

Introverts among elementary particles - neutrinos

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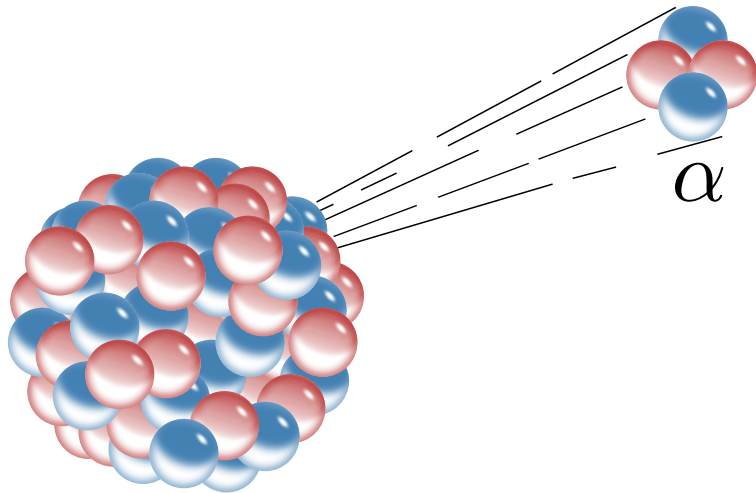


Learning objectives

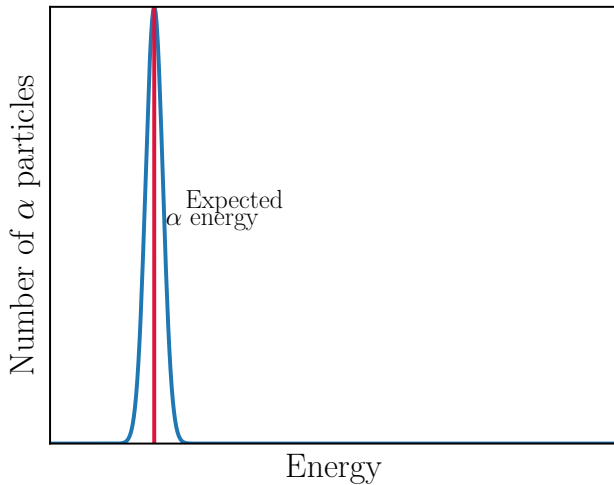
- Describe what is a neutrino
- Characterize the features of a good neutrino detector
- Solve the Solar neutrino problem

