The Search for Low-mass WIMPs

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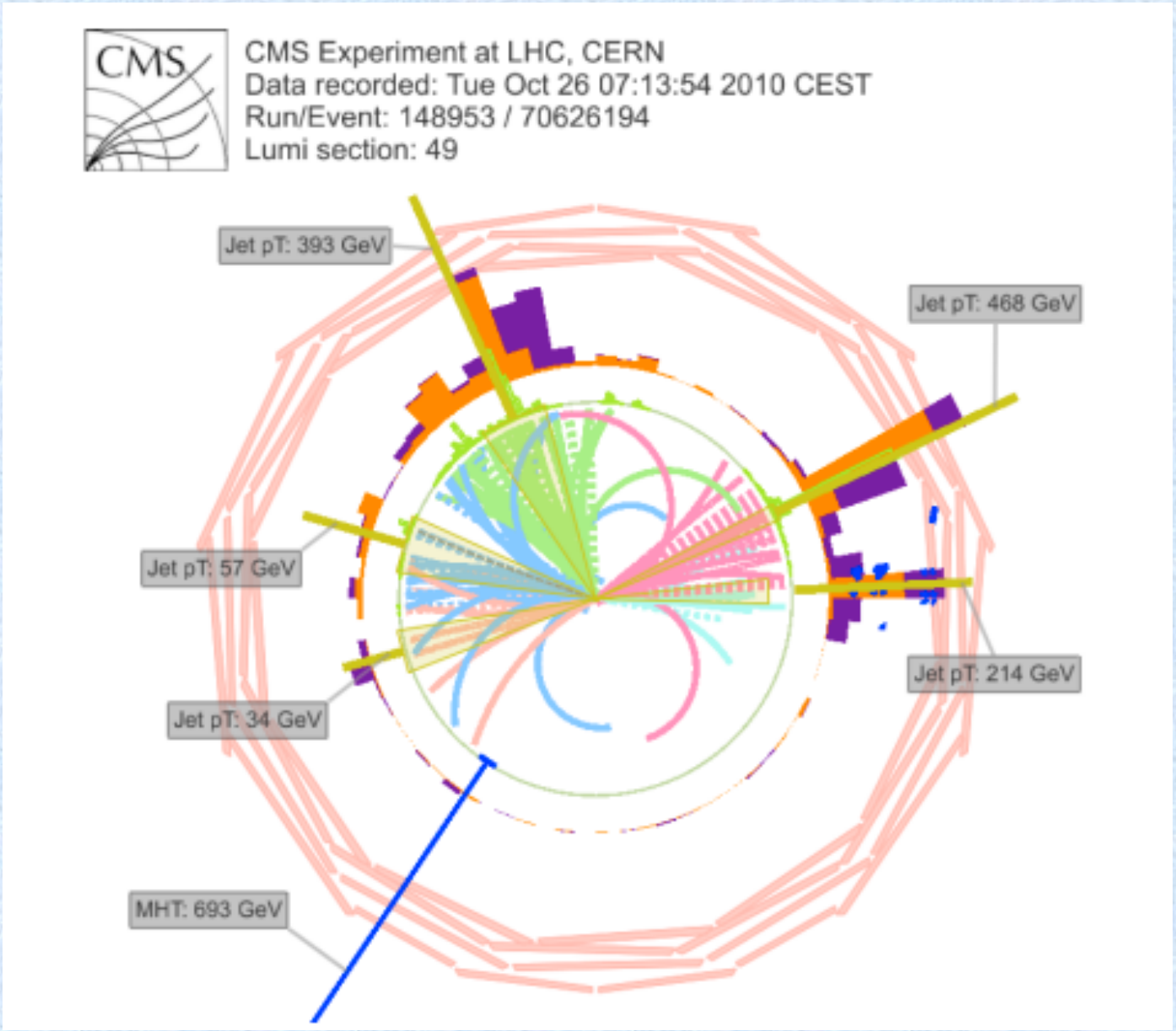

CMS
CMS Experiment at LHC, CERN
Data recorded: Tue Oct 26 07:13:54 2010 CEST
Run/Event: 148953 / 70626194
Lumi section: 49
Jet pT: 393 GeV
Jet pT: 468 GeV
Jet pT: 57 GeV
Jet pT: 214 GeV
Jet pT: 34 GeV
MHT: 693 GeV

