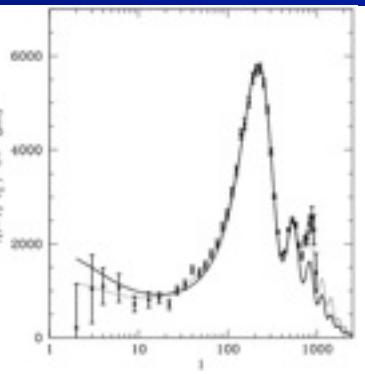
Dark Matter Review

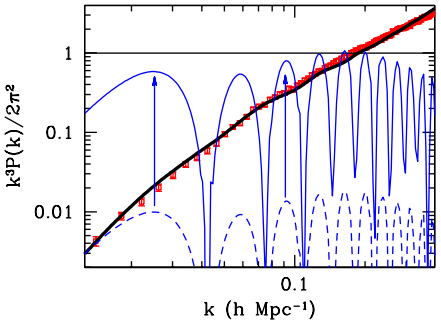
Pasquale D. Serpico

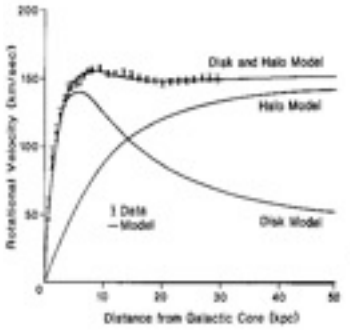
- **Importance:** Dark matter is an astrophysical and cosmological problem that calls for a “fundamental physics” explanation
- **What kind of new physics?** I will hopefully clarify some common misunderstanding (among particle physicists)
- **The “WIMP paradigm”**: collider, direct searches and indirect searches
- Current status and some near future expectations

RPP Grenoble - 16 January 2013

Observational proofs







CMB anis. **(Growth & Pattern of) Large Scale Structures** **Clusters (X-rays, lensing)** **Galaxies (rotation curves, fits...)** **Dwarfs**

"Cosmological" → **"Astrophysical"**

(growing effect of non-linearities, baryonic gas dynamics, feedbacks...)

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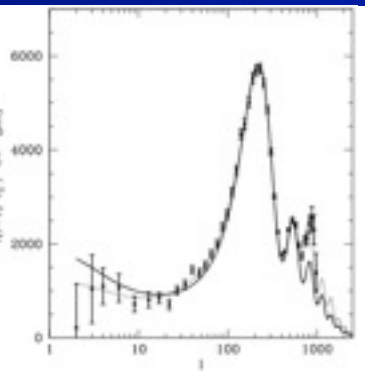

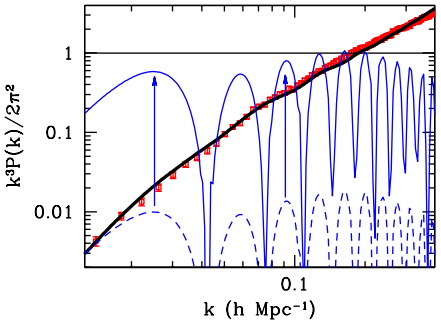

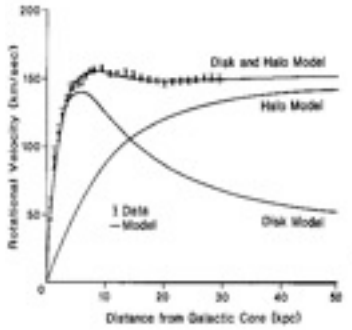

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Cosmological Evidence is of paramount importance for Particle Physics!

I. Based on exact solutions or linear perturbation theory applied to simple physical systems (gravity, atomic physics...): credible and robust!

II. Suggests additional species, rather than a modification of gravity.

III. Tells us that the largest fraction of required dark matter is non-baryonic, rather than brown dwarf stars, planets, etc.

Crucial conclusion

Only possible SM candidate: ν's (which are also "stable"). But they do not work being

1. too light

Direct mass limits combined with splittings from oscillation experiments impose upper limit of about 7 eV to the sum (After Katrin, potentially improved to ~0.7 eV)

$$\Omega_\nu = \frac{\rho_\nu}{\rho_c} \simeq \frac{\sum_i m_i}{45\,\mathrm{eV}}$$

$\Omega_{DM} \approx 0.3$(WMAP) $\Rightarrow \Sigma m_i \approx 15$ eV

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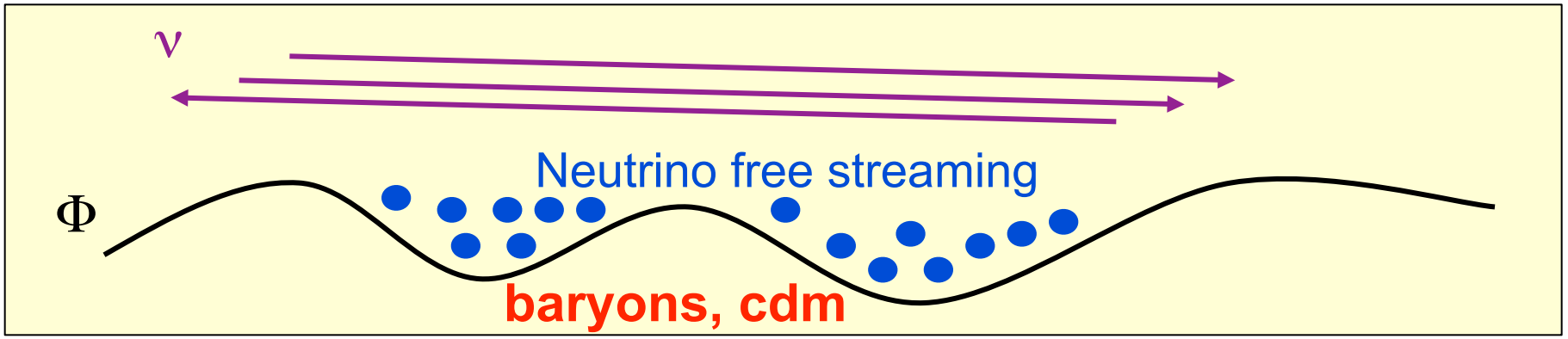

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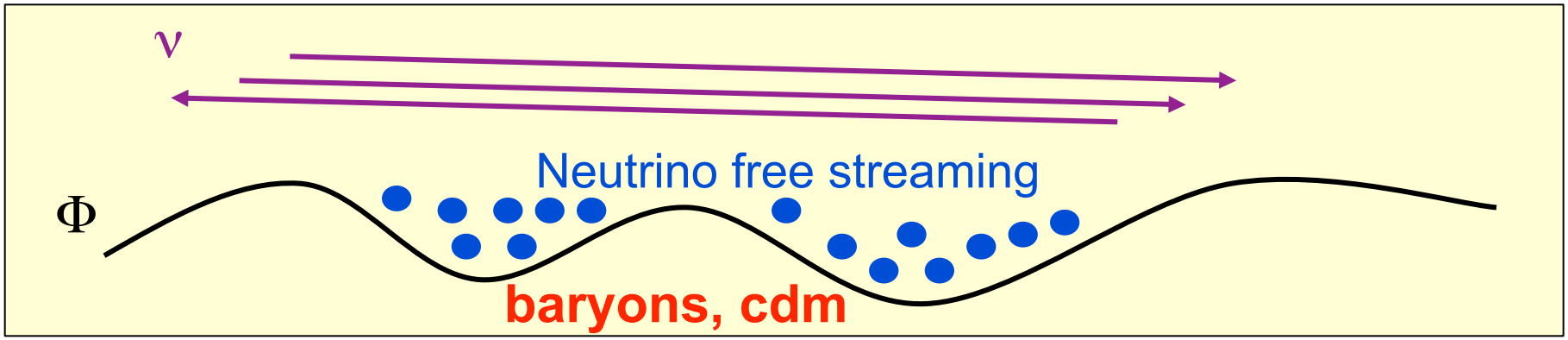

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This implies that Dark Matter requires "new physics", beyond the theories of the SM and/or gravity known today.

Is the production of DM by itself restrictive on BSM?

I.e, do we get major restrictions on particle physics scales and scenarios (not merely model parameters!) by requiring a dynamical mechanism for its generation?

... Not really! A whole zoo exists, here is a sub-set:

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- **Coherent Field Oscillations**

Paradigmatic case: μeV to meV **axions**, whose final abundance depends on the value of the mass (or PQ scale,~O(10^{12} GeV)) and the initial misalignment angle (θ)
Searches via microwave cavities.

- **Asymmetric DM (possibly with "strong" interactions)**

Similar or even common origin of DM and baryons? Linked to baryogenesis, GUT scale? Linked to a strongly interacting sector BSM at TeV scale?

- **Sterile (~1-100 keV) Neutrinos (coupled via Yukawas)**

Populated (non-thermally, in general) by oscillations with active ones. Note: No new physics *above* the electroweak scale would be needed!
X-ray line signature?

- **Superheavy Dark Matter (~10^{13} GeV, only gravity coupled)**

Spontaneous particle creation generically takes place in time-dependent gravitational background*
If lifetime in a (relatively narrow) range, possible signatures in UHECRs...

*Massive scalar field in FRW metric is equivalent to an auxiliary scalar field in Minkowski with t-dependent mass. Hence its E is not conserved, particle production can take place at the expense of gravity.

WIMPs: the "matter counterpart" of CMB?

- Early universe was a cosmic hot plasma, cooling down with time (expansion)

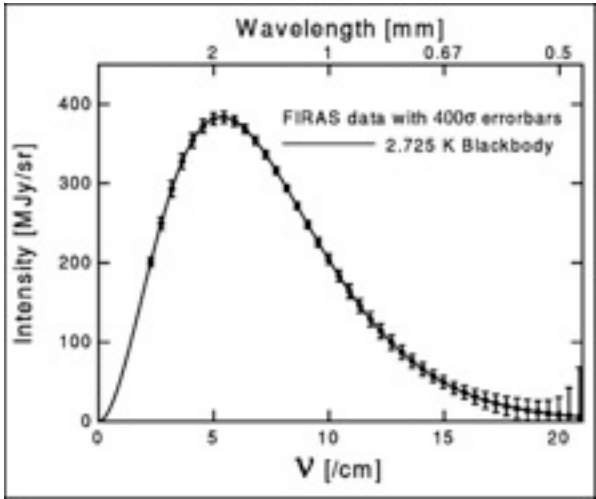
- We expect that all particles which exchange E quickly enough among themselves compared with the expansion rate of the universe will achieve kinetic equilibrium. Similarly, if number changing processes are fast, chemical equilibrium is achieved. Naively, compare:

$$\Gamma_a = \sum_b n_b \langle \sigma_{ab} v \rangle \quad \text{with} \quad H \sim \sqrt{G_N \rho_{tot}} \sim \sqrt{G_N} T^2$$

$\Gamma \gg H$	$\Gamma \sim H$	$\Gamma \ll H$
process at equilibrium	freezing-out	decoupled

- CMB formed this way: it is the best blackbody around, since it is negligibly affected by processes after decoupling

- **Thermal WIMPs paradigm:** non-relativistic, matter counterpart of the above background, which has right properties to be the dark matter...



WIMP miracle... and hard facts

A textbook calculation can prove that

$$\Omega_X h^2 \simeq \frac{0.1\,\mathrm{pb}}{\langle \sigma v \rangle}$$

dimensionally, for EW scale masses & couplings, one gets the right value!

$$\langle \sigma v \rangle \sim \frac{\alpha^2}{m^2} \simeq 1\,\mathrm{pb} \left(\frac{200\,\mathrm{GeV}}{m} \right)^2$$

- but the numerator depends from widely different cosmological parameters (Hubble parameter, CMB temperature) and the Planck scale. Is this match simply a coincidence?
- The (dis)agreement can be used to constrain particle physics as in original Lee-Weinberg model: theories predicting too large relic values for a (meta)stable “X” are disfavoured/excluded.
- has even been used as guideline in TeV-scale BSM model-building! (e.g. split susy...)

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In practice, one has to take care of many effects (coannihilations, resonances,...) Relic density calculations have reached a certain degree of sophistication and are often automatized with publicly available software.

MicrOMEGAs: a code for the calculation of Dark Matter Properties including the **relic density**, direct and **indirect rates** in a general supersymmetric model and other models of New Physics

http://lapth.in2p3.fr/micromegas/

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One example of such computations: following talk by Quentin LE BOULC'H

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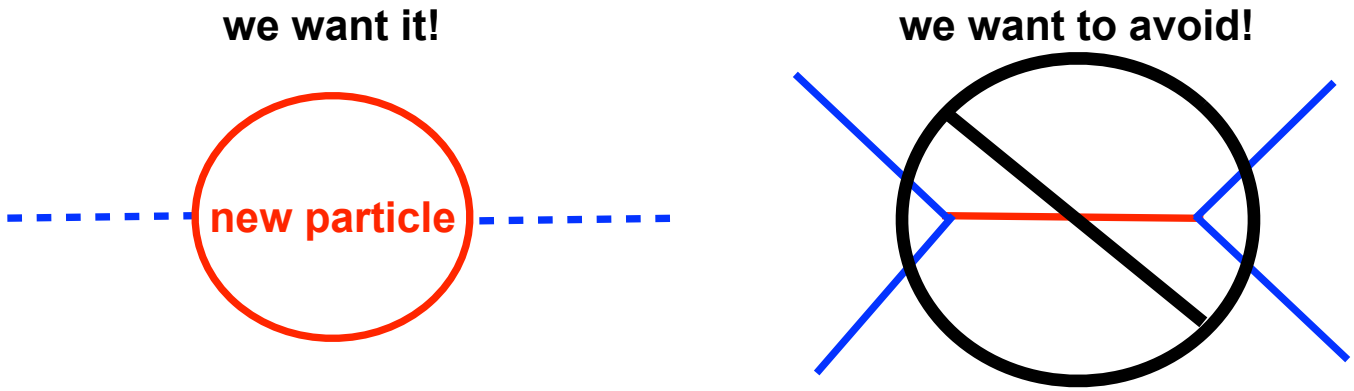
Link with colliders

- If one has a strong prior for new TeV scale physics (~with ew. strength coupling) due to the hierarchy problem, precision ew data (e.g. from LEP) suggest that tree-level couplings SM-SM-BSM should be avoided!



