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Book of abstracts

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Metastable dark energy

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We build a model of metastable dark energy, in which the observed vacuum energy is the value of the scalar potential at the false vacuum. The scalar potential is given by a sum of even self-interactions up to order six. The deviation from the Minkowski vacuum is due to a term suppressed by the Planck scale. The decay time of the metastable vacuum can easily accommodate a mean life time compatible with the age of the universe. The metastable dark energy is also embedded into a model with SU(2)R symmetry. The dark energy doublet and the dark matter doublet naturally interact with each other. A three-body decay of the dark energy particle into (cold and warm) dark matter can be as long as large fraction of the age of the universe, if the mediator is massive enough, the lower bound being at intermediate energy level some orders below the grand unification scale. Such a decay shows a different form of interaction between dark matter and dark energy, and the model opens a new window to investigate the dark sector from the point-of-view of particle physics.

Plenary 7 / 5

Radiative SM Yukawas from dark dynamics

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I discuss how the observed hierarchy in the Standard Model Yukawa couplings may radiatively originate from the dark sector dynamics. The associated dark interactions and the mediator sector that transfers the dark mass hierarchy to the Standard Model Yukawa sector offer distinguishing experimental tests at high and low energy experiments.

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Gauged Lepton Flavour

Mr. QUÍLEZ LASANTA, Pablo [1]; Prof. GAVELA, Belen [2]; Dr. ALONSO, Rodrigo [3]; Prof. GRINSTEIN, Benjamin [4]; Dr. MERLO, Luca [5]; Dr. FERNANDEZ MARTINEZ, Enrique [5]

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The flavor lepton symmetry is gauged for both the Standard Model flavor group and its extension with three degenerate right-handed neutrinos. As a consequence of anomaly cancellation, exotic leptons are introduced which induce a see-saw mechanism that generates the masses of the SM leptons. This see-saw-like pattern induces promising phenomenological signals in the \mu-\tau sector.

Dark matter 1 / 7

Particle Dark Matter Constraints: the Effect of Galactic Uncertainties

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Collider, space, and Earth based experiments are now able to probe several extensions of the Standard Model of particle physics which provide viable dark matter candidates. Direct and indirect dark matter searches rely on inputs of astrophysical nature, such as the local dark matter density or the shape of the dark matter profile in the target in object. The determination of these quantities is highly affected by astrophysical uncertainties. The latter, especially those for our own Galaxy, are ill-known, and often not fully accounted for when analyzing the phenomenology of particle physics models. In this paper we present a systematic, quantitative estimate of how astrophysical uncertainties on Galactic quantities (such as the local galactocentric distance, circular velocity, or the morphology of the stellar disk and bulge) propagate to the determination of the phenomenology of particle physics models, thus eventually affecting the determination of new physics parameters. We present results in the context of two specific extensions of the Standard Model (the Singlet Scalar and the Inert Doublet) that we adopt as case studies for their simplicity in illustrating the magnitude and impact of such uncertainties on the parameter space of the particle physics model itself. Our findings point toward very relevant effects of current Galactic uncertainties on the determination of particle physics parameters, and urge a systematic estimate of such uncertainties in more complex scenarios, in order to achieve constraints on the determination of new physics that realistically include all known uncertainties.

Plenary 6 / 8

New Physcis in the Flavour Sector

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After reviewing the current experimental hints for new physics in the flavor sector I investigate their implications for model building and collider searches.

Plenary 2 / 9

Postinflationary vacuum instability

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I'll discuss the role of the inflaton-Higgs couplings in stabilizing the vacuum during and after inflation.

Plenary 1 / 10

Compressed spectra

DELGADO, Antonio [1]

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In this talk I will present alternative techniques to discover supersymmetric models in where mass difference between NLSP and the LSP is so small than standard searches fail.

Plenary 7 / 11

New Physics in a Rare Decay of Beryllium-8?

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A fascinating result from an experiment by the ATOMKI group looks at a rare transition of a Beryllium 8 nucleus from an excited state to the ground state, and finds strong statistical evidence for something badly modeled by our current understanding of the nuclear physics. I will review the experiment and its results, and discuss new physics interpretations.

Collider / 12

Constraining the Inert Doublet Model

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We present an overview on the parameter space of the Inert Doublet Model, a two Higgs doublet model with a dark matter candidate. We include current theoretical and experimental constraints for the model and comment on collider benchmarks contained in the Higgs Cross Section Working Group Yellow Report.

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Last news on the singlet extension of the Standard Model

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I discuss the parameter space of the Higgs singlet extension of the Standard Model, with a special focus on the setup of an improved electroweak renormalization scheme using non-linear gauge fixing. Generic constraints on the models parameter space will also be discussed.

Flavor / 14

Muon g-2 and related phenomenology in vector-like extensions of the MSSM

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We analyze two minimal supersymmetric constrained models with low-energy vector-like matter preserving gauge coupling unification. In one we add to the MSSM spectrum a pair of 5-plets of SU(5), in the other a pair of 10-plets. We show that the muon g-2 anomaly can be explained in these models while retaining perturbativity up to the unification scale, satisfying electroweak and flavor precision tests and current LHC data. We examine also some related phenomenological features of the models, including Higgs mass, fine-tuning, dark matter and several LHC signatures. We stress that the parameter space consistent with g-2 is entirely in reach of the LHC with a moderate increase in luminosity with respect to the current data set.

Dark matter 1 / 15

A new search channel for simplified models of dark matter at the LHC

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We introduce a new set of simplified models to address the effects of 3-point interactions between the dark matter particle, its dark co-annihilation partner, and the Standard Model degree of freedom, which we take to be the tau lepton. We investigate these effects as well as the discovery potential for dark matter co-annihilation partners at the LHC. A small mass splitting between the dark matter and its partner is preferred by the co-annihilation mechanism and suggests that the co-annihilation partners may be long-lived (stable or meta-stable) at collider scales. It is argued that such long-lived electrically charged particles can be looked for at the LHC in searches of anomalous charged tracks.

Plenary 2 / 16

Leptogenesis after Inflation in a Pati-Salam Model

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In this talk I discuss a supersymmetric Pati-Salam model of fermion masses and mixing angles which fits low energy data. The model is then extended to include an inflationary sector which is shown to be consistent with Bicep2-Keck-Planck data. The energy scale during inflation is associated with the PS symmetry breaking scale.
Finally, the model is shown to be consistent with the observed baryon-to-entropy ratio necessary for Big Bang Nucleosynthesis.
It turns out that only the heaviest right-handed neutrino decays produce the correct sign of the baryon-to-entropy ratio.
Nevertheless, we obtain the observed value due to the process of instant reheating.

Flavor / 17

Two viable models of SM fermion mass generation

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In the first part of my talk I will discuss the first multiscalar singlet extension of the Standard Model (SM), that generates tree level top quark and exotic fermion masses as well as one and three loop level masses for charged fermions lighter than the top quark and for light active neutrinos, respectively, without invoking electrically charged scalar fields. That model, which is based on the S3xZ8 discrete symmetry, successfully explains the observed SM fermion mass and mixing pattern and features a viable scalar dark matter candidate. The second part of my talk is devoted to the discussion of the first model for radiatively generating the hierarchy of the Standard Model (SM) fermion masses:tree-level top quark mass; 1-loop bottom, charm, tau and muon masses; 2-loop masses for the light up, down and strange quarks as well as for the electron; and 4-loop masses for the light active neutrinos. That model is based on a softly-broken S3xZ2 discrete symmetry and has a scalar sector that consists only of one SM Higgs doublet and three electrically neutral SM-singlet scalars. The model features a viable scalar dark matter candidate.

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Colored window on dark sectors

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This talk will present a comprehensive study of simplified models of dark matter with a colored coannihilation partner. Dark matter relic density prediction and LHC phenomenology of the dark sector will be discussed for various SU(3) representations of the colored partner. The importance of Sommerfeld enhancement and bound state formation effects in the early Universe will be underlined.

Plenary 2 / 19

The other Fermion-Compositeness

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TBA

Plenary 2 / 20

On axions and ALPs.

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I will first motivate axions and ALPS in general, including the new recent directions on heavy (QCD) axions. I will then discuss ALPs effective couplings in all generality, within two different setups for electroweak symmetry breaking: the the linear and non-linear expansion. Complete basis for both cases up to NLO are determined. Associated new bounds are derived on the strengths of those couplings. Future prospects will be analyzed as well, contemplating LHC and High Luminosity LHC sensitivities. Mono-Z, mono-W, W-photon plus missing energy and on-shell top final states are most promising signals expected in both frameworks. In addition, non-standard Higgs decays and mono-Higgs signatures are especially prominent and expected in non-linear realizations.

Collider / 21

Recent progresses in Higgs mass calculations in BSM models

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I will give an overview of recent progresses in the Higgs mass calculations in BSM models. This includes generic two-loop corrections which can be applied to any renormalisable BSM model. Also a general handling of a large separation between the electroweak scale and the scale of new physics is discussed. The implementation of these developments in the public tool SARAH are briefly discussed. It is shown that with this setup the theoretical uncertainty of many BSM models has shrunk significantly and is now on the level of the MSSM.

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Augury of Darkness

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Dirac fermion dark matter models with heavy Z' mediators are subject to stringent constraints from spin-independent direct searches and from LHC bounds,cornering them to live near the Z' resonance. Such constraints can be relaxed, however, by turning off the vector coupling to Standard Model fermions, thus weakening direct detection bounds, or by resorting to light Z' masses, below the Z pole, to escape heavy resonance searches at the LHC. In this work we investigate both cases, as well as the applicability of our findings to Majorana dark matter. We derive collider bounds for light Z' gauge bosons using the CLS method, spin-dependent scattering
limits, as well as the spin-independent scattering rate arising from the evolution of couplings between the energy scale of the mediator mass and the nuclear energy scale, and indirect detection limits.

Pheno 3 / 23

Phenomenology of CP4 3HDM

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CP4 3HDM is the minimal multi-Higgs model based on the CP-symmetry of order 4. Here, we develop its phenomenology within two main versions: the one with the scalar dark matter, and the one with CP4 extended to the fermion sector. Both versions are tractable analytically and lead to characteristic signals which can be probed at colliders and in astrophysical observations.

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Observable Gravitational Waves from Higgs Inflation in Supergravity

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We consider models of chaotic inflation driven by the real parts of a conjugate pair of Higgs superfields involved in the spontaneous breaking of a grand unification symmetry at a scale assuming its Supersymmetric value. Employing Kaehler potentials with a prominent shift-symmetric part proportional to c- and a tiny violation, proportional to c+, included in a logarithm we show that the inflationary observables provide an excellent match to the recent Planck and Bicep2/Keck Array results setting, e.g., 0.0064<= c+/c- <=1/N where N=2 or 3 is the prefactor of the logarithm. Deviations of these prefactors from their integer values above are also explored and a region where hilltop inflation occurs is localized. Moreover, we analyze several possible stabilization mechanisms for the non-inflaton accompanying superfield using just quadratic terms. In all cases, inflation can be attained for subplanckian inflaton values with the corresponding effective theories retaining the perturbative unitarity up to the Planck scale.

Flavor / 25

The Axiflavon: A Minimal Axion Model from Flavor

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I will discuss a simple QCD axion model that arises from identifying Peccei-Quinn with Froggatt-Nielsen symmetries. In this scenario the flavor problem of the Standard Model is addressed by a U(1) flavor symmetry, which naturally leads to an axion that solves the strong CP problem and constitutes a viable Dark Matter candidate. The ratio of the axion mass and its coupling to photons is related to SM fermion masses and predicted within a small range, as a direct result of the observed hierarchies in quark and charged lepton masses. The same hierarchies determine the axion couplings to fermions, making the framework very predictive and experimentally testable by future axion and precision flavor experiments.

