Dark Matter Experiments Using an ERL[1]

Stephen Benson

On behalf of the Collaborations: LIPSS, DarkLight

ERL2011, Oct. 16-20, 2011

Tsukuba, Japan

Abstract

ERLs may be used to discover most of the missing mass of the universe. I will describe two experiments using an ERL to attempt to detect weakly interacting bosons that might make up over 70% of the universe's mass.

[1]Notice: Authored by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177. The U.S. Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce this manuscript for U.S. Government purposes. This work supported by the Office of Naval Research Award N00014-06-1-1168, the Joint Technology Office, the Commonwealth of Virginia, the Air Force Research Laboratory, and by DOE under contract DE-AC05-060R23177.

felman@jlab.org

Collaborations

- **LIPSS & LIPSS 2** – **LI**ght **P**seudoscalar and **S**calar **S**earch
- Spokespersons: O. K. Baker (Yale) & A. Afanasev (GWU)
- **DarkLight** – **D**etecting **A** **R**esonance **K**inematically with e**L**ectrons **I**ncident on **G**aseous **H**ydrogen **T**arget.
- Spokespersons: P. Fisher (MIT) and R. Milner (MIT)

LIPSS Collaboration

[Ref. 2]

A. Afanasev (Co-Spokesperson). R. Ramdon

George Washington University,

(Formerly at Hampton University)

G. Biallas, J.R. Boyce, T. Robinson, M. Shinn

Jefferson Lab

K. Beard

Muons, Inc.

M. Minarni

Universitas Riau

(Formerly at Yale)

O.K. Baker (Spokesperson), P. Slocum

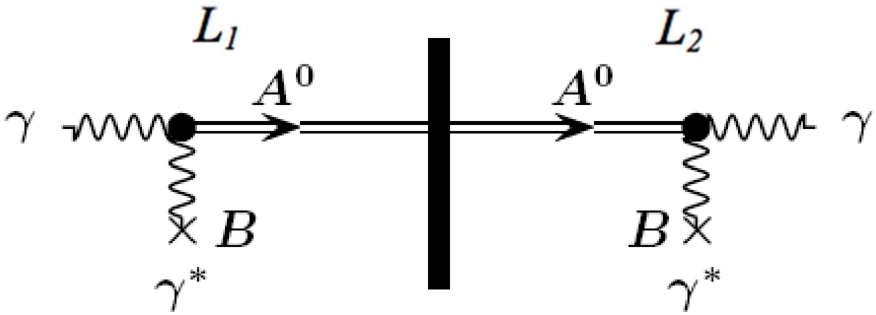
Yale University

Jefferson Lab

LIPSS Technique: light shining through a wall

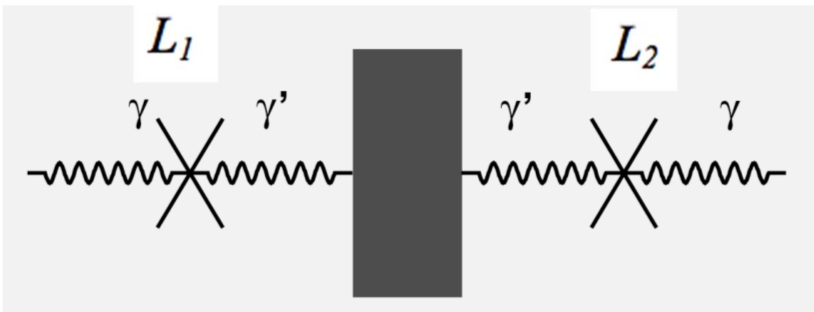
can suppress background by over 20 orders of magnitude ! ! !

kW lasers, ultra low noise detectors, . . .



- couple polarized laser light with magnetic field
- Sikivie (1983); Ansel'm (1985); Van Bibber et al (1987): [Ref: 3-5]

