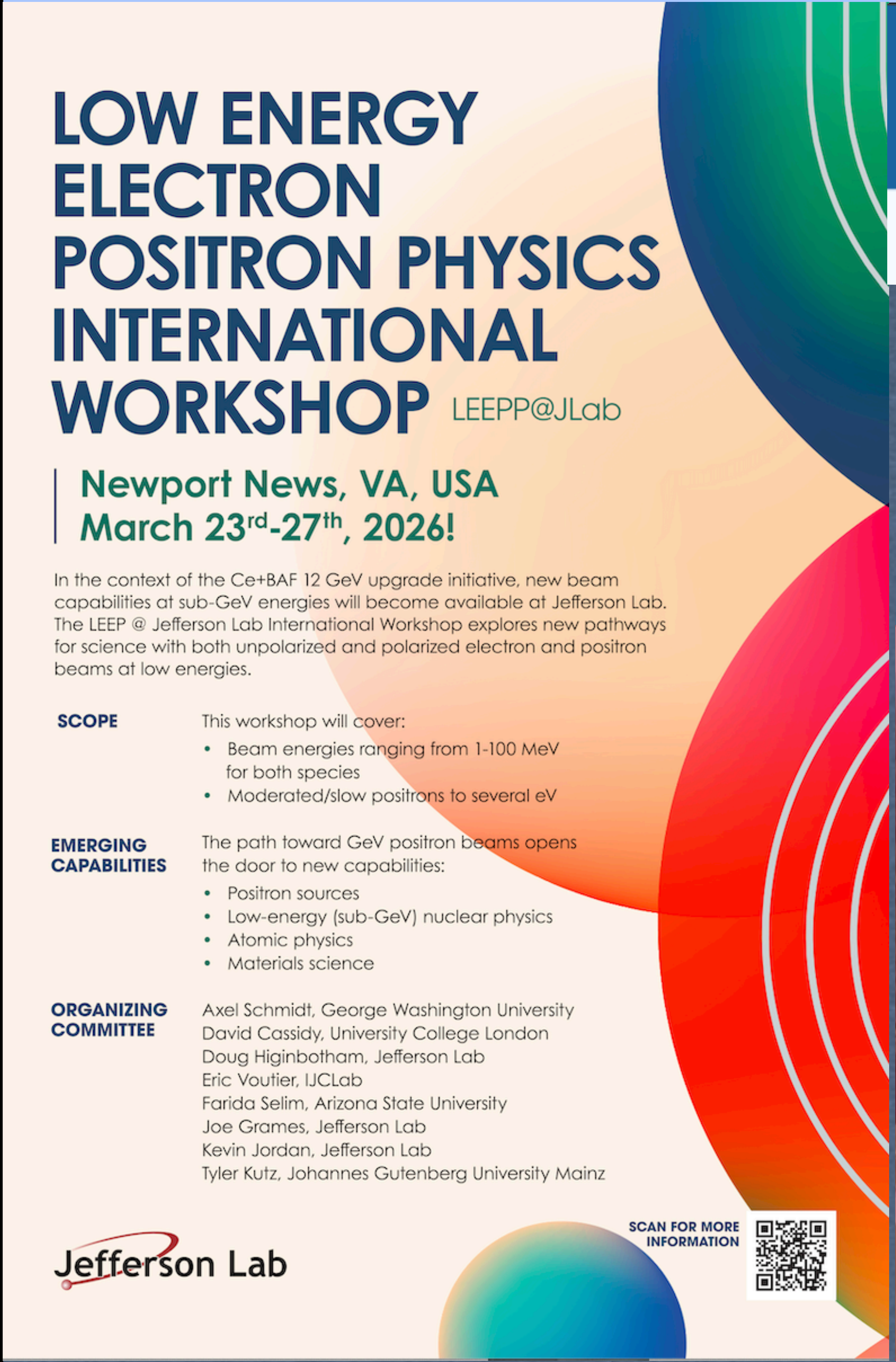


LOW ENERGY ELECTRON POSITRON PHYSICS INTERNATIONAL WORKSHOP LEEPP@JLab

Newport News, VA, USA
March 23rd-27th, 2026!

In the context of the Ce+BAF 12 GeV upgrade initiative, new beam capabilities at sub-GeV energies will become available at Jefferson Lab. The LEEP @ Jefferson Lab International Workshop explores new pathways for science with both unpolarized and polarized electron and positron beams at low energies.

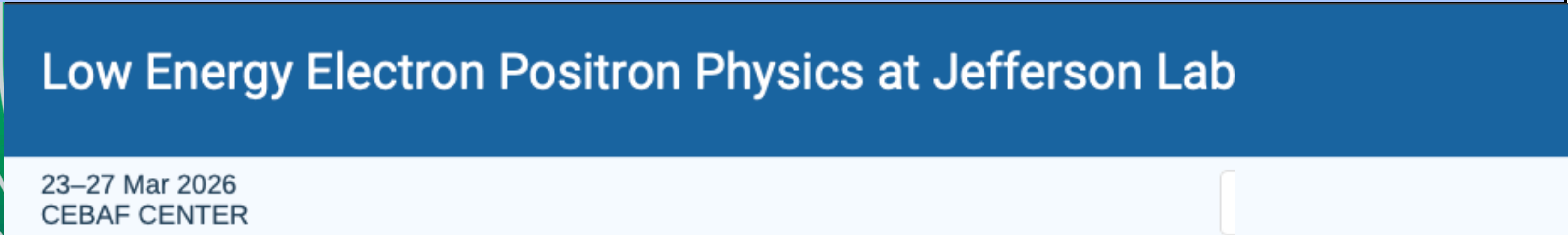
SCOPE This workshop will cover:
- Beam energies ranging from 1-100 MeV for both species
- Moderated/slow positrons to several eV

EMERGING CAPABILITIES The path toward GeV positron beams opens the door to new capabilities:
- Positron sources
- Low-energy (sub-GeV) nuclear physics
- Atomic physics
- Materials science

ORGANIZING COMMITTEE
Axel Schmidt, George Washington University
David Cassidy, University College London
Doug Higinbotham, Jefferson Lab
Eric Voutier, IJCLab
Farida Selim, Arizona State University
Joe Grames, Jefferson Lab
Kevin Jordan, Jefferson Lab
Tyler Kutz, Johannes Gutenberg University Mainz

Jefferson Lab

SCAN FOR MORE INFORMATION



Low Energy Electron Positron Physics at Jefferson Lab

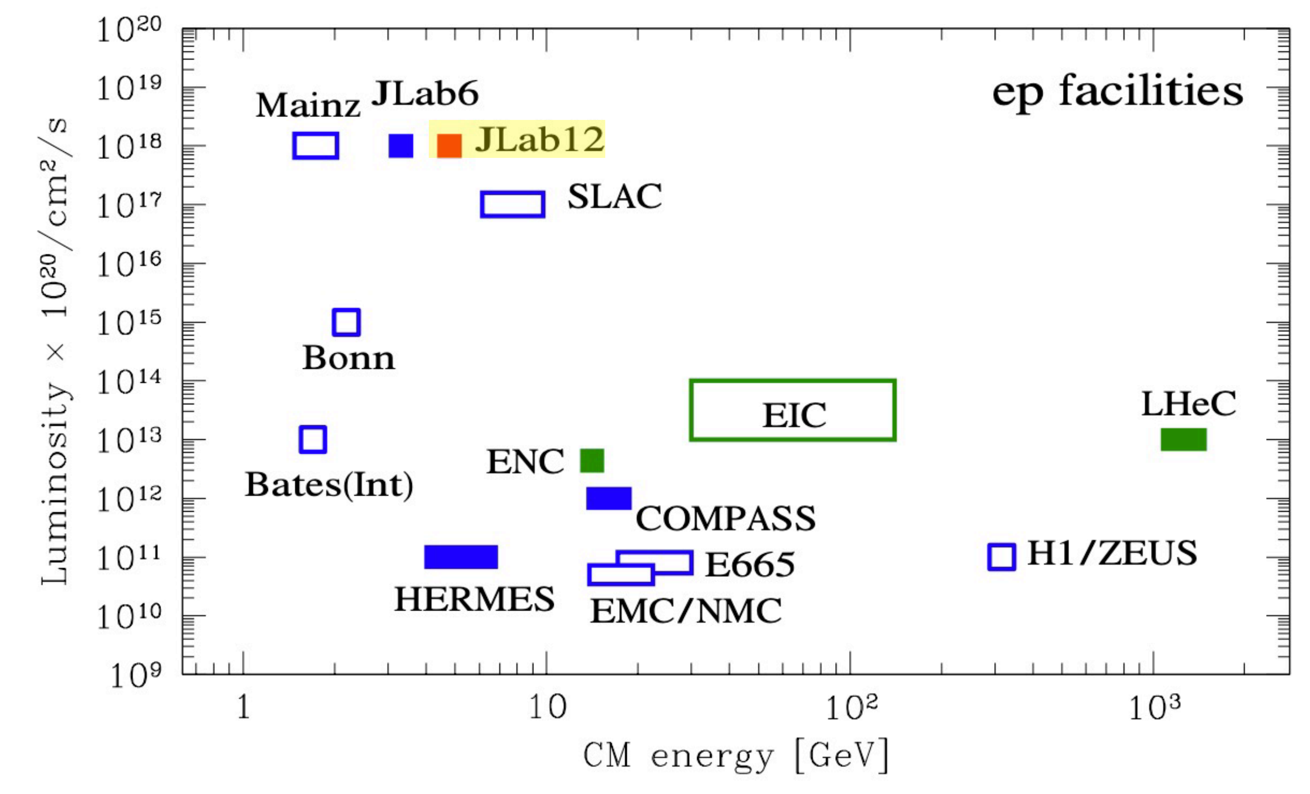
23–27 Mar 2026
CEBAF CENTER

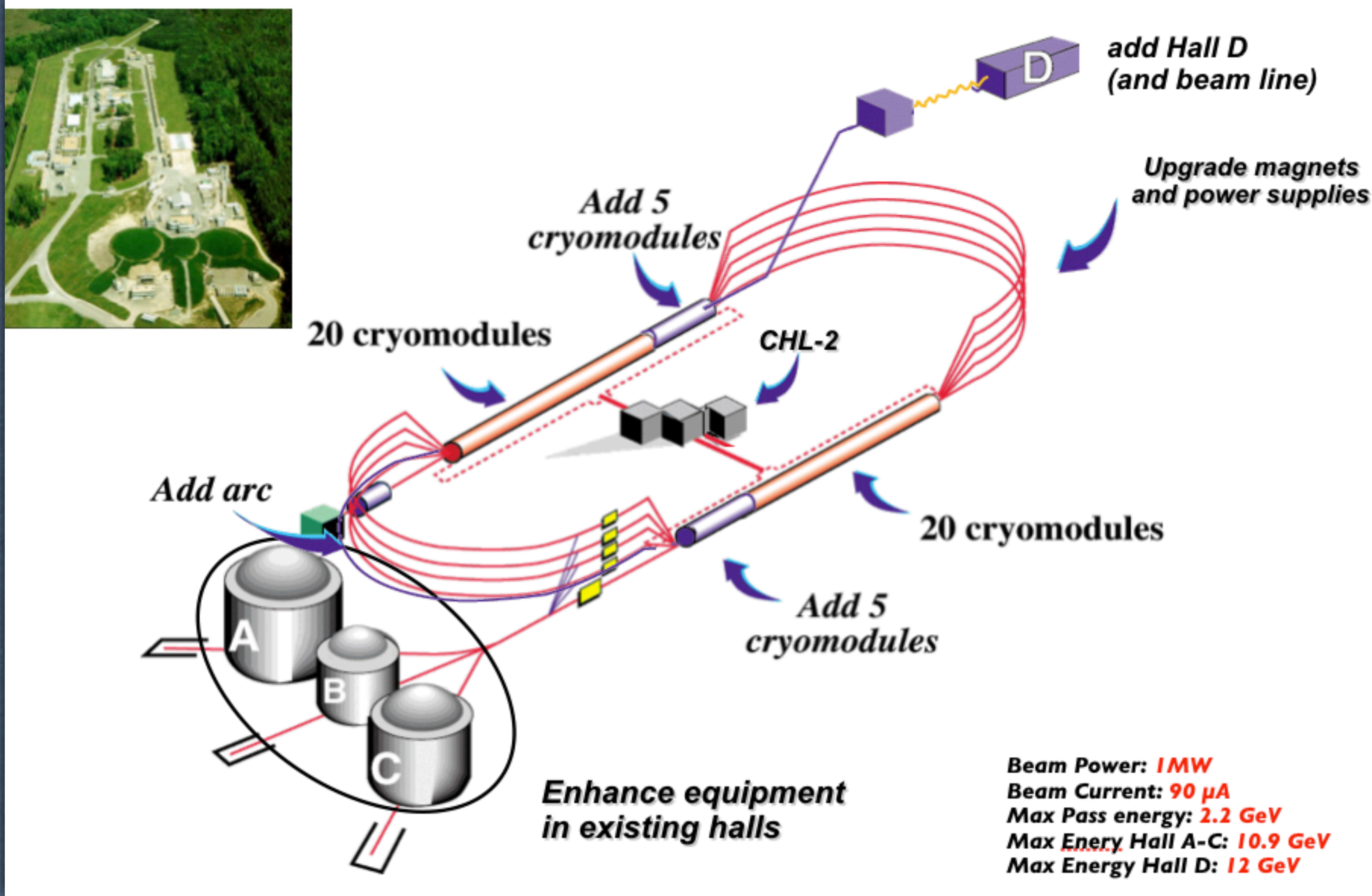
Dark sector searches at CeBAF and Ce+BAF

M.Battaglieri (INFN)

Jefferson Lab's accelerator site

Jefferson Lab
The intensity frontier





✳Primary Beam: Electrons

✳ Beam Energy: 12 GeV

- 10 > λ > 0.1 fm
- nucleon → quark transition
- baryon and meson excited states

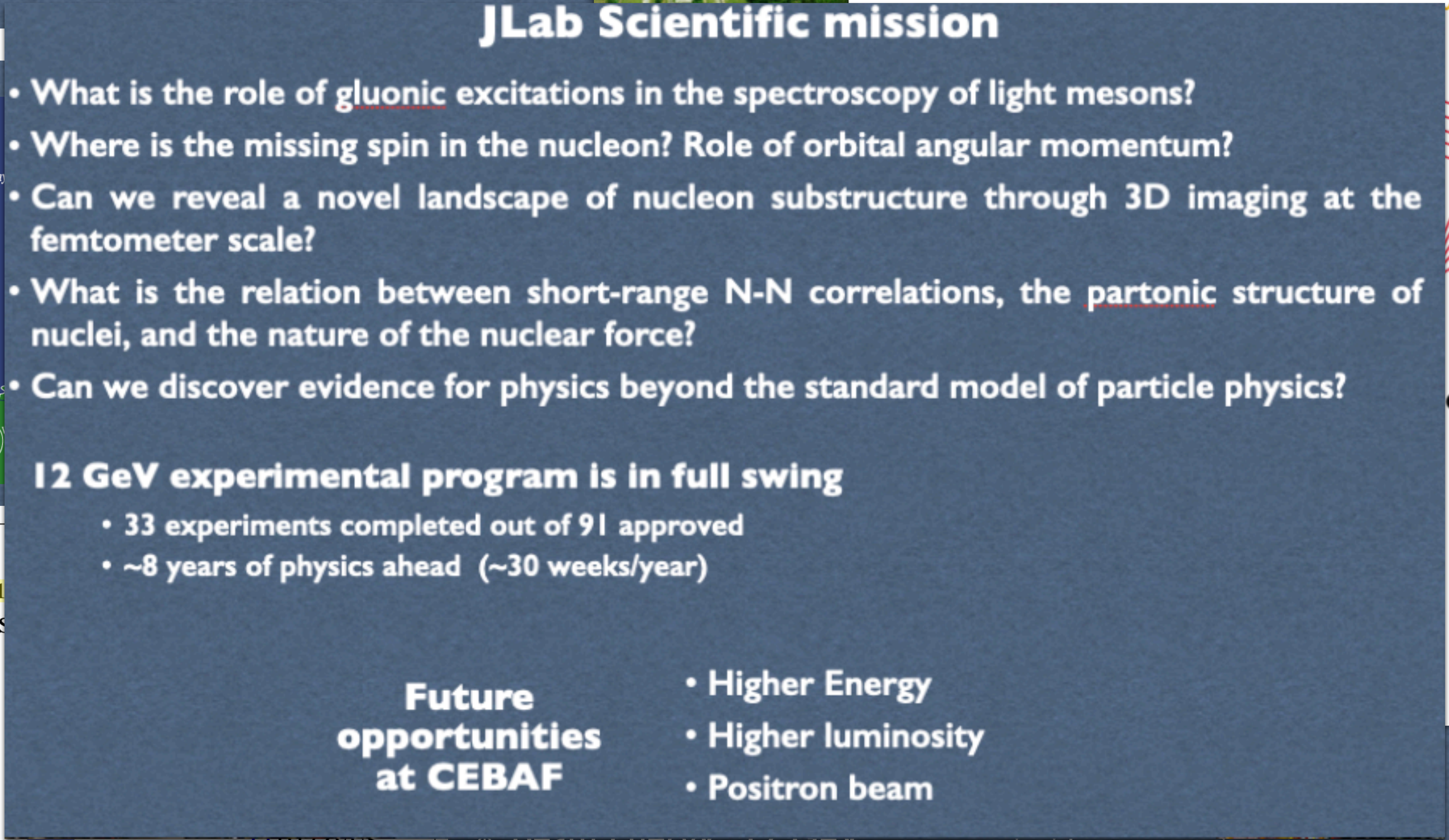
✳100% Duty Factor (cw) Beam

- coincidence experiments
- Four simultaneous beams
- Independent E and I

✳ Polarization

- spin degrees of freedom
- weak neutral currents

Jefferson Lab
The inter



JLab Scientific mission

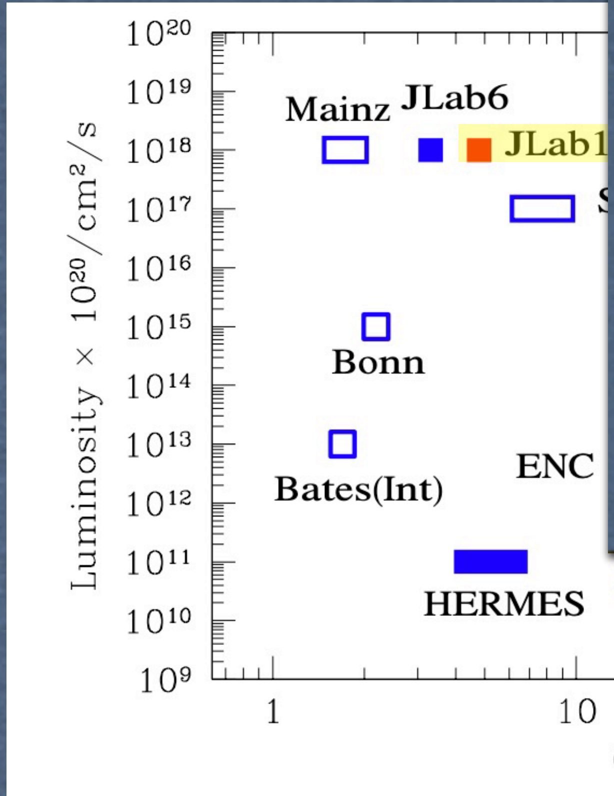
- What is the role of gluonic excitations in the spectroscopy of light mesons?
- Where is the missing spin in the nucleon? Role of orbital angular momentum?
- Can we reveal a novel landscape of nucleon substructure through 3D imaging at the femtometer scale?
- What is the relation between short-range N-N correlations, the partonic structure of nuclei, and the nature of the nuclear force?
- Can we discover evidence for physics beyond the standard model of particle physics?

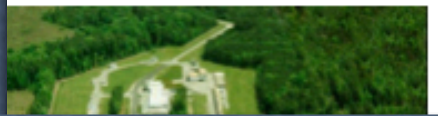
12 GeV experimental program is in full swing

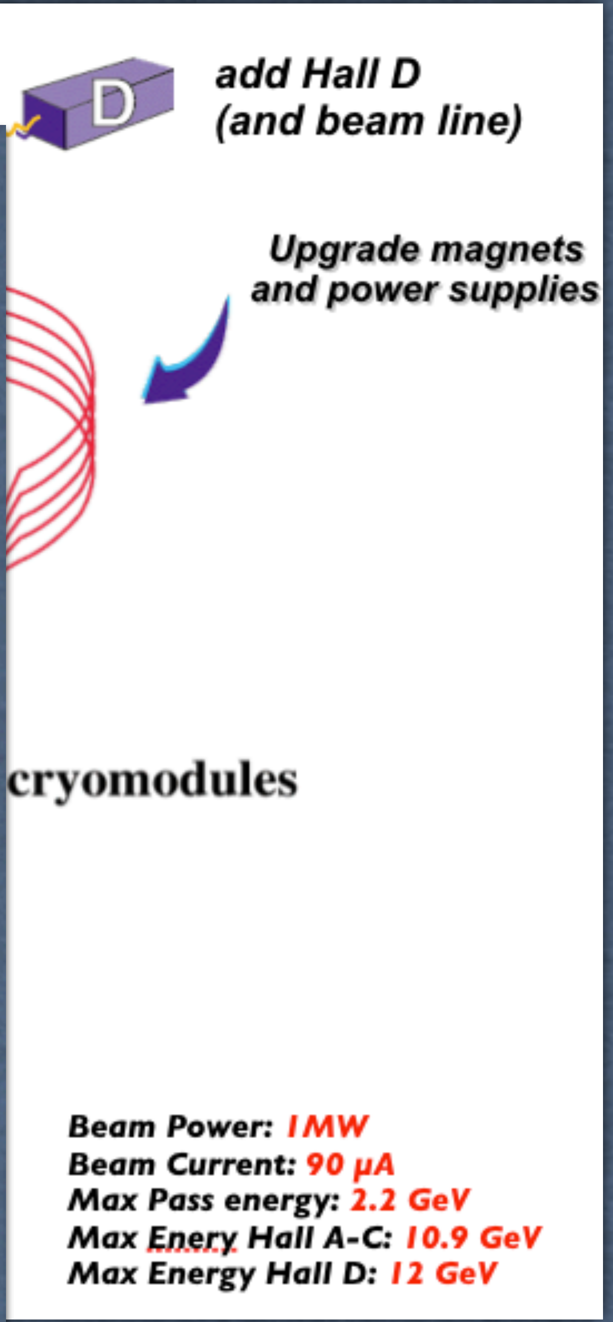
- 33 experiments completed out of 91 approved
- ~8 years of physics ahead (~30 weeks/year)

Future opportunities at CEBAF

- Higher Energy
- Higher luminosity
- Positron beam







Beam Power: 1MW
Beam Current: 90 μA
Max Pass energy: 2.2 GeV
Max Enery Hall A-C: 10.9 GeV
Max Energy Hall D: 12 GeV

✳ Beam Energy: 12 GeV

- 10 > λ > 0.1 fm
- nucleon → quark transition
- baryon and meson excited states

- coincidence experiments
- Four simultaneous beams
- Independent E and I

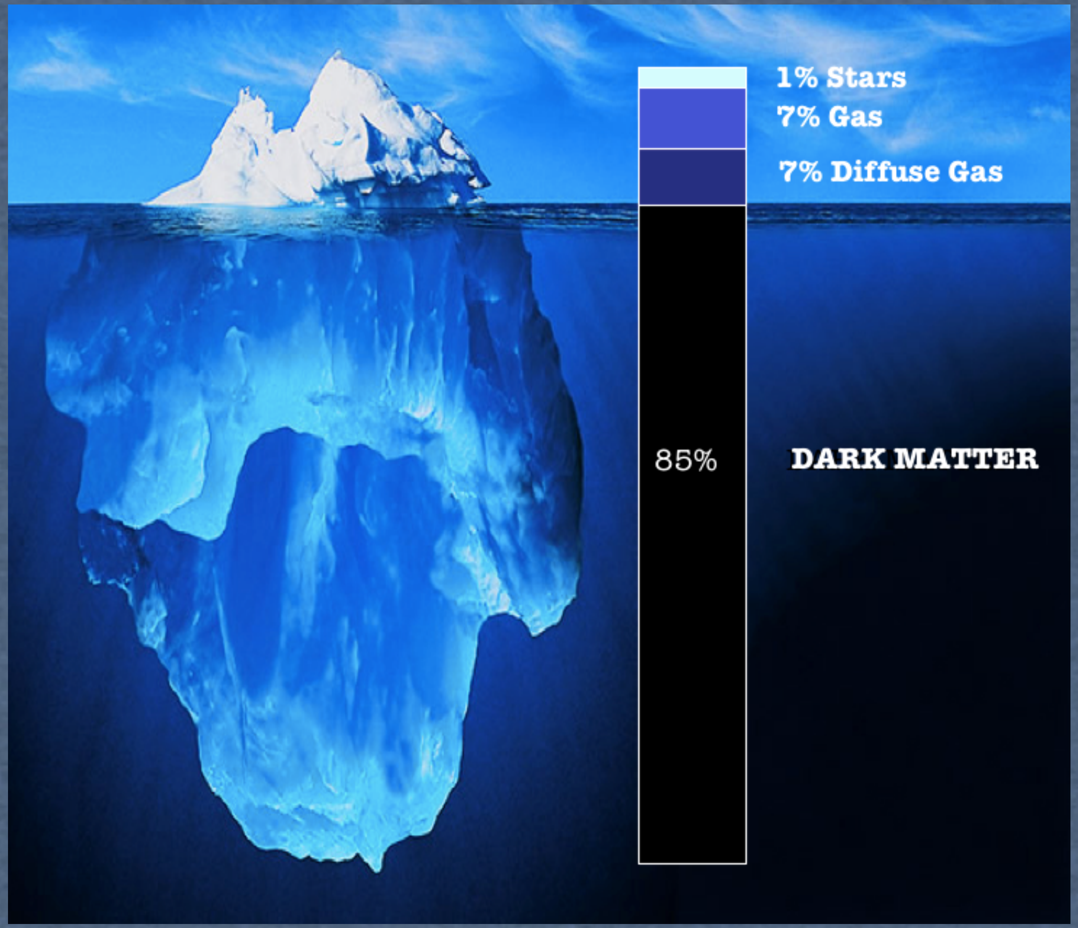
✳ Polarization

- spin degrees of freedom
- weak neutral currents

Dark Matter (DM) vs Baryonic Matter (BM)

Compelling astrophysical indications about DM existence

★ How much DM w.r.t. BM?



