Search for the Cosmic Neutrino Background and the Nuclear Beta Decay.

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Cosmic Microwave Background Radiation

(Photons in the Maximum 2 mm)

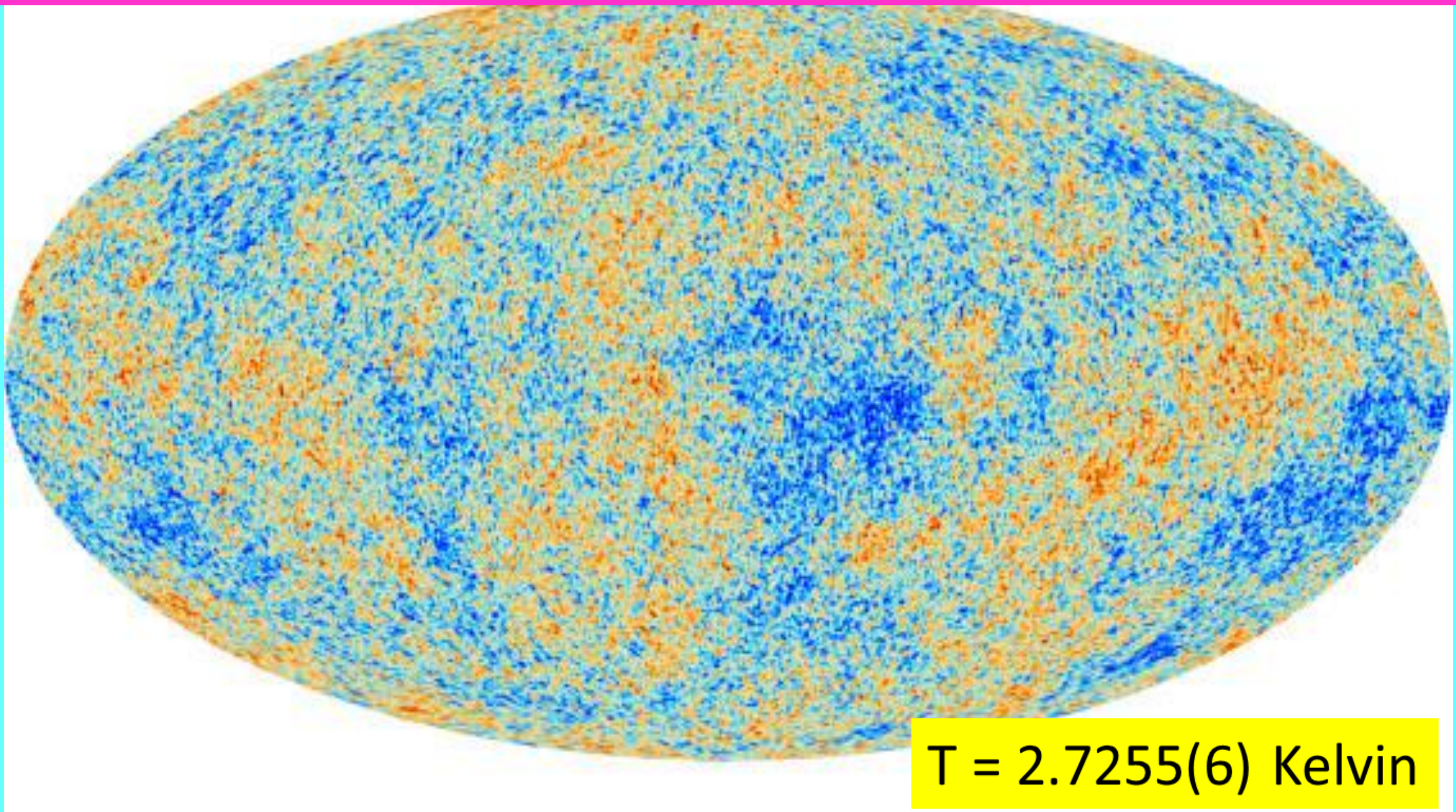
Decoupling of the photons from matter about 300 000 years after the Big Bang, when the electrons are captured by the protons and He4 nuclei and the universe gets neutral. Photons move freely.

