CNUGS 2026

May 26 - June 13, 2026
Jefferson Lab, Newport News, VA

Launching in 2026, CNUGS builds on the legacy of Hampton University's HUGS program with a re-imagined three-week format.

Join us for advanced training in nuclear and hadronic physics plus exciting new tracks in AI, machine learning, and data science—featuring an integrated AI/ML bootcamp and collaborative hackathon.

Acceptance into the program is competitive, with a limited number of scholarships contingent on grant support from the U.S. Department of Energy.

Topical Seminars

JLab Science: Present and Future
Doug Higinbotham (JLab)

Light Dark Matter
Marco Battaglieri (INFN Genova, Italy)

Global QCD Analysis
Zhite Yu (BNL)

The Prad Experiment
Tyler Hague (JLab)

Full Lectures

Intro to QCD and Small-x Physics
Ming Li (HU)

Hadron Spectroscopy
TBC

Lattice QCD (5 hrs)
Kostas Orginos (W&M)

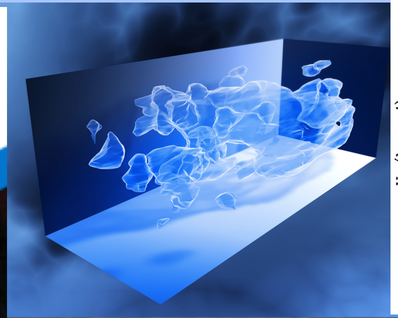
Mechanical Properties of Hadrons
Adam Freese (CNF)

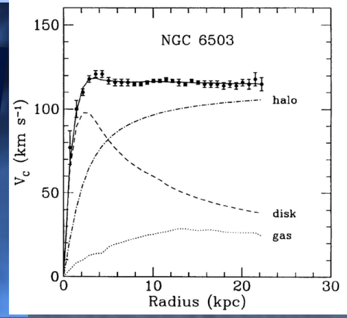
Spin Structure of the Proton
TBC

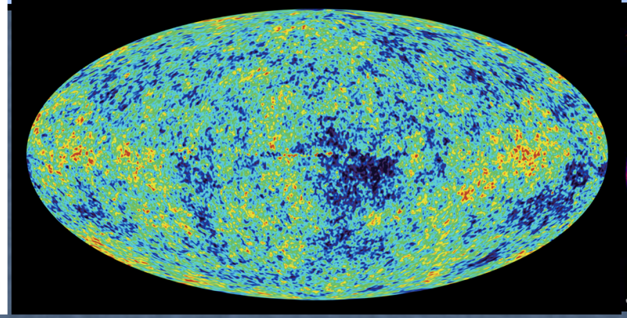
Experimental Symmetry Tests: Parity Violation at JLab and Beyond
Krishna Kumar (UMass, Amherst)

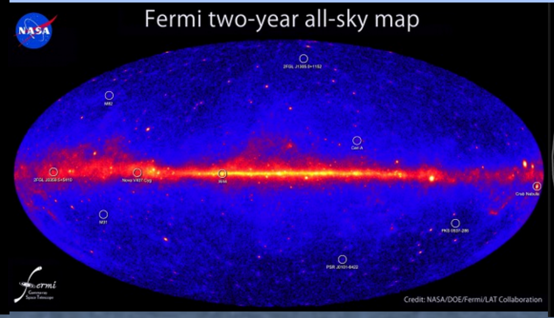
AI/ML Bootcamp & Hackathon

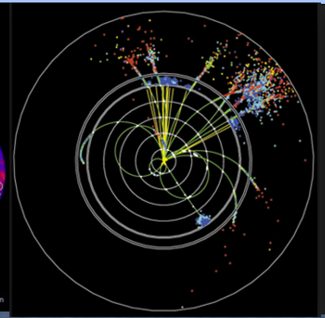
Jefferson Lab · Christopher Newport University · U.S. Department of Energy · jlab.org/cnugs

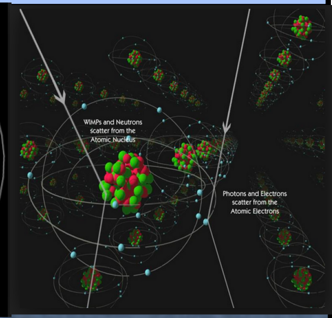












Light Dark Matter searches

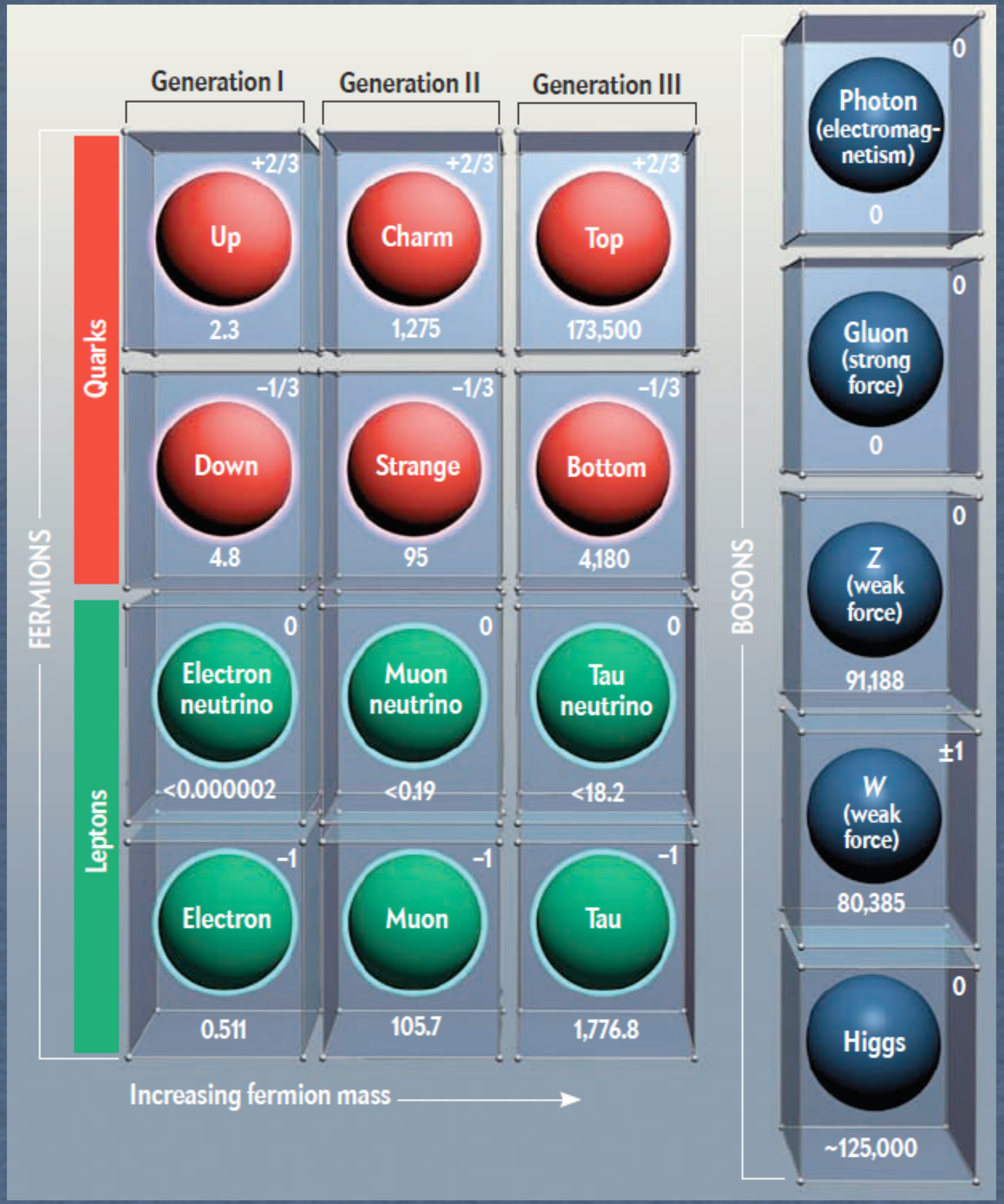
M.Battaglieri (INFN-Genova)

Jefferson Lab · clas · eJLab12 · Brookhaven National Laboratory · ePIC · INFN

OUTLOOK

- The Dark Matter (DM) , thermal DM, Light DM and the fifth force (Dark Sector)
- LDM at accelerators (the high intensity frontier)
- Experimental techniques: fixed target experiments
- Completed and planned experiments
- Searching for visible and invisible LDM's decays
- Experimental techniques: pair production (bump hunting and vertexing), meson decays, beam dumps, positron annihilation, missing energy/momentum, secondary beams and search for other LDM flavours
- LDM searches at accelerators: status and plans

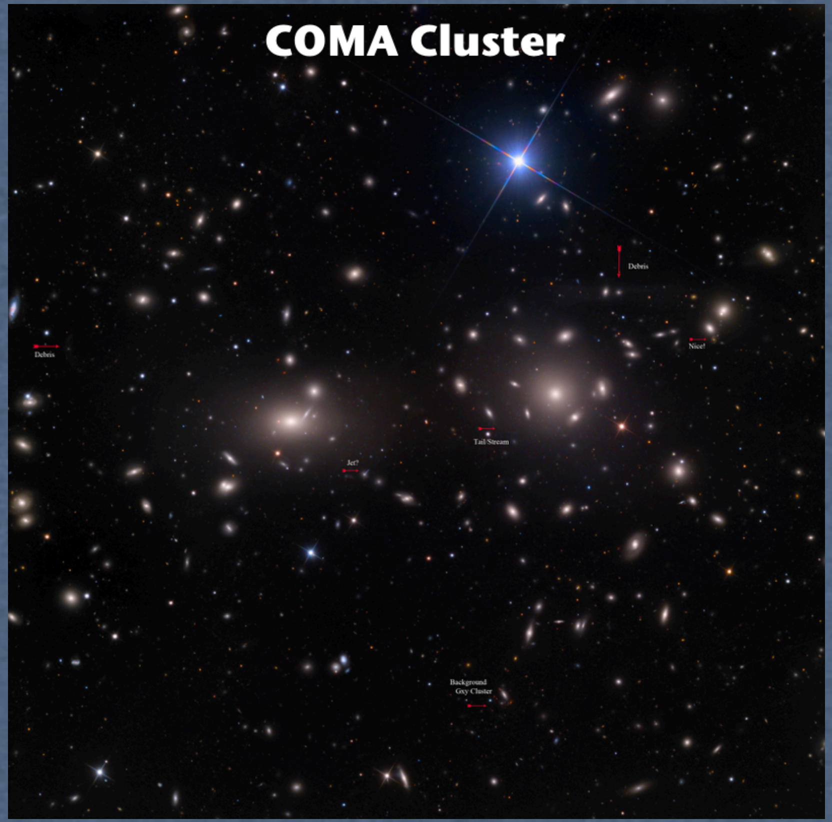
Standard Model of particles and interaction

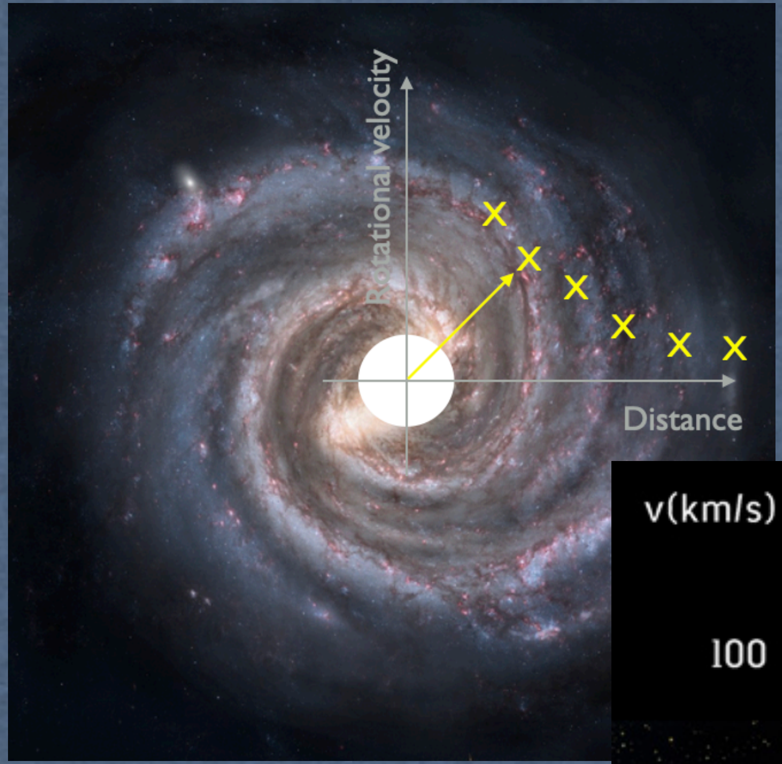


More precise SM prediction
$(g-2)_e$
1 part over 10^{12}

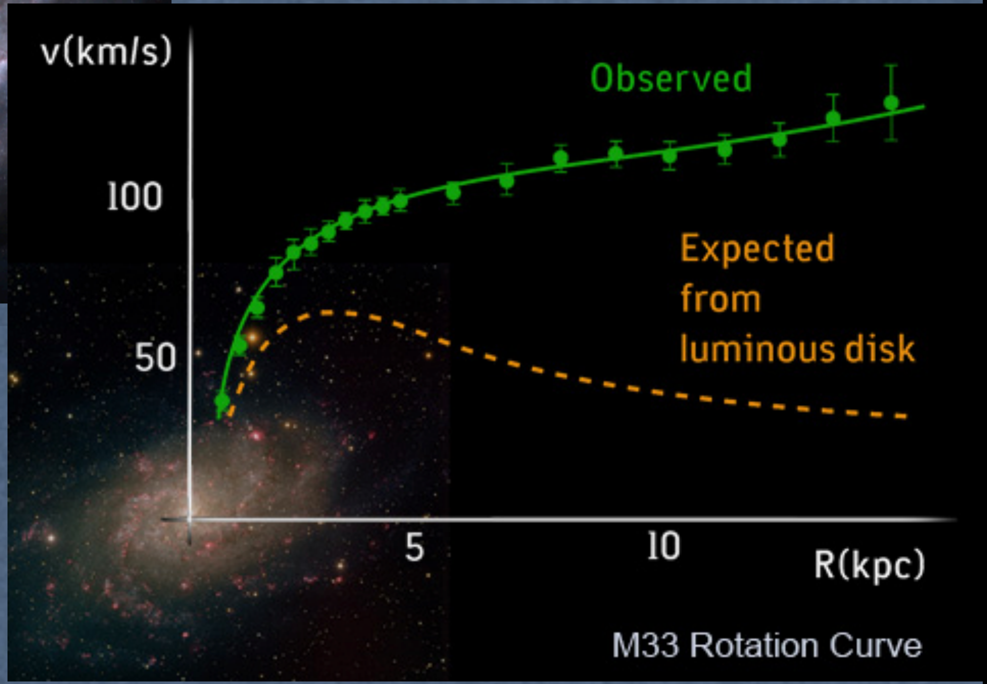
some anomalies ...

1935: Zwicky, Coma and Dark Matter
The gravity of the Stars is not enough to hold clusters together





1970s: Rubin and Flat Rotation Curves



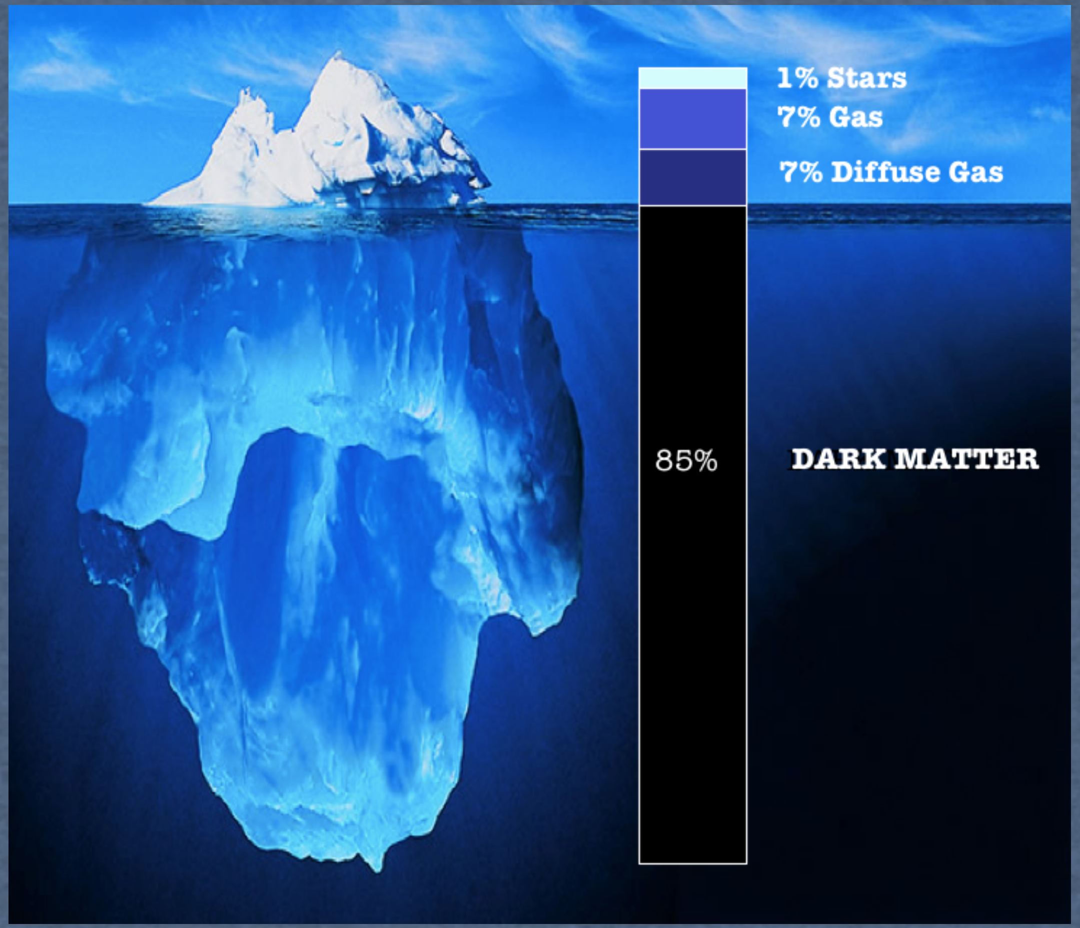
beside visible matter there should be something else
➨ DARK MATTER

- ★ Gravitational lensing
- ★ Mass balance
- ★ CMB
- ★ Clusters of galaxies
- ★ Cluster collisions
- ★ …

Compelling astrophysical indications about DM existence

Dark Matter (DM) vs Baryonic Matter (BM)

★ 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

Particles:
quarks, leptons

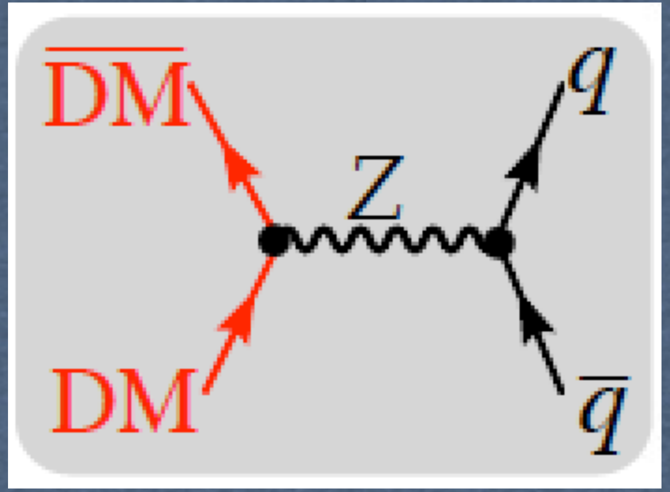
Force-carriers:
gluons, γ, W, Z, graviton (?), Higgs, ...

Known particles & new force-carriers

Two options:

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

Any guess about the DM mass and interaction?



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

Yes, if we do a couple of assumptions:

★ DM thermal origin

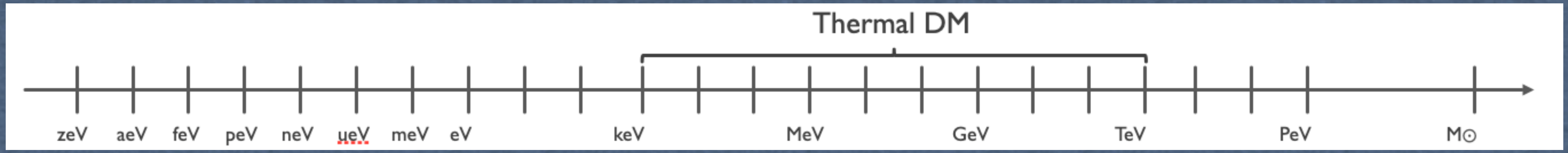
in the early Universe DM was in thermal equilibrium with regular matter (via annihilation)

★ DM as thermal relic from the hot early Universe

Minimal DM abundance is left over to the present day

Correct DM density for an annihilation xsec: $\langle \sigma v \rangle \sim 3\times10^{-26}\ cm^3/s \sim 1/(20\ TeV)^2$

★Mass constraints:
- mass too low: can not become non-relativistic in time
- mass too high: overproduced in early Universe



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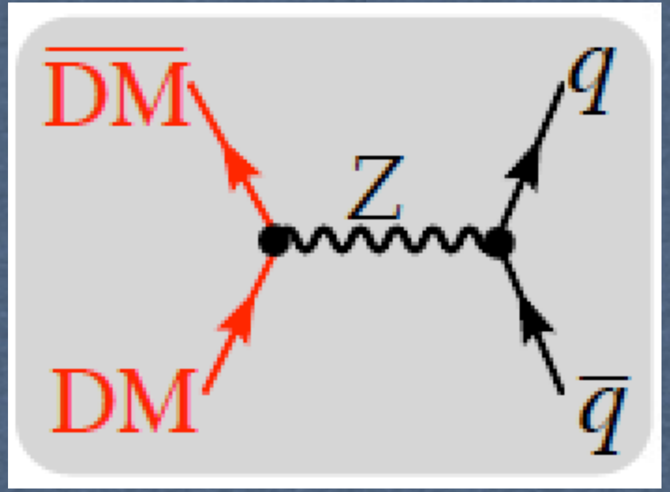

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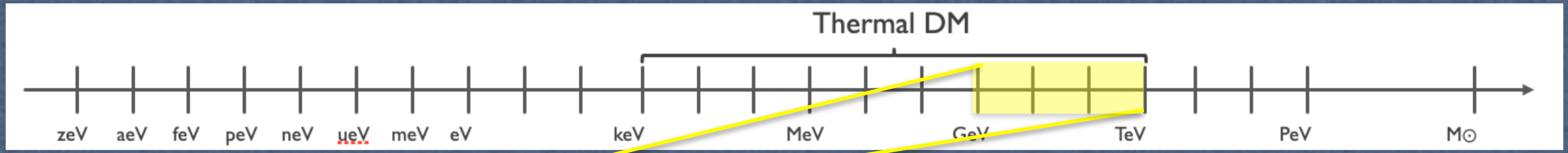
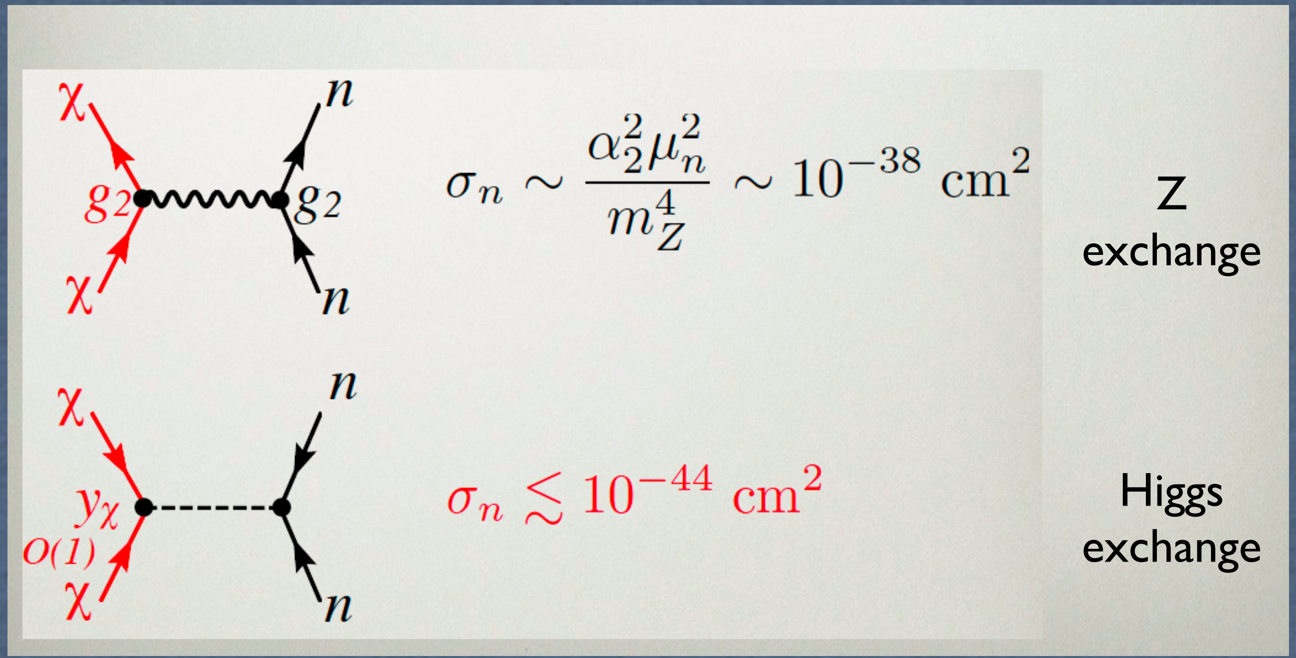


WIMPs (Weakly Interacting Massive Particles)

- Massive DM with massive mediator
- For ~100 GeV DM mass, weak-scale mediators provide reasonable annihilation rate and range of DM-scattering rates

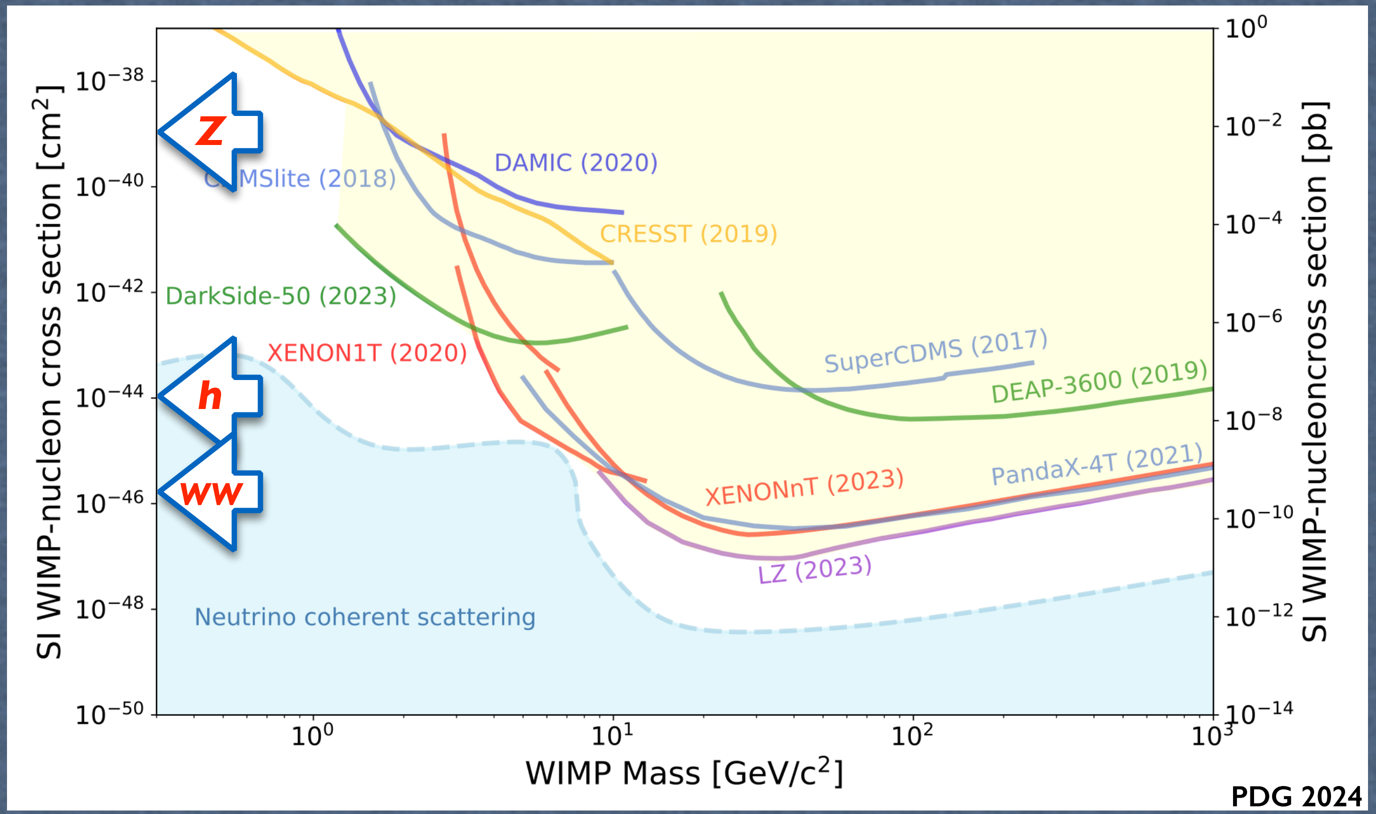


Thermal origin suggests DM interactions and mass in the vicinity of the weak-scale

Exploring the WIMP's option

Slow-moving cosmological weakly interacting massive particles

★ Experimental limits



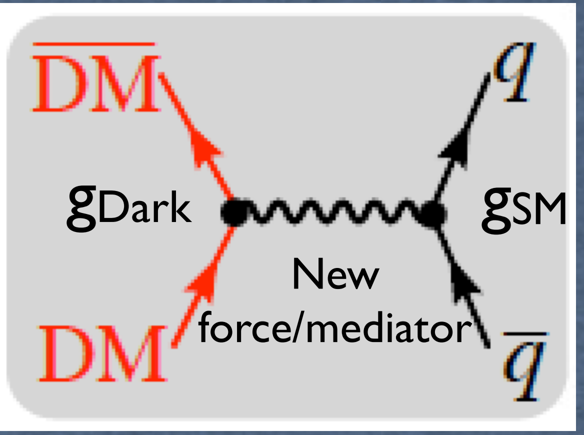
- DM detection by measuring the (heavy) nucleus recoil
- Constraints on the interaction strength from the DM Direct Detection limits
  - Scattering through Z boson ($\sigma \sim 10^{-39}$cm^2): ruled out
  - Approaching limits for scattering through the Higgs ($\sigma \sim 10^{-45}$cm^2)
  - Close to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

✳ No signal observed in Direct Detection

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

★ (Obvious) first guess: DM interaction in the range of the weak force scale (WIMPS) with DM mass in the range of TeV

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



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

Light Dark Matter

Light Dark Matter (<TeV) naturally introduces light mediators

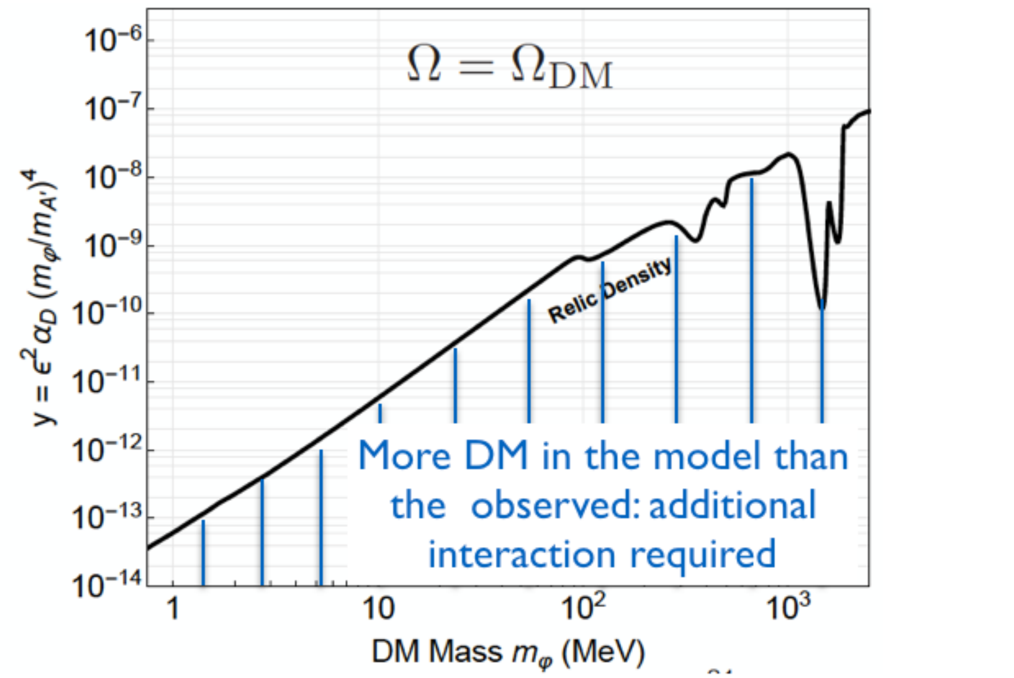
New interaction

★ Definition of [adimensional] variable $y \sim g^2_{Dark}\, g^2_{SM}\, (M_{DM}/M_{mediator})^4 \sim \langle \sigma v \rangle\, M^2_{DM}$

$$\langle \sigma v \rangle \propto \epsilon^2 \alpha_D \frac{m_\varphi^2}{m_{A'}^4} = \epsilon^2 \alpha_D \frac{m_\varphi^4}{m_{A'}^4} \frac{1}{m_\varphi^2} = \frac{y}{m_\varphi^2}$$

Usually computed for $m_{A'}/m_{\phi/\chi} = 3$

But thermal target largely insensitive to this ratio



Neutral doors (portals)

Forces / Matter	EM	Weak	Strong	New force?
Electron	✓	✓	—	—
Neutrino	—	✓	—	—
Quarks	✓	✓	✓	—
Dark Matter?	—	—	—	✓

★ The new force should be weak

★ Different combination of DM and mediator masses are possible:

- heavy WIMPs / heavy mediators
- light WIMPs / light mediators
- heavy WIMPs /light mediators
- light WIMPs / heavy mediators

focus of this talk!

★ Small number of interactions allowed by Standard Model symmetries with dimensionless couplings

★ Some of them can be tested directly (e.g. rare B-decay such as B → K + A')

Vector Portal	$\frac{1}{2}\epsilon_Y F^Y_{\mu\nu} F'^{\mu\nu}$	kinetic mixing?
Higgs Portal	$\epsilon_h \|h\|^2 \|\phi\|^2$	exotic rare Higgs decays?
Neutrino Portal	$\epsilon_\nu (hL)\psi$	not-so-sterile neutrinos?
Axion Portal	$\frac{1}{f_a} a F_{\mu\nu}\tilde{F}^{\mu\nu}$	axion-like particles?

New scalars, vectors or fermions are expected to mediate new interactions

The vector portal

✳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

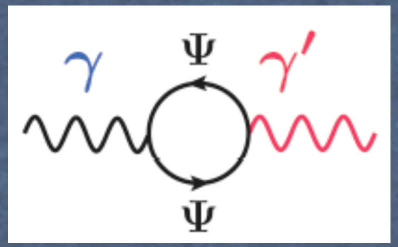
A simple way to go beyond the SM (not yet excluded!):

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

Color Electroweak Hypercharge Hidden sector

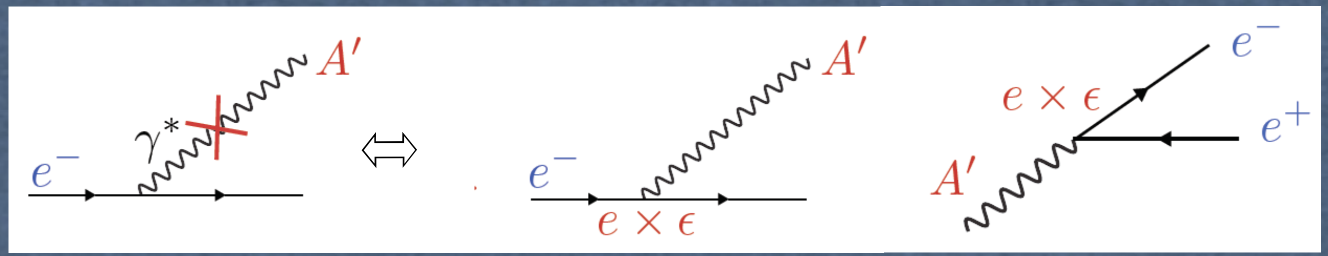
$$\mathcal{L}_{\rm eff} = \mathcal{L}_{\rm SM} - \frac{1}{4}X_{\mu\nu}X^{\mu\nu} - \frac{\chi}{2}X_{\mu\nu}F^{\mu\nu} + \frac{m^2_{\gamma'}}{2}X_\mu X^\mu$$

Hidden Visible

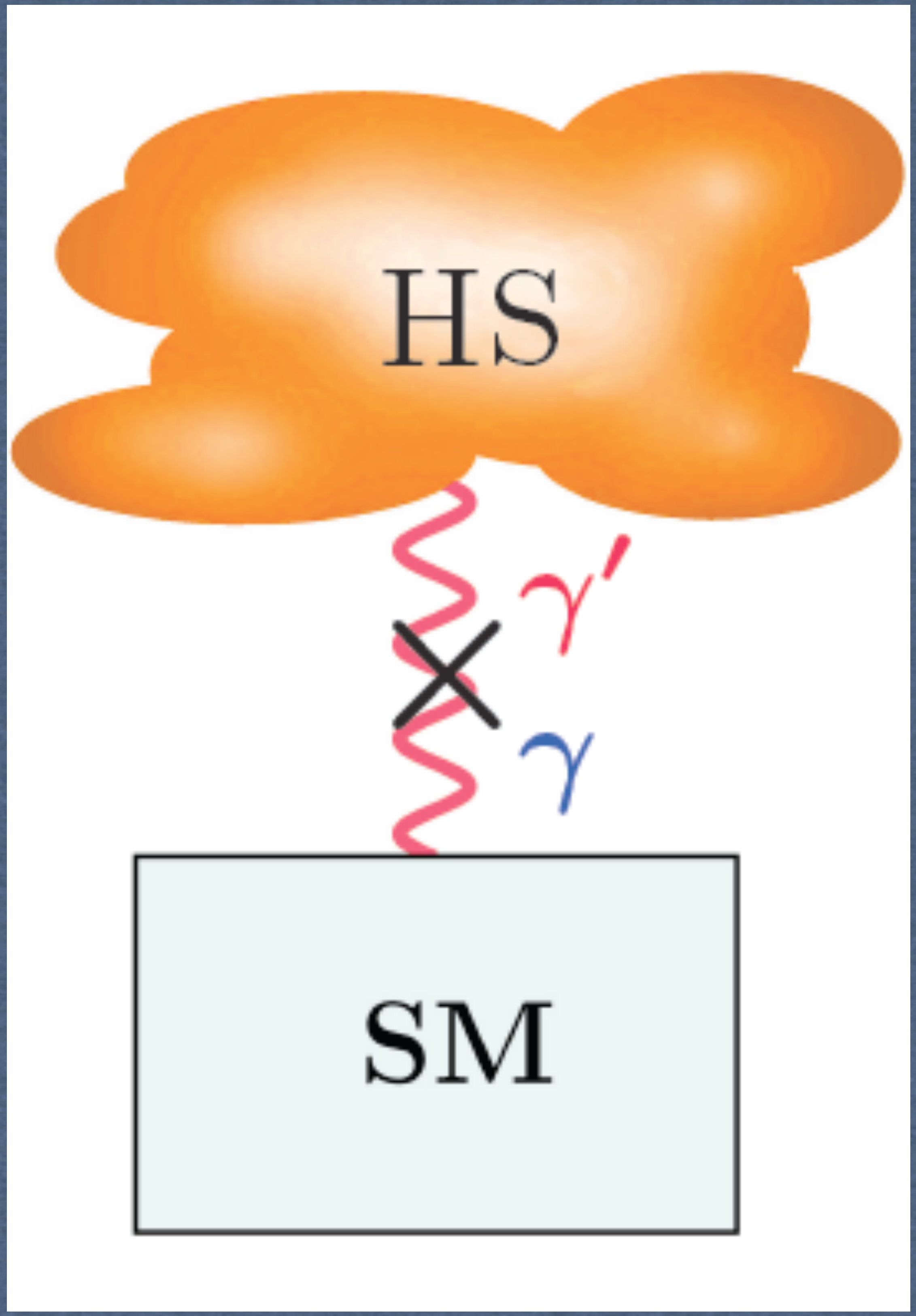


γ'/A' couples to SM via electromagnetic current (kinetic mixing)

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



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



A lesson from history

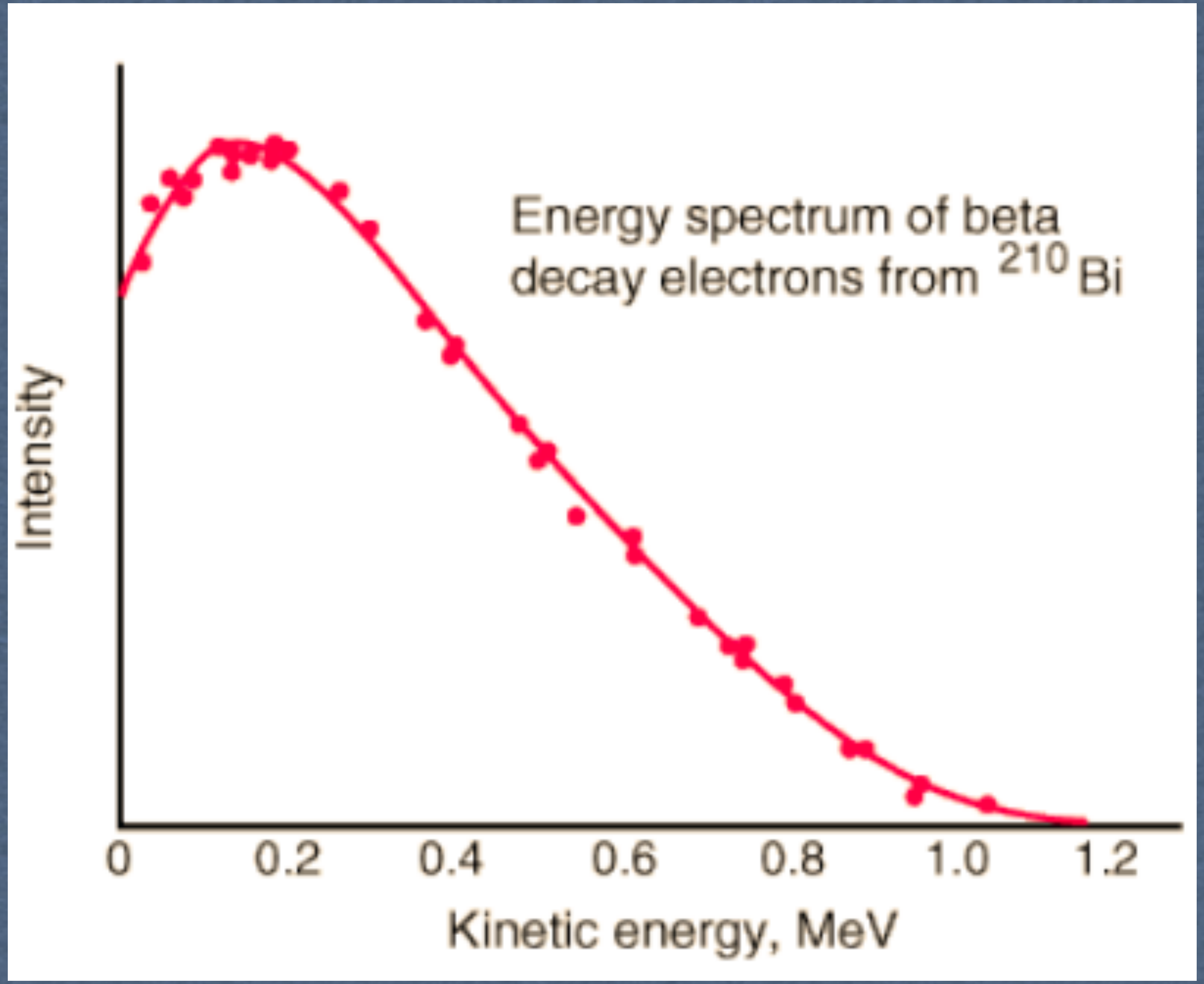
An historical example of a ‘Standard Model’ and ‘hidden sector’

★ Back in the ’30 the Standard Model of the elementary particles was: photon, electron and nucleons

★ Beta decay:

$n \rightarrow p + e^-$

Continuous spectrum!



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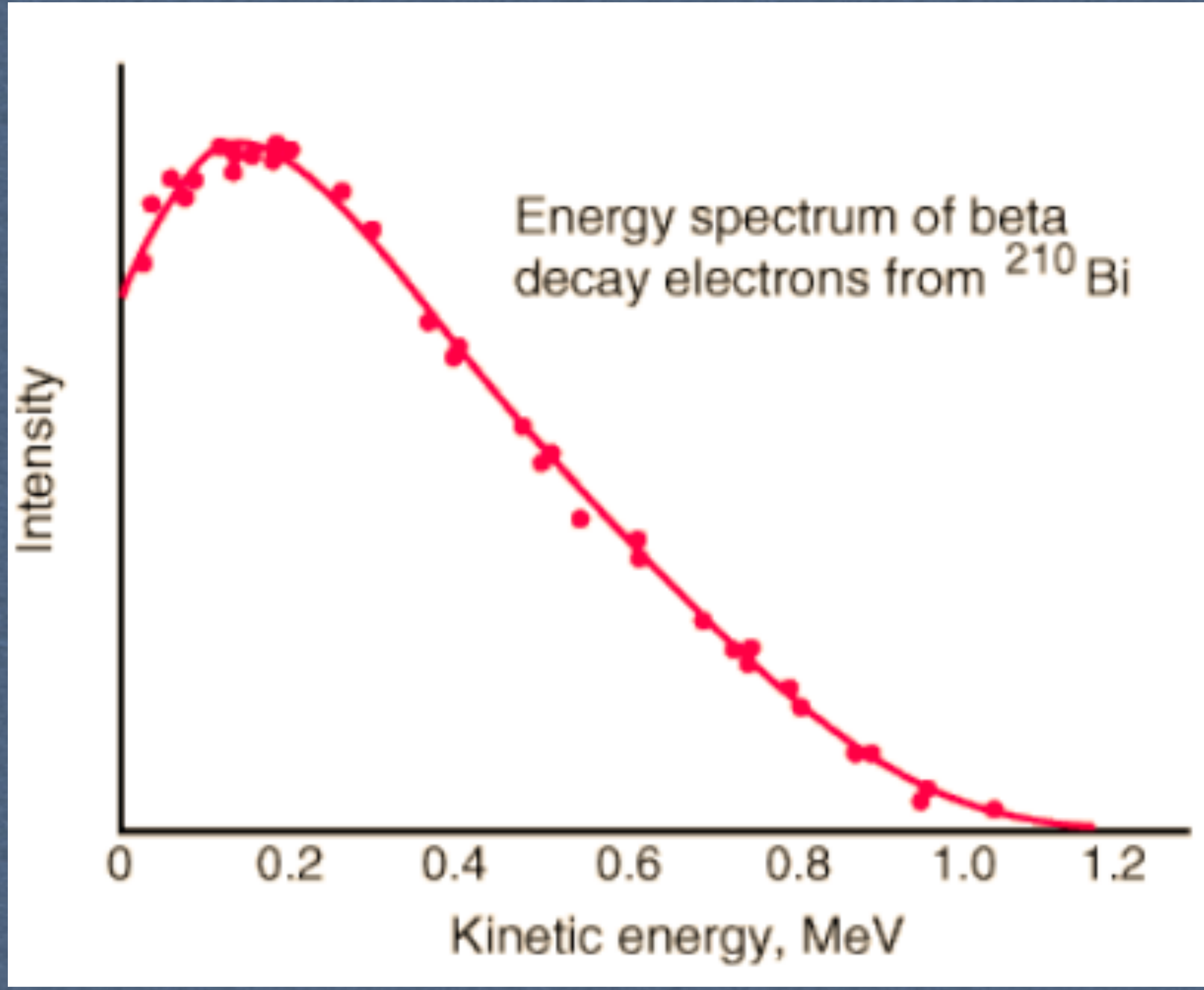


★ Pauli proposes a radical solution - the neutrino!

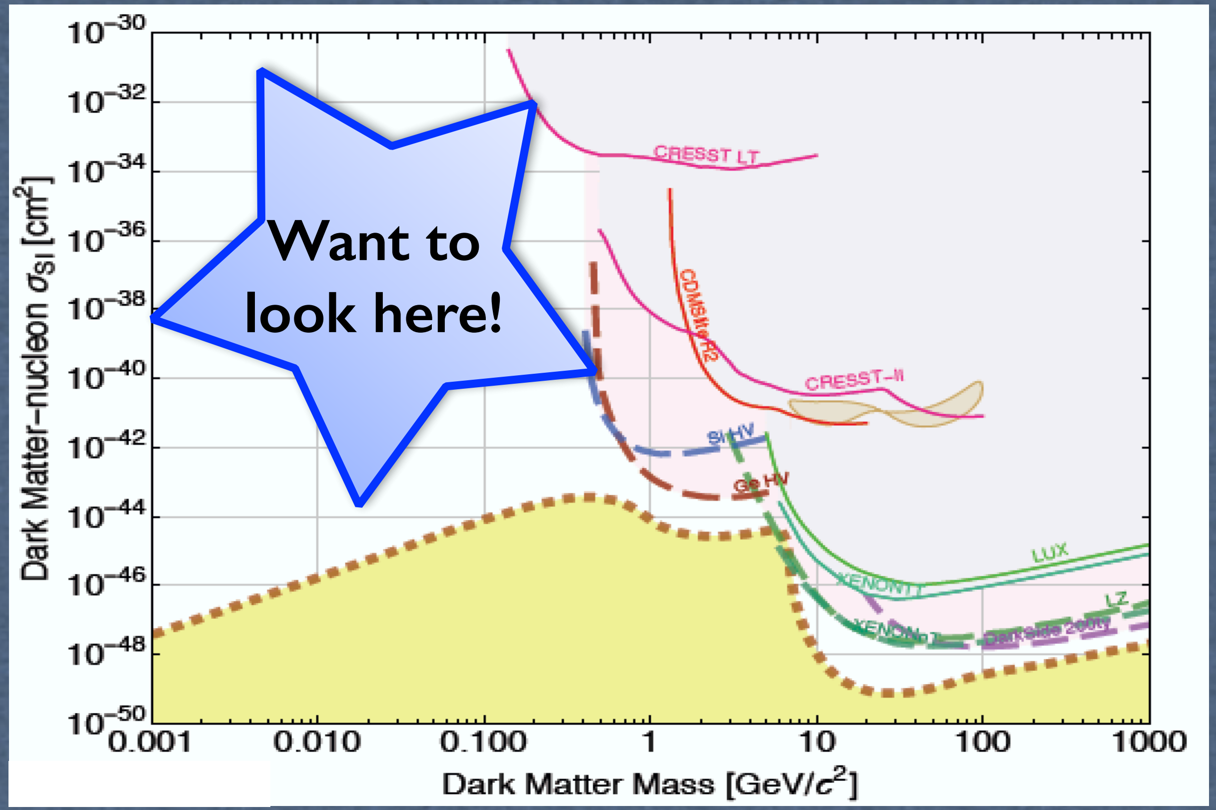
$n \rightarrow p + e^- + \bar{\nu}_e$

★ Perfect example of a hidden sector!

