Suche nach Dunkler Materie mit ANTARES und KM3NeT

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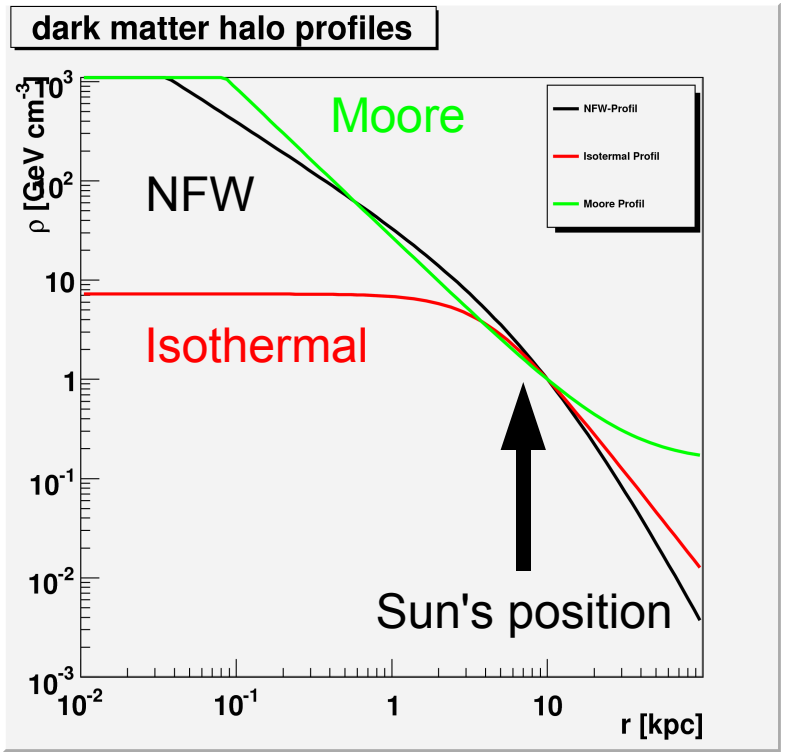
Supersymmetry

- SUSY Operator Q: boson => fermion / fermion => boson
- Creates spectrum of additional particles
- Most simple: Minimal Supersymmetric Standard Model (MSSM):
- N=1 SUSY (use Q only once) – double number of particles
- Names: just add s- for new bosons (e.g. selectron) and -ino for new fermions (e.g. Wino)
- Why? - Solve fine tuning problem (loop corrections to Higgs mass cancel naturally)
- Problem: No SUSY particles detected (or even seen directly)
- Solution: SUSY must be broken (higher masses)
- But not too much (“soft breaking”) to still cancel loop terms

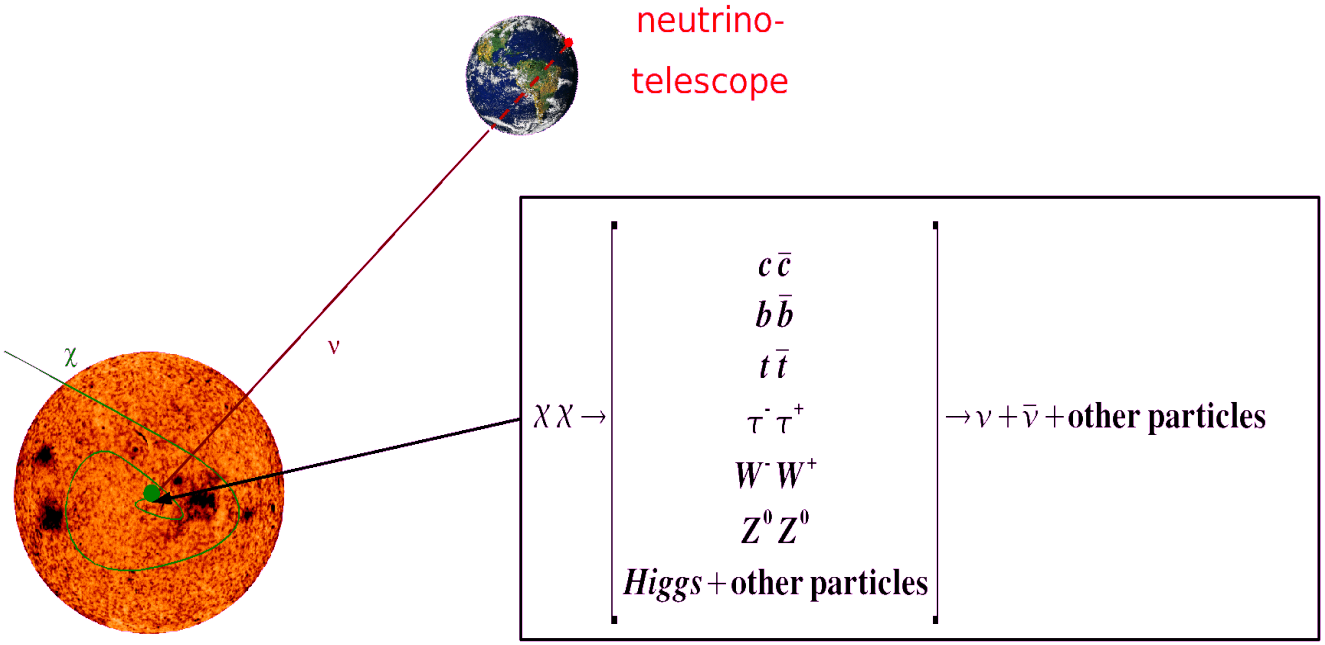
Supersymmetric Dark Matter & Galactic Halo

