I presented this talk at the public reception in Orr, MN on May 1st, following the ground breaking ceremony at the Ash River site. My two goals for the next several minutes are to help explain what a neutrino is and how it fits into our understanding of particle physics and to outline the scientific goals of the NOvA experiment. As you follow along with these notes, please click or press “page down” whenever you see a “[next]” in the text. For example: this one: [next]

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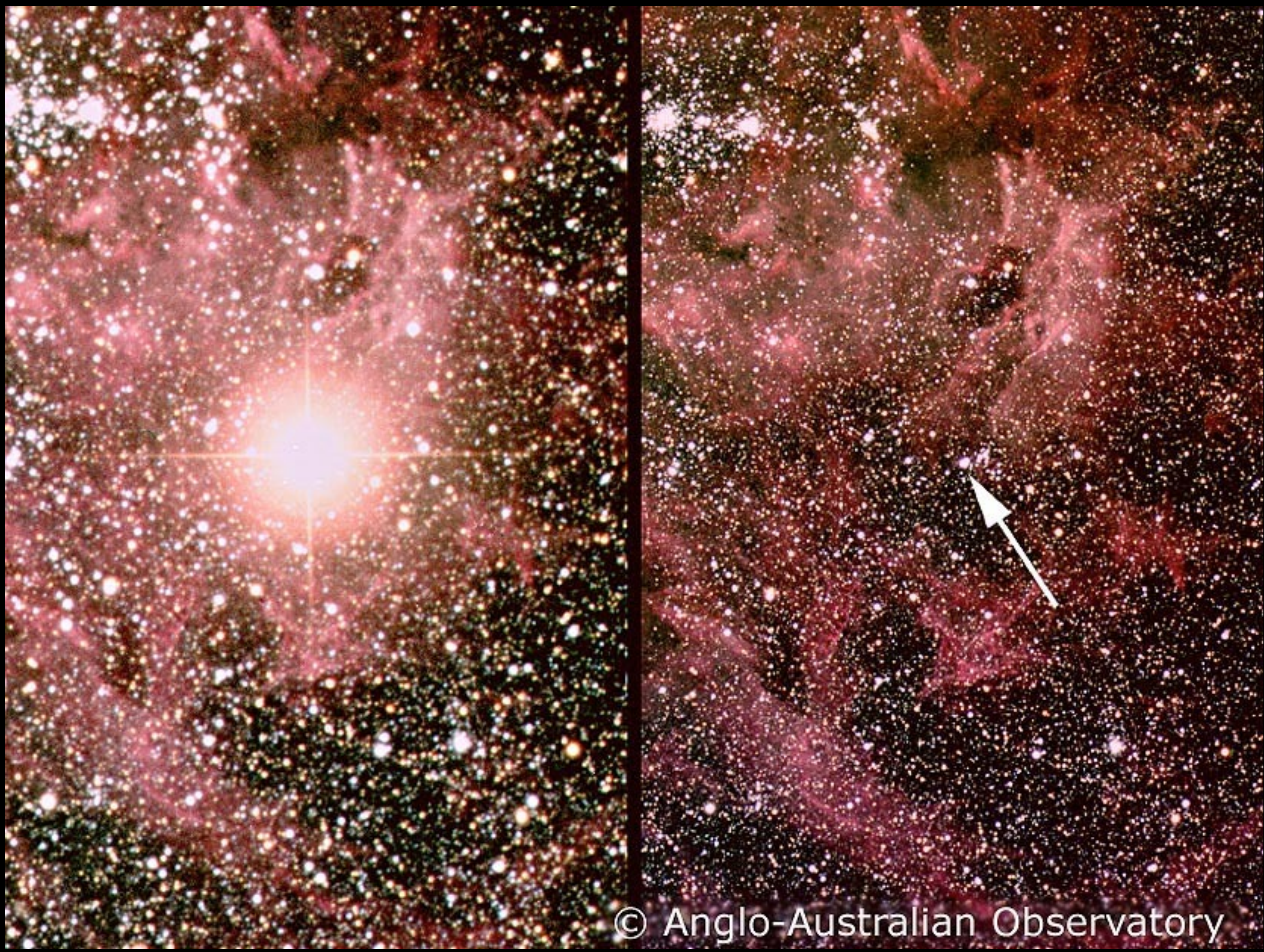

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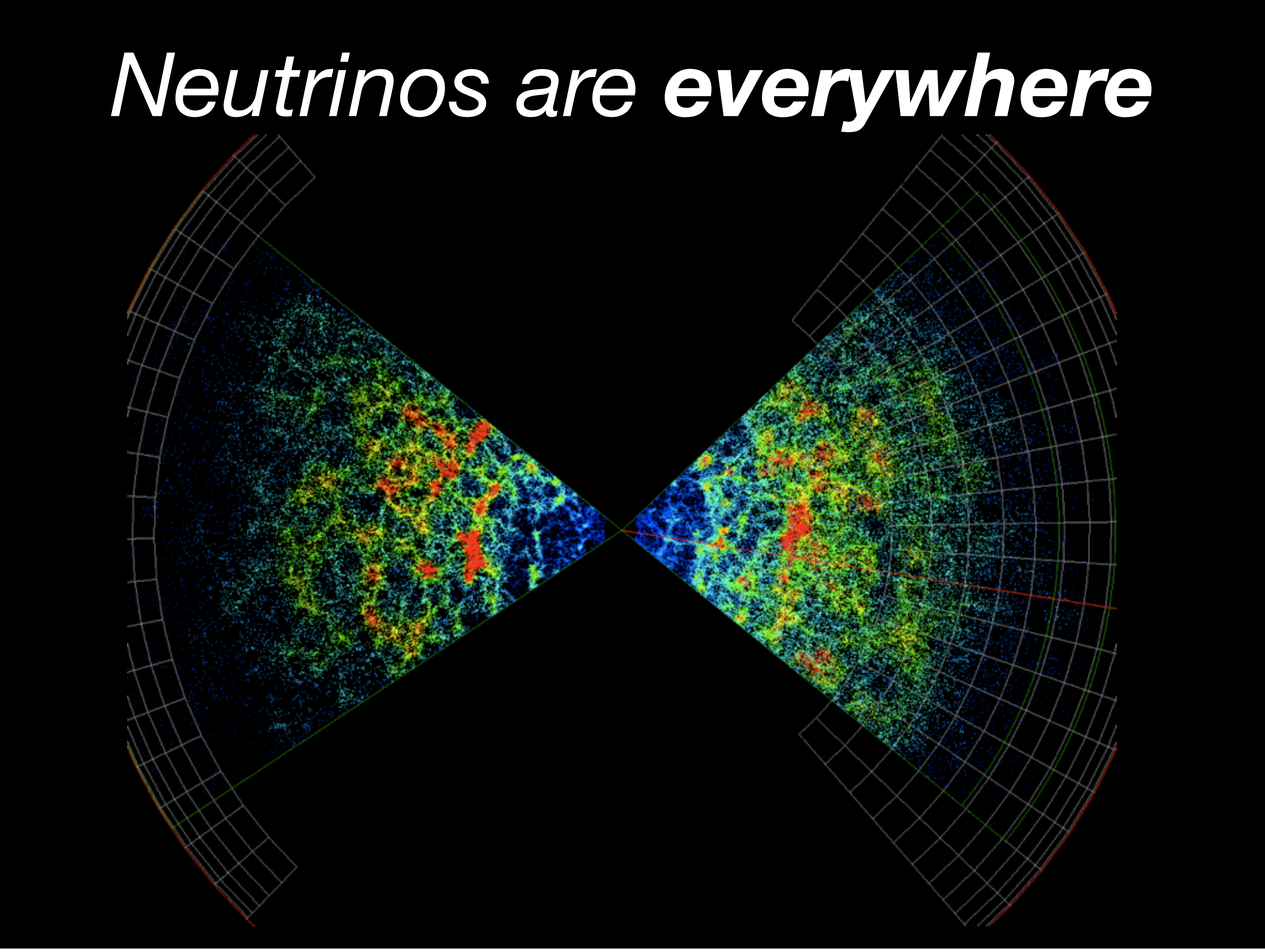

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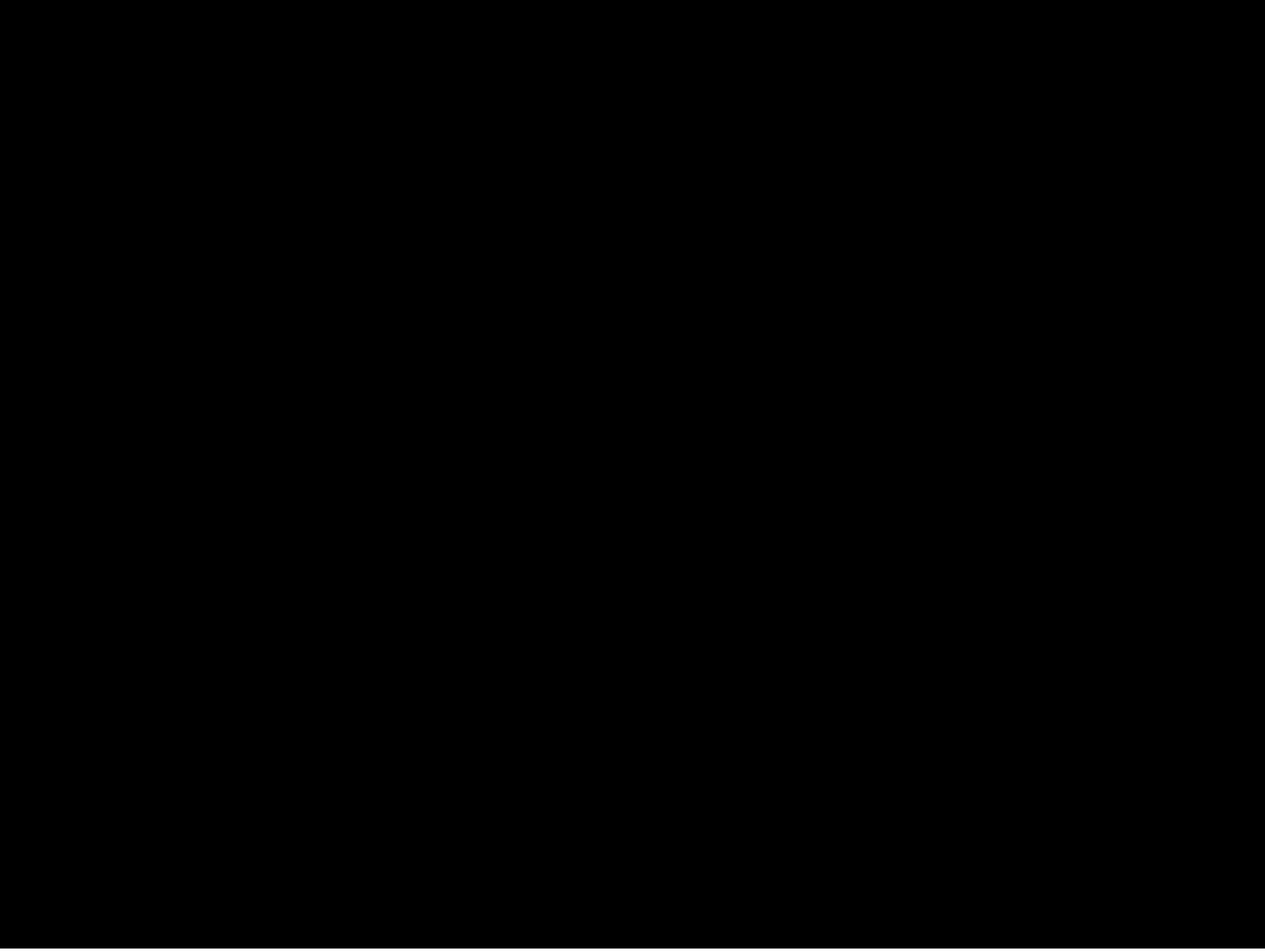

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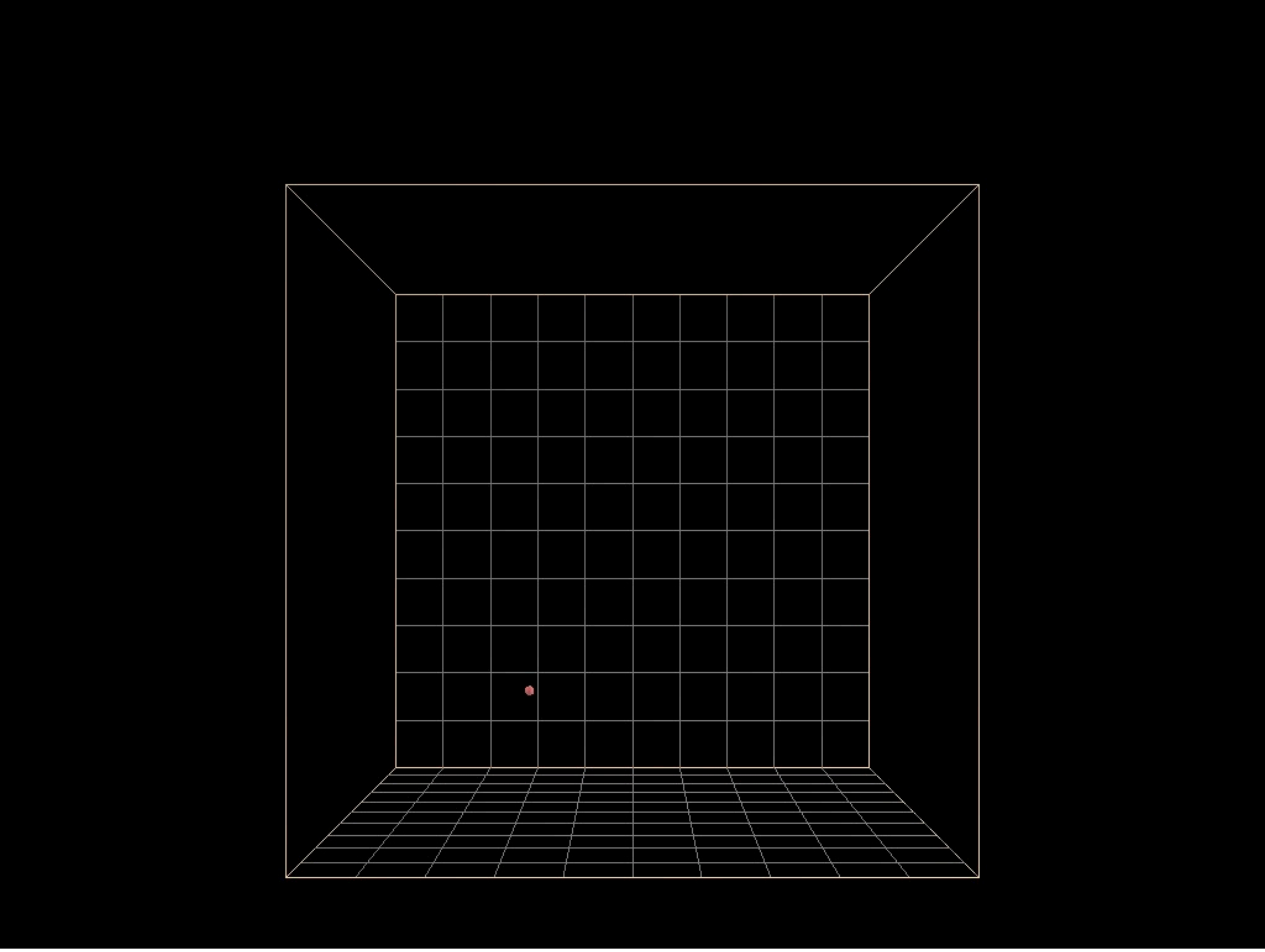

