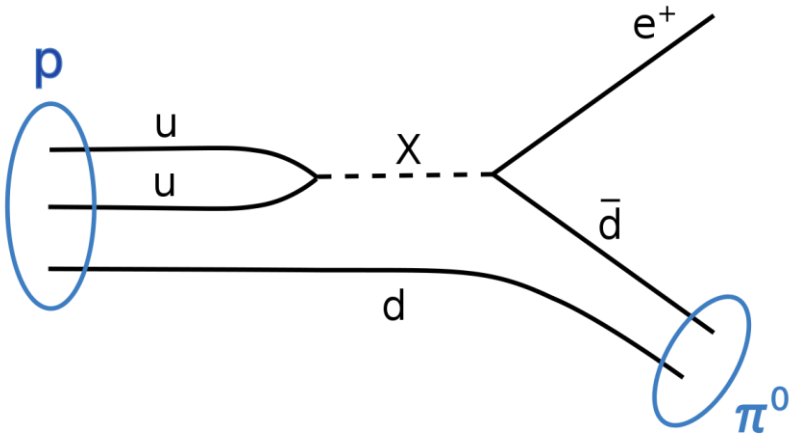
Supersymmetry (SUSY)



- SUSY doubles the number of particles compared to Standard Model and imposes symmetry among fermions and bosons. New particles can mediate the proton decay.

Why baryon number violation is important

Grand Unified Theories (GUTs)



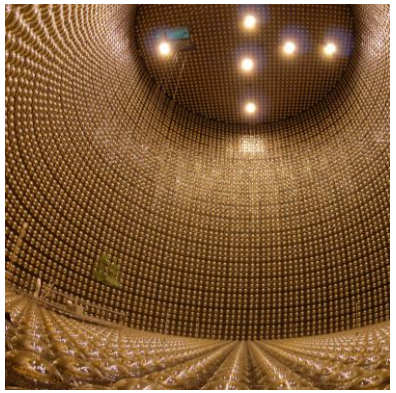
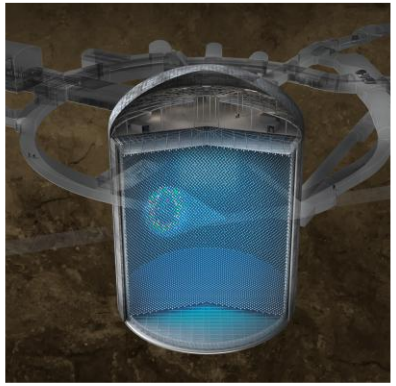
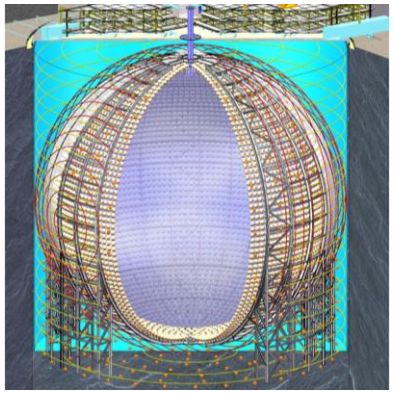
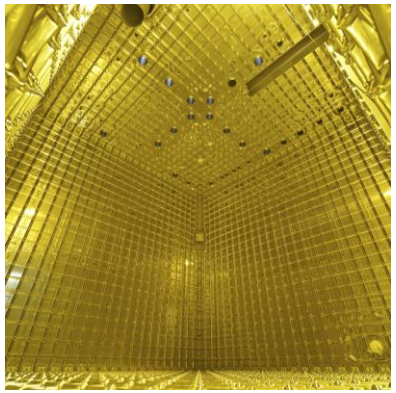
- GUTs, which can unify the fundamental forces of nature, predict that the proton can decay into lighter particles.

Example: proton decay

$$\tau_P \sim \frac{m_X^4}{m_p^5}$$

$$\Gamma(p \to e^+\pi^0) \sim \frac{1}{10^{34}\ yr}\left(\frac{10^{15} GeV}{m_X}\right)^4$$

Detectors

	Super-K	Hyper-K	JUNO	DUNE
				
Location	Kamioka, Japan	Kamioka, Japan	Guangdong, China	South Dakota, USA
Start	1996	2028	2025	2030
Type	Water Cherenkov	Water Cherenkov	Liquid Scintillator	Liquid Argon TPC
Fiducial Mass	~22.5 kton	~187 kton	~20 kton	4 × 17 kton (~70 kton)
Depth	~1000 m	~600 m	~700 m	~1.5 km
Baseline/ Source	Atmospheric / solar ν + J-PARC beam (295 km)	J-PARC beam (295 km) + atmospheric	53 km reactor ν	Fermilab beam (1300 km)
Key Sensitivity	Atmospheric & solar ν, proton decay	CP violation, oscillations, proton decay	Mass ordering (reactor ν)	CP violation, mass ordering

Standard Model Effective Field Theory

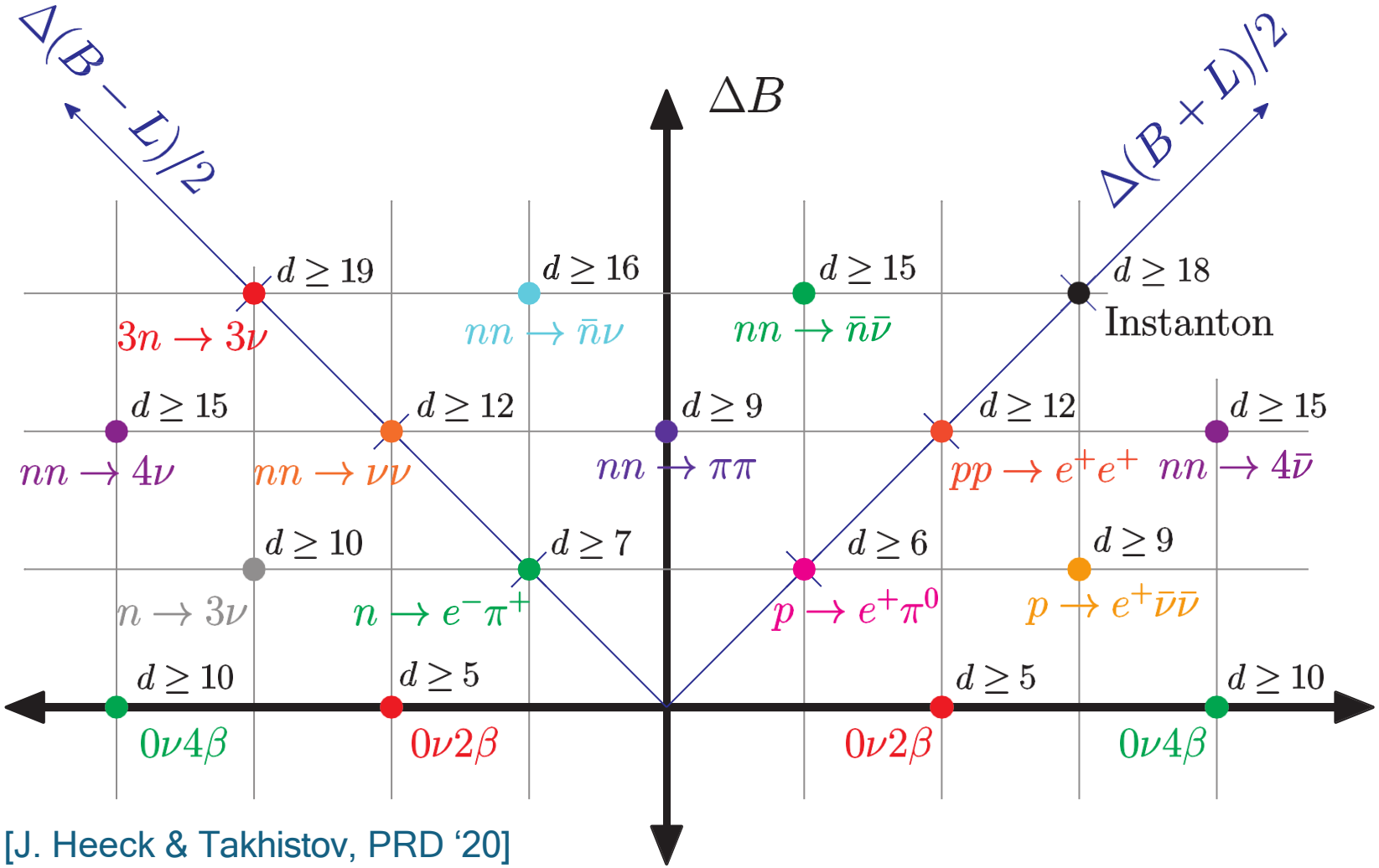
$$\mathcal{L} = \mathcal{L}_{SM} + \frac{LLHH}{\Lambda} + \sum_i \frac{\mathcal{O}_i}{\Lambda^2} + \sum_i \frac{\mathcal{O}_i'}{\Lambda^3} + \sum_i \frac{\mathcal{O}_i''}{\Lambda^4} + \sum_i \frac{\mathcal{O}_i'''}{\Lambda^5} + \sum_i \frac{\mathcal{O}_i''''}{\Lambda^6} \ldots$$

Dim 6	Dim 7	Dim 8	Dim 9	Dim 10
$\Delta B = \Delta L = 1$	$\Delta B = -\Delta L = 1$	$\Delta B = \Delta L = 1$	$\Delta B = 1, \Delta L = -1$ $\Delta B = 1, \Delta L = 3$ $\Delta B = 2, \Delta L = 0$	$\Delta B = 1, \Delta L = 1$ $\Delta B = 1, \Delta L = -3$

- Baryon and lepton number violation is sensitive for $d \gg 6$, unlike any other experiment.