Today: ~550 Photons /cm^3 (~340 Neutrinos/cm^3)

Planck Satellite Temperature Fluctuations

Comic Microwave Background (Release March 21. 2013)

$\varepsilon(f) = (8\pi h/c^3)\, f^3 df/[\exp(hf/k_B T)-1]$[Energy/Volume]



T = 2.7255(6) Kelvin

Neutrino Decoupling and Cosmic Neutrino Background

For massless-massive Neutrinos:

$$N_{Fermions}(f) \propto \frac{1}{exp((h \cdot f)/(k_B T)) + 1}$$

$$f = frequency; h = Planck's\ Wirkungsquantum$$

$$\Omega_\nu = 3 \cdot \frac{7}{8} \cdot (\frac{4}{11})^{4/3} \cdot \Omega_{rad} = 0.68 \cdot \Omega_{rad}$$

$$\Omega(m)_\nu = \Omega(m=0)_\nu \frac{\sum m_\nu c^2}{kinetic\ Energy = 3 k_B T} = \frac{\sum m_\nu c^2}{45 eV}$$

Estimate of Neutrino Decoupling

Universe Expansion rate: H=(da/dt)/a;

a ~ 1/T; (today, Planck) → H = 67km/(sec*Mpc)

$\sim \nu$ Interaction rate: $\Gamma = n_{e\text{-}e+} \langle \sigma v_{relative} \rangle$

