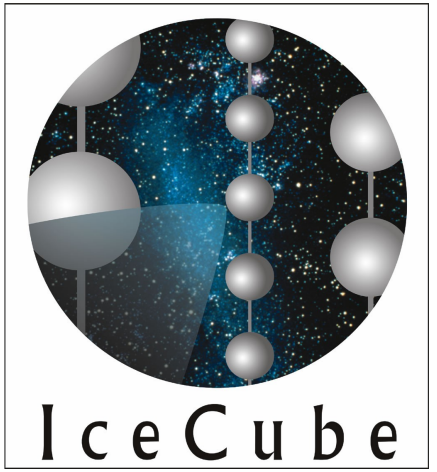
Searches for Dark Matter Annihilations in the Sun and Earth with IceCube and DeepCore

Matthias Danninger

for the IceCube collaboration



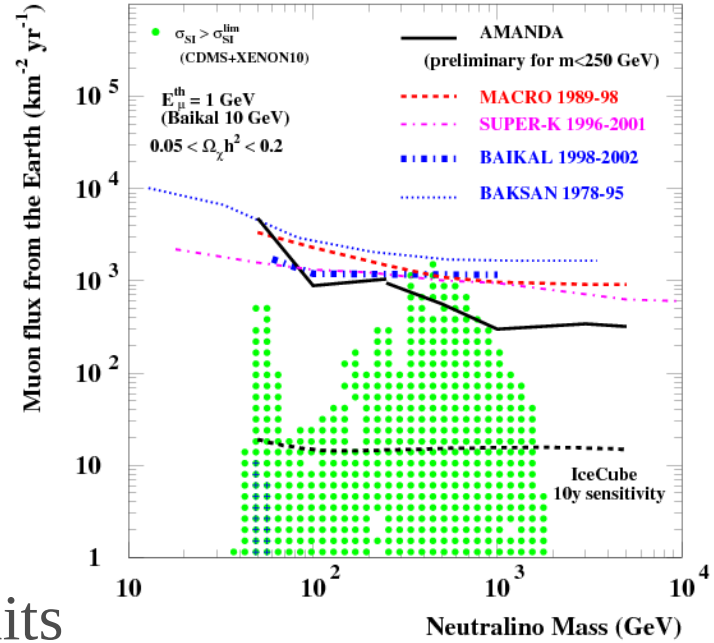
Content

Overview:

- IceCube (see **IceCube status** plenary talk by D. Williams)
- DeepCore → key facts

Dark Matter searches:

- Earth  → work in progress, no new results
- Sun 
  - → neutrinos from Dark Matter
  - → considered WIMP models
  - → analysis strategy & current limits



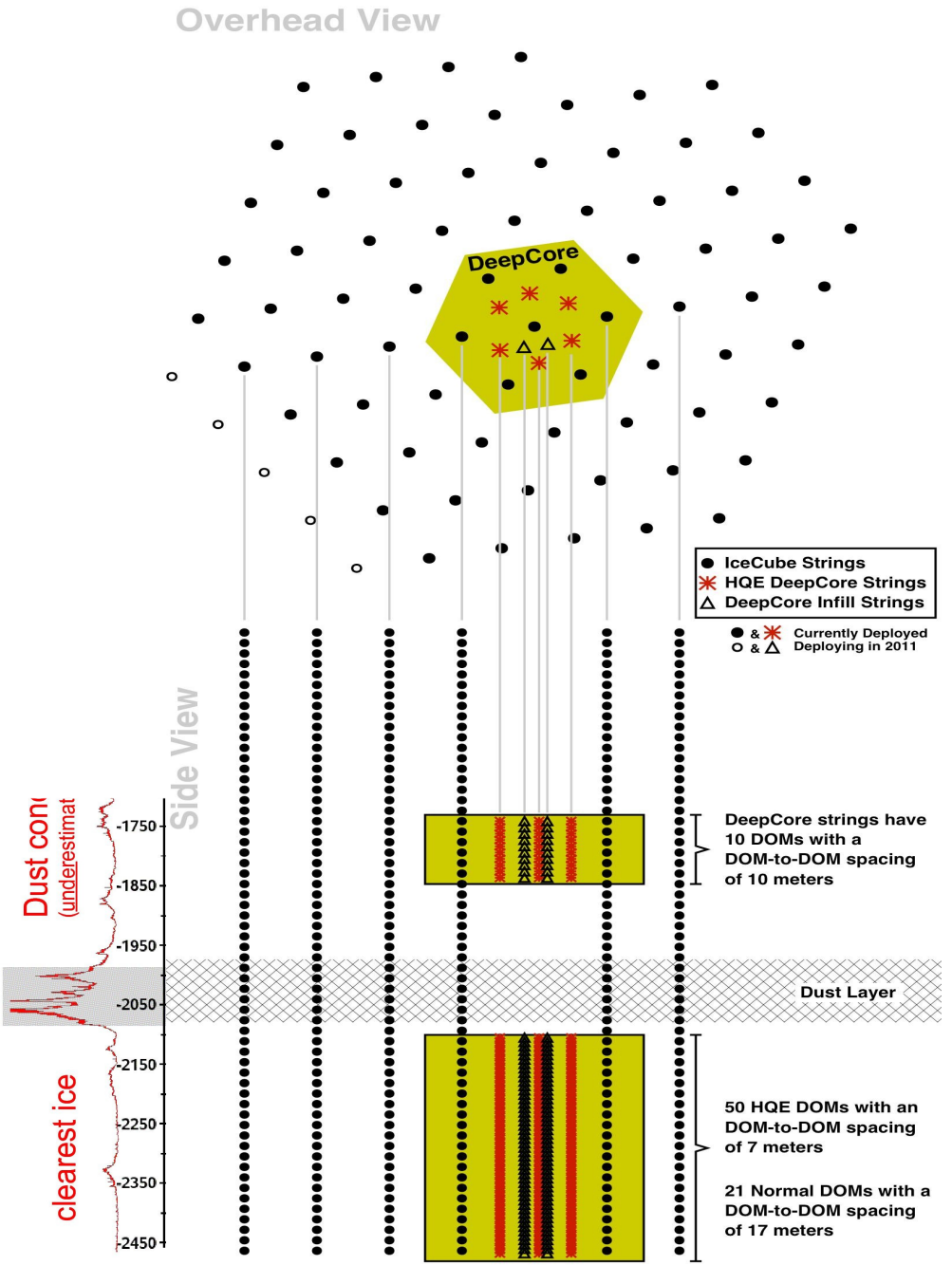
Looking forward: (IceCube&DeepCore prospects)

