Searching for Dark Matter in the center of the Earth with IceCube

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Astropacticle Physics 2014

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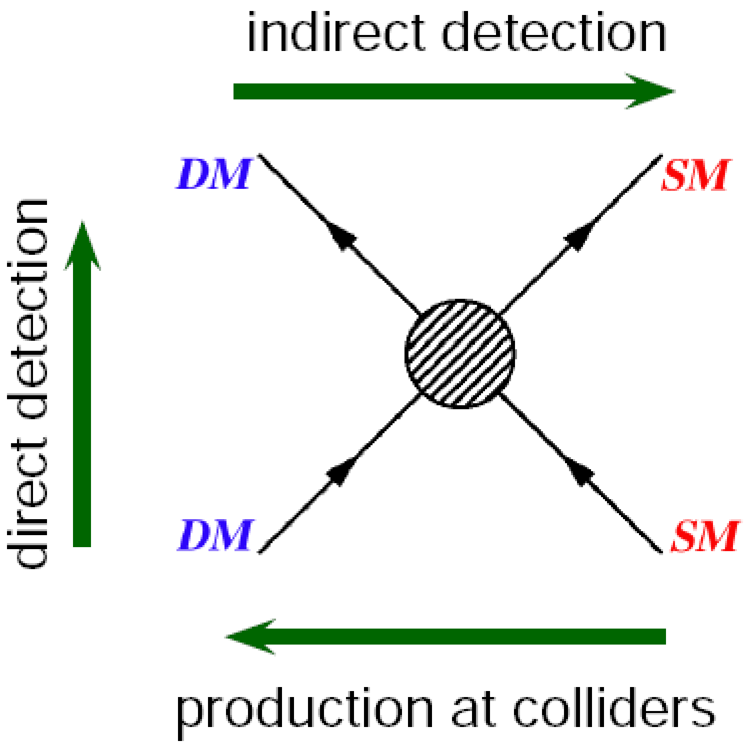
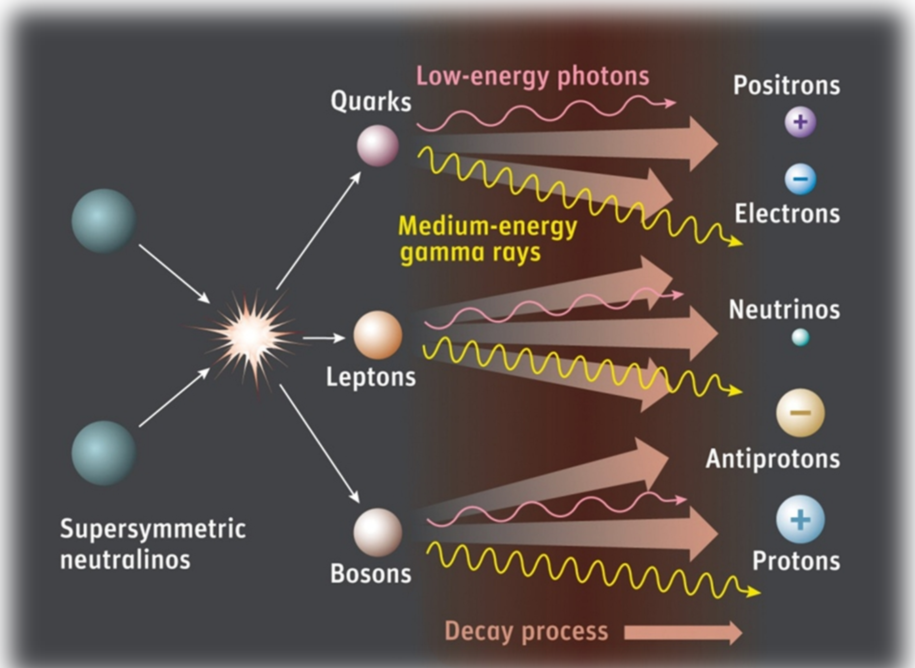
Vrije Universiteit Brussel

One way to look for Dark Matter is via *indirect detection.*





IceCube can determine the muon and thus the neutrino direction.

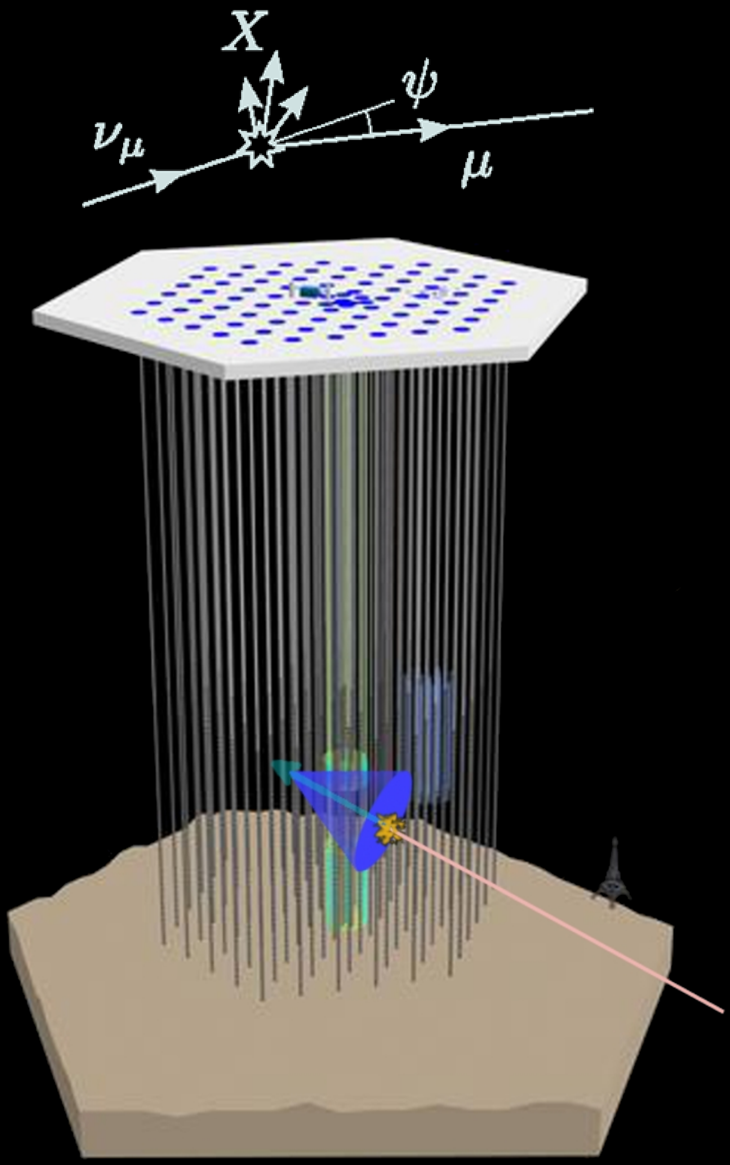
Detector completion in December 2010.

5160 DOMs on 86 strings.

Central part : DeepCore

- Deployed in deepest, clearest ice,
- lowers energy threshold to ~10 GeV,
- IceCube as active veto (muon shield).

Knowing the muon direction ≈ knowing the neutrino direction .



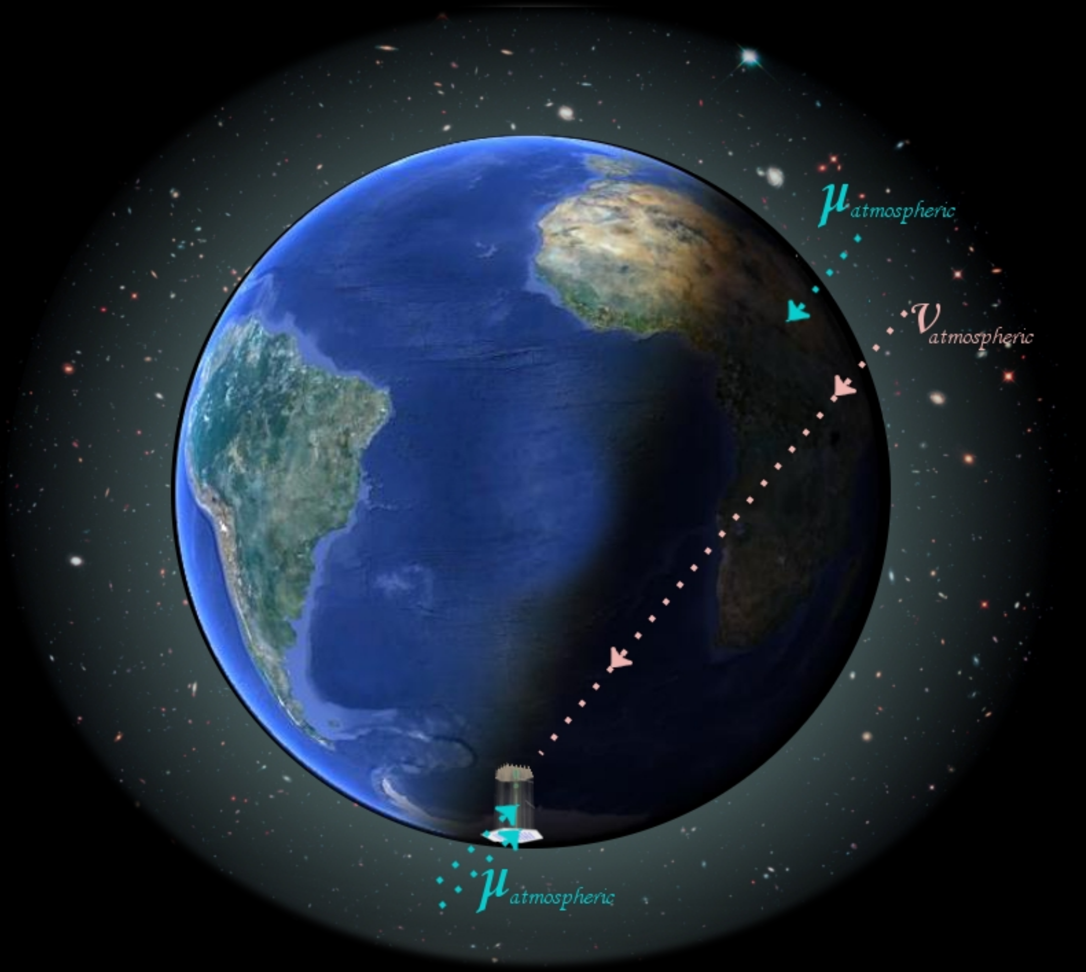
A lot of background is constantly coming from all directions.

Background :

Produced in the atmosphere by cosmic rays.

Few 10^{10} muons and 10^{5} neutrinos per year.

GeV to PeV energies.