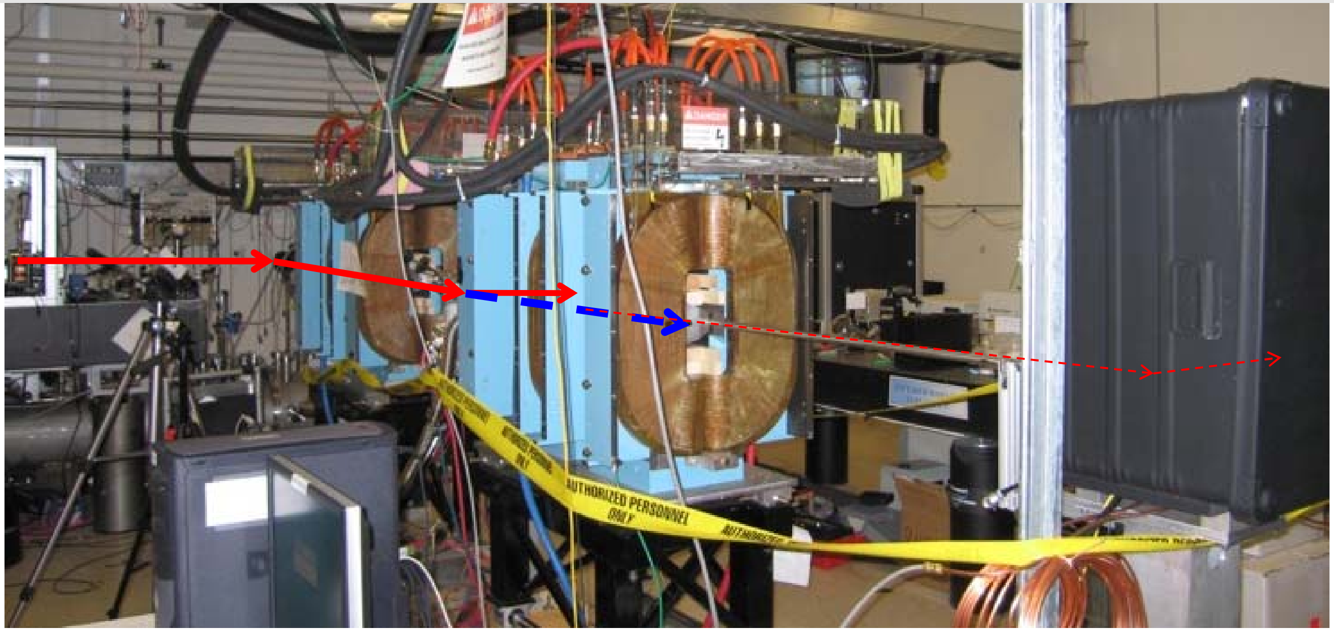
$$P_{\gamma\to\mathrm{LNB}} = P_{\mathrm{LNB}\to\gamma} = \frac{(gB)^2}{\frac{m^4}{4\omega^2}} \sin^2\left(\frac{m^2 L}{4\omega}\right) \approx \frac{1}{4}(gBL)^2 \text{ , for } L_1 = L_2 = L$$

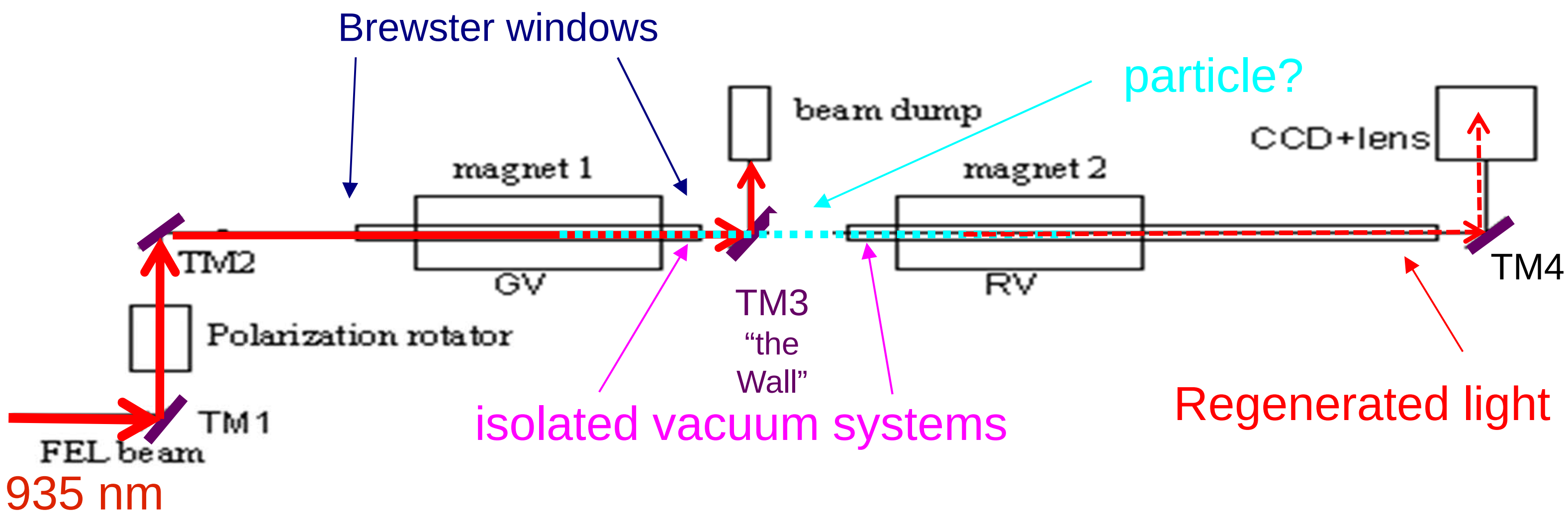


- kinetic mixing
- no magnetic field
- Afanasev et al (2009) [Ref. 6]

