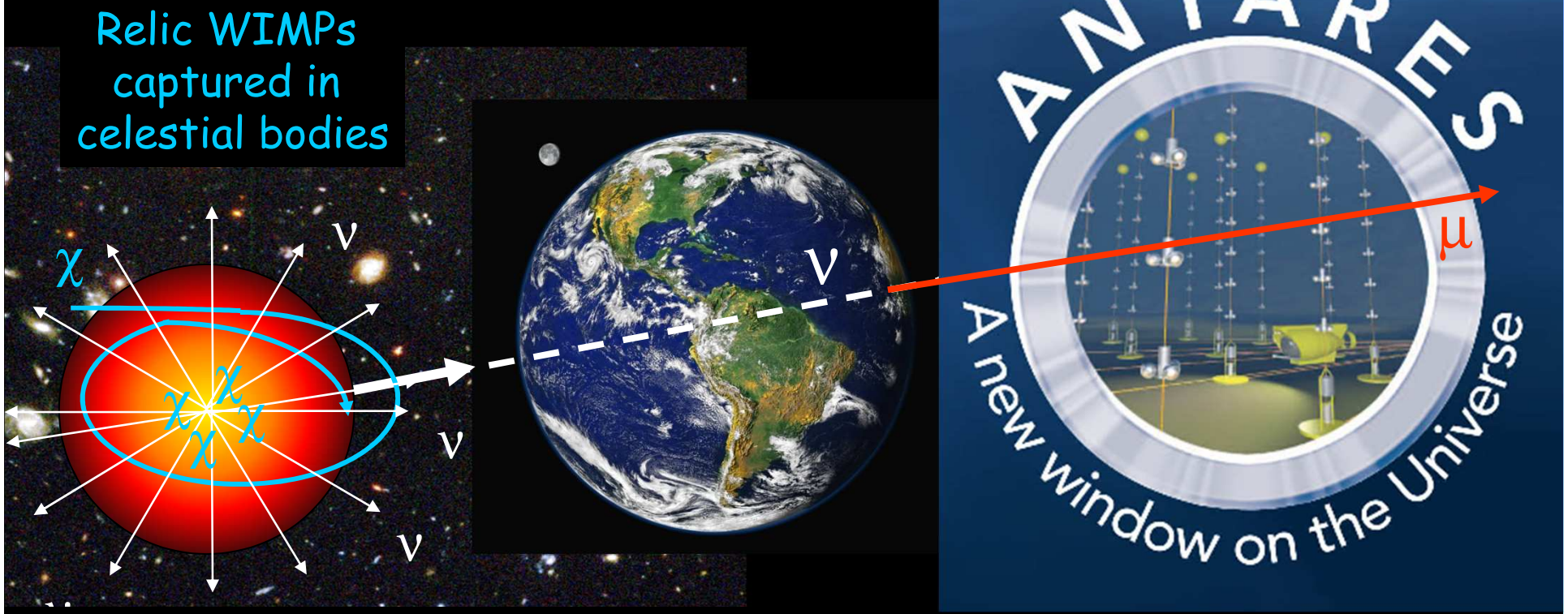
Indirect search for Dark Matter with the ANTARES Neutrino Telescope

Vincent Bertin - CPPM-Marseille
on behalf of the ANTARES Collaboration

Topics in Astroparticle and Underground Physics – Munich – September 2011

Indirect detection of WIMPs in a neutrino telescope



$\chi\chi$ self-annihilations into c,b,t quarks, τ leptons or W,Z,H bosons can produce significant high-energy neutrino flux

Potential $\chi\chi \rightarrow \nu$ sources are Sun, Earth & Galactic Centre

Signal less affected by astrophysical uncertainties than γ-ray indirect detection

Indirect search towards the Sun with ANTARES

- **ANTARES neutrino telescope** located by 2500m depth in **Mediterranean Sea** in South of France (Toulon)
  → See **J.J.Hernandez talk** in Astro. Messenger session (Tuesday 6/09) for **ANTARES results overview**

- **Detector** building started in 2006, **completed in May 2008**
- **Current analysis** based on **2007** (5-lines) + **2008** (9-10-12 lines) data
  → about **1000 upgoing neutrino** candidates (in **~295 effective days**)
- **Event selection** based on **fast and robust track reconstruction** algorithm (Astroparticle Physics 34 (2011) 652)

