Toward A Consistent Picture For CRESST, CoGeNT and DAMA

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Cosmology on the Beach
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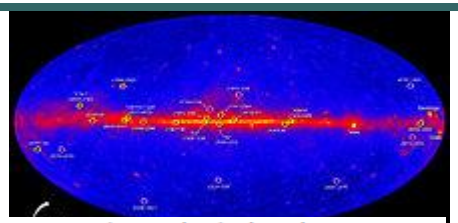
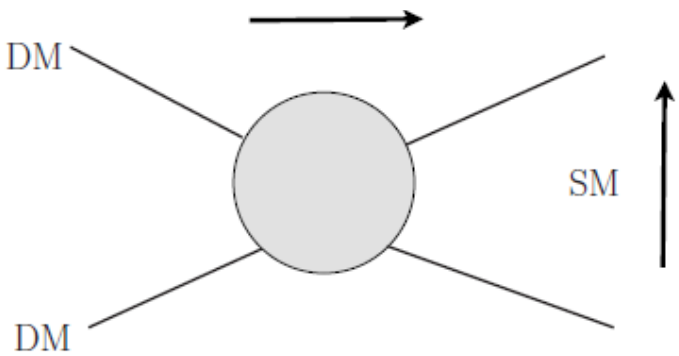
How are we looking for dark matter?

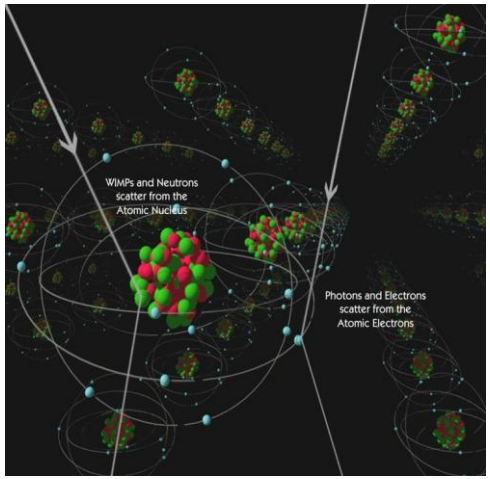


Indirect detection:
AMS2, PAMELA, Fermi-LAT
.....

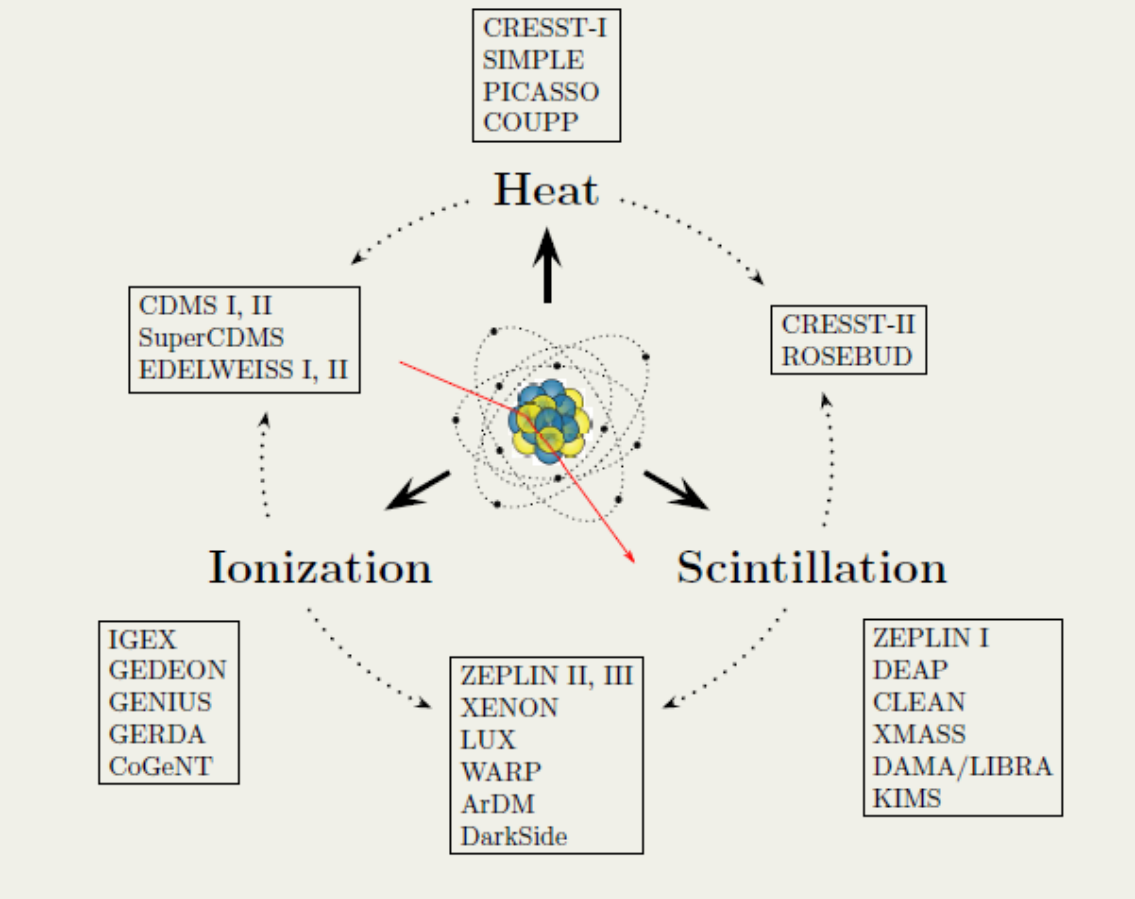


Collider searches:
LEP
LHC
Tevatron

Direct detection:
CDMS
CoGeNT
COUPP
CRESST
DAMA
XENON
.....



