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WIMP searches with AMANDA B-10

Joakim Edsjö

for

the AMANDA Collaboration

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The AMANDA Collaboration

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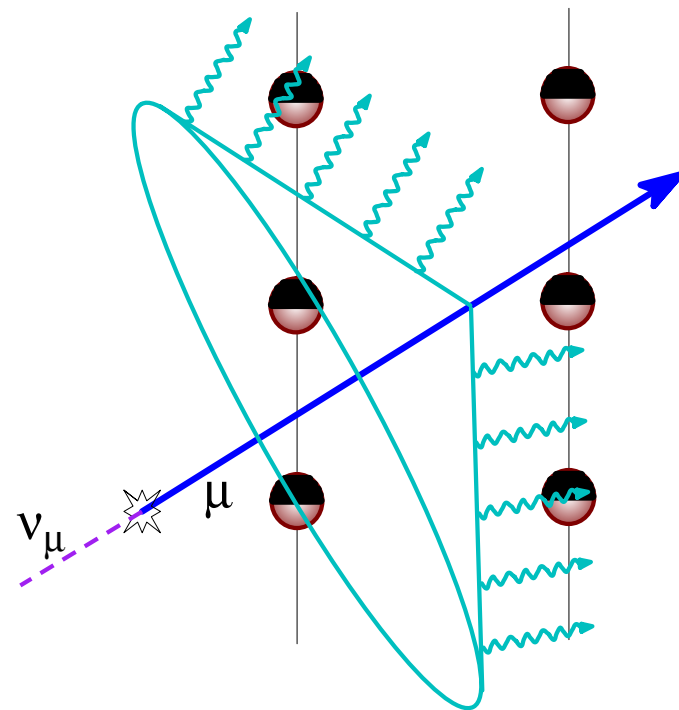(15) University of Uppsala, Uppsala, Sweden
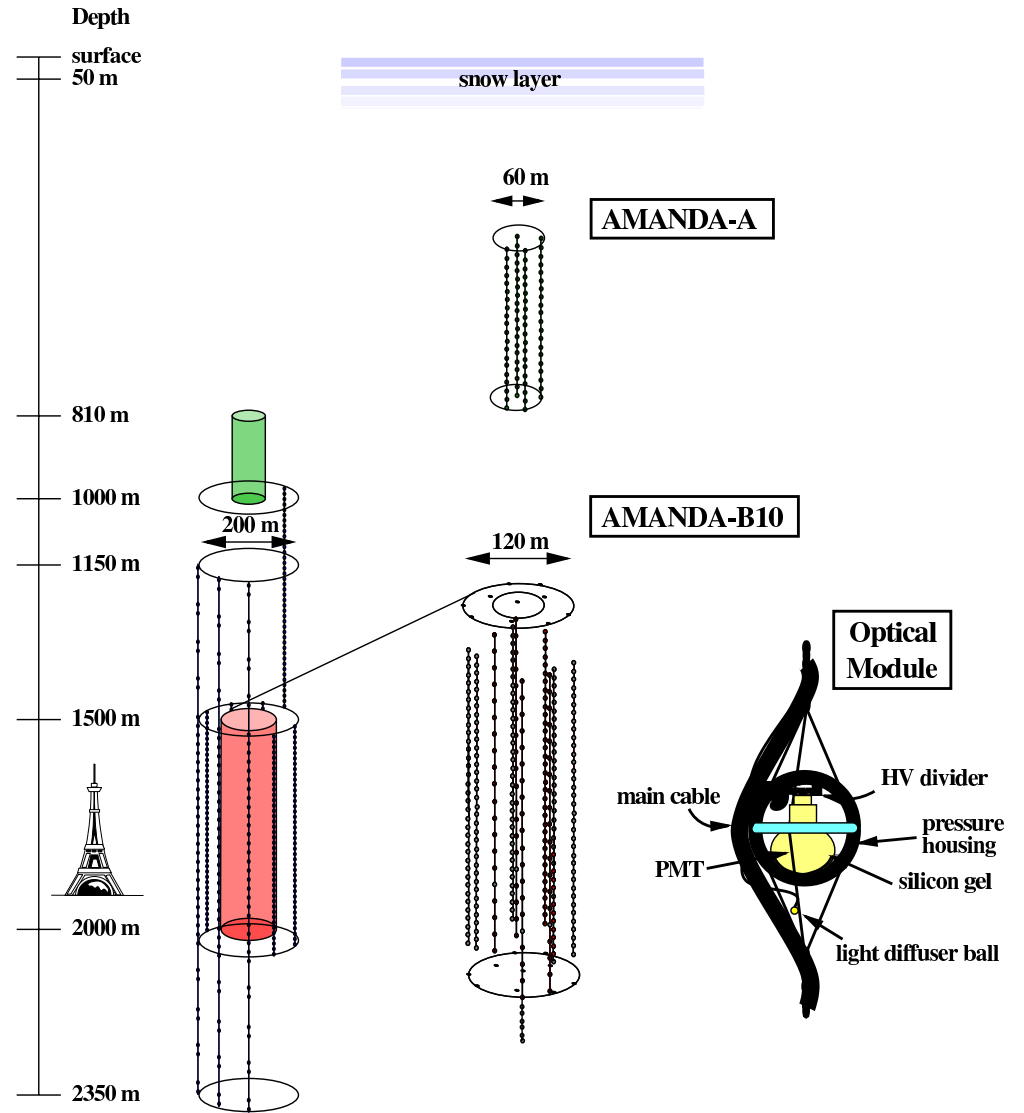
Detection Method for ν_μ

- Cherenkov photons are detected by an array of PMTs

- Tracks are reconstructed by a maximum likelihood method using photon arrival times.

