

# The Status of the keV-scale sterile neutrino search with KATRIN

Anton Huber for the KATRIN Collaboration

Vist at the TROITSK Nu-mass II Experiment December 2016



## **Overview**



### The KATRIN Experiment and the neutrino mass

- Main goal of KATRIN
- Measurement principle and components
- Status
- The KATRIN Experiment and sterile neutrinos
  - Imprint of a sterile neutrino on tritium beta decay
  - How to use KATRIN
  - Two main planned measurement and sensitivity
    - Phase-0 with current setting
    - Phase-1 with new Detector
- Conclusion and time to discuss

# The KATRIN experiment





# The stoy of KATRIN includes a long journey...





# ... with some tight situations...





# ... and some very big machines...





# ... and many curious people ...





# ... and finaly...





# ... the final destination!





7090 (2004)

KATRIN Collaboration, FZKA Scientific Report

Improvement of a factor of 10

sensitivity of years

- Probing the neutrino mass with a  $m(v_e) = 200 \text{ meV} (90\% \text{ CL}), \text{ after } 3$

# **KATRIN** Experiment













Gaseous molecular tritium source of high **stability**: (< 10<sup>-3</sup>) and **luminosity**: (10<sup>11</sup> decays/sec)

# The KATRIN experiment





# The KATRIN experiment



















**Detector Section** 



retarding potential U [eV]





- All Components are on the site
- Alignment and connection are prepared, all parts connected
- First Light measurement took place on 14<sup>th</sup> of October this year

# The first alignment measurements





ramping of the pre-spectrometer magnet (variing the size of the flux tube)

# The first alignment measurements



- first alignment measurments has been performed this november
- everything is fine and works as expected
- at the moment: "Chrismas Break" for maintainance work
- the next measurement phase with more calibration and comissioning measurements starting in march/april next year
- Nu-mass data taking starting next autumn

... and, there is also something important to do ...

# KATRIN and the keV-scale sterile neutrino

# **Tritium beta decay**





# **Tritium beta decay**





# **Tritium beta decay**





# Imprint of sterile v's on $\beta$ -spectrum





# Imprint of sterile v's on $\beta$ -spectrum





# **Cosmological constraints**





# **Cosmological constraints**





# The challenge of sterile v search





# **Statistical sensitivity**



## PRELIMINARY



# Karlsruhe Institute of Technology

# Theoretical corrections to the $\beta$ -spectrum



# **Detailed sensitivity studies**



#### Spectral fit approach:

"How do theoretical uncertainties impact the sensitivity to find the signature of a sterile neutrino ?"



Sensitivity of next-generation tritium beta-decay experiments for keV-scale sterile neutrinos

S. Mertens,<sup>a,d</sup> T. Lasserre,<sup>b,c</sup> S. Groh,<sup>d</sup> G. Drexlin,<sup>d</sup> F. Glück,<sup>d,f</sup> A. Huber,<sup>d</sup> A.W.P. Poon,<sup>a</sup> M. Steidl,<sup>d</sup> N. Steinbrink<sup>e</sup> and C. Weinheimer<sup>e</sup>

### Wavelet approach:

"Is a precise knowledge of the spectrum necessary to find the signature of a sterile neutrino ?"



#### Wavelet Approach to Search for Sterile Neutrinos in Tritium $\beta$ -Decay Spectra

S. Mertens,<sup>1,2</sup> K. Dolde,<sup>2</sup> M. Korzeczek,<sup>2</sup> F. Glueck,<sup>2,3</sup> S. Groh,<sup>2</sup> R. D. Martin,<sup>1,\*</sup> A. W. P. Poon,<sup>1</sup> and M. Steidl<sup>2</sup>

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Systematic effects related to :

- Source Section
  - scattered electrons arrive at detector







Systematic effects related to :

Source Section

- scattered electrons arrive at detector
- Spectrometer Section
  - electrons pass through spectrometer with high surplus energy





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#### Visit at TROITSK December 2016

# Ongoing sensitivity studies

Systematic effects related to :

Rear Wall

- back scattering and auger electrons
- Detector Section
  - Backscattering
  - Charge sharing
  - Pile-up
  - Etc.

