AstroFit & Fittino

Results from a CMSSM fit using Combined Constraints from Astroparticle and Collider Physics

Nelly Nguyen*, T. Bringmann, D. Horns, Fittino Collaboration

University of Hamburg
nelly.nguyen@desy.de

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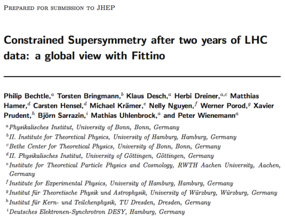
Fittino Collaboration

- Philip Bechtle, Torsten Bringmann, Klaus Desch, Herbi Dreiner, Matthias Hamer, Carsten Hensel, Michael Krämer, Nelly Nguyen, Werner Porod, Xavier Prudent, Björn Sarrazin, Mathias Uhlenbrock and Peter Wienemann
- For further information, see 1204.4199

AstroFit Project

- Torsten Bringmann, Nelly Nguyen, Nils Plambeck, Faruk Sellami, Dieter Horns
- For further information, see 1202.1385

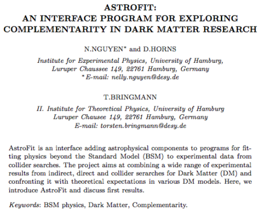


PREPARED FOR SUBMISSION TO JHEP

Constrained Supersymmetry after two years of LHC data: a global view with Fittino

Philip Bechtle,[a] Torsten Bringmann,[b] Klaus Desch,[a] Herbi Dreiner,[a,c] Matthias Hamer,[d] Carsten Hensel,[d] Michael Krämer,[e] Nelly Nguyen,[f] Werner Porod,[g] Xavier Prudent,[h] Björn Sarrazin,[i] Mathias Uhlenbrock,[a] and Peter Wienemann[a]

[a] *Physikalisches Institut, University of Bonn, Bonn, Germany*
[b] *II. Institute for Theoretical Physics, University of Hamburg, Hamburg, Germany*
[c] *Bethe Center for Theoretical Physics, University of Bonn, Bonn, Germany*
[d] *II. Physikalisches Institut, University of Göttingen, Göttingen, Germany*
[e] *Institute for Theoretical Particle Physics and Cosmology, RWTH Aachen University, Aachen, Germany*
[f] *Institute for Experimental Physics, University of Hamburg, Hamburg, Germany*
[g] *Institut für Theoretische Physik und Astrophysik, University of Würzburg, Würzburg, Germany*
[h] *Institut für Kern- und Teilchenphysik, TU Dresden, Dresden, Germany*
[i] *Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany*



**ASTROFIT:
AN INTERFACE PROGRAM FOR EXPLORING
COMPLEMENTARITY IN DARK MATTER RESEARCH**

N.NGUYEN* and D.HORNS

*Institute for Experimental Physics, University of Hamburg,
Luruper Chaussee 149, 22761 Hamburg, Germany
E-mail: nelly.nguyen@desy.de

T.BRINGMANN

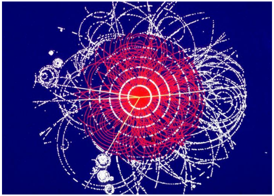
*II. Institute for Theoretical Physics, University of Hamburg
Luruper Chausee 149, 22761 Hamburg, Germany
E-mail: torsten.bringmann@desy.de*

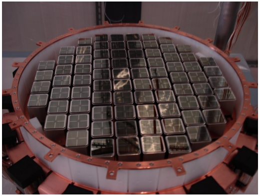
AstroFit is an interface adding astrophysical components to programs for fitting physics beyond the Standard Model (BSM) to experimental data from collider searches. The project aims at combining a wide range of experimental results from indirect, direct and collider serarches for Dark Matter (DM) and confronting it with theoretical expectations in various DM models. Here, we introduce AstroFit and discuss first results.

Keywords: BSM physics, Dark Matter, Complementarity.