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AMANDA-II
Feb. 2000

Depth

surface
50 m

snow layer

60 m

AMANDA-A

810 m

1000 m

200 m

1150 m

120 m

AMANDA-B10

1500 m

Optical Module

main cable

HV divider

pressure housing

PMT

silicon gel

light diffuser ball

2000 m

2350 m

AMANDA as of 2000
Eiffel Tower as comparison
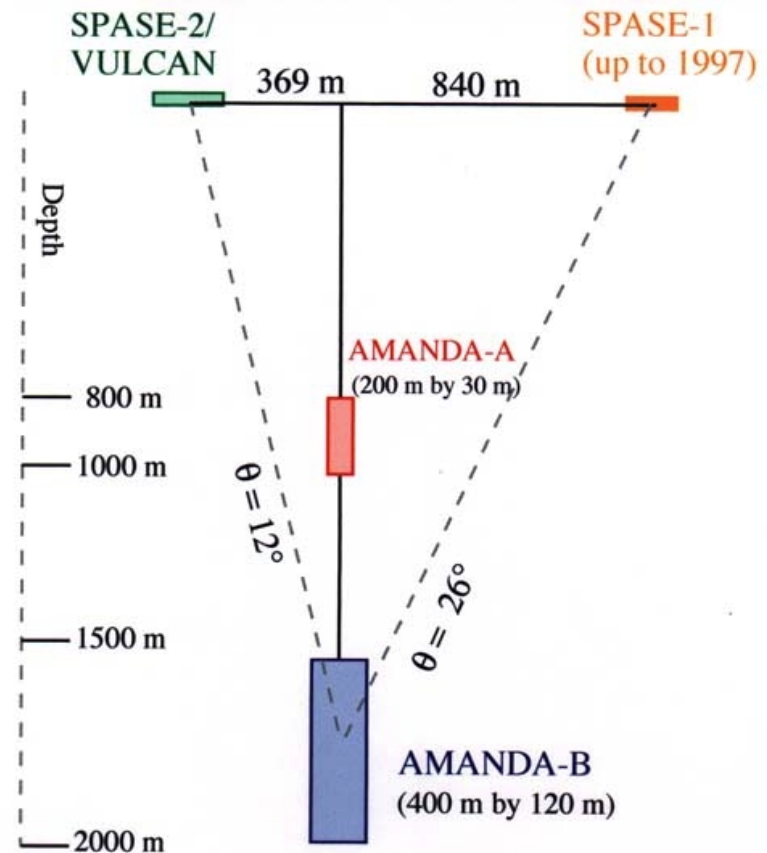(true scaling)

zoomed in on
AMANDA-A (top)
AMANDA-B10 (bottom)
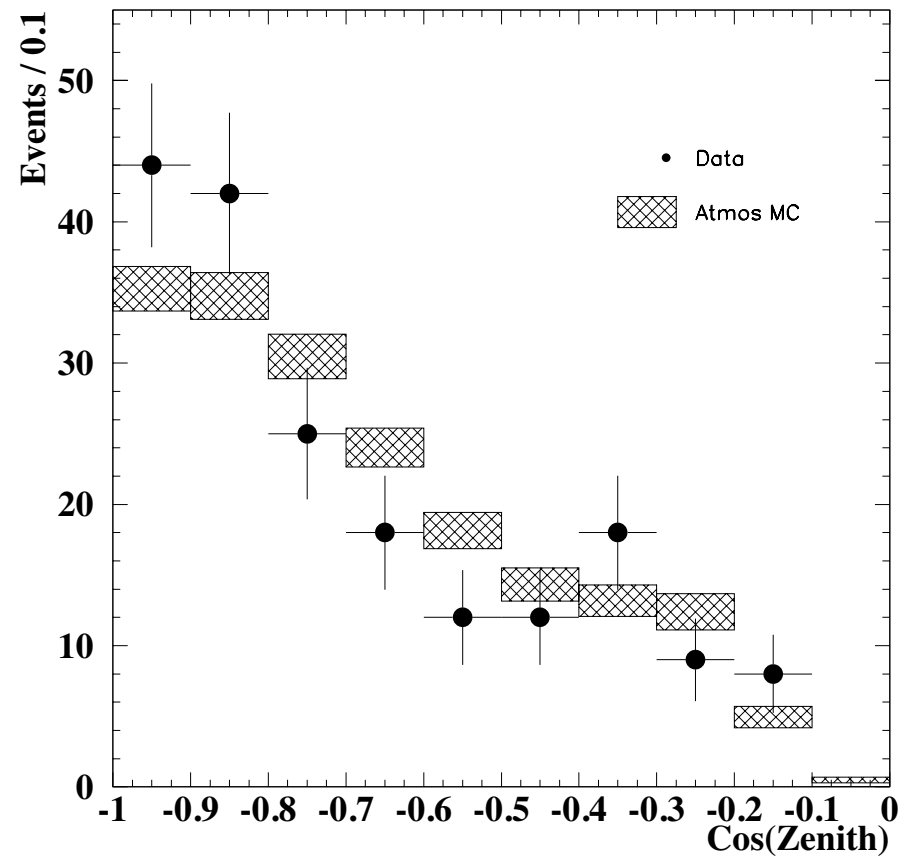
zoomed in on one
optical module (OM)