$$P_{trans} = 16\chi^4\left[\sin\left(\frac{\Delta k L_1}{2}\right)\sin\left(\frac{\Delta k L_2}{2}\right)\right]^2 \qquad \Delta k = \omega - \sqrt{\omega^2 - m_{\gamma'}^{\ 2}}$$

LIPSS "Light Shining through a Wall" (LSW) technique

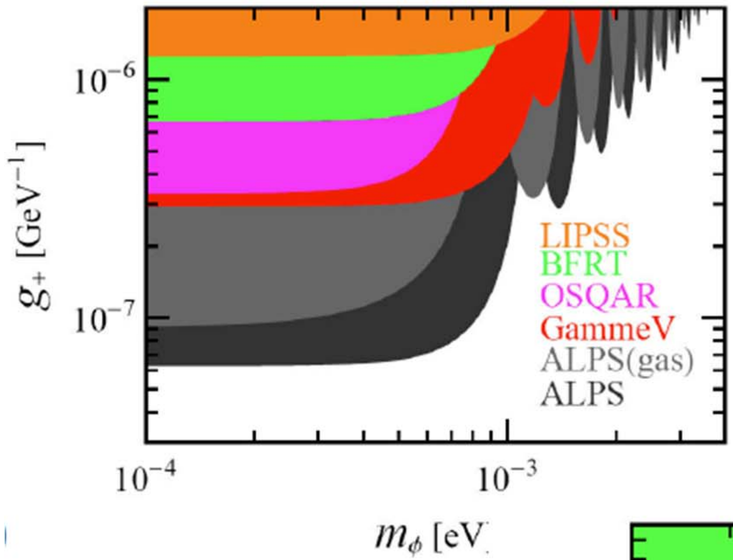




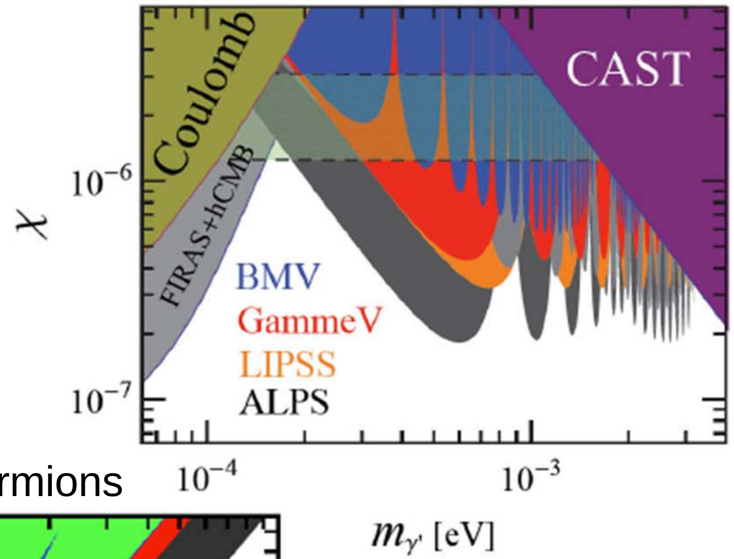
[Ref. 7]

