A PROBE FOR DARK SECTOR MEDIATORS WITH A PROTON BEAM

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DarkQuest is a unique proposal to upgrade existing detectors (SpinQuest @ FNAL) and greatly extend the mass reach of the search for visible-decaying dark sectors.

I will talk about the expected sensitivity, upgrade plans and ongoing simulation studies.
Big opportunity to probe dark sectors in MeV-GeV regime with high-intensity accelerators and fixed-target experiments
A proton beam will yield *higher effective luminosities* than a lepton beam and DarkQuest’s (existing) short baseline (5 m) makes it *unique for LLP searches* (*z*$_{\text{displaced}}$: 5 -10m)

For $\chi$ prod.: $m_{\text{med}} > 2m_\chi$
Proton Bremsstrahlung is enhanced by $\alpha_s/\alpha_{EM}$

Large production of light mesons

$E_{\text{beam}} = 120 \text{ GeV}, 1.44 \times 10^{18} \text{ POT}, \epsilon = 10^{-6}$

Berlin, Gori, et. al. (2018)
120 GeV proton beam: max. intensity of $1 \times 10^{13}$ protons/ 4s. spill and beam spot $\sim 6$-7 mm

RF frequency: 53 MHz

Expected luminosity: $1 \times 10^{18}$ Protons on Target (POT) in 2023-2025 and $1 \times 10^{20}$ (>2025)
A' TO DI-LEPTONS REACH FROM PHENO STUDIES

Berlin, Gori, et. al. (2018)
and N. Blinov
Heavy Neutral Leptons

- e.g. $B^\pm/D_s^\pm \to \ell^\pm N$
- with $N \to \ell^\pm \pi^\mp$

Dark Scalars

- e.g. $B \to KS, K \to \pi S$
- with $S \to \ell^+\ell^-$

Axion-like particles

- e.g. $\gamma Z \to aZ$
- with $a \to \gamma \gamma$

Fermionic Inelastic Dark Matter

- e.g. $A' \to \chi_1\chi_2$
- and $A' \to \chi_1 e^+e^-$
EXISTING SPECTROMETER COMPONENTS

- **Absorber** $(15\lambda_I)$ and **dump** $(30\lambda_I)$
- **Drift chambers** for tracking
- **Target**
- **Focusing magnet** $(1.9T)$: $\Delta p_T \sim 2.9$ GeV
- **Tracking magnet** $(0.4T)$: $\Delta p_T \sim 0.4$ GeV

High-momentum signal focused near beam line

2017 Random data
$m_{A'} = 30$ GeV
$m_{A'} = 470$ GeV
EMCAL UPGRADE TASKS

2 existing EMCAL sectors @ BNL: 1296 readout ch./sector

Ongoing and future tasks:
- Update from PMT to SiPMs (ADC+TDC)
- Design SiPM readout (e.g. from EMPHATIC experiment)
- Integrate with current DAQ
EMCAL energy resolution

- Fit result: 0.9% $\oplus \frac{7.1\%}{\sqrt{E}}$
- Previous test beam results: 2.1% $\oplus \frac{8.1\%}{\sqrt{E}}$

Geometric acceptance ($\sim$ pheno-predictions)

- POT = $1.44 \times 10^{18}$, $\epsilon = 10^{-5}$
- $E_{\text{dep}} > 10\% E_e$
- $z_{\text{decay}} : 5 - 6 m$
COLLABORATION

- Growing team of experimentalist and theorists (~ 1 year old)

- Establishing strong connections with SpinQuest collaboration

- LongQuest proposes new far detector and further upgrades (PID, new dump and fast tracking) see Tsai et. al. (2021) - ongoing studies for Snowmass!

- We welcome new collaborators! Contact us: cmantill@fnal.gov, ntran@fnal.gov

Experimentalists:
BU: Zeynep Demiragli, David Sperka, Amitav Mitra
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Theorists:
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SUMMARY

➤ DarkQuest offers a low cost (~500k) opportunity to expand the mass reach for light dark sector mediators

➤ Plans for EMCAL upgrade that adds electron/photon channel

➤ Ongoing simulation studies: integration of EMCAL, displaced tracking, signal and background yields

➤ Planned Timeline: SpinQuest will run (Fall 2021-2022): parasitic run w. dimuons, and DarkQuest aims for Fall 2023-2025