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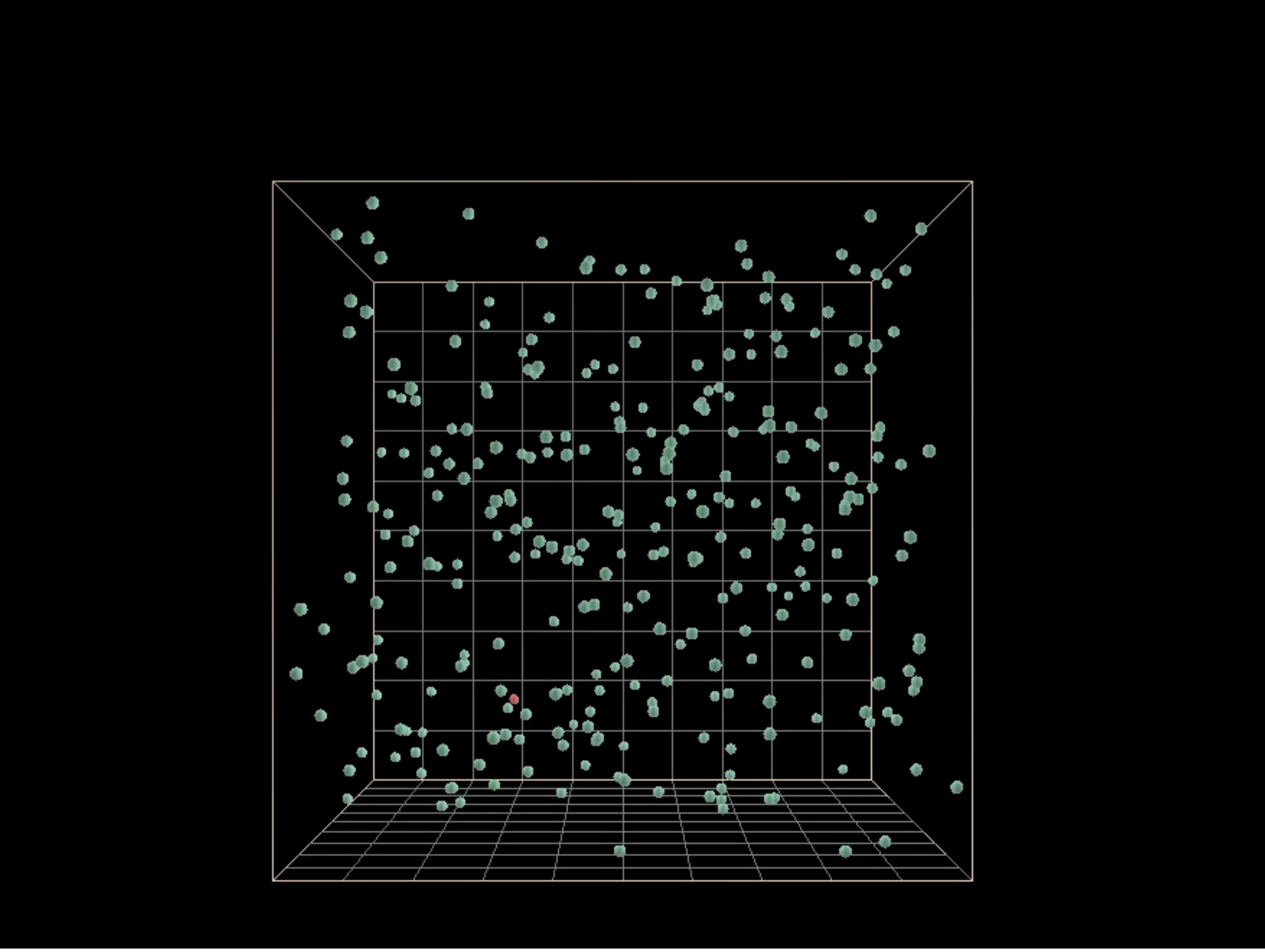

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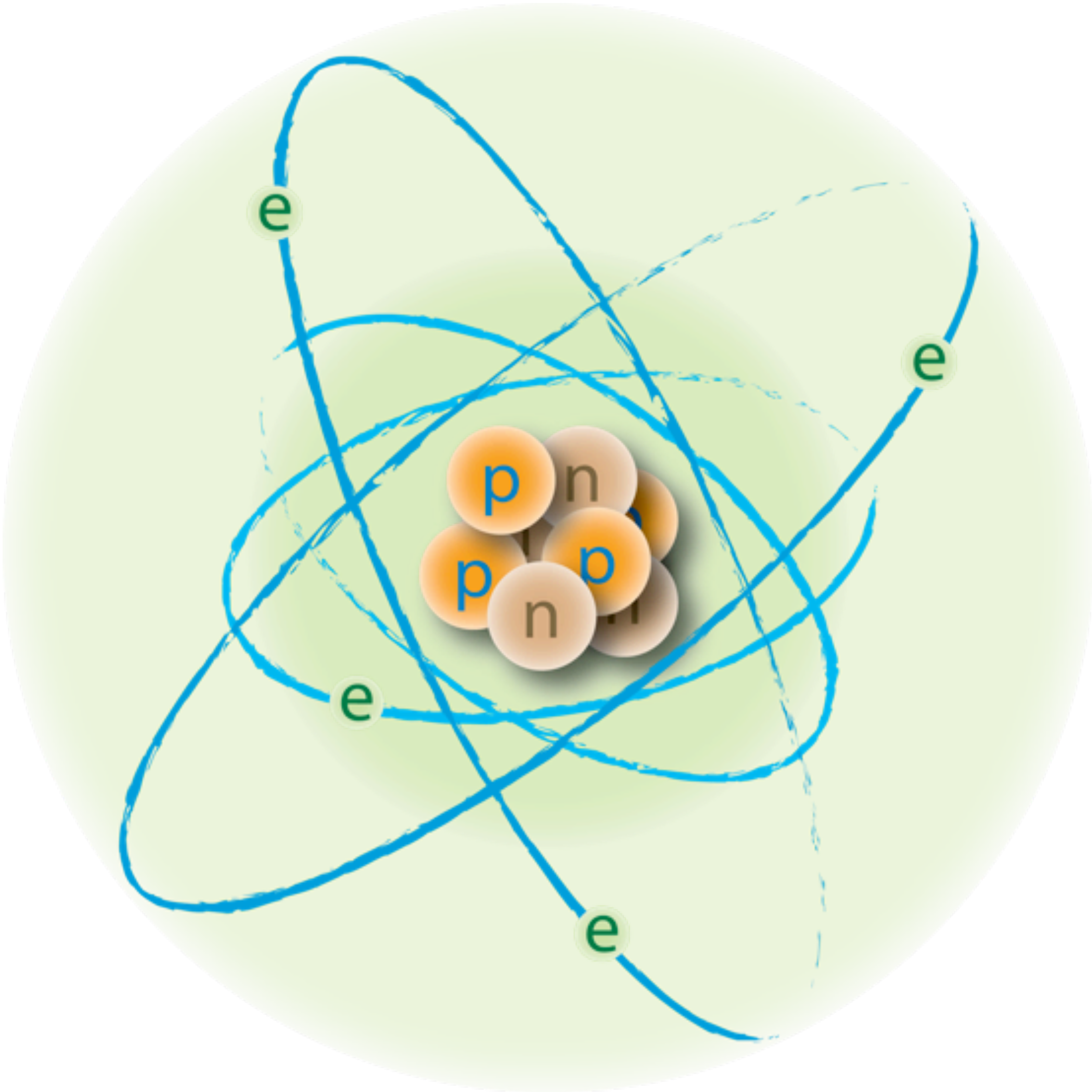

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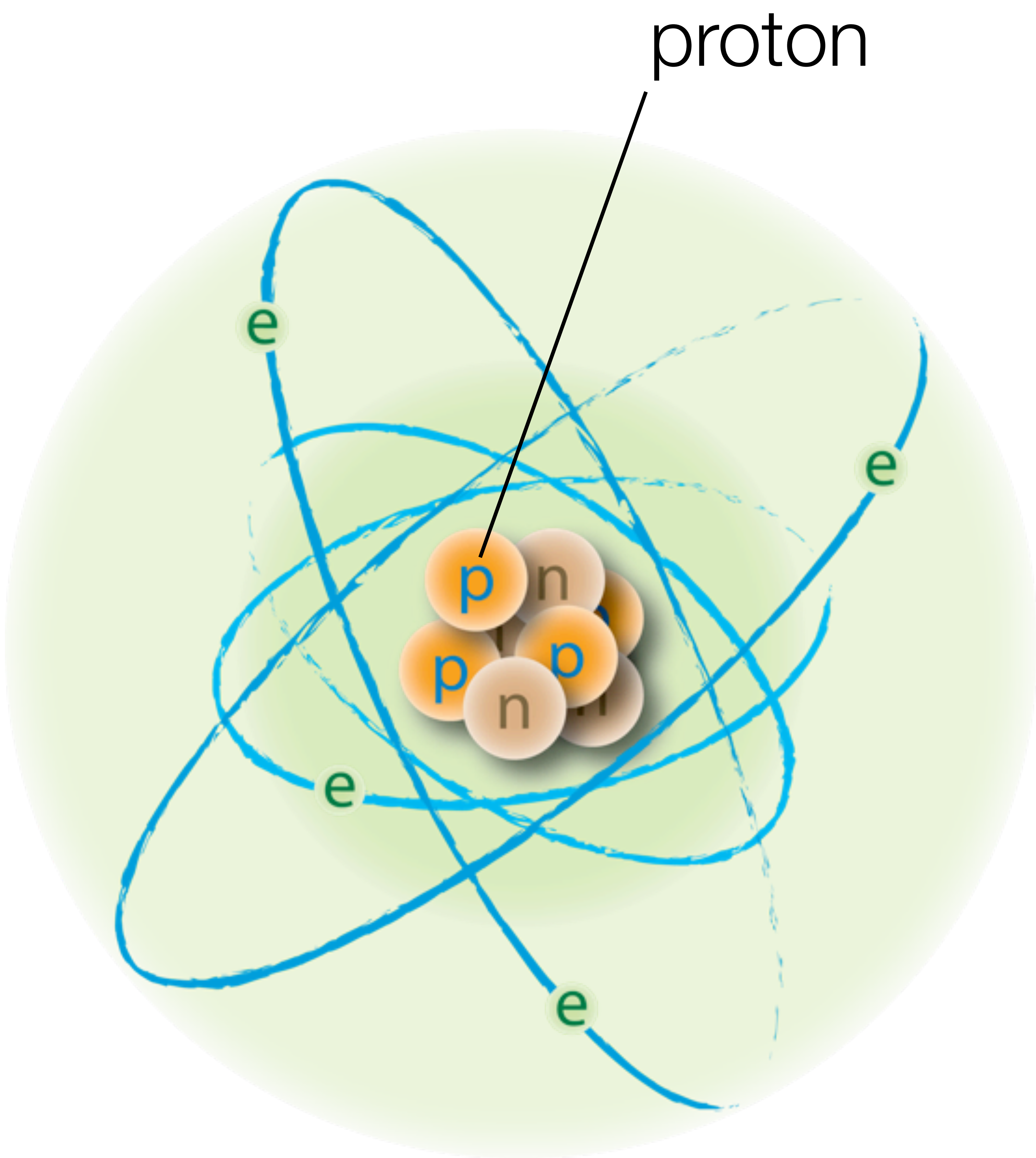

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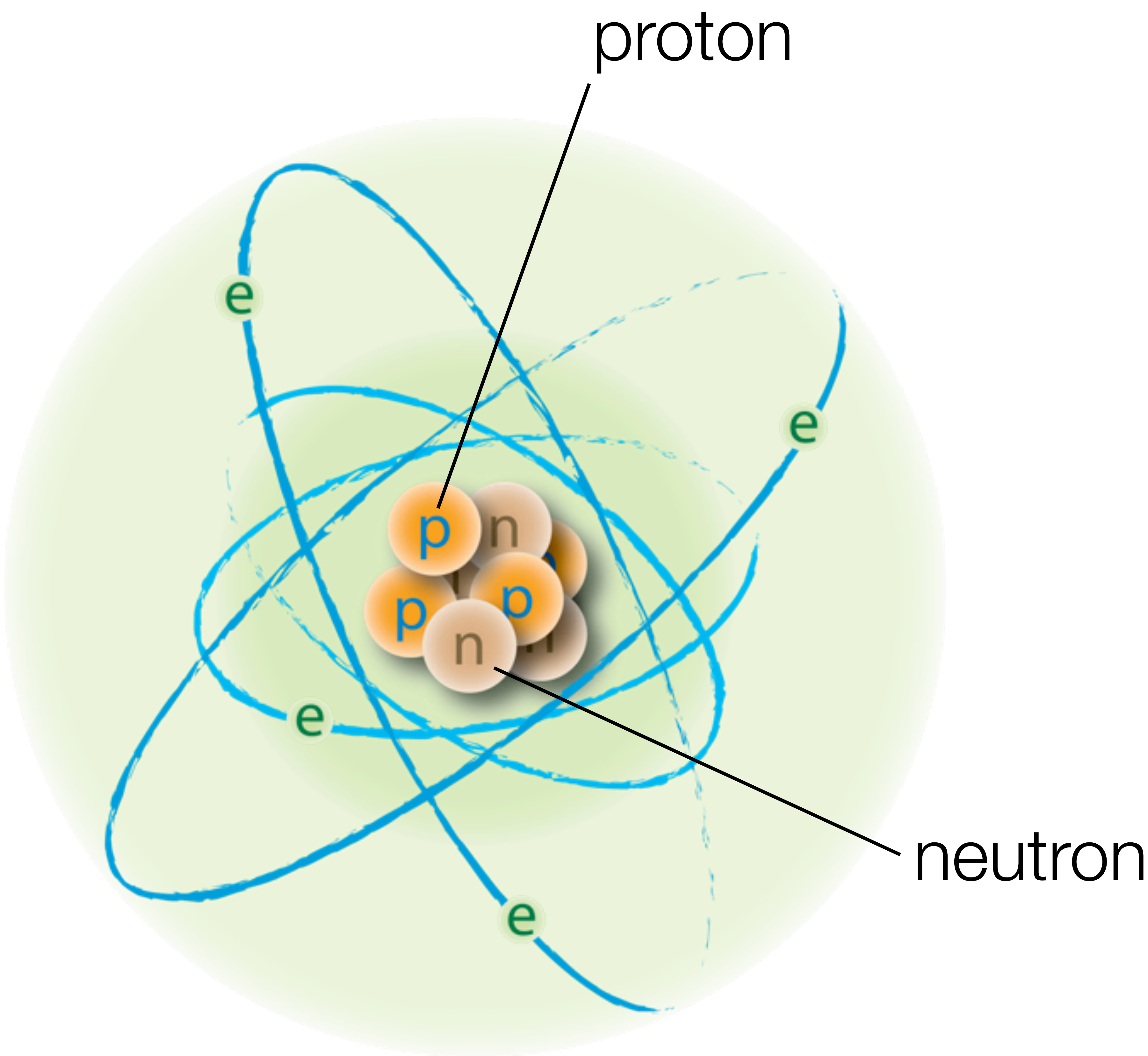