- Neutralino possible LSP
- Created in the early universe
- Stable because of R-Parity => still there (but two can annihilate)
- Dark Matter drives structure formation
- Galaxies have halos of Dark Matter
- Various parameterizations of Halo but at Sun's position all have Neutralino density ~ 0.3 GeV/cm³

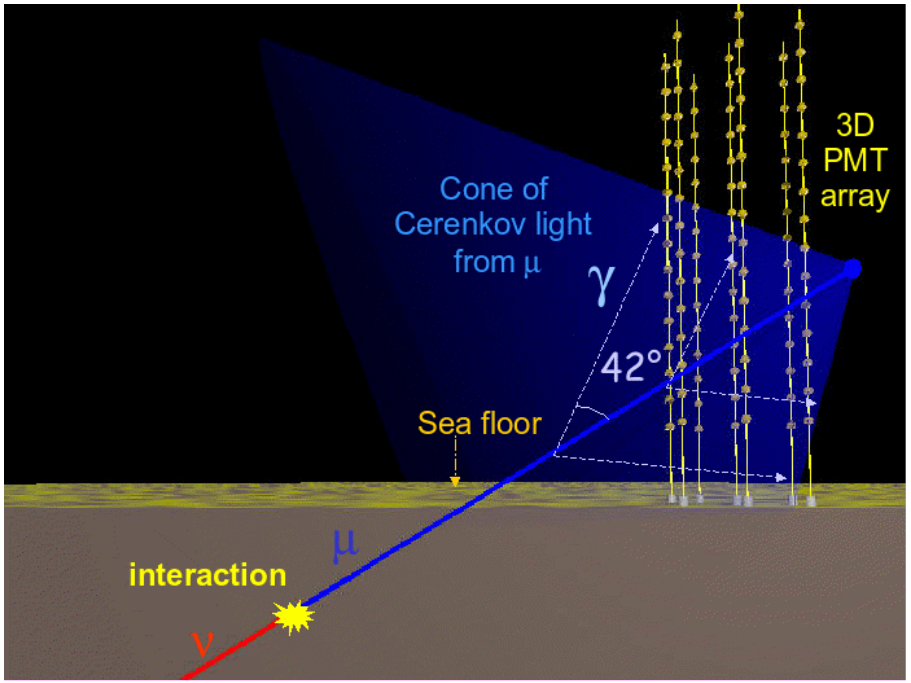


Indirect Search for Dark Matter

- Neutralinos annihilate => primary annihilation products (quarks, gauge bosons, leptons) decay into neutrinos
- Could look at halo directly, but we can do better because...
- Elastic scattering => Wimps bound to massive stellar objects (Sun)
- Increase of Neutralino density => Annihilation rate enhanced



