Combining accelerators with Dark Matter Direct Detection

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Introduction

- Accelerators as Dark Matter (DM) experiments
- Necessity of measuring DM cross sections on earth
- Multi-experiment approach: importance of Direct Detection experiments

In the framework of a neutralino DM, a set of experimental measurements from accelerators $d = (d_1, d_2, ..., d_n)$ is supposed. Their constraining power is studied and we determine estimates for a number of physical quantities $p = (p_1, p_2, ..., p_m)$ describing the DM.

Introduction

- Simulation of a detection in Direct Detection experiments
- DM-nucleon coupling can be Spin Independent σ_{SI} (Xenon, CDMS, ...) and Spin Dependent σ_{SD} (COUPP, ...)
- Independent constrains on the mass and the cross section of the DM can be obtained.

Discrepancies can appear in the comparison between the two experimental techniques. They would be indications of a non-standard description of DM, as regards local density or velocity distribution.

pMSSM

SUSY models defined by 24 parameters

- gaugino masses: m_1, m_2, m_3
- sfermion masses: $m^2_{\tilde{Q}}$, $m^2_{\tilde{u}}$, $m^2_{\tilde{d}}$, $m^2_{\tilde{L}}$, $m^2_{\tilde{e}}$
- Higgs masses: m_A, μ
- ratio of Vacuum expectation values: $\tan\beta$
- trilinear terms just for heaviest generation: A_t, A_b, A_τ

Since our starting point is the set of (simulated) accelerator data d, we are bound to consider a benchmark model.
But in the determination of final results p, a scan of the whole 24 dimensional parameter space is operated.
The 24 dimensional parameter space is weighted by the likelihood function $\mathcal{L}(x|d)$:

$$\mathcal{L}(x|d) = \prod_{i=1,n} \exp[-(d_i - d_i(x))^2/2\sigma_i^2]. \qquad (1)$$

Markov chains

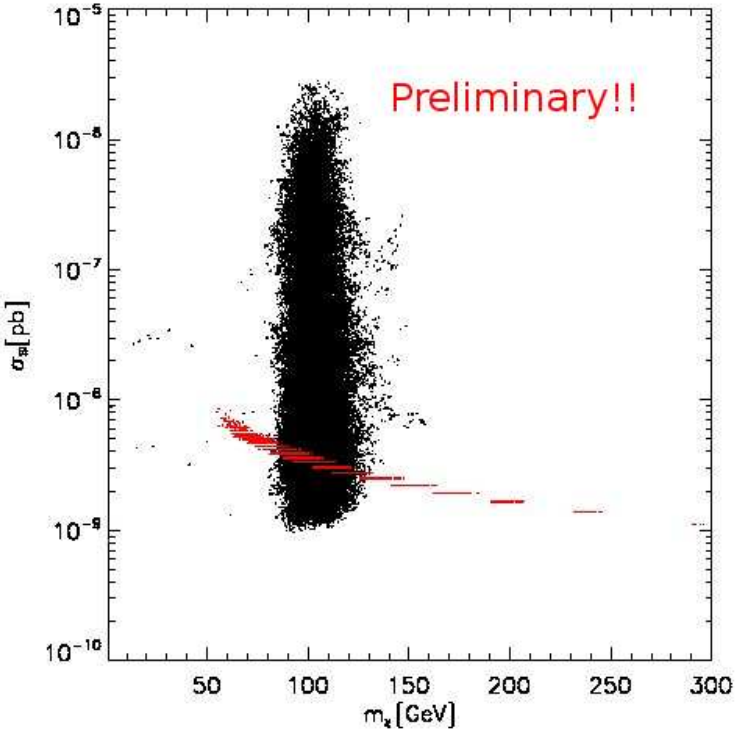
- Markov chains technique is applied, since complete grid scan is computationally unbearable
- flexible way of using the likelihood and inserting/modifying experimental constrains
- an available and common code (SuperBayeS) has been updated.

The Markov chain evolves preferring points at high likelihood so that the density of the points in the chain $\{q_i\}$ maps the likelihood itself.
Stastically speaking, the technique is based on the Bayes theorem:

