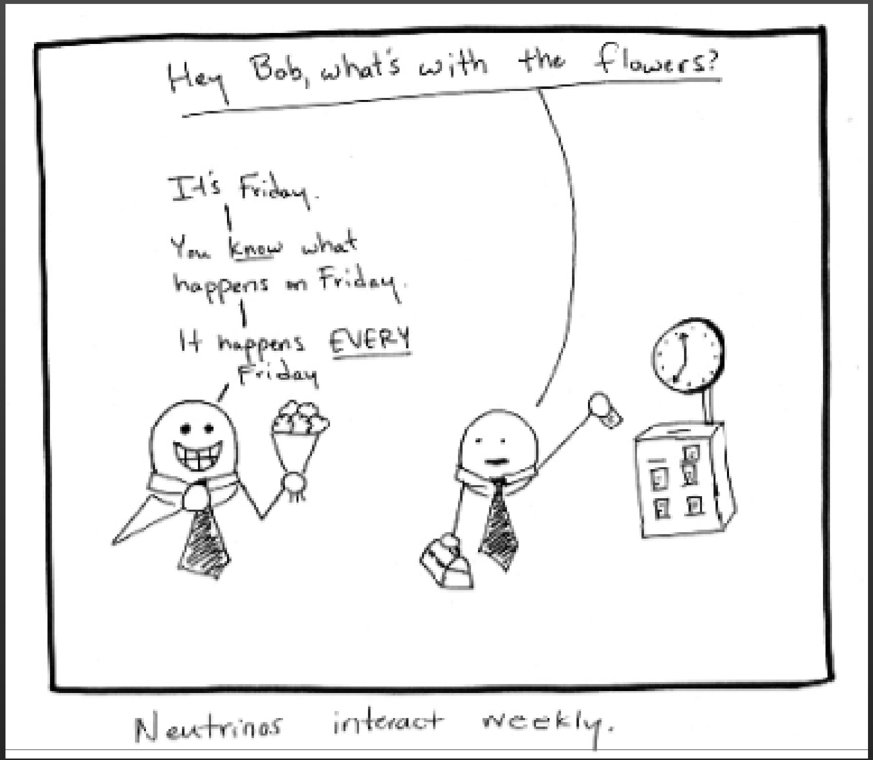


Nefarious Neutrinos

Alex George
University of Pittsburgh

Introduction

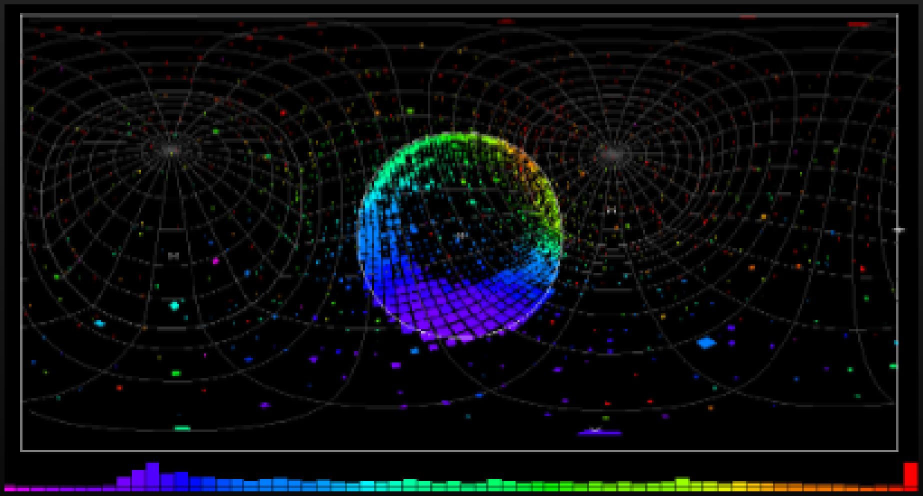
- My research is conducted through the Neutrino Group at Pitt



- Neutrino physics is a sub-branch of particle physics (particle → lepton → neutrino)