Conclusions

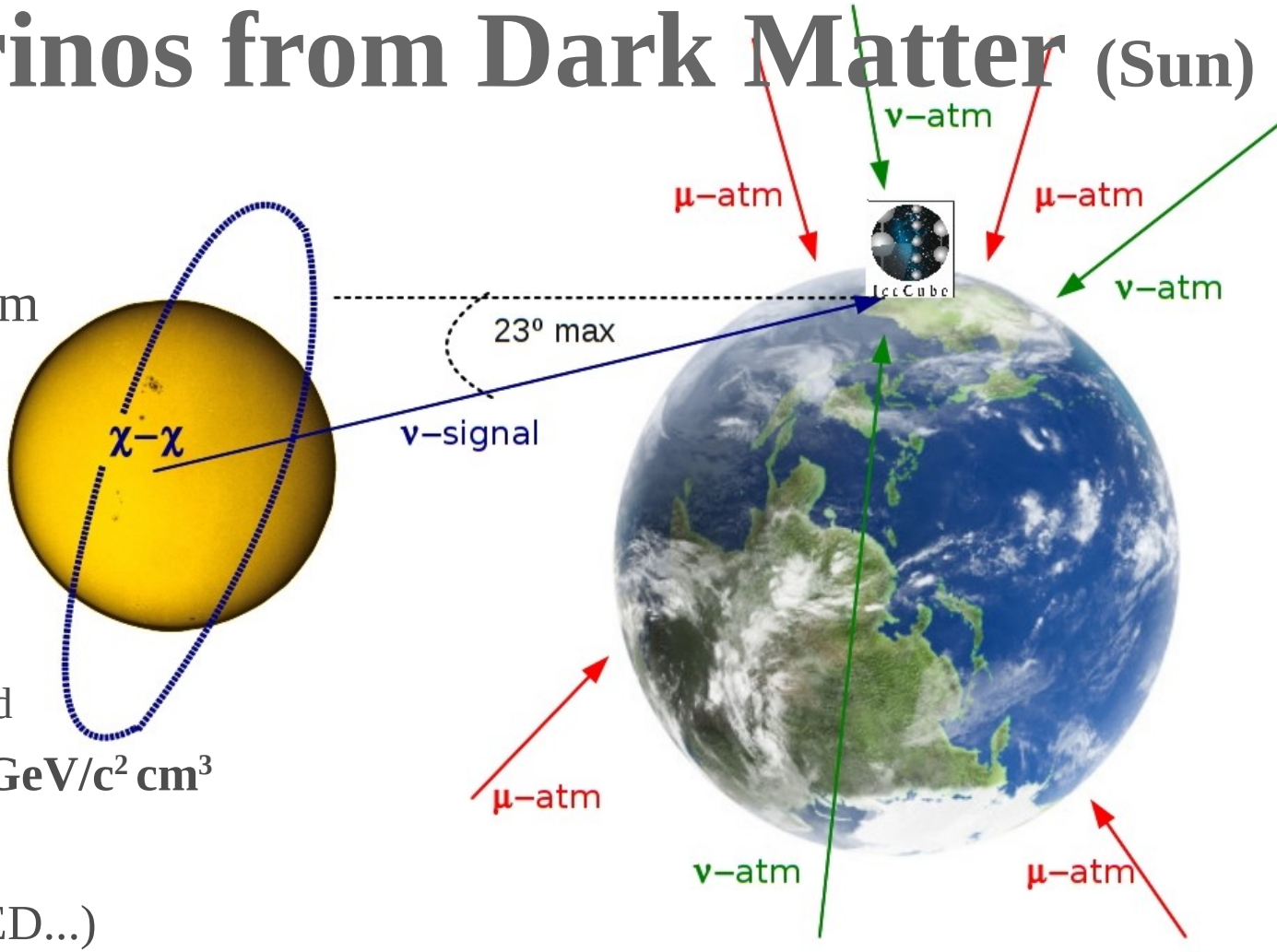
Deep Core

- 6 additional strings – 60 High Quantum Efficiency PMTs (deployed in deep ice)
- 7m DOM spacing (17m standard), 72m inter-string spacing.

  → focus energies (few GeV~1TeV)
- 4π detector using IceCube as an active veto. Southern sky sources (GC) and year round observation for the Sun.



Neutrinos from Dark Matter (Sun)



signature:

ν excess over background from Sun direction

physics uncertainties involved:

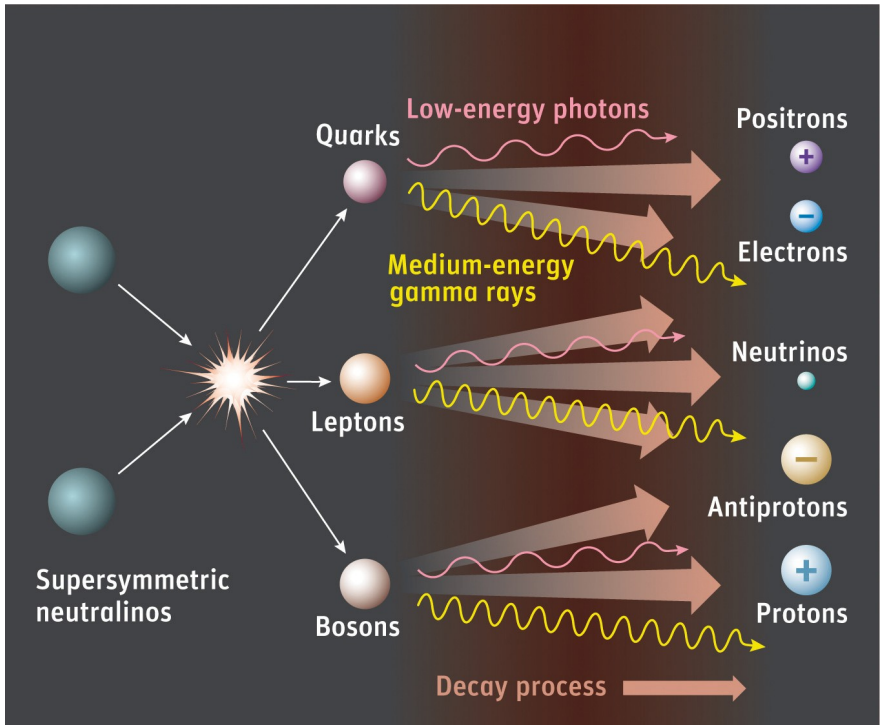
- relic density calculations
- DM distribution in the halo
  - → smaller effect for this method
  - → mean density ρ_{local} = **0.3 GeV/c² cm³**
- velocity distribution
- WIMP properties (MSSM/UED...)
- interaction of WIMPs with matter (capture)
  - → planetary effects (high masses)
  - → Sun composition
- self interaction (annihilation)

background:

atm μ ~***O*(10⁹)** events/year (downwards)

atm ν ~***O*(10³)** events/year (all directions)

Investigated DM candidates



- arise in extensions of the Standard Model
- assumed to be stable: relics from the Big Bang
- mass from few GeV to few TeV

candidates:

- **MSSM**: lightest super-symmetric particle (LSP) neutralino,

  $\chi^0_1 = z_{11}\,\mathbf{B} + z_{12}\,\mathbf{W}^3 + z_{13}\,\mathbf{H}^0_1 + z_{14}\,\mathbf{H}^0_2$

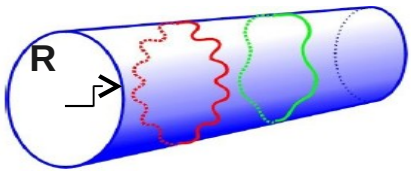
  simulation of "softest" and "hardest" case

  hard: m(χ^0_1) [35 GeV – 5 TeV] ($\boldsymbol{\tau^+\tau^-}$ / $\mathbf{W^+W^-}$)

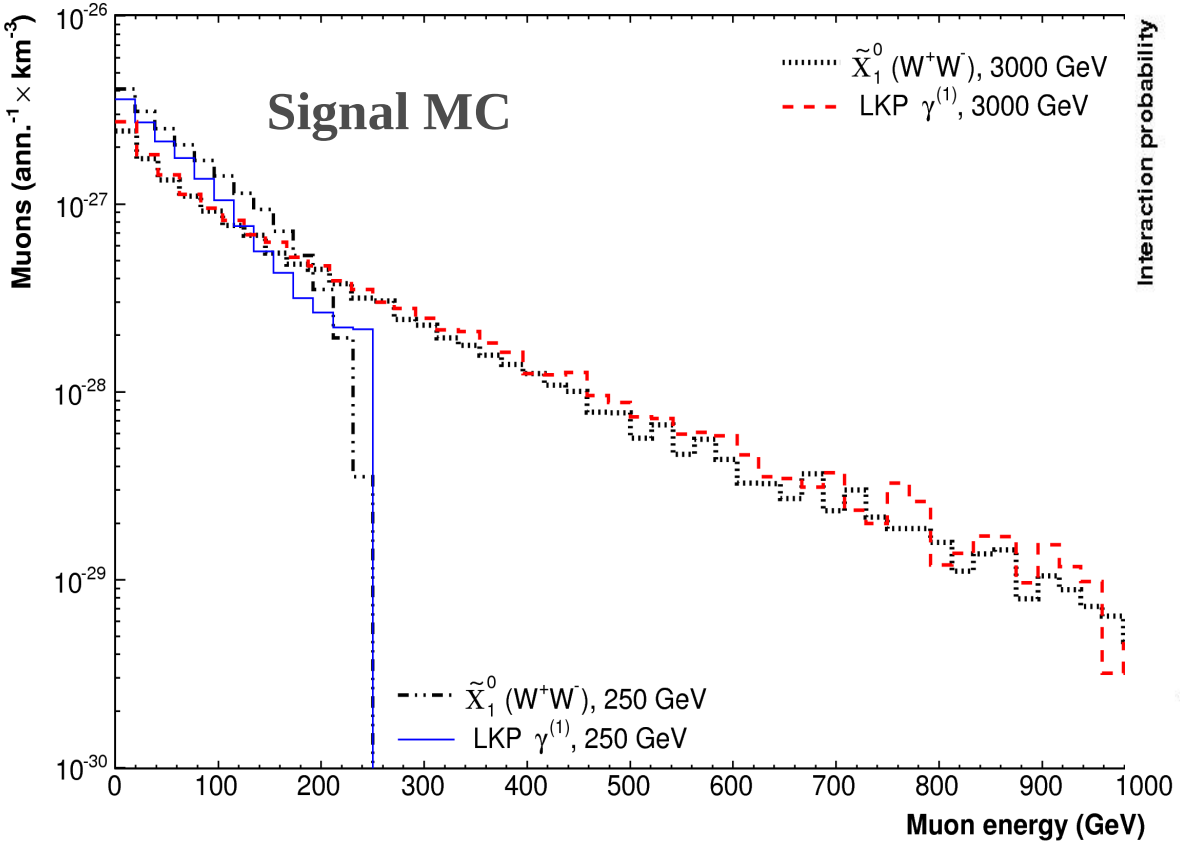
  soft: m(χ^0_1) [35 GeV – 5 TeV] (**b b**)

