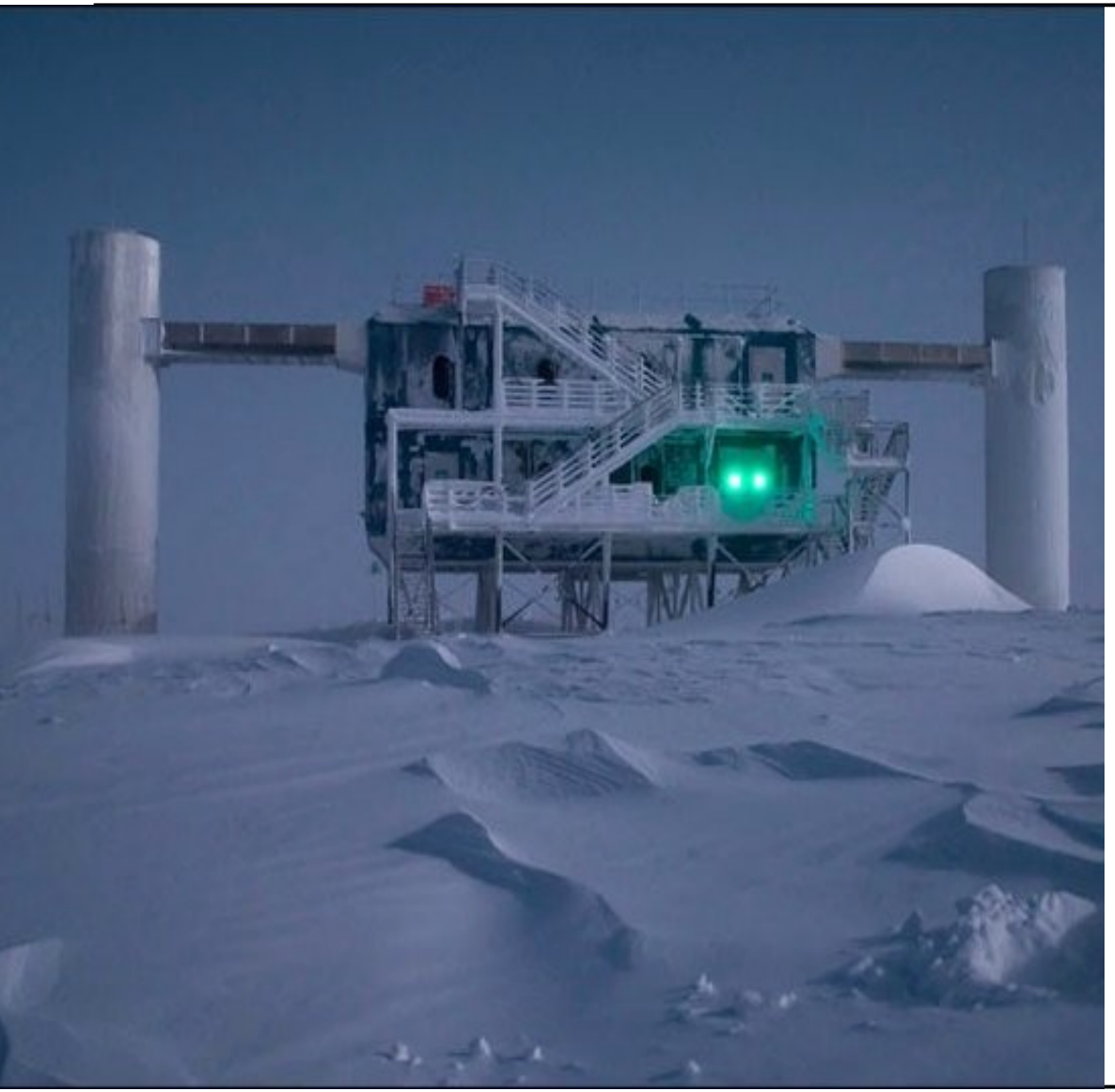


IceCube group at IIHE: Dark Matter signals from the Earth

KUBEC Workshop on Dark Matter 2014

Jan Lünemann, Vrije Universiteit Brussel
for the IceCube Collaboration

WIMP searches

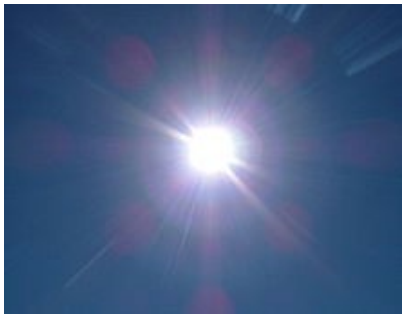
Targets for WIMP searches with IceCube:

annihilation cross section

dwarf galaxies
and other halos

Galactic center / halo

scattering cross section

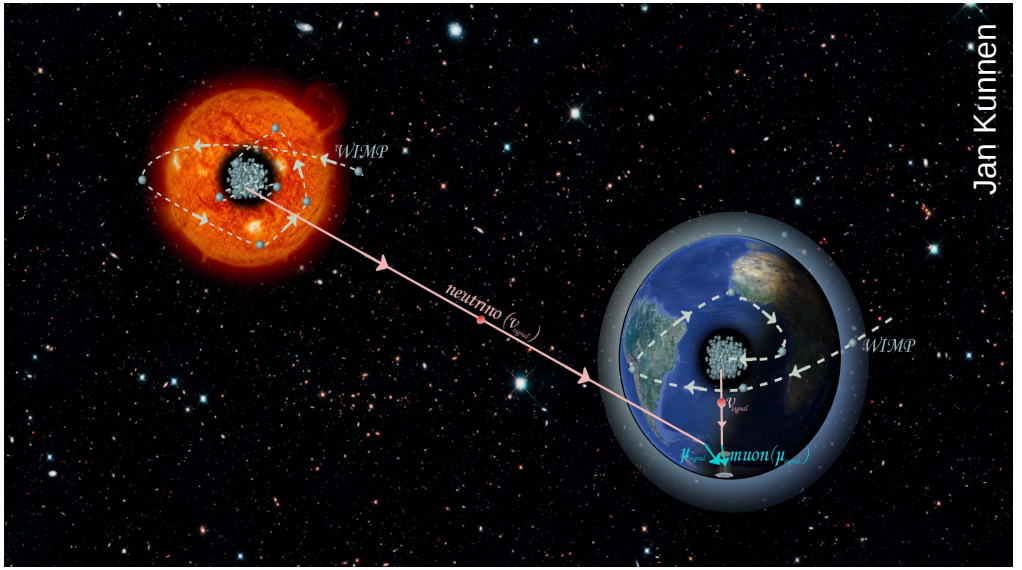


Sun

Earth

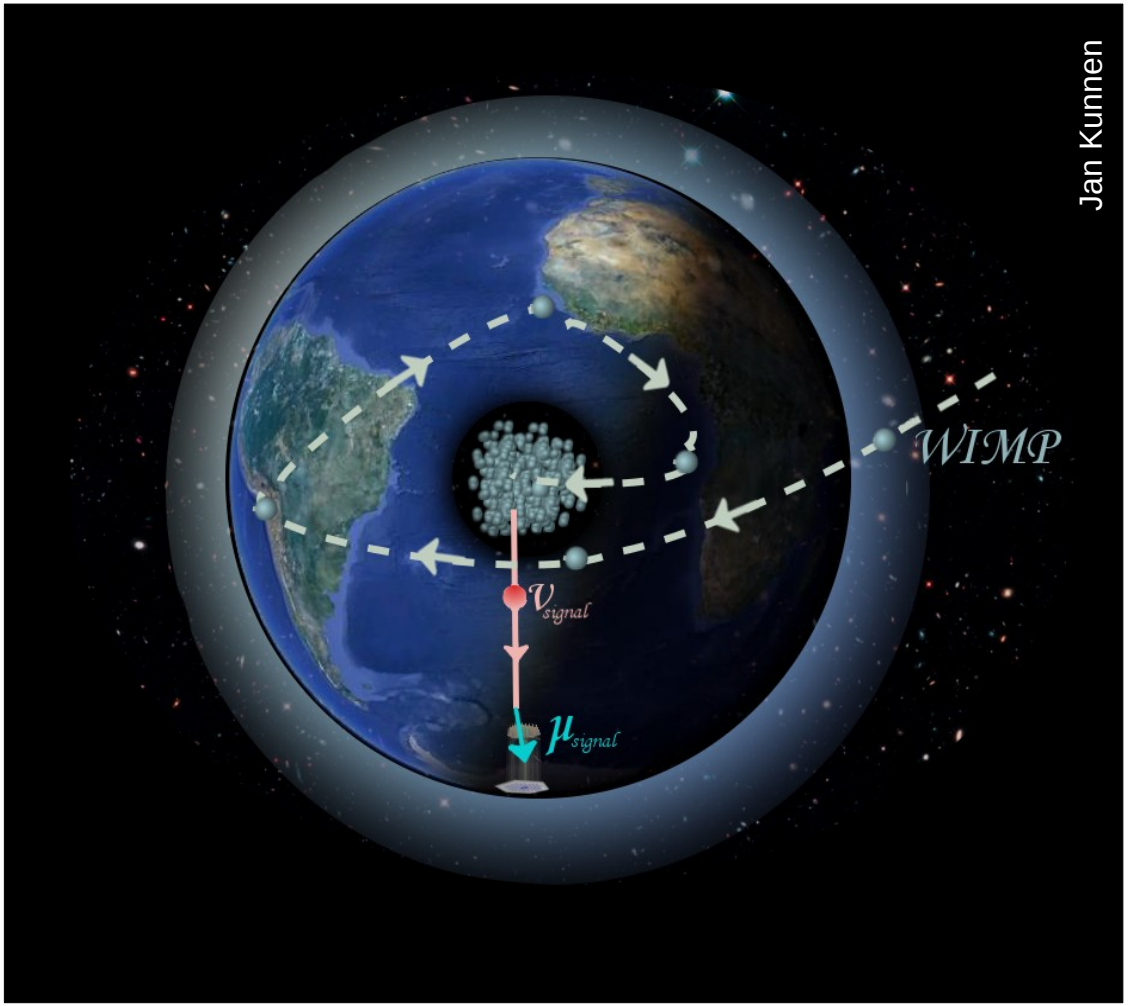
Signal

- Dark matter could scatter and be captured in heavy celestial bodies
- WIMP-Annihilation could produce a neutrino signal that can be detected by IceCube



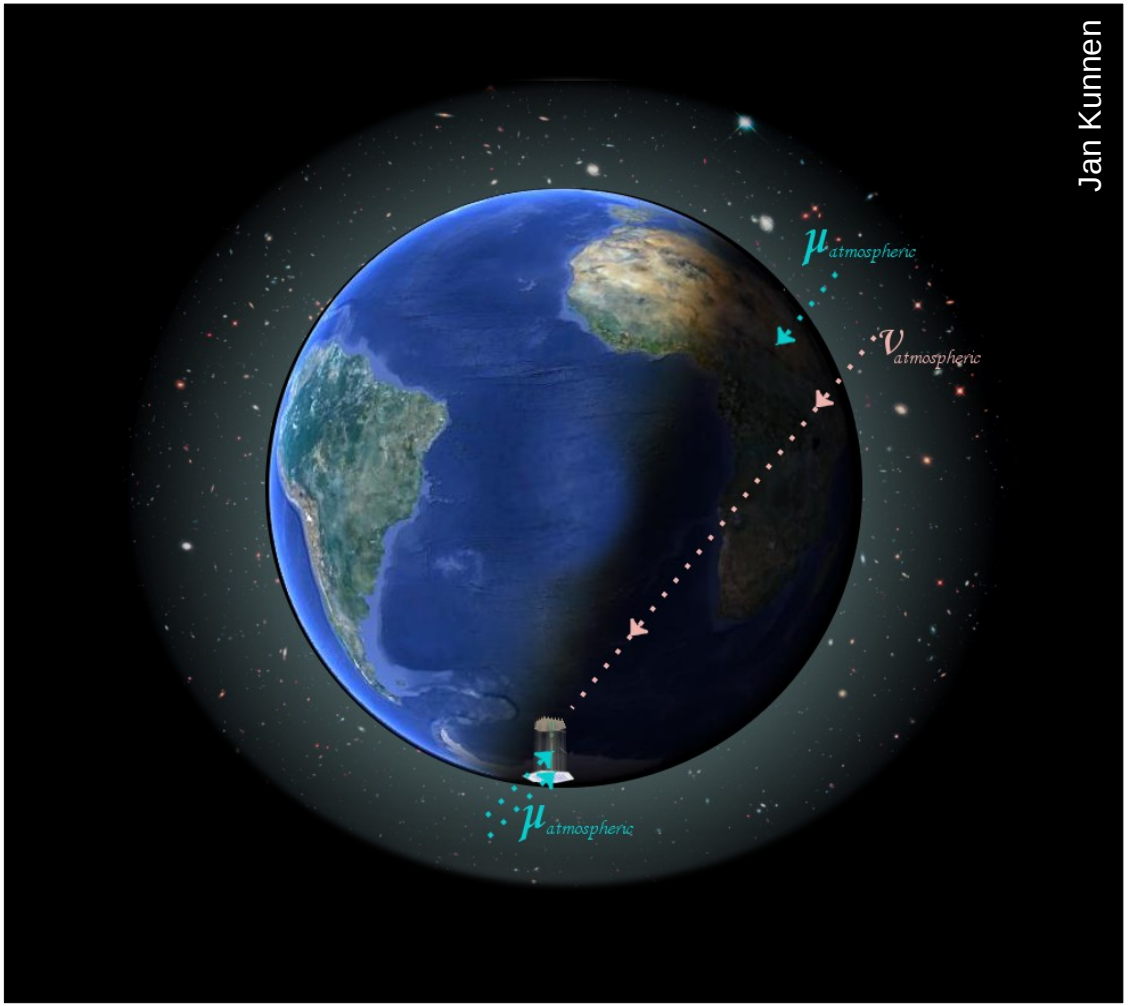
DM signal from Earth

- Neutrino signal from annihilating dark matter would come from center of Earth
- Maximum a few 10^3 events per year (more = excluded)
- GeV to TeV energies



