
The DarkLight Project

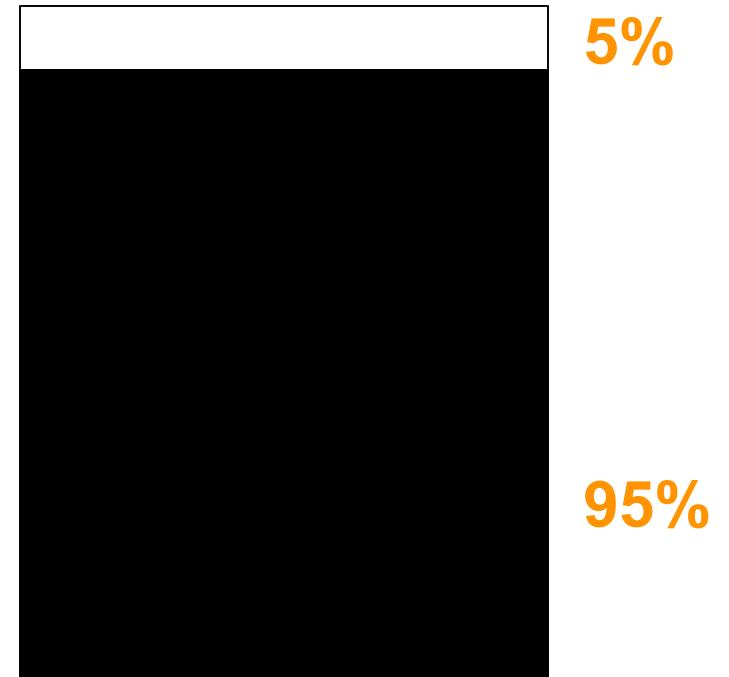
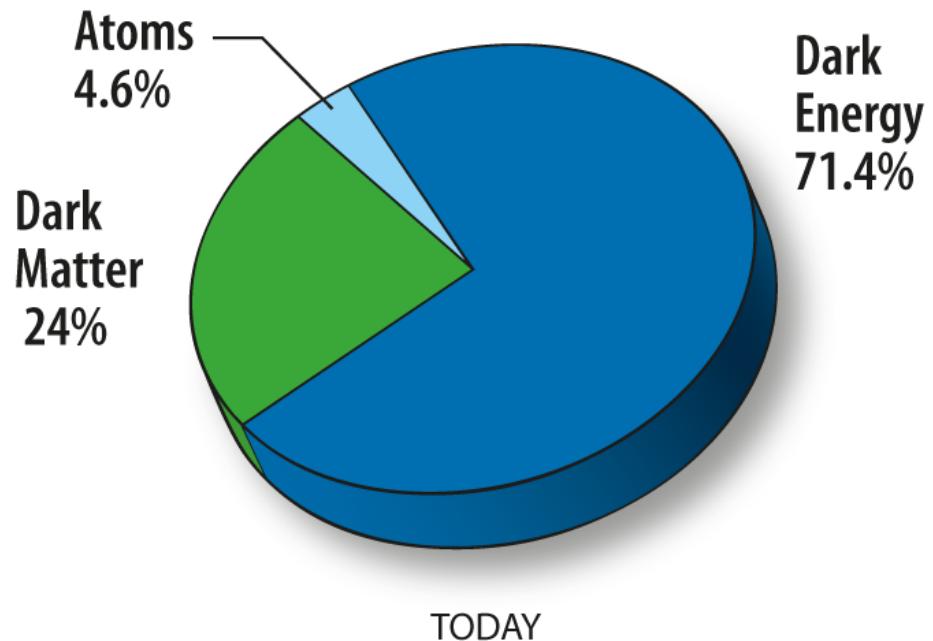


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Composition of the universe

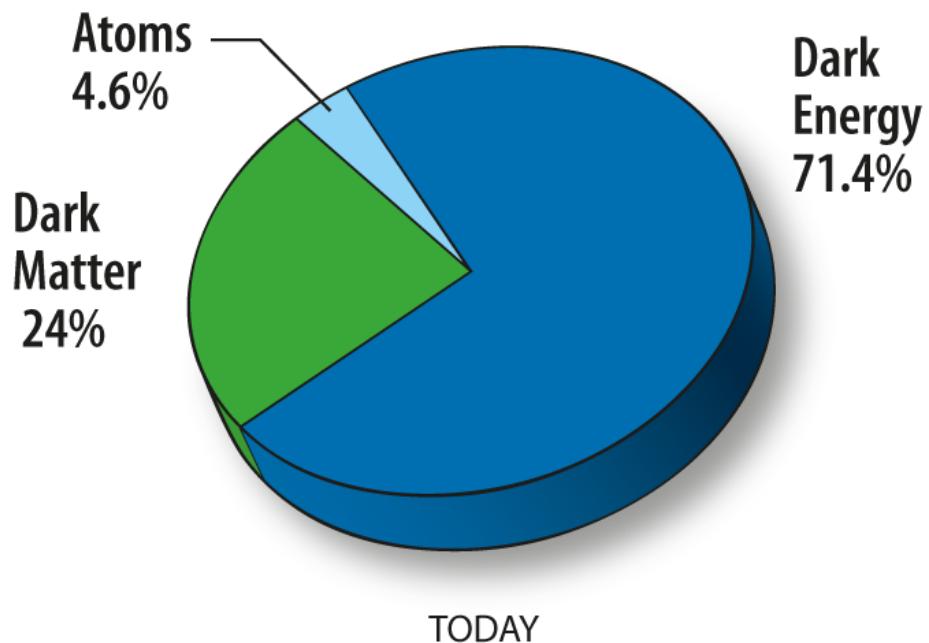


Ordinary matter: < 5%

Dark matter: Galactic scales

Dark energy: Inflation at largest scales

Composition of the universe



Ordinary matter: < 5%

Dark matter: Galactic scales

Dark energy: Inflation at largest scales



The nature of dark matter

Little is known about DM beyond gravity

Most preferred explanations:
>>100 GeV WIMP
Possible light DM and mediators

How can we study DM?



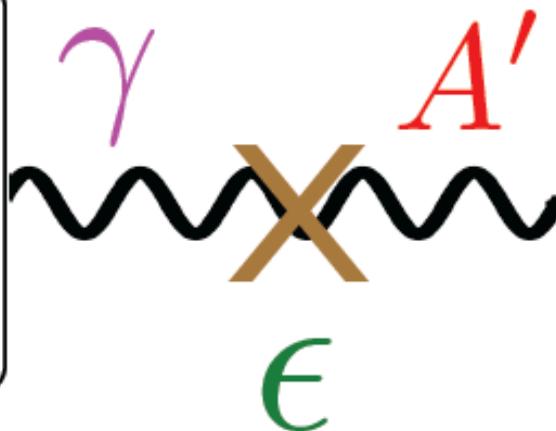
The nature of dark matter

Interaction with the Standard Model

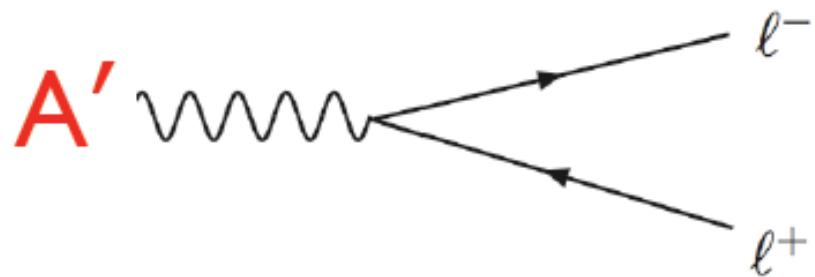


The dark sector

Standard Model
 quarks, leptons
 $g \quad W^\pm, Z \quad \gamma$



Hidden Sector
 dark matter?
 A' (massive)



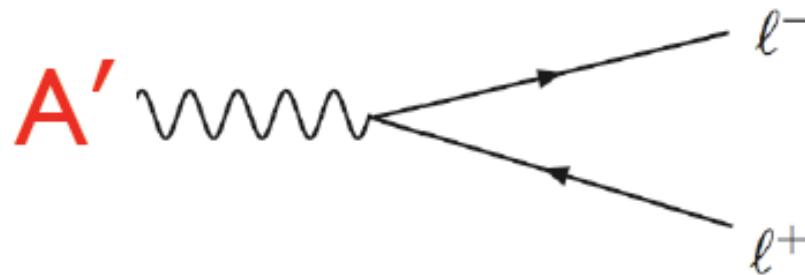
$(A' \rightarrow \text{hidden sector also possible})$

Simultaneous explanation for

- Cosmic ray positron excess (PAMELA, FERMI, AMS02)
- Absence of anti-proton excess (PAMELA)
- Anomalies in direct detection experiments (e.g. DAMA/LIBRA)
- Natural explanation for muon $g_\mu - 2$ anomaly [Be-8, R_p]