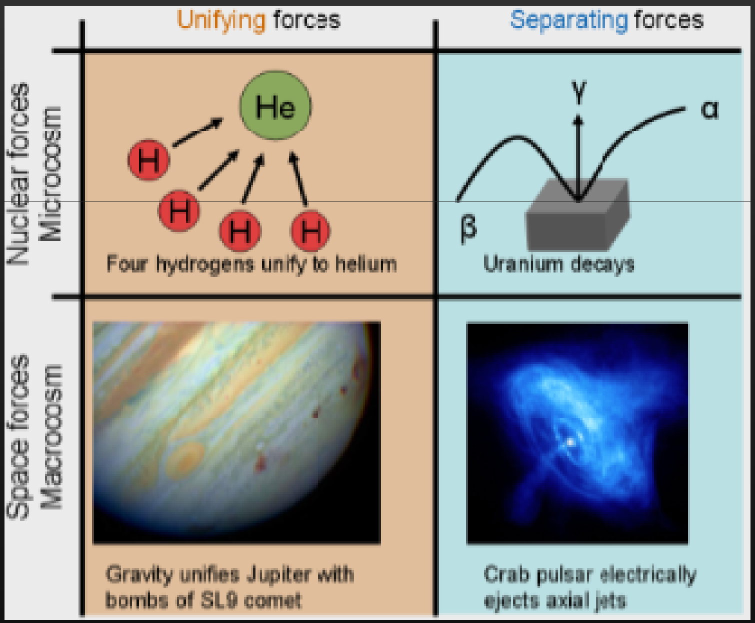
Why do we care about neutrinos?

- As particle physicists, our job is to study particles – neutrinos are one of the least-understood particles that exists.
- Currently, all physics described by Standard Model. Neutrinos offer a window to change the standard model
- There's a lot of them – about 10 million just in the space your body takes up



So what's the problem?

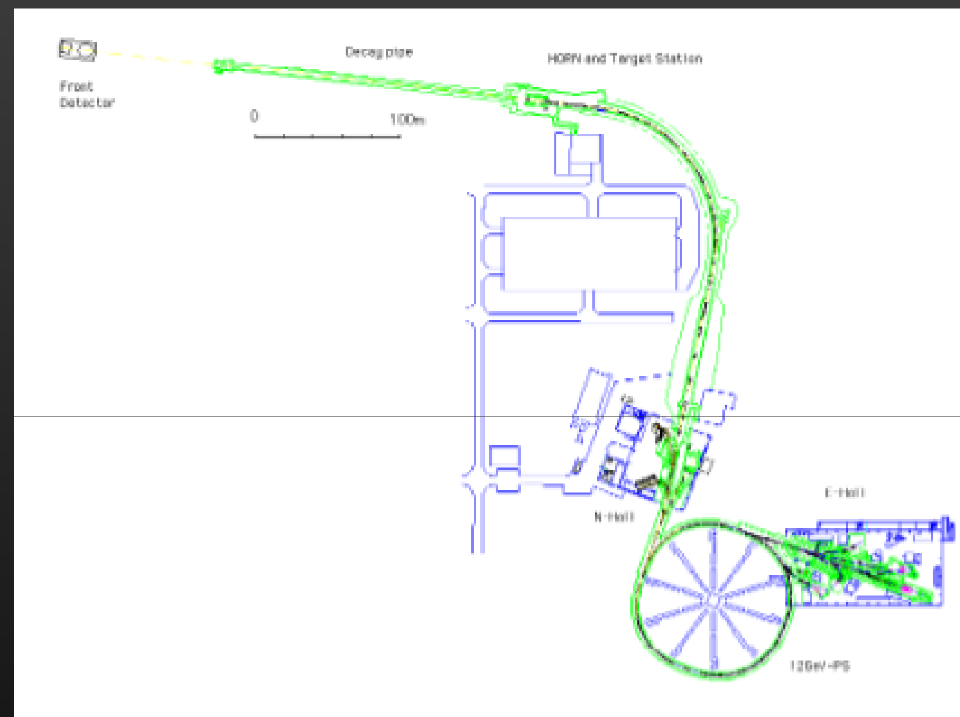
- Neutrinos are:
  - chargeless (can't use EM force)
  - colorless (can't use strong force)
  - nearly massless (can't use Gravitational force)



- Weak force is the only thing that's left. But doesn't interact very often!
  - Median decay time is "light year of lead."

What to do?