From: G. Buchmueller et al June 2011

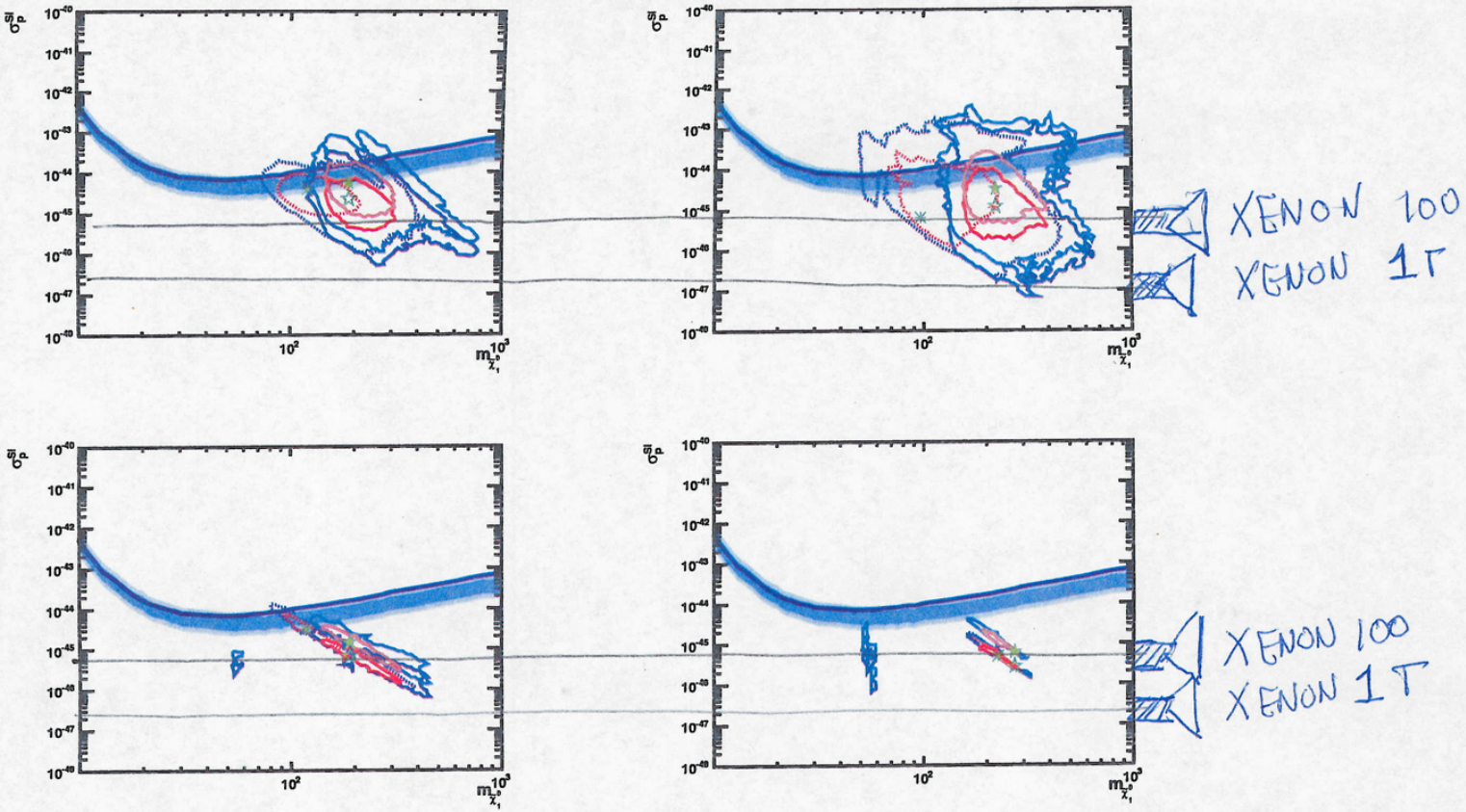
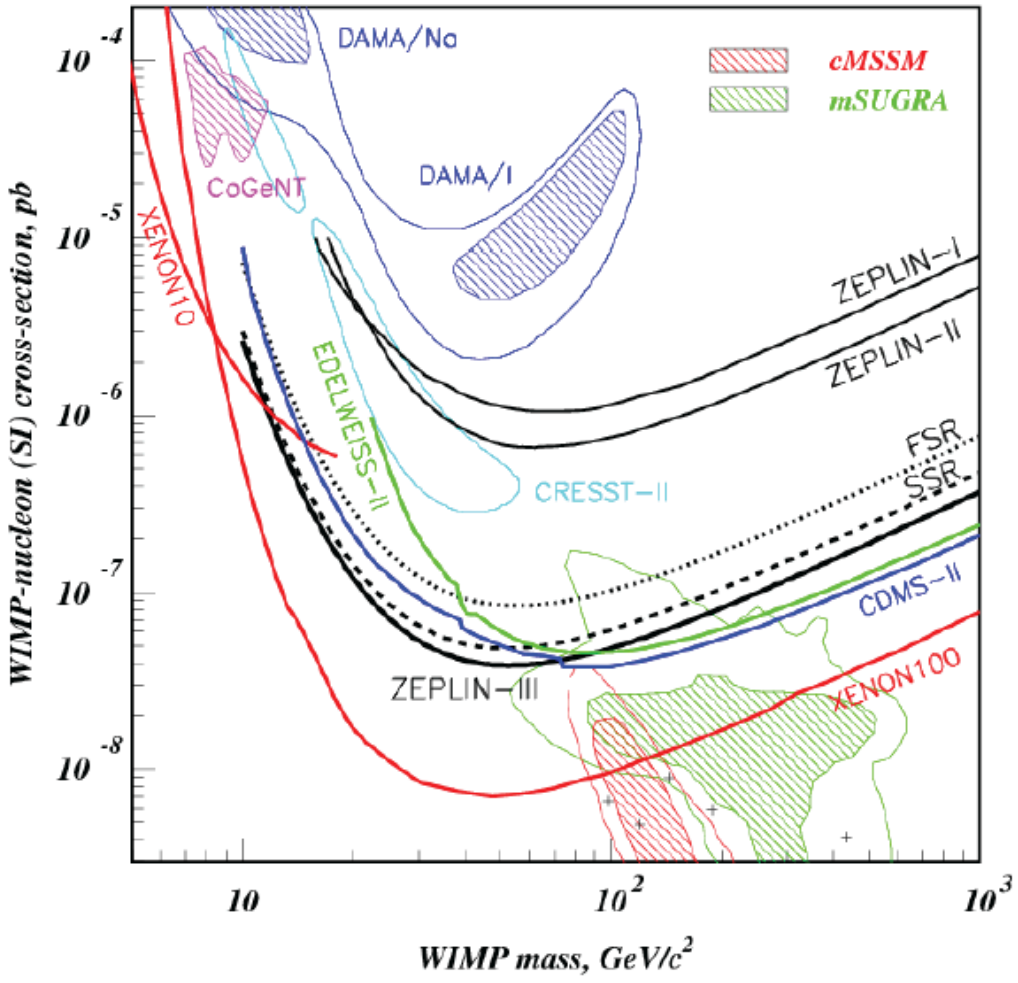


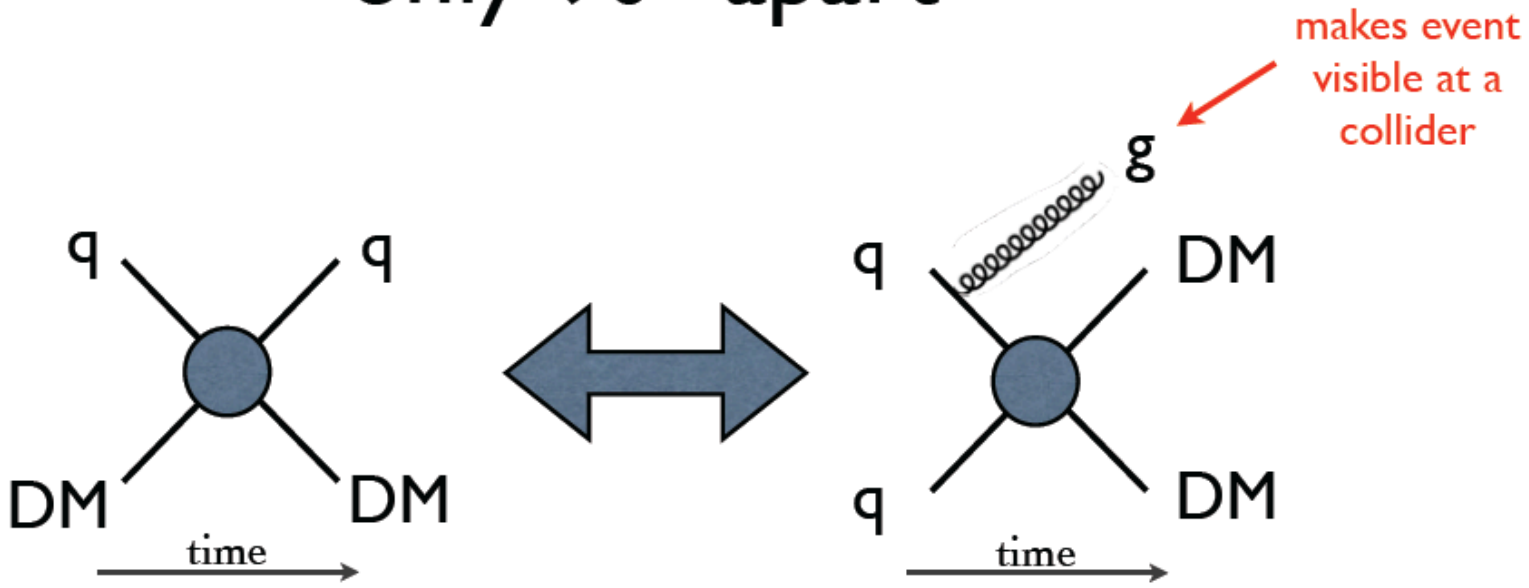
Figure 10. *The correlation between the spin-independent dark matter scattering cross section* $\sigma_p^{\rm SI}$ *and* $m_{\tilde{\chi}_1^0}$ *prior to the inclusion of the current Xenon100 results in the CMSSM (upper left panel), in the NUHM1 (upper right panel), in the VCMSSM (lower left panel) and in mSUGRA (lower right panel). In each panel, we show the 68 and 95% CL contours (red and blue, respectively), the dotted curves correspond to our pre-2010-LHC results, and the solid lines include the 2010 LHC results. Results assuming* $\Sigma_{\pi N} = 50$ MeV *are shown as brighter coloured curves and* $\Sigma_{\pi N} = 64$ MeV *as duller coloured curves, in each case disregarding uncertainties. The green 'snowflakes' (open stars) (filled stars) are the best-fit points in the corresponding models. Also shown is the 90% CL Xenon100 upper limit [24] and its expected sensitivity band.*

DAMA Interpretation and Current Limits



From ZIII Araujo
2008 results - no channeling

Monojets and direct detection, only 90° apart



Birkedal, Matchev, Perelstein (2004)

Beltran, Hooper, Kolb, Krusberg, Tait (2010)

Goodman, Ibe, Rajaraman, Shepherd, Tait, Yu (2010)

Bai, Fox, Harnik (2010)

