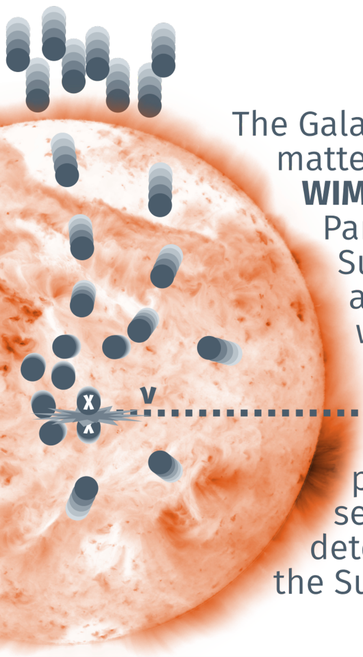
Exploring Dark Matter Models with PINGU Events

Christoph.Raab@ulb.ac.be (Bruxelles)
Carlos Pérez de los Heros (Uppsala)
Roberto Ruiz de Austri (València)
IceCube-PINGU Collaboration

Introduction

Indirect DM Search



The Galaxy is enveloped in a dark matter **halo,** often assumed to be **WIMPs** (Weakly Interacting Massive Particles). They **scatter** on the Sun as it moves through the halo an accumulate in the solar core, where they mutually **annihilate**.

Several annihilation channels produce neutrinos. In indirect searches for dark matter we try to detect these as they escape from the Sun, Earth or other dense regions.

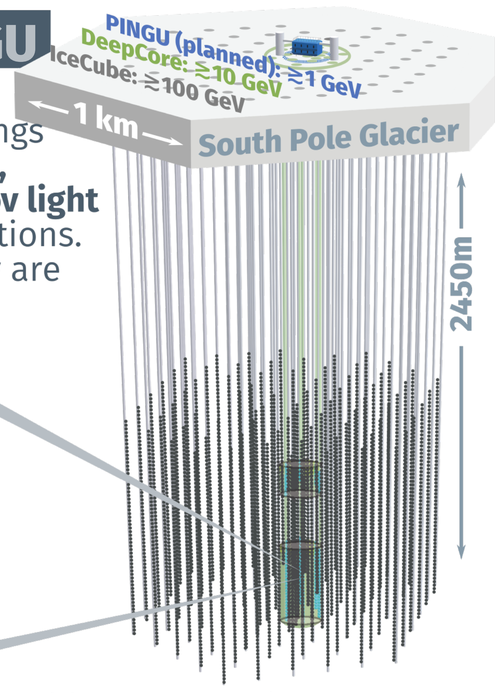
Messengers

Neutrinos make good **messenger particles** since they escape the Sun almost **directly**. This way, their energies carry accurate information about the **annihilation spectrum** and with that the properties of the annihilating WIMPs.

The main challenge is actually **detecting** them. We need **neutrino telescopes** of large volume.

IceCube-PINGU

IceCube-DeepCore is 5260 PMTs on 86 strings spread over **1km³ ice,** registering **Cherenkov light** from particle interactions. Direction and energy are reconstructed.

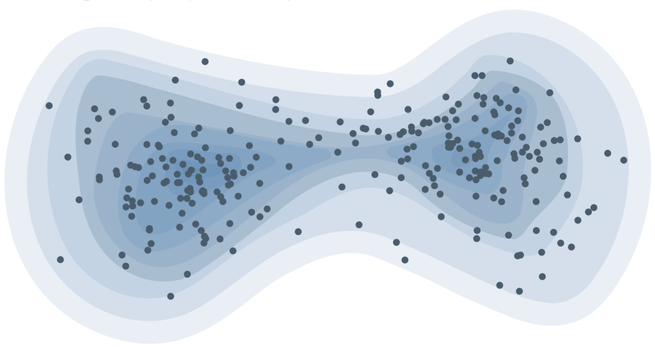


PINGU is proposed to add 40 more strings as an in-fill the size of DeepCore, an even higher PMT density.

Method

Scans

The **NMSSM** (Next-to-Minimal Supersymmetric extension of the of the Standard Model) has over 130 parameters which are sampled with **MultiNest**, according to physical priors.



For each in this **set of viable WIMP candidates**, the halo density and relative velocity are varied as well. The **MicrOMEGAs** software then predicts all physical results, like the neutrino flux $d\Phi/dE_\nu$ at Earth.

Statistics

The original method paper from 2011 uses a **likelihood function** which relates a model ***M*** to the data ***D*** using observables of the events ***{i}***, related by a parameterized detector description.