LIPSS Results

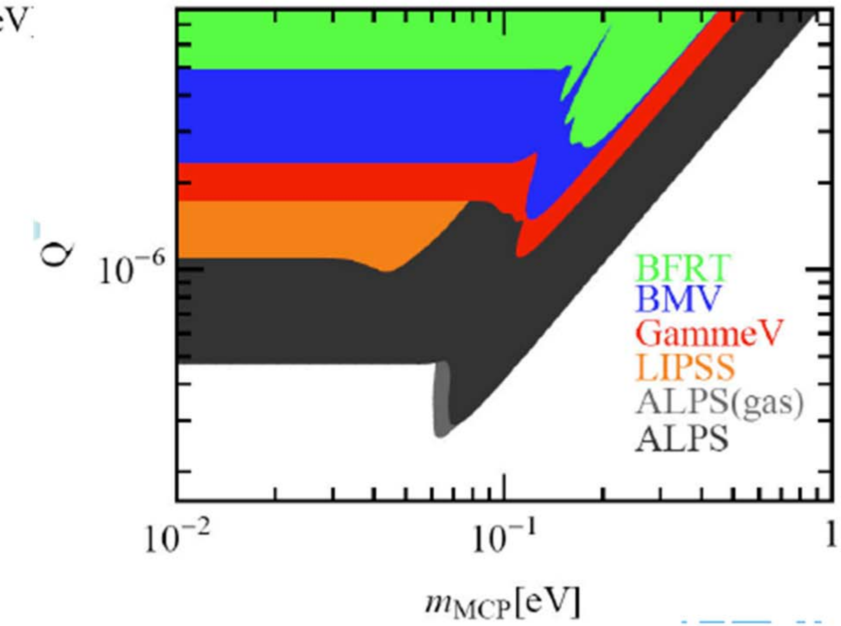
Scalars



Paraphotons

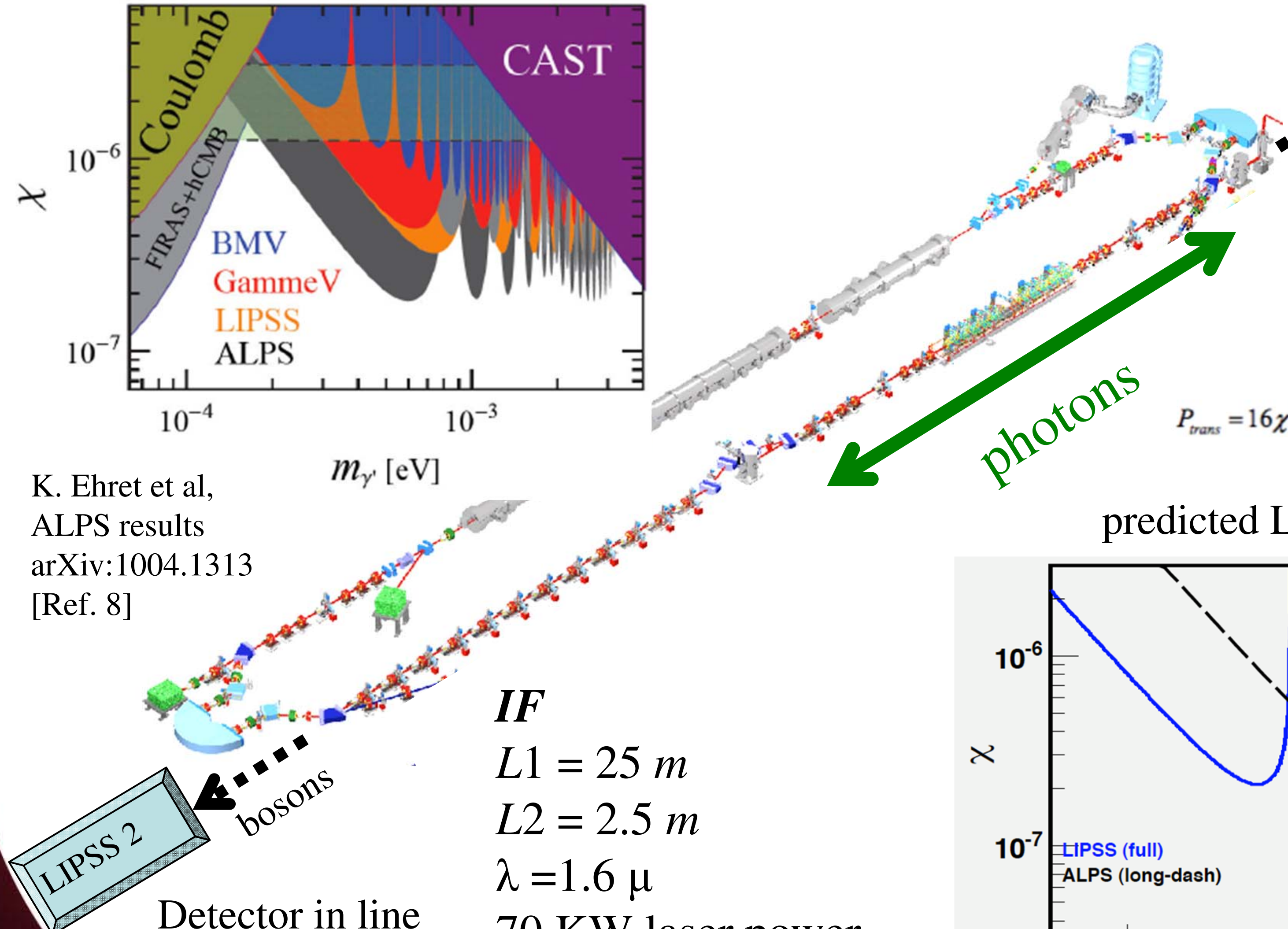


Millicharged fermions



K. Ehret et al, ALPS results
arXiv:1004.1313 [Ref. 8]

LIPSS-2 Photon-boson kinetic mixing: next steps



K. Ehret et al, ALPS results arXiv:1004.1313 [Ref. 8]

