The search for secluded dark matter with the IceCube neutrino telescope

...

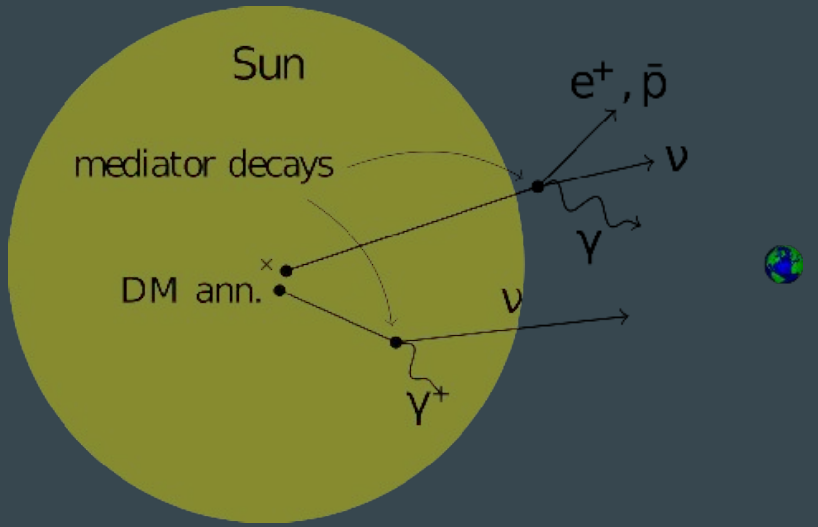
Christoph Tönnis 18.5.2021
for the IceCube Collaboration
VLVnT 2021 Valencia

성균관대학교
SUNG KYUN KWAN UNIVERSITY(SKKU)

IceCube
South Pole Neutrino Observatory

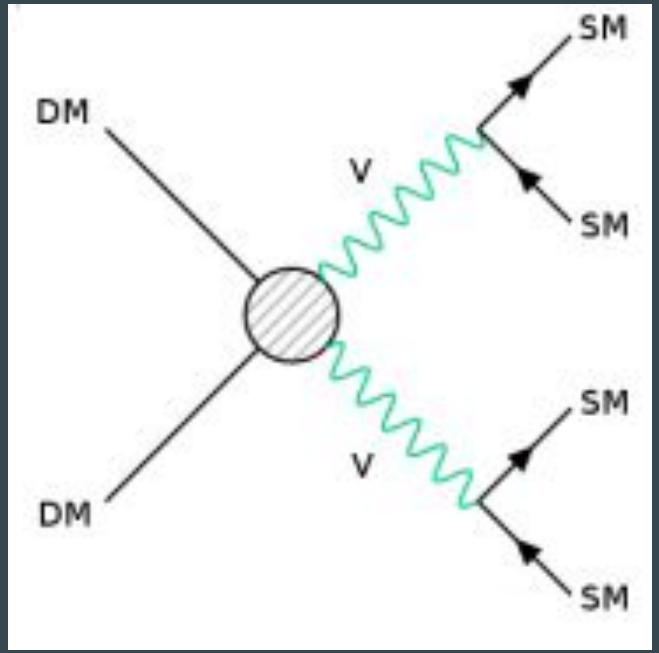
Secluded dark matter

- Secluded dark matter is a unique type of model for dark matter
- In this model Dark matter particles do not directly decay or annihilate into standard model particles
- Instead in dark matter annihilations metastable mediators are produced
- After a lifetime that can range from microseconds to 10 seconds the mediator decays into some standard model particle
- This mediator is itself not a standard model particle and can avoid interactions with baryonic matter
- In case of annihilations of dark matter accumulated in the Sun absorption in the solar plasma can be avoided



