

# Dark Matter

**Between Now and Never**

Leszek Roszkowski

Univ. of Sheffield, England and  
Soltan Institute for Nuclear Studies, Warsaw, Poland

# Dark Matter Programme at GGI

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- venue: Galileo Galilei Institute, Florence
- dates: 26 April - 19 June 2010
- organizers: H. Baer, L. Covi, L. Roszkowski and P. Ullio

# Cosmology After WMAP...

Post WMAP-5yr (April 08)

...+ACBAR+CBI+SN+LSS+...

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$$\text{Hubble } H_0 = 100 h \text{ km/s/Mpc}$$

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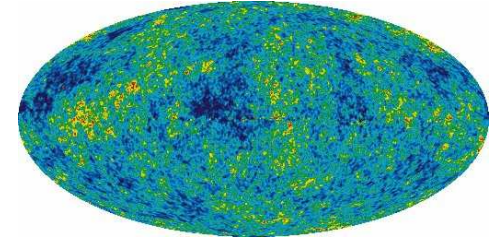
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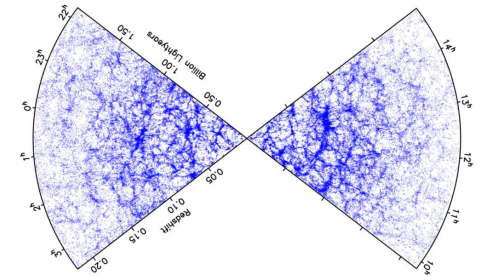
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CMB (WMAP, ACBAR, CBI,...)



LSS (2dF, SDSS, Lyman- $\alpha$ )



assume simplest  $\Lambda$ CDM model

- matter  $\Omega_m h^2 = 0.1378 \pm 0.0043$
- baryons  $\Omega_b h^2 = 0.02263 \pm 0.00060$
- $\Rightarrow \Omega_{CDM} h^2 = 0.1152 \pm 0.0042$
- $h = 0.696 \pm 0.017$
- $\Omega_\Lambda = 0.715 \pm 0.20 \dots$

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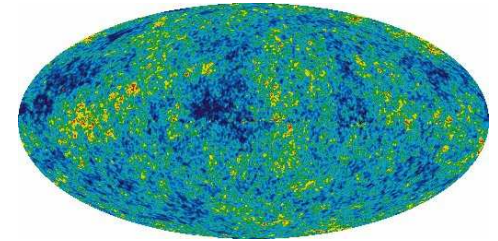
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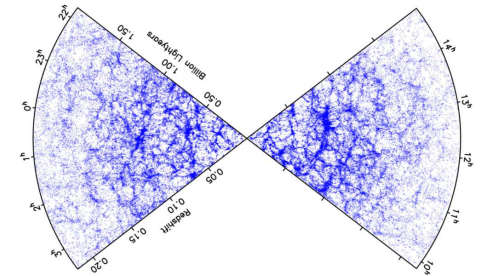
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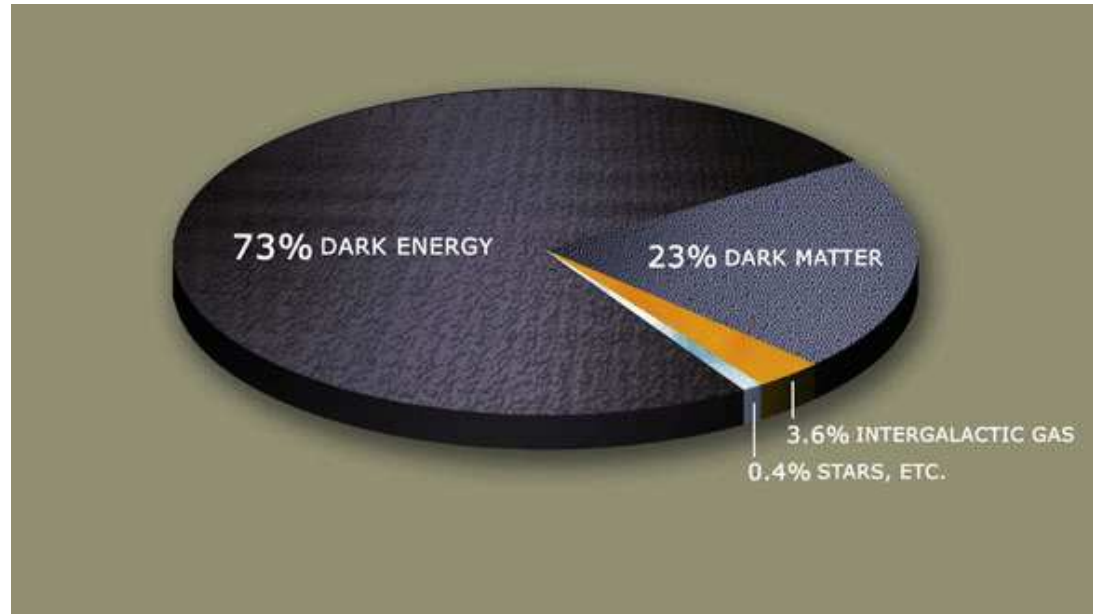
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● concordance model works well

● main components: dark energy and dark matter

factor of 4-10 improvement expected from Planck

# Cosmic Pie



# Outline



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Some anomalies and hints – DM origin of 'signal' not convincing.

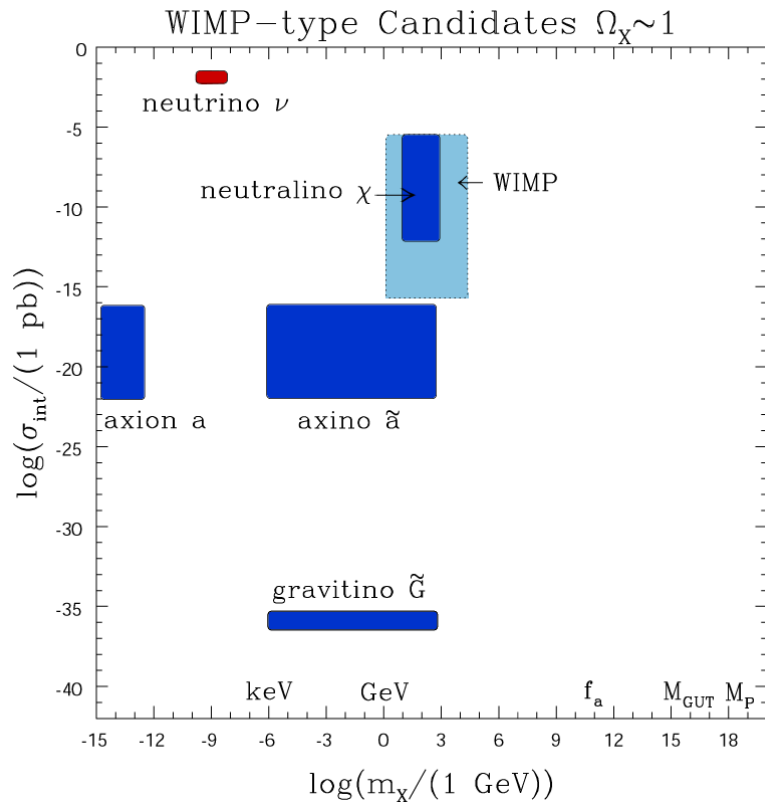
# DM: The Big Picture

\* – not invented to solve the DM problem

*well-motivated*\* particle candidates with  $\Omega \sim 0.1$

# DM: The Big Picture

L.R. (2000), hep-ph/0404052



- neutrino  $\nu$  – hot DM
- neutralino  $\chi$
- “generic” WIMP
- axion  $a$
- axino  $\tilde{a}$
- gravitino  $\tilde{G}$

- vast ranges of interactions and masses
- different production mechanisms in the early Universe (thermal, non-thermal)
- need to go beyond the Standard Model
- WIMP candidates testable at present/near future
- axino, gravitino EWIMPs/superWIMPs not directly testable, but some hints from LHC

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it is much (!) harder to invent a (lasting) model of  
'new physics'

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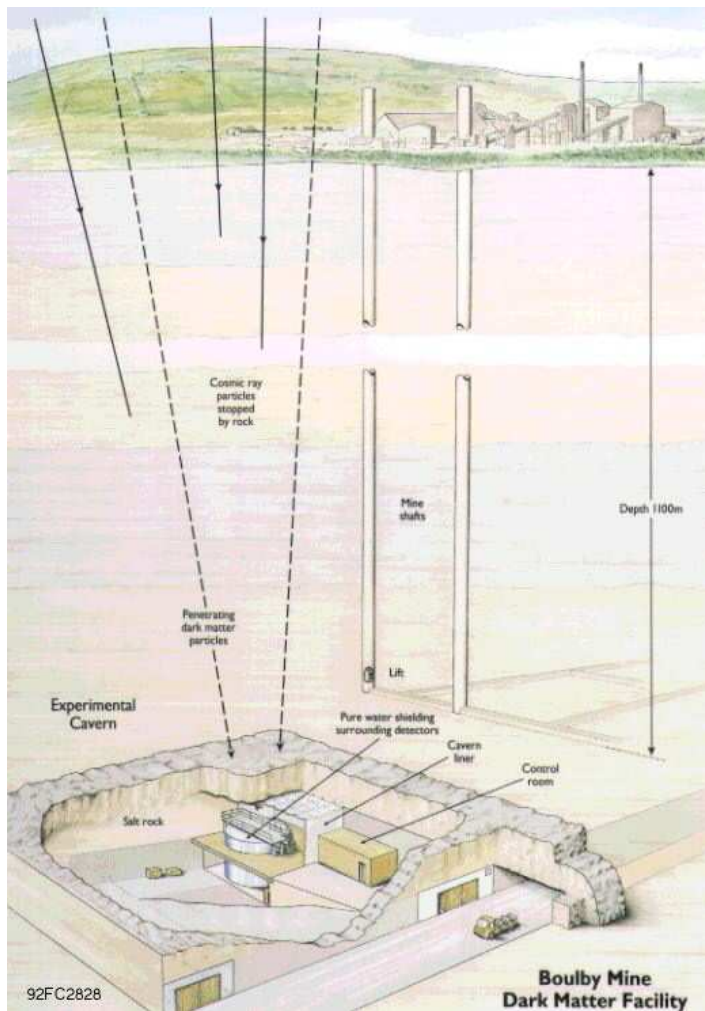
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- other ideas: traces of WIMP annihilation in dwarf galaxies, in rich clusters, etc
  - more speculative