Theory / 26

Towards an asymptotically safe completion of the Standard Model

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We explore a possibility to UV-complete the Standard Model in an asymptotically safe manner. We assume the existence of NF new types of vector-like fermions which minimally couple to SU(3) and/or SU(2) of the SM and modify the running of the corresponding gauge couplings in such a way that at least one of them is not asymptotically free anymore. We classify the emerging UV fixed points and discuss their dependence on transformation properties of the new fermions under the gauge symmetries. We also show that additional constraints on the structure of the BSM sector arise if one requires a UV fixed point to be connected to the Standard Model through a well-defined RG trajectory.

Flavor / 27

Domestic Axion

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We identify a phenomenologically viable solution to the strong CP problem in which the axion is composed entirely out of Standard Model fermion species. The axion consists predominantly of the η' meson with a minuscule admixture of a pseudoscalar bilinear composite of neutrinos, η_{ν} [1]. The Peccei-Quinn symmetry is an axial symmetry that acts on the up quark and the neutrino species. It is spontaneously broken by the QCD condensate of quarks as well as the condensate of neutrinos, which forms in case non-perturbative gravitational effects make the gravitational θ-term physical [2]. The up-quark mass is spontaneously generated by the neutrino condensate, which plays the role of an additional composite Higgs doublet with the compositeness scale of the order of the neutrino masses. Such a scenario is highly economical: it solves the strong CP problem, generates the up-quark and neutrino masses from fermion condensates, and simultaneously protects the axion shift symmetry against gravitational anomaly. The phenomenology is different from the standard hidden axion case. One of the experimental signatures is the existence of a gravity-competing isotope-dependent attractive force among nucleons at (sub)micron distances.

[1] G. Dvali, S. Folkerts, and A. Franca, "How neutrino protects the axion", Phys. Rev. D89, 105025 (2014), arXiv:1312.7273 [hep-th].
[2] G. Dvali and L. Funcke, "Small neutrino masses from gravitational θ-term", Phys. Rev. D93, 113002 (2016), arXiv:1602.03191 [hep-ph].

Dark matter 2 / 28

Scalar field dark matter and the Higgs field

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We discuss the possibility that dark matter corresponds to an oscillating scalar field coupled to the Higgs boson. We argue that the initial field amplitude should generically be of the order of the Hubble parameter during inflation, as a result of its quasi-de Sitter fluctuations. This implies that such a field may account for the present dark matter abundance for masses in the range $10^{-6} - 10^{-4}$ eV, if the tensor-to-scalar ratio is within the range of planned CMB experiments. We show that such mass values can naturally be obtained through either Planck-suppressed non-renormalizable interactions with the Higgs boson or, alternatively, through renormalizable interactions within the Randall Sundrum scenario, where the dark matter scalar resides in the bulk of the warped extra-dimension and the Higgs is confined to the infra-red brane.

Collider / 29

Electroweak Testing of Vector-like quarks and Higgs-boson pair production at NLO

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We consider the Higgs pair production at the LHC Run II with one vector-like quark (VLQ) exclusively couple to the SM Higgs and up-quark and this simple scenario is realised with more than one VLQ multiplets, where a substantial mixing of T and T' is in place and results in a loose EWPT bound. In the case of a light VLQ, the dominant Higgs pair production comes from the pair and single productions of VLQs, with the T quark decaying into one Higgs plus a light jet. Using the MG model implementation at NLO, we can show both the pure QCD and EW contributions to this process play an important role, depending on the coupling and mass of vectorlike quark. We reconstruct the di-Higgs signals from the 4b and 2b 2 gamma channels using a resolved approach for the low mass and using the fat-jet technique for the high mass. We will present a detailed study of kinematic distributions at the Next to Leading Order and demonstrate the possibility to put bounds on the model parameters.

Collider / 30

Production of extra quarks decaying to Dark Matter at the LHC beyond the Narrow Width Approximation

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Studying how ATLAS and CMS searches for supersymmetry in the t tbar + MET final state constrain scenarios with a fermionic top partner and a dark matter candidate, we show that the efficiencies of the considered searches are quite similar for scalar and fermionic top partners. Therefore, in general, efficiency maps for stop–neutralino simplified models can also be applied to fermionic top-partner models, provided the narrow width approximation holds in the latter.
This motivates the exploration of finite width effects in the production and decay of extra heavy quarks at the LHC, this dynamics being normally ignored in standard experimental searches. For this reason we assess the regions of validity of current approaches and study the impact of the Dark Matter candidate spin on the exclusion.

Cosmo 2 / 31

Higgs Dynamics During And After Inflation

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Current measurements of the Higgs boson and top quark mass favor metastability of the electroweak vacuum in the Standard Model. This raises some questions when we consider the evolution of our universe: how the universe ended up in such an energetically disfavored state? Why it remained there during inflation? These problems can be addressed by assuming for the Higgs a direct coupling with the inflaton and/or a non-minimal coupling to gravity. In this talk I will review the effects of these interactions on the Higgs dynamics during the inflationary period and the subsequent period of particle production, namely reheating. I will show that there exists a favorable range of parameters that allows to explain why the universe remained in the electroweak vacuum throughout the cosmological history.

Theory / 32

The linear/non-linear sigma model for the Goldstone Higgs

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In the context of the minimal SO(5) linear {\sigma}-model, a complete renormalizable Lagrangian -including gauge bosons and fermions- is considered, with the symmetry softly broken to SO(4). The scalar sector describes both the electroweak Higgs doublet and the singlet {\sigma}. Varying the {\sigma} mass would allow to sweep from the regime of perturbative ultraviolet completion to the non-linear one assumed in models in which the Higgs particle is a low-energy remnant of some strong dynamics. We analyze the phenomenological implications and constraints from precision observables and LHC data. Furthermore, we derive the d <= 6 effective Lagrangian in the limit of heavy exotic fermions.

Pheno 2 / 33

Vaccuum expectation values and spontaneous CP violation in multi-Higgs potentials

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We analyse various multi-Higgs scalar potentials with discrete symmetries and find, for each potential, Vacuum Expectation Values (VEVs).

Using CP-odd basis Invariants that indicate the presence of Spontaneous CP Violation we separate VEVs into those that do or do not violate CP. In the latter case, we identify for which of the VEVs there is Spontaneous Geometrical CP Violation (where the VEVs have ``calculable'' phases, i.e.\ VEV phases that take specific values without depending on the numeric value of the parameters in the potential).

Flavor / 34

The NA62 experiment at CERN

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K+->pi+nunu is one of the theoretically cleanest meson decay where to look for indirect effects of new physics complementary to LHC searches. The NA62 experiment at CERN SPS is designed to measure the branching ratio of this decay with 10% precision. NA62 had pilot runs in 2014-15 and took data in 2016, and a status of the analysis will be presented.

Collider / 35

Closing the window for compressed electroweakinos at a 100 TeV collider

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When considering the MSSM parameter space, the "mostly Higgsino" scenario is the most difficult one, that can not be probed neither at the LHC nor at a future collider. The electroweak splittings between the chargino and neutralino lie between 344 MeV and 500-600 MeV, and thus traditional long lived searches lose stem. In this talk I will examine the sensitivity of a future 100 TeV proton-proton to this scenario for two strategies. First I will present the results of an optimized tracker setup targeting charged particles with lifetimes of a few mili-meters. Second, I will show an study in the di-lepton plus missing energy channel (mono-Z). I conclude that one can completely close the whole parameter space for thermal Higgsinos at the 100 TeV collider.

Dark matter 3 / 36

A pitfall in the standard way of calculating the dark matter relic density

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Kinetic decoupling of dark matter (DM) typically happens much later than chemical freeze-out. In fact, local thermal equilibrium is an important assumption for the usual relic density calculations based on solving the Boltzmann equation [for its 0-th moment] describing the DM number density. But is this assumption always justified? In this talk I will address this question and discuss the consequences of more accurate treatments, one relying on the inclusion of higher moments of the Boltzmann equation and the second on solving the evolution of the phase space distribution function fully numerically. I will show explicit examples where such a more accurate treatment is necessary. One of these is the Scalar Singlet model, often referred to as the simplest WIMP DM possibility from a model-building perspective.

Collider / 37

Searching the Relaxion at Particle Accelerators

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I will discuss experimental searches for the relaxion.

Flavor / 38

Higgs-Flavon mixing and Dark Matter

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We employ a version of the Froggatt-Nielsen mechanism at TeV scale, with only the leptons and the complex flavon transforming non--trivially under the corresponding symmetry group. The real part of flavon mixes with the Higgs introducing Lepton Flavour Violating (LFV) processes which are constrained by experiment. The imaginary part of flavon, however, is very weakly coupled to leptons and is long lived which we show could play the role of Dark Matter.

Cosmo 2 / 39

Preheating and light fields

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Talk shall describe the role of light fields indirectly coupled to the background during preheating. In our previous study we proved that non-perturbative production of states associated with such fields can be sizeable due to quantum corrections, also for the massless case. Talk will extend this study considering interacting field formalism that copes with the secular growth problem observed before. Possible ways of quenching the process of preheating by additional light sector and analogies with instant preheating shall be presented.

Dark matter 1 / 40

Dark matter in the Sun: scattering off electrons vs nucleons

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The annihilation of dark matter (DM) particles accumulated in the Sun could produce a flux of neutrinos, which is potentially detectable with neutrino detectors/telescopes and the DM elastic scattering cross section can be constrained. Although the process of DM capture in astrophysical objects like the Sun is commonly assumed to be due to interactions
only with nucleons, there are scenarios in which tree-level DM couplings to quarks are absent, and even if loop-induced interactions with nucleons are allowed, scatterings off electrons could
be the dominant capture mechanism. We consider this possibility and study in detail all the ingredients necessary to compute the neutrino production rates from DM annihilations in
the Sun (capture, annihilation and evaporation rates) for velocity-independent and isotropic, velocity-dependent and isotropic and momentum-dependent scattering cross sections for DM
interactions with electrons and compare them with the results obtained for the case of interactions with nucleons. Moreover, we improve the usual calculations in a number of ways and
provide analytical expressions in three appendices. Interestingly, we find that the evaporation mass in the case of interactions with electrons could be below the GeV range, depending on the high-velocity tail of the DM distribution in the Sun, which would open a new mass window
for searching for this type of scenarios.

Plenary 5 / 41

Stringy origin of discrete R-symmetries

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We discuss the appearance of discrete symmetries in the low energy limit of realistic string realizations of the super-symmetric standard model. These symmetries originate from geometric properties of compactified space and stringy selection rules. Particular attention is paid to discrete R-symmetries and their connection to the extra-dimensional Lorentz group. Phenomenological consequences of discrete R-symmetries are discussed in detail.

Flavor / 42

CP-violation and baryon-asymmetry from dynamical Yukawas at the weak scale.

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Dynamical Yukawas open new possibilities for electroweak baryogenesis. In this talk I will focus on the CP-violation and the calculation of the baryon-asymmetry. Starting from first principles, I will derive the general form of the CP-violating semiclassical force and the diffusion equations for models with varying Yukawa couplings. This represents a very general framework to determine the baryon-asymmetry generated in a given model. I will discuss the necessary ingredients for successful baryogenesis and I will apply this framework to different models and discuss the CP-violation and the amount of baryon-asymmetry produced.

Theory / 43

Solving the Goldstone boson catastrophe and two-loop Higgs masses in non-supersymmetric models

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After the Higgs discovery, precision calculations of its properties are of great importance in the study of extensions of the Standard Model. The state-of-the-art calculation of Higgs masses is now at two-loop order for generic theories, performed in the Landau gauge. However, these calculations are plagued by infrared divergences due to tachyonic running Goldstone masses -- the so-called Goldstone boson catastrophe (GBC). I will present the recent solution to this problem in the context of general renormalisable field theories [1609.06977] and the study of two-loop corrections to Higgs masses in non-supersymmetric models, made possible by the implementation of the solution to the GBC in SARAH.

