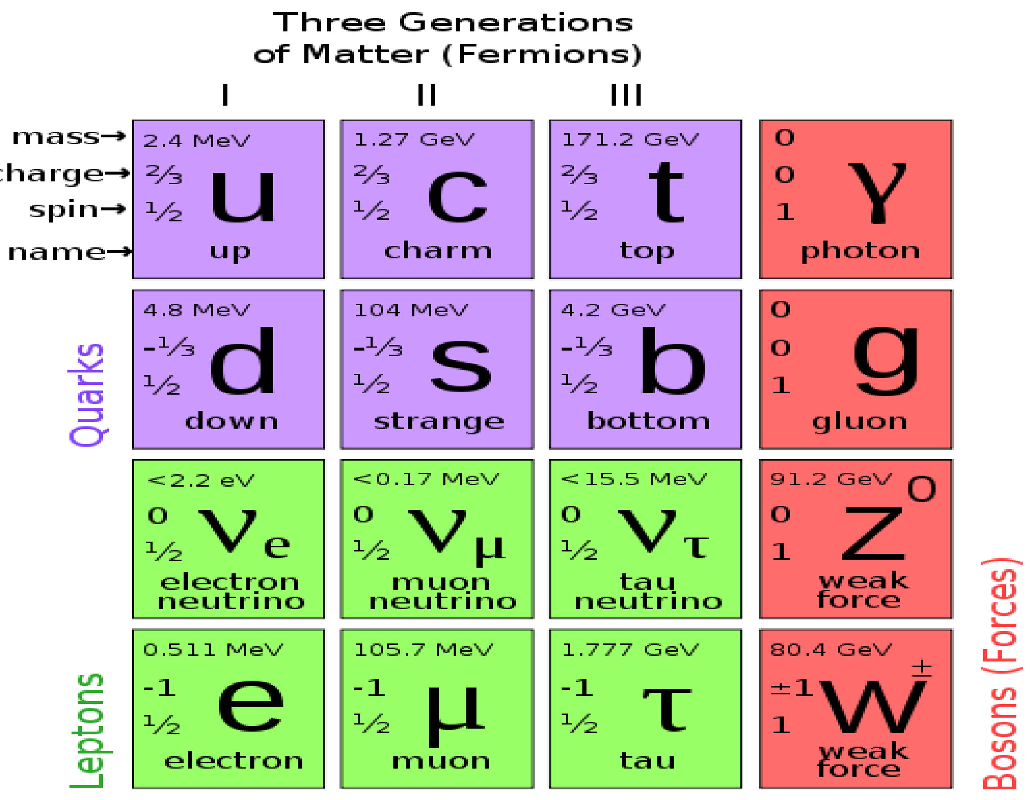
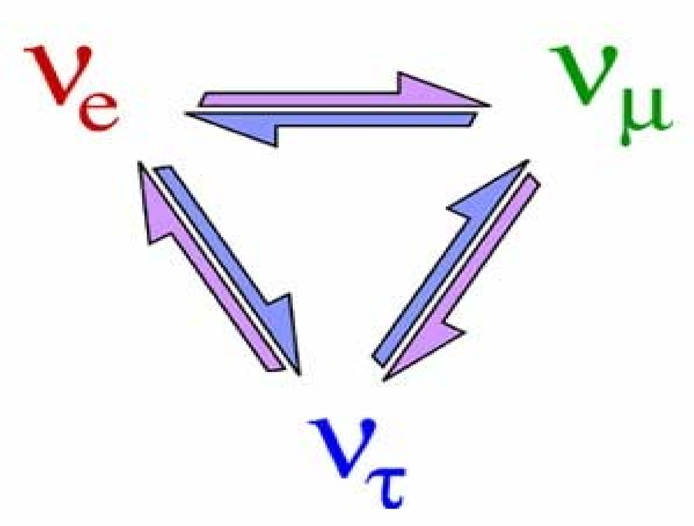
NA61 / T2K Collaboration
Neutrino Physics

The Standard Model comprises three flavours of neutrinos.



Neutrino oscillation is a quantum mechanical phenomenon. It is the transition between three lepton flavours (electron, muon and tau) of neutrinos. A neutrino created with a specific lepton flavour can later be measured to have a different flavour.

