Dark Sector Science in 2019

Philip Schuster (SLAC)

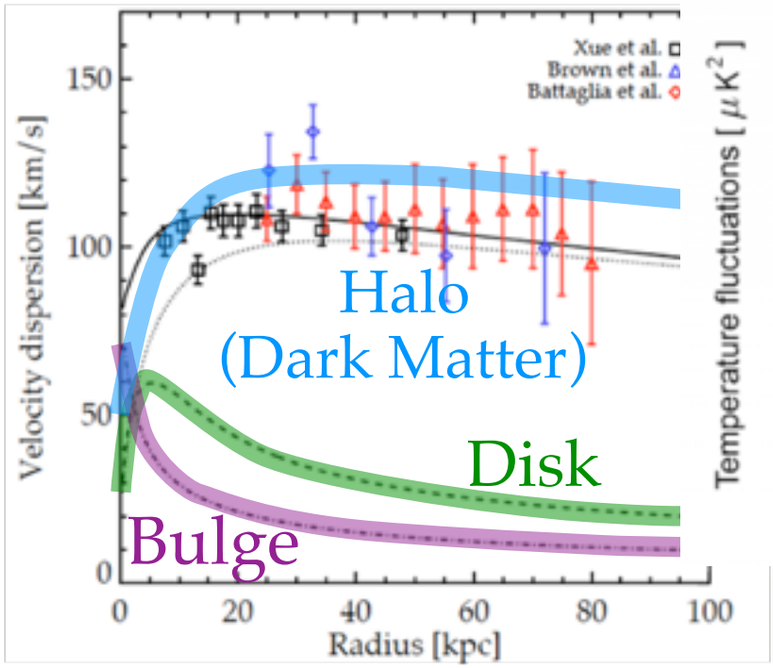
Jefferson Lab Seminar
January 30, 2019

Outline

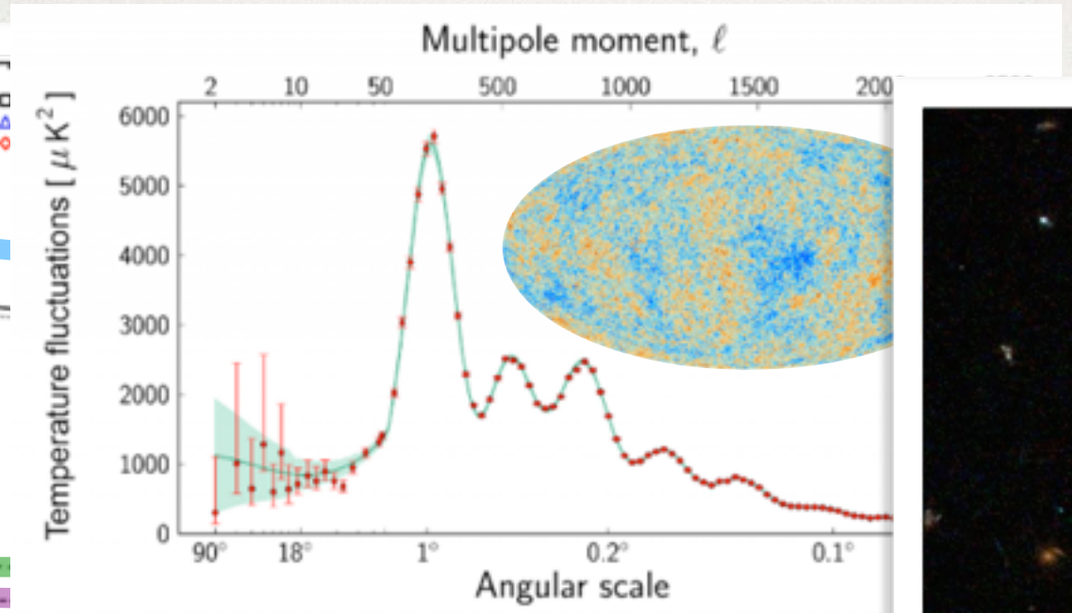
This talk is intended as a primer on the motivation for dark sectors (and dark photons) and to explain the important contributions of Jefferson Lab experiments to this science in 2019

- Dark matter, dark sectors, and the broadening of the US dark matter search program
- Dark photons in the MeV-GeV mass range
- Dedicated dark photon experiments at Jefferson Lab in 2019 (APEX & HPS)
- The future

Dark Matter



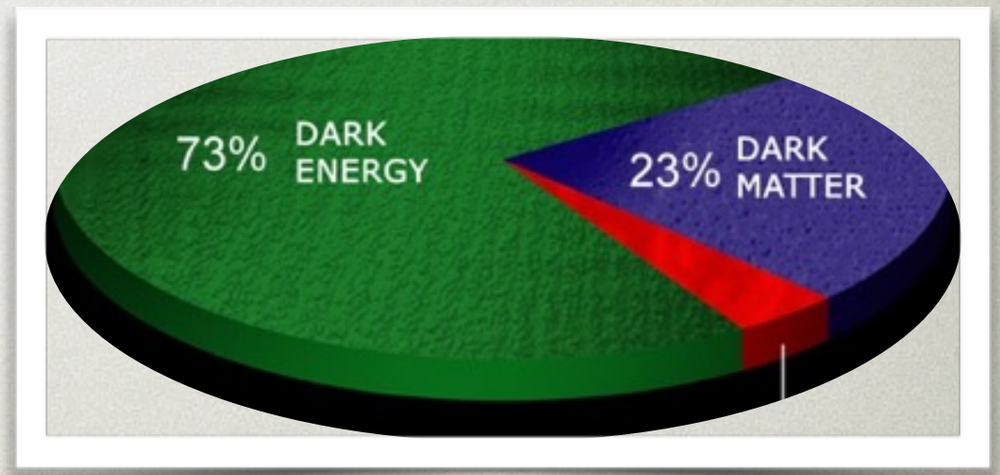
Rotation curves



CMB Power Spectrum

Lensing

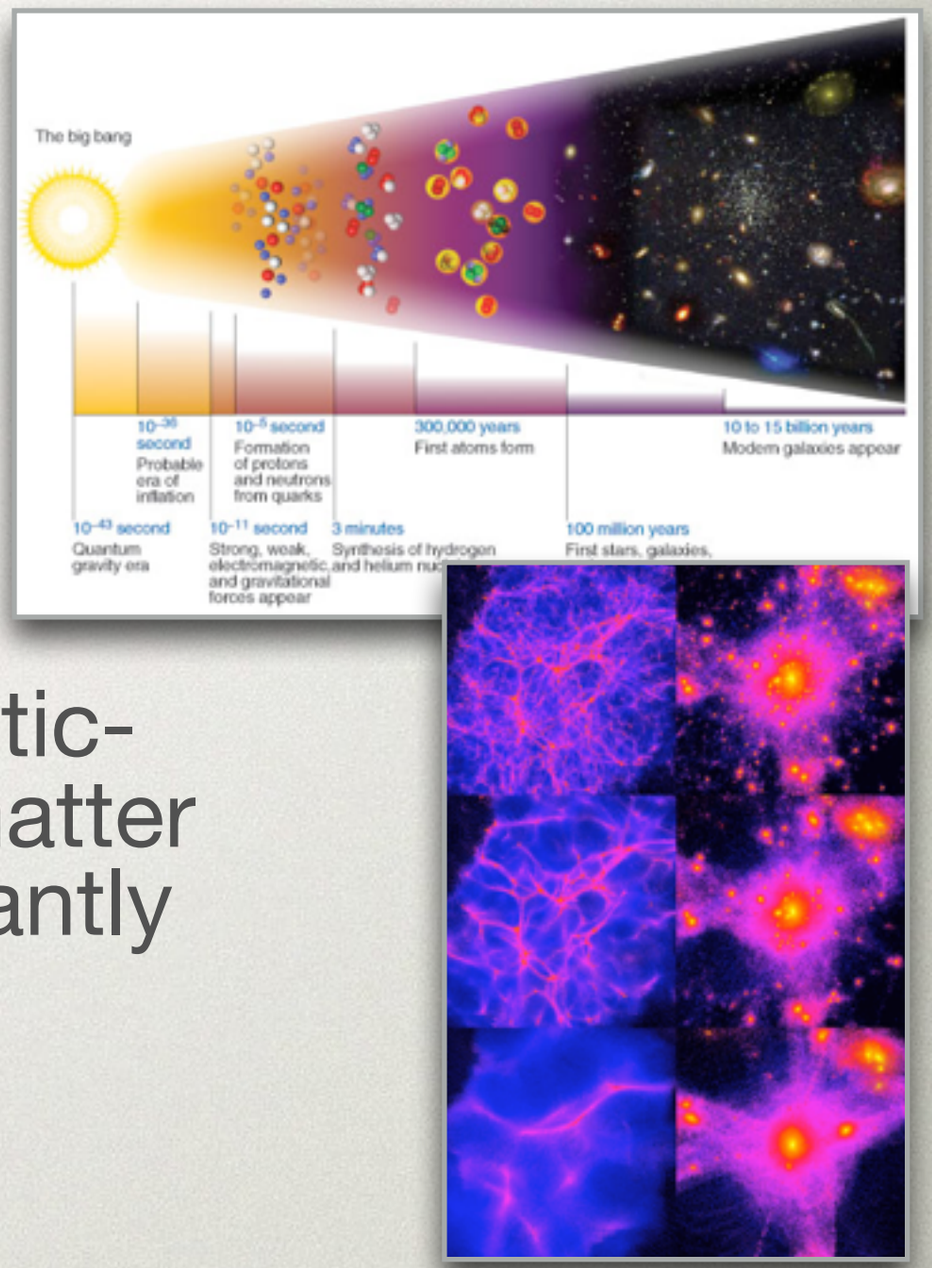
We know there is new physics in the form of dark matter!



<u>But what is it?</u>

Dark Matter Hints

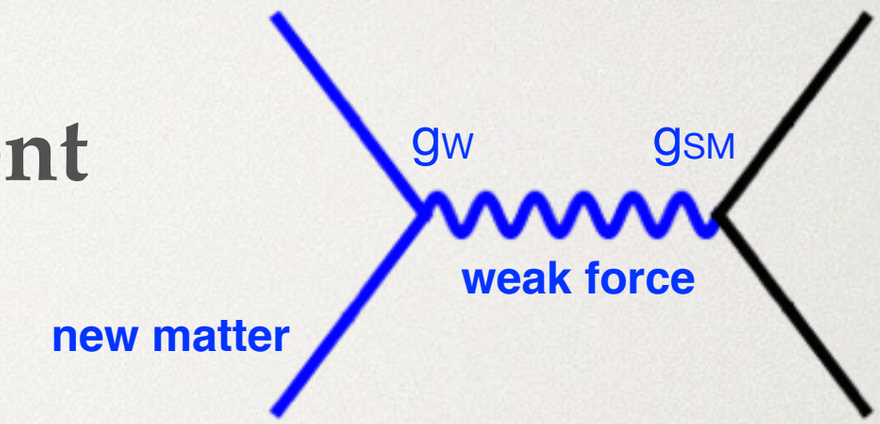
- **Old** – dark matter imprint in Cosmic Microwave Background → made during or before big bang
- **Cold** – dark matter must have been non-relativistic to form small cosmological structures
- Can't have strong- or electromagnetic-strength interactions with familiar matter (even weak interactions are significantly constrained by data)



This leaves a lot of room for speculation…

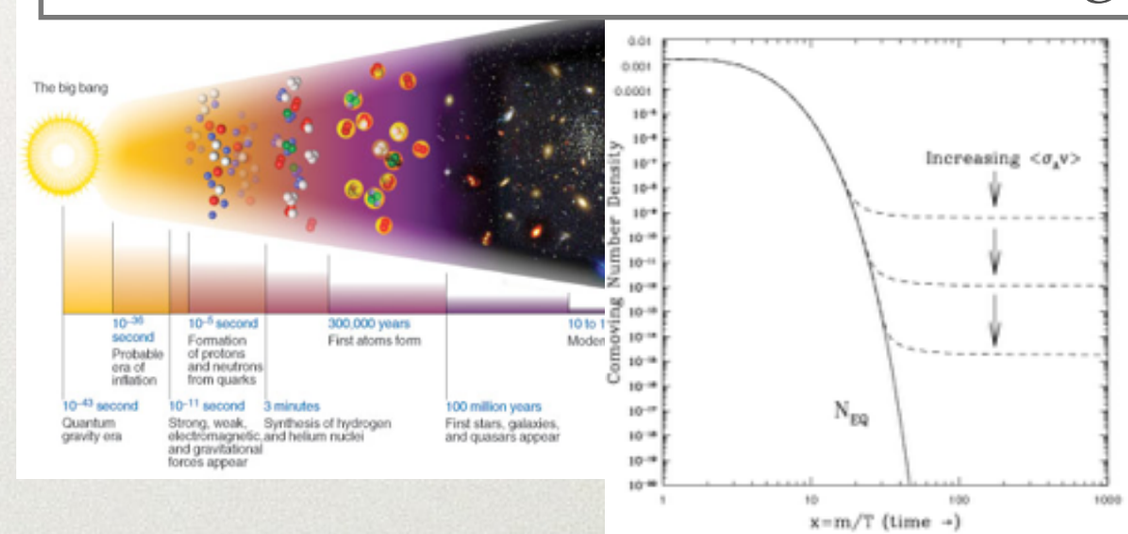
A Strong Candidate: WIMP DM

Simple, familiar particle content

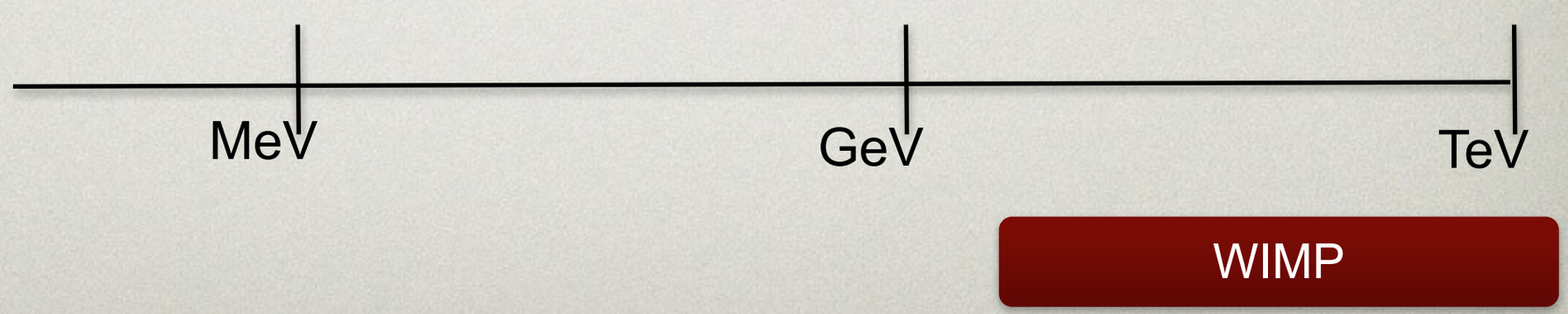


Simple, predictive cosmology

DM with thermal freeze-out origin

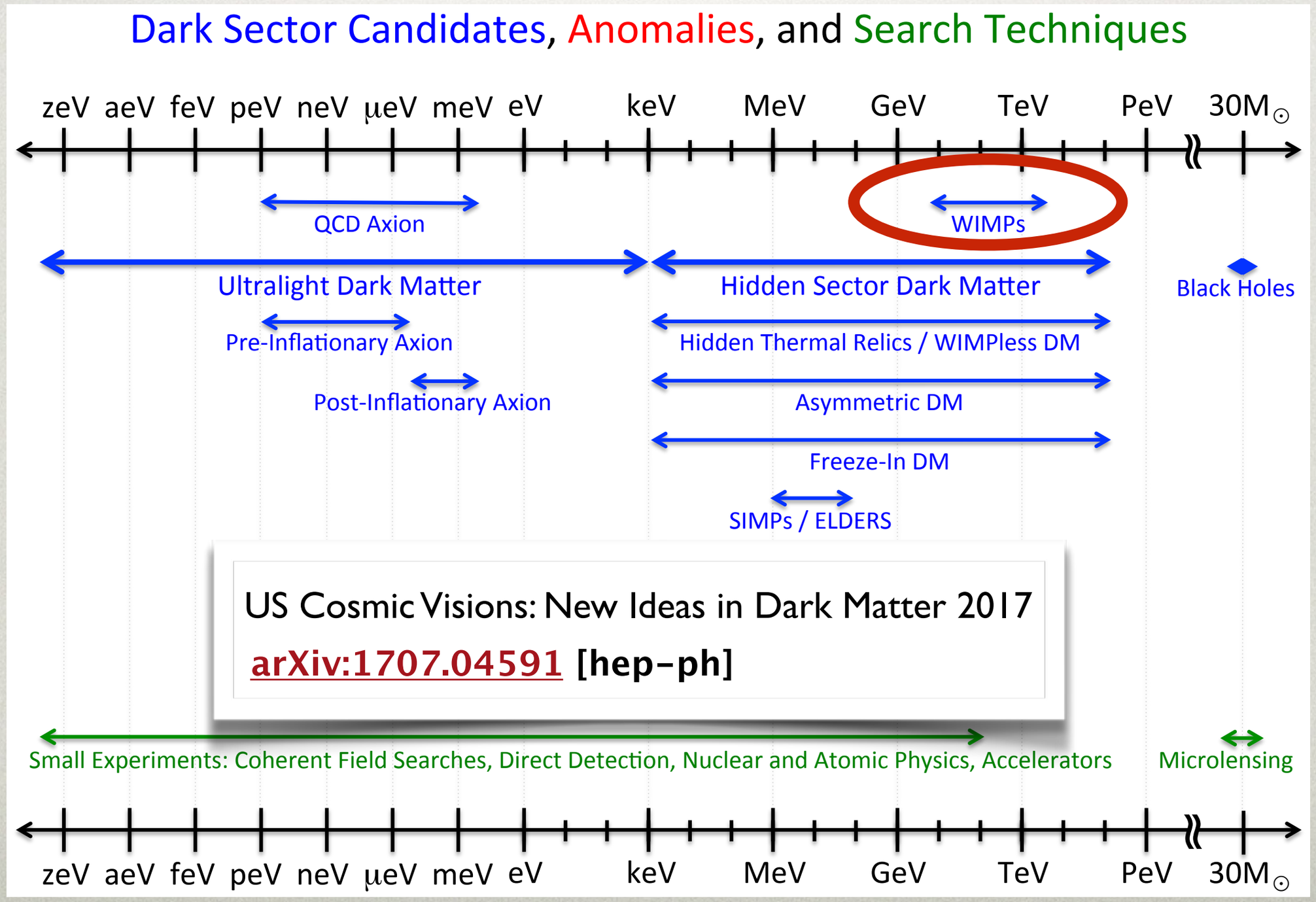


Motivated mass range



Moving Beyond WIMPs

Developing simple ideas beyond the WIMP hypothesis — in response to powerful limits from LHC and direct detection experiments — has arguably been one of the most important developments in particle phenomenology over the last 10 years!



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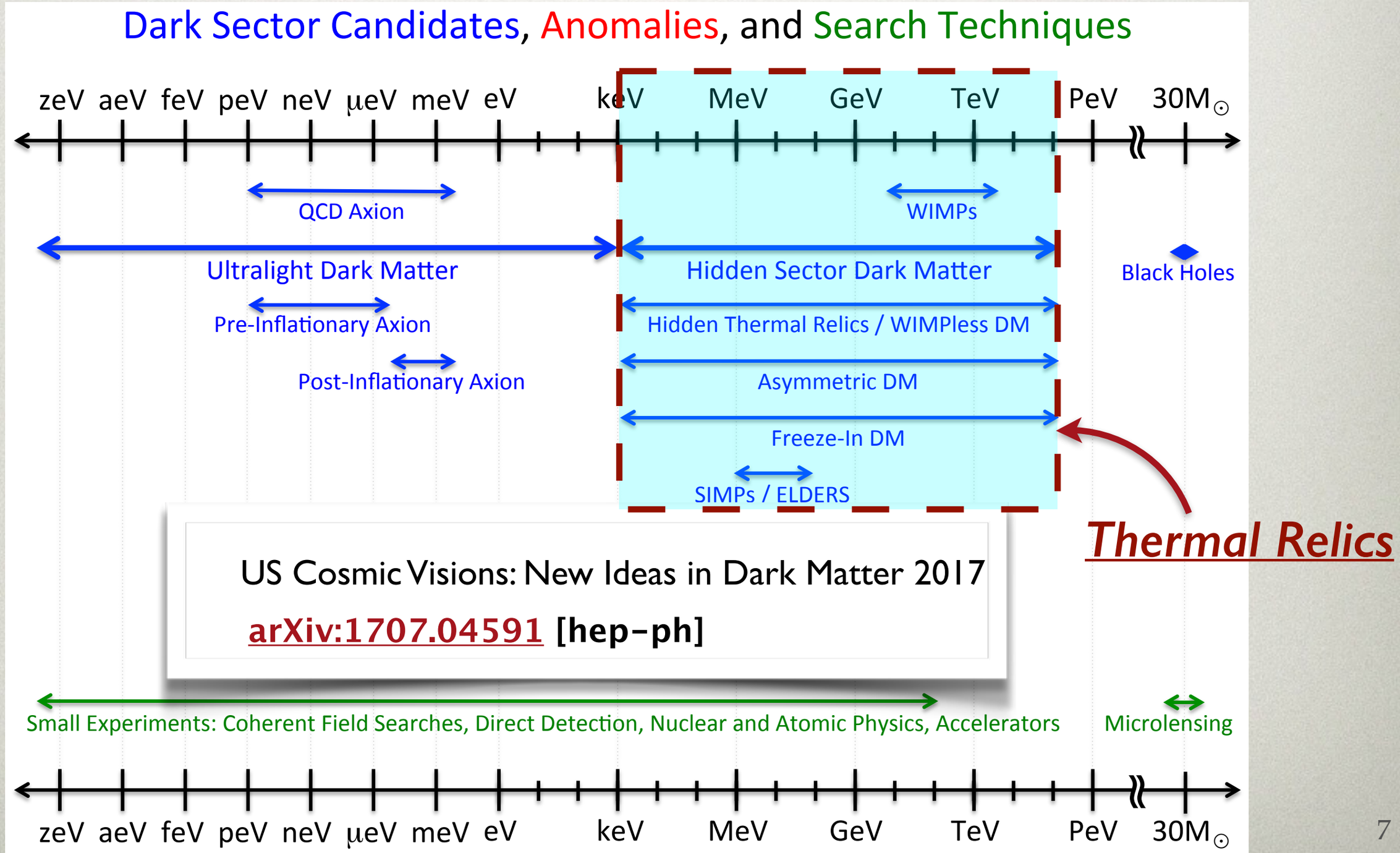
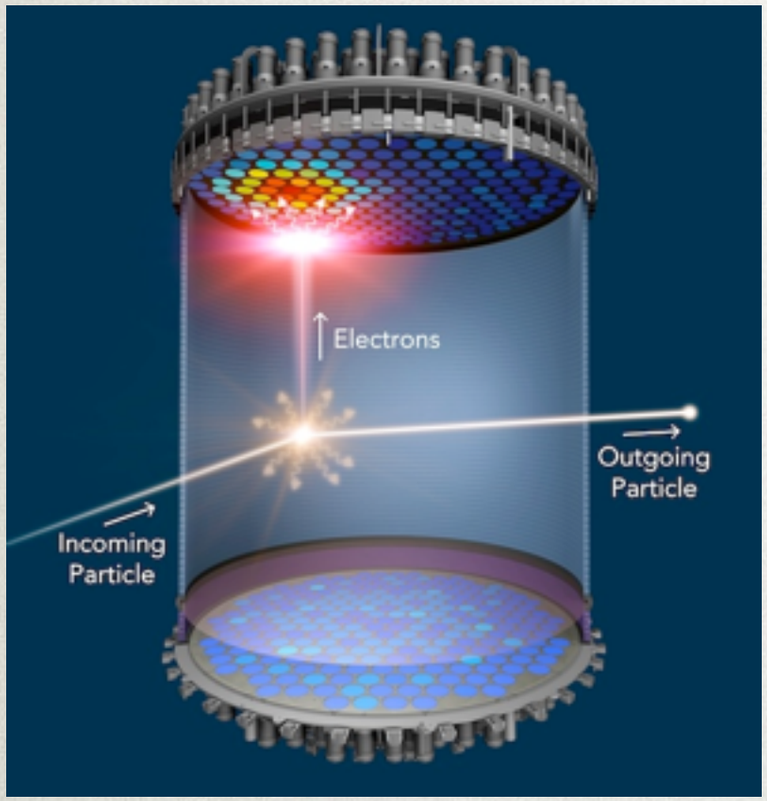
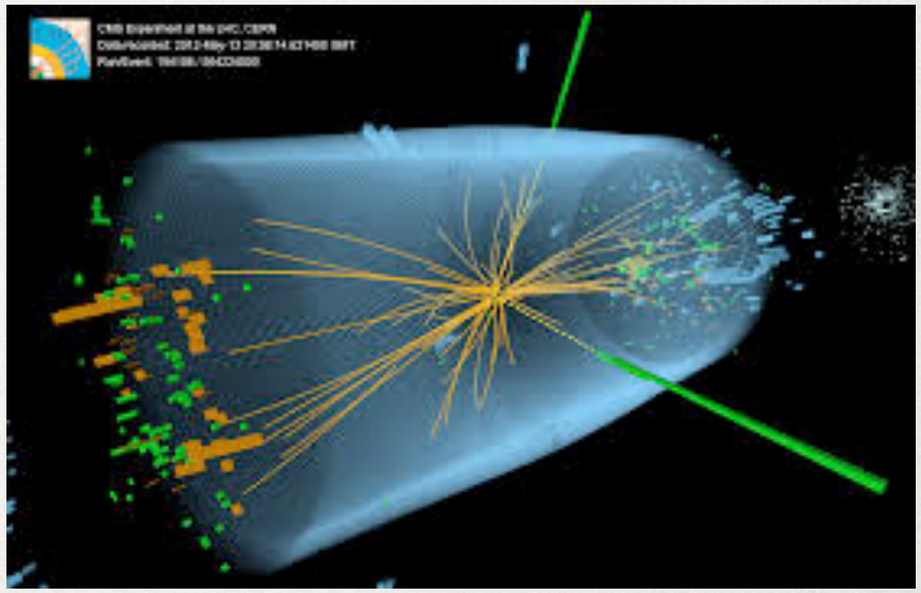


Lessons From Data



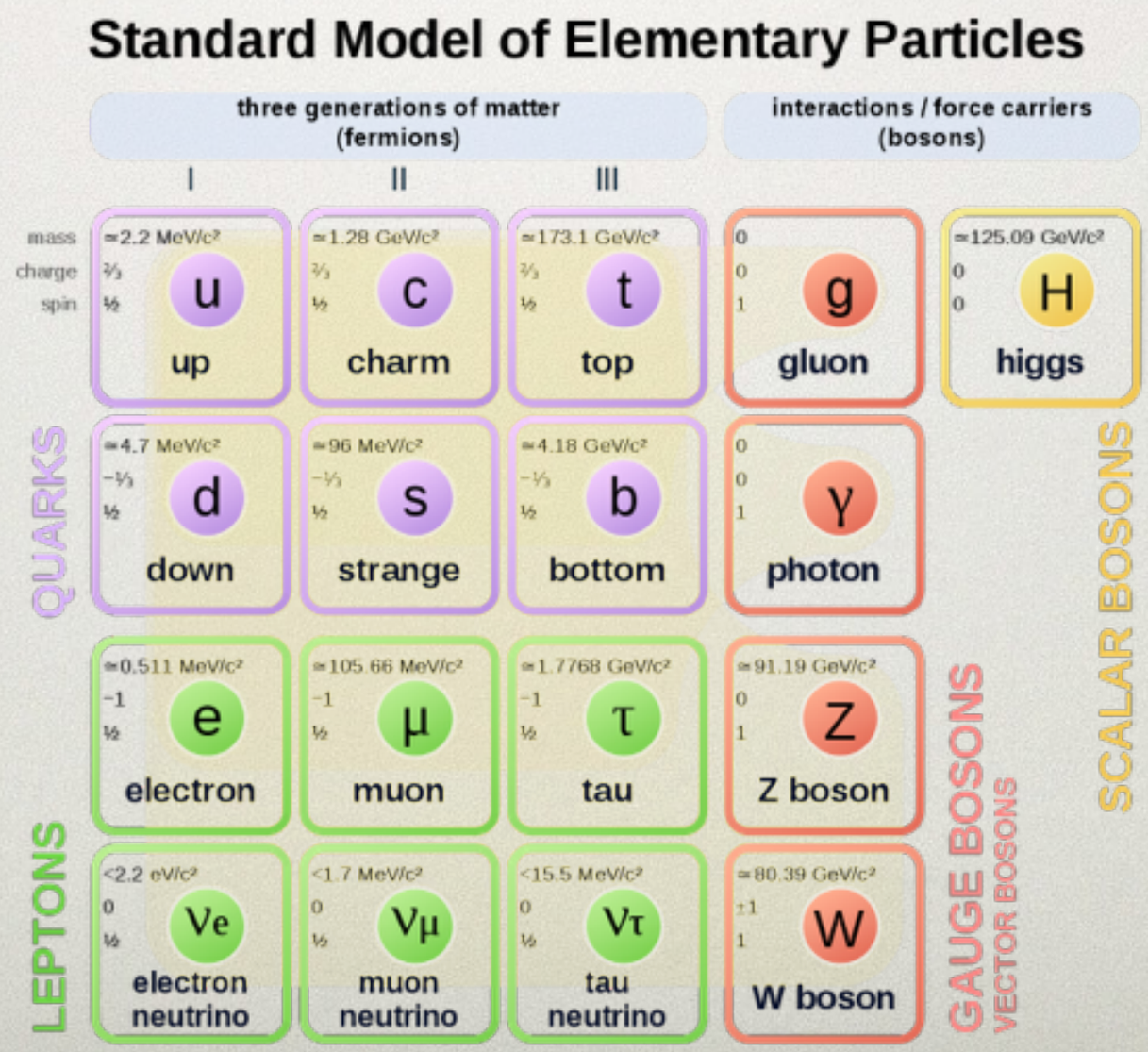


Direct detection and LHC experiments have very good sensitivity to DM interacting through W/Z/h bosons!

