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January 18, 2013

Centro de Fisica Teorica de Particulas
Instituto Superior Tecnico
Lisboa, Portugal

Dear search committee,

I am writing to apply for a postdoctoral position in theoretical particle physics at the CFTP of IST, Lisbon. I am currently a postdoctoral fellow at DESY, Hamburg, and have a Ph.D. from the Oskar Klein Centre, Stockholm University.

My research interest is in dark matter phenomenology. In particular I study the prospects for discovery of various dark matter models at the CERN Large Hadron Collider (LHC), and how their LHC signatures would complement those from astrophysical experimental probes. I am also interested in cosmological inflation and dark energy, and have previously done phenomenological studies of modified gravity models of dark energy.

For more details please refer to my submitted statement of research interests. I have also submitted a copy of my curriculum vitae. Letters of recommendation will be sent to you by Wilfried Buchmüller, Joakim Edsjö and Malcolm Fairbairn. I appreciate your consideration and I look forward to hearing from you.

Sincerely,

Sara Rydbeck

Curriculum Vitae

Sara Rydbeck

Contact information

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DESY, Theory Group
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D-22607 Hamburg
GERMANY

E-mail: sara.rydbeck@desy.de

Research interests

Dark matter theory and phenomenology, LHC signatures, connection between and complementarity of collider and astrophysical experiments; Electroweak symmetry breaking; Baryogenesis; Dark energy; Inflation.

Positions held

2011 – present: Postdoctoral fellow,
DESY, Hamburg.

2006 – 2011: Graduate fellow,
The Oskar Klein Centre, Stockholm University.

Education

June 21, 2011: Degree of Doctor of Philosophy, Subject: Theoretical Physics,
The Oskar Klein Centre for Cosmoparticle physics, Stockholm University.
Supervisor: Joakim Edsjö. Assistant supervisor: Lars Bergström.

November 26, 2009: Degree of Licentiate of Philosophy, Subject: Theoretical Physics,
Stockholm University.

August 29, 2006: Degree of Bachelor of Science (Filosofie magisterexamen) with a Major in Physics, Stockholm University.

Publications

[5] S. Bobrovskyi, J. Hajer, SR, "Long-lived higgsinos as probes of gravitino dark matter at the LHC," [arXiv:1211.5584 [hep-ph]].

[4] M. Gustafsson, SR, L. Lopez-Honerez, E. Lundstrom, "Status of the inert doublet model and the role of multileptons at the LHC," Phys. Rev. D86 (2012) 075019 [arXiv:1206.6316 [hep-ph]].

[3] J. Edsjo, E. Lundstrom, SR and J. Sjolin, "Early search for supersymmetric dark matter models at the LHC without missing energy," JHEP **1003** (2010) 054 [arXiv:0910.1106 [hep-ph]].

[2] M. Fairbairn and SR, "Expansion history and f(R) modified gravity," JCAP **0712** (2007) 005 [arXiv:astro-ph/0701900].

[1] SR, M. Fairbairn and A. Goobar, "Testing the DGP model with ESSENCE," JCAP **0705** (2007) 003 [arXiv:astro-ph/0701495].

Presentations

- Theory seminar, Bethe Center for Theoretical Physics, Bonn, November 12, 2012,: "Long-lived higgsinos as probes of gravitino dark matter at the LHC".
- GRAPPA seminar, November 5, 2012, Amsterdam: "Long-lived higgsinos as probes of gravitino dark matter at the LHC".
- Contributed talk, IDM 2012, Chicago: "The inert doublet model in light of LHC and XENON".
- DESY theory seminar, November 21, 2011: "The inert doublet model and multilepton signatures at the LHC".
- Poster at the COSMO conference, Tokyo, 2010: "Search for supersymmetric dark matter in first LHC run".
- Invited speaker at the DJ conferences in Gothenburg, March 16, 2010, and in Stockholm, October 20, 2010.
- Contributed talk, ENTApP meeting, Spain, 2007: "Can cosmology rule out non-Einstein gravity?".
- Contributed talk, Cargese summer school, 2007: "Expansion history and *f(R)* modified gravity".

Academic experience

	Referee for JCAP.
2008:	Science secretary at the IDM conference, Stockholm.
2008 – 2011:	Development of the undergraduate course *Physics and Gender*, equal opportunities work and teaching assistant on the course *Analytical Mechanics*, Department of Physics, Stockholm University.
2007 – 2009:	Teaching assistant on the undergraduate courses *Analytical Mechanics, Quantum Physics, Mechanics* and *Fundaments of Quantum Physics*, Department of Physics, Stockholm University.

