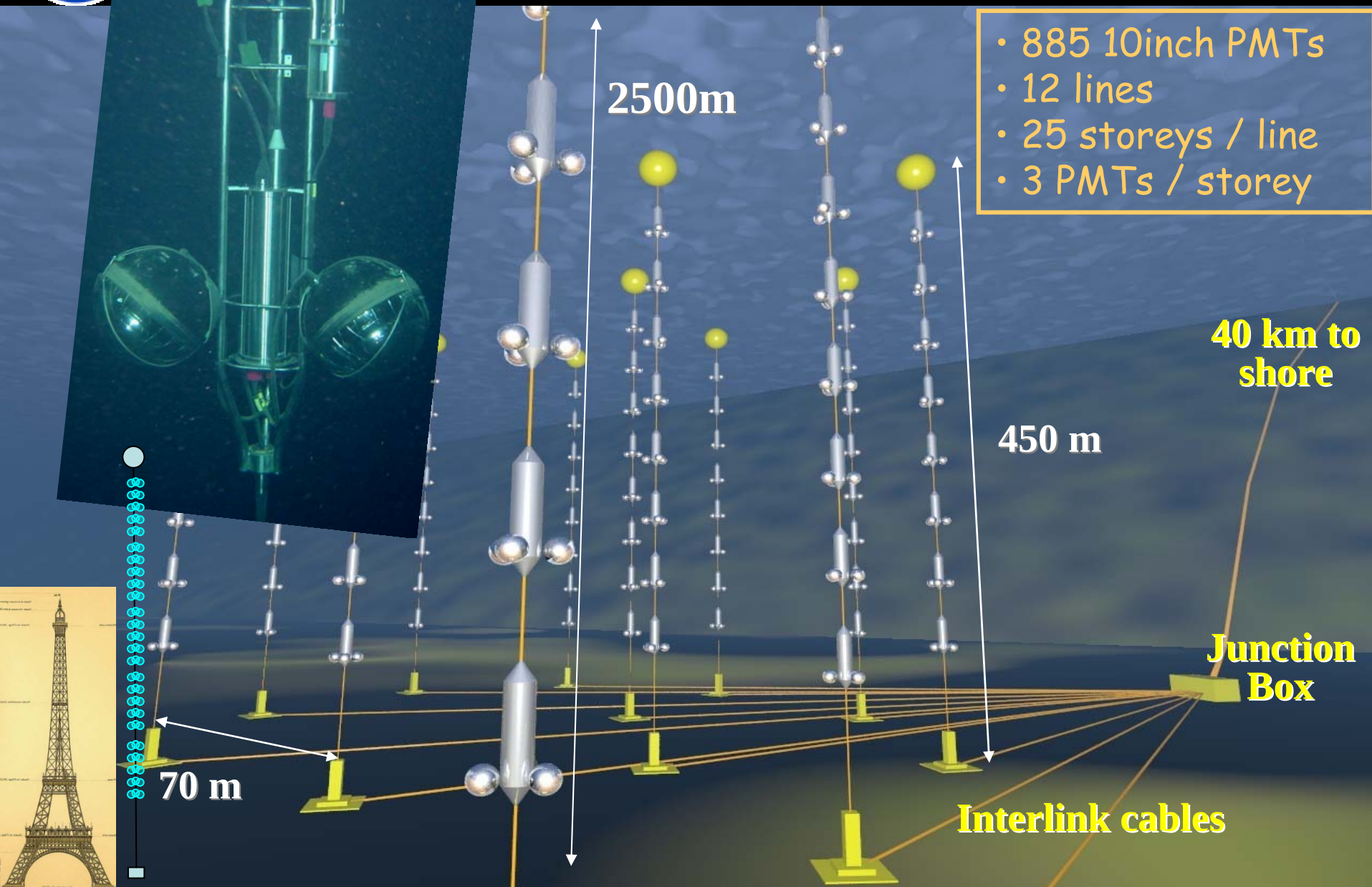
Indirect Dark Matter search in the Sun direction using the data 2007-2008 for the two common theoretical framework (CMSSM, mUED)

Ziad Charif on behalf of the ANTARES collaboration

CPPM - Marseille

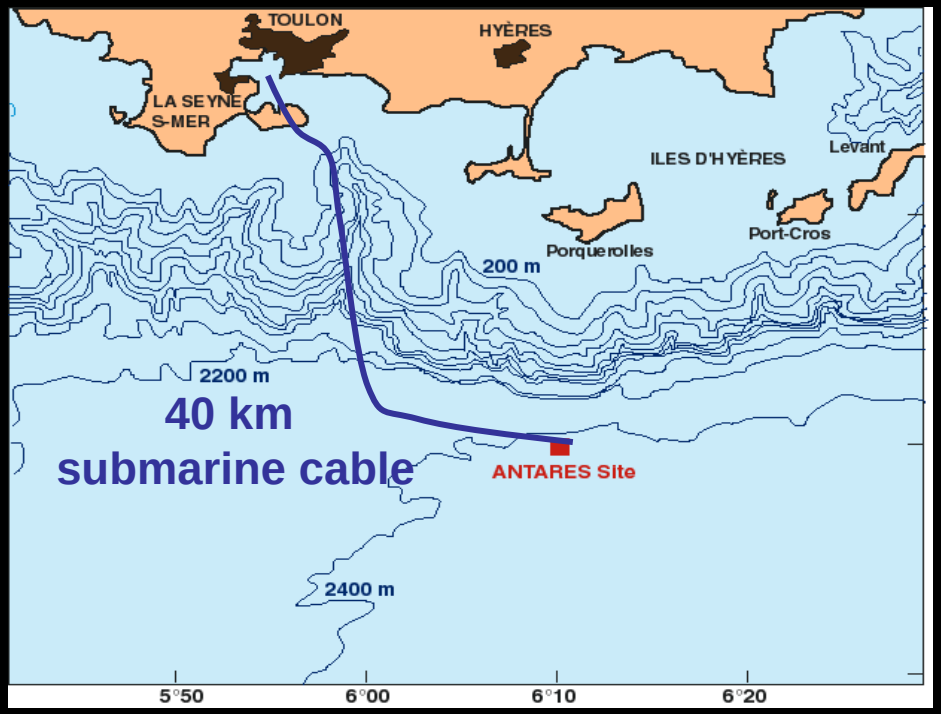
19/07/2012

The ANTARES detector

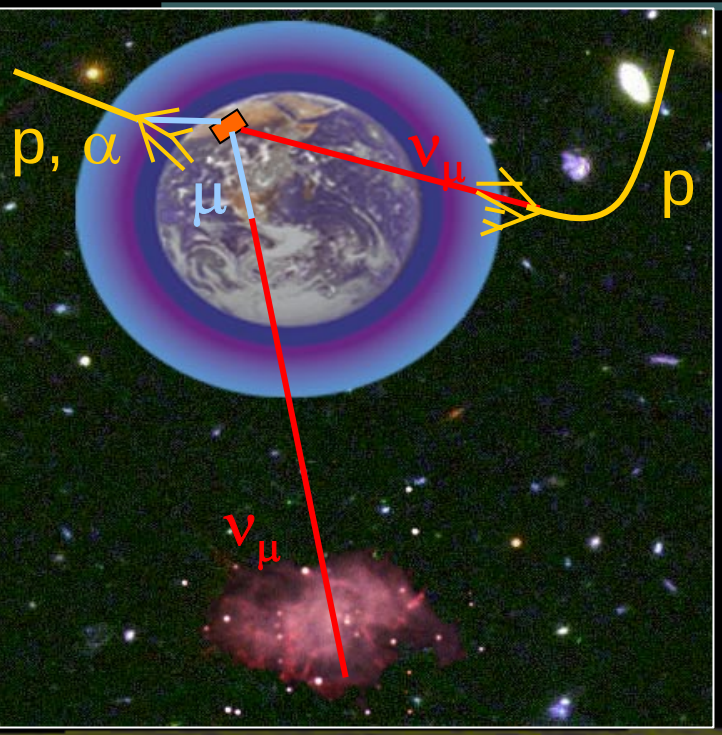


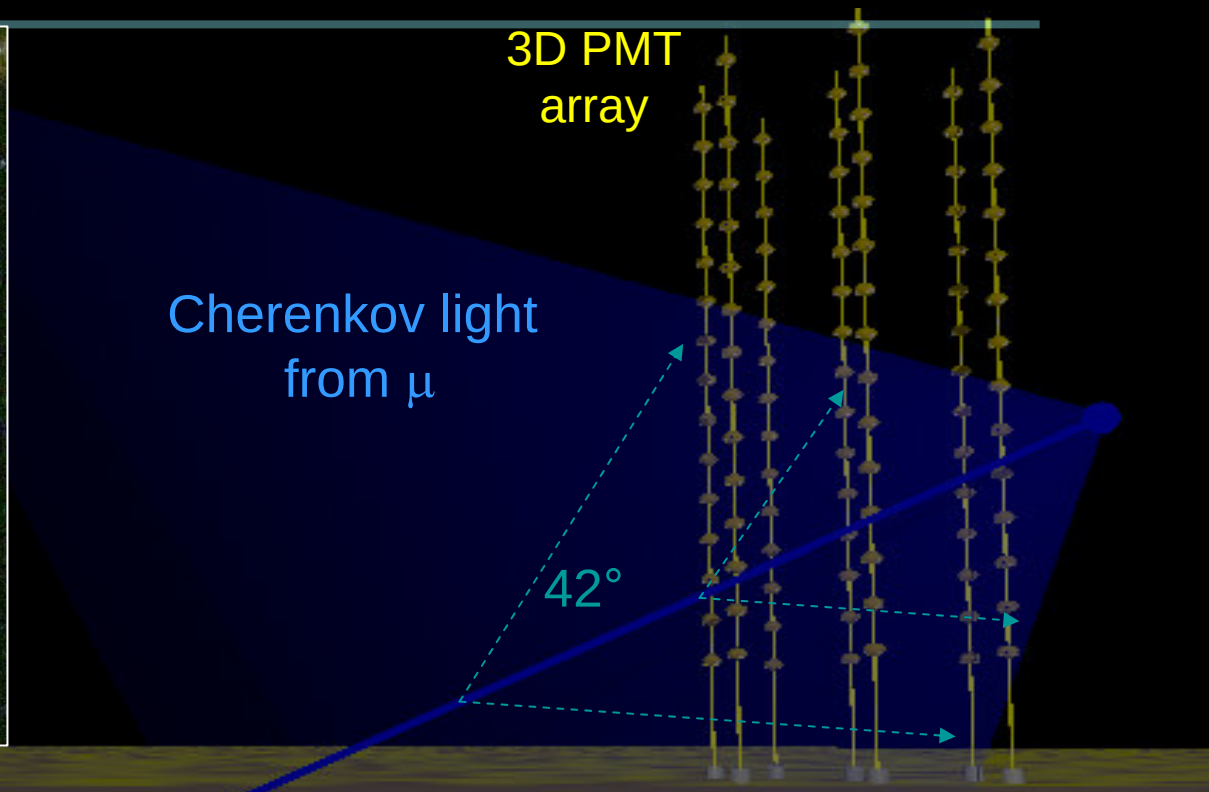
- 885 10inch PMTs
- 12 lines
- 25 storeys / line
- 3 PMTs / storey

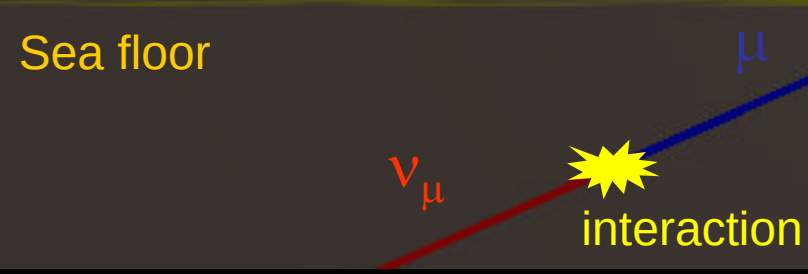
The ANTARES site & infrastructure



Detection principle





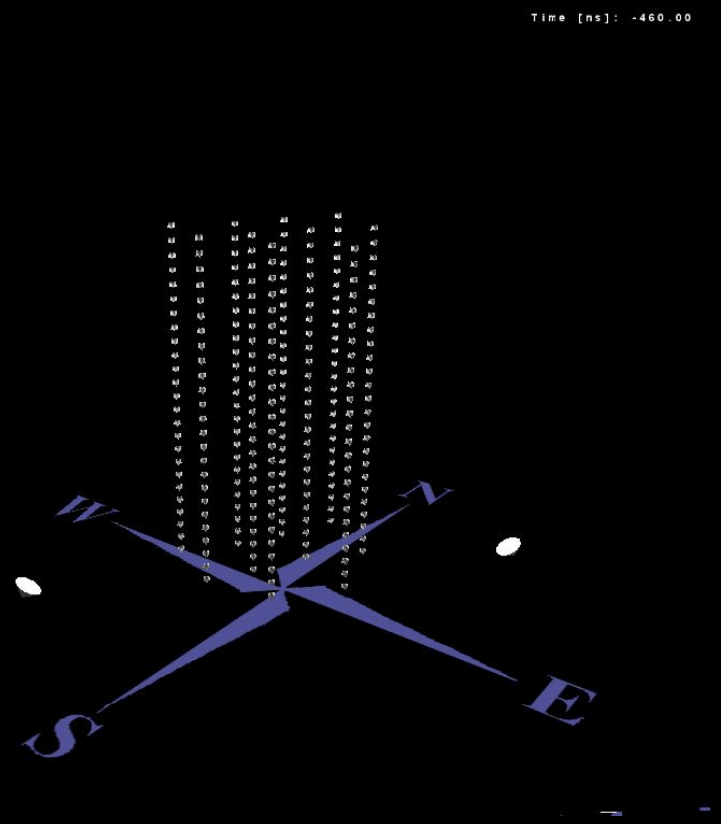


The reconstruction is based on local coincidences compatible with the Cherenkov light front

