

# The Origin of Mass in Subatomic Particles

Cameron Walker

# Introduction

- ▶ Rest mass energy

- ▶  $E=mc^2$

- ▶ For a proton ( $m = 1.67 \cdot 10^{-27}$  kg) this is  $1.5 \cdot 10^{-10}$  J

- ▶  $3.6 \cdot 10^{15}$  protons would charge your phone for about a month

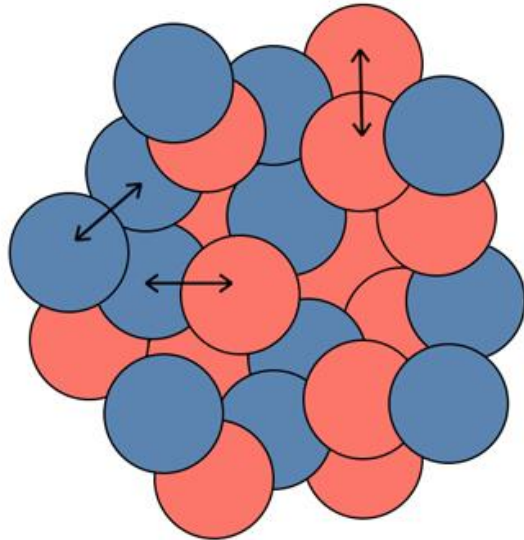
# How Does Energy Condense into Matter?

- ▶ How do you get the formation of particles like protons and electrons?

