Neutrino Mass Hierarchy

Connie, Sundeep, Mat, Zain, Kat

Why should we determine the neutrino order hierarchy?

Help solve cosmological problems

Understand the standard model better

Find out why neutrinos have mass

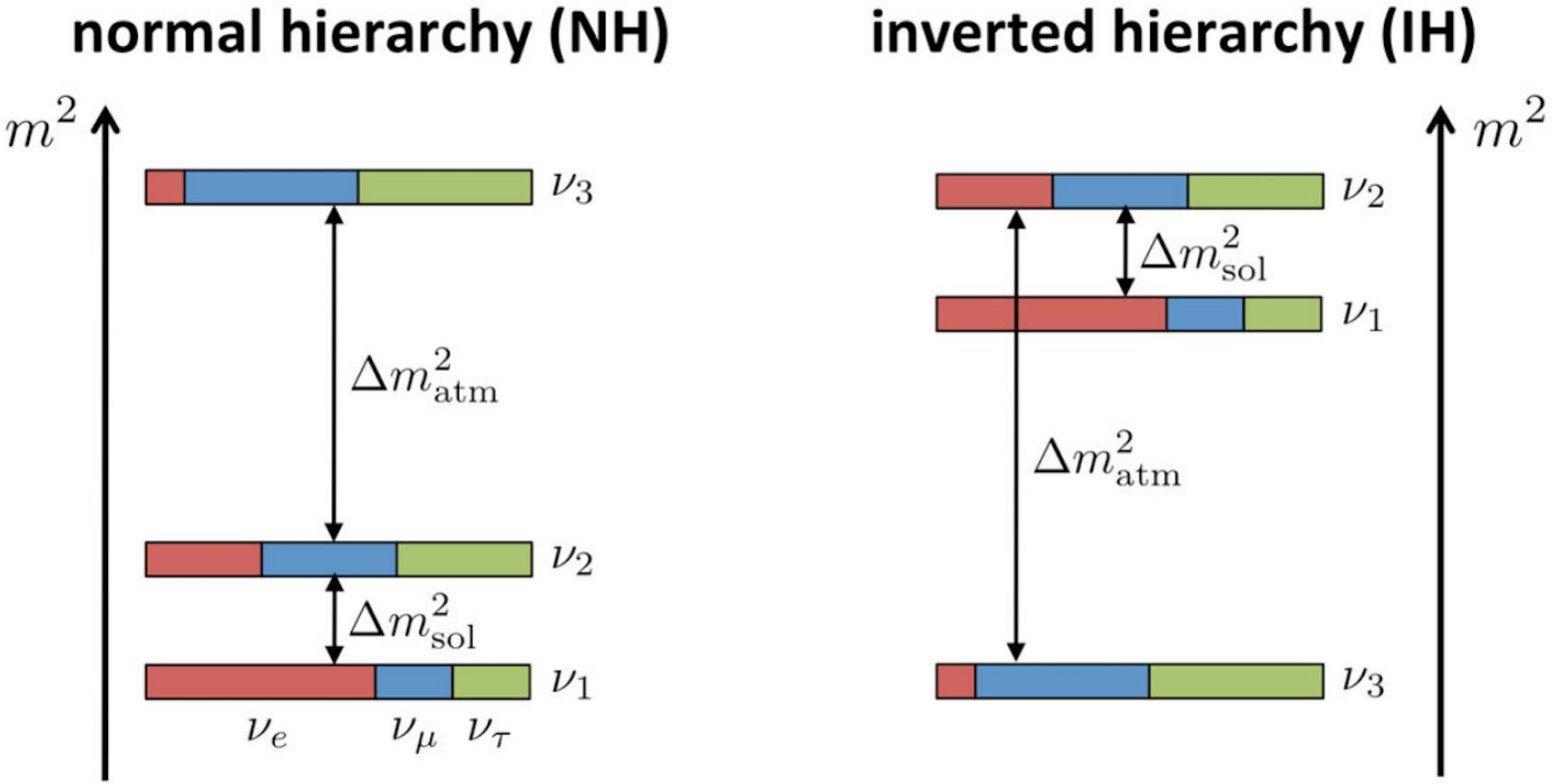
Hopefully expand our knowledge on particles beyond the standard model as well

