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Book of Abstracts

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Exotic Prompt and Non-Prompt Leptonic Decays as a Window to the Dark Sector with ATLAS

Author: Miriam Deborah Joy Diamond[1]

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Results of searches for both prompt and non-prompt leptonic decays of new dark sector particles in proton-proton collisions with the ATLAS detector are presented. Searches that encompass a wide range of new particle masses, lifetimes and degrees of collimation of leptonic decay products are discussed. The results are interpreted in the context of models containing new gauge bosons (dark photons or dark Z bosons) that give rise to lepton-jets or to more general displaced leptonic signatures that could be a viable dark matter candidate.

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Searching for Dark Matter with the ATLAS Detector

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While it is known that about 85% of the matter in the universe is in the form of Dark Matter (DM), little is known about its properties. As they should interact only weakly, if DM particles are produced in the proton-proton collisions at the LHC, they would be measured as missing transverse momentum (MET) in the detectors. Recent results from the ATLAS experiment based on the presence of large MET along with a variety of objects will be discussed.

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Higgs Inflation and UV completion

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I will discuss ultraviolet completion of the Standard Model Higgs inflation. I will argue why the Standard Model Higgs cannot be the inflaton once quantum corrections are taken into account.I will argue in this respect MSSM (minimal supersymmetric Standard Model) is still a plausible candidate to explain dark matter, baryogenesis and large scale structures.

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Dark Forces in the Sky: signals from Z' and the dark Higgs

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We consider the indirect detection signals for a self-consistent hidden U (1) sector, containing a fermionic dark matter candidate, dark gauge boson and a Dark Higgs. The presence of an additional scalar, the Dark Higgs, provides a mass generation mechanism for the dark sector particles and is required to avoid unitarity violation at high energies. We find that the inclusion of the additional scalar to the sector opens up a new two-body channel and allows fermionic dark matter annihilation to be used to probe the properties of a scalar final state. We examine the phenomenology of the sector with a focus on this new process, and determine the limits on the model parameter space from Fermi data on Dwarf Spheriodal Galaxies and other relevant experiments.

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Gravitational Wave Instabilities in the Cosmic Neutrino Background

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We investigate the propagation of gravitational waves through the cosmic neutrino background, assuming it carries a non-zero lepton asymmetry. In this background, the graviton dispersion relation is found to exhibit birefringent behaviour leading to an enhancement/suppression of the gravitational wave amplitudes depending on the polarisation, where the magnitude of this effect is related to the size of the lepton asymmetry. The heralding of the new era of gravitational wave astronomy may allow the investigation of this behaviour and provide an indirect way to learn about the properties of the cosmic neutrino background and the neutrino sector.

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Searches for dark matter in hadronic final states at CMS

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Searches in CMS for dark matter in final states with invisible particles recoiling against hadronic final states are presented. Various topologies and kinematic variables are explored, as well as jet substructure as a means of tagging heavy bosons. The focus of the talk is the recent results obtained using data collected at the Run-II of the LHC.

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Searches for dark matter in non-hadronic final states at CMS

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Searches in CMS for dark matter in final states with invisible particles recoiling against leptons and photons are presented. Various topologies are explored, covering several specific dark-matter production modes. The talk focuses on the recent results obtained using data collected at Run-II of the LHC.

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Relic density and baryogenesis from natural SUSY with mixed axion-higgsino dark matter

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We describe an eight-coupled-Boltzmann equation calculation of the mixed axion-higgsino dark matter scenario which is expected from natural SUSY. Typically the relic density is axion dominated unless late decaying axinos or saxions feed the WIMP abundance. While thermal leptogenesis is barely viable, non-thermal and Affleck-Dine leptogenesis remain robust scenarios to generate the matter-anti-matter asymmetry.

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Distinguishing between Warm Dark Matter and Late Kinetic Decoupling using CMB spectral distortions.

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Recently a number of alternative dark matter models have been introduced as a means of explaining the physics of small-scale structure formation. These include, warm dark matter and dark matter with late kinetic decoupling both of which differ substantially from the canonical cold dark matter formalism. One interesting way of constraining the phenomenology in these models is to look at the characteristic imprint they leave on the photon spectrum left over from the Big Bang. These imprints are known as spectral distortions in the literature and arise due to spatial fluctuations in the photon temperature along the line of sight. As a result, the thermal history of the photon bath gives us a unique insight into the evolution of the early universe. In this talk I will show how this insight

can be used to constrain the phenomenology of these dark matter models, in particular noting that the signatures can be used to distinguish between warm dark matter and late kinetic decoupling scenarios.

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Constraints on cosmological viscosity from GW150914 observation

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It has been shown that gravitational waves propagate through ideal fluids without experiencing any dispersion or dissipation. However, if the medium has a non-zero shear viscosity, gravitational waves will be dissipated at a rate proportional to $G\eta$. We test Dark Matter and Dark Energy models with non-zero shear viscosity by calculating the dissipation of GW150914 which propagates over a distance of 410 Mpc through the dissipative
fluid and comparing the data with the theoretical prediction. We put an upper bound on the shear viscosity of the cosmological fluid as $< 10^9$ Pa sec which is close to the critical viscosity of fluids at which the viscous pressure becomes significant for the dynamics of the Universe. We show that future observations of gravitational waves at LIGO have the potential of detecting any possible viscosity of Dark Matter and Dark Energy. Finally, we comment on how this could be related to a lower bound on the self-interaction cross-section of Dark Matter.

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Freeze-in of light dark matter

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We investigate the production of keV sterile neutrino dark matter via the decay of a frozen-in complex scalar with a feeble Higgs portal coupling. Sterile neutrinos at the keV range is an attractive class of model because it can naturally explain Standard Model neutrino masses and can be cosmologically warm dark matter. This is the first time a complex scalar has been considered in this scenario, and the presence of a light pseudo-Nambu Goldstone boson component, caused by spontaneously breaking a U(1) global sterile neutrino number symmetry, leads to highly interesting behaviour. Moreover, this is a robust model that can be applied to generic light fermion dark matter candidates.

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Gravitationally Bound Condensates Formed by Bosons with Potential Energy V(A)= (1-cos(A/f)

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We review our recent work on gravitationally bound condensates formed by Hermitian bosons interacting with a potential energy $\Lambda^4[1-\cos(A/f)]$. We have used an expansion method to simplify the equations of motion. The expansion parameters are the binding energy of the condensed bosons, and the ratio between the scale of the Bose field f and the Planck mass. Applying our analysis to QCD axions, we find that the condensates have a limiting mass of $\mathcal{O}(10^{19})$ kg and a size of $\mathcal{O}(100)$ km.

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Top-philic Scalar DM with a Vector-like Top Partner

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We consider a scalar top-philic Dark Matter (DM) S coupling, apart from the Higgs portal, exclusively to the right-handed top quark t_R and a colored vector-like top partner T with a Yukawa coupling y_{ST} which we call the topVL portal. When the Higgs portal is closed and y_{ST} is perturbative (< 1), $TS \to (W^+b, gt)$, $SS \to t\bar{t}$ and $T\bar{T} \to (q\bar{q}, gg)$ provide the dominant annihilation contributions to obtain the correct thermal relic density in light, medium and heavy DM mass range, respectively. However, large $y_{ST} \sim \mathcal{O}(10)$ can make $SS \to gg$ dominate via the loop-induced coupling C_{SSgg} in the $m_S < m_t$ region. In this model it is the C_{SSgg} coupling that dominates DM-nucleon scattering in the direct detection, which can be large when $SS \to gg$ dominates the DM annihilation. The current LUX results can exclude the $SS \to gg$ dominating scenario and the expected sensitivity of XENON-1T may further test $y_{ST} > 1$, and $0.5 < y_{ST} < 1$ may be covered in the future LUX-ZP experiment. The indirect detection results from Fermi gamma-ray observations can also exclude the $SS \to gg$ dominating scenario and play a complementary role to direct detection in the heavy DM mass region, of which one order of magnitude of sensitivity improvement will push DM mass to be heavier than about 400, 600, 1000 GeV for $y_{ST} = 0.3, 0.5, 1.0$, respectively. The colored top partner T and its anti-particle can be produced in pair at the hadron collider. They will decay 100% into $t\bar{t} + E_T^{miss}$ signal when kinematically open and receive constraints from the corresponding CMS measurements at 8 TeV. We found that the top partner mass in the range 300 (450)-850 GeV can be excluded for m_S =0 (200) GeV.

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Layered dielectric haloscopes: a new way to detect axion dark matter

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Axions and axion-like particles are among the best-motivated candidates for dark matter. In particular, the QCD axion is capable of not only providing a dark matter candidate, but it also gives a natural explanation for the strong CP problem. Consequently, the detection of dark matter axions is of great interest as it would solve two of the most significant problems of modern physics. To this end, we introduce a new method to detect galactic dark-matter axions using dielectrics. When a dielectric interface is inside a strong parallel magnetic field, the oscillating axion field acts as a source of microwaves, which emerge in both directions perpendicular to the surface. These microwaves compensate for a discontinuity in the axion induced electric field. Crucially, the emission rate can be boosted by multiple parallel layers judiciously placed to achieve constructive interference. Starting from the axion-modified Maxwell equations, we calculate the efficiency of this new "layered dielectric haloscope" approach. This technique may prove useful in the well-motivated high-frequency range of 10-100 GHz (axion mass
40-400 μeV), where traditional cavity resonators have difficulties reaching the required volume. This would allow one to study axion dark matter generated by the topological defects, which occur if the reheating temperature after inflation was lower than the Peccei-Quinn scale. Unlike a cavity resonator it is possible for dielectric haloscopes to conduct a broadband search. In particular, we study the relation between the power generated and the bandwidth, the connection between the emission and reflection functions, the required placement precision for meter-scale disks, and the impact of small but non-vanishing axion velocities.

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Search for Dark matter with XENON1T Experiment

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Astronomical and cosmological observations strongly suggest the presence of dark matter. The direct search for evidence of Weakly Interacting Massive Particle (WIMP) dark matter continues to be one of the forefront activities in experimental particle physics. In this talk I will give an overview of the evidences of dark matter and present in particular XENON1T experiment which has achieved world-leading sensitivities in WIMP-nucleon interactions using liquid xenon time projection chambers (TPCs), first with the XENON10 and later with the XENON100 experiments. The actual phase of the experiment consists of an unprecedented one ton fiducial (three tons total) volume of ultra pure liquid xenon as both target and detection medium. The data-taking will start soon and should reach sensitivities down to 10-47 cm2 after two ton years of exposure. I will present the upgrade to the ton scale which was only possible due to a massive research and development program encompassing every aspect of the detector. The current and future stages of the XENON experiment in the context of the global dark matter search will also be discussed.

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Reconstructing WIMP dark matter properties through signal measurements in direct detection, Fermi-LAT, and CTA

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I will examine the projected ability to reconstruct the mass, scattering, and annihilation cross section of dark matter in the new generation of large underground detectors in combination with diffuse gamma radiation from expected 15 years of data from Fermi-LAT observation of 46 local spiral dwarf galaxies and projected CTA sensitivity to a signal from the Galactic Center. I will consider several benchmark points inspired by rather general extensions of the Standard Model, spanning a wide range of WIMP mass, different annihilation final states, and large enough event rates to warrant detection in one or more experiments. Direct and indirect detection experiments can be used in complementarity to ameliorate the respective determinations, which in individual experiments can at best be rather poor. A remarkable improvement in WIMP reconstruction can be achieved by combining discovery data from Fermi-LAT and/or CTA, or by combining gamma-ray observatories with direct detection experiments.

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Searches for dark matter in heavy-flavor final states at CMS

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Searches in CMS for dark matter in final states with invisible particles recoiling against top or bottom quarks are presented. Various topologies are explored, covering several specific dark-matter production modes. The focus of the talk is the recent results obtained using data collected at the Run-II of the LHC.

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The DEAP-3600 Dark Matter Direct Detection Experiment

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DEAP-3600 is a single phase liquid argon (LAr) dark matter experiment, located 2 km underground at SNOLAB, in Sudbury, Ontario. The detector has 1 tonne fiducial mass of LAr. The target sensitivity to spin-independent scattering of 100 GeV WIMPs is 1×10^{-46} cm^2. The DEAP-3600 background target is <1 background events in the WIMP region of interest in 3 tonne-years exposure. The strategies to achieve this background are pulse shape discrimination to mitigate electron recoils, ultra-low radioactivity materials for detector construction to reduce neutron and alpha backgrounds, and in-situ sanding of the acrylic vessel to mitigate radon exposure of surfaces during construction and fabrication. Detector commissioning is underway and the WIMP search begins in 2016. This talk reports on recent progress from the DEAP-3600 experiment.

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Theoretical uncertainty of the supersymmetric dark matter relic density

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To gain for a more precise prediction of the supersymmetric dark matter relic density, we have calculated next-to-leading order SUSY-QCD corrections to neutralino (co)annihilation processes including Coulomb enhancement effects. We demonstrate that these corrections can have significant impact and are thus of general interest for parameter studies. For particle physics observables at colliders, it is common practice to estimate the theoretical uncertainty by studying the variations of the predicted cross sections with a priori unpredictable scales. In astroparticle physics, this has so far not been possible, since most of the observables were calculated at Born level only, so that the renormalization scheme and scale dependence could not be studied in a meaningful way. Thus, we present the fi rat quantitative study of the theoretical uncertainty of the neutralino dark matter relic density from scheme and scale variations.

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Nonperturbative Dynamics in Dark Matter Freezeout

Author: William Shepherd[1]

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I discuss the cosmological impact of dark matter bound state formation in the early universe in the context of complete simplified models of dark matter interactions. In particular, I show that the effects of relativity on the nature and behavior of these bound states are important to correctly describe the physics in cases of interest. I continue on to discuss the implications of these interactions for the parameter space of well-motivated models of dark matter, especially in the context of unitarity considerations which lead to upper bounds on the mass of thermal dark matter.

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Unitarity constraints for Effective Field Theories

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Effective Field Theories have shown to suffer from some validity problems when applied to DM search at collider. EFT operators are generated by integrating out heavy mediators of some UV theory, and therefore are valid up to some energy scale below the mass of the integrated out particles.
To overcome such problems, different proposals have been made. An appealing possibility is certainly to switch from EFT to simplified models. Anyway this enlarges the parameter space and introduces some model dependence.
It would be certainly useful to be able to work with EFT, despite of such validity issues, given its model-independent and simple framework. A development in such direction was the introduction of truncation of the simulated events.
To calculate the expected cross section, one may retain only the events that have a momentum transfer below a certain treshold, usually identified with the mass of the heavy integrated out mediator. In this talk we analyse limitations coming from unitarity bounds, showing that in some cases unitarity may break at energies below the mass of the heavy mediator, and therefore in such cases additional constrains have to be enforced on the EFT.

Using the K matrix formalism, we propose a way to force the theory to satisfy such additional constrains.

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Mass-constraining variables to confront dark matter production at the LHC

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After successful discovery of the Higgs boson, the LHC presently confronts the major challenge in searching for new physics. Any such observation necessitates the determination of mass and other quantum numbers like spin, polarization etc for the new resonance. Most of the BSM theories motivated from profound experimental indication of dark matter (DM), trying to accommodate them as some stable BSM particle within their framework. In a wide class of such scenario, any production of heavy resonance particles eventually decay semi-invisibly resulting at least two massive stable undetectable particles in the final state. Reconstruction of these events at a hadron collider or the mass determination of these new particles are challenging. Here we discuss two interesting mass-constraining variables, M_{2Cons} and $\sqrt{\hat{s}}$, which possess an array of rich features having the ability to use on-shell mass constraints inclusively. We argue the consequence of applying the additional resonance mass-shell constraint in the context of a semi-invisible antler decay topology produced at the LHC. Our proposed variable, under additional constraint, develops a new kink solution at the true masses. This enables one to determine the invisible (DM) particle mass simultaneously with the parent particle mass from these events. We also demonstrate the ability of these constrained variables to reconstruct the semi-invisible events with the momenta of invisible particles and thus improving the measurements to reveal the properties of new physics.

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Dark matter annihilation into right-handed neutrinos and the galactic center gamma-ray excess

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We have studied a specific case that the dark matter particles annihilate into right-handed neutrinos. We calculate the predicted gamma-ray excess from the galactic center and compare our results with the data from the Fermi-LAT. An approximately 10-60 GeV right-handed neutrino with heavier dark matter particle can perfectly explain the observed spectrum. The annihilation cross section ⟨σv⟩ falls within the range 0.5-4×10−26 cm3/s, which is roughly compatible with the WIMP annihilation cross section. This presentation is based on our work 1512.02899.

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Sidereal modulation searches for the direct detection of self-interacting dark matter

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I will outline the unique direct detection phenomenology which arises if dark matter is self-interacting. The crucial point is that, in the Earth frame, the halo wind interaction with Earth-captured dark matter generically results in a spatially dependent near-Earth dark matter environment. This implies distinctive signatures in the direct detection signal, including latitudinal dependence, and modulation with sidereal day. The sidereal modulation is particularly interesting, since it can only have a cosmological origin. Some examples will be shown from dark matter simulations with dark photon self-interactions. I will then describe some model-independent search strategies for sidereal modulation signals of unknown shape, in the hope of encouraging experimental colleagues to perform such searches.

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Minimal Majoronic Dark Radiation and Dark Matter Model and its Phenomenology

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We study the simplest singlet Majoron model for the dark radiation and dark matter and it 1-loop RGE running.
We found that a smaller effective number of neutrinos $\triangle N_{eff} \sim 0.05$ is preferred.
Moreover, a heavy scalar dark matter, ρ, of mass $1.5 - 4$ TeV is required by the stability of the scalar potential
and an operational type-I see-saw mechanism for neutrino masses. A neutral scalar, S, of mass in the $10 - 100$ GeV range
and its mixing with the standard model Higgs as large as 0.1 is also predicted.
The dominant decay modes are S into $b\bar{b}$ and/or a pair
of Majorons. A sensitive search will come from rare Z decays
via the chain $Z \to S + f\bar{f}$, where f is a Standard Model fermion, followed by S into a pair
of Majorons and/or b-quarks.
The interesting consequences of dark matter bound state due to the sizable $S\rho\rho$-coupling
are discussed as well. In particular, shower-like events with an apparent neutrino energy at M_ρ could contribute to the
observed effective neutrino flux in underground neutrino detectors such as IceCube.

