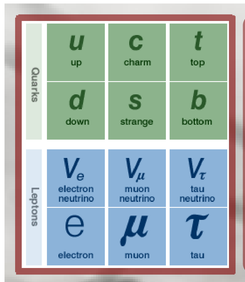
Big Questions in Particle Physics

Matter ~ Anti-Matter Asymmetry



For every Matter particle there is an Anti-Matter counterpart:

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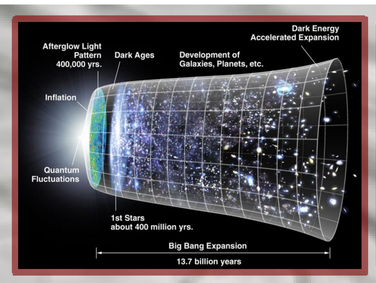
Same Mass

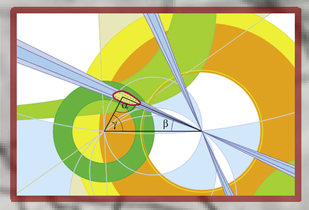
Opposite Charges



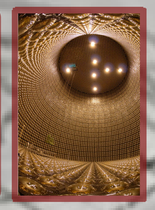
In the Big Bang Matter and Anti-Matter were made in equal amounts

Today the Universe contains almost only matter:
Where has all the anti-matter gone?
Why does physics treat matter and anti-matter differently?

We know quarks and anti-quarks behave differently...
...but not different enough



Do neutrinos and anti-neutrinos behave differently?



How else could the asymmetry be explained?

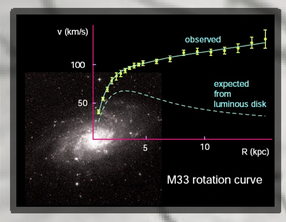
Dark Matter & Energy

The Universe Contains

Matter	Dark Matter	Dark Energy
5%	23%	72%

First Evidence of Dark Matter

Rotational velocity of galaxies deviates from that expected based on their visible matter.



In merging galaxy clusters, gravitational lensing reveals that Dark Matter (blue) has separated from the visible matter (red)

Accelerating recession of distant galaxies: Dark Energy

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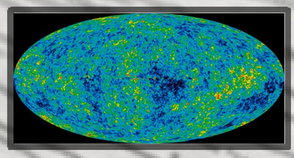
"flatness", structure and evolution of the Universe:
Requires Dark Energy & constrains Dark Matter



What is Dark Matter?

MACHOs

Black holes, neutron stars etc. Ruled out by observations.

Neutrinos

Only accounts for a fraction. Interferes with stellar evolution and Universersal structure.

Super-Symmetry

Adds many more massive particles to those already known

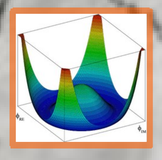
WIMPs

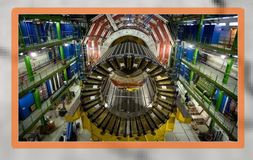
Any other Weakly Interacting Massive Particle yet to be discovered...

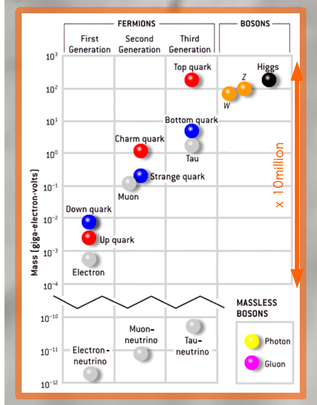
Something Else?

Mass

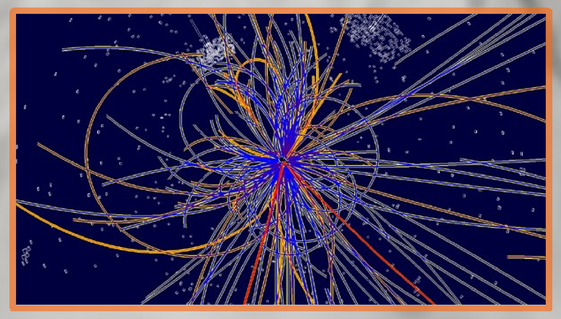
> The Standard Model doesn't allow particles to have mass
> The Higgs mechanism can solve this...
> ...and results in a new particle: The Higgs Boson







The LHC at CERN hopes to find the Higgs Boson



Will the Higgs Boson be found?

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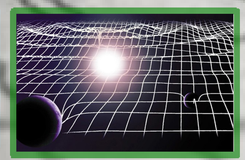
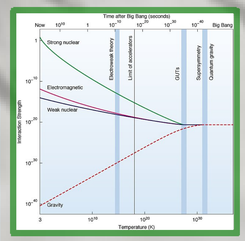
If not, how else do particles get mass?

electron-neutrino	electron	top quark
< 2 eV	511 keV	172 GeV

Mass Scales

Unification





Gravity

Strong

Weak

EM

Electroweak

Grand Unified Theory

Theory of Everything

The Four Forces	EM	Weak Force	Strong Force	Gravity

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