Impact of indirect detection searches on direct searches

Piero Ullio
SISSA & INFN (Trieste)

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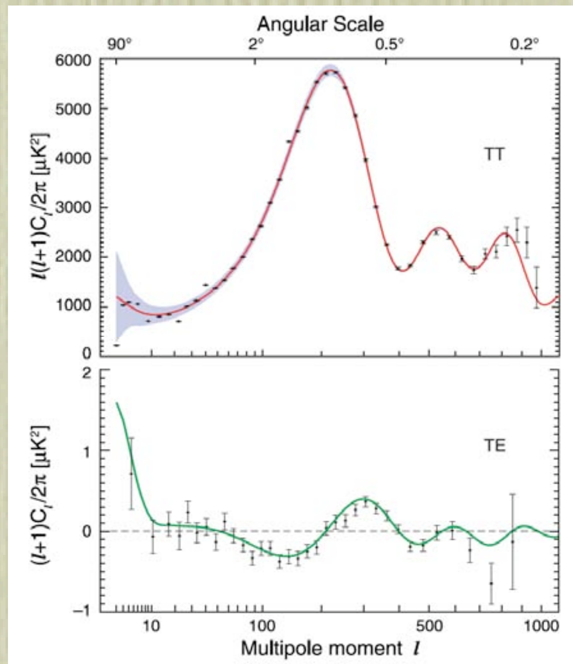
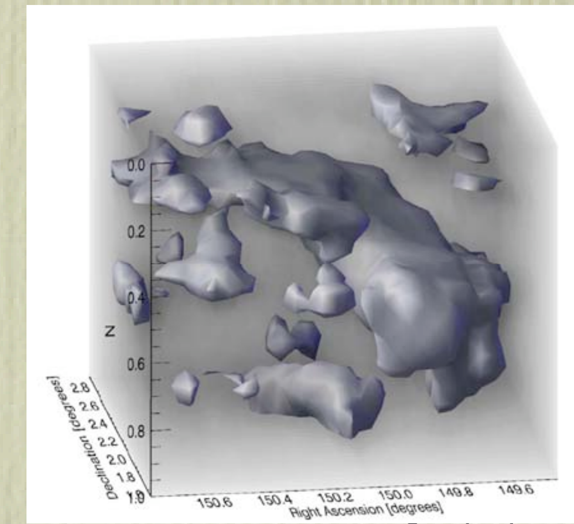
Outline:

- The appeal of the thermal relic picture (or slight variants) as a framework for the generation of the dark matter component.
- WIMP interactions with ordinary matter: model independent approaches and their limitations.
- Neutrino telescope searches and their complementarity with direct detection.
- Halo annihilation signals: antiproton upper limits and antideuteron detection perspectives; the cosmic lepton puzzle and picture in gamma-rays.
- The cross-correlation among DM signals as route to DM detection.

Overwhelming evidence for CDM as building block of all structures in the Universe, from the largest scales down to galactic dynamics:

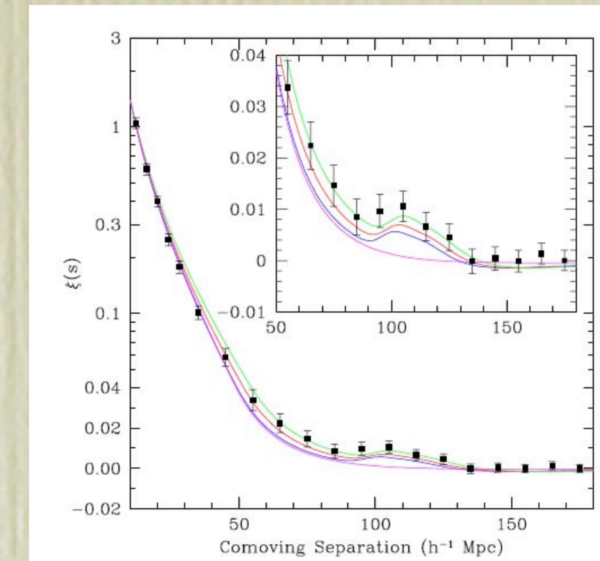


CMB

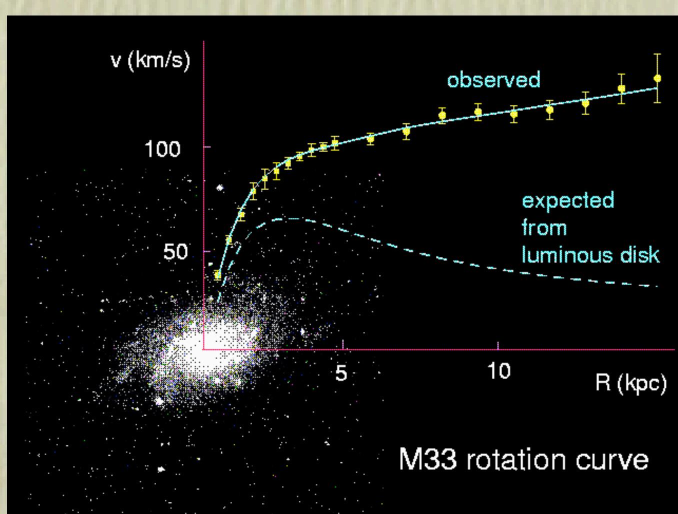


grav. scaffold

galaxy clusters



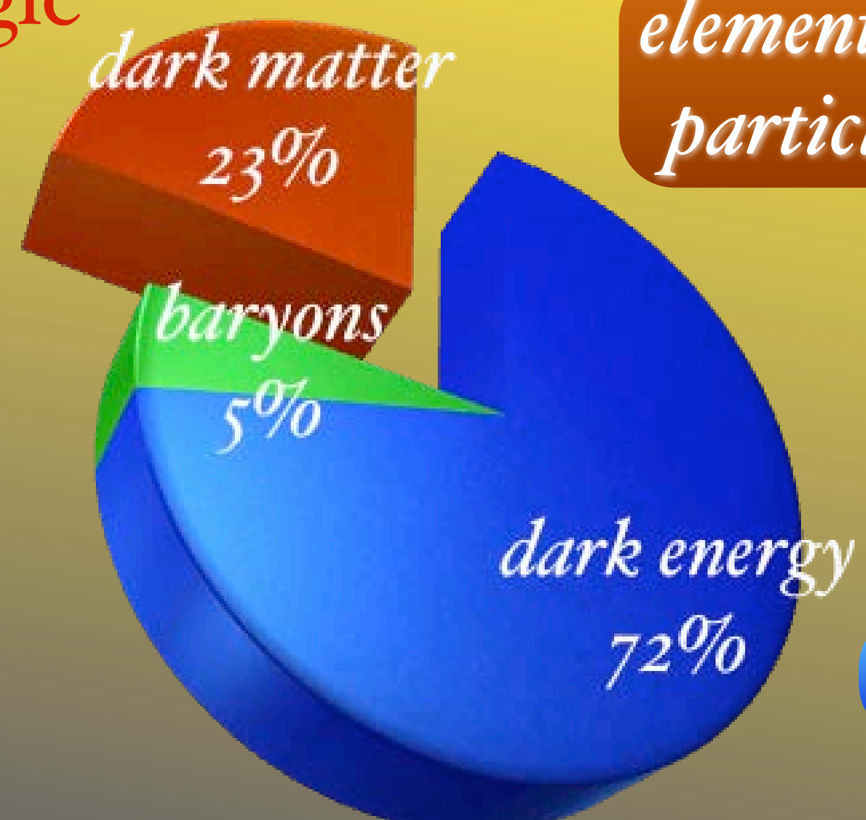
BAO



galaxies

+ many others:

All point to a single "concordance" model (assuming GR as the theory of gravity):



elementary particles?

???

Cosmological and astrophysical observations suggest that dark matter is: an optically-dark (i.e. dissipation-less), collision-less, classical fluid with negligible free-streaming effects. This excludes some models, such as, e.g., baryonic DM and hot DM (e.g. SM neutrinos).

From the cosmologist perspective, Non-baryonic Cold DM is the preferred paradigm (i.e., for DM only gravity matters). Not helping much the particle physicist: there are only (weak) upper limits on the DM interaction strength, while other crucial properties (e.g., the mass scale) are missing.

The picture becomes slightly more focussed addressing the question: How was DM generated? The most beaten paths have been:

i) DM as a ***thermal relic product*** (or in connection to thermally produced species);
ii) DM as a ***condensate***, maybe at a phase transition; this usually leads to very light scalar fields;
iii) DM ***generated at large T***, most often at the end of (soon after, soon before) inflation; candidates in this scheme are usually supermassive.

Example of case (ii): axion dark matter; or of case (iii): Wimpzillas. Their phenomenology depends critically on the specific DM scenarios.

CDM particles as thermal relics

Let χ be a stable particle, with mass M_χ, carrying a non-zero charge under the SM gauge group. Processes changing its number density are:

$$\chi\bar{\chi} \leftrightarrow P\bar{P}$$

with P some (lighter) SM state in thermal equilibrium. The evolution of the number density is described by the Boltzmann equation:

$$\frac{dn_\chi}{dt} + 3Hn_\chi = -\langle\sigma_A v\rangle_T \left[(n_\chi)^2 - (n_\chi^{eq})^2\right]$$

dilution by Universe expansion

thermally averaged annihilation cross section

$P\bar{P} \rightarrow \chi\bar{\chi}$

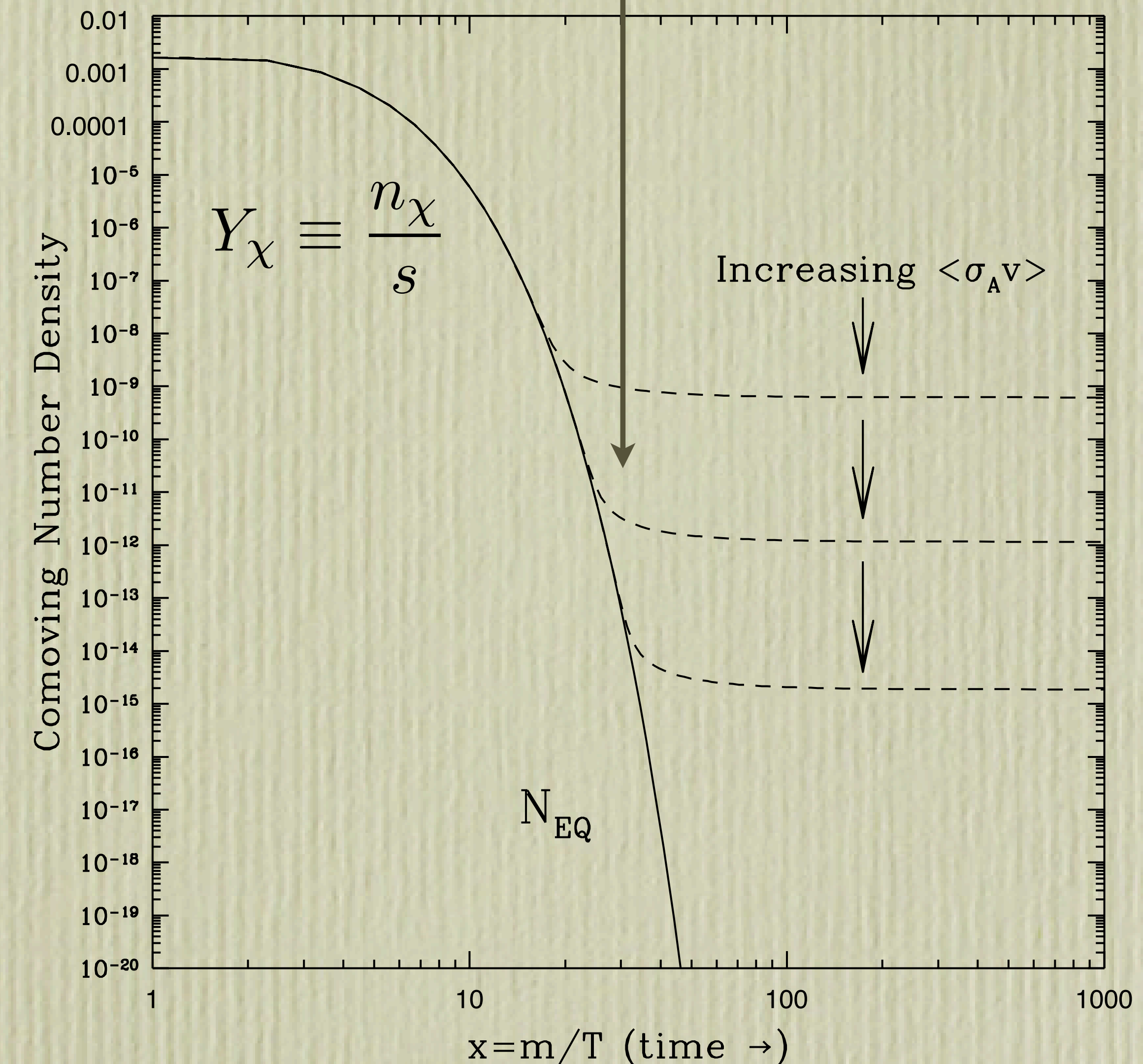
$\chi\bar{\chi} \rightarrow P\bar{P}$

χ in thermal equilibrium down to the freeze-out T_f , given, as a rule of thumb, by:

$$\Gamma(T_f) = n_\chi^{eq}(T_f)\langle\sigma_A v\rangle_{T=T_f} \simeq H(T_f)$$

After freeze-out, when $\Gamma \ll H$, the number density per comoving volume becomes constant. For a species which is non-relativistic at freeze-out:

$$\Gamma(T_f) \simeq H(T_f)$$



$$\Omega_\chi h^2 \simeq \frac{M_\chi\, s_0\, Y_\chi^{eq}(T_f)}{\rho_c/h^2}$$

(freeze-out + entropy conservation)

$$\simeq \frac{M_\chi\, s_0}{\rho_c/h^2}\, \frac{H(T_f)}{s(T_f)\langle\sigma_A v\rangle_{T_f}}$$

(standard rad. dominated cosmology)

$$\simeq \frac{M_\chi}{T_f}\, \frac{g_\chi^\star}{g_{\rm eff}}\, \frac{1\cdot 10^{-27}{\rm cm}^{-3}{\rm s}^{-1}}{\langle\sigma_A v\rangle_{T=T_f}}$$

with: $M_\chi/T_f \sim 20$

$$\Omega_\chi h^2 \simeq \frac{3\cdot 10^{-27}{\rm cm}^{-3}{\rm s}^{-1}}{\langle\sigma_A v\rangle_{T=T_f}}$$ → WIMP

The WIMP recipe to embed a dark matter candidate in a SM extension: foresee an extra particle χ that is stable (or with lifetime exceeding the age of the Universe), massive (non-relativistic at freeze-out) and weakly interacting.

WIMP dark matter candidates:

A simple recipe in which, maybe, the most delicate point is the requirement of stability. You can enforce it via a discrete symmetry:

- R-parity in SUSY models
- KK-parity in Universal Extra Dimension models (Servant & Tait, hep-ph/0206071)
- T-parity in Little Higgs models (Bickedal et al., hep-ph/0603077)
- Z_2 symmetry in a 2 Higgs doublet SM extension (the "Inert doublet model", Barbieri et al. hep-ph/0603188)
- Mirror symmetry in 5D models with gauge-Higgs unification (Serone et al., hep-ph/0612286)
- ...

or via an accidental symmetry, such as a quantum number preventing the decay: [Mirror DM], [DM in technicolor theories] (Gudnason et al., hep-ph/0608055), "minimal" DM (Cirelli et al., hep-ph/0512090) , ...

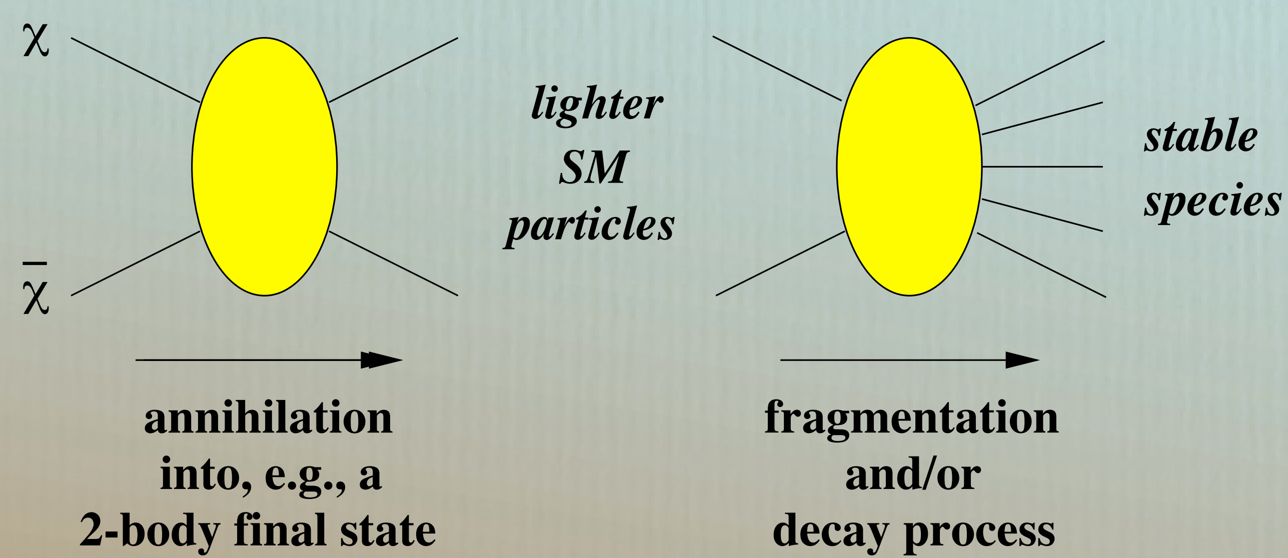
In most of these, DM appears as a by-product from a property considered to understand or protect other features of the theory.

Incomplete list of models and very incomplete list of references!

Indirect detection of WIMP dark matter

A chance of detection stems from the WIMP paradigm itself:

Pair annihilations of WIMPs in DM halos (i.e. at T≅0)



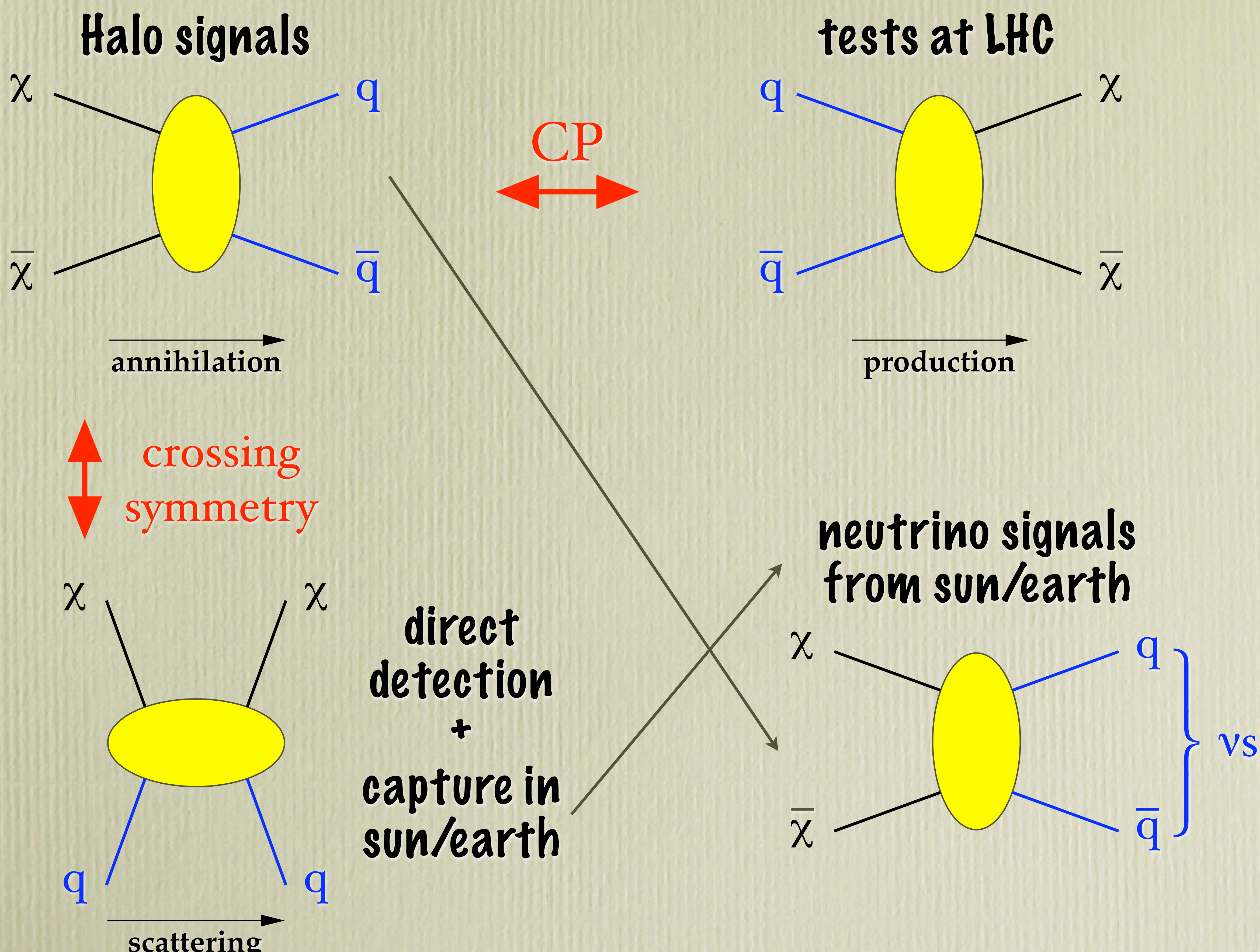
Focus on:
antiprotons,
positrons,
antideuterons,
gamma-rays,
(neutrinos)

- $(\sigma v)_{T\simeq 0} \overset{?}{\sim} \langle \sigma v \rangle_{T=T_f}$
- final state branching ratios
- $N_{\chi-\mathrm{pairs}} \propto [\rho_\chi(r)]^2 \simeq [\rho_{\mathrm{DM}}(r)]^2$

