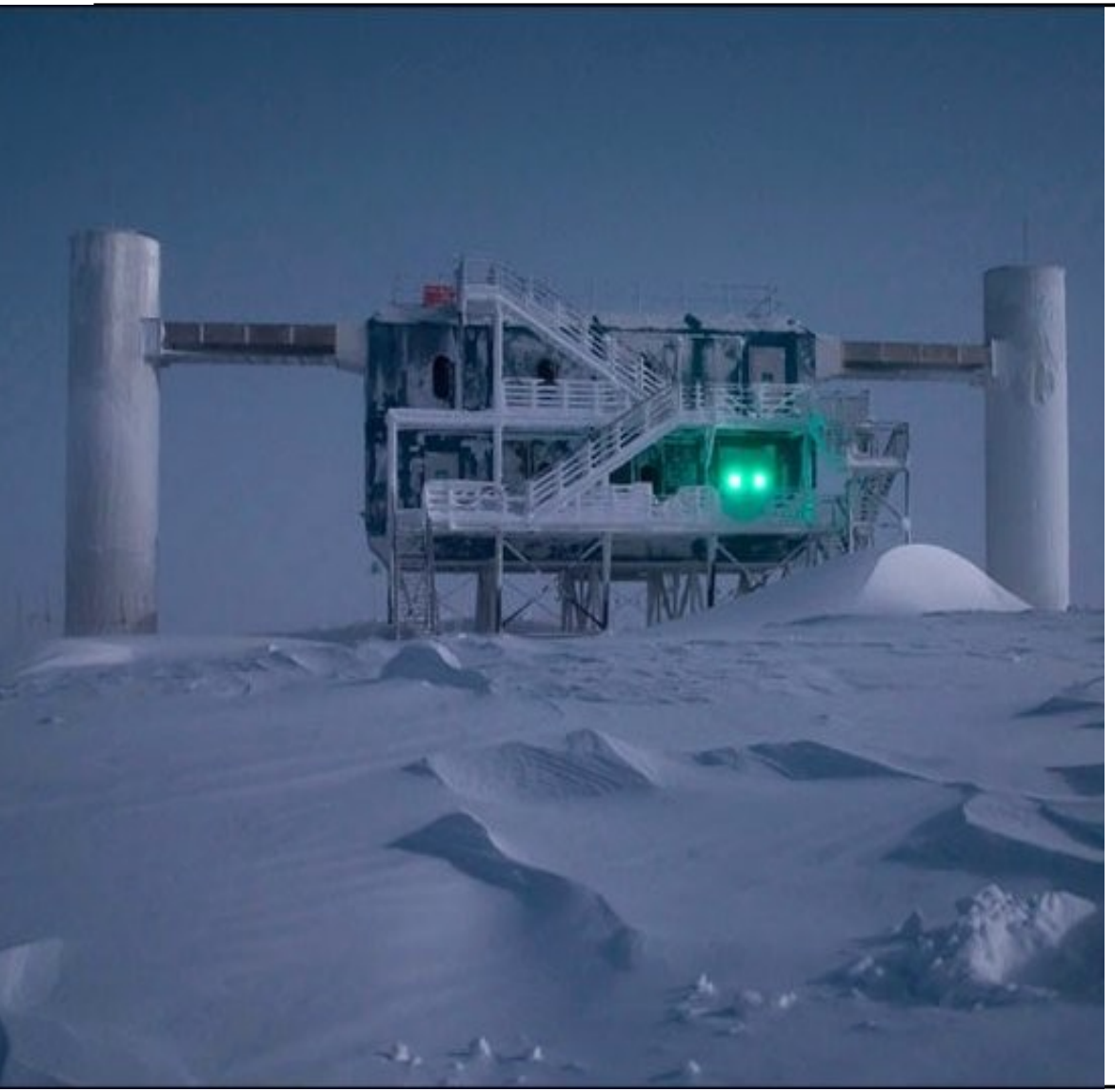


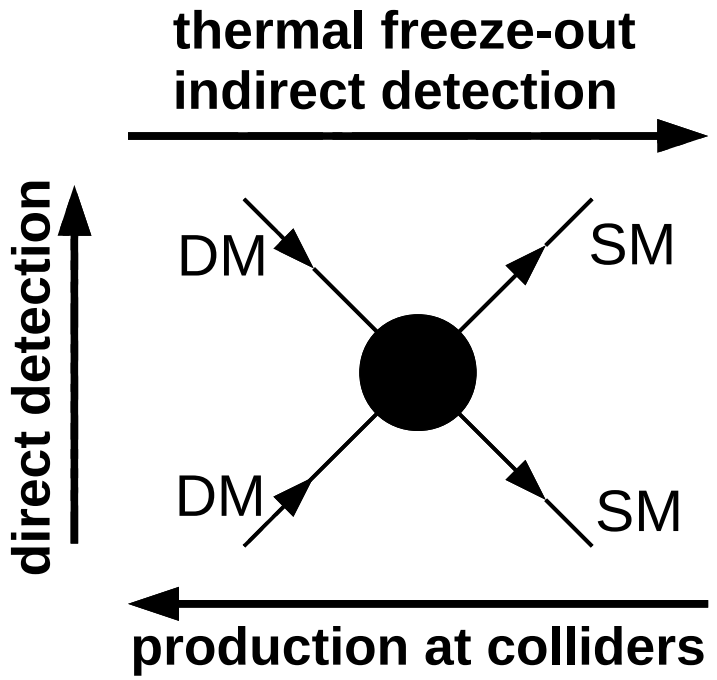
Dark Matter searches with IceCube

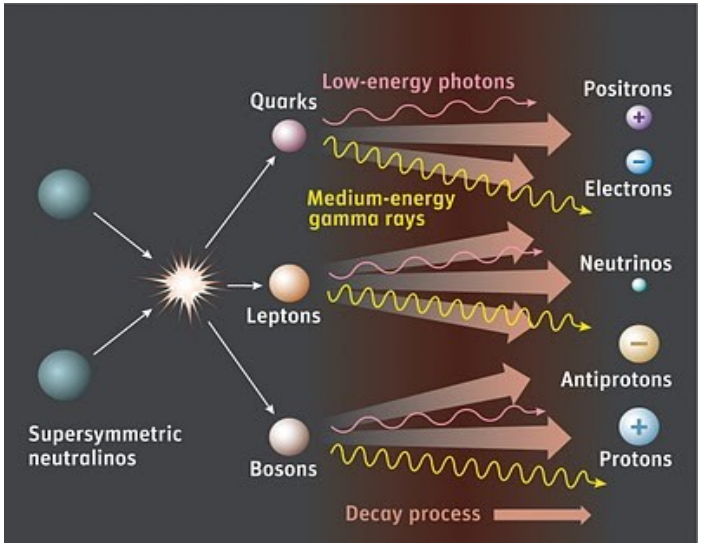
Rencontres de Blois 2014

Jan Lünemann, Vrije Universiteit Brussel