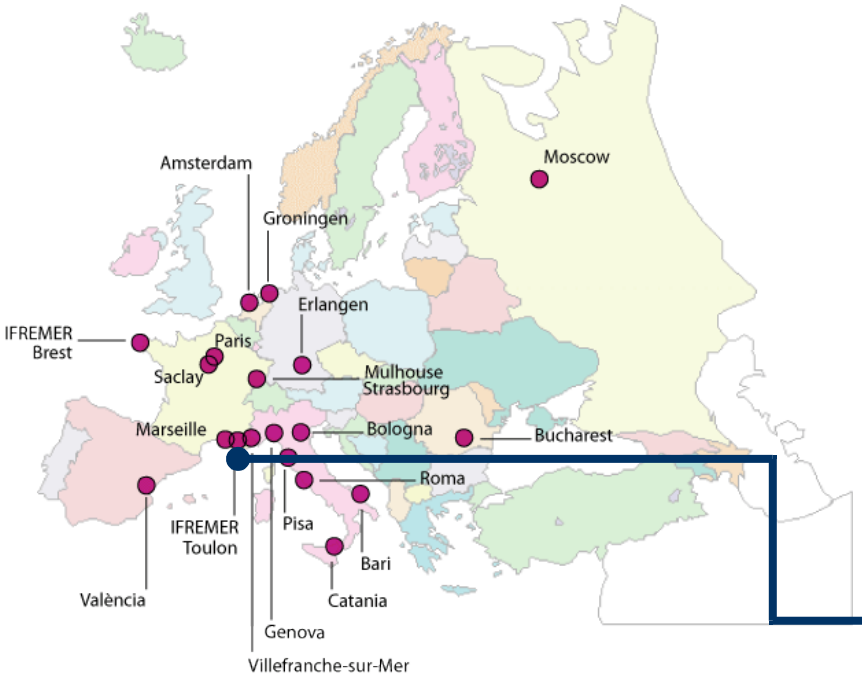
Neutrino Telescope: Detection Principle



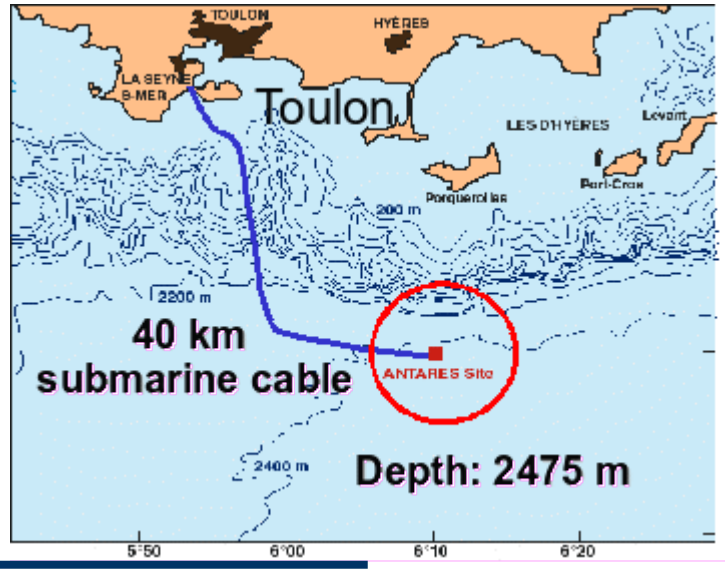
- Neutrinos can penetrate Earth
- CC interaction in the vicinity of the detector => muon with (almost) same trajectory
- Muon emits Cerenkov light when traversing water
- Position and time of Cerenkov photons detected allow reconstruction of muon path

The ANTARES Collaboration and Site

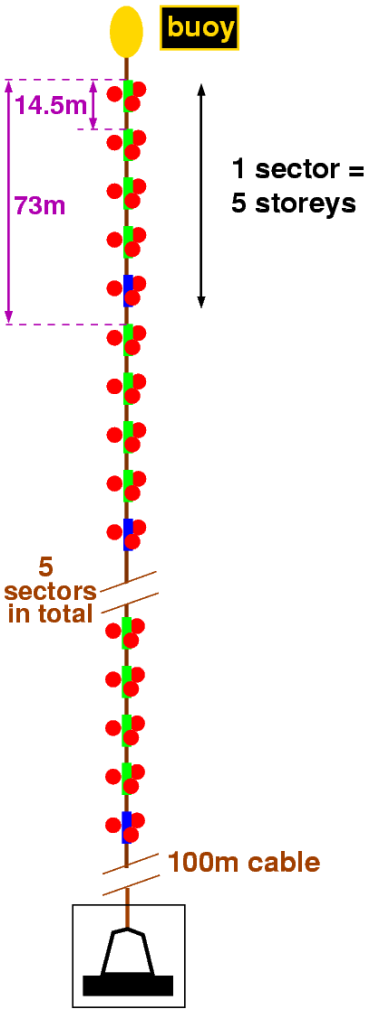
24 Institutes from 7 Countries



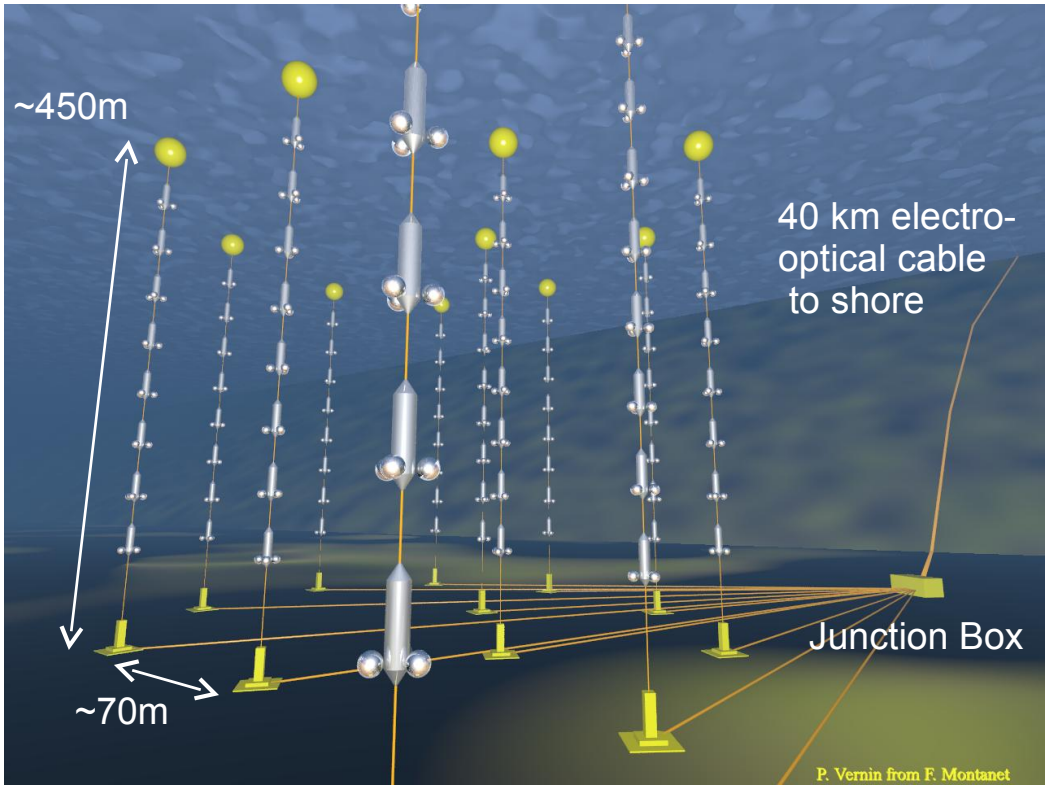
Detector located in Mediterranean near Toulon at 2475 m depth (to shield from atmospheric muons)



