The Project

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The context

This year will see the launch of the much awaited Large Hadron Collider, LHC. The main raison d'être of this major international project has been the elucidation of the mechanism of symmetry breaking and the concomitant problem of the mass of all elementary particles through the search of the elusive Higgs particle. The Higgs is the missing link in the much successful Standard Model, SM, description of high energy physics. In fact, when it comes to the sector of symmetry breaking, there are numerous theoretical arguments that hint to New Physics so that we expect a wealth of new data at the LHC. Apart from various theoretical arguments, most recent observations like the celebrated WMAP (Wilkinson Microwave Anisotropy Probe) have confirmed that ordinary matter accounts for a minute portion of what constitutes the Universe at large. There is an overwhelming dominance of Dark Energy and Dark Matter, DM. This, in itself, is New Physics. Add to this that the majority of models for the New Physics whose primary aim is a better description of the Higgs sector of the SM provide as a bonus a candidate for DM, it is fair to say that we are witnessing the emergence of a strong cross breeding between high energy collider physics on the one hand and cosmology and astrophysics on the other to unravel the mystery of DM. It is also important to stress that at about the same time as the LHC will be gathering data, other significant experiments (PLANCK, GLAST, AMS, HESS, CDMS, Edelweiss,...) will have provided or will be providing unprecedented information on DM and hence on the New Physics. It is therefore of utmost importance to get ready for the analyses and combination of the wealth of data from these upcoming non-collider observations with those at the LHC. This will also pave the way to search strategies for a future international e+e- Linear Collider, ILC. This important programme is only possible if a cross-border particle-astroparticle collaboration is set up, having at its disposal common or complementary tools to conduct global combined analyses. Moreover it is crucial to associate theorists and experimentalists from these two communities for such a project.

{mospagebreak title=Objectives} Objectives

Our proposal is to develop, interface and exploit such tools for the prediction, simulation and analysis of Dark Matter signals from a combination of terrestrial and non terrestrial observations, paying particular attention to the uncertainties that usually afflict astrophysical calculations and SM backgrounds that pollute New Physics signals. Our objectives include:

1)
Complete and precise computation of the relic density of dark matter in different models of new physics (Supersymmetry, extra-dimensions, little Higgs). The goal is to match the accuracy of PLANCK (<3%). This requires computation of one-loop corrections to some of the dominant processes for DM annihilation.
A task that has never been addressed so far.

2)
Development and improvements of tools for the predictions of signals from indirect detection of DM annihilation into photons, antiprotons, positrons, neutrinos and anti-deuterons in different models. Potential of astroparticle experiments (AMS, HESS, GLAST...) to probe various scenarios of New Physics and differentiate between them taking into account different astrophysical hypotheses such as the distribution of DM.

3)
Development of tools for analysis of signal and background to new particles production at colliders (LHC, ILC). Interpretation of signals and extraction of fundamental parameters of the New Physics model.

4)
Strategies to correlate between DM signals in astroparticle, cosmology and colliders. Constraints on models and exploiting the information from colliders to refine predictions on dark matter in astroparticle and cosmology and/or vice-versa.

The core of the project is as precise a determination as possible of the microscopic properties of New Physics, in particular that which constitutes or is related to Dark Matter. We therefore plan to further develop, improve and generalise micrOMEGAs, the first complete and accurate public code for the calculation of the relic density in the Minimal Supersymetric Standard Model, MSSM. This code has been completed thanks to the use of sophisticated computer-aided techniques for automatic calculations of a large number of cross sections. A major objective of this project is to extend micrOMEGAs to other models of New Physics, in particular models with extra dimensions and Little Higgs models. Moreover, the code shall provide cross sections for the LHC and ILC, as well as the cross sections relevant for indirect detection of DM. For the latter, we need to implement hadronisation and decay of the products of DM annihilation, final state radiation as well as the propagation of anti-protons and positrons. To this aim the astroparticle theorists of the collaboration are working on a global simulation tool (CRAC) for γ rays, pbar, e+ and neutrinos, with a plan of incorporating anti-deuterons. An important aspect in this regard is the possibility to choose between different DM distributions and in particular critically gauge the issue of clumps.

