First Results from Cryogenic Dark Matter Search in the Soudan Underground Laboratory

Akerib et. Al

Physical Review Letters 19 Nov, 2004

CDMS Setup

- Direct detection of WIMP
- Set of four Ge and two Si ZIP (Z-dependent ionization and phonon) detectors (Z1 – Z6) stacked in a tower formation
- 5-cm thick scintillator muon veto enclosing the shielding identifies charged particles that pass through.
- WIMP search data taken 08/11/2003 to 01/11/2004

ELECTRON AND NUCLEAR RECOILS

- Background particles(gamma and beta) scatter off electrons
- WIMPS and neutrons scatter off nuclei.
- ZIP detectors discriminate between electron and nuclear recoils through:

  - > IONIZATION YIELD : ionization/phonon signal. For a given energy, electrons have higher ionization yield than recoiling nuclei.

  - > PHONON TIMING CUTS: athermal phonon signals due to nuclear recoils have longer time rises and occur later than those due to electron recoils.

GAMMA AND NEUTRON CALIBRATIONS

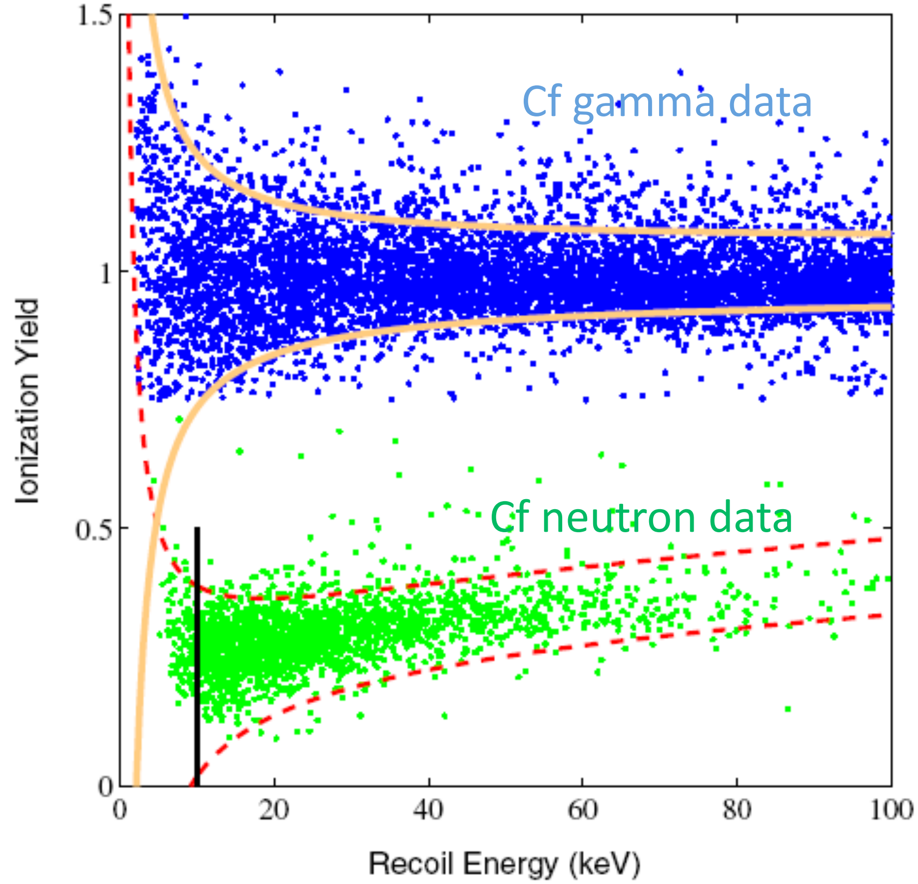


FIG. 1 (color online). Ionization yield versus recoil energy for calibration data with a ^{252}Cf gamma and neutron source for detectors Z2, Z3, and Z5 in Tower 1 showing the $\pm 2\sigma$ gamma band (solid curves) and the $\pm 2\sigma$ nuclear-recoil band (dashed curves) for Z5, the detector with the worst noise of these three. Events with ionization yield < 0.75 (gray) are shown only if they pass the phonon-timing cuts. The vertical line is the 10 keV analysis threshold for these three detectors.

NEUTRONS VS. WIMPS

- Neutrons produced in the shield by muons are tagged by the veto scintillator with efficiency > 99%.
- Unvetoed neutron background is expected due to cosmic-ray muon interactions in the walls of the cavern.
- Events due to neutrons can be distinguished from those of WIMPS:
  - Neutrons scatter in more than one detector and about the same rate in Si and Ge.
  - WIMPS do not multiple scatter, and occur ~ 6 times more in Ge than in Si detectors.