The Importance of Complementarity in Dark Matter Research

- Combining results from each dark matter (DM) research field can help to constrain model parameter spaces even further
- Studies on agreements and conflicts between experiments and how they arise help understanding the nature of DM
- e.g. do collider produced particles resemble DM in the Universe?
- Considering many approaches can mitigate uncertainties from single methods (model dependencies, background estimations)

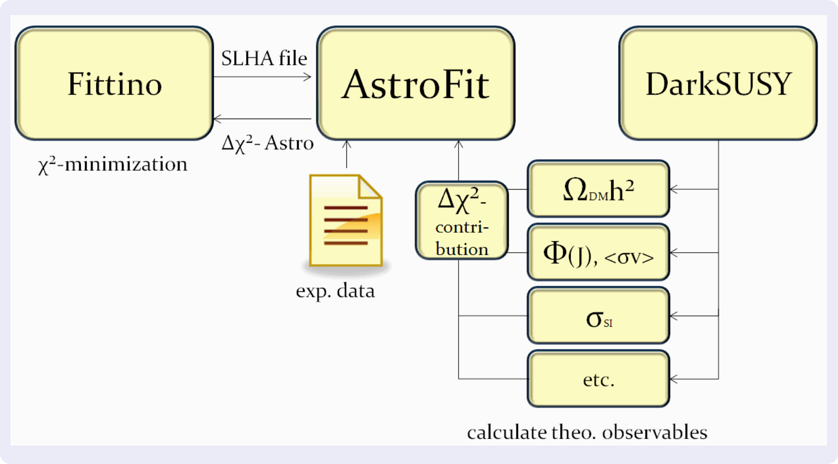




Fittino & AstroFit: Techniques and Observables

- Markov Chain Monte Carlo (MCMC) scan of parameter space
- χ^2-function to determine best fit models and 1 and 2 σ regions
- Accomodated theory codes:
  SPheno, Higgsbounds, SoftSUSY, AstroFit, etc.
- Particle physics input from LEP/SLC, Tevatron and LHC
  (LHC data from 2011 with $\sqrt{s} = 7, \quad L = 5\ \text{fb}^{-1}$)
- Input from direct detection experiments
  (DAMA/LIBRA, CoGeNT, Xenon100, Xenongoal, Xenon1T)
- Input from indirect searches (H.E.S.S. and Fermi-LAT)
- Cold dark matter relic density (WMAP)

Program Structure of AstroFit



Studied CMSSM Scenarios

Scenarios

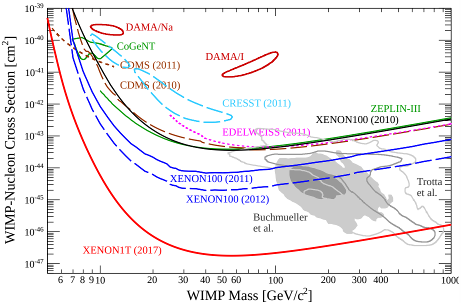
- Basic LHC scenario: LHC, HB, Xenon100, Fermi-LAT, WMAP
- Impact of direct detection signal regions and upper limits
- Impact of the cold dark matter relic density
- Impact $m_{h^0} = 126$ GeV vs. Higgsbounds (114-142 GeV)
- Impact of indirect detection photon flux upper limits from dwarf spheroidal galaxies
- Impact of the LHC compared to pre LHC

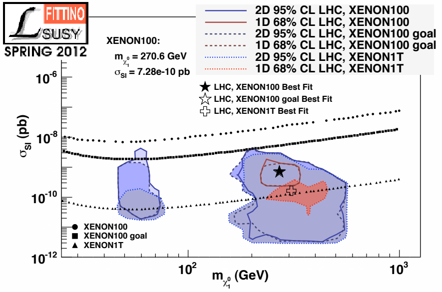
Parameters

- M_0 – common scalar mass
- $M_{1/2}$ – common gaugino mass
- A_0 – common trilinear coupling
- $tan\beta$ – ratio of Higgs VEV
- sign(μ) – sign of Higgsino mass parameter

Results from Direct Detection

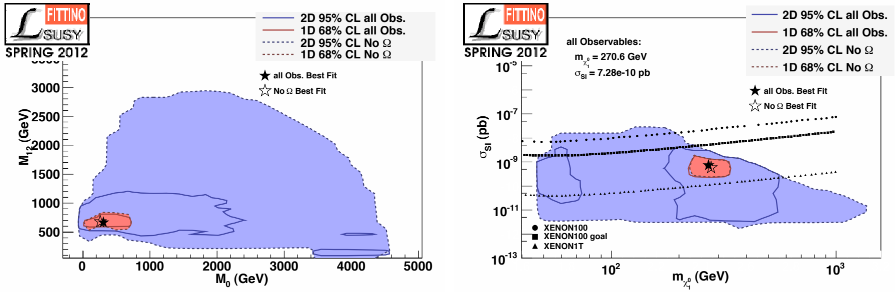
- Conflict between claimed signals and upper limits
- Signal regions not compatible → χ^2-values too high
- Current upper limits can be accomodated in the CMSSM
- Future limits increase constraints on parameters