SPASE-AMANDA

- Calibration of absolute pointing

- Calibration of pointing resolution

- Calibration of signal efficiency

Data / MC Comparison
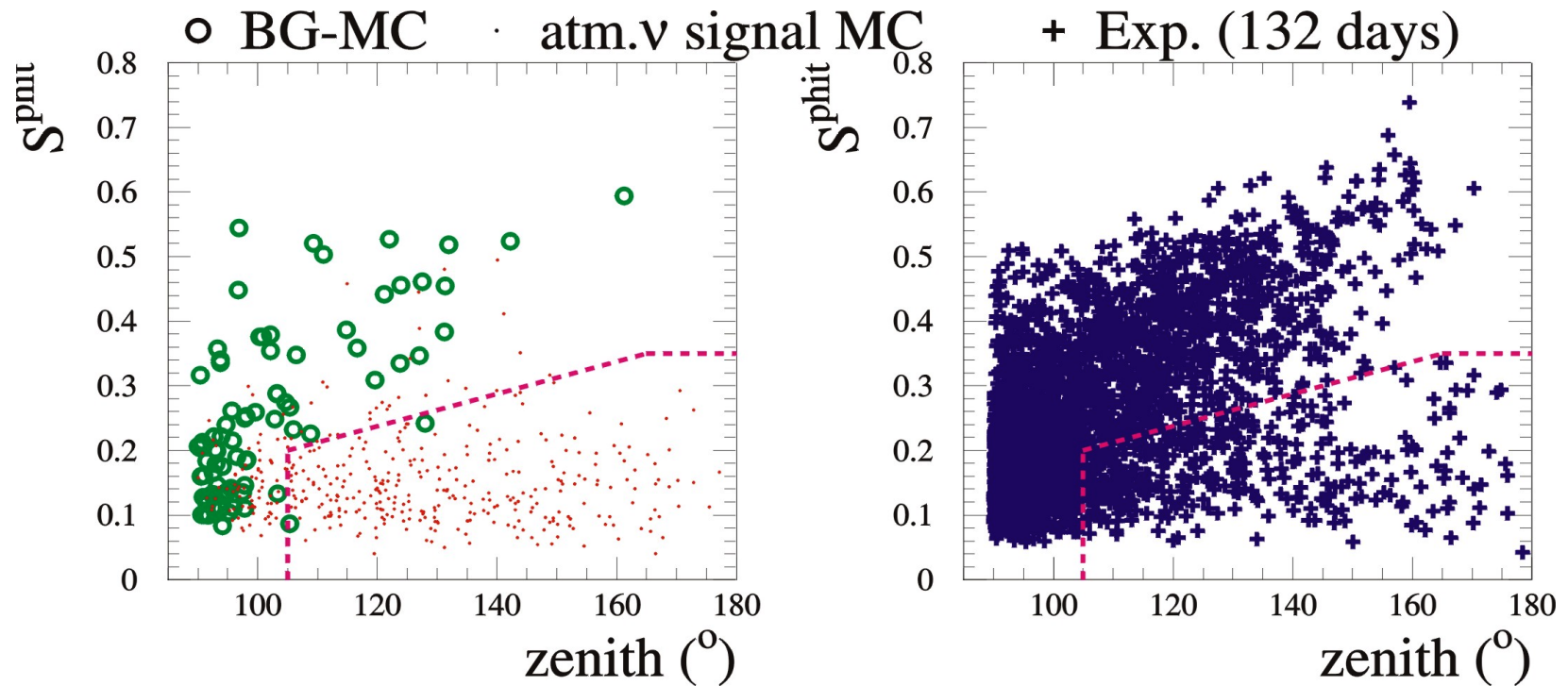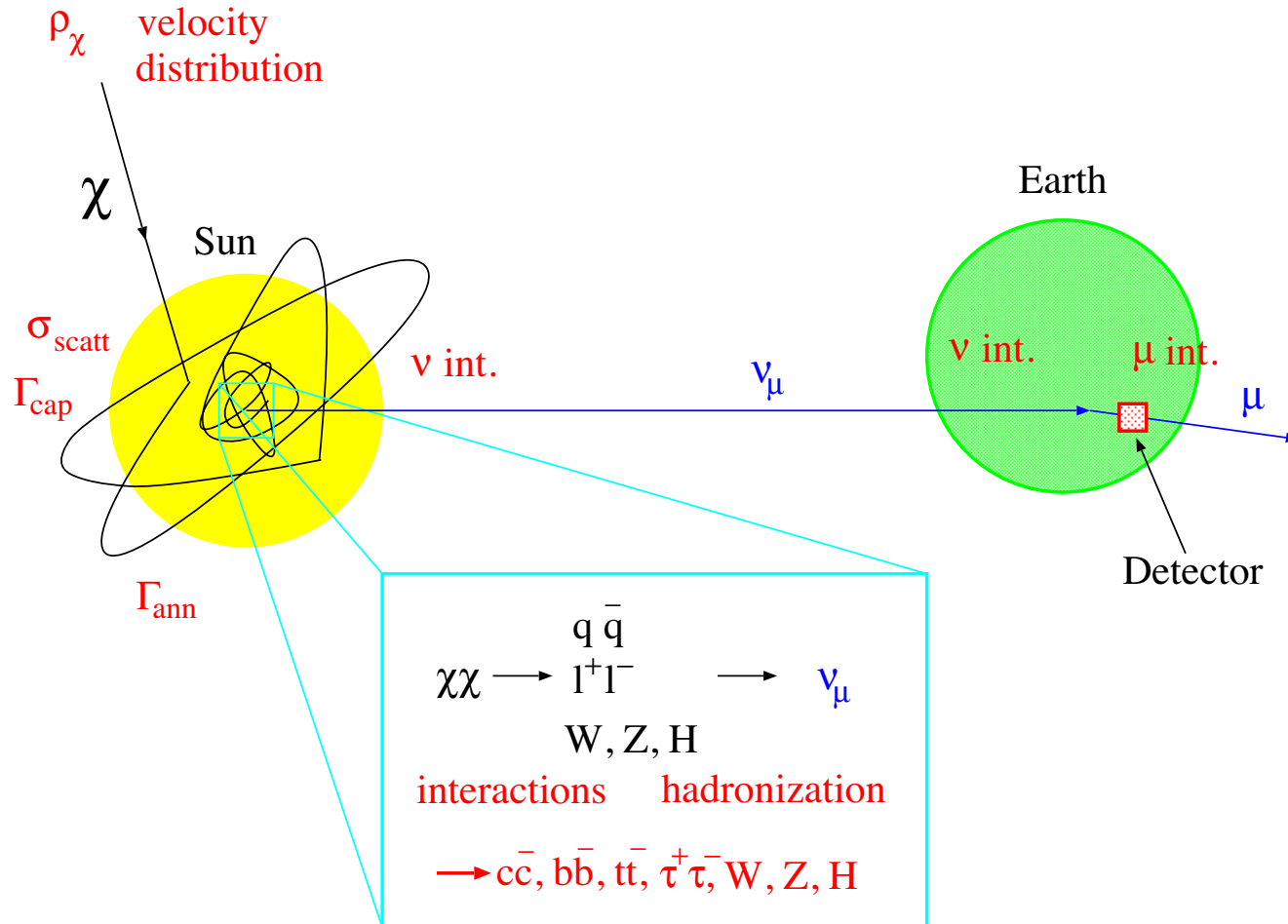
- Data and atmospheric ν MC compared.

