Search for Pairs of Long-Lived Particles at BaBar

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Motivation

While the Standard Model (SM) is well established experimentally, key questions remain unanswered, such as the nature of dark matter. These questions motivate many searches for new physics (NP), i.e. phenomena or particles beyond the SM.

Several NP scenarios contain **long lived particles (LoLiPs)**, which would appear in the collider as displaced vertices or missing energy, depending on their lifetime.

Daphna Peimer, under the supervision of Abner Soffer, searched for **one** such LoLiP per electron-positron collision at the BABAR experiment and calculated constraints for relevant models [1]. While Daphna's analysis was very inclusive, its few assumptions resulted in high background, as shown in FIG. 1.

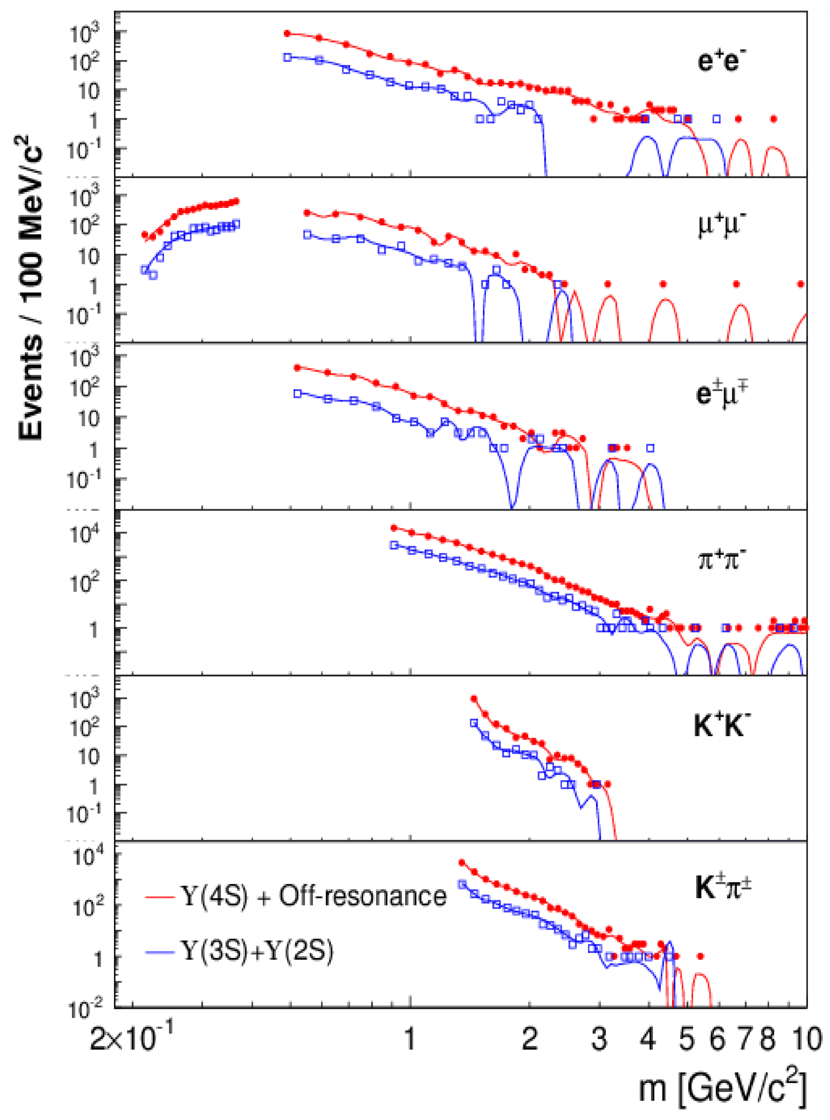


FIG. 1: Mass spectrum of background events in the 1-LoLiP search

In our study we focus on NP scenarios in which **two** LoLiPs are produced. This dramatically reduces the background, making for a much more sensitive search in this scenario.
We present our simulation studies in preparation for an actual measurement.

Model

We study a model where a new leptophilic Higgs is radiated in $e^+e^- \to \tau^+\tau^-$ events and decays to two long-lived, hidden-sector gauge bosons, as shown in FIG. 2.

