RESUME

Subhaditya Bhattacharya

Department of Physics and Astronomy
University of California, Riverside, USA
subhab@ucr.edu

WORKS DONE SO FAR

- Worked in the non-Abelian discrete symmetry D7 of the heptagon. This is successfully applied to both quark and lepton mass matrices, including CP violation. The CP violating parameter J in the quark sector is constrained in this model by m_d, m_s, m_b, $|V_{us}|$, $|V_{ub}|$, $|V_{cb}|$. Within one standard deviation of all six measurements, we obtain J in agreement with data. In the neutrino sector, we obtain $|m_{1,2}|$ as well as $|m_3| = m_{ee}$ as functions of $\sin^2(2\theta_{23})$ and also predict $\sin\delta_{CP}$ as a function of $\sin^2(2\theta_{23})$.

  –Reference: Subhaditya Bhattacharya, Ernest Ma, Alexander Natale, and Daniel Wegman, e-Print: arXiv:1210.6936 [hep-ph].

- Worked in effective field theory operators that can yield lepton number violation involving leptons and gauge bosons that can yield a large amount of neutrinoless double beta decay within the experimental limit. Neutrinoless double beta ($0\nu\beta\beta$) decay can in general produce electrons of either chirality, in contrast with the minimal Standard Model (SM) extension with only the addition of the Weinberg operator, which predicts two left-handed electrons in the final state. We classify the lepton number violating (LNV) effective operators with two leptons of either chirality but no quarks. We point out that, for each of the three chirality assignments, e_Le_L, e_Le_R and e_Re_R, there is only one LNV operator of the corresponding type to lowest order, and these have dimensions 5, 7 and 9, respectively. Neutrino masses are always induced by these extra operators but can be delayed to one or two loops, depending on the number of RH leptons entering in the operator. Then, the comparison of the $0\nu\beta\beta$ decay rate and neutrino masses should indicate the effective scenario at work, which confronted with the LHC searches should also eventually decide on the specific model elected by nature. We also list the SM additions generating these operators upon integration of the heavy modes, and discuss simple realistic examples of renormalizable theories for each case.

  –Reference: Francisco del Aguila, Alberto Aparici, Subhaditya Bhattacharya, Arcadi Santamaria, Jose Wudka, JHEP 1206 (2012) 146, e-Print: arXiv:1111.6960 [hep-ph]

- Worked in a realistic model of neutrino masses that yield large Neutrinoless double beta ($0\nu\beta\beta$) decay rate. The minimal Standard Model extension with the Weinberg operator does accommodate the observed neutrino masses and mixing, but predicts a neutrinoless double beta ($0\nu\beta\beta$) decay rate proportional to the effective electron neutrino mass, which can be then arbitrarily small within present experimental limits. However, in general $0\nu\beta\beta$ decay can have an independent origin and be near its present experimental bound; whereas neutrino masses are generated radiatively, contributing negligibly to $0\nu\beta\beta$ decay. We provide a realization of this scenario in a simple, well defined and testable model, with potential

LHC effects and calculable neutrino masses, whose two- loop expression we derive exactly. We also discuss the connection of this model to others that have appeared in the literature, and remark on the significant differences that result from various choices of quantum number assignments and symmetry assumptions. In this type of models lepton flavor violating rates are also preferred to be relatively large, at the reach of foreseen experiments. Interestingly enough, in our model this stands for a large third mixing angle,$\sin^2(2\theta_{23}) > 0.008$, when $\mu \to eee$ is required to lie below its present experimental limit.

