# The Neutron as a Fundamental Physics Laboratory

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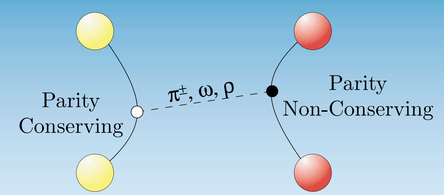
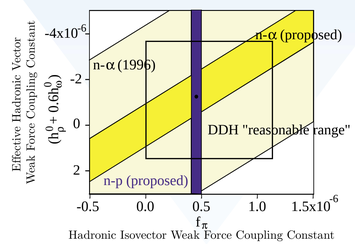
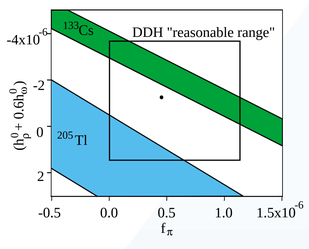
## NEUTRON-NUCLEON INTERACTIONS

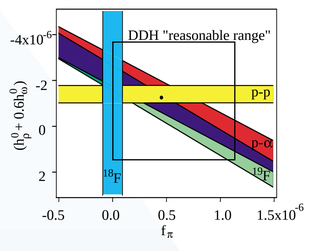



### Neutron Spin Rotation in Liquid Helium

### Parity Violation in the Reaction $\vec{n} + p \rightarrow d + \gamma$



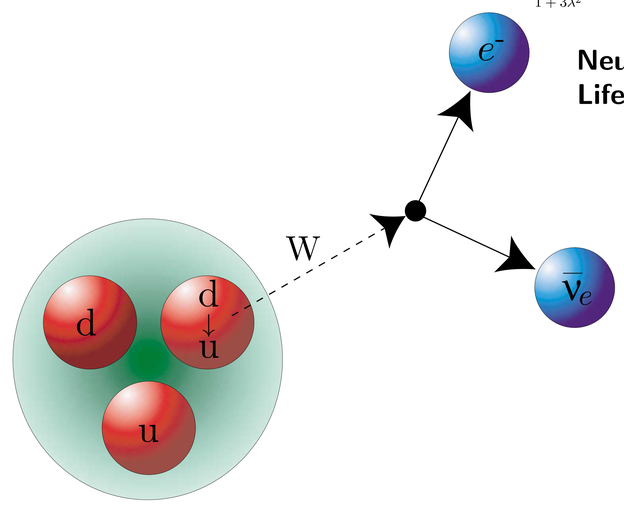




### Atomic Physics

- Nuclear anapole moment studies
  - $^{133}$Cs
  - $^{205}$Tl

### Nuclear Physics

- Longitudinal polarization asymmetry ($A_L$)
  - $\vec{p} + p$ (15, 45 MeV)
  - $\vec{p} + {}^4$He (46 MeV)
- Gamma ray asymmetry ($A\gamma$)
  - $^{19}$F
- Circular polarization ($P\gamma$)
  - $^{18}$F




## NEUTRON BETA DECAY

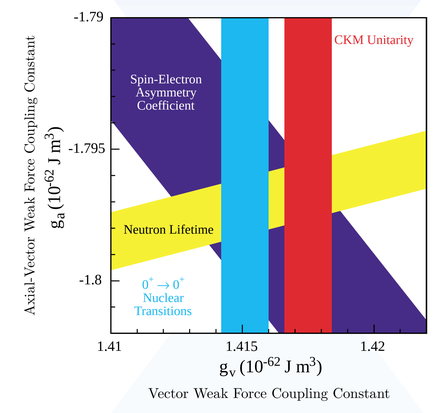
$$dW \propto \left[1 + a\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + \vec{\sigma}_n \cdot \left(A\frac{\vec{p}_e}{E_e} + B\frac{\vec{p}_\nu}{E_\nu} + D\frac{\vec{p}_e \times \vec{p}_\nu}{E_e E_\nu}\right)\right]$$

| | | | | | |
|---|---|---|---|---|---|
| $\tau_n \propto \frac{1}{(g_v^2 + 3g_a^2)}$ | $= 886.7 \pm 1.9$ s | neutron lifetime | $a = \frac{1-\lambda^2}{1+3\lambda^2}$ | $= -0.102 \pm 0.005$ | electron-neutrino asymmetry |
| $A = -2\frac{\lambda^2+\lambda}{1+3\lambda^2}$ | $= -0.1162 \pm 0.0013$ | spin-electron asymmetry | $D = 2\frac{\lambda \sin\phi}{1+3\lambda^2}$ | $\leq 0.0015$ | T-odd triple-product |
| $B = 2\frac{\lambda^2-\lambda}{1+3\lambda^2}$ | $= 0.990 \pm 0.008$ | spin-neutrino asymmetry | $\lambda = \left\lvert\frac{g_a}{g_v}\right\rvert e^{i\phi}$ | $= -1.2664 \pm 0.0031$ | coupling constant ratio |

### Neutron Lifetime

### Asymmetry Coefficients

### Tests of the Standard Model




### Nuclear Physics

- Superallowed Fermi beta decays ($0^+ \rightarrow 0^+$ transitions):
  - $^{10}$C
  - $^{14}$O
  - $^{26m}$Al
  - $^{34}$Cl
  - $^{38m}$K
  - $^{42}$Sc
  - $^{46}$V
  - $^{50}$Mn
  - $^{54}$Co
- Pion beta decay ($0^- \rightarrow 0^-$ transition)

### High Energy Physics

- CKM Unitarity
  - $V_{ud}^2 + V_{us}^2 + V_{ub}^2 = 1$
- $V_{us}$ from Kaon decay
- $V_{ub}$ from B-meson decay
- $g_v = G_F V_{ud}$