SEARCHES FOR WIMP DARK MATTER WITH THE ICECUBE NEUTRINO DETECTOR

GUSTAV WIKSTRÖM

FOR THE ICECUBE COLLABORATION

Stockholm University
INDIRECT DETECTION OF WIMP ANNIHILATION IN CELESTIAL OBJECTS BY OBSERVING MUONS FROM EMITTED HIGH-E NEUTRINOS

WIMP = LSP (MSSM NEUTRALINO) OR LKP (UED B1)

GRAVITATIONAL ACCUMULATION OVER BILLION YEARS IN:

- EARTH (CLOSE) (FEW ANNIHIL.) (FIXED SOURCE) LOW $\sigma$ FLUX
- SUN (QUITE CLOSE) (MORE ANNIHIL.) (LOW BACKGR.) MEDIUM $\sigma$ FLUX
- GALACTIC CENTRE (FAR) (LOTS OF ANN.) (HIGH BACKGR.?) LOW $\sigma$ FLUX
INDIRECT DETECTION VS. DIRECT DETECTION

INDIRECT DETECTION HAS:

* MORE SENSITIVE TO SPIN-DEPENDENT INTERACTIONS (E.G. THE SUN IS A HUGE PROTON TARGET, FOR WHICH SD INTERACTION IS IMPORTANT)

* LESS SENSITIVE TO SPIN-INDEPENDENT INTERACTIONS (A² COHERENCE NOT PRESENT IN HYDROGEN)

* MORE SENSITIVE TO LOW WIMP VELOCITIES, BUT LESS SENSITIVE TO HIGH VELOCITIES (EFFICIENT GRAVITATIONAL TRAPPING)

* POSSIBILITY OF SAMPLING PASSED REGIONS WITH HIGHER WIMP RELIC DENSITY ("VACUUMING" SPACE FOR DM...)
SUN IS THE BEST OPPORTUNITY:
LARGE MASS, RELATIVELY CLOSE, VISIBLE FROM ICECUBE
LOOKING FOR NEUTRINOS FROM THE SUN:

DURING HALF THE YEAR (AUSTRAL WINTER) THE SUN IS BELOW THE HORIZON AT SOUTH POLE

ABOVE THE HORIZON THERE'S TOO MUCH ATM. MUON BACKGR.

SUMMER

WINTER

HEAVY MUON BACKGR.

SOLAR-WIMP NEUTRINOS AND MUONS

SIGNAL MC
ICECUBE-22 STRING 2007 ANALYSIS
NEUTRALINO ANNIHILATION IN THE SUN:

USED 104 DAYS LIVETIME (SUN BELOW HORIZON, AUSTRAL WINTER)

NEUTRALINO SIGNAL SIMULATED WITH WIMPSIM (BLENNOW, EDSJÖ, OHLSSON 2008)

MASSES: 250, 500, 1000, 3000, 5000 GeV

ANNIHILATION CHANNELS: 2 endpoint spectra chosen

W⁺W⁻ (HARD) NEUTRINO ENERGIES UP TO NEUTRALINO MASS

b b̅b̅ (SOFT) NEUTRINOS FROM SECONDARY PROCESSES

FULL PROPAGATION THROUGH SUN (ABSORPTION IMPORTANT)

FULL 3-FLAVOUR NEUTRINO OSCILLATION
WHAT IS THE ENERGY WE'RE LOOKING AT?

LOW MEAN MUON ENERGY --> SHORT TRACKS, FEW HITS

Absorption in the Sun important
ANALYSIS TECHNIQUE:
REMOVE ATM. MUON EVENTS UNTIL EXP. DATA IS DOMINATED BY ATM. NEUTRINO EVENTS

*PRELIMINARY*

MOSTLY NEUTRINO EVENTS
SVM OUTPUT: CAN WE MATCH EXP. DATA WITH ATM. BACKGROUND? YES!
EFFECTIVE VOLUME FOR NEUTRALINO SIGNAL FOR FINAL SAMPLE: VOLUME OF DETECTOR WITH 100% EFFICIENCY

*PRELIMINARY*

**HARD**

**SOFT**

Neutralino mass (GeV) vs. Effective volume (km$^3$)
SHAPE ANALYSIS:

FIT ANGULAR DISTRIBUTION IN EXP. DATA WITH MC SIGNAL AND BACKGROUND FROM RANDOMIZED EXP. DATA

*PRELIMINARY*

WIMP MODEL DEPENDENCE
EVALUATE SHAPE FIT WITH LOG-LIKELIHOOD OF RANK (FELDMAN-COUSINS) TO CONSTRUCT CONFIDENCE REGIONS FOR THE SIGNAL CONTENT.

EXAMPLE PLOT

SIGNAL CONTENT GIVES UPPER LIMIT ON #WIMP EVENTS

90 % conf. region
FROM LIMIT ON #WIMP EVENTS AND EFFECTIVE VOLUME
UPPER LIMIT (90% CL) ON MUON FLUX FROM THE SUN

*PRELIMINARY*
SYSTEMATIC UNCERTAINTIES ON EFFECTIVE VOLUME:
*PRELIMINARY*

* Neutrino oscillation: 4%
* Neutrino-nucleon xsec: 3%
* Muon propagation in ice: <1%
* Photon propagation & absolute OM sensitivity: 17-24%
* Spread in OM sensitivity: <5%
* Time & position calibration: <5%
* Signal MC statistics: 3-5%

TOTAL SYSTEMATIC ON V_{eff}: 19-26%
CURRENT PROGRESS:

ICECUBE-40 STRING (2008) SEARCH ON ITS WAY

NEUTRALINO AND LKP WIMP

SEARCH EXTENDED TO 50 GeV

EXPECTED SENSITIVITY INCREASE BY FACTOR ~3 COMPARED TO ICECUBE-22 STRING?

SENSITIVITIES:

PROBING UNTESTED MODELS!

*VERY PRELIMINARY*
FUTURE: THE DEEP CORE

ICECUBE-86 STRING DETECTOR BY 2010-2011

POSSIBILITY OF LOOKING ABOVE HORIZON
BY USE OF VETO

GALACTIC CENTRE
SEARCH POSSIBLE!

VERY COMPETITIVE
SENSITIVITY
FOR LOW MASSES

*VERY PRELIMINARY*
SENSITIVITIES

![Graph showing sensitivities for dark matter search](image-url)
SUMMARY OF WIMP SEARCHES WITH ICECUBE

* ICECUBE 22-STRING SEARCH READY. BEST LIMIT ON WIMP ANNIHILATION

* ICECUBE 40-STRING SEARCH UNDER WAY

* BOTH NEUTRALINO AND KALUZA-KLEIN SIGNAL MODELS

* DEEPCORE WILL MAKE IT POSSIBLE TO SEARCH FOR WIMPS IN GALACTIC CENTRE

* ICECUBE WILL BE COMPETITIVE WITH DIRECT SEARCHES IN A FEW YEARS

* ICECUBE IS ALSO GOOD FOR EARTH WIMP SEARCHES SEARCH COMING UP