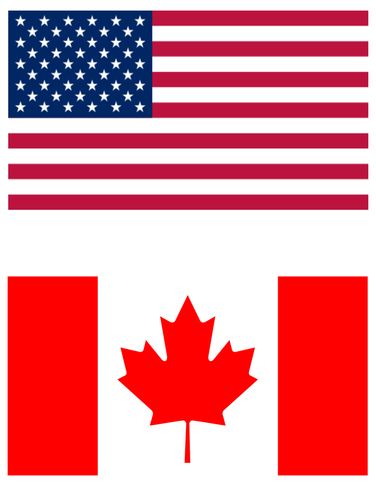

Q-weak: A Search For New Physics Beyond the Standard Model at the TeV Scale

Collaborating Institutions: *College of William and Mary, University of Connecticut, Instituto de Fisica, Universidad Nacional Autonoma de Mexico, University of Wisconsin, Hendrex College, Louisiana Tech University, University of Manitoba, Massachusetts Institute of Technology, Thomas Jefferson National Accelerator Facility, Virginia Polytechnic Institute & State University, TRIUMF, University of New Hampshire, Yerevan Physics Institute, Mississippi State University, University of Northern British Columbia, Ohio University, Hampton University, University of Winnipeg, University of Virginia, George Washington University, Syracuse University, Idaho State University, Christopher Newport University, University of Zagreb*

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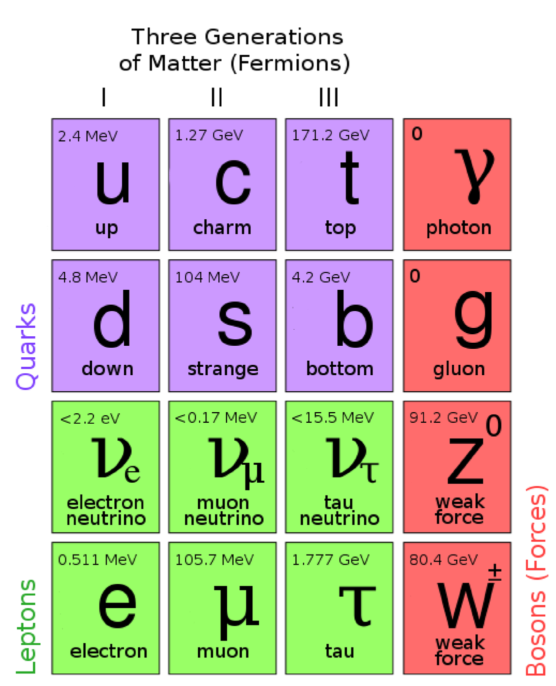
The Standard Model of Particle Physics describes the interactions between fundamental particles.

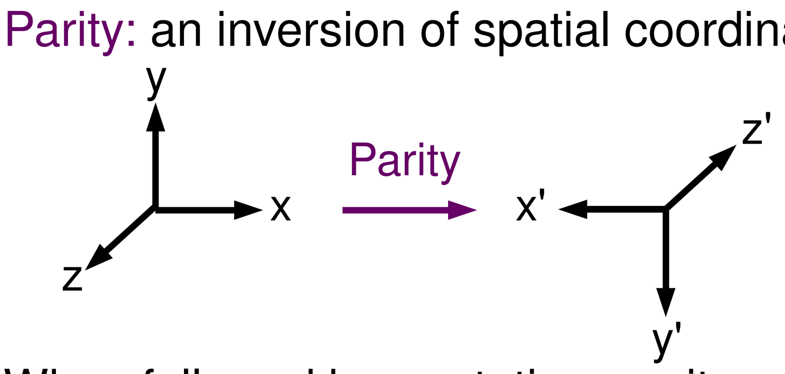


Similar to an *electric charge*, quarks and leptons also carry a *weak charge*, which describes their interaction with the weak force.