Second, we aim at a more precise determination of the microscopic DM properties in the context of supersymmetry. We will pursue the development of SloopS, an automatic code for the calculation at one-loop of any process in the MSSM. This general one-loop treatment is very challenging, requiring a coherent renormalisation programme. An independent code dealing with QCD corrections to neutralino annihilation is also being developed and will aid for cross checks. This will eventually enable a precision calculation of the relic density of a SUSY DM candidate on a par with the accuracy expected from PLANCK. It will also permit to confront some of the supersymmetric precision cross sections at colliders.

The third important part of the project revolves around the determination of properties of new particles at colliders within the context of SUSY as well as other models of New Physics. We plan to exploit the tools we have been developping to work out the collider phenomenology of DM candidates originating from New Physics. We also plan to extend and improve the code SFitter in order to perform global analyses for the LHC and ILC by making fits to various (discriminating) observables, including also information and constraints from cosmological experiments. This will require the joint effort of a team of theorists and experimentalists.

We feel that the importance and impact of such global codes for unified analyses has yet to be appreciated. For example, if future colliders discover SUSY particles and probe their properties, one could predict the dark matter density and would constrain cosmology with the help of precision data provided by WMAP and PLANCK. It would be highly exciting if the precision reconstruction of the relic density from observables at the colliders does not match PLANCK's determination: this would mean that the post-inflation era is most probably not radiation dominated. The same collider data on the microscopic properties of DM when put against a combination of data from direct/indirect detection can also give strong constraints on the astrophysical properties of DM such as its distribution and clustering that reveal much about galaxy formation.

The project will be carried by a collaboration between members of LAPP, LAPTH (Annecy), LPSC (Grenoble) and IAP (Paris). The teams have a proven track record in the different aspects of the project. Indeed, the members from the LAPP experimental teams are heavily implicated in collider physics (LHC-ILC) and astroparticle physics (AMS-HESS) and have been a driving force in data analysis and simulations (LEP, Babar). The astrophysicists of LAPTH and IAP draw from a recognised astrophysics team heavily involved in indirect signals of Dark Matter with sophisticated codes for the propagation of cosmic ray anti-protons and positrons. They are also known for some seminal contributions, most recently to the subject of DM overdensities (clumps, intermediate mass black holes). A member of the LPSC team working on direct detection (MIMAC) completes our astrophysics task force. The particle physicists of LAPTH an LPSC have conducted some of the most complex calculations in the standard model and supersymmetry. They are also heavily involved in DM studies (through the code micrOMEGAs code, for example) and where among the first to work on the DM-Collider connection. Most of these feats would not have been possible were it not for the exploitation of automated codes for the SM and the New Physics. Automation will hence be at the heart of our project. Combined with the expertise and the complementarity of the teams we believe that such an ambitious and original project will be brought to fruition if these teams are strengthened.

{mospagebreak title=Original aspects} Original Aspects

The LHC (Large Hadron Collider) at CERN (Geneva) is a major international project that

will become reality in a few months with the very first collisions and data taking. The raison d'être of such a machine is to understand the mechanism of symmetry breaking, to unravel the nature of the vacuum and to probe into the mystery of dark matter, DM, by revealing its microscopic properties.
Although the LHC research program has traditionally centred around the discovery of the Higgs, it has since been clear that the standard description of this particle calls for models of New Physics. Until a few years ago the epitome of this New Physics has been supersymmetry which when endowed with a discrete symmetry furnishes a good dark matter candidate. Recently a few alternative scenarios have been put forward, originally also to solve the Higgs problem but it has been discovered that, generically, their most successful and viable implementation (in accord with electroweak precision data, proton decay) fares far better if a discrete symmetry is embedded. This symmetry is also behind the existence of a possible dark matter candidate. From another viewpoint, the last few years have witnessed spectacular advances in cosmology and astrophysics confirming that ordinary matter is a minute part of what constitutes the Universe at large. At the same time that the LHC will be gathering data, a host of non-collider experiments will be carried out in search of DM (AMS, GLAST,HESS, PAMELA, SuperCDMS, Edelweiss,..) or for the determination of the cosmological parameters, with unprecedented level of accuracy, making cosmology enter the era of precision, almost akin of the LEP legacy.

