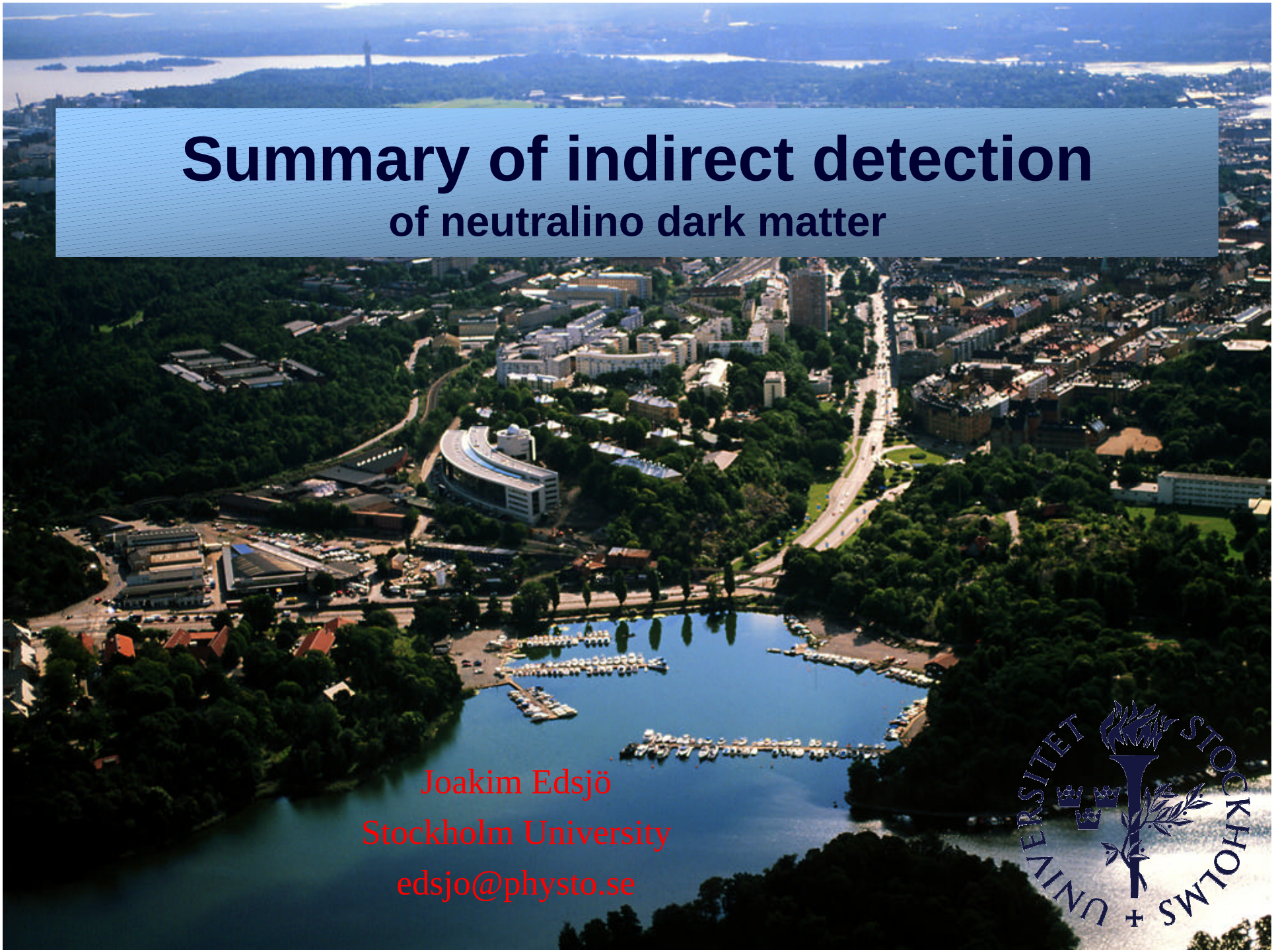
Summary of indirect detection

of neutralino dark matter



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Outline

Will focus on these in the MSSM!

- WIMPs as Dark Matter – Neutralinos
- Indirect detection techniques
- Current direct detection limits and their implications for neutrino telescopes
- Conclusions

The MSSM – general

The Lightest Supersymmetric Particle (LSP)

Usually the neutralino. If R-parity is conserved, it is stable.

The Neutralino – χ

$$\tilde{\chi}_1^0 = N_{11}\tilde{B} + N_{12}\tilde{W}^3 + N_{13}\tilde{H}_1^0 + N_{14}\tilde{H}_2^0$$

Gaugino fraction

$$Z_g = |N_{11}|^2 + |N_{12}|^2$$

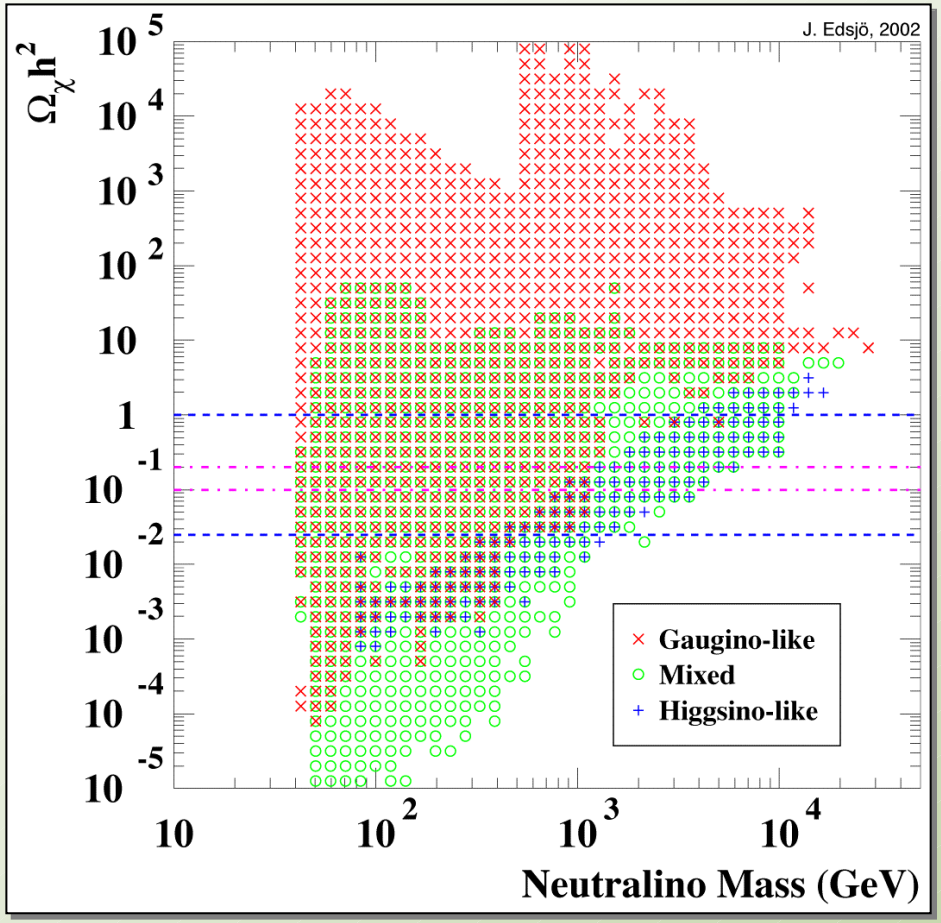
1. Select MSSM parameters
2. Calculate masses, etc
3. Check accelerator constraints
4. Calculate relic density
5. $0.05 < \Omega_\chi h^2 < 0.2$?
6. Calculate fluxes, rates,...