# Short Range vs. Long Range Forces

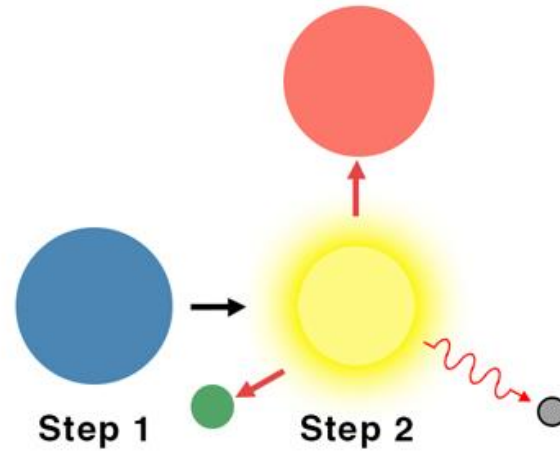
## Nuclear Force

1. Strong



● Neutron    ● Proton

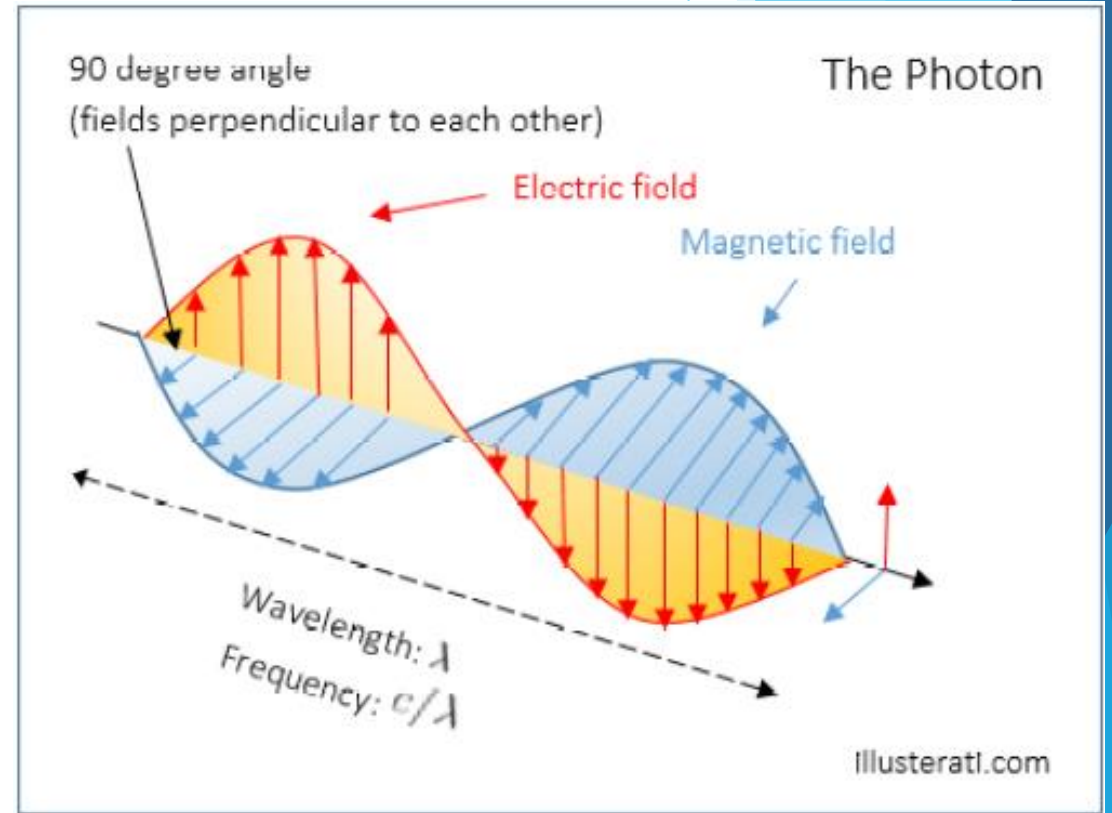
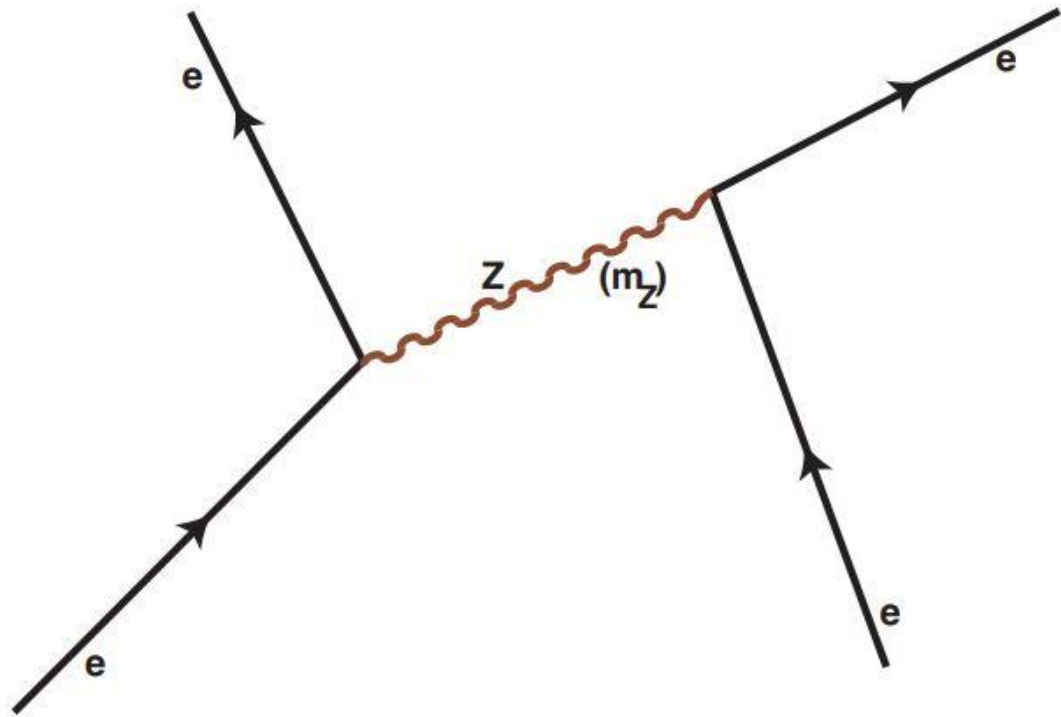
2. Weak