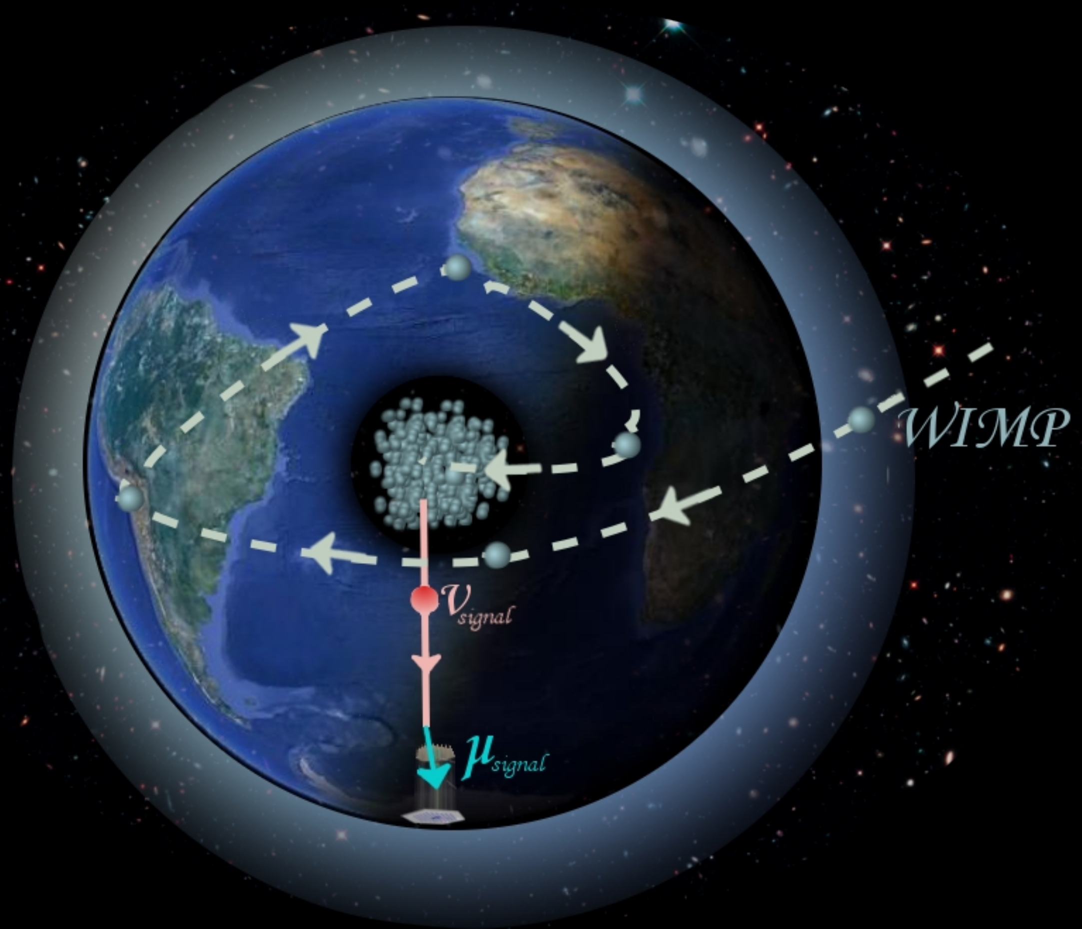
neutrinos could come from the center of the Earth.

Signal neutrinos :

Coming from WIMP annihilations in the center of the Earth.

Maximum a few 10^3 events per year (more = excluded).

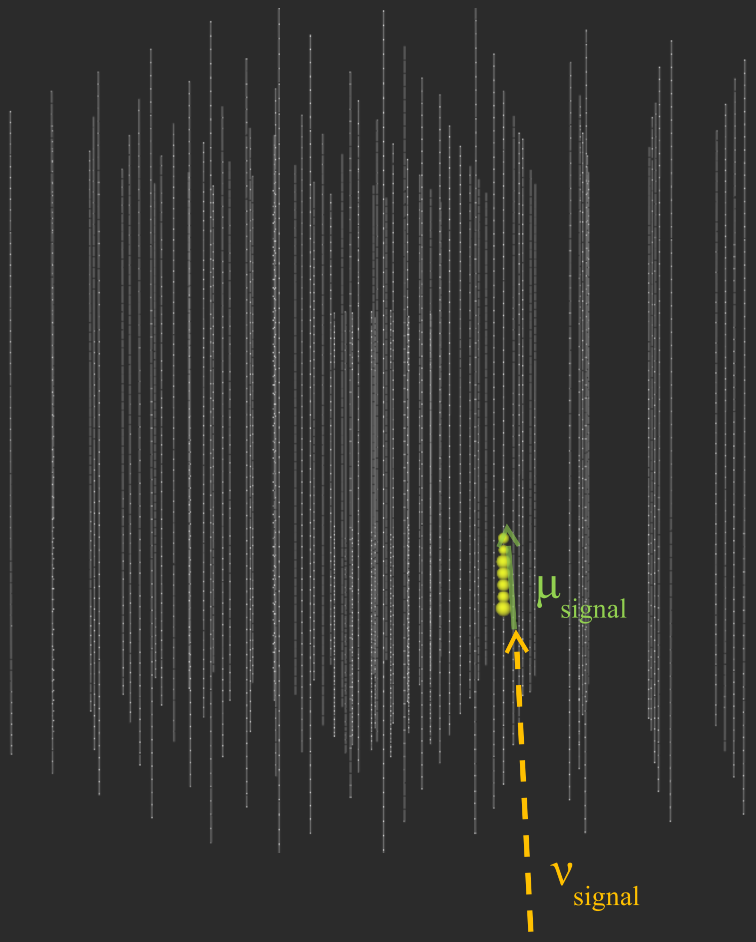
GeV to TeV energies.



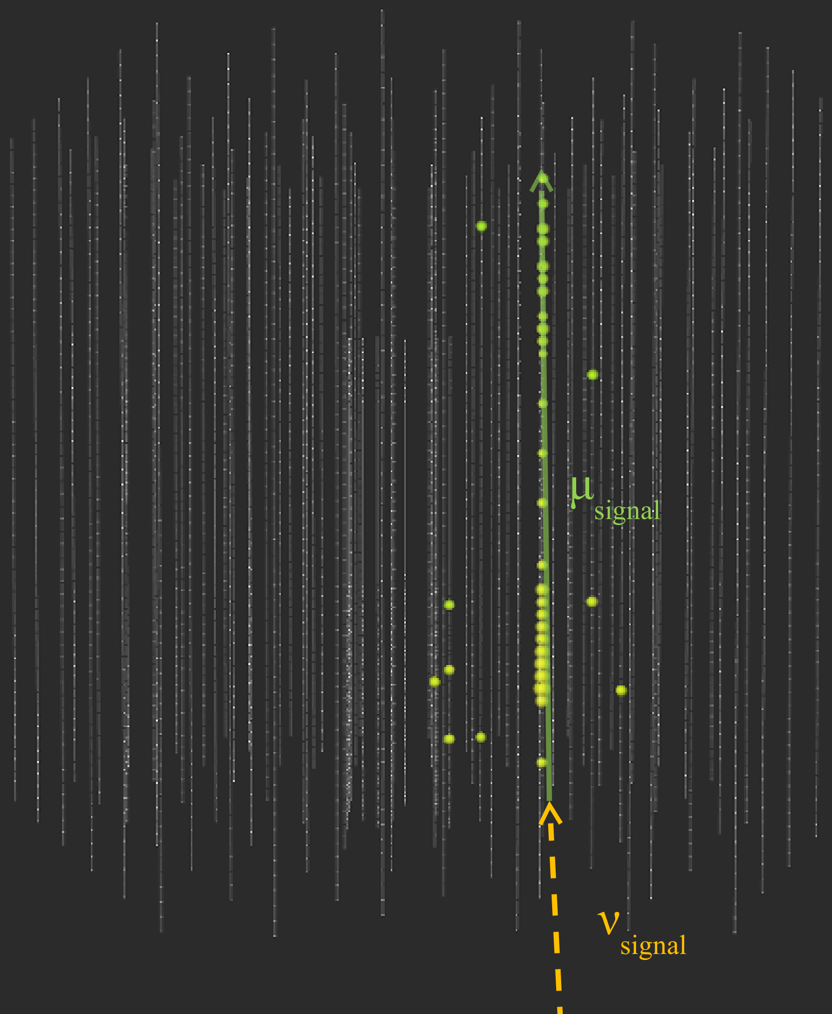
in this analysis we cannot just define an off-source region →
need to rely on simulations and extrapolation methods.