for the IceCube Collaboration

Detection of Dark Matter

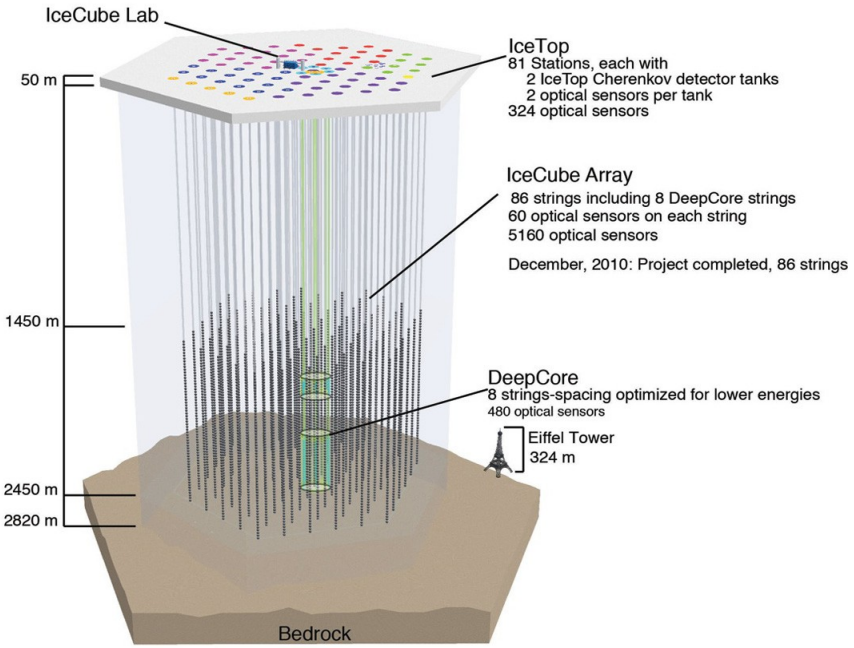
- Annihilation of WIMPs could produce a neutrino signal from regions of dark matter overdensities





