Scientific highlights

a) The origin of mass
(Palaiseau, Saclay, Bonn, Greece, INFN, Trieste, Lisbon, Madrid, Valencia, Oxford, Warsaw, CERN, US-team)

Substantial progress was made in the understanding of flavor physics. The impact of LEP-2 data on the Electroweak Symmetry Breaking was analyzed. A high-precision scheme was proposed, Supersymmetry Parameter Analysis, and provided a repository for computer programs relating the Lagrangian parameters to physical observables at LHC and e^+e^- linear colliders, i.e. masses, mixings, decay widths and production cross sections for sparticles. An analysis of the recent experimental results from Tevatron experiments has been performed, suggesting possible non-standard CP violation in Bs mixing. A proposal for performing model-independent jets plus missing energy searches was presented.

Considerable progress was made in constructing a model with an extended gauge symmetry which generates the masses and bi-tri-maximal mixing observed in the lepton sector together with the observed masses and mixings in the quark sector. Models based on discrete non-abelian lepton flavor symmetries, as well as on gauge anomalous horizontal $U(1)$ symmetries, were found and testable neutrino mixing sum rules were derived. The structure of CP violation and flavor changing neutral currents (FCNC) has been examined. FCNC were also investigated in string-derived supergravity models, while the gauge coupling evolution and $b - \tau$ Yukawa unification were analyzed in brane models. A detailed analysis of the fermion masses and mixing in the Froggatt-Nielsen model has been performed. Fermion mass textures and flavor physics have been studied in particular in the supersymmetric $SO(10)$. Theories where proton decay is prevented by exact, anomaly-free discrete symmetries were obtained from models with broken abelian flavor symmetries, accommodating realistic neutrino mass matrices and higgsino masses.

The metastability constraint on the Higgs potential has been studied, as well as the probability of vacuum decay, taking into account gravitational corrections. A simple description of models where electroweak symmetry breaking is triggered by a light composite Higgs, which emerges from a strongly-interacting sector as a pseudo-Goldstone boson has been developed. An effective low-energy Lagrangian approach proves to be useful for LHC and ILC phenomenology below the mass scale of the new resonances. Phenomenological prospects include the study of high-energy longitudinal vector boson scattering, strong double-Higgs production and anomalous Higgs couplings. Moreover, models in which the Higgs boson appears as a pseudo-Goldstone boson were critically analyzed and difficulties to comply with the electroweak precision tests and B-physics constraints were pointed out. The phenomenology of 'unparticle' models in connection with the Higgs field has been addressed. A unified model has been contructed within the little-Higgs approach to solve the little hierarchy problem. A mechanism for double protection of the Higgs potential, by SUSY and global symmetry, was studied. Various non-supersymmetric approaches to the hierarchy problem have been analyzed. In particular, a detailled study of the pair production and detection at the LHC of fermionic top partners has been performed. Model independent considerations have been developed in higgsless models with the electroweak symmetry breaking triggered by a new strong interaction. A comprehensive study of the flavor structure of 5D warped models, that provide a dual description to strongly interacting composite Higgs models has been conducted.

New methods to investigate the CKM matrix using three-body B decays were proposed. NLO QCD corrections to the electric dipole moment of the neutron were computed, and their phenomenological impact was assessed. A study of the Unitarity Triangle within the Standard Model (SM) and beyond was performed, using experimental results in B physics. Various aspects related to the theoretical prediction of the anomalous magnetic moments of electron, muon and tau lepton have been studied. The muon $g-2$ is particularly well suited to unveil or constrain effects of physics beyond the Standard Model. Rare decays in models of Minimal Flavor Violation were analysed and the Standard Model prediction for the muon anomalous magnetic moment was investigated. Lepton number violation and the 'little fine-tuning' problem have been studied. The complementarity between lepton flavour violation and LHC experiments has been analysed to probe supersymmetric grand unified theories. The impact of various experimental constraints (lepton flavor and CP violation, neutrino oscillations, baryon asymmetry of the universe, electric dipole moments) on supersymmetric seesaw models and New Physics model building was analyzed.

Models for neutrino masses and mixings were proposed and confronted with the experimental data, together with their influence in LHC and astrophysics. They account naturally for the observed maximal mixing angles, and the experimental uncertainties on the solar and atmospheric parameters were analyzed. A mechanism of screening of the Dirac structure in the seesaw mechanism and lepton mixing has been proposed. The most general seesaw equation for neutrino masses in left-right symmetric models into the right-handed neutrino spectrum was resolved and the constraints from leptogenesis were extracted. A novel supersymmetric $SO(10)$ seesaw mechanism with low B-L breaking scale was suggested, and a systematic study of the renormalization group evolution of the neutrino mass parameters both for Majorana and Dirac masses was undertaken. A detailed analysis of the constraints on neutrino mass parameters and CP phases that can be obtained by future neutrino-less double beta decay experiments was performed.