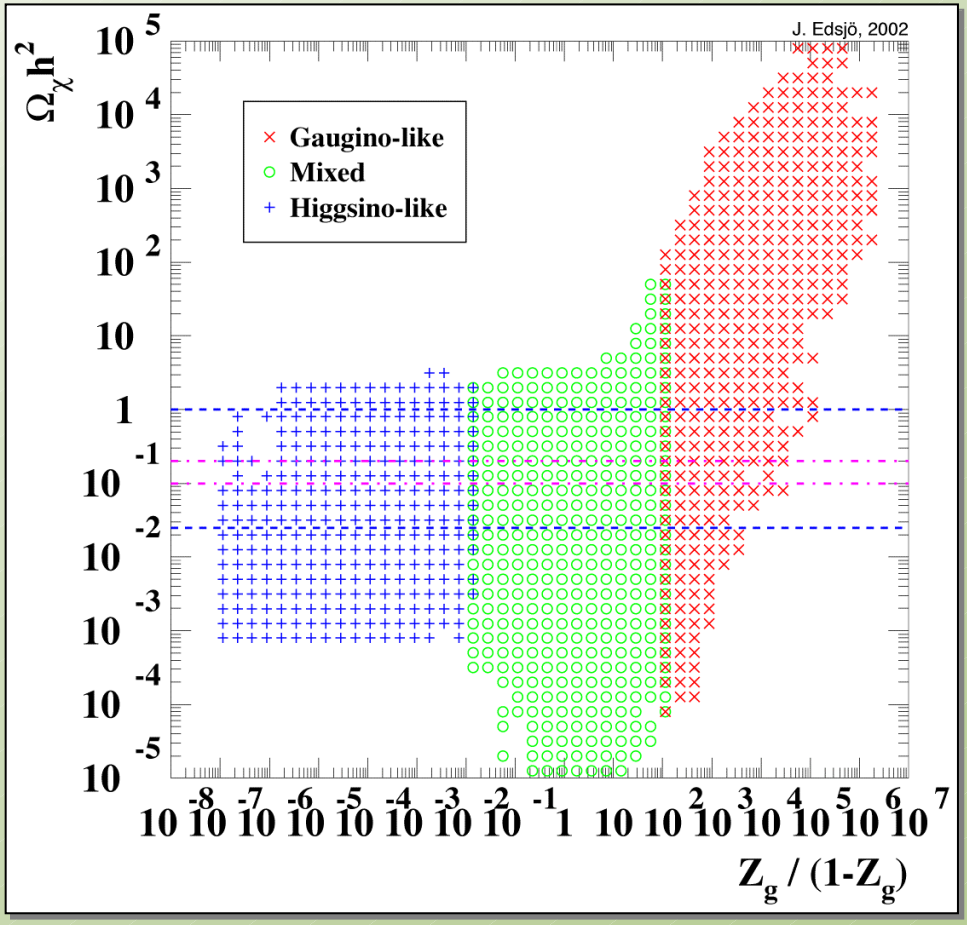
Calculation done with

DarkSUSY

www.physto.se/~edsjo/darksusy/

Relic density vs mass and composition





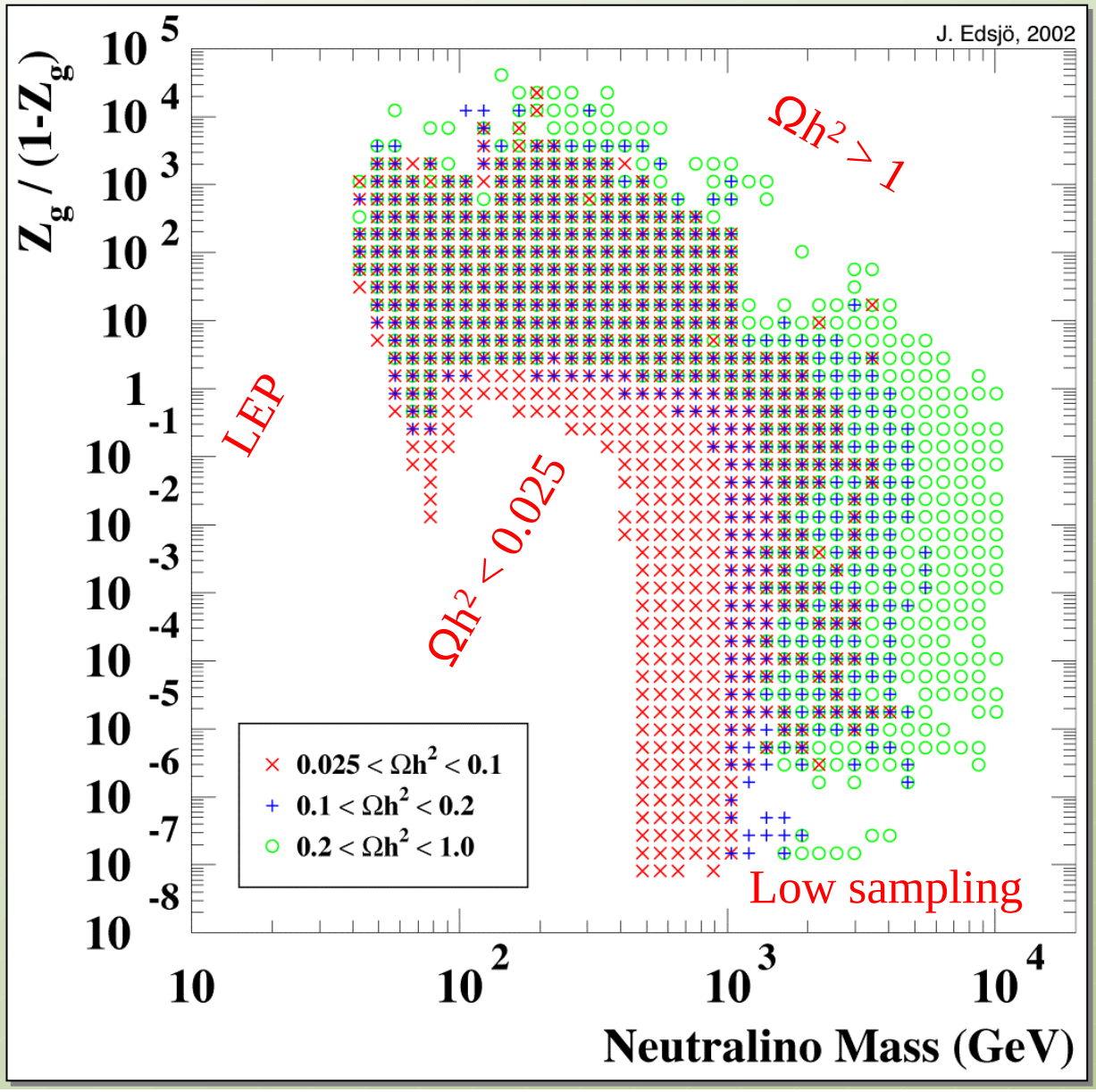
The neutralino is cosmologically interesting for a wide range of masses and compositions!

The m_χ-Z_g parameter space

Gauginos

Mixed

Higgsinos

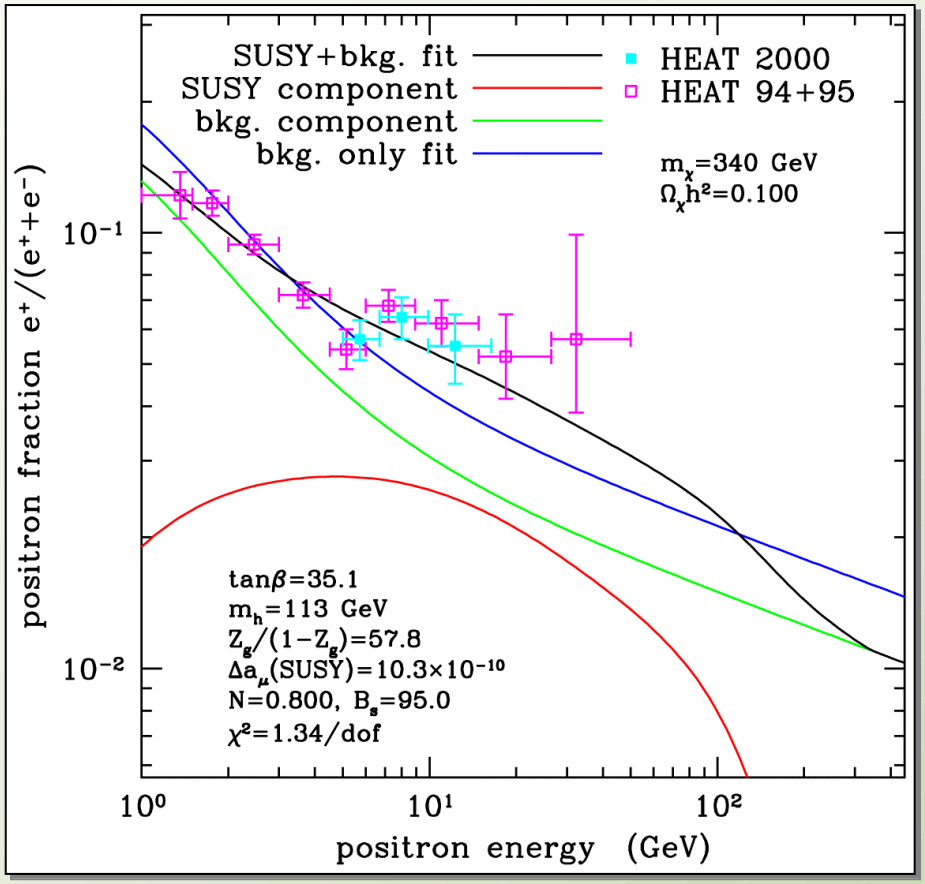


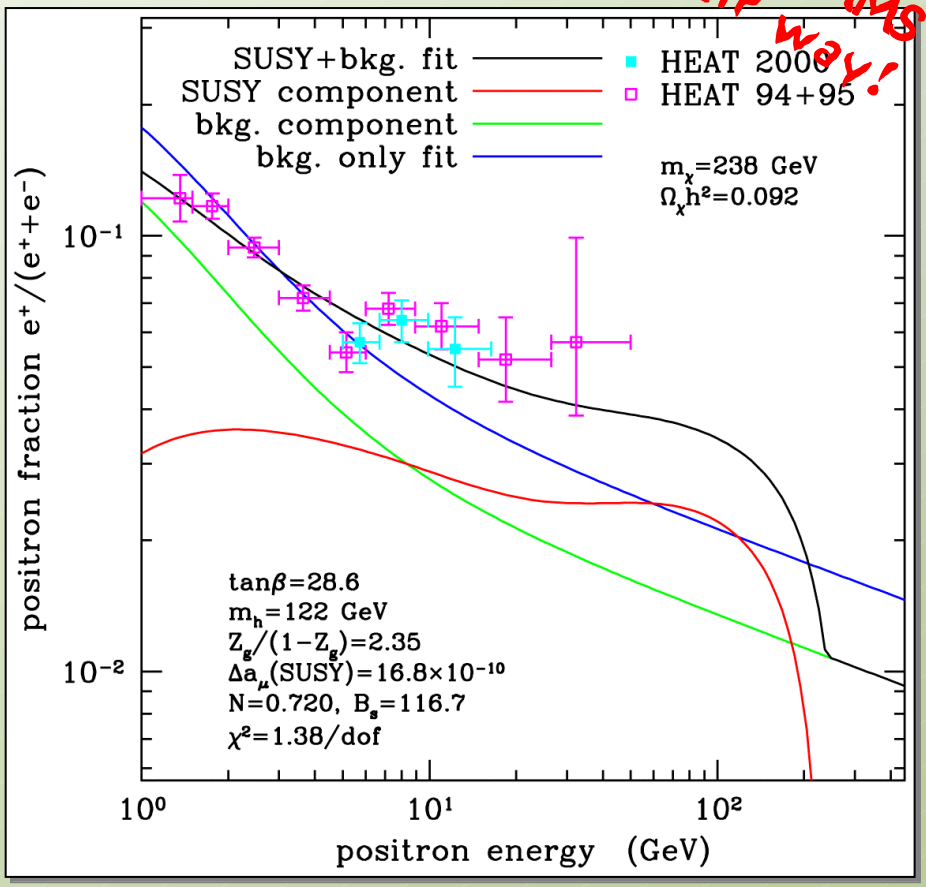
WIMP search strategies

- Direct detection
- Indirect detection:
  - neutrinos from the Earth/Sun
  - antiprotons from the galactic halo
  - positrons from the galactic halo
  - antideutrons from the galactic halo
  - gamma rays from the galactic halo
  - gamma rays from external galaxies/halos
  - synchrotron radiation from the galactic center / galaxy clusters
  - gammas from around the sun
  - ...

Positrons – example spectra

Pamela & AMS on their way!