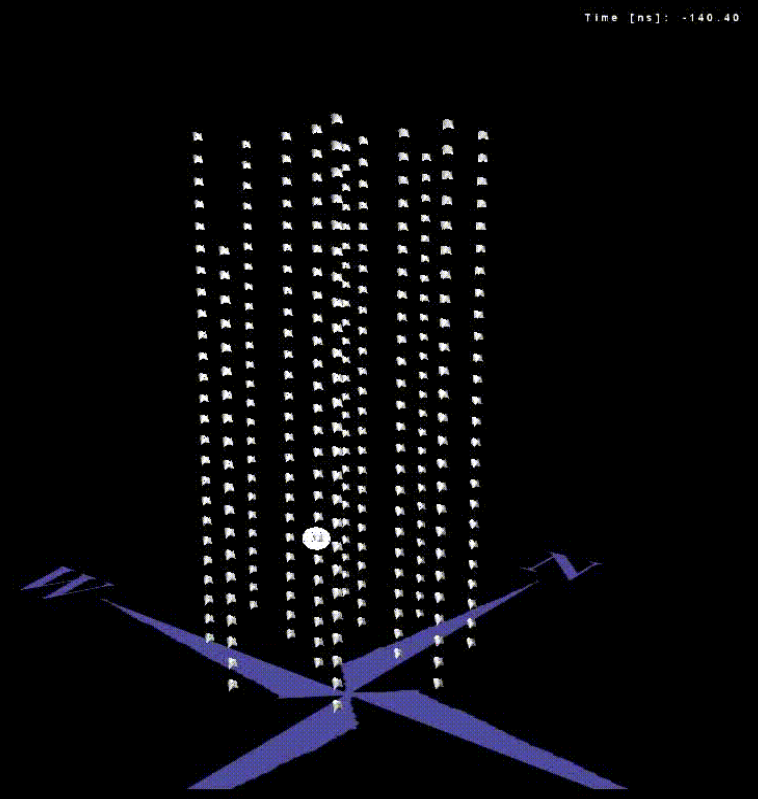
- Main detection channel: ν_μ interaction giving an ultra-relativistic μ (ν_e and ν_τ also)
- Energy threshold ~ 10 GeV
- 24hr operation, more than half sky coverage

Example of events

reconstructed up-going neutrino
detected in 6/12 detector lines

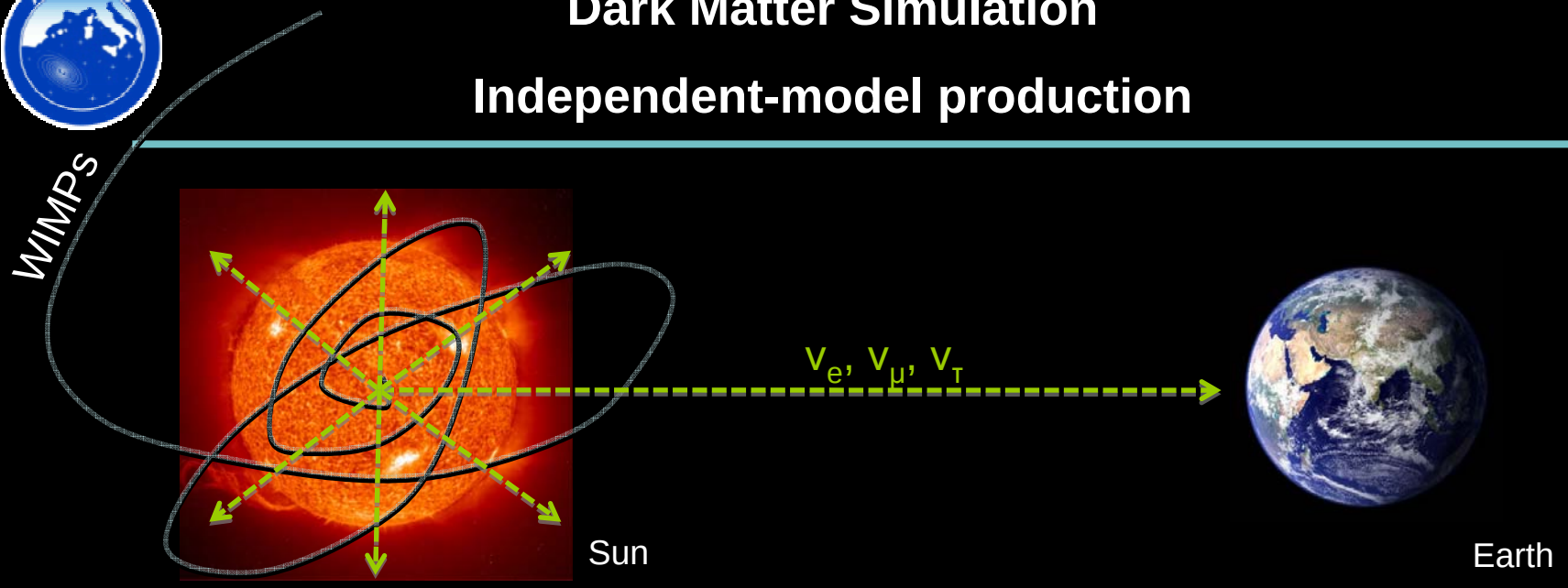


reconstructed down-going muon
detected in all 12 detector lines



Dark Matter Simulation

Independent-model production

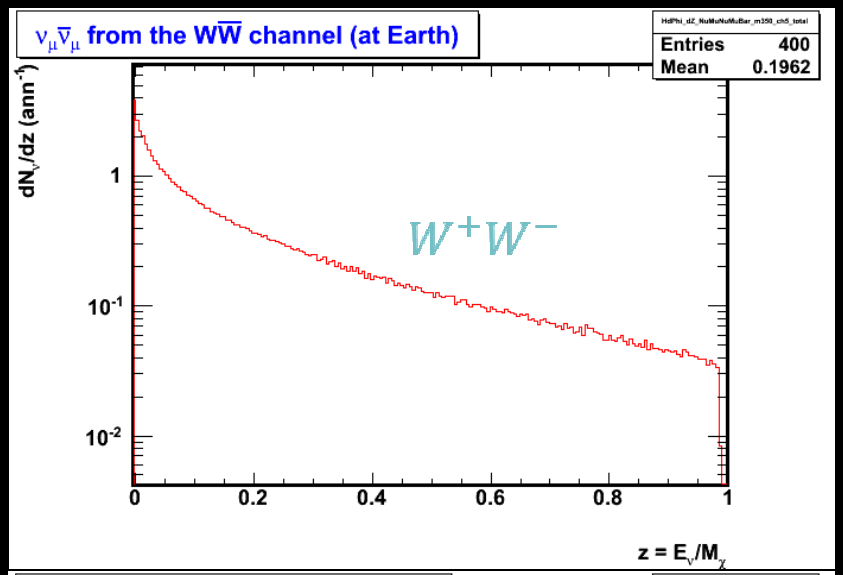


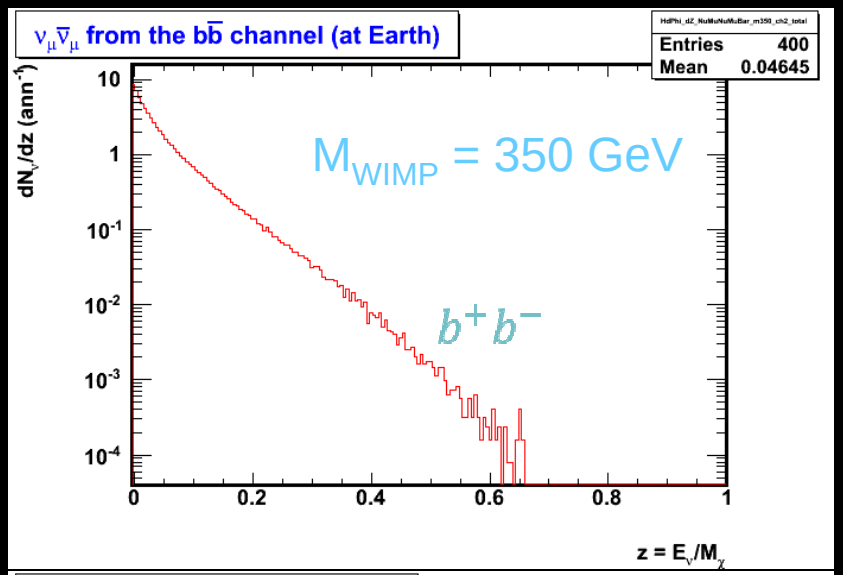
- Blennow, Edsjö, Ohlsson (03/2008): “WIMPSIM” model-independent production
- Great statistics with 12×10^6 WIMPs self-annihilations
- Capture rate and annihilations in equilibrium at the Sun core
- Annihilations in c,b and t quarks, τ leptons and direct channels
- Interactions taken into account in the Sun medium
- Three flavors oscillations, regeneration of τ leptons in the Sun medium (Bahcall et al.)
- Available parameters (WIMPs mass, oscillations parameters, ...)

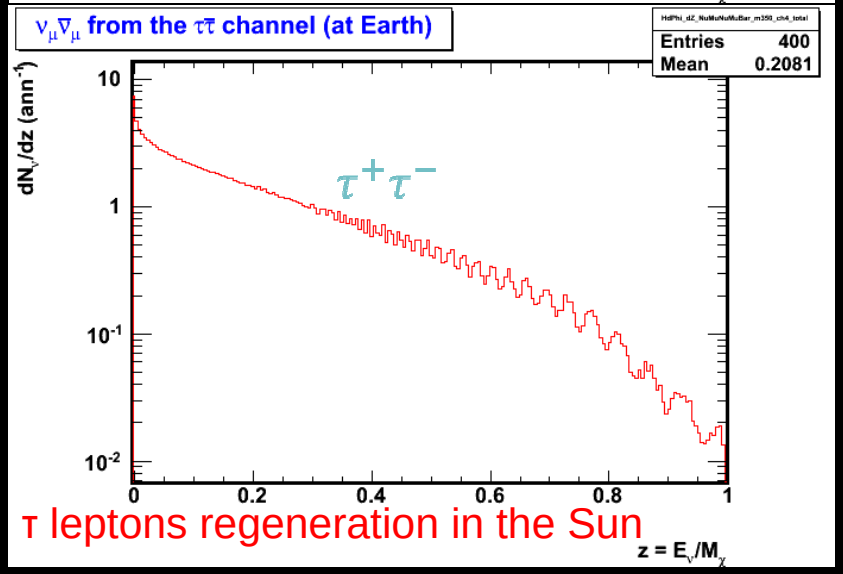
Dark Matter Simulation

Independent-model production

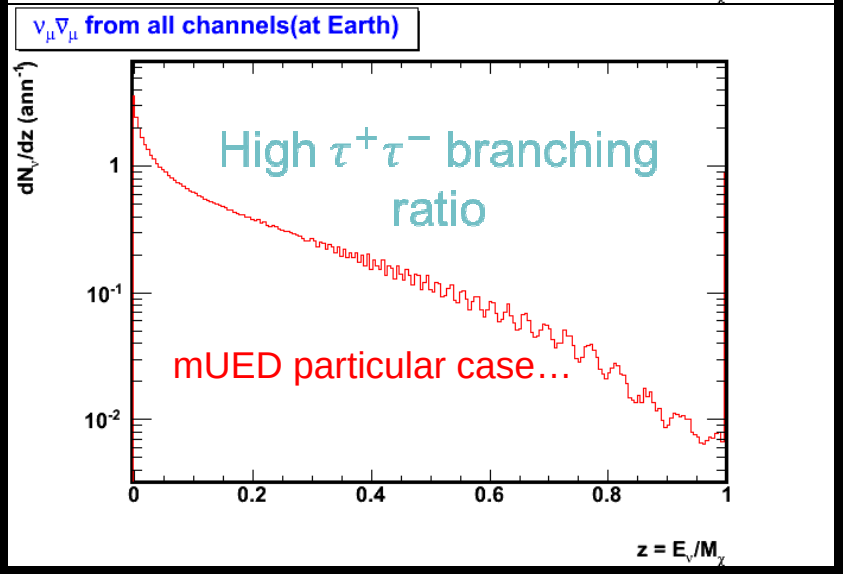
MAIN ANNIHILATION CHANNELS







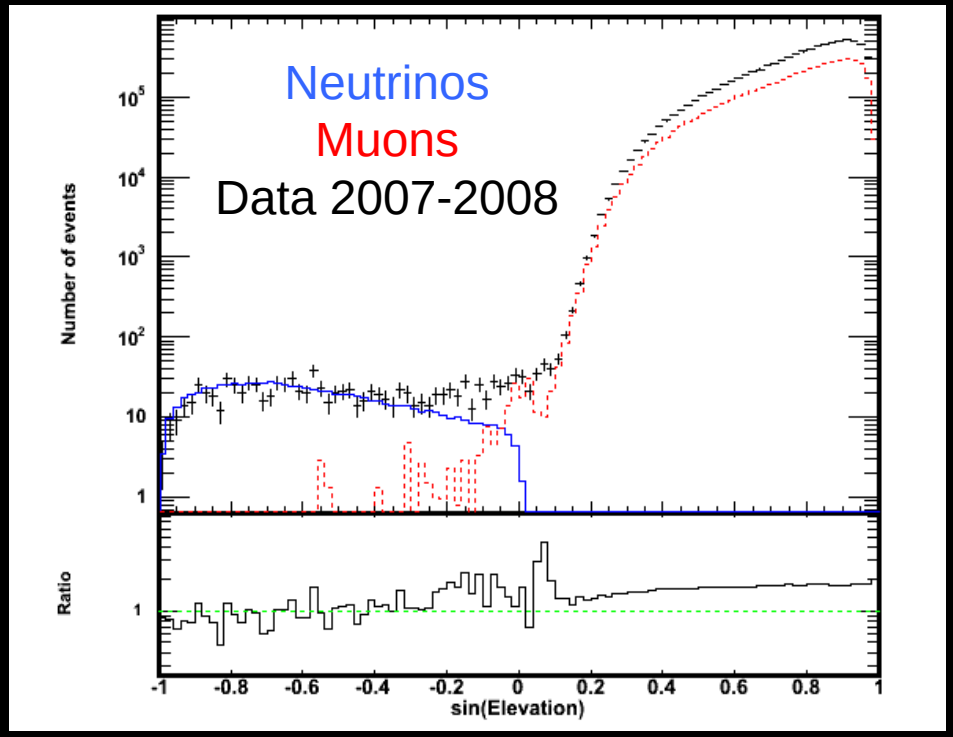
τ leptons regeneration in the Sun



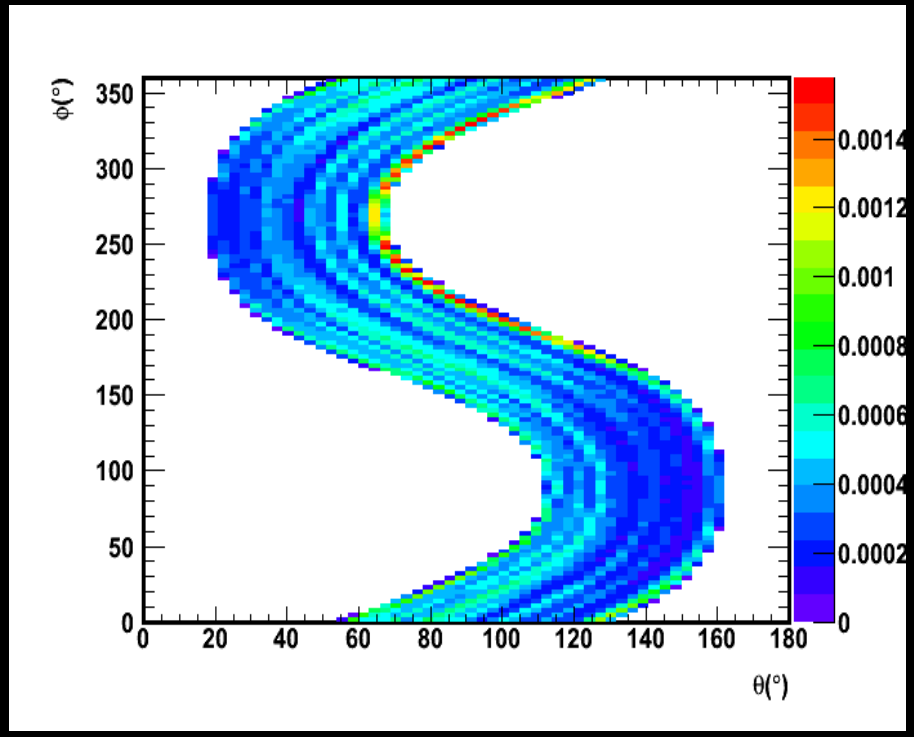
Background in the Sun direction

- Using the scrambled data 2007-2008 (from 5 to 12 lines) in (theta, phi), time (Modified Julian Date) (~294.6 days)
- Fast algorithm for muon track reconstruction (Astro. Phys. 34 (2011) 652-662)
- Using the Sun distribution weighted by its visibility for Antares

