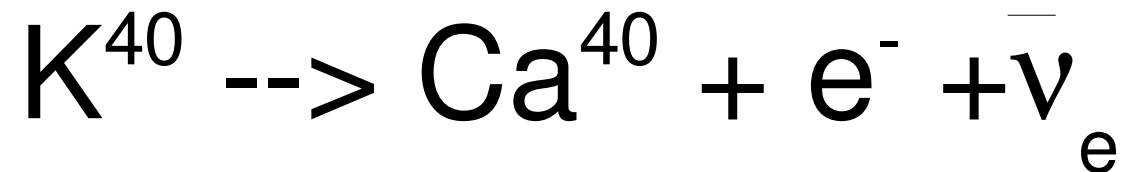
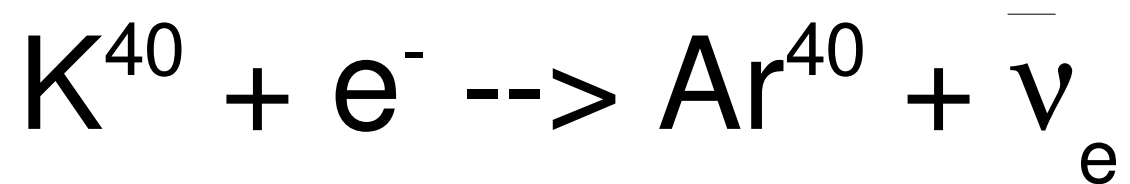
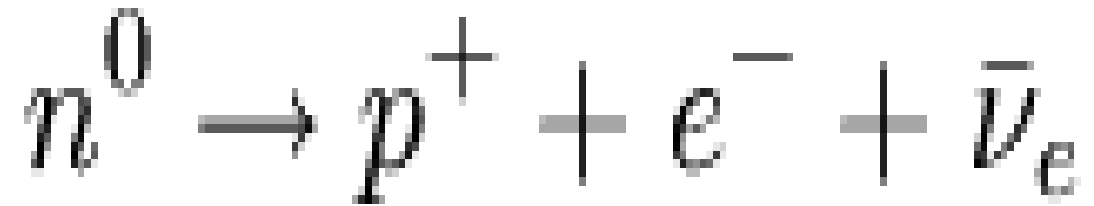


Linus Pauling

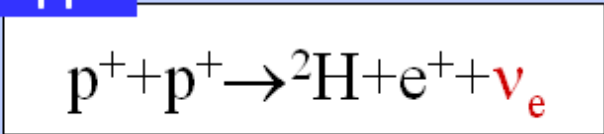


Where did the missing momentum/energy go...?

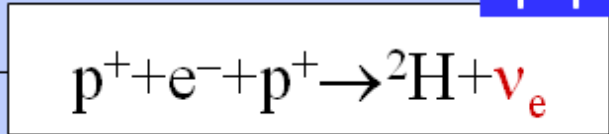


... a neutrino! (1930)