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Indirect detection of sub-GeV dark matter

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Since the WIMP paradigm has dominated for decades, dark matter (DM) in the sub-GeV mass range is only now receiving significant attention. I will discuss indirect detection of such models in light of the recently proposed ComPair experiment, which will increase sensitivity to 1–100 MeV gamma rays by two orders of magnitude. Using a scalar-mediated model as an example, I illustrate how to apply chiral perturbation theory to compute the cross section for dark matter annihilation to pions. I also present the gamma ray spectrum resulting from the subsequent charged and neutral pion decay. Finally, I explain how to perform this analysis for theories with different mediators and discuss cosmological issues.

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The status of KIMS-NaI experiment at Yangyang underground laboratory

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The Korea Invisible Mass Search (KIMS) searches for WIMP dark matter signals using an array of ultra-pure NaI(Tl) crystals. The target goal of the KIMS-NaI experiment is to confirm or reject the DAMA/LIBRA claim of an annual modulation signature in similar NaI(Tl) crystals. We have studied the properties of more then ten prototype NaI(Tl) crystals, each with different internal radioisotope contaminations in order to characterize the internal backgrounds and learn how how they can be reduced. To date, we have achieved background levels of 2.5 counts/kg/keV/day in the 10 keV energy region. We have prepared a first phase of a collaborative effort with the DM-Ice group, called COSINE-100, that is using a 100 kg array of crystals from the KIMS & DM-Ice R&D projects placed in a liquid scintillator veto tank at the Yangyang underground laboratory. While this first phase operates, we will develop NaI(Tl) crystals with background levels that are below 1 counts/day/keV/kg for the next phase of the experiment. In this presentation, we will report on the current status of COSINE-100 and the status of our R&D on techniques for producing a 200 kg array of lower background crystals for the next phase of the experiment.

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Combined analysis of effective Higgs portal dark matter models

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We combine and extend the analyses of effective scalar, vector, Majorana and Dirac fermion Higgs portal models of Dark Matter (DM), in which DM couples to the Standard Model (SM) Higgs boson via an operator of the form $\mathcal{O}_{\rm DM}\, H^\dagger H$. For the fermion models, we take an admixture of scalar $\overline{\psi}\psi$ and pseudoscalar $\overline{\psi} i\gamma_5 \psi$ interaction terms. For each model, we apply constraints on the parameter space based on the Planck measured DM relic density and the LHC limits on the Higgs invisible branching ratio. For the first time, we perform a consistent study of the indirect detection prospects for these models based on the WMAP7/Planck observations of the CMB, a combined analysis of 15 dwarf spheroidal galaxies by Fermi-LAT and the upcoming Cherenkov Telescope Array (CTA). We also perform a correct treatment of the momentum-dependent direct search cross-section that arises from the pseudoscalar interaction term in the fermionic DM theories. We find, in line with previous studies, that current and future direct search experiments such as LUX and XENON1T can exclude much of the parameter space, and we demonstrate that a joint observation in both indirect and direct searches is possible for high mass WIMPs. In the case of a pure pseudoscalar interaction of a fermionic DM candidate, future gamma-ray searches are the only class of experiment capable of probing the high mass range of the theory.

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Searches for Axion-Like Particles with NGC1275: Observation of Spectral Modulations

Authors: Andrew J Powell[1]; Francesca Day[1]; Joseph Conlon[2]; Marcus Berg[3]; Markus Rummel[None]; Nicholas Jennings[1]; Sven Krippendorf[1]

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Axion-like particles (ALPs) can induce localised O(10%) oscillatory modulations in the spectra of photon sources passing through astrophysical magnetic fields. Ultra-deep Chandra observations of the Perseus cluster contain over 5×10ˆ5 counts from the central NGC1275 AGN and represent a dataset of extraordinary quality for ALP searches. We use these to search for X-ray spectral irregularities from the AGN. The absence of irregularities at the O(30%) level allows us to place leading constraints on the ALP-photon mixing parameter g_aγγ⊠1.5−5.4×10ˆ{−12}GeVˆ{−1} for axion mass m_a⊠10ˆ{−12}eV, depending on assumptions on the magnetic field realisation along the line of sight. At O(10%) level two modulations are present at high statistical significance, an excess in the 2-2.2 keV region and a deficit at 3.4-3.5 keV. We are unable to account for these through conventional instrumental or astrophysical processes and, interpreted as a signal, they would correspond to an ALP-photon coupling in the range g_aγγ~1−5×10ˆ{−12}GeVˆ{−1}. This talk is based on 1605.01043.

Dark Matter and Particle Astrophysics / 217

Constraints on dark matter annihilation to fermions and a photon

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We consider Majorana dark matter annihilation to fermion - anti-fermion pair and a photon in the effective field theory paradigm, by introducing dimension 6 and dimension 8 operators in the Lagrangian. For a given value of the cut-off scale, the latter dominates the annihilation process for heavier dark matter masses. We find a cancellation in the dark matter annihilation to a fermion - anti-fermion pair when considering the interference of the dimension 6 and the dimension 8 operators. Constraints on the effective scale cut-off is derived while considering indirect detection experiments and the relic density requirements and then comparing them to the bound coming from collider experiments.

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Right-handed sneutrino dark matter

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The superpartner of the right-handed neutrino provides an alternative
to the neutralino WIMP dark matter in supersymmetry.
We consider the case where this feebly interacting particle is
produced via the decay of the long-lived next-to-lightest charged sfermion.
After taking into account constraints such as dark matter relic
density or big-bang nucleosynthesis, we discuss the discovery propect
at future runs of the LHC notably through the charged track signatures.

Dark Matter and Particle Astrophysics / 192

Semi-analytical approaches in particle cosmology

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We propose a general method to analytically solve transport equations as well as the bubble wall profile during a cosmic phase transition. For the bubble wall profile we approximately solve the general one dimensional problem and derive a perturbative series of corrections to this ansatz and prove convergence. We then present general analytic solutions for coupled transport equations that govern the behavior of particle number densities during a phase transition. Finally we derive a perturbative series that relaxes the usual approximation that inactivates VEV dependent relaxation and CP violating source terms at the bubble wall and through the symmetric phase.

Dark Matter and Particle Astrophysics / 191

Colour Breaking Baryogenesis

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We propose a new cosmological scenario for the production of the baryon asymmetry of the Universe which exploits a multistep phase transition in which SU(3) color symmetry is fist broken and then restored. Baryon production occurs during the initial transition mainly due to spontaneous breaking of B-L near the phase boundary. The same B-L violation leads to washout far away from the wall. However, as long as the second transition is not first-order and occurs before the total baryon asymmetry is depleted, all washout processes are quenched and some fraction of the baryon asymmetry produced persists as the observed baryon asymmetry of our Universe. We illustrate this mechanism with a simple model that reproduces the observed baryon asymmetry and discuss how certain aspects of such a scenario may potentially be probed by future electric dipole moment and collider searches.

Experimental and Collider Aspects of SUSY / 36

Search for stable massive SUSY particles with the ATLAS detector

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Several supersymmetric models predict the production of massive long-lived supersymmetric particles. Such particles, if charged, may be detected through abnormal specific energy loss or long time-of-flight to the calorimeters. The talk presents recent results from searches of long-lived supersymmetric charged particles using proton-proton collisions at a centre of mass energy of 13 TeV with the ATLAS detector.

Experimental and Collider Aspects of SUSY / 59

Search for supersymmetry in events with photons and missing transverse momentum

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The results of searches for new physics in final states with photons and missing transverse energy are reported. The searches are based on samples of proton-proton collisions collected with the CMS detector, both at 8 and at 13 TeV. The results are interpreted in models of supersymmetry with gauge-mediated SUSY breaking, covering both strong production (13 TeV results) and electroweak production (8 TeV results).

Experimental and Collider Aspects of SUSY / 31

Search for gluinos decaying via top or bottom squarks with the ATLAS detector

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Naturalness arguments favour supersymmetric particle spectra with the partners of the Higgs boson, top and bottom quarks, and gluons within the reach of the LHC. Searches for gluinos decaying to the lightest supersymmetric particle via real or virtual third generation squarks are thus well motivated. This talk present searches performed by the ATLAS collaboration with such final states, using data recorded at 13 TeV centre of mass energy.

Experimental and Collider Aspects of SUSY / 32

Search for direct stop and sbottom pair production with the ATLAS detector

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Naturalness arguments favour supersymmetric particle spectra with relatively light partners of the top and bottom quarks. Top or bottom squarks with masses less than a few hundred GeV can give rise to direct pair production rates in proton-proton collisions at the LHC that can be observed with the ATLAS detector. The talk presents recent ATLAS results from searches for direct stop and sbottom pair production, using data recorded at 13 TeV centre of mass energy.

Experimental and Collider Aspects of SUSY / 60

Search for supersymmetry in the multijet and missing transverse momentum channel in pp collisions at 13 TeV

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A search for new physics is performed based on multijet events with large missing transverse momentum produced in 13 TeV proton-proton collisions. The data sample, corresponding to an integrated luminosity of 2.3 fb-1, was collected with the CMS detector at Run 2 of the CERN LHC. The data are examined in search regions of jet multiplicity, bottom-quark jet multiplicity, missing transverse momentum, and the scalar sum of jet transverse momenta. Exclusion limits are presented for simplified supersymmetric models of gluino

pair production.These results significantly extend the limits from LHC Run 1.

Experimental and Collider Aspects of SUSY / 35

Search for R-parity violating supersymmetric signals with the ATLAS detector

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R-parity violation introduces new signatures to be considered in the search for supersymmetry at the LHC. Strongly interacting resonances may decay to jets, sleptons may decay via lepton-flavour violating processes and lightest supersymmetric particles may decay into many particles with or without missing transverse momentum. The talk presents recent results from searches of supersymmetry in resonance production and R-parity violating signatures with the ATLAS detector.

Experimental and Collider Aspects of SUSY / 56

Search for supersymmetry in the single-lepton final state with CMS

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Results of searches for supersymmetry in events with a single, isolated electron or muon are presented. The data set
comprises proton-proton collisions at a centre-of-mass energy of 13 TeV, recorded by the CMS experiment. The results are interpreted in models of strong production of supersymmetric particles, with decay chains yielding third-generation or light quarks, a lepton, and missing transverse energy.

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Inclusive searches for squarks and gluinos in final states with two opposite sign leptons with the ATLAS detector

Author: Jonathan Long[1]

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The decay of pair produced sparticles to the lightest supersymmetric particle via intermediate supersymmetric particles can yield final states with two opposite sign electrons or muons, jets, and

missing transverse momentum. The searches performed by the ATLAS collaboration on this final state are reported, using data recorded at 13 TeV centre of mass energy. This includes two related searches, one searching at deviations from the Standard Model prediction on a wide range of values of the di-lepton invariant mass, the other one focusing on the region of the Z boson peak.

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Search for supersymmetry in events with two or more leptons in pp collisions at 13 TeV at CMS

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A search for supersymmetry is performed using events with two or more isolated leptons and jets in the final state using the CMS detector. Results are based on a sample of protonproton collisions at a centre-of-mass energy of 13 TeV at the LHC corresponding to an integrated luminosity of 2.3 fb-1. Constraints are set on the gluino and sbottom pair production cross section; model independent limits and selection efficiencies are also provided for additional model testing.

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Searches for SUSY in photons and tau channels with the ATLAS detector

Author: Jovan Mitrevski[1]

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The talk presents searches for the prompt decay of supersymmetric particles in events containing photons or taus and large transverse missing momentum, performed by the ATLAS experiment. The final states considered are particularly motivated in gauge mediated supersymmetry breaking models with a light gravitino as the lightest supersymmetric particle.

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Singlino-Higgsino Dark Matter in the NMSSM

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We study a simplified scenario in the next-to-minimal supersymmetry standard model where the electroweak sector has a split spectrum with light singlino and higgsinos and the lightest neutralino

$\tilde{\chi}_1^0$ is singlino-dominated. Serving as a dark matter candidate, $\tilde{\chi}_1^0$ should have either resonant annihilation effects or sizable higgsino components to satisfy the observed relic abundance. The sensitivities of LHC trilepton and dilepton searches and dark matter detection experiments are investigated. Near future direct and indirect dark matter searches are promising to cover the parameter regions where collider searches lose their sensitivities.

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Search for third generation squarks in pp collisions at 13 TeV at CMS

Author: Florent Sylvain Lacroix[1]

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We present results from the search for third generation squarks (stops and bottoms) in pp collisions at 13 TeV with the CMS detector.

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Inclusive searches for squarks and gluinos in fully hadronic final states with the ATLAS detector

Author: Manfredi Ronzani[1]

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Despite the absence of experimental evidence, weak scale supersymmetry remains one of the best motivated and studied Standard Model extensions. This talk summarises recent ATLAS results on inclusive searches for promptly decaying supersymmetric squarks and gluinos in events containing jets, missing transverse momentum, and no leptons. The results presented are based on the data recorded at 13 TeV centre of mass energy.

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Search for supersymmetry in hadronic final states with the MT2 variable

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We present a search for supersymmetry in hadronic final states with transverse momentum imbalance as measured by the MT2 variable. Results are based on 2.3 fb-1 of 13 TeV

proton-proton collisions collected with the CMS detector . The results are interpreted as limits on the masses of potential new colored particles in a variety of simplified models of supersymmetry, significantly improving existing the 8 TeV limits.

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Inclusive searches for SUSY using the razor variables in CMS

Author: Javier Mauricio Duarte[1]

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We present the latest SUSY search results using the razor kinematic variables in CMS. An inclusive strategy is adopted using multijet events with zero or one lepton, categorized in the number jets and b-tags, which is sensitive to a wide variety of SUSY scenarios. Results are interpreted in terms of limits of gluino pair production decaying to stops, sbottoms, and squarks, as well as squark pair production.

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Searches for electroweak production of SUSY particles with the ATLAS detector

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Many supersymmetry models feature gauginos and also sleptons with masses less than a few hundred GeV. These can give rise to direct pair production rates at the LHC that can be observed in the data sample recorded by the ATLAS detector. The talk presents recent searches results obtained by the ATLAS collaboration, including interpretations of the run 1 searches in a reduced sector of parameter space of the phenomenological pMSSM, and in General Gauge Mediation models.

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The 750 GeV anomaly

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Applications of the Recursive Jigsaw to searches for SUSY

Authors: Lawrence Lee Jr[1]; Marco Santoni[1]; Paul Douglas Jackson[1]

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In R-parity conserving SUSY models one anticipates searching for signal events where multiple missing neutral particles are present in a final state. Typical collider signatures for such events leverage large missing transverse momentum and high values of inclusive quantities such as the effective mass. In addition, specific features of distributions can be targeted with variables that preserve end-points and other observable shapes.

Through application of the Recursive Jigsaw reconstruction technique we demonstrate methods by which one can extract information in events sensitive to the underlying mass-splittings and particle properties. By application of well-defined rules, and imposing a view of the event that satisfies a particular "decay tree", we demonstrate an approach that provides further handles to probe challenging signals. Searches for gluino and squark pair-production, third generation particles and direct electroweak-ino pairs are all used by way of example.

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SUSY discovery potential of the ATLAS detector at an upgraded LHC

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The so-called high-luminosity upgrade of the LHC will impose new technological challenges to the ATLAS detector, requiring the partial upgrade of the detector. Scenarios of SUSY sparticle production, among others, have been used as benchmark to drive the design of the component upgrades, and to evaluate the sensitivity of the upgraded accelerator and detector. This talk will give an overview of the expected sensitivity that the ATLAS experiment will have to SUSY sparticle production with 3000 fb-1 pf proton-proton collisions collected at a centre of mass energy of 14 TeV.

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pMSSM scans in ATLAS

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Multidimensional scans of the pMSSM have been used in ATLAS to assess the experiment sensitivity to classess of models usually not well represented by simplified models. Such scans require a well defined approach in generating signal events and deciding which ones should be passed through the CPU-intensive detector simulation and for which ones the sensitivity can be instead parametrised. They also impose challenges in deciding how the experiment sensitivity should be summarised. The talk will discuss in detail hos such large-scale scans have been approached by ATLAS, touching upon recent results obtained.

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Inclusive searches for squarks and gluinos in final states with one or two same sign leptons with the ATLAS detector

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Despite the absence of experimental evidence, weak scale supersymmetry remains one of the best motivated and studied Standard Model extensions. This talk summarises recent ATLAS results on inclusive searches for promptly decaying supersymmetric squarks and gluinos in events containing jets, missing transverse momentum, and either one or two same sign light leptons. The results presented are based on the data recorded at 13 TeV centre of mass energy.

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Search for SUSY in hadronic final states with the AlphaT variable at CMS

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An inclusive search for supersymmetric processes that produce final states with jets and missing transverse momentum is performed in pp collisions at a centre-of-mass energy of 13 TeV. A dimensionless kinematic variable, aT, is used to discriminate between events with genuine and misreconstructed missing transverse momentum. A data sample corresponding to an integrated luminosity of 2.3 fb-1, recorded by the CMS experiment at the LHC, is analysed. The observed signal candidate event counts are found to be in agreement with the expected contributions from standard model processes and the result is interpreted in the mass parameter space of supersymmetric simplified models.

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Mass and event reconstruction under constraint in semi-invisible production at the LHC

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Semi-invisible production at the Large Hadron Collider are often theoretically essential or experimentally convenient signatures originated from a large class of physics models beyond the standard model. Be it light neutrino or some heavy exotic dark matter, observing absence being the signature of their presence, and any study looking into these neutral, stable missing particles remains complex. Here starting from an organizing principle, we present the developments on some of the constrained variables useful for deriving properties and couplings associated with these invisible particles.

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Compressed SUSY with the Recursive Jigsaw

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The Recursive Jigsaw reconstruction technique provides a powerful way to tackle challenging SUSY final states with multiple missing particles. By altering the input "decay tree" we demonstrate a new approach to considering compressed SUSY signatures from a variety of different sources. The imposition of this decay tree provides a clear way to define which objects are associated with an ISR system and those which are candidate decay products of the SUSY system. From this choice a set of variables emerge, providing a method to distinguish compressed cases from the pernicious standard model backgrounds present.
We introduce this new approach, comparing it briefly to other methods used to probe this phase-space and demonstrate it's power through application to several compressed final states. We will further touch on the applicability of this same method to other physics processes where the use of conventional kinematic handles breaks down.