BLIND ANALYSIS

- Nuclear-recoil region of WIMP search data not inspected till all cuts and thresholds were defined using gamma and neutron calibrations.
- Combination of ionization yield and phonon-timing cuts rejects electron recoils, and accepts nuclear recoils.
- Recoil energy between 10 and 100 keV were taken for all Ge detectors except Z1, whose larger noise required a threshold of 20 keV.

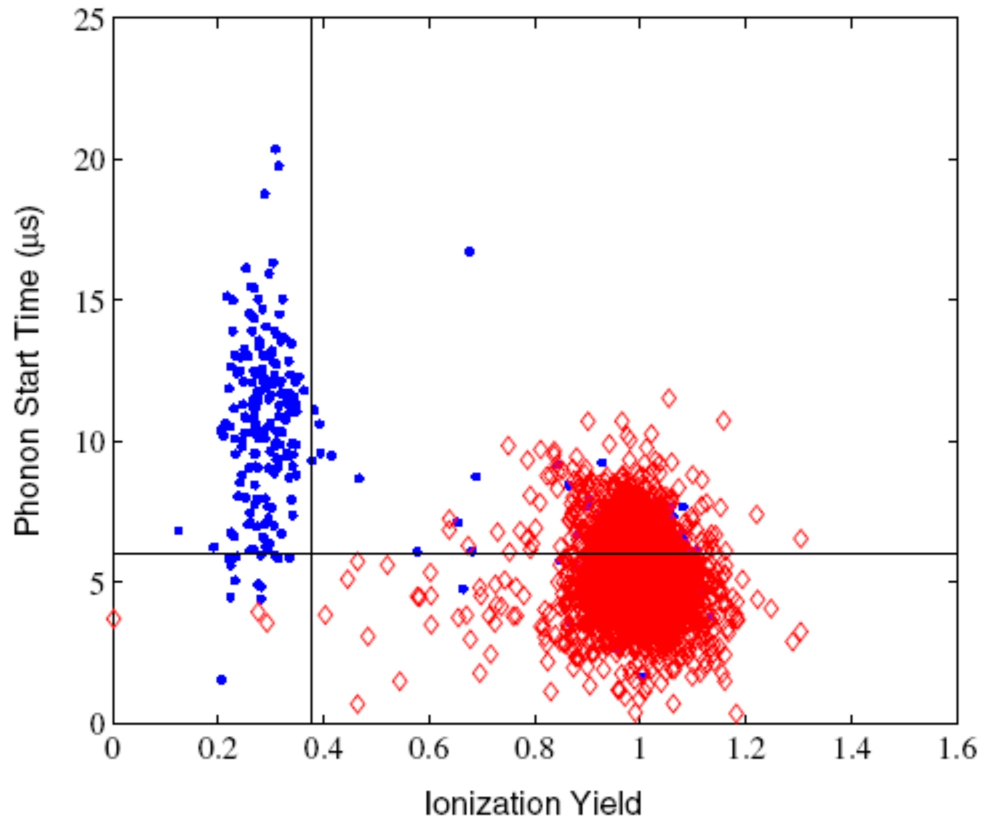


FIG. 2 (color online). Phonon start time versus ionization yield for ^{133}Ba gamma-calibration events (diamonds) and ^{252}Cf neutron-calibration events (dots) in the energy range 20–40 keV in detector Z5 in Tower 1. Lines indicate typical timing and ionization-yield cuts, resulting in high nuclear-recoil efficiency and a low rate of misidentified surface events.