The ingredients most at odds with data underlying WIMPs is that they are heavy (~GeV and up) and their interactions are mediated by the W/Z bosons

Lessons From History

Known ~5% of Universe is rather interesting.
If history is any guide, expect the next ~25% to have surprises in store for us!



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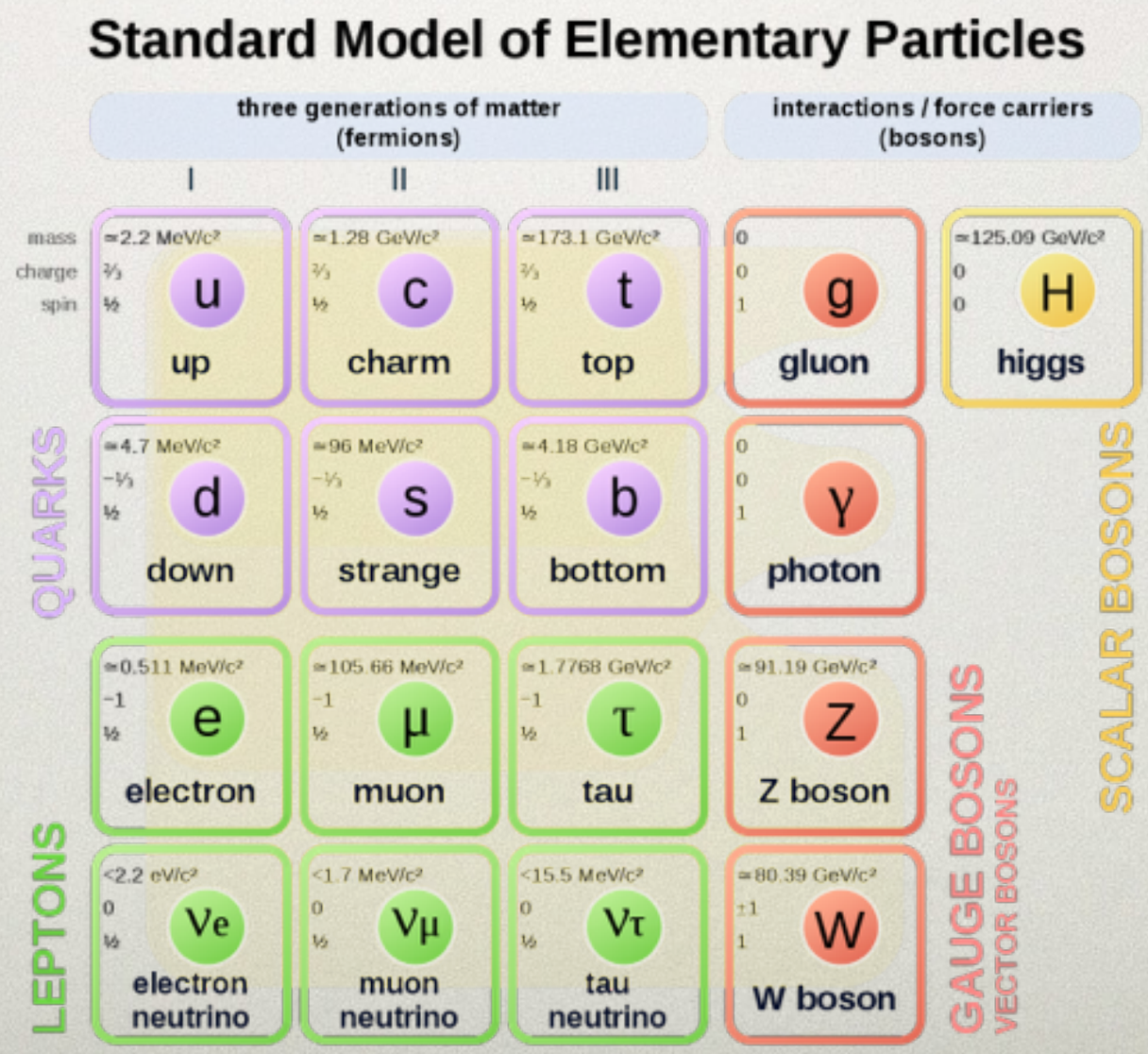
Elementary Dark Matter?
matter content?

?...	?...	DM
?...	?...	?...
?...	?...	?...
?...	?...	?...

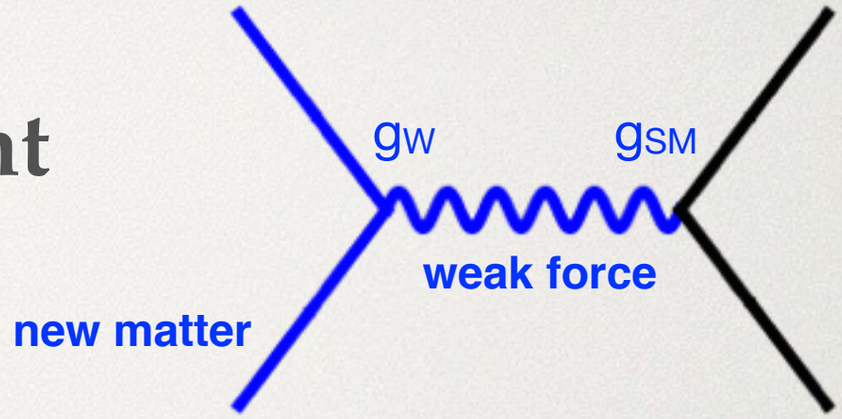


Dark Matter Force Carriers?

A'
?...
?...
?...

Lessons From History

Simple, familiar particle content



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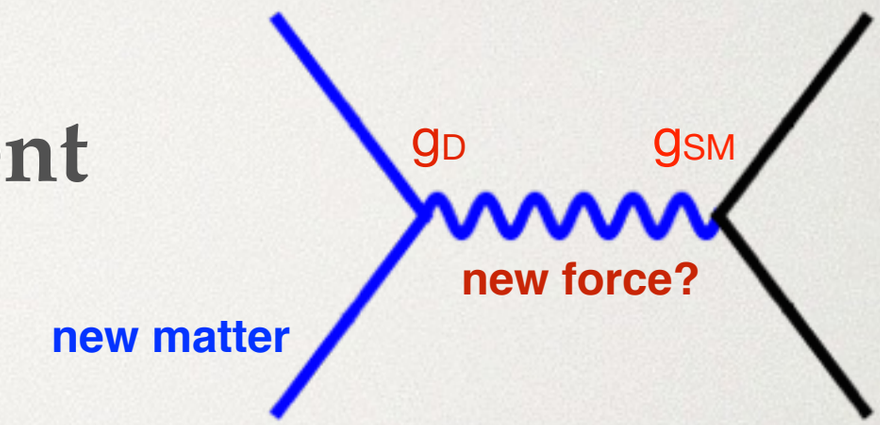
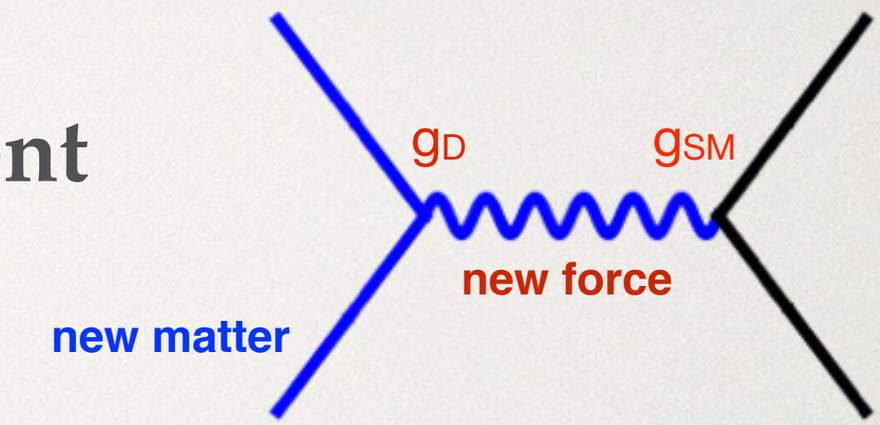


So, what if dark matter (like all other known matter) is charged under its own forces?

New Forces Interacting with The Standard Model

Simple, familiar particle content



Standard Model symmetries allow two types of (dim. 4) interactions with new force carriers at low-energy

Vector Mixing $\frac{1}{2}\epsilon_Y \, F^Y_{\mu\nu} F'^{\mu\nu}$

Higgs Mixing $\epsilon_h \, |h|^2 |\phi|^2$

+ a few other closely related possibilities…(see 1707.04591)

New Forces Interacting with The Standard Model

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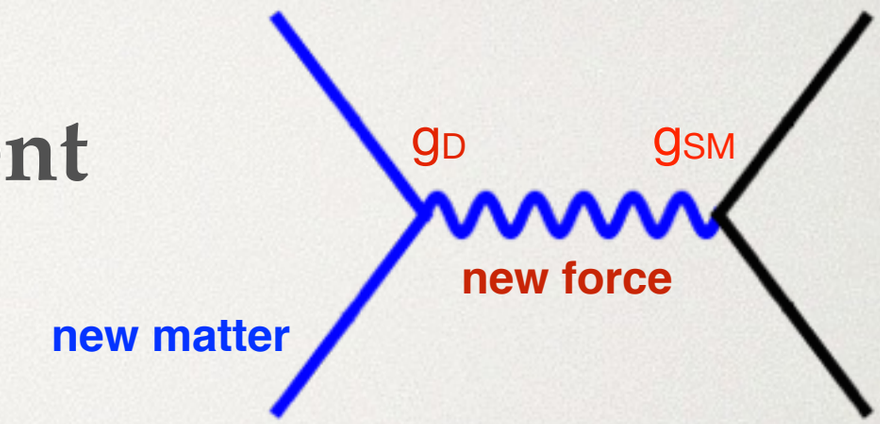

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Vector Mixing $\frac{1}{2}\epsilon_Y F^Y_{\mu\nu} F'^{\mu\nu}$

Higgs Mixing $\epsilon_h |h|^2 |\phi|^2$

Most compatible with cosmology & simple dark matter models, and illustrates much of the essential physics

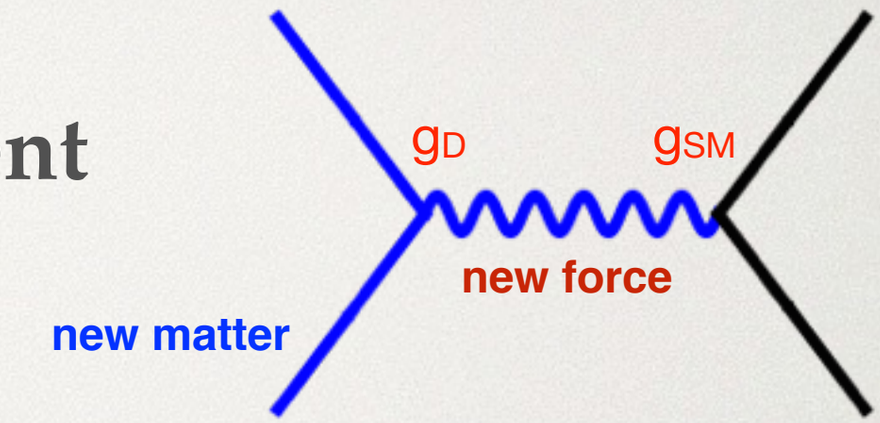
focus of this talk

Increasingly constrained by LHC

(though other scalar couplings less constrained)

Hidden Sector Dark Matter & Dark Photons

Simple, familiar particle content



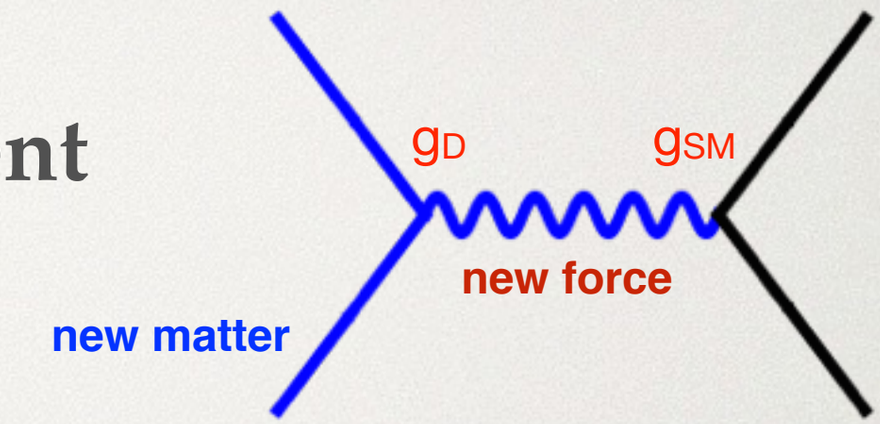
Dark Matter charged under a new force

"Dark Photons" are the simplest realization of this broad idea (captures much of the essential phenomenology!)

A Strong Candidate: Hidden Sector DM

(interacting through dark photon)

Simple, familiar particle content



Provides a familiar and simple explanation for dark matter stability (i.e. lightest charged particle is stable!)

A Strong Candidate: Hidden Sector DM

(interacting through dark photon)

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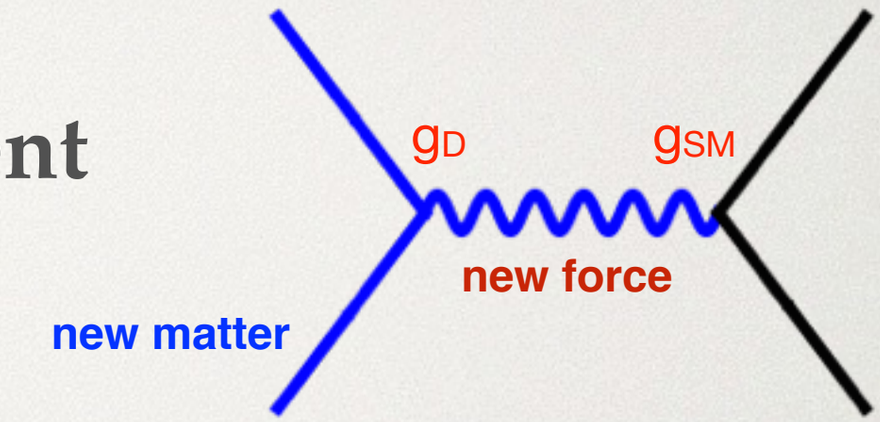
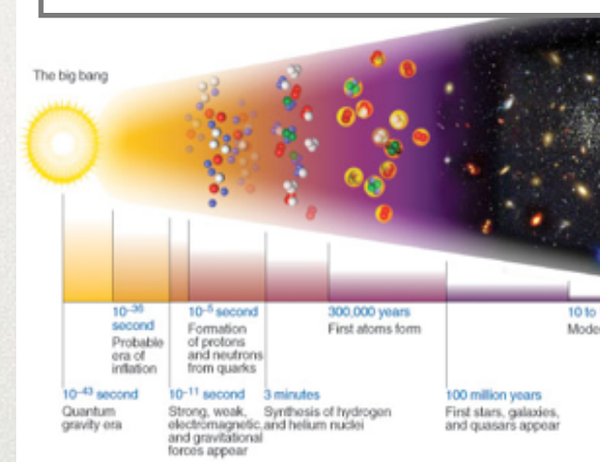
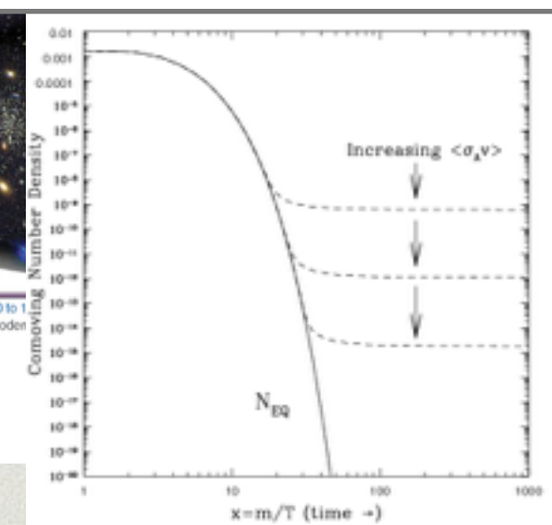


Simple, predictive cosmology

DM with thermal freeze-out origin





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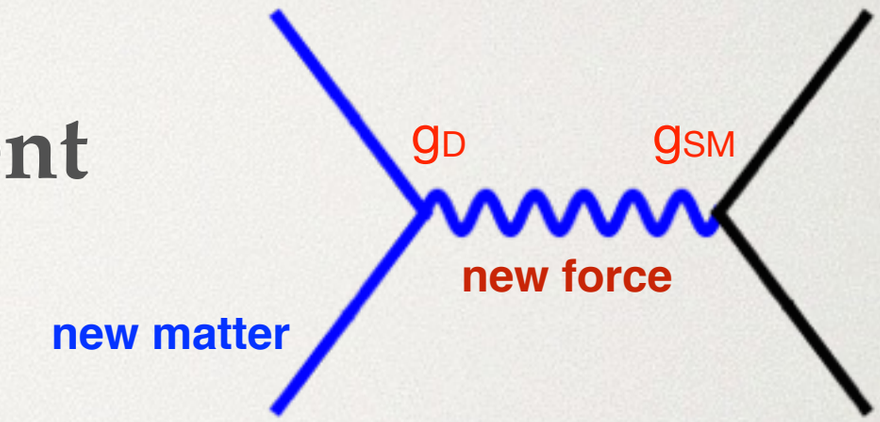

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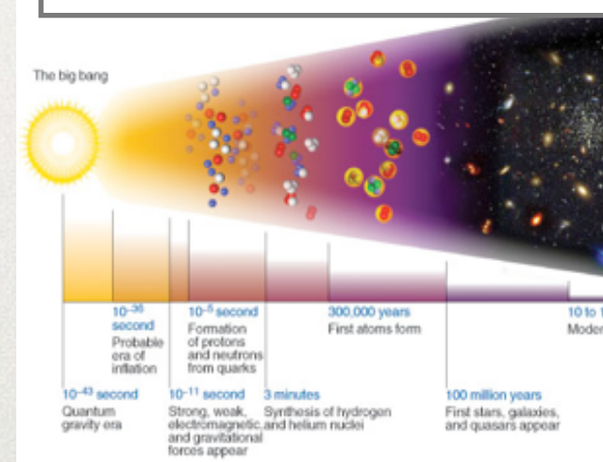
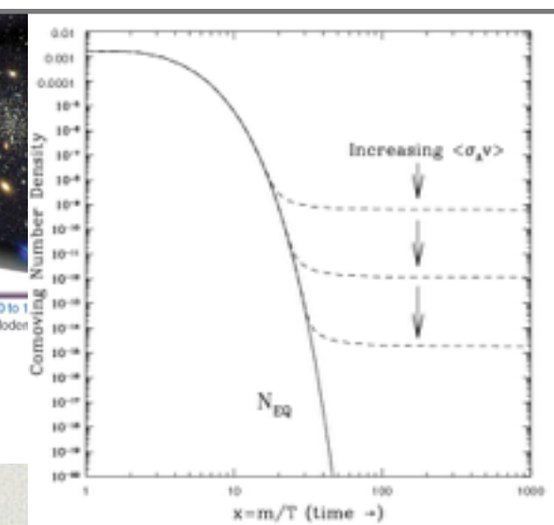
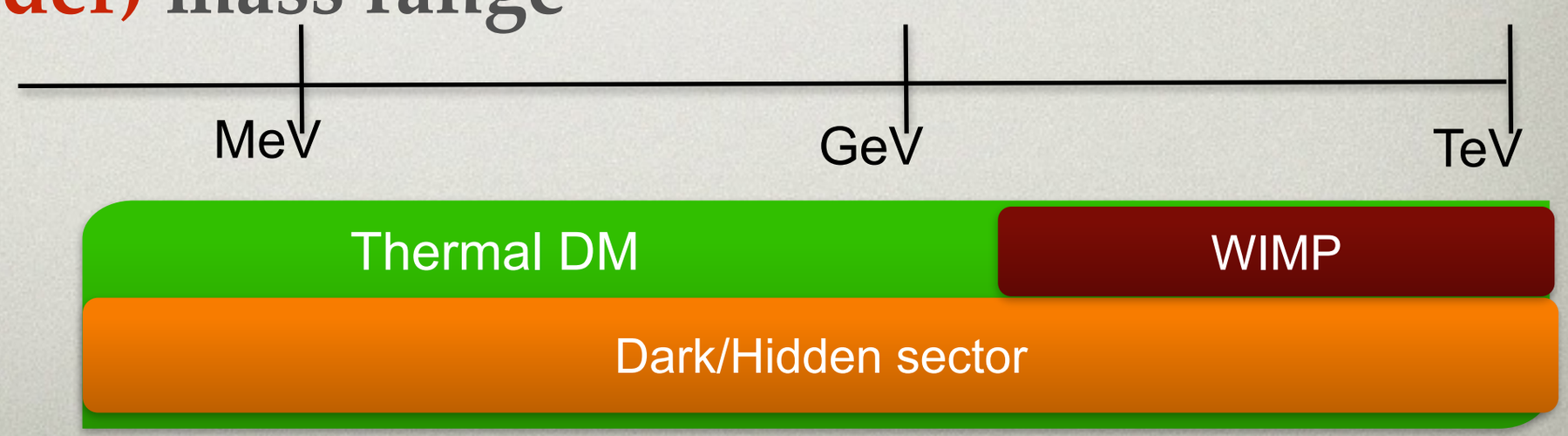


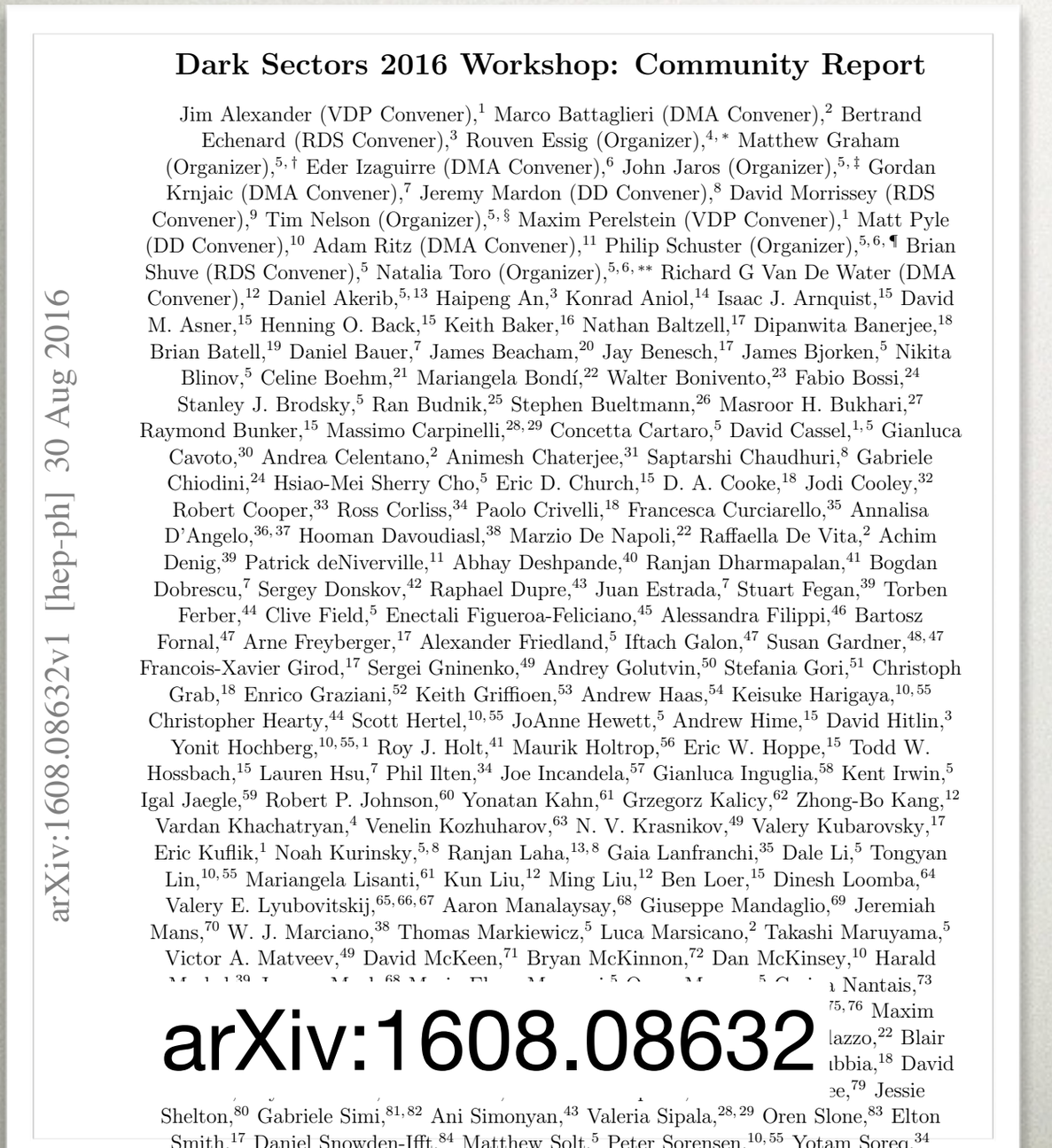


Motivated (broader) mass range



Planning Next Steps

Significant planning efforts under way in 2016-2018 to define and launch a new (small-scale) program of dark matter studies to capture the broader landscape of well-motivated possibilities

