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Falsifying the Universe with Martin since 2014

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University College London

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Baryon Asymmetry Generation and Washout

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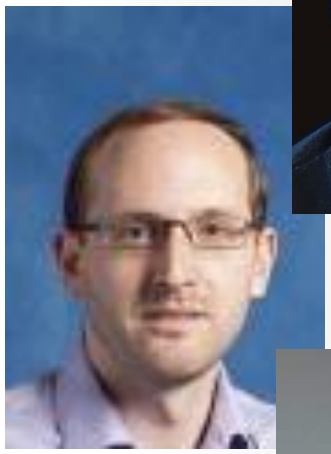
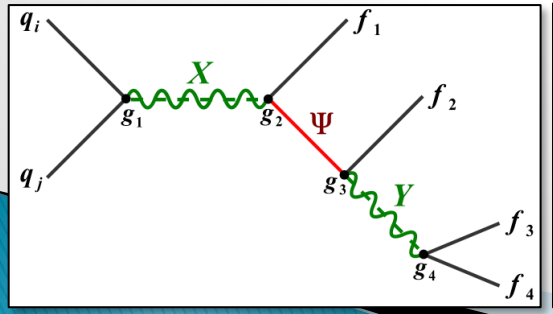
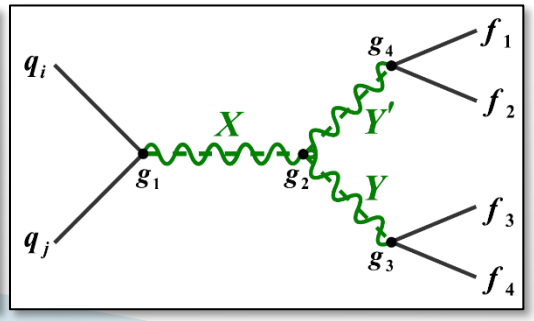


- Classic Example: High-Scale Leptogenesis
  - Generation via heavy neutrino decays
  - Competition with LNV washout processes
  - Conversion to baryon asymmetry
    - EW sphaleron processes at $T \approx 100\ \mathrm{GeV}$
    - Observed asymmetry

$$\eta_B \equiv \frac{n_B - n_{\bar{B}}}{n_\gamma} = (6.20 \pm 0.15) \times 10^{-10}$$

- What if we observe lepton number violating processes at the LHC or in $0\nu\beta\beta$?





Induced Washout

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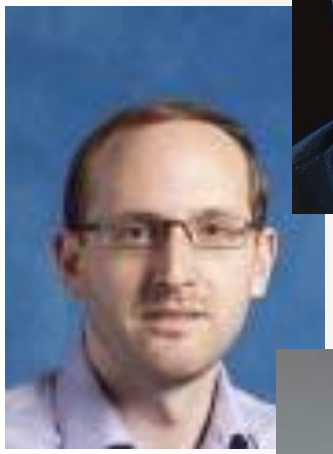
- Compare LHC cross section with lepton number asymmetry washout

$$\frac{\Gamma_W}{H} > 3 \times 10^{-3} \frac{M_P M_X^3}{T^4} \frac{K_1(M_X/T)}{f_{q_1 q_2}(M_X/\sqrt{s})} \times (s\, \sigma_{\mathrm{LHC}})$$

  - Lower limit on total washout rate
    - Neglecting other washout processes

$$\log_{10} \frac{\Gamma_W}{H} > 7 + 0.6 \left(\frac{M_X}{\mathrm{TeV}} - 1 \right) + \log_{10} \frac{\sigma_{\mathrm{LHC}}}{\mathrm{fb}}$$

  - Observation of LNV @ LHC corresponds to highly effective washout $\Gamma_W/H \gg 1$
    - Excludes Leptogenesis models that generate asymmetry above M_X