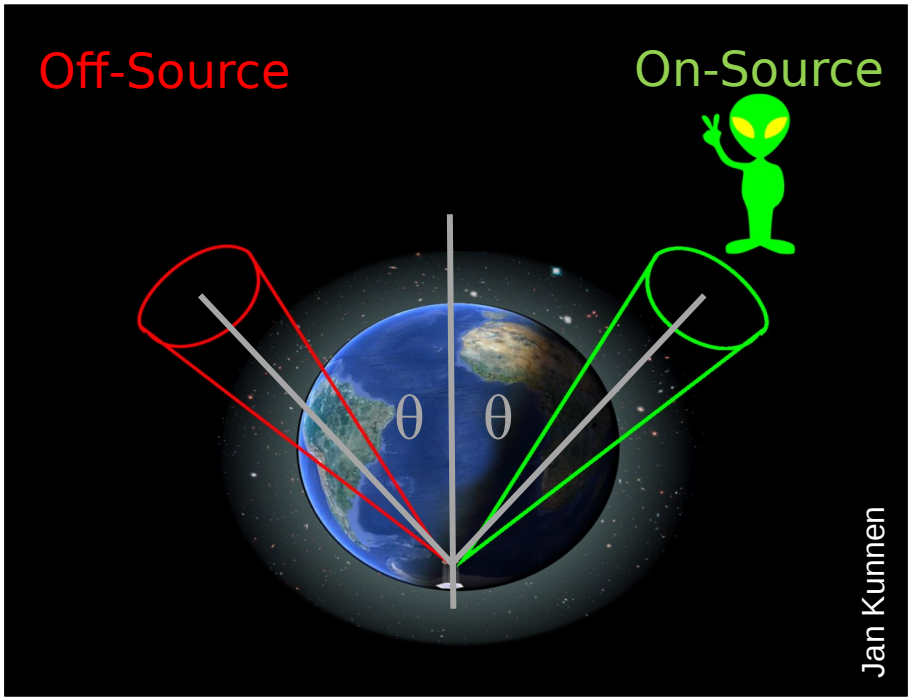
Background

- Background coming from all directions
  - Produced in the atmosphere by cosmic rays
- Few 10^{10} muons and 10^{5} neutrinos per year
- GeV to PeV energies

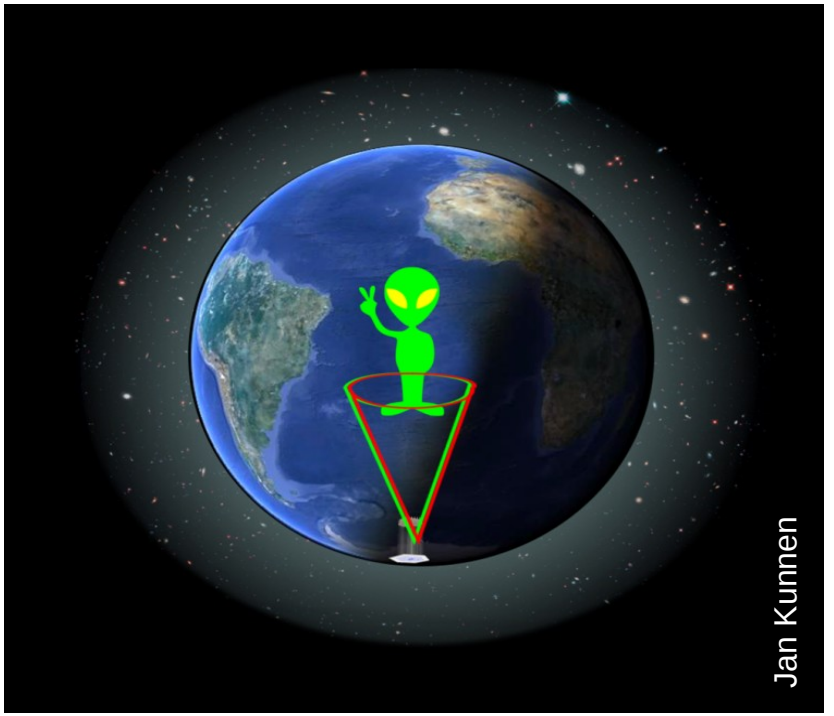


Background

Background rate depends on zenith
→ cannot define off-source region by changing azimuth



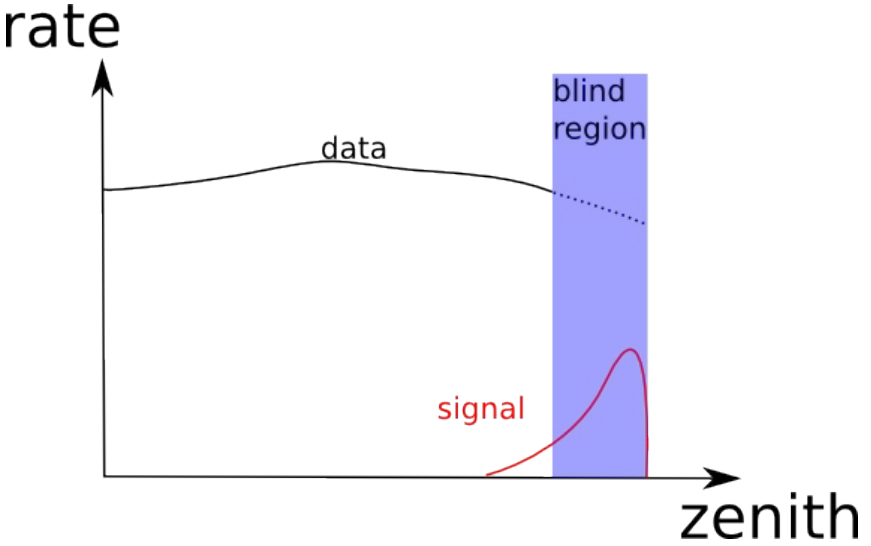
Other searches:
Background estimated
by off-source data