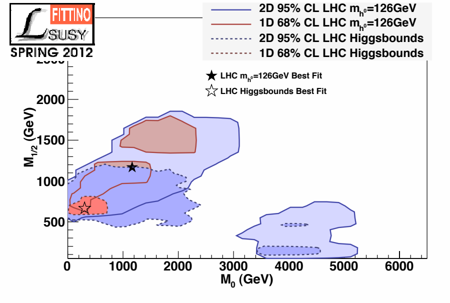
Left figure from Xenon Collaboration: 1206.6288

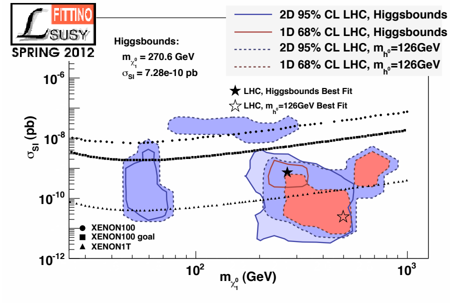
Results from Relic Density



- From WMAP: $\Omega_{\mathrm{CDM}}h^2 = 0.1123 \pm 0.0118$
- Relic Density still most stringent constraint
- Comparable results between DarkSUSY and MicrOmegas

Results from Higgs Mass

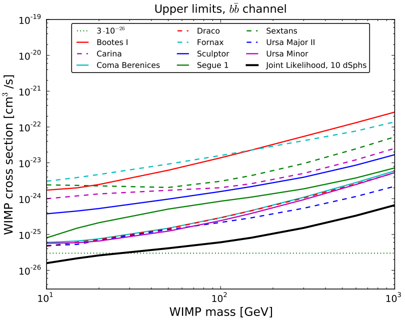


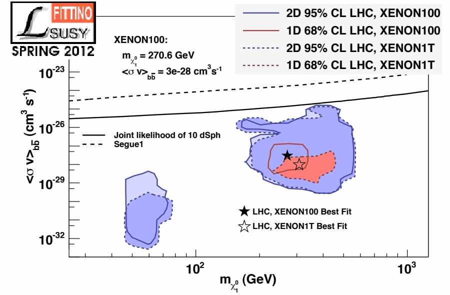


- $m_{h^0} = 126 \pm 3$ GeV
- Higgs mass worsens fit from $\chi^2 = 13.1$ to $\chi^2 = 18.4$ (9 d.o.f.)
- Entire mass spectrum shifted upwards to higher masses
- Barely compatible with CMSSM

Results from Indirect Detection

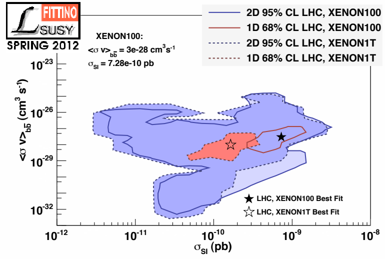
- No distinct constraints from indirect detection yet
- All channel treatment of stacked dwarfs will yield first results
- Many new development from various instruments
- Yet setting important limits for complementarity study





Perspective with Indirect Detection

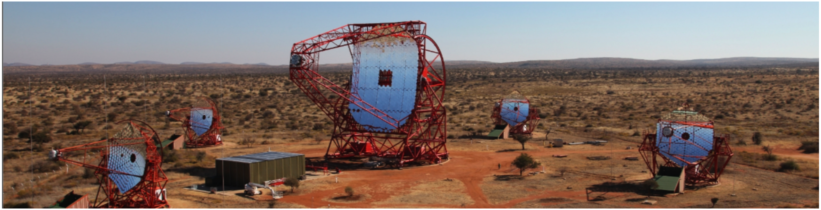
Combined Impact



Future Implementations

- Gamma-ray line searches (i.e. C. Weniger, see 1204.2797)
- Gamma-ray studies of the galactic center and galactic halo
- Antimatter data (positrons, antiprotons)
- U.L. from neutrino experiments