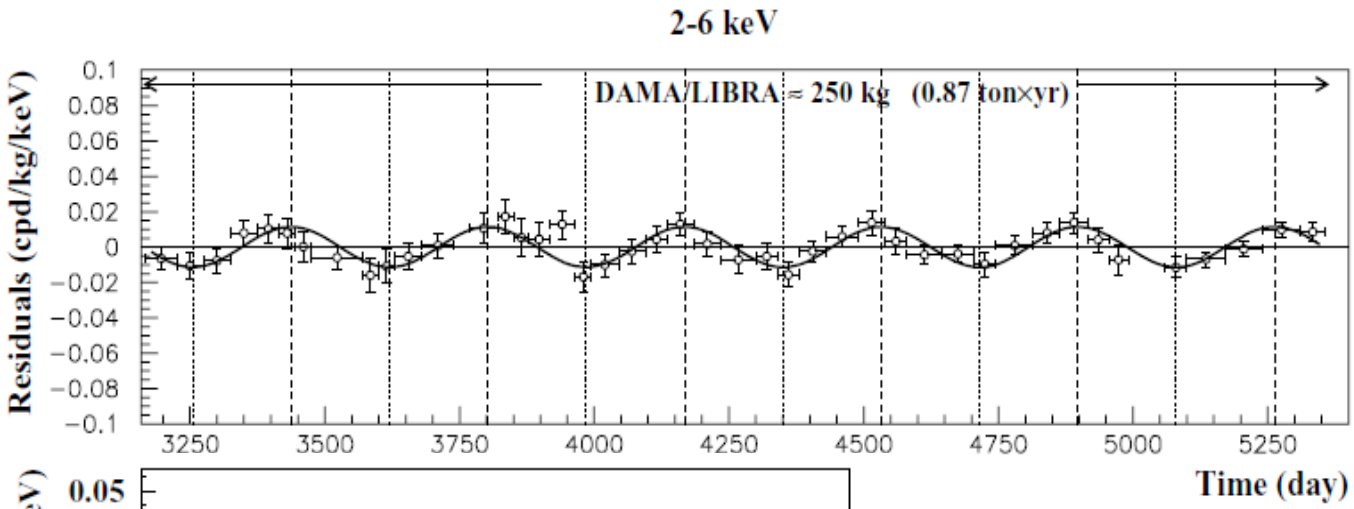
Current Direct Detection Experiments

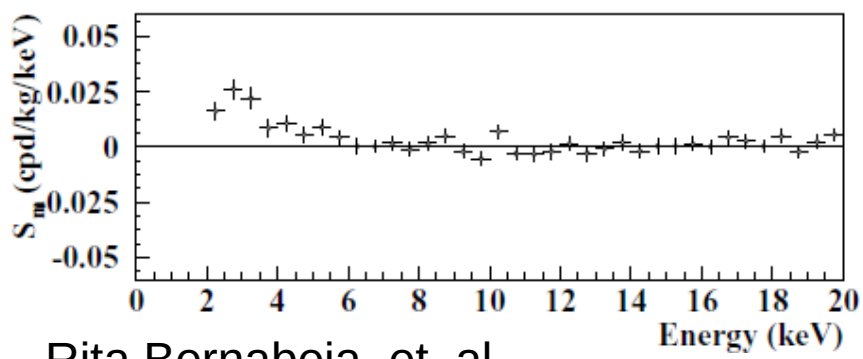


Are we already detecting dark matter?

- Three dark matter direct detection experiments (DAMA/LIBRA, CoGeNT, and CRESST-II) have each reported signals which are not consistent with known backgrounds
- The signals resemble that predicted for a dark matter particle with mass of ~10 GeV and cross section with nucleons ~10^{-41}- 10^{-40} cm^2
- These signals are also faced by null results of several other experiments
- Can the signals of these experiments be explained by a single species of dark matter particle, without conflicting with the constraints of other experiments?

DAMA (NaI) Claim





8.9σ measurement of modulation

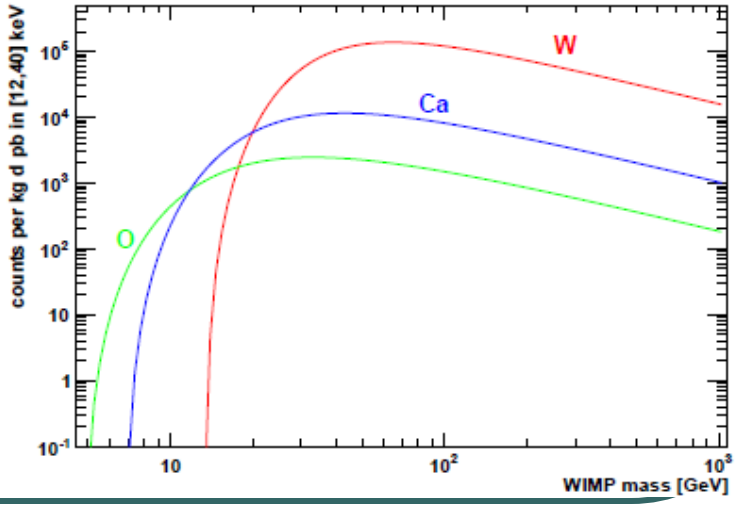
1.17 ton-years of data over 13 annual cycles

Rita Bernabeia, et. al.