Monte-carlo versus 2007-2008 data



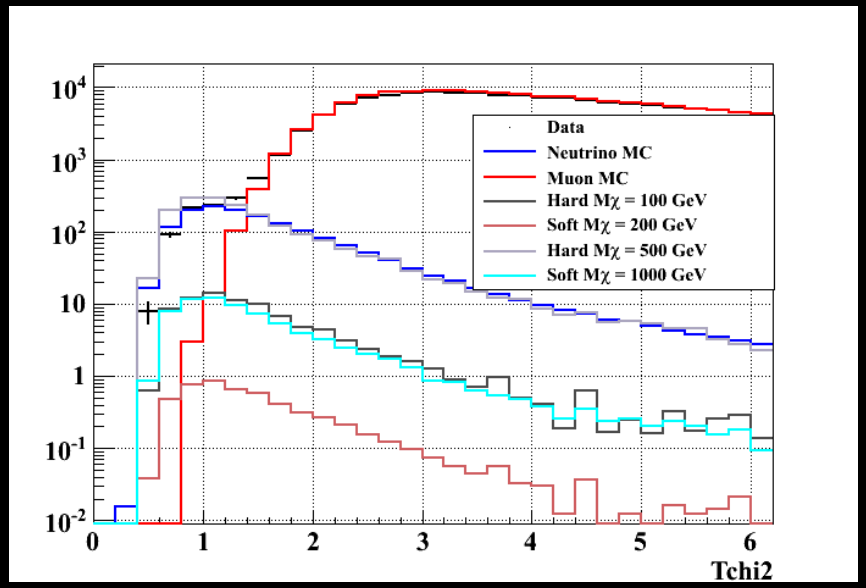
Example of Sun tracking in horizontal coordinates

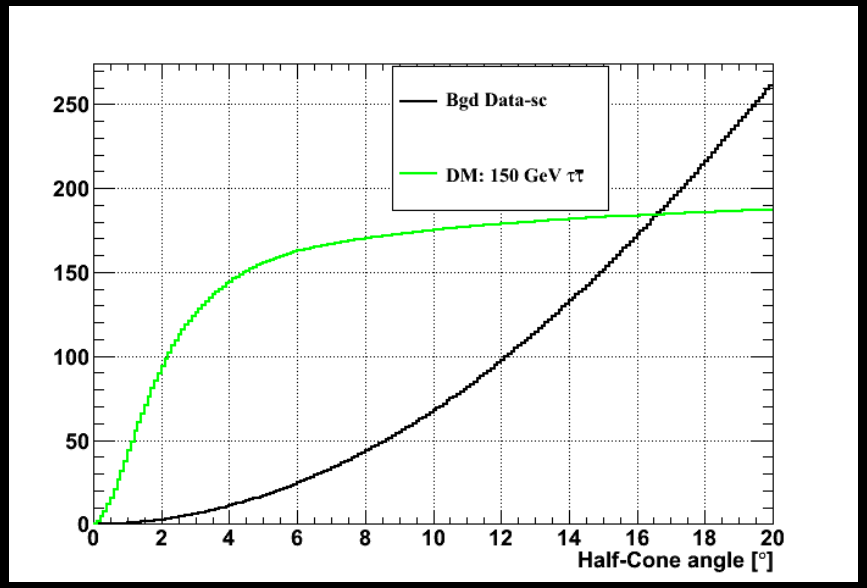


Discriminating variables

χ^2 (track quality) : Separates badly reconstructed down-going muons and up-going neutrinos

Half-Cone angle (centered around the Sun) : Separates up-going atmospheric neutrinos and dark matter neutrinos

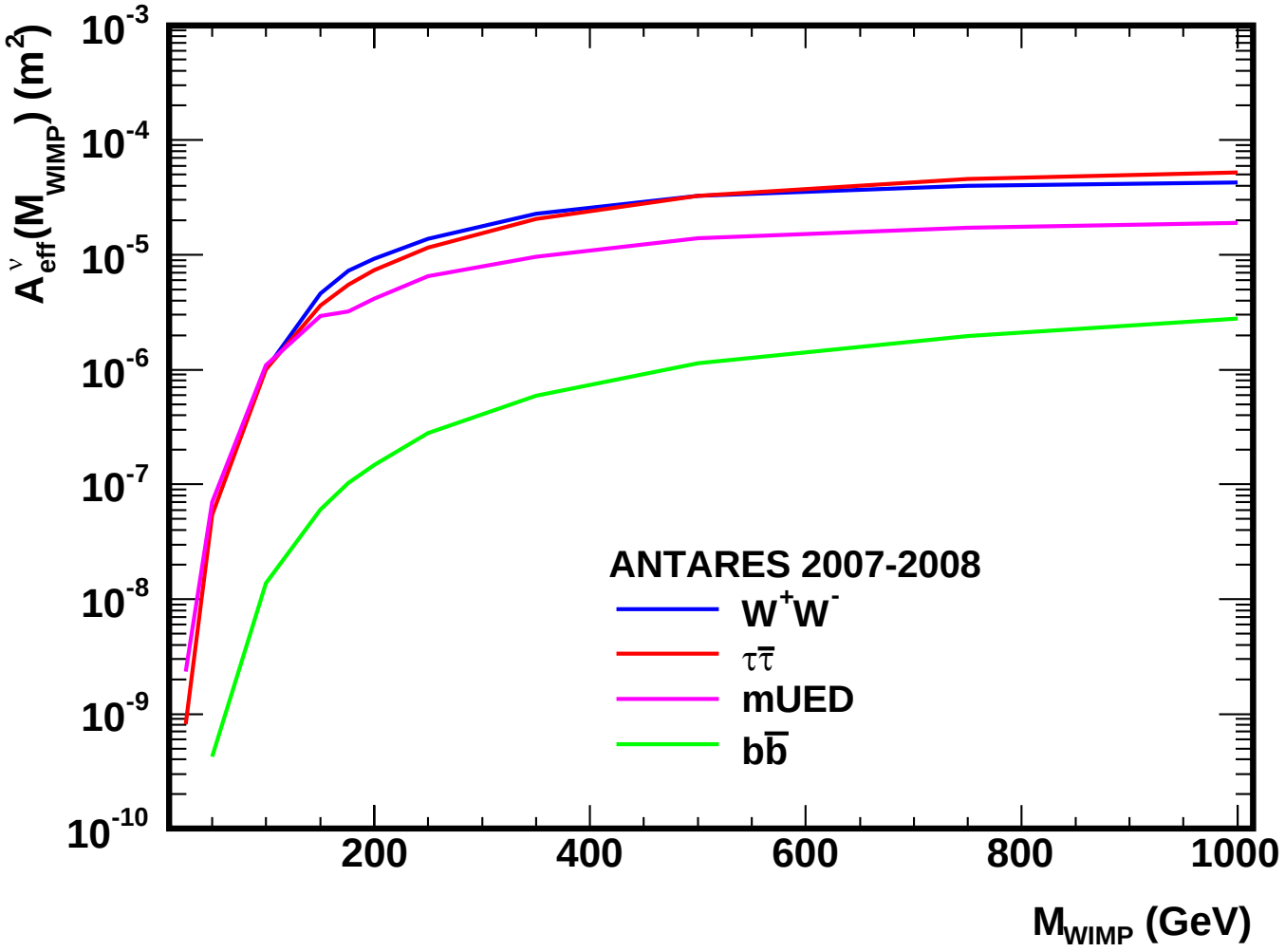




Dark Matter Simulation

Independent-model production

Define an Efficiency per channel per WIMP mass

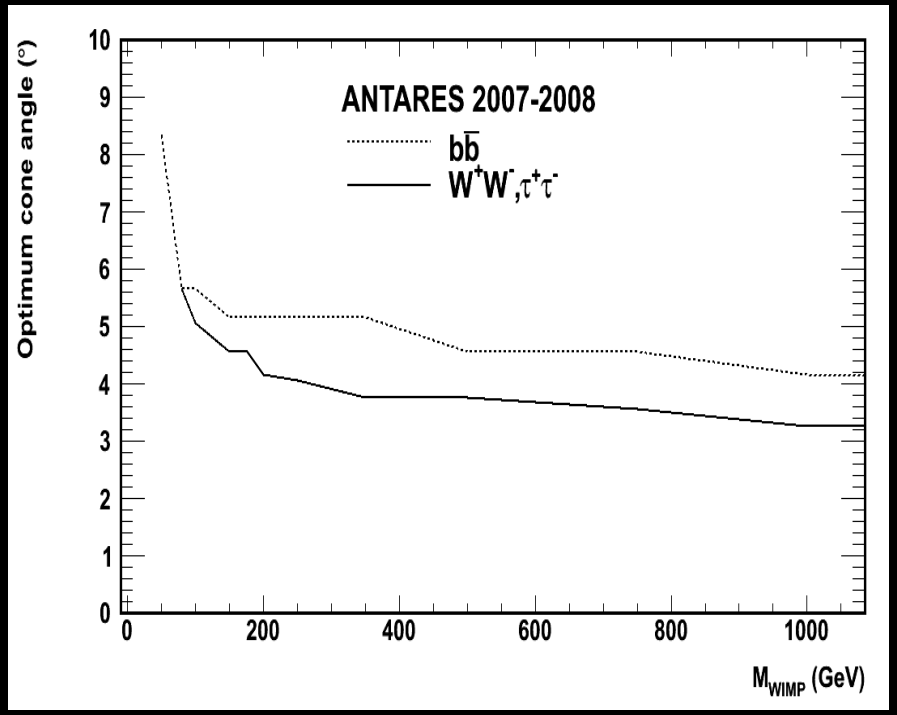


Dark Matter Signal and cuts optimisation

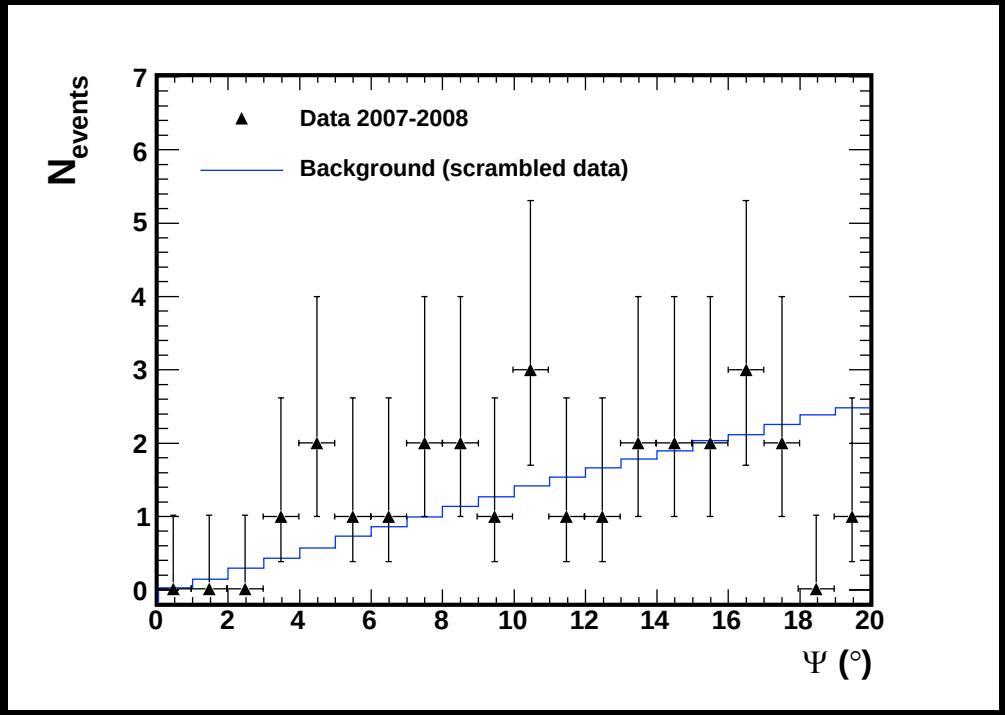
- Neutrino flux at the earth, from the Dark Matter coannihilation, are convoluated with the efficiency of the detector for a cuts parameter space (Q,cone)
- Neutrino background from the scrambled data in the Sun direction is evaluated in the same space
- Minimize this quantity:

