

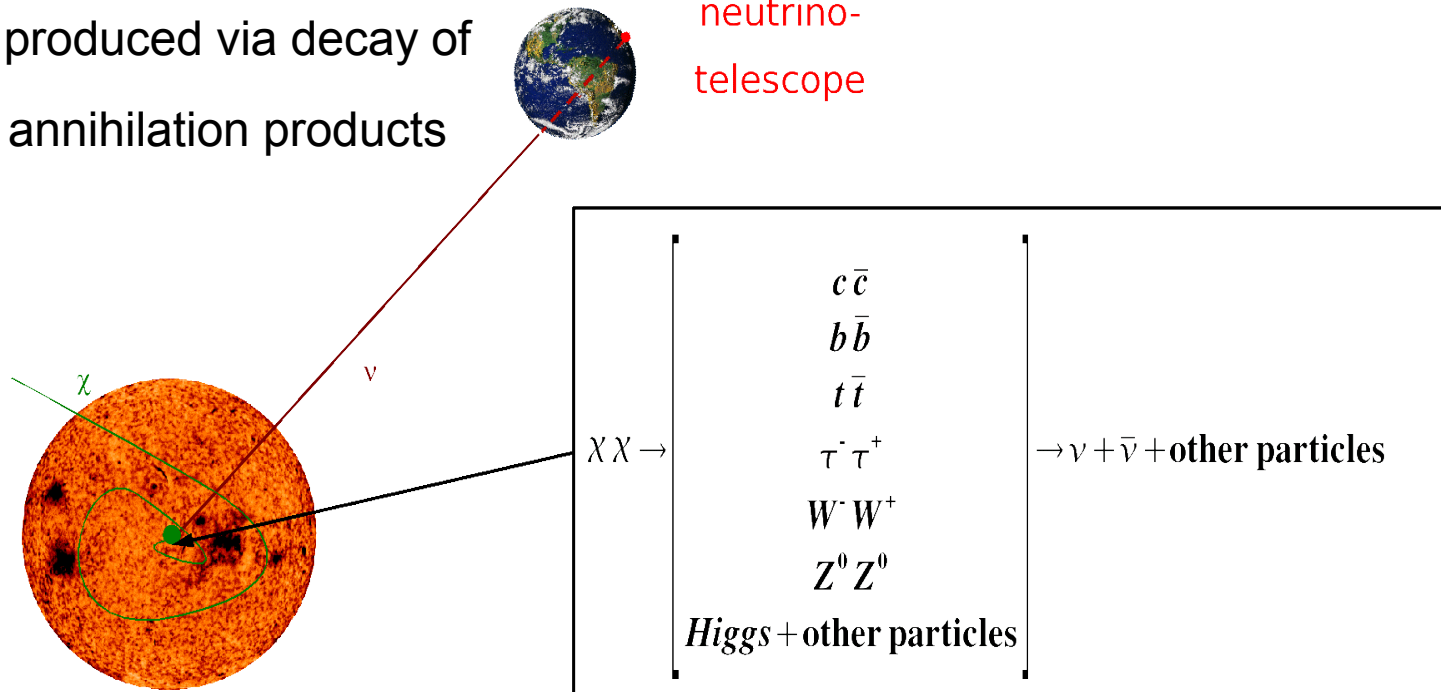
Indirect Dark Matter Search with the ANTARES Neutrino Telescope



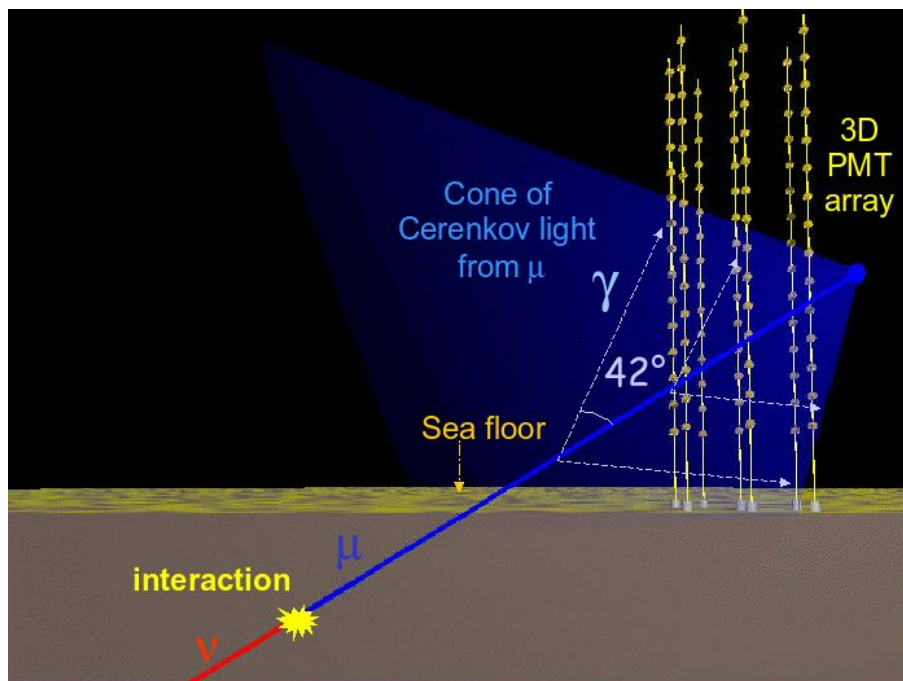
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University of Erlangen-Nuremberg
GDR Terascale@Heidelberg, 15.10.2009

Indirect Dark Matter Search with NT

- WIMPs scatter elastically on and get gravitationally bound to massive stellar objects like **Sun** and Earth
- Resulting increase of WIMP density enhances rate of WIMP self-annihilation
- Neutrinos produced via decay of primary annihilation products