The event topology will be different for different WIMP models

A typical *signal* event if m_x = 50 GeV

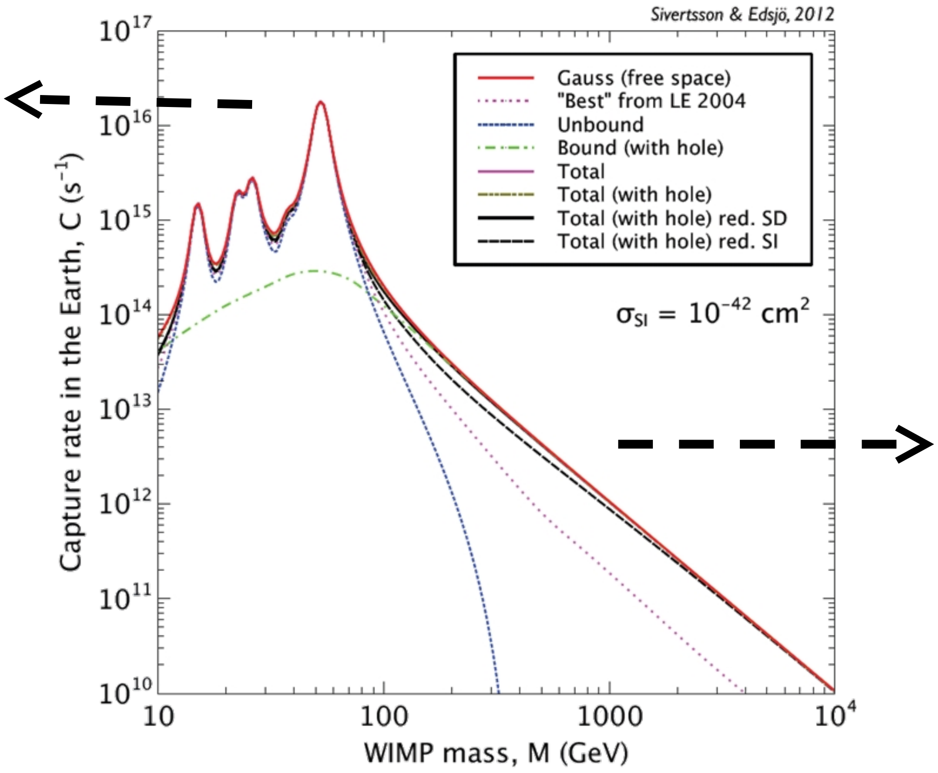


A typical *signal* event if m_x = 1 TeV



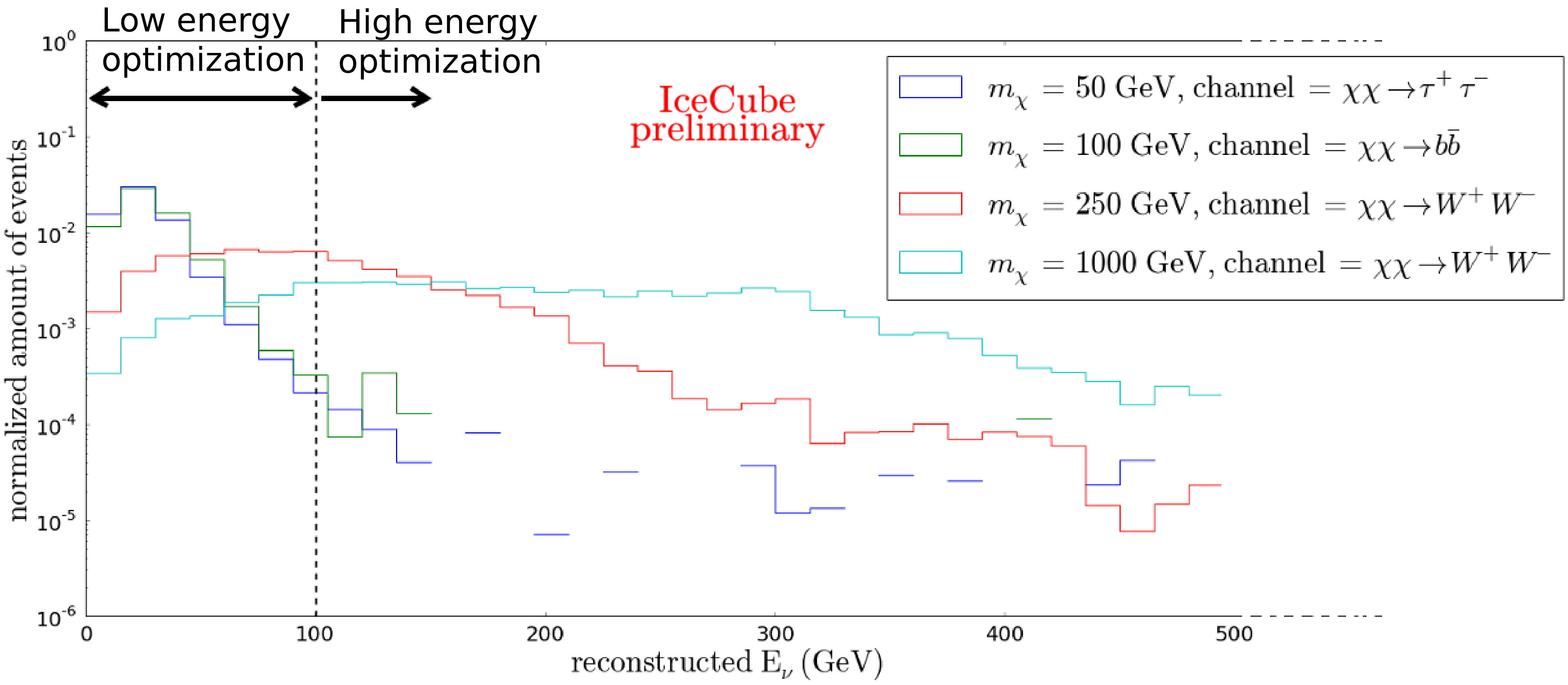
To be sensitive to a big parameter space,
2 statistically independent analyses are done.

Optimize on
50 GeV WIMPs
$\chi\chi \rightarrow \tau^+\tau^-$



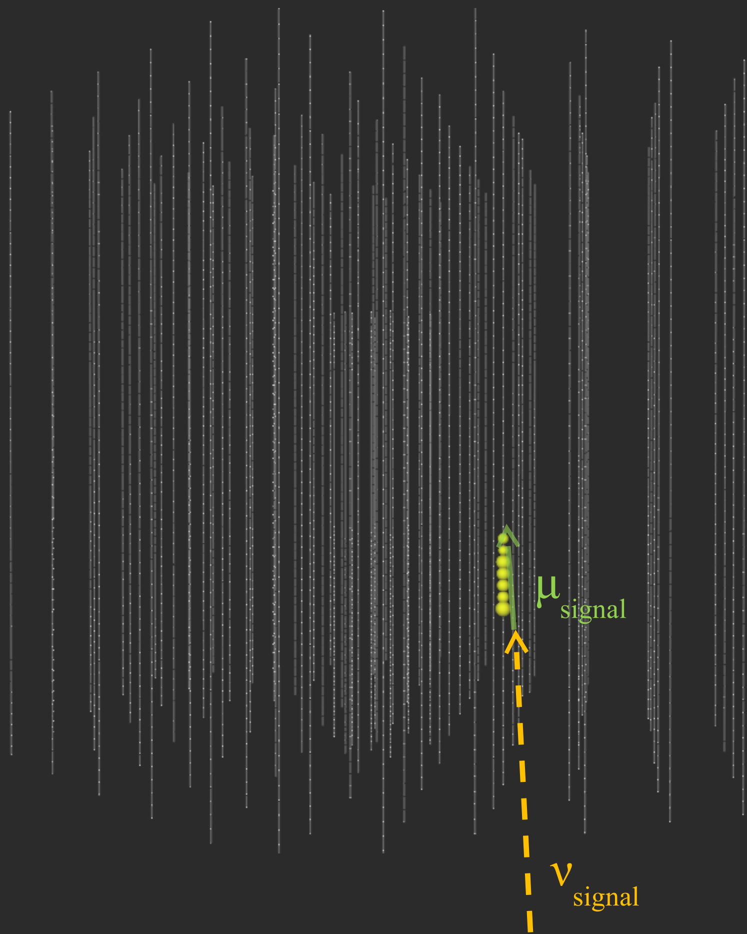
Optimize on
1 TeV WIMPs
$\chi\chi \rightarrow W^+W^-$
to increase
efficiencies at
higher masses

How do we split the dataset?
By cutting on the reconstructed energy.

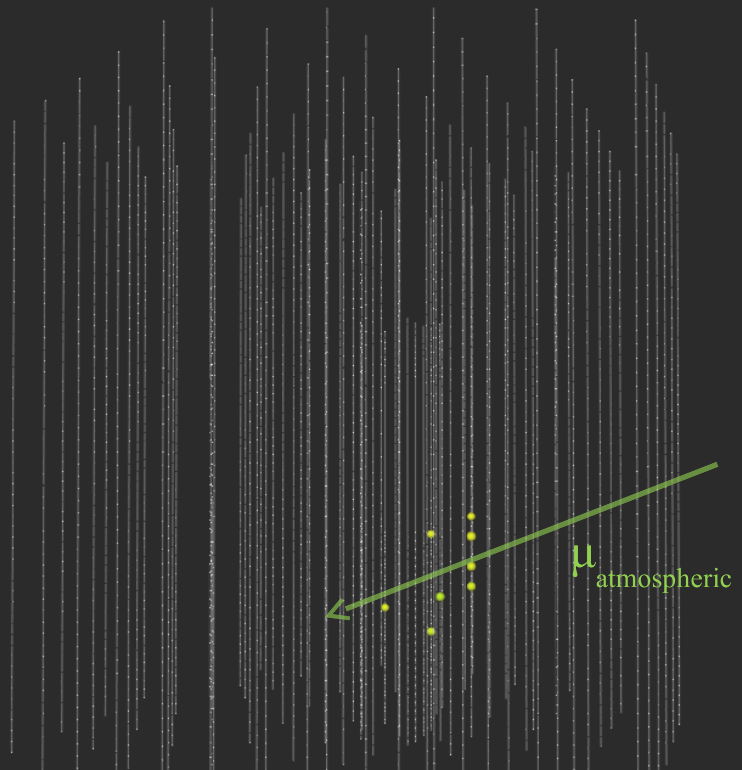


Look at events to optimize the Low Energy event selection.

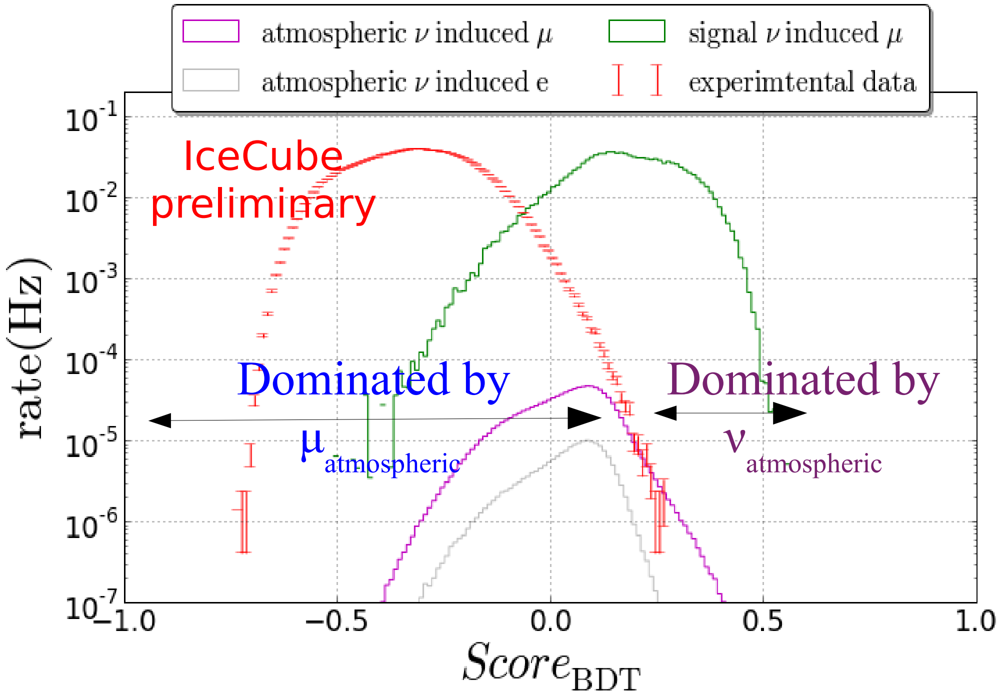
A typical *signal* event
if m_x = 50 GeV



A more difficult to catch
atmospheric muon event



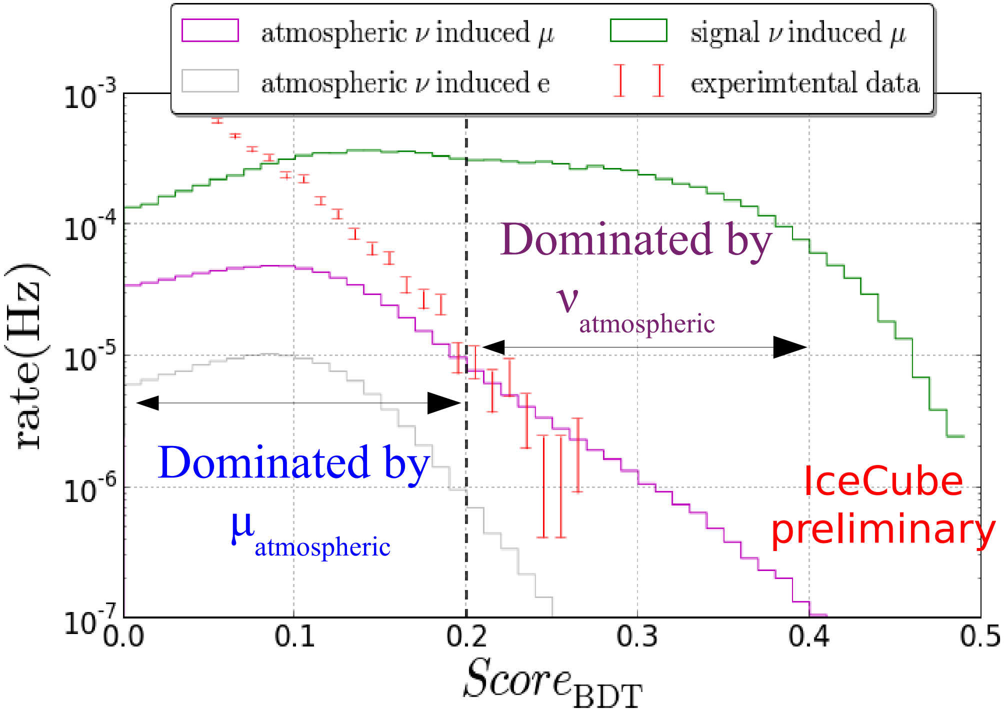
This muon sneaks in and makes some SLC hits on the outer strings, that are removed by hit cleaning.