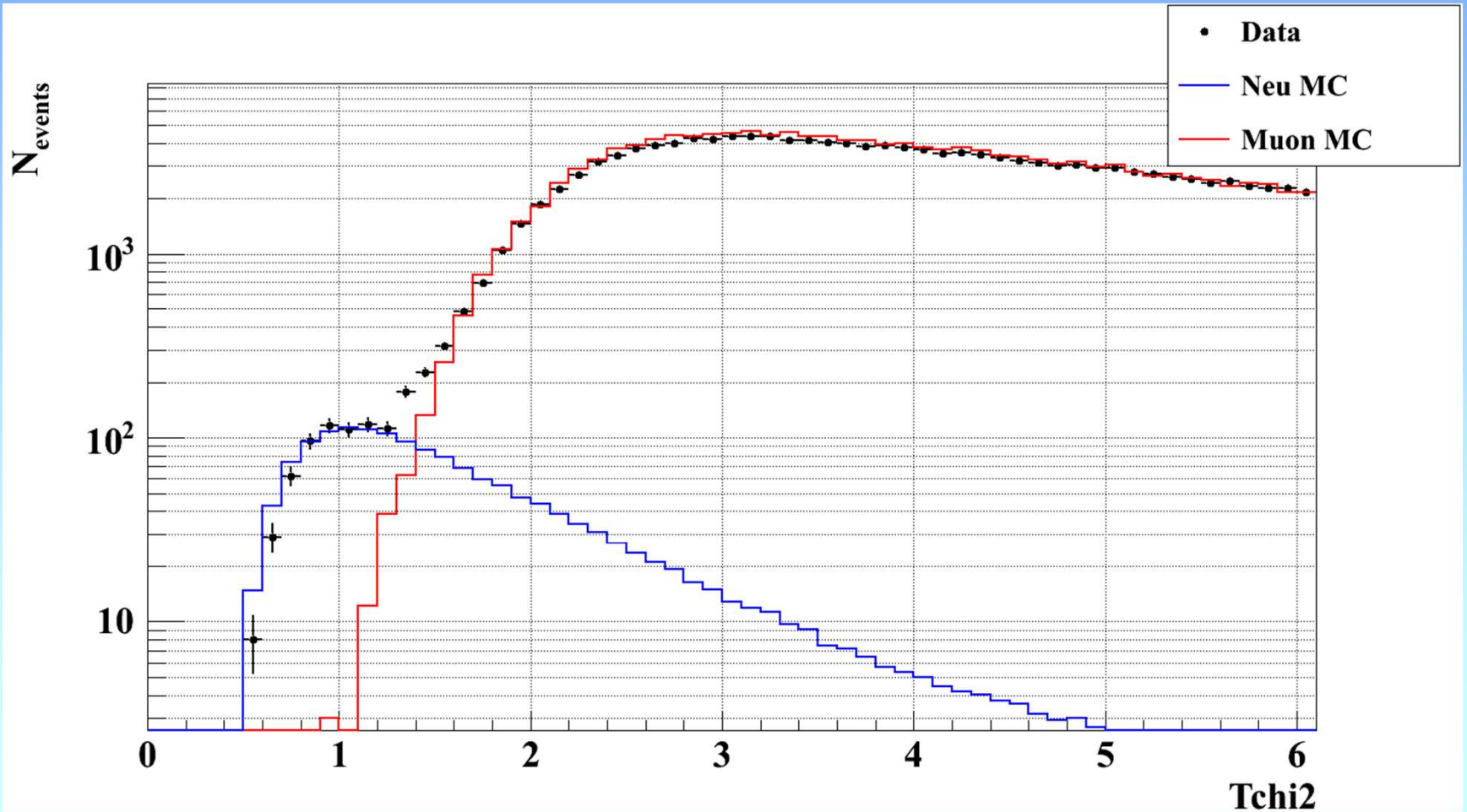
- **Binned search** towards the direction of the **Sun** (visibility below horizon)
- **Background** from atm. neutrinos and muons estimated from MC simulation and **scrambled data**
- **Signal energy spectrum** derived from **WIMPSIM** simulation package for different **WIMP masses** and **annihilation channel** hypotheses

Event selection : fit quality

Quality parameter of the track reconstruction for upgoing events

→ very good agreement data vs. Monte Carlo events

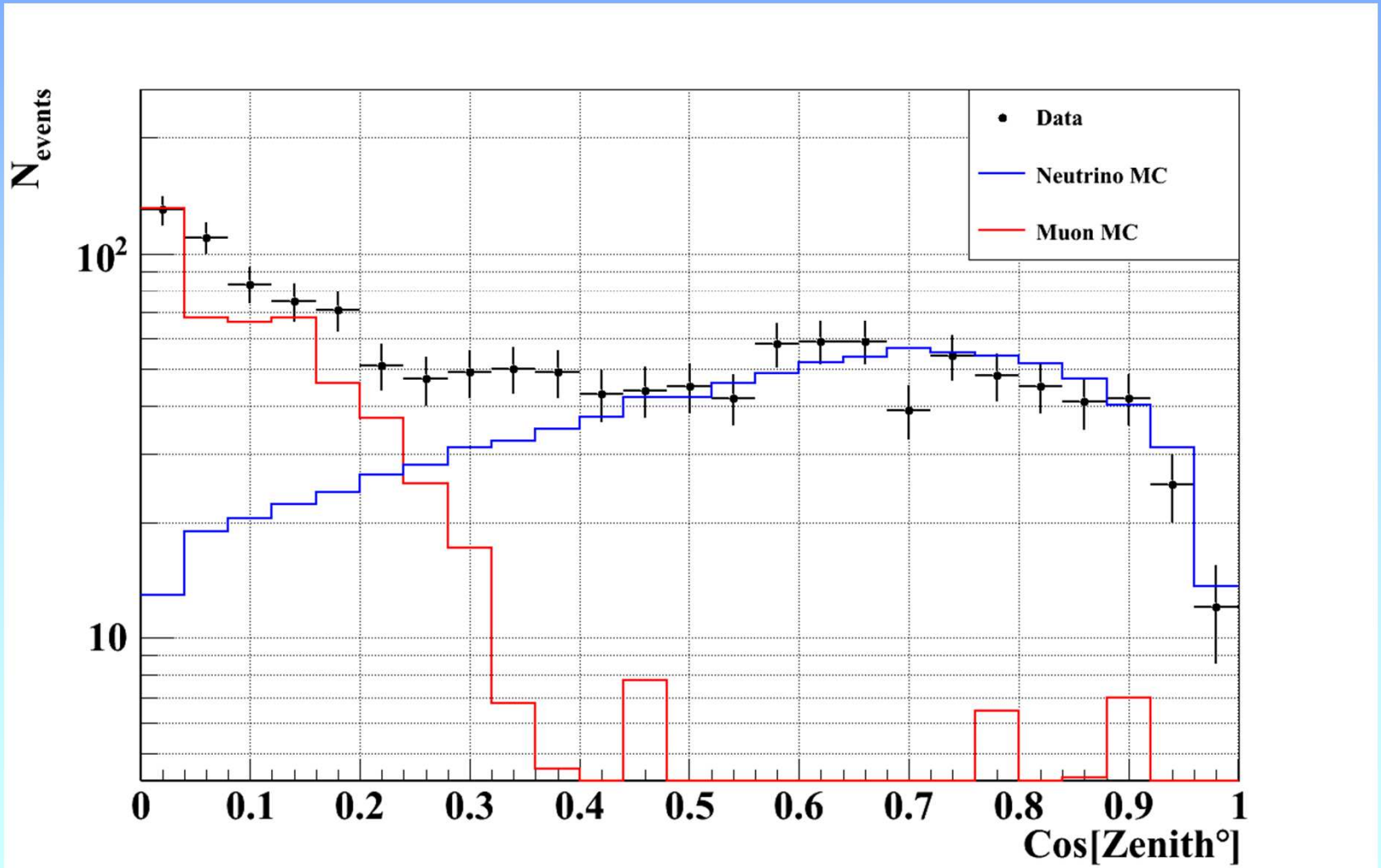
→ good separation between neutrino and muon events