Neutrino Telescope: Detection Principle

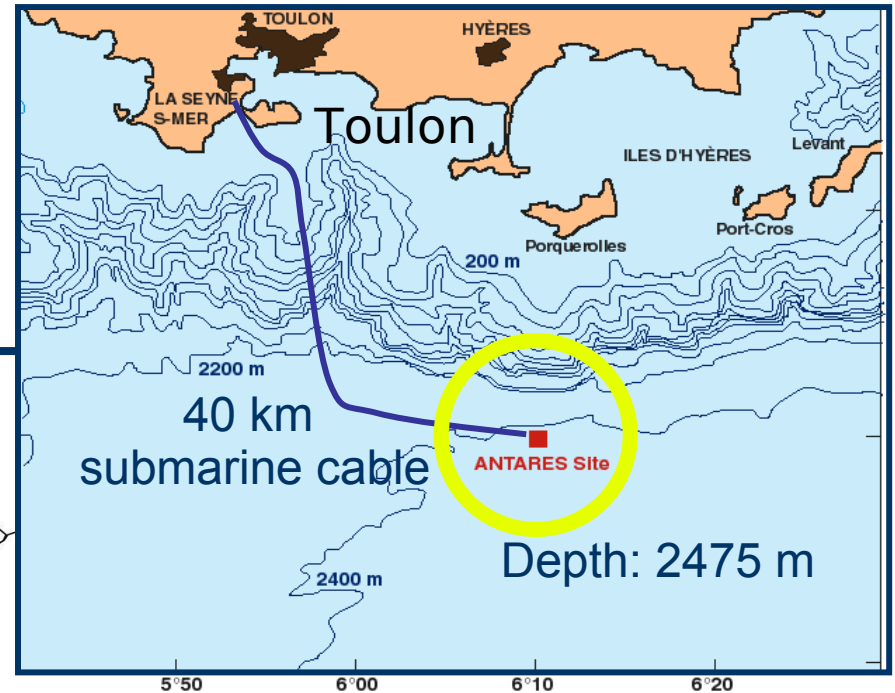
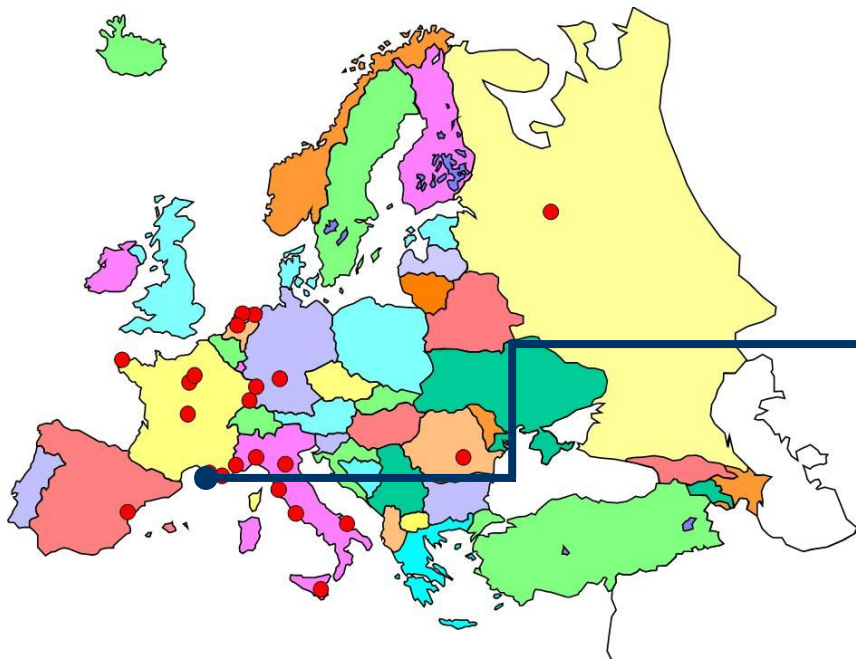


- Neutrinos can penetrate Earth
- CC interaction in the vicinity of the detector => muon with (almost) same trajectory
- Muon emits Cerenkov light when traversing water
- Position and time of Cerenkov photons detected allow reconstruction of muon path

The ANTARES Collaboration and Site

24 Institutes from 7 Countries

Detector located in Mediterranean
near Toulon at 2475 m depth (to
shield from atmospheric muons)