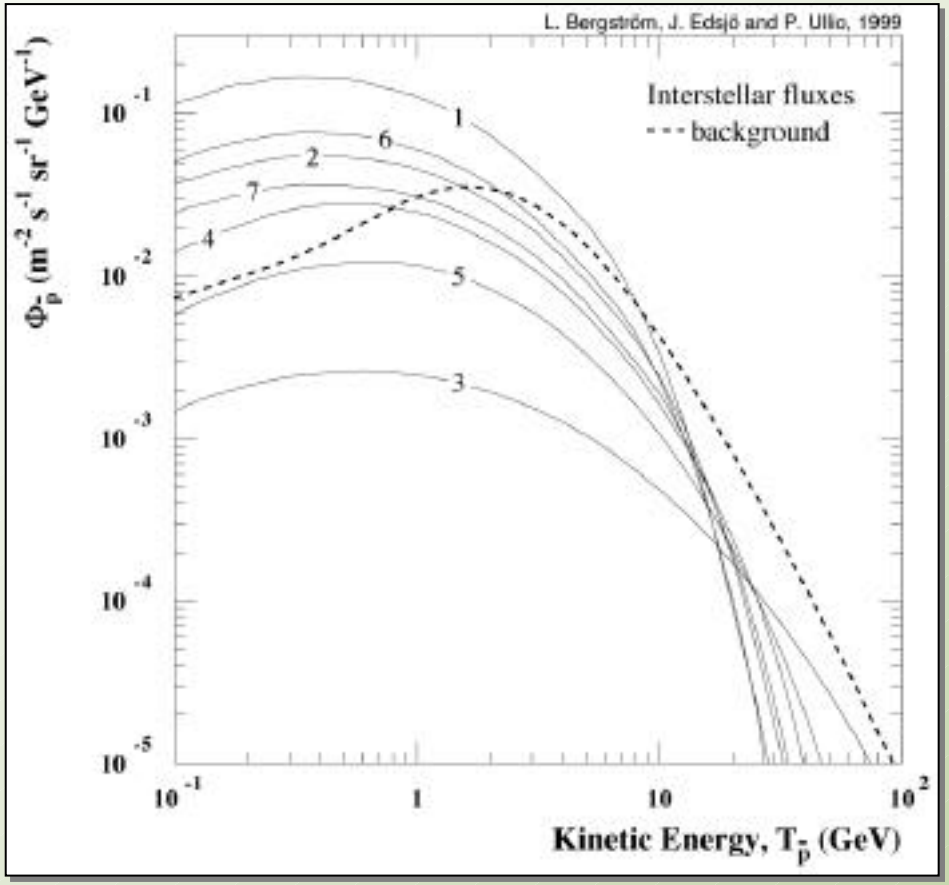


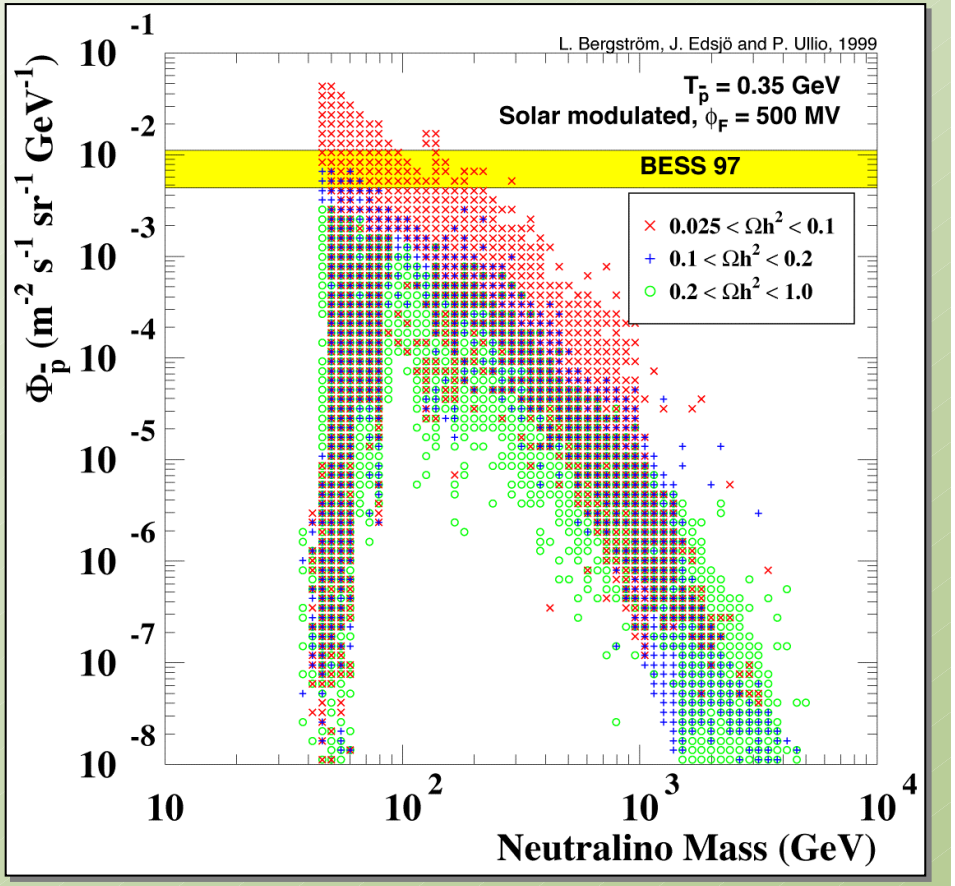
The HEAT feature at ~7 GeV can be fit better with neutralinos than without, *but...*

...the signal strength needs to be boosted, e.g. by clumps,

...and the fit is not perfect

Antiproton signal



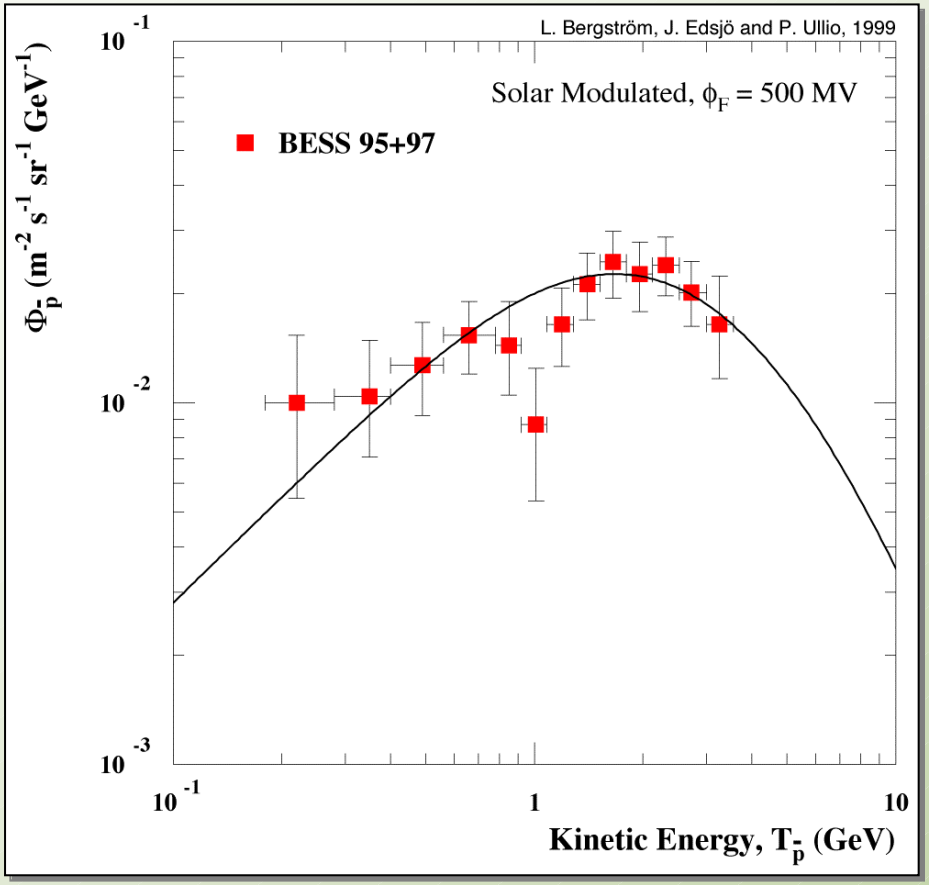


Easy to get high fluxes, but...

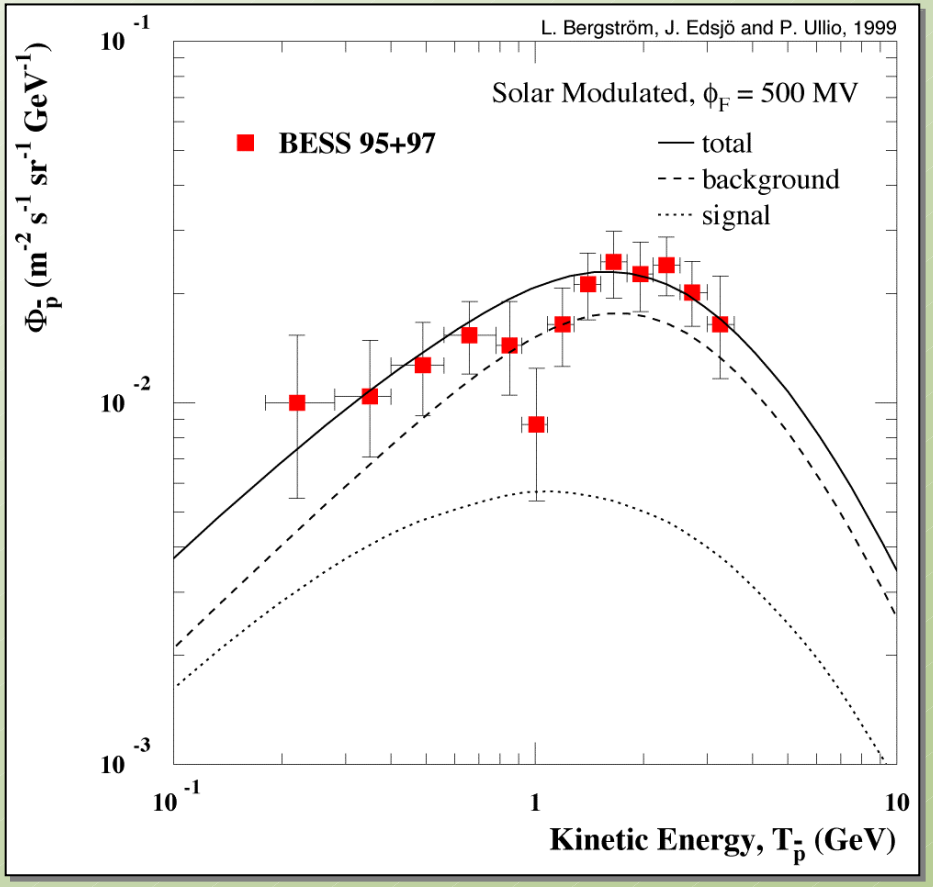
Antiprotons – fits to Bess data

Pamela & AMS on their way!