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

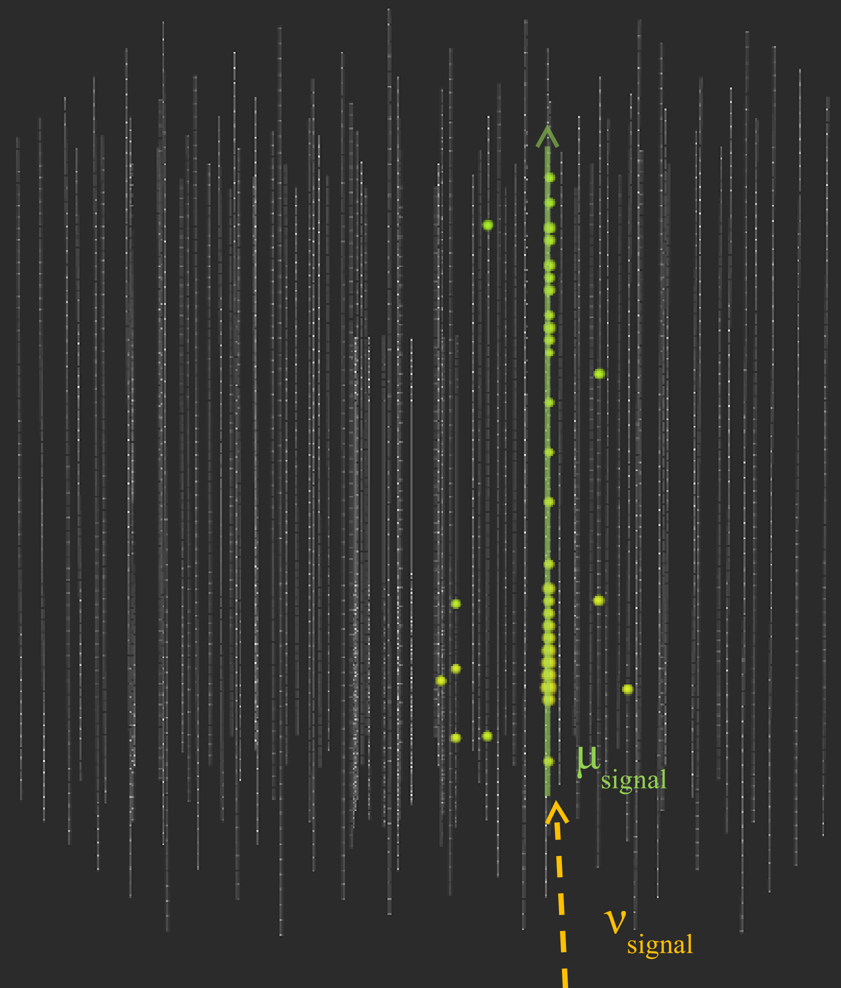
The BDT cut was chosen such that the final sample has a purity (neutrino rate/total rate) > 90%.

This way, we have a very pure final sample, on which we can do a statistical analysis.

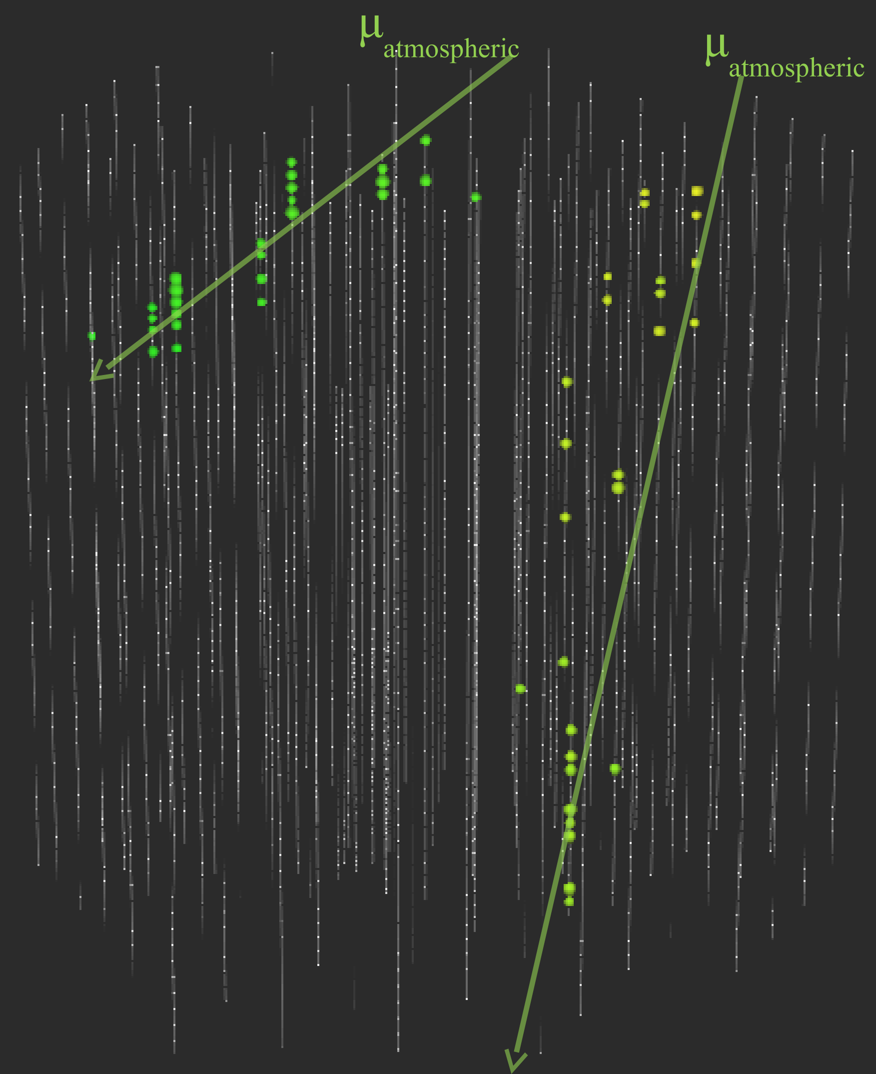


Look at events to optimize the event selection.
(Work by I. Ansseau)