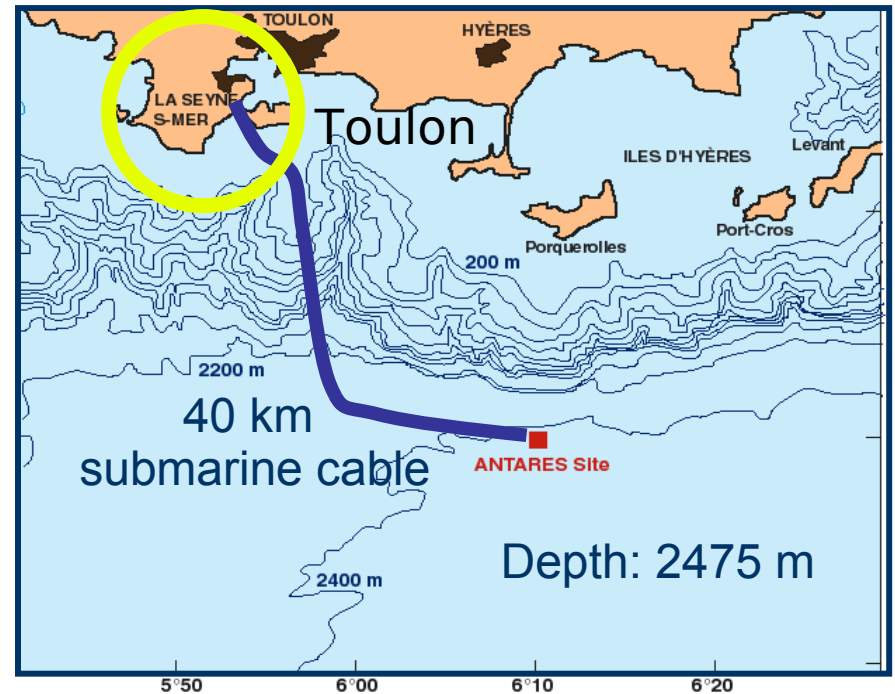


The ANTARES Collaboration and Site

Shore Station “Michel Pacha” in
La Seyne sùr Mer

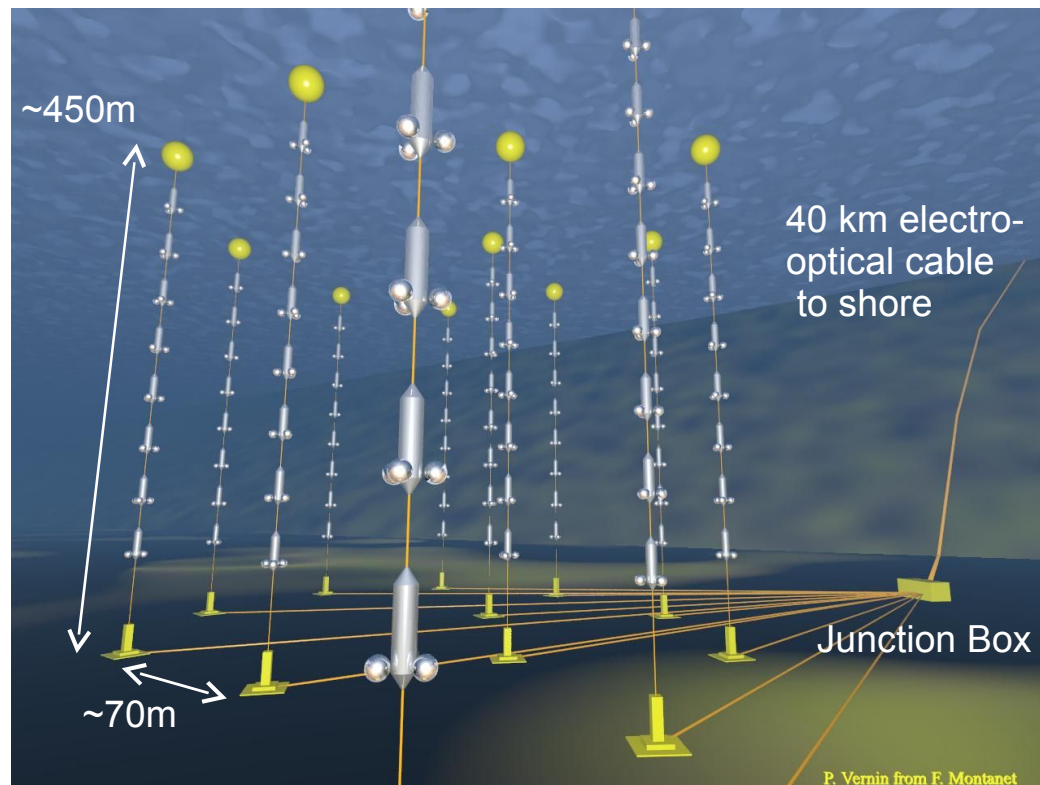
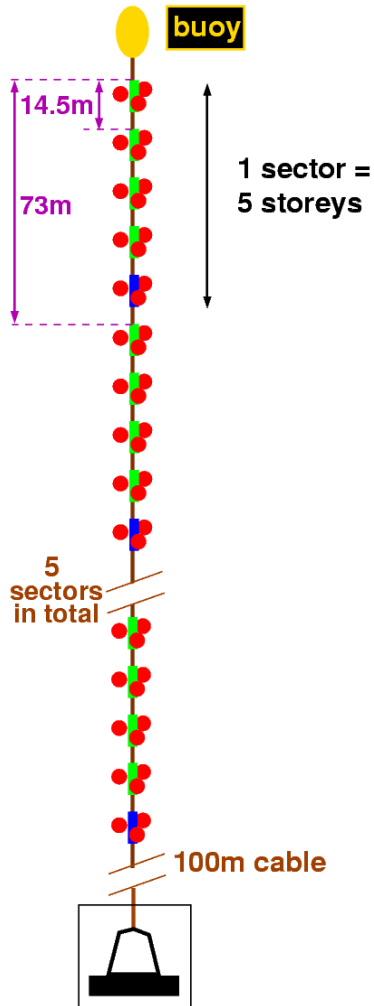