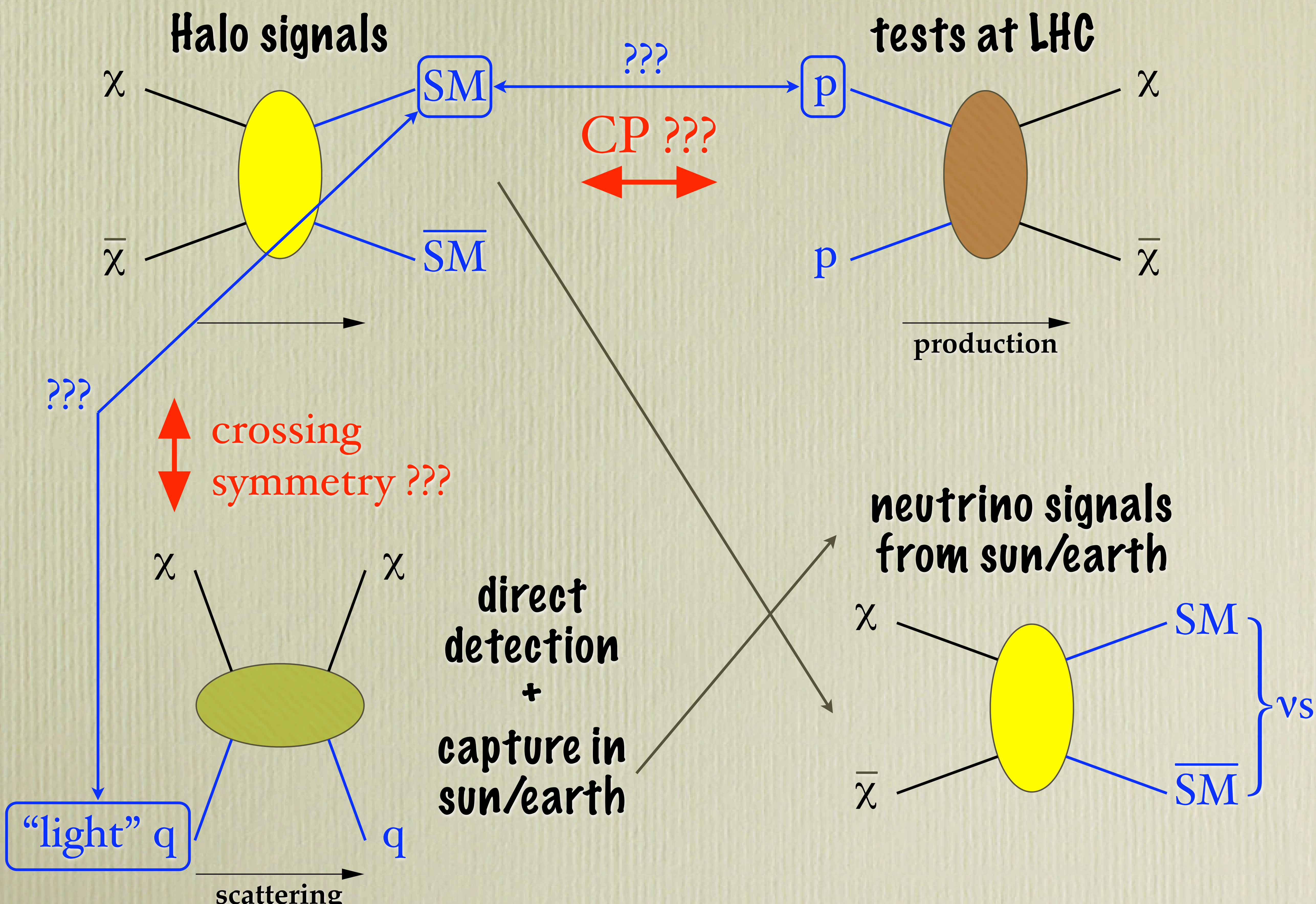
} WIMP DM source function

Dynamical observations (?)/
N-body simulations (?)

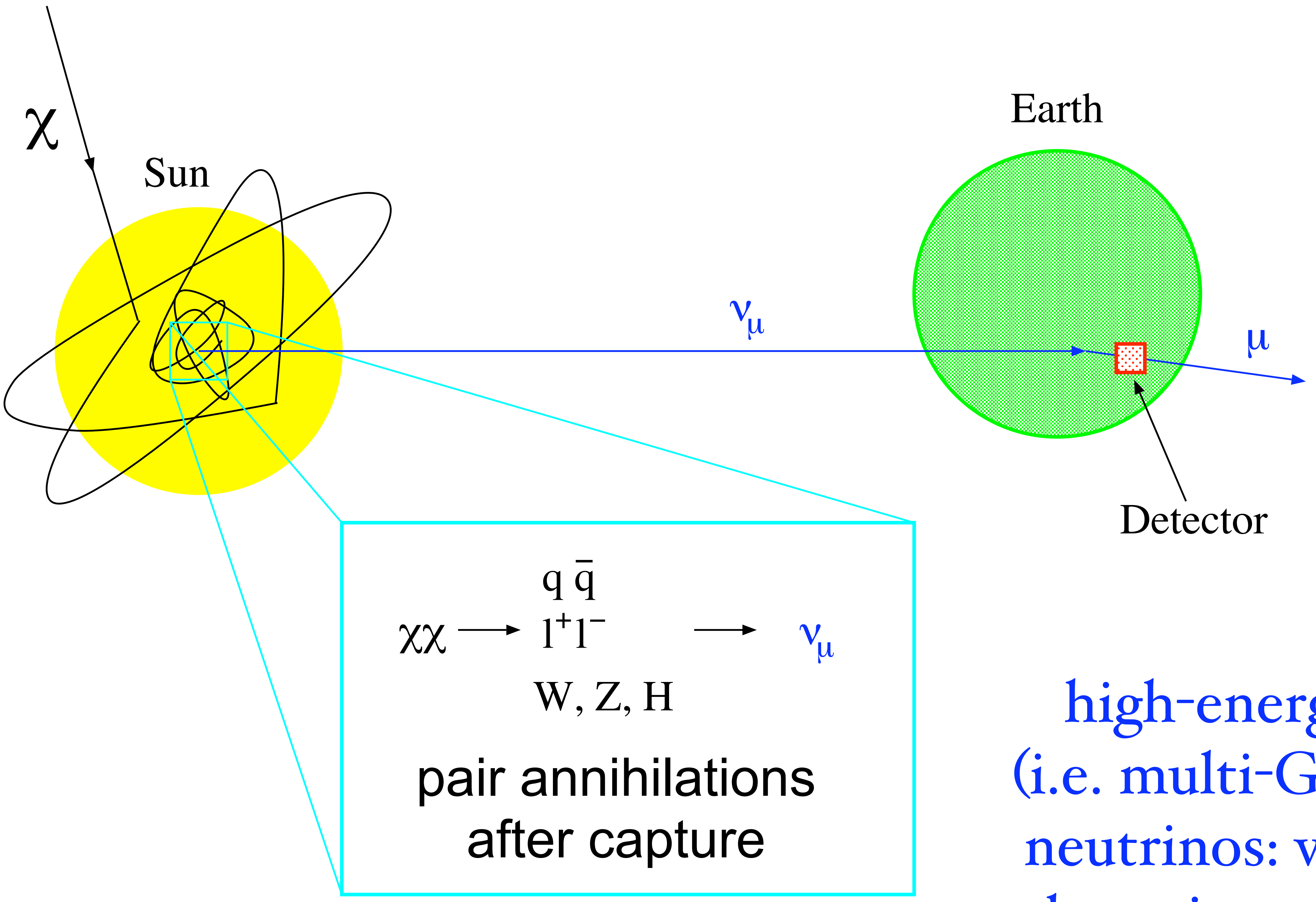
WIMP coupling to ordinary matter



WIMP coupling to ordinary matter ???



WIMP searches with neutrino telescopes



high-energy
(i.e. multi-GeV)
neutrinos: very
clean signature!

The WIMP number density inside the Sun/Earth obeys the equation:

$$\frac{dN}{dt} = \boxed{C_c} - \boxed{C_a} N^2$$

capture annihilation

which gives the WIMP annihilation rate:

$$\Gamma_a \equiv \frac{1}{2} C_a N^2 = \frac{1}{2} C_c \tanh^2(t/\tau)$$

with: $t = t_\odot \simeq 4.5 \cdot 10^9$ years & $\tau \equiv 1/\sqrt{C_c C_a}$.

For $\tau \ll t_\odot$ capture and annihilation have reached equilibrium:

$$\Gamma_a = \frac{1}{2} C_c \longrightarrow \Phi_\mu \begin{cases} \propto\!\!\!\!\sim \ \sigma_{\chi\, p}^{SD} & \text{Sun} \\ \propto \ \sigma_{\chi\, p,n}^{SI} & \text{Earth} \end{cases}$$

(??? - rarely in equilibrium)

Spin-dependent versus spin-independent

For WIMP DM in the form of Majorana fermions, there are two terms contributing to the scattering cross section in the non-relativistic limit:

not coherent

Axial-vector
(spin-dependent)

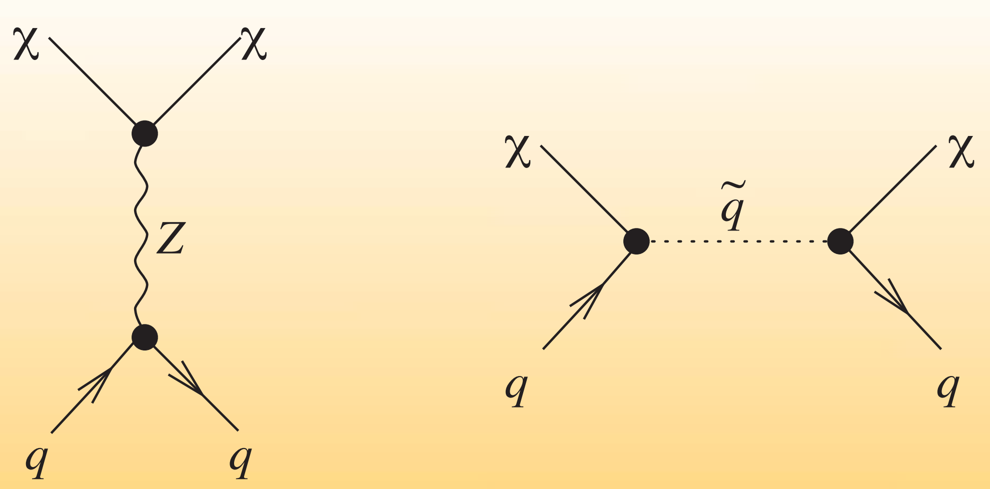
$$\mathcal{L}_A = d_q \; \bar{\chi}\gamma^\mu\gamma_5\chi\bar{q}\gamma_\mu\gamma_5 q$$

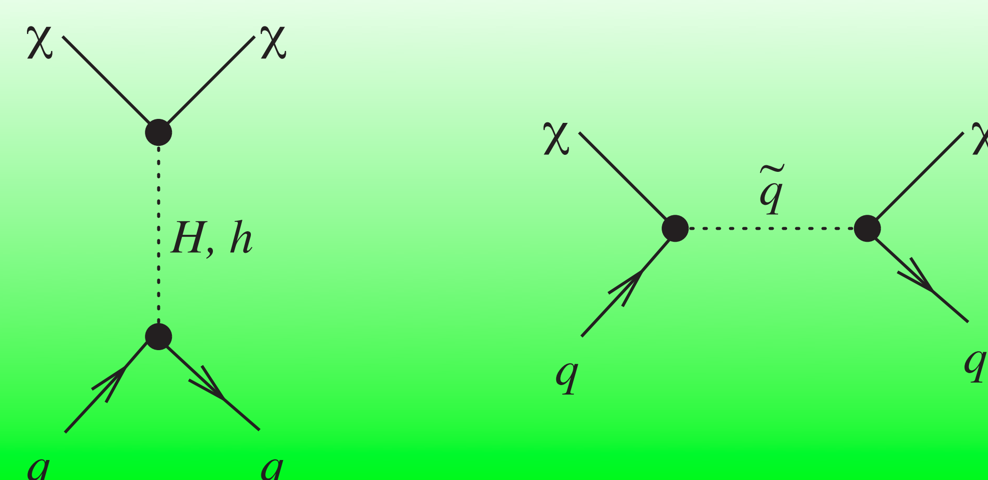
coherent

Scalar
(spin-independent)

$$\mathcal{L}_{\rm scalar} = a_q \bar{\chi}\chi\bar{q}q$$

In case of neutralinos in the MSSM:





For dirac fermions also:

coherent

$$\text{Vector: } \mathcal{L}^q_{vec} = b_q \; \bar{\chi}\gamma_\mu\chi\,\bar{q}\gamma^\mu q$$

For spin-0 or spin-1 WIMPs the discussion is analogous.

Under “standard” assumptions in a “standard” WIMP scenario, the SI and SD scattering cross section on a nucleon (either on a proton or a neutron) are comparable: coherence wins and you are roughly a factor A^2 (with A is the atomic number of target nuclei in a detector or the sun/earth) more sensitive to SI then to SD.

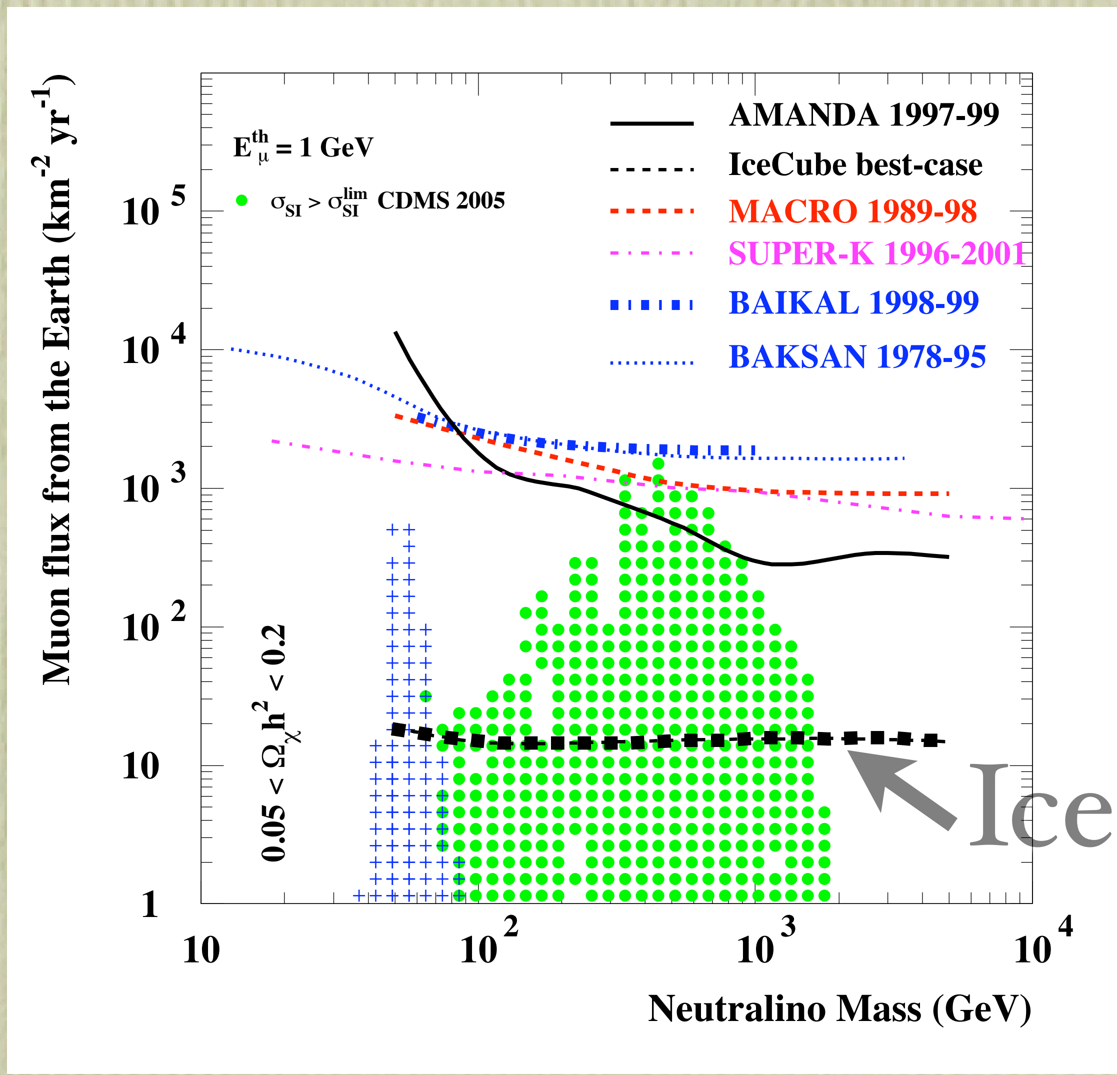
For the Earth, SI coupling determines capture, however equilibrium is rarely reached: under “standard” assumptions for the WIMP distribution in the DM halo, direct detection sets stronger limits., except possibly for very light (below few GeV) WIMPs. [Note that, since the ν signal refers to a time-integrated effect, it is essentially insensitive to inhomogeneities in the dark matter distribution, such as dark matter substructures (???) or fluctuations in a given profile at a fixed radius due to streams (???), which may have instead an impact on direct detection.]

For the Sun, capture is mainly driven by the SD, equilibrium is a more frequent configuration: ν telescopes are usually more sensitive to this regime than direct detection, assuming “standard” annihilation modes.

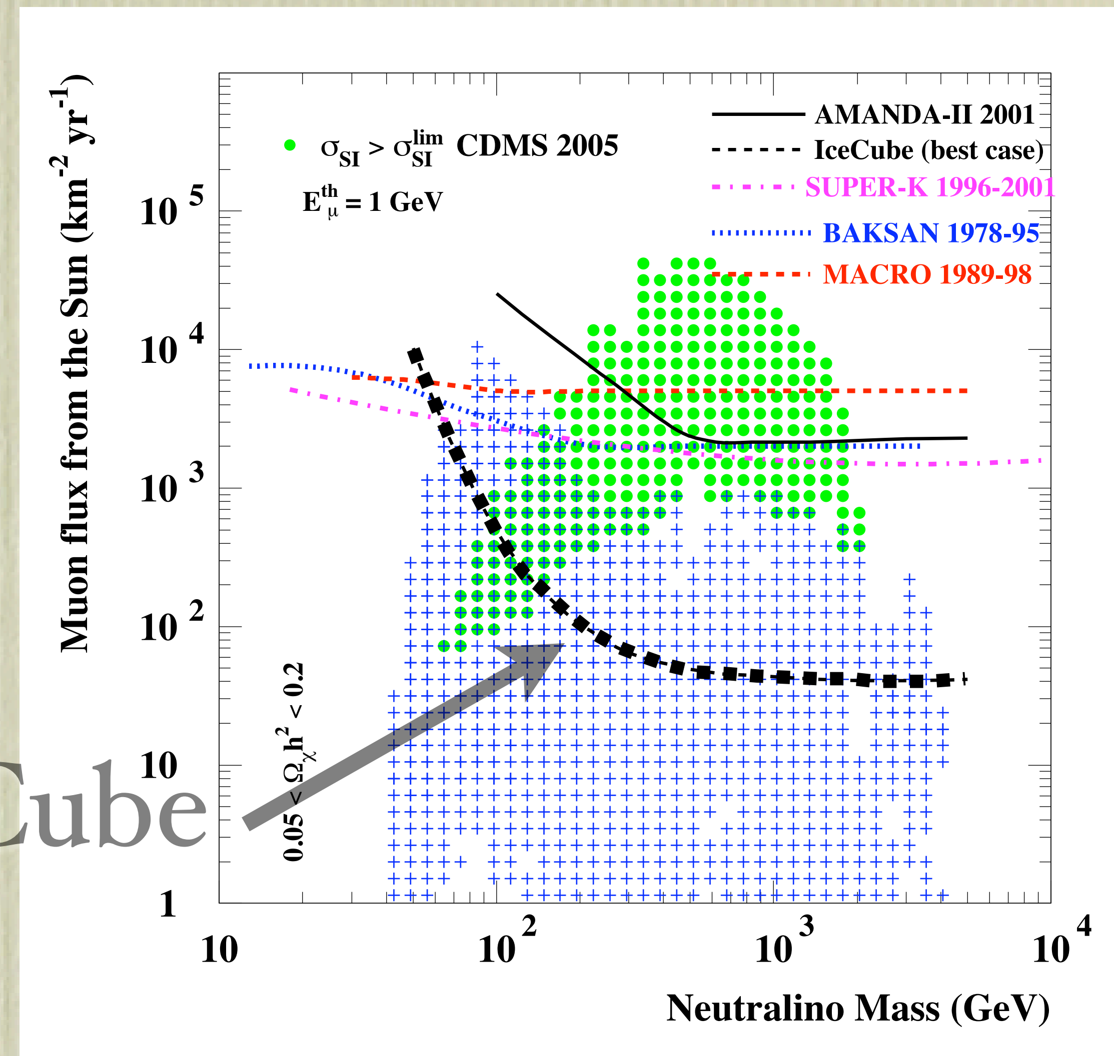
[Way too many “standard”s in this slide; watch out for caveats]

The ν signal from the Earth versus the ν signal from the Sun, keeping in mind direct detection results: the standard lore is that the Sun wins. E.g. a general scan for neutralino dark matter candidates within the MSSM:

Flux from the Earth



Flux from the Sun



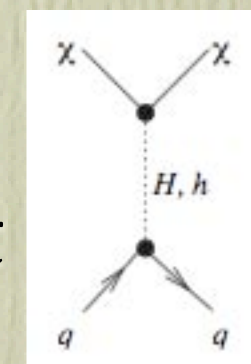
IceCube

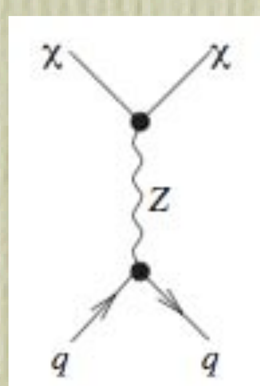
● model excluded by the 2005 CDMS SI limit