$$Limit = \frac{\mu_{90}}{Aeff(Mwimp) * Teff}$$

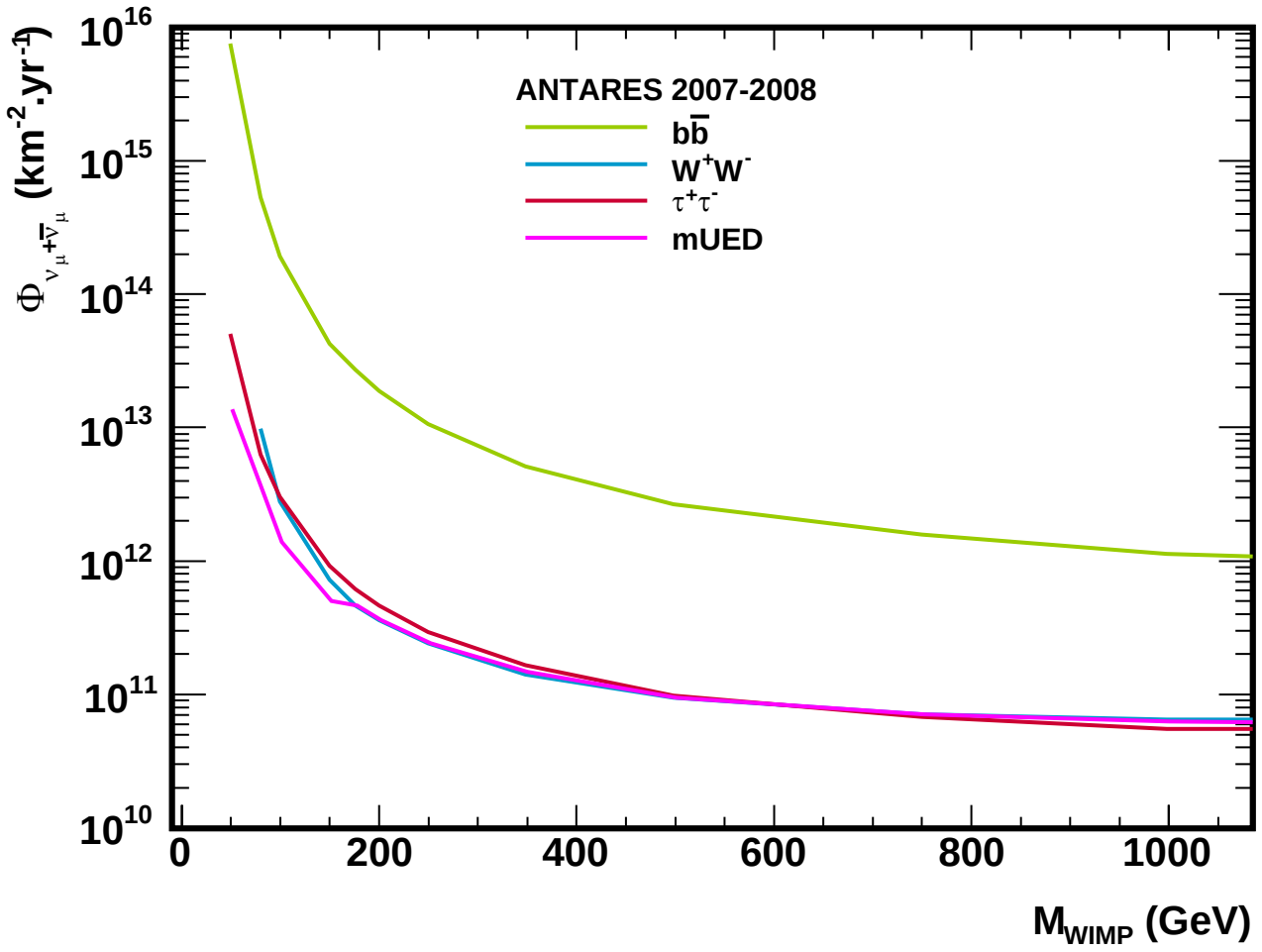
Optimum cone angles around the Sun



Average upper limit (Feldman-Cousins) VS DATA 2007-2008



Dark Matter Signal and Neutrino flux limit



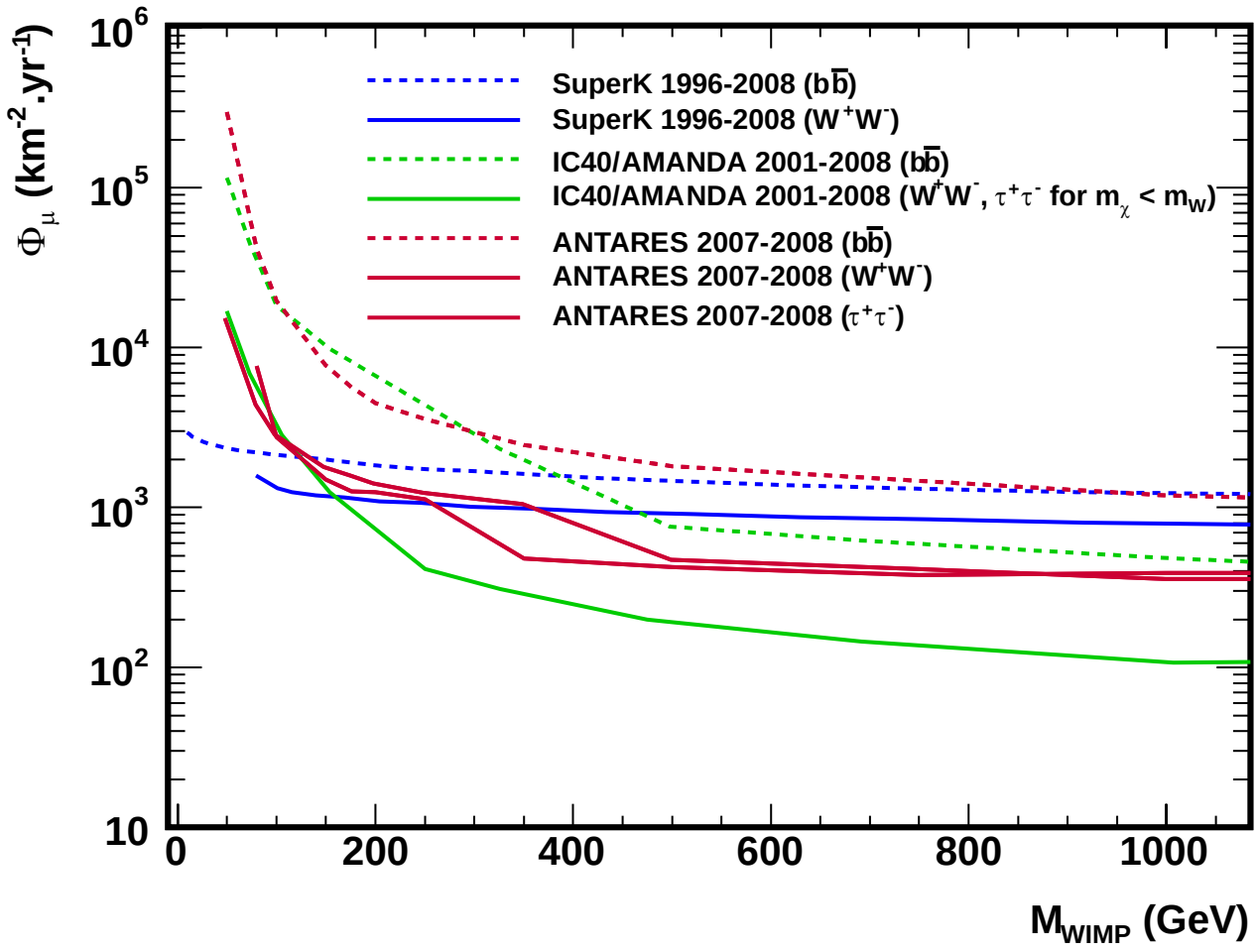
For CMSSM:
Branching ratios = 1
(WW, bb, ττ)

For mUED:
Theoritical branching ratios taken into account

Reason:
High dependence of branching ratios over CMSSM parameter space

Φ_ν X σ_ν X R_μ X Nucleon density X P_{earth} $\longrightarrow$ Φ_μ

Dark Matter Signal and CMSSM Muon flux limit



Flux Φ_μ

↕

Annihilation rate Γ

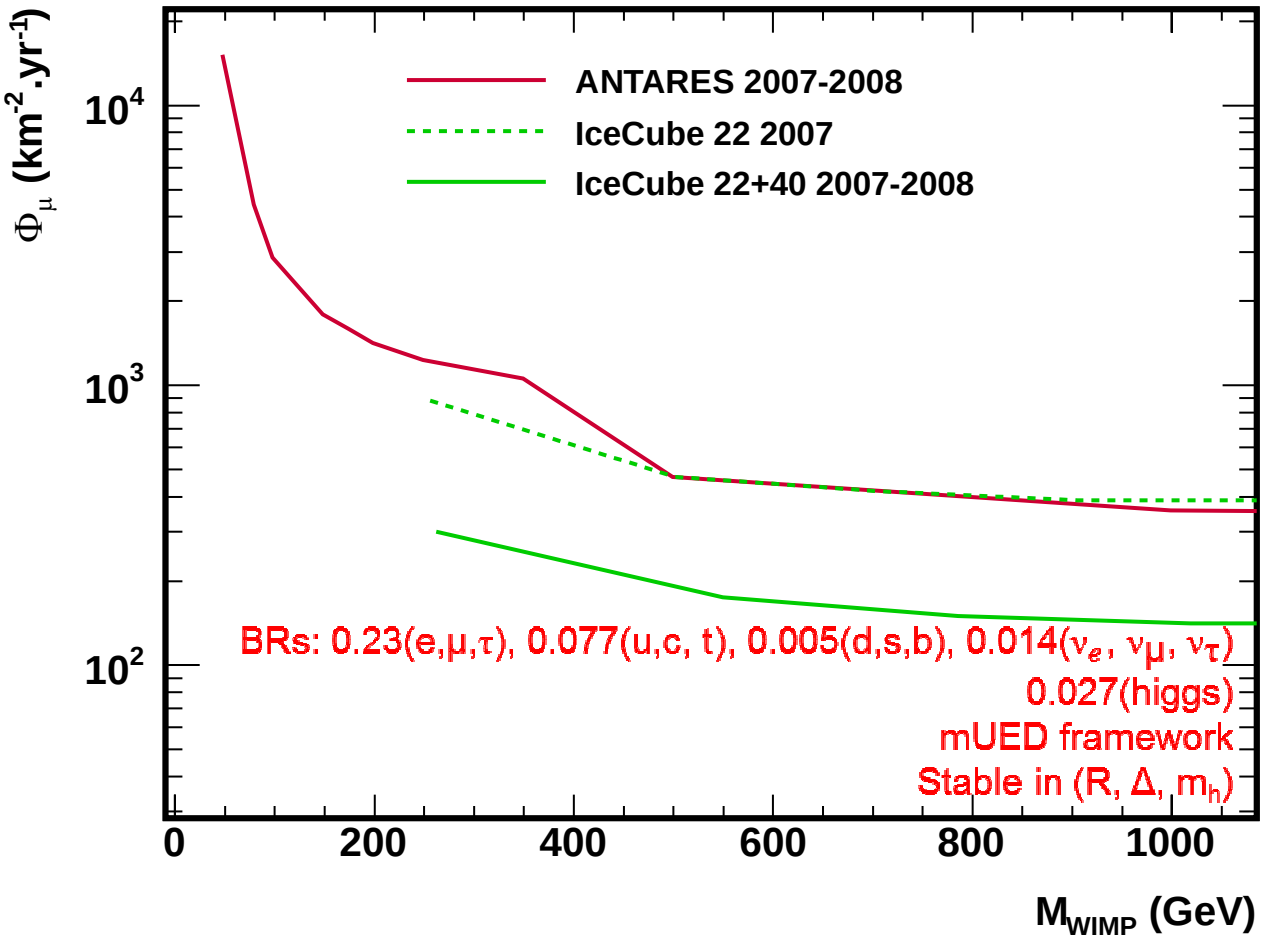
↕

Capture rate C

↕

Cross-section σ_{SD}

Dark Matter Signal and mUED Muon flux limit



Flux Φ_μ

↕

Annihilation rate Γ

↕

Capture rate C

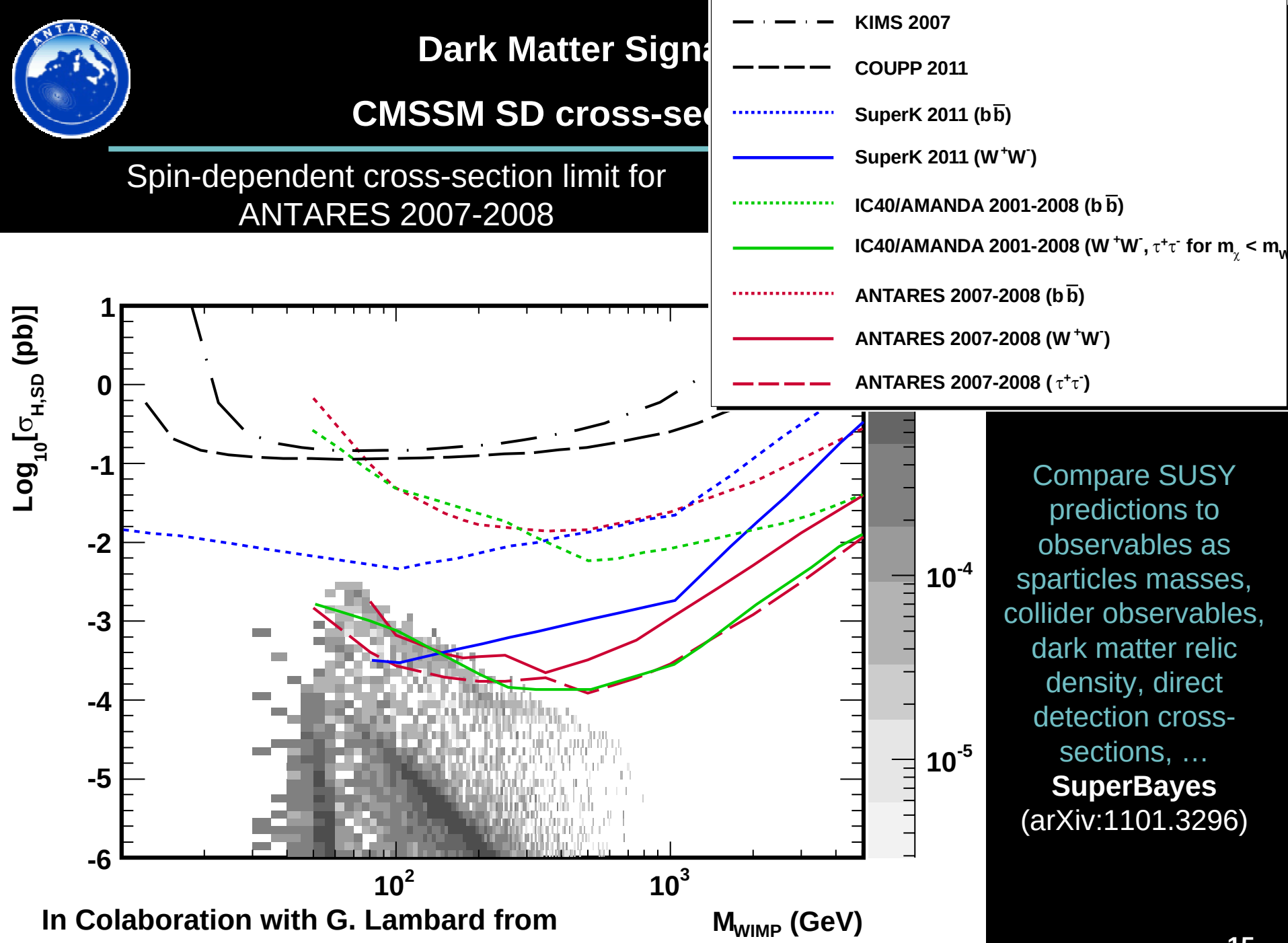
↕

Cross-section σ_{SD}

Dark Matter Signa

CMSSM SD cross-se

Spin-dependent cross-section limit for ANTARES 2007-2008



Compare SUSY predictions to observables as sparticles masses, collider observables, dark matter relic density, direct detection cross-sections, …