Background only

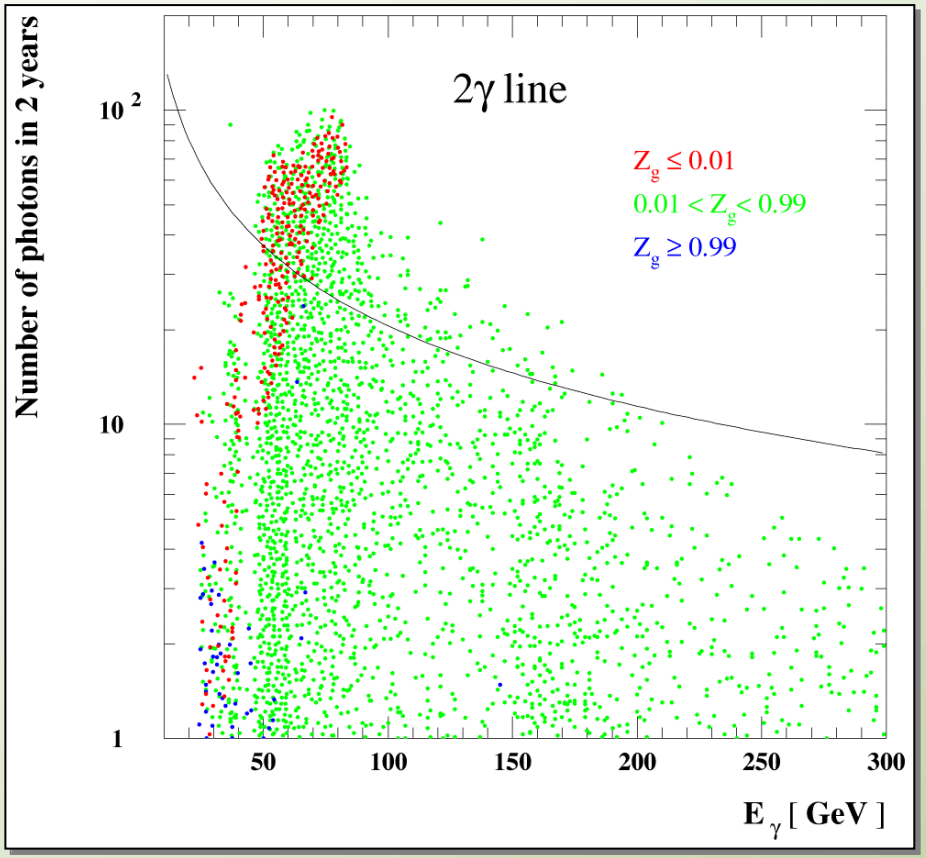


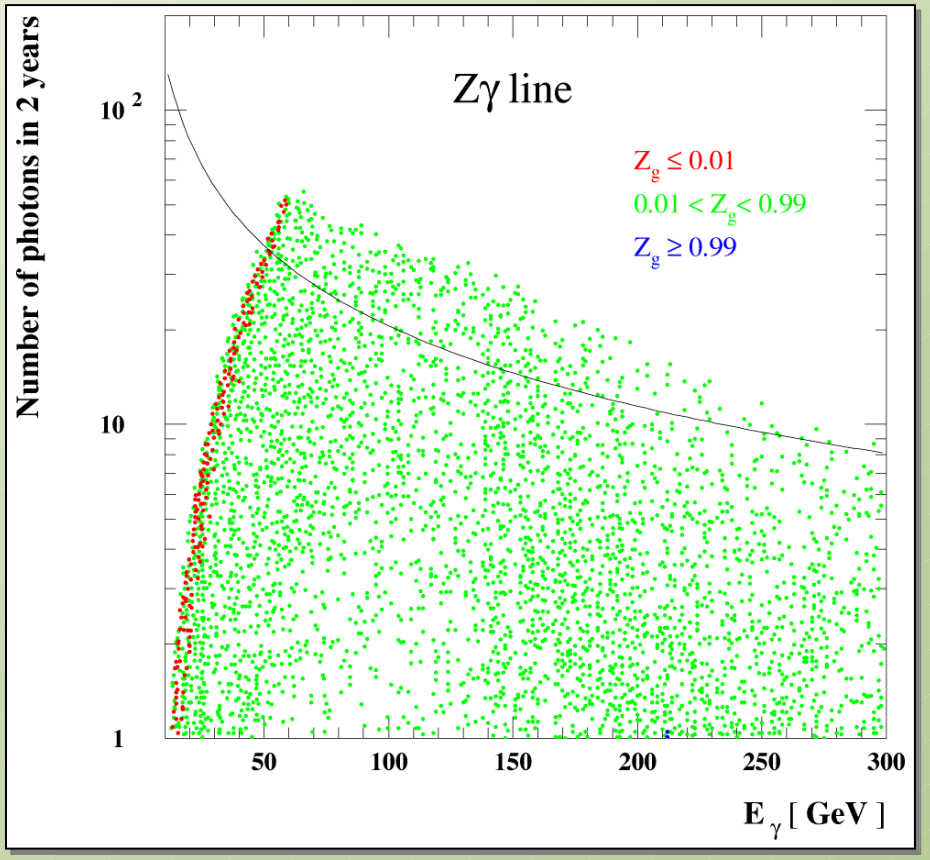
Background + signal



⇒ No need for, but room for a signal.

