

Searching for dark forces with

# DARKLIGHT

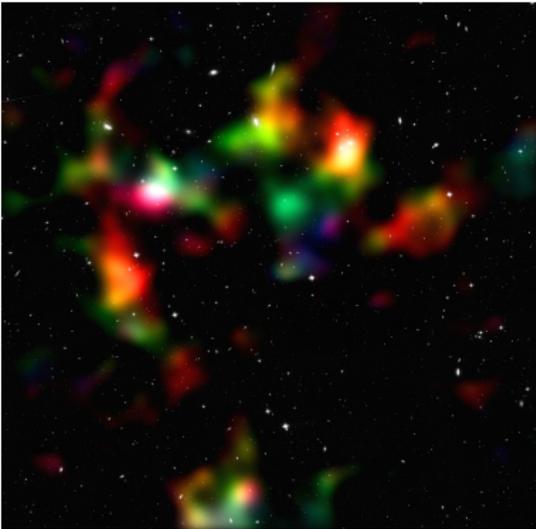
at the Jefferson Laboratory  
Free Electron Laser

Rebecca Russell, MIT

July 25, 2011

19th Particles & Nuclei International Conference

# What are dark forces?



COSMOS dark matter distribution

NASA, ESA, P. Simon and T. Schrabback

The universe appears to be filled with cold dark matter, which could be a relic particle that interacts only through

- **Weak force**
- **Gravitation**
- **... forces beyond the Standard Model?**

# Dark matter annihilation

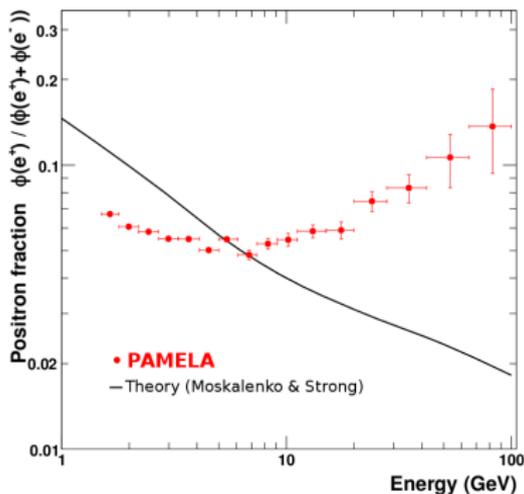
Indirect detection of dark matter:

## Annihilation products in cosmic radiation?

**WMAP haze:** Excess microwave emission around galactic center

Synchrotron radiation from relativistic electrons and positrons?

**PAMELA/HEAT/AMS-01/ATIC/Fermi/HESS:** Cosmic positron excess



High positron fraction in 10-100 GeV range

PAMELA Collaboration, Nature 458 (2009) 607-609.

# A possible explanation

- Positron excess orders of magnitude larger than what is allowed by thermal relic abundance – even including SUSY neutralino
- Large cross section into leptons but low cross section into hadrons – PAMELA antiproton results and measurements of galactic gamma rays

**New force in the dark sector can simultaneously explain all of these anomalies**

- Sommerfeld enhancement of low-mass interaction increases annihilation cross section at low velocities

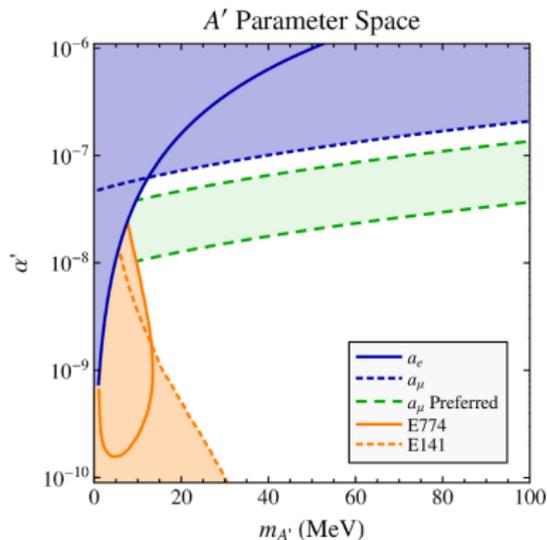
**Suggests a sub-GeV scale boson  
'heavy photon'  $A'$**

# Experimental bounds on $A'$

## Low-mass, high-coupling region of parameter space

- Beam dump axion searches in the 1980s at Fermilab and SLAC
- $A'$  contribution to the anomalous magnetic moments of leptons ...

$a_\mu$  currently disagrees with the SM by 3.4 standard deviations!



