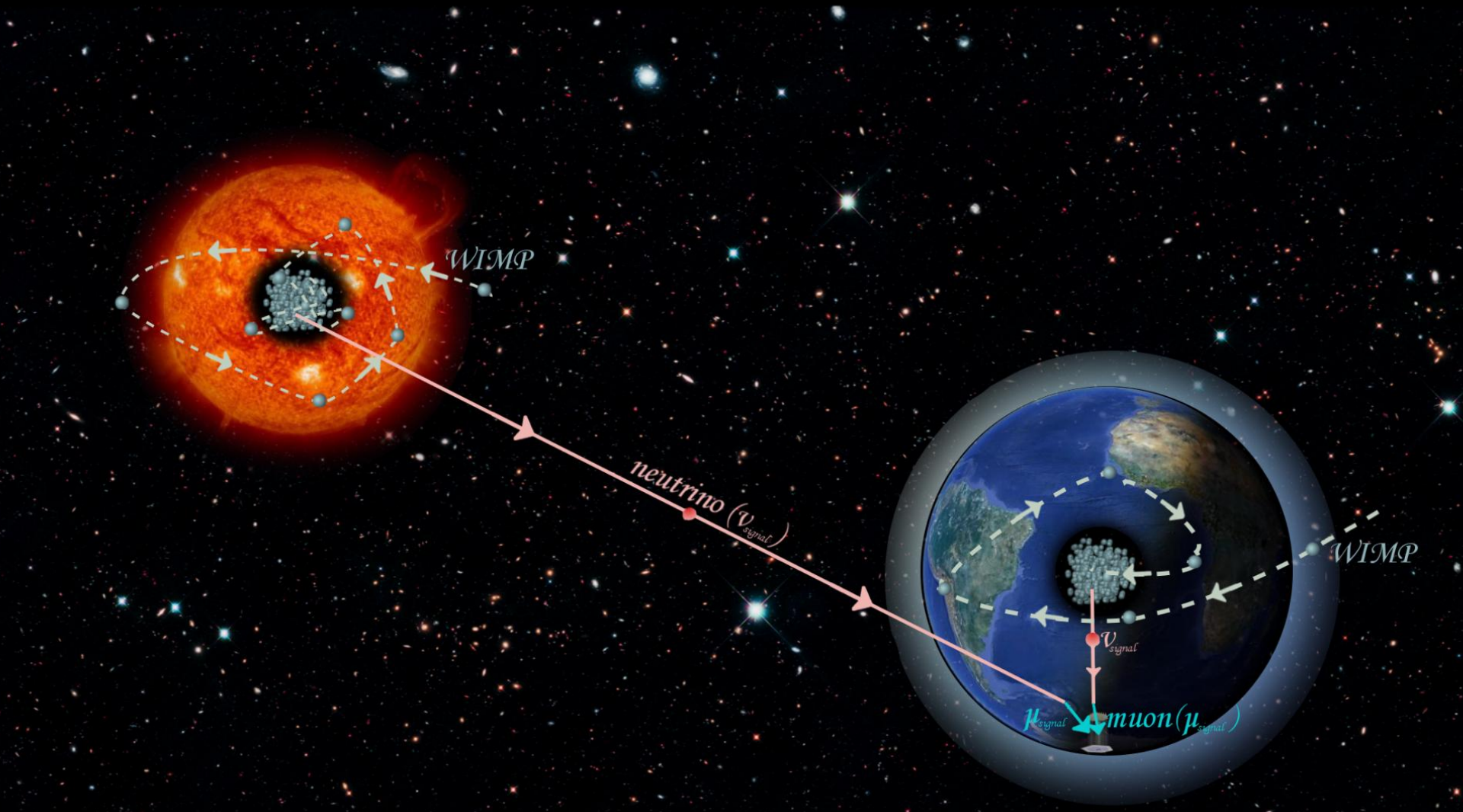
Earth WIMP search with IceCube

Jan Kunnen for the IceCube Collaboration

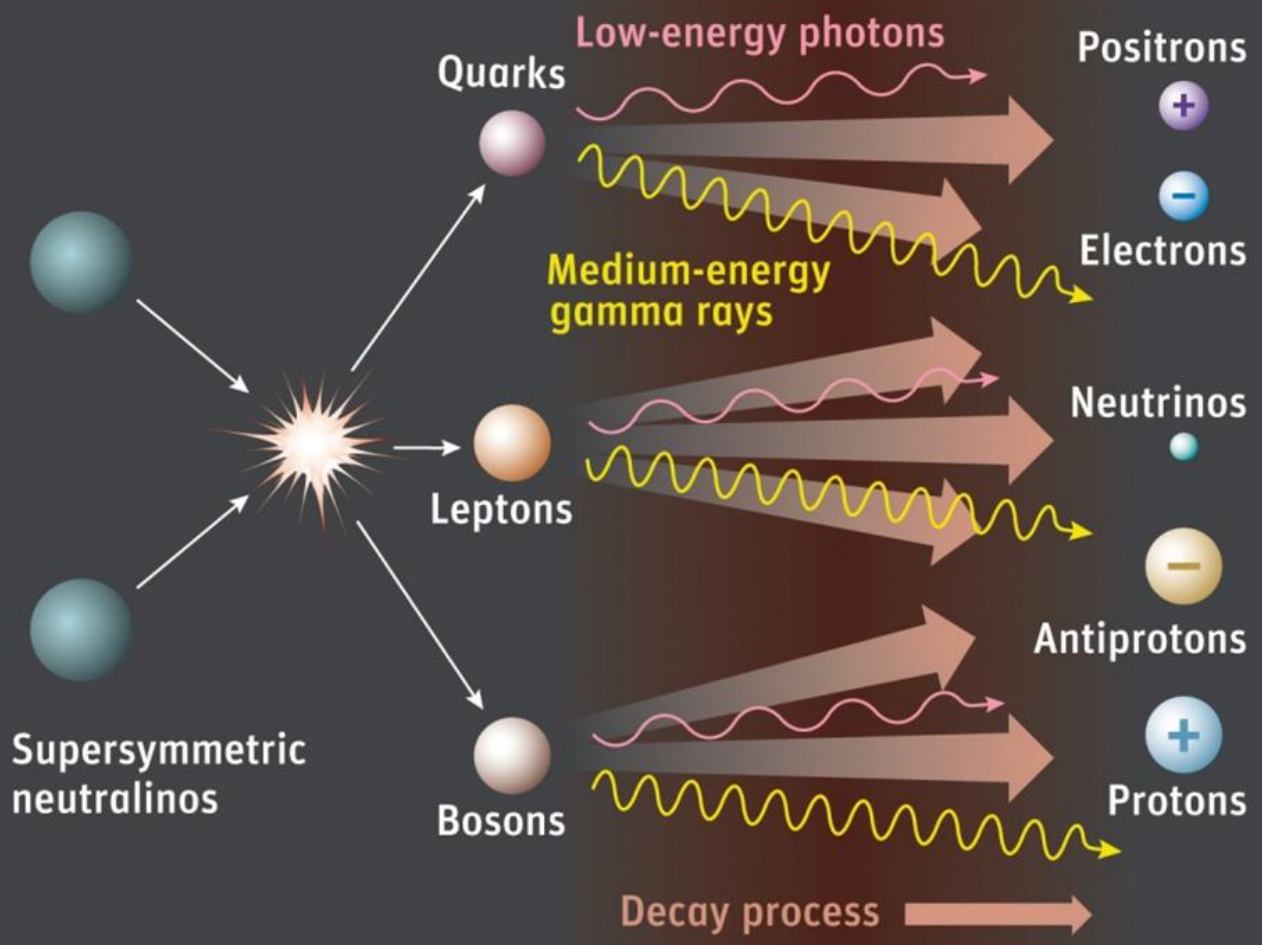
Outline

1. Indirect Earth WIMP detection with neutrinos
   I. how,
   II. status,
   III. theoretical predictions
2. The IceCube Neutrino Detector
3. Signal and Background
4. Expected Sensitivity
5. Summary and Conclusion

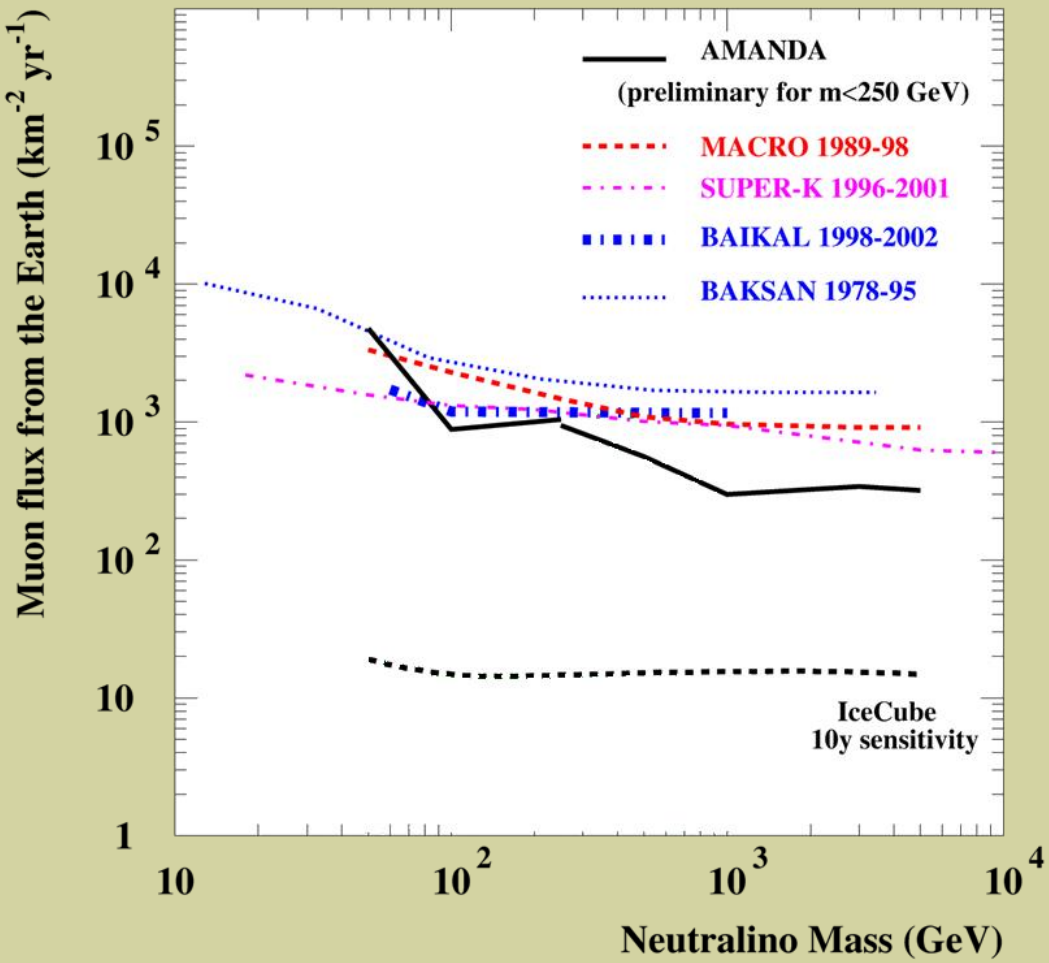
Indirect WIMP detection with neutrinos : WIMP capture