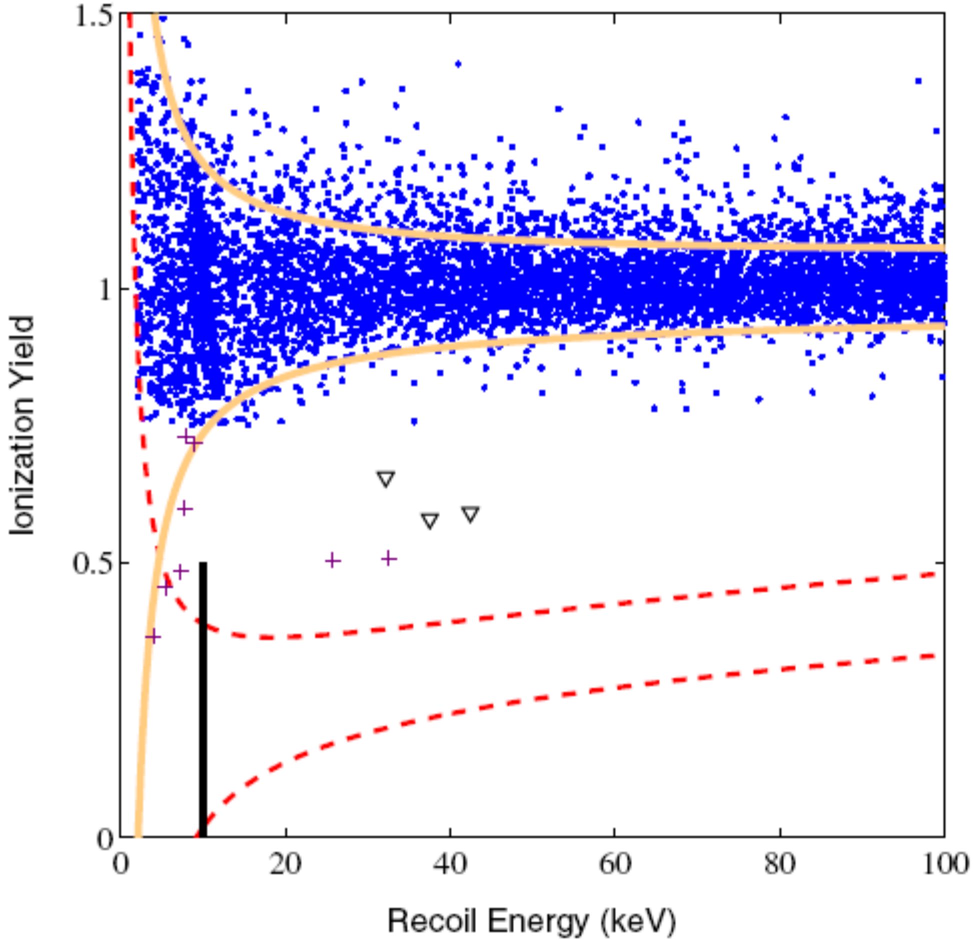


FIG. 4 (color online). Ionization yield versus recoil energy for WIMP-search data from Z2 (triangles), Z3, and Z5 (+) in Tower 1, using the same yield-dependent cuts and showing the same curves as in Fig. 1. Above an ionization yield of 0.75, the events from all three detectors are drawn as identical points in order to show the 10.4 keV Ga line from neutron activation of Ge.

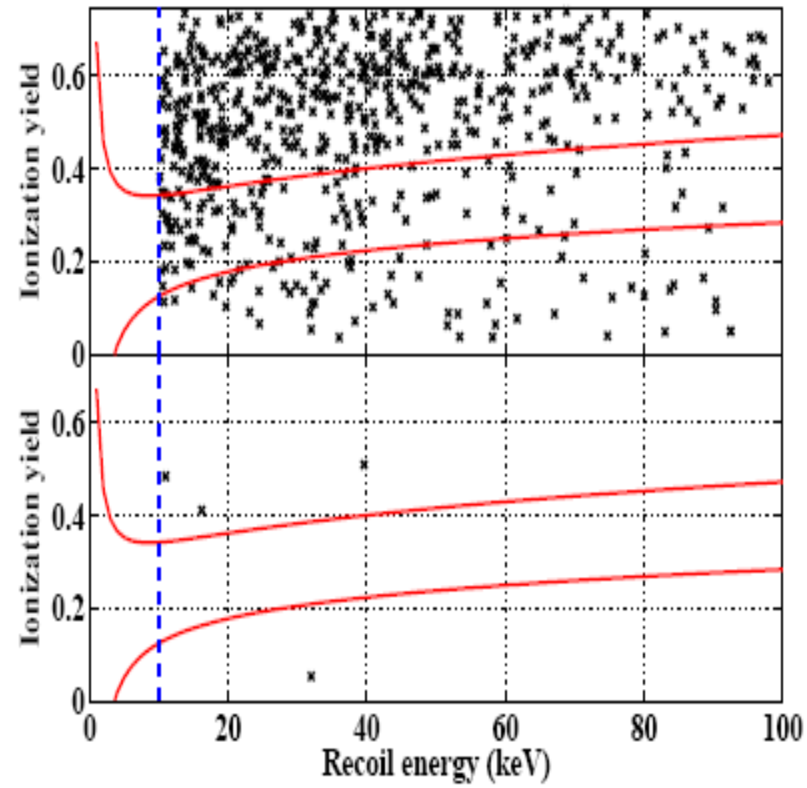


FIG. 3: Top: Ionization yield versus recoil energy in all detectors included in this analysis for events passing all cuts except the ionization yield and surface electron recoil rejection cuts. The signal region between 10 and 100 keV recoil energies was defined using neutron calibration data and is indicated by the curved lines. Bulk electron recoils with yield near unity are above the vertical scale limits. Bottom: Same, but after applying the surface electron recoil rejection cuts. No events are seen within the signal region.