Caveats

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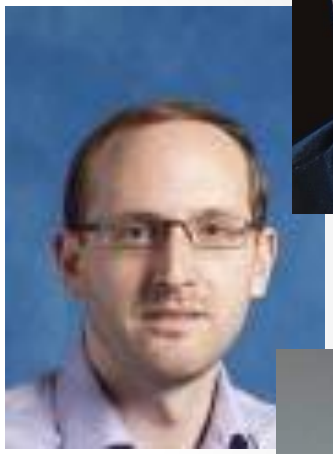

- Cannot exclude scenarios that generate a lepton number asymmetry below observed scale M_X
  - But strong limits still apply
- Asymmetry can be present in one lepton generation only
  - Unambiguous falsification requires observation of LNV in all flavours (or observation of low energy LFV such as $\tau \to e\gamma$)
- Sphalerons only affect LH leptons…What if LNV is observed for RH leptons only?
  - Not an issue as all LH and RH charged fermions are in thermal equilibrium $\approx M_{EW}$
- Symmetry in new sector coupled via hypercharge induces $(B-L)$ chemical potential
  (Antaramian, Hall, Rašin '93)

Caveats

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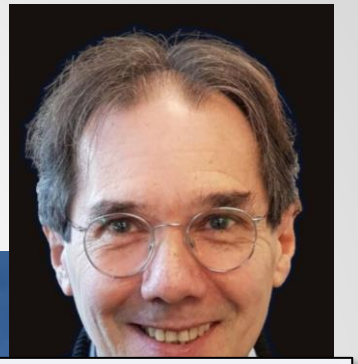

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  - But strong limits still apply

Falsifying High-Scale Leptogenesis at the LHC #6

Frank F. Deppisch (University Coll. London), Julia Harz (University Coll. London), Martin Hirsch (Valencia U., IFIC) (Dec 16, 2013)

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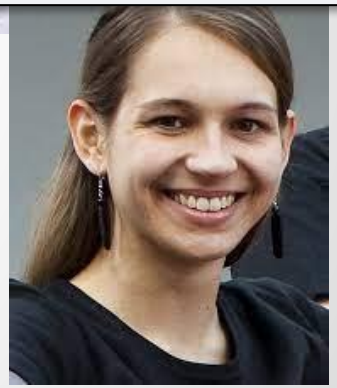

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Washout via $0\nu\beta\beta$ operators

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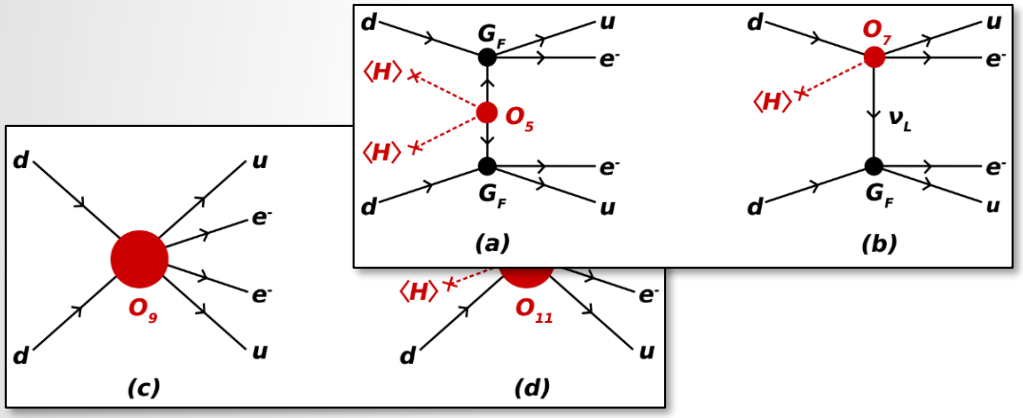
- Analogous analysis using LNV effective operators of mass dimensions 5, 7, 9, 11
  - 129 Operators