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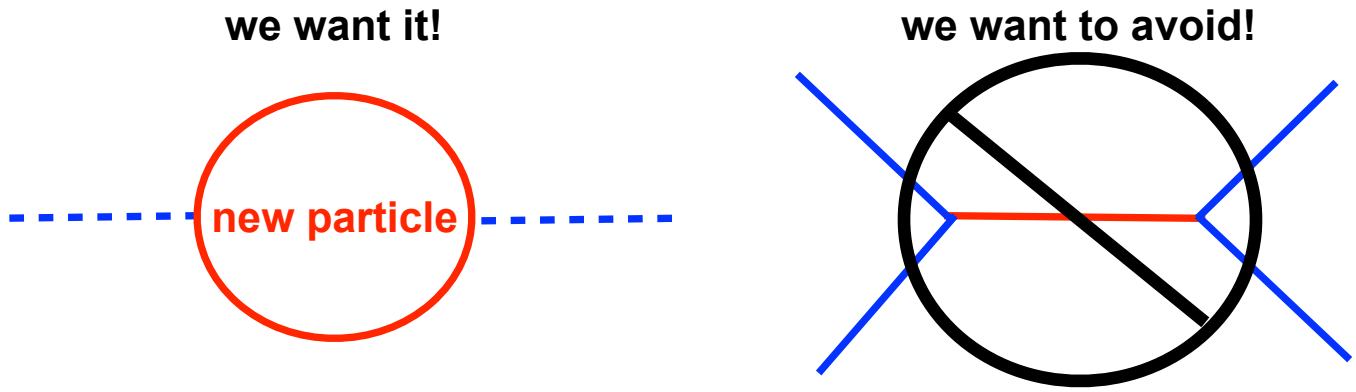

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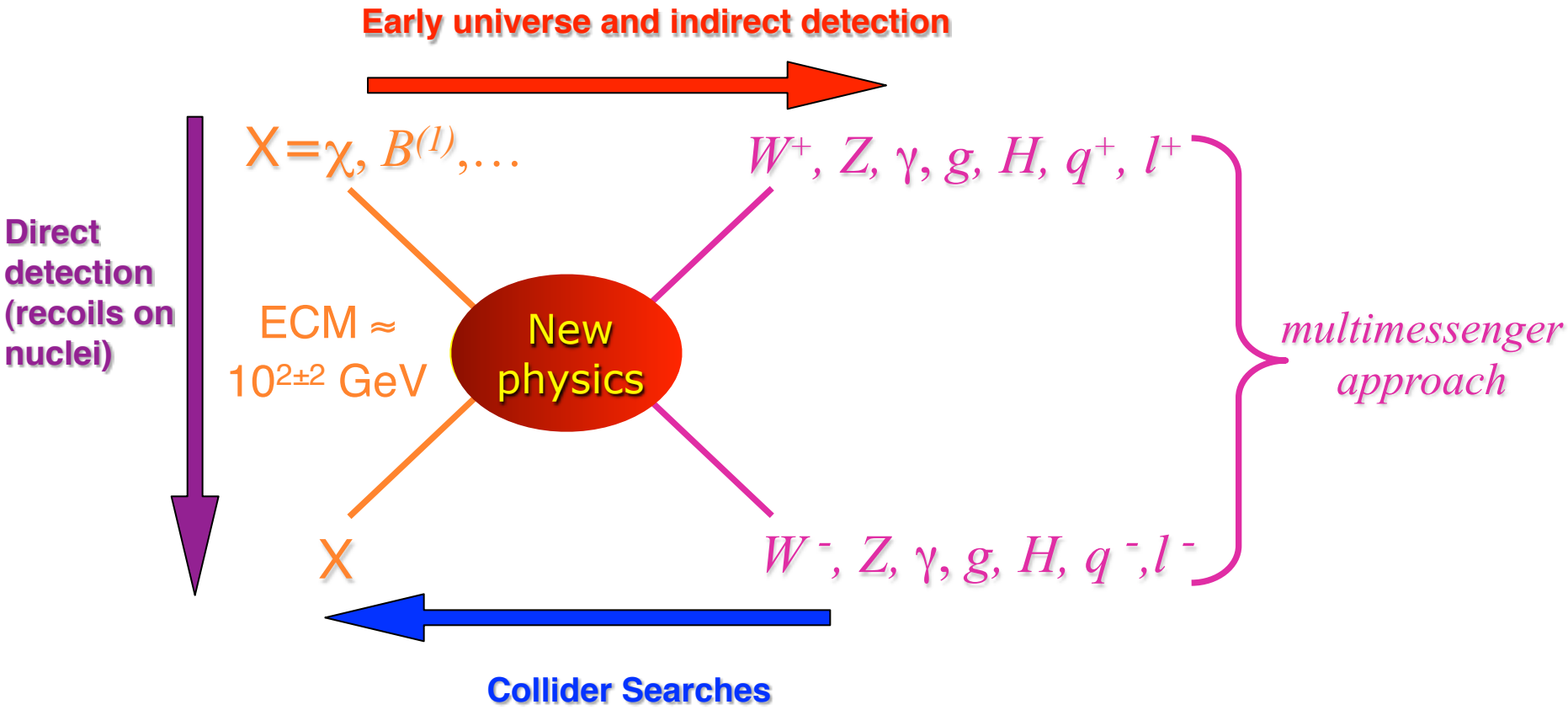
➡ Automatically makes lightest new particle stable!
➡ May have other benefits (e.g. respect proton stability bounds...)

In a sense, some WIMP DM (too few? too much?) is "naturally" expected for consistency of the currently favored framework for BSM physics at EW scale.

Beware of the reverse induction:

LHC is now testing this paradigm, but if no new physics is found at EW scale it is at best the WIMP scenario to be disfavored, not the "existence of DM"

WIMP (not generic DM!) “discovery program”

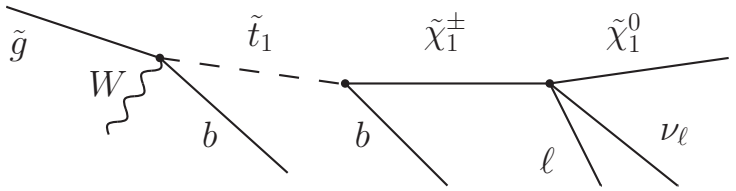


- ✓ demonstrate that astrophysical DM is made of particles (locally, via DD; remotely, via ID)
- ✓ Possibly, create DM candidates in the controlled environments of accelerators
- ✓ Find a consistency between properties of the two classes of particles. Ideally, we would like to calculate abundance and DD/ID signatures → link with cosmology/test of production

DM@colliders: The model-dependent way

Dark Matter studies at LHC are mostly model-dependent.

Either one can limit oneself to processes involving "chains" ending with large $\not{E}$, which allow at most to check if a "stable" particle (on detector scale!) has been produced, and in some cases to constrain its mass (scale).



$$M_{\rm eff} = \sum_i p_T^{{\rm jet},i} + \sum_i p_T^{{\rm lep},i} + E_T^{\rm miss}$$

For a review, Barr & Lester 1004.2732

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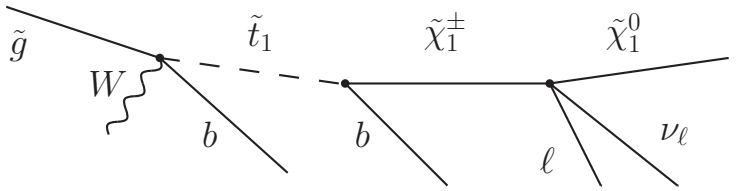

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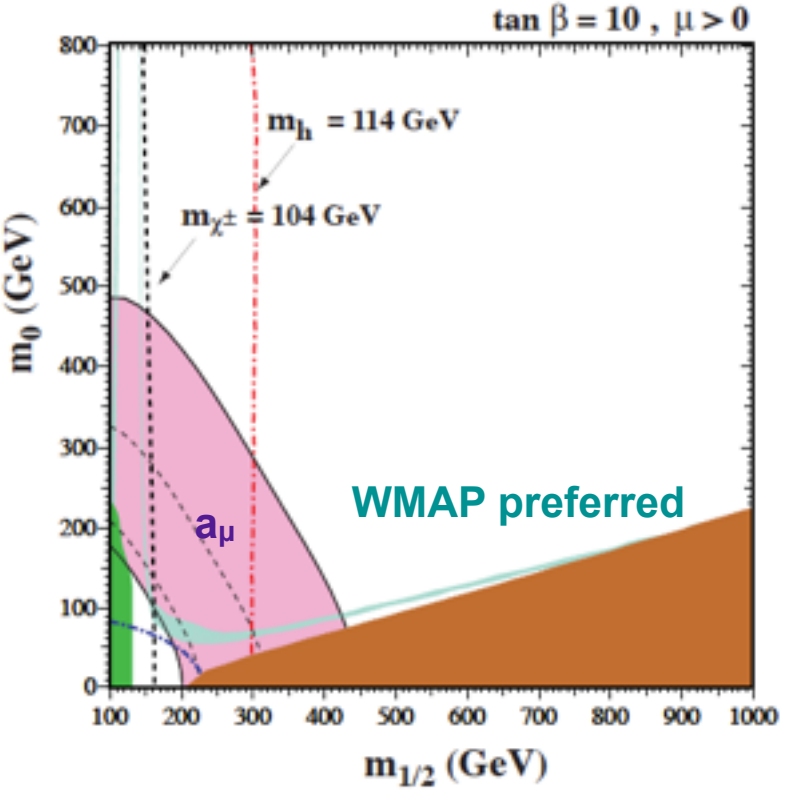
Alternative Strategy: Pick "benchmark" models (e.g. in CMSSM), derive bounds on DM from bounds on "observable" object and theoretical relations, with plots e.g. in m_0-$m_{1/2}$ for different tan β... hope to learn "generic lessons"



For a review, Ellis & Olive 1001.3651
(results now outdated...)

DM production at colliders, EFT approach

From the “WIMP paradigm” it follows that one can produce DM “as in the early universe”, via

$$(SM)(SM) \rightarrow XX$$

- Main problem: the dominating channel $(SM)(SM) \rightarrow XX$ is obviously invisible.
- One may consider the “large $\not{E}$” channel $(SM)(SM) \rightarrow XXY$ with Y= γ, jet(s)

unavoidably produced at least by initial state leptons/quarks.

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✤ One may consider the "large $\not{E}$" channel (SM)(SM) → XXY with Y= γ, jet(s) unavoidably produced at least by initial state leptons/quarks.

✤ One can parameterize DM-SM interactions in an EFT approach. E.g., for a Dirac fermion:

$$\mathcal{L} = \mathcal{L}_{SM} + i\bar{X}\gamma^{\mu}\partial_{\mu}X - M_X\bar{X}X + \sum_q \sum_{i,j} \frac{G_{qij}}{\sqrt{2}} \left[\bar{X}\Gamma_i^X X\right]\left[\bar{q}\Gamma_q^j q\right]$$

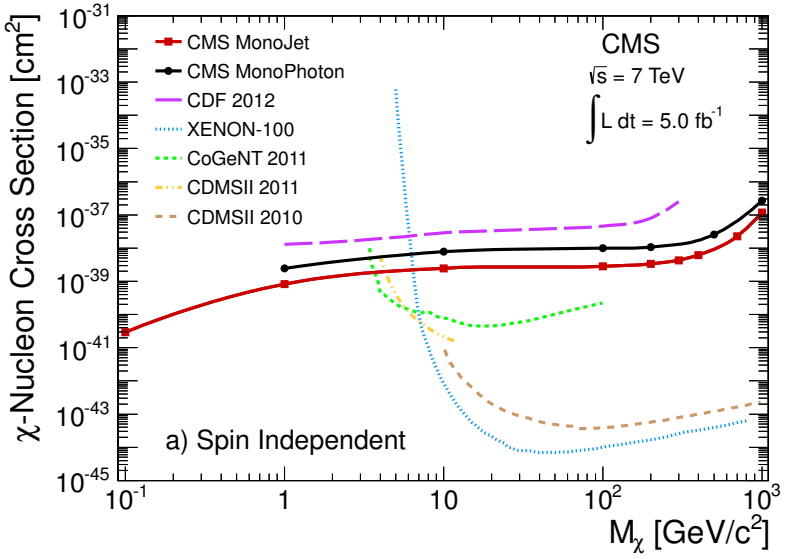
✤ Map the effective operators into signatures of missing energy+jet(s) as well as DD cross sections. Remarkable bounds already now!

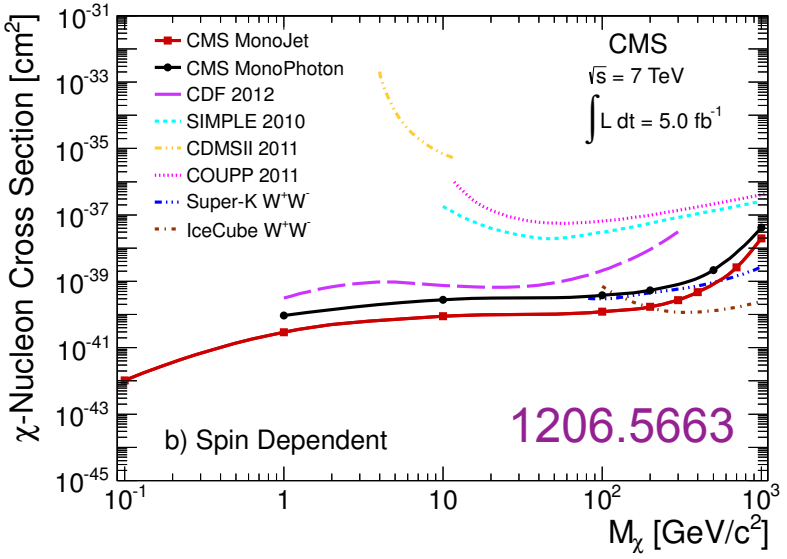
✤ Of course breaks down when/if BSM physics at low scale is present, hence it is complementary to explicit models (troublesome already @ LHC-7 TeV...)

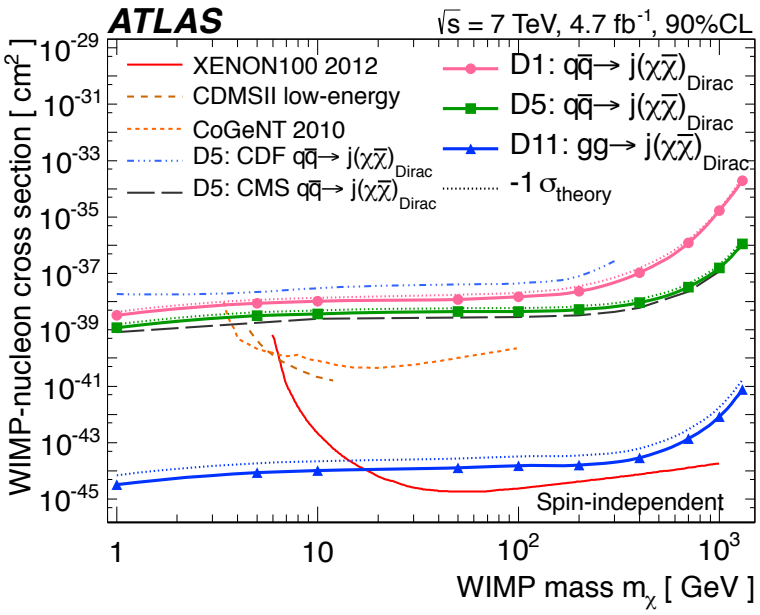
Incomplete list:

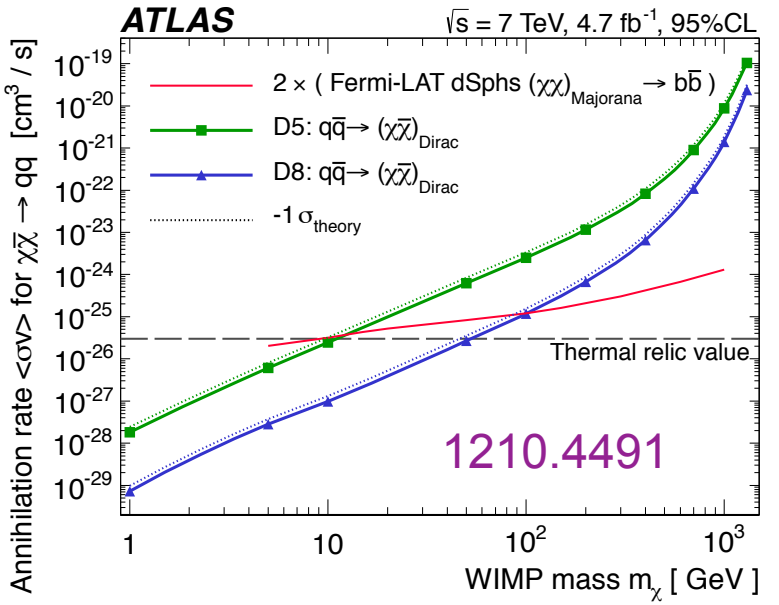
Beltran, Hooper, Kolb, Krusberg, Tait, 1002.4137 Bai,Fox, Harnik, 1005.3797
Goodman et al, 1005.1286 (majorana) Goodman et al, 1008.1783 (dirac, scalar)
M. Buckley, 1104.1429 (EFT for asymmetric DM) ...

