DARK PHOTON SEARCH AT BELLE

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Mass Range of Dark Photon: 0.27 - 3 GeV/c^2
Mass Range of Dark Higgs: 0.54 - 10.86 GeV/c^2

MELBOURNE, ICHEP 2012
OUTLINE

- Motivation
- Strategy
- Signal Efficiency
- Background
- Preliminary Results

Belle Detector

- SC solenoid 1.5T
- CsI(Tl) $16x_0$
- TOF counter
- Aerogel Cherenkov cnt. $n=1.015-1.030$
- Si vtx. det. 3/4 lyr. DSSD

Asymmetric detector for $CP$ violation studies.
MOTIVATION

- Dark photon and Dark Higgs are coupled through the dark sector.
- This theory may explain the inconsistencies observed in astrophysical data and dark matter experiments.


PREVIOUSLY AND RECENTLY

summary of astrophysical and cosmological constrains and experimental limits

BaBar Results:
J. Jaeckel and A. Ringwald, arXiv:1002.0329
y-axis: kinetic mixing, x-axis: dark photon mass
SEARCH FOR THE DARK PHOTON AND DARK HIGGS AT BELLE

\[ e^+ e^- \rightarrow A h' \rightarrow \text{AAA} \] with \( A \rightarrow l^+ l^- \) (\( l=e \) or \( \mu \)) or hadrons


- Belle Exp. at KEK B-factory
- \( L = 1021 \text{ fb}^{-1} \) at \( \Upsilon(1S, 2S, 3S, 4S, 5S) \) and continuum
- channels presented today
  - \( e^+ e^- \rightarrow 3e^+ 3e^- \)
  - \( e^+ e^- \rightarrow 3\mu^+ 3\mu^- \)
  - \( 0.27 < m_A < 3 \text{ GeV}/c^2 \)
  - \( 0.54 < m_{h'} < 10.86 \text{ GeV}/c^2 \)
The analysis strategy consists of looking at the exclusive reactions where all final states are measured. First, energy and momentum conservation are checked. Secondly, an invariant mass analysis of the invariant masses of all combinations of three disjunct pairs of opposite signs were calculated.

Four or six charged tracks (with same identification but opposite sign) can be combined into $n^+n^-$, number of pairs of opposite sign, in

$$N = n^+n^-!$$

Thus for six tracks with three negatively and three positively charged:

- composed of one particle type (leptons or hadrons), there are different combinations
- composed of two different particle types (i.e., $e$ and $\pi$ or $e$ and $\mu$ or $\mu$ and $\pi$), there are different combinations
- composed of three different particle types, there is only one possibility, among which all combinations with three masses ($m_1^A$, $m_2^A$, and $m_3^A$) "equal" and $m_{h'} > 2m_A$ are chosen.
DETECTION EFFICIENCY

$e^+ e^- \rightarrow Ah' \rightarrow AAA \rightarrow 3l^+ 3l^-$

- $e^+ e^- \rightarrow 3e^+ 3e^-$
  - Efficiency: about 18%

- $e^+ e^- \rightarrow 3\mu^+ 3\mu^-$
  - Efficiency: about 40%
**BACKGROUND ESTIMATION**

- No realistic background model is available. Data driven background estimation: one pair of opposite sign and two pairs of the same sign are calculated.
  - Estimate background using "same sign" events
    \[ e^+ e^- \rightarrow A h' \rightarrow A(l^+ l^-) A(l^+ l^+) A(l^- l^-) \]
  - Order masses of lepton pairs \( m_A^1 > m_A^2 > m_A^3 \) and plot \( m_A^1 - m_A^3 \) vs. \( m_A^1 \)

\[ e^+ e^- \rightarrow 3e^+ 3e^- \]
\[ e^+ e^- \rightarrow 3\mu^+ 3\mu^- \]
**BACKGROUND ESTIMATION: NORMALIZATION**

1. **sideband** events are used to **normalize** same sign to opposite sign.
2. background estimated from the number of counts in the signal region of the same sign distribution.
BACKGROUND ESTIMATION:
MC TEST, PREDICTION

Background estimation method verified successfully with MC for experimental data, predicted BG is

- > 20 events for electron final state (see plot)
- 0 event for muon final state

Double Check after normalization

Data: \( e^+ e^- \rightarrow 3e^+ 3e^- \)
Preliminary Results

- Assume number of events observed = number of background
- Upper Limit (90% C.L.) determined by Feldman-Cousins method
- Sensitivity scales nearly linearly with integrated luminosity

\[ e^+ e^- \rightarrow 3e^+ 3e^- \]

\[ e^+ e^- \rightarrow 3\mu^+ 3\mu^- \]
SUMMARY

!=- From our control data sample, we found that: background is estimated to be small, implying Sensitivity scales nearly linearly with integrated luminosity

!=- The results will be unblinded soon.

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THANK YOU~