Outreach

November 18, 2009:	Physics representative in the researcher panel at "Den Levande Frågelådan" for fifth graders in Aula Magna, Stockholm university.
April 1, 2009:	Popular talk about symmetries and symmetry breaking for the Täby-Jarlabanke Rotary club.
May 2008:	Interviewee for "Vetenskapens värld", a science show about gravitation broadcasted on Swedish national television on September 1, 2008.

Grants

2010: K. & A. Wallenberg Foundation Grant, 10 000 SEK.

2010: Rhodin Foundation Grant, 10 000 SEK.

2009: Co-applicant, together with B. Åsman, for grant received from the Swedish government's Delegation for Equal opportunities in higher education (DJ), 490 000 SEK.

2006: HEAC (High Energy Astrophysics and Cosmology Centre) Doctoral Fellowship, AlbaNova University Centre, 5 recipients from a field of >120.

Conferences and workshops

September 25 – 28, 2011	DESY Theory workshop "Lessons from the first phase of the LHC", Hamburg.
July 23 – 27, 2012	"Identification of dark matter (IDM 2012)", Chicago.
June 18 – 21, 2012	"TOOLS 2012", Stockholm.
September 27 – 30, 2011	DESY Theory workshop "Cosmology meets Particle Physics – Ideas & Measurements", Hamburg.
August 1 – 5, 2011	"TeV Particle Astrophysics (TeVPA)", Stockholm.
February 13 –19, 2011	"Unsolved problems in Astrophysics and Cosmology", Benasque.
September 15 –17, 2010	"OKC PROSPECTS Workshop", AlbaNova, Stockholm.
September 27 – October 1, 2010:	"COSMO/CosPA", Tokyo.
July 12 – 16, 2010:	"PPC 2010 - IV International Workshop on the Interconnection between Particle Physics and Cosmology", Torino.
June 29 – July 2, 2010:	"TOOLS 2010 - Tools for SUSY and the New Physics, Sharpening our Tools", Winchester.
January 6 – 10, 2009:	"The LHC and Dark Matter Workshop", Michigan Center for Theoretical Physics, Ann Arbor.
August 18 – 22, 2008:	"Identification of Dark Matter" (IDM), Albanova, Stockholm.
June 30 – July 4, 2008:	"TOOLS for the new physics and its background", Max-Planck-Institut fur physik, Munich.
January 3 – 7, 2008:	The 20th Nordic Particle Physics Meeting, Spåtind.
September 10 – 12, 2007:	ENTApP meeting, Matalascanas.

Schools and courses

November 15 – 19, 2010:	"Advanced simulation techniques in particle physics and cosmology", Niels Bohr Institute, Copenhagen.
August 8 – 17, 2008:	"Nordita Summer School on De Sitter Cosmology", Stockholm.
June 16 – 28, 2008:	Cargese Summer School "Theory and Particle Physics: the LHC perspective and beyond", Corsica.
July 30 – August 11 2007:	Cargese Summer School "Cosmology and Particle Physics Beyond the Standard Models", Corsica.
January 7 – 12, 2007:	5th Nordic Winter School in Particle Physics and Cosmology, Gausdal.
July 3 – 12, 2006:	European Summer University 2006, "Particles and the Universe", Strasbourg.

Skills

- **Languages (computer):** Fortran and Perl. I have some experience also with IDL, C++, HTML.
- **Languages (natural):** Swedish (native), English (fluent), French (good), German (fair), Italian (basic).
- **Software:** MadGraph/MadEvent, Pythia, Prospino, Softsusy. Some experience also with Mathematica, ROOT, DarkSUSY, GADGET.

Referees

Prof. Wilfried Buchmüller
DESY, Hamburg
buchmuwi@mail.desy.de

Prof. Joakim Edsjö
Oskar Klein Centre, Stockholm University
edsjo@fysik.su.se

Dr. Malcolm Fairbairn
Department of Physics, King's College London
malcolm.fairbairn@kcl.ac.uk

Research Statement

Sara Rydbeck

My current research focuses on phenomenological aspects of particle dark matter. In particular, I am interested in the prospects for discovery of various dark matter model scenarios at the CERN Large Hadron Collider (LHC), and how their LHC signatures would complement those from astrophysical experimental probes, such as indirect and direct detection.

I want to find out what we an learn about the theoretical origin of dark matter and its possible connection to electroweak symmetry breaking, to supersymmetry breaking and to baryo- and leptogenesis.