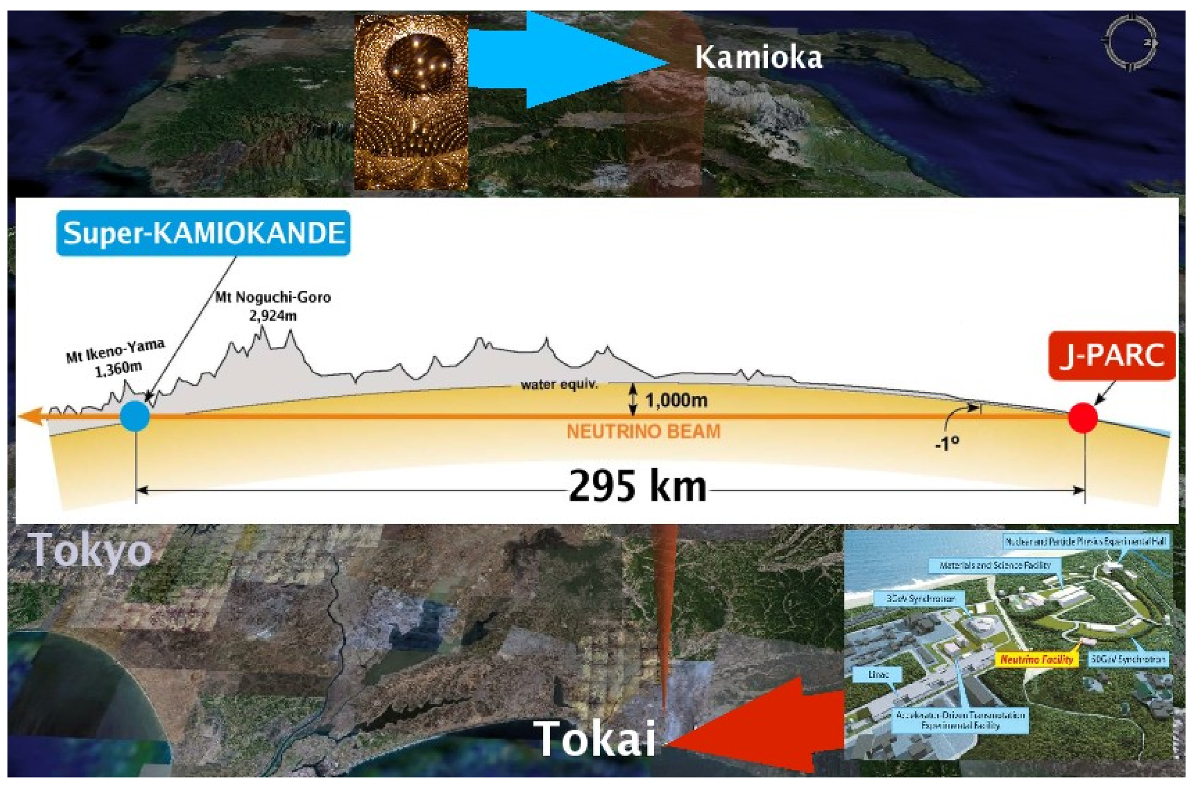


The probability of measuring a particular flavour for a neutrino varies periodically as it propagates. Neutrino oscillation is of theoretical and experimental interest since observation of the phenomenon implies that the neutrino has a non-zero mass. The oscillation probability in the two flavour case is given by:

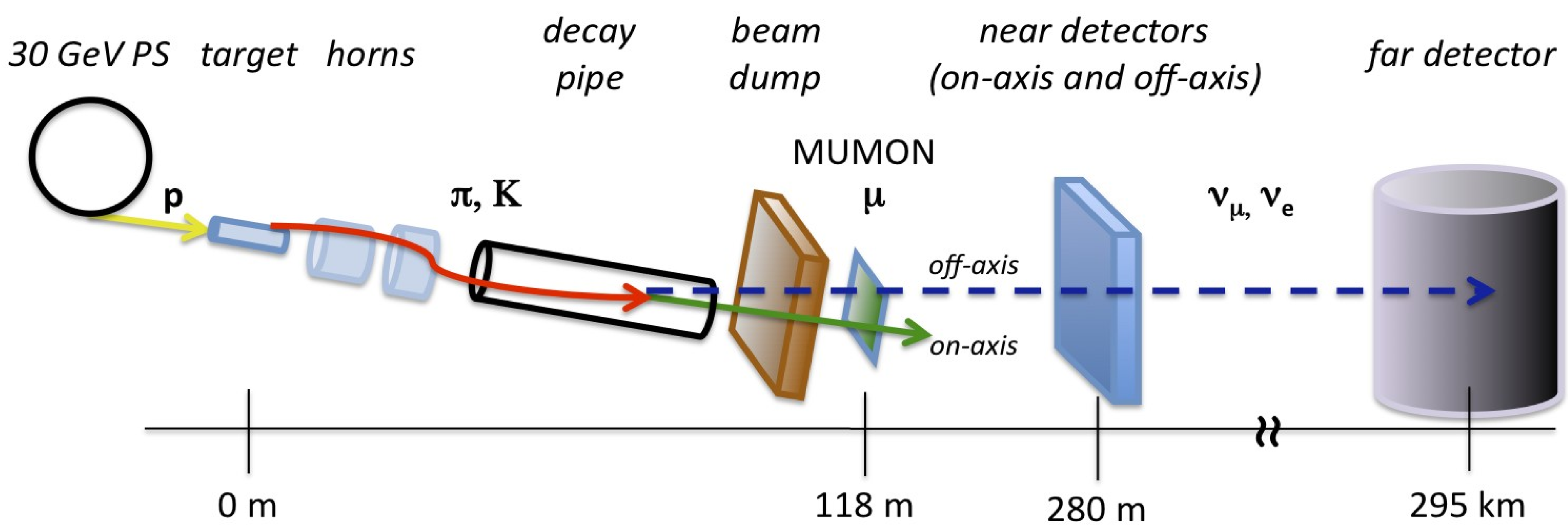
$$P_{\nu_\alpha \to \nu_\beta, \alpha \neq \beta} = \sin^2(2\theta)\sin^2\left(\frac{1.27\Delta m^2 L}{E}\frac{GeV}{eV^2 km}\right)$$

where *L* is the distance of propagation, *E* the energy of the neutrino, Δm^2 and θ are the square of the mass difference and the mixing angle between the two flavours α and β.

T2K (Tokai to Kamioka) is a long baseline neutrino oscillation experiment at J-PARC, Japan, with the aim to precisely measure the ν_μ disappearance and ν_e appearance. To generate neutrinos a high intensity 30 GeV proton beam impinging on a 90 cm long carbon target is used, whereby mesons (π, K) are produced which decay into neutrinos ($\nu_{\mu,e}$).