40km electro-optical cable for power
and data transmission

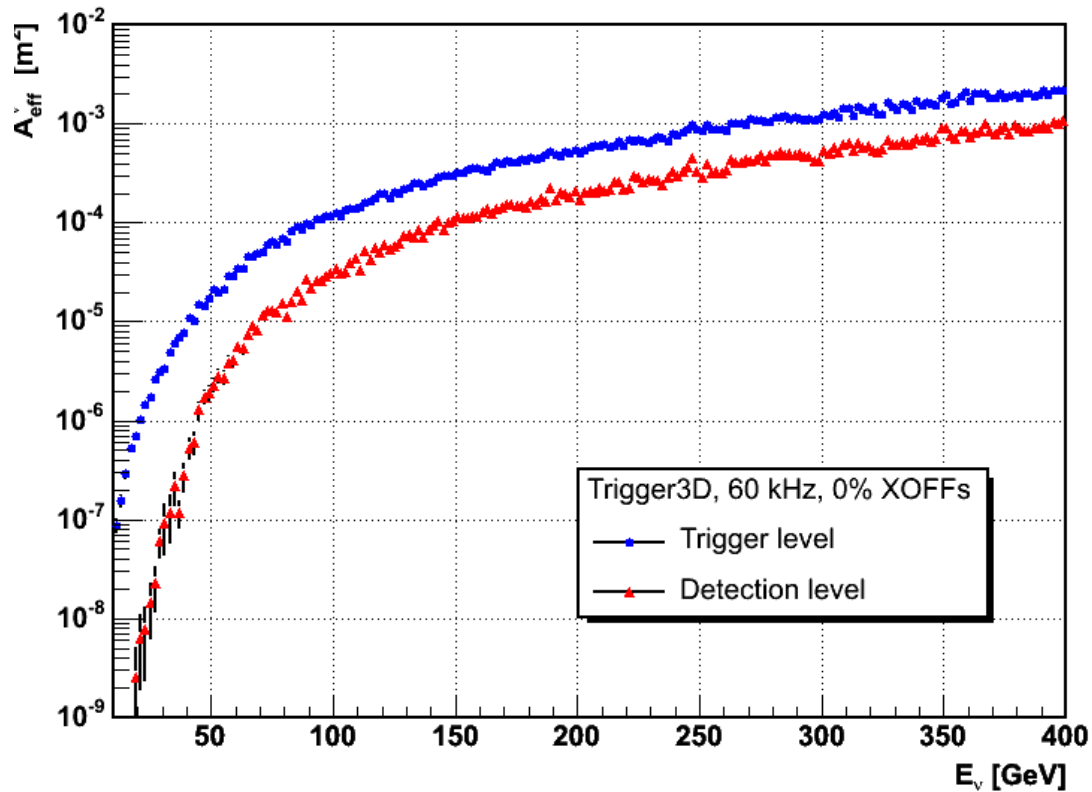


The ANTARES Detector

- 12 Lines + IL, $\sim 0.1\text{km}^2$ geometric area
- Each line: 25 storeys with 3 PMTs per storey
- 12-Line detector now complete (mid-2008)
- Data from ANTARES 5-Line (2007) has been analysed



ANTARES Neutrino Effective Area in the low-energy regime

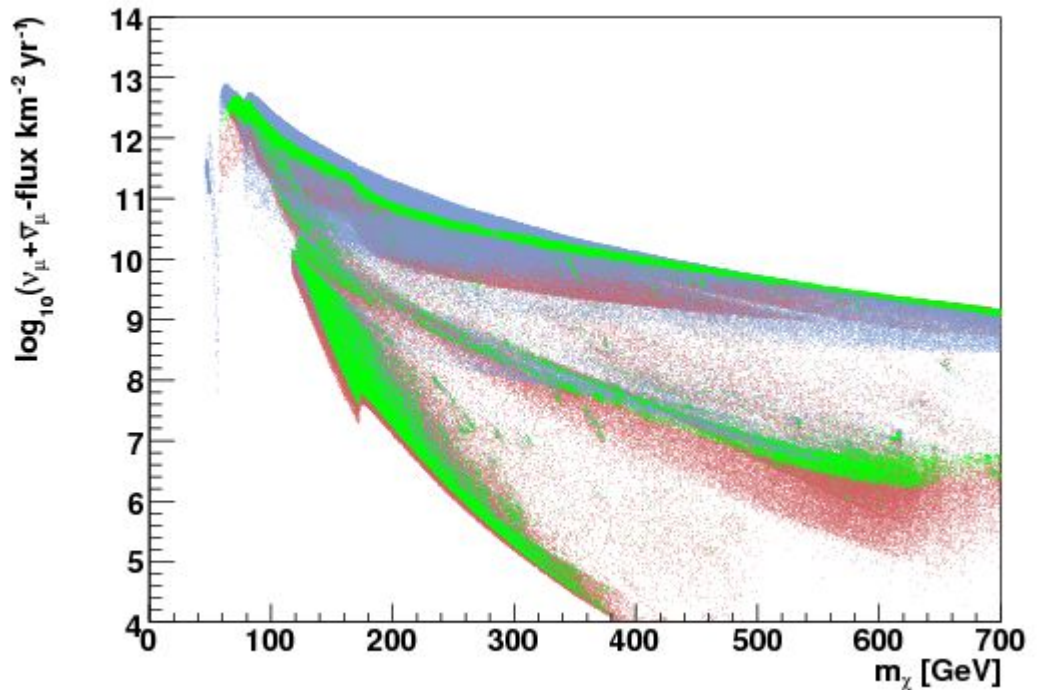


ANTARES Low-Energy Effective Area

60 kHz background rate from K-40 decay and bioluminescence

Neutrino Flux from mSugra Dark Matter Annihilation in the Sun

- Integrated ν_μ and $\bar{\nu}_\mu$ flux with 10 GeV threshold neutrino energy plotted against m_χ
- From random walk scan of mSugra Parameter Space (four parameters, one sign) guided by relic density compared to WMAP
- Calculated with DarkSUSY
- Includes oscillation effects in matter (MSW) and vacuum
- RGE-code: ISASUGRA



Relic density of mSugra models

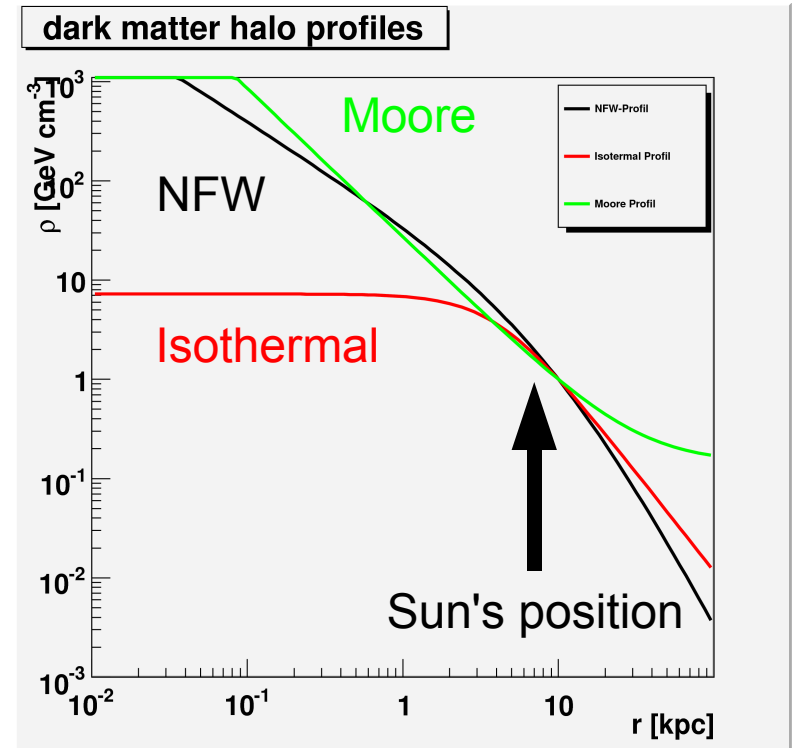
● WMAP favoured (2 sigma)

