Project A05, Poster 2

Solar neutrinos as background for the direct dark matter search

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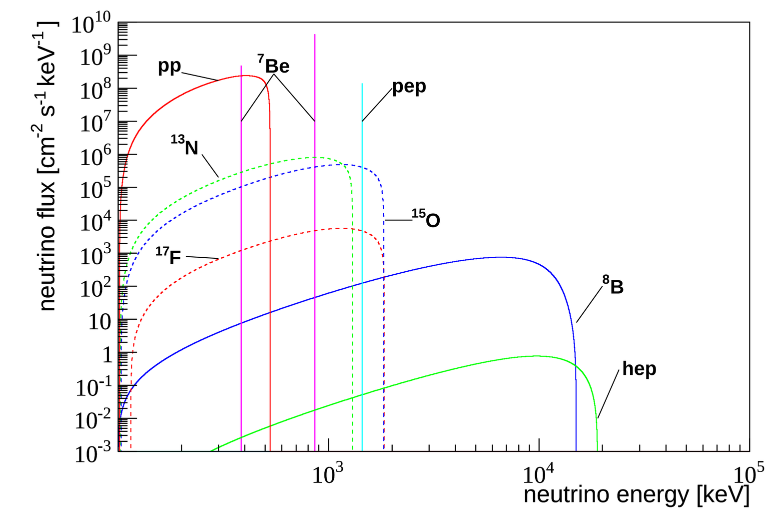
Solar neutrino spectrum



Solar neutrino spectrum (dashed lines: CNO-cycle)

- Neutrinos scattering coherently off a nucleus (CNNS, see first poster) mimic a WIMP scattering event
- Strongest natural neutrino source: solar neutrinos (see picture on the left)
- Expected count rate for solar neutrinos is about 10^4 per ton-year (for zero energy threshold, see below)

→ **Solar neutrinos can be a background source for the direct dark matter search**

Count rate calculation

Count rate R for neutrinos:

$$R = N_t \int_0^\infty dE_\nu \Phi(E_\nu) \int_0^{\frac{2E_\nu^2}{M}} dE_{rec} \frac{d\sigma(E_\nu, E_{rec})}{dE_{rec}}$$

N_t: number of target nuclei, E_ν: neutrino energy, $\Phi(E_\nu)$: neutrino flux, M mass of target nucleus, E_{rec}: recoil energy, $\sigma(E_\nu, E_{rec})$ cross section for CNNS (see first poster)

Count rate for mono energetic pep neutrinos in germanium (for zero energy threshold):

$$R_{pep} = N_t \cdot 1.41 \cdot 10^8 \frac{1}{\text{cm}^2\text{s}} \cdot 4.2 \cdot 10^{-45} \frac{\text{cm}^2}{\text{MeV}^2} N^2 \cdot (1.442\,\text{MeV})^2 = 532 \frac{1}{\text{ton-year}}$$

The recoil spectrum is given by:

$$\frac{dR(E_{rec})}{dE_{rec}} = N_t \int_{\sqrt{\frac{E_{rec}M}{2}}}^\infty dE_\nu \Phi(E_\nu) \frac{d\sigma(E_\nu, E_{rec})}{dE_{rec}}$$

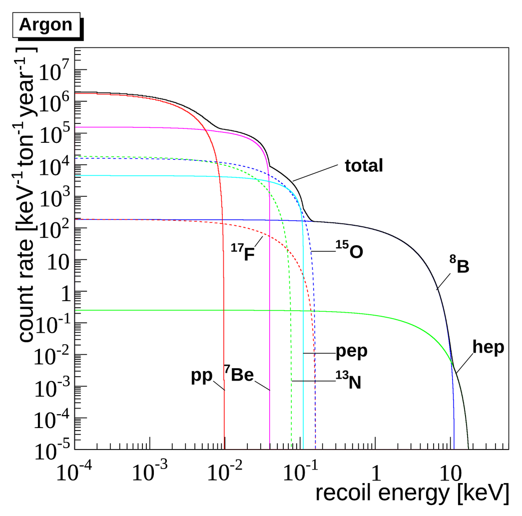
The count rate R_{th} above an energy threshold E_{th} is given by:

$$R_{th} = \int_{E_{th}}^\infty dE_{rec} \frac{dR(E_{rec})}{dE_{rec}}$$

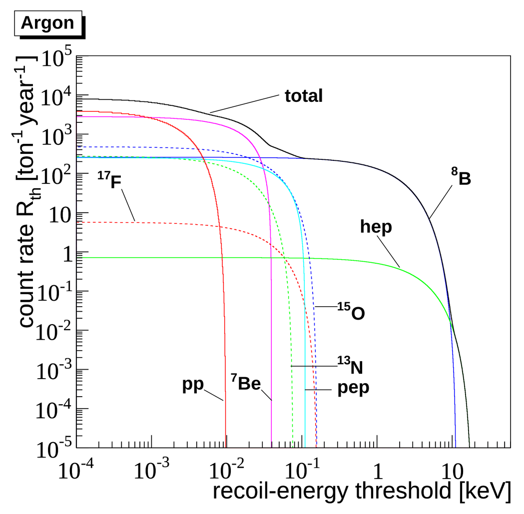
→ ***These calculations and their results are published in arXiv:1003.5530v1 [hep-ph] and submitted to Astroparticle Physics.***

Count rates for solar neutrinos for different target materials

Argon



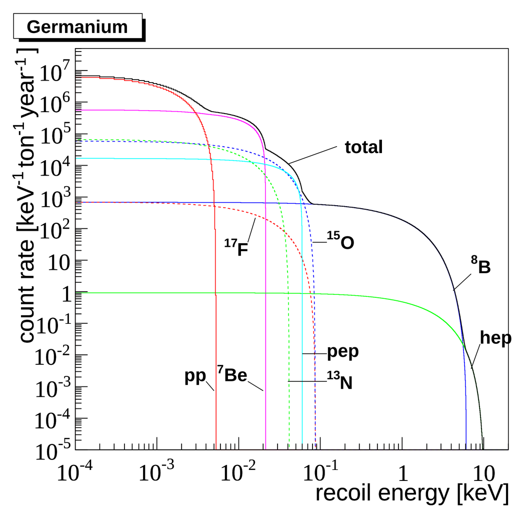
Recoil spectrum of solar neutrinos



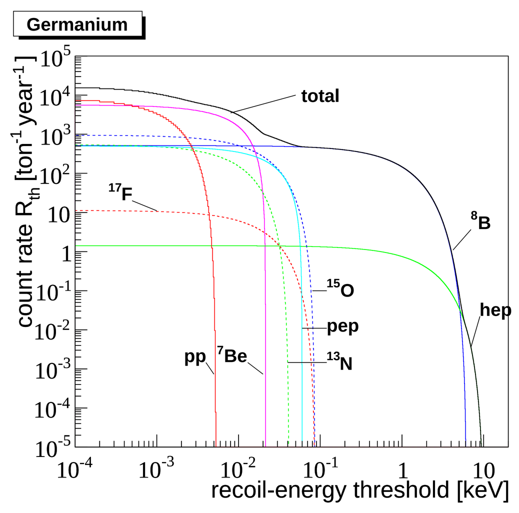
Count rates above an energy threshold E_{th}

E_{th} [keV]	0	**8.66**	18.8
count rate per ton-year	$8.1 \cdot 10^3$	**0.1**	0.0

Germanium



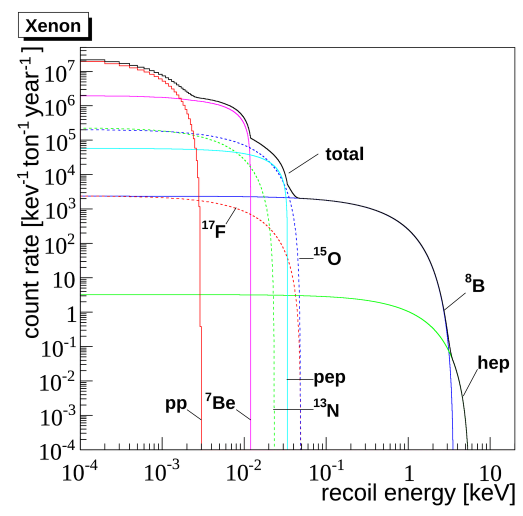
Recoil spectrum of solar neutrinos



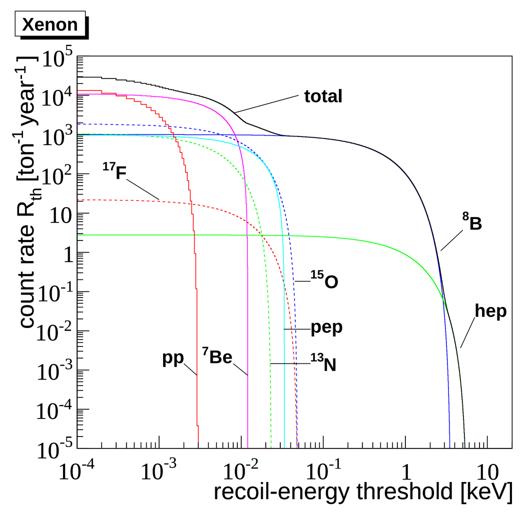
Count rates above an energy threshold E_{th}

