

Correlations
in Partonic
and
Hadronic
Interactions

CPHI 2018

September 24-28
Yerevan Physics Institute



Accelerator based Dark Matter searches

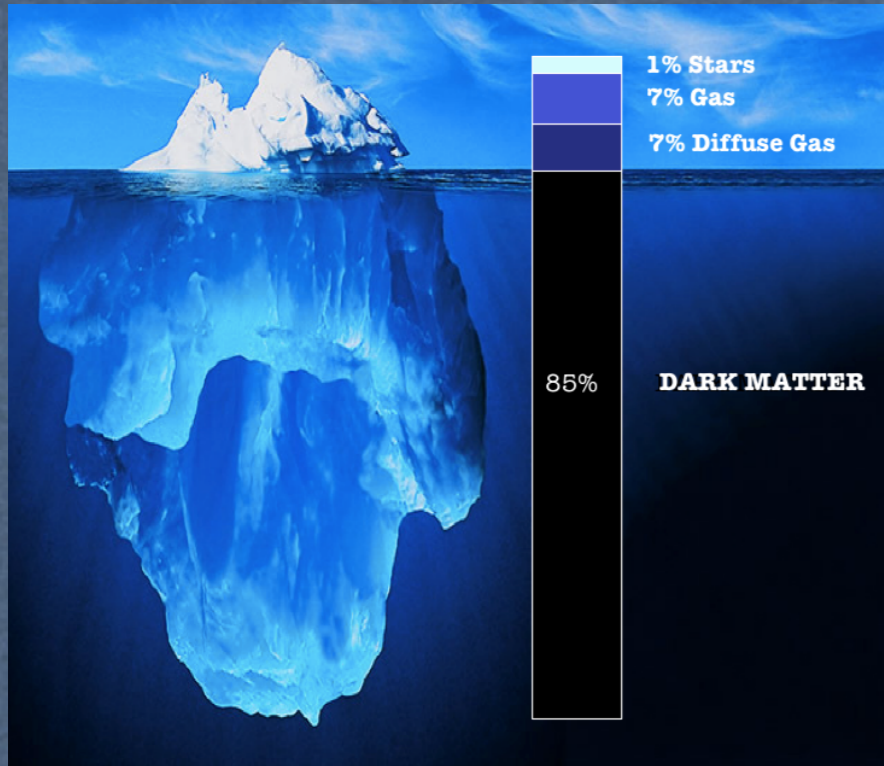
M. Battaglieri
INFN-GE Italy

482580764

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 through the **same forces**
- ★ **New matter** interacting through **new forces**

Any guess about the DM mass and interaction?

Yes, if we do a couple of assumptions:

★ DM thermal origin

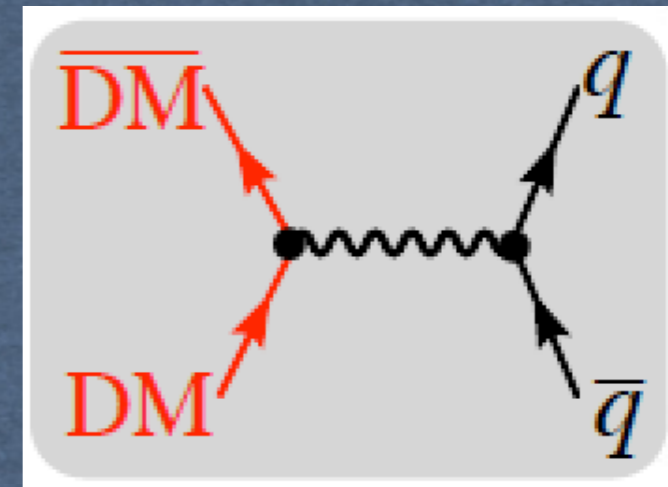
in the early Universe DM was in thermal equilibrium with regular matter (via annihilation)

★ 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:

$$\langle \sigma v \rangle \sim 3 \times 10^{-26} \text{ cm}^3/\text{s} \sim 1/(20 \text{ TeV})^2$$



$$\langle \sigma v \rangle \sim M_{\text{DM}}^2 / M_{\text{mediator}}^4$$

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

$$\sigma_n \sim \frac{\alpha_2^2 \mu_n^2}{m_Z^4} \sim 10^{-38} \text{ cm}^2$$

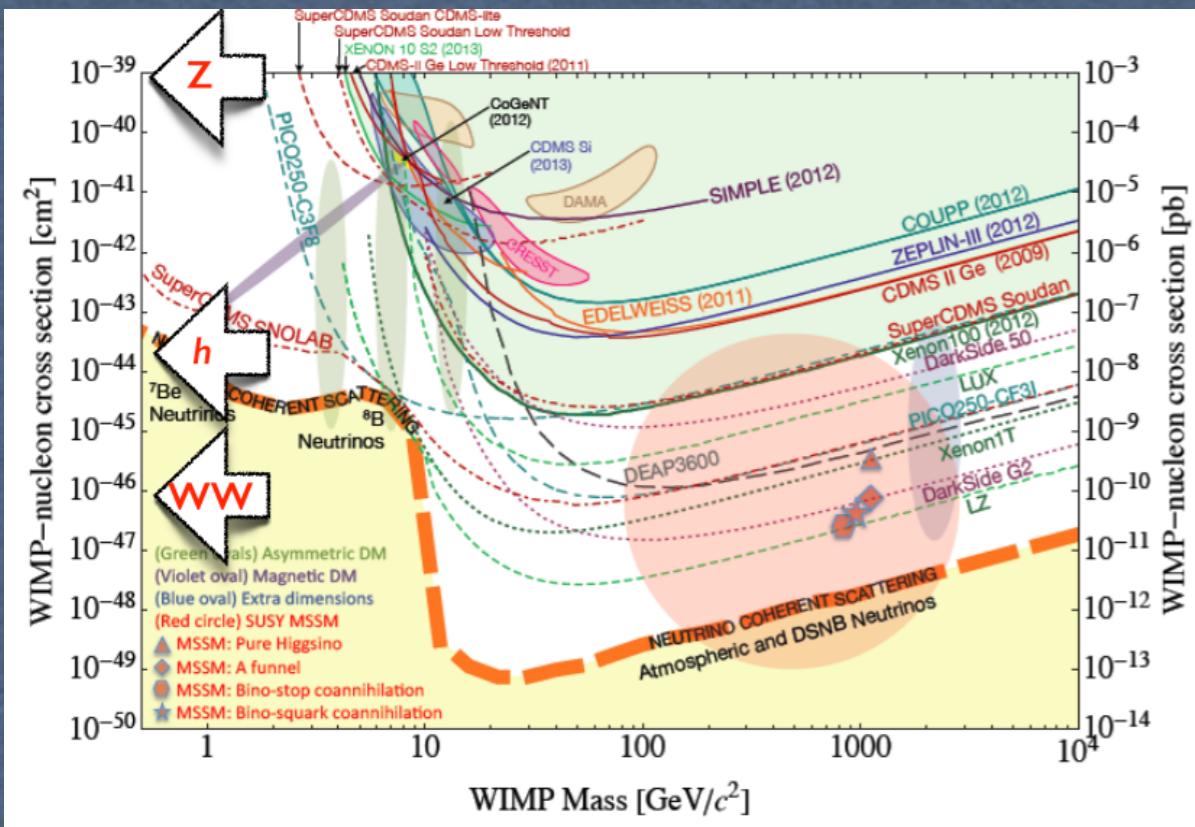
Z exchange

$$\sigma_n \lesssim 10^{-44} \text{ cm}^2$$

Higgs exchange

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 ($\sigma \sim 10^{-39} \text{cm}^2$): ruled out
 - Approaching limits for scattering through the Higgs ($\sigma \sim 10^{-45} \text{cm}^2$)
 - Close to irreducible neutrino background

Direct Detection

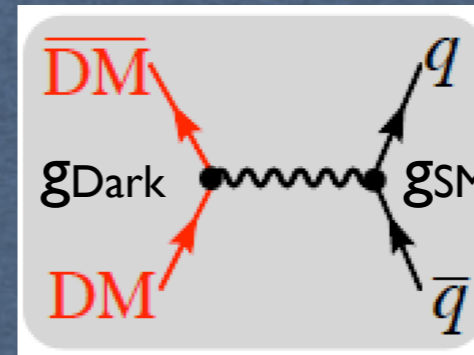


- * No signal in direct detection
- * Experiments have (almost) no sensitivity to (light) DM ($< 1 \text{ GeV}$)

Any guess about the DM mass and interaction?

- ★ (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)



$$\langle \sigma v \rangle \sim g_{\text{Dark}}^2 g_{\text{SM}}^2 \frac{M_{\text{DM}}^2}{M_{\text{mediator}}^4}$$

Light Dark Matter

Light Dark Matter (<TeV) naturally introduces light mediators

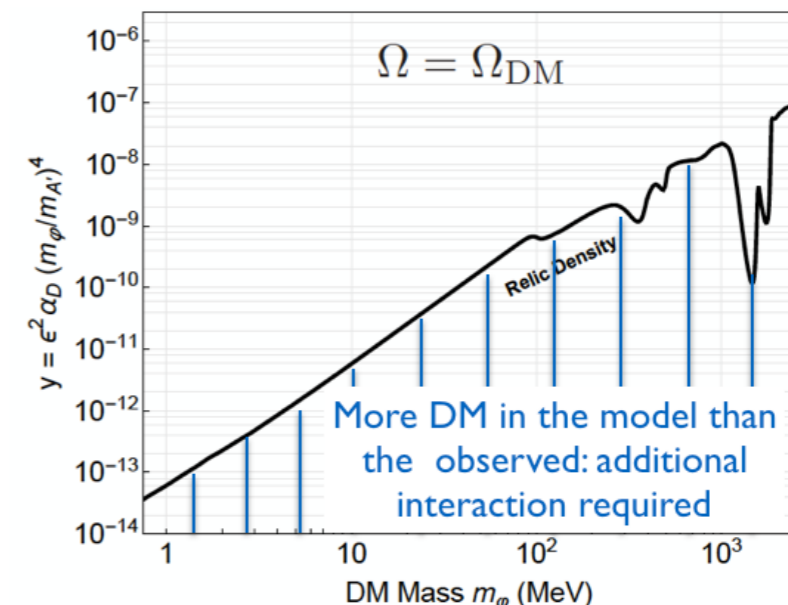
New interaction

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

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

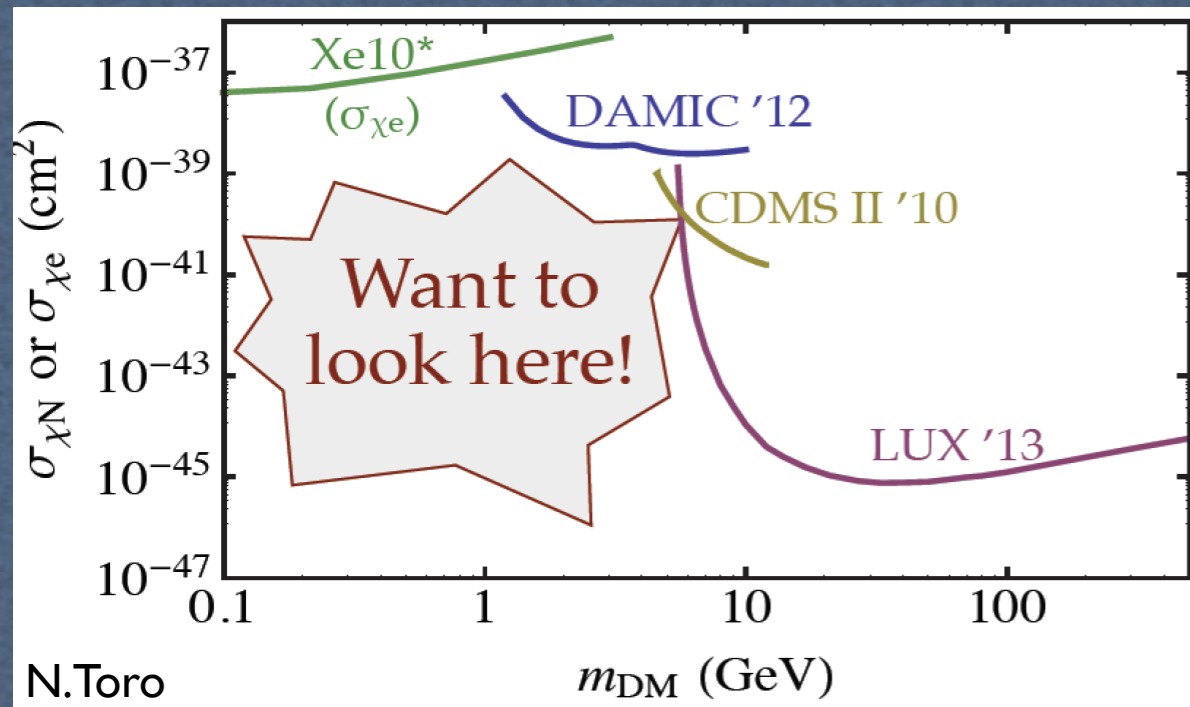
Computed for $m_{A'}/m_{\phi/\chi} = 3$

But thermal target largely insensitive to this ratio



Light Dark Matter

★ Experimental limits



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

- Direct Detection is (almost) impossible
 - 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

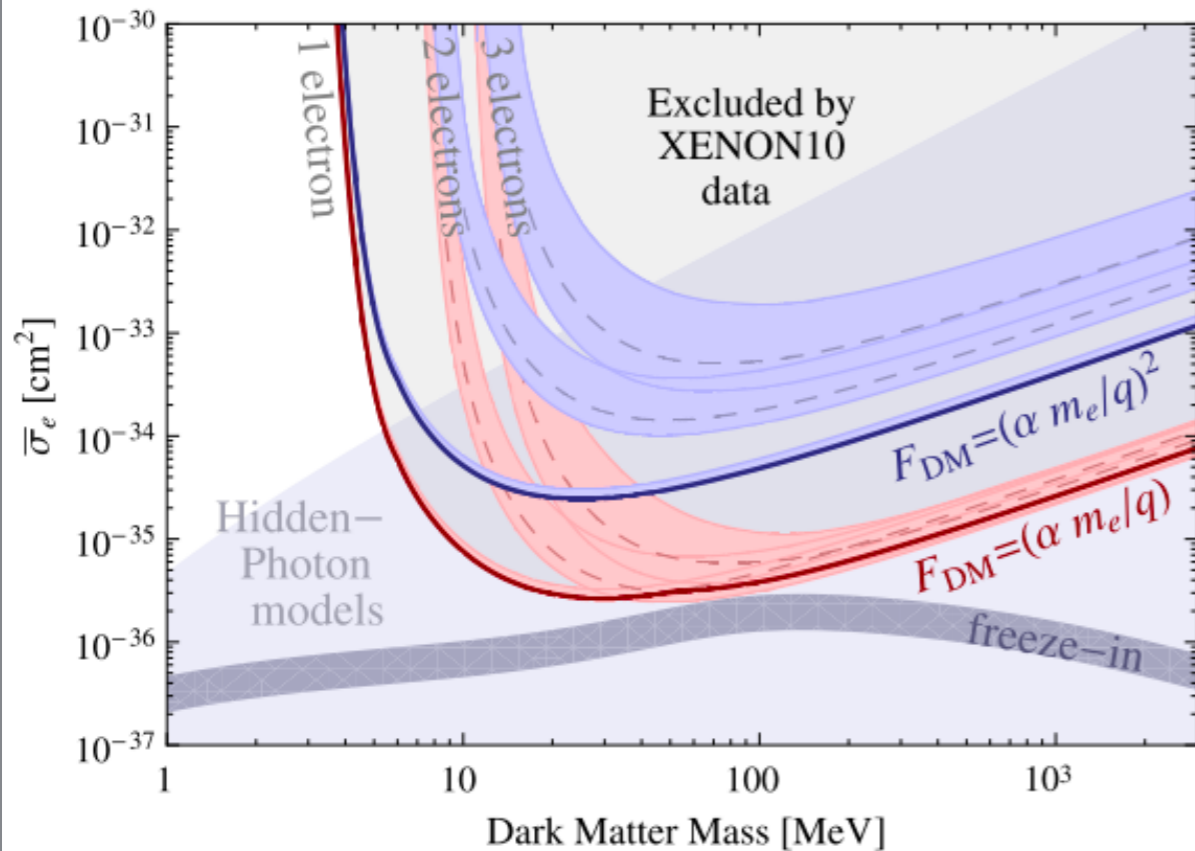
WIMPs

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

Can be explored at accelerators!