- Good agreement

Signal/background: atm ν

Arb. normalization between signal and BG

○ BG-MC · atm.ν signal MC + Exp. (132 days)

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WIMPs from Sun/Earth

ρ_χ velocity distribution

χ

Sun

σ_{scatt}

Γ_{cap}

ν int.

ν_μ

Earth

ν int. μ int.

μ

Detector

Γ_{ann}

$$\chi\chi \longrightarrow \begin{array}{c} q\,\bar{q} \\ l^+l^- \\ W, Z, H \end{array} \longrightarrow \nu_\mu$$

interactions   hadronization

$\longrightarrow c\bar{c}, b\bar{b}, t\bar{t}, \tau^+\tau^-, W, Z, H$
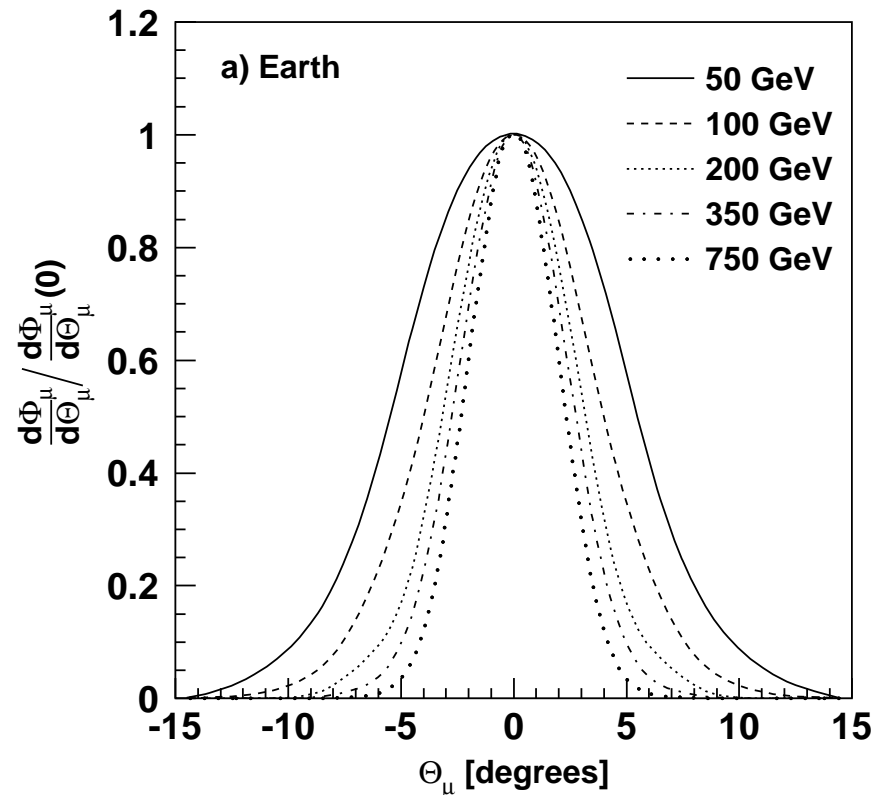
Angular Spread of WIMP signal

- Angular spread decreases as WIMP mass increases, reducing atm. ν background

a) Earth

50 GeV
100 GeV
200 GeV
350 GeV
750 GeV

$\frac{d\Phi_\mu}{d\Theta_\mu} / \frac{d\Phi_\mu}{d\Theta_\mu}(0)$

Θ_μ [degrees]

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Cuts for WIMP search

- Level 1: $\theta_{LF} \geq 50º$
- Level 2: $\theta_{ML} \geq 80º$, cut on # of hits
- Level 3: $\theta_{ML} \geq 140º$, cuts on # of hits
- Level 4: Iterative Discriminant Analysis
- Level 5: $\theta_{LF} > 130º$, $\theta_{ML} \geq 165º$,
  cuts on track length and
  number of hits, ...

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Efficiency for WIMPs

$m_\chi = 250$ GeV, hard spectrum

- Optimized cuts for almost vertical upward moving muons.

- The simulated WIMP signal is reduced to 30% after reducing background by 10^8.