The dark sector

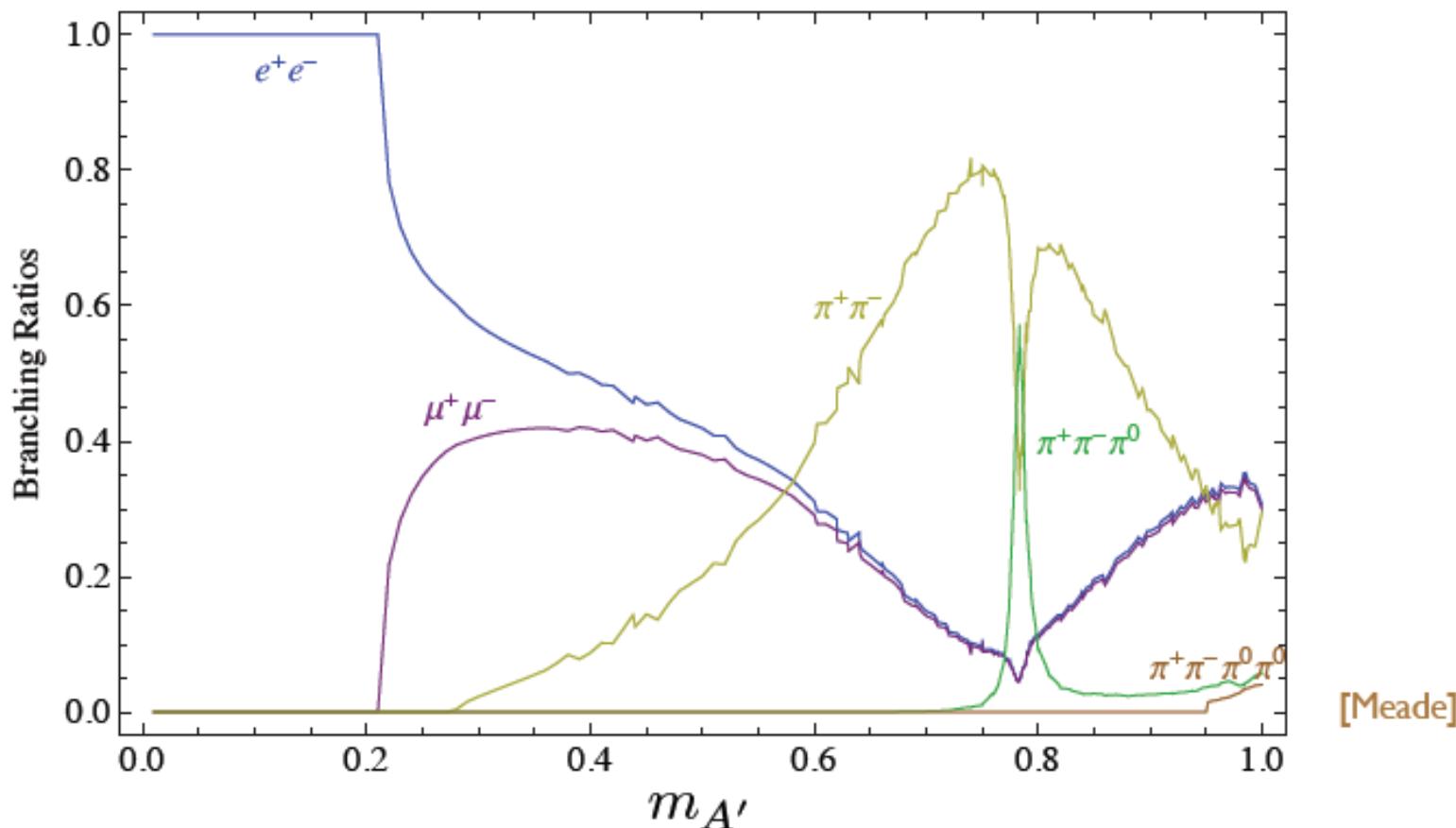
A' can decay to Standard Model particles



$A' \rightarrow$ hidden sector possible, too

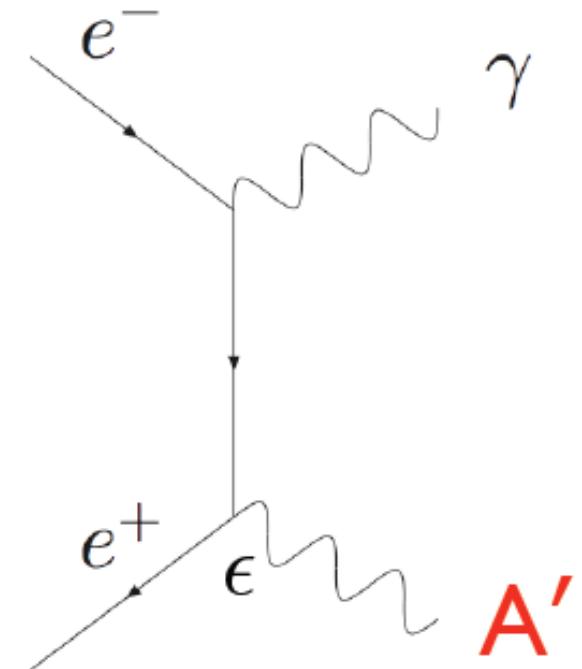
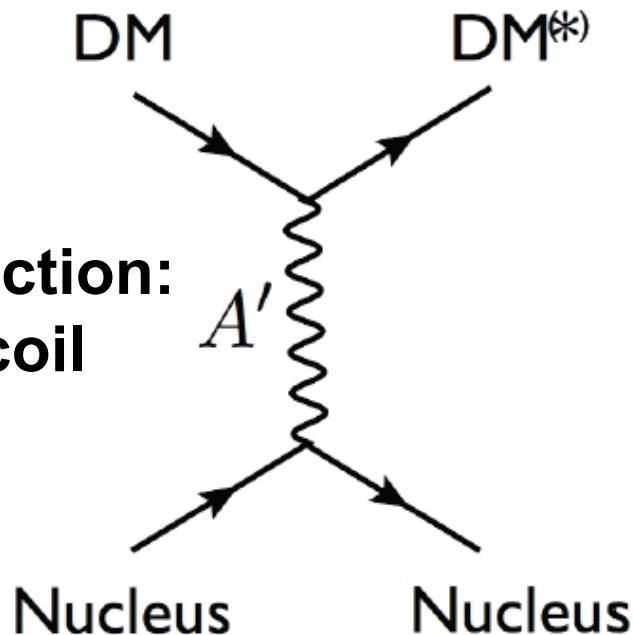
Absence of antiprotons limits A' mass

Below ~ 200 MeV/c² only e^+e^-

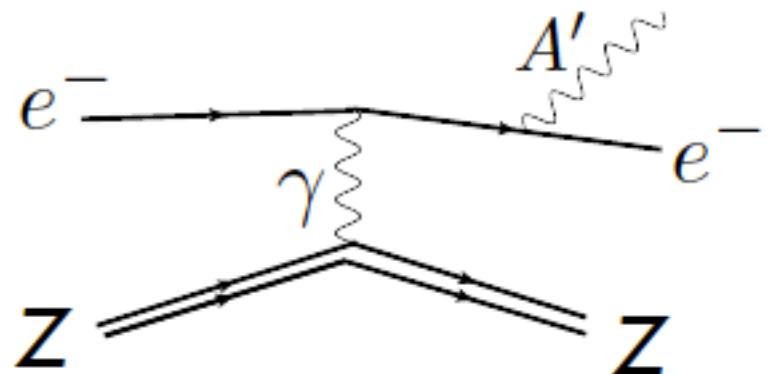


Experimental A' searches

e⁺e⁻ collisions, meson decays:
A' → l⁺l⁻ and invisible



Fixed-target experiments:
A' → l⁺l⁻ and invisible
A' long-lived – displaced vertex
A' short-lived – production rate



DarkLight



Detecting **A** Resonance **K**inematically with
eLectrons **I**nincident on a **G**aseous **H**ydrogen **T**arget