[*Weinberg '79 & '80*]

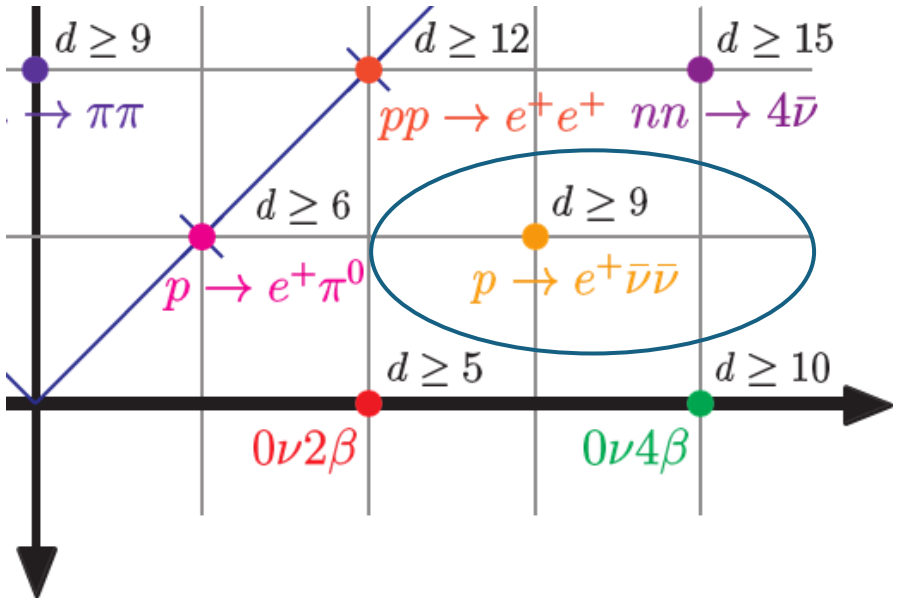
BNV landscape



[J. Heeck & Takhistov, PRD '20]

Weinberg's selection rule (Example)

Impose $U(1)_{3B-L}$ on SMEFT



Weinberg's selection rule (Example)

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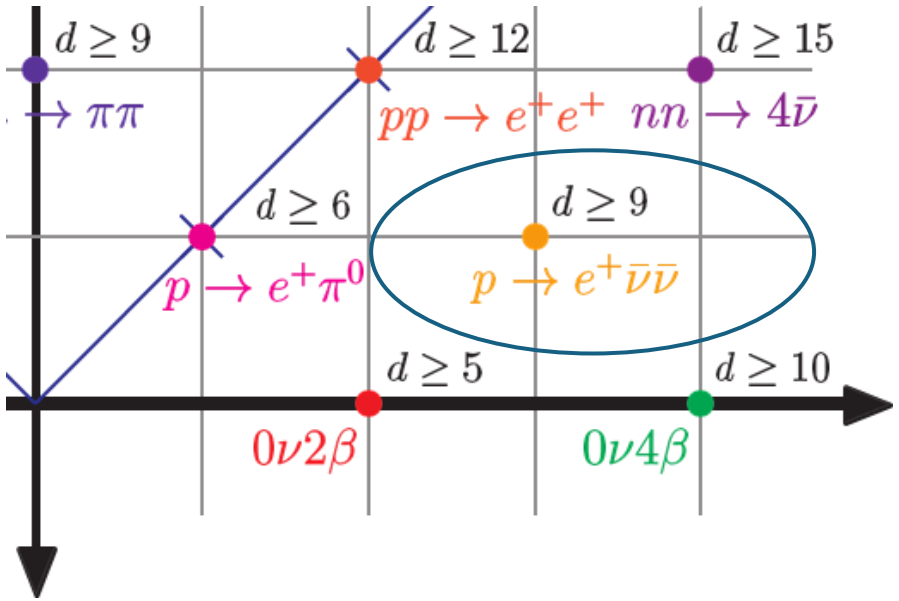
$(\Delta B, \Delta L) = (1, 3)$

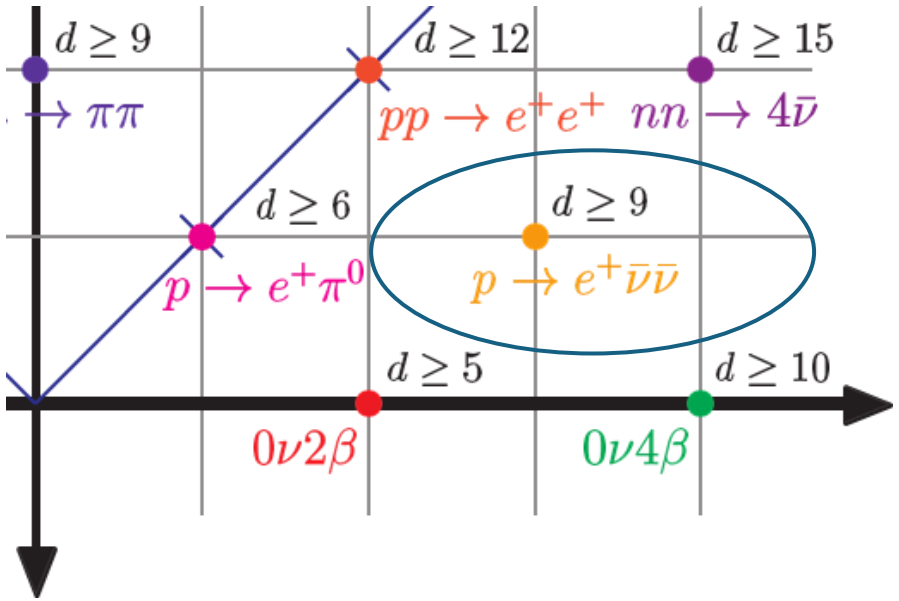


Weinberg's selection rule (Example)

Impose $U(1)_{3B-L}$ on SMEFT

$$(\Delta B, \Delta L) = (1, 3)$$

$$d_{min} \geq \underbrace{\frac{9}{2}|\Delta B| + \frac{3}{2}|\Delta L|}_{\text{[Kobach '16; Helset, Kobach, '19]}} + \underbrace{\delta_{sign(\Delta B \Delta L),-1}\delta_{|\Delta L \bmod 2|,1}}_{\text{[DS, Heeck, PLB '25, arXiv:2505.06172]}}$$



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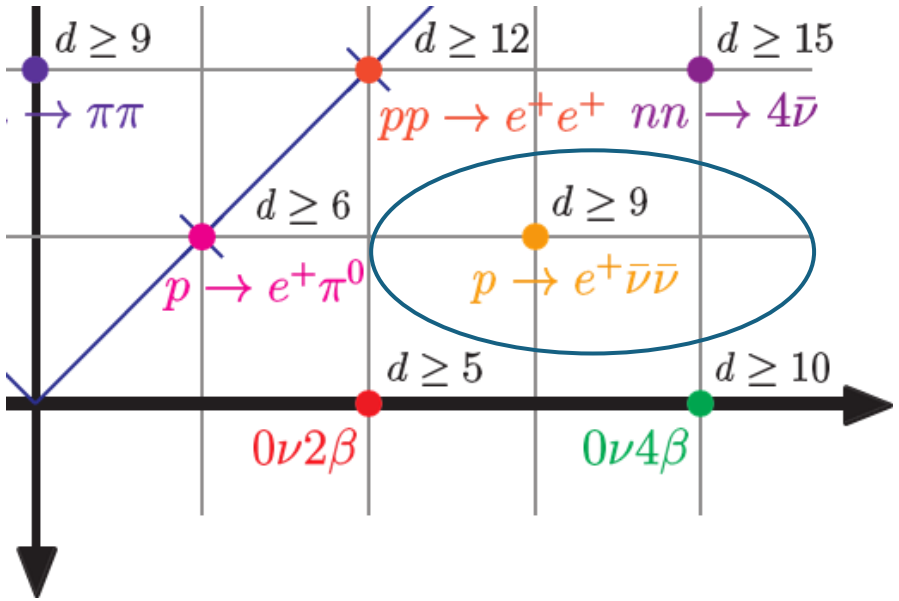
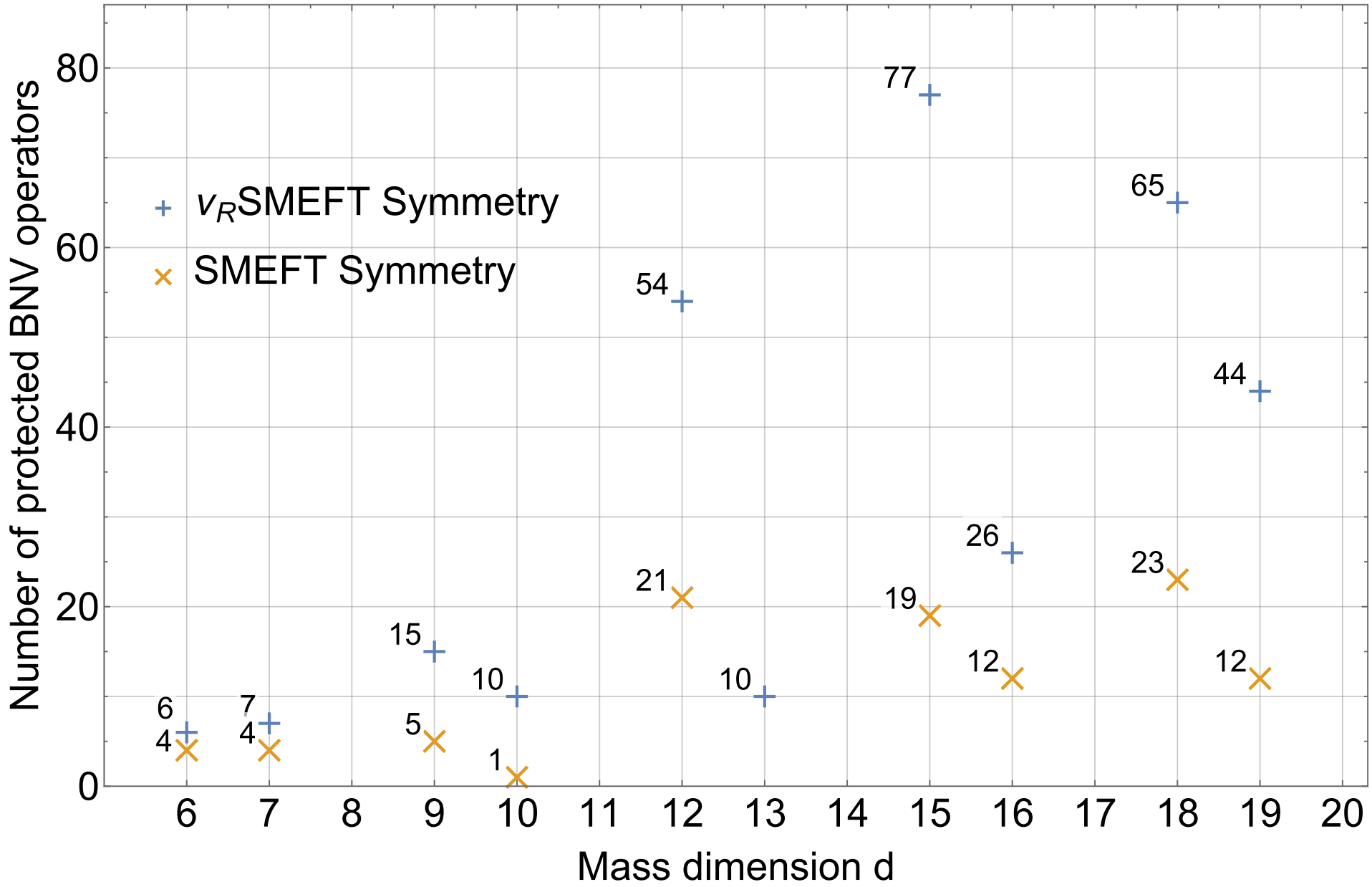
$$d_{min} \geq 9$$



$$\tau(p \to e^+\bar{\nu}\bar{\nu}) \simeq 10^{32}\ yr \left(\frac{\Lambda}{300\ TeV}\right)^{10}$$

