The Majorana vs. Dirac Question

Are neutrinos —

Majorana fermions $\bar{\nu} = \nu$

or

Dirac fermions $\bar{\nu} \neq \nu$

The answer will tell us something about the origin of the tiny neutrino masses.

A New Approach

Baha Balantekin, André de Gouvêa, B.K.

arXiv:1808.10518, Phys.Lett. B789 (2019) 488

Baha Balantekin, B.K.

arXiv:1805.00922, Ann.Rev.Nucl.Part.Sci. 68 (2018) 313

B.K.

arXiv:1805.07523, Proc.Moriond Electroweak (2018) 323

– and ongoing work by Jeffrey Berryman, Patrick Fox, André de Gouvêa, B.K., Kevin Kelly, Jennifer Raaf

Suppose we discover
a Heavy Neutrino N
whose decays we can study.

(Several hundred MeV < m_N < Several TeV)

A heavy neutrino is being sought
at CERN, J-PARC, and Fermilab.

If a detector *has electric charge discrimination,* one can collect, for example, separate samples of $N \to \mu^- \pi^+$ and $N \to \mu^+ \pi^-$.

If N is a Majorana fermion N^M

$$\Gamma\left(N^M \to \mu^- \pi^+\right) = \Gamma\left(N^M \to \mu^+ \pi^-\right)$$

There will be as many $\mu^- \pi^+$ pairs as $\mu^+ \pi^-$ ones from N decays.

If N is a Dirac fermion N^D

$N^D \to \mu^- \pi^+$ only, and $\overline{N^D} \to \mu^+ \pi^-$ only.

If a detector *does not have electric charge discrimination*,
we can measure only *the sum*
of the $N \to \mu^- \pi^+$ and $N \to \mu^+ \pi^-$ decays.

If N is a Majorana fermion N^M

CPT ➡ an ***isotropic*** $\mu\pi$ angular distribution.

If N is a Dirac fermion N^D

The *Standard Model* ➡ a very ***non-isotropic***
$\mu\pi$ angular distribution.

Real-world sensitivities to the distinction between Dirac N and Majorana N are being explored.

> ***Leptonic mixing implies that if N is a Majorana fermion, so are all the other neutrinos.***

“The Search for Leptonic CP Violation”

for the

CERN COURIER

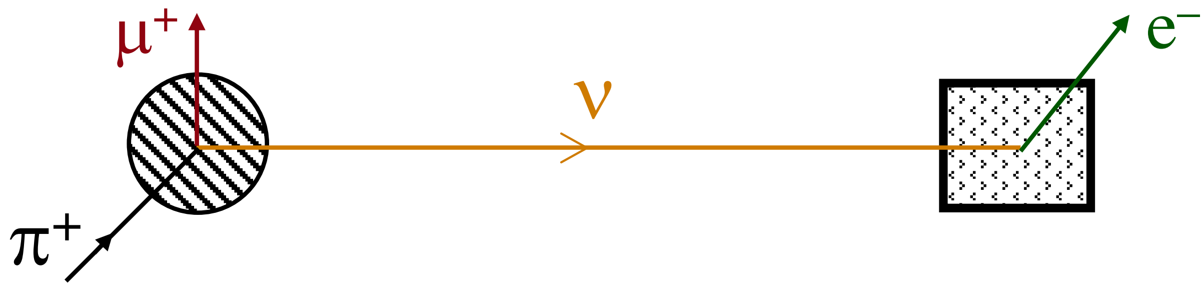
This search is universally described as the search for —

$$P\left(\bar{\nu}_\mu \rightarrow \bar{\nu}_e\right) \neq P\left(\nu_\mu \rightarrow \nu_e\right)$$

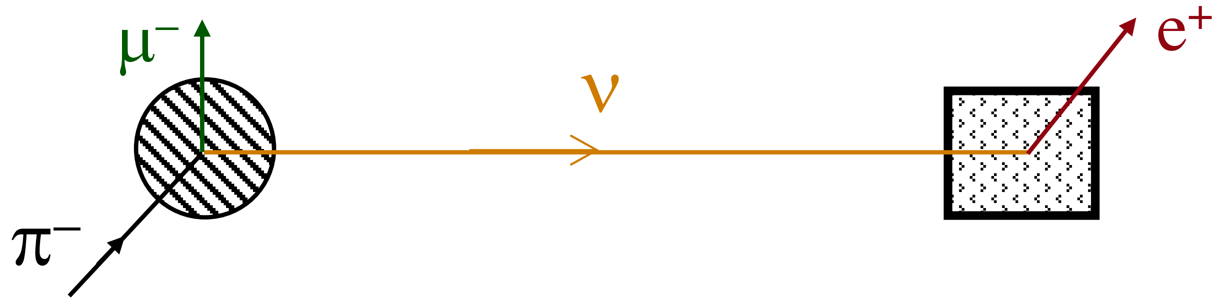
But what if $\bar{\nu} = \nu$??

The actual experiment will —

Compare



with



If these two CP-mirror-image processes have different rates, CP invariance is violated.