Systematic study of 3-3-1 models without exotic electric charges

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Systematic study of the $SU(3)_c \otimes SU(3)_L \otimes U(1)_X$ local gauge symmetry

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Abstract

We review in a systematic way how anomaly free $SU(3)_c \otimes SU(3)_L \otimes U(1)_x$ models without exotic electric charges can be constructed, using as basis closed sets of fermions which includes each one the particles and antiparticles of all the electrically charged fields. Our analysis reproduce not only the known models in the literature, but also shows the existence of several more independent models for one and three families not considered so far. A phenomenological analysis of the new models is done, where the lowest limits at a 95 % CL on the gauge boson masses are presented.

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Overview

Abstract

- We review in a systematic way how anomaly free $SU(3)_c \otimes SU(3)_L \otimes U(1)_x$ models without exotic electric charges can be constructed, using as basis closed sets of fermions which includes each one the particles and antiparticles of all the electrically charged fields.
- Our analysis reproduces not only the known models in the literature, but also shows the existence of several more independent models for one and three families not considered so far.
- A phenomenological analysis of the new models is done, where the lowest limits at a 95 % CL on the gauge boson masses are presented.

Sets of particles

- Restricting ourselves to models without exotic electric charges, we have built 12 sets of particles S_i from triplets, antitriplets and singlets of $SU(3)_L \otimes U(1)_X$.
- These sets are constructed in such a way that they contain the charged particles and their respective antiparticles.

Sets of particles

- $S_1 = [(\nu_e^0, e^-, E_1^-) \oplus e^+ \oplus E_1^+]_L$ with quantum numbers $(1, 3, -2/3)$; $(1, 1, 1)$ and $(1, 1, 1)$ respectively,
- $S_2 = [(e^-, \nu_e^0, N_1^0) \oplus e^+]_L$ with quantum numbers $(1, 3^*, -1/3)$ and $(1, 1, 1)$ respectively,
- $S_3 = [(d, u, U) \oplus u^c \oplus d^c \oplus U^c]_L$ with quantum numbers $(3, 3^*, 1/3)$; $(3^*, 1, -2/3)$; $(3^*, 1, 1/3)$ and $(3^*, 1, -2/3)$ respectively,
- $S_4 = [(u, d, D) \oplus u^c \oplus d^c \oplus D^c]_L$ with quantum numbers $(3, 3, 0)$; $(3^*, 1, -2/3)$; $(3^*, 1, 1/3)$ and $(3^*, 1, 1/3)$ respectively,
- $S_5 = [(N_2^0, E_2^+, e^+) \oplus E_2^- \oplus e^-]_L$ with quantum numbers $(1, 3^*, 2/3)$ $(1, 1, -1)$, and $(1, 1, -1)$ respectively,
- $S_6 = [(E_3^+, N_3^0, N_4^0) \oplus E_3^-]_L$ with quantum numbers $(1, 3, 1/3)$ and $(1, 1, -1)$ respectively,
- $S_7 = [(e^-, \nu_e^0, N_1^0) \oplus (N_2^0, E^+, e^+) \oplus E^-]_L$ with quantum numbers $(1, 3^*, -1/3)$; $(1, 3^*, 2/3)$ and $(1, 1, -1)$ respectively,
- $S_8 = [(\nu_e^0, e^-, E^-) \oplus (E^+, N_1^0, N_2^0) \oplus e^+]_L$ with quantum numbers $(1, 3, -2/3)$, $(1, 3, 1/3)$ and $(1, 1, 1)$ respectively,
- $S_9 = [(e^-, \nu_e, N_1^0) \oplus (E^-, N_2^0, N_3^0) \oplus (N_4^0, E^+, e^+)]_L$ with quantum numbers $(1, 3^*, -1/3)$;$(1, 3^*, -1/3)$ and $(1, 3^*, 2/3)$ respectively,
- $S_{10} = [(\nu_e, e^-, E_1^-) \oplus (E_2^+, N_1^0, N_2^0) \oplus e^+ \oplus (N_3^0, E_2^-, E_3^-) \oplus E_1^+ \oplus E_3^+]_L$ with quantum numbers $(1, 3, -2/3)$; $(1, 3, 1/3)$; $(1, 1, 1)$; $(1, 3, -2/3)$; $(1, 1, 1)$, and $(1, 1, 1)$ respectively,
- $S_{11} = [(e^-, \nu_e, N_1^0) \oplus (N_2^0, E_1^+, e^+) \oplus (N_3^0, E_2^+, E_3^+) \oplus E_1^- \oplus E_2^- \oplus E_3^-]_L$ with quantum numbers $(1, 3^*, -1/3)$; $(1, 3^*, 2/3)$; $(1, 3^*, 2/3)$; $(1, 1, -1)$; $(1, 1, -1)$, and $(1, 1, -1)$ respectively,
- $S_{12} = [(\nu_e^0, e^-, E_1^-) \oplus (E_1^+, N_1^0, N_2^0) \oplus (E_2^+, N_3^0, N_4^0) \oplus e^+ \oplus E_2^-]_L$ with quantum numbers $(1, 3, -2/3)$; $(1, 3, 1/3)$; $(1, 3, 1/3)$; $(1, 1, 1)$, and $(1, 1, -1)$; respectively.