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Towards a phenomenological MSSM fit with Fittino

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The phenomenological Minimal Supersymmetric Standard Model (pMSSM) is investigated in the light of constraining experimental and observational data from precision measurements, astrophysics, direct supersymmetry searches at the LHC and measurements of the properties of the Higgs boson by means of a global fit using the program Fittino. Emphasis is set on a precise description of the limits from the full set of LHC SUSY searches and on the measures needed to finally proceed towards calculating a p-value for pMSSM models.

In addition, Fittino is used in combination with SModelS, a tool for interpreting simplified model results, and CheckMATE, a tool for the inclusive re-interpretation of LHC searches, to find important signatures for non-excluded regions in the simplified models published by the LHC collaborations.

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The Recursive Jigsaw Reconstruction technique

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Signal events where multiple missing neutral particles are present in a final state represent challenging topologies to search for new physics at the LHC. The key to any search is the ability to separate background-like events from signal-like events. Identifying such signal-like events, and extracting their properties, is exacerbated by
a lack of knowledge of the particle masses and some missing kinematic handles. The "Recursive Jigsaw" reconstruction technique introduces a new approach to extracting information in events with open final states resulting from pair-production of objects.

We demonstrate sensitive analysis strategies to search for beyond standard model signatures by decomposing the final state objects into hemispheres and further sub-dividing them where necessary, based on the topology of interest. Backgrounds are controlled without recourse to conventional approaches based on variables such as missing transverse momentum and effective mass to select regions of sensitivity. Applications of the technique will be shown.

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Investigating light NMSSM pseudoscalar states with boosted di-tau tagging

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We study a class of realizations of the Next-to-Minimal Supersymmetric Standard Model that is motivated by dark matter and Higgs data, and in which the lightest pseudoscalar Higgs boson mass is smaller than twice the bottom quark mass and greater than twice the tau lepton mass. In such scenarios, the lightest pseudoscalar Higgs boson can be copiously produced at the LHC from the decay of heavier superpartners and will dominantly further decay into a pair of tau leptons that is generally boosted. We make use of a boosted object tagging technique designed to tag such a ditau jet, and estimate the sensitivity of the LHC to the considered supersymmetric scenarios with 20 to 50˜fb^{-1} of proton-proton collisions at a center-of-mass energy of 13˜TeV.

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Experimental Constraints on Baryon Number Violation in Supersymmetry

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Baryon number violation (BNV) features in a number of physics beyond the Standard Model and is experimentally well motivated as it is one of the conditions for baryogenesis. In this talk, experimental results which are sensitive to BNV will be discussed in the context of R-parity violating supersymmetric scenarios with non-zero BNV couplings and a simplified sparticle mass spectrum. Focus is placed on processes in which baryon number is the only hitherto conserved quantity which is violated unlike, for example, single nucleon decay in which lepton number and baryon number must be violated. The suite of results considered comprises neutron-antineutron oscillations, dinucleon decays, precision measurements of flavour transitions and CP-violation as well as LHC searches. The relative contributions of the different experimental observables in constraining BNV processes are studied. The impact of a new proposed search at the European Spallation Source for neutron-antineutron oscillations, which is projected to improve sensitivity in the neutron-antineutron oscillation probability by three orders of magnitude, is also quantified.

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Single top squark production as a probe of natural supersymmetry at the LHC

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Light top squarks (stops) and light higgsinos are the key features of natural supersymmetry (SUSY), where the higgsinos are nearly degenerate and act as the missing transverse energy (ET) at the LHC. Besides the pair production via strong interaction, the stop can be produced via the electroweak interaction. The determination of the electroweak properties of the stop is an essential task for the LHC and future colliders. So, in this paper, we investigate the observability of the single stop production in natural SUSY at LHC.

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The Global And Modular BSM Inference Tool (GAMBIT)

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With the flood of data from particle and astrophysics experiments increasing all the time, it is harder than ever to test beyond Standard Model (BSM) physics theories in a comprehensive and rigorous manner. I will present a new tool for performing global fits of generic new physics models using a very wide range of particle and astrophysics measurements. Results from studies of supersymmetric parameter spaces and Higgs portal dark matter scenarios will be presented.

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Naturalness and light Higgsinos: a powerful reason to build the ILC

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Natural SUSY with light, nearly mass-degenerate Higgsinos is a theoretically well motivated scenario which would in general escape LHC searches. An
electron-positron collider would provide a clean environment where the Higgsinos would be either discovered or excluded. We present a detailed study of
precision measurements of Higgsinos at the proposed International Linear Collider with $\sqrt{s}$ = 500 GeV, using a Geant4-based simulation of the International
Large Detector concept. The scenarios considered have Higgsino mass differences of 10 - 20 GeV and a heavy scalar sector. The precision measurements can be used
to determine the parameters of NUHM2. Alternatively, weak scale gaugino masses can be extracted which allows for tests of gaugino mass unification.

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Dissecting Jets and Missing Energy Searches Using n-body Extended Simplified Models

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New physics scenarios for the LHC are often characterized by Simplified Models, where the decay of a given particle is represented by an operator involving a minimal number of fields. Such decay operators can be generalized beyond the standard cases to describe a wide variety of final state multiplicities. This approach, which we dub the n-body extension of Simplified Models, provides a unifying treatment of the signal phase space resulting from a large class of new physics scenarios. In this talk, we present its first application, in the context of multijet plus missing energy searches. We present a global performance study aiming at identifying which set of observables yields the best discriminating power against the largest Standard Model backgrounds for a wide range of signal jet multiplicities. Our analysis compares combinations of one, two and three variables, placing emphasis on the enhanced sensitivity gain resulting from non-trivial correlations. To this end, machine-learning techniques known as boosted decision trees are employed. We compare and classify performance of combinations of missing energy, energy scale and energy structure observables, and we demonstrate that observables from each of the three classes are required to achieve optimal performance. This work additionally serves to demonstrate the utility of n-body extended Simplified Models as a diagnostic for unpacking the relative merits of different search strategies, thereby motivating their application to other signatures of new physics beyond jets and missing energy.

Flavour Physics / **46**

Search for new physics phenomena with heavy flavour quarks in ATLAS

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ATLAS has a wide programme of activities in B-physics. The results of studies in the electro-weak sector and beyond SM searches will be discussed, including CP violation and mixing in the B0_s and B0 systems, rare decay of B0_(s) to muon pairs, and angular correlations in the decay of B0 to K*0 mu+mu-.

Flavour Physics / **102**

Lepton Flavor and Number Violation in Left Right Models

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If the Left-Right Symmetric Model (LRM) realized at the TeV scale provides the correct explanation of the diboson excess observed at the 8 TeV LHC by ATLAS and CMS, then there are numerous implications for physics at lower energy scales involving many aspects of the leptonic sector. These include lepton number-violating processes such as $\beta\beta_{0\nu}$, lepton flavor-violating (LFV) processes, such as $\mu \to 3e$, $\mu \to e\gamma$ and $\mu \to e$ conversion, as well as lepton number-conserving processes, such as M{\o}ller scattering, the $g-2$ of the muon and μ decay itself. To explore these numerous implications we have performed a detailed examination of the relevant parameter space of the LRM to ascertain the capabilities of these various processes to probe this space and the complementarity among them. We find that future measurements of both $\mu \to e$ conversion and $\mu \to 3e$ will be particularly valuable in this regard. Even if the connection to the diboson excess is surrendered we find that the important complementarity of these multiple probes of the LRM leptonic sector is maintained.

Flavour Physics / **94**

Heavy flavor result from CMS

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The available statistics of heavy flavored particles collected at the LHC in pp collisions at 7, 8 and 13 TeV provides an excellent opportunity to test the standard model and probe for New Physics. A review of selected recent measurements on heavy flavors by CMS based on LHC Run I and Run II data is presented, along with future prospects.

Flavour Physics / **133**

Radiative b-hadron decays at LHCb

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Radiative b-hadron decays are sensitive probes of New Physics through the study of branching fractions, CP asymmetries and measurements of the polarisation of the photon emitted in the decay. During Run 1 of the LHC, the LHCb experiment has collected large samples of radiative b-hadron decays. We present here the latest LHCb measurements, including new results on the time dependence of $B_s \to \phi\gamma$ decays. These results help constrain the size of right-handed currents in extensions of the Standard Model.

Flavour Physics / **134**

Rare leptonic and semileptonic b-hadron decays

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Rare leptonic and semileptonic decays of B, D and K mesons provide sensitive indirect probes of effects beyond the Standard Model (SM). In the SM, these decays are forbidden at tree level and are therefore suppressed. In particular, the $b \to s\ell^+\ell^-$ processes give access to many observables where effects of New Physics can be observed. The LHCb experiment is designed for these searches due to its large acceptance and trigger efficiency, as well as its excellent invariant mass resolution and particle identification capabilities. Recent results on these searches will be presented. Moreover the possibility to measure new theoretically clean observables, such as the $B_s \to \mu\mu$ effective lifetime, will be also shown.

Flavour Physics / **157**

SUSY-related lepton and hadron flavour results from Belle

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SUSY-related lepton and hadron flavour results from Belle

Flavour Physics / **79**

Studies of the rare decays B -> K* l+ l- and B -> K pi pi gamma and search for B+ -> K+ tau+ tau- at BABAR

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Flavour changing neutral current processes, such as B -> K(*)l+l- *where l = e+, mu+, tau+ are highly suppressed in the Standard Model (SM). These rare decays occur at lowest order via 1-loop diagrams, and contributions from virtual particles in the loop allow one to probe large mass scales at relatively low energies. We present here the most recent results based on the full BABAR data sample, collected at the energy of the Y(4S) resonance, which corresponds to 471 million BBbar pairs.*
In particular, the decays B -> K l+l- (both charged and neutral modes) are studied using an angular analysis to extract the quantities A_FB and F_L, which are sensitive to potential effects of physics beyond the Standard Model. Furthermore, the quantity P_2, which is subject to smaller theoretical uncertainties and is more sensitive to non-SM contributions, is extracted.
We also present a search for the B+ -> K+ tau+ tau- decay. This search is performed on the recoil of a fully reconstructed B-meson decay from the decay of Y(4S) -> B+B-, by looking for activity compatible with B+ -> K+ tau+ tau- decay and leptonic decays of the two tau's in the rest of the event.
Finally, we report the measurement of the CP asymmetry in the radiative decay B0->Ks0 pi- pi+ gamma, a quantity that is sensitive to possible processes where non-SM photon helicities are involved. The structure of the hadronic final state is studied using the isospin-related decay B+ ->K+ pi- pi+ gamma.

Flavour Physics / 109

GUT Scale Threshold Effects on Proton Decay

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The supersymmetric grand unified theories (SUSY GUTs) are the promising models beyond the standard model for particle physics.
The standard SUSY GUTs predict that there exist the baryon-number violating processes, such as proton decay.
It is important to estimate quantum corrections on these processes in order to predict precise nucleon lifetime since there exists a large scale running between the GUT scale and 1 GeV where the nucleon matrix elements are calculated.
In this work, we have evaluated the GUT scale threshold corrections to the Wilson coefficients of the dimension-six baryon-number violating operators,
and then we have estimated the effect of the threshold corrections on the decay rate in the minimal and non-minimal SUSY SU(5) GUTs.
This talk will be based on our recent papers [arXiv:1503.08561] and [arXiv:1603.03568].

Flavour Physics / 9

Common origin of flavour anomalies and neutrino masses

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The same leptoquarks that explain the recently observed anomalies in rare B meson decays can generate naturally small Majorana neutrino masses at one-loop level through mixing with the standard model Higgs boson. We explore flavour model realisations with at least two leptoquark mediators to address these unresolved phenomena of the SM.

Flavour Physics / 47

Studies of Higgs and flavour physics at the high pT frontier (top & FCNC) with ATLAS

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The studies performed by ATLAS in the sector of flavour physics in the high-pT range will be discussed, including FCNC in top decays involving coupling to gamma, Z, and Higgs, single top production, and lepton-flavour violation in Higgs decays.

Flavour Physics / **50**

Search for K+ to pi+ nu nu at NA62

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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 took data in pilot runs in 2014 and 2015 reaching the final designed beam intensity. The quality of data acquired in view of the final measurement will be presented.

Flavour Physics / **110**

Searching for neutrinoless double beta decay with CUORE and CUORE-0

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The Cryogenic Underground Observatory for Rare Events (CUORE)
is a 1-ton scale double beta decay experiment based on cryogenic bolometers currently
in its final stages of construction at the Gran Sasso National Laboratory (LNGS).
The detector consists of an array of 988 TeO_2 crystals arranged in a cylindrical compact structure of 19 towers.
Its primary goal is to search for neutrinoless double beta decay of ^{130}Te, a process that, if observed, would probe the Majorana nature of the neutrinos and demonstrate lepton number violation.
CUORE-0 was the CUORE demonstrator: with 52 CUORE-like bolometers it served as a proof-of-concept of the CUORE technology and,
in combination with its predecessor CUORICINO, produced the most stringent limits to the half life of ^{130}Te.
In this talk we will present the final CUORE-0 results on neutrinoless double beta decay
and the corresponding detector performance. We will also discuss the status of the CUORE experiment and its physical potential.

Flavour Physics / **132**

Tests of Lepton Flavour Universality and searches for Lepton Flavor Violation at LHCb

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The Standard Model predicts, with small uncertainties, the ratios of branching fractions of rare decays involving different lepton flavours to be unity up to lepton mass corrections. The universality of lepton couplings has been tested using the LHCb run 1 dataset, resulting in some tensions with the predicted values. Lepton non-universality would be a major departure from the Standard Model and may also be accompanied by lepton flavour violation. Recent tests of lepton flavour universality and searches for lepton flavour violation decays at LHCb will be presented.

Flavour Physics / **165**

The final result of the MEG experiment and the status of the MEG II experiment

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The MEG experiment, which searches for a lepton flavor violating muon decay, $\mu^+ \to e^+\gamma$, to explore new physics like SUSY-GUT, started physics data taking in 2008 at Paul Scherrer Institute in Switzerland, and finished it in 2013. Its innovative detector system enabled orders of magnitude better sensitivity than previous experiments. The analysis result of the full dataset of the MEG experiment is presented here.

In order to improve the sensitivity, it is necessary to improve resolutions and detection efficiencies of all the detector components, and to increase the muon beam intensity. The construction of the MEG II experiment is now in progress, and we will strat engineering run in 2017, aiming at one order of magnitude better sensitivity that the MEG experiment. The status of the MEG II experiment is also discussed.

Flavour Physics / **159**

LHC vs. Precision Experiments - A comparison of LFV D6 operators QQLL at the LHC and Precision Experiments

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Precision experiments usually lead to the best limits on lepton flavour violating operators. However in light of the new possibilities at the LHC, one might wonder, how its capability to test lepton flavour violating processes compares to precision experiments.
I will present a sensitivity study of the LHC to lepton flavour violating operators of dimension 6 with two same flavour quarks and different flavour leptons and compare its reach to results from precision measurements of lepton flavour violating processes. For light quarks precision measurements yield the most stringent constraints. The LHC complements precision measurements for operators with heavier quarks. Competitive limits can already be set on the cutoff scale $\Lambda > 600–800$ GeV for operators with right-handed τ leptons using the LHC run 1 data.

Flavour Physics / 178

Analysis of $B \to PP, PV$ decays in Factorization Assisted Topological Amplitude Approach

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We analyze charmless two-body non-leptonic B decays $B \to PP, PV$ under the framework of factorization assisted topological amplitude approach, where $P(V)$ denotes a light pseudoscalar (vector) meson. Compared with the conventional flavor diagram approach, we consider flavor $SU(3)$ breaking effect assisted by factorization hypothesis for topological diagram amplitudes of different decay modes, factorizing out the corresponding decay constants and form factors from non-factorization (factorization) topological amplitudes after parameterizing (factorized in factorization framework) it as associated magnitude χ and strong phase ϕ (effective Wilson coefficient). These non-perturbative parameters are universal that can be extracted from current abundant experimental data of $B \to PP, PV$ simultaneously. With these best fitted parameters, we predict branching fractions and CP asymmetries of 97 decay modes, which are in good agreement with measured data or to be test in the LHCb and the Belle-II experiments in the future. The long-standing $\pi\pi$ and πK-CP puzzles are resolved with favorable color-suppressed tree emission diagram C.

Flavour Physics / 181

Results from the Daya Bay Experiment (On Behalf of the Daya Bay Experiment Collaboration)

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The Daya Bay Experiment has been measuring reactor antineutrino disappearance on short baseline with unprecedented precision since 2011. It was the first experiment which in 2012 observed a non-zero value of mixing angle θ_{13}. Experiment benefits from the large statistics, precise knowledge of background and unique layout with 8 functionally identical antineutrino detectors deployed in the three underground experimental halls near the nuclear power plant complex in Southern China.\\
We will present latest results on the measurement of the oscillation parameters $\sin^2 2\theta_{13}$ and $|\Delta m^2_{ee}|$. The Daya Bay Experiment can go with its precise measurement beyond 3-flavour neutrino framework. We will show updated search for light sterile neutrino in the antineutrino oscillations.\\
Measurement of the absolute reactor anti-neutrino flux will be also presented. Being lower than the theoretical predictions, it favors the so called 'reactor anomaly' which is in an agreement with previous measurements of other short-baseline experiments. The result can be explained by existence of sterile neutrino at the scale of $\Delta m^2 \sim 1$ eV^2.\\
Moreover, we will show recent search for time dependent sidereal modulation of the antineutrino oscillations as possible indication of the CPT and Lorentz Invariance violation.

Flavour Physics / 184

Mass Insertions vs. Mass Eigenstates calculations in Flavor Physics

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I will discuss the relation between QFT amplitudes calculated in the "interaction" basis and "mass eigenstate" basis, especially important for flavor physics. I will present and prove a theorem in matrix analysis allowing to algebraically translate an amplitude written in mass eigenbasis into flavor mass insertions, without performing diagrammatic calculations in the interaction basis. The mentioned technique works to any mass insertion order for amplitudes involving scalar, vector and fermion particles. I will also describe MassToMI Mathematica package automatizing such translation and discuss its application to physical examples of neutron Electric Dipole Moment and Higgs boson decays in the MSSM.