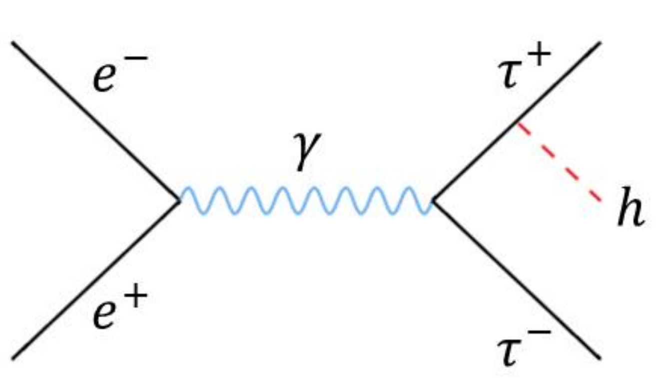


FIG. 2: Feynman diagram of the model

Model

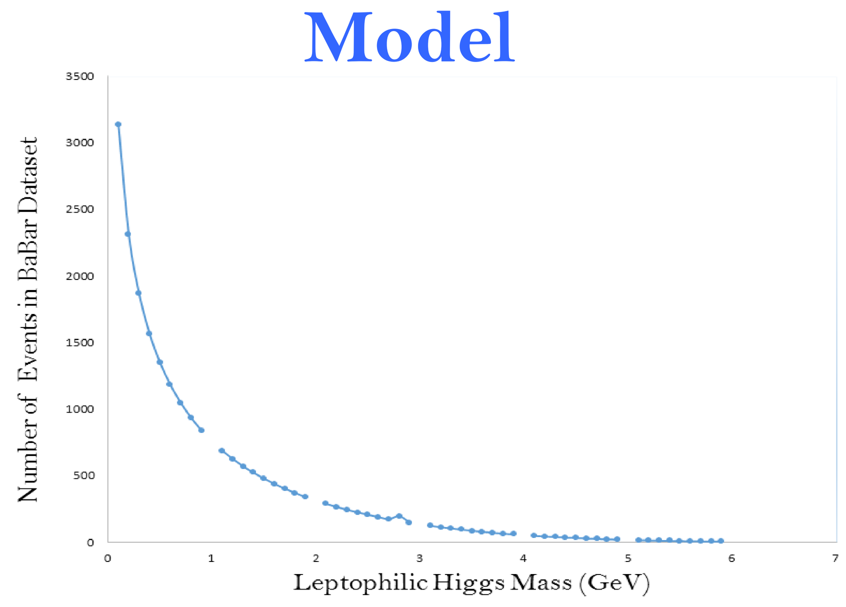
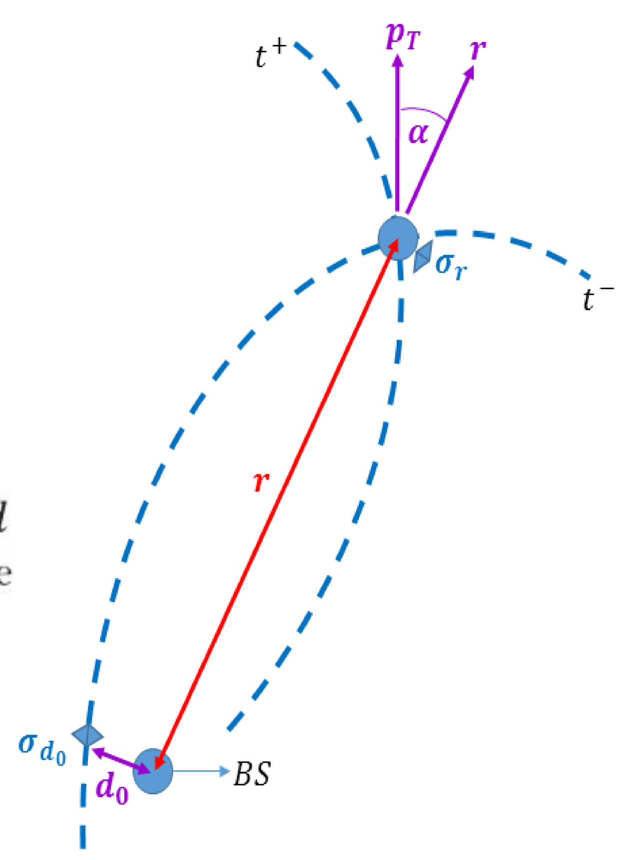


FIG. 3: Expected number of signal events in the dataset vs. leptophilic Higgs mass

The expected number of signal events in the BABAR dataset for a given coupling, shown in FIG. 3, was evaluated with MadGraph simulation [2] as a function of the leptophilic Higgs mass.

Event selection

- ❑ Form vertex out of track pairs
- ❑ **Require:**
  - $\chi^2 < 10$
  - $r > 0.5\ cm$
  - $\sigma_r < 0.2\ cm$
  - $r/\sigma_r > 5$
  - $d_0/\sigma_{d_0} > 3$
  - $\alpha < 0.01\ rad$
  - No hits before the vertex
- ❑ **Remove:**
  - e^+e^- and $\mu^+\mu^-$ with mass cuts



The masses of LoLiP pair candidates found in two dominant types of simulated background events are shown in FIG. 4.