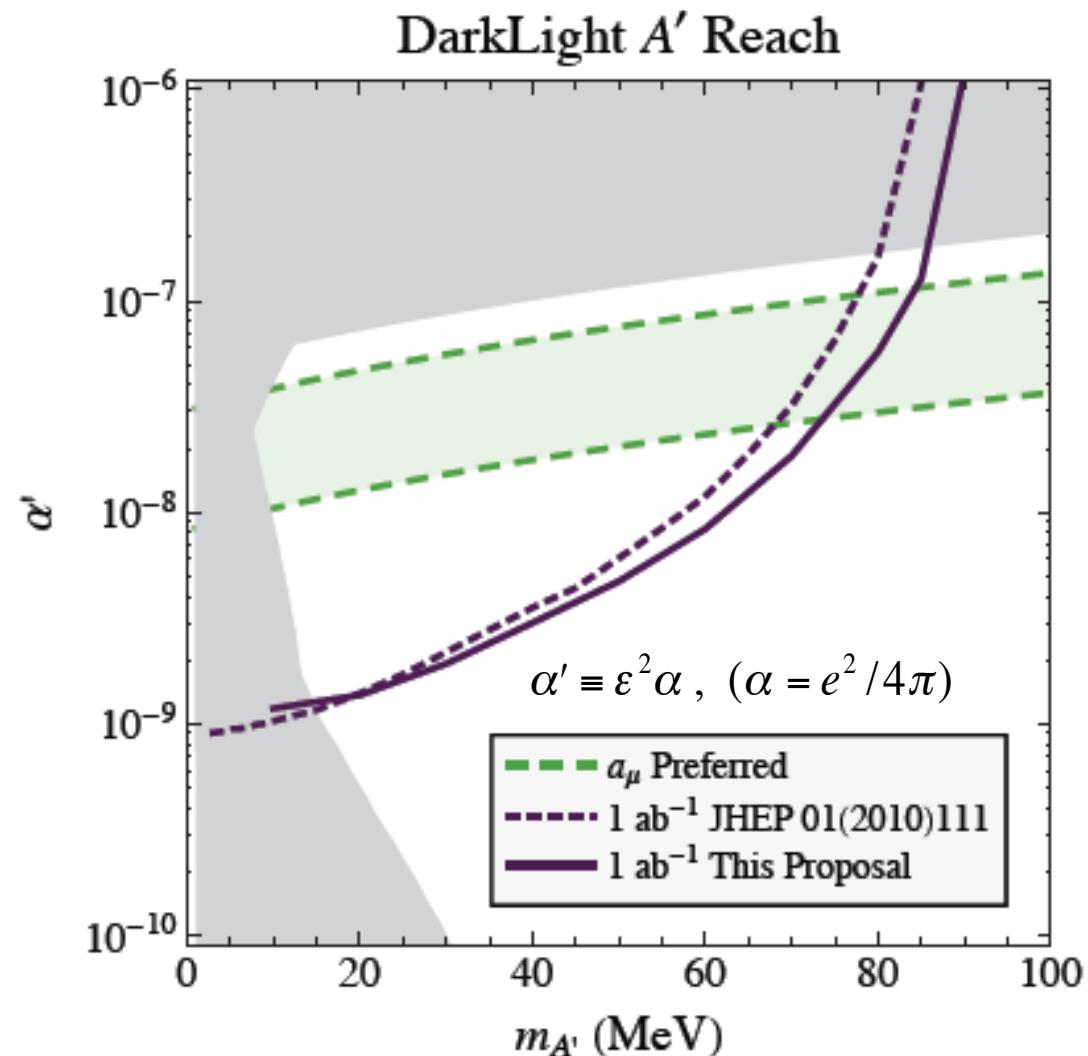
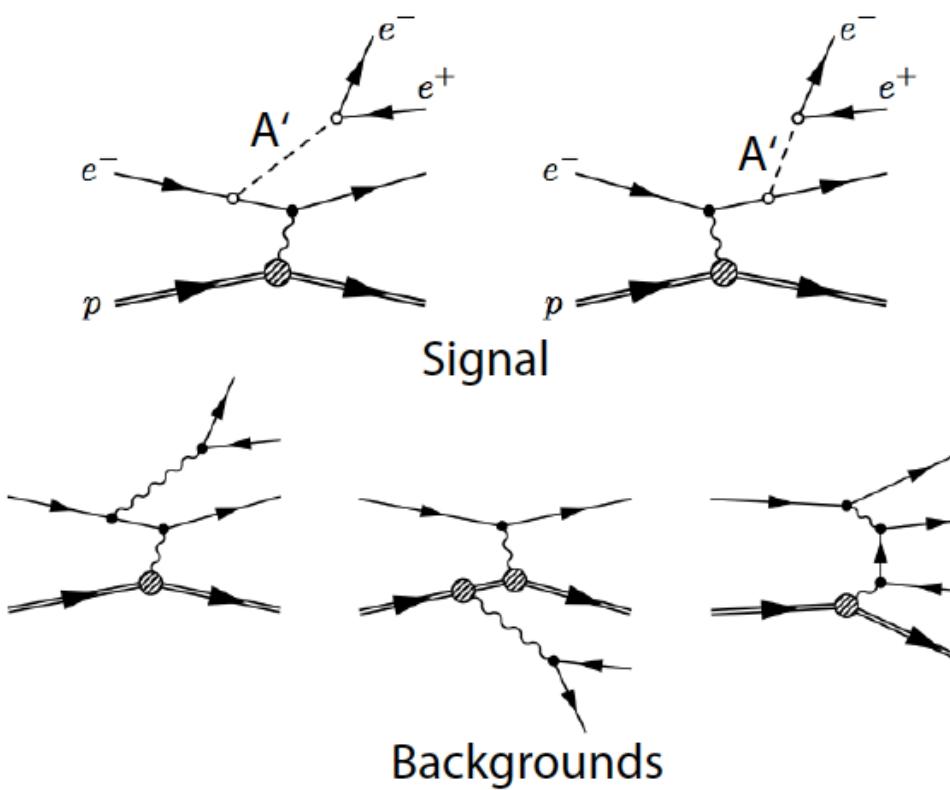


DarkLight

- Dark photons (universal coupling) well motivated by dark matter observations (astronomical, direct, positrons) in combination with $g_\mu - 2$ anomaly
- To be run at the Low Energy Recirculator Facility (LERF) at Jefferson Lab
- Search for visible decays modes of $A' \rightarrow e^+e^-$ in $ep \rightarrow epA' \rightarrow epee$ with complete reconstruction of final state
- Search for invisible decays $A' \rightarrow X$ in $ep \rightarrow epX$
- DarkLight sensitive to dark photons with masses < 100 MeV/c² in the region of the $g_\mu - 2$ welcome band
- **DarkLight phase 1:**
Funded (NSF-MRI) in 2014, HU responsible for lepton tracker
Running of phase 1a in 2016 and phase 1a/b/c in 2017/18
- **DarkLight phase 2:**
Ultimate reach, design in progress, 2018+

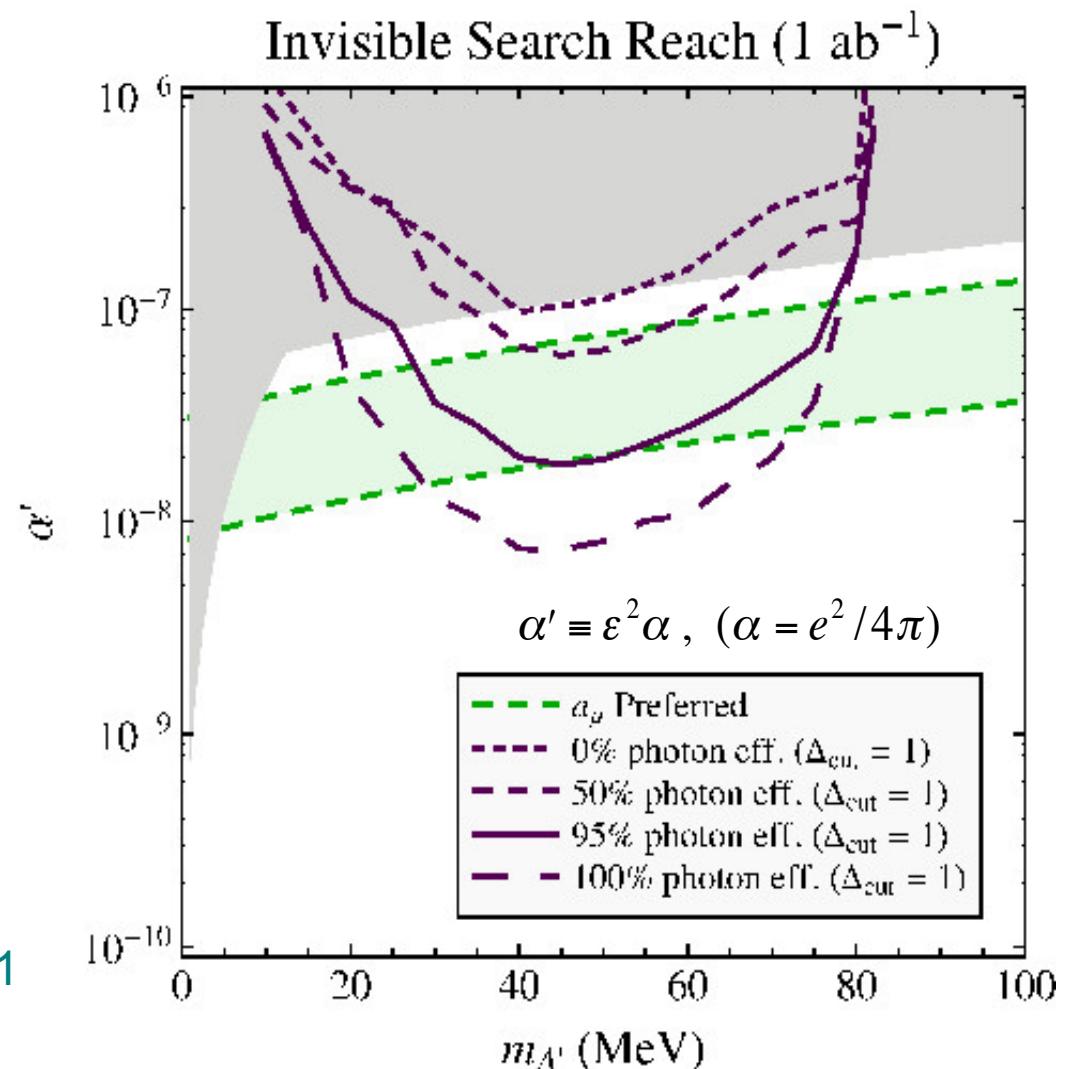
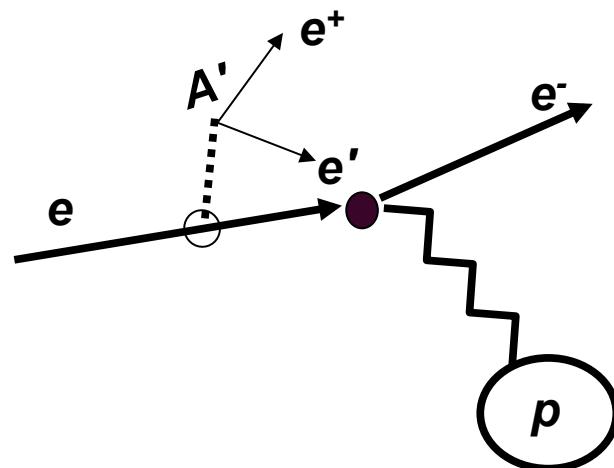
DarkLight sensitivity: visible decay

