Simulation of Axion-like Particle Production at DarkQuest

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DarkQuest

DarkQuest is a collaboration at Fermilab searching for beyond-standard model particles using a fixed target beam dump. The detector features a iron target and a 120 GeV proton beam. Planned updates will expand the sensitivity to dark sector particles, such as an axion-like particle (ALP).

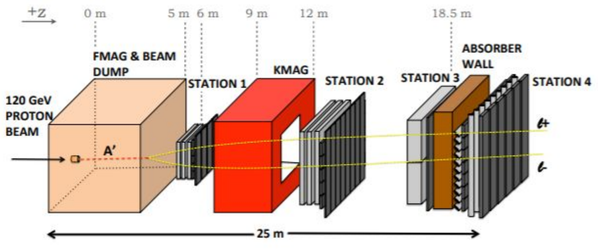

Figure 1: Current Layout of DarkQuest[1]

Axion-like Particles

- Theoretical elementary particle in beyond-Standard Model (SM) physics
- Massive
- Spinless
- Related to symmetry breaking at high energies
- Weak Coupling to SM particles
  - photons, gluons, electrons, etc.

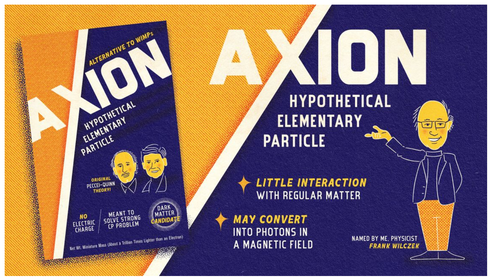

Figure 2: Axion Illustration [2]

Motivation

DarkQuest presents a unique opportunity to use an existing detector to explore untested parameter space for an axion-like particle in the search for beyond the standard model physics. By simulating the production of an ALP and evaluating DarkQuest's sensitivity to it, we can determine the region of parameter space in which DarkQuest could make a discovery.

ALP Production

Using Monte Carlo integration methods, I simulated the scattering and production of an ALP using ...

- Direct-Photo Production
  - $pN \rightarrow p\pi^0 N,\ \pi^0 \rightarrow \gamma\gamma,\ \gamma N \rightarrow aN$
- Proton Bremsstrahlung
  - $pN \rightarrow paN$

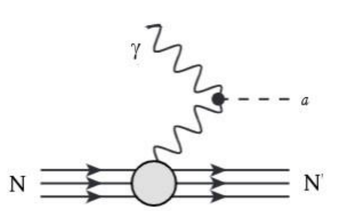

Figure 3: Feynman Diagram of Direct-Photo Production

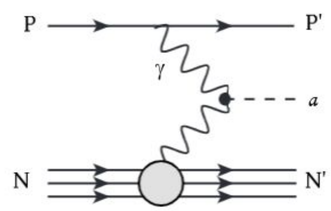

Figure 4: Feynman Diagram of Proton Bremsstrahlung

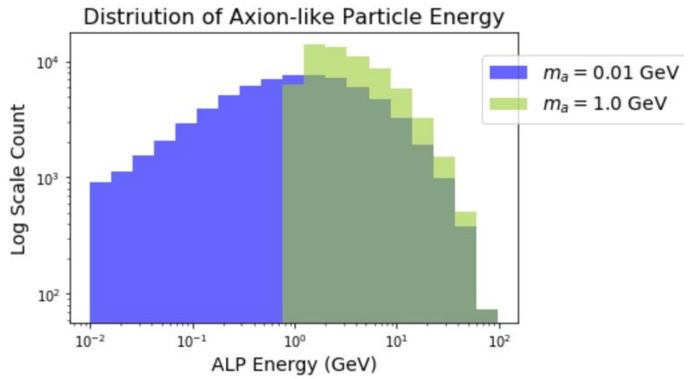

Figure 5: Number of Events as a function of ALP mass

Sensitivity

ALP are long lived particles: they travel a macroscopic distance before decaying into two photons. DarkQuest's sensitivity can then be constructed based on the number of ALP's that decay within the decay region of the detector and into photons that have enough energy to activate a 'trigger'.

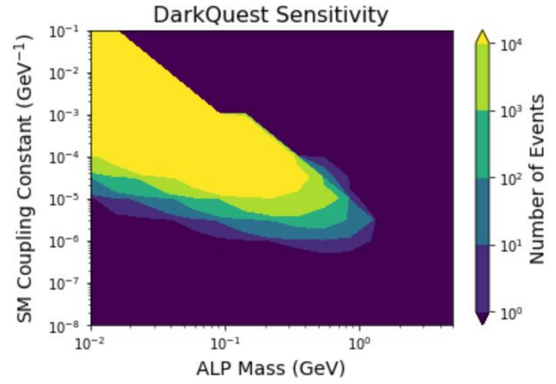

Figure 6: Sensitivity Plot

Next Steps

- Conclude the analysis of DarkQuest's sensitivity to an axion-like particle coupled to photons
- Study DarkQuest's sensitivity to other ALP couplings
- Use simulations to conduct detailed detector studies

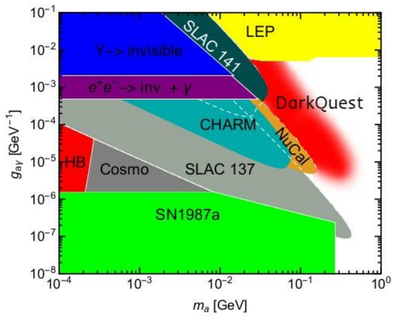

Figure 7: Current constraints on ALP parameter space [2]

Acknowledgements

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[1] A. Berlin, S. Gori, P. Schuster and N. Toro, Dark Sectors at the Fermilab SeaQuest Experiment, Phys. Rev. D 98 (2018) 035011, [1804.00661]. [2] Illustration by Sandbox Studio, Chicago with Steve Shanabruch, found on Symmetry, article title The Other Dark Matter Candidate [3] B. D˙obrich, J. Jaeckel, F. Kahlhoefer, A. Ringwald and K. Schmidt-Hoberg, ALPtraum: ALP production in proton beam dump experiments, JHEP 02 (2016) 018, [1512.03069].

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