Exploring the DAMSA Experiment: Simulating The Case of a Portable Experiment

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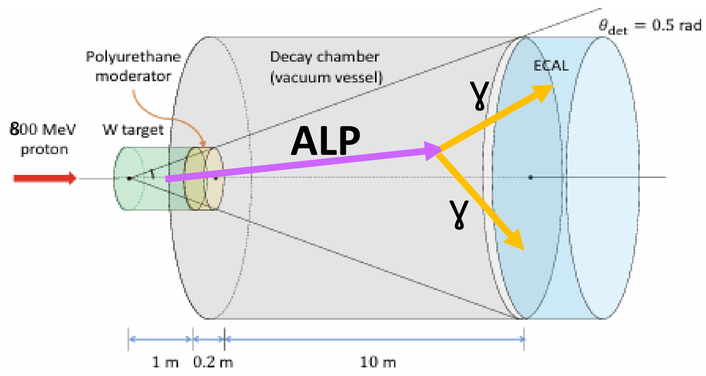
Introduction

- DAMSA is a novel experimental approach aimed at detecting dark-sector particles, such as axion-like particles (ALPs) and dark photons in low mass regime.
- Simulated the case of a Portable DAMSA.

What's DAMSA(潭思)?

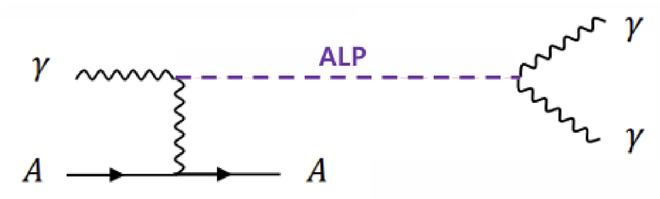
- **DA**rk **M**essenger **S**earches at an **A**ccelerator
- Aimed to detect low mass ALPs and dark photons.
- Utilizes high-flux proton beams(800MeV) from PIP-II proton accelerator at Fermilab, with the detector strategically positioned immediately downstream of the proton beam dump.

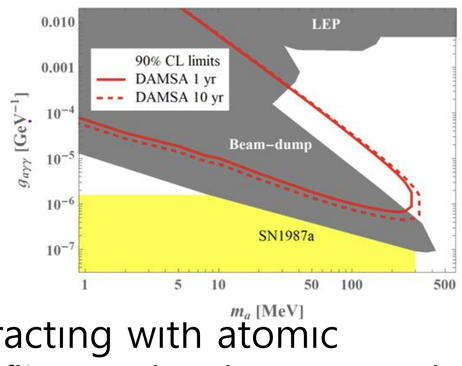


Early DAMSA layout cand

- 1m tungsten target
- 0.2m neutron moderator
- 10m decay chamber (covered by steel frame)
- Detector (ECAL)

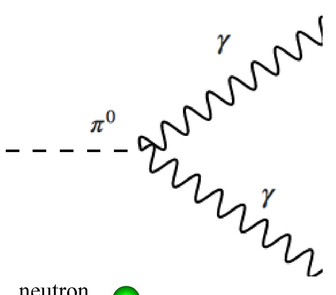
DAMSA's Signal : Primakoff process





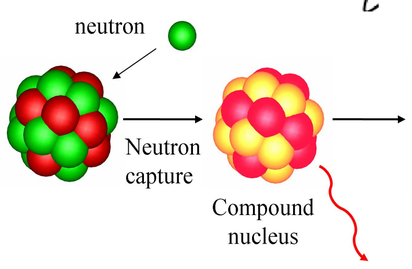
- ALPs can be produced by photons interacting with atomic system(target). Once produced, an ALP flies to the detector and can decay into two photons inside the decay chamber.

Possible Backgrounds



Neutral pion decay

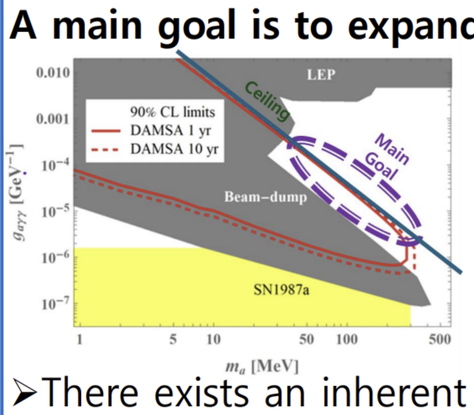
- As neutral pion cannot escape target, photon pair hardly reach detector.
- Reject photon pairs reconstructed outside decay chamber.