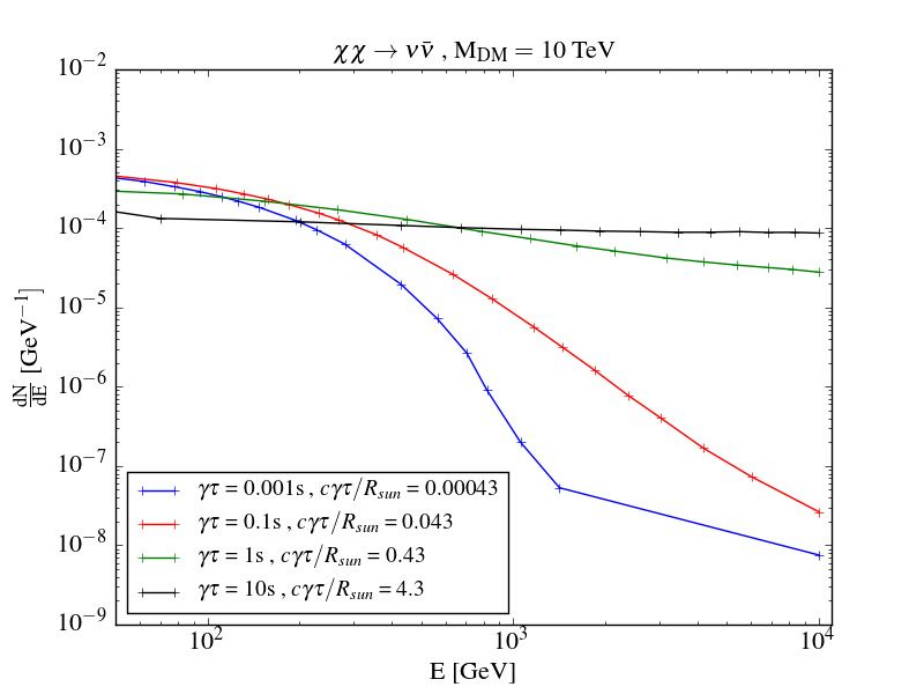
Theoretical motivation

- Secluded dark matter is theoretically well motivated
  - Can explain the positron excess detected in PAMELA, AMS-II and FERMI (F. Chen, J. M. Cline, A. R. Frey, Phys. Rev. D 80 (2009) 083516.)
  - Many dark matter models naturally include a mediator like dark photons or Z' models (M. Pospelov, A. Ritz and M. B. Voloshin, Phys. Lett. B 662 (2008) 53. ; I. Z. Rothstein, T. Schwetz and J. Zupan, JCAP 07 (2009) 18.)
  - Secluded dark matter models decouple dark matter scattering and annihilation and allow to explain accelerator results



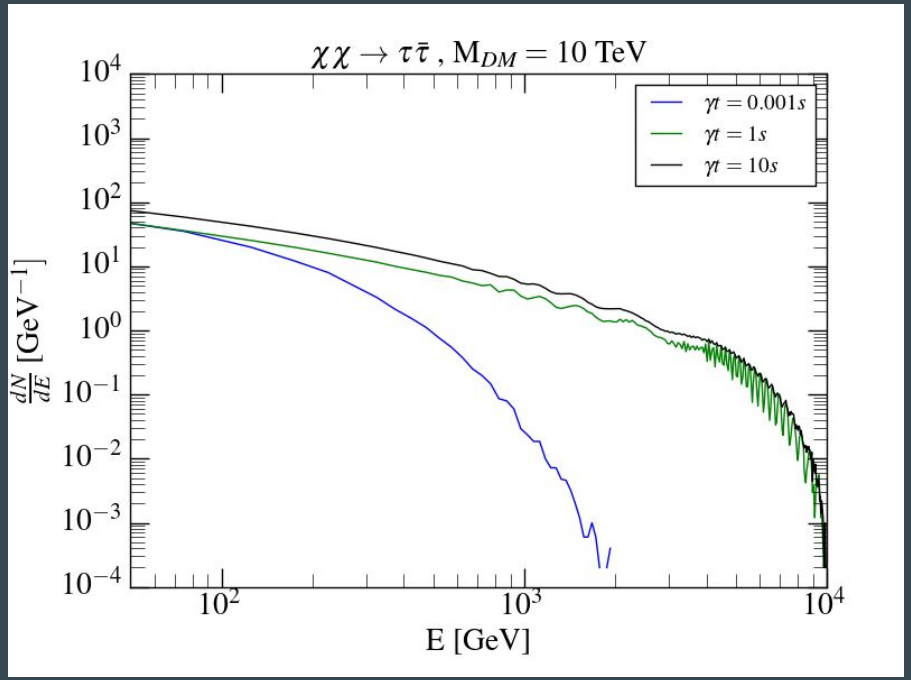
This analysis

- This analysis looks for secluded dark matter in the Sun
- Due to absorption in the Sun neutrino signals are strongly reduced at all energies
- Beyond 1 TeV of energy almost all neutrinos are being absorbed
- For lifetimes above 2.3 s mediators generated by dark matter in the Sun will escape the Solar plasma before decay
- In such a case the neutrino signal would be significantly enhanced, especially at energies above 1 TeV



WIMPSIM spectra

- Spectra have been generated for dark matter masses of up to 75 TeV and cover dark matter decays into W-bosons, neutrinos, tau leptons and bottom quarks
- Different masses of the mediator ranging from 1 GeV to 1 TeV were simulated
- Mediator lifetimes ranging from 1 ms to 10s were simulated
- The spectra include effects from neutrino oscillations



Method

- An unbinned likelihood method is used
- The likelihood function has the following shape:

$$\mathcal{L}(n) = \prod_{i=0}^{N} \left(\frac{n}{N} S(\psi_i, E_i) + \frac{N-n}{N} B(\psi_i, E_i) \right)$$

- N is the sample size, S describes the signal behaviour as a function of the angular separation of an event to the Sun ψ_i and its energy E_i for event number i. B is the corresponding function describing the background.
- The background part of the likelihood is generated from time scrambled background
- Using this likelihood the IceCube northern tracks sample from 2011 to 2016 with 1057.8 days of livetime is being analysed