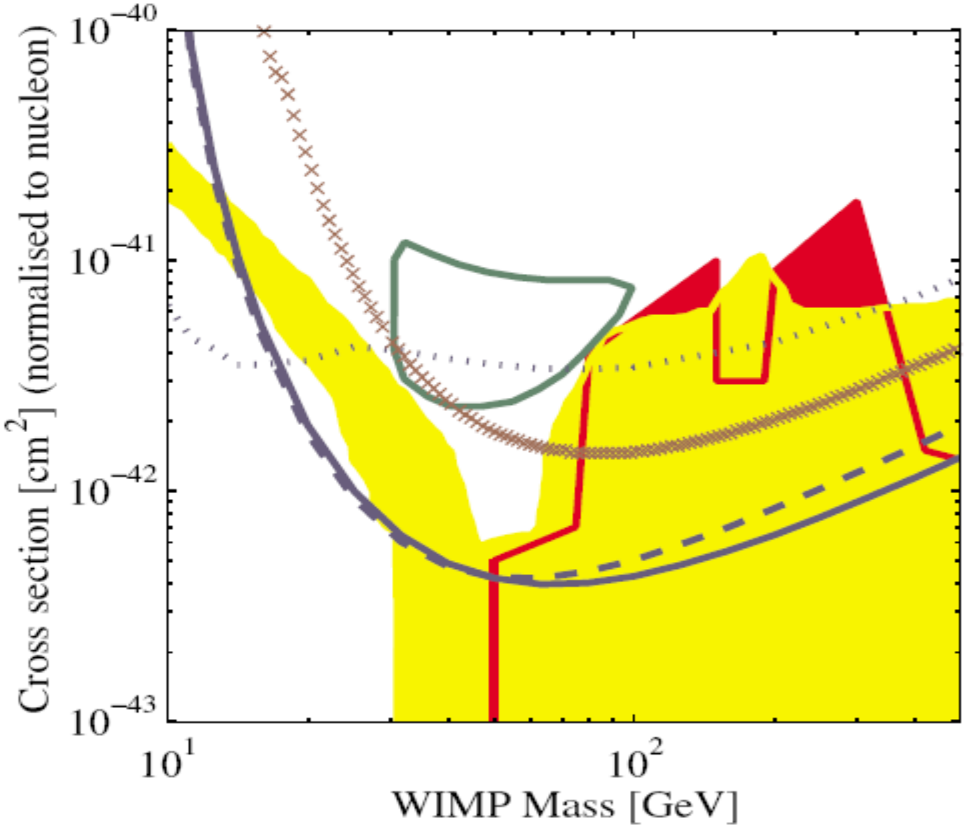


FIG. 5 (color online). New limit on the WIMP-nucleon scalar cross section from CDMS II at Soudan with no candidate events in 19.4 kg d effective Ge exposure (solid curve). Parameter space above the curve is excluded at the 90% C.L. These limits constrain supersymmetry models, for example, [8] (dark gray) and [9] (light gray). The DAMA (1–4) 3σ signal region [18] is shown as a closed contour. Also shown are limits from CDMS at SUF [17] (dotted curve), EDELWEISS [19] ($\times$'s), and the second, nonblind analysis of CDMS II at Soudan with one nuclear-recoil candidate event (dashes). All curves [20] are normalized following [10], using the Helm spin-independent form factor, A^2 scaling, WIMP characteristic velocity $v_0 = 220\ \mathrm{km\,s^{-1}}$, mean Earth velocity $v_E = 232\ \mathrm{km\,s^{-1}}$, and $\rho = 0.3\ \mathrm{GeV}\,c^{-2}\,\mathrm{cm^{-3}}$.