● lower than WMAP

● higher than WMAP

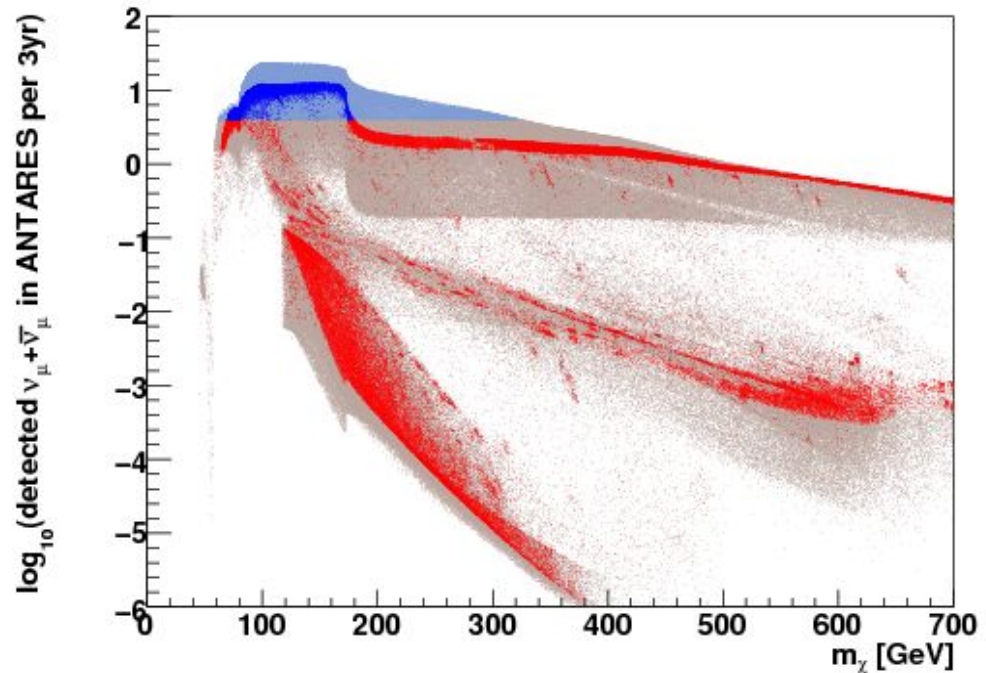
Influence of Galactic Halo Structure

- Various parameterizations of Halo but at Sun's position most have Neutralino density $\sim 0.3 \text{ GeV/cm}^3$
- Possible clumpiness averaged by capture in Sun
- Navarro-Frenk-Whit profile used



Detection Rate from mSugra Dark Matter Annihilation in the Sun

- Sensitivity calculated for three years of taking data
- Unified approach of Feldman-Cousins used
- Background from atmospheric neutrinos and misreconstructed atmospheric muons
- 3° radius search cone