Irreducible Anomaly Free Sets (IAFS)

- With these sets, we built the IAFSs L_i, Q_i^I, Q_i^{II} and Q_i^{III} depending on their quark content

i	Vector-like lepton sets (L_i)	One quark set (Q_i^I)	Two quark sets (Q_i^{II})	Three quark sets (Q_i^{III})
1	$S_1 + S_5$	$S_4 + S_9$	$S_1 + S_2 + S_3 + S_4$	$3S_2 + S_3 + 2S_4$
2	$S_2 + S_6$	$S_3 + S_{10}$	$2S_1 + S_3 + S_4 + S_7$	$3S_1 + 2S_3 + S_4$
3	$S_7 + S_8$	$S_2 + S_4 + S_7$	$2S_2 + S_3 + S_4 + S_8$	
4	$S_{10} + S_{11}$	$S_1 + S_3 + S_8$	$3S_2 + S_3 + S_4 + S_{12}$	
5	$S_9 + S_{12}$	$2S_1 + S_3 + S_6$	$3S_1 + 2S_3 + S_{12}$	
6	$S_1 + S_6 + S_7$	$2S_2 + S_4 + S_5$	$3S_2 + 2S_4 + S_{11}$	
7	$S_6 + S_8 + S_9$	$S_1 + S_4 + 2S_7$	$3S_1 + S_3 + S_4 + S_{11}$	
8	$S_2 + S_5 + S_8$	$S_2 + S_3 + 2S_8$		
9	$S_5 + S_7 + S_{10}$	$S_1 + S_2 + S_3 + S_{12}$		
10	$S_2 + S_7 + S_{12}$	$S_1 + S_2 + S_4 + S_{11}$		
11	$S_1 + S_8 + S_{11}$	$S_4 + 3S_7 + S_{10}$		
12	$S_1 + 2S_6 + S_9$	$S_3 + 3S_8 + S_9$		
13	$S_6 + 2S_7 + S_{10}$	$2S_1 + S_3 + S_7 + S_{12}$		
14	$S_5 + 2S_8 + S_9$	$2S_1 + S_4 + S_7 + S_{11}$		
15	$S_5 + S_6 + S_9 + S_{10}$	$2S_2 + S_3 + S_8 + S_{12}$		
16	$S_2 + 2S_5 + S_{10}$	$2S_2 + S_4 + S_8 + S_{11}$		
17	$S_1 + 2S_7 + S_{12}$	$3S_2 + S_3 + 2S_{12}$		
18	$S_1 + S_2 + S_{11} + S_{12}$	$3S_2 + S_4 + S_{11} + S_{12}$		
19	$S_2 + 2S_8 + S_{11}$	$3S_1 + S_3 + S_{11} + S_{12}$		
20	$2S_1 + S_6 + S_{11}$	$3S_1 + S_4 + 2S_{11}$		
21	$2S_2 + S_5 + S_{12}$			

Irreducible Anomaly Free Sets (IAFS)

- From the IAFSs it is possible to systematically build 3-3-1 models.