Flavour Physics / **210**

Top Flavor Changing Neutral Higgs Interactions at the LHC

Author: Chung Kao[1]

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A general two Higgs doublet model (2HDM) is adopted to study the signature of flavor changing neutral Higgs (FCNH) decay $\phi^0 \to t\bar{c} + \bar{t}c$, where ϕ^0 could be a CP-even scalar (H^0) or a CP-odd pseudoscalar (A^0) as well as $t \to ch^0$. Measurement of the light 125 GeV neutral Higgs boson (h^0) couplings at the Large Hadron Collider (LHC) favor the decoupling limit or the alignment limit of a 2HDM, in which gauge boson and diagonal fermion couplings of h^0 approach Standard Model values. In such limit, FCNH couplings of h^0 are naturally suppressed by a small mixing parameter $\cos(\beta - \alpha)$, while the off-diagonal couplings of heavier neutral scalars ϕ^0 are sustained by $\sin(\beta - \alpha) \sim 1$. We study physics background from dominant processes with realistic acceptance cuts and tagging efficiencies. Promising results are found for the LHC running at 13 or 14 TeV collision energies.

Flavour Physics / **220**

Leptonic CP violation and mass hierarchy in the presence of sterile neutrino

Authors: Shivani Gupta[1]; Zachary Matthews[1]

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We investigate the impact of a light sterile neutrino (~ eV) on the prospective data expected from currently running long-baseline experiments T2K and NOνA. If the future short baseline experiments confirm the existence of an eV scale sterile neutrino, then the 3+1 scheme will modify the mass hierarchy and CP-violation searches of the 3 active neutrino scenario in these two experiments (taken alone and in combination). We perform a detailed study of the sensitivity of these two experiments in the presence of new active sterile mixing angles and Dirac CP-violating phases. T2K and NOνA may give the first indications of new CP phases involved in such a 3+1 scenario and enable the extraction of more information on this enlarged active sterile mixing parameter sector.

Flavour Physics / **182**

Impact of Z' Boson on Pure AnnihilatioDecays

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We study the $B_s \to \pi^+\pi^-$ and $B_d \to K^+K^-$ decays in the standard model and the family non-universal Z' model. Since none of the quarks in final states is the same as the initial quark, these decay modes can occur only via power-suppressed annihilation diagrams. Despite the consistence of the standard model prediction with the available data, there is a surviving room for a light Z' boson. Taking into account the Z' contribution, we find theoretical results for branching fractions can better accommodate the data. With the relevant data, we also derive a constraint on the parameter space for the Z'. Moreover, for the $B_d \to K^+K^-$, both the direct and the mixing-induced CP asymmetry are sensitive to the couplings between Z' and fermions in the parameter spaces constrained by data. The measurements at future experimental facilities, including the LHC-b, Belle-II and the proposed high energy e^+e^- collider, will provide us useful hints for direct searching for the light Z' boson.

Formal Field and String Theory / **135**

Cyclic Leibniz rule, cohomology and non-renormalization theorem in lattice supersymmetry

Author: Makoto Sakamoto[1]

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We first discuss that a full supersymmetry algebra cannot be realized on lattice. This comes from the fact that the Leibniz rule of space-time

derivatives in the continuum cannot hold for finite difference operators on lattice by the no-go theorem. We then propose a modified Leibniz rule, called a cyclic Leibniz rule (CLR), on lattice, and consider a complex supersymmetric quantum mechanics equipped with the CLR.
It is shown that the CLR allows two of four supercharges of the continuum theory to preserve, while a naive lattice model can realize one supercharge at the most. A striking feature of our lattice model is that there are no quantum corrections to potential terms in any order of perturbation theory. This is one of characteristic properties of supersymmetric theory in the continuum. It turns out that the CLR allows to have a non-trivial cohomology and plays a crucial role in the proof of the non-renormalization theorem.

Formal Field and String Theory / **160**

Component versus Superspace Approaches to D=4, N=1 Conformal Supergravity

Author: Ryo Yokokura[1]

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We show the equivalence between the superspace formulation and the conventional component field approach based on the superconformal tensor calculus of $calN = 1$ conformal supergravity in four dimensions, and that superspace formulation does not have the restriction previously discussed by Kugo and Uehara.
We present also the correspondences of the conformal multiplets.
This talk is based on the preprint arXiv:1602.04441.

Formal Field and String Theory / **140**

DBI action of real linear superfield in 4D N=1 conformal supergravity

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We construct the Dirac-Born-Infeld (DBI) action of a real linear multiplet in 4D N = 1 supergravity. Based on conformal supergravity, we derive the general condition under which the DBI action can be realized, and show that it can be constructed in the new minimal supergravity. We also generalize it to the matter coupled system.

Formal Field and String Theory / **67**

Supergravity Spectra in Type IIB Flux Compactifications

Author: Callum Brodie[1]

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I will present results from work done with David Marsh (DAMTP, Cambridge) on the spectra of type IIB flux compactifications at large complex structure, as reported in our paper in JHEP (arXiv:1509.06761). In this work we considered four-dimensional effective supergravities arising in the low-energy limit of flux compactifications of type IIB string theory, and we computed the spectra of the Hessian matrix and the matrix that governs the critical point equation, at large complex structure. We found both spectra analytically in a subspace of the moduli space, independently of many details of the compactification. The resulting eigenvalue distributions are remarkably given by highly degenerate eigenvalues at integer multiples of the value of the superpotential and the gravitino mass. In this subspace, while the spectrum of the Hessian matrix contains no tachyons, there are also no critical points. Our results imply that proposed random matrix theory models are inapplicable at large complex structure, and we argue that for more general compactifications, existing 'universality theorems'in the random matrix theory literature may not apply. In this poster, after outlining the context, I will present the key results of this work. I will also include a discussion contrasting our results with the expectations from the much-used continuous flux approximation, and outlining the implications for the applicability of random matrix theory to the statistical modelling of the string theory landscape.

Formal Field and String Theory / **15**

Supersymmetry, multi-instantons, and the necessity of Lefshetz thimbles

Author: Erich Poppitz[None]

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Studies of four-dimensional confining supersymmetric theories on $R^3 \times S^1$ have shown, via the power of supersymmetry, that instanton-antiinstanton "topological molecules" have profound effects on their vacuum structure. In the calculable semiclassical regime, these are found responsible for center stability, confinement, and discrete chiral symmetry breaking. These configurations also play crucial role in recent studies of "resurgence"-the fascinating interplay of perturbative and nonperturbative physics. They also exist in nonsupersymmetric theories, but their identification has been hampered by the lack of a controlled way to distinguish them from the perturbative vacuum.

We shall argue, using non-supersymmetric path integral methods, that the inclusion of instanton-antiinstanton configurations in the path integral requires the use of "Lefshetz thimbles", i.e. the complexification of (at least some) the integration paths in field space. We show that the corresponding results agree with those predicted by supersymmetry and discuss avenues for current and future work.

Formal Field and String Theory / **112**

”Infinite derivative Ghost free Gravity, holography, and deSitter and Anti-deSitter propagator”

Author: Anupam Mazumdar[1]

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I will discuss the most generic covariant construction of infinite derivative theory of gravity which is ghost free and singularity free around Minkowski background. I will discuss the propagator, Euclidean aspect of Quantum Gravity, Holographic interpretation of infinite derivative gravity, and describe how to obtain Ghost free propagator around
deSitter and Anti-deSitter backgrounds.

The talk will be based on summary of following results:
Phys.Rev.Lett. 108 (2012) 031101,
Phys.Rev.Lett. 114 (2015) no.20, 201101,
Class.Quant.Grav. 32 (2015) no.21, 215017, and
“ e-Print: arXiv:1602.08475 [hep-th]”,

Formal Field and String Theory / **119**

BPS Boojums in N=2 supersymmetric gauge theories

Authors: Filip Blaschke[None]; Masato Arai[1]; Minoru Eto[2]

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We study 1/4 Bogomol’nyi-Prasad-Sommerfield (BPS) composite solitons of vortex strings, domain walls and boojums in N=2 supersymmetric Abelian gauge theories in four dimensions. We obtain both numerical and analytical solutions to the 1/4 BPS equations with the finite gauge coupling constant. We examine various configurations and clarify how the shape of the boojum depends on the coupling constants and moduli parameters. We find a semi-local boojum with a size moduli which appears when the semi-local string ends on the domain wall. Dyonic solutions are also obtained. When the configuration is extended to the dyonic case, the domain wall becomes an electric capacitor storing electric charges on its skin.

Formal Field and String Theory / **197**

Supersymmetric nonlocal theories

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We construct N = 1 supersymmetric nonlocal theories in four dimension. We discuss Higher derivative extension of Kahler potential as well as that of superpotential. Then, we obtain the on-shell condition. As a concrete example, we consider nonlocal extension of the O'RAIFERATAIGH model and discuss how the mass formula is modified in comparison to the local case.

Formal Field and String Theory / **223**

Spectrum and mode functions in the presence of a brane-localized mass in six dimensions

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In many extra-dimensional models, brane-localized mass terms are introduced in order to decouple unnecessary exotic particles from the four-dimensional effective theory. However, it should be noted that the impacts of the brane-localized terms become smaller as the codimensions increase. Thus it should numerically be checked how heavy the exotic parcticles can be by them. Here we study the effects of a brane-localized mass on
the KK mass eigenvalues and the mode functions of a bulk field in two-dimensional compact space.

Formal Field and String Theory / **151**

Holographic models with a small cosmological constant at Finite Temperature

Author: Bithika Jain[1]

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The cosmological constant problem can be reformulated in the brane world models. It was recently proposed that in "**generalized**"**holographic Randall-Sundrum** like models of spontaneously broken conformal invariance, a **naturally light dilaton** can be obtained via the condensation of a near marginal operator. The resulting 4D effective cosmological constant is also suppressed. We discuss a "**soft-wall**" realization of the Randall Sundrum geometry where the infrared brane plays a lesser role as a cutoff for large curvature effects and low energy observables such as spectrum of states are largely insensitive to its position. We then explore the finite temperature behavior of such models by studying geometries which include a horizon or a "black brane"along the extra dimension in the presence of non-trivial scalar field vacuum expectation value. A **first order geometric phase transition** proceeds via bubble nucleation between the two different gravity solutions. We shall then compare these results to the Randall Sundrum phase transition with Goldberger-Wise stabilization.

Formal Field and String Theory / 211

Higgs and Coulomb Branch Localization in Quiver Quantum Mechanics

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We derive the localization formula for $calN = 4$ supersymmetric quiver quantum mechanics in the Higgs and Coulomb branch. The partition function (index) is exactly evaluated and it is shown that the path integral is localized at fixed points, which are given by solutions to the BRST equations combined with D-term and F-term conditions. We give some examples of the quiver theory and classifications of their fixed points. We also discuss a gravitational description of the localization in the Coulomb branch.

Formal Field and String Theory / 174

Soft-Collinear Supersymmetry

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Soft-Collinear effective theory (SCET) is a framework for organizing the infrared structure of theories that manifest soft and collinear divergences in the Feynman diagram expansion. We provide the first demonstration that SCET can be made compatible with supersymmetry (SUSY). SCET is formulated by expanding fields along a light-like direction, and then subsequently integrating out degrees-of-freedom that are away from the light-cone. This can be done consistently with a well-defined power counting parameter. Naively, the presence of a specific frame obscures Lorentz invariance and provides a possible obstruction for compatibility with extended space-time invariance, i.e., SUSY. In order to demonstrate that the SCET limit of SUSY Yang-Mills is itself consistent, we develop a formalism for 2-component fermions in the collinear limit, and then provide the first derivation of the SCET Lagrangian expressed in light-cone gauge. A proof that N = 1 SUSY Yang-Mills can be formulated in a self-consistent manor, and is given in terms of component Lagrangians (obstructions for chiral theories such as the Wess-Zumino model are also ellucidated). A novel "collinear superspace" is introduced, and can be used to derive the light-cone gauge SUSY SCET theory directly by integrating out half of superspace. Furthermore, this can be bootstrapped back to the full theory to yield the first direct derivation of the full theory SUSY Yang-Mills on-shell superspace action. Our formalism paves the way to explore the soft-collinear limit of N = 4 SYM or N = 8 supergravity.

Formal Field and String Theory / 190

The SSM with Suppressed SUSY Charge

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A new version of the SSM Action is constructed. The constuction starts with the usual SSM before any breaking is implemented. So there are the usual Chiral SU(2) Doublets and Singlets for the Left and Right Quark and Lepton Superfields, and the usual two Chiral SU(2) Doublets for the Higgs Superfields. One more Chiral SU(2) Triplet Higgs Superfield is added. These are coupled as usual to the Gauge Superfields for $SU(3)\times SU(2)\times U(1)$. No other Superfields are used, and no spontaneous or explicit breaking of SUSY is assumed. No hidden or messenger sector is assumed. There is a Master Equation that implements exact SUSY in this starting theory.

The Chiral multiplets are then subjected to a set of 'Exchange Transformations', which remove some or all of the Scalars from the Chiral Multiplets. These change the Chiral Multiplets into two new kinds of SUSY Multiplet that have Suppressed SUSY Charge'.
The Exchange Transformations preserve SUSY exactly, in the sense that the resulting model still exactly satisfies a new Master Equation for SUSY.

These Exchange Transformations are chosen so that all the Squarks and Sleptons are removed. So this new SSM is exactly equal to the old Standard Model in its Matter sector. The Higgs sector has half of its Scalar Fields removed. The remaining Higgs Scalars develop VEVs to give mass to the Quarks and Leptons, and they also spontaneously break the Gauge symmetry from $SU(2)\times SU(1)$ down to $U(1)$. One major difference from the old Standard Model is the prediction of two new Higgs Bosons, and their masses, which are predicted to be approximately 13.4 TeV. Another major difference is the prediction of Gauginos and Higgsinos which are degenerate in Mass with the Gauge and Higgs Bosons. These Gauginos and Higgsinos are also uncoupled to the Quarks and Leptons.

Formal Field and String Theory / **203**

Magnetized orbifold models of dynamical supersymmetry breaking

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Magnetic fluxes in extra dimensional space can be an origin of the flavor structure of the standard model. In particular, in higher-dimensional supersymmetric Yang-Mills (SYM) theories compactified on magnetized orbifolds, several MSSM-like models were constructed successfully.
In this work, we derive dynamical supersymmetry breaking models from a single SYM theory compactified on magnetized orbifolds to combine with the MSSM-like models mentioned above. In magnetized orbifold models, essential structure of dynamical supersymmetry breaking mechanism, such as, field contents, their couplings and the number of flavors of SU(N) gauge theory, is completely determined by the structure of extra dimensional space. We research configurations of the magnetic fluxes and orbifold projections in a systematic way. As the result, we found several suitable configurations to generate the dynamical supersymmetry breaking. Furthermore, in some of the obtained configurations, orbifold projections eliminate all of extra massless modes which will cause problems in phenomenology of particle physics and cosmology.
We also discuss its association with other sectors, such as, the MSSM sector and moduli stabilization mechanisms.

Formal Field and String Theory / **219**

Nambu–Jona-Lasinio Model of Dynamical Supersymmetry Breaking

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Supersymmetry is undoubtedly a popular candidate for physics beyond the Standard Model. However, the origin of soft supersymmetry breaking masses has been usually depicted intricately in the literature via extra hidden/mediating sectors. Thus, a simple theory for the generation of the soft masses would be more compelling. In this talk, I will present the prototype model with a four-superfield interaction term that induces a real two-superfield composite with vacuum condensate. The latter has supersymmetry breaking parts, which we show to bear nontrivial solution following a standard nonperturbative analysis for a Nambu–Jona-Lasinio type model. No other messenger sector, or hidden sector is needed. Moreover, the analysis of effective theory picture, and the presence of the expected Goldstino along with the supersymmetry breaking, will be discussed.

Formal Field and String Theory / **236**

Partiton Function of U(N) 5D Gauge Theory with Hyper-multiplets via 2D Topological Field Theory Amplitudes

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Engineering of supersymmetric(SUSY) gauge theories in string theories is a powerful tool to study the SUSY gauge theories and has lead to many fascinating dualities. It has been recently found that SUSY indices of certain SUSY gauge theories are related to two dimensional topological field theories (TFTs). For example, U(1) gauge theory with g-adjoint hyper-multiplets can be engineered using Calabi-Yau Three-folds (CY3s) that are Cˆ2 bundles over genus-g surfaces. Vafa et.al. and Pandharipande et. al. have shown that the partition function of the topological string theory on these CY3s can be obtained via partition functions of certain 2-d TFT which is just the q-deformed Yang-Mills theory. The partition function of the gauge theory itself can be built from amplitudes of the 2d TFT which are just the open string amplitudes of the corresponding CY3.

We generalize this result to U(N) gauge theory with g-adjoint hyper-multiplets via geometric engineering on a Calabi-Yau three-fold that is A_N (resolution of singularity) fibration on genus-g curve by relating the open string theory amplitudes on this Calabi-Yau with the amplitudes of 2-d TFT which in this case is just quiver q-deformed gauge theory.

Note: This talk is built upon the work that is published in JHEP 1512 (2015) 017.

Formal Field and String Theory / **212**

Localization and Supersymmetric Entanglement Renyi entropy

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We calculate Renyi entropy in supergravity background and recover the trivial entanglement entropy from localization terms. We calculate the two-point function of the energy-momentum tensors and study the analytic properties of Renyi entropy in large-N limit. We find the gravity duals of the supersymmetric Renyi entropies as a supersymmetric topological AdS4 black hole and evaluate the on-shell action together with the free energy for the gravity dual solution.

Higgs Physics / 20

Measurement of properties of the Higgs Boson in fermionic decay channels using the ATLAS detector

Author: Carlo Enrico Pandini[1]

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The final Run 1 and first Run 2 results on the measurement and searches for the Higgs boson and Higgs boson pair production in the fermion decay channel with the ATLAS detector are presented.

Higgs Physics / 21

Search for the 125 GeV Higgs Boson produced in association with top quarks: final run-1 results and first run-2 results from the ATLAS collaboration

Author: Ricardo Jose Morais Silva Goncalo[1]

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The search for the production of the Higgs Boson with a pair of top-anti-top quarks is both very important and very challenging. The final results from run-1 are presented, with about 20 fbˆ(-1) of data at 8 TeV, as well as first run-2 results with 3.2 fbˆ(-1) of data at 13 TeV.

Higgs Physics / 22

Combined ATLAS+CMS measurement of the properties of the Higgs Boson

Author: Eric Feng[1]

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A review of the combination of the Higgs boson coupling measurements
using the data collected in 2011 and 2012 by the ATLAS and CMS experiments is presented.