I am also interested in cosmological inflation and dark energy, and have previously done phenomenological studies of modified gravity models of dark energy.

Below follows a description of projects that I have been or am currently involved in, as well as an outlook as to where I plan to focus my future research.

Current and previous research

Supersymmetric dark matter at colliders

Experimental astroparticle physics is an active and exciting field but methods of indirect and direct detection of dark matter suffer from uncertainties due to astrophysics and the unknown distribution of the dark matter. If new physics models explaining the dark matter show up at particle accelerators, it would provide us with an invaluable way of determining its properties in a more controlled environment.

Supersymmetry is an attractive theoretical framework and weak scale supersymmetry, motivated by the hierarchy problem, is one of the most well studied hypotheses for physics beyond the Standard Model (SM).

Neutralino WIMPs in the pMSSM

An extra virtue of (R-parity conserving) Minimal Supersymmetric extensions of the standard model (MSSM) is the possibility of a dark matter candidate when the lightest supersymmetric particle (LSP) is a neutralino.

In collaboration with J. Edsjö, E. Lundström and J. Sjölin, I studied the prospects for discovery of supersymmetric dark matter models using signatures particularly useful for early analyses of LHC data. We focused on phenomenological MSSM models that give a relic density of dark matter compatible with the WMAP measurements.

For the spectrum generation, relic density calculations as well as other constraints from existing data, we used the DarkSUSY code. For the detector level study we used the MadGraph/MadEvent event generator and its interfaces to Pythia and the PGS detector simulation.

Decaying gravitino dark matter in the light-higgsino scenario

The light-higgsino scenario, in which two higgsino-like neutralinos and a higgsino-like chargino are light (of the order 100 GeV) and the other superparticles heavy, has been motivated by its ability to reconcile electroweak naturalness with multi-TeV scalar superpartners. Such a spectrum is consistent with a Higgs mass of ~ 126 GeV within the MSSM and can be obtained in GUT models.

Because the higgsinos are nearly mass degenerate and the strongly interacting superparticles are out of reach, such a scenario is difficult to probe at the LHC. The prospects change if we allow for R-parity violation, which leads to a consistent cosmology allowing for leptogenesis and gravitino dark matter. The limits on decaying gravitino dark matter from gamma-ray searches with the Fermi-LAT put a lower bound on the higgsino NLSP decay length, giving rise to a displaced-vertex collider signature.

Together with two Ph.D. students at DESY, S. Bobrovskyi and J. Hajer, I studied of the prospects for detection of this scenario at the LHC in the 8 TeV run. We used SOFTSUSY for the spectrum generation, PROSPINO for NLO cross section calcultations, MadGraph/Madevent and Pythia. For the detector simulation we used Delphes with a modification to take into account the radial information, and ROOT to analyse the events. We show that the reach in the R-parity violation parameter is improved compared to current indirect detection bounds on decaying dark matter, and that with our choice of signature, the higgsino mass can be determined soon after a signal excess has been found.

Alternative dark matter models

Although the LHC is a hadron collider, the unprecedented energies and luminositites that has been and will be reached also motivate searches for electroweak models. In fact, during the very successful running of the LHC since 2009, no new strongly interacting physics has been found so far.

The inert doublet model (IDM) is an extension of the standard model by an extra Higgs doublet. This (SU(2)) doublet couples to the gauge bosons but not directly to fermions, which is why it is called "inert". The model can be constructed by demanding an unbroken discrete Z_2 symmetry under which the inert doublet is odd and all the standard model fields are even. Due to this symmetry, the lightest inert particle is stable and a viable dark matter candidate.

Prior to my work with M. Gustafsson, L. Lopez-Honorez and E. Lundström, existing limits from experiments such as the Large Electron Positron (LEP) collider, as well as direct and indirect dark matter searches, only partially constrained the IDM parameter space. We did a full status update including both theoretical and experimental constraints on the model, in particular taking into account the constraints from XENON-100 (direct detection) and the LHC Higgs searches. We also showed, before the discovery of a 126 GeV boson at the LHC, that for the high Higgs masses that was one of the motivations for the model, the tetralepton plus missing energy signature would constitute a possible discovery channel at the LHC.

Although we are four authors on the paper, the main bulk of the work was performed by myself and M. Gustafsson in close collaboration. The completion of the paper took unusually long but I also learned much from it, both because of the depth with which we performed the analysis and the many different aspects that we included in the study.