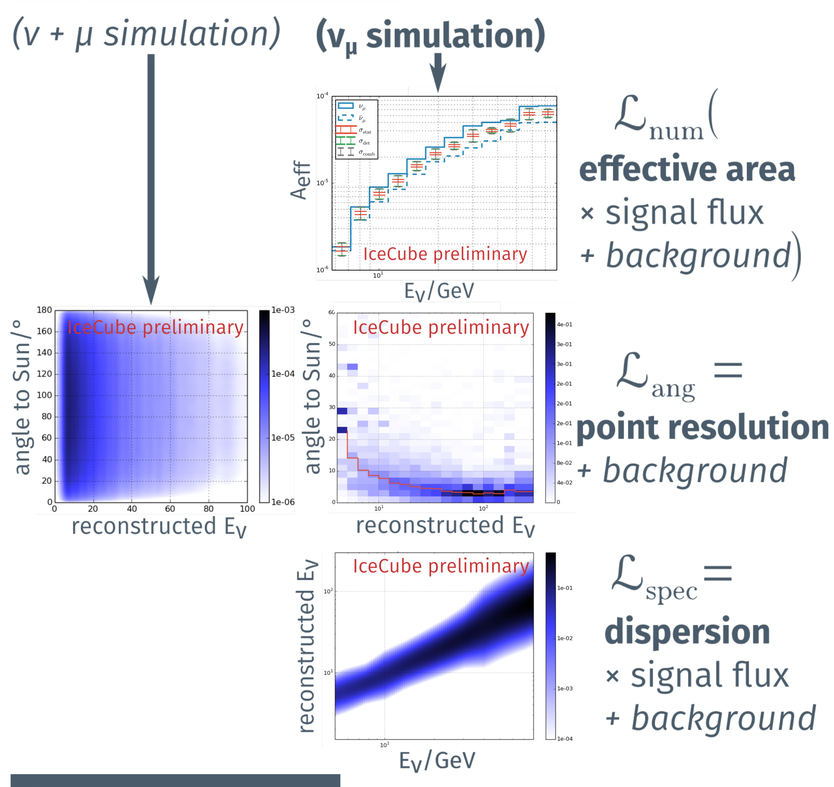
$$\mathcal{L}_{\text{total}}(n_{\text{tot}}, D|M) = \mathcal{L}_{\text{num}} \prod_i \mathcal{L}_{\text{ang},i}\,\mathcal{L}_{\text{spec},i}$$

We updated the implementation for PINGU, as shown on the right. Originally, limits were computed with $\mathcal{L}_{\text{num}}$, using only event rates and systematics. We follow the same principle but switch to the **CLs-method**, which includes a more detailed treatment of systematic uncertainties.

$$\mathcal{L}(\mu, s', b', \eta_j) = \left[\frac{(\mu s + b)^N}{N!}\, e^{-(\mu s + b)}\right] f(s')\, f(b') \prod_j g(\eta_j)$$

This method is implemented numerically in the **OpTHyLiC** software.