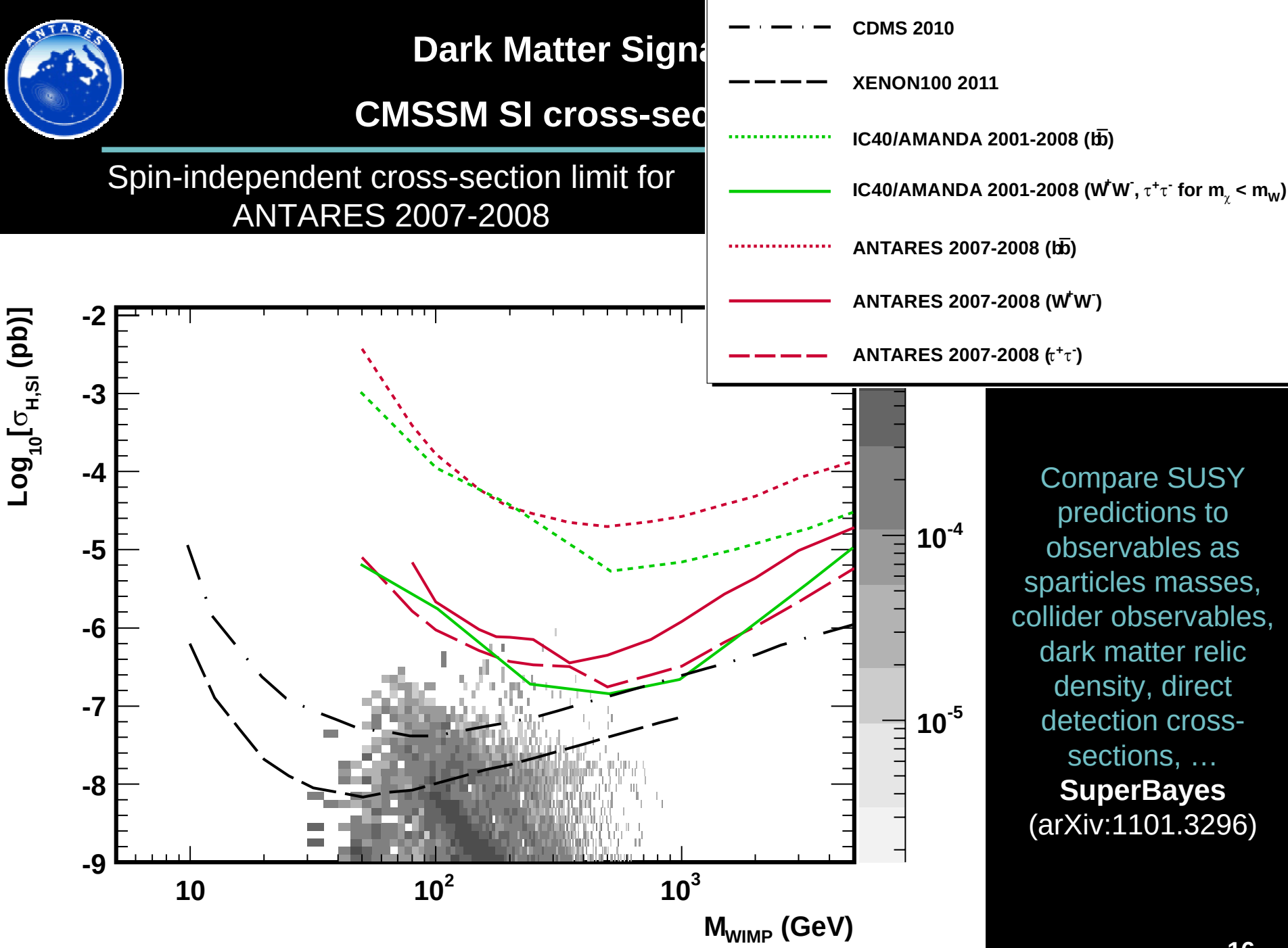
SuperBayes (arXiv:1101.3296)

In Colaboration with G. Lambard from IFIC Valencia

Dark Matter Signa

CMSSM SI cross-sec

Spin-independent cross-section limit for ANTARES 2007-2008



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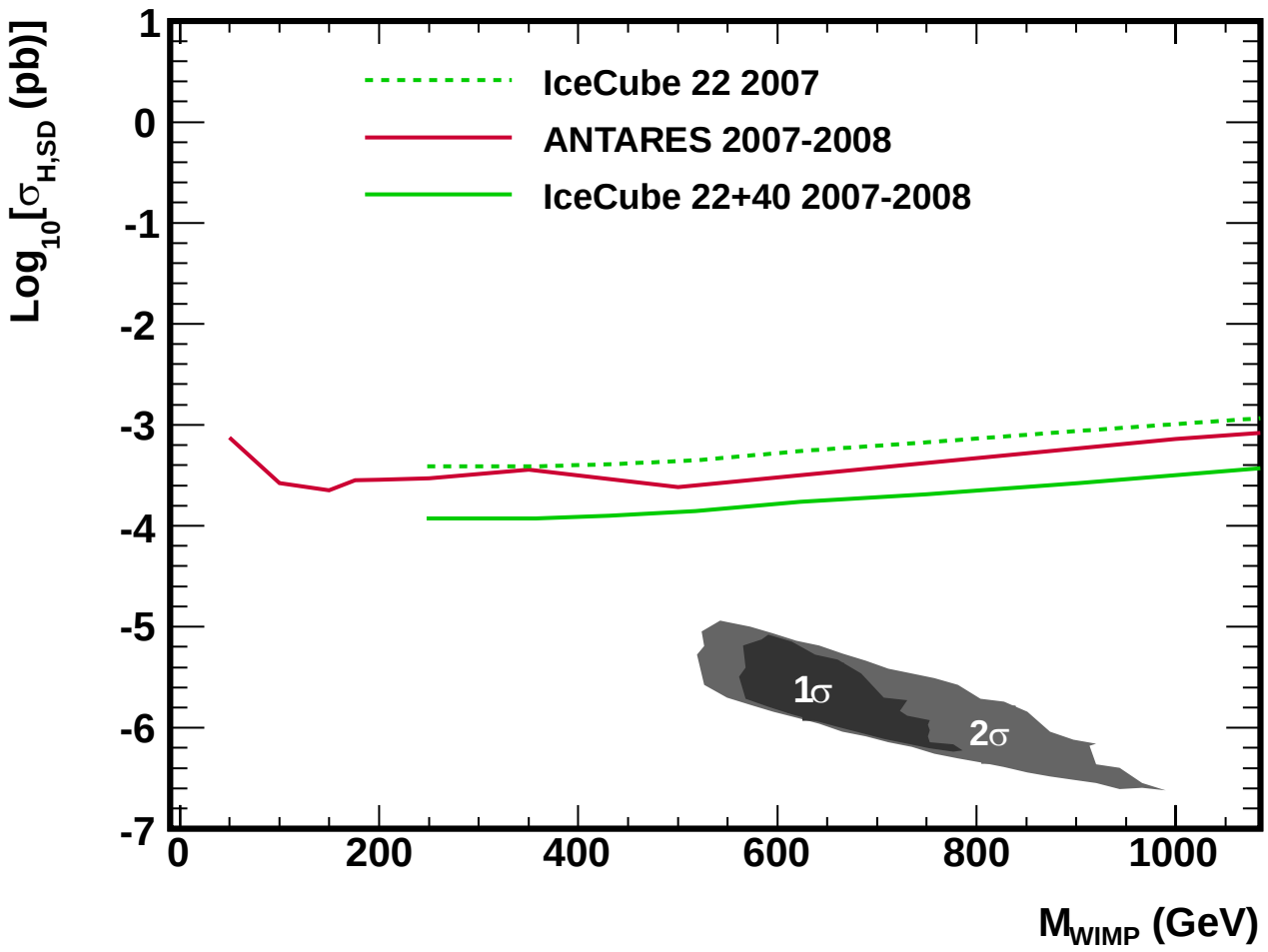
Dark Matter Signal and mUED SD cros-section limit

Spin-dependent cross-section limit for ANTARES 2007-2008



Compare mUED predictions to observables as KK masses, collider observables, relic density, direct detection cross-sections, …

SuperBayes *modified version* (Physical Review D 83, 036008 (2011))

Prospect with 2007-2010 Data

Additional improvement of:

10X - 2X between 50 GeV and 200 GeV for the Soft spectrums

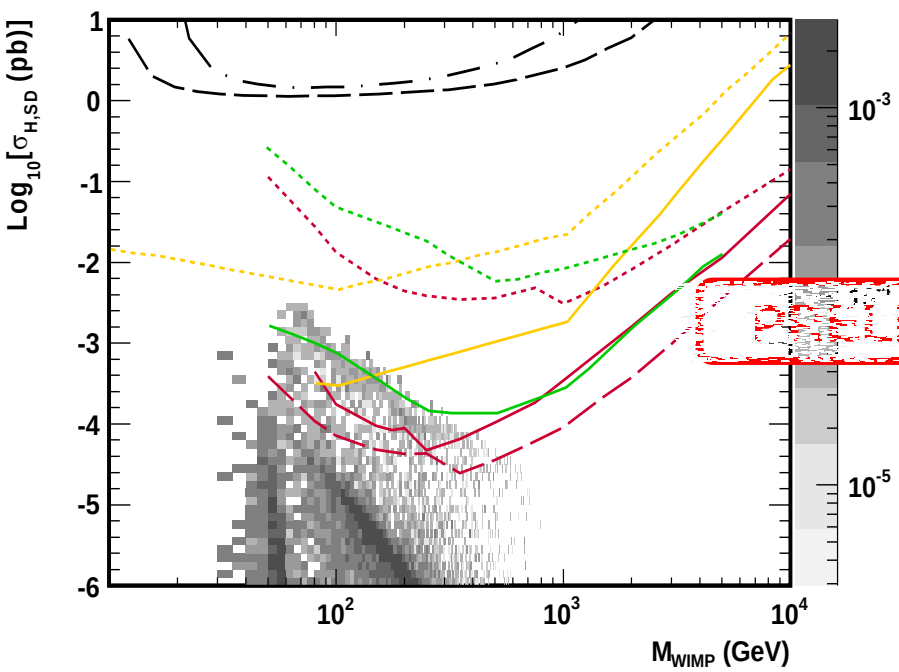
2X up to 100 GeV for the Hard spectrums

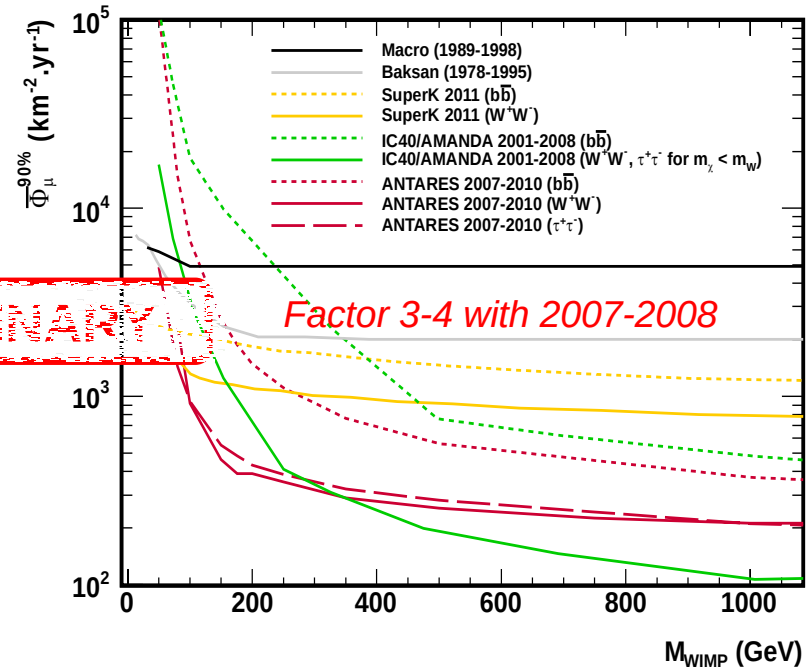
2X up to 1000 GeV for the hard spectrums

Use of extra variables (energy-lilke).

Reconstruction strategy optimized for low energy events.

Reconstruction strategy optimized for high energy events.





Summary & Conclusions

- Reached the limits for the CMSSM, and mUED, in muon flux, and spin-(in)dependent cross-section, with comparisons to the other experiments
- Antares and IceCube gives an opportunity to constraint the dark matter parameter spaces
- Good complement to the direct detection experiments

- Article for the present limits to be submitted for publication (in draft)

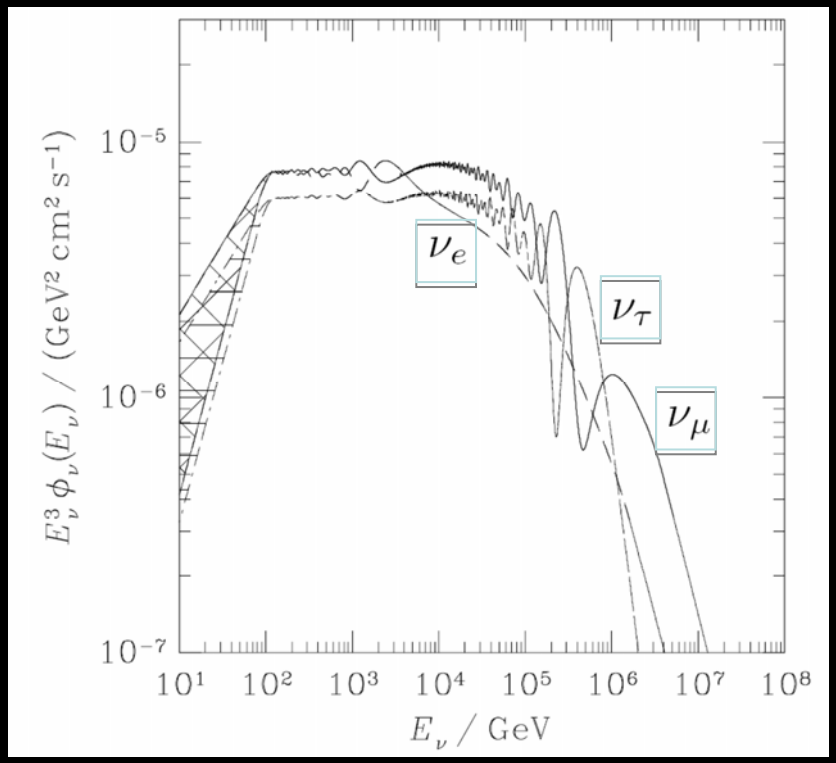
- Galactic center first sensitivities waited for the next month
- Enhancement of the present limits for the Sun with the period 2007-2010 of data, passing from a binned to an unbinned method.
- Data for 2011 under preperation, with statistics slightly latger than 2009 and 2010 combined.