★ Does DM participate to non-gravitational interactions?
★ Is DM a new particle?

★ Constraint on DM mass and interactions

- should be '*dark*' (no em interaction)
- should weakly interact with SM particles
- should provide the correct relic abundance
- should be compatible with CMB power spectrum

… assuming that the gravity is not modified
and DM undergoes to other interactions

★ We can use what we know about standard model particles to build a DM theory

Use the SM as an example: SM = $U(1)_{EM} \times SU(2)_{Weak} \times SU(3)_{Strong}$

Particles, interactions and symmetries

Known particles
& new force-
carriers

Particles:
quarks, leptons

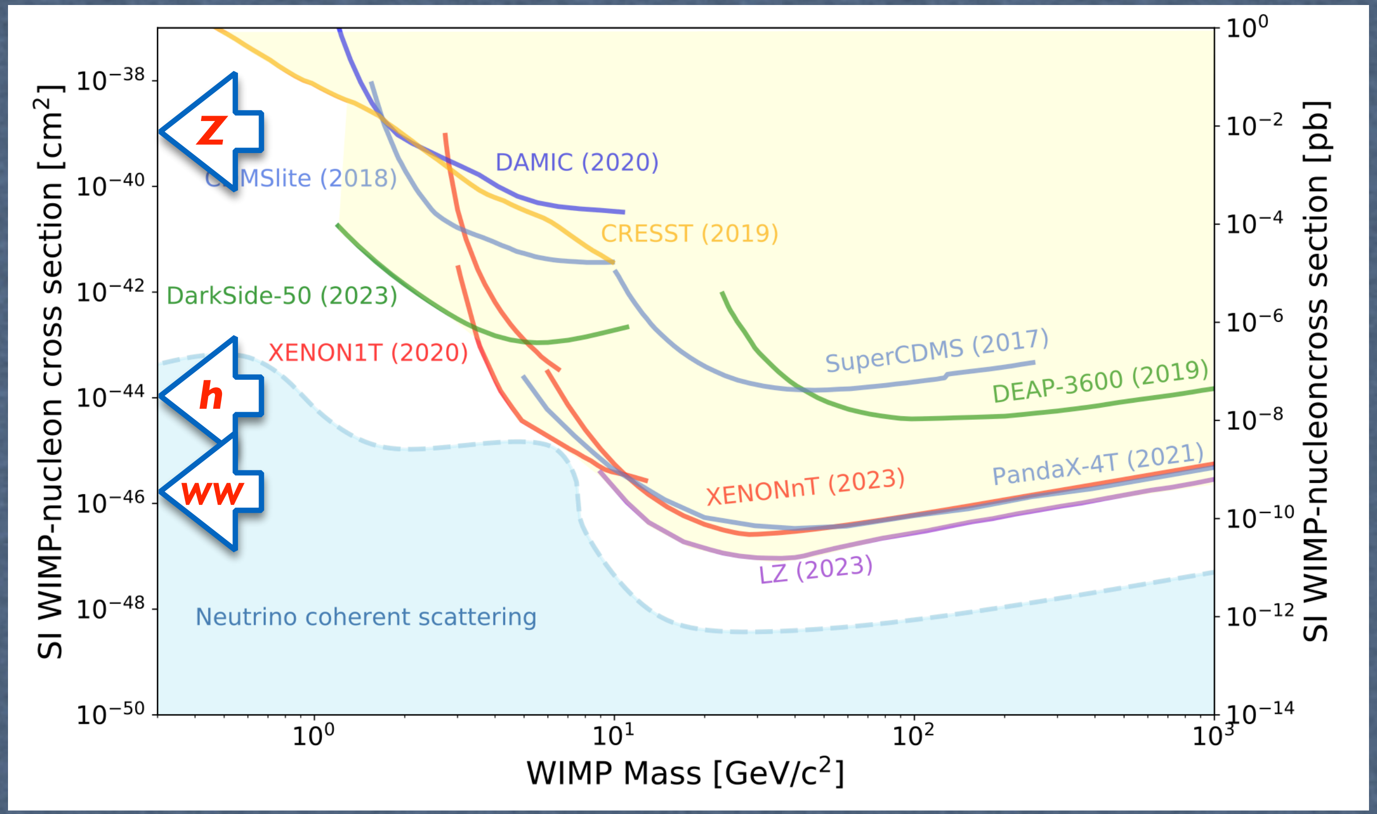
Force-carriers:
gluons, γ, W, Z, graviton (?), Higgs, ...

Two options:

★ New matter interacting trough the same forces
★ New matter interacting through new forces

Exploring the WIMP's option

★ Experimental limits



Slow-moving cosmological weakly interacting massive particles

- DM detection by measuring the (heavy) nucleus recoil
- Constraints on the interaction strength from the DM Direct Detection limits
  - Scattering through Z boson ($\sigma \sim 10^{-39}$cm^2): ruled out
  - Approaching limits for scattering through the Higgs ($\sigma \sim 10^{-45}$cm^2)
  - Close to irreducible neutrino background

✳ No signal observed in Direct Detection

✳ Experiments have reduced sensitivity to (light) DM (<1 GeV)

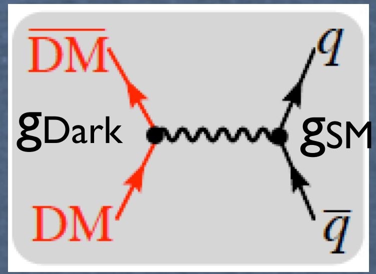
Light Dark Matter

Light Dark Matter (<TeV) naturally introduces light mediators

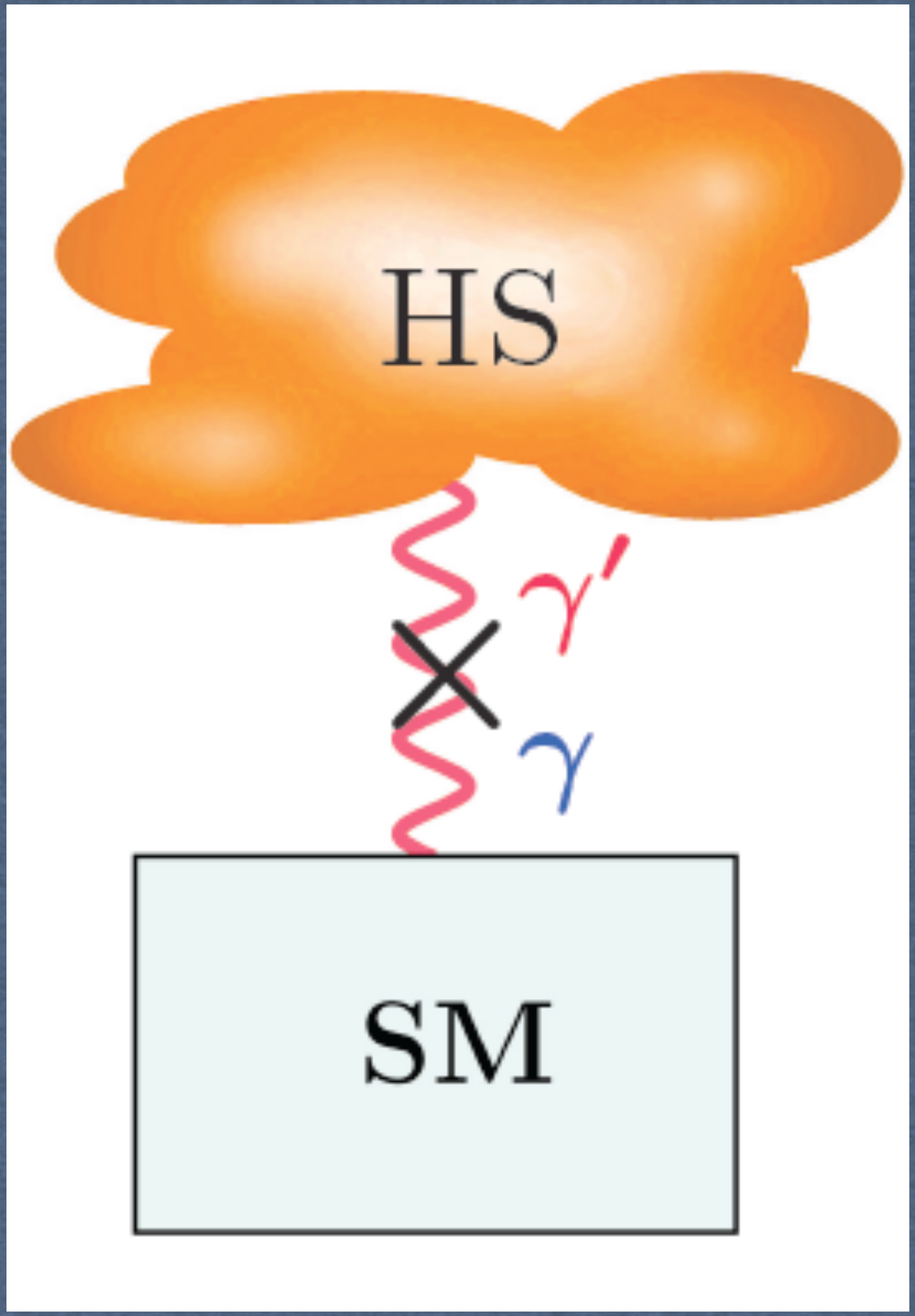
New interaction

WIMPs paradigm is not the only option (keeping the DM thermal origin)

$\langle \sigma v \rangle \sim g^2_{Dark}\, g^2_{SM}\, M^2_{DM}/M^4_{mediator}$



Introducing a new force in nature



- Hidden sector (HS)
  present in string theory and super-symmetries

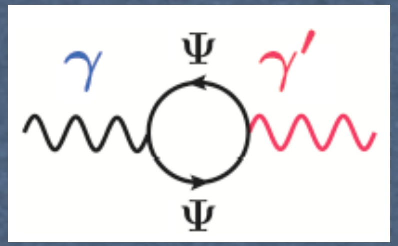
  - HS not charged under SM gauge groups (and v.v.)
    no direct interaction between HS and SM
    HS-SM connection via messenger particles

A simple way to go beyond the SM (not yet excluded!):

SU(3)$_C$ x SU(2)$_L$ x U(1)$_Y$ **x extra U(1)**

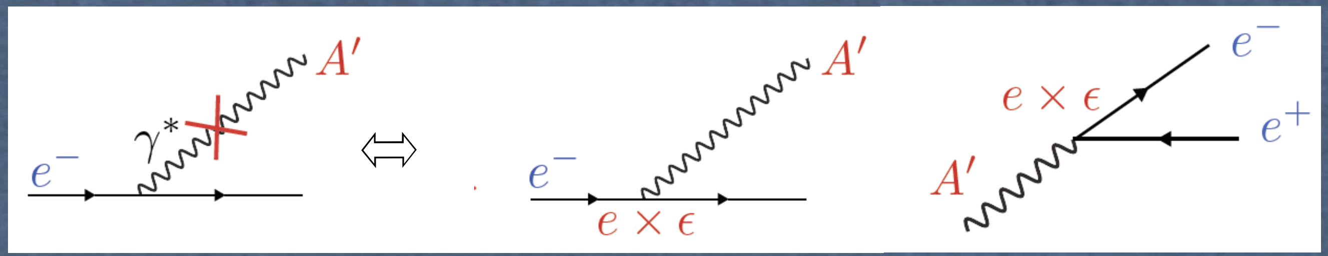
Color Electroweak Hypercharge Hidden sector

$$\mathcal{L}_{\rm eff} = \mathcal{L}_{\rm SM} - \frac{1}{4}X_{\mu\nu}X^{\mu\nu} - \frac{\chi}{2}\overset{\text{Hidden}}{X_{\mu\nu}}\underset{\text{Visible}}{F^{\mu\nu}} + \frac{m^2_{\gamma'}}{2}X_\mu X^\mu$$



γ'/A' couples to SM via electromagnetic current (kinetic mixing)

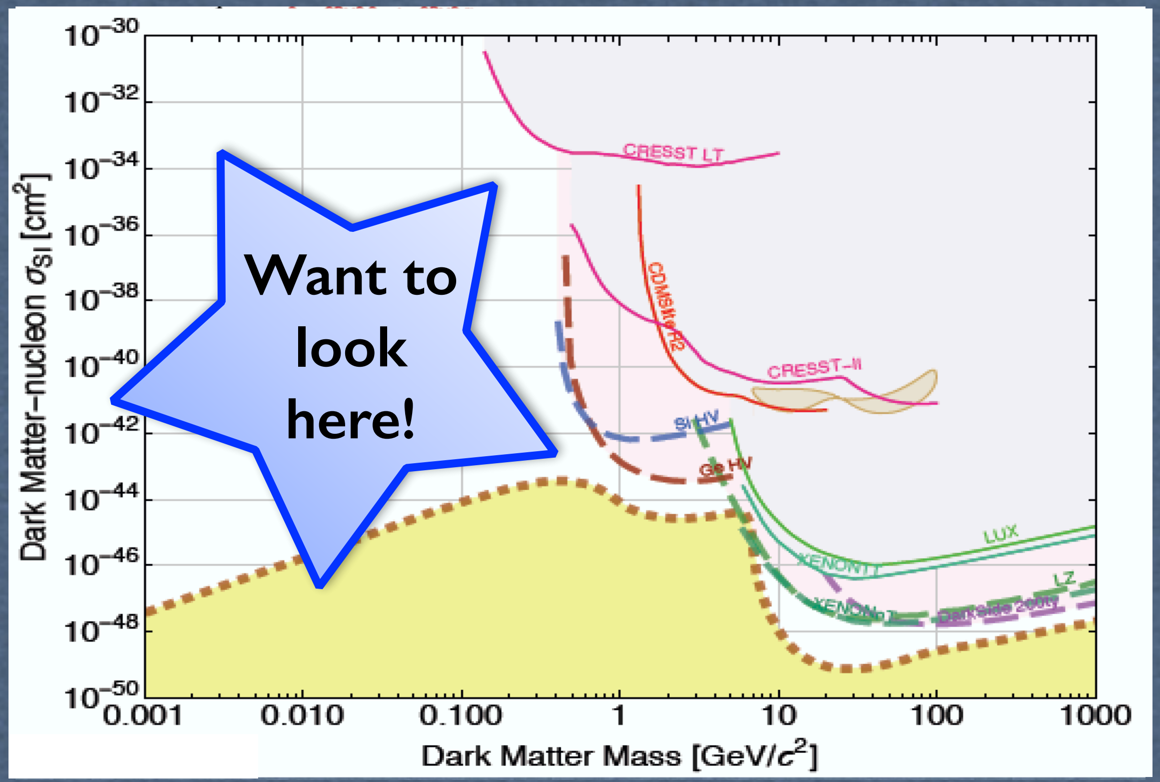
➜ $A_\mu \rightarrow A_\mu + \varepsilon a_\mu$ $\chi=\varepsilon \sim 10^{-6}\text{-}10^{-2}$ ($\alpha^{DarkProton} = \varepsilon^2 \alpha_\mu$)



Ψ can be a huge mass scale particle
(M_Ψ~1EeV) coupling to both SM and HS

Light Dark Matter

★ Experimental limits



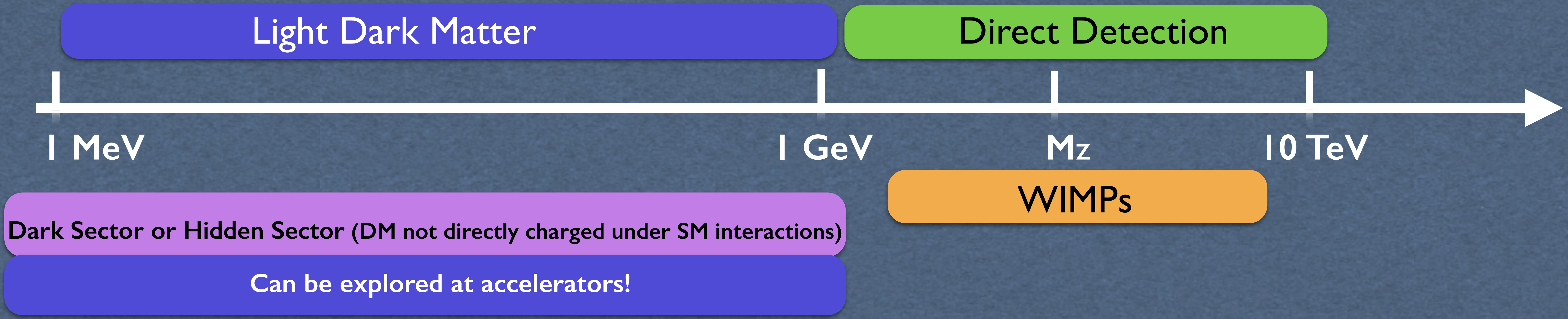
Light Dark Matter with a (almost) weak interaction (new force!)

- Direct Detection is difficult
  - Low mass elastic scattering on heavy nuclei produces small recoil
  - eV-range recoil requires a different detection technology
  - Directionality may help to go behind existing limits at large masses

Accelerators-based DM search

covers an unexplored mass region extending the reach outside the classical DM hunting territory

- **High intensity**
- **Moderate energy**



Light Dark Matter

Direct Detection

1 MeV

1 GeV

Mz

10 TeV

WIMPs

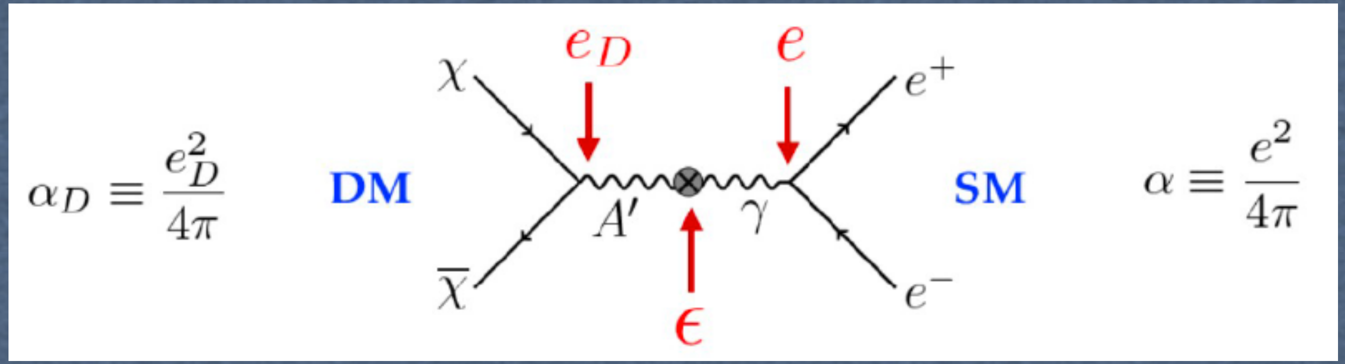
Dark Sector or Hidden Sector (DM not directly charged under SM interactions)

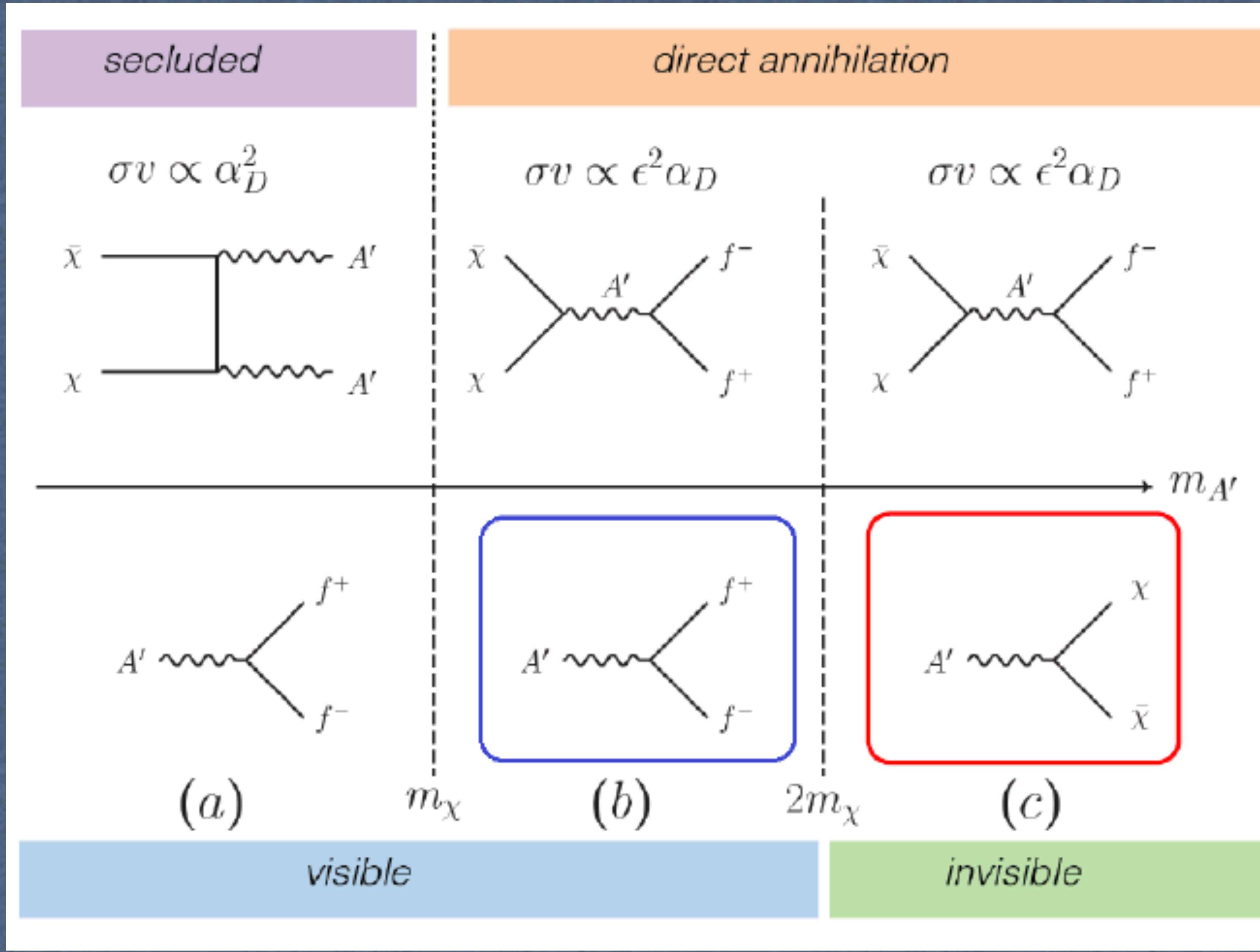
Can be explored at accelerators!