Rajaraman, Shepherd, Tait, Wijanco (2011)

Fox, Harnik, Kopp, Tsai (2011)

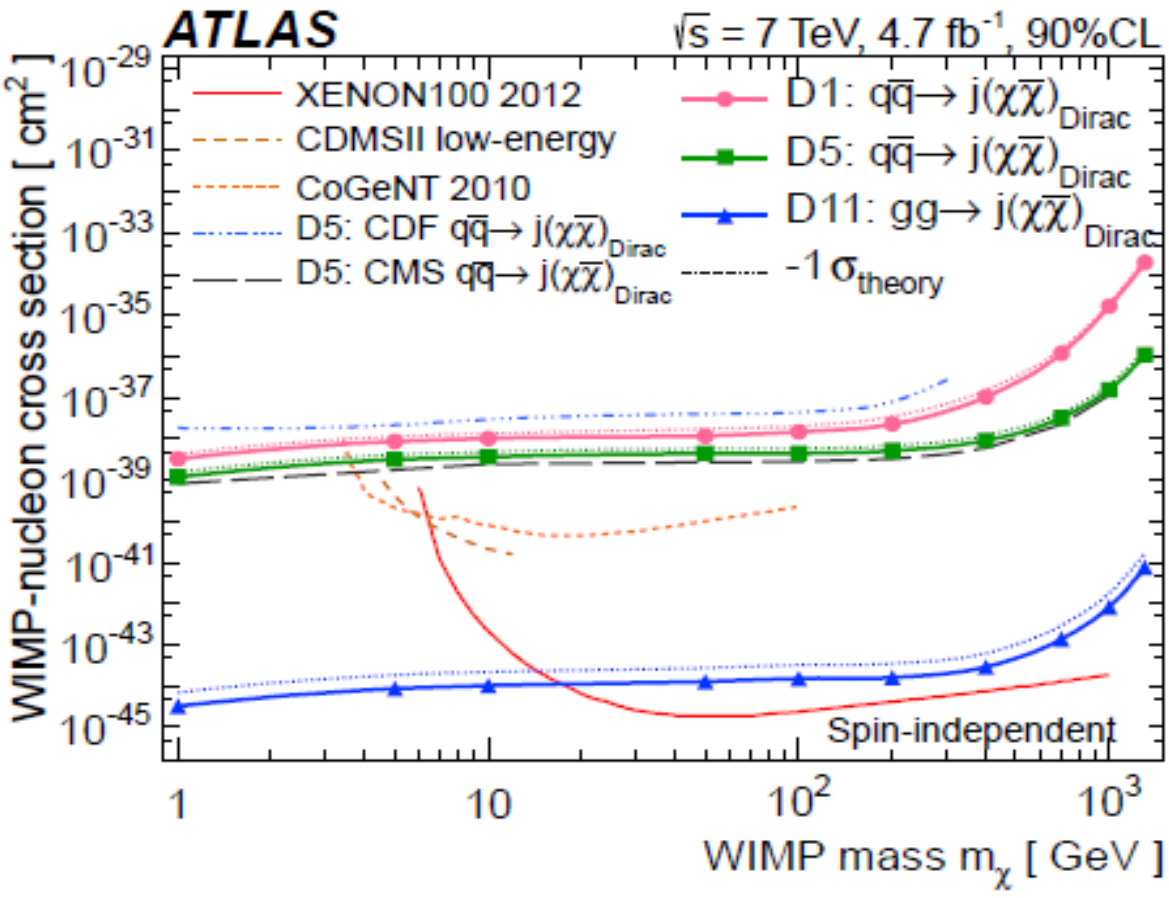


Figure 5. Inferred 90% CL ATLAS limits on spin-independent WIMP-nucleon scattering. Cross sections are shown versus WIMP mass m_χ. In all cases the thick solid lines are the observed limits excluding theoretical uncertainties; the observed limits corresponding to the WIMP-parton cross section obtained from the $-1\sigma_{\text{theory}}$ lines in figure 4 are shown as thin dotted lines. The latter limits are conservative because they also include theoretical uncertainties. The ATLAS limits for operators involving quarks are for the four light flavours assuming equal coupling strengths for all quark flavours to the WIMPs. For comparison, 90% CL limits from the XENON100 [70], CDMSII [71], CoGeNT [72], CDF [19], and CMS [21] experiments are shown.

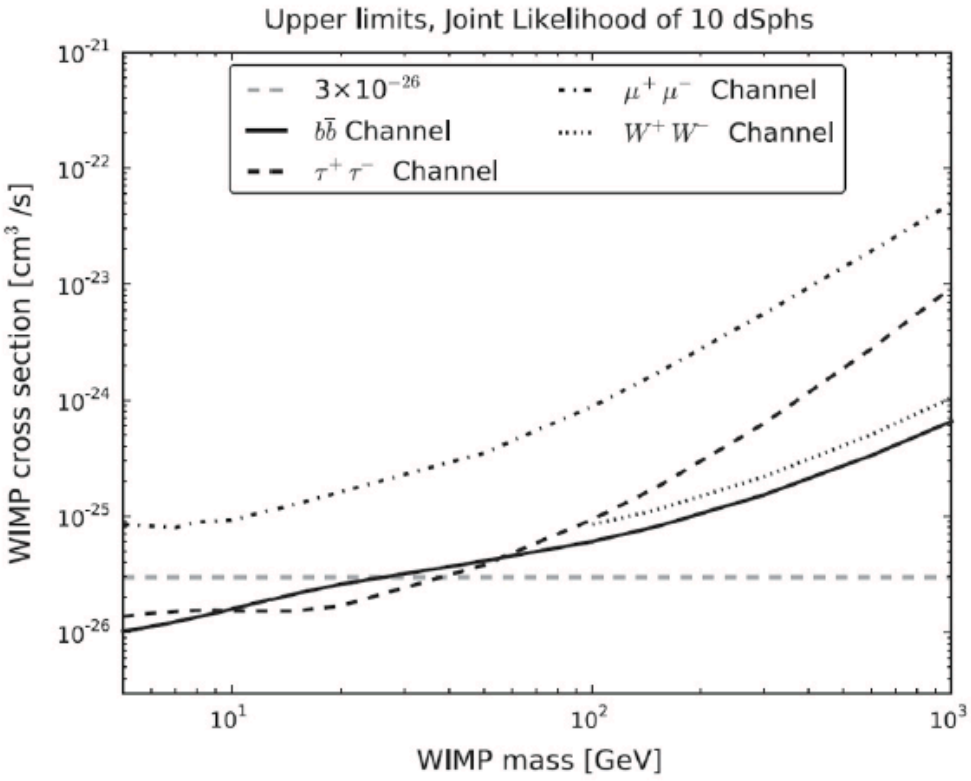
Dwarf Spheroidal Galaxies

PRL 107, 241302; arXiv:1108.3546

- **Robust constraints come from a joint likelihood analysis of**
  - **10 dwarf galaxies**
  - **200 MeV - 100 GeV gamma-rays**
  - **2 years of data**
  - **4 annihilation channels**

- **Exclude the conventional thermal cross section for a WIMP with mass < 30 GeV annihilating to $b\bar{b}$ or $\tau^+\tau^-$.**