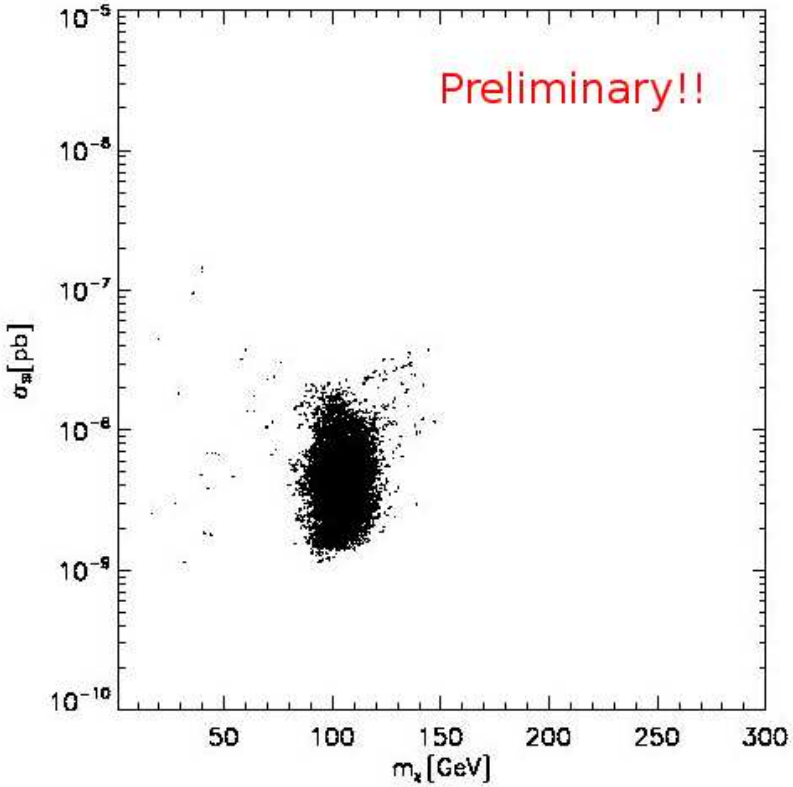
$$prob(q_i|d) = prob(d|q_i)\pi(q_i). \quad (2)$$

Spin Independent cross section

Posterior distribution functions (pdf) for the quantities p we are interested in can be determined.

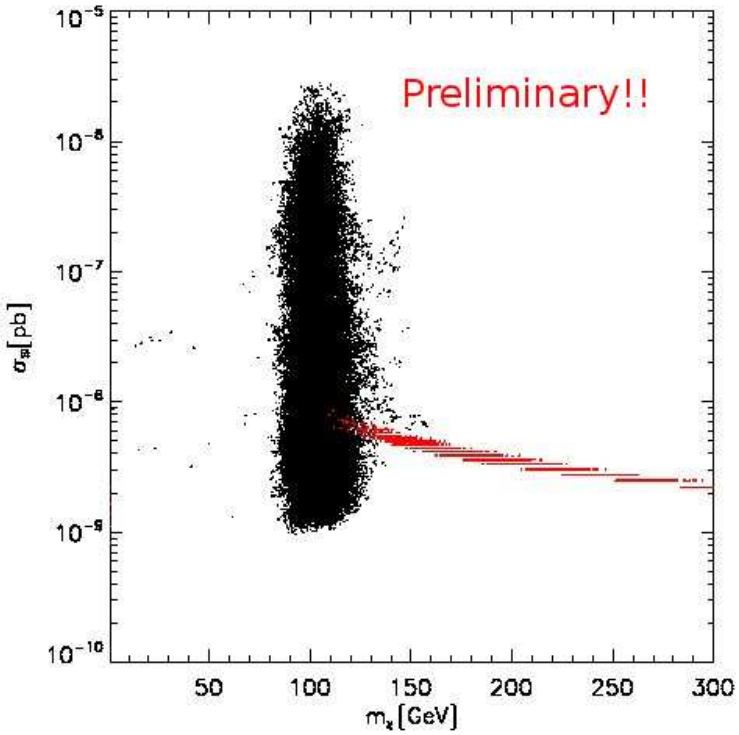


Only colliders (black) and only Direct Detection (red).



Colliders and Direct Detection.