Icecube Collaboration & DarkSUSY, 2007

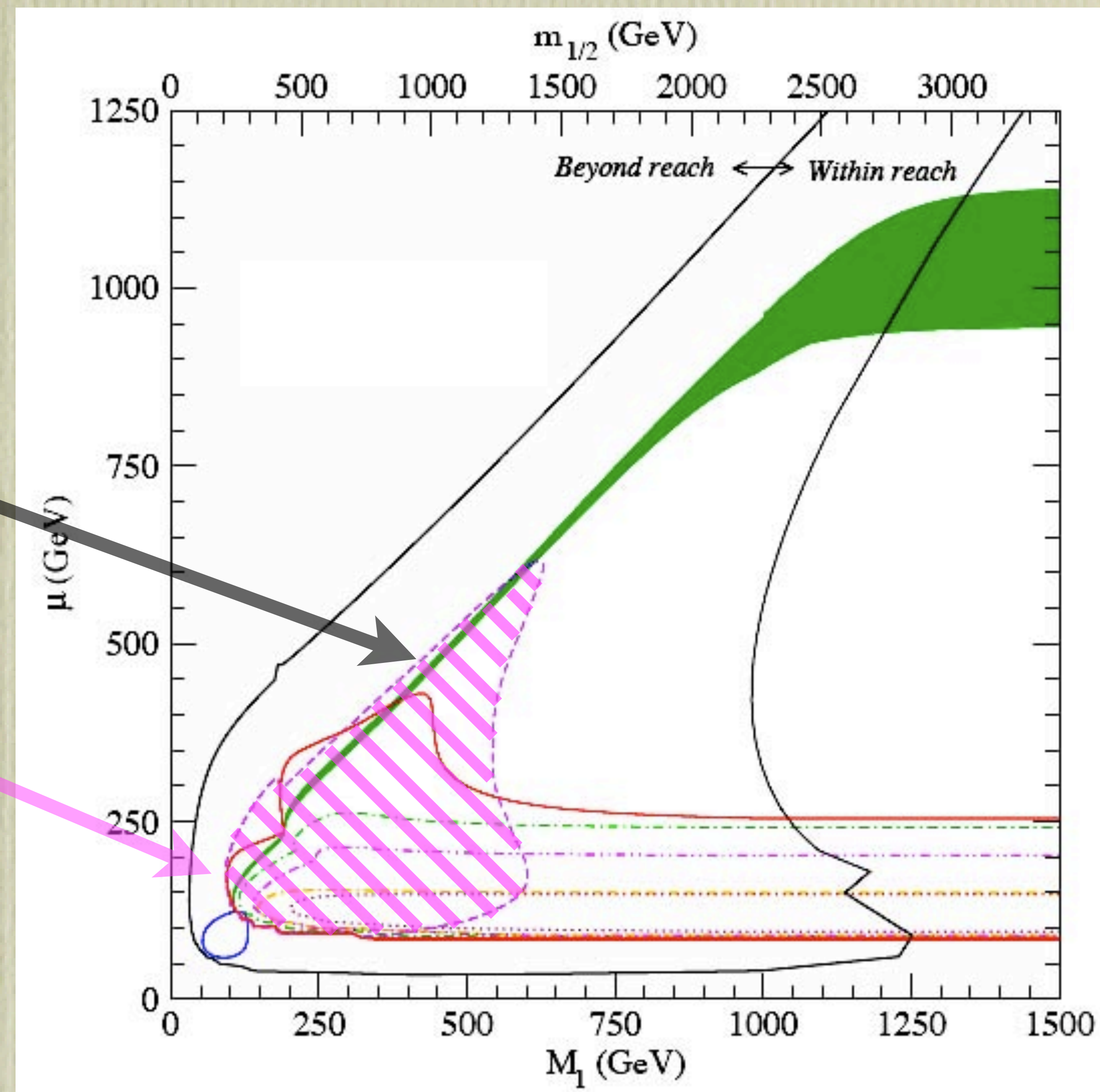
SI (direct detection) versus SD (ν signal from the Sun): the standard lore is that SI wins. E.g., MSSM in a split-SUSY-like configuration (heavy scalars, large gaugino-higgsino mixing):

~1-ton direct detector SI limit





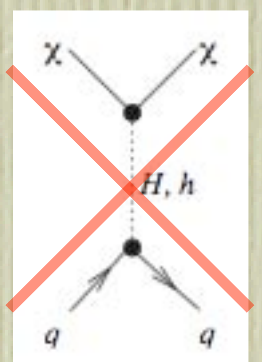
IceCube



Note: this is an example in which annihilation cross section and scattering cross section are NOT related via crossing symmetry

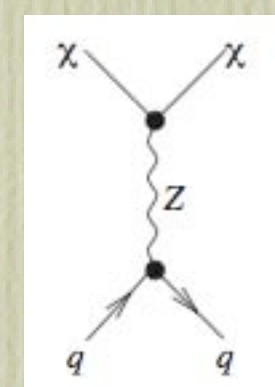
Baer, Krupovnickas, Profumo & P.U., 2006

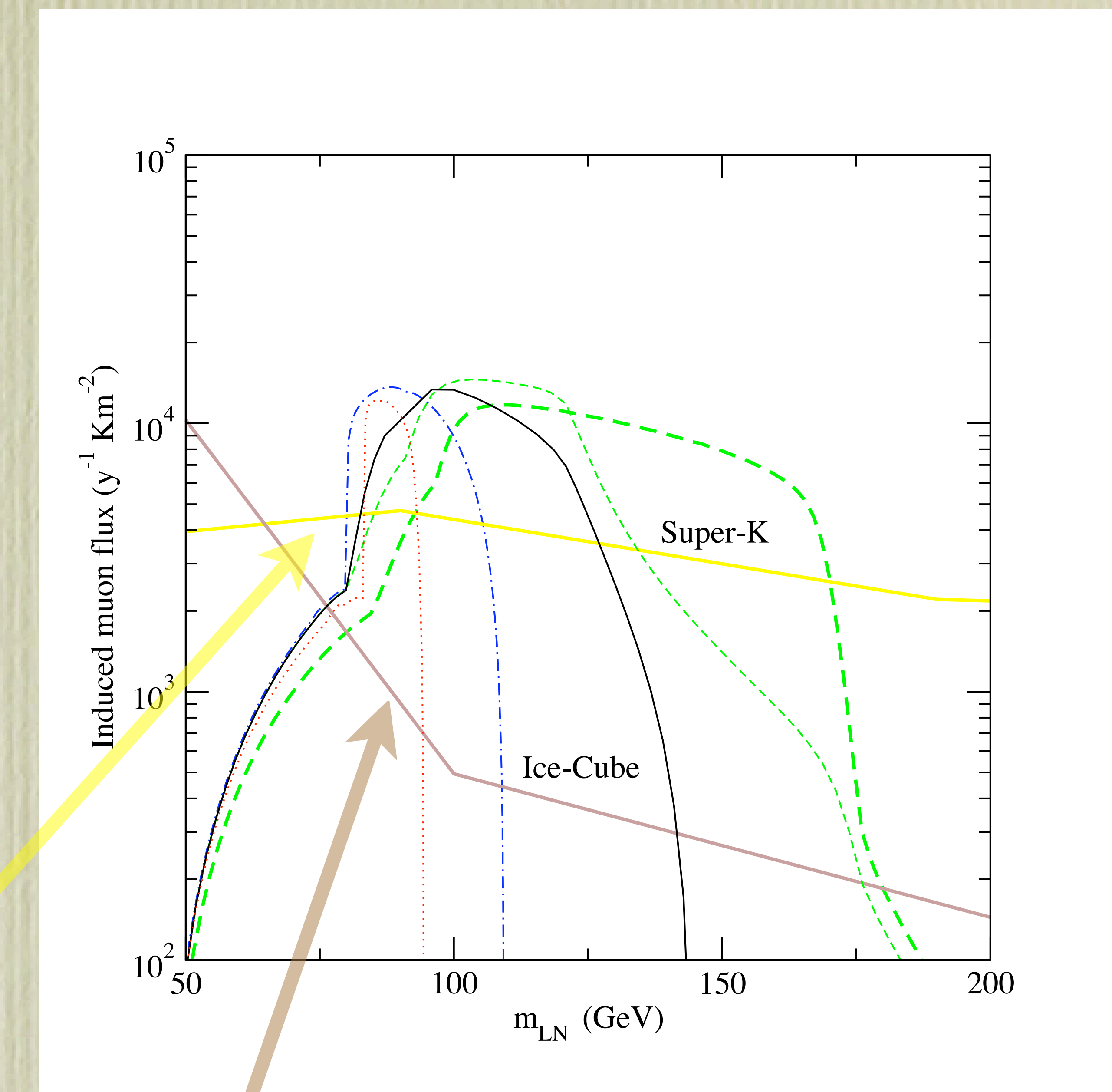
SI (direct detection) versus SD (ν signal from the Sun): there are also cases in which the standard lore does not apply, and the pattern is reversed. E.g., a model with large Yukawa couplings introduced in an EW baryogenesis context:



very suppressed, direct detection is not excluding any region of the parameter space

enhanced, ν signal from the Sun fairly large





Provenza, Quiros & P.U., 2006

Super-Kamiokande, setting relevant constraints

IceCube will probe a fair fraction of the parameter space.

reverse the argument:

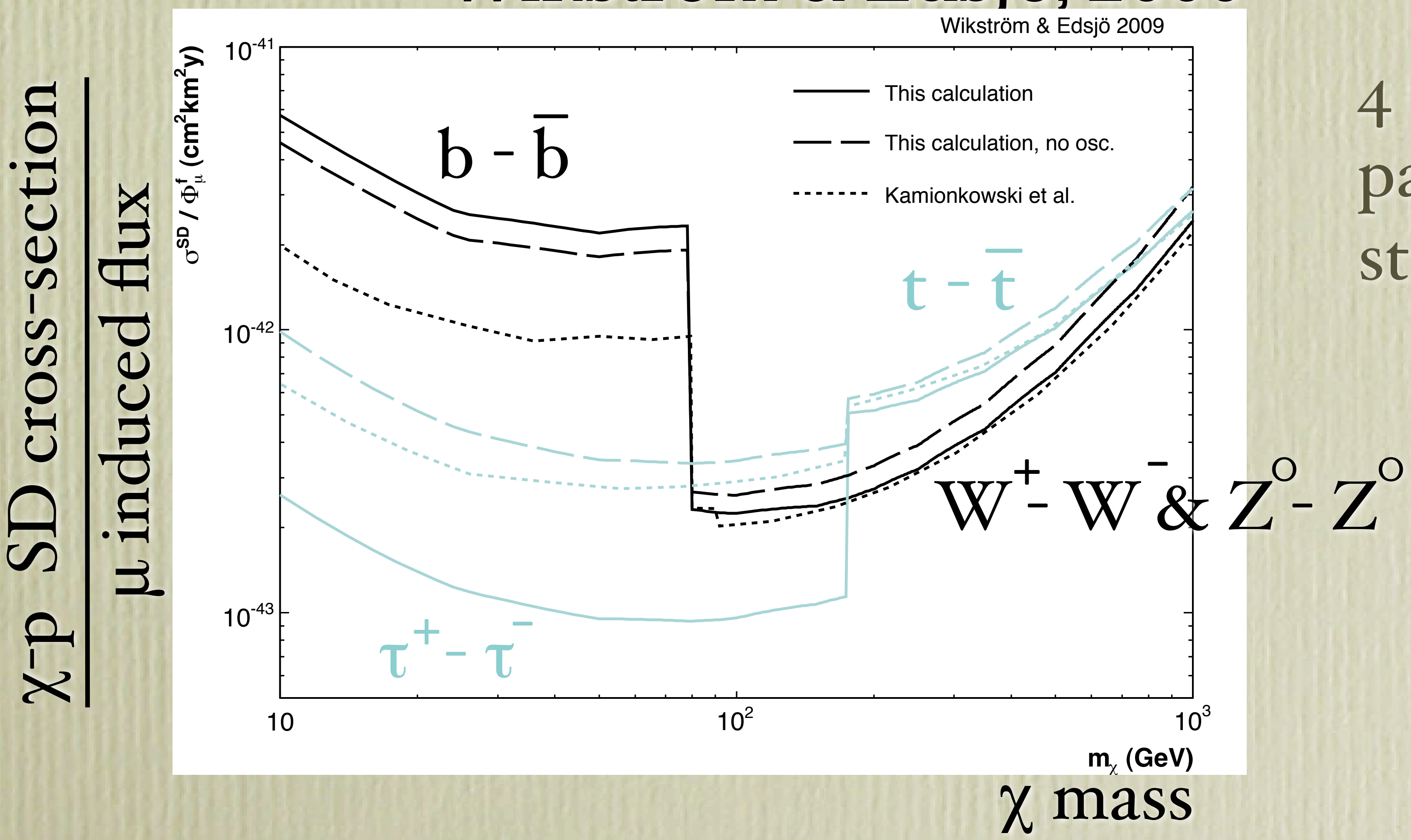
Independently of the specific WIMP framework, is it possible to test the interpretation of a given a positive signal in a direct detection experiment searching for a ν signal from the Sun,?

Yes, assuming (**Kamionkowski et al., 1995**):

I) equilibrium between capture and annihilation in the Sun;

II) WIMP annihilation modes for which the ν yield is not suppressed.

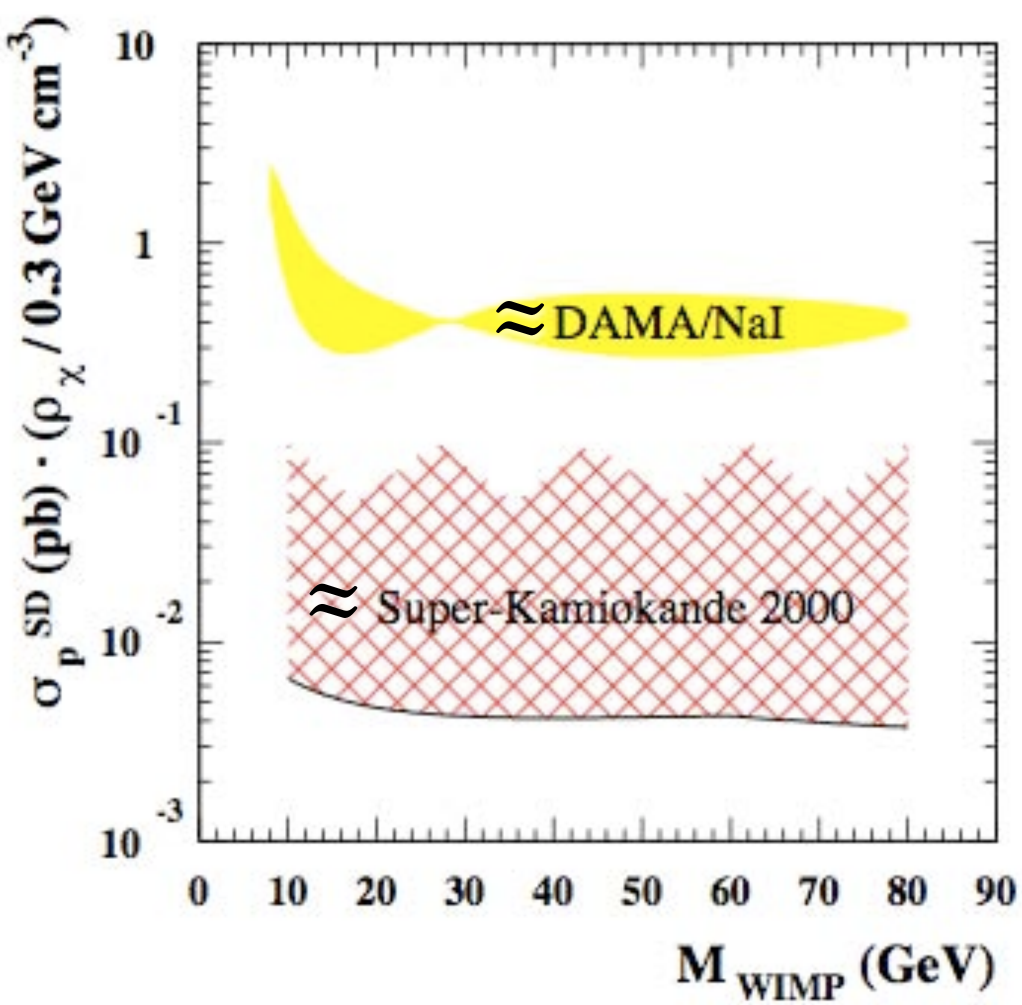
Wikström & Edsjo, 2009



4 sample (& extreme) pair annihilation final states

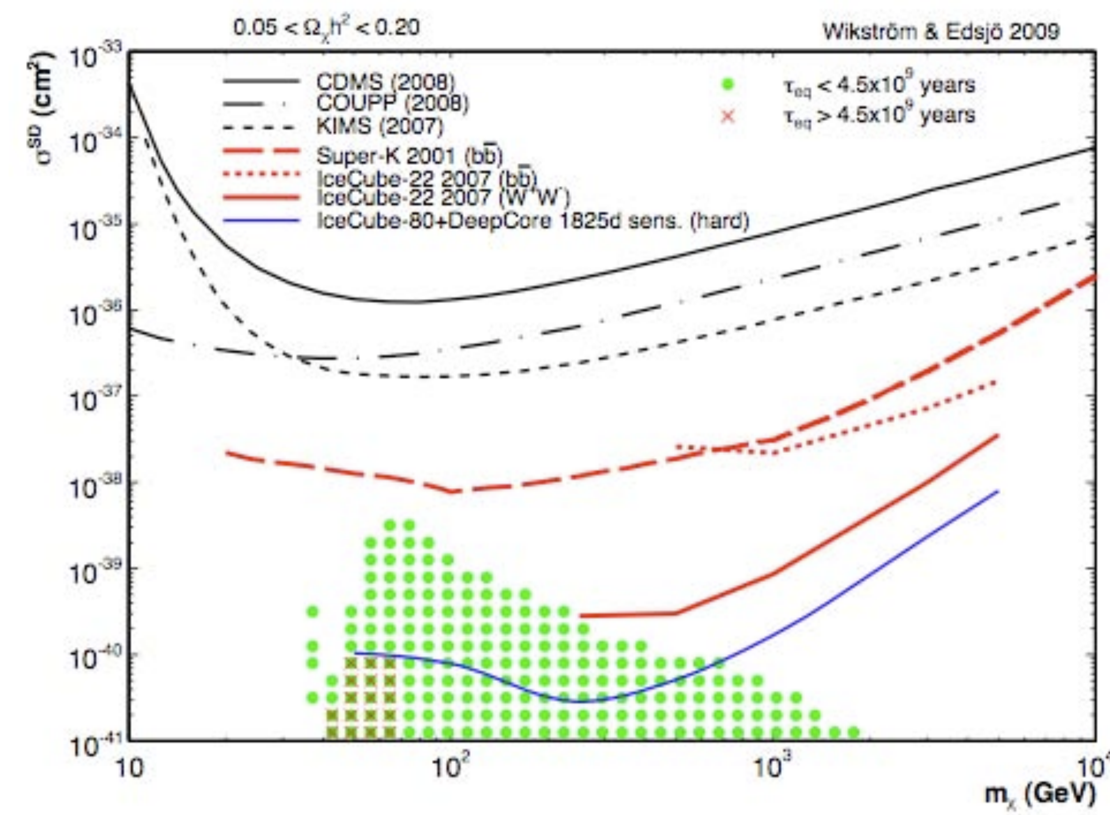
Early and recent applications of this idea:

DAMA/LIBRA annual modulation effect and χ-p SD interactions



P.U., Kamionkowski & Vogel,2001

comparison with recent χ-p SD searches



Wikström & Edsjo, 2009

WARNING: there are loopholes in these arguments

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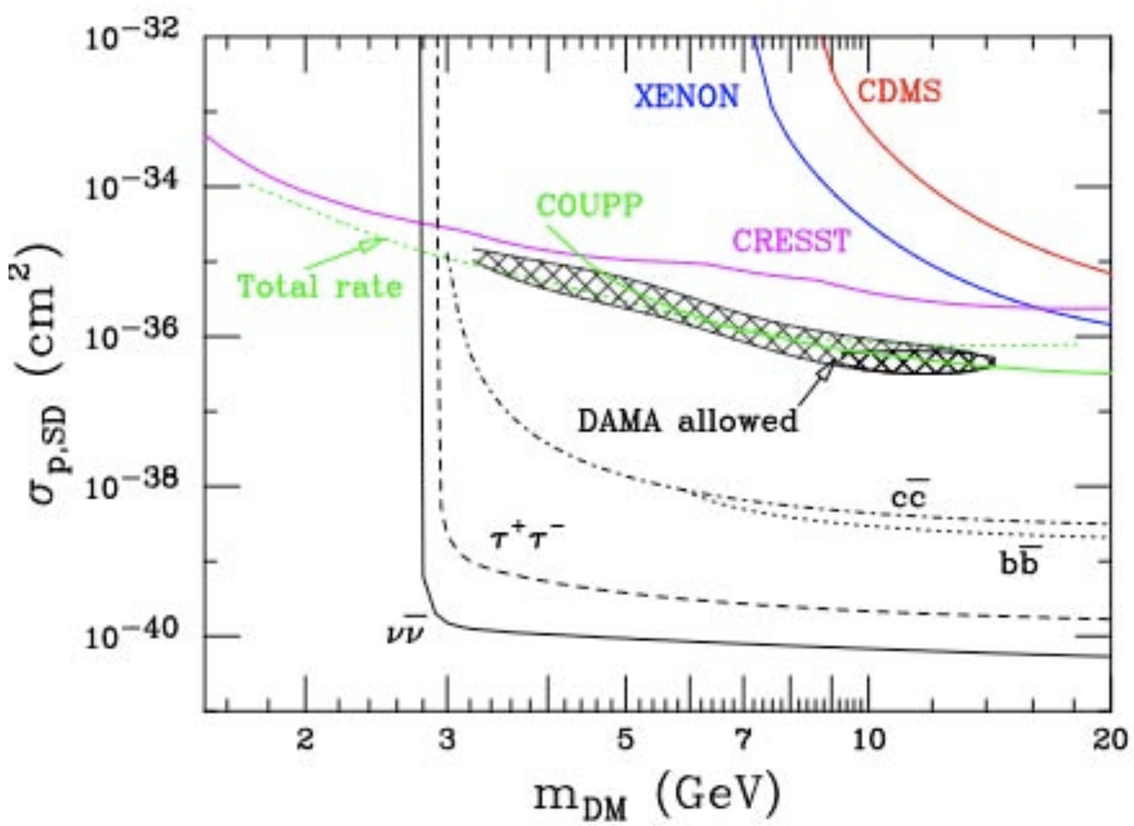
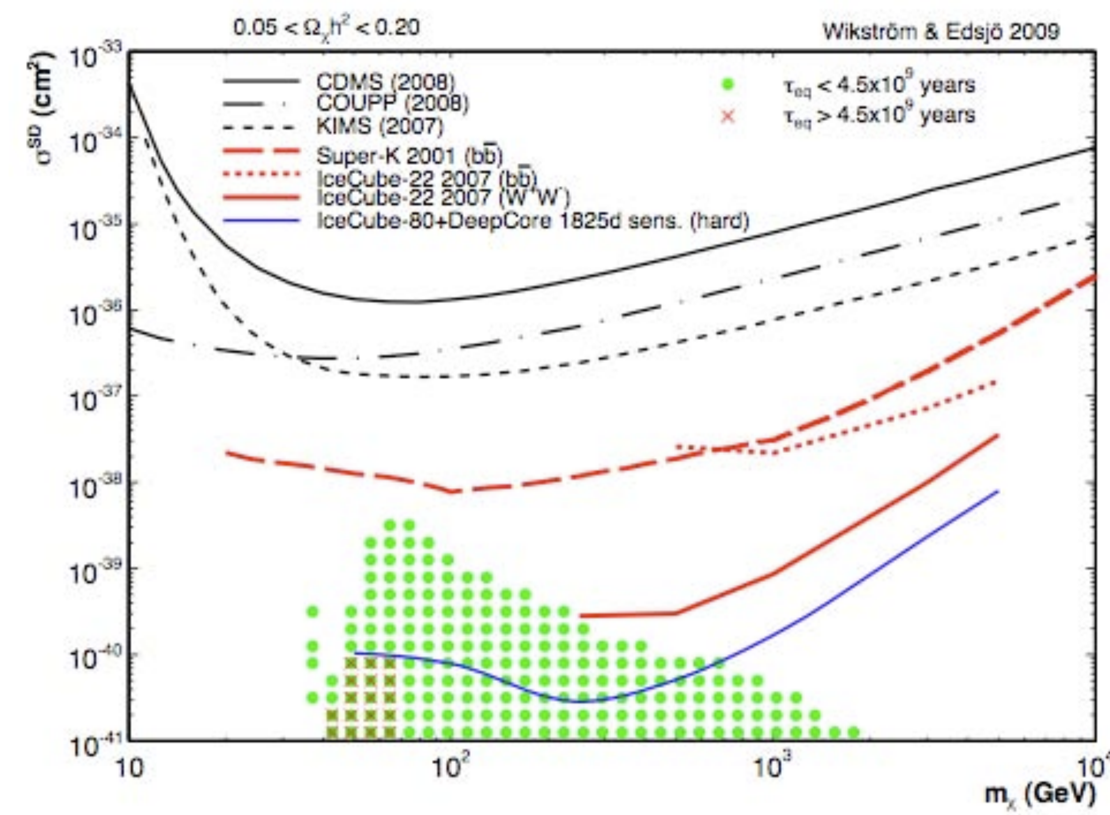


Hooper et al., 2008

comparison with recent χ-p SD searches



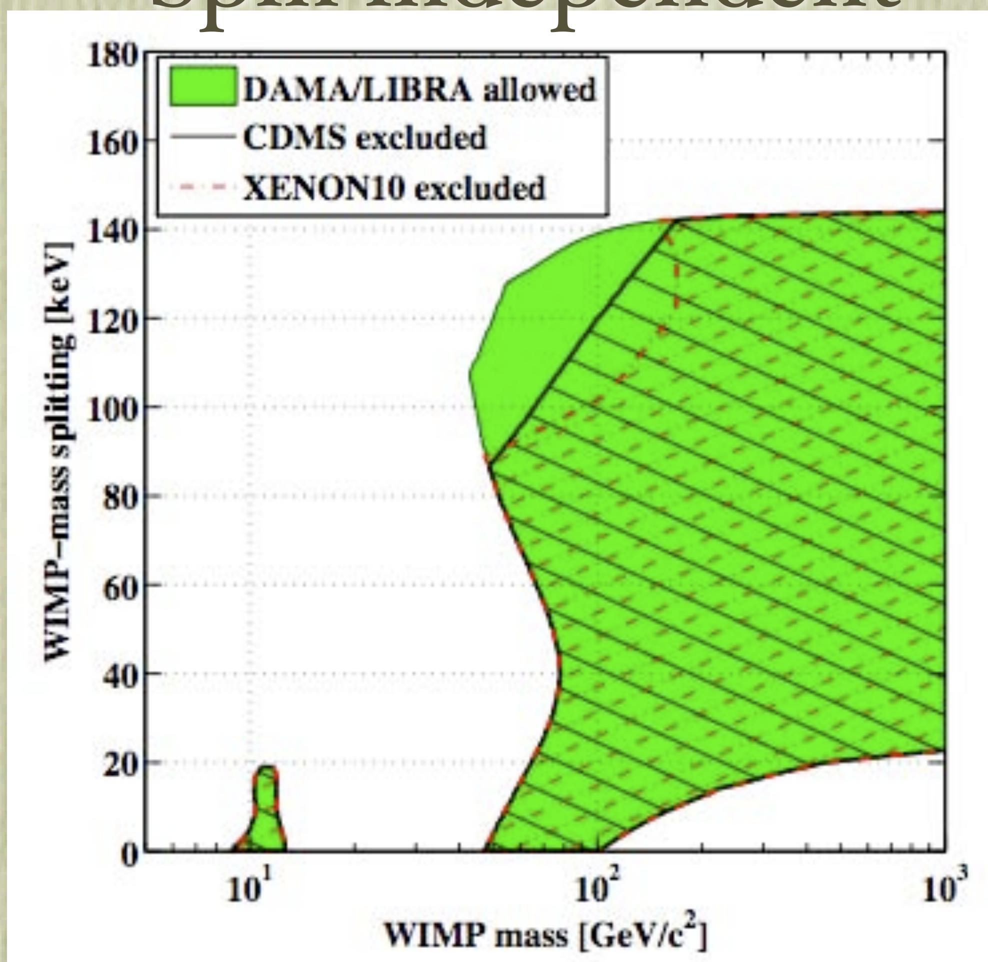
Wikström & Edsjo, 2009

WARNING: there are loopholes in these arguments

What the DAMA (CoGeNT) signal out of the WIMP framework?

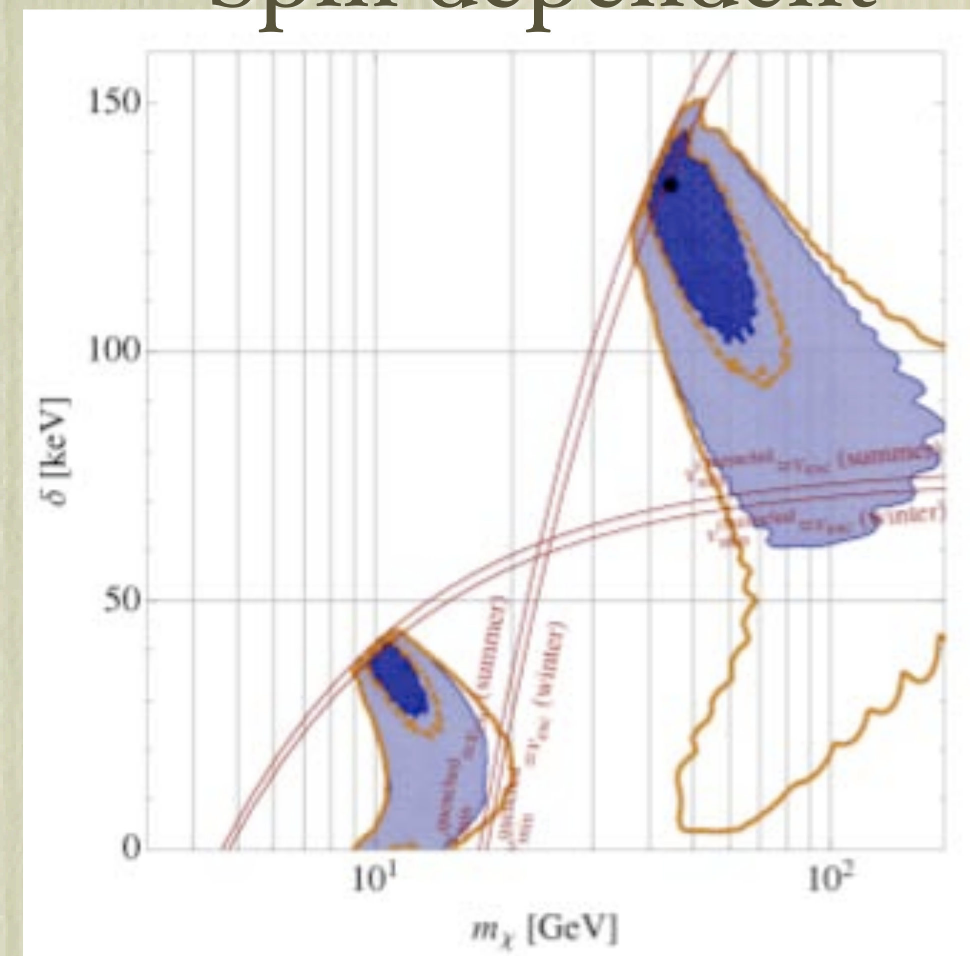
Advocate, e.g., **Inelastic Dark Matter** (Smith & Weiner, 2001), assuming the existence of two (or more) dark states with mass splittings of the order of 100 keV and imposing only inelastic scattering:

Spin independent

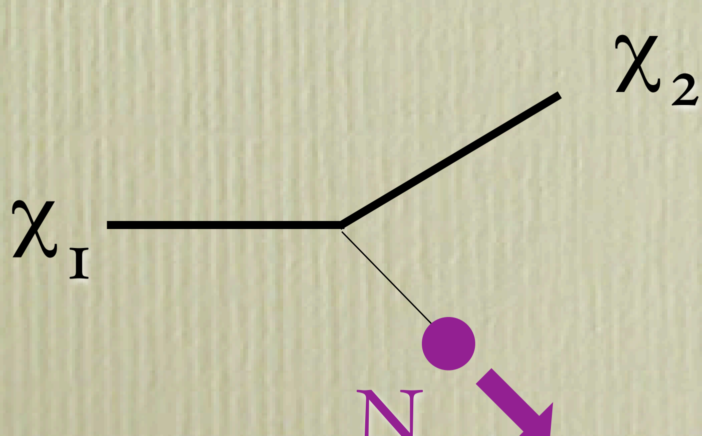


Ahmed et al., arXiv:0912.3592

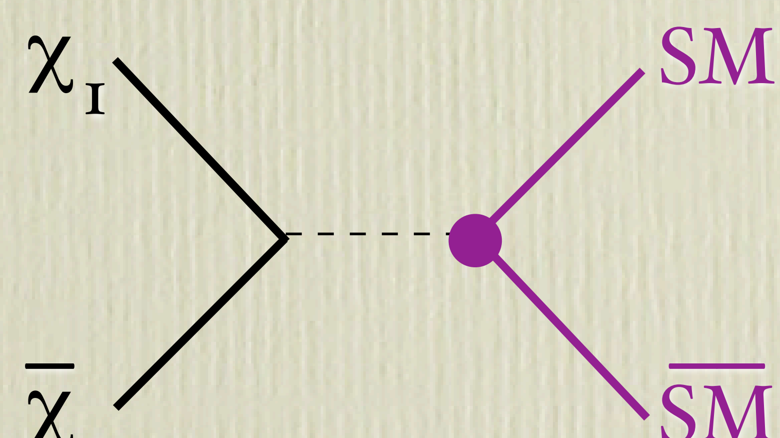
Spin dependent



Kopp et al., arXiv:0912.4262

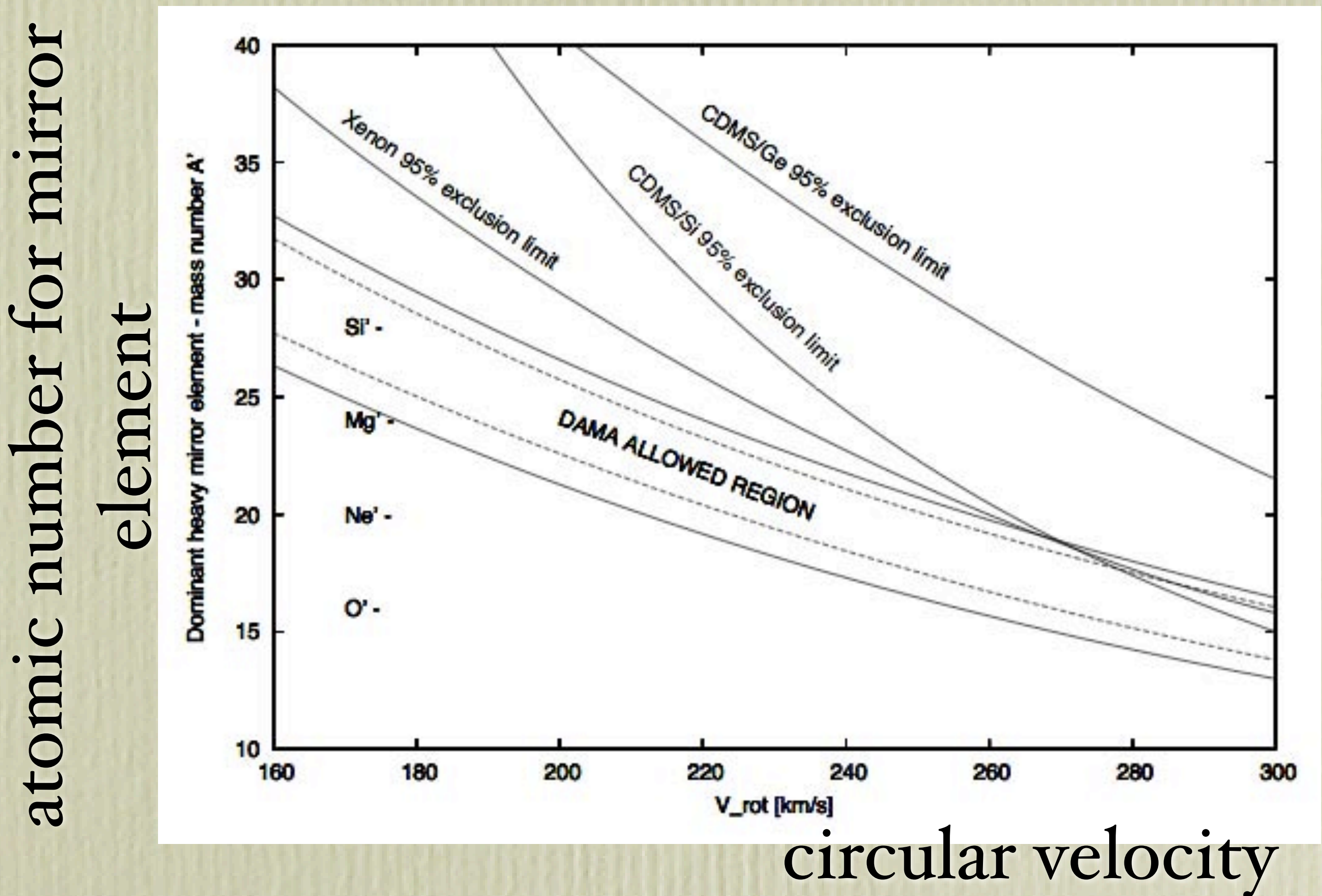


tunable on direct detection results but with feeble connections to the pair annihilation process:



What the DAMA (CoGeNT) signal out of the WIMP framework?

Advocate, e.g., **Mirror Dark Matter** (Foot et al., 1991; Berezhiani et al., 2001), assuming the existence of mirror baryons interacting with ordinary matter via a sizable photon-mirror photon kinetic mixing:



Foot, arXiv:0804.4518

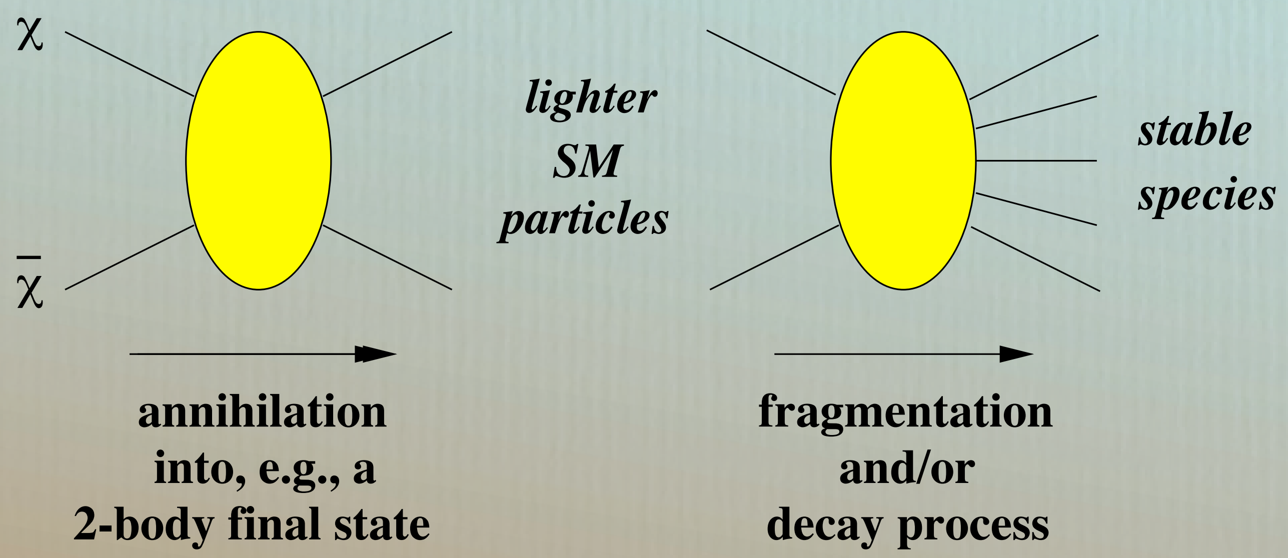
In this model the dark matter component does not contain antiparticles, hence there are no pair annihilation signals, including the ν signals.

Analogous picture for **Asymmetric Dark Matter** (Kaplan, 1992).

Indirect detection of WIMP dark matter

A chance of detection stems from the WIMP paradigm itself:

Pair annihilations of WIMPs in DM halos (i.e. at T≅0)



Focus on:
antiprotons,
positrons,
antideuterons,
gamma-rays,
(neutrinos)

Search for the species with low or well understood backgrounds from other known astrophysical sources.

For "standard" annihilation rates, final states and DM density profiles, the ratio signal over background is the largest for antiprotons (antideuterons), can be sizable for gamma-rays, is fairly small for positrons and very small for neutrinos.

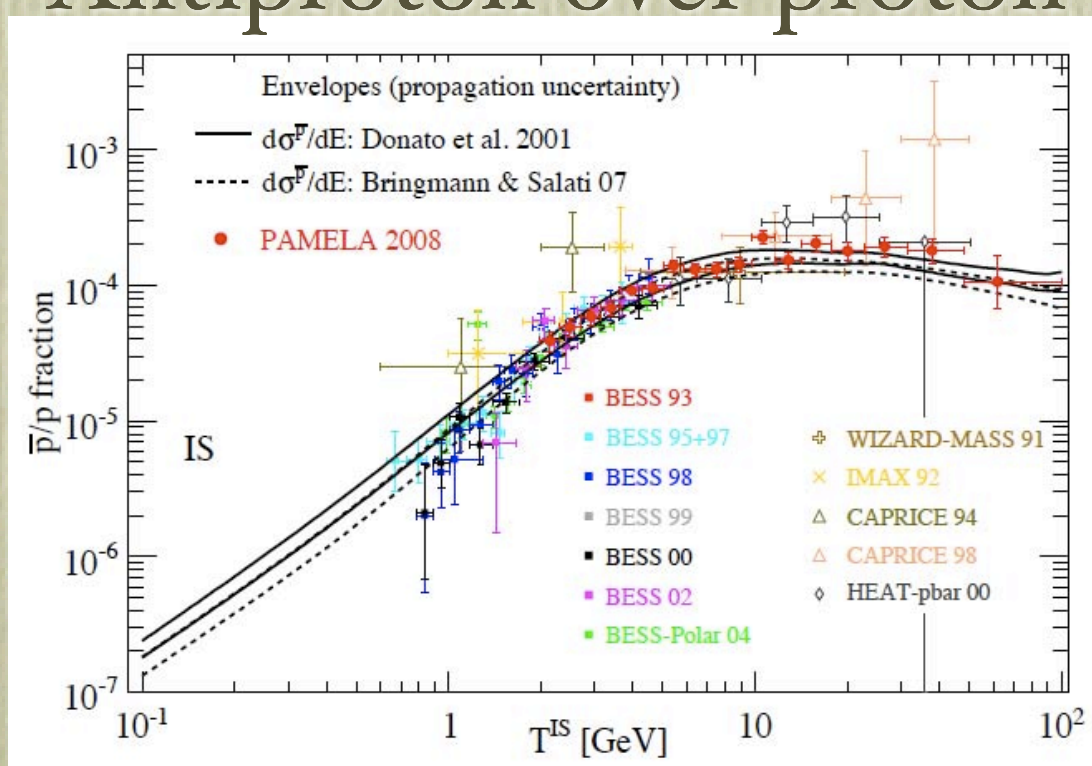
The $\bar{p}$ measurements are consistent with secondaries:

Antiprotons are generated in the interaction of primary proton and helium cosmic rays with the interstellar gas (hydrogen and helium), e.g., in the process:

$$p + H \rightarrow 3\,p + \bar{p}$$

Use the parameter determination from the B/C ratio, to extrapolate the prediction for the $\bar{p}/p$ ratio: excellent agreement for secondaries only!