A typical *signal* event
if m_x = 1 TeV



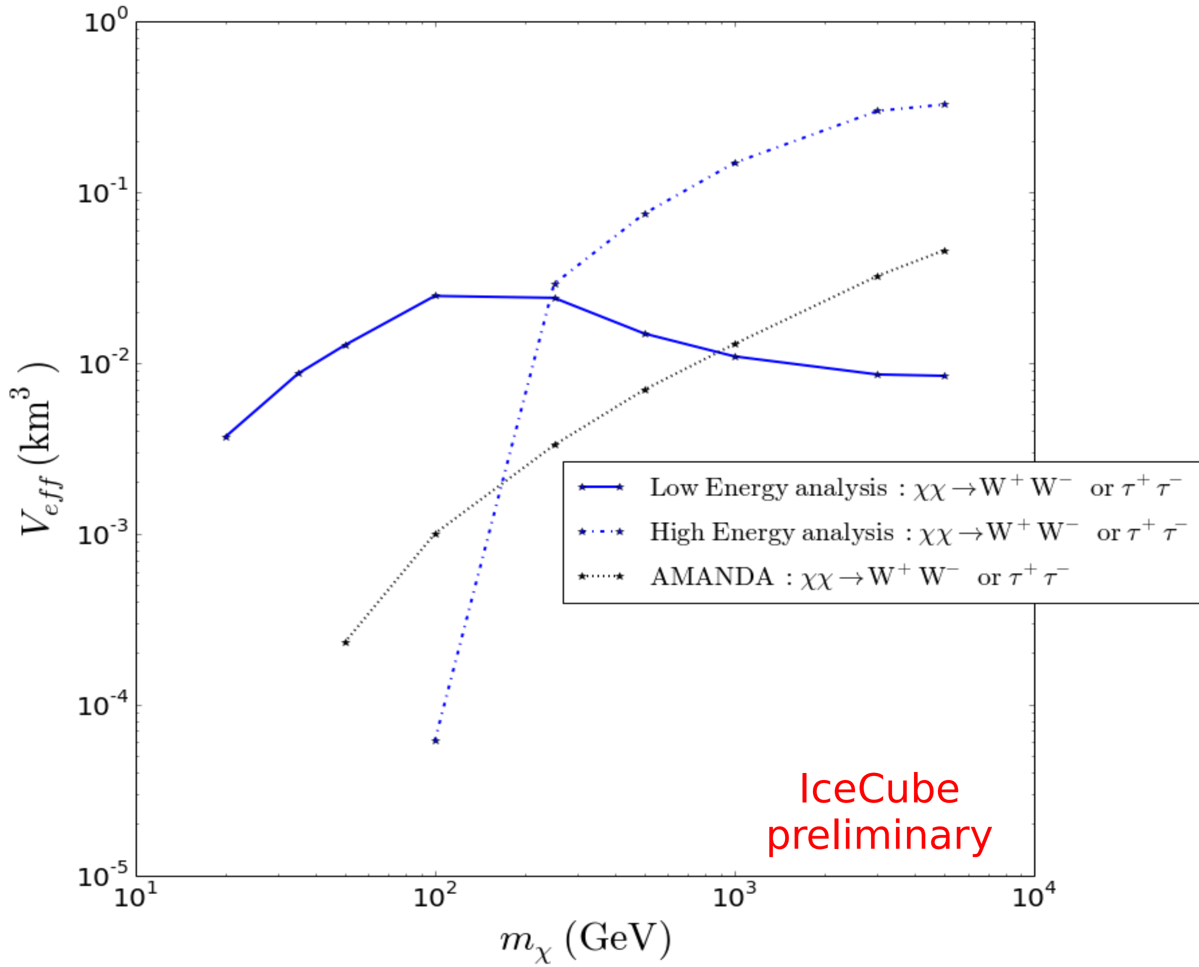
A typical *background* event



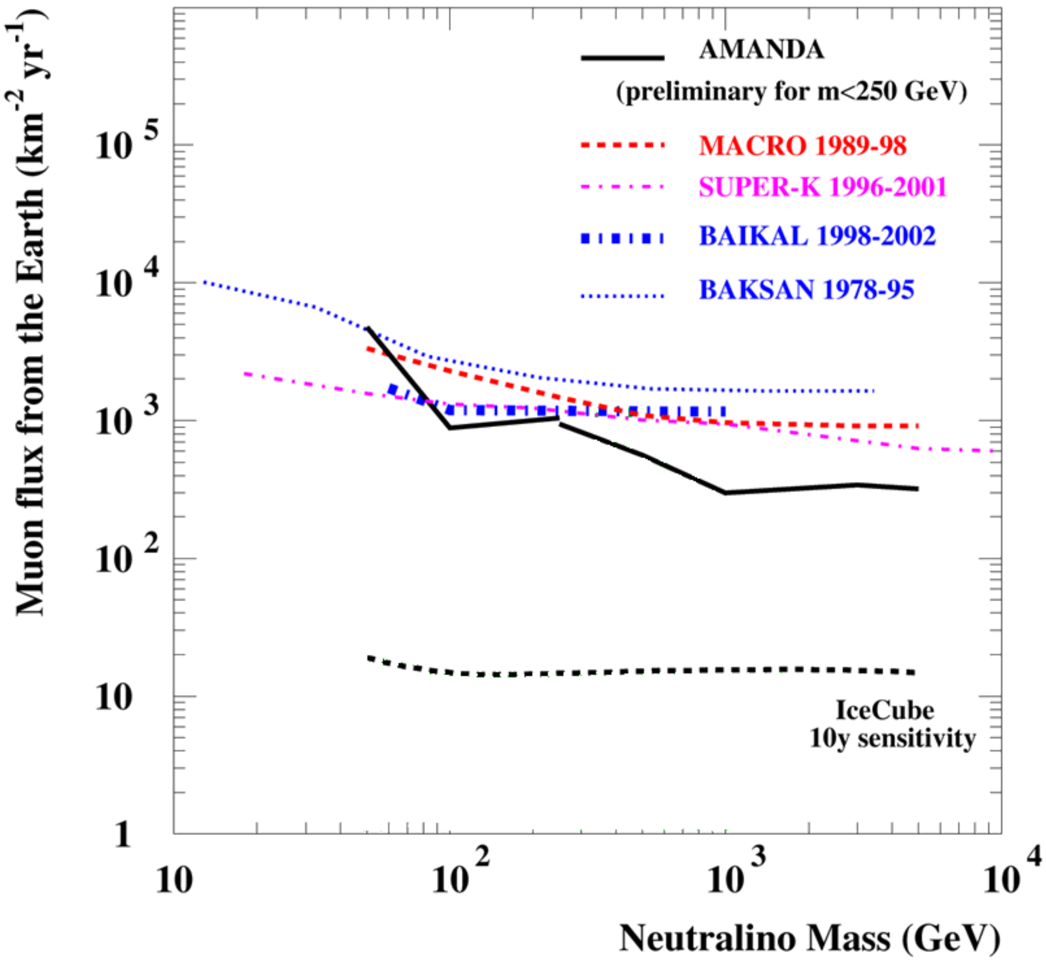
The effective volume improves more than 1 order of magnitude compared to AMANDA, as geometrically expected.

$$V_{eff_{cut}} = \frac{n_{cut}}{n_{gen}} V_{gen}$$

When we compare the best V_{eff} of the 2 IceCube searches with the V_{eff} of AMANDA, we see an increase in effective volume of 1-2 orders of magnitude, as expected from the detector geometries.



The first Earth WIMP search with IceCube is being done. Let's look at the sensitivity.



Most recent result dates from AMANDA.

We picked up the analysis again!

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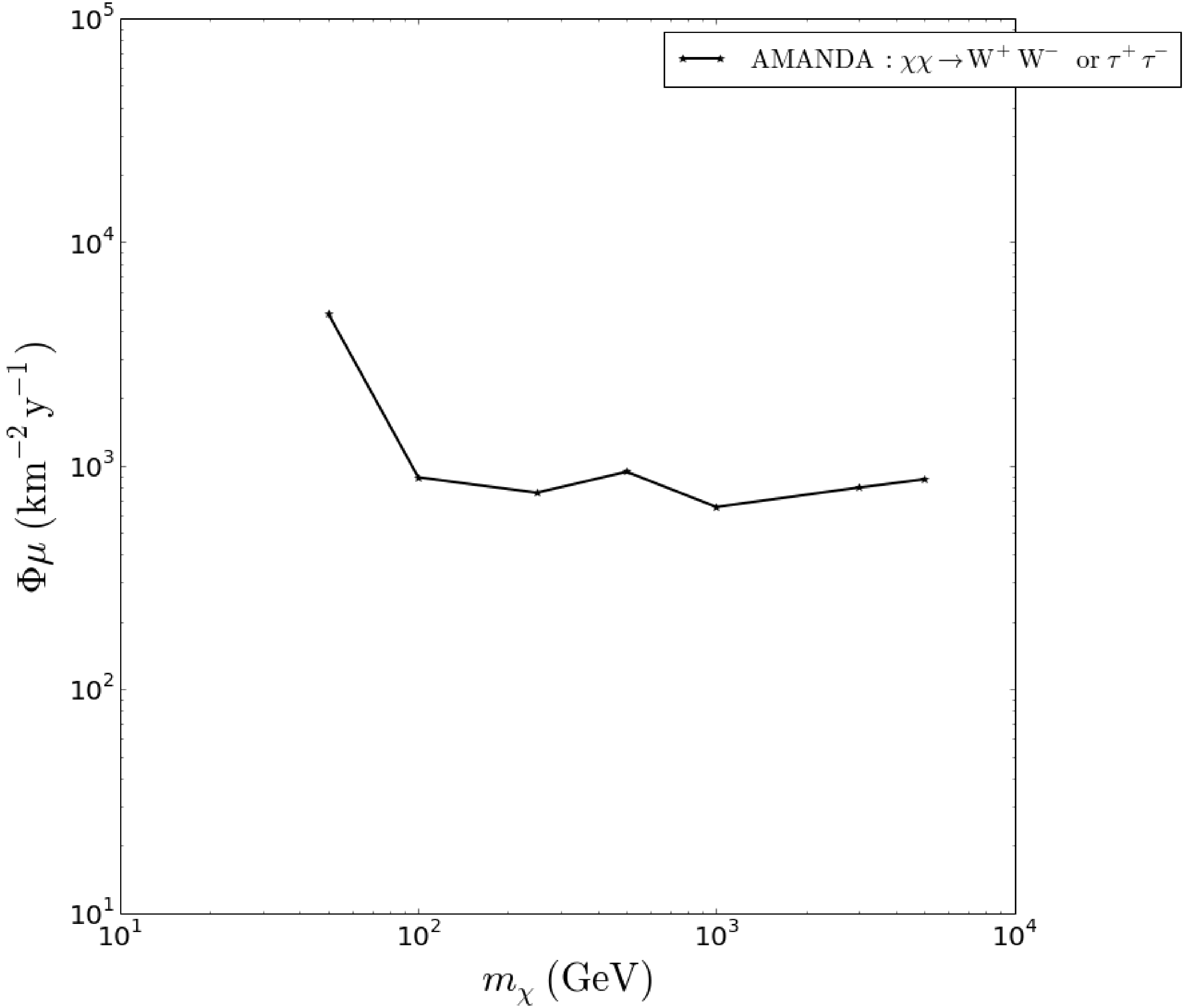
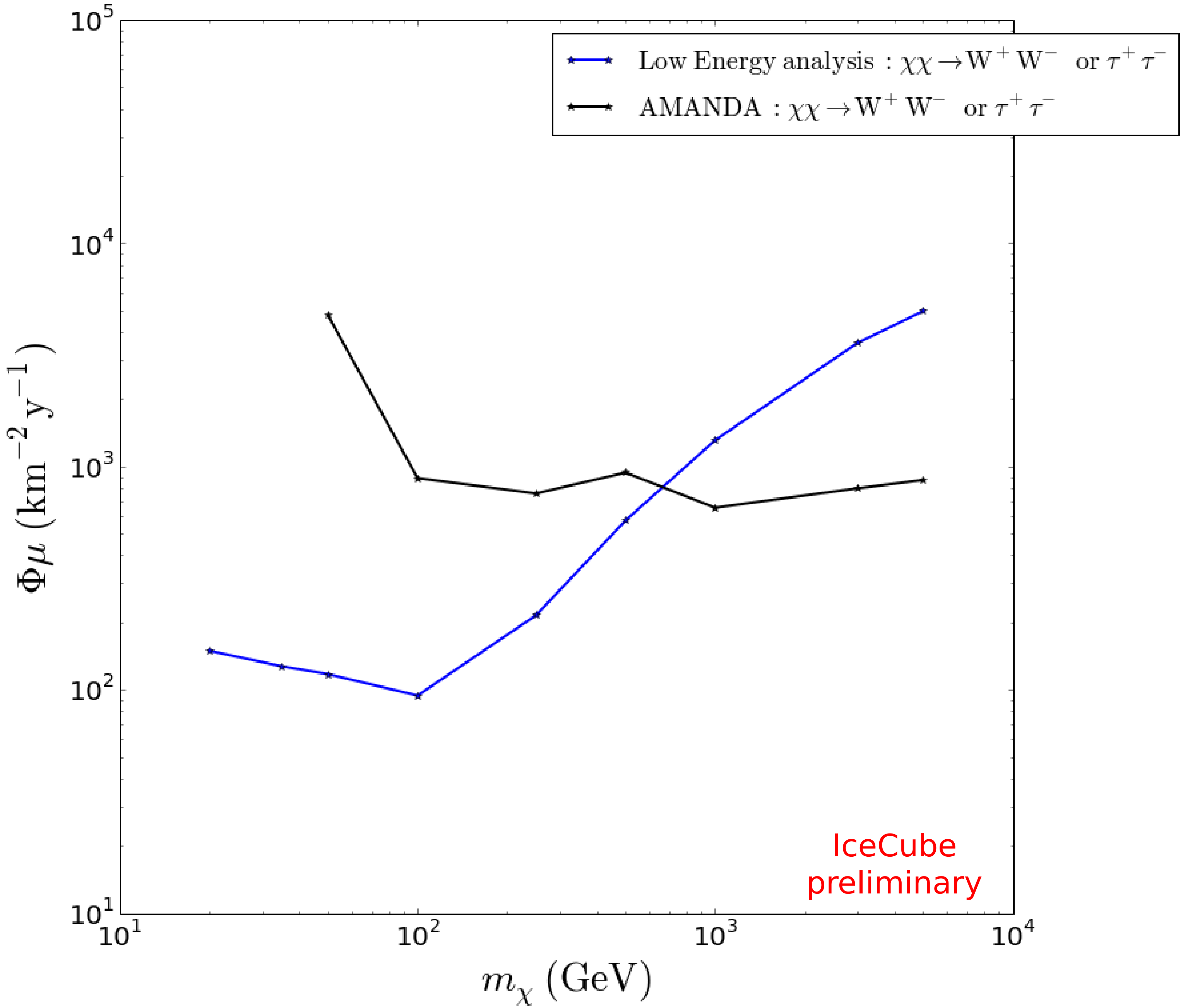
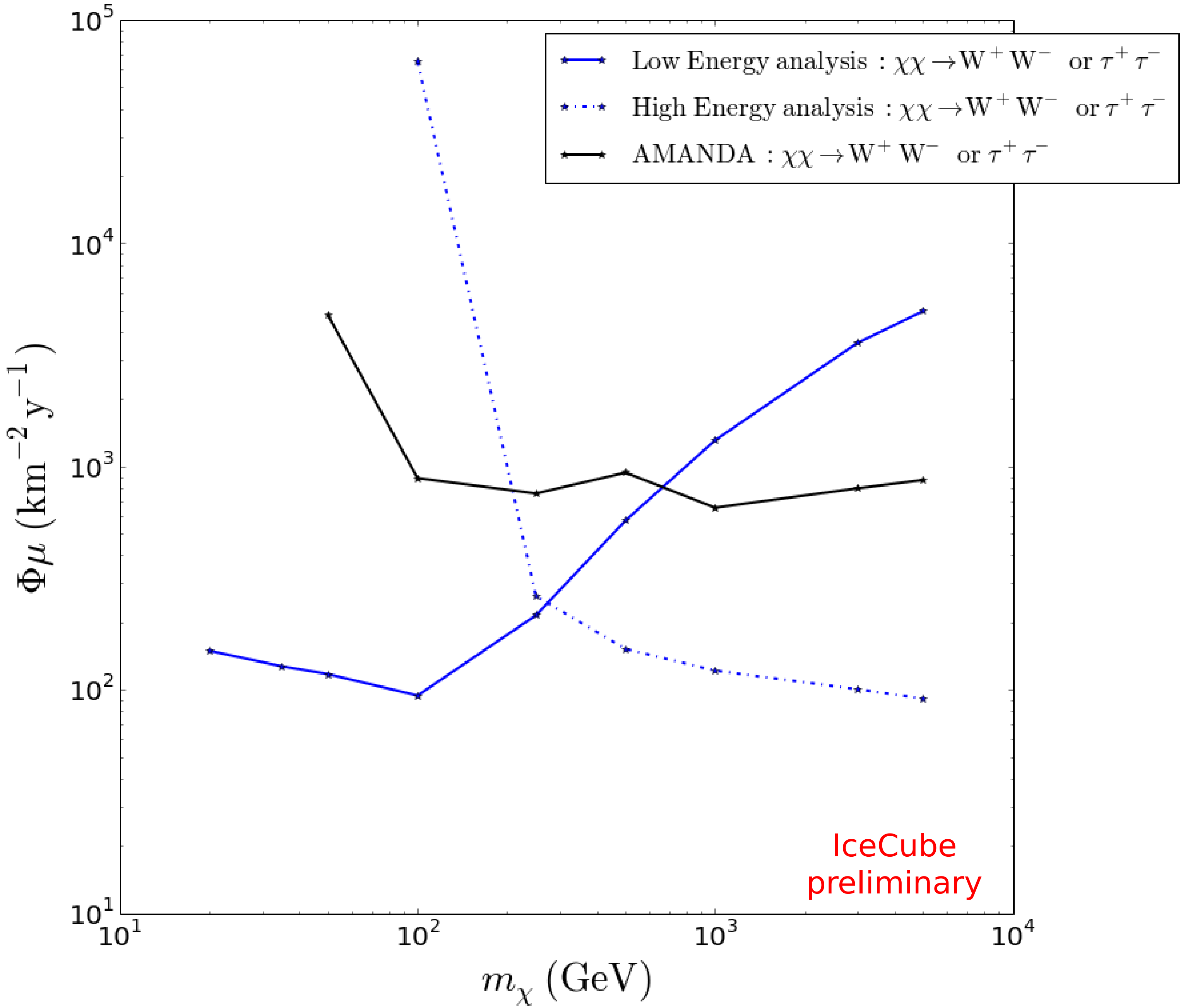