Gamma lines – rates in GLAST



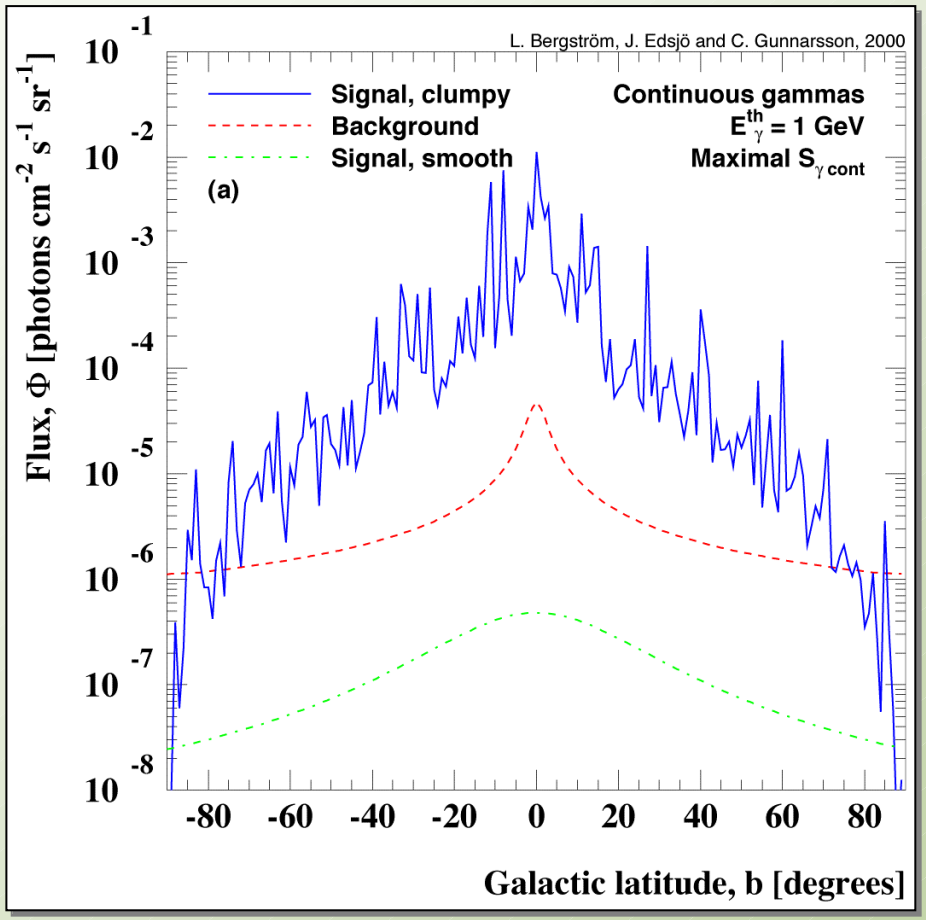


NFW halo profile, $\Delta\Omega \approx 1$ sr

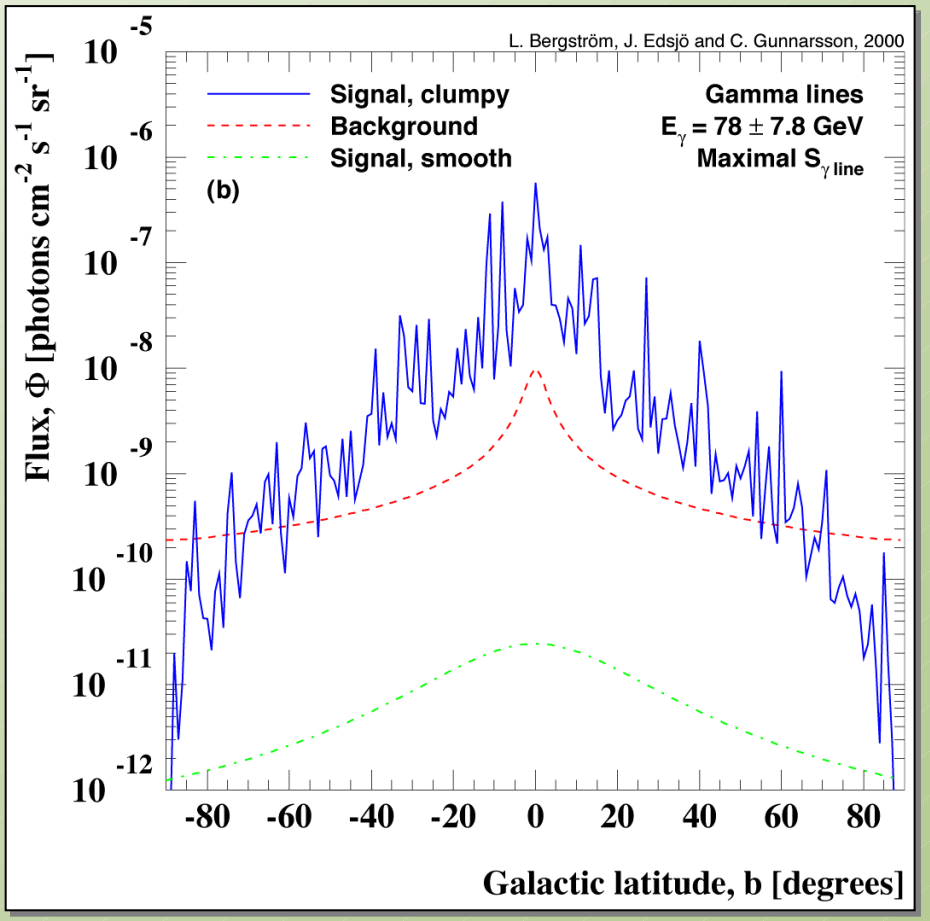
Bergström, Ullio & Buckley, ’97

Gamma fluxes from simulated halo

Continuous gammas



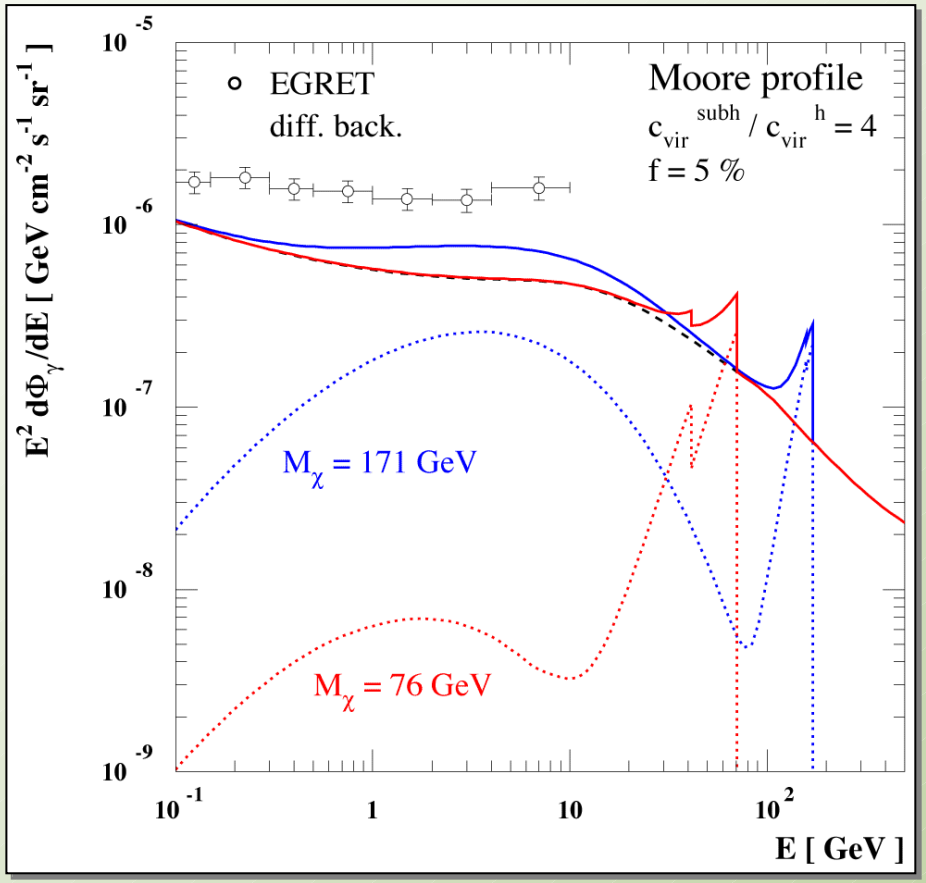
Gamma lines



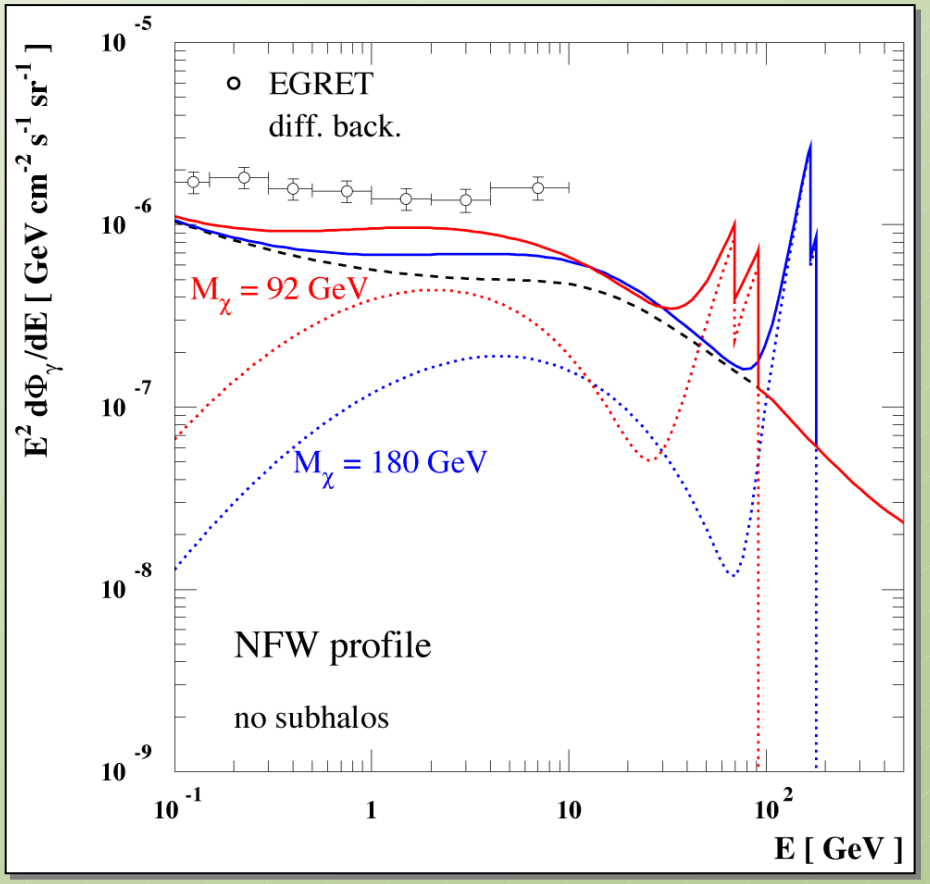
N-body simulations from Calcáneo-Roldan and Moore, Phys. Rev. D62 (2000) 23005.

Cosmological gamma rays

Thermal production



Non-thermal production



Ullio, Bergström, Edsjö & Lacey, astro-ph/0207125

Edelweiss June 2002

LYCEN 2002-31
June 14th, 2002

Improved Exclusion Limits from the EDELWEISS WIMP Search

The EDELWEISS Collaboration:
A. Benoît[1], L. Bergé[2], A. Broniatowski[2], L. Chabert[1], B. Chambon[3], M. Chapellier[4], G. Chardin[5], P. Charvin[5,6], M. De Jésus[3], P. Di Stefano[2], D. Drain[3], L. Dumoulin[2], J. Gascon[3], G. Gerbier[3], E. Gerlic[3], C. Goldbach[7], M. Goyot[4], M. Gros[5], J.P. Hadjout[4], S. Hervé[5], A. [illegible], A. de Lesquen[5], M. Loidl[5], J. Mallet[5], S. Marnieros[2], O. Martin[illegible], N. Mirabolfathi[2], L. Mosca[5,6], X.-F. Navick[5], G. Nollez[7], P. P[illegible], C. Riccio[5,6], V. Sanglard[3], M. Stern[3], L. Vagneron[3]

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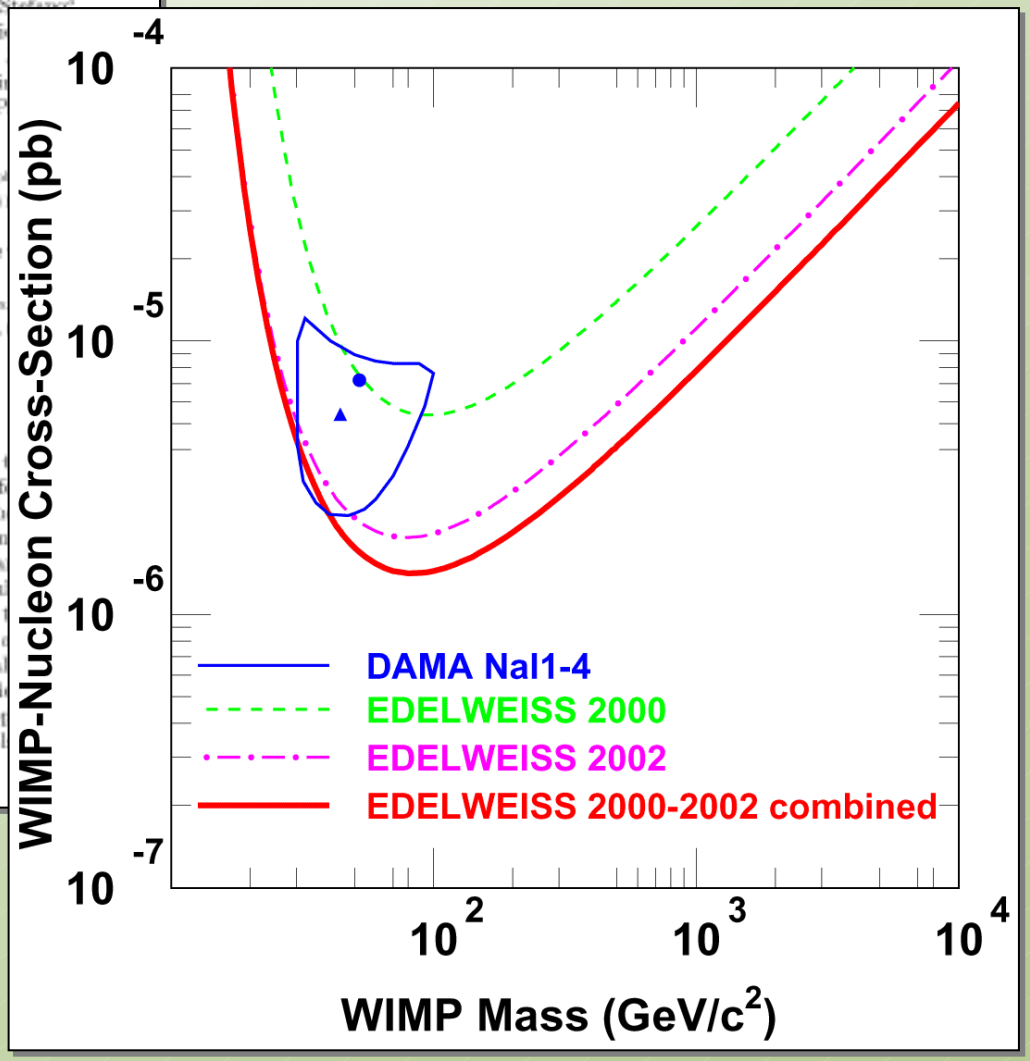
[4]CEA, Centre d'Études Nucléaires de Saclay, DSM/DIRECAM, 91191 Gif-sur-Yvette Cedex
[5]CEA, Centre d'Études Nucléaires de Saclay, DSM/DAPNIA, 91191 Gif-sur-Yvette Cedex,
[6]Laboratoire Souterrain de Modane, CEA-CNRS, 90 rue Polset, 73500 Modane, France
[7]Institut d'Astrophysique de Paris, INSU-CNRS, 98 bis Bd Arago, 75014 Paris, France

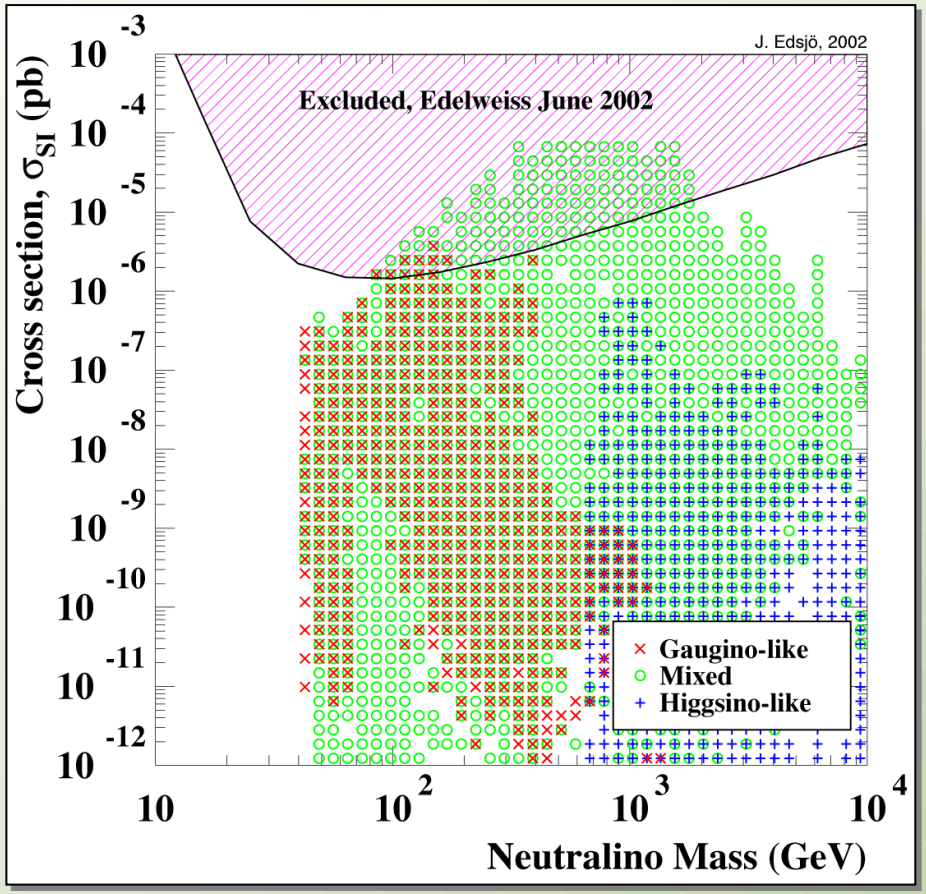
Abstract

The EDELWEISS experiment has improved its sensitivity for t[illegible] search for WIMP dark matter. In the recoil energy range relevant f[illegible] masses below 10 TeV/c^2, no nuclear recoils were observed in th[illegible] volume of a heat-and-ionization cryogenic Ge detector operated in [illegible] background environment of the Laboratoire Souterrain de Modane, Fréjus Tunnel, during an effective exposure of 7.4 kg·d. This resul[illegible] bined with the previous EDELWEISS data to derive a limit on t[illegible] section for spin-independent interaction of WIMPs and nucleons as [illegible] of WIMP mass, using standard nuclear physics and astrophysical [illegible] tions. This limit excludes at more than 99.8%CL a WIMP candi[illegible] a mass of 44 GeV/c^2 and a cross-section of 5.4×10^{-6} pb, as rep[illegible] the DAMA collaboration. A first sample of supersymmetric model[illegible] excluded at 90%CL.