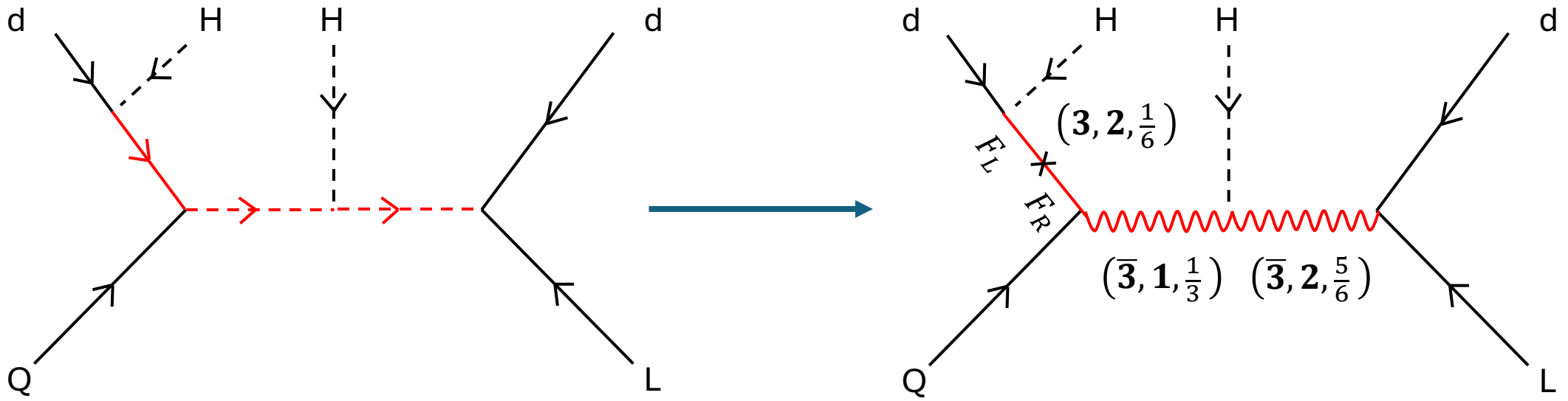
Symmetry protected operators



UV completions

$$\left(\mathbf{3}, \mathbf{1}, -\tfrac{1}{3}\right)$$

$SU(3) \times SU(2) \times U(1)$



$$F_{\left(\mathbf{3},\mathbf{2},\frac{1}{6}\right)} \quad V_{\left(\overline{\mathbf{3}},\mathbf{1},\frac{1}{3}\right)} \quad V_{\left(\overline{\mathbf{3}},\mathbf{2},\frac{5}{6}\right)}$$

GroupMath

https://renatofonseca.net/groupmath

Sym2Int

https://renatofonseca.net/sym2int

[Heeck, **DS**, Thapa, arXiv:2603.17050]

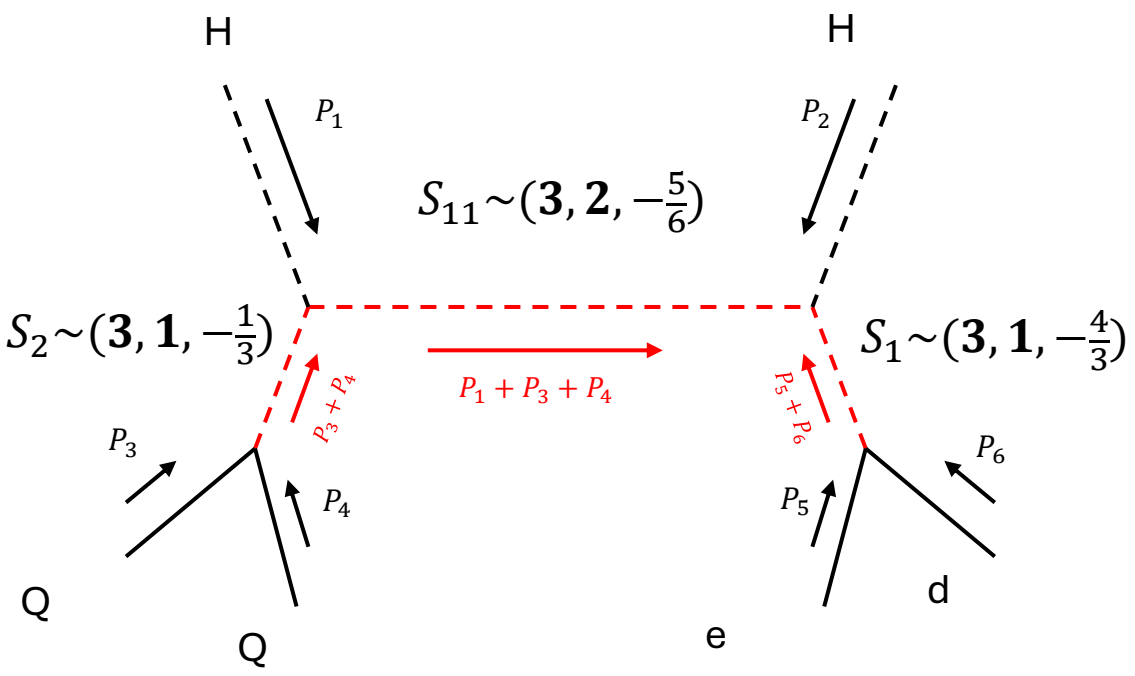
Derivative operators

- H↔H asymmetry

$$2 \otimes 2 = 1_A \oplus 3_S$$

$$\uparrow$$

$$\mathrm{H} \otimes \mathrm{H}$$



$$\longrightarrow \frac{1}{(P_1 + P_3 + P_4)^2 - m_{S_{11}}^2} \approx \boxed{-\frac{1}{m_{S_{11}}^2}} - \frac{(P_1 + P_3 + P_4)^2}{m_{S_{11}}^4} + \cdots$$

Vanishes due to H↔H

$\longrightarrow$ $edHD^2(HQQ)$, dim 10 operator

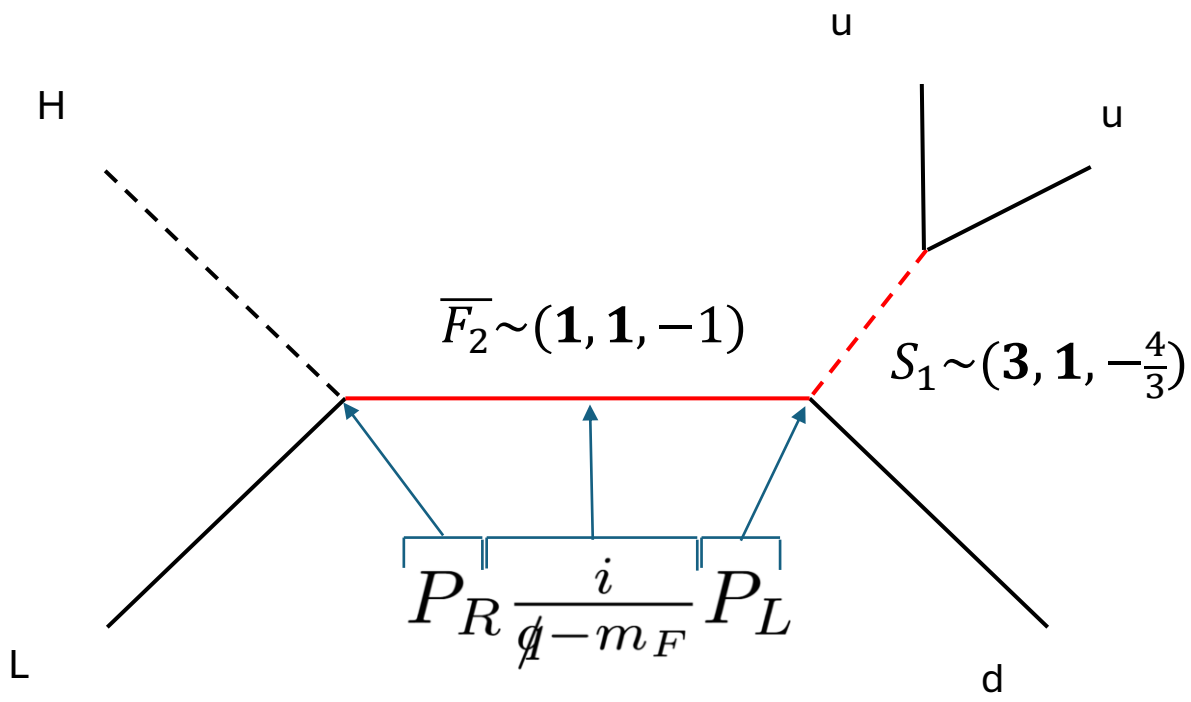
[Idea based on paper by J. Gargalionis, R. Volkas. 2009.13537]

Derivative operators

- Chirality protected operators

dim 8 operators:

$$DuudL\overline{H}, DuuQe\overline{H}, DudQ\nu\overline{H},$$
$$DuQQL\overline{H}, DQQQ\nu\overline{H}, \ldots$$



$$\longrightarrow \quad P_R \frac{(\not{q} + m_F)}{\not{q}^2 - m_F^2} P_L \simeq -\frac{1}{m_F} \underbrace{P_R P_L}_{=0} - \frac{\not{q}}{m_F^2} P_L + \mathcal{O}\left(\frac{1}{m_F^4}\right)$$

$$\rightsquigarrow \quad \frac{uud\not{D}(LH^*)}{m_F^2 m_s^2} \sim \frac{uud\not{D}(LH^*)}{\Lambda^4} \quad , \text{ dim 8 Operator}$$