Selected events : zenith angle

Zenith distribution of selected events (Tchi2 < 1.6)

→ strong reduction of the atmospheric muon background

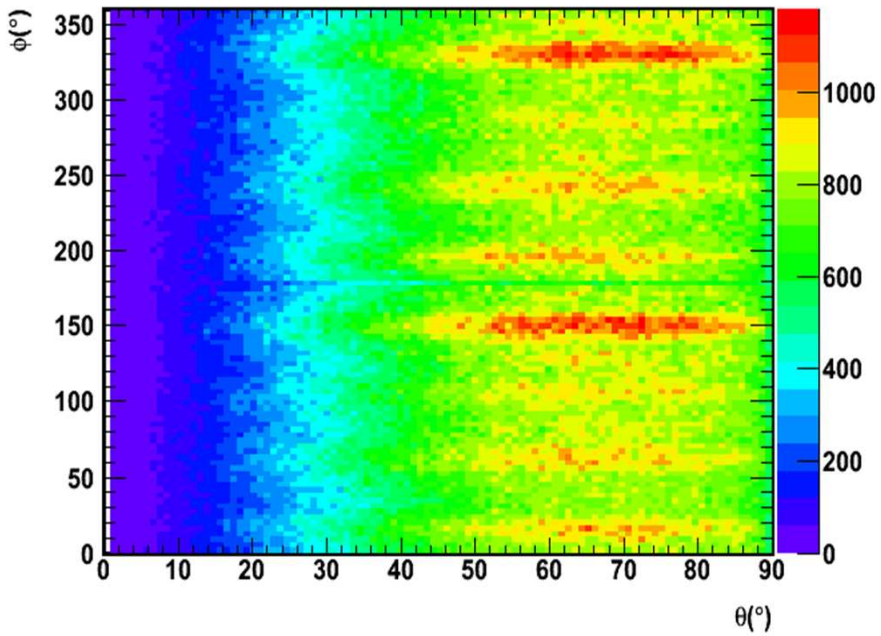


Background in the Sun direction

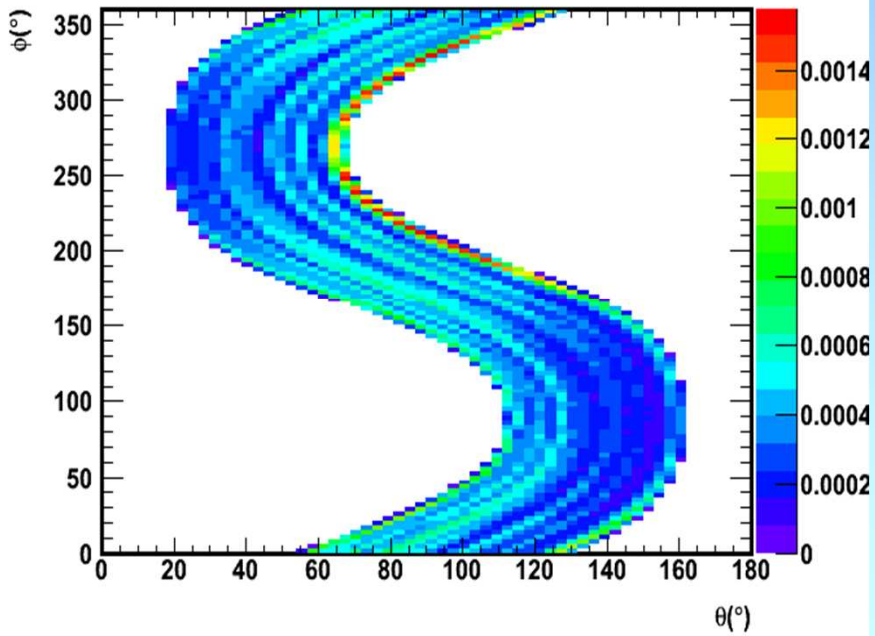
- Background estimated from data scrambled in time and (θ,φ)
- Using the Sun visibility at the ANTARES location

- Background due to neutrinos coming from CR interactions in the Sun corona negligeable (<1% of atmospheric neutrinos)