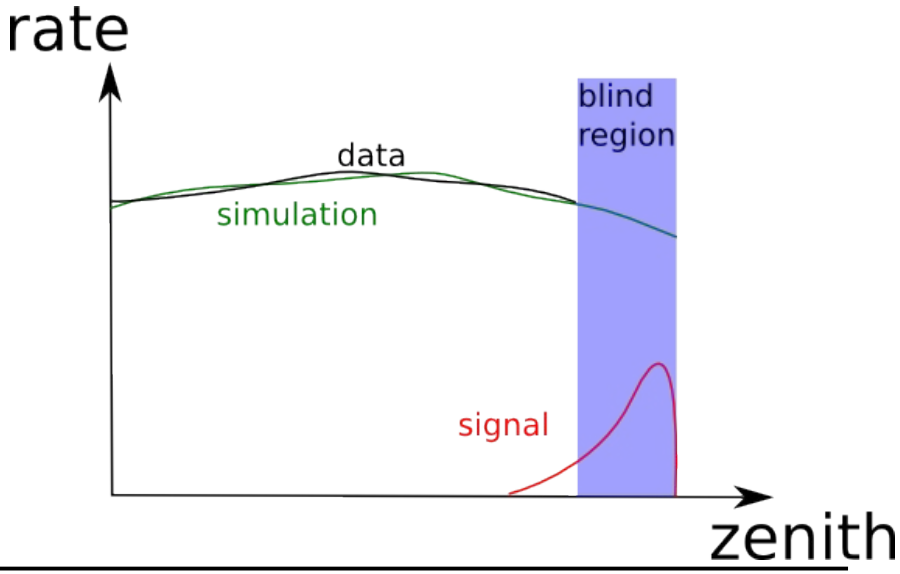


Earth searches:
Background estimated
by simulation

Background

- Instead: estimate background by
  - Extrapolate background expectation from neighboring region
- or
  - Simulation of background and (compare with data in off-source region)