New particles

Dimension 6	$S_{3\otimes1\otimes-\frac{4}{3}}$, $S_{3\otimes1\otimes-\frac{1}{3}}$, $S_{3\otimes1\otimes\frac{2}{3}}$, $S_{3\otimes3\otimes-\frac{1}{3}}$, $V_{3\otimes2\otimes-\frac{5}{6}}$, $V_{3\otimes2\otimes\frac{1}{6}}$
Dimension 7	$S_{3\otimes2\otimes\frac{1}{6}}$, $S_{3\otimes2\otimes\frac{7}{6}}$, $V_{3\otimes1\otimes-\frac{1}{3}}$, $V_{3\otimes1\otimes\frac{2}{3}}$, $V_{3\otimes3\otimes\frac{2}{3}}$, $F_{1\otimes1\otimes0}$, $F_{1\otimes1\otimes1}$, $F_{1\otimes2\otimes\frac{1}{2}}$, $F_{1\otimes3\otimes0}$, $F_{3\otimes1\otimes-\frac{1}{3}}$, $F_{3\otimes1\otimes\frac{2}{3}}$, $F_{3\otimes2\otimes-\frac{5}{6}}$, $F_{3\otimes2\otimes\frac{1}{6}}$, $F_{3\otimes3\otimes-\frac{1}{3}}$
Dimension 8	$S_{1\otimes1\otimes0}$, $S_{1\otimes3\otimes0}$, $S_{1\otimes3\otimes1}$, $S_{3\otimes2\otimes-\frac{11}{6}}$, $S_{3\otimes2\otimes-\frac{5}{6}}$, $S_{3\otimes4\otimes-\frac{5}{6}}$, $S_{3\otimes4\otimes\frac{1}{6}}$, $V_{3\otimes1\otimes-\frac{4}{3}}$, $V_{3\otimes3\otimes-\frac{4}{3}}$, $V_{3\otimes3\otimes-\frac{1}{3}}$, $F_{1\otimes2\otimes\frac{3}{2}}$, $F_{1\otimes3\otimes1}$, $F_{1\otimes4\otimes\frac{1}{2}}$, $F_{3\otimes2\otimes\frac{7}{6}}$, $F_{3\otimes3\otimes\frac{2}{3}}$, $F_{3\otimes4\otimes\frac{1}{6}}$
Dimension 9	$S_{1\otimes1\otimes1}$, $S_{1\otimes1\otimes2}$, $S_{1\otimes2\otimes\frac{1}{2}}$, $S_{6\otimes1\otimes-\frac{4}{3}}$, $S_{6\otimes1\otimes-\frac{1}{3}}$, $S_{6\otimes1\otimes\frac{2}{3}}$, $S_{6\otimes3\otimes-\frac{1}{3}}$, $S_{8\otimes2\otimes\frac{1}{2}}$, $S_{1\otimes2\otimes\frac{3}{2}}$, $S_{1\otimes4\otimes\frac{1}{2}}$, $S_{1\otimes4\otimes\frac{3}{2}}$, $S_{3\otimes1\otimes\frac{5}{3}}$, $S_{3\otimes3\otimes\frac{2}{3}}$, $S_{3\otimes3\otimes\frac{5}{3}}$, $V_{1\otimes1\otimes0}$, $V_{1\otimes1\otimes1}$, $V_{1\otimes2\otimes\frac{1}{2}}$, $V_{1\otimes2\otimes\frac{3}{2}}$, $V_{1\otimes3\otimes0}$, $V_{6\otimes2\otimes-\frac{5}{6}}$, $V_{6\otimes2\otimes\frac{1}{6}}$, $V_{3\otimes1\otimes\frac{5}{3}}$, $V_{8\otimes1\otimes0}$, $V_{8\otimes1\otimes1}$, $V_{8\otimes3\otimes0}$, $V_{3\otimes2\otimes\frac{7}{6}}$, $V_{3\otimes4\otimes\frac{1}{6}}$, $V_{3\otimes4\otimes\frac{7}{6}}$, $F_{6\otimes1\otimes-\frac{4}{3}}$, $F_{6\otimes1\otimes-\frac{1}{3}}$, $F_{6\otimes1\otimes\frac{2}{3}}$, $F_{6\otimes2\otimes-\frac{5}{6}}$, $F_{6\otimes2\otimes\frac{1}{6}}$, $F_{6\otimes3\otimes-\frac{1}{3}}$, $F_{3\otimes1\otimes-\frac{4}{3}}$, $F_{3\otimes1\otimes\frac{5}{3}}$, $F_{8\otimes1\otimes0}$, $F_{8\otimes1\otimes1}$, $F_{8\otimes2\otimes\frac{1}{2}}$, $F_{8\otimes3\otimes0}$, $F_{3\otimes3\otimes-\frac{4}{3}}$, $F_{3\otimes4\otimes-\frac{5}{6}}$, $F_{1\otimes1\otimes2}$
Dimension 10	$S_{1\otimes2\otimes\frac{5}{2}}$, $S_{6\otimes2\otimes-\frac{11}{6}}$, $S_{6\otimes2\otimes-\frac{5}{6}}$, $S_{6\otimes2\otimes\frac{1}{6}}$, $S_{6\otimes2\otimes\frac{7}{6}}$, $S_{6\otimes4\otimes-\frac{5}{6}}$, $S_{6\otimes4\otimes\frac{1}{6}}$, $S_{8\otimes1\otimes0}$, $S_{8\otimes1\otimes1}$, $S_{8\otimes3\otimes0}$, $S_{8\otimes3\otimes1}$, $S_{1\otimes5\otimes0}$, $S_{3\otimes1\otimes-\frac{7}{3}}$, $S_{3\otimes3\otimes-\frac{7}{3}}$, $S_{3\otimes3\otimes-\frac{4}{3}}$, $S_{3\otimes5\otimes-\frac{4}{3}}$, $S_{3\otimes5\otimes-\frac{1}{3}}$, $S_{3\otimes5\otimes\frac{2}{3}}$, $V_{1\otimes1\otimes2}$, $V_{1\otimes3\otimes1}$, $V_{1\otimes3\otimes2}$, $V_{1\otimes4\otimes\frac{1}{2}}$, $V_{6\otimes1\otimes-\frac{4}{3}}$, $V_{6\otimes1\otimes-\frac{1}{3}}$, $V_{6\otimes1\otimes\frac{2}{3}}$, $V_{6\otimes3\otimes-\frac{4}{3}}$, $V_{6\otimes3\otimes-\frac{1}{3}}$, $V_{6\otimes3\otimes\frac{2}{3}}$, $V_{3\otimes2\otimes\frac{13}{6}}$, $V_{8\otimes2\otimes\frac{1}{2}}$, $V_{8\otimes2\otimes\frac{3}{2}}$, $V_{8\otimes4\otimes\frac{1}{2}}$, $V_{3\otimes2\otimes-\frac{11}{6}}$, $V_{3\otimes4\otimes-\frac{11}{6}}$, $V_{3\otimes4\otimes-\frac{5}{6}}$, $F_{6\otimes1\otimes\frac{5}{3}}$, $F_{6\otimes2\otimes\frac{7}{6}}$, $F_{6\otimes3\otimes\frac{2}{3}}$, $F_{6\otimes4\otimes\frac{1}{6}}$, $F_{3\otimes1\otimes-\frac{7}{3}}$, $F_{3\otimes2\otimes-\frac{11}{6}}$, $F_{8\otimes1\otimes2}$, $F_{8\otimes2\otimes\frac{3}{2}}$, $F_{8\otimes3\otimes1}$, $F_{8\otimes4\otimes\frac{1}{2}}$, $F_{1\otimes3\otimes2}$, $F_{1\otimes4\otimes\frac{3}{2}}$, $F_{1\otimes5\otimes0}$, $F_{1\otimes5\otimes1}$, $F_{3\otimes3\otimes\frac{5}{3}}$, $F_{3\otimes4\otimes\frac{7}{6}}$, $F_{3\otimes5\otimes-\frac{1}{3}}$, $F_{3\otimes5\otimes\frac{2}{3}}$

Fully explored in literature
[*2306.12578, 1711.10391 ...*]

Incomplete results in literature
[*2306.12578, 2307.10380 ...*]

Incomplete results in literature
[*2306.12578 ...*]

Fraction of results in literature
[*1210.6598, 9307254 ...*]

[Heeck, **DS**, Thapa, arXiv:2603.17050]