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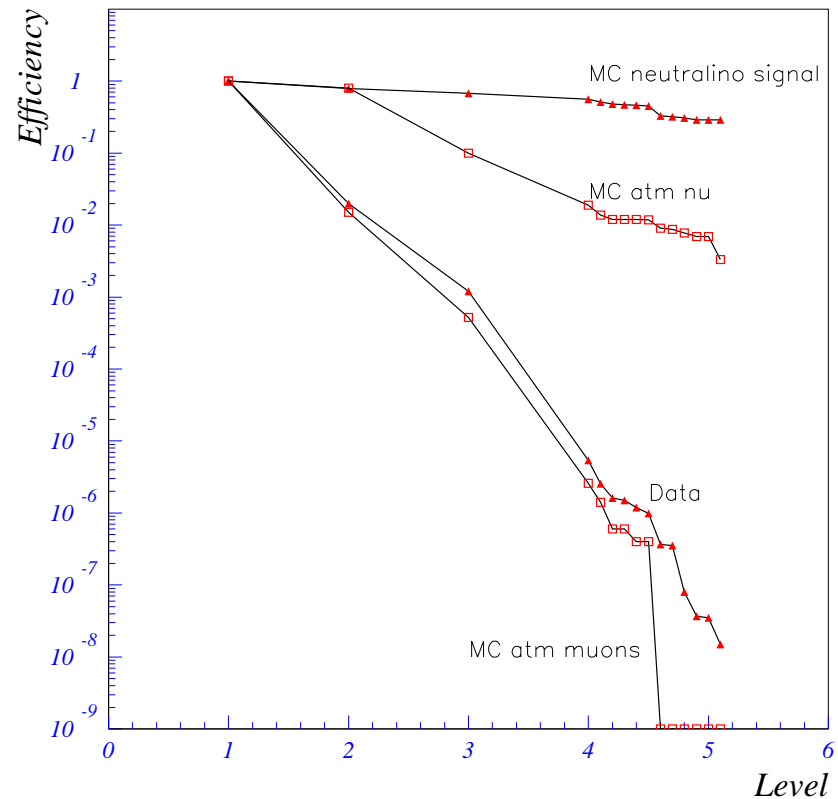
Event reduction

Events left at different cut levels

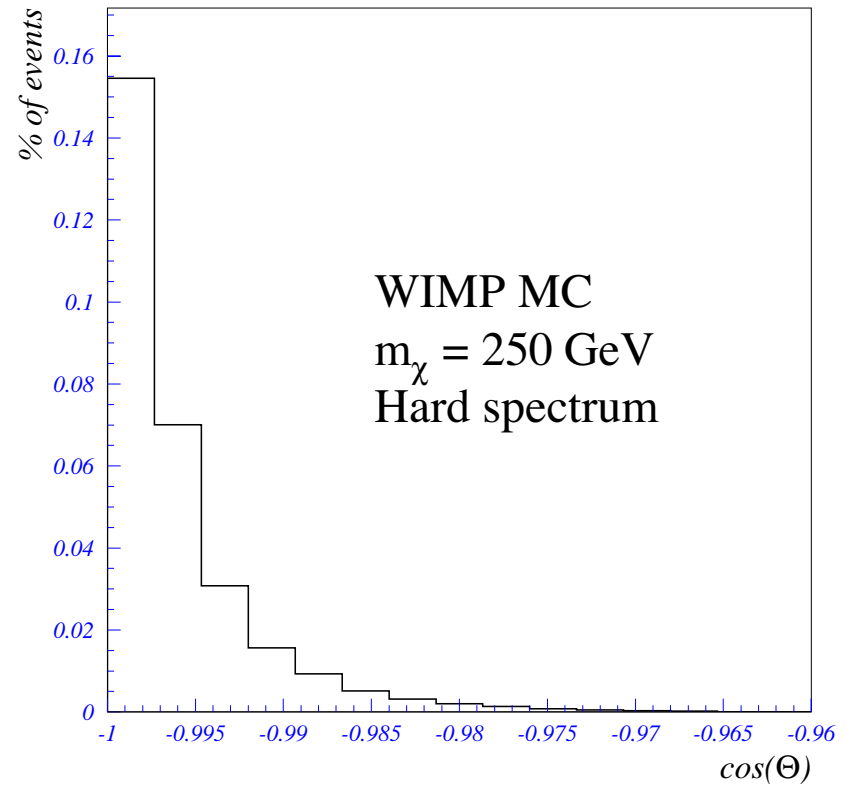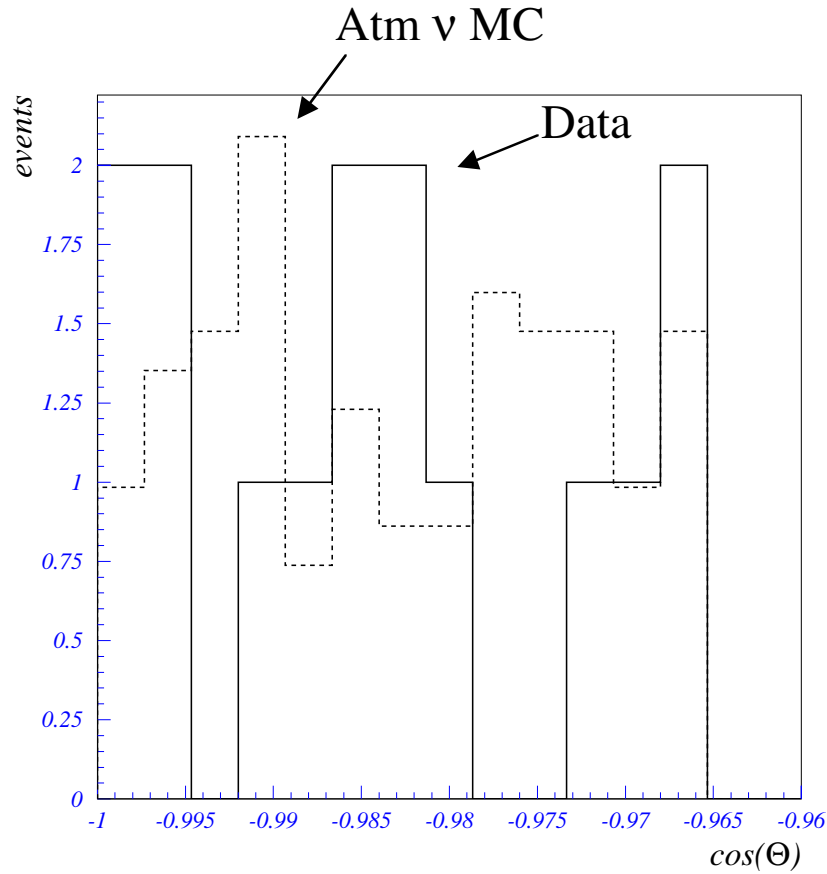| Cut level	Data 135 d.	MC atm. muons 1 d.	MC Neutralinos m_χ=250 GeV	MC Atm. neutrinos 135 d.
0	10^9	5×10^6	100%	5013
2	2×10^7	7×10^4	79%	4002
3	1.2×10^6	2588	68%	490
4	5442	13	56%	93
5	15	0	29%	16.6

