Branon Phenomenology

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In brane-world models with low tension, the fluctuations of the brane along the extra dimensions (branons) are the only relevant new low-energy modes. Such branon fields are in general massive, stable and weakly interacting, and accordingly they are natural candidates to explain the universe missing mass problem. On the other hand, the branon phenomenology is very rich because they couple to all the Standard Model particles. Distinctive branon signals could be observed in next colliders and in dark matter searches.

1. INTRODUCTION

In flexible brane-world (BW) models, branons are the only new relevant low-energy particles [1, 2]. The SM-branon low-energy effective Lagrangian reads [1, 3, 4]:

$$\mathcal{L}_{Br} \;=\; \frac{1}{2}g^{\mu\nu}\partial_\mu\pi^\alpha\partial_\nu\pi^\alpha - \frac{1}{2}M^2\pi^\alpha\pi^\alpha\frac{1}{8f^4}(4\partial_\mu\pi^\alpha\partial_\nu\pi^\alpha - M^2\pi^\alpha\pi^\alpha g_{\mu\nu})T^{\mu\nu}\,. \tag{1}$$

Branons interact by pairs with the SM energy-momentum tensor $T^{\mu\nu}$, and their couplings are suppressed by the brane tension f^4. In fact, they are generically stable and weakly interacting. These features make them natural dark matter [5, 6] candidates. On the other hand, the branon phenomenology is very rich since they are coupled with the entire SM. The branon signals can be characterized by their number N, the brane tension scale f, and their masses M. For example, from the effective action given in Equation (1), one can calculate the relevant cross-sections for different branon searches in colliders (see Table I and References [4, 7, 8]).

Experiment	$\sqrt{s}$(TeV)	$\mathcal{L}(\mathrm{pb}^{-1})$	f_0(GeV)	M_0(GeV)
HERA [1]	0.3	110	16	152
Tevatron-I [1]	1.8	78	157	822
Tevatron-I [2]	1.8	87	148	872
LEP-II [2]	0.2	600	180	103
Tevatron-II [1]	2.0	10^3	256	902
Tevatron-II [2]	2.0	10^3	240	952
ILC [2]	0.5	2×10^5	400	250
LHC [1]	14	10^5	1075	6481
LHC [2]	14	10^5	797	6781
CLIC [2]	5	10^6	2640	2500

Table I: Summary of the main analysis related to direct branon searches in collider experiments. All the results are performed at the 95 % c.l. Two different channels have been studied: the one marked with an upper index [1] is related to monojet production, whereas the single photon is labelled with an upper index [2]. The table contains seven experiments: HERA, LEP-II, the I and II Tevatron runs, ILC, LHC and CLIC. The data corresponding to the four last experiments are estimations, whereas the first three analysis have been performed with real data. $\sqrt{s}$ is the center of mass energy associated to the total process; $\mathcal{L}$ is the total integrated luminosity; f_0, the bound in the brane tension scale for one massless branon ($N = 1$) and M_0 the limit on the branon mass for small tension $f \to 0$.

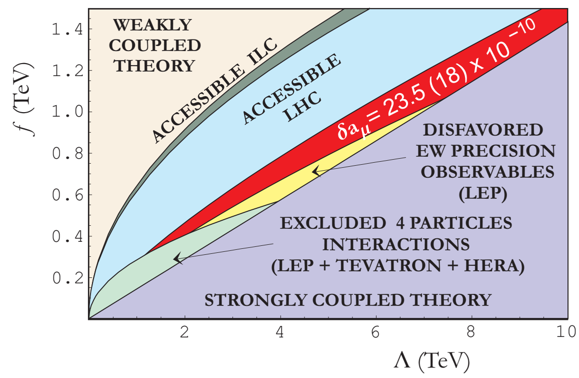

Figure 1: Main limits from branon radiative corrections in the $f-\Lambda$ plane for a model with $N=1$. The (red) central area shows the region in which the branons account for the muon magnetic moment deficit observed by the E821 Collaboration [11], and at the same time, are consistent with present collider experiments (whose main constraint comes from the Bhabha scattering at LEP) and electroweak precision observables. Prospects for future colliders are also plotted.