The ANTARES Detector



- 12 Lines + IL, all operational since May 30th 2008
- Each line: 25 storeys with 3 PMTs per storey
- 885 PMTs total (one sector acoustic particle detection)



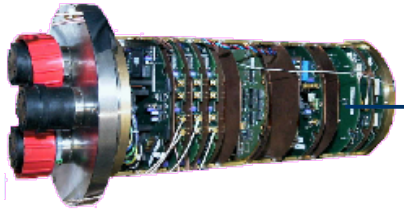
Shore Station

View from the control room

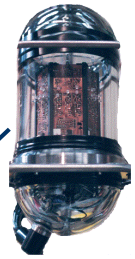
Looks also nice from outside

Detection and Calibration Elements

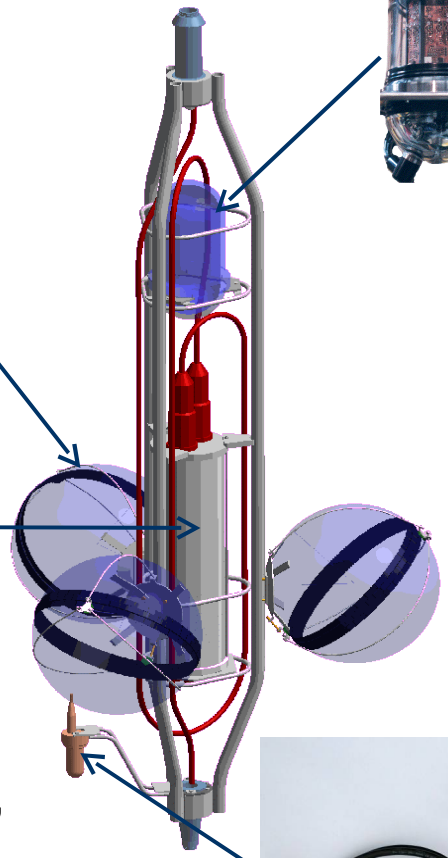
Optical Module
(10” PMT in 17” glass sphere)
photon detection

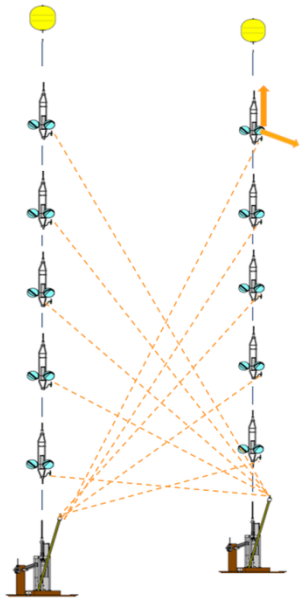


Local Control Module
(in Titanium container)
Front-end ASIC, Clock, DAQ/SC,
Compass and Tiltmeter for
measuring storey orientation