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Events at level 5 + θ_{ML} cuts

Preliminary: Systematic uncertainties are not included.

Level 5	Data	Atm. neutrinos	Neutralinos $m_\chi = 250$ GeV	90% C.L. on signal
$\theta > 165^o$	15	16.6	29%	7.0
$\theta > 172.5^o$	4	4.6	26%	4.5

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Event distributions at level 5

Atm ν MC

Data

events

2

1.75

1.5

1.25

1

0.75

0.5

0.25

0

-1   -0.995   -0.99   -0.985   -0.98   -0.975   -0.97   -0.965   -0.96

$cos(\Theta)$

% of events

0.16

0.14

0.12

0.1

0.08

0.06

0.04

0.02

0

-1   -0.995   -0.99   -0.985   -0.98   -0.975   -0.97   -0.965   -0.96
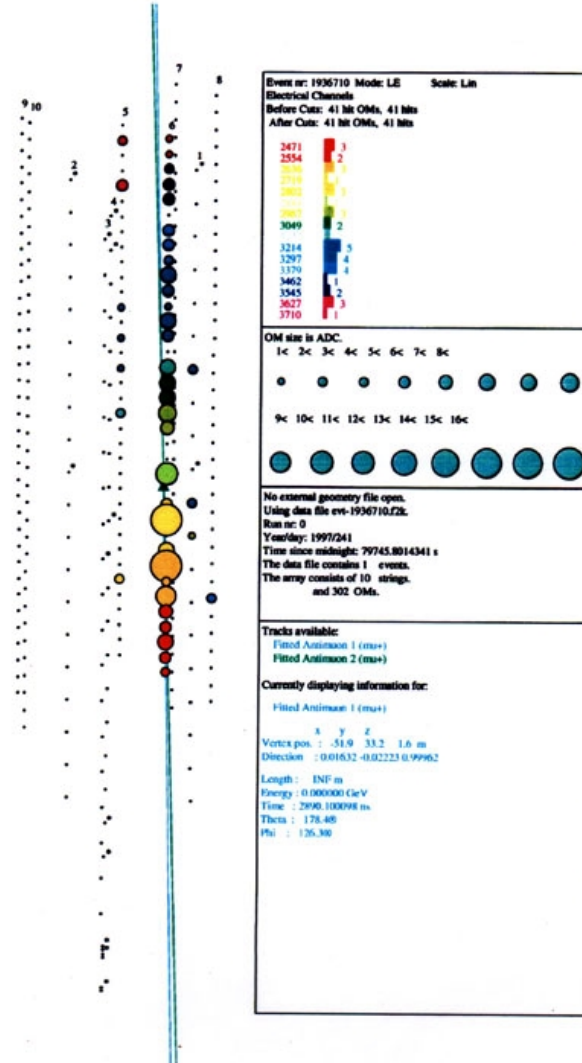
$cos(\Theta)$