Summary and Outlook



Summary

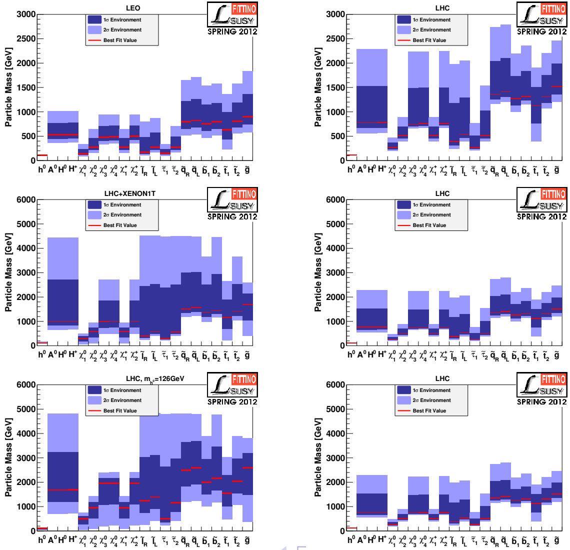
- Thorough investigation of the CMSSM as DM scenario
- Uniting information from indirect, direct and collider searches
- Investigated compatibility with Higgs, Xenon100, etc.

Outlook

- New follow-up study focussing on Higgs
- Studies of other DM and less constrained SUSY models, already in Fittino: MSSM24, AMSB, GMSB, NMSSM
- Extensions especially in the part of indirect searches

Mass Distributions

1. Before LHC compared to LHC
2. Xenon100 vs. Xenon1T
3. Higgsbounds vs. $m_{h^0} = 126$ GeV



Other Studies not shown here

- Non-minimal model (NUHM1) study
- Comparison between Bayesian and Frequentist statistics
- Studies of fine-tuning
- Studies of $(\mathrm{B_s} \to \mu\mu)$ processes
- Impact of individual observables
- ... and many more

Fit Process in Fittino

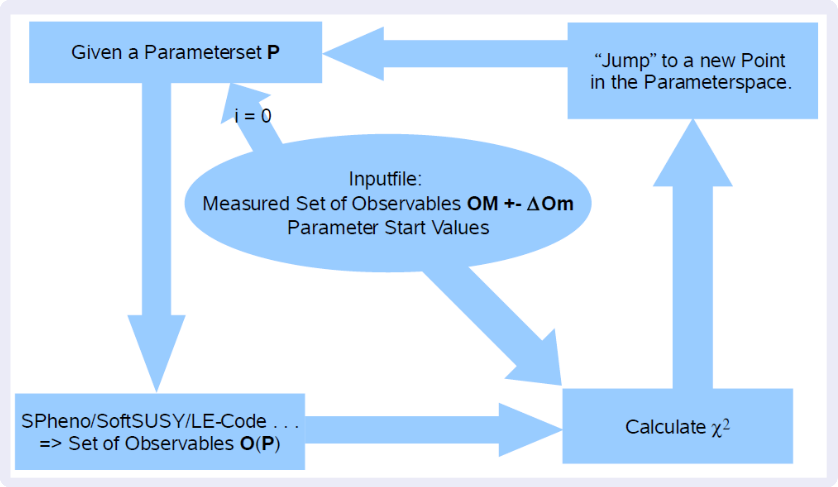


Chart by Matthias Hamer, Uni Göttingen

Observables

Observables in Fittino

- Results from LEP, Tevatron
- Latest results from LHC
- Hint for $m_{h^0} = 126 \pm 3$ GeV
- e.g.:
  - B-physics, Z-physics (masses, edges, widths, ...)
  - Constraints on Higgs mass
  - Anomalous magnetic moment of muon $(g-2)_\mu$

Observables in AstroFit

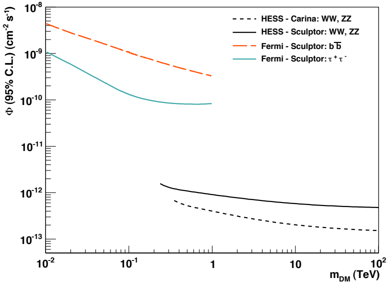
- Results from indirect/direct detection (H.E.S.S., Fermi CoGeNT, Xenon100, etc.)
- Relic density (from WMAP)
- e.g.:
  - $\Omega_{\mathrm{DM}} h^2 = 0.1123 \pm 0.0035$
  - Photon flux u.l.
  - Upper limits on $\langle \sigma v \rangle$
  - σ_{SI} from direct detection