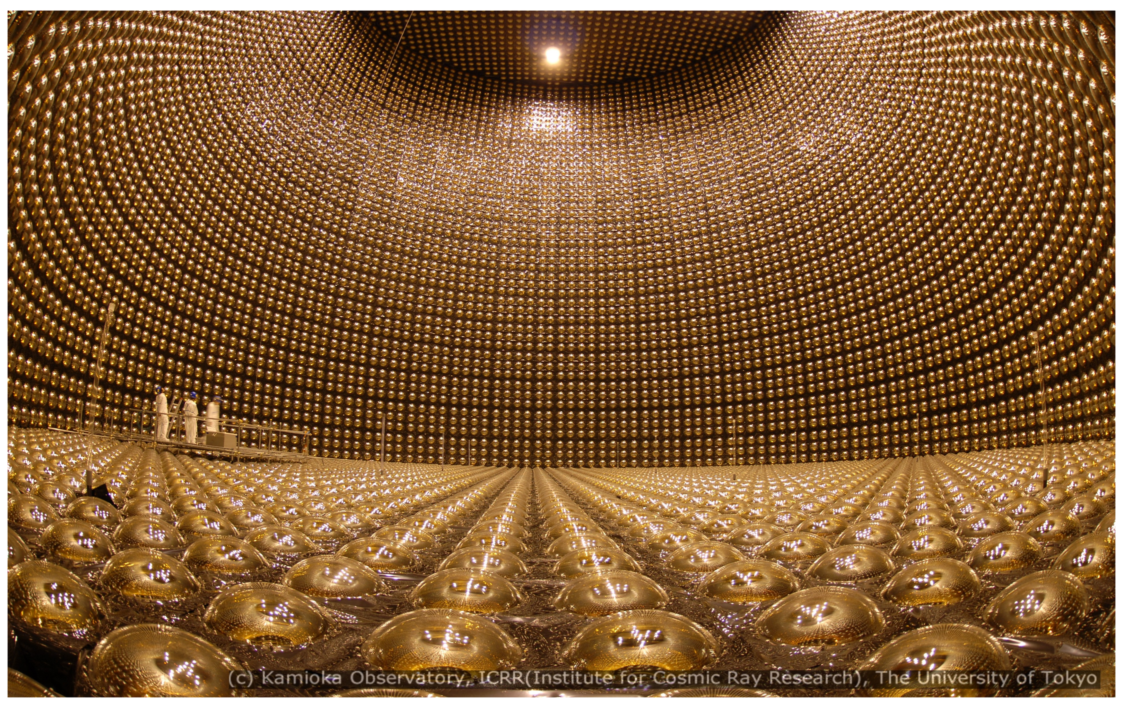


The far detector (Super-Kamiokande) is filled with 50'000 tons of pure water. A neutrino interaction with the electrons or nuclei of water can produce a charged particle that moves faster than the speed of light in water (although slower than the speed of light in vacuum). This creates a cone of light known as Cherenkov radiation which can be observed through the 11 146 photomultipliers.

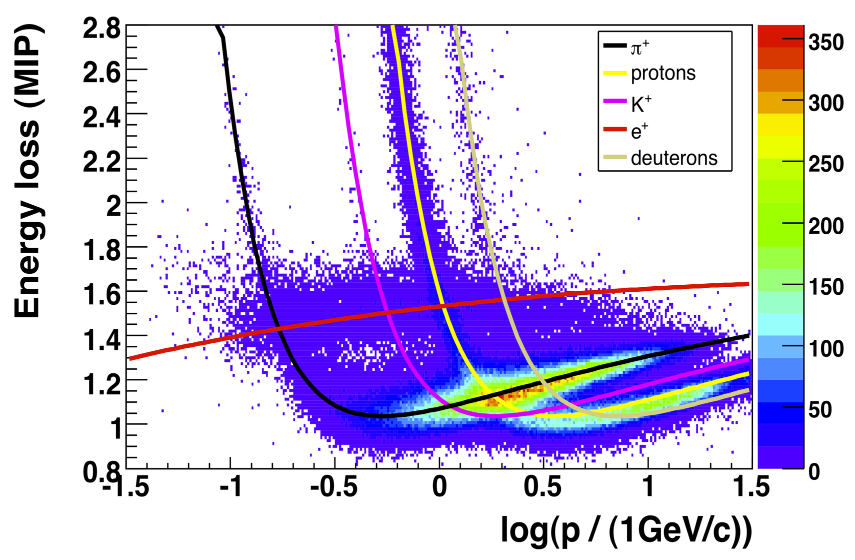


Neutrino oscillations can be probed by comparing the neutrino flux measured at Super-Kamiokande (SK) to the one predicted at SK. In order to predict the flux at SK one uses the near detector measurements and extrapolates them with the help of Monte Carlo (MC) predictions to SK. Up to now, these MC predictions depend on hadron production models. For more precise predictions measurements of pion and kaon production off the carbon target are essential. The aim of the NA61/SHINE measurements for T2K is to provide this information.

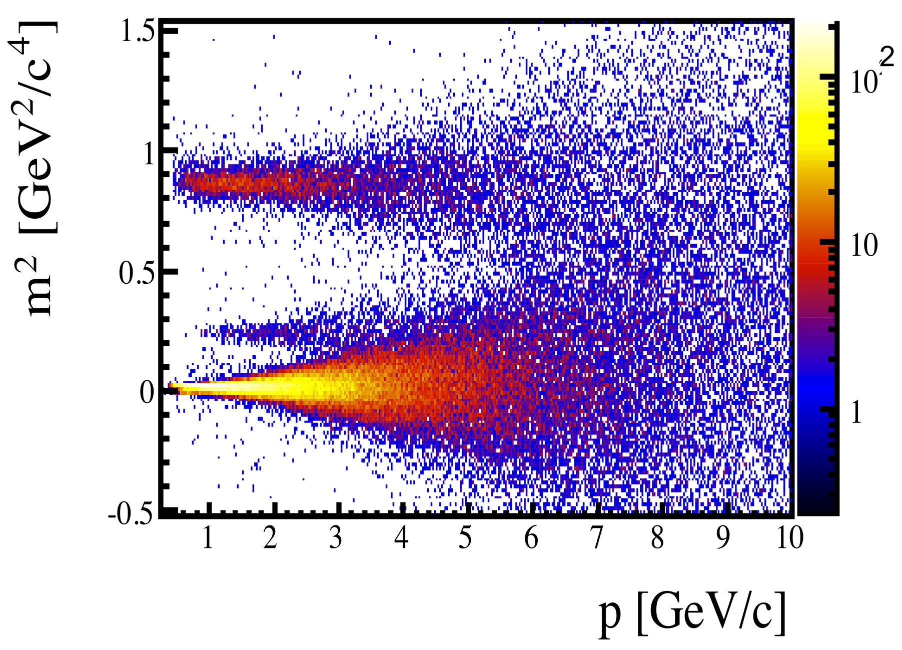
In order to identify hadrons (π, K, protons), the NA61 experiment combines two measurements:
- energy loss in **T**ime **P**rojection **C**hamber (TPCs)
- **T**ime-**o**f-**F**light in ToF walls (ToF)