- **Include uncertainties in the solid-angle-integrated J-factor.**



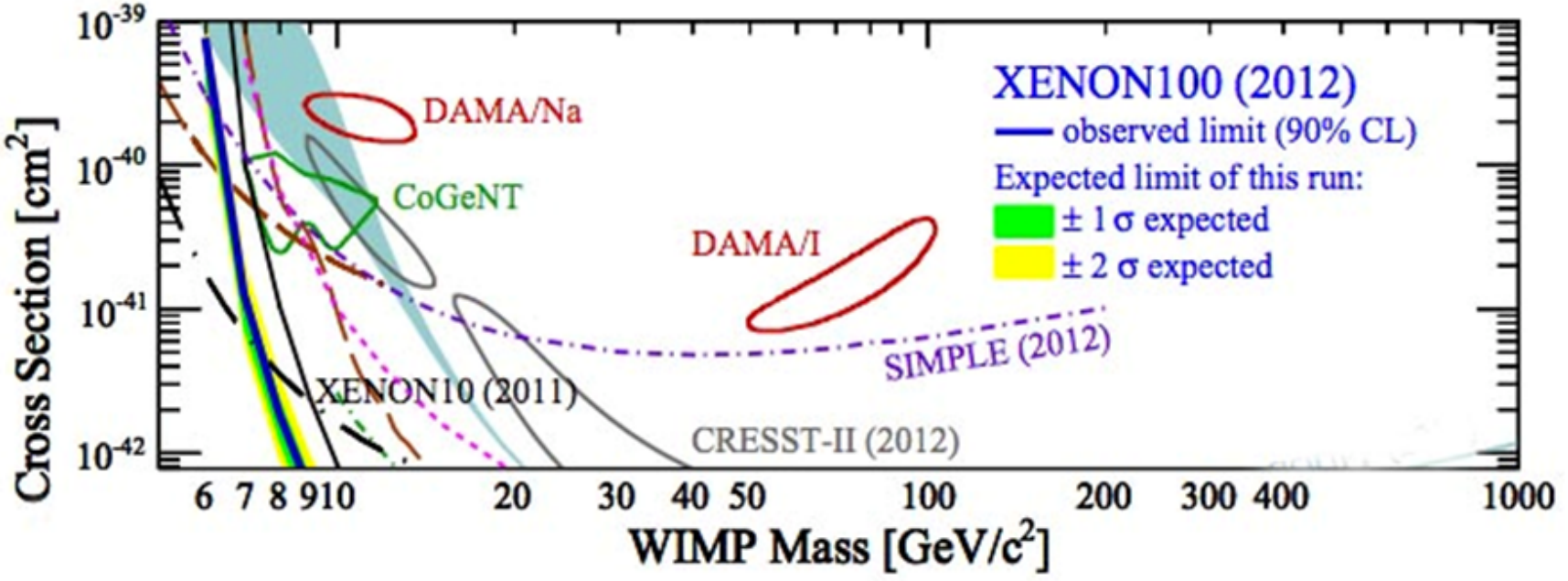


Figure 1. An enlargement of the low mass scale of WIMP searches from the recent XENON100 225 day paper (E. Aprile et al, "Dark Matter Results from 225 Live Days of XENON100 Data," http://arxiv.org/abs/1207.5988).

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The expected background spectrum in NaI dark matter detectors and the DAMA result

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ABSTRACT

Detailed Monte Carlo simulations of the expected radioactive background rates and spectra in NaI crystals are presented. The obtained spectra are then compared to those measured in the DAMA/NaI and DAMA/LIBRA experiments. The simulations can be made consistent with the measured DAMA spectrum only by assuming higher than reported concentrations of some isotopes and even so leave very little room for the dark matter signal. We conclude that any interpretation of the annual modulation of the event rate observed by DAMA as a dark matter signal, should include full consideration of the background spectrum. This would significantly restrict the range of dark matter models capable of explaining the modulation effect.

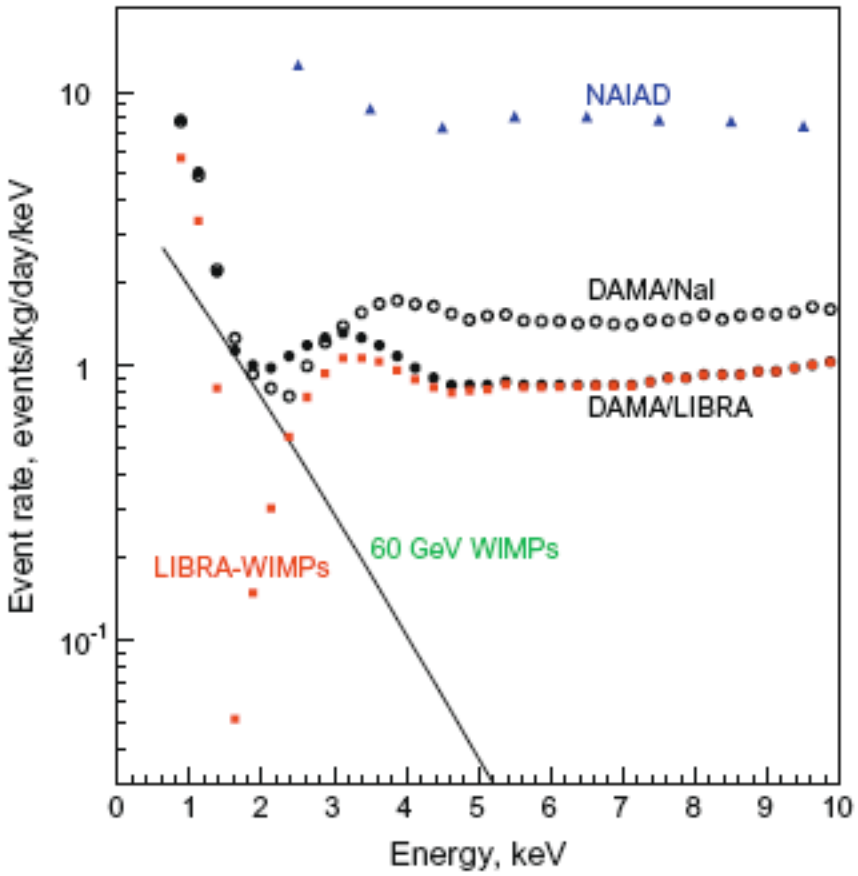


Fig. 3. Energy spectra of single hit events as reported by the DAMA/NaI [2] (open circles) and DAMA/LIBRA [3] (filled circles) experiments. The spectrum of events expected from 60 GeV WIMP interactions with the spin-independent cross-section of 7×10^{-6} pb in the isothermal halo model is shown as example by the solid curve (labeled as '60 GeV WIMPs'). The difference between the measured DAMA/LIBRA spectrum and the WIMP signal is plotted as filled squares (labeled as 'LIBRA-WIMPs'). An example spectrum from one of the NAIAD crystals is shown by filled triangles.

How To Measure the Correct Annual Variation Due To WIMP Interactions and the Earth's Movement Around the Sun

$$\text{Expected Variation of WIMP Signal } V = \frac{\text{Observed Variation of WIMP Interaction}}{\text{Fraction of Data that has WIMPs}}$$

Most models give an expected value of less than 10% but could go to 20%

DAMA Observation of V

$$V = \frac{\text{DAMA Annual Variation of Energy}}{\text{Fraction of Data with WIMPs}}$$

DAMA Annual Variation: 2-4 KeV ~2.5-3%
Fraction of Data with WIMPs: [0-20%]

4. Recent studies of the effect of K(40) in the DAMA experiment

In reference 11 it is shown that the bulk of the singles signal in DAMA is due to radioactive background. Now a new study (see Fig. 3) shows that less than 0.14 Cpd (Fig. 3) can at most be due to WIMPs. This means that the annual variation of the possible WIMPs signal would have to exceed 20%, which is outside any DM model. Reference 12 gives the results presented in Fig. 3. The excellent agreement with Ref. 11 and the excellent fit strongly suggest this is little or no WIMP signal in the data.

