TROITSK NU-MASS: from electron to sterile neutrino

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Historic remark

Vladimir Lobashev (1934-2012)
– the inspirer and the actual leader of the experiment

From 1994 to 2004 "Troitsk nu-mass" experiment performed direct measurements of the electron anti neutrino mass in Tritium beta decay

Final data are on top of the list in Particle Data Group

Citation: J. Beringer *et al.* (Particle Data Group), PR **D86**, 010001 (2012) and 2013 partial update for the 2014 edition (URL: http://pdg.lbl.gov)

Neutrino Properties

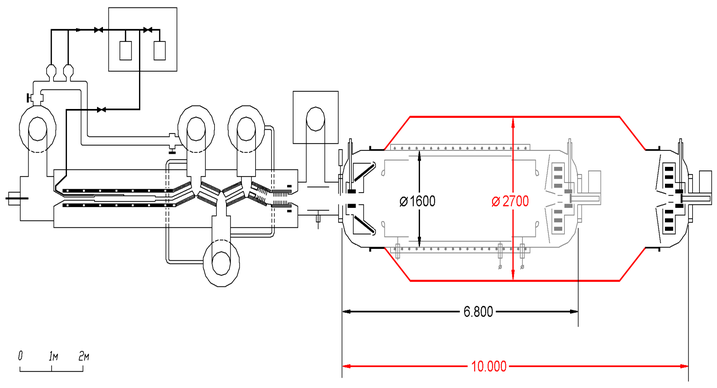
A REVIEW GOES HERE – Check our WWW List of Reviews

$\overline{\nu}$ MASS (electron based)

Those limits given below are for the square root of $m^{2(\mathrm{eff})}_{\nu_e} \equiv \sum_i |U_{ei}|^2 m^2_{\nu_i}$. Limits that come from the kinematics of $^3\mathrm{H}\beta^-\overline{\nu}$ decay are the square roots of the limits for $m^{2(\mathrm{eff})}_{\nu_e}$. Obtained from the measurements reported in the Listings for "$\overline{\nu}$ Mass Squared," below.

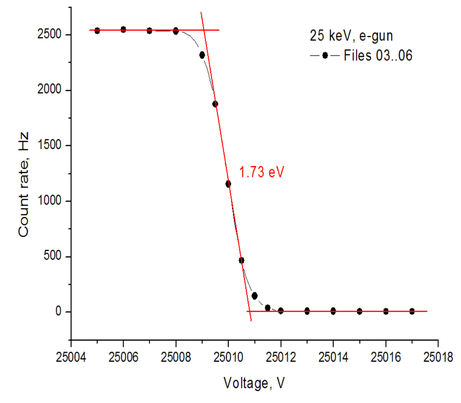
VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT
< 2 OUR EVALUATION					
< 2.05	95	[1] ASEEV	11	SPEC	^{3}H β decay
< 2.3	95	[2] KRAUS	05	SPEC	^{3}H β decay

2005-2009 Design and construction of new spectrometer:

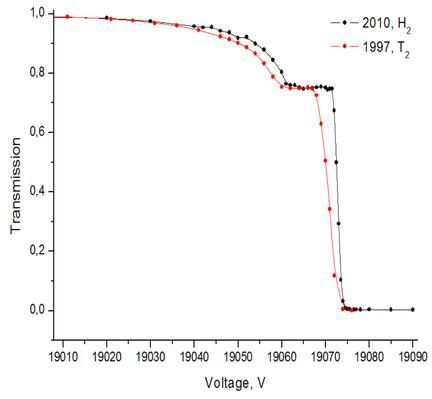


New spectrometer of "Troitsk nu-mass":
new spectrometer vessel, new electrode, + old superconducting coils + old Windowless Gaseous Tritium Source

View of 10 m - long new spectrometer



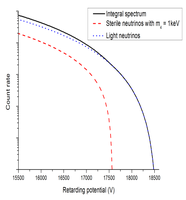
Commissioning in 2010. Two times better energy resolution ~ 1.5-1.8 eV



Measurement of electron scattering in H2 Compared to old spectrometer vessel

Meanwhile...

Reanalyze old data in a search of sign of sterile neutrino

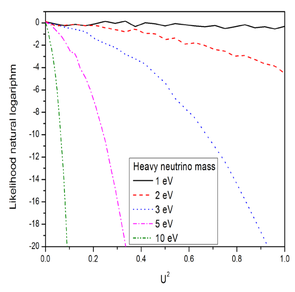


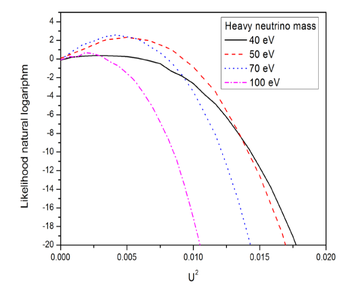
Split description of our integral spectrum into "normal" and "exotic" parts

$$S(E) = NF(E)(E+m_e)p_e(E_0-E)\cdot\left[U^2_{e4}\sqrt{(E_0-E)^2-m_4^2}+(1-U^2_{e4})(E_0-E)\right]$$