–Reference: Francisco del Aguila, Alberto Aparici, Subhaditya Bhattacharya, Arcadi Santamaria, Jose Wudka, JHEP 1205 (2012) 133, e-Print: arXiv:1111.6960 [hep-ph]

- In a Standard Model (SM) extension with additional SU(2), where the gauge bosons are neutral, the lightest one can serve as a dark matter candidate with a global U(1) symmetry imposed (this serves as a modified R-parity). We explore such a dark-vector-gauge boson model to find a consistent region of parameter space allowed by the WMAP constraints on relic abundance and direct detection. This indicates that the dark matter can be as heavy as 1TeV. We see that a signature in opposite sign dilepton associated with a single jet and large missing energy can be explored to discover such a model at the on-going LHC.

  –Reference: Subhaditya Bhattacharya, J.Lorenzo Diaz-Cruz, Ernest Ma, Daniel Wegman, Phys.Rev. D85 (2012) 055008, e-Print: arXiv:1107.2093 [hep-ph]

- We discuss large non-universality in the Higgs sector at high scale in supersymmetric theories, in the context of the Large Hadron Collider (LHC). In particular, we note that if ${m_{H_u}}^2 - {m_{H_d}}^2$ is large and negative ($\simeq 10^6$ GeV^2) at high scale, the lighter slepton mass eigenstates at the electroweak scale are mostly left chiral, in contrast to a minimal supergravity (mSUGRA) scenario. We use this feature to distinguish between non-universal Higgs masses (NUHM) and mSUGRA by two methods. First, we study final states with same-sign ditaus. We find that an asymmetry parameter reflecting the polarization of the taus provides a notable distinction. In addition, we study a charge asymmetry in the jet-lepton invariant mass distribution, arising from decay chains of left-chiral squarks leading to leptons of the first two families, which sets apart an NUHM scenario of the above kind.

  –Reference: Subhaditya Bhattacharya, (UC, Riverside) , Sanjoy Biswas, Biswarup Mukhopadhyaya, (Harish-Chandra Res. Inst.) , Mihoko M. Nojiri, JHEP 1202:104,2012; e-Print: arXiv:1105.3097 [hep-ph]

- Our aim in this work was to find a scenario within the gravity mediated SUSY breaking (SUGRA) framework and select a class of final states that warrant a discovery at the very early runs of the LHC. It turns out that such a situation can be associated with a scenario where gluinos are sufficiently light and so are the third generation scalars while the first two family scalars are heavy. We find that this can be achieved from a high-scale set-up with scalar mass non-universality in the third family and gaugino mass non-universality with $M_3 < M_1, M_2$. We show that the final state channels which are most favorable in such a region of parameter space are $4b + \not{E_T}$, $4b + \ell + \not{E_T}$ and $2b + 2\ell + \not{E_T}$. We also justified our claim by comparing the results with a minimal supergravity (mSUGRA) scenario with similar gluino mass. But the benchmark points have already been discarded by now.

  –Reference: Subhaditya Bhattacharya, S. Nandi, e-Print: arXiv:1101.3301 [hep-ph]

- We discussed the signals at the Large Hadron Collider (LHC) for scenarios with non-universal gaugino masses in supersymmetric (SUSY) theories. We perform a

multichannel analysis, and consider the ratios of event rates in different channels such as $jets + \not{E}_T$, *same* - and *opposite-sign dileptons* $+jets + \not{E}_T$, as well as $single - lepton$ and *trilepton* final states together with $jets + \not{E}_T$. Low-energy SUSY spectra corresponding to high-scale gaugino non-universality arising from different breaking schemes of SU(5) as well as SO(10) Grand Unified (GUT) SUSY models are considered, with both degenerate low-energy sfermion masses and those arising from a supergravity scenario. Certain broad features emerge from the study, which may be useful in identifying the signatures of different GUT breaking schemes and distinguishing them from a situation with a universal gaugino mass at high scale. The absolute values of the predicted event rates for different scenarios are presented together with the various event ratios, so that these can also be used whenever necessary.

–Reference: Subhaditya Bhattacharya, AseshKrishna Datta, Biswarup Mukho padhyaya, JHEP 0710:080,2007, arXiv:0708.2427 [hep-ph].