It is high time that our community, at large, grasped and exploited the new opportunities offered by this new paradigm[1]. This will only be possible if a strong cross-border collaboration between astrophysicists and collider physicists, both theorists and experimentalists, comes together and has at its disposal common and complementary precision tools for the analysis of the forthcoming data. The stakes are high. For example, if future colliders discover supersymmetric particles and probe their properties, one could predict the dark matter density of the Universe and would constrain cosmology with the help of precision data provided by WMAP and PLANCK[1]. It would be highly exciting if the precision reconstruction of the relic density from observables at the colliders does not match PLANCK's determination, this would mean that the post-inflation era is most probably not entirely radiation dominated[2]. One can also think of many situations where the same collider data on the microscopic properties of DM when put against a combination of data from direct and indirect detection can give strong constraints on the astrophysical properties of DM such as its space and velocity distribution as well as clustering (clumps,..), that may reveal much about galaxy formation[3]. One can also take another perspective. Imagine a situation like what might occur at the LHC with some new particles having been discovered but one is unable to determine the mass of the neutral stable dark matter candidate. An extraction of this mass from a direct detection experiment (from the nuclear recoil energy), backed up perhaps by a fit to the indirect detection experiments, even after allowing for astrophysical uncertainties, can greatly help in further constraining the particle physics model or discriminating between different models. This will directly impact on the phenomenology at the LHC while strengthening and reshaping the strategy for the future e+e- International Linear Collider, ILC. The core of our project is at the heart of these important issues. These are the kind of global analyses that our team wants to perform within this project once, and while, the needed cross-border tools have been, or are, being developed.

{mospagebreak title=Multidisciplinary aspects} complementarity, know-how and value-added of the teams

Our proposal is to develop, improve, generalise, interface and exploit such common and complementary tools for the prediction and analysis of Dark Matter signals from a combination of terrestrial and non terrestrial observations, paying particular attention to the uncertainties that usually afflict astrophysical calculations and SM backgrounds that pollute New Physics signals. This requires a know-how in building of codes and complex calculations for cross sections of relevance at the colliders, both for the SM and the New Physics as well as for Dark Matter annihilation. For the latter, the ability to convolute with the astrophysical and/or cosmological properties, weighing at every stage the different hypotheses and uncertainties that entail this part of the calculation, is crucial. Last but not least, exploitation of these codes is best evaluated and physics studies best conducted in conjunction with experimentalists versed in simulations and who have developed and interfaced tailor-made tools for data analyses.

The proposal is carried by an ongoing collaboration between teams from LAPP, LAPTH, LPSC and IAP that have a proven track record in the different aspects of the project. This is a rare mix. Indeed, the present members from the two experimental teams at LAPP involved in the project are heavily implicated, on the one hand in collider physics (LHC and ILC) and the other in astrophysics (AMS and HESS). They all have been a driving force in data analysis and simulations (electroweak fits[4], supersymmetry searches at LEP[5], standard model and SUSY event generators for e+e-[6], authors of codes such as SFitter [7] for SUSY fits at the LHC and ILC, codes to study aspects of Universal Extra Dimensions, UED, at the LHC[8]...).

Part of the theory members of LAPTH teaming with a young recruit from IAP draw from a recognised astrophysics team heavily involved in indirect signals of Dark Matter with sophisticated codes for the propagation of cosmic ray anti-protons[9] and positrons and studies of gamma rays[10,11]. The impact of clumps and boost factors[12] such as might occur for example with the formation of intermediate mass black holes[13] are also hot topics. There is also interests in unconventional cosmological scenarios of the early universe[2]. The particle physicists of LAPTH are among the few theorists that have conducted some of the most complex calculations in the Standard Model (multi-leg processes at one-loop)[14,15], in supersymmetry[16,17] and the Higgs (two-loop)[18]. They have furnished the popular public code micrOMEGAs[19] for the calculation of the relic density in various models of supersymmetry[19]. Many of these calculation feats would not have been possible were it not for the exploitation of automated codes for the SM[15] and the New Physics[19,20].

Automation will be an important component of this project. It will help build up a modular structure of codes that easily incorporate New Physics models ``turning their Lagrangian'' into simulation codes. Combined with the expertise and the complementarity of the teams we believe that such an ambitious and original project will be brought to fruition if these teams are strengthened. The possibility for our teams to invite other world experts, beside incorporating young post-docs, and to organise small interactive Workshops is a key element of the project and a source of momentum for the collaboration.

Since the emphasis of the project will be on the development and the exploitation of codes and tools, to stress the feasibility of the project it is important to point out that many first-class codes, most of which are now public and widely used, have been developed by the members of the project

- CRAC: (Cosmic Ray Alpine Code), code for the galactic propagation of antiprotons[9].