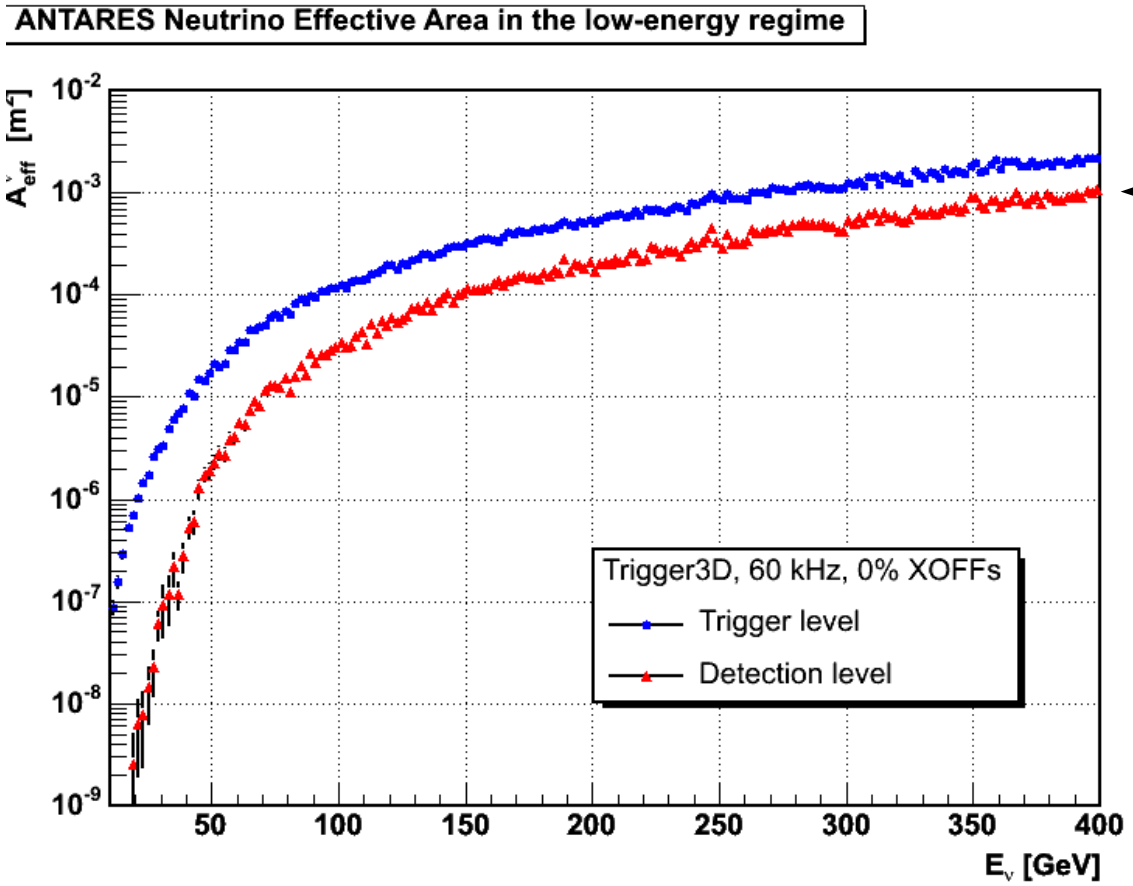


Optical Beacon
with blue LEDs
Timing calibration
(4 per line)





Hydrophone
Storey position by
acoustic triangulation
(5 per line)



10cm²

Effective area:
Equivalent to size of a detector with 100% efficiency

ANTARES Low-Energy Effective Area

60 kHz background rate from K-40 decay and bioluminescence

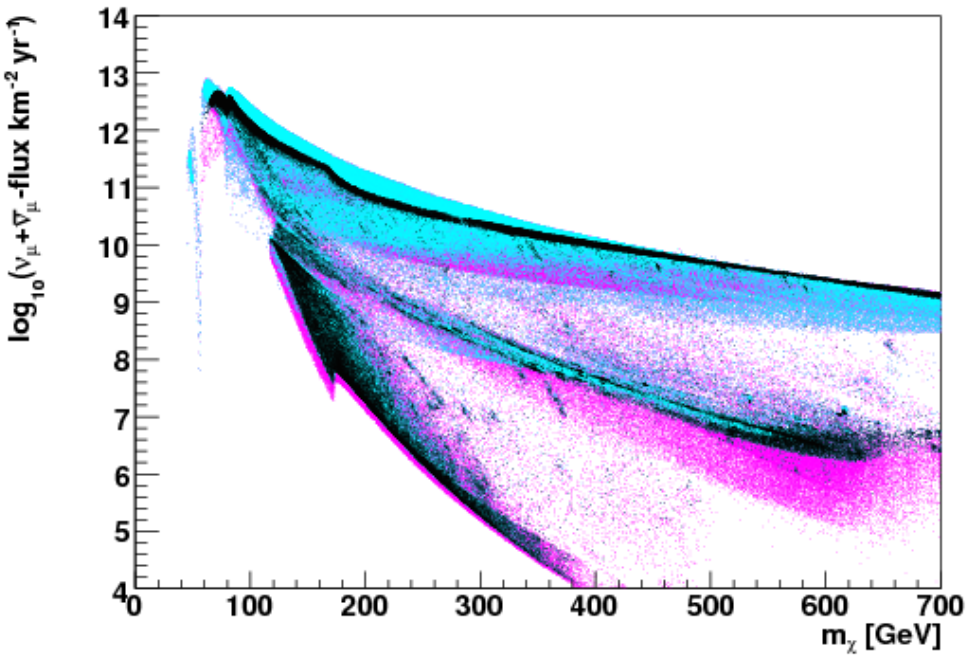
mSUGRA parameter space scan

- Four free parameters + one sign parameter space at GUT scale: m_0 , $m_{½}$, sign (μ), A_0 ,tan (β)
- Dark Matter relic density known from WMAP measurement (2б: $0.094 < \Omega_{CDM}h^2 < 0.129$)
- Calculations based on DarkSUSY
  - Random walk used to scan for WMAP conform models
  - Neutrino oscillations in matter and vacuum included
  - ISASUGRA RGE-code used
  - Top-quark mass 172.5 GeV
  - NFW halo model