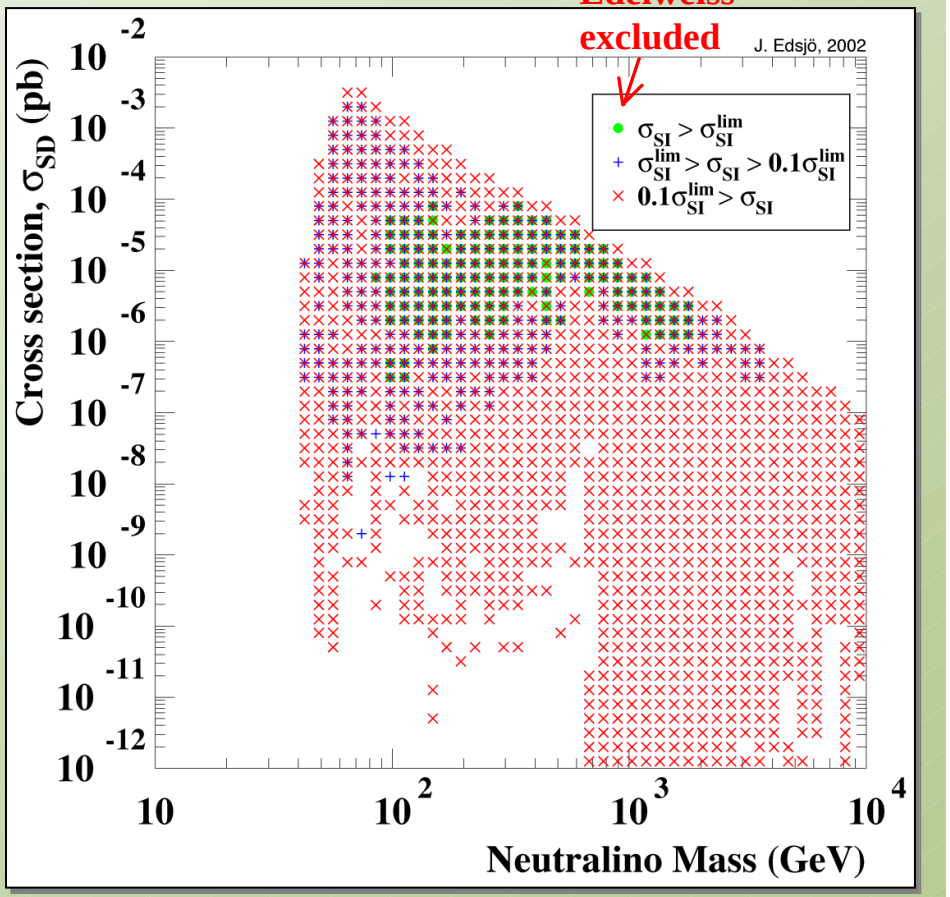


Direct detection – current limits

Spin-independent scattering



Spin-dependent scattering

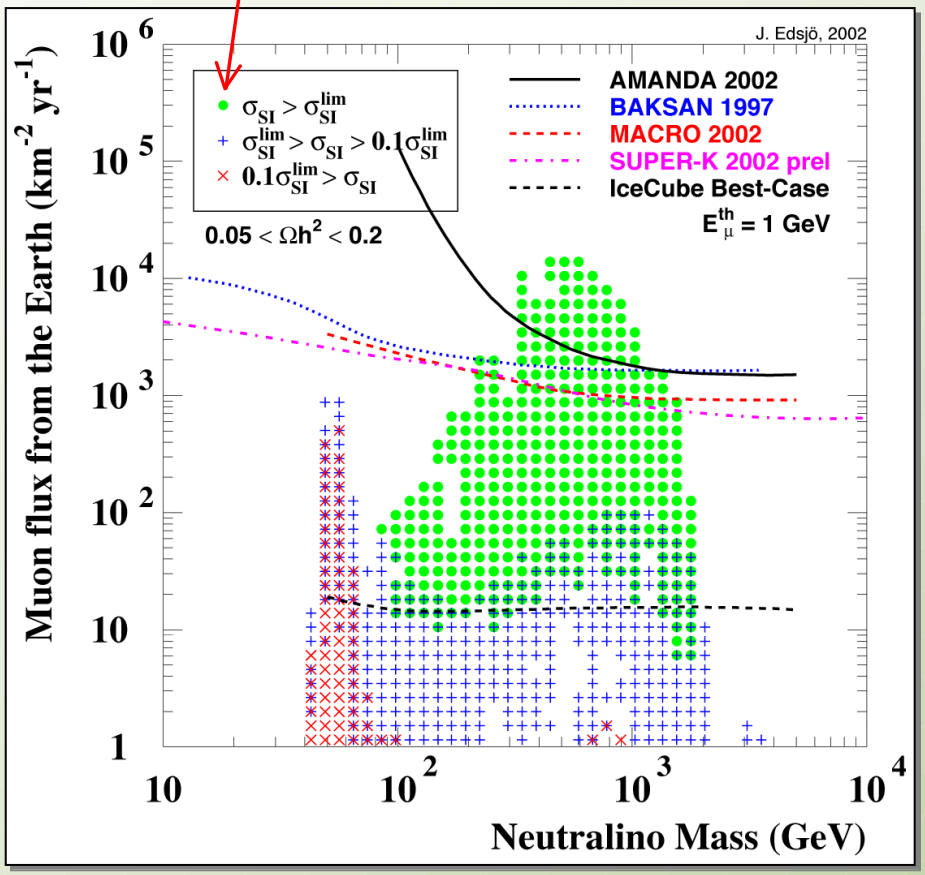


Direct detection experiments have started exploring the MSSM parameter space!

Limits: μ flux from the Earth/Sun

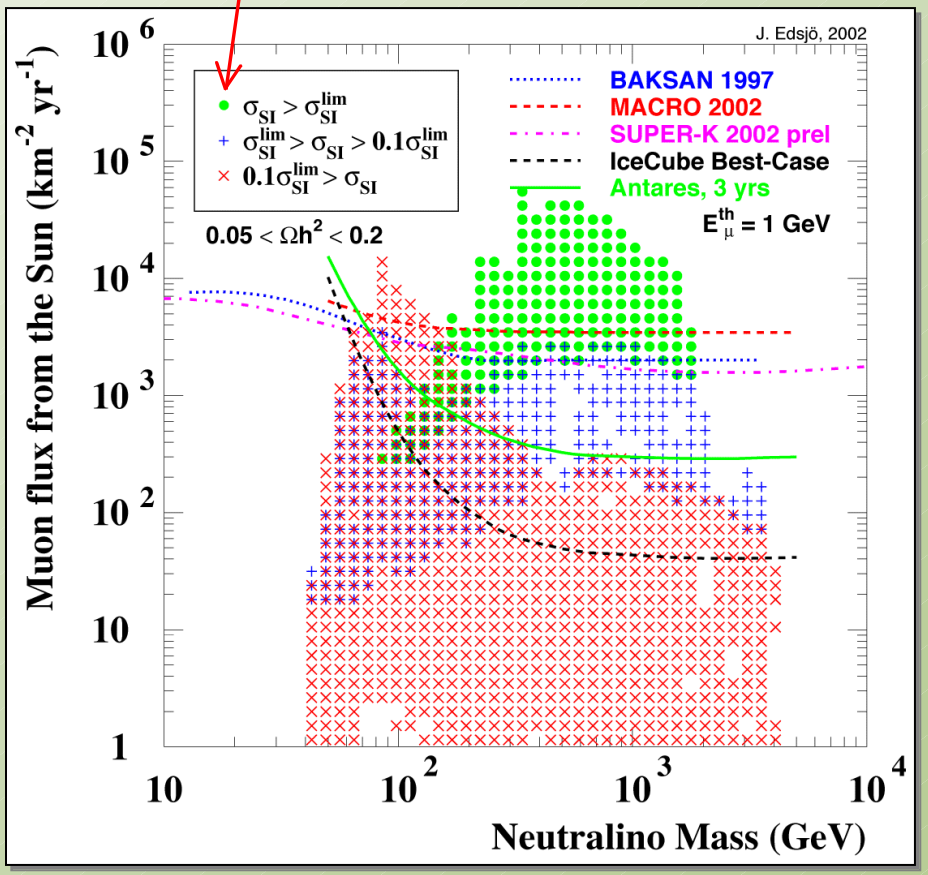
Edelweiss excluded

Earth



Edelweiss excluded

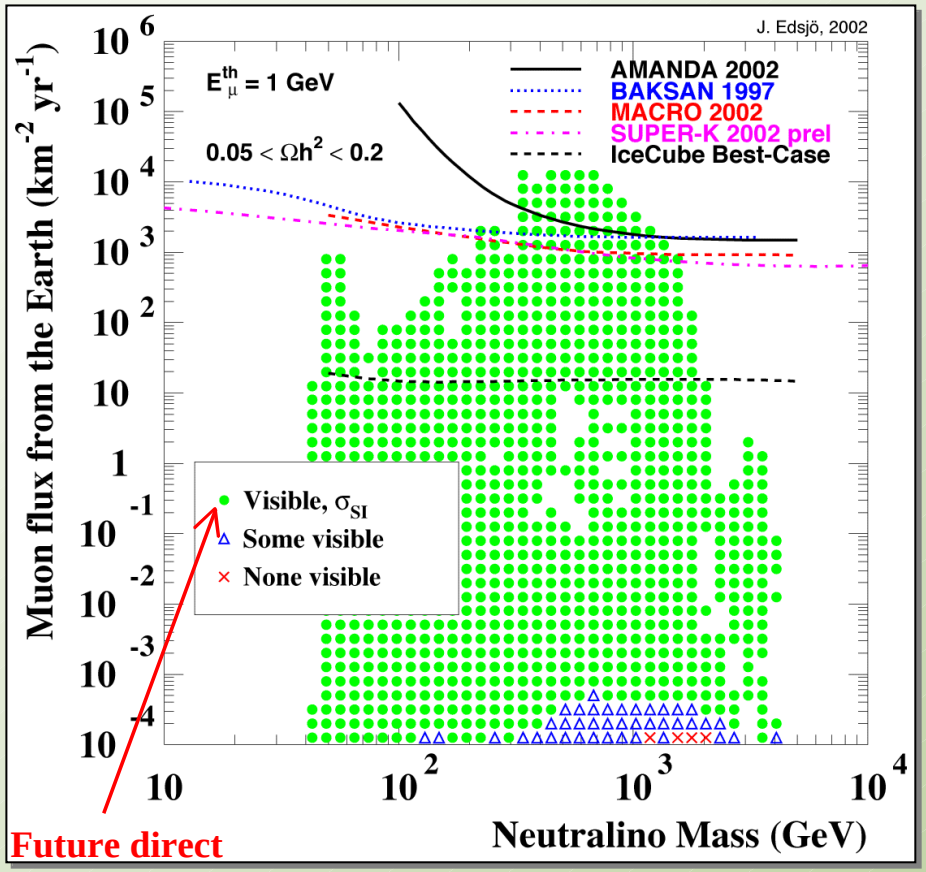
Sun



- Super-K limit from Shantanu Desai's talk yesterday, converted to full flux with 1 GeV threshold
- Macro limit from Ivan de Mitri's talk yesterday, converted to a Φ_μ limit (hard spectrum, 1 GeV threshold)
- Antares expected 3 yrs limits from Susan Cartwright's talk yesterday (hard, conv. to 1 GeV threshold)