- Grace-Loop: Automatic calculation of multi-leg processes in the electroweak theory[14].

- MicrOMEGAs: Code for the dark matter relic density, originally in the context of supersymmetry, that has recently been extended to incorporate a generic model. It is also being developed for applications to direct and indirect detection[13].

- Pythia_UED: a Pythia-based generator tool for Universal Extra-Dimension at the LHC[8].

- SDECAY, SUSY_HIT: Code that computes the decay of supersymmetric particles[16].

- SFitter: Code for the reconstruction of the fundamental parameters of supersymmetry from simulations or experimental measurements. Under development to include fits to other model of electroweak symmetry breaking [7].

- SloopS: General code, under development, for one-loop calculations in susy with application to collider data, precise relic density predictions and indirect detection [20,21].

- SusyBSG: a powerful code for bÒs γ in supersymmetry[22].

- SUSY_SCT: a SUSY spectrum comparison tool[23].

{mospagebreak title=An inter-woven structure} An inter-woven structure

An example of the intended general structure, based on a modular construction around some of the tools being developed by the collaboration, is depicted in the Figure below. Such a structure naturally allows analyses at the colliders and in indirect detection. Such a structure reinforces the complementarity of the teams involved in the project.

As emphasized above, one of the forte of the project revolves around the exploitation of the automatic calculation of cross sections both at tree-level and, for SUSY, at one-loop. We can therefore quite easily implement any new model of New Physics at the Lagrangian level and pass it to micrOMEGAs that originally was set up to generate cross sections for the relic density calculations. micrOMEGAs can now also provides cross sections for colliders and for indirect detection. This part of the project is carried by the particle theorists team. These cross sections can then be used for predictions for indirect detection. This step, however, requires a substantial input from the theoretical astrophysicists as well as their experimental counterpart in the team. Indeed the ongoing collaboration[12,23] intends to implement sophisticated codes for the propagation of charged particles, modelling of the halo profiles as well as detailed description of dense substructure (clumps). An interface with PYTHIA and later HERWIG for fragmentation and decay is the job of the experimental astrophysics team, whose other input is the modelling of the background and full simulation including detector resolutions.

At the same time, cross sections for the same New Physics model provided by micrOMEGAs will be exploited by the collider physics team. An important tool here will be a generalisation of SFitter to models of New Physics other than supersymmetry. From a simulation of well chosen observables, SFitter will return ``measurements'' on the fundamental and underlying parameters  of the New Physics.  In the context of Dark Matter this can serve for a ``collider determination of the relic density'' to be compared with the more direct value extracted from a combination of cosmological and astrophysical measurements. This is another reason we would also like to generalise micrOMEGAs to take into account scenarios for the early universe that deviate from the pure assumption of thermal relics and radiation domination (kination[2], etc..). A collaboration between the two theory teams is foreseen. Of course, at this point, comparison of data or simulations from the colliders and from the astrophysics experiments is also to be carried within our collaboration, with due care to the astrophysical uncertainties for example.

We want, within this project, to improve even further on this scheme, especially as concerns supersymmetry. This is another important facet of our project. micrOMEGAs, though very complete, is to a large extent based on tree-level calculations. It is crucial, especially in order to match the accuracy of PLANCK and the ILC, to give predictions at the loop level. We are developing the automatic code SloopS for this purpose. This code will then be exploited by micrOMEGAs and SFitter, as well as SDECAY. The most characteristic signal of DM annihilation into monochromatic gamma rays is also loop induced and therefore can be tackled by SloopS. We therefore view the development of SloopS as essential.

The problem of
flavour is also on our agenda, in particular some effort is being devoted to a new powerful routine for bÒs γ[22].
This observable is very sensitive to New Physics.

Having
all these tools and codes at our disposal we will be able to conduct trustworthy global analyses of the kind described in. One more important addition, with the automatic codes we are developing and the modular structure we are setting up, it will be easy for us to implement novel models swiftly. Should for example the LHC hint at new signals that would be hard to interpret within today's popular scenarios, our task force can react rapidly by implementing new effective theories and confirming the consistency of the proposal both at the LHC, indirect precision measurements (g-2, bÒs γ..) and in astrophysics experiments.

Let us
now turn to some of the details and in part technicalities of the project.