All up-going events from 2007-2008 data



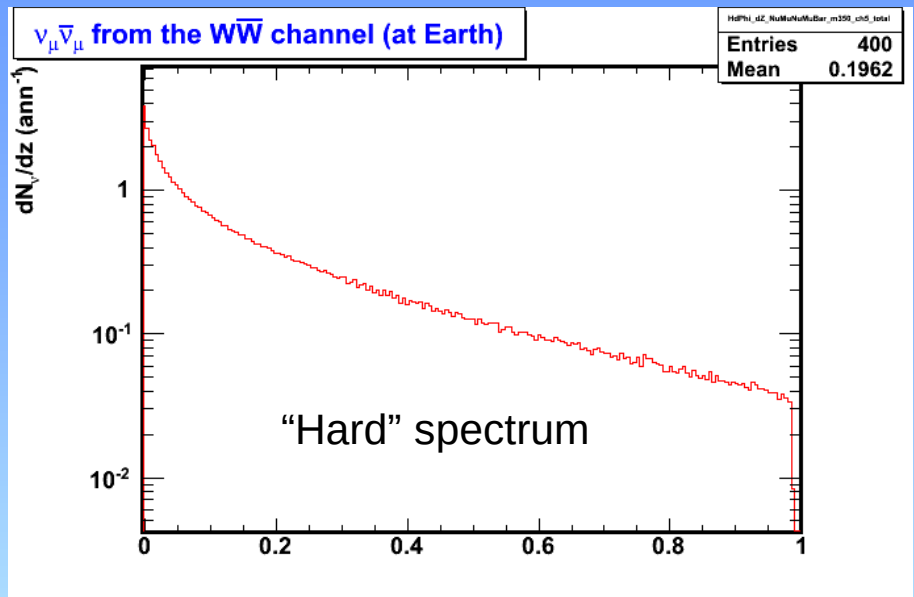
Example of Sun tracking in horizontal coordinates