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



WIMP search

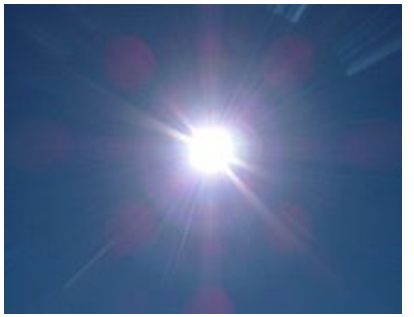
Targets for WIMP searches with IceCube:

annihilation cross section

dwarf galaxies
and other halos

Galactic center / halo

scattering cross section



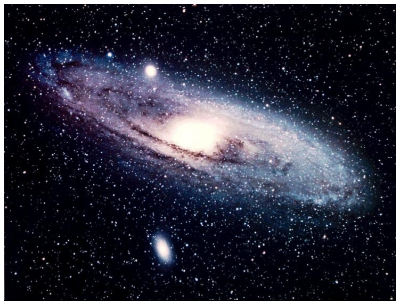
Sun

Earth

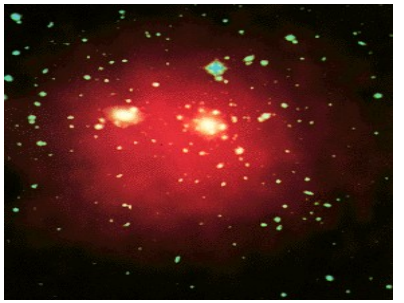
Distant halos

- Dwarf spheroidal galaxies
  - Popular targets for gamma telescopes, because of small gamma background
- Galaxies
  - Andromeda
- Galaxy clusters
  - Coma
  - Virgo
- IC59: Phys. Rev. D 88, 122001
- IC79 / IC86: in preparation

Segue 1



Andromeda



Coma cluster

Neutrino flux

- Pairwise annihilation of dark matter could produce an observable neutrino flux

$$\frac{d\Phi(\Delta\Omega)}{dE} = \frac{\langle\sigma_A v\rangle}{4\pi \cdot 2m_\chi^2}\frac{dN}{dE}J(\Delta\Omega)$$

$\langle\sigma_A v\rangle$ Annihilation cross-section, velocity averaged

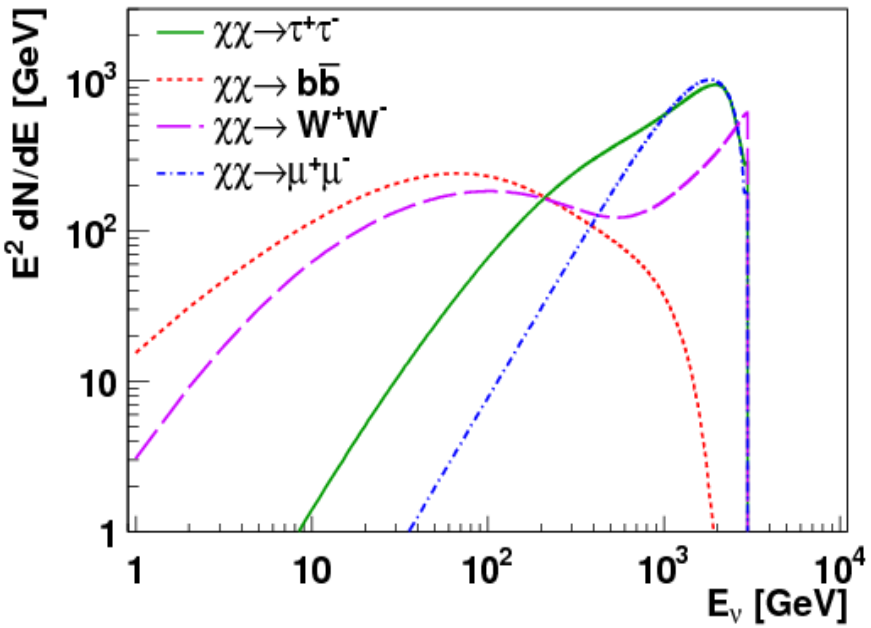
$\frac{dN}{dE}$ Neutrino spectrum per annihilation

$$J(\Delta\Omega) = \int_{\Delta\Omega} d\Omega \int_{l.o.s.} \rho_\chi^2(s) ds$$