Name	Model	AFS
Model **A**	Q_1^{III}	$3S_2 + S_3 + 2S_4$
Model **B**	Q_2^{III}	$3S_1 + 2S_3 + S_4$
Model **C**	$Q_1^{I} + Q_1^{II}$	$S_1 + S_2 + S_3 + 2S_4 + S_9$
Model **D**	$Q_2^{I} + Q_1^{II}$	$S_1 + S_2 + 2S_3 + S_4 + S_{10}$
Model **E**	$Q_2^{I} + 2\ Q_1^{I}$	$2S_4 + 2S_9 + S_3 + S_{10}$
Model **F**	$2\ Q_2^{I} + Q_1^{I}$	$S_4 + S_9 + 2S_3 + 2S_{10}$
Model **G**	$3\ Q_1^{I}$	$3(S_4 + S_9)$
Model **H**	$3\ Q_2^{I}$	$3(S_3 + S_{10})$
Model **I**	$3\ Q_6^{I}$	$3(2S_2 + S_4 + S_5)$
Model **J**	$3\ Q_5^{I}$	$3(2S_1 + S_3 + S_6)$

Irreducible Anomaly Free Sets (IAFS)

- By combining the IAFSs from Table, it is possible to find a large number of models. By restricting to models with a minimal content of exotic fermions, we found 1682 models which could be of phenomenological interest.
- We reported some of them, with their corresponding embeddings.

Model	j	SM Lepton Embeddings	Universal —	$2+1$	— Lepton Configuration	— LHC-Lower limit (TeV)
A	-	$3S_2^{\bar{\ell}+e^+}$	✓	×	$3C_2$	4.87
B	-	$3S_1^{\ell+e^+}$	✓	×	$3C_1$	5.53
C^j	1	$S_1^{\ell+e^+}+S_2^{\bar{\ell}+e^+}+S_9^{\bar{\ell}+e'^+}$	×	×	$C_1+C_2+C_3$	
	2	$(S_1^{\ell}+S_9^{e'^+})+S_2^{\bar{\ell}+e^+}+(S_9^{\bar{\ell}}+S_1^{e^+})$	×	✓	$2C_2+C_4$	4.87
D^j	1	$S_1^{\ell+e^+}+S_2^{\bar{\ell}+e^+}+S_{10}^{\ell+e^+}$	×	✓	$2C_1+C_2$	5.53
	2	$S_1^{\ell+e^+}+S_{10}^{2\ell+2e^+}$	✓	×	$3C_1$	5.53
E^j	1	$2S_9^{\bar{\ell}+e'^+}+S_{10}^{\ell+e^+}$	×	✓	C_1+2C_3	5.75
	2	$S_9^{2\bar{\ell}}+S_{10}^{\ell+3e^+}$	×	✓	C_1+2C_2	4.98
	3	$S_9^{2\bar{\ell}+e'^+}+S_9^{\bar{\ell}+e'^+}+S_{10}^{e^+}$	×	✓	C_2+2C_3	5.75
	4	$S_9^{2\bar{\ell}+e'^+}+S_9^{\bar{\ell}}+S_{10}^{2e^+}$	×	✓	$2C_2+C_3$	4.98
	5	$S_9^{2\bar{\ell}}+S_9^{\bar{\ell}}+S_{10}^{3e^+}$	✓	×	$3C_2$	4.98
	6	$S_9^{2\bar{\ell}+e'^+}+S_{10}^{\ell+2e^+}$	×	×	$C_1+C_2+C_3$	
	7	$(S_9^{2\ell+e'^+}+S_{10}^{e^+})+(S_{10}^{\ell}+S_9^{e'^+})$	×	×	$C_2+C_3+C_4$	
	8	$(S_9^{2\ell}+S_{10}^{2e^+})+(S_{10}^{\ell}+S_9^{e'^+})$	×	✓	$2C_2+C_4$	4.98
	9	$S_9^{\bar{\ell}+e'^+}+S_{10}^{2\ell+2e^+}$	×	✓	$2C_1+C_3$	5.53
	10	$S_9^{\ell+e'^+}+(S_{10}^{2\ell+e^+}+S_9^{e'^+})$	×	×	$C_1+C_3+C_4$	
	11	$S_9^{\bar{\ell}}+S_{10}^{2\ell+3e^+}$	×	✓	$2C_1+C_2$	5.53
	12	$(S_9^{\bar{\ell}}+S_{10}^{e^+})+(S_{10}^{2\ell+e^+}+S_9^{e'^+})$	×	×	$C_1+C_2+C_4$	
	13	$(S_9^{\bar{\ell}}+S_{10}^{e^+})+(S_{10}^{2\ell}+2S_9^{e'^+})$	×	✓	C_2+2C_4	7.0
F^j	1	$S_9^{\bar{\ell}+e'^+}+S_{10}^{2\ell+2e^+}$	×	✓	$2C_1+C_3$	5.53
	2	$(S_9^{\bar{\ell}}+S_{10}^{e^+})+S_{10}^{2\ell+2e^+}$	×	✓	$2C_1+C_2$	5.53
	3	$(S_9^{\bar{\ell}}+S_{10}^{e^+})+(S_{10}^{2\ell+e^+}+S_9^{e'^+})$	×	×	$C_1+C_2+C_4$	
	4	$(S_9^{2\bar{\ell}+e'^+}+S_{10}^{e^+})+S_{10}^{\ell+e^+}$	×	×	$C_1+C_2+C_3$	
	5	$(S_9^{2\bar{\ell}}+S_{10}^{2e^+})+S_{10}^{\ell+e^+}$	×	✓	C_1+2C_2	4.98
	6	$(S_9^{2\bar{\ell}}+S_{10}^{2e^+})+(S_{10}^{\ell}+S_9^{e'^+})$	×	✓	$2C_2+C_4$	4.98
	7	$S_{10}^{2\ell+2e^+}+S_{10}^{\ell+e^+}$	✓	×	$3C_1$	5.53
	8	$S_{10}^{2\ell+2e^+}+S_{10}^{\ell}+S_9^{e'^+}$	×	✓	$2C_1+C_4$	5.53
G	-	$3S_9^{\bar{\ell}+e'^+}$	✓	×	$3C_3$	5.53
H	-	$3S_{10}^{\ell+e^+}$	✓	×	$3C_1$	5.53
I^j	1	$3S_2^{\bar{\ell}+e^+}$	✓	×	$3C_2$	4.87
	2	$2S_2^{\bar{\ell}+e^+}+S_2^{\bar{\ell}}+S_5^{e'^+}$	×	✓	$2C_2+C_3$	4.87
	3	$S_2^{\bar{\ell}+e^+}+2S_2^{\bar{\ell}}+2S_5^{e'^+}$	×	✓	C_2+2C_3	5.53
	4	$3S_2^{\bar{\ell}}+3S_5^{e'^+}$	✓	×	$3C_3$	5.53
J	-	$3S_1^{\ell+e^+}$	✓	×	$3C_1$	5.53

