Searches for an invisible dark photon at BABAR

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PANIC 2017, Beijing, China

Outline

- BABAR detector and data
- Dark photon overview
- Previous dark photon searches @ BABAR
- New: dark photon \rightarrow invisible
 - arXiv:1702.03327, to appear in PRL

BABAR energy and dataset







Resonance	L(fb ⁻¹)	#(10 ⁶)
Υ(4 <i>S</i>)	424	471
Y(3S)	28	121
Υ(2 <i>S</i>)	14	99
Off-resonance	48	

The BABAR Detector















Impact on g - 2

Constraints from $A' \rightarrow$ visible



See next talk by Dayong WANG for BESIII results

More BABAR dark photon searches



BABAR muonic photon (Z') search

- Motivated by (g 2)_μ
 & proton radius anomaly
- In scenarios with sterile- ν DM
- Weakens previous searches
- BABAR searched for $m_{\mu\mu}$ peak in $e^+e^- \rightarrow 4\mu$ PRD 94 (2016) 011102







Search for $A' \rightarrow$ invisible

• All constraints based on visible A' decays don't apply if $m_{A'} > 2m_{\chi}$ and the A' decays predominantly to invisible dark-sector states, e.g.,



- So we reconstruct $e^+e^- \rightarrow \gamma + \text{missing}$
- Exploit known initial state, clean environment, detector hermeticity
- Photon energy in center-of-mass frame related to the missing mass:

$$E_{\gamma}^* = \frac{s - M_X^2}{2\sqrt{s}}$$

• where $M_X^2 = m_A$, for signal

Dedicated trigger

2-level trigger system – L1 (hardware) and L3 (software). A single-photon trigger introduced late in BABAR run:

- L1 requires an EMC cluster with $E_{\gamma} > 800 \text{ MeV}$
- L3 has 2 single-photon lines:



Trigger line	Trigger selection	Offline selection	Luminosity
"LowM"	$E_{\gamma}^{*} > 2 \text{ GeV}$	$E_{\gamma}^* > 3 \text{ GeV}$	$53 {\rm fb}^{-1}$
"HighM"	$E_{\gamma}^{*} > 1~{ m GeV}$	$E_{\gamma}^* > 1.5~{ m GeV}$	35.9 fb^{-1}
	Center-of-mass frame		

• L3 also requires that there are no additional tracks

Backgrounds

• HighM region:

- Used for $24 < M_X^2 < 69 \text{ GeV}^2$
- Dominant background: $e^+e^- \rightarrow e^+e^-\gamma$ with e^+e^- undetected

• LowM region:

- Used for $-4 < M_X^2 < 36 \text{ GeV}^2$
- Dominant background: $e^+e^- \rightarrow \gamma\gamma$ with one γ undetected



Background suppression BDT

- Trained separately for LowM & HighM
- γ_1 (highest-energy, primary γ):
 - # of EMC clusters
 - 2 cluster-shape variables
 - $-\cos\theta_1^*$
- γ_2 (2nd-highest-energy, secondary γ)
 - Energy
 - $-\cos\theta_2^*$
 - γ_1 γ_2 azimuthal distance
- Total EMC energy excluding γ_1
- Escaping photon:
 - Azimuthal and polar distance of \vec{p}_{miss} to the edge of the nearest EMC crystal
 - Azimuthal distance of γ_1 to IFR cluster closest to \vec{p}_{miss}
 - $-\cos 6\phi_{\rm miss}$



Event selection regions





Events in each region:

	LowM	HighM
Tight	32	
Loose &! Tight	187	
Loose		1,020
Control	~100 k	~1.1 M

Signal yield extraction

vents /(1 GeV²)

- Fit M_X^2 distribution simultaneously in the tight, loose, and control regions for 166 hypotheses of $m_{A'}$
- Signal and $\gamma\gamma$ -background PDFs:
 - Crystal Ball functions
 (Gaussian + exponential tail) from simulation.
 - E_{γ} resolution in MC corrected with $\gamma\gamma$ events with $\gamma \rightarrow e^+e^-$ conversion
- $e^+e^-\gamma$ -background PDF:
 - Polynomials and exp(polynomials)





ε^2 results of the 166 fits



Dark photon constraints



Conclusions

- The dark photon is an attractive "portal" for DM-SM interactions
- Various searches for A' →visible
 (by BABAR and other experiments)
- Those constraints are not applicable if $A' \rightarrow$ invisible dominates
- Complementary searches 10^{-2} for $A' \rightarrow invisible \qquad \omega$
- BABAR search greatly expands the excluded m_A , range