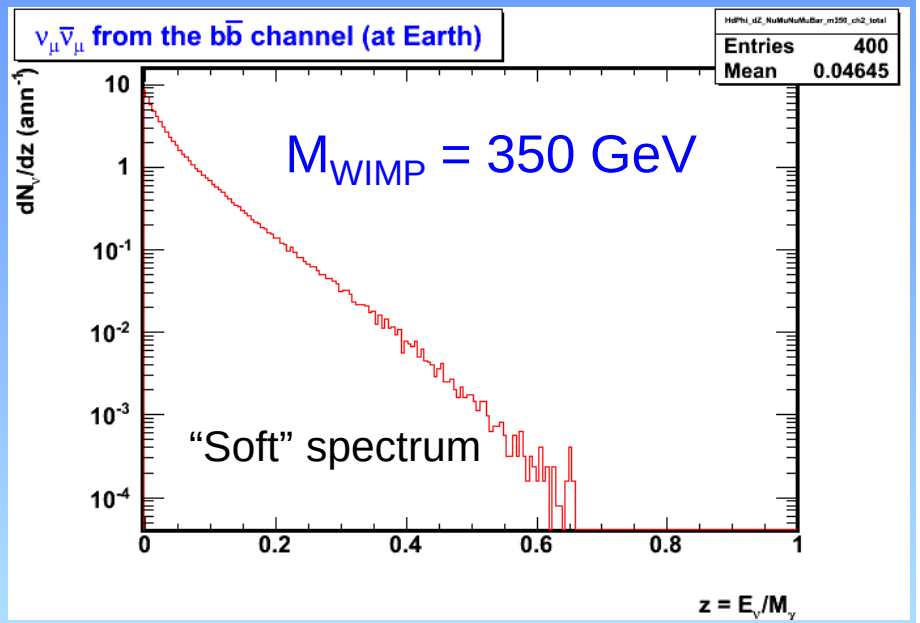


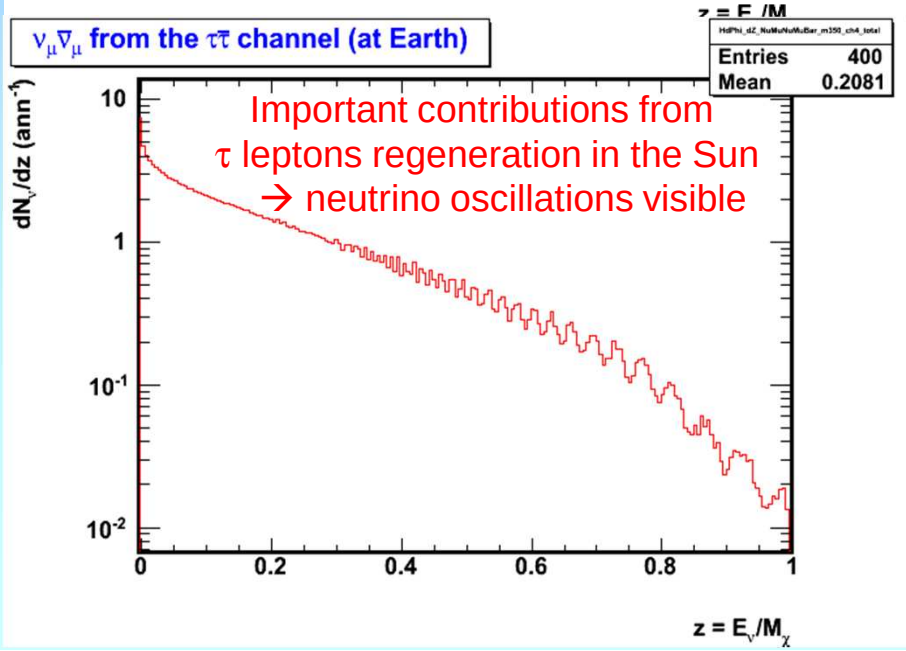
Neutrino signal from WIMP annihilations

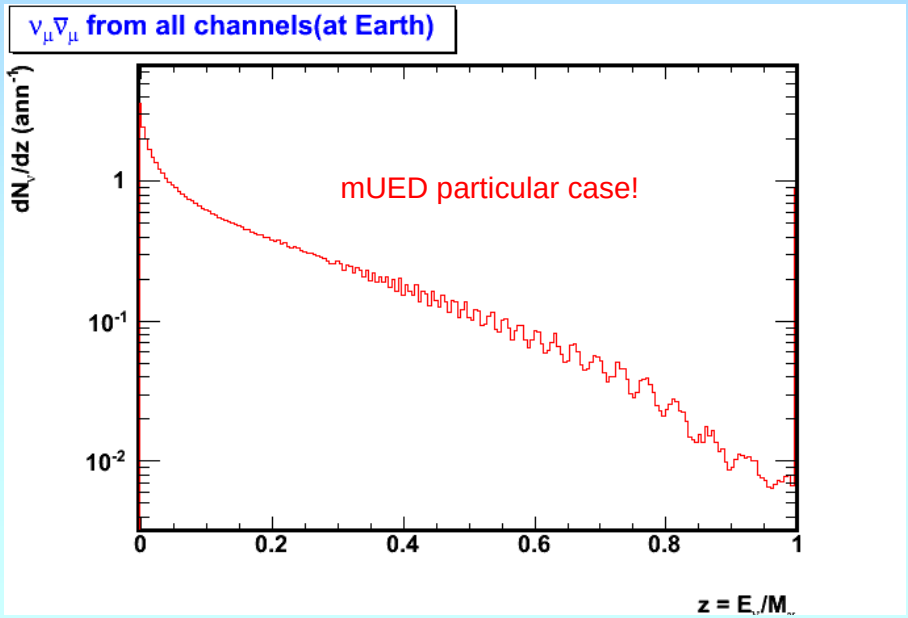
- The WIMPSIM package (Blennow, Edsjö, Ohlsson, 03/2008) used to generate events in the Sun in a model-independent way
- Large statistics with 3×10^6 WIMPs annihilations
- Capture rate and annihilations in equilibrium at the Sun core
- Annihilations in c,b and t quarks, τ leptons, WW/ZZ bosons and direct channels
- Neutrino interactions in the Sun medium taken into account
- Three flavor oscillations, regeneration of τ leptons in the Sun medium (Bahcall et al.)
- Available parameters: WIMPs mass, oscillation parameter values...

Neutrino spectrum of main decay channels







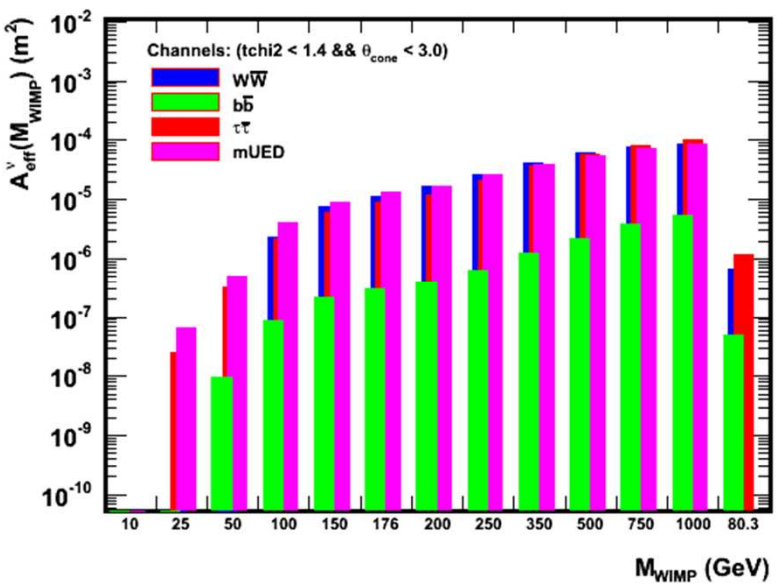


Selection optimization and signal efficiency

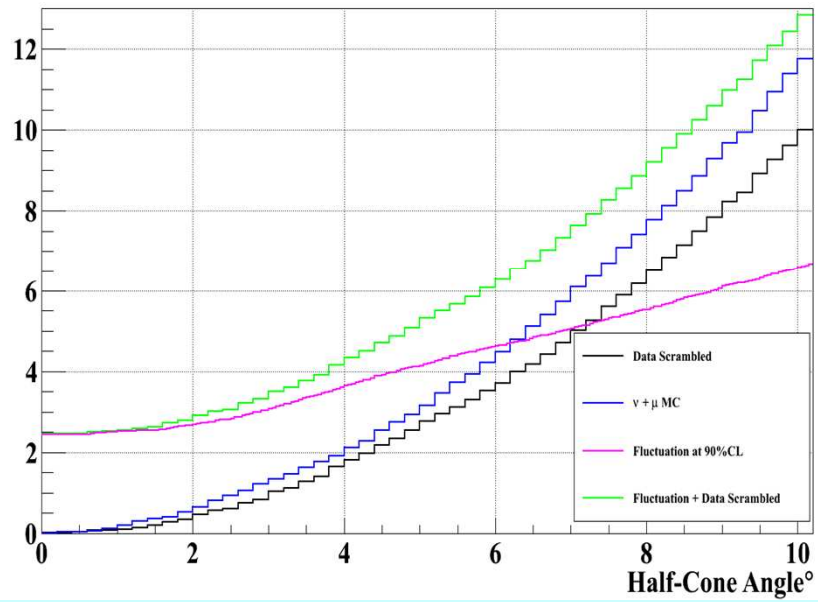
- **Neutrino fluxes** at the Earth produced by Dark Matter coannihilation are **convoluated** with the **detector efficiency** for given selection parameter sets (track fit quality, cone size)
- **Neutrino background** given by **scrambled data in the Sun direction** is evaluated for the same selection set
- **Optimization of sensitivity** performed by minimizing

$$Sensitivity = \frac{\bar{\mu}_{90}}{Aeff\,(Mwimp) \times Teff}$$

Effective area estimated
for all selection cuts (Tchi2,cone)

