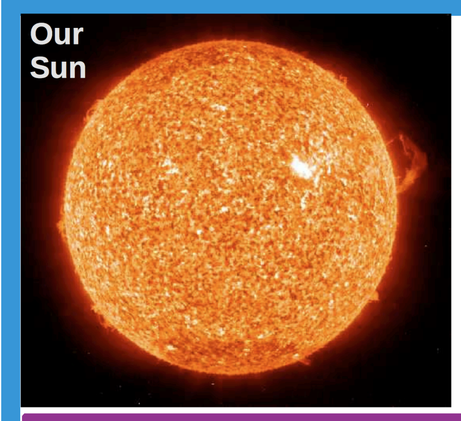
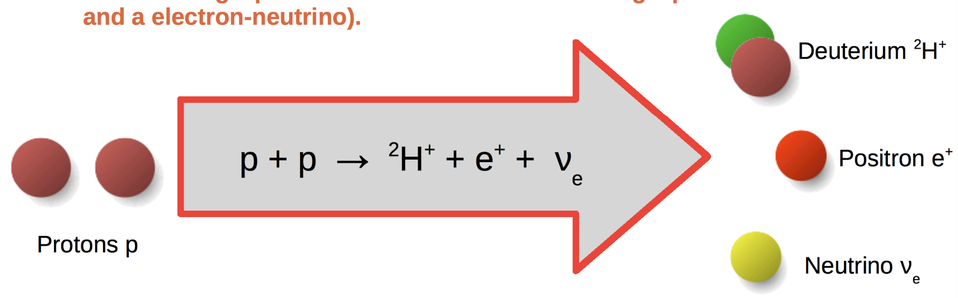
Neutrinos – mysterious Particles

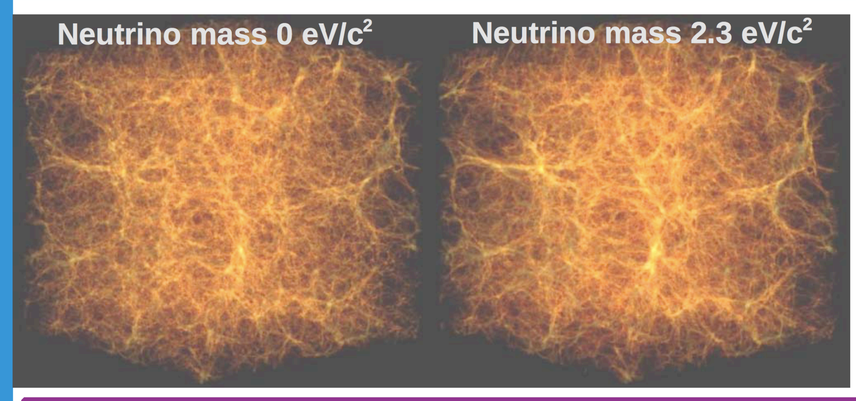


Thermonuclear FUSION inside the SUN
Two protons fusing together to a deuterium nucleus (by transforming a proton to a neutron while releasing a positron and a electron-neutrino).



Neutrinos are the lightest known elementary particles; they are electrical neutral and rarely interact with ordinary matter. There are 3 families/types of neutrinos. Neutrinos are produced in multiple reactions, e.g. in nuclear fusion like inside of our sun. Scientists tried to weigh the mass of the neutrino, however, no scale was precise enough to date. So it is lighter than one part in a billion (10^{-9}) the mass of a proton. For this reason, scientists are currently building the **KATRIN experiment** on the KIT site to measure the mass of the neutrino.

