Simulated Photo-nuclear Kaon Production for LDMX

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Light Dark Matter eXperiment (LDMX)

The Light Dark Matter Experiment, LDMX, is a proposed experiment for detecting sub-GeV dark matter. LDMX looks for dark matter produced in an electron fixed target setup through the recreation of primordial interactions between dark matter and Standard Model Particles.

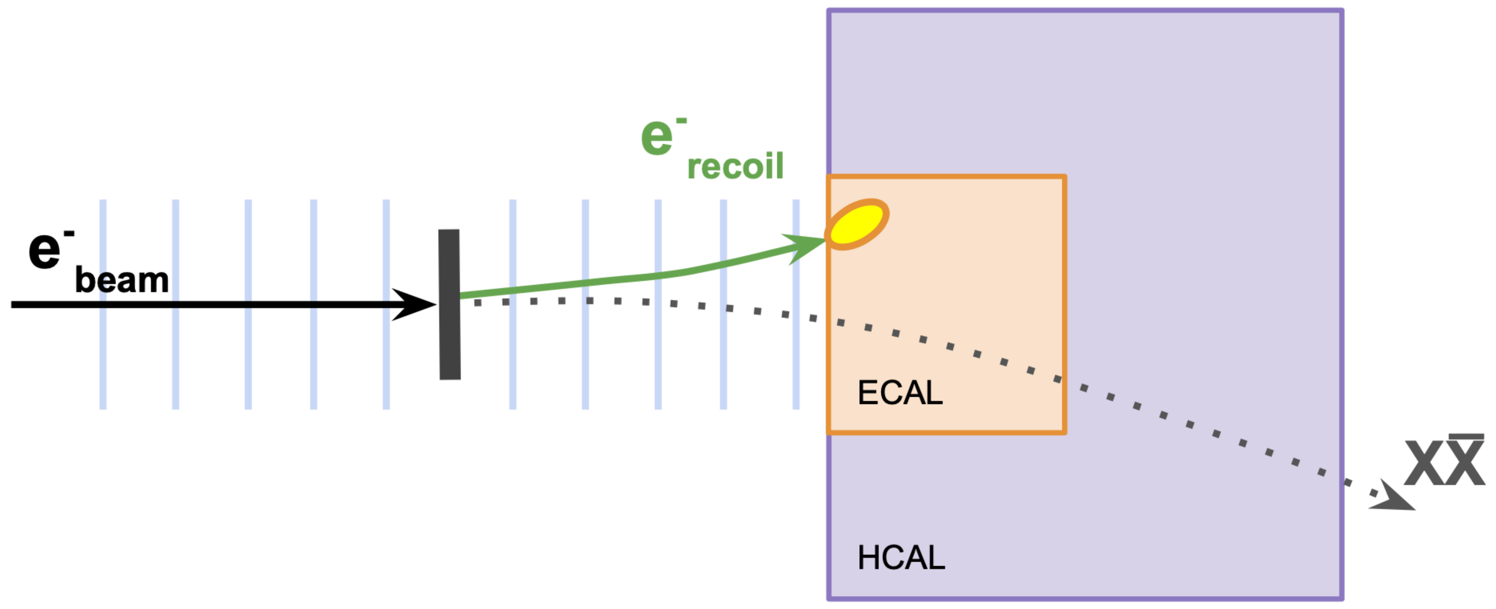

Fig. 1: Conceptual drawing of the LDMX experiment, showing the electron beam passing through a tagging tracker, a thin tungsten target, the recoil tracker, the electromagnetic calorimeter, and hadron calorimeter.

Goal: K-long background rate

Photo-nuclear events, originated when a Bremsstrahlung photon interacts with the target, can produce hadrons that, if undetected, mimic our dark matter signal. Neutral kaons (K-short) that decay into charged pions are reconstructible in the ECAL, but those that decay into neutrinos (K-long or K+) can go undetected. Understanding the yields and kinematics in K-short decay allows to understand the rate of the neutrino background.

