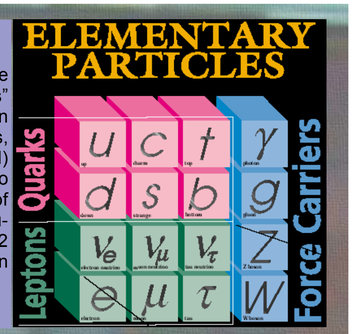
The Main Injector Neutrino Oscillation Search

MINOS

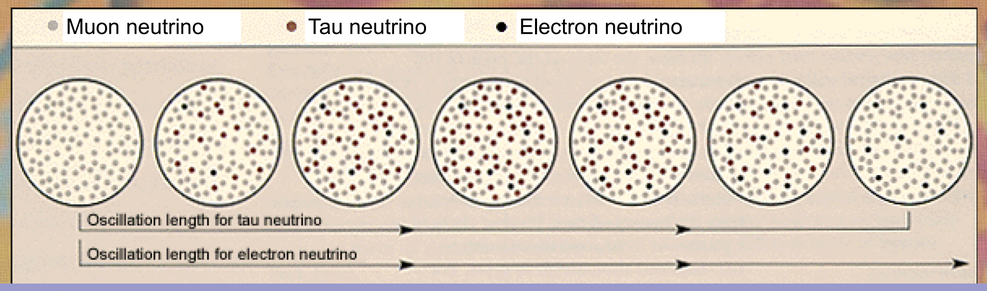
Photo: AIP, Emilio Segrè Visual Archives

What are neutrinos?
A new particle was suggested by Pauli (pictured) in 1930 to explain the apparent non-conservation of energy in beta decay, i.e. $n \rightarrow p + e^{-} + \nu$. This particle was later called the electron neutrino, and was discovered in 1956.

Where do neutrinos fit into everything?
In the "Standard Model" of particle physics there are 3 "generations" of particles. In the first generation are the "up" and "down" quarks, which make-up the proton (uud) and neutron (udd). There are also 3 "flavours" of "leptons", the first of which is the electron and it's conjugate electron neutrino. The other 2 flavours of neutrino are the muon and tau.



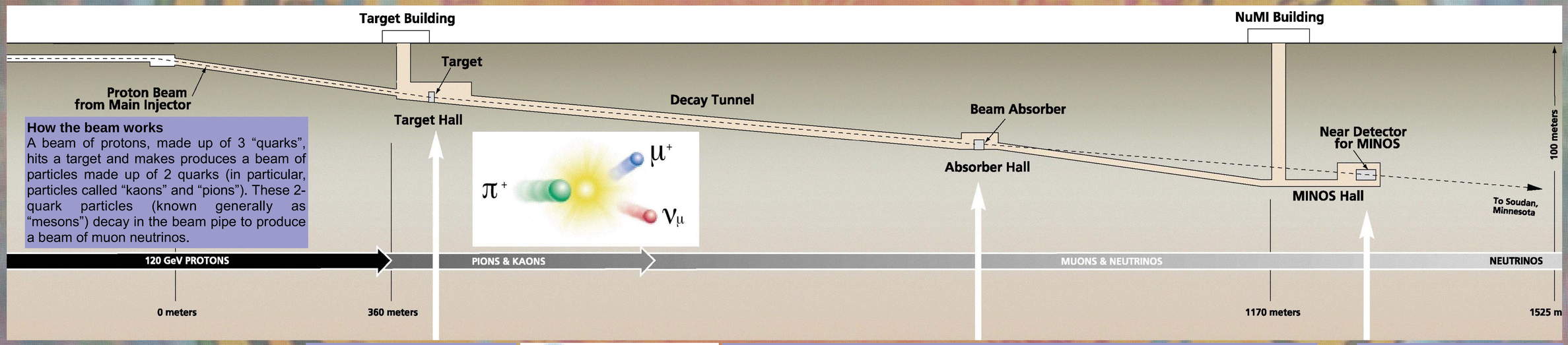
What is "neutrino oscillation"?
In MINOS, for example, we start-off with muon neutrinos. These neutrinos can change flavour, however, to electron and tau neutrinos. The neutrino loses the properties of the muon neutrino and instead interacts like, say, a tau neutrino. Consider, as an analogy, Clarke Kent oscillating into Superman and back again (with the MINOS long baseline as an analogy to the phone booth).
Pontecorvo suggested that neutrinos oscillate in 1957, and this was observed by the Super-Kamiokande collaboration in 1998.