New particles

Dim 11	$S_{6\otimes1\otimes\frac{5}{3}}$, $S_{6\otimes3\otimes\frac{2}{3}}$, $S_{6\otimes3\otimes\frac{5}{3}}$, $S_{6\otimes5\otimes\frac{2}{3}}$, $S_{8\otimes2\otimes\frac{3}{2}}$, $S_{8\otimes4\otimes\frac{1}{2}}$, $S_{8\otimes4\otimes\frac{3}{2}}$, $S_{1\otimes3\otimes2}$, $S_{1\otimes5\otimes1}$, $S_{1\otimes5\otimes2}$, $S_{3\otimes2\otimes\frac{13}{6}}$, $S_{3\otimes4\otimes\frac{7}{6}}$, $S_{3\otimes4\otimes\frac{13}{6}}$, $V_{1\otimes5\otimes1}$, $V_{6\otimes2\otimes\frac{7}{6}}$, $V_{6\otimes4\otimes\frac{1}{6}}$, $V_{6\otimes4\otimes\frac{7}{6}}$, $V_{3\otimes5\otimes-\frac{1}{3}}$, $V_{8\otimes1\otimes2}$, $V_{8\otimes3\otimes1}$, $V_{8\otimes3\otimes2}$, $V_{8\otimes5\otimes1}$, $V_{3\otimes3\otimes\frac{5}{3}}$, $V_{3\otimes5\otimes\frac{2}{3}}$, $V_{3\otimes5\otimes\frac{5}{3}}$, $F_{6\otimes2\otimes-\frac{11}{6}}$, $F_{6\otimes3\otimes-\frac{4}{3}}$, $F_{6\otimes4\otimes-\frac{5}{6}}$, $F_{6\otimes5\otimes-\frac{1}{3}}$, $F_{3\otimes2\otimes\frac{13}{6}}$, $F_{8\otimes5\otimes0}$, $F_{3\otimes4\otimes-\frac{11}{6}}$, $F_{3\otimes5\otimes-\frac{4}{3}}$, $F_{1\otimes2\otimes\frac{5}{2}}$
Dim 12	$S_{6\otimes1\otimes\frac{8}{3}}$, $S_{3\otimes1\otimes-\frac{10}{3}}$, $S_{3\otimes1\otimes\frac{8}{3}}$, $S_{8\otimes1\otimes2}$, $S_{8\otimes2\otimes\frac{5}{2}}$, $S_{8\otimes5\otimes0}$, $S_{15\otimes1\otimes-\frac{4}{3}}$, $S_{15\otimes1\otimes-\frac{1}{3}}$, $S_{15\otimes1\otimes\frac{2}{3}}$, $S_{15\otimes1\otimes\frac{5}{3}}$, $S_{15\otimes1\otimes\frac{8}{3}}$, $S_{15\otimes2\otimes-\frac{11}{6}}$, $S_{15\otimes2\otimes-\frac{5}{6}}$, $S_{15\otimes2\otimes\frac{1}{6}}$, $S_{15\otimes2\otimes\frac{7}{6}}$, $S_{15\otimes3\otimes-\frac{1}{3}}$, $S_{15\otimes3\otimes\frac{2}{3}}$, $S_{15\otimes3\otimes\frac{5}{3}}$, $S_{15\otimes4\otimes-\frac{5}{6}}$, $S_{15\otimes4\otimes\frac{1}{6}}$, $S_{15\otimes5\otimes\frac{2}{3}}$, $S_{10\otimes1\otimes-2}$, $S_{10\otimes1\otimes-1}$, $S_{10\otimes1\otimes0}$, $S_{10\otimes1\otimes1}$, $S_{10\otimes1\otimes2}$, $S_{10\otimes3\otimes-1}$, $S_{10\otimes3\otimes0}$, $S_{10\otimes3\otimes1}$, $S_{10\otimes5\otimes0}$, $S_{1\otimes1\otimes3}$, $S_{1\otimes3\otimes3}$, $S_{6\otimes1\otimes-\frac{7}{3}}$, $S_{6\otimes3\otimes-\frac{7}{3}}$, $S_{6\otimes3\otimes-\frac{4}{3}}$, $S_{6\otimes5\otimes-\frac{4}{3}}$, $S_{6\otimes5\otimes-\frac{1}{3}}$, $S_{1\otimes6\otimes\frac{1}{2}}$, $S_{3\otimes2\otimes-\frac{17}{6}}$, $S_{3\otimes4\otimes-\frac{17}{6}}$, $S_{3\otimes4\otimes-\frac{11}{6}}$, $S_{3\otimes6\otimes-\frac{11}{6}}$, $S_{3\otimes6\otimes-\frac{5}{6}}$, $S_{3\otimes6\otimes\frac{1}{6}}$, $S_{3\otimes6\otimes\frac{7}{6}}$, $V_{1\otimes1\otimes3}$, $V_{6\otimes1\otimes-\frac{7}{3}}$, $V_{6\otimes1\otimes\frac{5}{3}}$, $V_{6\otimes2\otimes\frac{13}{6}}$, $V_{6\otimes5\otimes-\frac{1}{3}}$, $V_{3\otimes1\otimes-\frac{7}{3}}$, $V_{3\otimes2\otimes-\frac{17}{6}}$, $V_{8\otimes1\otimes3}$, $V_{15\otimes1\otimes-\frac{7}{3}}$, $V_{15\otimes1\otimes-\frac{4}{3}}$, $V_{15\otimes1\otimes-\frac{1}{3}}$, $V_{15\otimes1\otimes\frac{2}{3}}$, $V_{15\otimes1\otimes\frac{5}{3}}$, $V_{15\otimes2\otimes-\frac{5}{6}}$, $V_{15\otimes2\otimes\frac{1}{6}}$, $V_{15\otimes2\otimes\frac{7}{6}}$, $V_{15\otimes2\otimes\frac{13}{6}}$, $V_{15\otimes3\otimes-\frac{4}{3}}$, $V_{15\otimes3\otimes-\frac{1}{3}}$, $V_{15\otimes3\otimes\frac{2}{3}}$, $V_{15\otimes4\otimes\frac{1}{6}}$, $V_{15\otimes4\otimes\frac{7}{6}}$, $V_{15\otimes5\otimes-\frac{1}{3}}$, $V_{10\otimes2\otimes-\frac{3}{2}}$, $V_{10\otimes2\otimes-\frac{1}{2}}$, $V_{10\otimes2\otimes\frac{1}{2}}$, $V_{10\otimes2\otimes\frac{3}{2}}$, $V_{10\otimes4\otimes-\frac{1}{2}}$, $V_{10\otimes4\otimes\frac{1}{2}}$, $V_{1\otimes2\otimes\frac{5}{2}}$, $V_{1\otimes4\otimes\frac{3}{2}}$, $V_{1\otimes4\otimes\frac{5}{2}}$, $V_{1\otimes5\otimes0}$, $V_{6\otimes2\otimes-\frac{11}{6}}$, $V_{6\otimes4\otimes-\frac{11}{6}}$, $V_{6\otimes4\otimes-\frac{5}{6}}$, $V_{3\otimes1\otimes\frac{8}{3}}$, $V_{3\otimes3\otimes\frac{8}{3}}$, $V_{8\otimes5\otimes0}$, $V_{3\otimes3\otimes-\frac{7}{3}}$, $V_{3\otimes5\otimes-\frac{7}{3}}$, $V_{3\otimes5\otimes-\frac{4}{3}}$, $F_{1\otimes1\otimes3}$, $F_{6\otimes1\otimes-\frac{7}{3}}$, $F_{3\otimes1\otimes\frac{8}{3}}$, $F_{15\otimes1\otimes-\frac{4}{3}}$, $F_{15\otimes1\otimes-\frac{1}{3}}$, $F_{15\otimes1\otimes\frac{2}{3}}$, $F_{15\otimes1\otimes\frac{5}{3}}$, $F_{15\otimes2\otimes-\frac{5}{6}}$, $F_{15\otimes2\otimes\frac{1}{6}}$, $F_{15\otimes2\otimes\frac{7}{6}}$, $F_{15\otimes3\otimes-\frac{1}{3}}$, $F_{15\otimes3\otimes\frac{2}{3}}$, $F_{15\otimes4\otimes\frac{1}{6}}$, $F_{10\otimes1\otimes-1}$, $F_{10\otimes1\otimes0}$, $F_{10\otimes1\otimes1}$, $F_{10\otimes1\otimes2}$, $F_{10\otimes2\otimes-\frac{1}{2}}$, $F_{10\otimes2\otimes\frac{1}{2}}$, $F_{10\otimes2\otimes\frac{3}{2}}$, $F_{10\otimes3\otimes0}$, $F_{10\otimes3\otimes1}$, $F_{10\otimes4\otimes\frac{1}{2}}$, $F_{6\otimes2\otimes\frac{13}{6}}$, $F_{6\otimes3\otimes\frac{5}{3}}$, $F_{6\otimes4\otimes\frac{7}{6}}$, $F_{6\otimes5\otimes\frac{2}{3}}$, $F_{3\otimes2\otimes-\frac{17}{6}}$, $F_{3\otimes3\otimes-\frac{7}{3}}$, $F_{8\otimes2\otimes\frac{5}{2}}$, $F_{8\otimes3\otimes2}$, $F_{8\otimes4\otimes\frac{3}{2}}$, $F_{8\otimes5\otimes1}$, $F_{1\otimes4\otimes\frac{5}{2}}$, $F_{1\otimes5\otimes2}$, $F_{1\otimes6\otimes\frac{1}{2}}$, $F_{1\otimes6\otimes\frac{3}{2}}$, $F_{3\otimes4\otimes\frac{13}{6}}$, $F_{3\otimes5\otimes\frac{5}{3}}$, $F_{3\otimes6\otimes-\frac{5}{6}}$, $F_{3\otimes6\otimes\frac{1}{6}}$, $F_{3\otimes6\otimes\frac{7}{6}}$
Dim 13	$S_{3\otimes2\otimes\frac{19}{6}}$, $S_{10\otimes2\otimes-\frac{1}{2}}$, $S_{10\otimes2\otimes\frac{1}{2}}$, $S_{10\otimes2\otimes\frac{3}{2}}$, $S_{10\otimes2\otimes\frac{5}{2}}$, $S_{10\otimes4\otimes\frac{1}{2}}$, $S_{10\otimes4\otimes\frac{3}{2}}$, $S_{6\otimes2\otimes\frac{13}{6}}$, $S_{6\otimes4\otimes\frac{7}{6}}$, $S_{6\otimes4\otimes\frac{13}{6}}$, $S_{6\otimes6\otimes\frac{1}{6}}$, $S_{6\otimes6\otimes\frac{7}{6}}$, $S_{8\otimes3\otimes2}$, $S_{8\otimes5\otimes1}$, $S_{8\otimes5\otimes2}$, $S_{1\otimes4\otimes\frac{5}{2}}$, $S_{1\otimes6\otimes\frac{3}{2}}$, $S_{1\otimes6\otimes\frac{5}{2}}$, $S_{3\otimes3\otimes\frac{8}{3}}$, $S_{3\otimes5\otimes\frac{5}{3}}$, $S_{3\otimes5\otimes\frac{8}{3}}$, $V_{6\otimes2\otimes-\frac{17}{6}}$, $V_{10\otimes1\otimes-1}$, $V_{10\otimes1\otimes0}$, $V_{10\otimes1\otimes1}$, $V_{10\otimes1\otimes2}$, $V_{10\otimes3\otimes0}$, $V_{10\otimes3\otimes1}$, $V_{10\otimes3\otimes2}$, $V_{10\otimes5\otimes1}$, $V_{1\otimes6\otimes\frac{1}{2}}$, $V_{1\otimes6\otimes\frac{3}{2}}$, $V_{6\otimes3\otimes\frac{5}{3}}$, $V_{6\otimes5\otimes\frac{2}{3}}$, $V_{6\otimes5\otimes\frac{5}{3}}$, $V_{3\otimes6\otimes-\frac{5}{6}}$, $V_{3\otimes6\otimes\frac{1}{6}}$, $V_{8\otimes2\otimes\frac{5}{2}}$, $V_{8\otimes4\otimes\frac{3}{2}}$, $V_{8\otimes4\otimes\frac{5}{2}}$, $V_{8\otimes6\otimes\frac{1}{2}}$, $V_{8\otimes6\otimes\frac{3}{2}}$, $V_{3\otimes4\otimes\frac{13}{6}}$, $V_{3\otimes6\otimes\frac{7}{6}}$, $V_{3\otimes6\otimes\frac{13}{6}}$, $V_{1\otimes2\otimes\frac{7}{2}}$, $F_{15\otimes2\otimes-\frac{11}{6}}$, $F_{15\otimes2\otimes\frac{13}{6}}$, $F_{15\otimes3\otimes-\frac{4}{3}}$, $F_{15\otimes3\otimes\frac{5}{3}}$, $F_{15\otimes4\otimes-\frac{5}{6}}$, $F_{15\otimes4\otimes\frac{7}{6}}$, $F_{15\otimes5\otimes-\frac{1}{3}}$, $F_{15\otimes5\otimes\frac{2}{3}}$, $F_{10\otimes2\otimes-\frac{3}{2}}$, $F_{10\otimes3\otimes-1}$, $F_{10\otimes4\otimes-\frac{1}{2}}$, $F_{10\otimes5\otimes0}$, $F_{6\otimes3\otimes-\frac{7}{3}}$, $F_{6\otimes4\otimes-\frac{11}{6}}$, $F_{6\otimes5\otimes-\frac{4}{3}}$, $F_{6\otimes6\otimes-\frac{5}{6}}$, $F_{6\otimes6\otimes\frac{1}{6}}$, $F_{3\otimes3\otimes\frac{8}{3}}$, $F_{8\otimes6\otimes\frac{1}{2}}$, $F_{3\otimes5\otimes-\frac{7}{3}}$, $F_{3\otimes6\otimes-\frac{11}{6}}$, $F_{1\otimes3\otimes3}$