pp

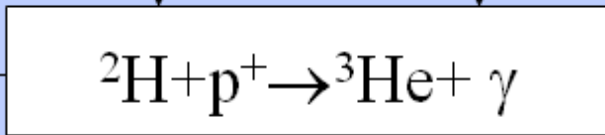


pep

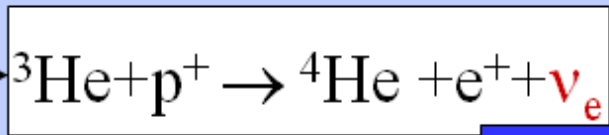


99,77 %

0,23 %

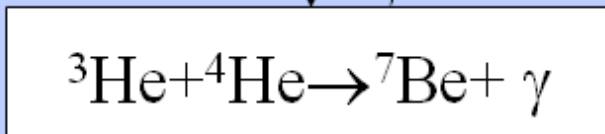


10^{-5} %



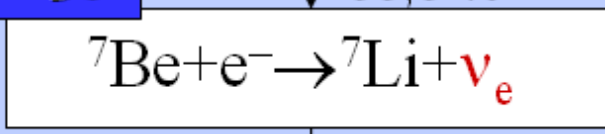
hep

15,08 %

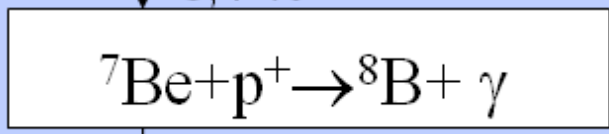


${}^7\text{Be}$

99,9 %

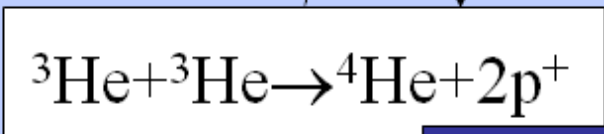


0,1 %

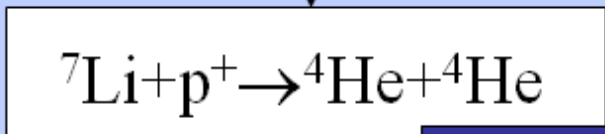


${}^8\text{B}$

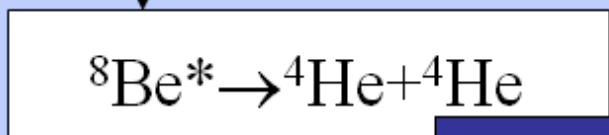
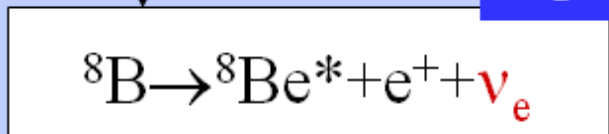
84,92 %



