

Detached vertex analysis from the 2016 dataset Analysis review update

A. Celentano, on behalf of the review
committee (C. Bravo, T. Cao)

Detached vertex analysis

Current review status:

- Whole 2016 dataset (L1L1 and L1L2) fully unblinded (July 2021st) after RC and EC green-light
- On-going discussion to finalize review and proceed to publication.

Today's talk:

- Show the analysis review status to the HPS collaboration
- **Get feedback concerning next steps:** which physics results should be included in the publication and thus should be scrutinized by the review committee?

We all want the results from the 2016 dataset to be published in the (very) near future.

Search for Long-Lived Dark Photons with the Heavy Photon Search Experiment at JLab

Matt Solt^{1,✉}, Pierfrancesco Butti¹, Mathew Graham¹, Tongtong Cao³

¹SLAC National Accelerator Laboratory, Menlo Park, CA 94205

²Stanford University, Stanford, CA 94305

³Thomas Jefferson National Laboratory, Newport News, VA 23606

Abstract

A heavy photon (also called a dark photon or A') is a hypothetical vector boson that arises from a massive $U(1)$ abelian gauge symmetry. Heavy photons kinetically mix with the Standard Model photon, thus they are a natural portal to hidden sectors that are favored in a variety of dark sector scenarios, particularly for dark matter at the sub-GeV mass scale. The Heavy Photon Search Experiment (HPS) is a fixed target experiment at Jefferson Laboratory dedicated to searching for heavy photons in the MeV - GeV mass range and kinetic mixing strength $\epsilon^2 \sim 10^{-5} - 10^{-10}$. It does so through two distinct searches - a search for a narrow mass resonance and, for sufficiently small couplings, a search for secondary vertices beyond a large prompt QED background.

In order to perform such searches, the HPS utilizes a compact, forward acceptance spectrometer that must be able to reconstruct particle masses and vertices with extreme precision. Heavy photons are electro-produced from a continuous electron beam incident on a thin tungsten foil, and HPS is able to reconstruct the momentum of the subsequent decays to e^+e^- pairs using a silicon vertex tracker (SVT). HPS currently has three data sets - engineering runs in 2015 and 2016 as well as a physics run with an upgraded detector in 2019 - all at different beam energies and currents. Presented in this analysis note are the results from the displaced vertex search from the HPS 2016 Engineering Run which was taken with a 2.3 GeV, 200 nA continuous electron beam and collected a total luminosity of 10753 nb^{-1} (equivalent to 5.4 days of continuous beam).

The 2016 Engineering Run displaced vertex search was performed in the mass range 60 - 150 MeV and in the range of $\epsilon^2 \sim 10^{-10} - 10^{-8}$, and the new results, which have a sensitivity to canonical A' production of ~ 0.4 events over a region of mass/coupling parameter space, exclude A' production above 7.88 times the canonical cross-section at a mass of 82.0 MeV and $\epsilon^2 = 1.68 \times 10^{-9}$. Even though HPS had insufficient data to set meaningful limits on the canonical A' production, this analysis demonstrated that the displaced vertex method is viable, backgrounds can be reduced to acceptable levels, and larger data sets can yield real exclusions or discovery. In fact, the background required to perform a displaced A' search (0.5 background events per mass search bin) was achieved in the unblinded 10% portion of the data set by implementing a new set of cuts. This significant background reduction stands as a considerable improvement over the previous analysis and approaches the sensitivity needed to observe the first A' candidates. After unblinding the entire data set, the remaining background events were studied and a search for decays which are further downstream and miss part of the acceptance of the tracker was performed.