Neutrino Decoupling

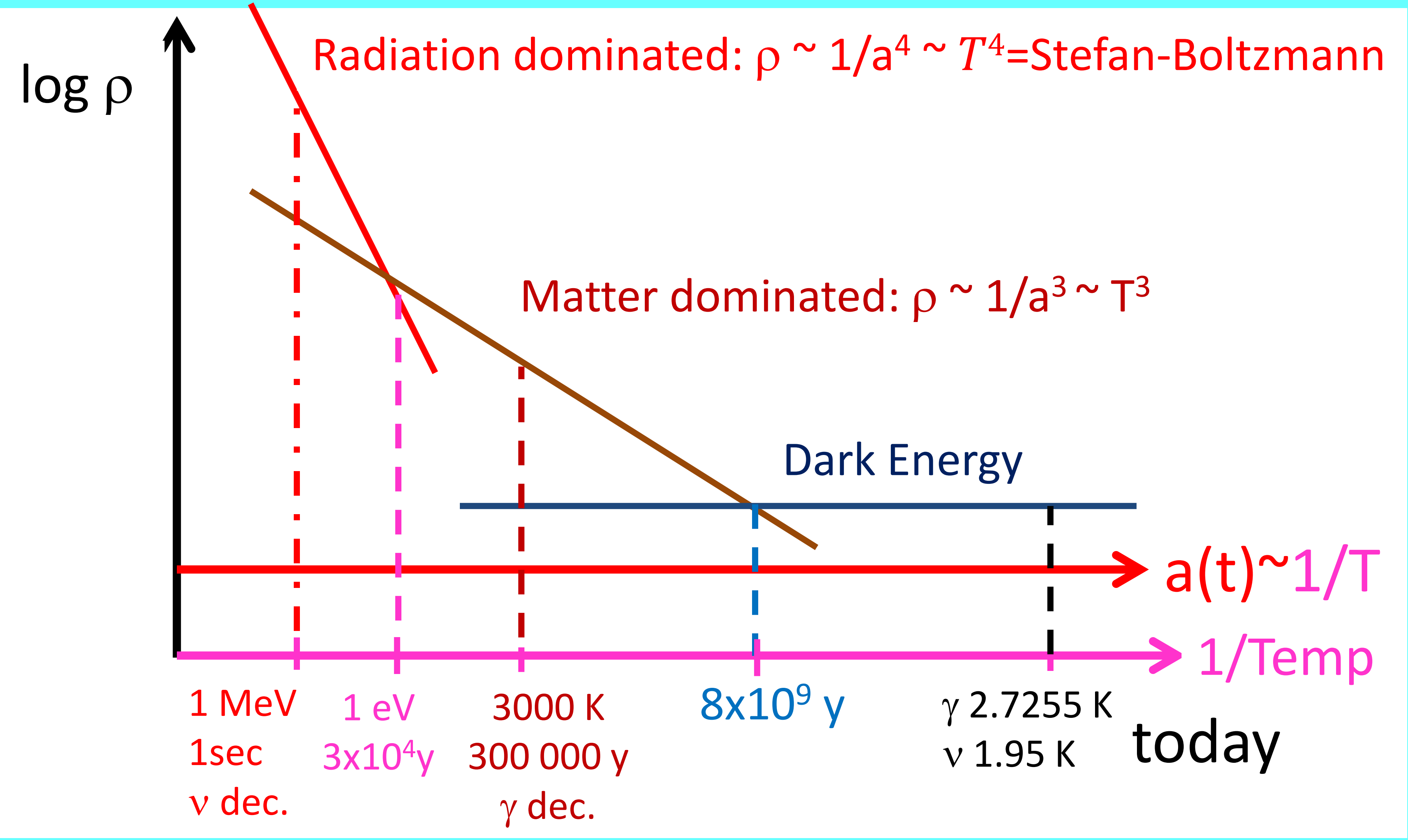
$\Gamma / H = (k_B T / 1 MeV)^3 \sim 1$

$T(Neutrinos)_{decoupl} \sim 1 MeV \sim 10^{10}$ Kelvin;

today: $T_\nu = 1.95$ K

Time after Big Bang: 1 Second

(Energy=Mass)-Density of the Universe



Mass of the Electron Neutrino? Tritium decay (Mainz + Troisk)

$$^3H \rightarrow \ ^3He + e^- + \nu_e^c$$

With $E_0 = Q + m_e; \quad Q = 18.562 keV$

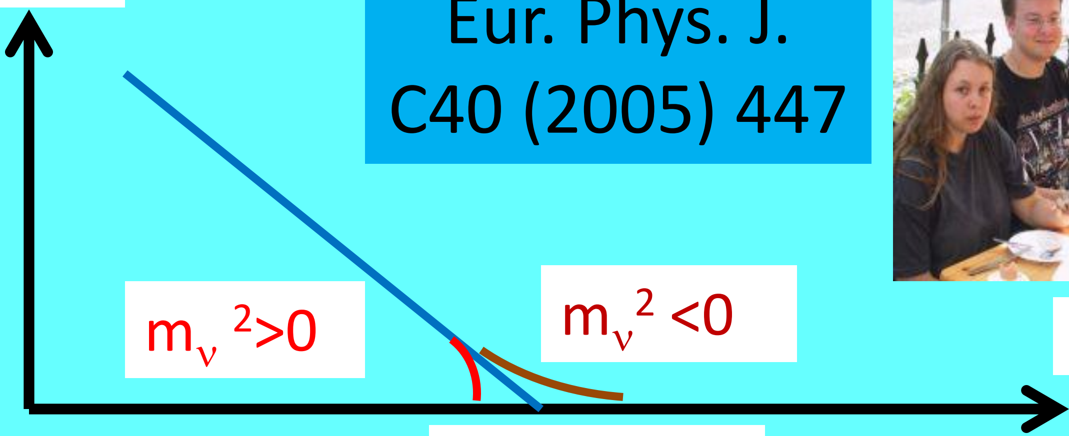
$$E_e = \sqrt{m_e^2 + p_e^2} \qquad E = T_e = E_e - m_e$$

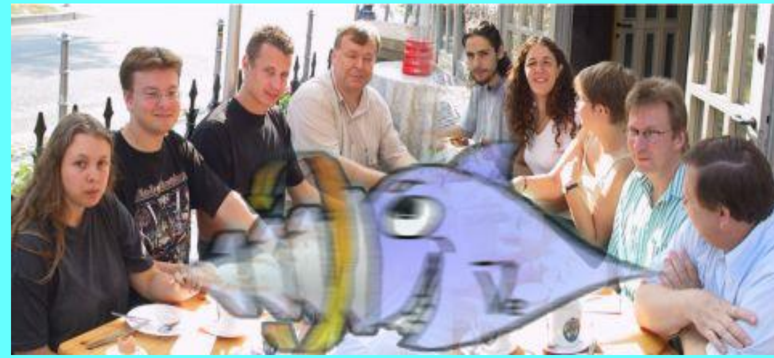
$$\frac{dN_e}{dE} = K \cdot F(E,Z) \cdot p_e E_e (E_0 - E_e) \sum_{j=1}^{3} |U_{ej}|^2 \sqrt{(E_0 - E_e)^2 - m(\nu_j)^2}$$