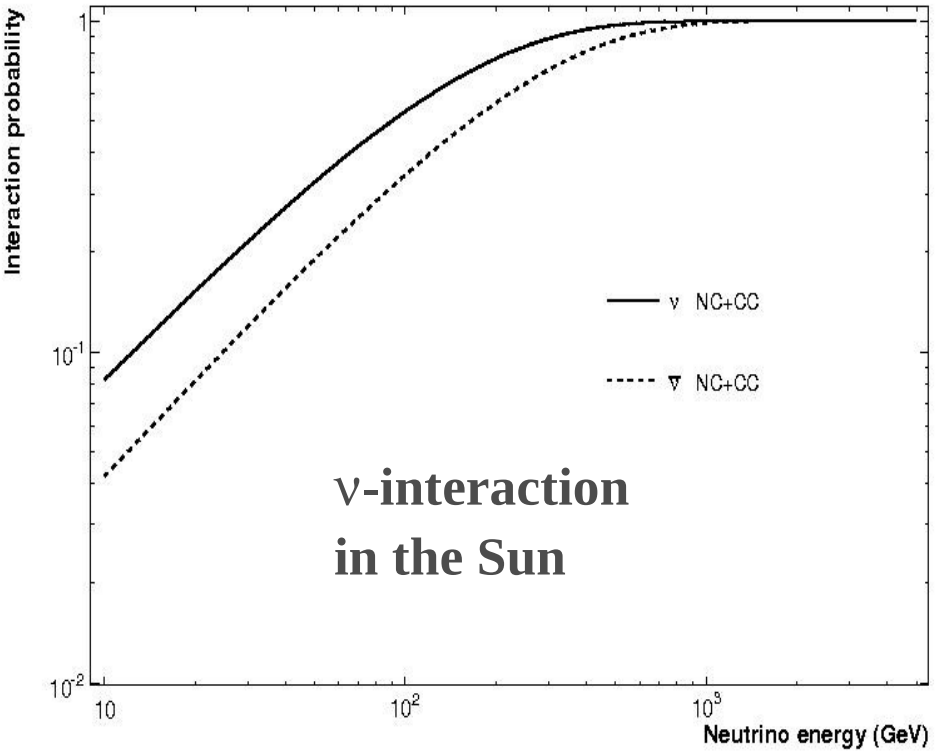
- **Universal extra dimensions**: Lightest Kaluza-Klein particle (LKP), $\mathbf{B}^{(1)}$ or $\boldsymbol{\gamma}^{(1)}$

  fixed branching ratios: m($\boldsymbol{\gamma}^{(1)}$) [250 GeV–3TeV]



Low Energy neutrino Search





ν-energies of ~ 1 TeV have high interaction probability in Sun

→ Sun becomes ν-opaque

→ low mean muon energy in detector → short tracks with few hits

Analysis strategy

Remove atmospheric muon events until data sample is dominated by atmospheric neutrino events

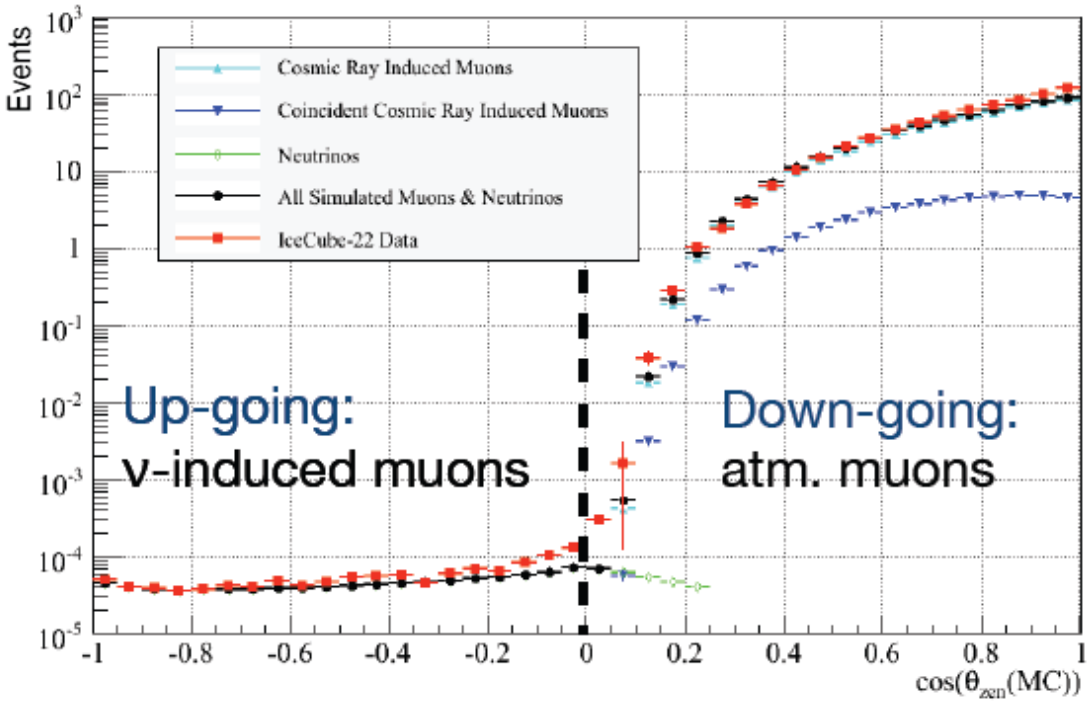
Experimentally obtained quantity

$$\Gamma_{\nu\mu} \leqslant \frac{N_{90}}{V_{\text{eff}} \cdot t}$$

Γ_A

Φ_μ

$C_c \sim \sigma_{SD}$



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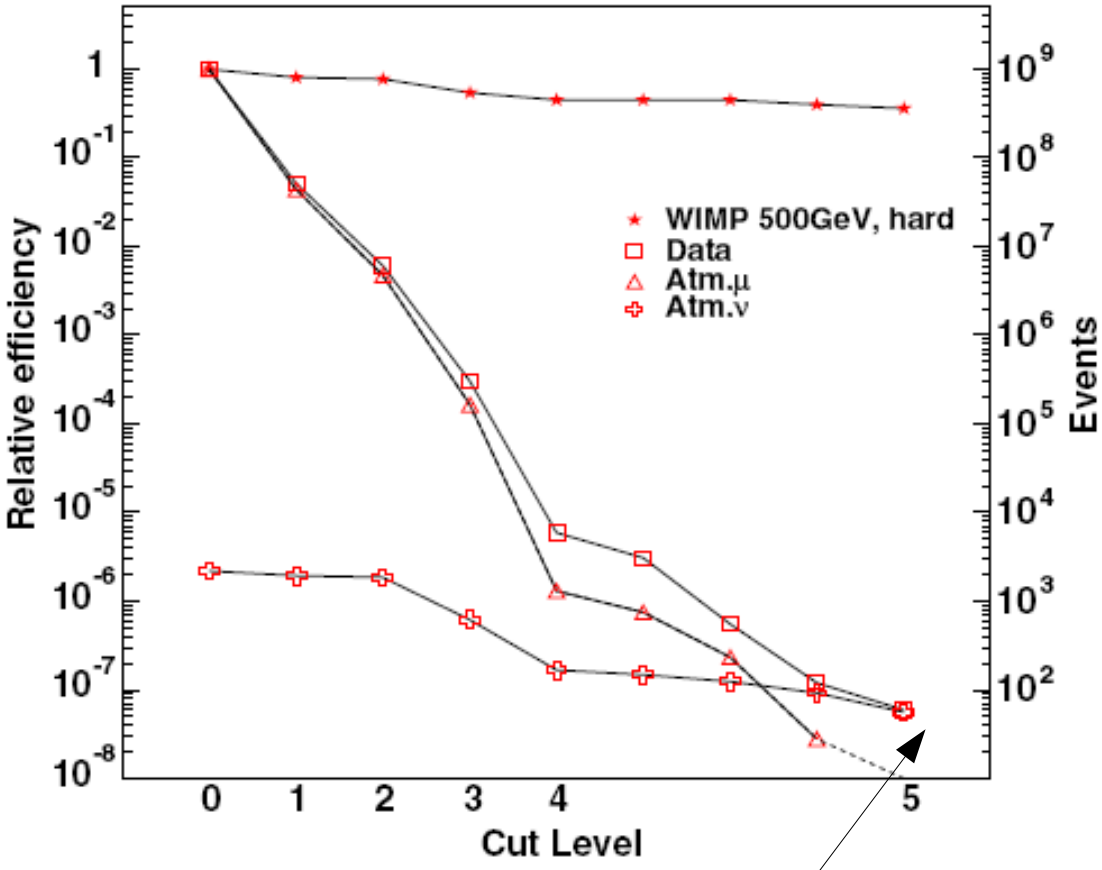