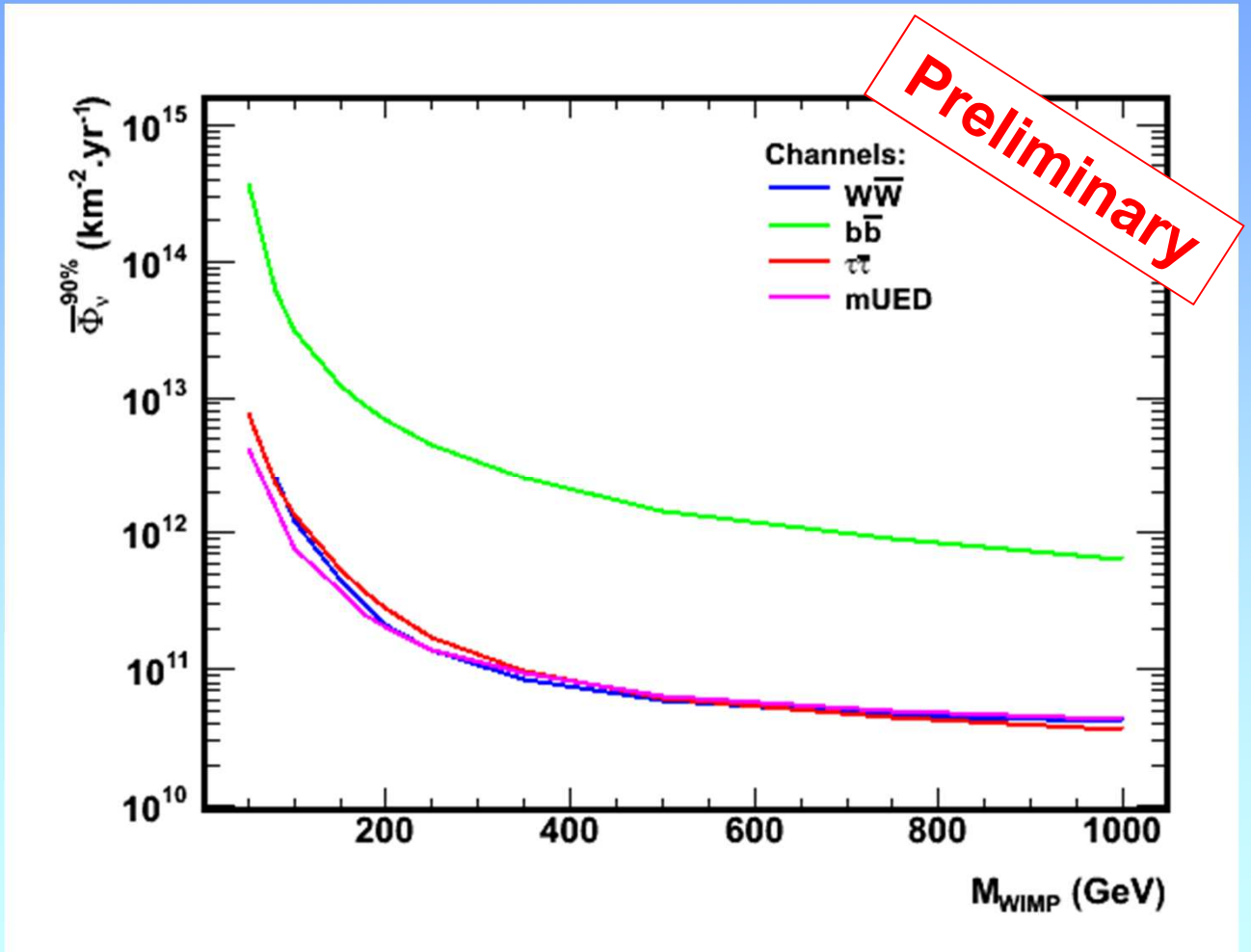


Background in Sun direction and
Average upper limit (Feldman-Cousins)