[✉]Corresponding author. E-mail: mrsolt@slac.stanford.edu

Detached vertex analysis: (a very long) history

- **January 2020:** HPS EC approved the review committee for the 2016 analysis.
- **February 2020:** first RC meeting with AT. A first version of the analysis note was released to RC after this.
- **March 2020:** RC sent first round of comments to AT.
- **April 2020:** second RC meeting with AT, focused on L1L1 data unblinding.
 - Deadlines imposed by 2020 Jeopardy / Matt S. graduation.
- **May 2020:** RC sent second round of comments to AT.
- **June 2020:** third RC meeting with AT, focused on L1L1 data unblinding.
 - **June 11th:** approval for L1L1 unblinding communicated to EC.
- **June/July 2020:** L1L1 (preliminary) results shown during JLab users meeting and during PAC-48 (HPS Jeopardy review)

What is required for unblinding: **From the second RC round of comments sent to AT**

We understand that there is a compelling requirement for data unblinding to happen before the full analysis note is ready. In the following, we list the minimal requirements that have to be satisfied before the unblinding can take place. We underline that the final decision will be taken by the HPS EC.

1. The full set of cuts to be applied to L1L1 must be decided and frozen, and reviewed by the committee. This include in particular the decision on the vertex quality cut.
2. The study on the radiative cut and V0 projection to target cut mentioned in the previous section has to be completed.
3. The study on the impact parameter described in the next section has to be completed. It is critical the systematics of this particular cut are understood.

By doing so, the committee feels that an unbiased sample of L1L1 events, ready for the physics analysis, will be obtained.

PAC48 REPORT

Jefferson Lab

48th PROGRAM ADVISORY CO

Summary: The PAC recommends the approval of 135 PAC days of beam time for running with beam energies from ≈ 2 GeV to ≈ 4 GeV.

September 25, 2020

Detached vertex analysis: (a very long) history

- **April 2021:** updated analysis note, L1L2 section worked out.
 - A significant amount of time was required to re-align after almost one year...
- **May 2021:** RC meeting focused on L1L2 unblinding, comments sent to AT.
- **June 2021:** green-light for L1L2 unblinding.
- **June 2021:** updated version of the analysis note, including results from the full 2016 dataset
- **July 2021:** fifth round of RC comments sent to AT.
- **August 2021:** final version of the analysis note.
- *Sept/Oct/Nov 2021: the 2021 HPS run.*
- **November 2021:** latest re-cap AT-RC meeting.

Introduction:

From the fourth RC round of comments sent to AT

The review committee met on May 20th, 2021 to discuss the current status of the analysis, based on the analysis note draft sent to us by M. Graham on May 16th, 2021. The committee focused on Chapter 5.1, "Tight selection L1L2", in order to review the procedures used to select events within this category, looking ahead to give approval to the unblinding of the full dataset.

The general consensus of the committee is that the procedures adopted in this section are robust and the results generally well motivated, in particular considering that most of these reflect the analysis strategy for the L1L1 category, already fully scrutinized by the review committee.

We report in the following some comments and remarks. We anticipate that, if these will be positively solved, we are ready to provide our consensus for unblinding.

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Vertex RC Meeting, November 9 2021

Created by Mathew Graham, last modified on Nov 09, 2021

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- Details: <https://confluence.slac.stanford.edu/display/hpsg/DAWG+Meetings>

Intro slides

Pertinent Documents:

- MG's June 2021 unblind talk (June 25)
- RC Comments Post-unblinding/systematics (July 22)
- Matt Solt's responses to post-unblinding comments (Aug 8)
- Vertex Analysis Note (Aug 8)