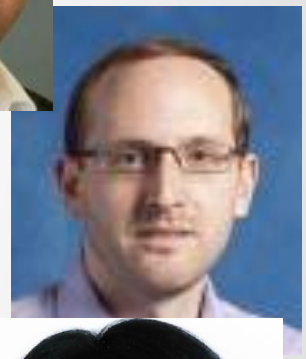


  - Matching to $0\nu\beta\beta$ operators

$$m_e\epsilon_5 = \frac{g^2v^2}{\Lambda_5},\ \frac{G_F\epsilon_7}{\sqrt{2}} = \frac{g^3v}{2\Lambda_7^3},\ \frac{G_F^2\epsilon_{\{9,11\}}}{2m_p} = \{\frac{g^4}{\Lambda_9^5}, \frac{g^6v^2}{\Lambda_{11}^7}\}.$$

$$T_{1/2} = 2.1 \times 10^{25}\ \mathrm{y} \cdot \left(\Lambda_D/\Lambda_D^0\right)^{2d-8}$$





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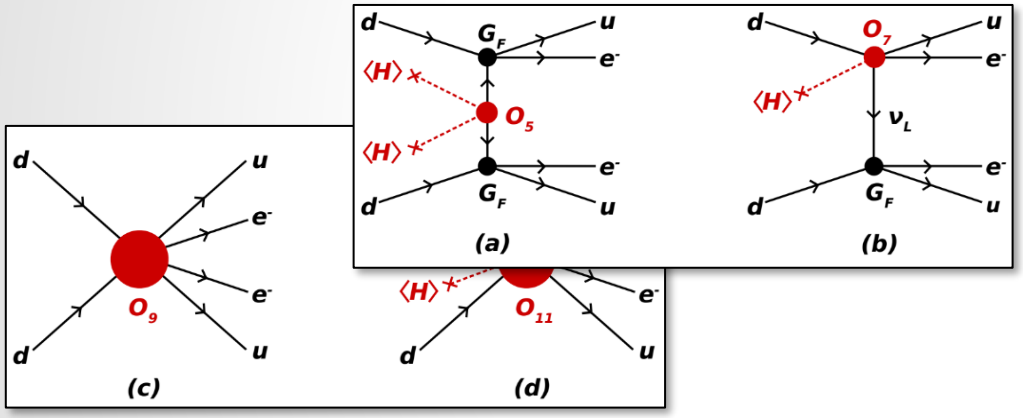

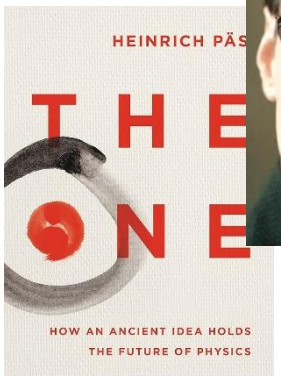

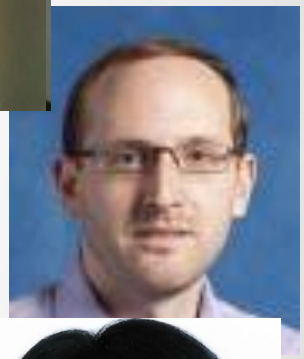

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$$T_{1/2} = 2.1 \times 10^{25}\ \mathrm{y} \cdot \left(\Lambda_D / \Lambda_D^0\right)^{2d-8}$$