Flavor / 44

The Zee model: connecting neutrino masses to Higgs lepton flavor violation

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I will discuss the Zee model, a radiative neutrino mass model with possible large lepton flavor violating Higgs (HLFV) decays, in particular $h\rightarrow \tau \mu$. In the first part I will analyse the effective operators responsible for HLFV and their tree level UV completions. By imposing constraints from charged lepton flavour violating observables, like $\tau \rightarrow \mu \gamma$, upper limits on BR$(h\rightarrow \tau \mu)$ can be set for the different realizations. In the second part of the talk, I will discuss the connection of HLFV to popular neutrino mass models. We will argue why most neutrino models generate very suppressed HLFV at one loop level. On the other hand, the general Zee model generates HLFV at tree level. We will present results of a full parameter scan which show how the model is fully testable by LHC and LFV searches.

Pheno 3 / 45

Dark matter assisted electroweak phase transition

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We investigate the model containing two Higgs doublets and a singlet scalar field (2HDMS). In this model, the singlet field plays the candidate for dark matter, which could interact with nucleon via extended Higgs sector with maximal isospin violation and thus lead to a suppressed cross section below the present LUX limits, while producing a correct relic density.

Assisted by the dark matter field, this model can achieve an interesting two-step first-order electroweak symmetry-breaking transition, wherein the baryon asymmetry of the early Universe is generated in the first step and avoided to be washed out during the second. As a result, this two-step transition mechanism can lead to strong supercooling and low nucleation temperatures relative to the critical temperature, which can significantly alter the usual phase transition pattern in 2HDMs.

Collider / 46

Production of strongly interacting states at the LHC in R-symmetric SUSY

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Experimental limits on the masses of SUSY states from searches at the LHC are becoming quite stringent, especially for the mass of the gluino of the MSSM.
The MRSSM is an alternative supersymmetric model which features an continuous R-symmetry and it leads to a Dirac-type gluino.
Compellingly, it is natural for a Dirac gluino to have a large mass outside the current bounds.

For an accurate prediction of the production strongly interacting SUSY states at the LHC next-to leading order corrections are relevant and need to be considered.
This has not yet been done for the case of Dirac gluinos and it is our goal to remedy this for the MRSSM.
In this talk I will present our progress of calculating the NLO SUSY-QCD corrections in the MRSSM for the production at the LHC. Special
emphasis will be put on the differences between the MSSM and the MRSSM.

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Cosmo 2 / 48

Rescuing (very) low scale SUSY breaking in sgoldstino-less inflation models

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In this talk I will discuss how models of sgoldstino-less inflation can be motivated in a UV complete set up and explore to which point they can actually handle very low scale SUSY breaking. I will thus present the constrained superfield formalism and its general features regarding its embedding in a UV complete framework. Then I will show why such a formulation is generically in tension with assumptions made about the heavy UV completion sector, and does not allow so easily to ask for a very low supersymmetry breaking scale. Finally I will present a model where the UV sector mass scale is inflaton-dependant allowing to access (very) low masses of the gravitino at the end of the inflationary epoch while still ensuring a satisfying sgoldstinoless dynamics during inflation.

Dark matter 3 / 49

Cosmic abundances of SIMP dark matter

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Thermal production of light dark matter with sub-GeV scale mass can be attributed to 3⟶2 self-annihilation processes. We consider the thermal average for annihilation cross sections of dark matter at 3⟶2 and general higher-order interactions. A correct thermal average for initial dark matter particles is important, in particular, for annihilation cross sections with overall velocity dependence and/or resonance poles. We apply our general results to benchmark models for SIMP dark matter and discuss the effects of the resonance pole in determining the relic density.

Collider / 50

Constraining the Higgs trilinear coupling from single-Higgs processes in the SMEFT

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In scenarios where the only anomalous contribution to single-Higgs observables originates from the Higgs cubic self coupling, it has been recently noticed that the bounds on the Higgs trilinear from those observables might complement and compete with the constraints coming from double Higgs production. We study to what extent this statement holds true when one considers a general deviation on Higgs couplings in the EFT framework. We show that inclusive observables are not enough to isolate the Higgs trilinear effect from the other deviations. However, we present a strategy to disentangle this flat direction using the kinematic information in the differential cross sections.

Dark matter 1 / 51

Towards understanding the thermal history of the Universe through direct and indirect detection of dark matter

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We will discuss to what extent prospective detection of dark matter by direct and indirect-detection experiments could shed light on whether all dark matter was generated thermally via the freeze-out process in the early Universe. By simulating signals that could be seen in near future and using them to reconstruct dark matter properties, we show that, in the model-independent approach the answer is generally negative, except for a thin sliver in the parameter space. However, with additional theoretical input the hypothesis about the thermal freeze-out as the dominant mechanism for generating dark matter can potentially be verified. We illustrate this with two examples: an effective field theory of dark matter with a vector messenger and a higgsino or wino dark matter within the MSSM.

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Flavor origin of dark matter and neutrino mixing

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We propose a flavor symmetric extension of the Standard Model which establishes a correlation between the relic abundance of dark matter and non-zero \theta_13. The flavor symmetry is allowed to be broken at a high scale to a remnant Z_2 symmetry, which ensures the stability of the dark matter. On the other hand, it provides a deviation of the A4-based tri-bimaximal neutrino mixing thereby generating non-zero \theta_13. This results in a range of Higgs portal type of coupling of the dark matter which can be potentially accessible at various ongoing and future direct and collider search experiments. We also discuss the involvement of nonzero leptonic CP phase \delta, which plays an important role in the analysis.

Plenary 1 / 54

Lattice gauge theory beyond the standard model

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Lattice gauge theory is a non-perturbative framework that enables numerical analyses of strongly interacting quantum field theories from first principles. This approach is broadly applicable, and in recent years it has produced increasingly valuable information about strongly coupled gauge theories beyond QCD, in contexts ranging from composite dark matter to electroweak symmetry breaking and extended supersymmetry. I will present a selection of recent results from these lattice investigations, focusing on connections to current experiments.

Pheno 1 / 55

Enlarging regions of the MSSM parameter space for large tan(beta)

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We study the conditions under which regions of the Minimal Supersymetric Standard Model (MSSM) that are constrained by experimental searches for decays of the heaviest CP-even and CP-odd Higgss H, A to tau-lepton pairs can be "resurrected" by allowing decays into supersymmetric particles. These regions tend to be associated with large values of $\tan\beta$ and somewhat light m_{H}, m_A. In particular we concentrate in possible decays into sbottom, stop and stau pairs, whose left-right couplings to H can be maximized in regions of large trilinear coupllings A_{b}, A_{τ} for sbottoms and staus, or large bi-linear SUSY Higgs mass μ for stops. Due to the $\tan\beta$-enhancement in the production cross-sections via gluon-fusion and in association with bottom-quark pairs for H and A, we find that down-type sfermions, in particular, sbottoms perform a better job in allowing more parameter space than up-type sfermions such as stops, which require much larger values of μ to compensate for $\tan\beta$. Vacuum stability due to color and electromagnetic charge breaking as well as flavour observables constraints and direct searches for SUSY particles are imposed. We also associate the lightest CP-even the 125 GeV SM-like Higgs and impose the experimental constraints from the LHC. After carefully performing a scan of the parameter space we find that it is indeed possible to extend the regions currently constraint by LHC searches, specially those that correspond to large values $\tan\beta$.

Plenary 7 / 56

Estimating J-factors of dSphs for indirect dark matter detections

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The TeV scale WIMP having a weak charge (e.g. Wino, Higgsino) recently attracts many attentions. While such a WIMP is hard to be detected at collider and direct dark matter detection experiments, it is expected to be efficiently searched for at indirect dark matter detection experiments, for its annihilation cross section is boosted by the Sommerfeld enhancement. Among various indirect detection methods, observing gamma-rays from dSphs are thought to be the most robust way to detect the WIMP. On the other hand, we have to know how the WIMP is distributed inside each dSph to predict the signal flux accurately. In this talk, I would like to talk about recent developments on determining the distributions (i.e. J-factors) based on the papers arXiv:1603.08046 and 1608.01749.

Cosmo 1 / 57

Vacuum decay of an oscillating scalar field

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The lifetime of a meta-stable vacuum is often decisive in assessing the consistency of a theory. In the case where a classical scalar field is oscillating around a meta-stable vacuum, we present the time-dependent tunneling probability for its quantum decay, but also the subsequent fate of the true vacuum bubble. Interestingly, while the lifetime is significantly shorter than the vacuum-to-vacuum one, the most probable tunneling events at large oscillations collapse back to the fake vacuum, falling short of generating a phase transition.

Dark matter 2 / 58

Multi-component dark matter scenarii: vector and fermions case

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It is plausible that dark sector of our universe has more than one stable particles which contribute to the observed dark matter relic abundance. I will present a generic discussion of multi-component dark matter scenarios where two or three dark sector particles are stable. As a specific two (three) component dark matter scenario, I will consider a model where a vector and Majorana fermion(s) are stable. The stability of our multi-component dark matter scenarios is ensured due to presence of discrete symmetries.

Collider / 59

Phenomenology of Twin Photon

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In this talk, I will present phenomenology of dark photon within Twin Higgs models. In particular, we discuss bounds arising from collider physics and constraint the kinetic mixing of twin photon with the SM photon.

Dark matter 2 / 60

Self-Interacting Vector Dark Matter with Higgs Portal

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We study a self-interacting vector dark matter model, which is connected to the Standard Model sector through the Higgs portal. We focus on the case in which the vector dark matter is of broadly electroweak scale, and the mass of the dark Higgs of O(1-10 MeV). As a result, the model can achieve the strong dark matter self interaction, which is needed to solve the small scale problems in our cosmology. Depending on the strengths of the portal interaction and the dark gauge interaction, the correct dark matter relic abundance in our cosmology can be achieved by several mechanisms, such as freeze-in, reannihilation, dark sector freeze-out, and visible freeze-out. Consequently, we find that only the freeze-in mechanism can be compatible with the required dark matter self-interactions. We also consider the other constraints from cosmologies, dark matter direct and indirect searches.

Plenary 3 / 61

Cosmological Signals of the Mirror Twin Higgs

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I consider the cosmological implications of the Mirror Twin Higgs framework. In this scenario the twin photon and neutrinos constitute dark radiation, while the twin baryons constitute a subcomponent of dark matter. The twin baryons and twin photons behave like a tightly coupled fluid during the radiation dominated era, leading to acoustic oscillations that suppress the growth of structure. I show that this class of theories may offer a solution to the \$H_0\$ and \$\sigma_8\$ problems of large scale cosmology.

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The trilinear Higgs coupling in single Higgs observables

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Recently it has been noted that the effects of the Higgs trilinear can be probed in single Higgs observables. However, these studies neglect the effect of other operators entering in Higgs physics. We perform global study and describe the different flat directions that arise, and propose several way on how to lift them in the LHC-HL phase.