# Go underground/–ice/–water

... or to space

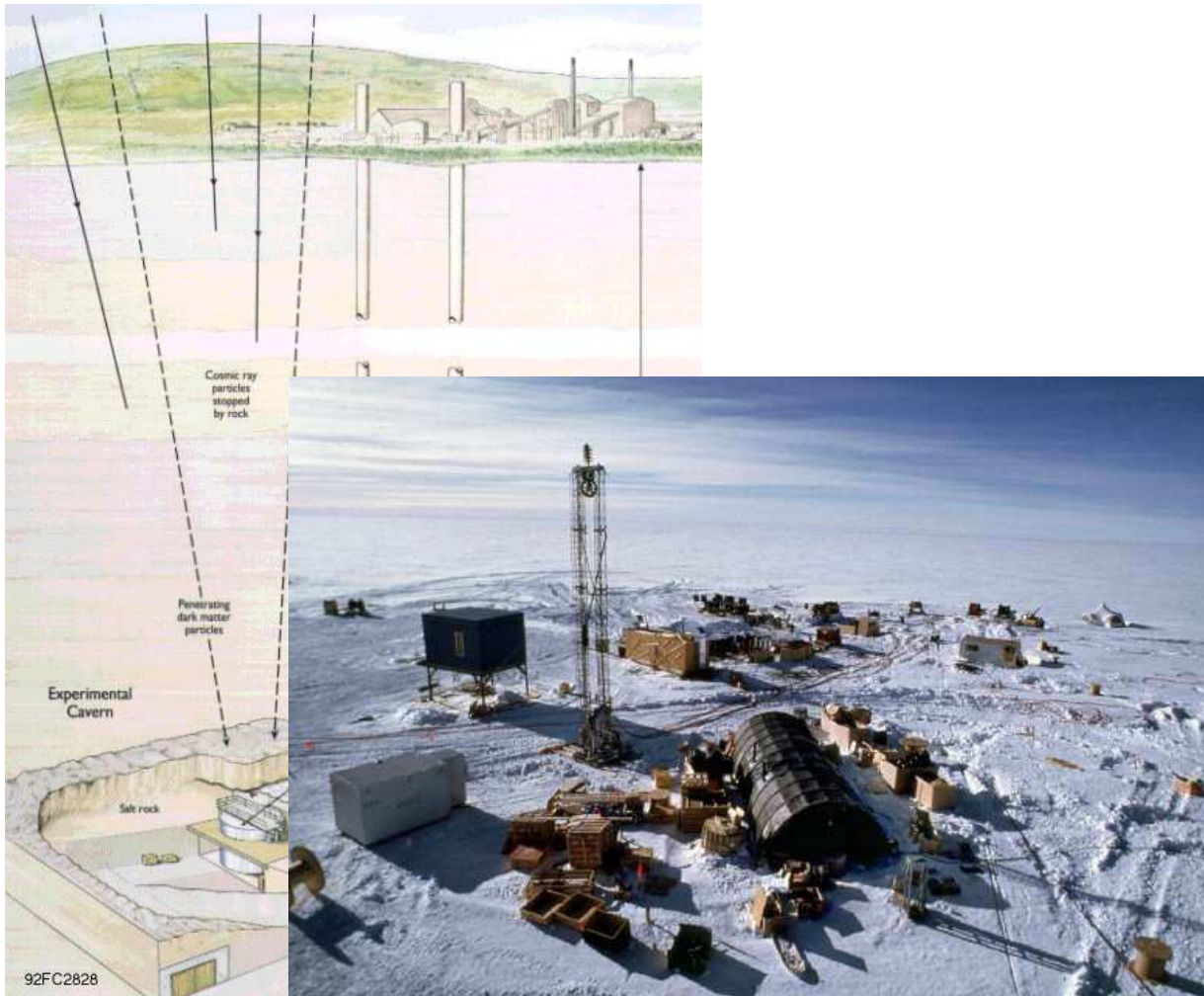
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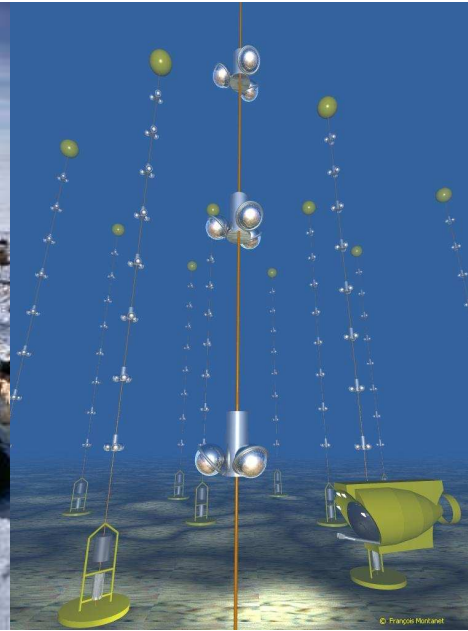
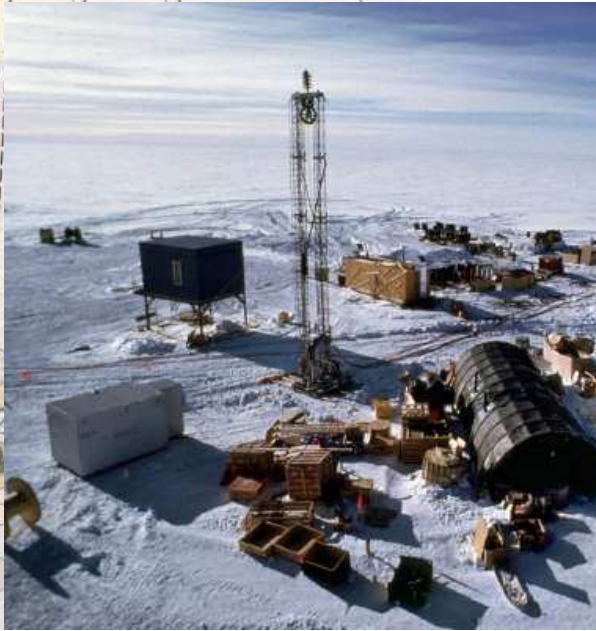
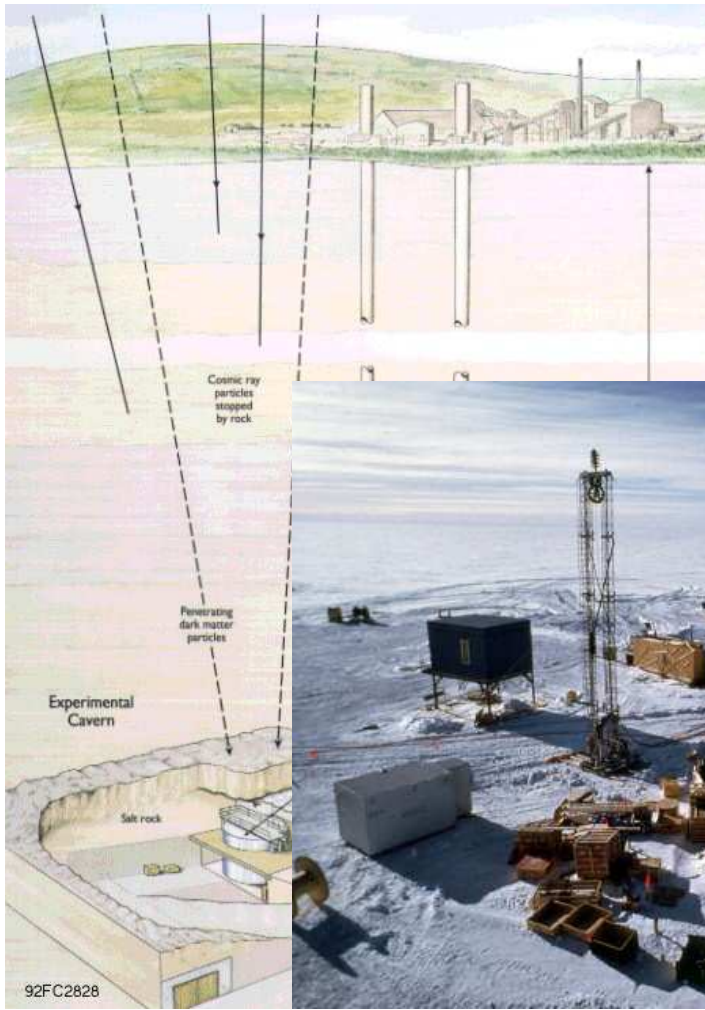
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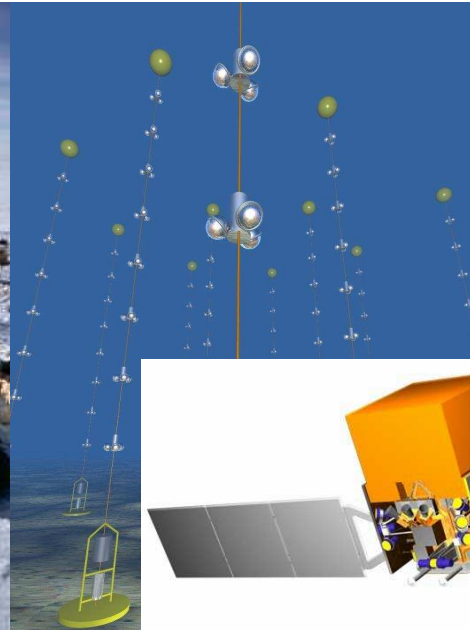
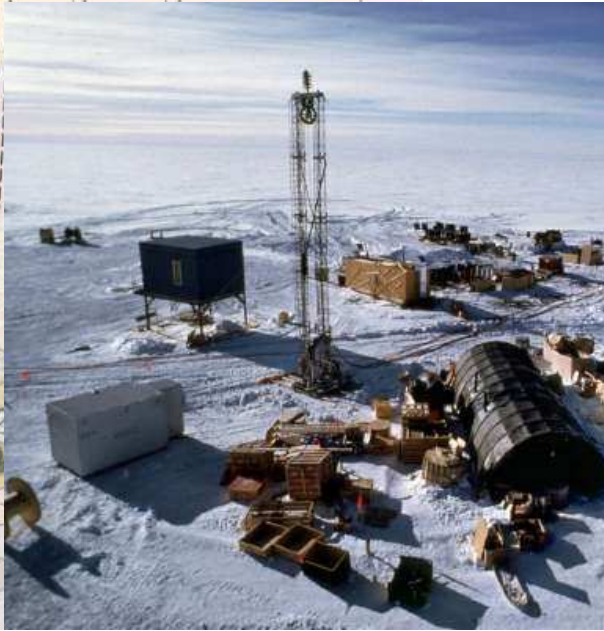
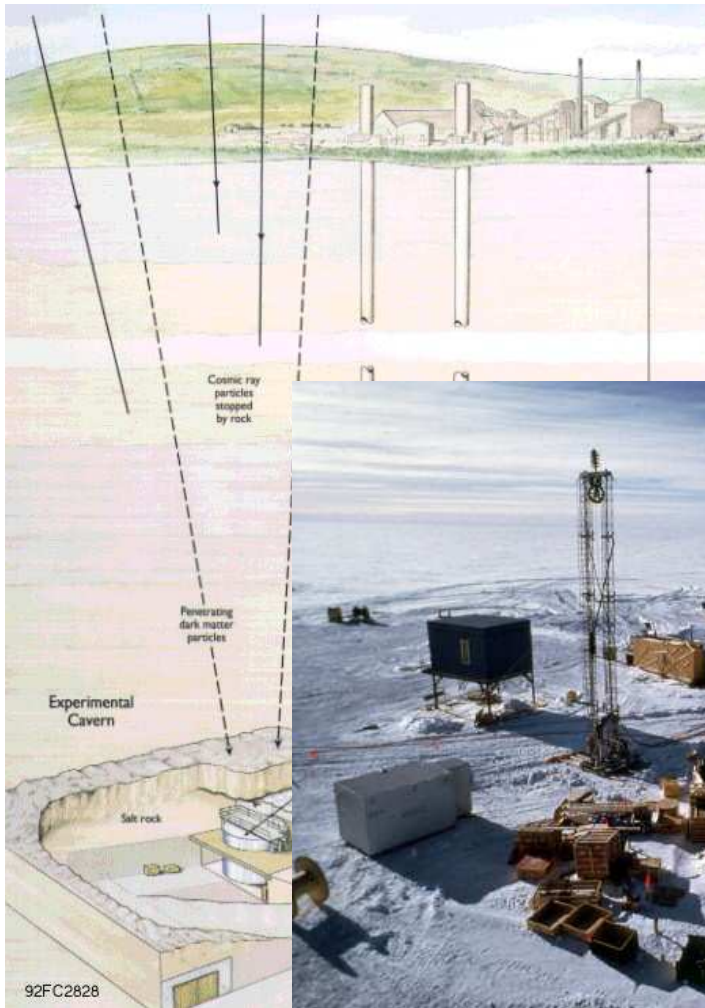
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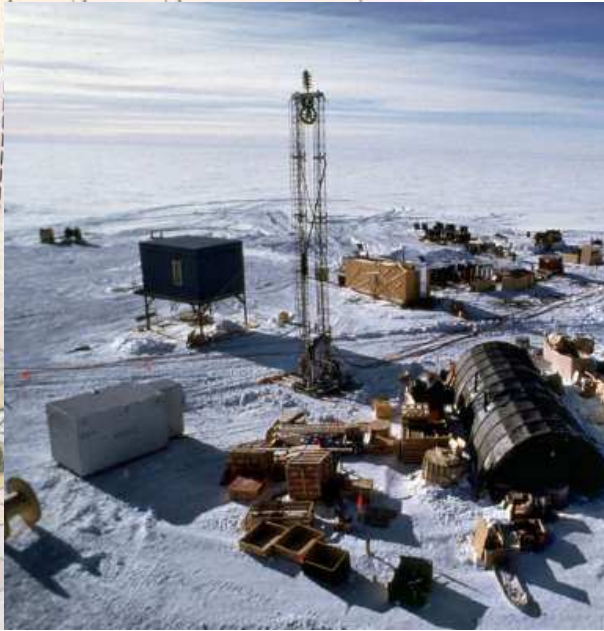
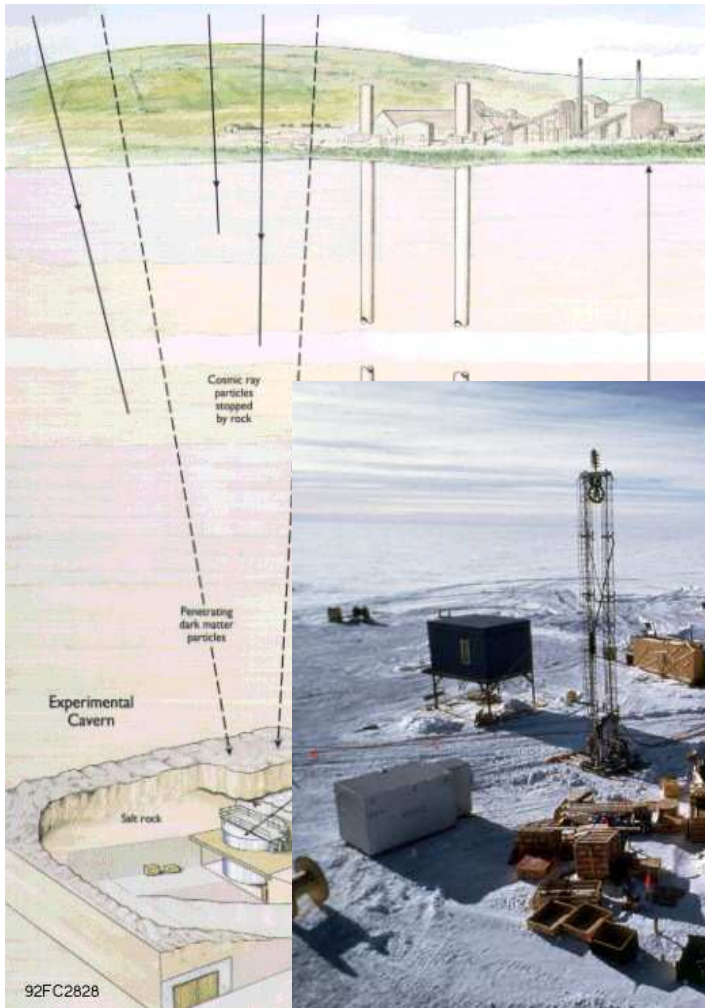
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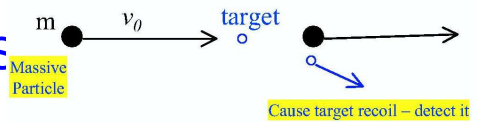
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impressive experimental effort

