**General Scientific Goals**

- Incorporation of massive neutrinos in the SM.
- Search for neutrino oscillation pattern.
- Number of neutrino flavors? Sterile neutrinos?
- High-precision measurements and determination of all neutrino mixing parameters.
- Confirmation of the MSW effect.
- Investigation of the Earth matter density profile.
- Astrophysical aspects.
Recent $\nu$’s from Experiments

- **June 1998**: Super-Kamiokande. Strong evidence for atmospheric neutrino oscillations. \( \Rightarrow \) Neutrinos are massive.

- **June 2001**: SNO. First direct indication of a non-electron neutrino flavor component in the solar neutrino flux.

- **April 2002**: SNO. Total solar neutrino flux measured via NC interactions is consistent with the SSM.

- **December 2002**: KamLAND. Reactor $\bar{\nu}_e$ disappearance at high C.L. Confirmation of the LMA solution.
The Nobel Prize in Physics 2002

December 10, 2002:

“for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos”

Raymond Davis Jr.  Masatoshi Koshiba
(Homestake)  (Kamiokande)
Present Values of the Neutrino Oscillation Parameters

Neutrino mixing:

\[ U = \begin{pmatrix}
C_{13}C_{12} & S_{12}C_{13} & S_{13}e^{-i\delta_{CP}} \\
-S_{12}C_{23} - S_{23}S_{13}C_{12}e^{i\delta_{CP}} & C_{23}C_{12} - S_{23}S_{13}S_{12}e^{i\delta_{CP}} & S_{23}C_{13} \\
S_{23}S_{12} - S_{13}C_{23}C_{12}e^{i\delta_{CP}} & -S_{23}C_{12} - S_{13}S_{12}C_{23}e^{i\delta_{CP}} & C_{23}C_{13}
\end{pmatrix}, \]

where \( S_{ab} \equiv \sin \theta_{ab} \) and \( C_{ab} \equiv \cos \theta_{ab} \).

Neutrino mass squared differences:

\[ \Delta m_{ab}^2 = m_a^2 - m_b^2, \]

where \( m_a \) (\( a = 1, 2, 3 \)) is the mass of the \( a \)th neutrino mass eigenstate.
**Present Values of the Neutrino Oscillation Parameters**

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<td>$\Delta m_{21}^2$</td>
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**: Bilarge leptonic mixing, i.e., $\theta_{12}$ and $\theta_{23}$ are large and $\theta_{13}$ is small.**
The Research Group

Research Topics & Interests:

- Neutrino oscillations (three flavors, in matter)
- Alternative scenarios: neutrino decoherence and neutrino decay
- Matter density effects for LBL experiments
- Neutrino oscillation tomography
- Supernova neutrinos
- Neutrino mass models (matrix textures)
- Deconstructed large extra dimensions
The Research Group

Personnel – KTH Neutrino Theory:

- Håkan Snellman, professor
- Tommy Ohlsson, assistant professor
- David Bergström, diploma student
- Tiglet Besara, diploma student
- Magnus Jacobson, diploma student
- Robert Johansson, diploma student
- Diego Pallin, diploma student
The Research Group

International Collaborators:

- Manfred Lindner, TUM, Munich, Germany
- Gerhart Seidl, TUM, Munich, Germany
- Walter Winter, TUM, Munich, Germany
- Ricard Tomàs, MPI, Munich, Germany
- Samoil M. Bilenky, JINR, Dubna, Russia
- Evgeny Kh. Akhmedov, IST, Lisboa, Portugal
- Yasaman Farzan, SLAC, Stanford, USA
Current Research Projects

Bergström, Ohlsson & Snellman:
“Series Solutions of Neutrino Oscillations in Matter with Linear Density Variation”

- Power series solutions of third order ordinary differential equations
- Constant matter density – the unperturbed problem
- Linear term as a small perturbation
- Algorithm for an arbitrary matter density distribution
Current Research Projects

Pallin & Snellman:
“Quantum Field Theory Treatment of Neutrino Oscillations in Vacuum and in Matter”

- QFT of neutrino oscillations
- Wave packets
- Green’s functions in matter
- Two flavor resonance formula for neutrino oscillations in matter
Current Research Projects

Jacobson & Ohlsson:
“Extrinsic CPT violation in Neutrino Oscillations in Matter”

- Neutrino oscillation transition probabilities
- Perturbation theory of the evolution operator
- Derivation of CPT probability differences
- A special case: step-function matter density profiles
- Numerical examples
**Current Research Projects**

**Besara & Snellman:**

“The Nature of the Neutrinos: Dirac versus Majorana”

- Massive neutrinos
- Discrete symmetries and lepton numbers
- Electromagnetic properties of massive neutrinos
- Search for Majorana neutrinos: double $\beta$-decay
Current Research Projects

Ohlsson & Winter:
“The Role of the Earth’s Matter Density for LBL Neutrino Oscillation Experiments”

- The relevance of matter effects. Models for the Earth’s matter density uncertainty.
- The mean density as measured quantity. Random fluctuations.
- The Fourier expansion method. Uncertainty in the mean density (= first Fourier coefficient).
- Examples for the effects of the Earth’s matter density and its uncertainty.
- Superbeams and neutrino factories.
Current Research Projects

Ohlsson & Seidl:
“Deconstructed Extra Dimensions and Neutrino Oscillations”

- Probing deconstructed extra dimensions with neutrinos. Investigation of neutrino oscillations using different topologies of theory space.
- Neutrino oscillation patterns. Derivation of neutrino oscillations transition probabilities using deconstructed extra dimensions.
- Investigation of the influence from Kaluza–Klein states on three flavor neutrino oscillations.
Recent Publications (2002 – )

- B. Jacobsson, T. Ohlsson, H. Snellman, and W. Winter
  *Effects of Random Matter Density Fluctuations on the Neutrino Oscillation Transition Probabilities in the Earth*
  hep-ph/0112138

- B. Jacobsson, T. Ohlsson, H. Snellman, and W. Winter
  *The Effects of Matter Density Uncertainties on Neutrino Oscillations in the Earth*
  J. Phys. G (to be published)
  hep-ph/0209147
Recent Publications (2002 – )

- M. Lindner, T. Ohlsson, and W. Winter
  Decays of Supernova Neutrinos
  astro-ph/0105309

- M. Lindner, T. Ohlsson, R. Tomàs, and W. Winter
  Tomography of the Earth’s Core Using Supernova Neutrinos
  Astropart. Phys. (to be published)
  hep-ph/0207238

- T. Ohlsson
  Testing CPT Invariance with Neutrinos
  hep-ph/0209150