ppI

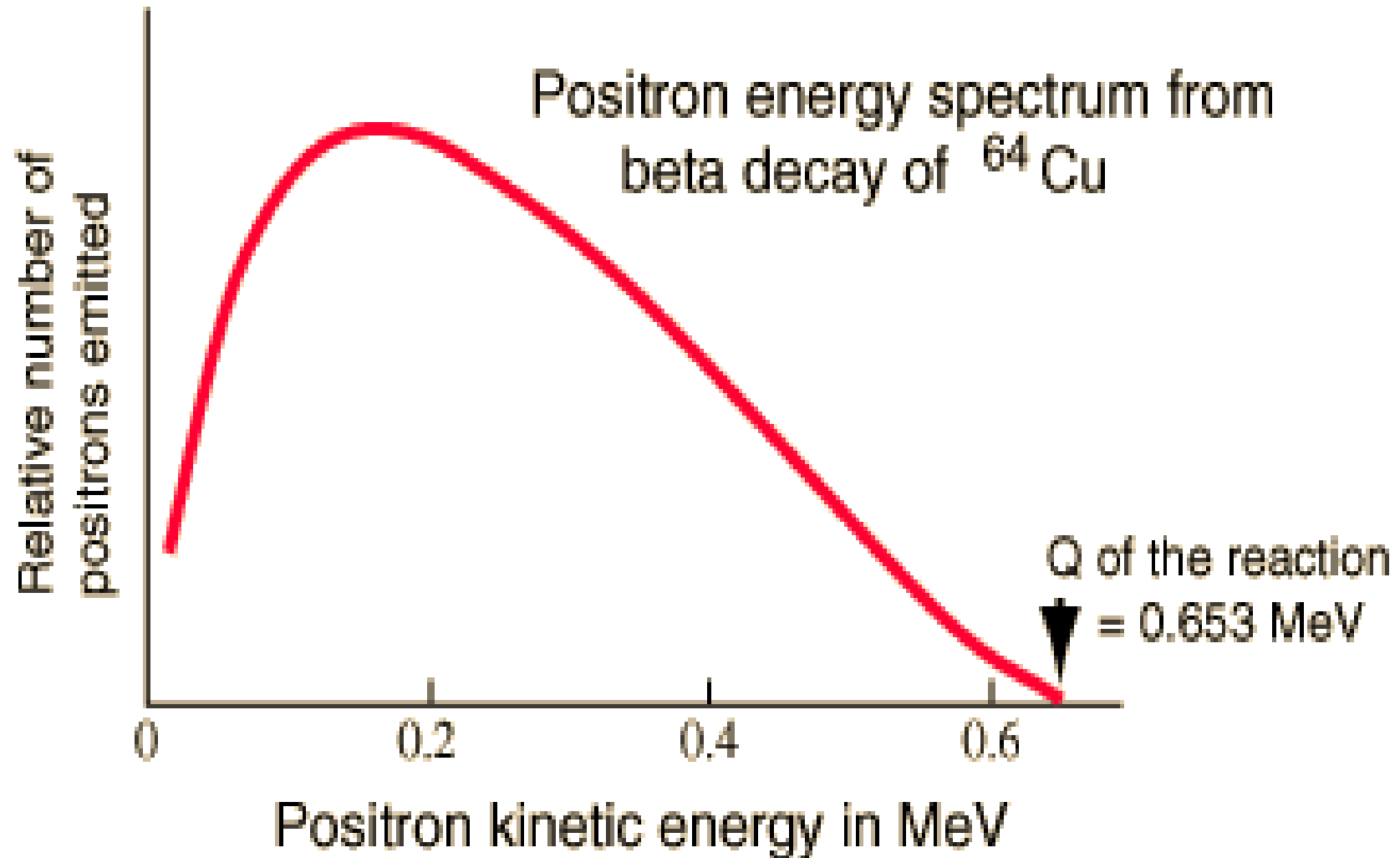


ppII



ppIII

Example of missing energy



<http://hyperphysics.phyastr.gsu.edu/hbase/nuclear/beta.html>

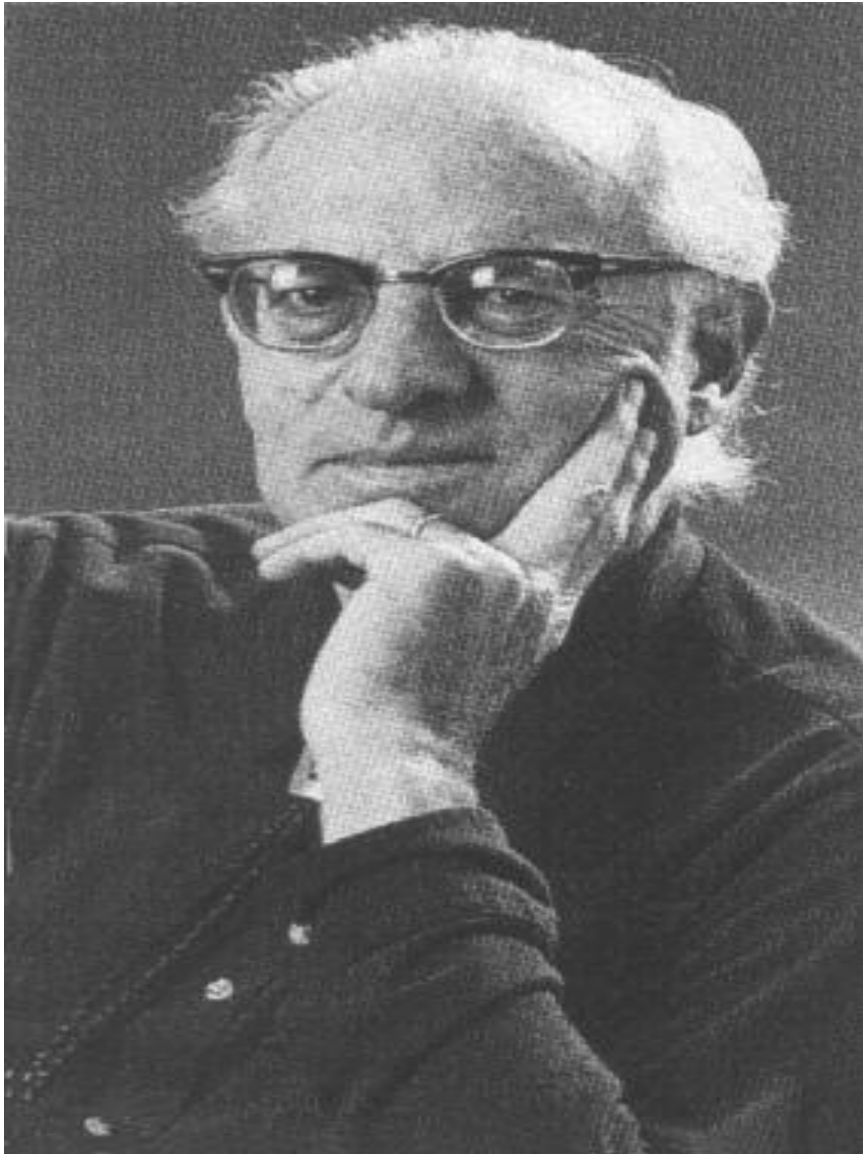
Facts and Figures

- a neutrino is leptonic (no quarks inside)
- Mass of neutrino $< 2 \text{ eV}/c^2$ (e- has mass of $511000 \text{ eV}/c^2$)
- charge of neutrino: neutral
- spin of neutrino: $\frac{1}{2}$
- a neutrino has its own antiparticle
- extremely low cross section (weakly interacting, $1 \times 10^{-43} \text{ cm}^2$)



