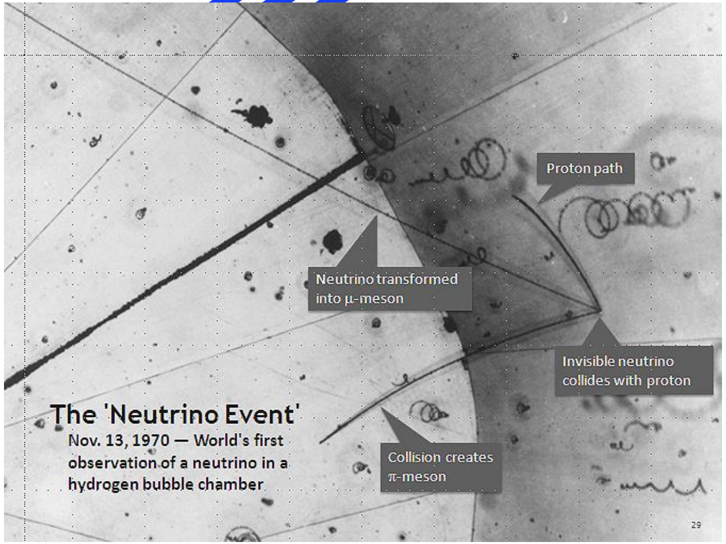
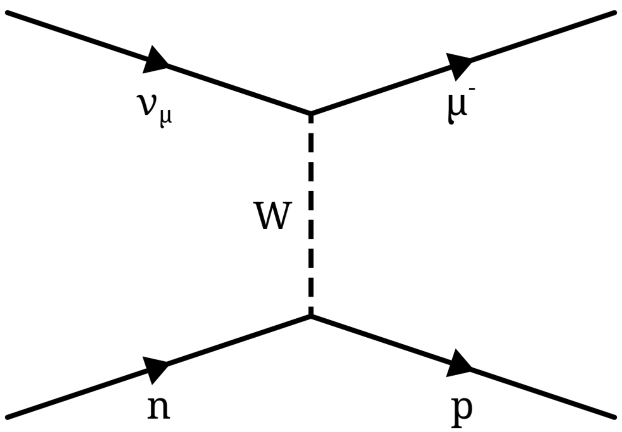




Neutrino Physics

Pernilla, Christine, Murray, Ujjwal, Karin

Curriculum Connections to the Neutrino

Neutrinos can be introduced in various curricula in different ways. However it is not a specific topic in any of the curriculum topics we looked at, with the possible exception of the standard model.

https://st2.depositphotos.com/1001911/7684/v/450/depositphotos_76840879-stock-illustration-depressed-emoticon.jpg

Curriculum Connections to the Neutrino

If a teacher is talking about the sun, they might talk about the fact that the sun is emitting many neutrinos.

If beta decay is a part of the curriculum, then the production of a neutrino should be mentioned.

Since the Standard Model is part of many curricula, neutrino mass, the lepton family and the three generations of the neutrino are obviously connected.

While discussing the scientific method, a teacher might talk about the circumstances of the prediction and discovery of the neutrino and/or the problems the neutrino is causing for the Standard Model

https://cliweb.org/wp-content/uploads/2021/09/Brain-1024x1024.jpg

Key Ideas - Why a Neutrino?

The neutrino was proposed in 1930 by Wolfgang Pauli to keep the conservation of momentum and energy (and spin if you go that far) during ***β***-decay. This is another instance in science when a convenient (particle, planetary mass, black hole, etc) proves to be a real entity. Clyde Cowan and Frederick Reines found experimental evidence of the particle in 1956.

https://static1.personality-database.com/profile_images/d6eaf4cce3904c33bfae57195a436fff.png