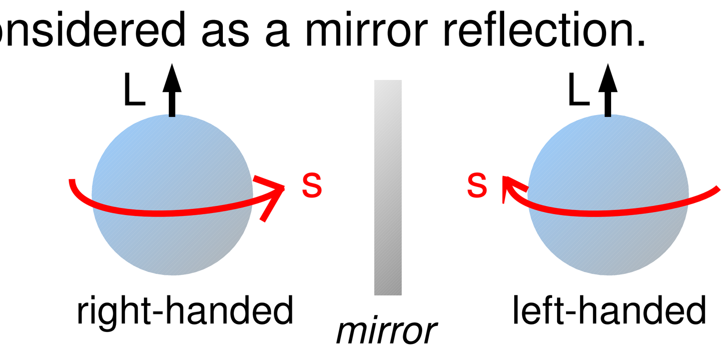
Particle	Electric Charge	Weak Vector Charge
electron	-1	$Q^e_W \approx 0.07$
u quark	+2/3	$-2C_{1u} \approx +1/3$
d quark	-1/3	$-2C_{1d} \approx -2/3$
proton (uud)	+1	$Q^p_W \approx 0.07$
neutron (udd)	0	$Q^n_W = -1$

A *symmetry* in physics is the invariance of a system under a transformation (examples: translation, rotation, reflection). *Symmetries* lead to conserved quantities that can be observed.

Parity: an inversion of spatial coordinates.



When followed by a rotation, parity can be considered as a mirror reflection.



L = orbital angular momentum, s = particle spin

Under parity, certain objects such as position and momentum change sign:

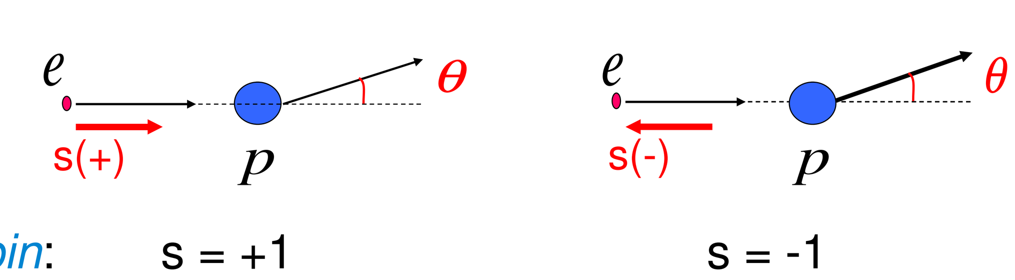
$$\mathcal{P}(\vec{r}) = -\vec{r}\,, \quad \mathcal{P}(\vec{p}) = -\vec{p}$$

while others such as angular momentum are unchanged:

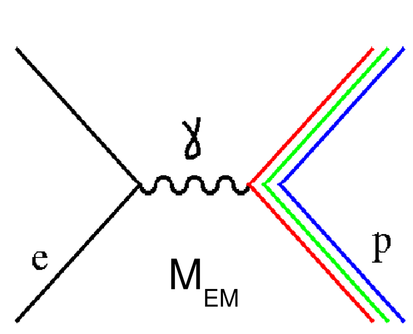
$$\mathcal{P}(\vec{L}) = \mathcal{P}(\vec{r}) \times \mathcal{P}(\vec{p}) = \vec{L}$$

In the weak interaction, *parity is not a conserved symmetry!* This means right-handed and left-handed particles behave differently when interacting weakly!

Q-weak uses *Parity-Violating Electron Scattering* to measure an asymmetry in electron-proton scattering.