# SUSY: Prospects for direct detection

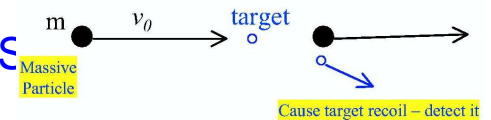
Bayesian analysis, flat priors, MCMC scan of 8 params (4 SUSY+4 S



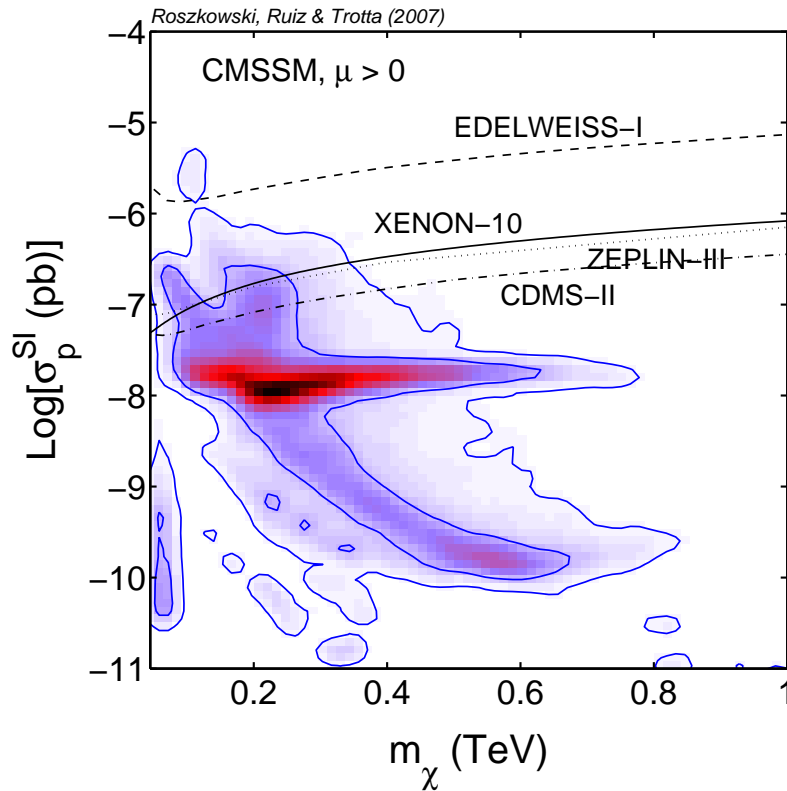
The diagram illustrates a direct detection process. On the left, a black dot labeled 'm' represents a 'Massive Particle'. An arrow labeled  $v_0$  points to the right, indicating its velocity. This particle is moving towards a 'target', represented by a smaller black dot on the right. A horizontal arrow points from the target to the right, representing its recoil. A blue arrow points downwards from the target, labeled 'Cause target recoil - detect it'. The text 'Bayesian analysis, flat priors, MCMC scan of 8 params (4 SUSY+4 S' is partially visible on the left side of the diagram.