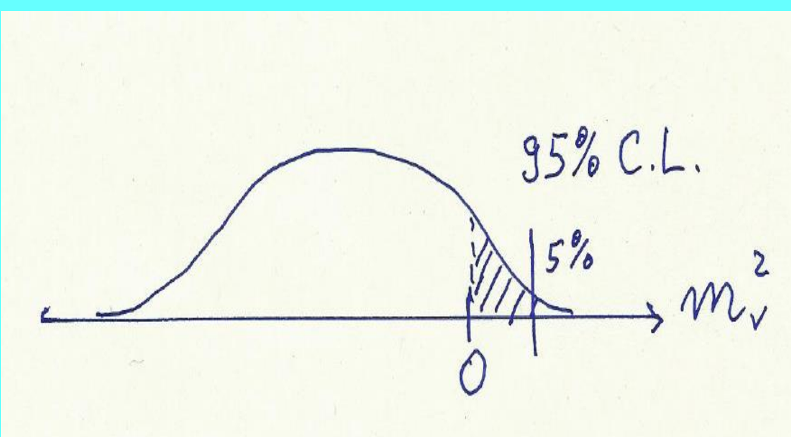
Distinguish flavor (production) e, μ, τ and mass $i = 1, 2, 3$ eigenstates.

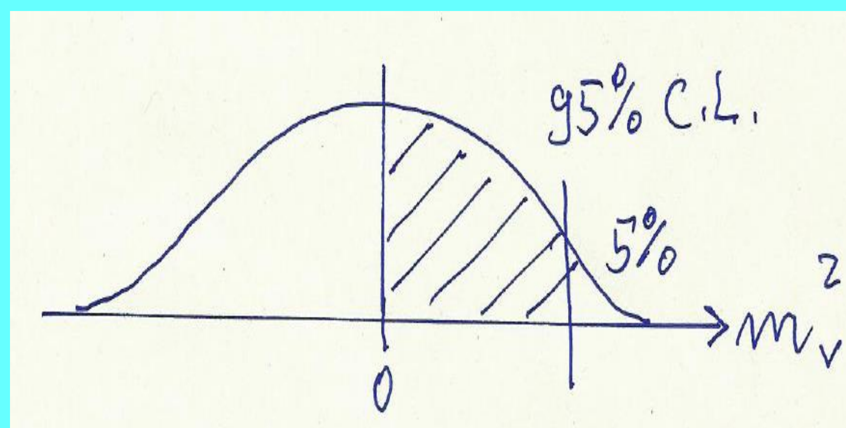
Measurement of the upper Limit of the Neutrino Mass in Mainz: $m_\nu < 2.2$ eV 95% C.L.