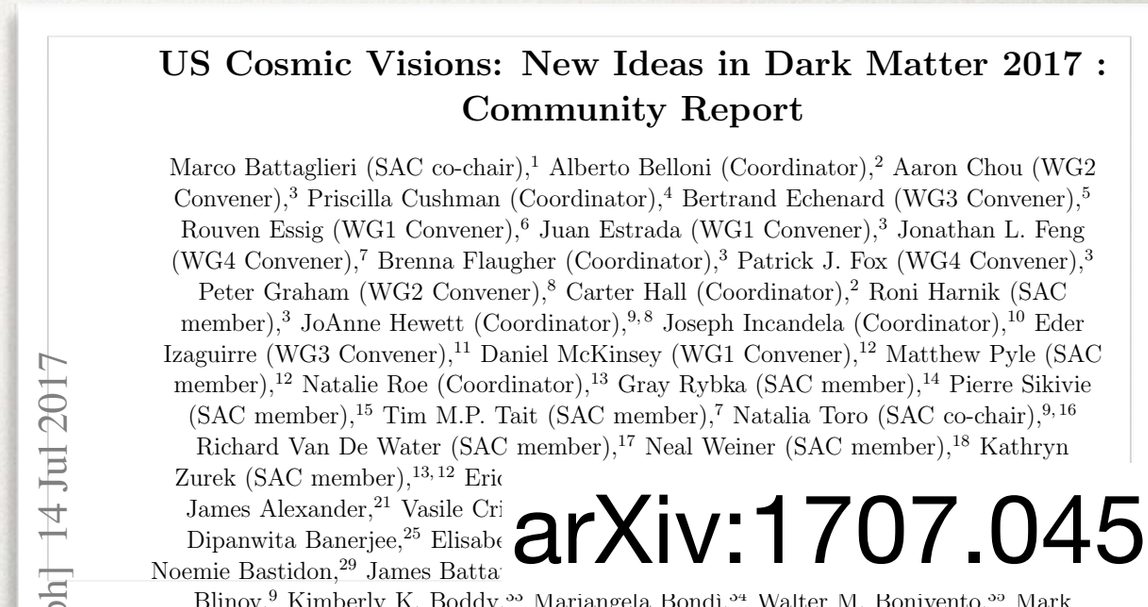


Dark Sectors 2016 Workshop: Community Report

Jim Alexander (VDP Convener),[1] Marco Battaglieri (DMA Convener),[2] Bertrand Echenard (RDS Convener),[3] Rouven Essig (Organizer),[4,*] Matthew Graham (Organizer),[5,†] Eder Izaguirre (DMA Convener),[6] John Jaros (Organizer),[5,‡] Gordan Krnjaic (DMA Convener),[7] Jeremy Mardon (DD Convener),[8] David Morrissey (RDS Convener),[9] Tim Nelson (Organizer),[5,§] Maxim Perelstein (VDP Convener),[1] Matt Pyle (DD Convener),[10] Adam Ritz (DMA Convener),[11] Philip Schuster (Organizer),[5,6,¶] Brian Shuve (RDS Convener),[5] Natalia Toro (Organizer),[5,6,**] Richard G Van De Water (DMA Convener),[12] Daniel Akerib,[5,13] Haipeng An,[3] Konrad Aniol,[14] Isaac J. Arnquist,[15] David M. Asner,[15] Henning O. Back,[15] Keith Baker,[16] Nathan Baltzell,[17] Dipanwita Banerjee,[18] Brian Batell,[19] Daniel Bauer,[7] James Beacham,[20] Jay Benesch,[17] James Bjorken,[5] Nikita Blinov,[5] Celine Boehm,[21] Mariangela Bondí,[22] Walter Bonivento,[23] Fabio Bossi,[24] Stanley J. Brodsky,[5] Ran Budnik,[25] Stephen Bueltmann,[26] Masroor H. Bukhari,[27] Raymond Bunker,[15] Massimo Carpinelli,[28,29] Concetta Cartaro,[5] David Cassel,[1,5] Gianluca Cavoto,[30] Andrea Celentano,[2] Animesh Chaterjee,[31] Saptarshi Chaudhuri,[8] Gabriele Chiodini,[24] Hsiao-Mei Sherry Cho,[5] Eric D. Church,[15] D. A. Cooke,[18] Jodi Cooley,[32] Robert Cooper,[33] Ross Corliss,[34] Paolo Crivelli,[18] Francesca Curciarello,[35] Annalisa D'Angelo,[36,37] Hooman Davoudiasl,[38] Marzio De Napoli,[22] Raffaella De Vita,[2] Achim Denig,[39] Patrick deNiverville,[11] Abhay Deshpande,[40] Ranjan Dharmapalan,[41] Bogdan Dobrescu,[7] Sergey Donskov,[42] Raphael Dupre,[43] Juan Estrada,[7] Stuart Fegan,[39] Torben Ferber,[44] Clive Field,[5] Enectali Figueroa-Feliciano,[45] Alessandra Filippi,[46] Bartosz Fornal,[47] Arne Freyberger,[17] Alexander Friedland,[5] Iftach Galon,[47] Susan Gardner,[48,47] Francois-Xavier Girod,[17] Sergei Gninenko,[49] Andrey Golutvin,[50] Stefania Gori,[51] Christoph Grab,[18] Enrico Graziani,[52] Keith Griffioen,[53] Andrew Haas,[54] Keisuke Harigaya,[10,55] Christopher Hearty,[44] Scott Hertel,[10,55] JoAnne Hewett,[5] Andrew Hime,[15] David Hitlin,[3] Yonit Hochberg,[10,55,1] Roy J. Holt,[41] Maurik Holtrop,[56] Eric W. Hoppe,[15] Todd W. Hossbach,[15] Lauren Hsu,[7] Phil Ilten,[34] Joe Incandela,[57] Gianluca Inguglia,[58] Kent Irwin,[5] Igal Jaegle,[59] Robert P. Johnson,[60] Yonatan Kahn,[61] Grzegorz Kalicy,[62] Zhong-Bo Kang,[12] Vardan Khachatryan,[4] Venelin Kozhuharov,[63] N. V. Krasnikov,[49] Valery Kubarovsky,[17] Eric Kuflik,[1] Noah Kurinsky,[5,8] Ranjan Laha,[13,8] Gaia Lanfranchi,[35] Dale Li,[5] Tongyan Lin,[10,55] Mariangela Lisanti,[61] Kun Liu,[12] Ming Liu,[12] Ben Loer,[15] Dinesh Loomba,[64] Valery E. Lyubovitskij,[65,66,67] Aaron Manalaysay,[68] Giuseppe Mandaglio,[69] Jeremiah Mans,[70] W. J. Marciano,[38] Thomas Markiewicz,[5] Luca Marsicano,[2] Takashi Maruyama,[5] Victor A. Matveev,[49] David McKeen,[71] Bryan McKinnon,[72] Dan McKinsey,[10] Harald

arXiv:1608.08632v1 [hep-ph] 30 Aug 2016

arXiv:1608.08632



US Cosmic Visions: New Ideas in Dark Matter 2017 : Community Report

Marco Battaglieri (SAC co-chair),[1] Alberto Belloni (Coordinator),[2] Aaron Chou (WG2 Convener),[3] Priscilla Cushman (Coordinator),[4] Bertrand Echenard (WG3 Convener),[5] Rouven Essig (WG1 Convener),[6] Juan Estrada (WG1 Convener),[3] Jonathan L. Feng (WG4 Convener),[7] Brenna Flaugher (Coordinator),[3] Patrick J. Fox (WG4 Convener),[3] Peter Graham (WG2 Convener),[8] Carter Hall (Coordinator),[2] Roni Harnik (SAC member),[3] JoAnne Hewett (Coordinator),[9,8] Joseph Incandela (Coordinator),[10] Eder Izaguirre (WG3 Convener),[11] Daniel McKinsey (WG1 Convener),[12] Matthew Pyle (SAC member),[12] Natalie Roe (Coordinator),[13] Gray Rybka (SAC member),[14] Pierre Sikivie (SAC member),[15] Tim M.P. Tait (SAC member),[7] Natalia Toro (SAC co-chair),[9,16] Richard Van De Water (SAC member),[17] Neal Weiner (SAC member),[18] Kathryn Zurek (SAC member),[13,12] Eric

James Alexander,[21] Vasile Cri

Dipanwita Banerjee,[25] Elisabe

Noemie Bastidon,[29] James Batta

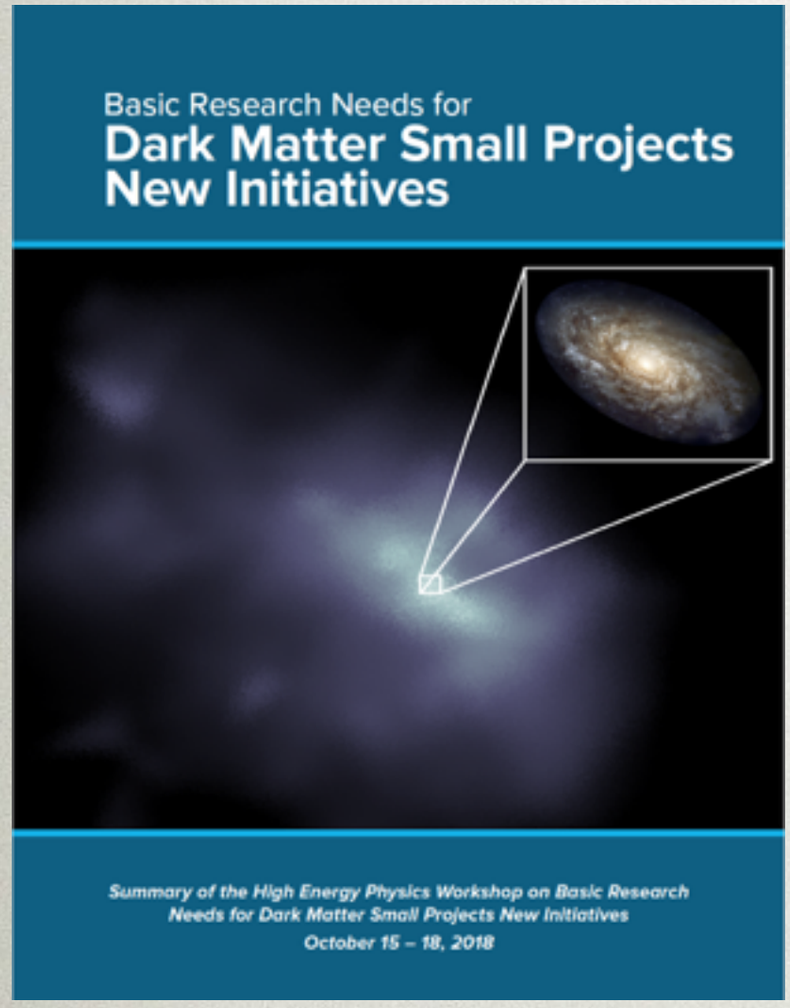
Blinov,[9] Kimberly K. Boddy,[35] Mariangela Bondì,[24] Walter M. Bonivento,[25] Mark

14 Jul 2017

arXiv:1707.04591

- Dark Sectors 2016 report — Establish the community and scope of science
- 2017 US Cosmic Visions report — Sharpen the science case and ideas for new experiments

Basic Research Needs study for Dark-Matter Small Projects



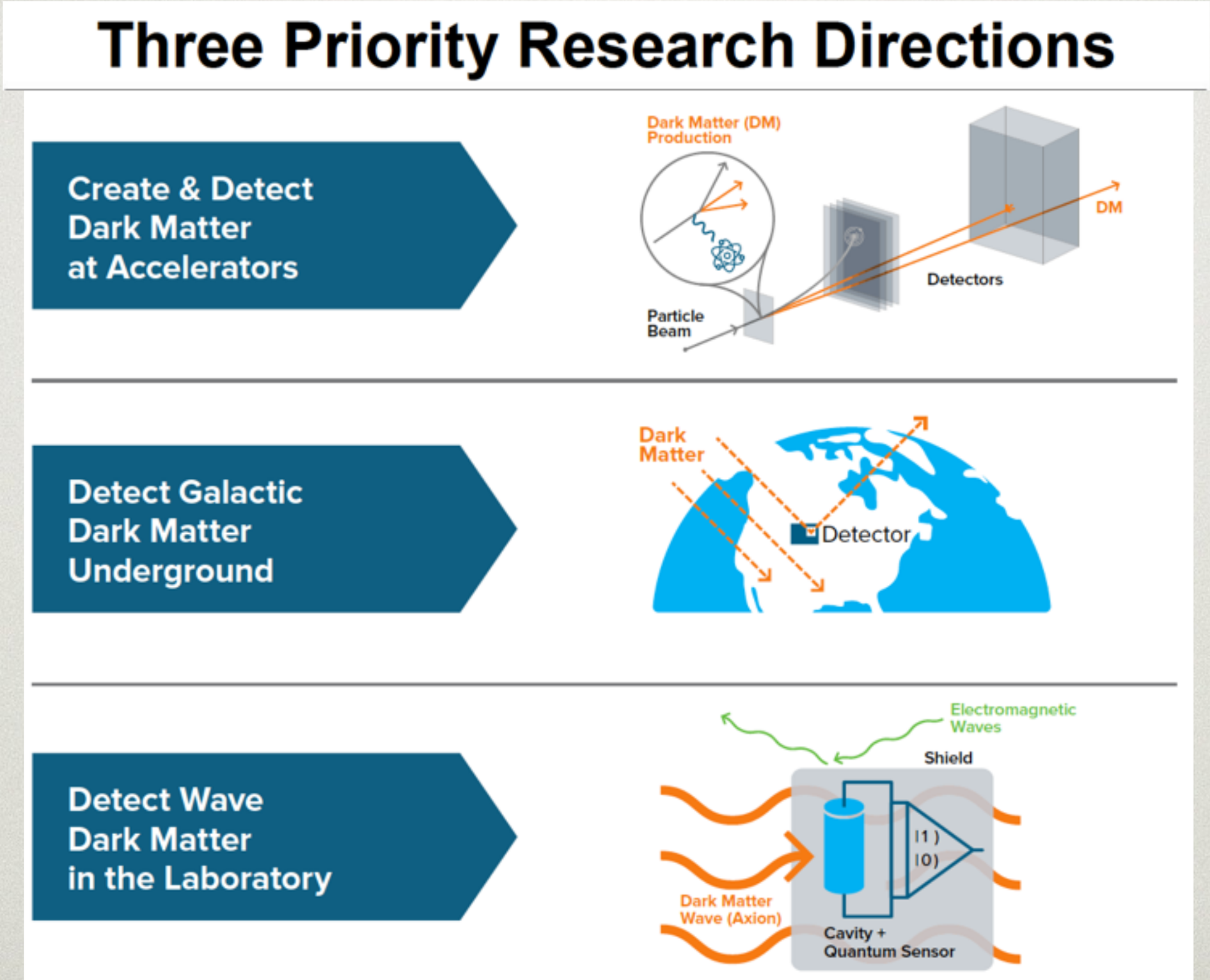
Shaped by formal DOE oHEP charge:

- Identify priority science opportunities and high impact parameter space targets
- Identify high impact opportunities which can be pursued by small projects
- Suggest opportunities that could be pursued by future small projects

HEPAP Brochure
— https://science.energy.gov/~/media/hep/hepap/pdf/201811/BRN_Dark-Matter-Brochure_HEPAP_201811.pdf

Rocky Kolb's November 2018 HEPAP talk
— https://science.energy.gov/~/media/hep/hepap/pdf/201811/RKolb-HEPAP_201811.pdf

An Emerging Program



Rocky Kolb's November 2018 HEPAP talk

— https://science.energy.gov/~/media/hep/hepap/pdf/201811/RKolb-HEPAP_201811.pdf

An Emerging Program

Priority Research Directions (alphabetical order)

- **PRD #1: Create and detect dark matter particles and associated forces below the proton mass, leveraging DOE accelerators that produce beams of energetic particles.**

  The interactions of energetic particles recreate the conditions of dark matter production in the early Universe. Small experiments using established detector technology can detect dark matter production with sufficient sensitivity to test compelling explanations for the origin of dark matter and explore the nature of its interactions. These experiments draw on the unique capabilities of multiple DOE accelerators (Continuous Electron Beam Accelerator Facility, Linac Coherent Light Source-II, Spallation Neutron Source, Los Alamos Neutron Science Center, and the Fermilab complex) to enable transformative new science without disrupting their existing programs.

- **PRD #2: Detect individual galactic dark matter particles below the proton mass through interactions with advanced, ultra-sensitive detectors.**

  Galactic dark matter passes through the earth undetected every second. Recent advances in particle theory highlight new compelling paradigms for the origin of dark matter and its detection. Revolutionary technological advances now allow us to discover individual dark matter particles ranging from the proton mass to twelve orders of magnitude below, through their interactions with electrons and nuclei in advanced detectors. New small projects leveraging these theoretical and technological advances would be carried out by using DOE laboratories, infrastructure, personnel, and underground facilities, such as the Sanford Underground Research Facility.

- **PRD #3: Detect wave dark matter using innovative technologies with emphasis on resolving a decades-old mystery of the physics inside the nucleus, the so-called "QCD axion."**

  Recent theoretical advances and developments in quantum sensors enable the search for dark matter waves over twenty-two orders of magnitude in the ultralight mass range previously inaccessible to observation. Discovery of these dark matter waves would provide a glimpse into the earliest moments in the origin of the Universe and the laws of nature at ultrahigh energies, far beyond what can be probed in particle colliders. DOE resources, infrastructure, technology capabilities, and personnel are required to achieve maximum impact.

HEPAP Brochure

— https://science.energy.gov/~/media/hep/hepap/pdf/201811/BRN_Dark-Matter-Brochure_HEPAP_201811.pdf

An Emerging Program

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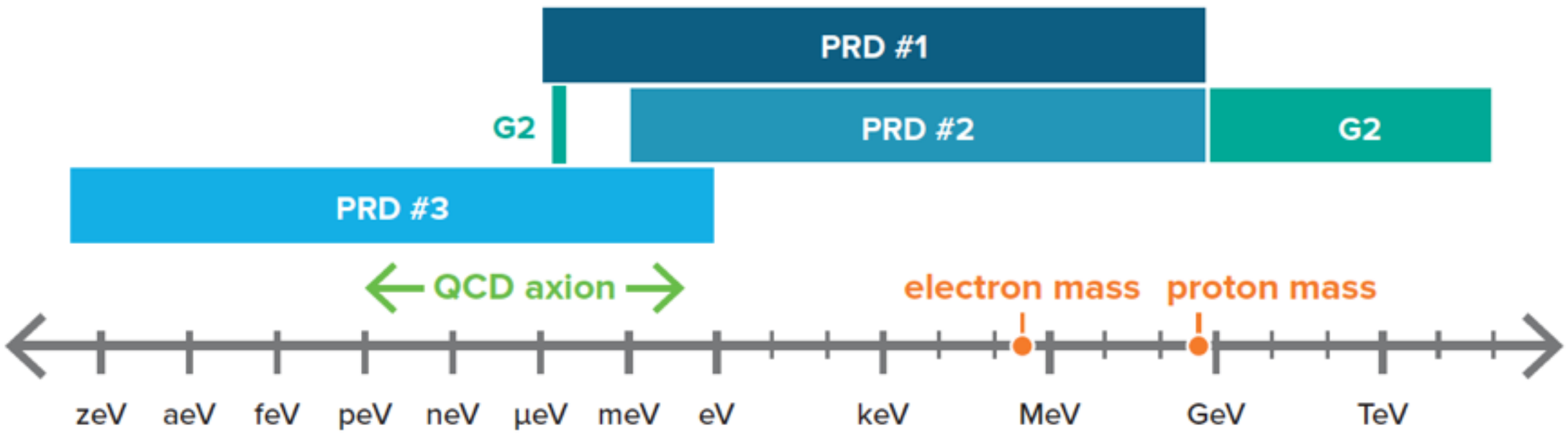

Mass range explored by the three PRDs in search for dark matter spans roughly thirty orders of magnitude, from zepto to giga electronvolts. Range for each PRD indicates regions accessible with existing technologies and regions requiring more R&D to increase detection sensitivity. All three PRDs are needed to achieve broad sensitivity and, in particular, to reach different key milestones. Mass range for G2 program included for comparison.

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All three PRD's are extremely interesting, but in the interest of time I will focus on PRD#1, as this relates directly to ongoing Jefferson Lab efforts.

Underground Research Facility.

- **PRD #3: Detect wave dark matter using innovative technologies with emphasis on resolving a decades-old mystery of the physics inside the nucleus, the so-called "QCD axion."**

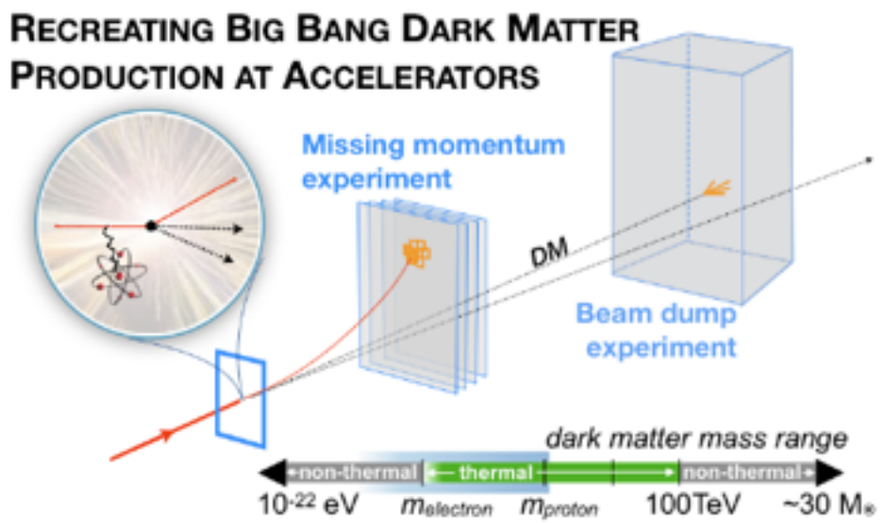
  Recent theoretical advances and developments in quantum sensors enable the search for dark matter waves over twenty-two orders of magnitude in the ultralight mass range previously inaccessible to observation. Discovery of these dark matter waves would provide a glimpse into the earliest moments in the origin of the Universe and the laws of nature at ultrahigh energies, far beyond what can be probed in particle colliders. DOE resources, infrastructure, technology capabilities, and personnel are required to achieve maximum impact.

HEPAP Brochure

— https://science.energy.gov/~/media/hep/hepap/pdf/201811/BRN_Dark-Matter-Brochure_HEPAP_201811.pdf

An Emerging Program

Create and detect dark-matter particles and associated forces below the proton mass, leveraging DOE accelerators.



Two thrusts: The first thrust exploits dark-matter production reactions to fully explore the range of dark-matter interaction strengths that could generate the observed abundance of dark matter through thermal reactions in the early Universe. The second thrust calls for broad exploration of the production of particles related to light dark matter (i.e. a dark sector) and their subsequent decays into familiar matter.

Thrust 1 (near-term): Use particle beams to explore interaction strengths singled out by thermal dark matter through 10-1000-fold improvements in sensitivity over current searches.

By improving particle-beam measurements of dark-matter's interactions with leptons and hadrons by a factor of 10–1000, most of the predictive milestones for thermal dark matter below the proton mass can be thoroughly explored.

Thrust 2 (near-term and long-term): Explore the structure of the dark sector by producing and detecting unstable dark particles.

Accelerator-based missing-momentum and beam-dump experiments are capable of producing not only dark matter, but also other related particles (the "dark sector"). Such a dark sector is needed for thermal dark matter lighter than the proton.

The science described in this PRD is motivating new efforts at laboratories around the world, including CERN, KEK, Mainz, and INFN. In this global landscape, the capabilities of the US DOE accelerator infrastructure – in particular, multi-GeV CW electron beams and high-intensity proton beams – provide unique opportunities. By leveraging existing DOE accelerator infrastructure, US small projects can provide world leading contributions to this important and vibrant new science.

Rocky Kolb's November 2018 HEPAP talk

— https://science.energy.gov/~/media/hep/hepap/pdf/201811/RKolb-HEPAP_201811.pdf

Future Goals

(in my own words!)

Key goals for accelerator experiments:

- Produce and detect sub-GeV dark matter directly
- Produce and detect sub-GeV mediator particles directly
- ***Test coupling-mass combinations directly relevant to thermal origin dark matter, in additional to broad exploration***

For sub-GeV dark matter and dark forces, achieving these goals requires experiments with low to moderate energy beams over a range of beam intensities

Future Goals

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Significant Jefferson Lab contributions!

For sub-GeV dark matter and dark forces, achieving these goals requires experiments with low to moderate energy beams over a range of beam intensities

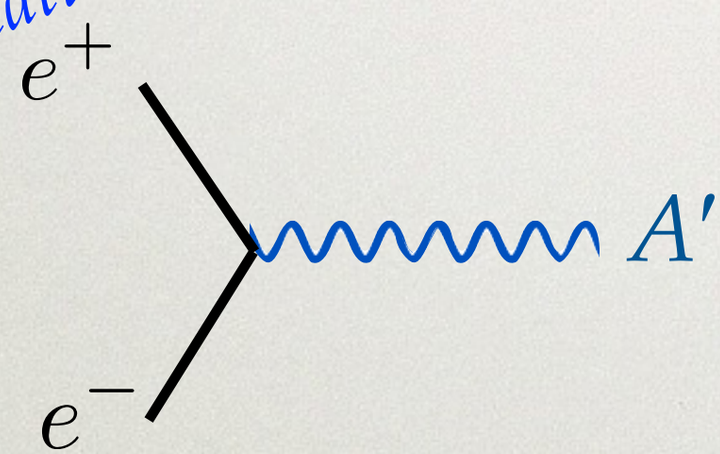
Physics of Dark Photons

Nicest (common) example is vector-photon kinetic mixing $\frac{1}{2}\epsilon_Y \, F^Y_{\mu\nu} F'^{\mu\nu}$

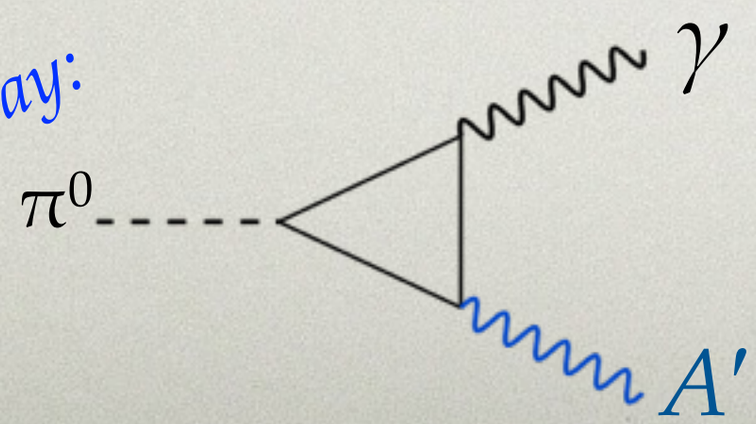
Vector mixing effectively gives matter of electric charge qe a vector A′ coupling $\propto q\varepsilon e$

$\Rightarrow$ *Wherever there are photons (and sufficient phase space), there are "dark" photons*

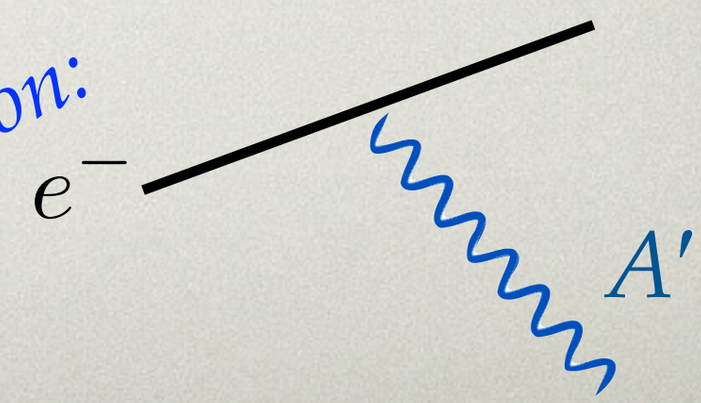
Annihilation:



Decay:

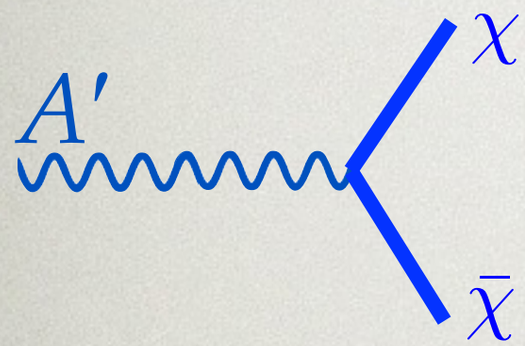


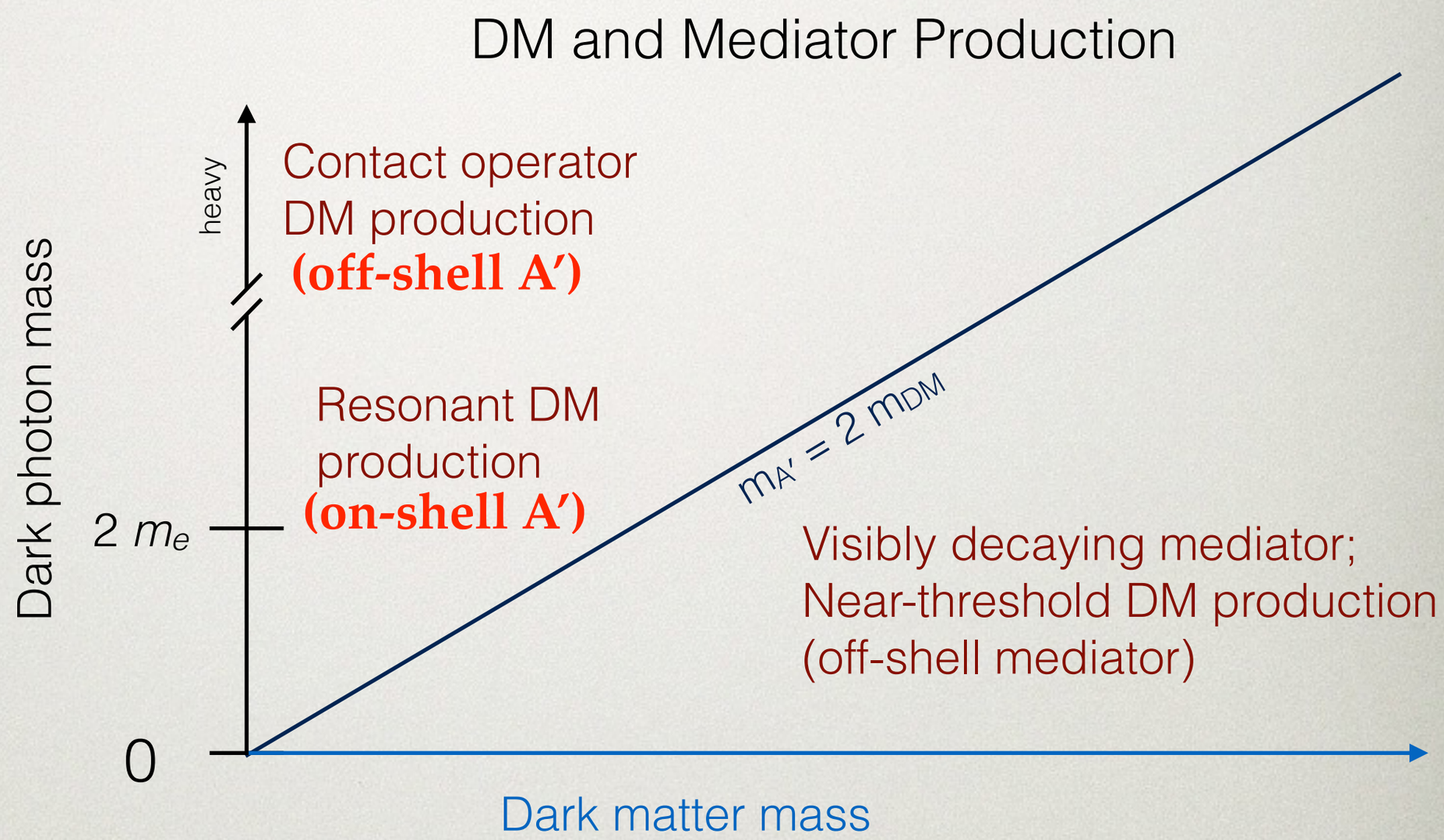
Radiation:



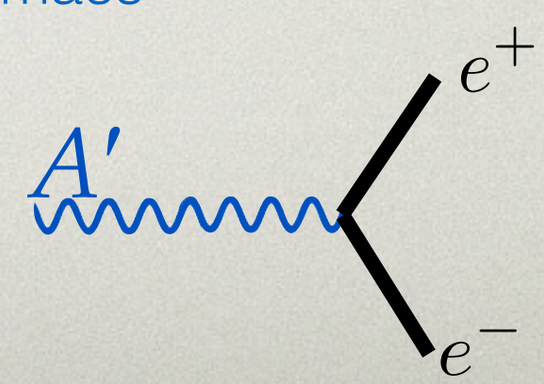
Organizing the Physics

(Vector kinetic mixing as an example — most models work similarly)