Mostly neutrino events in final data sample

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Abbasi et al., *Phys. Rev. Lett.* **102**, 201302 (2009)

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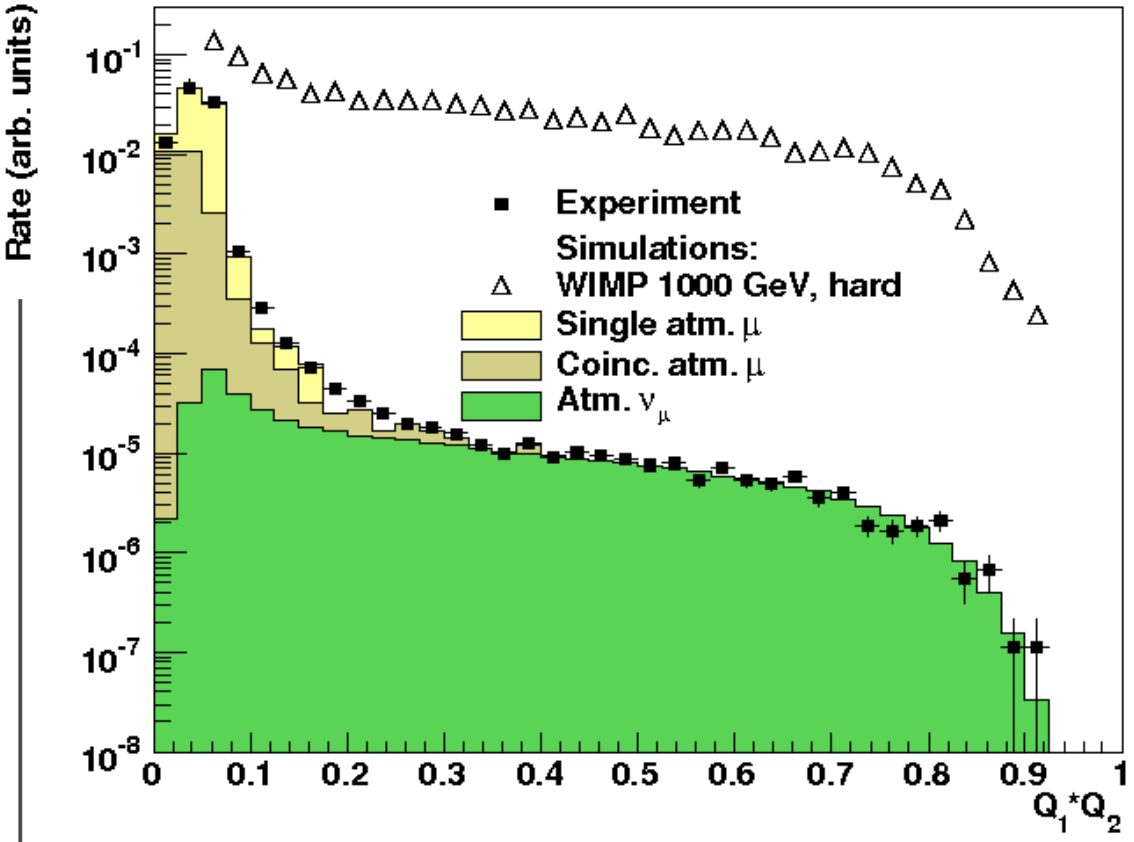

SVM output value from signal simulations, data and three background components

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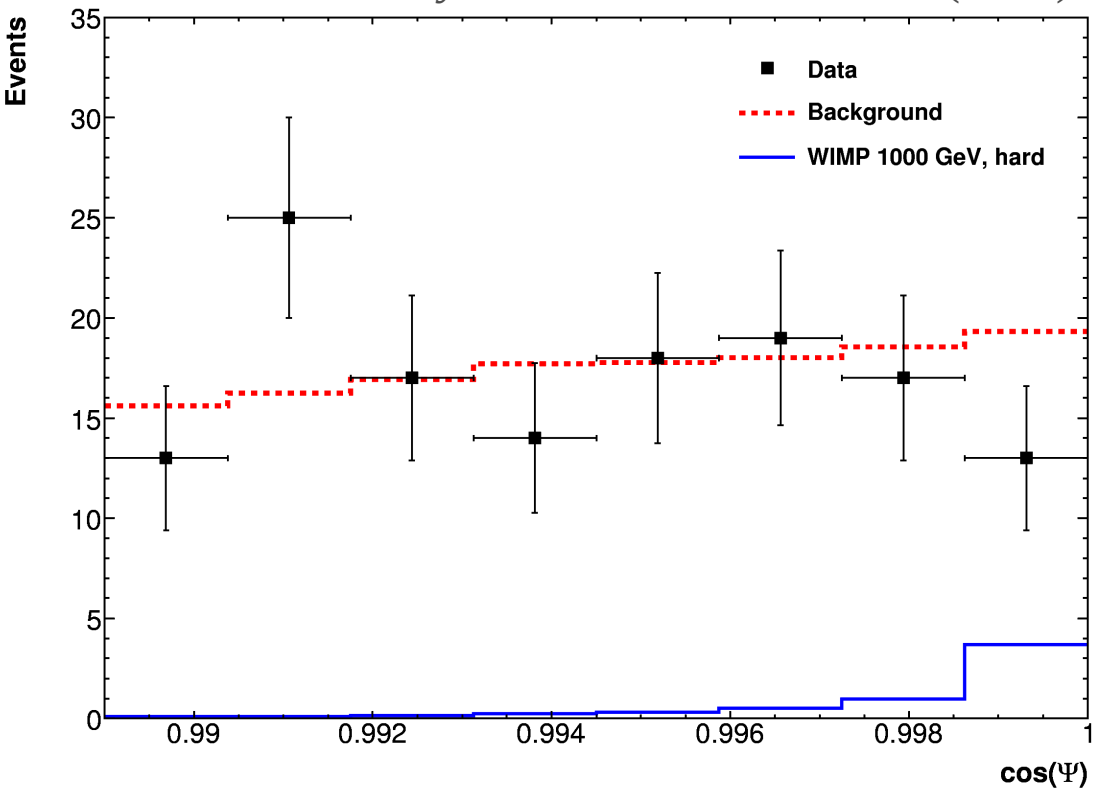
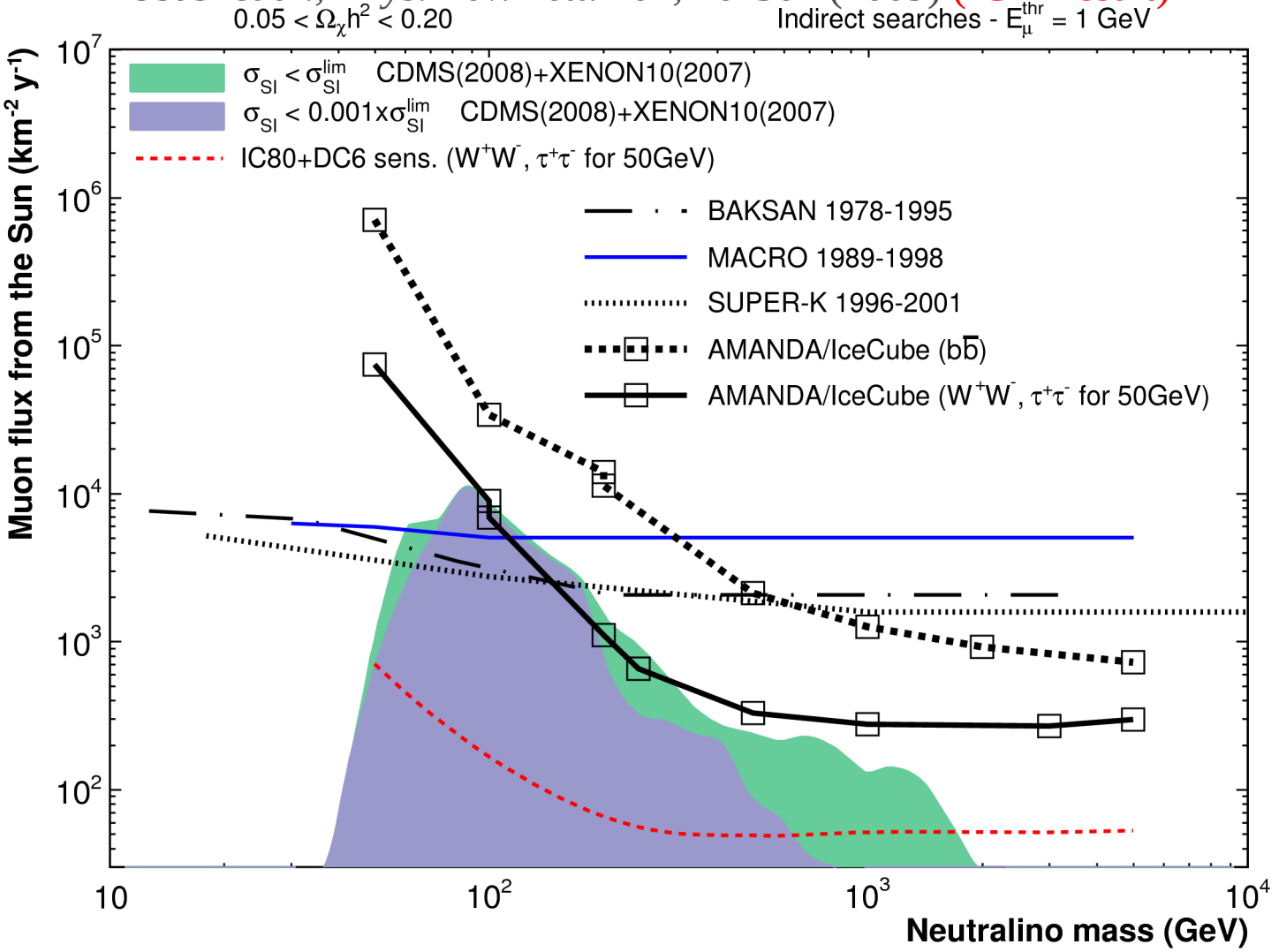