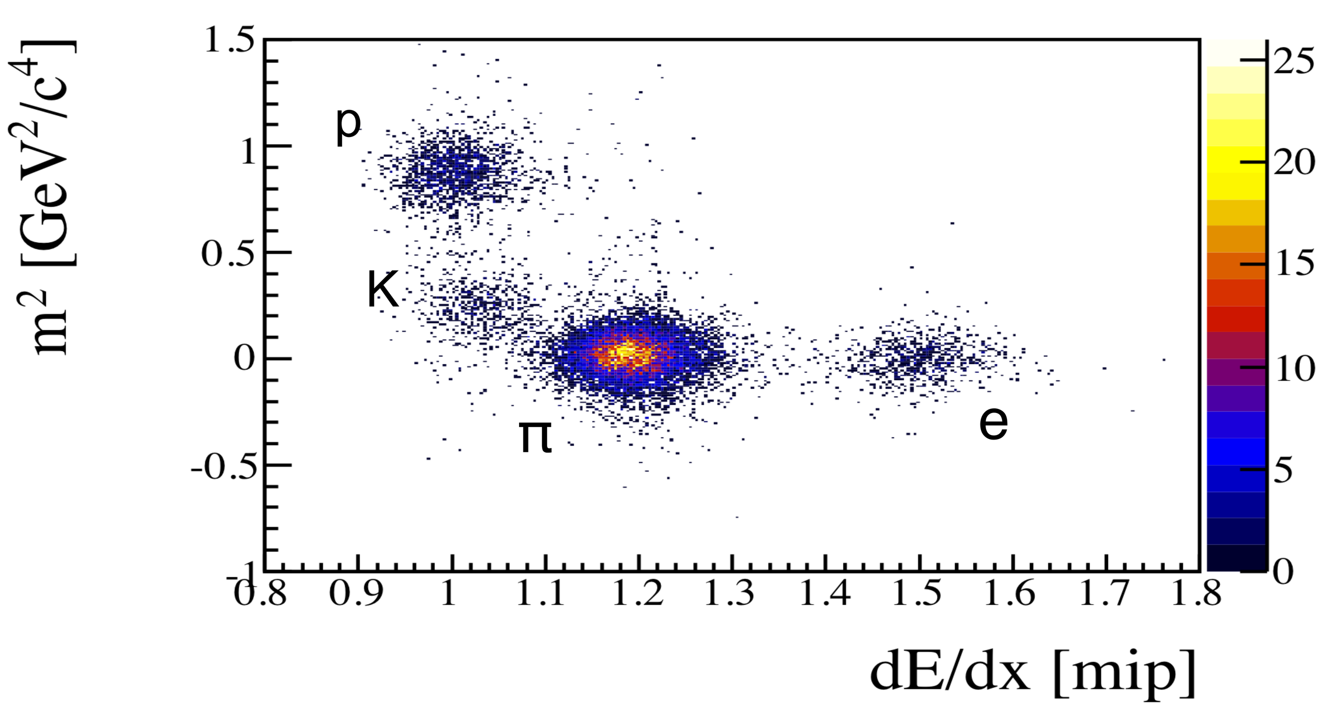
The inside of the far detector with its 11'146 photomultipliers



Energy loss in TPC: dE/dx vs momentum with Bethe- Bloch parameterization.



Time of flight in ToF: mass square vs momentum for pions kaons and protons.



As seen on the graph above, the combination of dE/dx with ToF allows a precise particle identification, hence a better understanding of the production of pions, kaons and protons off the carbon target.