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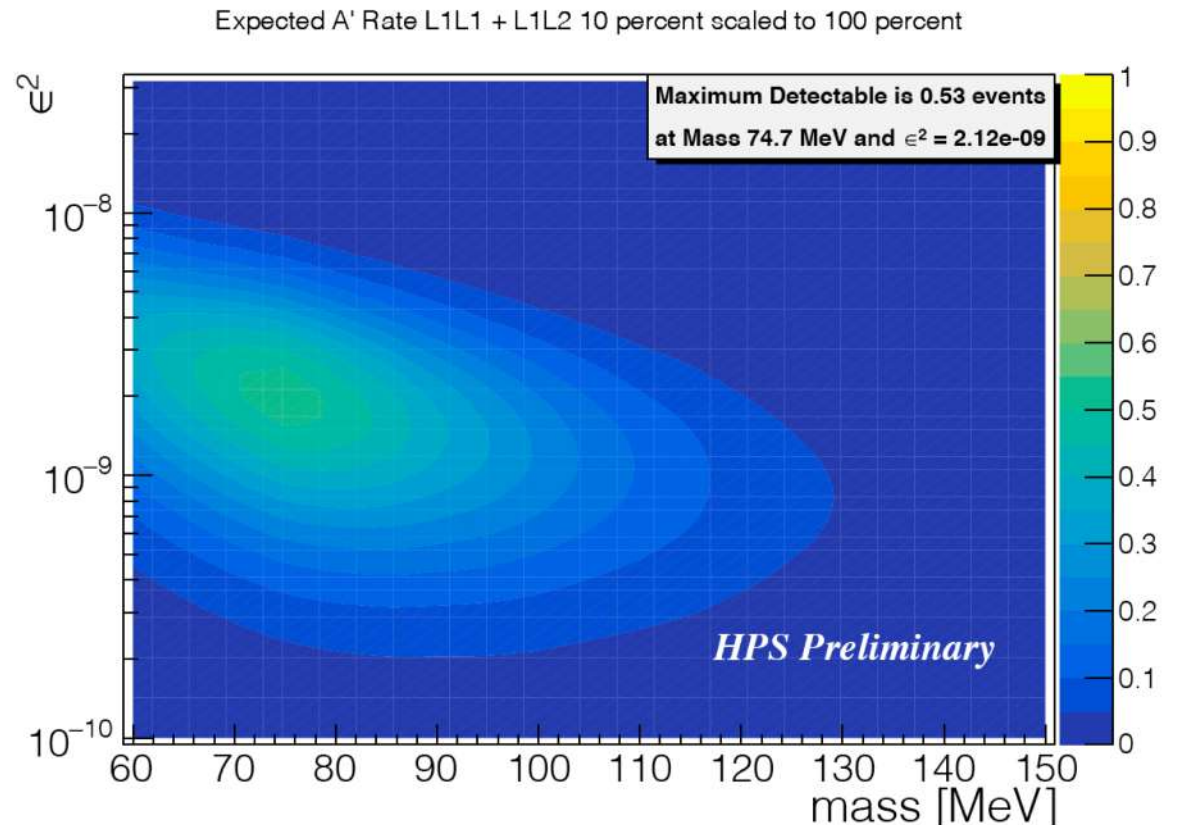
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Detached vertex analysis: where are we?

Well-established points:

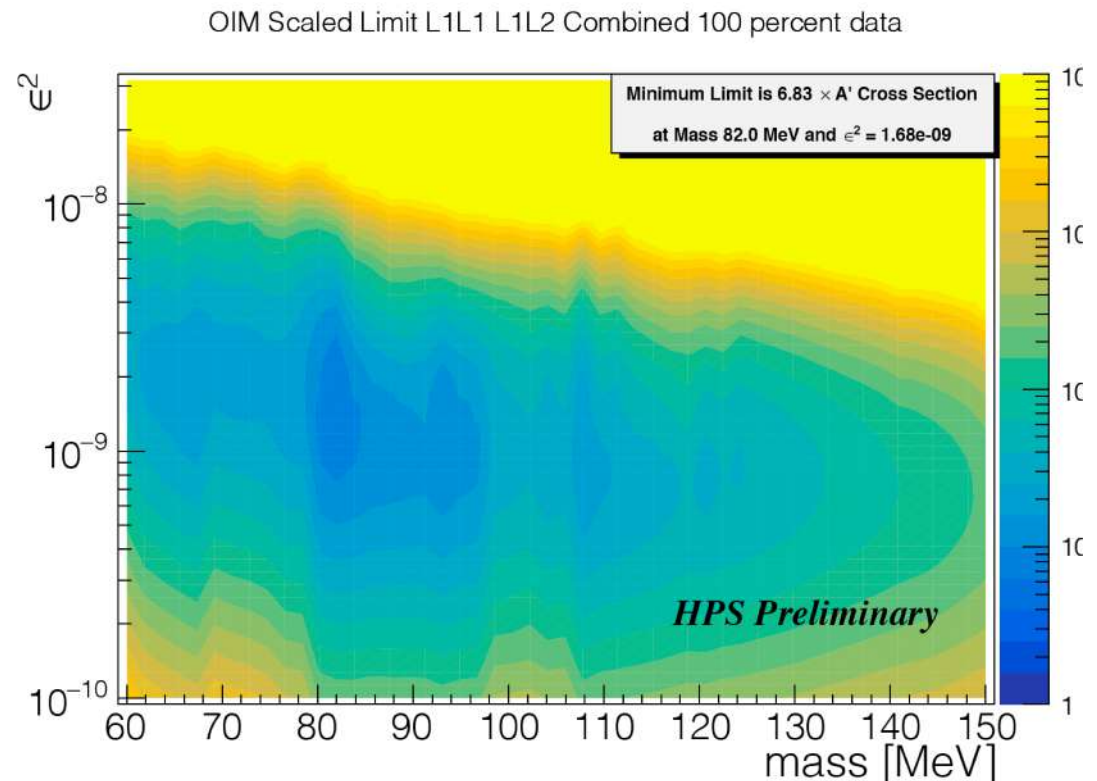
- Full 2016 dataset has been unblinded (L1L1/L1L2)
- Given the limited 2016 statistics, no exclusion limits to the dark photon “vanilla” model will be set.