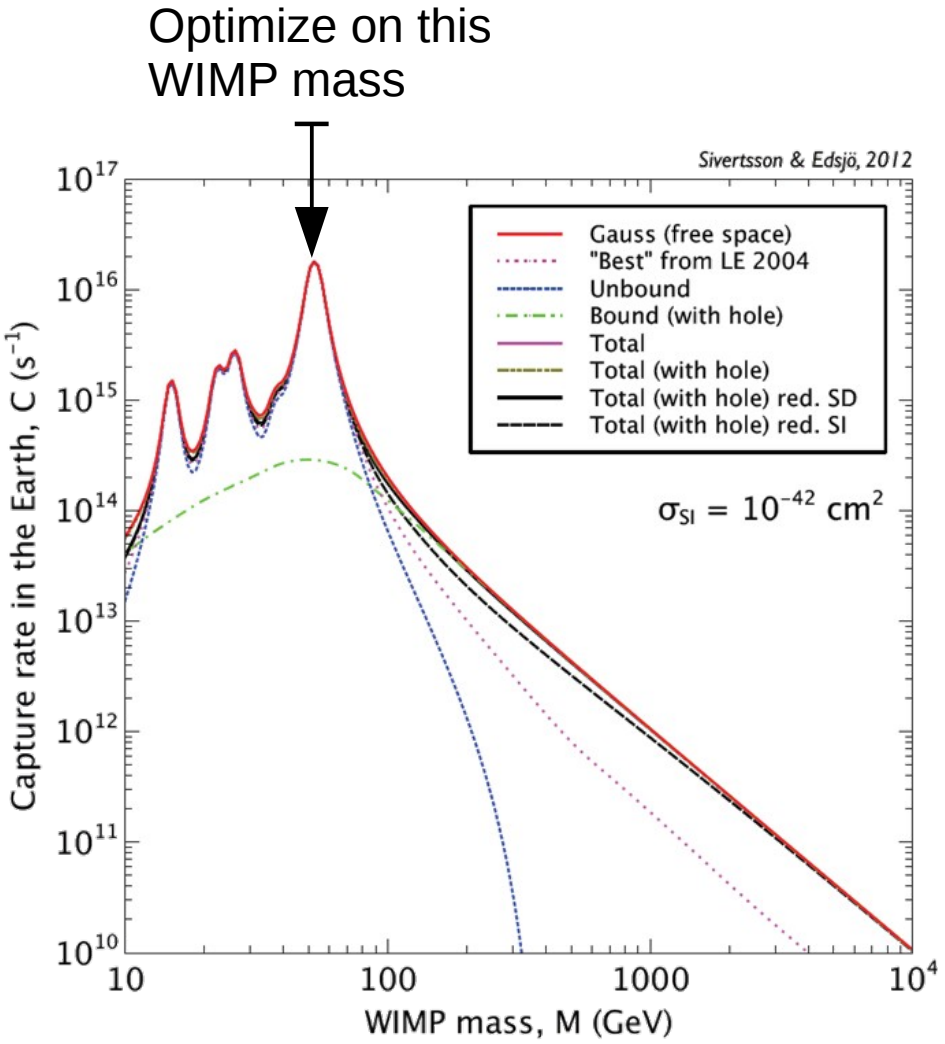




Capture rate

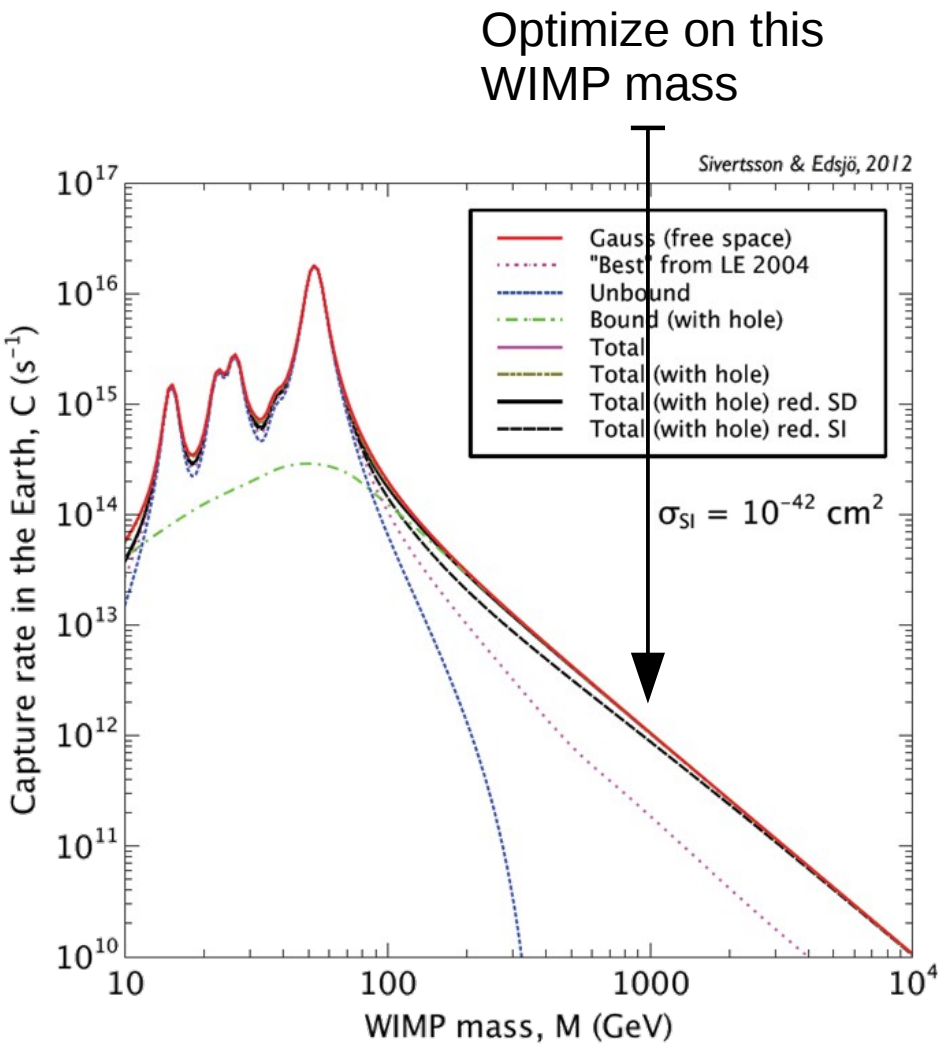
- Capture rate depends on WIMP mass
- Resonance with heavy inner elements of Earth
- Optimize analysis on $m_\chi = 50$ GeV

$$\chi\chi \to \tau^+\tau^-$$



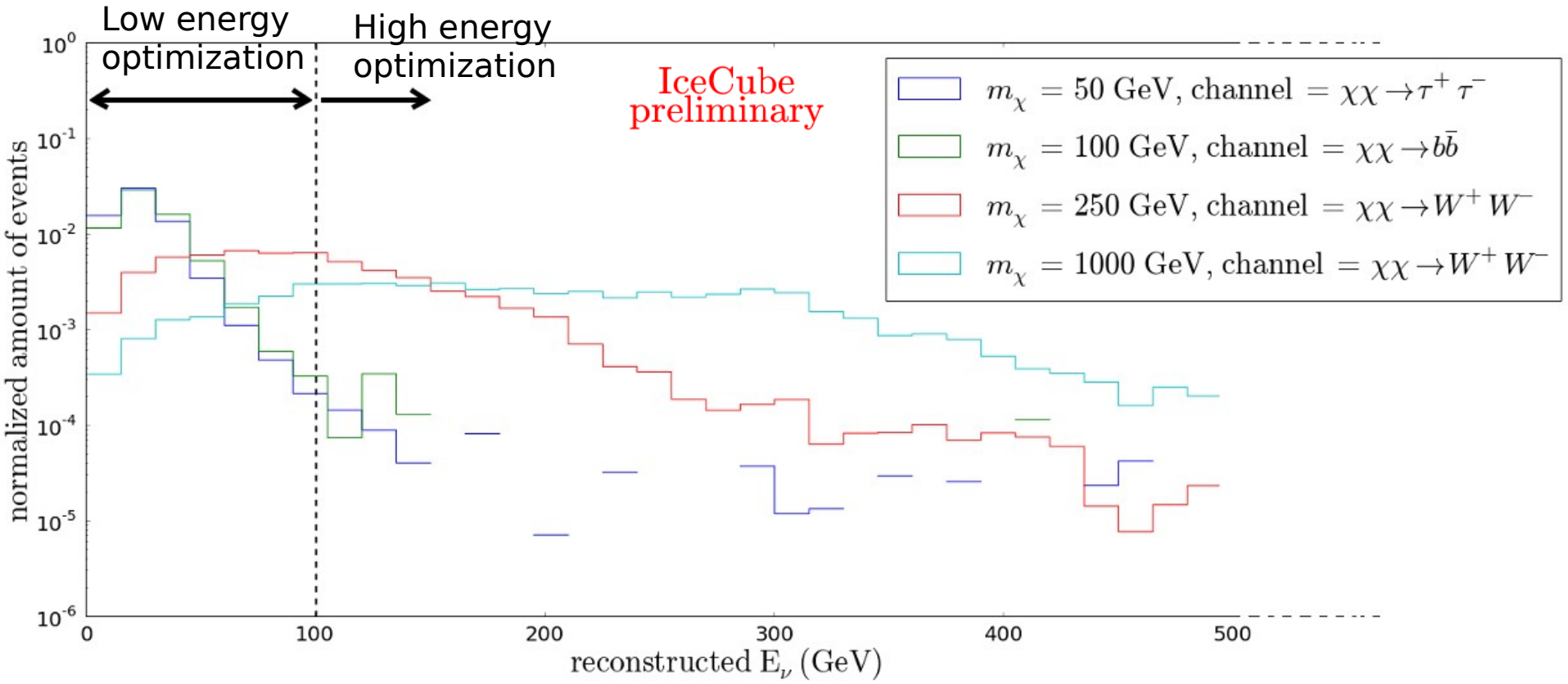
Capture rate

- A second independend analysis is done, to be also sensitive to larger WIMP masses
- Data sample is split at neutrino energy of 100GeV
- Optimize analysis on $m_\chi = 1$ TeV $\chi\chi \to W^+W^-$