Scanned Parameter Space:
$0 < m_0 < 8000$ GeV
$0 < m_{½} < 2000$ GeV
sign (μ) = +1
$-3m_0 < A_0 < -3m_0$
$0 < \tan(\beta) < 60$

mSugra Dark Matter Neutrino Flux

- Integrated ν_μ and $\bar{\nu}_\mu$ flux above 10 GeV threshold energy plotted against m_χ
- ~4 million scanned parameter sets

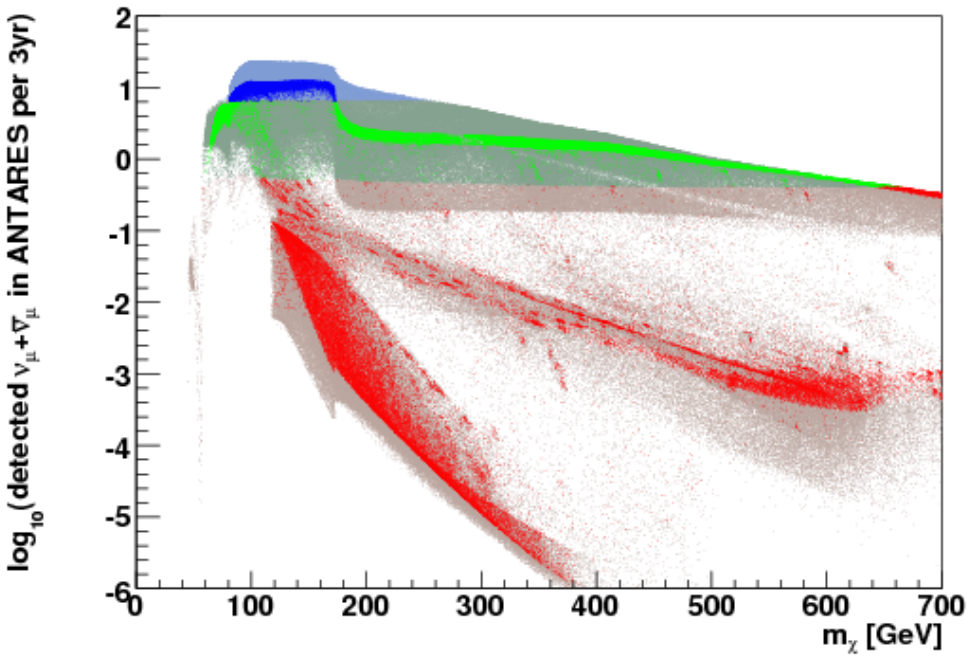


Relic density of mSugra models

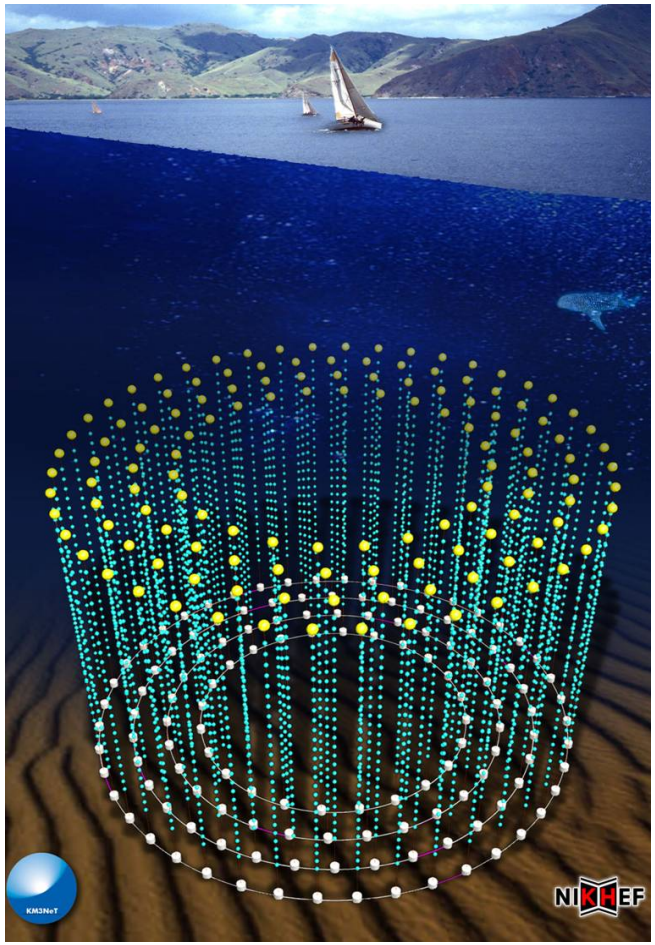
- WMAP favoured (2 sigma)
- lower than WMAP
- higher than WMAP