Well practiced at LHC...



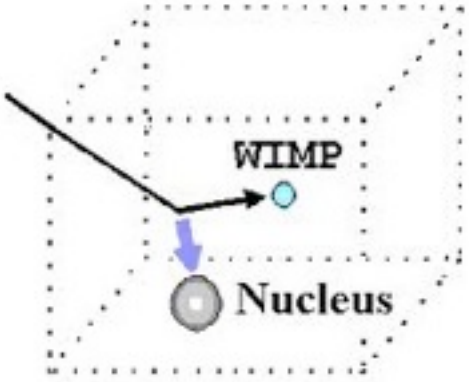






Direct Detection

Strategy: measure recoil energy (**Not larger than ~O(100) keV!**) from elastic scattering of local DM WIMPs with detectors underground (to shield them from cosmic-rays & their induced "activation").



Observables:

- Rate and spectrum of the recoils (different channels!)
- Time-dependence (modulation): distinctive feature
- Event Directionality (key for future! At R&D stage, requires gaseous detectors...)

e.g. MIMAC@LPSC

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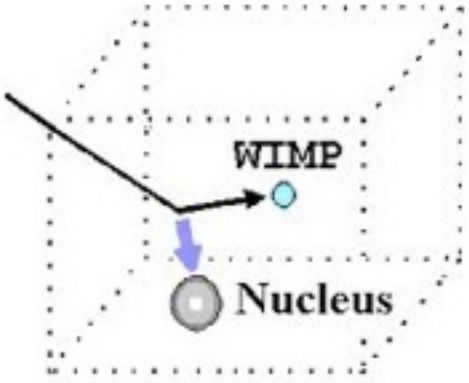

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"standard" expression

$$\frac{dR}{dE_R} = N_T \frac{\rho_X}{m_X} \frac{\sigma\, m_A}{2\,\mu_{AX}^2} \mathcal{I}(v_{min}) \quad \text{with} \quad \mathcal{I}(v_{min}) \equiv \int_{v_{min}} d^3\vec{v}\, \frac{f(\vec{v})}{v}$$

$$v_{min} = \sqrt{\frac{E_R\, m_A}{2\mu_{X\,A}^2}}$$

The role of v_{min} is especially important close to thresholds...

contains "astrophysical" dependence from the velocity distribution

In general, x-section σ is the sum of spin-dependent contribution plus spin-independent (the latter typically dominant: ~A^2 times bigger for coherence)

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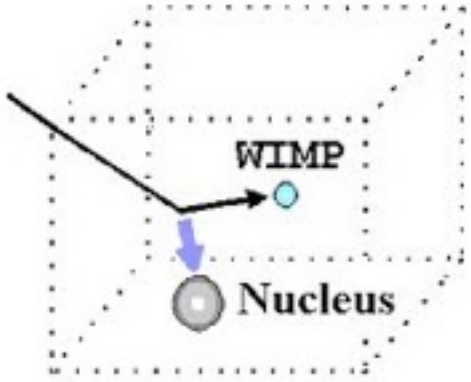

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One example where this form is not correct: following talk by Paolo PANCI

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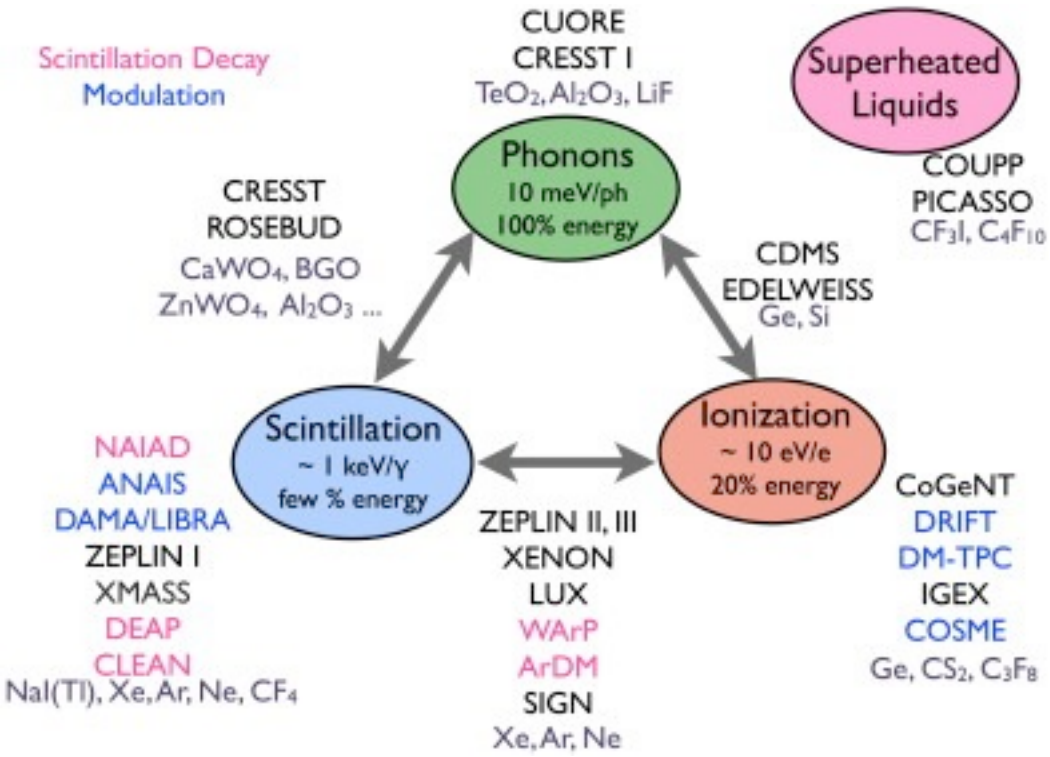
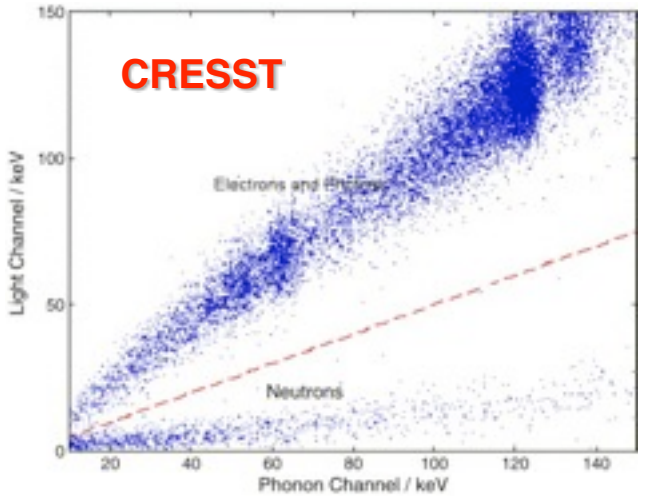
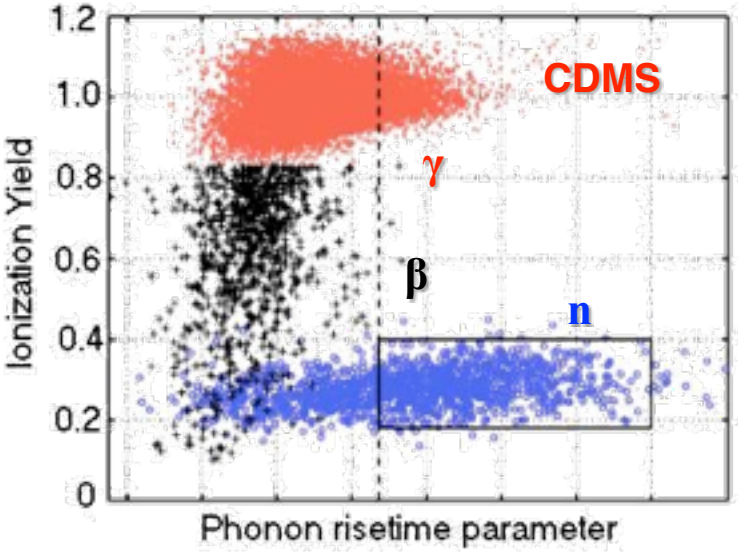
The exp. race: background rejection techniques

despite low “noise” (high purity materials, low cosmic ray rate...), many phenomena can cause energy deposition (e.g. radioactive decays); largest worry is to separate “e.m.-like” recoils from “nucleon-like” recoils (like expected from WIMPs)

Strategy: event by event, measure different channels energy is deposited into (+e.g. position in the detector, for surface vs. bulk events). Select region where expecting <1 fake event leakage (based on known backgrounds)







Sometimes surprises...

Letters to Nature

Nature **422**, 876-878 (24 April 2003) | doi:10.1038/nature01541; Received 20 November 2002; Accepted 10 March 2003

Experimental detection of α-particles from the radioactive decay of natural bismuth

Pierre de Marcillac, Noël Coron, Gérard Dambier, Jacques Leblanc & Jean-Pierre Moalic *

1. Institut d'Astrophysique Spatiale, CNRS & Université Paris Sud, UMR 8617, Bât. 121, 91405 Orsay Cedex, France

Correspondence to: Noël Coron Correspondence and requests for material should be addressed to P.d.M. (e-mail: Email: pierre.demarcillac@ias.u-psud.fr) or N.C. (e-mail: Email: noel.coron@ias.u-psud.fr).

The only naturally occurring isotope of bismuth, ^{209}Bi, is commonly regarded as the heaviest stable isotope. But like most other heavy nuclei abundant in nature and characterized by an

▲ Top

*French group developing low-temperature bolometers for dark matter direct detection...

IOP A website from the Institute of Physics

physicsworld.com

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News archive
- 2012
- 2011
- 2010

Bismuth breaks half-life record for alpha decay

Apr 23, 2003

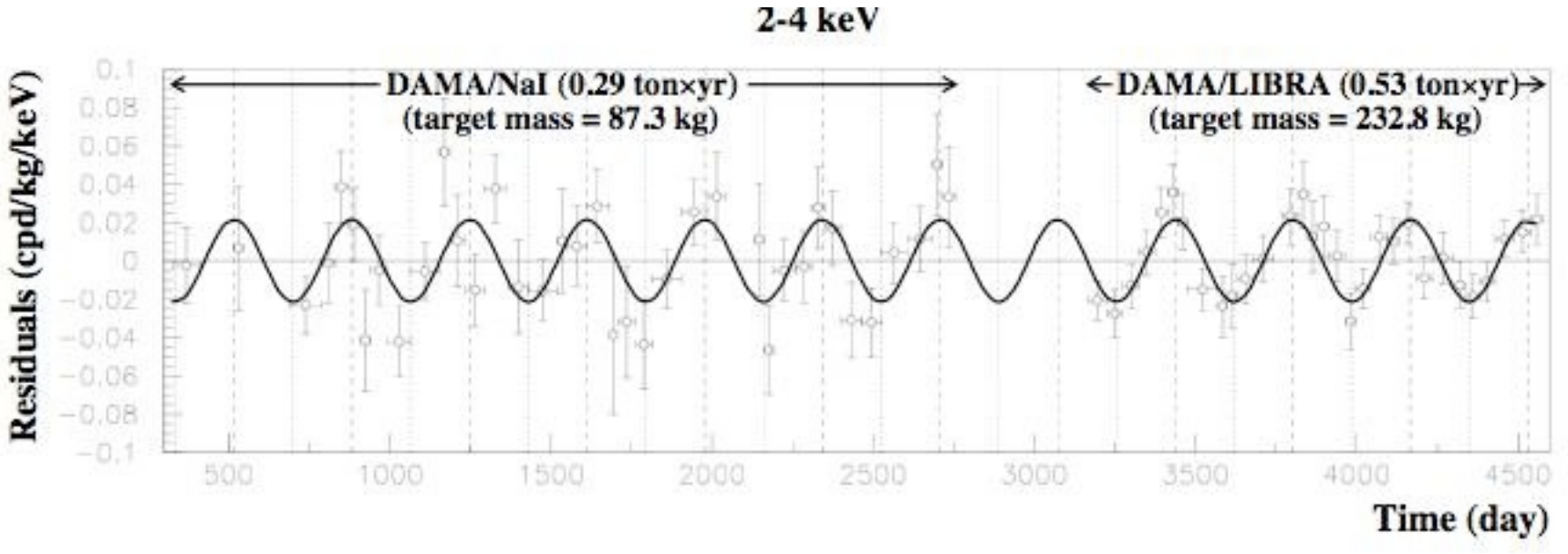
message: don't be surprised if DM researchers should hit "new", unexpected backgrounds...

Experimental situation

La battaglia di Marciano by ***Giorgio Vasari*** possibly covers a lost-and much more important!-work by ***Leonardo da Vinci,*** **La battaglia di Anghiari**
("Cerca Trova", masked in the back of the painting means "Seek Find" in Italian...)

Similarly, is the "conflicting" attitude in the community due to "hidden" big prize at stake?

Experimental situation

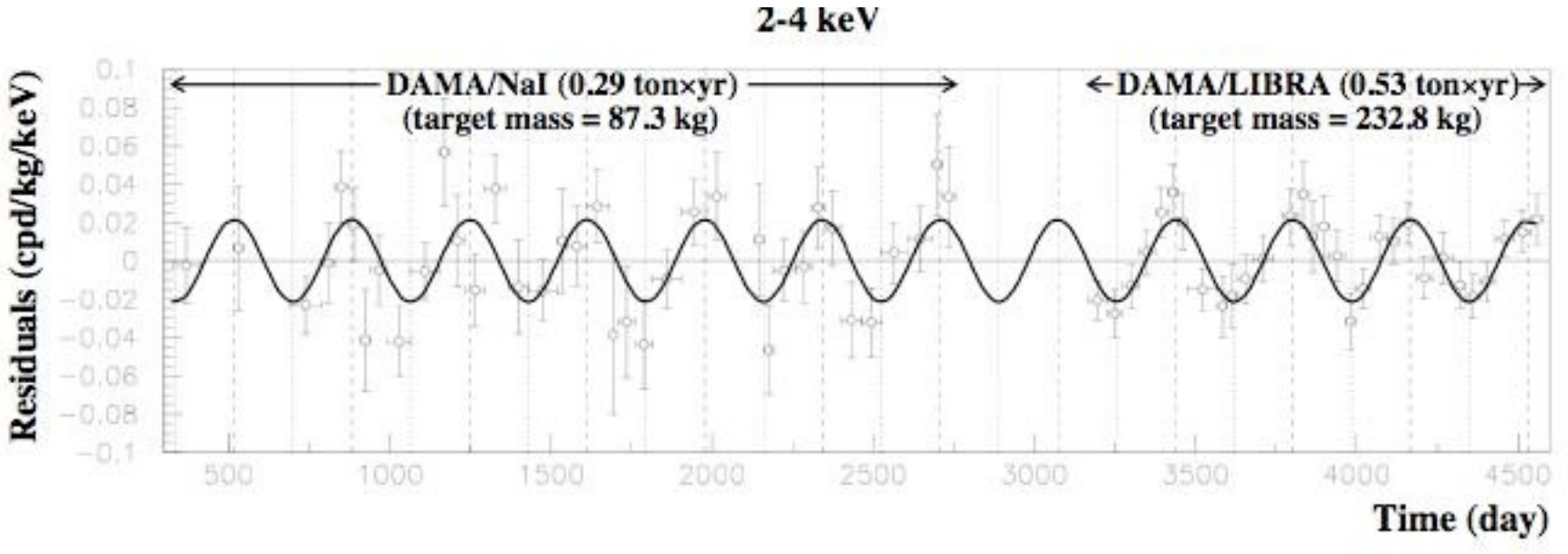


Long-standing result by **DAMA** (& **DAMA-LIBRA**) observing at >8 σ a modulation signal whose energy, frequency and phase properties are consistent with DM interpretation