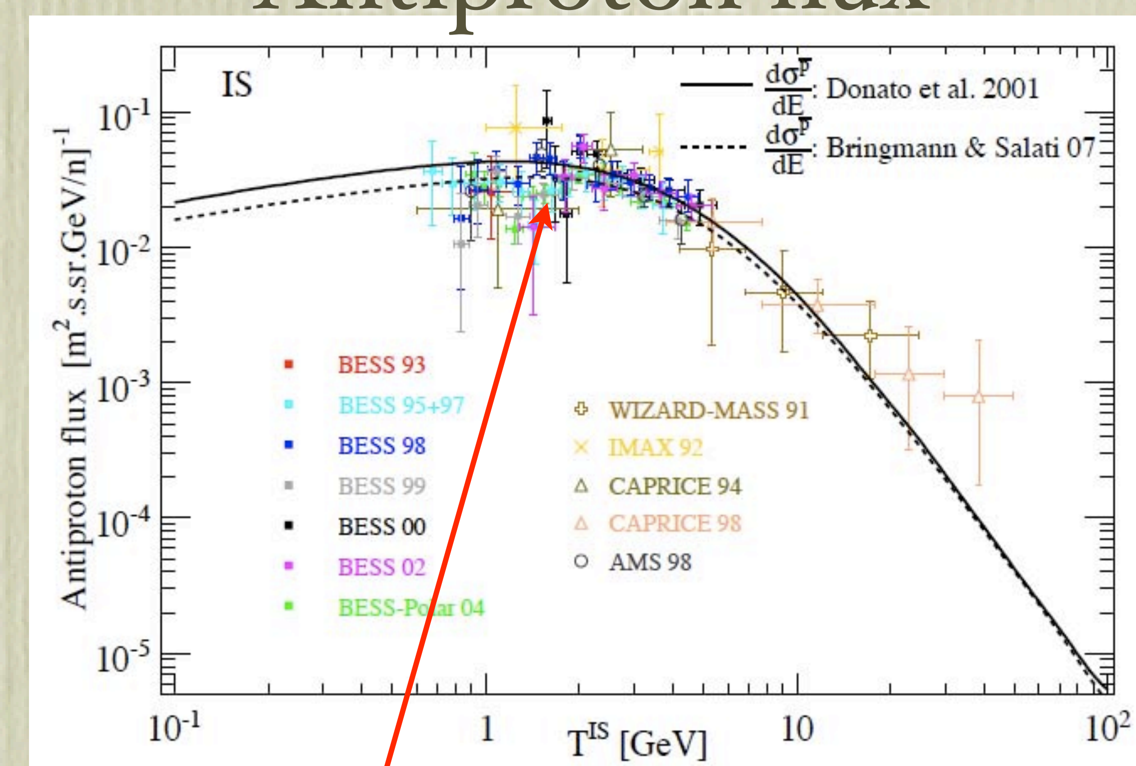
Antiproton over proton



Donato et al., arXiv:0810.5292

Latest Pamela data: Adriani et al., arXiv:0810.4994

Antiproton flux



kinematic peak expected for secondaries, not for a primary component

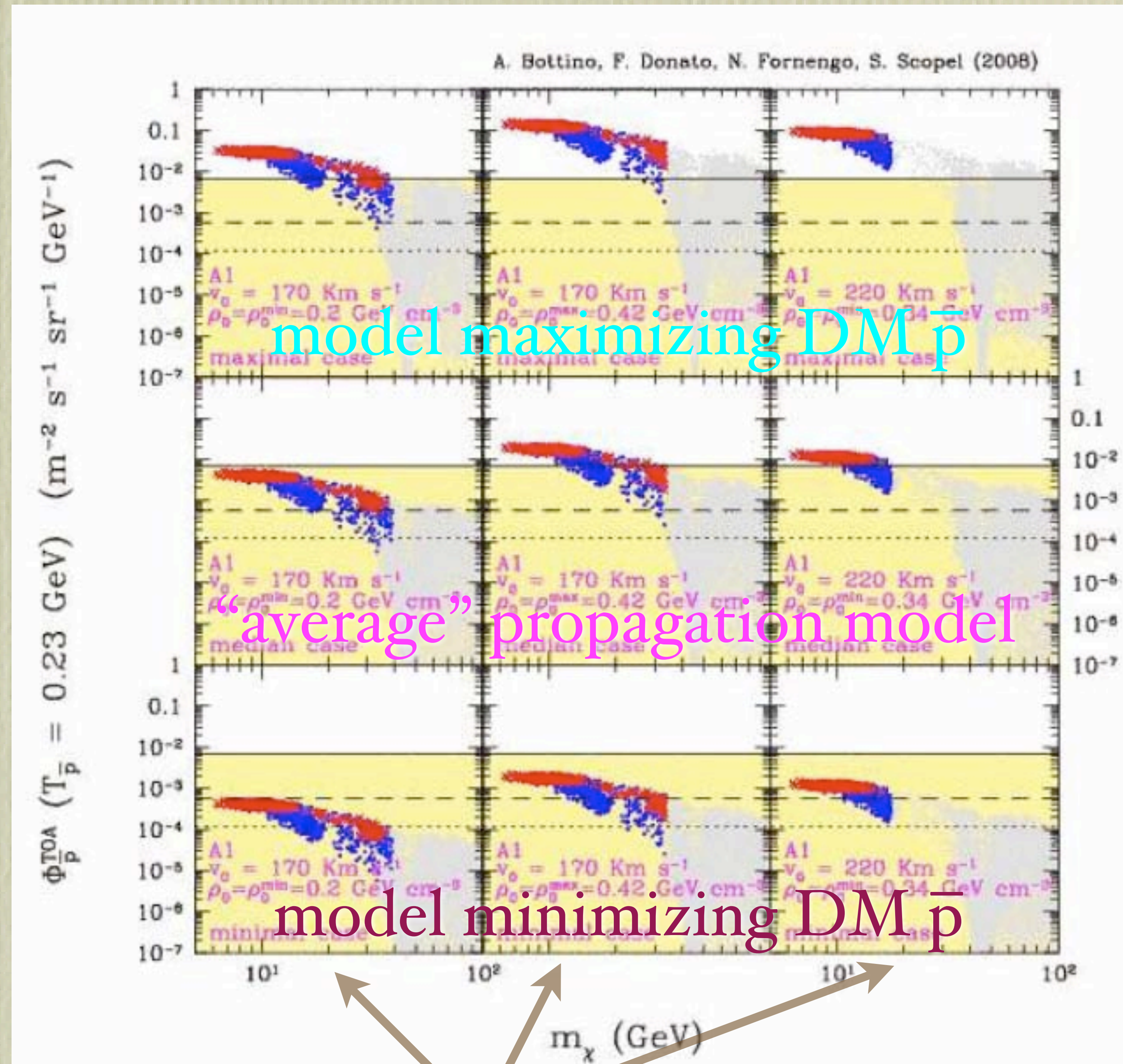
Antiproton fluxes versus direct detection

A few delicate points to make the comparison:

Do crossing symmetry arguments apply?
E.g., for light neutralinos in the MSSM (no gaugino mass unification) there is a very tight correlation between direct detection and hadronic annihilation channels. This is not guaranteed in all models.

Is the cross correlation reliable, given the uncertainties in cosmic ray propagation and DM halo models?

Red: compatible with DAMA and WMAP
Blue: compatible with DAMA but low Ω



three different halo models

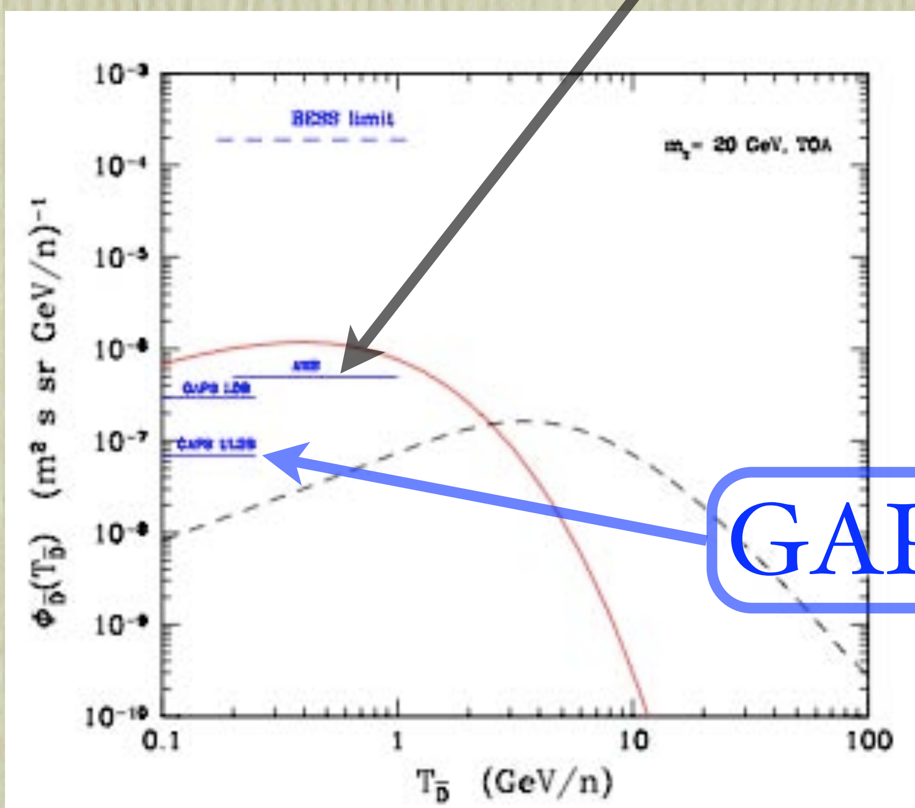
Bottino, Donato, Fornengo & Scopel, 2008

Antideuteron fluxes versus direct detection

A few delicate points to make the comparison:

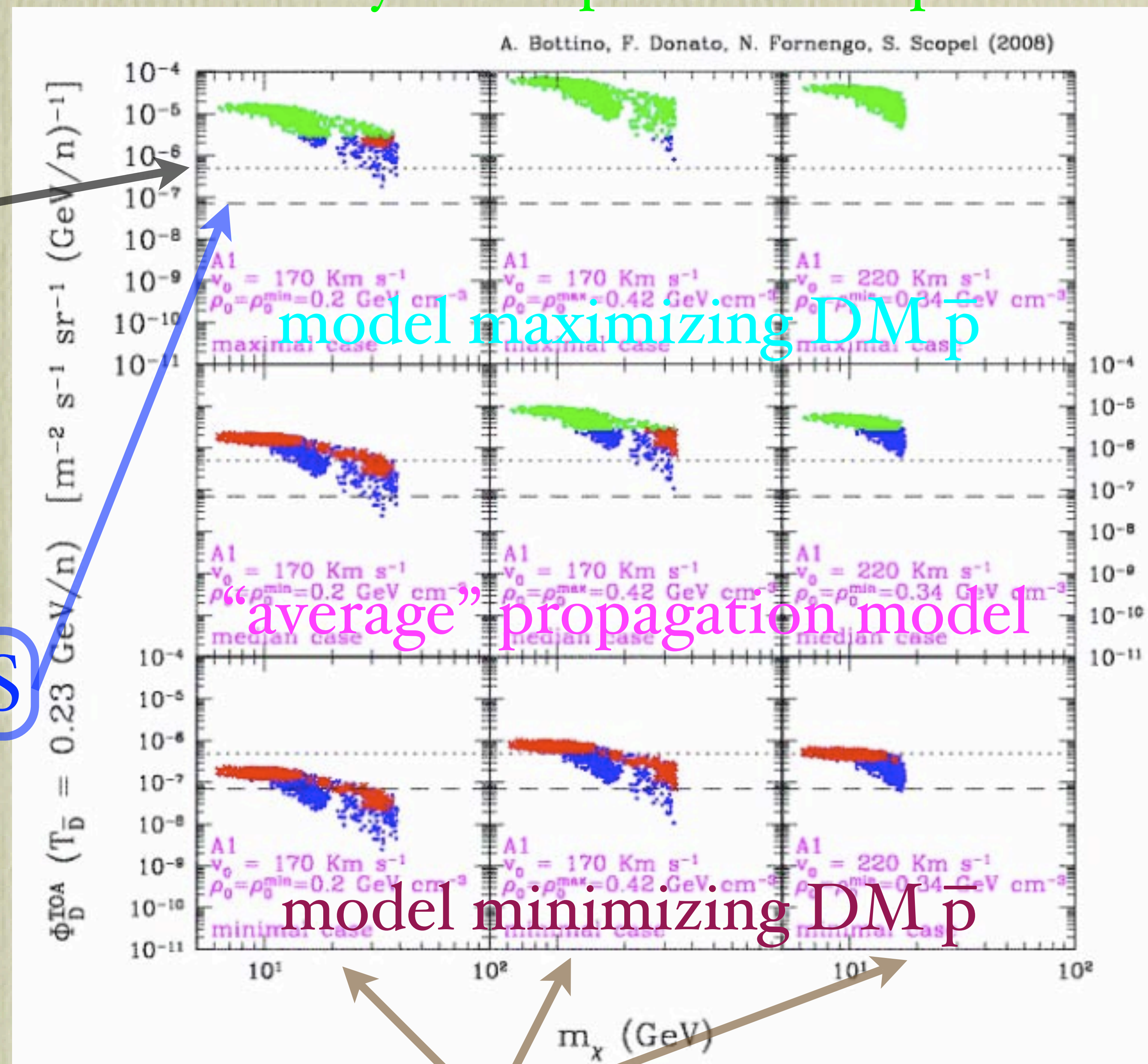
Do crossing symmetry arguments apply?

Red: compatible with DAMA and WMAP
Blue: compatible with DAMA but low Ω
Green: already incompatible with $\bar{p}$



AMS

GAPS



model maximizing DM $\bar{p}$

"average" propagation model

model minimizing DM $\bar{p}$

three different halo models

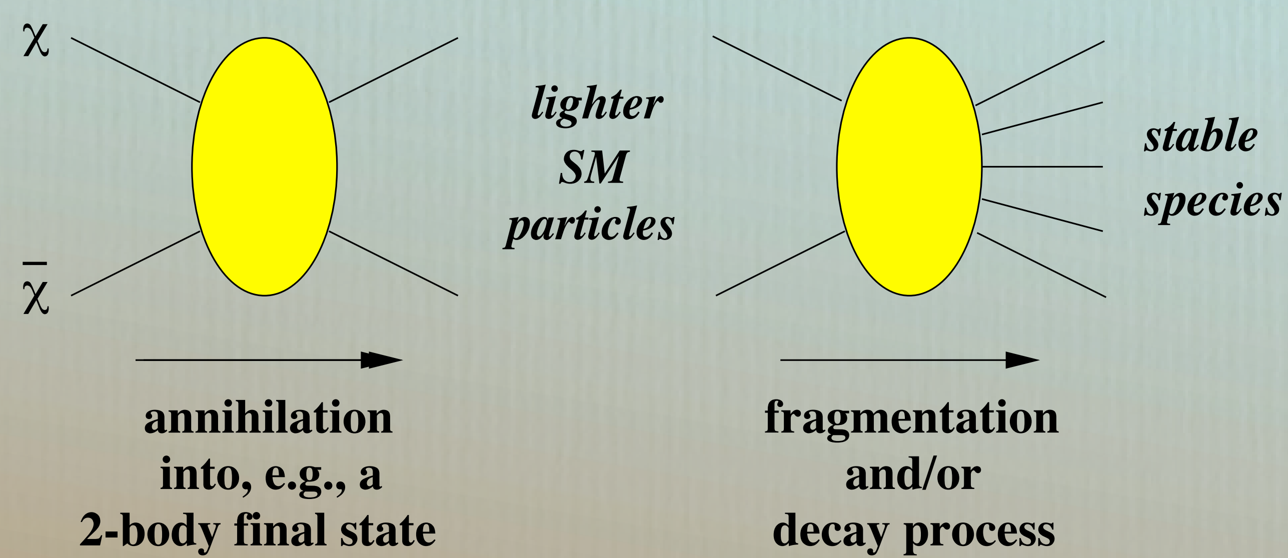
NOTE: much cleaner signature compared to $\bar{p}$

Bottino, Donato, Fornengo & Scopel, 2008

Indirect detection of WIMP dark matter

A chance of detection stems from the WIMP paradigm itself:

Pair annihilations of WIMPs in DM halos (i.e. at $T \cong 0$)



Focus on: antiprotons, positrons, antideuterons, gamma-rays, (neutrinos)

Signatures:

I) in energy spectra: One single energy scale in the game, the WIMP mass, rather then sources with a given spectral index; edge-line effects?

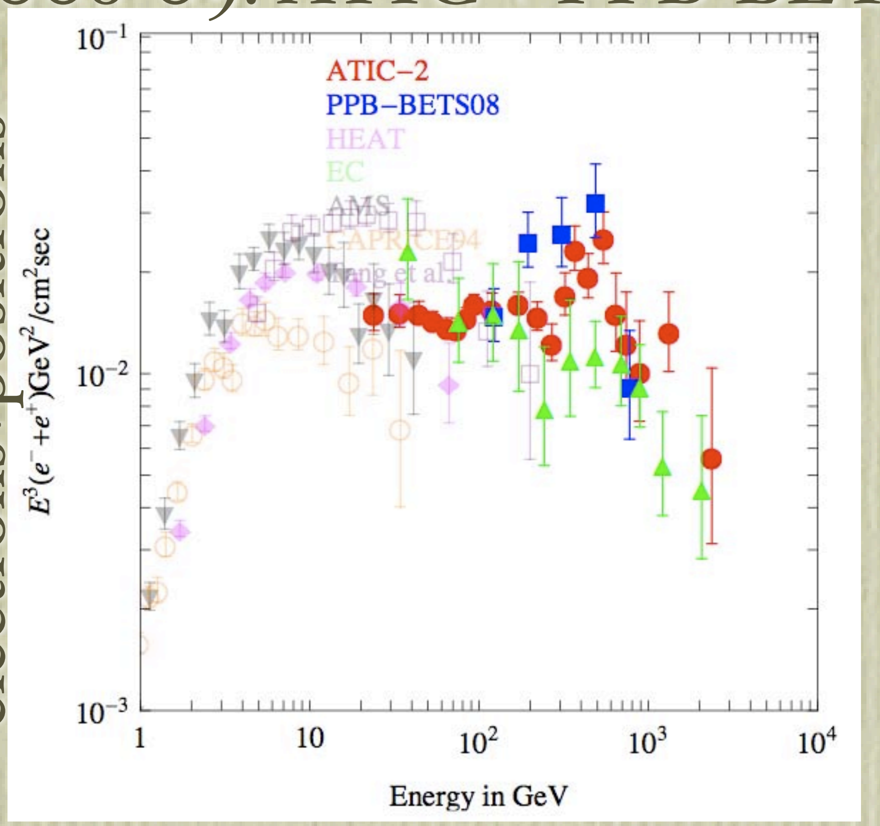
II) angular: flux correlated to DM halo shapes and with DM distributions within halos: central slopes, rich substructure pattern.

A fit of a featureless excess may set a guideline, but will be inconclusive.