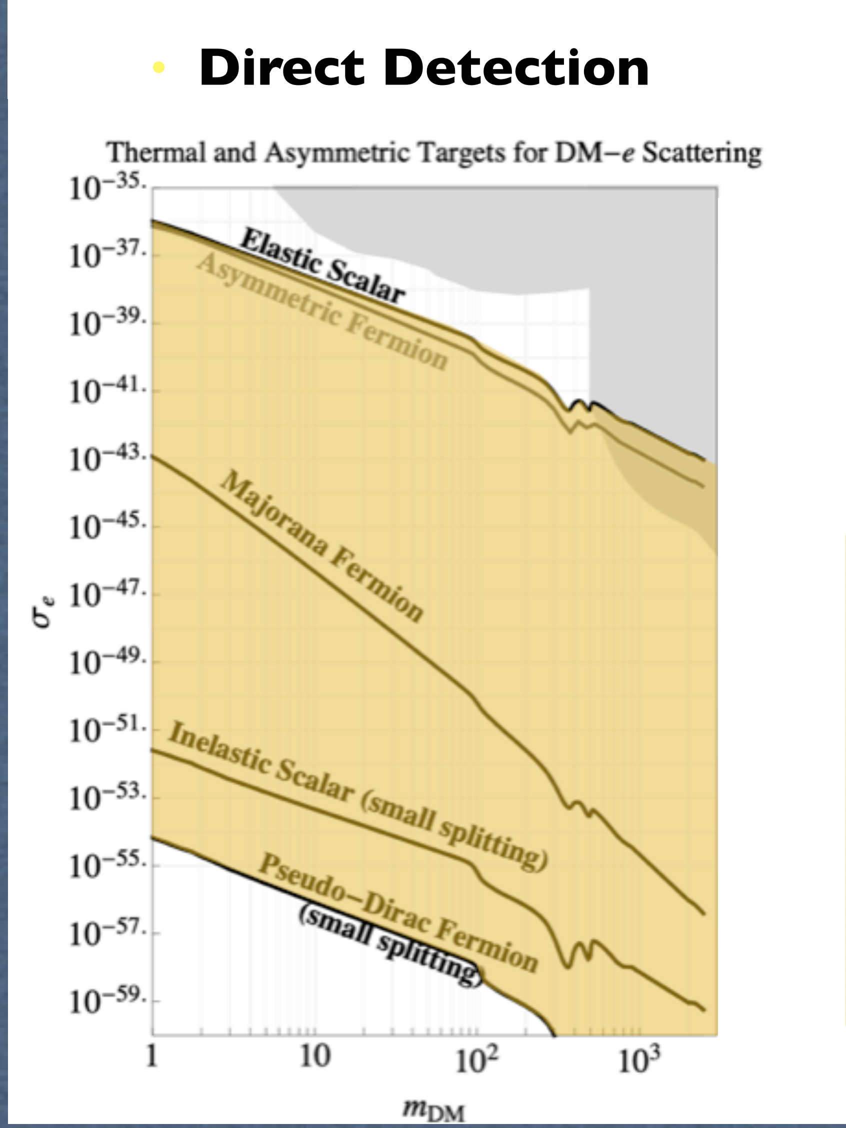
- neutrino is electrically neutral
- very weakly interacting and light
- interacts with "Standard Model" through "portal" - $(\bar{p}\gamma^\mu n)(\bar{e}\gamma^\mu \nu_e)$
- [… more precisely $(\bar{p}\,\gamma^\mu\,(1-g_A\gamma^5)\,n)(\bar{e}\,\gamma^\mu\,(1-\gamma^5)\,\nu_e)$]

Light Dark Matter

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



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



- Large dependence (20 orders of magnitude!) of e-DM scattering cross section by the spin details of the DM nature (fermion, scales, pDirac, …)
- Cross section has a strong dependence on the DM velocity: $\sigma \sim v^0, v^2, v^4$ (Galactic DM $v \sim 10^{-3}$)
- In relativistic regime, this kinematic suppression disappears (10^{-20} difference to *O(1)-O(10)*)

Light Dark Matter

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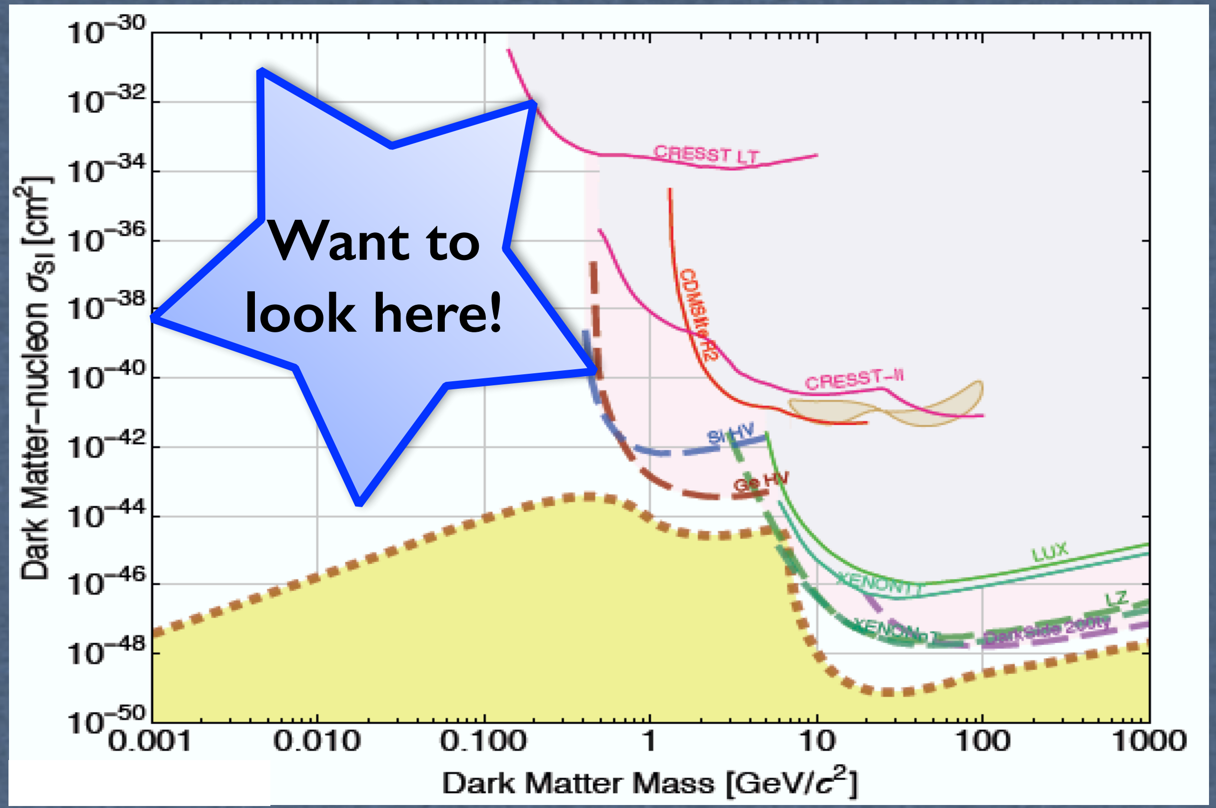


Unique features of accelerator-based (L)DM search

✳ Tagging wrt cosmic anomalies (clear way of distinguish DM from other effects)

✳ Unprecedented sensitivity in the keep-out zone for direct DM search

✳ High intensity electron beam available to play a significant role in LDM search

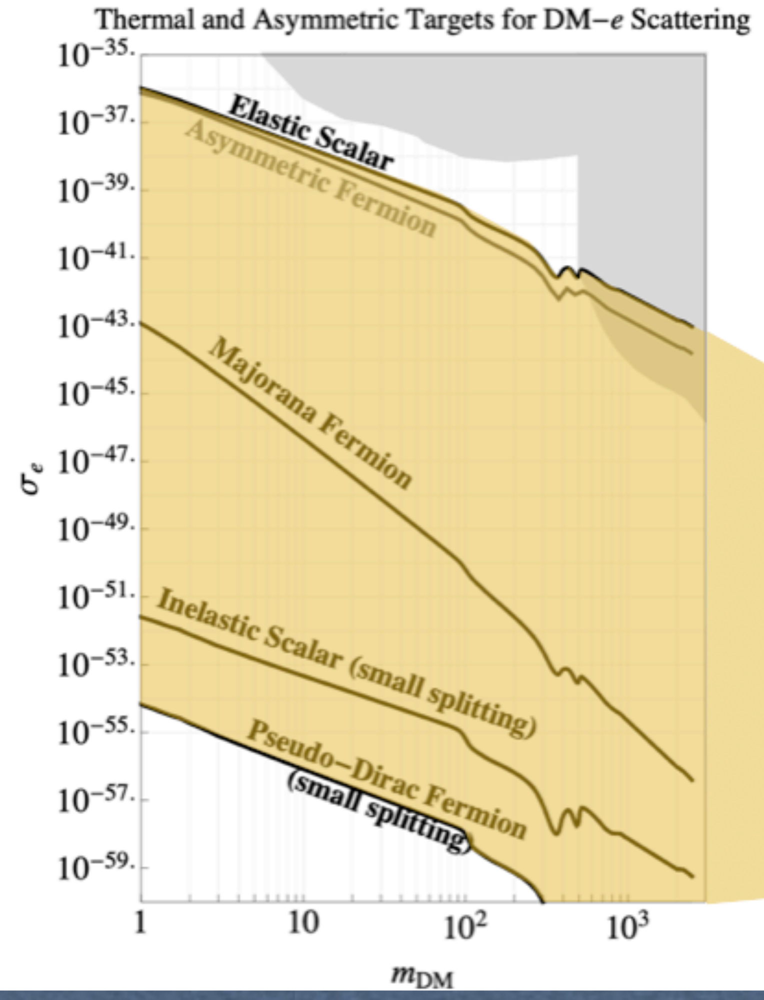
- Accelerators-based DM search
  - covers an unexplored mass region extending the reach
  - outside the classical DM hunting territory

Particle beams
- High intensity
- Moderate energy

Intensity frontier

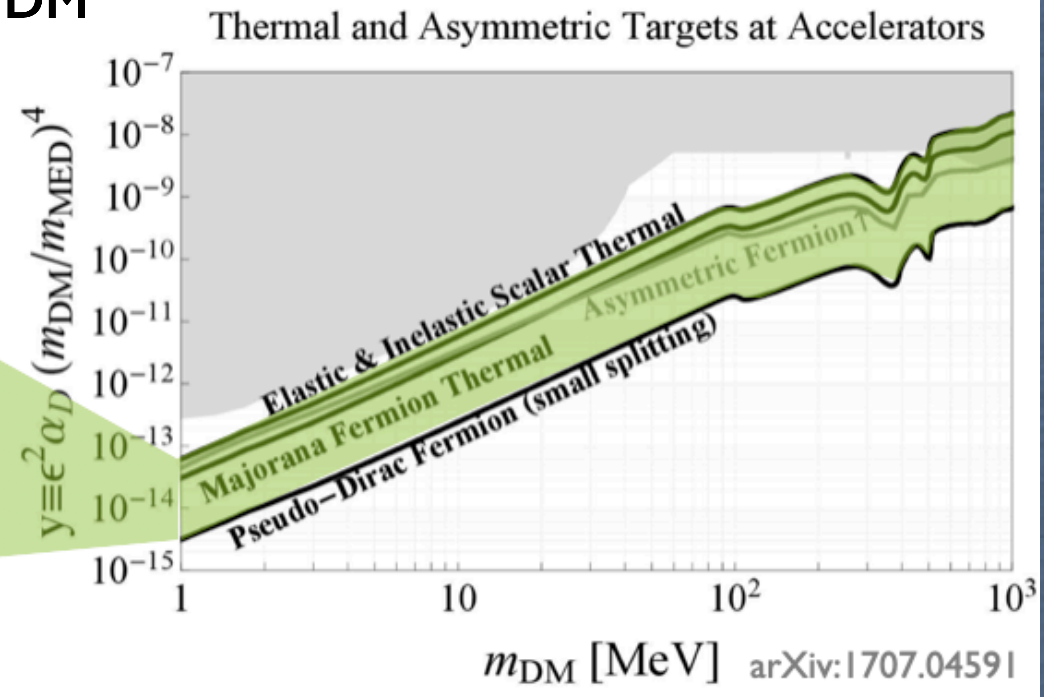
- **Direct Detection**

- Non-relativistic scattering: sensitive to **operator hierarchy and velocity suppression**
- Relativistic scattering probes the **fundamental interaction**
- Most spin-dependent differences washed out



- **Accelerator based experiment**

Relativistic DM

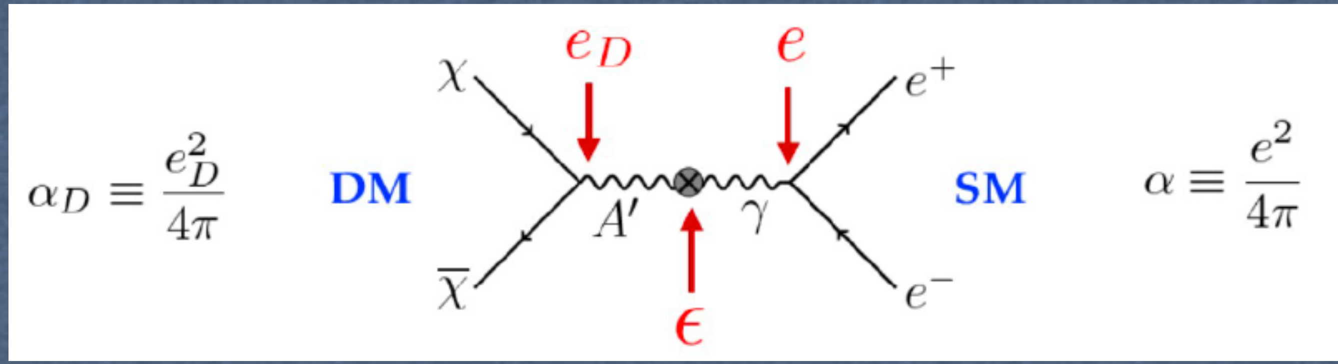


arXiv:1707.04591

Dark Photon Signatures

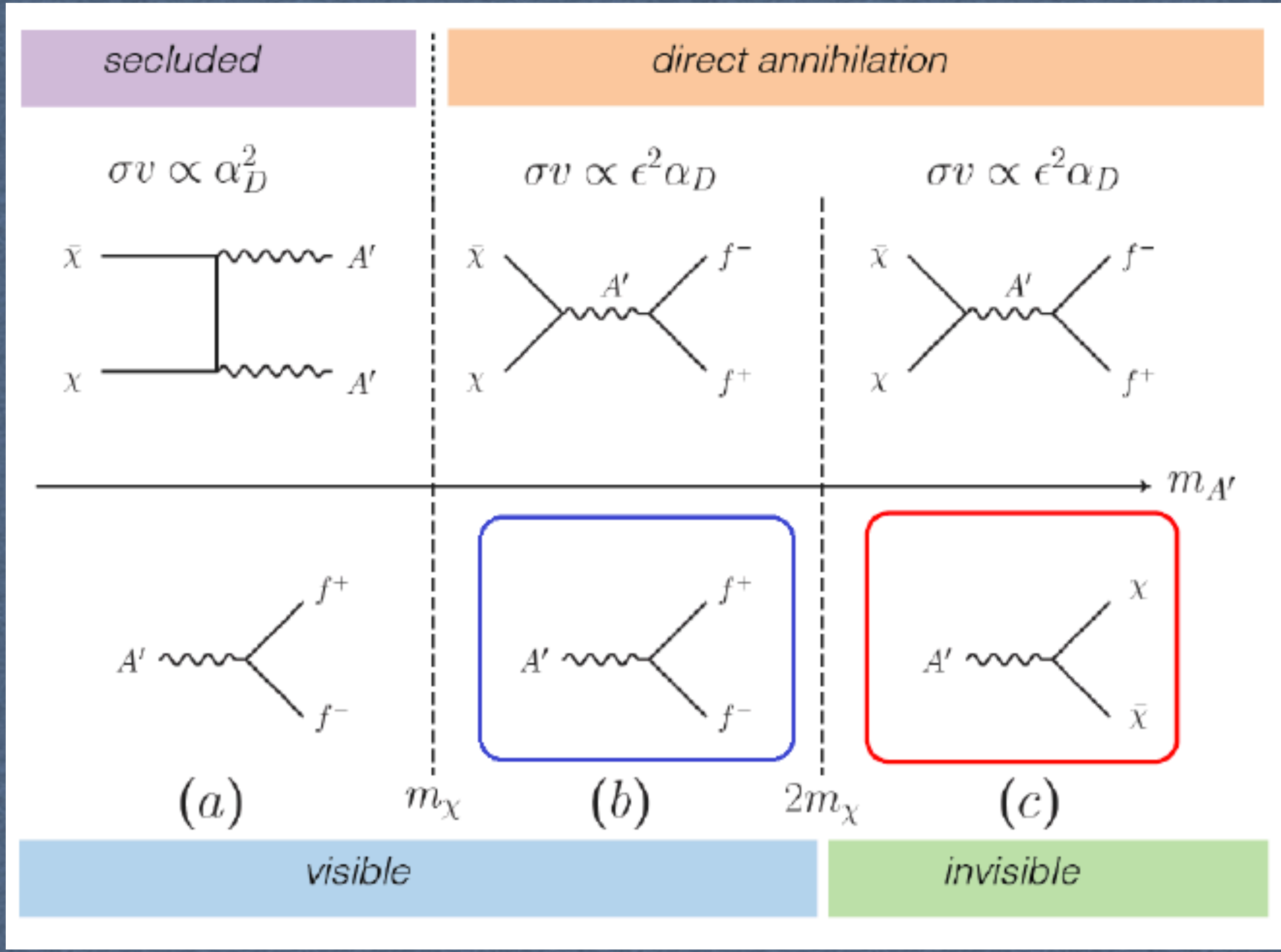
Vector mediated Light Dark Matter

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

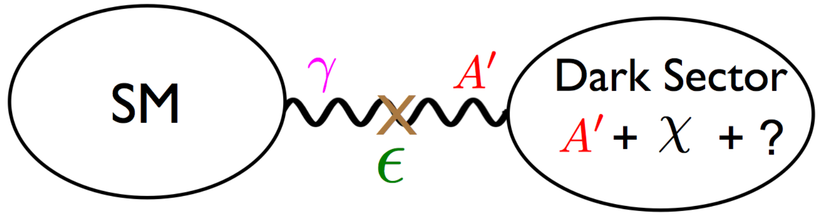


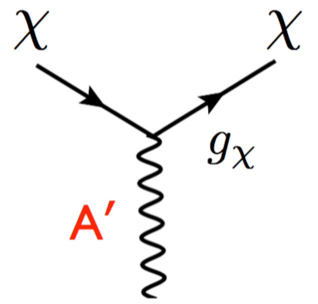
A' interaction scenarios

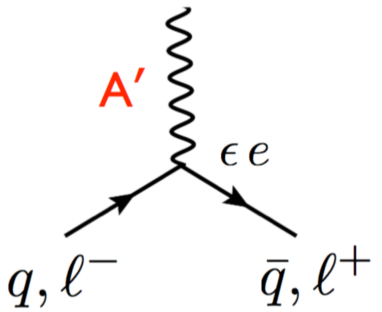
- **Secluded**: no constraints by cosmology for accelerator based experiments. Any ε allowed
- **Visible decay**: final state contains SM particles
- **Invisible decay**: A' decays to Dark Sector invisible particles



Dark forces and dark matter
(Light WIMPs - light mediators)



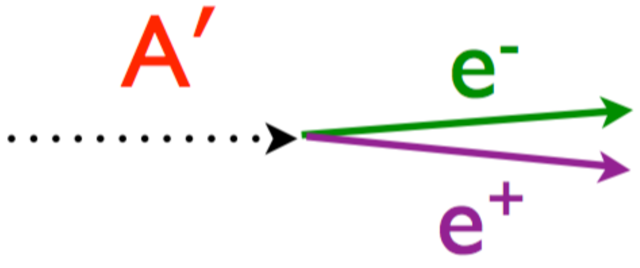




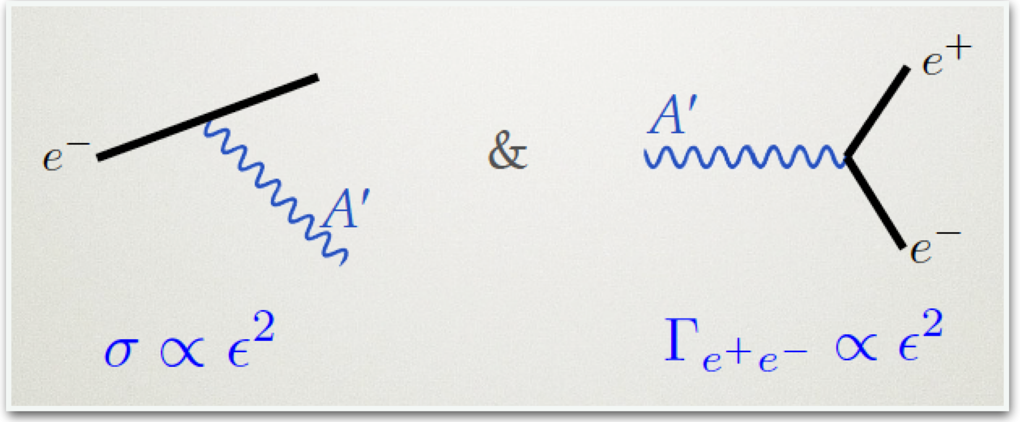
4 parameters: $m_\chi, m_{A'}, \epsilon, g_\chi$

$m_\chi \sim m_{A'} \sim \mathrm{MeV} - 5\ \mathrm{GeV}$

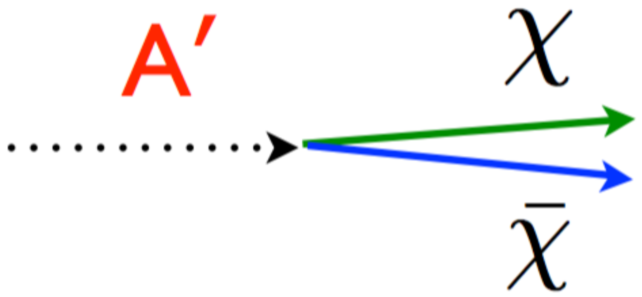
Visible



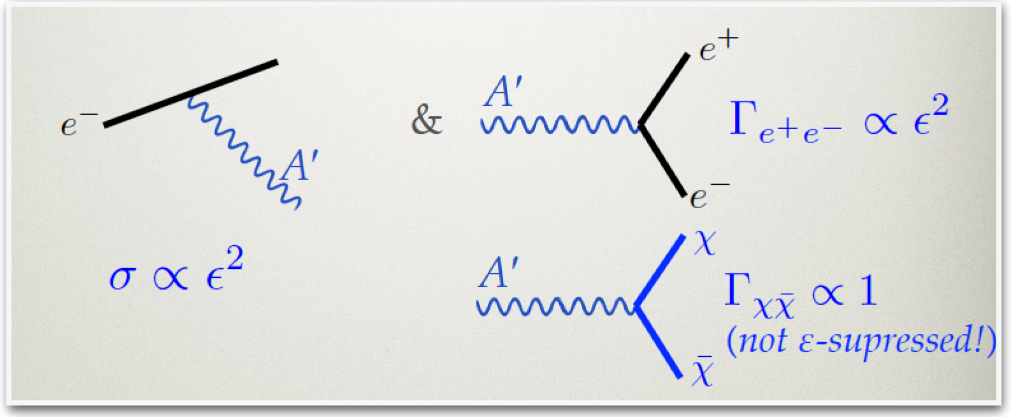
- *Minimal* decay
- Decay regulated by ε^2
- Independent on m_χ
- Requires $m_{A'} < 2m_\chi$



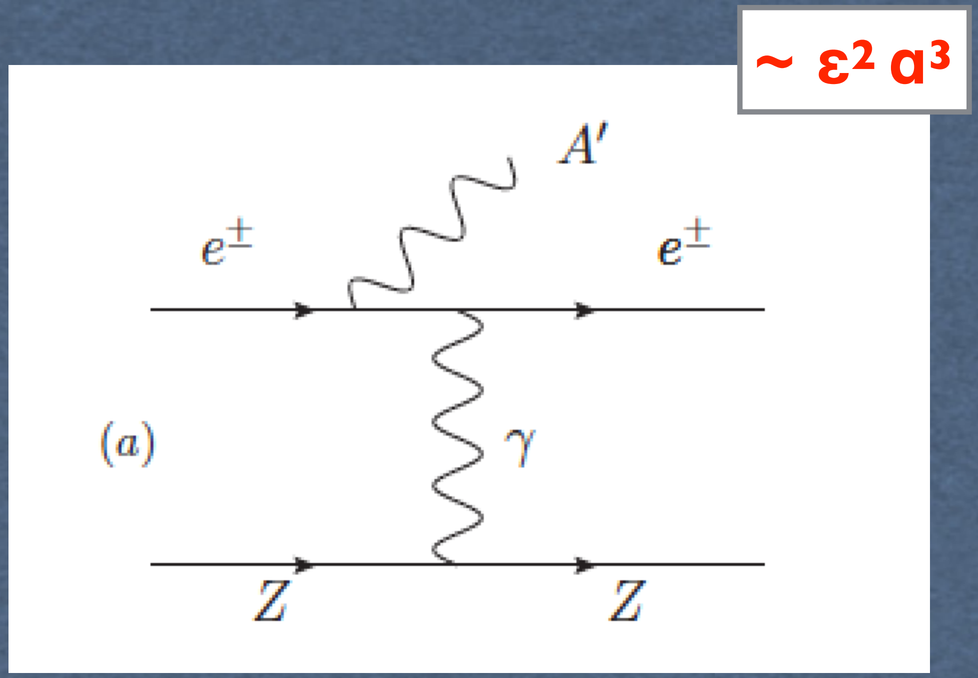
Invisible



- $m_\chi < 2m_{A'}$
- i) stable and invisible
- ii) decays to SM particles
- Independent on ε

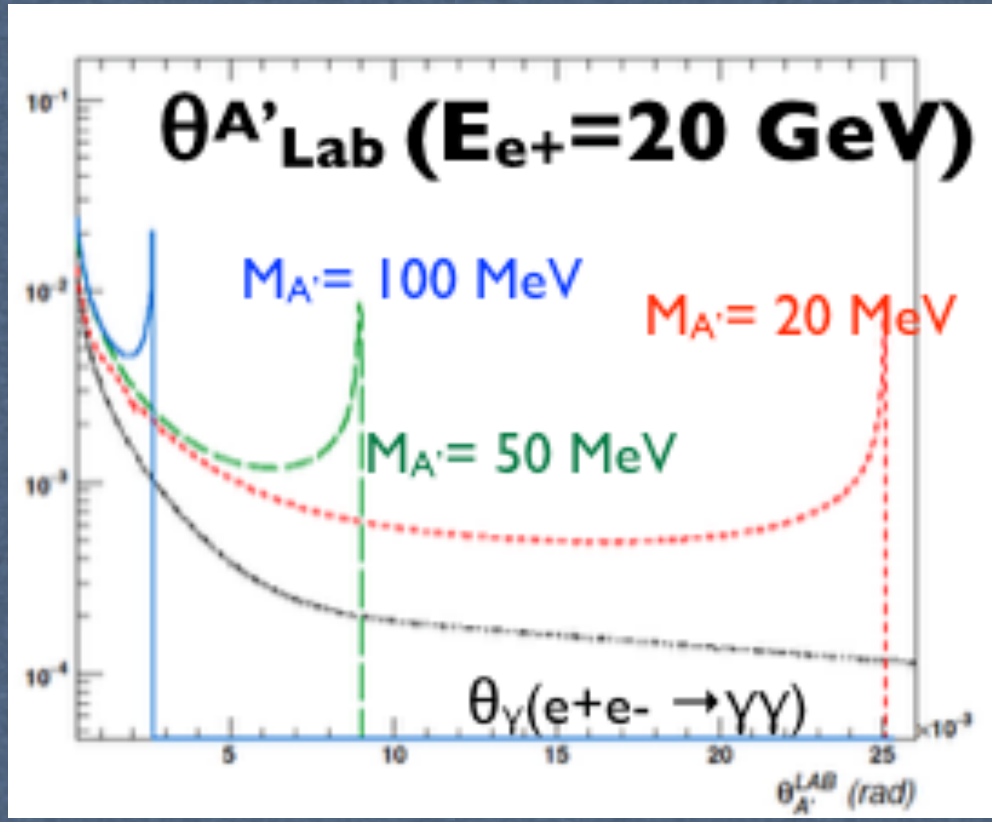


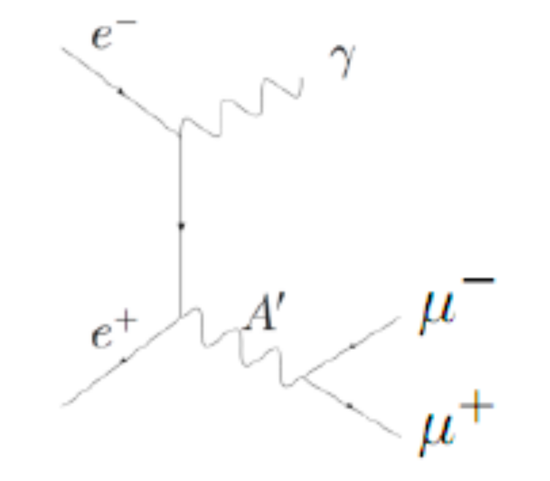
A' Production mechanisms - e$^{\pm}$



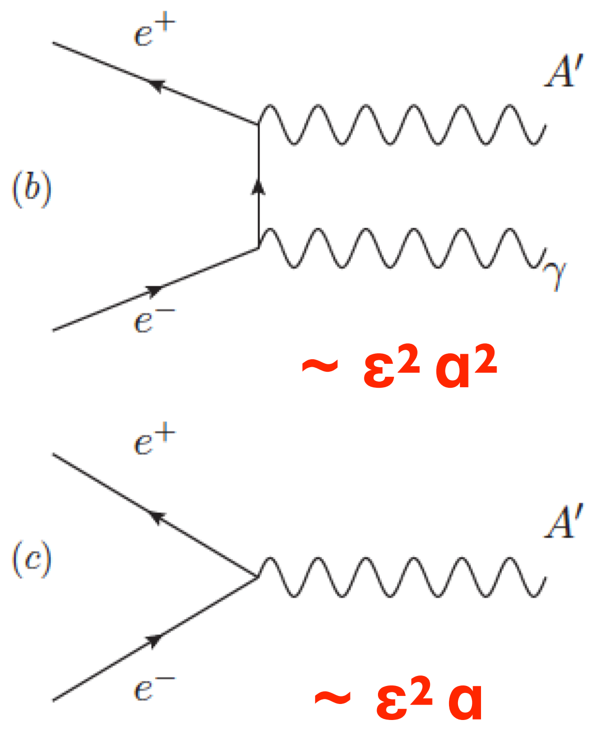
The Weizsacker-Williams approximation (*A'-strahlung*)

- The incoming electron 'see' a fast-moving cloud of effective photons to scatter from
- Photons are almost on-shell (low Q2) → transverse photons ~ $e^- \gamma_{Real}$ scattering
- Same treatment as the regular *bremstrahlung*
- Regularisations occurs in the case of interest $M_{A'} >> M_{e-}$
- Effective photon flux χ is critical, accounting for nuclear effect using FF





A' Production - positrons



- **NON-RESONANT annihilation**
  - **A' along (e^+e^-) direction**
- **RESONANT annihilation**

- **Two-body process**
- **A' forward-peaked along e^+ direction**
- **$E_{A'} = E_R = m^2_{A'}/2m_e$**

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

L.Marsicano et al. Phys.Rev.Lett. 121 (2018) 4, 041802

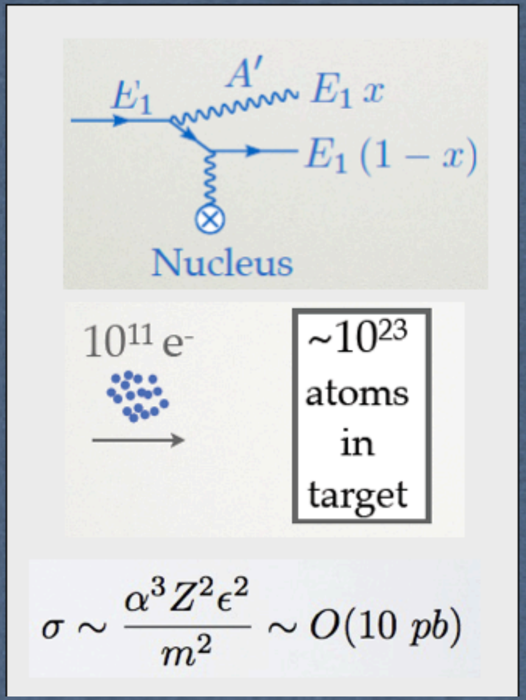
- Known and used
- Collider (missing mass experiments)
- Thin target experiments (visible decay)

e+e- → γ' γ → μμ γ
➜ BABAR, BELLE, KLOE, CLEO

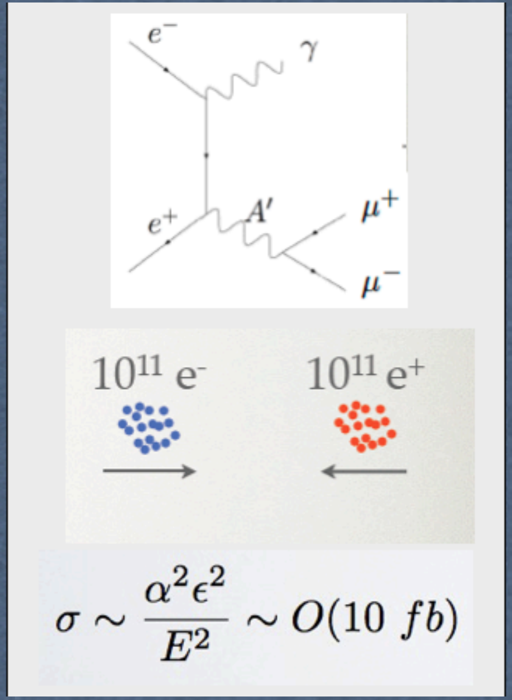
Experimental techniques

Fixed target vs. collider

Fixed Target



e+e- colliders

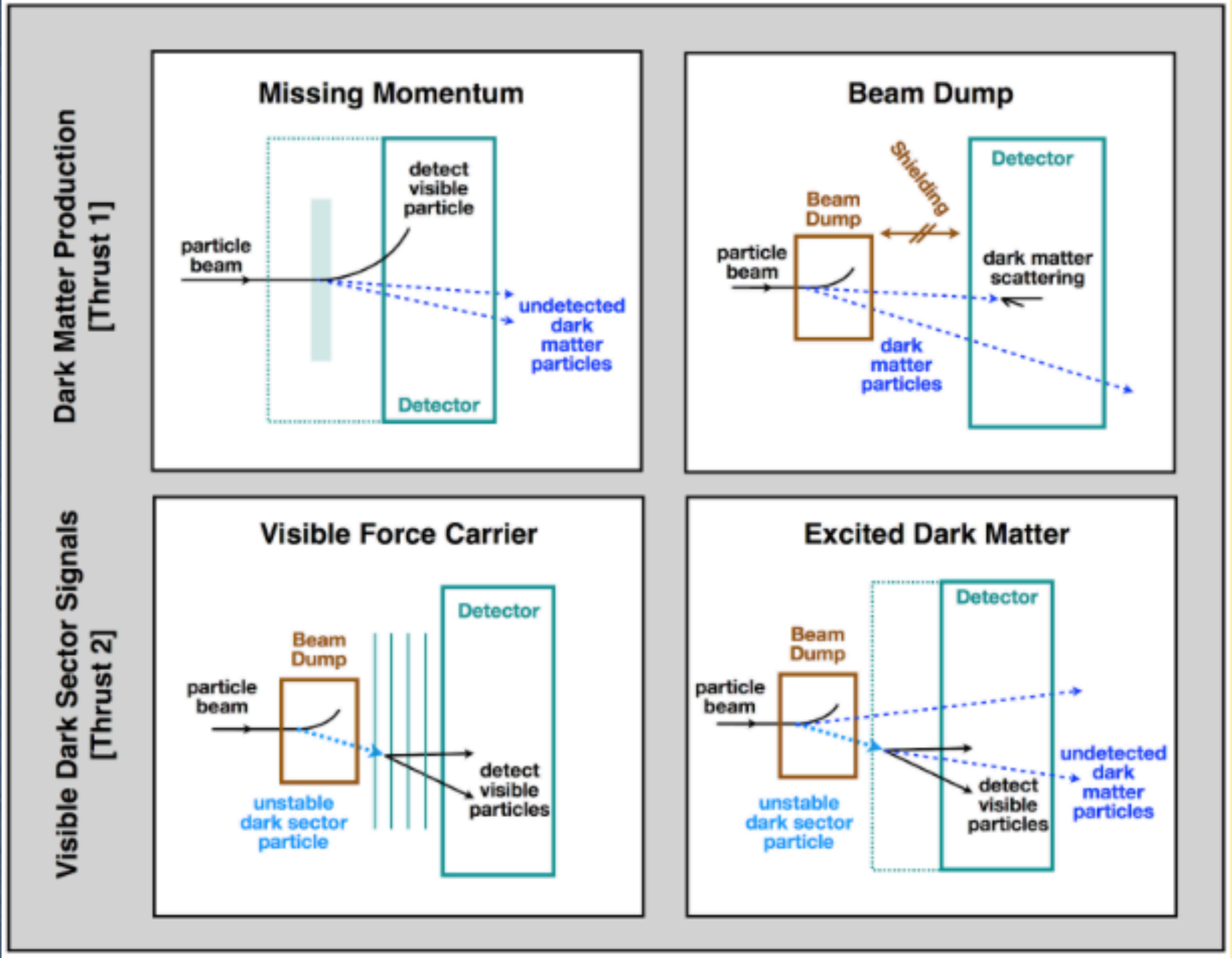


- high backgrounds
- limited A' mass

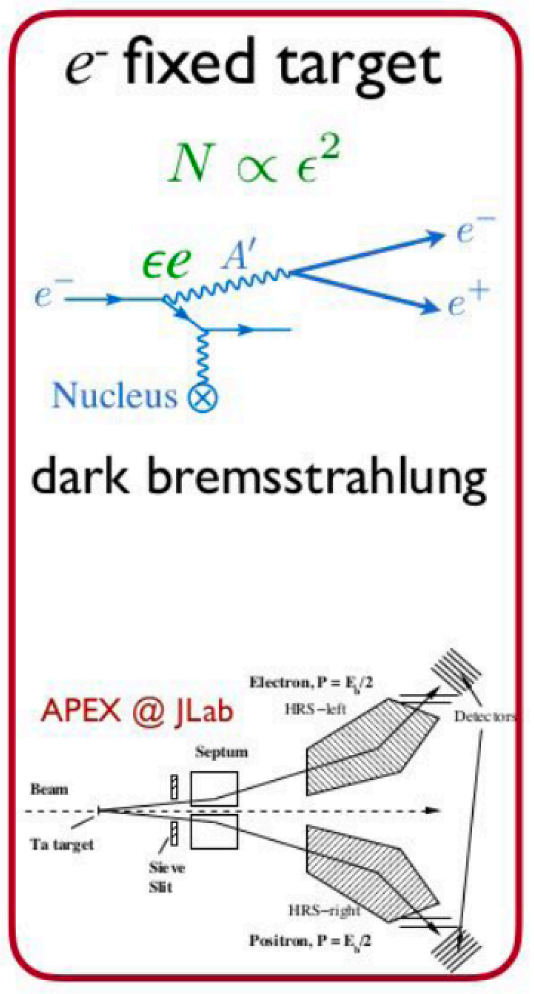
- low backgrounds
- higher A' mass

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

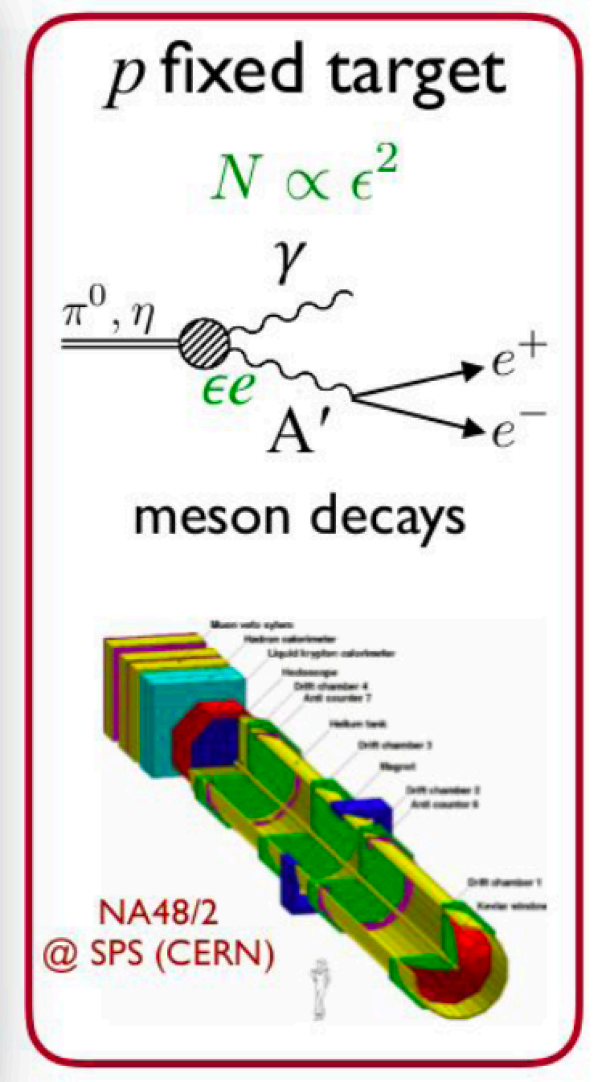
Fixed target



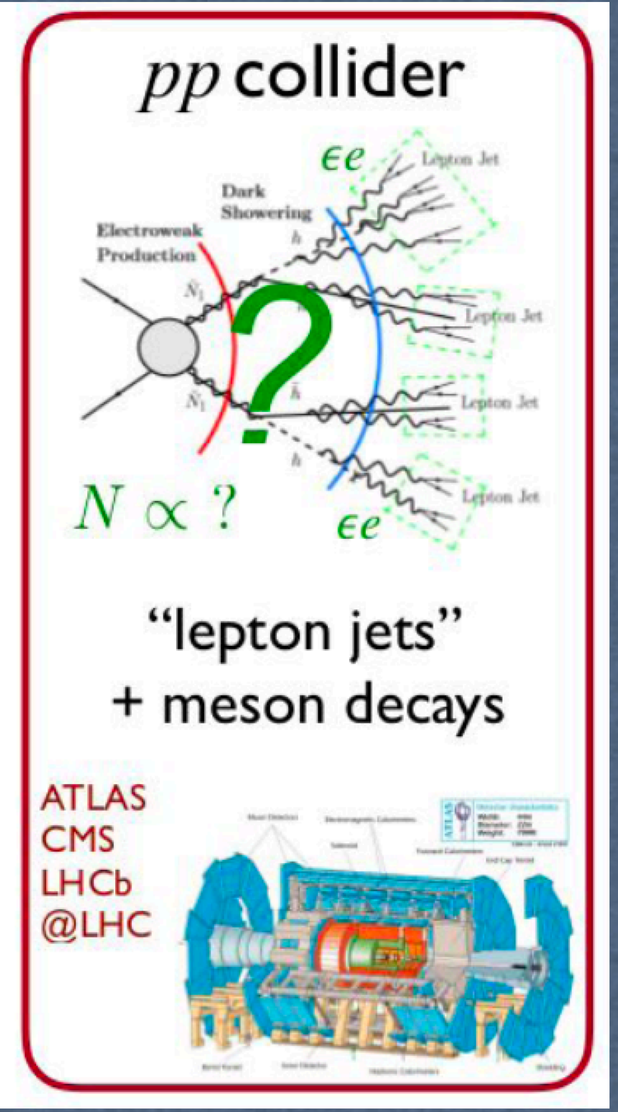
A' visible and invisible decay at accelerators

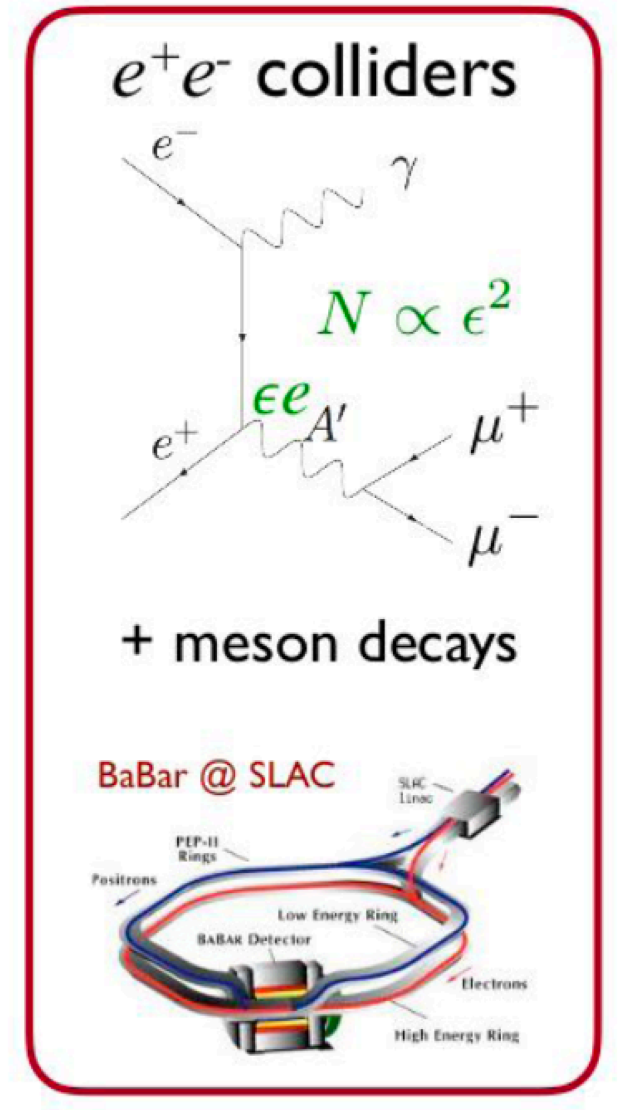


Fixed target:
e N →N γ'→ N Lepton Lepton+
➜ **JLAB, MAINZ**

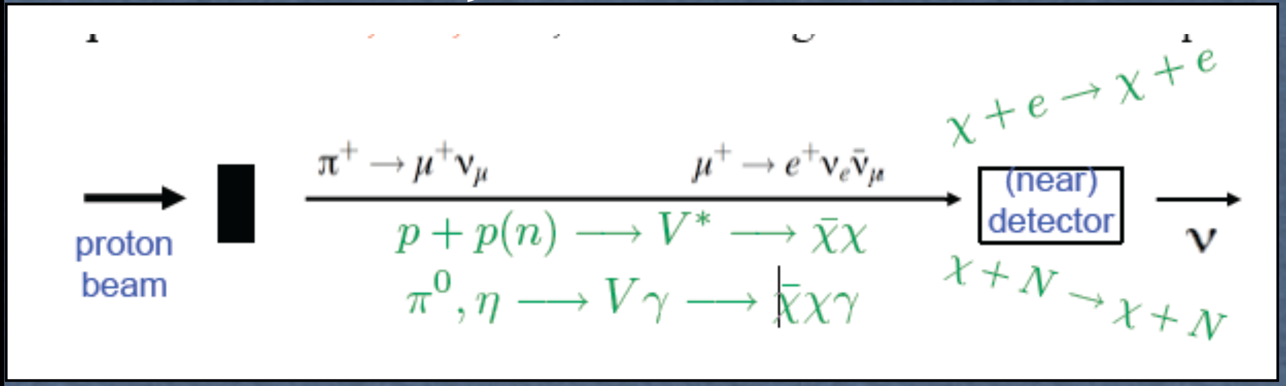


High Energy Hadron Colliders:
pp → lepton jets
➜ **ATLAS, CMS, CDF&D0**





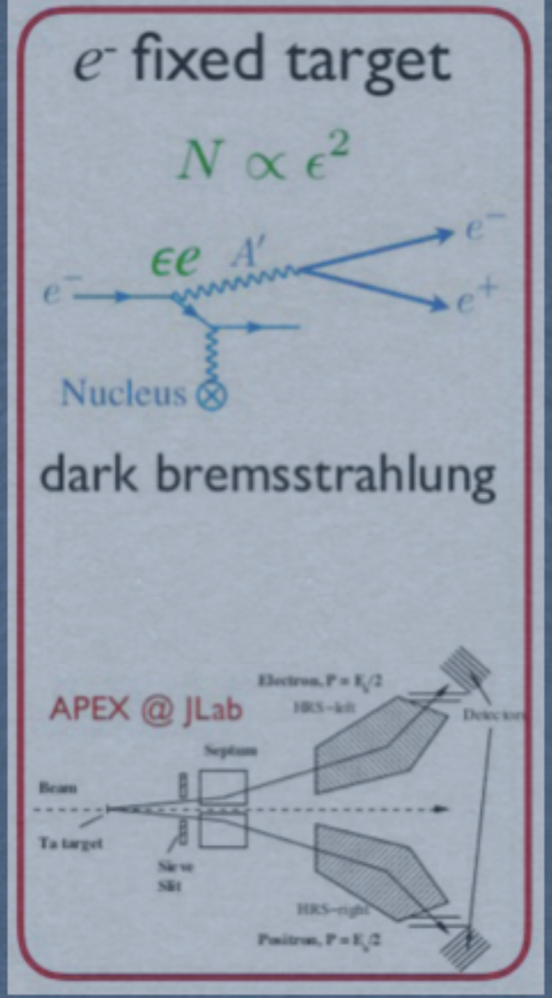
Fixed target:
p N →N γ'→ p Lepton Lepton+
➜ **FERMILAB, SERPUKHOV**



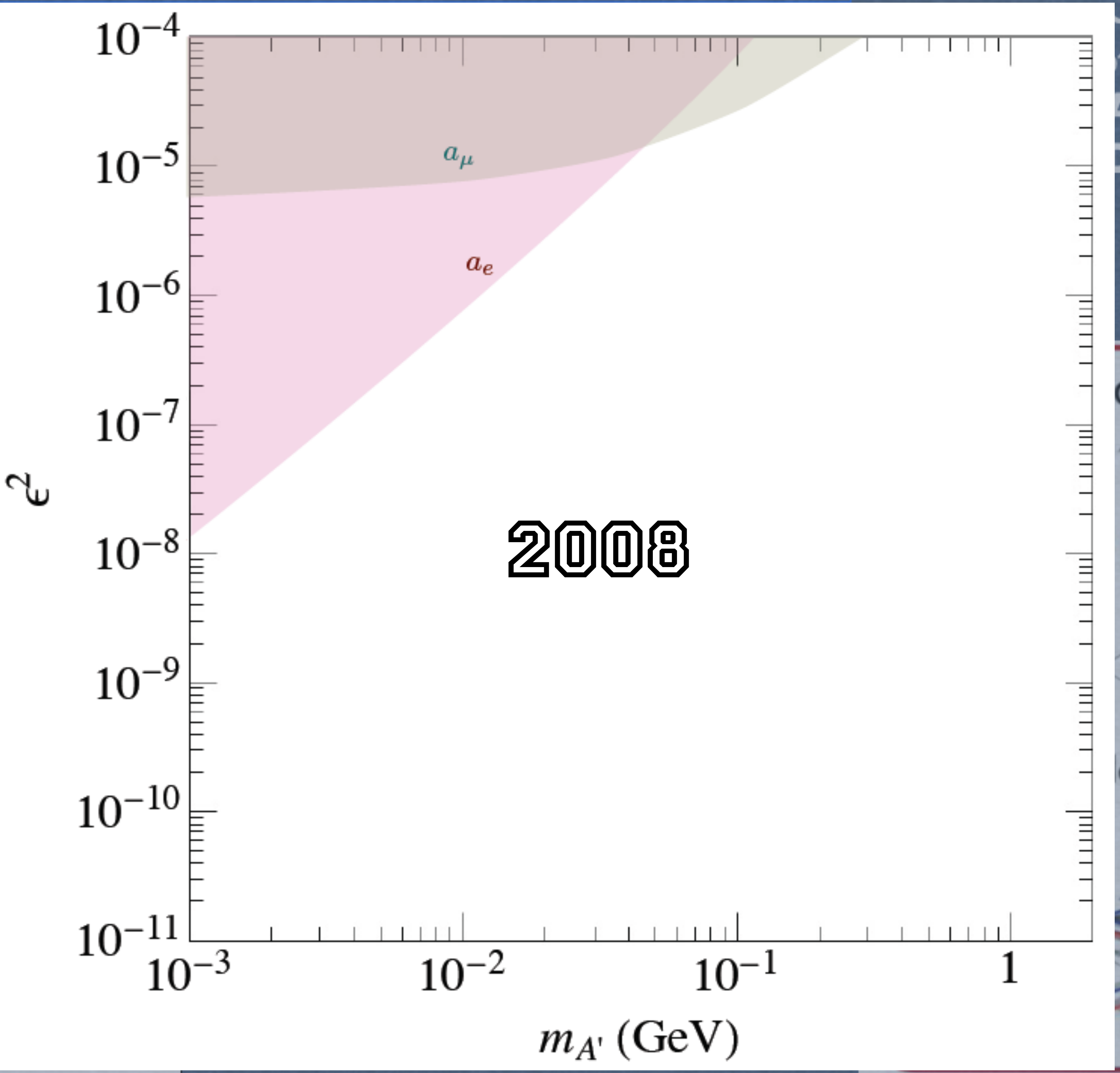
Meson decays:
π^0, η, η', ω, → γ' γ (M)
→Lepton Lepton + γ (M)
➜ **KLOE, BES3, WASA-COSY, PHENIX**