Cosmo 2 / 64

High-Scale Supersymmetry and Inflation Unified

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The rather large mass of the Standard Model Higgs boson as well as the lack of evidence for superparticles at the LHC imply that supersymmetry (SUSY)--if it exists in nature--is likely to be broken at a high energy scale. In such a case, supersymmetry is no longer responsible for the naturalness of the electroweak scale. At the same time, the scenario of high-scale SUSY breaking opens up various possibilities that are usually out of reach in the case of low-scale SUSY breaking. As I am going to demonstrate in this talk, SUSY breaking close to the scale of grand unification may, for instance, give rise to a stage of successful hybrid inflation in the early universe. This observation lends support to the idea that the dynamics of SUSY breaking, inflation, and grand unification may all be unified at a single high energy scale. In particular, I will discuss models of F-term and D-term inflation that can be obtained in the context of dynamical SUSY breaking in strongly interacting supersymmetric gauge theories. A lesson learned from these models is that supersymmetry might, in fact, play a different role in nature than conventionally believed: As it turns out, supersymmetry's main purpose might actually be to ensure a certain shape of the inflaton potential rather than a certain shape of the Standard Model Higgs potential. This talk is based on recent work in collaboration with Tsutomu T. Yanagida (1604.04911 [hep-ph]) and Valerie Domcke (1702.02173 [hep-ph]).

Cosmo 1 / 65

Gravitational waves from domain walls in the Standard Model with nonrenormalizable operators

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The study of the renormalization group improved effective potential of the Standard Model has revealed the existence of a local maximum at field strengths of the order of 10^10 GeV. If the Standard Model is valid for very high energy scales, then the possibility of the production of cosmological domain walls in the early Universe occurs.

We investigated the dynamics of networks of domain walls using lattice simulations. In our previous research we assumed that the Standard Model is valid up to the Planck scale. Recently we studied scenario in which the Standard Model breaks down at much lower scales using the formalism of Effective Field Theory. A nonrenormalizable operator was included in the Lagrangian density and its impact on the evolution of networks of domain walls was investigated. Our recent results will be presented.

Dark matter 2 / 66

Dark matter from dark gauge groups

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Dark gauge groups, coupled to the Standard Model via the Higgs portal, can provide WIMP dark matter in a simple and appealing way. After reviewing the origin of dark matter stability in this framework, I discuss different mechanisms that lead to a natural suppression of direct detection rates below present-day limits, without a fine-tuning of parameters.

Pheno 1 / 67

Baryogenesis in the extended Standard Model by a Complex Singlet and Iso-Doublet Vector Quark

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CP violation of the SM is insufficient to explain the baryon asymmetry in the universe and therefore an additional source of CP violation is needed. Here the extension of the SM by a neutral complex scalar singlet with a nonzero vacuum expectation value (cSMCS) plus a heavy vector quark pair is considered. This model offers the spontaneous CP violation and proper description in the baryogenesis, it leads strong enough first-order electro-weak phase transition to suppress the baryon-violating sphaleron process.

Dark matter 3 / 68

Physics Opportunities at Dark Matter "Colliders"

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In this talk, I discuss a novel dark matter (DM) detection strategy for the models with non-minimal dark sector. The main ingredients in the underlying DM scenario are a boosted DM particle and a heavier dark sector state. The relativistic DM impinged on target material scatters off inelastically to the heavier state which subsequently decays into DM along with lighter states including visible (Standard Model) particles. The expected signal event, therefore, accompanies a visible signature by the secondary cascade process associated with a recoiling of the target particle, differing from the typical neutrino signal not involving the secondary signature. I then discuss various kinematic features followed by DM detection prospects at large volume neutrino detectors with a model framework where a dark gauge boson is the mediator between the Standard Model particles and DM. I also briefly make comment on the potential of applying this idea to fixed target experiments.

Plenary 3 / 69

Twin Higgs, naturalness and SUSY

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I will discuss the general structure of mirror symmetry breaking in the Twin Higgs scenario. I will show that a significant gain in fine tuning can be achieved if the symmetry is broken hardly. Weakly coupled UV completions can naturally accommodate this scenario. I will analyze SUSY UV completions and present a simple Twin SUSY model with a tuning of around 10% and colored superpartners as heavy as 2 TeV. Finally I will comment on the phenomenological aspects of our proposal.

Pheno 2 / 70

New signs of supersymmetry: the R-axion

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Is there any generic sign of supersymmetry, that has not yet been satisfactorily explored?
In this talk I will argue that the answer is yes in the particle of the R-axion, the pseudo-Goldstone boson of the U(1)^R symmetry, and I will motivate experimental searches in light of this observation.
I will focus on R-axion masses in the GeV to TeV range, which are relevant for hadron and lepton colliders, as well as for flavour factories. Current bounds allow for the exciting possibility that the R-axion will be the first sign of SUSY to show up at such experiments.
The considerations developed here open new directions in phenomenology and model building, that I will briefly sketch.

Theory / 71

Nilpotent inflation and gauge mediation of SUSY breaking: when cosmology meets particle physics

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In inflation models with nilpotent fields it is typically difficult to achieve a low energy susy breaking scale at the end of inflation without having inconsistencies. In this talk I present a UV-completed model based on the alpha-attractor formalism that does not suffer from these problems and where one can realize gauge mediation of susy breaking at the end of inflation. In addition, the UV-completed model predicts reheating parameters, such as the reheating temperature and the gravitino abundance. In particular the inflaton couplings with the Standard Model are suppressed, hence leading generically to a small reheating temperature and alleviating the gravitino overproduction problem. I identify the region of parameters space that is compatible with the LHC constraints, solves the gravitino problem, and which presents a value of ns inside Planck's 2 sigma contour.

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Pseudo-Goldstone sterile neutrino at the LHC

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We study the experimental signature at the LHC of a sterile neutrino in the 1 GeV - 1 TeV mass range arising as the supersymmetric partner of a pseudo-Goldstone boson. Contrary to the standard scenario, in which the heavy sterile neutrino is produced and decays through its mixing with the standard model neutrinos, in our model the sterile neutrino is produced in decays of neutralinos and charginos. This makes it possible to access much smaller mixing angles than in the usual case. We consider the possibility of reconstructing the sterile neutrino mass and its mixing angles with the standard model neutrinos using displaced vertices.

Dark matter 1 / 73

Simplified Dark Matter Models with Z': gauge invariance and mass generation

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We consider the indirect detection signals for models containing a fermionic DM candidate, a dark gauge boson, and a dark Higgs field. Compared with a model containing only a dark matter
candidate and vector mediator, the addition of the scalar provides a mass generation mechanism for the dark sector particles which, in some cases, is required in order to avoid unitarity violation at high energies. We demonstrate that the dark matter interaction types, and hence the annihilation processes relevant for relic density and indirect detection, are strongly dictated by the mass generation mechanism chosen for the dark sector particles, and the requirement of gauge invariance. We outline important phenomenology of such two-mediator models, which is missed in the usual single-mediator simplified model approach.
We also demonstrate that the dark matter
interaction types, and hence the annihilation processes relevant for relic density and indirect
detection, are strongly dictated by the mass generation mechanism chosen for the dark sector
particles, and the requirement of gauge invariance.

Pheno 2 / 74

Precision and New Physics After LHC Run2

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After several years of exploration of the TeV scale, the Large Hadron Collider is now putting strong bounds on the existence of new physics at the weak scale. I will discuss the scope of these bounds and their impact on theories of physics beyond the Standard Model. I will argue that precision studies of SM processes are sensitive probes of new physics and can provide a unique handle to probe the scenarios of new physics. In particular I will discuss the reach from precision searches on scenarios that have proven hard to probe with standard search strategies or are just outside the LHC kinematic reach. The role of top quark precision observables and electroweak precision measurements will be discussed in detail.

Pheno 3 / 75

Naturalness and Dark Matter in the BLSSM

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We study the naturalness properties of the B – L Supersymmetric Standard Model (BLSSM) and compare them to those of the Minimal Supersymmetric Standard Model (MSSM) at both low (i.e., Large Hadron Collider) energies and high (i.e., unification) scales. By adopting standard measures of naturalness, we assess that, in presence of full unification of the additional gauge couplings and scalar/fermionic masses of the BLSSM, such a scenario reveals a somewhat higher degree of Fine-Tuning (FT) than the MSSM, when the latter is computed at the unification scale and all available theoretical and experimental constraints, but the Dark Matter (DM) ones, are taken into account. Yet, such a difference, driven primarily by the collider limits requiring a high mass for the gauge boson associated to the breaking of the additional U(1)B–L gauge group of the BLSSM in addition to the SU(3)C × SU(2)L × U(1)Y of the MSSM, should be regarded as a modest price to pay for the former in relation to the latter, if one notices that the non-minimal scenario offers a significant volume of parameter space where numerous DM solutions of different compositions can be found to the relic density constraints, unlike the case of the minimal structure, wherein only one type of solution is accessible over an ever diminishing parameter space. In fact, this different level of tension within the two SUSY models in complying with current data is well revealed when the FT measure is recomputed in terms of the low energy spectra of the two models, over their allowed regions of parameter space now in presence of all DM bounds, as it is shown that the tendency is now opposite, the BLSSM appearing more natural than the MSSM.

Dark matter 3 / 76

Early kinetic decoupling of dark matter with resonant annihilation

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In models with resonantly enhanced dark matter annihilation, the coupling of dark sector to the visible one is suppressed with respect to non-resonant scenarios. Consequently the cross section for scattering of dark matter on light states in the thermal bath is diminished and temperatures of the kinetic and chemical decoupling are similar. Moreover, due to the resonance enhancement, dark matter annihilation cross-section has large temperature dependence and is still effective, even then both sectors are decoupled. This leads to the interesting interplay between dark matter temperature and density. The resulting modifications of dark matter relic abundance will be presented alongside the consequences for direct and indirect detection and dark matter self-interactions.

Dark matter 3 / 78

Asymmetric thermal-relic dark matter

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Dark matter that possesses a particle-antiparticle asymmetry requires a larger annihilation cross-section compared to symmetric dark matter, in order to deplete the dark antiparticles and account for the observed dark matter density. I will discuss dark matter with long-range interactions, in particular dark matter coupled to a light vector or scalar force mediator. Accurate determination of the relic abundance requires inclusion of Sommerfeld enhancement and consideration of bound state formation. Due to the Sommerfeld enhancement, highly asymmetric dark matter with long-range interactions can have a significant annihilation rate in halos today, potentially larger than symmetric dark matter of the same mass with contact interactions. Finally, I will discuss the unitarity bound on the inelastic cross-section and why it can be realised only by long-range interactions. I will showcase upper bounds on the mass of symmetric and asymmetric thermal-relic dark matter for s-wave and p-wave annihilation, and exhibit how these bounds strengthen as the dark asymmetry increases.

Theory / 79

Phenomenological aspects of magnetized SYM theories in higher-dimensions

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The supersymmetric Yang-Mills (SYM) theories in higher-dimensional spacetime compactified on magnetized tori/orbifolds would have rich dynamical structures with the flavorful chiral spectra generated below the compactification scale. We show some phenomenological aspects of them, especially focusing on a realization of supersymmetric standard model and a mechanism of dynamical supersymmetry breaking.

80

Higgs self couplings and phase transitions

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Higgs boson's properties are being extensively studied at the LHC. Current measurements of Higgs' couplings point to a SM like Higgs and put stringent bounds on possible extensions of the SM. However, to understand the dynamics of electroweak symmetry, it is crucial to measure trilinear and quartic Higgs interactions. Higgs self-interactions measurements will constrain the form of Higgs potential. In this talk we carefully examine the interplay between the Higgs potential and electroweak phase transition (EWPT). If the electroweak phase transition is strongly first-order then it opens up the possibility of EW baryogenesis. Previous studies of EWPT have used the high temperature approximation, which we examine and find that the common lore of low sensitivity of Higgs' cubic coupling is changed by a factor two or three. This will enable the ILC and FCC to probe first-order EWPT with only a 10% precision of measurement. We then discuss how this newly found increased sensitivity to EWPT in the plane of cubic and quartic couplings opens a window of classifying BSM scenario, and also indicates the importance of the Higgs quartic self-coupling as a probe of EWPT.