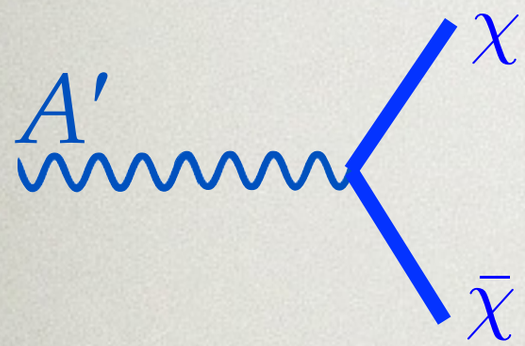


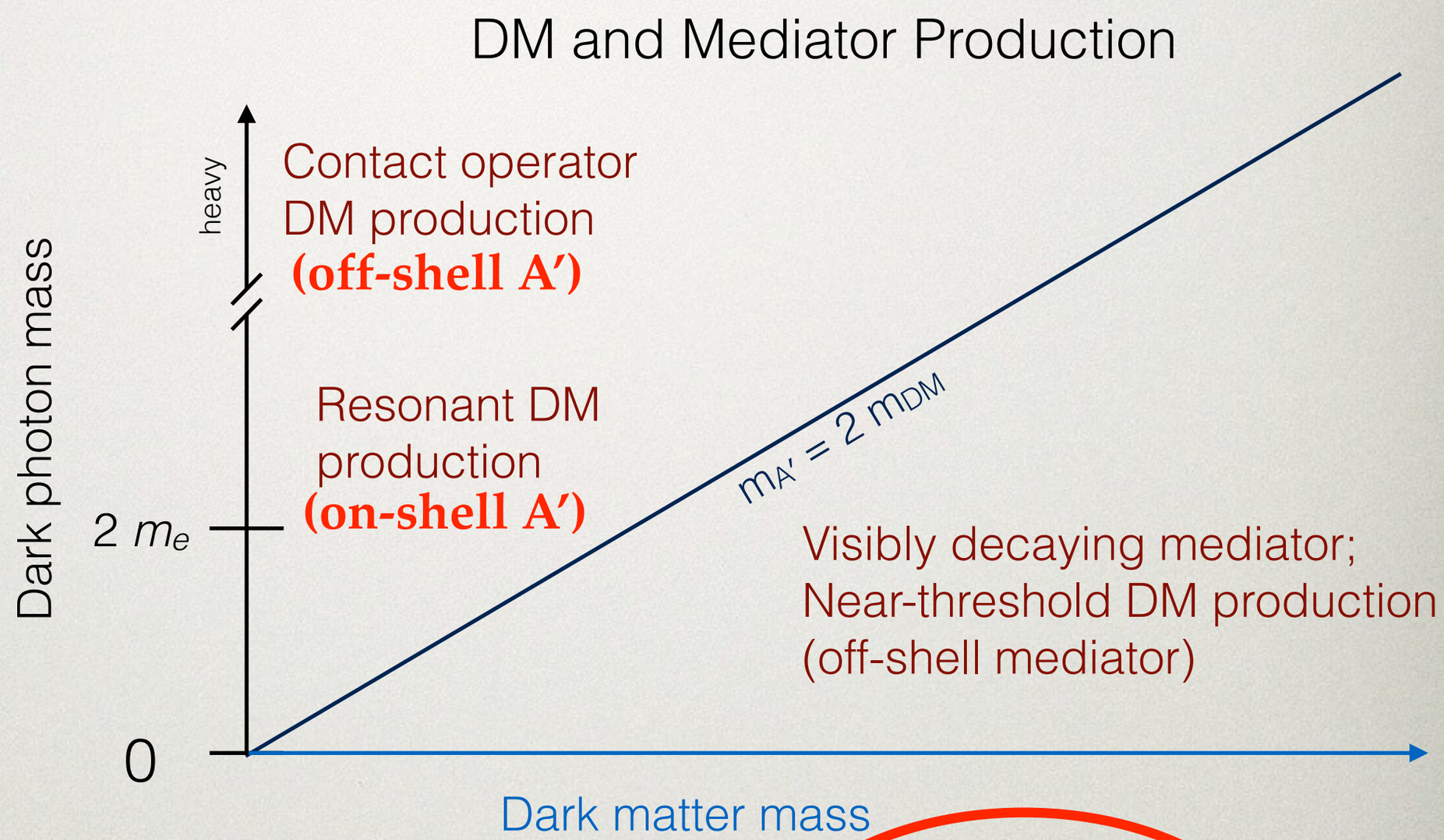
Search for both the mediator and DM itself!



Organizing the Physics

(Vector kinetic mixing as an example — most models work similarly)





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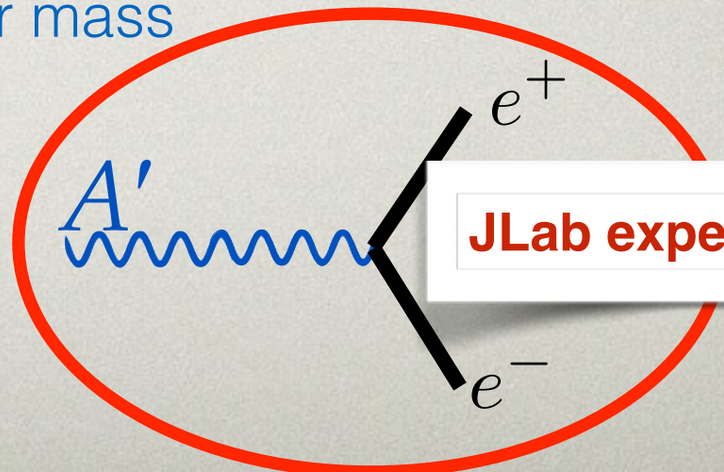
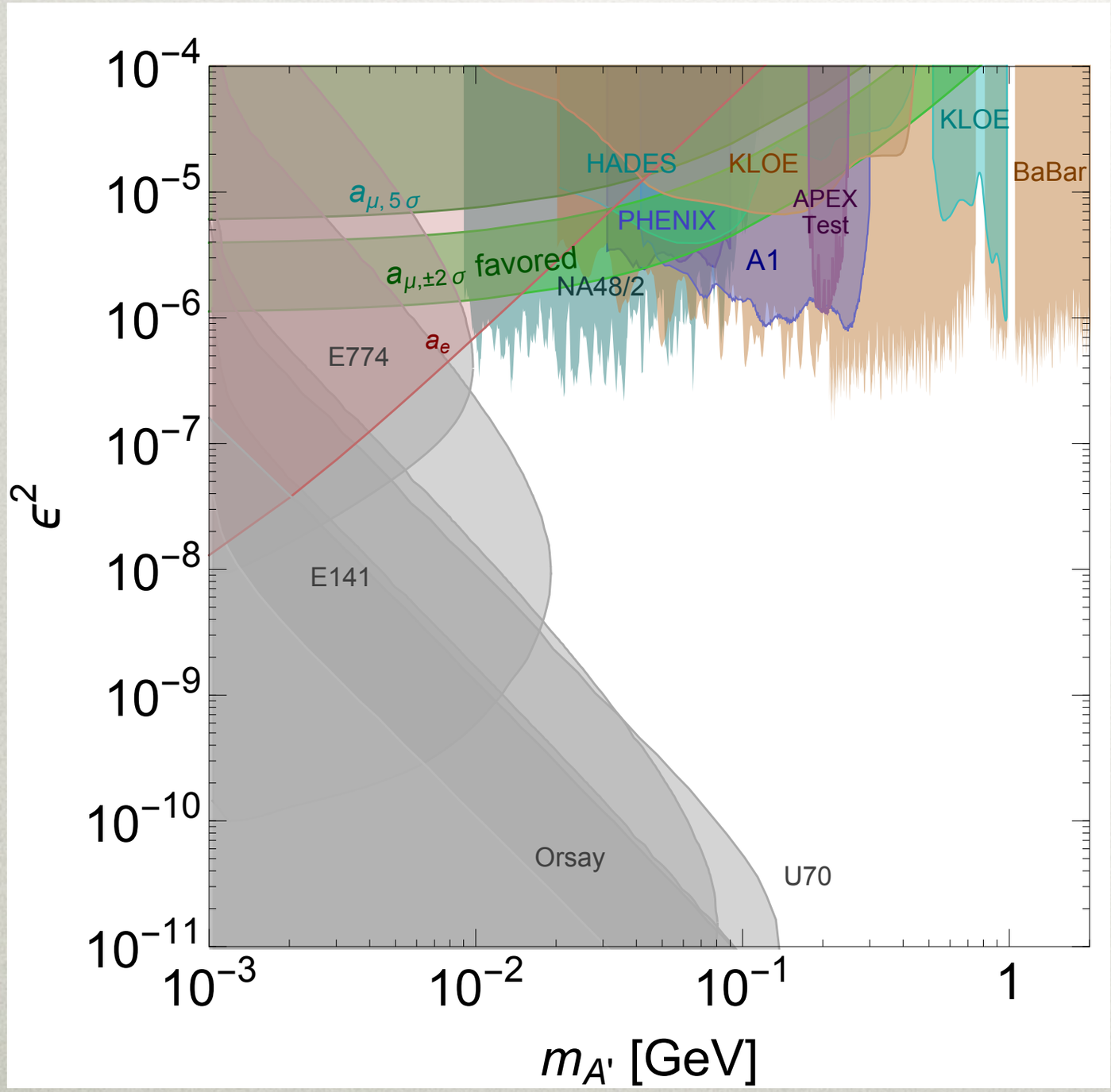
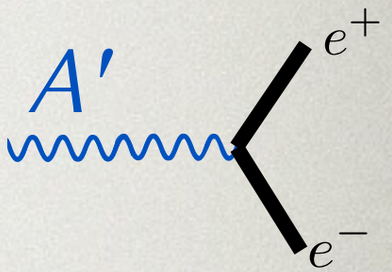


JLab experiments!

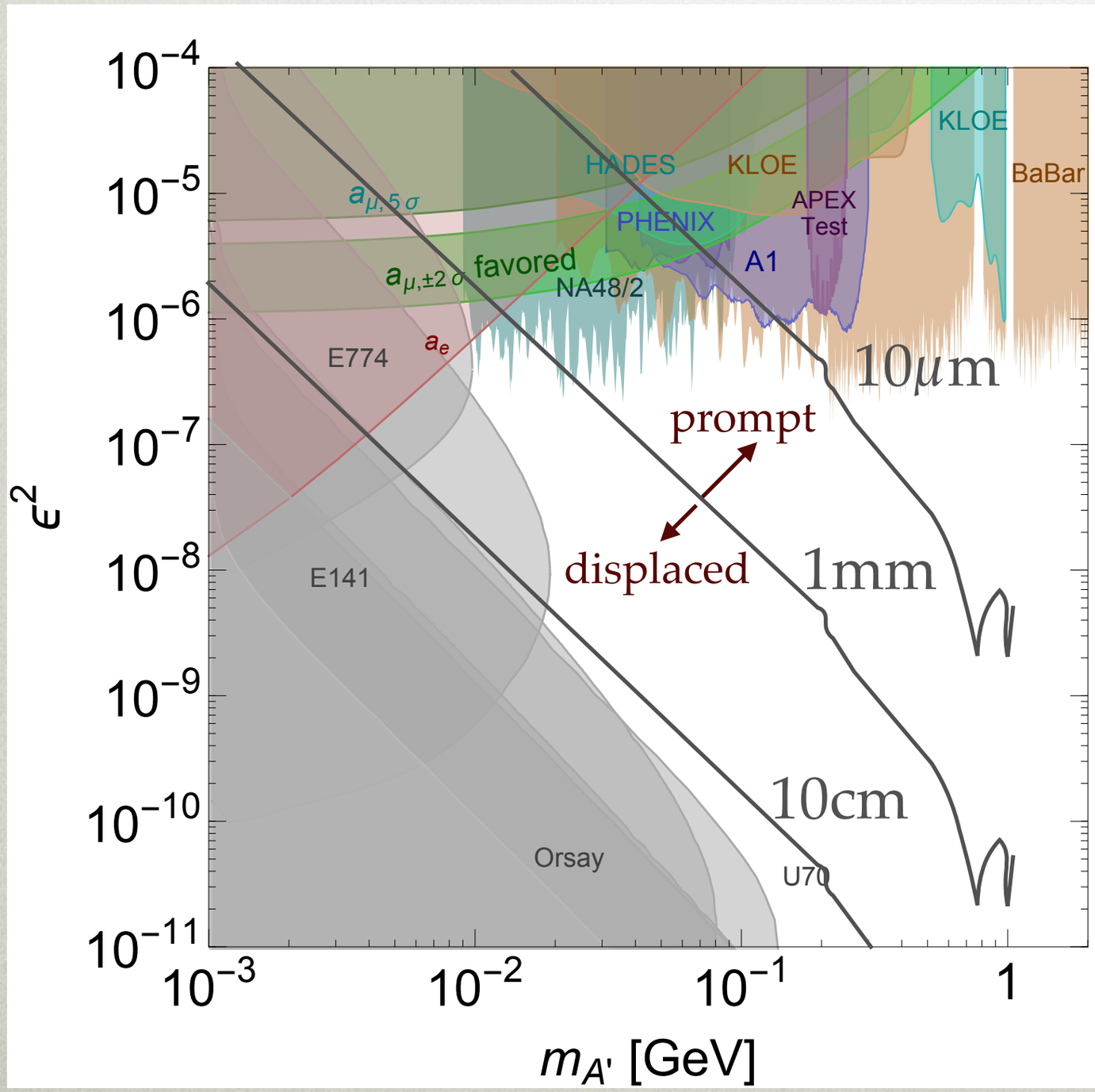
Visible "Dark Photons"

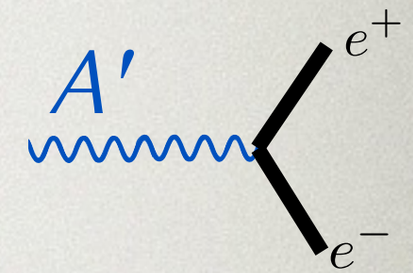




Natural parameter space is illustrated by coupling on y-axis, mediator mass on x-axis.

Visible "Dark Photons"



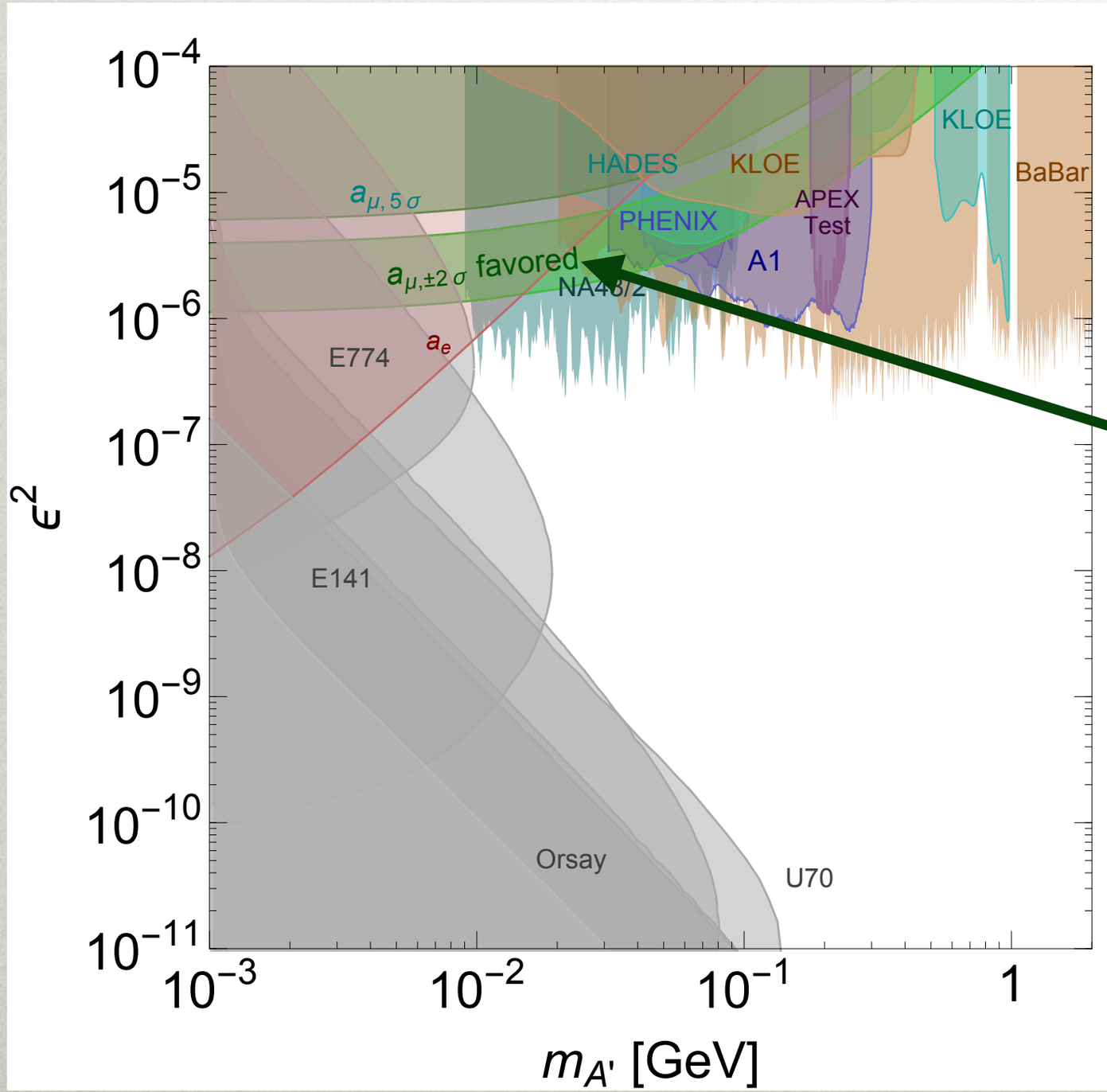


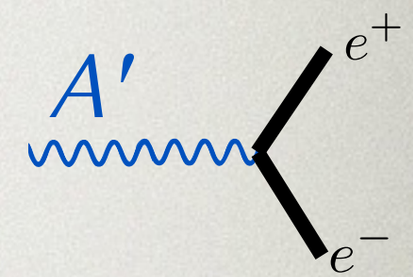
Red / green: e,μ anomalous dipole moments

All other colors: Pair resonance searches

Gray: Beam Dump

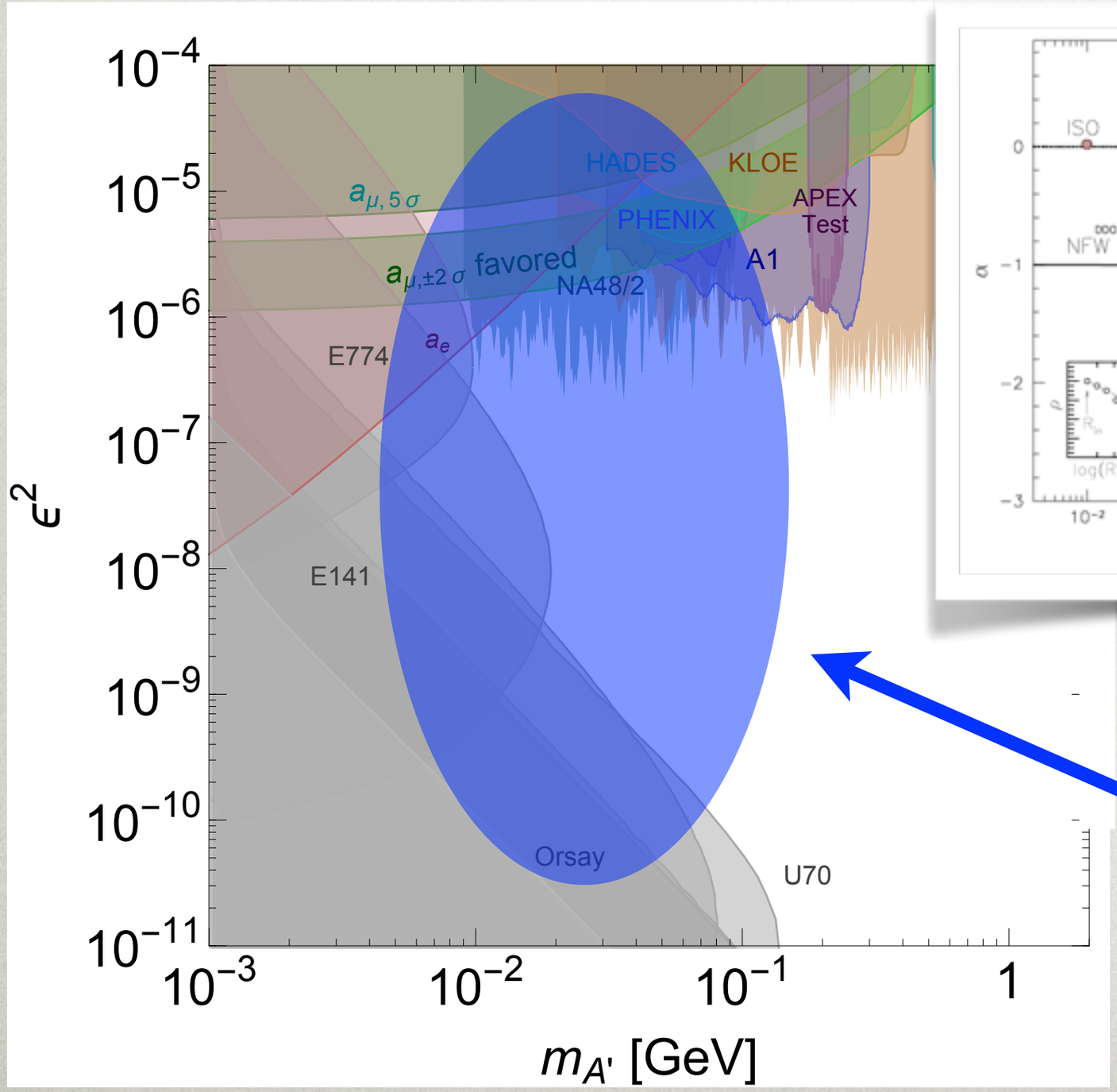
Visible "Dark Photons"

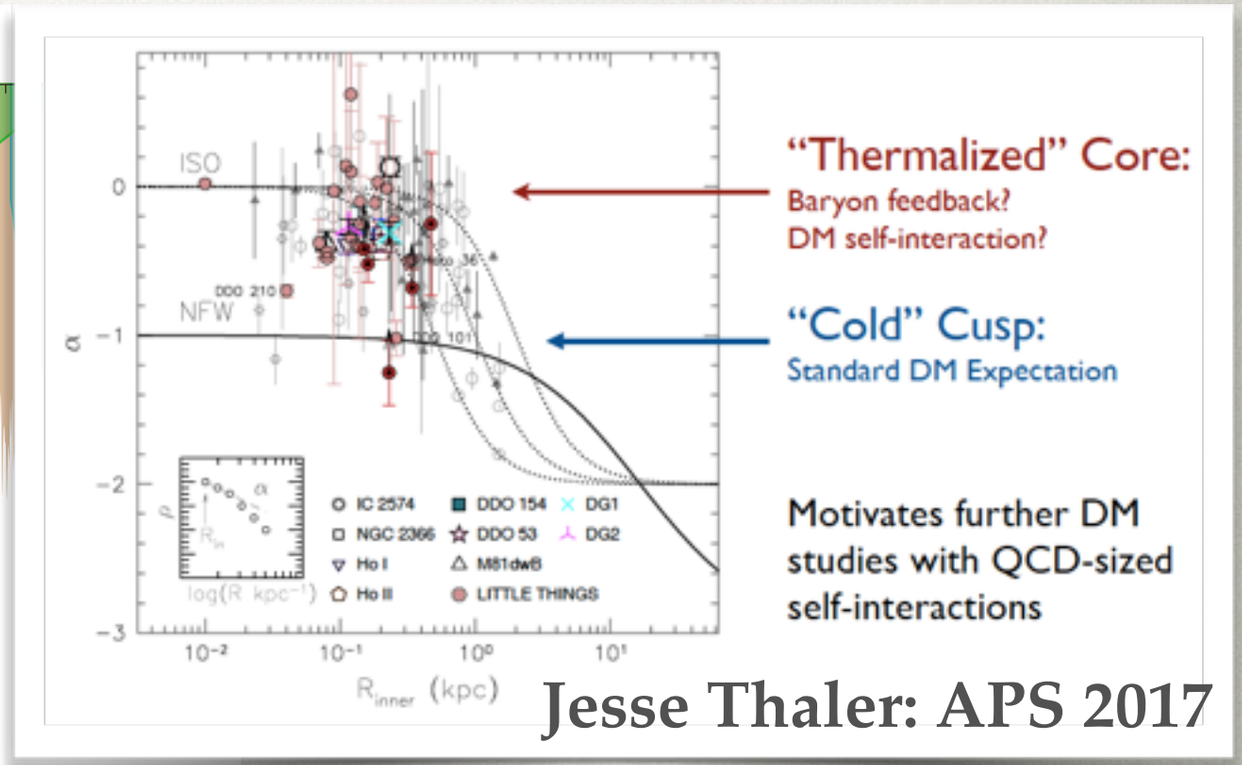




Recent accelerator experiments have tested interpretation of muon g-2 anomaly from dark photon — if it decays visibly!