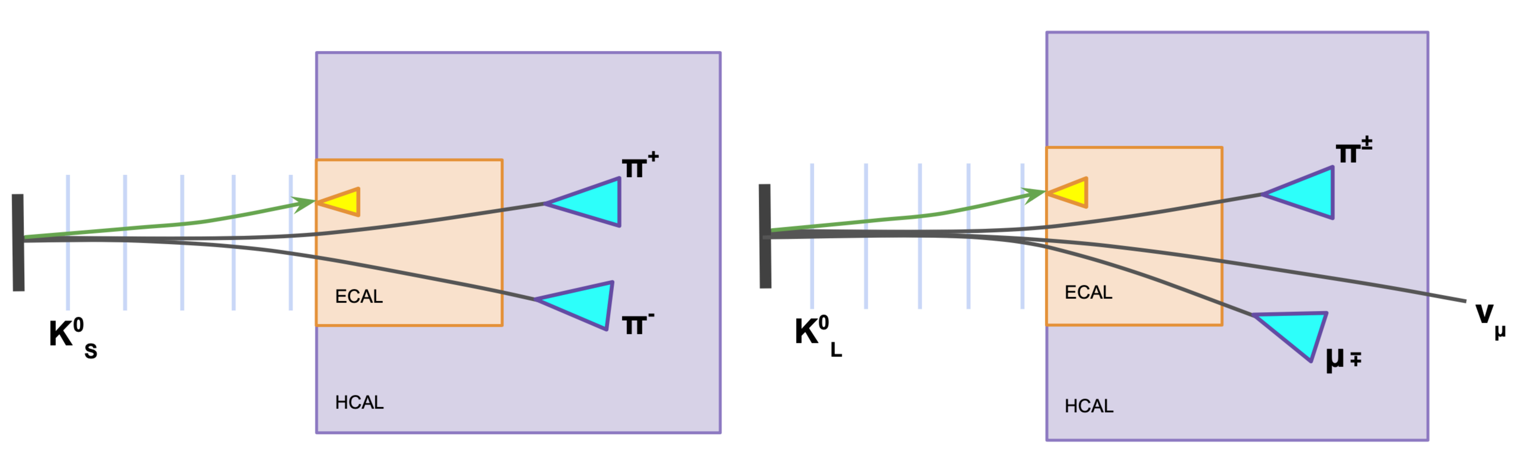

Fig. 2: Drawing of the LDMX experiment, showing the decay of K-short (left) and K-long(right) traveling from the target, through the tagging tracker, ECAL, HCAL, and where the products are detected in the ECAL and HCAL.

Simulated event generation

- Photo-nuclear events with 4 GeV incident electron
- Events have a Bremsstrahlung process in the target region with a photon energy > 2.5 GeV (*electron recoil < 1.5 GeV*)
- Arbitrary large bias factor (1e9) to artificially increase background rate
  - Biased Event Rate:
    - 1 Truth K_S per 48 Events Generated
  - Non Biased Event Rate:
    - 1 Truth K_S per 50,000 Events Generated
    - K_S rate with 1e16 EOT: **~3.4e6 K_S**

Reconstructing K-short

We only consider particles with an angle less than 40 degrees from the beam line. This mask was applied to all daughters from the Kaon decay. We reconstruct the Kaon mass by looking at the daughters from simulation. We smear the momentum in the x, y, and z dimensions with the expected track resolution. We can reconstruct the mass with 20 GeV resolution.