$$P_{trans} = 16\chi^4\left[\sin\left(\frac{\Delta k L_1}{2}\right)\sin\left(\frac{\Delta k L_2}{2}\right)\right]^2$$

Detector in line with cavity

IF

$L1 = 25\ m$

$L2 = 2.5\ m$

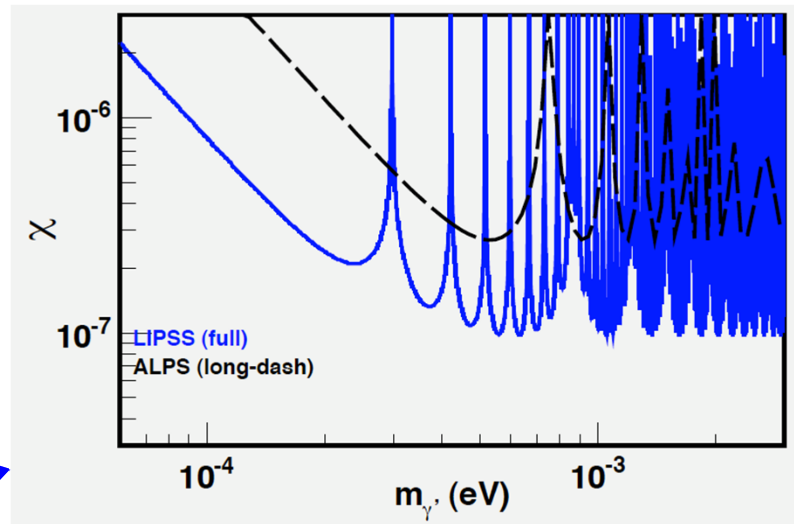
$\lambda = 1.6\ \mu$

70 KW laser power

$t \sim 10$ days

THEN

predicted LIPSS results



[Ref. 9]