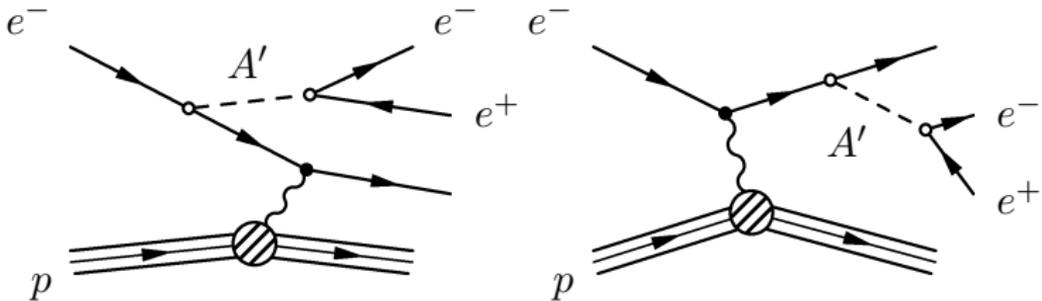
# DarkLight

- The DarkLight experiment will search in this very interesting low-mass region of parameter space – including the vast majority of the region preferred by the current value of  $a_\mu$
- Fixed target experiment, with 100 MeV electrons incident on a hydrogen target – interactions below pion threshold

**DarkLight will look for direct  $A'$  production and decay into an electron-positron pair in electron-proton scattering**

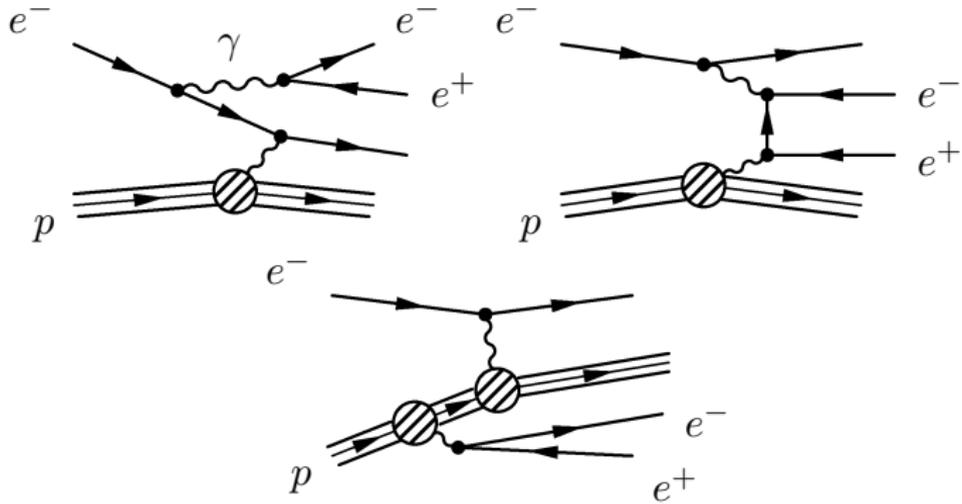
# $A'$ production

Dark forces in  $e^- p \rightarrow e^- p e^+ e^-$  scattering



- Select only events with an extra electron positron pair
- Invariant mass gives the mass of the dark force boson – straightforward way to search for the  $A'$

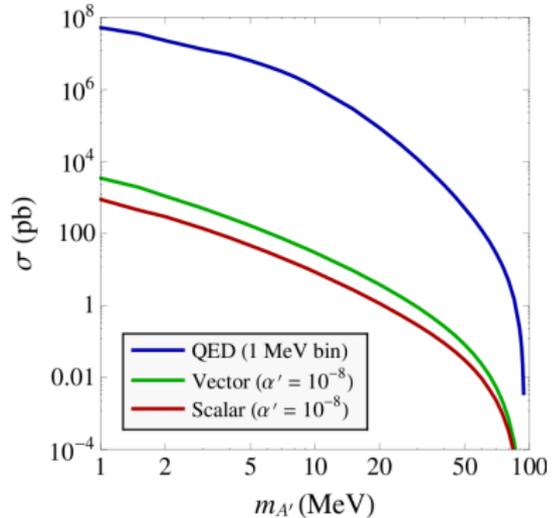
# Irreducible background



**All of these QED processes are indistinguishable from  $A'$  production and decay!**

# Irreducible background

- At this low energy energy, QED background events are more than 4 orders of magnitude more common
- **Signal appears as narrow resonance on huge, smooth QED background**



→ **Huge luminosity required**

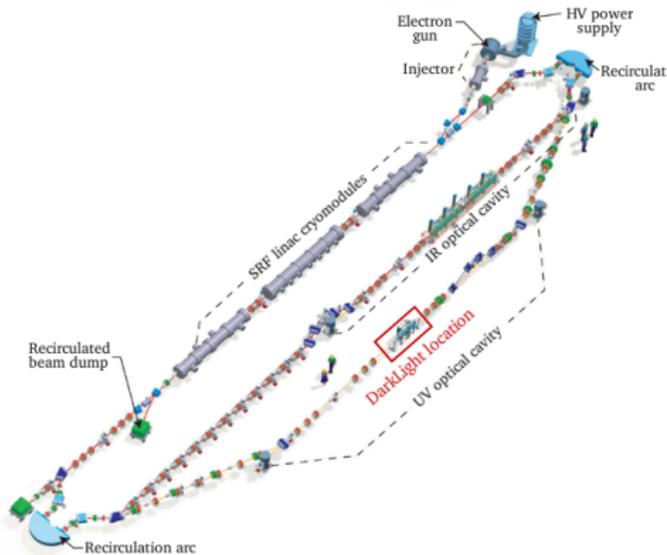
# The JLab FEL



- The Jefferson Lab free electron laser (FEL) is the only currently-operating FEL using a continuous wave superconducting energy recovering linac
- The FEL linac provides a unique **high-intensity electron source**