Dim 14	$S_{1\otimes2\otimes\frac{7}{2}}$, $S_{1\otimes4\otimes\frac{5}{2}}$, $S_{1\otimes4\otimes\frac{7}{2}}$, $S_{1\otimes6\otimes\frac{3}{2}}$, $S_{1\otimes6\otimes\frac{5}{2}}$, $S_{1\otimes7\otimes0}$, $S_{1\otimes7\otimes1}$, $S_{6\otimes2\otimes-\frac{17}{6}}$, $S_{6\otimes2\otimes\frac{13}{6}}$, $S_{6\otimes2\otimes\frac{19}{6}}$, $S_{6\otimes4\otimes-\frac{17}{6}}$, $S_{6\otimes4\otimes-\frac{11}{6}}$, $S_{6\otimes4\otimes\frac{7}{6}}$, $S_{6\otimes4\otimes\frac{13}{6}}$, $S_{6\otimes6\otimes-\frac{11}{6}}$, $S_{6\otimes6\otimes-\frac{5}{6}}$, $S_{6\otimes6\otimes\frac{1}{6}}$, $S_{6\otimes6\otimes\frac{7}{6}}$, $S_{3\otimes2\otimes-\frac{23}{6}}$, $S_{3\otimes2\otimes\frac{19}{6}}$, $S_{3\otimes3\otimes-\frac{10}{3}}$, $S_{3\otimes3\otimes\frac{8}{3}}$, $S_{3\otimes5\otimes-\frac{10}{3}}$, $S_{3\otimes5\otimes-\frac{7}{3}}$, $S_{3\otimes5\otimes\frac{5}{3}}$, $S_{3\otimes5\otimes\frac{8}{3}}$, $S_{3\otimes7\otimes-\frac{7}{3}}$, $S_{3\otimes7\otimes-\frac{4}{3}}$, $S_{3\otimes7\otimes-\frac{1}{3}}$, $S_{3\otimes7\otimes\frac{2}{3}}$, $S_{3\otimes7\otimes\frac{5}{3}}$, $S_{8\otimes1\otimes3}$, $S_{8\otimes3\otimes2}$, $S_{8\otimes3\otimes3}$, $S_{8\otimes5\otimes1}$, $S_{8\otimes5\otimes2}$, $S_{8\otimes6\otimes\frac{1}{2}}$, $S_{15\otimes1\otimes-\frac{7}{3}}$, $S_{15\otimes2\otimes\frac{13}{6}}$, $S_{15\otimes2\otimes\frac{19}{6}}$, $S_{15\otimes3\otimes-\frac{7}{3}}$, $S_{15\otimes3\otimes-\frac{4}{3}}$, $S_{15\otimes4\otimes\frac{7}{6}}$, $S_{15\otimes4\otimes\frac{13}{6}}$, $S_{15\otimes5\otimes-\frac{4}{3}}$, $S_{15\otimes5\otimes-\frac{1}{3}}$, $S_{15\otimes6\otimes\frac{1}{6}}$, $S_{15\otimes6\otimes\frac{7}{6}}$, $S_{10\otimes2\otimes-\frac{5}{2}}$, $S_{10\otimes2\otimes-\frac{3}{2}}$, $S_{10\otimes2\otimes-\frac{1}{2}}$, $S_{10\otimes2\otimes\frac{1}{2}}$, $S_{10\otimes2\otimes\frac{3}{2}}$, $S_{10\otimes2\otimes\frac{5}{2}}$, $S_{10\otimes4\otimes-\frac{3}{2}}$, $S_{10\otimes4\otimes-\frac{1}{2}}$, $S_{10\otimes4\otimes\frac{1}{2}}$, $S_{10\otimes4\otimes\frac{3}{2}}$, $S_{10\otimes6\otimes-\frac{1}{2}}$, $S_{10\otimes6\otimes\frac{1}{2}}$, $V_{1\otimes2\otimes\frac{7}{2}}$, $V_{1\otimes3\otimes3}$, $V_{1\otimes5\otimes2}$, $V_{1\otimes5\otimes3}$, $V_{1\otimes6\otimes\frac{1}{2}}$, $V_{1\otimes6\otimes\frac{3}{2}}$, $V_{6\otimes1\otimes\frac{8}{3}}$, $V_{6\otimes2\otimes-\frac{17}{6}}$, $V_{6\otimes3\otimes-\frac{7}{3}}$, $V_{6\otimes3\otimes\frac{5}{3}}$, $V_{6\otimes3\otimes\frac{8}{3}}$, $V_{6\otimes5\otimes-\frac{7}{3}}$, $V_{6\otimes5\otimes-\frac{4}{3}}$, $V_{6\otimes5\otimes\frac{2}{3}}$, $V_{6\otimes5\otimes\frac{5}{3}}$, $V_{6\otimes6\otimes-\frac{5}{6}}$, $V_{6\otimes6\otimes\frac{1}{6}}$, $V_{3\otimes1\otimes-\frac{10}{3}}$, $V_{3\otimes2\otimes\frac{19}{6}}$, $V_{3\otimes3\otimes-\frac{10}{3}}$, $V_{3\otimes4\otimes-\frac{17}{6}}$, $V_{3\otimes4\otimes\frac{13}{6}}$, $V_{3\otimes4\otimes\frac{19}{6}}$, $V_{3\otimes6\otimes-\frac{17}{6}}$, $V_{3\otimes6\otimes-\frac{11}{6}}$, $V_{3\otimes6\otimes-\frac{5}{6}}$, $V_{3\otimes6\otimes\frac{1}{6}}$, $V_{3\otimes6\otimes\frac{7}{6}}$, $V_{3\otimes6\otimes\frac{13}{6}}$, $V_{8\otimes2\otimes\frac{5}{2}}$, $V_{8\otimes2\otimes\frac{7}{2}}$, $V_{8\otimes4\otimes\frac{3}{2}}$, $V_{8\otimes4\otimes\frac{5}{2}}$, $V_{8\otimes6\otimes\frac{1}{2}}$, $V_{8\otimes6\otimes\frac{3}{2}}$, $V_{15\otimes1\otimes\frac{8}{3}}$, $V_{15\otimes2\otimes-\frac{17}{6}}$, $V_{15\otimes2\otimes-\frac{11}{6}}$, $V_{15\otimes3\otimes\frac{5}{3}}$, $V_{15\otimes3\otimes\frac{8}{3}}$, $V_{15\otimes4\otimes-\frac{11}{6}}$, $V_{15\otimes4\otimes-\frac{5}{6}}$, $V_{15\otimes5\otimes\frac{2}{3}}$, $V_{15\otimes5\otimes\frac{5}{3}}$, $V_{15\otimes6\otimes-\frac{5}{6}}$, $V_{15\otimes6\otimes\frac{1}{6}}$, $V_{10\otimes1\otimes-2}$, $V_{10\otimes1\otimes-1}$, $V_{10\otimes1\otimes0}$, $V_{10\otimes1\otimes1}$, $V_{10\otimes1\otimes2}$, $V_{10\otimes3\otimes-2}$, $V_{10\otimes3\otimes-1}$, $V_{10\otimes3\otimes0}$, $V_{10\otimes3\otimes1}$, $V_{10\otimes3\otimes2}$, $V_{10\otimes5\otimes-1}$, $V_{10\otimes5\otimes0}$, $V_{10\otimes5\otimes1}$, $F_{1\otimes2\otimes\frac{7}{2}}$, $F_{1\otimes3\otimes3}$, $F_{1\otimes5\otimes3}$, $F_{1\otimes6\otimes\frac{5}{2}}$, $F_{1\otimes7\otimes0}$, $F_{1\otimes7\otimes1}$, $F_{1\otimes7\otimes2}$, $F_{6\otimes1\otimes\frac{8}{3}}$, $F_{6\otimes2\otimes-\frac{17}{6}}$, $F_{6\otimes3\otimes-\frac{7}{3}}$, $F_{6\otimes3\otimes\frac{8}{3}}$, $F_{6\otimes4\otimes-\frac{11}{6}}$, $F_{6\otimes4\otimes\frac{13}{6}}$, $F_{6\otimes5\otimes-\frac{4}{3}}$, $F_{6\otimes5\otimes\frac{5}{3}}$, $F_{6\otimes6\otimes-\frac{5}{6}}$, $F_{6\otimes6\otimes\frac{1}{6}}$, $F_{6\otimes6\otimes\frac{7}{6}}$, $F_{3\otimes1\otimes-\frac{10}{3}}$, $F_{3\otimes2\otimes\frac{19}{6}}$, $F_{3\otimes3\otimes-\frac{10}{3}}$, $F_{3\otimes3\otimes\frac{8}{3}}$, $F_{3\otimes4\otimes-\frac{17}{6}}$, $F_{3\otimes5\otimes-\frac{7}{3}}$, $F_{3\otimes5\otimes\frac{8}{3}}$, $F_{3\otimes6\otimes-\frac{11}{6}}$, $F_{3\otimes6\otimes\frac{13}{6}}$, $F_{3\otimes7\otimes-\frac{4}{3}}$, $F_{3\otimes7\otimes-\frac{1}{3}}$, $F_{3\otimes7\otimes\frac{2}{3}}$, $F_{3\otimes7\otimes\frac{5}{3}}$, $F_{8\otimes1\otimes3}$, $F_{8\otimes3\otimes3}$, $F_{8\otimes4\otimes\frac{5}{2}}$, $F_{8\otimes5\otimes2}$, $F_{8\otimes6\otimes\frac{1}{2}}$, $F_{8\otimes6\otimes\frac{3}{2}}$, $F_{15\otimes2\otimes-\frac{11}{6}}$, $F_{15\otimes2\otimes\frac{13}{6}}$, $F_{15\otimes3\otimes-\frac{4}{3}}$, $F_{15\otimes3\otimes\frac{5}{3}}$, $F_{15\otimes4\otimes-\frac{5}{6}}$, $F_{15\otimes4\otimes\frac{7}{6}}$, $F_{15\otimes5\otimes-\frac{1}{3}}$, $F_{15\otimes5\otimes\frac{2}{3}}$, $F_{15\otimes6\otimes\frac{1}{6}}$, $F_{10\otimes2\otimes-\frac{3}{2}}$, $F_{10\otimes2\otimes\frac{5}{2}}$, $F_{10\otimes3\otimes-1}$, $F_{10\otimes3\otimes2}$, $F_{10\otimes4\otimes-\frac{1}{2}}$, $F_{10\otimes4\otimes\frac{3}{2}}$, $F_{10\otimes5\otimes0}$, $F_{10\otimes5\otimes1}$, $F_{10\otimes6\otimes\frac{1}{2}}$
Dim 15	$S_{1\otimes1\otimes4}$, $F_{15\otimes1\otimes-\frac{7}{3}}$