R. Bernabei et al. Eur. Phys. J. C 56, 333 (2008) arXiv:0804.2741

No known/proposed systematics seems to explain all the features of the signal

Experimental situation



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No known/proposed systematics seems to explain all the features of the signal

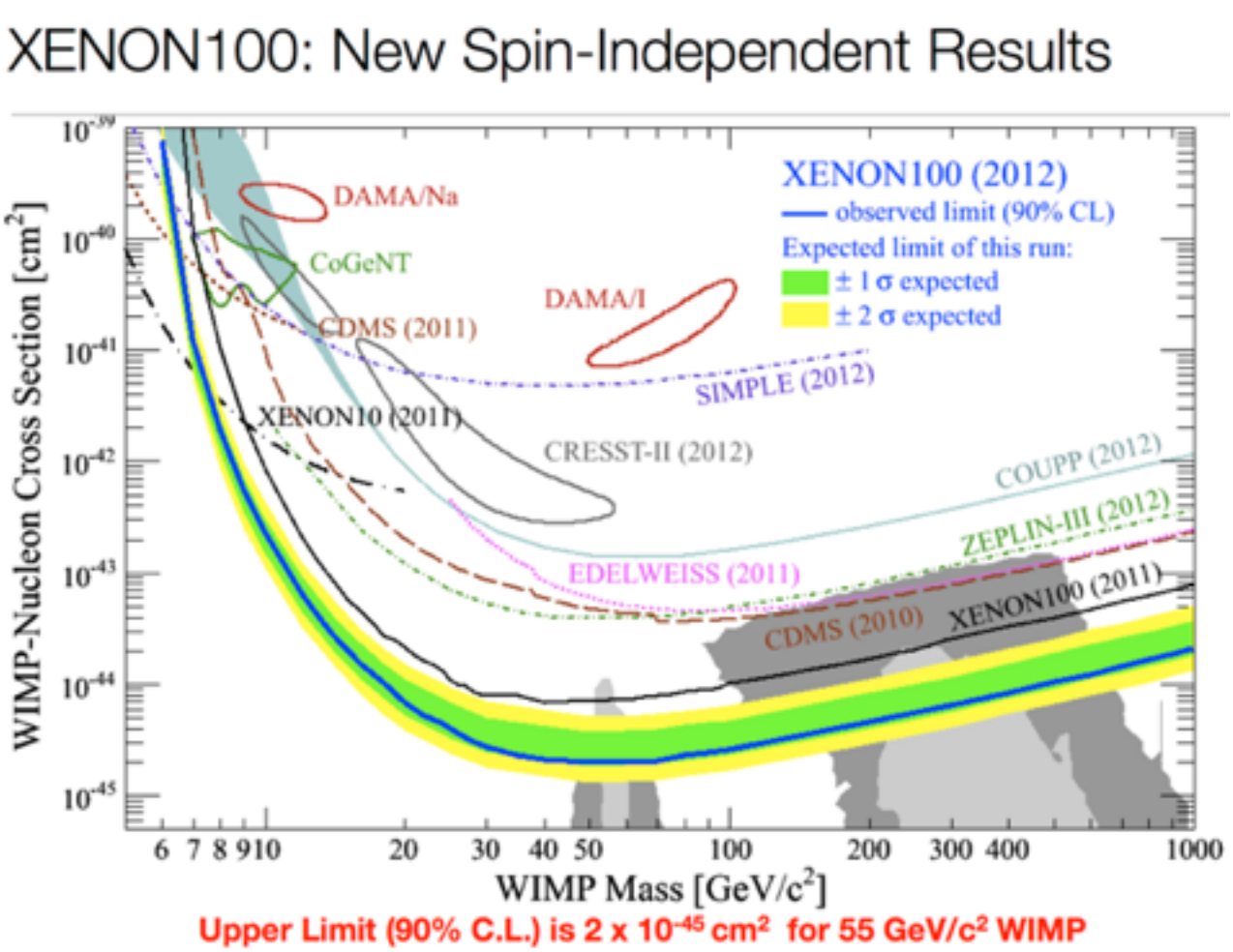
Excesses of low-energy events (and low-significance hint of modulation) reported by **CoGent**, see e.g.

C.E. Aalseth et al., PRL 106, 131301 (2011)

Excess (no sensitivity to modulation) also reported by **CRESST**!

G. Angloher, Eur. Phys. J. C 72, 1971 (2012) arXiv:1109.0702

Are signals & bounds consistent? Well...



from E. Aprile's talk at Dark Attack 2012

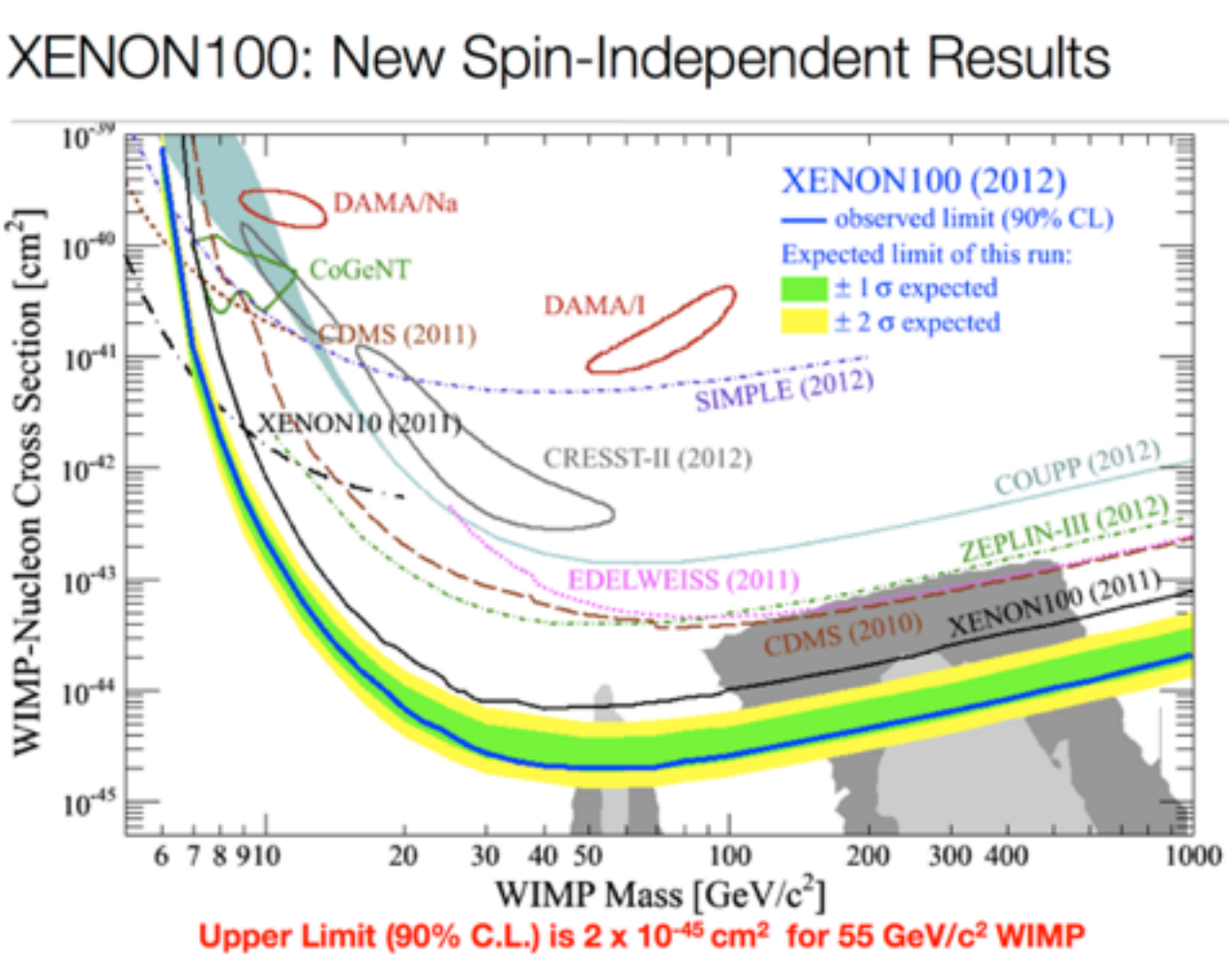
at face value, for standard assumptions ($f(v)$, WIMP...) signals inconsistent among themselves and with bounds from XENON, CDMS.

BUT

I. many experimental subtleties (e.g. close to thresholds, background subtractions, energy-scales, channeling...)

II. comparisons are intrinsically model-dependent

Are signals & bounds consistent? Well...



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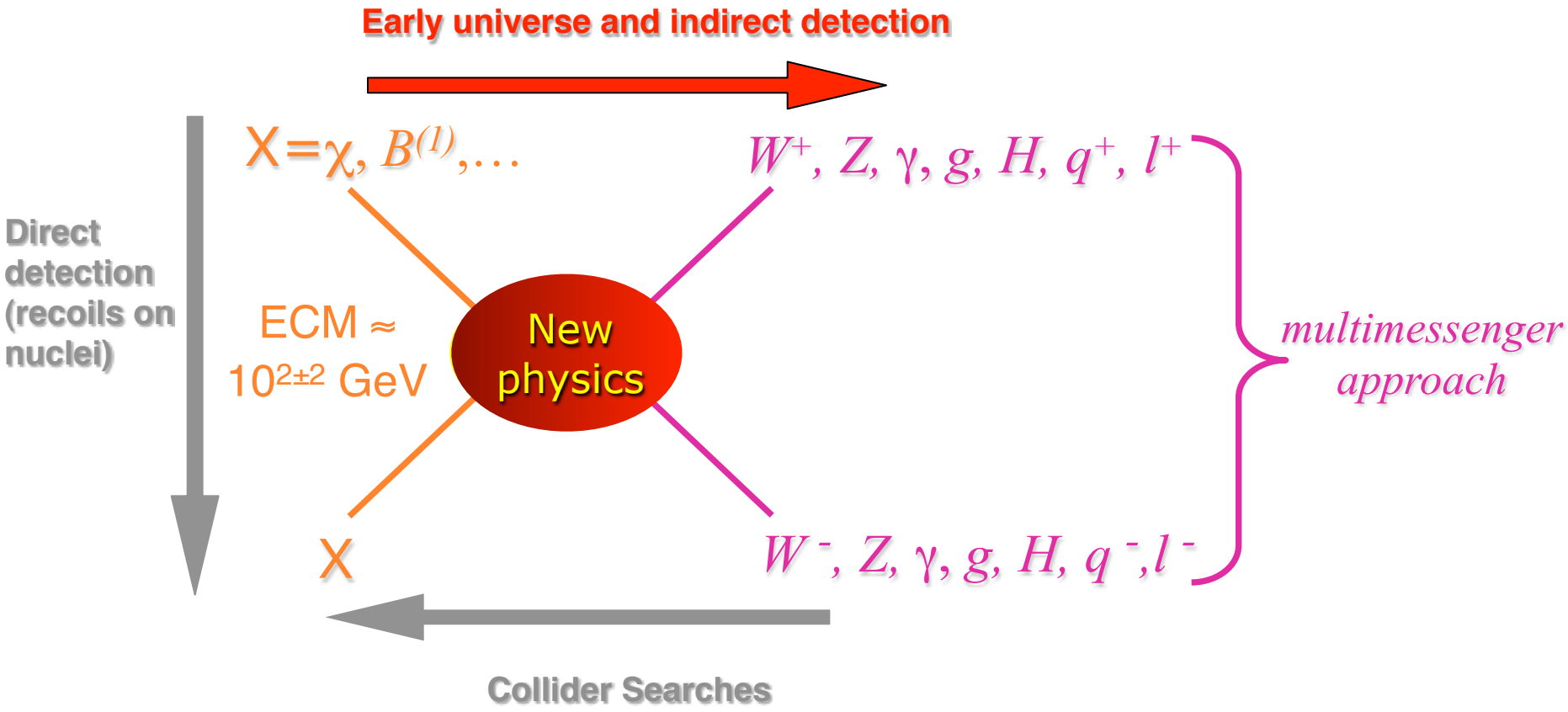
II. comparisons are intrinsically model-dependent

CHALLENGE: for theory, have a coherent picture of all the data

it's not astrophysics to blame for an apparent disagreement!
J. Herrero-Garcia, T. Schwetz and J. Zupan, arXiv:1205.0134

for experimentalists, perhaps should repeat a DAMA-type experiment (it is mandatory to understand what was measured by DAMA)

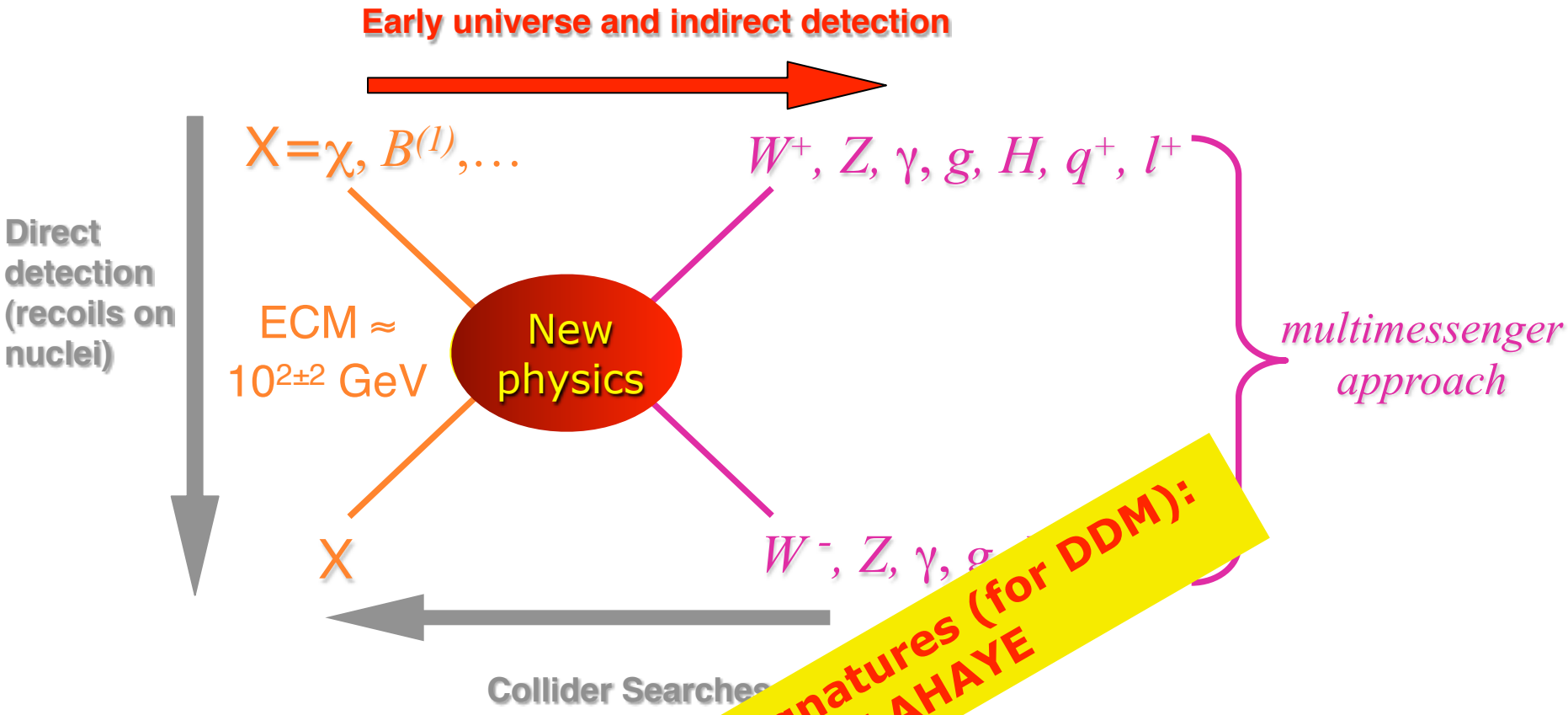
WIMP indirect detection



The link with early universe stands modulo some caveats

- $\langle \sigma v \rangle_{T \simeq 0} \overset{?}{\sim} \langle \sigma v \rangle_{T = T_f}$ Ok for S-wave annihl., otherwise must be specified
- Signatures DO depend on b.r. of different channels (only total rate in early universe)
- rates depend on astrophysical distribution of DM... observations/simulations needed!