Dark Photon Signatures

Vector mediated Light Dark Matter

- Vector-Portal: DM-SM interaction mediated by U(1) gauge-boson (dark photon or A') couples to electric charge

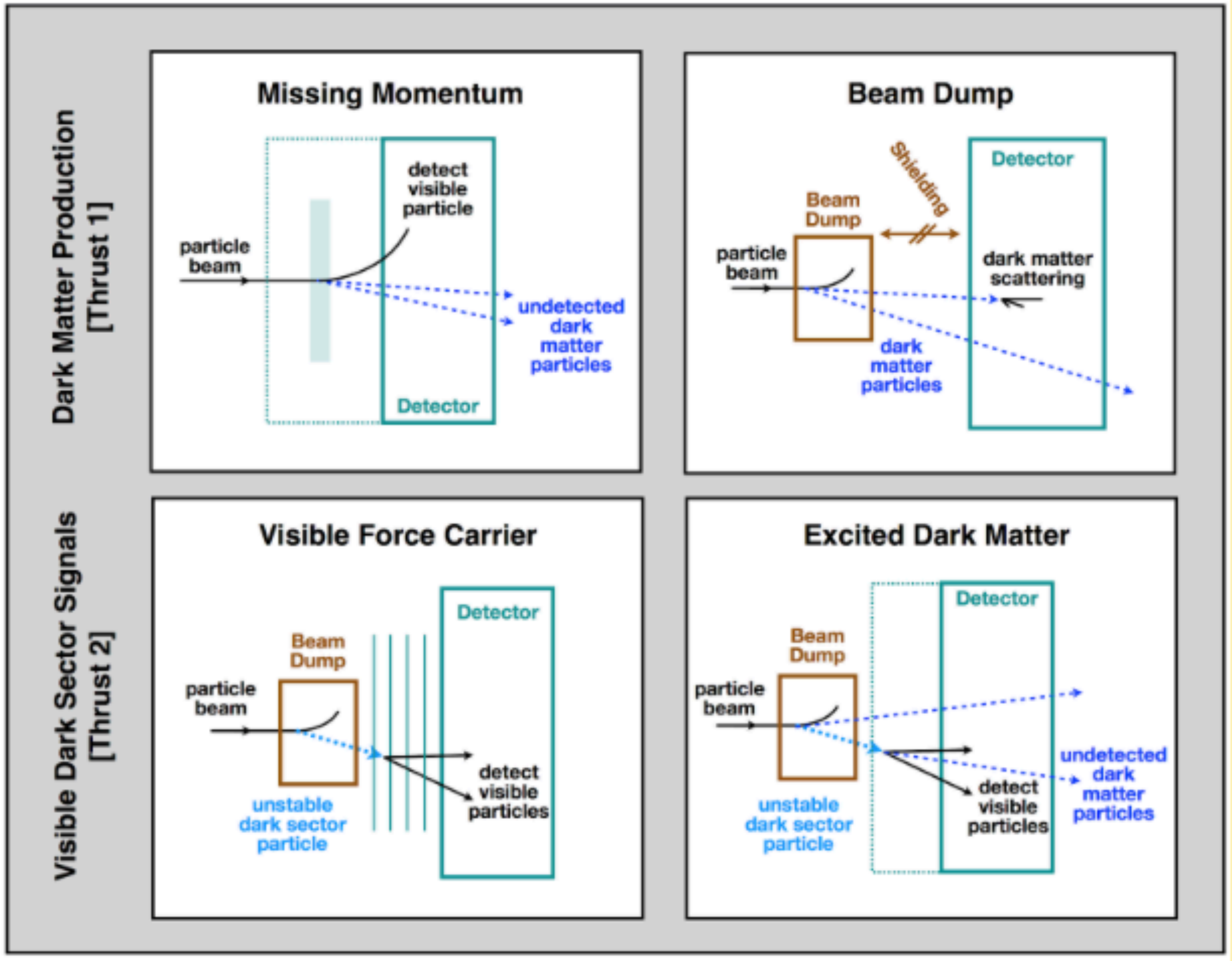




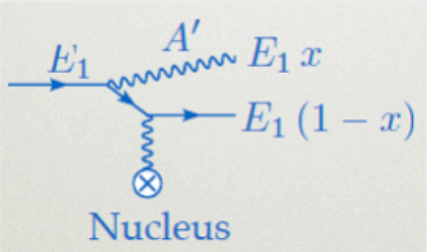
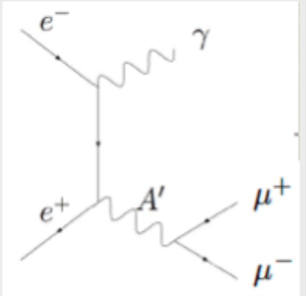
A' interaction scenarios

- **Secluded**: no constraints by cosmology for accelerator based experiments. Any ε allowed
- **Visible decay**: final state contains SM particles
- **Invisible decay**: A' decays to Dark Sector invisible particles

Experimental techniques



Fixed target vs. collider

	Fixed Target	e+e- colliders
Process		
Luminosity	10^{11} e- ~10^{23} atoms in target	10^{11} e- 10^{11} e+
Cross-Section	$\sigma \sim \frac{\alpha^3 Z^2 \epsilon^2}{m^2} \sim O(10\ pb)$	$\sigma \sim \frac{\alpha^2 \epsilon^2}{E^2} \sim O(10\ fb)$

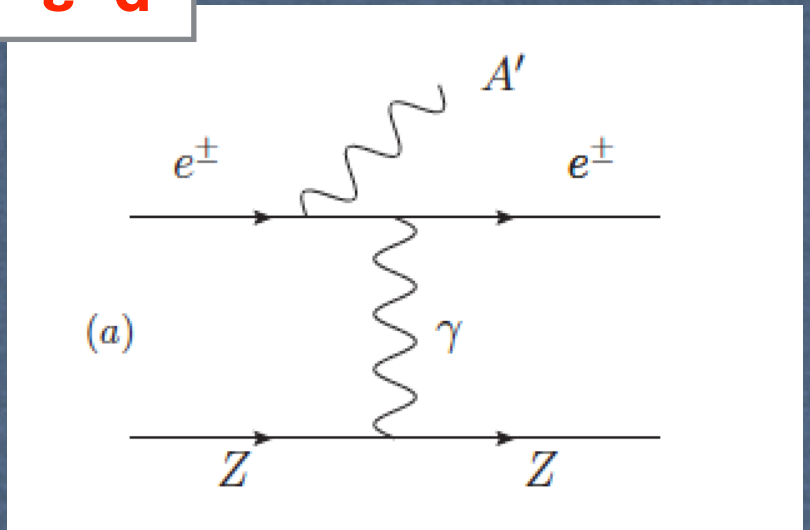
- high backgrounds
- limited A' mass

- low backgrounds
- higher A' mass

✳ $1/M_{A'}$ .vs. $1/E_{beam}$
✳ Coherent scattering from Nucleus (~Z^2)

A’ Production mechanisms - e$^{\pm}$

~ $\varepsilon^2 \alpha^3$



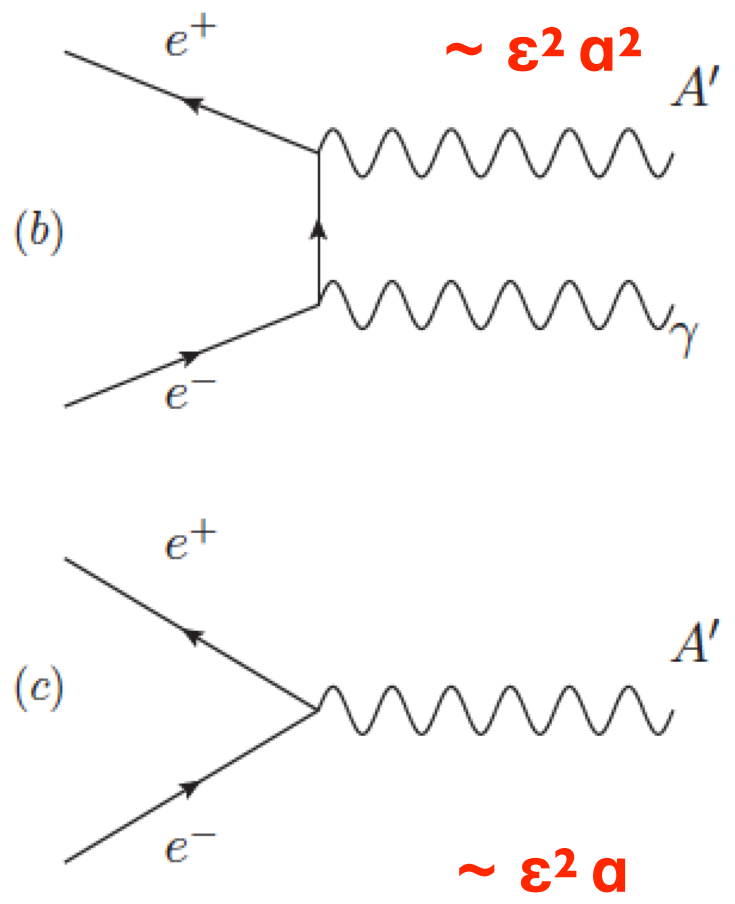
The Weizsacker-Williams approximation (*A’-strahlung*)

- The first tree-level mechanism proposed

A’ Production - resonant/non-resonant production

- Specific for positron annihilation
- Ideal configuration: positron beam (Ce+BAF?)
- Backup: electron beam (CEBAF) on a beam dump as a positron source (EM shower’s e+ have any energy in the range of 0 - E$_{\text{beam}}$ peaked at low energy)

L. Marsicano et al. Phys. Rev. Lett., 121(4) 041802, 2018
L. Marsicano et al. Phys. Rev. D, 98 (1) 015031, 2018



~ $\varepsilon^2 \alpha^2$

- **NON-RESONANT annihilation**

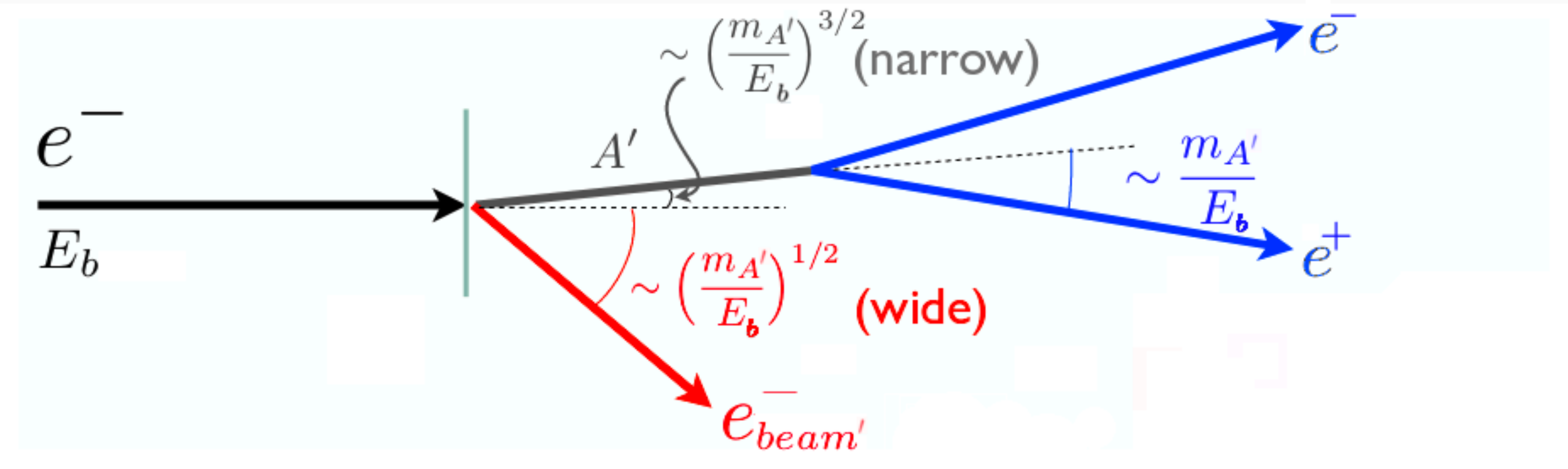
~ $\varepsilon^2 \alpha$

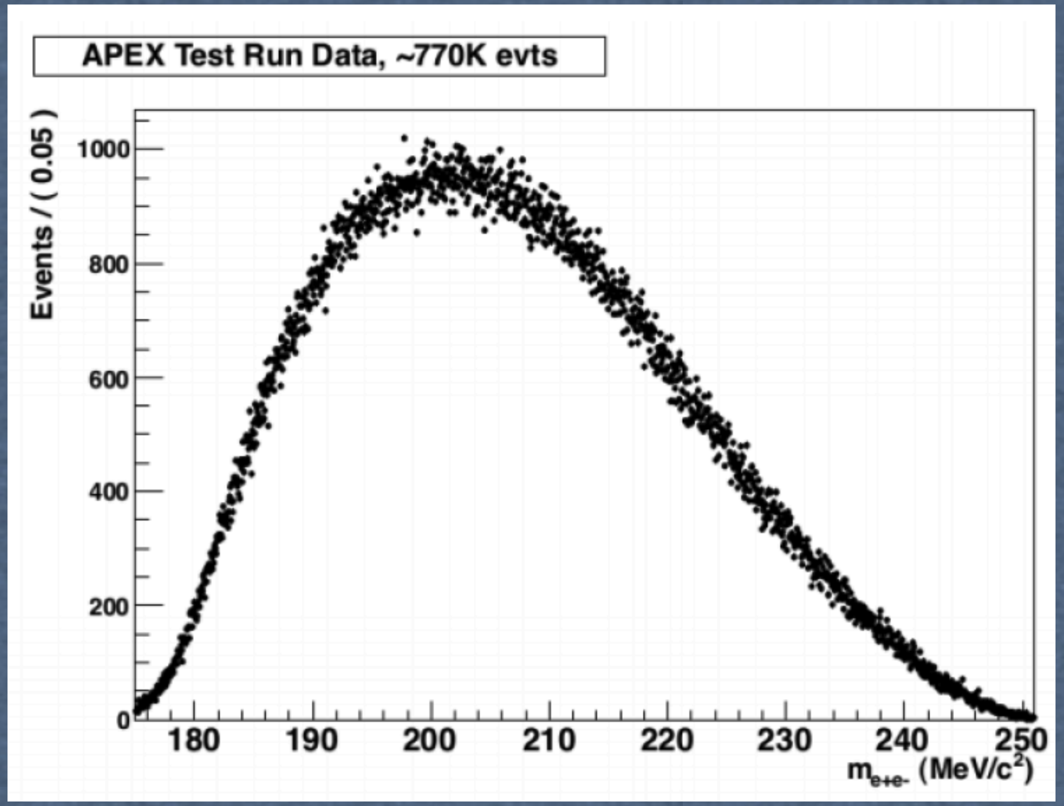
- **RESONANT annihilation**

$$\sigma_r = \sigma_{\text{peak}} \frac{\Gamma^2_{A'}/4}{(\sqrt{s}-m_{A'})^2+\Gamma^2_{A'}/4} ,$$

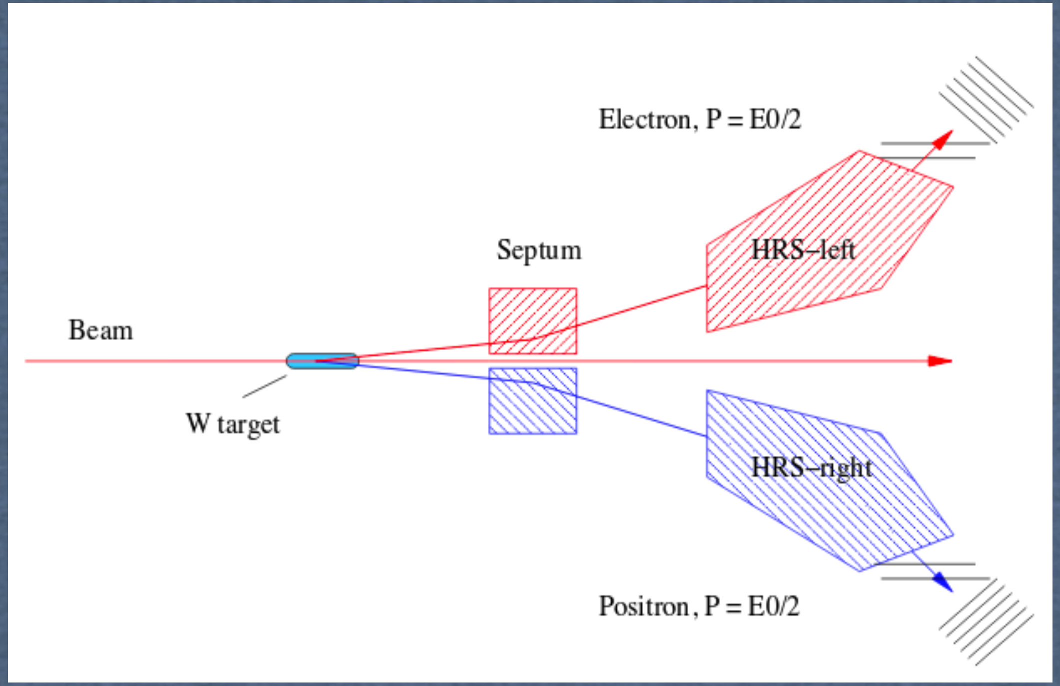
APEX: A-Prime EXperiment
visible decay

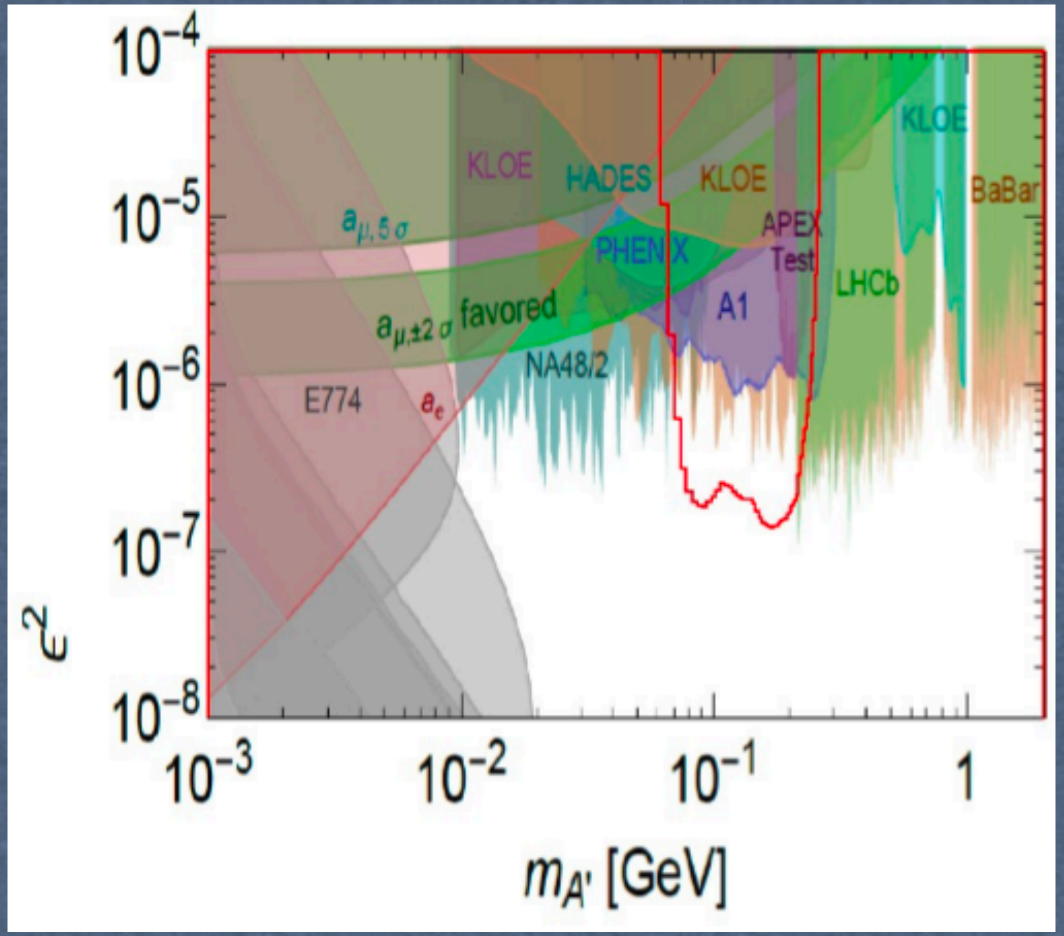
e- fixed target experiment installed in HALL A searching for dark photon visible decay





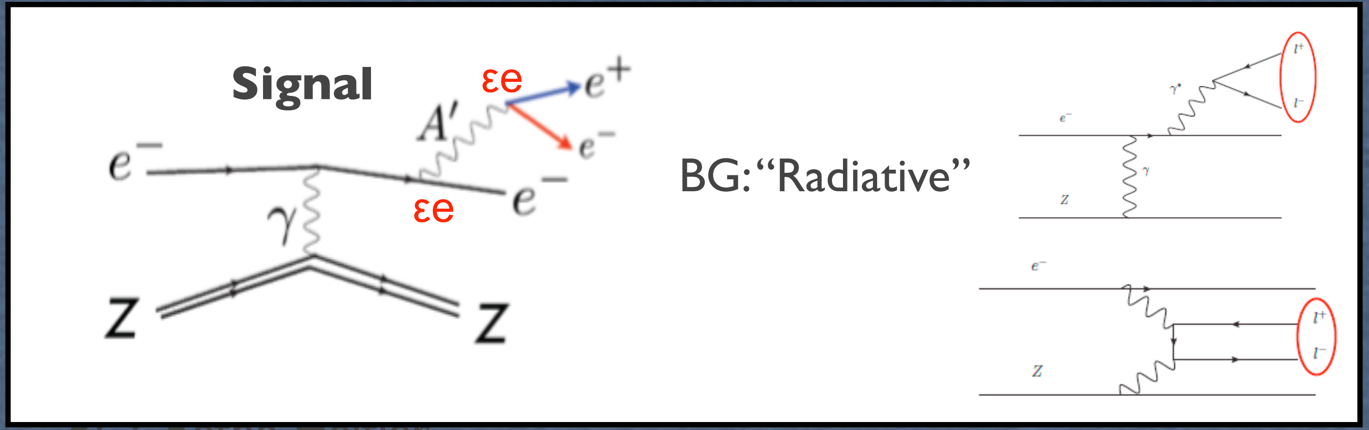
- Dark photon searched as a narrow resonance in e+e- mass over a smooth QED background
- Two High Resolution Spectrometers (HRSs) in coincidence to measure events with an e- in one arm and e+ in the other
- Standard HRS detector stack in both arms: Scintillators: S0 and S2(timing), VDC (tracking), Cherenkov and Calorimeters (PID)



