IFIC/21-0xx

Authors[a],

[a] *Departament de Fìsica Teòrica and Instituto de Física Corpuscular (IFIC), Universitat de València – CSIC, E-46100 Valencia, Spain.*

Abstract

Abstract

Esquema básico

- Motivation: strengthened δa_μ deviation from SM expectation together with two very different δa_e values
- "arguments"
  - simple class of models: 2HDM's with tree level neutral flavour conservation (+CP conservation)
  - reproducing δa_μ alone appears to be feasible in $\mathbb{Z}_2$ models (I, II, X, Y) or in Aligned model, BUT already in conflict with perturbativity since $\frac{n_\tau}{n_\mu} = \frac{m_\tau}{m_\mu}$ in these models
  - next simple model is gℓFC, more parameters and no perturbativity problem, δa_μ and "old" value of δa_e (-8.7×10^{-13}) can be reproduced in certain regions of parameter space
  - one can consider a "new" value of δa_e (4.8×10^{-13}) and an "average" value (-2.0×10^{-13}) in addition to the "old" value: they cover $\pm$ signs and different sizes (a factor $\frac{1}{4}$ between "old" and "average")
  - one can consider different perturbativity assumptions for n_ℓ (relevant for example to analyse if δa_e can be obtained at one loop)
- analyses
  - for 2 different perturbativity assumptions (same bound $\simeq$ 100 GeV as in previous paper, or bound $\simeq$ 246 GeV); it is not just the allowed regions in the different n_ℓ that change, allowed regions in other parameters ALSO CHANGE
  - for 4 different δa_e hypotheses (using the same prescription as in previous paper), "old", "new" "average" and "no constraint on δa_e" (to see the constraints from δa_μ alone)

- "minimal results": updated analysis with results that illustrate that non-SM δa_μ AND δa_e can be obtained for different scenarios concerning δa_e, in different allowed regions of parameter space in each case; impact of perturbativity "tolerance".
- "would be important": further interesting consequences in addition to ILC type results at the end of the previous paper.

Example points

Point	m_{H}	m_{A}	$m_{\mathrm{H}^\pm}$	t_β	$\mathrm{Re}\,(\mu_{12}^2)$	$\mathrm{Re}\,(n_e)$	$\mathrm{Re}\,(n_\mu)$	$\mathrm{Re}\,(n_\tau)$
1	1351	1547	1560	1.34	$-8.49\cdot10^5$	6.08	-95.0	-40.79
2	1522	1567	1485	1.90	$-9.17\cdot10^5$	9.09	-158.9	126.5
3	1049	1322	1332	6.88	$-1.56\cdot10^5$	29.86	-245.0	-75.75
4	663	876	888	11.9	$-3.67\cdot10^4$	22.09	-172.9	224.6
5	621	938	946	21.5	$-1.79\cdot10^4$	54.26	238.1	-74.57
6	350	855	860	22.7	$-5.38\cdot10^3$	17.31	-87.22	94.99
7	372	815	362	34.6	$-3.99\cdot10^3$	25.44	-98.21	85.64
*	360	810	352	186	$-6.99\cdot10^2$	-35.52	97.10	-119.2
8	364	812	355	100	$-1.32\cdot10^3$	46.18	-95.14	79.90
9	1573	1633	1540	1.70	$-9.89\cdot10^5$	-6.40	-130.2	152.6
10	1068	1184	1204	5.73	$-1.93\cdot10^5$	-14.47	-238.6	229.7
11	514	601	625	26.8	$-9.85\cdot10^3$	-23.06	-200.3	51.47
12	540	903	530	238	$-1.22\cdot10^3$	50.83	165.3	-123.1
12	566	919	556	190	$-1.68\cdot10^3$	79.07	171.5	-122.1
13	739	1127	1133	70.4	$-7.75\cdot10^3$	-103.1	230.9	-174.0
14	648	1074	1080	116	$-3.62\cdot10^3$	-58.76	-213.5	-37.76
15	499	885	891	152	$-1.64\cdot10^3$	-32.94	-161.8	-27.75
21	362	775	778	10.7	$-1.19\cdot10^5$	8.16	-72.8	222.5
22	277	494	502	10.8	$-6.6\cdot10^4$	9.12	-58.0	191.2
23	278	539	554	7.9	$-8.9\cdot10^4$	6.71	-53.1	189.7
24	450	790	798	13.6	$-1.47\cdot10^5$	12.7	-104.5	241.5
25	350	611	622	9.7	$-1.16\cdot10^5$	8.9	-71.5	231.2
26	367	810	817	10.8	$-1.23\cdot10^5$	10.3	-72.4	223.5
27	289	448	460	11.7	$-6.59\cdot10^4$	7.7	-68.8	219.0
28	294	538	549	8.5	$-9.05\cdot10^4$	7.4	-63.0	202.0