*Artist's rendition
of a neutrino*

Frederick Reines

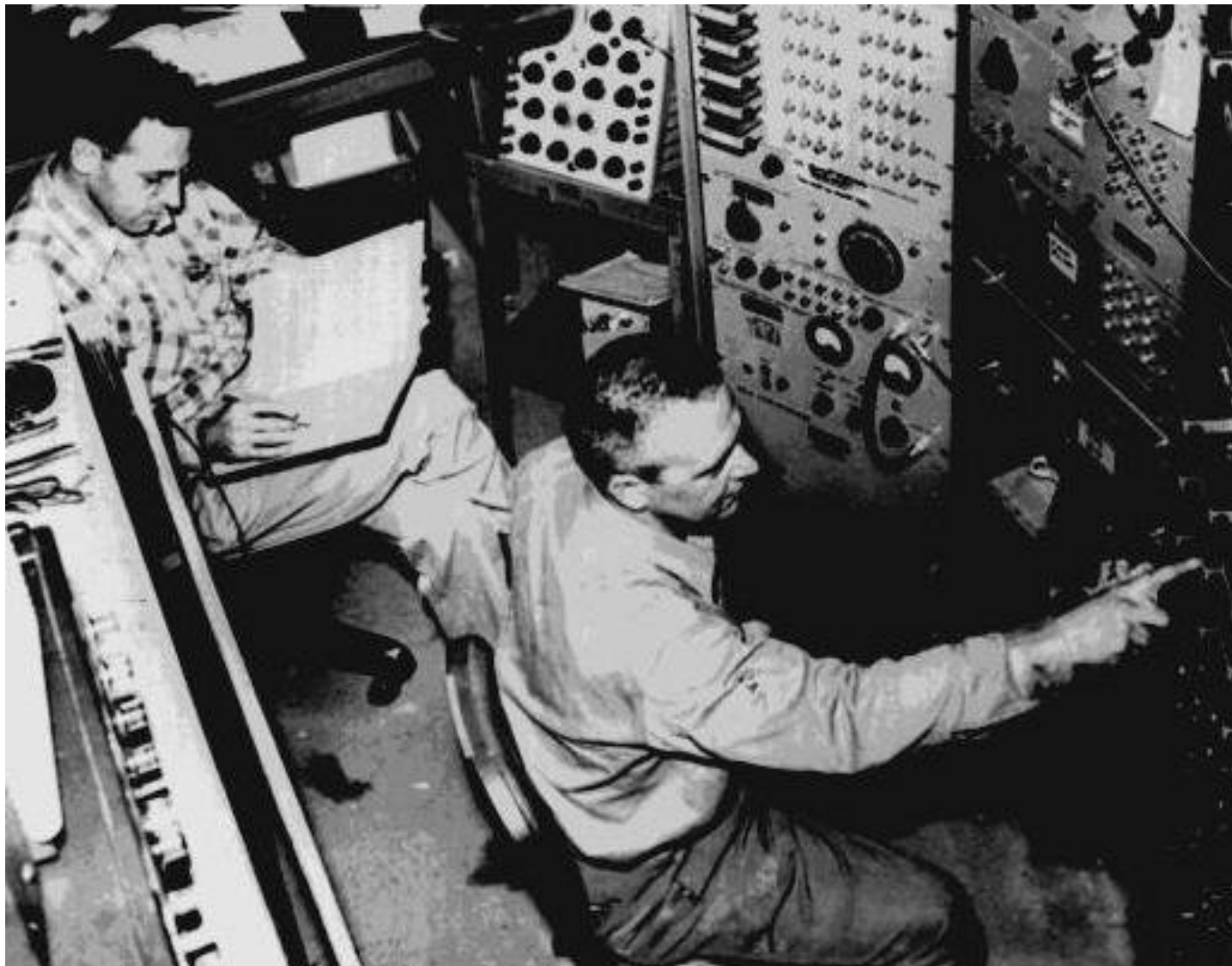


Clyde Cowan



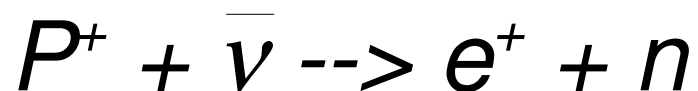