AMANDA : $\chi\chi \to W^+ W^-$ or $\tau^+ \tau^-$
10^5
10^4
10^3
10^2
10^1
$\Phi\mu$ ($km^{-2} y^{-1}$)
10^1
10^2
10^3
10^4
m_χ (GeV)

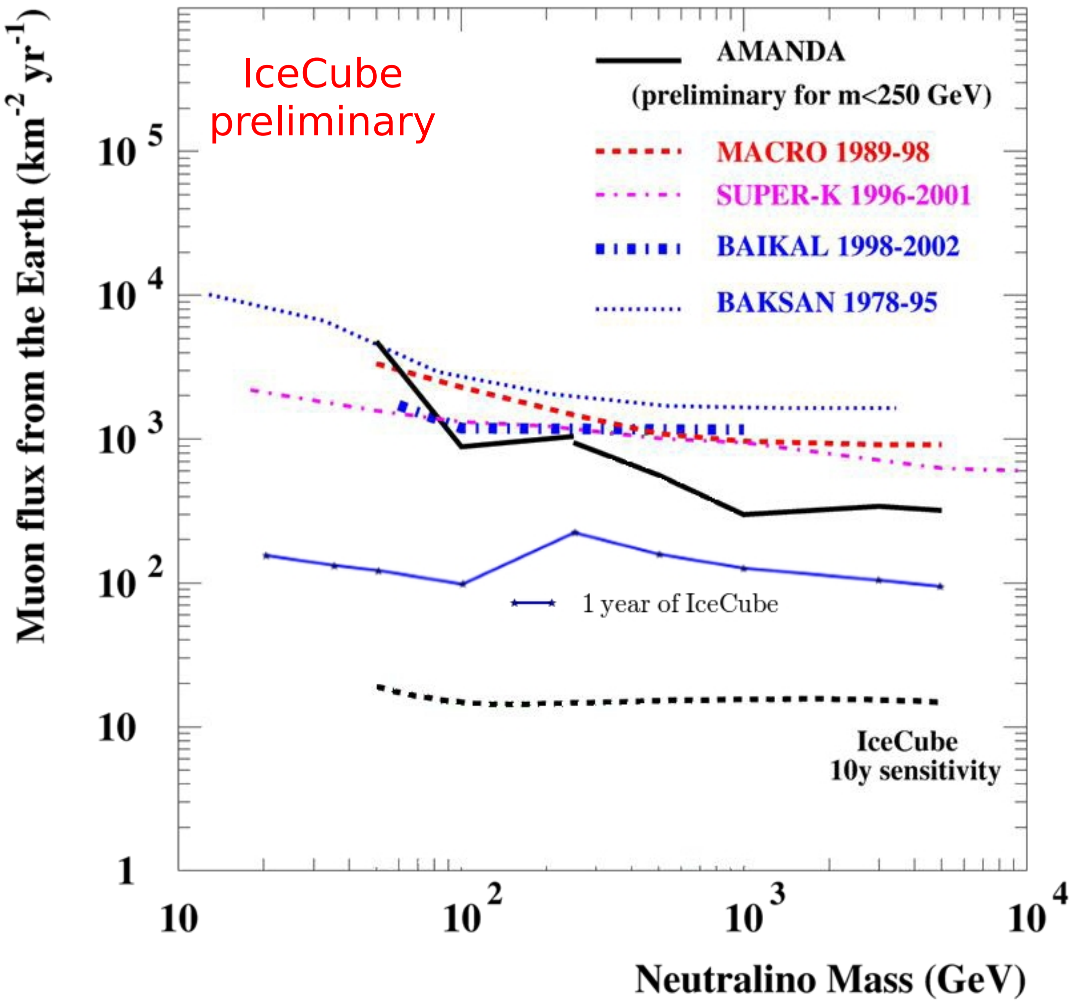


Low Energy analysis : $\chi\chi \rightarrow W^+W^-$ or $\tau^+\tau^-$
AMANDA : $\chi\chi \rightarrow W^+W^-$ or $\tau^+\tau^-$
IceCube preliminary
$\Phi\mu$ ($km^{-2}y^{-1}$)
m_χ (GeV)
10^1
10^2
10^3
10^4
10^5



Low Energy analysis : $\chi\chi \rightarrow W^+W^-$ or $\tau^+\tau^-$
High Energy analysis : $\chi\chi \rightarrow W^+W^-$ or $\tau^+\tau^-$
AMANDA : $\chi\chi \rightarrow W^+W^-$ or $\tau^+\tau^-$
$\Phi\mu$ ($km^{-2}y^{-1}$)
m_χ (GeV)
10^1
10^2
10^3
10^4
10^5
IceCube preliminary

An Earth WIMP search with IceCube is ongoing, stay tuned for results !



Results from IceCube are on the way.

Stay tuned for more results !

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Summary

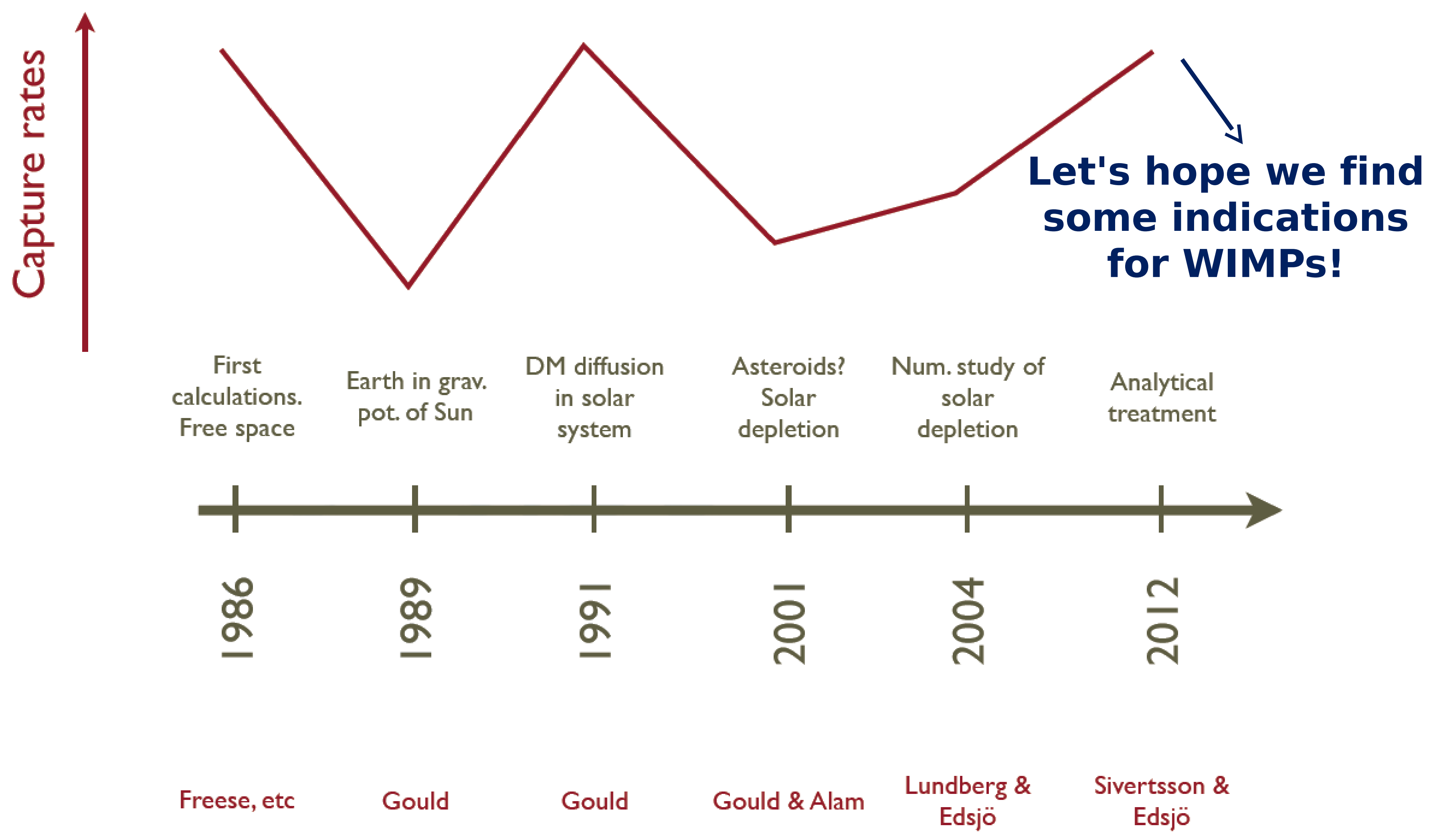
The first search for dark matter in the center of the Earth with IceCube is being designed.