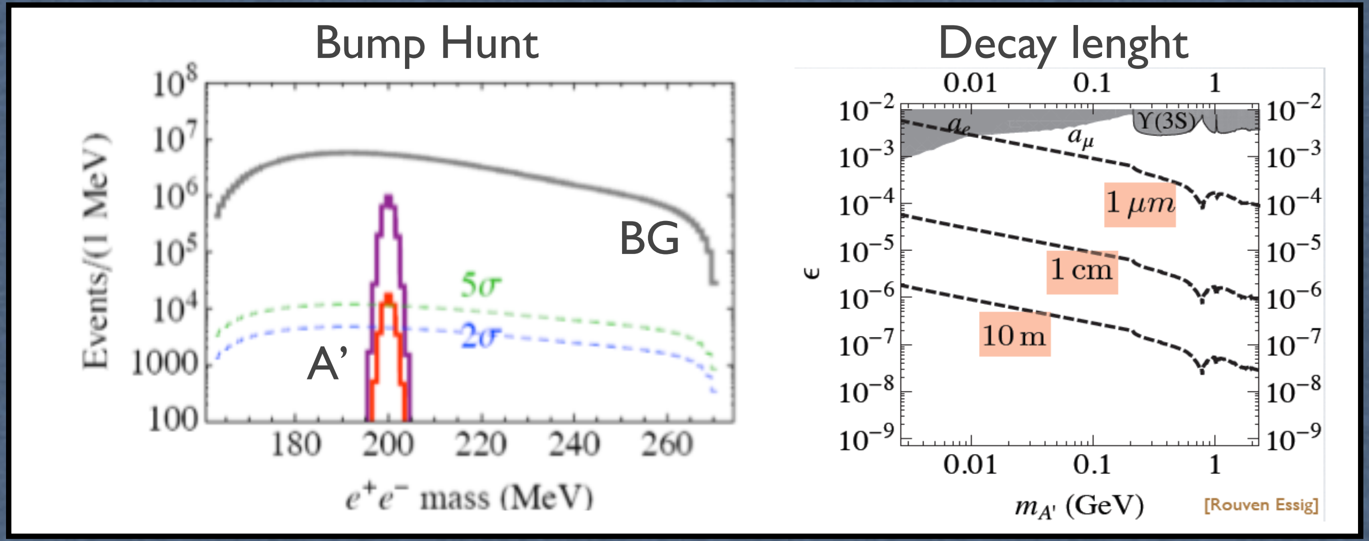


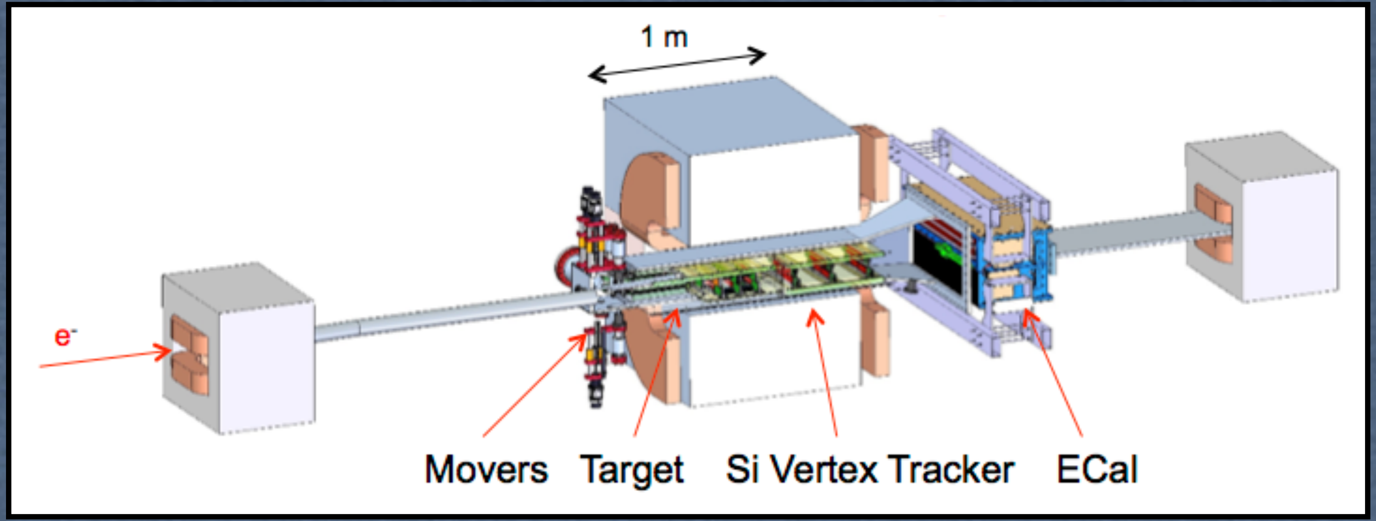
Heavy Photon Search @ JLab

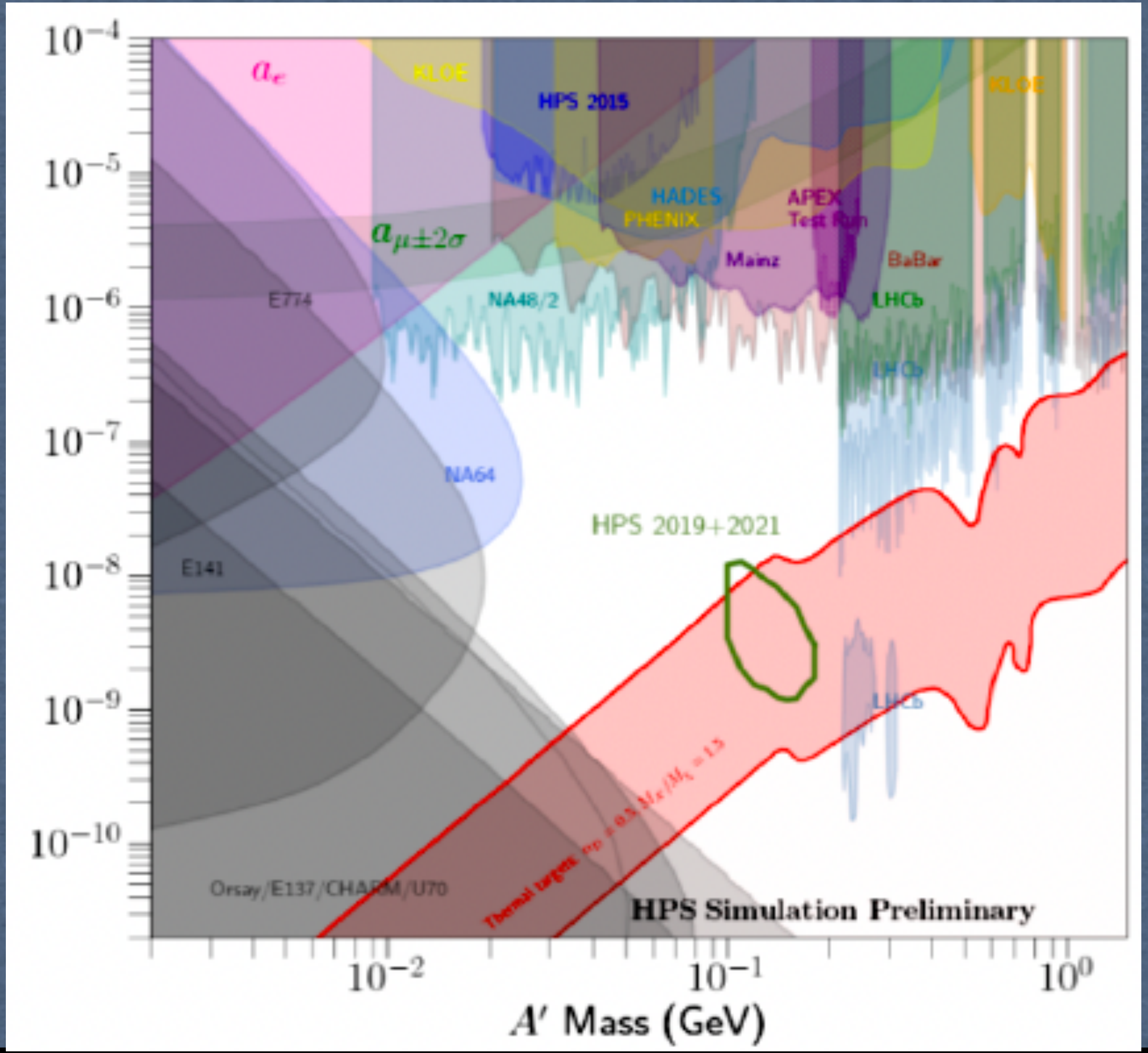
visible decay



BG: Bethe-Heitler







Heavy photon signatures in HPS

BH + Vertexing = enhanced experimental reach

1) Bump Hunting (BH)

Narrow e+e-resonance over a QED background

➥ good mass resolution: $\sigma_{A'mass}$~1 MeV

2) Secondary decay vertex (vertexing)

Detached vertex from few mm to tens cm

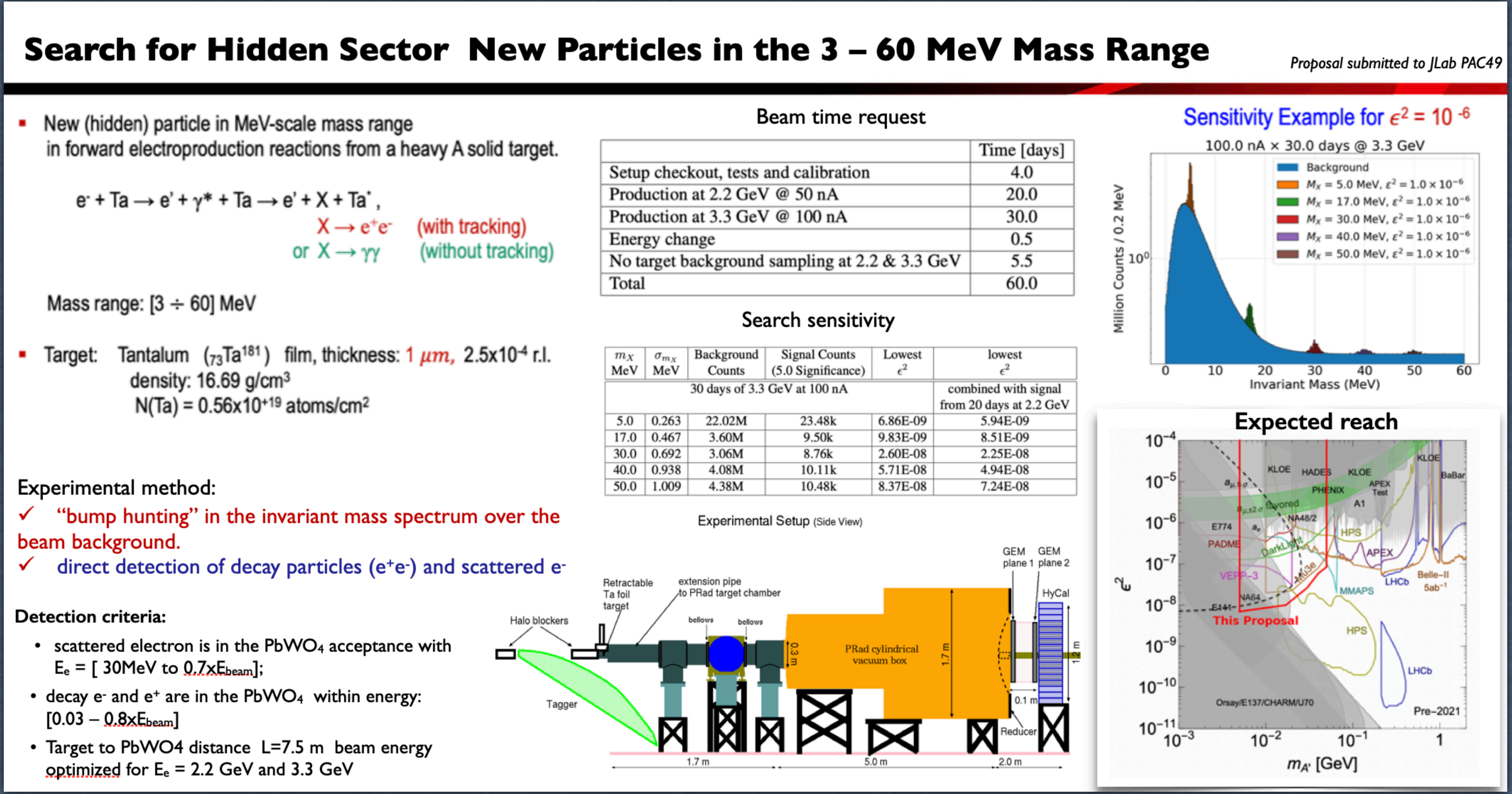
➥ good spacial resolution: σ_{vertex}~1mm

- 105 PAC more days of data taking approved, confirmed by PAC52

X17 search at JLab

visible decay

- Search for the X17 in e+e- invariant mass
- Presented to JLab PAC 49 in Aug 21 and granted a C2 approval



Search for Hidden Sector New Particles in the 3 – 60 MeV Mass Range

Proposal submitted to JLab PAC49

- New (hidden) particle in MeV-scale mass range in forward electroproduction reactions from a heavy A solid target.

$$e^- + Ta \rightarrow e' + \gamma^* + Ta \rightarrow e' + X + Ta^*,$$

$X \rightarrow e^+e^-$ (with tracking)

or $X \rightarrow \gamma\gamma$ (without tracking)

Mass range: [3 ÷ 60] MeV

- Target: Tantalum ($_{73}Ta^{181}$) film, thickness: 1 μm, 2.5x10^{-4} r.l.
  density: 16.69 g/cm^3
  N(Ta) = 0.56x10^{+19} atoms/cm^2

Experimental method:

✓ "bump hunting" in the invariant mass spectrum over the beam background.

✓ direct detection of decay particles (e^+e^-) and scattered e-

Detection criteria:

- scattered electron is in the PbWO$_4$ acceptance with E_e = [30MeV to 0.7xE_{beam}];
- decay e- and e+ are in the PbWO$_4$ within energy: [0.03 – 0.8xE_{beam}]
- Target to PbWO4 distance L=7.5 m beam energy optimized for E_e = 2.2 GeV and 3.3 GeV

Beam time request

	Time [days]
Setup checkout, tests and calibration	4.0
Production at 2.2 GeV @ 50 nA	20.0
Production at 3.3 GeV @ 100 nA	30.0
Energy change	0.5
No target background sampling at 2.2 & 3.3 GeV	5.5
Total	60.0

Search sensitivity

m_X MeV	σ_{m_X} MeV	Background Counts	Signal Counts (5.0 Significance)	Lowest ϵ^2	lowest ϵ^2
30 days of 3.3 GeV at 100 nA					combined with signal from 20 days at 2.2 GeV
5.0	0.263	22.02M	23.48k	6.86E-09	5.94E-09
17.0	0.467	3.60M	9.50k	9.83E-09	8.51E-09
30.0	0.692	3.06M	8.76k	2.60E-08	2.25E-08
40.0	0.938	4.08M	10.11k	5.71E-08	4.94E-08
50.0	1.009	4.38M	10.48k	8.37E-08	7.24E-08

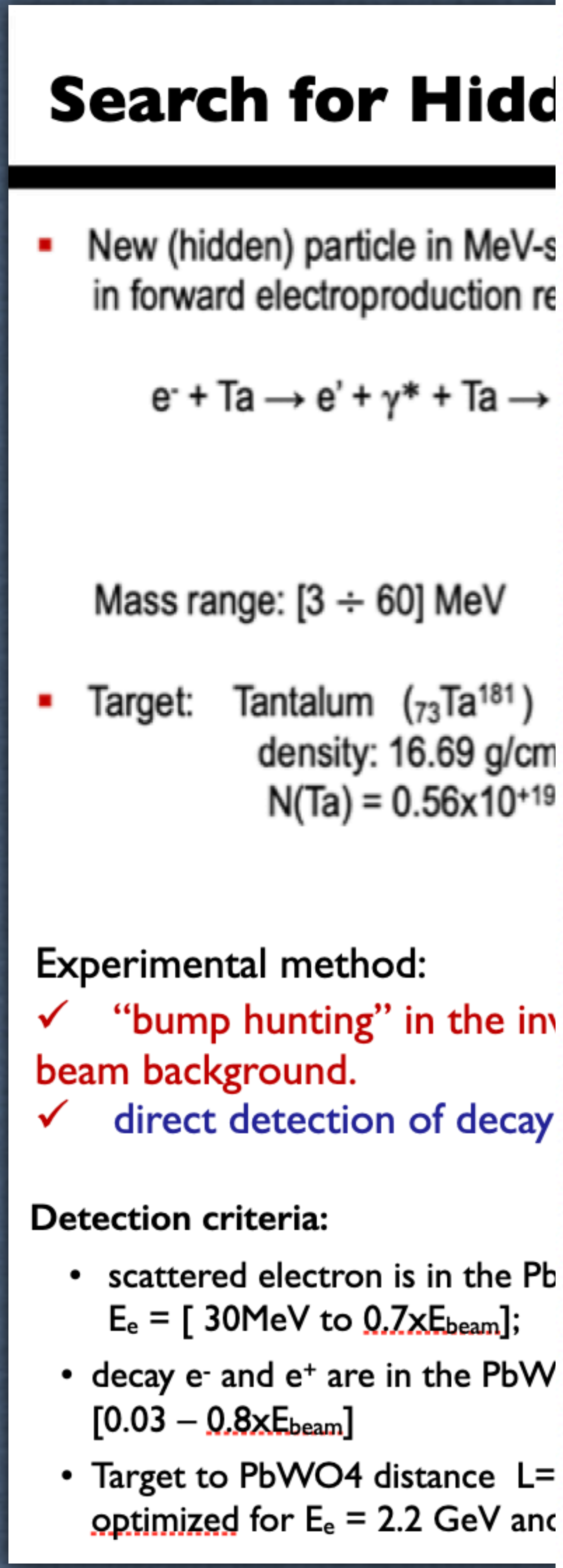
Experimental Setup (Side View)

Sensitivity Example for $\epsilon^2 = 10^{-6}$

Expected reach

X17 search at JLab

- Search for the X17 in e+e- invariant mass
- Presented to JLab PAC 49 in Aug 21 and granted a C2 approval
- Presented to JLab PAC 50 in Aug 2022 and granted A rate (full approval)
- Start data taking this week!



Search for Hidd

- New (hidden) particle in MeV-s
in forward electroproduction re

$e^- + Ta \rightarrow e' + \gamma^* + Ta \rightarrow$

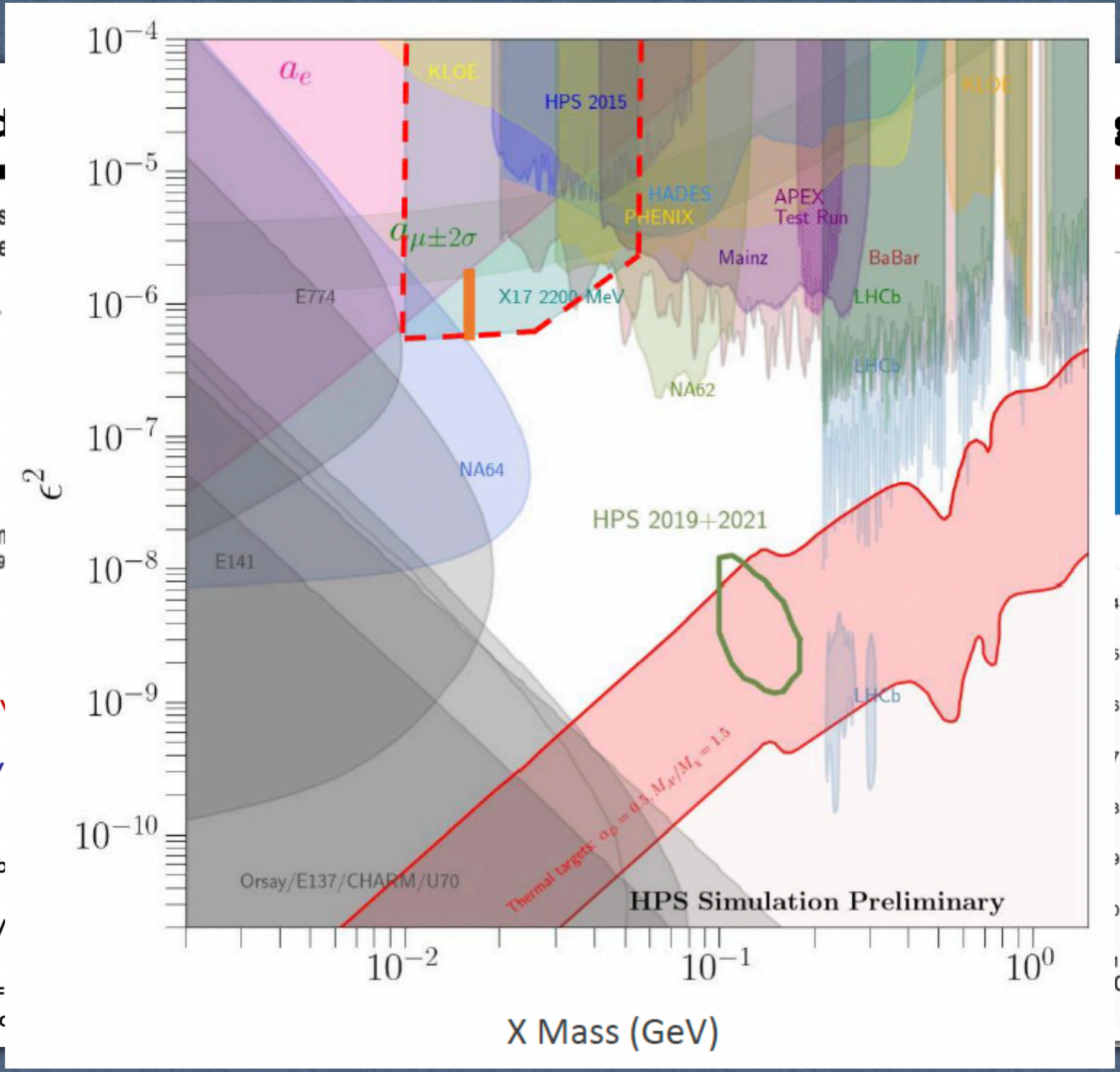
Mass range: [3 ÷ 60] MeV

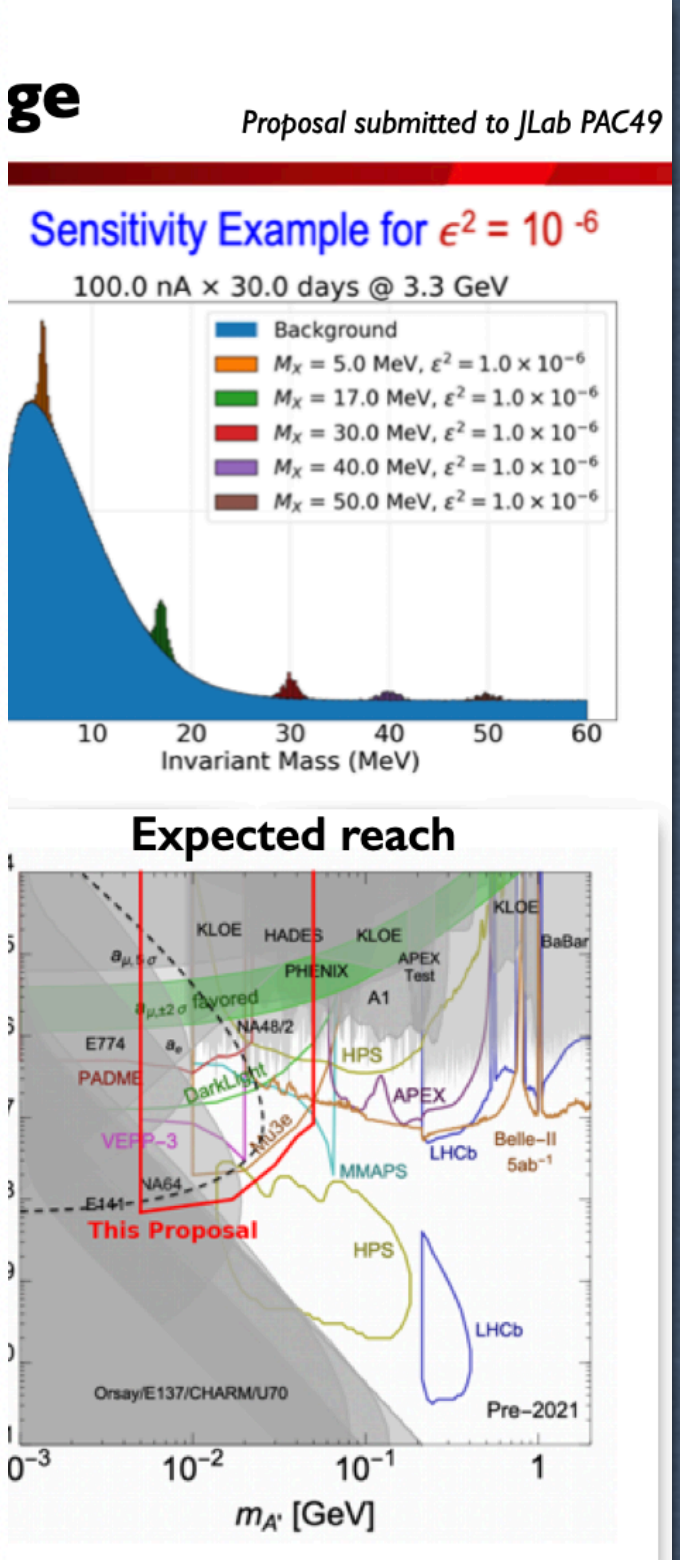
- Target: Tantalum ($_{73}Ta^{181}$)
density: 16.69 g/cm
N(Ta) = 0.56x10^{+19}

