Light Neutralinos in the NMSSM

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The NMSSM

- Minimal Supersymmetric SM + SU(2) singlet in the Higgs sector:

$$\mu\, H_1.\, H_2 \longrightarrow \lambda\, S\, H_1.\, H_2 + \frac{1}{3}\kappa\, S^3$$

- Enhanced Higgs spectrum: 3 CP-even, 2 CP-even neutral bosons.
- Singlet-like lightest Higgses could be almost decoupled from the SM! It is possible to have M_H << 100 GeV and/or M_A << 100 GeV.
- 5-state mixed neutralino lightest stable particle (LSP). The mass of the LSP is a mixture of the bino (M_1), wino (M_2), higgsino and singlino masses:

$$\chi_1^0 = N_{11}\tilde{B} + N_{12}\tilde{W}_3^0 + N_{13}\tilde{H}_d + N_{14}\tilde{H}_u + N_{15}\tilde{S}$$

Parameter boundaries

(GeV units)

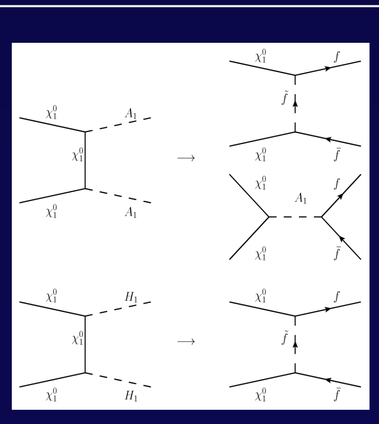
$$1 < M_1 < 100$$
$$100 < M_2 < 2000$$
$$0 < \mu < 1000$$
$$1 < \tan\beta < 75$$
$$0 < \lambda < 0.75$$
$$0 < \kappa < 0.65$$
$$-2000 < A_\lambda < 5000$$
$$-5000 < A_\kappa < 2000$$
$$-3000 < A_t < 3000$$
$$100 < M_{\tilde{l}} < 2000$$
$$300 < M_{\tilde{q}} < 2000$$

Scanning Parameter Space

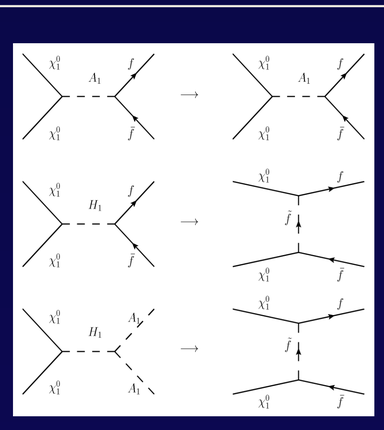
- Tools: micrOMEGAs 2.4 + NMSSMTools
- Large parameter space issue. Markov Chain Monte-Carlo scans: a random walk approach
- Points discriminated by priors (phenomenological framework) and likelihoods (fitting available data)
- Priors:
  - Parameter space boundaries
  - Neutralino mass below 15 GeV
  - Physical supersymmetric configuration
- Likelihoods:
  - Relic Density: at least 10% of the cosmological Dark Matter
  - Mass limits (chargino, sleptons…)
  - Higgs phenomenology
  - Muon anomalous magnetic moment
  - Rare B-meson decays and oscillations
  - Z invisible width

Neutralino annihilations

- Different behavior at freeze-out (v ≈ 0.4 x c) and at galactic annihilations (v ≈ (10^{-4} – 10^{-3}) x c):