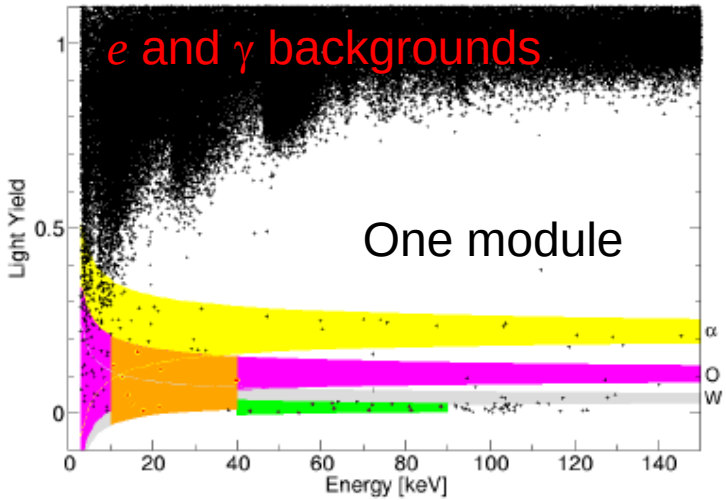
Nuclear Physics B (Proc. Suppl.) 212–213 (2011) 307–314

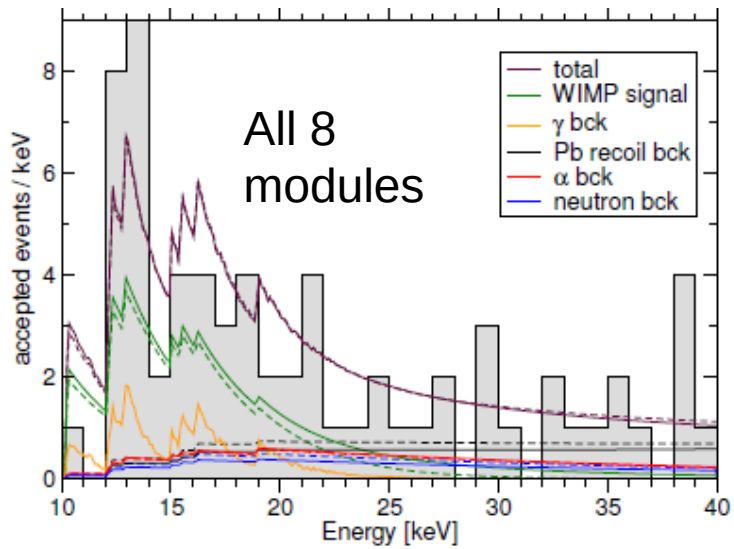
CRESST ($CaWO_4$)

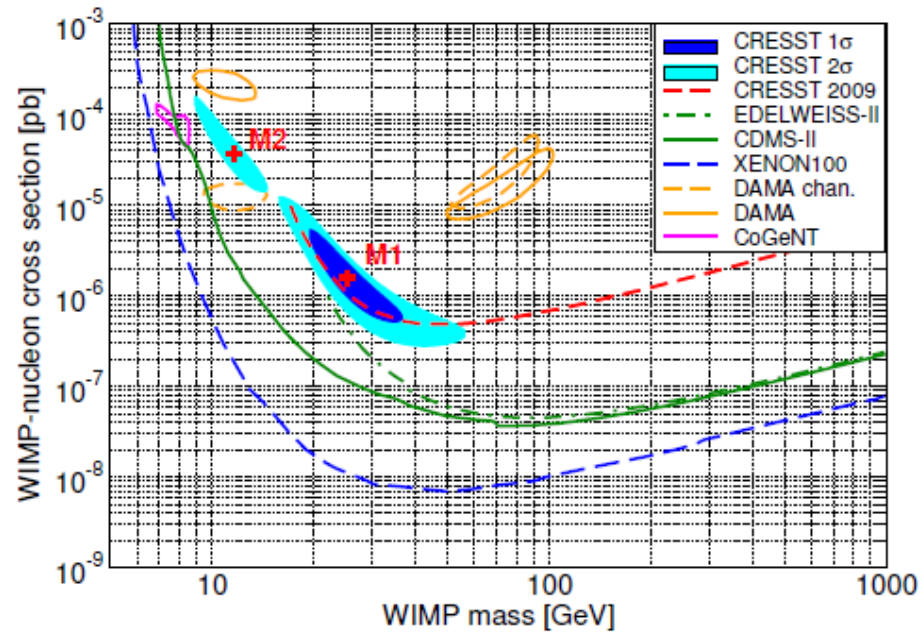
- Also located in Gran Sasso National Laboratory (Italy)
- Use both scintillation and phonon signals to reject backgrounds
- Detector “modules have a cylindrical shape (40mm in diameter and height) and weigh about 300 g
- The current experimental setup can accommodate up to 33 of these crystals, constituting a maximum target mass of about 10 kg.
- First data release was for 730 kg days (2011)



CRESST sees a signal not consistent with known backgrounds





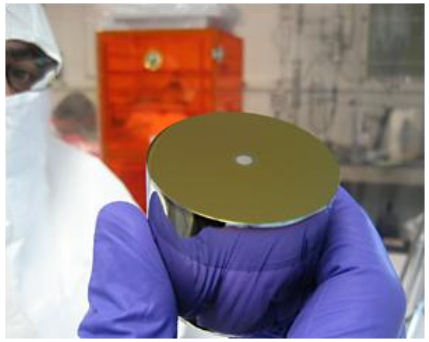


M1 rejects background only hypothesis at 4.7 σ (29 ± 8 events)