Observation of $0\nu\beta\beta$ / LFV

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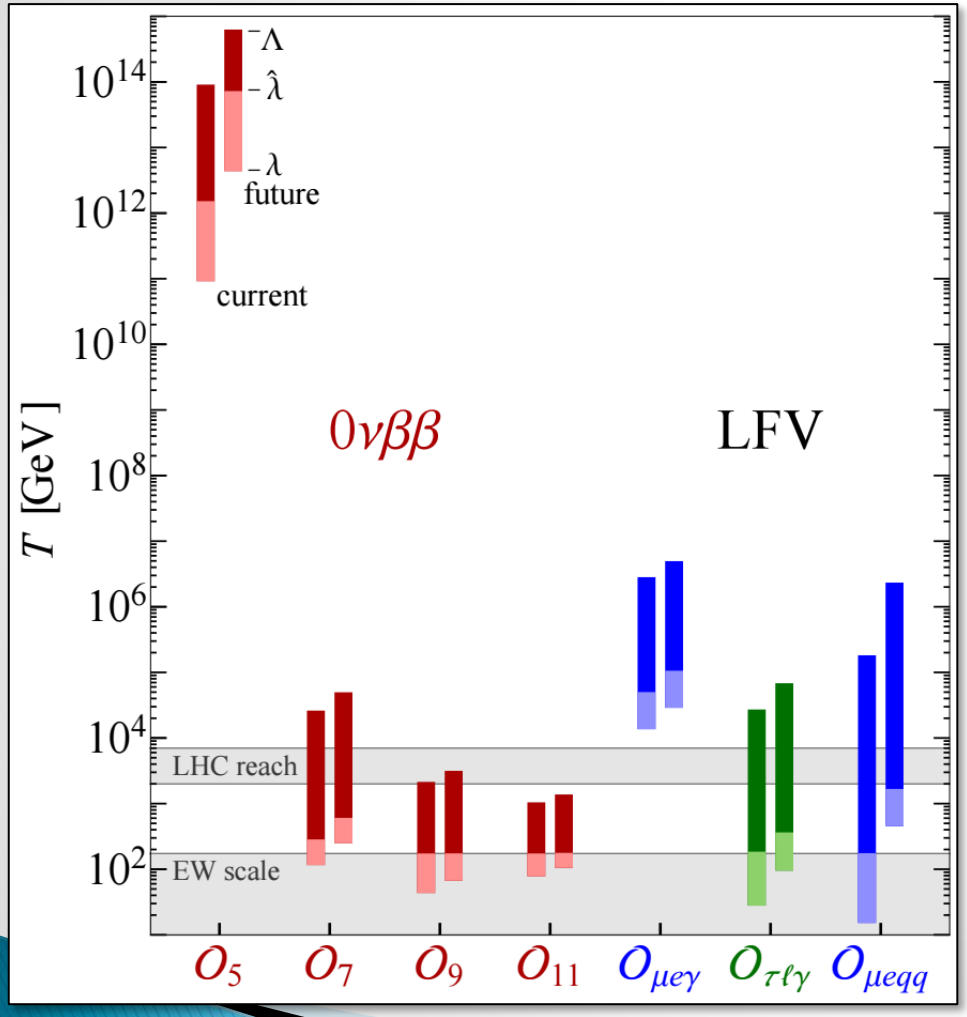

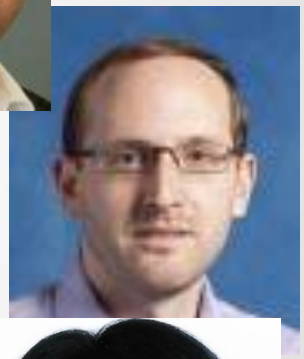

Majorons and RH Currents

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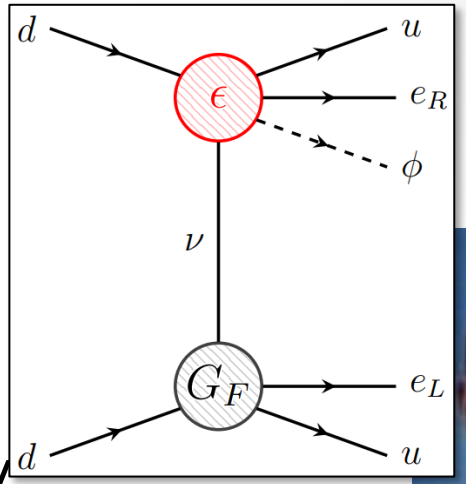
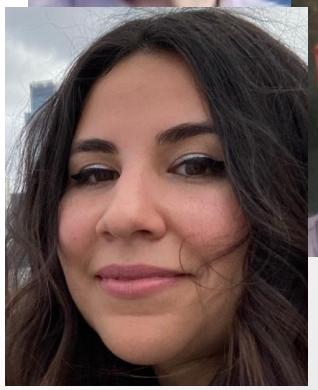
- Effective RH lepton currents with massless scalar ϕ