Table 1: Example points, masses and $\mathrm{Re}\,(n_\ell)$'s in GeV, $\mathrm{Re}\,(\mu_{12}^2)$ in GeV^2.

		1 loop			2 loop					
Point	δa_e	H	A	$H^{\pm}$	tH	tA	τH	τA	μH	μA
1	−7.29	0	0	0	0.469	0.521	−0.012	0.011	−0.003	0.003
2	−7.06	0	0	0	0.445	0.559	0.047	−0.051	−0.007	0.008
3	−8.40	−0.001	0.001	0	0.524	0.526	−0.145	0.113	−0.060	0.044
4	−7.53	−0.002	0.001	0	0.410	0.407	0.764	−0.554	−0.078	0.053
5	−7.12	−0.016	0.007	0	0.627	0.541	−0.734	0.425	0.313	−0.167
6	−6.96	−0.005	0.001	0	0.330	0.186	0.776	−0.207	−0.102	0.024
7	−7.01	−0.009	0.002	0	0.300	0.187	0.926	−0.295	−0.151	0.042
*	−7.06	−0.019	0.004	0	−0.078	−0.049	1.879	−0.574	−0.219	0.058
8	−8.41	−0.027	0.006	0	0.161	0.098	1.352	−0.419	−0.230	0.062
9	5.32	0	0	0	0.448	0.556	0.050	−0.053	−0.005	0.005
10	5.49	0	0	0	0.457	0.535	0.317	−0.305	−0.042	0.038
11	4.11	0.007	−0.005	0	0.432	0.518	0.508	−0.456	−0.270	0.228
12	3.44	0.037	−0.014	0	−0.124	−0.099	2.956	−1.450	−0.539	0.241
12	4.26	0.067	−0.026	−0.001	−0.187	−0.153	3.407	−1.755	−0.647	0.304
13	−1.93	−0.150	0.065	0.001	−1.120	−0.936	8.997	−5.098	−1.566	0.821
14	−0.87	−0.139	0.051	0.001	−0.995	−0.760	3.067	−1.515	2.308	−1.044
15	−0.89	−0.071	0.023	0	−0.543	−0.400	1.911	−0.853	1.529	−0.616
21	−7.24	0.001	0	0	0.307	0.199	0.779	−0.259	0.036	0.011
22	−9.84	−0.001	0	0	0.310	0.258	0.845	−0.388	−0.038	0.015
23	−8.87	−0.001	0	0	0.347	0.264	0.683	−0.271	−0.028	0.010
24	−7.36	−0.001	0	0	0.306	0.235	0.910	−0.416	−0.055	0.023
25	−8.37	−0.001	0	0	0.328	0.265	0.806	−0.377	−0.036	0.015
26	−9.03	−0.001	0	0	0.307	0.191	0.778	−0.245	−0.036	0.010
27	−7.53	−0.001	0	0	0.310	0.291	1.004	−0.578	−0.046	0.024
28	−8.84	−0.001	0	0	0.339	0.271	0.732	−0.319	−0.034	0.013

Table 2: Example points, δa_e values; columns 3 to 11 show the relative contributions of the different 1 and 2 loop terms to the value of δa_e in the second column.