mSugra models favoured by WMAP

● 90% CL excludable by ANTARES

● not excludable

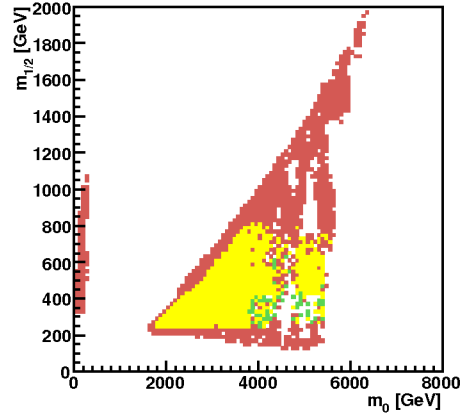
mSugra models disfavoured by WMAP

● 90% CL excludable by ANTARES

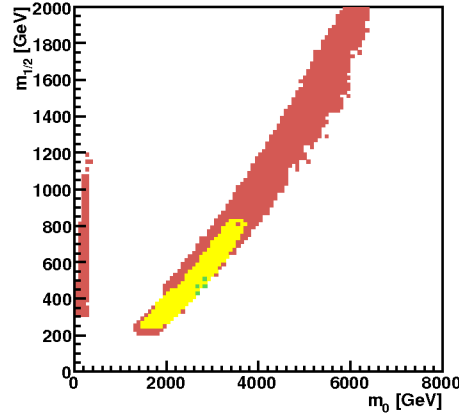
● not excludable

Exclusion Capabilities Parameter Space

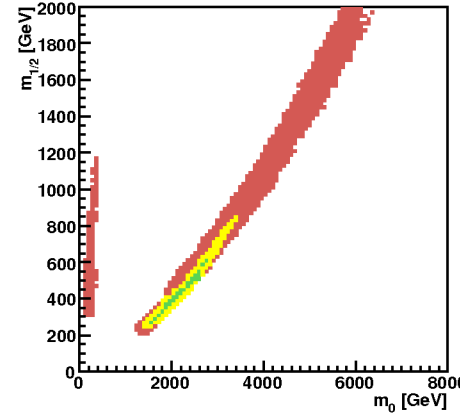
$0 < \tan\beta < 10$



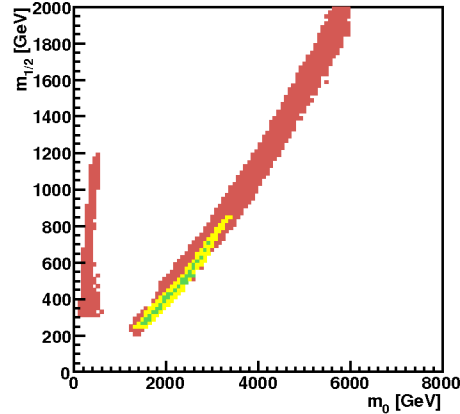
$10 < \tan\beta < 20$



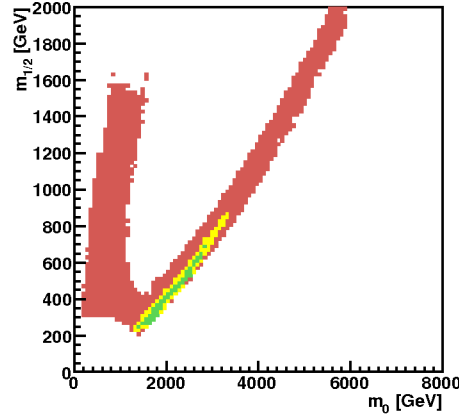
$20 < \tan\beta < 30$



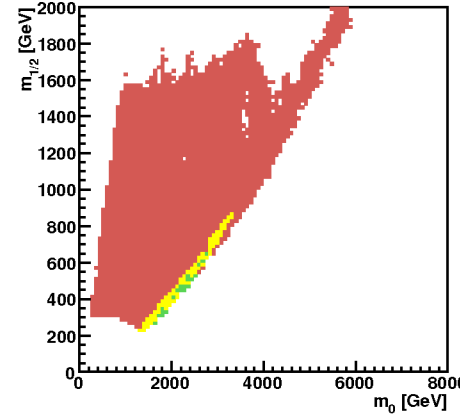
$30 < \tan\beta < 40$



$40 < \tan\beta < 50$



$50 < \tan\beta < 60$



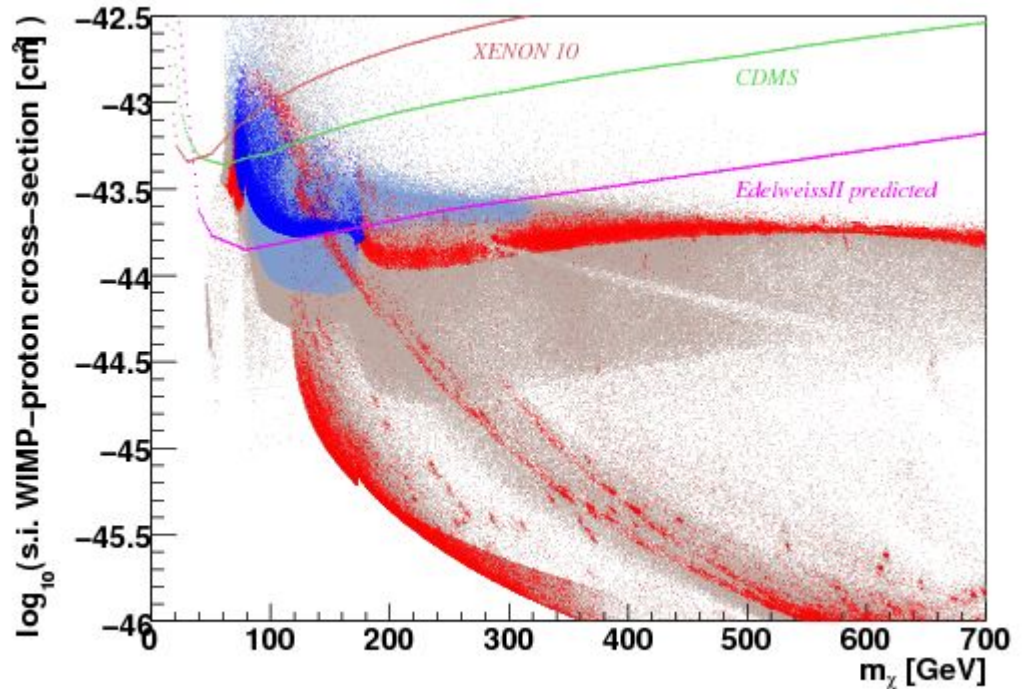
Excludable in 3 years at 90% CL: **all** **some** **none**
(A_0 varied between $-3m_0$ and $+3m_0$ and $\tan(\beta)$ within indicated slice)

Direct Detection SI

- Comparison to direct detection experiments sensitive to spin-independent WIMP-nucleon cross-section