Detached vertex analysis: where are we?

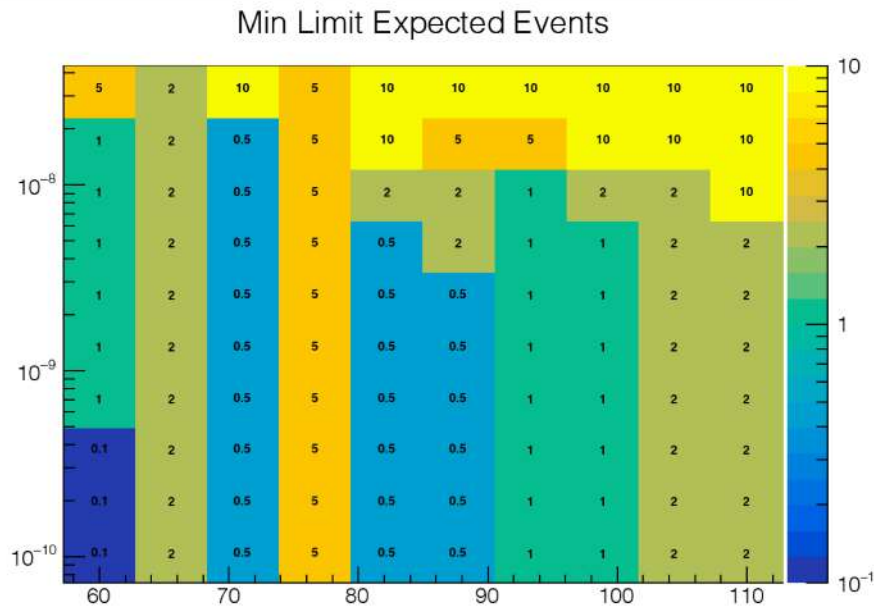
Well-established points:

- Full 2016 dataset has been unblinded (L1L1/L1L2)
- Given the limited 2016 statistics, no exclusion limits to the dark photon “vanilla” model will be set.
 - We can quantify the increase of statistics required to set any limit in the parameters space of this model.



Detached vertex analysis: which results do we want to publish?

z-cut systematics



We all agree (I hope!) that the results obtained from the 2016 run deserve to be shared with the HEP community.

- The result presented in the previous slide is clearly HPS-specific. In order to make it broader, i.e. let theorists to use it to test other models, we should complete it with a full phase-space map of the detector acceptance.
 - *This has not been included in the detached vertex analysis, and probably requires a significant amount of work. Do we need this?*
- The current “upper limit” can still be improved by fine-tuning some parts of the analysis (for example, the z-cut definition).
 - Should we aim for that, considering that still our result won’t be an exclusion limit?
 - Same question concerning the sophistication of the statistical procedure adopted to extract the upper limit.