Non-resonant channels

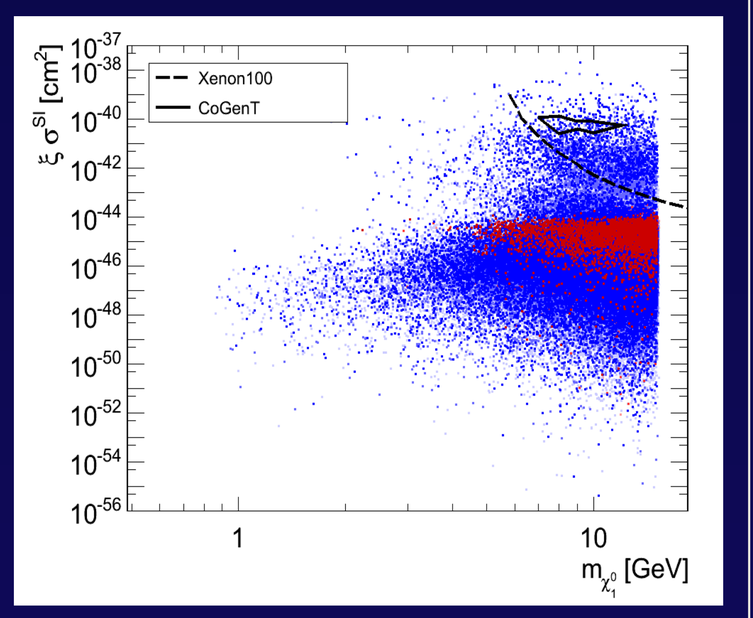


Resonant channels

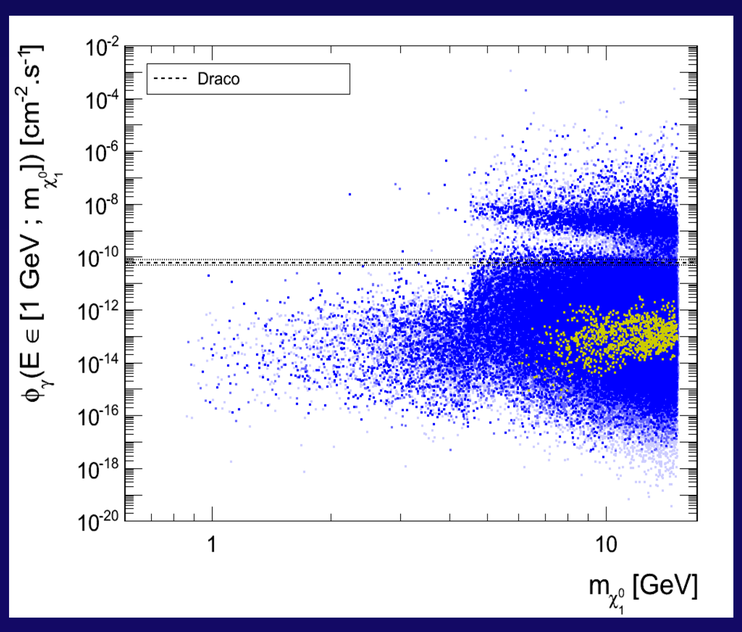
- Whenever the dominant channel is not the same at Early Universe and at quasi-rest there, there is a large suppression in the interaction rate: no indirect signals. The A-resonance, though, is not p-wave suppressed: a boost is obtained at low velocities, we expect large indirect signals.
- Final states: fermions of the Standard Model and light Higgs bosons (only in the Early Universe)

Direct Detection

- Neutralinos in CoGenT (and DAMA) regions
- …or neutralinos excluded by Xenon100
- Spin independent interactions: t-channel Higgs boson or s and u-channel squark exchanges
- A exchanges are chirally suppressed at v→0, while squarks are too heavy
- Large interactions: only possible via a light CP-even (singlet-like) Higgs: M_H^{-4} enchancement
- In red: excluded by Fermi-LAT limits on γ-rays (see Indirect Detection)



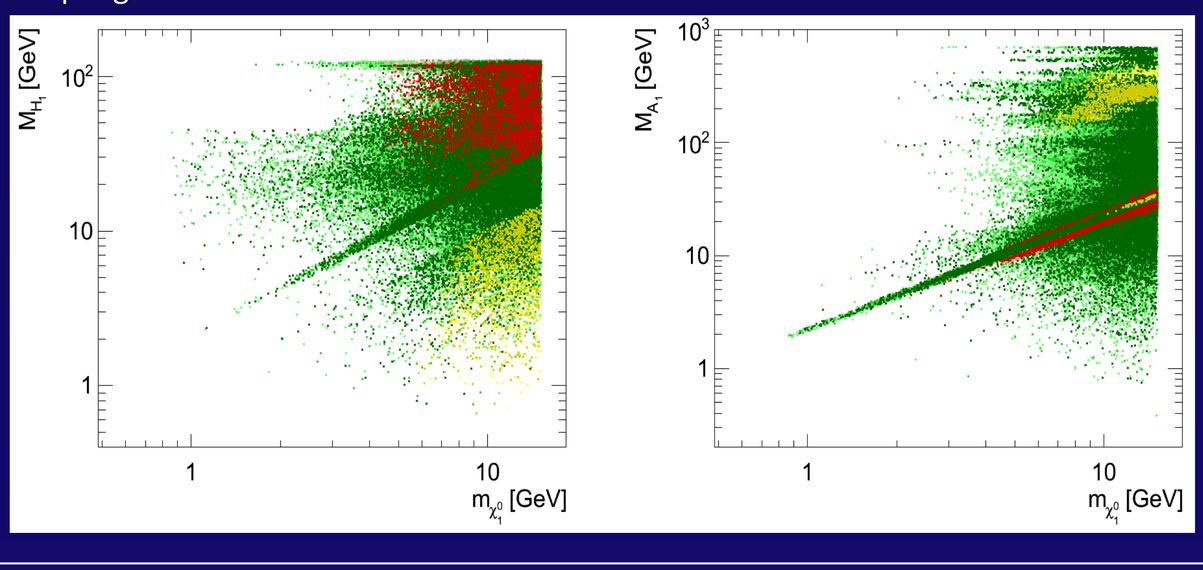
Indirect Detection



- Fermi-LAT null results → stringent limits on the γ-ray flux from Dark Matter annihilations from Draco dwarf spheroidal galaxy
- γ-rays from Dark Matter annihilations: decays of fermionic final states
- Large annihilations for light CP-odd (singlet-like) Higgs
- Excluded points have annihilation rates σv >> 10^{-26} cm^3 s^{-1} (the canonical freeze out rate) at v→0: A-pseudoscalar boson resonance
- Other checks (not further constraining):
  - antiprotons and positrons
  - radio light from the galactic center and clusters
- In yellow: points excluded by Xenon100 (see Direct Detection)

Light Higgs configurations

- Relic Density achieved by annihilation through or into light Higgs bosons (see the concentration of configurations towards the y=2x line in both panels suggesting resonances)
- In red: excluded by Fermi-LAT limits on γ-rays (see Indirect Dectection), in yellow: points excluded by Xenon100 (see Direct Detection) and in green: safe points.
- Yellow points in left panel suggest that the configurations yielding large SI interactions annihilate into H_1 pairs in Early Universe and thus have suppressed galactic annihilations
- Red points in the right panel are very correlated to the resonance: Indirect signals depend upon the fine-tuning of the resonance and neutralino-neutralino-pseudoscalar couplings



References: [micrOMEGAs: arXiv:hep-ph/055142, arXiv:0803.2360, arXiv:1004.1092] – [NMSSMTools: arXiv:hep-ph/0505022] – [CoGenT: arXiv:1002.4703] – [Xenon100: arXiv:1104.2549] – [Fermi-LAT: arXiv:1001.4531]