Higgs Physics / **25**

Search for a high mass Higgs Boson in fermionic decay modes using the ATLAS detector

Author: Blake Oliver Burghgrave[1]

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Several theories beyond the Standard Model, like the EWS or 2HDM models, predict the existence of high mass neutral or charged Higgs particles, which could decay into final states with fermions. In this presentation the latest ATLAS results on these searches will be discussed, using 3.2 ifb of p-p collisions at 13 TeV.

Higgs Physics / **82**

The Higgs boson profile at CMS

Author: Serguei Ganjour[1]

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The status of the Higgs boson parameter measurements (mass, spin/CP, couplings, off-shell cross sections and constraints on invisible width) from the CMS experiment will be discussed in this talk.

Higgs Physics / **232**

Non-MSSM Higgs searches with the CMS experiment

Author: Martin Flechl[1]

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Recent results on searches for Beyond Standard Model production of Higgs bosons at the LHC by the CMS collaboration in other than Minimal supersymmetric models are presented.

Higgs Physics / **209**

Measuring the Higgs Boson Trilinear and Quartic Couplings at the LHC

Authors: Chung Kao[None]; Duane Dicus[1]

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Thus far the results from the LHC indicate that the couplings of the Higgs boson to other particles are consistent with the Standard Model (SM). However the ultimate test as to whether this particle is the SM Higgs boson will be the trilinear Higgs coupling that appears in Higgs pair production and the quartic Higgs coupling that shows up in triple Higgs production.
To gain some sense about the likelihood of measuring the Higgs boson self couplings, we calculate the cross section and interferences for Higgs pair production and triple Higgs production in pp collisions at the LHC.

Higgs Physics / **80**

BSM Higgs searches with CMS experiment

Author: Ye Chen[1]

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Recent results on searches for Beyond Standard Model production of Higgs bosons at the LHC by the CMS collaboration are presented. Minimal supersymmetric models (MSSM), next-to-minimal supersymmetric models (NMSSM) and generic two-higgs-doublet models (2HDM) are explored. Additional Higgs bosons (pseudoscalar, charged, light and heavy scalars) are also looked for in multiple final states, including invisible decays.

Higgs Physics / **175**

Probing classically conformal B–L model with gravitational waves

Author: Ryusuke Jinno[1]

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We study the cosmological history of the classical conformal B–L gauge extension of the standard model, in which the physical scales are generated via the Coleman-Weinberg-type symmetry breaking. Especially, we consider the thermal phase transition of the U(1)B–L symmetry in the early universe and resulting gravitational-wave production. Due to the classical conformal invariance, the phase transition tends to be a first-order one with ultra-supercooling, which enhances the strength of the produced gravitational waves. We show that, requiring (1) U(1)B–L is broken after the reheating, (2) the B–L gauge coupling does not blow up below the Planck scale, (3) the thermal phase

transition completes in almost all the patches in the universe, the gravitational wave spectrum can be as large as ΩGW~10−8 at the frequency f~0.01-1Hz for some model parameters, and a vast parameter region can be tested by future interferometer experiments such as eLISA, LISA, BBO and DECIGO.

Higgs Physics / **224**

Unnatural Composite Higgs at the LHC

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Long-lived, colour-triplet scalars are a generic prediction of unnatural, or split, composite Higgs models where the spontaneous global-symmetry breaking scale f 10 TeV and an unbroken SU(5) symmetry is preserved. Since the triplet scalars are pseudo Nambu-Goldstone bosons they are split from the much heavier composite-sector resonances and are the lightest exotic, coloured states. This makes them ideal to search for at colliders. Due to discrete symmetries the triplet scalar decays via a dimension-six term and given the large suppression scale f is often metastable. We show that existing searches for collider-stable R-hadrons from Run-I at the LHC forbid a triplet scalar mass below 845 GeV, whereas with 300 fb^{-1} at 13 TeV triplet scalar masses up to 1.4 TeV can be discovered. For shorter lifetimes displaced-vertex searches provide a discovery reach of up to 1.8 TeV. We also present exclusion and discovery reaches of future hadron colliders.

Higgs Physics / **19**

Measurement of cross sections and properties of the Higgs Boson in bosonic decay channels using the ATLAS detector

Author: Peter Kluit[1]

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The final Run 1 and first Run 2 results on the measurement of the cross sections and couplings of the Higgs boson in the diboson decay channel with the ATLAS detector are presented.

Higgs Physics / **24**

Search for a high mass Higgs Boson in bosonic decay modes using the ATLAS detector

Author: Dmitri Tsybychev[1]

[1] *Stony Brook University (US)*

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Several theories beyond the Standard Model, like the EWS or 2HDM models, predict the existence of high mass neutral Higgs particles, which could decay into final states with Weak bosons. In this presentation the latest ATLAS results on these searches will be discussed, using 3.2 ifb of p-p collisions at 13 TeV.

Higgs Physics / 26

Search for non-standard and rare decays of the Higgs boson with the ATLAS detector

Author: Philip Chang[1]

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Some theories predict Lepton Flavour Violating decays of the Higgs boson, while other predict enhanced decay rates in rare modes like Z-photon, J/Psi-photon, Phi-photon or into pairs of light pseudoscalar bosons “a”. Such decays are searched for using about 10 ifb of p-p collisions at 13 TeV.

Higgs Physics / 127

E6 inspired composite Higgs model and 750 GeV Diphoton Excess

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We consider a composite Higgs model embedded into a Grand Unified Theory (GUT) based on the E_6 gauge group. The phenomenological viability of this E_6 inspired composite Higgs model (E_6CHM) implies that standard model (SM) elementary fermions with
different baryon or lepton number should stem from different 27 representations of E_6. We present a six–dimensional orbifold GUT model in which the E_6 gauge symmetry is broken to the SM gauge group so that the appropriate splitting of the bulk 27–plets takes place. In this model the strongly coupled sector is localised on one of the branes and possesses an $SU(6)$ global symmetry that contains the $SU(3)_C \times SU(2)_W \times U(1)_Y$ subgroup. In this case the approximate gauge coupling unification can be attained if the right–handed top quark is a composite state and the elementary sector involves extra exotic matter beyond the SM which ensures anomaly cancellation.
The breakdown of the approximate $SU(6)$ symmetry at low energies in this model results in a set of the pseudo–Nambu–Goldstone states which include a Higgs doublet and scalar colour triplet. The presence of the TeV scale vector–like exotic quarks and scalar colour triplet may provide spectacular new physics signals that can be observed at the LHC. The possible interpretation of the 750 GeV diphoton excess within this composite Higgs model is also discussed.

Higgs Physics / 136

Higgs to SUSY decays

Author: Sven Heinemeyer[1]

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We present the full one-loop calculations of Higgs bosons to SUSY particles in the MSSM with complex parameters (cMSSM). They include SUSY-QCD and electroweak corrections, as well as real QED and QCD radiation. The size of the corrections are at the level of 10-20%, but can also be higher, depending on the parameter space. Consequently, the one-loop corrections should be included in any precision SUSY Higgs analysis. It is planned to include the results into our code FeynHiggs.

Higgs Physics / **150**

Unraveling the CP phase of top-Higgs coupling in associated production at the LHC

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We study the sensitivity of top polarization observables to the CP phase ζ_t in the top Yukawa coupling in the process $pp \to thj$ at the 14 TeV high-luminosity run of Large Hadron Collider (HL-LHC). We calculate the top polarization in this process as well as an azimuthal asymmetry of the charged lepton arising from the decay of the top in the laboratory frame. We find that the dependence of this laboratory-frame azimuthal asymmetry on the phase ζ_t is closely similar to the dependence of the top polarization on ζ_t. As compared to the cross section, which is sensitive to ζ_t for larger values, the lepton azimuthal asymmetry can provide a sensitive measurement of ζ_t for smaller values.

Higgs Physics / **187**

MSSM Higgs Interpretations after LHC Run 1

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Focussing on the MSSM Higgs sector, we present a multi-dimensional fit of the pMSSM to the LHC Run 1 results, taking into account the measurements of Higgs and low energy observables as well as constraints from direct SUSY searches. We investigate in how much the MSSM can provide a good description of the experimental data, and which parts of the MSSM parameter space are favoured. We analyse different viable scenarios where the Higgs signal is interpreted either as the light MSSM Higgs (via decoupling or alignment) or as the heavy MSSM Higgs.

Higgs Physics / **189**

Gravitational waves from nonlinearly realised electroweak phase transition

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The Higgs may be a singlet under a nonlinearly realised electroweak symmetry. Differing from the SM, anomalous Higgs cubic couplings are then permitted in the potential, which may lead to a first order electroweak phase transition. We find a range of cubic coupling that may lead to observable gravitational waves signatures at interferometer such as eLISA.

Higgs Physics / **101**

FeynHiggs: New and improved predictions for the (N)MSSM

Author: Sven Heinemeyer[1]

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We present new results and improved predictions for the Higgs sector in the (N)MSSSM, based on the implementation into our code FeynHiggs.

Higgs Physics / **233**

Study of Higgs Production in Bosonic Decay Channels at CMS

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A summary of the CMS results in the study of the Higgs boson in decays to bosons will be presented in this talk.

Higgs Physics / 234

Study of Higgs Production in Fermionic Decay Channels at CMS

Author: Daniel Salerno[1]

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A summary of the CMS results in the study of the Higgs boson in decays to fermions will be presented in this talk. The studies on the ttH production are also included in this talk.

Higgs Physics / 194

Boosting the charged Higgs search using jet substructure at the LHC

Author: Riley Patrick[1]

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Charged Higgs bosons are predicted in variety of theoretically well-motivated new physics models with extended Higgs sectors. In this study, we focus on a type-II two Higgs doublet model (2HDM-II) and consider a heavy charged Higgs with its mass ranging from 500 GeV to 1 TeV as dictated by the $b \to s\gamma$ constraints which render $M_{H^\pm} > 480$ GeV. We study the dominant production mode $H^\pm t$ associated production with $H^\pm \to W^\pm A$ being the dominant decay channel when the pseudoscalar A is considerably lighter. For such a heavy charged Higgs, both the decay products $W^\pm$ and A are relatively boosted. In such a scenario, we apply the jet substructure analysis of tagging the fat pseudoscalar and W jets in order to eliminate the standard model background efficiently. After performing the detailed detector simulation and applying the kinematical cuts, we present the LHC search sensitivities for the charged Higgs boson with mass up to 1 TeV in the $W^\pm A$ decay channel.

Higgs Physics / 195

Exploring tau lepton pairs from Higgs at the LHC

Authors: Abhaya Kumar Swain[1]; Pankaj Sharma[2]; Partha Konar[3]

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We study a noble approach in reconstructing the semi-invisible events by utilizing the constrained mass variable, M_{2Cons} and applied so in case of presently developing scenario, when a pair of the

third generation τ leptons originated from Higgs at LHC. Buoyed with a relatively large Yukawa coupling, the LHC has already started exploring this pair production to investigate the properties of Higgs in the leptonic sector. Dominant signatures through hadronic decay of tau, associated with invisible neutrinos compound the difficulty in the reconstruction of such events. Exploiting the already existing Higgs mass bound, the proposed method provides a unique event reconstruction and results in a significant enhancement in efficiency over the existing methods. After reconstructing the semi-invisible tau lepton pair events, we also study the CP properties of Higgs using tau-lepton momentum correlations.

Higgs Physics / **216**

Next-to-leading order unitarity fits of the Two-Higgs-Doublet Models

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We present global fits of the Two-Higgs-Doublet models with a softly broken Z_2 symmetry. The results were obtained with the public HEPfit package and combine the effects of various constraints coming from experiment (including LHC run I) and theory. As for the latter, we use for the first time the next-to-leading order contributions to the scattering matrix of "two scalar to two scalar" processes in a global Two-Higgs-Doublet model fit. We will discuss in detail how unitarity and perturbativity affect the model parameters.

Higgs Physics / **12**

Charged Higgs Study in the s-channel Single Top production at LHC

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With the current measurements performed by CMS and ATLAS experiments, the light charged Higgs scenario ($m_{H^\pm} < 160$ GeV), is excluded for most of the parameter space in the context of MSSM. However, there is still possibility to look for heavy charged Higgs boson particularly in the s-channel single top production process where the charged Higgs may appear as a heavy resonance state and decay to $t\bar{b}$. The production process under consideration in this paper is $pp \rightarrow H^\pm \rightarrow t\bar{b} + h.c.$, where the top quark decays to W^+b and W^+ boson subsequently decays to two light jets. It is shown that despite the presence of large QCD and electroweak background events, the charged Higgs signal can be extracted and observed at a large area of MSSM parameter space ($m_{H^\pm}$,tanβ) at LHC. The observability of charged Higgs is potentially demonstrated with 5σ contours and 95% confidence

level exclusion curves at different integrated LHC luminosities assuming a nominal center of mass energy of $\sqrt{s}$ = 14 TeV.

Higgs Physics / **237**

Higgs measurements at the Future Circular Colliders

Authors: Christophe Grojean[1]; Markus Klute[2]

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After the Higgs boson discovery, the precision measurements and searches for new phenomena in the Higgs sector are among the most important goals in particle physics. Experiments at the Future Circular Colliders (FCC) are ideal to study these questions. Electron-positron collisions up to an energy of 350 GeV (FCC-ee) provide the ultimate precision with studies of Higgs boson couplings, mass, total width and CP parameters, as well as searches for exotic and invisible decays. The feasibility of observation of the s-channel production e+e- ⟶ H(125) is reviewed. We conclude by noting the remarkable complementarity of the FCC-ee and FCC-hh colliders, which in combination offer the best possible overall study of the Higgs boson properties.

Higgs Physics / **225**

A Sequential Heavy Quark Doublet Q and a Light Dilaton D

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There is a cry in the wilderness: "Repent! The Higgs boson may be fictitious." (Phil Anderson, Nature Physics 2/2015). A light "Higgs" mode appears in a specially prepared superconductor material, where "amplitude modes" are much higher at twice the energy/mass gap. With the 125 GeV boson well established, could it be dynamical rather than elementary, and not in the Standard Model Lagrangian? We recount the possibility that an extra sequential quark Q with Yukawa coupling lambdaQ > 4pi could be the source of dynamical electroweak symmetry breaking, while the 125 GeV boson is a dilaton from spontaneous violation of scale invariance. To exclude the latter, one should make date-based measurements of both the vector-boson fusion and gluon-gluon fusion plus two-jet processes at the LHC, which can be achieved with Run 2 data. With such strong Yukawa coupling, the numerical solution of a "gap equation" is shielded from UV completion, though the actual UV should not be too far beyond, and likely related to the fundamental theory of Yukawa couplings. The 2mQ scale may be out of reach for the LHC, but QQ(bar) boundstates could be accessible, while supporting Bd -> mu+mu- and KL -> pi0 nu nu(bar) rare decays could emerge during the LHC Run2 period.

Higgs Physics / **49**

LHC Run-2 Bounds on the Z' boson mass in Classically Conformal U(1)' extended SM with Electroweak Vacuum Stability

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With the LHC Run-2 results at 13 TeV, we perform the calculation on the lower bound on the Z' boson mass in the context of the general U(1) gauged extension of the standard model with classically scale invariance and the electroweak vacuum stability at 2-loop level. The model is called the classically conformal U(1)' extended standard model which is a phenomenologically viable one that realizes Coleman-Weinberg-type breaking of the electroweak symmetry. The model can naturally provide a solution to one of the most important problem in the standard model, gauge hierarchy problem, and also solving the SM Higgs vacuum instability with having nonzero U(1)' charge of the SM Higgs, which is contrast to the U(1)$_{B-L}$ case. In this study, we perform the calculation at 2-loop level where we find the parameter regions for solving the SM Higgs instability. We plot the allowed parameter regions with three free parameters, the U(1)' gauge coupling, the U(1)' charge of the SM higgs, and the vacuum expectation value of the new additional singlet Higgs. We find that U(1)$_{B-L}$ and orthogonal model are excluded from having the electroweak vacuum stability with the currenct world average of the experimental data, $m_t = 173.34$ GeV and $m_h = 125.09$ GeV. Finally, we find that the current collider bounds are around $m_{Z'} > 3.5$ TeV, and naturalness bounds are around $m_{Z'} < 7$ TeV in order to avoid a fine-tuning severer than 10% level, where the Z' boson can be detected at the current LHC Run-2 experiment in the near future.

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The MoEDAL Experiment at the LHC –A New Experiment at the LHC's Discovery Frontier

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MoEDAL is a pioneering experiment designed to search for highly ionizing messengers of new physics such as magnetic monopoles or massive (pseudo-)stable charged particles.
Recently MoEDAL released its first results on a search for monopoles, using data collected at 8 TeV, and based on a prototype of the magnetic monopole trapper. The trapper material got analysed with a SQUID at the University of Zurich.
MoEDAL has also collected data with the full detector during the 2015 LHC run, using several monopole detection techniques, and these data are being analysed now. Recent results of MoEDAL and prospects for the upcoming LHC runs will be
discussed.

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Searches for Magnetic Monopoles and Anomalously Charged Objects with ATLAS

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Results of searches for highly ionising particles and particles with anomalously high electric charge produced in proton-proton collisions in the ATLAS detector are presented. Such signatures, encompassing particles with charges from 10 to 60 times the electron charge, involve high levels of ionization in the ATLAS detector and can arise from magnetic monopoles or models involving technicolor, doubly charged Higgs bosons or composite dark matter models.

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Searches for long-lived particles at CMS

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Many extensions of the standard model including SUSY predict new particles with long lifetimes, such that the position of their decay is measurably displaced from their production vertex. We present recent results of searches for exotic long-lived particles obtained using data recorded by the CMS experiment at Run-II of the LHC.

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Testing the Properties of the DiPhoton Resonance

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In this talk, I will present on the one hand information that we already have on the properties of the potential diphoton resonance at M˜750 GeV, with a special focus on the flavor structure. On the other hand, I will discuss how we can gain further insights, both directly on the resonance itself and it's relation with the sector of electroweak symmetry breaking, as well as on the physics producing/decaying it, via different precise measurements at the LHC.

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Searches for BSM physics in diphoton final state at CMS

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A search for new physics in high-mass diphoton events is presented. The analysis is performed by looking for bumps on the continuum diphoton mass spectrum. This clean signature is sensitive to high-mass gravitons predicted by models with extra dimensions and to scalar resonances arising from many extensions of the standard model. The talk focuses on the recent results obtained using data collected during the 2015 run as well as the first part of the 2016 run.