LDM - Direct Detection limits

Limits from XENON10



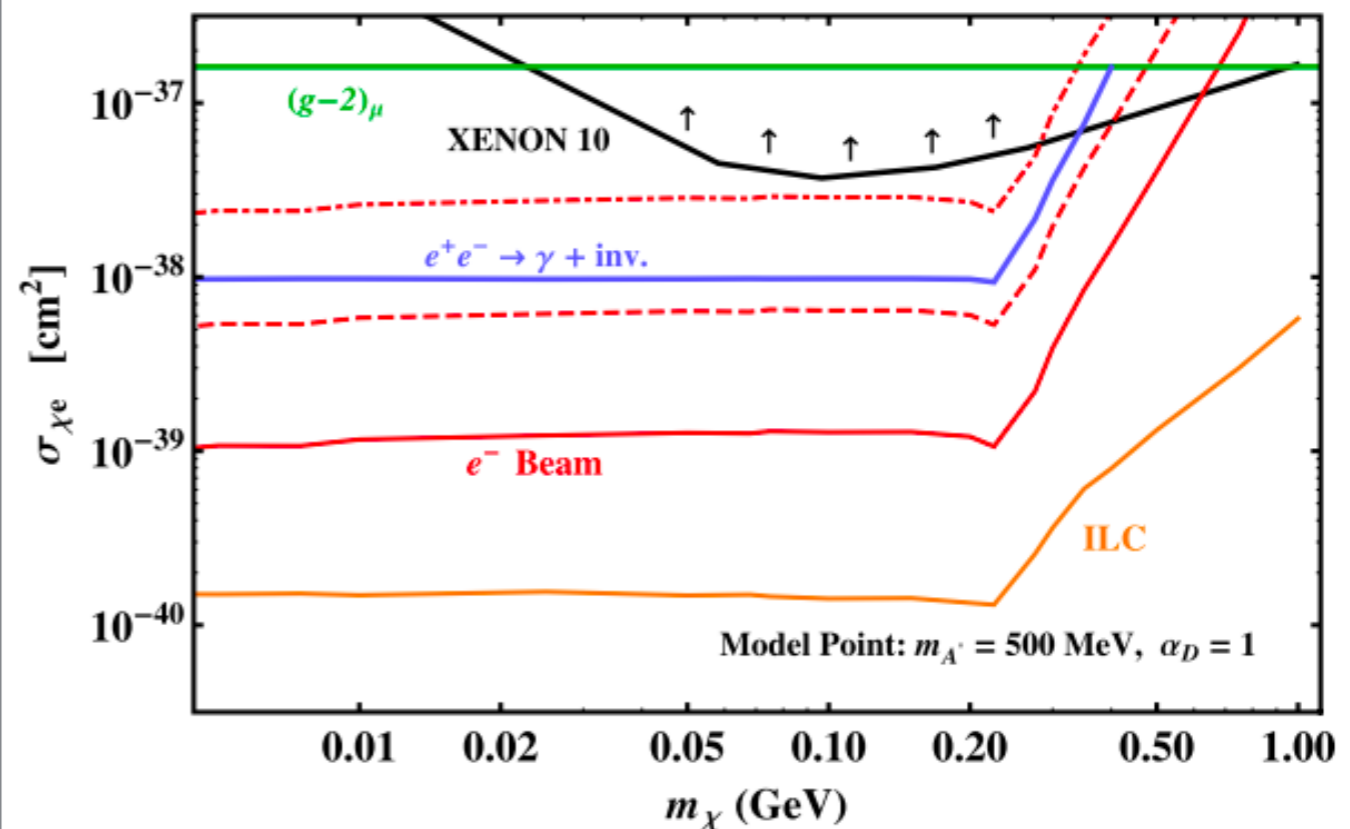
PhysRevLett. 109.021301 R.Essig, A.Manalaysay, J.Mardon, P.Sorensen, T.Volansky,

- Fixed target electron beam experiments can be $10^3 - 10^4$ more sensitive in the 1 MeV - 1 GeV mass range
- No experiments were designed to measure LDM (all limits come from reinterpretation of old experiments)

- Best limits on LDM interaction cross section obtained by direct DM detection (XENON10 and LUX)

- $\chi_{\text{cosmic-e}}$ scattering
- I-electron ionization sensitivity
- No FF for the scattering

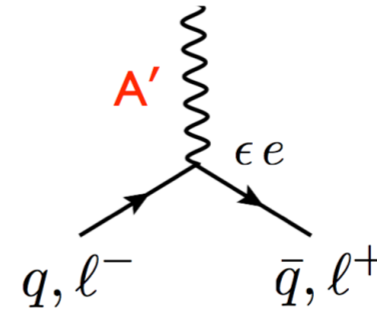
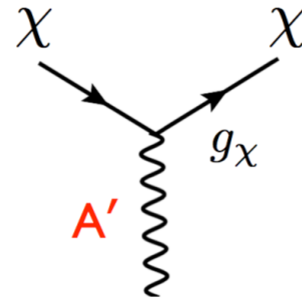
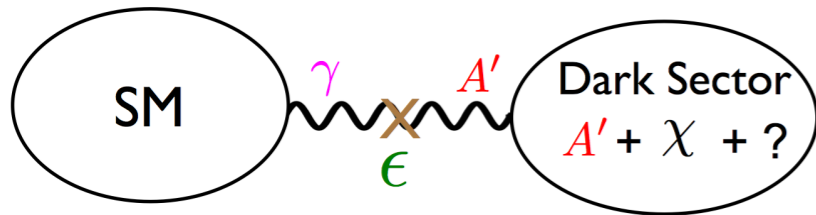
Fixed target & high intensity e- beam



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

Dark forces and dark matter

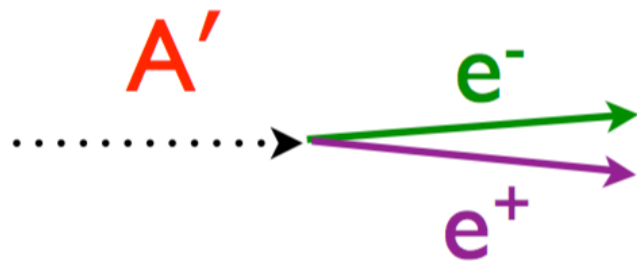
(Light WIMPs - light mediators)



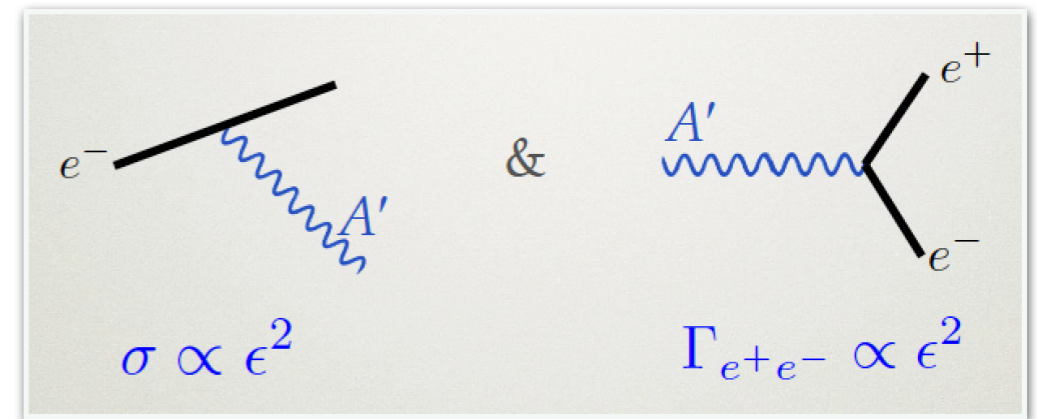
4 parameters: $m_\chi, m_{A'}, \epsilon, g_\chi$

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

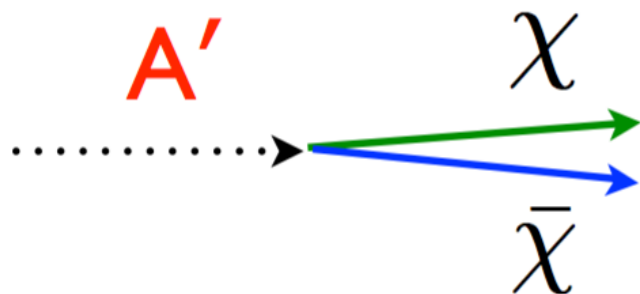
Visible



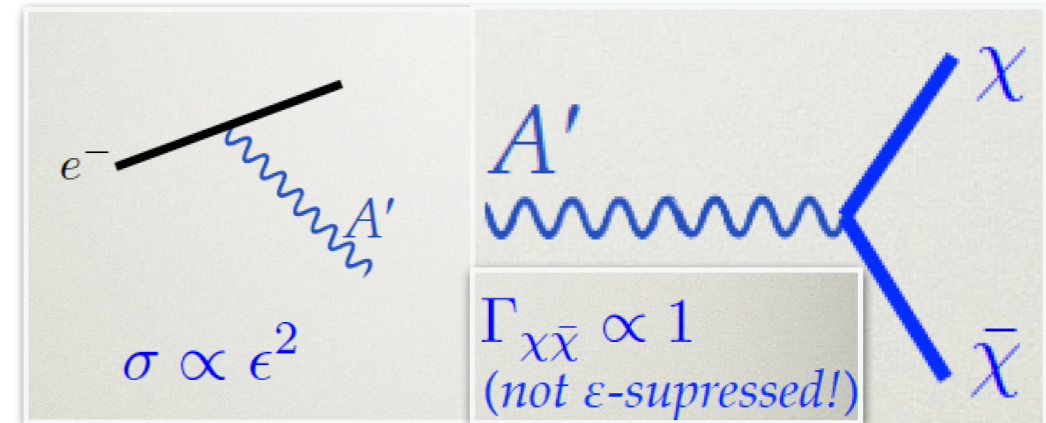
- Minimal decay
- Decay regulated by ϵ^2
- Independent of m_χ
- Requires $m_{A'} < 2m_\chi$



Invisible



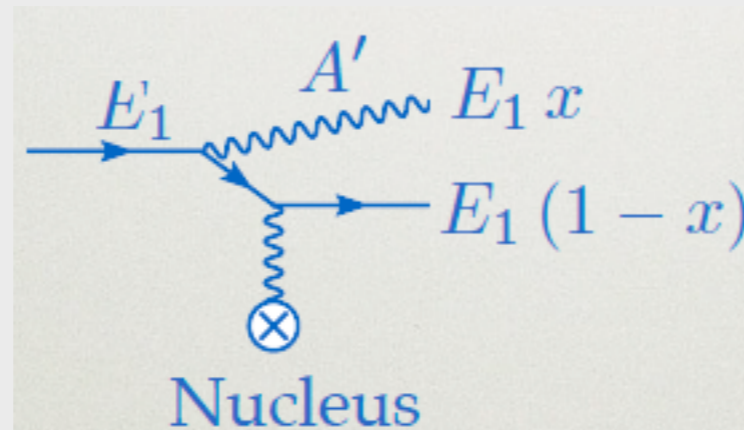
- Depends on 4 parameters
- $m_{A'} > 2m_\chi$ (on-shell)
- $\alpha_D = g_\chi^2/4\pi \gg \epsilon^2 \alpha_{EM}$



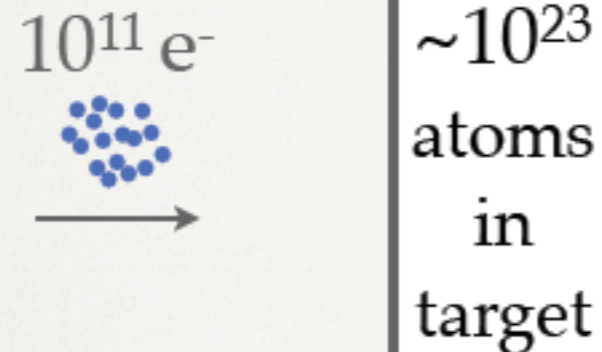
Fixed target vs. collider

Fixed Target

Process



Luminosity



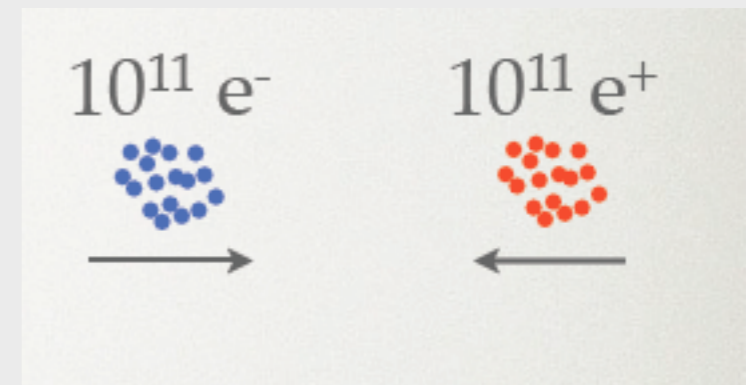
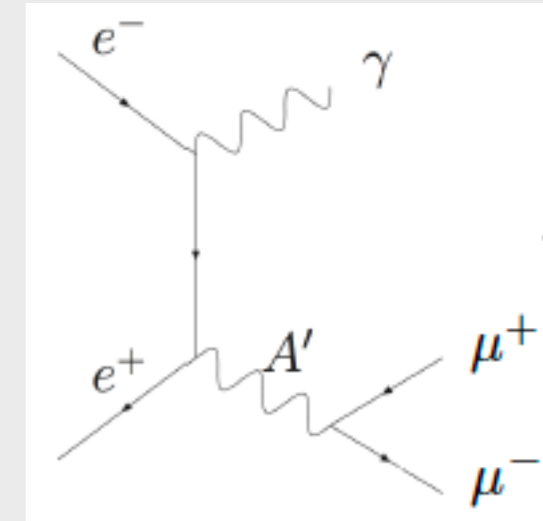
Cross-Section

$$\sigma \sim \frac{\alpha^3 Z^2 \epsilon^2}{m^2} \sim O(10 \text{ pb})$$

- * $1/M_{A'}$ vs. $1/E_{\text{beam}}$
- * Coherent scattering from Nucleus ($\sim Z^2$)

- high backgrounds
- limited A' mass

e^+e^- colliders



$$\sigma \sim \frac{\alpha^2 \epsilon^2}{E^2} \sim O(10 \text{ fb})$$

- low backgrounds
- higher A' mass

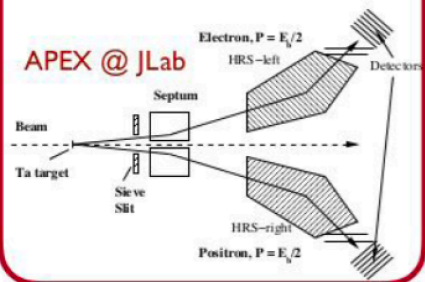
A' visible and invisible decay at accelerators

e^- fixed target

$$N \propto \epsilon^2$$



dark bremsstrahlung

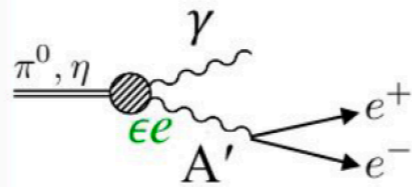


Fixed target:

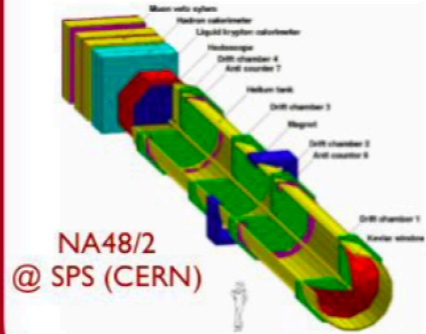
$e N \rightarrow N \gamma' \rightarrow N \text{ Lepton Lepton}^+$
→ JLAB, MAINZ

p fixed target

$$N \propto \epsilon^2$$

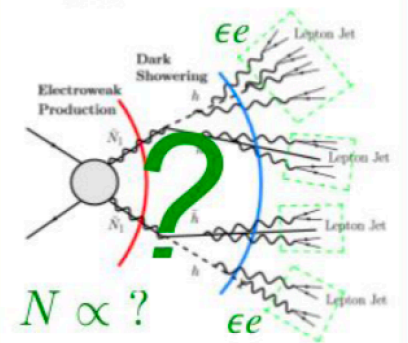


meson decays



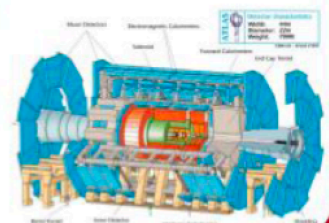
High Energy
 Hadron Colliders:
 $pp \rightarrow \text{lepton jets}$
→ ATLAS, CMS, CDF&D0

pp collider



“lepton jets”
 + meson decays

ATLAS
 CMS
 LHCb
 @LHC

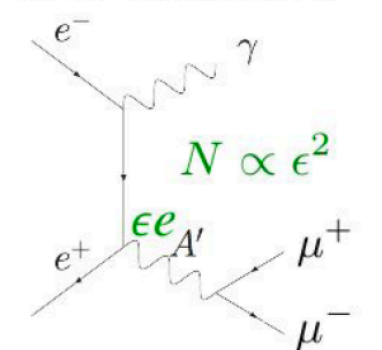


Meson decays:

$\pi^0, \eta, \eta', \omega' \rightarrow \gamma' \gamma (M)$
 $\rightarrow \text{Lepton Lepton} + \gamma (M)$

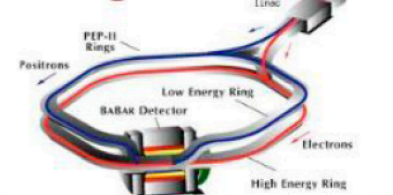
→ KLOE, BES3, WASA-COSY, PHENIX

e^+e^- colliders



+ meson decays

BaBar @ SLAC

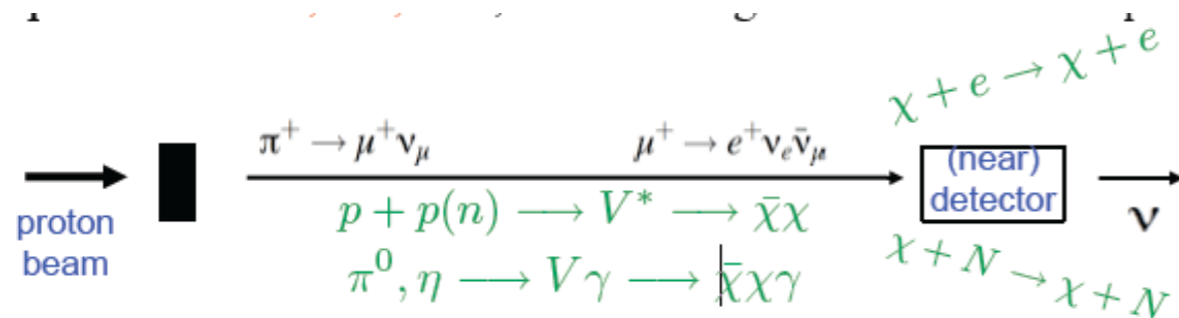


Annihilation:

$e^+e^- \rightarrow \gamma' \gamma \rightarrow \mu\mu \gamma$
→ BABAR, BELLE, KLOE, CLEO

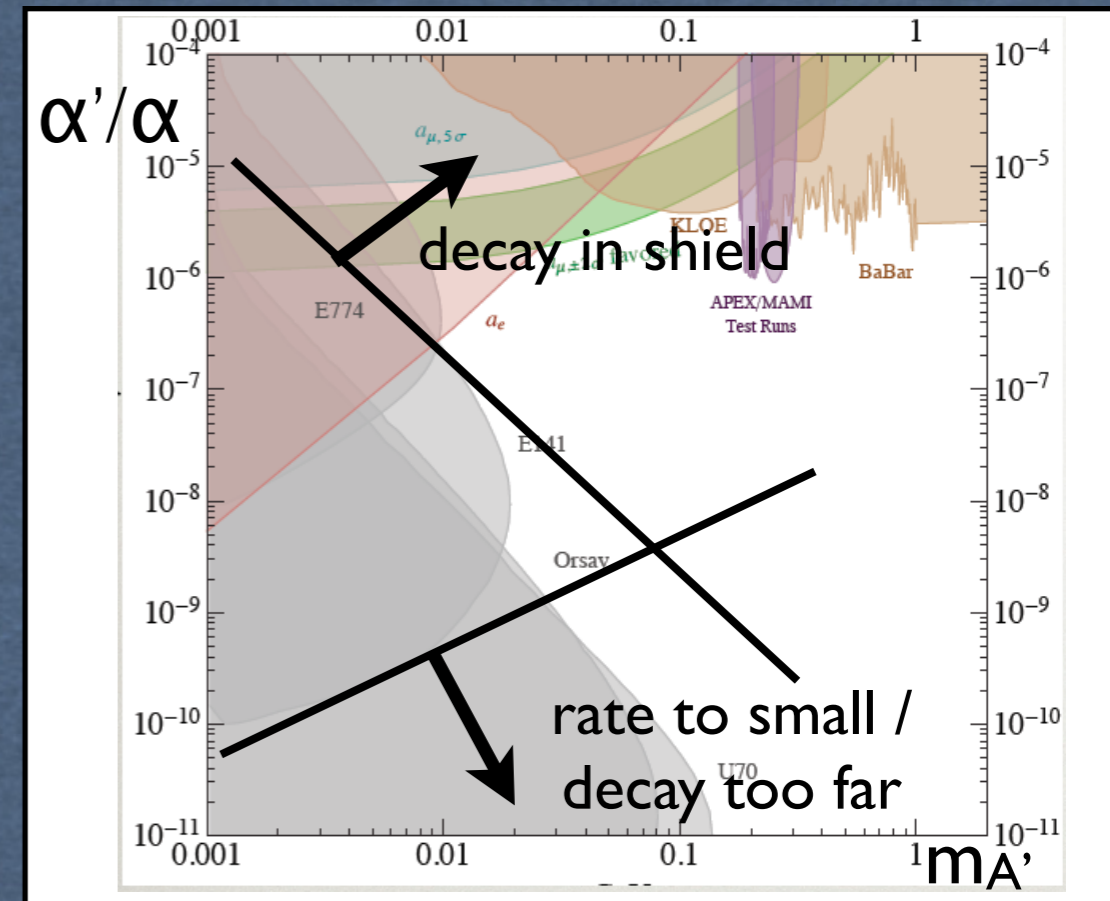
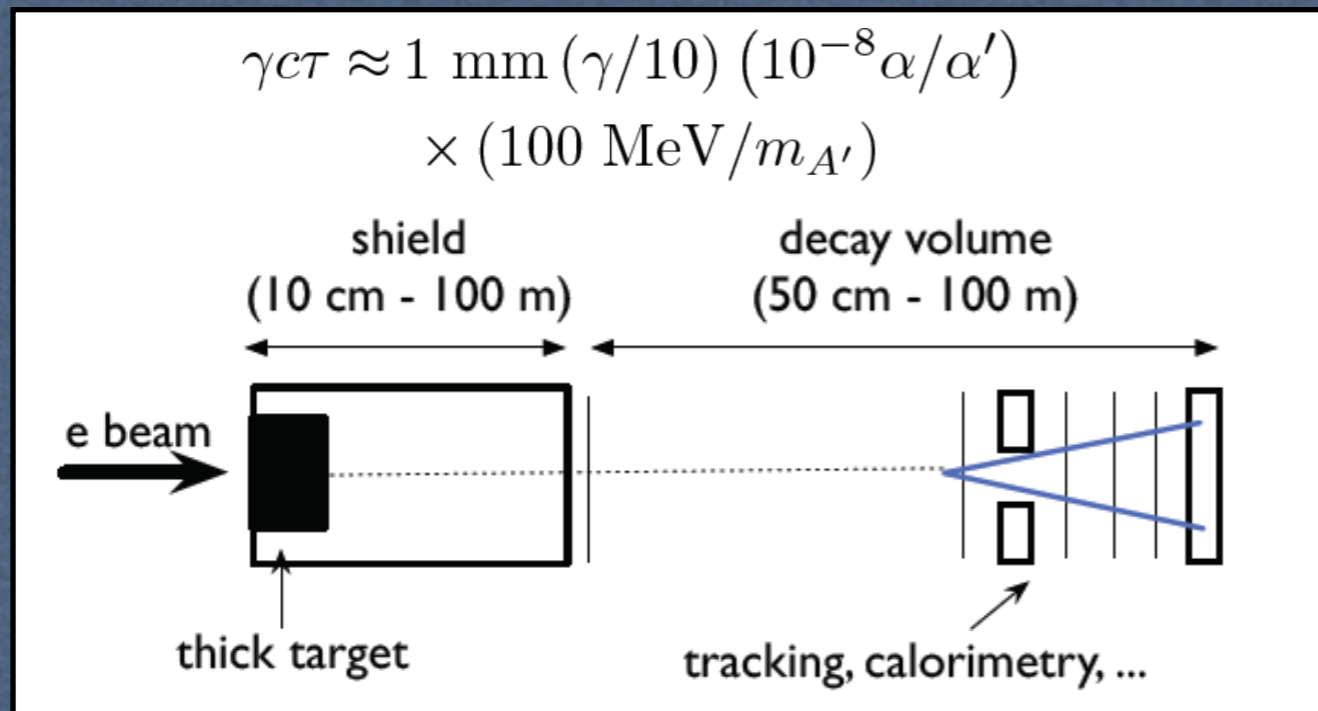
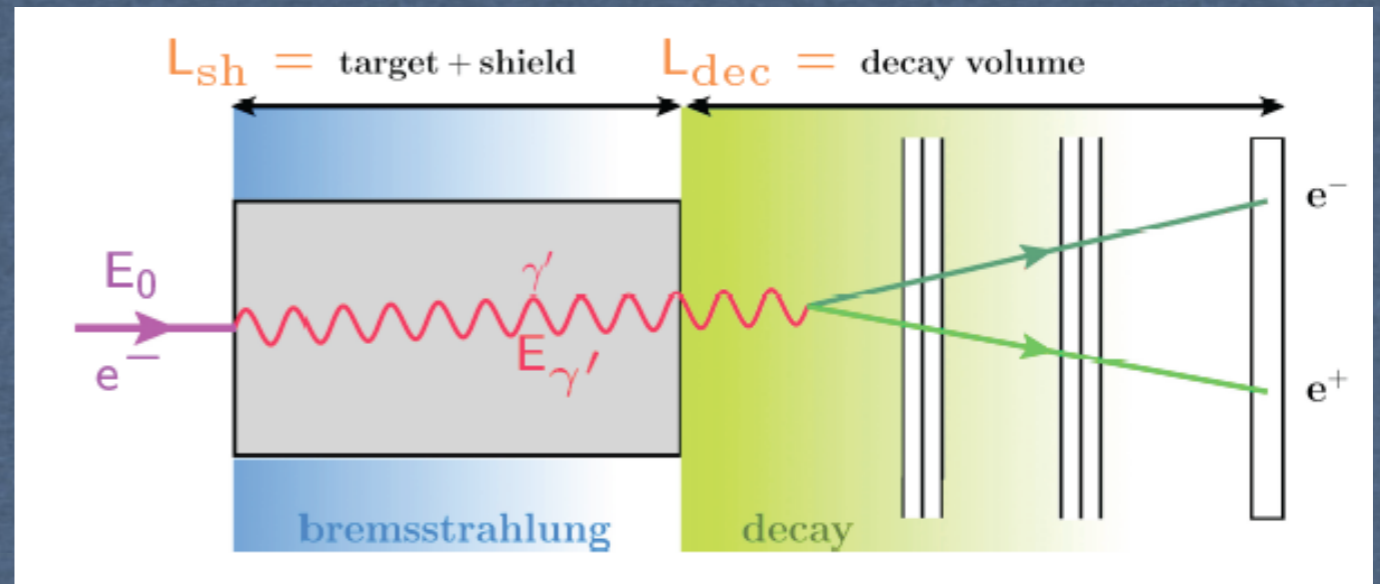
Fixed target:

$p N \rightarrow N \gamma' \rightarrow p \text{ Lepton Lepton}^+$
→ FERMILAB, SERPUKHOV



Beam-dump experiments - visible -

- * e- beam incident on thick target
- * A' is produced 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



HPS@JLab Heavy Photon Search

HEAVY PHOTON SEARCH

DM

Heavy photon signatures in HPS

1) Bump Hunting (BH)