Goal: Explore $e^+ e^-$ invariant mass spectrum from 10-90 MeV using the process $e^- p \rightarrow e^- p e^- e^+$

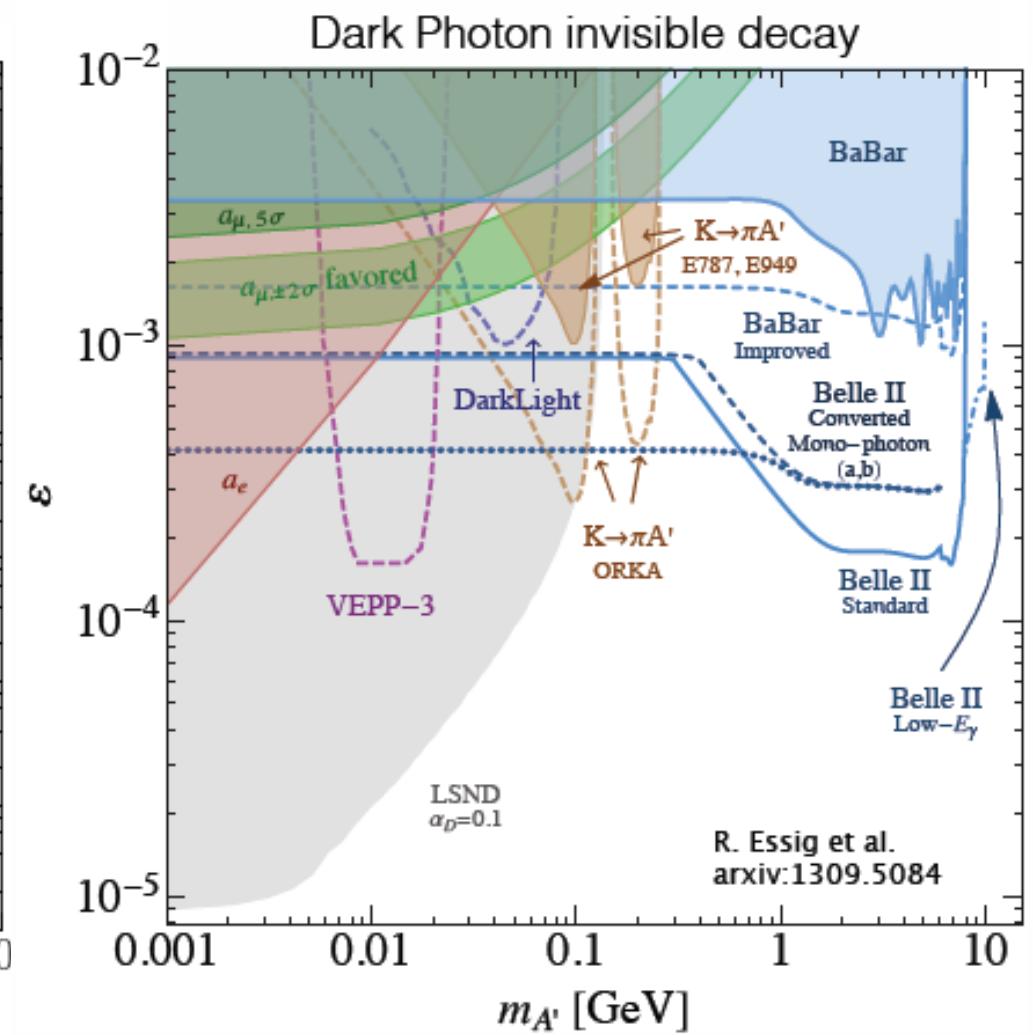
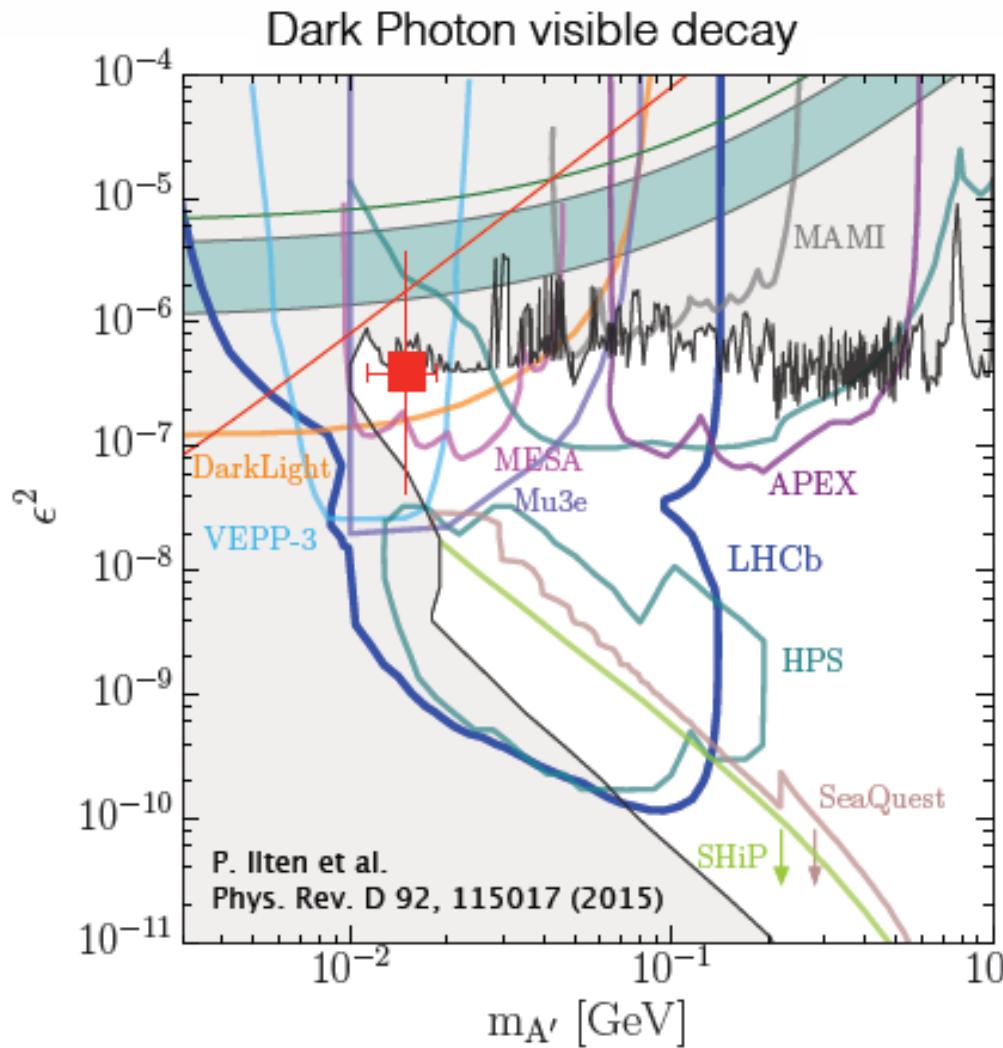


DarkLight sensitivity: invisible decay

- $ep \rightarrow epA'$ (“*invisible*”) observe only final state electron and proton,
- Backgrounds' kinematics different enough that they can be controlled
- Requires photon veto $ep \rightarrow e\gamma$