- Giving rise to long-range contribution to $0\nu\beta\beta\phi$ decay

$$\mathcal{M} = \epsilon^{\phi}_{RX} \frac{(G_F \cos\theta_C)^2}{\sqrt{2} m_p} \sum_N \int d^3x d^3y \int \frac{d^3q}{2\pi^2\omega} \phi(\mathbf{y}) e^{i\mathbf{q}(\mathbf{x}-\mathbf{y})}$$
$$\times \left\{ \left[\frac{J^{\rho\sigma}_{LX}(\mathbf{x},\mathbf{y}) u^L_{\rho\sigma}(E_1\mathbf{x}, E_2\mathbf{y})}{\omega + \mu_N - \frac{1}{2}(E_1 - E_2 - E_\phi)} - \frac{J^{\rho\sigma}_{XL}(\mathbf{x},\mathbf{y}) u^R_{\rho\sigma}(E_1\mathbf{x}, E_2\mathbf{y})}{\omega + \mu_N - \frac{1}{2}(E_1 - E_2 + E_\phi)} \right] - \left[E_1 \leftrightarrow E_2 \right] \right\}$$

  - No suppression with ν mass
- Calculation follows long-range η and λ $0\nu\beta\beta$ modes



Majorons and RH Currents

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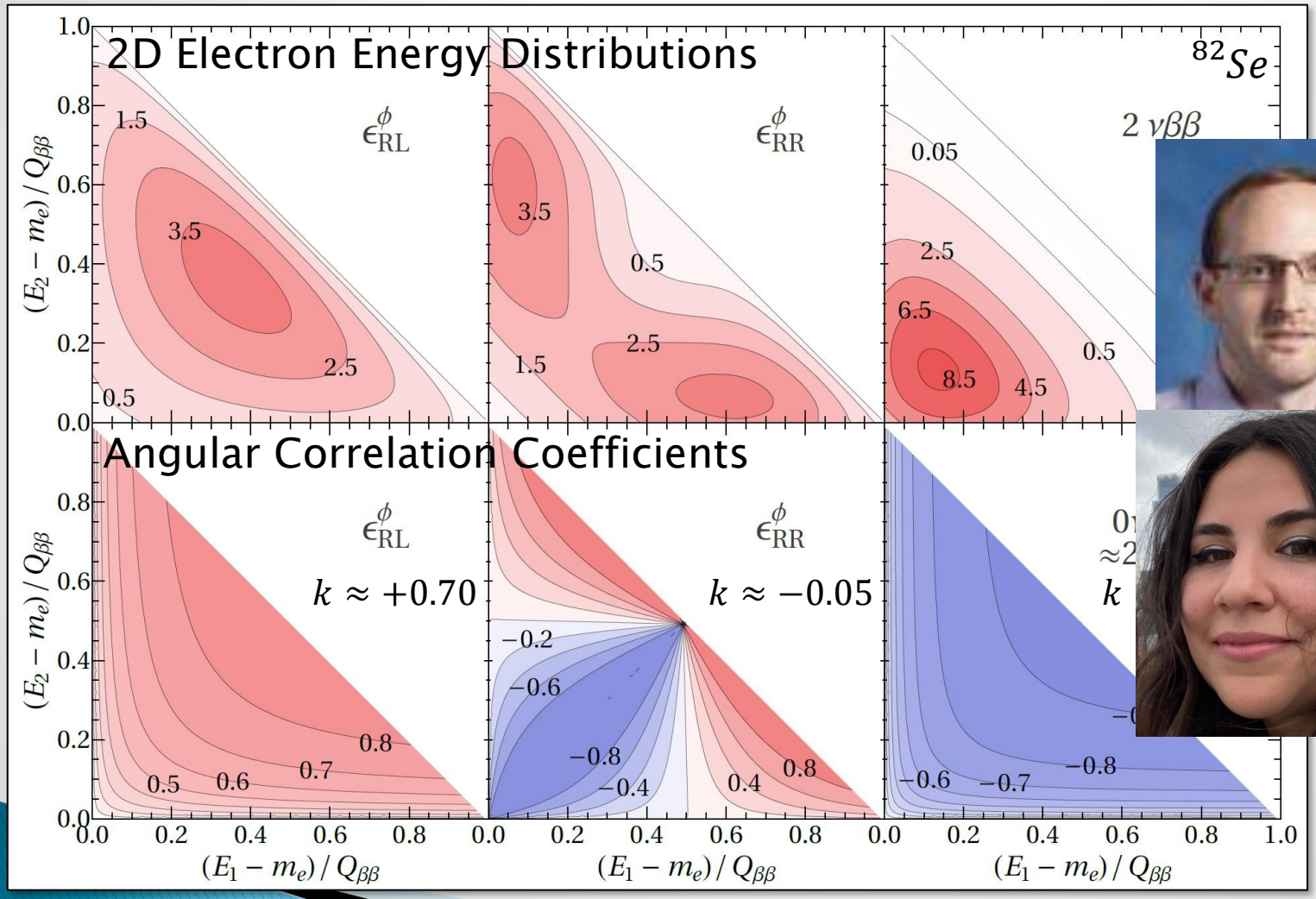