Events close to the direction of the Sun

Results: Neutralino DM (LSP)

Abbasi et al., *Phys. Rev. Lett.* **102**, 201302 (2009) (IC22 result)



IceCube-22 & study:
Only used data, when Sun is below the horizon

main syst. uncertainty:
Photon propagation in the ice & absolute DOM efficiency (~20%)

relate muon flux and WIMP-nucleon cross-section:

$$\Gamma_A = \frac{1}{2} C_C .$$

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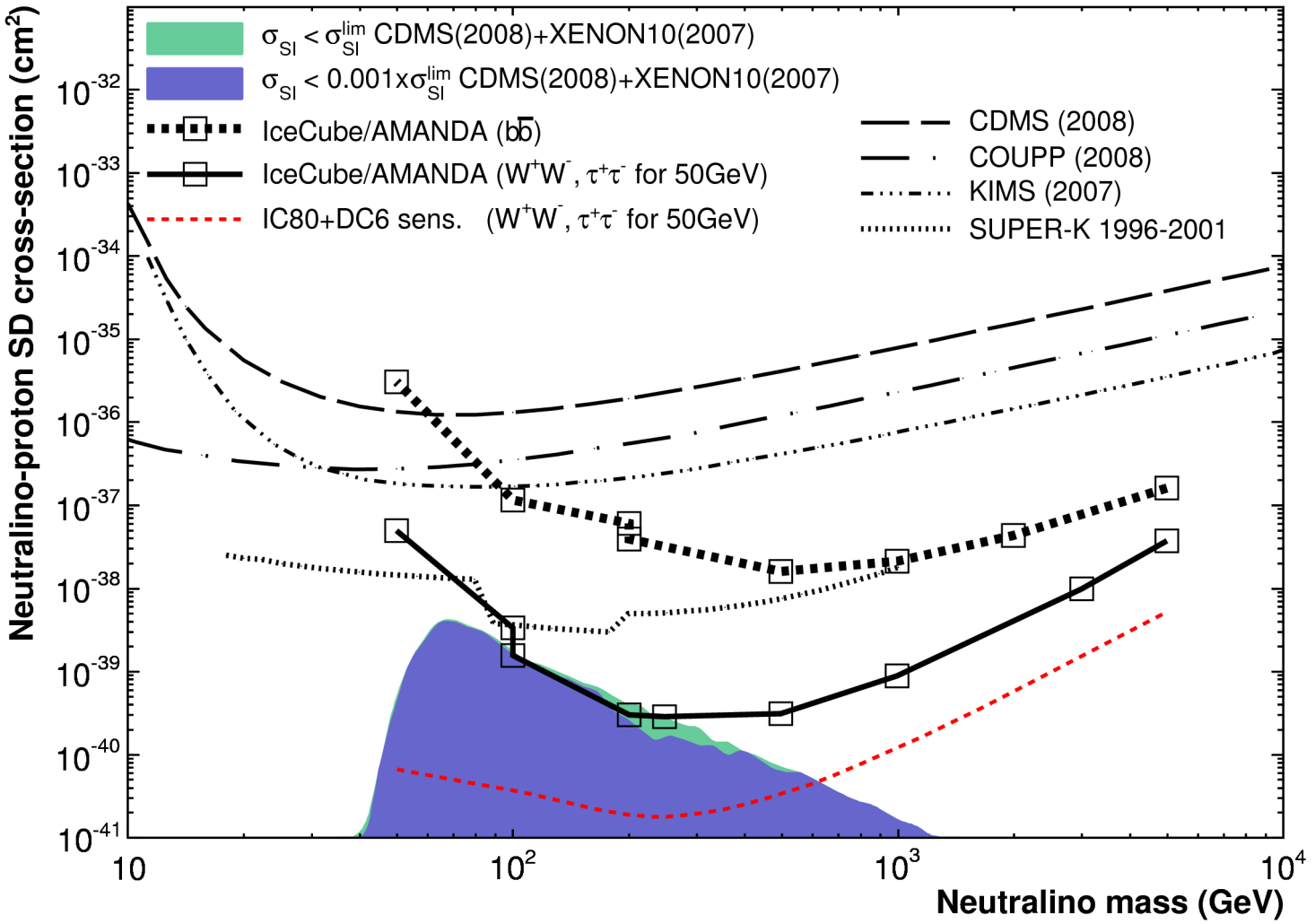

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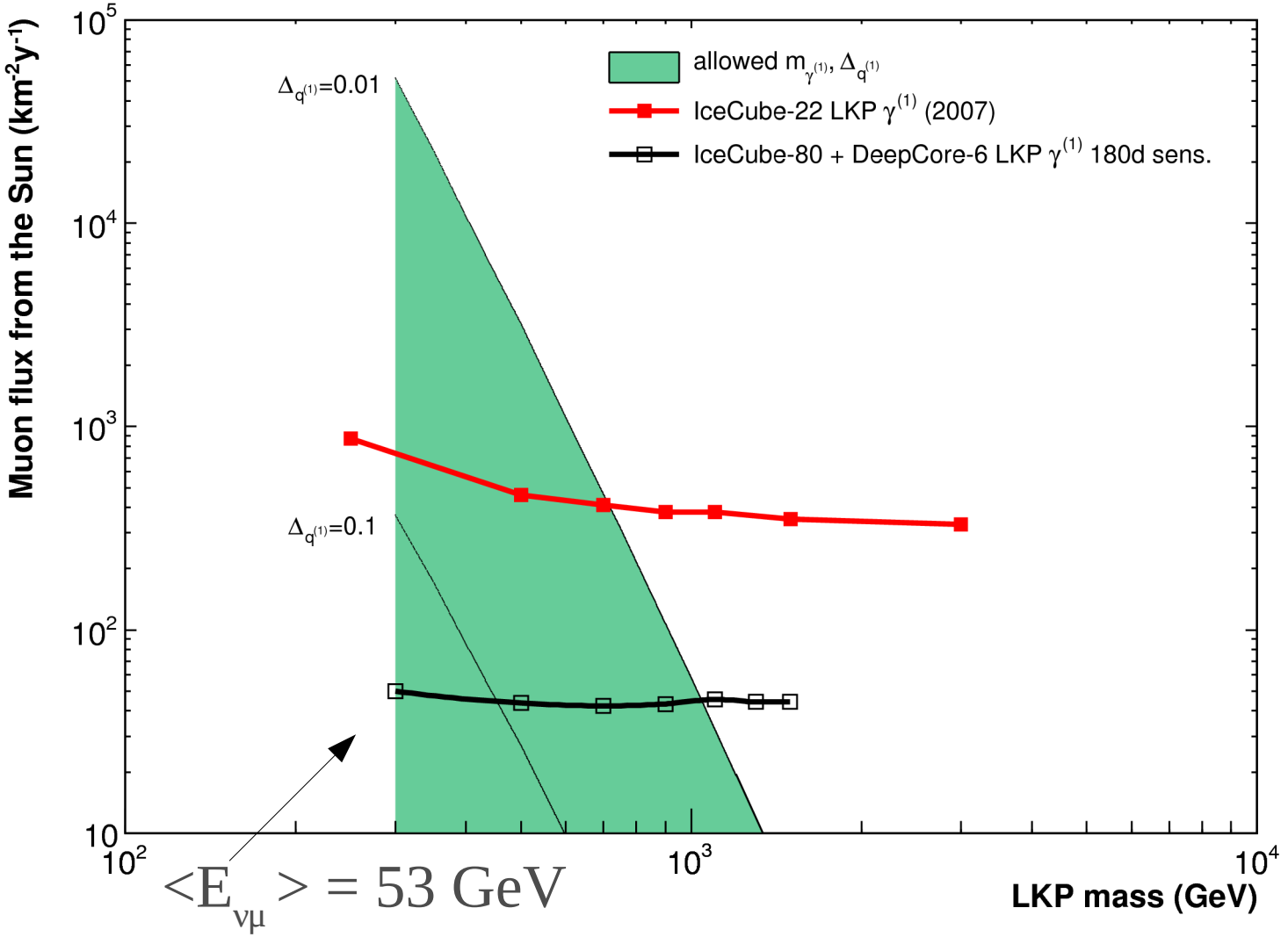

