International Journal of Modern Physics A

Search for exotic effects in η meson leptonic decays

Marcin Berłowski* for the WASA-at-COSY Collaboration,
The Andrzej Sołtan Institute for Nuclear Studies, 00-681 Hoża 69, Warsaw, Poland

Received Day Month Year
Revised Day Month Year

The search for the decay $\eta \to e^+e^-$ was carried out using the WASA detector at the COSY storage ring. Data were taken during a two week experimental run in Sept-Nov 2008 in which about 10^7 η mesons were collected from the reaction of $pp \to pp\eta$ at energy of 1.4 GeV. Background studies were performed for several different reactions. The performance of the WASA detector for the measurement of electron-positron pairs based on the single Dalitz decay of the η meson was studied. We also identified a statistically significant data sample of other more frequent leptonic decays.

Keywords: η meson decays, leptonic decays

PACS numbers: 13.20.-v, 14.40.Be

1. Introduction

The aim of this project is the search for the very rare eta meson decay $\eta \to e^+e^-$. In the Standard Model, this decay proceeds dominantly through the electromagnetic interaction. Branching ratio (BR) for the decay is suppressed relative to $\eta \to \gamma\gamma$ by α^2 and by $(m_e/m_\eta)^2$ from helicity conservation[3]:

$$BR_{theo}[\eta \to e^+e^-] \sim BR[\eta \to \gamma\gamma] \cdot \alpha^2 \cdot (m_e/m_\eta)^2$$

The small probability of this fourth-order electromagnetic transition makes the decay sensitive to hypothetical interactions that arise from physics beyond the Standard Model[2–4]. Today, the best limit $BR_{exp} < 2.7 \cdot 10^{-5}$ *at* $CL = 90\%$ comes from the CELSIUS/WASA experiment[1]. This number is five orders of magnitude larger then the value predicted from the Standard Model calculations ($BR_{theo} =\sim 10^{-9}$). An observation of a signal above this level could be evidence for an unconventional process which enhances this decay rate.

2. Experiment

The experiment WASA-at-COSY (at COoler SYnchrotron COSY) is located in the Forschungszentrum Jülich. A unique target system of frozen hydrogen droplets and

*E-mail address: Marcin.Berlowski@fuw.edu.pl

an internal proton beam was used. The target was designed with the aim to minimize the photon conversion in the target material. The η mesons were produced in the reaction $pp \to pp\eta$ at 1.4 GeV beam energy. We used a special trigger in which a high energy deposit in both sides of the electromagnetic calorimeter was demanded. This type of trigger should equally favor electromagnetic decays of η mesons like $\eta \to \gamma\gamma$, $\eta \to e^+e^-\gamma$, $\eta \to e^+e^-$. Energies and angles of the protons emitted at small polar angles are precisely measured in the forward detector. The decay products of the mesons are studied with a nearly 4π central detector consisting of a drift chamber in a magnetic field, a barrel of plastic scintillators and an electromagnetic calorimeter (1012 sodium-doped CsI crystals).

3. Results

Using the $\eta \to \gamma\gamma$ decay channel we estimate the number of η mesons collected in the data sample to be $\sim 4.4 \cdot 10^7$. This number is approximately forty times larger than the data sample used in the previous analysis[1]. It was found that the main sources of background are $pp \to pp\pi^+\pi^-$ due to a 100 time larger cross section and $pp \to pp(\eta \to e^+e^-\gamma)$ due to the same final state particles if the mass of the virtual photon is large and the photon is not observed. We observe 1517 event candidates in the data sample after full analysis which puts the branching ratio at the level $= 7.09 \cdot 10^{-5}$ (if all events are coming from background). The Monte Carlo signal acceptance (both reconstruction efficiency and geometrical acceptance) is 5.71%. The background from the direct production of two charged pions is at the level $1.2 \pm 0.6 \cdot 10^{-5}$ and we expect 525 ± 263 events coming from this background. The background from single Dalitz decays is at the level $1.22 \pm 0.23 \cdot 10^{-7}$ and we expect only 5.4 ± 1.0 events contributing to the $\eta \to e^+e^-$ background. Further studies of pile-up contributions (event mixing) are needed.

4. Summary

At this stage of the analysis we cannot go below the present limit for the branching ratio of the $\eta \to e^+e^-$ decay. There is further need for larger Monte Carlo samples for better statistical error evaluation. Monte Carlo simulations for pile-up and an estimate of the probability for those events is needed. The analysis of the new data taken in 2010 will start this year.

References

1. M. Berłowski *et al.* [CELSIUS/WASA], *Measurement of eta meson decays into lepton-antilepton pairs* Phys.Rev.D77:032004(2008) arXiv:0711.3531v3 [hep-ex]
2. P. Fayet, *Constraints on light dark matter and U bosons, from phi, psi, K+, pi0, eta and eta' decays* Phys.Rev.D74:054034(2006) arXiv:0607318v1 [hep-ph]
3. Q. Chang, Y.-D. Yang, *Rare decay pi0− > e + e− as a sensitive probe of light CP-odd Higgs in NMSSM* arXiv:0808.2933v1 [hep-ph]
4. Y. Kahn, M. Schmitt, and T.M.P. Tait, *Enhanced rare pion decays from a model of MeV dark matter* Phys.Rev.D78:115002(2008) arXiv:0712.0007v1 [hep-ph]