UV Model: LR

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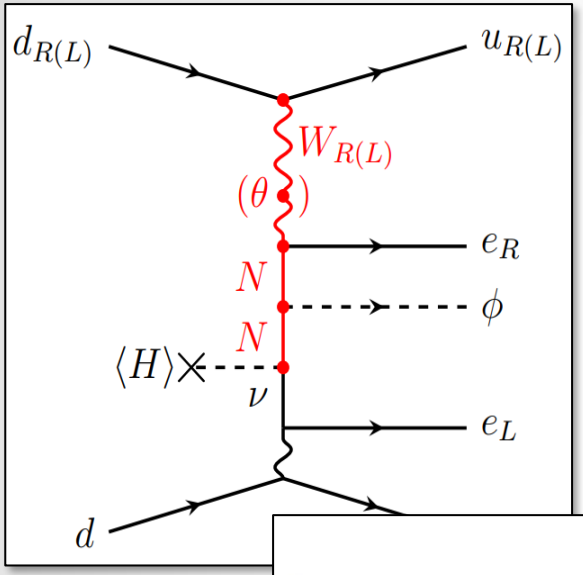
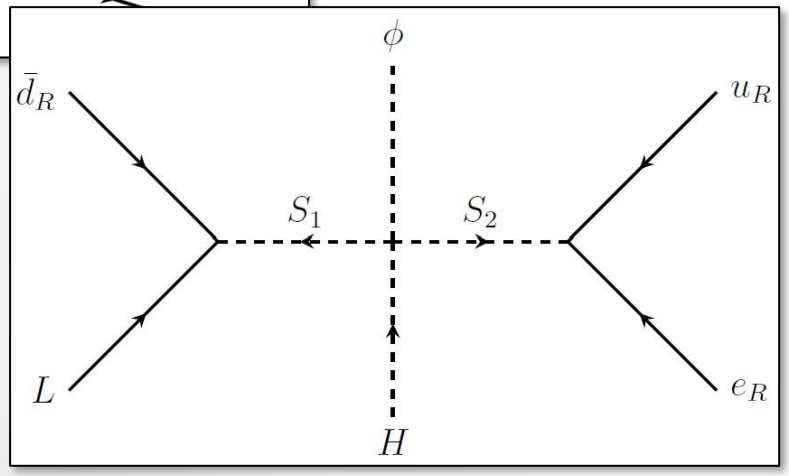
- Extended Gauge Symmetry