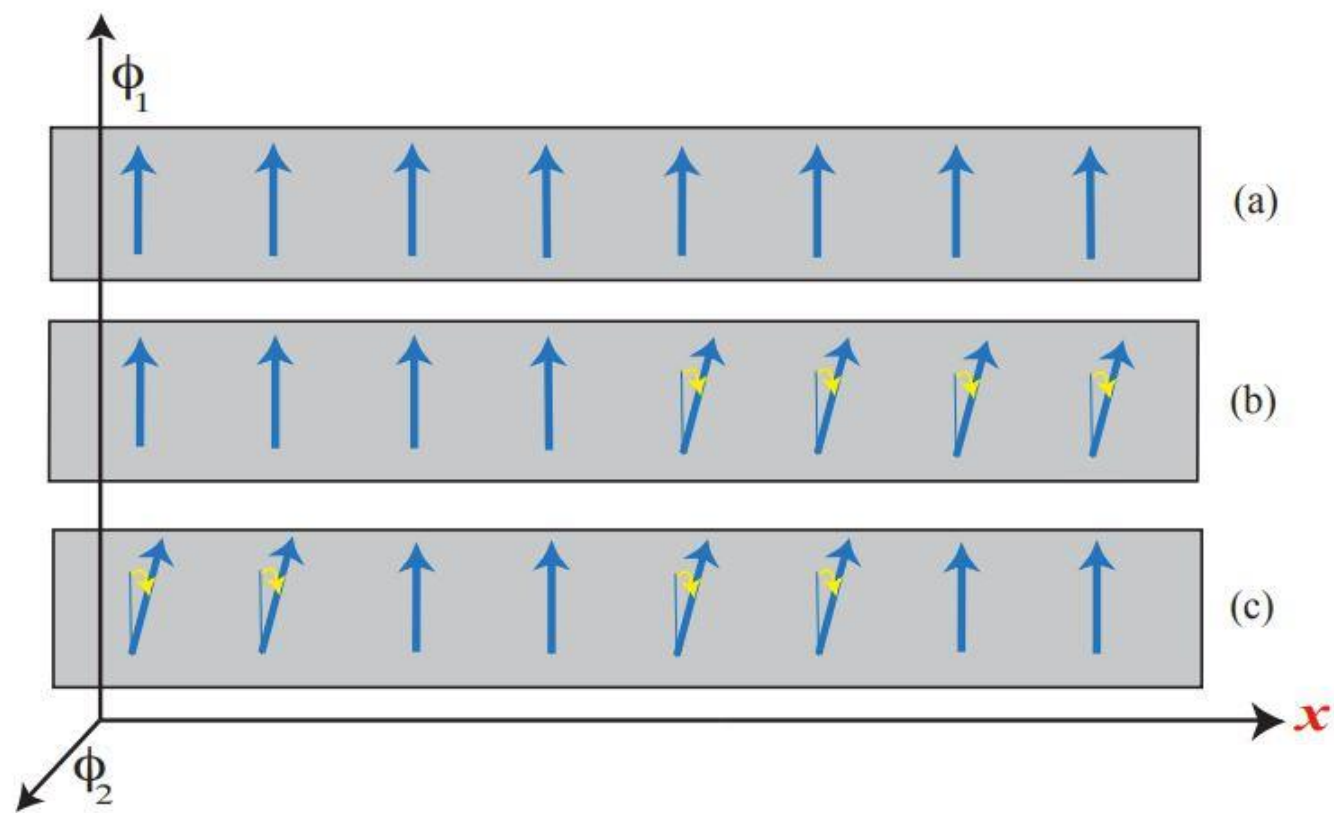
● Electron    ● Antineutrino

 Science Facts.net

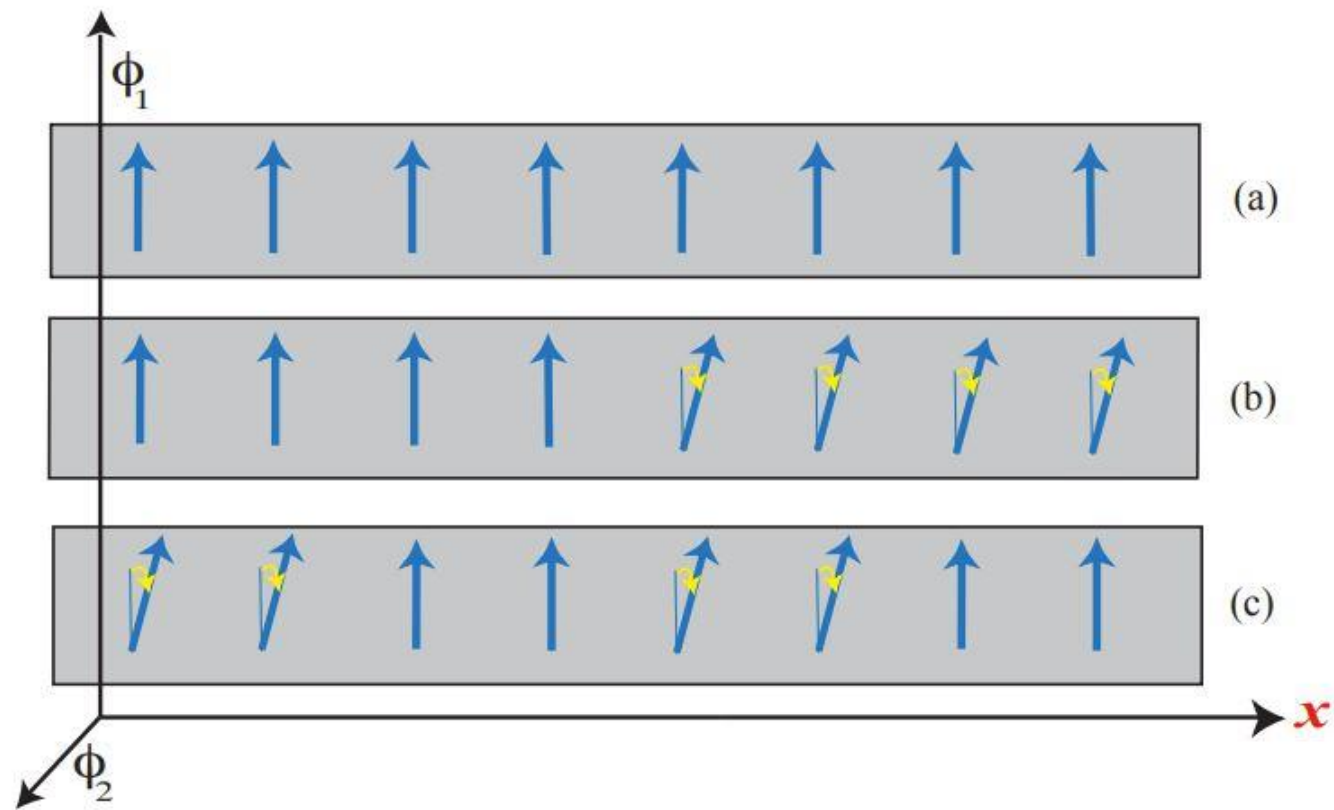
# Force carrying particles



# Symmetry

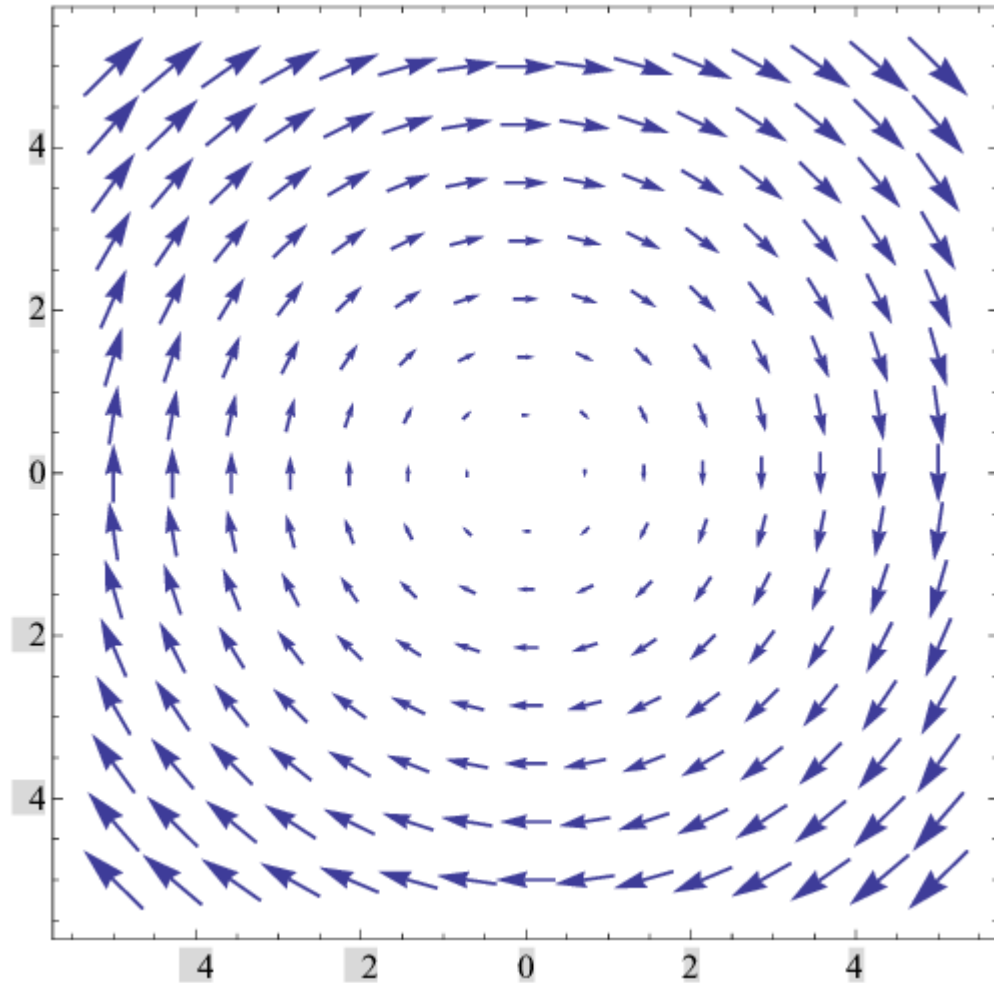


# NG Massless Boson



# Gauge vector field

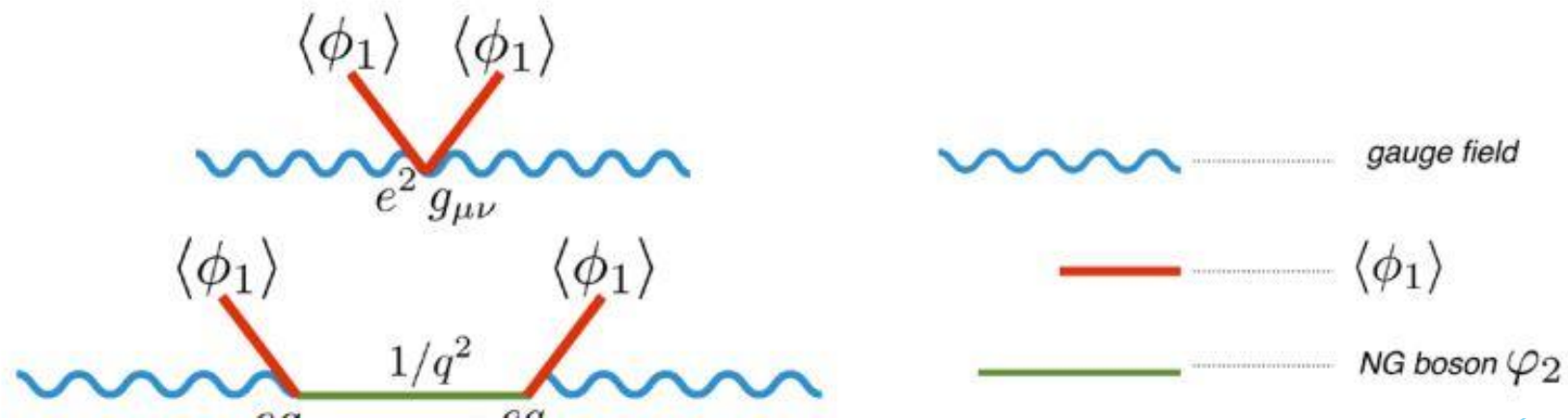
