TAsP: Theoretical Astroparticle Physics

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Main scientific activities and achievements during the year 2016.

Dark matter: The nature of dark matter (DM) is one of the most compelling questions in particle physics, and is an active topic of research in our group. If DM corresponds to a fundamental particle, it must be stable on the time scale of the Universe lifetime. $SO(10)$ grand unified theories can ensure the stability of new particles in terms of the gauge group structure, and in this respect are well suited to accommodate DM candidates. We have studied for the first time, as DM candidates, fermions transforming in the fundamental representation of $SO(10)$) [1] showing that, contrary to common expectations, this type of DM can have easily escaped all current direct detection searches.

Quasi Dirac neutrinos: Lepton number violation is searched for at the LHC using same-sign leptons plus jets. The standard lore is that the ratio of same-sign lepton to opposite-sign lepton events, R_{ll}, is equal to $R_{ll} = 1$ ($R_{ll} = 0$) for Majorana (Dirac) neutrinos. We have shown that for "quasi-Dirac" neutrinos, R_{ll} can have any value between 0 and 1, the precise value being controlled by the mass splitting versus the width of the quasi-Dirac resonances [2]. A measurement of $R_{ll} \neq 0, 1$ would then contain valuable information about the origin of neutrino masses. We have considered as an example the inverse seesaw mechanism in a left-right symmetric scenario, which is phenomenologically particularly interesting since all the heavy states in the high energy completion of the model could be within experimental reach. We have worked out as a prediction, a correlation between the values of R_{ll} and the ratio between the rates for heavy neutrino decays into W_L and Z bosons, and into three body final states ljj mediated by off-shell W_R exchange.

Where to search for axions: A major goal of axion searches is to reach inside the parameter space region of realistic axion models. The boundaries of this region where previously defined in terms of somewhat arbitrary criteria. We have proposed a new definition based on precise phenomenological requirements [3]. Considering hadronic axion models, we have classified the representations R_Q of the new heavy quarks Q, by requiring that *(i)* Q's are sufficiently short lived to avoid issues with long lived strongly interacting relics, *(ii)* no Landau poles are induced below the Planck scale. We have identified fifteen cases, which define a phenomenologically preferred axion window bounded by a maximum (minimum) value of the axion-photon coupling about twice (four times) larger than commonly assumed. This article has been highlighted by Physical Review Letter as Editors choice.

B-decay anomalies: A gauge extension of the Standard Model based on the extended gauge group $SU(2)_1 \times SU(2)_2 \times U(1)_Y$, broken spontaneously around the TeV scale to the electroweak gauge group, has been proposed as a way to alleviate the tensions in B-physics data, and in particular the hints of lepton universality violation in $b \to c\ell\nu$ and $b \to s\ell^+\ell^-$ decays reported by BaBar, Belle and LHCb [4]. Various properties of this model have been investigated further in ref. [5].

Neutrino mass models: A minimal model that can explain the generation of neutrino masses, and at the same time can account for the origin of dark matter, was proposed in ref. [6].

The LHC diphoton excess: A model for explaining the diphoton excess at 750 GeV reported at the end of year 2015 by the ATLAS and CMS collaborations (but now disappeared) has been put forth in ref. [7].

Publications

1 Dark matter from the vector of SO (10)
Sofiane M. Boucenna, Martin B. Krauss, Enrico Nardi (Frascati).
Published in Phys.Lett. B755 (2016) 168-176.

2 Quasi-Dirac neutrinos at the LHC
G. Anamiati, M. Hirsch (Valencia U., IFIC), E. Nardi (Frascati).
Published in JHEP 1610 (2016) 010.

3 Redefining the Axion Window
Luca Di Luzio (Durham U., IPPP & Durham U.), Federico Mescia (ICC, Barcelona U.), Enrico Nardi (Frascati).
Published in Phys.Rev.Lett. 118 (2017) no.3, 031801.

4 Phenomenology of an $SU(2) \times SU(2) \times U(1)$ model with lepton-flavour non-universality
Sofiane M. Boucenna (Frascati), Alejandro Celis (Munich U.), Javier Fuentes-Martin, Avelino Vicente (Valencia U., IFIC), Javier Virto (U. Bern, AEC).
Published in JHEP 1612 (2016) 059.

5 Non-abelian gauge extensions for B-decay anomalies
Sofiane M. Boucenna (Frascati), Alejandro Celis (Munich U.), Javier Fuentes-Martin, Avelino Vicente (Valencia U., IFIC)
Published in Phys.Lett. B760 (2016) 214-219.

6 Dark Radiative Inverse Seesaw Mechanism
Amine Ahriche (Constantine U. & Taiwan, Natl. Taiwan U.), Sofiane M. Boucenna (Frascati), Salah Nasri (United Arab Emirates U.).
Published in Phys.Rev. D93 (2016) no.7, 075036.

7 The LHC diphoton resonance from gauge symmetry
S. M. Boucenna (Frascati), S. Morisi (INFN, Naples & Naples U.), Avelino Vicente (Valencia U., IFIC).
Published in Phys.Rev. D93 (2016) no.11, 115008.

Editorial Work

1 Proceedings: *5th Young Researchers Workshop: Physics Challenges in the LHC Era*, Frascati, Rome, Italy, May 9-13, 2016.
Editor: Enrico Nardi
Published in Frascati Phys.Ser. 63 (2016) pp.1-60
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