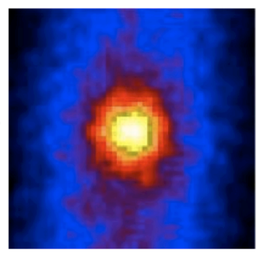
Did you know, that the sun is blowing out huge amounts of neutrinos permanently? On the earth, every second 100 billion (100.000.000.000) neutrinos are passing through each area of one square centimeter. Nuclear fusion is the energy source of the sun, during these processes the many neutrinos are just a side-product. Most neutrinos pass through the entire earth without any interaction, as well as they pass unseen and unnoticed our bodies.
The gigantic neutrino observatory KAMIOKANDE in Japan managed to catch 200-500 neutrinos per year. They computed the originating direction of the nightly detected neutrinos, which came from downwards – surprisingly, they pointed downwards and towards the sun - they had passed the entire planet earth!



Simulation of Troels Haugboelle: Todays mass distribution of the universe; Left: assuming neutrino mass 0; Right: assuming neutrino mass 2.3 eV/c^2; resulting in different distributions.

During the Big Bang many neutrinos were produced. They play a important role in the structure development of our universe (filaments, clusters, galxies), as they are so numerous, although their mass is so tiny – for the past as well as for the future.

The sun seen in “neutrino light” through the entire earth.

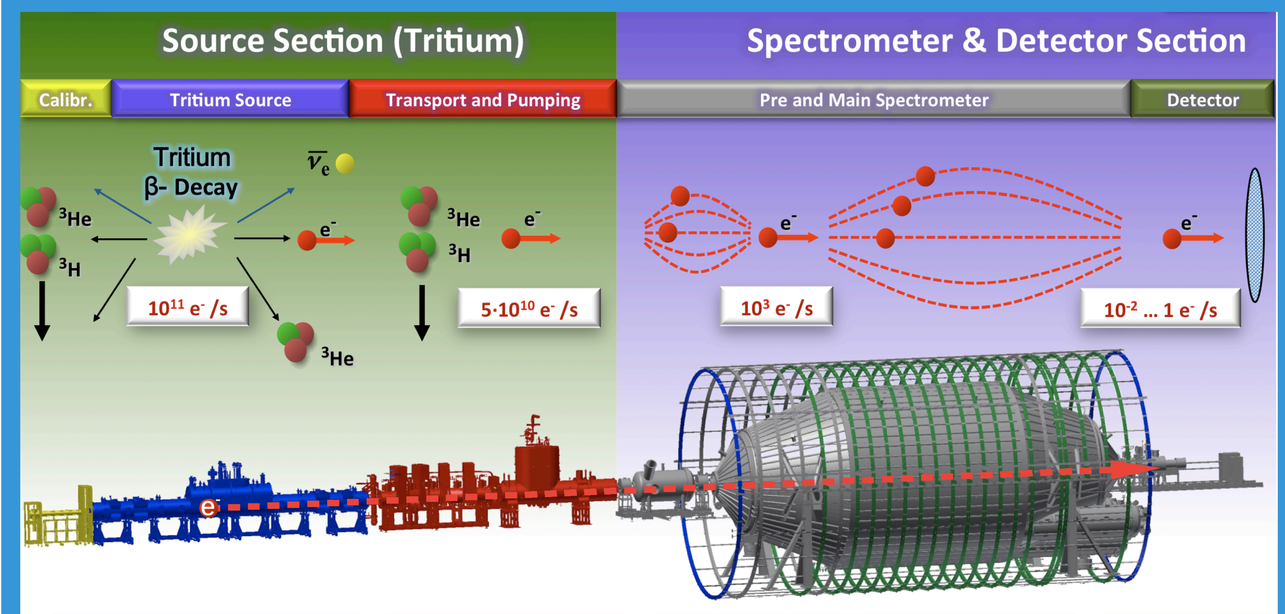


KAMIOKANDE (Japan): Image of the sun in “neutrino light”

1 square centimeter → 100.000.000.000 neutrinos per second

1 cm^2

KATRIN – The Karlsruhe Tritium Neutrino Experiment



The Tritium decay produces one anti-neutrino and one electron. While the neutrino escapes undetected, the electron starts its journey towards the detector.

Electrons are guided magnetically toward the spectrometer, while pumping out the tritium gas.