{mospagebreak title=Precision calculation} Precision calculation for DM and Collider studies in supersymmetry

In the previous
paragraph we already stressed the need to have a general automated code that can generate, at the loop level, any cross section in supersymmetry. This is crucial for as precise predictions as possible, in par with the foreseen accuracy on the cosmological parameters as well as observables at the colliders. Moreover, considering the issues of renormalisation schemes and parameter definitions, it is logical that the calculation of the relic density, which in our case will be incorporated into micrOMEGAs, be conducted in the same set-up and scheme as the cross sections calculations (in our case, fed to SFitter) and decays (in our case SDECAY). Considering that we know of no complete code even for cross sections at the colliders and that loop issues for the relic density pose more problem than for high energy calculations, this part of the project is highly ambitious but since it has ramifications on many parts of our modular structure it is worth the challenge. Moreover we have already tackled some important issues[20,21], like the loop induced monochromatic gamma ray signal through annihilation of neutralinos. Very recently an important foray in implementing a complete on-shell gauge invariant renormalisation has been made. Though there may remain challenges ahead we are certain that the SloopS project is realistic.

The development of this code within supersymmetry is very challenging and necessitates a major effort both at the technical level as well as at the theoretical level. In this proposal, a total of 4 months visitor (A. Semenov) is requested for the development of the code. Also there is a need for a postdoc (24 months) to work mainly on the exploitation of this code for DM and collider studies. Work on SloopS and its exploitation will cover at least the full duration of the grant. A detailed planning about this task is given in B-2-11.

{mospagebreak title=From cosmology to colliders} From cosmology to colliders and future developments of micrOMEGAs

A relic density calculation involves the contribution from a daunting number of processes and involves a large number of parameters. Automation is therefore needed. Within micrOMEGAs all cross sections calculations are performed automatically, once a model has been properly specified, through LanHEP . The modular approach we have taken is well adapted for extending to different models of New Physics.
The DM candidate is readily identified by the code once a new parity, in lieu of R-parity for supersymmetry, is defined. The code will then generate the Feynman rules, the cross sections and perform the thermal averaging for the relic density prediction. We have in fact just completed a new version of micrOMEGAs within this spirit ready to incorporate any generic model for DM.   One of the objectives of the project is to now include and study specific models that provide an alternative to supersymmetry for solving the hierarchy problem, such as models with extra dimensions or little Higgs models. Along side the working codes applicable to SUSY (MSSM, NMSSM, CP violation), these new physics codes will be interfaced to a generalisation of a tool such as SFitter for the extraction of parameters of the underlying theory at the colliders.
Indeed, micrOMEGAs is being set-up so that it also generates, for a given scenario and a set of parameters, all cross sections in e+e- or at the LHC that are kinematically accessible, as well as a table of decays. It will therefore be ideally suited for analyses of parameter extraction at the collider and confrontation with more direct cosmological measurements. This is where an interface with SFitter, generalised to other models than supersymmetry (and mSUGRA), comes in.

For the incorporation and study of the extra-dimensions (Xdim) and little Higgs models, the invitation of expert model builders for a couple of months would be highly effective and beneficial. For example, in the Xdim scenarii it would be interesting to see how one can go beyond the (minimal) Universal Extra-Dimension (UED). This should open up a variety of issues linked to the cut-off scale, like contributions from brane terms that are expected from the underlying theory. It could be interesting how one could extract these new parameters from the data with a tool such as SFitter. In the little Higgs models, considerations on the nature of the lightest stable DM candidate (heavy U(1) or heavy neutrino) should be addressed and compared. We think we can already embark on this part of the project in the second year of the project.

Further improvements and precision in the interface between micrOMEGAs and SFitter will be made the context of supersymmetry by the incorporation, into SFitter, of more precise one-loop cross sections derived from SloopS and 1-loop QCD corrected decays from SDECAY.
This should be attempted in the third year of the project. One can then critically review the required accuracy expected at the colliders to match the cosmological measurement, an issue we raised recently[1]. At the same time the possibility to include within micrOMEGAs,

different scenarios of the post-inflation era is planned with the collaboration of the astrophysics team who suggested[2], as an example, an acceleration of the expansion of the universe by a period of primordial kination at the time of decoupling.