Narrow e^+e^- -resonance over a QED background

→ good mass resolution: $\sigma_{A'_{\text{mass}}} \sim 1 \text{ MeV}$

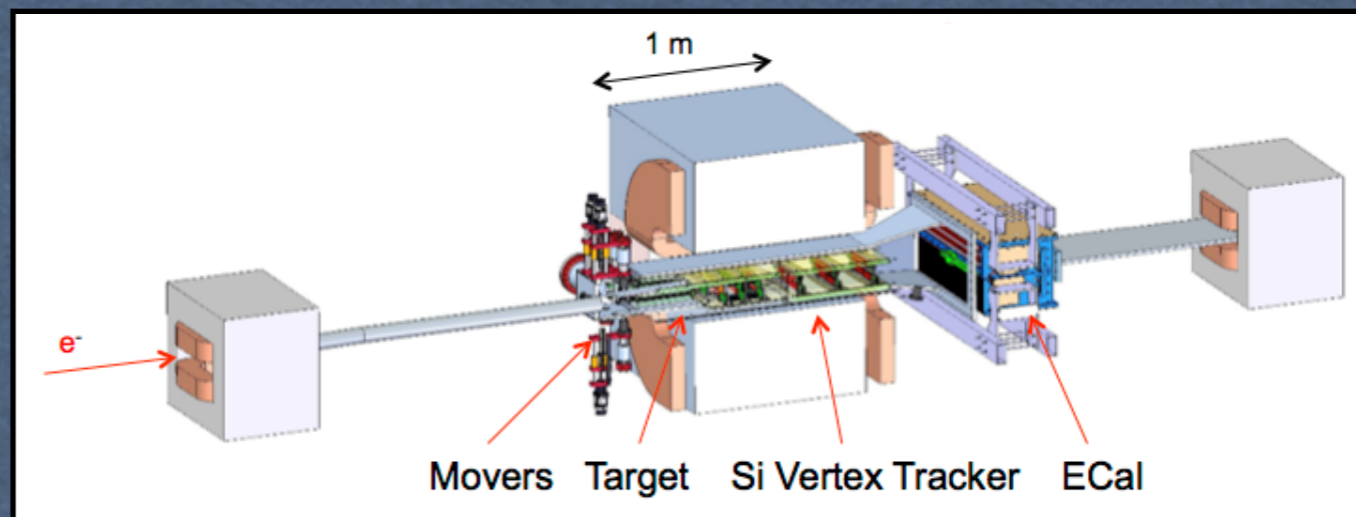
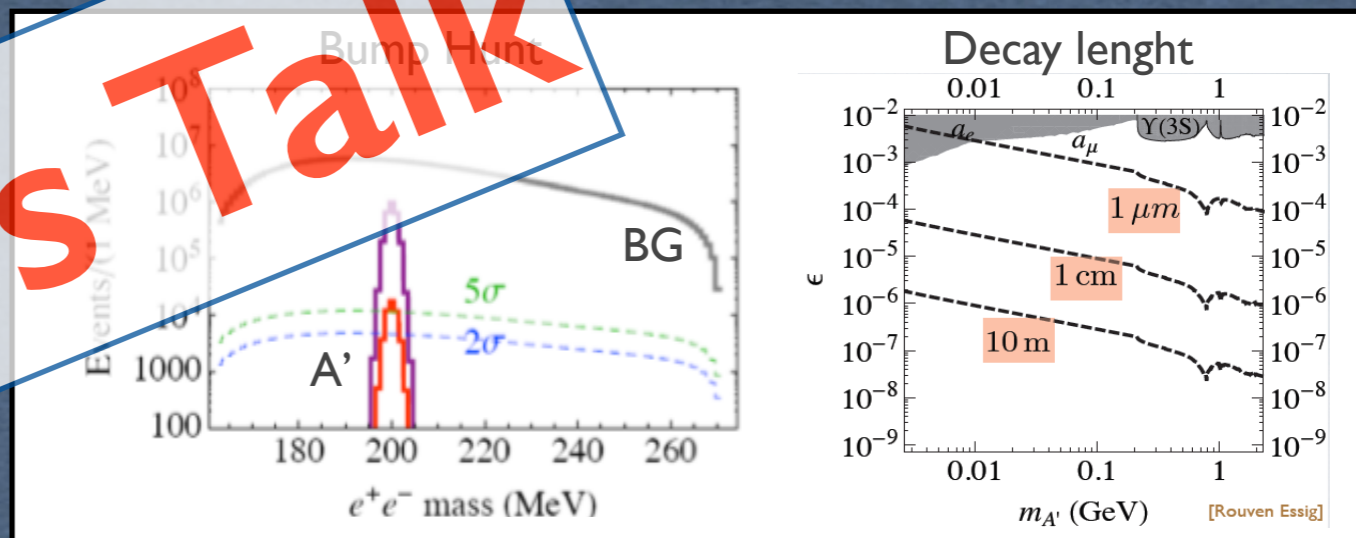
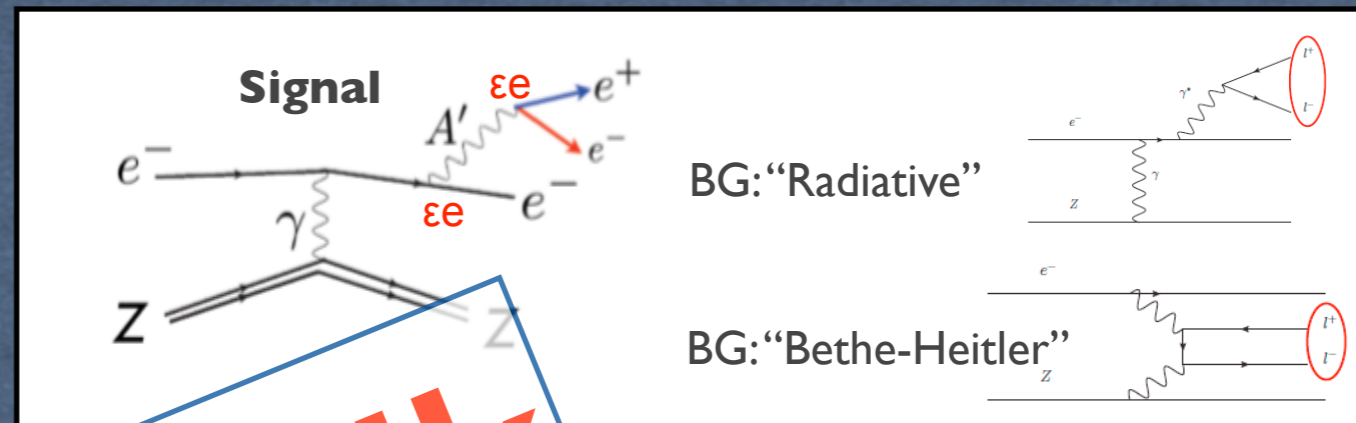
2) Secondary decay vertex (vertexing)

Detached vertex from few mm to tens cm

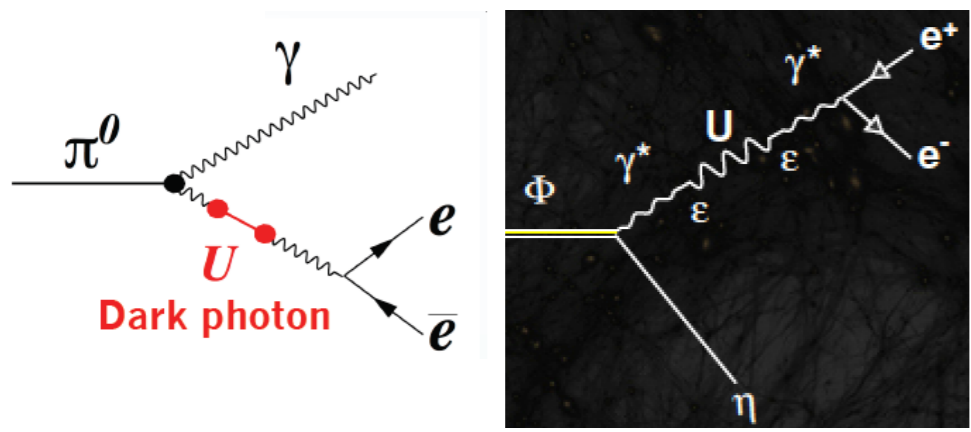
→ good spacial resolution: $\sigma_{\text{vertex}} \sim 1 \text{ mm}$

**BH + Vertexing =
enhanced
experimental reach**

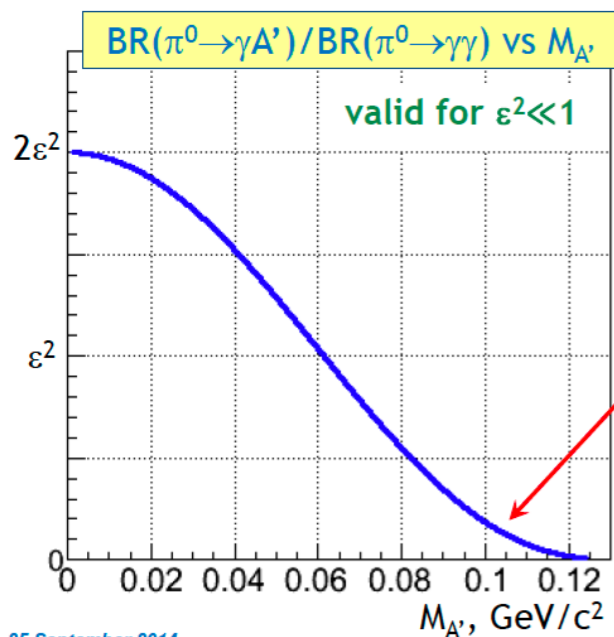
Rafo's Talk



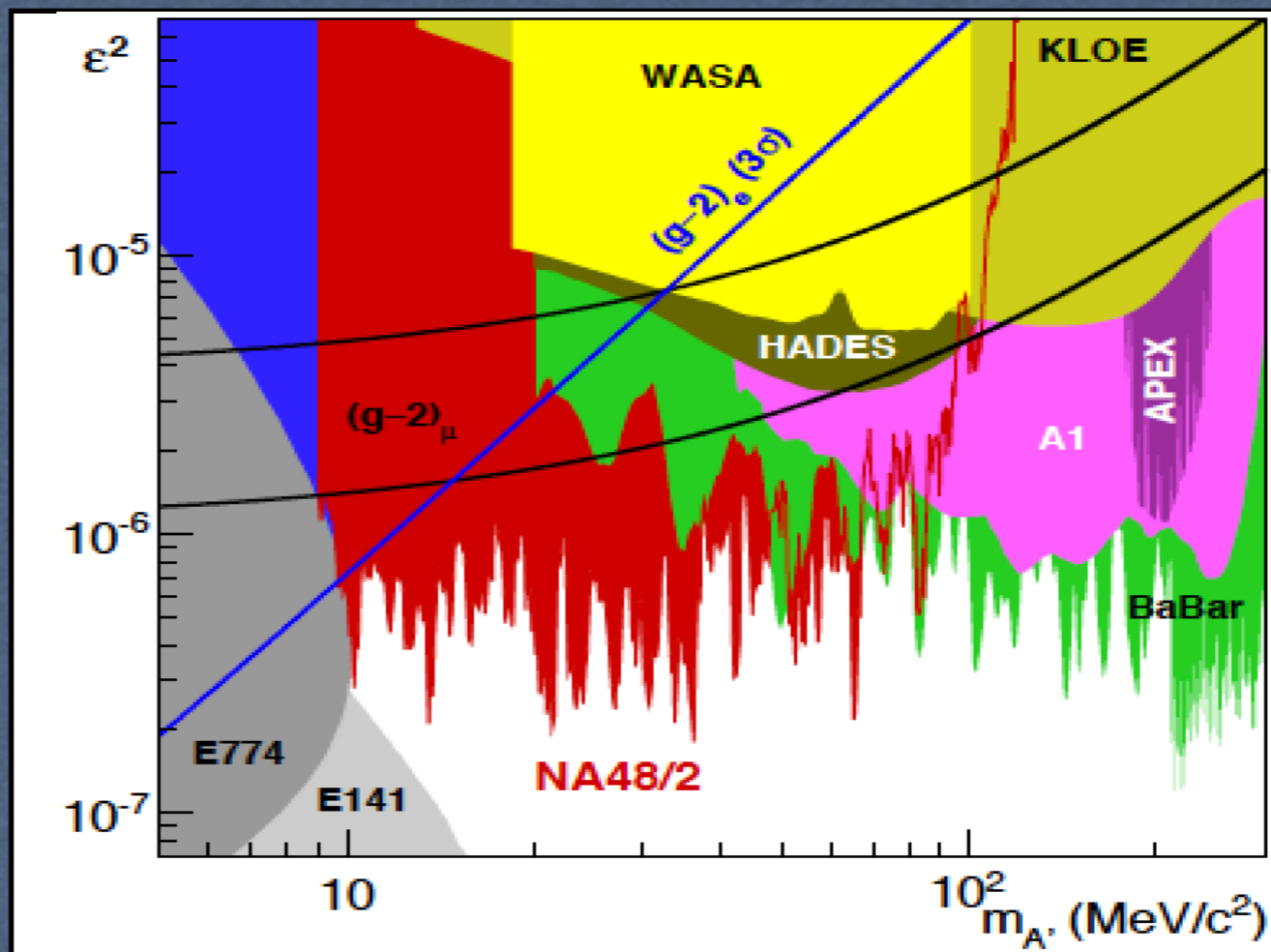
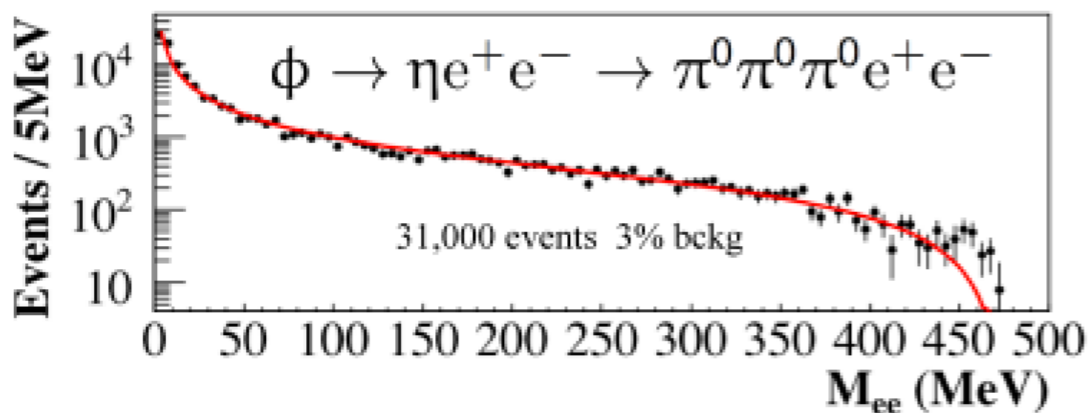
Meson Decay - The latest Results



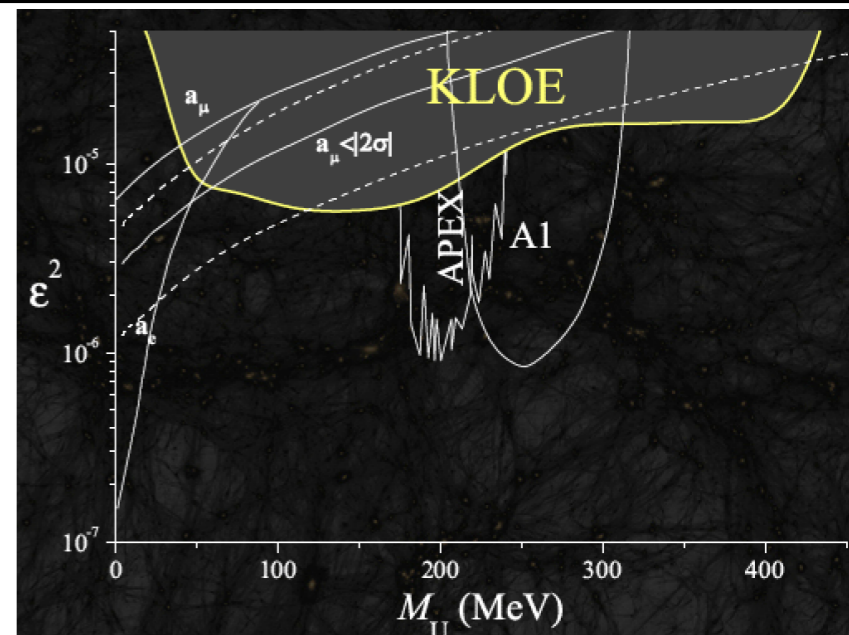
$K^\pm \rightarrow \pi^\pm \pi^0, \pi^0 \rightarrow \gamma A', A' \rightarrow e^+ e^-$



- $4 \times 10^{10} \pi^0$
- Acceptance $\sim 2.5\%$
- $\delta M \sim 1\% M_{ee}$



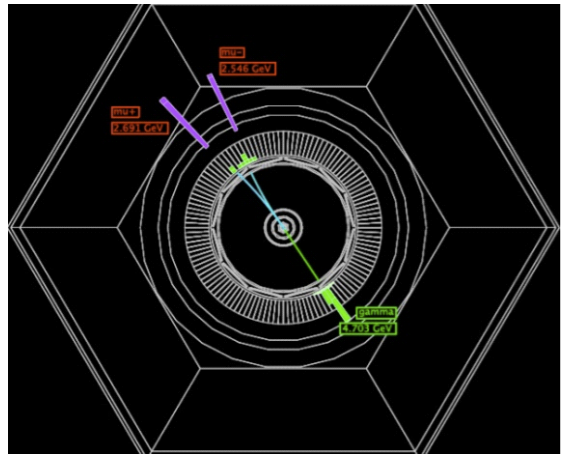
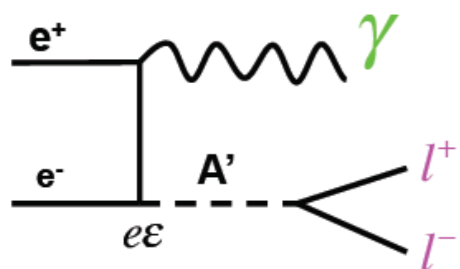
Phys. Lett. B 706 (2012) 251
 Phys. Lett. B 720 (2013) 111