2. RADIATIVE CORRECTIONS

In addition to the corresponding missing energy signatures, branons can also give rise to new effects through radiative corrections. By integrating out the branon fields in the action coming from $\mathcal{L}_{Br}$ it is possible to obtain an effective action for the SM particles [9, 10] whose more relevant terms are:

$$\mathcal{L}^{(1)}_{SM} \simeq \frac{N\Lambda^4}{192(4\pi)^2 f^8}\left\{2T_{\mu\nu}T^{\mu\nu}+T^{\mu}_{\mu}T^{\nu}_{\nu}\right\} . \quad (2)$$

Experiment	$\sqrt{s}$ (TeV)	$\mathcal{L}$ (pb^{-1})	$f^2/(N^{1/4}\Lambda)$ (GeV)
HERA ^{c}	0.3	117	52
Tevatron-I $^{a,\,b}$	1.8	127	69
LEP-II ^{a}	0.2	700	59
LEP-II ^{b}	0.2	700	75
Tevatron-II $^{a,\,b}$	2.0	2×10^3	83
ILC ^{b}	0.5	5×10^5	261
ILC ^{b}	1.0	2×10^5	421
LHC ^{b}	14	10^5	383

Table II: Limits from virtual branon searches at colliders (results at the 95 % c.l.) The indices ^{a,b,c} denote the two-photon, e^+e^- and e^+p (e^-p) channels respectively. The first four analysis have been performed with real data, whereas the final four are estimations. The first two columns are the same as in Table I, and the third one corresponds to the lower bound on $f^2/(N^{1/4}\Lambda)$.

Λ being the cutoff setting the limit of validity on the effective description of branon and SM dynamics used here. This new parameter appears when dealing with branon radiative corrections since the lagrangian in (1) is not renormalizable. The most relevant contribution of branon radiative correction at one loop is the modification of four-fermion interactions and fermion pair annihilation into two gauge bosons (see Table II). In addition , electroweak precision observables and the μ anomalous magnetic moment are corrected at two loops. In [9] has been shown that branons can explain the magnetic moment deficit of the muon found by the 821 Collaboration at the Brookhaven Alternating Gradient Syncrotron [11] and be consistent with the rest of measurements (See Figure 1). But it is more remarkable that the same parameter space which improve the fit of $g_\mu-2$ is able to explain the DM content of the Universe. In fact, if the branon mass is of the order of the electroweak scale, or more precisely, if the branon mass

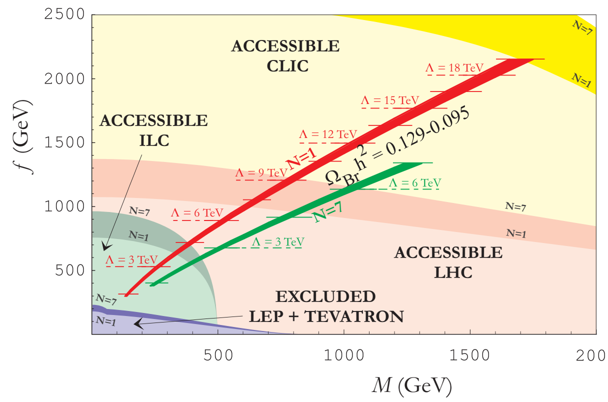

Figure 2: Branon abundance in the range: $\Omega_{Br}h^2 = 0.129 - 0.095$, in the $f - M$ plane (see [5] for details). The regions are only plotted for the preferred values of the brane tension scale f. The central values of Λ from [11] are also plotted. The lower area is excluded by single-photon processes at LEP-II and monojet signals at Tevatron-I [4]. The sensitivity of future collider searches for real branon production are also plotted (See [4] and Table I). The dependence on the number of branons in the range $N = 1 - 7$ can also be observed.

is between $M \sim 100$ GeV and $M \sim 1.7$ TeV, branons could form the total non baryonic DM abundance observed by WMAP [5] (see Figure 2).

Acknowledgments

JARC acknowledges the hospitality and collaboration of workshop organizers and conveners, and economical support from the NSF and Fulbright OLP. This work is supported in part by DGICYT (Spain) under project numbers FPA 2004-02602 and FPA 2005-02327, by NSF grant No. PHY–0239817 and by the Fulbright-MEC (Spain) program.

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