SEARCH FOR A NEW GAUGE BOSON IN π^0 LEPTONIC DECAY WITH WASA-AT-COSY*

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The WASA-at-COSY detector has recorded a high statistic run of π^0 decays. A search for a new vector boson in the e^+e^- invariant mass spectrum of $\pi^0 \to e^+e^-\gamma$ decay has been done. No new boson has been found and an upper limit has been set in the mass range of 30–100 MeV.

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1. Introduction

Several astrophysical observations of positron excess [1–4] suggest that a new gauge boson [5] could exist in the MeV scale since no muon/pion excess has been found at the same time. Leptonic decays of π^0 are a good place to look for such a new boson since one can create e^+e^- pairs abundantly with low background and compare a well formulated theory. The energy range of e^+e^- pairs from π^0 covers also the region where a new boson could explain the discrepancy between the Standard Model prediction and experimental data of the muon $g-2$.

2. Theory

2.1. π^0 meson

The π^0 meson is the lightest known hadron and hence it only decays via electroweak interaction. The most common decay is the decay to 2γ. Other known decays proceed via one or two virtual photons to electron positron pairs.

2.2. New boson

The large amount of virtual photons in its decays makes the π^0 a good candidate for looking for a new vector boson. In the simplest model, this boson is a U(1) boson with weak coupling to the ordinary photon [5].

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3. WASA-at-COSY

The WASA detector setup [9] is located at the COSY accelerator in Jülich, Germany [10]. The accelerator has the possibility to accelerate protons and deuterons up to 3.7 GeV. For π^0 production, the kinetic energy has been chosen to be 550 MeV. This is to maximize the production cross section (1.12 mbarn) below the two pion threshold in *pp* collisions. Small pellets of frozen hydrogen serve as the internal target. The advantage of pellets is to minimize external photon conversion in the target. The WASA detector consists of a forward detector (FD) for scattering products and a central detector (CD) for measurement of decays. The FD measures kinetic energy in the range hodoscope, ΔE, and time by plastic scintillators and angles by tracking detectors. In the CD, energy is measured by the electromagnetic calorimeter, ΔE and time by plastic scintillators and the Tracking detector (MDC) measures charge, angles and momentum.

4. Results

4.1. $\pi^0 \to e^+e^-\gamma$

4.1.1. Data selection

The final data of 2010 contains around 500 k $\pi^0 \to e^+e^-\gamma$ decays (Fig. 1). To achieve the highest possible statistics, one uses the event selection of 1 proton in the FD, e^+e^- in the central part of CD and no constraints on neutral tracks. The background channels left are then external conversion in the decay $\pi^0 \to 2\gamma$ and random coincidence events with a misidentification

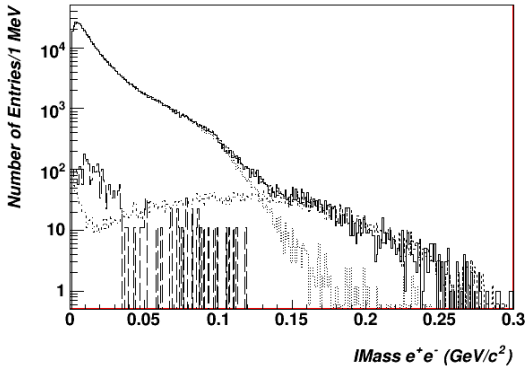


Fig. 1. Invariant Mass of e^+e^- after conversion reduction cuts. Solid line: data, dotted line: MC simulation of $\pi^0 \to e^+e^-\gamma$, long-dashed line: MC pair production from $\pi^0 \to 2\gamma$ decay, dot-dashed line: MC Coincidence of $\pi^0 \to e^+e^-\gamma$ and π^+ decays when π^+ is misidentified as a positron, short-dashed line: MC sum.

of π^+ as e^+. Random coincidence background is only important for masses over 100 MeV. The background from external conversion is at start at the same order as the $\pi^0 \to e^+e^-\gamma$ channel but is efficiently reduced to only a few percent by vertex location. WASA-at-COSY has a small interaction region due to its pellet target, and this region is sufficiently smaller than the beamtube radius of 35 mm.

4.1.2. New boson search

The invariant mass spectrum in Fig. 1 does not contain any signal from a new boson and a new upper limit can be set. The latest attempt to find the decay $\pi^0 \to \gamma U$ was done by the SINDRUM I Collaboration [11]. The upper limit then was based on a lower statistics sample only for events above 25 MeV/c^2. The new upper limit derived from this work is shown in Fig. 2. The WASA Collaboration has also a larger data sample recorded in 2012

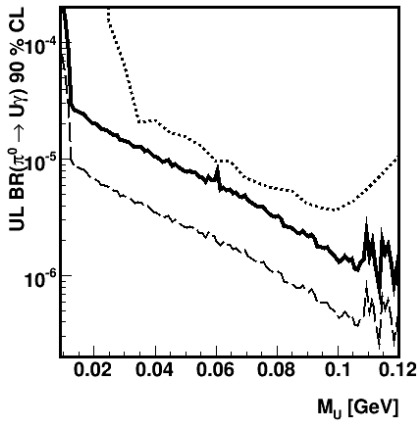


Fig. 2. U.L. for the decay $\pi^0 \to U\gamma \to e^+e^-\gamma$. Dotted line: SINDRUM I [11], solid line: WASA 2010, dashed line: WASA 2012 (expected).

that are under investigation. Also a new upper limit expectation based on the known statistical improvement are presented in Fig. 2. The branching ratio $\pi^0 \to \gamma U$ is related to ϵ^2 by [12]

$$\frac{\Gamma\left(\pi^0 \to \gamma U\right)}{\Gamma\left(\pi^0 \to \gamma\gamma\right)} = 2\,\epsilon^2 \left|F\left(M_U^2\right)\right|^2 \left(1 - \frac{M_U^2}{M^2}\right)^3 , \tag{1}$$

where $F(M_U^2)$ is the π^0 meson form factor at the new boson mass M_U. The corresponding 90% C.L. upper limit on the ϵ^2 parameter from WASA-at-COSY experiment in the range 20 MeV $< M_U <$ 100 MeV are given in Fig. 3 together with previous results.

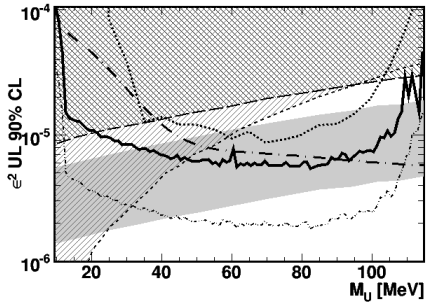


Fig. 3. U.L. ϵ^2. Dotted line: SINDRUM I [11], solid line: WASA 2010, double dot-dashed line: WASA 2012 (expected), dot-dashed: KLOE [14]. Tilted regions: long-dashed line: muon $g-2$ [13], short-dashed line: electron $g-2$ [13]. Grey region: Motivated region within 2σ by discrepancy between experiment and SM prediction of muon $g-2$ [13].

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