J-Factor:
“line-of-sight” Integral over squared mass density

Energy spectrum

- Spectrum depends on
  - WIMP mass
  - Annihilation channel
- Calculation of spectra with DarkSusy



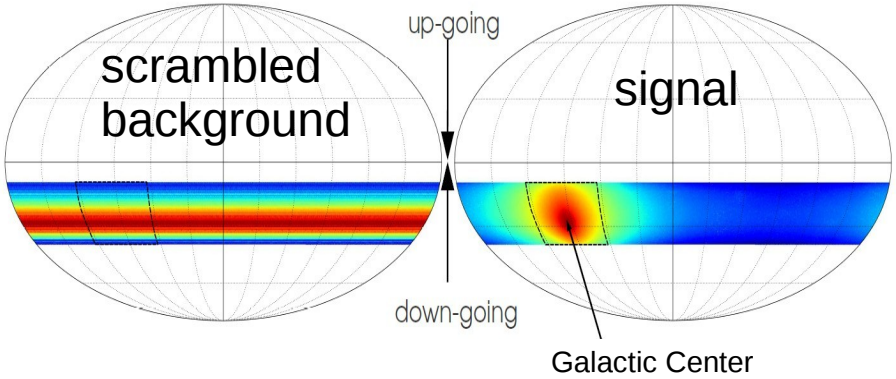
Spectra of μ neutrinos at earth after oscillation (WIMP mass 300 GeV)

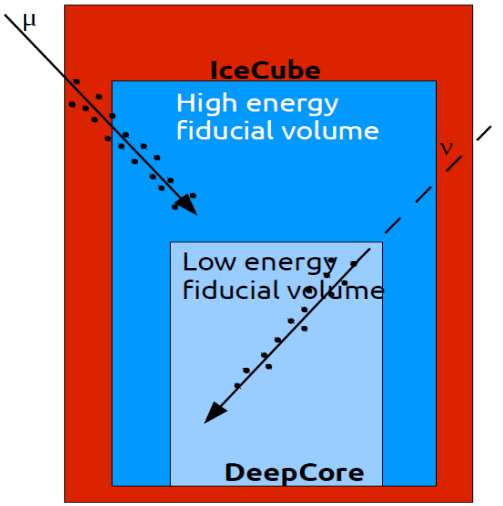
Distribution of dark matter

- Smooth profile e.g. NFW (cusped) or Burkert (cored)
- Subclusters
  - Boost of signal
  - Larger target region → not point like for IceCube
  - Effect depends on total mass of halo
  - Negligible for dwarf galaxies
- Recent studies (Sánchez-Conde & Prada, arXiv:1312.1729) show that boost is much smaller (factor ~35 instead of ~10^3 for galaxy clusters)
  - Will be considered in follow up analysis

Galactic center

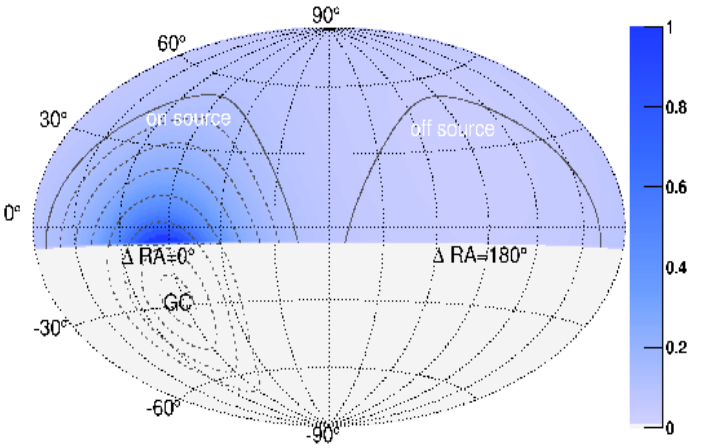
- In southern hemisphere
  → data dominated by atmospheric muons
- DeepCore: select starting tracks by using IceCube as veto $(m_\chi < 300\,\mathrm{GeV})$
- For $m_\chi > 300\,\mathrm{GeV}$: larger fiducial volume
- IC40: arxiv:1210.3557
- IC79: in preparation

