Search for Invisible Decays of a Dark Photon Produced in e + e − Collisions at BABAR

JC-93

Presented By: Amit Pathak

Object

We search for single-photon events in 53 fb^{-1} of e^+e^- collision data collected with the *BABAR* detector at the PEP-II B-Factory. We look for events with a single high-energy photon and a large missing momentum and energy, consistent with production of a spin-1 particle A' through the process $e^+e^- \to \gamma A'$; $A' \to$ invisible. Such particles, referred to as "dark photons," are motivated by theories applying a $U(1)$ gauge symmetry to dark matter. We find no evidence for such processes and set 90% confidence level upper limits on the coupling strength of A' to e^+e^- in the mass range $m_{A'} \leq 8$ GeV. In particular, our limits exclude the values of the A' coupling suggested by the dark-photon interpretation of the muon $(g-2)_\mu$ anomaly, as well as a broad range of parameters for the dark-sector models.

Introduction

- The nature of dark matter is one of the greatest mysteries of modern physics.
- It is transparent to electromagnetic radiation and we have only been able to infer its existence through gravitational effects.
- Since terrestrial searches for dark-matter interactions have so far yielded null results, it is postulated to interact very weakly with ordinary matter.
- Recently, models attempting to explain certain astrophysical observations as well as the muon $(g - 2)_\mu$ anomaly have introduced an appealing idea of a low-mass spin-1 particle, referred to as X or U, that would possess a gauge coupling of electroweak strength to dark matter, but with a much smaller coupling to the standard model (SM) hypercharge.
- Such a boson may be associated with a U(1) gauge symmetry in the dark sector and kinetically mix with the SM photon with a mixing strength $\varepsilon \ll 1$, hence the name "dark photon." Values as high as $\varepsilon \sim 10^{-3}$ and masses in a GeV range have been predicted in the literature.
- The decay modes of the dark photon depend on its mass and couplings, as well as on the particle spectrum of the dark sector.

- If the lowest-mass dark matter state χ is sufficiently light, $m\chi < mX/2$, then the dominant decay mode of the X is invisible, $X \to \chi\bar{\chi}$.
- The cleanest collider signature of such particles is the production of monochromatic single photons in $e+e- \to \gamma X$ accompanied by significant missing energy and momentum.
- We seek a signal of the dark photon X as a narrow peak in the distribution of M2X in events with a single high-energy photon.

Question by Ryuta

Q. At the very begining, one of motivation of the dark photon search is described as "models attempting to explain certain astrophysical observations [1-4]".

Could you introduce one(or some) of these astrophysical observations, especially how we can interprete the results to the dark photon (excess of e+/e- events ?) ?

Answer: We can discuss about this Fermi-LAT paper.

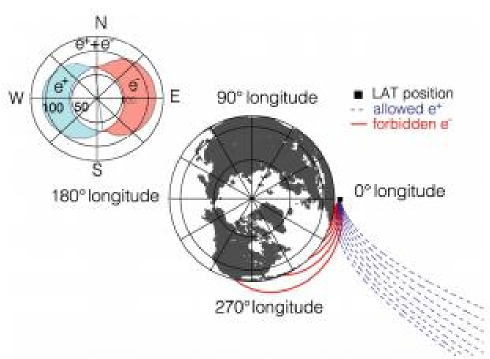

FIG. 1 (color online). Examples of calculated electron (red) and positron (blue) trajectories arriving at the detector, for 28 GeV particles arriving within the Equatorial plane (viewed from the North pole). Forbidden trajectories are solid and allowed trajectories are dashed. Inset: the three selection regions (electron-only, positron-only, and both-allowed) for the same particle energy and spacecraft position as the trajectory traces (viewed from the instrument position in the Equatorial plane).

We measured separate cosmic-ray electron and positron spectra with the Fermi Large Area Telescope. Because the instrument does not have an onboard magnet, we distinguish the two species by exploiting Earth's shadow, which is offset in opposite directions for opposite charges due to Earth's magnetic field. We estimate and subtract the cosmic-ray proton background using two different methods that produce consistent results. We report the electron-only spectrum, the positron-only spectrum, and the positron fraction between 20 and 200 GeV. We confirm that the fraction rises with energy in the 20–100 GeV range. The three new spectral points between 100 and 200 GeV are consistent with a fraction that is continuing to rise with energy.

Question by Xin

Question: In the paper, it says: “These limits assume that the dominant decays of the A0 are to the visible SM particles, but are not valid if there are low-mass invisible degrees of freedom.

Could you explain a bit more?

Answer: For this answer, I need to read the reference paper 8-16.

There are constraints on invisible decays of the A0 from kaon decays [17–19] and from the recent search for missing energy events in electron-nucleus scattering [20]

Question by Yuhang

Question: In fig.3,Why use the Mx2 on the Horizontal axis, not Mx？ Is there any special physical meaning?

Answer:

Question by Gu Shan

Question: In the sentence "we assume that a single A0 state exists in the range $0 < mA0 \leq 8$ GeV,"

What is the basis for this energy interval setting?

Answer:

Question by Yuzhen

Question: In Fig5, what is NA64? Is it an experiment? can you introduce some?

Answer: NA64 is an experiment at the CERN SPS.

We report on a direct search for sub-GeV dark photons (A'), which might be produced in the reaction $e^-Z \rightarrow e^-ZA'$ via kinetic mixing with photons by 100 GeV electrons incident on an active target in the NA64 experiment at the CERN SPS. The dark photons would decay invisibly into dark matter particles resulting in events with large missing energy. No evidence for such decays was found with 2.75×10^9 electrons on target. We set new limits on the $\gamma - A'$ mixing strength and exclude the invisible A' with a mass $\lesssim 100$ MeV as an explanation of the muon $g_\mu - 2$ anomaly.

DOI: 10.1103/PhysRevLett.118.011802

The link for the NA64 collaboration

https://doi.org/10.1103/PhysRevLett.118.011802

Thank You!!!