Parameter space

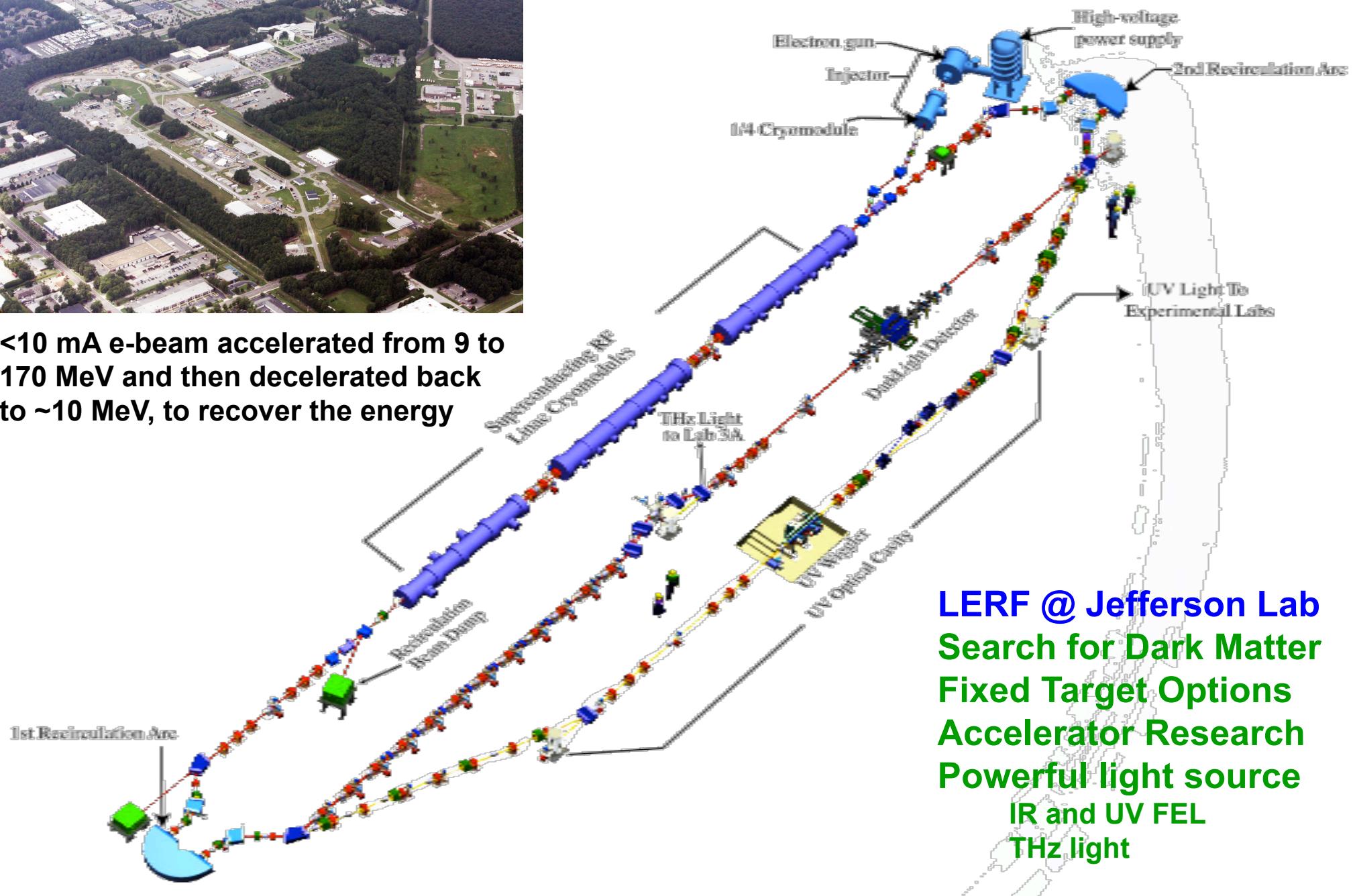


■ Beryllium-8 signal within DarkLight reach

Low-Energy Recirculator Facility (LERF)

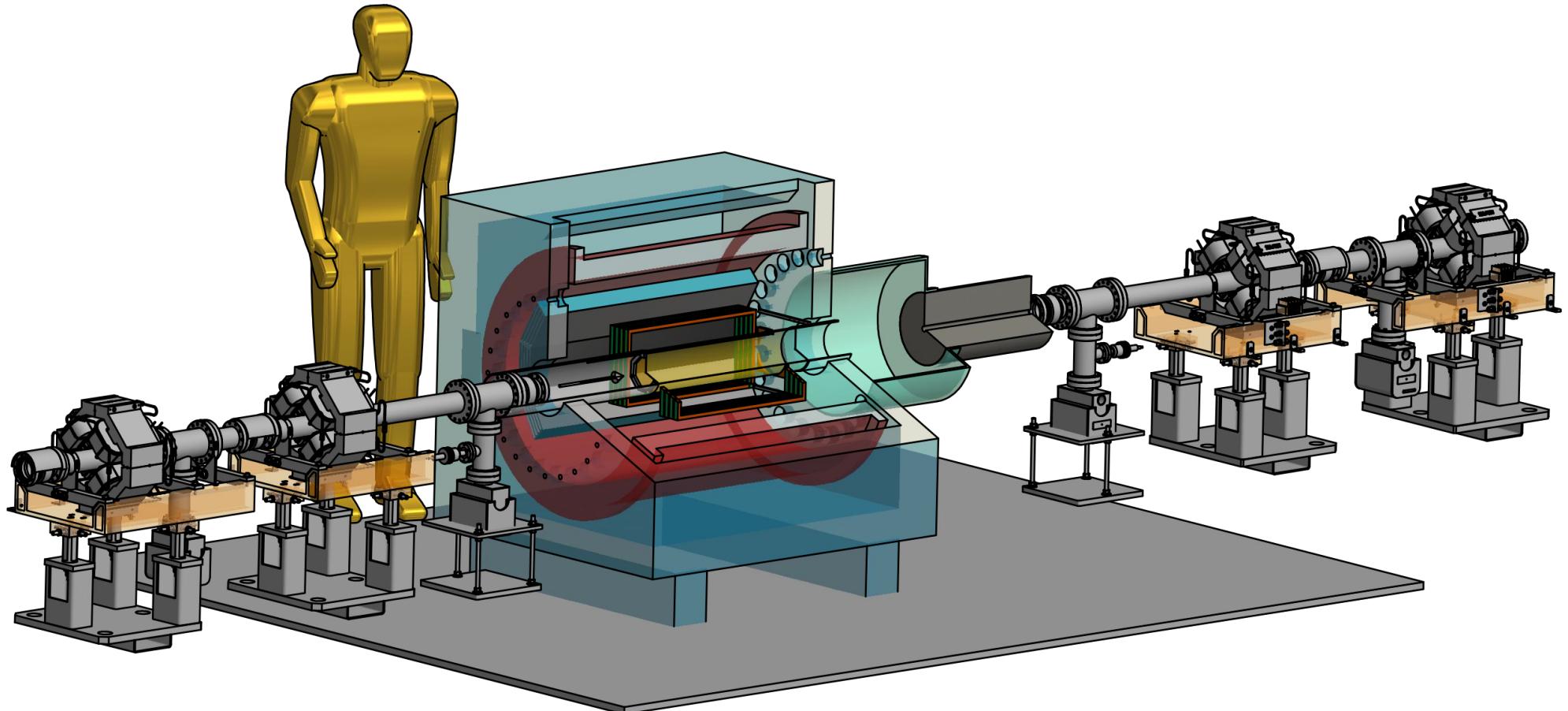


<10 mA e-beam accelerated from 9 to 170 MeV and then decelerated back to ~10 MeV, to recover the energy



DarkLight phases

- Phase 0: Transition of MW e-beams through mm apertures (2013)
- Phase 1a: Intern. target, prototype detector, to be redone (2016/17)
- Phase 1b: Møller process, test of streaming readout (2017/18)
- Phase 1c: Test of 17 MeV fifth force carrier (2017/18)
- Phase 2: Full measurement



NSF/MRI award 2014 (HU & MIT ~\$1M)

Phase 0 (2012/13)

PRL 111, 164801 (2013)

PHYSICAL REVIEW LETTERS

week ending
18 OCTOBER 2013

Transmission of Megawatt Relativistic Electron Beams through Millimeter Apertures