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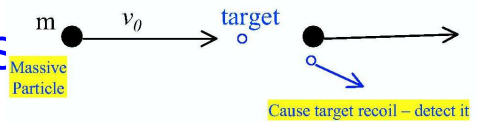
Constrained MSSM (mSUGRA)



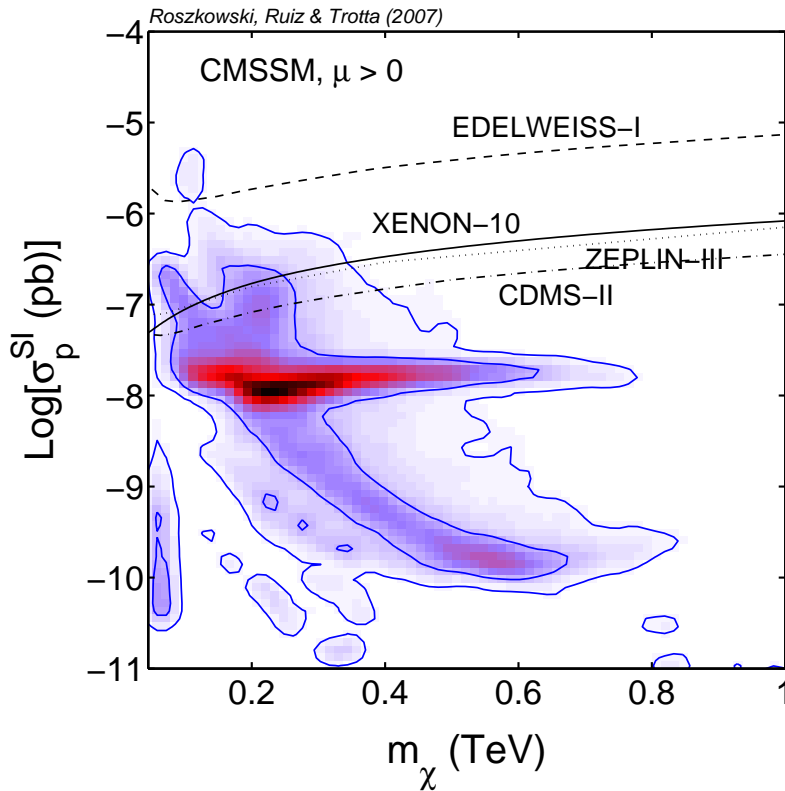
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$$\sigma_p^{SI} \lesssim 10^{-7} \text{ pb:}$$

also Zeplin-III

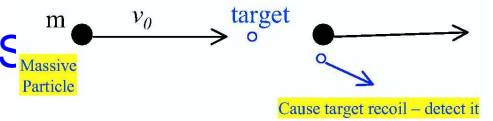
$\Rightarrow$  already explore 68% region

(large  $m_0 \gg m_{1/2} \Rightarrow$  heavy squarks)  
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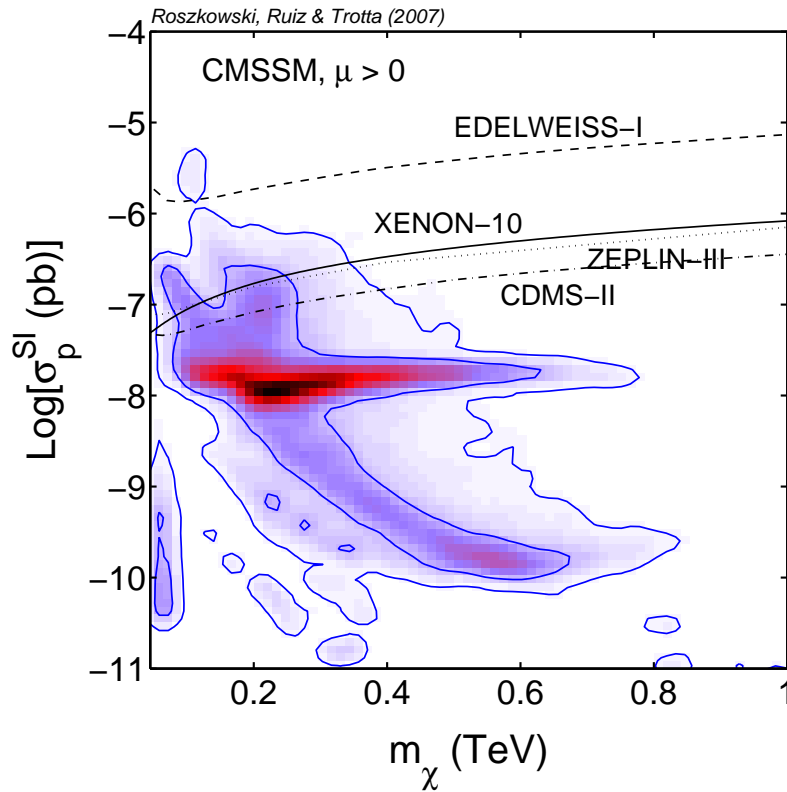
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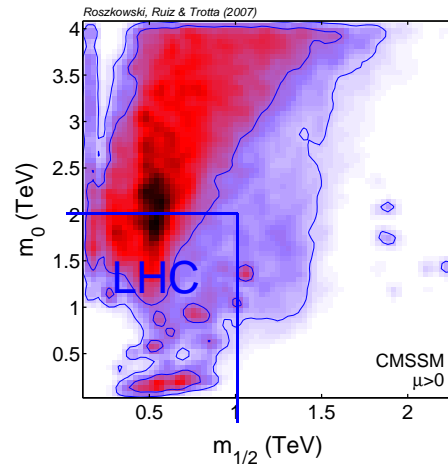
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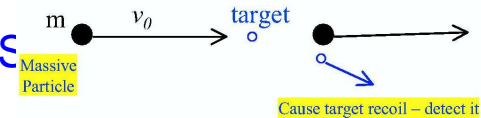
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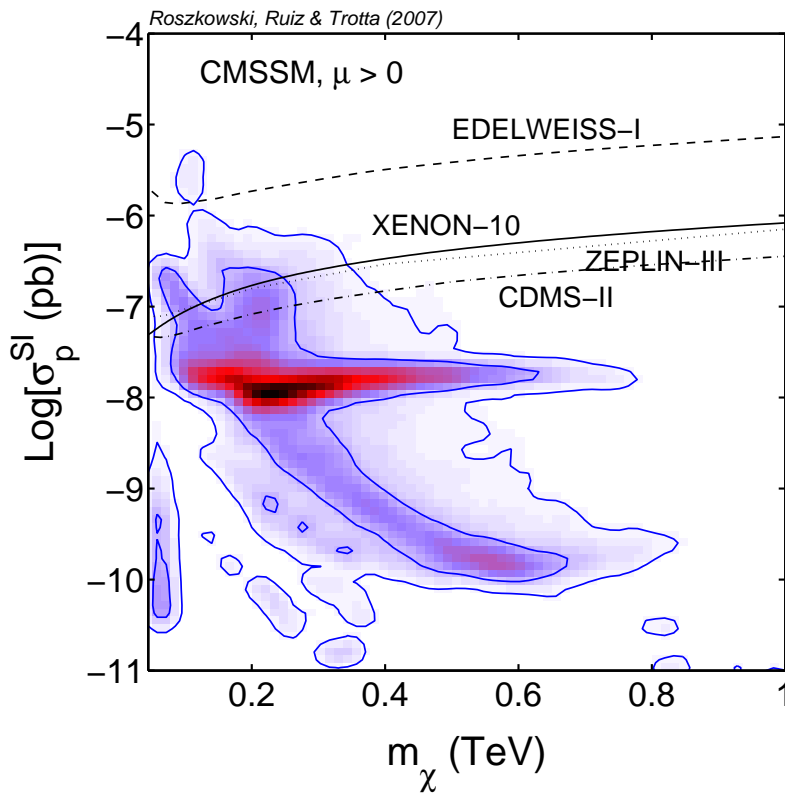


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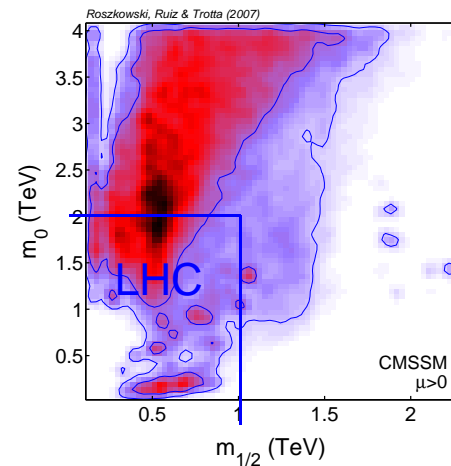
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$\Rightarrow$  **DD: prospects look very good**