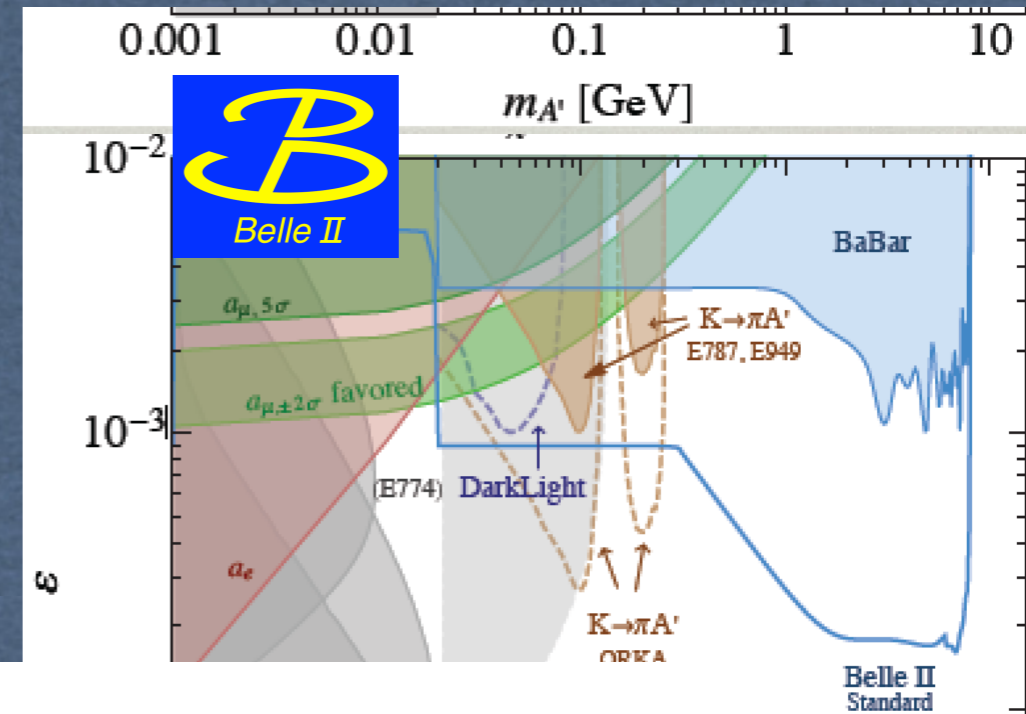
NA48/2

J.R. Batley et al.
 Arxiv: 1504.00607

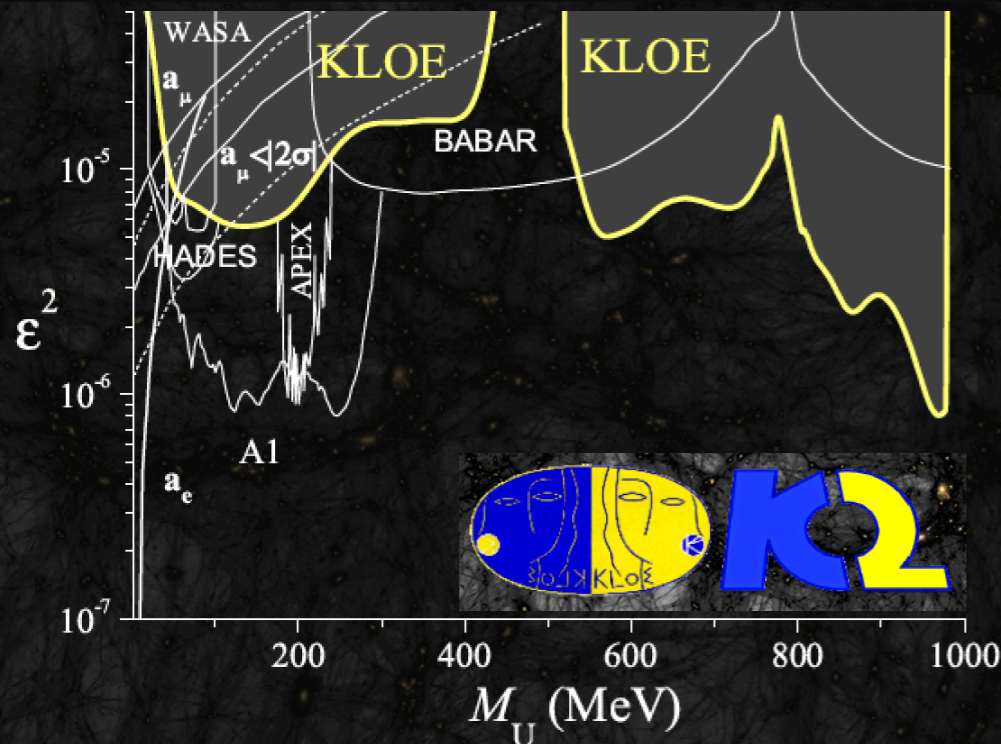
e+e- Colliders Recent & future results - visible -



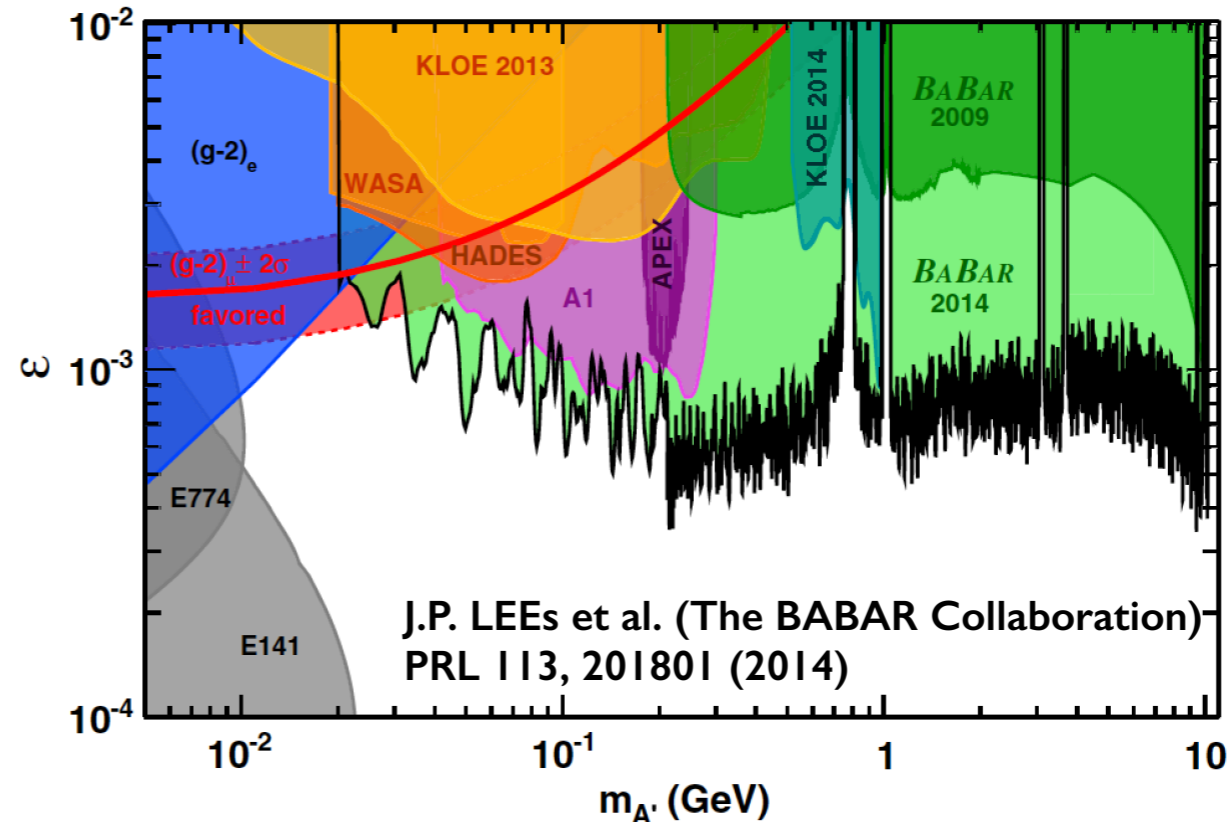
- 1 gamma + 2 opposite leptons
- Di-lepton mass fit to a bg
- Mass resolution: 1.5 MeV - 8 MeV
- Int (L) = 514 fb⁻¹



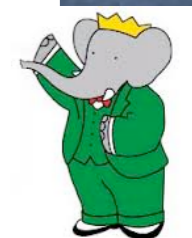
Phys. Lett. B 736 (2014) 459



- Events with μ+μ- detected
- L~ 240 pb⁻¹



J.P. LEES et al. (The BABAR Collaboration)
PRL 113, 201801 (2014)



Hunting for A' at accelerators

Fixed target: $e N \rightarrow N \gamma' \rightarrow N \text{ Lepton}^- \text{ Lepton}^+$

→ **JLAB, MAINZ**

Fixed target: $p N \rightarrow N \gamma' \rightarrow p \text{ Lepton}^- \text{ Lepton}^+$

→ **FERMILAB, SERPUKHOV**

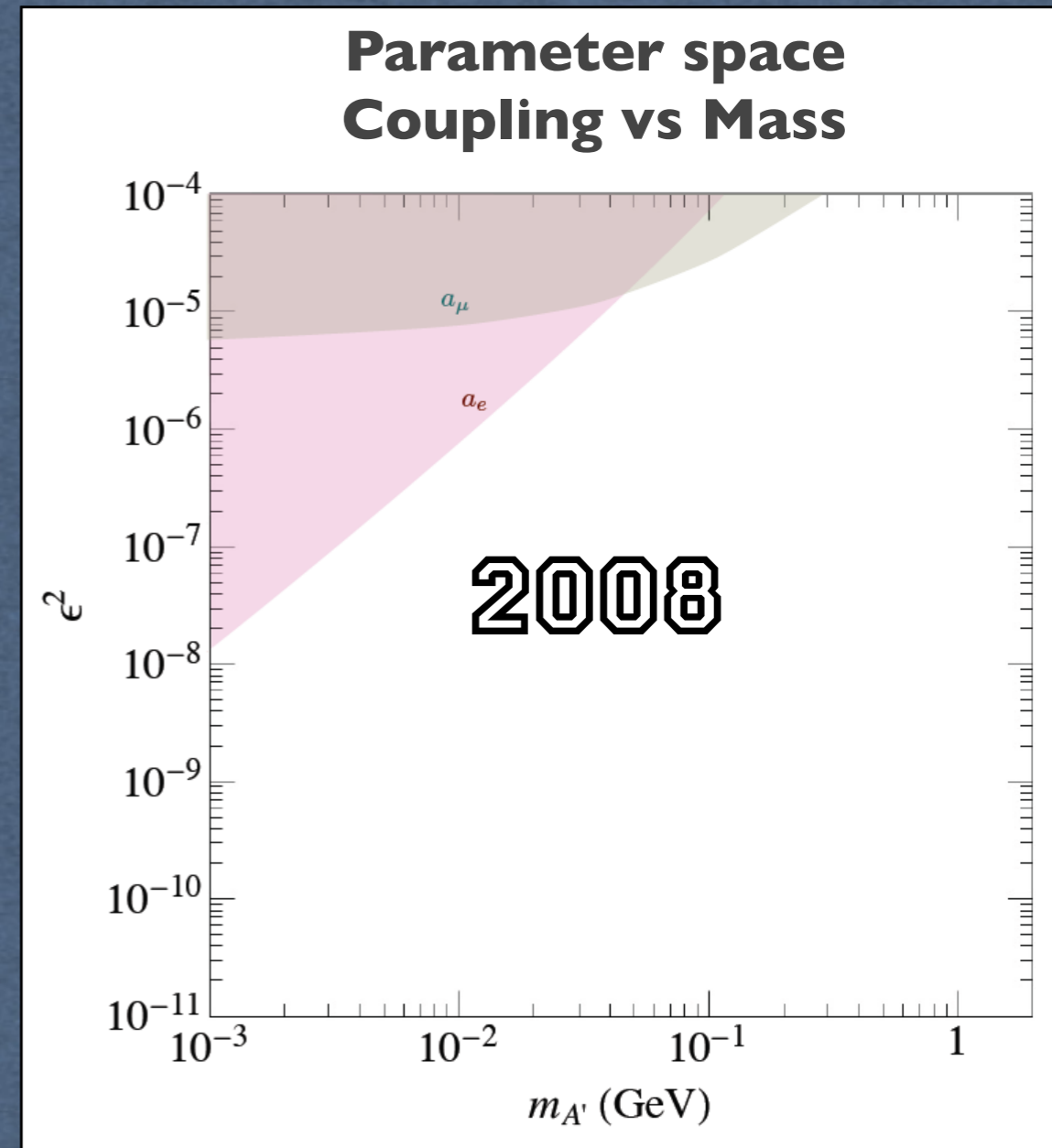
Annihilation: $e^+e^- \rightarrow \gamma' \gamma \rightarrow \mu\mu \gamma$

→ **BABAR, BELLE, KLOE**

Meson decays: $\pi^0, \eta, \eta', \omega, \omega' \rightarrow \gamma' \gamma \rightarrow \text{Lepton}^- \text{ Lepton}^+ \gamma$

→ **KLOE, BES3, NA48, HC**

coupling vs mass



Hunting for A' at accelerators

Fixed target: $e N \rightarrow N \gamma' \rightarrow N \text{ Lepton}^- \text{ Lepton}^+$

→ **JLAB, MAINZ**

Fixed target: $p N \rightarrow N \gamma' \rightarrow p \text{ Lepton}^- \text{ Lepton}^+$

→ **FERMILAB, SERPUKHOV**

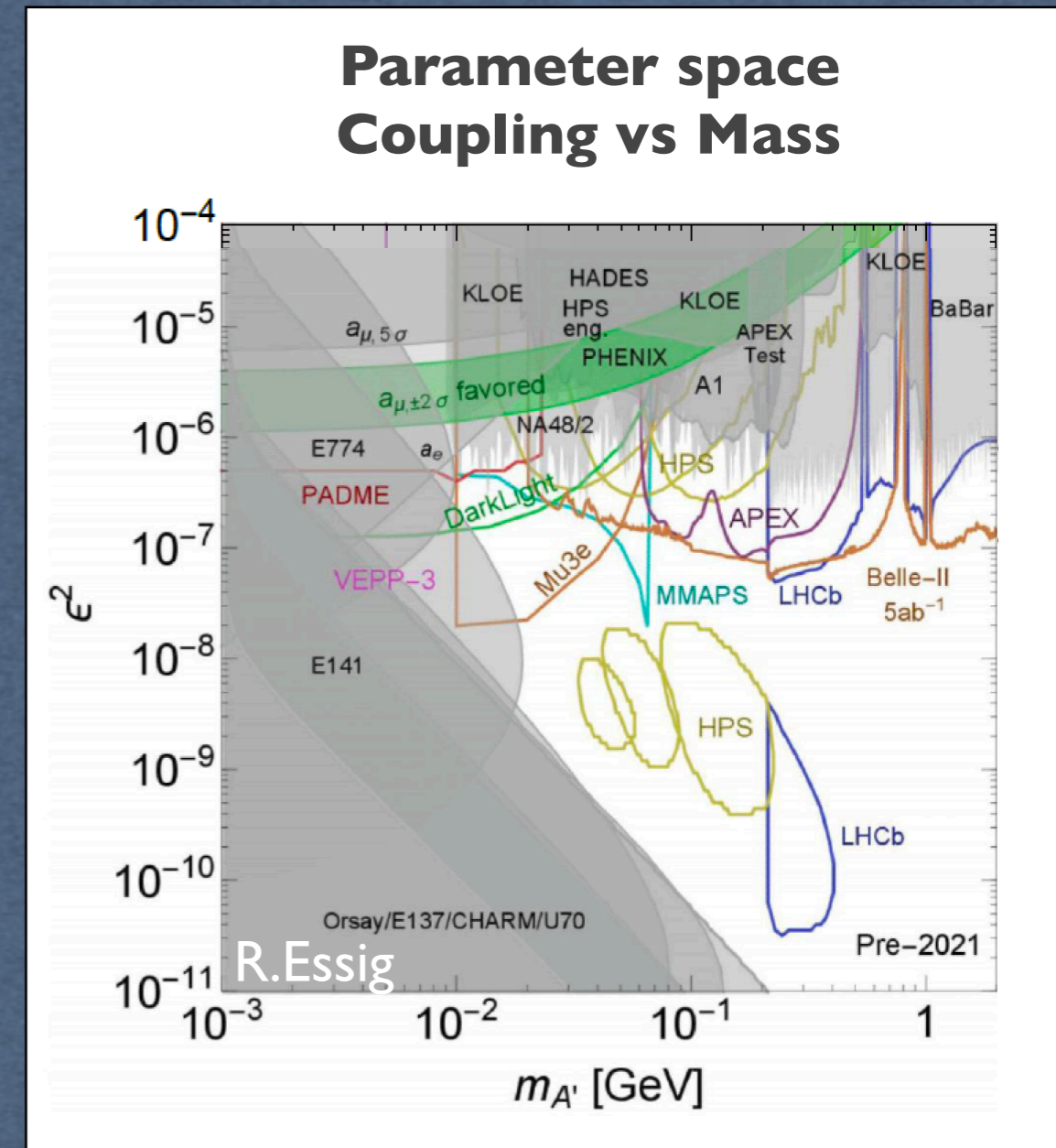
Annihilation: $e^+e^- \rightarrow \gamma' \gamma \rightarrow \mu\mu \gamma$