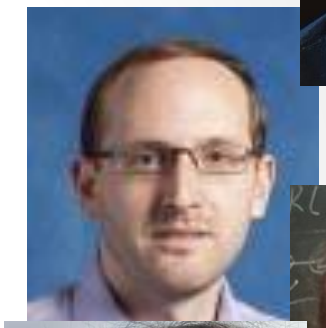
$$G_{LR} = SU(3)_C \times SU(2)_L \times SU(2)_R \times U(1)_X \to SU(3)_C \times SU(2)_L \times U(1)_Y$$

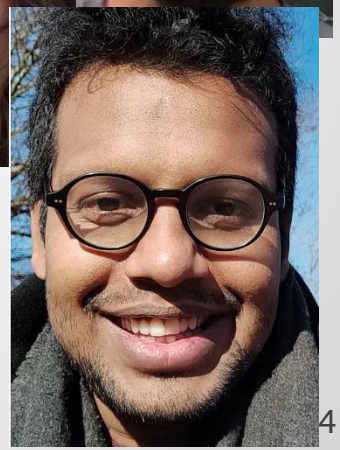
Field	$SU(2)_L$	$SU(2)_R$	$B-L$	ζ	X	$SU(3)_C$
q_L	2	1	1/3	0	1/3	3
q_R	1	2	1/3	0	1/3	3
ℓ_L	2	1	-1	0	-1	1
ℓ_R	1	2	-1	0	-1	1
$U_{L,R}$	1	1	1/3	+1	4/3	3
$D_{L,R}$	1	1	1/3	-1	-2/3	3
$E_{L,R}$	1	1	-1	-1	-2	1
$N_{L,R}$	1	1	-1	+1	0	1
χ_L	2	1	0	+1	1	1
χ_R	1	2	0	+1	1	1
ϕ	1	1	2	-2	0	1

UV Model: LR or LQ










Hirsch-Fest
- Absch(l)uss einer Mailegende -
20.10.2019
Waffeln
Spiel-straße
10:30 Uhr Familien-gottes-dienst
ab 11:45 Uhr Bewirtung
16:00 Uhr große Versteigerung es geht um Kopf und Kragen
URBACH
Antio Elafi Kalo Taxidi
griechisch: Adieu Hirsch = Gute Reise
Die Gartenschau geht zu Ende und mit ihr geht auch Urbachs stolzer Hirsch. Ursprünglich von den „Hahna Cumpana" als Maischerz geplant, gebaut und an Ort und Stelle gebracht, hat er über die Zeit der Remstalgartenschau viele Menschen erfreut und das Ortsbild Urbachs mit seiner stattlichen Erscheinung geprägt. Die einzelnen Schindeln des Hirschs können am Fest, als persönliche Erinnerung mit einem Hirschbranding und Teelicht versehen, erworben werden. Quasi ein Stück Hirsch und Gartenschau für zuhause. Als Highlight kann um 16:00 Uhr der Kopf samt Geweih ersteigert werden. Der komplette Erlös aus der Veranstaltung geht an den Kinder- und Jugendhospizdienst Sternentraum, die Bürgerstiftung Urbach sowie die Ölgäle Stiftung.
Deutsches Rotes Kreuz Ortsverein Urbach
Kinder- und Jugendhospizdienst Sternentraum
ölgäle stiftung
Kind und Jugend Bürgerstiftung Urbach
Gemeinde Urbach
Remstal Gartenschau 2019
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Thanks a lot for the Collaboration and Happy Birthday!
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