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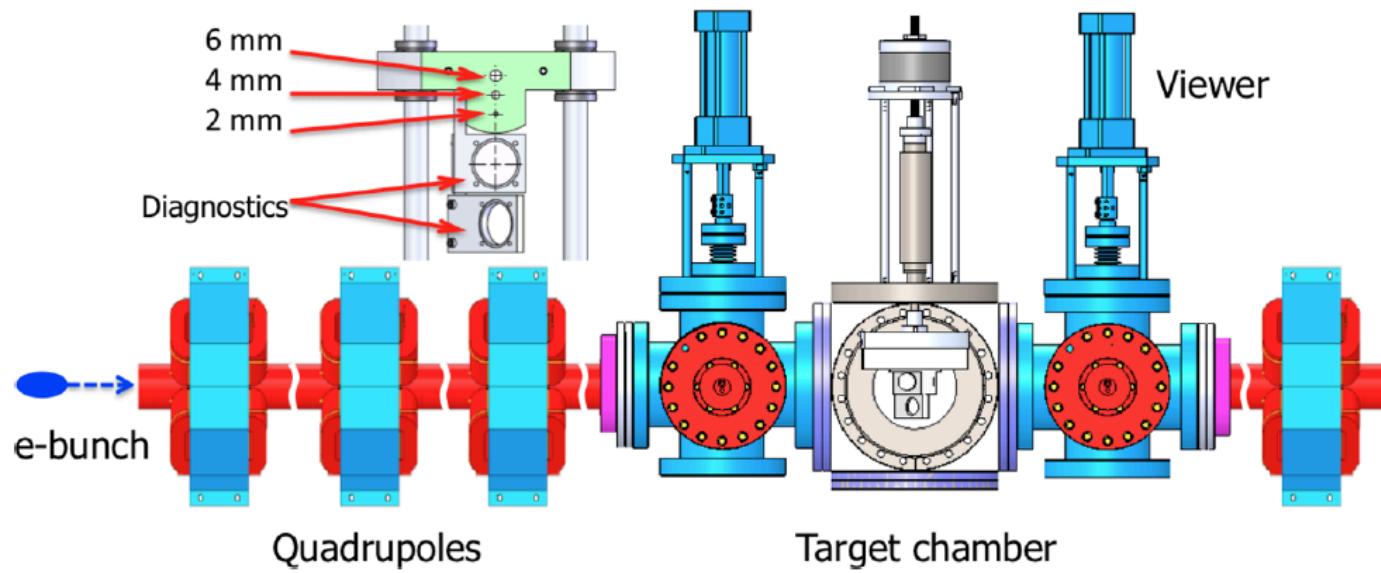
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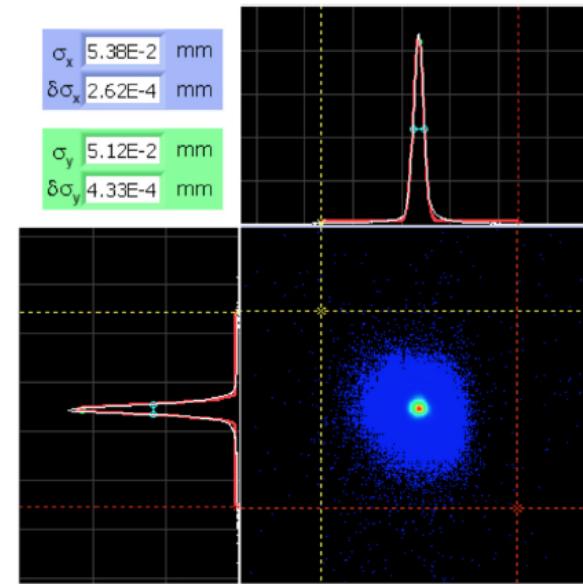
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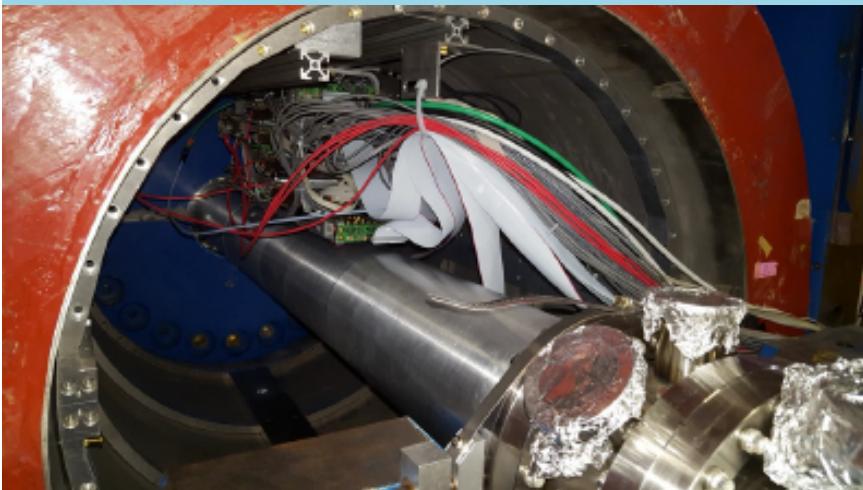
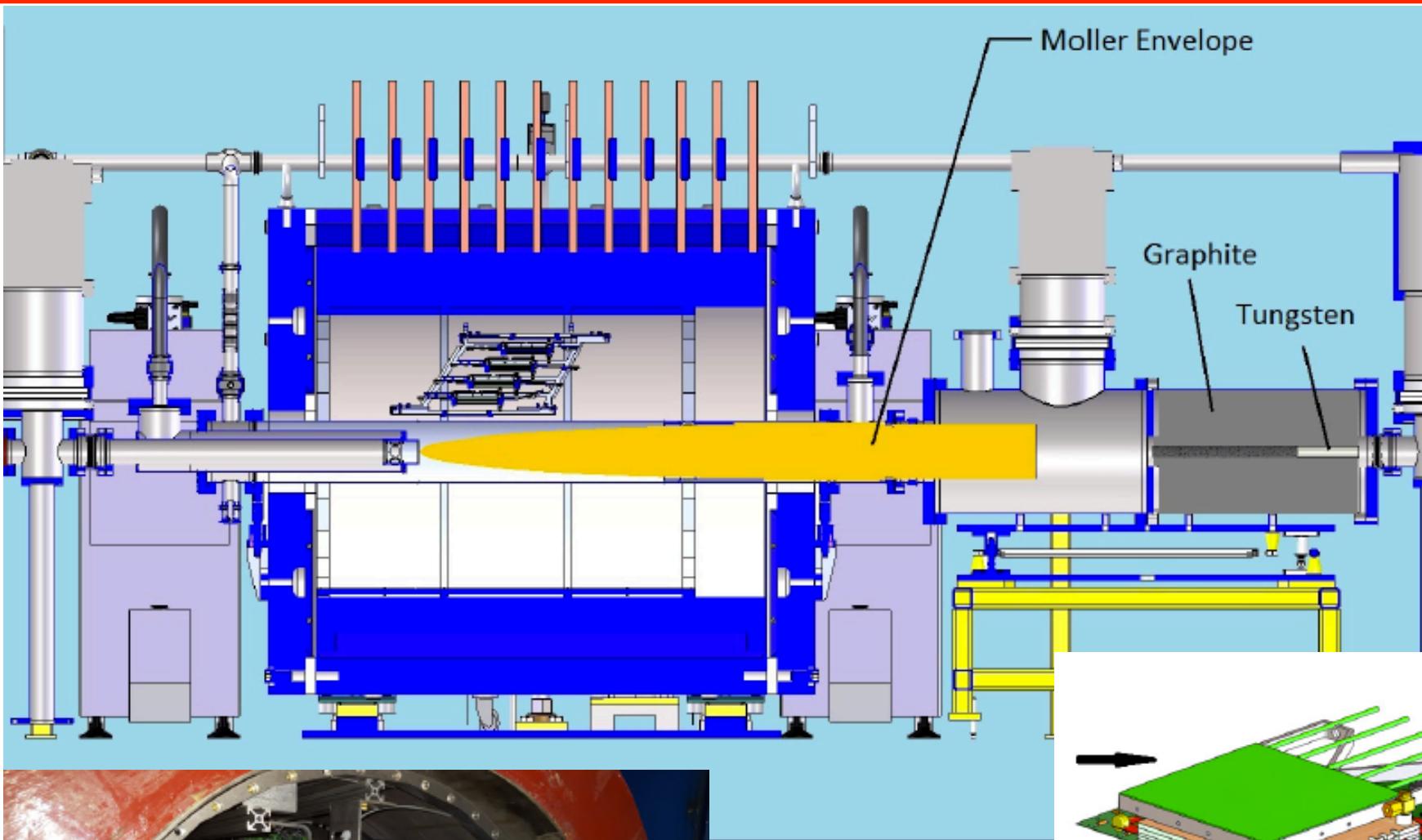
High-power, relativistic electron beams from energy-recovering linacs have great potential to realize new experimental paradigms for pioneering innovation in fundamental and applied research. A major design consideration for this new generation of experimental capabilities is the understanding of the halo associated with these bright, intense beams. In this Letter, we report on measurements performed using the 100 MeV, 430 kW cw electron beam from the energy-recovering linac at the Jefferson Laboratory's Free Electron Laser facility as it traversed a set of small apertures in a 127 mm long aluminum block. Thermal measurements of the block together with neutron measurements near the beam-target interaction point yielded a consistent understanding of the beam losses. These were determined to be 3 ppm through a 2 mm diameter aperture and were maintained during a 7 h continuous run.