Use 4-dimentional **likelihood function** by construct the following expression: product over all points in the spectrum

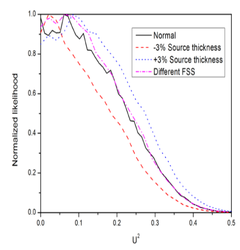
$$L(U^2_{e4}, E_0, N, bkg) = \prod_i \frac{1}{\sqrt{2\pi}\mu_i} e^{-\frac{(X_i-\mu_i)^2}{2\mu_i}}$$

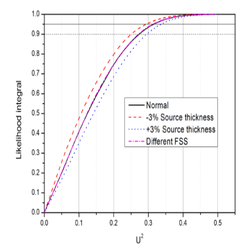


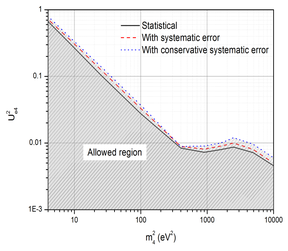


After integration over non-significant parameters

Check for systematics and then integrate likelihood functions, like this for m_4 = 5 eV



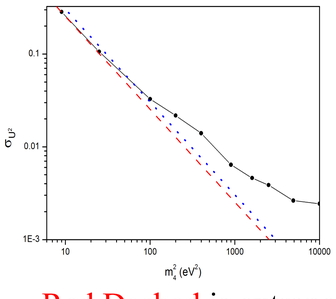




Finally, get 95% C.L.

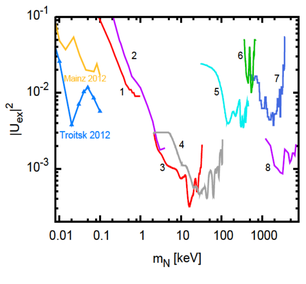
J. of Phys. G41 (2014) 015001, arxiv:1307.5687

Cross check: errors for published electron neutrino limit and for additional heavy mass are related at small m_4 $\quad \sigma(U^2_{e4}) \approx \frac{\sigma(m^2_\nu)}{m^2_4}$.



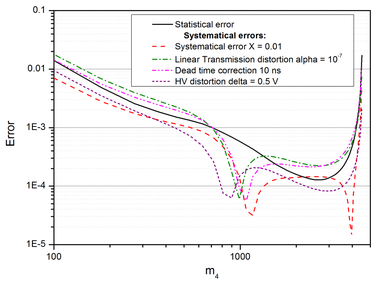
Red Dashed is extrapolation from Troitsk data, blue dots – from Mainz data; black dots and line are the current result for m_4

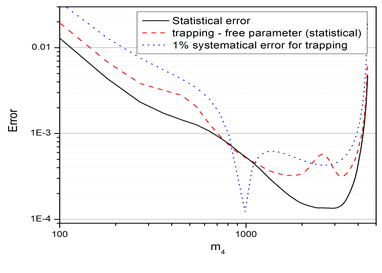
Upcoming plans: Go to a few keV heavy mass by measuring Tritium spectrum with the same apparatus in 14-19 keV range



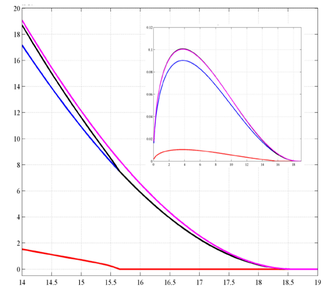
Current limits: data are taken from
1. M. Galeazzi et al., PRL 86 (2001) 1978
2. K.H. Hiddemann, H. Daniel, O. Schwentker, JPG 21 (1995) 63
3. E. Holzschuh et al., PL B451 (1999) 247
4. E. Holzschuh et al., PL B482 (2000) 1
5. K. Schreckenbach et al., PL 129B (1983) 265
6. M.M. Hindi et al., PR C58 (1998) 2512
7. M. Trinczek et al., PRL 90 (2003) 012501
8. J. Deutsch, M. Lebrun, R. Prieel NP A518 (1990) 149

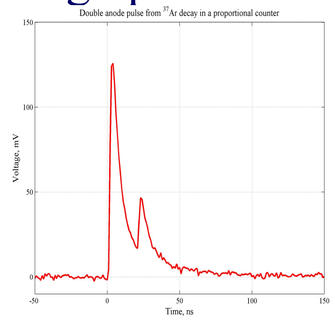
Error estimate after 20 days of running





Another approach: to measure the whole Tritium beta-spectrum with high precision





Use technique of pure quartz gas proportional counter with carbon cathode.
The major difference – fast signal readout with streaming at about 2 GS/sec sampling. Looking for collaborators !