Data interpretation 101 by W. Pauli

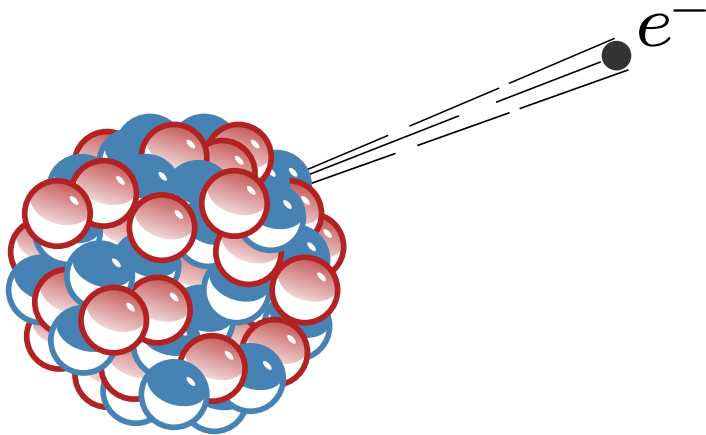
Alpha decay



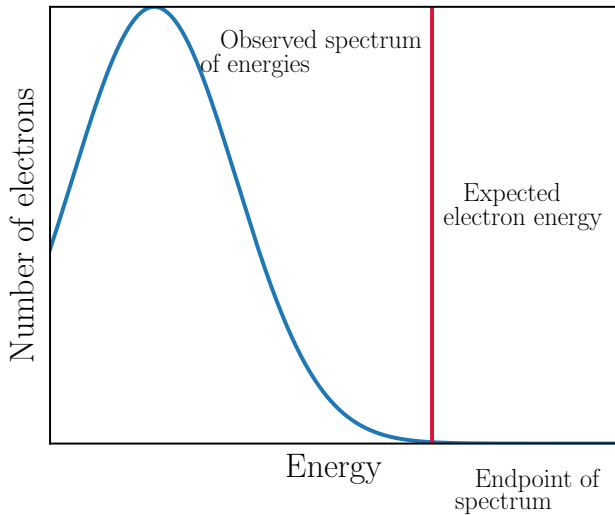
Alpha decay



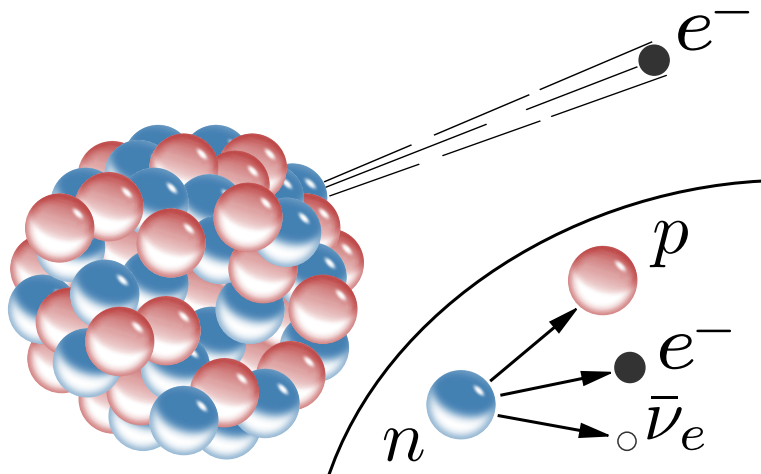
Beta decay



Beta decay



Beta decay



Neutrinos

Neutrino flavors



Neutrino flavors



Neutrino flavors



Neutrino flavors



Neutrino flavors



Neutrino flavors



How to catch a ghost?

Neutrino reactors



[Kurzgesagt, Wikipedia](#)

Neutrino reactors



[Kurzgesagt, Wikipedia](#)

Neutrino reactors



[Kurzgesagt, wikipedia](#)

Homestake experiment - neutrino detector



Homestake experiment - neutrino detector



① BIG detector

Homestake experiment - neutrino detector



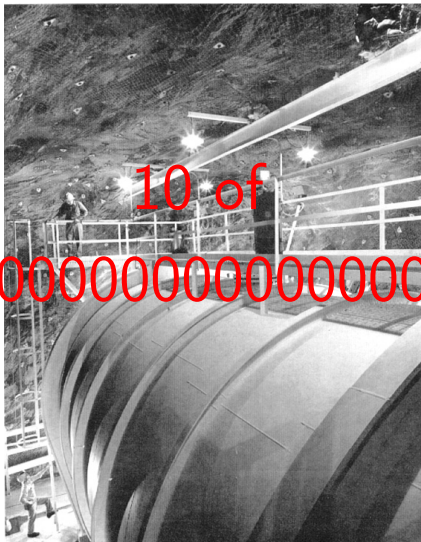
- ① BIG detector
- ② isolate from other crap

Homestake experiment - neutrino detector



- ① BIG detector
 - ② isolate from other crap
- 380 m³ of perchloroethylene (dry-cleaning fluid)
 - 1.5 km underground

Homestake experiment - neutrino detector



- ① BIG detector
- ② isolate from other crap

- 380 m³ of perchloroethylene (dry-cleaning fluid)

- 1.5 km underground



mass states \neq
flavor states



Problem

Why scientist measured only 3 neutrinos if they calculated that the expected number is 10?



The Infamous "Neutrino-burglar"

<https://astrodidyouknow.blogspot.com/2011/>

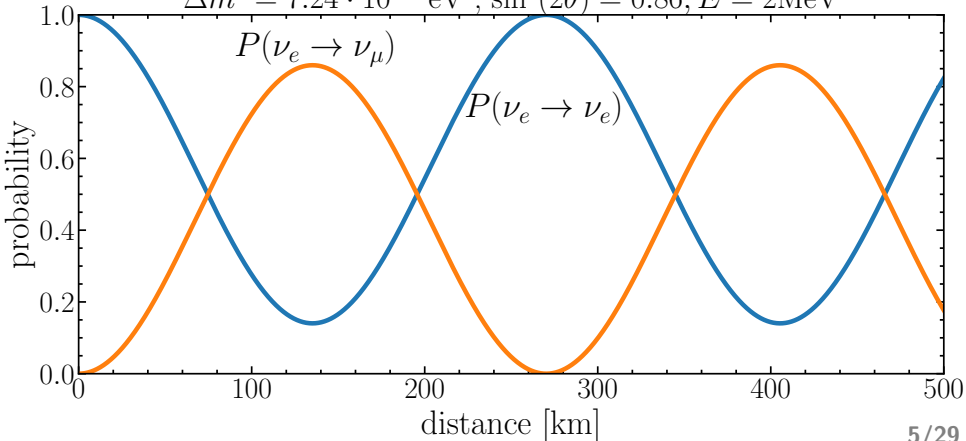
Neutrino oscillations in vacuum

2ν mixing = easy dependence on

$$P_{\nu_e \rightarrow \nu_e} = 1 - \sin^2 2\theta \sin^2 \frac{\Delta m^2 L}{4E}$$

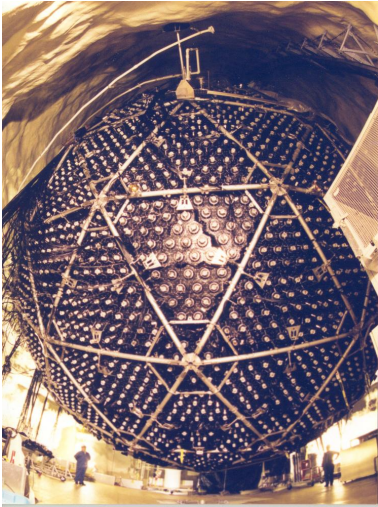
- mixing angle
- mass squared difference

$$\Delta m^2 = 7.24 \cdot 10^{-5} \text{ eV}^2, \sin^2(2\theta) = 0.86, E = 2\text{MeV}$$