		1 loop			2 loop					
Point	δa_μ	H	A	$H^\pm$	tH	tA	τH	τA	μH	μA
1	2.40	0.085	−0.063	−0.001	0.459	0.511	−0.012	0.011	−0.003	0.003
2	2.58	0.177	−0.162	−0.003	0.439	0.553	0.046	−0.050	−0.007	0.007
3	2.24	0.988	−0.614	−0.012	0.334	0.336	−0.093	0.072	−0.038	0.023
4	2.31	1.124	−0.639	−0.013	0.216	0.215	0.403	−0.292	−0.041	0.028
5	2.41	2.316	−1.024	−0.021	−0.169	−0.145	0.197	−0.114	−0.084	0.045
6	2.51	0.870	−0.157	−0.003	0.095	0.054	0.224	−0.060	−0.030	0.007
7	2.43	1.016	−0.224	−0.024	0.069	0.043	0.213	−0.068	−0.035	0.010
*	2.37	1.081	−0.227	−0.025	−0.013	−0.008	0.317	−0.097	−0.037	0.010
8	2.21	1.093	−0.233	−0.025	0.026	0.016	0.219	−0.068	−0.037	0.010
9	2.26	0.128	−0.115	−0.002	0.443	0.550	0.049	−0.053	−0.005	0.005
10	2.26	0.891	−0.705	−0.013	0.378	0.443	0.262	−0.253	−0.034	0.032
11	2.25	2.487	−1.778	−0.036	0.142	0.170	0.166	−0.149	−0.089	0.075
12	2.37	1.475	−0.538	−0.032	−0.012	−0.010	0.289	−0.142	−0.053	0.024
12	2.22	1.549	−0.598	−0.033	−0.016	−0.013	0.294	−0.151	−0.056	0.026
13	2.205	1.717	−0.747	−0.015	−0.046	−0.038	0.366	−0.207	−0.064	0.033
14	2.49	1.656	−0.615	−0.012	0.026	0.020	−0.080	0.040	−0.061	0.027
15	2.49	1.557	−0.509	−0.010	0.020	0.014	−0.069	0.031	−0.055	0.022
21	2.42	0.588	−0.136	−0.003	0.169	0.110	0.429	0.143	−0.020	0.006
22	2.29	0.651	−0.212	−0.004	0.175	0.146	0.477	−0.219	−0.021	0.009
23	2.35	0.531	−0.147	−0.003	0.214	0.163	0.422	−0.168	−0.018	0.006
24	2.54	0.769	−0.257	−0.005	0.151	0.116	0.448	−0.205	−0.027	0.011
25	2.36	0.623	−0.210	−0.004	0.194	0.157	0.476	−0.223	−0.021	0.009
26	2.38	0.578	−0.126	−0.003	0.169	0.105	0.428	−0.135	−0.020	0.005
27	2.49	0.779	−0.328	−0.007	0.172	0.162	0.558	−0.322	−0.026	0.013
28	2.65	0.597	−0.184	−0.004	0.200	0.160	0.432	−0.189	−0.020	0.008

Table 3: Example points, δa_μ values; columns 3 to 11 show the relative contributions of the different 1 and 2 loop terms to the value of δa_μ in the second column.

		1 loop			2 loop					
Point	δa_τ	H	A	$H^\pm$	tH	tA	τH	τA	μH	μA
21	$1.7 \cdot 10^{-6}$	1.378	-0.329	-0.011	-0.012	-0.008	-0.031	0.010	0.001	0
22	$1.8 \cdot 10^{-6}$	1.583	-0.526	-0.018	-0.013	-0.010	-0.034	0.016	0.001	0
23	$1.9 \cdot 10^{-6}$	1.481	-0.421	-0.014	-0.016	-0.014	-0.032	0.013	0.001	0
24	$1.2 \cdot 10^{-6}$	1.600	-0.543	-0.017	-0.013	-0.010	-0.038	0.017	0.002	0
25	$1.7 \cdot 10^{-6}$	1.617	-0.555	-0.018	-0.015	-0.012	-0.036	0.017	0.002	0
26	$1.7 \cdot 10^{-6}$	1.353	-0.305	-0.010	-0.012	-0.008	-0.031	0.010	0.001	0
27	$1.8 \cdot 10^{-6}$	1.856	-0.790	-0.027	-0.012	-0.012	-0.040	0.023	0.002	0
28	$1.8 \cdot 10^{-6}$	1.551	-0.489	-0.016	-0.016	-0.012	-0.034	0.015	0.001	0

Table 4: Example points, δa_τ values; columns 3 to 11 show the relative contributions of the different 1 and 2 loop terms to the value of δa_τ in the second column.