Irreducible Anomaly Free Sets (IAFS)

Model	j	SM Lepton Embeddings	Universal —	$2+1$	— Lepton Configuration	— LHC-Lower limit (TeV)
Q_3^{lj}	1	$3S_2^{\bar{\ell}+e^+}$	✓	×	$3C_2$	4.87
	2	$2S_2^{\bar{\ell}+e^+}+(S_2^{\bar{\ell}}+S_7^{e'^+})$	×	✓	$2C_2+C_3$	4.87
	3	$S_2^{\bar{\ell}+e^+}+(2S_2^{\bar{\ell}}+2S_7^{e'^+})$	×	✓	C_2+2C_3	5.53
	4	$3S_2^{\bar{\ell}}+3S_7^{e'^+}$	✓	×	$3C_3$	5.53
Q_7^{lj}	1	$3S_1^{\ell+e^+}$	✓	×	$3C_1$	5.33
	2	$2S_1^{\ell+e^+}+(S_1^{\ell}+S_7^{e'^+})$	×	✓	$2C_1+C_4$	5.33
	3	$S_1^{\ell+e^+}+(2S_1^{\ell}+2S_7^{e'^+})$	×	✓	C_1+2C_4	6.52
	4	$3S_1^{\ell}+3S_7^{e'^+}$	✓	×	$3C_4$	6.52
	5	$2S_1^{\ell+e^+}+S_7^{\bar{\ell}+e'^+}$	×	✓	$2C_1+C_3$	5.33
	6	$2S_1^{\ell+e^+}+(S_7^{\bar{\ell}}+S_1^{e^+})$	×	✓	$2C_1+C_2$	5.33
	7	$S_1^{\ell+e^+}+(S_1^{\ell}+S_7^{e'^+})+S_7^{\bar{\ell}+e'^+}$	×	×	$C_1+C_3+C_4$	
	8	$S_1^{\ell+e^+}+(S_1^{\ell}+S_7^{e'^+})+(S_7^{\bar{\ell}}+S_1^{e^+})$	×	×	$C_1+C_2+C_4$	
	9	$(2S_1^{\ell}+2S_7^{e'^+})+S_7^{\bar{\ell}+e'^+}$	×	✓	C_3+2C_4	6.52
	10	$(2S_1^{\ell}+2S_7^{e'^+})+(S_7^{\bar{\ell}}+S_1^{e^+})$	×	✓	C_2+2C_4	6.52
	11	$S_1^{\ell+e^+}+2S_7^{\bar{\ell}+e'^+}$	×	✓	C_1+2C_3	5.53
	12	$S_1^{\ell+e^+}+S_7^{\bar{\ell}+e'^+}+(S_7^{\bar{\ell}}+S_1^{e^+})$	×	×	$C_1+C_2+C_3$	
	13	$S_1^{\ell+e^+}+(2S_7^{\bar{\ell}}+2S_1^{e^+})$	×	✓	C_1+2C_2	4.87
	14	$(S_1^{\ell}+S_7^{e'^+})+2S_7^{\bar{\ell}+e'^+}$	×	✓	$2C_3+C_4$	5.53
	15	$(S_1^{\ell}+S_7^{e'^+})+S_7^{\bar{\ell}+e'^+}+(S_7^{\bar{\ell}}+S_1^{e^+})$	×	×	$C_2+C_3+C_4$	
	16	$(S_1^{\ell}+S_7^{e'^+})+(2S_7^{\bar{\ell}}+2S_1^{e^+})$	×	✓	$2C_2+C_4$	4.87
	17	$3S_7^{\bar{\ell}+e'^+}$	✓	×	$3C_3$	5.53
	18	$2S_7^{\bar{\ell}+e'^+}+(S_7^{\bar{\ell}}+S_1^{e^+})$	×	✓	C_2+2C_3	5.53
	19	$S_7^{\bar{\ell}+e'^+}+(2S_7^{\bar{\ell}}+2S_1^{e^+})$	×	✓	$2C_2+C_3$	4.87
	20	$3S_7^{\bar{\ell}}+3S_1^{e^+}$	✓	×	$3C_2$	4.87