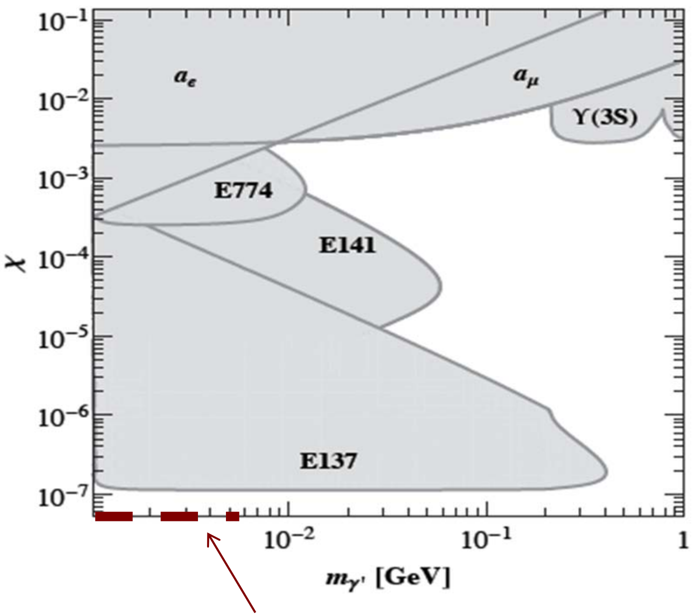
Jefferson Lab

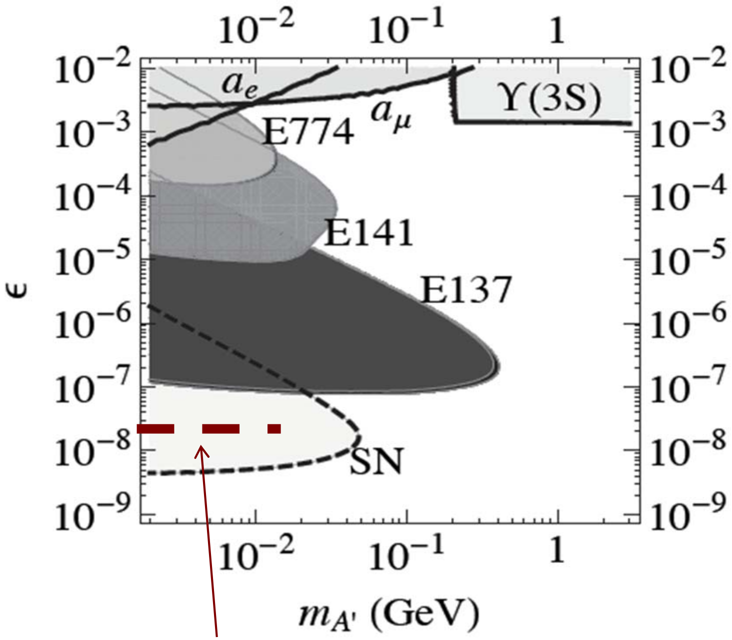
LIPSS – 2: Beam dumps and bosons

Preliminary discussion underway for one month running:

- Electron beam dump at the FEL (luminosity ~ 1 ab^{-1}/min)
- Electron beam dump at CEBAF (luminosity ~ 1 ab^{-1}/hour)

JD Bjorken et al, PhysRev D80, 075018 (2009); [Ref. 10]
Freytsis, Ovanesyan, Thaler ; arXiv:0909.2862; [Ref. 11]





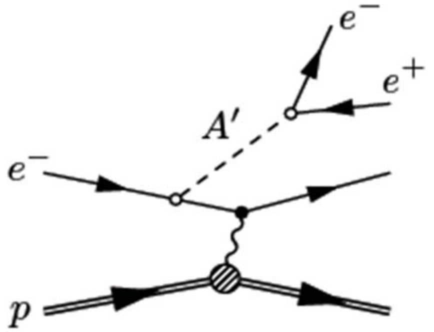
χ : CEBAF LIPSS ~2 x E137

ε : FEL LIPSS 3 x E137

DARKLIGHT

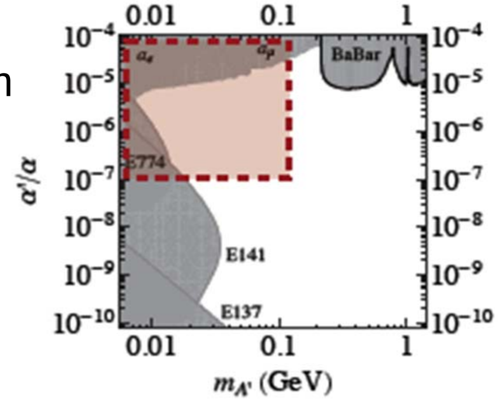
Detecting **A** **R**esonance **K**inematically with e**L**ectrons **I**ncident on a **G**aseous **H**ydrogen **T**arget

A Search for new light bosons using the Jefferson Lab FEL facility.



High Intensity, Low Energy Electron Beam
Using JLab's FEL on
Diffuse Hydrogen Gas Target

==> Luminosity: 1 ab^{-1}/month



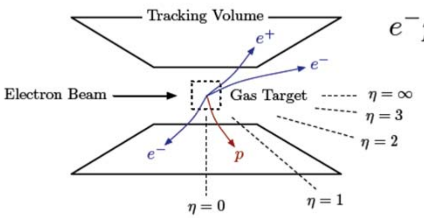
DarkLight Collaboration

Arizona State Ricardo Alarcon
Berkeley Marat Freytsis
JLab Steve Benson, Jim Boyce, David Douglas, Rolf Ent, Kevin Jordan, George Neil, Michelle Shinn
Maryland Ralph Fiorito, Patrick O'Shea
MIT Purnima Balakrishnan, Bill Bertozzi, Ray Cowan, Shalev Gilad, Peter Fisher*, James Hays-Wehle, Yoni Kahn, Aidan Kelleher, Richard Milner*, Becky Russell, Jesse Thaler, Sinh Thong, Christoph Tschalär
LANL Grigory Ovanesyan
*(Co-Spokespersons)

"Dark Force Detection in Low Energy e-p Collisions"
[Freytsis, Ovanesyan, JDT: arXiv:0909.2862 (JHEP 1001;111)]
[Ref. 11]