Another ongoing important development of micrOMEGAs, is carried out in close collaboration with both the theory and experimental astrophysics teams of the project. micrOMEGAs will also provide the ``partonic" non relativistic cross sections for the annihilation of the DM particles (as might occur in the halo of the galaxy) into all standard model channels. Members of the AMS-HESS team are interfacing hadronisation and decay as well as adapting the codes for the propagation of anti-protons and positrons provided by the astroparticle theorists of the project (see next section) in order to have a global simulation tool for γ rays, pbar, e+ and neutrinos[24] with a plan of incorporating anti-deuterons[25].The success of such an ambitious program requires an important technical support, for further development of the code. For this we request 4 months visit for A. Pukhov and a post-doc working on the analysis of HESS data.

Another independent development of micrOMEGAs is the adjunction of a module for direct DM detection. Although some tree-level treatment is straightforward to implement[26], there are some interesting scenarios where one-loop effects are important[27].

{mospagebreak title=The code CRAC} The modelling of charged cosmic rays and galactic propagation

As we have just mentioned in the last section, the weakly interacting massive particles that constitute DM which may be concealed in the Milky Way can reveal themselves through mutual annihilation giving rise to cosmic rays such as high-energy photons or antimatter nuclei. However, these induced radiations are hidden inside backgrounds that are produced in a more conventional way by the galactic primary cosmic rays impinging on the interstellar gas. Those backgrounds need to be theoretically determined with great accuracy in order to be able to extract from their precise measurement a DM signal which would appear as a small distortion. The astroparticle theory team has developed a cosmic ray propagation model and constrained the parameters describing it from the boron-to-carbon (B/C) ratio data[9]. This allows to quantitatively translate the spread due to variations of the propagation parameters that are consistent with data into an uncertainty band on the energy spectrum of secondary antiprotons -- those antiprotons that are produced in a conventional way by the spallation of primary nuclei on the gas of the Milky Way disc. The team has written a numerical code based on a semi-analytic approach which consists in expanding the cosmic ray densities on a basis of Bessel functions of zero-th order. As it stands now, this code incorporates the nuclei up to Fe as well as the antiprotons. In the near future, this code will also deal with the antideuterons[25]. A recent analysis of the LEP data suggests that the coalescence of two antinucleons may not be as frequent as previously estimated when a quark antiquark pair is produced -- which is the common situation when neutralinos, for example, annihilate. The team plans to investigate this issue and to re-analyse the process by which two antinucleons merge to yield an antideuteron.

Future developments of the CRAC code will incorporate the positrons whose propagation is described in a different way to accommodate the strong energy loss mechanisms that dominate in this case.

Another important aspect is the issue of clumpiness and the boost factors. Values for the smallest structures in galactic halos vary widely from 10-6 to 106 solar masses. Clumps (local non uniform distributions), understandably, enhance considerably the annihilation rate of DM. In most phenomenological studies, clumps are represented by a boost factor which is nothing else but an overall enhancement factor to be applied on the smooth dark matter distribution. This is most probably a naive way of implementing the presence of clumps. As a consequence the effective boost factor is different in the case of positron than in photons for example[12]. On the other hand, taking a conventional view of the boost factor as a multiplicative uniform factor there should be stronger correlations between different signals of DM indirect detection, even after taking into account the modelling of the propagation of the charged particles. The astrophysics theory team is building statistical tools that will be fruitfully applied to various cosmic ray antimatter species and to various dark matter distributions in order to compute the exact boost factors that come into play as a function of the energy.

Another approach is to further critically investigate the energy distributions, or spectral features, of the annihilation of DM in indirect detection that can constitute a smoking gun evidence that can not be faked by astrophysical processes. Examples are the gamma line signals or the sharp edges that can also help discriminate between models. The combination of different sources is also a handle.

As discussed previously it is planned to fully interface CRAC with micrOMEGAs. The input of the experimental astrophysicists will be instrumental for this stage as will be discussed next. At the same time it will be highly beneficial to exchange ideas and to actively collaborate with Lars Bergstrom, Alessandro Bottino, Bruno Guidernoni, Joseph Silk and Andrew Strong. With the latter for example, it is planned to incorporate an alternative propagation model so that we can fully and further control the astrophysical uncertainties when it will come to conduct analyses.