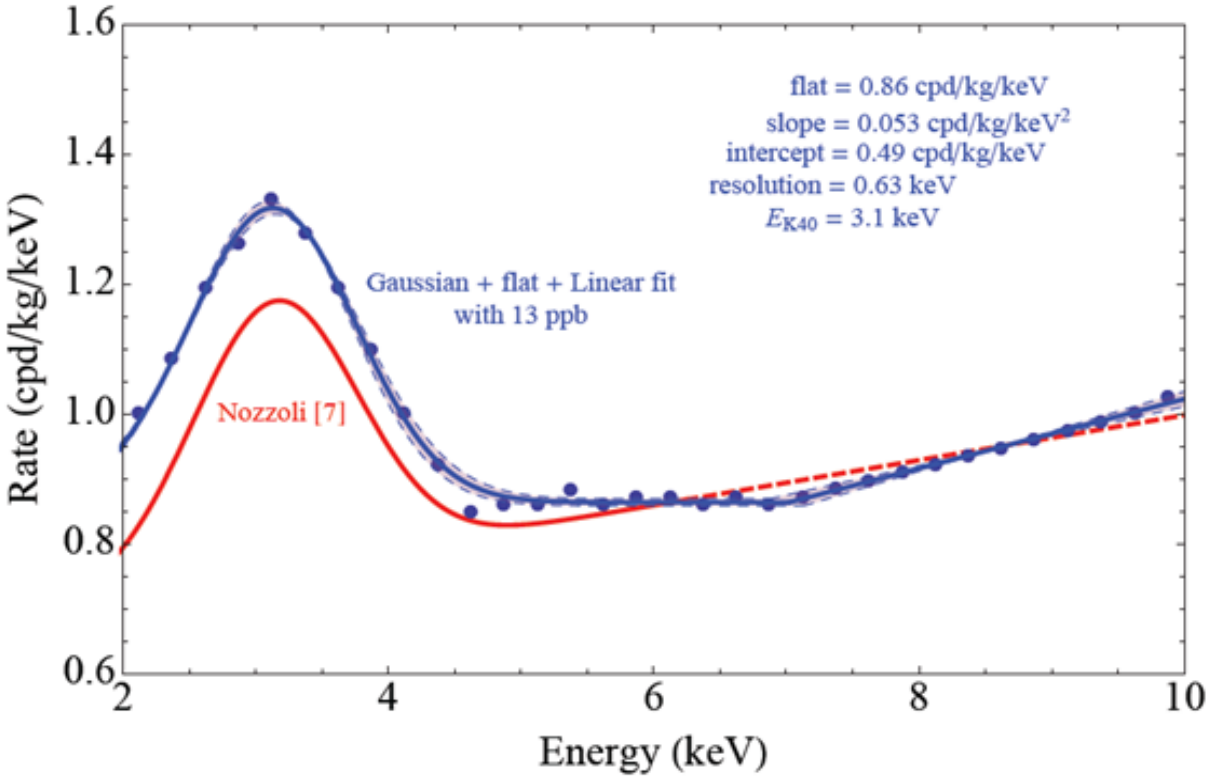
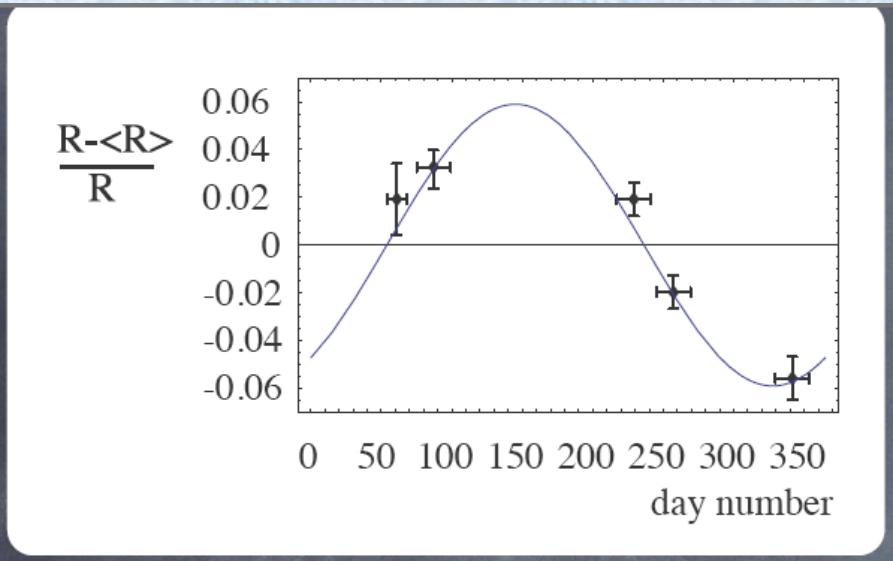


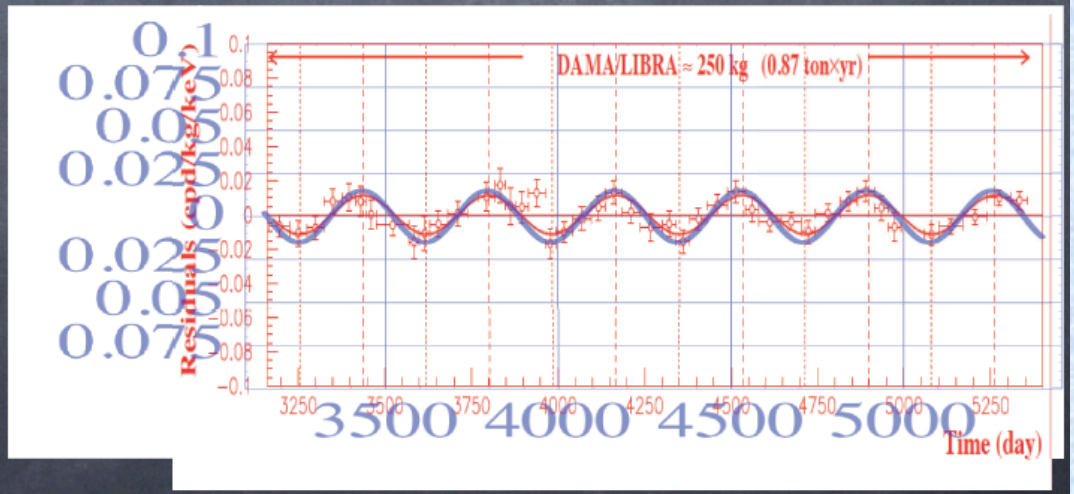
Figure 3. This figure shows the Dama/Libra (dots) and a fit to the data with the correct K (40) and the background from Ref. 11. There is also an estimate by DAMA (red). Even under these circumstances the amount of possible WIMP signal is very low. (Josef Pradler et al, "A reply to criticism of our work (arXiv:1210.5501) by the DAMA collaboration," http://arxiv.org/abs/1210.7548) [12]



ICARUS
neutron
time dependence...

predicts
DAMA/LIBRA
time
dependence...

arXiv:1006.5255 [hep-ph]