Cosmo 1 / 81

Gravitational waves from a supercooled electroweak phase transition and their detection with pulsar timing arrays

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We investigate the properties of a stochastic gravitational wave background produced by a first-order electroweak phase transition in the regime of extreme supercooling. We study a scenario whereby the percolation temperature that signifies the completion of the transition, T_p, can be as low as a few MeV (nucleosynthesis temperature), while most of the true vacuum bubbles are formed much earlier at the nucleation temperature, $T_n\sim 50$ GeV. This implies that the gravitational wave spectrum is mainly produced by the collisions of large bubbles and characterised by a large amplitude and a peak frequency as low as $f \sim 10^{-9}-10^{-7}$ Hz. We show that such a scenario can occur in (but not limited to) a model based on a non-linear realisation of the electroweak gauge group, such that the Higgs vacuum configuration is altered by a cubic coupling. In order to carefully quantify the evolution of the phase transition of this model over such a wide temperature range, we go beyond the usual fast transition approximation, taking into account the expansion of the universe as well as the behaviour of the nucleation probability at low temperatures. Our computation shows that there exists a range of parameters for which the gravitational wave spectrum lies at the edge between the exclusion limits of current pulsar timing array experiments and the detection band of the future Square Kilometre Array observatory.

Plenary 6 / 82

Z-mediated New Physics and Vector-Like Models

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Z-mediated New Physics as seen by SMEFT will be presented and illustrated with the help of Vector-Like Quark Models. In this context phenomenology or rare K and B decays will be discussed.

Dark matter 1 / 83

Searching for dipolar dark matter in beam dump and low mass direct detection experiements

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We study the possibility of detecting dark matter (DM) in a 400 GeV proton beam dump experiment E613 conducted at SLAC as well as low mass direct detection experiments. We consider an effective interaction lagrangian for DM that interacts with SM through its electric and magnetic dipole moments at one loop level which we refer to as dipolar DM. We present constraints on the parameter space between ~ 1-10 GeV from E613 experiment as well as CDMSLITE and CRESST II experiments which present the strongest constraints in the low DM mass region.

Flavor / 84

Nonstandard interactions at long baseline neutrino experiments

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Muon neutrino disappearance measurements at NOνA suggest that maximal θ_{23} is excluded at the 2.6σ CL. This is in mild tension with T2K data which prefer maximal mixing. We point out that the apparent departure from maximal mixing in NOνA may be a consequence of nonstandard neutrino propagation in matter. We then study such nonstandard matter effects in the next generation long-baseline experiments, DUNE, T2HK and T2HKK.

Pheno 1 / 85

Atomic probes of new physics

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I will discuss the sensitivity to new long range interactions of isotope shift measurements.
I will explain how to exploit the experimental precision of these measurements to constrain new physics using minimal theory inputs.
Then I will discuss the possible consequences of this result for neutrino non standard interactions and dark matter.

Cosmo 1 / 86

Gravitational wave, collider and dark matter signals of a singlet scalar electroweak baryogenesis

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I will discuss a simple extension of the SM with just an additional scalar singlet coupling to the Higgs. My main focus will be the possible probes of electroweak baryogenesis in this model including collider searches gravitational wave detection and direct dark matter detection experiments. I will show there are regions in the parameter space where observation of gravitational waves is the most promising way of finding evidence for this model.

Pheno 2 / 87

The leptonic future of the Higgs

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Precision study of electroweak symmetry breaking strongly motivates the construction of a lepton collider with center-of-mass energy of at least 240 GeV. Besides Higgsstrahlung (e+e- -> hZ), such a collider would measure weak boson pair production (e+e- -> WW) with astonishing precision. The weak-boson-fusion production process (e+e- -> \nu \bar{\nu} h) also provides an increasingly powerful handle at higher center-of-mass energies. The impact and complementarity of differential measurements, at different center-of-mass energies and for several beam polarization configurations, are studied in a global effective-field-theory framework. We define a "global determinant parameter" (GDP) which characterizes the overall strengthening of constraints independently of the choice of operator basis. The reach of the CEPC, CLIC, FCC-ee, and ILC designs is assessed.

Plenary 1 / 88

Gauge coupling unification without new particle thresholds

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I will discuss an interpretation of the gauge coupling unification scale which is not related to any new particle threshold. As a consequence the gauge hierarchy problem is put on different grounds, and the proton may be absolutely stable.

Dark matter 3 / 89

A systematic effective operator analysis of semi-annihilating dark matter

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Semi-annihilation is a generic feature of dark matter theories stabilized by symmetries larger than Z2. It contributes to thermal freeze out and cosmic ray signals, but is irrelevant for direct and collider searches. We use an effective operator approach to make the first model-independent study of the associated phenomenology, enumerating all semi-annihilation operators up to dimension 6, plus leading terms at dimension 7. We find that when the only light states charged under the dark symmetry are dark matter, the model space is highly constrained. If there can be additional light, unstable "dark partner" states the possible phenomenology greatly increases, at the cost of additional model dependence in the new particle decay modes. We find that for semi-annihilation to electrons and light quarks, the thermal relic cross sections can be excluded for dark matter masses up to 100 GeV, but significant model space for semi-annihilating dark matter remains. Finally, we illustrate the use of this framework by applying it to the AMS positron excess. We discuss the implications for explaining that excess using semi-annihilation, and the role that can be played by dark partner decays.

Plenary 7 / 90

On self-interacting dark matter with light mediators

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Coupling dark matter to light new particles is an attractive way to combine thermal production with strong velocity-dependent self-interactions. We point out that in such models the dark matter annihilation rate is generically enhanced by the Sommerfeld effect, and we derive the resulting constraints from the Cosmic Microwave Background and other indirect detection probes. For the frequently studied case of s-wave annihilation these constraints exclude the entire parameter space where the self-interactions are large enough to address the small-scale problems of structure formation.

Collider / 91

Production of Vector-like Quark Production at the LHC, Beyond the Narrow Width Approximation.

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This paper explores effects of both finite width and interference (with background) in the production and decay of extra heavy quarks at the Large Hadron Collider (LHC). This dynamics is normally ignored in the standard experimental searcher and we assess herein the regions of validity of current approaches. Further, we discuss the configuration of masses, widths and couplings where the latter breaks down.

Pheno 2 / 92

Alternative vevs in the NMSSM

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The Next-to-Minimal Supersymmetric Standard Model (NMSSM) is known to solve the mu-Problem of the MSSM by the cost of a few new parameters (and a singlet superfield). Considerations taking alternative vacuum expectation values (vevs) of the Higgs fields into account help to reduce the available free parameter space. Despite the general impossibility to derive analytic constraints, we guide towards certain estimates on relations among the involved parameters. In contrast to the MSSM, the phenomenology of charge and color breaking minima is very different and the NMSSM appears to be more stable under large squark mixing than the MSSM. The main constraints come from the couplings to the singlet and thus the NMSSM-specific parameters can be reasonably well kept under control.

Plenary 7 / 93

An Ultralight Axion in Supersymmetry and Strings and Cosmology at Small Scales

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Dynamical mechanisms to generate an ultralight axion of mass $\sim10^{-21}-10^{-22}\,\eV$ in supergravity and strings are discussed. An ultralight particle of this mass provides a candidate for dark matter that may play a role for cosmology at scales $10 {\rm kpc}$ or less. An effective operator approach for the axion mass provides a general framework for models of ultralight axions, and in one case recovers the scale $10^{-21}-10^{-22}\,\eV$ as the electroweak scale times the square of the hierarchy with an $O(1)$ Wilson coefficient.} We discuss several classes of models {realizing this framework where an ultralight axion of the necessary size can be generated.
In one class of supersymmetric models an ultralight axion is generated by instanton like effects. In the second class higher dimensional operators involving couplings of Higgs, standard model singlets, and axion fields naturally lead to an ultralight axion.
Further, for the class of models considered the hierarchy between the ultralight scale and the weak scale is maintained. We also discuss the generation of an ultralight scale within string based models. Here it is shown that in the {single modulus} KKLT moduli stabilization scheme an ultralight axion would require an ultra-low weak scale. However, within the Large Volume Scenario, the desired hierarchy between the axion scale and the weak scale is achieved. A general analysis of couplings of Higgs fields to instantons within the string framework is discussed and it is shown that the condition necessary for achieving such couplings is the existence of vector-like zero modes of the instanton.
Some of the phenomenological aspects of these models are also discussed. \\

Theory / 94

Models of broken supersymmetry with constrained superfields.

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An effective description for theories with spontaneous supersymmetry breaking can be obtained by imposing constraints on superfields, both for global and local supersymmetry. In particular, even if the supersymmetry breaking scale is assumed to be very high, superspace methods can still be used to study effective theories in the low energy regime, where some of the degrees of freedom can be decoupled.
I will review the main techniques that have been developed recently in this context and I will apply them to discuss models in which supersymmetry is broken and non-linearly realized, both in the global and in the local case. I will also show that, in some circumstances, a non-linearly realized theory of supersymmetry can be interpreted as a linearly realized one.

Dark matter 2 / 95

A Minimal Model of Gravitino Dark Matter

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Motivated by the absence of signals of new physics in both searches for new particles at LHC and for a Weakly Interacting Massive Particle (WIMP) dark matter candidate, we consider a scenario where supersymmetry is broken at a scale above the reheating temperature. The low energy particle content consists then only in Standard Model states and a gravitino. We investigate the possibility that the latter provides the main component of dark matter through a freeze in mechanism from annihilation of thermalized Standard Model particles. We focus on the case where its production through scattering in the thermal plasma is well approximated by the non-linear supersymmetric effective Lagrangian of the associated goldstino and identify the parameter space allowed by the cosmological constraints, allowing the possibility of large reheating temperature compatible with leptogenesis scenarios, alleviating the so called ”gravitino problem”.
We considered the framework of high scale supersymmetry, where the scale of super-partners MSUSY lies above the reheating temperature whereas the gravitino mass m3/2 stays below. In this case, there still exist processes which produce thermally gravitinos through scattering of the Standard Model particles at the earliest time of reheating. This scale pattern m3/2 ≪ TRH ≪ MSUSY is common in some string models with high-scale supersymmetry breaking and opens new possibilities in model building.

Pheno 2 / 96

Vacuum stability of the triple-doublet model

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The coexistence of vacua of diferente natures in the triplet-doublet model is analysed, with and without any soft breaking term. Constraints on the parameter space of the model arising from the requirement of absolute vacum stability are derived.

Collider / 97

Update on R-Parity violation at the LHC

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We examine in detail the current LHC coverage of signatures arising from the R-Parity-violating Minimal Supersymmetric Standard Model. We take into account all experimental analyses for prompt signatures within this context, both explicit searches for RPV signals as well as other analyses containing applicable experimental signatures. These are contrasted with well-motivated phenomenological scenarios whereby we take the R-Parity-violating CMSSM as a guideline, imposing both Higgs and flavour constraints. We find that the analyses performed by the experimental collaborations provide very good coverage of relevant signatures. Finally, we address the question of whether R-Parity violation can ease the stringent collider constraints on models with CMSSM boundary conditions. We find that virtually all R-Parity-violating CMSSM models are either more strongly constrained or similarly constrained in comparison to the R-Parity-conserving CMSSM.

Cosmo 1 / 98

Electroweak baryogenesis and gravitational waves in two-Higgs-doublet models

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We show that simple Two Higgs Doublet models still provide a viable explanation for the matter-antimatter asymmetry of the Universe via electroweak baryogenesis, even after taking into account the recent order-of-magnitude improvement on the electron-EDM experimental bound by the ACME Collaboration. Moreover we show that, in the region of parameter space where baryogenesis is possible, the gravitational wave spectrum generated at the end of the electroweak phase transition is within the sensitivity reach of the future space-based interferometer LISA.