WIMP indirect detection



One example of such signatures (for DDM): following talk by Timur DELAHAYE

- $\langle \sigma v \rangle_{T\simeq 0} \overset{?}{\simeq} \langle \sigma$ $_f$ Ok for S-wave annihl., otherwise must be specified
- Signatures D b.r. of different channels (only total rate in early universe)
- rates depend strophysical distribution of DM... observations/simulations needed!

Where to look for Gamma rays

To first approximation — particle physics — astrophysics

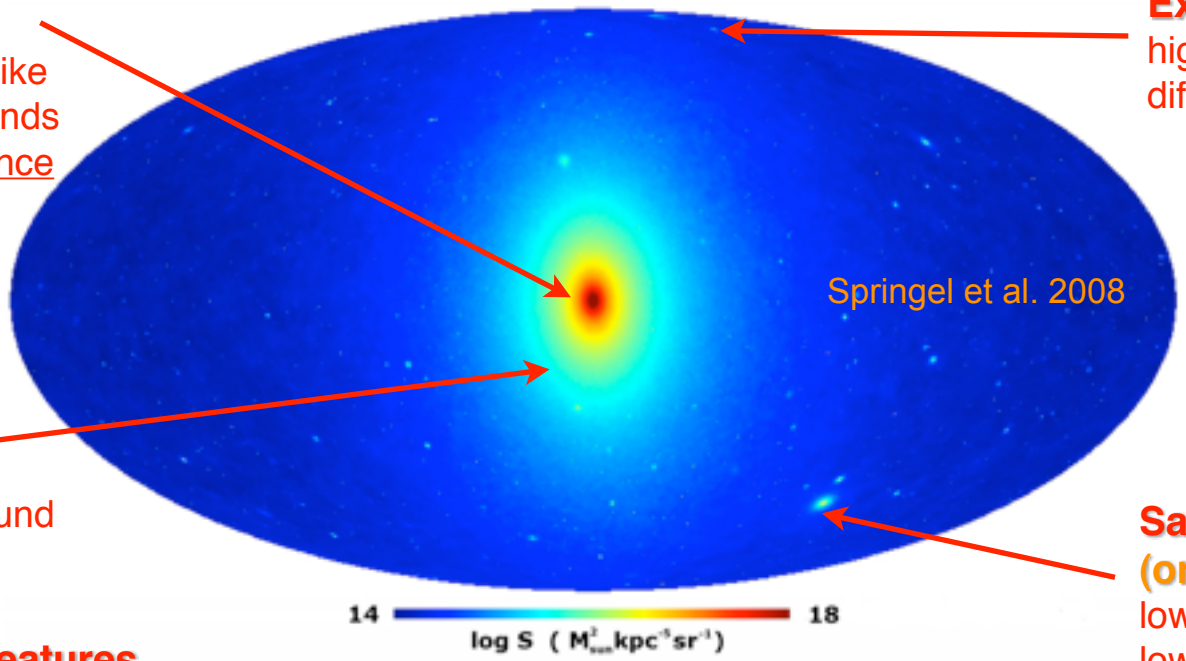
$$\Phi_\gamma(E_\gamma,\Omega) = \left[\frac{\mathrm{d}N_\gamma}{\mathrm{d}E_\gamma}(E_\gamma)\frac{\langle\sigma v\rangle}{8\pi m_X^2}\right]\int_{\mathrm{los}}\rho^2(\ell,\Omega)\,\mathrm{d}\ell$$

[particle] ⊗ (astro) factorization holds if $<\sigma\, v>$ is v-independent & if prompt emission dominates

What is the picture of the "DM - gamma sky" suggested by simulations?
(but the actual gamma-ray sky is astrophysically crowded and bright...)

Galactic Center
high statistics, point-like and diffuse backgrounds
halo-model dependence

Extragalactic
high statistics, lot of diffuse backgrounds

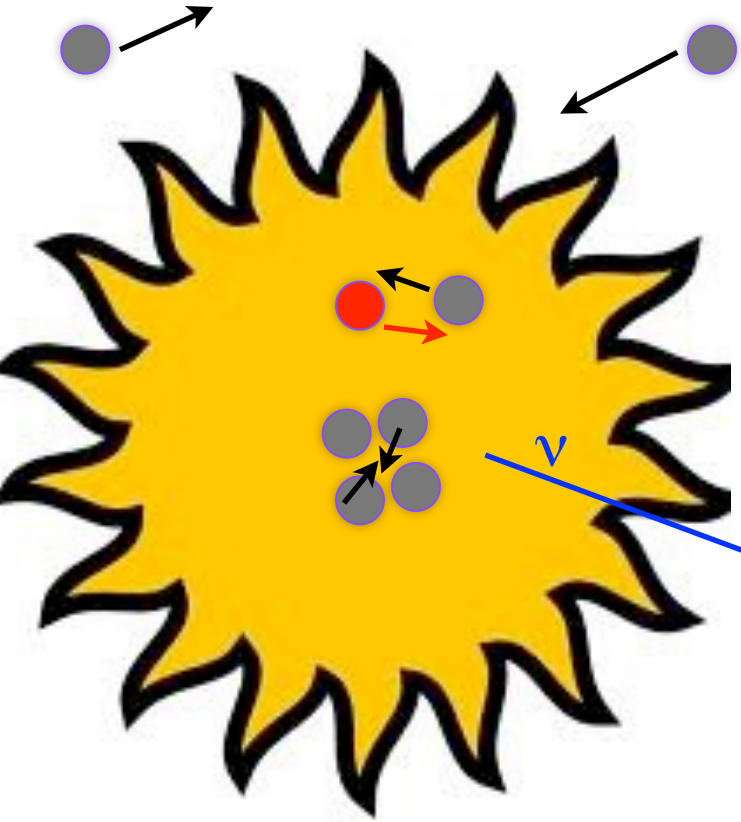


MW Halo
high statistics,
high diffuse background

Satellites (or Clusters)
low background (?),
low statistics

Lines/Spectral Features

Neutrinos from the Sun



$$\dot{N} = C - C_A N^2$$

If equilibrium is reached btw the two, the annihilation signal rate writes:

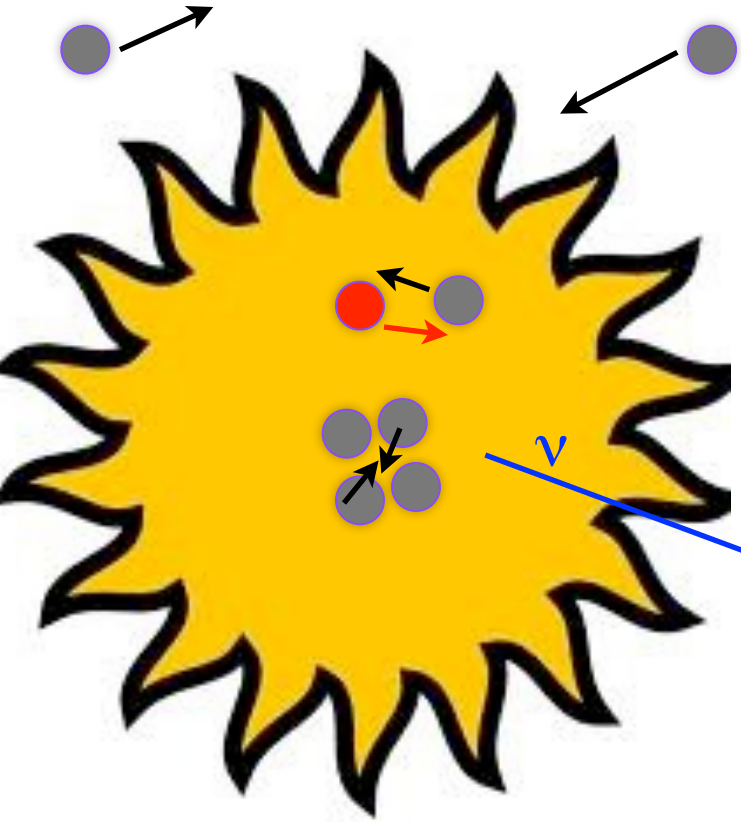
$$\Gamma_A = \frac{C_A}{2} N_{\rm eq}{}^2 = \frac{C}{2}$$

ν

$$C \propto \sigma \, \rho_{\rm DM}$$

"just like" (although not exactly) DD experiments!

Neutrinos from the Sun



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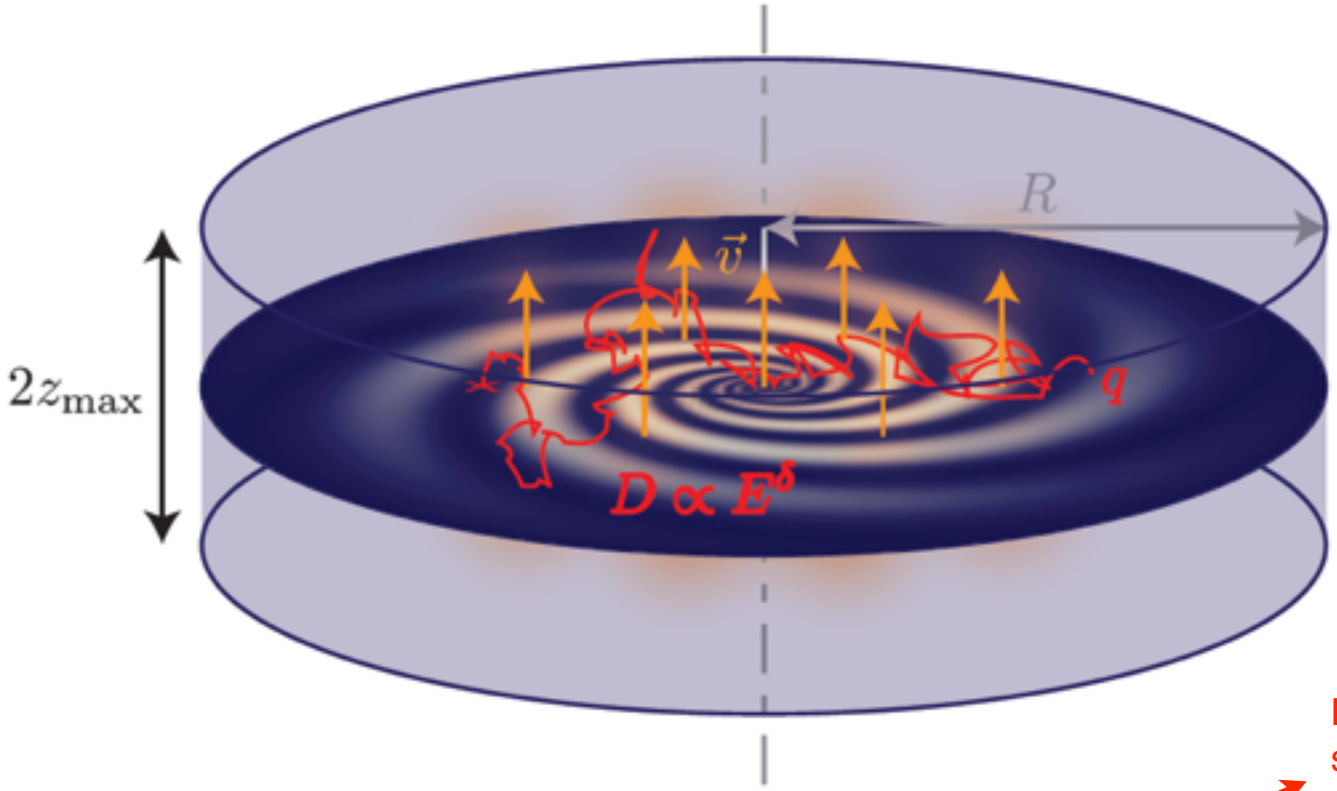
"just like" (although not exactly) DD experiments!

more sensitive to low-v tail of f(v), as well as averaged over time...

What about charged particles?

Not only DM physics (sigma's, b.r.) and astrophysics (halo distribution) matter, but also plasma astrophysics (diffusion in the Galaxy)
Antimatter is preferred due to lower astro background



$$\Phi_a(E_a) = \left[\frac{dN_a}{dE_a}(E_a) \frac{\langle \sigma v \rangle}{8\pi m_X^2} \right] \mathcal{F}_a(E_a, \ldots)$$

Functional of the spectrum and astrophysics!

Additional complication for e+e-: relevant E-losses, local effects...

Different codes are available to solve for a given input

http://galprop.stanford.edu/

http://www.desy.de/~maccione/DRAGON/

See also M. Cirelli et al.,
"PPPC 4 DM ID: A Poor Particle Physicist ***Cookbook*** *for Dark Matter IndirectDetection,"*
JCAP 1103, 051 (2011), arXiv:1012.4515

http://lpsc.in2p3.fr/usine/

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DRAGON Documentation: Index Page

1.0.0

Introduction

The CR propagation equation from a continuos distribution of sources can be written in the general form

$$\frac{\partial N^i}{\partial t} - \nabla\cdot(D\nabla - v_c)N^i + \frac{\partial}{\partial p}\left(\dot{p} - \frac{p}{3}\nabla\cdot v_c\right)N^i - \frac{\partial}{\partial p}p^2 D_{pp}\frac{\partial}{\partial p}\frac{N^i}{p^2} = Q^i(p,r,z) + \sum_{j>i} c\beta n_{gas}(r,z)\sigma_{ji}N^j - c\beta n_{gas}\sigma_{in}(E_k)N^i$$

Here $N^i(p,r,z)$ is the number density of the i-th atomic species; p is its momentum; β its velocity in units of the speed of light c; σ_{in} is the total inelastic cross section onto the ISM gas, whose density is n_{gas}; σ_{ij} is the production cross-section of a nuclear species j by the fragmentation of the i-th one; D is the spatial diffusion coefficient; v_c is the convection velocity. The last term on the l.h.s. describes diffusive reacceleration of CRs in the turbulent galactic magnetic field.