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Searches for BSM physics in dijet and multijet final states at CMS

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Results of searches for new physics in the dijet and multijet final states are presented. These include model-independent and model-specific searches using the dijet invariant mass spectrum and the dijet angular distributions, searches for black holes, quantum and microscopic, in multijet events, as well as searches for RPV SUSY in events with paired dijets. This talk focuses on the recent results obtained using data collected during the 2015 run as well as the first part of the 2016 run.

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Searches for BSM physics in dilepton, multilepton, and lepton+MET final states at CMS

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Numerous new physics models, e.g., theories with extra dimensions and various gauge-group extensions of the standard model, predict the existence of new particles decaying to dilepton, multilepton, and lepton+MET final states. This talk presents searches for new physics in these three leptonic final states at CMS, focusing on the recent results obtained using data collected during the 2015 run as well as the first part of the 2016 run.

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Searches for BSM physics in final states with leptons and jets at CMS

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Results of searches for new particles such as leptoquarks, heavy neutrinos, and W bosons with right-handed couplings in final states with leptons (charged or neutral) and jets are presented. The emphasis is given to the recent results obtained using data collected at Run-II of the LHC.

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Search for a high mass diphoton resonance using the ATLAS detector

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The search for a spin-0 or spin-2 state decaying into two photons, in a large mass range is presented, using 3.2 ifb of p-p collisions at 13 TeV.

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Search for ttbar resonances with the ATLAS detector

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In the present talk the search for new resonances decaying to ttbar. The search is performed with the ATLAS experiment at the LHC using proton-proton collision data. The current status of the ATLAS searches will be reviewed, addressing the used analysis techniques, in particular the selection criteria, the background modelling and the related experimental uncertainties.

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Search for vector-like quarks with the ATLAS detector

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New vector quarks appear in many beyond the Standard Model trying to cancel the mass divergence for the Higgs boson. At the LHC such new quarks can be produced singly or in pairs and, depending on their decays, can originate several different final states. A topological approach was followed by ATLAS, allowing to comprehensively cover such final states in a model independent way. The status of these searches

will be reviewed, with emphasis on the complementarity between the different analysis.

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Searches for new phenomena in high-pT lepton final states and jets using the ATLAS detector

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Searches for physics beyond the Standard Model are performed in final states with at least one high-pT lepton and jets. These searches target a large range of beyond the Standard Model phenomenology ranging from leptoquarks, heavy leptons and strong gravity effects. The full 2015 LHC proton-proton dataset is combined with the data which has been collected so far during 2016, at $\sqrt{s}$ = 13 TeV.

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Searches for new phenomena in high-pT lepton final states using the ATLAS detector

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Searches for physics beyond the Standard Model are performed in final states with high-pT leptons (including tau final states). We will present results of searches for resonant, and non-resonant phenomena in dilepton final states, searches for new phenomena in lepton + missing momentum and lepton flavour violating final states. These searches target a large range of beyond the Standard Model phenomenology ranging from new massive W'or Z'bosons, Gravitons, extra dimensions, black holes, contact interactions and heavy sneutrinos. The full 2015 LHC proton-proton dataset is combined with the data which has been collected so far during 2016, at $\sqrt{s}$ = 13 TeV.

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Searches for new resonances decaying into bosons with the ATLAS detector

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Many extensions to the Standard Model predicts new particles decaying into two bosons (WW, WZ, ZZ , W/Zgamma, W/ZH and HH) making this a smoking gun signature. Searches for such diboson resonances have been performed in final states with different numbers of leptons , photon and jets where new identification techniques to disentangle the decay products in highly boosted configuration are being used. This talk summarizes ATLAS searches for diboson resonances with LHC Run 2 data.

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Searches for physics beyond the Standard Model using jet-based resonances with the ATLAS Detector

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Run2 of the LHC, with its increased center-of-mass energy, is an unprecedented opportunity to discover physics beyond the Standard Model. One interesting possibility to conduct such searches is to use resonances based on jets. The latest search results from the ATLAS experiment, based on either inclusive or heavy-flavour jets, will be presented.

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Search for fermionic top partners at CMS

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We present results of searches for massive top and bottom quark partners using proton-proton collision data collected with the CMS detector at the CERN LHC at a center-of-mass energy of 8 and 13 TeV. These fourth-generation vector-like quarks are postulated to solve the Hierarchy problem and stabilize the Higgs mass, while escaping constraints on the Higgs cross section measurement. The vector-like quark can be produced singly or in pair and their decays result in a variety of final states, containing top and bottom quarks, gauge and Higgs bosons. We search using several categories of reconstructed objects, from multi-leptonic to fully hadronic final states. We set exclusion limits on both the vector- like quark mass and cross sections, for combinations of the vector-like quark branching ratios.

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Search for heavy resonances coupling to third generation quarks at CMS

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Many models of physics beyond the Standard Model (SM) contain enhanced couplings to third generation quarks. We present an overview of searches for new physics containing top and bottom quarks in the final state, using proton- proton collision data collected with the CMS detector at the CERN LHC at a center-of-mass energy of 13 TeV. These results cover non-SUSY based extensions of the SM, including heavy gauge bosons or excited third generation quarks. Decay channels to vector-like top partner quarks, such as T, are also considered. This results in a top-pair-like final state, as the T decays to a W boson and bottom quark; however the reconstructed mass of the T can be used to further signal discrimination. We explore the use of jet substructure techniques to reconstruct the highly boosted objects in events, enhancing the sensitivity of these searches.

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Search for heavy resonances decaying to dibosons at CMS

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Beyond the standard model theories like Extra-Dimensions and Composite Higgs scenarios predict the existence of very heavy resonances compatible with a spin 0 (Radion),spin 1 (W', Z') and spin 2 (Graviton) particle with large branching fractions in pairs of standard model bosons and negligible branching fractions to light fermions. We present an overview of searches for new physics containing W, Z or H bosons in the final state, using proton-proton collision data collected with the CMS detector at the CERN LHC.
Many results use novel analysis techniques to identify and reconstruct highly boosted final states that are created in these topologies. These techniques provide increased sensitivity to new high-mass particles over traditional search methods.

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Exotica searches with LHCb

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A flexible trigger system, excellent vertex locator, ring imaging Cherenkov (RICH) detectors, and forward acceptance allow unique direct searches to be performed at LHC energies using data collected with the LHCb detector, in particular dealing with complementary New Physics parameter regions. A summary of results will be presented, including several SUSY related results, such as searches for long-lived heavy charged particles, as well as displaced particles decaying into jet pairs.

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Radiative Left-Right symmetry breaking from flavour enhanced trinification

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In this talk I will present our recent work on a non-supersymmetric trinification GUT with a global $\mathrm{SU}(3)$ flavour symmetry. The $\mathrm{SU}(3)$ flavour symmetry solves many of the persistent issues of traditional trinification model building, where models typically contain an uncomfortably large number of free parameters and naturally prefers GUT scale masses for the Standard Model (SM) fermions. In our model, the trinification symmetry group (gauge and global) is spontaneously broken down to the standard Left-Right symmetric gauge group, together with an extra $\mathrm{SU}(2) \times \mathrm{U}(1)$ global symmetry. Upon integrating out the heavy states at this scale, we obtain an effective Left-Right symmetric model which spontaneously breaks to the SM gauge group at a lower scale by means of RG running.

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Backreaction of particle production on false vacuum decay

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As originally described by Rubakov, particles are produced during the tunneling of a metastable quantum field. We propose to extend his formalism to compute the backreaction of these particles on the semiclassical decay probability of the field. The idea is to integrate out the external bath of particles by computing the reduced density matrix of the system. Following this approach, we derive an explicit correction factor in the specific case of scalar particle production in flat spacetime. In this given framework, we conclude that the backreaction is ultraviolet finite and enhances the decay rate. Moreover, in the weak production limit, the backreaction factor is directly given by one half of the total number of created particles. In order to estimate the importance of this correction, we apply our formalism to a toy model potential which allows us to consider both the decay of a homogeneous bounce and the nucleation of a thin-wall bubble. In the former case, the impact of the created particles is parameter dependent and we exhibit a reasonable choice of variables for which ones the backreaction is significant. In the latter case, we conclude that the backreaction is always negligible.

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Heavy Fermion Bound States for Diphoton Excess at 750GeV

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A colored heavy particle with sufficiently small width may form non-relativistic bound states when they are produced at the large hadron collider\,(LHC), and they can annihilate into a diphoton final state. The invariant mass of the diphoton would be around twice of the colored particle mass. In this paper, we study if such bound state can be responsible for the 750 GeV diphoton excess reported by ATLAS and CMS. We found that the best-fit signal cross section is obtained for the SU(2)L singlet colored fermion X with YX=4/3. Having such an exotic hypercharge, the particle is expected to decay through some higher dimensional operators, consistent with the small width assumption. The decay of X may involve a stable particle χ, if both X and χ are odd under some conserved Z2 symmetry. In that case, the particle X suffers from the constraints of jets + missing ET searches by ATLAS and CMS at 8 TeV and 13 TeV. We found that such a scenario still survives if the mass difference between X and χ is above ~ 30 GeV for mX~375 GeV. Even assuming pair annihilation of χ is small, the relic density of χ is small enough if the mass difference between X and χ is smaller than ~ 40 GeV.

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750 GeV Diphoton Resonance in Warped Geometries

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We examine the scenario of a warped extra dimension containing bulk SM fields in light of the observed diphoton excess at 750 GeV. We demonstrate that a bulk spin-2 graviton whose action contains localized kinetic brane terms is compatible with the excess, while being consistent with all other constraints. This model contains a single free parameter, the mass of the first gauge Kaluza-Klein excitation. The scale of physics on the IR-brane is found to lie in the range of a few TeV, relevant to the gauge hierarchy.

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The 750 GeV diphoton LHC excess from Singlets in Exceptional Supersymmetric Standard Model

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The 750-760 GeV diphoton resonance may be identified as one or two scalars and/or
one or two pseudoscalars contained in the two singlet superfields $S_{1,2}$
arising from the three 27-dimensional representations of E_6. We study the corresponding collider signature within the exceptional supersymmetric standard model (E$_6$SSM).This model is based on the SM gauge group together with an extra $U(1)_N$ gauge symmetry under which right–handed neutrinos have zero charge. To ensure anomaly cancellation the low energy matter content of the E$_6$SSM involve three 27 representations of E_6. Thus E$_6$SSM predicts Z' boson and extra matter beyond the MSSM. In particular, the low–energy spectrum of the E$_6$SSM involves three families of Higgs–like doublets,three families of exotic quarks and three SM singlets S_i that carry $U(1)_N$ charges. The E$_6$SSM Higgs sector contains one family of the Higgs–like doublets and one SM singlet S_3 that develops vacuum expectation values (VEV) breaking $U(1)_N$ gauge symmetry and inducing

masses of exotic states mentioned above. The fermion and scalar components of other Higgs–like superfields form Inert Higgsino and Inert Higgs states respectively. Two lighter singlets $S_{1,2}$ with masses around 750 GeV can couple to Inert Higgsino and exotic quarks giving rise to diphoton excess. We calculate the branching ratios and cross-sections for the two scalar and two pseudoscalar states associated with the $S_{1,2}$ singlets, including possible degeneracies and maximal mixing, subject to the constraint that their couplings remain perturbative up to the unification scale.

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Probing the interplay between TeV scale heavy vector resonances and top partners at the LHC

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Fermionic and vector resonances are a generic prediction of theories where electroweak symmetry breaking is triggered by new strongly interacting dynamics at the TeV scale.
We work in a "discrete" **two site** prescription of the **Composite Higgs model** where the spontaneous breaking of the SO(5)/SO(4) coset gives the Standard Model gauge bosons and six heavy vector resonances. We implement a **partially composite scenario** for the top sector which gives us the 1/3, 2/3 and 5/3 charged top partners. The direct and indirect (electroweak and flavor precision) constraints and requirement of naturalness impose stronger bounds on the heavy vectors than the top partners. This mild hierarchy between the top partners and the heavy vector resonances modifies the search strategy for vector resonances at the LHC. We find that when kinematically allowed, decays of heavy vector resonances to top partners dominate over pure Standard Model final states. We focus on the decay modes where top partner is singly produced. As a part of the **"no loose" strategy for heavy vector resonances**, these signatures with strongly boosted tops need to be considered. These **searches for top partners from vector resonances** can aid in hunting top partners and also discover (exclude) vector resonances at the 13 TeV run of the LHC.

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The hierarchy problem in non-supersymmetric extended models

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Efforts building models of Grand Unification have overwhelmingly been within the framework of Supersymmetry, since it provides the dual benefit of a solution to the hierarchy problem and gauge coupling unification. Any non-supersymmetric model of Grand Unification must necessarily include an alternative solution to the hierarchy problem. In this talk, I will discuss mechanisms such as asymptotic safety and the multiple point principle that provide interesting high scale boundary conditions on the Higgs quartic coupling leading to the prediction of the light Higgs boson. I will review the well known predictions within the Standard Model and describe new work on extended

Higgs sectors and the predictions that such boundary conditions enforce. I will also look forward to how these ideas may be used in the construction of a believable non-supersymmetric Grand Unified Theory.

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Asymptotically Safe QCD

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We discuss the possibility that QCD is not asymptotically free and develops instead an interactive UV fixed point. This can happen if the Standard Model is extended by a set of N_F vector-like fermions that transform non-trivially under $SU(3)_c$, with Yukawa-type interactions mediated by a $N_F \times N_F$ matrix scalar field. We point out that the 750 GeV diphoton excess can be explained within such a framework.

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Grand Unification in the light of preliminary LHC hints of W_R

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In the LHC Run 1 CMS reported a 2.8σ excess in the $(2e)(2jets)$ channel around 2.1 TeV. We take this as a hint of the production of a right-handed weak gauge boson, W_R, of the left-right symmetric model arising from an $SO(10)$ grand unified theory. We show that a W_R with mass in the TeV region if embedded in $SO(10)$ requires $0.64 \leq g_R/g_L \leq 0.78$, when one abides by the Extended Survival Hypothesis. A unique symmetry-breaking route – the order being left-right discrete symmetry breaking first, followed by $SU(4)_C$ and finally $SU(2)_R$ – is also picked out. The $L \leftrightarrow R$ discrete symmetry must be broken around 10^{16} GeV while the GUT scale is pushed to 10^{18} GeV. So, in this model observation of proton decay in ongoing searches is unlikely. On the flip side, the $SU(4)_C$ breaking scale can be as low as 10^6 GeV so that $n - \bar{n}$ oscillation or flavour changing decays such as $K_L \to \mu e$ and $B_{d,s} \to \mu e$ may be detectable. The Higgs scalars responsible for symmetry breaking at various stages are uniquely identified so long as one adheres to a minimalist principle. We also remark on

the scope of interpreting the O(TeV)-scale LHC Run 1 diboson and Run 2 diphoton indications within this model.

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Naturalness of the relaxion mechanism

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The relaxion mechanism is a novel solution to the hierarchy problem that utilizes the dynamics of an axion-like field. I discuss results from the first statistical analysis of the relaxion mechanism (arXiv:1602.03889), in which we quantified the relative plausibility of a QCD and a non-QCD relaxion model versus the Standard Model with Bayesian statistics, which includes an automatic penalty for fine-tuning. We included experimental constraints upon the weak-scale, $\theta_{\rm QCD}$ and inflationary observables measured by Planck/BICEP. Whilst we confirmed that relaxion models could solve the hierarchy problem, we found that their unconventional cosmology demolishes their plausibility.

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Diphoton Excess at 750 GeV from a Radion in the Bulk-Higgs Scenario

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We show that the recent diphoton excess observed by the ATLAS and CMS collaborations might originate from the radion of a warped extra dimension when the Higgs is located in the bulk. In this case the couplings of the radion to massive gauge bosons are suppressed, allowing it to evade existing searches. In the presence of kinetic and mass mixing with the Higgs, due to strong constraints from diboson searches, only points near what we denominate the alignment region are able to explain the diphoton signal and evade current experimental constraints. The radion always has a sizeable branching ratio into top pairs, which provides a model independent channel to probe this scenario in the near future. If alignment is strong it is also possible that diHiggs decays may dominate, providing stronger constraints and interesting perspectives for future collider searches.

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Light scalars in composite Higgs models in the light of LHC di-boson searches

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Models of compositeness can successfully address the origin of the Higgs boson as a pseudo-Goldstone of a spontaneously broken global symmetry, and flavour physics via the partial compositeness mechanism. If the dynamics is generated by a simple underlying theory defined in terms of a confining gauge group with fermionic matter content, there exists only a finite set of models that have the correct properties to account for a composite Higgs and composite top partners at the same time. As a prediction of these models, one obtains additional light composite scalars. We study the phenomenology of these additional scalars in the light of di-boson resonance searches at LHC.

This presentation is based on JHEP 1511 (2015) 201, arXiv:1512.04508, arXiv:1512.07242, and work to be completed, soon.

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Implication of a 750 GeV Diphoton Resonance for Heavy Quark Searches

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The hinted diphoton excess at a mass of 750 GeV suggests the existence of heavy quarks that mediated the resonance production via gluon fusion. The decay of the heavy quark into Sq, with q being a SM quark, could provide a new search channel for heavy quarks.
We consider the case of a singlet vector-like partner of the top quark and show that it can be searched for at the 13 TeV LHC through its decay into a scalar resonance in the 2\gamma+\ell final state, especially if the diphoton branching ratio of the scalar S is further enhanced by the contribution of non coloured particles. We further show that conventional heavy quark searches can be sensitive to this new decay pattern also when S decays into jets by slightly tightening the current selection cuts. Finally we comment about the possibility of disentangling the heavy quark decay to St from other standard decay patterns by scrutinising appropriate kinematic distributions.

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Constraining Exotic Signatures Using Simplified Models

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Simplified models are a successful way of interpreting current LHC searches for models beyond the standard model (BSM). So far most simplified models have focused on topologies featuring a missing transverse energy (MET) signature. However, in some BSM theories other, more exotic, signatures occur. We discuss the utility of applying the simplified models framework to exotic signatures, such as heavy stable charged particles (HSCP). As a physical application we investigate the CMSSM stau co-annihilation strip containing long-lived staus, which presents a potential solution to the Lithium problem. Applying both MET and HSCP constraints we show that, for low values of tanβ, all this region of parameter space either violates Dark Matter constraints or is excluded by LHC searches.