LHC constraints

- We report LHC constraints for models with the first two families having SM fermions with identical charges, including some of the classical 3-3-1 models.
- We can see that, independent of the model, the mass value of the new neutral gauge boson for all the 3-3-1 models considered in this paper, is above 4.87 TeV.

Model	SM Particle embedding	Short Notation	LHC - Lower limit in TeV
$C_1 + \bar{q}$	$\ell \subset 3,\ \ e^+ \subset 1,\ \ q \subset 3^*$	$\ell{+}e^+{+}\bar{q}$	5.53
$C_1 + q$	$\ell \subset 3,\ \ e^+ \subset 1,\ \ q \subset 3$	$\ell{+}e^+{+}q$	5.33
$C_2 + \bar{q}$	$\ell \subset 3^*,\ e^+ \subset 1,\ \ q \subset 3^*$	$\bar{\ell}{+}e^+{+}\bar{q}$	4.98
$C_2 + q$	$\ell \subset 3^*,\ e^+ \subset 1,\ \ q \subset 3$	$\bar{\ell}{+}\ e^+{+}q$	4.87
$C_3 + \bar{q}$	$\ell \subset 3^*,\ e^+ \subset 3^*,\ q \subset 3^*$	$\bar{\ell}{+}\ e'^+{+}\bar{q}$	5.75
$C_3 + q$	$\ell \subset 3^*,\ e^+ \subset 3^*,\ q \subset 3$	$\bar{\ell}{+}\ e'^+{+}q$	5.53
$C_4 + \bar{q}$	$\ell \subset 3,\ \ e^+ \subset 3^*,\ q \subset 3^*$	$\ell{+}\ e'^+{+}\bar{q}$	7.00
$C_4 + q$	$\ell \subset 3,\ \ e^+ \subset 3^*,\ q \subset 3$	$\ell{+}\ e'^+{+}q$	6.52

LHC constraints

$$\bar{f} f \rightarrow Z'_\mu$$

$C_1, \quad \ell \subset 3,\ e \subset 1$ (as in S_1)		
Fields	Vectorial	Axial
ν_e	$-\frac{1}{2}\left(\frac{\cos\theta}{\delta} + \sin\theta\right)$	$-\frac{1}{2}\left(\frac{\cos\theta}{\delta} + \sin\theta\right)$
e	$\frac{1}{2}\left[\sin\theta(1 - 4\sin^2\theta_W) - \frac{\cos\theta}{\delta}(1 + 2\sin^2\theta_W)\right]$	$\frac{1}{2}\left[\sin\theta - \frac{\cos\theta}{\delta}(1 - 2\sin^2\theta_W)\right]$