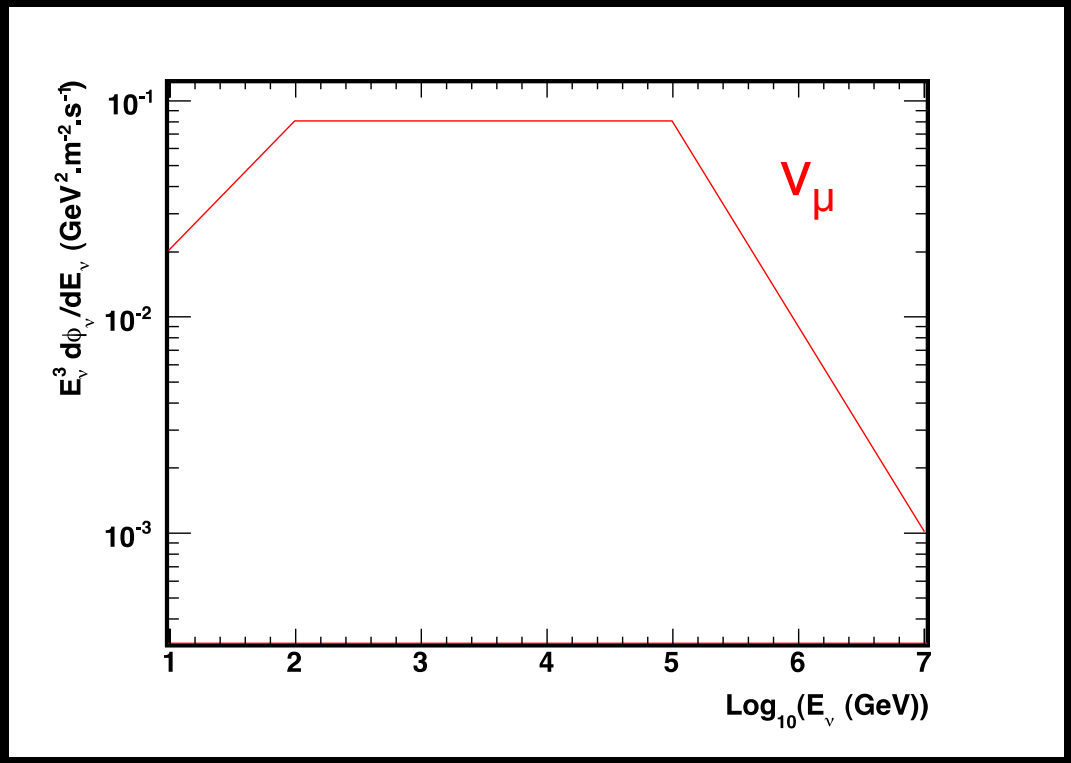
BACKUP

Background in the Sun direction

- Interactions p-p give a production of neutrinos through the decay products

De C. Hettlage et al., Astropart.Phys. 13 (2000) 45-50 Simple parameterization averaged on the oscillations

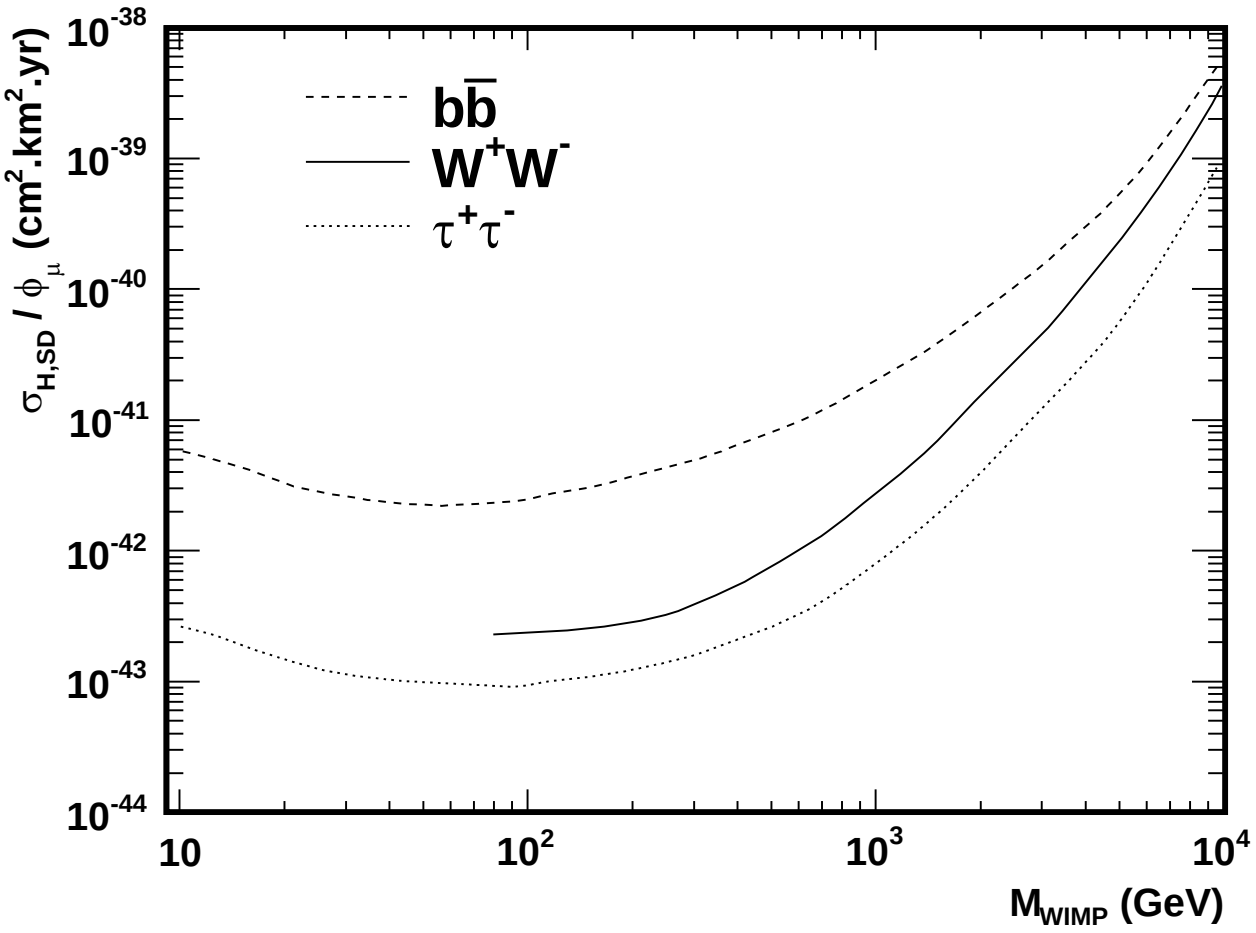




It doesn't represent more than 10^{-3} events per year in a 12 lines configuration (few events for a km³), 0.4% of the total atmospheric background

From Dark Matter muon flux to the SD cross-section

Convertion factor from muon flux to spin-dependent cross-section



Conservative view on the local region:

-Jupiter Effect

-w/o additional disk in the dark matter halo

-local density 0.3 GeV.cm^{-3}

(arxiv:0903.2986v2)

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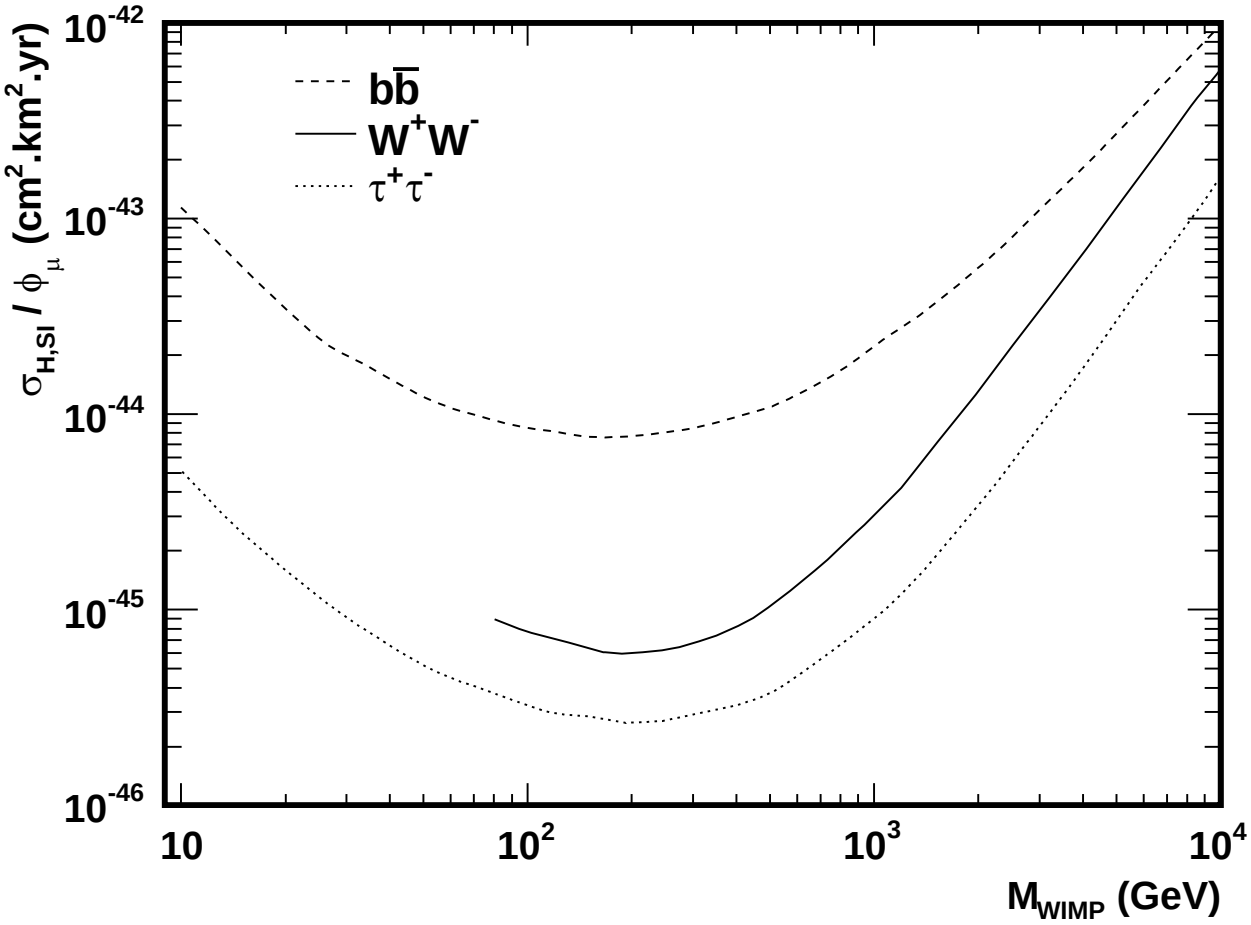

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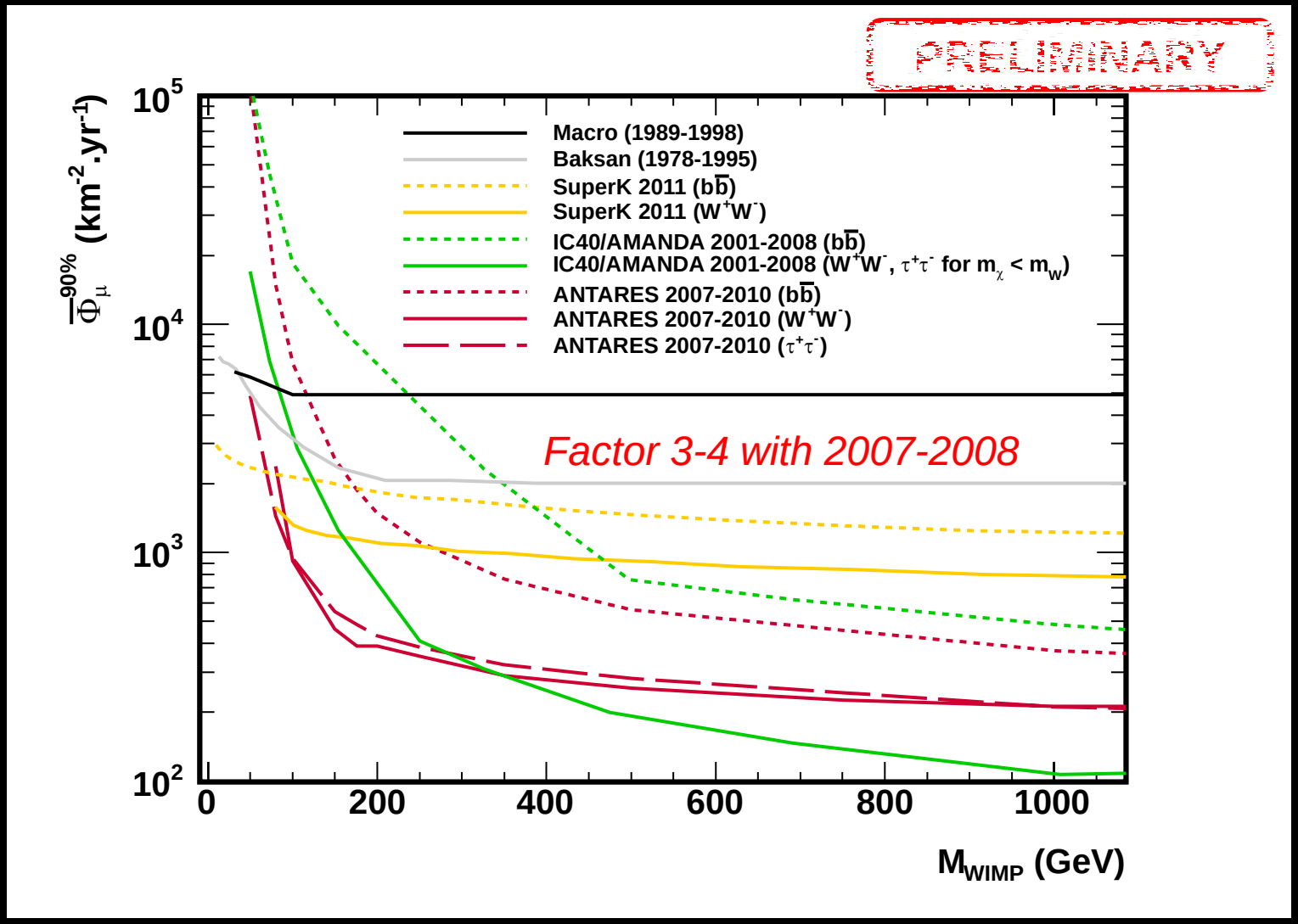
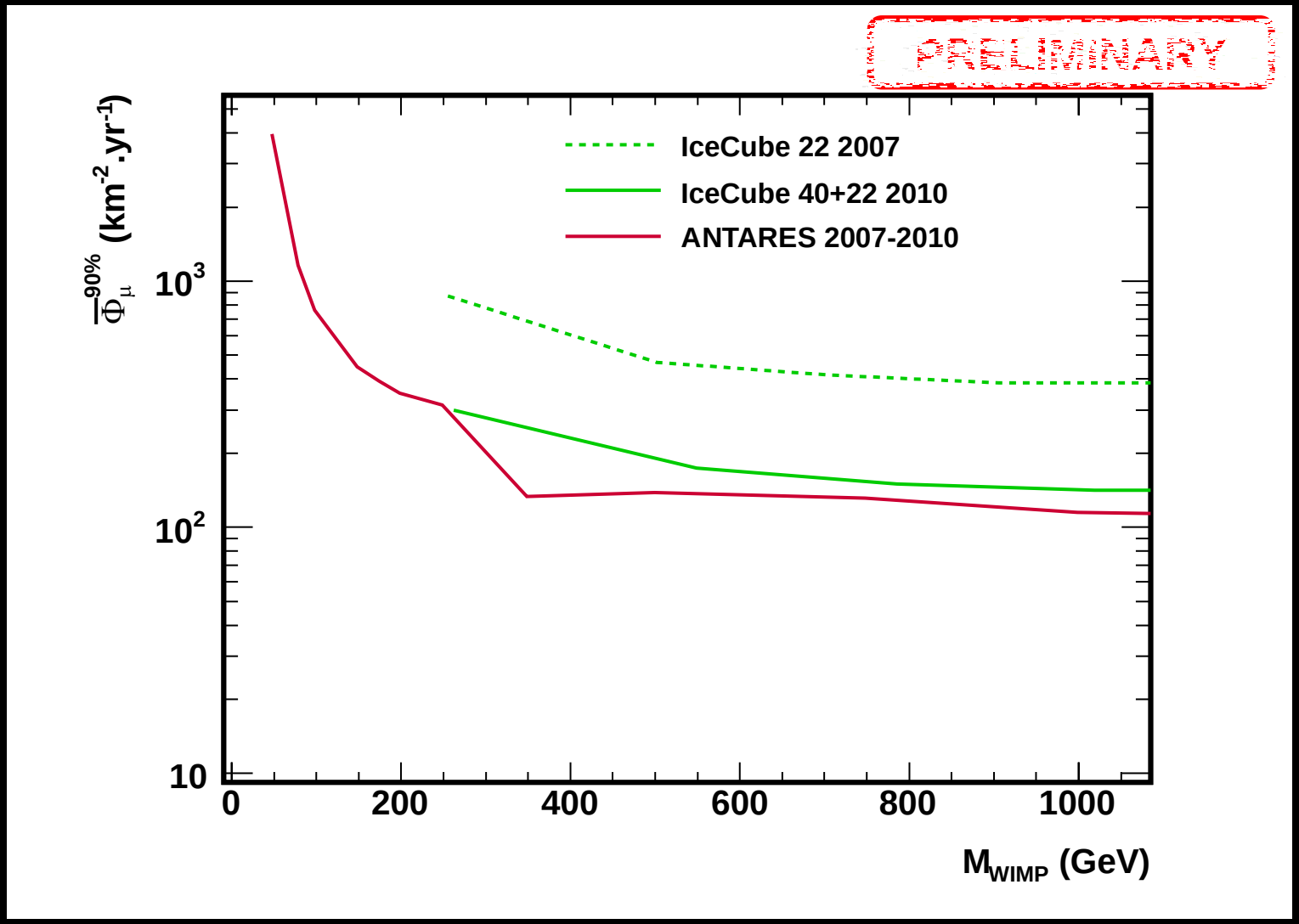
Prospectives
ANTARES 2007-2010