https://pbs.twimg.com/media/E6k_bBMWYAEx7dp.jpg

Key Ideas - Mass and Size

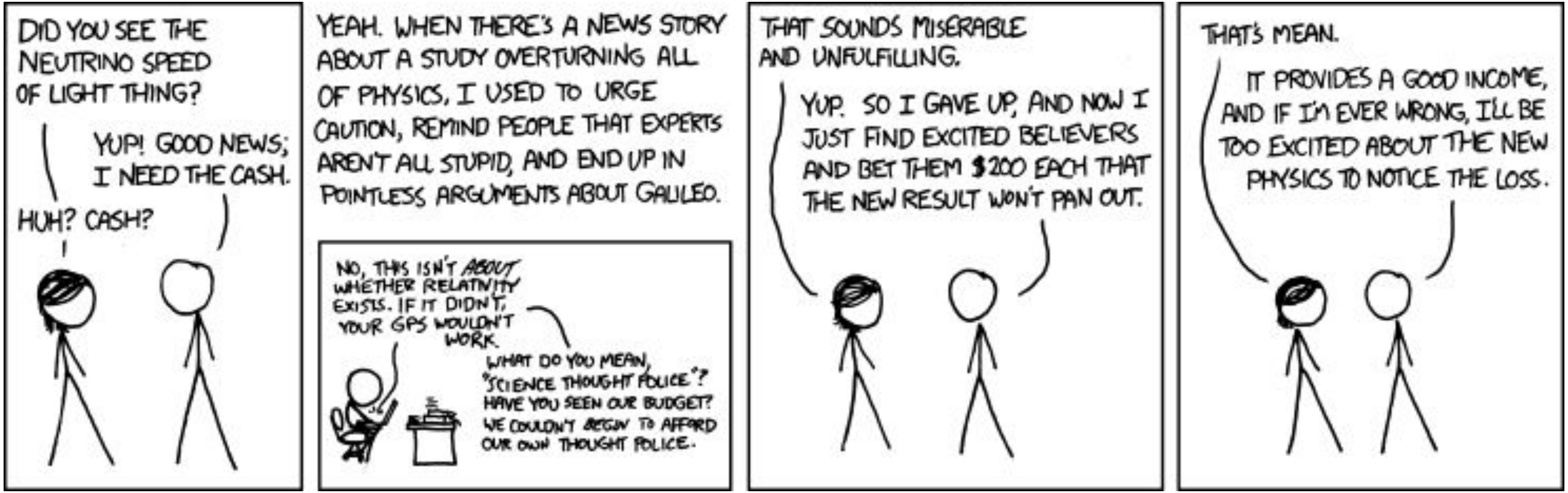
Neutrinos initially were thought to have zero mass. Experimental results indicate that there should be some mass (upper limit of 0.09 eV vs. 511000 eV mass for an electron).

We believe that neutrinos are also elementary point particles. They have no length or volume and are not made up of combinations of particles.

https://www.symmetrymagazine.org/sites/default/files/styles/2015_hero/public/images/standard/Header_How_do_neutrinos_get_their_mass.jpg?itok=mra_Uqdo

Key Ideas - Speed

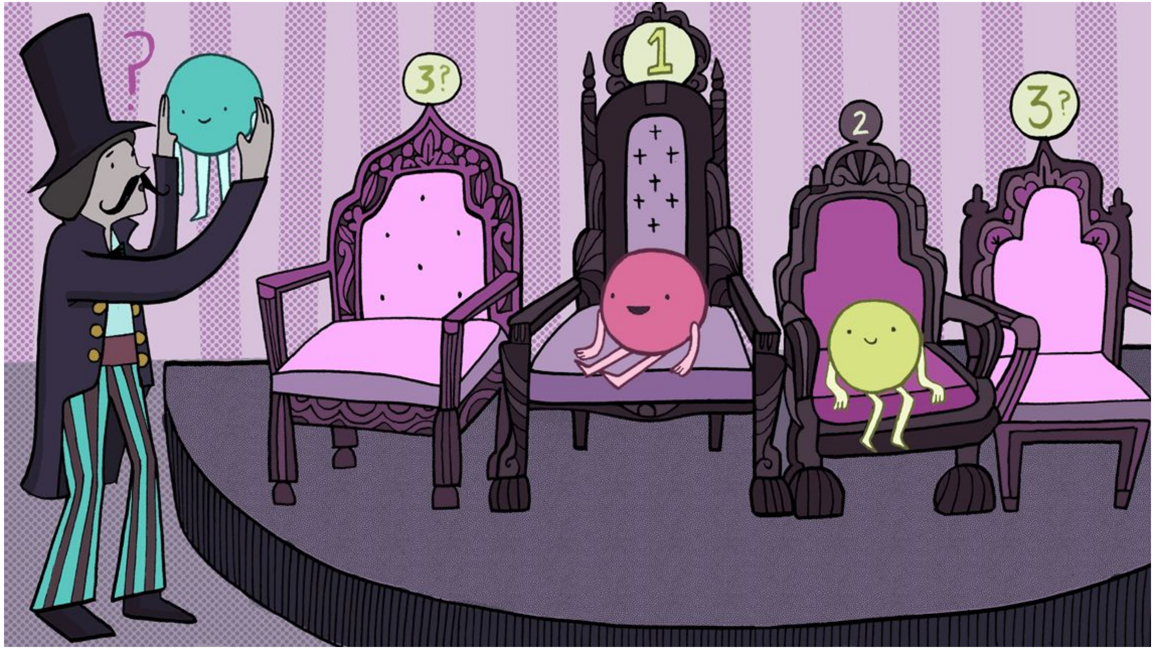
Because Neutrinos were thought to be massless they needed to move at the speed of light. Now we believe that they have mass they move at slightly less than the speed of light, although our current detectors are not able to find a difference between their actual speed and the speed of light. With experimental error included, it can look as if neutrinos move faster than the speed of light. We don't believe they are.