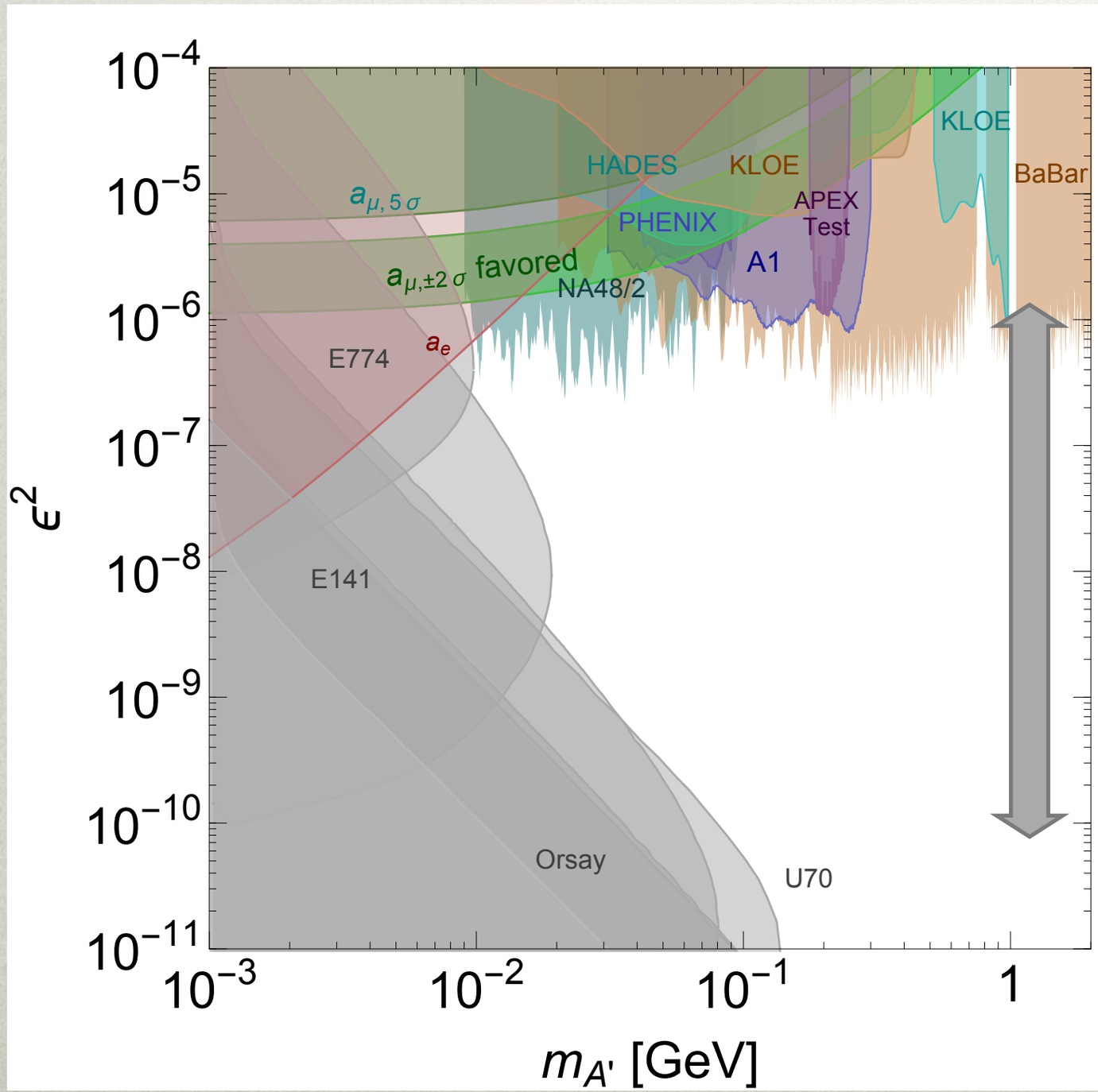
Visible "Dark Photons"

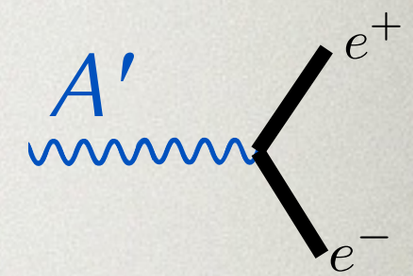




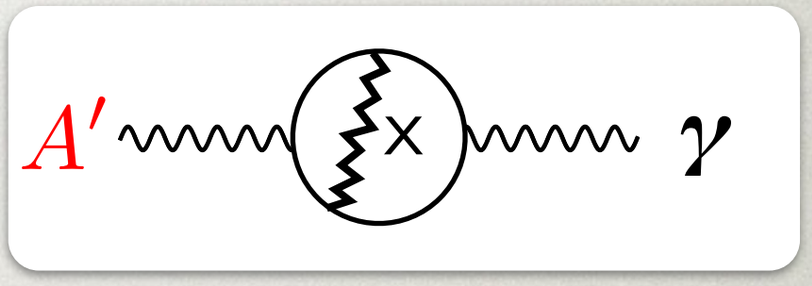
Hints from measured structure for DM self-interactions

Visible "Dark Photons"



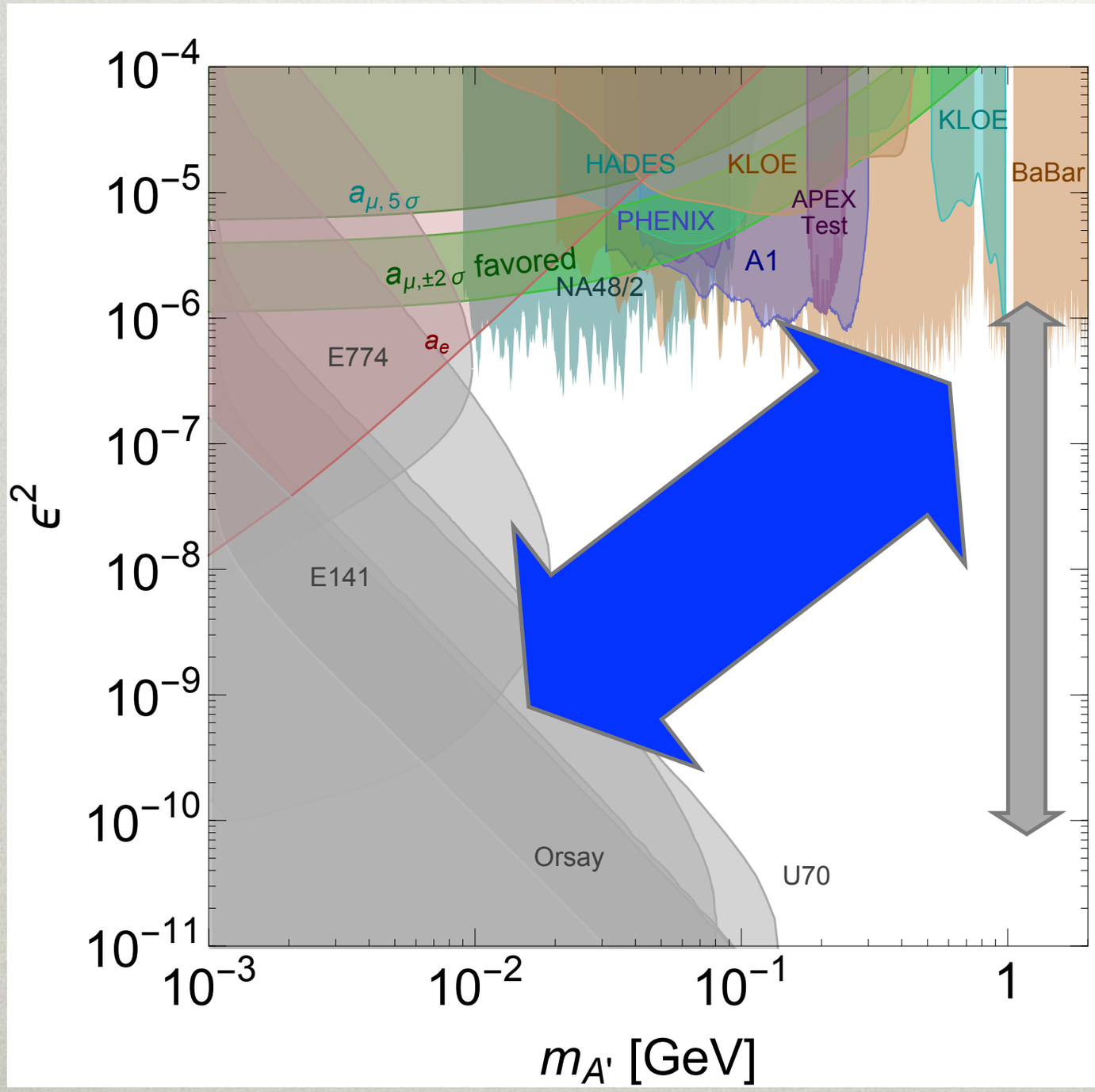


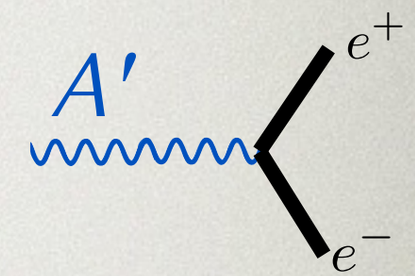
Mixing in Grand Unified Theories



Tree-level and one-loop forbidden.
2-loop mixing is expected!

Visible "Dark Photons"

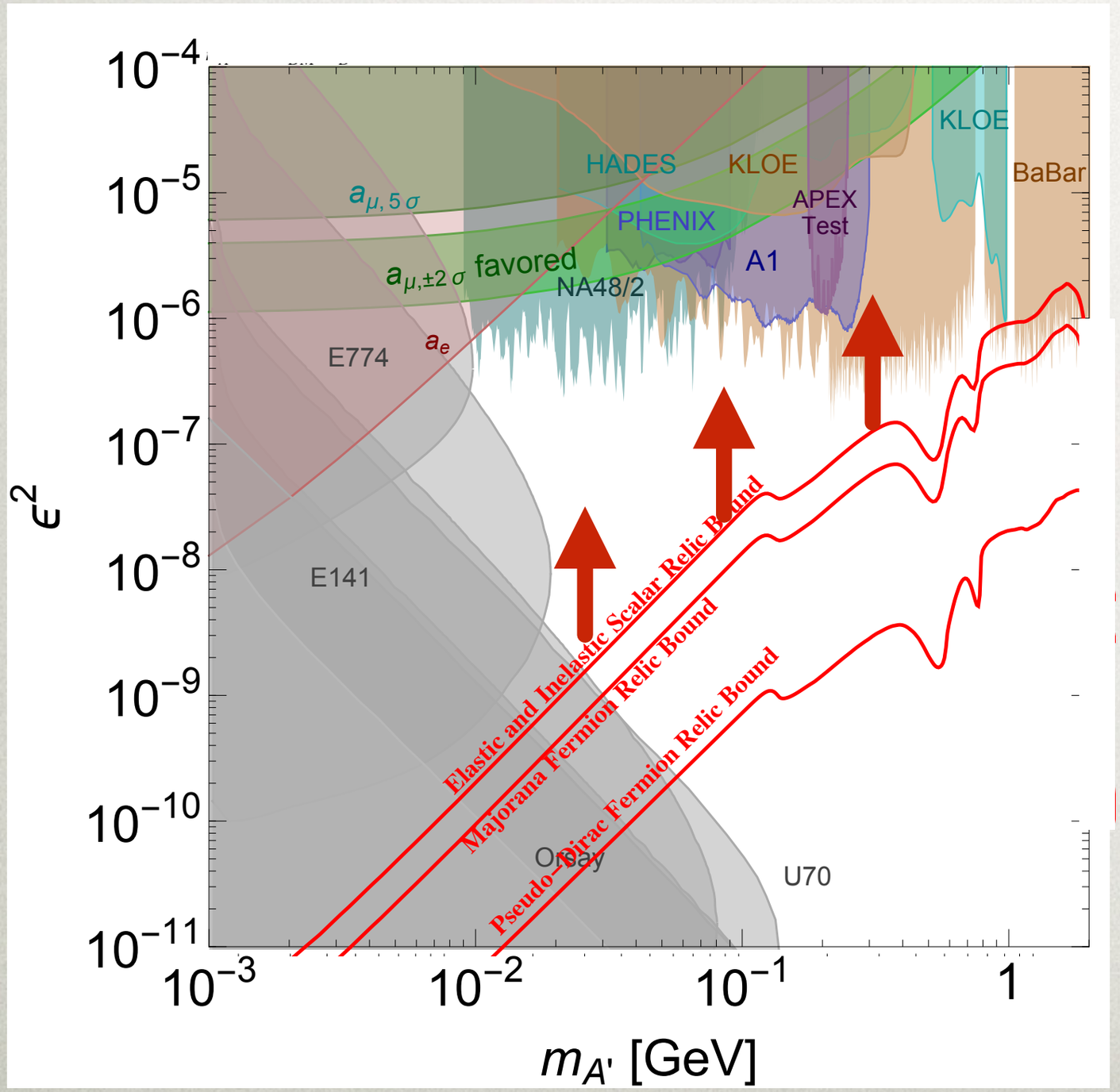




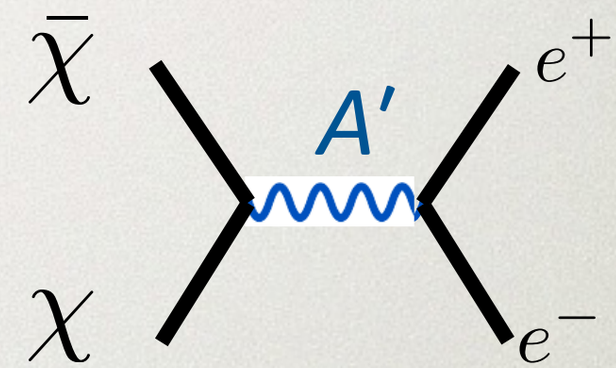
Mixing in Grand Unified Theories

sub-GeV mass scale compatible with epsilon magnitude coupling to SM Higgs

Visible "Dark Photons"



Early universe thermal freeze-out cross-section bounded by DM abundance



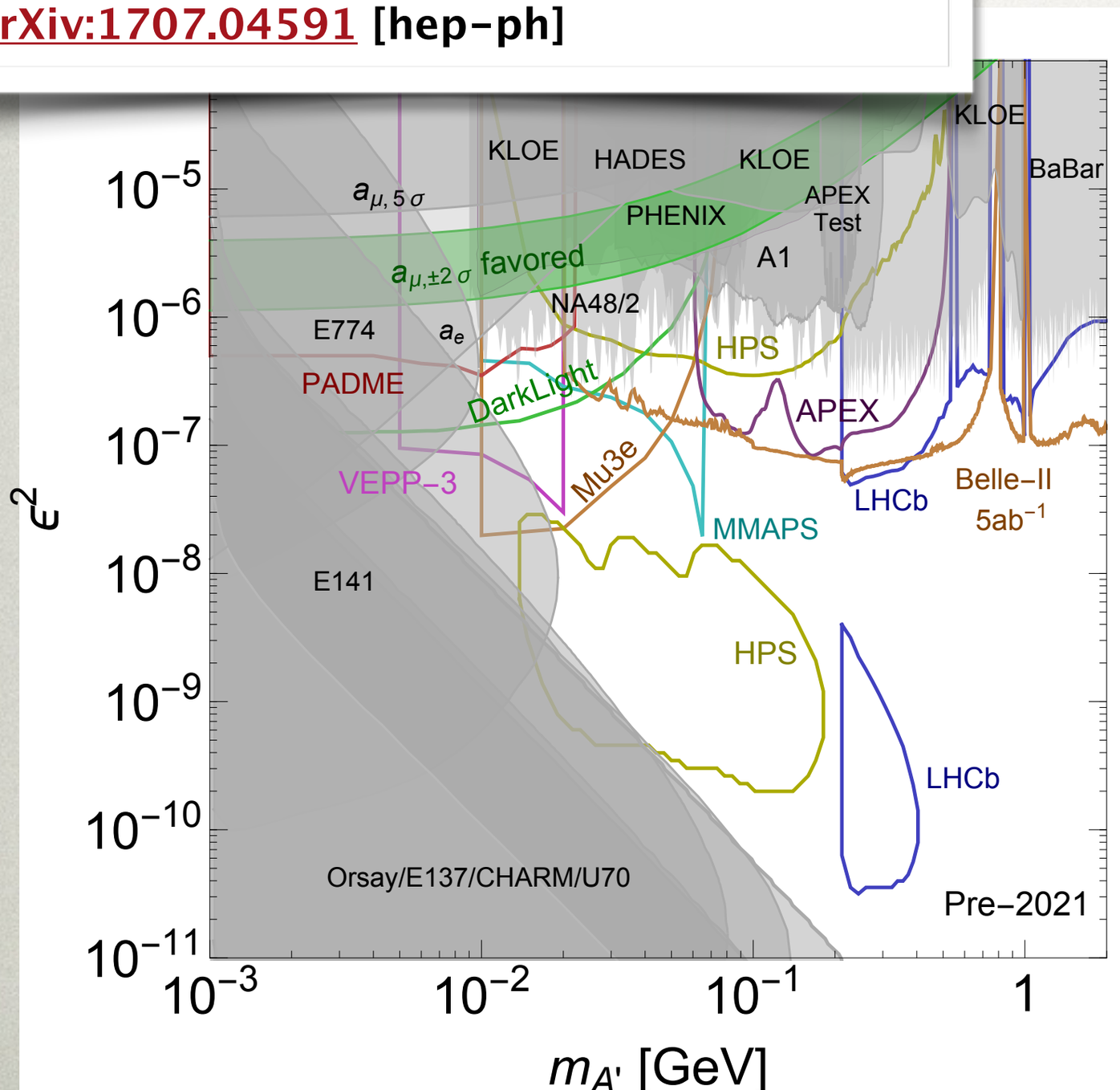
$$\sigma v \sim \alpha_D \epsilon^2 \alpha \times \frac{m_\chi^2}{m_{A'}^4}$$

For part of DM-A' mass range, provides a <u>lower limit</u> on mediator coupling vs mass!

Near Future Opportunities!

US Cosmic Visions: New Ideas in Dark Matter 2017

arXiv:1707.04591 [hep-ph]



Incredible progress expected with next round of small-scale experiments

* GUT-level coupling
* well-motivated mass range
* thermal dark matter region of interest
* (not discussed) Be8, EDGES…

Program is multi-purpose — will uniquely test many models beyond kinetic mixing and beyond vector mediators!

Dark Sectors at JLab: 2019

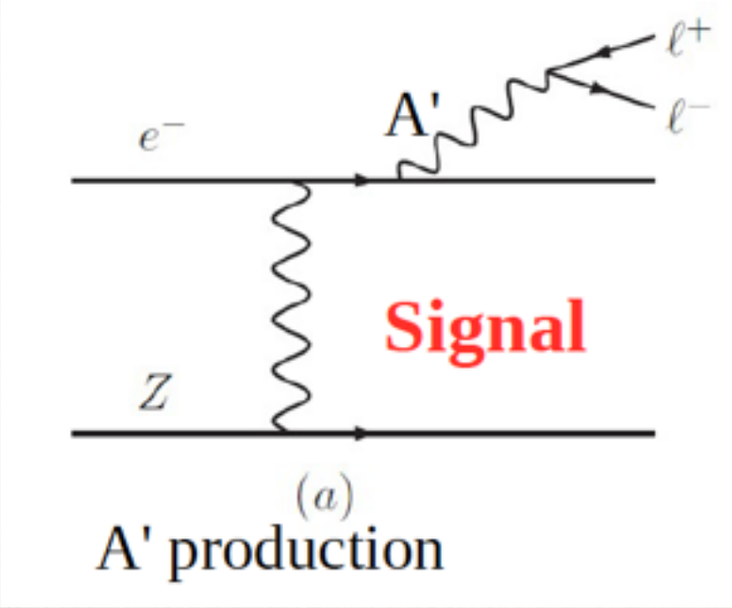
Two Jefferson Lab experiments that address dark matter/dark sector physics goals have upcoming runs in 2019!

APEX — “A Prime EXperiment" in Hall A (February-March run!)

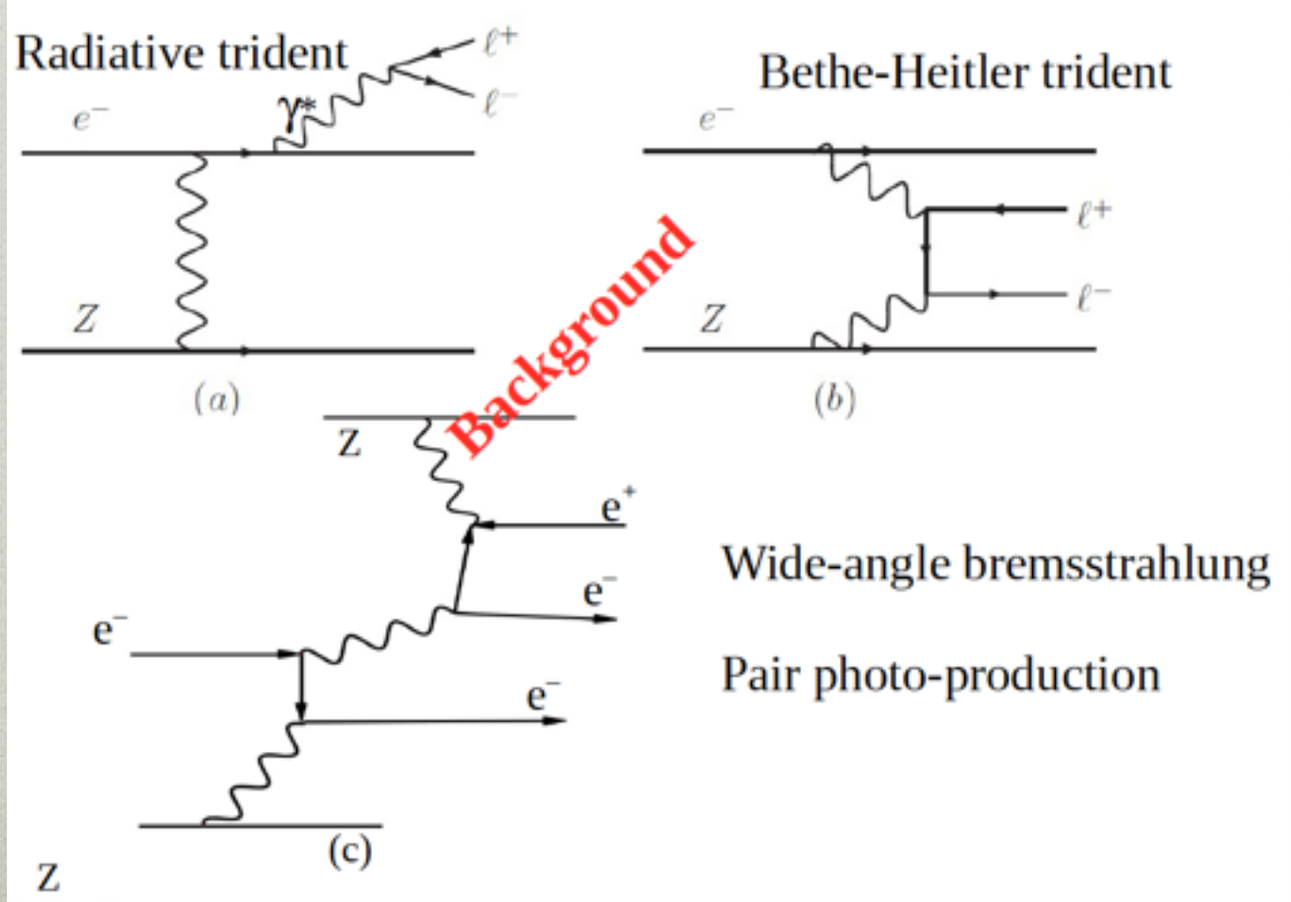
HPS — “Heavy Photon Search” in Hall B (June-August run!)

I’ll describe the approach common to these experiments first

Dark Sectors at JLab: 2019

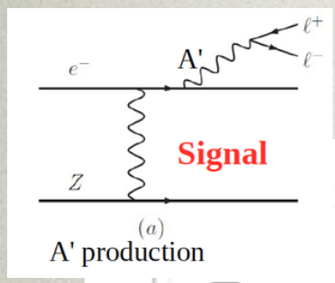


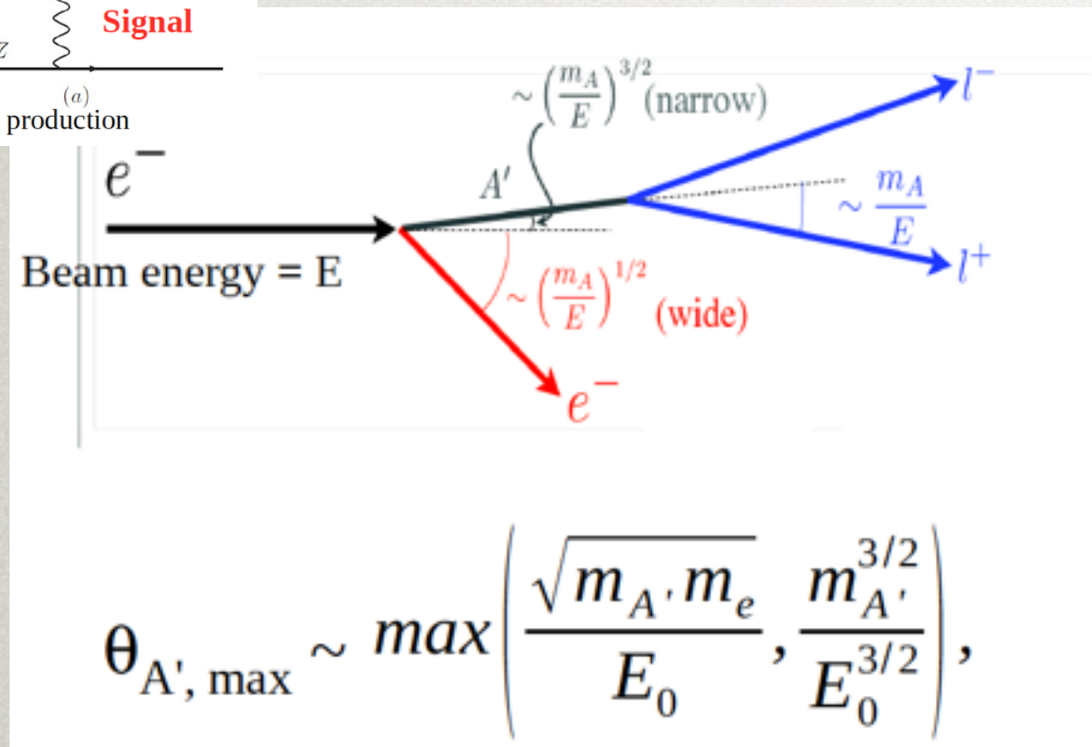
Signal process occurs via A'-emission off beam electron scattering on high-Z target



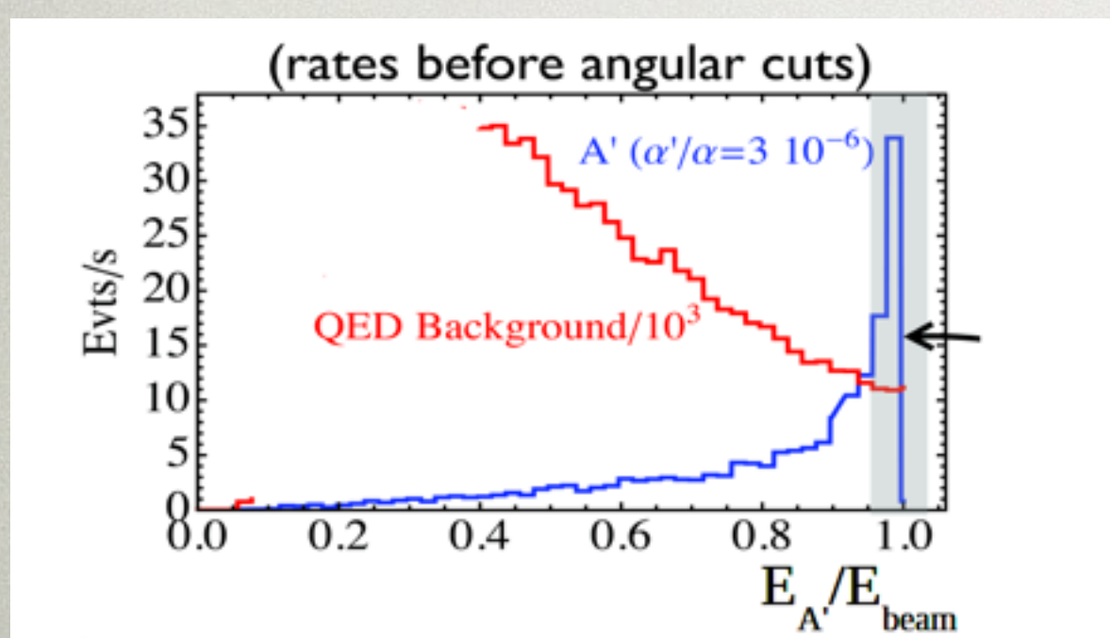
Kinematically irreducible backgrounds originate from “trident” reactions

Dark Sectors at JLab: 2019

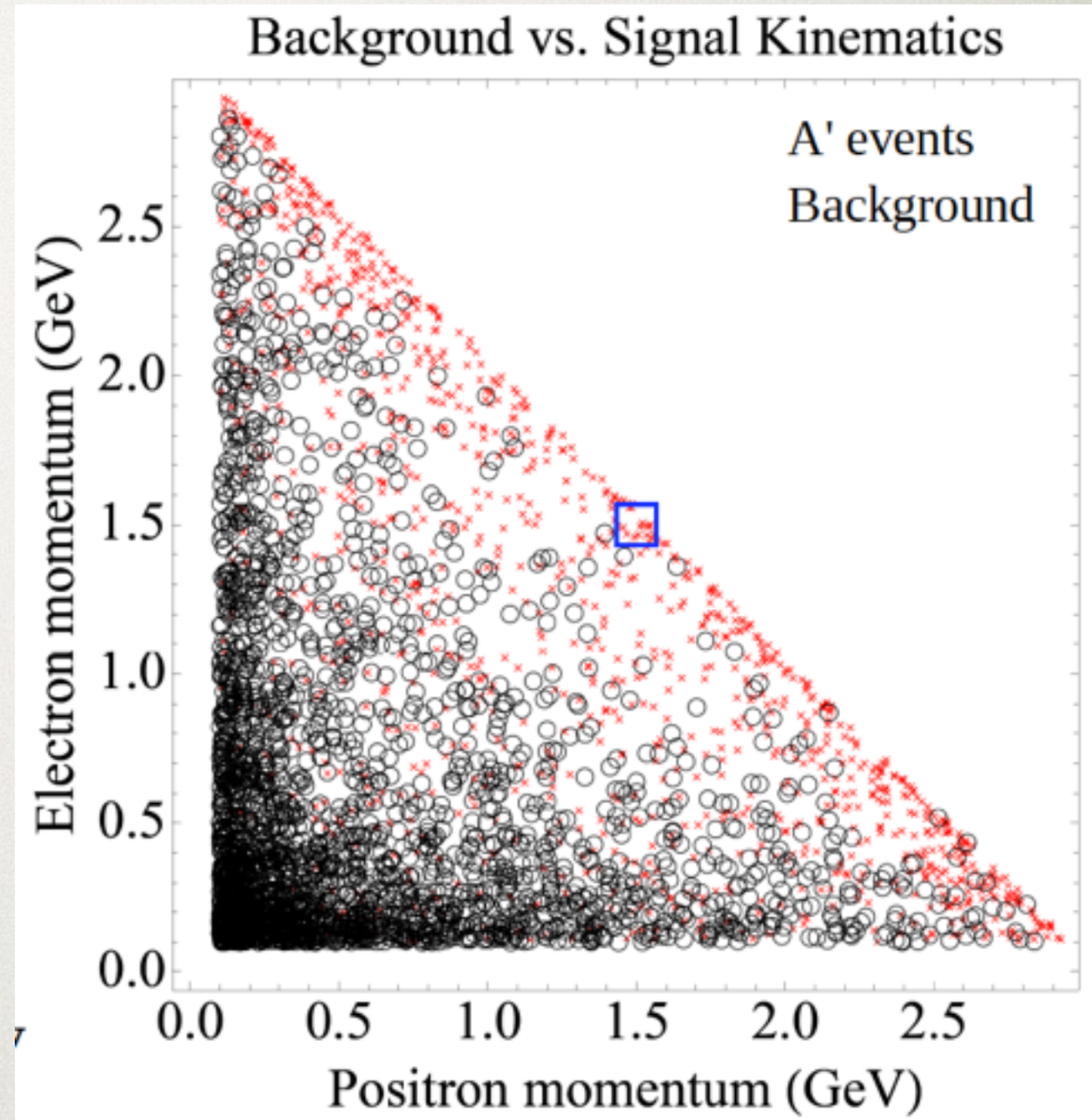




$$\theta_{A',\,\max} \sim max\left(\frac{\sqrt{m_{A'} m_e}}{E_0}, \frac{m_{A'}^{3/2}}{E_0^{3/2}}\right),$$