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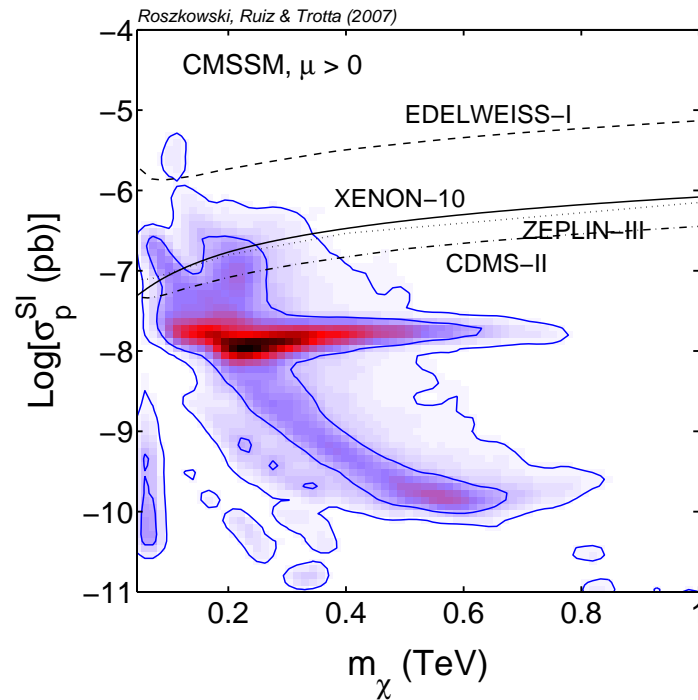
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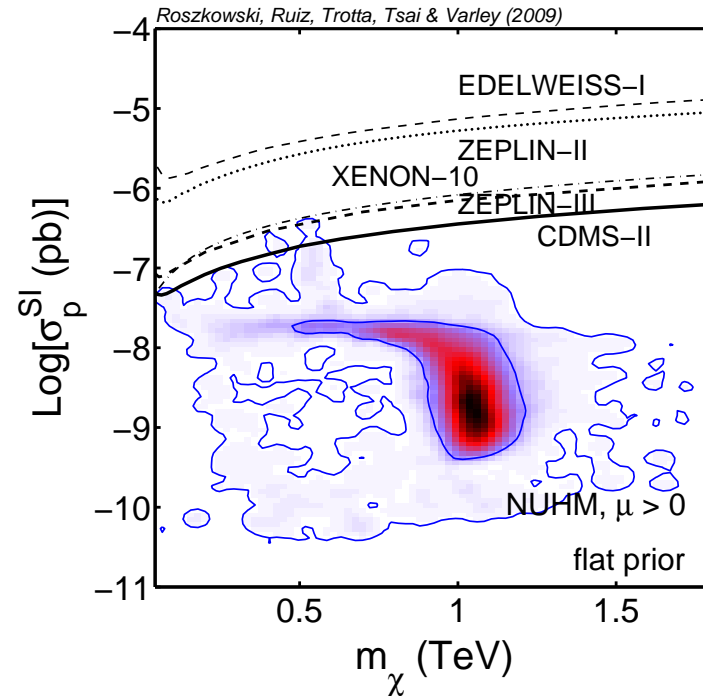
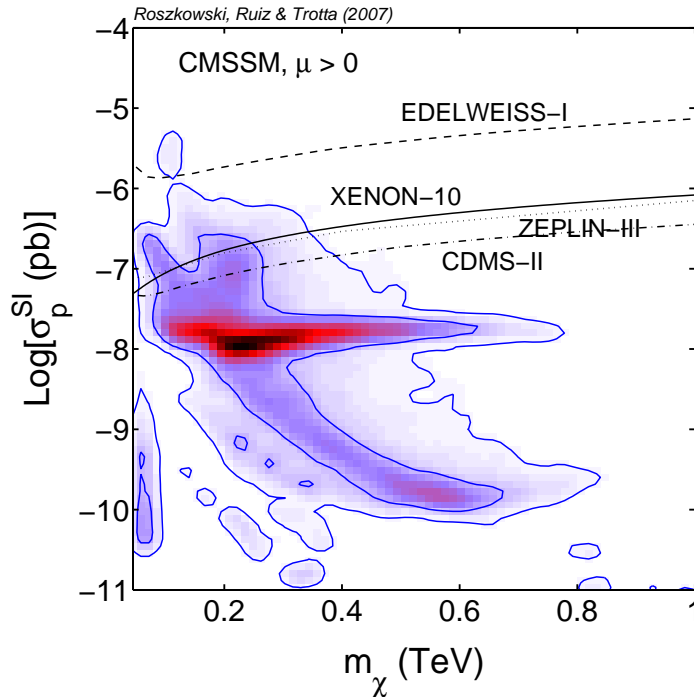
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Non-Universal Higgs Model (NUHM)

$$m_{H_u}^2, m_{H_d}^2 \neq m_0^2$$

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higgsino DM region at  $m_\chi \simeq 1$  TeV

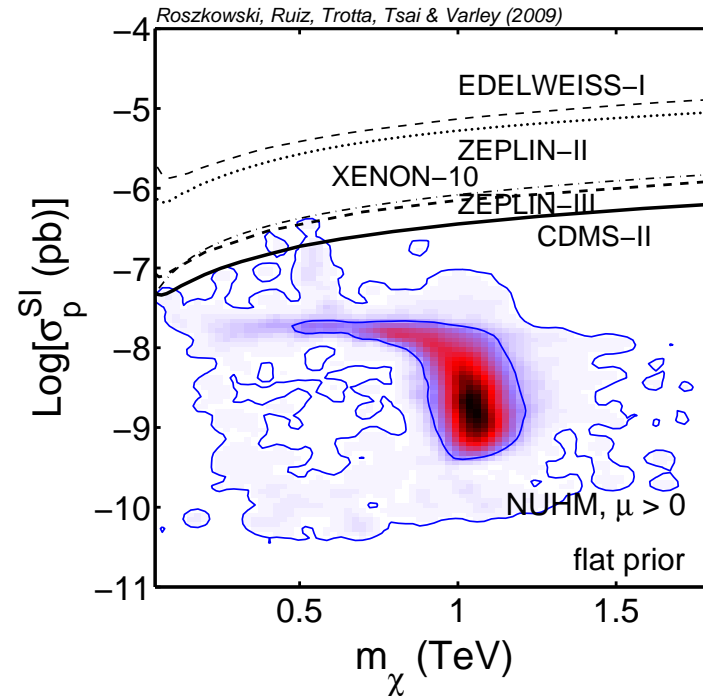
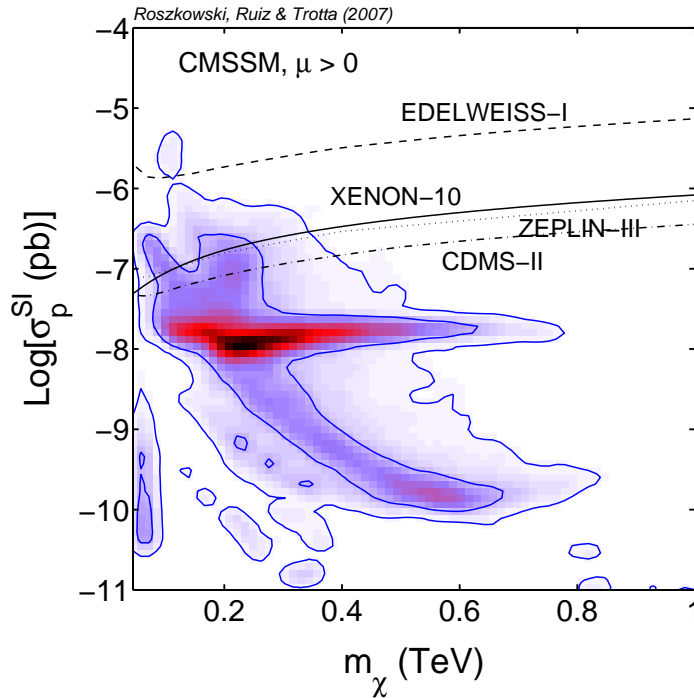
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Bayesian analysis, flat priors

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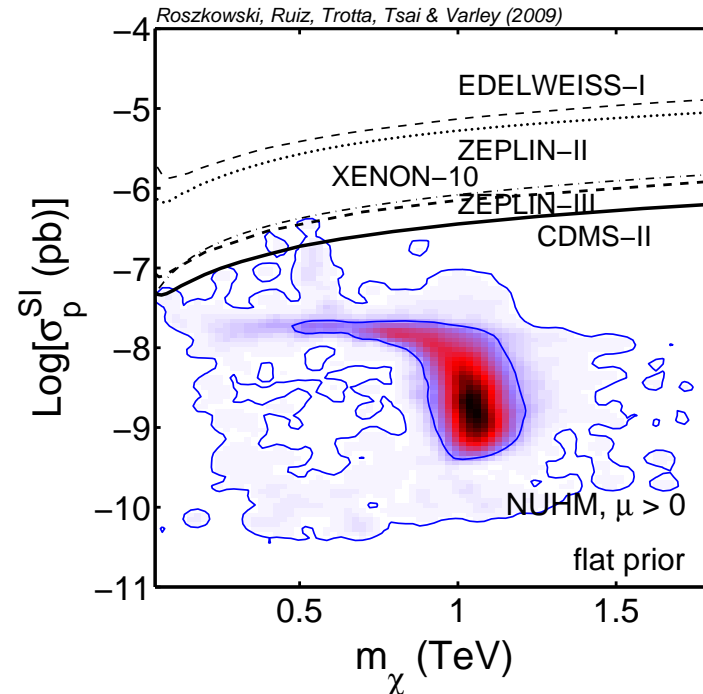
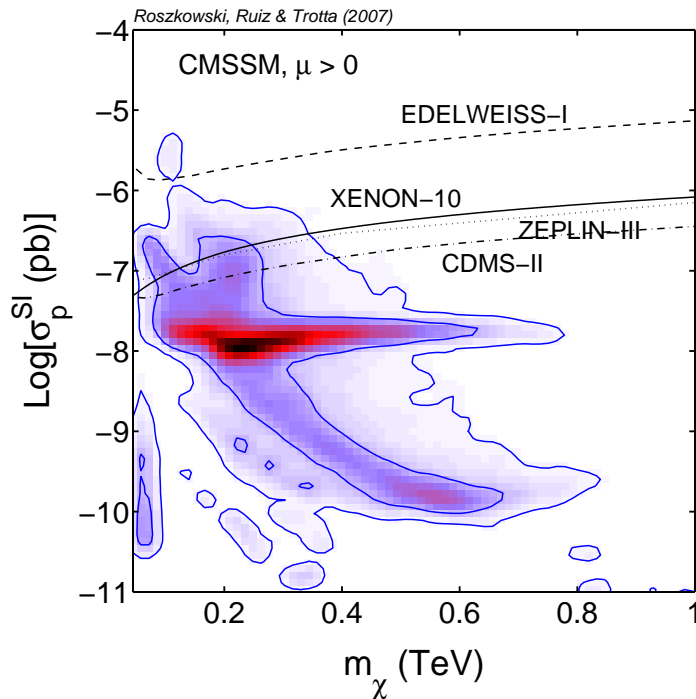
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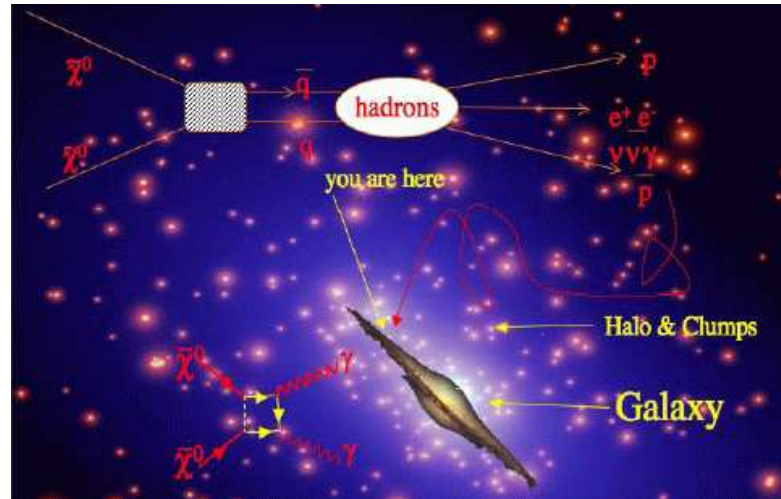
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collider signatures also similar