Experimental method:
✓ "bump hunting" in the inv
beam background.
✓ direct detection of decay

Detection criteria:

- scattered electron is in the Pb
E_e = [30MeV to 0.7xE_{beam}];
- decay e- and e+ are in the PbW
[0.03 – 0.8xE_{beam}]
- Target to PbWO4 distance L=
optimized for E_e = 2.2 GeV anc





ge

Proposal submitted to JLab PAC49

Sensitivity Example for $\epsilon^2 = 10^{-6}$

Expected reach

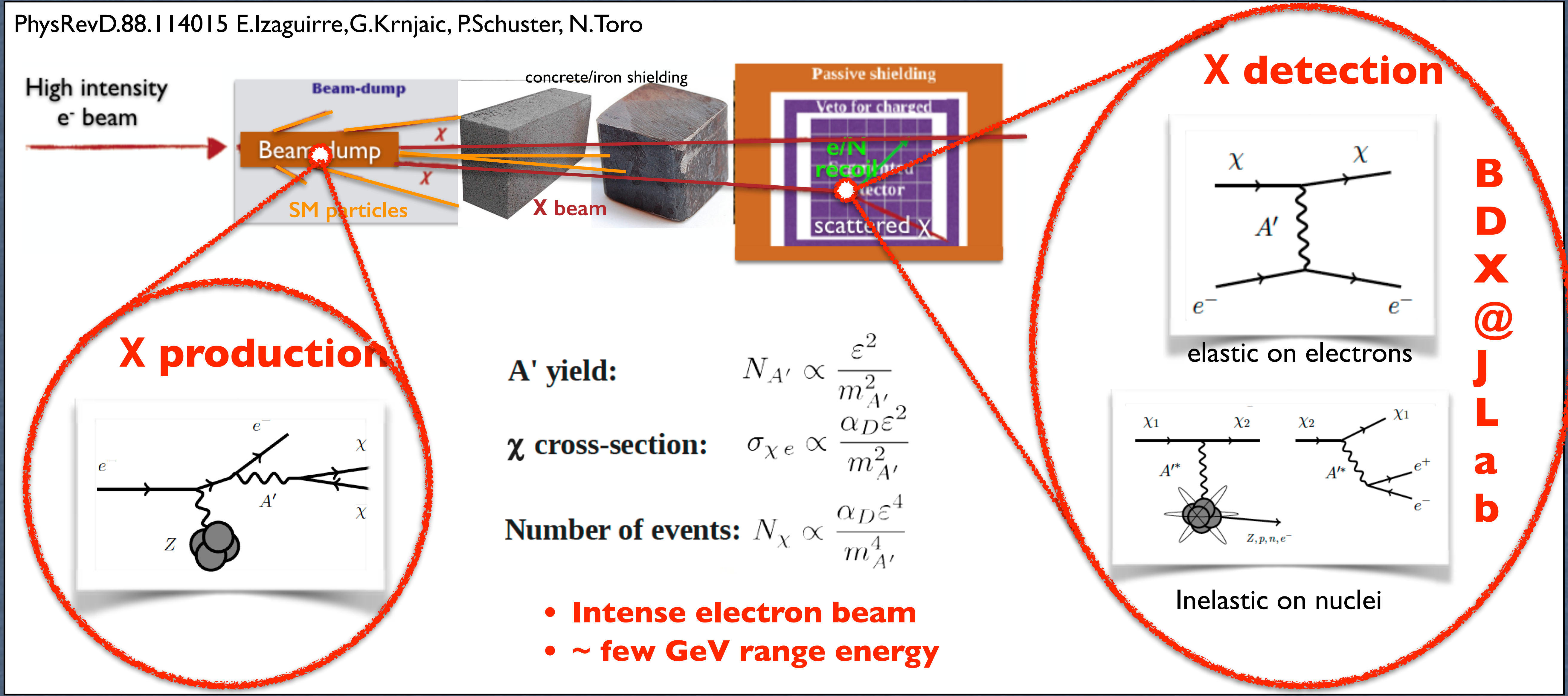
The BDX experiment

invisible decay

Two step process

I) An electron radiates an A' and the A' promptly decays to a χ (DM) pair

II) The χ (in-)elastically scatters on a e-/nucleon in the detector producing a visible recoil (GeV)



PhysRevD.88.114015 E.Izaguirre,G.Krnjaic, P.Schuster, N.Toro

elastic on electrons

Inelastic on nuclei

A' yield: $N_{A'} \propto \frac{\varepsilon^2}{m^2_{A'}}$

χ cross-section: $\sigma_{\chi e} \propto \frac{\alpha_D \varepsilon^2}{m^2_{A'}}$

Number of events: $N_\chi \propto \frac{\alpha_D \varepsilon^4}{m^4_{A'}}$

- **Intense electron beam**
- **~ few GeV range energy**

Experimental signature in the detector: **X-electron → EM shower ~GeV energy**

BDX-MINI @JLab

invisible decay

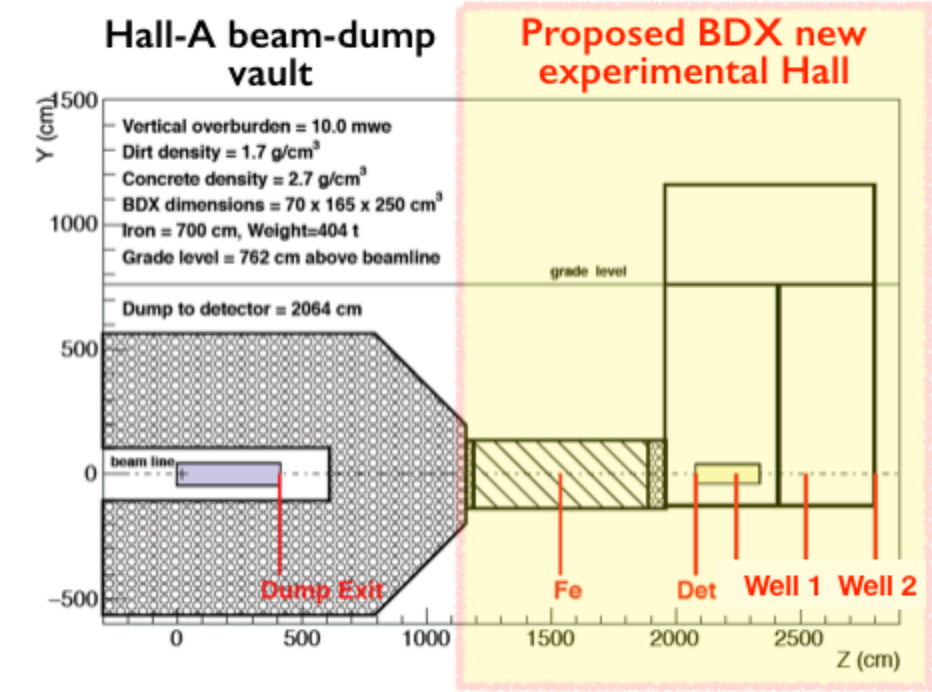
BDX-MINI: small-scale demonstrator to prove the validity and feasibility of the BDX experiment

- Installed in March 2019
- Run form Dec 2019 to Aug 2020
- Collected 4e21 EOT (40% BDX!) in ~4 months (+ cosmics)
- Good detector performance with high duty factor
- Data analysis in progress

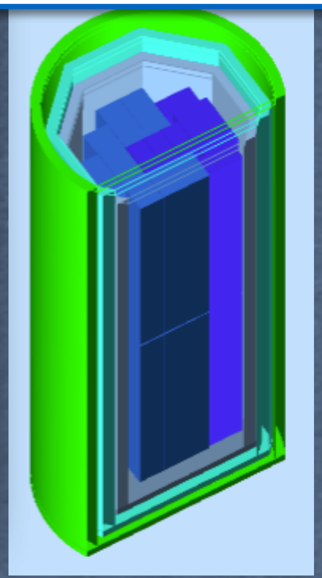
- Two wells dug for bg muon tests
- E_{beam}=2.2 GeV, no muons
- Limited reach but first physics result!

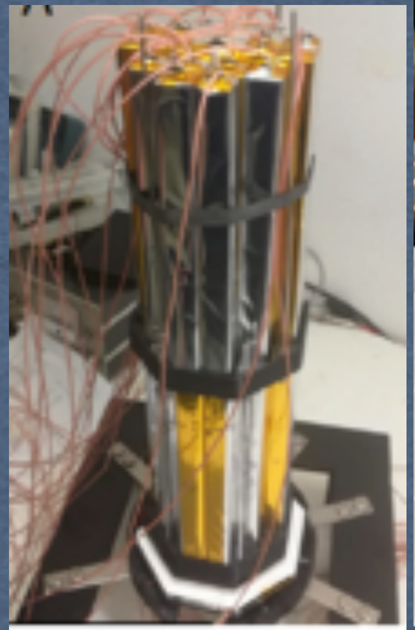
- 44 PbWO4 PANDA/FT-Cal crystals (~1% BDX active volume)
- 6x6 mm2 SiPM readout
- 2 active plastic scintillator vetos: cylindrical and octagonal (8 sipm each) + 2x lids + Passive W shielding

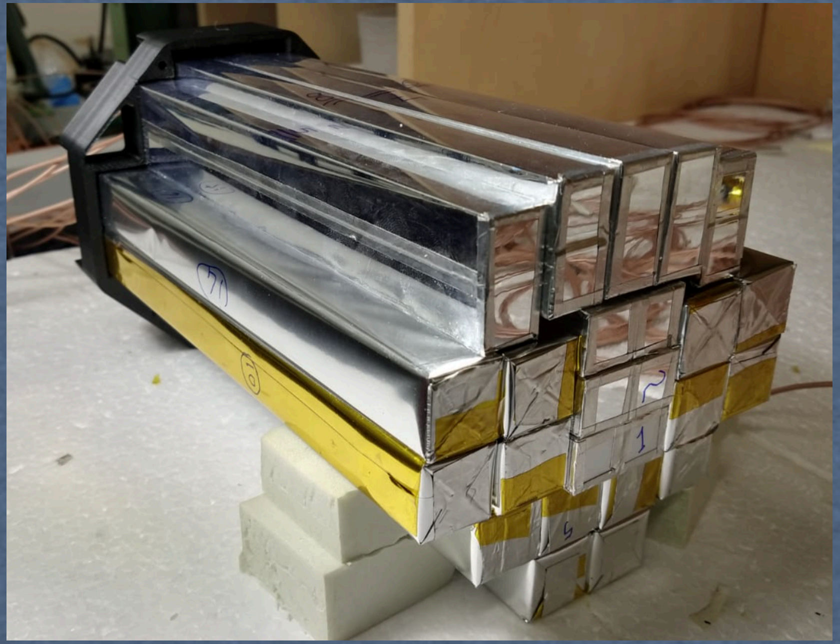
Downstream of the Hall-A beam dump
- TODAY -



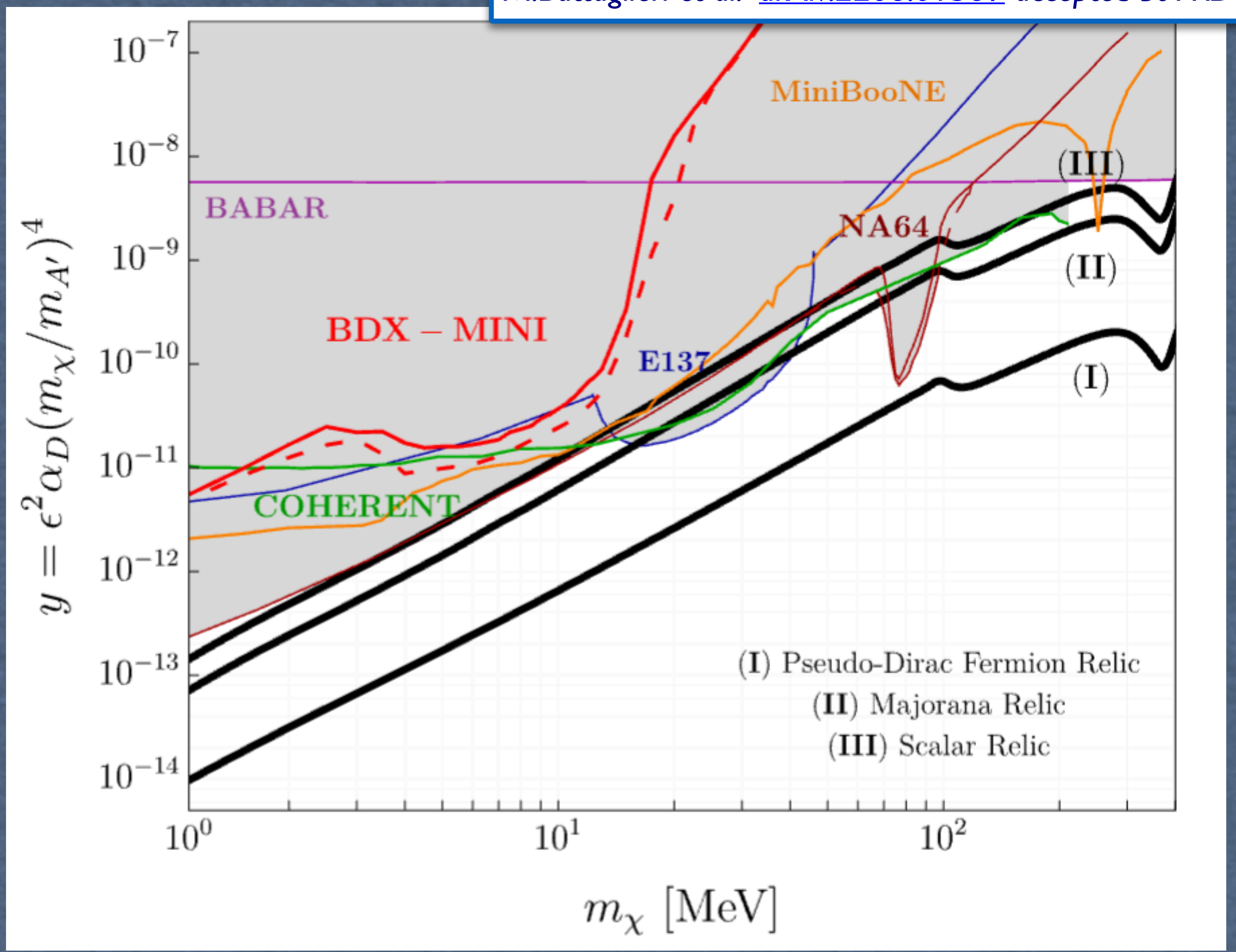
M.Battaglieri et al. EPJC (2021) 81: 164







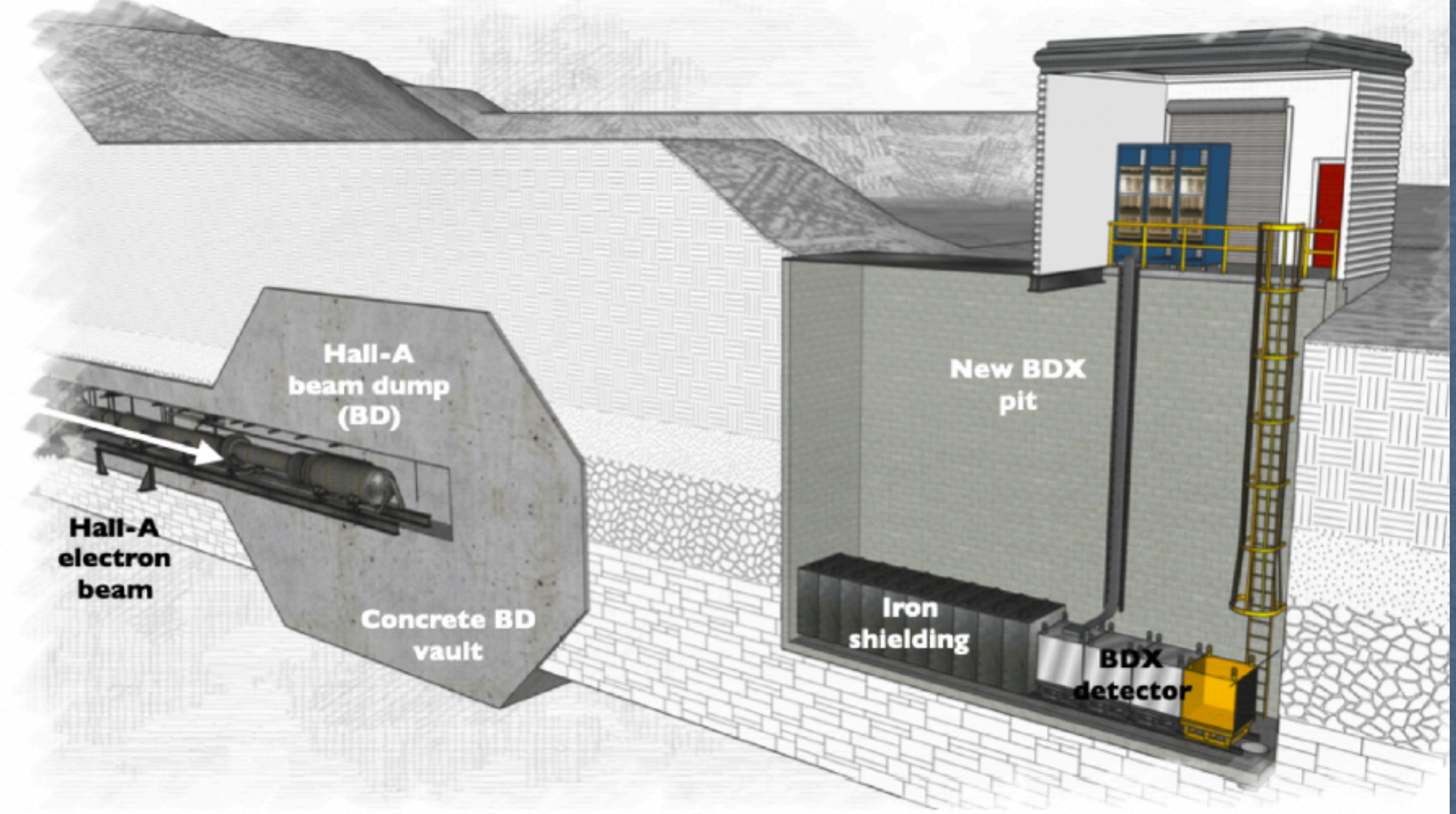
M.Battaglieri et al. arXiv:2208.01387 accepted bt PRD



- Data-taking completed, analysis completed
- Results provide exclusion limits similar to the best existing experimnts (E137, NA64, BaBar, …)

BDX @ JLab

approved by JLab 2018 PAC with max rate (A)

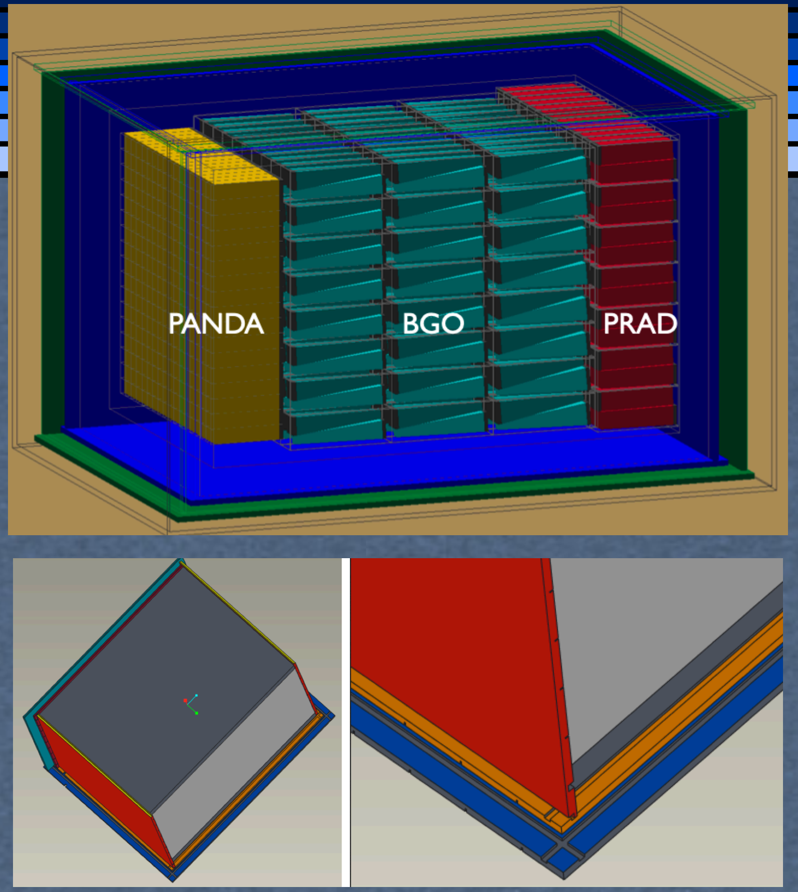


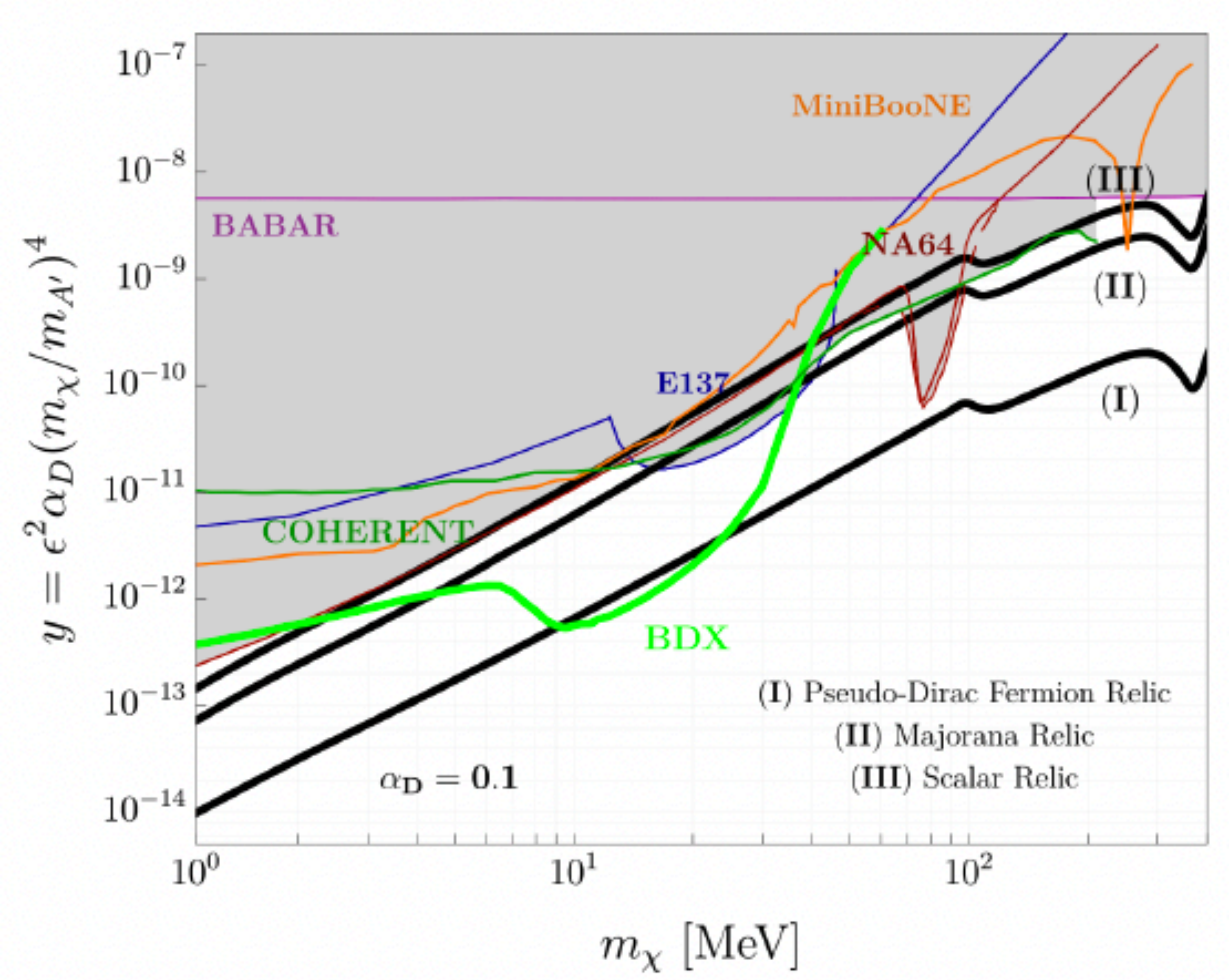
★ High energy beam available: 11 GeV
★ The highest available electron beam current: ~65 uA
★ The highest integrated charge: 10^{22} EOT (41 weeks)
★ New experimental hall (~2$M) at JLab
★ BDX detector: 3 tons of active target + veto's layers
★ Expected to run in parallel to teller experiment