Sensitivity to neutrino flux

Sensitivity to neutrino flux for ANTARES 2007-2008 data

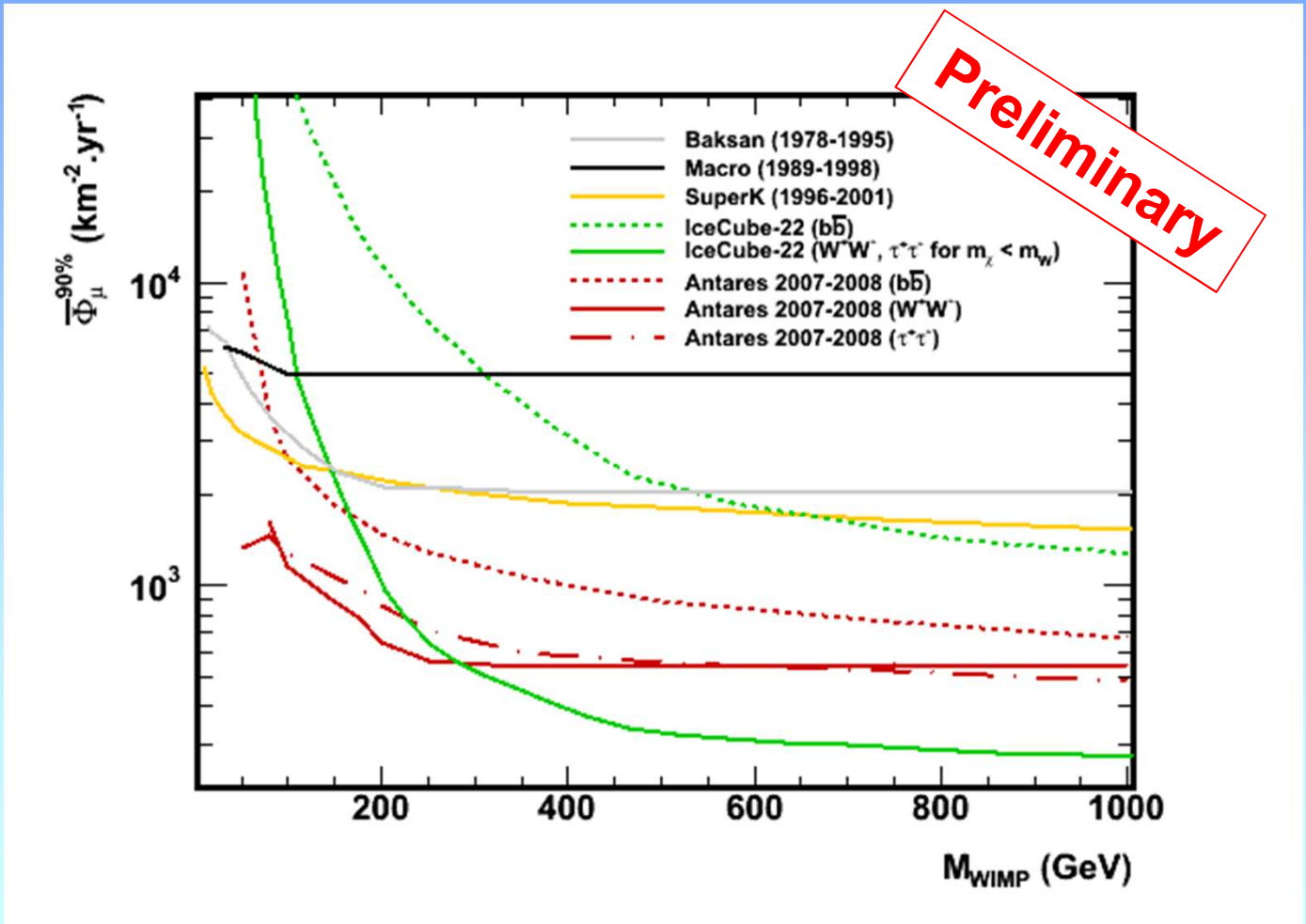


For CMSSM:
Branching ratios = 1
(for WW, bb, $\tau\tau$)
(Large variation of branching ratios over CMSSM parameter space)