⇒ LHC, DM: it will be hard to distinguish models

# Indirect detection

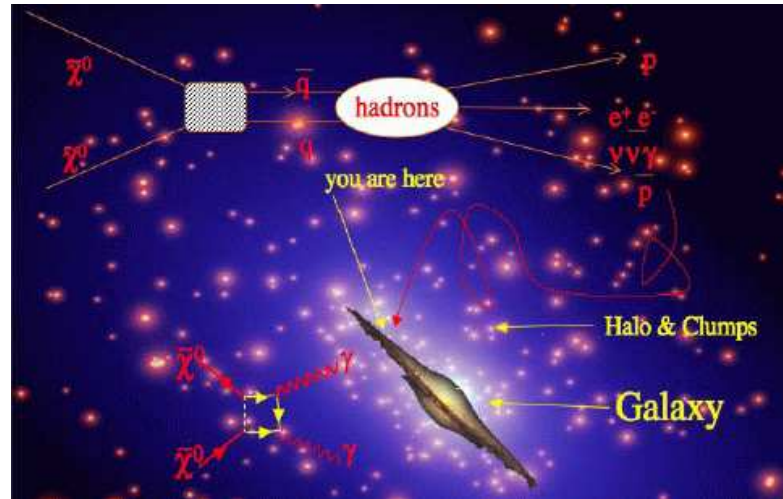
# Indirect detection



- look for traces of WIMP annihilation in the MW halo ( $\gamma$ -rays,  $e^+$ 's,  $\bar{p}$ , ...)
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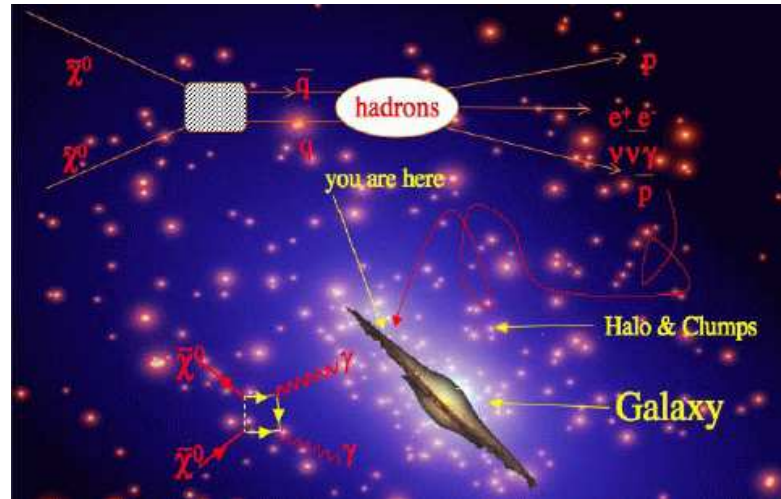


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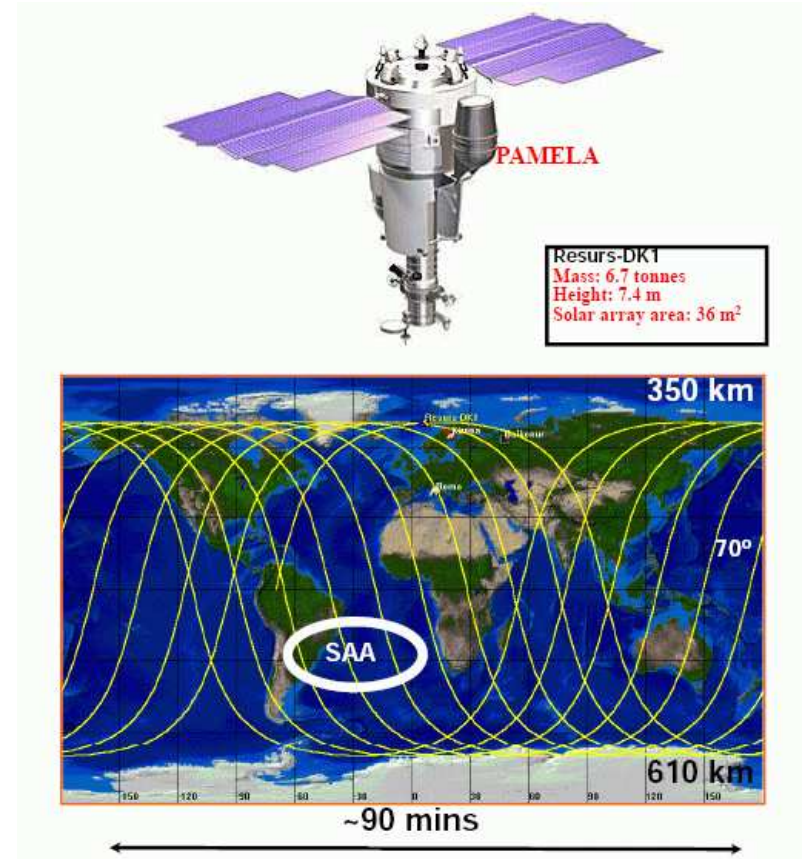
- PAMELA
- Fermi (GLAST)



# $e^+$ data from PAMELA & DM

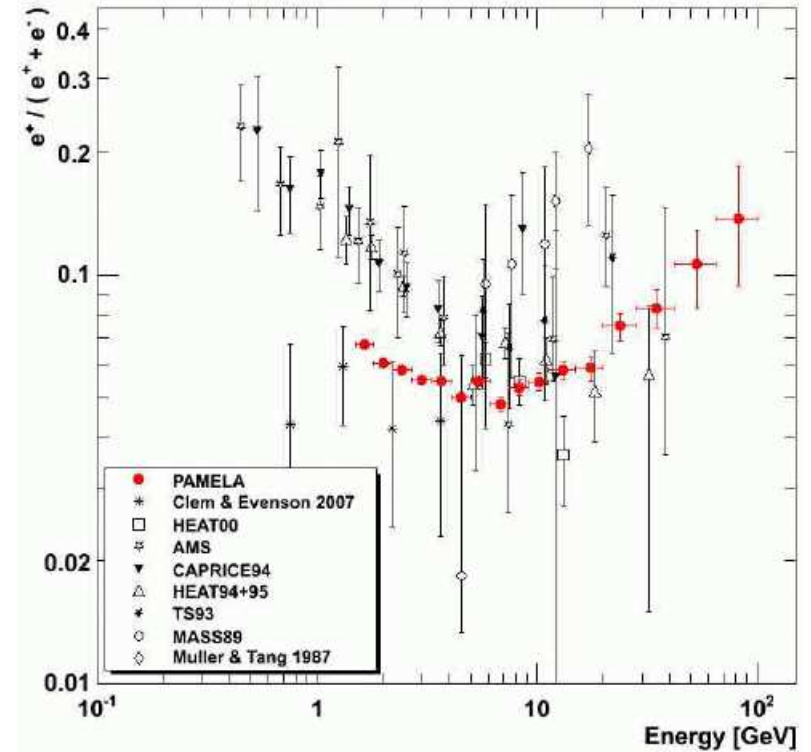
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PAMELA satellite (since 2007)



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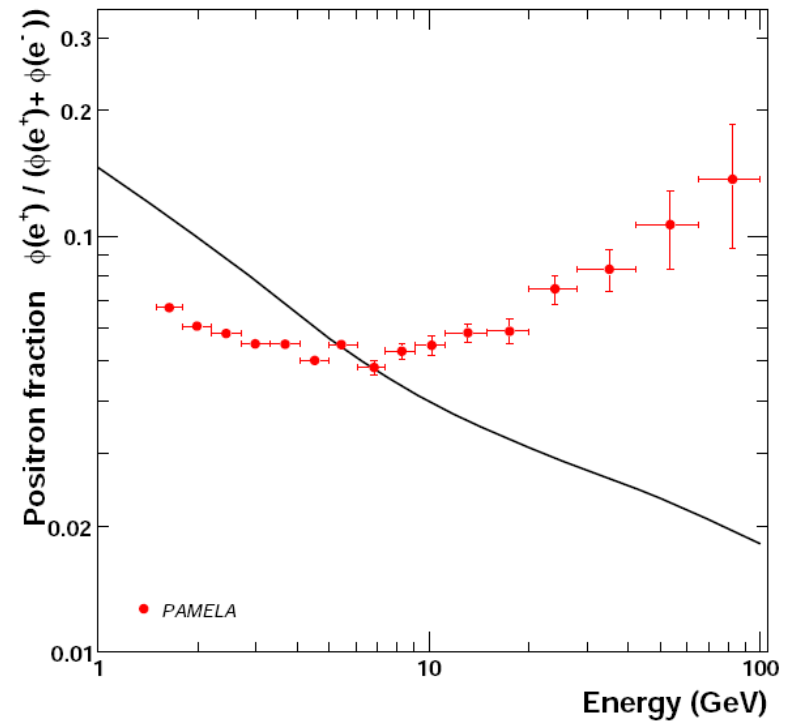
$e^+ / (e^+ + e^-)$  ratio,  $\bar{p}$  flux, ...