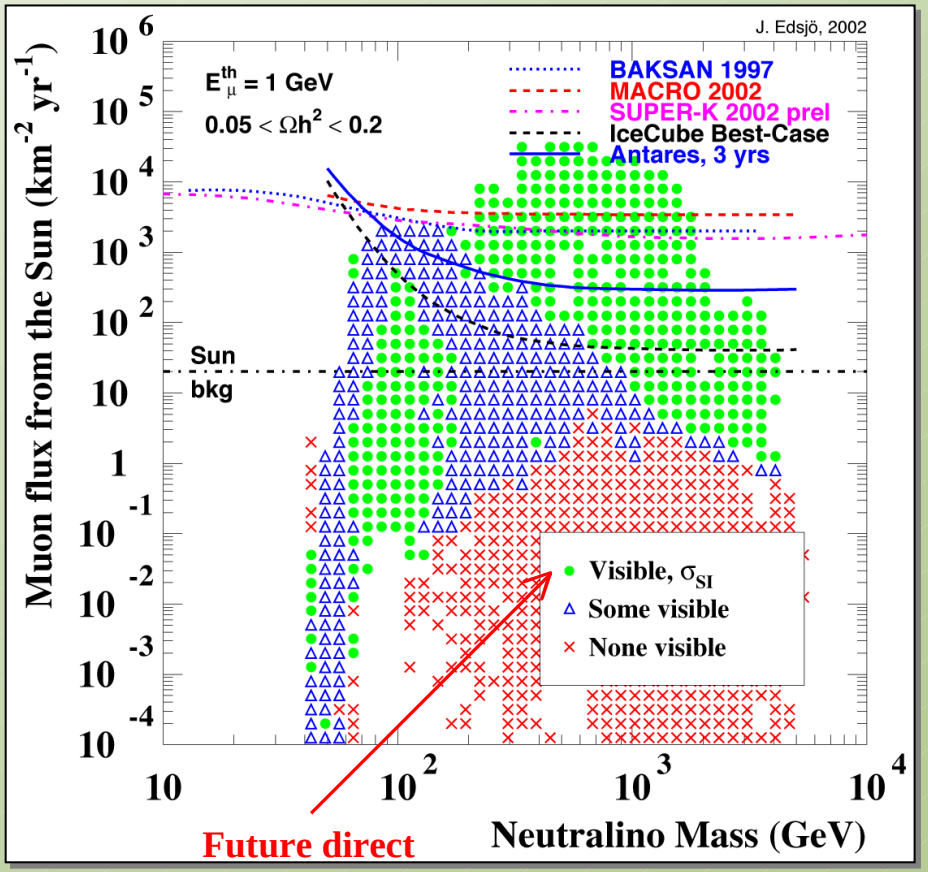
Flux from Earth/Sun and future direct detection limits

Earth



Future direct detection exps.

Sun



Future direct detection exps.

Comparing different searches

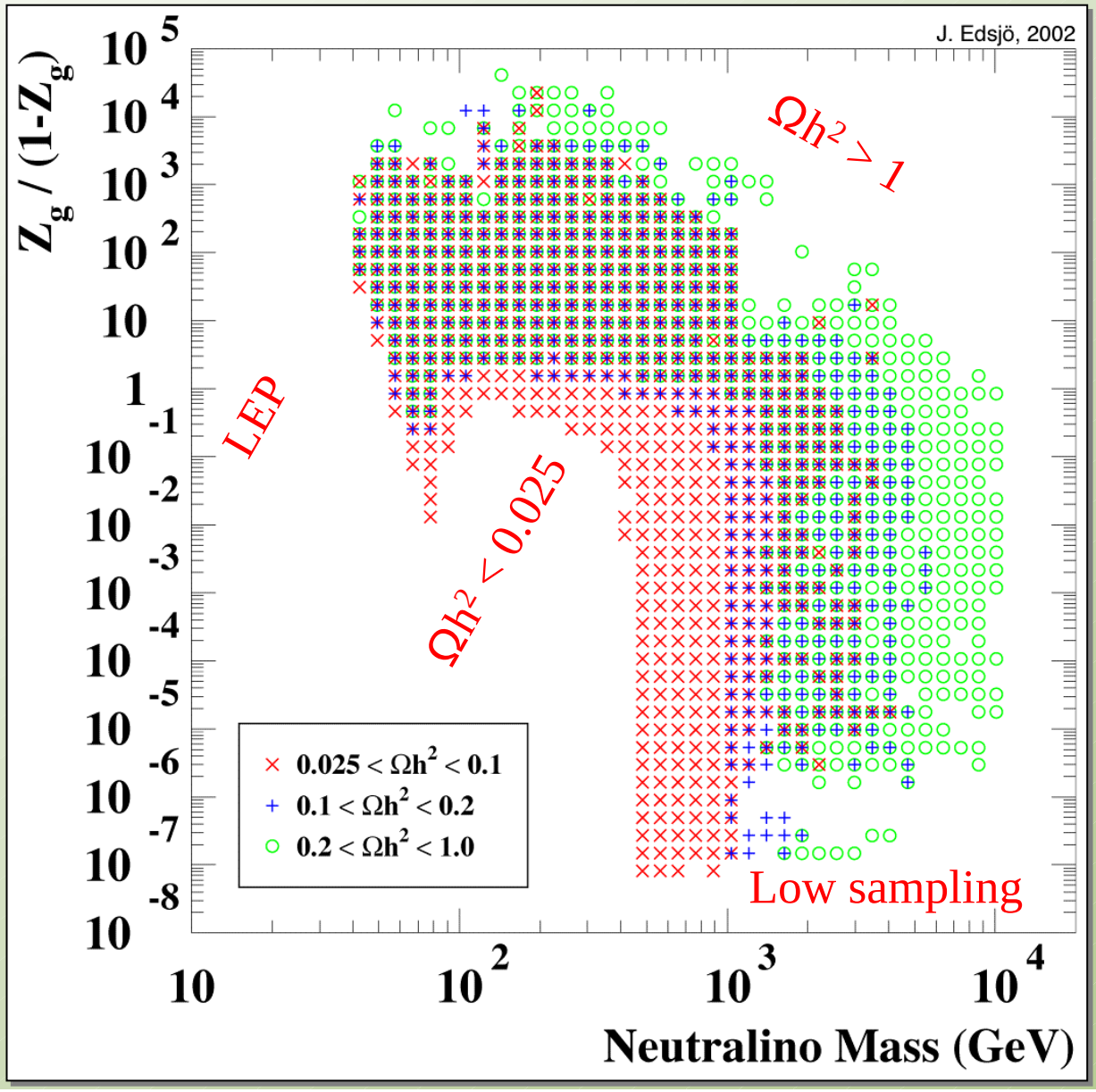
- Take all future searches with expected sensitivities within the coming 5–10 years.
- Determine which areas in the m_{χ}-Z_g parameter space they can explore.
- Compare!

The m_χ-Z_g parameter space

Gauginos

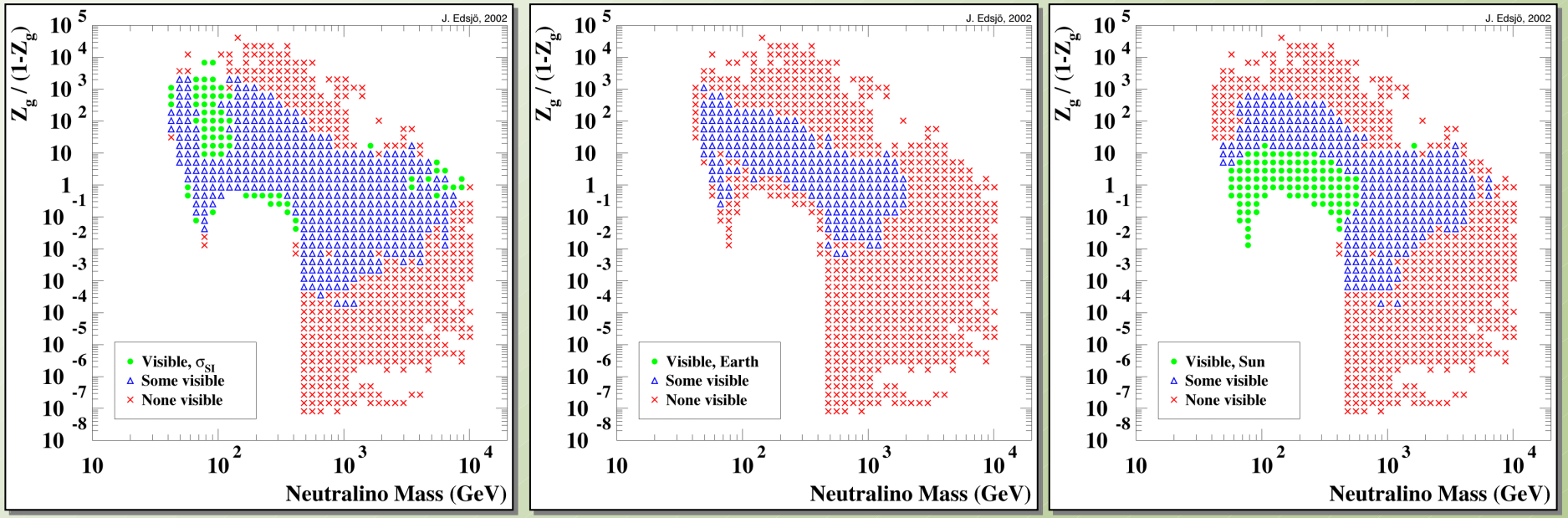
Mixed

Higgsinos



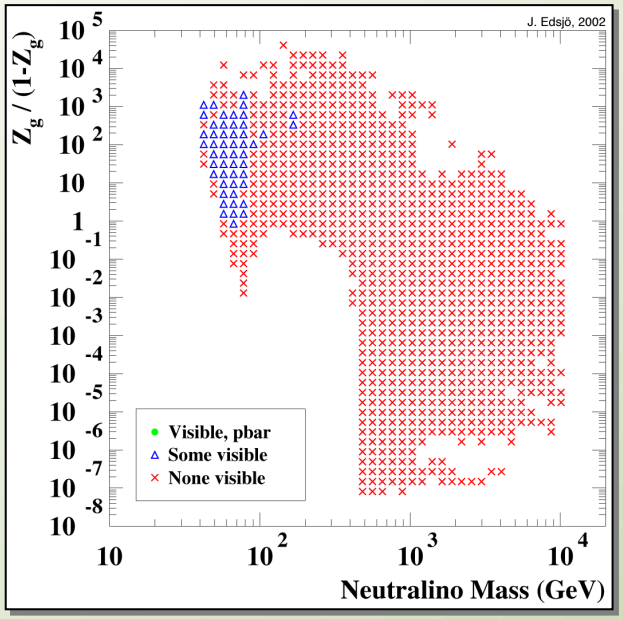
MSSM parameter space
Future probed regions I