Theory / 99

Effective action from M-theory on twisted connected sum G2-manifolds

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We present a detailed analysis of the 4d low-energy effective N=1 SUGRA theory from M-theory compactified on G2-manifolds of the Kovalev's twisted connected sum type, which are constructed via gluing of a pair of non-compact asymptotically cylindrical Calabi-Yau threefolds augmented with a circle. In the spectrum of Kovalev's G2-manifolds we identify two universal neutral N=1 chiral moduli fields: the overall volume modulus of the G2 and the so-called Kovalevton -- which parametrizes the limit on which the Ricci-flat G2-metrics are approximated by the Ricci-flat metrics on the Calabi-Yaus used in Kovalev's construction. In this limit we arrive at a simple semi-classical Kaehler potential of the effective N=1 SUGRA action that fulfills the no-scale condition. Furthermore we are able to decompose exactly the effective N=1 SUGRA theory in terms of gauge theory sectors with extended supersymmetries, and achieve Abelian/non-Abelian gauge symmetries -- including the Standard Model gauge group -- with various matter content.

Plenary 4 / 100

A new twist on multifield inflation

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In multi-field inflation, light fields are usually avoided because they can potentially induce large levels of isocurvature perturbations that are inconsistent with observations. They can also lead to evolution of the curvature perturbation on super horizon scales and loss of predictability. Here we consider the extreme case in which the isocurvature perturbation becomes approximately massless (“ultralight”) while still coupled to the curvature perturbation, a situation that arises naturally in models involving pseudo-Nambu-Goldstone bosons or poorly stabilized moduli. Remarkably, both problems cure each other and the result is a viable model of inflation.

Collider / 101

Phenomenology of the clockwork solution to the hierarchy problem

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The linear dilaton geometry in five dimensions, rediscovered recently as a continuum limit of the clockwork mechanism, offers a solution to the electroweak-Planck hierarchy problem that is qualitatively different from scenarios with warped (Randall-Sundrum) or large flat extra dimensions. In this talk, I will discuss various phenomenological aspects of this scenario. I will emphasize several previously overlooked collider signatures and outline certain types of LHC searches that they motivate.

Collider / 102

Natural SUSY and Higgs measurements at Future Lepton Colliders

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In this talk, I will show the results of constraining a natural SUSY model using the Higgs coupling measurements at the future lepton colliders and the muon anomalous magnetic moment measurements.

Flavor / 103

A natural S_4 x SO(10) model of flavour

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I will present a renormalisable supersymmetric $ S_4 \times SO(10) $ GUT of flavour, where the Yukawa structure of all fermions is determined by the vacuum expectation values of three $ S_4 $ triplet flavons, in the CSD3 alignments.
The model accurately fits all available quark and lepton data, and predicts a leptonic $ CP $ phase $ \delta^l \approx - 60^\circ $.
Essentially all quark mixing is realised in the down-type quark Yukawa matrix, and analytical estimates for the quark mixing angles are given. The down-type masses and quark mixing angles are all fitted by only four real parameters, leading to some tension in the predicted observables, which can be ameliorated by assuming rather large SUSY threshold corrections.
A hierarchy in the flavon VEVs fixes the scales of all but one parameter, with all dimensionless couplings in the renormalisable theory naturally $\mathcal{O}$(1).
The model contains only "named" representations of the gauge group (i.e. up to the adjoint), and breaks to the MSSM. A $ \mu $ term of $\mathcal{O}$(TeV) can be realised, as well as doublet-triplet splitting.

Pheno 3 / 104

Vacuum Stability and Landau Poles of SU(3) Scalars

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We calculate renormalisation group equations and vacuum stability conditions for models that contain the Standard Model and a higher colour multiplet that leaves the strong coupling asymptotically free, up to and including the 15' of SU(3). In contrast to the other multiplets, the scalar self-couplings of the representations 3 and 8 of SU(3) "walk", rather than run, and remain perturbative over a vast energy range. In order to find the vacuum stability conditions, we calculate the orbit space for the self-couplings of the higher multiplet, which, especially for the 15 and 15' of SU(3), is rather non-trivial. We present a simple approximation of the orbit space in terms of the simplex containing its complex hull. The results have relevance for some models of flavour and dark matter. Knowledge of the exact vacuum stability conditions is also a necessary preliminary to finding asymptotically safe solutions for scalar quartic couplings.

Plenary 5 / 105

Hairs of discrete symmetries

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Gauge symmetries are known to be respected by gravity because gauge charges carry flux lines, but global charges do not carry flux lines and are not conserved by gravitational interaction. For discrete symmetries, they are spontaneously broken in the Universe, forming domain walls. Since the realization of discrete symmetries in the Universe must involve the vacuum expectation values of Higgs fields, a string-like configuration (hair) at the intersection of domain walls in the Higgs vacua can be realized. We show the hairs of discrete symmetries in the bottom-up approach.

Dark matter 1 / 106

Simulations of Dark Matter Self-Interactions via Collisionless Shocks

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While dark matter self-interactions may solve several problems with structure formation, so far only the effects of two-body scatterings of dark matter particles have been considered. If a subdominant component of dark matter is charged under an unbroken U(1) gauge group, collective dark plasma effects need to be taken into account to understand its dynamics. Plasma instabilities can lead to collisionless dark matter shocks in galaxy cluster mergers which might have been already observed in the Abell 3827 and 520 clusters.
Using the Gadget2 package, we have conducted simulations of such cluster collisions with dark matter and dark plasma components. In this talk I will report on the setup of the simulations and present our latest results.

Dark matter 2 / 108

Well-tempered n-plet dark matter

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In this talk I will present simple models of fermionic WIMP dark matter where the dark matter candidate is a mixture of a gauge singlet and an SU(2) triplet, quadruplet or quintuplet. The triplet case, in particular, is a straightforward generalisation of well-tempered wino-bino dark matter in the MSSM with moderately heavy higgsinos and decoupled squarks and sleptons. The dark matter mass is taken to be around the electroweak scale, while the mixing is induced by higher-dimensional operators with a suppression scale that can be as low as a TeV. Obtaining the correct thermal relic density and avoiding direct detection bounds lead to tight constaints on the parameter space. These models can be potentially tested at the LHC and by upcoming direct detection experiments.

Cosmo 1 / 109

On reheating in alpha attractor models of inflation

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With increasing accuracy of CMB data, a thorough, quantitative understanding of the post-inflationary reheating era becomes more and more important for constraining different models of inflation. In particular, a precise computation of the non-homogeneous field evolution during preheating is desirable.
In this talk I will present the results of such computation for single field inflation model based on alpha-attractors models of inflation. I will show the Floquet analysis of field perturbations evolution, as well as the results of full non-linear simulations of the field evolution. I will discuss the importance of studying the dynamics of both scalar fields present in the model.

Cosmo 2 / 110

Supersymmetry and the CMB observables

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Cosmic inflation and big bang nucleosynthesis match observations to impressive accuracy however, in between stretches a huge range of energy scales that are neither well understood nor strongly constrained. The increasing sensitivity of the CMB data offers us a unique and very promising window to these "dark" cosmic high energies. In this talk I will present results of my current research that show how the CMB observables may give us non-trivial information about the physics that operates beyond the Standard Model of particle physics (BSM), emphasizing particularly on the supersymmetric models.

Cosmo 2 / 111

Loop corrections in curved spacetime -- could they really generate the Starobinsky inflation?

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One of the mostly debated topic in modern cosmology is model building for inflation. Recent data seem to favor simple models, amongst them there is the Starobinsky model based on the modification of the gravitational action. Its characteristic feature is the presence of the
Ricci scalar squared term. It is often assumed that such a term could be generated by the loop correction of the matter sector. We will show by explicit calculations how to obtain such a term in the framework of quantum field theory in curved spacetime. Surprisingly, the obtained results seem to indicate that the attained inflationary action leads to an incorrect model of the inflation.

Pheno 2 / 112

A few techniques in using standard model effective field theory

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Standard model effective field theory is a useful bridge to connect models of new physics with experimental observables. There are generically three steps in using it---matching, running, and mapping. I would like to briefly review this procedure, with emphasis on a few relevant techniques. First, the covariant derivative expansion method allows one to perform calculations in a manifestly gauge-covariant manner. It can be used to simplify both the matching and the running steps. Second, in order to perform the running step most efficiently, one presumably would like to work with a set of complete but independent effective operators---an operator basis. I will present a systematic method of determining the content of an operator basis, as well as explicitly constructing it. Finally, with a particular choice of the operator basis, one typically needs to make use of the various redundancy relations among the effective operators to remove or trade operators, in order to bring the Lagrangian into its canonical form. In this procedure, the equation of motion redundancy relation should be utilized through field redefinition. I will clarify how this procedure works.

Cosmo 2 / 113

Dark inflation

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I will present the Idea of an inflaton without direct couplings to any additional fields. I will show a possible mechanisms of reheating together with implications of dark inflation on predictions of inflation, thermal history of the Universe, electro-weak phase transition and gravitational waves production.

Pheno 1 / 114

Dynamical relaxation in 2HDM

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The dynamical relaxation provides an interesting solution to the hierarchy problem in face of the missing signatures of any new physics in recent experiments. Through a dynamical process taking place in the inflationary phase of the universe it manages to achieve a small electroweak scale without introducing new states observable in current experiments, all while maintaining technical naturalness. In this talk I will present some aspects of applying this mechanism (in its double-scanning variant) to models with two Higgs doublets. I will show how a simple approximation can be used to derive an explicit formula for the final, relaxed vevs, and how in general the dynamical relaxation fails to produce small vevs if multiple scalars are relaxed simultaneously. I will also discuss the possible ways out of this problem and the conditions that must be satisfied for relaxation to remain viable.

Dark matter 2 / 115

Scalar Dark Matter in Multi-Inert Doublet Models

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A stable scalar particle arising from an extended scalar sector is a natural Dark Matter candidate. In this talk we present results for the 3HDM, the Standard Model with two additional inert doublets, where it is possible to have CP-mixing effects in the dark sector and a stable Dark Matter candidate. We discuss the new regions of DM mass with a correct relic density with respect to other scalar models and constrain the parameter space of the model using recent results from the LHC and DM direct and indirect detection experiments. We also propose collider signatures for further studies of the model.

Talk based on JHEP 1612 (2016) 014 and work in progress in collaboration with A. Cordero-Cid, J. Hernandez-Sanchez, V. Keus, S. F. King, S. Moretti and D. Rojas.

Cosmo 1 / 116

Gravitational Wave Oscillations in Bigravity

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I present consistent equations for gravitational wave oscillations in bigravity. In this framework a second dynamical tensor field is introduced in addition to General Relativity and coupled such that one massless and one massive linear combination arise. Here, only one of the two tensors is the physical metric coupling to matter, and thus the basis in which gravitational waves propagate is different from the basis where the wave is produced and detected. Therefore, one should expect - in analogy to neutrino oscillations - to observe an oscillatory behavior. I show how this behavior arises explicitly, discuss phenomenological implications in light of the first ever observed gravitational wave events GW150914 and GW151226 and present new limits on the graviton parameter space in bigravity.

Pheno 2 / 117

Charge Breaking Minima in the NMSSM

Dr. STAUB, Florian [1]; OPFERKUCH, Toby [2]; Dr. KRAUSS, Manuel [3]

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I will present our findings regarding the impact of charge-breaking minima on the vacuum stability of the NMSSM. In contrast to Two-Higgs-Doublet Models like the MSSM, at both tree- and loop-level there exists global charge-breaking minima. Consequently, many regions of parameter space are rendered metastable, which otherwise would have been considered stable if these charge-breaking minima were neglected. I will give an overview of these regions as well as discussing the impact that these new scalar field directions have on otherwise metastable vacuum configurations.