Indirect WIMP detection with neutrinos : WIMP annihilation



Current limits on neutrino induced Muon flux coming from Earth WIMPs



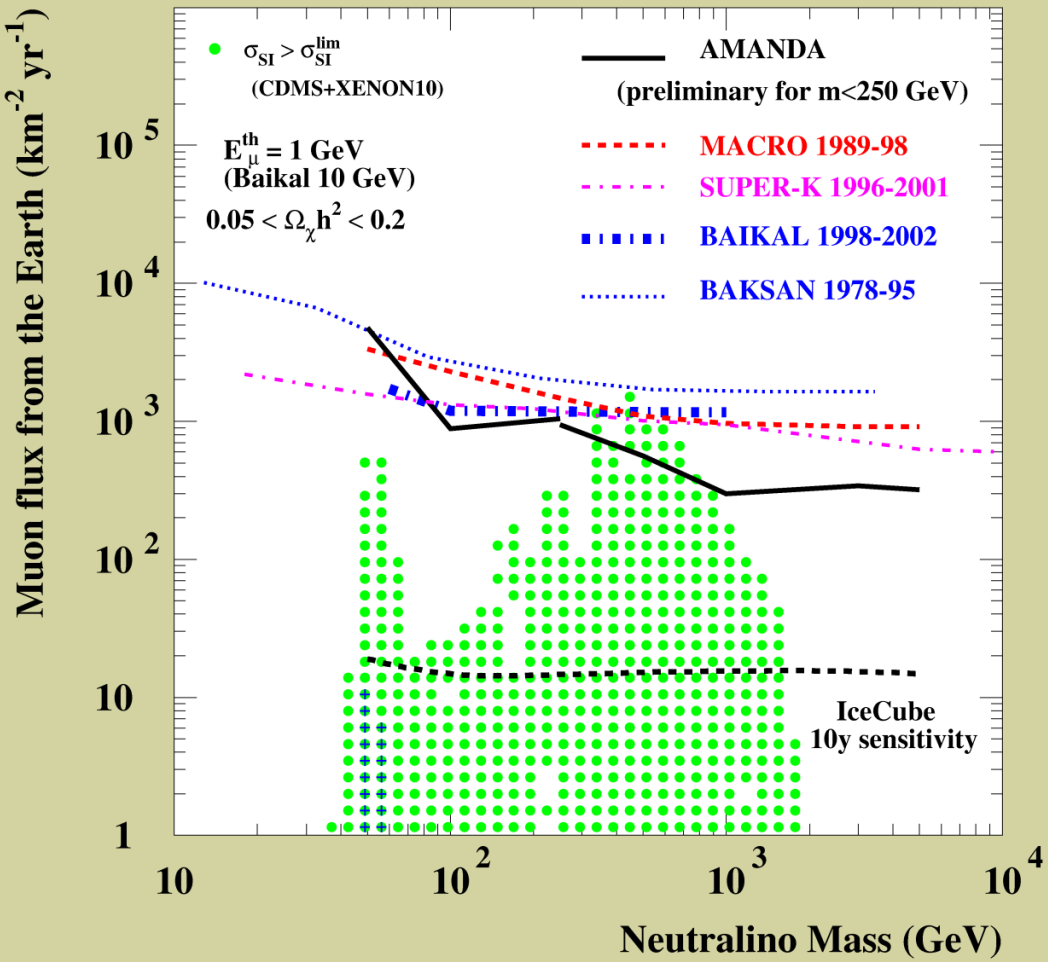
Most recent result dates from AMANDA.

No Earth WIMP analysis with IceCube yet.

Time to pick up the analysis again!

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

Current limits on neutrino induced Muon flux coming from Earth WIMPs



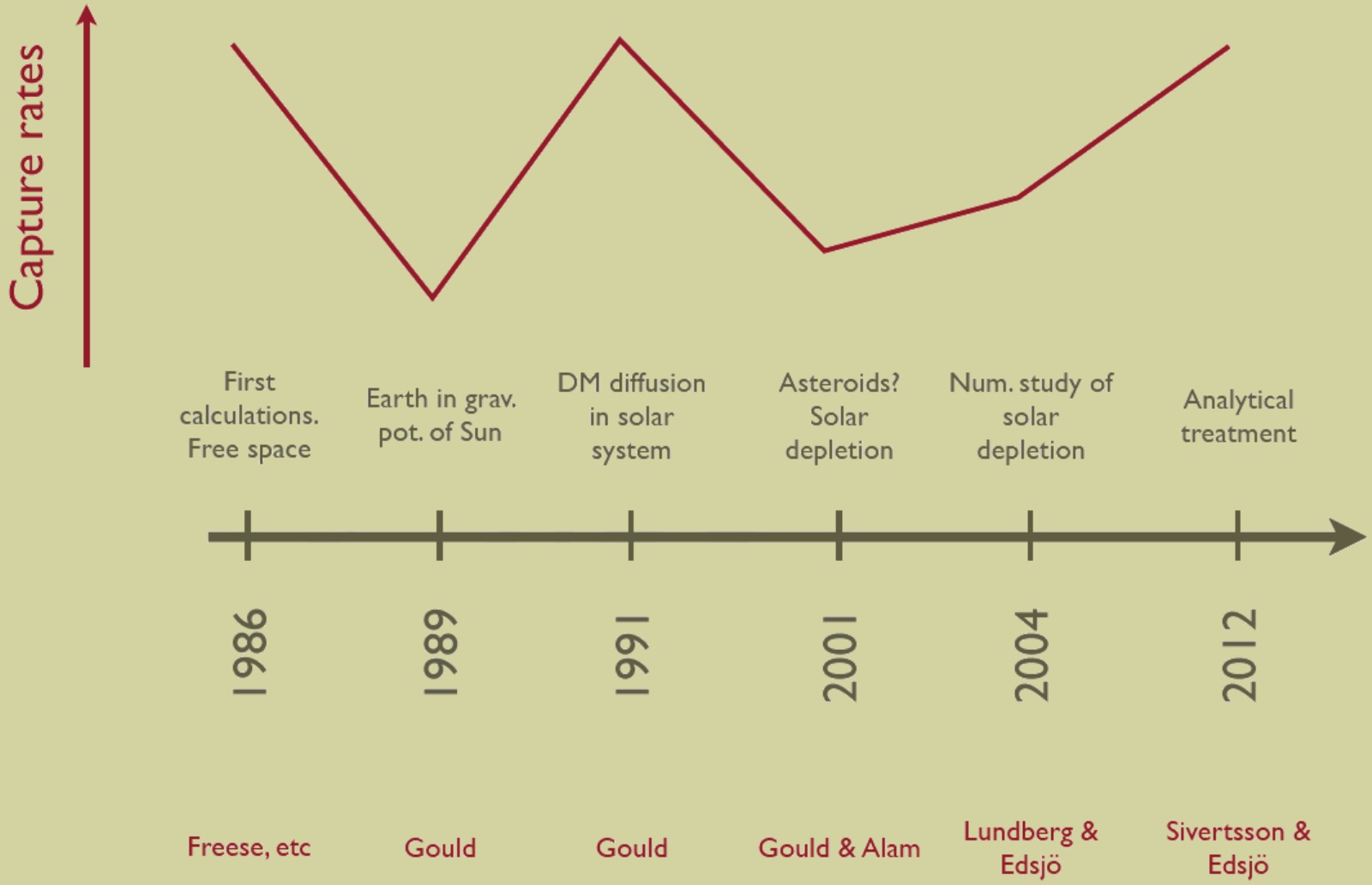
Most recent result dates from AMANDA.

No Earth WIMP analysis with IceCube yet...

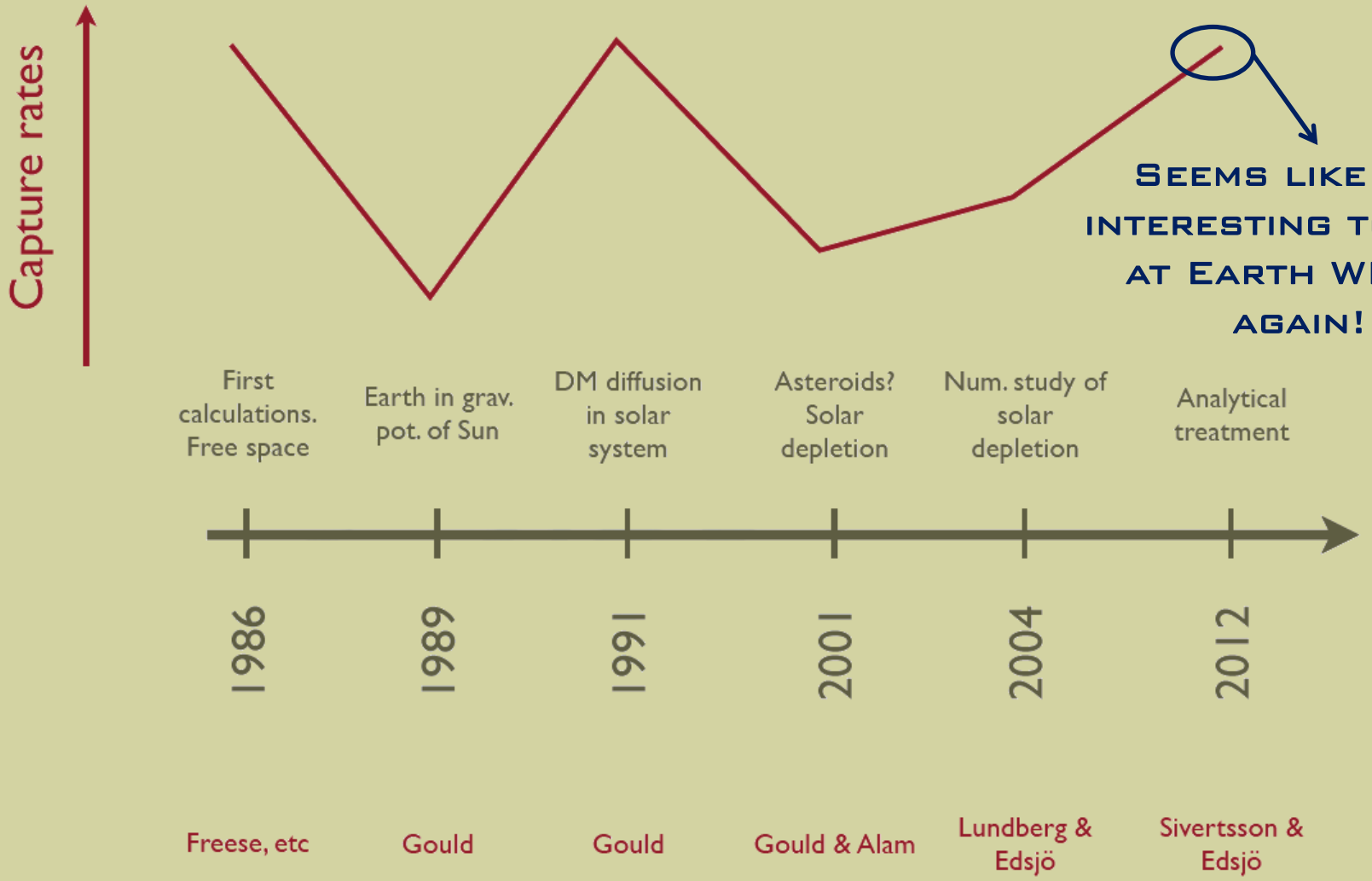
Time to pick up the analysis again!