Spin Independent cross section

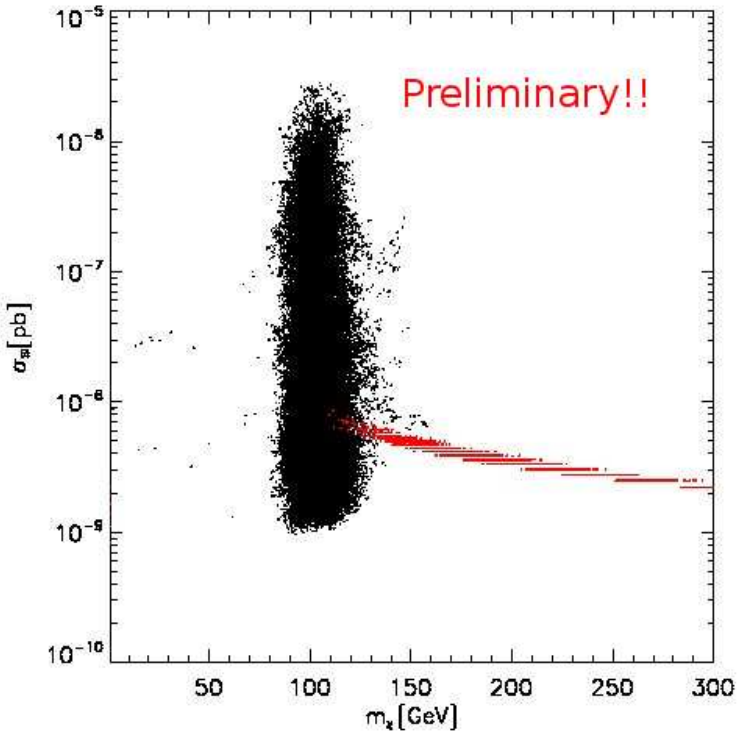


Discrepancies are possible.
It will be interpretated as a non-standard local density or velocity distribution:

$$N_{\text{events}} = \frac{2\rho_\chi \sigma_{\text{SI}} \mu_{A\chi}^2 A^2 v_0}{\sqrt{\pi} m_\chi m_A \mu_{p\chi}^2} \mathcal{F}. \quad (3)$$

They can be reconciled introducing a normalization parameter ξ in the total integrated rate.
The combined use of accelerator and Direct Detection data will be able to estimate how large is ξ.

Spin Independent cross section

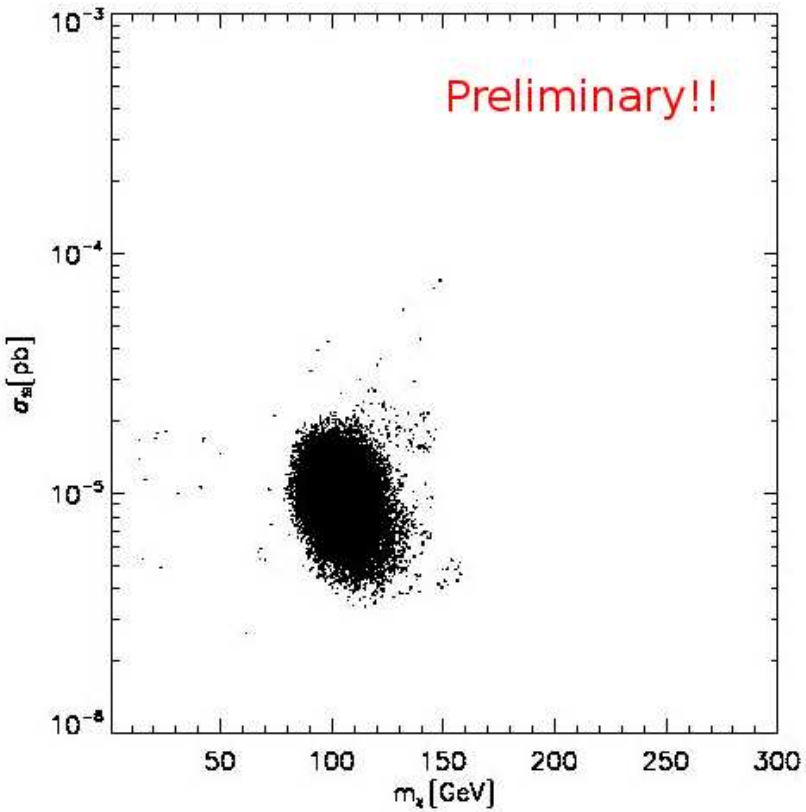


Discrepancies are possible.
It will be interpretated as a non-standard local density or velocity distribution:

$$N_{\text{events}} = \xi \frac{2\rho_\chi \sigma_{\text{SI}} \mu_{A\chi}^2 A^2 v_0}{\sqrt{\pi} m_\chi m_A \mu_{p\chi}^2} \mathcal{F}. \quad (3)$$

They can be reconciled introducing a normalization parameter ξ in the total integrated rate.
The combined use of accelerator and Direct Detection data will be able to estimate how large is ξ.

Spin Dependent cross section



- Comparison between 'accelerator only' and 'Direct Detection only'
- COUPP cannot reconstruct the energy of the recoiling nuclei
- Determination of possible discrepancy, measuring the ξ parameter.

Summary

- Accelerator data from new physics will constrain neutralino cross section. Details depend on the benchmark model
- Direct Detection experiments can be used at the same time. Accuracy in the estimation depends on the exposition
- Discrepancies are possible
- Combined use of both kinds of data will narrow down the uncertainty and also provide information of normalization scale ξ.