Eur. Phys. J. C40 (2005) 447







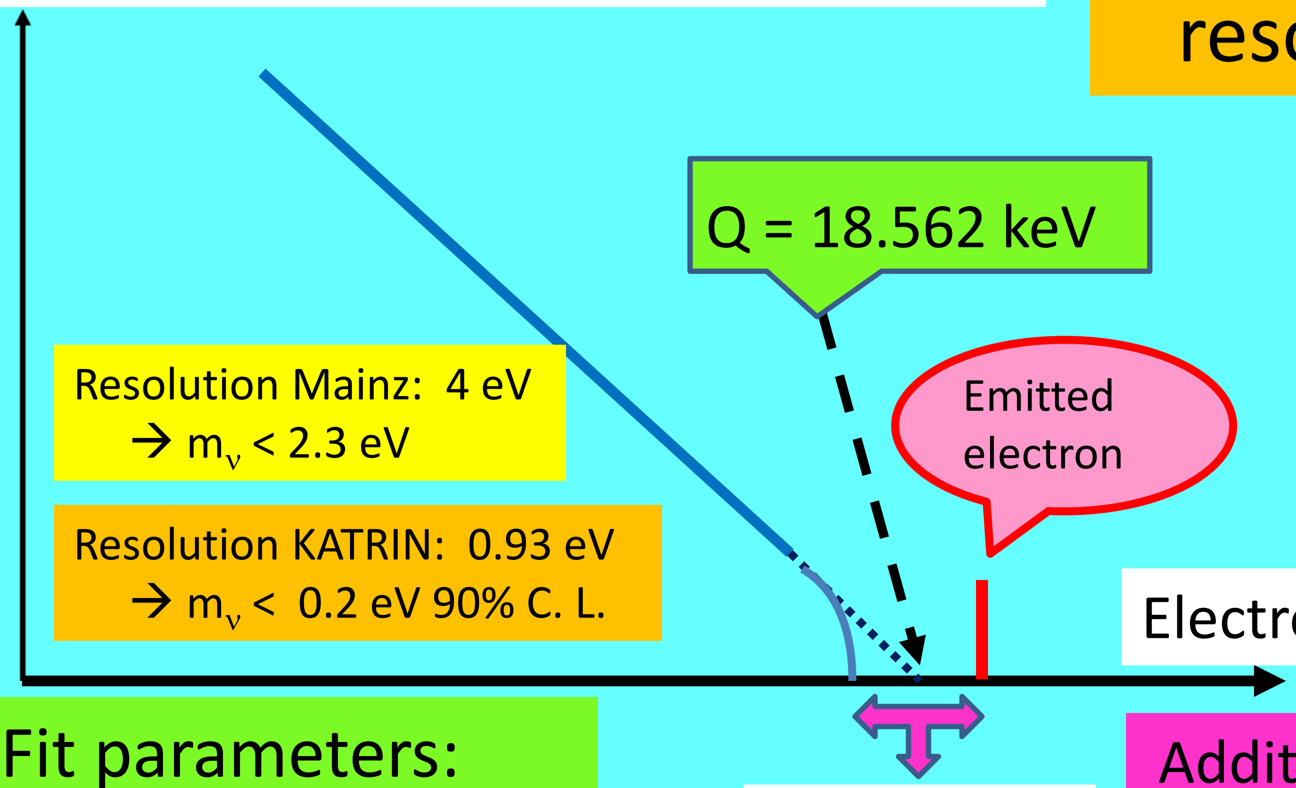


Search for Cosmic Neutrino Background CνB by Beta decay: Tritium

Kurie-Plot of Beta and induced Beta Decay:

$\nu(CB) + {}^{3}H(1/2^{+}) \rightarrow {}^{3}He\,(1/2^{+}) + e^{-}$

Infinite good resolution



Fit parameters:

m_ν^2 and Q value meV

Additional fit: only intensity of CνB

Neutrino Capture: ν(relic) + ^3H → $^3He + e^-$

$$\Gamma^{\nu}(^3H) = \frac{1}{\pi}(G_F \cos(\vartheta_C))^2 \cdot F_0(Z+1, E_e) \cdot [B_F(^3H) + B_{GT}(^3H)] p_e E_e \cdot \frac{n_{\nu e}}{< n_{\nu e} >} \cdot < n_{\nu e} >$$

$$\Gamma^{\nu}(^3H) = 4.2 \cdot 10^{-25} \frac{n_{\nu e}}{< n_{\nu e} >} [year^{-1}]; \quad for\ one\ Tritium\ atom$$

20 μg(eff) of Tritium → $2x10^{18}$ T_2-Molecules:

$N_\nu$capture(KATRIN) = $1.7x10^{-6}$ $n_\nu/<n_\nu>$ [$year^{-1}$]