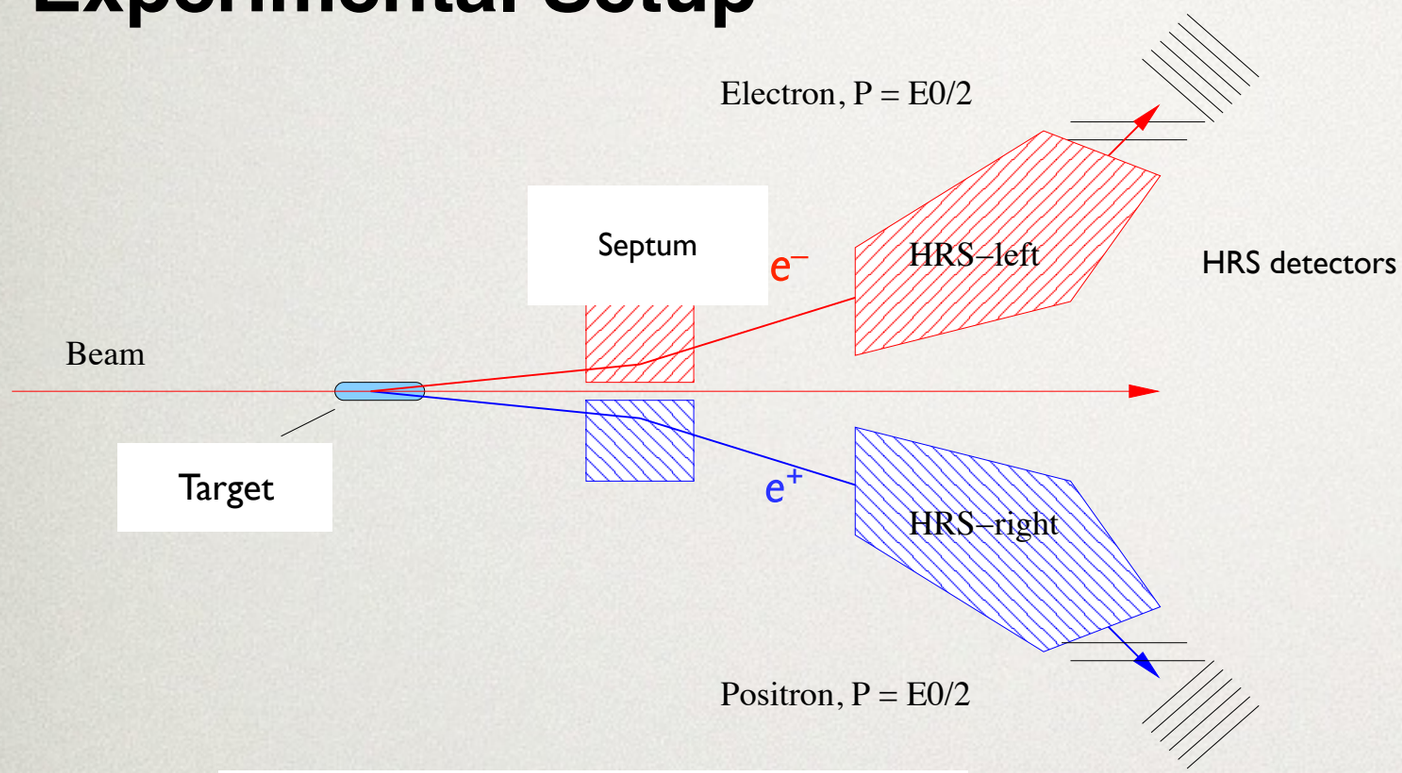
A′ products carry (almost) full beam energy

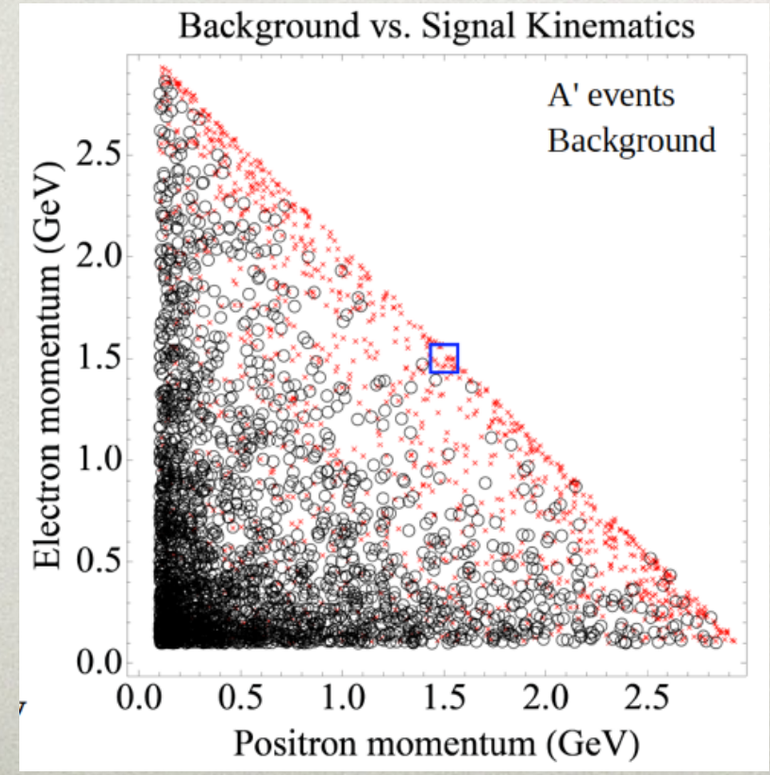


Signal and background peaked at opposite ends of phase space!

APEX @ JLab: 2019

Experimental Setup



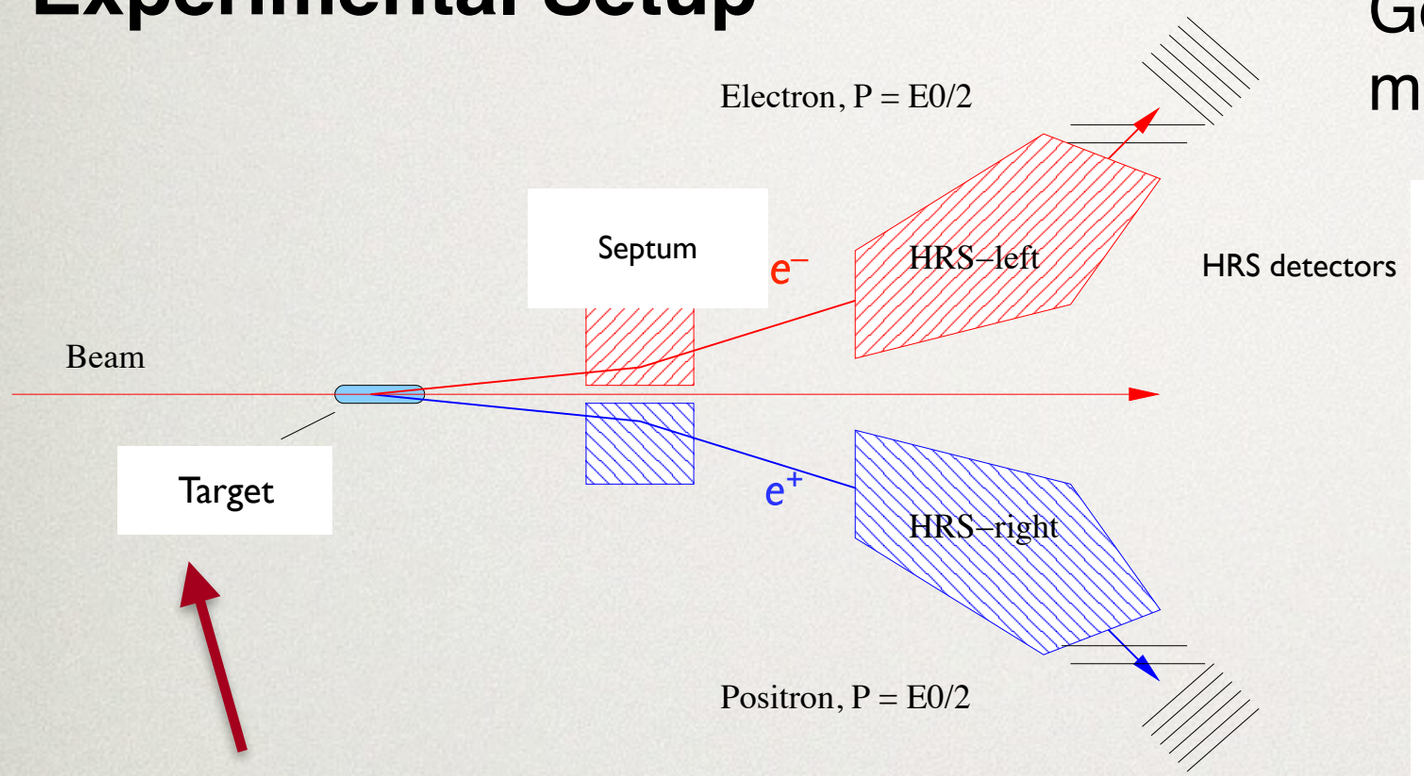


Approach: Detect narrow (signal) resonance in electron-positron pairs above smooth trident background near the energy endpoint

Symmetric kinematics well matched to maximizing signal to background

APEX @ JLab: 2019

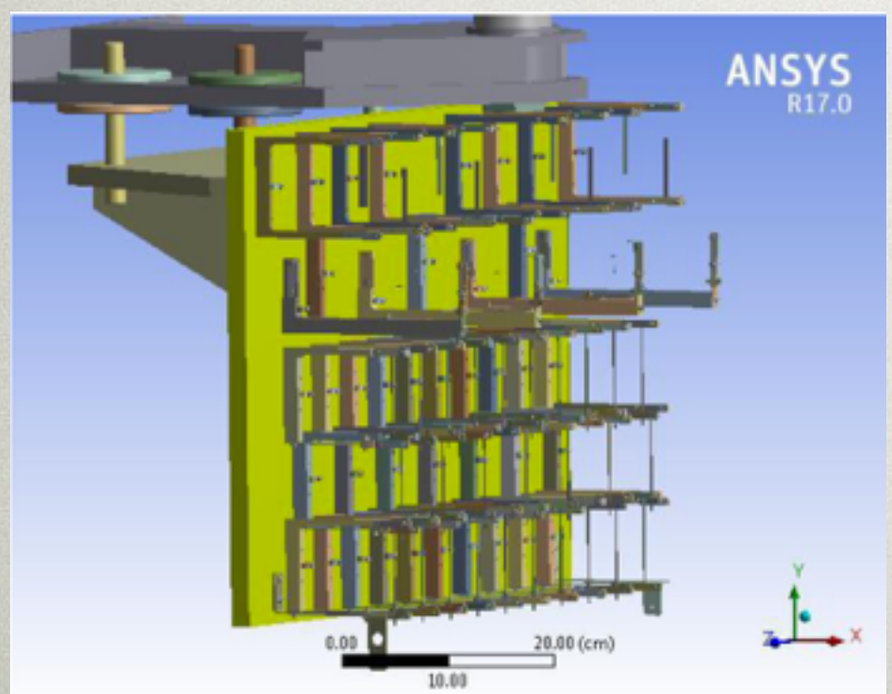
Experimental Setup



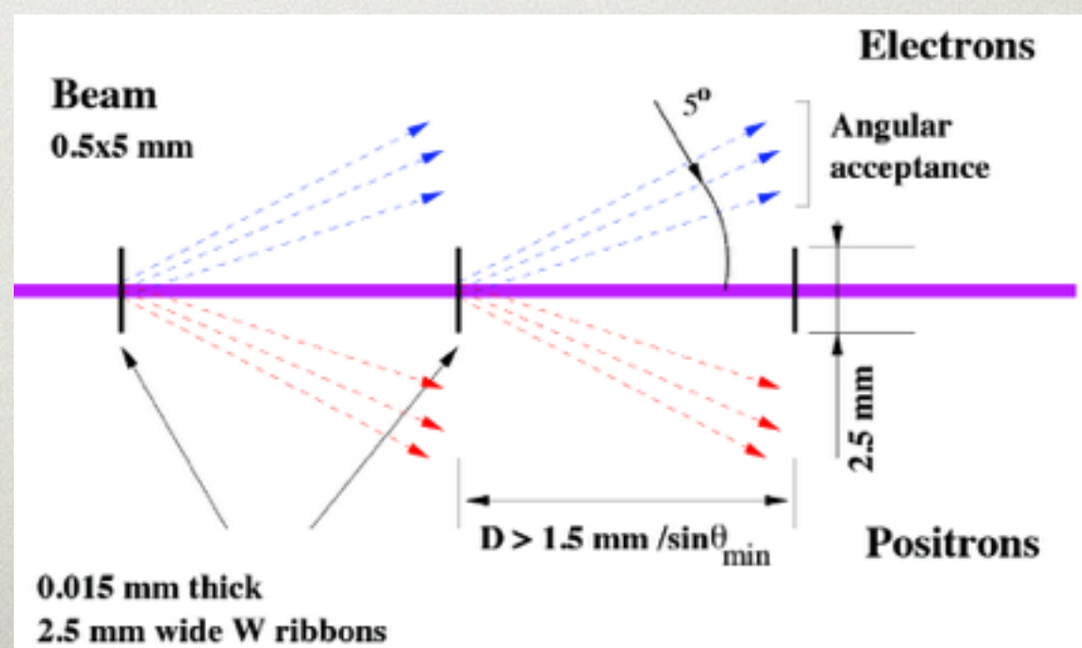
Good mass resolution requires minimal scattering in target!

Target:

- multiple foil target allows to achieve high rate and good (A') mass resolution while keeping multiple scattering to a minimum;
- such design of the target provides wide A' mass range for each fixed beam energy;
- by using high-Z targets (tungsten and tantalum) we maximize the production rate of electron/positron pairs as compared to pions.

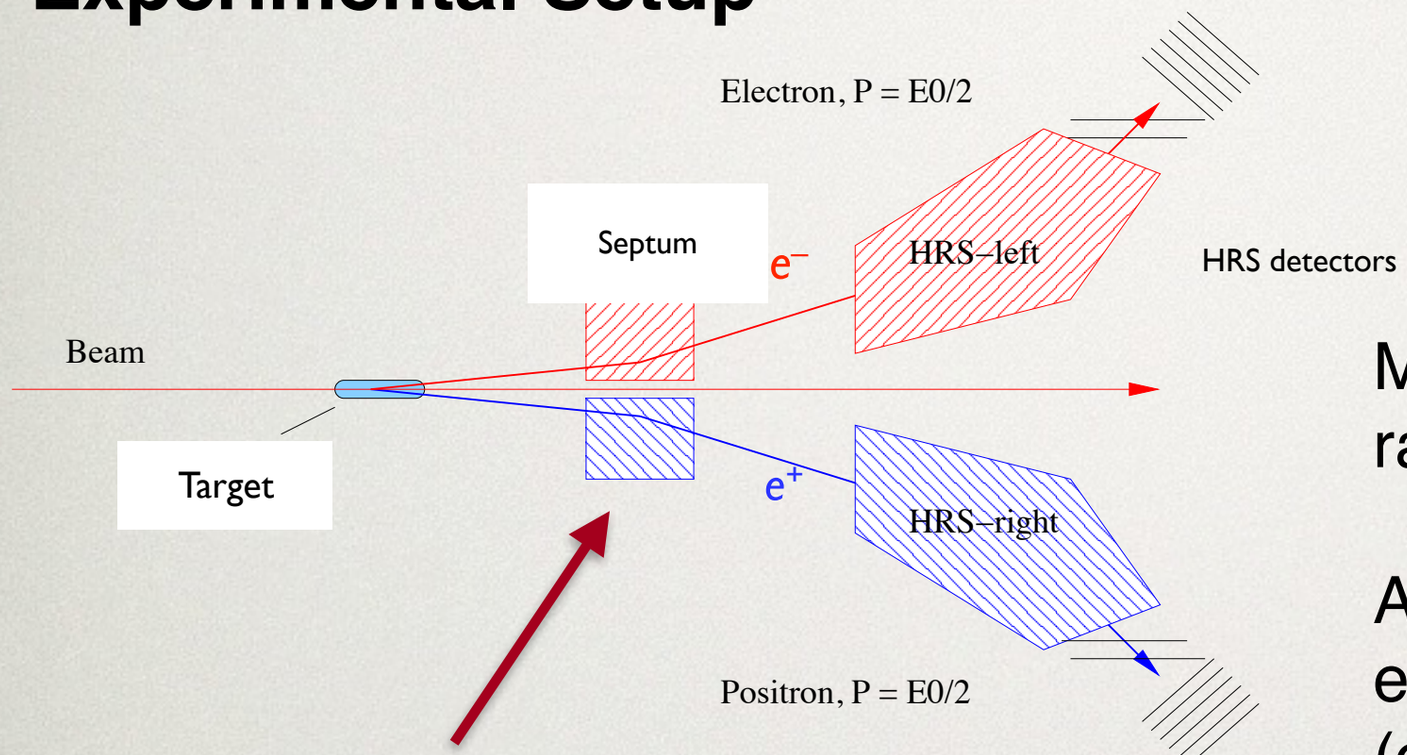


Project led by Silviu Covrig and team!



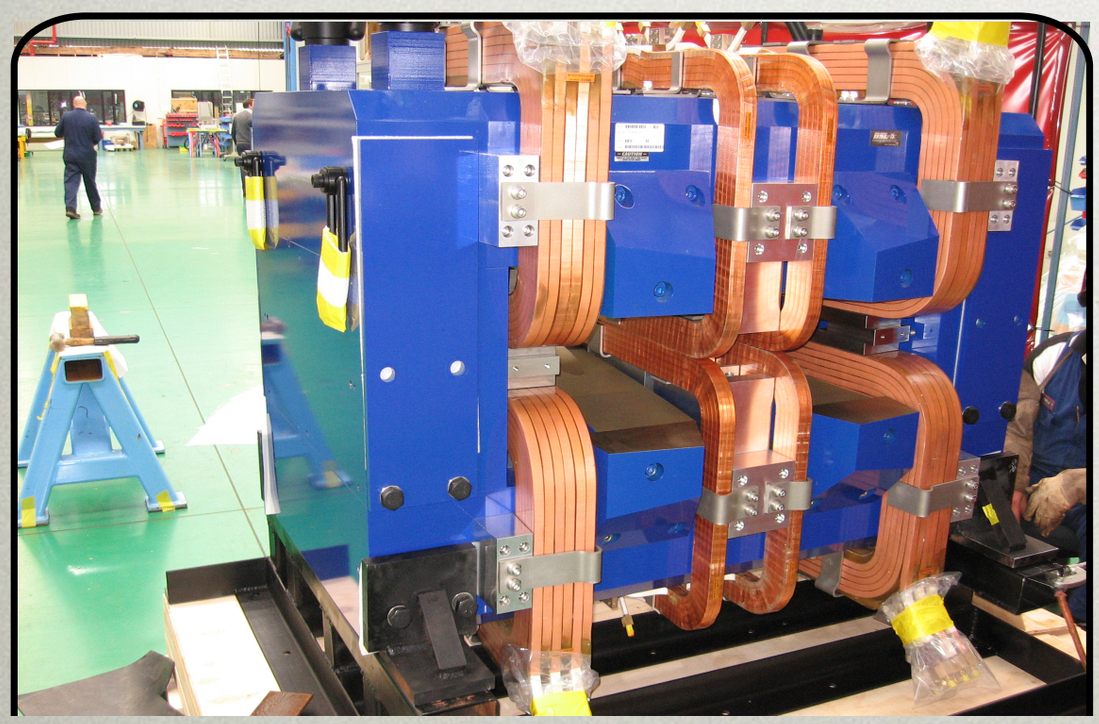
APEX @ JLab: 2019

Experimental Setup



Measuring 100's of MeV mass range requires forward kinematics

At same time, want relatively high energy electron-positron energy (compared to beam) to avoid potential hadronic backgrounds



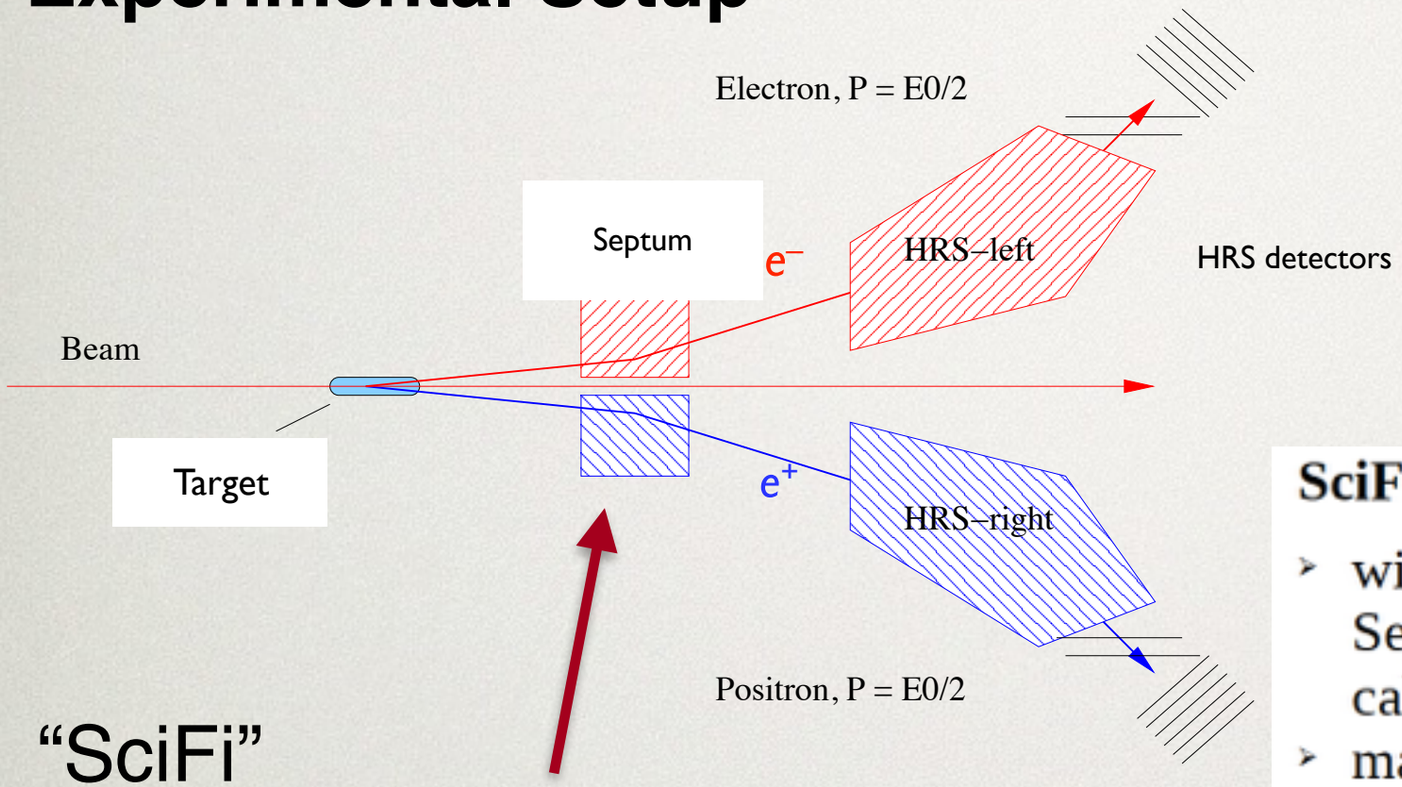
New septum:

- allows registration of small-angle e^+e^- pairs in HRS;
- provides operation for full momentum range of the experiment (up to 2.2 GeV);
- has a good magnetic shielding of the beam line.

Project led by collaborators at Carnegie Mellon, NCCU, Cal State LA, Perimeter, Stony Brook, UVA, Rutgers, Hebrew University

APEX @ JLab: 2019

Experimental Setup



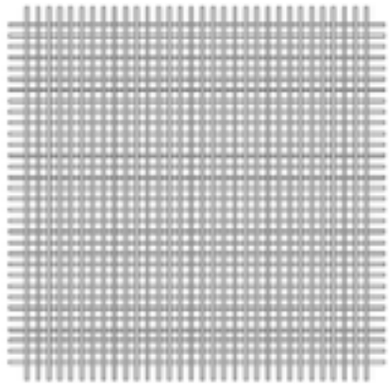
"SciFi"

The pictures are taken from Toshiyuki Gogami, Hall A weekly meeting

SciFi (Scintillator Fibers hodoscopes):

- with 8.8 cm x 10.3 cm active area in front of Septum Magnet SciFi will allow optics calibration to 0.1 mrad precision;
- makes possible HRSR optics calibration without change of HRS polarity.

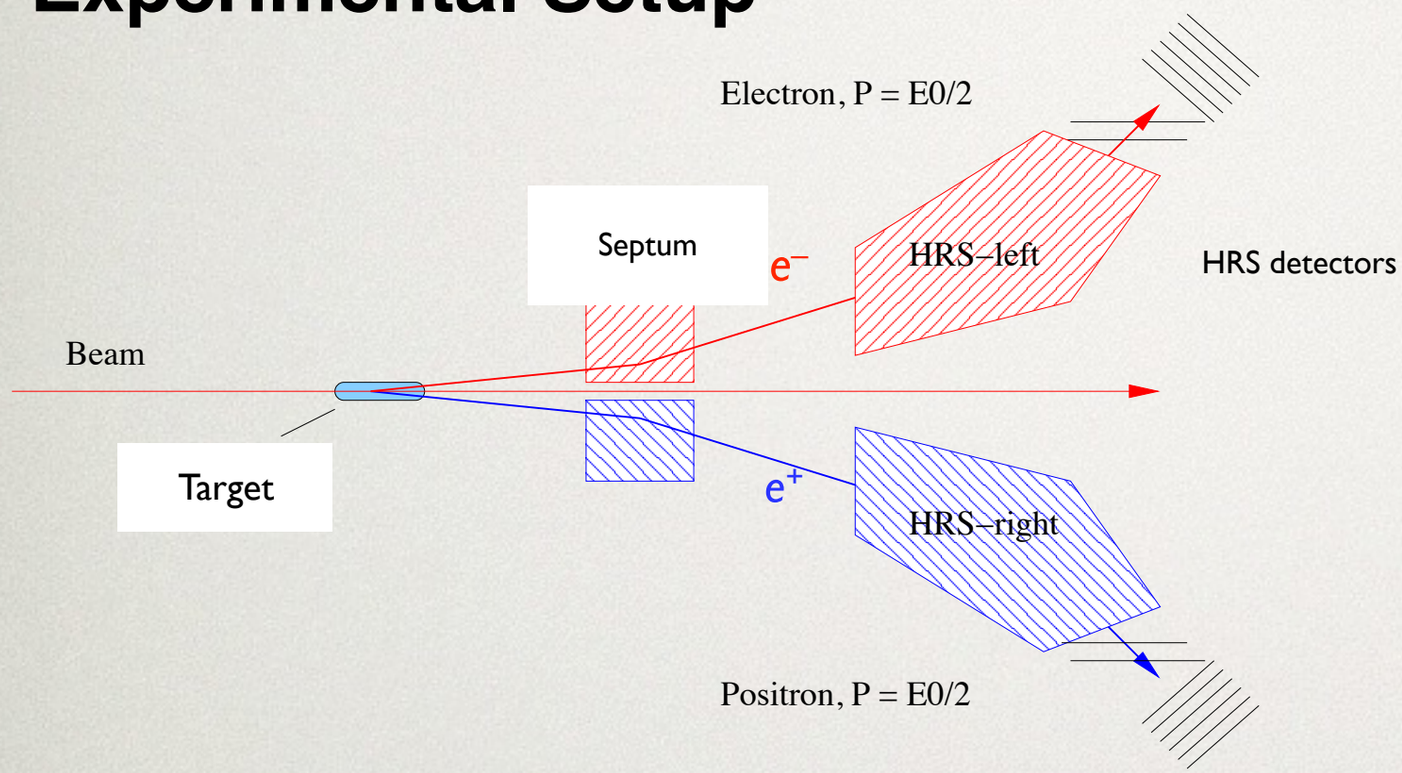
64 scintillation fibers:
32(V) and 32(H) directions
Size: 8.8(H) × 10.3 (V) cm^2
Fiber Ø – 1 mm

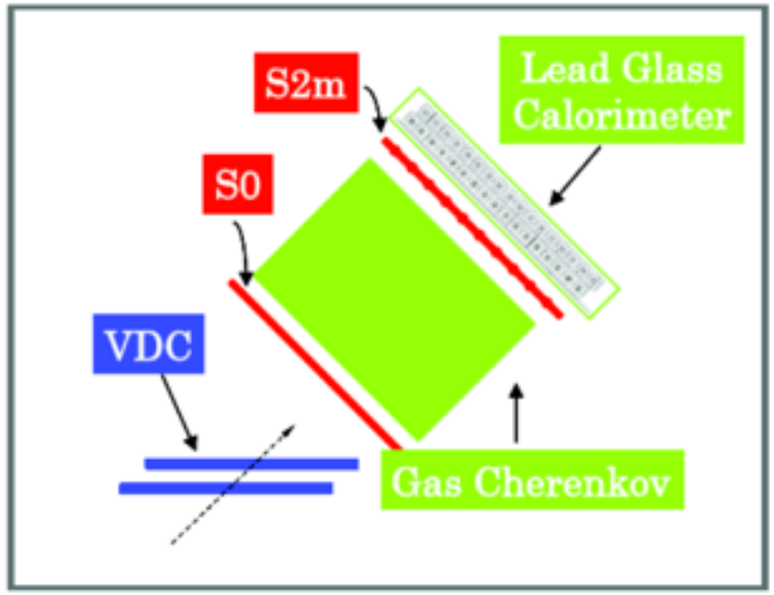


Recent efforts led by U. of Glasgow, Andrew Moyer, Toshiyuki Gogami, and many others over past several years!