The problem we are trying to solve

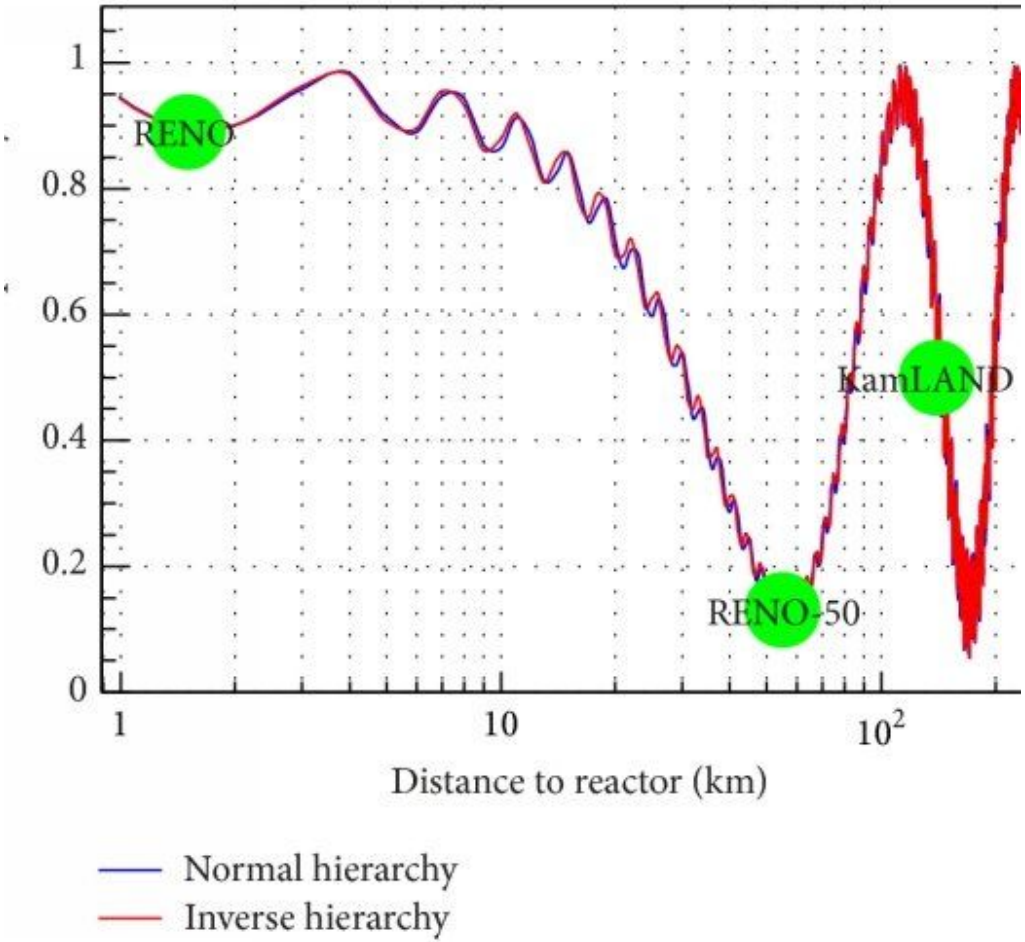
- Neutrinos are observed to oscillate between flavours

$$P(\nu_e \rightarrow \nu_e) = 1 - \sin^2 2\theta \sin^2 \left[\frac{(m_2^2 - m_1^2)x}{2E}\right]$$

- From this, we can determine the magnitude of the difference in mass between their state but we don't know whether this mass difference is positive or negative.