Annihilation:
e+e- → γ' γ → μμ γ
➜ **BABAR, BELLE-II, KLOE, CLEO**

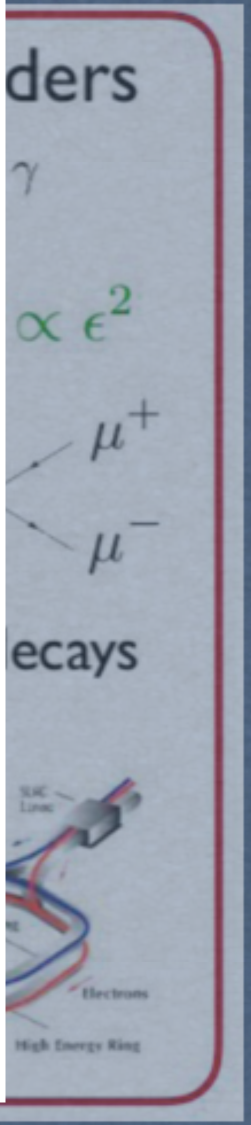
A' visible decay at accelerators



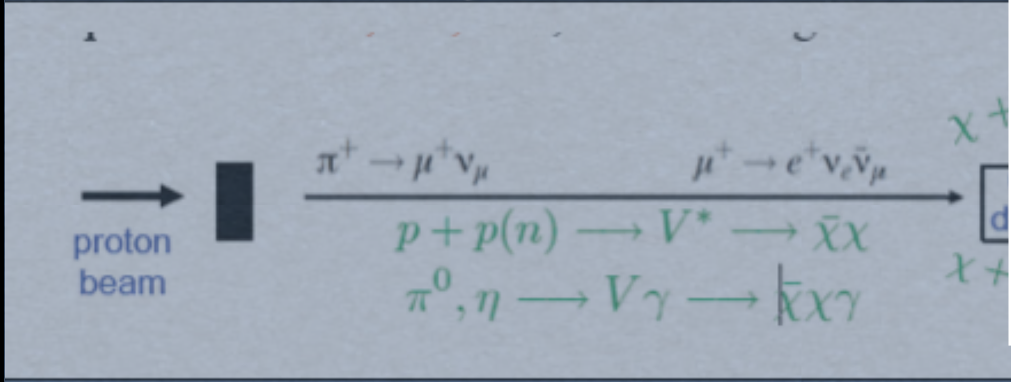
Fixed target:
e N →N γ'→ N
→ JLAB, MA



Colliders:
ton jets
AS, CMS,
D0



Fixed target:
p N →N γ'→ p Lepton Lepton+
→ **FERMILAB, SERPUKHOV**



Annihilation:
e+e- → γ' γ → μμ γ
→ **BABAR, BELLE-II, KLOE, CLEO**

Beam-dump experiments - visible -

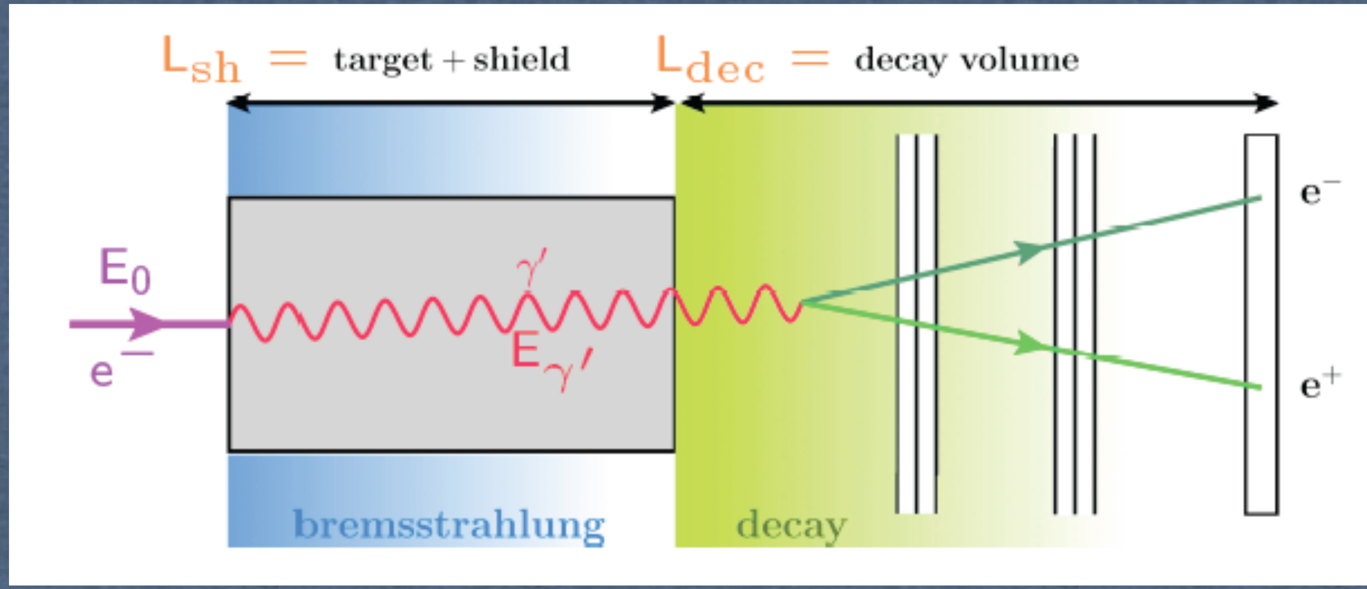
✳ e- beam incident on thick target

✳ A' is produce in a process similar to ordinary Bremsstrahlung

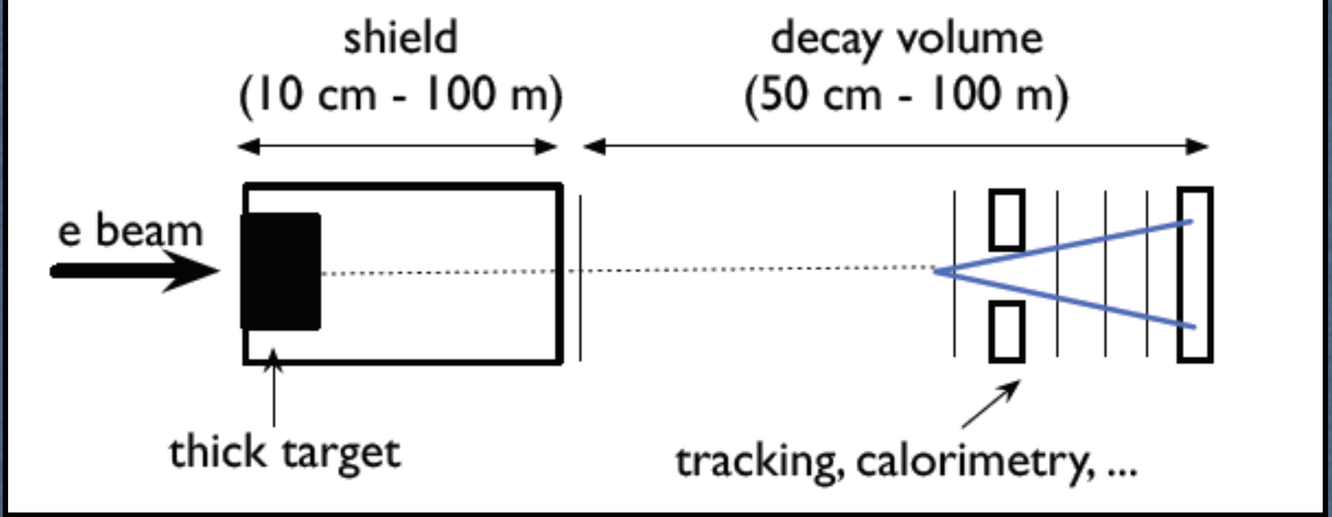
✳ A' carries most of the beam energy

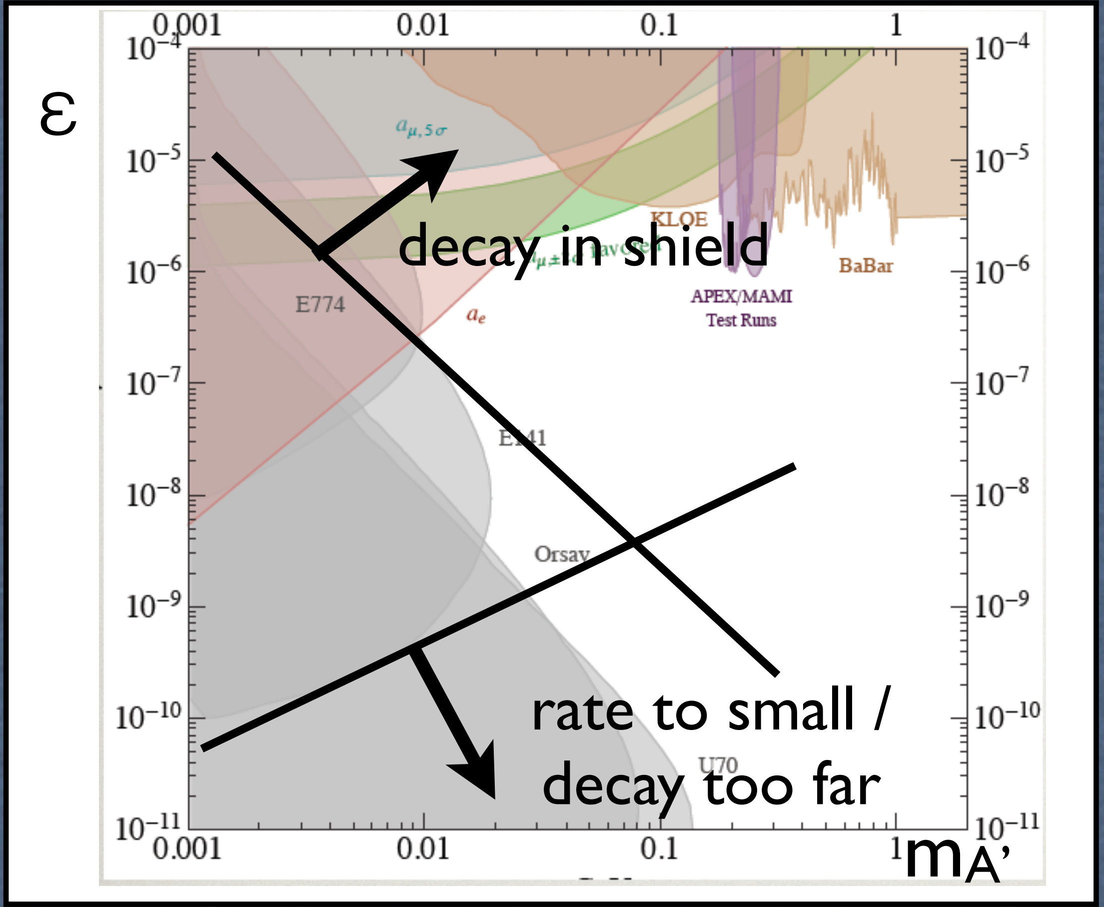
✳ A' emitted forward at small angle

✳ A' decays before the detector

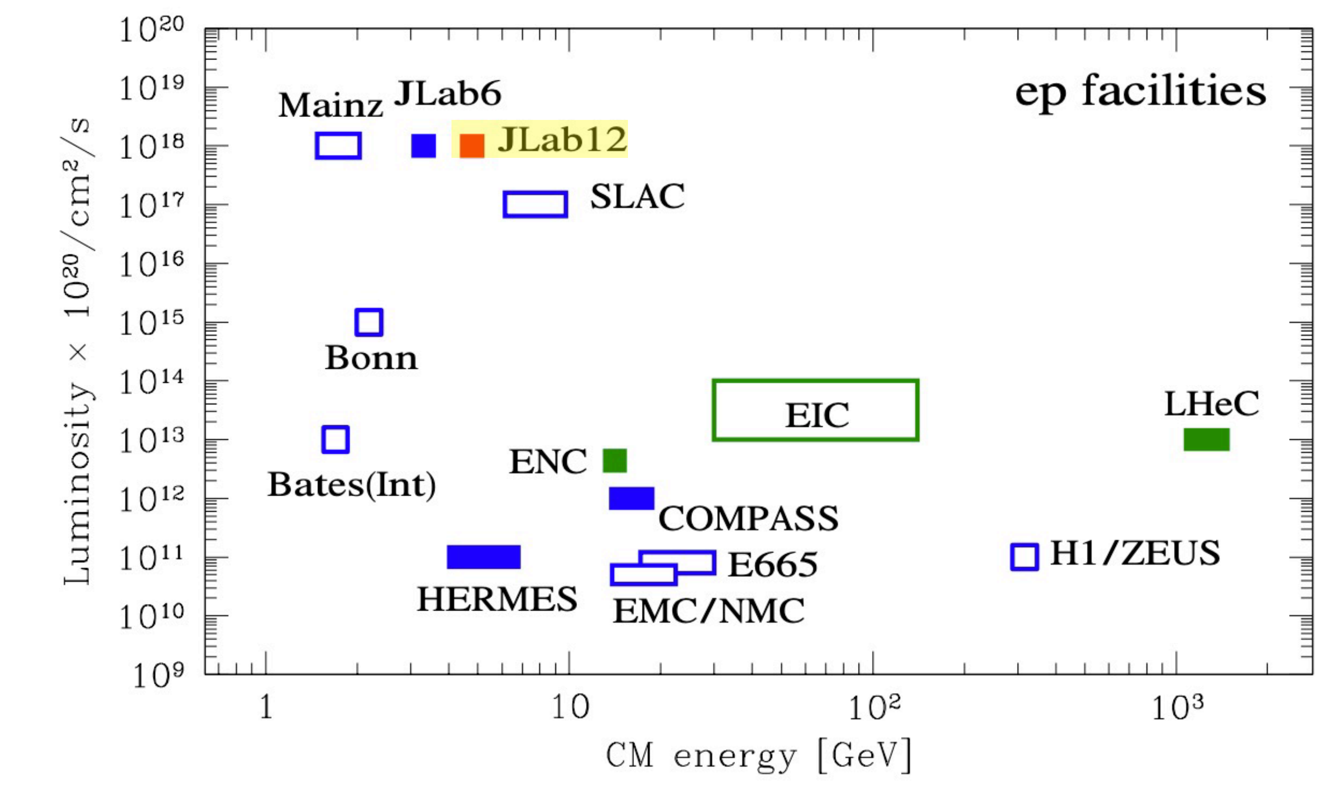


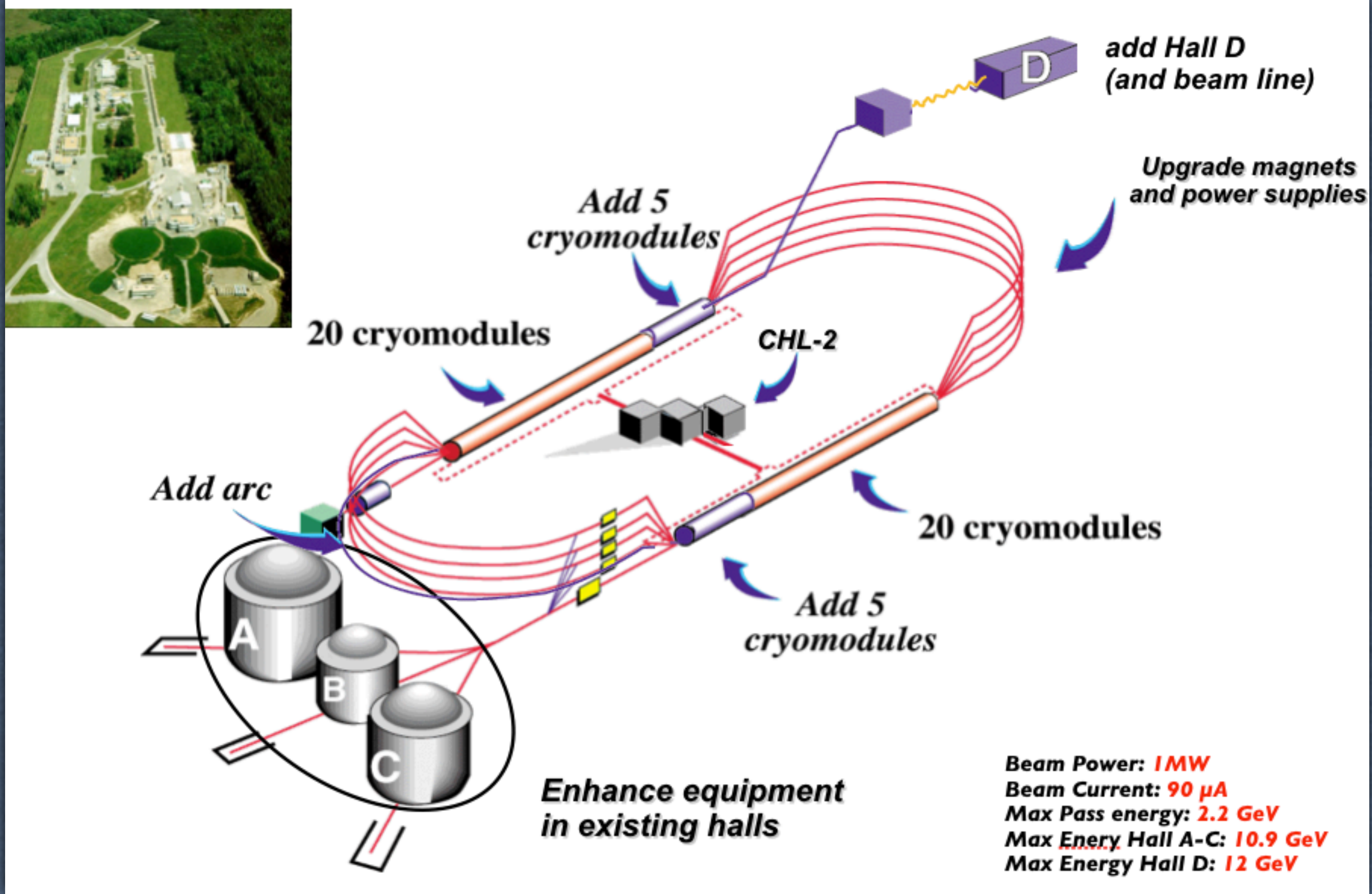
$$\gamma c\tau \approx 1 \text{ mm} \, (\gamma/10) \, (10^{-8}\alpha/\alpha') \times (100 \text{ MeV}/m_{A'})$$





Jefferson Lab
The intensity frontier





✳ Primary Beam: Electrons

✳ Beam Energy: 12 GeV

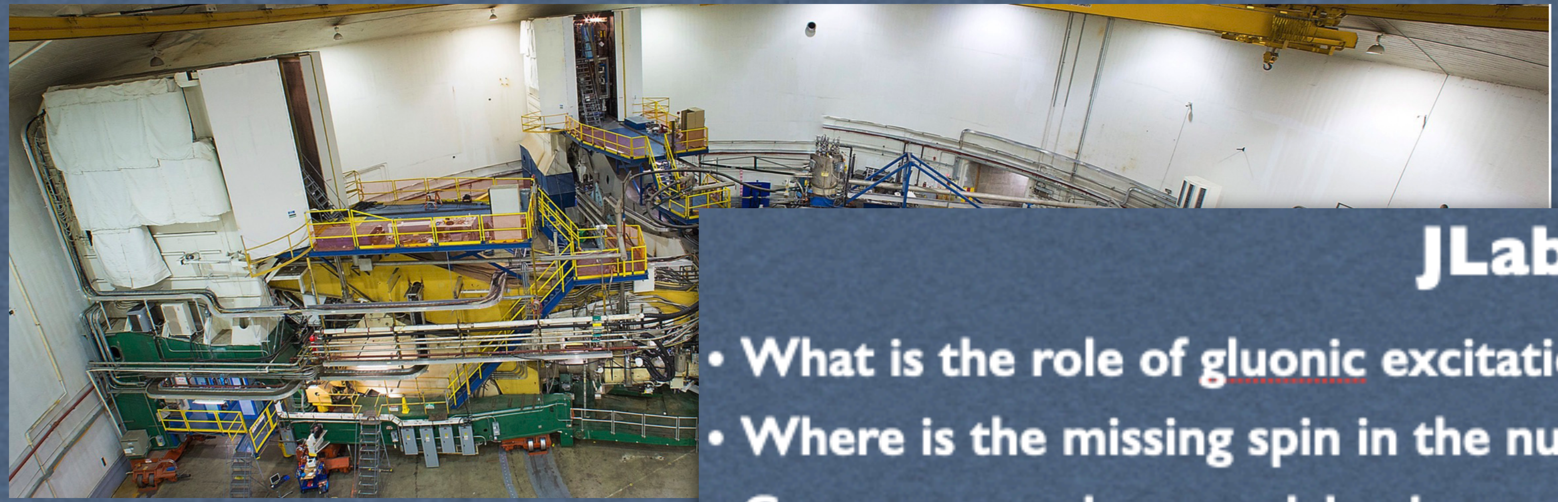
- $10 > \lambda > 0.1$ fm
- nucleon → quark transition
- baryon and meson excited states

✳ 100% Duty Factor (cw) Beam

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

✳ Polarization

- spin degrees of freedom
- weak neutral currents

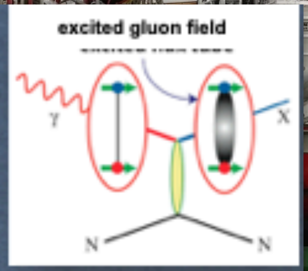


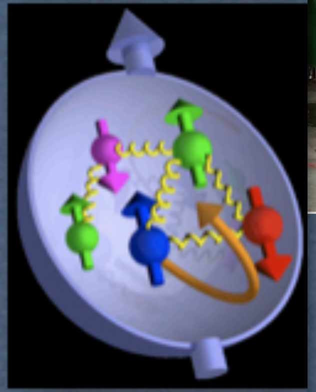
Hall A

Hall C

JLab Scientific mission

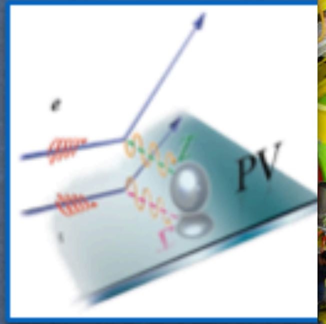
- What is the role of gluonic excitations in the spectroscopy of light mesons?
- Where is the missing spin in the nucleon? Role of orbital angular momentum?
- Can we reveal a novel landscape of nucleon substructure through 3D imaging at the femtometer scale?
- What is the relation between short-range 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?





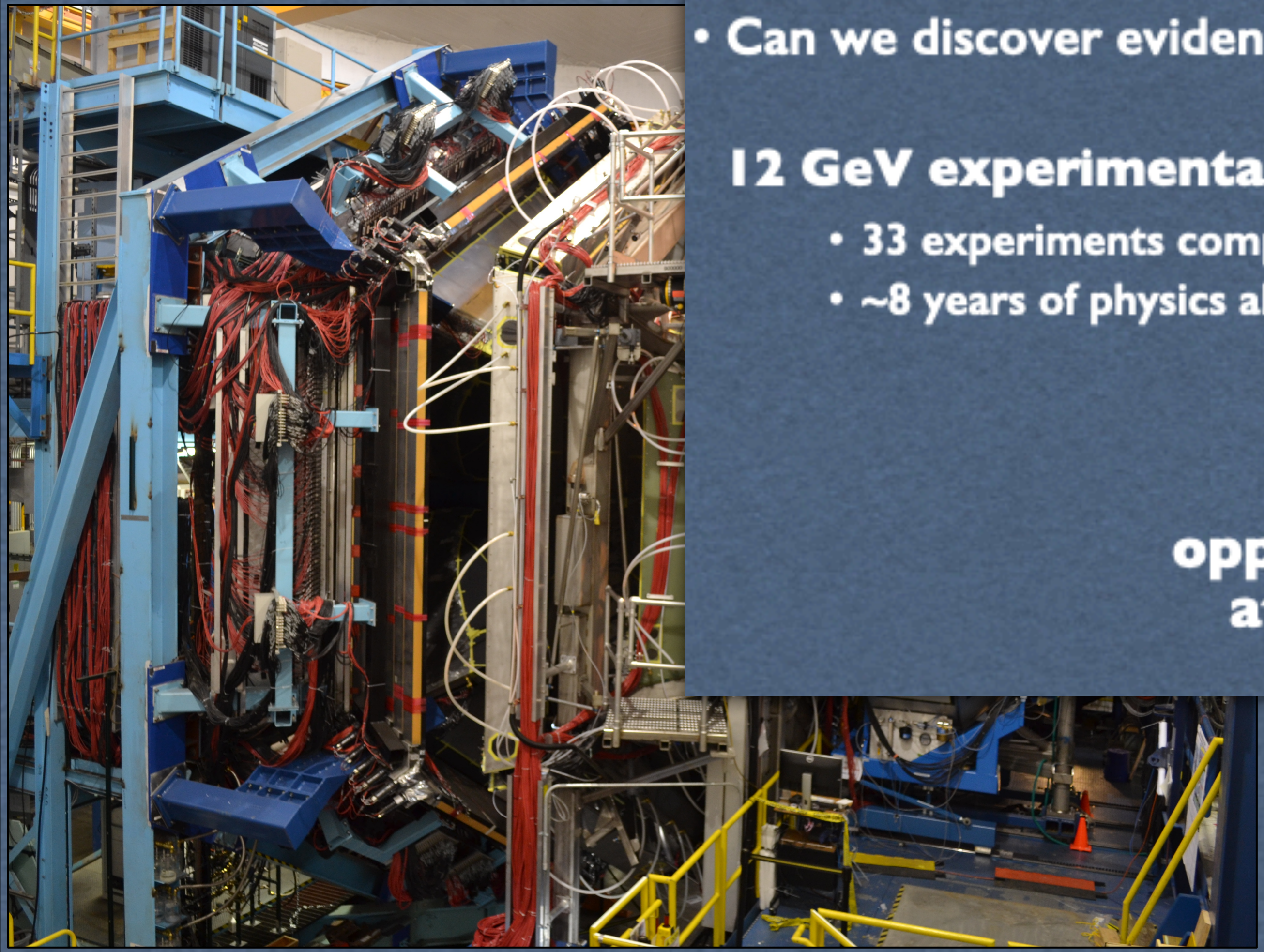
12 GeV experimental program is in full swing

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



Future opportunities at CEBAF

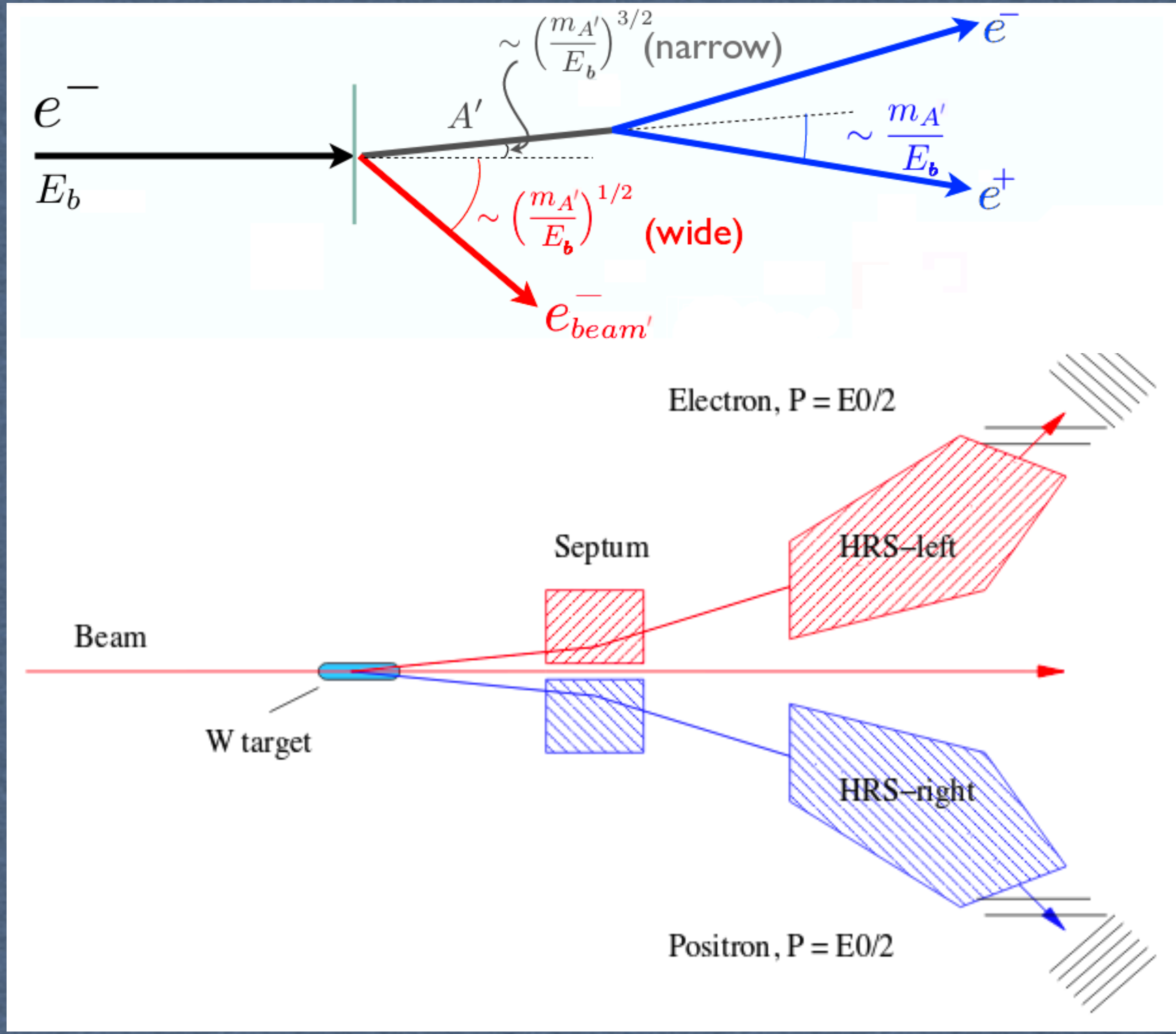
- Higher Energy
- Higher luminosity
- Positron beam

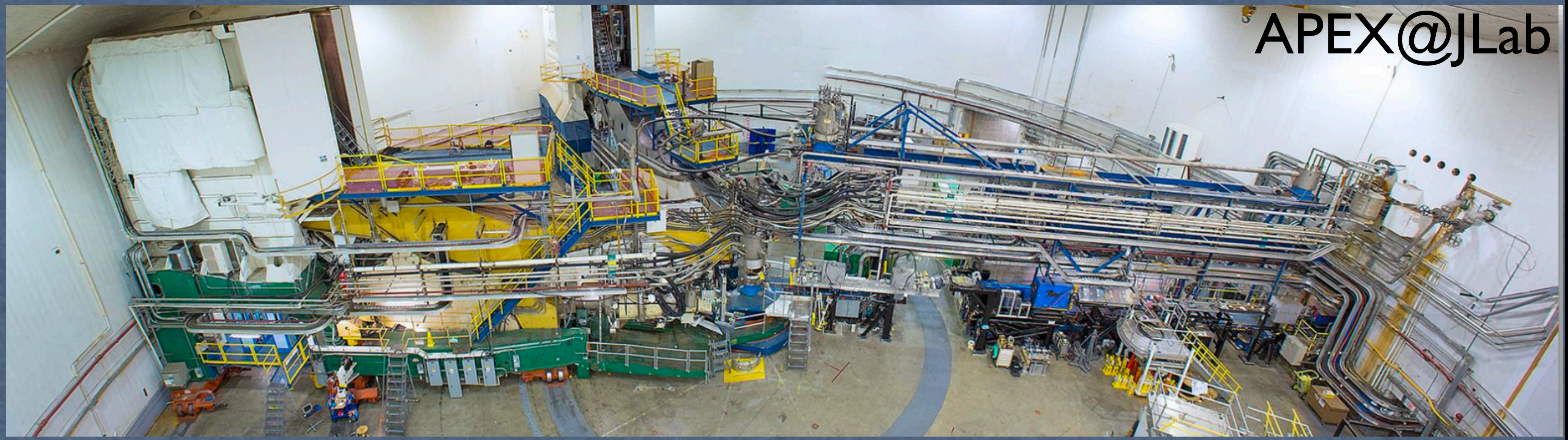


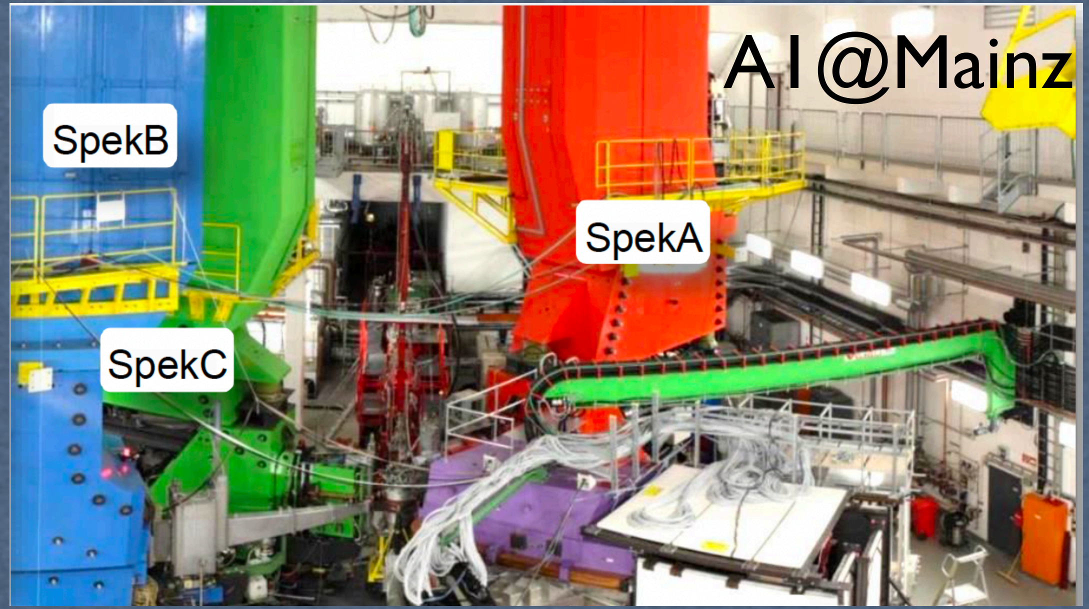
Hall B

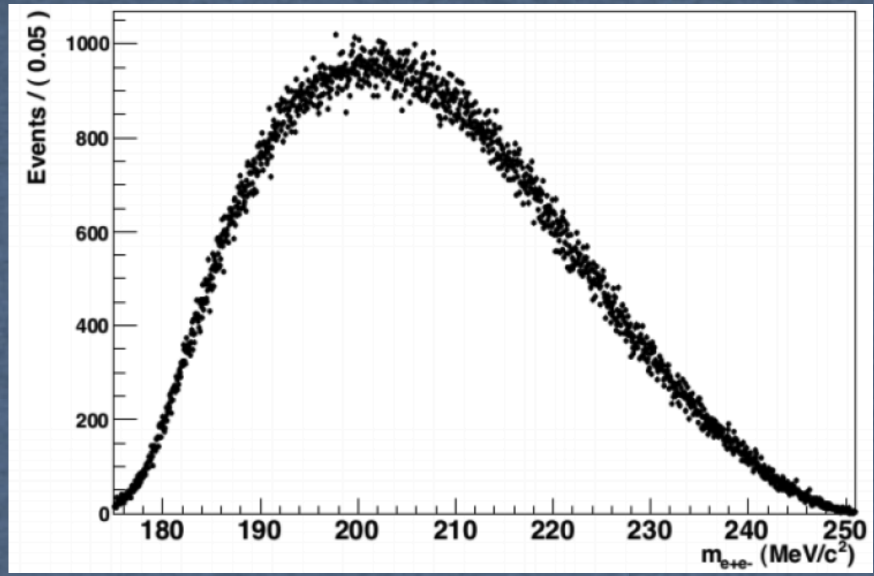
Hall D

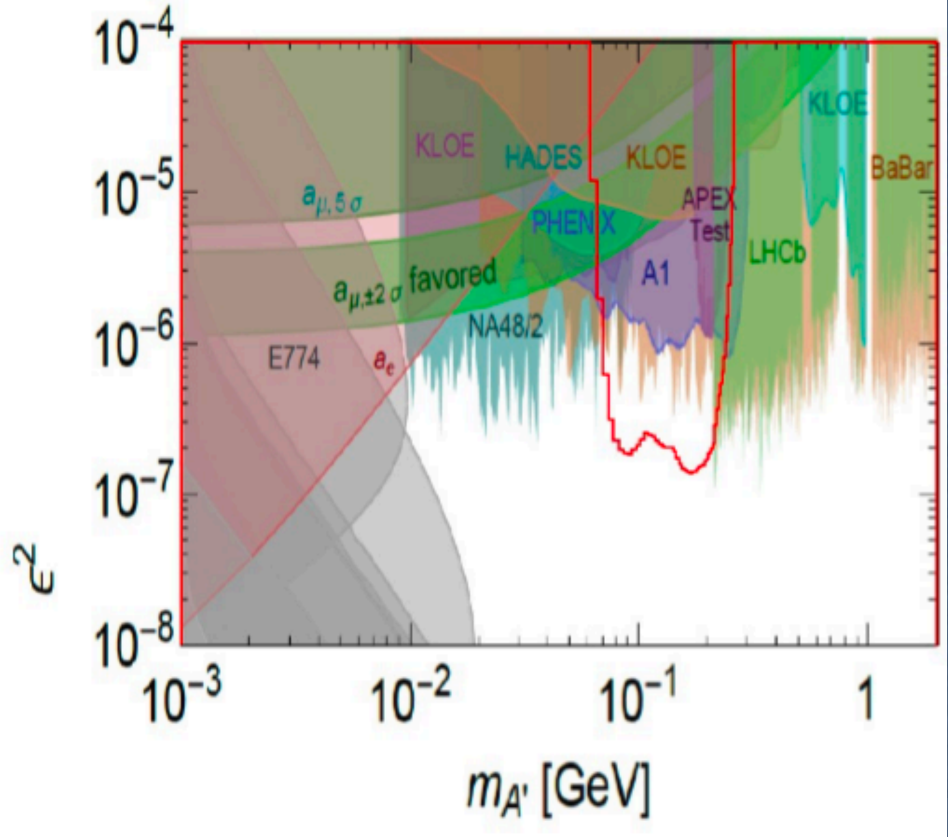
APEX@JLab and A1@Mainz





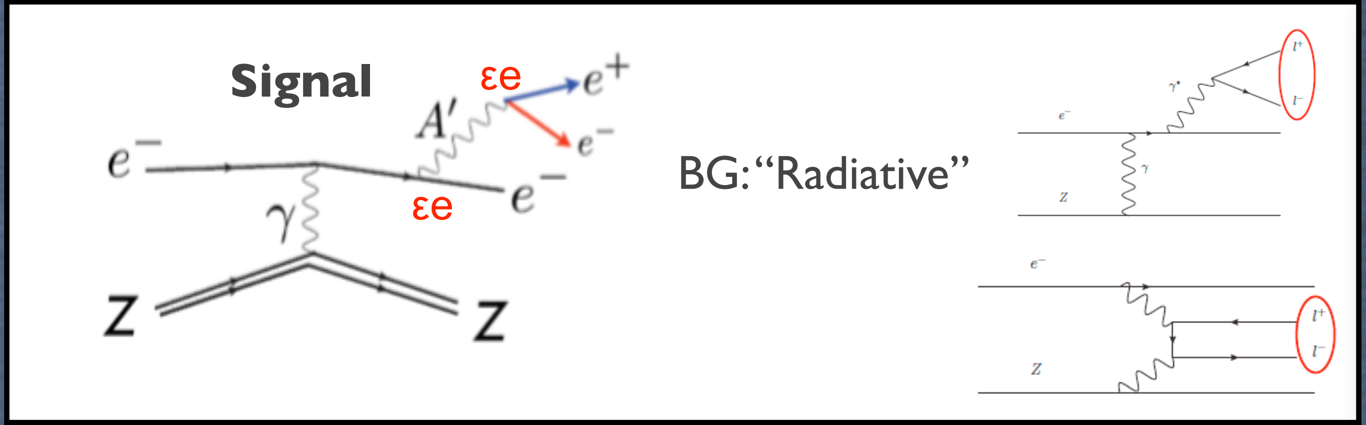


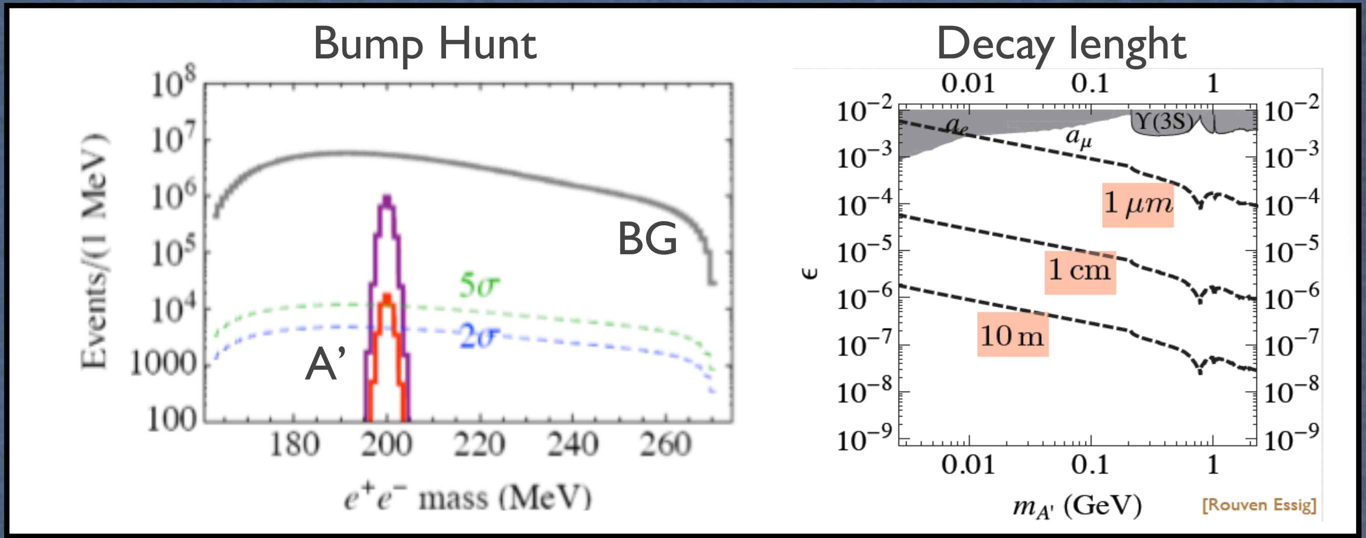


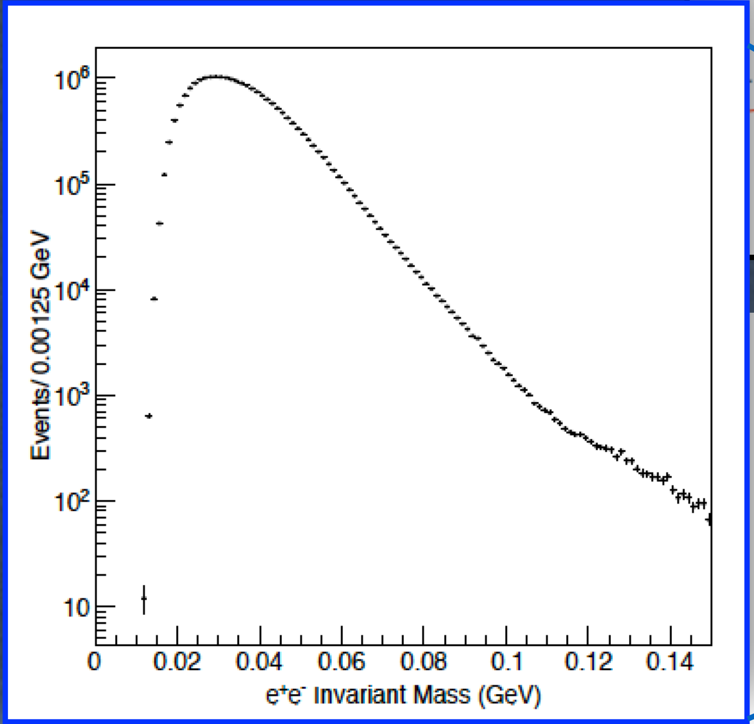


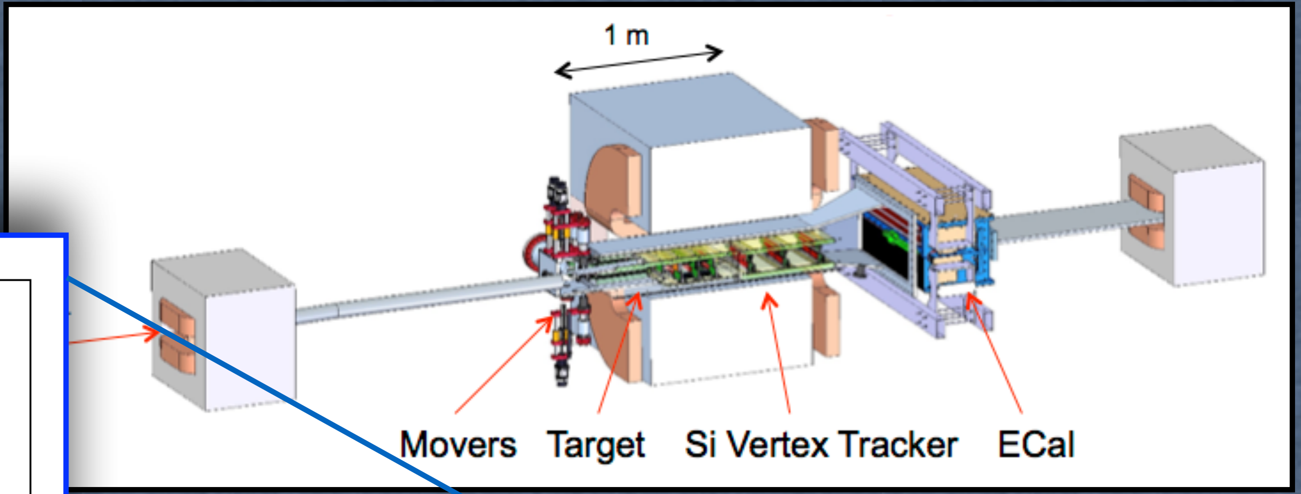
- Dark photon searched as a narrow resonance in e+e- mass over a smooth QED background
- Two High Resolution Spectrometers (HRSs) in coincidence to measure events with an e- in one arm and e+ in the other

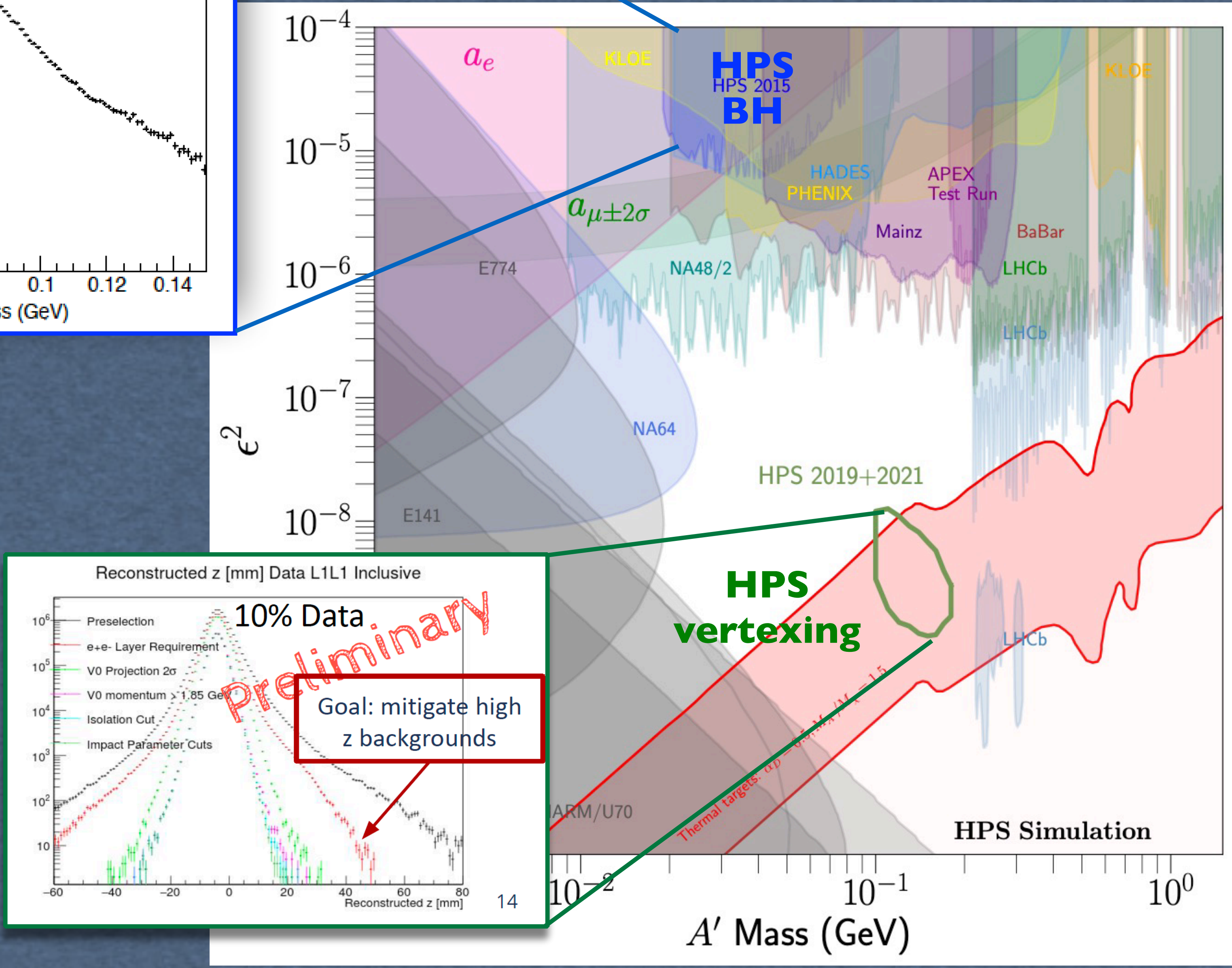
Heavy Photon Search @ JLab
visible decay











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

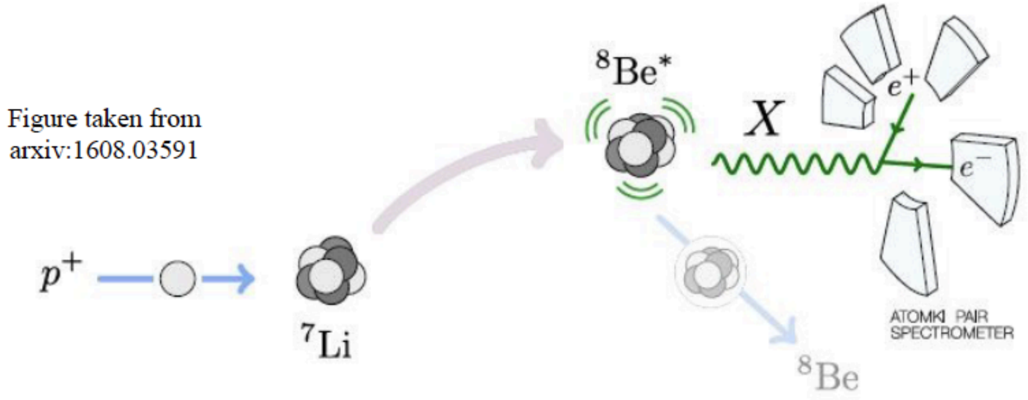
➥ good spacial resolution: σ_{vertex}~1mm

Heavy photon signatures in HPS

BH + Vertexing = enhanced experimental reach

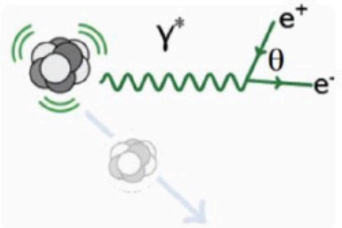
X17 The Atomki anomaly

Figure taken from arxiv:1608.03591



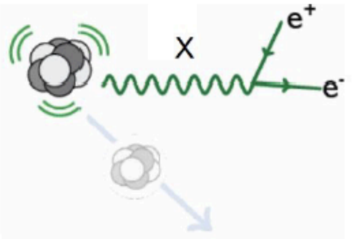
Energy released in nuclear transitions is $O(1-10)$ MeV

QED processes:



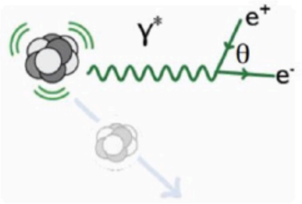
~ second order in QED coupling

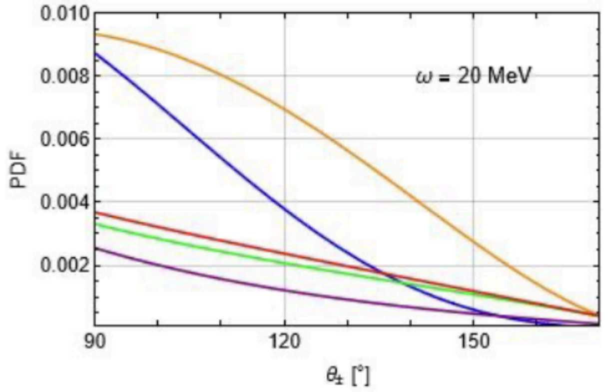
NP processes:



~ first order in NP coupling

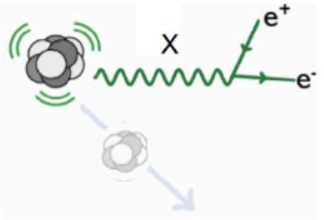
QED:

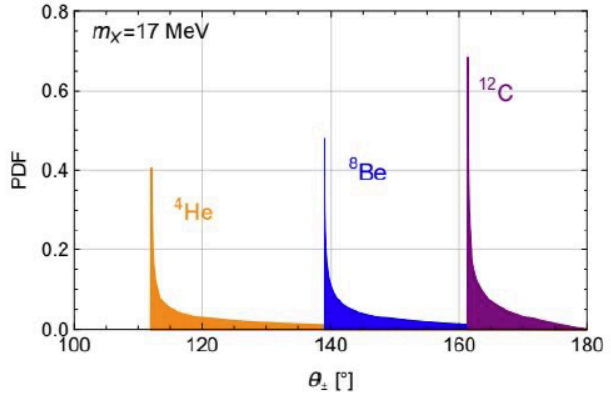




At large angles, QED predicts that the angular correlation of lepton pairs drops rapidly.