Muons flux limit for ANTARES 2007-2010 in CMSSM



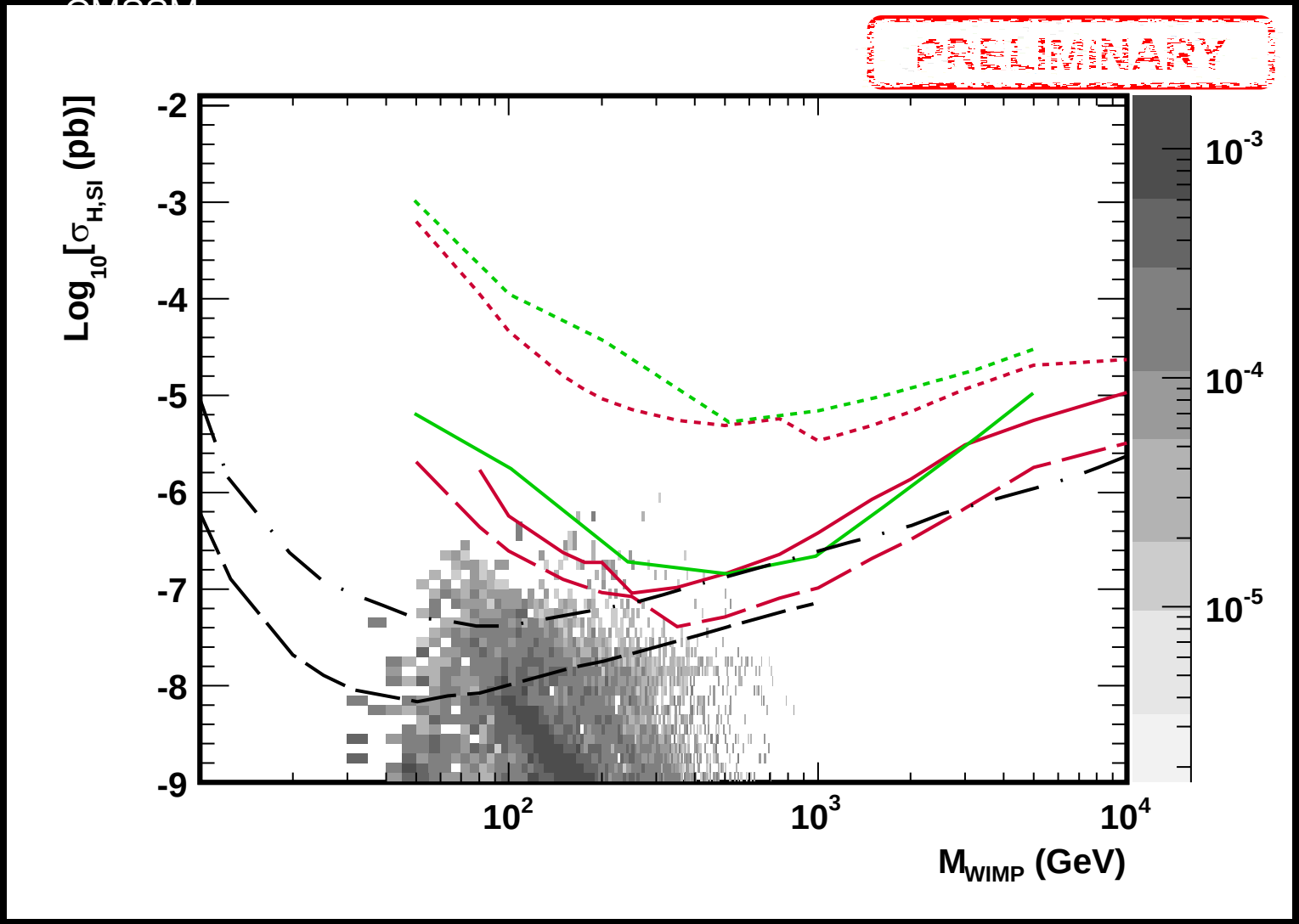
Prospectives
ANTARES 2007-2010

Muons flux limit for ANTARES 2007-2010 in mUED



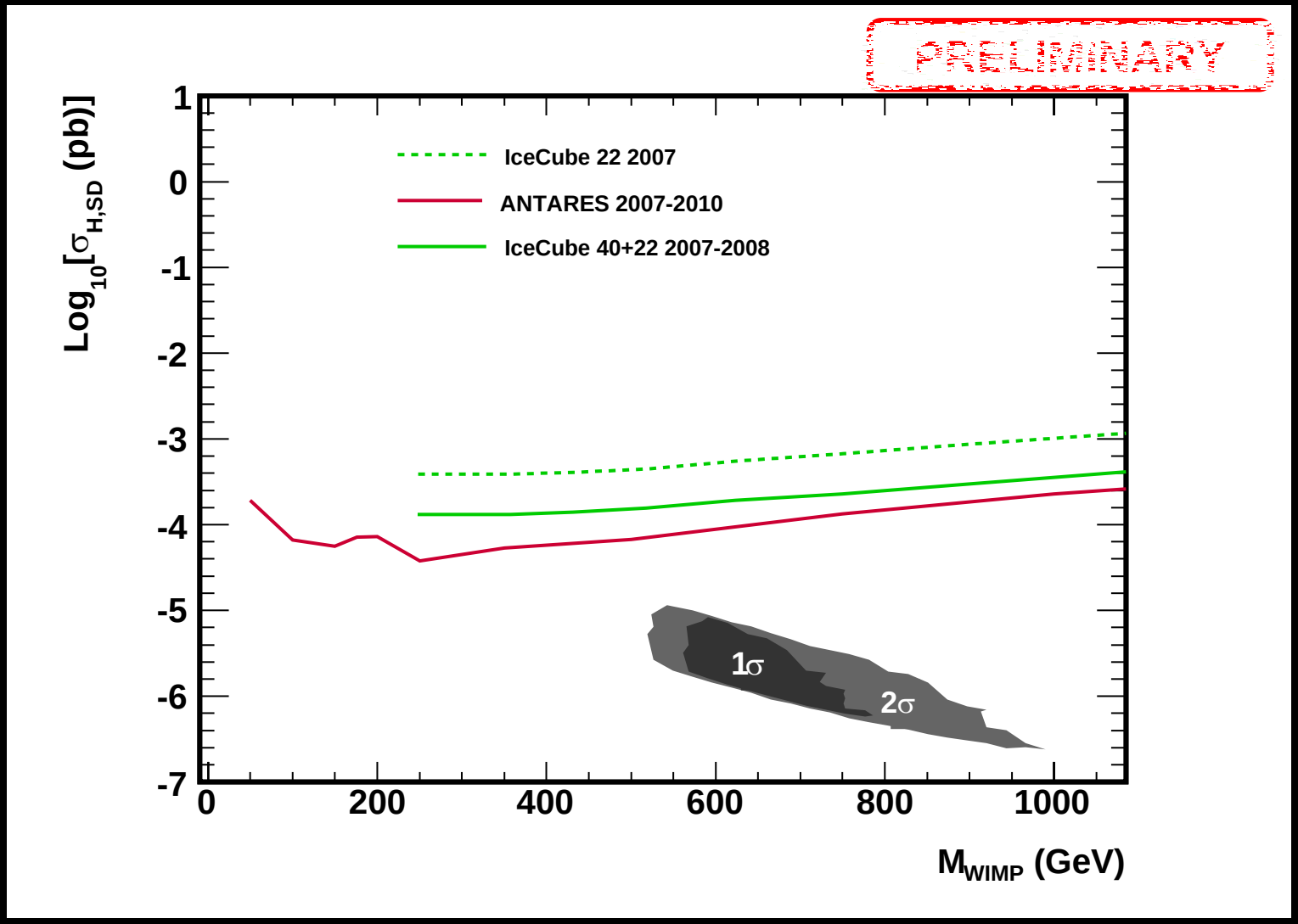
Prospectives
ANTARES 2007-2010

Spin-independent cross section limit for ANTARES 2007-2010 in



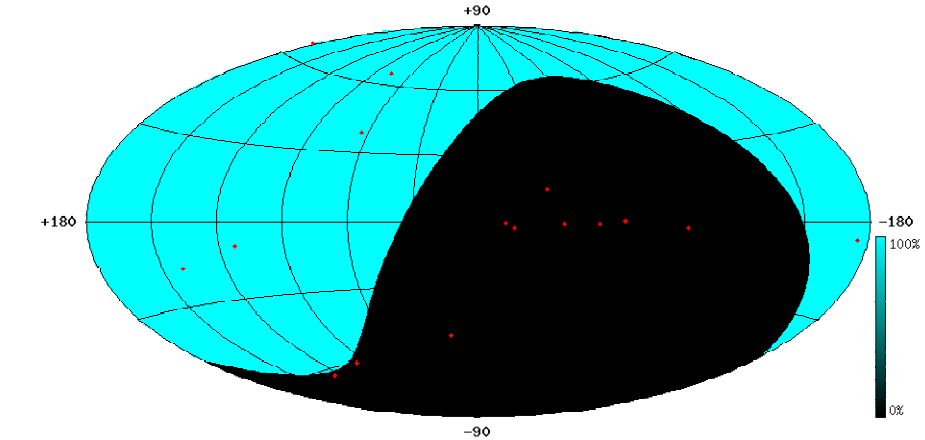
Prospectives
ANTARES 2007-2010

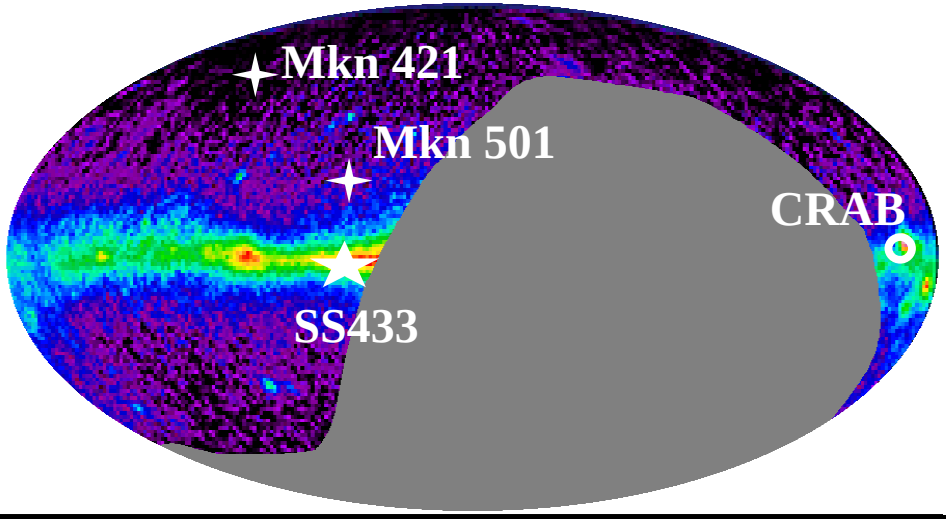
Spin-dependent cross section limit for ANTARES 2007-2010 in mUED



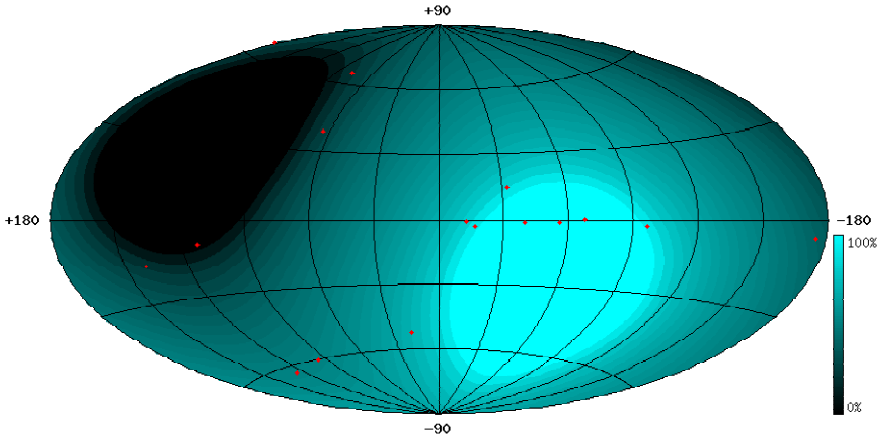
Region of Sky Observable by Neutrino Telescopes

