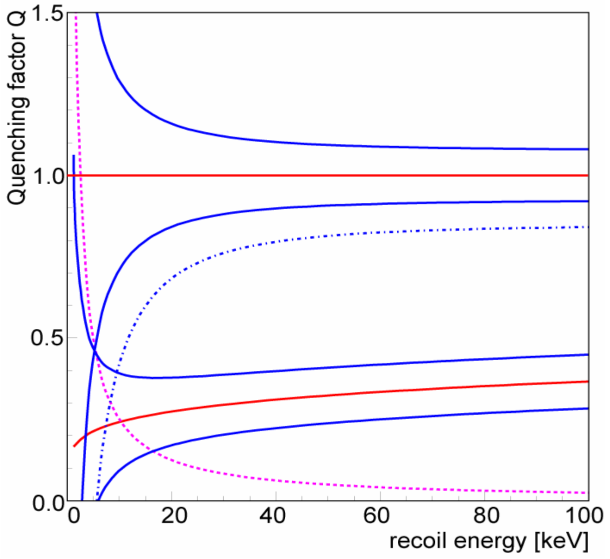
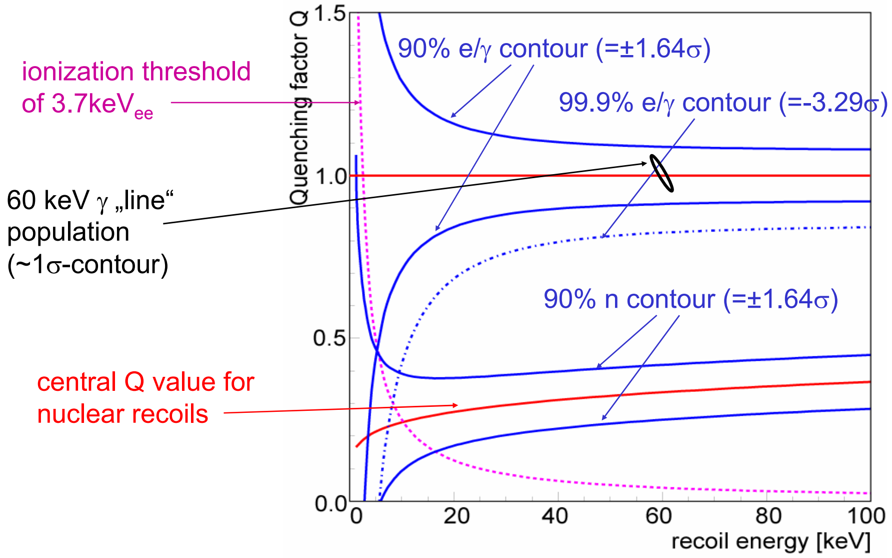
exercise #1: Direct WIMP search with bolometers

a) explain the different curves of the plot

b) plot the 1-σ contour of a population of events from a 60 keV „γ line“ with an experimental energy resolution of $\sigma(E_{recoil})$=10% and $\sigma(E_{ionisation})$=2%



exercise #1: Direct WIMP search with bolometers



exercise #2: Direct WIMP search with bolometers

In direct DM searches, WIMP´s can be detected via elastic scattering off nuclei of the detector material. Assume a WIMP with $m(\chi)$=50GeV/c^2 hitting a Ge nucleus with a relative velocity of v=300km/s.

In the case of a central collision, what is the transferred energy E_{recoil}?

How does this compare to the energy transfer of a WIMP collision with an electron of the Ge atom?

exercise #2: Direct WIMP search with bolometers

$m(\chi)$ = 50GeV/c^2 with velocity of $v(\chi)$ = 300km/s
→ $E(\chi)$ = ½ $m(\chi)c^2$ 10^{-6} $(v/c)^2$ = 25 keV

elastic collision: energy transfer

$$\Delta E = \frac{4m(\chi)\cdot m(Ge)}{[m(\chi)+m(Ge)]^2}\cdot E(\chi)\cdot\cos^2\theta$$

with the scattering angle Θ in the lab system.
Maximal energy transfer ΔE for central collision, assume m(Ge)=72.6GeV
→ ΔE = 0.966 $E(\chi)$ = 24.15 keV

