Particle theory – BayesFITS and beyond

Enrico Maria Sessolo National Centre for Nuclear Research

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The BayesFITS group at Hoża 69

- Research group at National Centre for Nuclear Research, formed in 2011 by L. Roszkowski
- Originally funded by a 5-year grant, ~5.4 Mzl, within Welcome Program of Foundation for Polish Science, January 2011 – December 2015
- New "Maestro" grant awarded by NCN:

"Ciemna materia: modele teoretyczne, cząstki kandydatki i perspektywy ich doświadczalnego odkrycia" (Dark matter: theoretical models, particle candidates and prospects for their experimental discovery)

5 years, started 1 June 2016 3 296 604 PLN



Leszek Roszkowski (Head)

In the framework of the NCN grant:

Luc Darmé, Soumya Rao (postdocs)

Collaboration's stable members:

Andrzej Hryczuk, Kamila Kowalska, Enrico Maria Sessolo, Sebastian Trojanowski

Former members:

Nils-Erik Bomark, Antonio Figueiredo, Małgorzata Kazana, Shoaib Munir, Yue-Lin Sming Tsai, Andrew J. Williams



The group's work tries to address fundamental issues like...

- New physics beyond the Standard Model
- The nature of dark matter (it constitutes 1/4 of the matter in the Universe)
- Higgs physics





Statistical Bayesian approach

Why is this important

There is compelling experimental evidence for physics beyond the SM

- The existence of DM
- Neutrino masses
- Baryogenesis
- Inflation
- Grand Unification?
- Unification of all four forces of nature?
-

OUR TASK:

- Derive information for new physics beyond the Standard Model through a global approach that uses all available experimental data
- Develop new tools

PARTICLE PHYSICS

Collider signatures, LHC searches

ASTROPHYSICS

Underground DM searches, γ-ray telescopes, neutrino telescopes

COSMOLOGY

Early Universe, inflation, BBN...

Where is the new physics?

No convincing hint from the LHC:



* Only a selection of the available mass limits on new states or phenomena shown

Still...

- Higgs boson looks like a fundamental scalar
- Higgs boson is "light" (<130 GeV)

SUSY

Low energy SUSY remains arguably the best motivated scenario for BSM physics

Supersymmetry

Still most interesting framework for BSM physics...

Higgsino

SUSY force

a

Z

W



Every SM particle has a "superpartner" with different spin

- Solves gauge hierarchy
- Gauge coupling unification
- Relates EWSB to a heavy top quark •
- Excellent dark matter candidate: the lightest neutralino
- Can be predictive: E.g. in CMSSM 4 free parameters: $m_0, m_{1/2}, A_0, aneta, ext{sgn}\mu$

Higgs boson discovery (July 2012) First hints Nov 2011

mH = 125 GeV





Physics 2013





Photo: Pnicolet via Wikimedia Commons François Englert Photo: G-M Greuel via Wikimedia Commons

Peter W. Higgs

What does this discovery imply for SUSY?

Bayesian implications of LHC bounds and a 125 GeV Higgs





Many claimed... "SUSY in bad shape ... "

We were among first to claim: *m_h* = 125 GeV => SUSY heavier than expected

Bayesian implications of LHC bounds and a 125 GeV Higgs

2013-14

Kowalska, Roszkowski, Sessolo 1302.5956 (JHEP 1306, 2013) Roszkowski, Sessolo, Williams 1405.4289 (JHEP 1408, 2014)



New region, new dark matter candidate

DM properties

Map regions to (m_X, σ_{SI}) plane used by experimentalists



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DM properties

This region will be searched for in underground experiments



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Close collaboration with experiments

LHC In Fowlie *et al.* PRD 2012, PRD 2013; Kowalska *et al.* JHEP 2013, Kowalska, Sessolo PRD 2013... and more ...

XENON100, XENON-1T

In Roszkowski, Sessolo, Williams JHEP (May, Nov 2014)



СТА

In Roszkowski, Sessolo, Williams JHEP (Nov 2014) Roskowski *et al.* JCAP 2016



We are well known... and a brand name for Bayesian analyses in the world!



Group's output

- So far 36 papers published or accepted by group members (mostly JHEP, PRD, JCAP)
 On average 32 citations/paper
 Our best cited paper: 146 citations and counting
- One major review (Physics Reports by Roszkowski), two more topical ones published
- Currently a big review is being completed by four group members

Several:

- invited talks (Tsai plenary review talk at COSMO-12 in Beijing, Sessolo at TMEX-14, Madrid 2015, COSMO-16, Roszkowski PLANCK '13, '15...)
- conference presentations
- seminar talks (Europe, including CERN, and USA)
- Several local (NCBJ, UW) and external collaborators (Valencia, Montpellier, Southampton, Sheffield, Tallin, Korea, India, USA...)

Miscellanea of topics

The numerical tools developed in the group have been used for more published investigations...

- Natural SUSY at the LHC
 [Kowalska, Sessolo, 1307.5790 (PRD 88, 2013)]
- Fine tuning and heavy SUSY [Kowalska, Roszkowski, Sessolo, Trojanowski, 1402.1328 (JHEP 1404, 2014)]
- Gravitino dark matter and the 3.5 keV line [Bomark, Roszkowski, 1403.6503 (PRD 90, 2014)]
- SUSY models with GUT symmetries at the LHC [Kowalska, Roszkowski, Sessolo, Williams, 1503.08219 (JHEP 1506, 2015)]
- Less-simplified models of dark matter [Choudhury, Kowalska, Roszkowski, Sessolo, Williams, 1509.05771, (JHEP 2016)]
- Early Universe, alternative DM candidates [Roszkowski, Trojanowski, Turzynski, 2013-2016]and more....

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What can we learn from a DM signal?

Roszkowski, Sessolo, Trojanowski, Williams, 1603.06519 (JCAP 1608, 2016)

What can one say of • DM m

- DM mass m_{χ} • DM scattering cross section
 - tion σ_p^{SI} ction $\langle \sigma v
 angle$
 - DM annihilation cross section $\langle \sigma \rangle$
- Dominant annihilation channel

E.g. DM mass reconstruction at CTA:



The future

- Analyses of new models in the pipeline (vector-like matter, Dirac gauginos...)
- Dark matter signatures of E-WIMPs
- DM reconstruction and complementarity of collider and neutrino detectors
- Eyes open on possible LHC anomalies and signals

Summary

- We are the recognized world leaders in global Bayesian statistical analyses of supersymmetric models
- We produced clear predictions for the LHC and DM experiments
 - 1TeV higgsino dark matter
 - Will be probed by tonne scale detectors and gamma ray telescopes
- Numerous published papers on several topics of high energy physics
- Fruitful collaborations with international groups
- New substantial grant guarantees sustained output