Light Dark Matter eXperiment

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A Thermal Relic

Plentiful evidence for dark matter!

- Assuming DM has thermal origin
  - Constrains viable mass window
  - Sets minimum annihilation cross section
Looking for Light Dark Matter

Amazing direct detection work has been done to explore WIMP phase space!

- LDM regime largely unexplored, well motivated
  - However, SM forces cannot give observed matter density
    - New, light forces must be present
    - Vector mediator (dark photon) a simple, but predictive model
Significant velocity dependence for direct detection cross section leaves some targets out of reach.

Relativistic nature of accelerators wipes out velocity dependence.

Thermal targets are within reach!
LDM Accelerator Searches

To maximize LDM yield, mediator production must be maximized!

Largest cross section for production realized via dark bremsstrahlung

\[ \sigma \propto \frac{Z^2 \epsilon^2}{m_{A'}^2} \]

Can also be off-shell
LDMX is an electron fixed-target, missing momentum experiment

With $10^{16}$ electrons on target, LDMX can probe thermal targets over the MeV-GeV range
Dark Bremsstrahlung

With massive mediator kinematics quite different from SM bremsstrahlung

Signal

Single, low energy deposition
Wide angle recoil
DM
No other activity in calorimeters
Missing $p$ and $E$ carried away by DM

Recoil Energy Distribution

Recoil $p_T$ Distribution
Backgrounds

Irreducible neutrino backgrounds < $10^{-16}$
Tracking System

- **Tagging Tracker**
  - **Objective:** Verify incoming electron has beam energy and **veto** otherwise

- **Recoil Tracker**
  - **Objective:** Identify low-momentum, recoiling electrons

**18D36 Dipole Field**

- **Field Strength (kGauss)**
- **Z (cm)**

- reconstructed 4 GeV beam $e^-$
- $\mu = 3.994 \pm 0.00005$
- $\sigma = 0.048 \pm 0.00008$

- worst-case beam background
- off-trajectory 1.2 GeV sample (actually can't originate from beampipe)

**Designed with experience from HPS**
Electromagnetic Calorimeter

- **Objective:** Make high-speed energy measurements with excellent resolution and radiation hardness

Hardware based on CMS forward calorimeter upgrade
 Trigger

- Primary physics trigger
  - Total energy deposition in the first 20 layers of the ECal
  - **Trigger on low energy!**
  - Reduce beam particle rate from 46 MHz to 4 kHz
Hadronic Calorimeter

- **Objective:** Assist ECal in vetoing photonuclear

Takes advantage of CMS Phase I upgrade
Physics Potential

LDMX Phase I:
$10^{14}$ EOT @ 4 GeV

LDMX Phase II:
$10^{16}$ EOT @ 8 GeV

0.1 – 0.3 $X_0$ Target

Sensitivity extends down to lower masses
**Summary**

- Accelerator-based experiments uniquely sensitive to sub-GeV range
  - Missing momentum technique has the best sensitivity
- **LDMX** has broad sensitivity over sub-GeV mass range

**Other physics potential**
- Displaced vertex from visibly decaying mediators
- Displaced electron-positron showers that result from DM co-annihilation models
- Dark Vectors decaying to neutrinos
- Photonuclear and electronuclear measurements for neutrino scattering
Dealing with Photons

- **Photonuclear events**
  - Currently able to reject on the order of a few \(10^{13}\) EOT
  - Investigating overproduction of exotic final state kinematics in Geant4

- **Extremely hard, backwards going hadrons**
  - Overproduced by perhaps orders of magnitude!

- **Muon conversion**
  - Can be treated similarly to photonuclear
  - Currently can veto all but a few in \(10^{13}\) EOT
  - Looking at Geant4 form factor implementation