CDMS: arXiv:0802.3530

XENON: arXiv:0706.0039



mSUGRA models favoured by WMAP

● 90% CL excludable by ANTARES

● not excludable

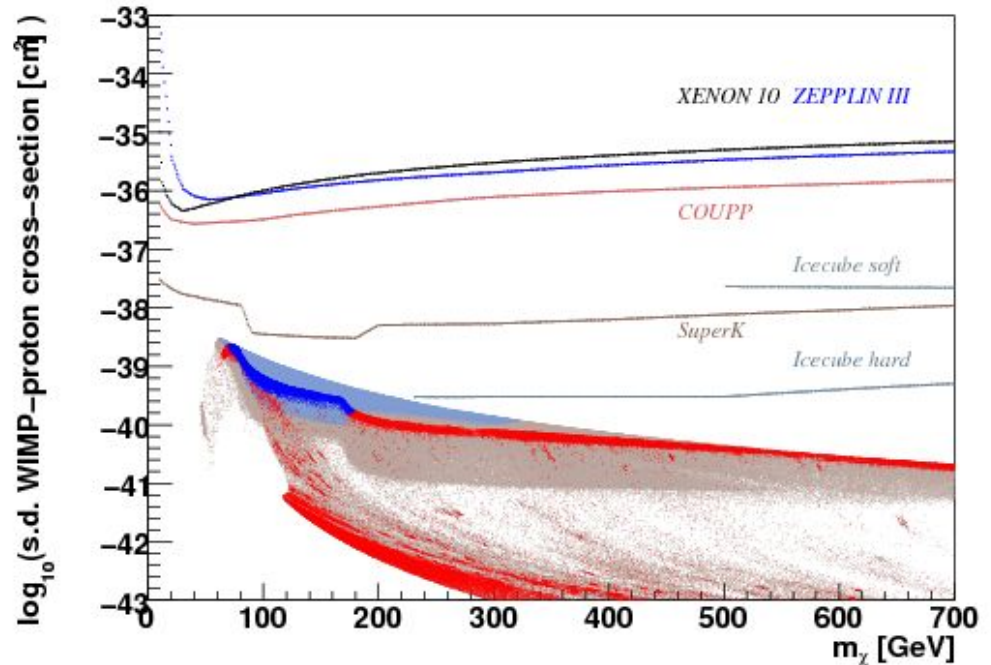
mSUGRA models disfavoured by WMAP

● 90% CL excludable by ANTARES

● not excludable

Direct Detection SD

- Comparison to direct detection experiments sensitive to spin-dependent WIMP-nucleon cross-section and other indirect detection experiments
- Almost direct relation since annihilation rate tied to WIMP interaction with hydrogen in the Sun