{mospagebreak title=Indirect detection} Interfacing CRAC and micrOMEGAs, experimental issues

The experimental astrophysics team is part of both the HESS and AMS collaborations. It is therefore best suited for search strategies based on a precise measurement of the energy spectra of various cosmic rays like gamma rays (HESS and AMSg) as well as charged particle such as positrons, anti-protons and anti-deuterons (AMS). As part of our project and with tight connections with the theorists on this project , the team is developing a cosmic ray spectrum generator [24] including: the annihilation cross section rates and products (based on MicrOMEGAs, Sloop and interface with Pythia), the dark matter profile models (in our Galaxy or spheroidal galaxies, clumpy structure), the propagation of charged particles (CRACand the detector performance and acceptance. Armed with these tools we can perform various analyses considering the wealth of data that is, and will soon be, available for indirect detection. Among some of the first investigations, the team will first focus on HESS data analyses and interpretations. This concerns the centre of the galaxy, where a rather hard spectrum has already been observed (in the 100 GeV to few TeV range). Those galaxies which present a cuspy luminous matter profile are a source of interest for the indirect search of dark matter. The generator will also be used to perform a grand scan "a la LEP" over different SUSY breaking scenarios and other theoretical model extensions (NMSSM, extra-dimensions,..). This scan will be used for the present data interpretation and to derive sensitivity domains with HESSII (access to lower energy range, above 50 GeV). Similarly, with this tool we will explore the complementarity between the ground telescopes and the space detector (GLAST, AMS).

A large part of the group has been involved in the construction of the electromagnetic calorimeter of the AMS-02 mission. This sub-detector is a key ingredient to separate the rare positrons from the proton background, as well as the anti-protons from the electron background and to identify gamma rays. Different MSSM configurations have been tested to estimate AMS sensitivity in the gamma and positron channels [24,28] and scenarios proposing clumpy structure in the galactic dark matter are being and will be further investigated. Further studies, will include the antiproton and anti-deuteron, in particular by handling the complete propagation issues. Then, in order to derive experimental sensitivities, we want to apply the same propagation models for both the background and signal. When all the ingredients will be included in the generator, we will combine the different channels (charged particles and gamma) and explore the complementarity for SUSY scenarios, but also other theoretical model extensions. A critical and detailed global re-analysis of the supposed EGRET excess involving all members of the ToolsDmColl is also on the agenda.

{mospagebreak title=The LHC fits} A generalised SFitter, phenomenology at the LHC and ILC

As we have argued repeatedly in this proposal, the microscopic properties of DM will most unambiguously be probed through precision analyses at the colliders, hence the need for accurate simulation tools and ``fitters'' for the extraction of the underlying parameters. If these are measured precisely, important constraints on both the cosmology and the astrophysics of DM will be made. To this end one needs to measure not only the mass but a set of couplings from a large set of well chosen observables. It may well be, that unless one makes strong guesses on the model, the LHC will only be able to furnish a few, though important, hints or measurements leaving a more refined analysis for the ILC, provided the latter has enough energy. We are lucky to have in our project a team of experimental particle physicists, from the LHC and the ILC, which has the expertise in event generators and tools like SFitter that will be interfaced to the cross sections provided by micrOMEGAs so that we are in a position to conduct the kind of global analyses.

Apart from the development of SFitter and the UED event generator developed for ATLAS by the members of our project[8], some of the avenues pursued by the team, in conjunction with the project, is to investigate, within different models of New Physics, new sets of observables beside some golden channels (like the dileptons in the case of supersymmetry at the LHC) that are conducive to a useful extraction of parameters. For example, a preliminary investigation indicates that within some manifestation of supersymmetry, some cascade decays of the neutralino may yield the sign of the μ parameter. Precision investigation of the Higgs may also yield information on DM. An invisible Higgs may be an indication of decays into the DM candidate[29]. Much needs to be done to determine the best observables especially for non supersymmetric models, although some preliminary studies have been made for UED in the ATLAS environment in view of disentangling between models[8].

With the one-loop cross sections that SloopS will provide, there are some exciting precision analyses to be made in the context of the LHC and ILC for the microscopic properties of DM. Moreover the development of more sophisticated event generators, incorporating polarisation effects and beamsstrahlung, can be exploited to optimise the detector design for the best signal efficiency and the lowest background.

Detailed studies of the collider phenomenology of DM candidates from New Physics, model determination and parameter extraction, are very involved and require a full-time occupation. We hence request a post-doc for this topic. The post-doc (18 months) will be working at LPSC in Grenoble under the guidance of S. Kraml and M. Klasen. She or he will also, naturally, have strong links with the LAPP (SFitter group) and LAPTH theorists.