# The FEL and DarkLight

- The DarkLight apparatus could replace the UV undulator in the current FEL setup
- FEL would be run at a low energy of 100 MeV, low charge of 10-20 pC per bunch, and high repetition rate of 750 MHz  
→ **10 mA beam current**



# Experimental design

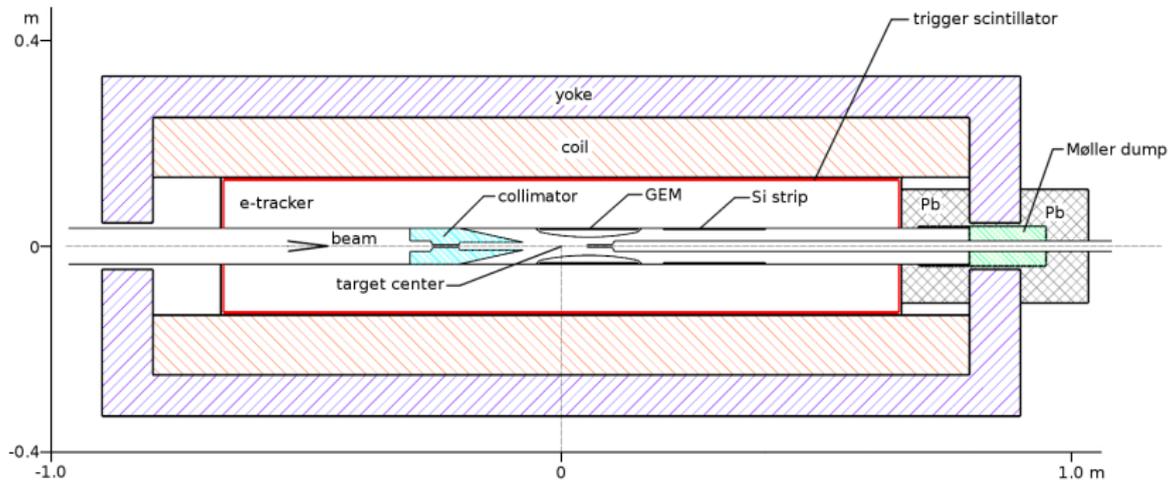
## Basic DarkLight design:

### A compact solenoidal detector surrounding a windowless hydrogen gas target

- Differential vacuum pumping system (50 Torr-liter/s of hydrogen gas) for target with  $10^{19}$  atoms/cm<sup>2</sup>
- 1 Tesla longitudinal magnetic field to contain Møller scattered electrons and provide 1 MeV energy resolution
- Detection of 10-100 MeV electrons/positrons and 1-5 MeV recoil protons

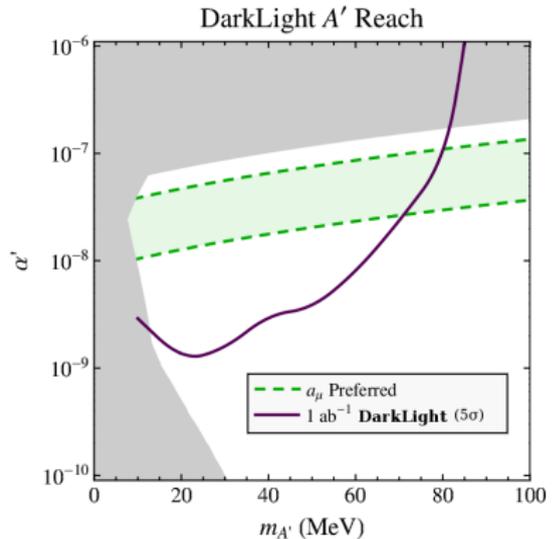
### Full 4-particle event reconstruction

# Experimental design



# Reach

- 1 month of running provides  $1 \text{ ab}^{-1}$  integrated luminosity
- Covers most of the  $a_\mu$  preferred region
- **Complementary to other planned experiments**



# Timeline

- Letter of Intent submitted in January 2010
- Proposal submitted to Jefferson Lab in November 2010 and considered by PAC 37: **DarkLight approved conditional upon completion of design**
- Design in progress – anticipate completion early in 2012
- Program of tests with FEL beam being prepared right now