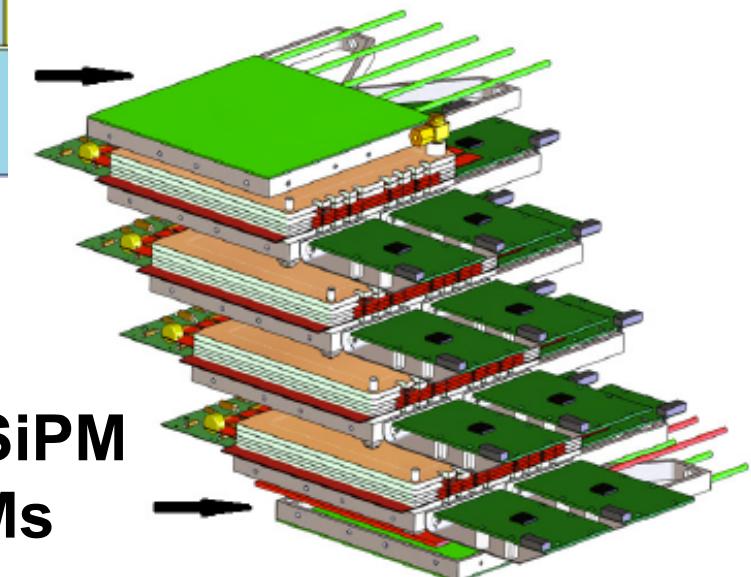
R. Alarcon et al.,
PRL111, 164801 (2013)



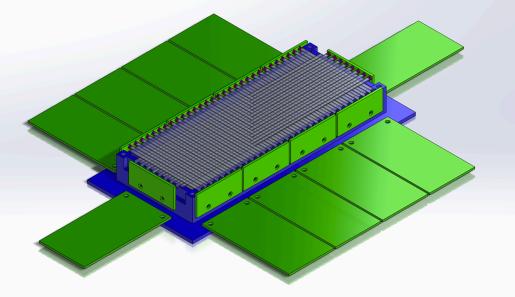
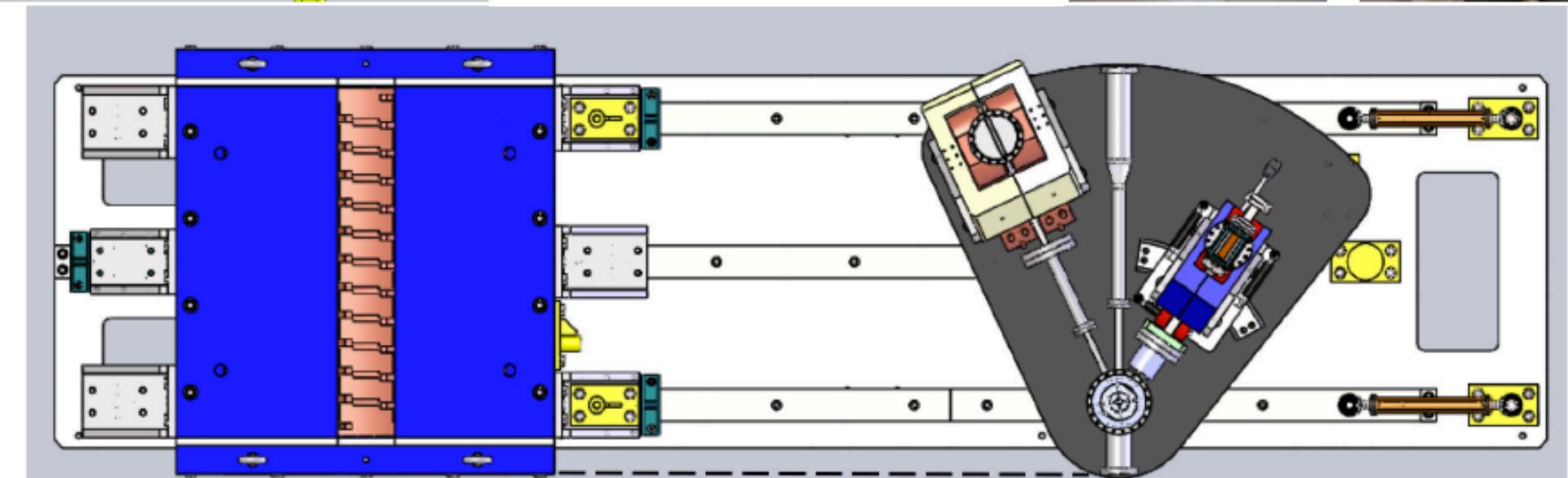
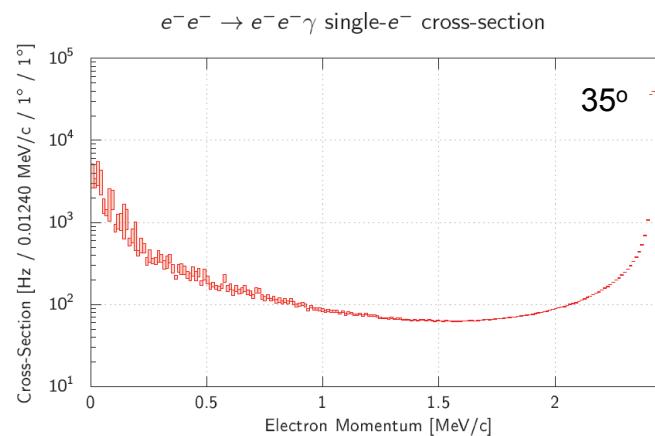
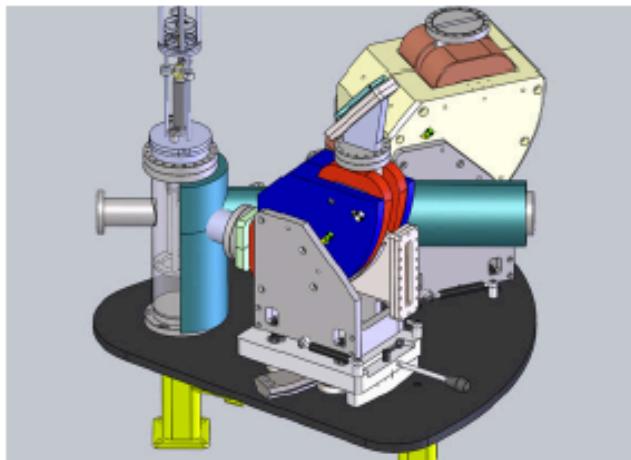
DarkLight phase 1a (2016)



Prototype: SiPM
scint. + GEMs



DarkLight phase 1b/1c (2017/18)