NP:



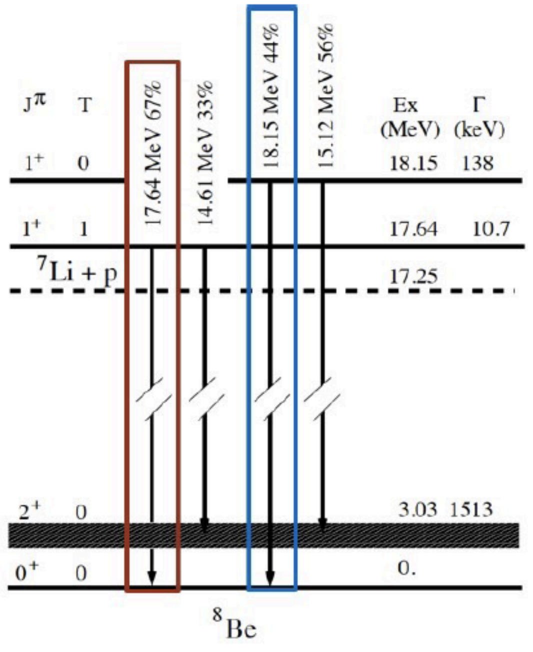


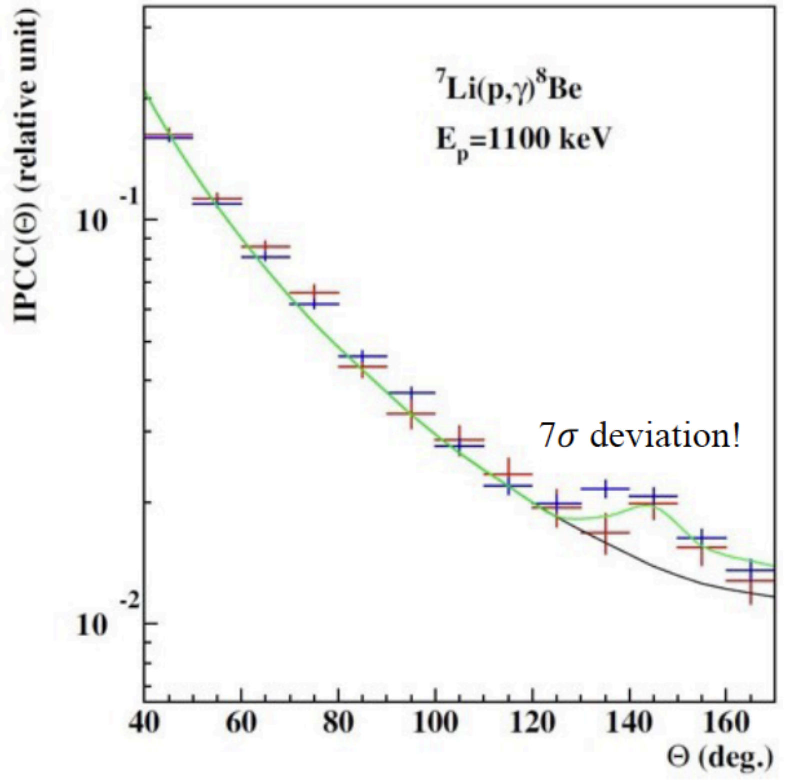
Bump-like distribution peaked at large angles!

X17 The Atomki anomaly

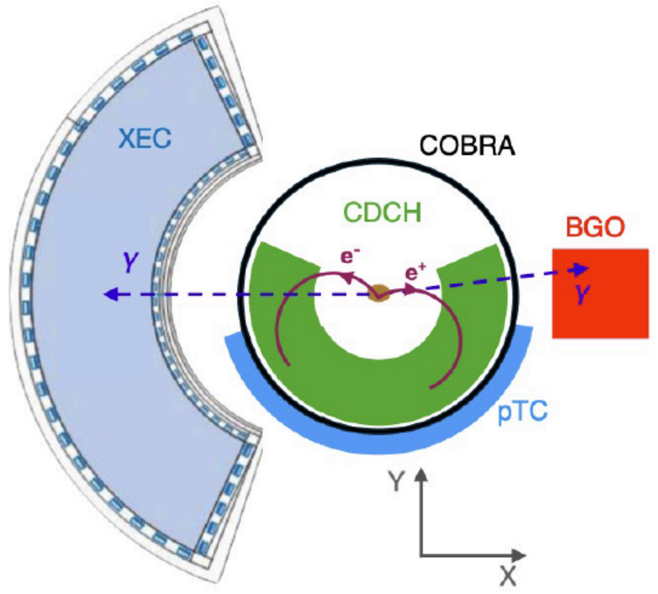
- In 2016 and 2018 the ATOMKI collaboration investigated the 18.15 MeV energy level of Beryllium8.
- They observed an anomalous peak of events in both the measurements.

Phys.Rev.Lett. 116 (2016) 4, 042501
J. Phys.: Conf. Ser. 1056 012028

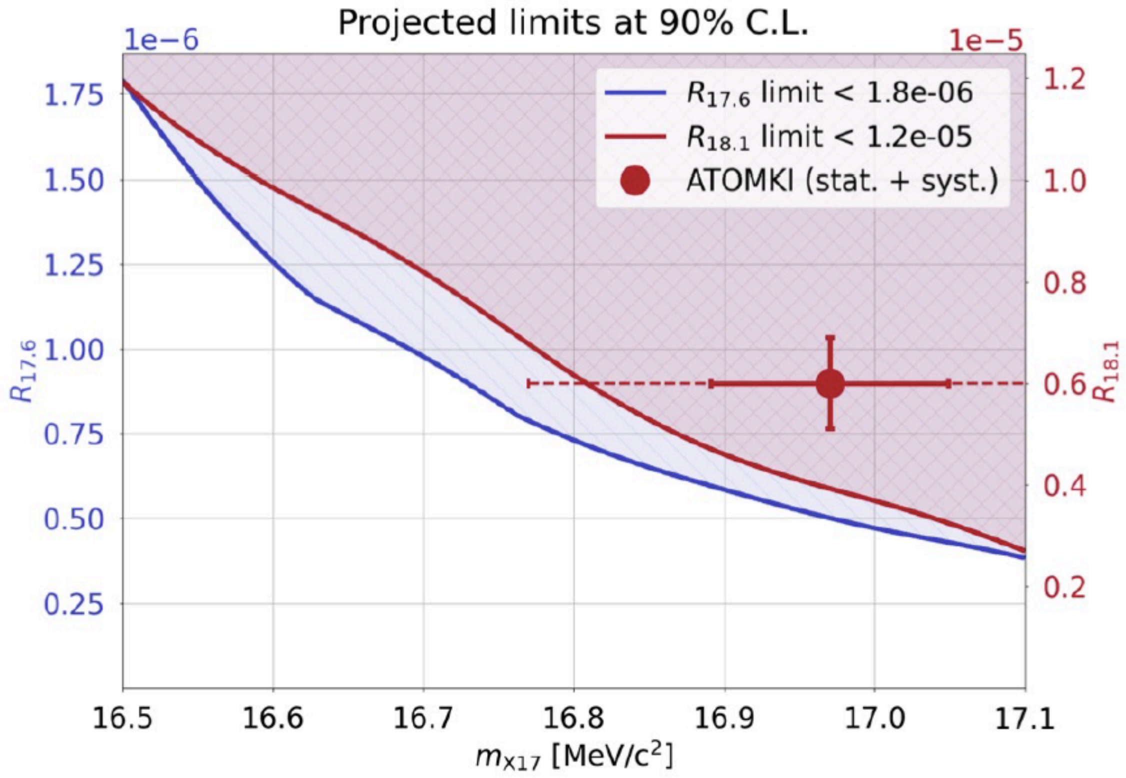




Unconfirmed by MEG-II



- In order to confirm the Atomki anomaly, MEG-II re-measured the Beryllium transitions at the PSI
- They took data during 2023 with energy beam at 1080 keV.
- Their results show no significant signal.
- They conclude that their measurement agrees with Atomki result with a *p*-value of 6% (1.5σ)



X17 search at JLab

- Search for the X17 in e+e- invariant mass
- Currently running at JLab

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, 2.5×10^{-4} r.l.
  density: 16.69 g/cm^3
  N(Ta) = $0.56\times10^{+19}$ 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 $0.7\times E_{beam}$];
- decay e^- and e^+ are in the $PbWO_4$ within energy: [0.03 – $0.8\times E_{beam}$]
- Target to PbWO4 distance L=7.5 m beam energy optimized for E_e = 2.2 GeV and 3.3 GeV

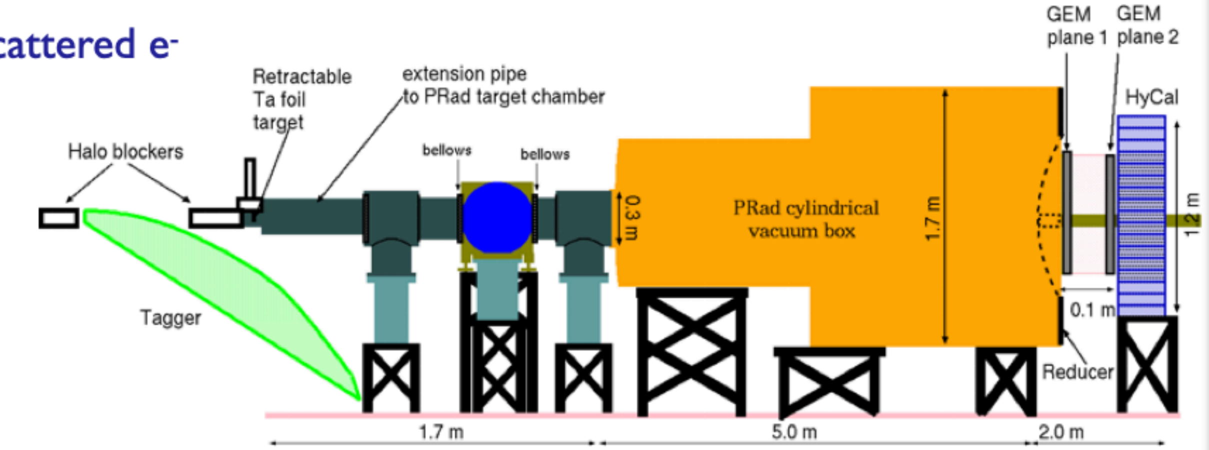
Beam time request

	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

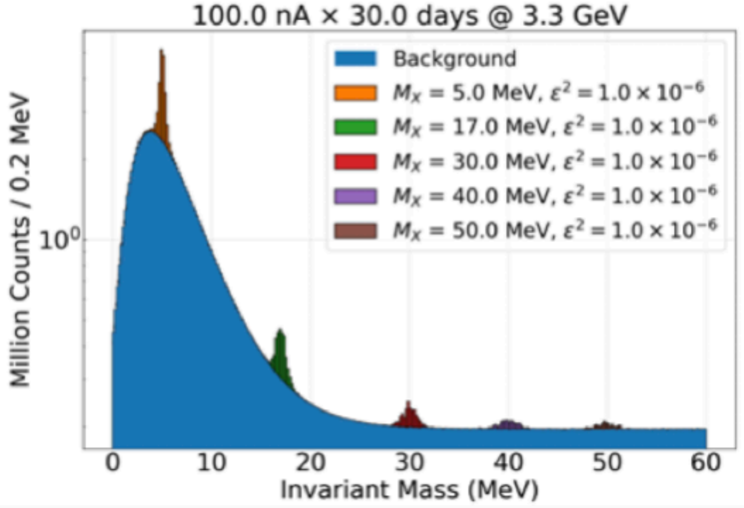
Search sensitivity

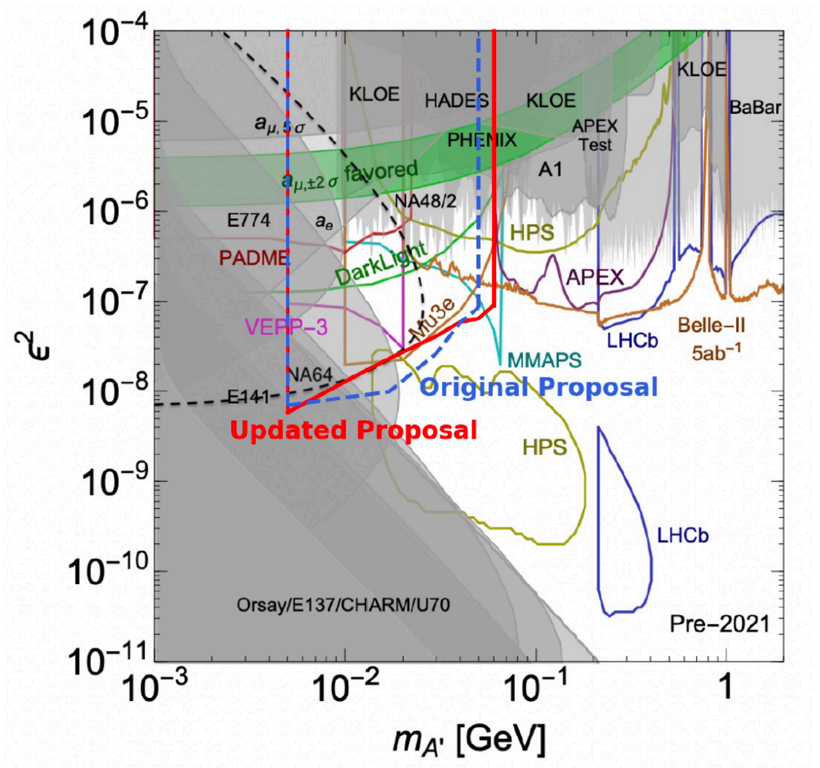
m_X MeV	σ_{m_X} MeV	Background Counts	Signal Counts (5.0 Significance)	Lowest ϵ^2	lowest ϵ^2
30 days of 3.3 GeV at 100 nA					combined with signal from 20 days at 2.2 GeV
5.0	0.263	22.02M	23.48k	6.86E-09	5.94E-09
17.0	0.467	3.60M	9.50k	9.83E-09	8.51E-09
30.0	0.692	3.06M	8.76k	2.60E-08	2.25E-08
40.0	0.938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



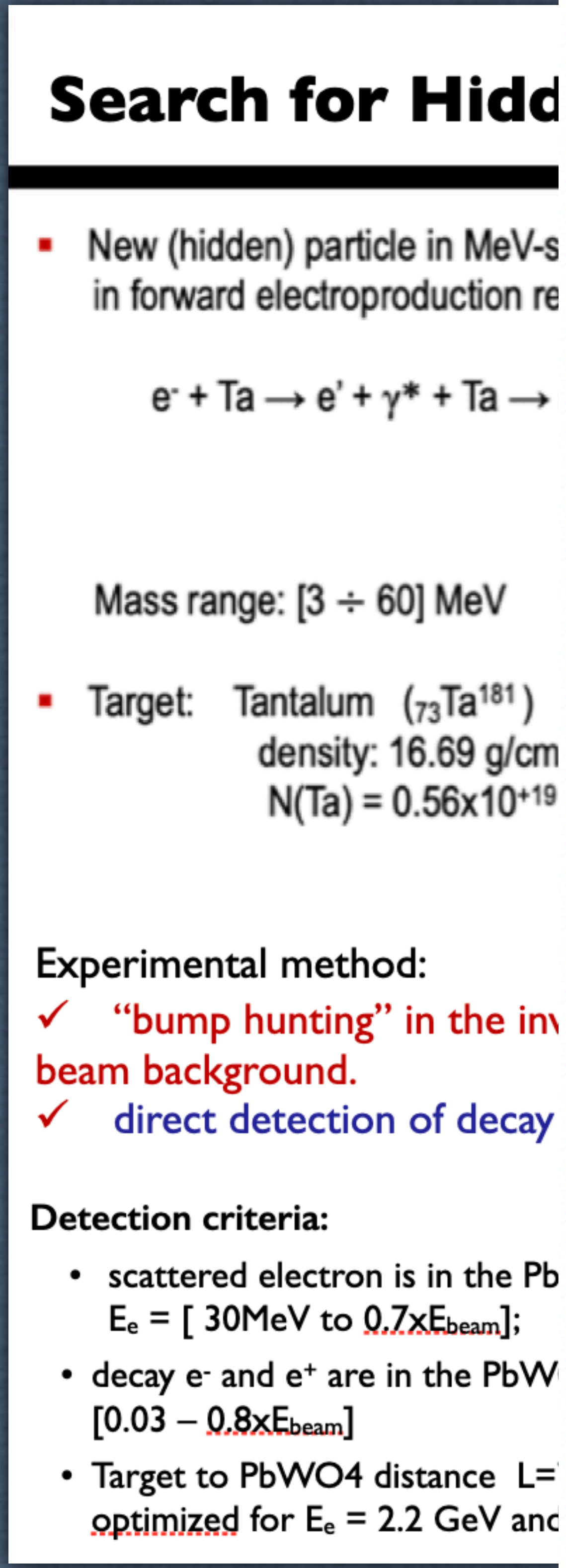
Sensitivity Example for $\epsilon^2 = 10^{-6}$





X17 search at JLab

- Search for the X17 in e+e- invariant mass
- Currently running at JLab



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) = $0.56\times10^{+19}$

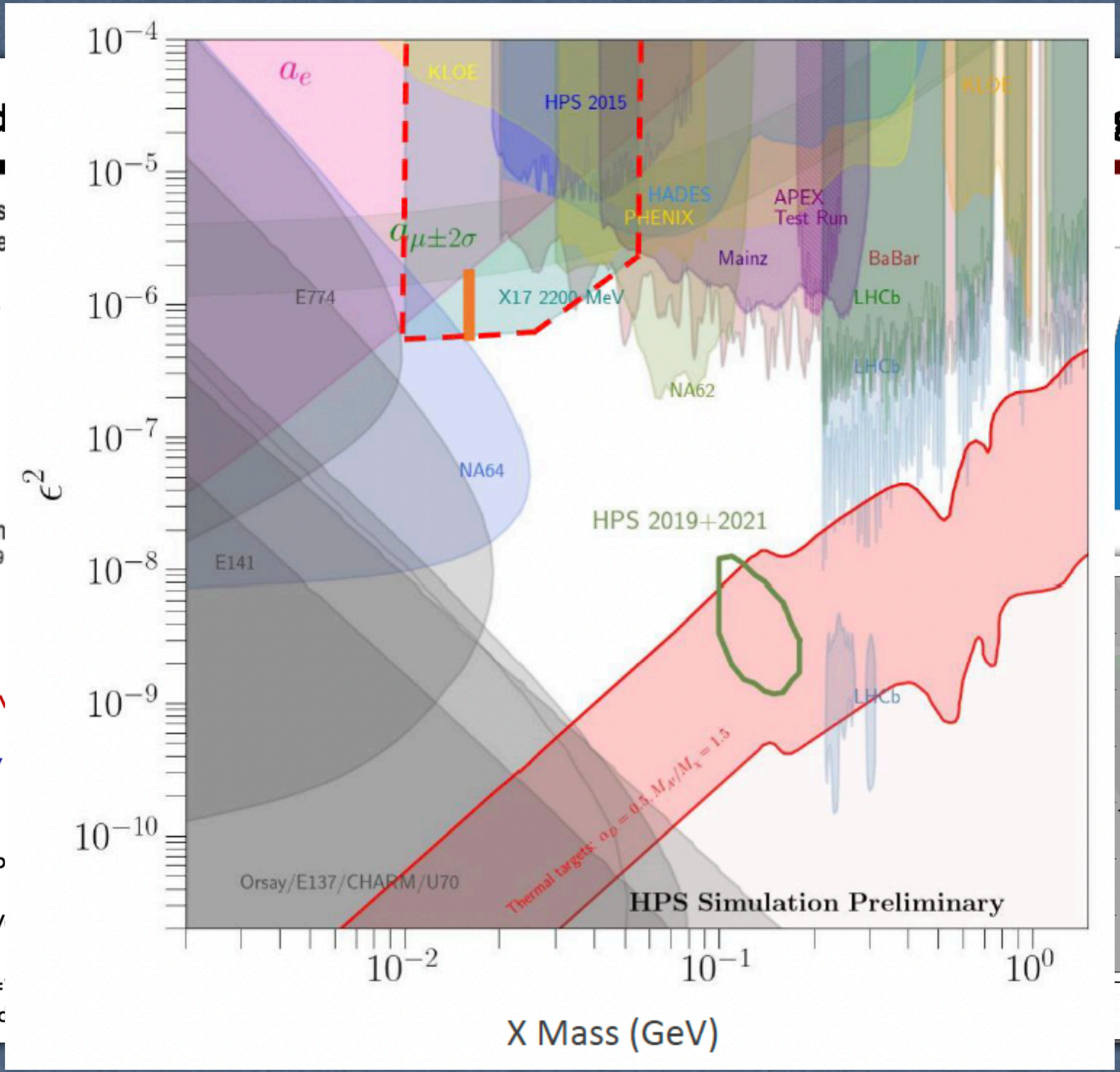
Experimental method:

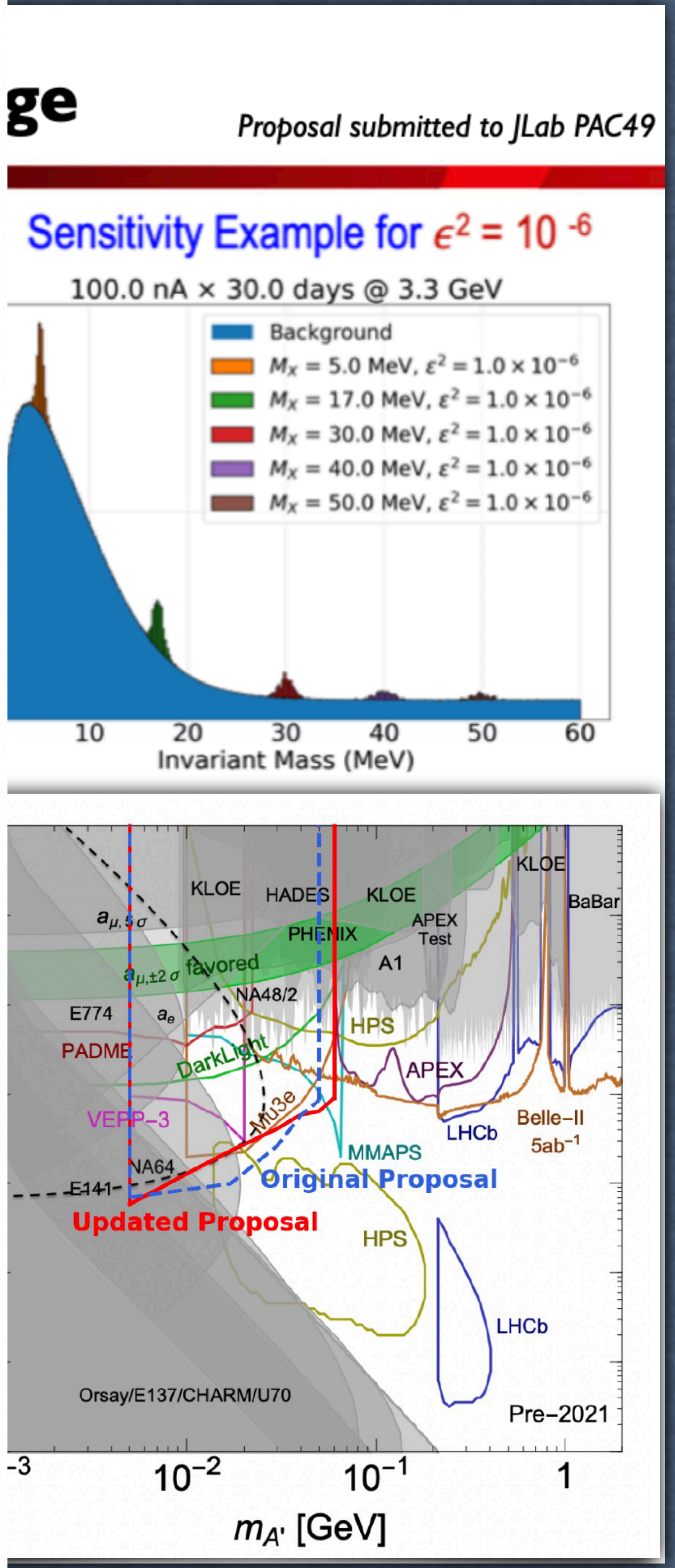
✓ "bump hunting" in the inv beam background.

✓ direct detection of decay

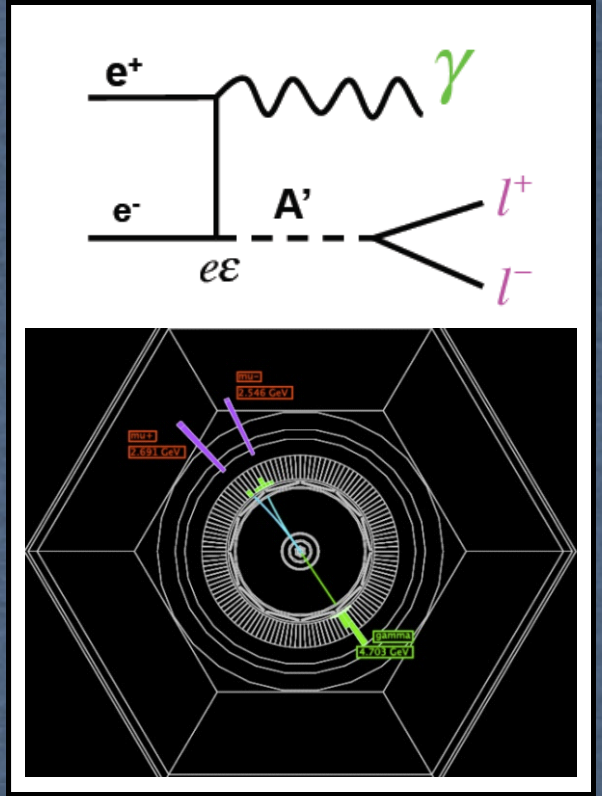
Detection criteria:

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

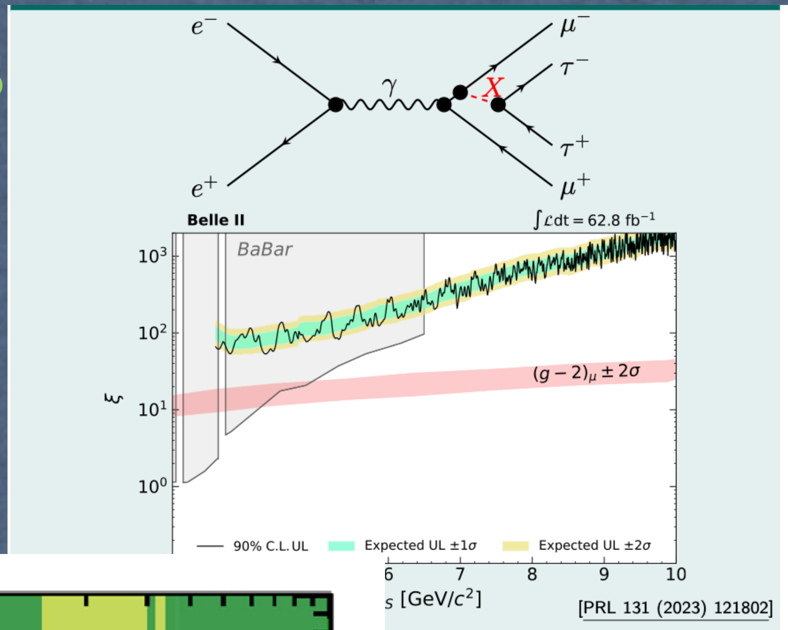




e+e- Colliders
- visible -

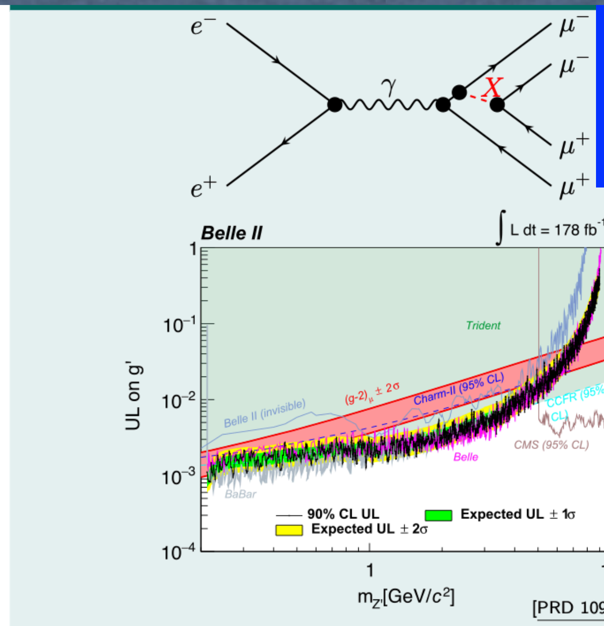


- 1gamma + 2 opposite leptons
- Di-lepton mass fit to a bg
- Mass resolution: 1.5 MeV - 8 MeV
- Int (L) = 514 fb^{-1}

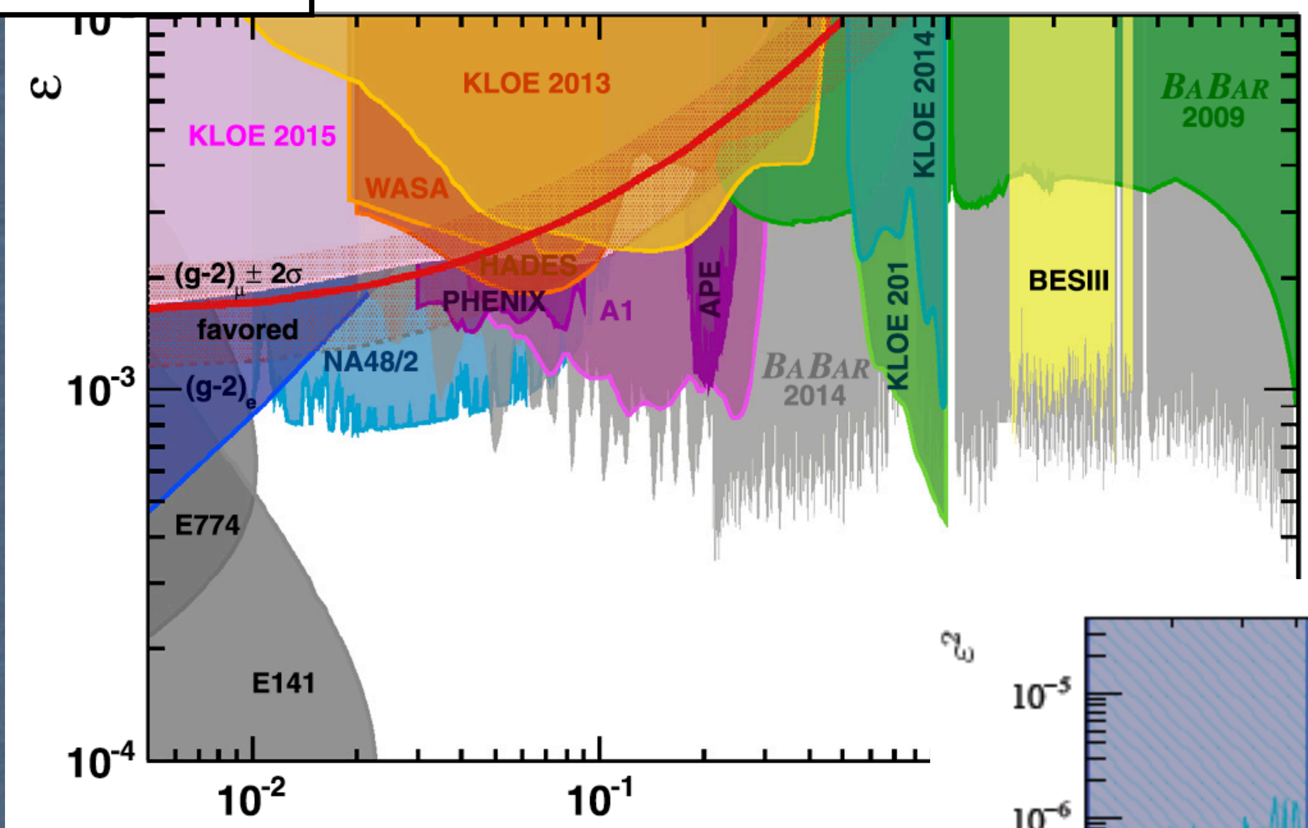


ed above 6.5 GeV/c^2

r ALPs



- Exclude Z' and muophilic scalar explanations for $(g-2)_\mu$ over wide mass range



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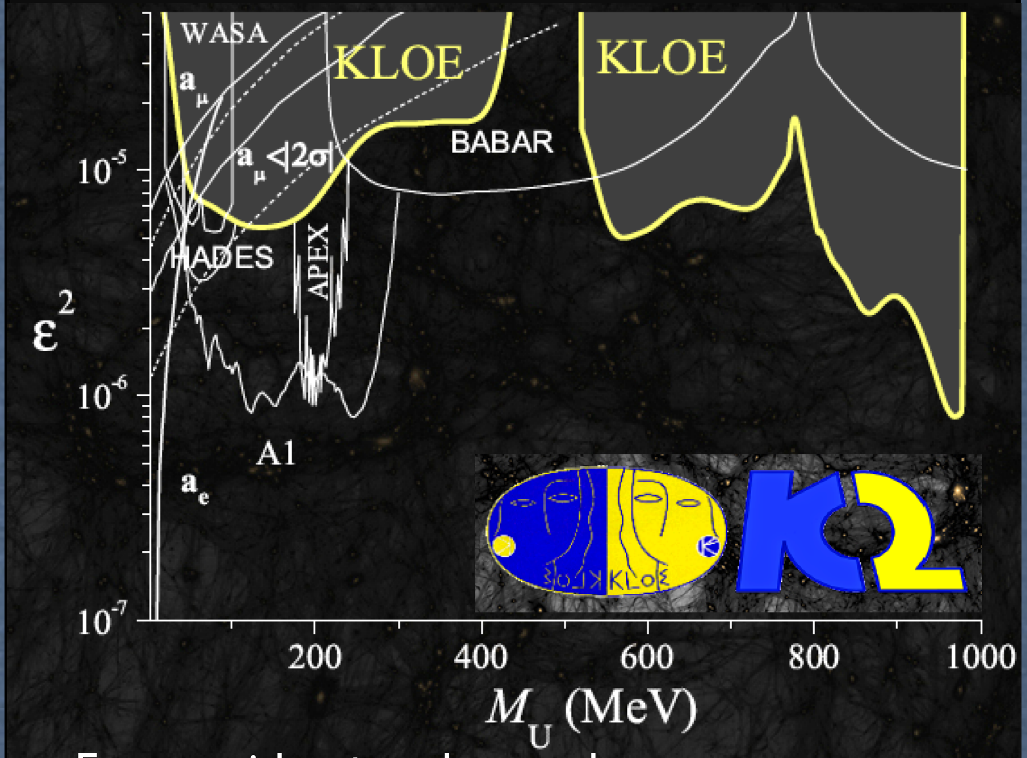
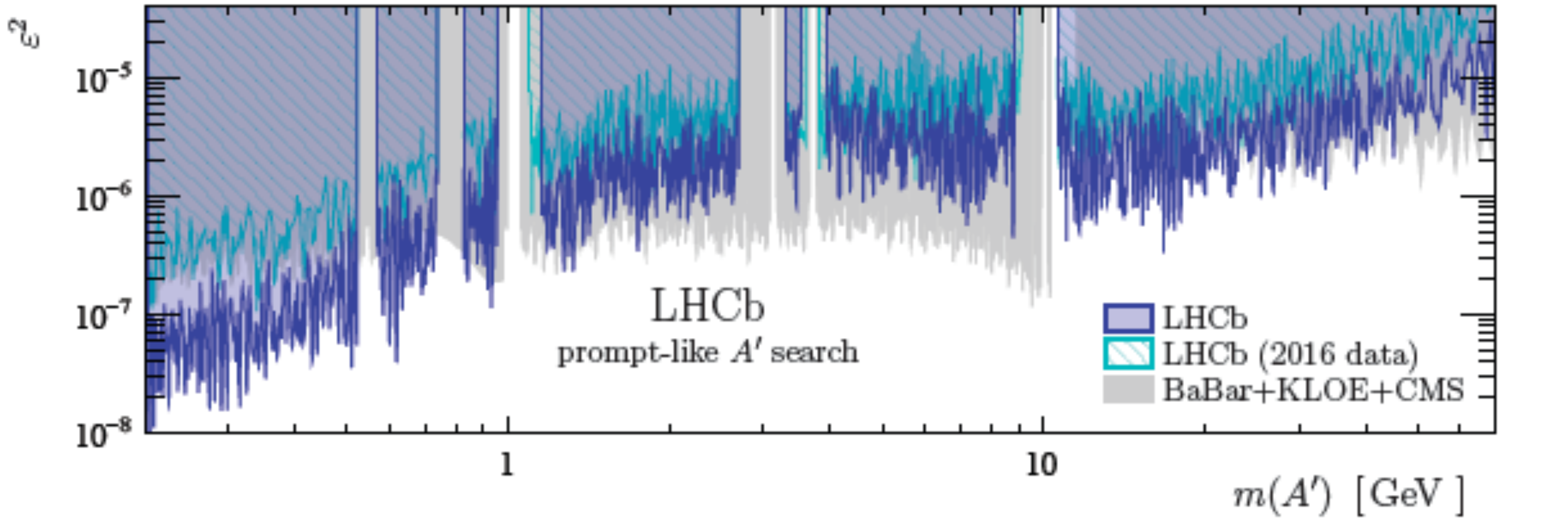
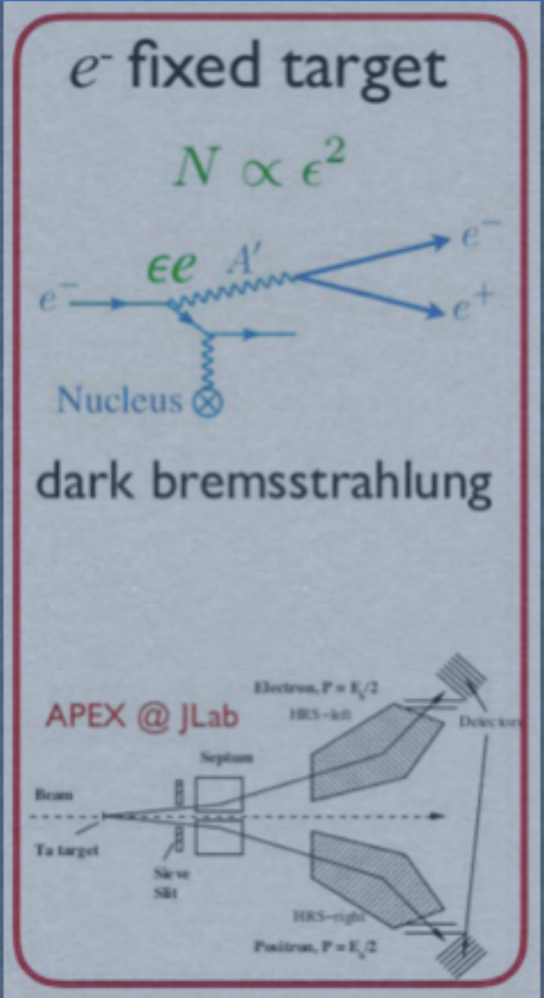
Phys. Lett. B 736 (2014) 459



- Events with μ+μ- detected
- L~ 240 pb^{-1}



A' visible decay at accelerators



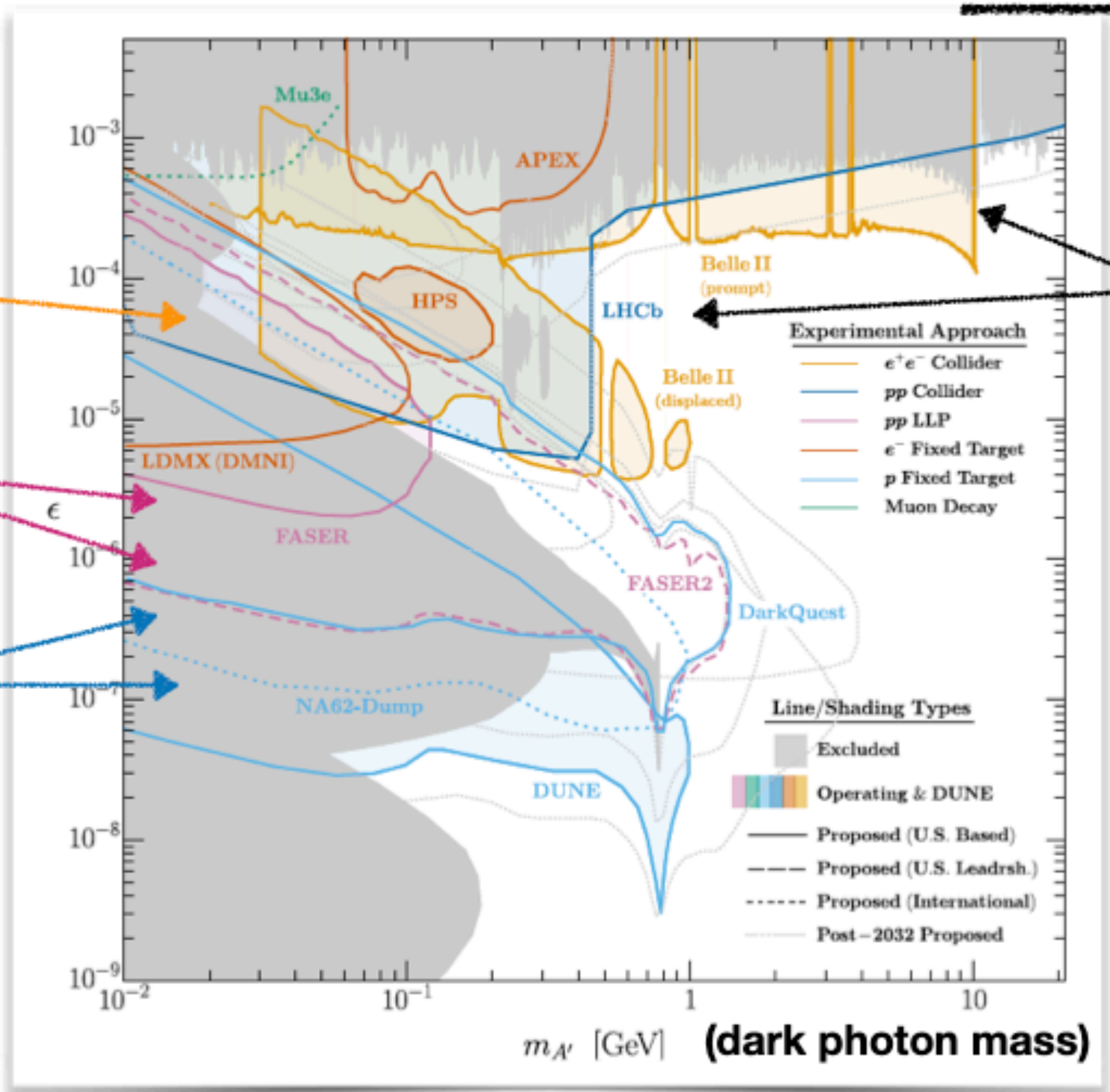
Fixed targ…
e N →N …
→ JLAB…

$\epsilon B^{\mu\nu} A'_{\mu\nu}$

electron fixed target

forward detectors

proton beam-dump



energy frontier

Colliders

Batell et al., 2207.06905

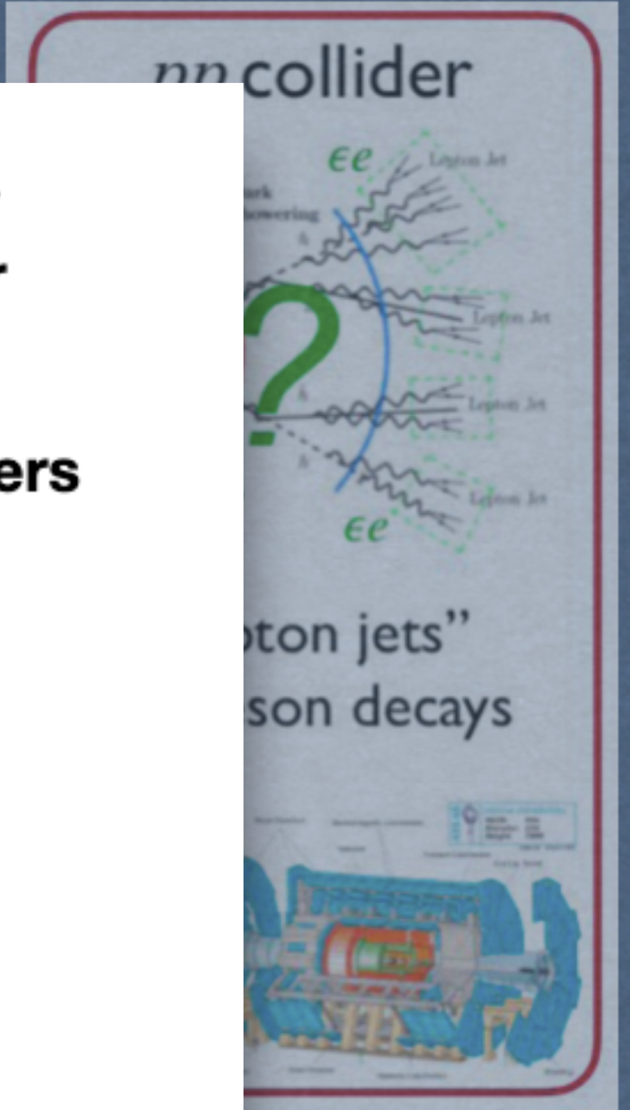
S.Gori

This entire parameter space predicts a **dark sector in thermal equilibrium** with the SM

2023

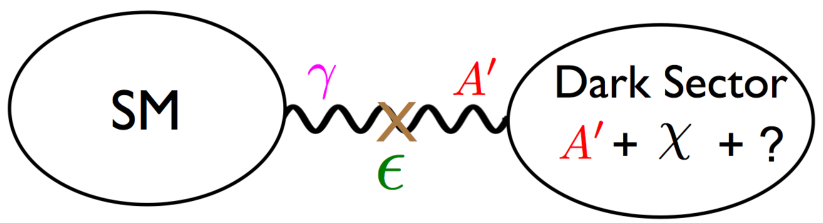
ArXiv:2305.01715 :Feebly Interacting Particles: FIPs 2022 workshop report

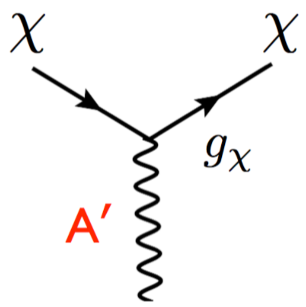
Fixed target:
p N →N γ'→ p Lepton Lepton+…
→ FERMILAB, SERPUKH…

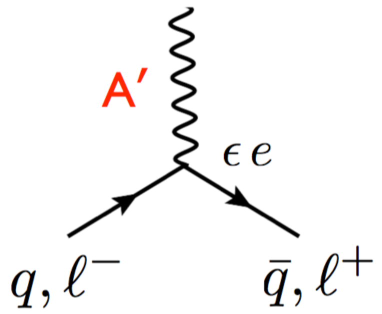


…R, BELLE-II, …EO

Dark forces and dark matter
(Light WIMPs - light mediators)



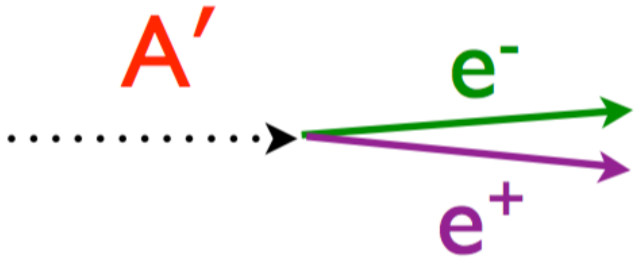




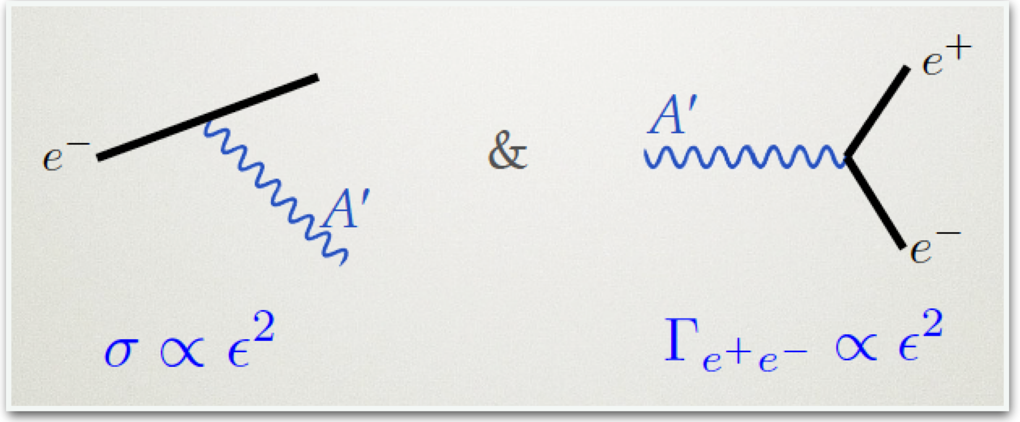
4 parameters: $m_\chi, m_{A'}, \epsilon, g_\chi$

$$m_\chi \sim m_{A'} \sim \text{MeV} - 5\ \text{GeV}$$

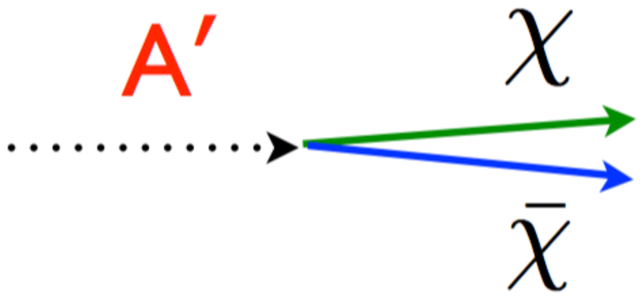
Visible



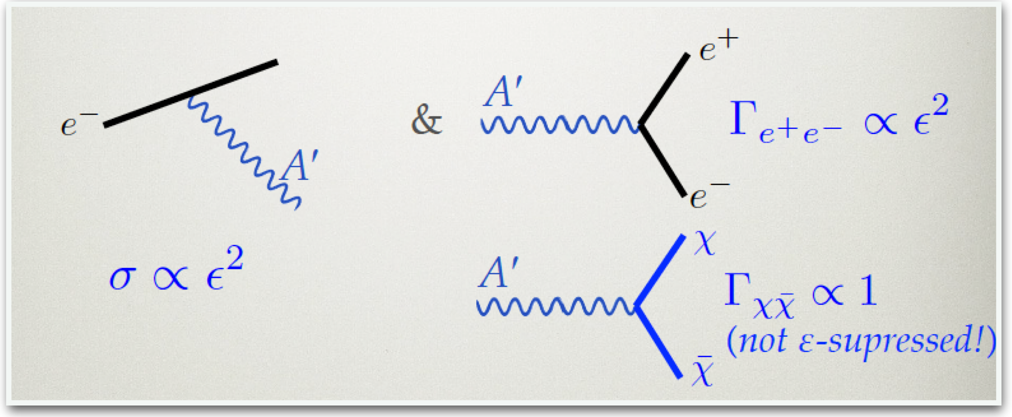
- *Minimal* decay
- Decay regulated by ε^2
- Independent on m_χ
- Requires $m_{A'} < 2m_\chi$