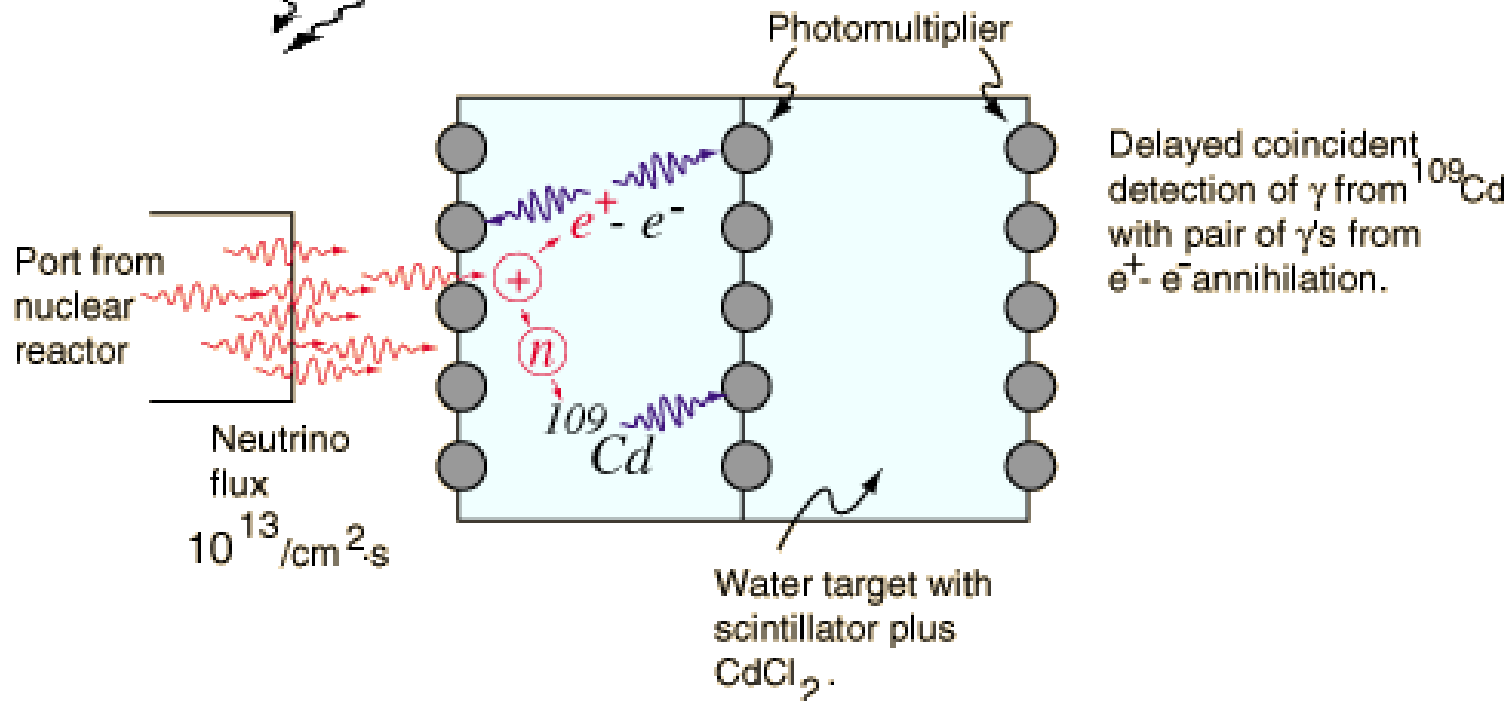
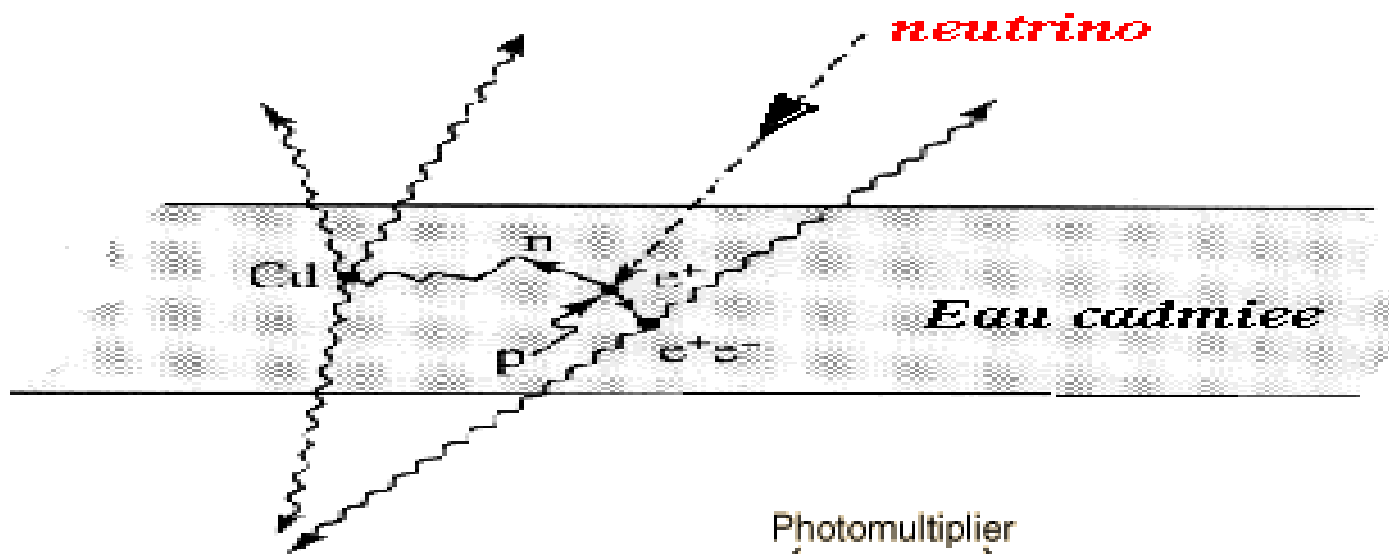
They won the Nobel Prize in 1995