Point	$S \to$	$e\bar{e}$	$\mu\bar{\mu}$	$\tau\bar{\tau}$	$t\bar{t}$	HZ	AZ	H$^{\pm}W^{\mp}$
1	H	$7 \cdot 10^{-4}$	0.170	0.031	0.797	–	0	0
	A	$6 \cdot 10^{-4}$	0.134	0.025	0.678	0.163	–	0
2	H	0.001	0.400	0.253	0.345	–	0	0
	A	0.001	0.393	0.249	0.357	0	–	10^{-4}
3	H	0.013	0.881	0.084	0.022	–	0	0
	A	0.008	0.570	0.054	0.016	0.351	–	0
4	H	0.006	0.368	0.621	0.005	–	0	0
	A	0.005	0.289	0.488	0.005	0.213	–	0
5	H	0.045	0.868	0.085	0.002	–	0	0
	A	0.022	0.424	0.042	0.001	0.511	–	0
6	H	0.018	0.449	0.533	$2 \cdot 10^{-4}$	–	0	0
	A	0.001	0.035	0.042	$7 \cdot 10^{-4}$	0.921	–	0
7	H	0.037	0.547	0.416	$3 \cdot 10^{-4}$	–	0	0
	A	0.002	0.029	0.022	$2 \cdot 10^{-4}$	0.460	–	0.487
*	H	0.051	0.379	0.571	$4 \cdot 10^{-6}$	–	0	0
	A	0.004	0.027	0.041	$6 \cdot 10^{-6}$	0.452	–	0.477
8	H	0.121	0.515	0.363	$3 \cdot 10^{-5}$	–	0	0
	A	0.006	0.027	0.019	$2 \cdot 10^{-5}$	0.461	–	0.487
9	H	$6 \cdot 10^{-4}$	0.250	0.344	0.405	–	0	0
	A	$6 \cdot 10^{-4}$	0.244	0.336	0.415	0	–	0.003
10	H	0.002	0.508	0.471	0.020	–	0	0
	A	0.002	0.502	0.465	0.022	0.010	–	0
11	H	0.012	0.926	0.061	0.001	–	0	0
	A	0.012	0.924	0.061	0.002	0	–	0
12	H	0.124	0.582	0.295	$2 \cdot 10^{-5}$	–	0	0
	A	0.026	0.122	0.062	$9 \cdot 10^{-6}$	0.377	–	0.412
13	H	0.113	0.566	0.321	10^{-4}	–	0	0
	A	0.053	0.264	0.150	$8 \cdot 10^{-5}$	0.533	–	0
14	H	0.068	0.903	0.028	$8 \cdot 10^{-5}$	–	0	0
	A	0.018	0.242	0.008	$3 \cdot 10^{-5}$	0.732	–	0
15	H	0.039	0.934	0.027	$5 \cdot 10^{-5}$	–	0	0
	A	0.008	0.185	0.005	$2 \cdot 10^{-5}$	0.802	–	0

Table 5: Example points, decay branching ratios of H, A.

Point	$S \to$	$e\bar{e}$	$\mu\bar{\mu}$	$\tau\bar{\tau}$	$t\bar{t}$	HZ	AZ	$\text{H}^{\pm}W^{\mp}$
21	H	$1.2 \cdot 10^{-3}$	0.096	0.902	$7 \cdot 10^{-4}$	–	0	0
	A	$3.6 \cdot 10^{-4}$	0.028	0.265	0.0036	0.703	–	0
22	H	0.0021	0.084	0.9138	0	–	0	0
	A	0.0012	0.0486	0.5280	0.0076	0.4146	–	0
23	H	0.0011	0.0727	0.9261	0	–	0	0
	A	0.0005	0.0326	0.4152	0.0121	0.5396	–	0
24	H	0.0023	0.1569	0.8388	0.00195	–	0	0
	A	0.001	0.07	0.3759	0.0027	0.550	–	0
25	H	0.0013	0.0872	0.9111	0.0003	–	0	0
	A	0.00075	0.0484	0.5062	0.0071	0.4375	–	0
26	H	0.0019	0.0946	0.9026	0.00086	–	0	0
	A	0.0005	0.0251	0.2393	0.0032	0.7319	–	0
27	H	0.0011	0.0897	0.9092	0	–	0	0
	A	0.0009	0.0740	0.750	0.0064	0.1686	–	0
28	H	0.0012	0.0886	0.910	0	–	0	0
	A	0.0006	0.047	0.479	0.011	0.463	–	0

Table 6: Example points, decay branching ratios of H, A.