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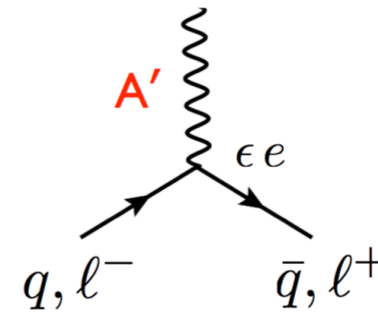
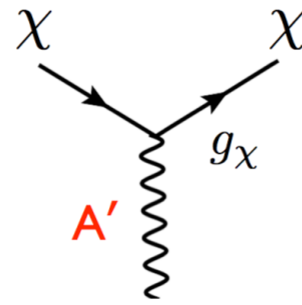
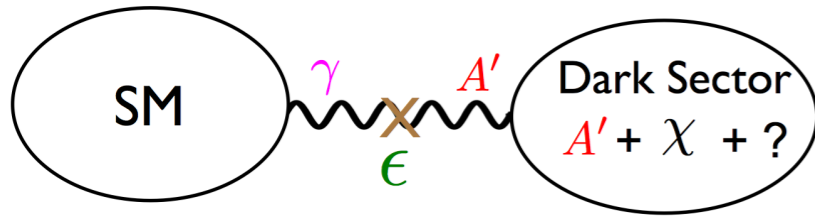
Meson decays: $\pi^0, \eta, \eta', \omega, \omega' \rightarrow \gamma' \gamma \rightarrow \text{Lepton}^- \text{ Lepton}^+ \gamma$

→ **KLOE, BES3, NA48, HC**

**No positive signal (so far) but
limits in parameter space
coupling vs mass**

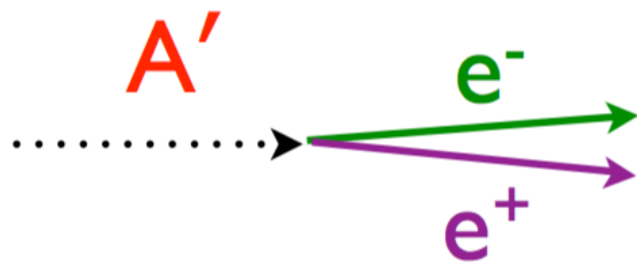


Dark forces and dark matter (Light DM - light mediators)

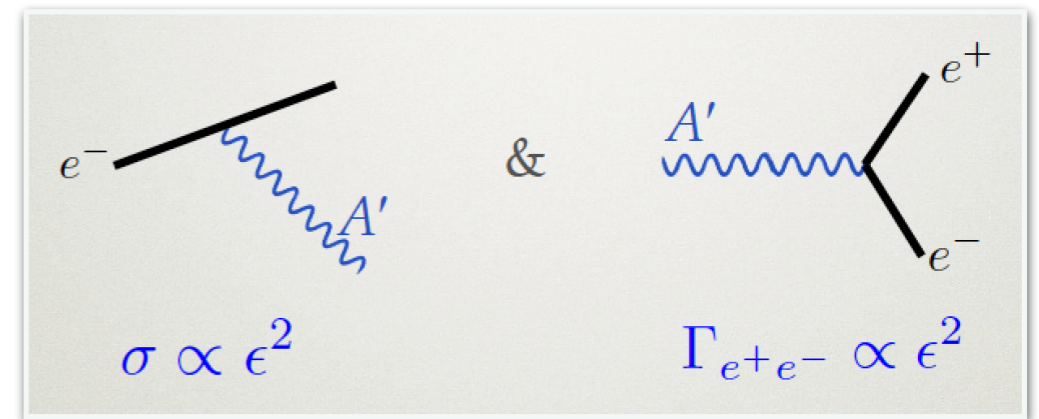


4 parameters: $m_\chi, m_{A'}, \epsilon, \alpha_D$
 $m_\chi, \sim m_{A'}: \text{MeV} - \text{GeV}$

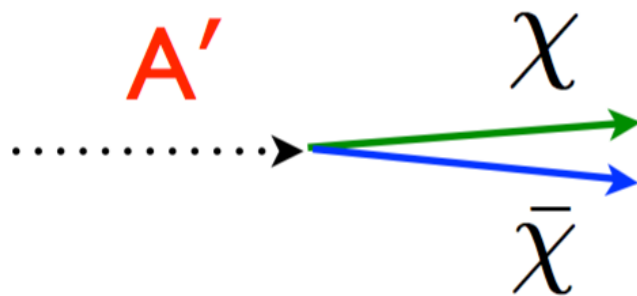
Visible



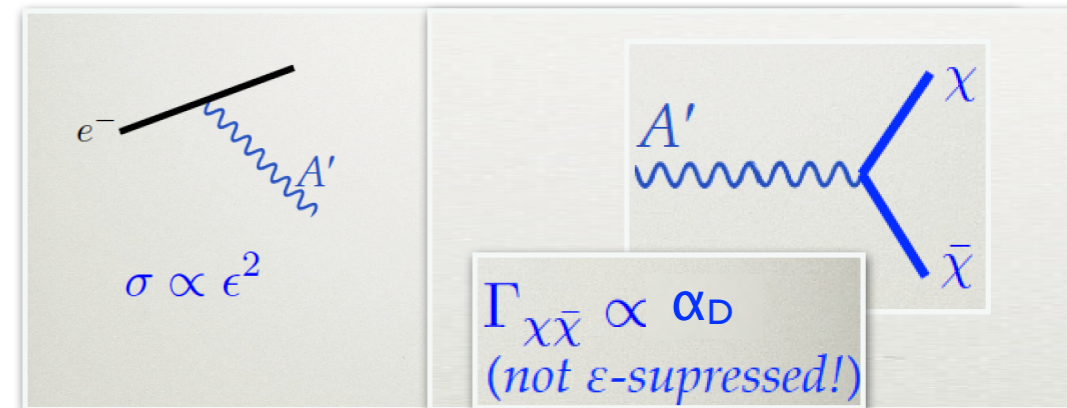
- Minimal decay
- Decay regulated by ϵ^2
- Independent of m_χ
- Requires $m_{A'} < 2m_\chi$ (on-shell)



Invisible



- Depends on 4 parameters
- $m_{A'} > 2m_\chi$ (on-shell)
- $\alpha_D = g_\chi^2/4\pi \gg \epsilon^2 \alpha_{EM}$



Particle physics search of A' - invisible -

Fixed target: $e N \rightarrow N \gamma' \rightarrow N \text{ Lepton}^- \text{ Lepton}^+$

→ **JLAB, MAINZ**

Fixed target: $p N \rightarrow N \gamma' \rightarrow p \text{ Lepton}^- \text{ Lepton}^+$

→ **FERMILAB, SERPUKHOV**

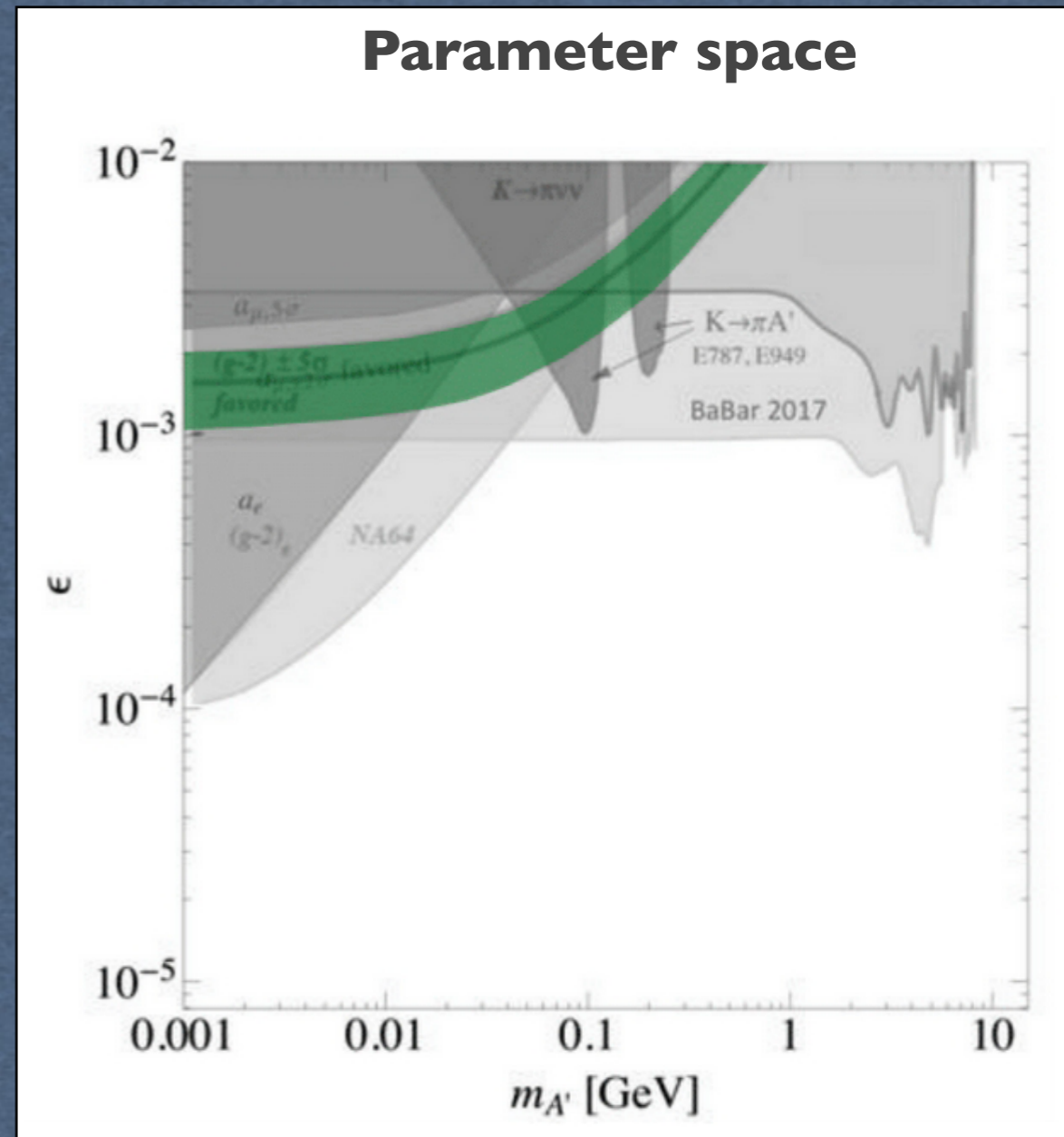
Annihilation: $e^+e^- \rightarrow \gamma' \gamma \rightarrow \mu\mu \gamma$

→ **BABAR, BELLE, KLOE**

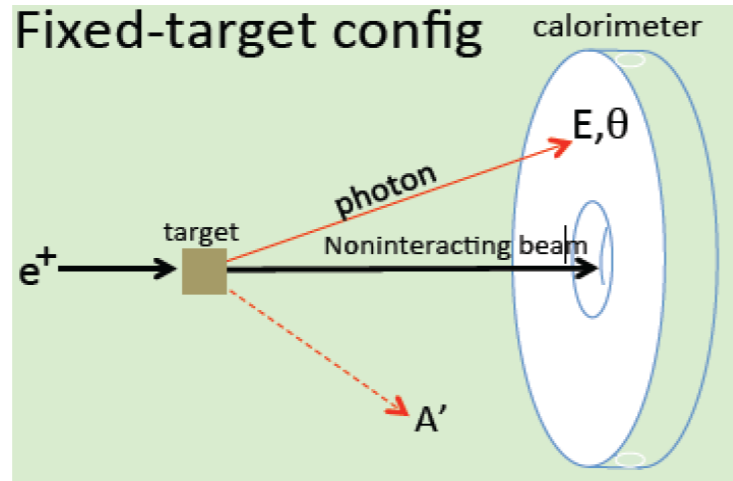
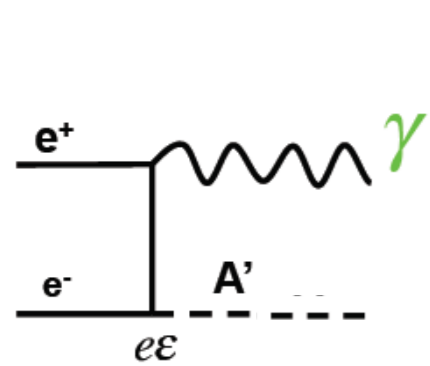
Meson decays: $\pi^0, \eta, \eta', \omega, \omega' \rightarrow \gamma' \gamma \rightarrow \text{Lepton}^- \text{ Lepton}^+ \gamma$