Fraction of results in literature [*1212.4556 ...*]

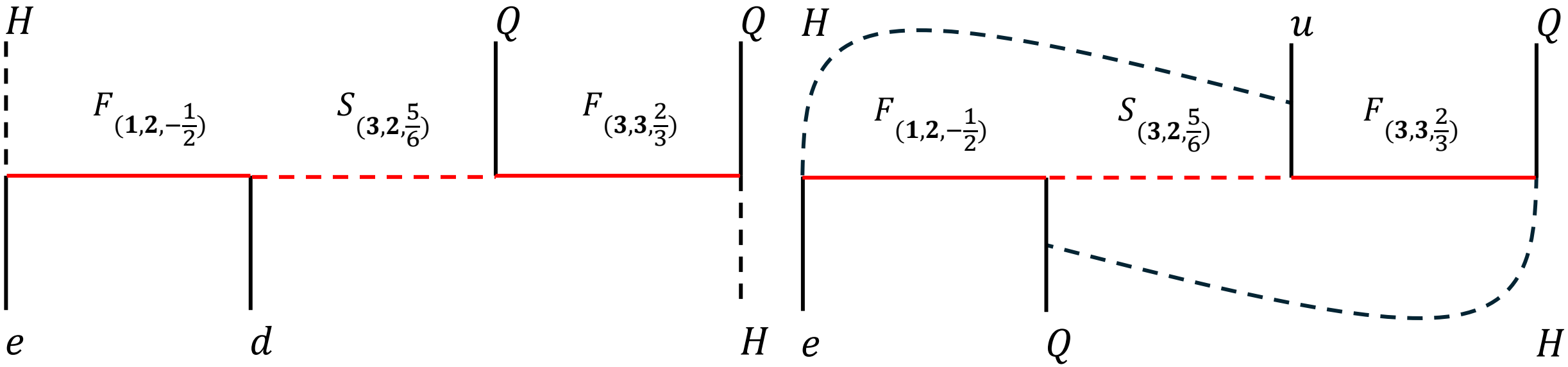
Only includes symmetry protected operators

[Heeck, **DS**, Thapa, arXiv:2603.17050]

Accidentally protected operators

Particular UV completion only generates d=8, $(\Delta B, \Delta L)=(1,1)$ operator $HHQQde$

Loop-induced d = 6 operator $QQue$ generated by the same particles

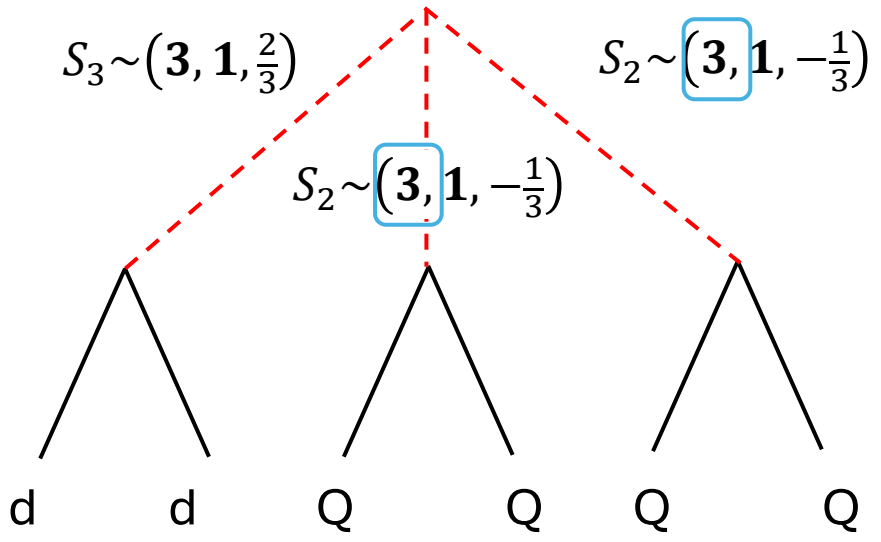


Generations of internal particles

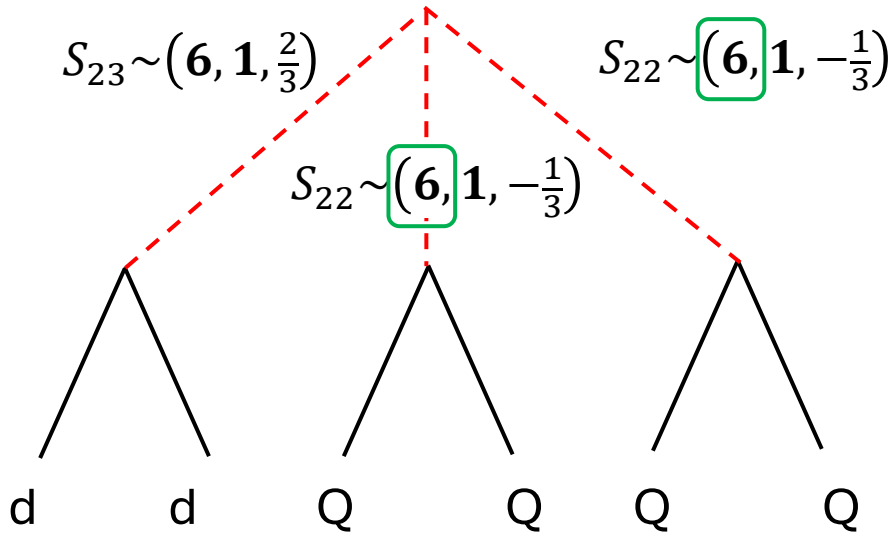
$$3 \otimes 3 = \boxed{\bar{3}_A} \oplus \boxed{6_S}$$

$$\uparrow$$

$$Q \otimes Q$$



Requires 2 generations of S_2



Requires 1 generation of S_{22}

UV completions (SMEFT)

$\mathcal{O}^j(\mathcal{T}_8^8)$	UV Completions
$\mathcal{O}^1_{8,(1,1)}$	$F_4F_8S_5$ $F_1F_8S_5$ $F_8F_{14}S_5$ $F_6F_8S_5$
$\mathcal{O}^2_{8,(1,1)}$	$F_3F_{14}S_{11}$ $F_3F_6S_{11}$ $F_8F_{14}S_{11}$ $F_6F_8S_{11}$
$\mathcal{O}^3_{8,(1,1)}$	$F_{11}F_8S_{11}$ $F_2F_8S_{11}$ $F_8F_9S_{11}$ $F_5F_8S_{11}$
$\mathcal{O}^4_{8,(1,1)}$	$F_4F_9S_{13}$ $F_4F_9S_5$ $F_4F_5S_5$ $F_1F_9S_5$ $F_1F_5S_5$ $F_{11}F_{14}S_{12}$ $F_{11}F_{14}S_{11}$ $F_2F_{14}S_{11}$ $F_{11}F_6S_{11}$ $F_2F_6S_{11}$ $F_9F_{14}S_{13}$ $F_9F_{14}S_5$ $F_5F_{14}S_5$ $F_6F_9S_5$ $F_5F_6S_5$ $F_9F_{14}S_{12}$ $F_9F_{14}S_{11}$ $F_5F_{14}S_{11}$ $F_6F_9S_{11}$ $F_5F_6S_{11}$
$\mathcal{O}^5_{8,(1,1)}$	$F_4F_7S_5$ $F_1F_7S_5$ $F_7F_{14}S_{15}$ $F_6F_7S_5$ $F_4F_8S_5$ $F_1F_8S_5$ $F_8F_{14}S_5$ $F_6F_8S_5$ $F_{11}F_8S_{11}$ $F_2F_8S_{11}$ $F_{11}F_{13}S_{11}$ $F_2F_{13}S_{11}$ $F_8F_9S_{11}$ $F_5F_8S_{11}$ $F_{13}F_9S_{11}$ $F_5F_{13}S_{11}$
$\mathcal{O}^6_{8,(1,1)}$	$F_{13}F_9S_5$ $F_5F_{13}S_5$ $F_8F_{14}S_{11}$ $F_6F_8S_{11}$
$\mathcal{O}^7_{8,(1,1)}$	$F_3F_7S_5$ $F_{10}F_8S_{11}$ $F_3F_8S_{11}$ $F_{10}F_{13}S_{11}$ $F_8F_8S_{11}$ $F_7F_{13}S_5$ $F_3F_8S_5$ $F_{10}F_{13}S_{10}$ $F_8F_{13}S_5$ $F_7F_{13}S_{10}$ $F_8F_{13}S_{11}$

Dimension 6 UV completions:

S_1, S_2, S_3, S_4

Dimension 7 UV completions:

$S_3S_6, S_5S_4, S_2S_5, S_3S_5, F_5S_3, F_7S_6,$
$F_3S_3, F_7S_4, F_2S_4, F_1S_2, F_9S_5, F_5S_5,$
$F_8S_3, F_1S_3, F_7S_5, F_8S_5$

Accidentally protected UV completions (SMEFT)

$\mathcal{O}^j(\mathcal{T}_8^8)$	UV Completions
$\mathcal{O}^1_{8,(1,1)}$	$F_4F_8S_5$ $F_1F_8S_5$ $F_8F_{14}S_5$ $F_6F_8S_5$
$\mathcal{O}^2_{8,(1,1)}$	$F_3F_{14}S_{11}$ $F_3F_6S_{11}$ $F_8F_{14}S_{11}$ $F_6F_8S_{11}$
$\mathcal{O}^3_{8,(1,1)}$	$F_{11}F_8S_{11}$ $F_2F_8S_{11}$ $F_8F_9S_{11}$ $F_5F_8S_{11}$
$\mathcal{O}^4_{8,(1,1)}$	$F_4F_9S_{13}$ $F_4F_9S_5$ $F_4F_5S_5$ $F_1F_9S_5$ $F_1F_5S_5$ $F_{11}F_{14}S_{12}$ $F_{11}F_{14}S_{11}$ $F_2F_{14}S_{11}$ $F_{11}F_6S_{11}$ $F_2F_6S_{11}$ $F_9F_{14}S_{13}$ $F_9F_{14}S_5$ $F_5F_{14}S_5$ $F_6F_9S_5$ $F_5F_6S_5$ $F_9F_{14}S_{12}$ $F_9F_{14}S_{11}$ $F_5F_{14}S_{11}$ $F_6F_9S_{11}$ $F_5F_6S_{11}$
$\mathcal{O}^5_{8,(1,1)}$	$F_4F_7S_5$ $F_1F_7S_5$ $F_7F_{14}S_{15}$ $F_6F_7S_5$ $F_4F_8S_5$ $F_1F_8S_5$ $F_8F_{14}S_5$ $F_6F_8S_5$ $F_{11}F_8S_{11}$ $F_2F_8S_{11}$ $F_{11}F_{13}S_{11}$ $F_2F_{13}S_{11}$ $F_8F_9S_{11}$ $F_5F_8S_{11}$ $F_{13}F_9S_{11}$ $F_5F_{13}S_{11}$
$\mathcal{O}^6_{8,(1,1)}$	$F_{13}F_9S_5$ $F_5F_{13}S_5$ $F_8F_{14}S_{11}$ $F_6F_8S_{11}$
$\mathcal{O}^7_{8,(1,1)}$	$F_3F_7S_5$ $F_{10}F_8S_{11}$ $F_3F_8S_{11}$ $F_{10}F_{13}S_{11}$ $F_8F_8S_{11}$ $F_7F_{13}S_5$ $F_3F_8S_5$ $F_{10}F_{13}S_{10}$ $F_8F_{13}S_5$ $F_7F_{13}S_{10}$ $F_8F_{13}S_{11}$