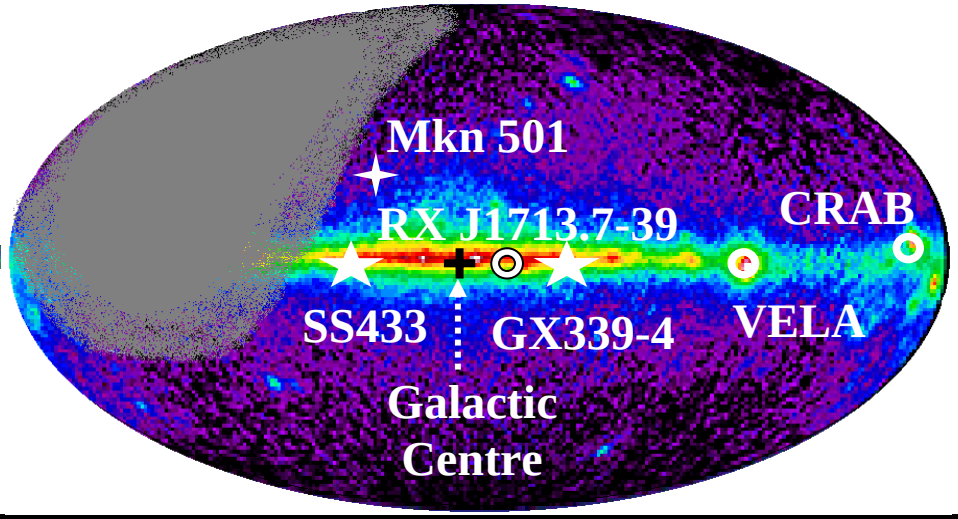
IceCube (South Pole)





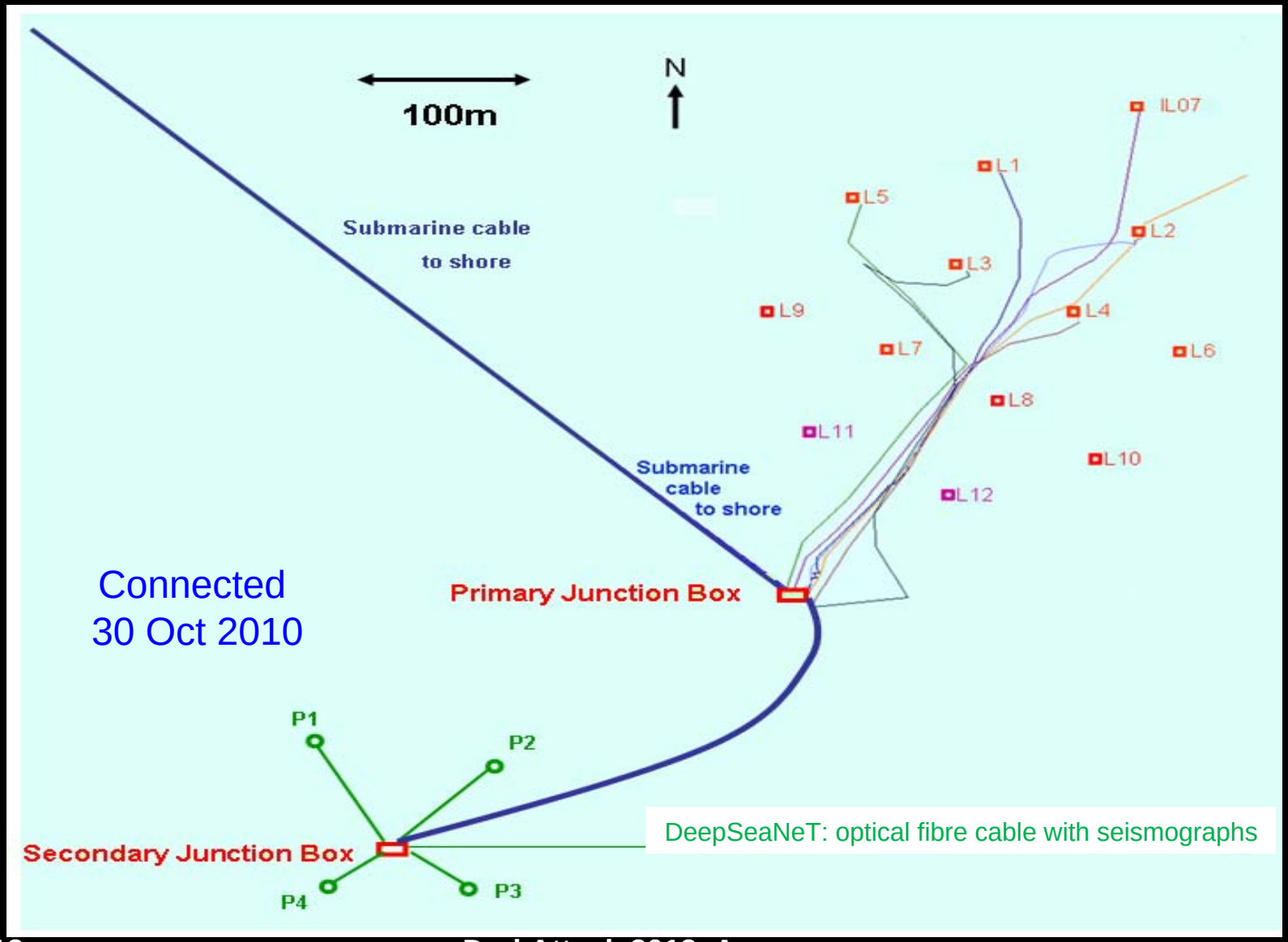
ANTARES/KM3NeT (43° North)



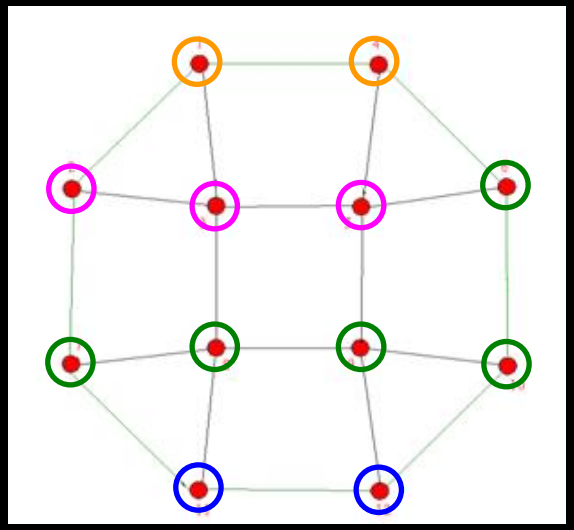


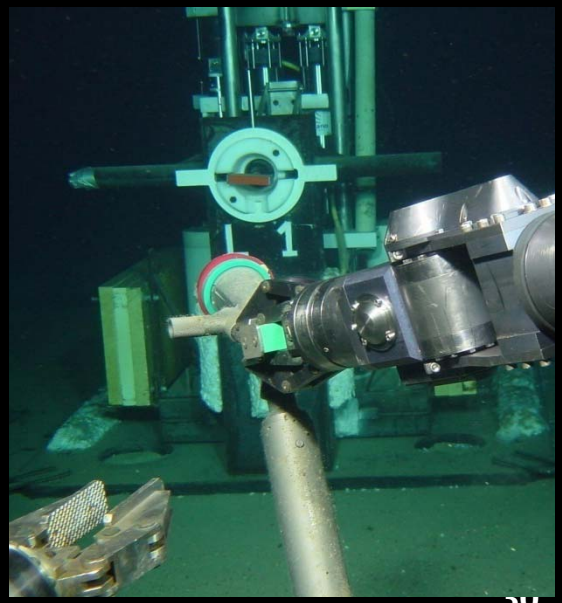
→ Emphasis on study of galactic sources

The ANTARES Infrastructure



2006 – 2008: Building phase of the Detector

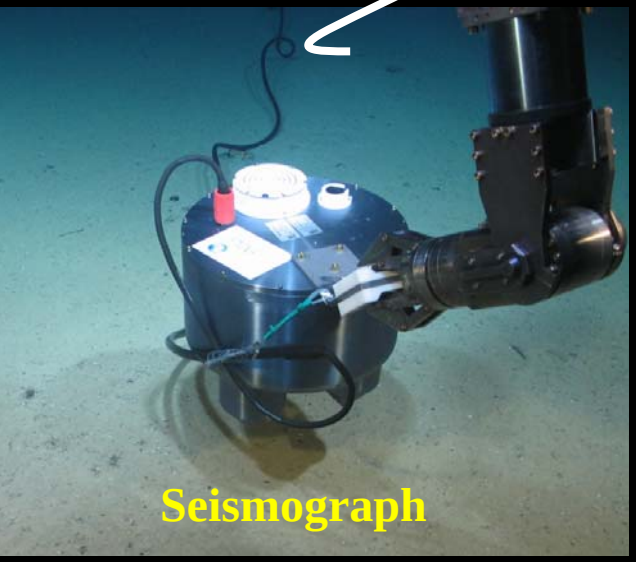


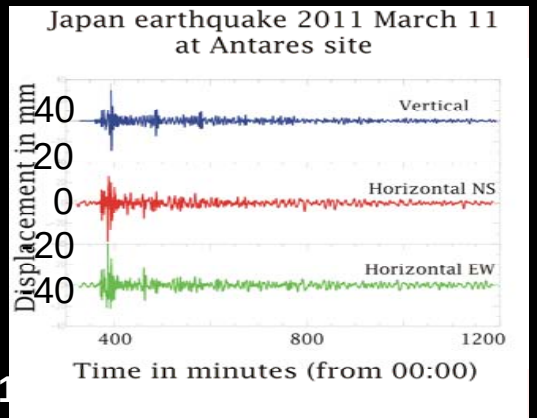


• **Junction box**	**2001**
• **Main cable**	**2002**
• **Line 1, 2**	2006
• **Line 3, 4, 5**	01 / 2007
• **Line 6, 7, 8, 9, 10**	12 / 2007
• **Line 11, 12**	05 / 2008

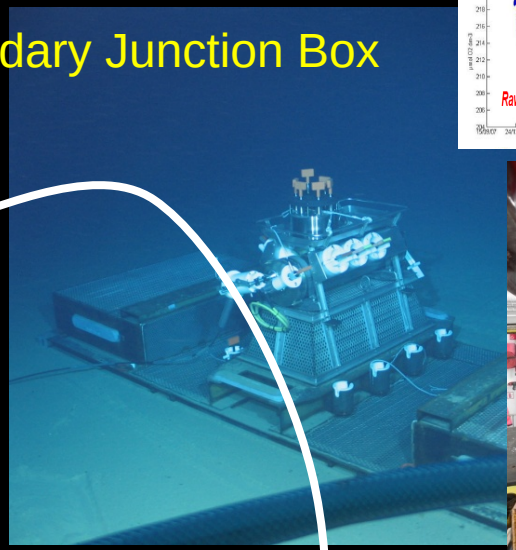
Secondary Junction Box

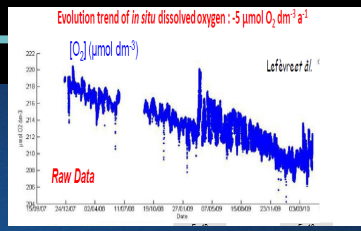
Connected
30 Oct 2010

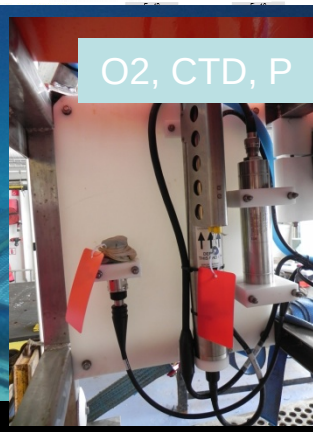


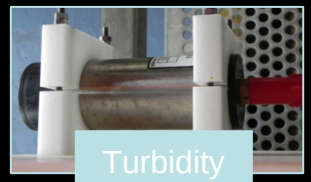


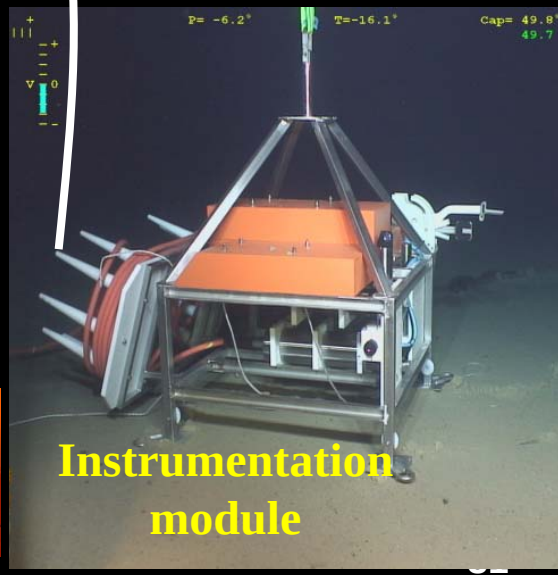
Secondary Junction Box











0.000 sec -2500m IuSEApher/biocam www.ipnl.in2p3.fr/ebcmos

Signal computation method

- Usually, we need :
  - Flux (example: WW) at the surface of the Earth
  - Capture rate into the Sun, dependent on the SD, SI cross-section
  - Annihilation rate Γ ~ 0.5 * C (equilibrium condition)

$$\frac{d\varphi}{dE d\Omega} = \frac{\Gamma}{4\pi d^2} \sum_i B_i \frac{dN_i}{dE_i}$$

$$C_\otimes \simeq 3.35\times10^{18} s^{-1} \times \left(\frac{\rho_{local}}{0.3\,GeV.cm^{-3}}\right) \times \left(\frac{270\,km.s^{-1}}{v_{local}}\right) \times \left(\frac{\sigma_{H,SD}}{10^{-6}\,pb}\right) \times \left(\frac{TeV}{M_{WIMP}}\right)^2$$

  - Flux from WIMPSIM
  - Cross-section from Analytic computation, or simulation in the parameter space of the models
  - For Kaluza-Klein, Branching ratio not so dependent on the location in the parameter space (R, Δ, and SM Higgs mass m_h)
  - For CMSSM, it's different… Equilibrium in the Sun well/not reached, SD/SI very dependent on the parameter space, branching ratios very dependent, main channel chosen is not so obvious -> large systematic from the sensitivity computed
  - Need a simulation, and fast one, to compute the cross-sections, the capture rate, etc, for the allowed parameter space

SuperBayes v1.35

Supersymmetry Parameters Extraction Routines for Bayesian Statistics

- Multidimensional SUSY parameter space scanning
- Compare SUSY predictions to collider observables, dark matter relic density, direct detection cross-sections, …
- Using a new generation Markov Chain Monte Carlo for a full 8-dim scan of CMSSM
- Using PISTOO farm at CC-Lyon to run it

- Well documented (articles, Website), as DarkSUSY package

- Parameter set of CMSSM (m_0, $m_{1/2}$, A_0, $\tan\beta$)
- « Nuisance parameters » from SM (m_t, m_b, α_{em}, α_s)