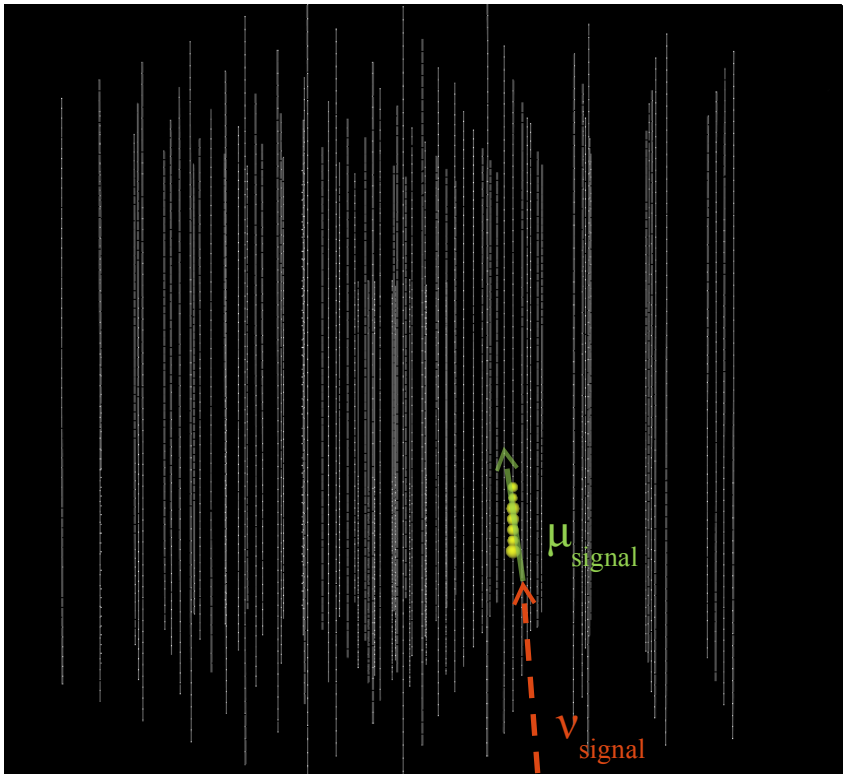
Data split

Cutting on the reconstructed energy.

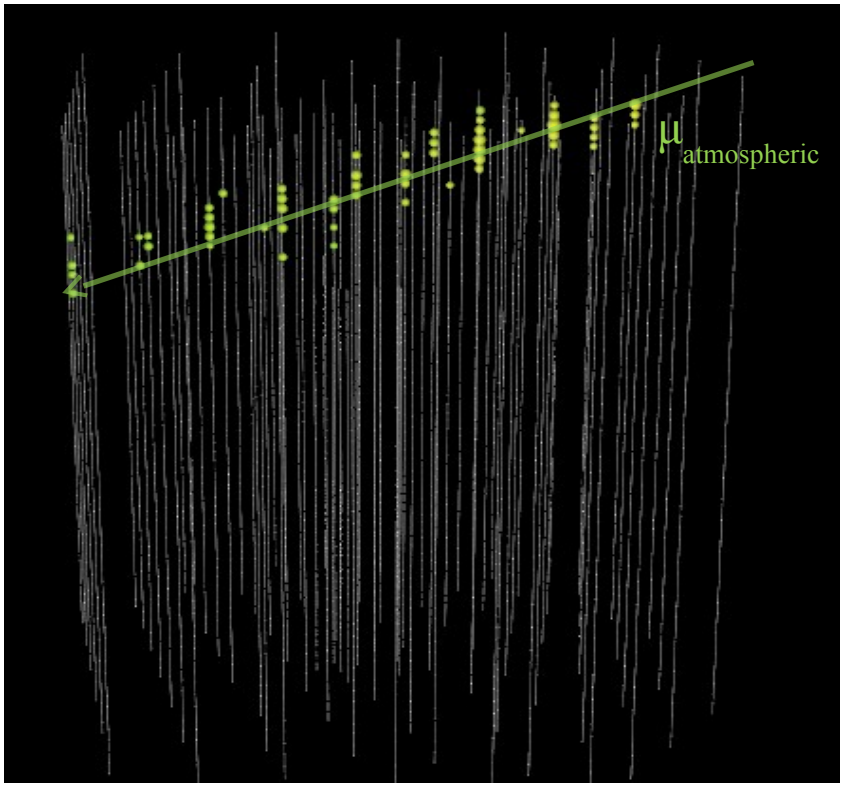


Background Reduction

A typical *signal* event
if m_x = 50 GeV



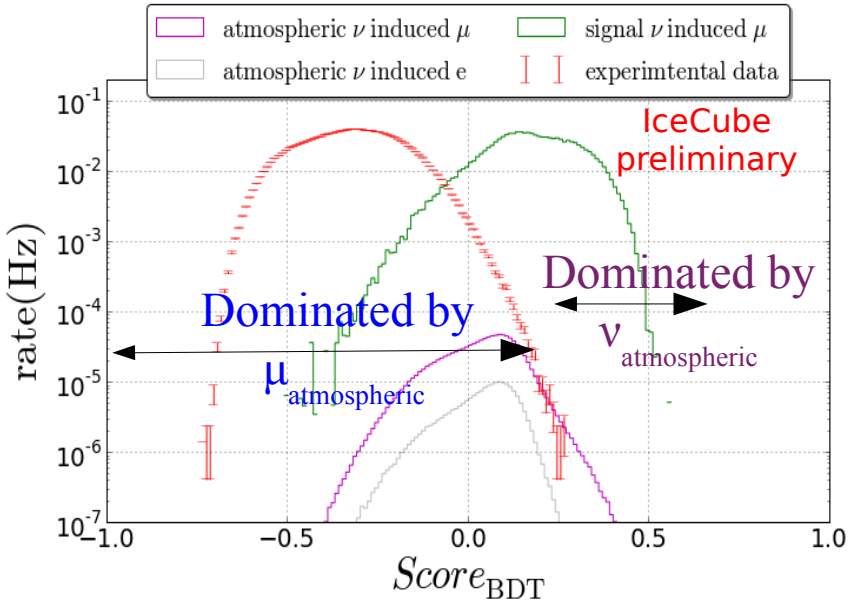
A typical *background* event



Background Reduction

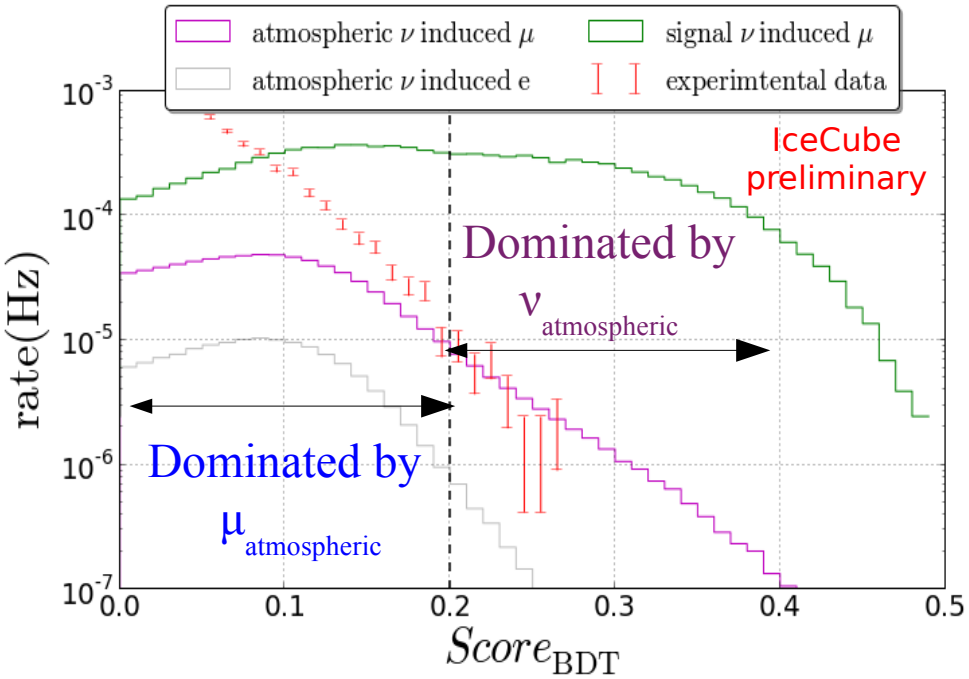
- How to distinguish between background and signal:
  - Reconstructed direction
    - Signal events come from below
  - Quality of reconstruction
    - Poorly reconstructed background events can appear upgoing
  - Additional topological variables