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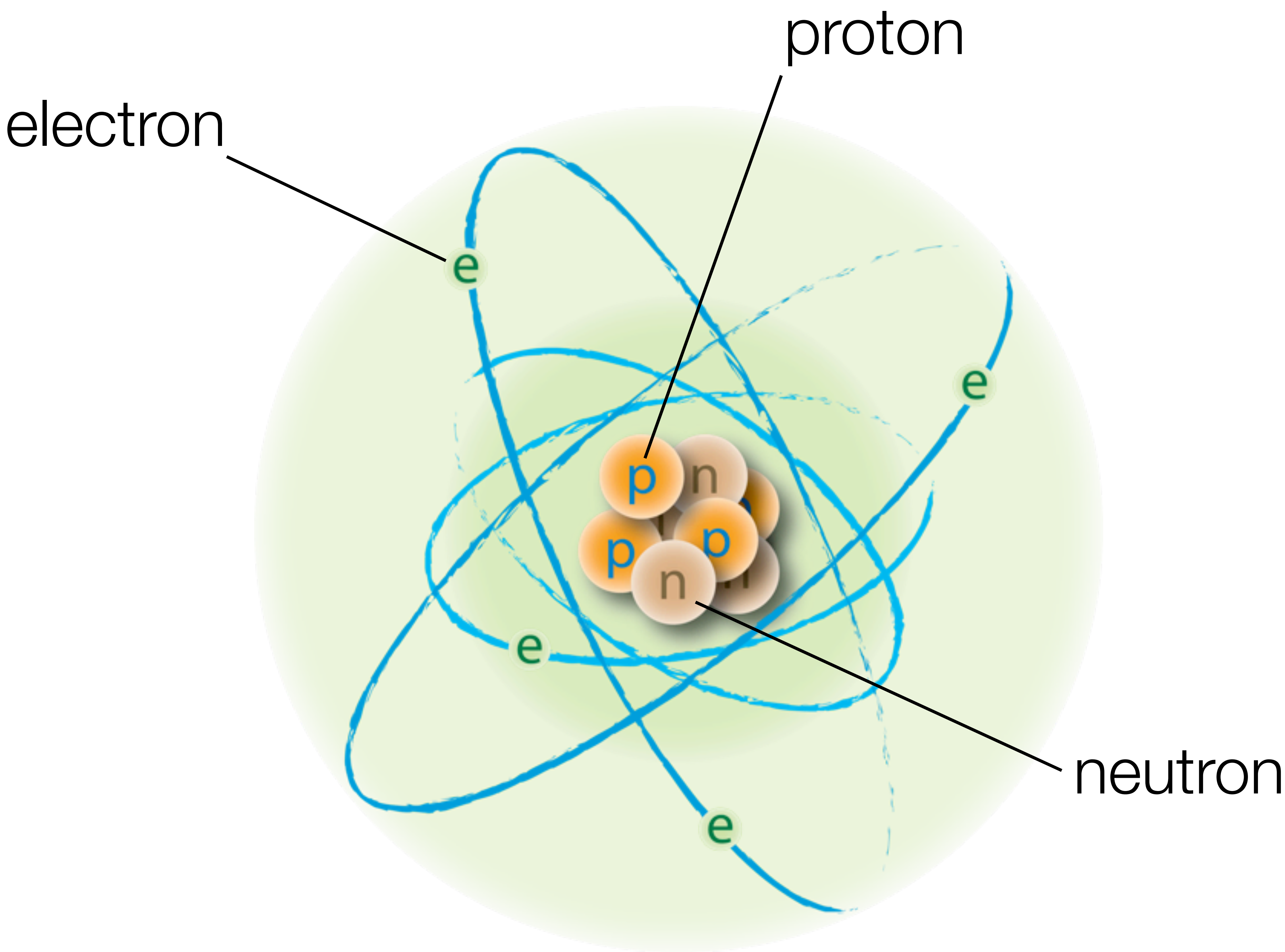

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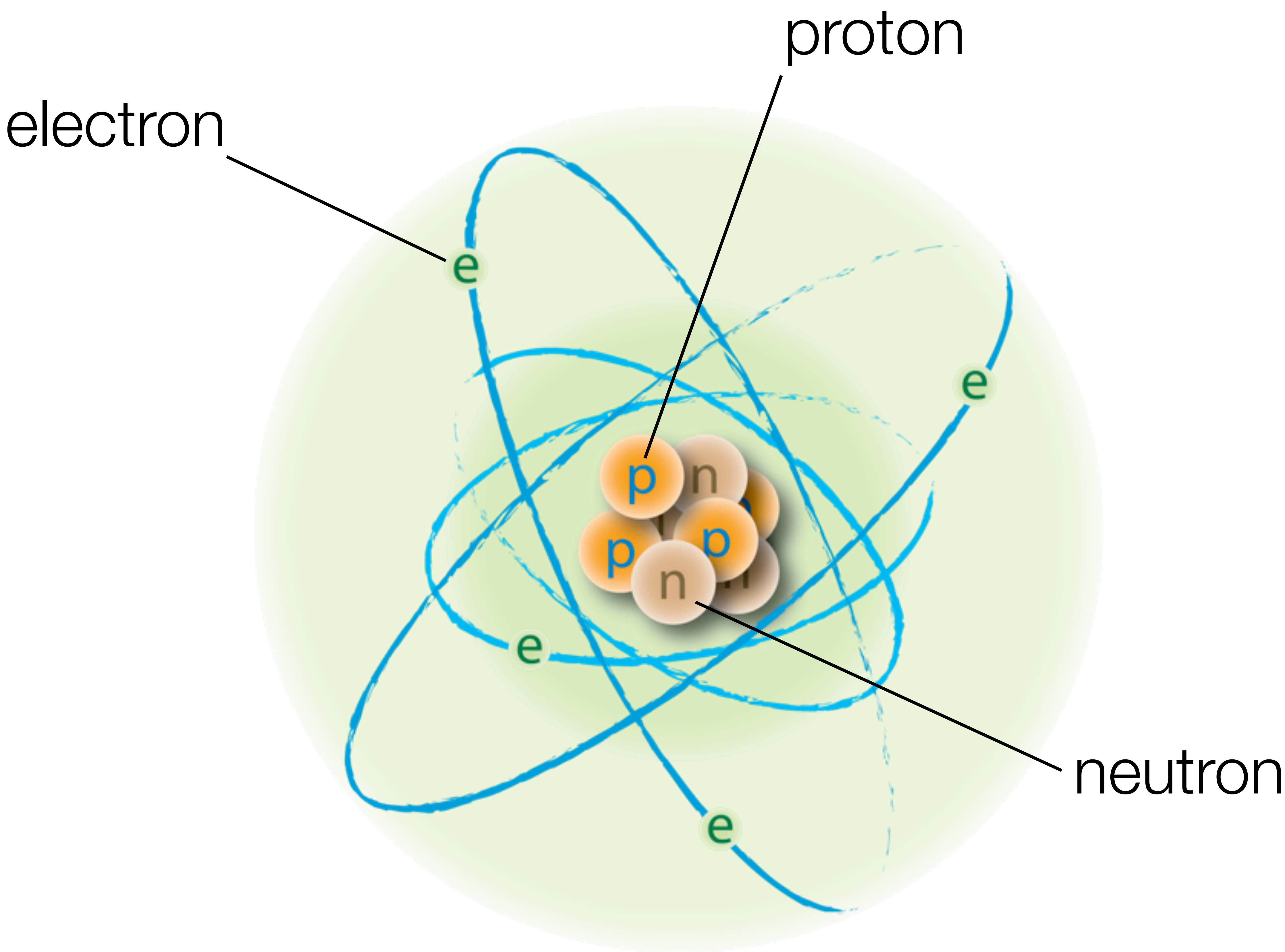

neutron decay

$$n \rightarrow p + e$$

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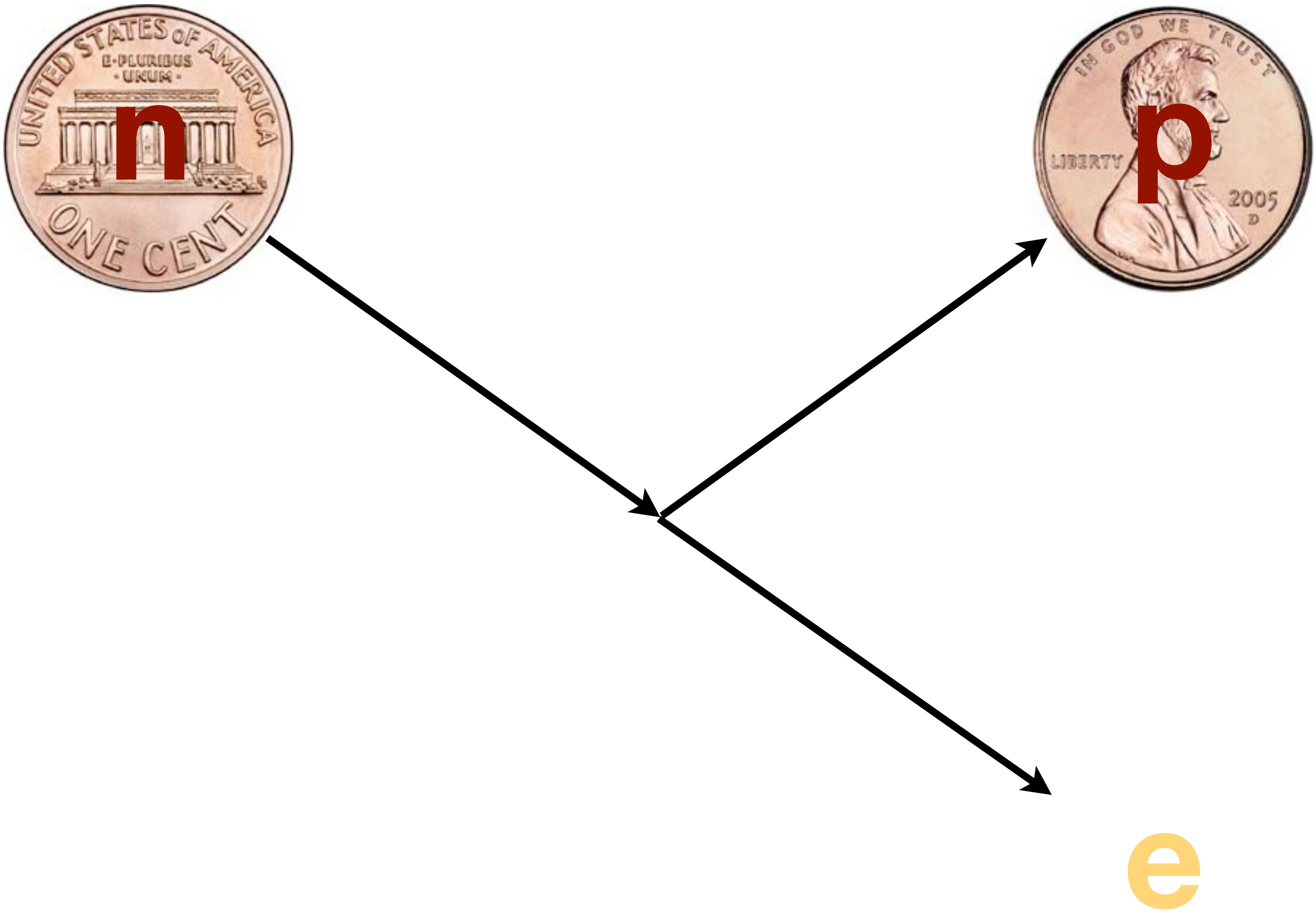

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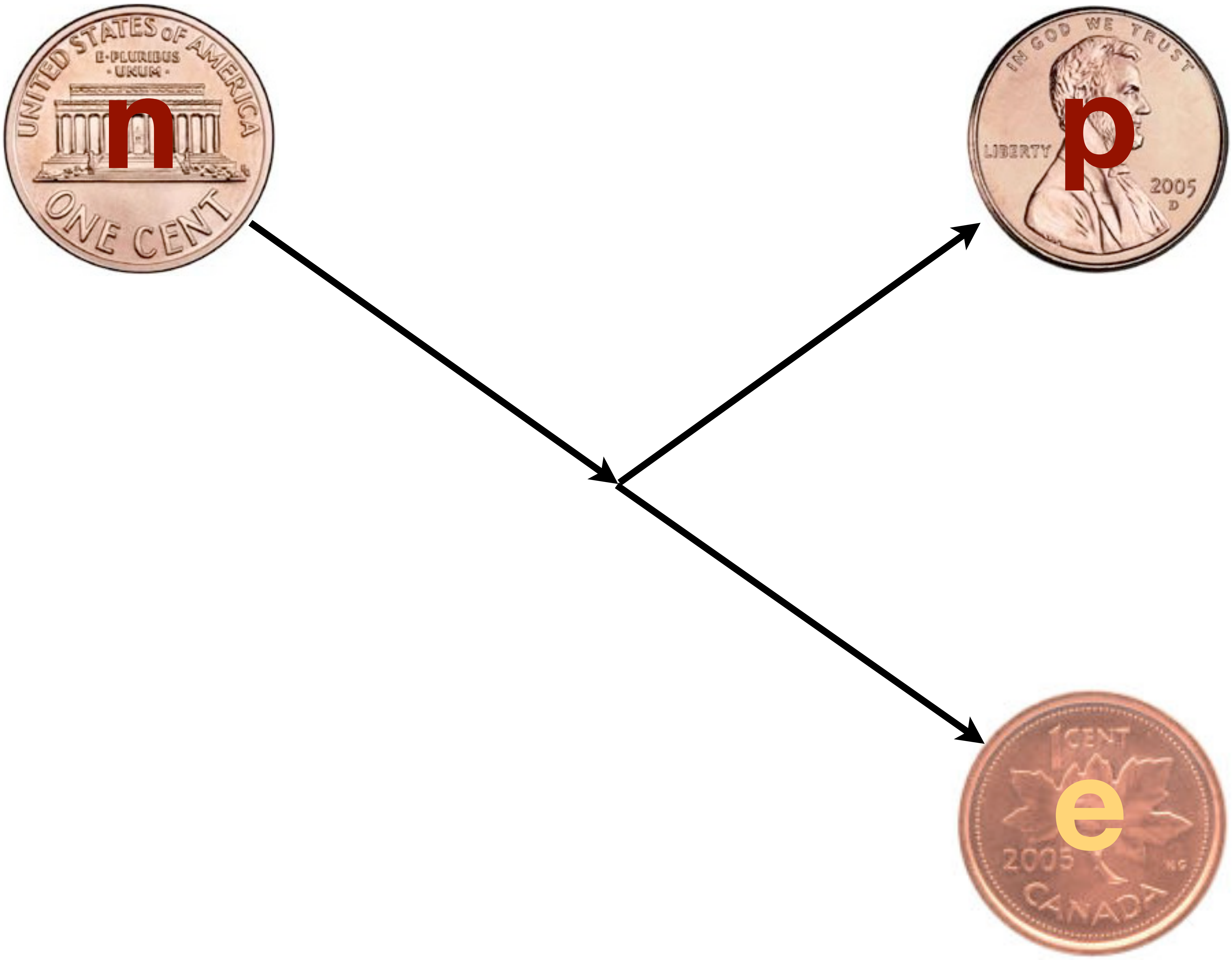