- The interaction rate is very low, so to compensate we have to use a lot of neutrinos. That's not a problem – neutrinos are abundant!
- Experimental setup:
  - make a neutrino beam ($\sim 10^{20}$/s) and fire it into a neutrino detector.
  - a few (~3/day) will decay weakly, and we can analyze the decay



Above: the setup for the K2K experiment

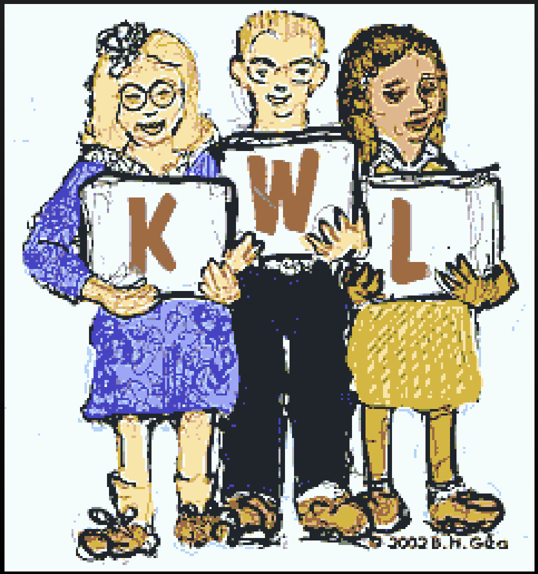
Status?

Know

- Mass and Flavor Eigenstates incompatible
- Oscillations between different flavors
- Mass eigenstates very small < 1 eV/c^2
- Sources:
    - Left over from big bang
    - Supernovae
    - Nuclear Reactors