Invisible

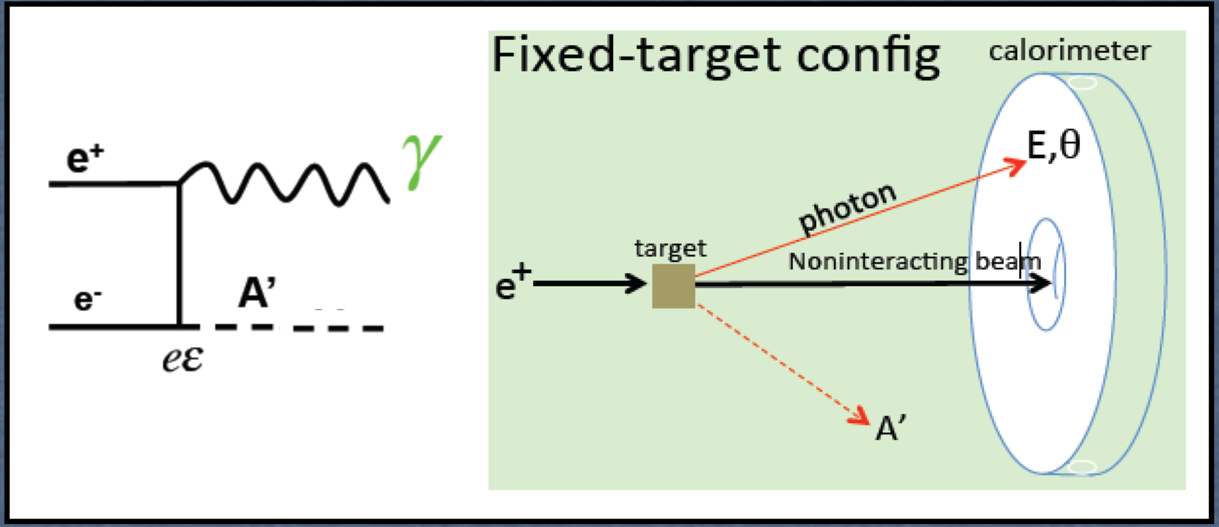


- $m_\chi < 2m_{A'}$
- i) stable and invisible
- ii) decays to SM particles
- Independent on ε



e^+ annihilation on fixed (thin) target

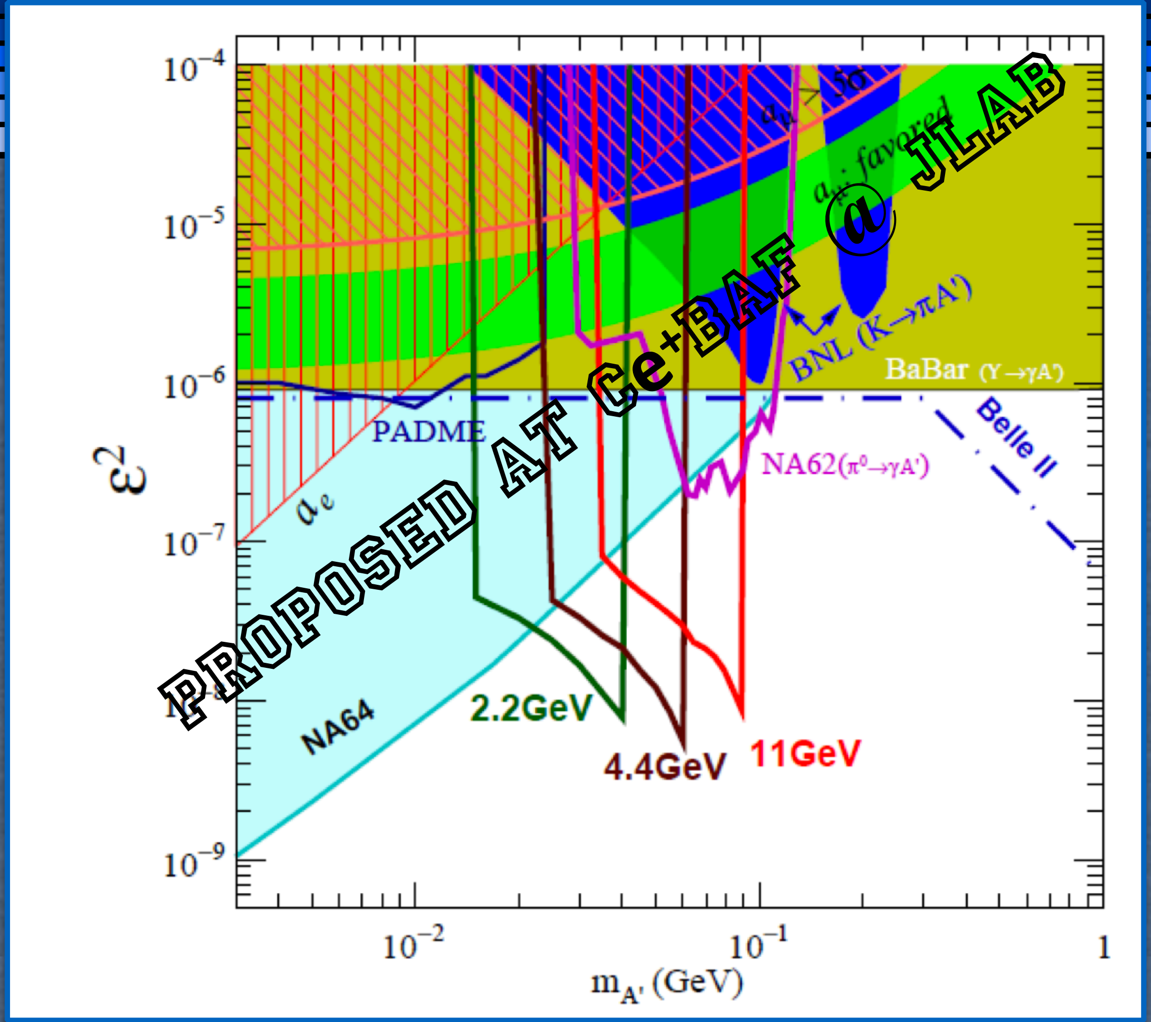
visible/invisible



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

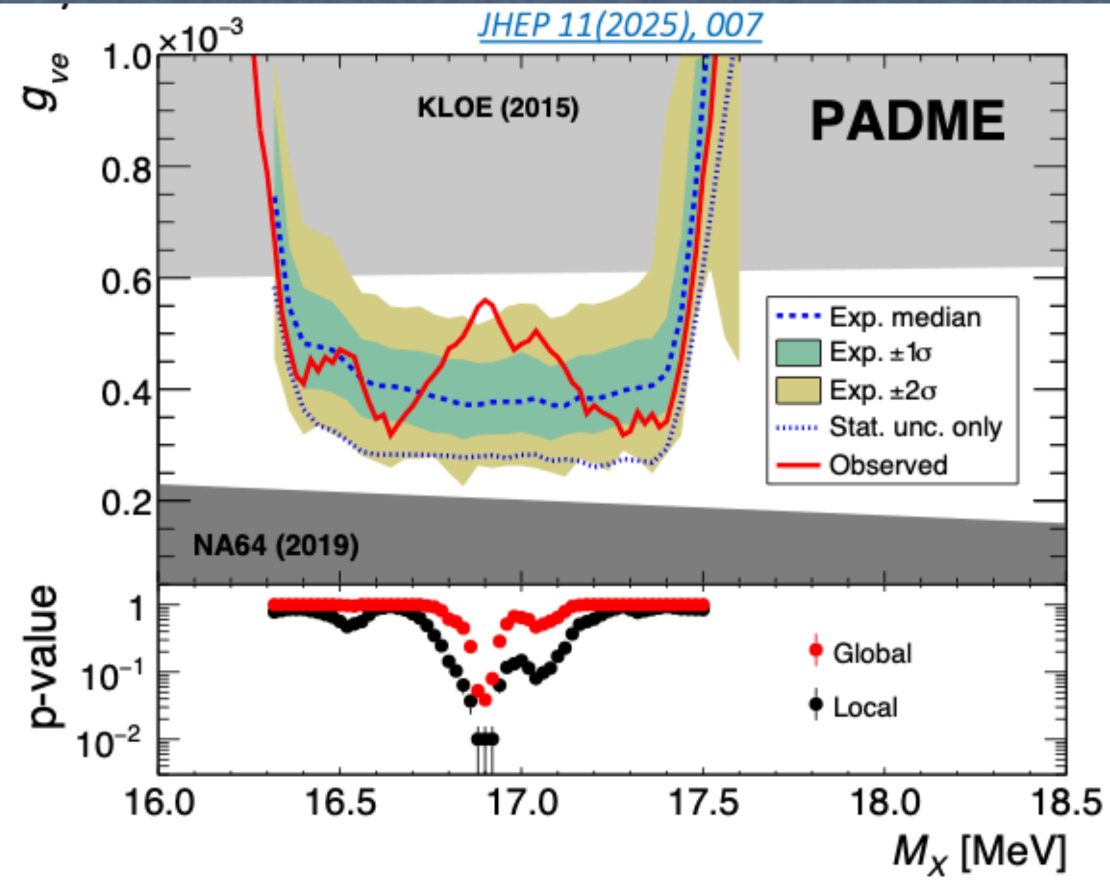


VEPP3
- E_{e+} = 500 MeV
- EOT ~ 10^{15} - 10^{16} year^{-1}

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}

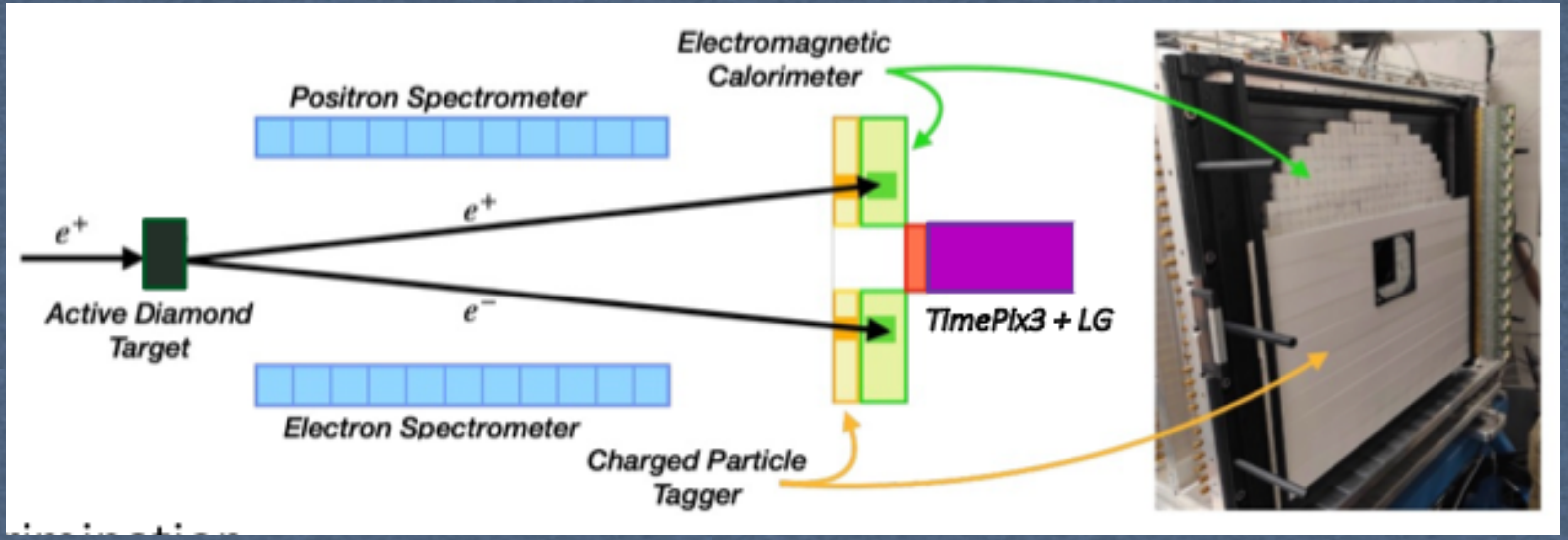
JLab (future)
- E_{e-} = 11 GeV
- EOT ~ 10^{18} - 10^{19} year^{-1}



PADME @ LNF

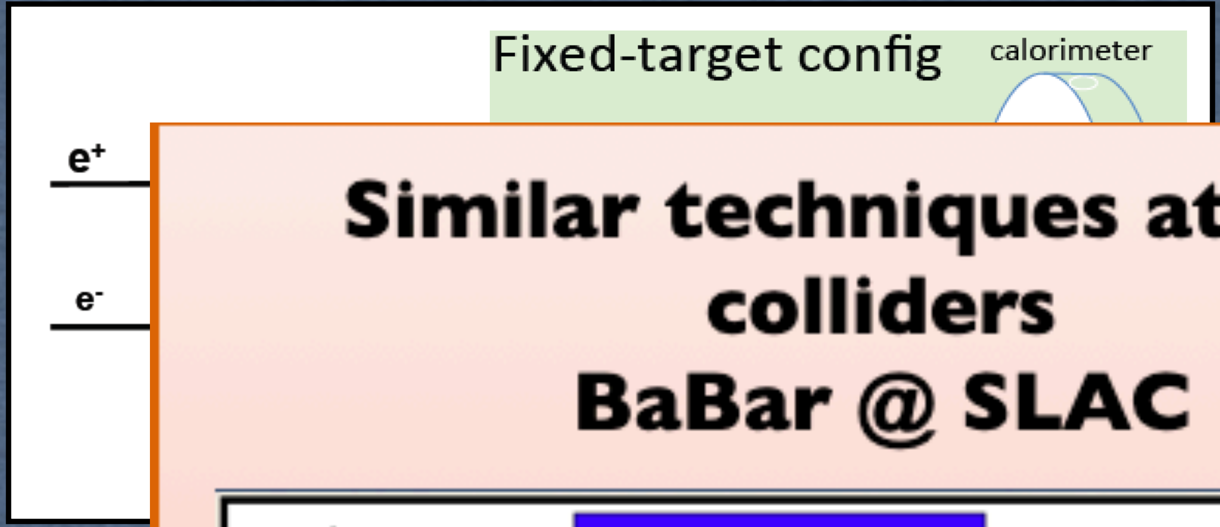
invisible/visible

- 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



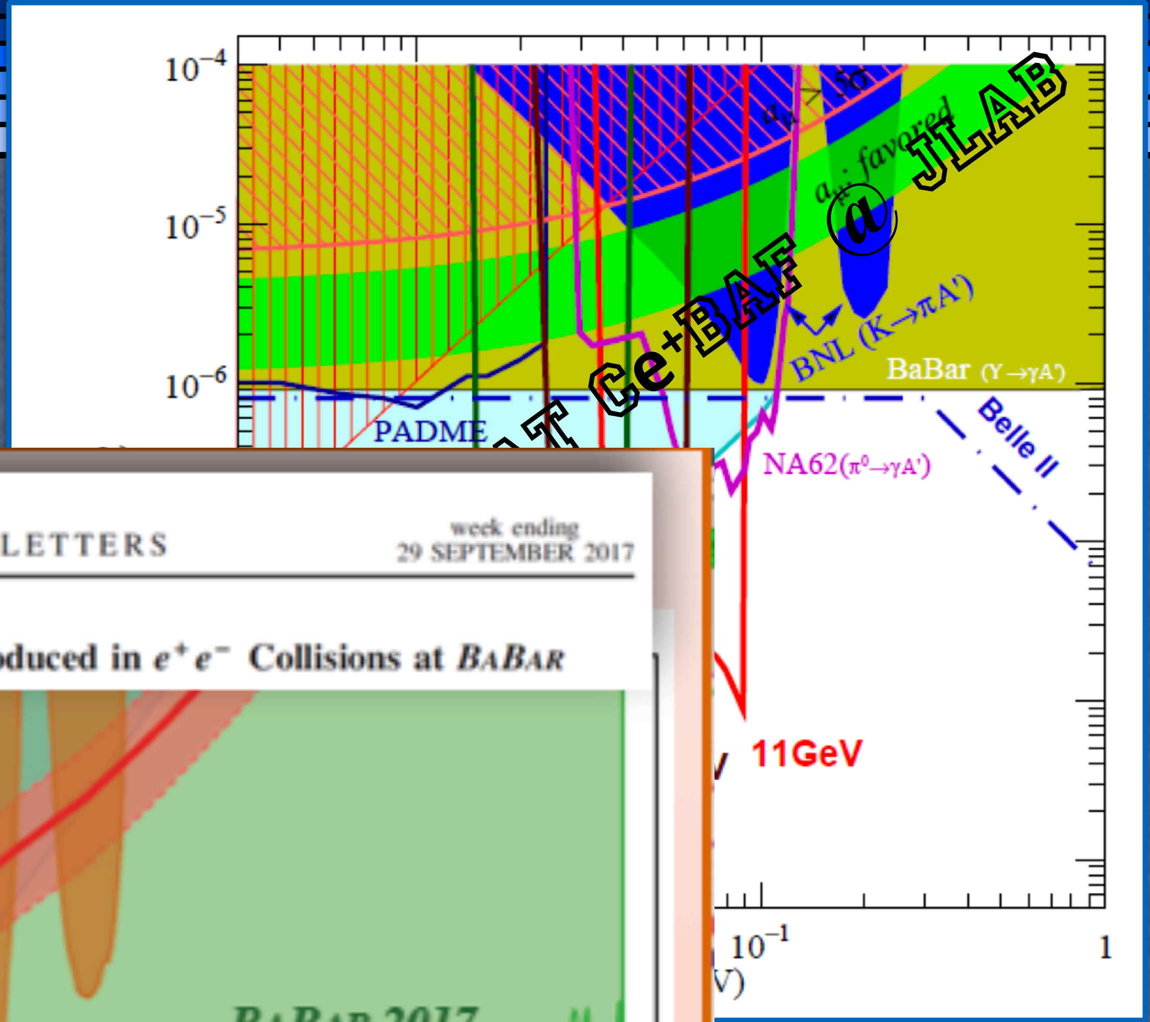
e^+ annihilation on fixed (thin) target

visible/invisible



Missing mass search:

- Independent of A' decay mechanism

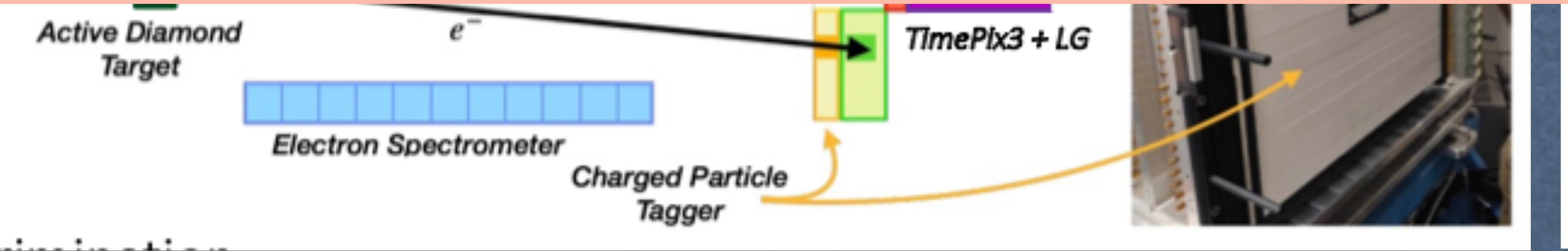


VEPP

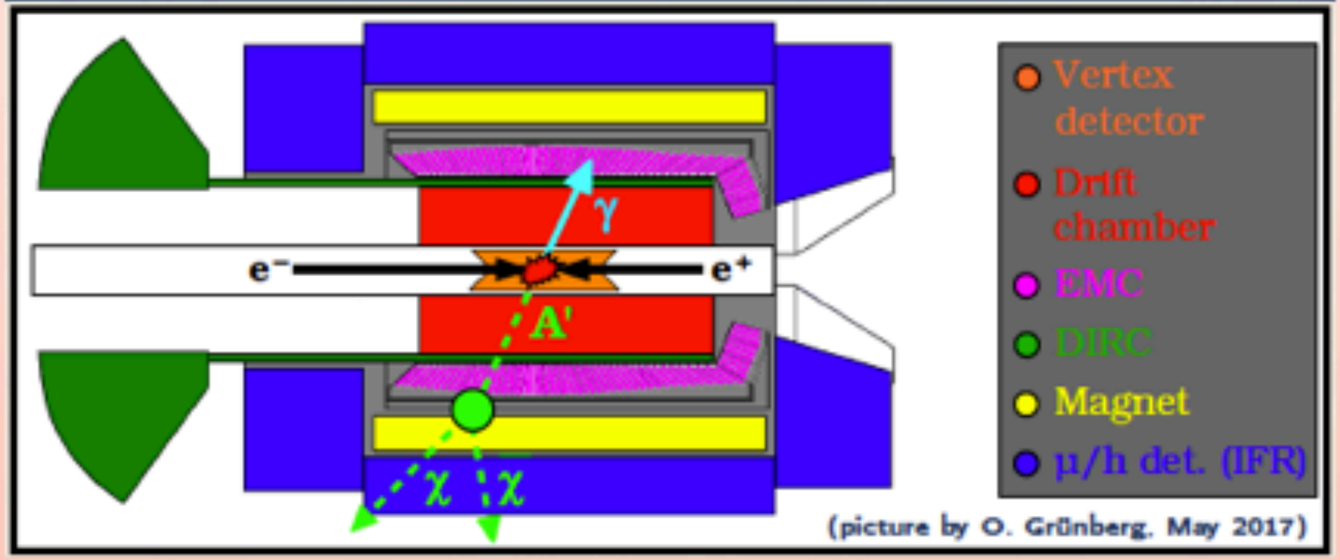
Corne

PA

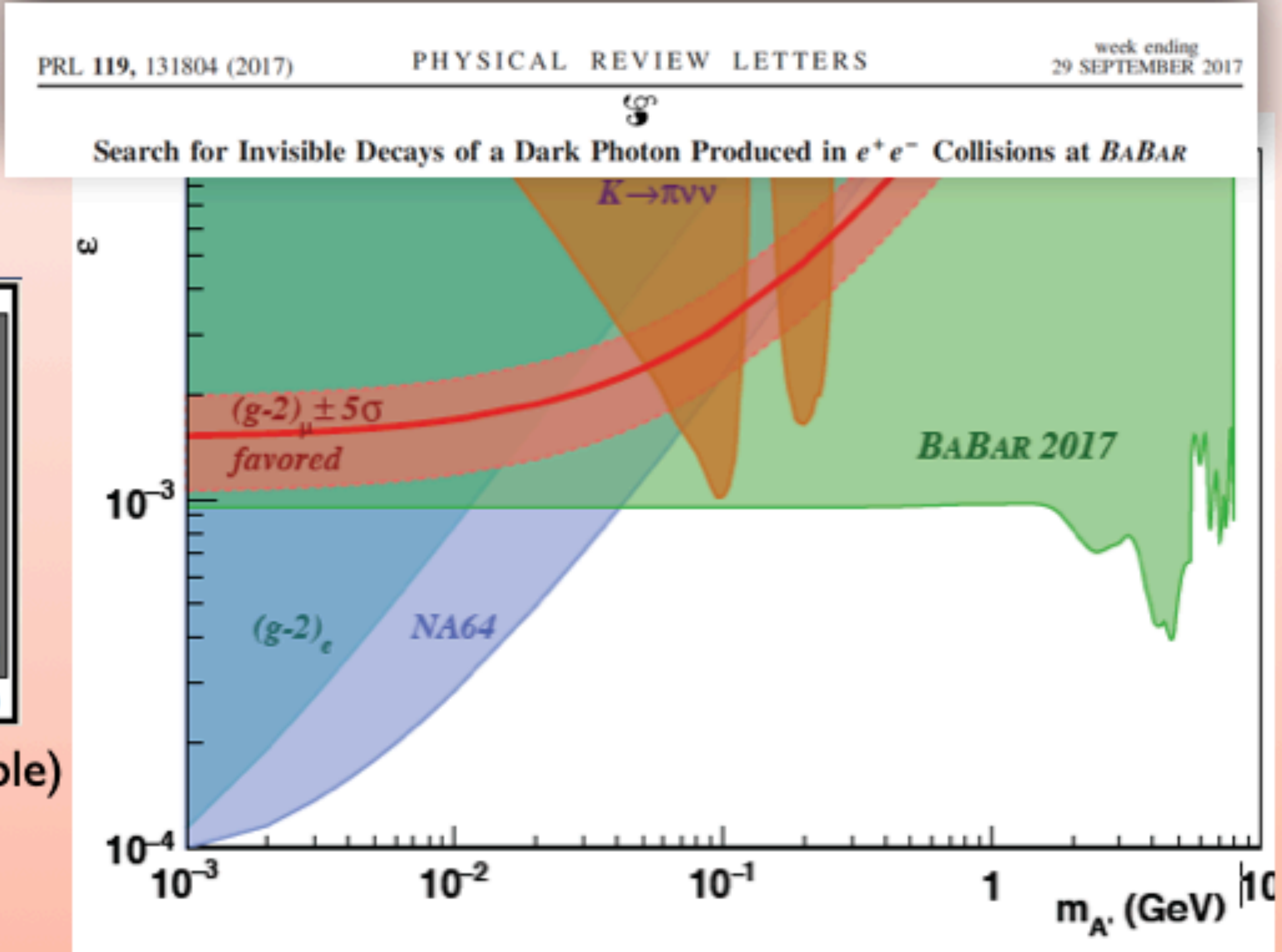
- e+ b
- Diam
- EM calorimeter: ... BGO crystals
- TIMEPIX3 for bem spot
- ~6 10^{11} POT (+ 5 10^{11} POT on tape)
- Focus on X17 visible decay

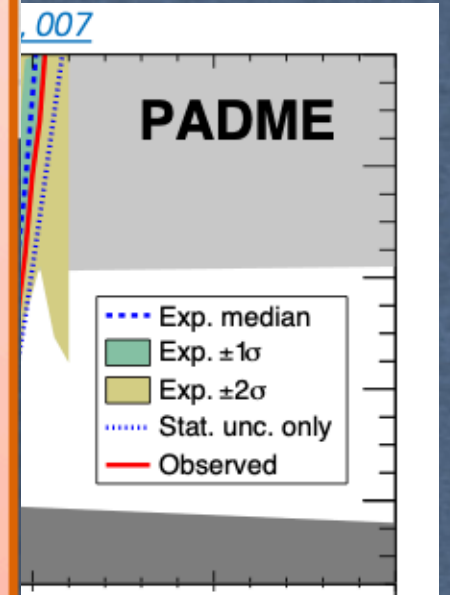


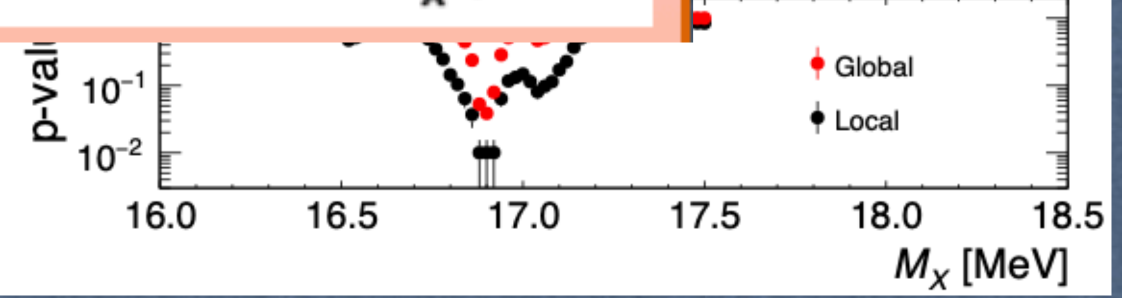
Similar techniques at e^+e^- colliders BaBar @ SLAC



- Missing mass exp (e- e+ → γ A' with A' → invisible)
- Mono-photon trigger
- Exclusion plots based on ~50 fb^{-1}







The BDX experiment

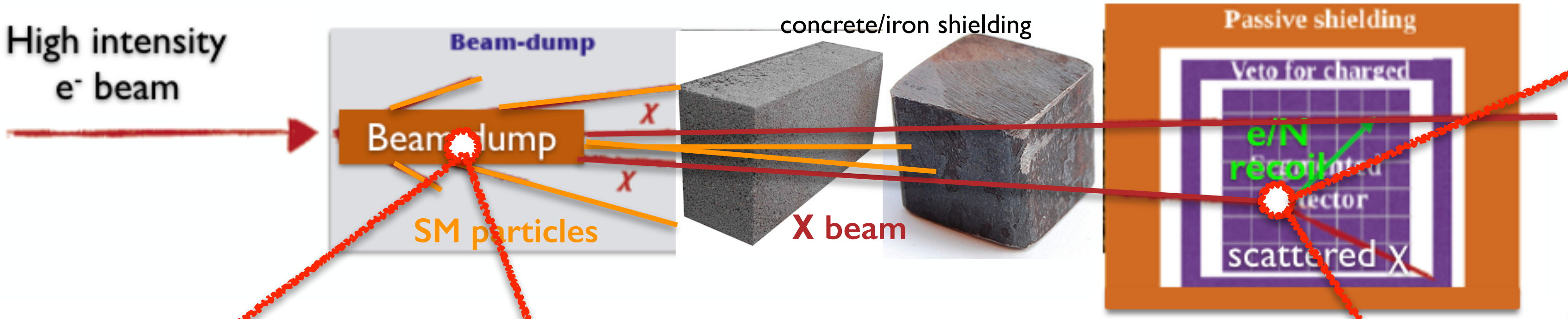
invisible decay

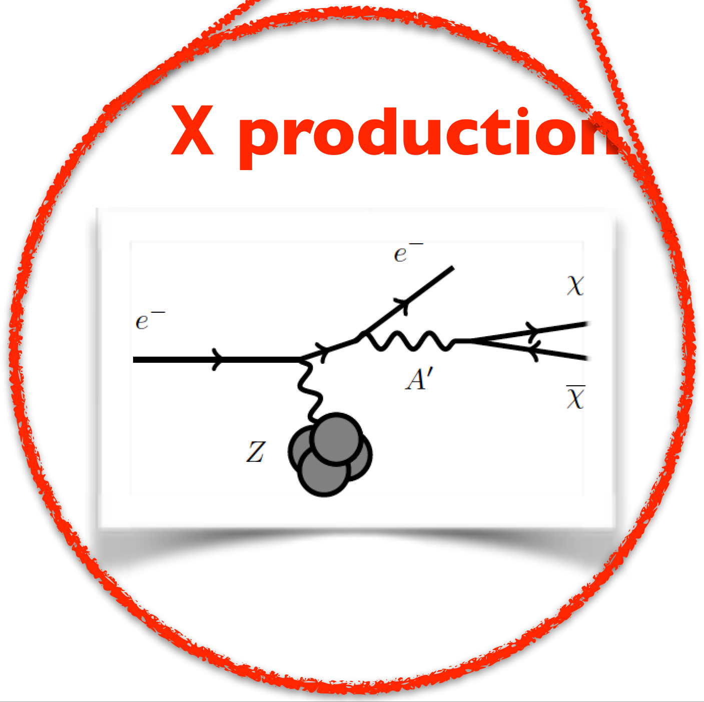
Two step process

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



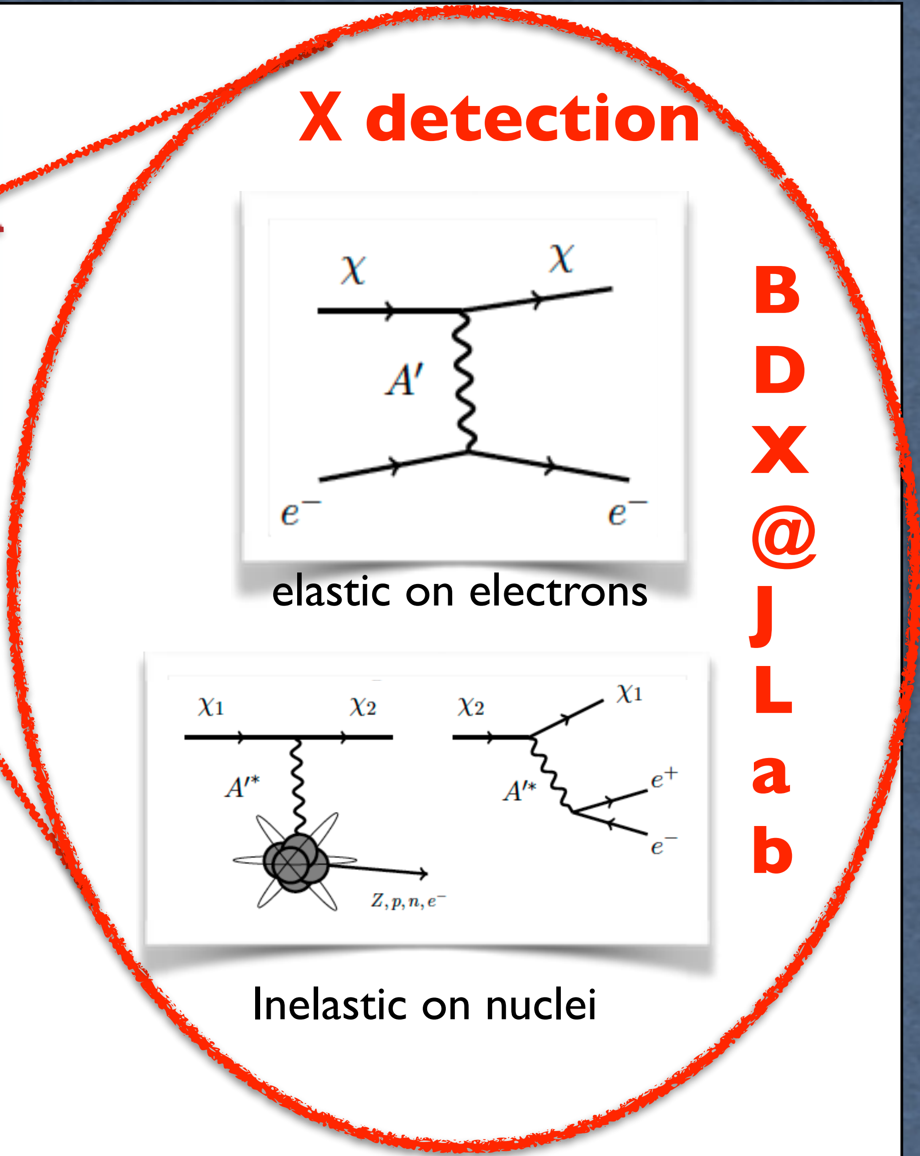


A' yield: $N_{A'} \propto \frac{\varepsilon^2}{m_{A'}^2}$

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

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

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

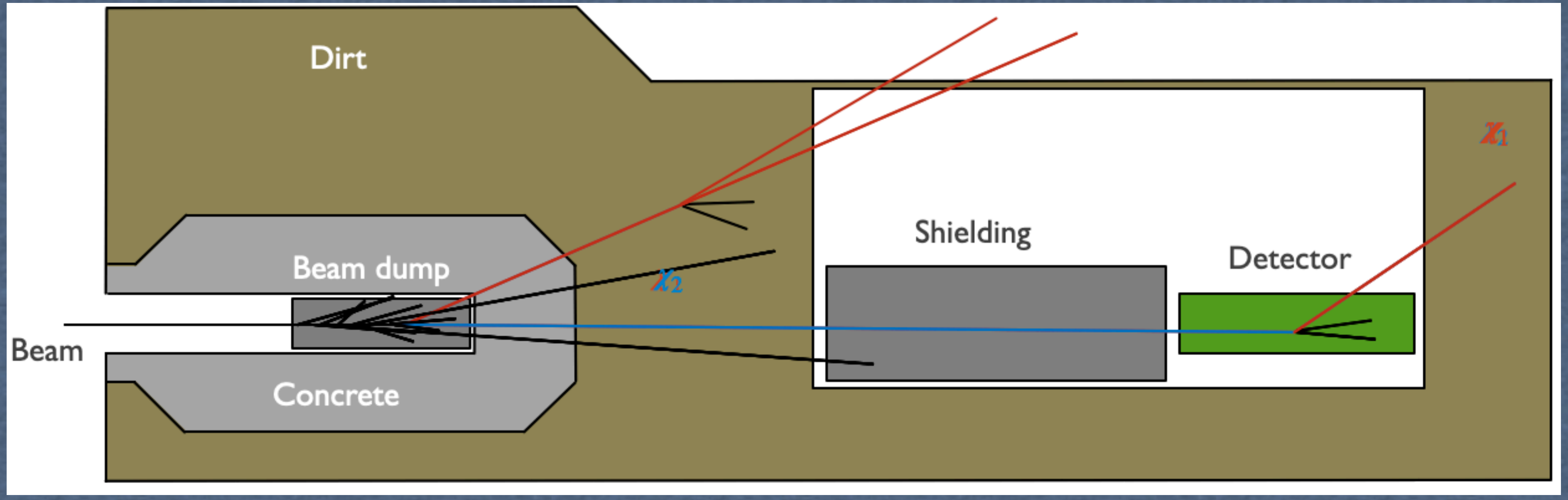


Experimental signature in the detector: **χ-electron → EM shower ~GeV energy**

Signal vs. background

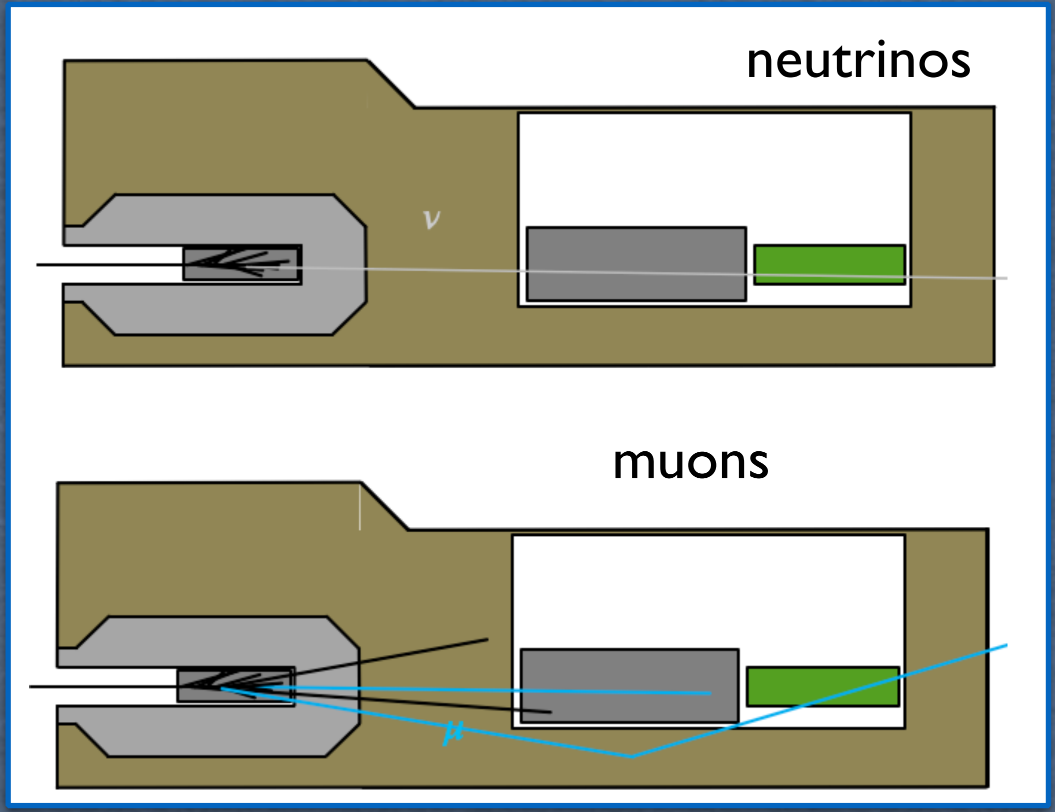
Signal

- **Light Dark Matter** can interact with electrons and nuclei producing an e.m shower with large energy deposition (>100 MeV) in the detector



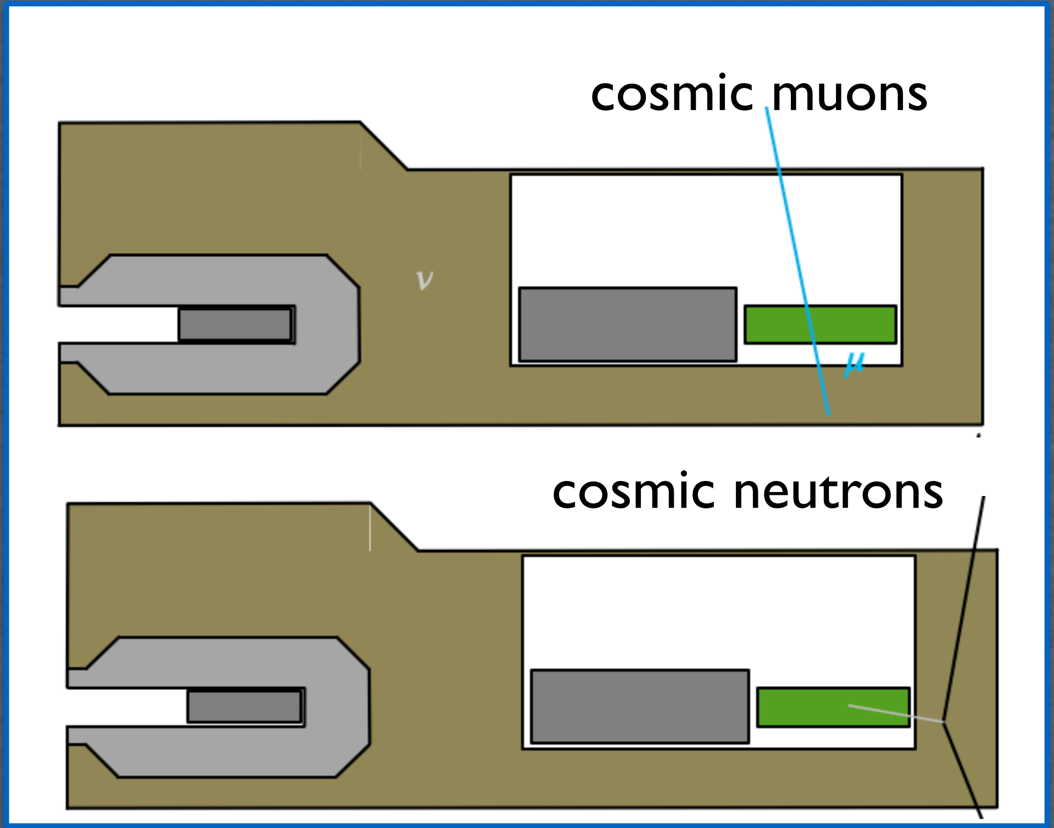
Beam related background:

- Neutrinos can mimic DM interaction
- High energy muons can propagate through shielding reaching the detector



Cosmic background

- CW beam prevents time coincidence
- Cosmic muons
- Cosmic nueutron (spallation)



The BDX detector

Detecting LDM

Detector requirements
- EM showers detection capability (~GeV)
- Compact foot-print
- Low DAQ threshold to include nucleon recoil detection (~MeV)
- Segmentation for topology id

Rejecting the bg

- Beam-related
- Cosmic

Active veto requirements
- High efficiency (>99%) to MIPs
- Fast (~ns) for time coincidence with the calorimeter
- Segmentation for bg rejection

Passive veto made by lead bricks
- Lead vault for low energy gamma and avoid self-veto

BDX technology

E.M. calorimeter

↓

A **homogeneous crystal**-based detector combines all necessary requirements

Active veto

↓

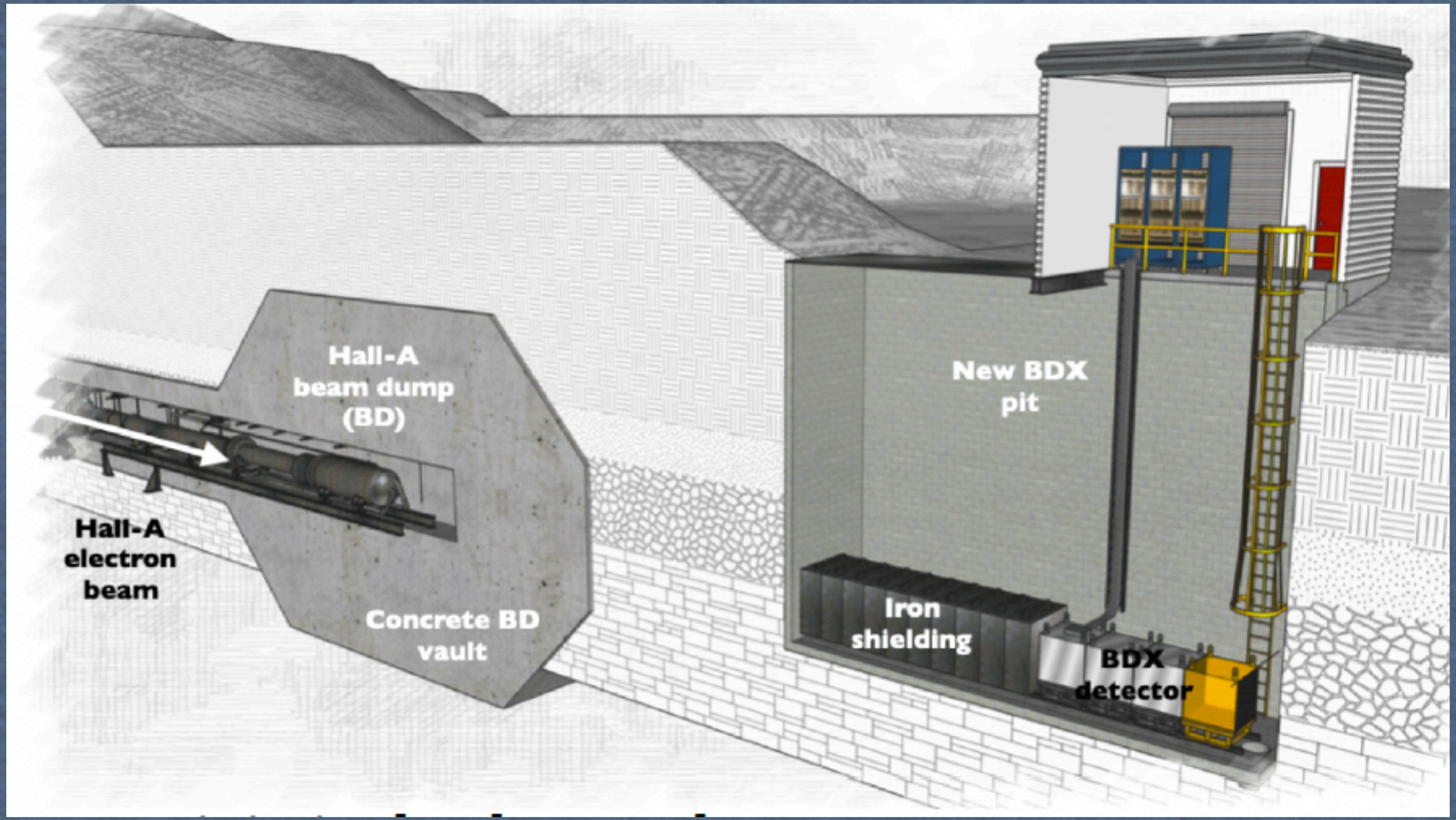
Two layers: of **plastic scintillator**
IV/OV: WLS + SIPM

Passive veto

Lead vault

BDX @ JLab

approved by JLab 2018 PAC with max rate (A)

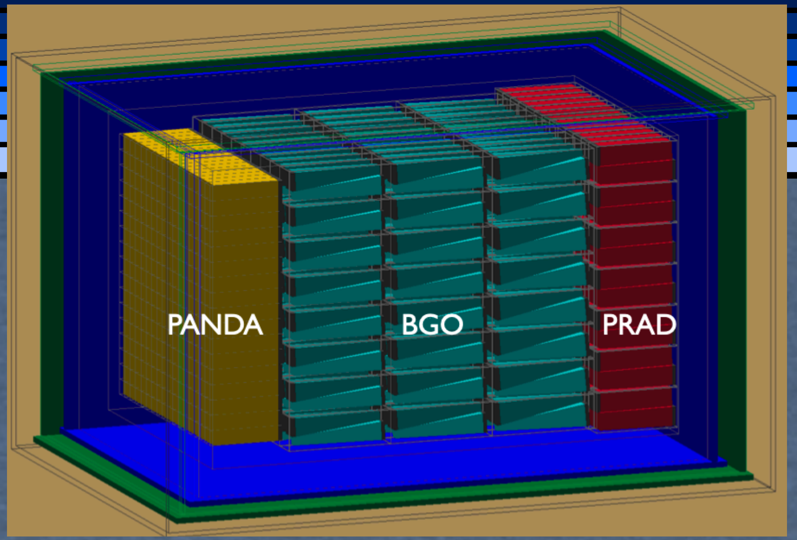


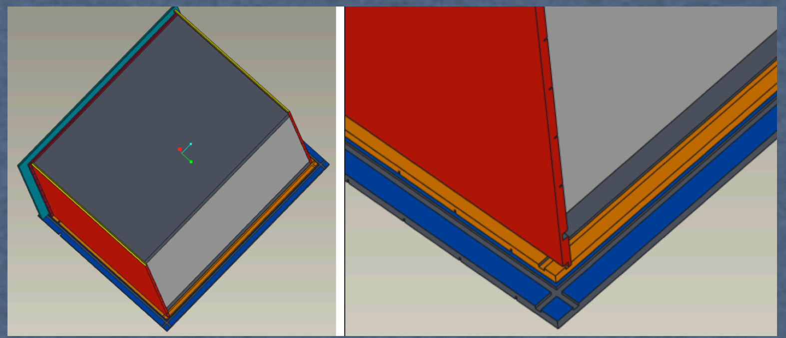
★ High energy beam available: 11 GeV
★ The highest available electron beam current: ~65 uA
★ The highest integrated charge: 10^{22} EOT (41 weeks)
★ New experimental hall (~2$M) at JLab
★ BDX detector: 3 tons of active target + veto's layers
★ Expected to run in parallel to teller experiment

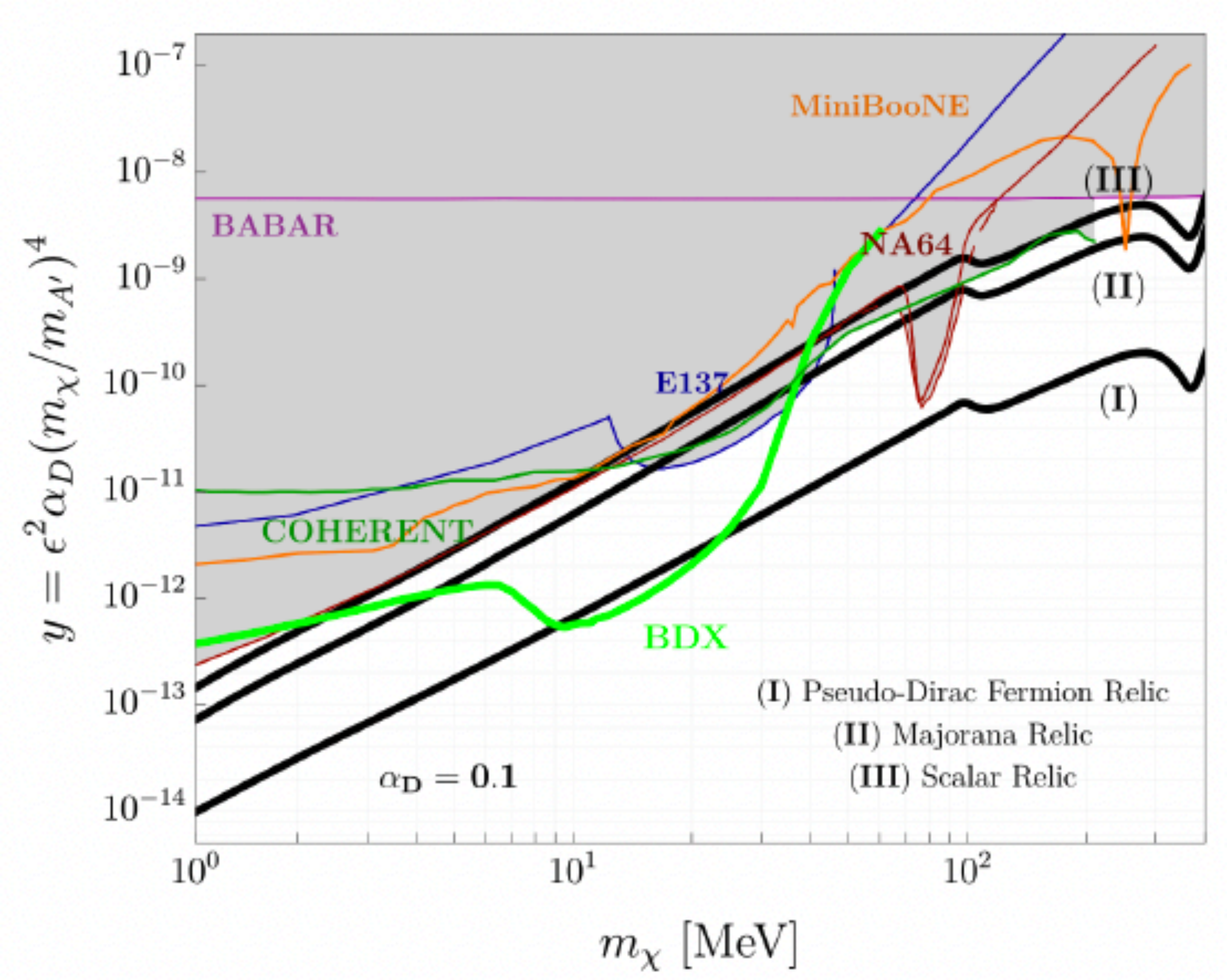
BDX detector

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

BDX-MINI @JLab
invisible decay

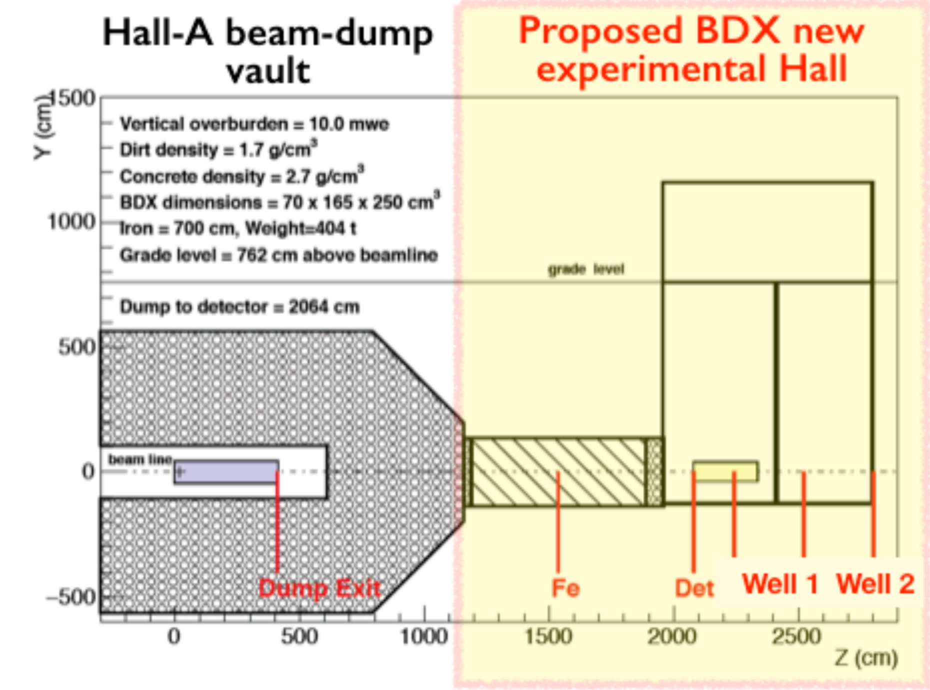
BDX-MINI: small-scale demonstrator to prove the validity and feasibility of the BDX experiment

- 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

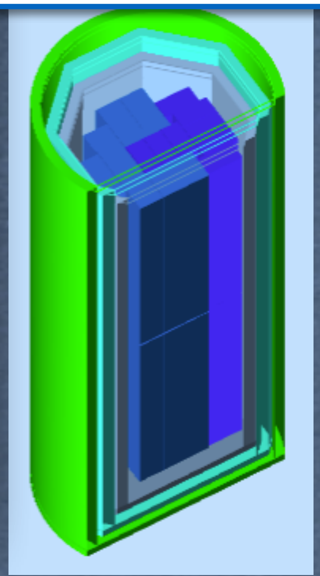
- Two wells dug for bg muon tests
- E_{beam}=2.2 GeV, no muons
- Limited reach but first physics result!