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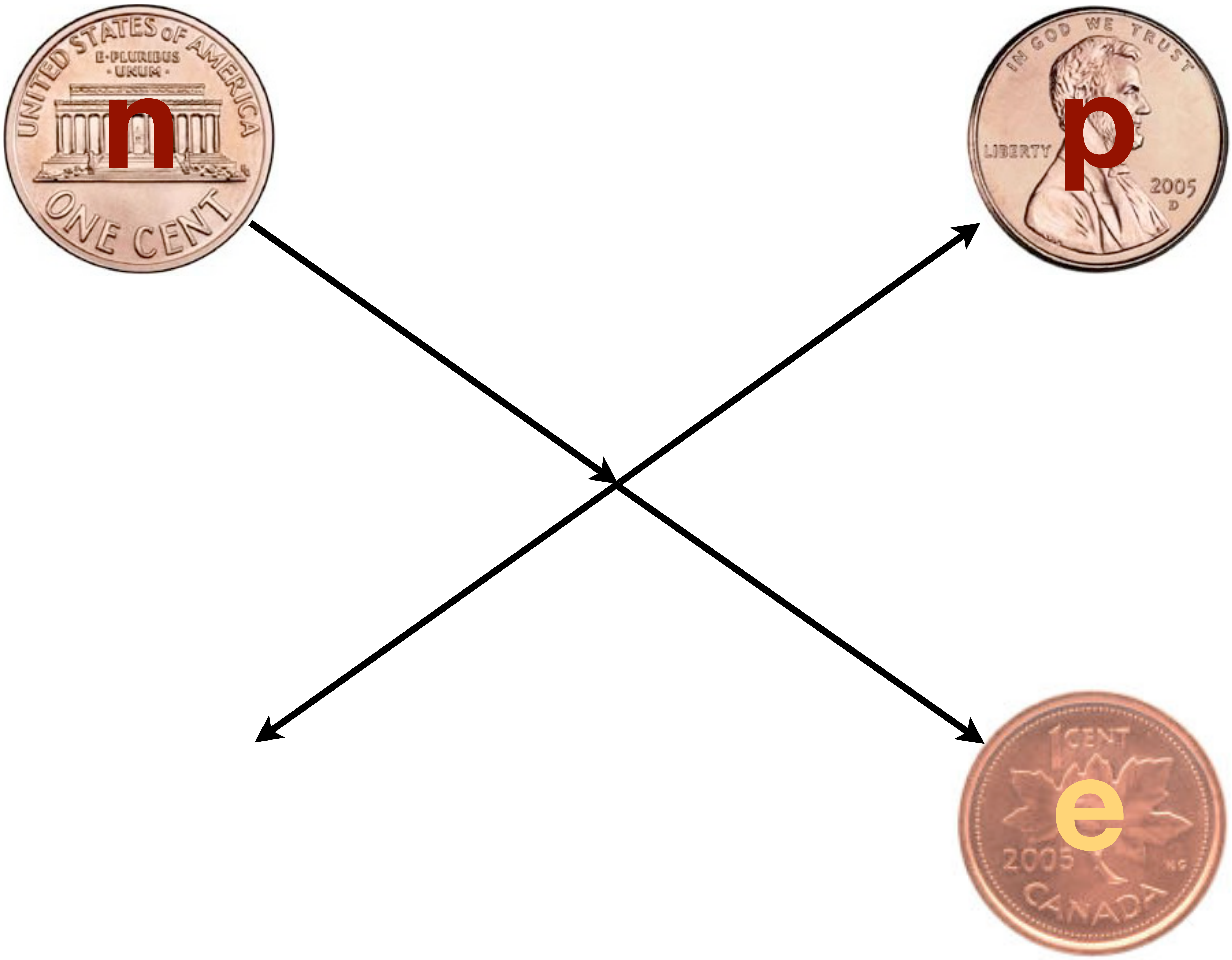

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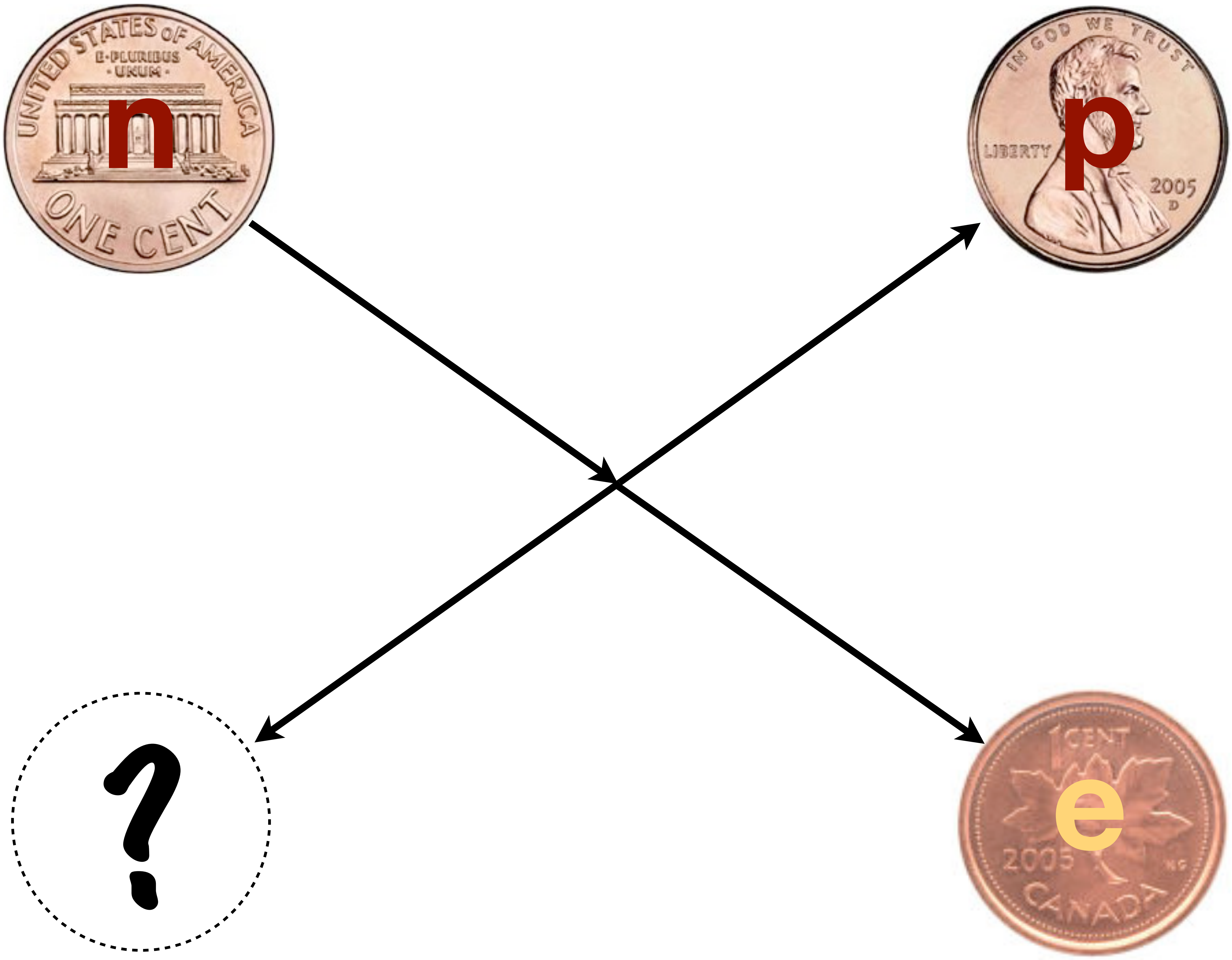

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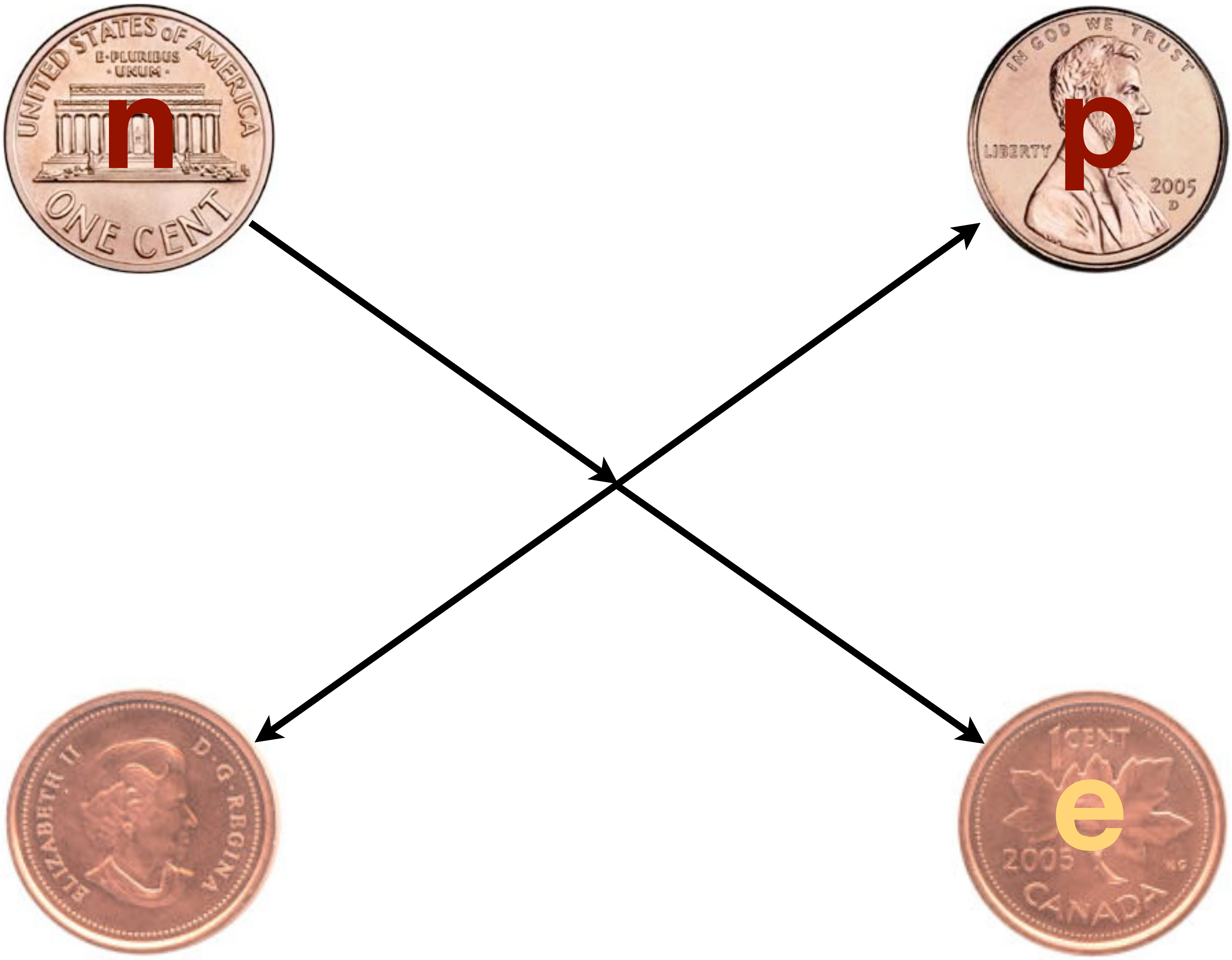

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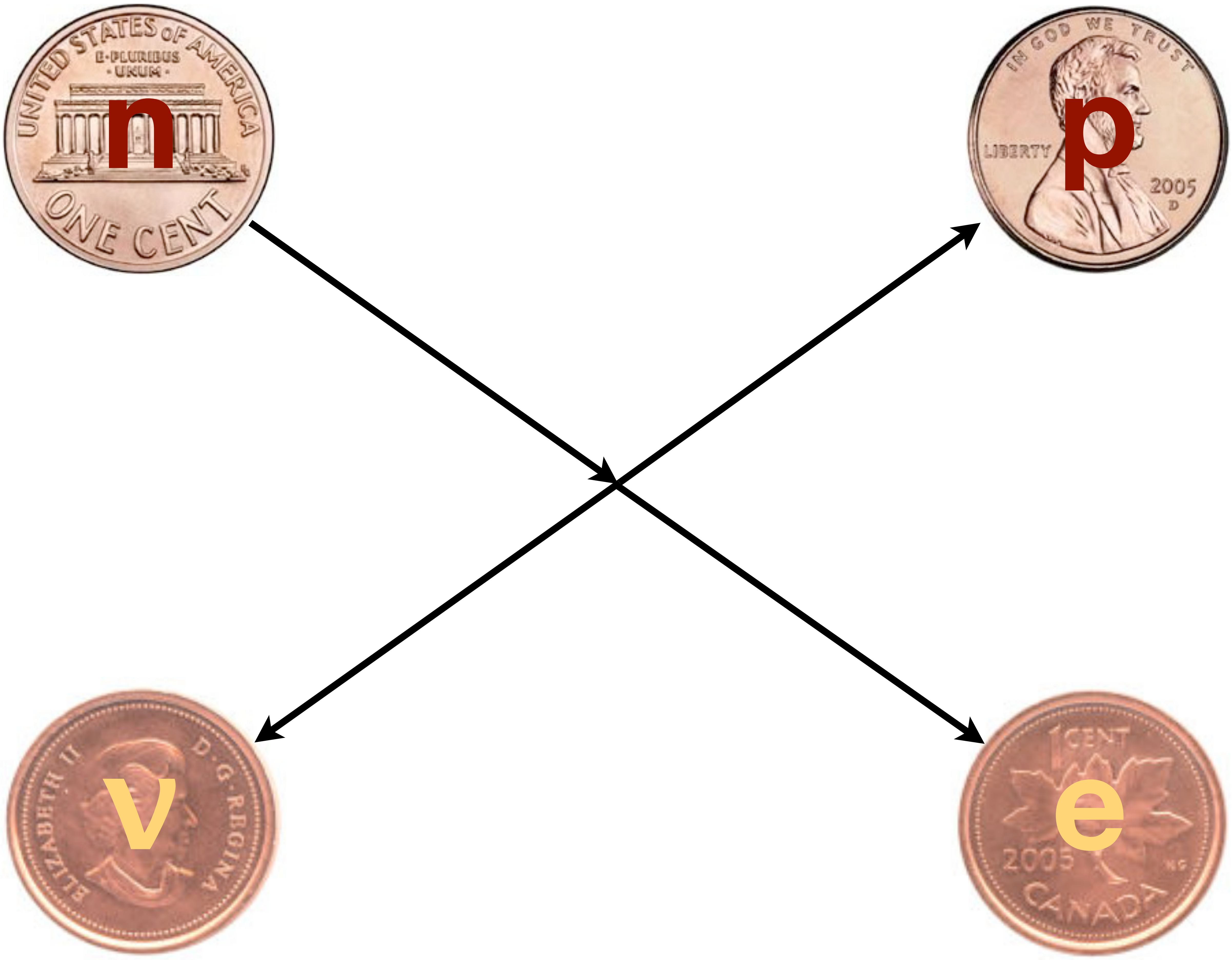