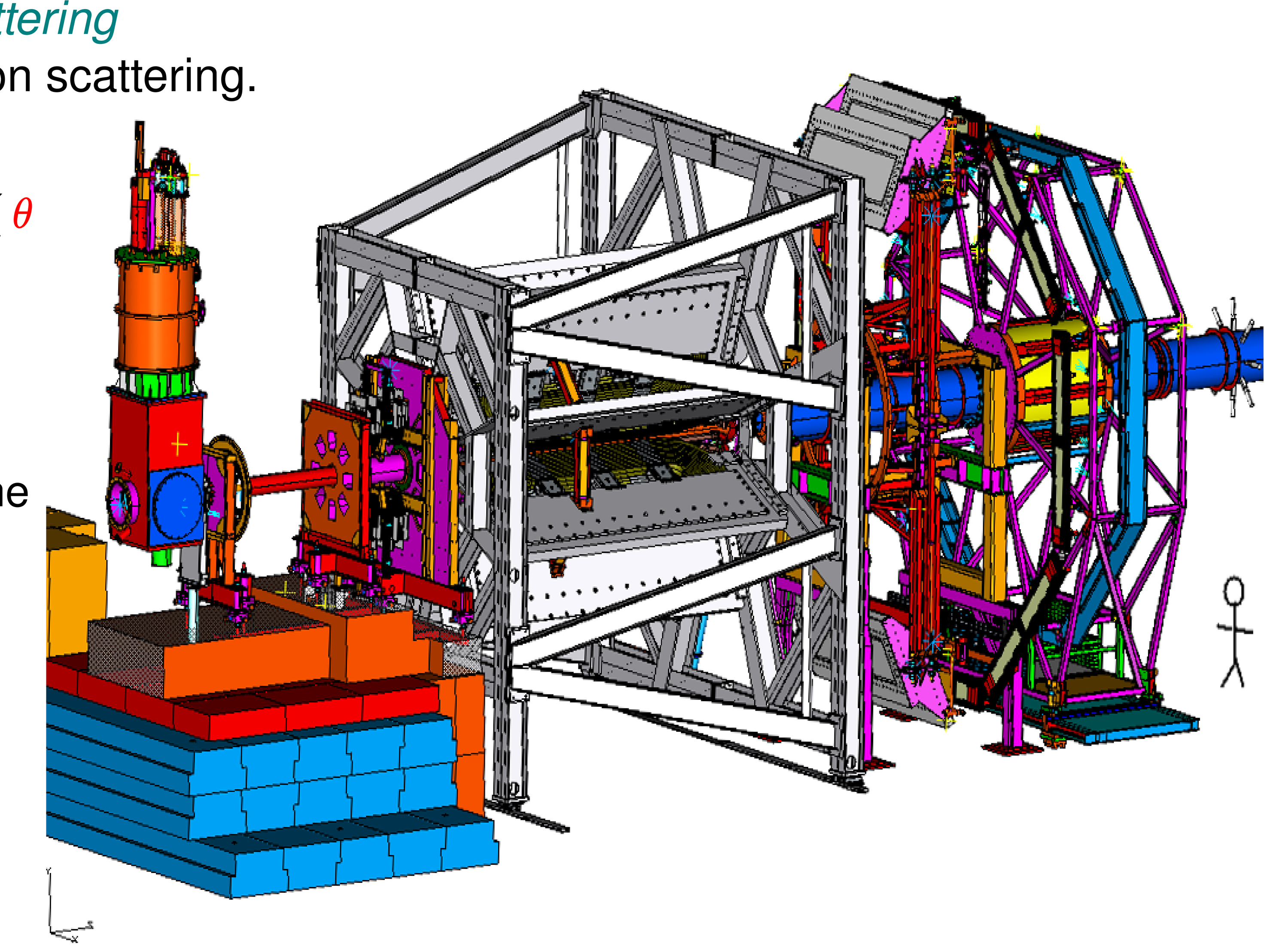
In *e-p* scattering, the electrons interact with the quarks in the proton electromagnetically and weakly.



M_{EM} — *Electromagnetic conserves parity*

M_{NC} — *Weak neutral-current violates parity*

By changing the electron *spin*, an asymmetry can be measured in how many particles are detected for each spin state.



Electrons with an energy of 1.165 GeV scatter from protons in a 35 cm long liquid hydrogen target. Those with the desired kinematics pass through a collimator and are bent in a toroidal magnetic field. The electrons are focused onto a ring of eight quartz detectors.