Different phenomenological studies were performed, addressing the physics potential of future neutrino facilities, interacting to this end with the experimental Physics Neutrino Community. The goal of these studies is to ascertain the ultimate precision in the determination of the detailed pattern of neutrino mass differences and mixing angles that can be achieved experimentally, a prerequisite to understand their origin and their relationship to the analogous parameters in the quark sector. Among these, and of particular interest lately, is a realistic study of the recently proposed high gamma Beta Beam experiments as well as a future low-energy neutrino factory. On the other hand, the coherent contribution of neutrons in neutrino-nucleus scattering was suggested for detecting supernova neutrinos. A new type of radiation detector was proposed with a performance already close to fulfill the demands of many challenging projects from low energy neutrino physics to dark matter detection. Moreover, the TPC detector of the proposed experiment NOSTOS was shown to exhibit a high sensitivity in (extragalactic) supernova neutrinos.

b) Supersymmetric phenomenology
(Palaiseau, Saclay, Bonn, Greece, INFN, Trieste, Lisbon, Madrid, Valencia, Oxford, Warsaw, CERN, US team)

The supersymmetry phenomenology has been extensively investigated. In particular, in the MSSM, the light Higgs-boson radiation off a light-chargino pair was studied for linear colliders. The production of a single neutralino was considered at hadron colliders and a relevant code named PLATONgluino was released. Benchmark surfaces suitable for studying the phenomenology of Higgs bosons in the MSSM have been explored. They are chosen so that the supersymmetric relic density is generally compatible with the range of cold dark matter density preferred by WMAP and other observations. These benchmark surfaces are specified assuming that gaugino masses, soft trilinear supersymmetry-breaking parameters and the soft supersymmetry-breaking contributions to the squark and slepton masses are universal, but not those associated with the Higgs multiplets. The prospects for probing experimentally these benchmark surfaces at the Tevatron collider, the LHC, the ILC, in B physics and in direct dark-matter detection experiments have been studied. The complete computation of 1-loop electroweak corrections to the $W^{\pm}$-boson production at LHC was performed, as well as the code gamgamZZ was prepared for calculating all possible observables related to the process $\gamma\gamma \to ZZ$ in the SM and the MSSM. An improved method was proposed for hadron-collider mass determination of new states that decay to a massive, long-lived state like the LSP in the MSSM. It can be used for relatively rare processes, such as neutralino pair production at LHC. The Supersymmetry Les Houches Accord, which provides a tool for conveying spectral and decay information for supersymmetry in experimental analyses, was extended to the MSSM with violation of CP, R-parity, and flavour, as well as to the simplest next-to-minimal model. A Fortran code, CPsuperH2, has been developed to analyze CP and flavor physics in the Higgs sector. The code automatizes calculations of the Higgs-boson pole masses and implements two- and three-body Higgs decays. The detectability of the (constrained) CMSSM Higgs at the Tevatron has been analyzed in detail, while a detailed Bayesian fits to present data were carried out and implications for LHC SUSY searches were determined.

A detailed study of the Higgs sector in models that go beyond the minimal supersymmetric standard model (MSSM) was given and collider signatures were studied. The idea of "improved naturalness was introduced – the new physics that cuts off the quadratic divergence from the top quark may be at energies above those accessible to the LHC, in which case this facility will have an interesting non-standard Higgs sector to explore. Motivated by the absence, so far, of any direct signal of low-energy supersymmetry, network members explored the consequences of making the lightest Higgs boson in supersymmetry relatively heavy, up to about 300 GeV, via the introduction of a chiral singlet with a superpotential interaction with the Higgs doublets. This framework, called lambda susy, was found to deviate significantly from the MSSM or the standard NMSSM, and was analyzed in different areas: Electroweak Precision tests, Dark Matter, naturalness bounds on superparticle masses, LHC signals, and gauge coupling unification. There is a rich Higgs sector with LSP Higgsino dark matter below the TeV, while all other superpartners, apart from the top squarks, may naturally be heavier than 1-2 TeV. Other theories studied include twin Higgs models, 2 Higgs doublet theories with a light Higgs, and two Higgs doublet models with one inert having no expectation value and no coupling to fermions. Predictions are given for multilepton events with missing transverse energy at LHC, and for the direct detection of dark matter. Natural explanation of the fact that the supersymmetry breaking scale is bigger than the EWSB scale was also proposed within models with extended electroweak gauge groups. Supersymmetry and global symmetries were used to stabilize the Higgs mass for the gauge groups $SU(2)_L \times SU(2)_R \times U(1)$ and $SU(3)_W \times U(1)$. Another viewpoint, based on the statistics of vacua, on the issue of fine-tuning in supersymmetry was proposed. Its most likely expectation is that a 1-loop hierarchy between the Z-boson mass and the sparticle masses exists, thus explaining why sparticles are elusive at LEP and also why they should be found at the LHC. It was also pointed out that, given the

LEP bounds on sparticle masses, the most favourable situation to obtain a realistic Dark Matter candidate within supersymmetry is for the lightest supersymmetric particle to be a "well tempered" combination of bino with chargino or higgsino. This also implies the generic presence of almost degenerate neutralinos at the LHC. Supersymmetric models with the Higgs realized as Goldstone boson of a spontaneously broken extended global symmetry, avoiding excessive fine tuning, were also proposed.

