Joint ILIAS–CAST–CERN Axion Training

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INTRODUCTION

CERN: axion-training **OPEN** to public → **open course**

→ **open to challenging questions in axion-physics!**

. . . .

CERN - DG: **Open Access** policy → Journals, Books, Data

to fully utilize the internet!

CAST → to release data!

A long-standing + challenging problem in particle physics:

The understanding of CP violation & non-CP violation in QCD

→ Strong CP problem

→ Peccei-Quinn

→ axion

→ axions + WIMPs → dark matter candidates

→ axions @ Sun

→ axions @ lab

→ axions everywhere ?

→ Earth + Space exp.'s & accelerator + non-accelerator exp.'s

→ theoretical formalism = complicated, …

→ this training

→ these lecturers

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CP Conservation in the Presence of Pseudoparticles*

1571x

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(Received 31 March 1977)

We give an explanation of the *CP* conservation of strong interactions which includes the effects of pseudoparticles. We find it is a natural result for any theory where at least one flavor of fermion acquires its mass through a Yukawa coupling to a scalar field which has nonvanishing vacuum expectation value.

It is experimentally obvious that we live in a world where *P* and *CP* are good symmetries at the level of strong interactions. In the context of quantum chromodynamics the strong interactions

grangian.

If all fermions which couple to the non-Abelian gauge fields are massless then the various θ choices give equivalent theories.[1,3] This is most

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Constraints imposed by *CP* conservation in the presence of pseudoparticles*

1043x

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(Received 31 May 1977)

We elaborate on an earlier discussion of *CP* conservation of strong interactions which includes the effect of pseudoparticles. We discuss what happens in theories of the quantum-chromodynamics type when we include weak and electromagnetic interactions. We find that strong *CP* conservation remains a natural symmetry if the full Lagrangian possesses a chiral U(1) invariance. We illustrate our results by considering in detail a recent model of (weak) *CP* nonconservation.

I. INTRODUCTION

The appearance of this additional term shows the problem to which we address ourselves. It appears

Experimental Tests of the "Invisible" Axion

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(Received 13 July 1983)

Experiments are proposed which address the question of the existence of the "invisible" axion for the whole allowed range of the axion decay constant. These experiments exploit the coupling of the axion to the electromagnetic field, axion emission by the sun, and/or the cosmological abundance and presumed clustering of axions in the halo of our galaxy.

PACS numbers: 14.80.Gt, 11.30.Er, 95.30.Cq

Some time ago, it was shown that the strong *CP* problem[1] can be solved[2] by the introduction of a light pseudoscalar particle,[3] called the axion a. The properties of the axion depend mainly on the magnitude v of the vacuum expectation value that spontaneously breaks the $U_{PQ}(1)$ quasisymmetry which was postulated by Peccei and Quinn[2] and of which the axion is the pseudo-Goldstone boson. The axion mass and its couplings to ordinary particles are all inversely proportional to v. As far as the solution to the strong *CP* problem is concerned, the value of v is arbitrary.[4] Past experiments,[5] attempting to produce and detect axions in the laboratory, essentially rule out values of v near 250 GeV. Moreover the range 250 GeV $\lesssim v \lesssim 10^8$ GeV is ruled out by considering the effect axions have on stellar evolution.[6] Stars emit too many axions for those values of v. The axion with $v \gtrsim 10^8$ GeV is so weakly coupled[4] that it has been called "invisible." It was thought, incor-

In that case, the axion density near the sun's location is about

$$\rho_{a,\text{halo}} \simeq \frac{10^{-24}\text{ g}}{\text{cm}^3} \simeq \frac{0.5\times 10^{12}\text{ axions}}{\text{cm}^3}\left(\frac{v}{10^{10}\text{ GeV}}\right)\frac{1}{r}, \quad (1)$$

where we have used the following expression for the axion mass ($\hbar = c = 1$ everywhere):

$$m_a = 1.24\times 10^{-3}\text{ eV}[(10^{10}\text{ GeV})/v]r = \frac{2\pi}{10^{-1}\text{ cm}}\left(\frac{10^{10}\text{ GeV}}{v}\right)r = \frac{2\pi}{\frac{1}{3}\times 10^{-11}\text{ sec}}\left(\frac{10^{10}\text{ GeV}}{v}\right)r. \quad (2)$$

r is a model dependent number of order $N/6$, where N is the number of vacua of the axion model.[7,9] These halo axions have velocities $\beta \lesssim 10^{-3}$,

PHYSICAL REVIEW D
PARTICLES AND FIELDS

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Design for a practical laboratory detector for solar axions

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(Received 19 September 1988)

We present a practical design for a detector sensitive to axions and other light particles with a two-photon interaction vertex. Such particles would be produced in the solar interior by Primakoff conversion of blackbody photons and could be detected by their reconversion into x rays (average energy about 4 keV) in a strong laboratory magnetic field. An existing large superconducting magnet would be suitable for this purpose. The transition rate is enhanced by filling the conversion region with a buffer gas (H_2 or He). This induces an effective photon mass (plasma frequency) which can be adjusted to equal the axion mass being searched for. Axion-photon conversion is then coherent throughout the detector volume for all axion energies. Axions with mass in the range 0.1 eV $\lesssim m_a \lesssim$ 5 eV can be detected using gas pressures of 0.1–300 atm. Axions with the standard coupling strength to photons would give counting rates of 10^{-5}–10 sec^{-1} over this mass range. The search would definitively test one of the only two regions of axion parameters not excluded by astro-

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Search for Solar Axions

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(Received 22 May 1992)

We have searched for a flux of axions produced in the Sun by exploiting their conversion to x rays in a static magnetic field. The signature of a solar axion flux would be an increase in the rate of x rays detected in a magnetic telescope when the Sun passes within its acceptance. From the absence of such a signal we set a 3σ limit on the axion coupling to two photons $g_{a\gamma\gamma} \equiv 1/M < 3.6 \times 10^{-9}$ GeV^{-1}, provided the axion mass $m_a < 0.03$ eV, and $< 7.7 \times 10^{-9}$ GeV^{-1} for $0.03 < m_a < 0.11$ eV.

PACS numbers: 14.80.Gt, 95.85.Qx, 96.60.Vg

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➔ **~40x worse than CAST**

~1998

AXION SEARCHES

are

- ○ MANDATORY
- ○ FUN, CREATIVE
- ○ PROCEEDING

➔ start with

➔ R. Peccei

[redacted]