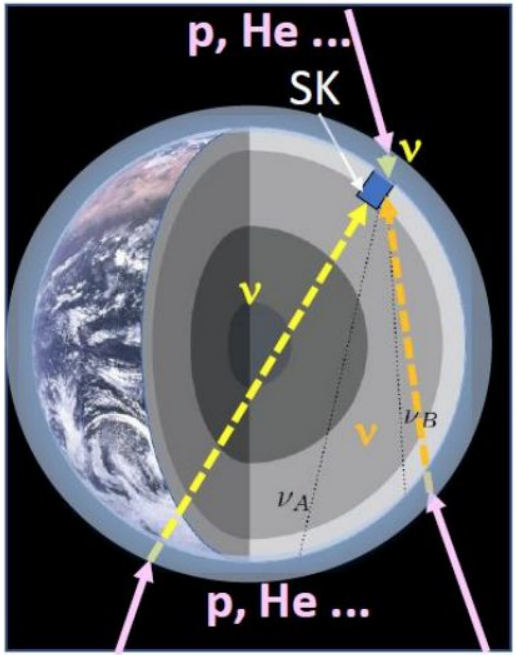
- This means that we can order the masses in two ways (we know that the mass of state 2 is greater than state 1, but we don't know if state 3 is greater or less than state 1.

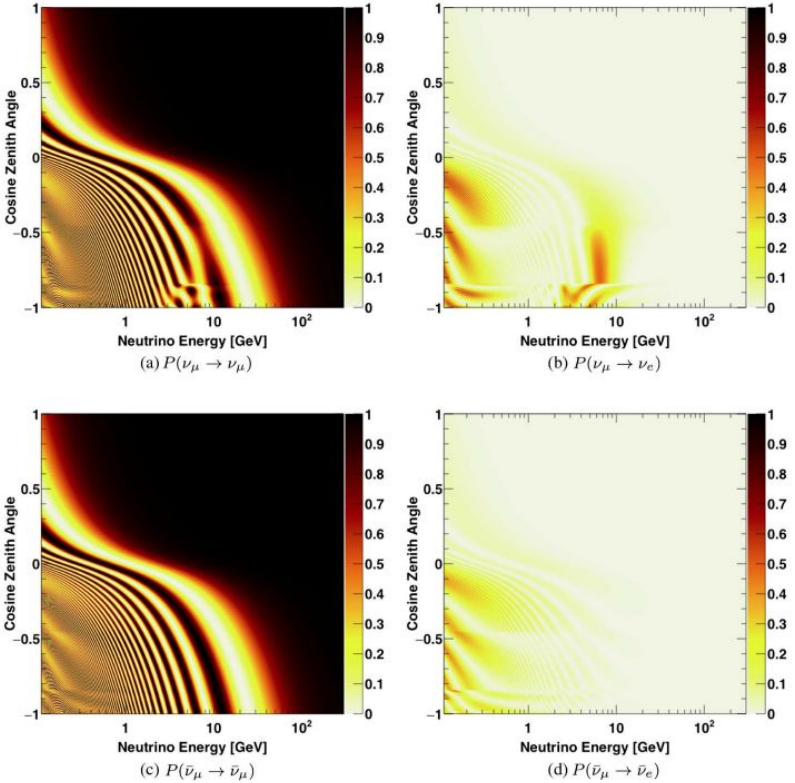


A diagram that shows the different probability distributions for a flavour change, depending on whether the hierarchy is normal or inverted

Need very sensitive equipment and lots of data to distinguish between the red and blue lines; best to do it while amplitude is small