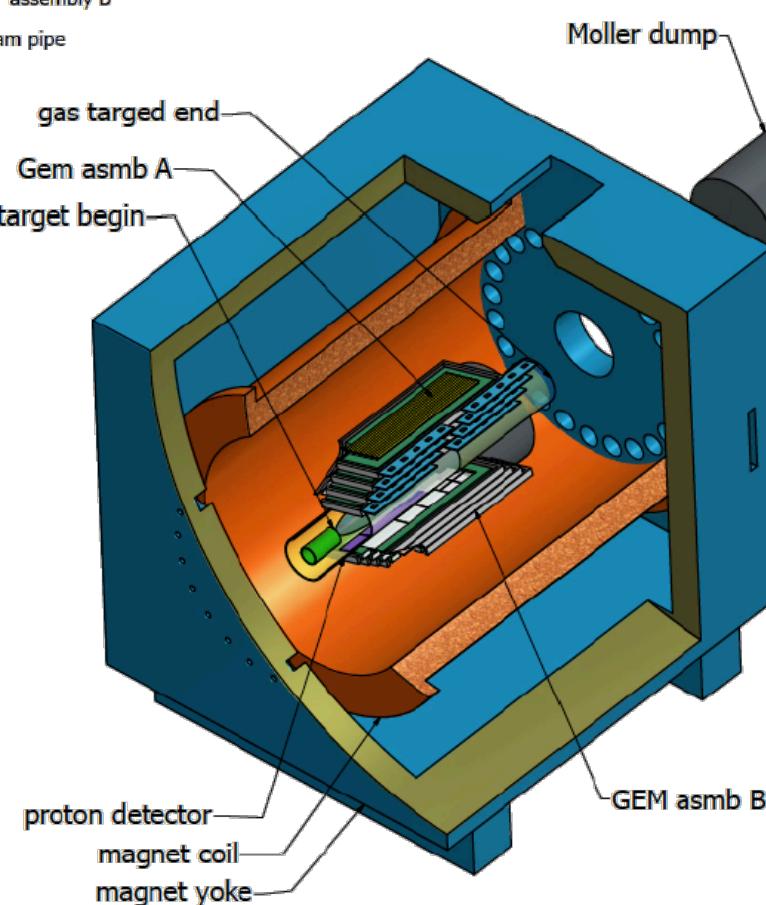
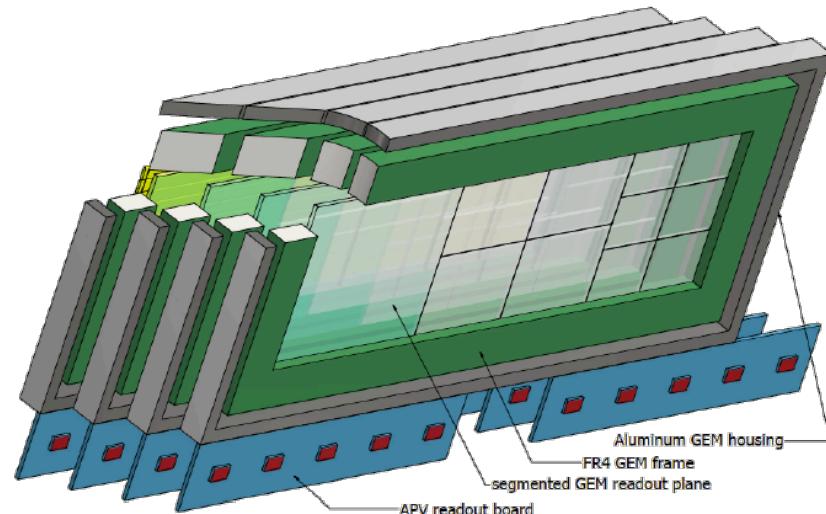
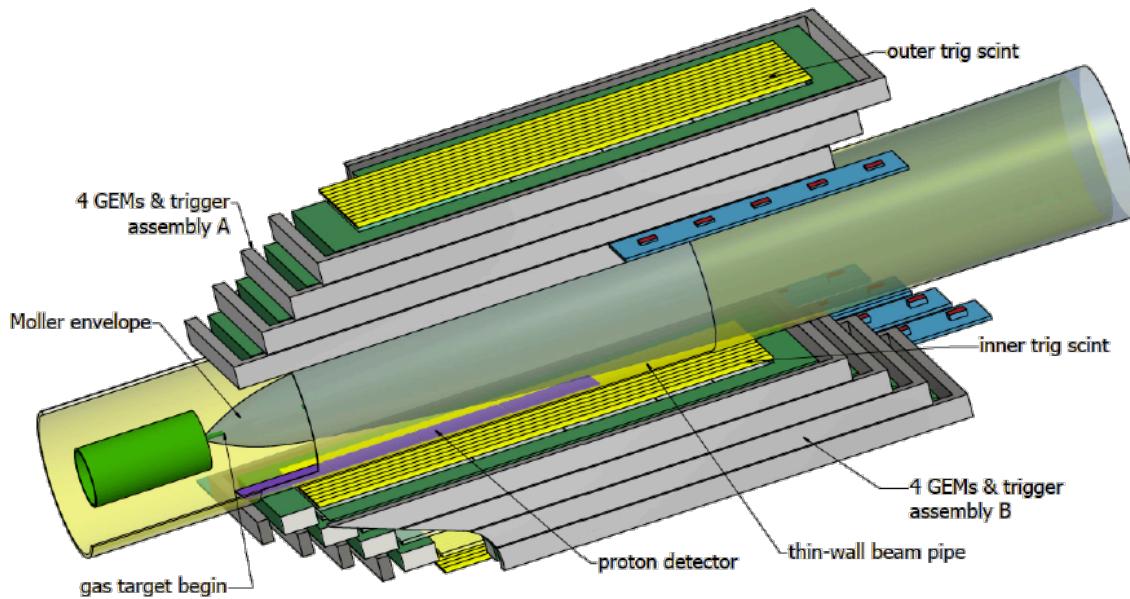


High precision radiative
Møller scattering
Scintillating fiber tracker

Beam
Direction

C. Epstein

GEMs for DarkLight Phase 1c (MRI)



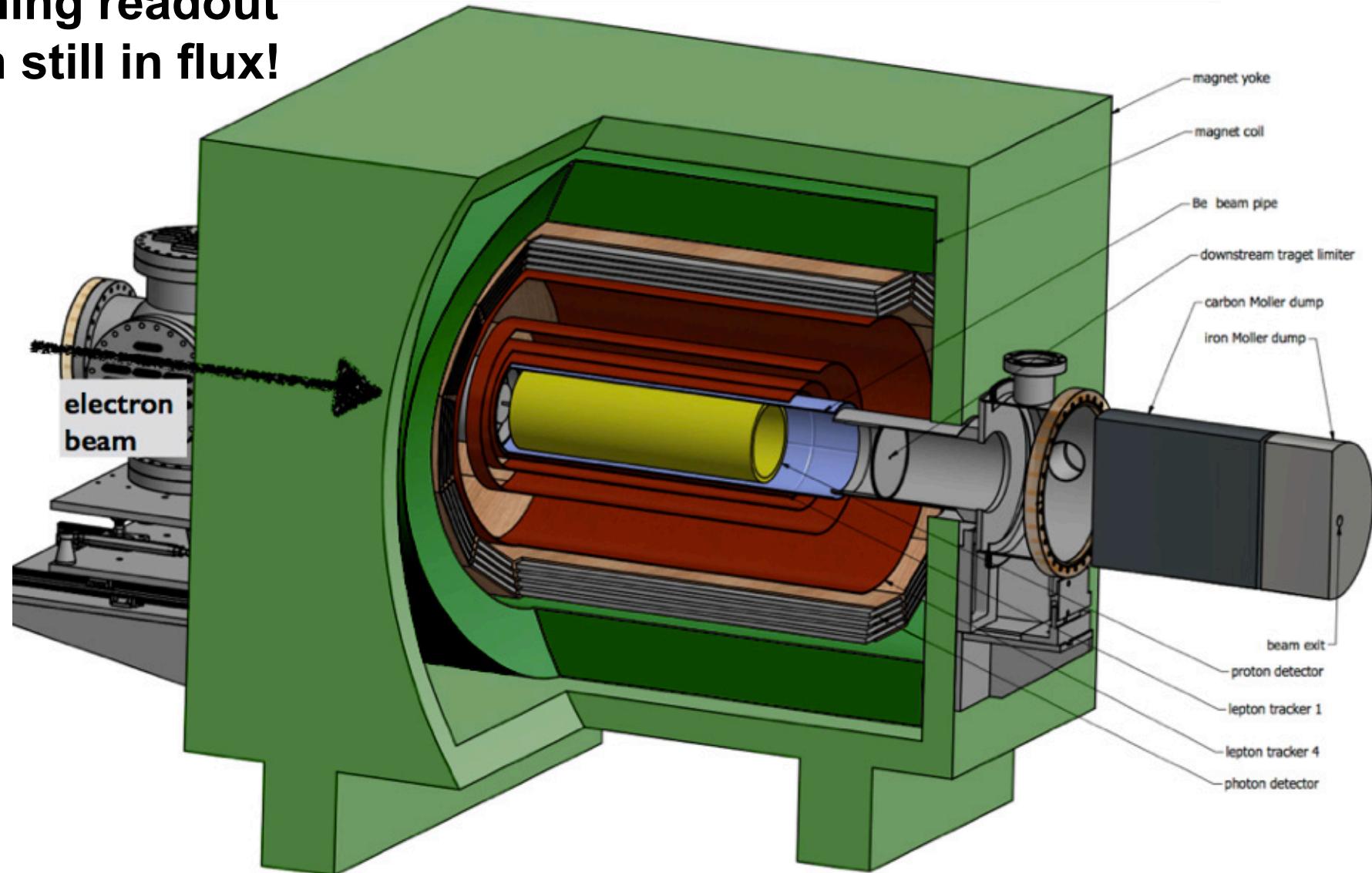
**For lepton tracking
in $e p \rightarrow e p e e$**

**Compatible with use
in dipole spectrometer**



Phase 2 concept

- Beryllium beam pipe
- Proton detector: Silicon strip
- Lepton tracker 4 layers GEM/MicroMegas, >60,000 channels
- Streaming readout
- Design still in flux!



Summary

- Dark photons, or fine-tuned bosons (e.g. protophobic, leptophobic) can be searched with DarkLight @ Jlab (LERF) at low A' masses 10-90 MeV/c² (visible and invisible)
- Very high beam power (energy recovery), low energy, very thin target, minimal materials
- Staged approach in phases 1 (funded 1a, 1b, 1c), and 2
- Pioneering run in 2012 [PRL 111, 164801 (2013)], engineering run in 2016, follow-up envisioned 2017-18
Anticipated program for 2017–2020+
- Project size suitable at <\$10M
- LERF running costs \$120-200k / week

Collaboration

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Backup

CEBAF and LERF Beam Parameters

	LERF	CEBAF
Max. Energy	170 MeV NA	11 GeV (ABC) 12 GeV (D)
Duty Factor	CW	CW
Max. Beam Power	>1 MW	1 MW
Bunch Charge (Min-Max)	60-135 pC	0.004 fC – 1.3 pC
Repetition Rate on Target	4.68–74.85 MHz	31.2 – 499 MHz
Nominal Hall Repetition Rate	74.85 MHz	249.5/499 MHz
Number of Exp. Halls	1	4
Max. Number of Passes	1	5.5
Emittance (geometric) at full energy	50 nm-rad(X)/30 nm-rad(Y) @135 pC	3 nm-rad(X)/1 nm-rad(Y)
Energy Spread at full energy	0.02%	0.018%
Polarization	None	>85%