ΔE with collision on electron m(e-)=0.511MeV:
→ ΔE = {4x0.000511x50}/$\{50.000511\}^2$ $E(\chi)$ = 4.1 10^{-5} $E(\chi)$ ≈ 1eV !!

exercise #3: Kinematics of ß decays

Determine the value of the retarding potential, at which the ß-decay signal count rate Γ_{e-} is twice the expected background rate of $\Gamma_{e-} = 2\Gamma_{bg} = 2x0.01$ counts/s = 0.02 cts/s.

The amount of T_2 molecules in the source is $N(T_2)=3.2\ 10^{19}$, the Tritium half life is $T_{1/2}=12.3$ years, the endpoint energy is $E_0=18575$ eV. Applying a retarding potential of $V=E_0/q$ - 1V =18574V, the measured signal rate is only ~10^{-13} of the total ß-spectrum of the integrating spectrometer. To determine the spectral shape of the ß electrons, assume a ß-spectrum with vanishing neutrino mass near the endpoint E_0.

exercise #3: Kinematics of ß decays

number of T nuclei in source: $N(T)=2\ N(T_2)=6.4\ 10^{19}$
$T_{1/2}=12.3$ years → decay rate $\Gamma = 1/\tau = 1/(\tau/\ln 2) = 1.8\ 10^{-9}$ /s
we simplify and assume ALL decay electrons going into the spec.:
$N(E=18547eV)/N_{tot}=10^{-13}$ with $N(E) \sim (E_0-E)^3$
so we get $\Gamma_{e-}(U=18547V)=10^{-13}$ x $6.4\ 10^{19}$ x $1.8\ 10^{-9}$ = 0.01152 /s

$\Gamma_{e-} = 2\Gamma_{bg}$ = 0.02 /s for $(0.02/0.01152)^{1/3}$ V below 18575V → 18573,8V

(we also neglected the energy of the final states of $(He\text{-}T)^+$ molecules)

Klaus Eitel, Search for Cosmological Dark Matter European Summer University, July 10, 2006

exercise #4: neutrino mass from SN ToF

Discuss how a „time-of-flight“ measurement of Supernova neutrinos can be used to determine the neutrino mass. What are the difficulties?

Determine the time-of-flight T of a neutrino with mass m_ν and energy $E_\nu >> m_\nu$ with a distance L of the source (emission time t_0) and the detector (detection time t).
Assume two neutrinos ν_1 and ν_2 emitted at times t_{01} and t_{02} with energies E_1 and E_2. What is the difference of the arrival time Δt?

Take Supernova SN1987A and the detection of ν´s by Kamiokande:
E_1=43.4MeV, E_2=15.6MeV, Δt=9s, L=50kpc
What upper limit on m_ν can be extracted assuming Δt_0=0?

exercise #4: neutrino mass from SN ToF

$$T = t - t_0 = \frac{L}{\mathrm{v}} = \frac{L}{c}\cdot\frac{E_\nu}{p_\nu c} = \frac{L}{c}\frac{E_\nu}{\sqrt{E_\nu^2 - m_\nu^2}} \approx \frac{L}{c}\cdot\left(1 + \frac{m_\nu^2}{2E_\nu^2}\right)$$

$$\Delta t = t_2 - t_1 = \Delta t_0 + \frac{Lm_\nu^2}{2c}\cdot\left(\frac{1}{E_2^2} - \frac{1}{E_1^2}\right)$$

$$m_\nu^2 = \frac{2c\Delta t}{L}\cdot\left(\frac{1}{E_2^2} - \frac{1}{E_1^2}\right)^{-1} = 0.39\cdot\frac{\Delta t/\sec\cdot(E_1/MeV)^2}{L/50kpc}\cdot\frac{1}{\alpha^2 - 1}eV^2$$

$$\text{with} \quad \alpha = \frac{E_1}{E_2} > 1 \quad \text{we deduce} \quad m(\nu_e) < 31\,\text{eV}$$