- We studied possible signatures of non-universal scalar masses in supersymmetry at the Large Hadron Collider (LHC). This is done, via multichannel analysis, based largely on the ratios of event rates for different final states, aimed at minimizing irregularity in the pattern due to extraneous effects and errors. We studied (a) squark-slepton non-universality, (b) non-universality in sfermion masses of the third family, (c) the effects of $SO(10)$ D-terms in supersymmetric Grand Unified Theories. After presenting an elaborate numerical analysis of like- and opposite-sign dileptons, inclusive and hadronically quiet trileptons as well as inclusive jet final states, we point out specific features of the spectrum in each case, which can be differentiated in the above channels from the spectrum for a minimal supergravity scenario with a universal scalar mass at high scale. The event selection criteria, and the situations where the signals are sizable enough for a comparatve study, are also delineated. It is found that, with some exceptions, the trilepton channels are likely to be especially useful for this purpose.

  –Reference: Subhaditya Bhattacharya, AseshKrishna Datta, Biswarup Mukho padhyaya, Phys.Rev.D78:035011,2008, arXiv:0804.4051 [hep-ph].

- We investigate the parameter space of the minimal supersymmetric Standard Model (MSSM) where the gluino and squark masses are much above 1 TeV but the remaining part of the sparticle spectrum is accessible to the Large Hadron Collider at CERN. After pointing out that such a scenario may constitute an important benchmark of gaugino/scalar non-universality, we find that hadronically quiet trileptons are rather useful signals for it. Regions of the parameter space, where the signal is likely to be appreciable, are identified through a detailed scan. The advantage of hadronically quiet trileptons over other types of signals is demonstrated. After LHC data, this region of SUSY parameter space is perhaps most relevant now.

  –Reference: Subhaditya Bhattacharya, AseshKrishna Datta, Biswarup Mukho padhyaya, Phys.Rev.D78:115018,2008, arXiv:0809.2012 [hep-ph].

- We derive the non-universal gaugino mass ratios in a supergravity (SUGRA) framework where the Higgs superfields belong to the non-singlet representations **54** and **770** in a $SO(10)$ Grand Unified Theory (GUT). We evaluate the ratios for the phenomenologically viable intermediate breaking chain $SU(4)_C \times SU(2)_L \times SU(2)_R$ (G_{422}). After a full calculation of the gaugino mass ratios, noting some errors in the earlier calculation for **54**, we obtain, using the renormalisation group equations (RGE), interesting low scale phenomenology of such breaking patterns. Here, we assume the breaking of the $SO(10)$ GUT group to the intermediate gauge group and that to the Standard Model (SM) take place at the GUT scale itself. We also study the collider signatures in multilepton channels at the Large

Hadron Collider (LHC) for some selected benchmark points allowed by the cold dark matter relic density constraint provided by the WMAP data and compare these results with the minimal supergravity (mSUGRA) framework with similar gluino masses indicating their distinguishability in this regard.

–Reference: Subhaditya Bhattacharya, Joydeep Chakrabortty, Phys.Rev. D81:015007,2010, arXiv:0903.4196 [hep-ph].

- We performed a multilepton channel analysis in the context of the Large Hadron Collider (LHC) for WMAP compatible points in a model with non- universal scalar masses, which admits a Higgs funnel region of SUSY dark matter even for a small $\tan\beta$. In addition to two and three-lepton final states, four-lepton events, too, are shown to be useful for this purpose. We also compare the collider signatures in similar channels for WMAP compatible points in the minimal supergravity (mSUGRA) framework with similar gluino masses. Some definite features of such non-universal scenario emerge from the analysis.

  –Reference: Subhaditya Bhattacharya, Utpal Chattopadhyay, Debajyoti Choudhury, Debottam Das, Biswarup Mukhopadhyaya, Phys.Rev.D8:075009, 2010, arXiv:0907.3428 [hep-ph].