Detection Rate

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



KM3NeT

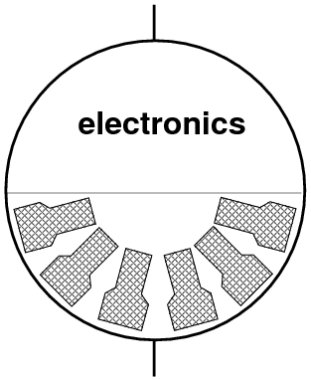


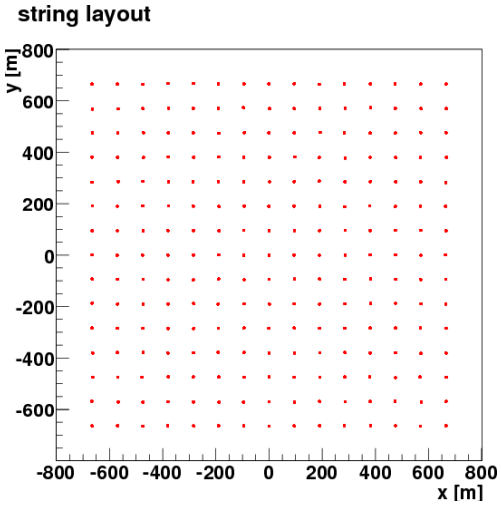
artist impression

- ANTARES,NEMO and NESTOR work together to build km^3-large detector in the Mediterranean

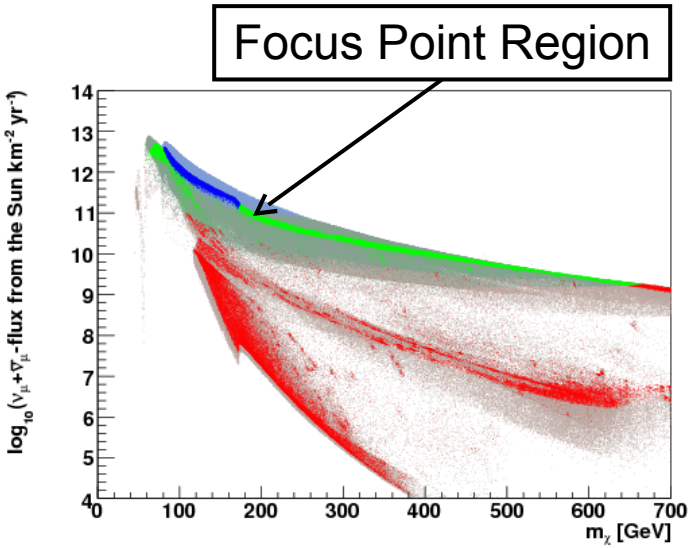
Detector proposal providing A_{eff}:

- 225 lines in grid configuration
- 36 Optical Modules per line
- 21 PMTs (3”) per OM



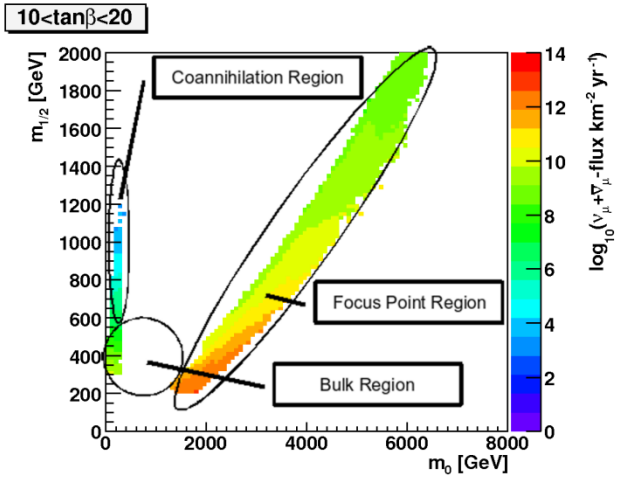


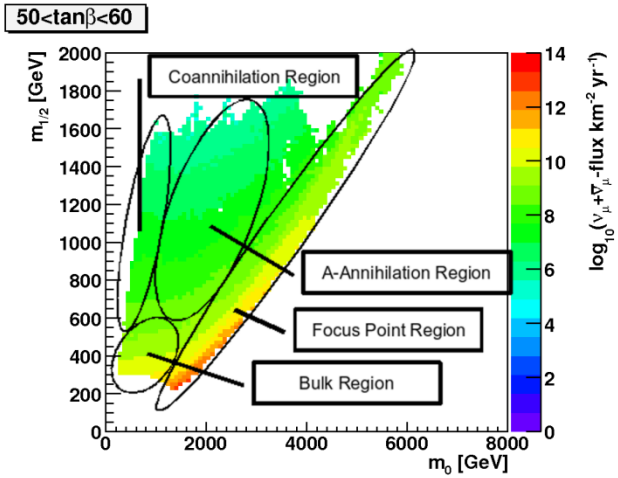
Limits on Neutrino Flux Parameter Space Regions



mSugra models favoured by WMAP
- 90% CL excudable by ANTARES
- 90% CL excludable by KM3NeT
- not excludable