Important effort has been dedicated to the study of supersymmetric candidates for dark matter and their possible detection. Models with spontaneous R-parity breaking were studied in detail. A detailed analysis of the SUSY spectrum was performed in theories with SUSY breaking via anomaly mediation and restricted by $SO(10)$ unification. A new anomaly mediated model with all scales generated dynamically was constructed avoiding the tachyonic slepton problem. Progress was made towards a fully calculable scenario of gravity mediated supersymmetry breaking, where the mixing between hidden and visible sector arises by quantum corrections at a high scale. The mechanism of mirage mediation was further developed. Studies of dynamical SUSY breaking in 4D field theories have shown that our universe might live in a metastable vacuum. Such vacua were shown to arise naturally following the evolution of the universe, relating the supersymmetry breaking and inflation scales. O'Reifeartaigh-type models for F-term supersymmetry breaking in gauge mediation scenario were investigated in the context of metastable vacua of gauge mediation that avoid FCNC, and their phenomenology was worked out. The phenomenology of hybrid models, where gravity and gauge mediations compete at the GUT scale has also been explored. Finally, the mu-Bmu problem in gauge mediation was addressed. A natural solution has been proposed, relying on the logarithmic dependence of the effective Kähler potential on the messenger superfields. Then, μ and $B\mu$ arise at one and two loops, respectively, while B has the same phase as the gaugino mass that solves the supersymmetric CP problem. An alternative approach was also found with $\mu^2 << B\mu$.

The structure of CP violation and FCNC in supersymmetric models with a family symmetry has been re-examined. It was shown that the effect of D-terms may be much smaller than previously thought and that the family symmetry can elegantly solve the SUSY CP problem. New constraints on SUSY flavor mixing have been obtained, in particular from recent measurements at the Tevatron, with important implications for LHC. The impact of the recent experimental data on Bs and $D-\bar{D}$ mixing on SUSY sources of flavour violation was assessed. In view of the up-coming measurements at the LHC, the pattern of gaugino masses were analyzed in popular mechanisms of supersymmetry breakdown. The calculation of gluino contributions to FCNC at the Next-to-Leading order was completed, while the corresponding phenomenological analysis is under way. Flavor changing neutral current processes were analyzed in low-energy supersymmetric extensions of the Standard Model, with emphasis on possible correlations between hadronic and leptonic flavor-changing contributions in the context of supersymmetric grand-unified theories. Other topics explored include 'Split Supersymmetry' and radiative seesaw mechanism in the context of grand unification. Models with 'Split extended Supersymmetry' where also analysed, as well as SUSY models with multiple higgsses. Minimal realistic GUT models, based on $SU(5)$ and $SO(10)$ gauge symmetry groups, have been explored and constraints from proton decay were obtained. On the other hand, it was shown that different pairings of quarks and leptons mixing generations in the same multiplet can lead to significant suppression of proton decay while keeping the correct fermion masses.

A detailed analysis was made of the effects of higher dimension operators in supersymmetric models including the MSSM. Among the physical consequences of this set of operators are the presence of corrections to the MSSM Higgs sector and the generation of "wrong"-Higgs Yukawa couplings and fermion-fermion-scalar-scalar interactions which have implications for supersymmetry searches at the LHC. Motivated by string theory constructions, the possibility to uplift a (supersymmetric) AdS vacuum to a positive cosmological constant was studied, using interactions of the matter in the hidden sector, and the resulting SUSY breaking patterns were analyzed. Particularpossibilities for SUSY-breaking soft terms have been explored from the phenomenological point of view. The MSSM phenomenology was examined under the assumption that the soft terms are generated by flux-induced supersymmetry breaking in a class of string theories. A constrained and predictive scenario was studied, with only one free mass parameter. Pseudo-goldstone bosons from supersymmetric Wilson Lines were studied on 5D orbifolds models. The possibility of assigning a lepton number to the goldstino was discussed, in the context of the non-linear realization of $N = 1$ supersymmetry: the resulting phenomenology includes the possibility of a Higgs boson decaying dominantly into invisible channels.

c) Particle astrophysics and cosmology
(Palaiseau, Saclay, Bonn, Greece, INFN, Trieste, Lisbon, Madrid, Valencia, Oxford, Warsaw, CERN, US team)

The network performed an extensive study of inflation in string and field theory models. Realistic possibilities have been identified and the observable implications were determined. The effective theory of inflation was analyzed and a parameter determination from WMAP data was performed. Two-stage inflationary models were proposed, consisting of a superheavy scale hybrid inflation followed by an intermediate scale modular one. Slow roll inflationary models with initial conditions set by eternal inflation and capable of generating the observed spectral index have been developed. Viable realizations of hybrid inflation in supergravity were found, addressing the problems of the initial conditions and the adequate suppression of the inflaton mass. Low-scale inflation supersymmetric models were also studied and found to be easier realized when the inflaton is close to a critical point than to an inflection point of the potential. Simple inflationary potentials in supergravity theories with no-scale Kähler potentials and moduli stabilization were investigated. The inflation in racetrack models from Wilson lines coming from the string has been shown to be viable and a possible origin of the initial conditions for inflation was identified. The possibility of forming sub-horizon black holes at the end of inflation has been studied. Progress was made towards the understanding of the initial conditions of the universe. A framework was proposed that combines the string landscape with no boundary initial conditions. In this framework, amplitudes for alternative histories for the universe are calculated with final boundary conditions only. This leads to a top down approach to cosmology, in which the histories of the universe depend on the precise question asked.