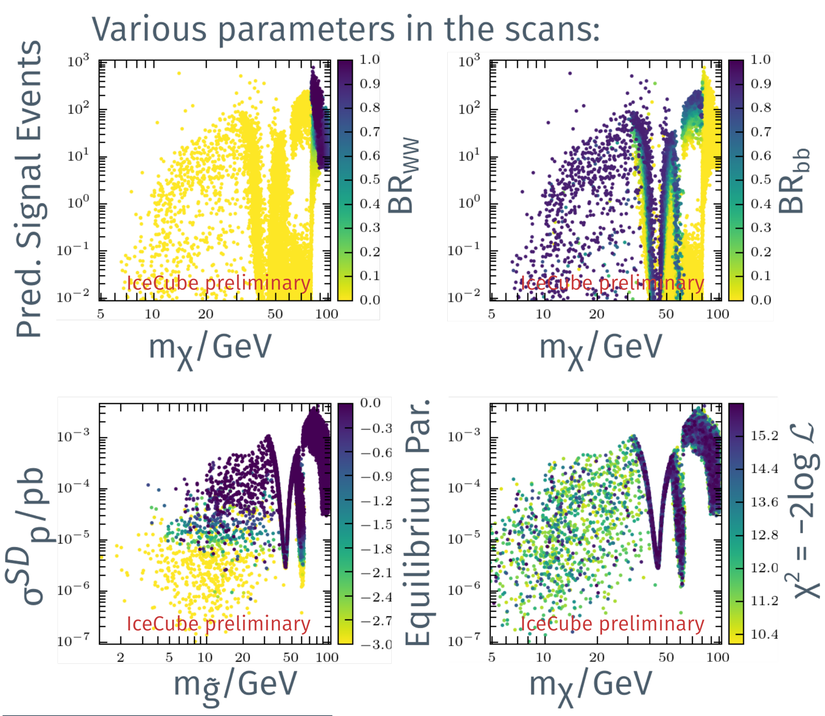
Implementation



Results

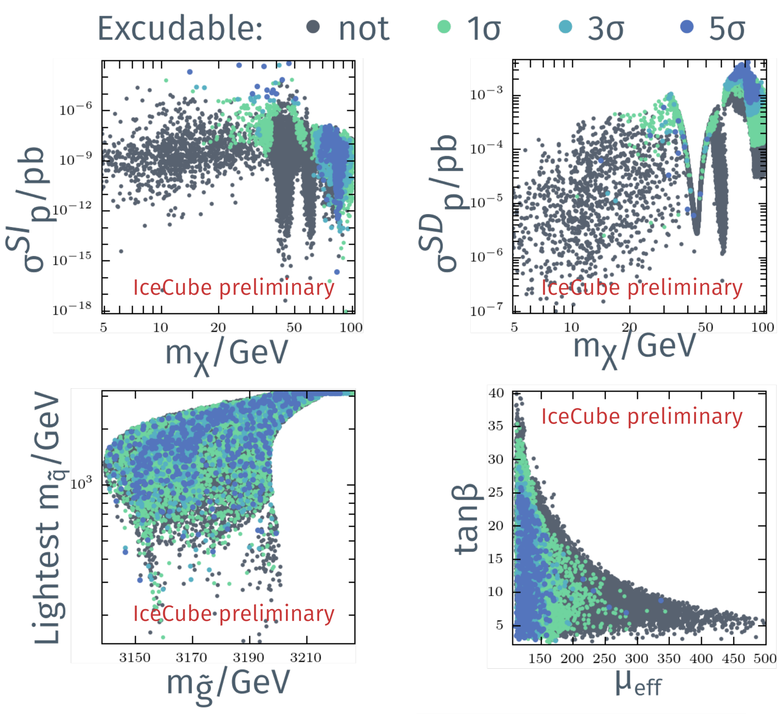
Parameters

Various parameters in the scans:



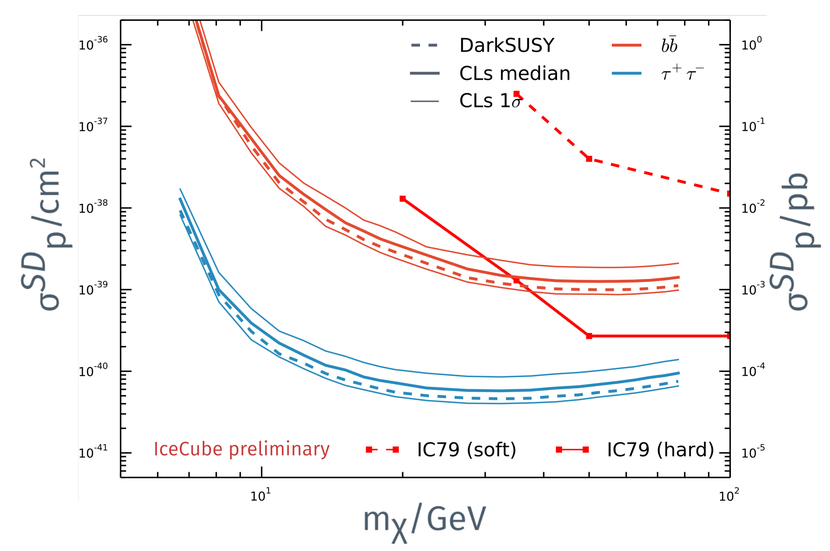
One-year Sensitivities

Excudable: not 1σ 3σ 5σ



Curves

We also apply the method on scans of **phenomenological models** which assume annihilation into one single channel. This yields limits in scattering cross section vs. WIMP mass, as traditional searches do.



Conclusions

Many physically viable models of supersymmetric dark matter in the context of the NMSSM wait to be excluded below the energy threshold of IceCube-DeepCore. Lowering this threshold with the addition of PINGU lets us delve deeper into the NMSSM parameter space. After one year of observation focussing on neutrinos from the Sun, many of those models predicting WIMP masses as low as 30 GeV are excludable at 3σ, and numerous models down to 50 GeV at 5σ.

Literature

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