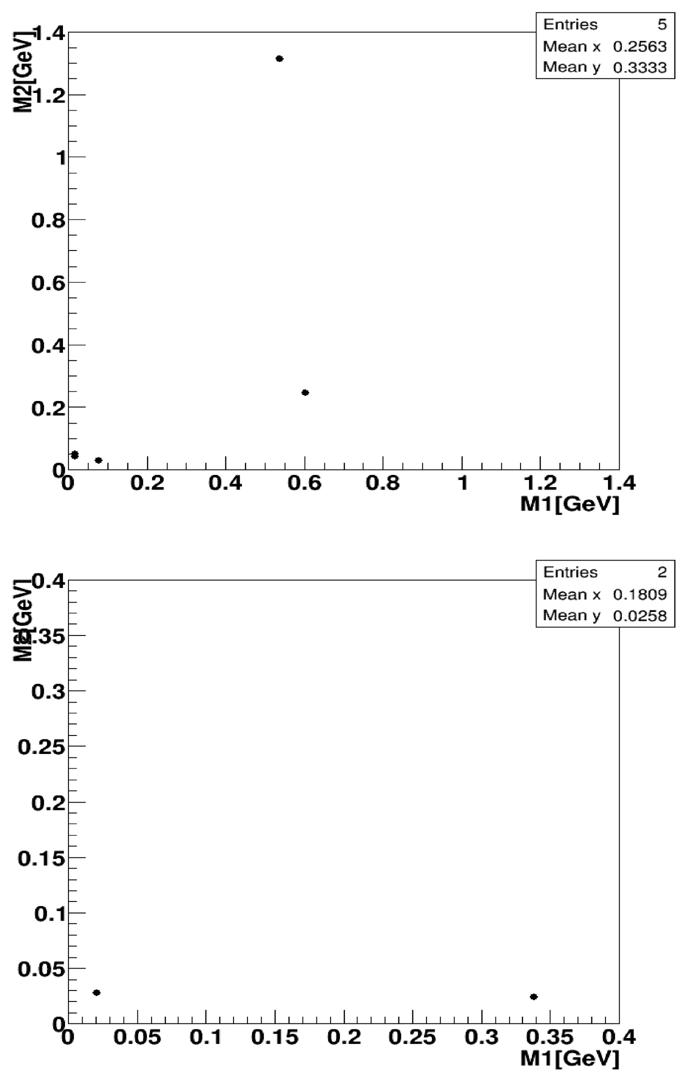


FIG. 4: Masses of the two LoLiP candidates, plotted against each other, in dominant background event types of the simulation

[1] BABAR Collaboration, Phys. Rev. Lett. 114 (2015) 171801, "Search for long-lived particles in e^+e^- collisions.
[2] J. Alwall, JHEP 1106 (2011) 128, "MadGraph 5: going beyond".

Background Estimation

A simple assumption - that the existence of one LoLiP in an event does not impact the probability to create a second LoLiP - makes it possible to estimate the 2-LoLiP background in a straightforward way. In this case, the 2-LoLiP and 1-LoLiP probabilities are related by:

$$P_p(2\ DV) \approx \frac{1}{2} P_p(1\ DV)^2$$

This relation is found to be approximately correct for simulated background events. However, further study is needed in order to understand some deviation from this formula.
Data control regions will be used to test the background estimation procedure.

Material-Interaction

Rejecting vertices that occur in detector-material regions will greatly reduce the background that arises from particle interactions with the detector. We are creating a detector material map, by using photon conversions (e^+e^- pair production by interactions of photons with material), as shown in FIG. 5.

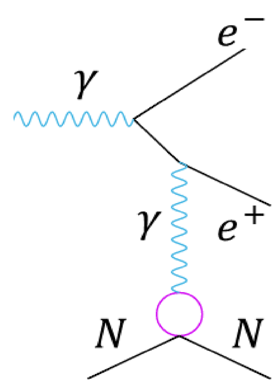


FIG. 5: Feynman diagram of e^+e^- production by photon conversion on a nucleus (N)

The xy distribution of photon-conversion vertices DVs is shown in FIG. 6 and will be used to construct the material map.

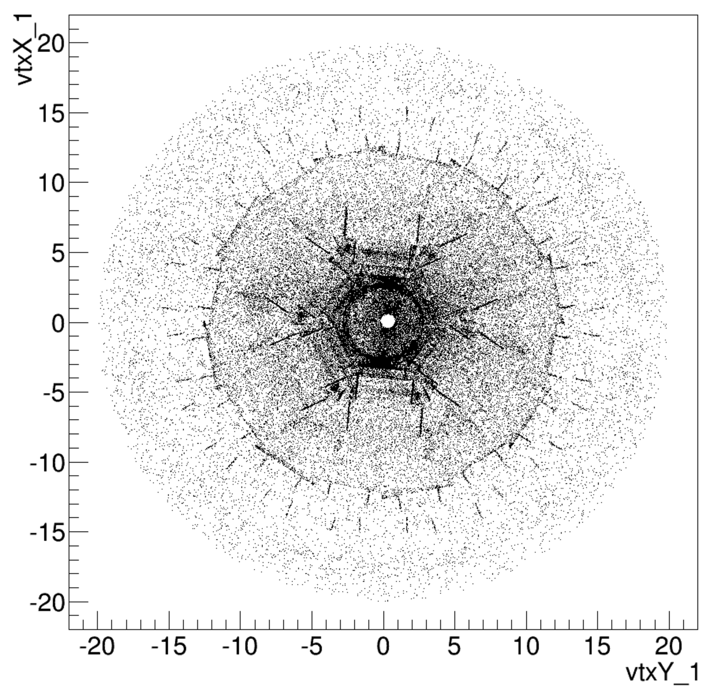


FIG. 6: The xy distribution of photon-conversion vertices maps the detector material

We will use the detector's structural symmetry to improve the statistical precision of the map.. The detector material regions will be excluded from the analysis and used as an additional control region to validate the background estimation.