



First Light Sterile Neutrino Results from KATRIN



Thierry Lasserre (CEA & APC), on behalf the KATRIN collaboration XIX International Workshop on Neutrino Telescopes, 24/02/2021



KATRIN measurement concept





KATRIN Working Principle

Windowless gaseous tritium source

- molecular tritium in closed loop system
- 10¹¹ decays/s





KATRIN Working Principle

Transport section

- magnetic guidance of electrons (@ 4 T)
- tritium flow reduction by > 10^{14} + tritium ion removal





KATRIN Working Principle









Measurement strategy

- # HV set points: 27
- interval: $E_0 40 eV, E_0 + 50 eV$
- scanning time: **2 hours**
- # scans: 274
- HV stability: **35 mV (ppm-level)**
- Background: 293 mcps





cea

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First KATRIN Neutrino Mass Result



Thierry Lasserre – XIX International Workshop on Neutrino Telesco KATRIN Collab, Phys. Rev. Lett. 123, 221802

eV-Sterile neutrino signature in KATRIN







Sterile $\boldsymbol{\nu}$ search in first science run

- same data set as for neutrino mass
- 3+1 sterile neutrino model
- grid search in $(m_4)^2$, $\sin^2 \theta$ plane



Sterile Neutrino Modeling



$$\frac{d\Gamma}{dE} = (1 - |U_{e4}|^2) \frac{d\Gamma}{dE} (m_{\beta}^2) + |U_{e4}|^2 \frac{d\Gamma}{dE} (m_{4}^2)$$

$$\lim_{k \to \infty} \lim_{k \to \infty}$$

Fit Parameters:

Ν

- m² neutrino mass (fixed/free/constrained)
- **E**_{0,fit} endpoint
 - signal normalization
- B energy-independent background rate

 m_4^2 4th neutrino mass $|U_{e4}|^2$ 4th neutrino mixing

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В





KATRIN 3+1 Neutrino Fit (40 eV range)



No evidence for sterile neutrino signal

Best fit	3v (NH)	3+1
m_4^2	-	73.0
$ \text{Ue}_4^2 $	-	0.034
p – value	0.41	0.50
χ^2	22.9	21.3
$\Delta \chi^2$	1.6 (54.5% C.L)	

Confidence Interval (95 % C.L.)

APC, CHIES, FRANCE

- χ^2 analysis, systematic effects included via covariance matrix
- Likelihood ratio for given sterile parameters: $\Delta \chi^2 (|U_{e4}|^2, m_4^2) = \chi^2 (|U_{e4}|^2, m_4^2) \chi^2_{best}$



Good approximation by Wilks' theorem: $\Delta \chi_c^2 = 5.99$ for the 95% C.L. 95 % quantile of χ^2 distribution with 2 dof was verified with >5000 MC simulations ($\Delta \chi_c^2 = 6.18$)

Case i) 40 eV fit range, m_{β} = 0 eV fixed



- Results in the $|U_{e4}^2|$ m_4^2 plane
- m_{β} = 0 eV fixed
- Sensitive to
 - $m_4^2 < 1000 \,\mathrm{eV^2}$
 - |U_{e4}|² > 0.02
- Limit directly comparable to Mainz/Troitsk

Case ii) 40 eV fit range, free m_{eta}





• Free m_{β}

- $ightarrow m_{eta}$ can be negative
- The most generic analysis
- Loosing sensitivity w.r.t. case i) for m_4^2 < 60 eV²
 - $\rightarrow m_{\beta}$ and m_4 correlation at large $|\text{Ue}_4^2|$

Synergy with oscillation experiments





- $\Delta m_{41}^2 = m_4^2 m_1^2 \approx \Delta m_{42}^2 \approx \Delta m_{43}^2$
- $\sin^2 2\Theta = 4 |U_{e4}|^2 (1 |U_{e4}|^2)$
- KATRIN
 - m_β and m_4
 - $\sin^2\Theta = |U_{e4}|^2$
- Conversion KATRIN -to- Oscillation
 - $\Delta m_{41}^2 \simeq m_4^2 m_\beta^2$
 - $sin^2 2\Theta = 4 sin^2 \Theta (1 sin^2 \Theta)$
- Projected KATRIN final sensitivity (1000 days of data – reduced background)



Conclusion

- High-quality data collected over 780 hours @25 GBg in 2019
- 2019: World Best Direct Neutrino Mass Measurement:

 m_{ν} < 1.1 eV (90% C.L.), Phys. Rev. Lett. 123, 221802

- 2020: First Results on the light sterile neutrino search, arXiv:2011.05087
- Currently : x 10 more statistics already acquired,

 \rightarrow New data release expected soon

 $\widetilde{}$ Z 0 [hep-ex] v1.05087 arXiv:201

Bound on 3+1 active-sterile neutrino mixing from the first four-week science run of KATRIN

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We report on the light sterile neutrino search from the first four-week science run of the KATRIN experiment in 2019. Beta-decay electrons from a high-purity gaseous molecular tritium source are analyzed by a high-resolution MAC-E filter down to 40 eV below the endpoint at 18.57 keV. We consider the framework with three active neutrinos and one sterile neutrino of mass m_{A} . The analysis is sensitive to a fourth mass state $m_4^2 \lesssim 1000 \text{ eV}^2$ and to active-to-sterile neutrino mixing



KATRIN

- Experimental site: Karlsruhe Institute of Technology (KIT)
- International Collaboration (150 members)
- Design sensitivity: 0.2 eV (90% CL)
 (1000 days of measurement time)



Thank you for your attention

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Tritium spectrum calculation



Y.-T. Lin et al, Phys. Rev. Lett. **124**, 222502 (2020)

A. Saenz et al, Phys. Rev. Lett. 84, 242 (2000) + updates serre – XIX International Workshop on Neutrino Telescop

M. Kleesiek et al, EPC C, 79 (3) (2019)

Complementary Investigations





10³

Case iii) 40 eV fit range, constrained m_{β}





• Constrained m_{eta}

Arbitrary constraint value, for illustration : 1 eV²

- Intermediate case, for illustration of the impact of an external constraint (here $m_{eta} < 1 \, \text{eV}$)
- Could be later used with with a bound from cosmology for instance

Interplay with $0\nu\beta\beta$ experiments