→ **KLOE, BES3, NA48, HC**

**No positive signal (so far) but
limits in parameter space
coupling vs mass**



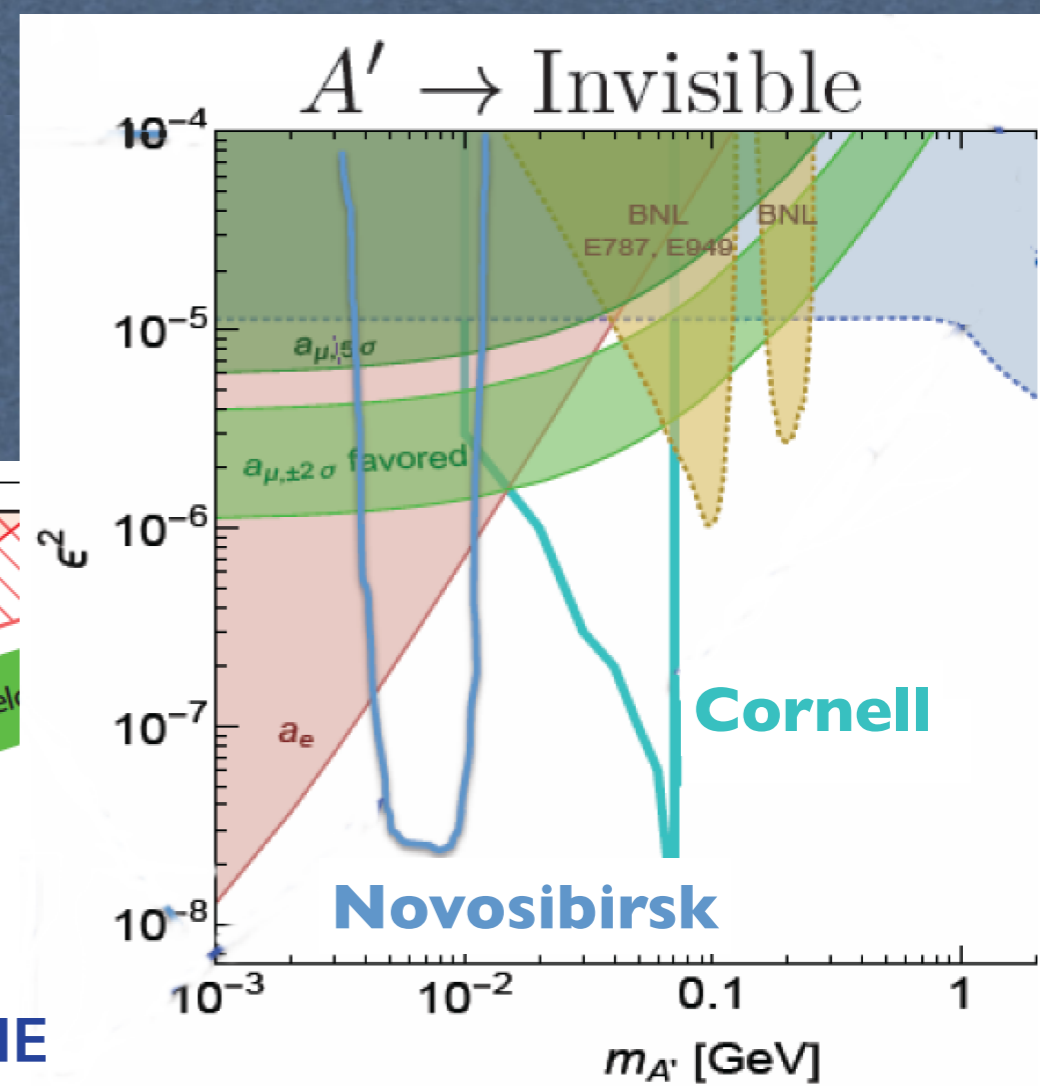
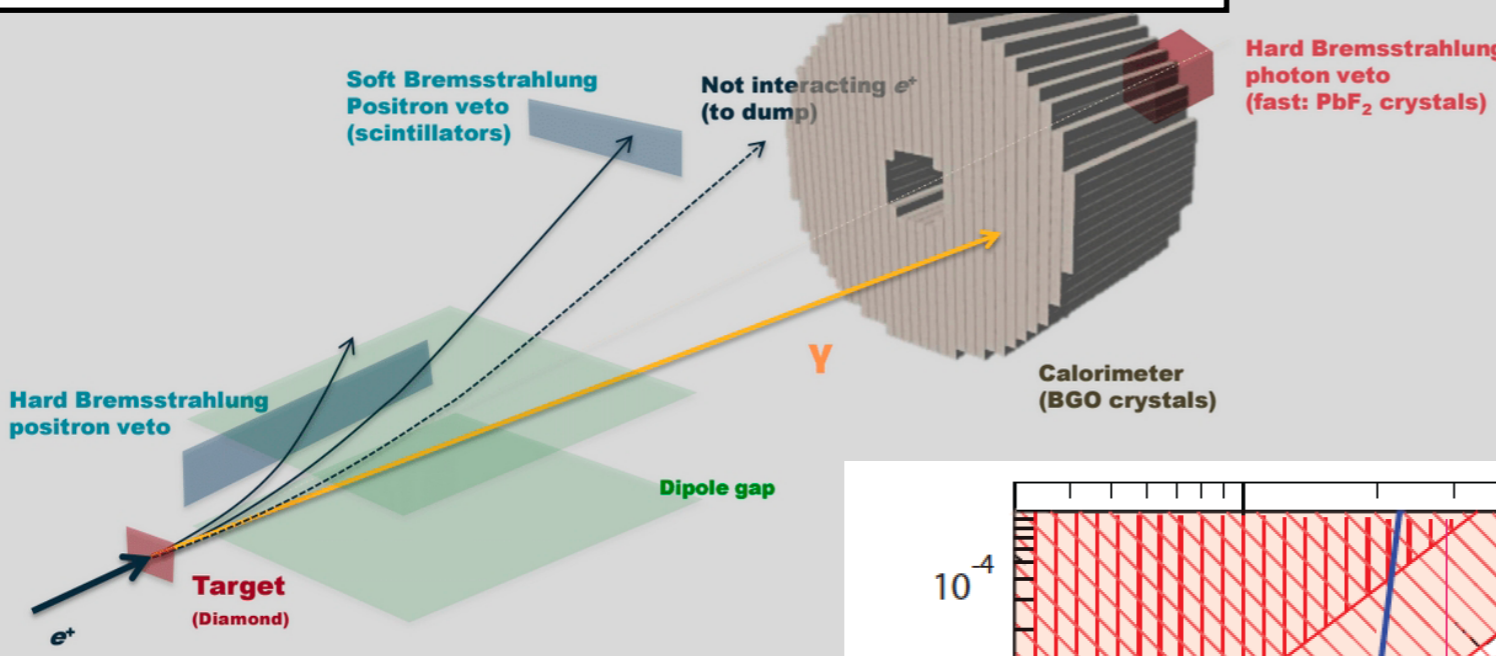
e^+ annihilation on fixed (thin) target - invisible -



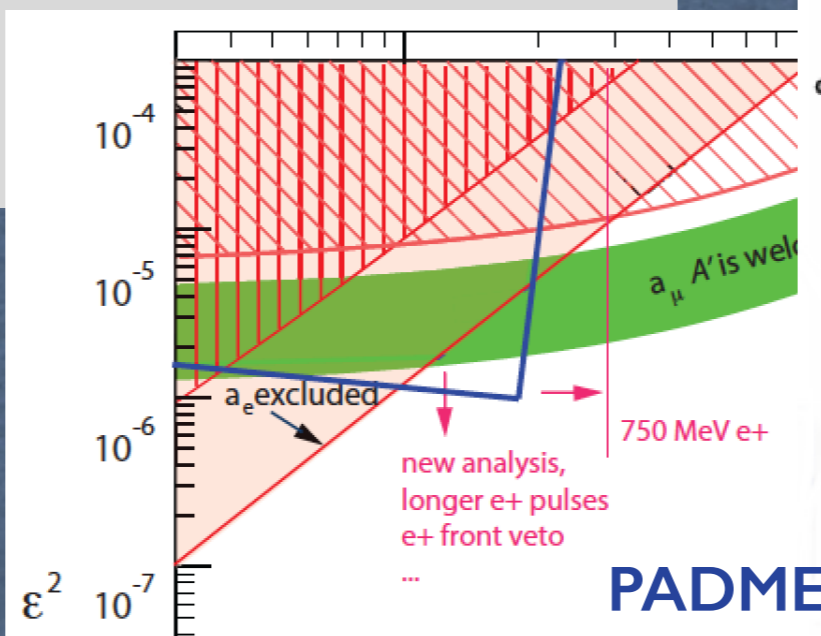
Missing mass search:

- 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

- **Novosibirsk**
- **LNF**
- **Cornell**



- VEPP3**
 - $E_{e^+} = 500$ MeV
 - $EOT \sim 10^{15} - 10^{16}$ year $^{-1}$
- LNF**
 - $E_{e^+} = 550$ MeV
 - $EOT \sim 10^{13} - 10^{14}$ year $^{-1}$
- Cornell**
 - $E_{e^+} = 5.3$ GeV
 - $EOT \sim 10^{17} - 10^{18}$ year $^{-1}$



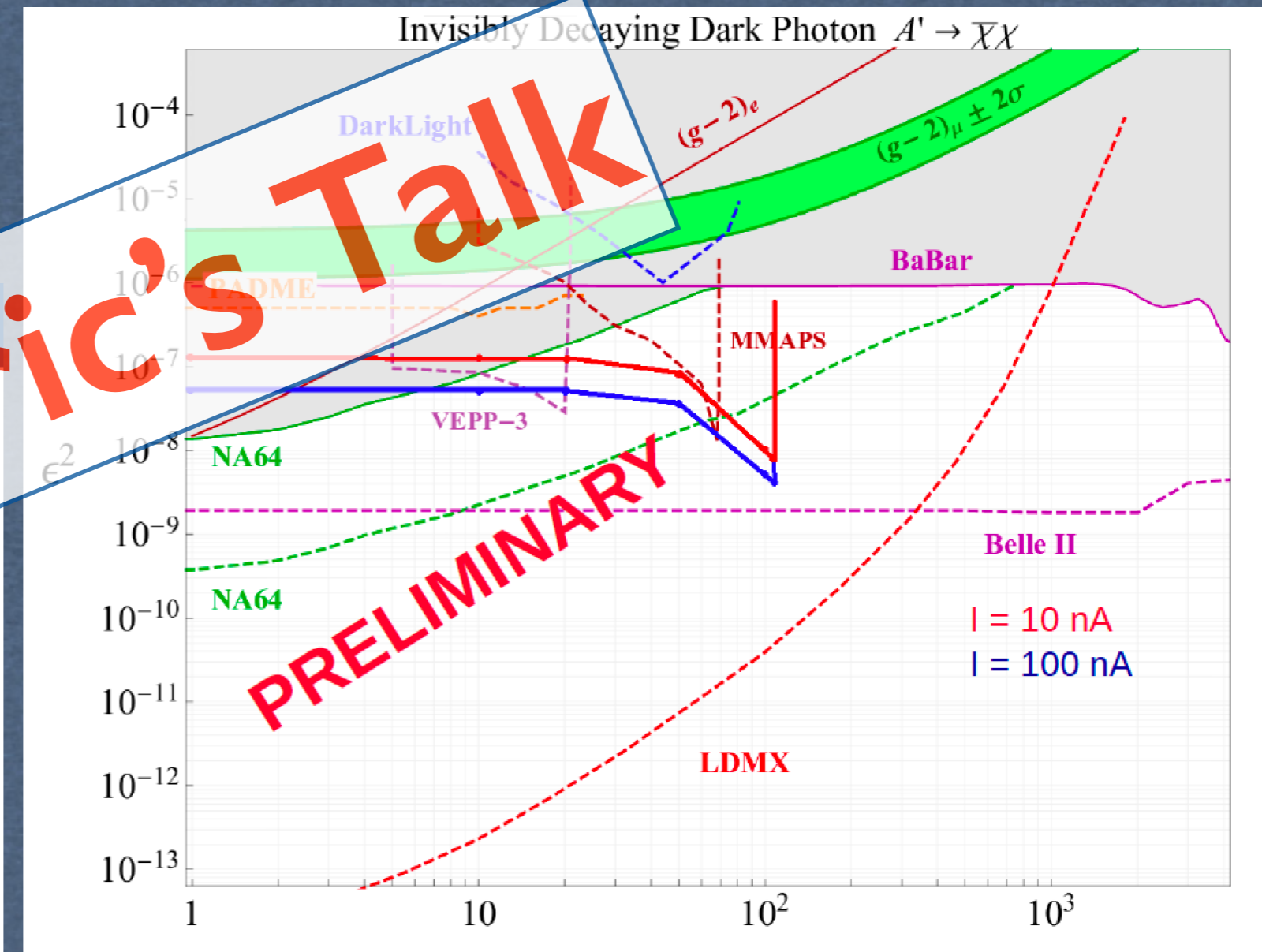
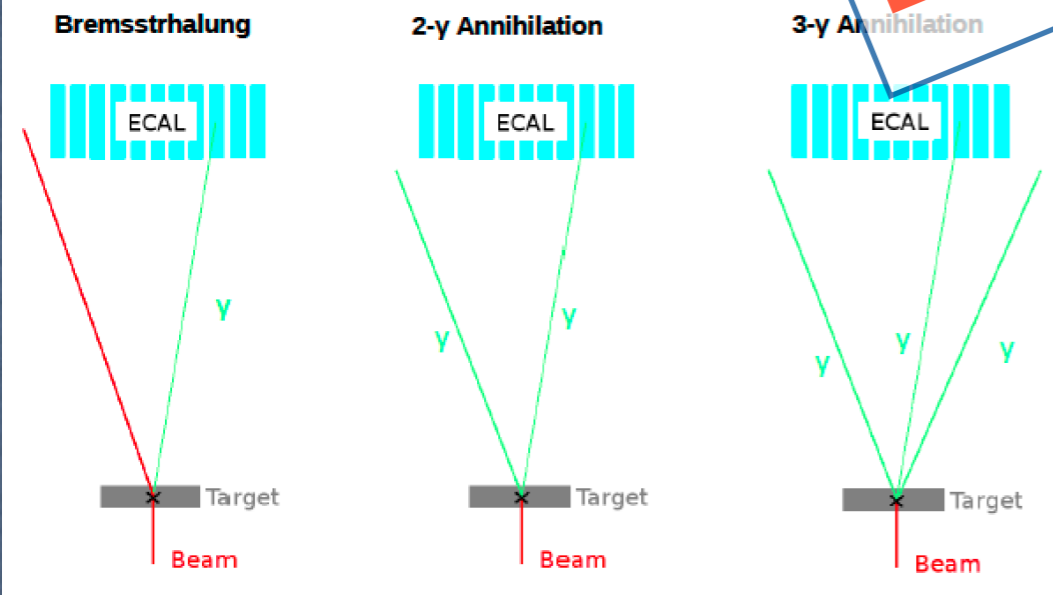
e^+ annihilation on fixed (thin) target

- Main limitation: limited energy in the CM $\sim \sqrt{E_{\text{beam}}}$
- High energy positron beams are not (yet) available
- The highest energy at JLab (~ 11 GeV) Max $m_{A'} \sim 106$ MeV



Main Background Processes

Main processes that result in a single gamma hitting the ECAL:



Eric's Talk

The BDX experiment

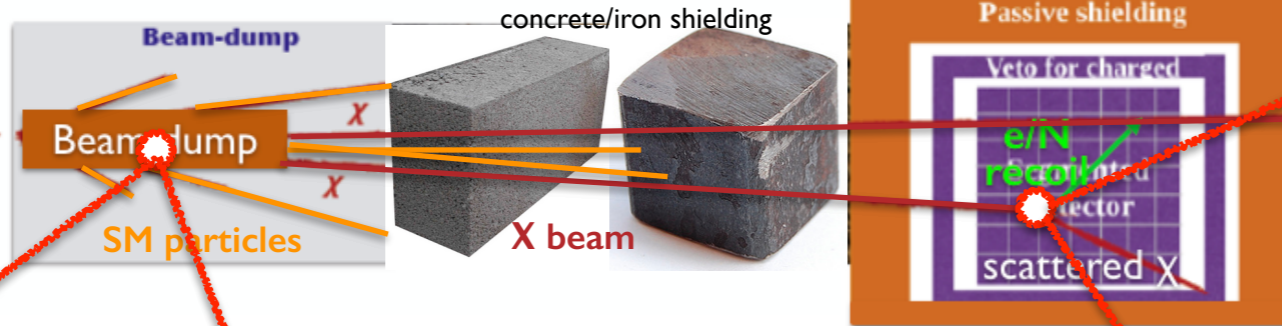
Two step process

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

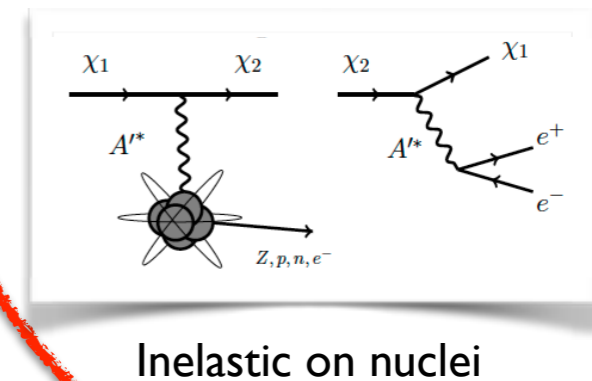
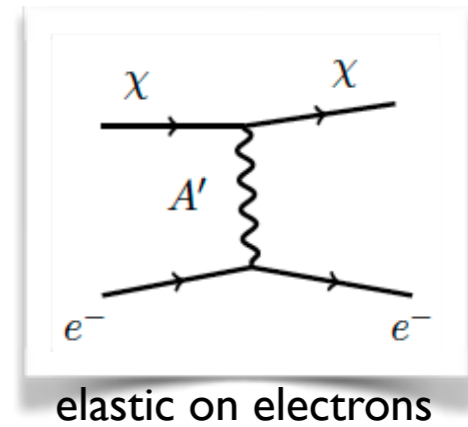
II) The χ (in-)elastically scatters on a e-/nucleon in the detector producing a visible recoil (GeV)