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

History of the Earth Capture Rate

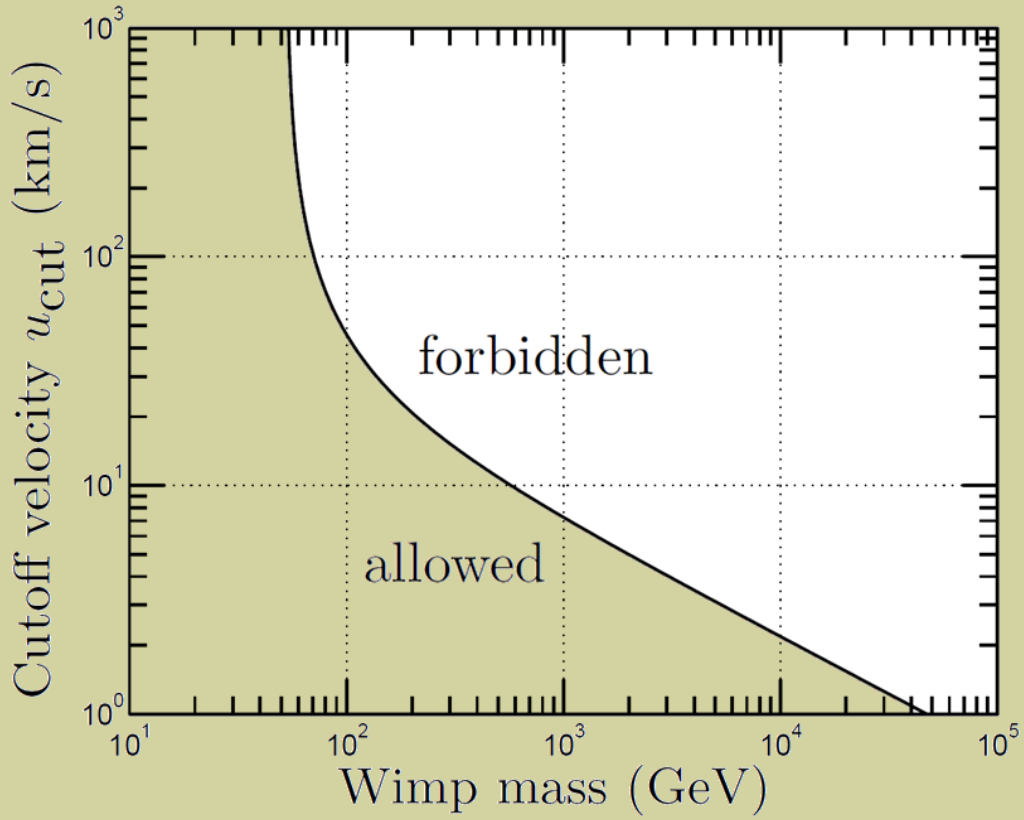


History of the Earth Capture Rate



Why are low velocities needed for Capture in the Earth?

Capture only occurs when a WIMP scatters off a nucleus to a velocity less than the escape velocity



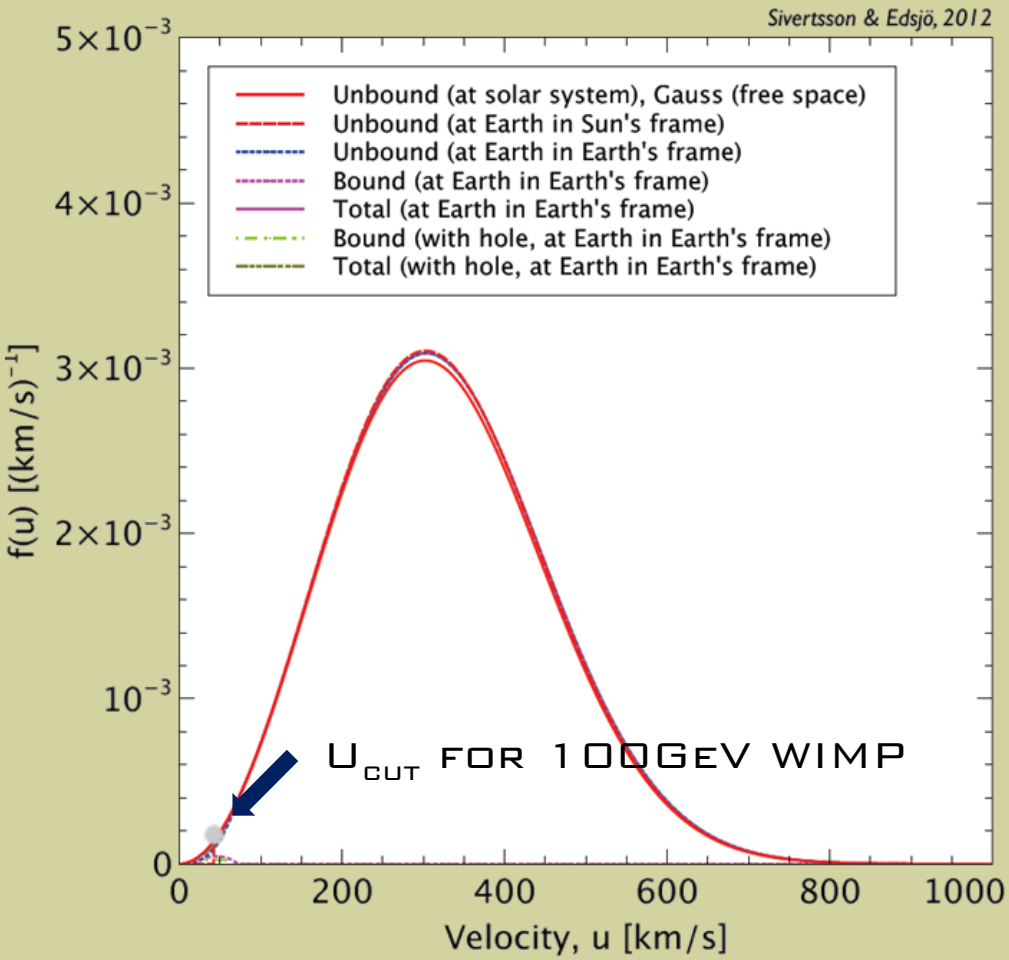
Capture on Fe, only if WIMP velocity is lower than

$$u_{cut} = 2\frac{\sqrt{M_\chi M_{Fe}}}{M_\chi - M_{Fe}} v_{esc}$$

Or, alternatively, for a given velocity, we can only capture WIMPs up to a maximal mass

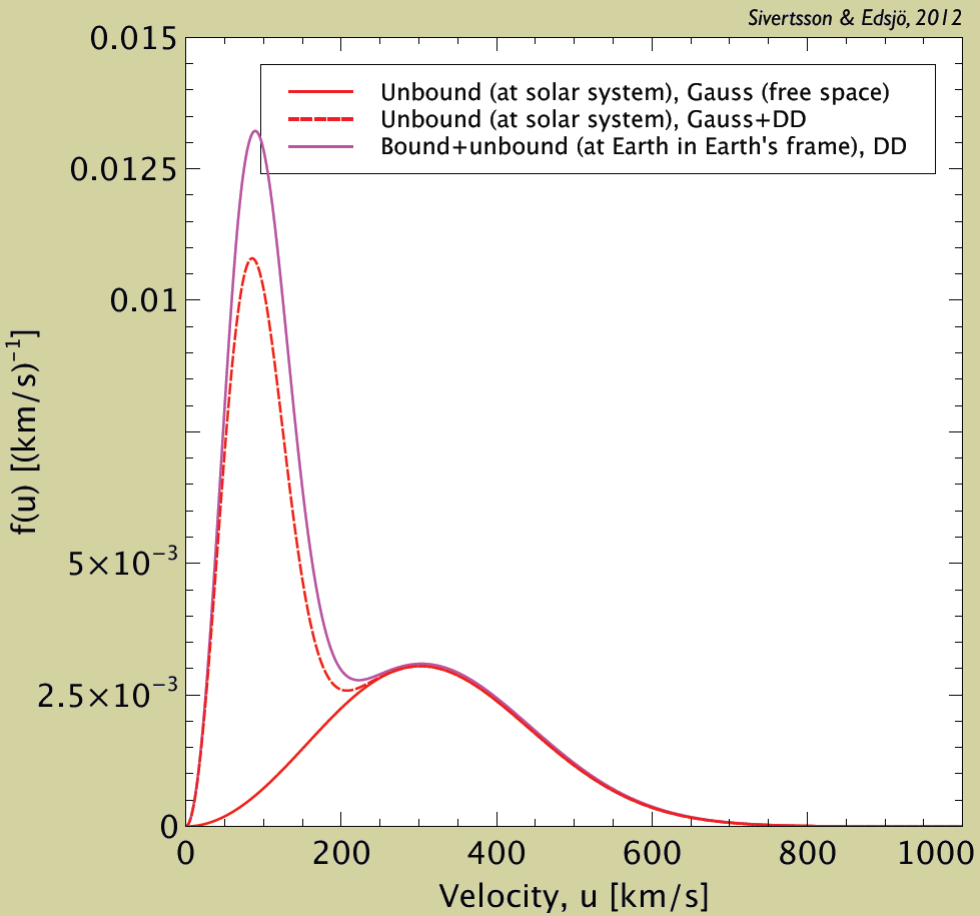
J. Lundberg, J. Edsjo, arXiv:astro-ph/0401113v1

The WIMP velocity distribution at the Earth



Most of the WIMPs in the Dark Halo have too high velocities to be captured by the Earth.

The WIMP velocity distribution in case of a dark disc



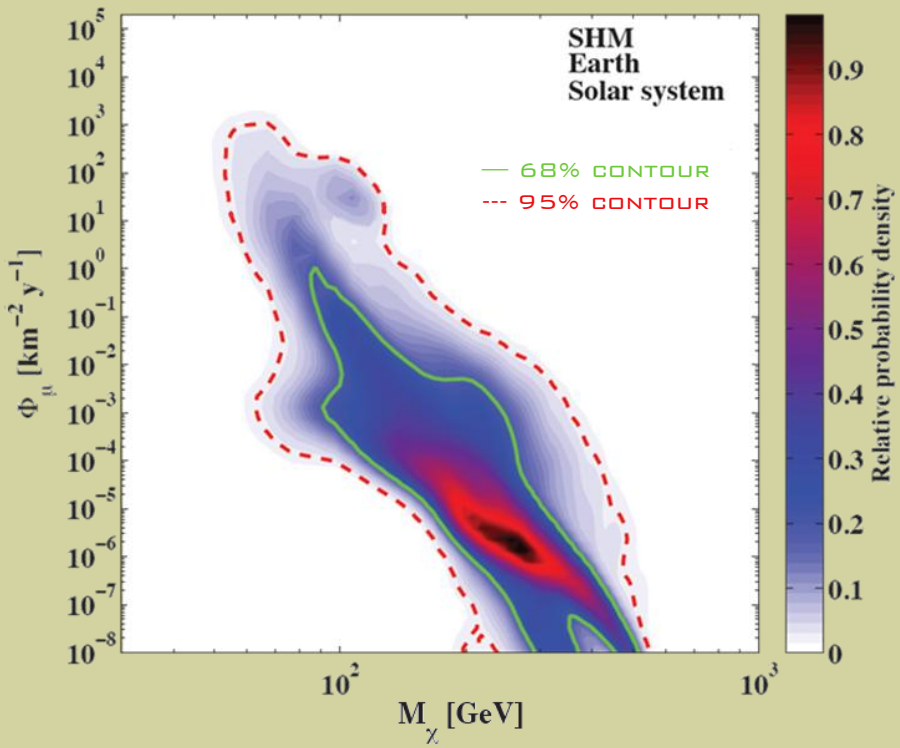
Simulations indicate existence of a thick disc of dark matter.