Flavor / 118

331 - Gauge Symmetry and the Fermion Mass Hierarchy

Prof. HUITU, Katri [1]; KOIVUNEN, Niko [1]

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A model based on SU(3)_CxSU(3)_LxU(1)_X gauge symmetry (331) is presented. One of the main features of the 331-models is their ability to explain the number of fermion generations. Our model utilizes three scalar triplets to give all the fermions a mass at tree-level. The scalar sector also enables the Froggatt-Nielsen mechanism, which is one of the best known ways of generating the fermion mass hierarchy. Our model thus explains the number of generations and the fermion mass hierarchy simultaneously.

This talk is based on work in progress, which is to be published soon.

Dark matter 3 / 119

Neutrino and dark matter phenomenology from an A4 Discrete Dark Matter Model

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In this talk, I will present two models based a scenario where the stability of dark matter and the phenomenology of the Neutrinos are related by the spontaneous breaking of a non--Abelian flavour symmetry (Discrete Dark Matter). In this set up, the breaking of the flavour symmetry is done at the Seesaw scale, in such a way, that the remaining symmetry stabilises the dark matter. I will show that in both models, the neutrino mass matrices achieve two--zero textures and accordingly I will present an update to this two--zero texture phenomenology. Furthermore, I will point the interesting correlation between $\sin^2 \theta_{23}$ and the sum of the light neutrino masses and the correlation between the lightest neutrino mass and the neutrino--less double beta decay parameter $\langle m_{\beta \beta}\rangle$, where a lower bound is obtained for both hierarchies, moreover, the regions are within the nearly future experimental sensitivities. Finally, I will present the dark matter phenomenology and bounds arising for the dark matter candidate in both models.

Dark matter 1 / 120

NLO corrections to general scalar singlet models and dark matter

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Scalar singlet extensions of the Standard Model (SM) are the simplest extensions of its Higgs sector. Nevertheless they are able to improve or solve several outstanding issues such as the origin of dark matter, explain the matter anti-matter asymmetry through electroweak baryogenesis or improve the RGE stability of the model up to high energy scales. In this talk I will discuss the importance of NLO electroweak corrections in general singlet extensions of the SM. I will focus on the corrections to the parameters of the theory, on approximate corrections to gluon fusion in decoupling limits, and on approximate corrections to the scalar triple couplings in scenarios with new heavy scalars. I will also show that, contrarily to the case of the simplest real scalar singlet dark matter model, a complex singlet model with a new Higgs mixing with the SM-like Higgs and a dark matter candidate, can still be made widely compatible with the latest dark matter direct detection bounds from LUX and to saturate the relic density as measured from the Planck data. This talk will be based on JHEP 1608 (2016) 073 and ongoing work to appear.

Collider / 121

Global effective field theory for top physics at lepton colliders

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We examine the constraints that future lepton colliders would impose on the top-quark effective field theory. All top-quark operators are simultaneously included and their effects are computed at next-to-leading order in QCD, including off-shell top effects, in the MadGraph_aMC@NLO framework. Statistically optimal observables are exploited and an operator-basis indepdendent metric is used to compare the global strengthening of constraints in different scenarios.

Pheno 2 / 122

From extra particles to the Standard Model Effective Field Theory

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In view of the variety of models and their predictions for physics beyond the Standard Model, a model independent approach to its extension is convenient. One such approach is adding non-renormalizable terms to the Standard Model Lagrangian to get an Effective Field Theory that parametrizes any new physics as seen from low energies.

Another possibility is to consider new particles that have linear (gauge invariant and renormalizable) couplings to the Standard Model. They can be classified according to their representation under the Standard Model gauge group. Their effects can be studied in a general way, without restricting to any particular model. This approach has several advantages. It is valid for energies around the masses of the new particles, whereas the effective field theory breaks at lower energies. Because these energies are available for us to study with this method, we can use it to describe direct production of new particles.

Even if no direct production of new particles is observed, as is the case at the moment in the LHC, we can still get information from the low energy precision observables. The new heavy particles can be integrated out to get an effective Lagrangian, some particular case of the Standard Model effective Lagrangian. We can therefore relate the parameters of the UV theory with new particles to the coefficients of the operators of the Standard Model Effective Field Theory. This allows us to put model independent bounds to new particles using precision observables that can be measured at the LHC.

When integrating out new particles, we should not only consider the integration of each of them, but also the possibility of integrating together particles of different types. Some combinations of new particles produce new effects in the effective Lagrangian that are not a sum of the effects of the separate particles.

The size of the calculations in this cases indicates the necessity of their treatment using computers. Such computer tools have been developed. They will be useful for futher Effective Field Theory calculations in any of it applications and in particular in physics beyond the Standard Model.

Pheno 1 / 123

New constraints on the 3-3-1 model with right-handed neutrinos

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In the framework of a 3-3-1 model with right-handed neutrinos and three scalar triplets we consider different spontaneous symmetry breaking patterns seeking for a non-linear realization of accidental symmetries of the model, which will produce physical Nambu-Goldstone (NG) bosons in the neutral scalar spectrum. We make a detailed study of the safety of the model concerning the NG boson emission in energy loss processes which could affect the standard evolution of astrophysical objects. We consider the model with a Z2 symmetry, conventionally used in the literature, finding that in all of the symmetry breaking patterns the model is excluded. Additionally, looking for solutions for that problem, we introduce soft Z2-breaking terms in the scalar potential in order to remove the extra accidental symmetries and at the same time maintain the model as simple as possible. We find that there is only one soft Z2-violating term that can get rid of the problematic NG bosons.

Dark matter 2 / 124

Dark matter production in non-thermal cosmology

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We studied the production of dark matter, dark radiation, and baryon asymmetry in the non-thermal cosmology from the decay of a heavy scalar or modulus field. These fields appear in beyond standard model physics like supergravity and superstring theory. Our main focus is moduli with low reheating temperatures which decay before Big Bang Nucleosynthesis (BBN). We used the result of precise calculation of degrees of freedom in the early universe, based on considering QCD equation of state from lattice QCD calculations. This helps us to have a more precise estimation of matter content of universe in a non-thermal scenario before BBN. This study is purely phenomenological, in the sense that all relevant particle physics parameters (masses and couplings, or annihilation cross sections) are simply treated as free parameters. The goal is to map out the region in this multi–dimensional parameter space that is compatible with cosmological observation.

Cosmo 1 / 125

Probing inflationary primordial black holes for the LIGO gravitaional wave events

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Primordial black holes (PBHs) are one of the candidates to explain the gravitational wave (GW) signals observed by the LIGO detectors. Among several phenomena in the early Universe, cosmic inflation is a major example to generate PBHs from large primordial density perturbations. In this talk, we discuss the possibility to interpret the observed GW events as mergers of PBHs which are produced by cosmic inflation. The primordial curvature perturbation should be large enough to generate a sizable amount of PBHs, and thus we have several other probes to test this scenario. We point out that the current pulsar timing array (PTA) experiments already put severe constraints on GWs generated via the second-order effects, and that the observation of the cosmic microwave background (CMB) puts severe restriction on its small-scale distortions, such as $¥mu$-distortion. In particular, it is found that the scalar power spectrum should have a very sharp peak at k ~ 10^6 Mpc^-1 to fulfill the required abundance of PBHs while evading constraints from the PTA experiments together with the mu-distortion.

Dark matter 2 / 126

Sharp spectral features from light dark matter decay via gravity portals

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So far, all evidence for the existence of dark matter is based on its gravitational interactions with the observable sector, and its precise particle nature remains mysterious. However, even if dark matter is stable against decay in flat spacetime, as commonly assumed in the literature, the presence of nonminimal couplings to gravity of the dark matter field can spoil this stability in curved spacetime, with potentially remarkable phenomenological implications. More specifically, a scalar dark matter candidate with a mass in the MeV-GeV region, destabilized through a linear coupling to the Ricci scalar, can decay into electron-positron pairs and photons, with implications for both the thermal history of the Universe and the present-day gamma-ray spectrum observed at Earth. Therefore, observations of the cosmic microwave background by the Planck satellite and of the extragalactic isotropic gamma-ray background as measured by COMPTEL, EGRET and Fermi LAT can be used to constrain the size of the nonminimal coupling parameter.

Cosmo 2 / 127

Warm Little Inflaton

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We show that inflation can naturally occur at a finite temperature T>H that is sustained by dissipative effects, when the inflaton field corresponds to a pseudo Nambu-Goldstone boson of a broken gauge symmetry. Similar to the Little Higgs scenarios for electroweak symmetry breaking, the flatness of the inflaton potential is protected against both quadratic divergences and the leading thermal corrections. We show that, nevertheless, nonlocal dissipative effects are naturally present and are able to sustain a nearly thermal bath of light particles despite the accelerated expansion of the Universe. As an example, we discuss the dynamics of chaotic warm inflation with a quartic potential and show that the associated observational predictions are in very good agreement with the latest Planck results. This model constitutes the first realization of warm inflation requiring only a small number of fields; in particular, the inflaton is directly coupled to just two light fields.

Main reference:
Phys. Rev. Lett. 117 (2016) no.15, 151301 (Editors' Suggestion)
[arXiv:1604.08838 [hep-ph]]

Dark matter 3 / 128

De-coannihilation: bound states rouse

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We point out that bound states of particles heavier than dark matter~(DM)
can increase the final DM relic density. It contradicts the conventional wisdom that the existence of heavy particles decreases the relic abundance by increasing annihilation cross-sections into standard model particles. In this work, two models are presents based on freeze-out and freeze-in scenarios, where multi-component DM can be naturally realized.

Dark matter 3 / 129

Can primordial Black Hole Dark Matter explain the gamma-ray excess at the Galactic Centre?

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The observation of gravitational waves by the Advanced LIGO revived the scenario that dark matter (DM) of the Universe consists of primordial black holes (PBH) produced by field fluctuations imprinted in the Cosmic Microwave Background anisotropies. At the same time, the prevailing paradigm of Weakly Interacting Massive Particles (WIMPs) has no experimental support. Notable exceptions to this claim could be provided by the well established gamma-ray anomaly, the 1-5 GeV gamma-ray excess from the Galactic Centre and Andromeda that may be interpreted as a signal of annihilating WIMPs. We show that radiation emitted by PBHs could also explain both the morphology and the energy spectrum of the gamma-ray excess. The accretion rate of those PBH is suppressed today, so the gamma-ray spectrum of 'starving' PBHs is peaked at high energies due to hadronic pion production. The morphology of the PHB signal, depending on the distributions of gas and PBHs at the Galactic Centre, is similar to the gamma-ray excess. Thus the morphology of and the energy spectrum of PBHs both mimic the ones commonly attributed to annihilating WIMPs. Our result demonstrates that PBHs provide a viable alternative view on DM without invoking any new particle physics at the electroweak scale. This result may have profound implications for cosmological observations by Gaia and LISA, for DM direct and indirect search experiments as well as for new physics searches at colliders.

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Phenomenology of supersymmetric models with a U(1)R baryon number

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We present the phenomenology of a supersymmetric extension of the Standard Model with an R-symmetry under which R-charges correspond to the baryon number. This identification allows for the presence in the superpotential of the R-parity violating term λ″UcDcDc without breaking baryon number, which loosens several bounds on this operator while changing considerably the phenomenology. We will examine recent ATLAS and CMS experimental searches and use these to place limits on the parameter space of the model. We will also present the implications this model has on baryogenesis.