E_{th} [keV]	0	**4.95**	10.3
count rate per ton-year	$1.6 \cdot 10^4$	**0.1**	0.0

Xenon



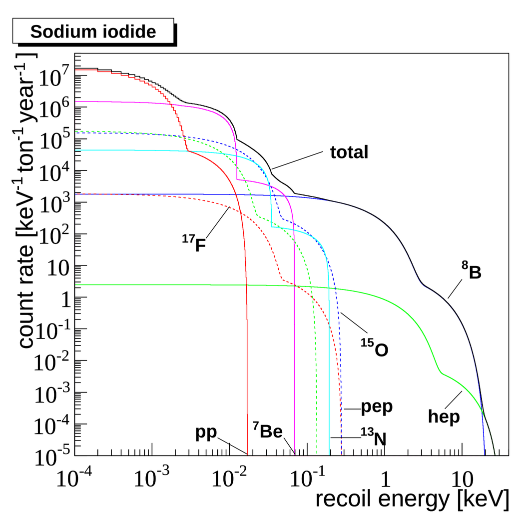
Recoil spectrum of solar neutrinos



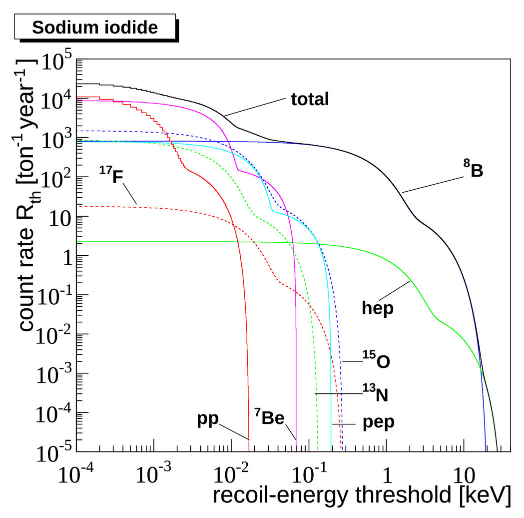
Count rates above an energy threshold E_{th}

E_{th} [keV]	0	**2.92**	5.7
count rate per ton-year	$3.0 \cdot 10^4$	**0.1**	0.0

Sodium iodide



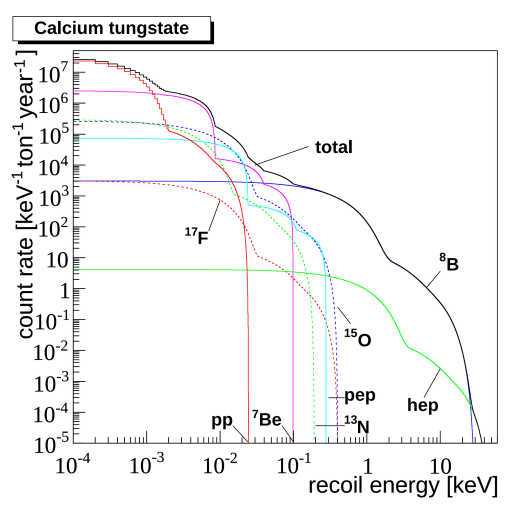
Recoil spectrum of solar neutrinos



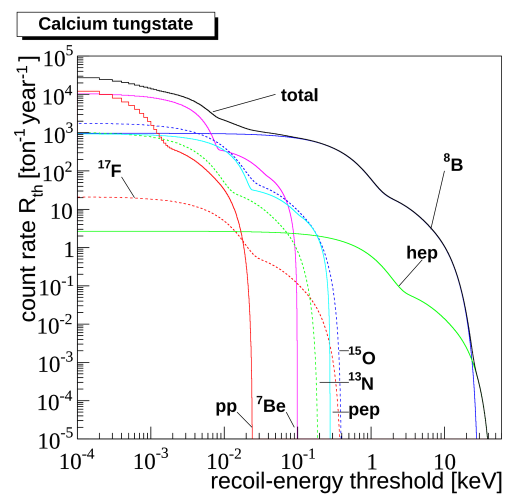
Count rates above an energy threshold E_{th}