Point	$S \to$	$\mu\bar{\mu}$	$\sigma^{\mu}_{\text{Obs}}$	$\tau\bar{\tau}$	$\sigma^{\tau}_{\text{Exp}}$	$\sigma^{\tau}_{\text{Obs}}$
21	H	8.94	9.52	83.6	54.9	106.1
	A	0.16	2.8	1.50	3.25	3.25
22	H	7.72	15.3	83.9	136.3	164.0
	A	2.51	5.9	27.3	20.8	50.6
23	H	12.6	15.2	160.0	135.3	164.0
	A	2.16	5.0	27.6	17.7	35.4
24	H	5.77	6.5	30.8	27.8	65.3
	A	0.22	2.7	1.17	2.9	2.9
25	H	9.44	10.0	98.7	59.9	113.6
	A	1.16	4.0	12.2	13.6	13.6
26	H	8.70	9.3	83.0	52.8	102.9
	A	0.107	2.5	1.026	2.70	2.70
27	H	6.78	14.1	68.7	124.5	164.5
	A	4.87	6.56	49.3	28.3	66.0
28	H	12.3	13.6	126.4	119.6	164.6
	A	2.71	5.0	27.8	17.7	35.7

Table 7: Example points, $\sigma([pp]_{\text{ggF}} \to S \to \ell\bar{\ell})$ (fb), $S = \text{H, A}$; $\sigma^{\mu}_{\text{Obs}}$ (fb) is the observed bound on $\sigma([pp]_{\text{ggF}} \to S \to \mu\bar{\mu})$, $\sigma^{\tau}_{\text{Exp}}$ (fb) is the expected bound and $\sigma^{\tau}_{\text{Obs}}$ (fb) is the observed bound on $\sigma([pp]_{\text{ggF}} \to S \to \tau\bar{\tau})$.

Point	$e\bar{\nu}$	$\mu\bar{\nu}$	$\tau\bar{\nu}$	$b\bar{t}$	HW^-
1	$5 \cdot 10^{-4}$	0.126	0.023	0.640	0.209
2	0.001	0.393	0.249	0.356	0
3	0.008	0.542	0.051	0.015	0.383
4	0.004	0.274	0.462	0.005	0.254
5	0.021	0.405	0.040	0.001	0.533
6	0.001	0.034	0.041	0.001	0.923
7	0.037	0.546	0.415	0.002	0
*	0.051	0.379	0.571	$6 \cdot 10^{-5}$	0
8	0.121	0.515	0.363	$3 \cdot 10^{-4}$	0
9	$6 \cdot 10^{-4}$	0.245	0.337	0.416	0
10	0.002	0.490	0.454	0.021	0.032
11	0.012	0.882	0.058	0.002	0.046
12	0.124	0.582	0.295	$4 \cdot 10^{-5}$	0
13	0.051	0.256	0.145	$8 \cdot 10^{-5}$	0.547
14	0.018	0.233	0.007	$3 \cdot 10^{-5}$	0.742
15	0.007	0.177	0.005	$2 \cdot 10^{-5}$	0.811
21	$3.5 \cdot 10^{-4}$	0.0276	0.2578	0.0035	0.7107
22	0.0011	0.0452	0.4913	0.00762·	0.4548
23	0.00047	0.0295	0.3755	0.01157	0.5829
24	0.0010	0.067	0.360	0.0026	0.569
25	0.0007	0.0453	0.4739	0.0068	0.4733
26	0.0005	0.0241	0.2305	0.0031	0.7418
27	0.0009	0.0686	0.6957	0.0067	0.2281
28	0.0006	0.043	0.444	0.010	0.502

Table 8: Example points, decay branching ratios $H^{\pm}$.