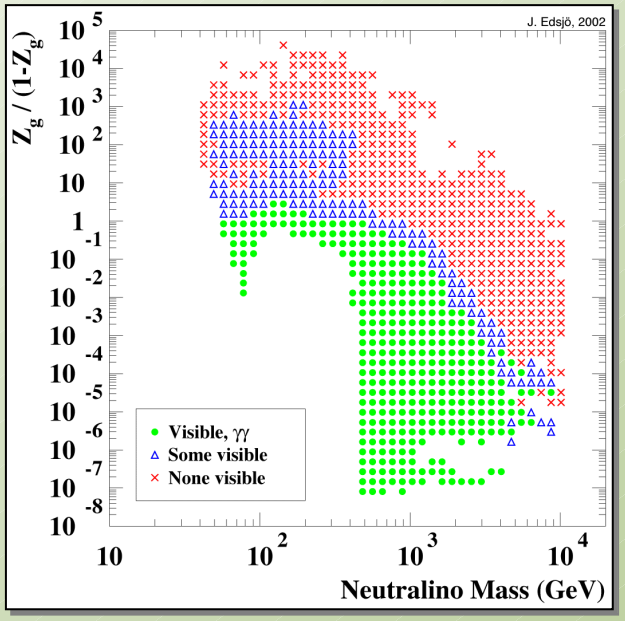
Direct detection | **Earth, km³** | **Sun, km³**

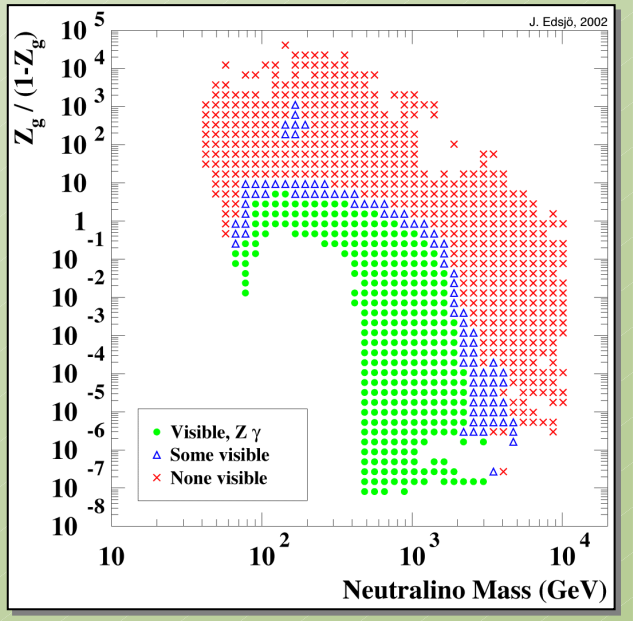


MSSM parameter space
Future probed regions II

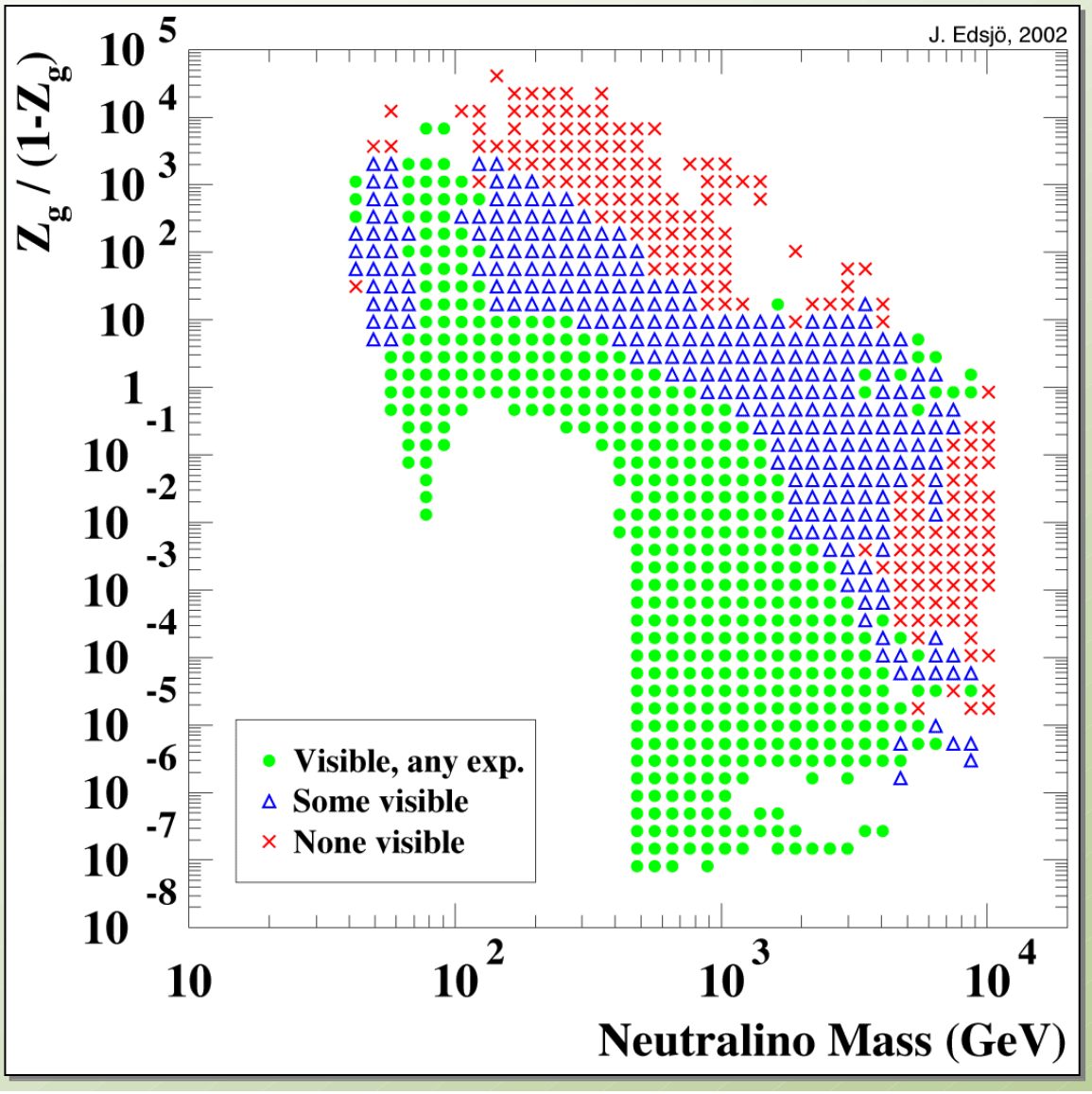
Antiprotons $\gamma\gamma$ $Z\gamma$







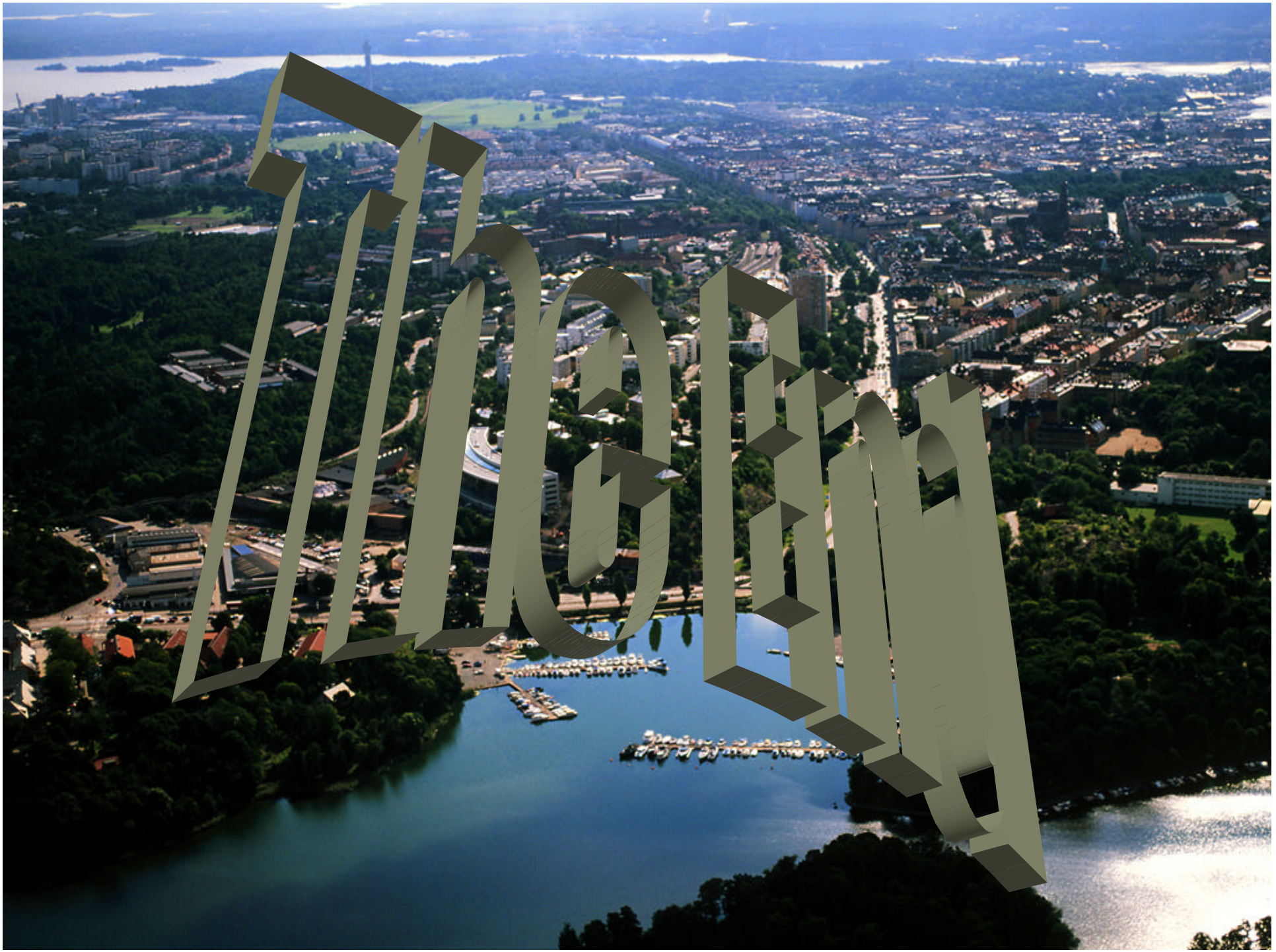
MSSM parameter space
All dark matter searches combined



Large parts of the parameter space can be probed by future searches.

Conclusions

- Many indirect searches on the way, some have started exploring the MSSM parameter space.
- **Antiprotons:** easy to get high rates and fit the spectrum, but no special features unless for heavy WIMPs and large boost factors.
- **Antideutrons:** The signal is low, but there seems to be a window < 1 GeV where the background is low.
- **Positrons:** intriguing positron excess in HEAT, Caprice and MASS 91 data. Fits are better with neutralinos with a boosted signal, but the fits are not perfect.
- **Neutrino telescopes:** Complementarity with direct searches for the Sun.
- **Gamma lines:** very nice feature, but signal model dependent. Cosmological gammas may be detectable by GLAST.
- **Spike at GC:** Signal can be high, if the cusp is steep enough and the black hole formation history is favourable.


Tiberim