O. Adriani et al., arXiv:0810.4995

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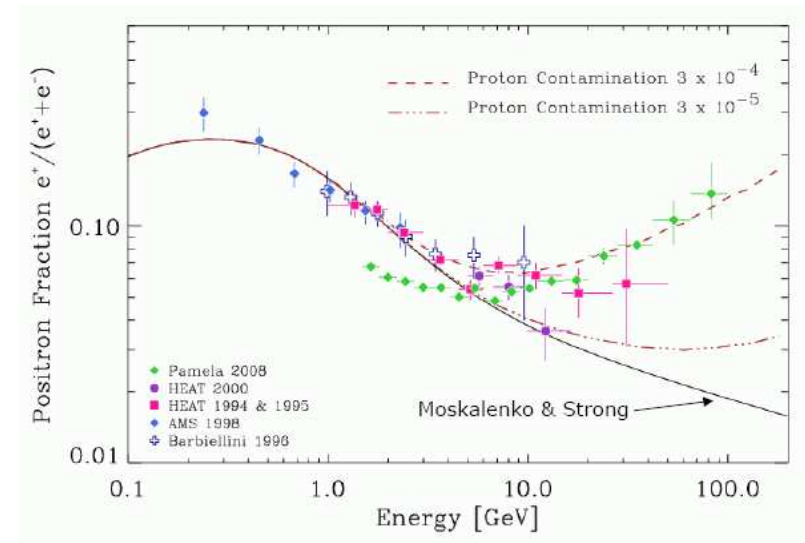
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also indication from ATIC at  $\sim 0.7 - 1$  TeV

$e^+$ : difficult measurement



Schubnell, Feb. 09

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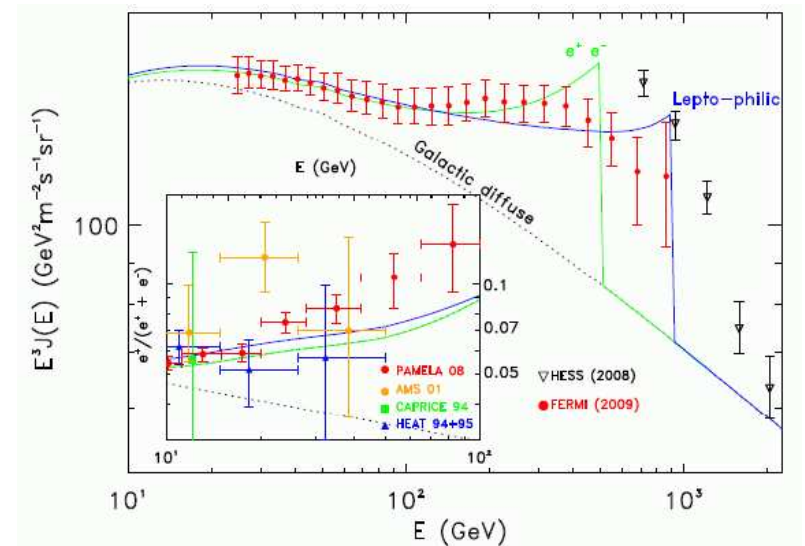
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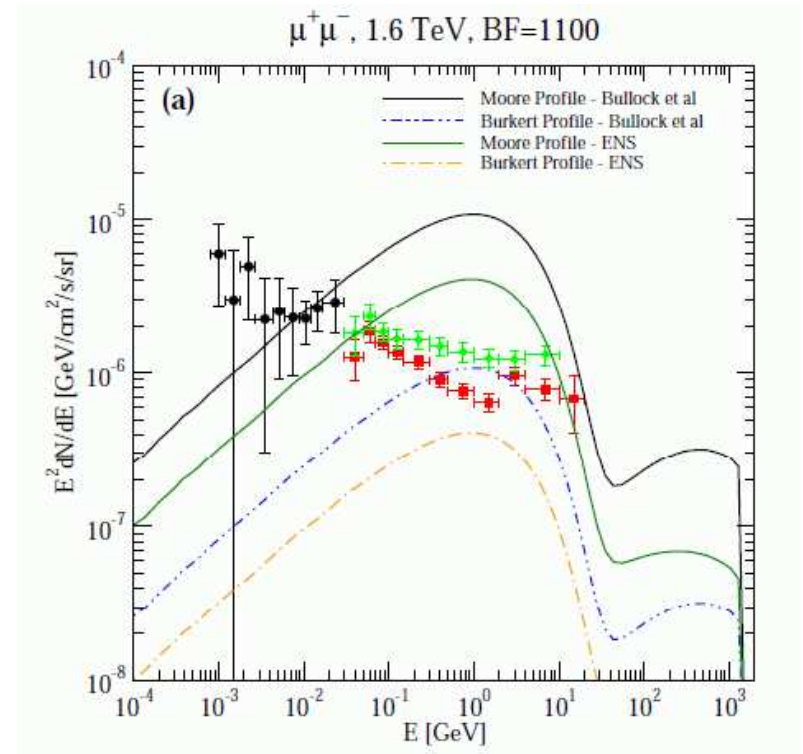
Grasso, et al., May 09

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Profumo+Jeltema, May 09

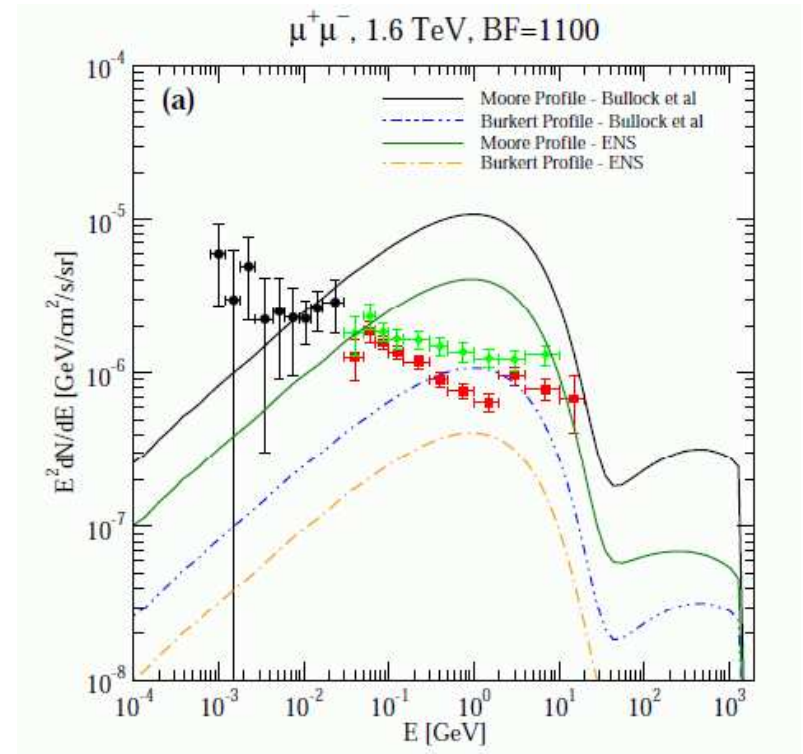


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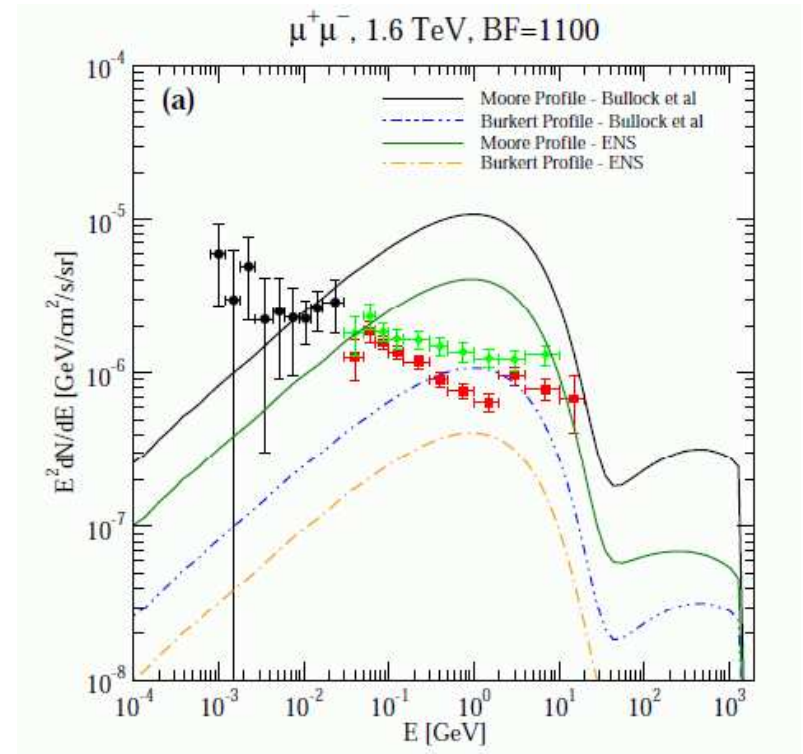
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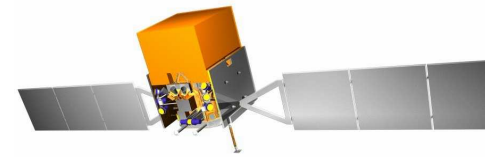


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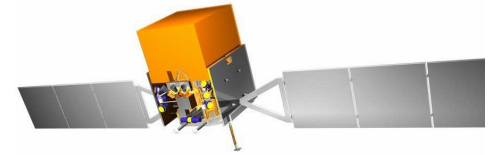
...pulsar explanation sufficient

# Fermi/GLAST



in orbit since 2008

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- full sky map in  $\gamma$ -ray spectrum,  $\sim 20$  MeV to  $\sim 300$  GeV
- superior energy and angular resolution
- improve accuracy/energy range of EGRET by an order of magnitude
- 1st year data to be released in August 09

