# Outline

- Relativistic Kinematics
  - (4-momentum)2 invariance, invariant mass
  - Hypothesis testing, production thresholds
  - Cross-sections, flux and luminosity, accelerators
  - Particle lifetime, decay length, width
- Classification of particles
  - Fermions and bosons
  - Leptons, hadrons, qu
  - Mesons, baryons
- Quark Model
  - Meson and baryon m
  - Isospin, strangeness, c, b, t quarks
- Particle Interactions
  - Colour charge, QCD, gluons, fragmentation, running couplings
  - Strong and weak decays, conservation rules
  - Virtual particles and range of forces
  - Parity, charge conjugation, CP
  - Weak decays of quarks
- Elect
- LHC
- Futur

Today

- Lecture 18 (4 slides/page) - Parity violation in weak interaction, helicity
  - Williams, pp. 305-310; see also Lecture 17 textbook references.
  - Halzen and Martin. p. 254
  - C.S. Wu, E. Ambler, R.W. Hayward, D.D. Hoppes, R.P. Hudson, "Experimental Test of Parity Conservation in Beta Decay", Phys. Rev. 105, 1413 (1957).

Previous lecture

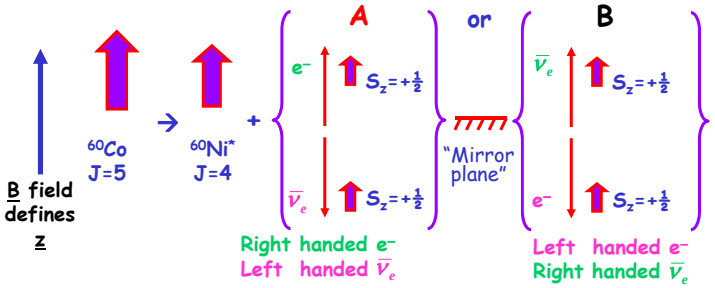
- Lecture 17 (4 slides/page) - Parity, Charge conjugation, Time reversal symmetries
  - Griffiths, pp. 136-144, 149-151, 161.
  - Perkins, pp. 71-76, 83-86,
  - Some experimental studies of T/CPT invariance
    - CERN Press Release, 7 Mar 2012 NEW 1st resonant transitions measured in antihydrogen
    - Phys. Rep. 374 (2003) pp.165-270, Physics at CPLEAR, A. Angelopoulos et al. (CPLEAR Collaboration), pg ~171.
    - preprint CERN-EP-2001-060, T-violation and CPT-invariance measurements in the CPLEAR experiment: a detailed description of the analysis of neutral-kaon decays to e pi nu , Angelopoulos et al.
    - Phys. Rev. D 83, 092001 (2011), Precise Measurements of Direct CP Violation, CPT Symmetry, and Other Parameters in the Neutral Kaon System

# P and T transformations

| Observable | Parity transform | Time, T, transform |
|---|---|---|
| Position, **r** | -**r** (vector) | **r** |
| Momentum, **p** | -**p** (vector) | -**p** |
| Spin, **σ** | **σ** (axial vector) | –**σ** |
| Longitudinal polarisation, **σ.p** | -**σ.p** (pseudoscalar) | **σ.p** |
| Electric field, **E** | -**E** (vector) | **E** |
| Magnetic field, **B** | **B** (axial vector) | -**B** |
| Magnetic dipole moment, **σ.B** | **σ.B** (scalar) | **σ.B** |
| Electric dipole moment, **σ.E** | -**σ.E** (pseudoscalar) | -**σ.E** |

# $^{60}$Co Parity violation experiment [Wu *et al* ,1956]

Basic process: $^{60}Co \rightarrow {}^{60}Ni^{*} + e^{-} + \bar{\nu}_e$
Nuclear spins aligned along z at low temperature (~0.01K)




- When leptons emitted parallel to +/- z, lepton spins constrained along +z
- Scenario B is mirror reflection of A (in plane ⊥ z), i.e. B is equivalent to parity transformed version of A.
- As scenario A is not observed, the weak interaction does change its behaviour during a parity transformation, i.e. parity is violated in the weak interaction