<http://www.ps.uci.edu/physics/news/nuexpt.html>



In the laboratory...

Nuclear reactor



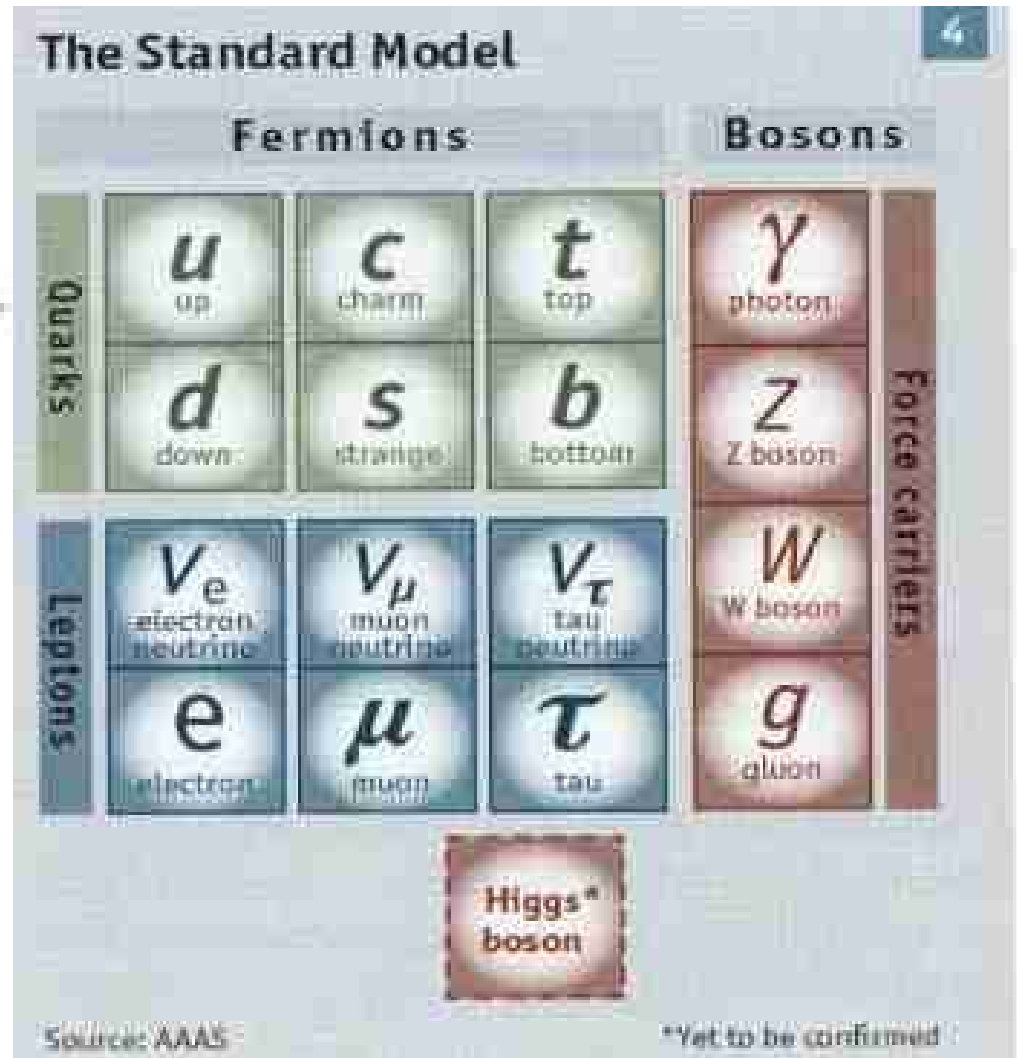
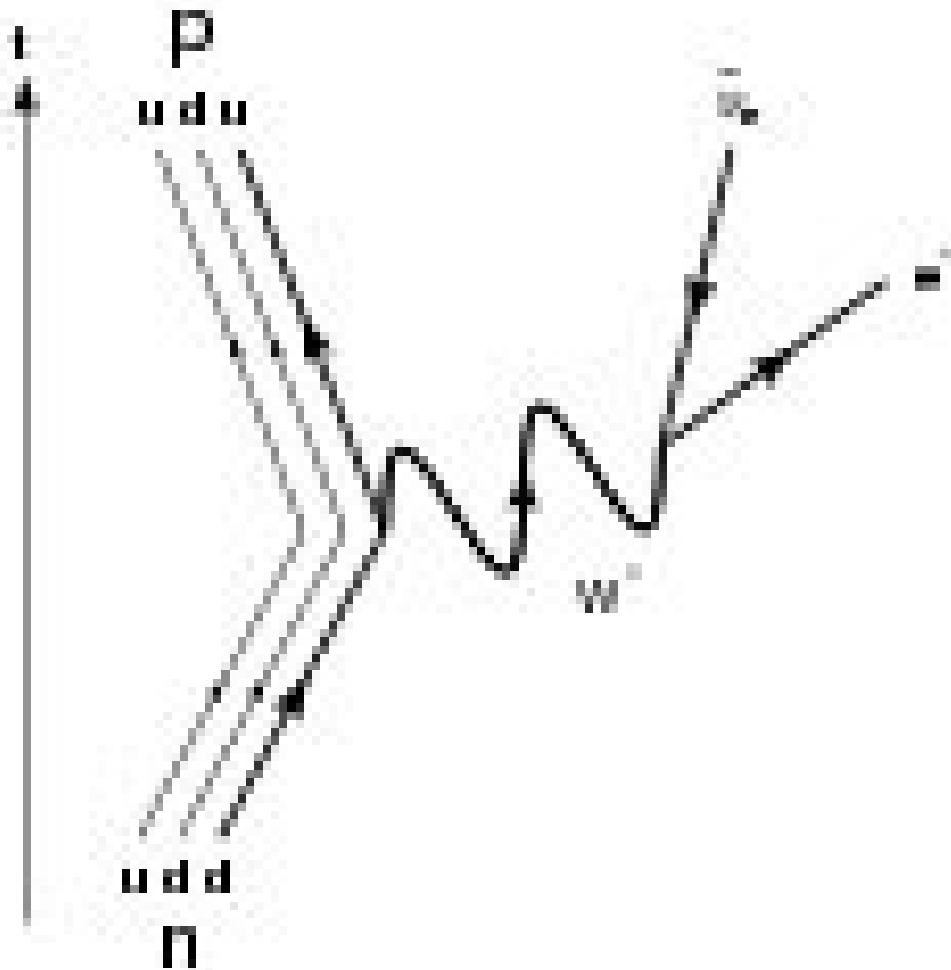
3 detections per hour