Every 590 000 years a count!! for $<n_\nu>$ = 56 cm^{-3}

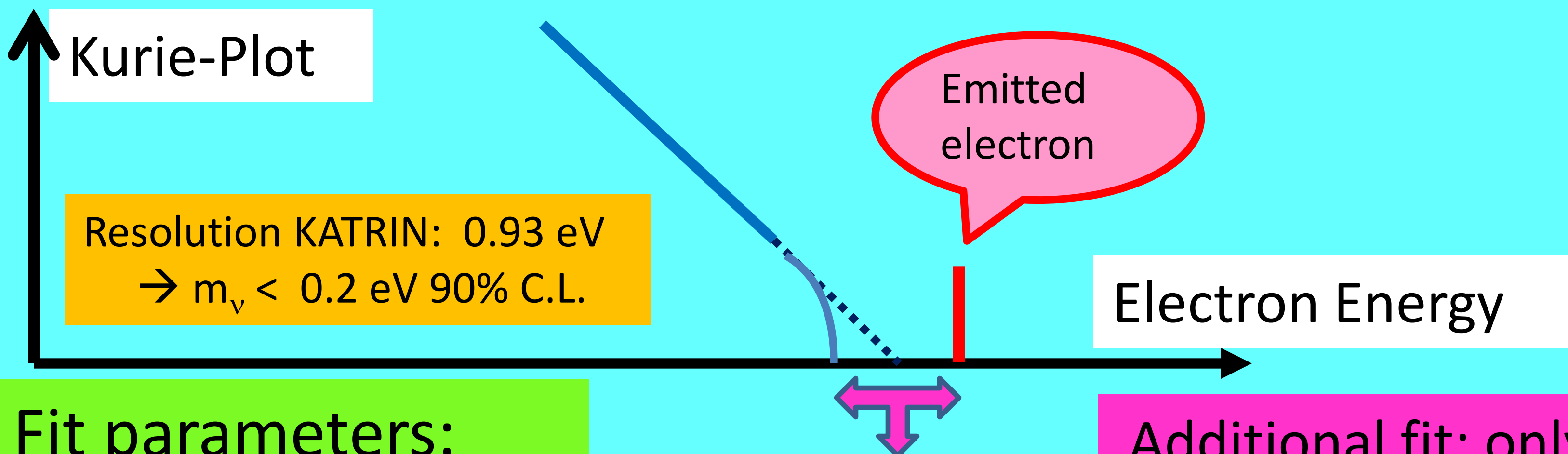
Two Problems

1. Number of Events with average Neutrino Density of $n_{\nu e}$ = 56 [Electron-Neutrinos/cm^{-3}]

   Katrin: 1 Count in 590 000 Years

   Gravitational Clustering of Neutrinos!!!???

2. Energy Resolution (KATRIN) $\Delta E \sim 0.93$ eV



2xNeutrino Masses

Fit parameters:
m_ν^2 and Q value meV

Additional fit: only intensity of CνB

Gravitational Clustering of Neutrinos

R.Lazauskas,P. Vogel and C.Volpe, J. Phys.g. 35 (2008) 025001;

Light neutrinos: Gravitate only on 50 Mpc (Galaxy Cluster) scale: $n_\nu/<n_\nu> \sim n_b/<n_b> \sim 10^3 – 10^4$; $<n_b>= 0.22\ 10^{-6}\ cm^{-3}$

A. Ringwald and Y. Wong: Vlasov trajectory simulations. Clustering on Galactic Scale possible (30 kpc to 1 Mpc) $n_\nu/<n_\nu> = n_b/<n_b> \sim 10^6$; (R = 30 kpc)

$N_\nu$capture(KATRIN) = $1.7x10^{-6}\ n_\nu/<n_\nu>$ ($year^{-1}$)
= 1.7 [counts per year]

Effective Tritium Source: 20 microgram → 2 milligram
$N_\nu$capture(KATRIN*) = $1.7x10^{-4}\ n_\nu/<n_\nu>$ ($year^{-1}$)
= 170 [counts per year]

Summary 1

- The Cosmic Microwave Background allows to study the Universe

  300 000 year after the BB.

- The Cosmic Neutrino Background

  1 sec after the Big Bang (BB):

  T_ν(today) = 1.95 Kelvin

Summary 2

1. Average Density: $n_{\nu e}$ = 56 [Electron-Neutrinos/cm^{-3}]
   Katrin: 1 Count in 590 000 Years
   Gravitational Clustering of Neutrinos $n_\nu/\langle n_\nu\rangle < 10^6$
   → 1.7 counts per year (2 milligram ^3H→ 170 per year)

2. Measure only an upper limit of n_ν