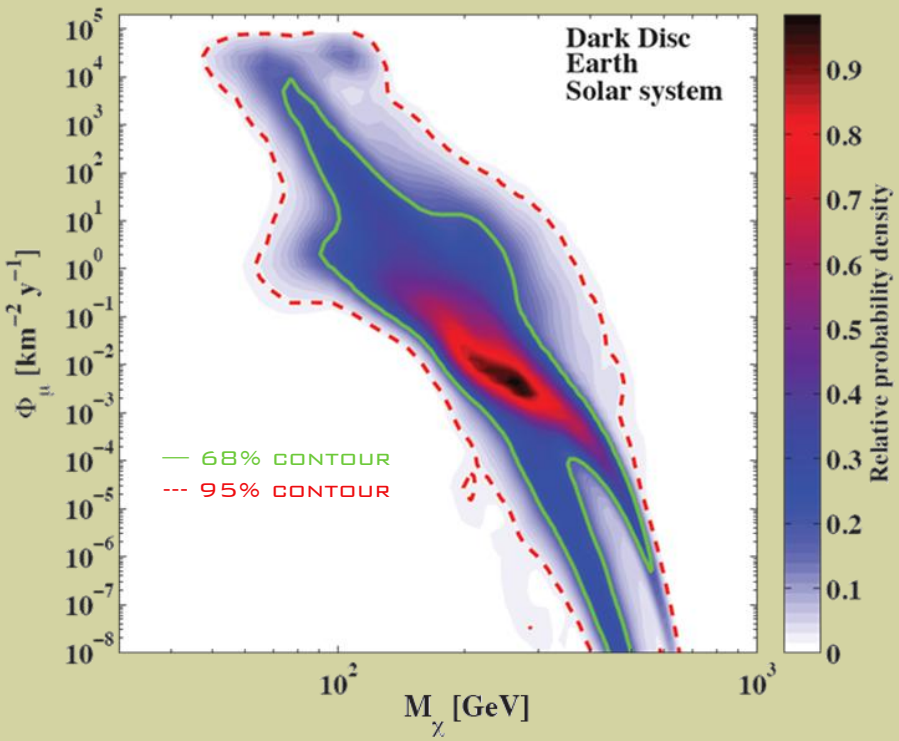
baryonic disc of the Milky Way draws satellites closer to the disc plane.

Result : thick disc of dark matter with

$$0{,}25 < \frac{\rho_d}{\rho_h} < 1{,}5$$

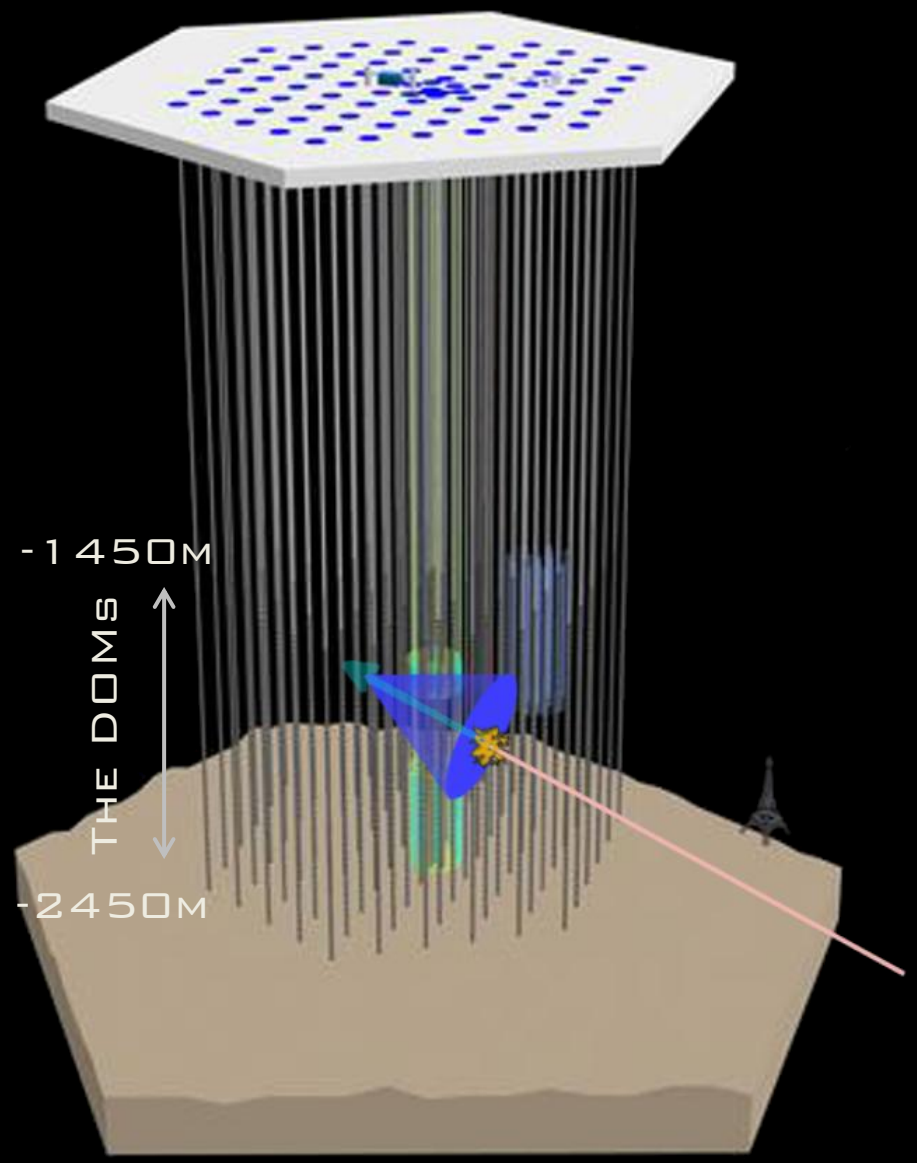
Predicted Muon Flux with and without Dark Disc





T. Bruch *et al.*, arXiv:astro-ph/0902.4001v2 (2009)

The IceCube Neutrino Observatory



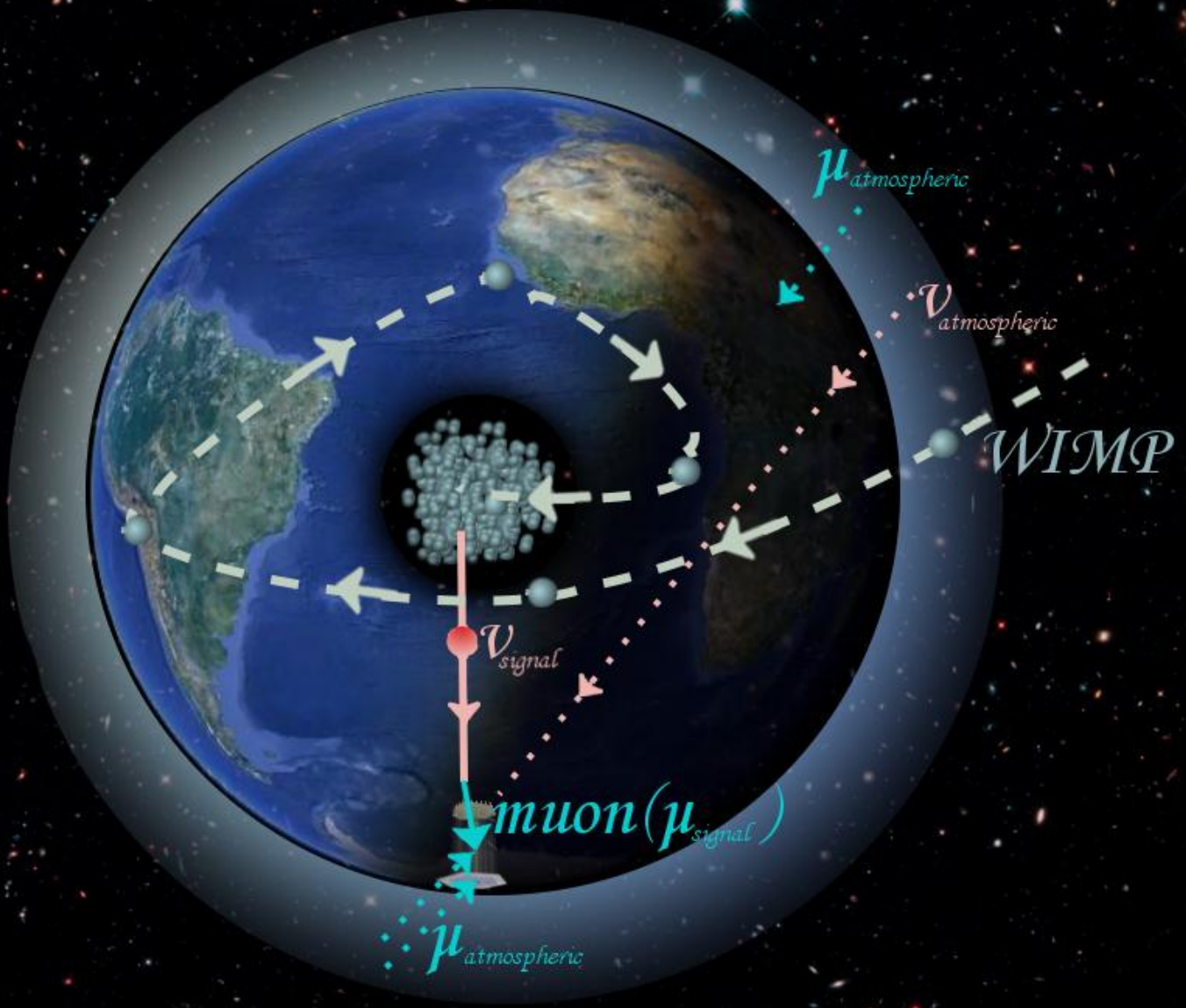
Detector completion in December 2010

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)