E_{th} [keV]	0	**11.55**	37.6
count rate per ton-year	$2.4 \cdot 10^4$	**0.1**	0.0

Calcium tungstate

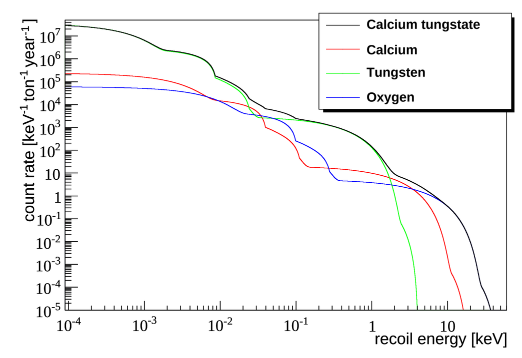


Recoil spectrum of solar neutrinos



Count rates above an energy threshold E_{th}

E_{th} [keV]	0	**16.39**	47.1
count rate per ton-year	$2.8 \cdot 10^4$	**0.1**	0.0



Recoil spectra for the different nuclei of $CaWO_4$

- Counts for larger recoil energies (>2 keV) mainly due to scatterings off oxygen
- It is possible to discriminate between W recoils and Ca or O recoils (see project B3)

⇒ Solar neutrino events with recoil energies >2 keV can be rejected

Count rates for W in $CaWO_4$

E_{th} [keV]	0	**2.08**	4.1
count rate per ton-year	$2.7 \cdot 10^4$	**0.1**	0.0

Limitations by solar neutrinos for the direct dark matter search

WIMP model

- Spin independent interaction
- WIMP scatters coherently off all nucleons
- Isothermal WIMP halo

⇒ Recoil spectrum of WIMPs (see picture on the right):

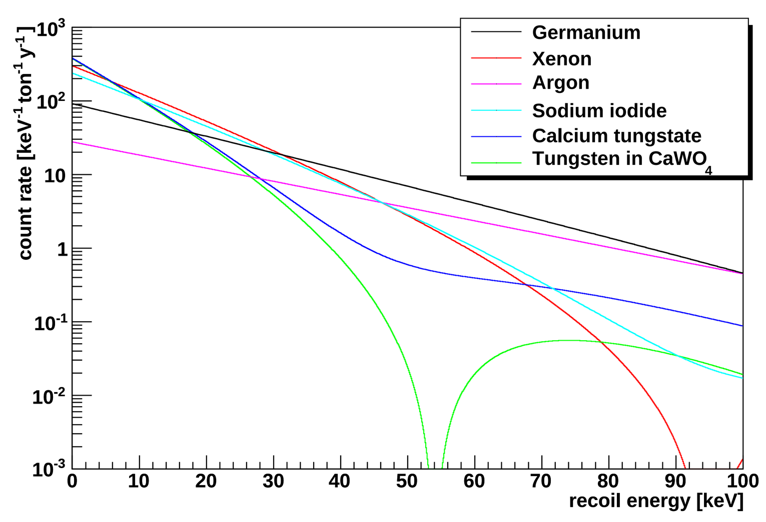
$$\frac{dR(E_{rec})}{dE_{rec}} = \frac{c_1 N_A \rho_D}{2\sqrt{\pi}\mu_1^2} \sigma_{WN} |F(E_{rec})|^2 v_0 \frac{A^2}{E_0} e^{-\frac{c_2 E_{rec}}{E_0 r}}$$

c_1, c_2: constants describing the annular modulation of the WIMP flux, N_A: Avogadro's number, ρ_D: local WIMP density, μ_1: reduced mass for A=1, σ_{WN}: WIMP-nucleon cross section, v_0: velocity of the earth relativ to the galaxy, A: mass number, E_0: kinetic energy of the WIMPs, E_{rec}: recoil energy, $r = 4\frac{M_D M_T}{(M_D+M_T)^2}$: kinematic factor, M_D: WIMP mass, M_T: mass of target nucleus