Neutron induced photon

- Apply arrival time difference cut to photon pairs.
- Require vertex resolution to be cm order.
- Apply neutron moderator.

A main goal is to expand DAMSA into the "prompt-decay" region.



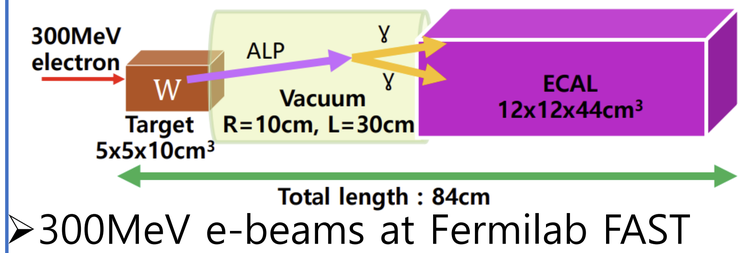
- ALPs decay promptly with relatively large coupling.
  - ✓ Long decay volume is unessential.
  - ✓ Two photons : mostly small angle.

arXiv:2401.09529

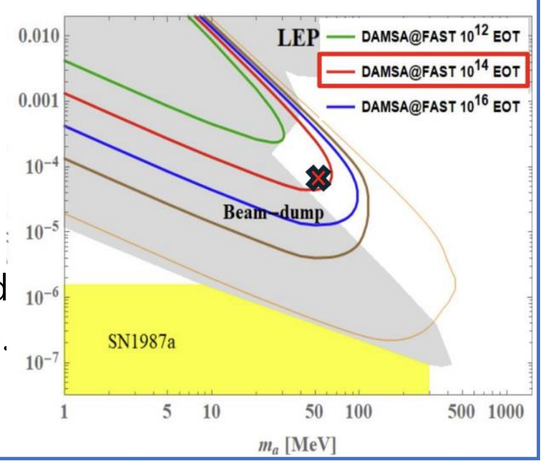
- There exists an inherent limitation dubbed beam-dump "ceiling" beyond which the sensitivity improvement slows down dramatically.
  - ✓ Depends on the beam energy and the detector distance from the target.
  - ✓ Large amount of data is not necessary to reach this region.

Portable DAMSA can probe the prompt-decay region quickly.

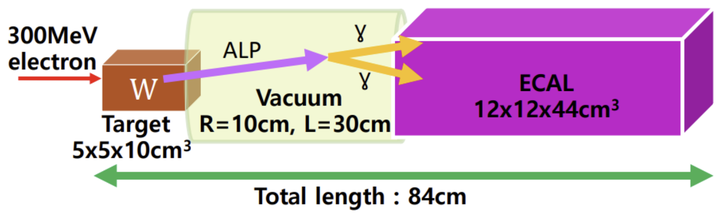
Portable DAMSA Experiment



- 300MeV e-beams at Fermilab FAST
  - ✓ Much reduced pion/neutron background
- Decay length should be at least 10cm.
  - ✓ For 50MeV ALP, $g_{arr} \sim 8 \times 10^{-5}\ GeV^{-1}$
  - ✓ Appropriate for prompt-decay region.