DRAGON adopts a second-order Cranck-Nicholson scheme with Operator Splitting and time overrelaxation to solve the diffusion equation. This provides fast a solution that is enough

USINE

a galactic cosmic-ray propagation code

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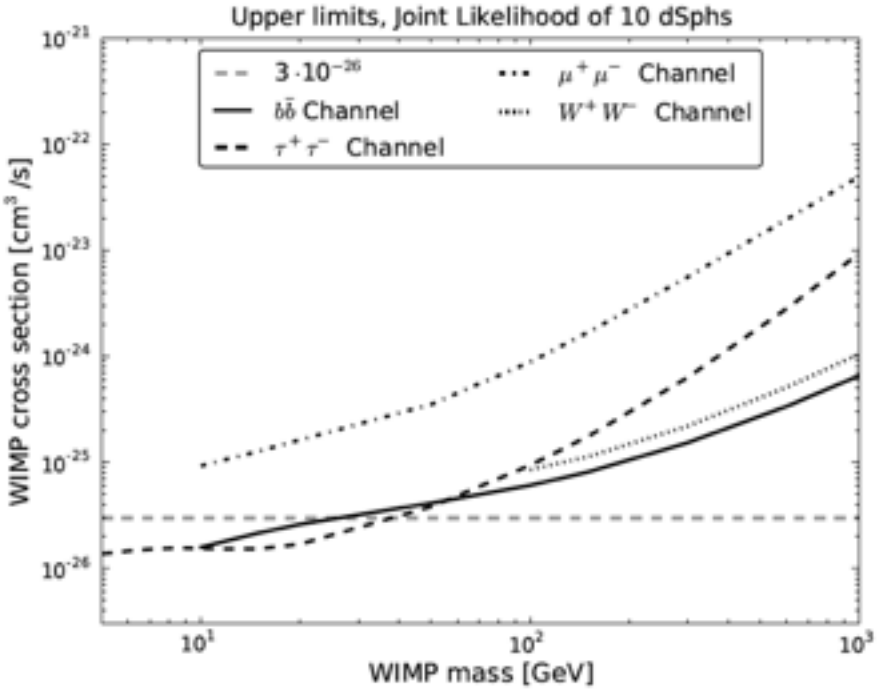
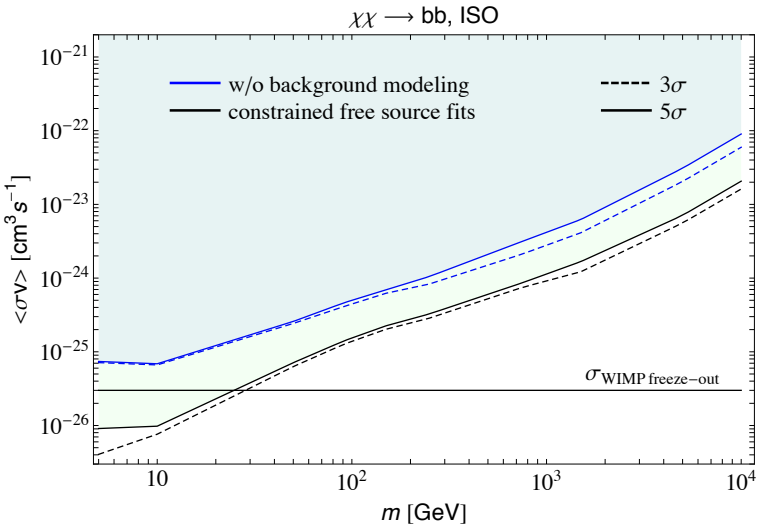
Goal 1. Probing the (thermal) WIMP paradigm

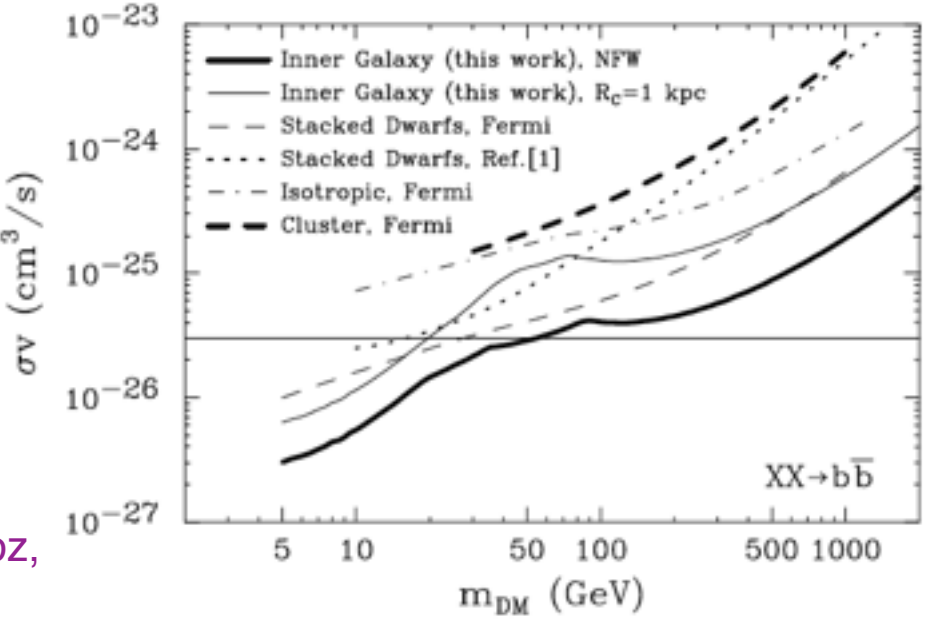
Fermi-LAT data allow to do it already up to the scale of tens of GeV (for ττ & bb channels)



Stacked dwarfs analysis,
Fermi-LAT collaboration, 1108.3546



Diffuse Galactic Gamma Rays,
Ackermann et al. [Fermi-LAT], 1205.6475
(w or w/o astro background)

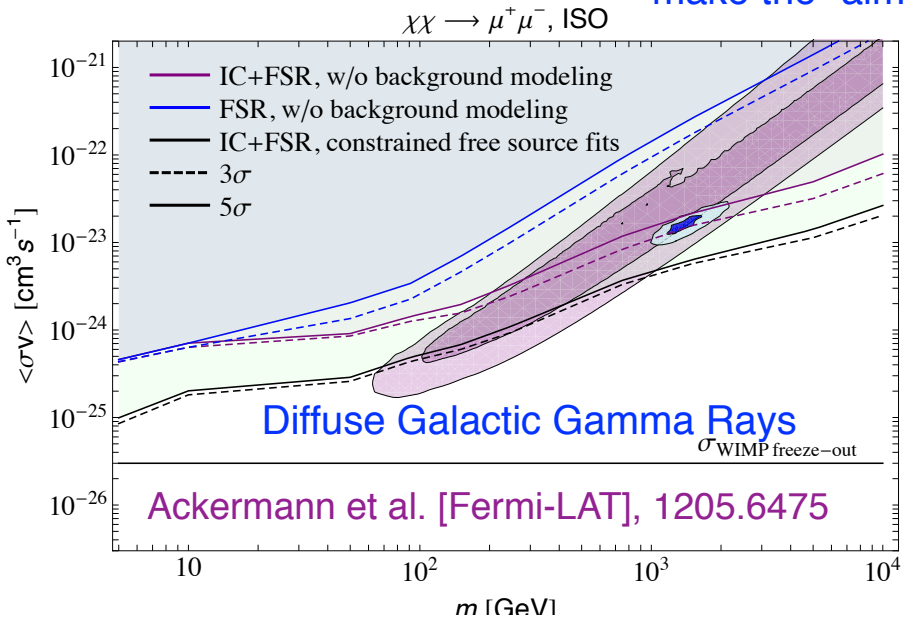


Galactic Center:
D. Hooper, C. Kelso and F. S. Queiroz,
arXiv:1209.3015

Goal 2. Clarifying other Ind. Det. anomalies

Well-known example, testing "PAMELA e+-fraction anomaly" via multi-messengers

(btw, its DM interpretation is *almost* excluded: and one has to work quite a bit, to make the "almost" not euphemistic...)



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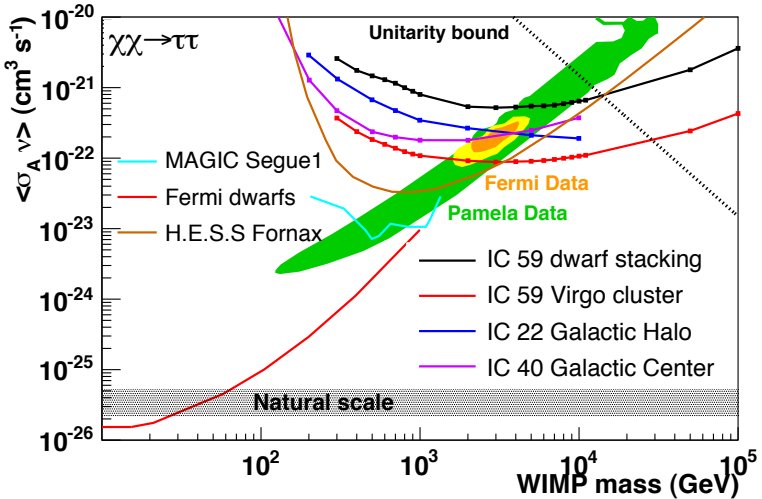
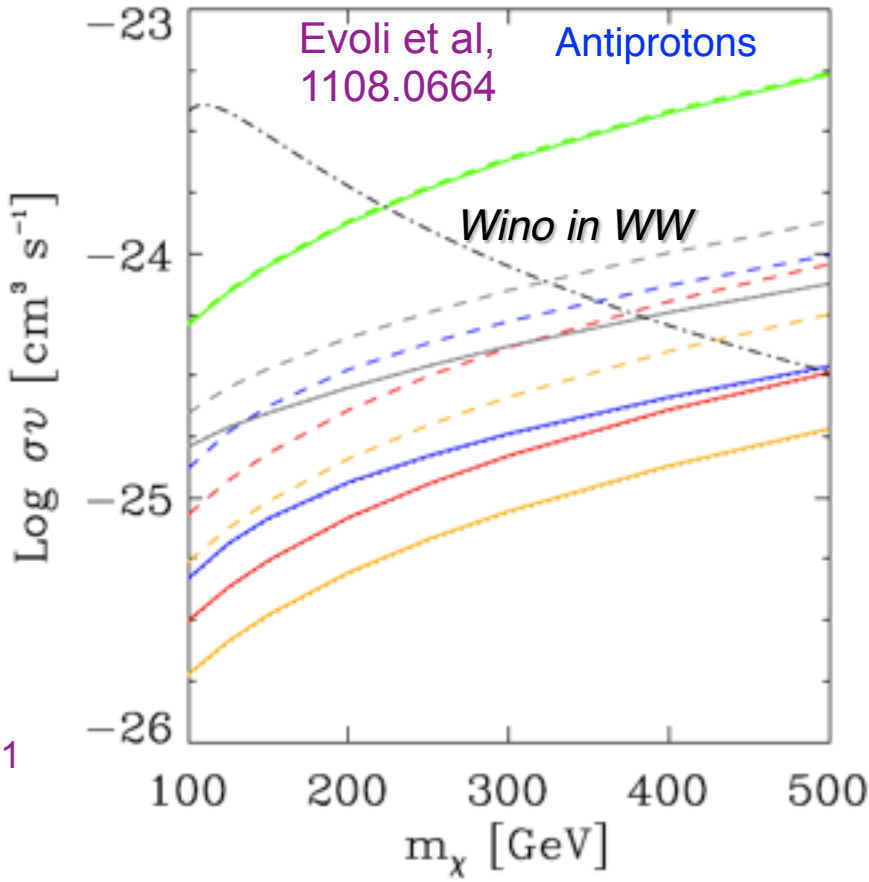


Neutrinos

C. Rott, arXiv:1210.4161

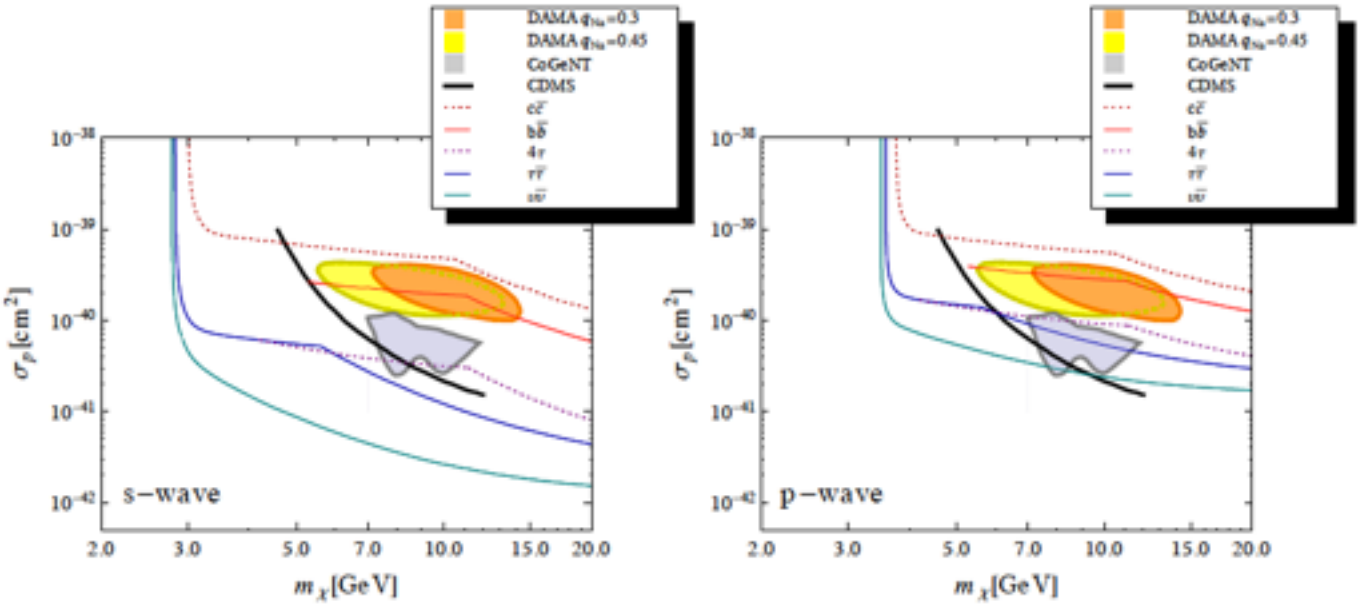


Different colors: different propagation parameters

Different linestyles: different halo shapes

Goal 3.: cross-check(s) collider or DD claims

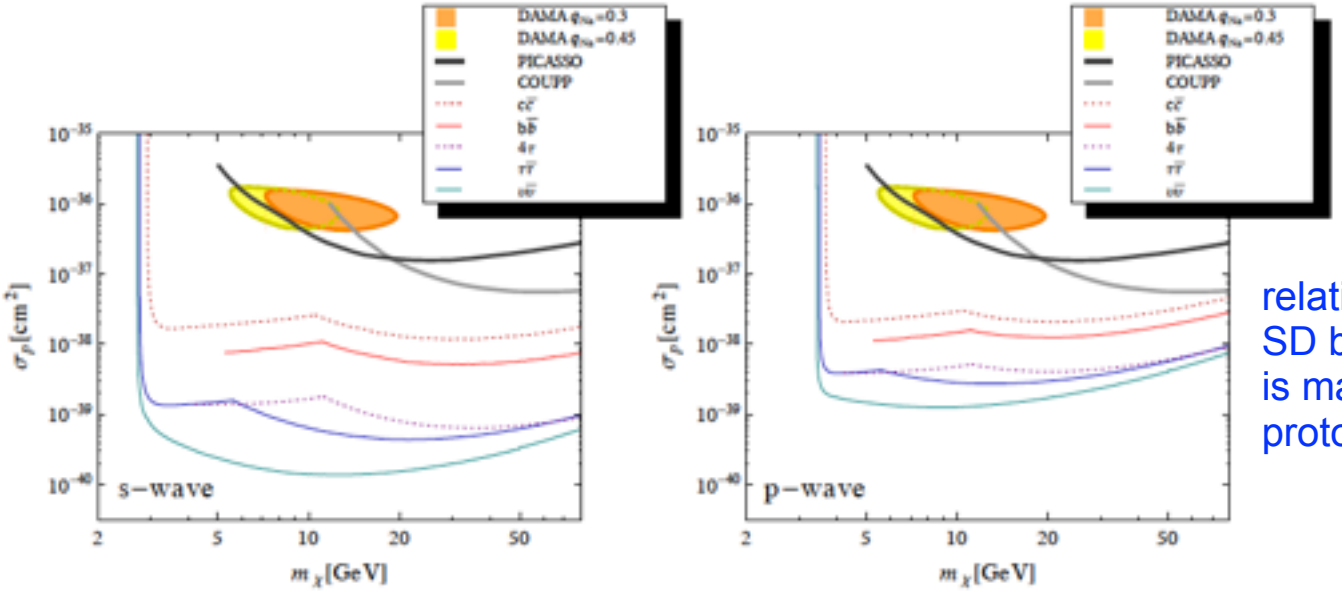
SI



neutrino bounds (from SK data)

Kappl & Winkler 1104.0679

SD



relatively stronger SD bounds (Sun is made mostly of protons)!