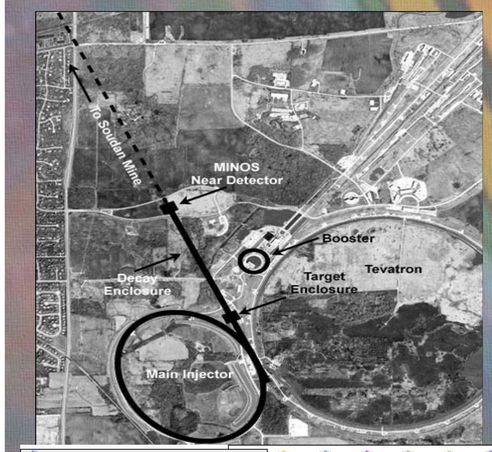
In this oscillation between muon (ν_μ), tau (ν_τ) and electron (ν_e) neutrinos, one "flavour" changes into another, and back again. There are different oscillation "potentials" for ν_τ and ν_e which (the different coloured dots) and different lengths over which the oscillations occur.

What MINOS will measure?

1. What is the maximum fraction of the neutrino beam that can change from one flavour to another?
2. If neutrinos oscillate, how great or small is the oscillation length? The oscillation length is the distance a beam of neutrinos, travelling at near the speed of light, would take to transform from one neutrino flavour to another—up to its maximum fraction—and back again.

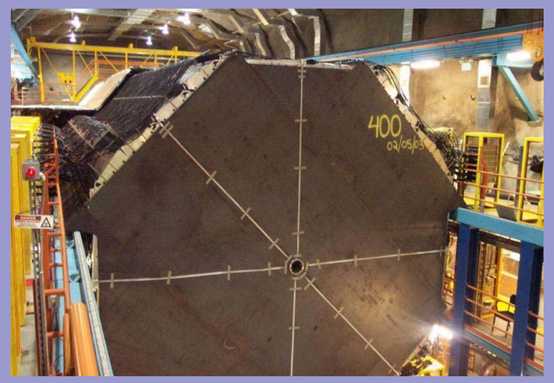


How the beam works
A beam of protons, made up of 3 "quarks", hits a target and makes produces a beam of particles made up of 2 quarks (in particular, particles called "kaons" and "pions"). These 2-quark particles (known generally as "mesons") decay in the beam pipe to produce a beam of muon neutrinos.

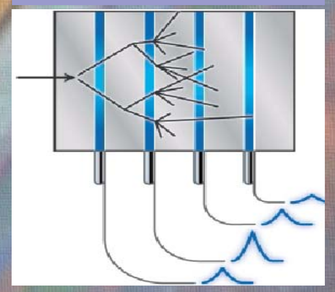


The Near Detector: 1 km
The "NearDet" measures the interaction rate, energy spectrum and flavour composition of the neutrinos. It is 3.8m by 4.8m by 282 planes of iron-scintillator sandwich. We don't yet expect any significant amounts of neutrino oscillation.

The Far Detector: 735 km
"FarDet" is 486 planes of 8m by 8m steel-scintillator sandwich, much bigger than the NearDet since the neutrino beam diverges with distance. This distance should give the original muon flavour neutrinos enough distance to significantly oscillate into tau neutrinos (given present knowledge), but not into electron neutrinos.



How will MINOS measure the energy?
The energy deposited in all the readout strips and planes after an event is summed.



NuMI-MINOS

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