BDX detector

E.M. Calorimeter + 3 veto's layers

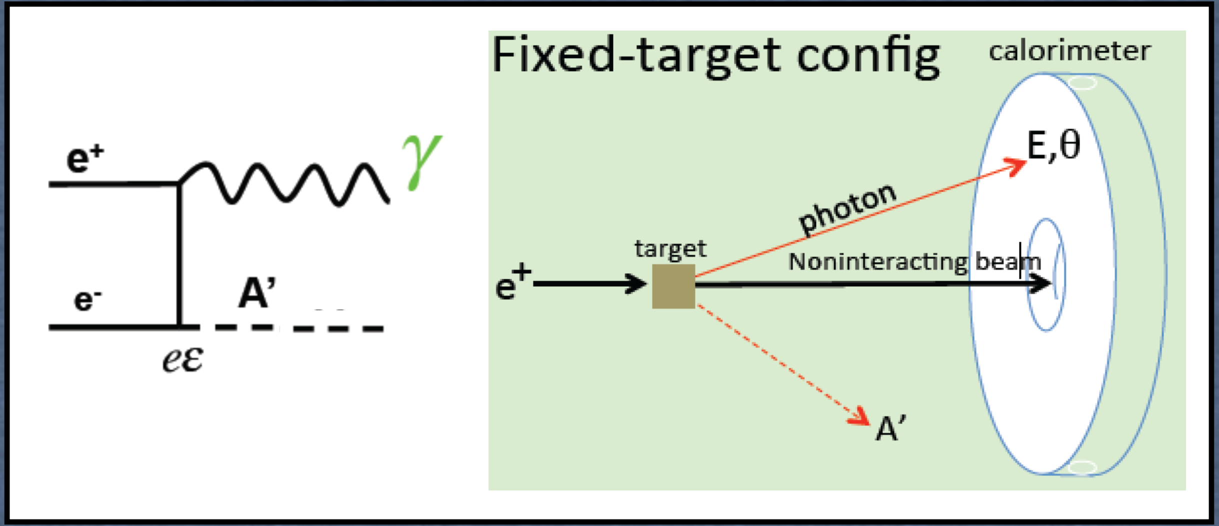
- 3 tons of active target (crystals)
- 480 BGO + 1200 PbWO + 800 PbWO
- 6x6 mm^2 Hamamatsu SiPM readout
- 2 Plastic scintillator veto's + WLS fibres + SiPMs
- Detector Size (L x H x W) : 1.6 x 1.2 x 1.1 m3





Accumulating 10^{22} EOT in ~1y BDX sensitivity is 10-100 times better than existing limits on LDM

e⁺ annihilation on fixed (thin) target
invisible



Missing mass search:
- Independent of A' decay mechanism
- Bump hunt (monophoton@collider)
- Need a positron beam

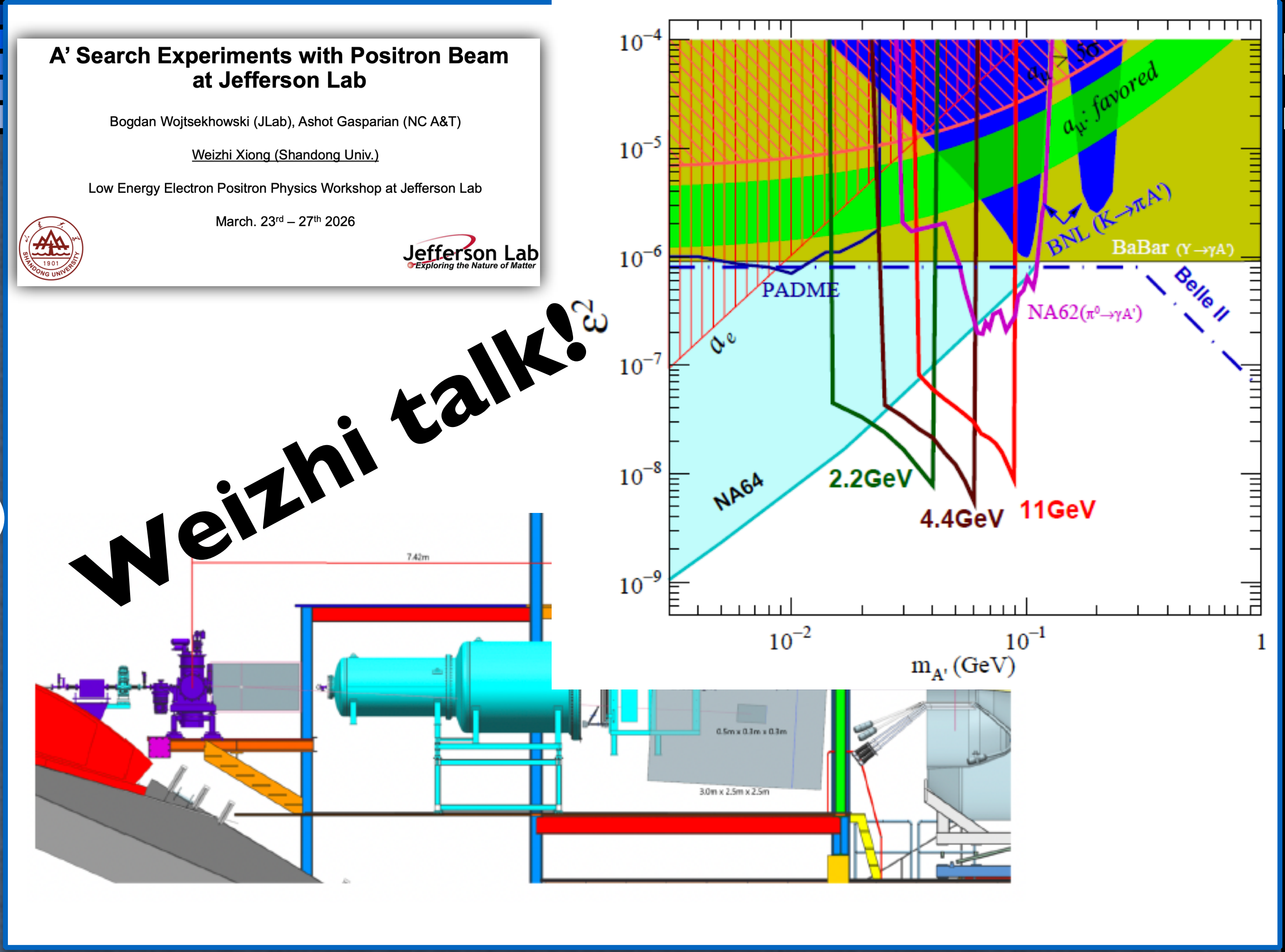
- Limited $M_{A'}$ accessible
  - 1 GeV beam: $M_{A'}$ < 31 MeV
  - 5 GeV beam: $M_{A'}$ < 71 MeV

VEPP3
- E_{e+} = 500 MeV
- EOT ~ 10^{15} - 10^{16} year^{-1}

LNF
- E_{e+} = 550 MeV
- EOT ~ 10^{13} - 10^{14} year^{-1}

Cornell
- E_{e-} = 5.3 GeV
- EOT ~ 10^{17} - 10^{18} year^{-1}

JLab (future)
- E_{e-} = 11 GeV
- EOT ~ 10^{18} - 10^{19} year^{-1}


A' Search Experiments with Positron Beam at Jefferson Lab

Bogdan Wojtsekhowski (JLab), Ashot Gasparian (NC A&T)

Weizhi Xiong (Shandong Univ.)

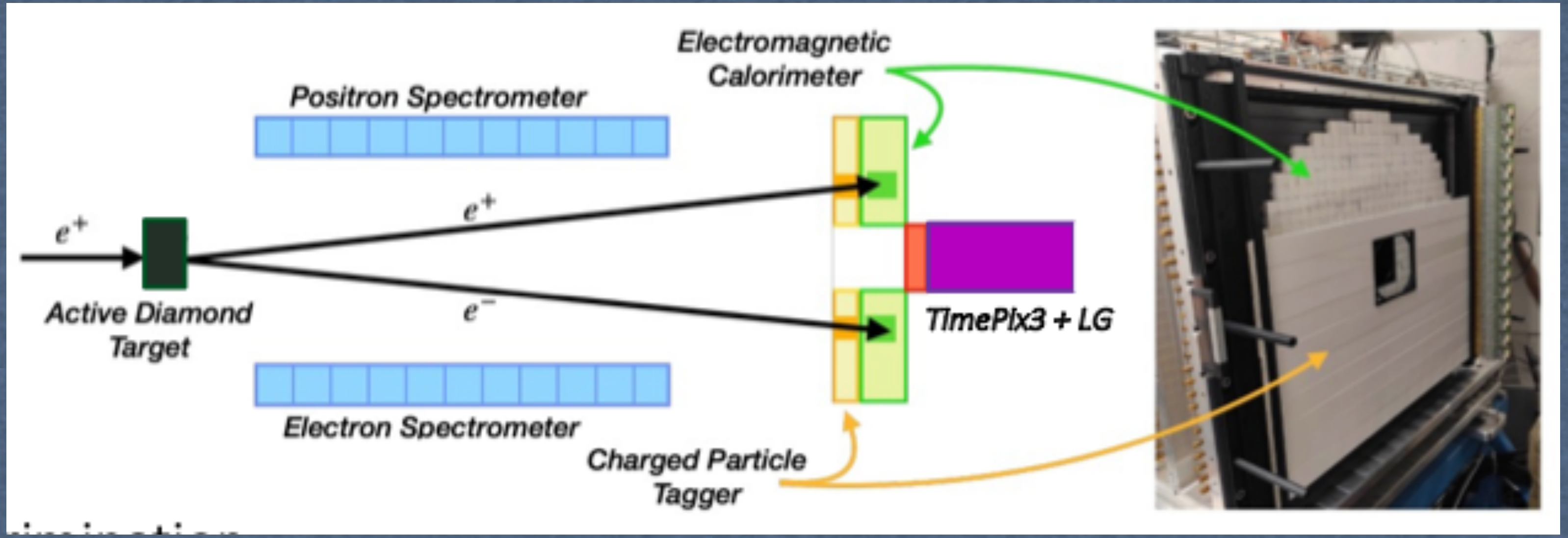
Low Energy Electron Positron Physics Workshop at Jefferson Lab

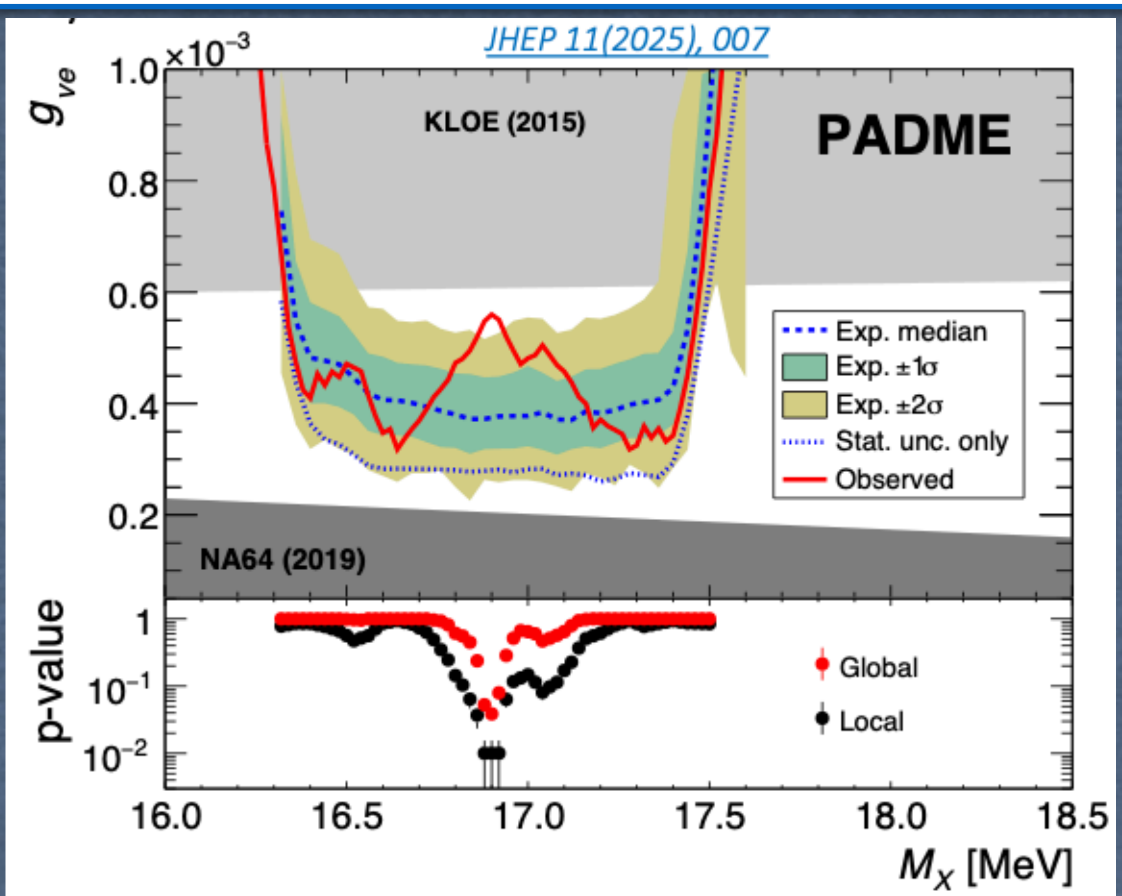
March. 23rd – 27th 2026

Weizhi talk!

PADME @ LNF
invisible/visible

- e+ beam 550MeV
- Diamond active target
- EM calorimeter: 616 BGO crystals
- TIMEPIX3 for bem spot
- ~6 10^{11} POT (+ 5 10^{11} POT on tape)
- Focus on X17 visible decay




JHEP 11(2025), 007

e^+ annihilation on fixed (thick) target

invisible

- *Active* beam-dump experiment (*á la* NA64 but with positron!)
- Clear signal (peak!) due to the annihilation: $M_{A'}$ = Sqrt(2 m_e E_{miss})
- Missing energy exp (e+ Z → e+ Z' A' with A' → invisible)
- 11 e+ beam, low current
- Active target (calorimeter)
- Exclusion plots based on 10^{13} POT
- Detector: ECAL to measure e+ and an HCAL as a veto

JPOS

Snowmass 2021

Light dark matter searches with positrons

Jim Alexander[1], Marco Battaglieri[2,3], Fabio Bossi[4], Andrea Bianconi[5,6], Mariangela Bondi[2], Andrea Celentano[2], Giovanni Costantini[5,6], Philip Cole[7], Raffaella De Vita[2], Annalisa D'Angelo[8,9], Marzio De Napoli[10], Andre Frankenthal[1], Paola Gianotti[4], Venelin Kozhuharov[4,11], Antonio Italiano[10], Lucilla Lanza[8], Marco Leali[5,6], Luca Marsicano[2,†], Valerio Mascagna[5,6], Mauro Raggi[12,13,‡], Nunzio Randazzo[10], Elena Santopinto[2], Elton Smith[3], Stepan Stepanyan[3], Maurizio Ungaro[3], Paolo Valente[13], and Luca Venturelli[5,6]

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[†]Contact author: luca.marsicano@ge.infn.it
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This LOI presents two complementary approaches to search for light dark matter with a multi-GeV energy positron beam. Light dark matter is a new compelling hypothesis that identifies dark matter with new sub-GeV "hidden sector" states, neutral under standard model interactions and coupling to ordinary matter through a new force. Accelerator-based searches at the intensity frontier are uniquely suited to explore the dark sector.

Using a high-intensity and high-energy positron beam, and exploiting a novel light dark matter production mechanism—positron annihilation on atomic electrons—the proposed experiments will be able to explore new regions in the light dark matter parameter space, confirming or constraining the hypothesis.

Introduction

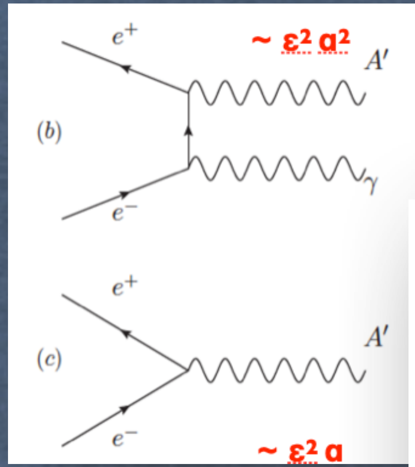
In recent years, a novel hypothesis for the nature of dark matter (DM) has been introduced. It predicts the existence of **light dark matter** (LDM) particles, with sub-GeV mass, interacting with standard model (SM) states through a new force. The simplest such model predicts LDM particles (denoted χ) with masses below 1 GeV, charged under a new force and interacting with SM particles via the exchange of a light spin-1 boson, usually referred to as a "heavy photon" or "dark photon" (A') (1–3). This picture allows for an entire new "dark sector" containing its own particles and interactions and is further compatible with the well-motivated hypothesis of DM thermal origin (4). This hypothesis assumes that, in the early Universe, DM and SM abundances reached thermal equilibrium through an annihilation mechanism. The present DM density, deduced from astrophysical measurements, is thus a relic remnant of its primordial abundance (4). The thermal origin hypothesis provides a relation between the currently observed DM density and the model parameters, resulting in a clear, predictive target for discovery or falsification (5).

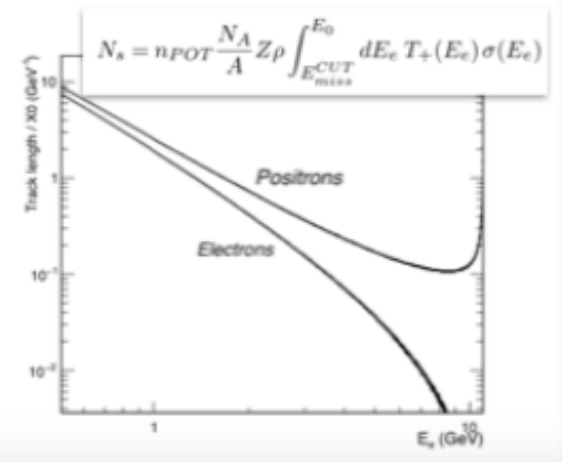
This constraint, within the minimal A' model, is valid for every DM and mediator variation up to order-one factors, provided that $m_{\rm DM} < m_{\rm MED}$.

Fig. 1. Three different A' production modes in fixed-target lepton beam experiments: (a) A'-strahlung in e^-/e^+-nucleon scattering; (b) A'-strahlung in e^+e^- annihilation; (c) resonant A' production in e^+e^- annihilation.