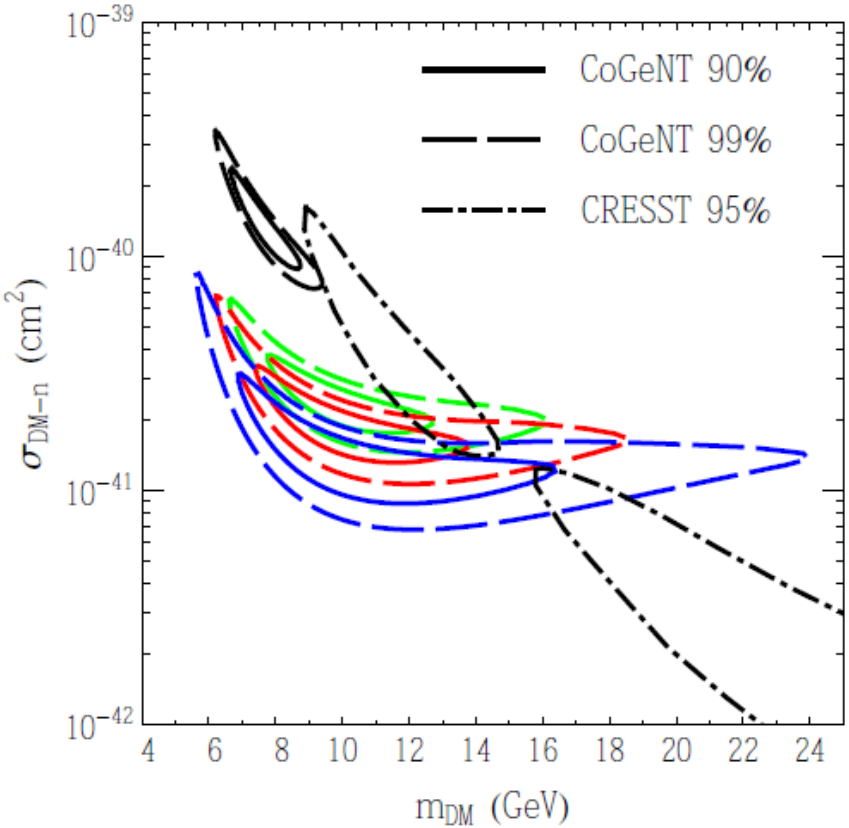
M2 rejects background only hypothesis at 4.3 σ (24 ± 8 events)

The CoGeNT (Ge) detector

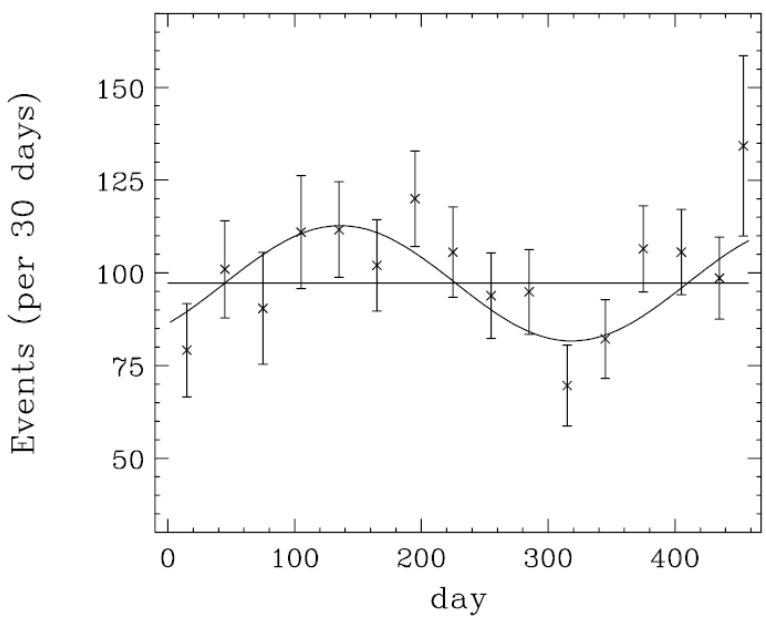
- Located in the Soudan Mine in Minnesota
- Low background and low energy threshold
- Uses ionization signal only with 0.33 kg fiducial mass
- Found an excess of events at low energy in first 56 day run (2010)
- Released 15 months of data (2011)
- Data is available by request



Consistency of CoGeNT and CRESST?



Modulation in the CoGeNT data



- We find modulation of 16±5% at the 2.7 sigma level
- The best fit to the peak is found to be at April 18±16 days
- DAMA peak is May 16±7 (2-4 keVee range) or May 26±7 (2-6 keVee range)
- N-body simulations of galaxy formation find 68% of realizations have a peak within 20 days of late May/early June