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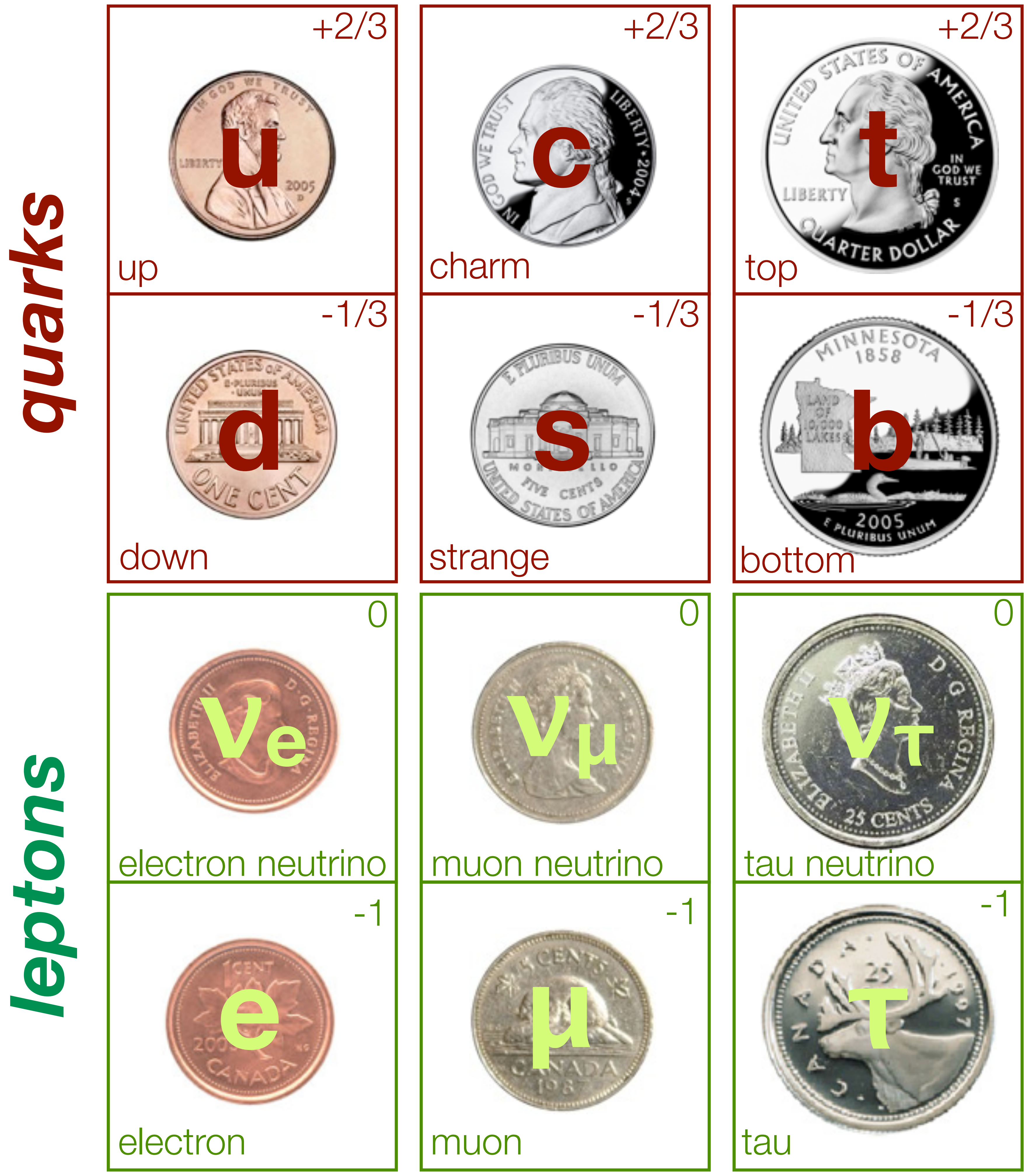
Project Poltergeist
1953

Los Alamos Science, Number 25 1997

Since the neutrino doesn't feel either of the forces that holds ordinary matter together, Pauli despaired that it would never be detected by an experiment. But it was detected 23 years later by a team lead by Fred Reines and Clyde Cowan in 1953 – an effort for which Reines would receive the Nobel prize in 1995. [next]

Today, we've been able to look inside of the proton and neutron and see that they are made of particles we call quarks. The proton and neutron are distinguished by the fact that the proton has more up quarks and the neutron has more down quarks. For reasons we don't understand, the pattern of particles we see in atoms repeats three times, with each repetition getting heavier and heavier. The electron is copied twice, once as a particle called the muon and once more as a tau particle. [next] Each of these electrically-charged leptons has a neutrino partner. So over all we have three neutrinos in our collection of fundamental particles. [next]



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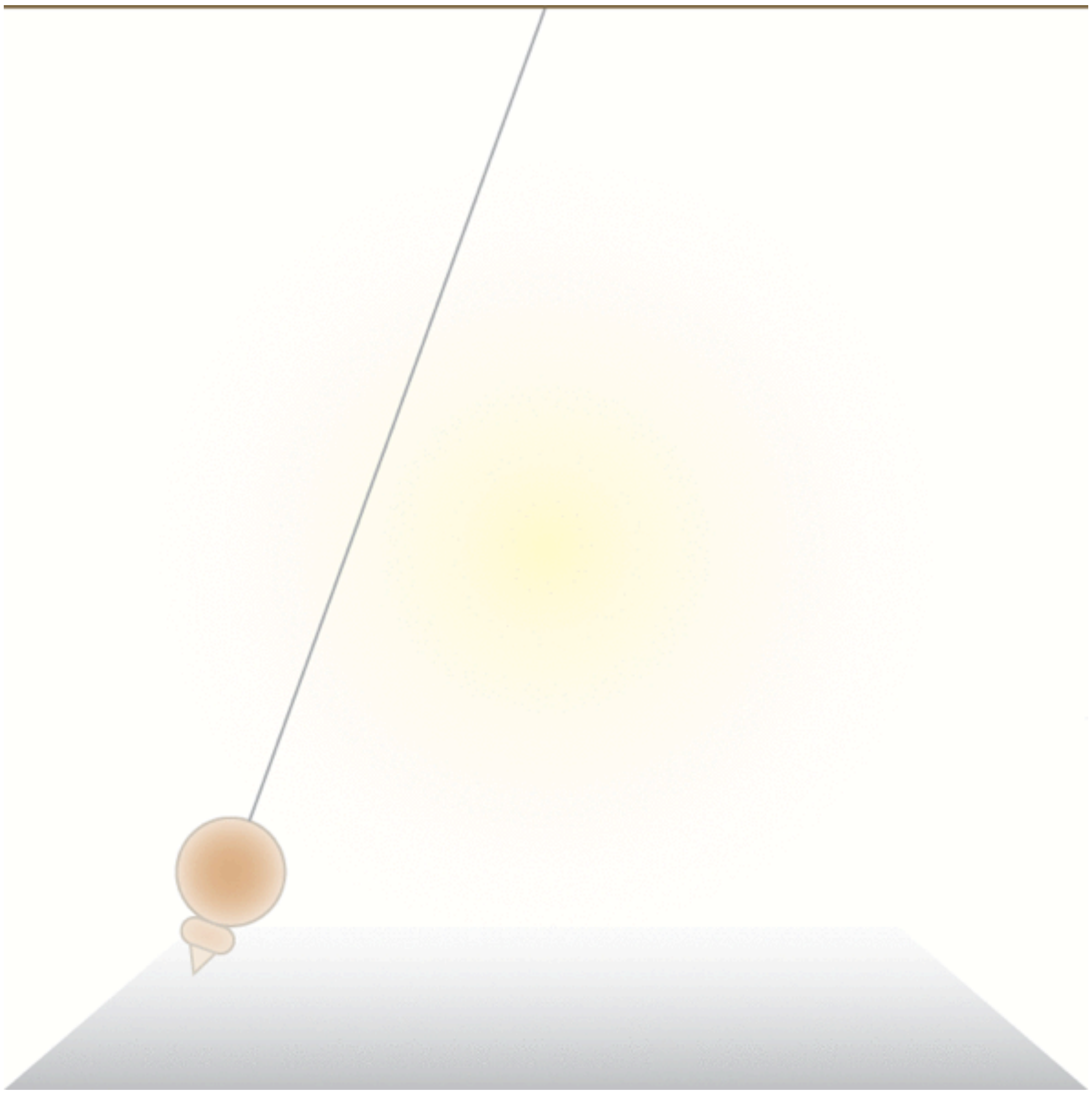
Neutrino Oscillations



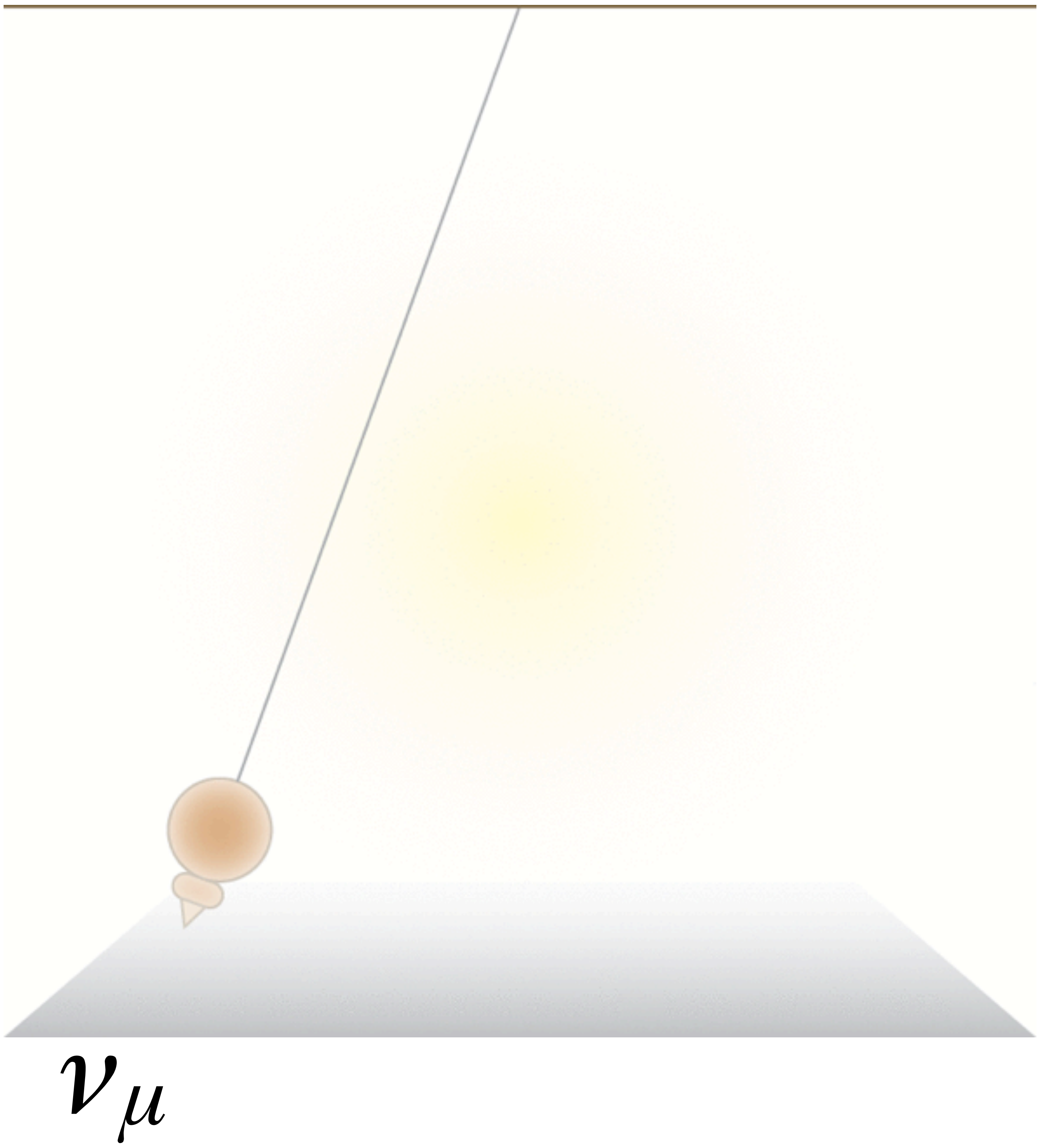
With three types of neutrinos, there is the possibility that what we call “a neutrino” is really a mixture and that mixture may not be static in time. If we produce a neutrino of a particular type now, it might be observed later on as another type. So, for example, if you produce a muon-type neutrino at one point in time [next] at some later point in time it may transform itself into an electron-type neutrino [next]. You needn’t mourn the loss of your muon neutrino as the process doesn’t stop there. [next] The electron neutrino will eventually transform itself back into the muon neutrino you started with, and the whole process repeats itself.

This process is called “neutrino oscillations” and it provided the first evidence 11 years ago that neutrinos in fact have a non-zero mass. Since then there has been a world-wide effort to understand how big these oscillations are and how fast they occur to better understand the basic properties of the neutrino.

Oscillations of muon-type to tau-type neutrinos have been seen by the MINOS detector which is taking data now in Soudan MN and oscillations of electron-type to muon and tau-type have also been seen.

