ICECUBE MASTERCLASS
AN AUTHENTIC ASTROPHYSICS RESEARCH EXPERIENCE

Icebreaker Activity

Neutrinos as pieces of the Standard Model of particle physics

What we need

At least one particle badge per student participating in the activity. If we have fewer students, each student can be given two to three particle identities.

Other resources that might be useful: a table of interaction properties, a table of the Standard Model of particle physics (link, fundamental particles and interactions)

List of particles provided

Six quarks (up, down, charm, strange, bottom, top), six leptons (electron, electron neutrino, muon, muon neutrino, tau, tau neutrino), five force carriers (photon, Z boson, W+ and W- bosons, gluon), Higgs boson, positron, antimuon, electron antineutrino, muon antineutrino.

Depending on the number of students, we could make two to three copies of the following particles: up and down quarks (to build protons and neutrons) and neutrinos, especially muon neutrinos. We could also print a few more antiparticles.

Activity proposal

When students arrive at the masterclass host institution, they will be given a badge with one (or more) particle identity. They will wear this badge in a way that other students can see the name of their particle(s).

Students will act like the particle(s) they have been assigned, following questions/suggestions from tutors or their own proposals. The following possible questions/exercises can be adapted based on the time available and the prior knowledge of the students.

This activity could last from 20 to 90 or more minutes. However, we would suggest about 30 minutes when used as an icebreaking activity for the masterclass.

i) The particles and their main properties

- We would like to get the students familiar with the particles. We will ask them to introduce themselves by saying their name, school and grade, and then have them introduce the particle(s) they will be portraying during this activity.

- Next, we would like the students to think a bit about the particle's properties and how these determine the way the particles behave in nature. Students will be requested to group themselves, as particles, by type—leptons/quarks/force carriers—or by charge, or to line up in order of increasing mass, etc.

ii) <u>Interactions in Nature and how they relate to particle properties</u>

- Tutors will start a discussion about the forces of Nature. We want to see how much the students can tell/guess before receiving further information. We will guide them toward the idea that there are four forces or interactions, which are mediated by special particles called the force carriers.
- We want the students to understand which properties determine how a given particle can interact and in which conditions a given interaction is important/dominant. (related resource: table of interaction properties)
- Finally, we will ask them to identify which interactions are relevant to their particle(s). Each student will write on his/her badge the interactions that they can "feel," and they will briefly explain why to others. Then, tutors can point to one particle/student and ask for all particles/students that interact with it to raise their hands (or to cluster around him/her).

iii) <u>IceCube particle interactions</u>

- We want the students to understand which particles are seen in IceCube and why we see those and not other particles. Tutors will introduce the conundrum of the source of high-energy cosmic rays. Tutors will guide students into thinking about what properties the generators of cosmic ray might have, and which particles they produce in addition to cosmic rays. We would like to arrive at the idea that photons and neutrinos also come from these powerful cosmic-ray generators.
- Tutors will guide students into thinking about what happens to the different types of particles travelling from their sources to the Earth, where we try to detect them to learn about the origin of cosmic rays. We want students to arrive at the idea that neutrinos are very special messengers and be able to explain why.
- We could finish here, concluding that that's why a detector such as IceCube was built and informing them that they will learn more about it in the first lecture of this masterclass.
- We could continue, introducing a few facts* about IceCube (how big it is and where it is located), including that by looking for these special neutrinos we also end up seeing plenty of muons and neutrinos coming from the atmosphere. And that distinguishing between these particles and learning about their properties is the secret to doing science with IceCube.
  *We do not want to explain a lot about IceCube, since they will have a dedicated talk later.