Astrophysics independent comparison

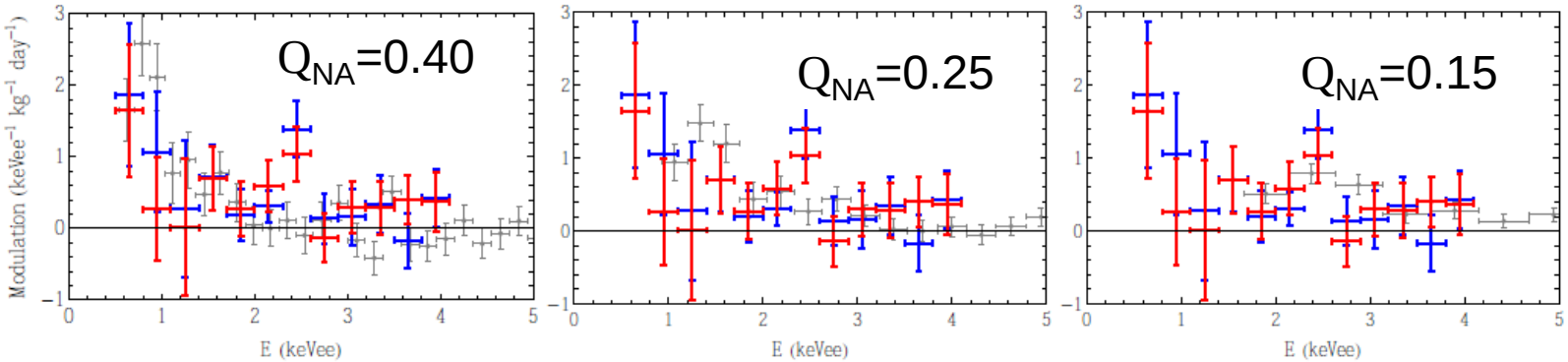
We would like to make comparisons between different experiments using as few assumptions and in the most model independent way possible.

$$\frac{dR}{dE_R} = N_T \frac{\rho_{DM}}{m_{DM}} \int_{|\vec{v}|>v_{\min}} d^3v\, v f(\vec{v}, \vec{v_e}) \frac{d\sigma}{dE_R}$$

Treat this as the “measurable” quantity

CoGeNT and DAMA modulation amplitudes are consistent

10 GeV WIMP

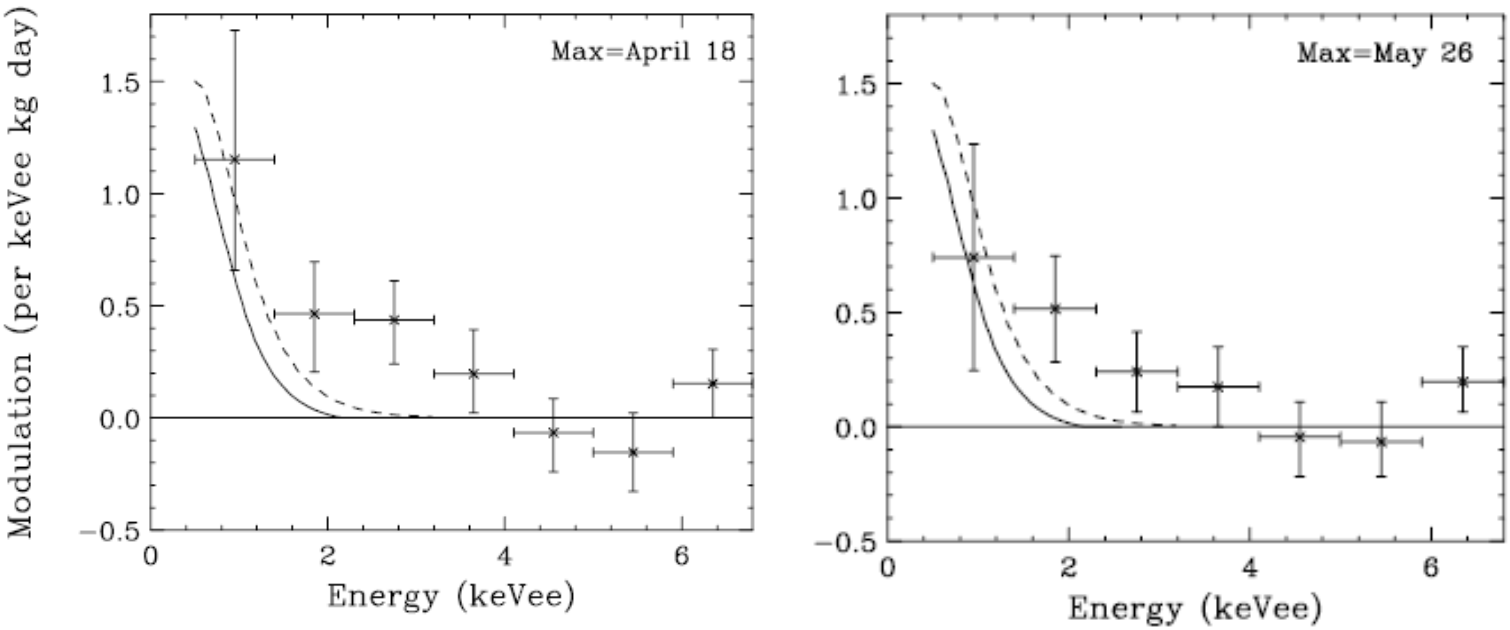


Independent of astrophysical uncertainties, the gray error bars are the what the DAMA signal would look like at the CoGeNT detector

Red error bars are the CoGeNT modulation for maximum phase May 26 (~SHM).

Blue error bars are the best fit maximum phase for CoGeNT (April 18).