Signal and Background

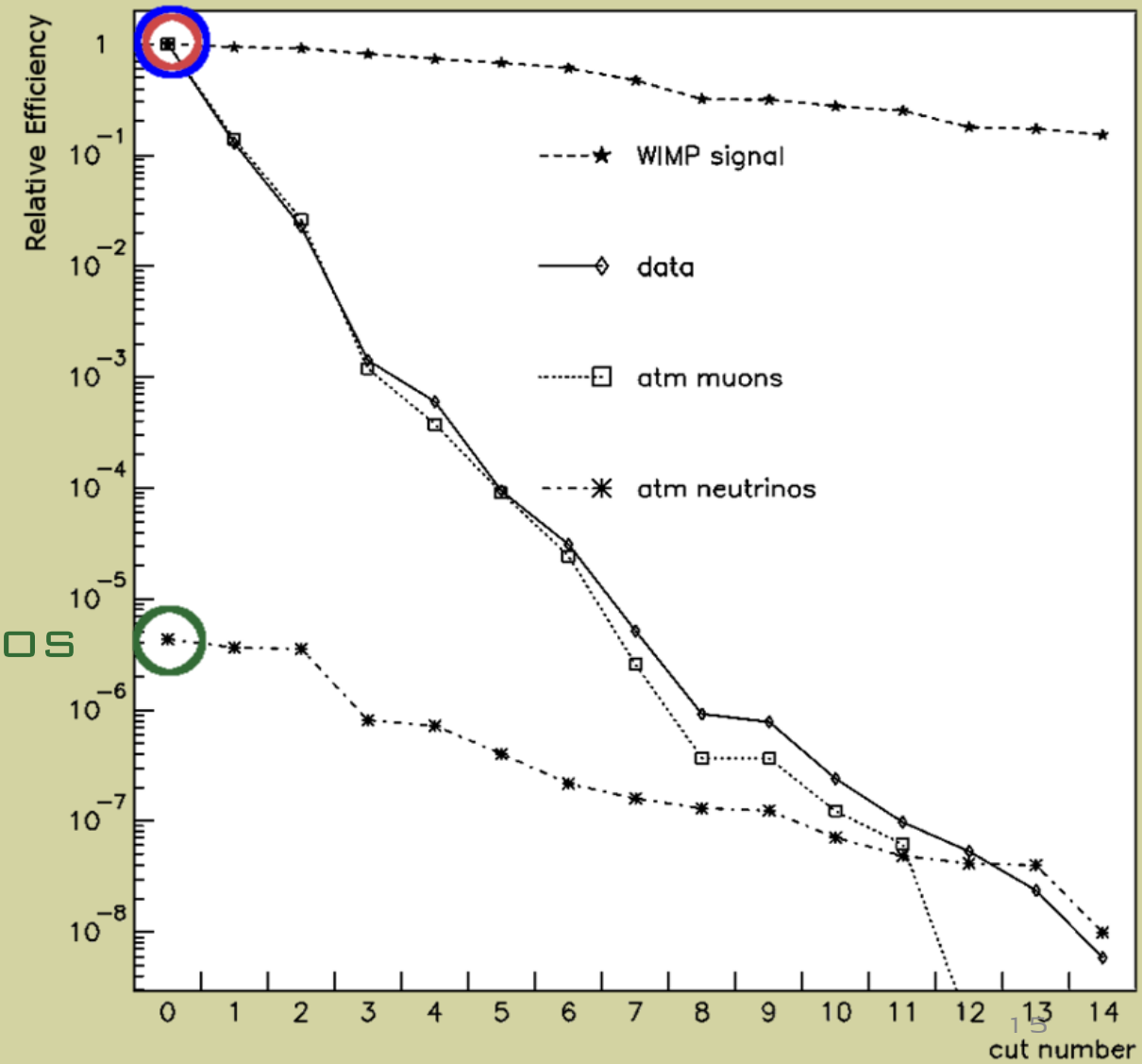


Removing the background : the AMANDA Earth WIMP analysis

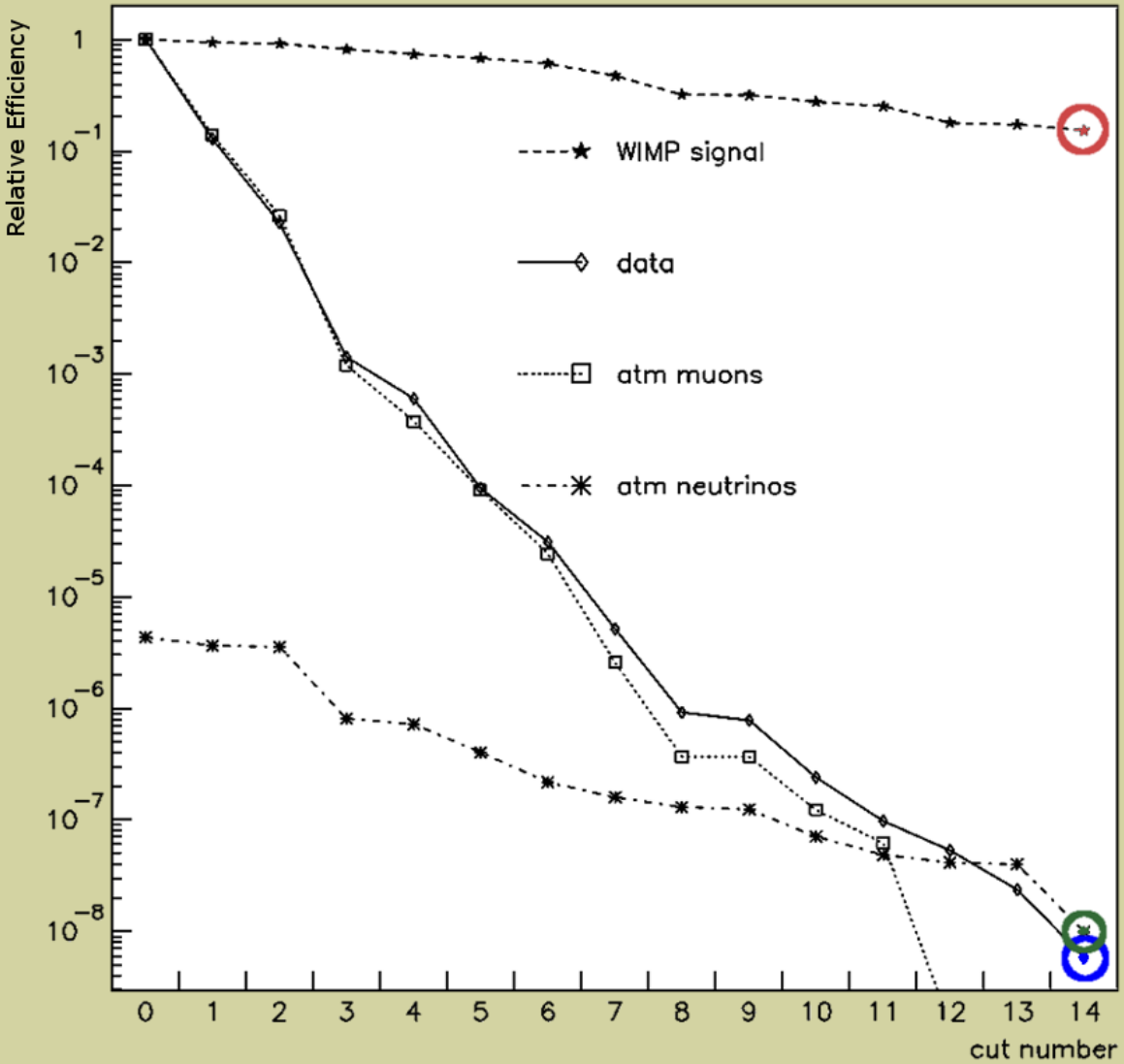
WIMP signal

data is dominated by atmospheric muons

atmosperic Neutrinos



Removing the background : the AMANDA Earth WIMP analysis



15% WIMP signal left

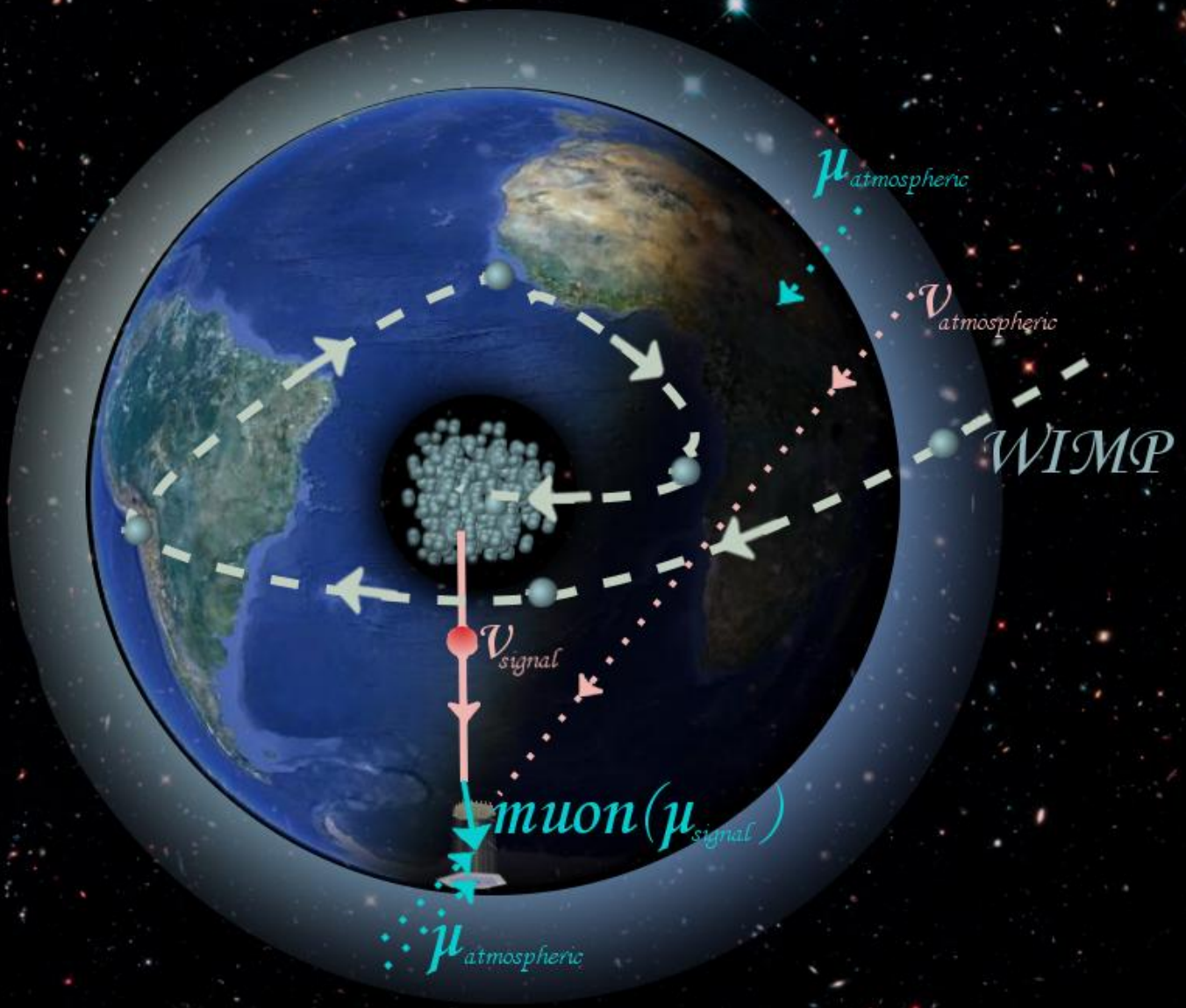
2,5% atmosperic Neutrinos left

atmospheric muon background reduced by a factor $>10^8$.

data is now dominated by atmospheric neutrinos

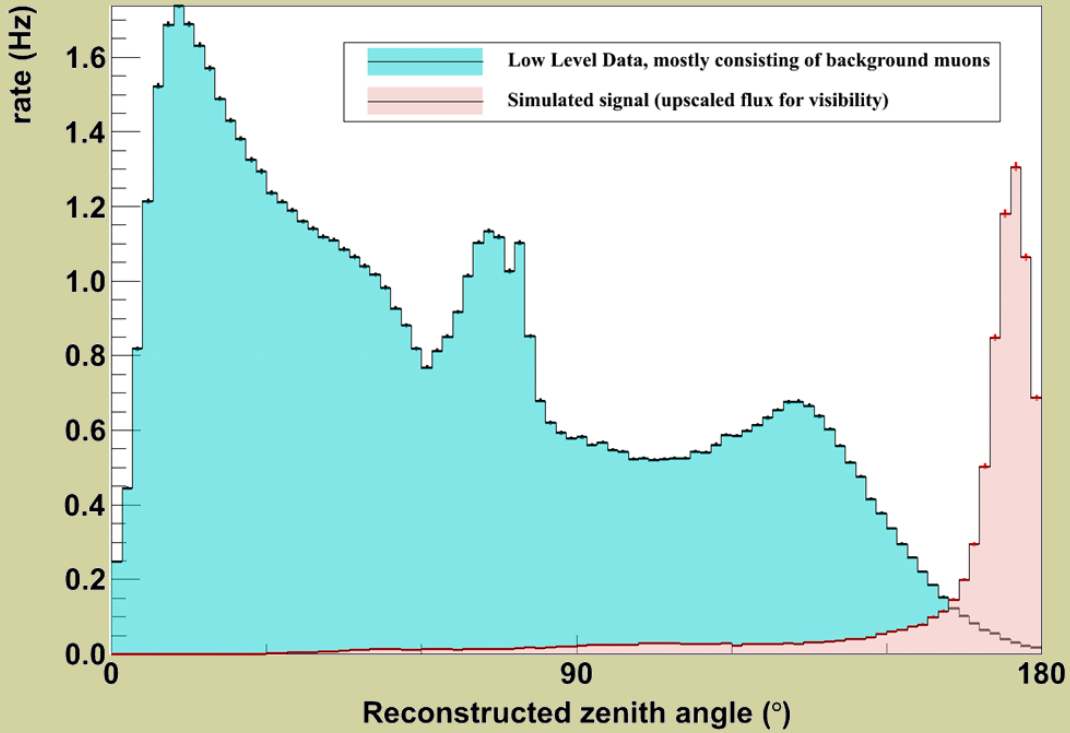
data agrees well with background predictions at all levels