Background Reduction



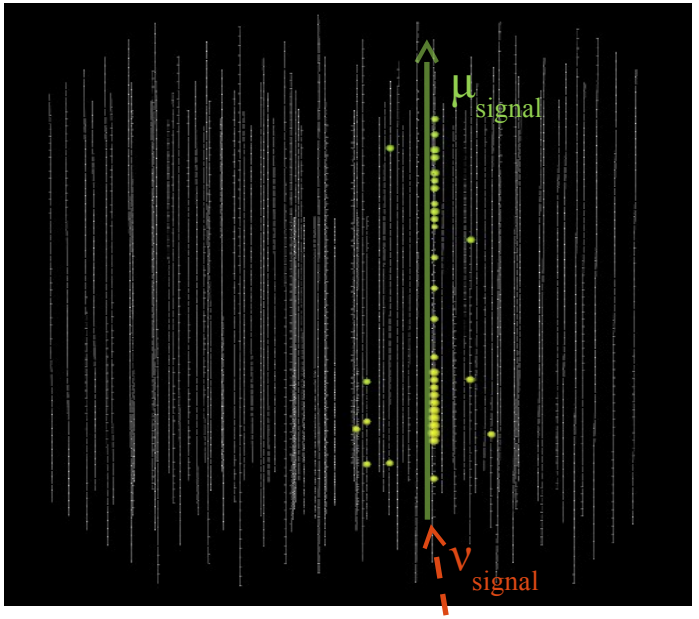
- BDT cut was chosen such that the final sample has a purity (neutrino rate/total rate) > 90%.
- Cut will be tuned to get optimal sensitivity

- Variables with good discriminating power are fed into a BDT
- trained on experimental data (atmospheric muon dominated) and 50 GeV WIMP neutrinos.

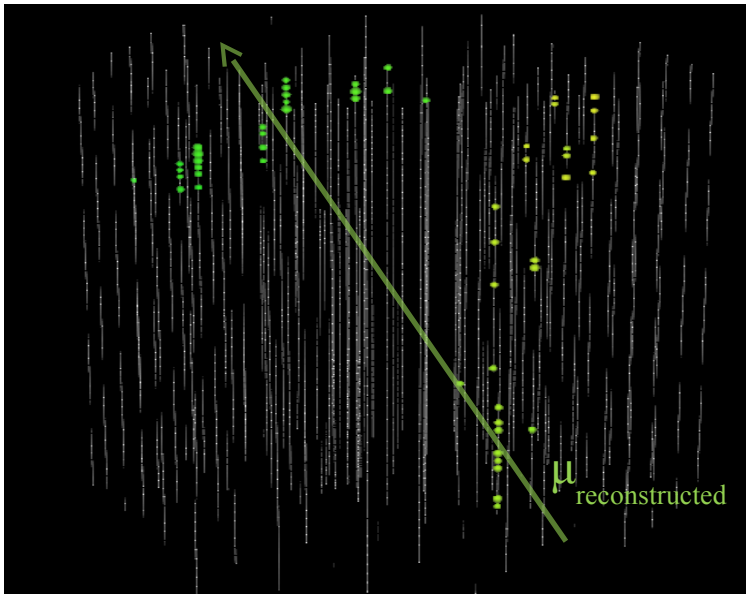


High Energy Background

- At higher energies coincident muons are more frequent
- Can be simulated as upgoing event