The statistical properties of cosmological perturbations have been analyzed comparing observations and theoretical expectations. Non-linear primordial adiabatic and isocurvature perturbations and their non-Gaussianity for various inflation models were studied, allowing to discriminate among different inflationary models. An analysis of the effect of supersymmetric flat directions in the reheat phase after inflation was also performed, showing that a significant level of non-Gaussianity in the cosmological perturbation can be produced under some general conditions. The full system of Boltzmann equations at second-order describing the evolution of the photon, baryon and Cold Dark Matter (CDM) fluids was obtained. Non-gaussianity was also shown to be large in a class of curvaton models, such as supersymmetric Peccei-Quinn models with the curvaton corresponding to an angular degree of freedom orthogonal to the axion. The mechanism can accommodate low-scale inflation with Hubble parameter at the TeV scale. The analysis of Sloan Digital Sky Survey data was continued and constraints on the cosmological parameters have been obtained. Investigation of scalar perturbations was also done in a bouncing cosmology, developing an analytical method and identifying non-singular gauge-invariant variables through the bounce. Renormalization Group methods have been applied to the computation of cosmological perturbations beyond linear order. The procedure has been applied to the calculation of the "baryonic wiggles" of the matter power spectrum, which is one of the most promising observables for discriminating among different Dark Energy models. Experimental signatures for the so-called "chameleon" solution to the dark energy problem have been studied in view of Casimir and afterglow experiments that are underway. The cosmological evolution of the universe was studied when the quintessence solution to the dark energy puzzle is modeled within supergravity, broken in a hidden sector, with observable matter in a third sector. The dependence of fermion masses on the quintessence field was computed. The possibility that Dark Energy results from theories with supersymmetric large extra dimensions has also been studied.

Signals for minimal Dark matter (DM) candidates were shown to be detectable in Cosmic Rays experiments, because electrically charged partners may leave tracks in water or ice experiments, like Icecube, after being produced in cosmic rays. DM candidates and dark energy sources have been studied in relation with new physics beyond the SM at the TeV scale. Possible relations between them were considered to explain the approximate coincidence of their energy density in the present cosmological epoch. Programs were made for calculating high-precision observables, the density of CDM in the universe, as well as the cross sections for CDM search experiments. Density profiles and velocity distributions of the lightest sparticle (LSP) in our vicinity were analyzed, and the spin contribution to the LSP-nucleon scattering cross section was exctracted. Constraints on the possible existence of a new gauge boson and light DM have been analyzed. The possibility that DM is made of heavy Dirac neutrinos was investigated; their mass should be in the range of GeV to a few TeV and they would have suppressed but non-zero coupling to Z and a coupling to an additional Z' gauge boson. A model-independent analysis was performed for the relic density and direct detection. These WIMP candidates may arise naturally as Kaluza-Klein states in extra-dimensional models. The effects of extra dimensions on supersymmetric DM components were studied with the computer code Dark Susy. The axino and gravitino LSP scenarios were studied as DM candidates with or without R-parity conservation. Focus on NLSP decays at LHC or ILC was considered to discriminate one scenario from the other. An alternative interpretation of dark matter and dark energy was proposed, in terms of ultra-light pseudo-Goldtsone-bosons arising from symmetry breaking in the neutrino sector, and its implications to future neutrino experiments were analyzed. Appart from the study of SUSY dark matter candidates, a minimal and predictive WIMP model has been proposed and its possible manifestations in astroparticle experiments have been studied. The expected fluxes of positrons and anti-protons from Dark Matter annihilations in the galactic halo have been computed and are in agreement with the preliminary results delivered by the PAMELA satellite in summer '08.

The cosmological manifestations of neutrinos and other light particles were analyzed in view of the results of the WMAP experiment. A study of neutrinos coming from supernovae has been completed and shown that their observation can detect sterile neutrino components more sensitively than earth based experiments. Different aspects of the possibility of producing the baryon asymmetry of the Universe through leptogenesis have been investigated. Leptogenesis was considered in a recently proposed novel seesaw model and its implications were studied in detail. In particular, successful leptogenesis can be achieved evading the so-called gravitino crisis. The CP violation required for thermal leptogenesis in models with see-saw neutrino masses, has been related to the CP violating phase δ, observable in neutrino oscillations. The properties of neutrinos for baryogenesis have been analyzed and an upper bound on the reheating temperature after inflation was derived. A non-thermal leptogenesis scenario has been constructed, following standard supersymmetric hybrid inflation, when the primordial lepton asymmetry is generated via the inflaton decay into light particles. This mechanism requires superpotential couplings violating R-parity that may lead to slepton decays detectable in future colliders. On the other hand, electroweak baryogenesis requires first order phase transition in electroweak symmetry breaking, involving higher order Higgs field interactions that could hardly been seen with accelerators. An effective field theory approach was used to study the electroweak phase transition and to parametrize new physics in terms of non-renormalizable operators in the Higgs potential. It has been shown that gravitational waves predicted by the transition might be detected in future experiments. The prospects for probing the electroweak phase transition at LISA through the production of a stochastic background of gravitational waves have been pointed out. The possibility that both the baryon asymmetry of the universe and the observed cold dark matter density are generated by decays of a heavy scalar field, which dominates the universe before nucleosynthesis, was investigated. Atom interferometry was also study and detectors were proposed to measure general relativistic effects, gravitational waves and the equivalence principle with very high precision.