Signal and Background



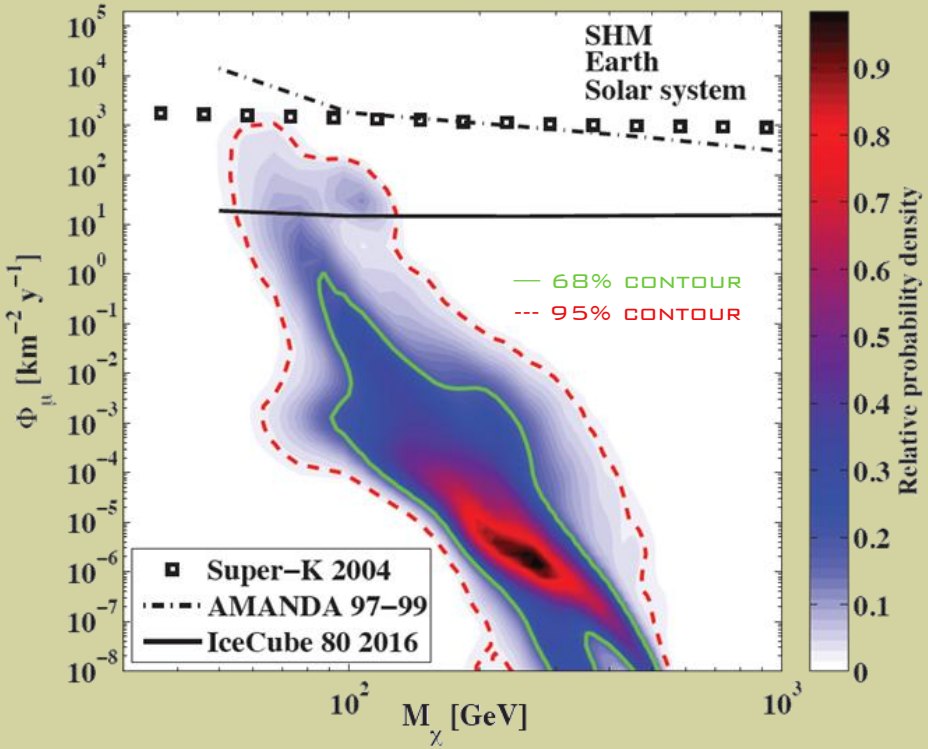
Selecting the interesting events

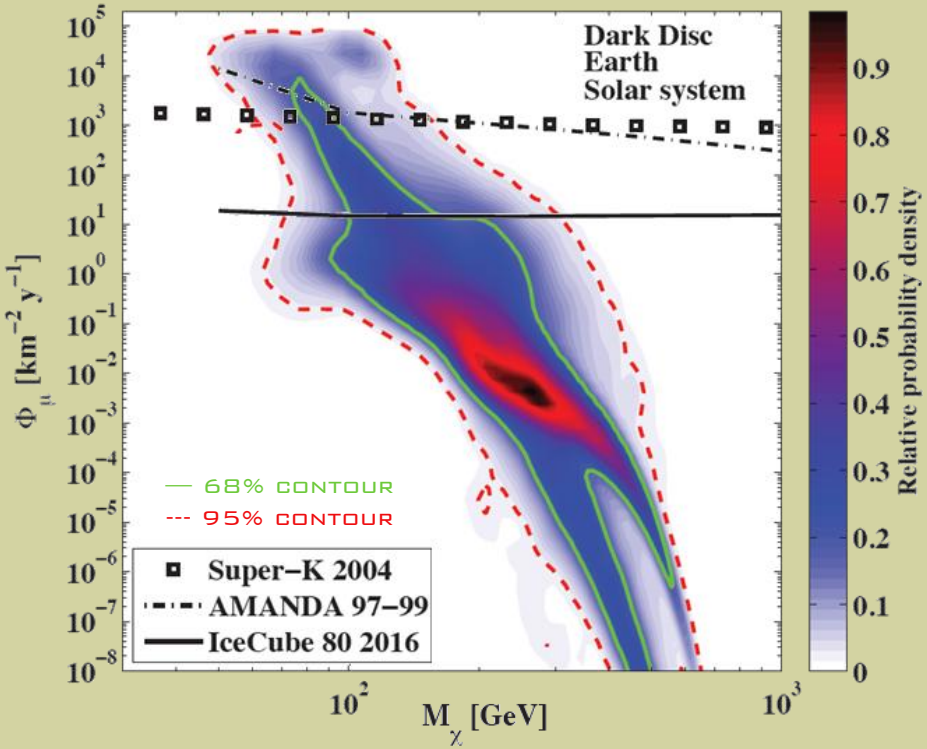
1. IceCube has a dedicated online filter to select Earth WIMP neutrinos.
2. High level filters have to be developped. Some parameters to base our selection on :



- Reconstructed zenith angle
- Veto layers
- Energy cuts
- ...

The predicted Muon flux with expected sensitivity





since we are looking for vertical tracks, each string practically acts as a single detector → going from 19 AMANDA strings to 86 IceCube strings is a huge increase in efficiency.

T. Bruch *et al.*, arXiv:astro-ph/0902.4001v2 (2009)

More details about my analysis

Similar to Solar, Galactic Centre, ... analyses, but in this analysis we cannot just define an off-source region → need to rely on simulations and extra-polation methods.

In order to work as model independent as possible, we select neutrinos coming from the center of the Earth, up to a certain energy, without further assumptions as signal.

We look for a bump in the neutrino rate from the direction of the center of the Earth.

Summary and Conclusion

1. Indirect Earth WIMP detection with neutrinos
   I. How -> WIMP capture and annihilation
   II. Status -> No IceCube limits yet
   III. theoretical predictions -> *HIGH* capture rate, dark disc ?
2. The IceCube Neutrino Detector
3. Signal and Background
4. Expected Sensitivity -> We will cut in the theoretical phase space!

The IceCube Collaboration

International Funding Agencies

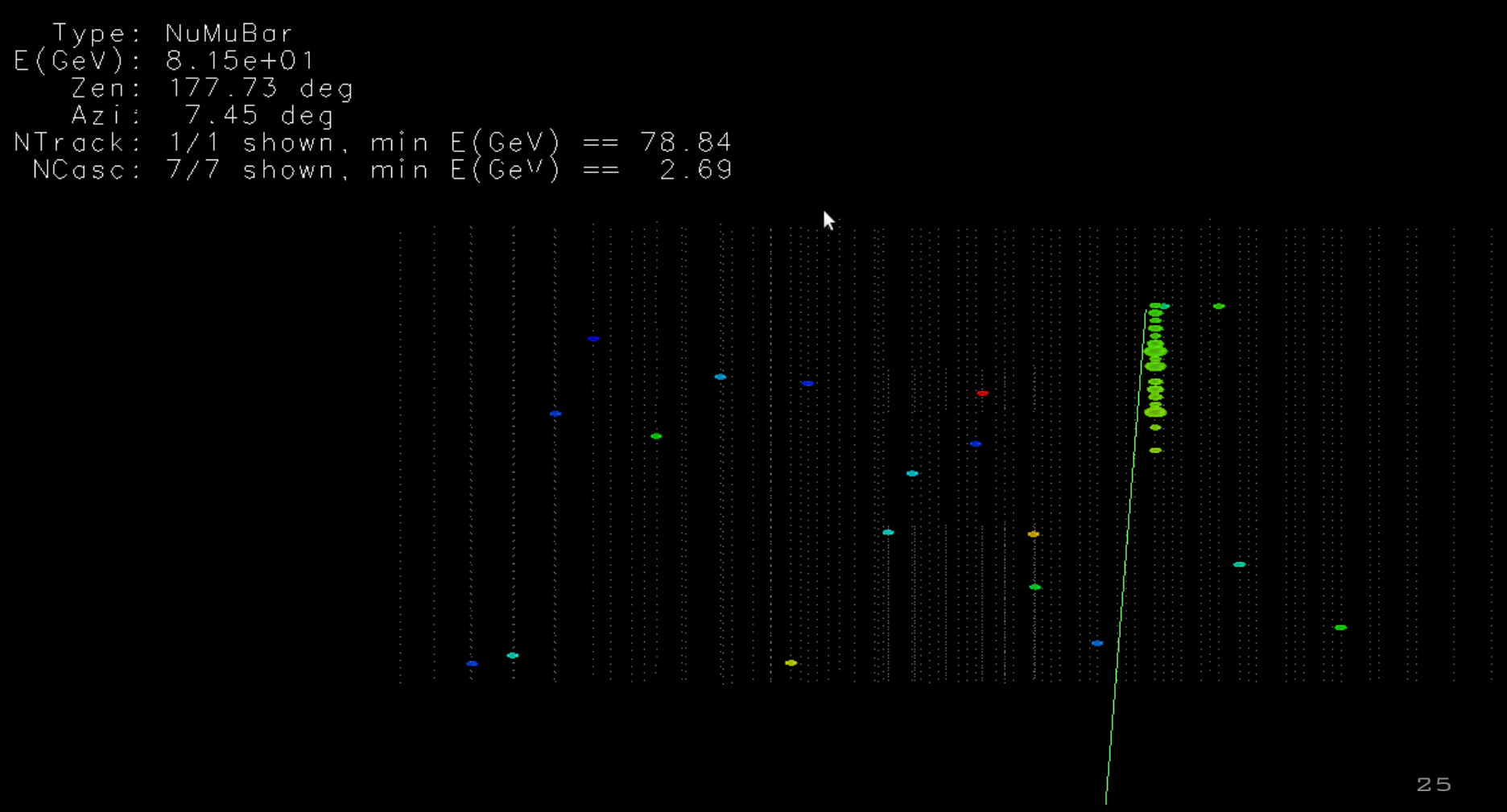
Fonds de la Recherche Scientifique (FRS-FNRS)
Fonds Wetenschappelijk Onderzoek-Vlaanderen (FWO-Vlaanderen)
Federal Ministry of Education & Research (BMBF)
German Research Foundation (DFG)
Deutsches Elektronen-Synchrotron (DESY)
Knut and Alice Wallenberg Foundation
Swedish Polar Research Secretariat
The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