Collider / 131

Current status of MSSM Higgs sector with LHC 13 TeV data

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ATLAS and CMS collaborations have reported the new results on Higgs search analyzing the LHC Run-II data. In this work we study the Higgs sector of the phenomenological Minimal Supersymmetric Standard Model (pMSSM), in the light of the new Higgs data, on and above the existing Run-I data, and comment on their relative impacts by performing a global fit analysis. One of the major impact of the new data on the parameter space comes from the $H \to \tau \tau$ direct search limit which rules out the high tanβ regions more efficiently than the Run-I data. Secondly, we show that the latest result of the rare radiative decay of the B meson presented by the Belle collaboration constrains significantly the low tanβ and low m_A region of the parameter space than its previous value. Further, we find that in a global fit the Run-II light Higgs signal strength data are at most comparable in strength with the corresponding Run-I data. Finally we discuss the possible decay modes of heavy Higgs bosons to supersymmetric particles.

Pheno 3 / 132

Radiative symmetry breaking with multiple scalar fields

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In this talk the Higgs portal model – a model with classical scale invariance which in the scalar sector contains an SU(2) doublet and a singlet will be presented. The possibility and pattern of radiative symmetry breaking will be studied along with the issue of generation of masses of all the particles by loop corrections. An important ingredient in this analysis is the RGE improved effective potential. A new method of performing the RGE improvement in presence of several scalar fields will be presented and used to show that the correct mass spectrum of the physical particles can be achieved. Moreover, the possibility of successful baryogenesis in this model will be discussed.

Dark matter 3 / 133

Supersymmetric Aspects of Sterile Neutrino Dark Matter

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Sterile neutrino dark matter, which remains a popular alternative to the WIMP paradigm, has generally been studied in non-supersymmetric setups. In this talk, we investigate dark matter properties of the sterile neutrino within an underlying theory that is supersymmetric. This setup demonstrates several interesting and novel dark matter features such as multiple populations from multiple production mechanisms, a population of cold+warm dark matter, and significant contributions to the effective number of relativistic degrees of freedom Neff during Big Bang Nucleosynthesis.

Cosmo 2 / 134

Cosmological Implications of Dark Matter Bound States

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The relevance of the Sommerfeld effect for annihilations of Dark Matter particles has been recognized long time ago. A second related phenomenon, so far almost forgotten, can give a sizable contribution: formation and subsequent decay of Dark Matter bound states. I will present generic formulæ for computing how bound states formation affects the thermal abundance of Dark Matter with non-abelian gauge interactions and highlights some interesting signatures that it can give in indirect detection experiments.

Theory / 135

Cosmological evolution of Yukawa couplings: the 5D perspective

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The cosmological evolution of standard model Yukawa couplings may have major implications for baryogenesis. In particular, as highlighted recently, the CKM matrix alone could be the source of CP-violation during electroweak baryogenesis provided that the Yukawa couplings were large and varied during the electroweak phase transition. We discuss a natural realisation of this idea in the context of Randall-Sundrum models and show that the geometrical warped approach to the fermion mass hierarchy may naturally display the desired cosmological dynamics. The key ingredient is the coupling of the Goldberger-Wise scalar, responsible for the IR brane stabilisation, to the bulk fermions, which modifies the fermionic profiles. This also helps alleviating the usually tight constraints from CP-violation in Randall-Sundrum scenarios. We show how the Yukawa couplings vary during the stabilisation of the Randall-Sundrum geometry and can thus induce large CP-violation during the electroweak phase transition. Using holography, we discuss the 4D interpretation of this dynamical interplay between flavour and electroweak symmetry breaking.

Cosmo 1 / 136

Gravitational waves from the asymmetric-dark-matter generating phase transition

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The baryon asymmetry, together with a dark matter asymmetry, may be produced during a first order phase transition in a generative sector. I will discuss the possibility of a gravitational wave signal in a model realising such a scenario. We find areas of parameter space with strong phase transitions which can be probed by future, space based, gravitational wave detectors. Other signals of this scenario include collider signatures of a Z′, DM self interactions, a contribution to ΔNeff and nuclear recoils at direct detection experiments.

Pheno 3 / 137

Phenomenological Comparison of Models with Extended Higgs Sectors

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Beyond the Standard Model (SM) extensions usually include extended Higgs sectors. Models with singlet or doublet fields are the simplest ones that are compatible with the ρ parameter constraint. The discovery of new non-SM Higgs bosons and the identification of the underlying model requires dedicated Higgs properties analyses. In this paper, we compare several Higgs sectors featuring 3 CP-even neutral Higgs bosons that are also motivated by their simplicity and their capability to solve some of the flaws of the SM. They are: the SM extended by a complex singlet field (CxSM), the singlet extension of the 2-Higgs-Doublet Model (N2HDM), and the Next-to-Minimal Supersymmetric SM extension (NMSSM). In addition, we analyse the CP-violating 2-Higgs-Doublet Model (C2HDM), which provides 3 neutral Higgs bosons with a pseudoscalar admixture. This allows us to compare the effects of singlet and pseudoscalar admixtures. Through dedicated scans of the allowed parameter space of the models, we analyse the phenomenologically viable scenarios from the view point of the SM-like Higgs boson and of the signal rates of the non-SM-like Higgs bosons to be found. In particular, we analyse the effect of singlet/pseudoscalar admixture, and the potential to differentiate these models in the near future. This is supported by a study of couplings sums of the Higgs bosons to massive gauge bosons and to fermions, where we identify features that allow us to distinguish the models, in particular when only part of the Higgs spectrum is discovered. Our results can be taken as guidelines for future LHC data analyses, by the ATLAS and CMS experiments, to identify specific benchmark points aimed at revealing the underlying model.

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Constraints on Relaxion Windows

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I will talk about the low energy phenomenology of the relaxion solution to the weak scale hierarchy problem. Assuming that the Hubble friction is responsible for a dissipation of the relaxion energy,
I identify the cosmological relaxion window which corresponds to the parameter region compatible with a given value of the acceptable number of inflationary e-foldings.
Then a variety of observational constraints on the relaxion window will be discussed, ranging from laboratory experiments to astrophysical and cosmological considerations.
It will be shown that majority of the parameter space with a relaxion mass greater than 100 eV and a relaxion decay constant below 10^7 GeV is excluded by existing constraints. There is an interesting parameter region with a relaxion mass between 0.2-10 GeV and a relaxion decay constant f ~ few-200 TeV, which is allowed by existing constraints, but can be probed by future beam dump experiments such as the SHiP experiment, or by improved EDM experiments.

Theory / 139

Light Higgs from Pole Attractor

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We present a new approach to the solution of the gauge hierarchy problem. The Higgs mass term, promoted to a field-dependent parameter, is naturally driven to small values due to an attractor behaviour of an auxiliary scalar field. This attractor behaviour arises from a singular non-canonical kinetic term.

Pheno 1 / 140

CP Violation with an unbroken CP transformation

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A CP conserving SU(3) gauge theory is spontaneously broken to T_7 by the vacuum expectation value (VEV) of a 15-plet. Even though the SU(3)-CP transformation is not broken by the VEV, the theory exhibits physical CP violation in the broken phase. This is because the SU(3)-CP transformation corresponds to the unique order-two outer automorphism of T_7, which is not a physical CP transformation for the physical T_7 states, and there is no other possible CP transformation. We explicitly demonstrate that CP is violated by calculating a CP odd decay asymmetry in the broken phase. This scenario provides us with a natural protection for topological vacuum terms, ensuring that a theta angle is absent even though
CP is violated for the physical states of the model.

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CMS summary

Dr. TKACZYK, Slawomir [1]

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Compressed spectra

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Higgs Properties, Dark Matter and the Electroweak Phase Transition in the (N)MSSM

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Testing 'Natural SUSY' at the LHC

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Light scalars: From lattice to the LHC via holography

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A Clockwork Theory

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Scale hierarchies and string phenomenology

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High-scale supersymmetry from flux compactifications

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Effective field theory for magnetic compactifications

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Relaxion for the EW scale hierarchy

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SUSY: News from Run 2 searches

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Tagging a monotop signature in natural SUSY

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BSM Higgs searches

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EFT analysis of aTGC @LHC

I will review current status of aTGC EFT analysis and explain a novel analysis improving aTGC sensitivity within the EFT regime.

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Status of twin supersymmetry

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Supersymmetric D-term Twin Higgs

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Minimal Mirror Twin Higgs

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Naturalness and precise gauge unification

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A Tale of Two Portals: Testing Light, Hidden New Physics at Future e+e- Colliders

We investigate the prospects for producing new, light, hidden states at a future $e^+ e^-$ collider in a Higgsed dark $U(1)_D$ model, which we call the Double Dark Portal model. The simultaneous presence of both vector and scalar portal couplings immediately modifies the Standard Model Higgsstrahlung channel, $e^+ e^- \to Zh$, at leadingorder in each coupling. In addition, each portal leads to complementary signals which can be probed at direct and indirect detection dark matter experiments. After accounting for current
constraints from LEP and LHC, we demonstrate that a future $e^+ e^-$ Higgs factory will have unique and leading sensitivity to the two portal couplings by studying a host of new production, decay, and radiative return processes. Besides the possibility of exotic Higgs
decays, we highlight the importance of direct dark vector and dark scalar production at $e^+ e^-$ machines, whose invisible decays can be tagged from the recoil mass method.

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Searches for dark matter in ATLAS

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A new mechanism to produce X-ray lines with unique morphology and spectrum

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Dark matter: from 10^-22 ev to 10^67 ev

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Superweakly and not so weakly interacting Dark Matter

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Dark matter mediator searches with colliders

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On the breaking of Lepton Flavour Universality in B decays

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A natural solution to LFU violation

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A Perturbative Randall-Sundrum Cosmological Phase Transition

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Unveiling the Secrets of Nature - An outlook on fundamental physics in 100 years

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Spin-dependent constraints on blind spots for singlino-Higgsino dark matter in the NMSSM

Current status of spin-independent (SI) direct detection experiments may suggest that the WIMP dark matter (e.g. nuetralinos in supersymmetric models) would interact very weakly with nucleons. The so-called blind spots in parameter space correspond to the limit of vanishing SI interaction. Recently, the spin-dependent (SD) direct detection experiments have become competitive to the SI ones. In my talk I will discuss the SI blind spots of thermal singlino-Higgsino dark matter in NMSSM and present current constraints and prospects for their SD interactions.

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Problems with changing Hilbert space in Quantum Mechanics. Questions for Cosmology

Let we have initially the infinite potential well disposed between points 0 and a_1 and than width of this well is changed during final time T $a_1\to a_2$. Standard methods of description of transition between the states of an initial and final well don't applicable since the states of these wells belong to the different Hilbert spaces.
We discuss two problems.
1. How to calculate probabilities of mentioned transitions.
2. How to compare complete measures of these spaces. In the terminology of regularization by well with finite depth V it corresponds transitions to the continuous spectrum which does not disappear at regularization removal $V\to\infty$.
How to calculate the probability of this transition.

The possible relation to the phenomena accompanied Electroweak transition in the earlier Universe is also discussed briefly.

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Charged composite Dark Matter

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Georg Philipp Telemann and traditional music from Poland and Moravia, ensemble "Les Musiciens de Saint-Julien"

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Piano concert, music of Fryderyk Chopin

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On Signatures and Preparation of Super-excited Initial States of Inflation

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We demonstrate that in some regions of parameter space, modified dispersion relations can lead to highly populated excited states, which we dub as "super-excited" states. In order to prepare such super-excited states, we invoke dispersion relations that have negative slope in an interim sub-horizon phase at high momenta. This behaviour of quantum fluctuations can lead to large corrections relative to the Bunch-Davies power spectrum, which mimics highly excited initial conditions. We identify the Bogolyubov coefficients that can yield these power spectra. In the course of this computation, we also point out the shortcomings of the gluing method for evaluating the power spectrum and the Bogolyubov coefficients. As we discuss, there are other regions of parameter space, where the power spectrum does not get modified. Therefore, modified dispersion relations can also lead to so-called "calm excited states" as well. We conclude by commenting on the possibility of obtaining these modified dispersion relations within the Effective Field Theory of Inflation.