Spectrum of Modulation

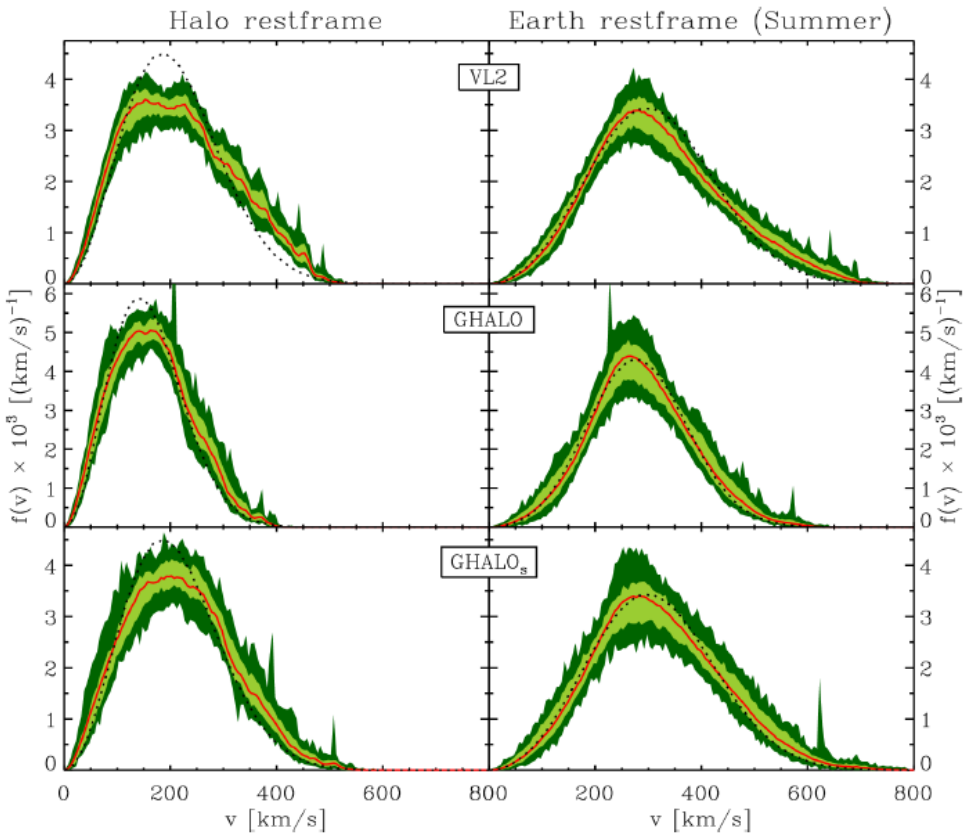


There is more modulation at higher energies than predicted in the standard halo model

Overall rate versus modulation

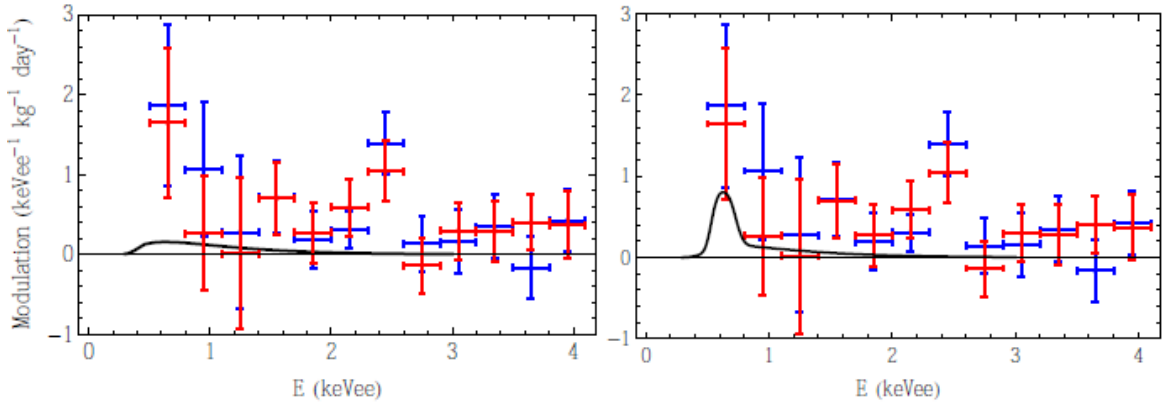
- The simplest comparison between the overall spectra and the modulation spectra are discrepant by a factor of at least a few. What are the possibilities for reconciling this discrepancy?
- Particle Physics
  - Inelastic dark matter
  - Form Factor Dark Matter
  - Resonant Dark Matter
- Astrophysics
  - Substructure within the halo (streams)

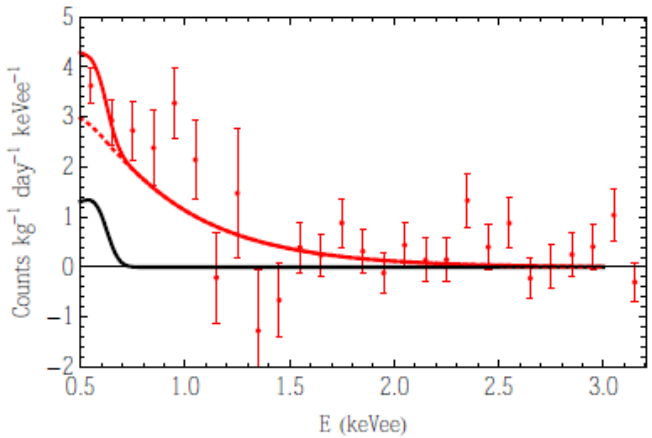
Simulations of the Velocity Distribution of Dark Matter in Our Galaxy



Michael Kuhlen, Neal Weiner, Jurg Diemand, Piero Madau, Ben Moore, Doug Potter, Joachim Stadel, Marcel Zemp: **JCAP 1002 (2010) 030**

Streams?