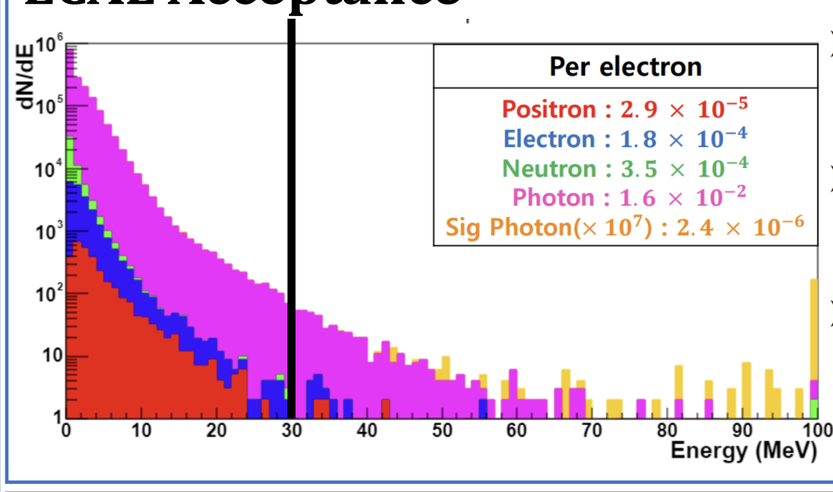


Portable DAMSA Geant4 Setup



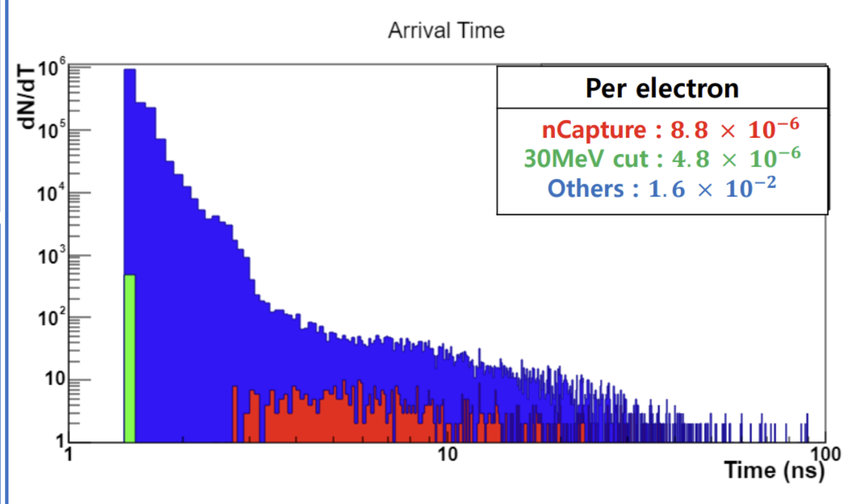
- Studies of signal and backgrounds
  - ✓ Beam : 10^8 electron beam per bunch.
- Produced 50MeV ALP signals with $g_{arr} = 10^{-4}\ GeV^{-1}$
  - ✓ Used Geant4 DMG4 toolkit for Signal production. (arXiv:2401.12573)
  - ✓ Only photons with energies greater than 100MeV can produce ALPs.
  - ✓ Mean decay length = 8.65cm (~target length)

ECAL Acceptance



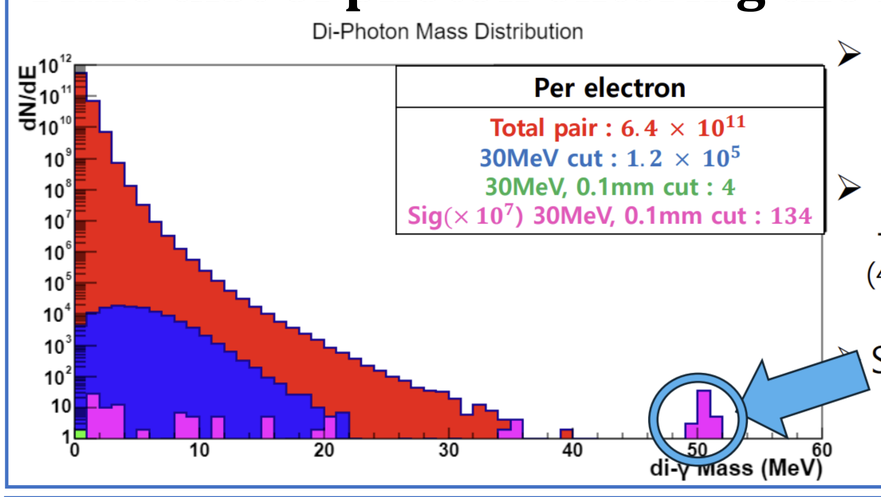
- Major particles are e+, e-, n, γ.
- For particles > 30MeV, all photons.
- Need to consider ways to reduce backgrounds : timing and vertex of two photons.

Time dist of photons entering the ECAL



- High-E(> 30 MeV) photons are within 0.1ns time diff.
- Two photons from the same ALP are most likely to be within 0.1ns time diff.
- Photons from neutrons may cause pileup from other bunches.

Time dist of photon entering the ECAL



- Di-photons with all possible combinations.
- With > 30MeV + 0.1mm vertex cut. ($4\ pairs\ from\ 10^8\ electrons$)
- Sig Photon pairs.

Discussion & Conclusion

- DAMSA is a novel experimental approach which utilizes high-flux beams and is aimed to detect ALPs and dark photons in low mass regime.
- DAMSA's main goal, prompt-decay region can be reached by Portable DAMSA.
- With good timing and vertex resolution, we plan to maximize our search sensitivity.

References

- DAMSA proposal - Phys. Rev. D **107**, L031901
- PIP-II beam dump experiment - arXiv:2311.09915 [hep-ex]
- Beam-dump ceiling effect - arXiv:2401.09529

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