As there is no good off-source region, simulation has to be used to estimate the background (cfr. neutrino oscillation analyses).

The dataset is split in 2 statistically independent sets, on which different optimizations are performed.

An improvement of a factor 10-100 is found w.r.t. the AMANDA search

History of the Earth Capture Rate



The IceCube Collaboration

Funding Agencies

Fonds de la Recherche Scientifique (FRS-FNRS)
Fonds Wetenschappelijk Onderzoek-Vlaanderen (FWO-Vlaanderen)
Federal Ministry of Education & Research (BMBF)
German Research Foundation (DFG)
Deutsches Elektronen-Synchrotron (DESY)
Japan Society for the Promotion of Science (JSPS)
Knut and Alice Wallenberg Foundation
Swedish Polar Research Secretariat
The Swedish Research Council (VR)
University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)

Backup slides

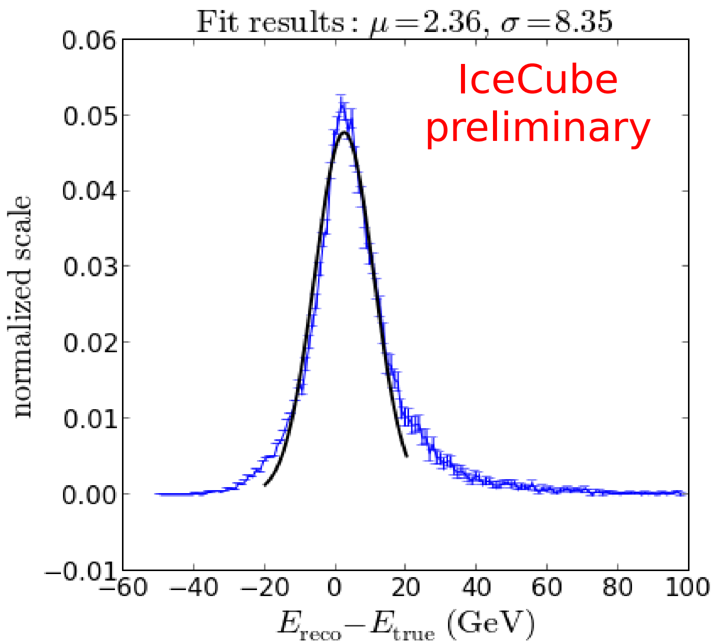
How do we split the dataset?
By cutting on the reconstructed energy.

The energy is calculated as

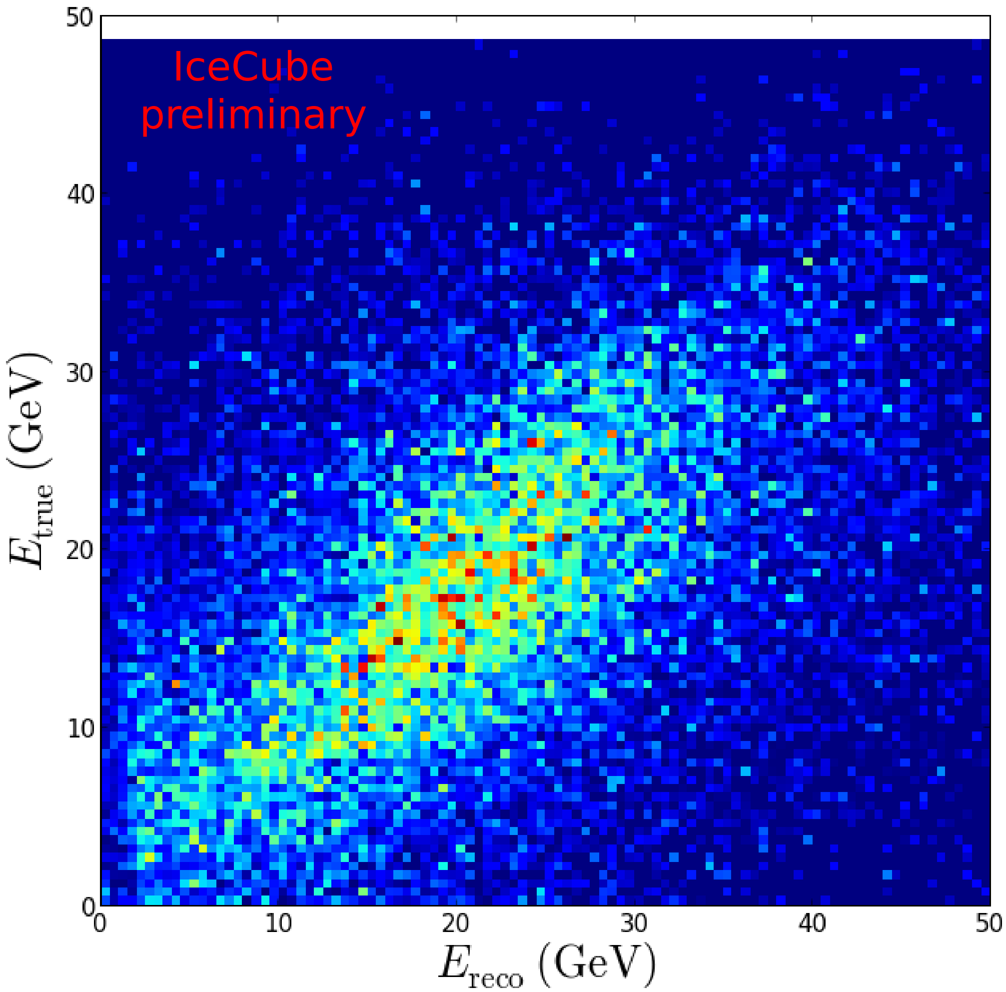
$$E_{\text{reco}} = (\exp(L_{\text{track,reco}} \cdot b) - 1) \cdot \frac{a}{b} + E_{\text{cascade}}$$

where

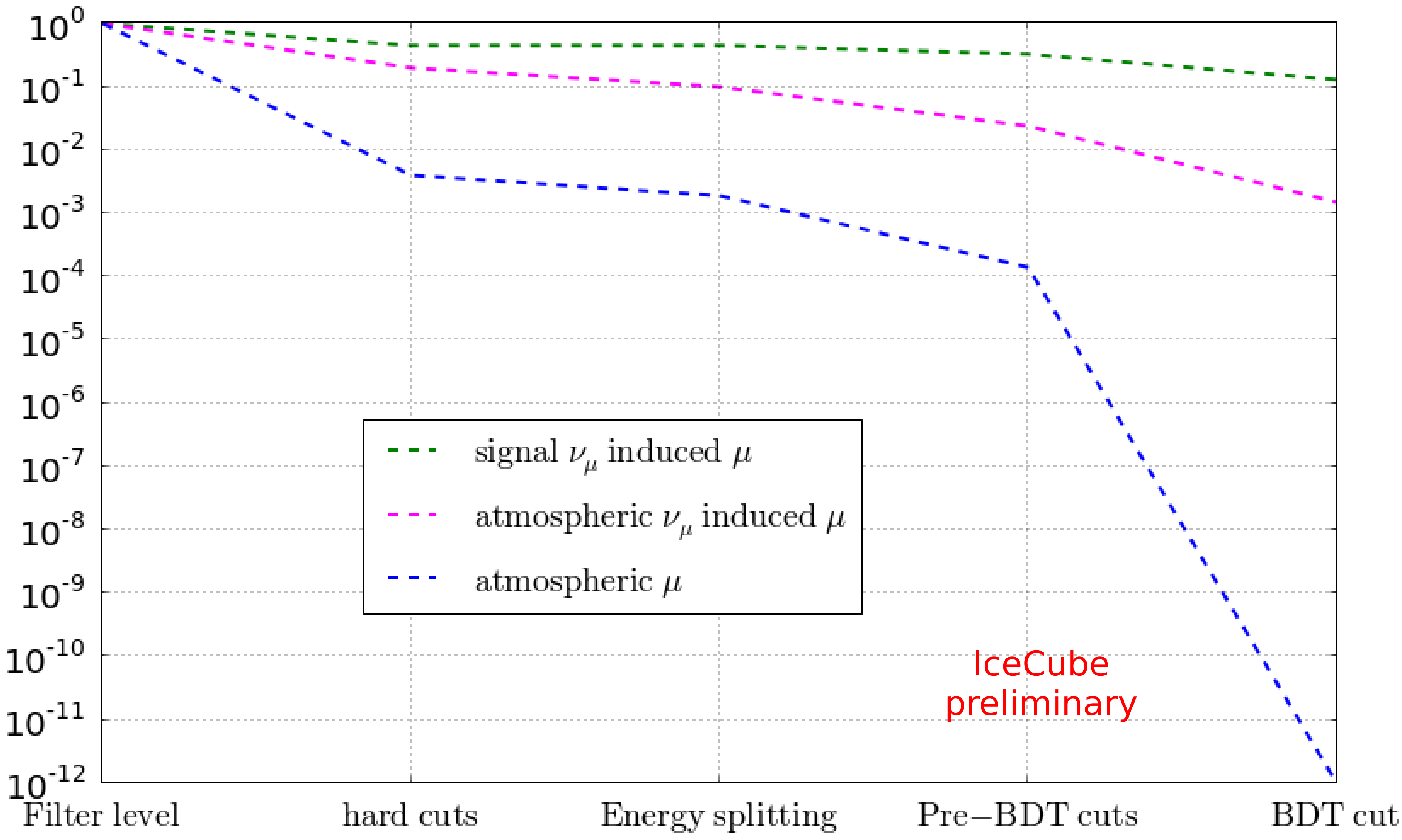
- a = 0.22565
- b = 0.00047
- $L_{\text{track,reco}}$ = reconstructed track length
- E_{cascade} = reconstructed cascade energy