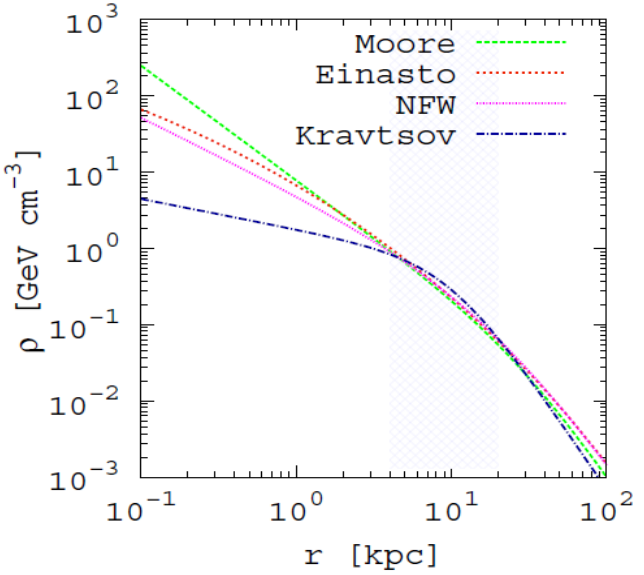




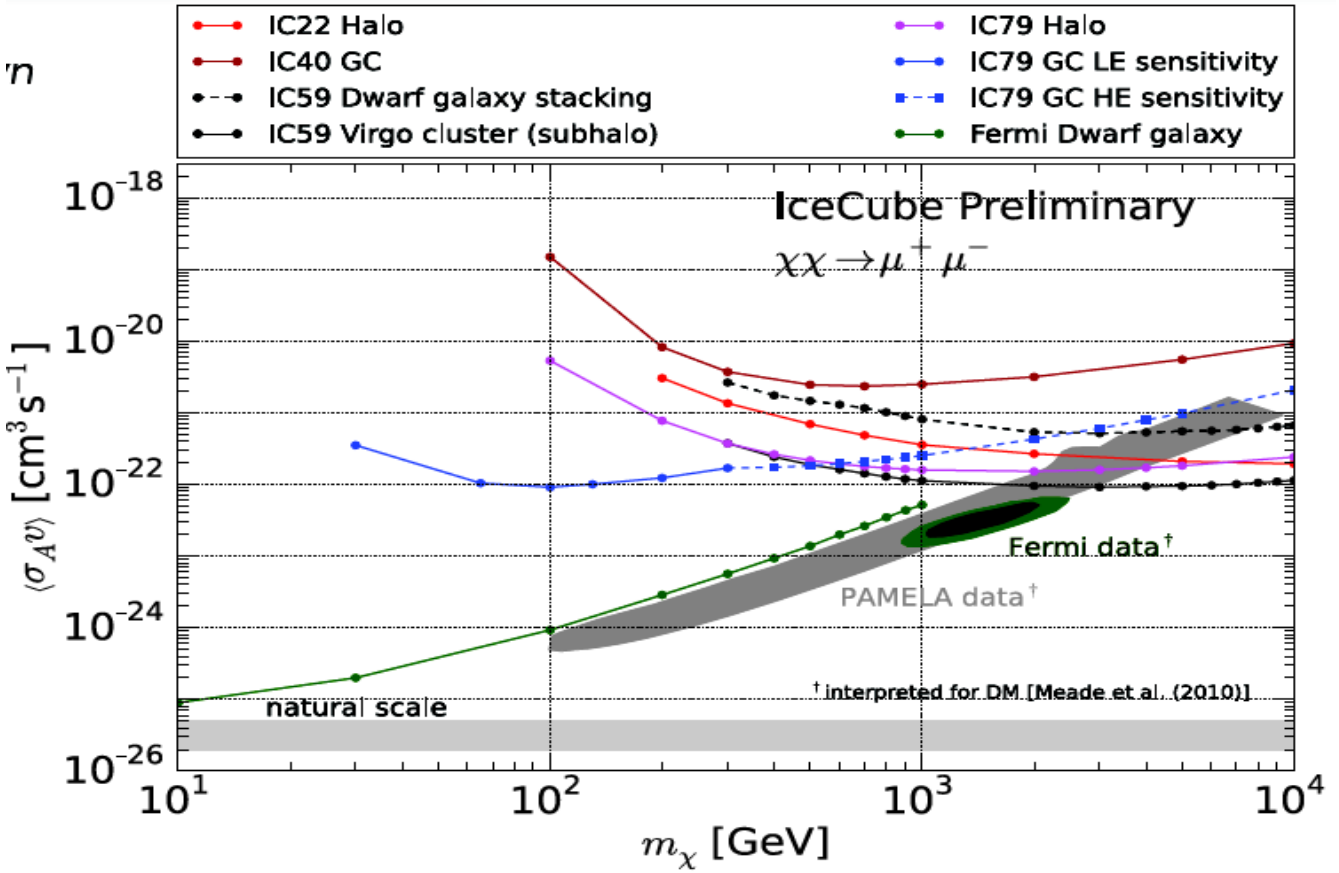
Galactic halo

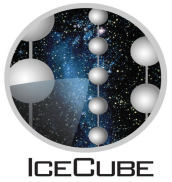
- Anisotropy expected in northern hemisphere
- Less dependent on halo profile
- IC22: PRD 84, 022004 (on-source/off-source)
- IC79: in preparation (multipole analysis)





Results

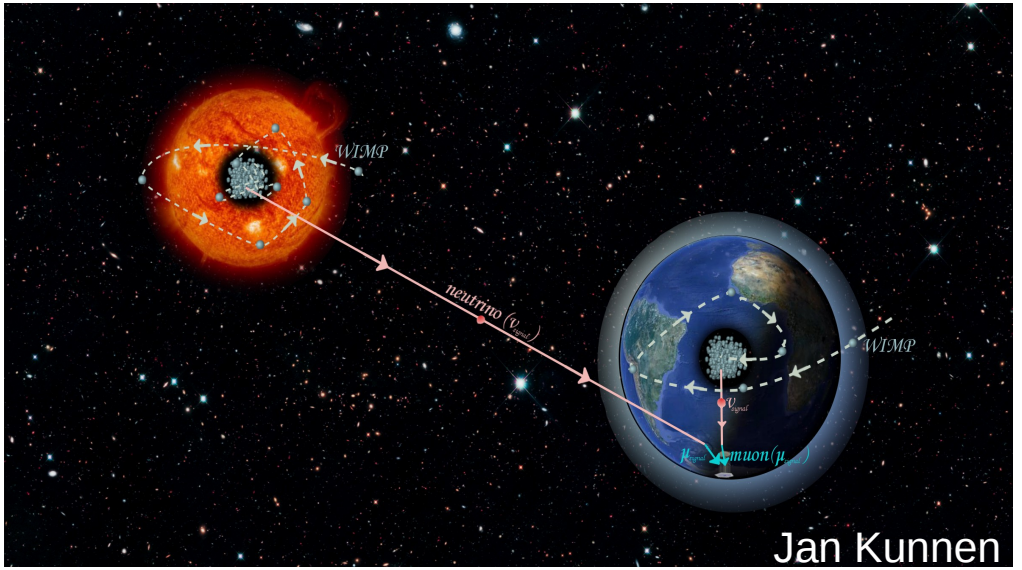

IC22 Halo
IC40 GC
IC59 Dwarf galaxy stacking
IC59 Virgo cluster (subhalo)
IC79 Halo
IC79 GC LE sensitivity
IC79 GC HE sensitivity
Fermi Dwarf galaxy
IceCube Preliminary
$\chi\chi \to \mu^+ \mu^-$
Fermi data†
PAMELA data†
† interpreted for DM [Meade et al. (2010)]
natural scale
$\langle \sigma_A v \rangle$ [cm^{3}s^{-1}]
m_χ [GeV]
10^{-18}
10^{-20}
10^{-22}
10^{-24}
10^{-26}
10^1
10^2
10^3
10^4