Dimension 6 UV completions:

S_1, S_2, S_3, S_4

Dimension 7 UV completions:

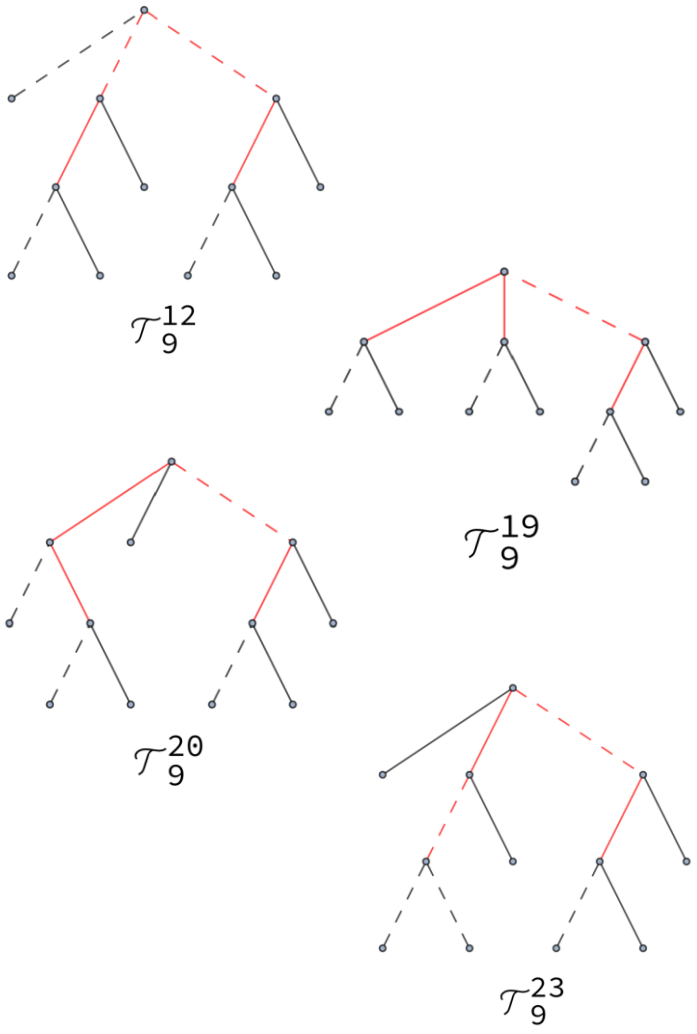
$S_3S_6, S_5S_4, S_2S_5, S_3S_5, F_5S_3, F_7S_6, F_3S_3, F_7S_4, F_2S_4, F_1S_2, F_9S_5, F_5S_5, F_8S_3, F_1S_3, F_7S_5, F_8S_5$

Accidentally protected UV completions

$\Delta B = 1, \Delta L = 1$

- Dim =10, 1 derivative, $\nu_{\mathrm{R}}\mathrm{SMEFT}$

Operator \ Topology	$\mathcal{T}_9^{12}$	$\mathcal{T}_9^{19}$	$\mathcal{T}_9^{20}$	$\mathcal{T}_9^{23}$
$DuuuL\bar{H}\bar{H}\bar{H}$				
$DuuQ\nu\bar{H}\bar{H}\bar{H}$				
$DuudLH\bar{H}\bar{H}$	$F_{11}F_{13}S_{10}S_{42}$	$F_{11}F_8F_{13}S_{42},\ F_7F_8F_{13}S_{42}$		
$DuuQeH\bar{H}\bar{H}$	$F_{13}F_9S_{10}S_{42}$		$F_{10}F_{41}F_{13}S_{42}$	$F_{41}F_{13}S_9S_{10}$
$DudQ\nu H\bar{H}\bar{H}$		$F_3F_7F_{13}S_{42}$	$F_3F_{11}F_{13}S_{42},\ F_7F_{13}F_{28}S_{42}$	
$DuQQLH\bar{H}\bar{H}$	$F_{11}F_{13}S_{42}S_{12},\ F_{13}F_9S_{42}S_{12}$	$F_{11}F_{13}F_9S_{42},\ F_2F_{13}F_9S_{42},$ $F_{11}F_5F_{13}S_{42},\ F_{11}F_{13}F_9S_{12},$ $F_{13}F_9F_9S_{12}$	$F_{11}F_9F_{15}S_{12},\ F_9F_9F_{15}S_{12}$	$F_4F_{29}S_9S_{13},\ F_{11}F_{15}S_8S_{12}$
$DQQQ\nu H\bar{H}\bar{H}$		$F_{11}F_8F_{13}S_{42},\ F_7F_8F_{13}S_{42}$		
$DuddLHH\bar{H}$				$F_{10}F_{45}S_9S_{10},\ F_7F_{45}S_9S_{10}$
$DudQeHH\bar{H}$	$F_{10}F_{14}S_{10}S_{42},\ F_7F_{14}S_{10}S_{42}$	$F_3F_7F_{13}S_{42}$	$F_3F_{11}F_{13}S_{42},\ F_{10}F_{11}F_{13}S_{42},$ $F_7F_{13}F_9S_{42},\ F_7F_{13}F_{45}S_{26}$	
$DddQ\nu HH\bar{H}$				
$DdQQLHH\bar{H}$	$F_7F_{14}S_{42}S_{12}$	$F_4F_7F_{14}S_{13},\ F_7F_{14}F_{14}S_{13},$ $F_{11}F_{14}F_{14}S_{42},\ F_{11}F_6F_{14}S_{42},$ $F_7F_{14}F_{14}S_{42},\ F_6F_7F_{14}S_{42}$	$F_4F_{14}F_{15}S_{13},\ F_{14}F_{14}F_{15}S_{13}$	$F_4F_{15}S_8S_{13},\ F_{12}F_{14}S_8S_{12},$ $F_{11}F_{46}S_9S_{12}$
$DQQQeHH\bar{H}$	$F_{10}F_{14}S_{42}S_{12}$	$F_{10}F_{14}F_{14}S_{42},\ F_{10}F_6F_{14}S_{42},$ $F_9F_{14}F_{14}S_{42},\ F_6F_9F_{14}S_{42}$	$F_{14}F_{14}F_{15}S_{12}$	
$DdddLHHH$				
$DddQeHHH$				

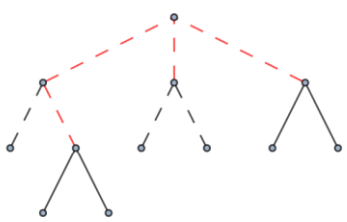


Accidentally protected UV completions

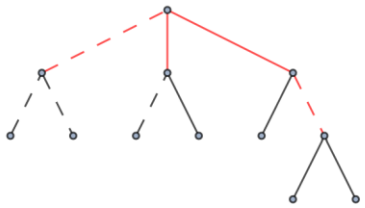
$\Delta B = 1, \Delta L = -1$

- Dim =9, 2 derivative, ν_{R}SMEFT

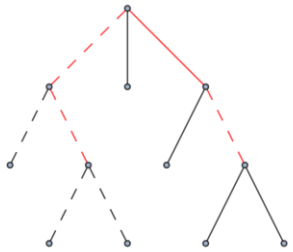
Operator \ Topology	$\mathcal{T}_9^6$	$\mathcal{T}_9^{14}$	$\mathcal{T}_9^{18}$	$\mathcal{T}_9^{19}$	$\mathcal{T}_9^{20}$
$DDddQ\bar{e}H\bar{H}\bar{H}$				$F_6F_7F_7S_{25}$, $F_{10}F_7F_7S_{25}$	$F_{22}F_6F_7S_{25}$, $F_{10}F_{22}F_7S_{25}$, $F_{22}F_7F_8V_{20}$
$DDdQQ\bar{L}H\bar{H}\bar{H}$					
$DDuddQ\bar{L}H\bar{H}$				$F_7F_7F_{13}S_{25}$, $F_2F_7F_7S_{25}$	$F_{22}F_7F_{13}S_{25}$, $F_2F_{22}F_7S_{25}$
$DDdddQ\bar{L}HH\bar{H}$					
$DDQQQ\bar{e}\bar{H}\bar{H}\bar{H}$	$F_9F_9S_6S_{26}$	$F_{22}F_9S_9S_6$	$F_{28}S_{22}S_9S_6$, $F_{22}S_{22}S_9S_6$	$F_9F_9F_9S_{26}$	
$DDuQQ\bar{L}\bar{H}\bar{H}\bar{H}$	$F_9F_9S_6S_{26}$	$F_{22}F_9S_9S_6$	$F_{28}S_{22}S_9S_6$, $F_{22}S_{22}S_9S_6$	$F_4F_9F_9S_{26}$	
$DDddQ\bar{\nu}HH\bar{H}$					
$DDQQQ\bar{\nu}H\bar{H}\bar{H}$					
$DDudQ\bar{\nu}H\bar{H}\bar{H}$					



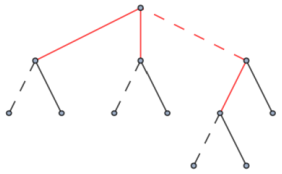
$\mathcal{T}_9^4$



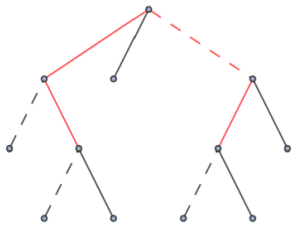
$\mathcal{T}_9^{14}$



$\mathcal{T}_9^{18}$



$\mathcal{T}_9^{19}$



$\mathcal{T}_9^{20}$

Conclusion:

- Baryon number violation is uniquely sensitive to heavy new physics, probing mass dimensions $\gg 6$.
- Operators of high mass dimension could potentially be dominant due to symmetry protection.
- Discussing all UV completions for operators without derivatives up to **d = 14** and symmetry-protected operators for **d = 15** as well as operators involving derivatives up **d = 12** and analyzing results show that higher mass dimension operators can be potentially dominant due to an accidental symmetry.
- Our methods can be easily applied to other operators—for example, those violating the lepton number. The only limiting factor is the presentation of actual results due to the large number of solutions.
- Useful for model building and for identifying new signatures to look for in the event of discovery in Super-Kamiokande, Hyper-Kamiokande, JUNO, or DUNE.

Thank you for your attention!