- ▶ Chosen for local symmetry



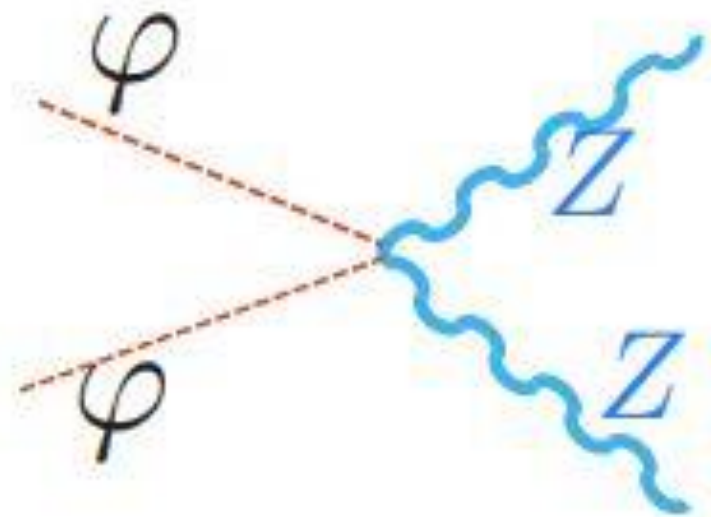


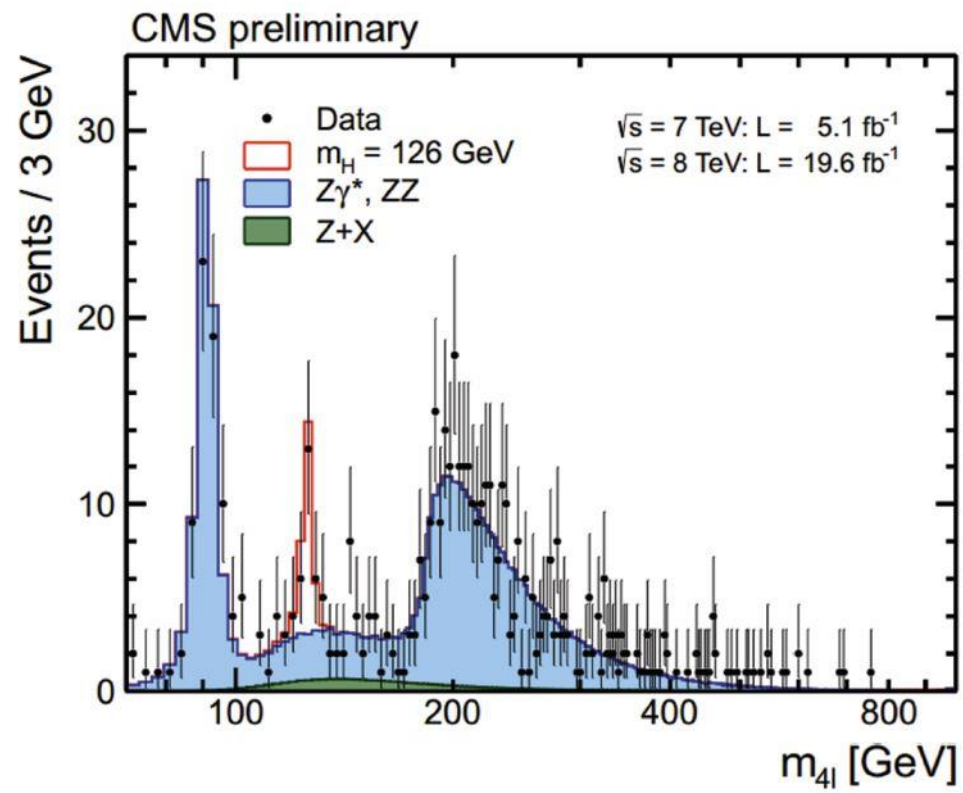
# Boson coupling produces longitudinal propagation

- ▶ Massless particles cannot have longitudinal propagation



These can couple to massive bosons





# Sources

- ▶ <https://news.energysage.com/how-many-watts-does-a-phone-charger-use/#:~:text=On%20average%2C%20phone%20chargers%20use,hours%20of%20electricity%20per%20year.> (9/15/22)
- ▶ <https://www.sciencefacts.net/nuclear-force.html>
- ▶ <https://www.differencebetween.com/difference-between-photon-and-vs-electron/>
- ▶ <https://www.nobelprize.org/uploads/2018/06/englert-lecture.pdf>
- ▶ [https://www.researchgate.net/figure/Pseudo-gauge-field-produced-using-the-deformation-vector-u-2xy-x-2-y-2-u-0-L\\_fig9\\_280773267](https://www.researchgate.net/figure/Pseudo-gauge-field-produced-using-the-deformation-vector-u-2xy-x-2-y-2-u-0-L_fig9_280773267)