curve: icarus phase
points: Dama/Libra data

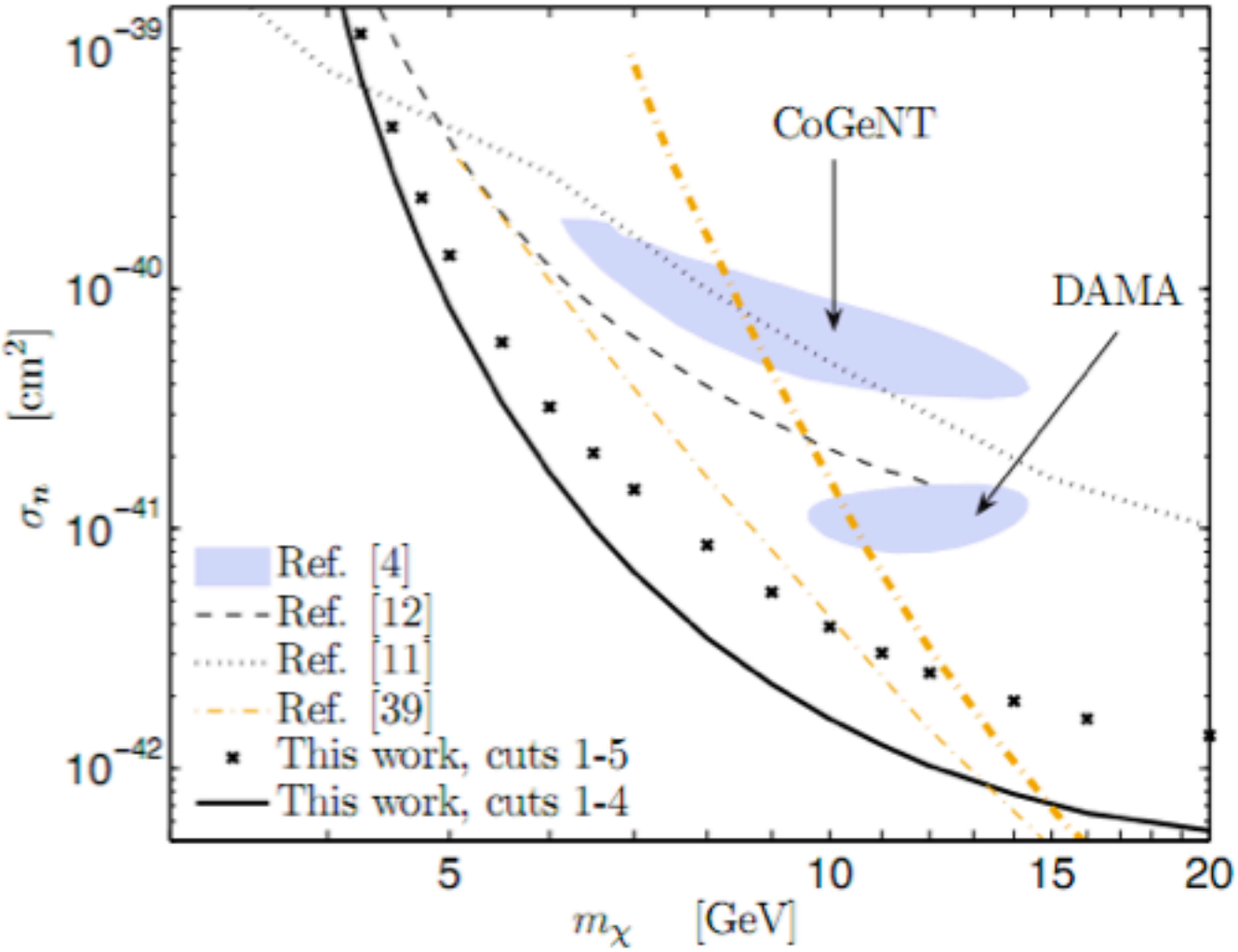
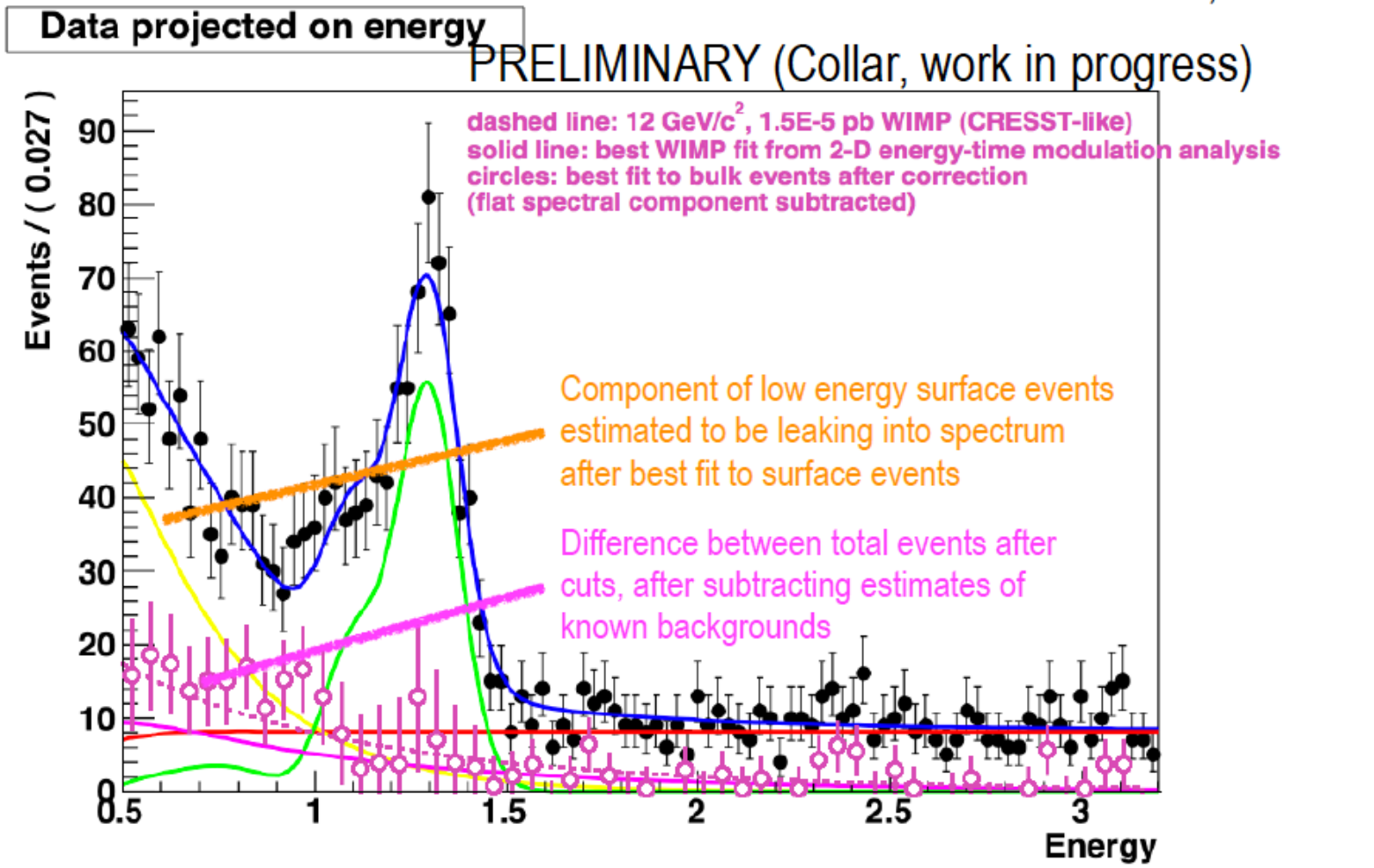


Figure 10. Curves indicate 90% C.L. exclusion limits on spin-independent σ_n for elastic dark matter scattering, obtained by CDMS (dotted [11] and dashed [12]), XENON100 (dash-dot [39]). 99% C.L. allowed regions consistent with the assumption of a positive detection are also shown, for signals from DAMA (with ion channeling) [4], and CoGeNT (assuming 30% exponential background) [4].