Dark energy in non-Einstein gravity

The observation of a late-time acceleration of the universe's expansion leads to the dark energy problem. The question of whether its resolution lies in a type of energy density or in some modification to our gravity theory is however open.

In my work with M. Fairbairn and A. Goobar, we investigated whether expansion histories alternative to the concordance ΛCDM model could or could not be ruled out by existing data. We considered two models of modified Einstein gravity: the Dvali, Gabadadze and Porrati (DGP) brane world model and an $f(R)$ low curvature modification to the Einstein-Hilbert action.

We used type Ia supernovae data and measurements of the baryon acoustic peak in the galaxy distribution as well as in the cosmic microwave background. We showed the difficulty of distinguishing between DGP and Einstein gravity with a cosmological constant due to systematic uncertainties in the data, while we found the $1/R$ model for cosmological expansion to be ruled out using its prediction for the thickness of the last scattering surface.

While these attempts to modify Einstein gravity were useful as toy models for our phenomenological study, the search for consistent theories of modified gravity, for example in the lines of massive gravity, is ongoing. As part of the Oskar Klein Centre in Stockholm, I benefited from the opportunity to follow both theoretical and observational developments closely.

Research plan

Supersymmetric dark matter at colliders

The MSSM has been much studied at colliders, as its rich phenomenology offers a large variety of signals beyond what can be produced in the SM. However, most analyses have been performed in the framework of theoretically very constrained scenarios such as mSUGRA/CMSSM. The virtue of such a model is the small number of free parameters, but it might be overly restrictive if one is interested in exploring all phenomenologically interesting manifestations of the MSSM. Also, the low energy parameter values of mSUGRA models depend on the RGE running between high and low energies, which may differ significantly between different calculators.

I am investigating ways to use data from the LHC for low-energy supersymmetric dark matter studies that are as model independent as possible.

Scanning the parameter space and the presentation of experimental data

Global fits

Many experiments, collider and astrophysical, exist now that are continuously pushing particle physics to new energies. Especially as these experiments observe excesses over known backgrounds, how we interpret the data and apply statistical methods to test hypotheses of new physics become important. There has been a lot of activity in recent years in order to investigate approaches to constraining the parameters of new physics models using different statistical methods and parameter space sampling techniques, resulting in an emergence of various software tools for this purpose. In particular, I am interested in implementing LHC observables such as mass edges, number counts and distribution shapes in such analyses, as well as thinking about ways of treating the multitude of free parameters in bottom-up approaches to understand supersymmetry breaking.

Simplified models

In general, I am looking into ways of estimating event rates in a more approximate way than through the procedure of the full event generation and detector simulation. Dedicated searches are very important, but cannot cover all possibilities. In order both to allow theorists to study a diversity of new models as well as allowing to apply approximate experimental results to parameter scans, I find the simplified model approach very interesting, in addition to the dedicated searches. I find the discussion between experimentalists and theorist on the presentation of data extremely important, and always discuss the LHC signatures I study with experts from the ATLAS and CMS experimental groups.

Alternative dark matter models

The supersymmetric neutralino and the inert Higgs scalar mentioned above belong to the class of dark matter candidates dubbed Weakly Interacting Massive Particles (WIMPs). Their relic abundance is determined by WIMP annihilations in the early universe, before they “freeze out” of equilibrium as the universe expands. Their weak scale cross section (and mass) naturally give rise to the observed relic density.

The relic density of baryons is thought to be generated through an unrelated process and is set by a primordial baryon-antibaryon asymmetry, which alone motivates new physics beyond the standard model in the form of baryogenesis scenarios. The fact that the density of dark matter and baryons are of the same order of the baryon density can then be considered a “coincidence problem” . The idea of **Asymmetric Dark Matter** (ADM) and related scenarios is that the dark matter density is set by the baryon asymmetry. Another interesting idea is **WIMPy baryogenesis** that addresses this coincidence problem by relating baryogenesis to WIMP annihilation.

I find the possible connection between baryogenesis/leptogenesis and dark matter very intriguing and would look forward to investigating ways to test this kind of hypotheses experimentally. ADM realizations in **R-parity breaking** NMSSM scenarios would, as is the case for supersymmetry and leptogenesis models with gravitino dark matter above, give interesting LHC signatures in the form of displaced vertices. Also, the standard way to calculate relic densities implemented in existing software assumes the freeze-out scenario, but alternative ways to generate the relic density such as in ADM or **freeze-in** scenarios would be interesting to explore.