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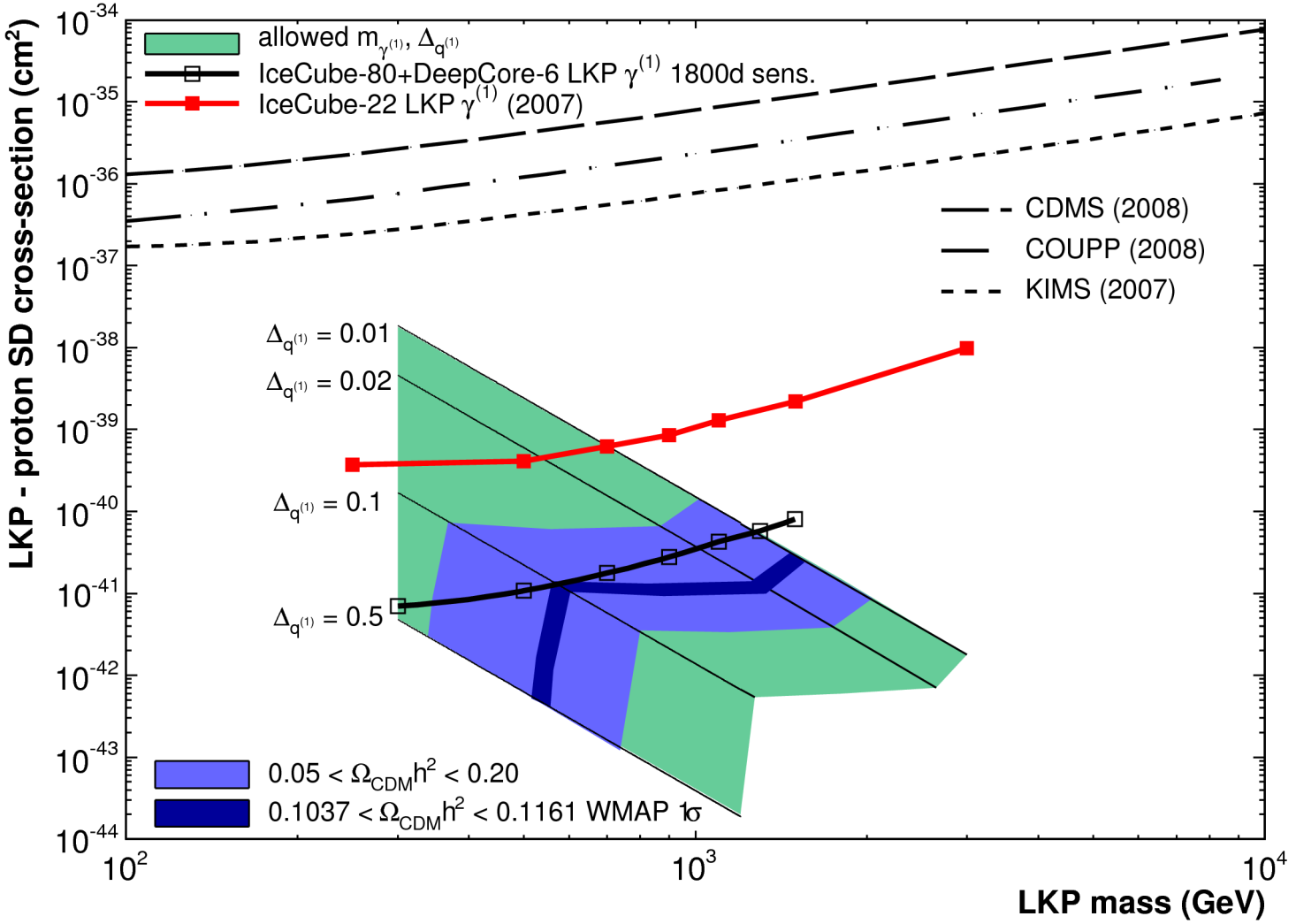

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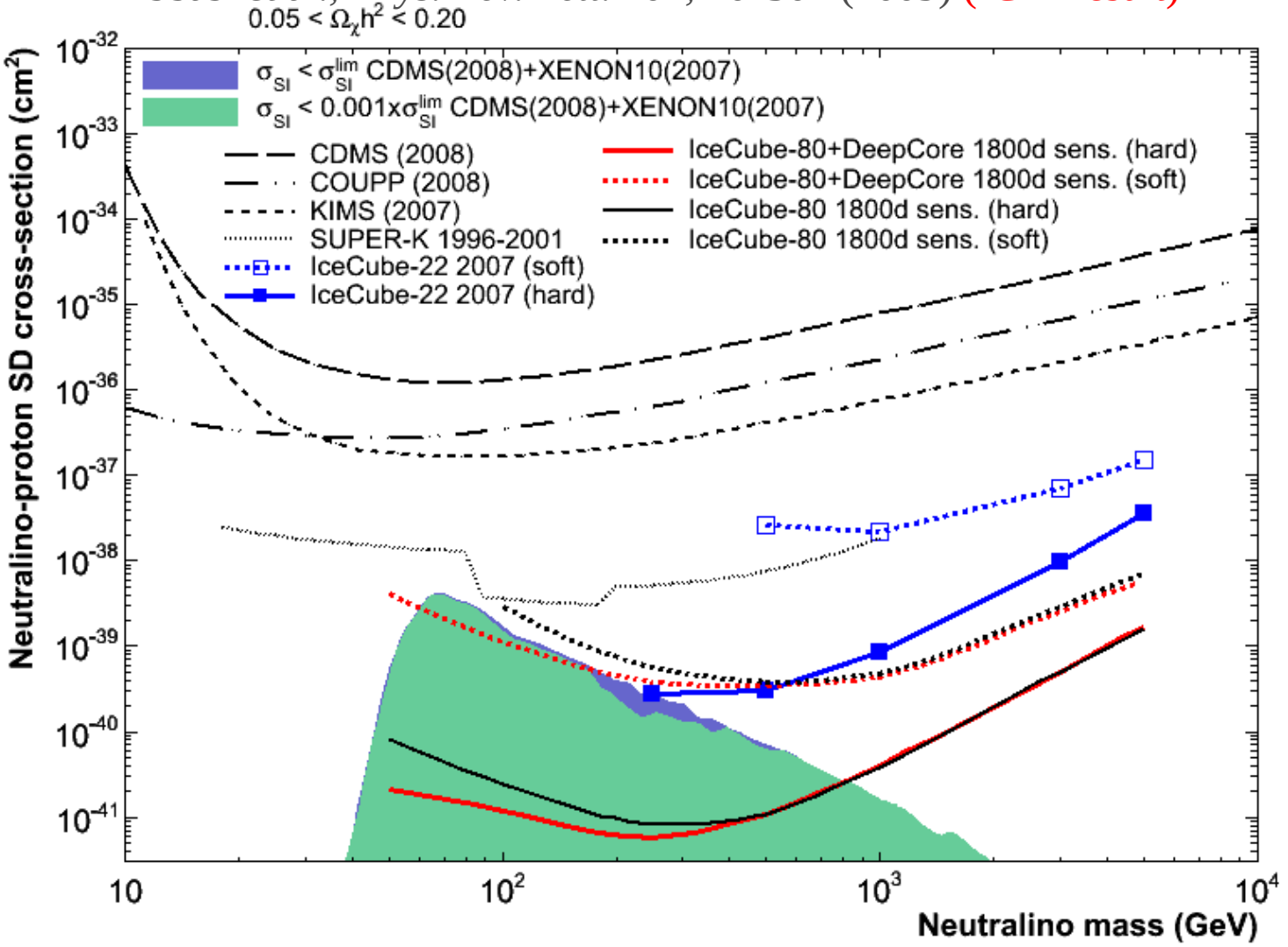