The focus on electrons and positrons because of recent experimental results:

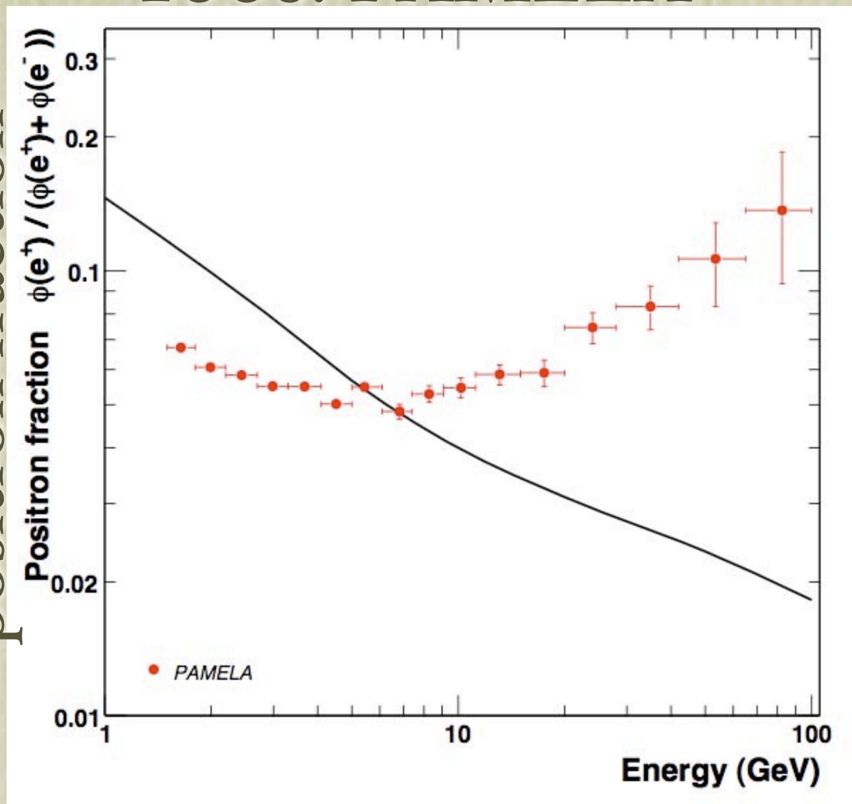
2008-09: ATIC + PPB-BETS

electrons+positrons



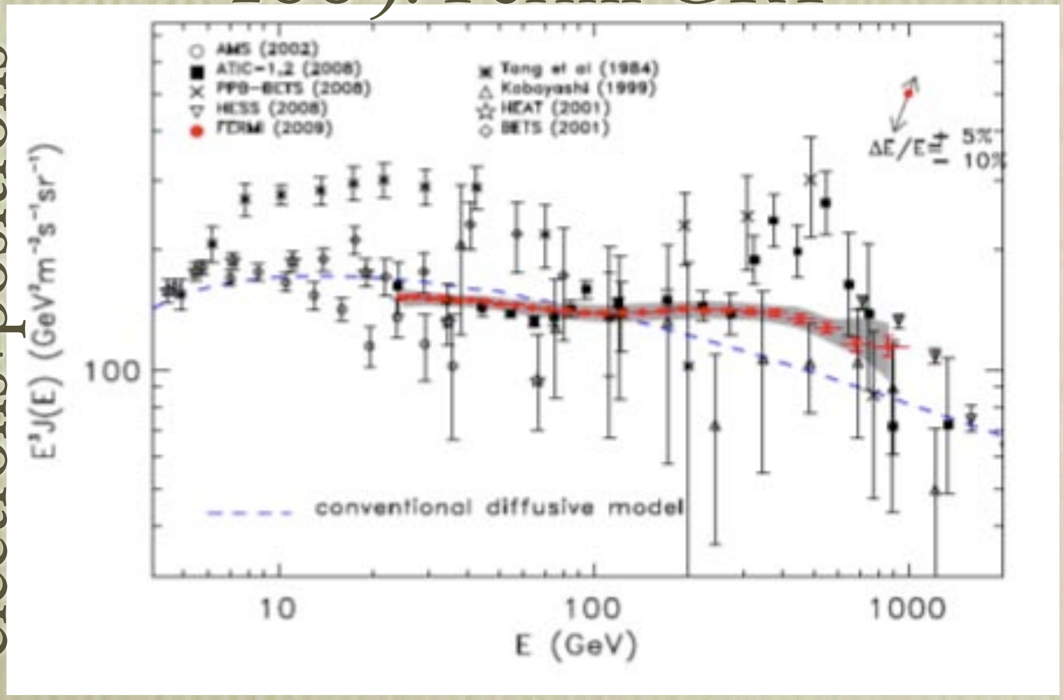
2008: PAMELA

positron fraction



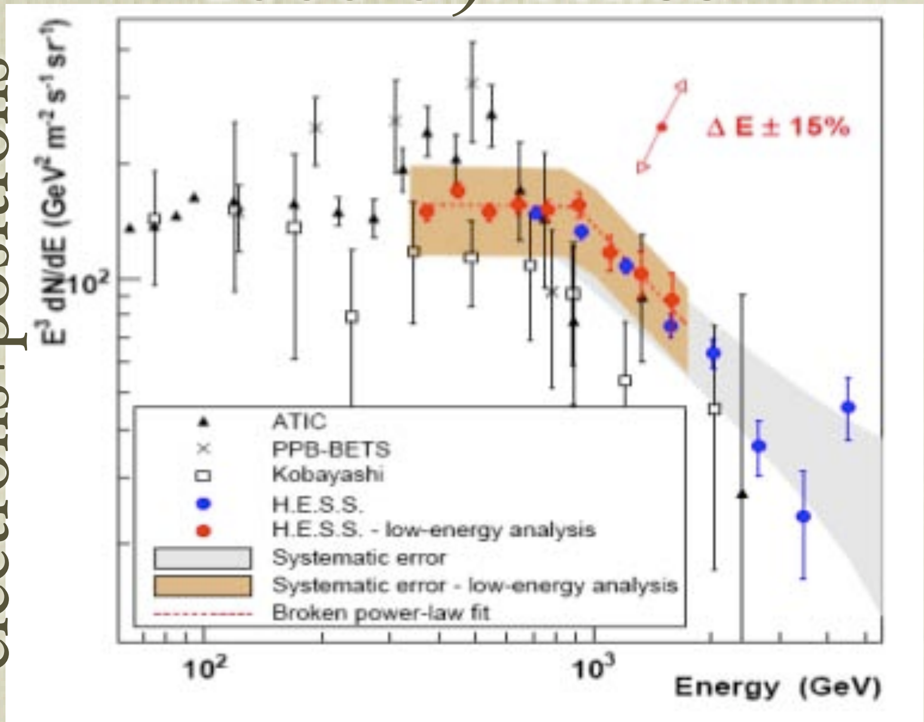
2009: Fermi GRT

electrons+positrons



2008-09: HESS

electrons+positrons



Electrons/positrons and the standard CR lore:

"Primary" CRs from SNe, "secondary" CRs generated in the interaction of primary species with the interstellar medium in "spallation" processes. Example: secondary Boron from the primary Carbon. Experimental data used to tune cosmic propagation parameters such as the spatial diffusion coefficient: $D_{xx}(p) \propto p^{\alpha}$

Looking at the ratio between the (secondary only) positron flux to the (mostly primary) electron flux, you expects it to scale like:

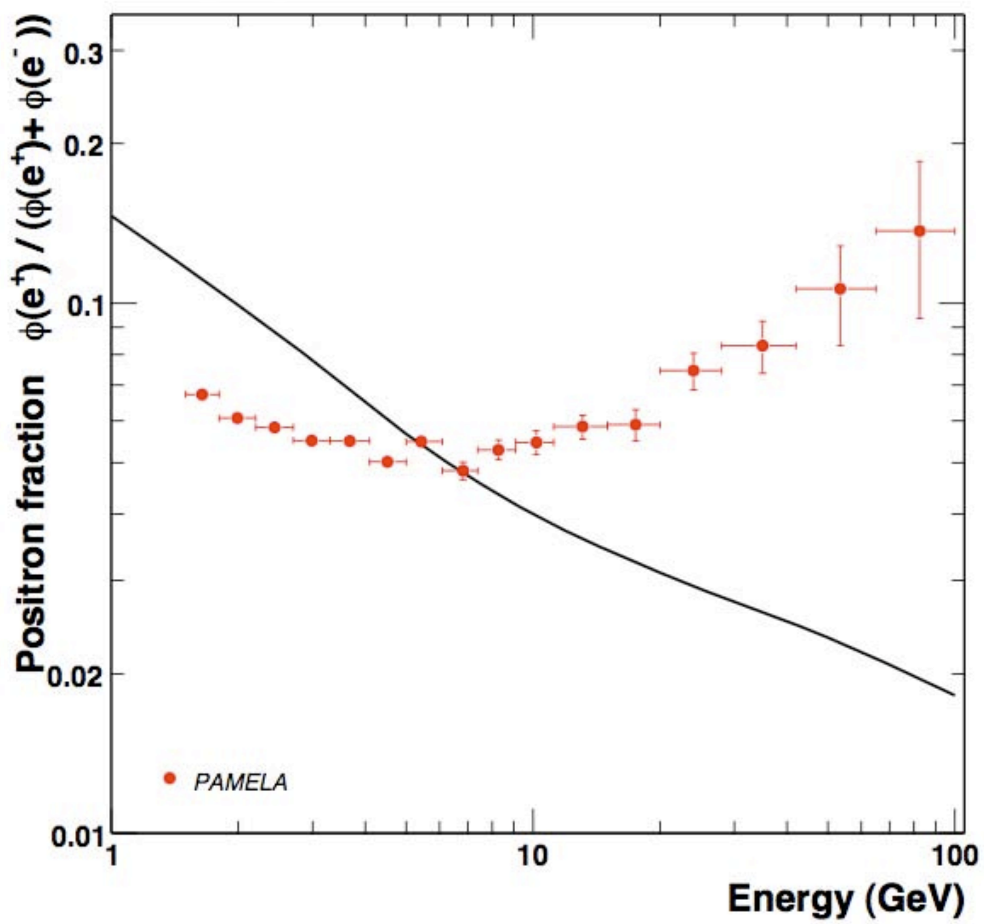
$$\frac{\phi_{e^+}}{\phi_{e^-}} \propto p^{-(\beta_{inj,p}-\beta_{inj,e}+\alpha)}$$

i.e. decreasing with energy since it would be hard to find a scheme in which:

$$\beta_{inj,p} - \beta_{inj,e} + \alpha$$

is negative.

PAMELA measured a rising positron fraction



Adriani et al., arXiv:0810.4995

How to explain a rising positron fraction?

- The propagation model is wrong: there are extra energy-dependent effects which affect secondary positrons (or primary electrons) but not the secondary to primary ratios for nuclei (at least at the measured energies), e.g.: Piran et al., arXiv:0905.0904; Katz et al., arXiv:0907.1686

- There is production of secondary species within the CR sources with a mechanism giving a sufficiently hard spectrum (reacceleration at SN remnants?), e.g.: Blasi, arXiv:0903.2794; Mertsch & Sarkar, arXiv:0905.3152

- There are additional astrophysical sources producing primary positrons and electrons: pulsars are the prime candidate in this list, e.g.: Grasso et al., arXiv:0905.0636

- There is an exotic extra source of primary positrons and electrons: a dark matter source is the most popular option in this class.

Primary electrons/positrons from DM WIMPs:

The relevant process is the pair annihilations of non-relativistic WIMPs in the DM halo, proceeding mostly through two-body final states:

$$\chi\bar{\chi} \to f\bar{f}$$

(the energy of f is equal to the WIMP mass) corresponding to the source function:

$$Q_i(r,E) = \langle\sigma v\rangle_0 \sum_f \frac{dN_i^f}{dE}(E) B_f \mathcal{N}_{\rm pairs}(r)$$

total rate

e$^+$/ e$^-$ energy spectra of two kinds:

branching ratio into f

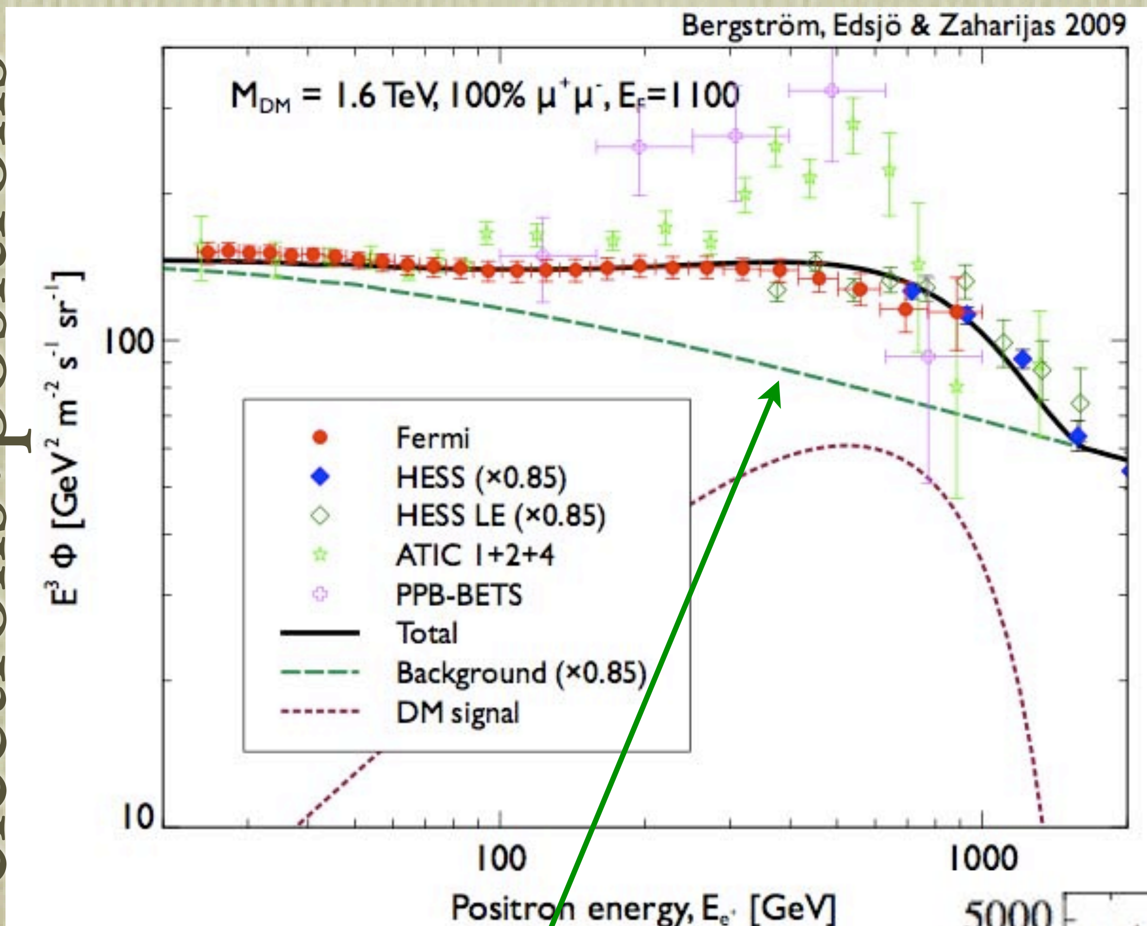
density of WIMP pairs

Soft spectra from, e.g., quark final states which produce charged pions decaying into leptons;

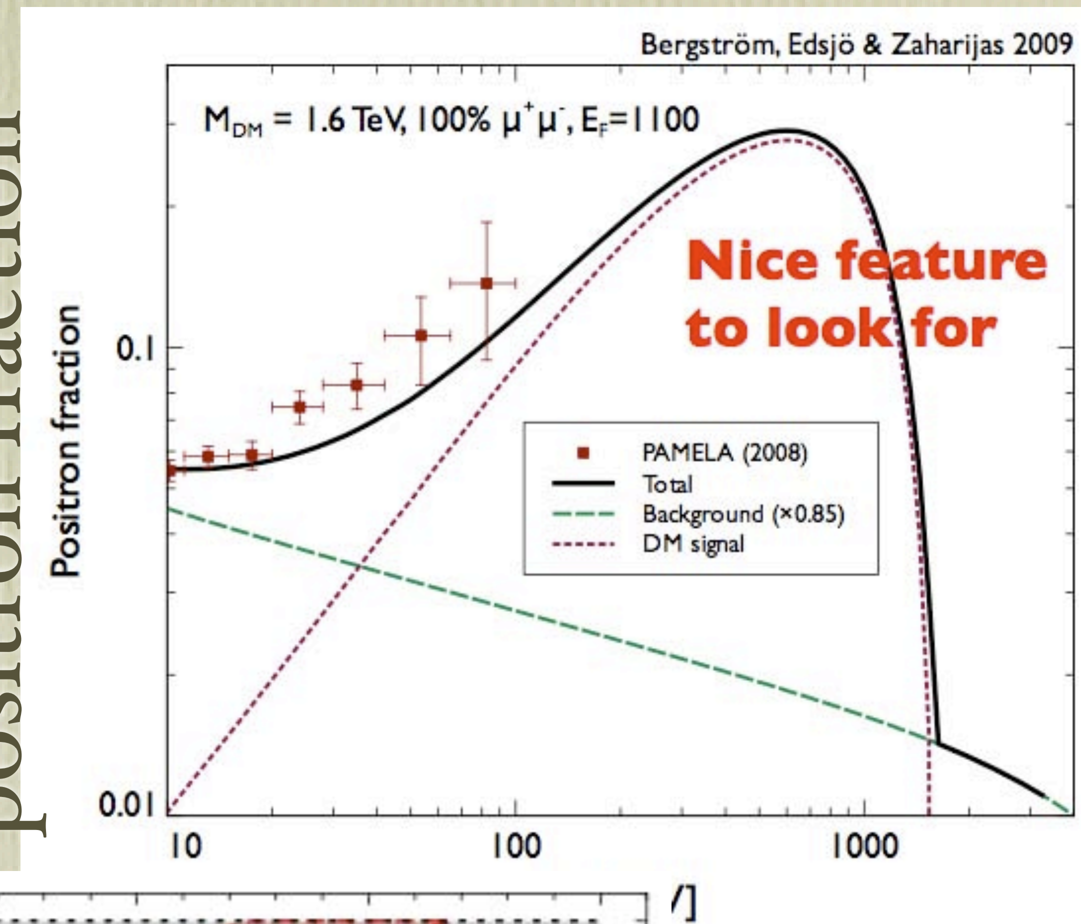
Hard spectra from, e.g., lepton or gauge boson final states, in which electrons and positrons are produced promptly or in a short decay chain.

Blind fit of Pamela/Fermi with a generic WIMP model (defined by WIMP mass and dominant annihilation channel), taking into account limits, e.g., from antiproton data:

electrons+positrons

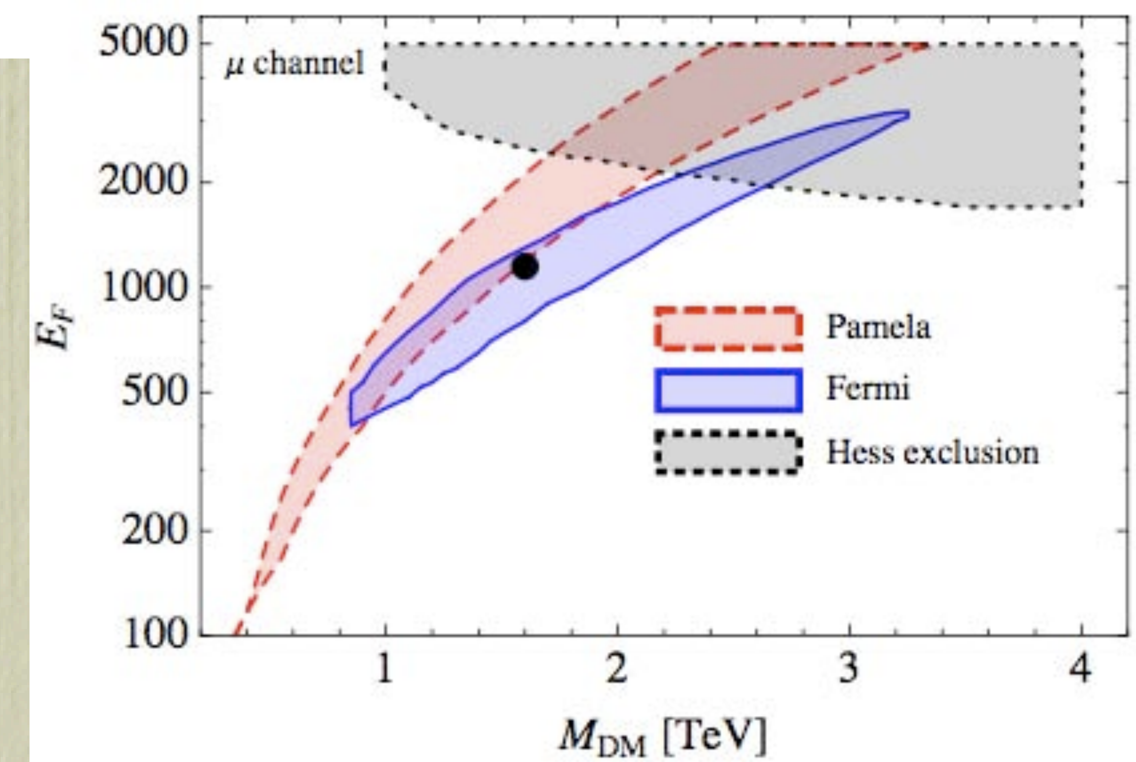


positron fraction



Bergström et al., arXiv:0905.0333

background ?!?



This "solution":

annihilation into muons, heavy WIMPs, large "enhancement factors"

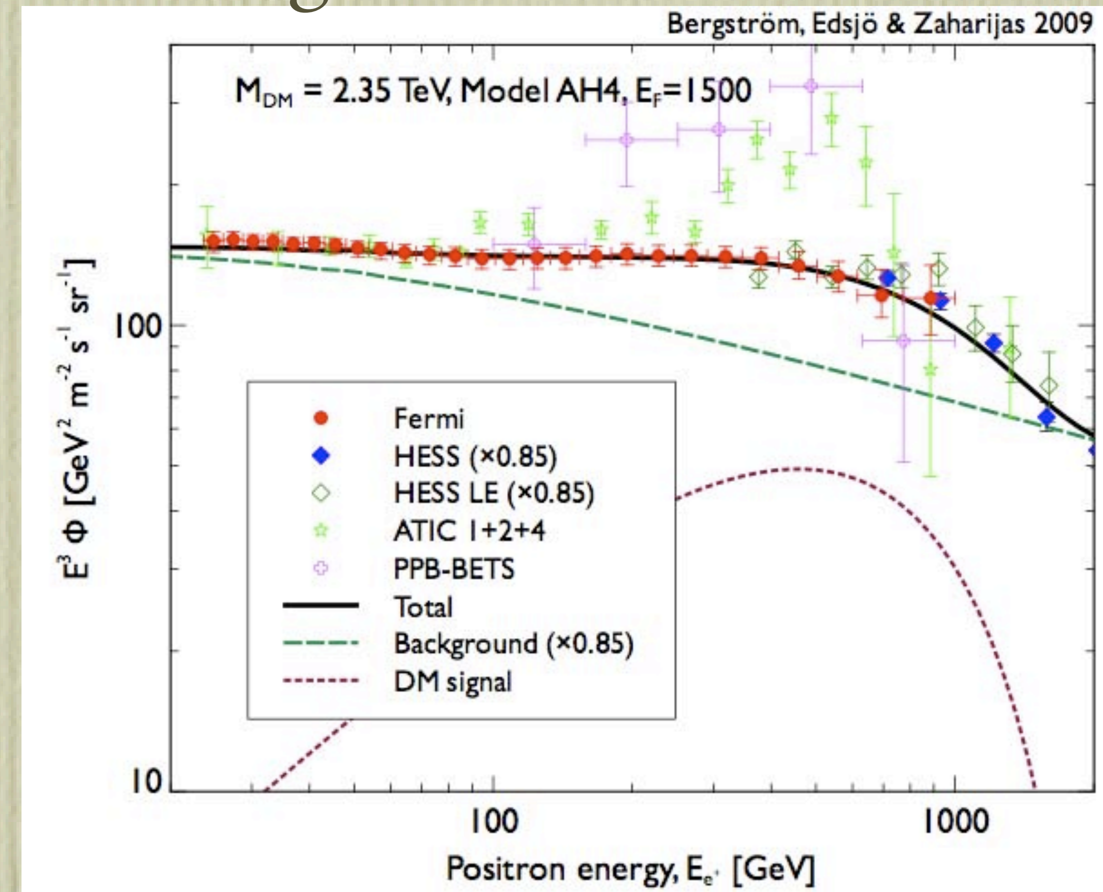
Slightly different results among the numerous fits to the recent data, but convergence on models which are very different from “conventional” WIMP models (e.g. neutralinos in the MSSM). DM seems to be:

- **heavy**, with WIMP masses above the 1 TeV scale;
- **leptophilic**, i.e. with pair annihilations with hard spectrum and into leptons only, or into light (pseudo)scalars which for kinematical reasons can decay into leptons only (there is very little room to accommodate a hadronic component which would manifest in the antiproton data - this point has been disputed by, e.g., Grajek et al., arXiv:0812.4555);
- with a **large** (order 1000 or more) **“enhancement factor”** in the source function, either: i) in the annihilation rate because $\langle \sigma v \rangle_{T_0} \gg \langle \sigma v \rangle_{T_{f.o.}}$ (non-thermal DM or decaying DM? Sommerfeld effect? a resonance effect?); or: ii) in the WIMP pair density because $\langle \rho_\chi^2 \rangle \gg \langle \rho_\chi \rangle^2$.