$C_2, \quad \ell \subset 3^*,\ e \subset 1$ (as in S_2)		
Fields	Vectorial	Axial
ν_e	$\frac{\cos\theta}{\delta}\left(\frac{1}{2} - \sin^2\theta_W\right) - \frac{\sin\theta}{2}$	$\frac{\cos\theta}{\delta}\left(\frac{1}{2} - \sin^2\theta_W\right) - \frac{\sin\theta}{2}$
e	$\sin\theta\left(\frac{1}{2} - 2\sin\theta_W^2\right) + \frac{\cos\theta}{\delta}\left(\frac{1}{2} - 2\sin\theta_W^2\right)$	$\frac{1}{2}\left(\frac{\cos\theta}{\delta} + \sin\theta\right)$

$C_3, \quad \ell \subset 3^*,\ e \subset 3^*$ (as in S_7)		
Fields	Vectorial	Axial
ν_e	$\frac{1}{2}\left[\frac{\cos\theta}{\delta}(1 - 2\sin^2\theta_W) - \sin\theta\right]$	$\frac{1}{2}\left[\frac{\cos\theta}{\delta}(1 - 2\sin^2\theta_W) - \sin\theta\right]$
e	$\sin\theta\left(\frac{1}{2} - 2\sin^2\theta_W\right) + \frac{3\cos\theta}{2\delta}(1 - 2\sin^2\theta_W)$	$\frac{1}{2}\left[\sin\theta - \frac{\cos\theta}{\delta}(1 - 2\sin^2\theta_W)\right]$

LHC constraints

$$\bar{f} f \to Z'_\mu$$

$C_4, \quad \ell \subset 3,\ e \subset 3^*$		
Fields	Vectorial	Axial
ν_e	$\frac{1}{2}\left(\sin\theta + \frac{\cos\theta}{\delta}\right)$	$\frac{1}{2}\left(\sin\theta + \frac{\cos\theta}{\delta}\right)$
e	$\frac{1}{2}\left[\sin\theta(1-4\sin^2\theta_W) + \frac{\cos\theta}{\delta}(1-2\sin^2\theta_W)\right]$	$\frac{1}{2}\left[\sin\theta(1-2\sin^2\theta_W) - \frac{3\cos\theta}{\delta}\right]$

$\bar{q}, \quad q \subset 3^*$ (as in S_3)		
Fields	Vectorial	Axial
u	$\frac{1}{6}\left[\sin\theta\left(-3+8\sin^2\theta_W\right) + \frac{\cos\theta}{\delta}\left(3+2\sin^2\theta_W\right)\right]$	$\frac{1}{2}\left[\frac{\cos\theta}{\delta}\left(1-2\sin^2\theta_W\right) - \sin\theta\right]$
d	$\left[\frac{1}{2} - \frac{2}{3}\sin^2\theta_W\right]\left[\sin\theta + \frac{\cos\theta}{\delta}\right]$	$\frac{1}{2}\left[\sin\theta + \frac{\cos\theta}{\delta}\right]$

$q, \quad q \subset 3$ (as in S_4)		
Fields	Vectorial	Axial
u	$\frac{1}{6}\left[\sin\theta\left(-3+8\sin^2\theta_W\right) + \frac{\cos\theta}{\delta}\left(5-8\cos^2\theta_W\right)\right]$	$-\frac{1}{2}\left[\frac{\cos\theta}{\delta} + \sin\theta\right]$
d	$\frac{1}{6}\left[\sin\theta\left(3-4\sin^2\theta_W\right) - \frac{\cos\theta}{\delta}\left(3-2\sin^2\theta_W\right)\right]$	$\frac{1}{2}\left[\sin\theta - \frac{\cos\theta}{\delta}\left(1-2\sin^2\theta_W\right)\right]$

Summary and conclusions

1. We found in a systematic way how anomaly free $SU(3)_c \otimes SU(3)_L \otimes U(1)_x$ models without exotic electric charges can be constructed, using as basis closed sets of fermions which includes each one the particles and antiparticles of all the electrically charged fields.
2. Our analysis reproduced not only the known models in the literature, but also shows the existence of several more independent models for one and three families not considered so far.
3. A phenomenological analysis of the new models was done, where the lowest limits at a 95 % CL on the gauge boson masses were presented. For all the 3-3-1 models considered, the mass value of the new neutral gauge boson is above 4.87 TeV.

THANK YOU!