Probing the χ-p cross section

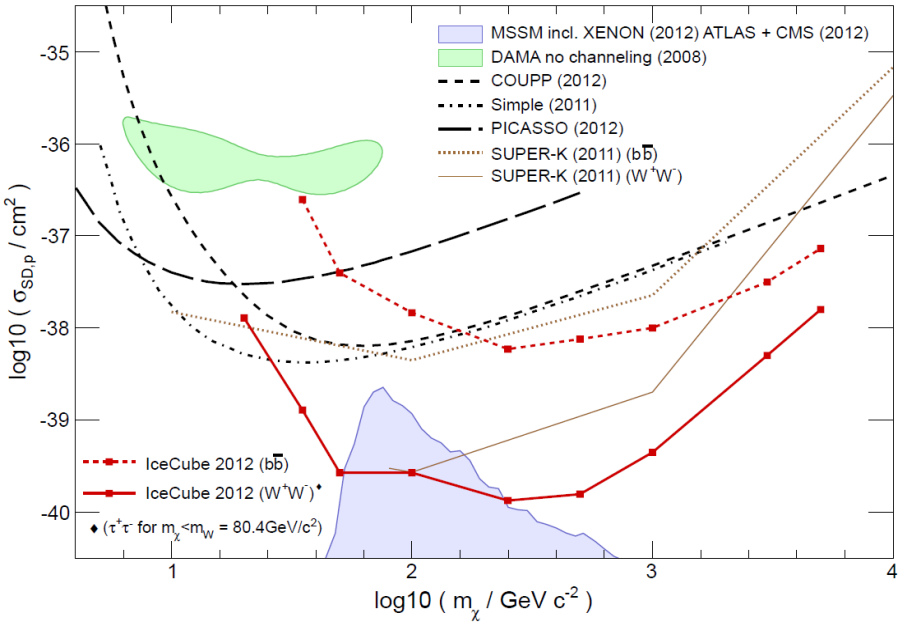
Sun & Earth

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

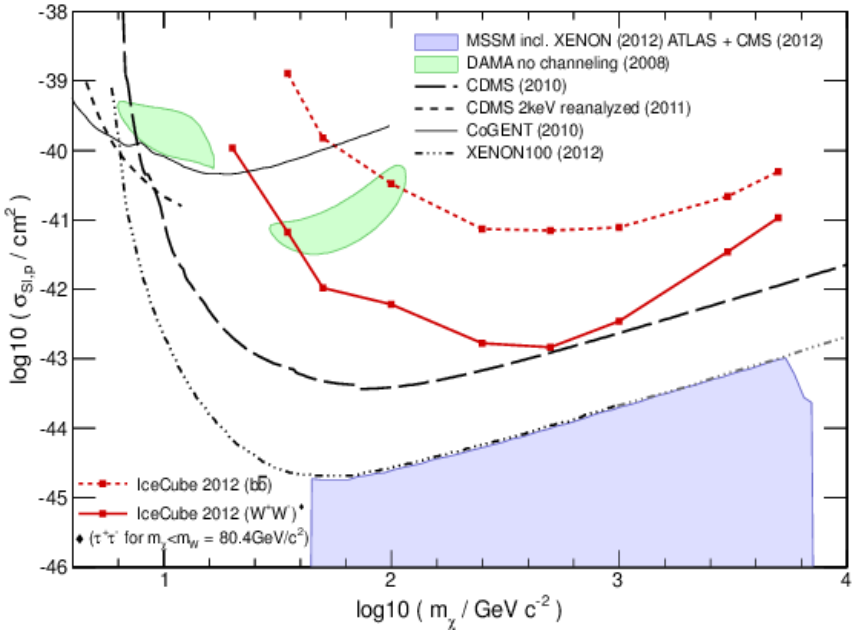


Sun

- Equilibrium between capture rate and annihilation rate
- Independent cuts for austral summer (down-going) and winter (up-going)



χ-p cross-section (spin-dependent)



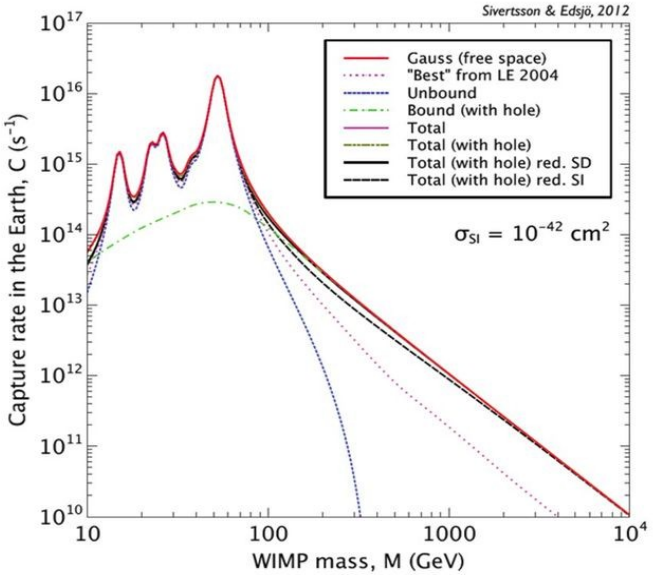
χ-p cross-section (spin-independent)