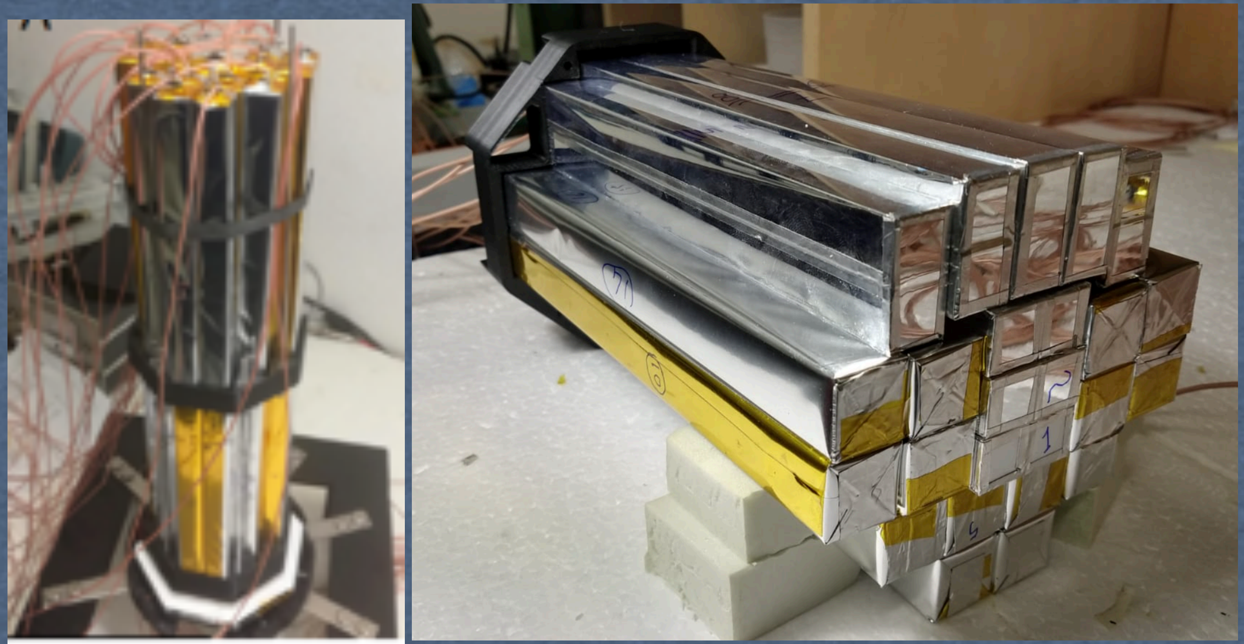
- 44 PbWO4 PANDA/FT-Cal crystals (~1% BDX active volume)
- 6x6 mm2 SiPM readout
- 2 active plastic scintillator vetos: cylindrical and octagonal (8 sipm each) + 2x lids + Passive W shielding

Downstream of the Hall-A beam dump
- TODAY -

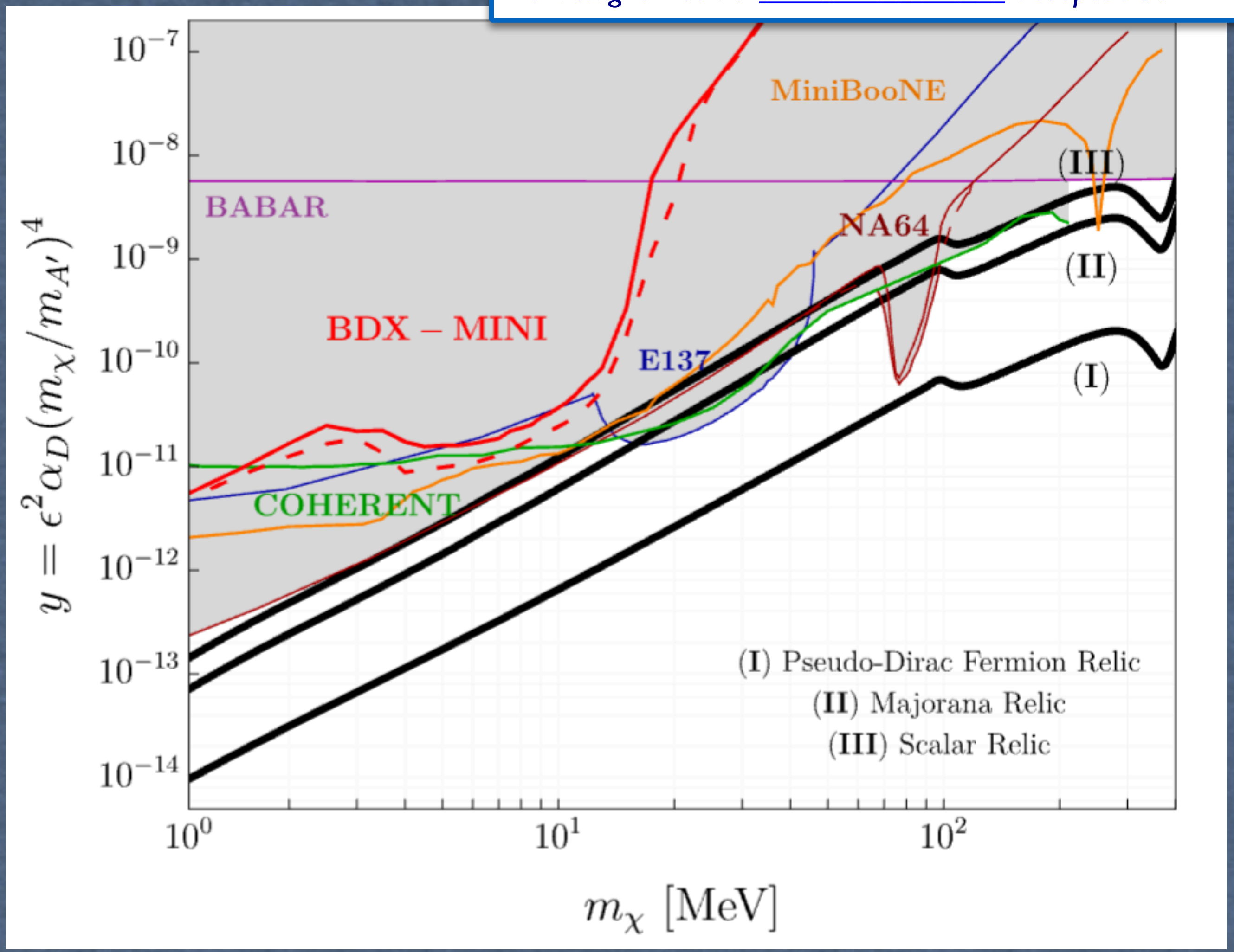


M.Battaglieri et al. EPJC (2021) 81: 164

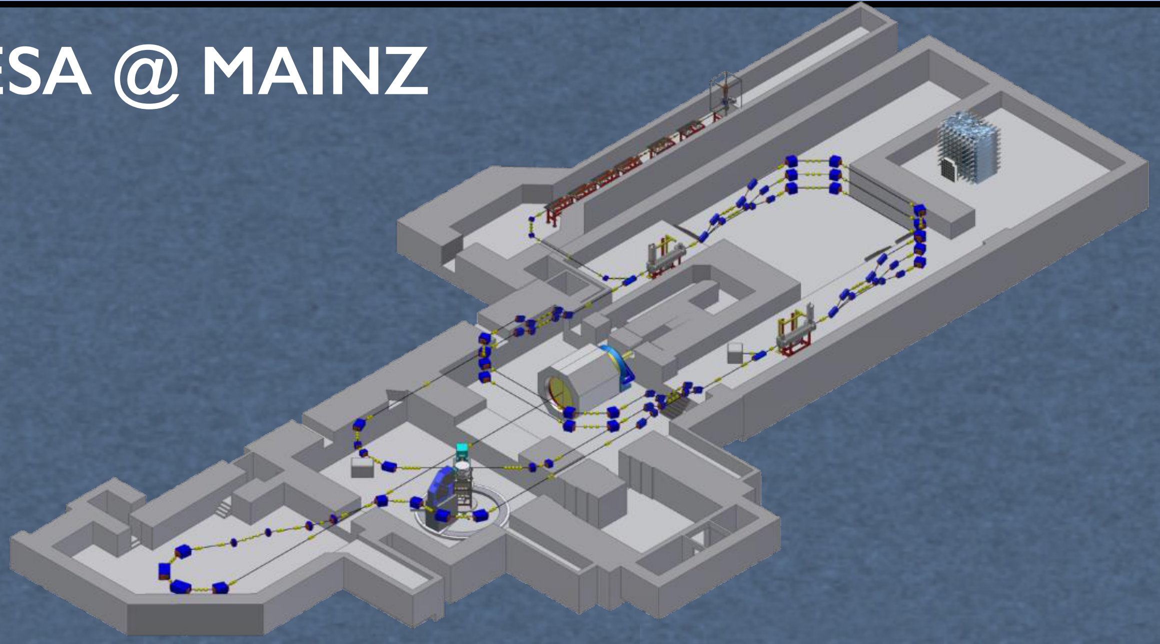




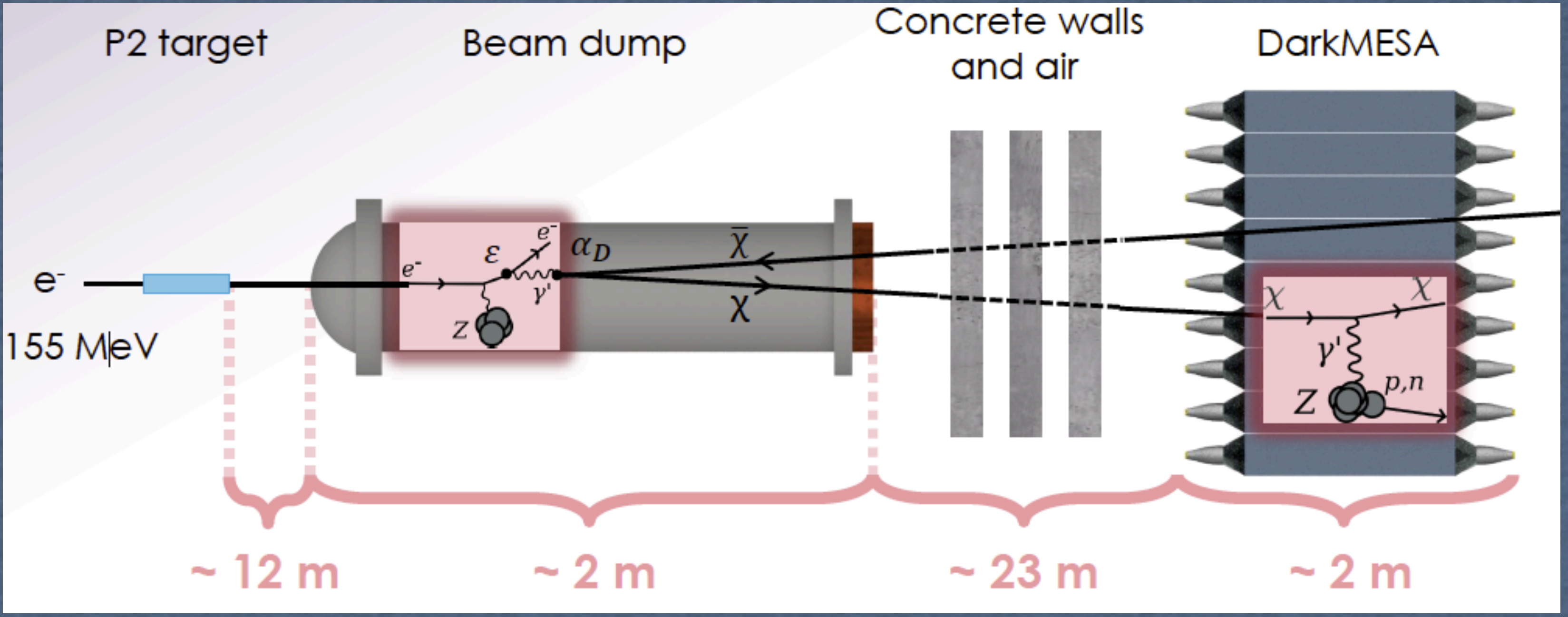
M.Battaglieri et al. arXiv:2208.01387 accepted bt PRD

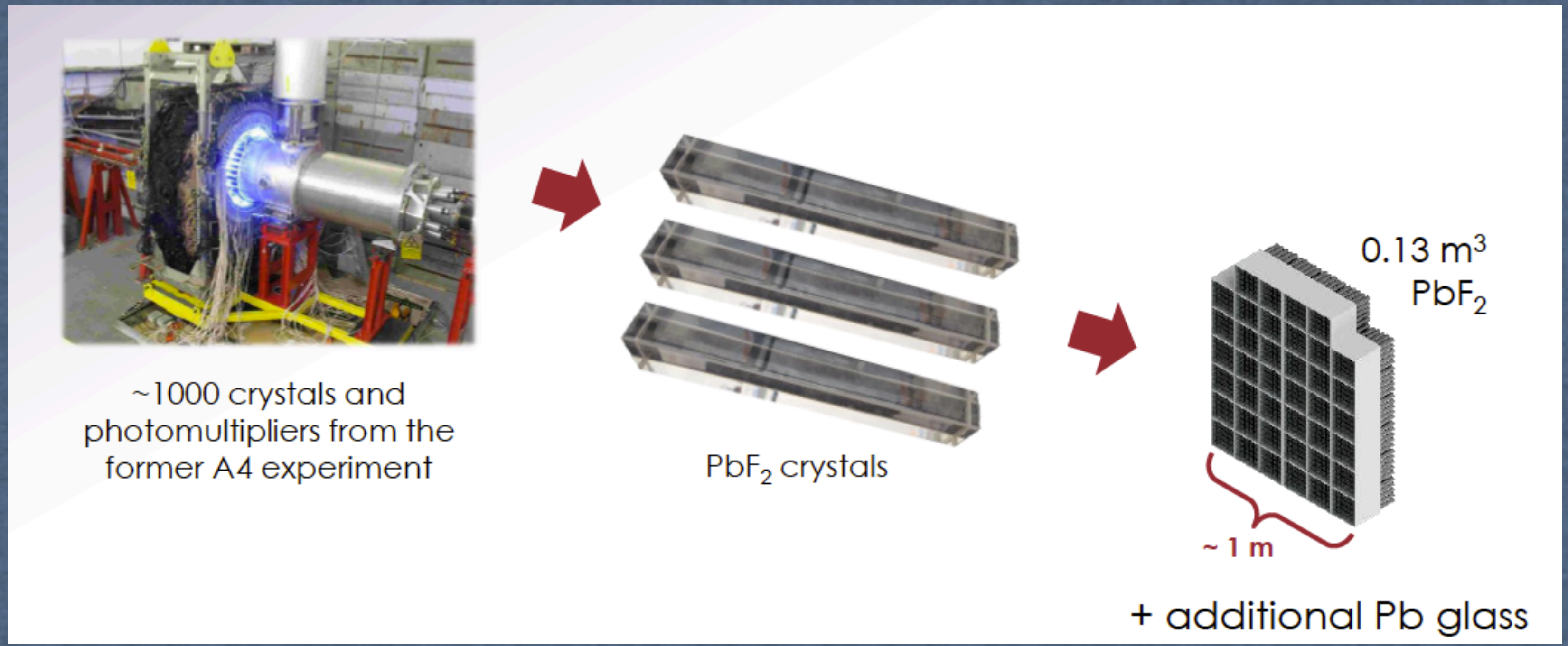


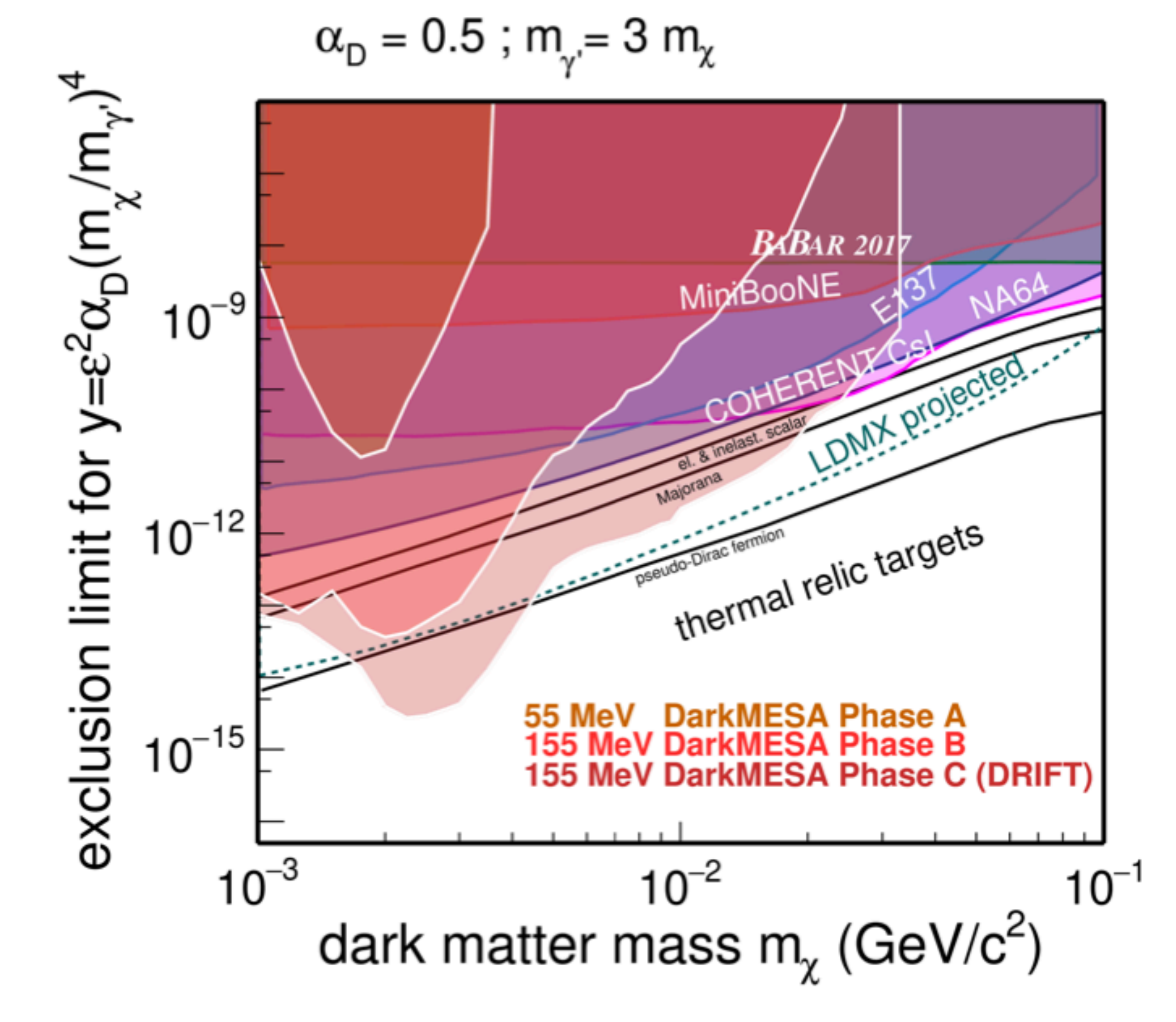
- Data-taking completed, analysis completed
- Results provide exclusion limits similar to the best existing experimnts (E137, NA64, BaBar, …)



BeamDump@MAINZ: DARKMESA



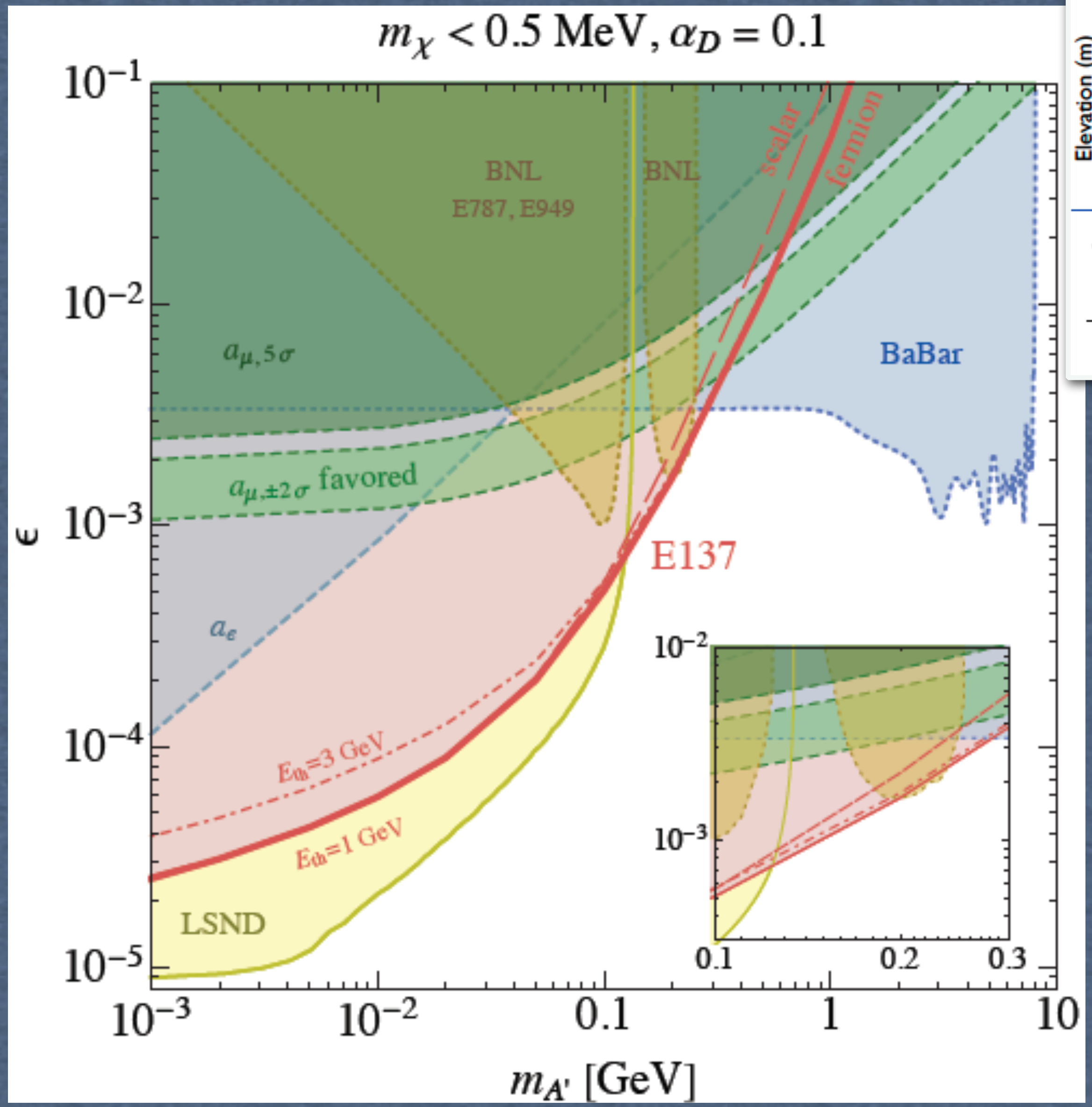


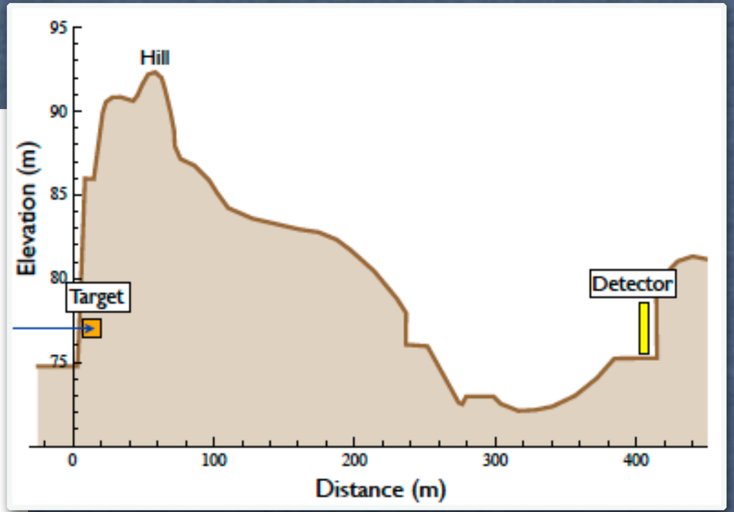


- αD=0.5and $m\gamma'=3 \cdot m\chi$
- $3 \cdot 10^{22}$ EOT
- Energy detection threshold 14 MeV
- Detector efficiency 90%
- No backgrounds

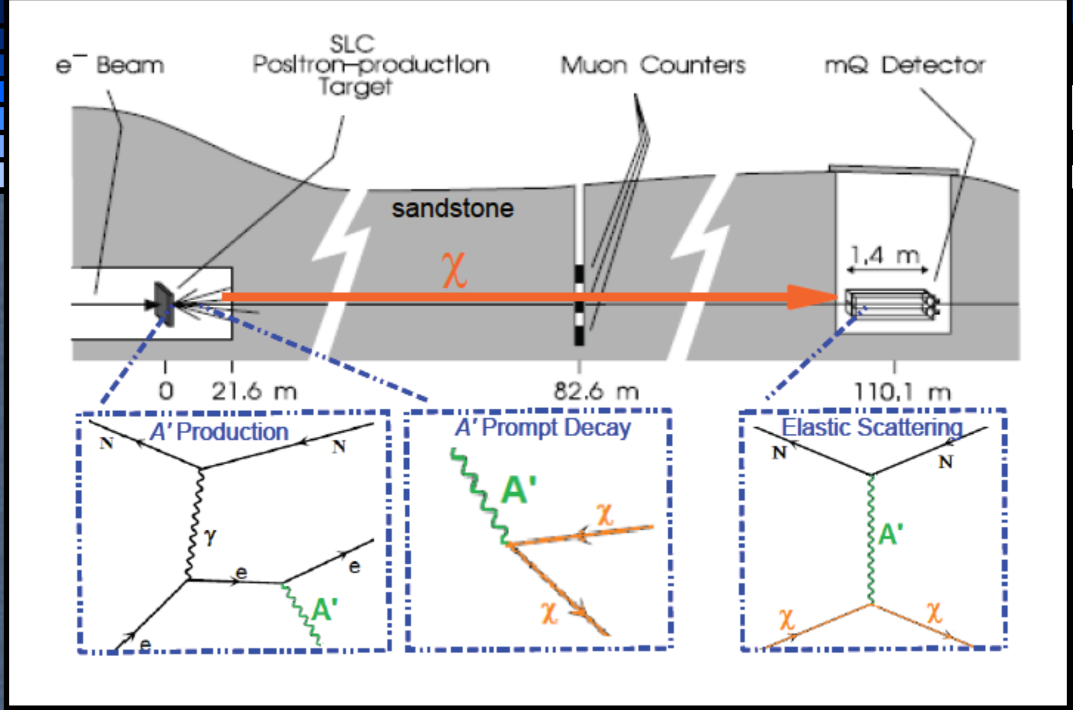
E137@SLAC (<1988)

- SLAC electron beam: 20 GeV, 1.6us pulse length, 180 pulse/s, 2×10^{20} EOT
- Detector: 8 r.l. em calorimeter (hodo + converter + MWPC)
- Size: 1.5m x1.0 m at ~380m from the BD
- Cosmic bg suppressed by directionality and time coincidence
- Detection Thr (X-e scattering only): 1-2 GeV
- 0 EVENTS DETECTED





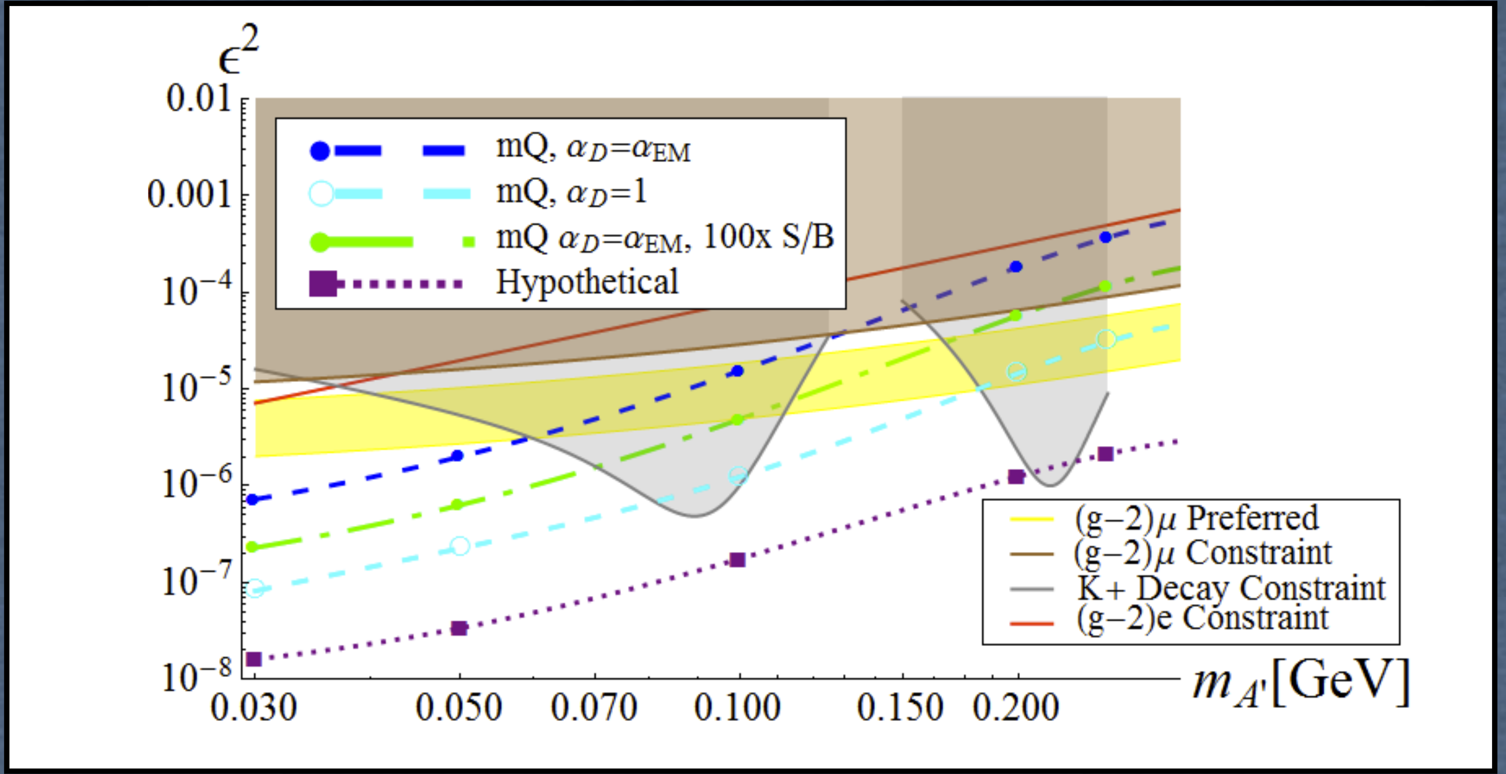
mCharge@SLAC (<1998)

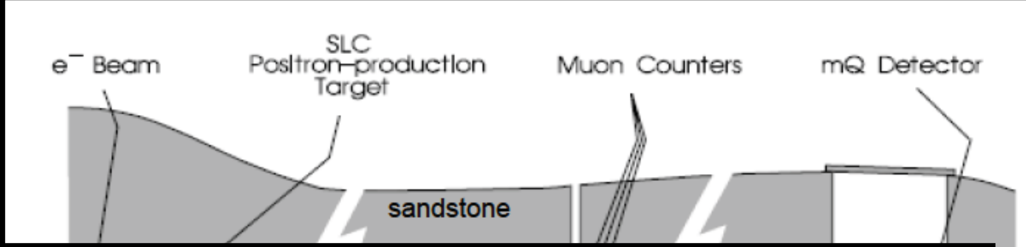


- SLAC electron beam: 29.5 GeV, ~20-30ps pulse length, 120 pulse/s, 10^{19} EOT
- Detector: (0.4x0.4)x1.3m plastic scintillator ~110m from the BD
- Cosmic bg suppressed by 250ns window with acc signal
- Detection Thr (X-N scattering only): 1pe - 100keV
- 146k 1pe bg counts

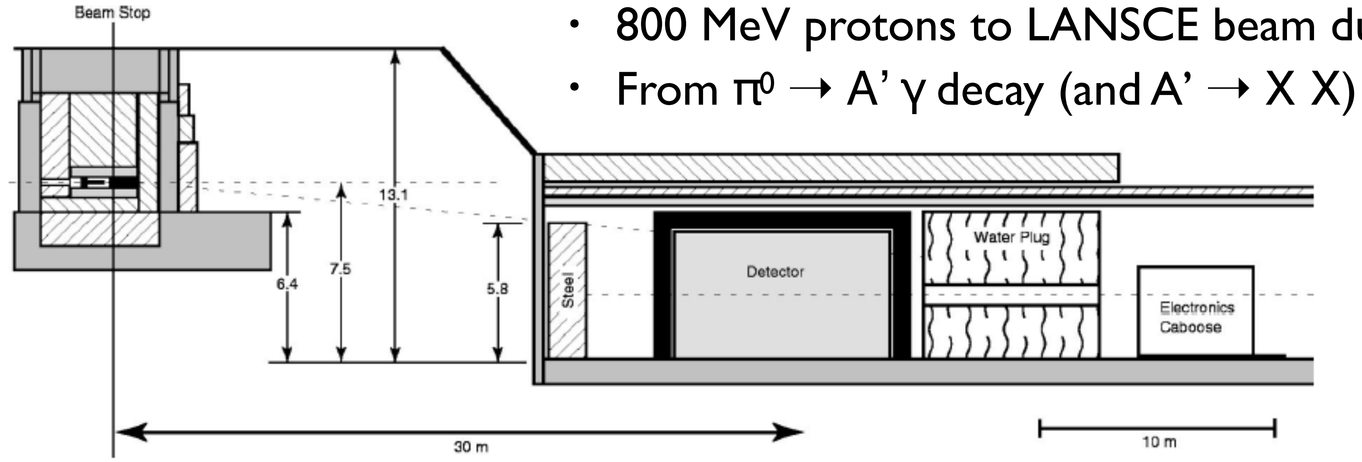
Reinterpreting old data

- Extracted upper limits suffer by poor knowledge of experimental details
- No e^- showering in the BD included: softer DM E spectrum and defocused DM beam
- Limits are overestimated by a factor ~3-4 (depending on the kinematics)



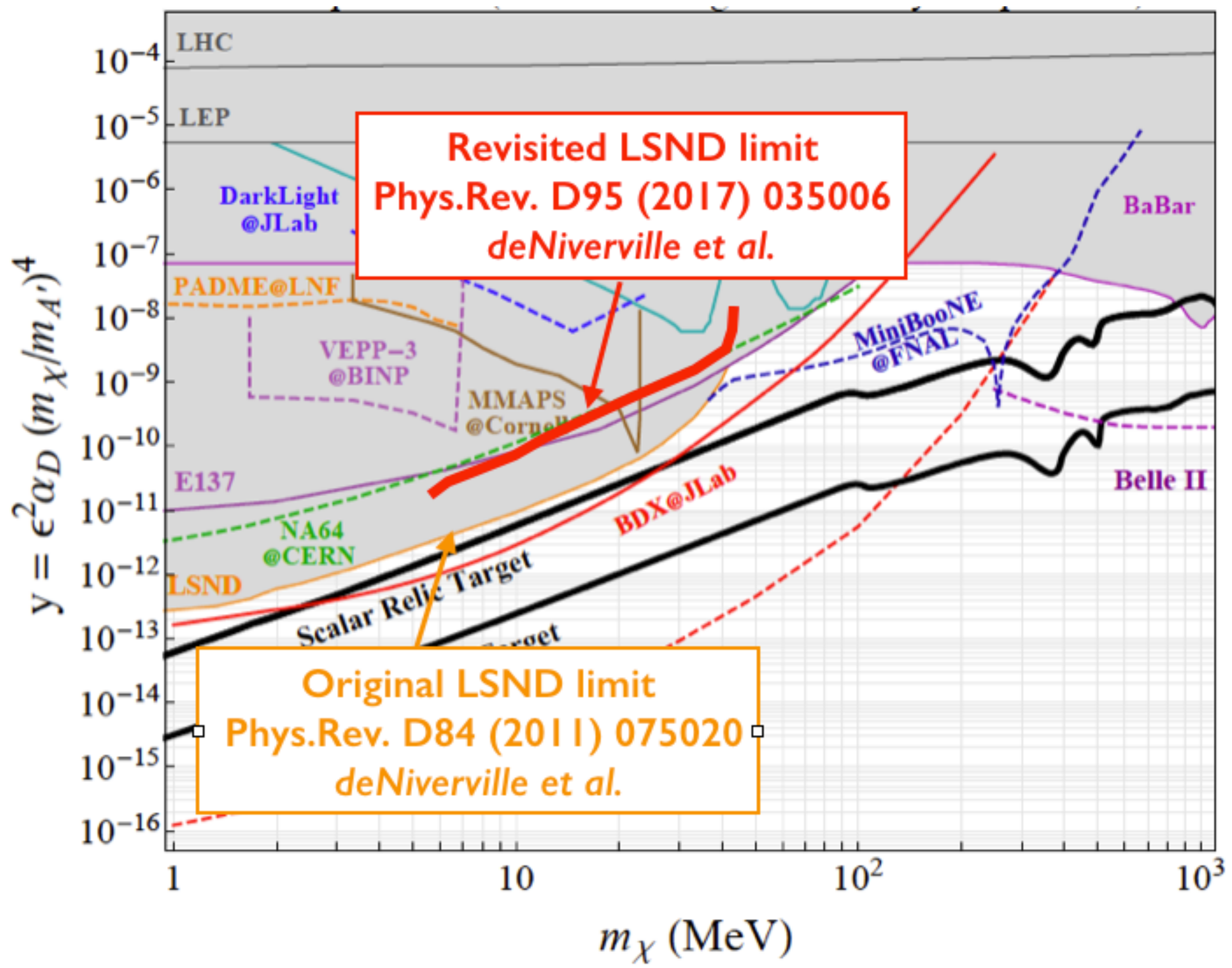


LSND@LosAlamos (1994/98)

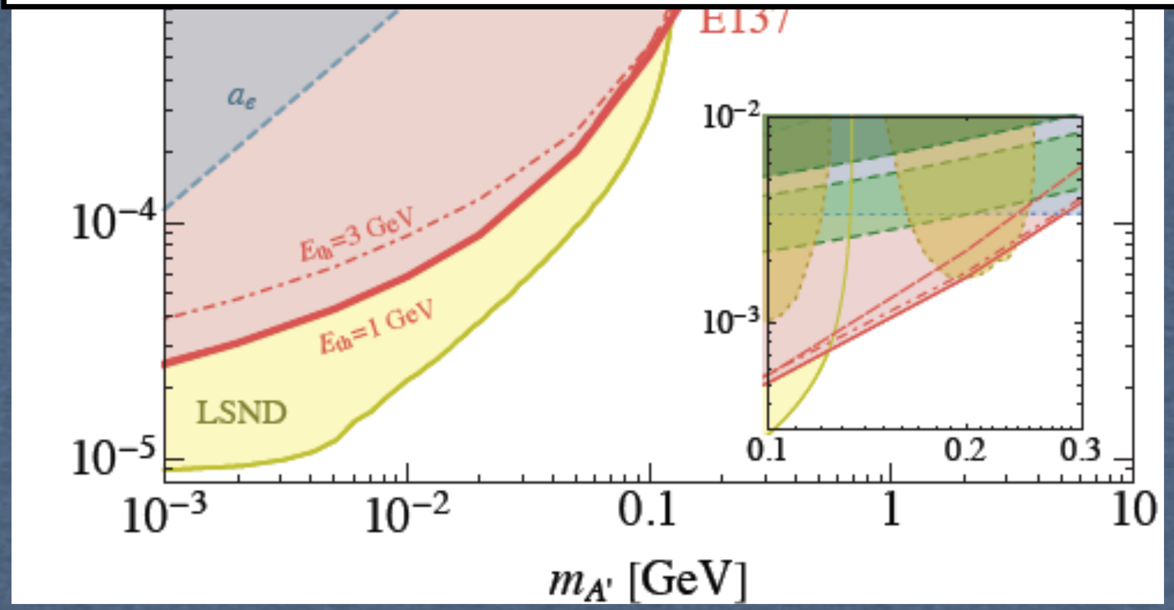


- 800 MeV protons to LANSCE beam dump
- From $\pi^0 \to A'\gamma$ decay (and $A' \to X X$)

- Upper limits extracted in 2011 using a wrong π^+ spectrum to normalise π^0
- Recently recalculated, fund to be overestimated by a factor ~4-5

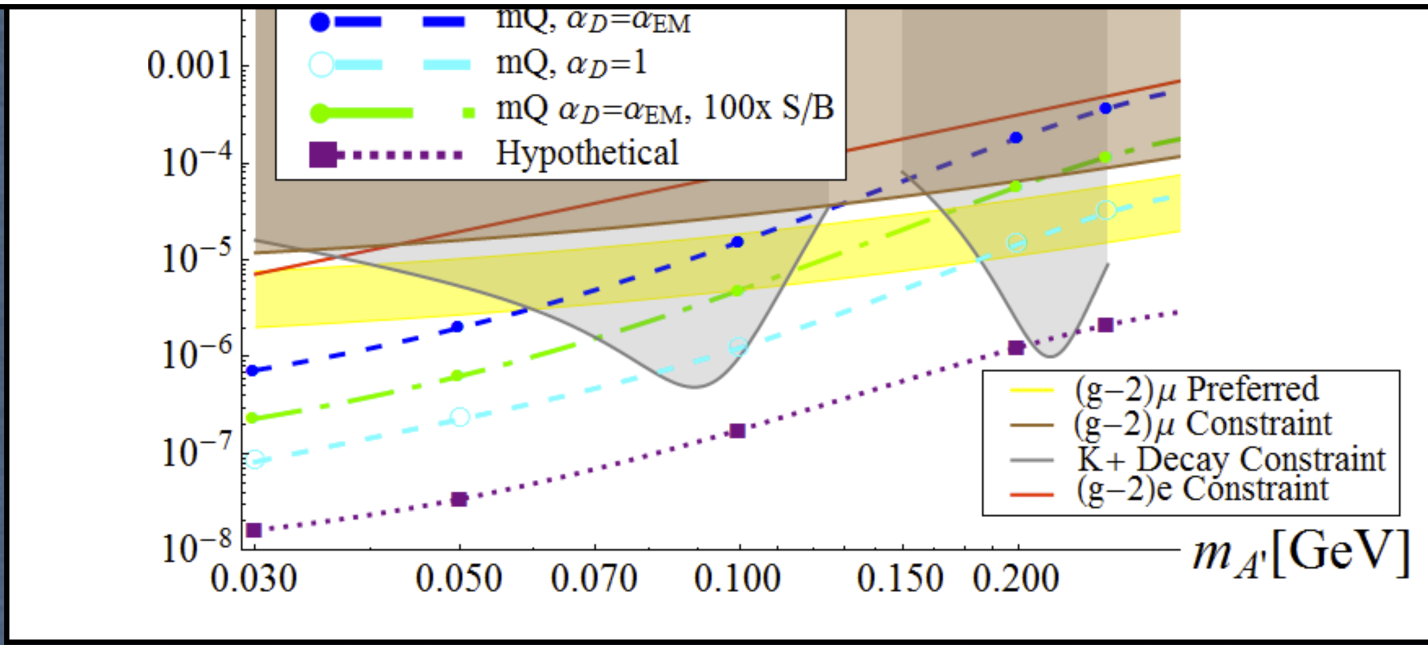


Need of new generation of beam-dump experiments optimised for LDM searches



old data

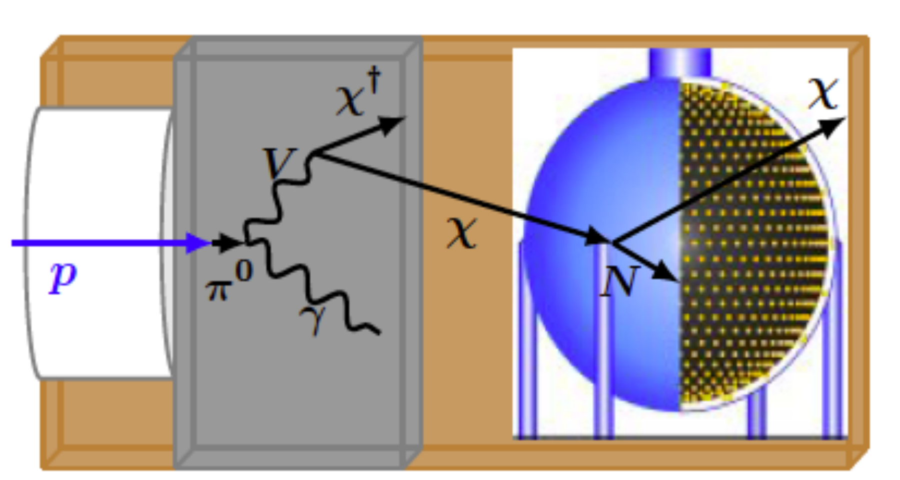
- Extracted upper limits suffer by poor knowledge of experimental details
- No e⁻ showering in the BD included: softer DM E spectrum and defocused DM beam
- Limits are overestimated by a factor ~3-4 (depending on the kinematics)



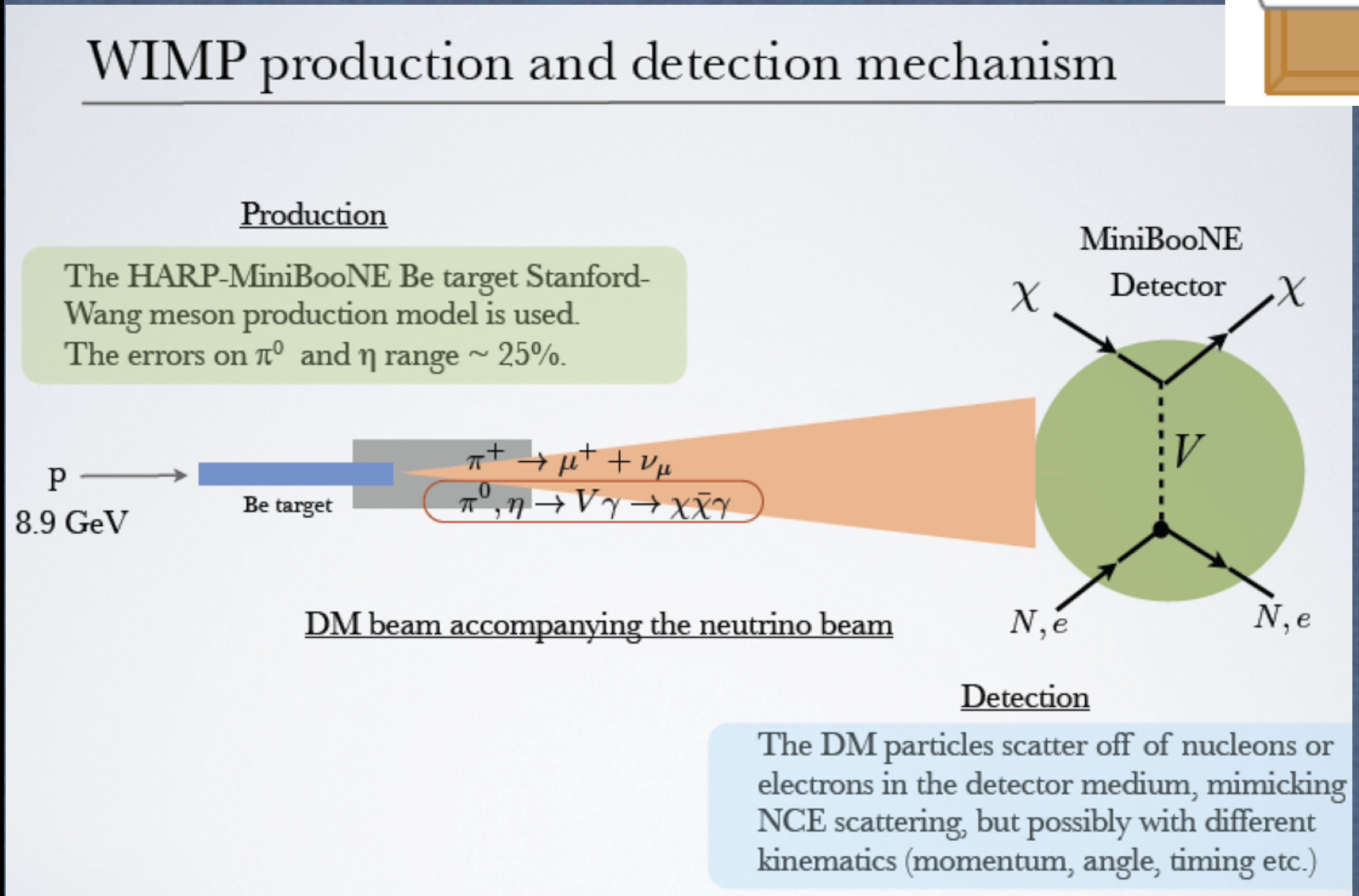
MiniBooNE@FERMILAB

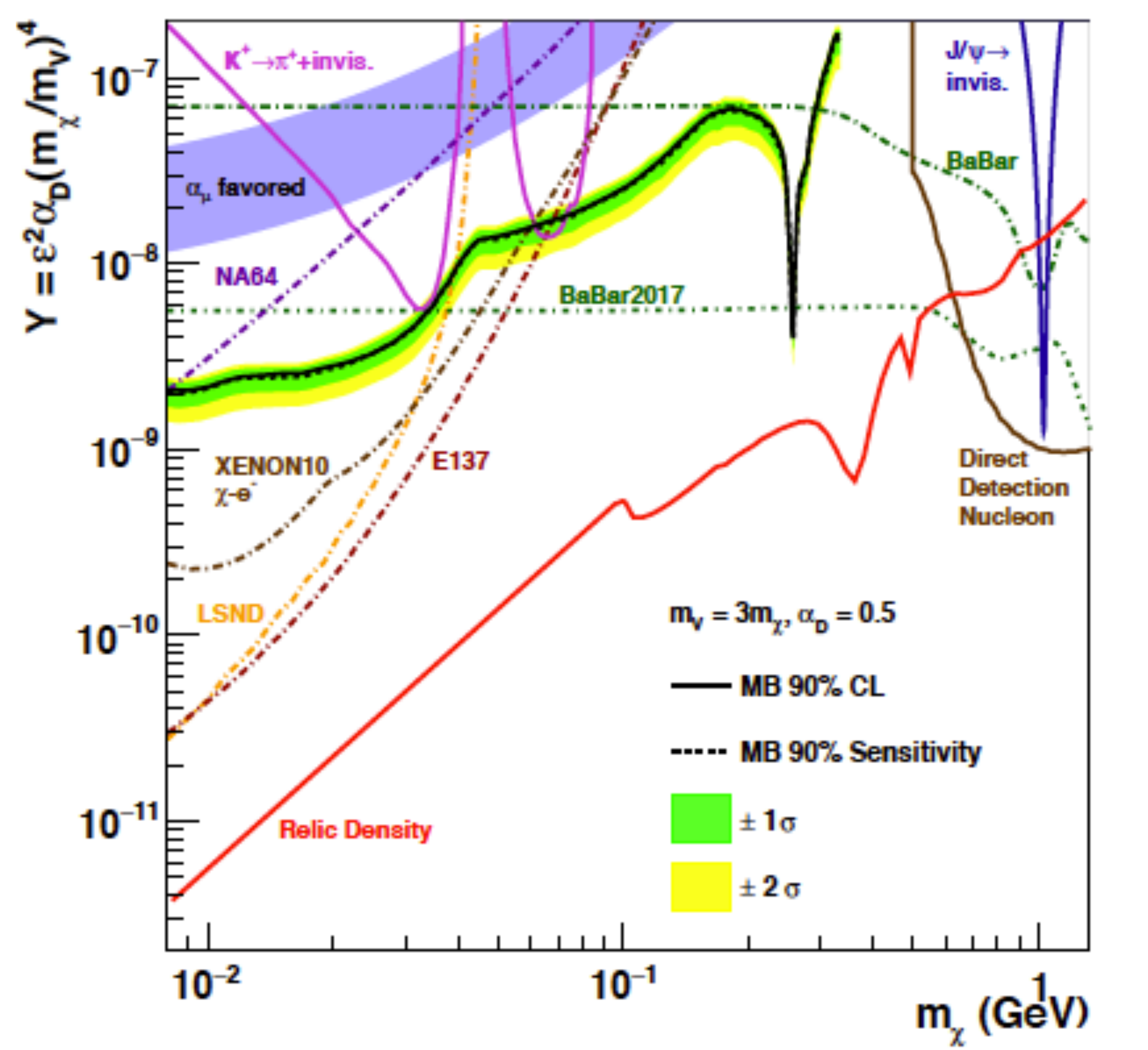
PRL **118,** 221803 (2017) PHYSICAL REVIEW LETTERS