APEX @ JLab: 2019

Experimental Setup





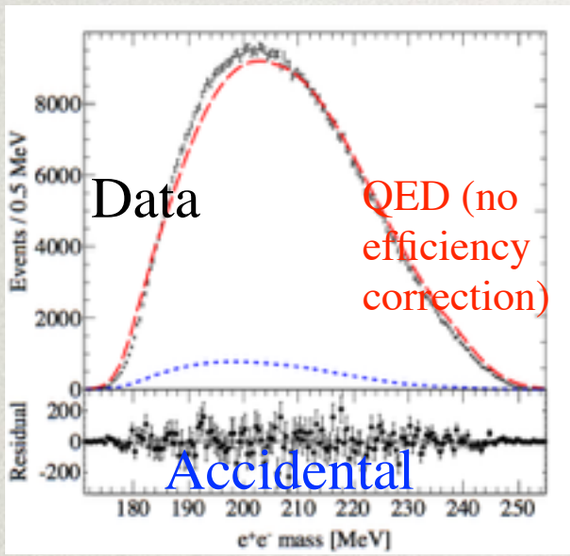
VDCs are used for tracking;
Cerenkov and calorimeter are used for particle identification;
s2m is used for trigger and timing.

Demonstrated that HRS has up to 5 MHz Rate operation capability with on-line coincidence 20 ns.
e^+e^- invariant mass resolution is ~0.5%.

Many thanks to recent efforts from Florian Hauenstein, Alexandre Camsonne, Bob Michaels, Evan McClellan and other tritium collaborators

APEX @ JLab: 2019

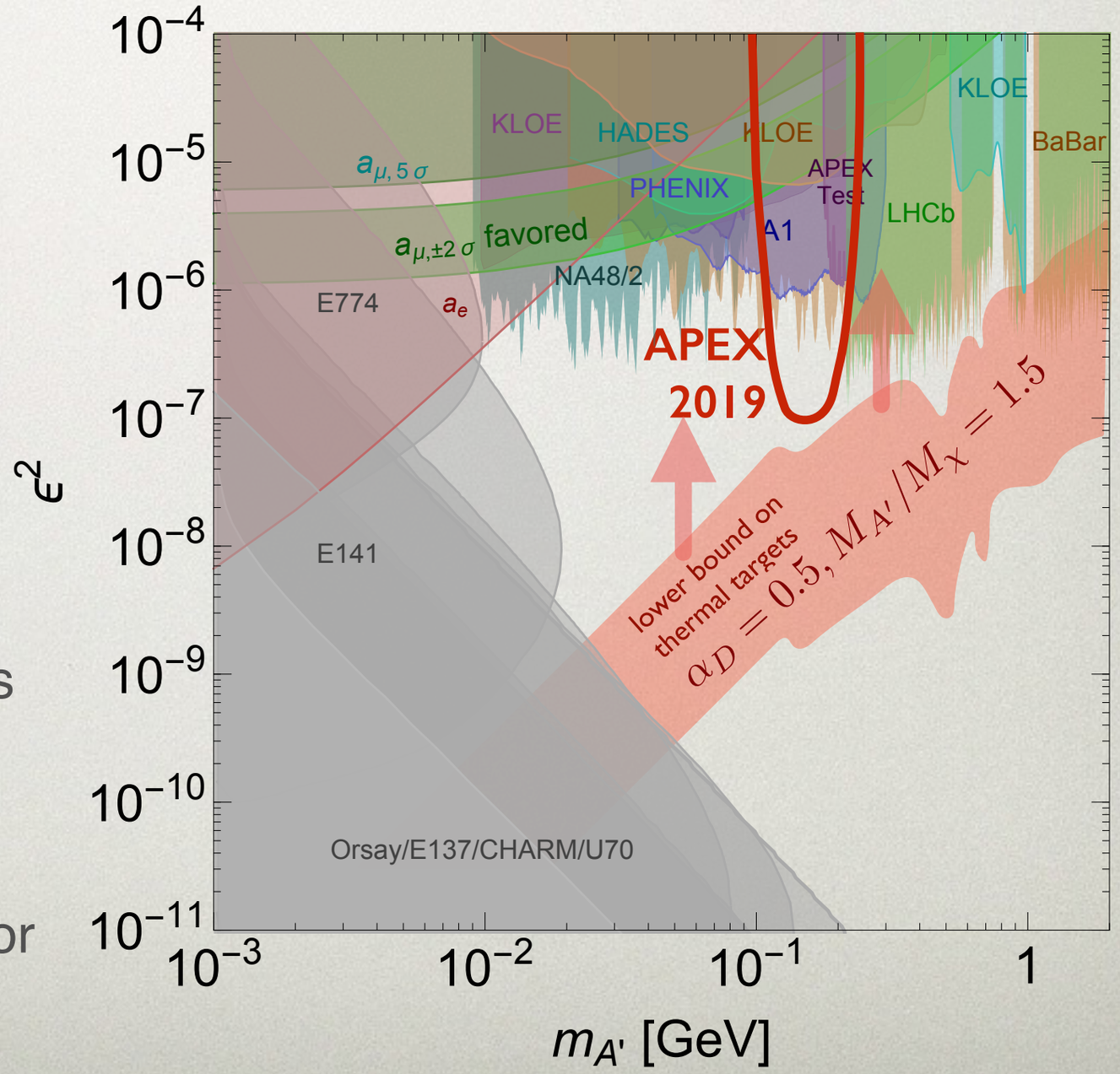
Test run (2010): concept & technical demonstration; weekend run achieved world-record sensitivity, highly cited PRL



- Begin exploring GUT range of coupling below muon threshold
- Explore part of the coupling-mass range motivated by thermal DM
- Aim to go to lower mass in future with low energy runs if possible, or altered kinematics configuration

2019 Physics Run (2/7 - 3/13): start with a single 2.2 GeV run configuration to deliver first physics results at high statistics.

Focus on mass range below muon threshold to complement CERN LHCb efforts



APEX @ JLab: 2019

A' Experiment (APEX):E12-10-009

Shift Worker Information	Documents	Other Links
• Run Plan	• Safety Documents	• APEX Wiki
• How To's	• DAQ and Trigger	• APEX online Replay github
• Daily Run Meeting	• Pr	
• Shift Schedule & sign up		
• Expert Call List		

APEX Spring 2019 Shift Schedule

Notes:
Shift requirements for authorship: We anticipate an APEX authorship requirement of 6 shifts during the run. Owl shifts will have a weight of 1.5, and all other shifts have weight 1.

APEX will operate with 2-person shift crews. Please DO NOT sign up for a "3rd" spot -- these will not be counted. You do not need cryotarget training to be TO.

IMPORTANT: All shift-takers must have taken the regular Hall A safety training including the hall walk-through SAF110. If you are new to the lab or to hall A, you must plan to arrive well ahead of time to complete this training (which will require access to the hall) prior to your first shift -- please contact spokespeople for details. All shift-takers will also need to spend some time prior to their first shift getting trained and familiar with their responsibilities. **Please contact Victoria Owen (vowen@jlab) to arrange this training**. Shadowing a previous shift crew for at least a few hours prior to your 1st shift also strongly encouraged.

Your permissions in this application
- You can sign up for shifts
- You can sign up as a shift leader
- You can sign up as a target operator

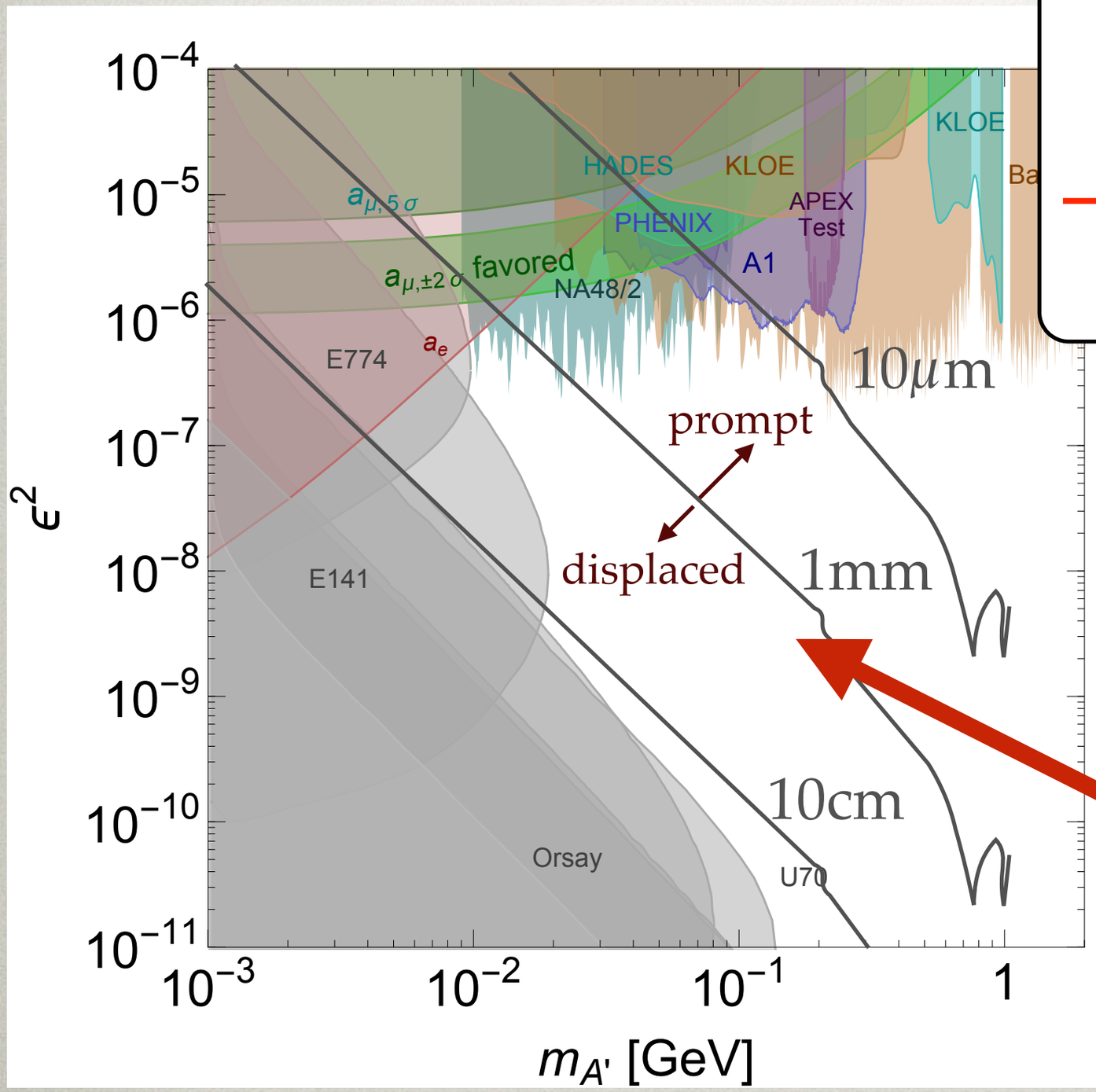
Run coordinators:

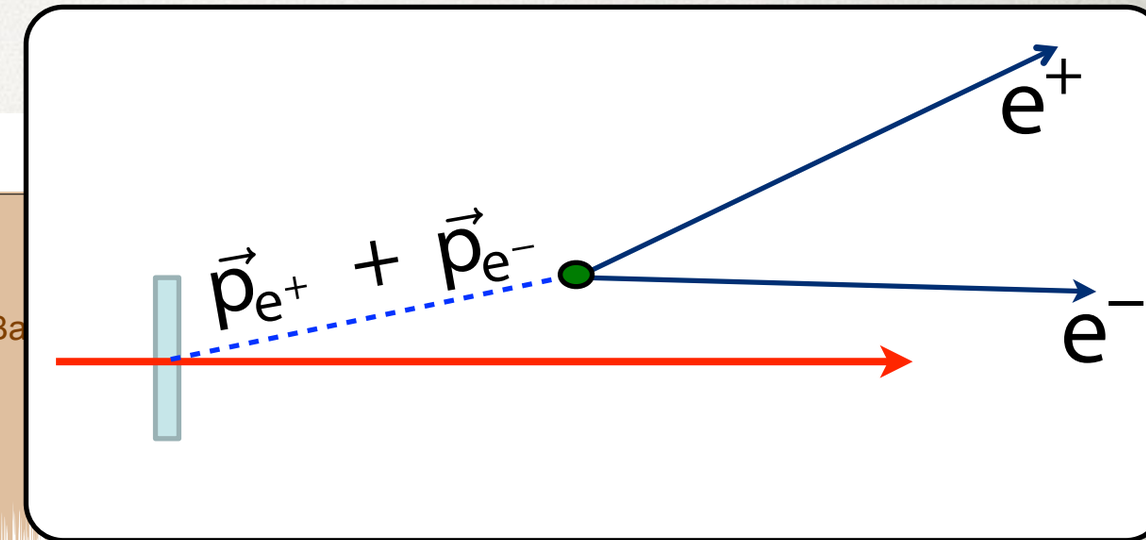
January 23-February 1	Evan McClellan
February 1-February 6	Ciprian Gal
February 6-February 13	Sanghwa Park
February 13-February 20	Shujie Li
February 20-February 27	Cameron Clarke

Hours Days	00:00- 08:00 (Owl Shift)	08:00- 16:00 (Day Shift)	16:00 - 24:00 (Swing Shift)
Wednesday, January 30 RC: Evan McClellan Show run plans Edit run plans	No Shift workers needed	*Shift canceled* SL: Deepak Bhetawal TO: Gabriel Niculescu 3rd:	*Shift canceled* SL: Charles Hyde TO: Ranit Das 3rd:
Thursday, January 31 RC: Evan McClellan Show run plans Edit run plans	*Shift canceled* SL: Rashad Mohamed Nuhman TO: Devi Adhikari 3rd:	*Shift canceled* SL: Chandan Ghosh TO: Gabriel Niculescu 3rd:	*Shift canceled* SL: Will Tireman TO: Ranit Das 3rd:
Friday, February 1 RC: Ciprian Gal Show run plans Edit run plans	*Shift canceled* SL: Andrew Puckett TO: Carlos Ayerbe Gayoso 3rd:	*Shift canceled* SL: Tim Holmstrom TO: Ranit Das 3rd:	*Shift canceled* SL: Will Tireman TO: Chandan Ghosh 3rd:
Saturday, February 2 RC: Ciprian Gal Show run plans Edit run plans	*Shift canceled* SL: Andrew Puckett TO: Carlos Ayerbe Gayoso 3rd:	*Shift canceled* SL: Yuichi Toyama TO: Nathaniel Lashley-Colthirst 3rd:	*Shift canceled* SL: Richard Lindgren TO: Ranit Das 3rd:
Sunday, February 3 RC: Ciprian Gal Show run plans Edit run plans	*Shift canceled* SL: Andrew Puckett TO: Carlos Ayerbe Gayoso 3rd:	*Shift canceled* SL: Yuichi Toyama TO: Nathaniel Lashley-Colthirst 3rd:	*Shift canceled* SL: Richard Lindgren TO: Ranit Das 3rd:
Monday, February 4 RC: Ciprian Gal Show run plans Edit run plans	*Shift canceled* SL: Andrew Puckett TO: Carlos Ayerbe Gayoso 3rd:	*Shift canceled* SL: Edward Brash TO: Ranit Das 3rd:	*Shift canceled* SL: Charles Hyde TO: Richard Lindgren 3rd:

Fantastic response to anticipated shift needs! Still some shifts left in March!

Displaced Vertices

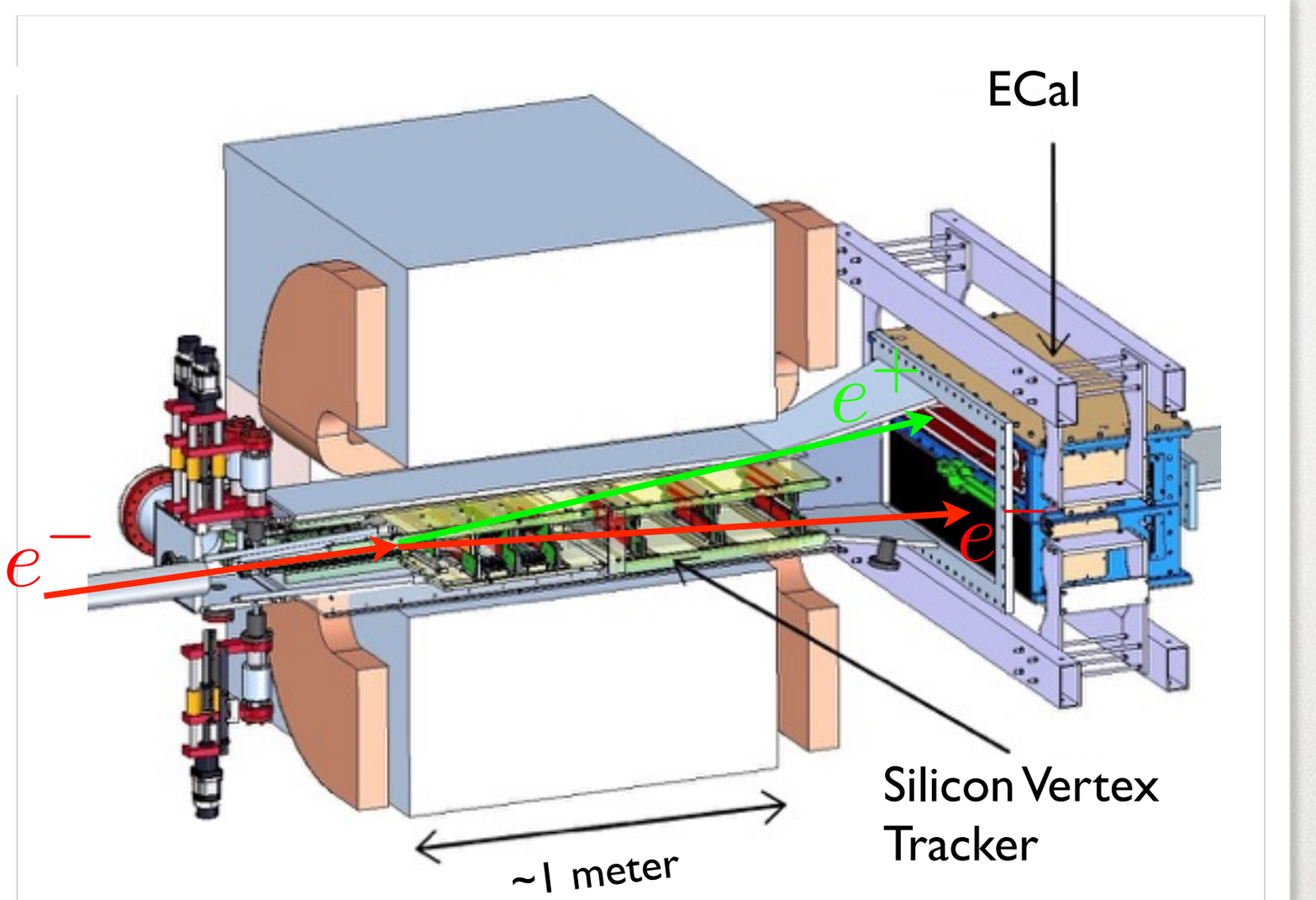


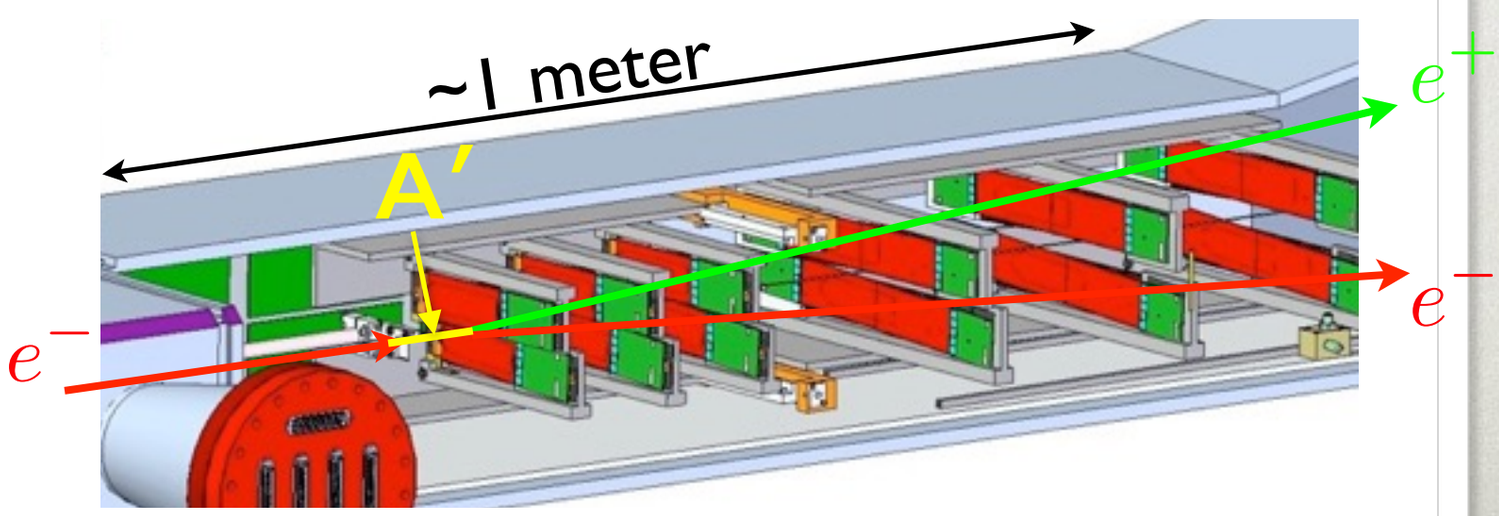


Key capability — precision tracking of electron/positrons to detect displaced decays

Allows sensitivity to very weak couplings with ~cm decay vertex

HPS @ JLab: 2019



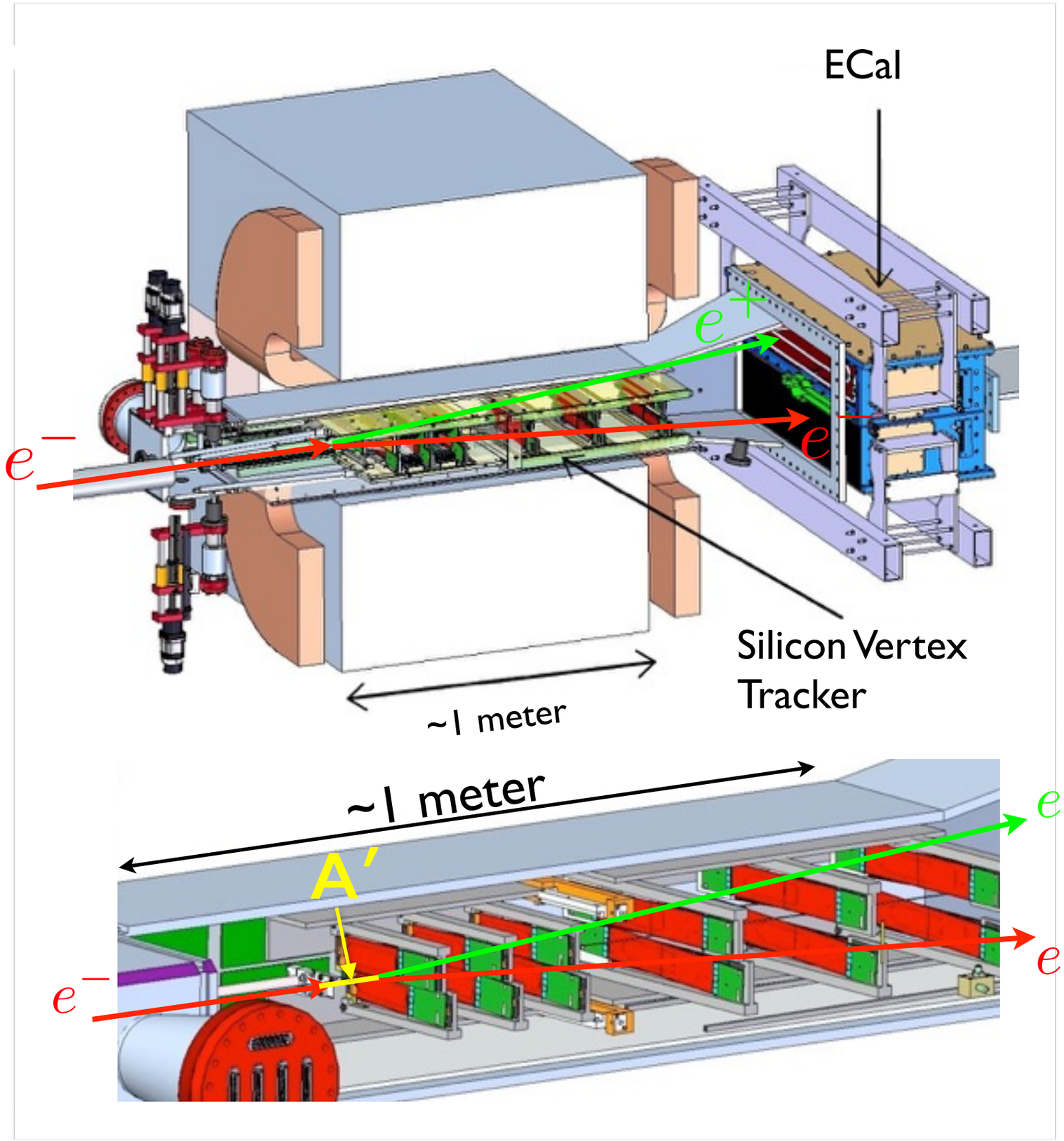


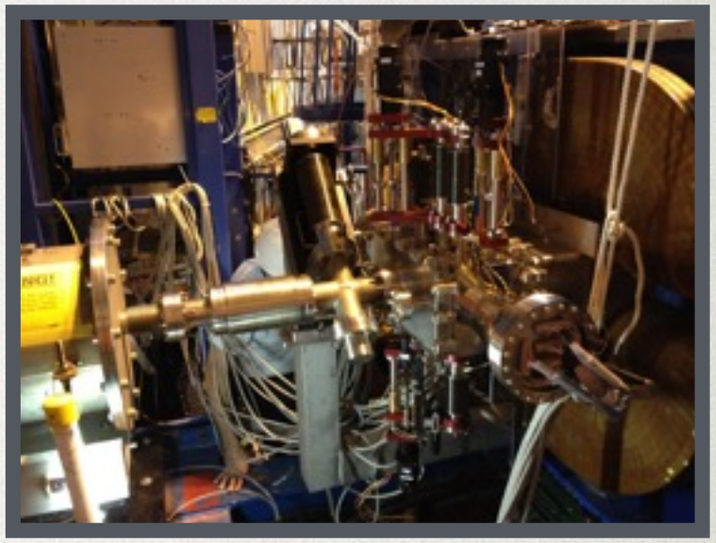
Compact e^+e^- spectrometer, immediately downstream of thin target in multi-GeV beam in Hall B.

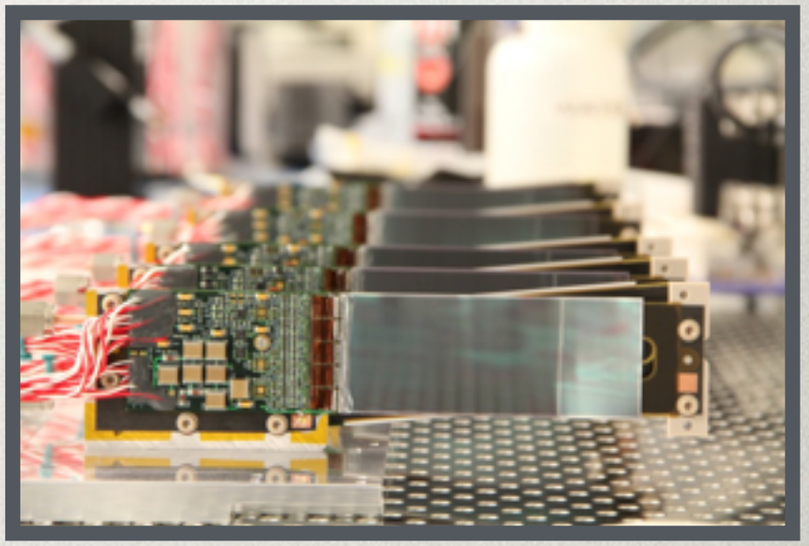
- Low-mass, high-rate (up to 4 MHz/mm^2) silicon tracker (SVT) allows ***vertexing long-lived A′***. SVT must suppress SM tridents from target by factor ~10^7
- $PbWO_4$ ECal trigger eliminates 10's MHz scattered single e^-.