Photon flux and $\langle \sigma v \rangle$ upper limits

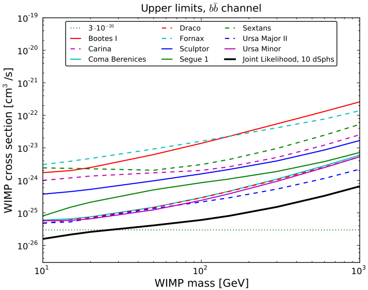
Calculation of Photon Flux

$$\frac{d\Phi(\Delta\Omega, E_\gamma)}{dE_\gamma} = \frac{1}{8\pi} \frac{\langle \sigma v \rangle}{m_\chi^2} \frac{dN_\gamma}{dE_\gamma} \times \bar{J}(\Delta\Omega)\Delta\Omega$$

$$\bar{J}(\Delta\Omega) = \frac{1}{\Delta\Omega} \int_{\Delta\Omega} d\Omega \int_{l.o.s.} dl \, \rho_{DM}^2(l)$$



left: HESS data (photon flux u.l.), [1012.5602]

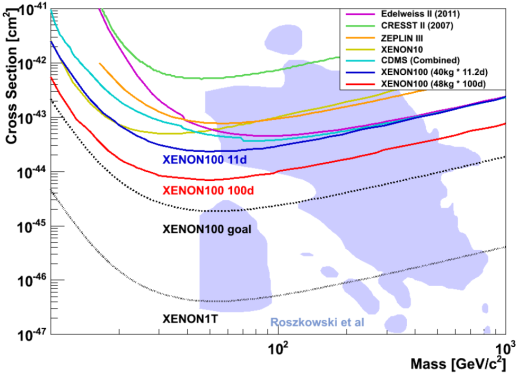


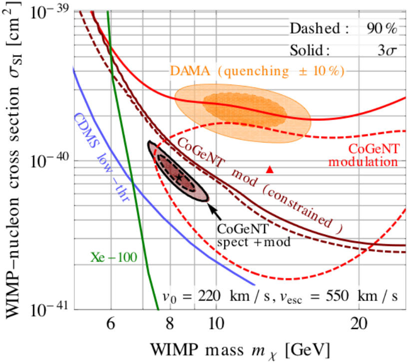
right: latest Fermi data ($\langle \sigma v \rangle$-limits), [1108.3546]

Example: Spin-Ind. Cross-Section, from Direct Detection

Calculation of Spin-Independent Cross-Section

$$\sigma^{SI}_{nucleon} = \frac{(Z\sqrt{\sigma_p} \pm (A-Z)\sqrt{\sigma_n})^2}{A^2}$$



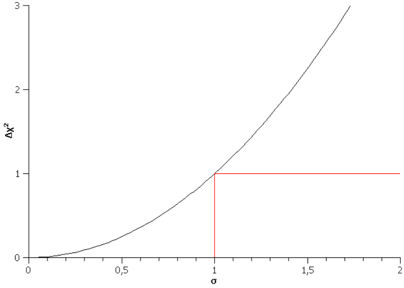


left: limits on σ_{SI} from the Xenon experiment
www.physik.uzh.ch/groups/groupbaudis/darkmatter/grouptalks/Marrodan_SemBonn_2011.pdf

right: containment regions from direct detection experiments, [1107.0717]

Calculation of χ^2 in AstroFit

- Continuous $\Delta\chi^2$-contribution
- Realized by extrapolation from given conficence levels
- For limits - calculation per confidence level, examples:
  $2\sigma \mathrel{\widehat{=}} \chi^2 = 4; \quad 3\sigma \mathrel{\widehat{=}} \chi^2 = 9; \quad 90\% \mathrel{\widehat{=}} \chi^2 = 2,71$
- For regions - calculation per containment regions
- For data points - using equation (see blue box)



χ^2-Calculation

$$\Delta\chi^2 = \sum \left(\frac{O_{exp} - O_{theo}}{\sigma_{exp}} \right)^2$$