mSugra models favoured by WMAP

● 90% CL excludable by ANTARES

● not excludable

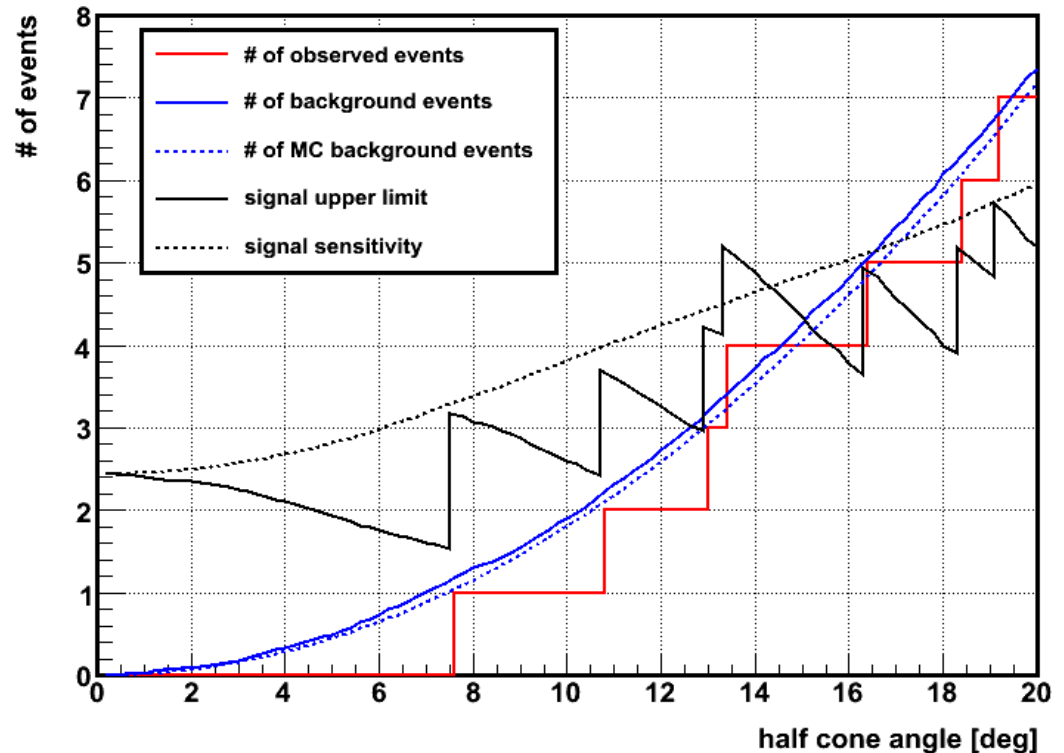
mSugra models disfavoured by WMAP

● 90% CL excludable by ANTARES

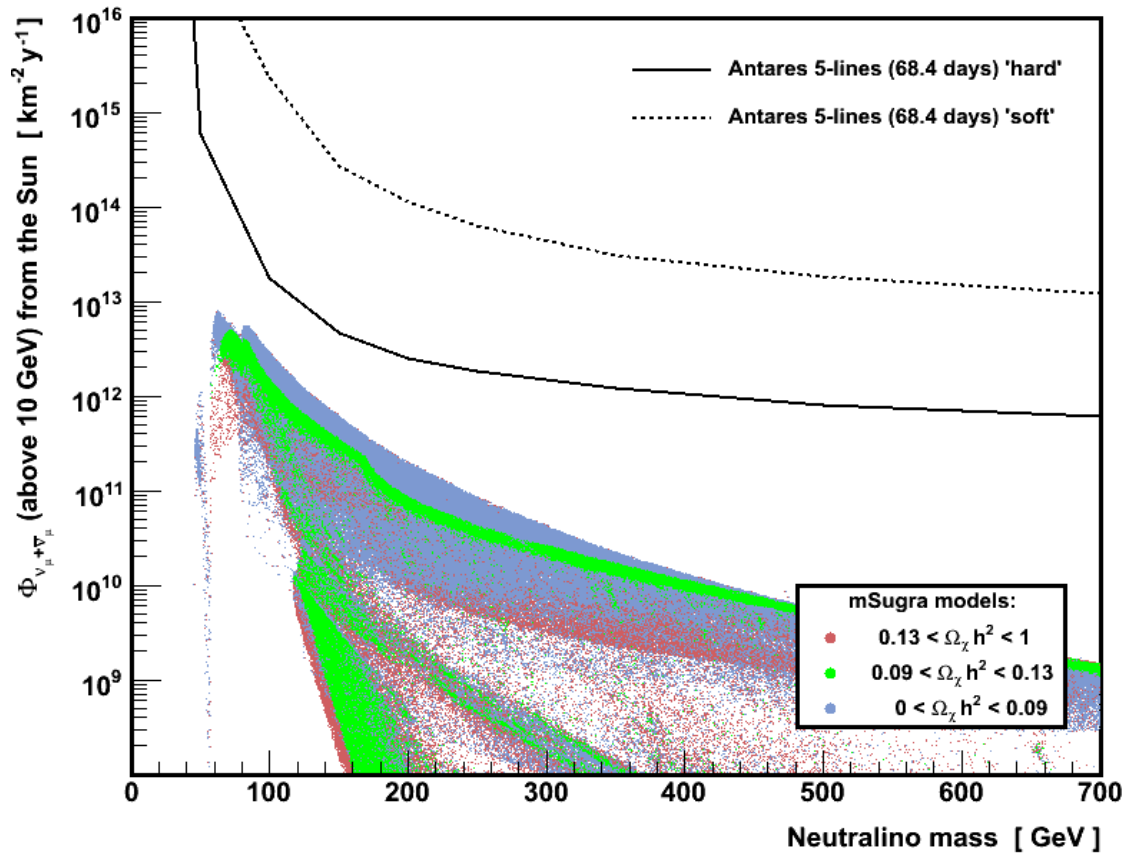
● not excludable

First Limit from ANTARES 5-Line (Sun)

- Reconstructed neutrinos from an effective lifetime of 68.4 days as a function of angular distance from Sun's direction
- Consistent with background estimation from both full sky measurement and MC
- Search cone for actual limit optimized from MC prior to analysis for different neutralino masses and hard/soft neutrino energy spectrum

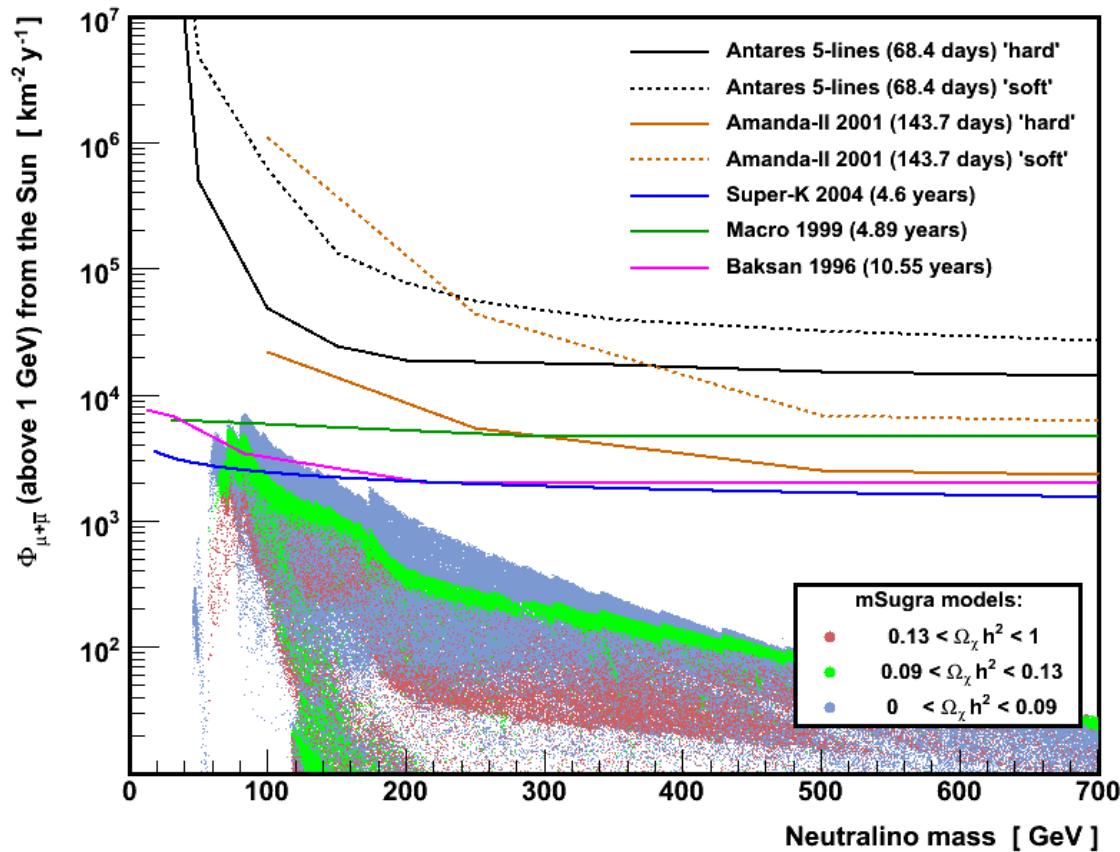


First Limit from ANTARES 5-Line (Sun)



- Limits for soft (b-quark) and hard (W-boson) annihilation channel
- mSugra parameter space not yet reached

First Limit from ANTARES 5-Line (Sun)



- Competitive limit given the short time of measurement
- Only 5/12 of the final detector used

Summary

- First limit from ANTARES 5-Line data
- mSugra parameter space (Focus Point Region) accessible to ANTARES in 3 years
- Complementary method of SUSY/dark matter search to direct detection and LHC
- Sensitivity to other SUSY scenarios (pMSSM, AMSB) and Kaluza-Klein DM is being studied
- Galactic Centre and Earth also under investigation