DARKLIGHT

Electron-Proton Collisions

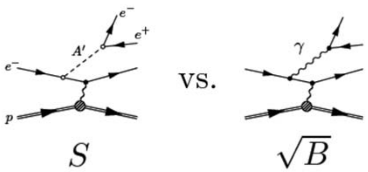


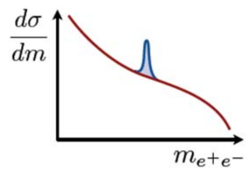
$$e^- p \to e^- p + A'$$
$$\hookrightarrow e^+ e^-$$

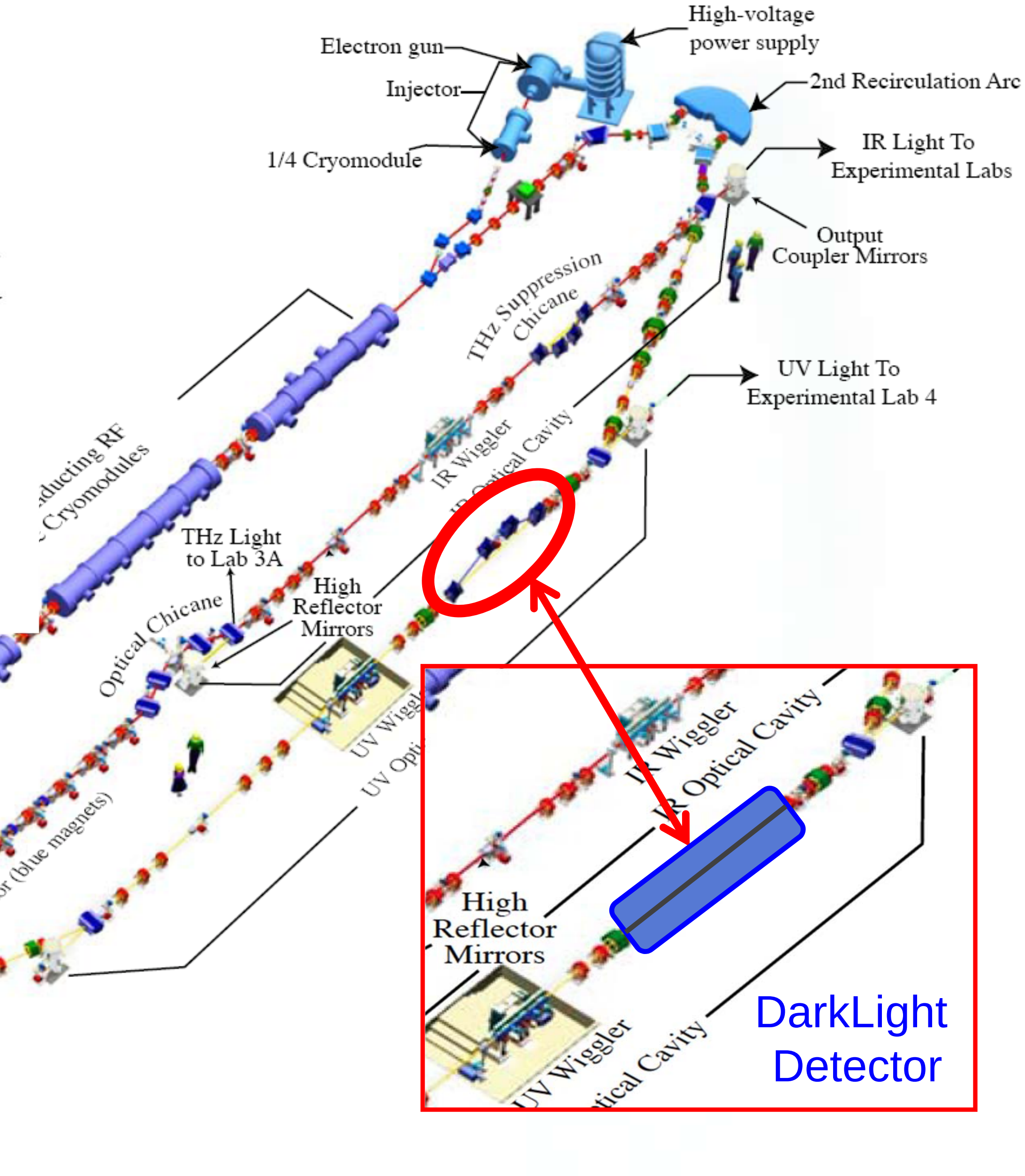
$E_{\text{beam}} \lesssim 140$ MeV

$\text{ab}^{-1}/\text{month}$

Narrow Resonance on Huge QED Background



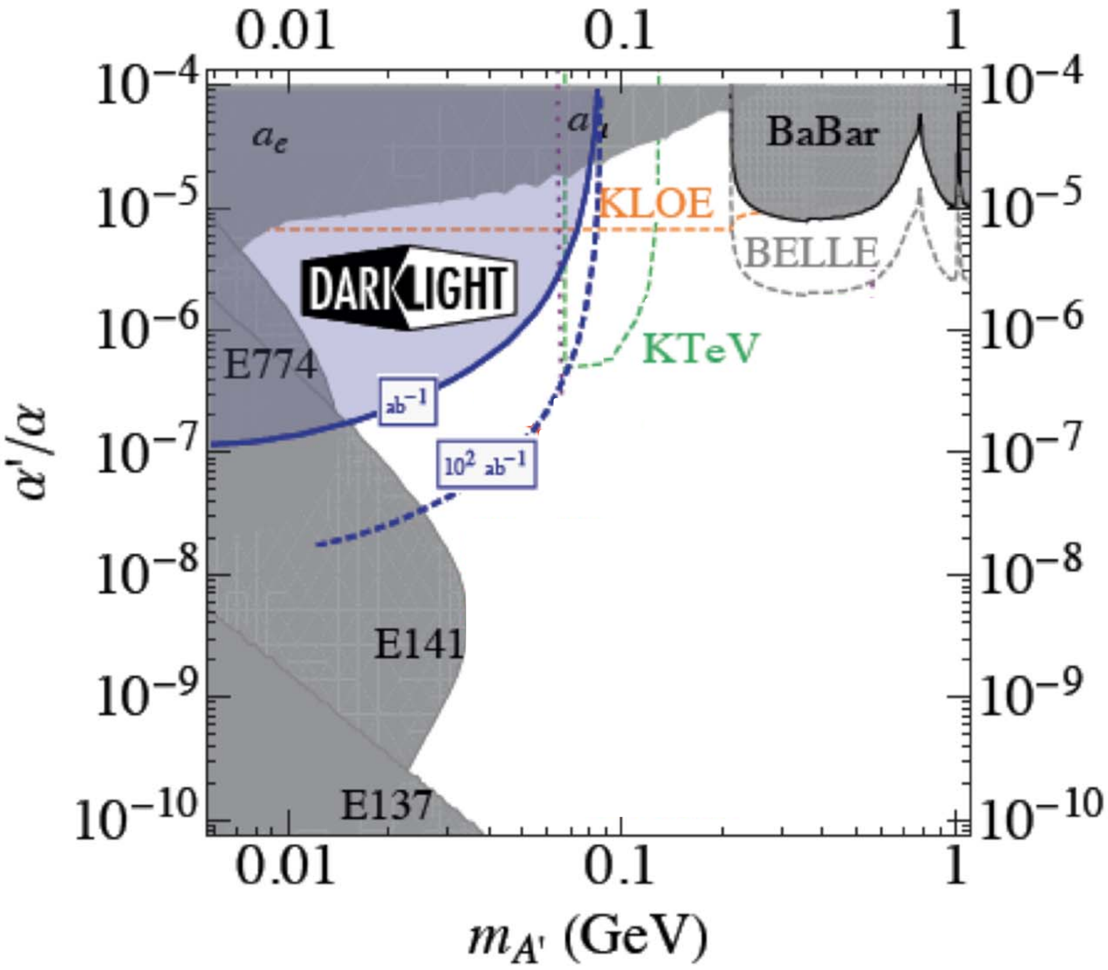




Projected Results

Coupling of
photon to electron:

$\alpha' \equiv \varepsilon^2 \alpha\,,\ \ (\alpha = e^2/4\pi)$



(DarkLight projected 5σ vs. other projected 2σ)

Beam Dynamics Issues in Dark Light

- The Dark Light experiment operates in a very different mode than the FEL. It is closer to a high energy ERL.
  - The energy spread must be small. Accelerate on crest.
  - The exhaust energy spread might be large, must use incomplete energy recovery.
  - Emittance growth is a serious issue.
  - Low charge is fine. Only need high average current
- The machine protection system must handle a large scattering source in the middle of the beamline.
- The experiment aperture is tiny but short (2 mm dia, 30 cm long)
- No need to go to high energy yet. 100 MeV is fine.

Summary

- Jefferson Lab is an ideal laboratory setting for exploration of dark matter.
- Use FEL facility for LIPSS, LIPSS 2, and DarkLight
- Published results for LIPSS.
- Set-up for DarkLight is in process.
- Jefferson Lab is poised to venture into large unexplored regions of parameter space.

Acknowledgments

The author would like to thank the collaborations, the Jefferson Lab Directorate, the ONR, and the DOE for their continued support for these exciting research programs.