Want to Know

- Oscillation Parameters
- Cross-Section
- Absolute Mass



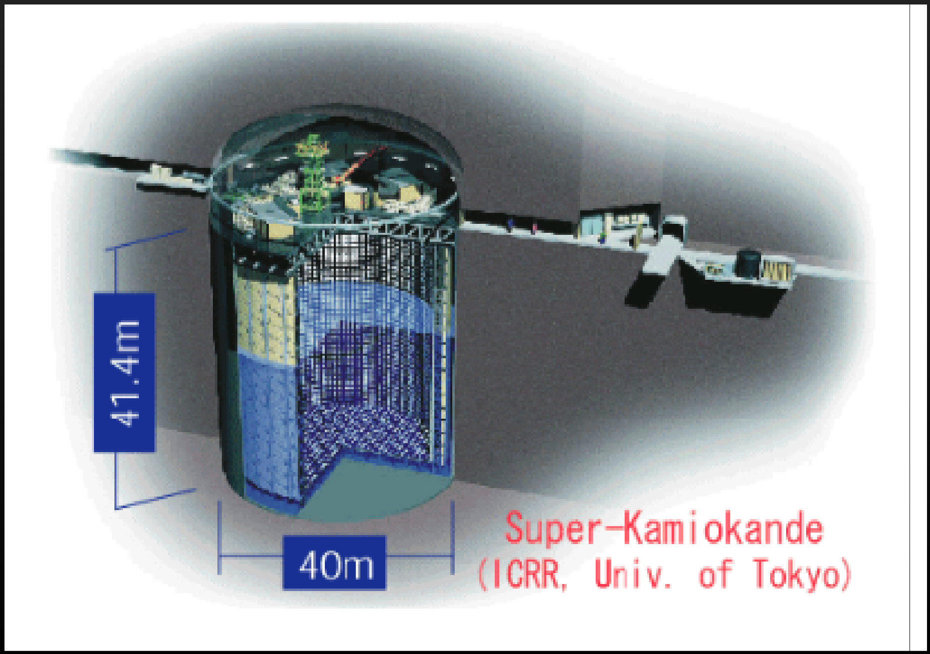
Summary

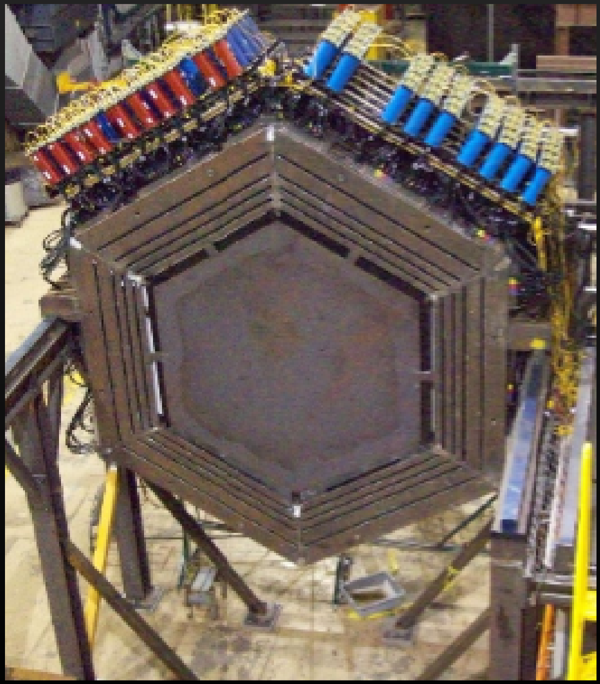
$$\begin{pmatrix} \nu_{e^-} \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & cos\theta_{23} & sin\theta_{23} \\ 0 & -sin\theta_{23} & cos\theta_{23} \end{pmatrix} \begin{pmatrix} cos\theta_{13} & 0 & sin\theta_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -sin\theta_{13}e^{i\delta} & 0 & cos\theta_{13} \end{pmatrix} \begin{pmatrix} cos\theta_{12} & sin\theta_{12} & 0 \\ -sin\theta_{12} & cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} e^{\frac{i\alpha_1}{2}} & 0 & 0 \\ 0 & e^{\frac{i\alpha_2}{2}} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} m_{e^-} \\ m_\mu \\ m_\tau \end{pmatrix}$$

1. Neutrinos have exotic properties
   - Oscillations
   - Indistinct mass/favor eigenstates
   - Few interactions
2. Difficult & Expensive Experiments
   - Low statistics → Indistinct Conclusions
   - Very expensive

The Pitt Group

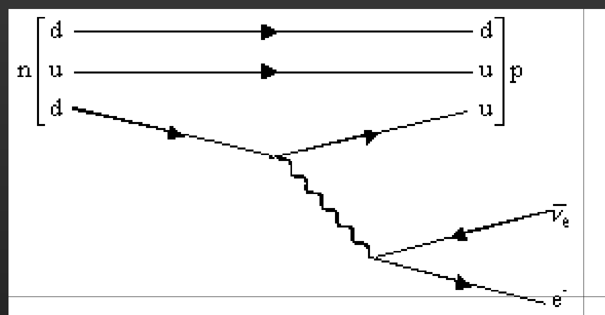
- MINERvA at Fermilab
  - Measure neutrino cross-sections
- T2K in Japan
  - Measure θ_{13} ($\nu_u \rightarrow \nu_e$ oscillations)





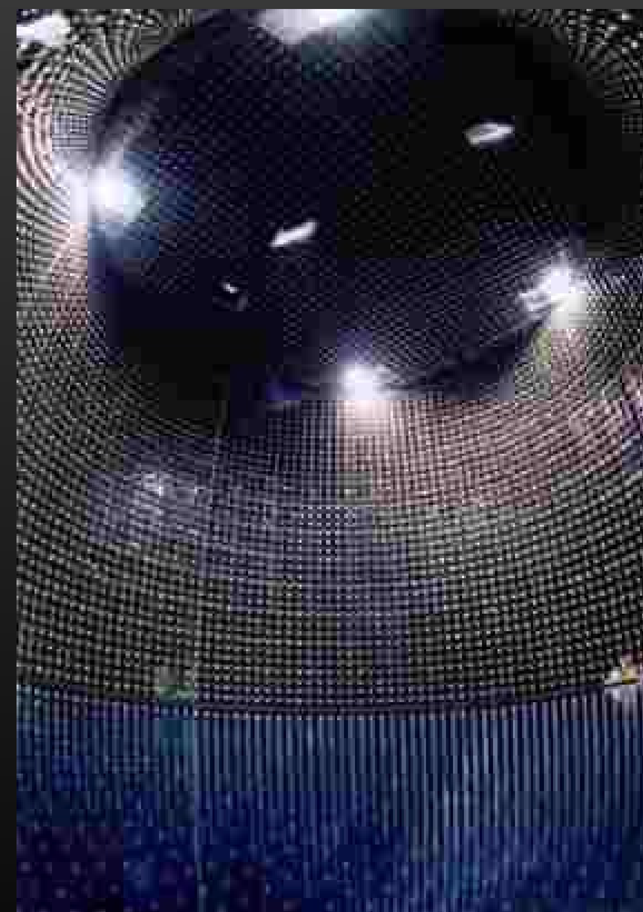
The Detector

- Neutrino Event is of form:



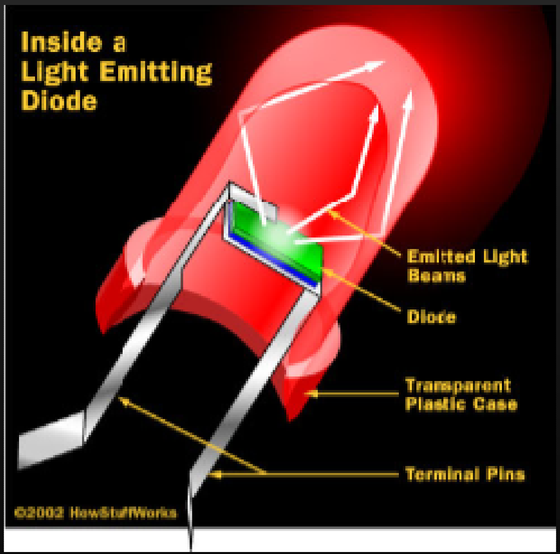
$$n + u_e \rightarrow p^+ + e^-$$

- The charged particles give off Cerenkov Light, which can be detected in the PMTs



Light Injection

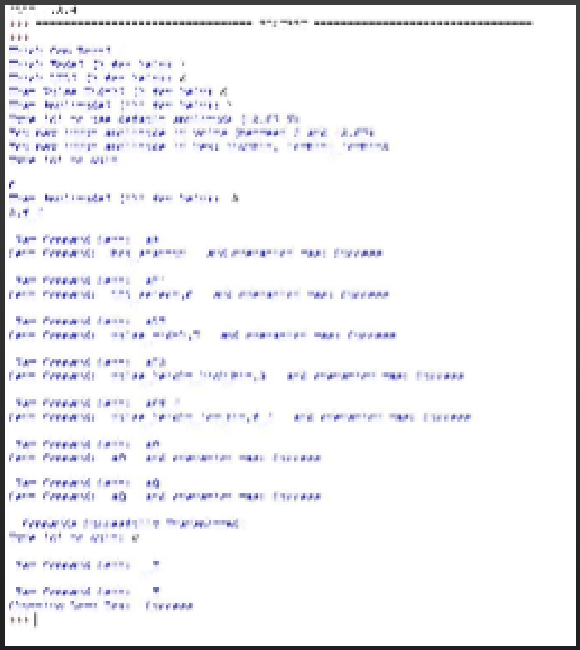
- In both experiments, we're working on the Light Injection System, used for calibration

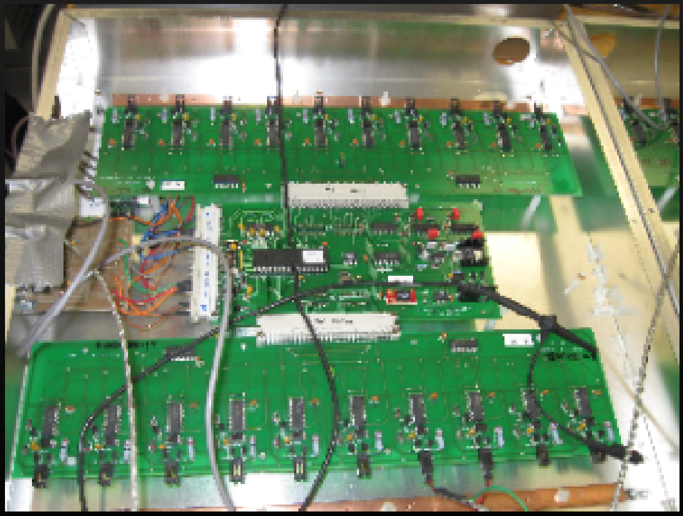


LED Fiber-Optic Cable PMT

Specific Tasks

- Choose LEDs
- Build a box to set the LED frequency, amplitude, on/off, etc., and the codes to run the box
- Build and test the optical fibers
- Use MonteCarlo methods to analyze the PMT gain





Outlook

As neutrino physics develops, the oscillation parameters can be refined.

Hopefully, it will be possible to come up with a theoretical basis for these parameters.

The biggest frontier is money: we have to find a cheaper way to get good results.