Ultra High energy astrophysical neutrinos (UHENs) and gamma ray emission from UHE cosmic ray sources have been studied to get insight on their nature and time structure. The possibility that the lightest neutralino in MSSM is a major component of the UHE cosmic-ray flux at PeV-EeV energies has been explored. Theoretical approaches and numerical tools were developed to address questions involving propagation of cosmic rays, γ-rays and neutrinos. The conditions to violate the null energy condition (NEC) were studied within an effective field theory approach; it was shown that NEC violation without instabilities, *i.e.* without ghosts or tachyons, implies the presence of superluminal modes and the breakdown of isotropy. Observational signals were determined to account for possible Lorentz symmetry violation at high energy, γ-ray spectra that could be significantly affected by axion-photon mixing, high energy cosmic rays and discrete sources of extra-galactic cosmic rays above 10^{17} eV. Non-standard cosmological scenarios, based on scalar-tensor gravity, were explored. Future large galaxy surveys will cover $\mathcal{O}(10^4)$ squared degrees on the sky, with primary goal to unravel the nature of the accelerated expansion of the universe. This likely involves new physics which could imply either a modification of our understanding of particle physics (if the acceleration is caused by the so-called "dark energy") or a change of our understanding of space and time (by modifying Einstein's General Relativity). Efforts were made to build up a set of robust tools, including Monte Carlo analysis, to maximize the physics extracted from large-scale structure data.

String and braneworld cosmology was investigated and the presence of a Gauss-Bonnet term in the bulk was considered. The effects of graviton KK excitations have been analyzed. Inflation in string inspired supergravity with the volume modulus playing the role of the inflaton was investigated. Models were constructed in which the gravitino mass is much smaller than the Hubble constant during inflation. The effective Friedmann equation for the brane universe in the Randall-Sundrum (RS) model was studied including a dark radiation term. Accelerated expansion on the brane was found to be possible only in the presence of negative pressure on the brane or in the bulk. The cosmological phase transition between the AdS-Schwarzschild phase (hot CFT phase) and the phase with RS1 geometry was studied. It was argued that gravitational waves, detectable at LISA, should provide a signal of this phase transition. Inflation was also studied in the context of string compactifications in the presence of fluxes. Construction of realistic superstring models of modified gravity at large cosmological scales was performed, realizing the DGP scenario.

d) String phenomenology
(Palaiseau, Saclay, Bonn, Greece, INFN, Trieste, Madrid, Oxford, Warsaw, CERN, US team)

Several research directions which explore the experimental consequences of string theory vacua were explored. Detectable traces from string models have been pointed out, such as gaugino masses, anomalous $U(1)$'s and light axion-like particles. Important progress has been obtained in the study of the effects of fluxes in string compactifications. In particular the study of flux-induced soft terms, and the moduli stabilization. Supersymmetry breaking by fluxes in toroidal type I models was studied and a gaugino mass term was shown to appear at (open string) 2-loop order, given by the corresponding topological partition function. General non-commuting magnetic deformations were considered, implying many surprising features of the corresponding vacua. M-theory compactifications on manifolds with G_2 holonomy or with $SU(3)$ structure were studied. Explicit examples with all moduli fixed which preserve $N = 2$ or $N = 1$ supersymmetry were analyzed. The vacuum structure of type II string theories, when compactified on manifolds with $SU(3) \times SU(3)$ structure has been analyzed, demonstrating that it is possible to find supersymmetric Minkowski vacua, with all moduli stabilized, at weak string coupling. Generically, the expectation values of moduli fields are parametrically controlled and can take arbitrarily large values. In the context of heterotic string compactifications on manifolds with $SU(3)$ structure the matter-field spectrum and superpotential was derived in the standard embedding case, opening up the possibility of phenomenological implications. Particular studies were made of geometric fluxes and internal magnetic fields. Realistic models were constructed with all geometric moduli fixed. Examples were found were both the metric moduli and recombination fields were stabilized. Metastable vacua in supersymmetric brane-world constructions have been obtained and analyzed. Moduli stabilization and potential uplifting were investigated in a variety of contexts. Phenomenological models have been proposed, where the dynamics of the stabilization is essentially supersymmetric, whereas the "uplift" of the cosmological constant is due to either an O'Rafearthaigh supersymmetry breaking sector, or to Fayet-Iliopoulos D-terms. Moduli stabilization was also studied in heterotic models, where the dilaton can be fixed by a gaugino condensate together with an uplifting sector like in type IIB models. The resulting signature is a mirage mediation pattern for the soft breaking terms.

Model building and experimental tests of theories motivated by the hypothesis that there is an enormous landscape of vacua in string theory has been performed. This suggests that certain fine-tunings may be environmentally reasoned, and motivates new models such as Split Supersymmetry. Explicit construction and a detailed phenomenological study of such models was undertaken. Consequences of having a large landscape of vacua have been explored. Possible prediction for the Higgs boson (and top quark) mass was investigated from simple assumptions about the probability distribution for the Higgs quartic coupling on the landscape. Similar studies were performed for the flavor structure of the Standard Model. The implications of Wilson line breaking for the unification of gauge couplings and the unification scale was studied, showing that they can readily bring the weakly coupled heterotic string into excellent agreement with experiment. New tools for constructing semirealistic string models have been derived. An algorithmic method to find all of the vacua of any given string-phenomenological system in a huge class of string compactifications was developed and Mathematica package STRINGVACUA was constructed. A series of realistic models have been derived from string theory and were studied. Many of them favor low energy supersymmetry, allow for the standard seesaw explanation of the smallness of neutrino masses, and yield conserved R-parity which is necessary for proton and SUSY dark matter stability. A systematic search of heterotic string model building has also been performed, including free fermionic constructions. A large amount of models has been found and studied, where the fermion generations come from $SO(10)$ spinors. A complete classification of Z_N orbifold compactifications of the $SO(32)$ heterotic string was given, showing interesting possibilities for model buildiing. The supersymmetric standard model has been obtained from a Z_6 orbifold compactification of the $E8 \times E8$ heterotic string, with no extra exotic particles and a natural hierarchy between the top and other Yukawa couplings. More models with intersecting branes were constructed. A complete analysis of orientifold compactifications involving Gepner models has been performed, with emphasis on MSSM phenomenological aspects.