https://www.explainxkcd.com/wiki/index.php/955:_Neutrinos

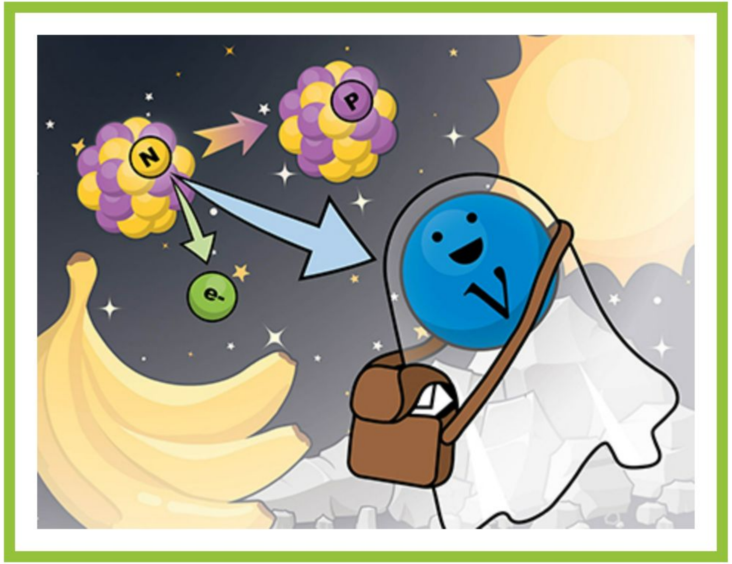
Key Ideas - Types of Neutrinos

Since the standard model shows three generations of fermions, the symmetry of three types of neutrinos seemed likely. This belief was followed by the discovery of the muon neutrino in 1962 and the tau neutrino in 1975. This is another case of the beauty of the theory leading us to discoveries.



https://neutrinos.fnal.gov/wp-content/uploads/2017/12/Mass_hierarchy_2.gif

Potential Students' Conceptions and Challenges



Credit: Tiffany Bowman, Brookhaven National Laboratory

NeutriNO - NOneutron
Harmful to the human body?
Ghostparticle?
Color?
Flavour?
Mass?
Interact?

Helpful Materials and Resources

Neutrinos: una introducción

Author(s): Susana Cebrián

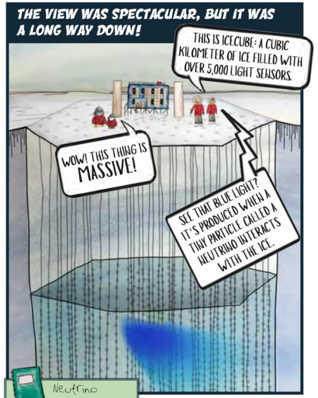
Traducido por Susana Cebrián. ¿Qué tienen en común la deriva continental, las centrales nucleares y las supernovas? Los neutrinos, como explica Susana Cebrián

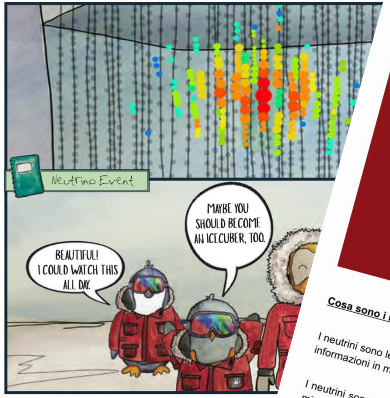
¿Qué son los neutrinos?