WIMP MC
m_χ = 250 GeV
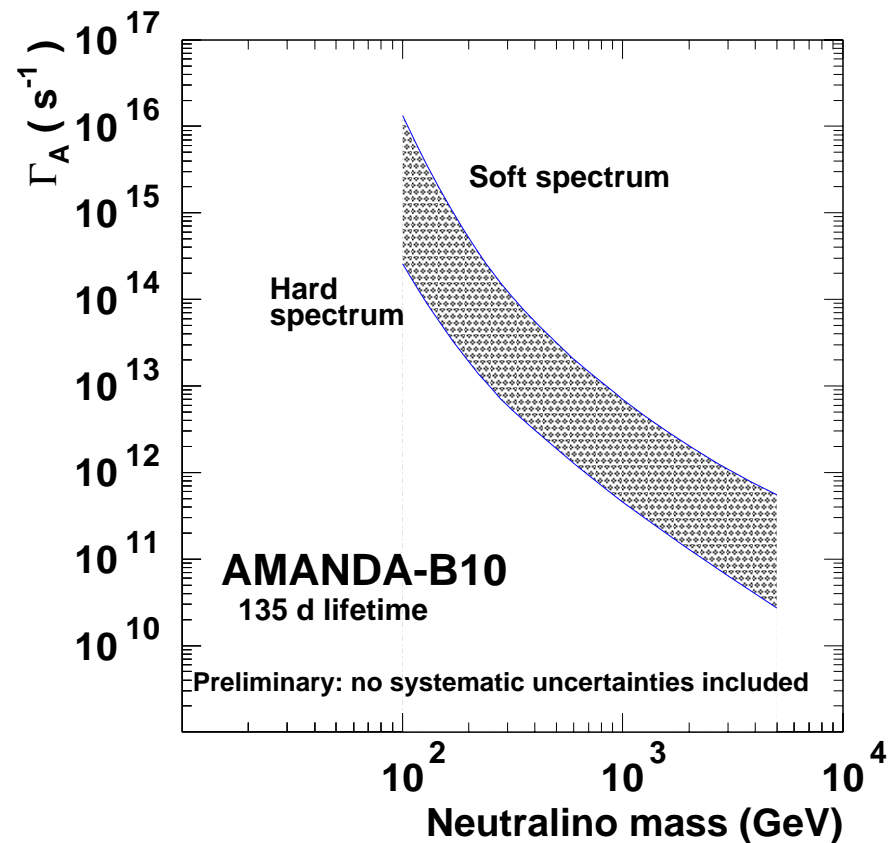Hard spectrum

AMANDA ν-candidate

- Early photons are red, late photons are blue. More photons are larger circles

- Bottom of array is towards center of Earth

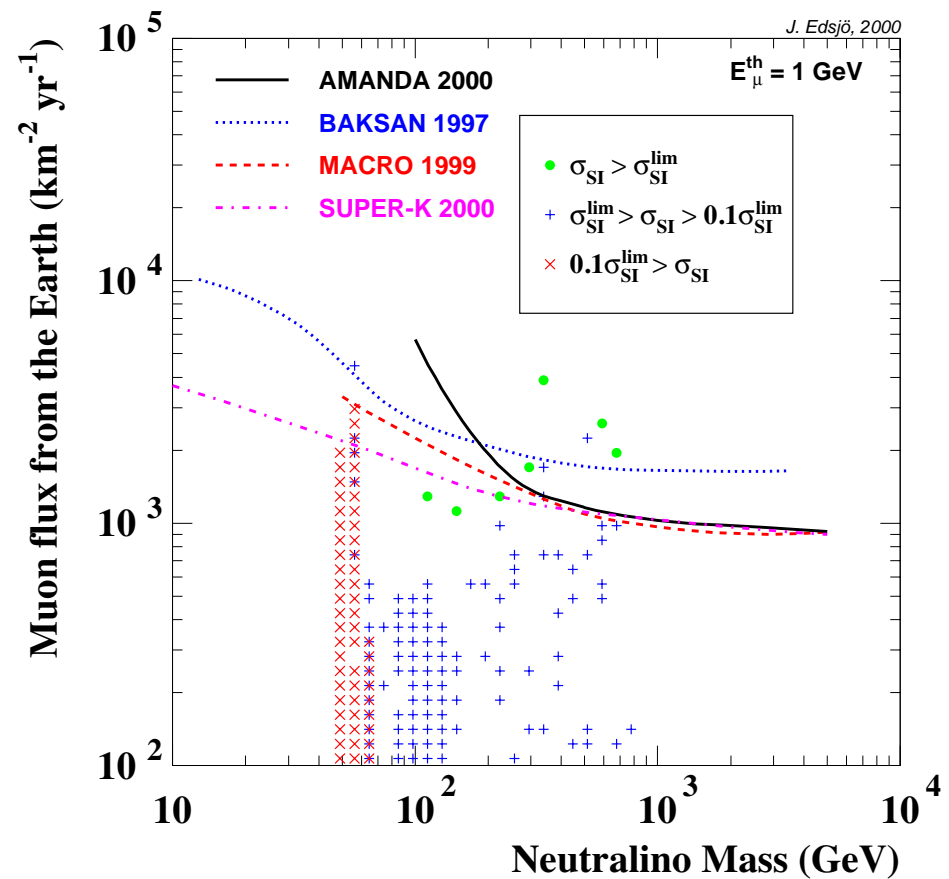- The muon is clearly traveling in the upward direction

Limits: Annihilation rate

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- Derived limits on the annihilation rate in the center of the Earth.

- **Preliminary:** systematic uncertainties are not included.

Soft spectrum

Hard spectrum

AMANDA-B10
135 d lifetime

Preliminary: no systematic uncertainties included

Γ_A (s^{-1}) vs Neutralino mass (GeV)

Limits: μ flux from the Earth

- AMANDA limits comparable to MACRO, Baksan and Super-Kamiokande.

- **Preliminary:** systematic uncertainties are not included.

J. Edsjö, 2000

$E^{th}_\mu = 1$ GeV

Legend:
- AMANDA 2000
- BAKSAN 1997
- MACRO 1999
- SUPER-K 2000
- $\bullet$ $\sigma_{SI} > \sigma^{lim}_{SI}$
- $+$ $\sigma^{lim}_{SI} > \sigma_{SI} > 0.1\sigma^{lim}_{SI}$
- $\times$ $0.1\sigma^{lim}_{SI} > \sigma_{SI}$

Y-axis: Muon flux from the Earth (km^{-2} yr^{-1})
X-axis: Neutralino Mass (GeV)