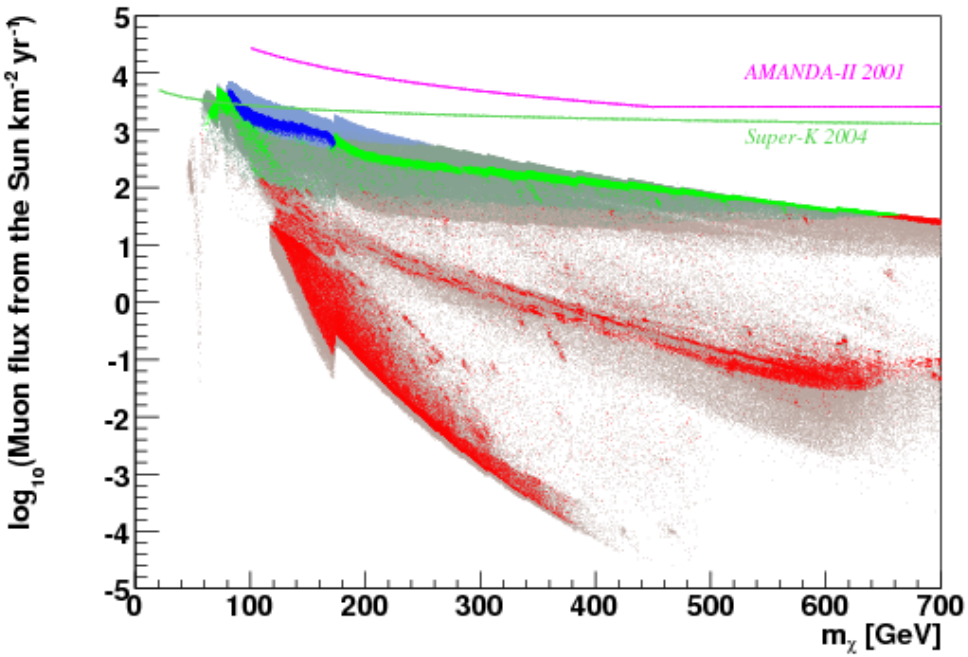
mSugra models disfavoured by WMAP
- 90% CL excludable by ANTARES
- 90% CL excludable by KM3NeT
- not excludable





Muon Flux

- Comparison to other neutrino experiments
- Site dependent quantity
- Derived from neutrino flux through ν to μ conversion rate extracted from DarkSUSY for different m_χ (approximation)



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- not excludable

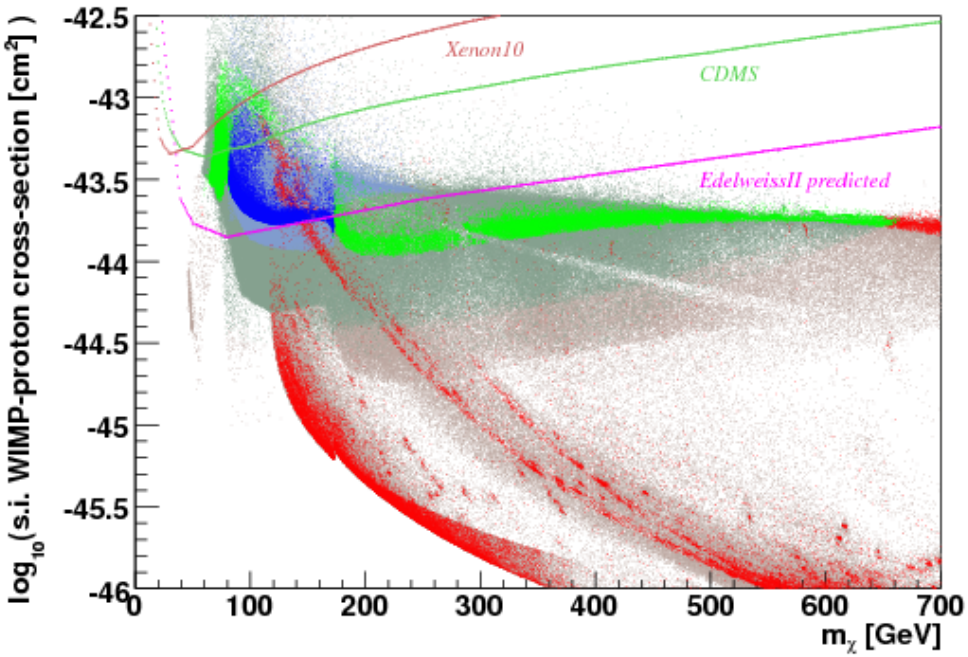
Direct Detection

•Comparison to direct detection experiments sensitive to spin independent WIMP-nucleon crossection

•Spin dependent scattering limits not yet low enough to put constraints on mSugra Dark Matter

CDMS: arXiv:0802.3530

XENON: arXiv:0706.0039



Summary/Outlook

- Limits on mSugra Dark Matter possible within three years of taking data
- Neutrino Telescopes complementary and competitive to direct-detection experiments

- New scans done for mSugra, (GMSB), AMSB and pMSSM with new DarkSUSY version and Suspect RGE code (Andi Spies)
- Working on low energy reconstruction to improve sensitivity