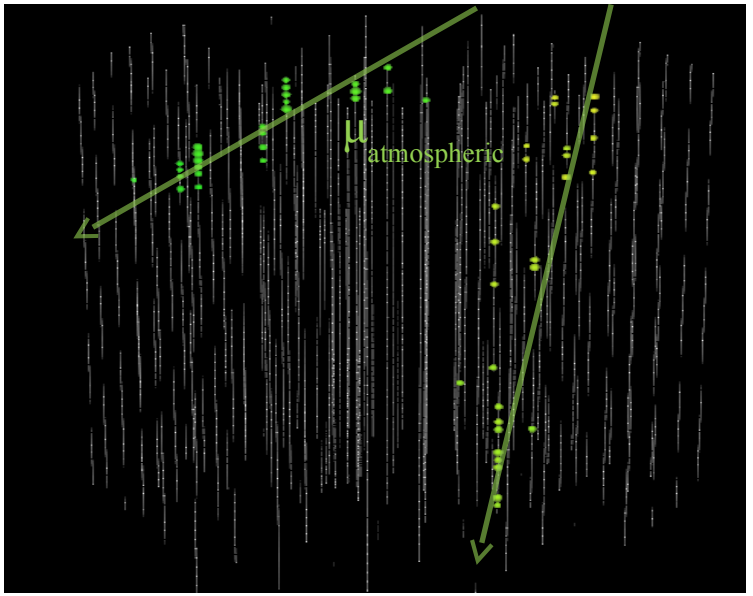
A typical *signal* event
if m_x = 1 TeV



A typical *background* event

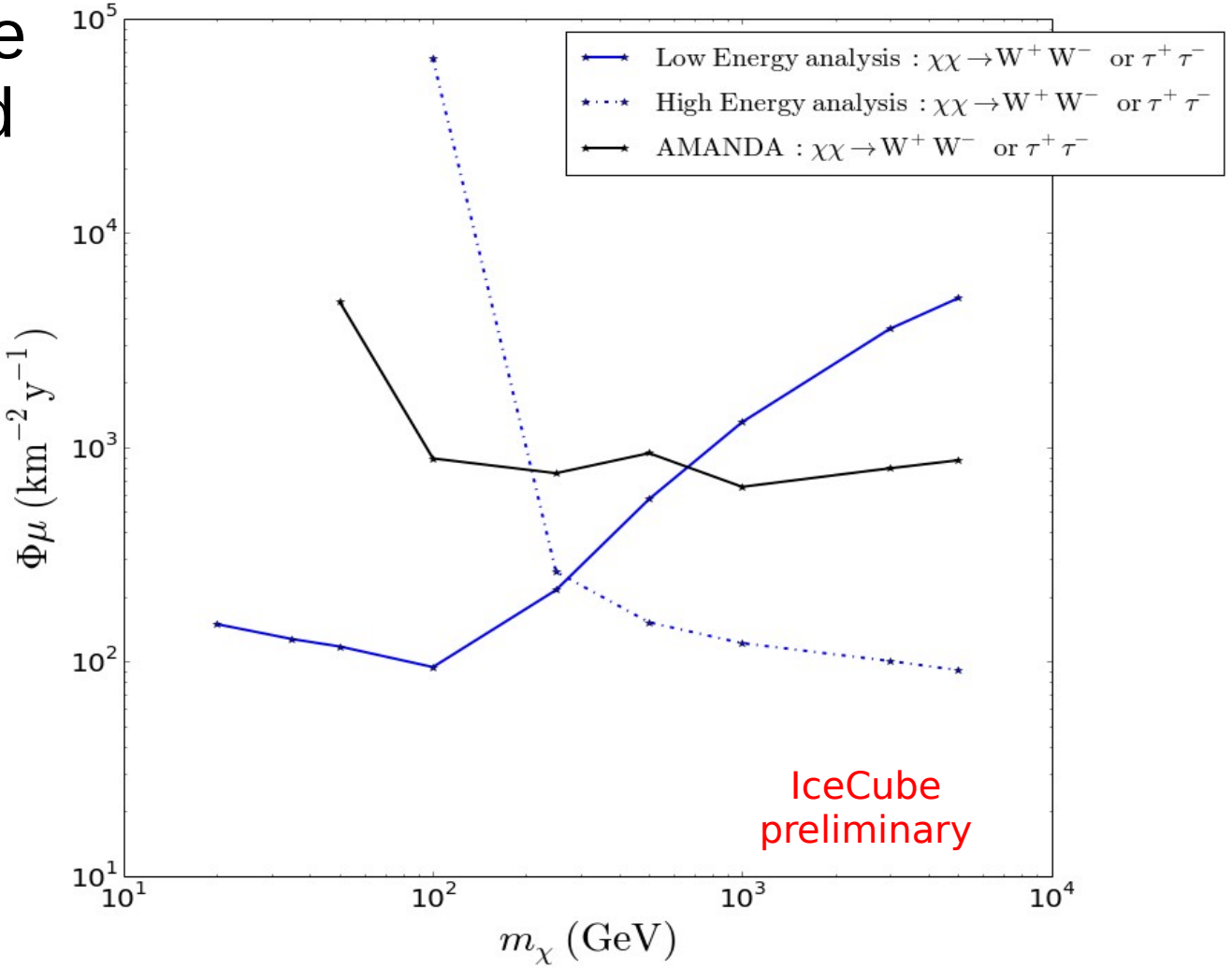
High Energy Background

- Split hit pattern
- Search for topological connected hits
- Reconstruct hit sets separately
- Reject downgoing events

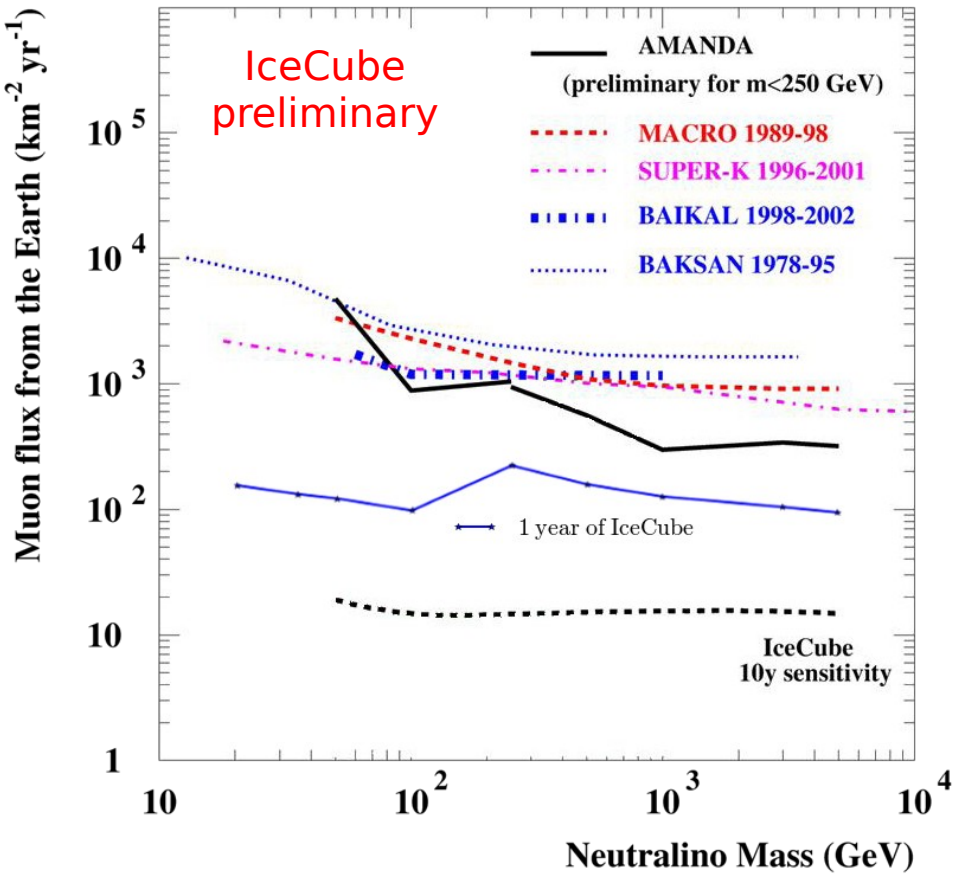


Sensitivity

- Sensitivity on the neutrino induced muon flux from the Earth



Sensitivity



- First Analysis with IceCube Data
- Increase of sensitivity by a factor ~10
- Work on improvements

A. Achterberg et al. / Astroparticle Physics 26 (2006) 129–139

Cross section

- Interpretation from neutrino flux to capture rate and cross-section is highly model dependent
  - Influence of gravitational potential of Sun and other planets
  - Probably no equilibrium between WIMP capture and annihilation
  - Capture rate depends on velocity distribution of WIMPs

Summary

- First search for dark matter in the center of the Earth with IceCube will be finished in the near future
- Two optimizations are performed for the low-energy and the high-energy region
- Analysis will be a factor 10-100 more sensitive than the last AMANDA search

IceCube

- 1 km³ of South Pole ice instrumented with 5160 optical modules
  - String spacing 125 m
  - DOM spacing 17 m
- DeepCore
  - String spacing 72 m
  - DOM spacing 7 m