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Explaining 750 GeV diphoton excess with scalar particles charged under new confining gauge interaction

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It is shown that a charged scalar particle χ of mass around 375 GeV charged under both $\mathrm{SU}(3)_{textscc}$ and a new confining
non-abelian gauge interaction can explain the 750 GeV diphoton excess. After pair production, these interactions confine the exotic scalar into non-relativistic bound states whose decays into photons can explain the discrepancy. Taking the new confining group to be $\mathrm{SU}(2)$, we find χ must carry an electric charge of $Q \sim [\frac{1}{2}, 1]$ to fit the data. Interestingly, we find that pair production of the scalars and the subsequent formation of the bound state dominates over direct bound state resonance production. This explanation is quite weakly constrained by current searches and data from the forthcoming run at the LHC will be able to probe our scenario more fully. In particular, at an invariant mass of around 750 GeV dijet, mono-jet, di-Higgs and jet + photon searches may be the most promising discovery channels.

This work is based on arXiv: 1604.06180 (work done in collaboration with John Gargalionis).

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The radion explanation of the 750 GeV di-photon excess at the LHC.

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The radion of the five-dimensional Randall-Sundrum model provides a very natural explanation of the excess in the di-photon channel at 750 GeV recently observed by ATLAS and CMS. Crucial future

experimental tests are proposed. Brief comparisons to other models employing extra dimensional physics are made.

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Overview of SUSY Searches with ATLAS

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SUSY with radiatively-driven naturalness and implications for LHC, ILC, WIMP and axion searches

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SUSY models

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Quark flavour experiment

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The 750 GeV anomaly

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Higher-order SUSY Higgs

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Plenary / **250**

A Dark Needle in a Bright Haystack: Two stories of Astrophysical Searches for Dark Matter

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Dark Matter Searches at ATLAS and CMS

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Techniques for Probing SUSY at Colliders

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Dark Matter Direct Detection

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A Dark Needle in a Bright Haystack: Two stories of Astrophysical Searches for Dark Matter.

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Dark Matter Searches at ATLAS and CMS

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Dark Matter Direct Detection

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Amplitudes

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Baryogenesis

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Inflation

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Belle II Physics and Construction Status

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SUSY models with gauge singlets

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SUSY Higgs

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LIGO

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Outlook

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Non-SUSY BSM Higgs

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Extracting fundamental physics from GW150914

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CMS Higgs experiment

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Plenary / **267**

Supersymmetry: to be or not to be?

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Abstract: "LHC data have so far shown no evidence of low energy (N=1)
supersymmetry, and it is thus not exluded that it is simply not there.
What would the implications of such a non-discovery be for the whole
idea of supersymmetry? In this talk I will discuss possible consequences of such a non-discovery from a more theoretical perspective, and point to an alternative scenario based on some strange numerology relating the
48 quarks and leptons of the Standard Model to the 48 spin-1/2 fermions of maximal N=8 supergravity remaining after complete breaking of supersymmetry. I will also explain how new theoretical concepts 'beyond' supersymmetry may help to explain the emergence of the Standard Model
from a Planck scale unified theory."

Plenary / **265**

Latest results from neutrino oscillation experiments

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Plenary / **268**

Non-linear supersymmetry

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Recently non-linear supersymmetry with goldstino type models proved to be extremely useful in cosmology. In the context of string theory it was discovered that anti-D3-brane with spontaneously broken susy, involves constrained superfields. This led to manifestly supersymmetric KKLT construction of de Sitter vacua landscape. It was also possible to construct de Sitter supergravity, thanks to non-linear supersymmetry. Advanced models of inflation, alpha-attractors, compatible with Planck data, are based on constrained superfields. We also review the recent progress in studies of Dirac-Born-Infeld-Volkov-Akulov on-shell amplitudes.

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Searches for SUSY at CMS

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ATLAS Higgs experiment

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Flavor physics theory

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Extended Higgs sectors and the alignment limit

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Naturalness

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Exotic searches at ATLAS and CMS

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Cosmic microwave background implications for particle physics.

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Precision Calculations and Simulations / **75**

Renormalization-Scale Uncertainty in the Decay Rate of False Vacuum

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It is sometimes discussed that we may be in a meta-stable vacuum and its decay time is longer than the age of universe. In most papers, the decay rate is estimated without calculating the pre-exponential factor because they believe that it is much less significant than the exponential suppression factor. What we point out is that this estimate can involve a large error owing to the renormalization scale uncertainty. Since the renormalization scale is relevant in calculation of bounce solution and its action, it modifies the decay rate and the uncertainty can be comparable to the exponential factor. To control the scale dependence, we explicitly calculate the pre-exponential factor and show that it is greatly reduced.

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HEPfit: a Code for the Combination of Indirect and Direct Constraints on High Energy Physics Models

Authors: Ayan Paul[1]; Debtosh Chowdhury[2]; Enrico Franco[3]; Jorge de Blas[4]; Laura Reina[5]; Luca Silvestrini[6]; Marco Ciuchini[7]; Marco Fedele[8]; Maurizio Pierini[9]; Mauro Valli[None]; Otto Eberhardt[10]; Satoshi Mishima[11]

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HEPfit is a flexible tool which, given the Standard Model or any new physics extension, allows one to:

i) perform a Markov Chain Monte Carlo (MCMC) based fit of the model to an specified set of experimental observables;

ii) obtain numerical predictions for observables.

HEPfit can be used either in Monte Carlo mode, to perform a Bayesian MCMC analysis of the given model, or as a library, to obtain predictions of observables for a given point in the parameter space of the model, allowing our computational tool to be used in any statistical framework. A large set of electroweak, flavour and Higgs observables are implemented in the code along with a sizable set of new physics models.

The code is publicly available from the website of the HEPfit Collaboration: http://hepfit.roma1.infn.it

The developer version can be obtained from: https://github.com/silvest/HEPfit

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Production of Heavy neutrino in next-to-leading order QCD at the LHC and beyond

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Majorana and pseudo-Dirac heavy neutrinos are introduced into the type-I and inverse seesaw models, respectively, in explaining the naturally small neutrino mass. TeV scale heavy neutrinos can also be accommodated to have a sizable mixing with the Standard Model light neutrinos, through which they can be produced and detected at the high energy colliders like LHC. We consider the Next-to-Leading Order QCD corrections to the heavy neutrino production, and study the scale variation in cross-sections as well as the kinematic distributions with different final states at 14 TeV LHC and also in the context of 100 TeV hadron collider. The repertoire of the Majorana neutrino is realized through the characteristic signature of the same-sign dilepton pair, whereas, due to a small lepton number violation, the pseudo-Dirac heavy neutrino can manifest the tri-leptons associated with missing energy in the final state. Utilizing the 8 TeV data at the ATLAS and CMS, we obtain prospective scale dependent upper bounds of the light-heavy neutrino mixing angles for the Majorana heavy neutrinos at the 14 TeV LHC and 100 TeV collider. Similar upper bounds on the mixing angles for the pseudo-Dirac neutrinos are discussed from multi-lepton search.

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Container technology for Phenomenology tools

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The MasterCode collaboration (http://cern.ch/mastercode) is concerned with the investigation and fits of supersymmetric models. Within the MasterCode collaboration, state-of-the-art HEP Phenomenology codes are consistently combined to provide the most precise prediction for supersymmetric models to be confronted with experimental data.

Generally speaking, for the type of software developed in HEP Phenomenology, there is a lack of tools to enable the easy development and deployment of applications. Phenomenology applications have many dependences in terms of libraries and compilers that makes it difficult to deploy on traditional batch clusters due to system software version conflicts and related issues.

In this work we propose a framework based on "Container technology" to fill this gap. In particular such developments allow us to easily build, modify, distribute and run Mastercode in containerized form over multiple Cloud infrastructures.

Such an advanced computing framework has the potential of speeding up the phases of development and deployment of complex scientific software used in our research, with the corresponding impact in the results.

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High-Precision Higgs Masses in the Complex MSSM

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Since the discovery of a Higgs-like particle at the LHC considerable effort has been undertaken to reveal its nature and properties. To make significant comparisons of the experimental measurements and theory predictions, high-precision calculations are necessary.
One of the particle's basic properties is its mass; due to the very precise measurement, the current MSSM prediction is challenged.

I will present the most recent status of the Higgs-particle spectrum in the CP-violating MSSM in the Feynman-diagrammatic approach with non-trivial renormalization. The known two-loop contributions (leading terms of $\mathcal{O}(\alpha_t\alpha_s + \alpha_t^2)$) are briefly reviewed and new results and implications of the full subleading QCD terms of $\mathcal{O}(\alpha_{\rm any}\alpha_s)$ are shown.

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Precise Higgs-mass predictions in the Next-to-Minimal Supersymmetric Standard Model

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The NMSSM represents an elegant and well motivated description for the observed Higgs-like particle at the LHC. In this theory a scalar singlet together with its superpartner is added to the Higgs-sector of the Minimal Supersymmetric Standard Model (MSSM). Compared to the MSSM the NMSSM provides a better description of the observed phenomenology including even the observed diboson excess at 750 GeV. Significant testing of the NMSSM by experimental measurements requires high-precision predictions for the parameters of the theory.

This talk will focus on the Higgs-mass predictions in the NMSSM at two-loop order obtained with Feynman-diagrammatic methods. The phenomenological impact of the genuine NMSSM contributions are discussed and compared to their MSSM counterparts. The presented results will be included in the upcoming NMSSM extension of the code FeynHiggs. This extension will be motivated and compared with other publicly available tools.

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CheckMATE and SUSY-AI

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A key research question at the Large Hadron Collider (LHC) is the test of models of new physics. In this talk, we want to present two tools to recast direct LHC results to (any) BSM models. First, we discuss CheckMATE (Check Models At Terascale Energies) which is a program package which accepts simulated event files in many formats for any model. The program then determines whether the model is excluded or not at 95% C.L. by comparing to many recent experimental analyses at the LHC. It is simple to use and the program structure allows for easy extensions to upcoming LHC results in the future. CheckMATE can be found at: http://checkmate.hepforge.org.
Testing if a particular parameter set of such a model is excluded by LHC data is a challenge: It requires the time consuming generation of scattering events, the simulation of the detector response, the event reconstruction, cross section calculations and analysis code to test against several hundred signal regions defined by the ATLAS and CMS experiment.
In the second part of the talk, we attack this challenge using a novel approach. A Machine Learning tool has learned to predict within a fraction of a millisecond if a model is excluded or not directly from the model parameters.
A first example (SUSY-AI) is presented for the phenomenological Supersymmetric Standard Model (pMSSM). About 310,000 pMSSM model sets - each tested with 200 signal regions by ATLAS - have been used to train and validate SUSY-AI. The code is now able to reproduce the ATLAS exclusion regions in 19 dimensions with an accuracy of at least 97%

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Precision Higgs mass predictions in minimal and non-minimal SUSY models

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Now that the Higgs mass has been well measured at the Large Hadron Collider (combined ATLAS and CMS mh = 125.09 \pm 0.24) it is very important that the precision of the Higgs mass prediction in SUSY models is improved. This is particularly challenging since both limits on the sparticles and the Higgs mass indicate that the SUSY scale may be quite large. A great deal of work has recently been directed at this in the MSSM with the state-of-the-art calculations ensuring that large logs are resummed when the SUSY scale is much bigger than the EW scale. However much less has been done on non-minimal SUSY models. Currently a two-loop calculation is available with SARAH/SPheno, but the precision is still limited due to large logarithms when the SUSY scale is large. Here we present an alternative algorithm for calculating the Higgs pole mass in and SUSY theories that combines an effective field theory (EFT) approach to resum large logs with a diagrammatic calculation of the Higgs pole mass. We implement this algorithm in FlexibleSUSY and use this to study the impact of these corrections in the MSSM, NMSSM, MRSSM and E_6SSM. In the MSSM we show that our Higgs mass prediction correctly interpolates between the known EFT results when the sparticles are heavy and fixed order calculations in the full theory when the sparticle masses are close to the electroweak scale. We compare our results to those in public codes and discuss the origin of the most significant deviations.

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Model independent constraints on new physics with HEPfit

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We present up to date limits from electroweak precision observables and Higgs-boson signal strengths on new physics beyond the Standard Model. We consider general extensions such as new physics in

the form of oblique parameters, modified Zbb couplings, or modified Higgs-boson couplings, as well as the model-independent parameterization given by the dimension-six Standard-Model effective Lagrangian. We compare these results with the projection of the fit with the expected experimental improvements at future e+e- colliders. All the results have been computed with HEPfit code.

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Signal Morphing techniques and possible application to Higgs properties measurements

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One way of describing deviations from the Standard Model is via Effective Field Theories or pseudo-observables, where higher order operators modify the couplings and the kinematics of the interaction of the Standard Model particles. Generating Monte Carlo events for every testable set of parameters for such a theory would require computing resources beyond the ones currently available in ATLAS. Up to now, Matrix-Element based reweighting techniques have been often used to model Beyond Standard Model process starting from Standard Model simulated events. In this talk, we review the advantages and the limitations of morphing techniques to construct continuous probability model for signal parameters, interpolating between a finite number of distributions obtained from the simulation chain. The technique will be exemplified by searching for deviations from the Standard Model predictions in Higgs properties measurements.

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Impact of Jet Veto Resummation on Slepton Searches

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Jet vetoes are a common tool in the experimental SUSY searches for eliminating the SM QCD background. They introduce large logarithms (of the jet veto scale over the partonic invariant mass) in the SUSY cross sections, which increase with the SUSY particle mass and need to be resummed to obtain reliable cross section predictions. Using slepton production as an example, we show that the theoretical uncertainties associated with the jet veto are large, and when taken into account have a sizeable impact already on present exclusion limits. This is improved by calculating the resummed cross section to higher order, which allows us to obtain accurate predictions even for high slepton masses, as probed by the LHC in the upcoming years.

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GAMBIT - A general-purpose Beyond-the-Standard-Model global fitting tool

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In this talk I will present an overview of GAMBIT, a soon-to-be released next-generation open-source global fitting tool, along with preliminary MSSM fit results. The GAMBIT project aims to fill a need in the phenomenology community for a robust and extensible tool for interfacing the physics calculators, advanced statistical sampling algorithms, and likelihood calculations that are necessary for performing statistically valid global parameter fits and model comparisons in Beyond-the-Standard-Model theories. The first public release of GAMBIT will be focused on SUSY and Higgs portal models, and will ship with a comprehensive set of likelihood calculations (experimental constraints) including a variety that are usually not included in SUSY global fits such as indirect dark matter searches (IceCube, FermiLAT) and on-the-fly LHC event simulation.

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Interpreting the simplified models results from the LHC with SModelS

Authors: Andre Lessa[1]; Federico Ambrogi[2]; Sabine Kraml[3]; Suchita Kulkarni[2]; Ursula Laa[4]; Veronika Magerl[5]; Wolfgang Waltenberger[2]

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SModelS is a tool designed for the interpretation of the LHC searches for Beyond Standard Model (BSM) physics based on Simplified Models Spectra (SMS).

SModelS performs the decomposition of arbitrary BSM scenarios featuring a Z2 symmetry into their SMS components, and evaluates the theoretical predictions for their production cross sections. These predictions are then compared with the results from the LHC searches implemented in a comprehensive and up-to-date database, in the form of cross section upper limit maps or signal efficiency maps.

In particular the usage of efficiency maps is one of the main new features of the upcoming version SModelS v1.1. It allows for the combination of different simplified models for the evaluation of cross section upper limits, thus increasing the constraining power of SModelS.

As an application, we show how SModelS has been used for the study of specific supersymmetric models not only to constrain the theory's parameter space, but also to highlight interesting regions currently

not covered by the experiments. This way we can also give feedback to the experiments for where to look next.

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Naturalizing Supersymmetry with a Two-Field Relaxion Mechanism

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We present a supersymmetric version of a two- eld relaxion model that naturalizes tuned versions of supersymmetry. This arises from a relaxion mechanism that does not depend on QCD dynamics and where the relaxion potential barrier height is controlled by a second axion-like eld. During the cosmological evolution, the relaxion rolls with a nonzero value that breaks supersymmetry and scans the soft supersymmetric mass terms. Electroweak symmetry is broken after the soft masses become of order the supersymmetric Higgs mass term and causes the relaxion to stop rolling for superpartner masses up to 10ˆ9 GeV. This can explain the tuning in supersymmetric models, including split-SUSY models, while preserving the QCD axion solution to the strong CP problem. Besides predicting two very weakly-coupled axion-like particles, the supersymmetric spectrum may contain an extra Goldstino, which could be a viable dark matter candidate.

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Phenomenological MSSM interpretation of CMS results

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Using a global Bayesian analysis, it is shown how the results from searches for supersymmetry performed by CMS constrain the Minimal Supersymmetric Standard Model (MSSM). The study is performed within the framework of the phenomenological MSSM (pMSSM), a 19-parameter realization of the R-parity conserving weakscale MSSM, that captures most of the latter's phenomenological features and which, therefore, permits robust conclusions to be drawn about the MSSM.

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Non-universal MSSM as the effective theory from flavour

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Flavour symmetries a la Froggatt-Nielsen provide a compelling way to explain the hierarchy of fermionic masses and mixing angles in the Yukawa sector. In Supersymmetric extensions of the SM where the breaking of Supersymmetry occurs at scales much larger than the breaking of flavour, this flavour symmetry must be respected not only by the Yukawas of the superpotential, but by the soft - breaking masses and trilinear terms as well. In this work we show that contrary to naive expectations, even starting with flavour blind soft breaking at a high scale, the effective theory obtained after integrating out the heavy flavour mediator fields is strongly non-universal. We explore the phenomenology of these SUSY models after the latest LHC searches for new physics.

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Natural Supersymmetry and Unification in Five Dimensions

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We explore unification and natural supersymmetry in a five dimensional extension of the standard model in which the extra dimension may be large, of the order of 1-10 TeV. Power law running generates a TeV scale At term allowing for the observed 125 GeV Higgs and allowing for stop masses below 2 TeV, compatible with a natural SUSY spectrum. We supply the full one-loop RGEs for various models and use metastability to give a prediction that the gluino mass should be lighter than 3.5 TeV for At > -2.5 TeV, for such a compactification scale, with brane localised 3rd generation matter. We also discuss models in which only the 1st and 2nd generation of matter fields are located in the bulk. We also look at electroweak symmetry breaking in these models.