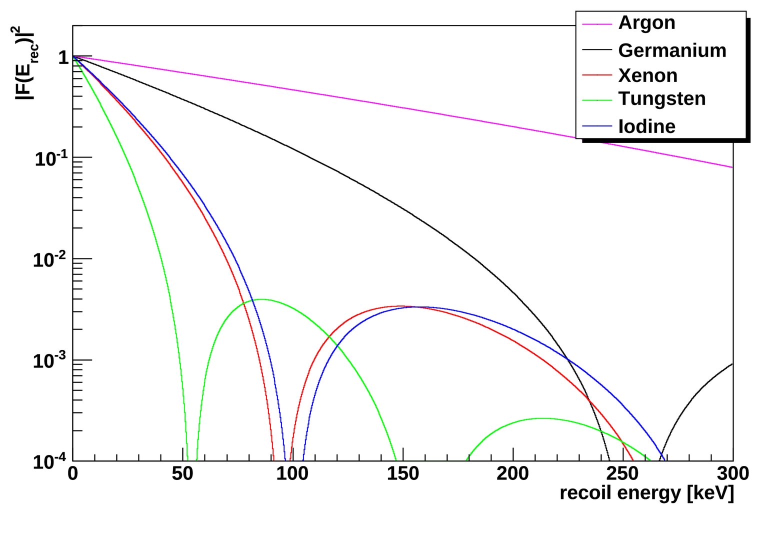
→ Helm form factor (see picture on the right):

$$F(q = \sqrt{2 M_T E_{rec}}) = \left(\frac{3 j_1(qR)}{qR}\right)^2 e^{-q^2 s^2}$$

q: transferred momentum, j_1: spherical Bessel function, R: effectiv nuclear radius, s: nuclear skin thickness



Recoil spectra for WIMPs for different target materials (WIMP mass: 60 GeV, cross section: 10^{-44} cm^2)



Helm form factor for different materials

Exclusion plot

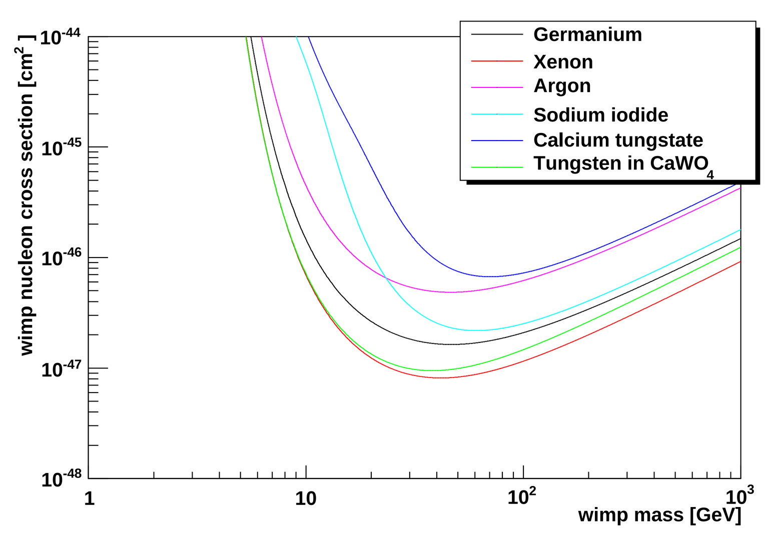
- Neutrinos can mimic WIMP events
- However, recoil energies of solar neutrinos are small (see above)

⇒ Solar neutrinos can be rejected by a proper choice of the energy threshold

→ Energy regions for an expected count rate for solar neutrinos of 0.1 counts per ton-year:

Material	energy region
Ar	8.66 - 100 keV
Ge	4.95 - 100 keV
Xe	2.92 - 100 keV
NaI	11.55 - 100 keV
$CaWO_4$	16.39 - 100 keV
W in $CaWO_4$	2.08 - 100 keV

- The energy region for $CaWO_4$ is given without discrimination between W, Ca and O recoils
- The energy region for W in $CaWO_4$ is given with discrimination between W, Ca and O recoils applied
- Exclusion plots (see picture on the right) for different target materials with the assumption of zero events in the optimal energy region given in the table



Exclusion plots for different target materials (Exposure 1 ton-year, 90% confidence level)

Results:

- Solar neutrinos have to be taken into account for sensitivities for the WIMP-nucleon cross section below 10^{-46} cm^2
- Xe and W in $CaWO_4$ (with discrimination between W, Ca and O recoils) are the best target materials if WIMP masses are >10 GeV.

→ A good discrimination between W, Ca and O recoils is very important for the use of $CaWO_4$ in direct dark matter search experiments.

→ For sensitivities below 10^{-48} cm^2 atmospheric neutrinos are becoming a background source.