For mUED:
Theoritical branching ratios taken into account

Sensitivity to muon flux

Sensitivity to muon flux for ANTARES 2007-2008 data



Flux Φ_μ

↕

Annihilation rate Γ

↕

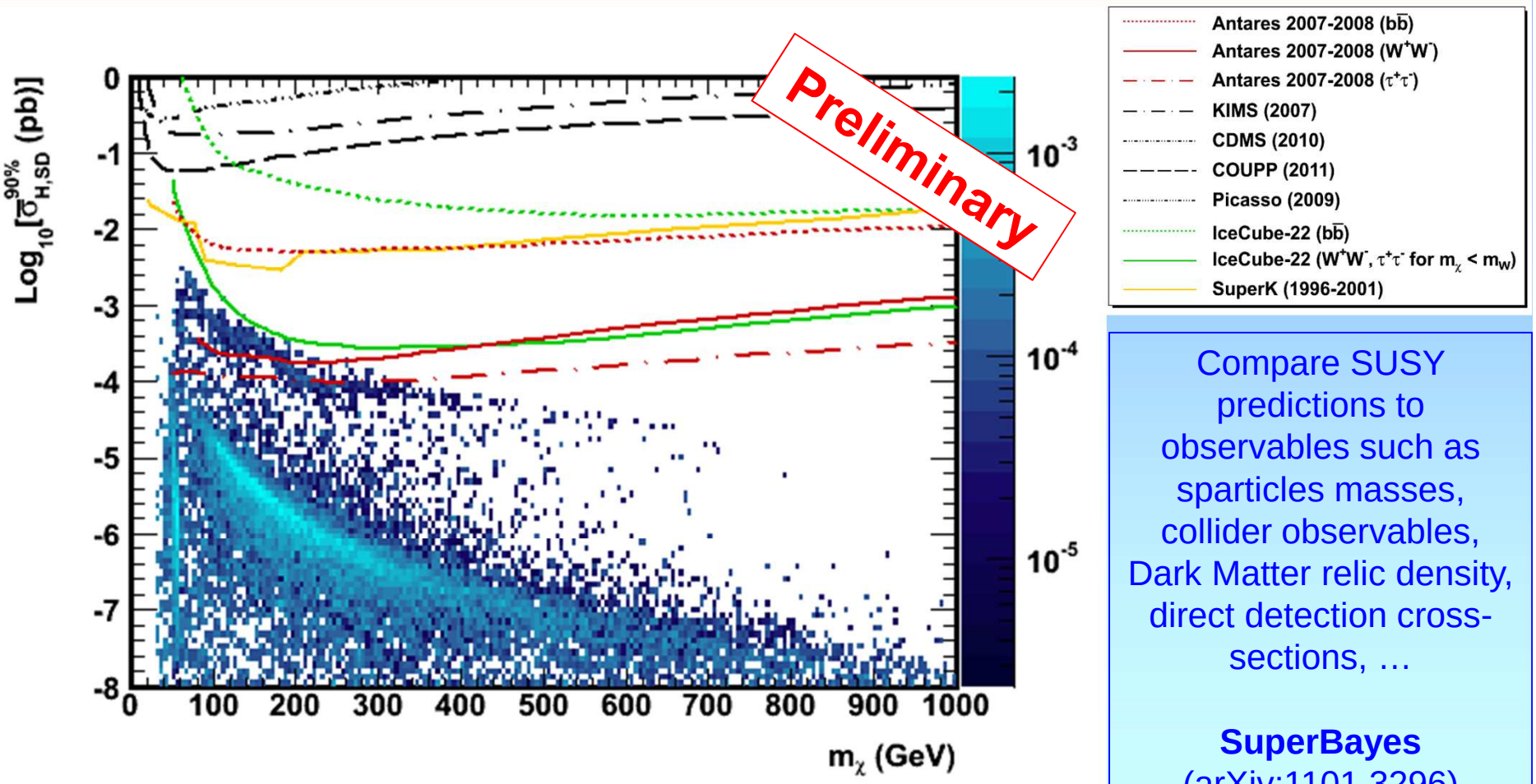
Capture rate C

↕

Cross-section σ_{SD}

Sensitivity to SD cross-section for CMSSM

Sensitivity to Spin-Dependent cross-section for ANTARES 2007-2008 data

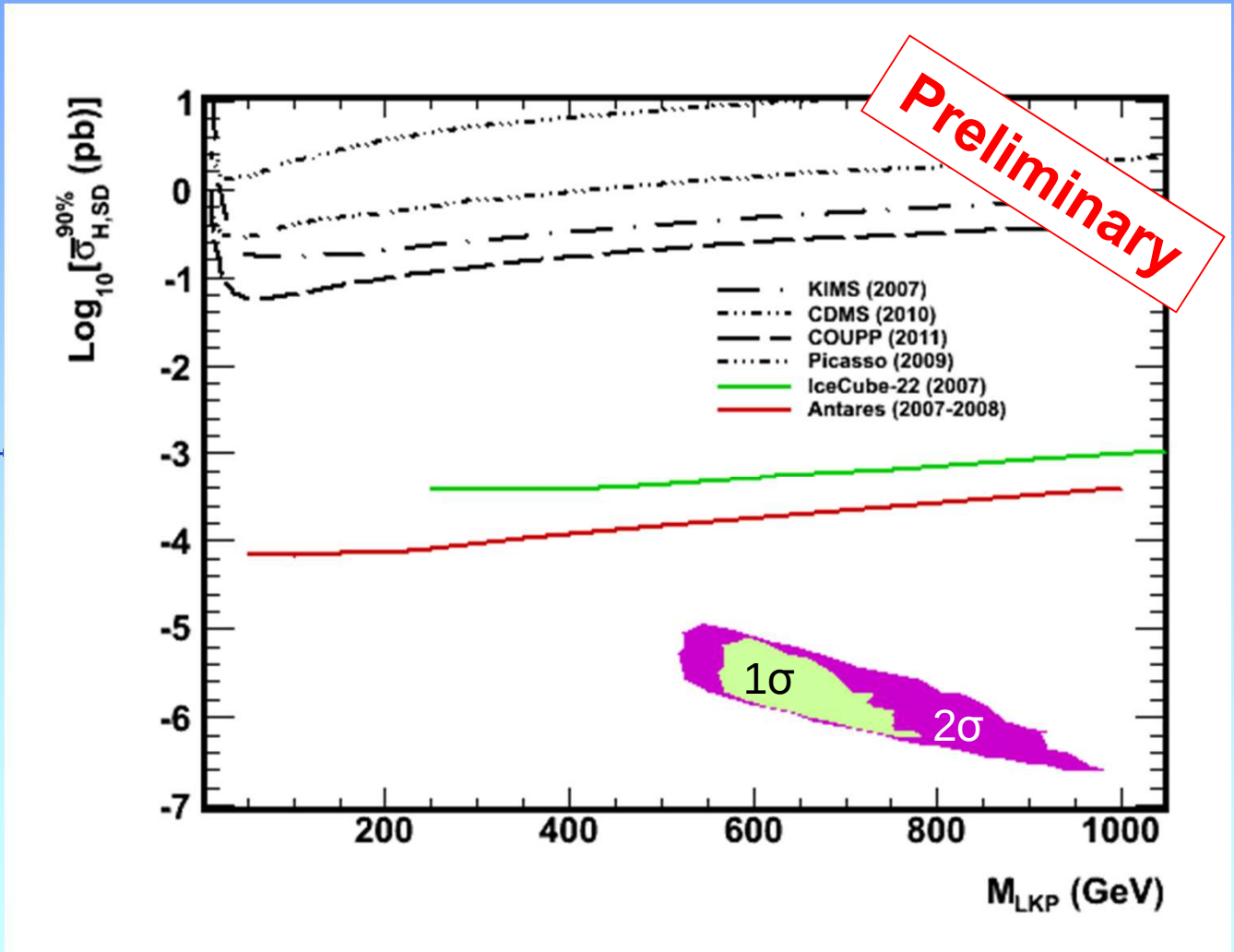


Compare SUSY predictions to observables such as sparticles masses, collider observables, Dark Matter relic density, direct detection cross-sections, …

SuperBayes
(arXiv:1101.3296)

Sensitivity to SD cross-section for mUED

Sensitivity to Spin-Dependent cross-section for ANTARES 2007-2008 data



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

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

Summary and Outlook

- **Indirect search for Dark Matter** is a **major goal** for neutrino telescopes (**important complementarity** to direct detection experiments)

- **Indirect search** towards the **Sun** performed by **ANTARES** within framework of two common Dark Matter models (**CMSSM, mUED**), **unblinding of data** will happen **soon**
- **Study of other sources** (Earth, Galactic Centre, dwarf galaxies…) in **progress** or to **be done**

- Analyses on **2007-2010 data** are in **progress**,
  > 3000 neutrino candidates already collected today !

Stay tuned for the BIG DARK DISCOVERY !!