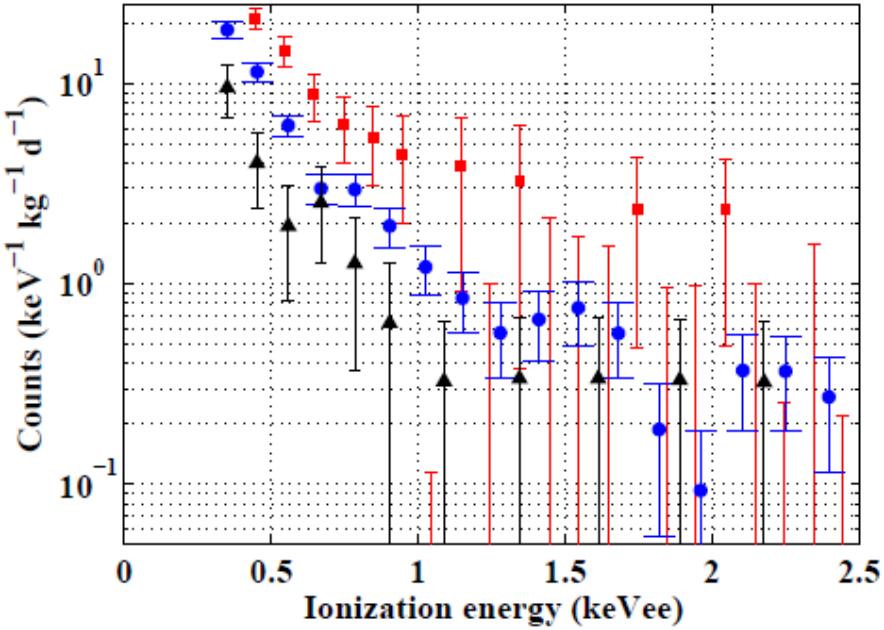


m=10 GeV

165 km/s, 20% of “smooth” halo

σ_n= 1.5E^{-41} cm^2

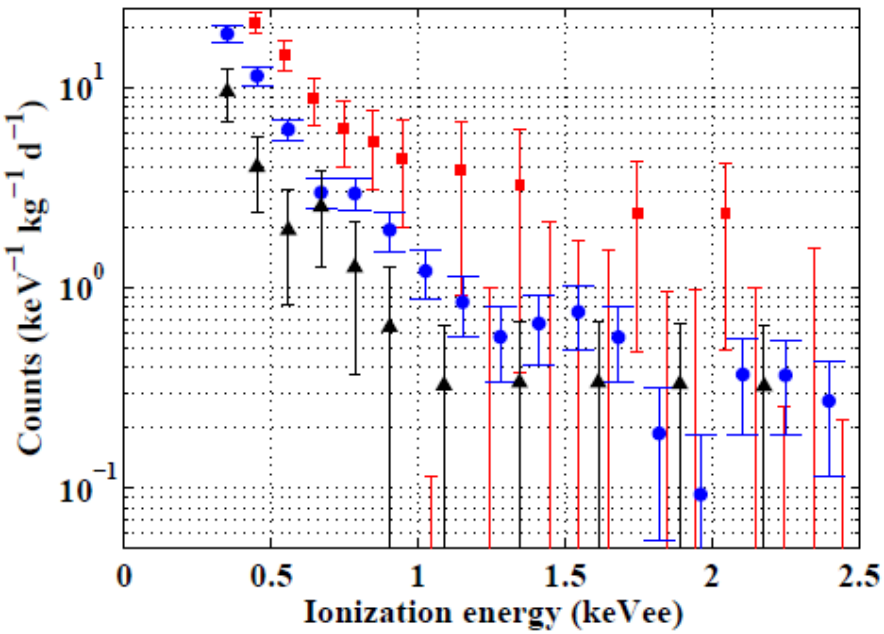
Is the spectrum consistent with CDMS?

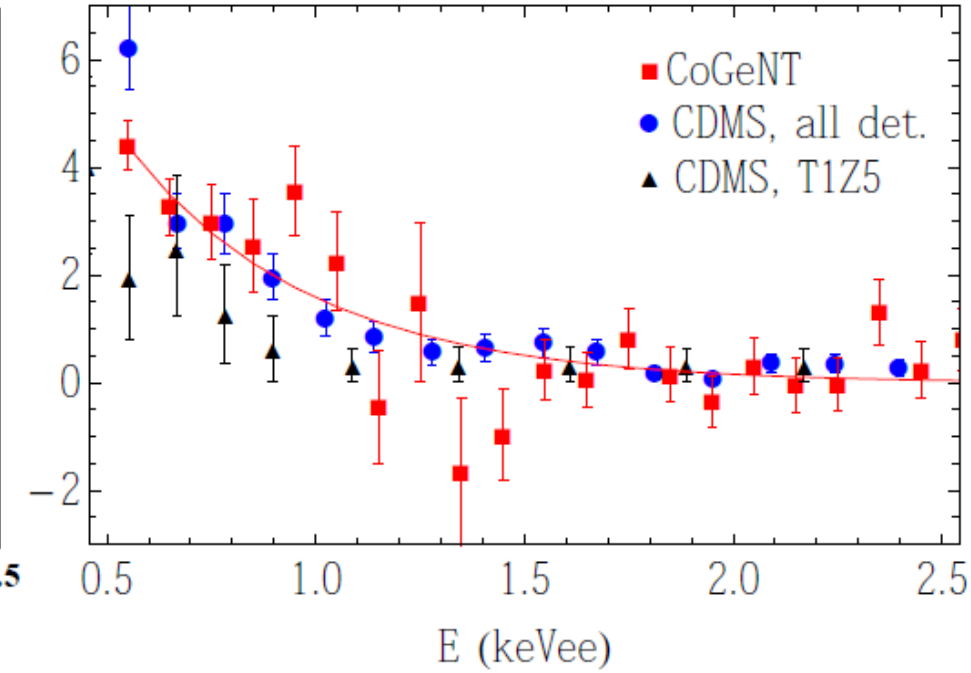


The original CoGeNT excess spectrum (that included the surface event contamination) was larger than the spectrum measured at CDMS.