Hard to extrapolate, on a general ground, a connection between this scenario and direct detection.

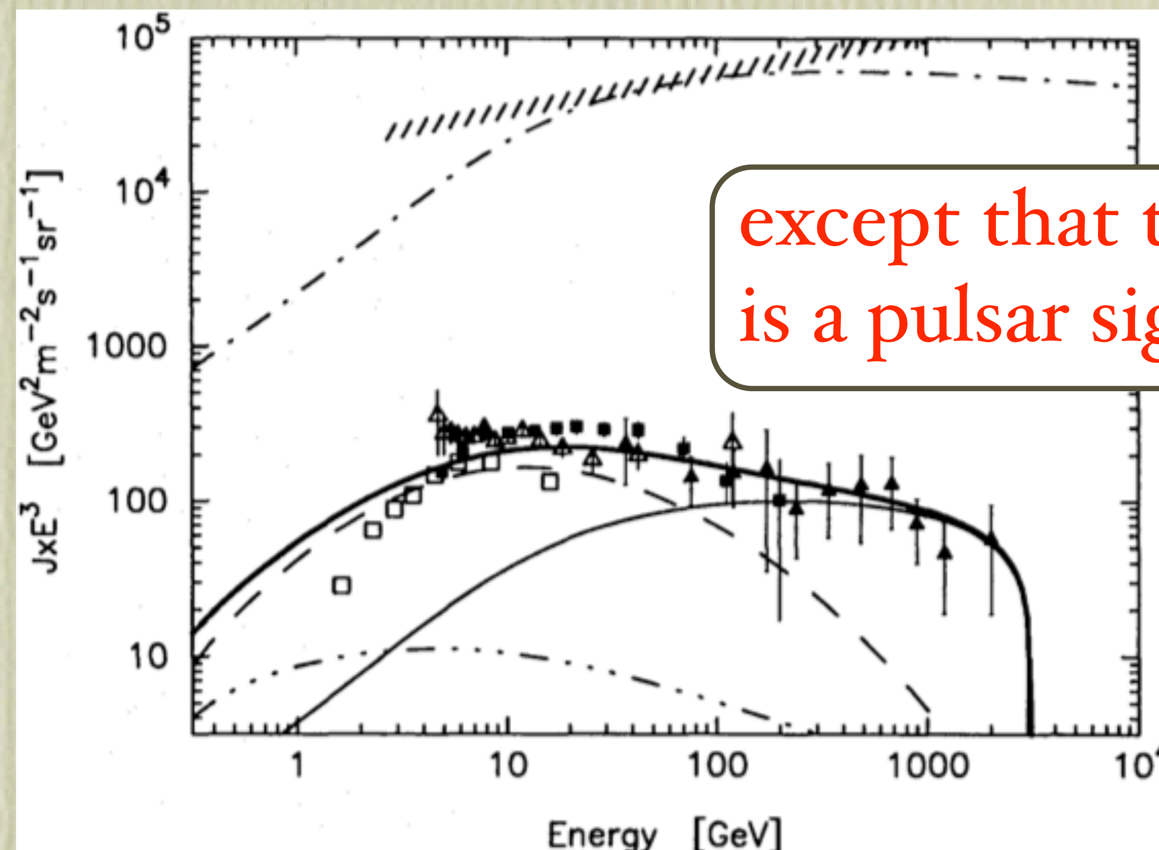
Caveat: we may have seen a DM signal, but have not seen a DM signature.

The sample fit of the data with a DM signal:



Bergström et al. on model by **Arkani-Hamed et al.**

is analogous to the signal foreseen in models of more than a decade ago:



except that this is a pulsar signal

Aharonian et al., 1995

Cleaner spectral features in upcoming higher statistics measurements (???).
Pay attention to cross correlations with other DM detection channels.

E.g.: a DM point source accounting for the PAMELA excess would be detected by the Fermi GST looking at the associated γ-ray flux

DM annihilations and gamma-ray fluxes:

The source function has exactly the same form as for positrons:

$$Q_i(r,E) = \langle \sigma v \rangle_0 \sum_f \frac{dN_i^f}{dE}(E) B_f \mathcal{N}_{\text{pairs}}(r)$$

total rate

branching ratio into f

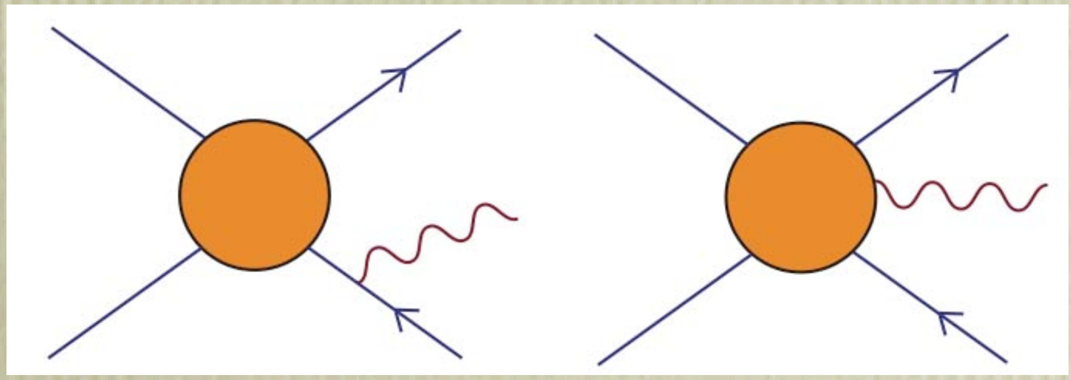
density of WIMP pairs

Prompt emission of γ-rays associated to three components:

I) Continuum: i.e. mainly from $f \to \ldots \to \pi^0 \to 2\gamma$

II) Monochromatic: i.e. the 1-loop induced $\chi\chi \to 2\gamma$ and $\chi\chi \to Z^0\gamma$ (in the MSSM, plus eventually others on other models)

III) Final state radiation (internal Bremsstralungh)

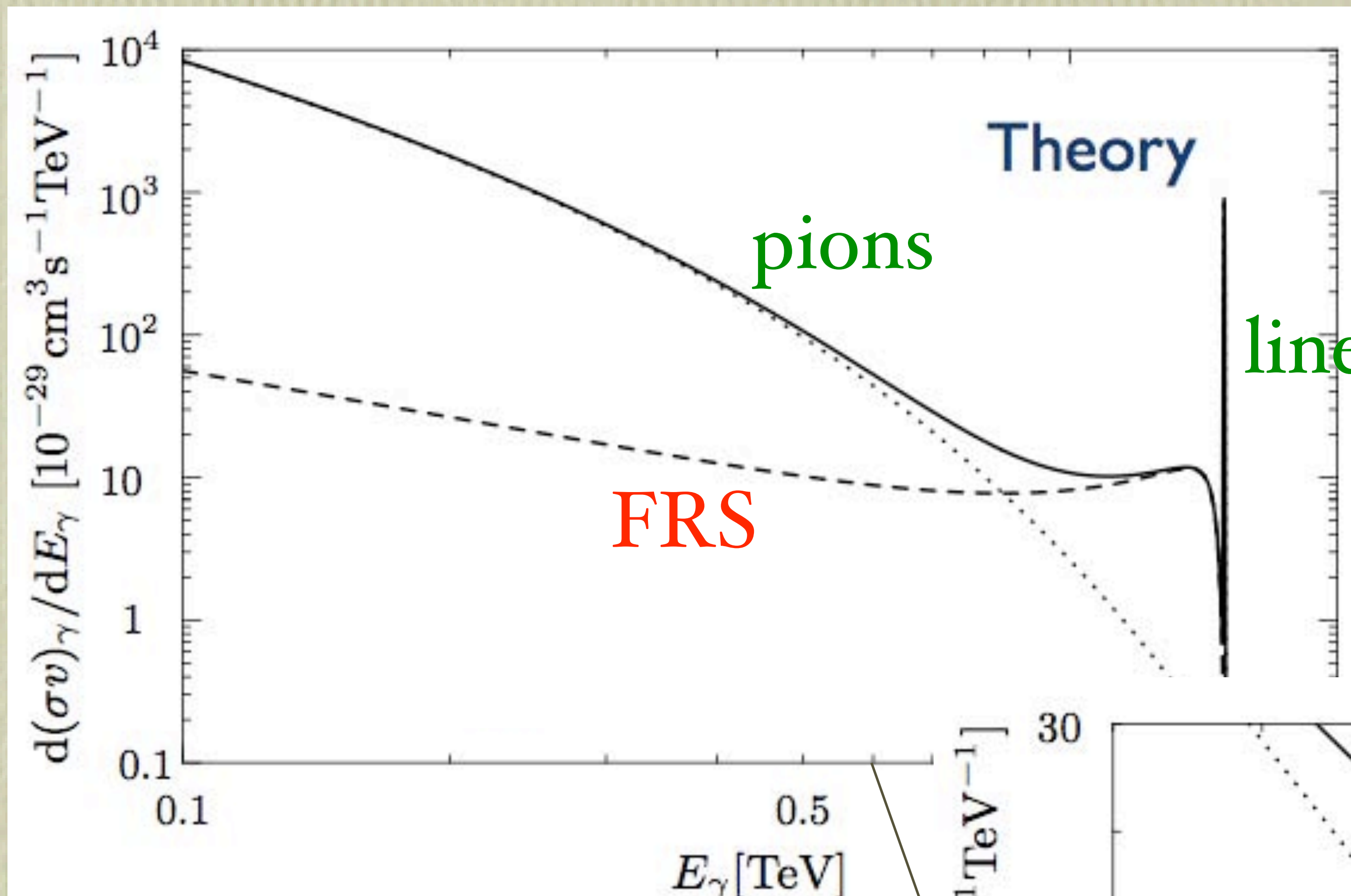


especially relevant for:

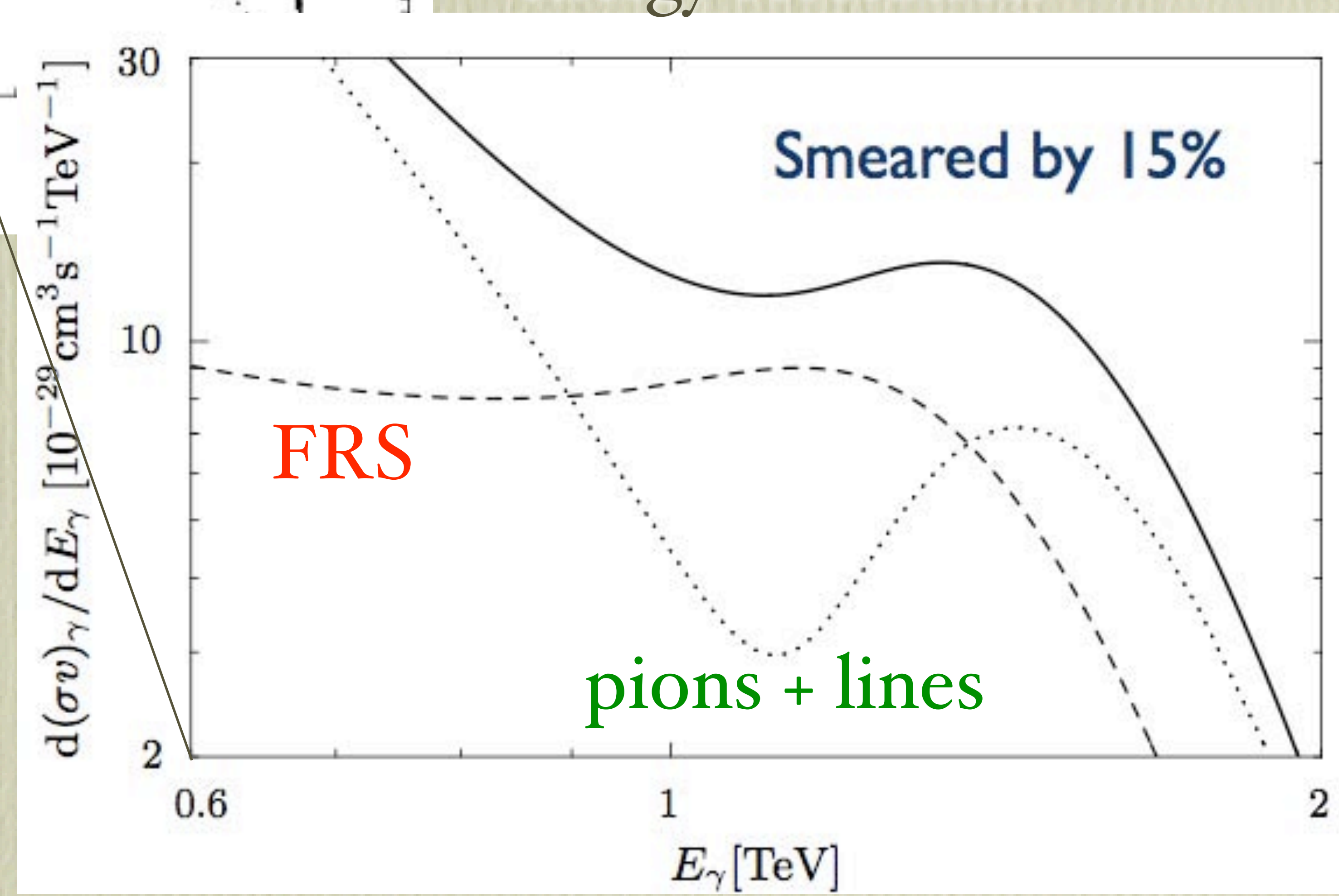
$\chi\chi \to l^+ l^- \gamma$

in case of Majorana fermions

Then for a model for which all three are relevant (e.g. pure Higgsino)The source function has exactly the same form as for positrons:



including a typical detector energy resolution



Bergström et al., astro-ph/0609510

The induced gamma-ray flux can be factorized:

$$\frac{d\Phi_\gamma}{dE_\gamma}(E_\gamma,\theta,\phi) = \frac{1}{4\,\pi} \boxed{\frac{\langle\sigma v\rangle_{T_0}}{2\,M_\chi^2} \sum_f \frac{dN_\gamma^f}{dE_\gamma} B_f} \cdot \boxed{\int_{\Delta\Omega(\theta,\phi)} d\Omega' \int_{l.o.s.} dl\ \rho_\chi^2(l)}$$

Particle Physics DM distribution

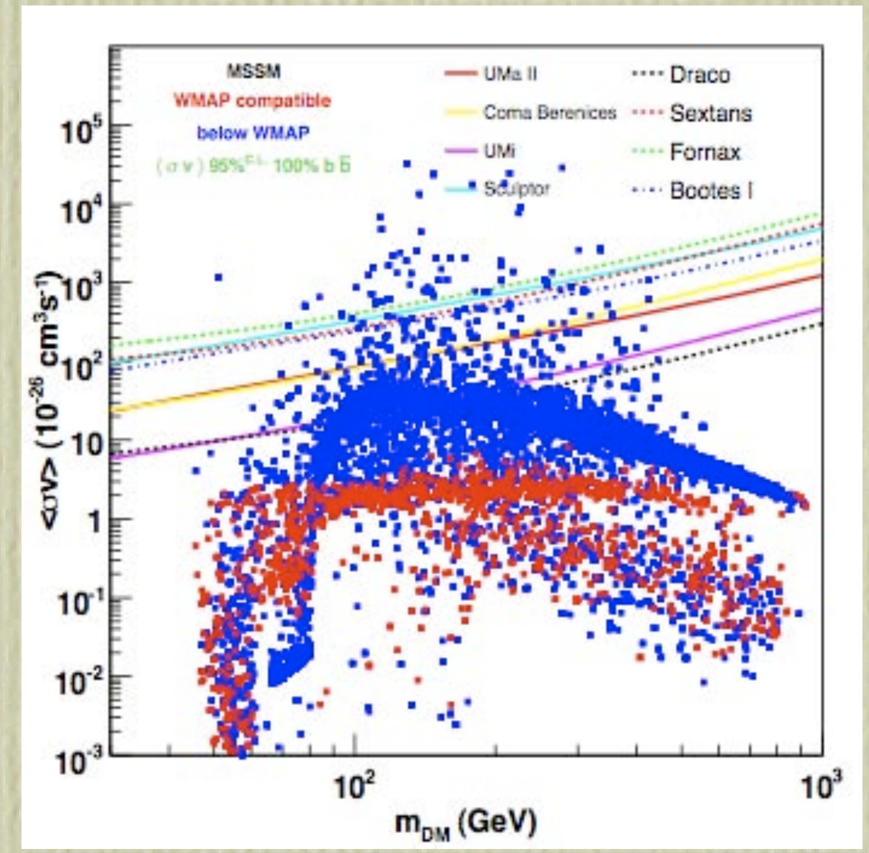
Targets which have been proposed:

- The Galactic center (largest DM density in the Galaxy)
- The diffuse emission from the full DM Galactic halo
- Dwarf spheroidal satellites of the Milky Way
- Single (nearby?) DM substructures without luminous counterpart
- Galaxy clusters
- The diffuse extragalactic radiation

All of these are suitable for the Fermi GRT. A number of "excesses" claimed in recent years; Fermi will allow for much firmer on them. Unfortunately only upper limits have been reported as first results.

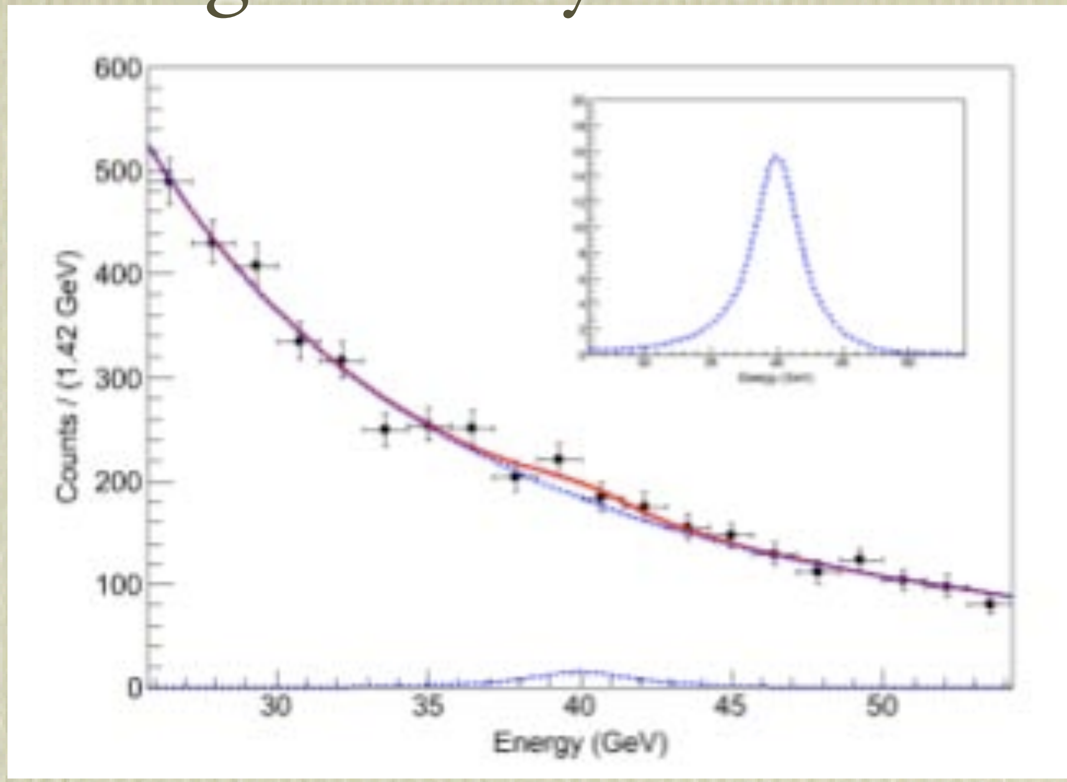
The first upper limits on DM gamma-ray fluxes from Fermi:

dwarf satellites



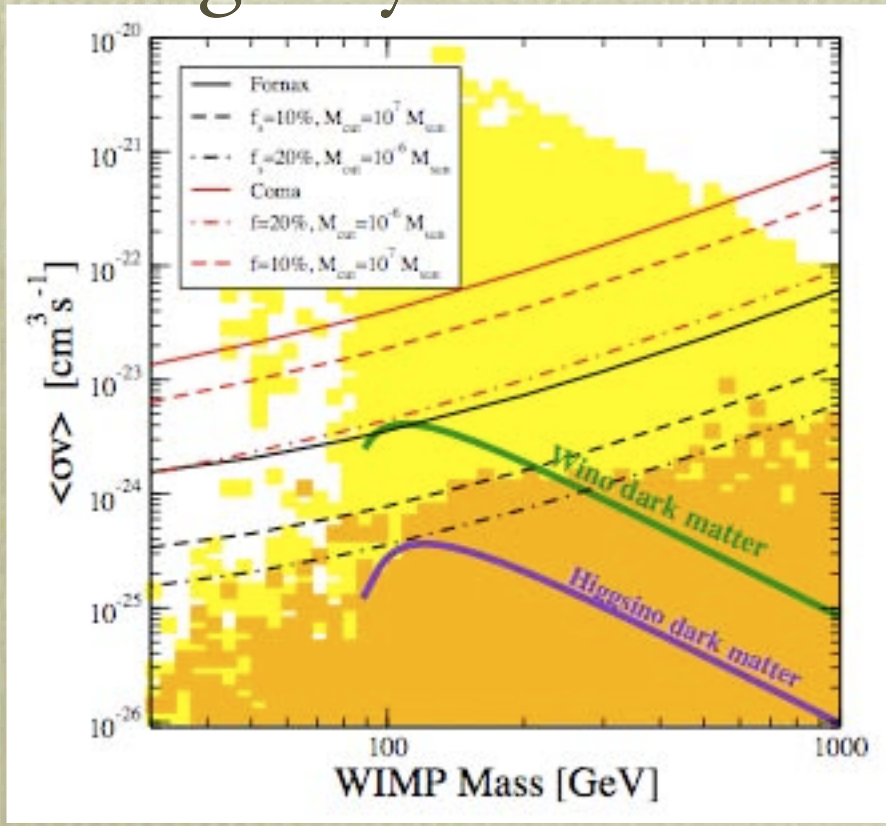
arXiv: 1001.4531

gamma-ray lines



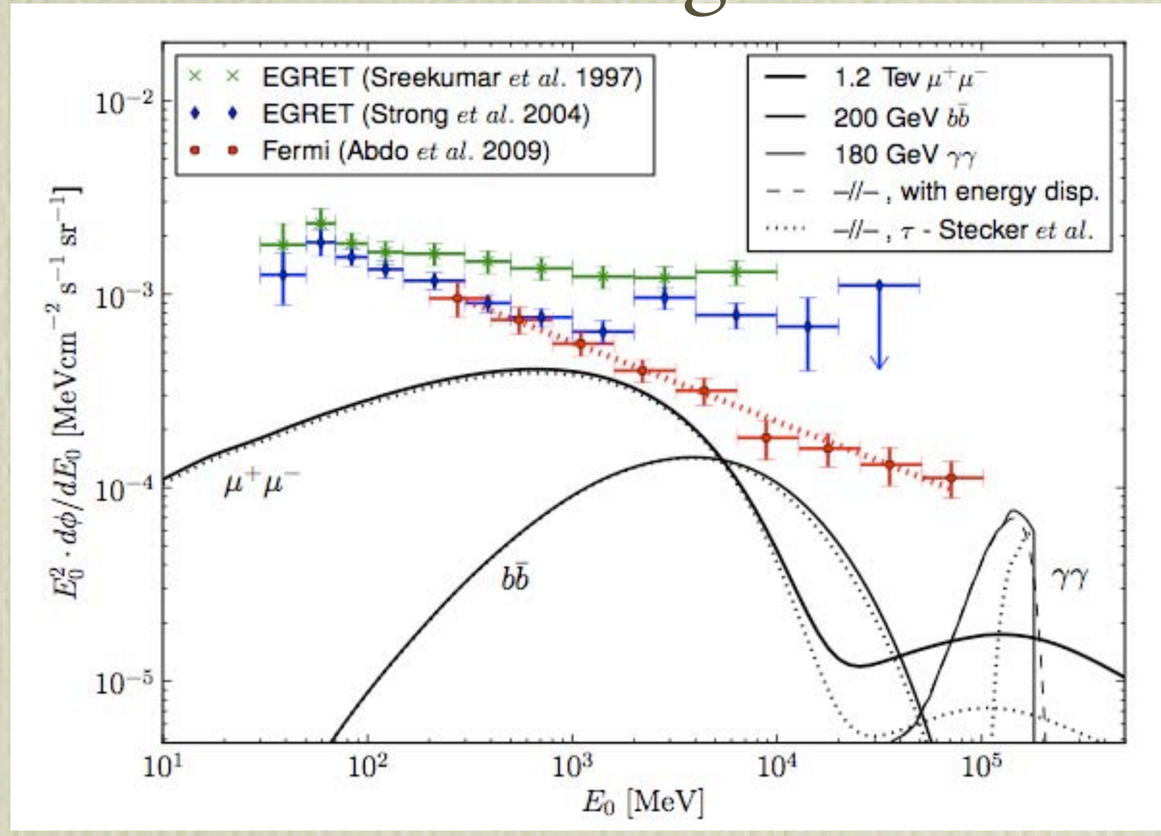
arXiv: 1001.4836

galaxy clusters



arXiv: 1002.2339

diffuse extragalactic



arXiv: 1002.4415

DM annihilations and radiative emission:

The annihilation yields give rise to a multicomponent spectrum:

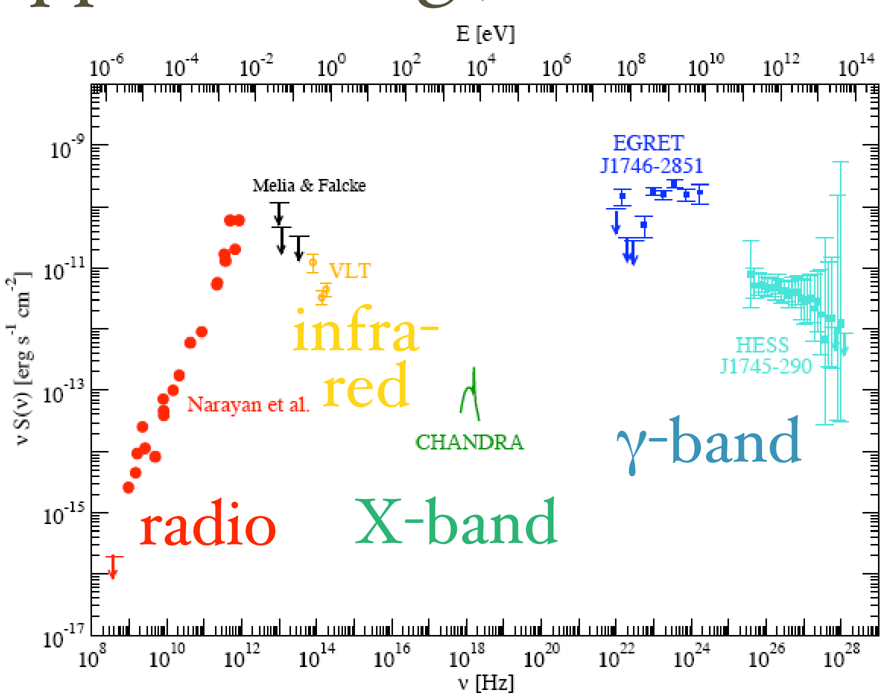
$$\chi\,\bar{\chi} \to \begin{cases} e^+\,e^- \\ l^+\,l^- \text{ or } \phi\,\phi \to \ldots + e^+\,e^- \\ P\,\bar{P} \to \ldots + \pi^\pm \to \ldots + e^\pm \end{cases}$$

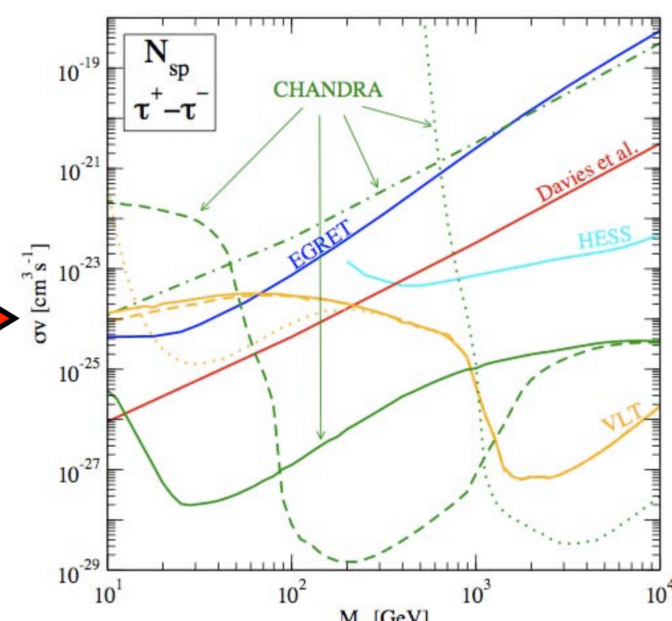
ambient backgrounds and fields

- Synchrotron
- Inv. Compton
- Bremstrahlung
- Coulomb
- Ionization

→ radio, IR, X-rays, γs

For certain DM sources is a very powerful (although model dependent) approach. E.g., the Galactic center (Sgr A*) has a well-measured seed:





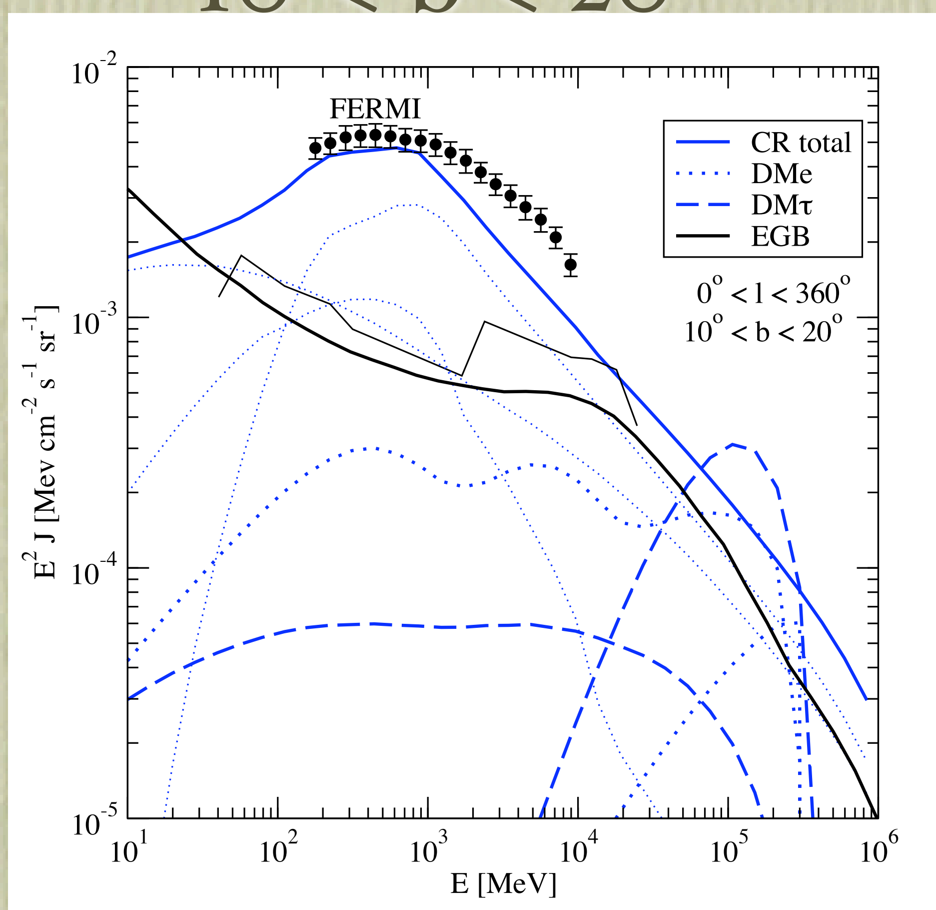
significant limits on WIMP models at any wavelength, unlikely the most stringent from the γ-band (even with Fermi)

Regis & P.U., arXiv: 0802.0234

Multifrequency approach to test local e^+/e^- excesses:

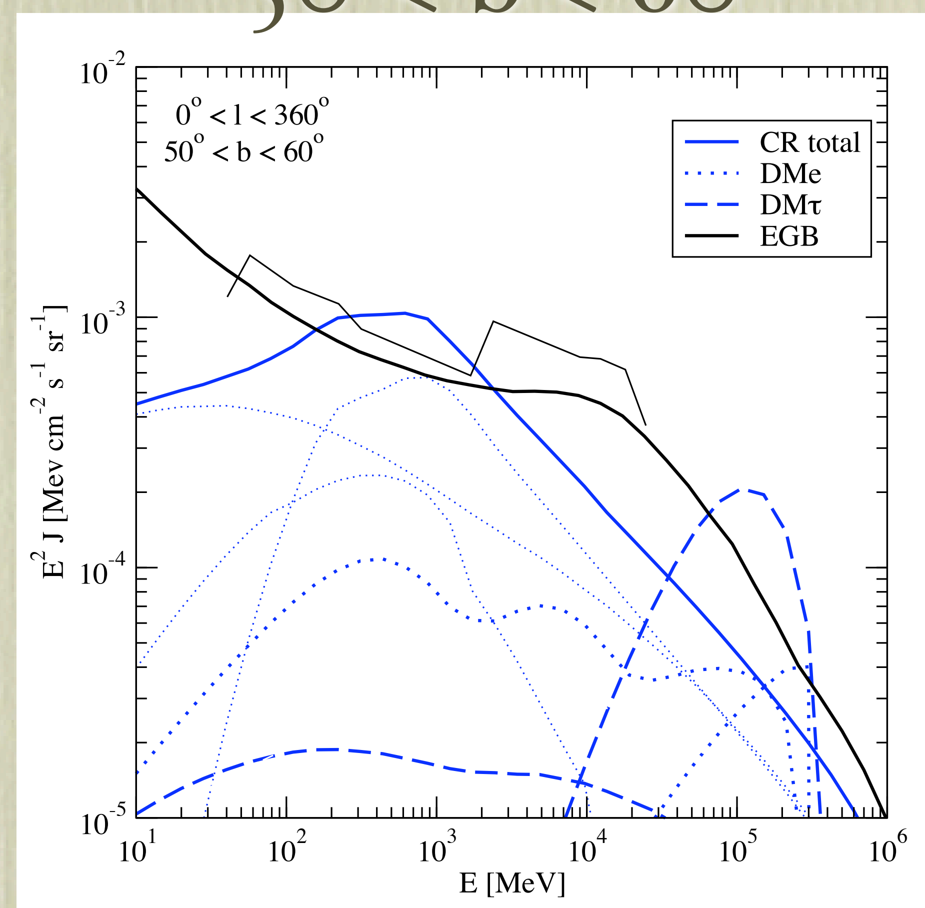
An excess from standard astrophysical sources would be confined to the galactic disc, one from DM annihilation would be spread out to a much larger scale, leading to different predictions for the IC radiation.
IC terms (plus FSR or pion terms) for two sample (leptophilic) models fitting the Pamela excess in the positron ratio:

$10^\circ < b < 20^\circ$



cross checked against Fermi preliminary data at intermediate latitudes

$50^\circ < b < 60^\circ$

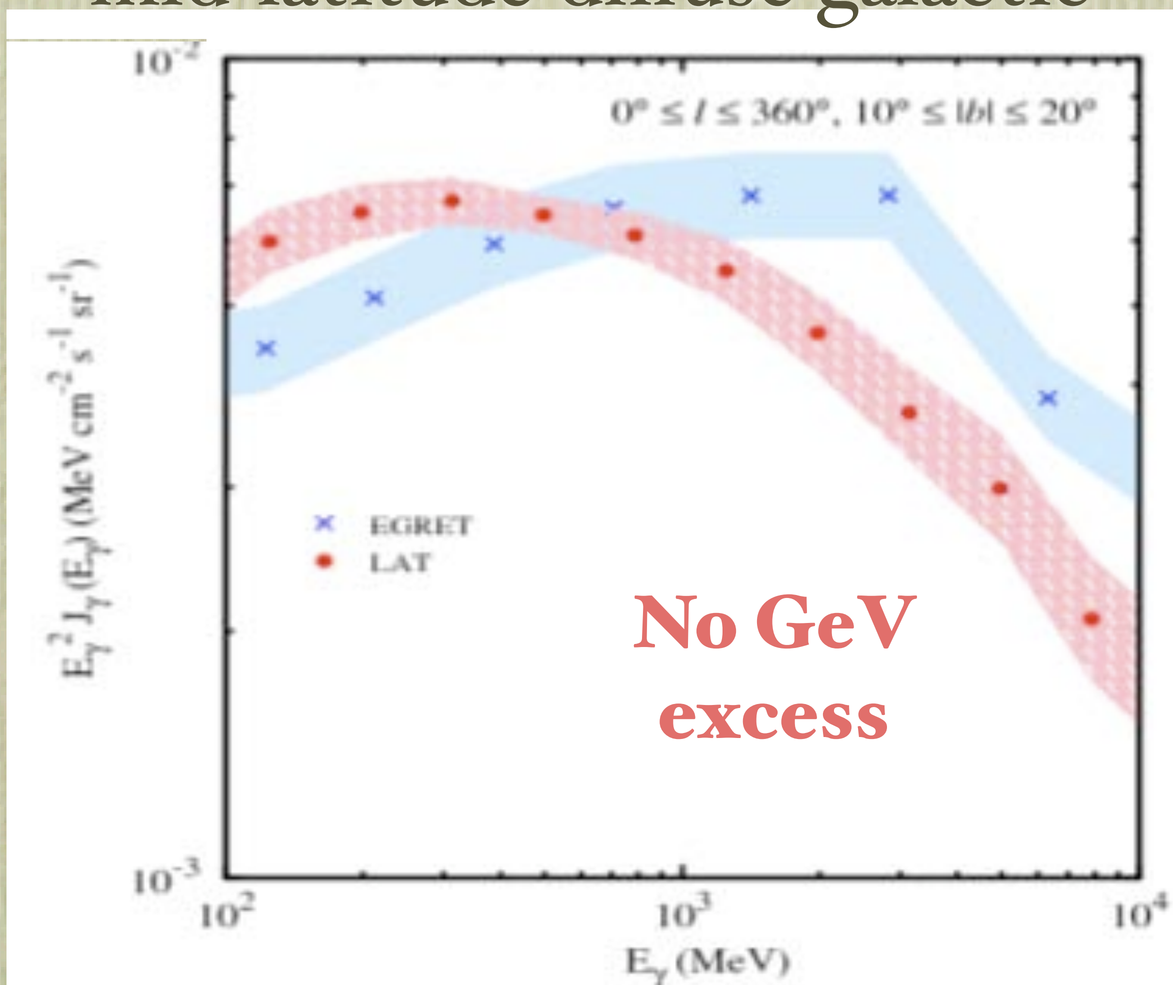


a more solid prediction when looking at high latitudes ...

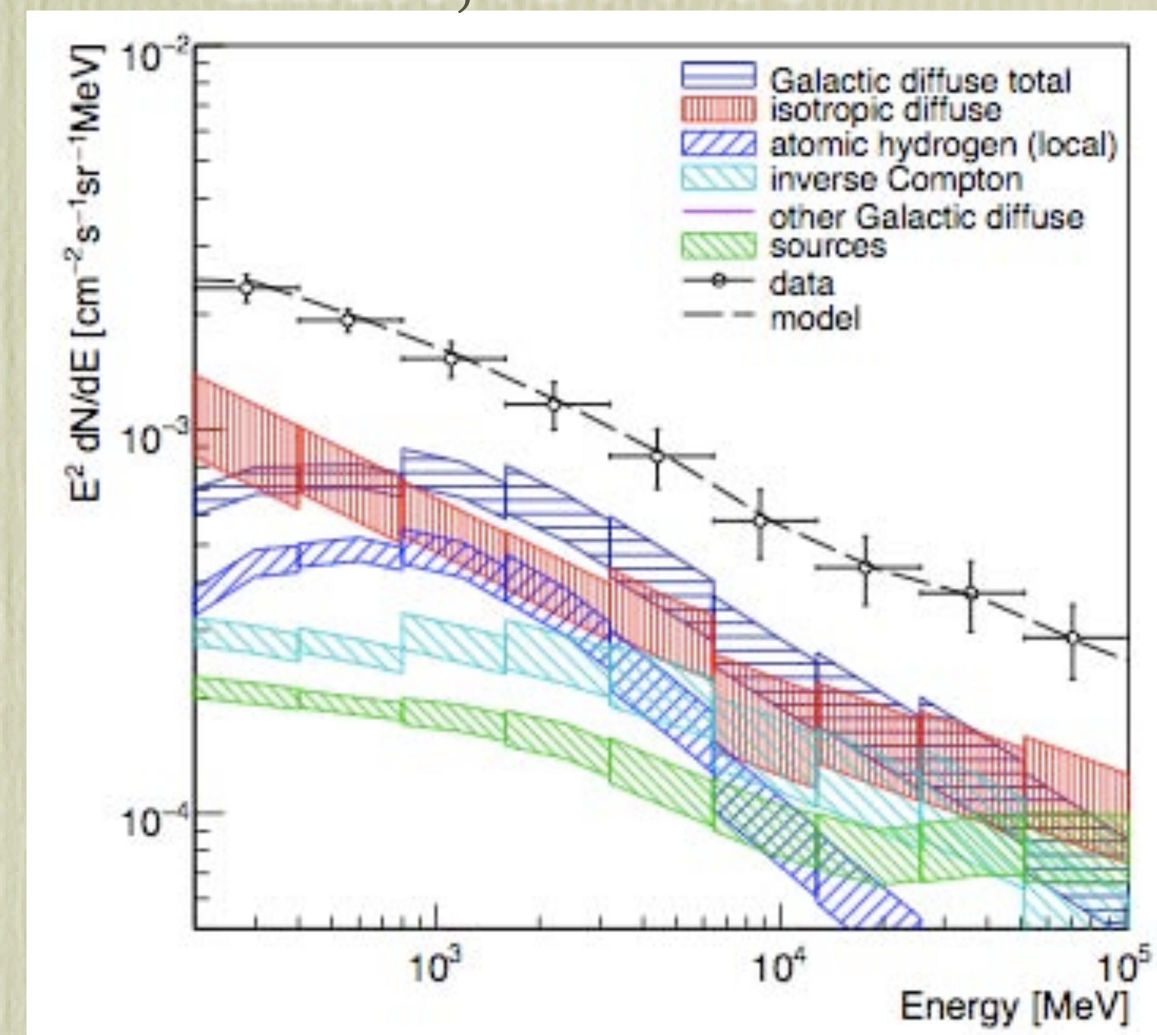
Regis & P.U., arXiv: 0904.4645

A result to be checked against data on the diffuse gamma-ray radiation at energies above 100 GeV which will soon be available. At present, Fermi has already excluded the EGRET GeV excess:

mid-latitude diffuse galactic



diffuse, | b | > 60°



arXiv: 1002.3603

What about an excess in the central region of the Galaxy - the Fermi gamma-ray “haze”? What about connections to the WMAP haze?

Conclusions:

- The WIMP framework offers definite patterns to link direct and direct detection, although model independent approaches have some limitations.

- Neutrino telescope searches are a powerful tool, complementary to direct detection both in the DM particle discovery potential and to address their nature.

- The DM interpretation of the cosmic lepton puzzle convergences on models with peculiar properties, whose link with direct detection is hard to access on general grounds.

- The cross-correlation among DM signals is the main route to DM identification. Indirect searches have large potentials in this respect with currently running experiments, such as Fermi and Pamela, and upcoming, such as AMS and ICECUBE.