Reconstructed energy for 50GeV WIMPs



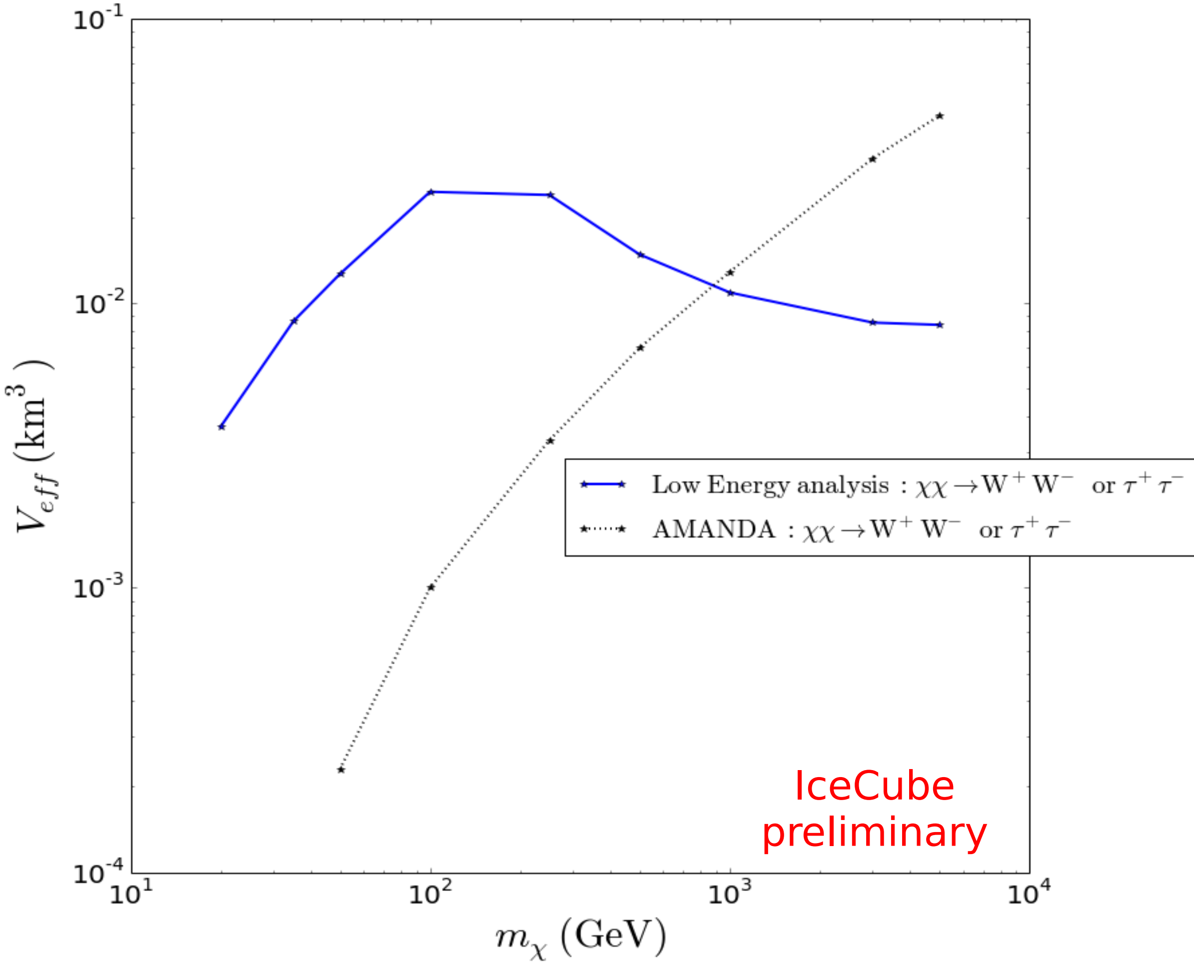
We keep 13 % of signal (50 GeV WIMP neutrinos),
and have a very pure (>90%) dataset of ~1000 events per year



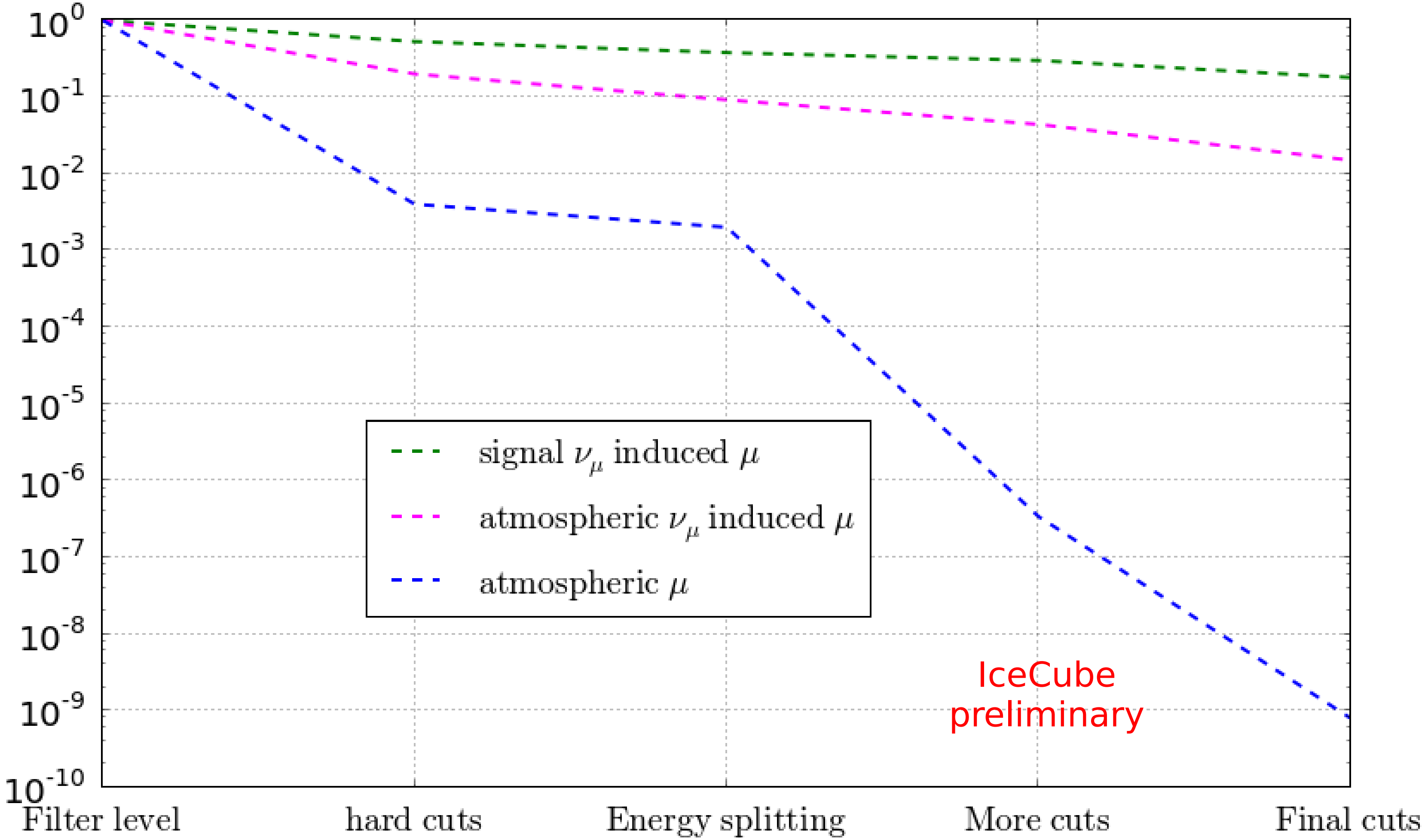
The effective volume improves more than 1 order of magnitude compared to AMANDA, as geometrically expected.

$$V_{eff_{cut}} = \frac{n_{cut}}{n_{gen}} V_{gen}$$

When we compare the best V_{eff} of the low energy search with the V_{eff} of AMANDA, we see an increase in effective volume of 1-2 orders of magnitude, as expected from the detector geometries.



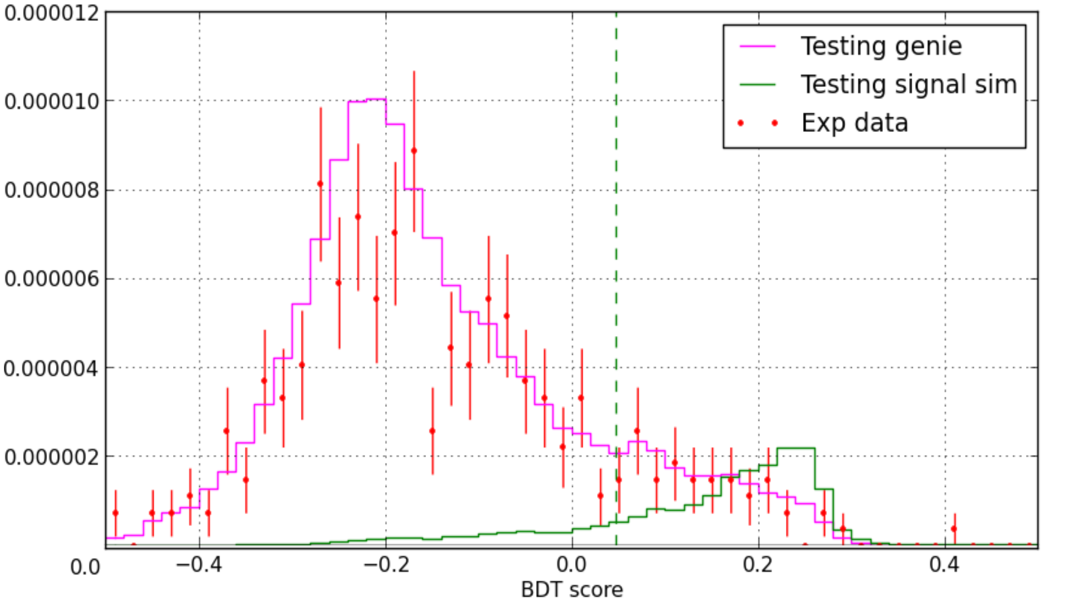
We keep 18 % of signal (1 TeV WIMP neutrinos),
and have a quite (~60 %) pure dataset of ~18000 events per year



Outlook

Improve the purity of the high energy sample.

Calculate sensitivities
by using a BDT score
distribution as likelihood



Ask for unblinding to get results.

Study the astrophysical uncertainties,
such as the velocity distibution etc.
(this is under investigation).