IC79: PRL 110 (2013) 131302

Earth

- Search for vertical up-going tracks
- Capture rate dominated by heavy elements
- Capture and annihilation not in equilibrium
- First IceCube analysis in preparation

reco energy < 100 GeV
Optimize on $m_\chi = 50\text{GeV}$
$\chi\chi \to \tau^+\tau^-$

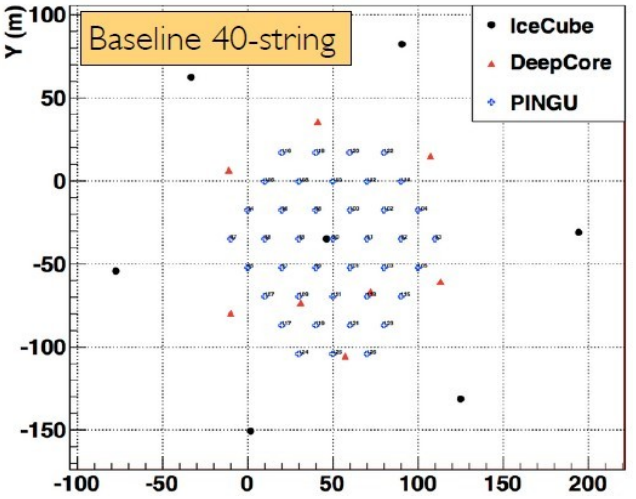


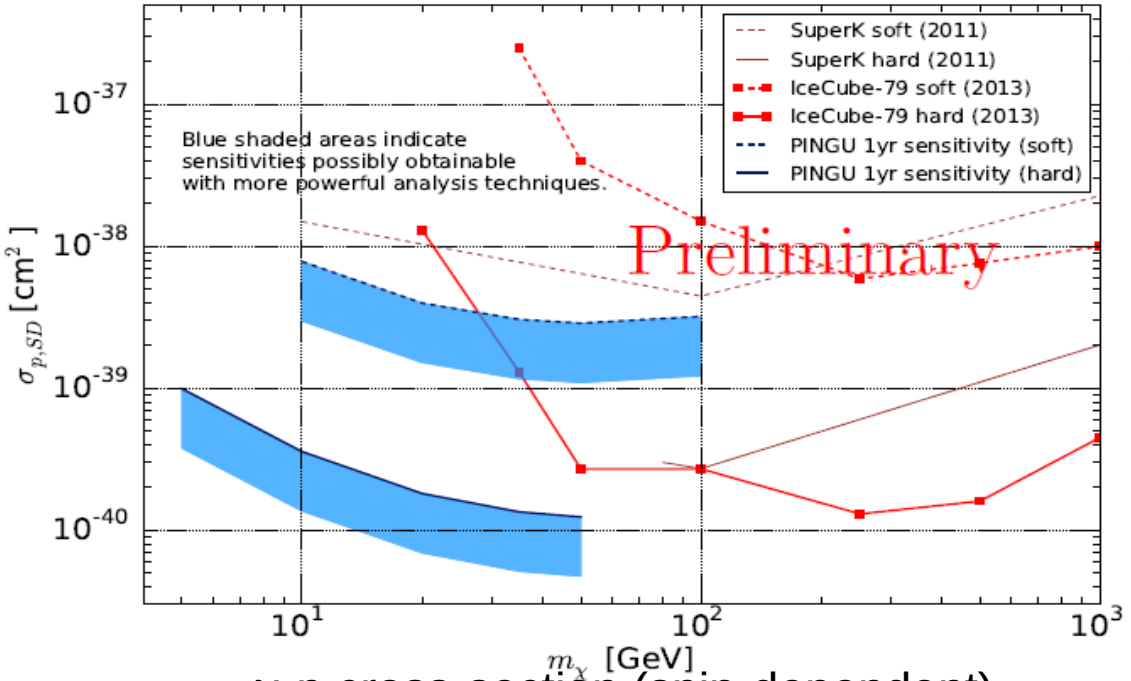
reco energy >100 GeV
Optimize on $m_\chi = 1$ TeV
$\chi\chi \to W^+W^-$

The future

PINGU

- High density instrumentation
- Low energy threshold: few GeV
- Reach WIMP masses of 5 GeV





χ-p cross-section (spin-dependent)

PINGU LOI:
arXiv:1401.2046

Summary

- Competitive limits on dark matter cross-sections
- Complementary to accelerator, direct and other indirect searches
- Analysis updates with fully deployed detector
- PINGU will make mass ranges at few GeV accessible

Stay tuned!