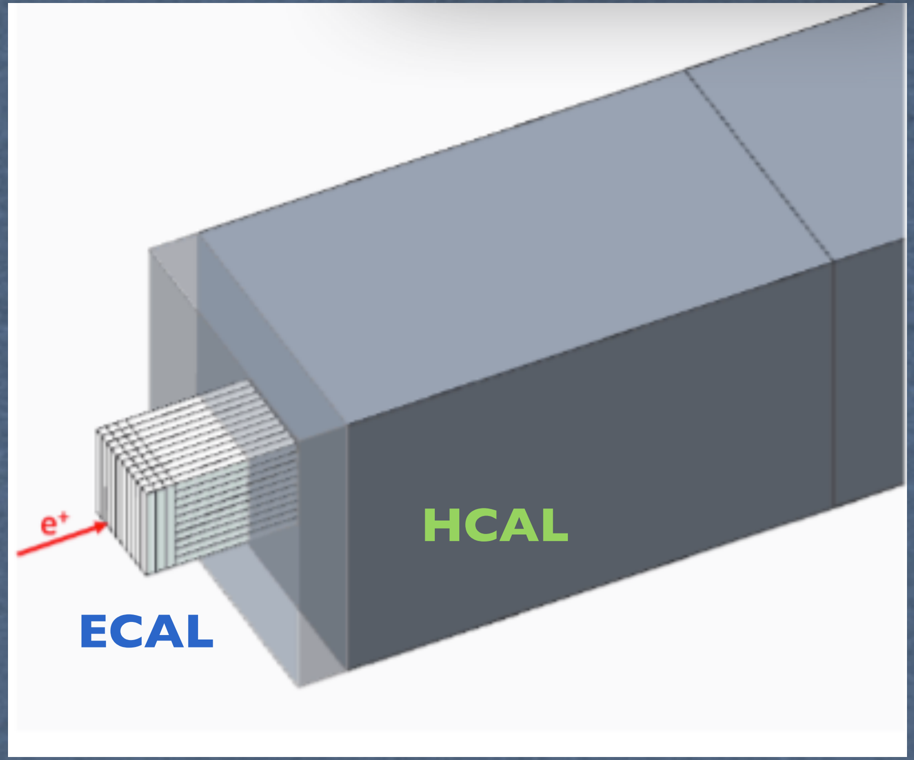
Dark sector searches with positron beams on fixed targets

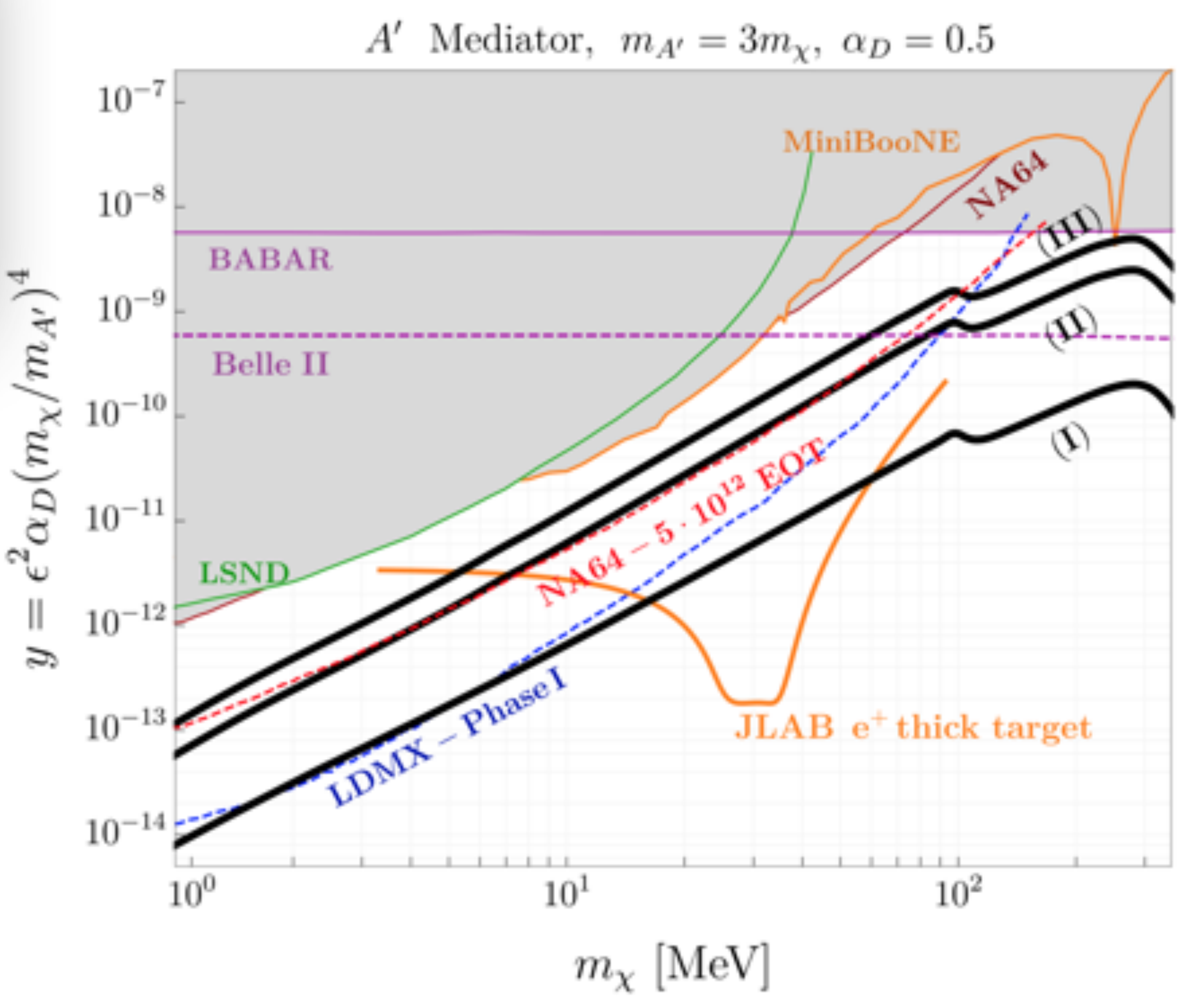
LDM particles can be produced in collisions of electrons or positrons of several GeV with a fixed target by the processes depicted in Fig. 1, with the final state A' decaying to a $\chi\overline{\chi}$ pair. For experiments with electron beams, diagram (a), analogous to ordinary photon bremsstrahlung, is the dominant process. However, for thick-target setups (where positrons are produced as secondaries from the developing electromagnetic shower), it has been recently shown that diagrams (b) and (c) actually give non-negligible contributions to select





$$N_s = n_{POT}\frac{N_A}{A}Z\rho\int_{E^{CUT}_{miss}}^{E_0} dE_e\, T_+(E_e)\sigma(E_e)$$



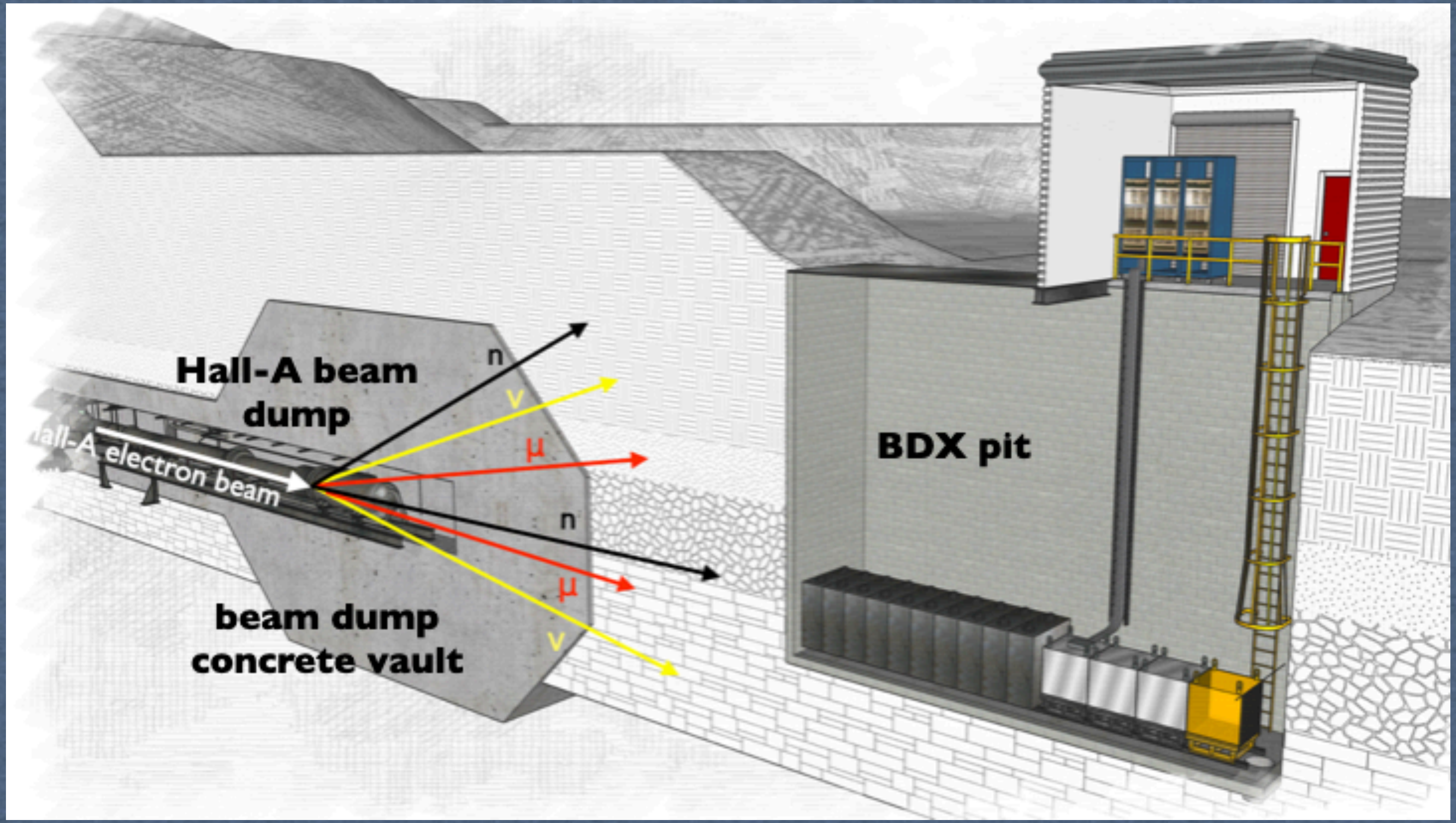


New physics perspectives at Jlab with secondary beams

- CEBAF provides a high-intensity 10 GeV (in future 20+ GeV) electron beam for extracted-beam experiments
- High-intensity secondary beams are produced in the dump(s) fully parasitically
- The machine can sustain up to ~MW power (100 uA @ 10 GeV, 200 uA @ 5 GeV)
- Hall-A routinely receives ~50-70 uA @11 GeV, Hall-D 7-8 uA @ 12 GeV

- The positron beam is expected in the near future

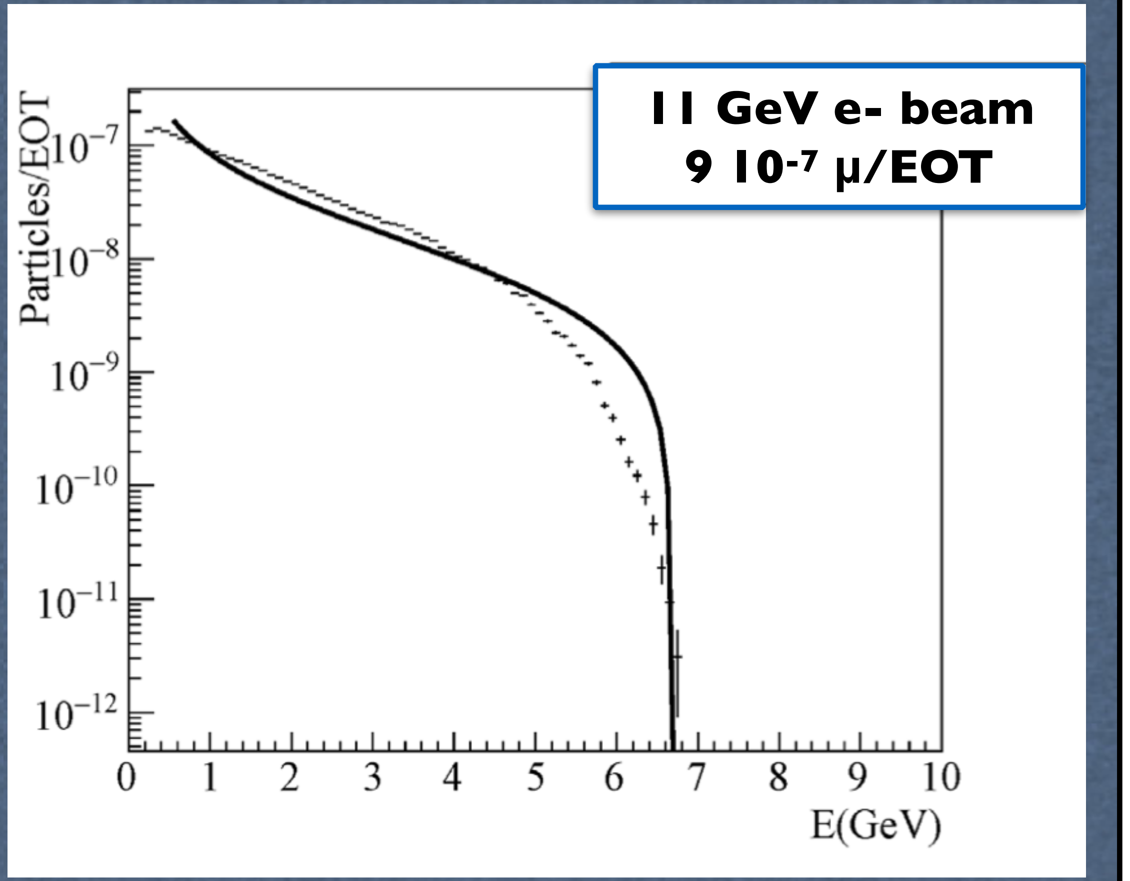
- High-intensity secondary beams:
  - Light Dark Matter (if it exists)
  - Muon
  - Neutrino
  - Neutrons



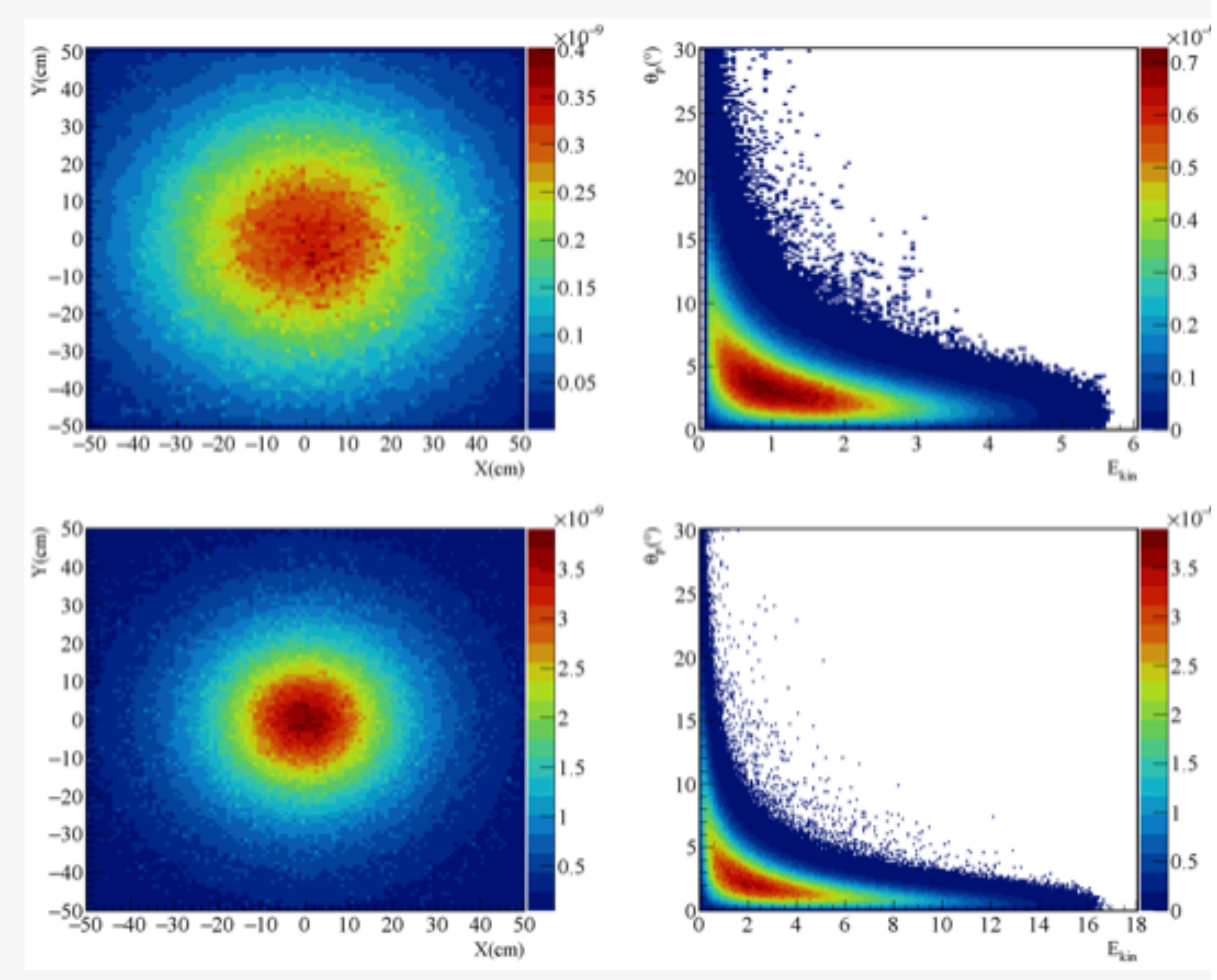
The muon beam

- The flux increases with the energy of primary beam:
- Muon flux (11 GeV e- beam): 9 10^{-7} μ/EOT
  - Rate ~ 3 10^{8} μ/s
- Muon (22 GeV e- beam): 5.3 10^{-6} μ/EOT
  - Rate ~2 10^{9} μ/s
- CERN's M2 beamline (E_μ>100GeV - Rate ~2 10^{7})
- Muon flux profile: σ_x and σ_y ~ 20 cm

- Bremsstrahlung-like energy spectrum



11 GeV e- beam
9 10^{-7} μ/EOT

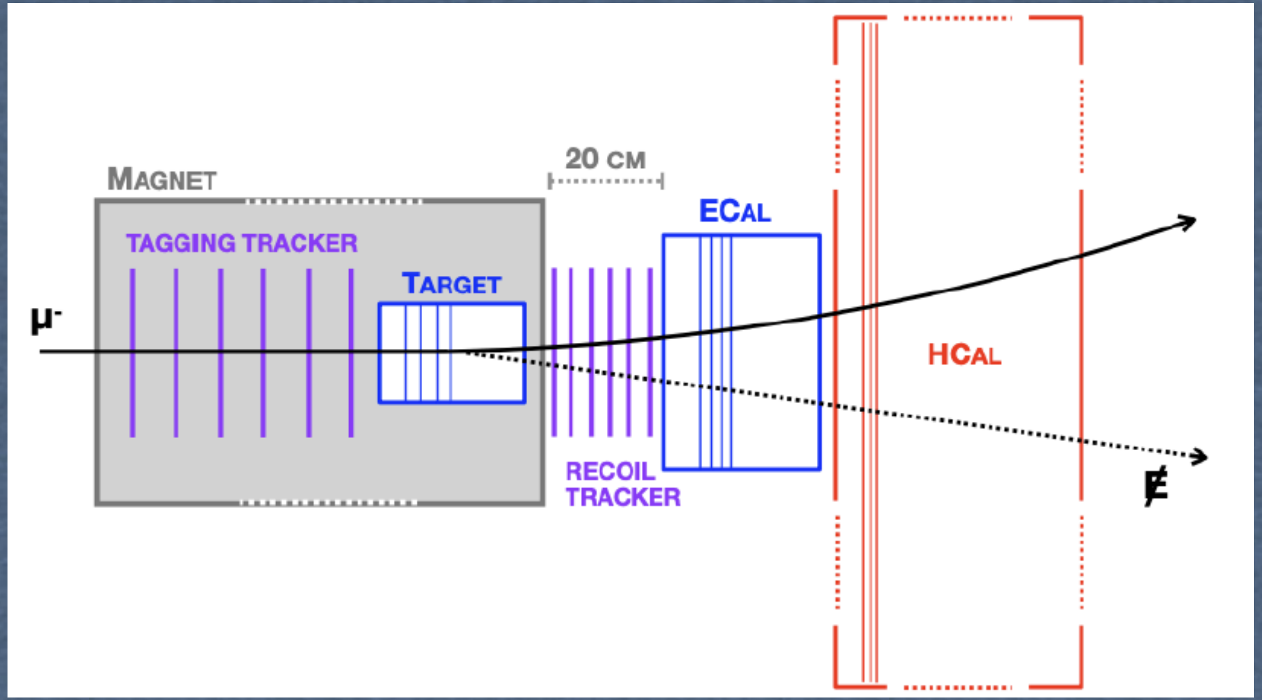


Beam Energy	Flux μ/EOT		σ_x (cm)	σ_y (cm)
	100 × 100 cm^2	25 × 25 cm^2		
11 GeV	9.8×10^{-7}	1.5×10^{-7}	24.6	25.1
22 GeV	7.6×10^{-6}	1.9×10^{-6}	20.9	20.9

Probing muon-philic forces with secondary muon beam

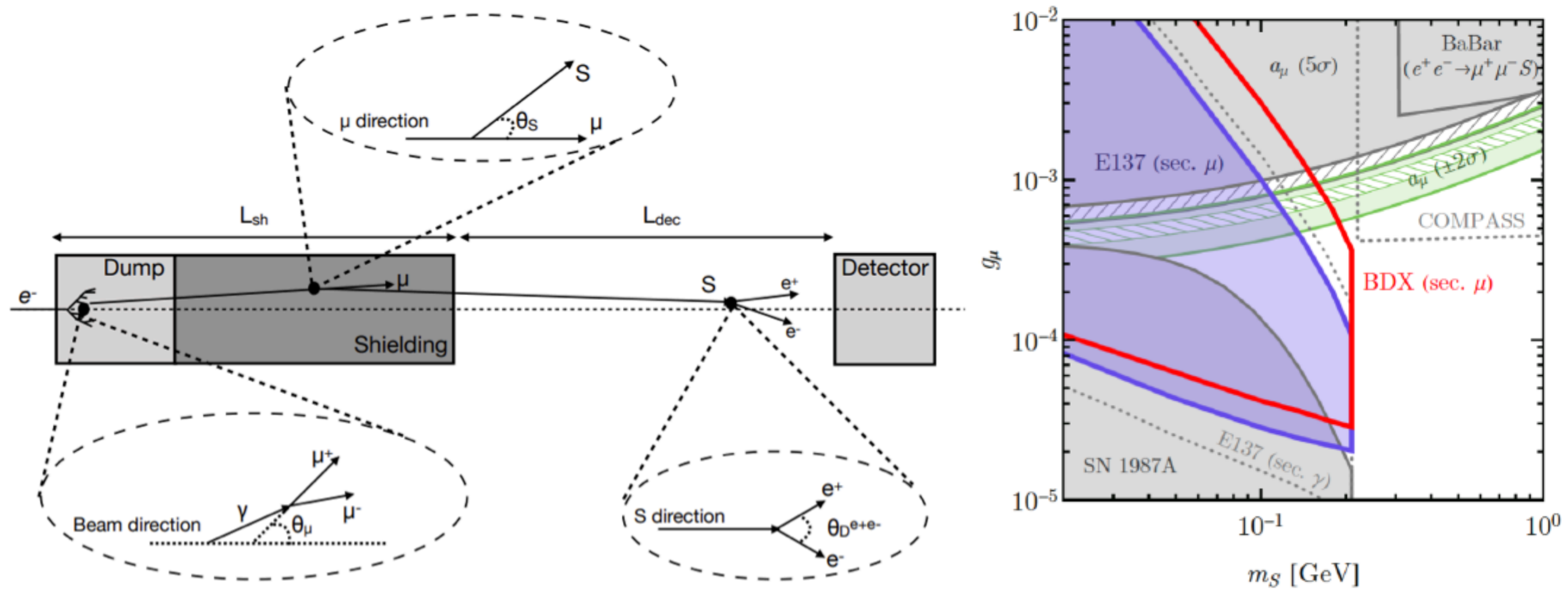
μ^3BDX @ JLab

- Fixed-target, missing-momentum experiment to probe invisibly decaying particles
- BSM Light gauge boson couples predominantly to muon and or tau
- Scalar or vector mediator of a new force
- Its existence would be a viable explanation of g-2 anomaly
- This experiment is similar to M^3 experiment proposed at FERMILAB



μBDX @ JLab

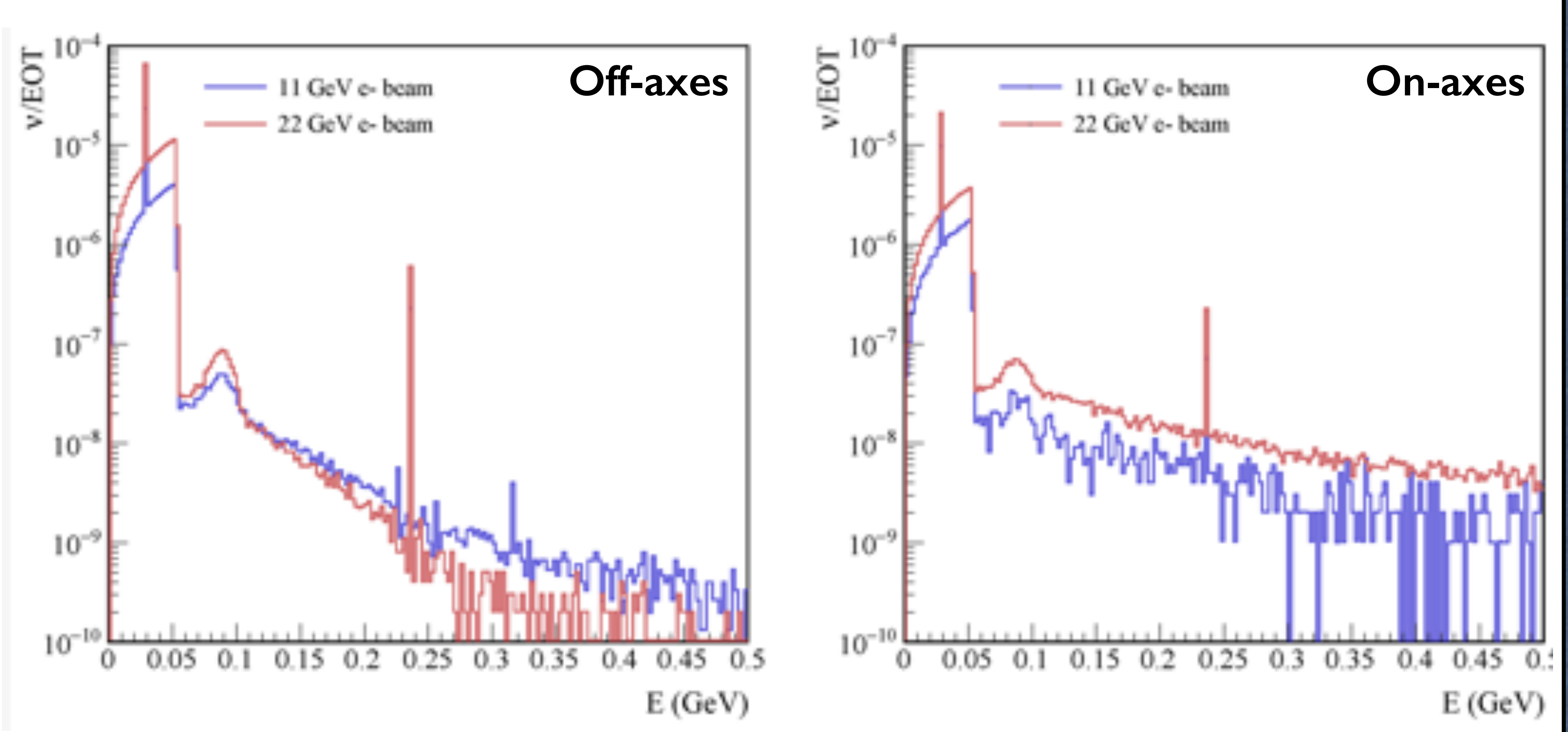
- Muon beam dump experiment to probe the visible decay into e+e-(γγ)
- Same infrastructure requested by BDX