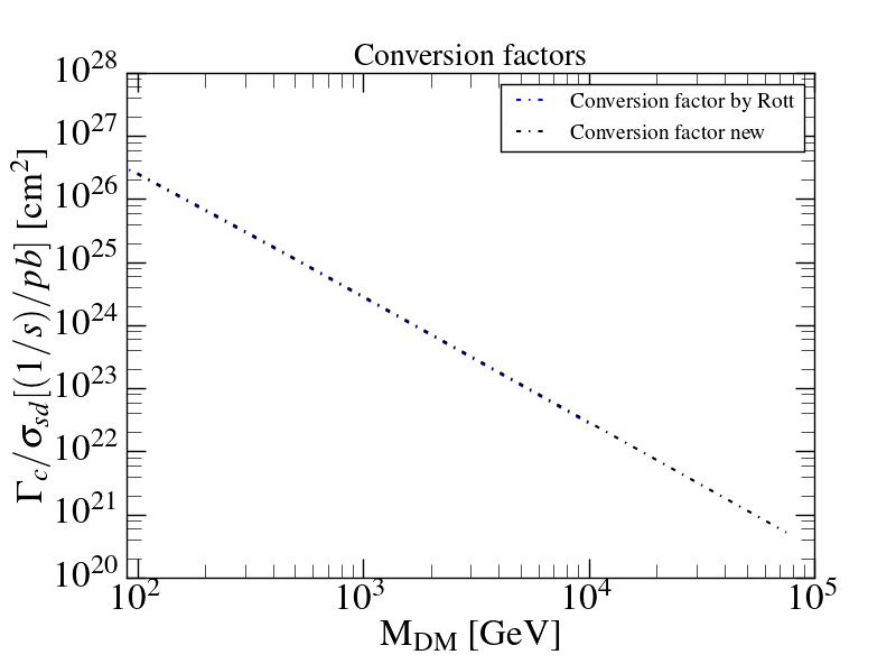
Sensitivity conversion

- This analysis seeks out to detect dark matter or, in the case of a null result, to restrict dark matter model parameters
- In the case of the latter and to compute sensitivities a conversion from neutrino fluxes to dark matter-nucleon scattering
- First neutrino fluxes Φ_ν are converted to annihilation rates with the equation

$$\Gamma_{ANN} = \Phi_\nu \frac{4\pi r_{Sun}^2}{\int \frac{dN}{dE} dE}$$

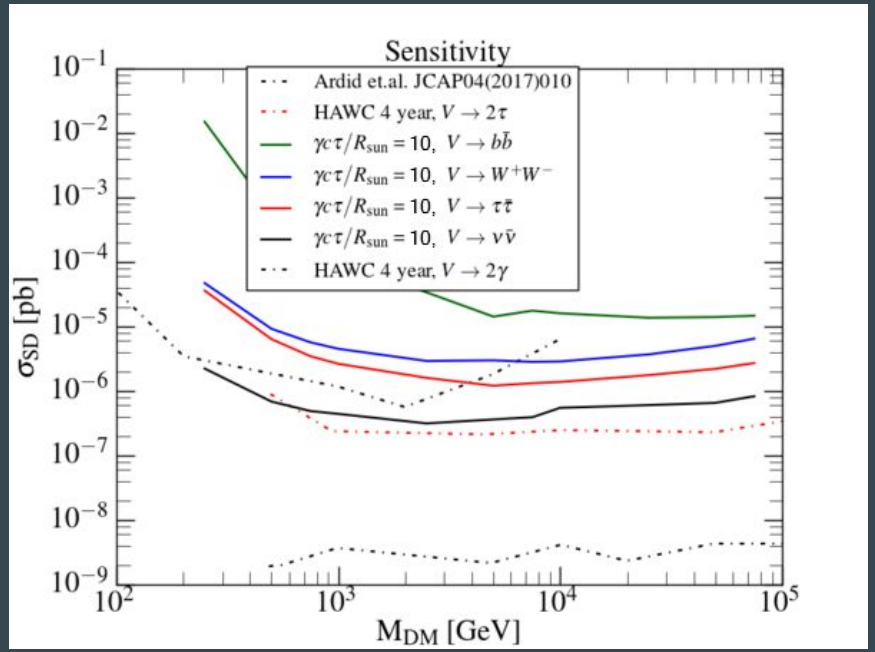
- r^2_{Sun} is the radius of the earth's orbit and the integral over the neutrino spectrum dN/dE is the number of neutrinos generated per annihilation
- The annihilation rate can be related to dark matter nucleon scattering assuming an equilibrium between dark matter capture in the Sun and using conversion factors calculated with the DarkSUSY simulation package

Conversion factors



- For the preliminary sensitivities conversion factors calculated by Rott et.al. (JCAP09(2011)029) have been used
- These did only extend to 10 TeV and further factors were needed to cover the range until 75 TeV
- On the left the conversion factors that were generated last year are shown in comparison to those generated by Rott et.al.
- They align exactly with the factors calculated by Rott et. al. since the same simulation code (DarkSUSY) was used

Sensitivities



The above sensitivities assume a mediator mass of 100 GeV

Summary

- The First sensitivities for secluded dark matter have been generated analysing 6 years of IceCube data
- The results surpass those of other neutrino experiments
- The analysis is to be unblinded in the foreseeable future
- An extension of the analysis to 9 years of data is planned