Some expected 2013 highlights

★ **Planck**
Interesting sensitivity to O(10) GeV WIMPs annihilating into light leptonic final states, via indirect effects on recombination.

★ **HESS-II**
First publications expected: some clarification of the Galactic Center region @ 100 GeV?

★ **IceCube/DeepCore**
Presentation of new bounds possible

★ **AMS**
We are all excitingly waiting to know what we'll learn...

★ **Fermi-LAT**
Pass8 data?

★ **LHC**
2012 data analyses

.... Plus much more!

Outlook & take-home message

Indirect probes (astrophysics & cosmology) tell us a lot: BSM physics is there!
However, they do not tell us its scale, and blind searches are more and more challenging, facing little known astrophysics (but improving fast!)

If DM is made of WIMPS, the combination of direct searches, colliders and indirect ones should pin it down

Colliders searches are progressing fast!

Direct Detection sensitivity, too... but puzzling, conflicting situation

Indirect Detection can profit of a large spectrum of detectors with largely improved reaches and is currently exploring "interesting" parameter space

But face poorly understood astrophysics and sometimes puzzling results!

Consistency checks/constrained searches more promising than blind ones!
ongoing/near future ID experiments will help with more sensitivity and precision as well as better understanding of astrophysical sources & propagation parameters

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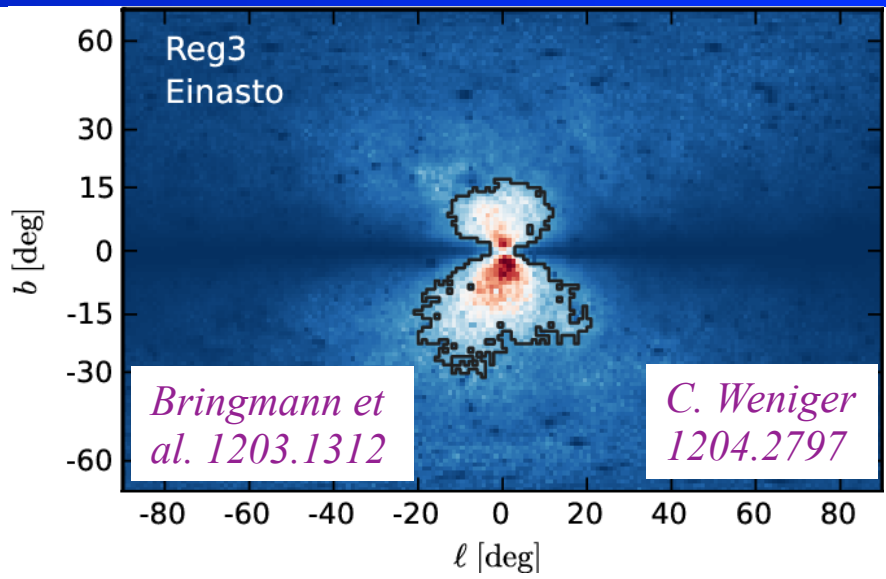
Recent example of puzzling result: ~130 GeV line...

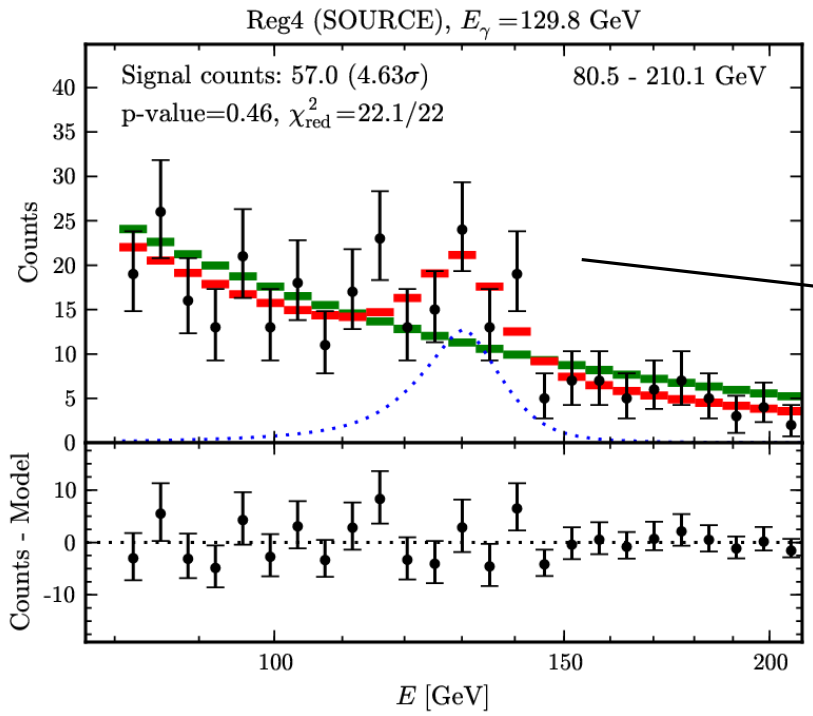
“Weniger et al.’s line”

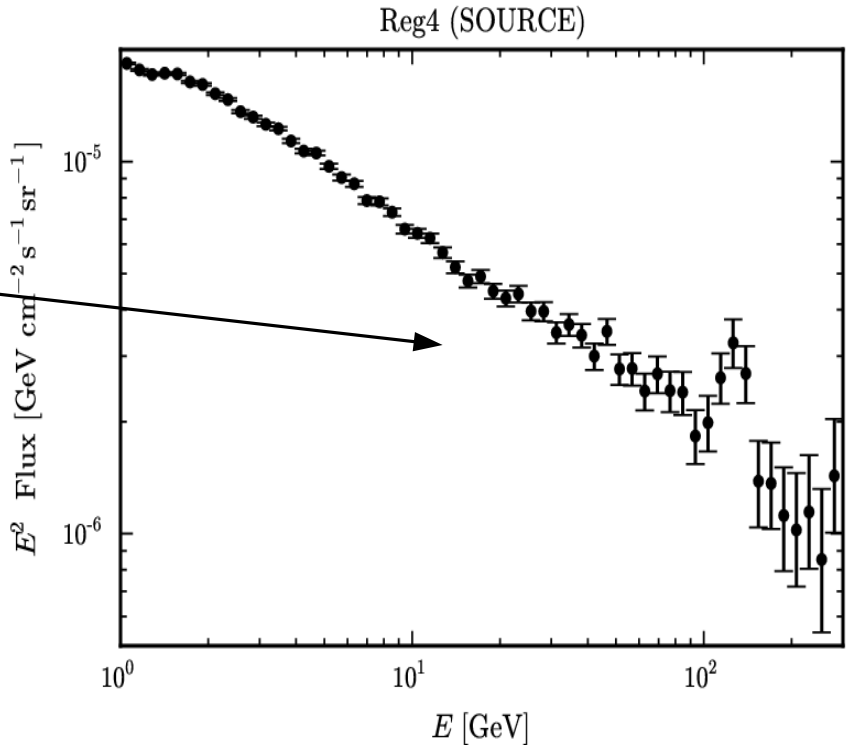
By using a S/N “optimized” search strategy (dependent on background and signal morphology), Weniger et al. claim observation of a line-like feature around ~130 GeV corresponding to a cross section around ~10^{-27} cm^3/s in the Fermi public data.

(note removal of Gal. Plane, higher background)



Sharp feature!





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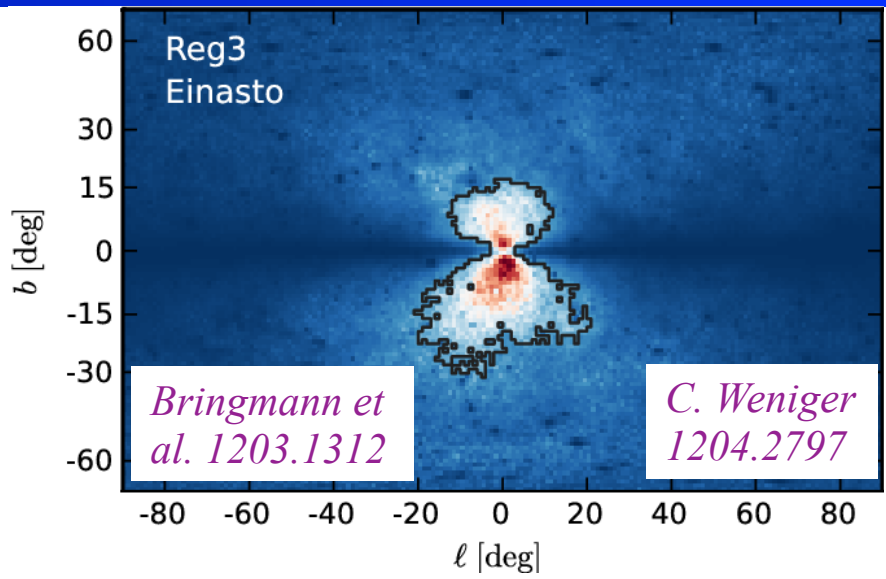
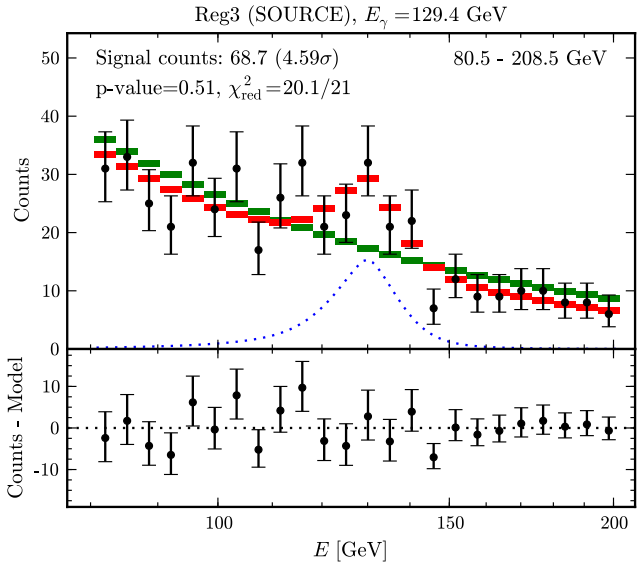


- Accounting for trials, the significance is a little above 3 sigma
- Mild preference (statistically insignificant) for a doublet of lines, with another at ~110 GeV. *Rajaraman et al, 1205.4723, Su, Finkbeiner 1206.1616*



C. Weniger 1204.2797

- ❖ Is this a statistical fluke?
- ❖ Is it instrumental? (but why only towards GC?)
- ❖ Is it astrophysical (but of what sort)?
- ❖ Is it the first glimpse of dark matter?

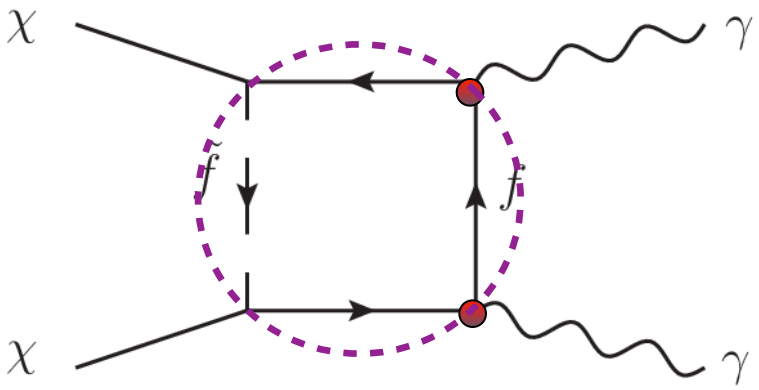
Theoretical Troubles

- Line annihilation requires two-body final state channels containing at least one photon (for SM final states, $\gamma\gamma$, γZ, γH) yielding the spectrum

$$\frac{dN}{dE} \propto \delta(E - E_\gamma)\,, \quad E_\gamma \leq m_\chi$$

- This must be a loop-level process, suppressed with respect to the tree-level by $\alpha^2 \sim 10^{-4}$

- Does it imply $\langle \sigma v \rangle \sim 10^{-23}$ cm^3/s, way too large for the thermal relic WIMP paradigm? How to produce it? Non-thermal WIMPs?



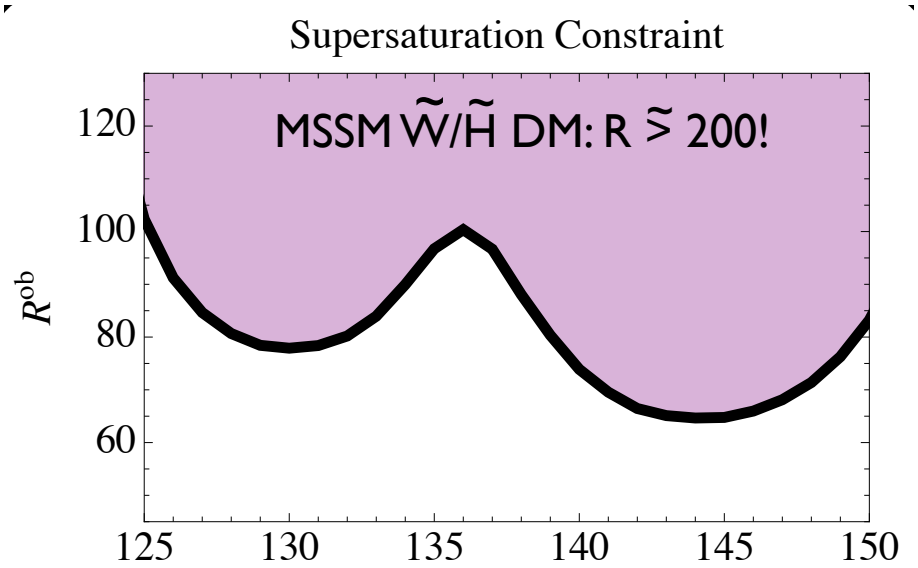
... or phenomenological ones: lack of continuum γ!?