The most general effective action of brane-world models may contain several anomalous $U(1)$ factors in the gauge group, with Stuckelberg, axionic and Chern-Simons-like couplings. The resulting phenomenology was investigated and some implications in Yukawa couplings, neutrino physics and flavor changing processes were analyzed. It has been pointed out the importance of string instantons in the generation of phenomenologically relevant operators, such as neutrino masses and μ-terms. A systematic search was carried for a class of supersymmetric type II orientifold constructions admitting boundary states associated with instantons giving rise to neutrino Majorana masses and other L- and/or B-violating operators. The perturbative four-dimensional effective theory describing heterotic M theory with branes and antibranes in the bulk space has also been derived. A new mechanism was introduced for producing locally stable de Sitter or Minkowski vacua, with spontaneously broken $N = 1$ supersymmetry and no massless scalars, applicable to superstring and M-theory compactifications with fluxes. The crucial ingredient is a gauged $U(1)$ that involves both an axionic shift and an R-symmetry. The computation of the effective action of brane-world scenarios has been extended and improved with particular focus on the determination of the soft supersymmetry breaking terms. The effective $N = 1$, $D = 4$ supergravity was derived for the seven main moduli of type IIA orientifolds with D6-branes and O6-planes, compactified on the $Z_2 \times Z_2$ orbifold and in the presence of generic fluxes. The effective theories of low scale orientifold models with anomalous $U(1)$s have been analyzed. Aspects of string cosmology have been investigated. A systematic study of string backgrounds within generalized flux compactifications was performed, and necessary conditions for embedding inflationary models were identified. Natural models of string inflation were found with definite experimental signatures, such as a spectral index $n_s \leq 0.95$. Motivated by brane physics, the cosmic string configurations of the non-linear Dirac-Born-Infeld action have been analyzed.

The "mirage mediation" of supersymmetry breaking was shown to have attractive phenomenological features, among which smaller fine tunning for obtaining the observed electroweak symmetry breaking scale. Mediation of supersymmetry breaking from the closed string (gravity) sector has been considered. Technical progress in the computation of the gaugino mass in open string theory was done by relating it to a class of topological amplitudes. It is found that a sizeable hierarchy between gauginos and sfermions can naturally arise. Also instrumental to this development is the possibility that the gravitino acquires mass by marrying in a R-symmetric way its Kaluza-Klein tower. The Majorana gaugino mass vanishes exactly in this limit, although supersymmetry is completely broken, leading to novel strategies for realistic model-building. Progress was made towards the realization of gauge mediated supersymmetry breaking in string theory. This was based on local Calabi-Yau geometries with two isolated singularities at which systems of D3- and D7-branes are located, corresponding respectively to the visible and hidden sectors, with supersymmetry broken at a meta-stable minimum. The scenario with split extended supersymmetry was further understood. In these models supersymmetry is broken by small deformations of intersection angles of D-branes, leading to tree-level scalar masses m_0. By an explicit one-loop string computation, gauginos were shown to acquire hierarchically smaller Dirac masses of order m_0^2 in string units, while the one-loop Higgsino mass of order m_0^4. The structure of SUSY breaking soft terms in Type IIB orientifold and F-theory models and its possible test at LHC has been adressed. A phenomenological study of an MSSM-type model obtained from G2 compactification of M-theory was performed; soft terms were computed and cosmological and astrophysical implications were investigated. In heterotic string compactifications, gaugino condensation was shown that can lead to doubly suppresed gravitino mass in the TeV range, even from condensates at GUT scale.

e) Extra dimensions, KK phenomenology and gravity modifications
(Palaiseau, Saclay, Bonn, Greece, INFN, Trieste, Madrid, Oxford, Warsaw, CERN, US team)

Several aspects of higher-dimensional theories have been investigated, especially concerning Kaluza-Klein (KK) phenomenology, modifications of Newton's law, and neutrinos. Results on axionic cosmic strings in superstring models were obtained. The proton lifetime was estimated in a class of grand unified theories formulated in five space-time dimensions, with natural doublet-triplet splitting. The possibility of new-physics effects in high energy neutrino interactions was studied, in the context of large extra dimensions and of a fundamental scale of gravity at the TeV. Dirac and Majorana neutrino masses from models with one extra dimension on an interval at 1 TeV have been explored. Improved bounds on universal extra dimensions and constraints on KK-neutrino dark matter have been obtained. Realistic dark matter candidates were obtained in models with warped extra dimensions with a discrete symmetry, such as Kaluza-Klein parity. Collider signals and dark matter properties were investigated. A detailed analysis of the flavor problem and of proton decay was performed in grand unified theories formulated in extra dimensions. Discrete flavor symmetries were analyzed, arising from compactification of two extra dimensions on the orbifold T^2/Z_2. In particular, it was shown that the A4 discrete symmetry that naturally leads to tri-bi-maximal neutrino mixing can be simply obtained as a remnant of space-time symmetry, starting from a model in six dimensions. On the other hand, a mechanism to protect flavour in warped 5D models was proposed using horizontal $U(1)$ symmetries; experimental constraints imply a Kaluza-Klein mass scale of at least 3 TeV.

