## Neutrinos from Neutralino Dark Matter Expected fluxes and searches

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# Outline

- Supersymmetric framework MSSM
- Neutrino-induced muons from neutralino annihilation in the Earth / Sun
  - Expected fluxes
  - Comparison with experiments

# The MSSM – parameters

- μ Higgsino mass parameter
- M<sub>2</sub> Gaugino mass parameter
- m<sub>A</sub> mass of CP-odd Higgs boson
- $\tan \beta$  ratio of Higgs vacuum expectation values
- m<sub>0</sub> scalar mass parameter
- $A_b$  trilinear coupling, bottom sector
- $A_t$  trilinear coupling, top sector

Parameter Unit	μ GeV	M <sub>2</sub> GeV	tan β 1	m <sub>A</sub> GeV	m <sub>0</sub> GeV	A <sub>b</sub> /m <sub>0</sub> 1	A/m <sub>0</sub> 1
Min	-50000	-50000	1	0	100	-3	-3
Max	+50000	+50000	60	10000	30000	3	3

## The MSSM – general

• The Neutralino  $-\chi$ 

 $\tilde{\chi}_{1}^{0} = N_{11}\tilde{B} + N_{12}\tilde{W}^{3} + N_{13}\tilde{H}_{1}^{0} + N_{14}\tilde{H}_{2}^{0}$ 

• Gaugino fraction

$$Z_{g} = \left| N_{11} \right|^{2} + \left| N_{12} \right|^{2}$$

#### **Calculation done with**



- 1. Select MSSM parameters
- 2. Calculate masses, etc
- 3. Check accelerator constraints
- 4. Calculate relic density
- 5.  $0.025 < \Omega_{\chi} h^2 < 1$  ?
- 6. Calculate fluxes, rates,...

## Neutralino capture and annihilation



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#### **Neutrino telescopes – how do they work?**

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The neutrino interacts with a nucleus in the ice and creates a muon.

- The muon emits *Cherenkov radiation*.
- The radiation is recorded by photomultipliers and the muon track can be reconstructed.

### **Angular Spread of WIMP signal – Earth**

Neutrinos

#### **Neutrino-induced muons**



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## Angular Spread of WIMP signal – Sun

#### **Neutrino-induced muons**

The angular spread decreases with increasing WIMP mass, making it easier to discriminate against the background of atmospheric neutrinos.



#### Neutrinos and muons from the Earth's atmosphere



Cosmic rays + Earth® atmosphere ↓ Muons and neutrinos

- $\Rightarrow Use the Earth as a$ **filter**by looking for upgoing muons.
- ⇒ Only atmospheric neutrinos remain as a background.

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## **Searches for neutrinos from WIMPs**

- IMB
- Macro
- Baksan
- Kamiokande, Super-Kamiokande
- Amanda, ICE<sup>3</sup>
- Antares

# The Amanda detector



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# **Event distributions Amanda B10, 1997 years data**



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#### AMANDA v-candidate

- Early photons are red, late photons are blue. More photons are larger circles.
- Bottom of array is towards center of the Earth.
- The muon is clearly traveling in the upward direction.

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	•	Y.	Yean/day: 1997/241
			Time since midnight: 79745.8014341 s
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## **Limits: Annihilation rate**

- Derived limits on the annihilation rate in the center of the Earth.
- **Preliminary:** systematic uncertainties are not included.



### Limits: **µ** flux from the Earth

- AMANDA limits comparable to MACRO, Baksan and Super-Kamiokande.
- **Preliminary:** systematic uncertainties are not included.



#### **Predicted fluxes and searches**

#### **Earth**

#### Sun



### **DAMA** claim and neutrino telescopes

- DAMA has claimed a direct detection signal.
- If interpreted as WIMPs, it can be searched for with neutrino telescopes.



# Flux from Earth/Sun and future GENIUS/CRESST limits

#### **Earth**

#### Sun



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#### MSSM parameter space Future probed regions



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# Conclusions

- The neutrino-induced muon fluxes from neutralino annihilations in the Earth and the Sun can be large and detectable.
- Current neutrino telescopes are probing the MSSM parameter space.
- Complementarity with direct searches, especially for the Sun.
- Future, bigger telescopes are under construction.