However, the oscillation shown here, muon-neutrino to electron-neutrino has not been seen, and it is the focus of the NOvA experiment.
[next]

Neutrino Oscillations



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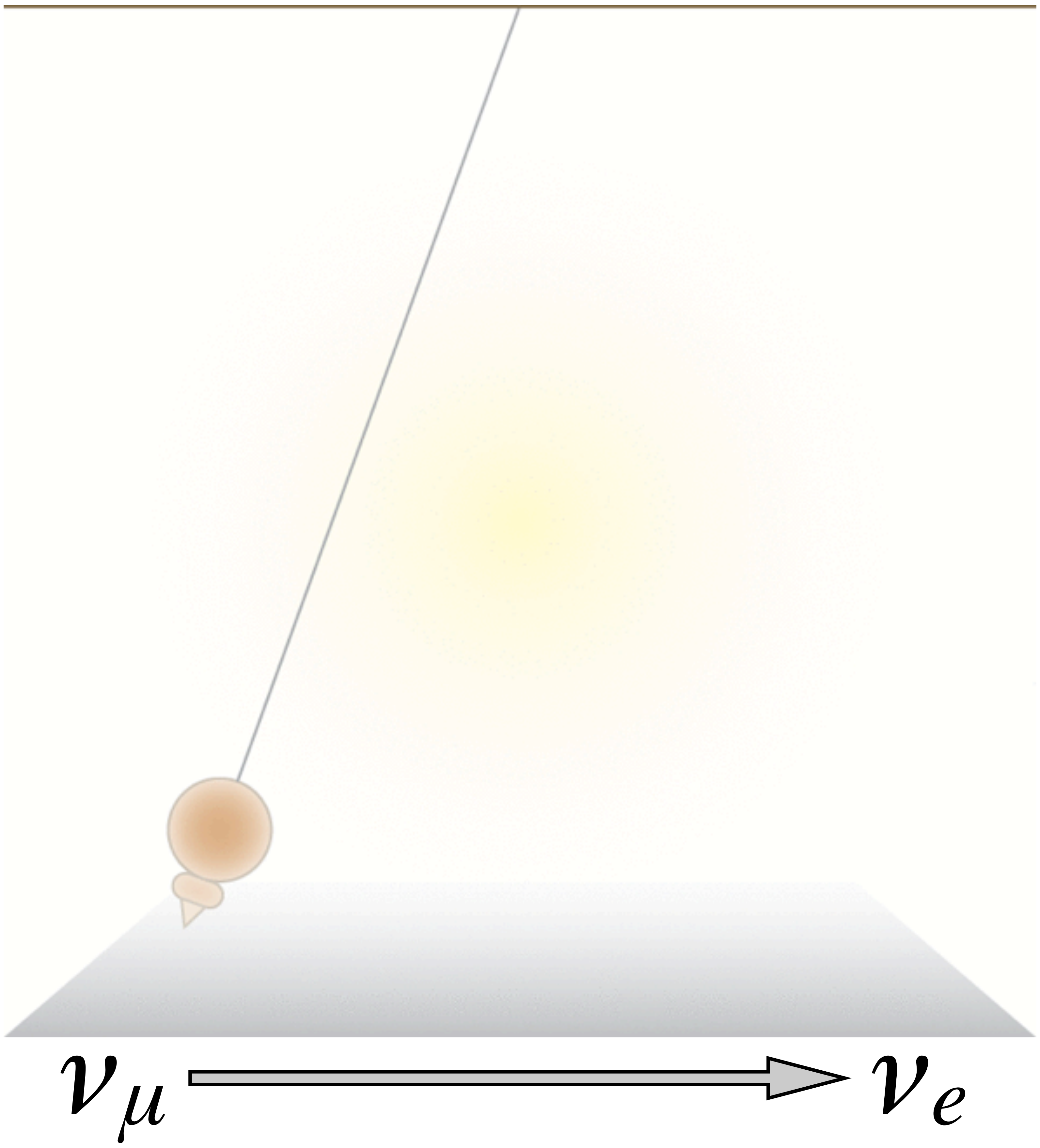

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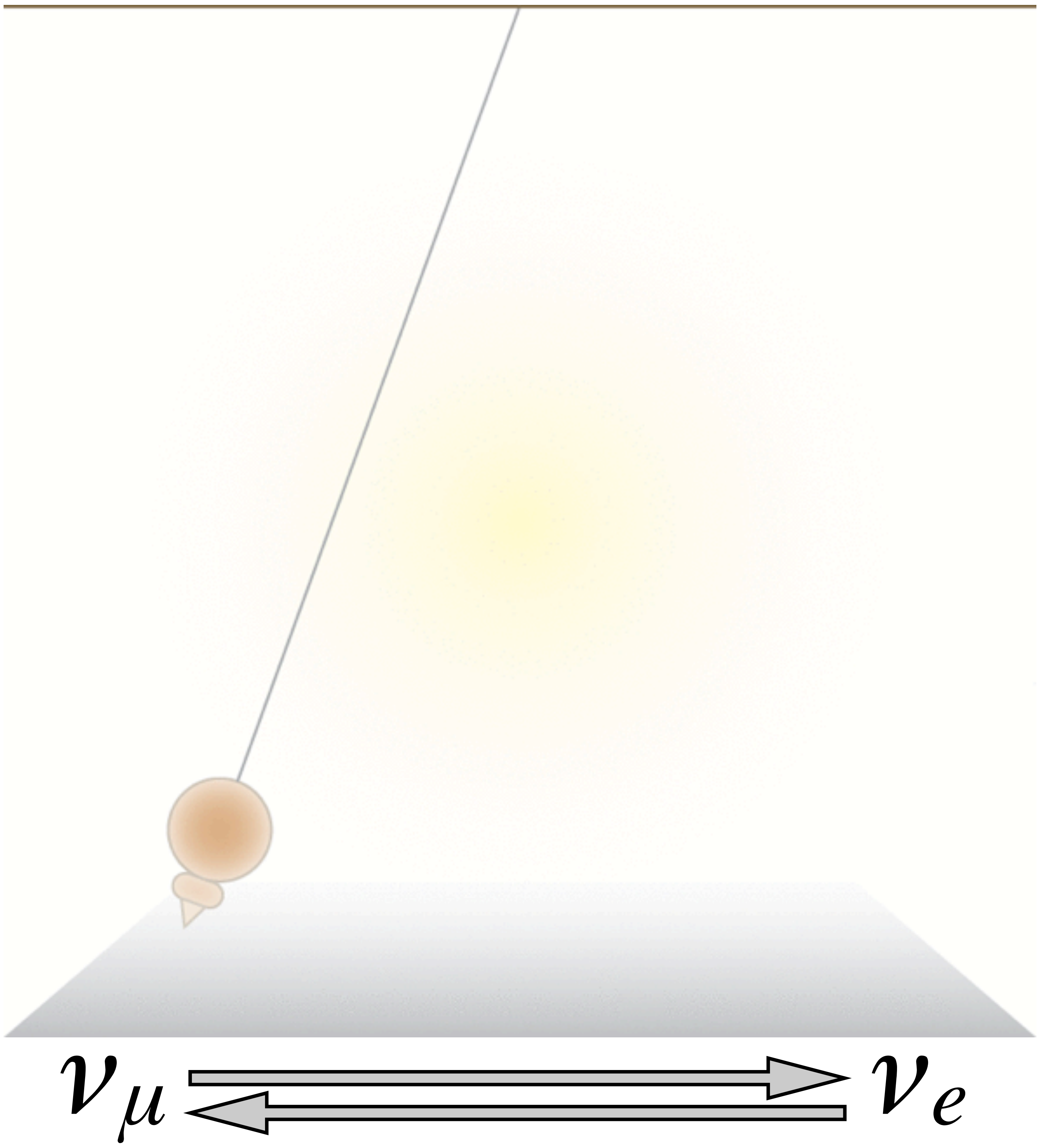

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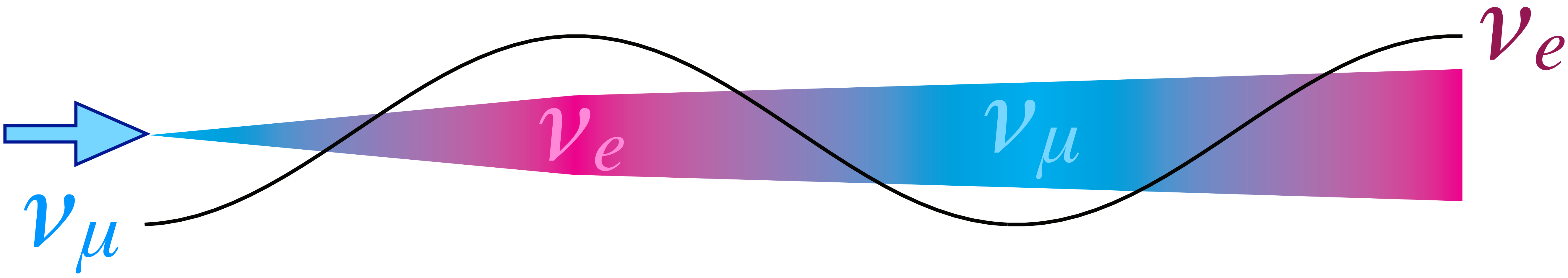
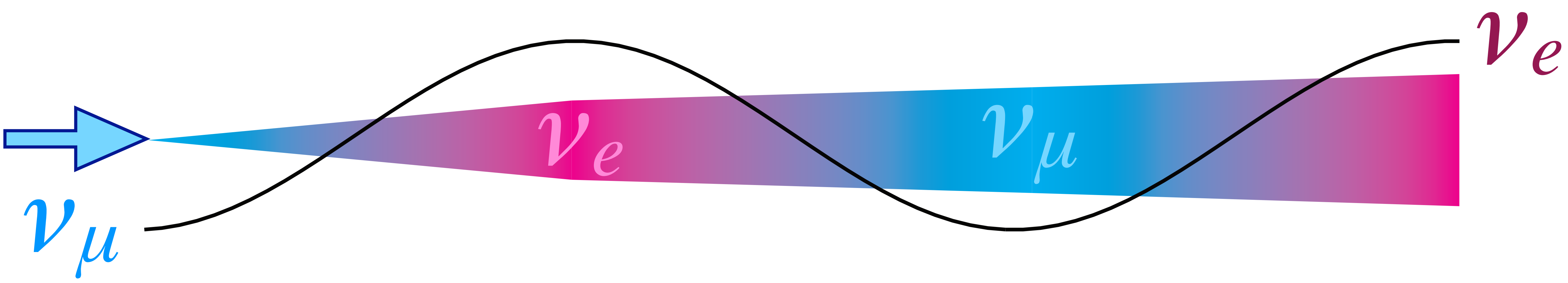
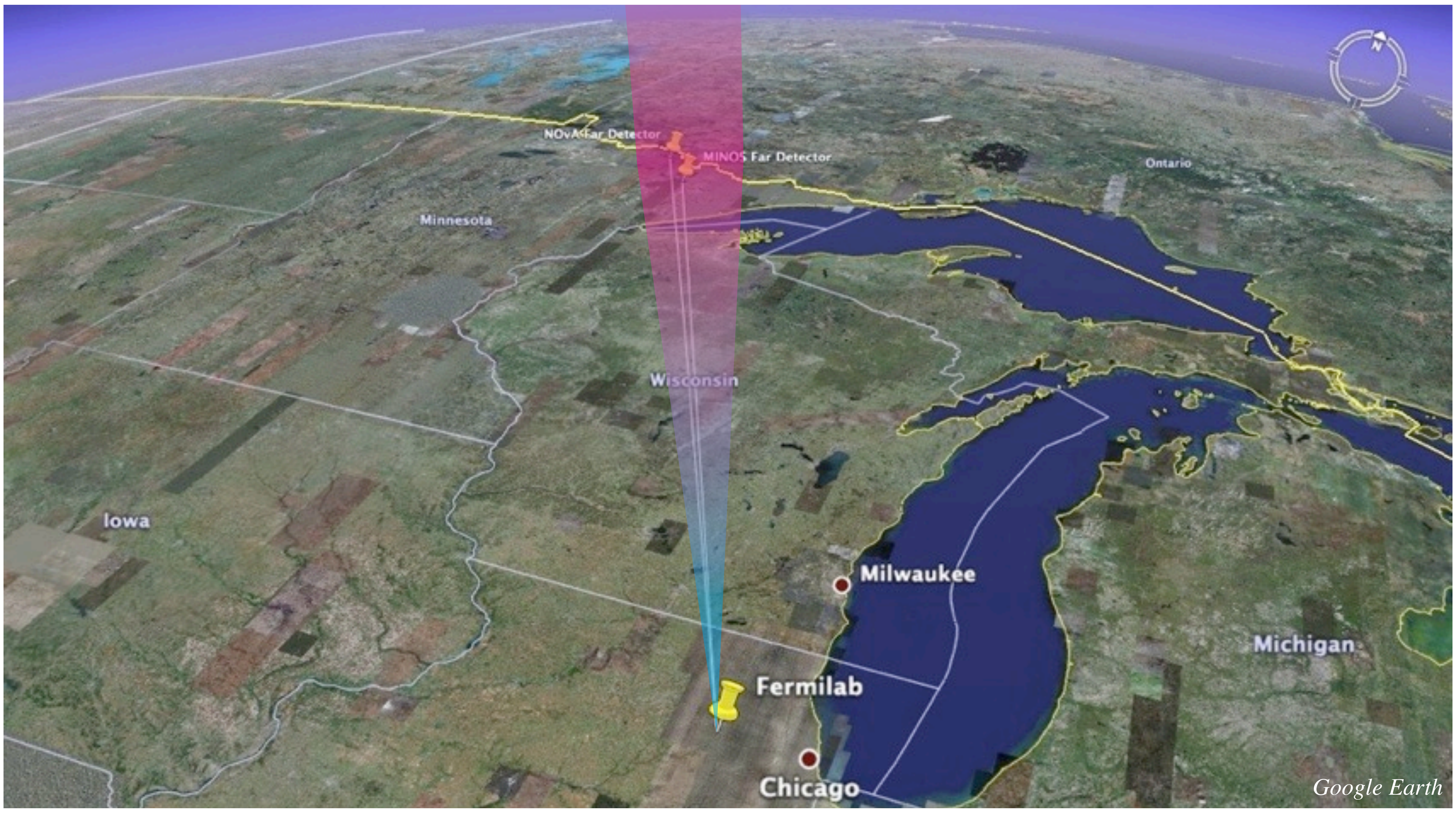


If the neutrino is set into motion, this oscillation creates a wave with the electron neutrino content rising and falling as you move away from the neutrino source. In our case, our source is the proton accelerators at Fermilab, just outside of Chicago. We're planning to put our detector in Ash River MN [next], to ride the crest of the electron neutrino oscillation and maximize our chances of seeing this, possibly quite rare, oscillation of muon to electron neutrinos. [next]