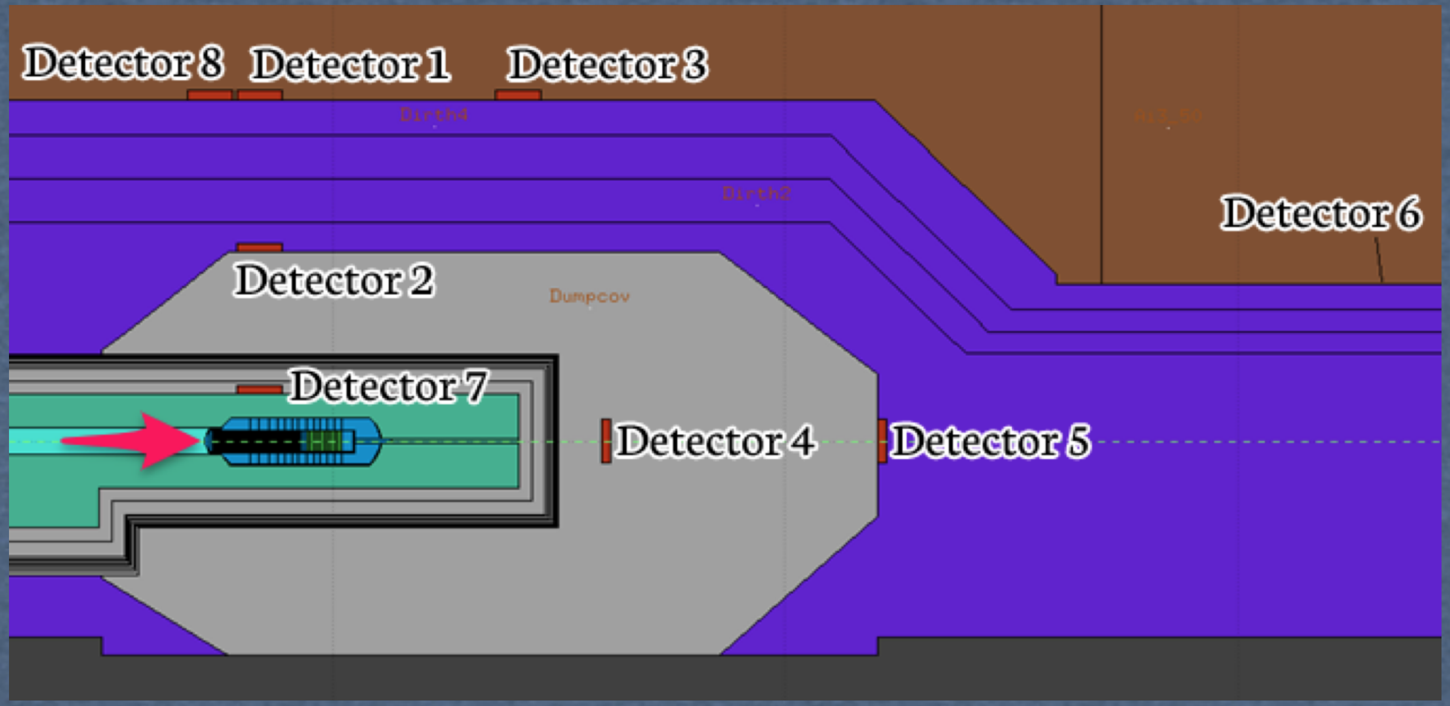
L. Marsicano et al., PRD 98, 115022 (2018)

Neutrino beam

- Neutrino flux estimated using FLUKA for 11 GeV and 22 GeV primary e- beam on Hall-A BD
- Flux scored on a plane downstream Hall-A beam dump (D5):
  - 11 GeV e- beam: 3 10^{17} ν/m^2/year (1 year corresponding to 10^{22} EOT)
  - 22 GeV e- beam: 9 10^{17} ν/m^2/year (1 year corresponding to 10^{22} EOT)
- Decay-At-Rest (DAR) energy spectrum



Beam Energy	Off-Axis Flux [ν/EOT/m^2]	On-Axis Flux [ν/EOT/m^2]
11 GeV	6.7×10^{-5}	2.9×10^{-5}
22 GeV	1.9×10^{-4}	6.3×10^{-5}



νBDX @ JLab

Detecting CEνNS at JLab

CEνNS (Coherent Elastic nu-Nucleus Scattering)

- Low-energy neutrinos (<100 MeV) coherent scatter on nucleus
- Cross-section scales as N^2
- The largest xsec for E_ν < 100 MeV
- First detected in 2017 on CsI by COHERENT (~134 events)
- Low recoil energy due to kinematics O(10 keV)

Why interesting?

- weak parameters -> mixing angle
- nuclear properties -> neutrons distribution radius
- sterile neutrino
- neutrino magnetic moment
- non standard interaction mediated by exotic particles

Requirements

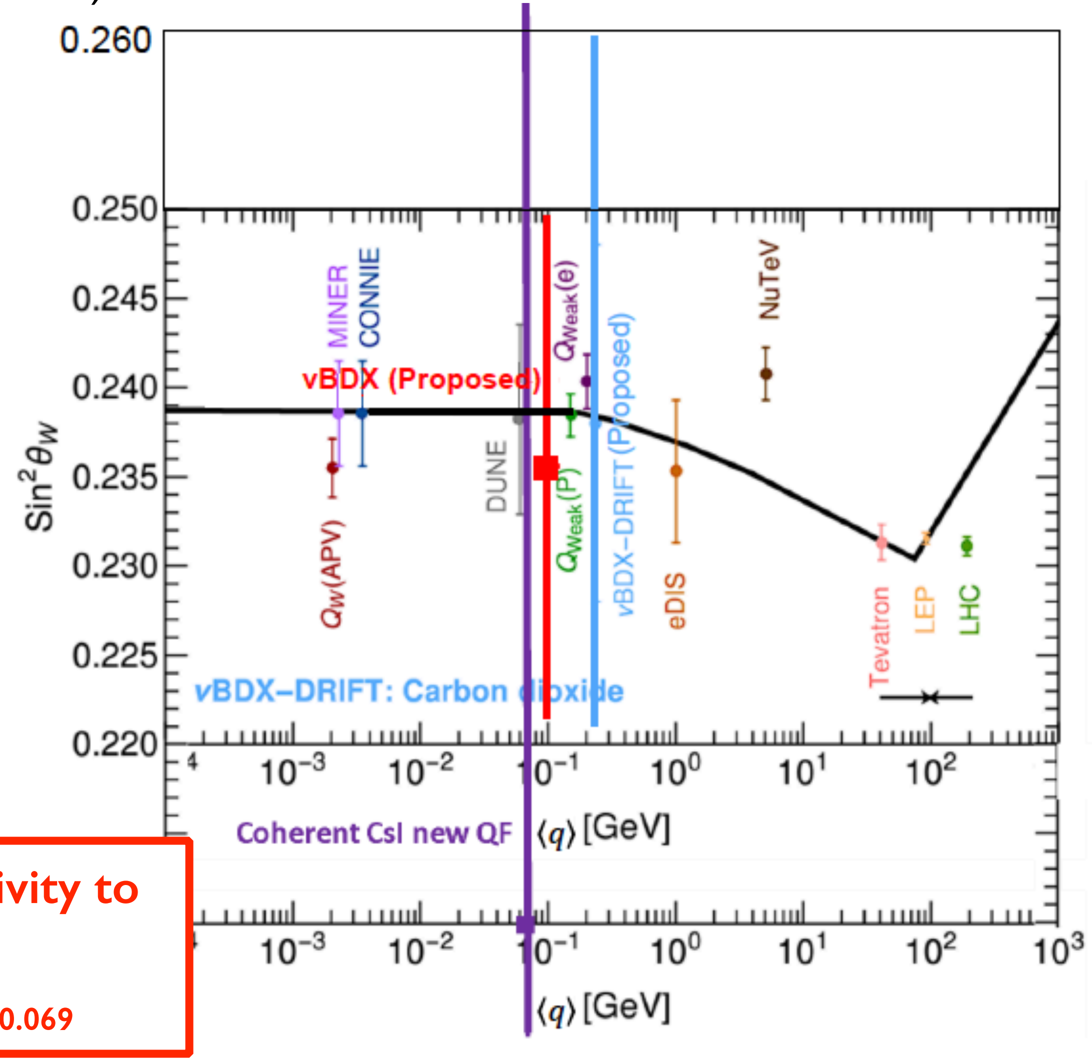
- High-intense ν-flux
- ν-flux energy range: few MeV - few 100 MeV
- detector sensitive to small energy deposition
- small background

Neutrino beam

- Produced by the interaction between e- beam and Hall A dump
- DAR energy spectrum: 10MeV - 300 MeV
- 11 GeV e- beam : ~10^{18} ν/m^2 at ~10 m above the dump for 10^{22} EOT
- 22 GeV e- beam: ~2 10^{18} ν/m^2 at ~10 m above the dump for 10^{22} EOT

The detector

- 10m above the dump
- ~1m^3 detection volume (CsI crystals or LAr-TPC)
- Veto system: active (plastic …) and passive (lead, water, borate silicone and/or cadmium sheet layers…)

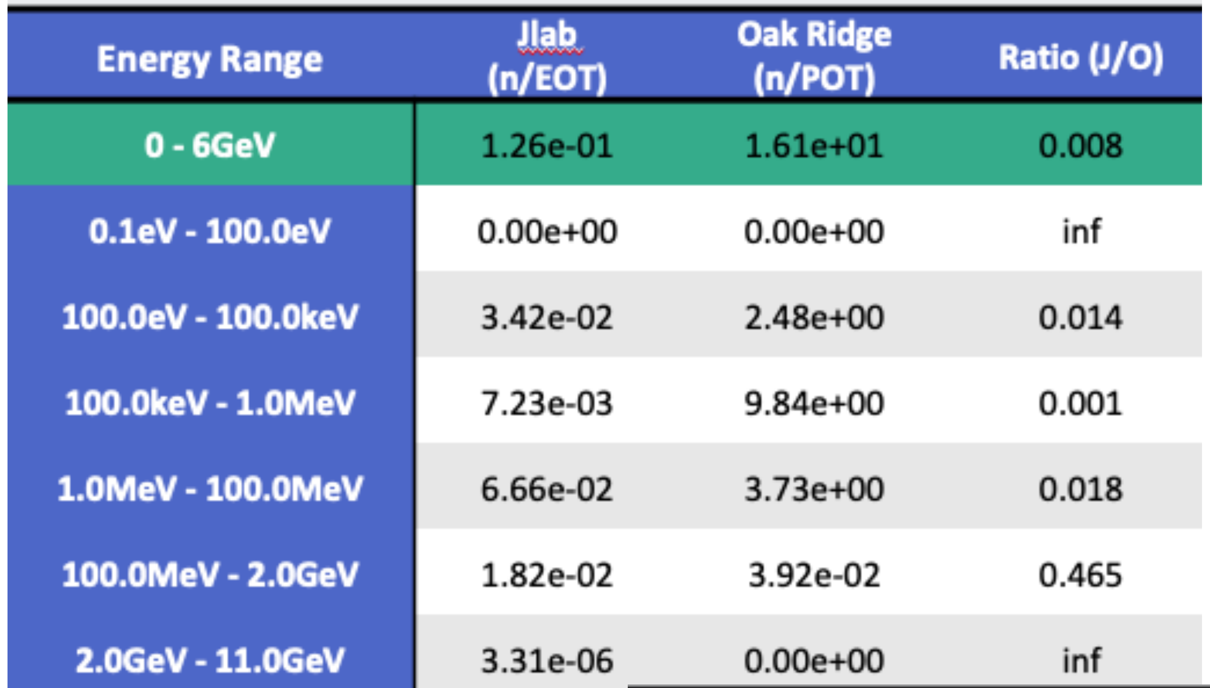


Projected νBDX sensitivity to θ_W

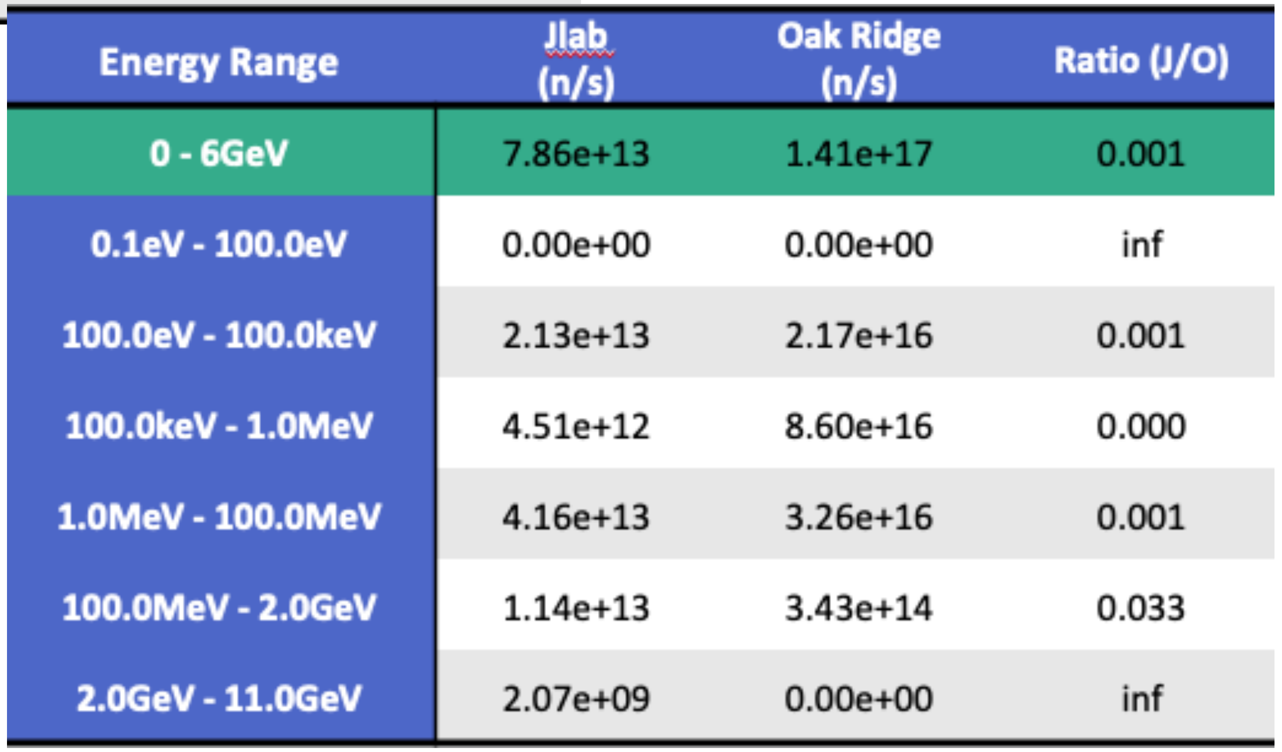
$\sin^2\theta_W = 0.209^{+0.072}_{-0.069}$

Neutrons: production

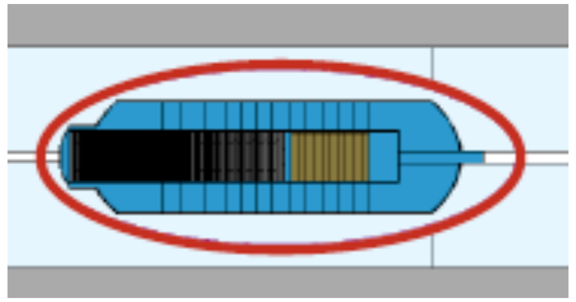
n/EOT (JLab, 11 GeV e- beam 100uA)
vs. n/POT (SNS, 1 GeV p beam, 1.4 mA)



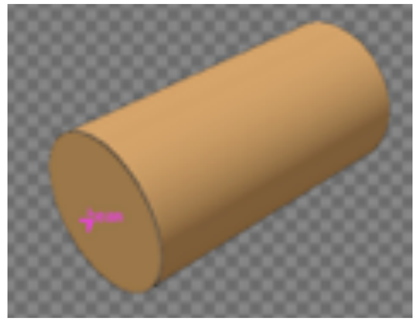
Energy Range	Jlab (n/EOT)	Oak Ridge (n/POT)	Ratio (J/O)
0 - 6GeV	1.26e-01	1.61e+01	0.008
0.1eV - 100.0eV	0.00e+00	0.00e+00	inf
100.0eV - 100.0keV	3.42e-02	2.48e+00	0.014
100.0keV - 1.0MeV	7.23e-03	9.84e+00	0.001
1.0MeV - 100.0MeV	6.66e-02	3.73e+00	0.018
100.0MeV - 2.0GeV	1.82e-02	3.92e-02	0.465
2.0GeV - 11.0GeV	3.31e-06	0.00e+00	inf



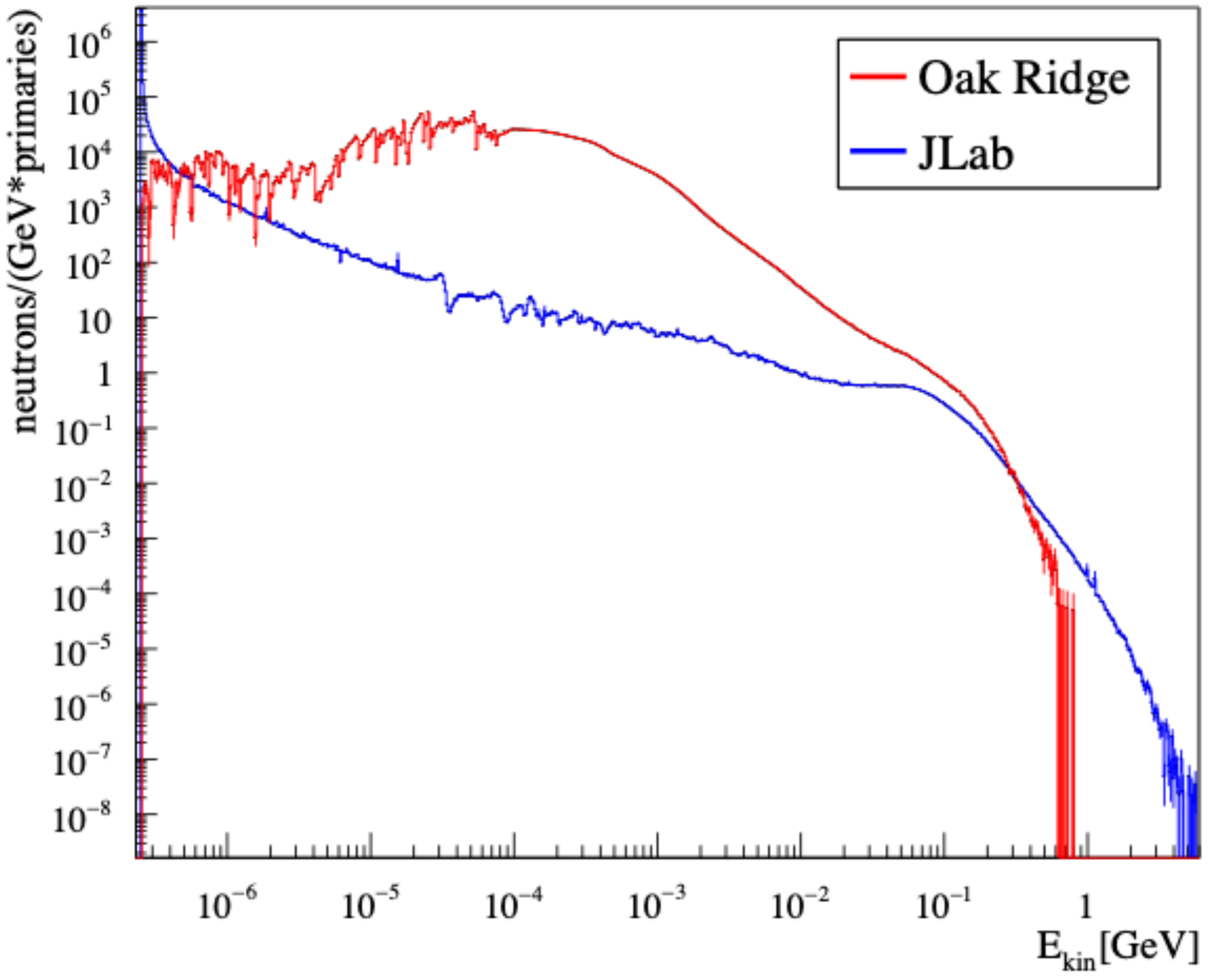
Energy Range	Jlab (n/s)	Oak Ridge (n/s)	Ratio (J/O)
0 - 6GeV	7.86e+13	1.41e+17	0.001
0.1eV - 100.0eV	0.00e+00	0.00e+00	inf
100.0eV - 100.0keV	2.13e+13	2.17e+16	0.001
100.0keV - 1.0MeV	4.51e+12	8.60e+16	0.000
1.0MeV - 100.0MeV	4.16e+13	3.26e+16	0.001
100.0MeV - 2.0GeV	1.14e+13	3.43e+14	0.033
2.0GeV - 11.0GeV	2.07e+09	0.00e+00	inf



JLab
electron beam
11 GeV
100uA = 6.3 10^{14} e/s
Hall-A BD target



SNS
proton beam
1 GeV
1.4 mA = 8.8 10^{15} p/s
Hg target



Conclusions

- ✳ The existence of dark matter provides a compelling motivation to explore new forces and particles over a wide range of masses.
- ✳ Accelerator-based searches for (light) dark matter offer a unique capability to distinguish potential signals from cosmic backgrounds and astrophysical anomalies.
- ✳ Extensive experimental programs are underway at high-intensity electron facilities such as JLab, Mainz, and SLAC, as well as at proton-beam facilities like FNAL and CERN.
- ✳ A new generation of dedicated, optimized experiments at the intensity frontier will probe the relic light dark matter scenario.
- ✳ Jefferson Lab is a world-leading facility for current and near-future light dark matter searches, with experiments such as APEX, HPS, X17, and BDX.
- ✳ Ce+BAF will enable new opportunities, including a unique 11 GeV positron beam.
- ✳ Secondary beams of muons, neutrinos, and neutrons further complement the broader program of beyond-the-Standard-Model searches.
- ✳ Discovery or decisive tests of the simplest dark matter scenarios could be achieved within the next ~5–8 years.