BACKUP SLIDES

A simulated upgoing neutrino

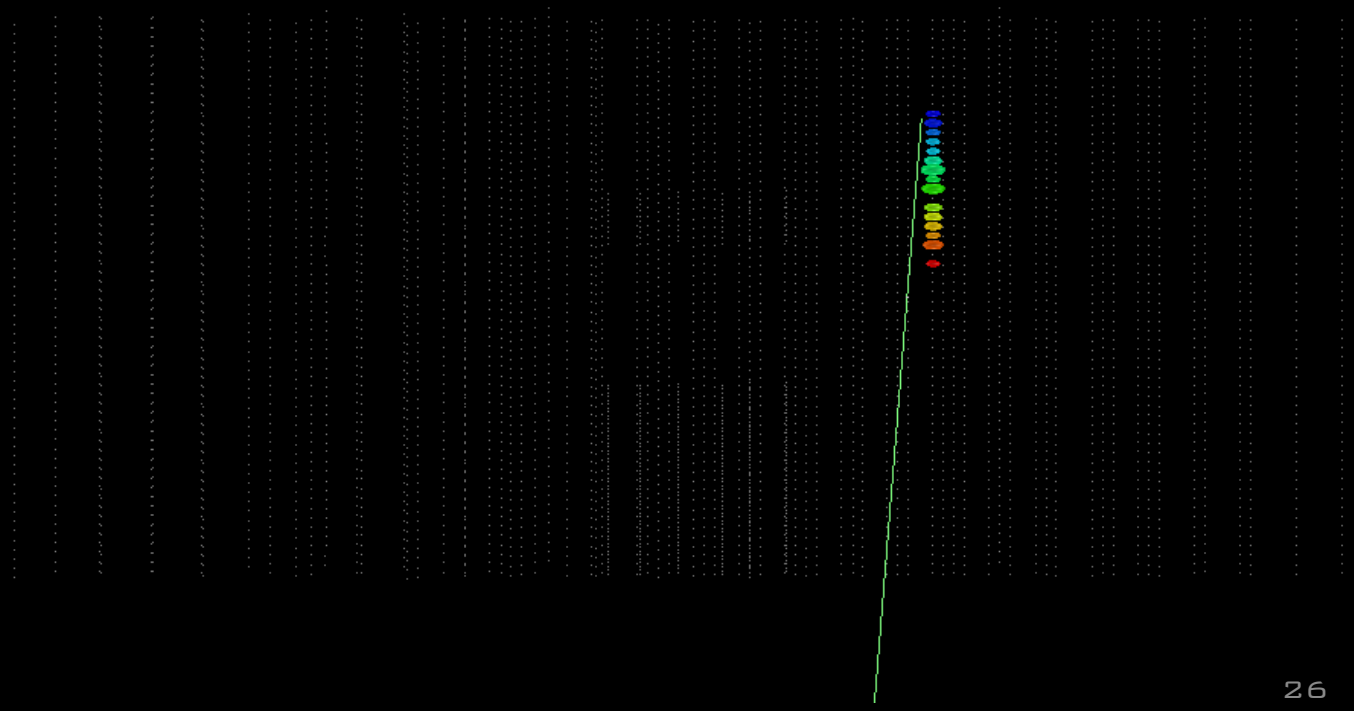
```
  Type: NuMuBar
E(GeV): 8.15e+01
   Zen: 177.73 deg
   Azi:  7.45 deg
NTrack: 1/1 shown, min E(GeV) == 78.84
 NCasc: 7/7 shown, min E(GeV) ==  2.69
```

A simulated upgoing neutrino



A simulated upgoing neutrino

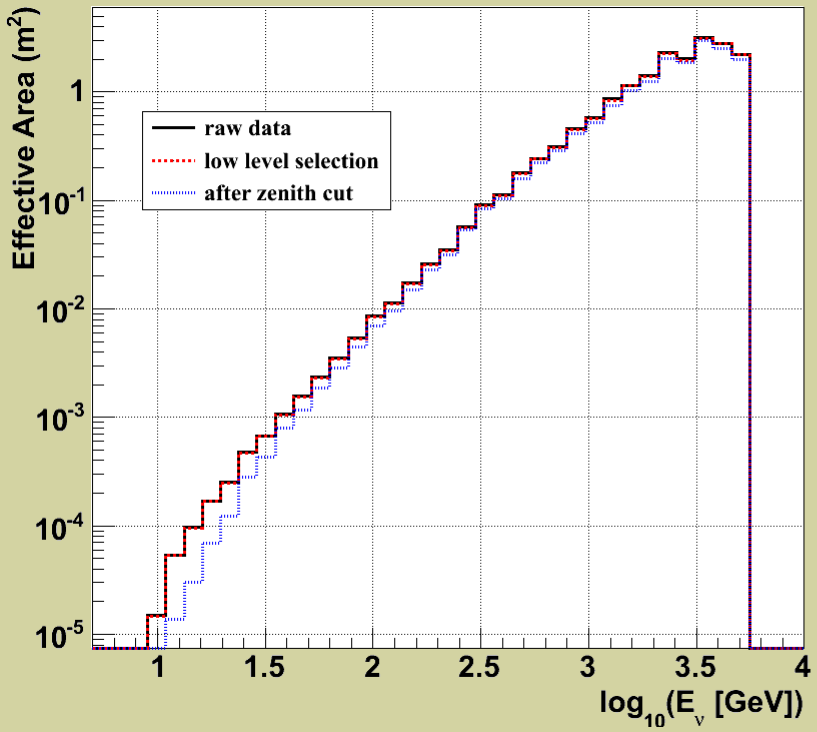
```
  Type: NuMuBar
E(GeV): 8.15e+01
   Zen: 177.73 deg
   Azi:  7.45 deg
NTrack: 1/1 shown, min E(GeV) == 78.84
 NCasc: 7/7 shown, min E(GeV) ==  2.69
```

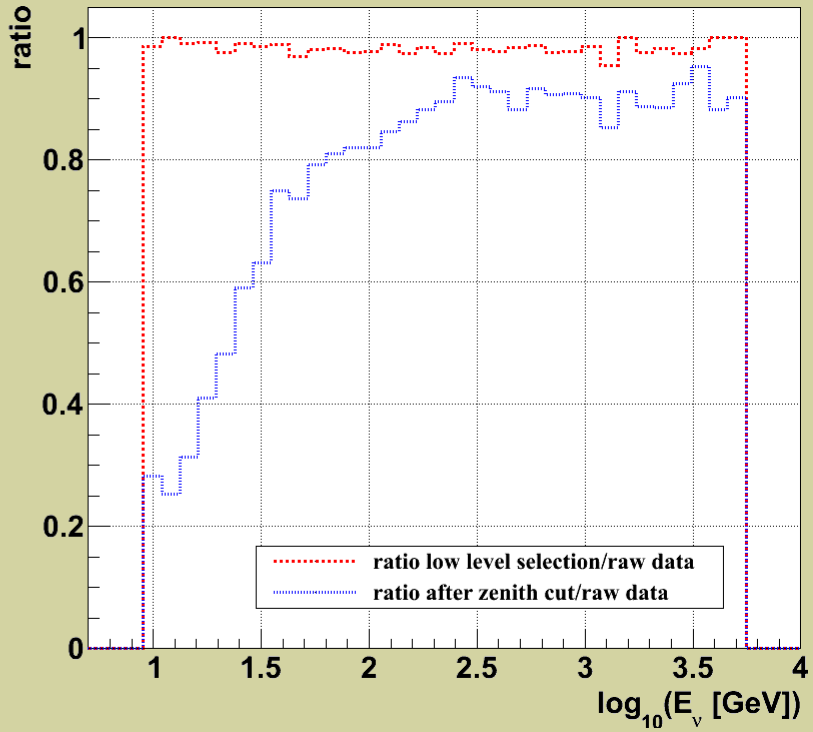


What should be optimized?

The effective area!

$$A_{eff} = \frac{observed\ event\ rate}{incoming\ flux}$$



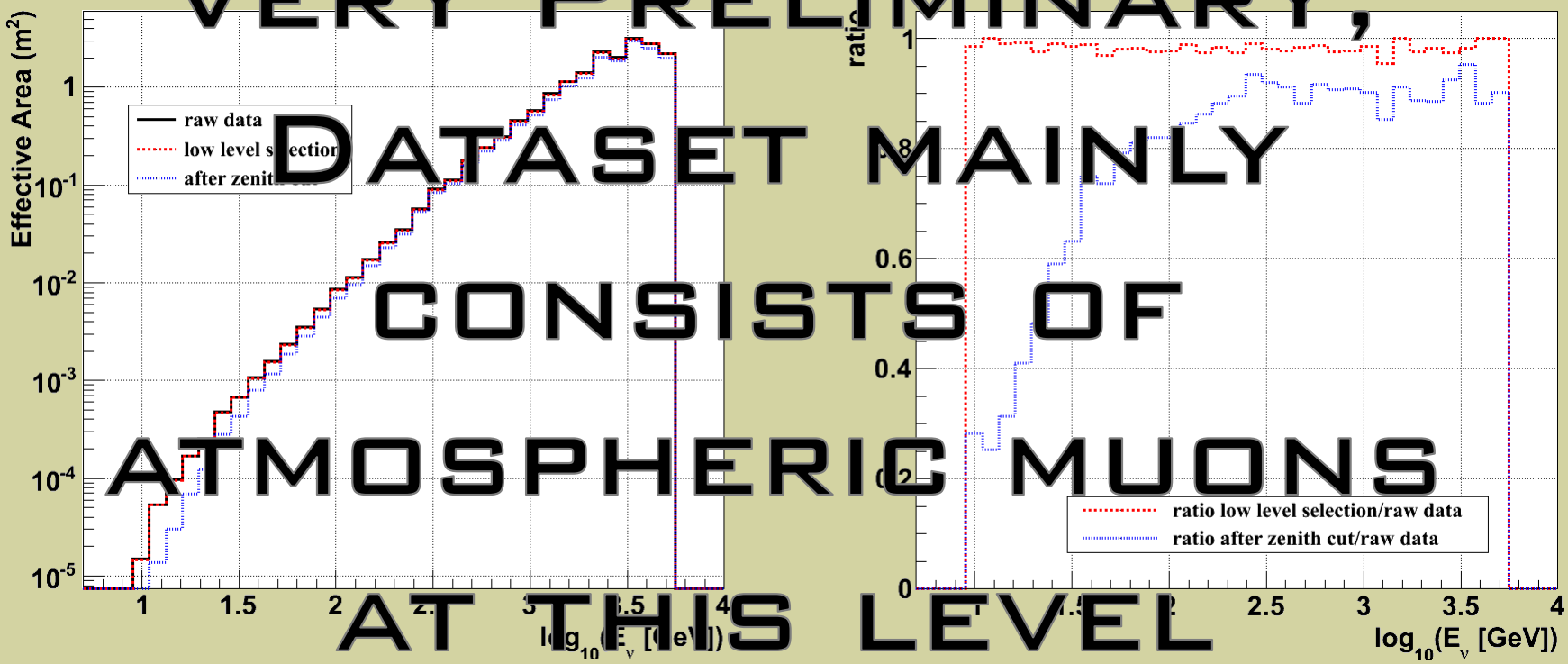


What should be optimized?

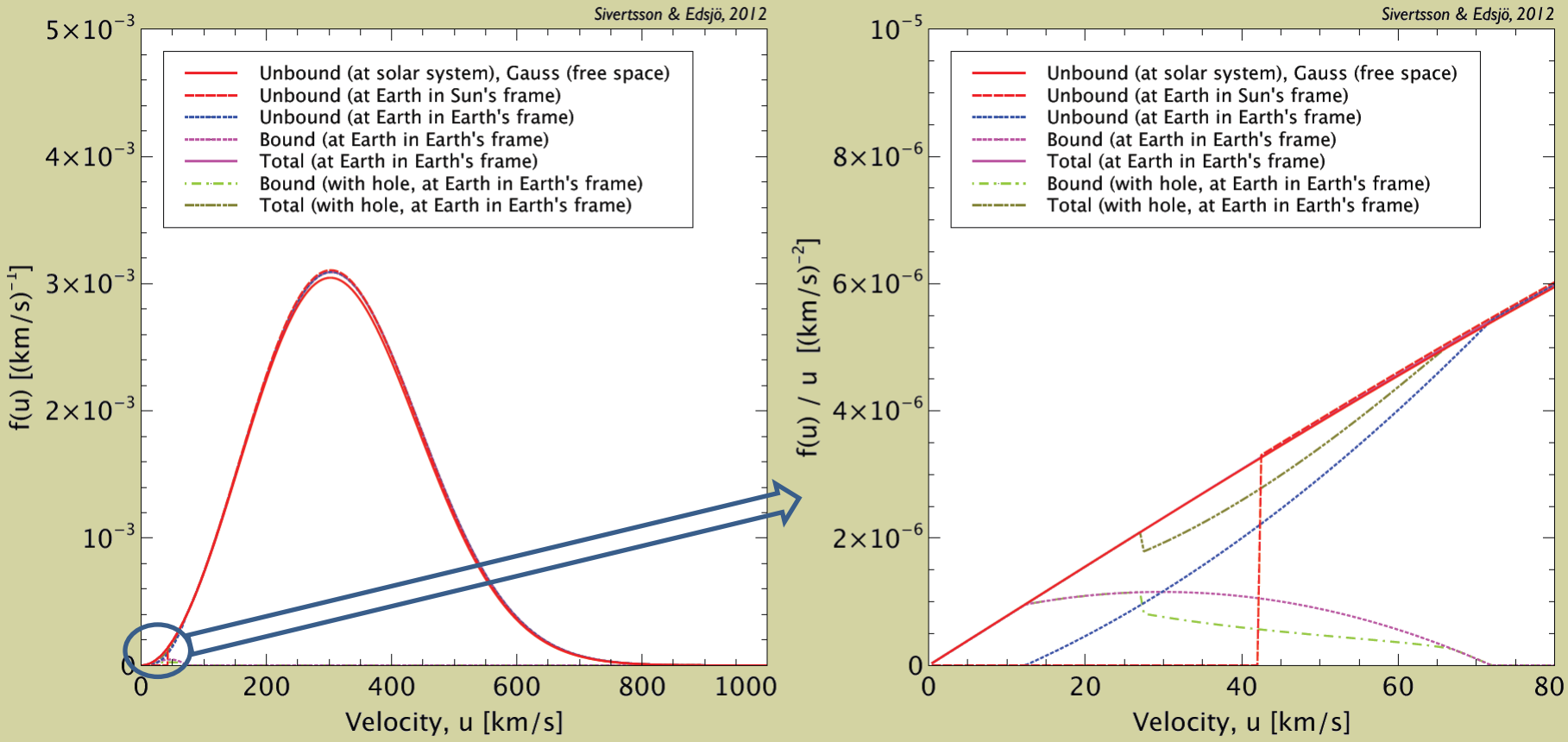
The effective area!