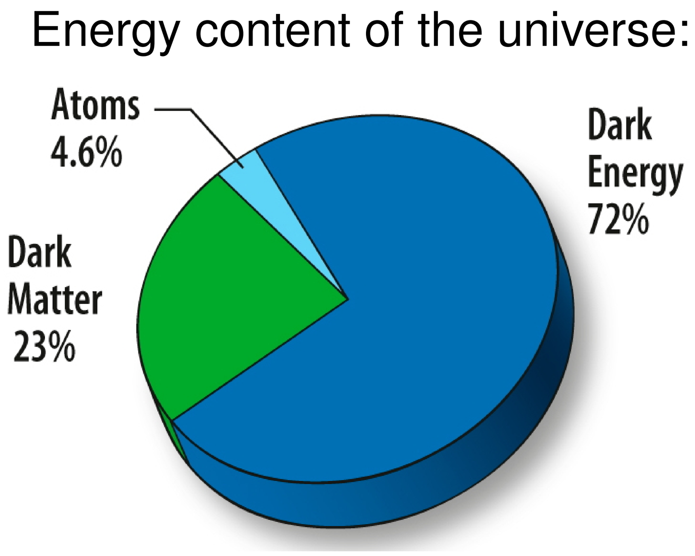
The asymmetry depends on momentum transfer - the amount of energy transferred from the electron to the quark in the proton upon scattering.

Q-weak will measure this asymmetry at very low momentum transfer. The weak interaction is much smaller than the electromagnetic interaction, leading to a very small asymmetry: ~250 parts per billion!

Q-weak will measure this asymmetry to a precision of 2%. From this, the weak charge of the proton can be determined to 4%. This high-precision measurement will be the first direct measurement of the weak charge of the proton, and will take about 2500 hours with a 150 μA beam current to complete. That's about 900 trillion electrons per second!

The Standard Model is an excellent theory, however it does not fully describe everything we observe in nature. Some unanswered questions are:

Energy content of the universe:

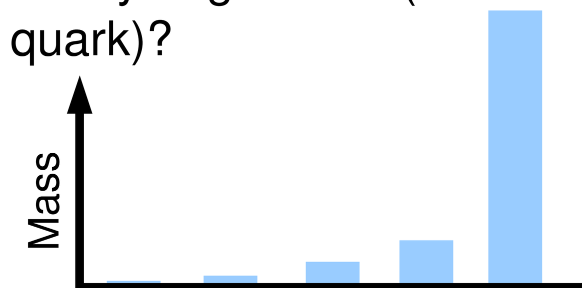


-what are dark energy and dark matter?

-why is there more matter than anti-matter?

-why are there 3 generations of quarks and leptons?

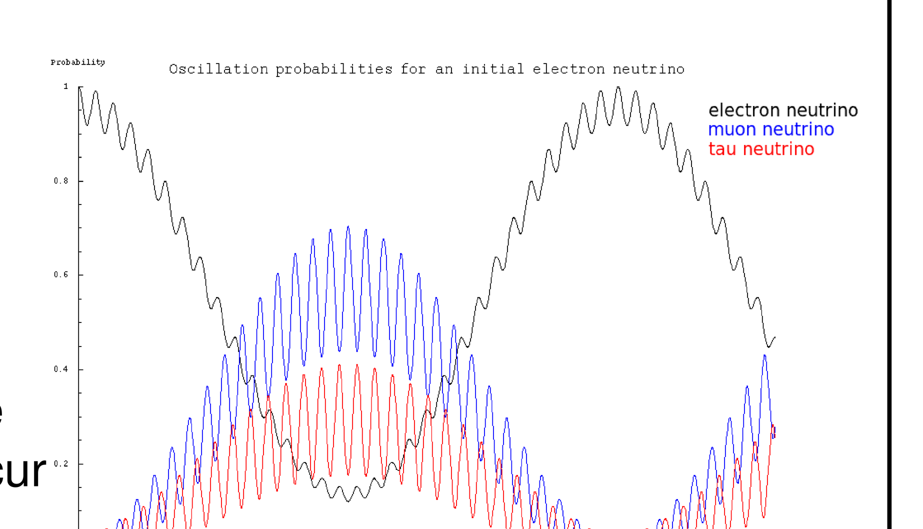
-why do some particles have no mass (like the photon), while others have a small mass (like the electron), and others have a very large mass (like the top quark)?



Physics beyond the Standard Model tries to answer some of these unanswered questions.

We already know there is something more going on, because neutrinos, which are predicted to be massless, do in fact have a small, but finite mass.

Neutrinos oscillate, or change from one type to another type. This can only occur if they have a mass.



Some physicists think a super-weak force might help explain the presence of dark matter observed by astronomers. It might also explain why elementary particles have the masses that they do.

Q-weak will try to see the small effects from a possible super-weak interaction. If it is there, our results will tell us something about the new theory.