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Future WIMP searches

- Systematic effects are studied right now.
- Cuts will be more optimized for WIMPs.
- 1998, 1999 and 2000 data will be included.
- WIMPs in the Sun will be searched for.
- AMANDA-II with 19 strings complete since Feb. 2000.
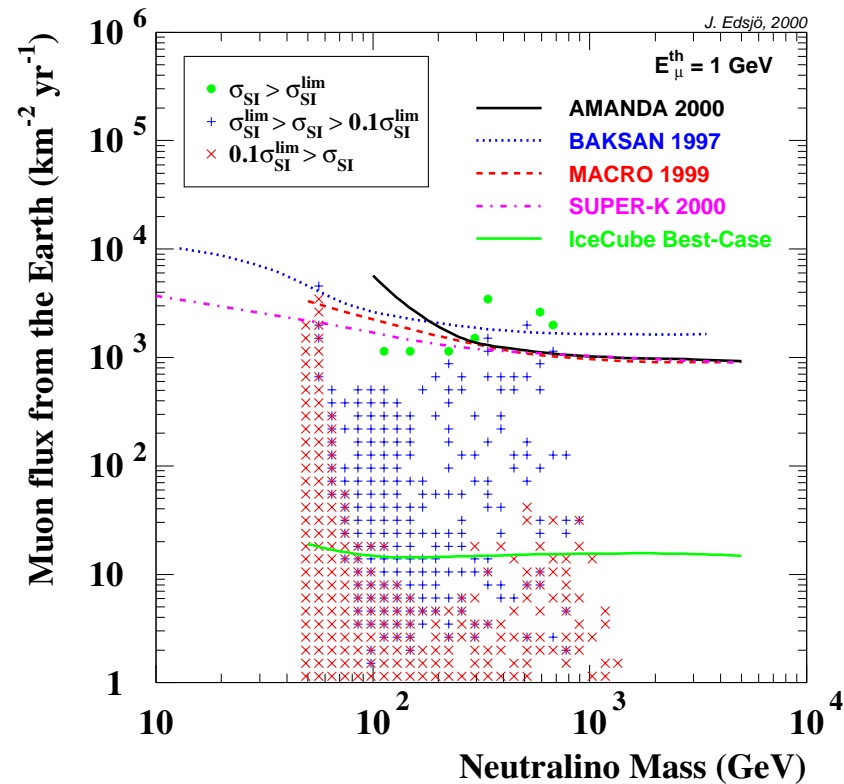- Ice^3 to be deployed 2002-2007 (hopefully)

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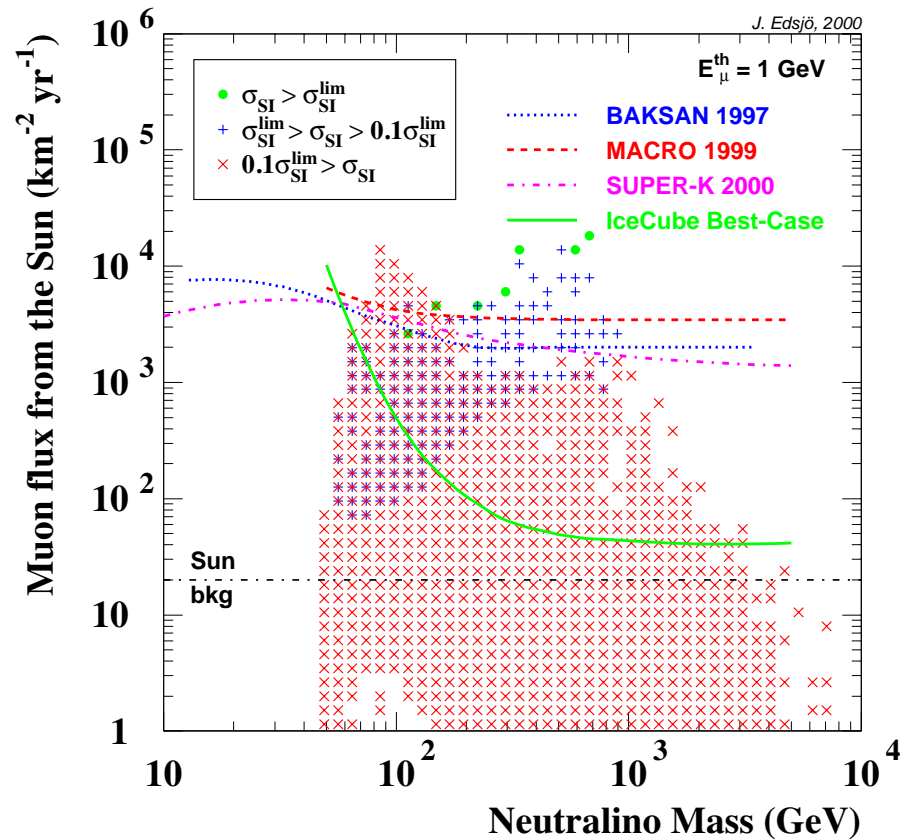# WIMPs from the Earth with Ice[3]

Optimized search for vertical neutrinos

- Ice[3] will improve the sensitivity several orders of magnitude

WIMPs from the Sun with Ice^3

- Ice^3 will improve the sensitivity several orders of magnitude.

J. Edsjö, 2000

$E_\mu^{th} = 1$ GeV

Legend:
- $\sigma_{SI} > \sigma_{SI}^{lim}$ (green dot)
- $\sigma_{SI}^{lim} > \sigma_{SI} > 0.1\sigma_{SI}^{lim}$ (blue plus)
- $0.1\sigma_{SI}^{lim} > \sigma_{SI}$ (red x)

- **BAKSAN 1997**
- **MACRO 1999**
- **SUPER-K 2000**
- **IceCube Best-Case**

Muon flux from the Sun (km^{-2} yr^{-1}) vs Neutralino Mass (GeV)

Sun bkg

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Conclusions

- 135 days of data in 1997 with AMANDA B-10. 1998-2000 data to be analyzed.

- Cuts optimized to look for neutrinos from WIMPs annihilating in the Earth.

- Muon flux limits are comparable to those from Baksan, Macro and Super-Kamiokande:
  $\Phi_\mu < 1000 \text{ km}^{-2} \text{ yr}^{-1}$ @ $m_\chi \sim 1$ TeV