Recent GoGeNT Analysis

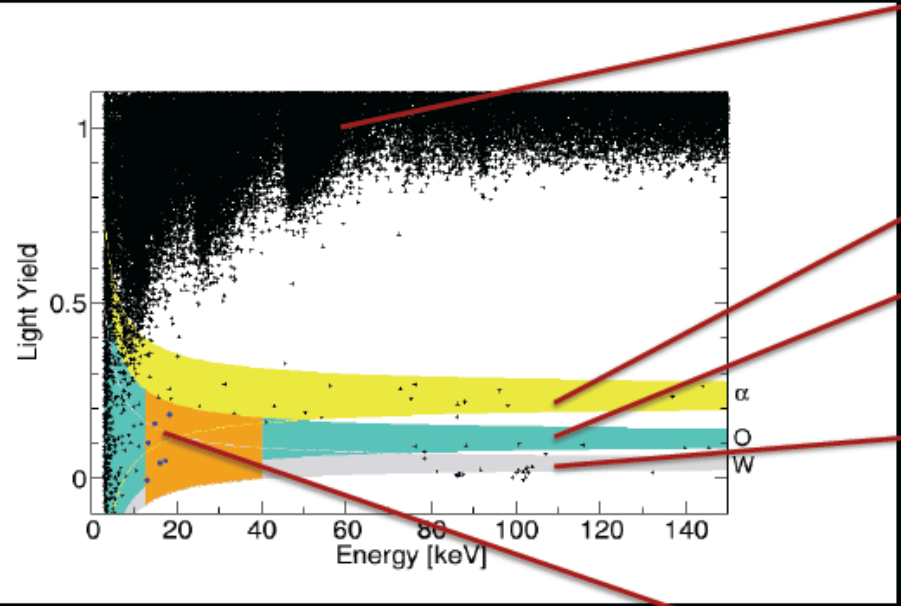
Plot from J Collar, Feb 2012



Spectral and modulation analysis in CoGeNT seem to point to a similar WIMP mass & coupling,
BUT then modulated amplitude is definitely not what you would expect from a vanilla halo (way too large).

Results of Run32 (2009-2011)

Data of one single 300g detector module in Run32:



Electron recoils: excellent discrimination of from e/γ−band and nuclear band

α−events: from surfaces

O-band: neutrons or „light"-WIMPs

W-band: expect „heavy"-WIMP interaction -> band is contaminated by recoiling ^{206}Pb nuclei from ^{210}Po α-decays (clamps), 103keV downwards

67 events at low energy observed in O, Ca and W-bands in all detector modules (~730kg d)

Acceptance region:

includes O, Ca and W recoil bands

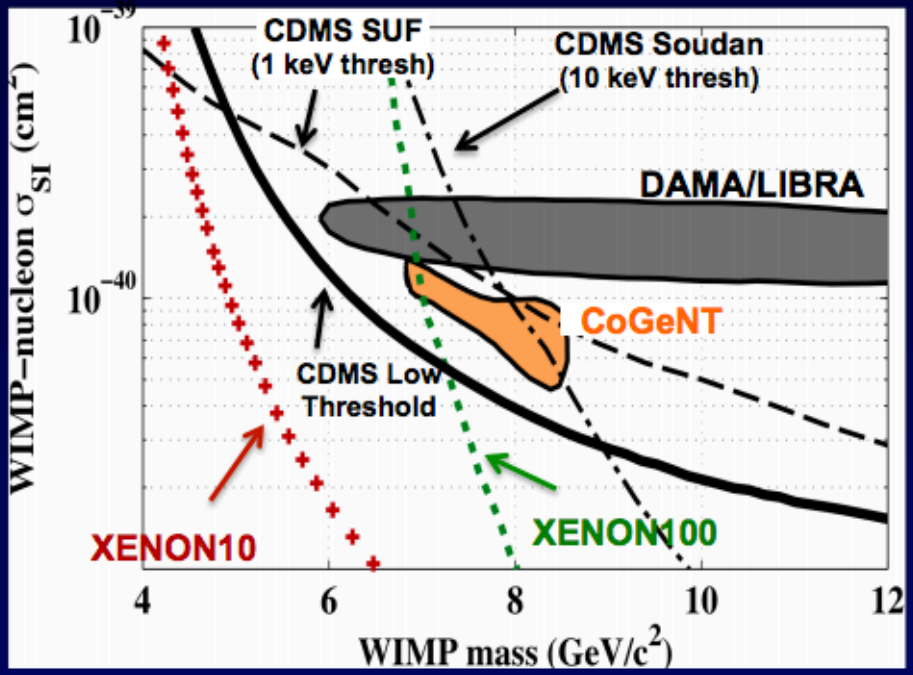
E_{max}: 40keV (WIMP signal negligible above)

E_{min}: e/γ-leakage of 1 event per module in whole data set (10 – 19keV, module dependent)

Low WIMP Mass Limits

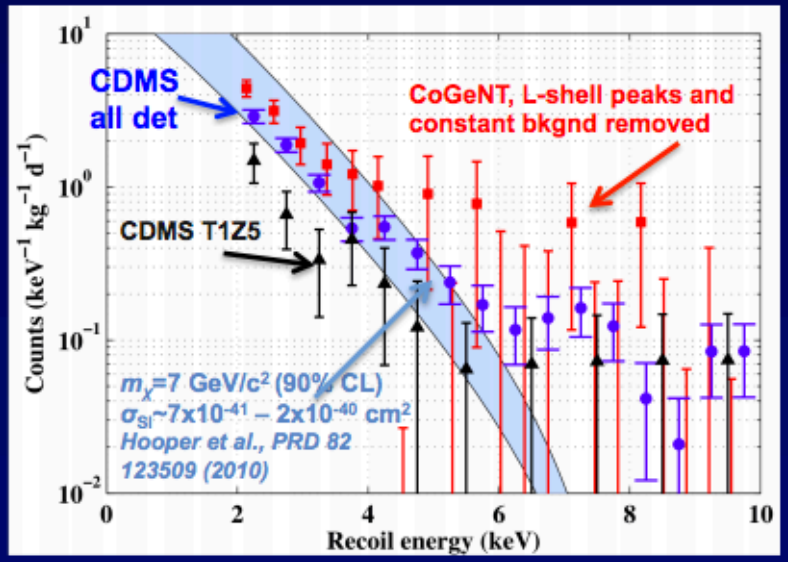
- Conservatively assume all candidates could be from WIMP
  NO background subtraction!
- Limits set using optimum interval method:

  S. Yellin, PRD, 66, 032005 (2002); arXiv:0709.2701v1 (2007)
- For spin-independent, elastic scattering, 90% CL limits incompatible with DAMA/LIBRA and CoGeNT excess



Ahmed et al., PRL 106, 131302 (2011); arXiv:1011.2482

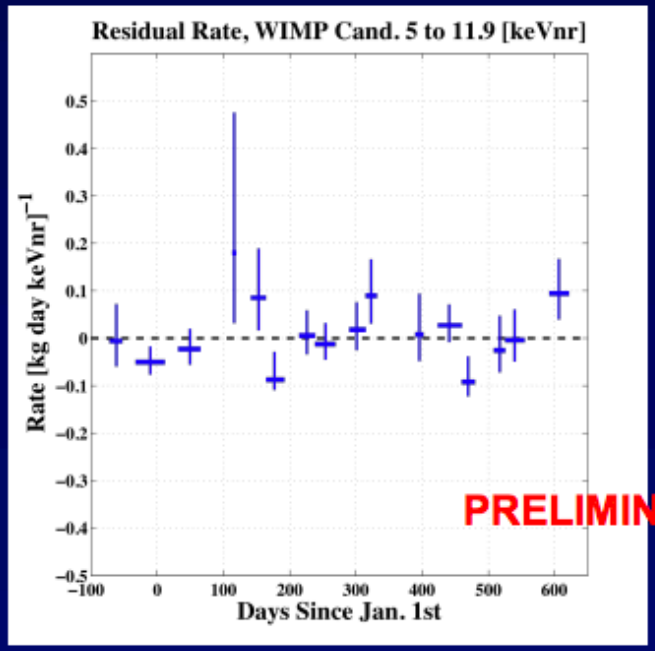
Note: CoGeNT region not updated for revision to surface event contamination