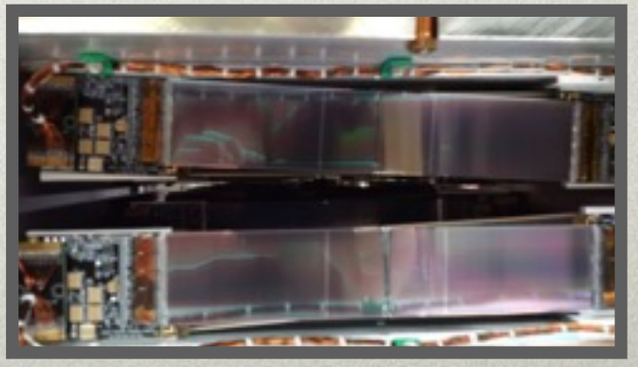
Short engineering runs in 2015 (1.7 days) and 2016 (5.4 days)

HPS @ JLab: 2019

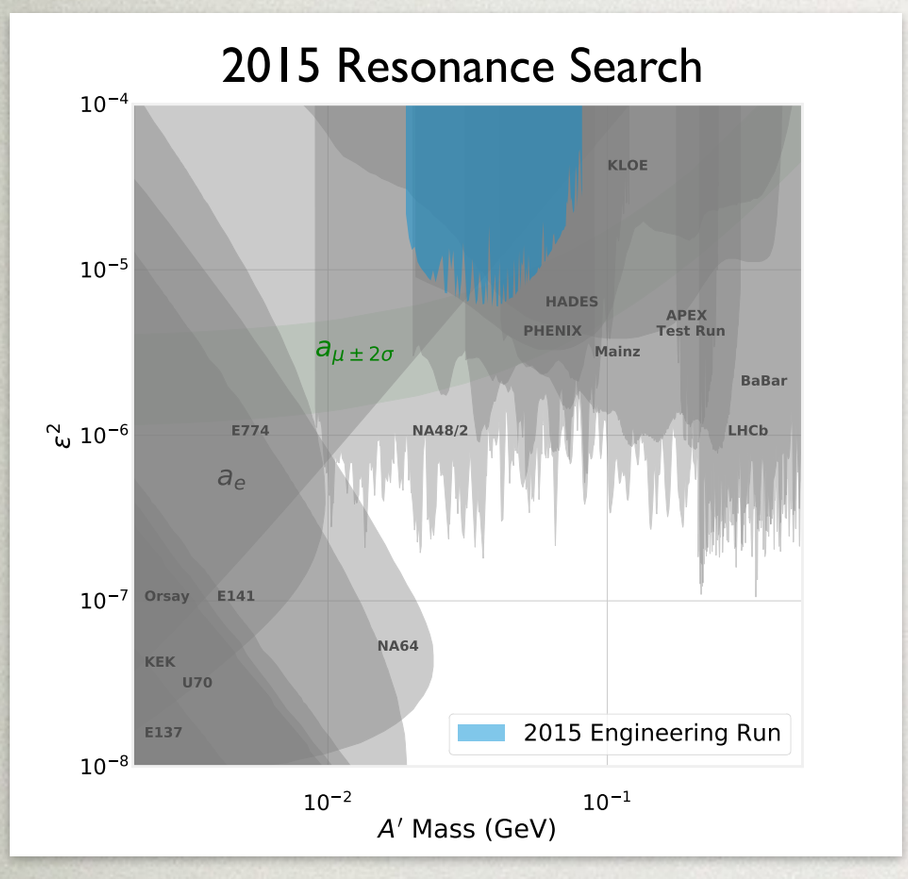








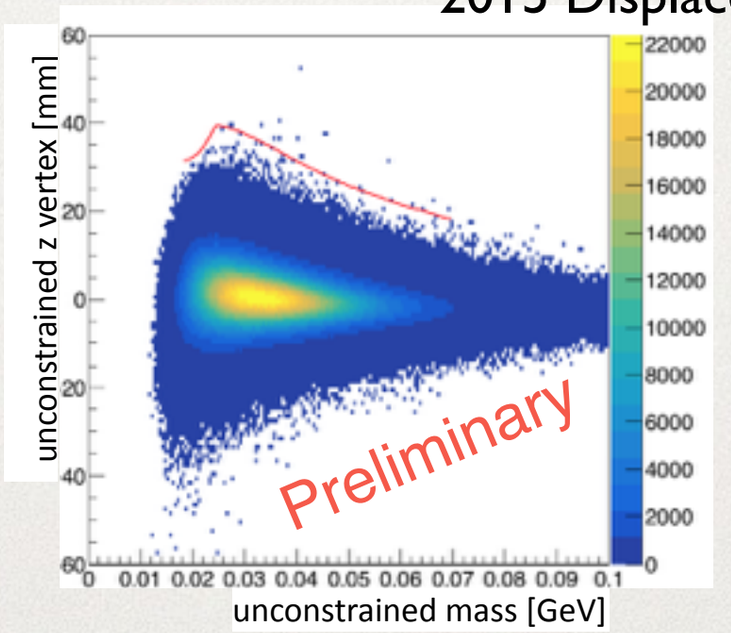
HPS @ JLab: 2019

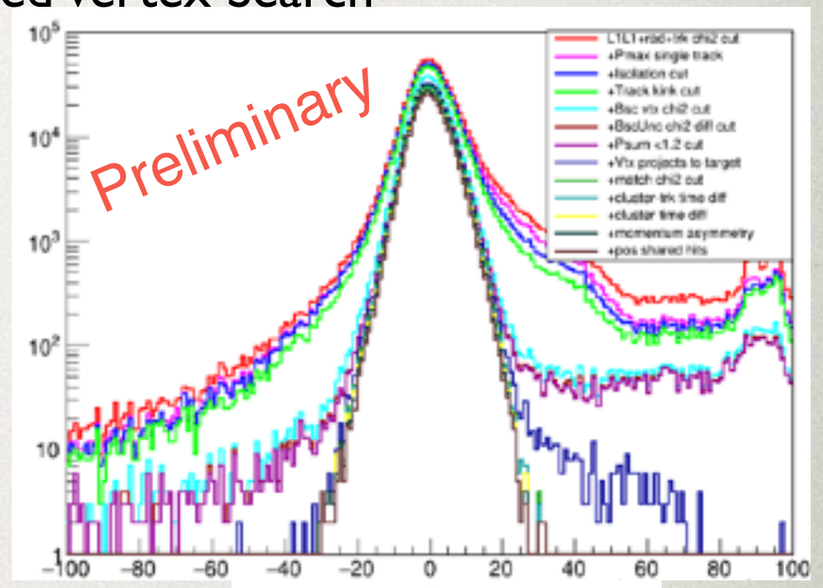


arXiv:1807.11530 [hep-ex]

Phys.Rev. D98 (2018) no.9, 091101

2015 Displaced Vertex Search





No new sensitivity for minimal dark photons, but analyses prove concept in advance of physics runs.

HPS @ JLab: 2019

arXiv:1807.11530 [hep-ex]

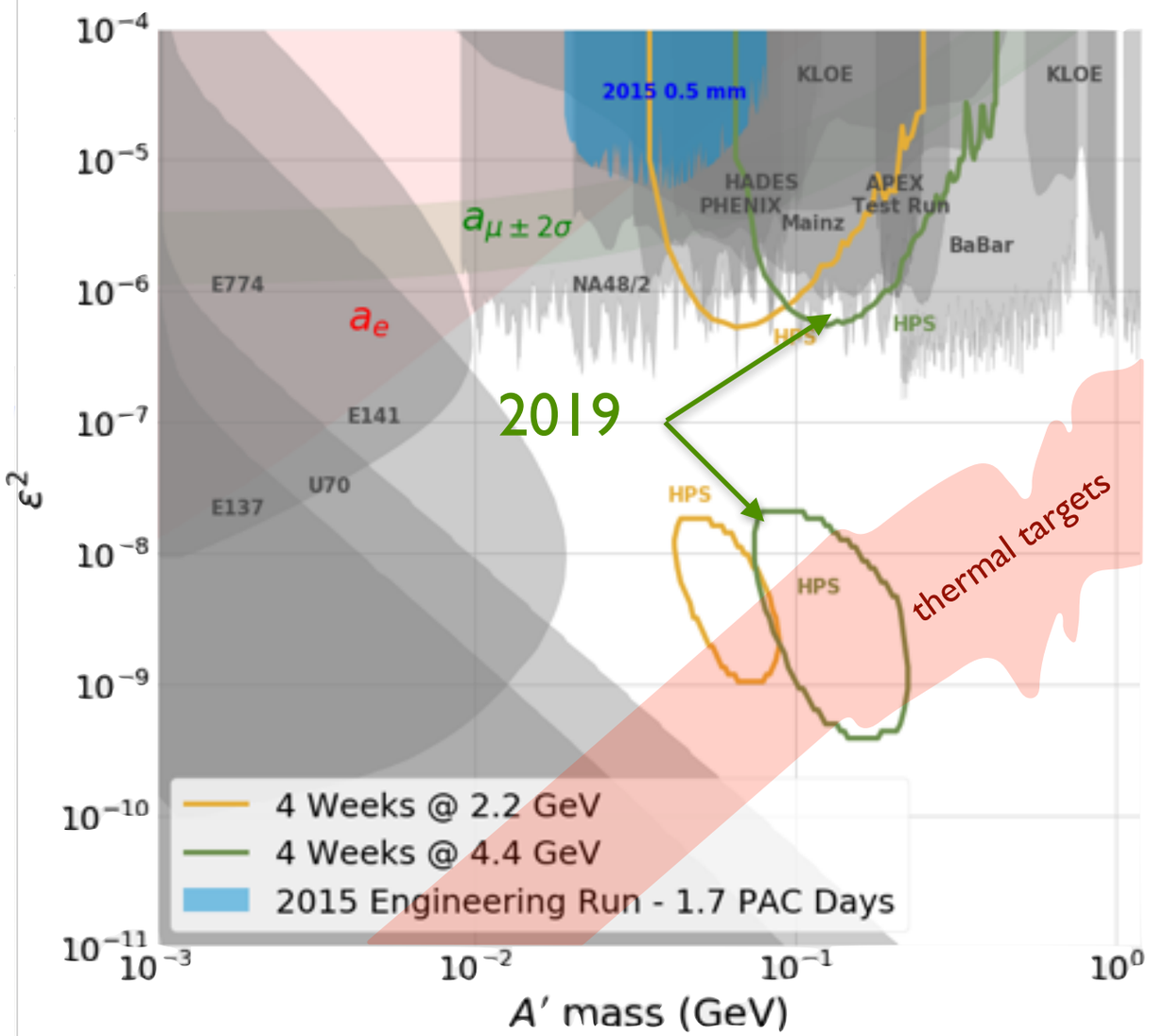
Phys.Rev. D98 (2018) no.9, 091101

2015 Resonance Search

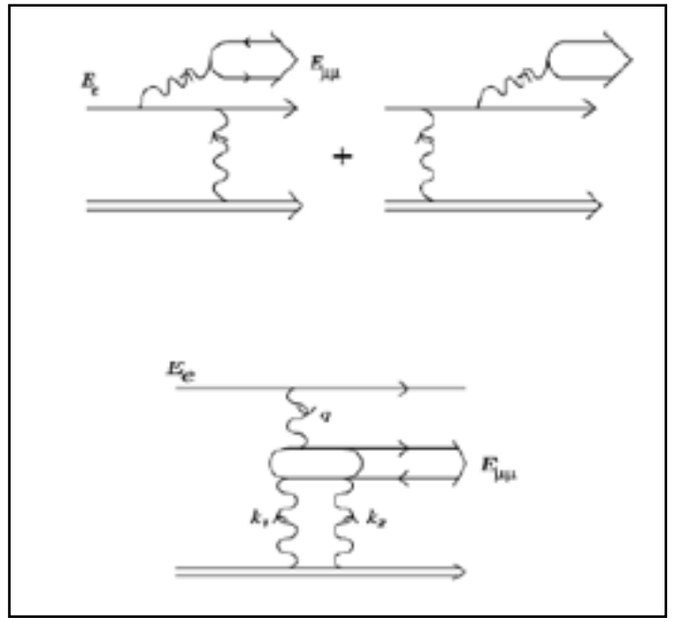
2015 Displaced Vertex Search

First physics run scheduled for 6/10 — 8/4/2019

8 weeks at 4.55 GeV, ≈ 4 weeks of data = 0.7 C (50% typical duty cycle)



HPS can also discover True muonium (ortho)!



Dark Sectors at JLab: 2019

Two Jefferson Lab experiments that address dark matter/dark sector physics goals have upcoming runs in 2019!

APEX — “A Prime EXperiment" in Hall A (February-March run!)

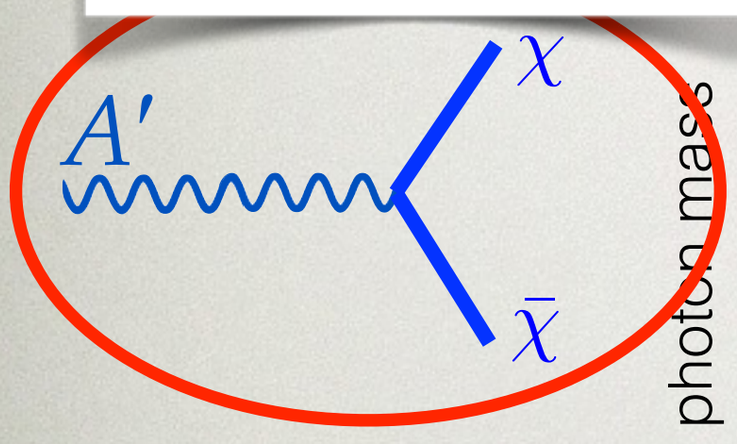
HPS — “Heavy Photon Search” in Hall B (June-August run!)

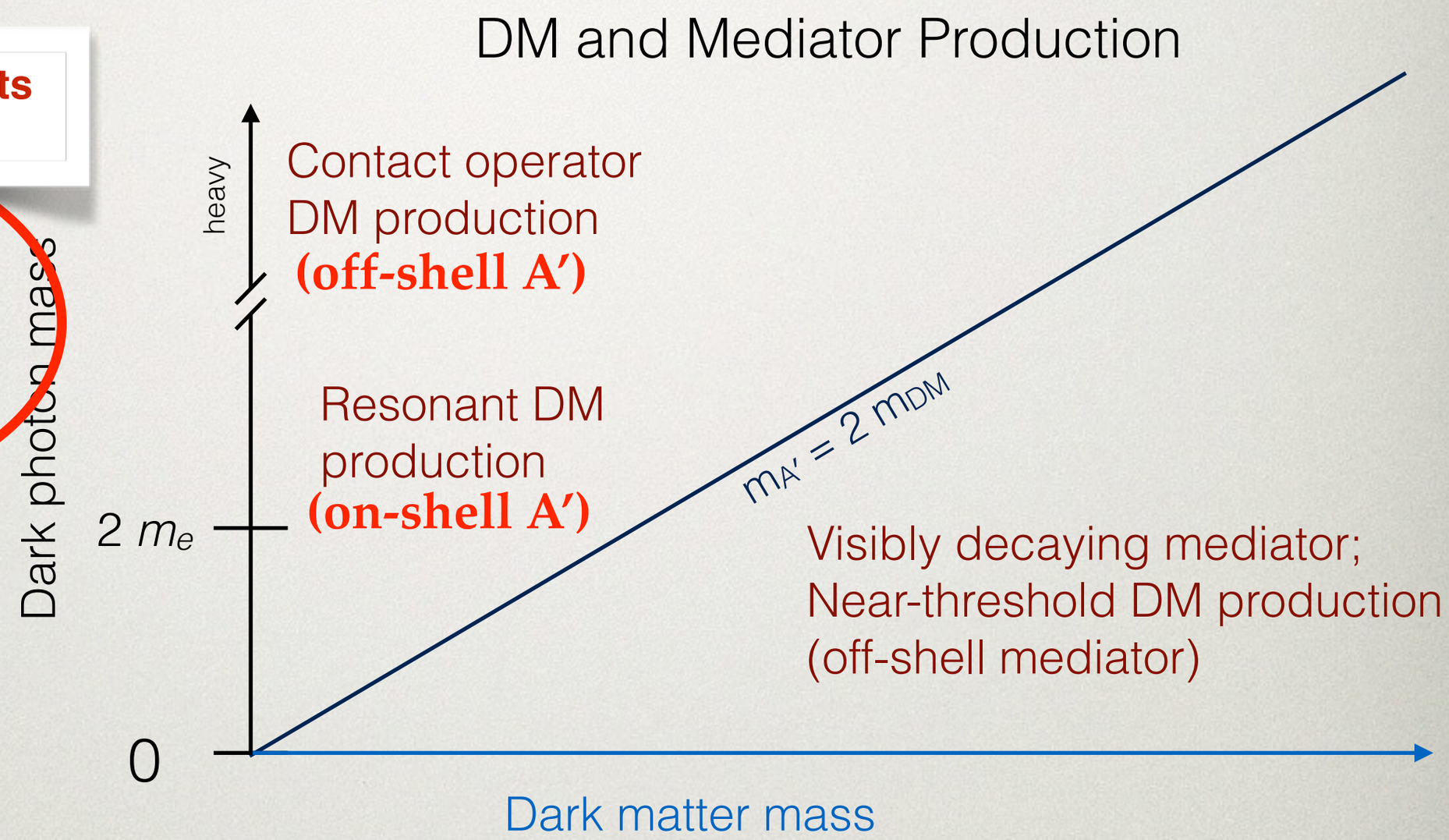
Exciting data expected this year!
Still plenty of room to get involved

Organizing the Physics

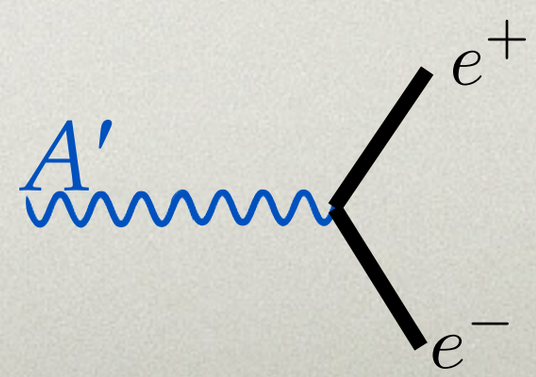
(Vector kinetic mixing as an example — most models work similarly)

JLab and other efforts in US as well!





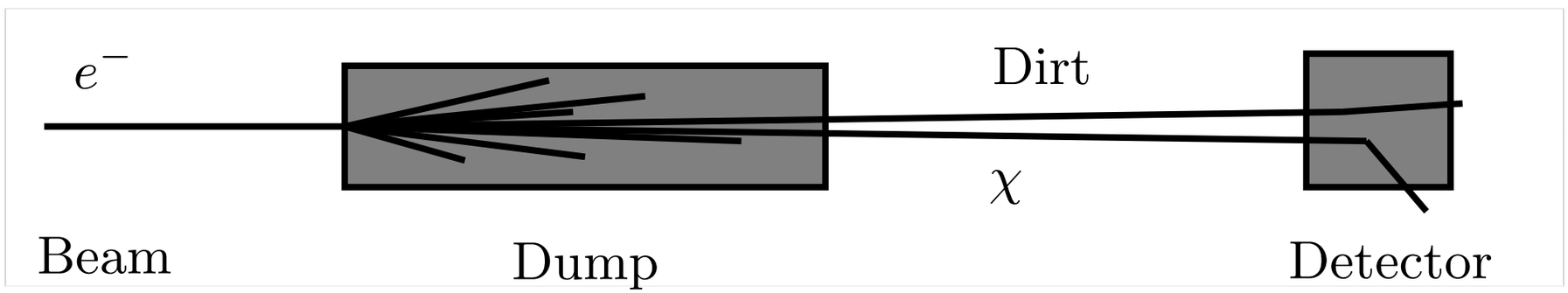
Search for both the mediator and DM itself!



Light Dark Matter Searches
at beam dumps

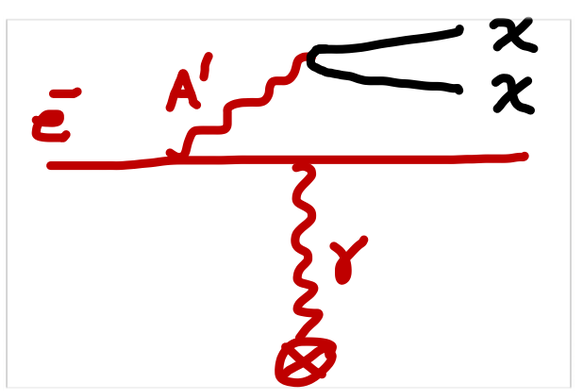
Dark Matter interacts weakly

$\Rightarrow$ passes through anything!

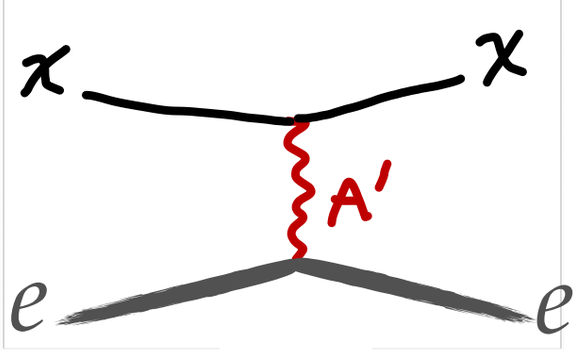


can use proton beams too!

Produce DM through the portal…



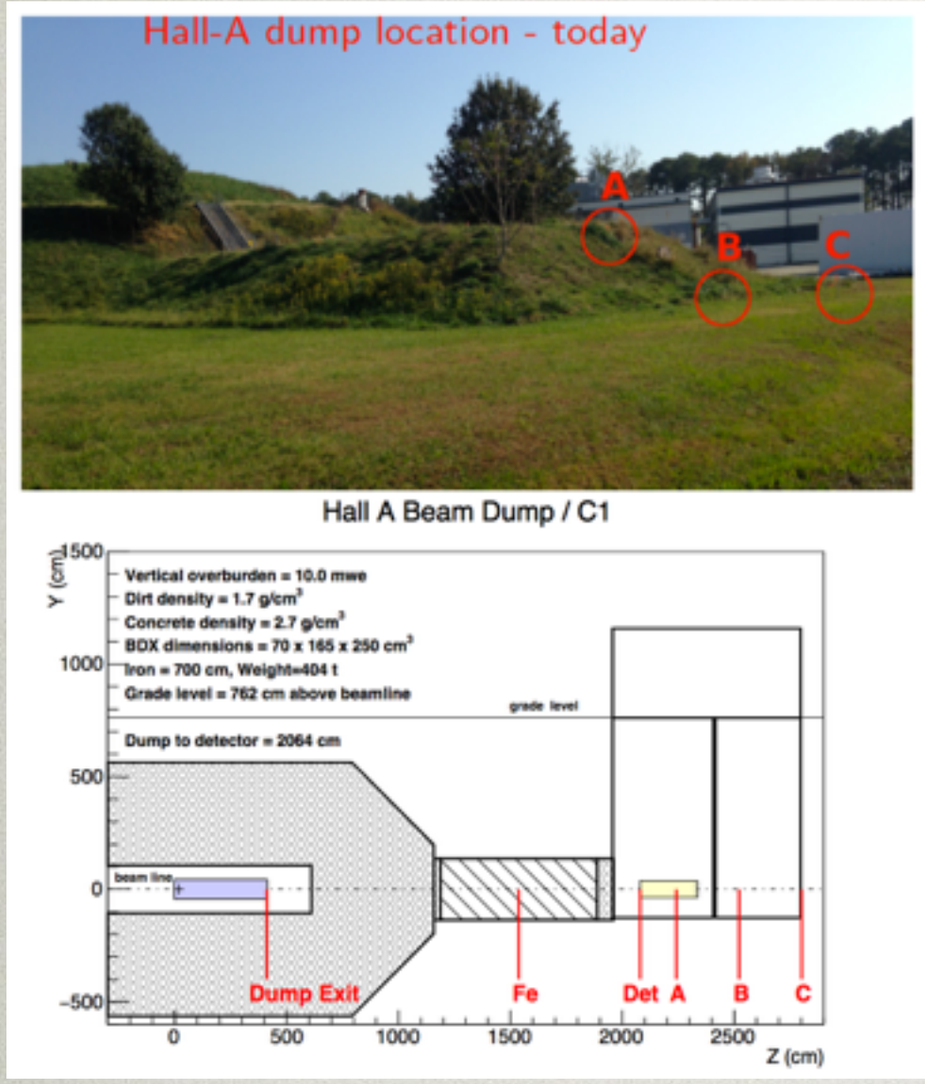
…detect its scattering downstream

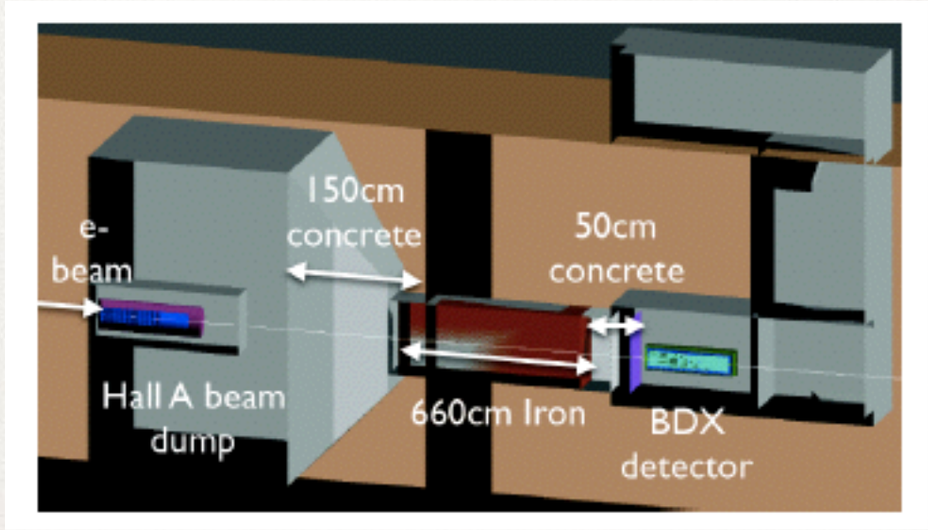


Izaguirre, Krnjaic, Schuster & NT PRD.88.114015 and 1403.6826

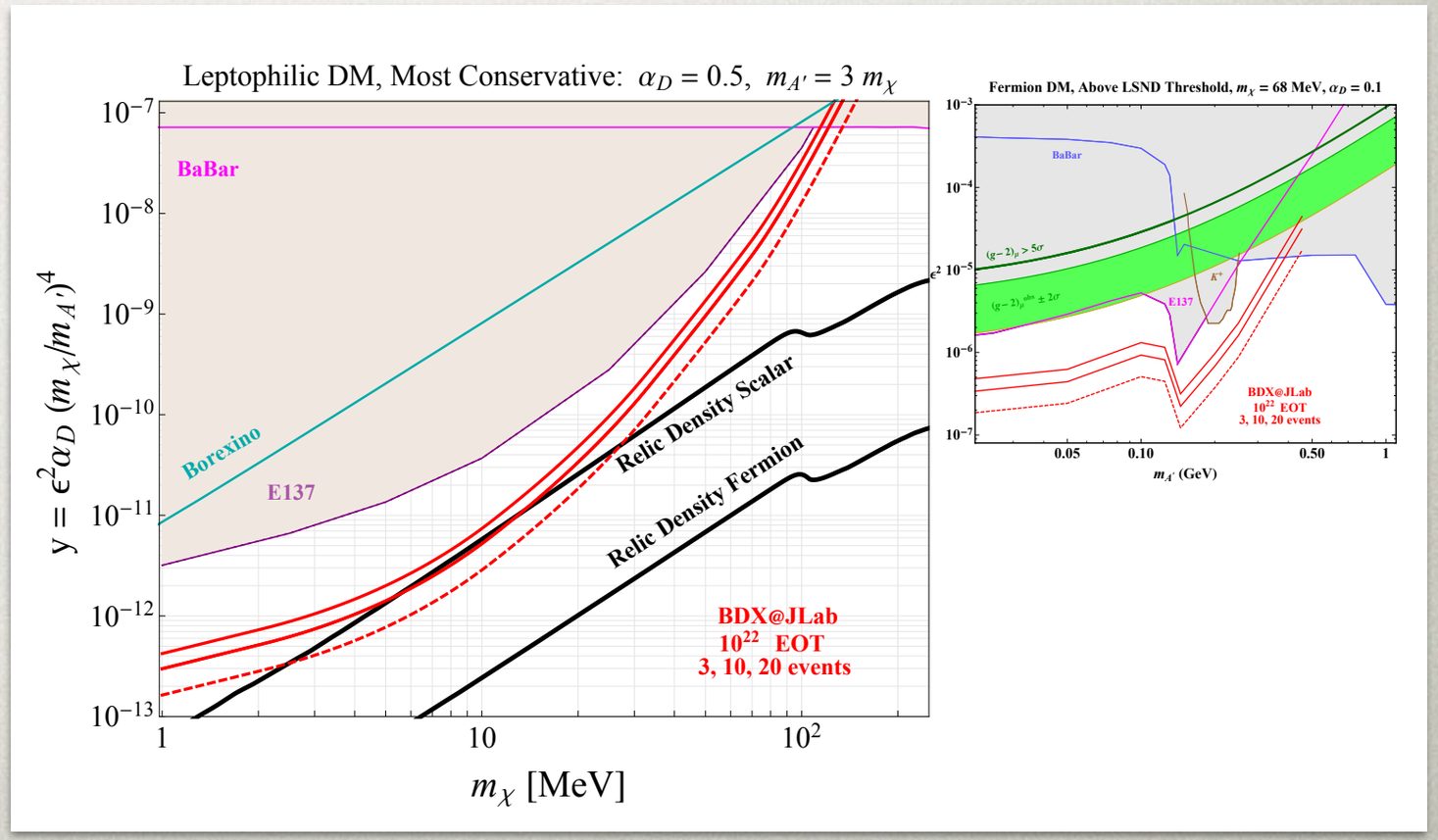
Beam Dump eXperiment @ JLab

BDX (parasitic behind JLab Hall A dump)





See: arXiv:1712.01518



New sensitivity to dark matter production!

Conclusions

Testing the dark sector idea is a critical step in our broadening effort to understand the particle nature of dark matter

- Sharp science case with vibrant community
- Important and well-defined parameter space sensitivity milestones (i.e. thermal dark matter, GUT strength couplings, DM self-interactions…)
- **Dedicated "dark force" experiments (APEX & HPS) collecting their first signifiant data in 2019!**
- Lively activity towards future experimental efforts to produce dark matter in electron beams