6D brane world scenarios were explored and fermion masses and mass gap was obtained. The renormalization of the gauge couplings in supersymmetric five and six dimensional non-abelian gauge theories coupled to hypermultiplets compactified on orbifolds to four dimensions has been computed. Composite Higgs models with extra dimensions have been proposed. Properties of pseudo-Goldstone Higgs in 5D warped models were investigated; in particular, flavor violating processes and Higgs production via gluon fusion. Gauge-Higgs unification models were studied: a radiative generation of the Higgs potential was achieved and the understanding of chiral symmetry breaking from five-dimensional spaces has been analyzed. A model with 4D brane-localized Higgs potential in six dimensions has been studied. Stability of the inter-brane distance in 5D models was analytically and numerically studied. Necessary and sufficient conditions for stability were given in several cases for static and inflationary backgrounds. New results were obtained for "higgssless" models of EWSB. A scenario with two TeV branes that aims at disentangling the EWSB to the top mass scale was proposed, avoiding conflict with electroweak precision measurements. Phenomenological implications of general warped 5-dimensional (5D) models were analyzed. It was shown that typically the so-called T-parameter is large unless the model has $SU(2)_R$ bulk symmetry or the KK scale is very large. In the higgsless version of the model, the S-parameter tends also to be large. Systematic methods have been developed to study 4D strongly coupled theories with pseudo-Goldstone bosons that have a dual description in terms of 5D gauge theories in arbitrary warped backgrounds. In this way, an access to strongly coupled dynamics that departs from conformal symmetry has been obtained. Moreover, the existence of a confining strong first order electroweak phase transition has been found in certain Randall-Sundrum-like models.

The energy emission rate for gravitons in the bulk from evaporating higher-dimensional non-rotating black holes was computed, showing a vector radiation dominance. Properties of rotating black holes in TeV scale gravity were analyzed and the complete radiation spectra and time evolution were calculated. The deconstruction of 5D gauge theories in the RS background was analyzed. Tools have been developed to deconstruct 5D gauge theories in curved AdS background and a connection has been established with the Migdal approach and Pade approximation to compute correlation functions in large N gauge theories. Theory of q-Bessel functions was used to prove explicitly that 5D theory can be approximated by deconstruction in all its perturbative range. In compactifications with two or more throats, it was shown that is possible to simultaneously solve the Standard Model hierarchy problem by the Randall-Sundrum mechanism while elegantly generating a suitable, phenomenologically allowed Peccei-Quinn scale for the axion. Scherk-Schwarz symmetry breaking induced by non-abelian fluxes in extra dimensional models has been studied. The size of supersymmetry-breaking effects has been addressed when the observable sector resides deep within a strongly warped region, with supersymmetry breaking not necessarily localized in that region. The dependence on the warping of the supersymmetry-breaking scale and the implications for the KKLT scenario of moduli stabilization with broken SUSY were determined. Consistent coset space dimensional reductions of higher-dimensional Yang-Mills theories were examined and the resulting four-dimensional Lagrangians were obtained. The gravitational wave signal generated by the cosmological phase transition into a warped space-time geometry was found to be detectable at the planned space interferometer, LISA. Multi-graviton theories have also been considered.

New effects of the holographic AdS/QCD models were studied. Extra dimensions also provide some crucial intuition in the exploration of infrared modifications of gravity. The behavior of gravity on braneworld models in higher co-dimensions, with extra dimensions stabilized by fluxes has been analyzed. Holographic duals of generalized Randall-Sundrum cosmology have been studied and grand-unified models were constructed. Higher dimensional supergravity with branes was studied, and effective 4D theories were obtained and analyzed. The study of extra dimensions and of modifications of gravity also propelled the realization that the absence of superluminal modes on arbitrary backgrounds provides a subtle but powerful constraint on effective field theories. A higher codimension generalization of the DGP model has been constructed which, unlike previous attempts, is free of ghost instabilities, providing a consistent model of gravity modification at large distances. In theories with a large number N of particle species, an upper bound on their mass $M_{Planck}/\sqrt{N}$ has been derived from black hole physics. This bound suggests a novel solution to the hierarchy problem in which there are $N \approx 10^{32}$ gravitationally coupled species, such as copies of the Standard Model. The black hole bound forces them to be at the weak scale, hence providing a stable hierarchy. Moreover, black holes would predominantly decay into Standard Model particles, and negligibly into the other species. The possibility that the unprecedented precision of atom interferometry can lead to laboratory tests of general relativity to levels that may rival or exceed those reached by astrophysical observations was explored. An experiment was proposed that within one year can test the equivalence principle several orders of magnitude better than the current limit and also probe general relativistic effects, such as the non-linear three-graviton coupling.

f) Dualities and non-perturbative effects
(Palaiseau, Saclay, Bonn, Greece, INFN, Trieste, Madrid, Oxford, Warsaw, CERN)

In the context of AdS/CFT correspondence, the spectrum of gauge invariant operators was derived for maximally supersymmetric Yang-Mills theories and was shown that after subtracting the tower of protected BPS multiplets, the states fall into long multiplets that are organized under a hidden $SO(10, 2)$ symmetry. Moreover, the results are in perfect agreement with those following from Kaluza-Klein reduction of type II strings on the warped AdS$\times S$ near-horizon geometry of Dp-branes and show impressive evidence for the conjectured holographic duality. Aspects of gravity and black holes have been studied within the AdS/CFT correspondence. A theoretical approach for counting microstates of 4D BPS black holes has also been proposed. Higher-dimensional rotating black holes were analyzed in braneworlds. Their evaporation into scalars on the brane was studied, as well as the emission of fermions and gauge bosons on the brane and scalars into the bulk. Analytic solutions were found and the absorption probabilities and Hawking radiation emission rates have been computed in both the high- and low-energy regimes. Progress was made in studying duality cascades and their infrared behavior for systems of D3-branes at singularities in the presence of fractional branes. New examples were found, where the infrared theory has a quantum deformed moduli space, given by a complex deformation of the initial geometry to a simpler one. An alternative quantum approach to gravitational collapse was also attempted by studying transplankian collisions in string theory.