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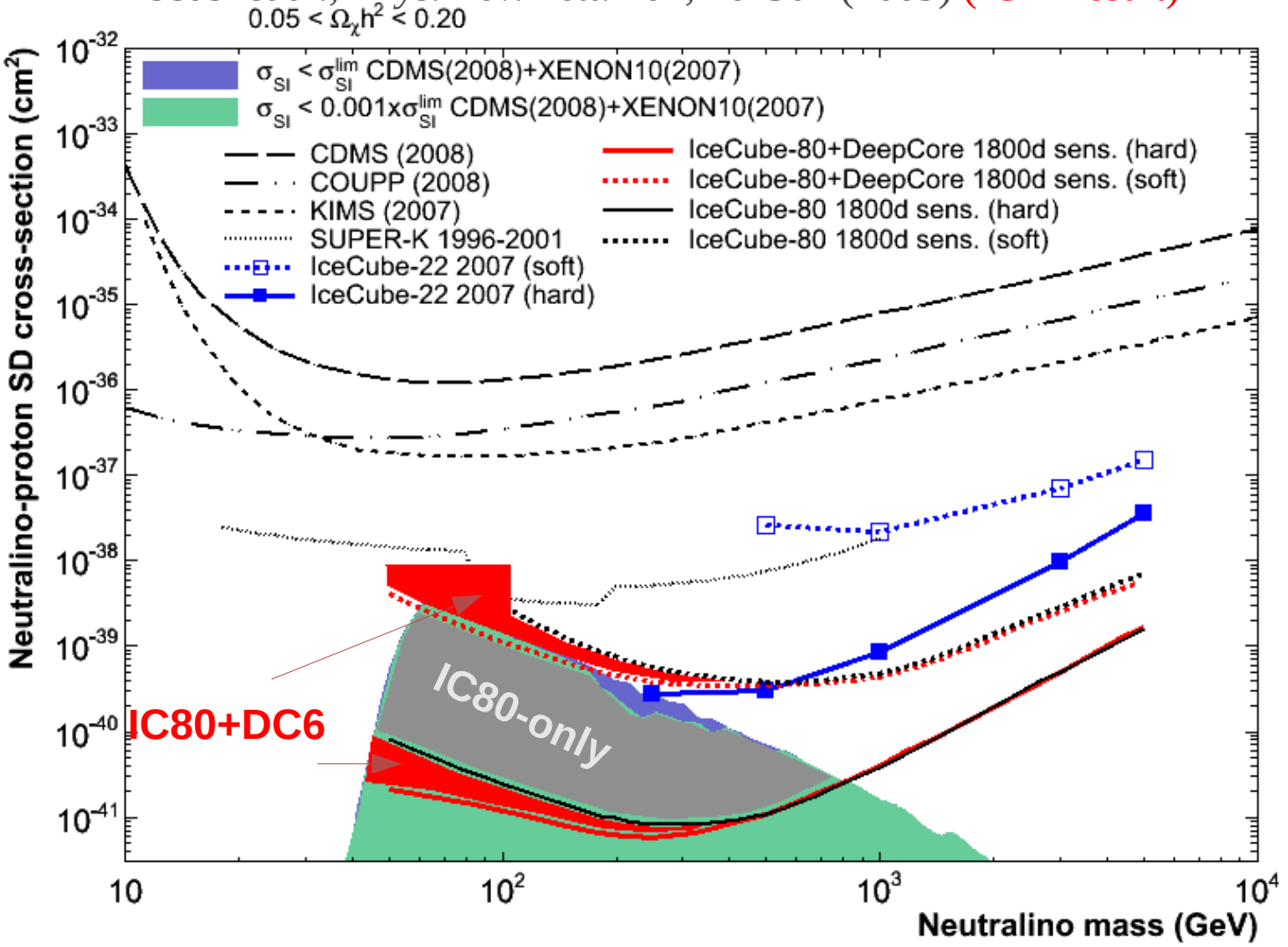

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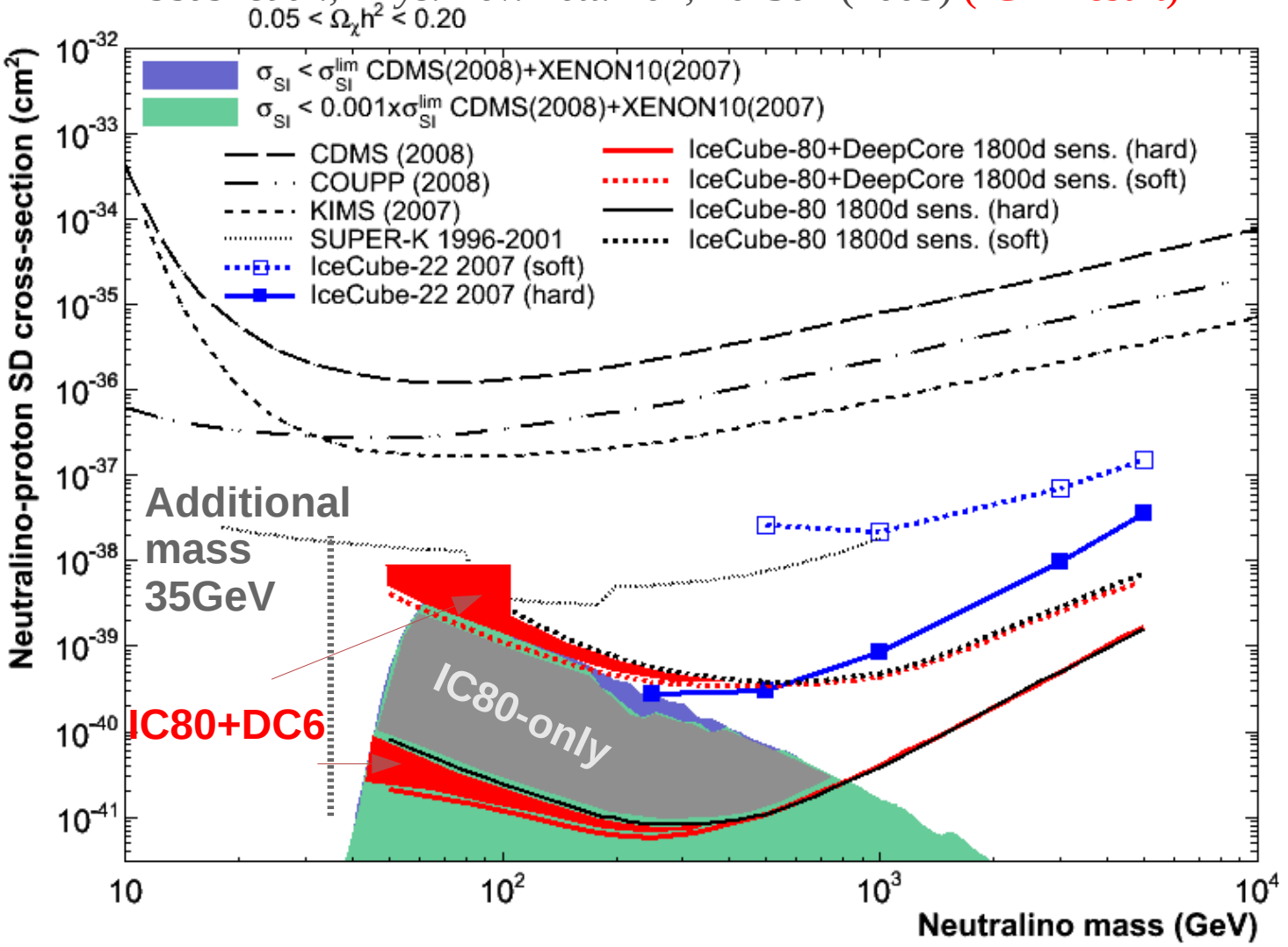

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Prospects: WIMP-Model-independent Result