The electron energy is measured by applying a retardation voltage. A electron is able to pass the spectrometer area, if and only if its speed respectively kinetic energy is large enough.

At the end of its journey the electron is counted in the silicon detector.

Magnetic fields: 0.0003 - 6 Tesla
Vacuum: 0.003 - 10^{-11} mbar

Geo-magnetic fields: 0.00005 Tesla
Atmospheric pressure: 1013 mbar

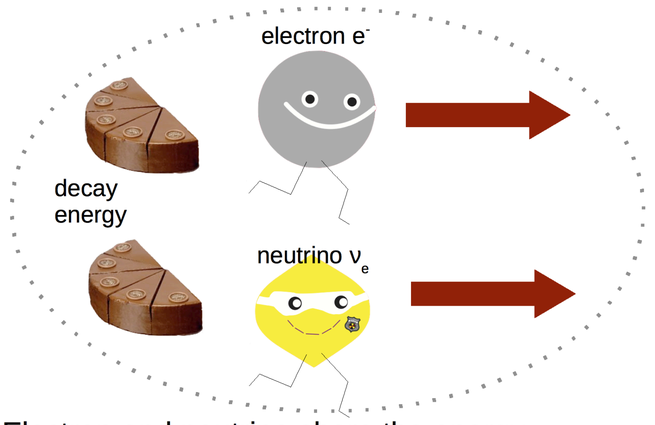
Interesting facts:
The main spectrometer is the core of KATRIN; its diameter is 10 meter, its length 23 meter and its weight 200 tons. Europe’s largest heavy-duty crane was necessary to lift it into the experiment hall.

Transport of the KATRIN main spectrometer vessel from Rhein harbour to the experiment hall on the KIT site

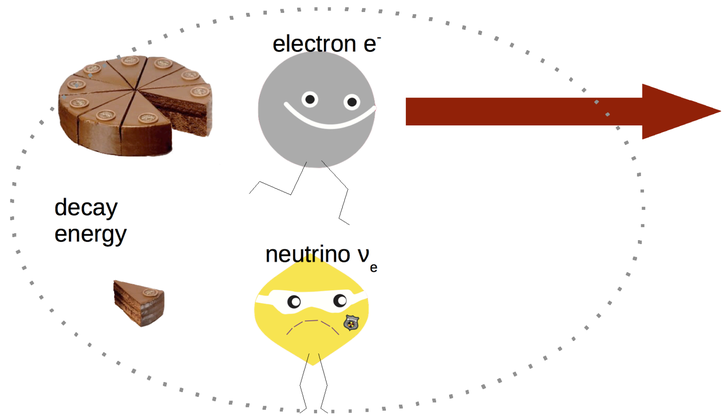
KATRINs purpose is to measure the *neutrino* mass, right? I do not understand, why we always talk about *electrons*!
Neutrinos are fleeting. After the tritium decay they just disappear – through any walls. They cannot be catched or detected directly. The physicists can trap electrons much easier than neutrinos. And they can draw conclusions from the energy of the electrons to determine the mass of the neutrino. Thus they measure the neutrino mass indirectly by measuring the energy of the electrons.

And how does this work?
Think of the released energy during the tritium decay as a cake. The electron and the neutrino need to share this cake. Each particle needs a minimal amount of of energy to produce its mass. The remaining part of the energy cake can be shared arbitrarily between both of them – this becomes kinetic energy of the according particle. The larger the piece of cake, the faster will be the speed of the particle after the decay.
Now imagine the electron grabs the largest possible piece of cake. This piece will always lack a tiny piece – the energy piece, which is required to produce the mass of the neutrino.

And how do the physicists actually realize the measurement of the neutrino mass?
They measure very precisely the speed (=kinetic energy) of the electrons. It will always lack a tiny piece of energy. This difference corresponds to the neutrino mass!



Electron and neutrino share the energy, both get kinetic energy.



Electron grabs maximum energy, all remaining energy needed for neutrino mass, no kinetic energy; electron has maximum speed.