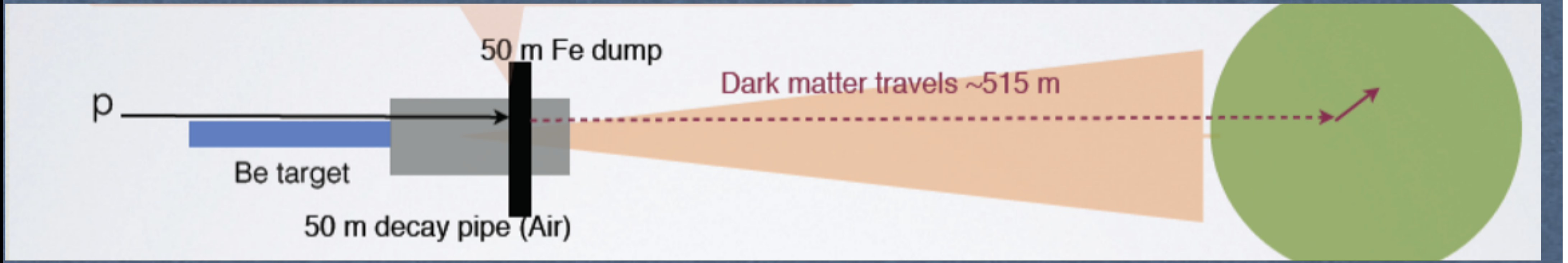
Dark Matter Search in a Proton Beam Dump with MiniBooNE



- BDX-like with an 8 GeV proton beam
- Cherenkov response of 12 m spherical detector with 800 tons mineral oil (CH2)
- Typical operation: 2x10^{20} protons on target (POT) per year
- Similar plans for T2K & ND280 (30 GeV p +50t near detector)

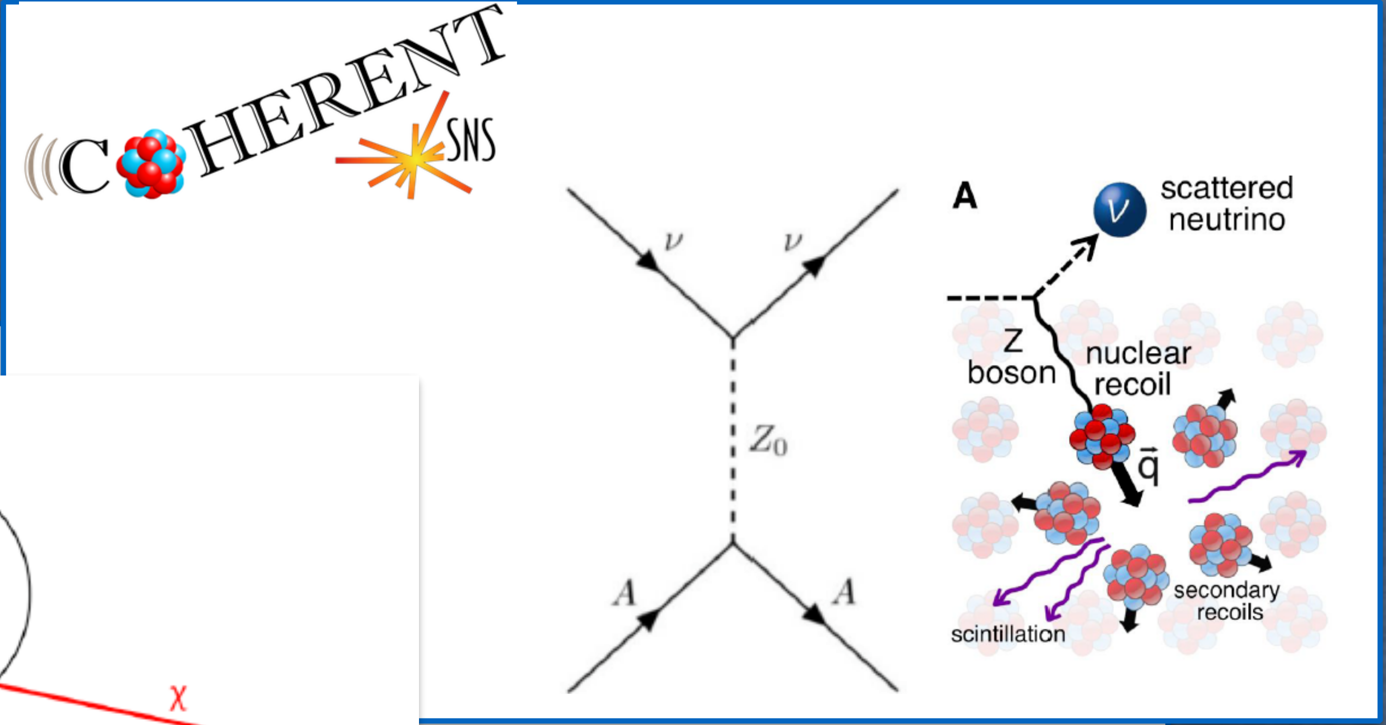






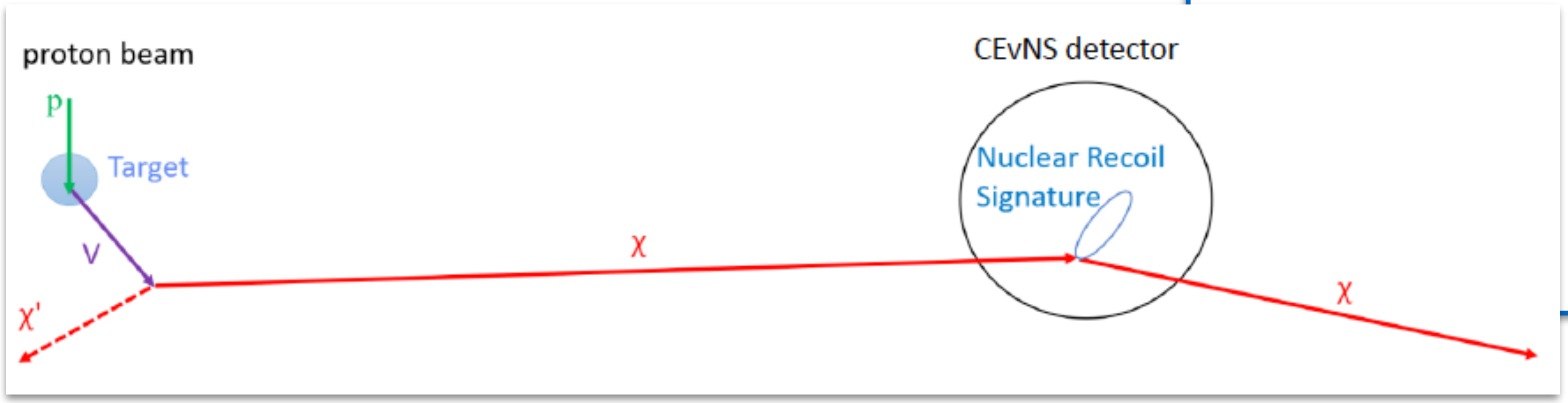
COHERENT@ORNL

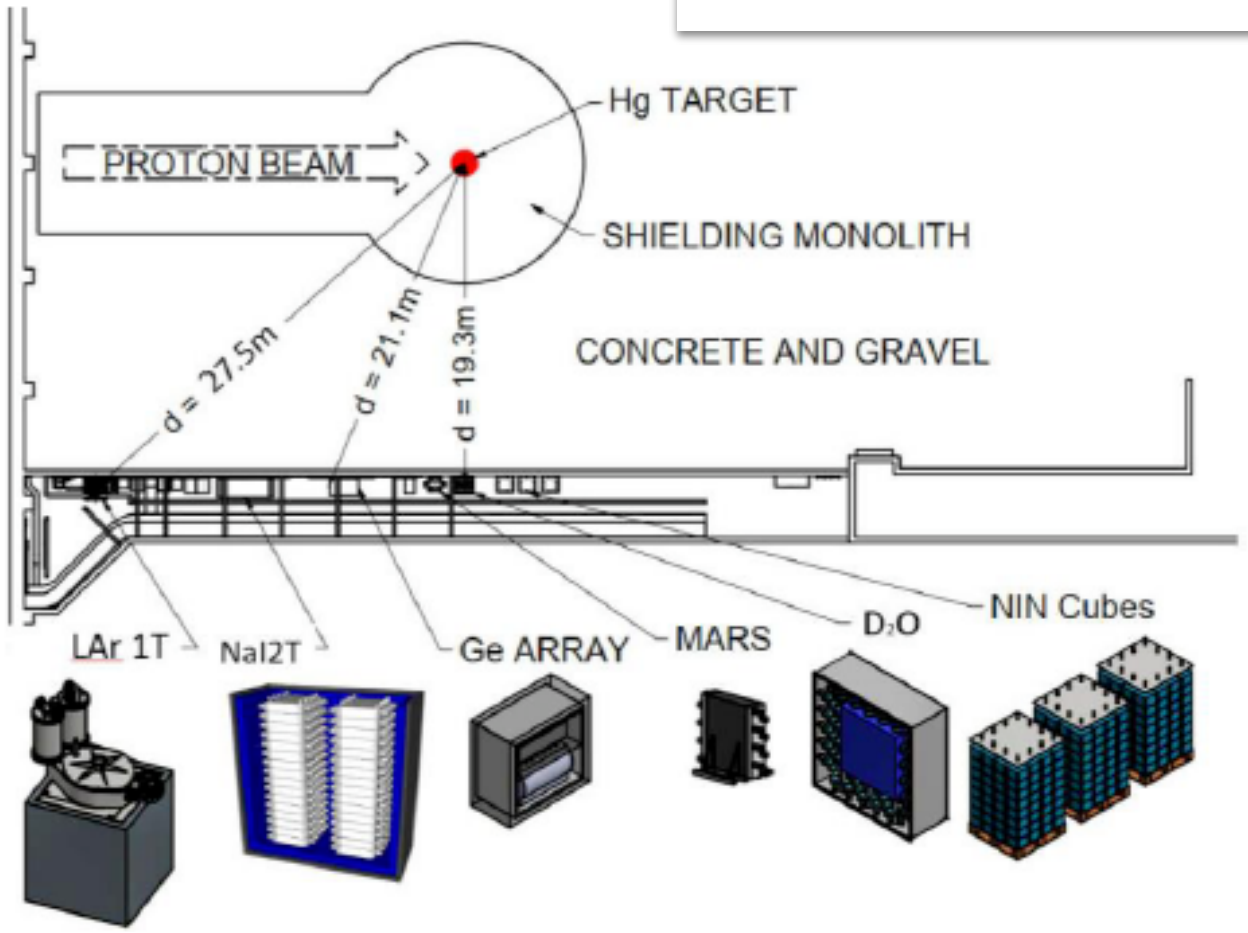
Coherent Elastic ν-Nucleus Scattering (CνENS)



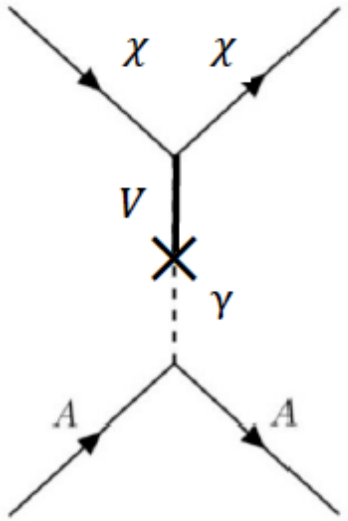
ORNL spallation Source

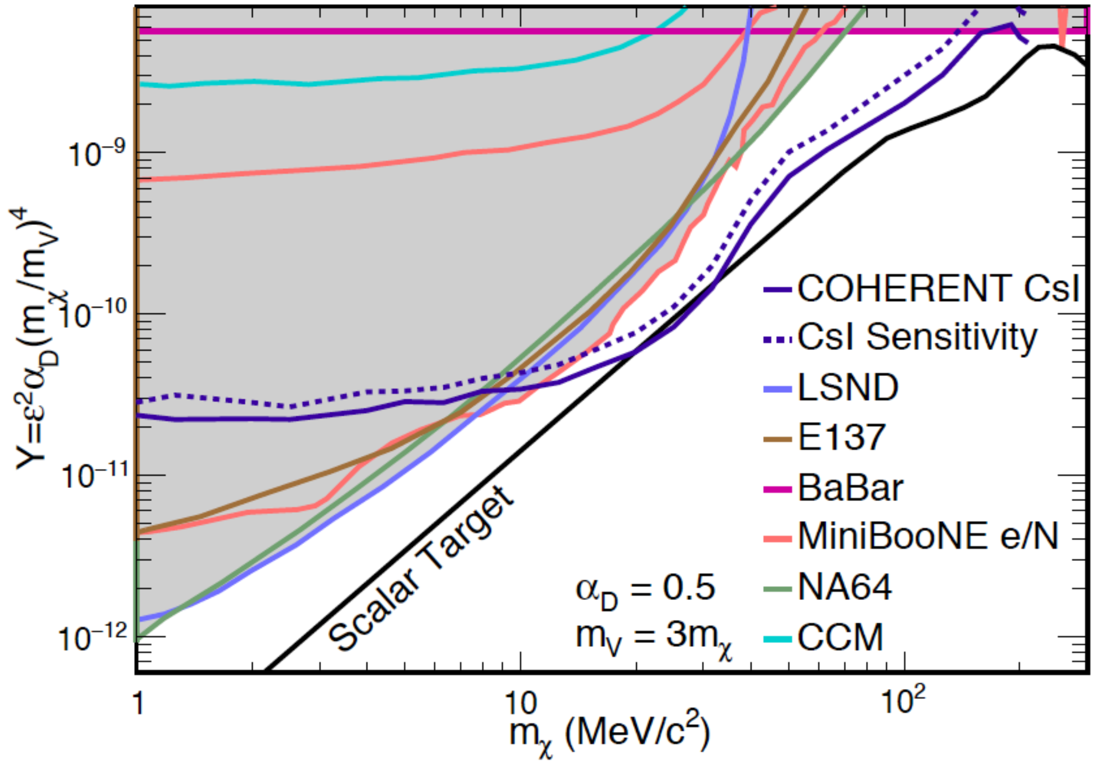
- 2 10^{23} POT
- 14.6 Kg NaI(Tl) detector
- Etr= 9keV$_{re}$



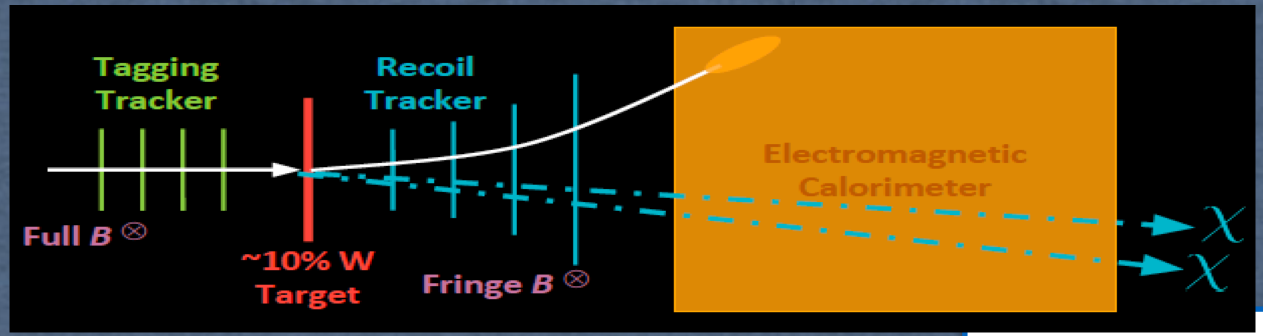


DM Scattering:

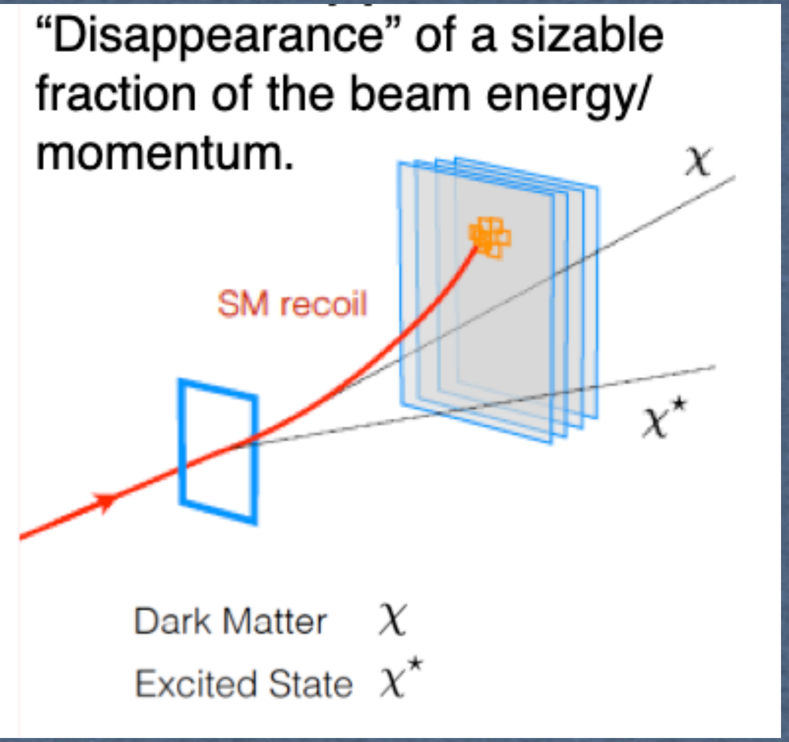




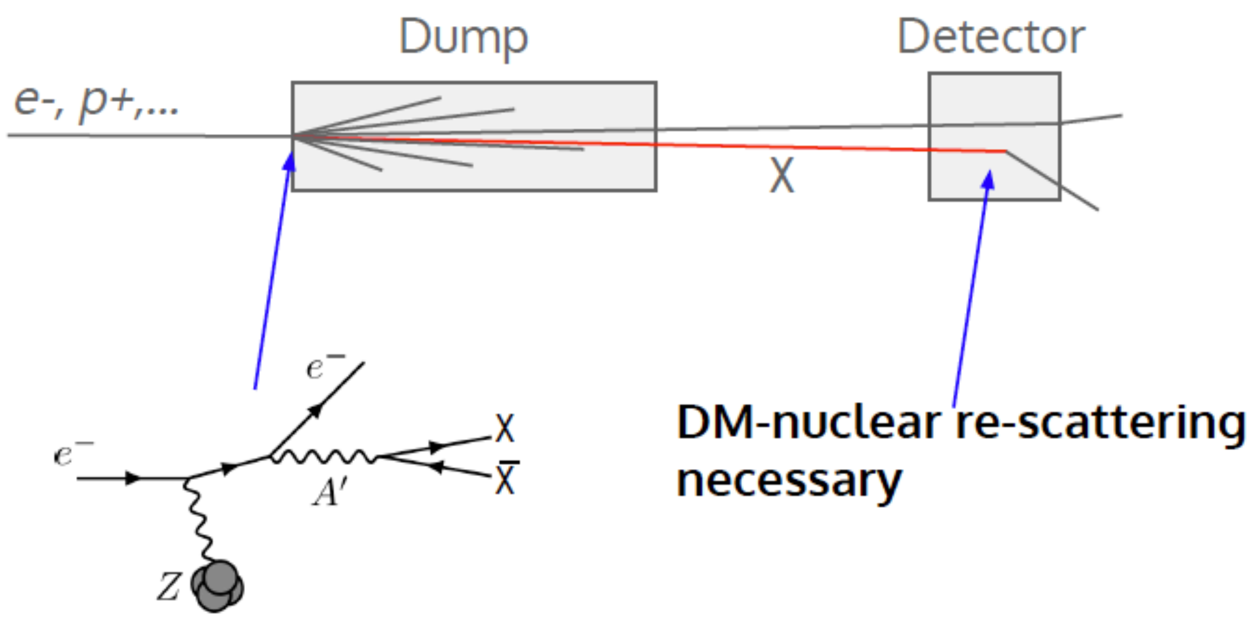
arXiv:2110.11453v1 [hep-ex] 21 Oct 2021 (COHERENT Coll.): First Probe of Sub-GeV Dark Matter Beyond the Cosmological Expectation with the COHERENT CsI Detector at the SNS



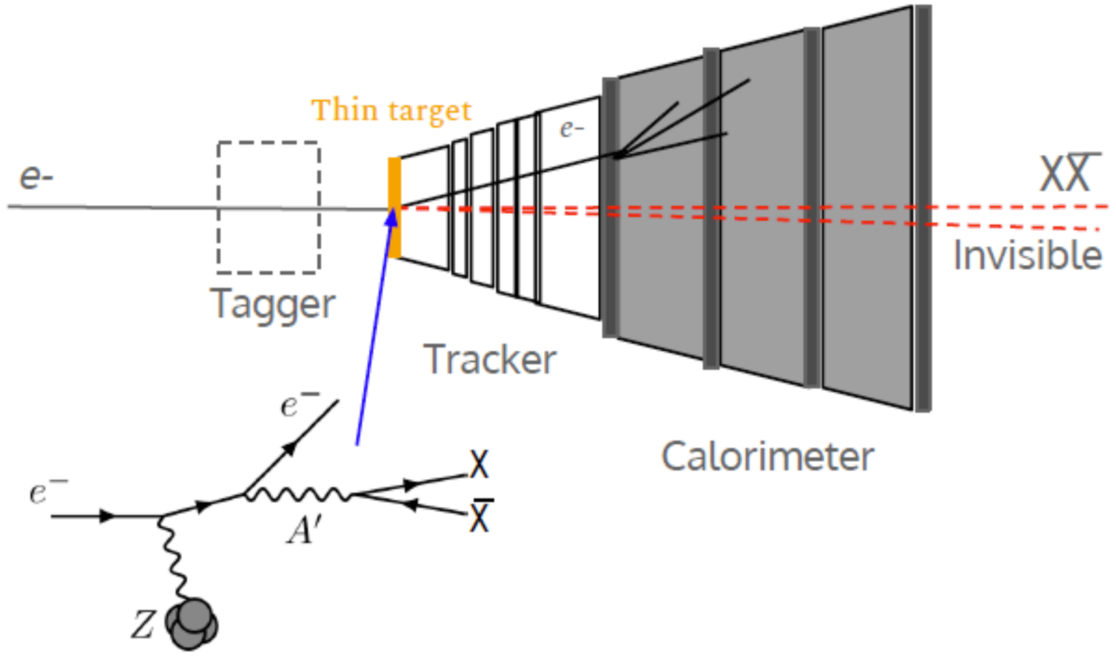
Missing energy/momentum BD experiments



Beam dump



Missing energy/momentum



- Energetic and intense beam
- Massive detector
- More reliable/convincing in case of positive finding

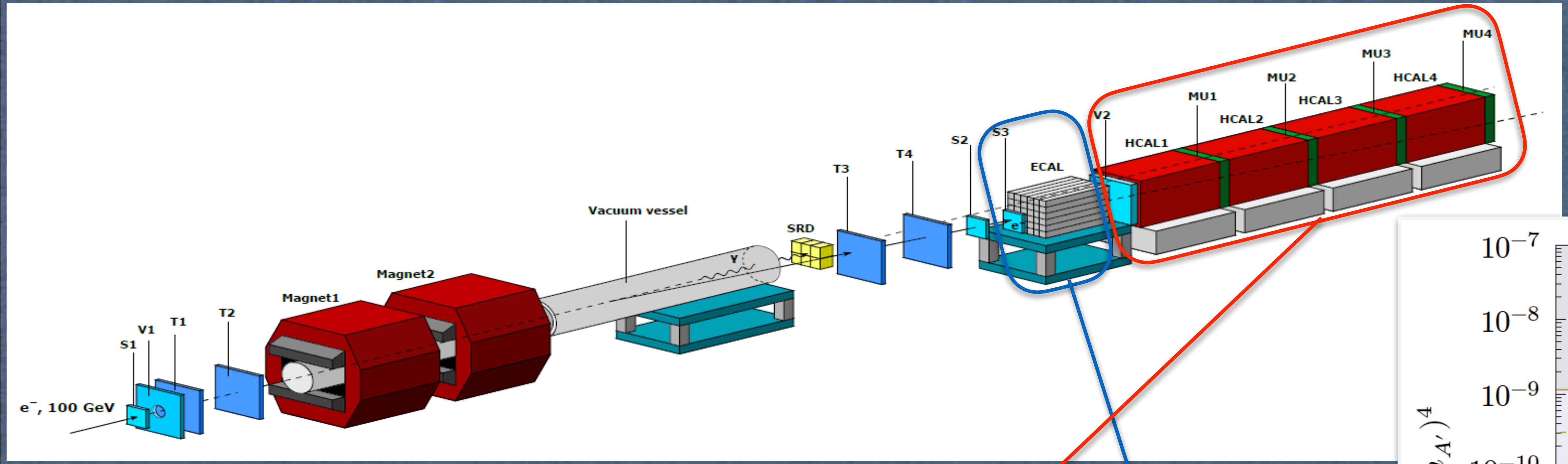
MissingMomentum vs BeamDump (disappearance vs appearance)

- Low pile-up
- High repetition rate
- Fast and sensitive detectors
- More sensitive in the exclusion plot

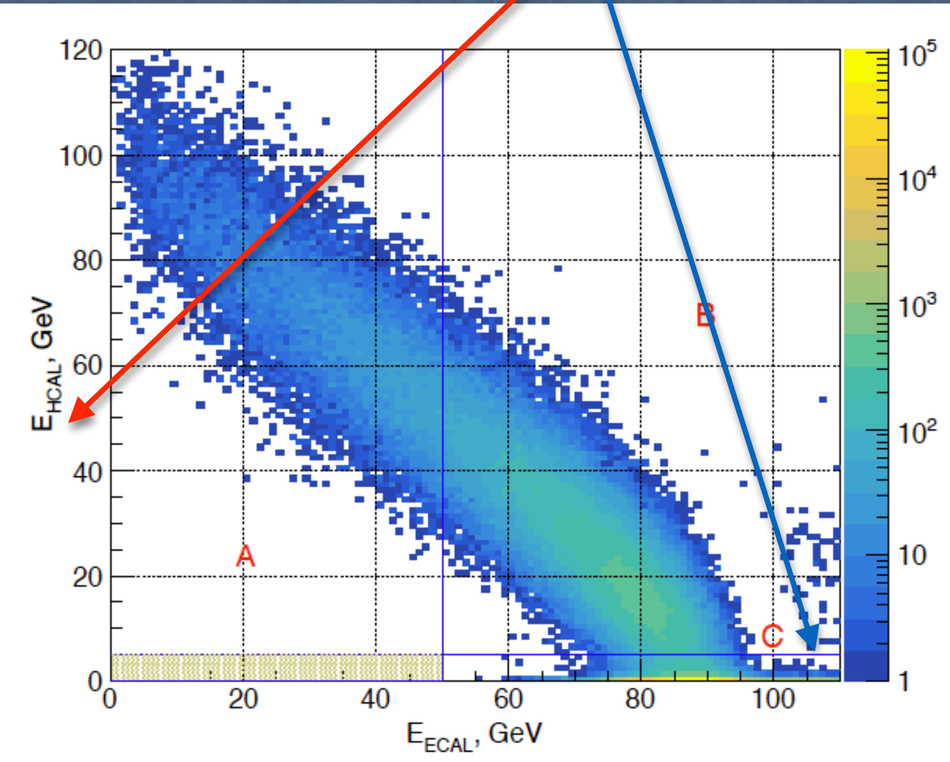
The two experimental approaches are complementary

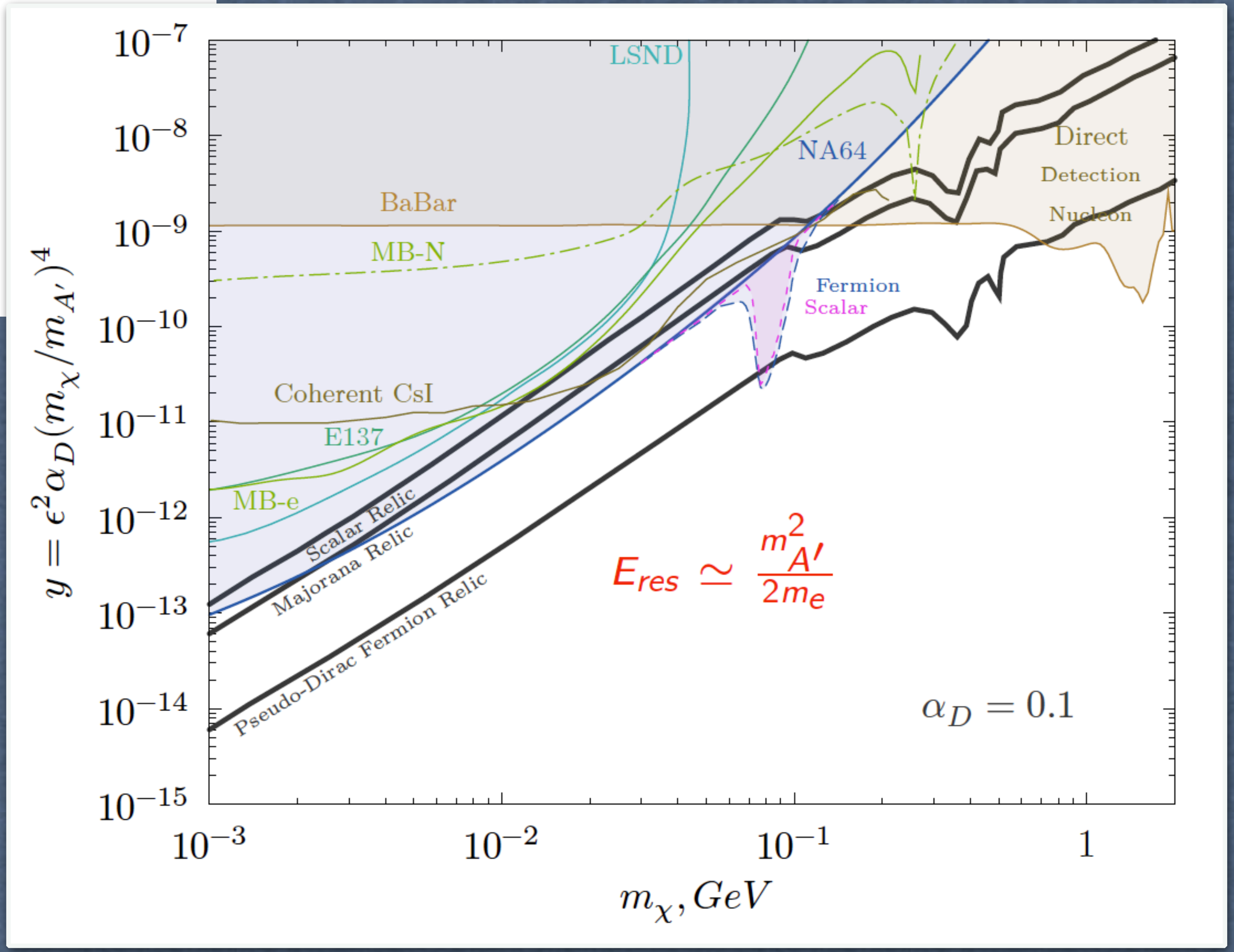
Missing energy/momentum BD experiments

NA64 experiment @ CERN SPS



- *Active* beam-dump experiment
- Missing energy exp (e Z → e Z' A' with A' → invisible)
- Operates at H4 beam line with100 GeV SPS electron beam at SPS
- Active target (calorimeter)
- Exclusion plots based on 10^{12} EOT

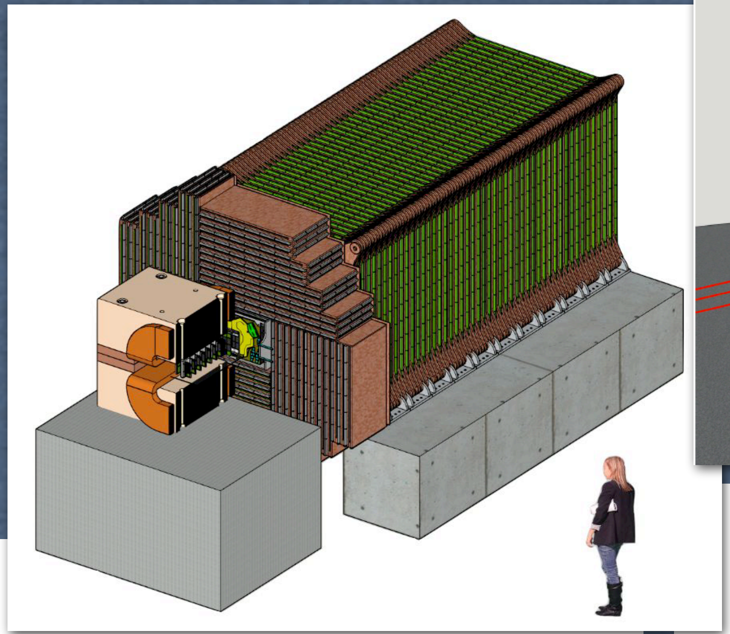


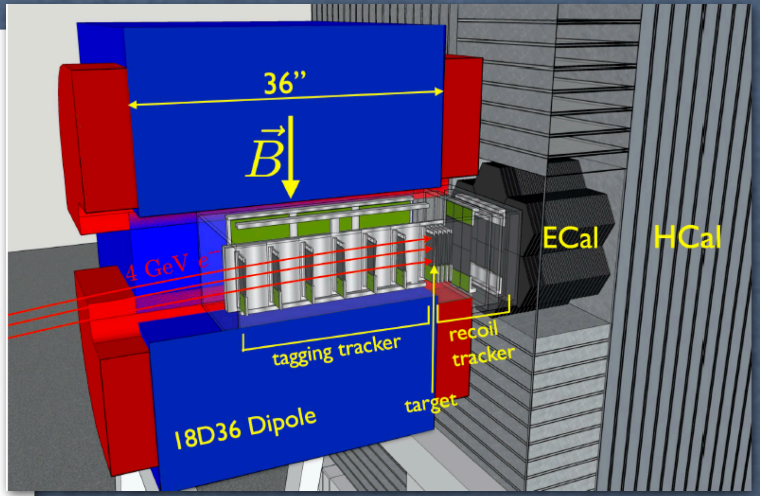


Missing energy/momentum BD experiments

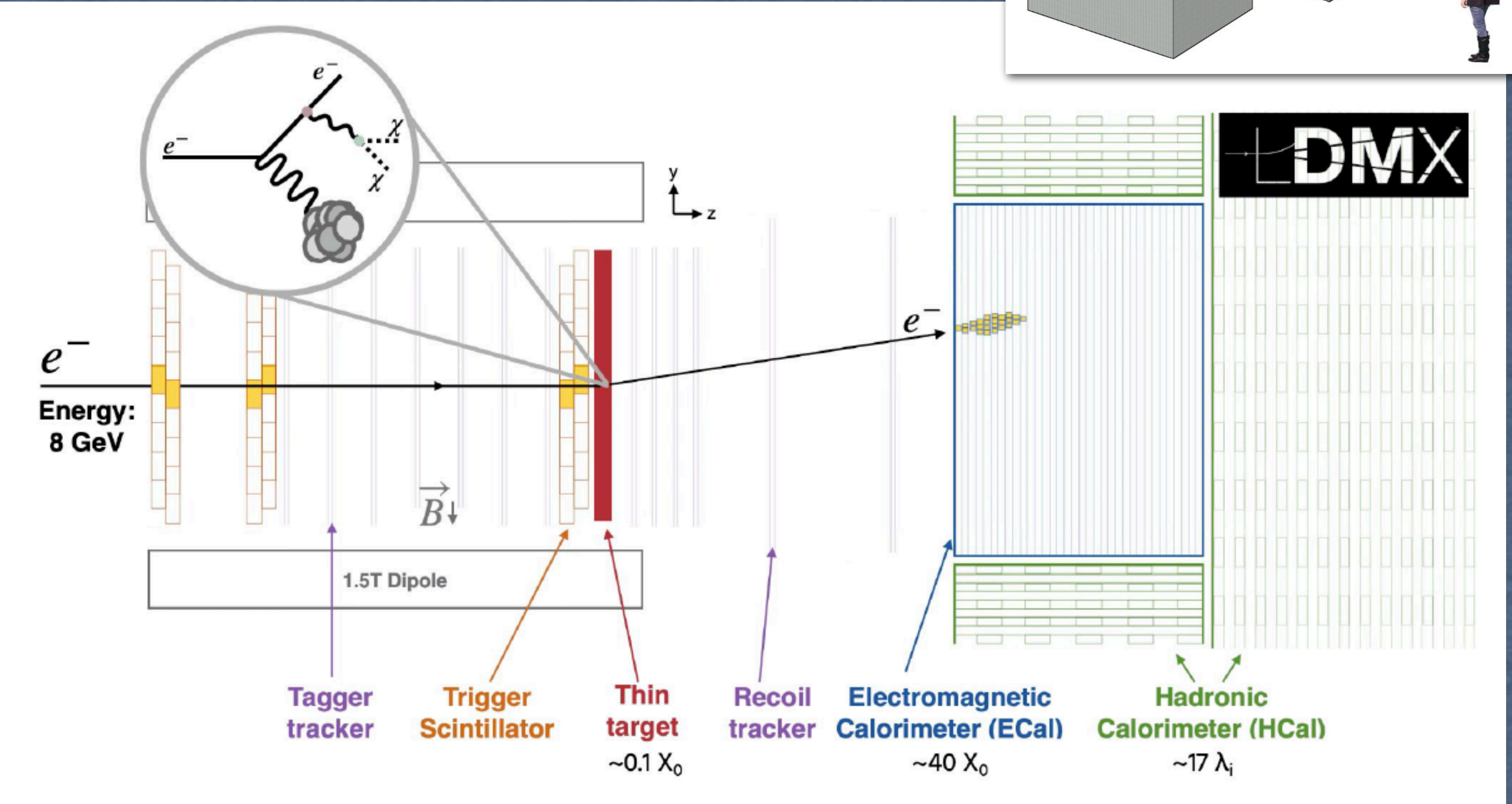
LDMX experiment @ SLAC (future)

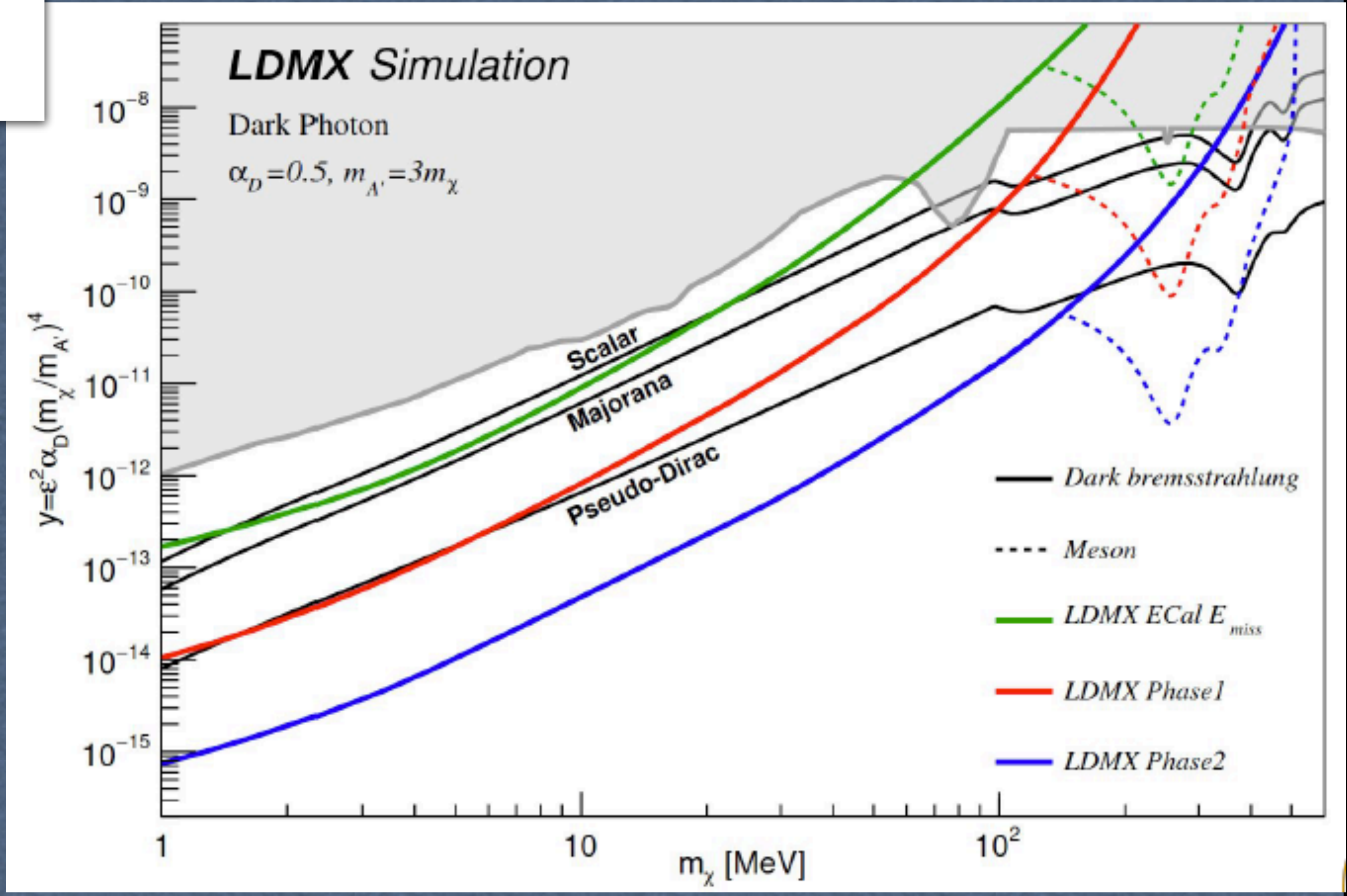
- Missing momentum and energy experiment
- Incoming electron is tagged
- Outcoming electron p is measured in the recoil tracker
- Outcoming electron energy measured by EMCal
- (neutral) hadrons measured in HCal





- Experimental technique will be tested with LDMAX Phase I (1e- / 25ns @ 4GeV)
- Final reach (ultimate) LDMX Phase II (1e- / 1ns @ 8GeV)





e^+ annihilation on fixed (thick) target

invisible

JPOS

Snowmass 2021

Light dark matter searches with positrons

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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.

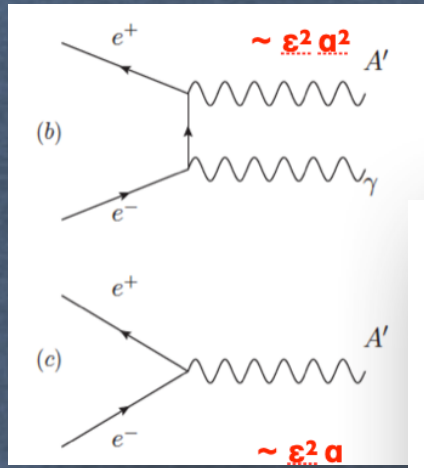
Introduction

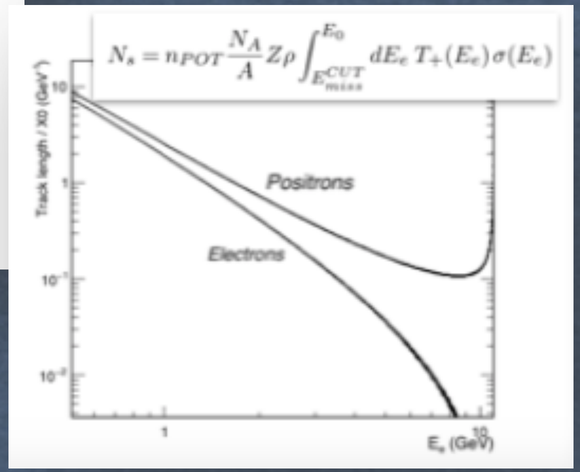
In recent years, a novel hypothesis for the nature of dark matter (DM) has been introduced. It predicts the existence of **light dark matter** (LDM) particles, with sub-GeV mass, interacting with standard model (SM) states through a new force. The simplest such model predicts LDM particles (denoted χ) 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 $m_{DM} < m_{MED}$.

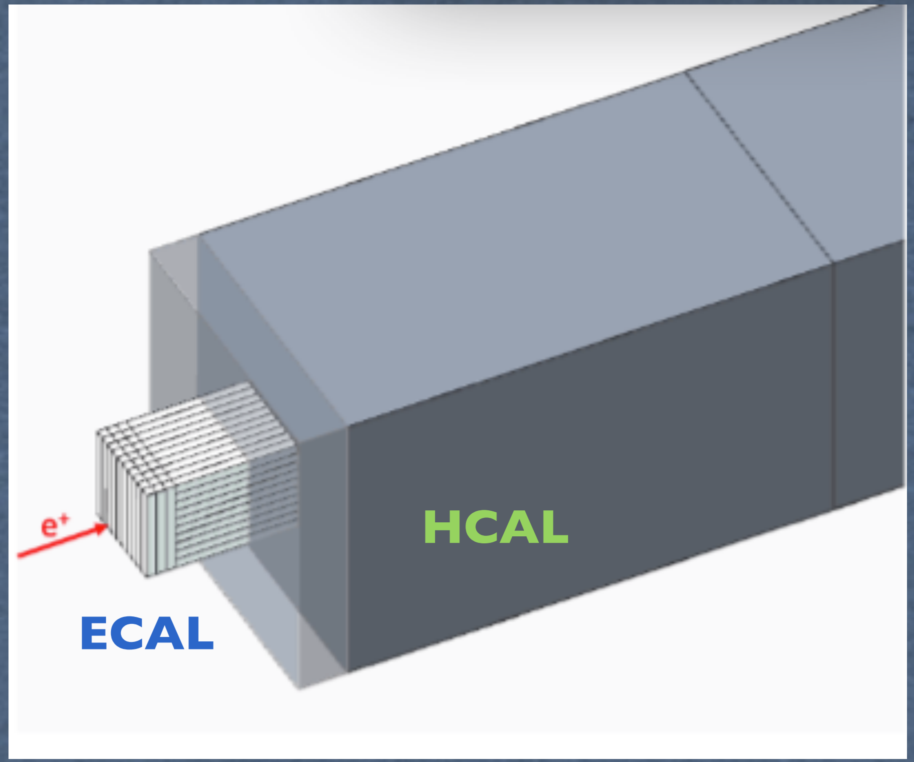
Fig. 1. Three different A' production modes in fixed-target lepton beam experiments: (a) A'-strahlung in e^-/e^+-nucleon scattering; (b) A'-strahlung in e^+e^- annihilation; (c) resonant A' production in e^+e^- annihilation.