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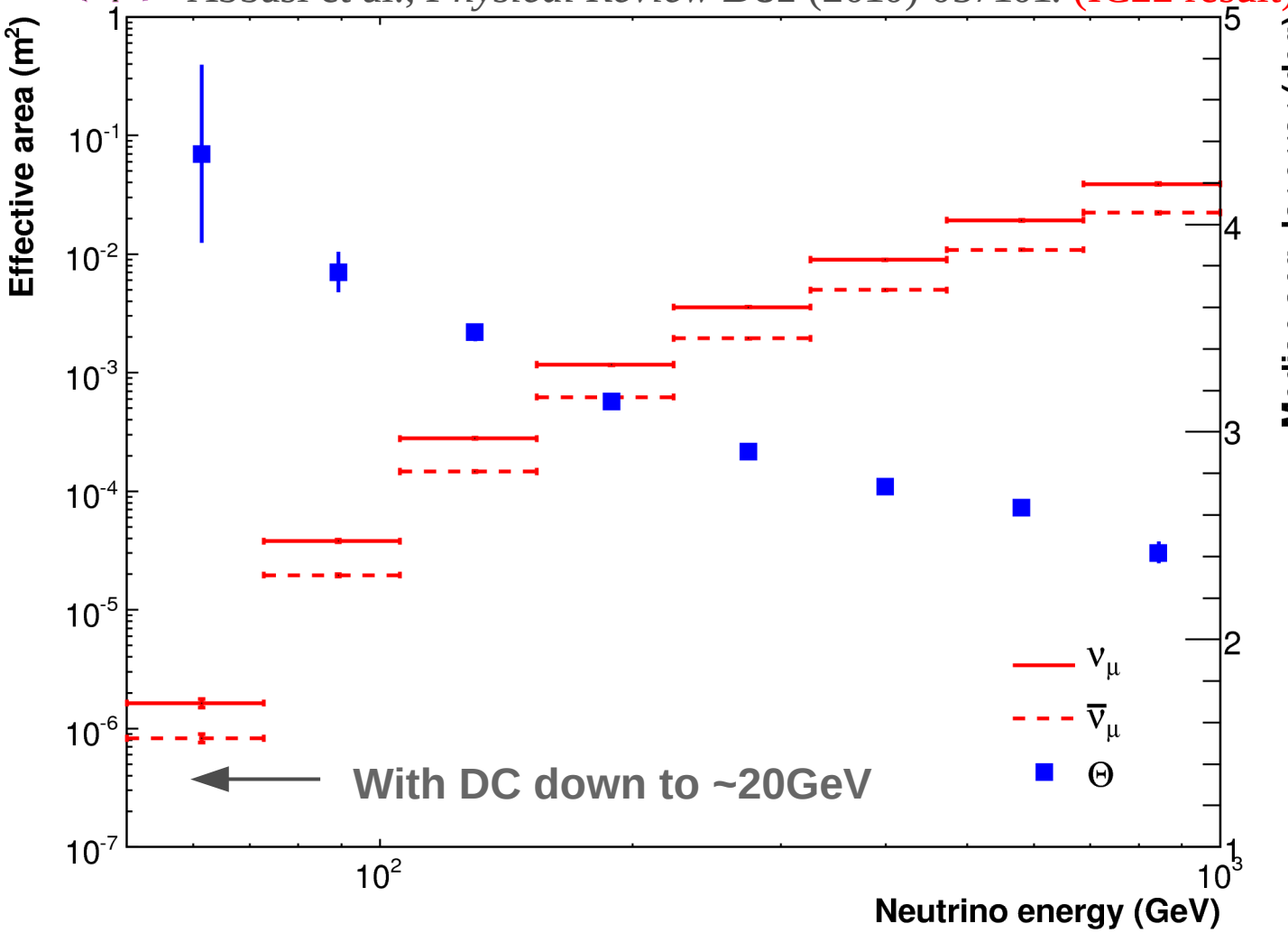
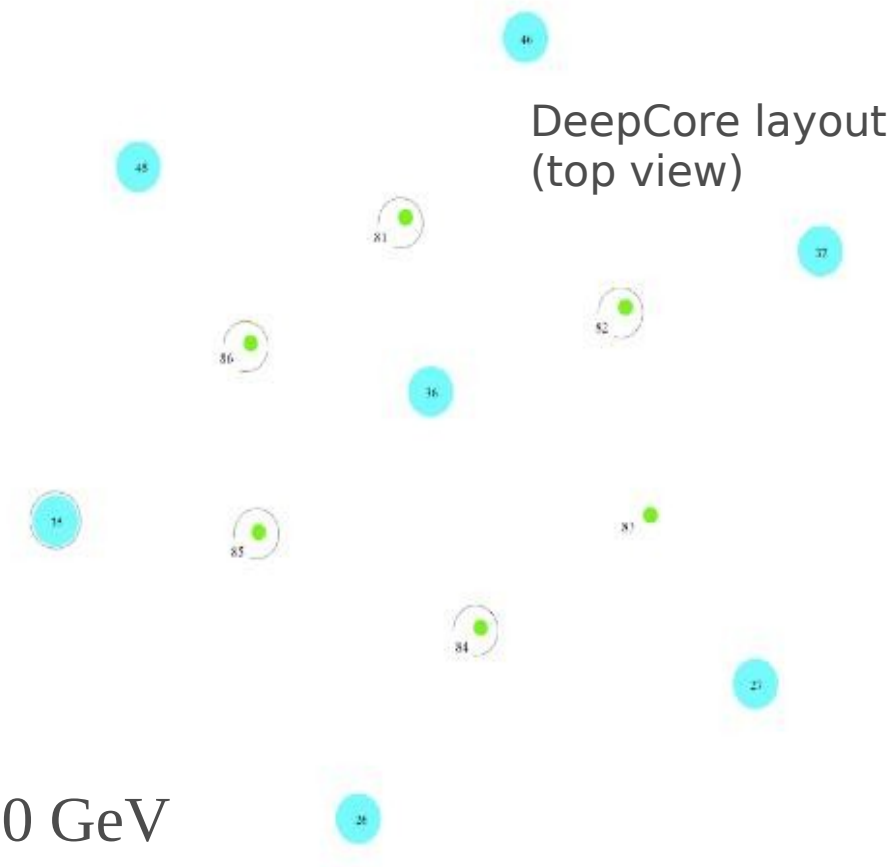


effective area for final event selection as function of $\mathbf{E}_\nu$ in the range 50-1000 GeV, for $\boldsymbol{\nu}_\mu$ and anti-$\boldsymbol{\nu}_\mu$ from the direction of the Sun.

The result is an average over the austral winter.

IC22: Systematic effects are in-cluded at the 1σ level, and statistical uncertainty of the same level are shown with error bars.

Conclusion


DeepCore layout
(top view)

AMANDA-II analysis are finishing

(full 6y-data result soon)

First IceCube results are published

→ IC22 results for searches from Sun & Halo

→ IC40 & IC59 analysis ongoing

→ IC79 incl. DeepCore is taking data

DeepCore makes low-energy region 10 ~ 100 GeV accessible for IceCube

<u>Looking forward:</u>

Including isolated hits and new reconstruction techniques

All year search for low WIMP masses (IceCube active veto for DeepCore)

String 79 & 80 will create even denser DeepCore array

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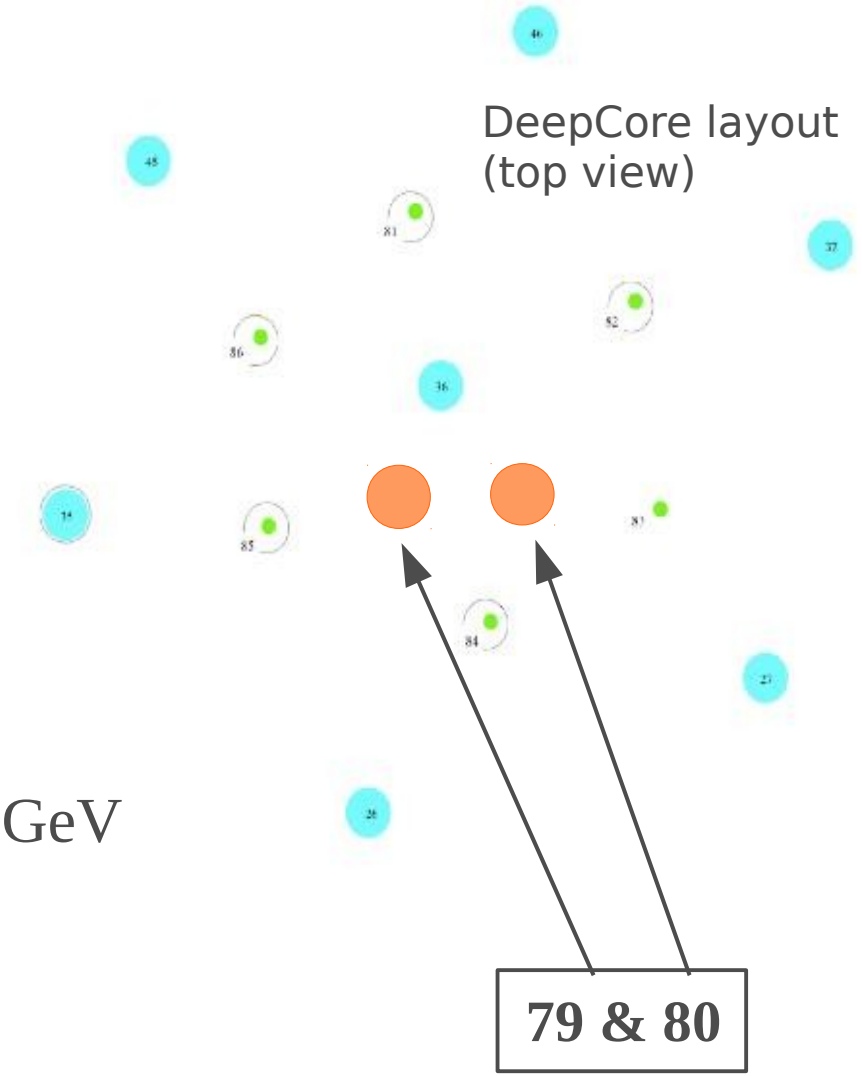

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