Neutrino Oscillations





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NOvA's Science

$\nu_\mu \longrightarrow \nu_e$

matter

$\bar{\nu}_\mu \longrightarrow \bar{\nu}_e$

anti-matter

NOvA will measure the muon-to-electron oscillation using both neutrinos and anti-neutrinos. The anti-neutrino measurements are made possible by Fermilab's ability to produce very intense beams and as part of NOvA we will be working to increase the intensity of the lab's proton source. By measuring both neutrinos and anti-neutrinos NOvA will help answer some basic questions about neutrinos and the universe. [next] For example, which of the three neutrinos is heaviest?
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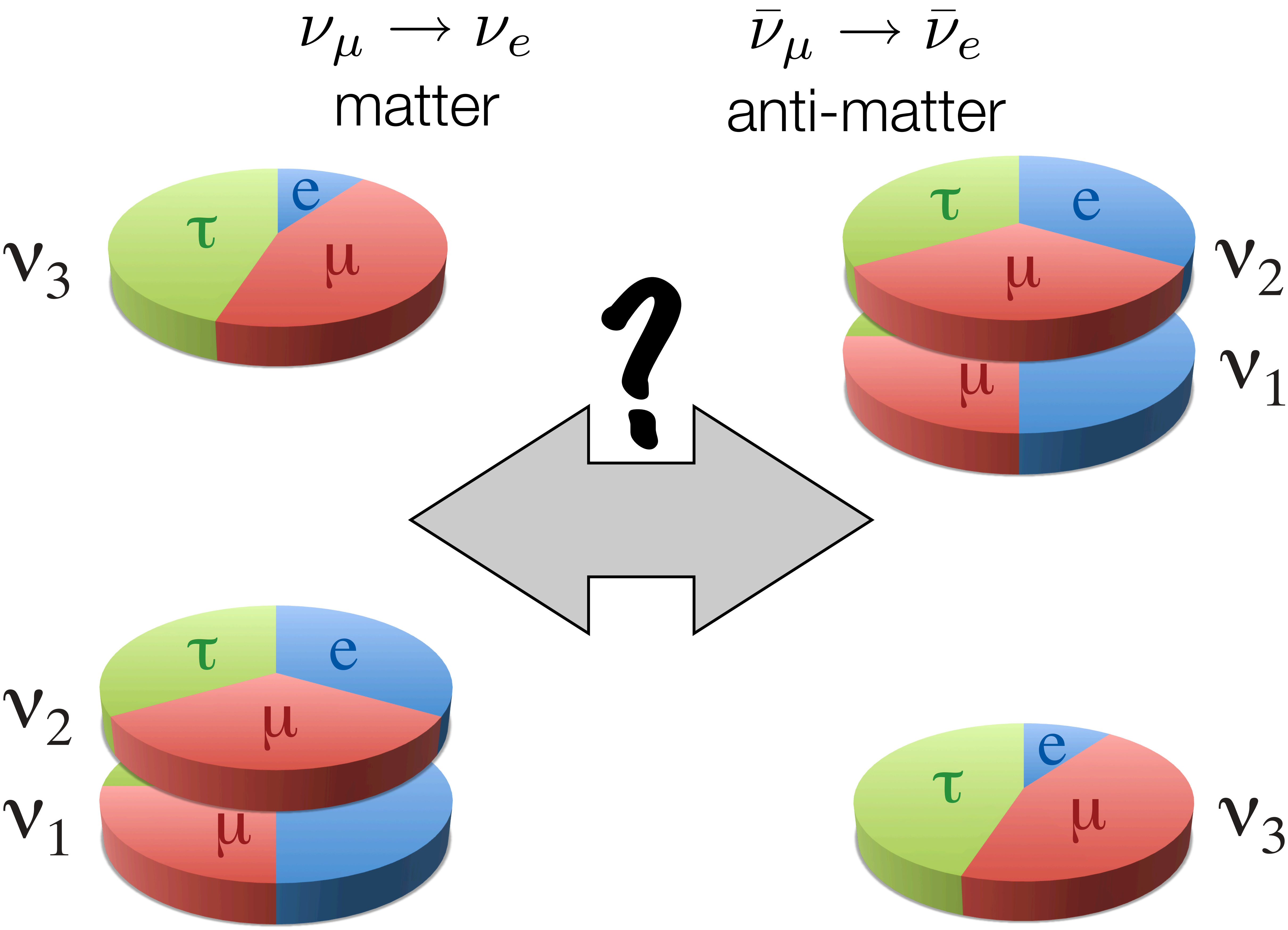

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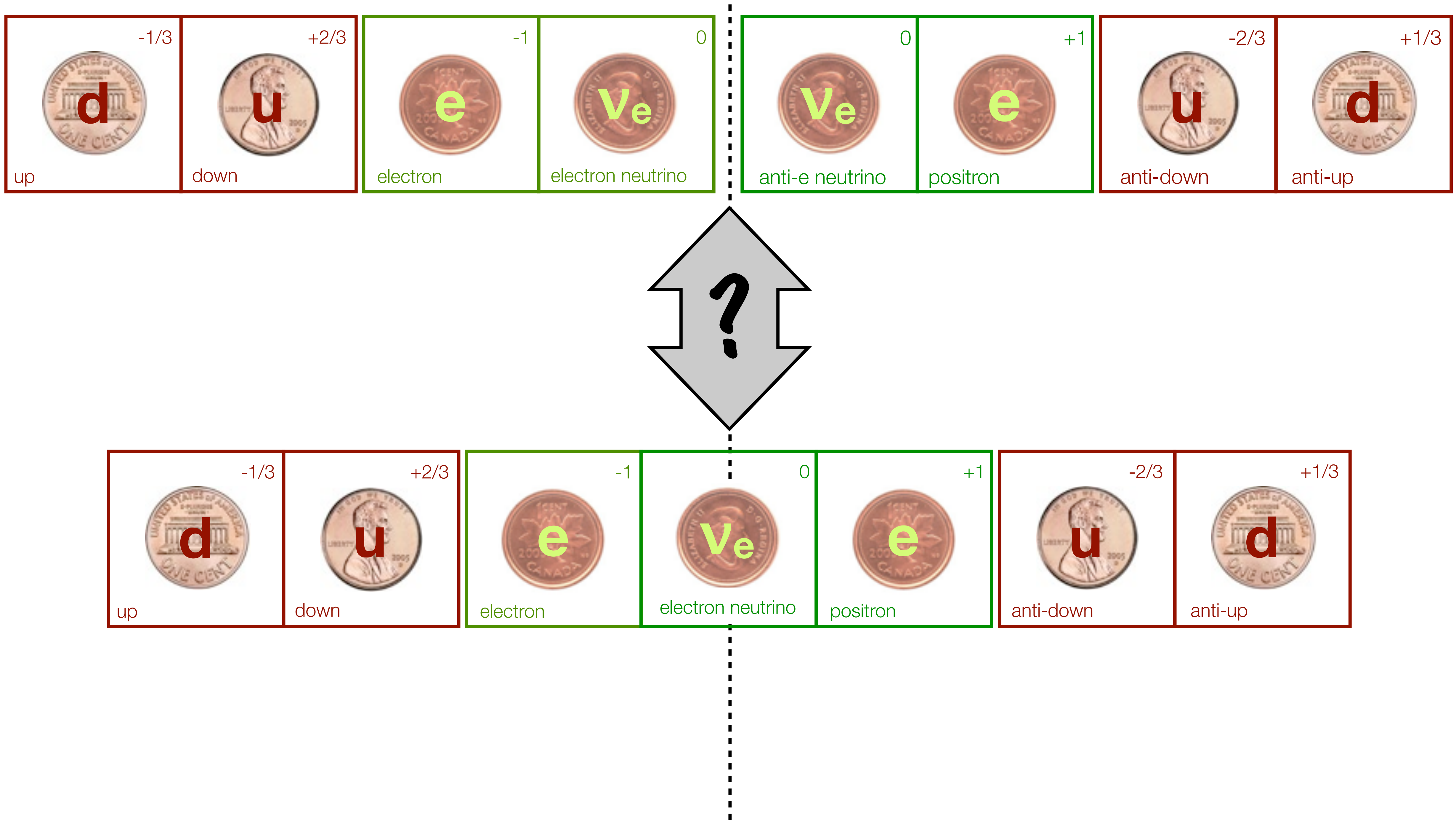
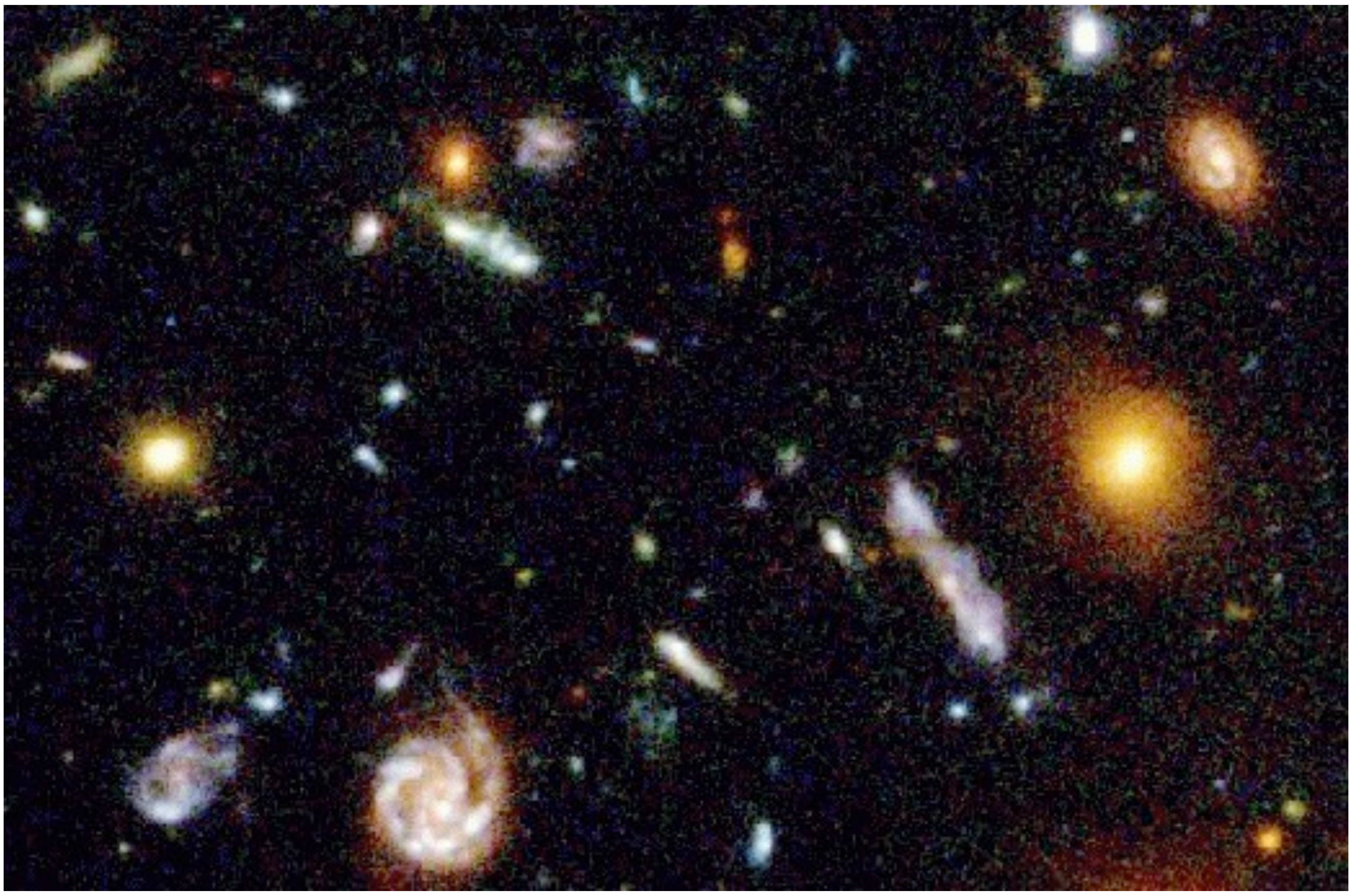


As it has zero electric charge, the neutrino is in the unique position that it could be its own anti-particle. It could be that the neutrino sits on one side of the matter-antimatter divide opposite its anti-matter reflection. Or the neutrino could site right on the fence that separates matter from anti-matter. Data from NOvA will help us find out. [next]

NOvA's Science

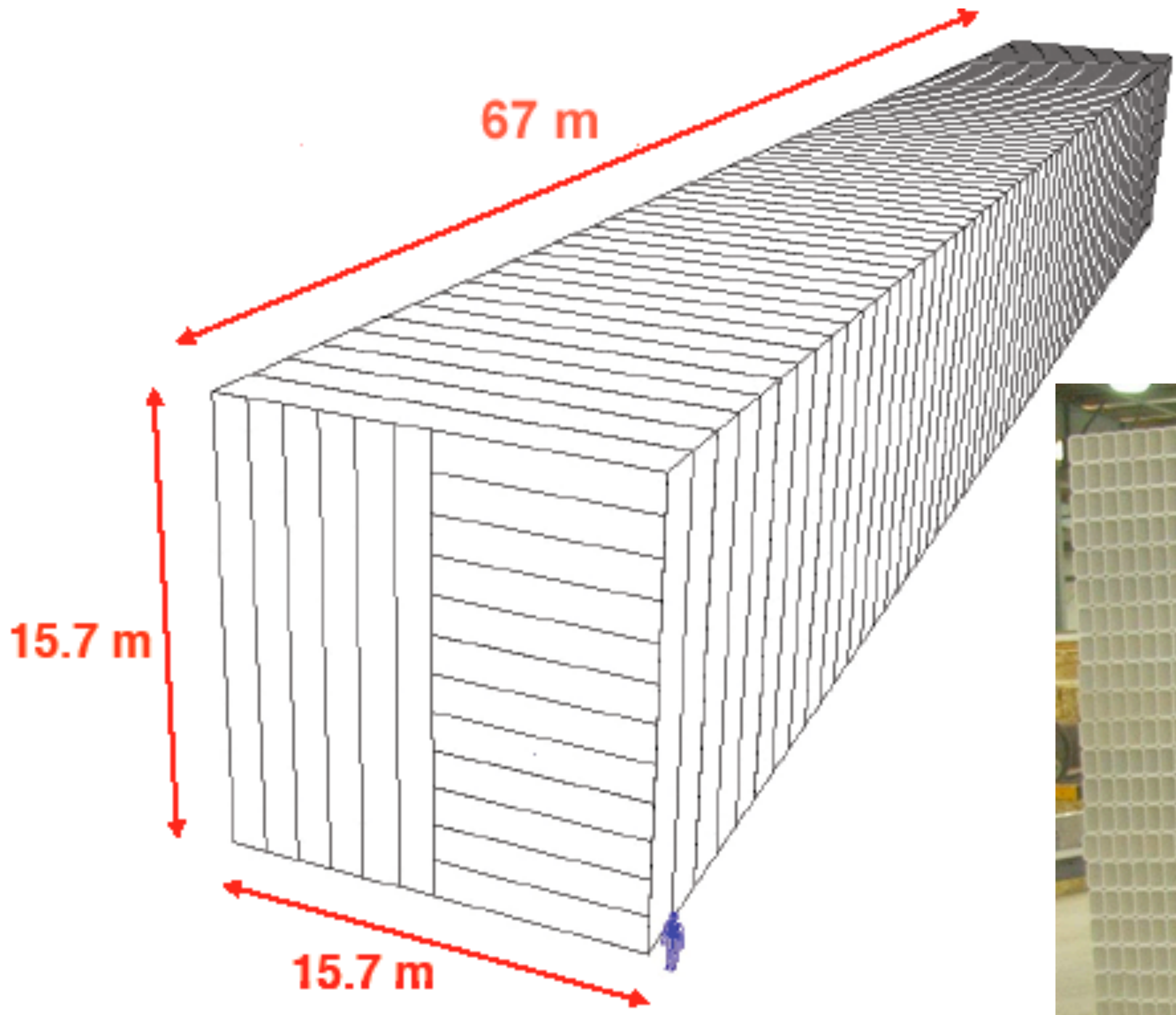
$\nu_\mu \rightarrow \nu_e$ matter

$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ anti-matter



A final question NOvA will help us answer amounts to "why is there something instead of nothing". As far as we've been able to see, for example in this picture from the Hubble Deep Field image, the universe is made of matter and there is no large accumulation of anti-matter. Now we physicists know how to create matter and anti-matter in the lab, but when we do it we always create equal amounts of matter and anti-matter. Had the Big Bang been up to us, all this matter and anti-matter would have recombined by now leaving a universe with nothing in it but radiation. Fortunately for us, there was something that caused the actual Big Bang to produce more matter than anti-matter so that we would have stars, galaxies, planents, you and me in the universe today. Neutrinos may have tipped the balance in favor of matter over anti-matter. NOvA will begin the study of this possibility. [next]