Investigated by E. Foerstner

Investiagted by Kai Dolde & Marc Korzeczek Masters Thesis Work of P.V. Grigorieva at KIT



### ... investigations still ongoing.







![](_page_39_Figure_0.jpeg)

![](_page_40_Figure_0.jpeg)

![](_page_41_Figure_0.jpeg)

# How to use KATRIN – the two measurements

![](_page_42_Picture_1.jpeg)

![](_page_42_Figure_2.jpeg)

> will be performed very soon> requiers a 'improvised' rate reduction

> requiers a new detector system> will be performed after KATRINdetermined the neutrino mass

# How to reduce the rate – phase-0

![](_page_43_Picture_1.jpeg)

![](_page_43_Figure_2.jpeg)

# How to reduce the rate – phase-0

![](_page_44_Picture_1.jpeg)

![](_page_44_Figure_2.jpeg)

# How to reduce the rate – phase-0

![](_page_45_Picture_1.jpeg)

![](_page_45_Figure_2.jpeg)

# **Novel detector design – phase-1 measurement**

![](_page_46_Picture_1.jpeg)

![](_page_46_Figure_2.jpeg)

# **Tristan Prototoype**

· 'sruhe Institute of Technology

- Key design features:
  - Very small point contacts
  - Thin entrance window (~10 nm)
  - Shared steering electrode
- HLL Max-Planck society Munich (experts on drift rings)
- LBNL in Berkeley (experts on thin deadlayers)
- develop low noise front-end electronics
  - at KIT, Karlsruhe
  - At CEA, Paris

![](_page_47_Picture_11.jpeg)

# **Tristan Prototoype**

![](_page_48_Picture_1.jpeg)

![](_page_48_Picture_2.jpeg)

![](_page_48_Picture_3.jpeg)

# **Tristan Prototoype**

![](_page_49_Picture_1.jpeg)

![](_page_49_Figure_2.jpeg)

,First Light' of TRISTAN Prototype measured at CEA

# **Preliminary Sensitivity**

![](_page_50_Picture_1.jpeg)

the phase-0 measurement

the phase-1 measurement

![](_page_50_Figure_4.jpeg)

# **Preliminary Sensitivity**

![](_page_51_Picture_1.jpeg)

the phase-0 measurement

the phase-1 measurement

![](_page_51_Figure_4.jpeg)

# **Summary and Conclusion**

![](_page_52_Picture_1.jpeg)

- The KATRIN Experiment Status
  - All components on-site
  - Alignment and final comissioning at the moment
  - Detailed commisoning measurements sheduled for next year
  - start data taking end of next year
- The KATRIN Experiment and sterile neutrinos
  - with the KATRIN source: statistical sensitivity  $\sin^2 \theta < 10^{-8}$
  - Study of **systematic uncertainties** is ongoing (goal is to optimize the experiment to reach a sensitivity of  $sin^2 \theta < 10^{-7}$
  - Two measurement ideas: teh phase-0 and the phase-1
  - **phase-0** will take place mid 2017 (preliminary:  $sin^2 \theta < 10^{-4}$ )
  - A new detector system (TRISTAN) is currently developed at KIT, CEA and Munich

#### Thanks for your attention

And special thanks to:

- N. Titov for inviting me and helping me to prepare this visit in Troitsk
- Susanne Mertens, TUM Munich
- Thierry Lasserre, CEA Paris
- David Radford, Oak Ridge
- Kai Dolde, KIT
- Marc Korzeczek, KIT
  - Ferenc Glück, KIT
  - Joachim Wolf, KIT
  - Guido Drexlin, KIT

# Hello from the entire KATRIN Collab.