UPDATED CDMS VS. PREVIOUS RESULT

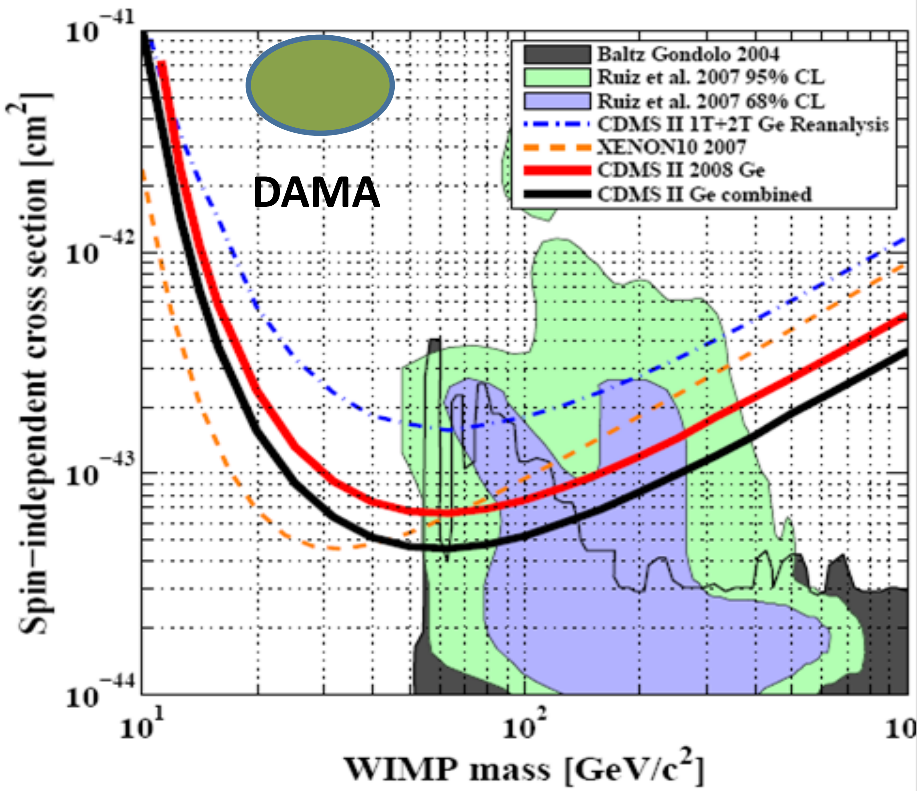
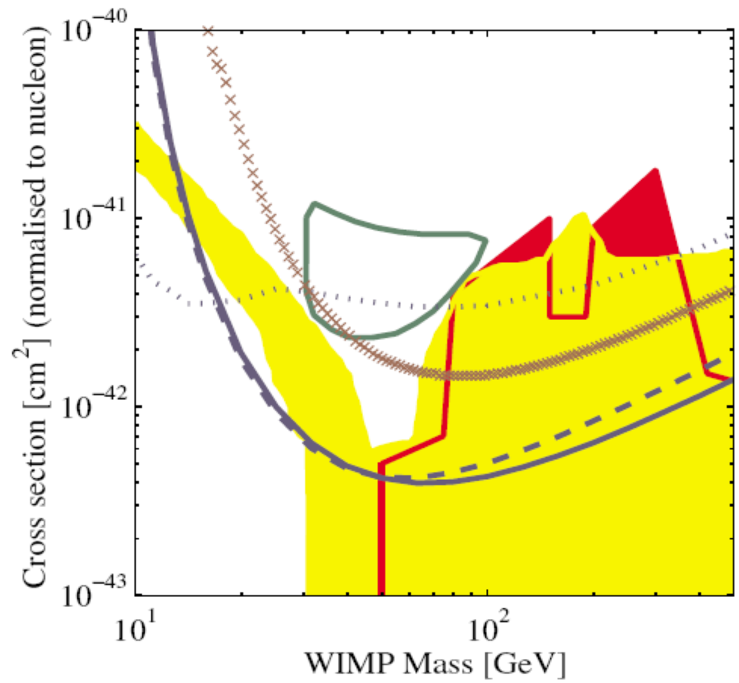


FIG. 4: Spin-independent WIMP-nucleon cross section upper limits (90% C.L.) versus WIMP mass. The upper curve (dash-dot) is the result of a re-analysis [17] of our previously published data. The upper solid line represents the limit derived from our new data set. The combined CDMS limit (lower solid line) reaches the same minimum cross section as that from Xenon10 [18] (dashed), but with more sensitivity at higher masses. Also shown are parameter ranges expected from different supersymmetric models described in [19] (grey) and [20] (95% and 68% confidence levels in green and blue, respectively). Plots courtesy of [22].



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