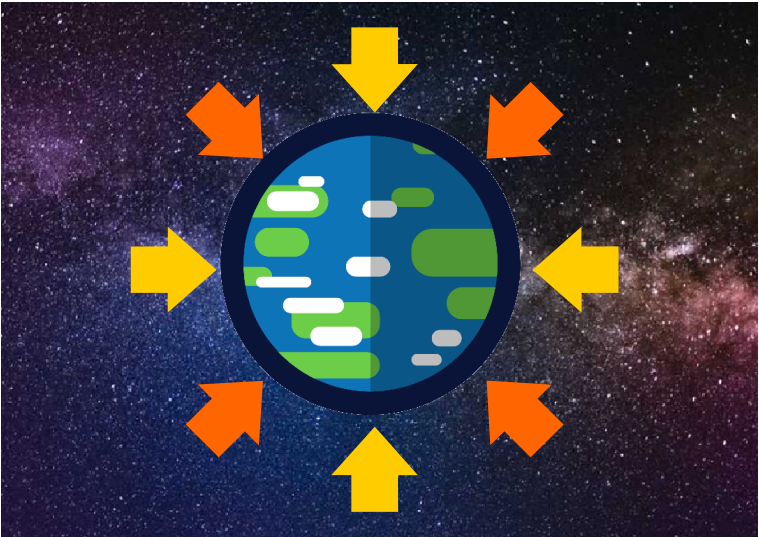
Hungry detector

Sudbury Neutrino Observatory (SNO)

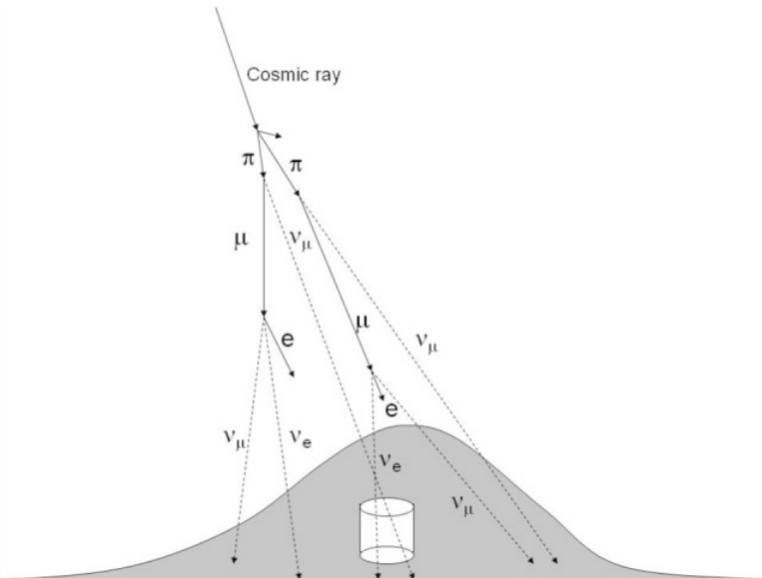


- 2.1 km underground
- filled with 1000 tonnes of heavy water
- sensitive to all neutrino flavors

Atmospheric neutrinos

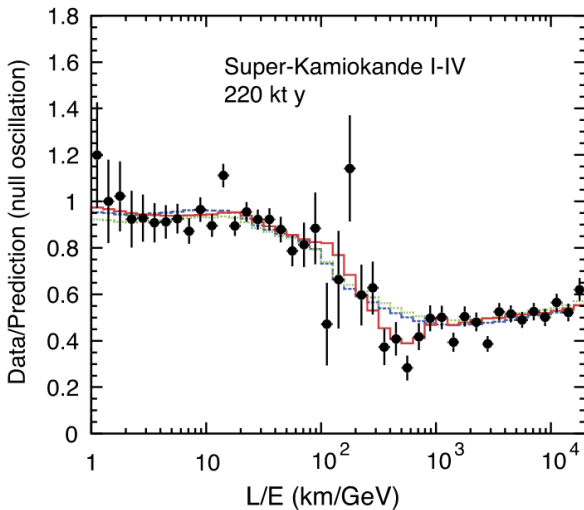


Atmospheric neutrinos



T. Kajita Proc. Japan Acad. B86 2010

Atmospheric neutrino problem



Summary

- Neutrinos are weakly interacting elementary particles
- We are constantly bombarded by neutrinos from various sources, terrestrial: nuclear power plants, atmosphere, humans and extraterrestrials: Sun, Supernovae and other astrophysical objects
- Neutrinos have masses, that manifested their existence by neutrino oscillations
- Neutrino oscillate - change identity (flavor) as they propagate