The AdS/CFT correspondence has been considered for non critical string backgrounds holographically related to $N = 1$ supersymmetric and non-SUSY gauge field theories. The one-loop corrections to the structure constants for gauge invariant operators were computed. $N = 1$ Seiberg dualities were proven by studying the dual string theory in the NS5 brane backgrounds using non-critical strings. Dual descriptions of dynamical symmetry breaking in 4D have been considered in higher dimensions. Remarkable results have been obtained with a proposal of a 'holographic extension' of QCD to five dimensions which seems to capture information on the hadronic spectra. The field theory β-function, asymptotic freedom, and confinement were realized. The glueball masses spectra are discrete, gapped, asymptotically linear, consistent with lattice data. A way to obtain pion masses in holographic QCD was proposed by certain deformations which break chiral symmetry. In the same approach, a dual to technicolor models was proposed. The predictions of holographic QCD for the $\Delta I = 1/2$ rule for kaon decays and the B_K parameter were determined giving results which agree with experimental data to an accuracy of about 25%. A possible holographic connection between the Regge limit in QCD and critical gravitational collapse of a perfect fluid in higher dimensions has been derived. It relates strong gravitational physics in the bulk with (non-SUSY) QCD at weak coupling in 4D.

$N = 1$ superpotentials have been studied in the context of supergrtavity, when fluxes and gaugino condensate are taken into account, or large D-terms. Generalized Calabi-Yau manifolds were used to describe supersymmetric backgrounds involving branes and fluxes. The issue of "mirror duality" in compactifications with background fluxes has been investigated. Geometrical mirrors corresponding to compactifications on manifolds with $SU(3)$ structure have been identified and their low energy effective action has been computed. A new and efficient method to systematically analyse 4D effective supergravities which descend from flux compactifications has been proposed. The framework for heterotic – type IIA duality has been extended to include various fluxes which can be turned on. It has been argued that in order to reproduce certain fluxes on the heterotic side, one needs to consider M-theory compactifications on special seven-dimensional manifolds with $SU(3)$ structure, where non-Abelian gauge symmetries appear. The study of D-branes in group manifolds and NS5 branes has been carried on. In view of recent works on effective membrane theories, a series of works were done on a maximally supersymmetric 3D theory which is superconformal invariant at least up to one loop level. Furthermore, three-dimensional Chern-Simons gauge theories with $N = 2$ supersymmetry and matter in the fundamental and adjoint representations have been implemented with branes. This context allowed to conjecture a Seiberg-like duality that relates Chern-Simons theories with non-trivial superpotentials and indicates an exact conformal window for a class of non-supersymmetric $U(N_c)$ gauge theories.

Multiple anomalous $U(1)$ symmetries in heterotic compactifications on smooth manifolds were studied, together with their singular orbifold limit. In the context of dual pairs of heterotic and type I freely-acting $Z_2 \times Z_2$ orbifolds models in four dimensions, non-perturbative contributions to the gauge coupling threshold corrections have been calculated on the type I side by exploiting perturbative calculations on the heterotic side. The instanton effects can then be combined with closed-string fluxes to stabilize most of the moduli. New interaction terms in closed string field theory were proposed with possible relevance on primordial universe behavior. New techniques were found to study the ultraviolet properties of $N = 8$ supergravity, which was conjectured to be a finite theory. Type II and type I models at finite temperature were constructed, whose Hagedorn phase transition can be explicitly studied at the perturbative level; these models share temperature duality. Non-perturbative processes in quantum physics using semiclassical methods have been investigated and tunneling phenomena have been described by unstable complex trajectories. A systematic procedure to stabilize these trajectories and to calculate the tunneling probability has been established.

Using the pure spinor formalism, a prescription for multiloop amplitudes was given for the first quantized superparticle, allowing for a possible definition of the topological M-theory. Topological couplings for vector- and hyper-multiplets of closed string compactifications to 4d on Calabi-Yau manifolds have been computed using the hybrid string formalism. A new class of $N = 4$ topological amplitudes was found and studied. An old issue in String Theory is to understand more deeply the role of massive excitations, in particular in the high-energy limit, and a natural key is a deeper understanding of higher-spin gauge fields. Work has focussed on several aspects of the free theory for higher spins: Higgs-like mechanism and off-shell description of geometrical unconstrained equations, and role of the unconstrained symmetry in the Vasiliev equations. Closed bosonic string field theory continued to be investigated. In particular the non-perturbative tachyon vacuum at high level has been studied and the 5-tachyon contact terms have been obtained at the quintic order of the theory. A breakthrough was made towards the understanding of tachyon condensation, by considering open string field theory in a new basis, where the star product simplifies considerably. An exact analytic solution representing the non-perturbative tachyon vacuum was thus found. The computation of the energy difference between the perturbative and non-perturbative vacua, analytically proves Sen's conjecture.