Imagen cortesía de Mark Tiele Westra

Los neutrinos, así llamados por s 'neutros y pequeños', están rodeándonos por todas partes diminutas partículas element en el espacio con velocidad las de la luz y no tienen ca Se pensó durante much tampoco tenían masa, pero hoy los científicos saben que estima que la masa del átomo de hidrógeno es más de veces mayor, pero la investigación continúa[w1].

La existencia de los neutrinos, una de las partículas Universo, fue postulada por el físico austriaco Wolf explicar las observaciones de la desintegración radiactiva cuando se construyeron los primeros reactores nucleares se pudo de un flujo de neutrinos (realmente de sus antipartículas, los antineutrinos; véase Landua & Rau, 2008, para más información sobre las antipartículas), procedentes de la desintegración de los fragmentos de fisión, lo





Neutrini

Cosa sono i neutrini?

I neutrini sono le particelle più elusive finora scoperte. Il loro studio è estremamente interessante e ci dà importantissime informazioni in molti campi della fisica: dalla struttura della materia alla struttura stellare, alla cosmologia.

I neutrini sono particelle prive di carica elettrica e con una massa estremamente piccola (che non si è ancora riusciti a misurare). I neutrini interagiscono molto raramente con la materia; possono infatti attraversare praticamente indisturbati enormi spessori di materia.

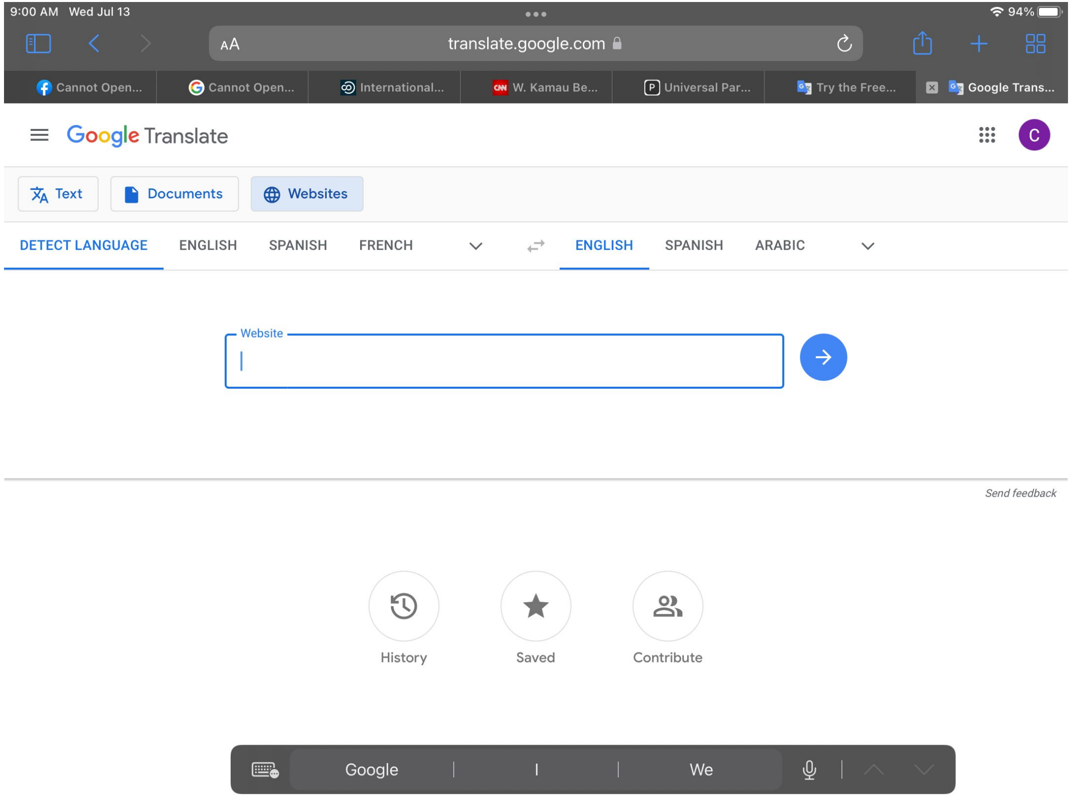
L'esistenza del neutrino fu proposta nel 1930 dal fisico austriaco W. Pauli per spiegare le osservazioni sperimentali relative al cosiddetto decadimento radioattivo di tipo beta dei nuclei atomici: tali osservazioni richiedevano che durante il decadimento fosse prodotta una particella neutra di massa molto piccola, all'epoca non rivelabile. E. Fermi elaborò ulteriormente questa ipotesi e diede al neutrino il suo nome.