...stay tuned

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e.g. CMSSM

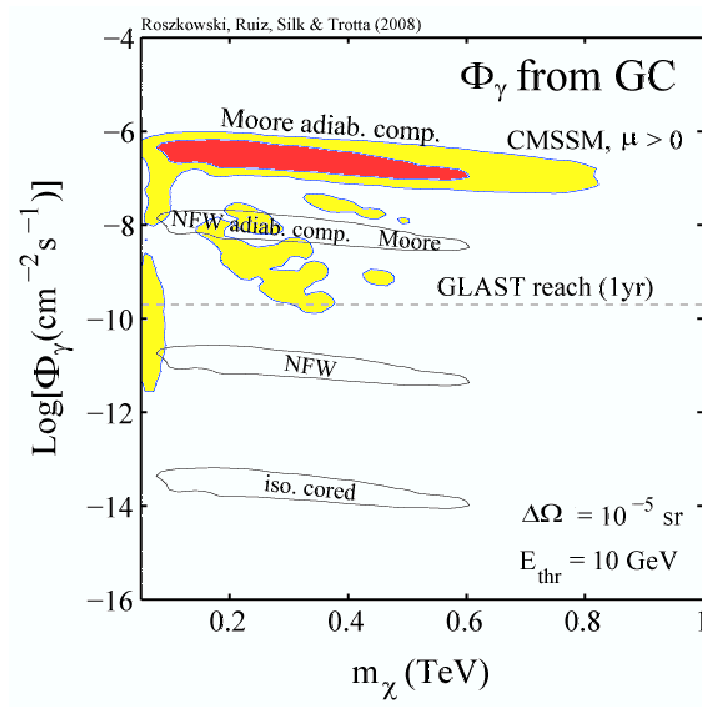
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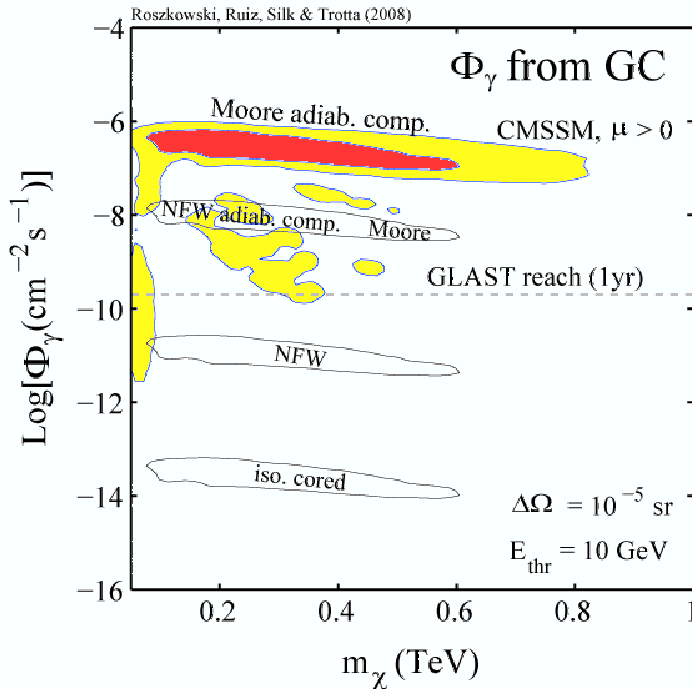
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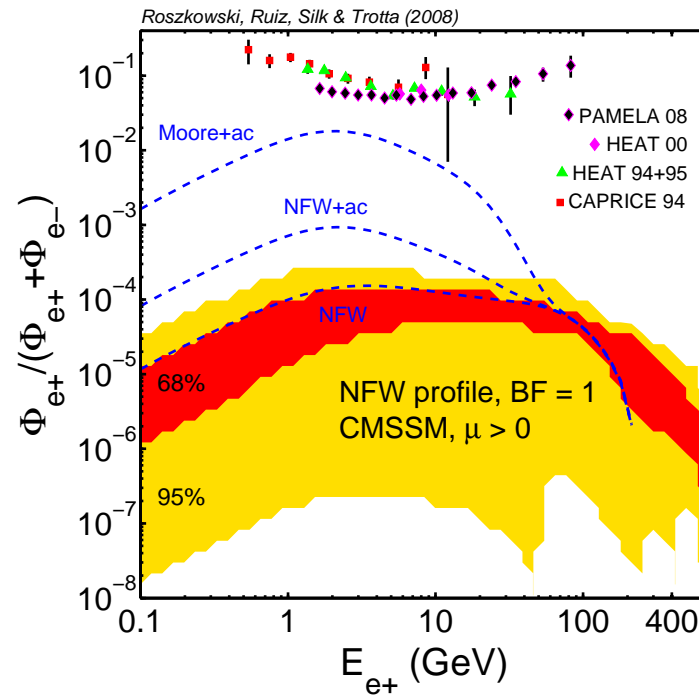
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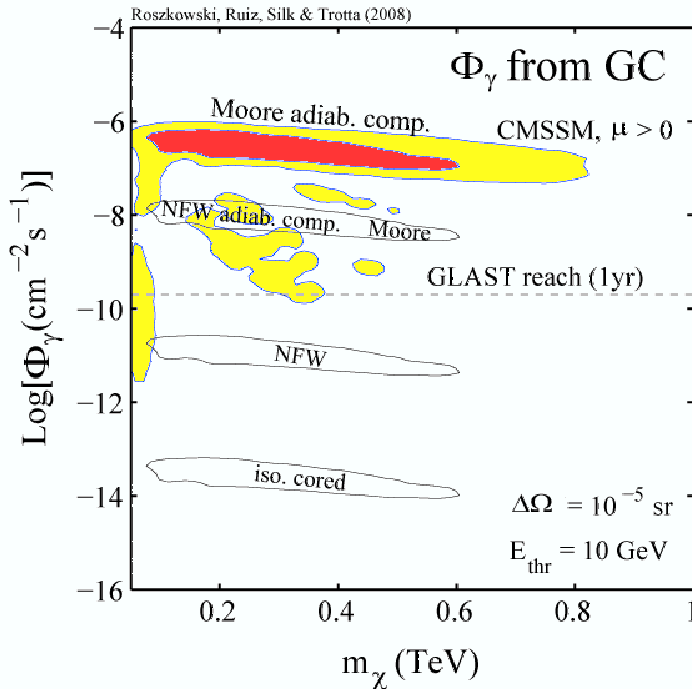
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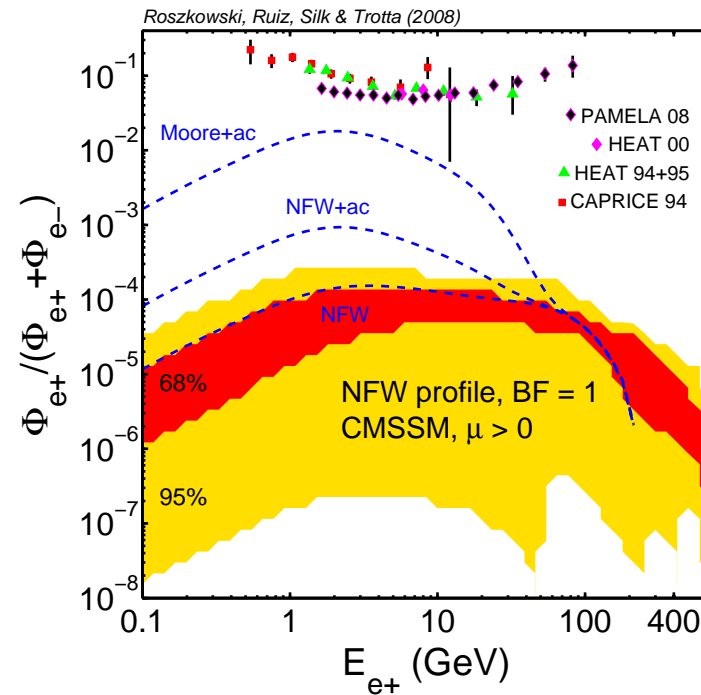
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...similar for NUHM, other unified SUSY models



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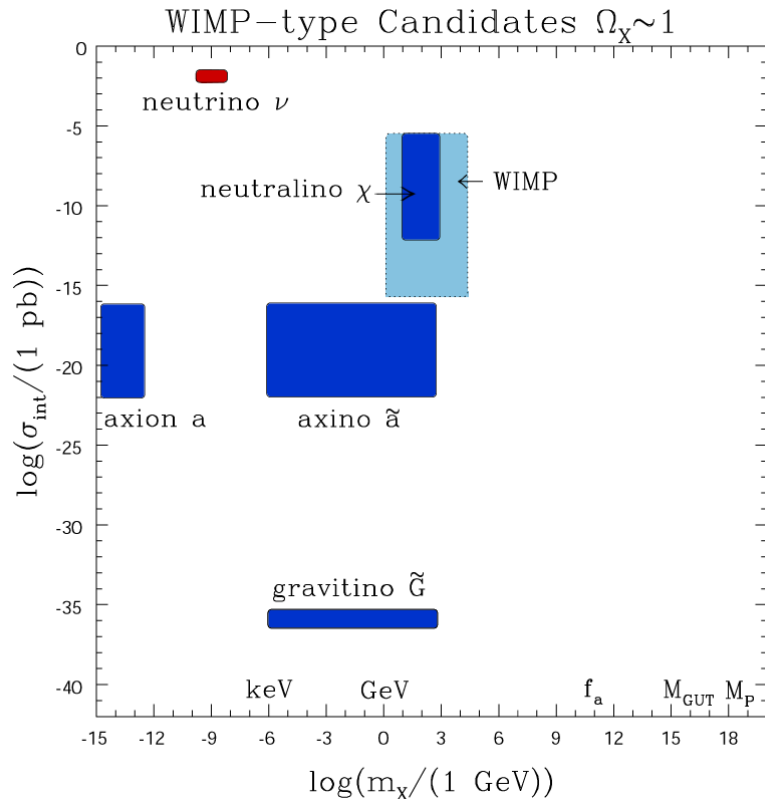
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...What if Nature has made a different choice?



# The Big Picture

well-motivated particle candidates such that  $\Omega \sim 0.1$



- neutrino  $\nu$  – hot DM
- neutralino  $\chi$
- “generic” WIMP
- axion  $a$
- axino  $\tilde{a}$
- gravitino  $\tilde{G}$

- **WIMP** (neutralino, weakly int'ing states, ...): discoverable now
- **EWIMP/superWIMP** (axino, gravitino, super-weakly int'ing states, ...): hopeless in direct detection, but hints possible at LHC

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- $\Rightarrow$  LHC: strong indications for EWIMP DM possible

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