Dark sector searches with positron beams on fixed targets

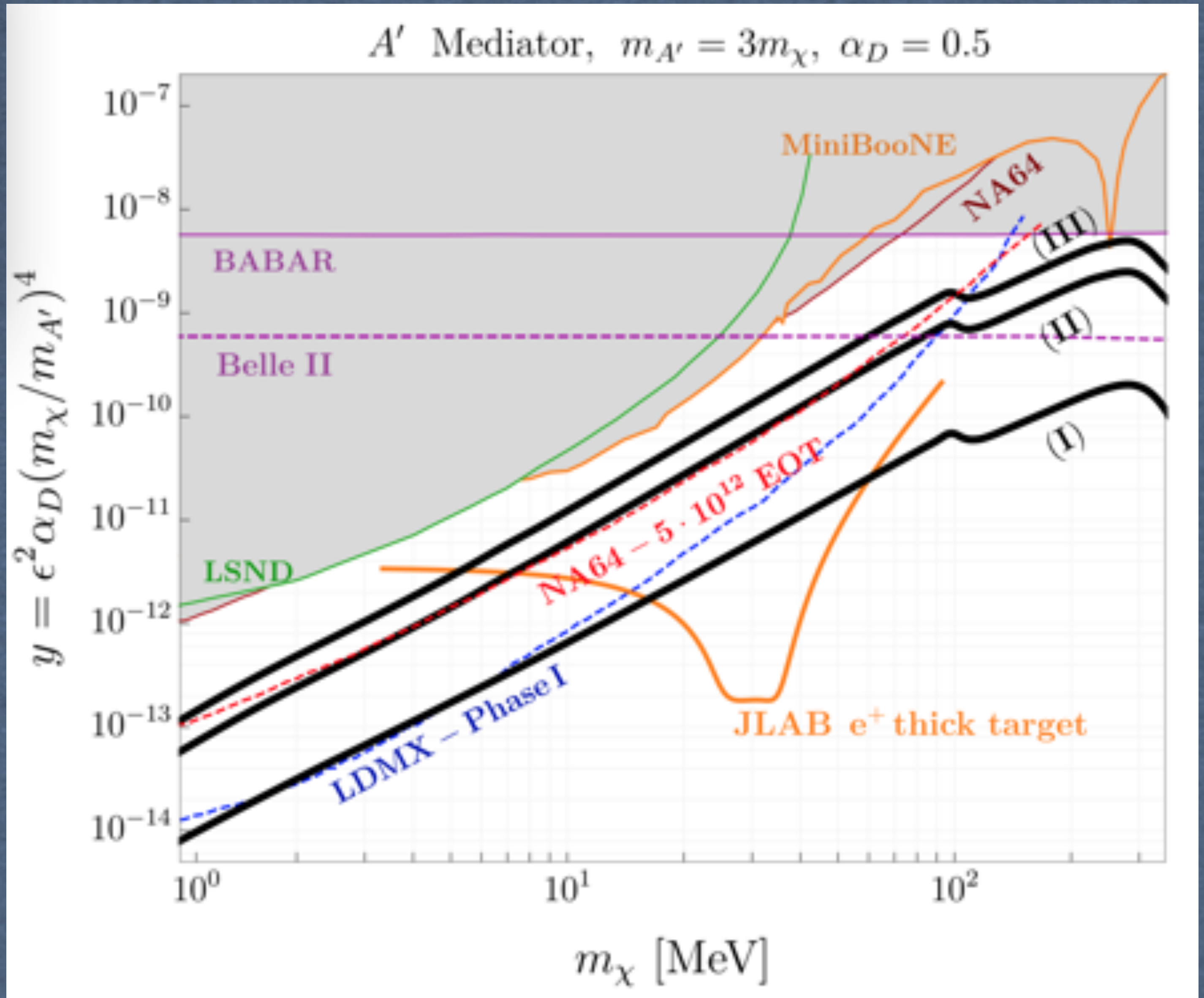
LDM particles can be produced in collisions of electrons or positrons of several GeV with a fixed target by the processes depicted in Fig. 1, with the final state A' decaying to a $\chi\overline{\chi}$ pair. For experiments with electron beams, diagram (a), analogous to ordinary photon bremsstrahlung, 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





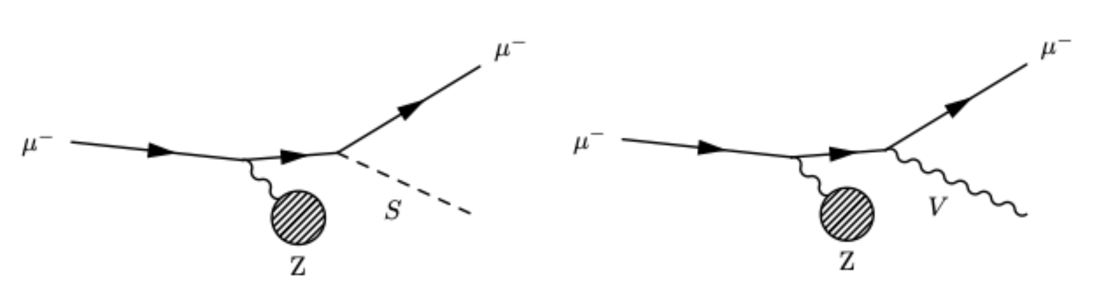


- *Active* beam-dump experiment (*á la* NA64 but with positron!)
- Clear signal (peak!) due to the annihilation: $M_{A'}$ = Sqrt(2 m_e E_{miss})
- Missing energy exp (e+ Z → e+ Z' A' with A' → invisible)
- 11 e+ beam, low current
- Active target (calorimeter)
- Exclusion plots based on 10^{13} POT
-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



Probing muon-philic forces with secondary muon beam

- Goal: extending LDM searches to muon-philic scenarios requires intense muon beams

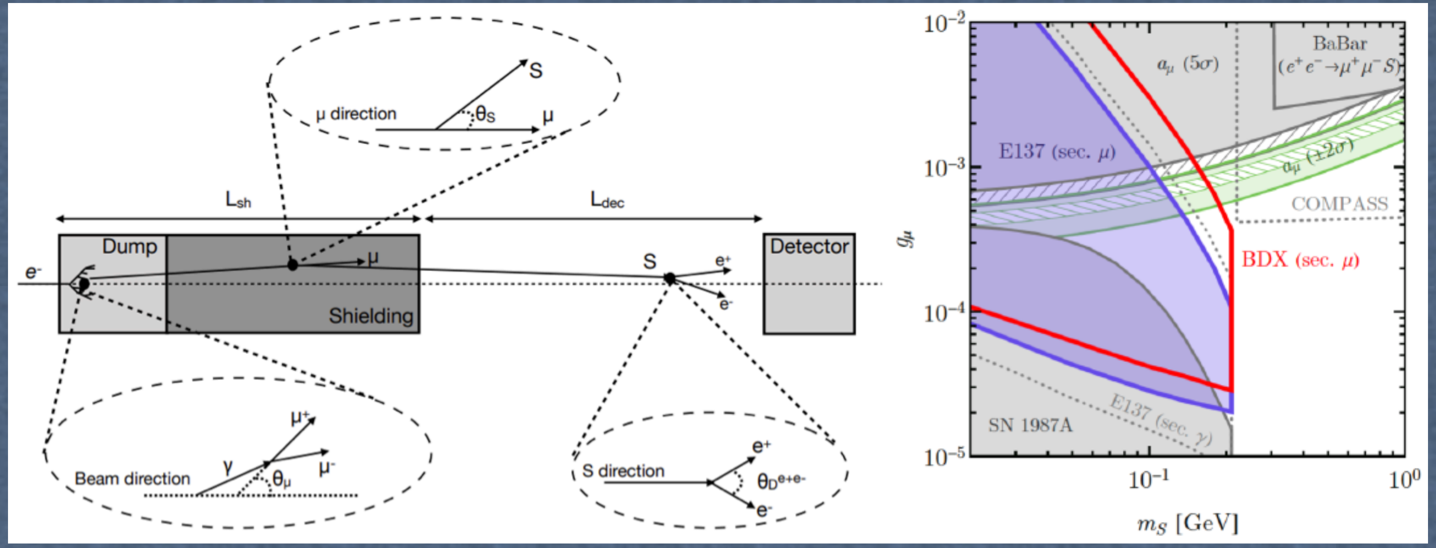


- VECTOR or SCALAR mediator produced with a similar mechanism of A'

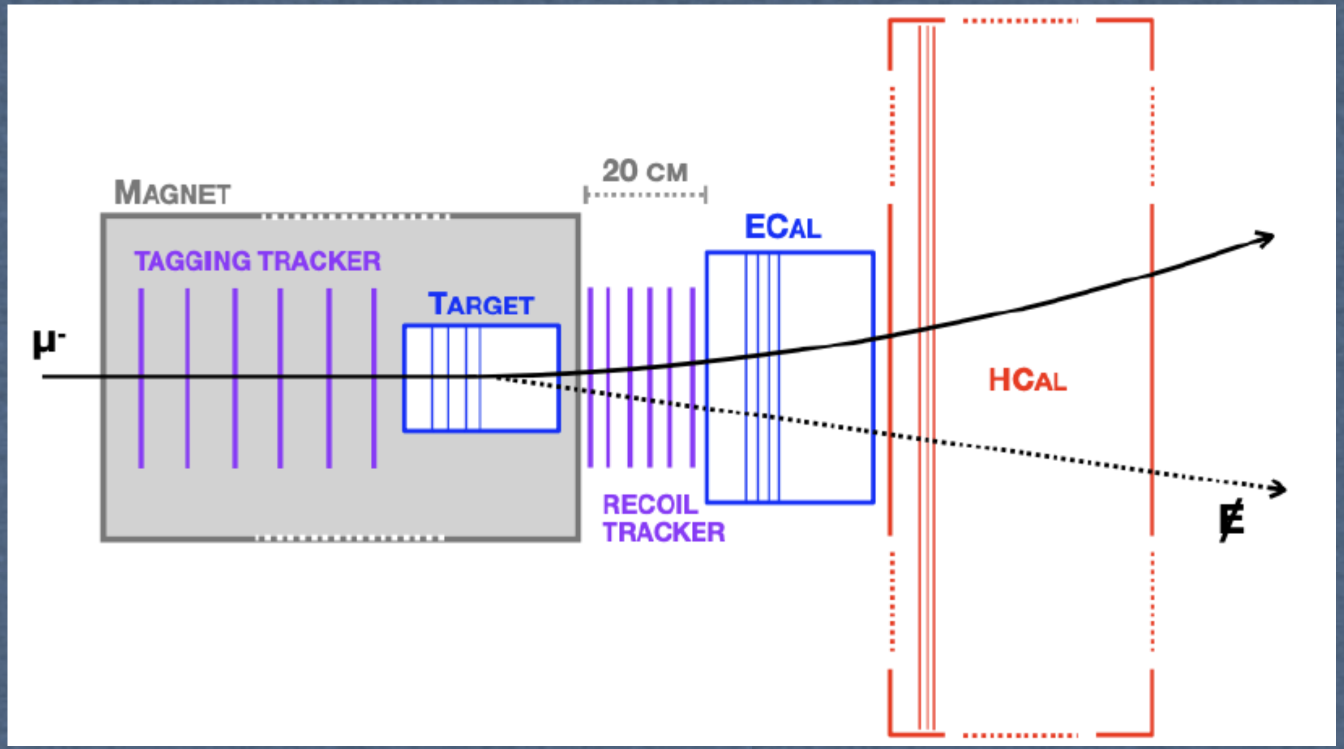
μBDX @ JLab

- 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)

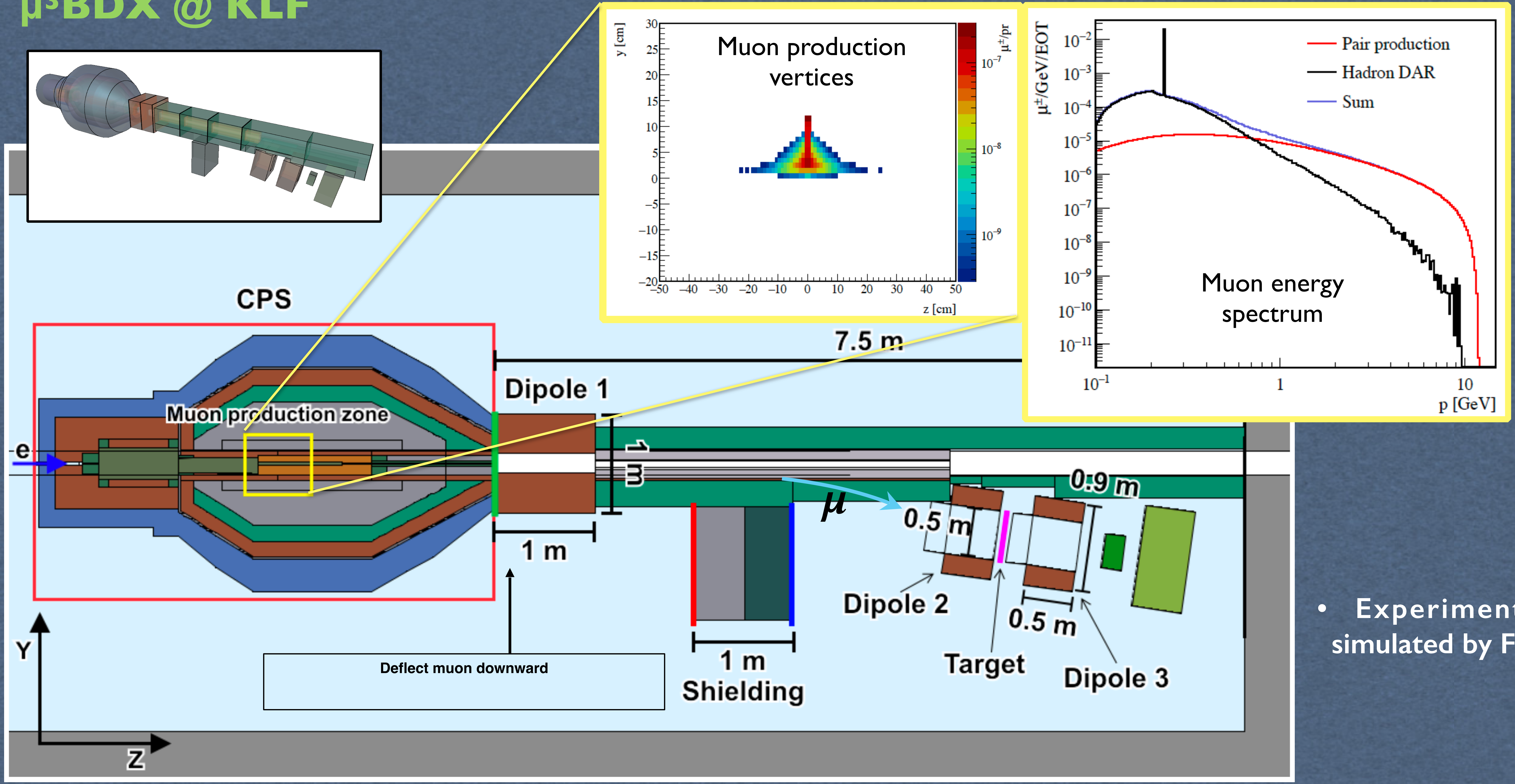


Muon Missing Momentum (μ³BDX @ JLab)



- 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 M³ experiment proposed at FERMILAB
  - PROS: Bremsstrahlung backgrounds suppressed, compact experiment, high precision (magnetic spectrometer)
  - CONS: requires a intense high-energy muon beam

μ³BDX @ KLF

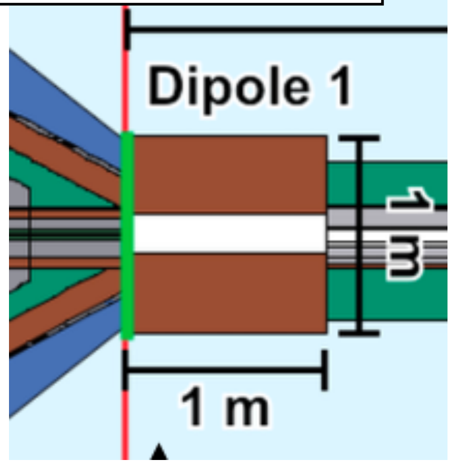


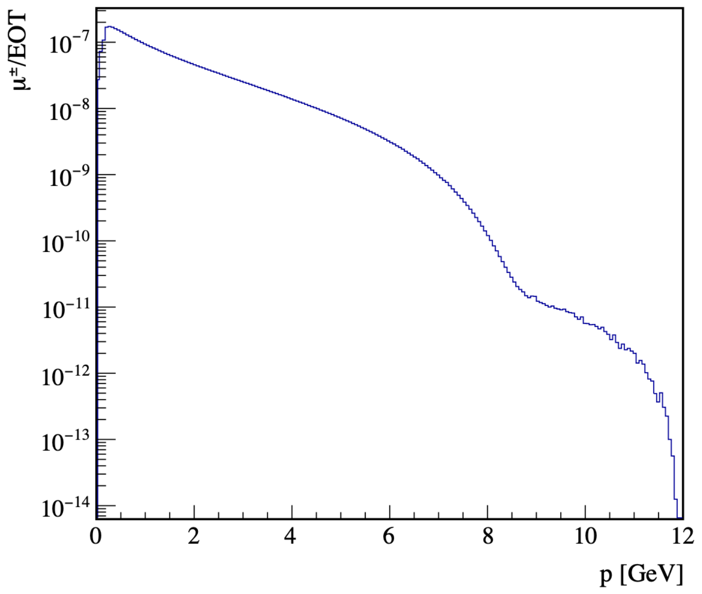
- Experimental setup simulated by FLUKA

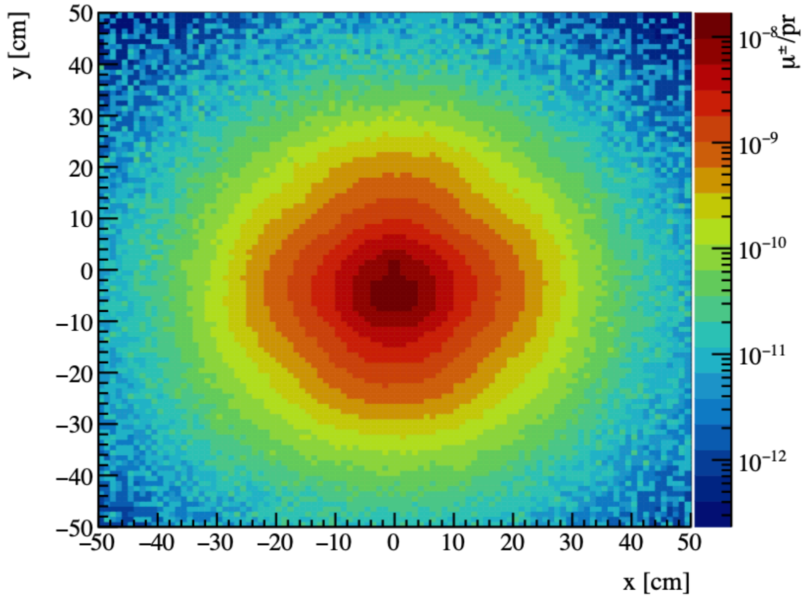
μ³BDX @ KLF

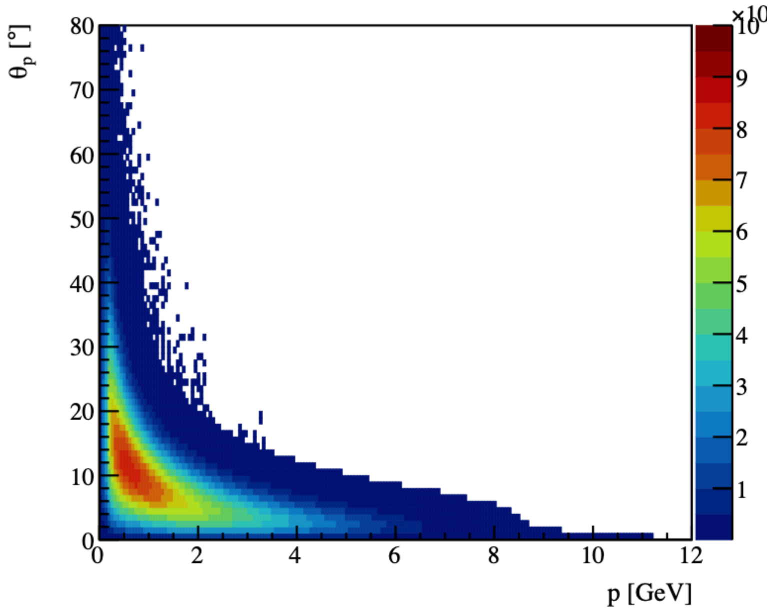
Element		Material	Dimension (x, y, z) [cm]	Magnetic field (B_x, B_y, B_z) [T]
Dipole 1	Yoke	Iron	92, 100, 100	0, 0, 0
	Bore	Vacuum	10, 20, 100	2, 0, 0
Dipole 2	Yoke	Iron	80, 90, 50	0, 0, 0
	Bore	Vacuum	20, 50, 50	−2, 0, 0
Dipole 3	Yoke	Iron	80, 90, 50	0, 0, 0
	Bore	Vacuum	20, 50, 50	2, 0, 0
Shielding	1st half	Lead	100, 114, 50	0, 0, 0
	2nd half	Concrete	100, 114, 50	0, 0, 0

- Muon flux downstream of Dipole 1

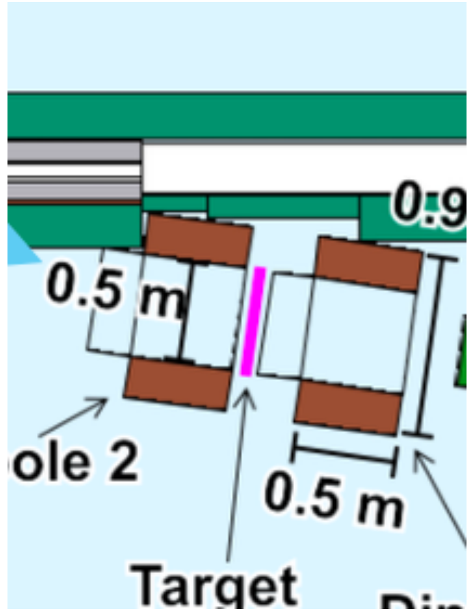


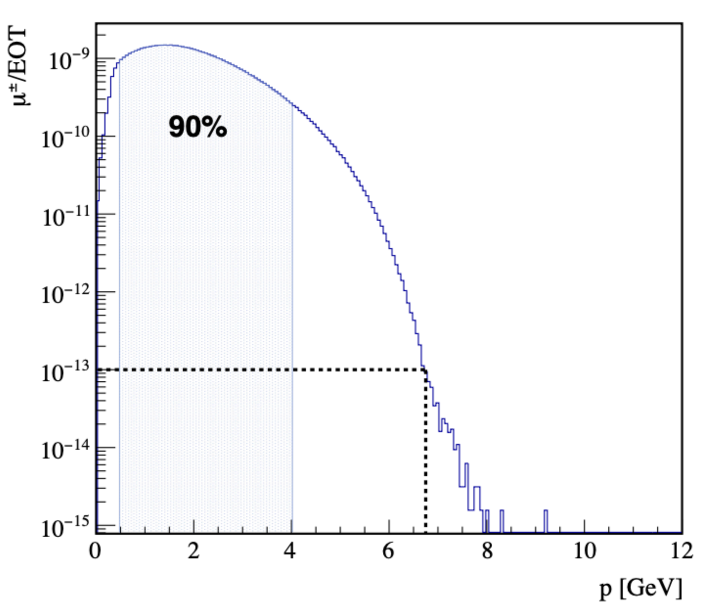


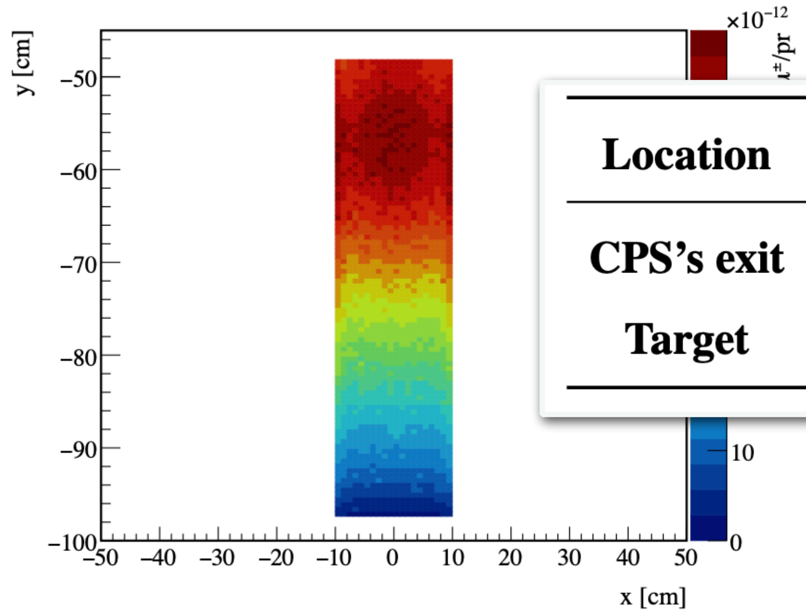




- Muon flux at the target position





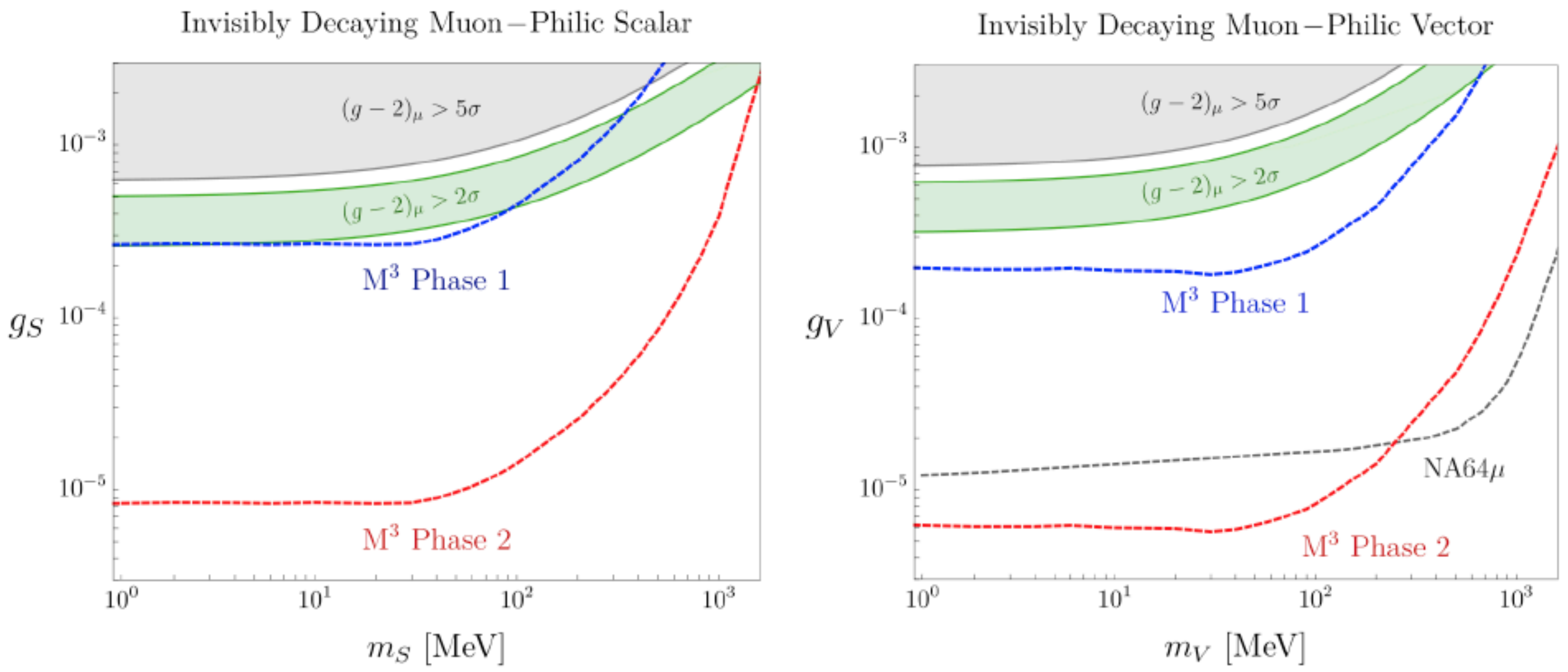


Location	Flux μ/s	σ_x (cm)	σ_y (cm)
CPS's exit	6.75×10^7	7.80	8.09
Target	$\sim 10^4$	$I_e = 2.7$uA	

μ³BDX @ KLF

- Mu
  Dip

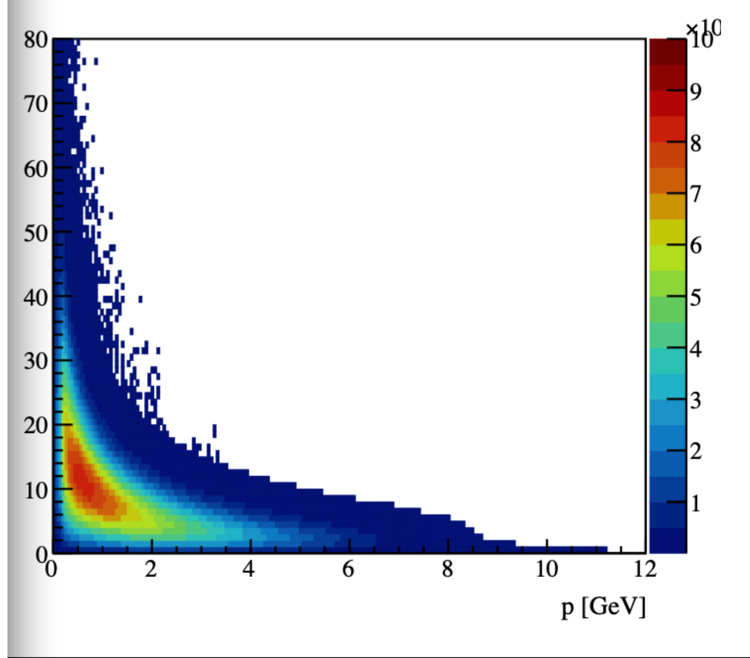
- Mu
  the
  pos



- muon beam $\sim$ 15 GeV
- Phase 1: 10^{10} MOT
- Phase 2: 10^{13} MOT

Similar M3@FNAL PhaseI MOT in 2 weeks of run!

(Phase II in ~3 years (with optimization))

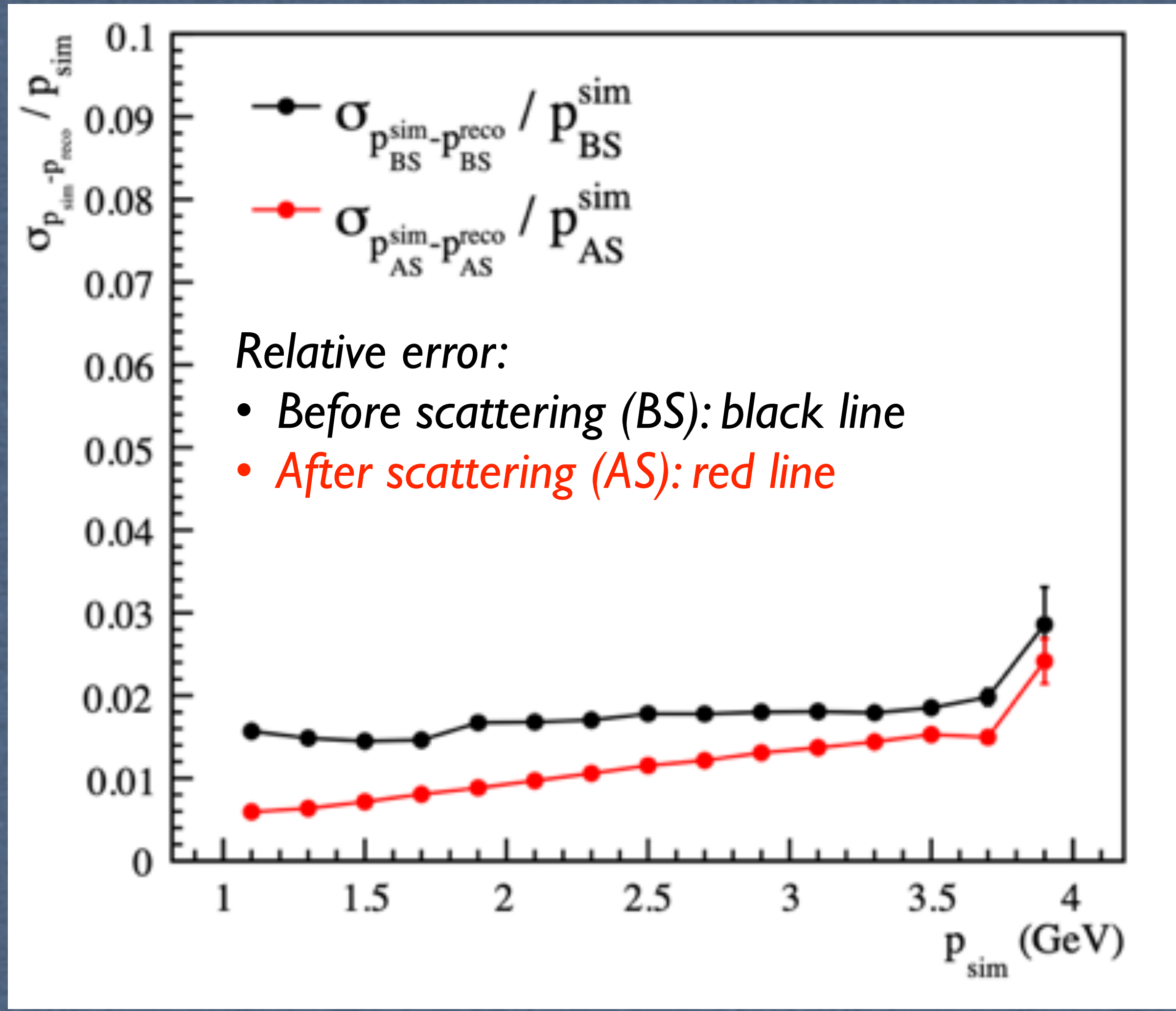


n	Flux μ/s	σ_x (cm)	σ_y (cm)
it	6.75×10^7	7.80	8.09
	$\sim 10^4$	$I_e = 2.7$uA	

μ^3BDX @ KLF

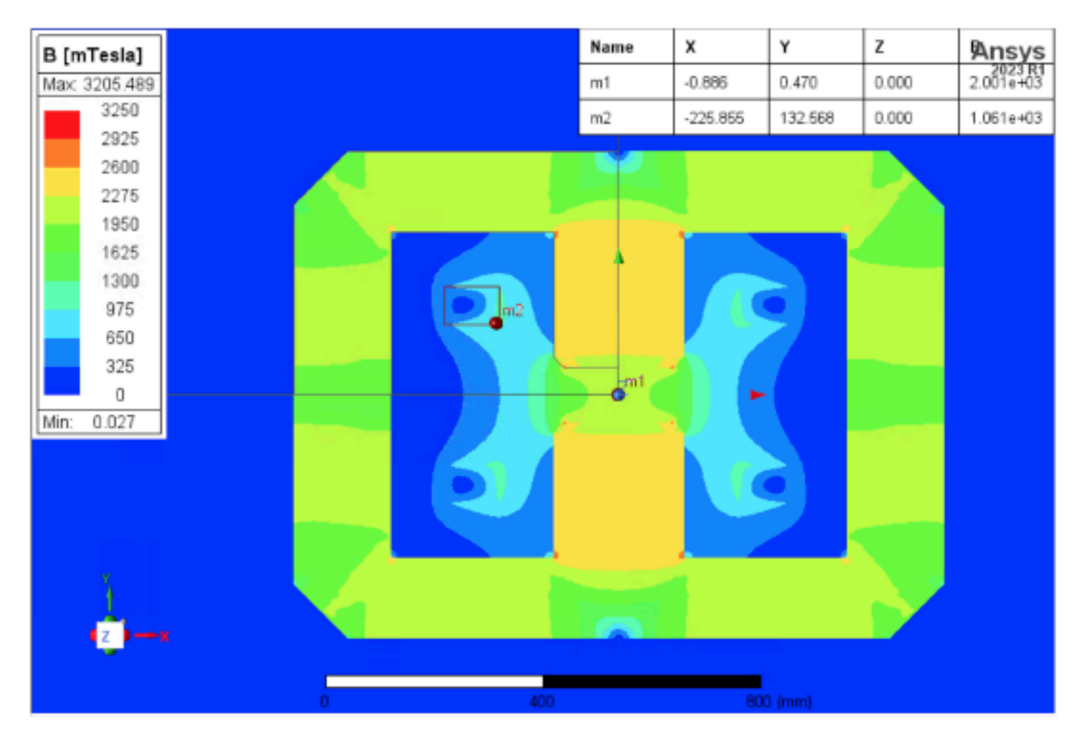
Assumptions

- No dead time between hits on the flux detectors, perfect particle Id
- The magnetic field of the dipoles is ideal (2 T on the axes)
- Tracking planes at the entrance of each dipole are separated by 20 cm
- Tracker resolution:
  - δX and δY: 75 μm
  - δZ: 250 μm
- Cut on incoming particles: 1 GeV < p_μ < 4 GeV



Realistic Magnet design

- 2 windings , 40 turns each with I=5kA
- The field at the center is ~1.95T, ITot=of 400 kA for each coil.



Results:

- **Momentum error < 5% for 1 < p_μ < 4 GeV**
- Error increases with momentum:
  - Higher pμ → smaller dipole displacement
  - Arc reconstruction in yz-plane worsens
  - Momentum measurement becomes less precise

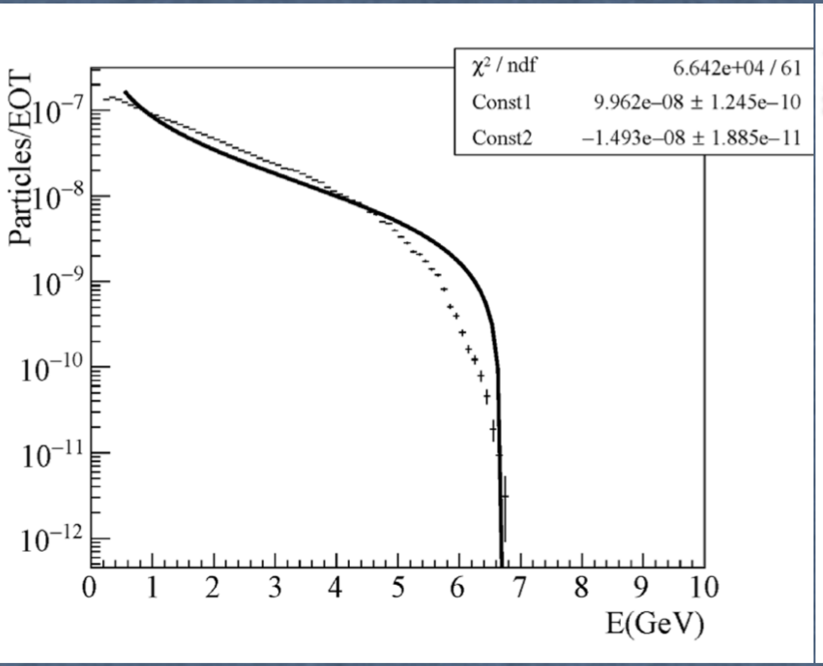
μ^3@KLF measurement would be sensitive to a missing momentum ~5%, down to ~ 50 - 200 MeV/c

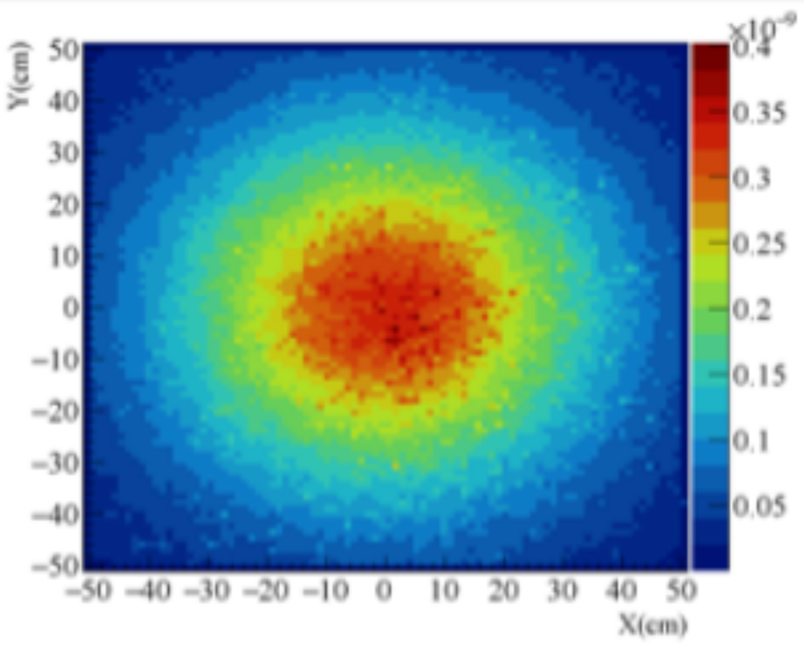
- **Final reach of the experiment (upper limits) in progress**

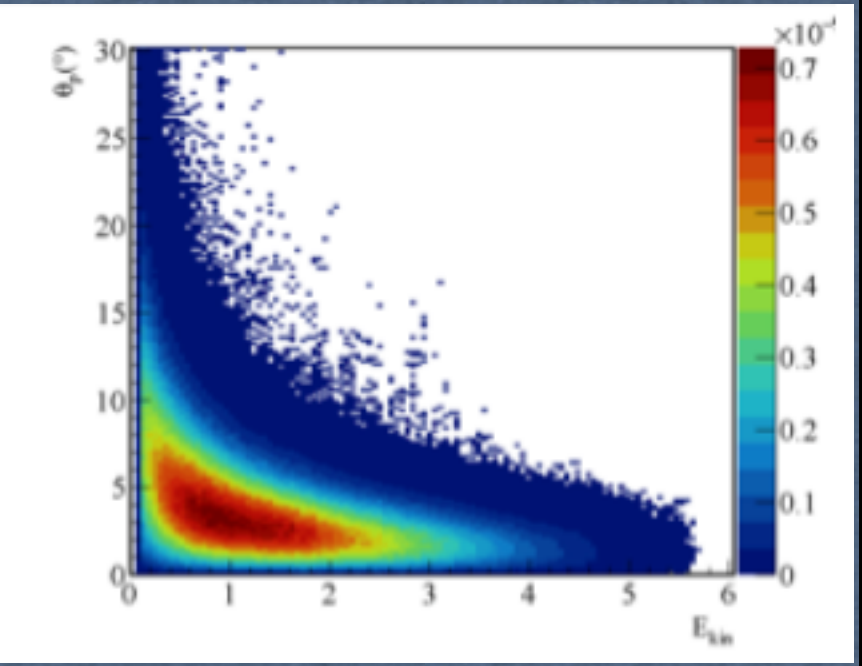
Secondary beams @ JLab (Hall-A BemaDump)

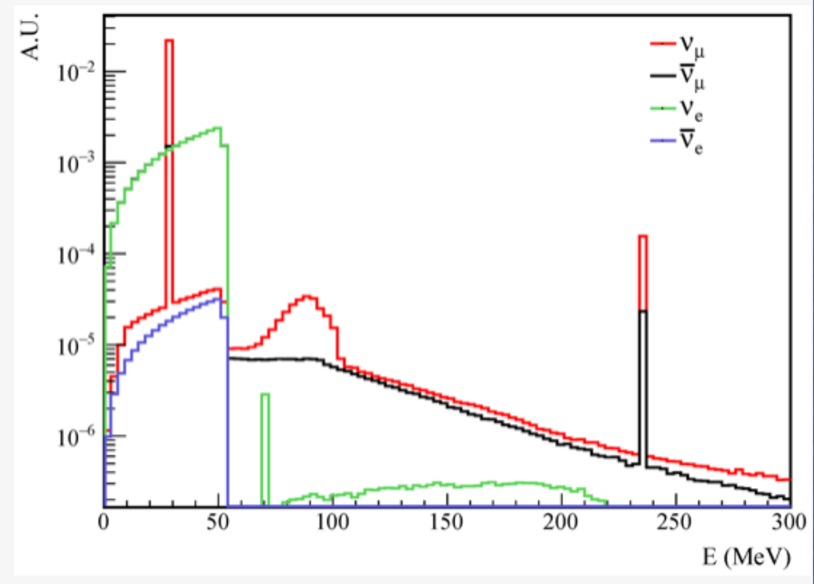
Muon beam

- Flux: 9 10^{-7} μ/EOT (Rate ~ 3 10^{8} μ/s for Ie=50uA)
- Up to 6 GeV, Bremms.-like E spectrum
- 20x20 cm2 beam spot







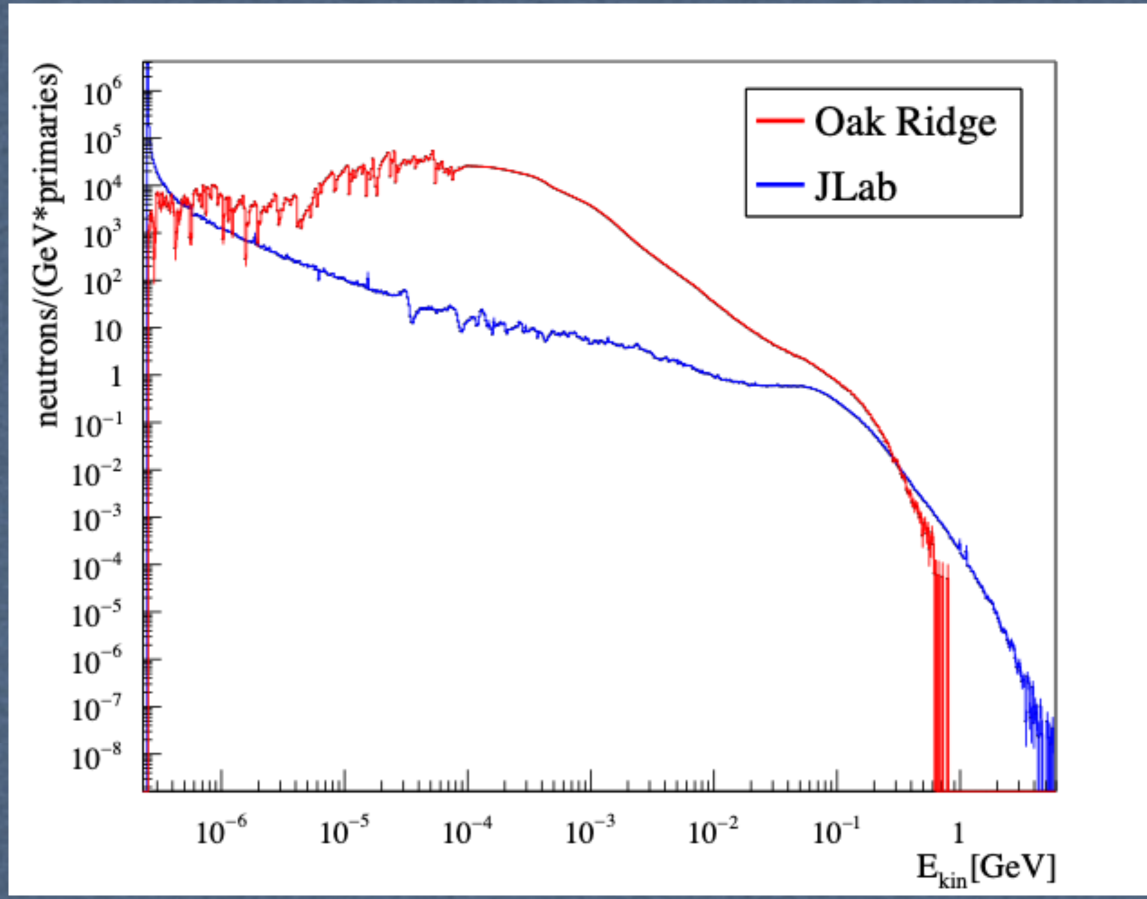


Neutrino beam

- Flux: 3 10^{17} ν/m²/year (1 year corresponding to 10^{22} EOT)
- Decay-At-Rest energy spectrum (0-50 MeV)

Neutron beam

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



BDX & beyond

Goal

explore opportunities offered by secondary beams at Jefferson Lab to leveraging BDX infrastructures

Format

sharing thoughts and ideas on muon, neutrino, neutron and LDM beams @ JLab

Program

two days of presentations, discussion time, flash talks

(Expected) outcome

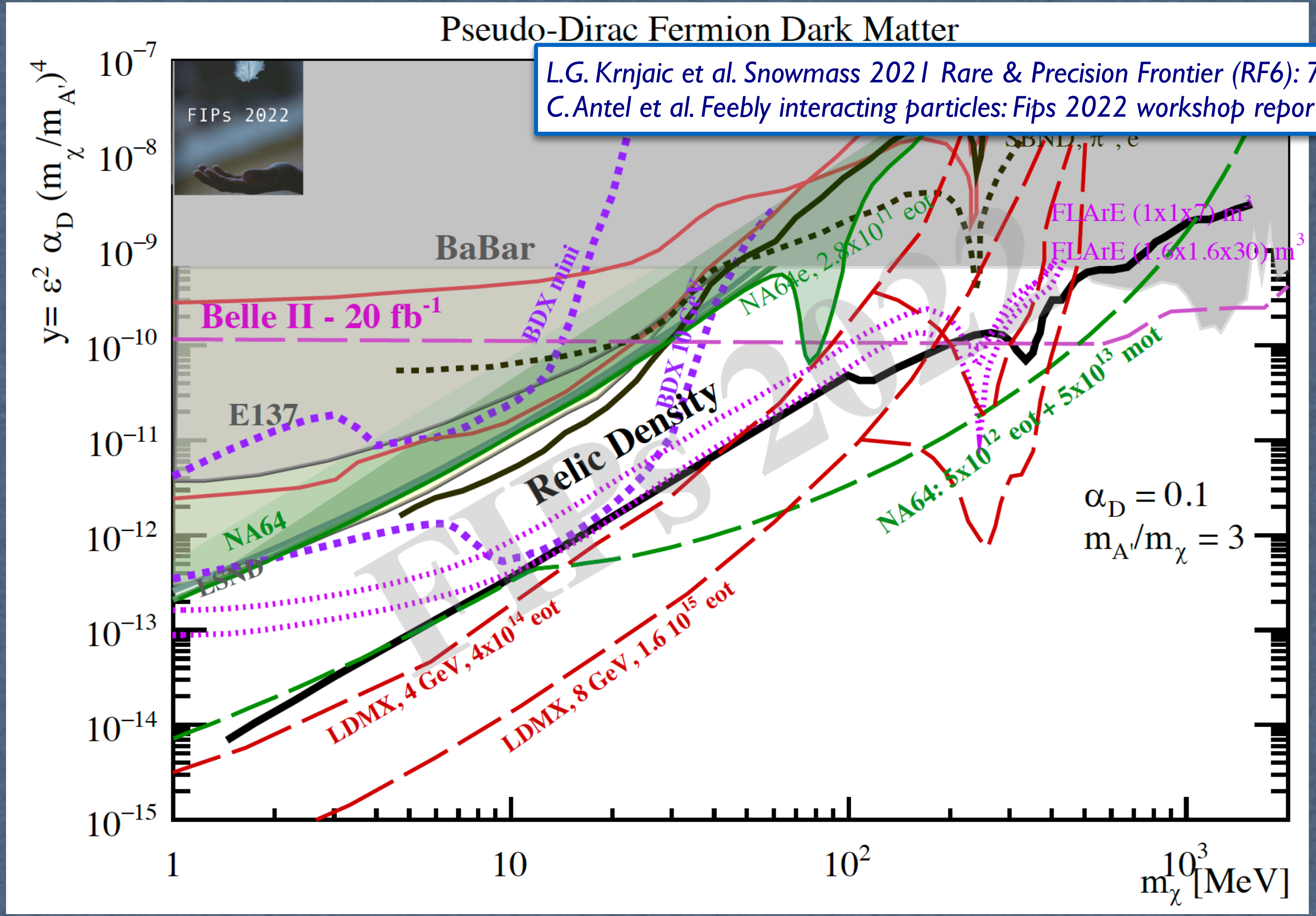
to build a new user community e deliver soon after a white paper with results of the brainstorming

Opportunities with secondary beams

- muons (published https://doi.org/10.3390/instruments8010001)
- neutrinos (published https://doi.org/10.3390/instruments8010001)
- neutrons (paper in preparation)

LDM searches status

Experiment	lab	beam	particle yield/$\mathcal{L}$	technique	portals	timescale
current						
ATLAS [1382]	CERN	pp, 13-14 TeV	up to 3 ab^{-1}	visible, invis.	(1,2,3,4)	2042
Belle II [1219]	KEK	e^+e^-, 11 GeV	up to 50 ab^{-1}	visible, invis.	(1,2,3,4)	2035
CMS [1383]	CERN	pp, 13-14 TeV	up to 3 ab^{-1}	visible, invis.	(1,2,3,4)	2042
Dark(Spin)Quest [1256]	FNAL	p, 120 GeV	$10^{18} \to 10^{20}$	visible	(1,2,3,4)	2024
FASER [1052]	CERN	pp, 14 TeV	150 fb^{-1}	visible	(1,2,3,4)	2025
LHCb [1384]	LHC	pp, 13-14 TeV	up to 300 fb^{-1}	visible	(1,2,3,4)	2042
MicroBooNE [1385]	FNAL	p, 120 GeV (NuMi)	$\sim 7 \times 10^{20}$ pot	visible	(2,4)	2015-2021
NA62 [1174]	CERN	K^+, 75 GeV	a few 10^{13} K decays	visible, invis.	(1,2,3,4)	2025
NA62-dump [1386]	CERN	p, 400 GeV	$\sim 10^{18}$ pot	visible	(1,2,3,4)	2025
NA64$_e$ [1387]	CERN	e^-/e^+, 100 GeV	up to $1 \cdot 10^{13}$ e^-/e^+	$\not{E}$, visible	(1,3)	< 2032
PADME [1300]	LNF	e^+, 550 MeV	$5 \cdot 10^{12}$ e^+ot	missing mass	(1)	< 2023
T2K-ND280 [1388]	JPARC	p, 30 GeV	10^{21} pot	visible	(4)	running
proposed						
BDX [1389]	JLAB	e^-, 11 GeV	$\sim 10^{22}$ eot/year	recoil e	(1,3)	2024-2025
CODEX-b [1030]	CERN	pp, 14 TeV	300 fb^{-1}	visible	(1,2,3,4)	2042
Dark MESA [1390]	Mainz	e^-, 155 MeV	150 μA	visible	(1)	< 2030
FASER2 [1068]	CERN	pp, 14 TeV	3 ab^{-1}	visible	(1,2,3,4)	2042
FLaRE [1068]	CERN	pp, 14 TeV	3 ab^{-1}	visible, recoil	(1)	2042
FORMOSA [1068]	CERN	pp, 14 TeV	3 ab^{-1}	visible	(1)	2042
Gamma Factory [1391]	CERN	photons	up to 10^{25} γ/year	visible	(1,3)	2035-2038?
HIKE-dump [1392, 1191]	CERN	p, 400 GeV	$5 \cdot 10^{19}$ pot	visible	(1,2,3,4)	<2038
HIKE-K$^+$ [1392, 1191]	CERN	K^+, 75 GeV	10^{14} K decays	visible, inv.	(1,2,3,4)	<2038
HIKE-K$_L$ [1392, 1191]	CERN	K_L, 40 GeV	10^{14} K decays	visible, inv.	(1,2,3,4)	<2042
LBND (DUNE) [1393]	FNAL	p, 120 GeV	$\sim 10^{21}$ pot	recoil e, N	(1,2,3,4)	< 2040
LDMX [1271]	SLAC	e^-, 4,8 GeV	$2 \cdot 10^{16}$ eot	$\not{p}$, visible	(1)	< 2030
M^3 [1394]	FNAL	μ, 15 GeV	10^{10} (10^{13}) mot	$\not{p}$	(1)	proposed
MATHUSLA [1395]	CERN	pp, 14 TeV	3 ab^{-1}	visible	(1,2,3,4)	2042
milliQan [1070]	CERN	pp, 14 TeV	0.3-3 ab^{-1}	visible	(1)	< 2032
MoeDAL/MAPP [1396]	CERN	pp, 14 TeV	30 fb^{-1}	visible	(4)	< 2032
Mu3e [1397]	PSI	29 MeV	$10^8 \to 10^{10}$ μ/s	visible	(1)	< 2038?
NA64$_\mu$ [1398]	CERN	μ, 160 GeV	up to 2×10^{13} mot	$\not{p}$	(1)	< 2032
PIONEER [1399]	PSI	55-70 MeV, π^+	$0.3 \cdot 10^6$ π/s	visible	(4)	phase I approved
SBND [1400]	FNAL	p, 8 GeV	$6 \cdot 10^{20}$ pot	recoil Ar	(1)	< 2030
SHADOWS [1401]	CERN	p, 400 GeV	$5 \cdot 10^{19}$ pot	visible	(2,3,4)	<2038
SHiP [1402]	CERN	p, 400 GeV	$2 \cdot 10^{20}$ pot	visible, recoil	(1,2,3,4)	<2038



L.G. Krnjaic et al. Snowmass 2021 Rare & Precision Frontier (RF6): 7 2022
C. Antel et al. Feebly interacting particles: Fips 2022 workshop report, 2023

From CERN-FIPs workshop report, (SNOWMASS22): several experiments planned/proposed (LHC, SLAC, Mainz, FNAL, KEK, PSI, LPARC) with a variety of beams (proton, leptons, photons), energies (from 150 MeV to 14 TeV) and experimental techniques (visible, invisible, recoil, ..) with a timeline that reaches ~2042

Conclusions

- Existence of Dark Matter is a compelling reason to investigate new forces and matter over a broad range of mass
- Accelerator-based (Light)DM search provides unique feature of distinguish DM signal from any other cosmic anomalies or effects (SNOWMASS 2022)
- Pletora of experimental techniques to cover the LDM broad parameter space
- Significant interests from funding agencies (DOE/NSF) and labs (CERN and JLab) to run small scale experiments with a great discovery potential
- Extensive experimental plans at high intensity e-facility to search for LDM: JLab, LNF, Mainz, SLAC (p-beam FNAL and CERN)
- A new generation of dedicated and optimised experiments at high intensity frontier will test the relic (light) dark matter scenarios
- 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 simplest scenarios will possible in the next ~5-8 years!