Another difference resulting from the normal/ inverse hierarchy



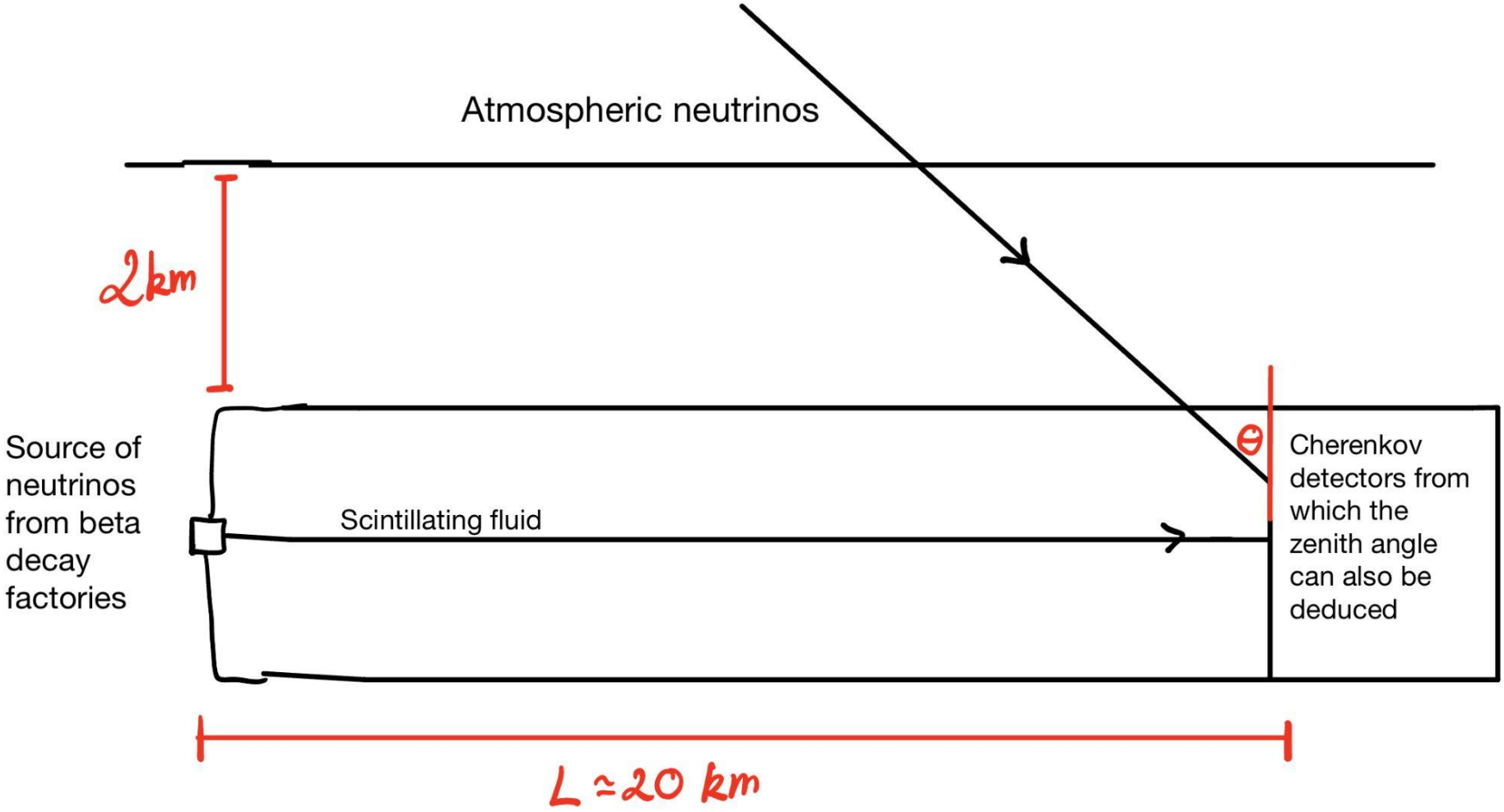


Previous experiments

- KATRIN Experiment (direct method)
- CMBR and large scale structure surveys (indirect method for neutrino mass)
- Neutrino oscillation facilities - the one that we are going to do/expand on (direct method)
- What level of accuracy would next-generation experiments need?

Our extension

- Nuclear reactor/neutrino laser
- Located near CERN by the Alps
- Detector set about 20km away from the laser (see graph on slide 5)
- Detecting our source as well atmospheric neutrinos to obtain two sets of data – appearance experiment
- Cylindrical stainless steel tank detector for neutrinos


Atmospheric neutrinos
2km
Source of neutrinos from beta decay factories
Scintillating fluid
θ
Cherenkov detectors from which the zenith angle can also be deduced
L ≃ 20 km

Considerations

- Beta decay factories for source of neutrinos
- Where the detector would be placed
- Type of fluid for the cherenkov radiation
- How to determine if the neutrino was atmospheric or from the neutrino laser

The Cuts we would make

The T2K neutrino beam is centered on 600MeV – source neutrinos would have a narrow spread of energies while atmospheric neutrinos could have much wider range, 100MeV → TeV scales so the velocity would be much higher – make cuts on the angle of the Cherenkov rings.

T2K beam is assumed to be straight so the zenith angle would be very close to 90˚ or more whereas atmospheric neutrinos would have significantly lower values.

Use the shape of Cherenkov rings to deduce whether one is a muon/ electron or tau. The shape can also tell us whether it is a stray particle