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Two (or more) Higgs bosons near 125 GeV in the complex NMSSM

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The two additional singlet-like Higgs bosons, one scalar and one pseudoscalar, of the next-to-minimal supersymmetric standard model (NMSSM) can result in some unique signatures at the Large Hadron Collider (LHC), helping establish the non-minimal nature of supersymmetry. In particular, there exists the possibility of one, or even both, of these new Higgs bosons being almost degenerate with the 125 GeV SM-like Higgs boson. When, motivated by the baryon asymmetry of the universe, CP-violating phases are explicitly invoked in the Higgs sector of the model, all the Higgs interaction eigenstates mix to give five CP-indefinite physical states. In such a scenario, when the mass difference between two (or more) Higgs bosons near 125 GeV is comparable to their widths, the off-diagonal contributions to the propagator matrix ought to be taken into account. We perform a detailed analysis of the impact of these contributions on the di-photon production in gluon fusion via Higgs resonance near 125 GeV at the current LHC run. We find that these effect can become quite

sizable, thereby invalidating both the narrow width approximation and the approach based solely on the tree-level interference, and thus considerably modifying the phenomenology of the observed Higgs boson.

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The NMSSM lives - with the 750 GeV diphoton excess

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We propose an NMSSM scenario that can explain the excess in the diphoton spectrum at 750 GeV recently observed by ATLAS and CMS. We show that in a certain limit with a very light pseudoscalar one can reproduce the experimental results without invoking exotic matter. The 750 GeV excess is produced by two resonant heavy Higgs bosons with masses ˜750 GeV, that subsequently decay to two light pseudoscalars. Each of these decays to collimated photon pairs that appear as a single photon in the electromagnetic calorimeter. A mass gap between heavy Higgses mimics a large width of the 750 GeV peak. The production mechanism, containing a strong component via initial b-quarks, ameliorates a possible tension with 8 TeV data compared to other production modes. We also discuss other constraints, in particular from low energy experiments. Finally, we discuss possible methods that could distinguish our proposal from other physics models describing the diphoton excess in the Run-II of the LHC.

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Probing Non-holomorphic MSSM via precision constraints, dark matter and LHC data

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In this analysis we explore the phenomenological constraints of models
with non-holomorphic soft SUSY breaking terms in a beyond the MSSM scenario
having identical particle content. The model referred as NHSSM shows various
promising features like the possibility of a strong reduction in electroweak fin
e-tuning even for a scenario of a heavy higgsino type of LSP, a fact that is unavailable in pMSSM models. The other important aspect is satisfying the muon $g-2$ data even for a small
$\tan\beta$ via a small value of coupling A'_μ associated with the tri-linear non-holomorphic soft term. Thus, a large SUSY contribution to muon $g-2$ is possible
even for a significantly large smuon mass $m_{\tilde{\mu_1}}$. The Higgs mass radiative corrections are contributed by both the holomorphic and non-holomorphic trilinear soft parameters A_t and A'_t, thus diluting the requirement to have a larger A_t
to satisfy the Higgs mass data. The model also provides with valid parameter space

satisfying the constraint of $B \to X_s + \gamma$ for large values of $\tan\beta$, a scenario unfavourable in pMSSM.

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The 750 GeV diphoton LHC excess from Singlets in Exceptional Supersymmetric Standard Model

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The 750-760 GeV diphoton resonance may be identified as one or two scalars and/or one or two pseudoscalars contained in the two singlet superfields $S_{1,2}$ arising from the three 27-dimensional representations of E_6. We study the corresponding collider signature within the exceptional supersymmetric standard model (E_6SSM). This model is based on the SM gauge group together with an extra $U(1)_N$ gauge symmetry under which right–handed neutrinos have zero charge. To ensure anomaly cancellation the low energy matter content of the E_6SSM involve three 27 representations of E_6. Thus E_6SSM predicts Z' boson and extra matter beyond the MSSM. In particular, the low–energy spectrum of the E_6SSM involves three families of Higgs–like doublets,three families of exotic quarks and three SM singlets S_i that carry $U(1)_N$ charges. The E_6SSM Higgs sector contains one family of the Higgs–like doublets and one SM singlet S_3 that develops vacuum expectation values (VEV) breaking $U(1)_N$ gauge symmetry and inducing masses of exotic states mentioned above. The fermion and scalar components of other Higgs–like superfields form Inert Higgsino and Inert Higgs states respectively. Two lighter singlets $S_{1,2}$ with masses around 750 GeV can couple to Inert Higgsino and exotic quarks giving rise to diphoton excess. We calculate the branching ratios and cross-sections for the two scalar and two pseudoscalar states associated with the $S_{1,2}$ singlets, including possible degeneracies and maximal mixing, subject to the constraint that their couplings remain perturbative up to the unification scale.

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On the smallness of the dark energy density in SUGRA models with Planck scale SUSY breaking and degenerate vacua

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In $N = 1$ supergravity (SUGRA) supersymmetric (SUSY) and non-supersymmetric Minkowski vacua originating in the hidden sector can be degenerate. This allows for consistent implementation of the multiple point principle (MPP) assumption.
We present no–scale inspired SUGRA model where the MPP assumption is realised at the tree–level without extra fine-tuning. In the supersymmetric phase in flat Minkowski space SUSY may be broken dynamically inducing tiny vacuum energy density which can be assigned, by virtue of MPP, to all other phases including the one in which we live.We argue that the measured

value of the cosmological constant, as well as the small
values of quartic Higgs self–coupling and the corresponding beta function at the Planck scale, which can be obtained by extrapolating the Standard Model (SM) couplings to high energies, can originate from supergravity (SUGRA) models with degenerate vacua.
This scenario is realised if there are at least three exactly degenerate vacua. In the first vacuum, associated with the physical one, local supersymmetry (SUSY) is broken near the Planck scale while the breakdown of the $SU(2)_W \times U(1)_Y$ symmetry takes
place at the electroweak (EW) scale. In the second vacuum local SUSY breaking
is induced by gaugino condensation at a scale which is just slightly lower than Λ_{QCD} in the physical vacuum. Finally, in the third vacuum local SUSY
and EW symmetry are broken near the Planck scale.

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New SUSY Fits with MasterCode

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New and updated SUSY fits, using the MasterCode framework, are presented. In particular, results for new GUT based models are discussed.

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Constraints on non-universal gaugino mass scenario using the latest LHC data

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We investigate exclusion limits on the the non-universal gaugino mass scenario
in the Minimal Supersymmetric Standard Model (MSSM), according the the latest results of the super-particle search at the LHC8 and the LHC13. In this scenario, suitable ratios of wino to gluino mass can realize the observed value of the Higgs boson mass, while keeping a small μ parameter.
Such a small μ parameter corresponds to the mass of higgsino, so that
lightest neutralino and chargino are higgsino-like and their masses are almost degenerate.
Besides, we find that the right-handed top squark tends to be lighter than other sfermions
and then the top squark search, where the top squark decays to a quark and higgsino, is relevant to our model.
In our analysis, the exclusion limits are derived using the data of the top squark searches
in the $bb + E_T^{\rm miss}$ and $tb + E_T^{\rm miss}$ channels.
Furthermore, the exclusion limit on gluino mass, which is crucial to our scenario, is investigated as well.
The analysis of the gluino is based on the data of the analysis with large missing energy and at least three b-tagged jets at the ATLAS experiment.
This work is based on PRD 93(2016) no.5, 055019.

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Mass Spectrum and Dark Matter in the CSE6SSM

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E_6 inspired SUSY models are a well-motivated class of models that can solve the μ problem in the MSSM and allow for the tree-level Higgs mass to be increased. In the simplest variants of these models, multiple exact and approximate discrete symmetries must be introduced for the model to be phenomenologically viable. Here we study a constrained version of a recently proposed E_6 inspired model, the CSE$_6$SSM, in which only a single, exact custodial symmetry is required. We perform scans over the parameter space of
the model to identify regions with a SM-like Higgs with a mass of 125 GeV and sparticle masses above existing limits. The obtained solutions lead to distinctive new physics signatures that would enable the model to be discovered at run II of the LHC. At the same time, the observed dark matter relic abundance is accounted for by the lightest MSSM-like neutralino. We find that in these scenarios the predicted direct detection cross sections are close to the current limits from LUX and would be easily discoverable at XENON1T.

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The 750 GeV diphoton excess: models and precision tools

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Indications from ATLAS and CMS of a potential new resonance at 750 GeV have seen a wide range of models put forward to explain the excess. Obtaining precise theoretical predictions for a given model can be a formidable computational challenge. On the other hand, relying on simpler analytical approximations often leads to important subtleties being neglected or missed. Here we describe extensions to the Mathematica package SARAH and
the spectrum generators FlexibleSUSY and SPheno that enable the automatic calculation of the required diphoton and digluon rates, including crucial higher order corrections, in a large class of models. We have implemented a large number of models presented in the recent literature. We explain how these may be used to rigorously test the proposed models, emphasising cases in which

the use of the tools makes a significant difference to the final
results. We then formulate a new SUSY model capable of accommodating the diphoton excess with a large width, and demonstrate the utility of the set-up by studying the new model in detail without having to neglect physically important effects.

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Di-Higgs signatures from R-parity violating supersymmetry as the origin of neutrino mass

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Motivated by the naturalness and neutrino mass generation, we study a bilinear R-parity violating supersymmetric scenario with a light Higgsino-like lightest supersymmetric particle (LSP). We observe that the LSP dominantly decays to νh in a large part of the parameter space, and thus study the pair production of electroweakinos followed by the decays $\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0 W^{\pm *}$ and $\tilde{\chi}_1^0 \to \nu h$. This leads to an interesting signature of Higgs boson pair production associated with significantly large missing transverse energy which is grossly distinct
from the di-Higgs production in the Standard Model. We investigate the perspective of probing such signatures by performing a realistic detector level simulation of both the signal and corresponding backgrounds for the high-luminosity high energy phase of the Large Hadron Collider (LHC). We also advocate some observables based on kinematical features to provide an excellent handle to suppress the backgrounds.

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Bayesian naturalness of Next-to-Minimal and Minimal Supersymmetric Models

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The discovery of a 125 GeV Higgs-like boson and null results in searches for new physics at the LHC have lead to renewed interest in next-to-minimal supersymmetric models and doubts about traditional measures of fine-tuning in supersymmetric models. We investigate fine-tuning in next-to-minimal and minimal supersymmetric models with Bayesian statistics by picking non-informative priors for superpotential and soft-breaking parameters (in contrast to informative priors for e.g., M_Z and $\tan\beta$) which, we argue, underpin fine-tuning arguments in supersymmetric models. Furthermore, we contrast our Bayesian analyses with traditional fine-tuning measures based upon derivatives of the Z-boson mass, including high- and low-scale measures, highlighting deficiencies in traditional fine-tuning measures.

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Compressed SUSY with 125 GeV Higgs

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A compressed spectrum is seen as an natural explanation for the elusiveness of low-energy supersymmetry at the LHC. Some characteristic signals, such as mono-jet + MET, had been accepted as its trademark signals although investigations suggested that lower limits on the supersymmetric particle masses are quite stringent in spite of compression. Also, most compressed SUSY scenarios studied so far are only partially compressed. In this backdrop, we make an exhaustive analysis of the compressed SUSY scenarios for the 13 TeV run of LHC, keeping the level of compression in the entire spectrum as high as possible. A broad class of benchmark spectra are thus considered, after ensuring consistency with the observed Higgs mass as well as the dark matter constraints. The rates of observable events in the high-energy run are obtained through detailed simulation, for both the multi-jet + MET and mono-jet + MET final states. We argue that the former is still more efficient to reveal a compressed SUSY spectrum first, while the latter can serve as a useful confirmatory channel.

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SUSY Predictions for Dark Matter Searches from MasterCode

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We present predictions for SUSY Dark Matter searches and analyses based on the MasterCode framework.

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Non-linearly realised electroweak symmetry in the MSSM and phenomenological aspects

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Minimal Supersymmetry offers an explanation for the Hierarchy Problem in the Standard Model of Particle Physics, however still requires fine tuning in order to receive the correct higgs mass. We can consider compressed spectrum SUSY, where we can decouple the sparticle sector from the electroweak physics and still maintain a light higgs mass. The phenomenology of such situations, including calculations of the muon g-2, dark matter relic density and other observables are explored. Alternatively, we explore the particle spectrum of a SUSY model with the electroweak symmetry non-linearly realised. With the higgs realised as an SM singlet field in this parameterisation, we discover a unique and rich spectrum relevant to collider phenomenology.

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The anomalous magnetic moment of the muon in a GUT model with A4 × Z5 family symmetry

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We will discuss the low energy predictions arising from a GUT scale Pati-Salam gauge group with an A4 × Z5 family symmetry. This results in four soft scalar masses at the GUT scale: one left-handed soft mass and three right-handed soft masses, one for each generation. We will show that this model can correctly describe measurements of the anomalous magnetic moment of the muon, which currently suffers a puzzling 3σ excess of the experimentally measured value over the theoretical prediction. As the consequence, the model predicts specific regions of the MSSM parameter space including light smuons and neutralinos, which may also potentially explain di-lepton excesses observed by CMS and ATLAS.

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Relation between the PMNS phase and proton decay in SUSY SO(10) models

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The accurate measurements of the neutrino oscillation parameters including a CP phase are
one of the important issues to understand the fermion mass hierarchy in unification picture.
It is expected that all the elements in the neutrino mass matrix can be obtained (up to Majorana phases)
after the accurate measurements.
Before the measurements of 13-mixing and the CP phase, it was not ready to argue if the (1,2) element is hierarchically smaller

than the (1,3) element of the neutrino mass matrix.
Currently, the (1,2) element is consistent to be zero up to experimental errors.
In grand unified theories, the size of the elements can be related to the one in the charged fermion Yukawa matrices,
and thus, it is related to the size of proton decay amplitudes in SUSY GUT models.
We discuss the relation between the CP phase and the proton decay amplitudes in SUSY SO(10) models,
and provide a prediction of the CP phase from the proton decay suppression.

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Vacuum Stability Bounds on Lepton Flavor Violating Tri-linear Soft-terms in the General MSSM

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The stability of the standard electroweak vacuum imposes constraints on flavor violating tri-linear soft terms which are comparable to the experimental bounds coming from the absence of the flavor changing neutral currents. Furthermore, contrary to the bounds coming from flavor changing neutral currents, the vacuum stability constraints do not decouple even if the scale of supersymmetry breaking is arbitrarily large. We pinpoint the regions in supersymmetric parameter space, compatible with vacuum stability and the experimental results from the LHC and predict the rates of various lepton flavor violating processes in these regions. Moreover, results coming from demanding the vacuum being meta-stable are juxtaposed to the ones in which vacuum being absolutely stable in nature. We further discuss the dependency on the other related supersymmetric parameters on the result. We assess the prospect for present and future flavor factories while keeping the supersymmetry breaking scale within the LHC reach.

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Dirac Gauginos and the Di-Photon Excess

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Supersymmetric models with Dirac masses for the gauginos have both a solid top-down theoretical motivation and a rich phenomenology. We show that the 750 GeV di-photon excess can be explained by the Minimal Dirac Gaugino Supersymmetric Standard Model without introducing any additional "ad-hoc" states. In this model, the resonance is identified with the scalar partner of the Dirac bino. We demonstrate that the 750 GeV excess can be achieved in this model while satisfying constraints arising from the scalar mixing with the Higgs boson, vacuum stability, gauge coupling unification and perturbativity of the couplings up to the GUT scale.

Considering different benchmark scenarios, we will present how this model is able to produce the intriguing 750 GeV di-photon signature.

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Electroweak symmetry breaking in models with vectorlike families

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I discuss electroweak symmetry breaking in SUSY models with extra vectorlike fields and show that under certain simple assumptions a 125 GeV Higgs can be achieved in a natural way. Implications for the properties of the Higgs boson and other collider phenomenology are also discussed.

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From E8-inspired SUSY trinification to a L-R symmetric theory

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In this talk we propose a new supersymmetric model based on the trinification gauge group with global SU(3) flavour symmetry. We aim at solving the major issues of conventional trinification GUTs, such us multi-TeV SM fermion masses, as well as providing a natural way to introduce a SU(2)_L x SU(2)_R symmetry. We investigate whether it is possible to spontaneously break the original gauge symmetry and find that the minimal field content allowing for stable vacuum solutions requires three copies of a full E6 27-plet, three gauge octets from an adjoint 78-plet and a flavour octet, all belonging to a common fundamental 246-plet of E8. Unlike older realizations, the new flavour symmetry forbids leptons from acquiring tree-level masses naturally suppressing them from the GUT scale. Besides gauge coupling unification we also predict novel features such as top-bottom-tau Yukawa unification alongside with Higgs-lepton unification, which are only possible in supersymmetric realizations of the trinification model.

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Diphoton signal of light Higgs Boson in NMSSM at the LHC.

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The next-to-minimal supersymmetric standard model (NMSSM)
with an extended Higgs sector offers at least one Higgs boson as the
Standard model (SM) like Higgs with a mass around 125 GeV.
We revisit the mass spectrum and couplings of non-SM-like
Higgs bosons taking into consideration most relevant constraints.
We evaluate the rates of productions of these non-SM-like Higgs bosons at the LHC for a variety of decay channels corresonding to the allowed region of the parameter space. We notice that for a substantial region of the parameter space the two-photon decay mode has a remarkably
large rate. In this study we emphasize that this diphoton mode can be
exploited to find the non-SM-like Higgs bosons of the NMSSM
and can also be a potential avenue to distinguish the NMSSM from the MSSM.
We plan to present also detection possibility of light pseudoscalar
Higgs boson(A_1) in the diphoton final states where A_1 is produced
via chargino-neutralino production. In this context we will present
signal sensitivity by computing the background in details
at the LHC with energy 13 TeV.

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Bottom Tau Unification in Supersymmetric Model with Anomaly-Mediation

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We study the Yukawa unification, in particular, the unification of the Yukawa coupling constants of b and τ, in the framework of supersymmetric (SUSY) model. We concentrate on the model in which the SUSY breaking scalar masses are of the order of the gravitino mass while the gaugino masses originate from the effect of anomaly mediation and hence are one-loop suppressed relative to the gravitino mass. We perform an accurate calculation of the Yukawa coupling constants of b and τ at the grand unified theory (GUT) scale, including relevant renormalization group effects and threshold correct ions. In particular, we study the renormalization group effects, taking into account the mass splittings among sfermions, gauginos, and the standard model particles. This talk will be based on our recent paper [arXiv:1604.02156].