The First Large Scale Experiment

The target was water with CdCl_2 dissolved in it. The positron was detected by its slowing down and annihilating with an electron producing two 0.5 MeV gamma rays in opposite directions. The pair of gamma rays was detected in time coincidence in liquid scintillator above and below the water by photomultiplier tubes detecting the scintillation light. The neutron was also slowed by the water and captured by the cadmium microseconds after the positron capture. In the capture several gamma rays were emitted which were also detected in the scintillator as a delayed coincidence after the positron's annihilation gamma ray detection. The detector contained 200 liters of water in two tanks with up to 40 kg of dissolved CdCl_2 . The water tanks were sandwiched between three scintillator layers which contained 110 5" photomultipliers each, and the whole experiment measured only about 2 meters in each direction.

<http://www.ps.uci.edu/physics/news/nuexpt.html>

Modern view of the neutrino



Wow Neutrinos!

Wherever you are on the earth, even deeply underground, you receive per second about **400 billions** neutrinos from the **sun**, but also **50 billions** neutrinos (but this number is not well known!) from the natural radioactivity of the **earth**, and **10 to 100 billions** neutrinos from **nuclear plants** all over the world. Fortunately for us, neutrinos interact very few and you can live as if they are not there!...

<http://www.lapp.in2p3.fr/neutrinos/anchiffres.html>

...and in our bodies?

Our body contains about 20 milligrams of Potassium 40, which is beta radioactive. As a consequence, we emit about **340 millions** neutrinos per day without knowing that. Neutrinos interact very few, there are thus 340 millions neutrinos per day, which run from our body at the speed of light until the end of the universe!...

<http://wwwlapp.in2p3.fr/neutrinos/anchiffres.html>

Bursts of neutrinos to pass under our feet

By SUSANNE QUICK

of the Milwaukee Journal Sentinel staff

Wednesday, July 31, 2002

Like a Star Wars storm trooper firing a laser blaster through the heart of a Jedi knight, a team of Illinois-based scientists will soon start shooting a stream of accelerated subatomic particles through the rocky core of Wisconsin....

...according to Rameika, "they go through skin, rock, bone all the time. And nobody notices them." So the neutrinos that will be shot through Wisconsin -- on a 455-mile trajectory originating in Batavia, Ill., and aimed at Soudan, Minn., in the far northeast -- shouldn't pose any unusual harm or injury to state residents, the scientists said. Even though the state capital is not directly in the path of the neutrino beam, it is close enough to the main current that Erwin speculates a few stray neutrinos might show up there...

...have a good summer, and please be careful...