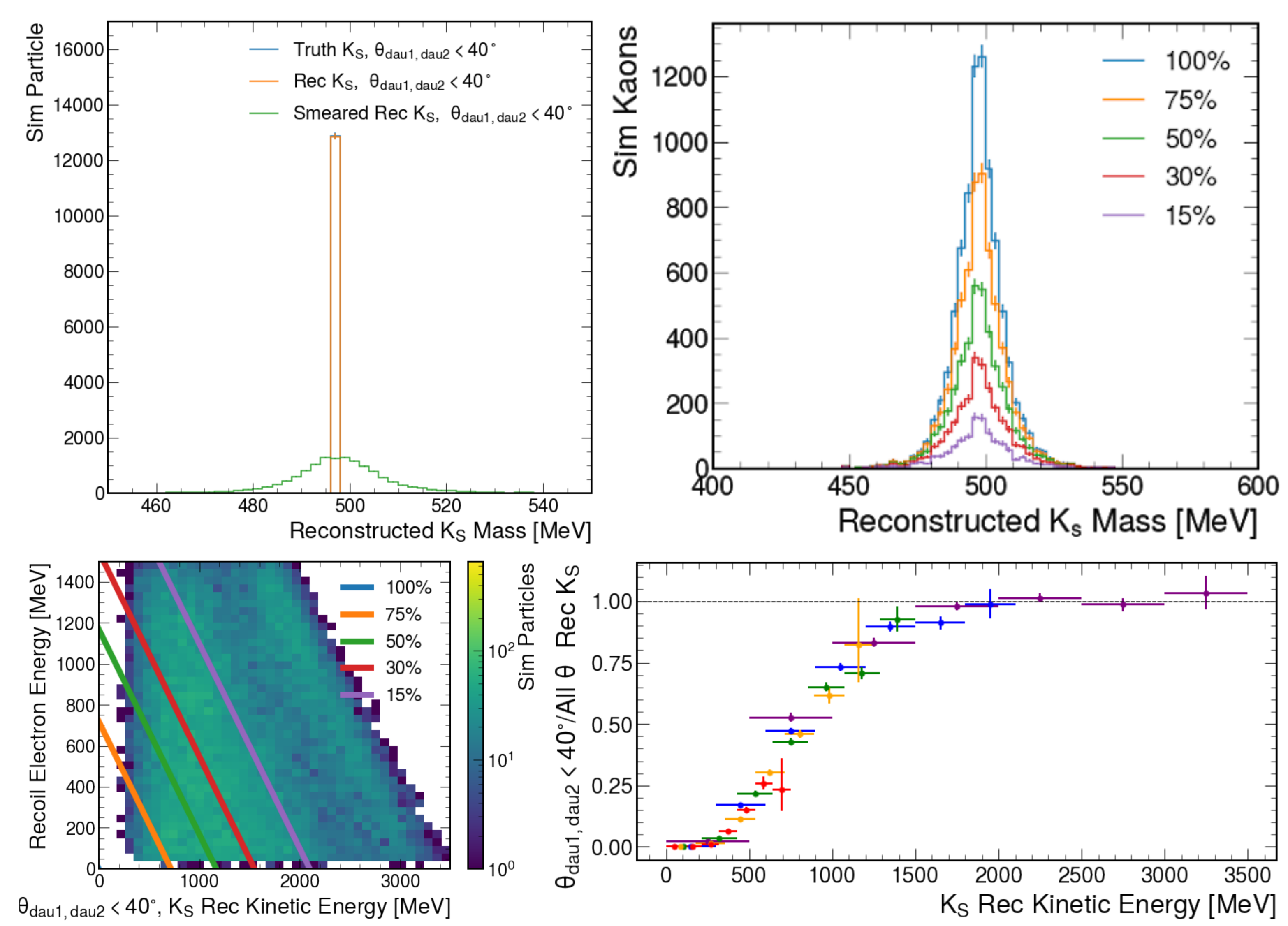

Fig. 3: (Top Left) Reconstructed K-short mass compared to truth values of the Kaon mass. (Top Right) Reconstructed K-short mass by percentile included from the most energetic.(Bottom Left) Kinetic energy of reconstructed Kaons vs. recoil electron and their percentile sectioning. (Bottom Right) ratio of all reconstructed K-short to reconstructed with theta cut, separated by energy percentile.