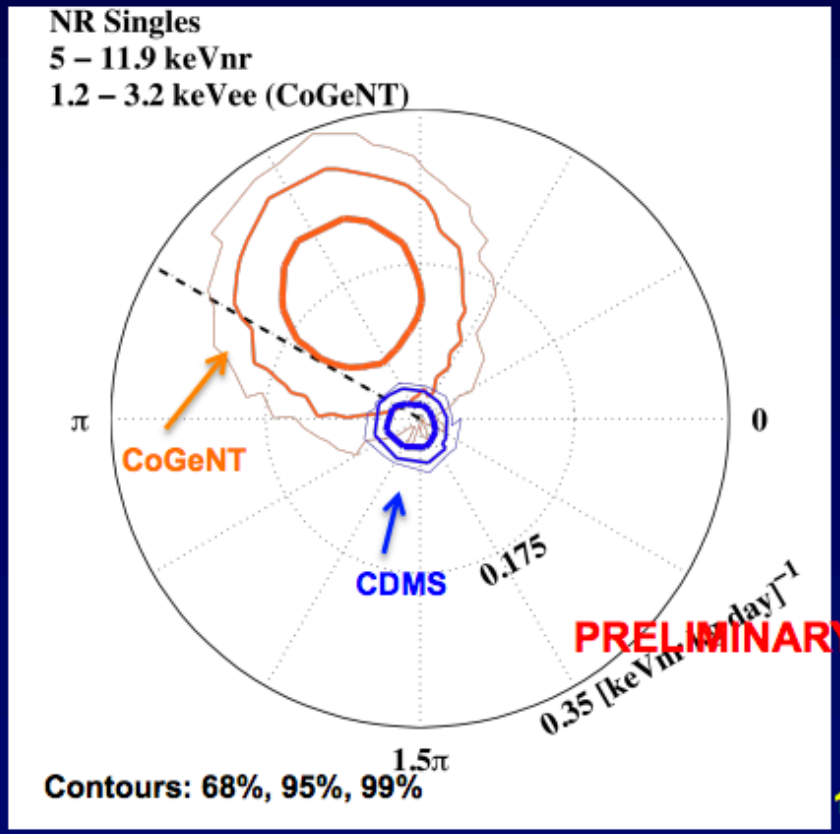


- If only a small fraction of the low-energy excess events in CoGeNT are due to WIMPs, then constraints from CDMS II can be avoided

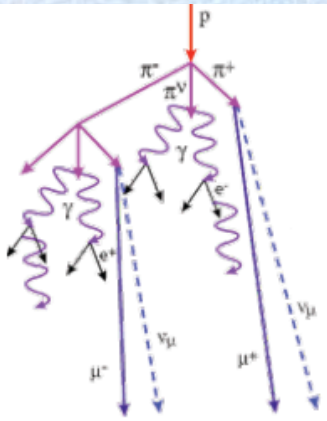
Results: Nuclear Recoil Singles

- No significant evidence for annual modulation
- In the energy range [5, 11.9] keV_{nr}, all modulated rate with amplitudes greater than 0.07 $[keV_{nr}\ kg\ day]^{-1}$ are ruled out with a 99% confidence.
  - Annual modulation signal of CDMS and CoGeNT are incompatible at >95% C.L. (preliminary) for the full energy range (if CoGeNT signal originates in a nuclear-recoil population)

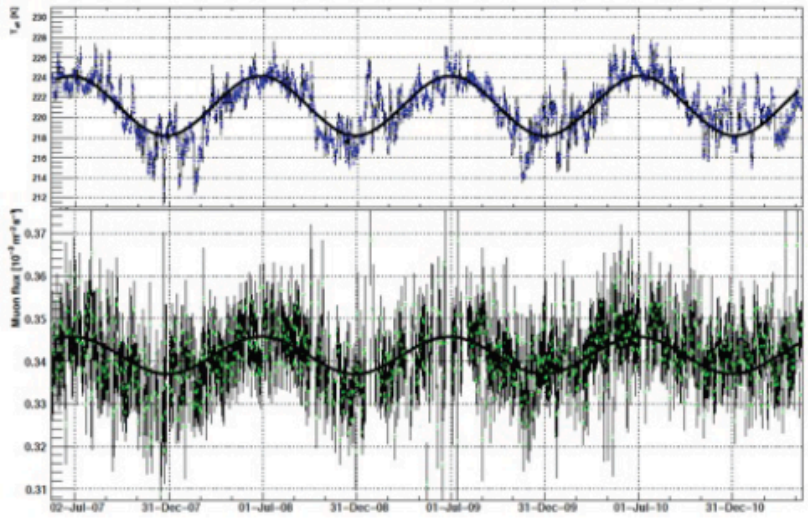




Muon Flux underground



- many measurements available, correlation with $T_{\rm eff}$ firmly established
  - LNGS: Macro, LVD, Borexino (DAMA location)
  - Soudan Mine: MINOS (CoGeNT location)
  - South Pole: Icecube

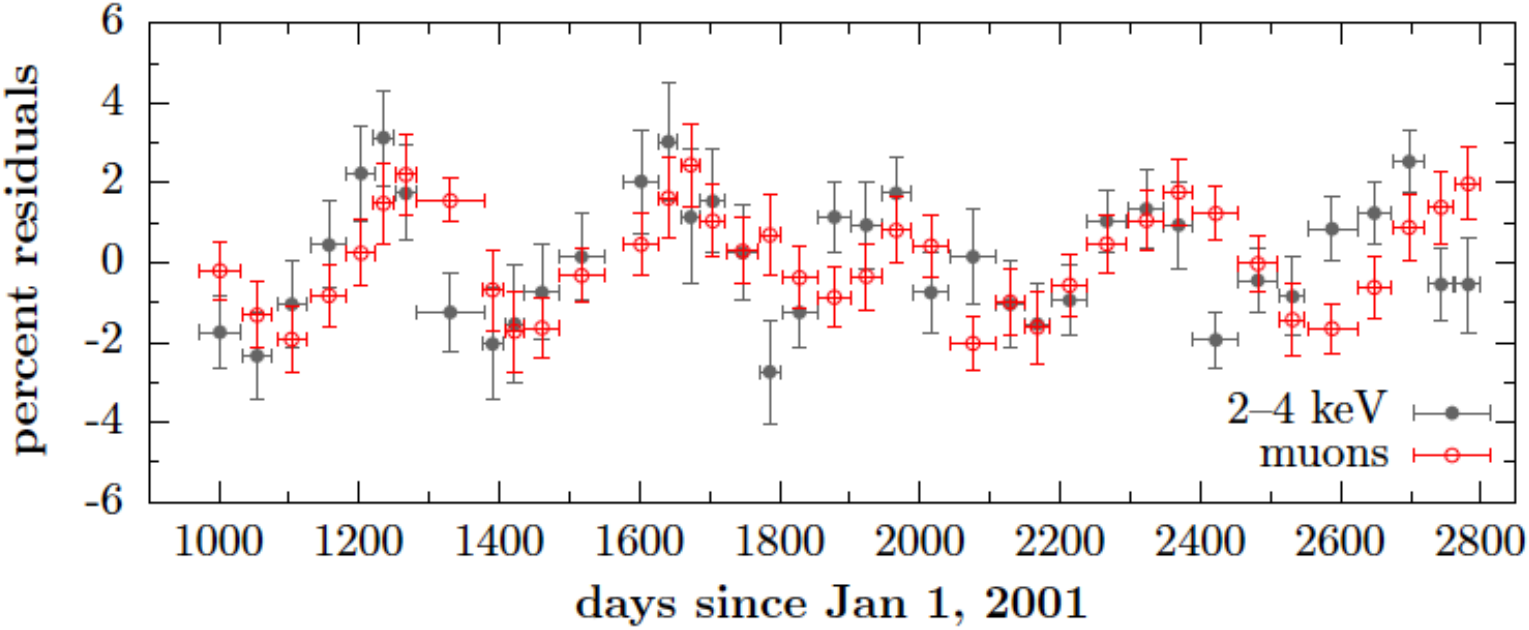


$T_{\rm eff}$

ϕ_μ

[Borexino 2011]

LVD and DAMA


percent residuals
6
4
2
0
-2
-4
-6
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
days since Jan 1, 2001
2–4 keV
muons