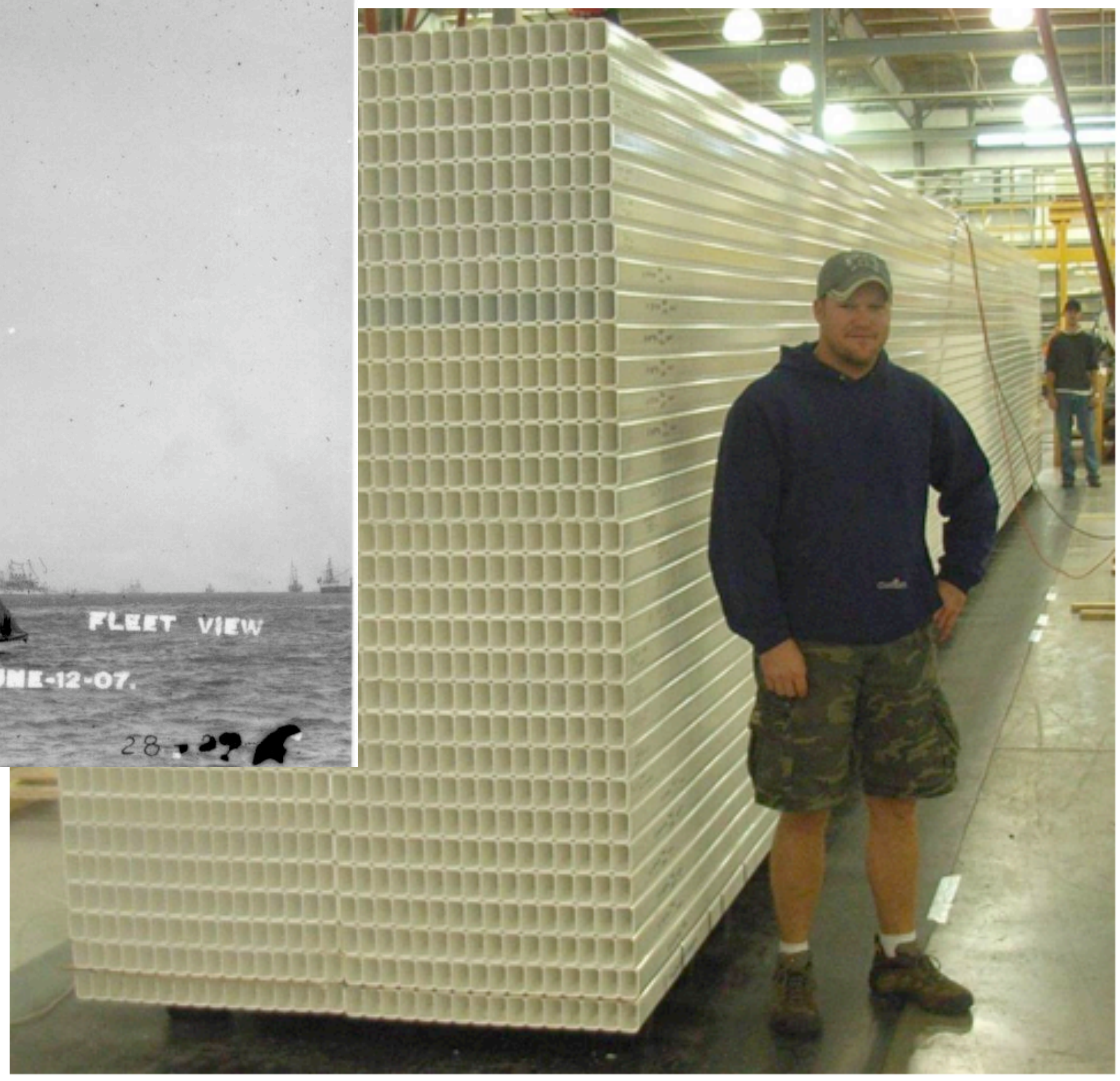
The NOvA Detector



To do this science, we need to detect these electron neutrinos and to see electron neutrinos we need a detector. The NOvA detector is a novel solution to the problem of building an extremely massive detector, while maintaining the ability to take high-resolution pictures of neutrino events. NOvA is big and it will weigh 33 million pounds - [next] roughly the weight of a battleship. [next] The height and width of the detector (53' x 53') is limited by the size of objects one can ship by truck and the length is comparable to that of a football field. The detector will be constructed from highly reflective PVC extruded in cells of 4 cm x 6 cm, 15 meters in length and we're fortunate that we've found a company interested in working with us as we learn how to construct these objects. [next]

The NOvA Detector

USS Minnesota



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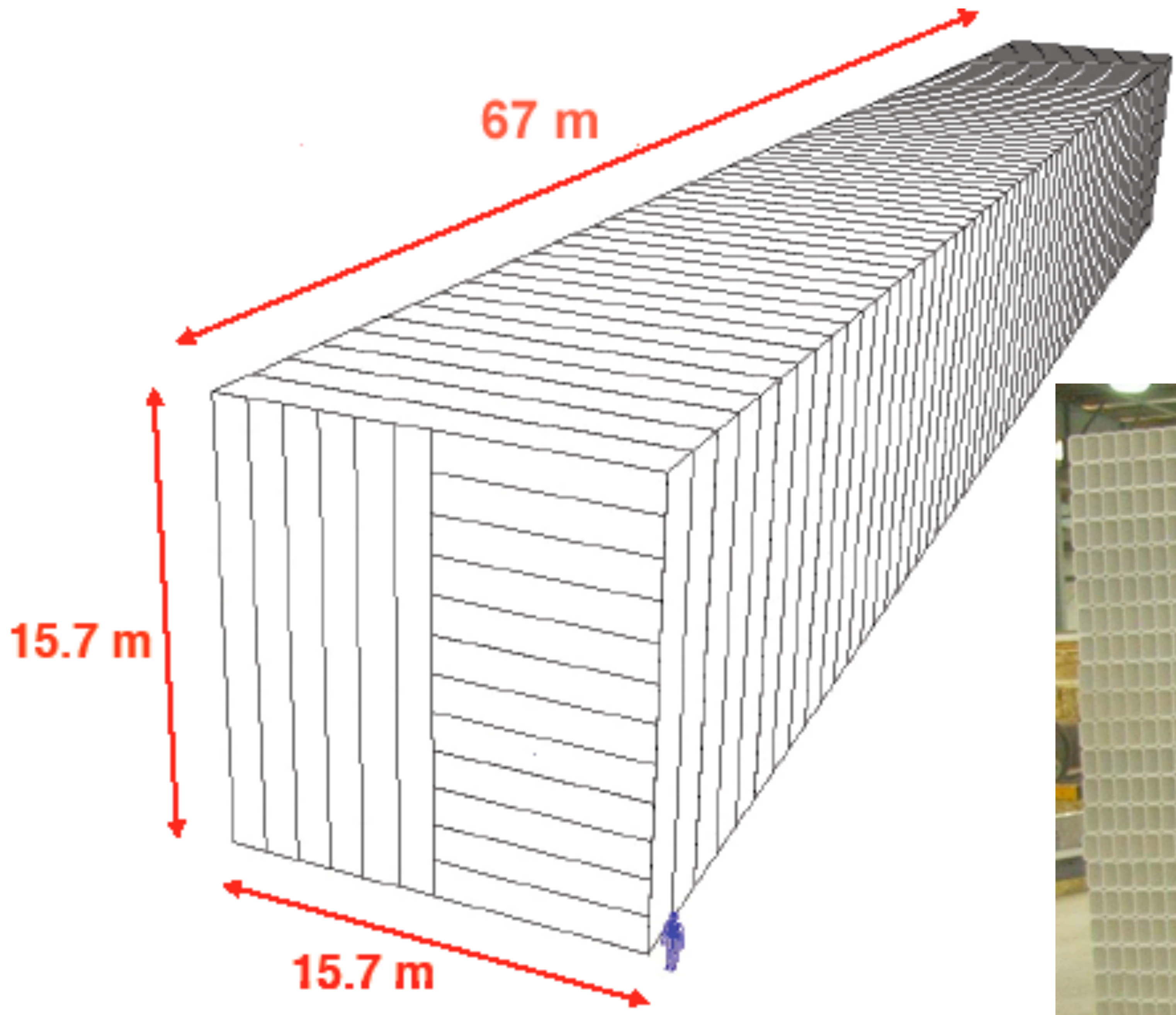

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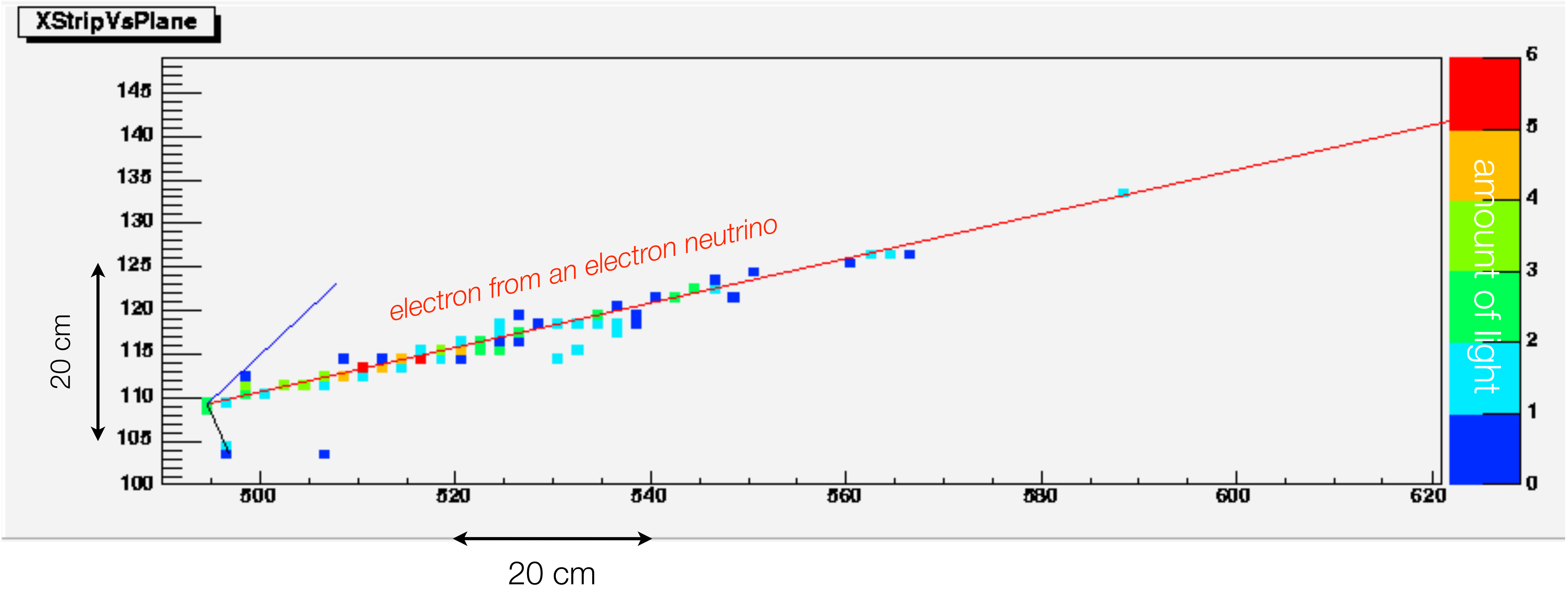
Electron neutrino interaction in NOVA

$2.5\ GeV\ \nu_e + p \rightarrow 1.9\ GeV\ e^- + 1.1\ GeV\ p + 0.2\ GeV\ \pi^+$



This will allow us to take high resolution pictures of the neutrino interactions in the detector like the one shown here. In this picture each square represents one of the PVC cells shown in the previous slide. In the interaction, the incident electron-neutrino is flipped to its charged partner the electron. We see this electron and it tags the incident neutrino as an electron-type neutrino. [next]

The NOvA Collaboration

at Argonne National Lab, 25 April 2009

Argonne National Laboratory - University of Athens - California Institute of Technology - University of California, Los Angeles - Fermi National Accelerator Laboratory - College de France - Harvard University - Indiana University - Lebedev Physical Institute - Michigan State University - University of Minnesota, Duluth - University of Minnesota, Minneapolis - The Institute for Nuclear Research, Moscow - Technische Universität München, Munich - State University of New York, Stony Brook - Northern Illinois University, DeKalb - Northwestern University - Ohio State University, Columbus - Pontifícia Universidade Católica do Rio de Janeiro - University of South Carolina, Columbia - Southern Methodist University - Stanford University - University of Tennessee - Texas A&M University - University of Texas, Austin - University of Texas, Dallas - Tufts University - University of Virginia, Charlottesville - The College of William and Mary - Wichita State University

This project requires a large team, some of whom are pictured above at a recent meeting at Argonne National Laboratory standing on a prototype of the first plane of the detector. We're all looking forward to first data from the completed experiment in 2014.