- We investigated the possibility of unitarity violation in the sequential neutrino mixing matrix in a scenario with extra compact spacelike dimensions. Gauge singlet neutrinos are assumed to propagate in one extra dimension, giving rise to an infinite tower of states in the effective four-dimensional theory. It is shown that this leads to small lepton-number violating entries in the neutrino mass matrix, which can violate unitarity on the order of one per cent.

  –Reference: Subhaditya Bhattacharya, Paramita Dey, Biswarup Mukhopadhyaya, Phys.Rev.D80: 075013,2009, arXiv:0907.0099 [hep-ph].

WORKS IN PROGRESS

- Work in progress to find a minimal extension of Standard Model with Dual dark matter. We have a simple model with singlet scalars and fermions with $Z_2 \times Z_2^{'}$ symmetry to accommodate them in a two-component dark matter scenario. The standard approximations to obtain relic density fails to describe the case and numerical solutions to Boltzman Equations is essential. We show that a large parameter space is allowed by WMAP constraints, while a some region near the resonance can satisfy constraints from direct detection by XENON 100.

  –Reference: Subhaditya Bhattacharya, Aleksandra Drozd, Bohdan Grzadkowski, Jose Wudka; to be submitted soon.

- Work in progress to show some nice signals of a warm dark matter model with left-right symmetry at LHC. 'Scotino', the warm dark matter candidate can be produced at LHC in a decay of exotic quark production, which ends up with a dilepton channel with jets and missing energy. We put a bound on the exotic quark masses from the present LHC data and predict discovery potential in the future run.

  –Reference: Subhaditya Bhattacharya, Ernest Ma, Daniel Wegman; to be submitted soon.

- Work in progress where we constrain the parameter space of the models providing large neutrinoless double beta ($0\nu\beta\beta$) decay rate from the recent measurements of Higgs to two photon decay width at LHC. We also study possible collider signatures of these models at LHC.

  –Reference: Francisco del Aguila, Alberto Aparici, Subhaditya Bhattacharya, Arcadi Santamaria, Jose Wudka; to be submitted soon.

- Multicomponent Dark Matter appears in Supersymmetric left-right models. Apart from the lightest neutralino, 'scotino' and an exotic scalar can co-exist as dark

matter. Work in progress to show the region of parameter space allowed by dark matter constraints. This also alleviates the tension of neutralino dark matter in MSSM.

–*Reference: Subhaditya Bhattacharya, Ernest Ma, Daniel Wegman.*

INTERESTS
FUTURE PLANS
IMPORTANCE

- We are working on models with additional scalars, the ones that produce large neutrinoless double beta decay. Higgs to two photon width at LHC constrains the parameter space of such models to a large extent. On the other hand, this sharpens the prediction in neutrino sector. While finishing the work on the specific model(s), we plan to take up a comparative study and see if we can conclude something more general. We are also looking for possible signatures of such new physics models at the LHC.
- Vector boson can be a dark matter candidate with a simple extension of the SM gauge group and leave imprints at the LHC. There are some other models with similar features. We plan to perform a generalized analysis to compare different dark-matter scenarios in terms of their signatures at the LHC.
- Multi-component dark matter has not been studied very extensively. A minimal extension with scalars and fermionic dark matter show that they satisfy all the constraints. It is important to study other possible extensions and do a comparative analysis in terms of dark matter constraints and LHC signatures. Left right supersymmetric models also predict multicomponent dark matter. A comparison of the allowed parameter space for such models with MSSM is important.
- LHC has left a very small allowed parameter space for the so-called CMSSM or mSUGRA. So, it is even more important to look for alternative supersymmetric scenarios that might have escaped detection and has a possibility of getting discovered at the future run of LHC. With some expertise of non-universal SUGRA models, I plan to study some of their possibilities at the present scenario.

CONTACT (Office) +1 951 827 2151
(Mobile) +1 951 824 0316
subhab@ucr.edu and subhaditya123@gmail.com