$$A_{eff} = \frac{observed\ flux}{generated\ event\ rate}$$

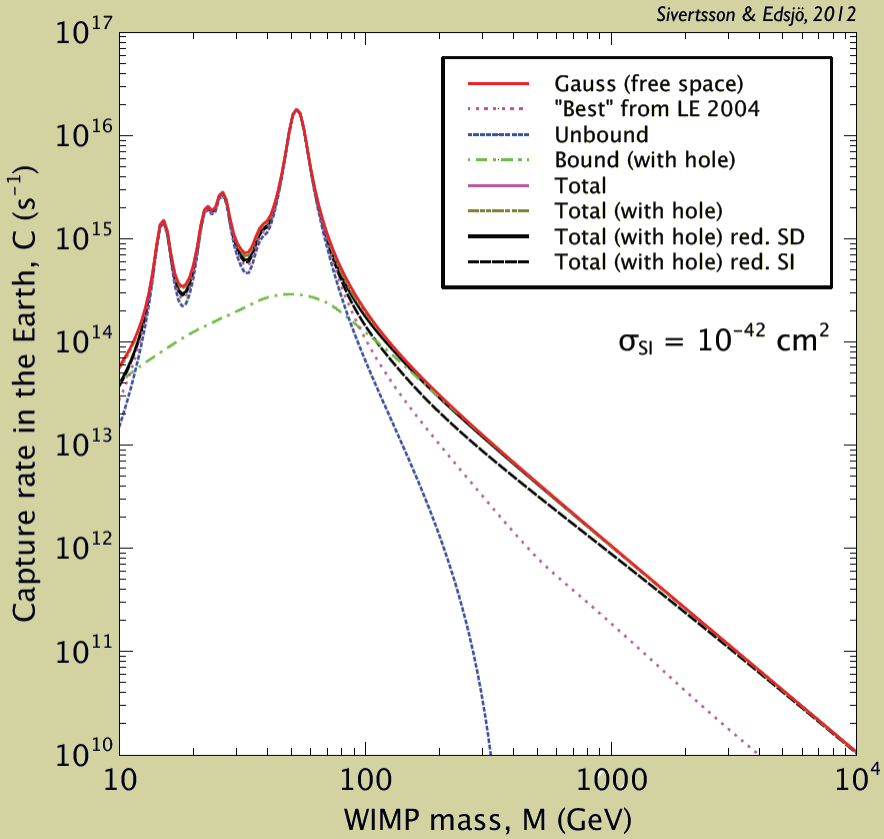
Very Preliminary, Dataset mainly consists of atmospheric muons at this level

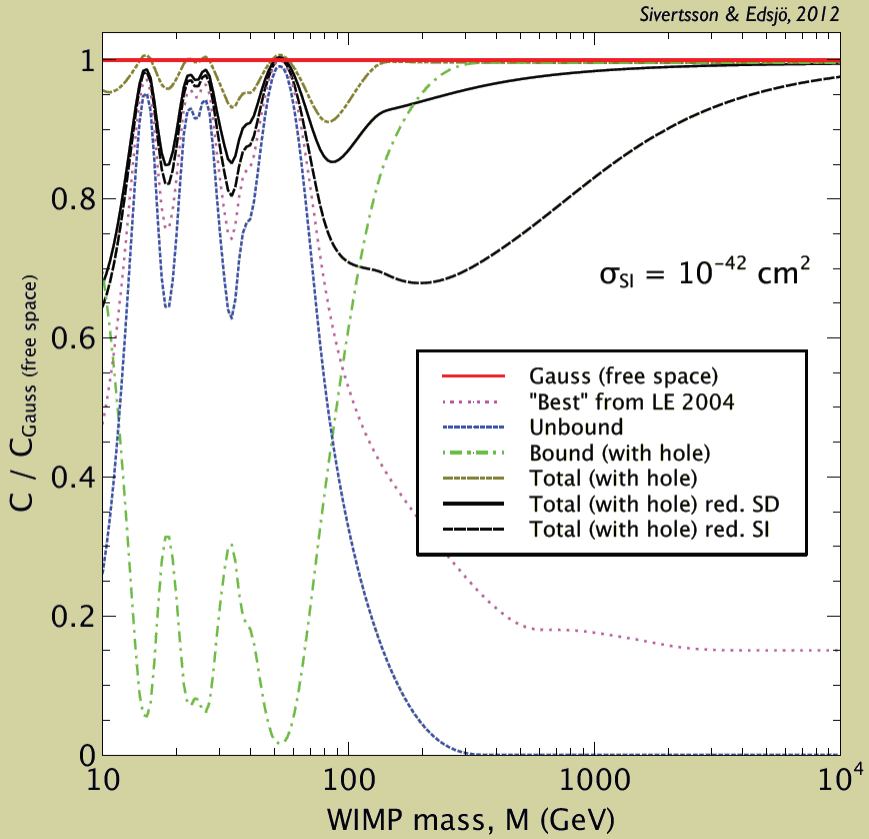


The WIMP velocity distribution at the Earth

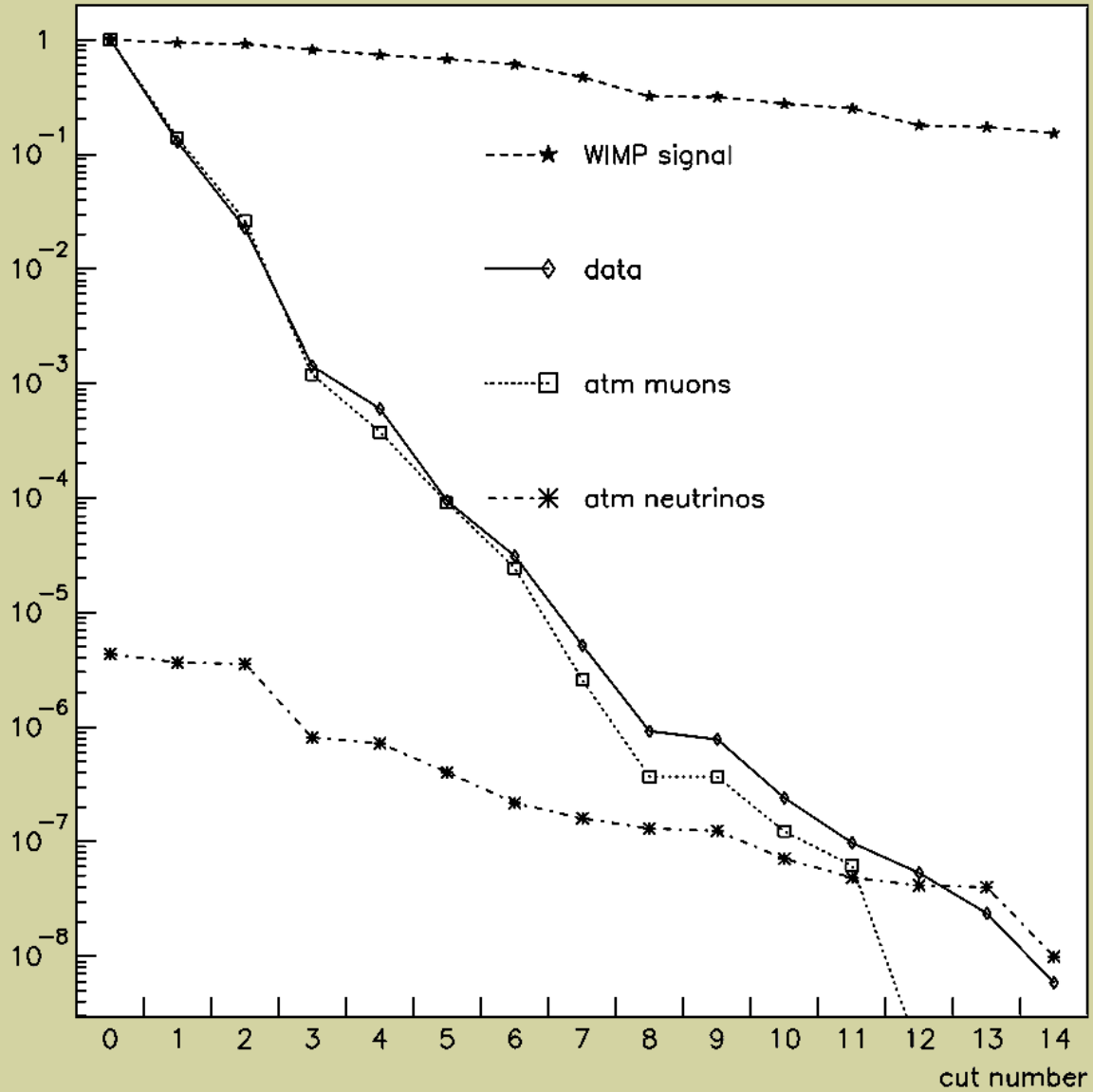


Earth Capture Rate





Removing the background : the AMANDA Earth WIMP analysis



Removing the background : the AMANDA Earth WIMP analysis

cut 1	$\theta(DW) > 65°$ OR (usdhits > 3 AND upratio > 0.42)
cut 1 b	$N_{\text{hits}} < 350$
cut 2	$\theta(16it_{DW}) > 80°$ OR $\theta(16it_{lf}) > 80°$
cut 3	$\theta(32it) > 140°$
cut 4	$N_{\text{dir}}(-15:75) > 5$
cut 5	$P_{ha} + P_{he} > 0.8$
cut 6	$raline > 0.5$
cut 7	$N_{\text{dir}}(-15:25) > 5$
cut 8	$\frac{\log\mathcal{L}(casc)}{\log\mathcal{L}(\mu)} > 0.96$
cut 9	$L_{\text{dir}}(-15:25) > 50\text{m}$
cut 10	$P_{ha} + P_{he} > 0.95$
cut 11	$\lvert S^{\text{van}}_{\text{dir}}(-15:75)\rvert < 0.25$
cut 12	0 rad$< \sigma_\theta < 0.11$ rad
cut 13	$N_{\text{dir}}(-15:25) > 6$
cut 14	$\theta(32it) > 170°$

Angular Resolution

The angular resolution below 300 GeV is dominated by the increasing kinematic angle between neutrino and muon