Helpful Materials and Resources

Resource Type	Source	Link
Google Translate for Websites: https://translate.google.com/ (Choose "Websites" option at the top)		
Article	FermiLab/ US Department of Energy	https://neutrino-classroom.org/external_docs/neutrino_60-seconds.pdf
Comic Strip	ICE Cube	https://icecube.wisc.edu/outreach/activities/rosie-gibbs/
Article	European journal for school sciences	https://www.scienceinschool.org/article/2011/neutrinos/
YouTube Video	FermiLab	https://www.youtube.com/watch?v=RGv-pcKRf6Q
Article	Frontiers for Young Minds	https://kids.frontiersin.org/articles/10.3389/frym.2020.00045
Article with Handout	Cosmos for Schools	http://cosmosforschools.com/PDFs/Lesson_011_handout.pdf
YouTube Video	FermiLab	https://www.youtube.com/watch?v=J8dRZjOD_ME
Collection of Activities	Neutrino Classroom	https://neutrino-classroom.org/TeachersGuideJuly2015/NeutrinoClassroomTeachersGuide-EditedJuly2015.pdf#page70
Collection of Articles and Activities	Fermilab	https://neutrinos.fnal.gov/
Collection of Posters and Videos	SNOLAB	https://www.snolab.ca/outreach/resources-for-students-educators/
Articles	Gran Sasso National Lab	https://www.lngs.infn.it/en/educational
Article	Smithsonian	https://www.smithsonianmag.com/science-nature/looking-for-neutrinos-natures-ghost-particles-64200742/

Helpful Resources and Materials

[Google Translate for Websites]



Best Practice Example

High School Students

<u>Sessions</u>	:	4	<u>Class organisation</u>	:	teams of 4 to 5 students Each team chooses a particule
<u>Time necessary</u>	:	4 x 1,5h	<u>Output</u>	:	1 poster for each team

The teacher provides :

- The names of different particles: neutrino, quark, electron, photon, muon, gluon, Higgs' boson …
- A list of questions the poster will have to address
- different ressources, articles, videos, …etc … covering :
  - the history of the discovery,
  - The names of the main scientists associated with the particle,
  - the principle of experiences undergone,
  - The keys datas and properties
- At least one question will not be addressed by the ressources and requires personal researches.

Best Practice Example

Junior High School Students

<u>Sessions</u>	:	2	<u>Class organisation</u>	:	Scavenger hunt for teams of 4 to 5 students
<u>Time necessary</u>	:	1 x 1,5h	<u>Output</u>	:	1 quiz for each team listing
		1 x 1,5h			1 question about each of the 10 particules

Session 1

- The teacher spreads out 10 small articles (with pictures and schematics) in a geographically limited area.
- Each article will cover one particle: neutrino, quark, electron, photon, muon, gluon, Higgs' boson …
- The teacher provides a quiz that will ask a different question for each particle: Name of the discoverer, principle of one experiment, properties (mass, charge, interactions, life duration, …), …

Session 2

- All 10 articles are given to all teams. After a group work (including personal researches is needed) each team gives a 3 minutes presentation explaining to the class which particle they find the most interesting and why.

Best Practice Example

Kinder garden

Sessions	:	2	Class organisation :	Session 1 : draw your disguise as a particule Session 2 : listen to other's mouvement
Time necessary	:	30 min 2 x 5 min	Output :	Creativity, and space organisation

Session 1

- Children are asked to choose the name of a particule (neutrino, quark, electron, photon, muon, gluon, Higgs' boson …) and draw on a mask shaped paper, the name, charge, mass, and decorate it as he/she likes.

Session 2

- Children put on the mask, in semi darkness, children will evolve in the dark and listen to others' mouvements to try and avoid collisions.