This is difficult to explain any way other than with detector systematics.

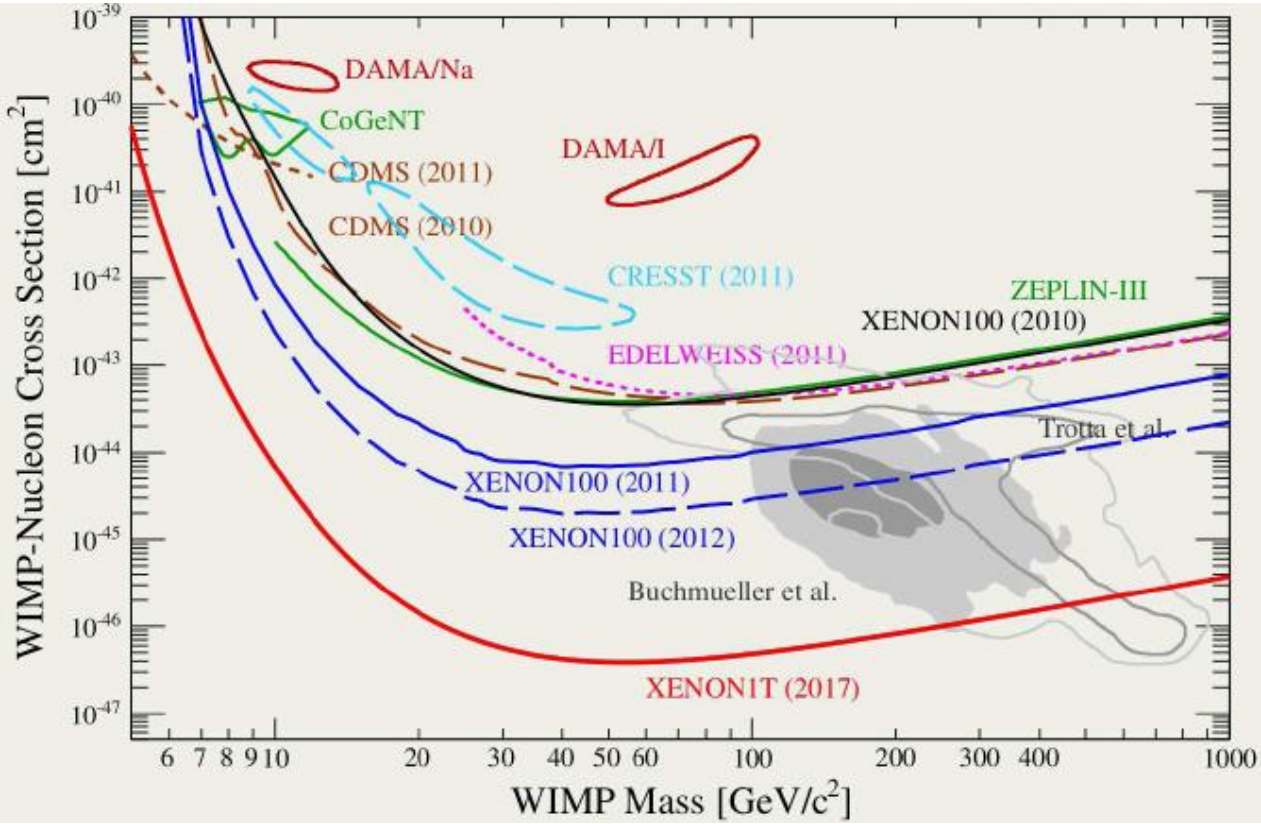
Is the spectrum consistent with CDMS?





Excluding these additional surface events in CoGeNT brings the two spectra into much better agreement

Caveat Emptor



Additional Evidence for Light WIMPs

- An increasingly compelling body of evidence has accumulated in support of dark matter in the form of ~10 GeV WIMPs
- In the first three years of publicly available FGST data, there is a component of gamma rays concentrated around the Galactic Center, with a spectrum peaked at GeV energies
- The spectrum and morphology of the observed emission can be easily accounted for with annihilating dark matter distributed with a halo profile similar to those inferred from simulations ($\rho \alpha r^{-1.3}$), with a mass of 7-12 GeV, and an annihilation cross section consistent with a simple thermal relic ($\sigma v \sim 3 \times 10^{-26}$ cm^3/s)
- This dark matter scenario also automatically leads to the observed WMAP Haze and to the peculiar signals from non-thermal radio filaments
- The gamma ray and radio filaments signals are very difficult to explain with known astrophysics
- Recent Fermi data analyzed for galaxy clusters that also points to this mass range

Conclusions and Future Outlook

- When considering reasonable uncertainties
  - CoGeNT and CRESST have similar overall spectra
  - CoGeNT and DAMA have similar modulation spectra
  - These rates are discrepant at least by a factor of a few
- Direct Detection
  - CoGeNT 2 year data to be released soon
  - CDMS is undertaking an annual modulation analysis, SuperCDMS
  - First C4 detector to be constructed soon
- Indirect detection
  - Much more work on the current and future Fermi data
  - Planck will measure the CMB with even greater precision
  - Will AMS see anything in positrons or electrons?
- Colliders
  - Light WiMPs open many possible signals at colliders
  - Some work has been done here, but still much to explore
  - Velocity dependent operators that could provide a particle physics resolution to the apparent discrepancy