- If it is DM, it should be accompanied by continuum photons (fragmentation/decay of heavy SM particles)

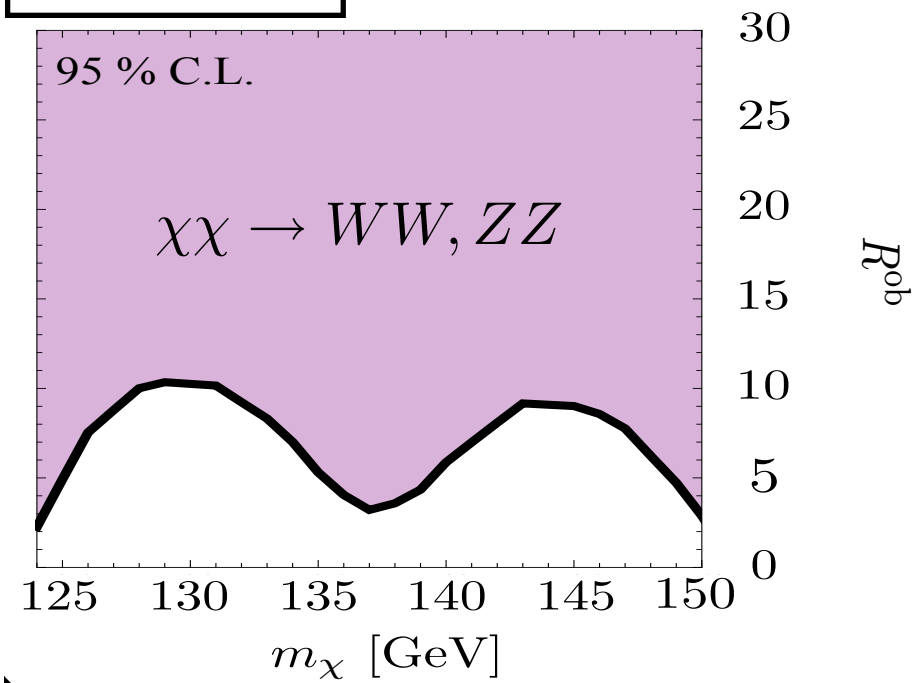
- Even in absence of astrophysical background (unrealistic) stringent bounds can be put from line/continuum **in the data**: line **b.r.≥10^{-2} !!!**
Enough to exclude MSSM neutralinos as cause of the feature...

- Under the assumption of power-law astro background **b.r.≥0.1-0.2 !!!**

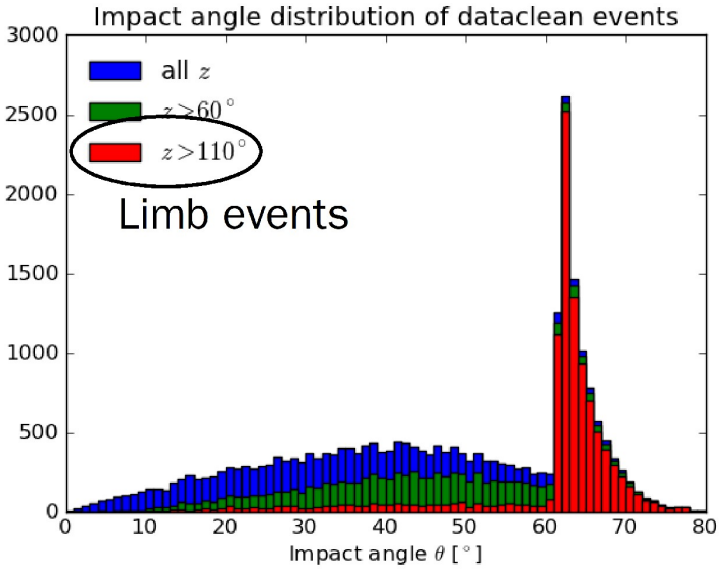
Definitely not what we had in mind! What room one has to build meaningful models like that? Debate in the community...



Cohen, Lisanti, Slatyer, Wacker, 1207.0800



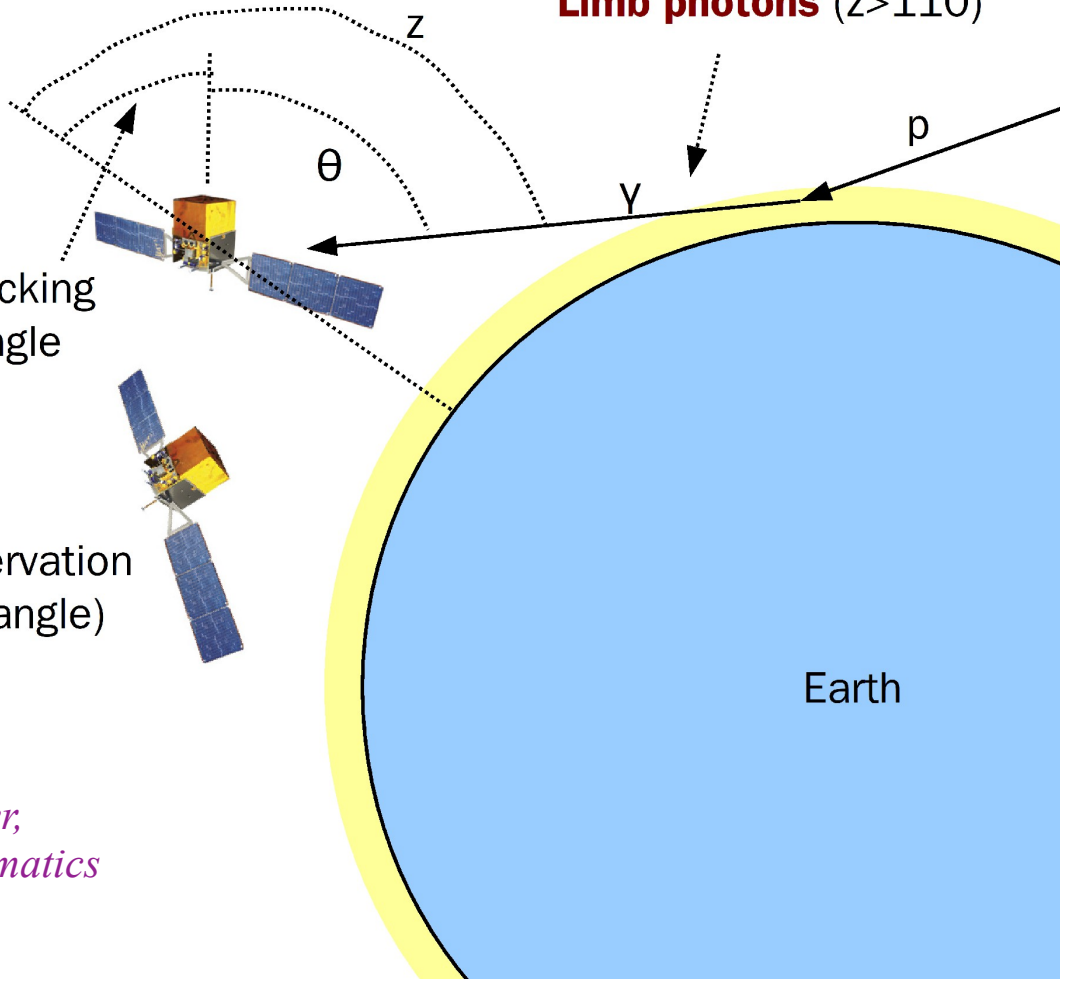
Looking for test samples: the Albedo Puzzle...



C. Weniger's talk at IDM 2012

Survey Mode
(rocking angle ~50deg)

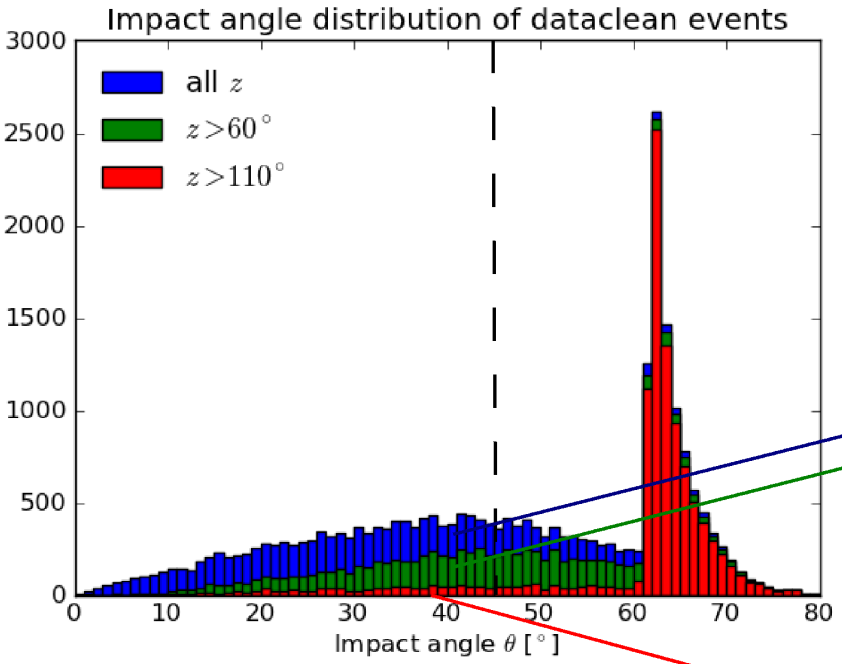
Limb photons (z>110)

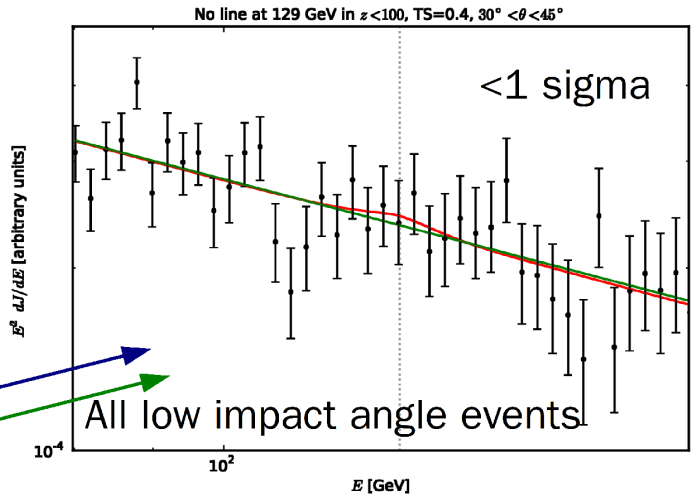


Target-of-opportunity observation
(potentially large rocking angle)

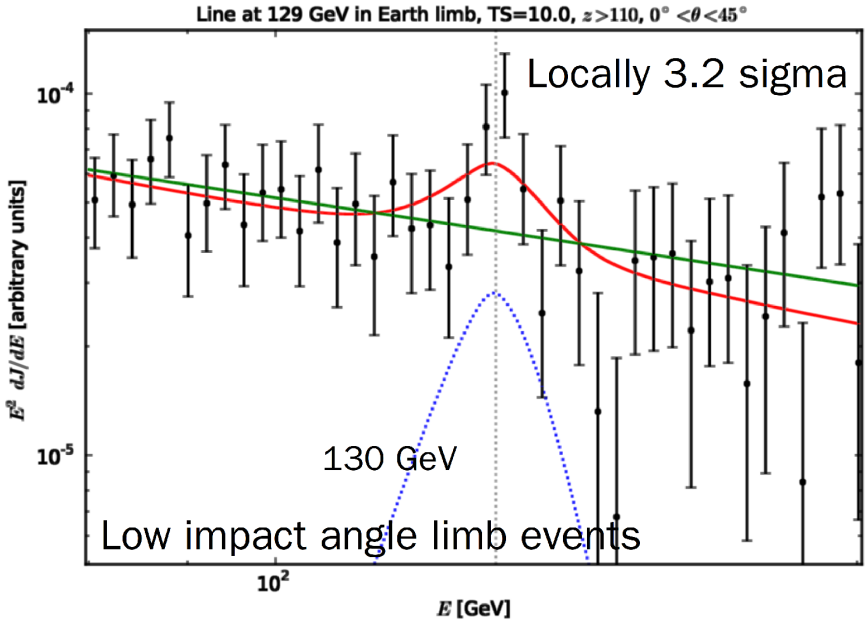
See also D. P. Finkbeiner, M. Su and C. Weniger, "Is the 130 GeV Line Real? A Search for Systematics in the Fermi-LAT Data," arXiv:1209.4562

Another 130 GeV line in part of limb data?





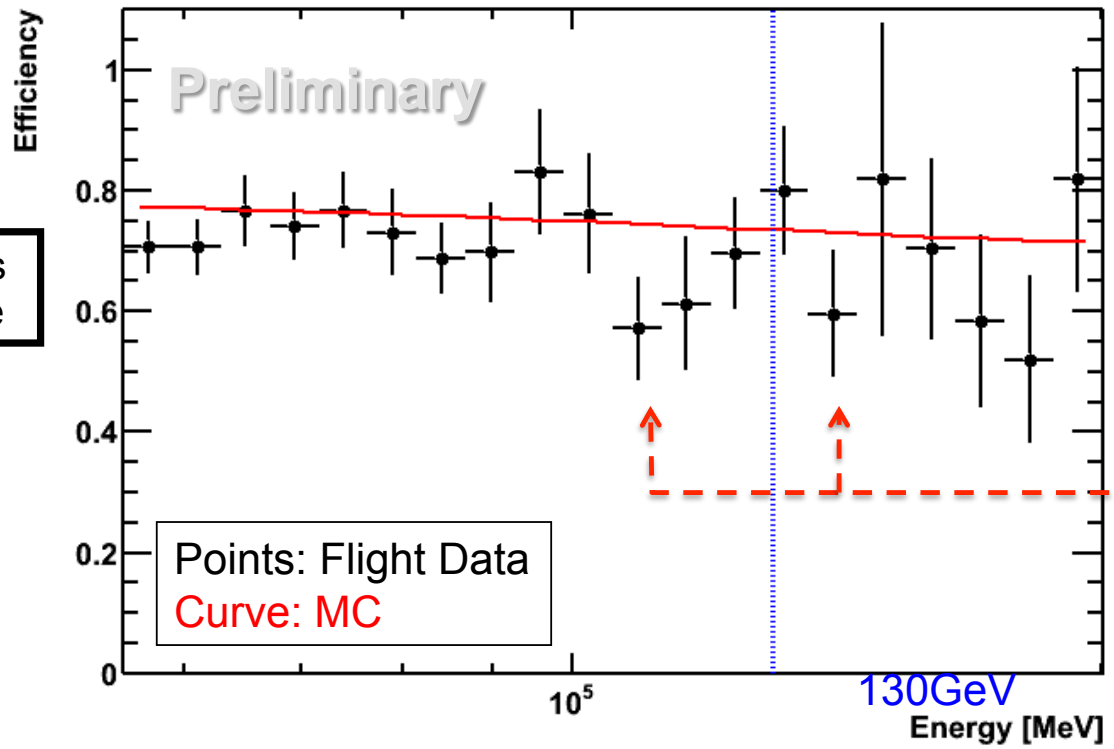
(same for all limb events)



- statistical (comes with a large trial factor)?
- systematic (why only there and at the GC)?

P7TRANSIENT to P7CLEAN Efficiency

Same data as previous slide



These dips in efficiency appear to be related to the CAL-TRK agreement.

E. Charles

The efficiency at ~115Gev is 0.57/0.75 = 0.75 percent of the MC prediction. This would imply a 30% boost in signal at 130GeV relative to the prediction from nearby energy bins.

From Fermi Symposium 2012

data cleaning and resolution improvements have lowered local significance from ~4.0 to 3.3 sigma... waiting for "Pass 8" processing

A. Albert

Summary

- **The most compelling potential DM signal is a strong spectral feature at 130GeV near the Galactic Center**
  - **Not caused by background contamination**
- **There is some indication that the feature in the GC is not a smooth distribution but actually 2 or 3 smaller "hot spots"**
- **A similar spectral feature is seen in the Earth Limb and is likely attributable to dips in efficiency at energies just above and below 130GeV**
  - **The Earth Limb instrumental features are not enough to explain all of the feature near the GC, however when accounted for they reduce the significance of the GC feature by up to 30%-50% depending on the ROI under consideration.**
  - **Hard-spectrum diffuse sources being "shaped" by features in the efficiency curve?**

E. Charles

Crucial conclusion & important lesson

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This implies that Dark Matter requires “new physics”, beyond the theories of the SM and/or gravity known today.

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Q.: Is the mere existence of DM restrictive on the type of physics responsible for it?

I.e, do we get major restrictions on particle physics scales and models by requiring a dynamical mechanism for its generation?

A.: Not really!