Truth K_L/K_S Ratio

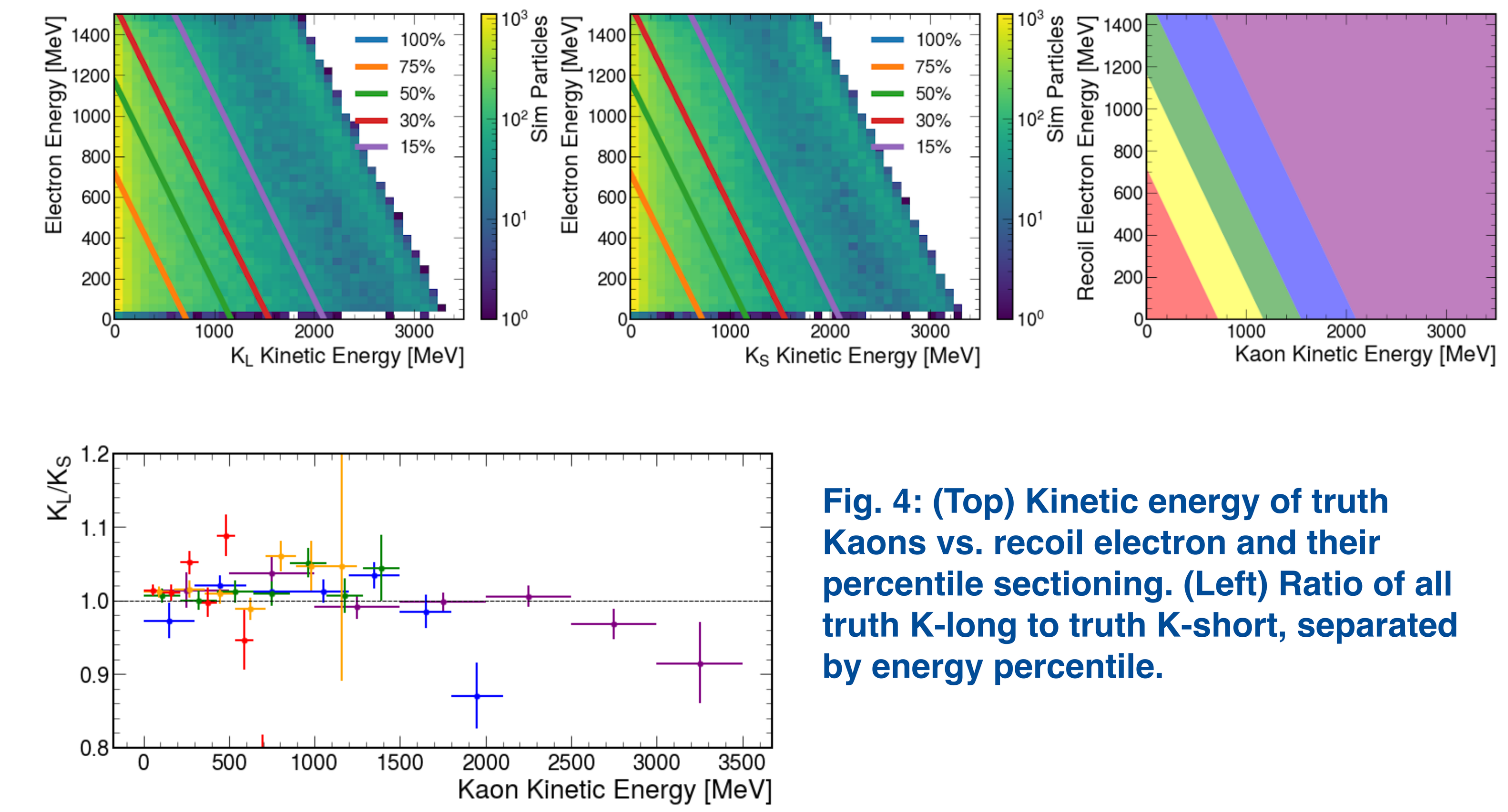

Fig. 4: (Top) Kinetic energy of truth Kaons vs. recoil electron and their percentile sectioning. (Left) Ratio of all truth K-long to truth K-short, separated by energy percentile.

In multiple types of events and different energy levels, the ratio of truth K-long to K-short remains around one. This is hopeful in that K-short can be used to account for the semi-visible decays of K-long.

Reconstructing K-long from K-short

The branching ratio acceptance and these ratios can reconstruct K-long by the following:

$$KL = \frac{KL}{K_S} * \frac{K_S(\pi^+\pi^- : measured)}{BR_{\pi^+\pi^-}}$$

These studies determined visible PN decays of K-short can successfully reconstruct the semi-visible PN decays of K-long.

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