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

High intensity e^- beam

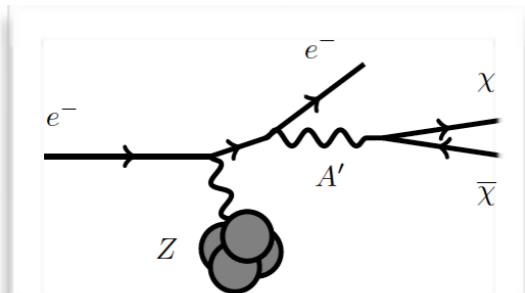


X detection



BDX @ JLab

X production



A' yield:

$$N_{A'} \propto \frac{\epsilon^2}{m_{A'}^2}$$

χ cross-section:

$$\sigma_{\chi e} \propto \frac{\alpha_D \epsilon^2}{m_{A'}^2}$$

Number of events:

$$N_\chi \propto \frac{\alpha_D \epsilon^4}{m_{A'}^4}$$

- Intense electron beam
- ~ few GeV range energy

Experimental signature in the detector:

X-electron \rightarrow EM shower ~GeV energy

BDX @ JLab

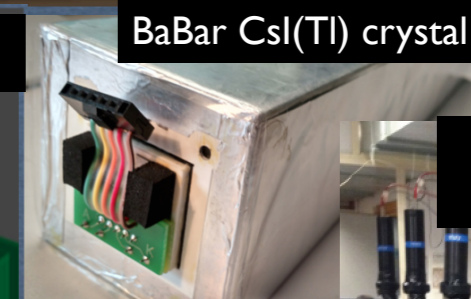
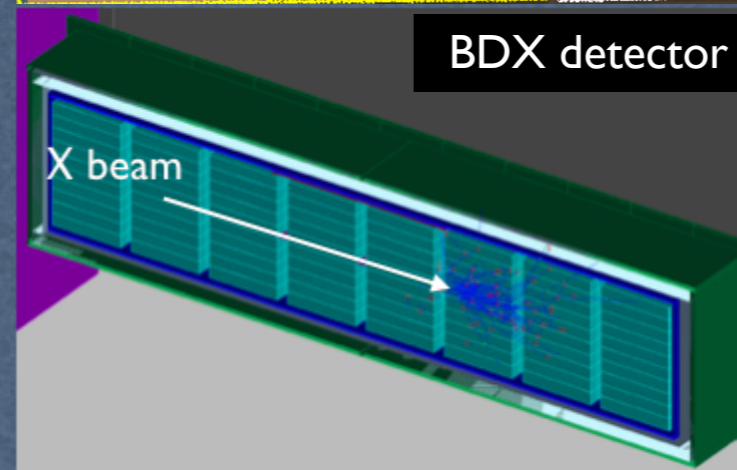
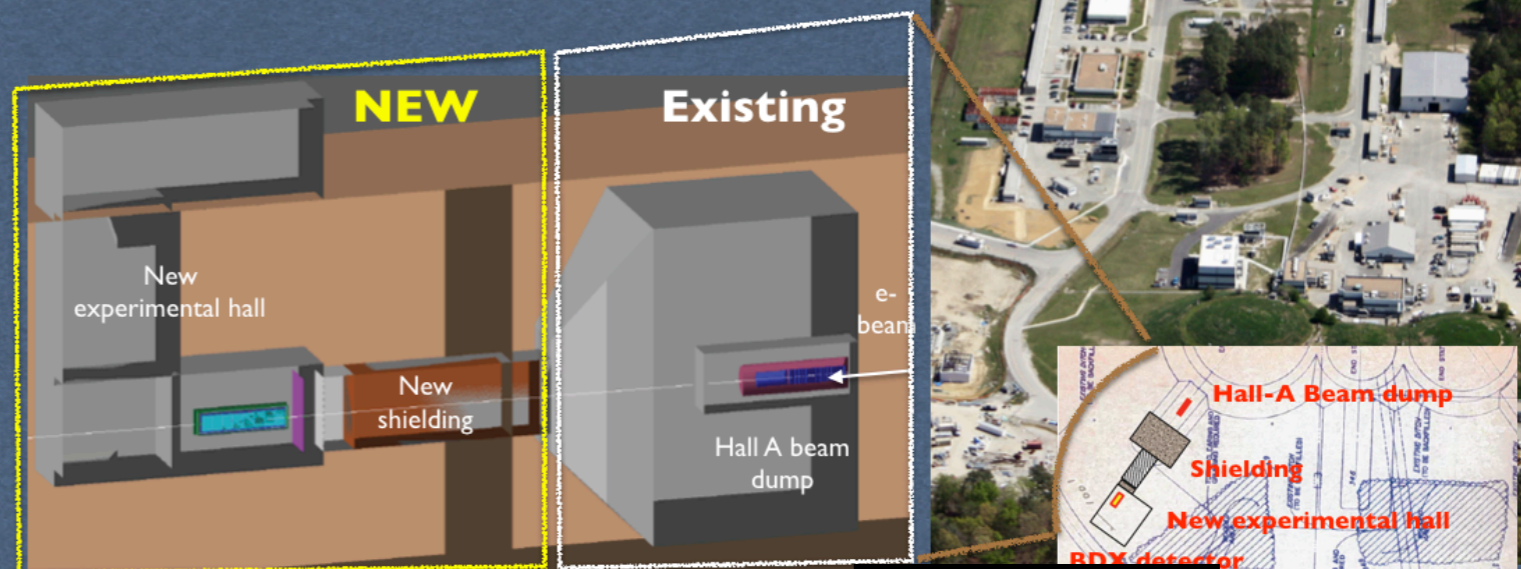
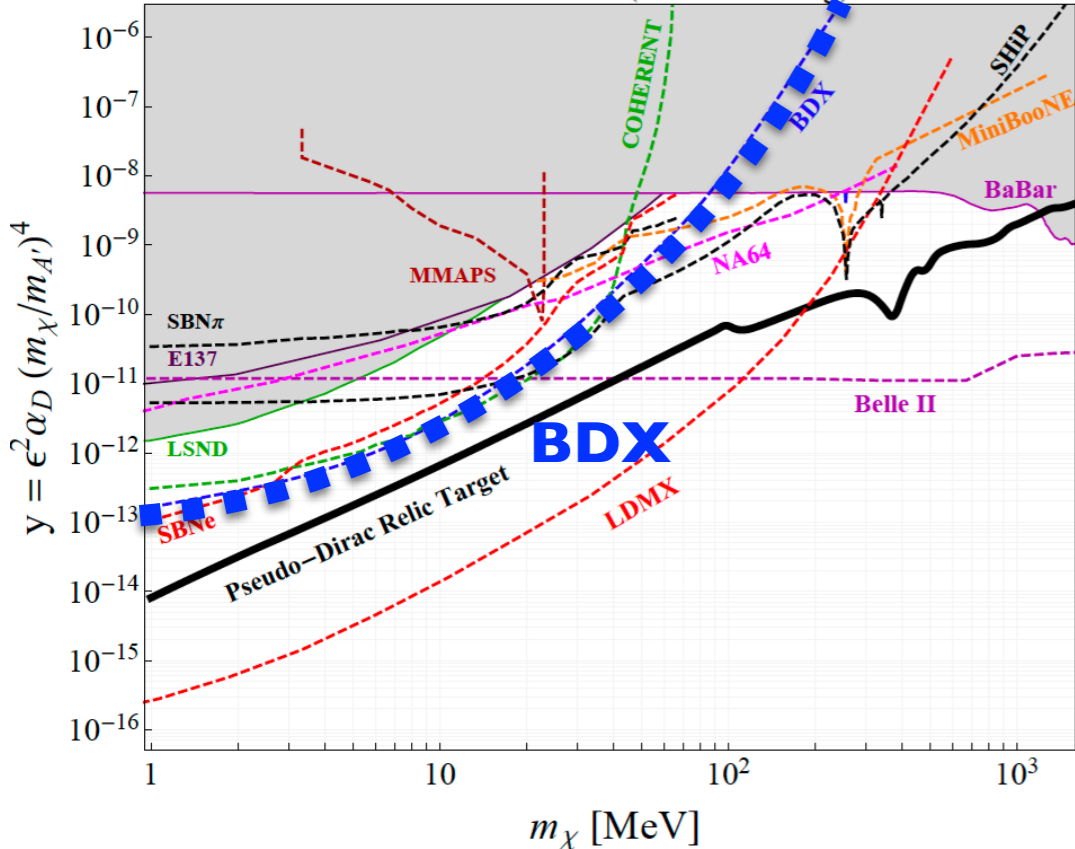
approved by JLab 2018
PAC with max rate (A)

- ★ High energy beam available: 11 GeV
- ★ The highest available electron beam current: ~65 uA
- ★ The highest integrated charge: 10²² EOT (41 weeks)
- ★ New experimental hall (~2\$M) at JLab
- ★ BDX detector (recycling BaBar Csl crystals) ~\$1M
- ★ Expected to run in ~2y



Expected BDX reach

Pseudo-Dirac DM (Kinetic Mixing)



Accumulating 10²² EOT in ~1y BDX
sensitivity is 10-100 times better
than existing limits on LDM

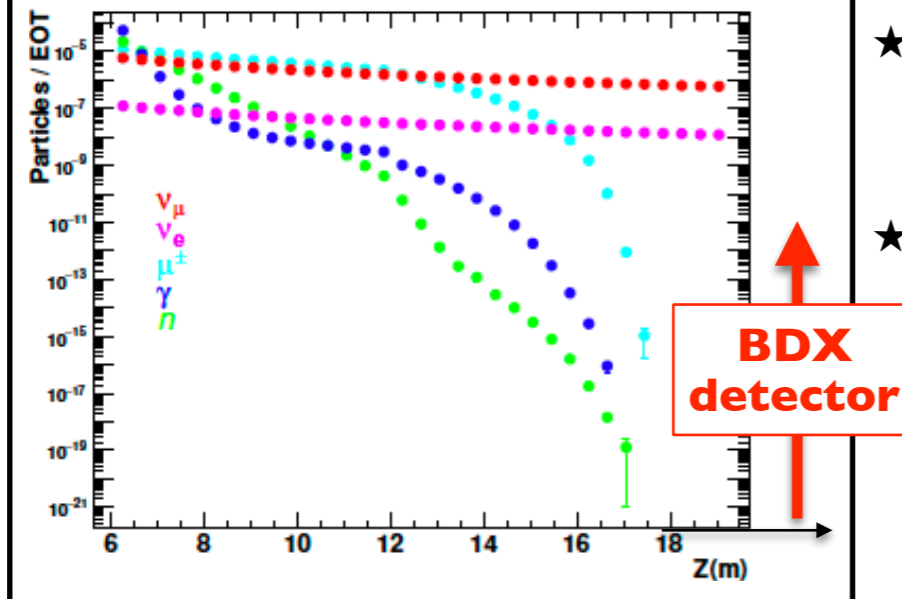
BDX detector: E.M. Calorimeter + Veto

- 8 modules 10x10 crystals each
- 800 Csl(Tl) crystals (from BaBar EMCal)
- 6x6 mm² Hamamatsu SiPM readout
- Plastic scintillator + WLS fibres, sips RO

BDX background assessment

Expected bg (FLUKA and GEANT4) for particles with $E > E_{Thr}$

$T_{\mu,n,\gamma} > 100 \text{ MeV} - T_v > 10 \text{ MeV}$

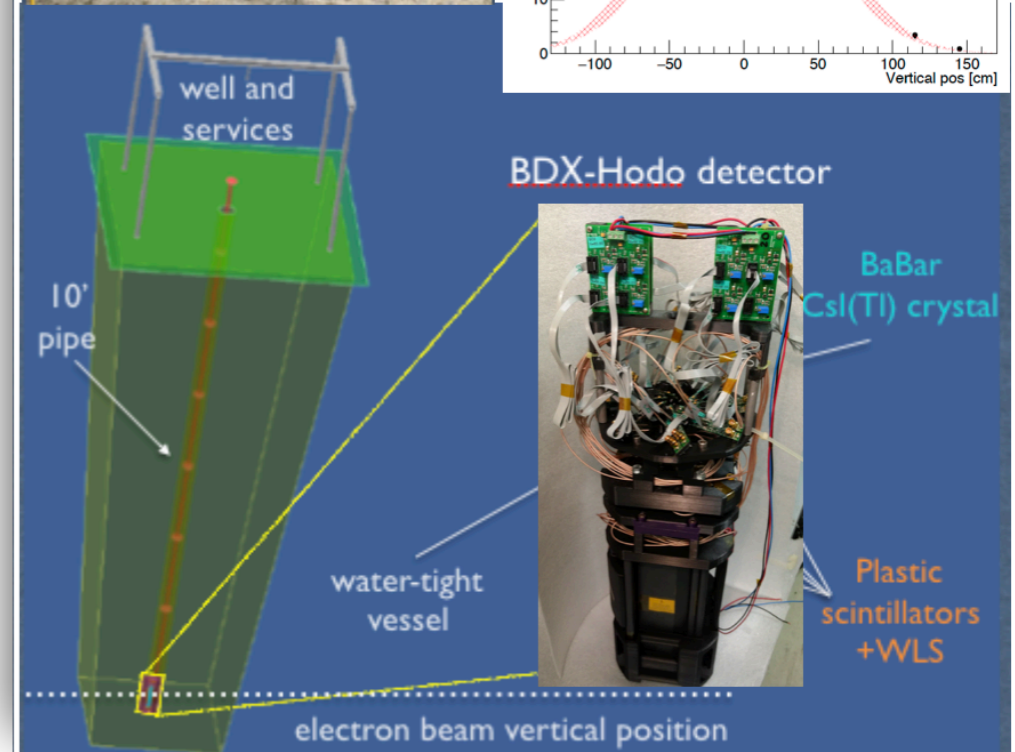
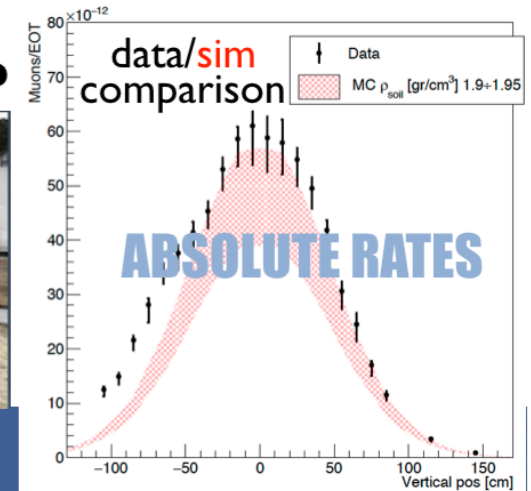
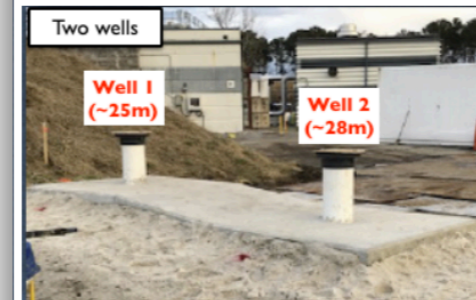


BDX detector

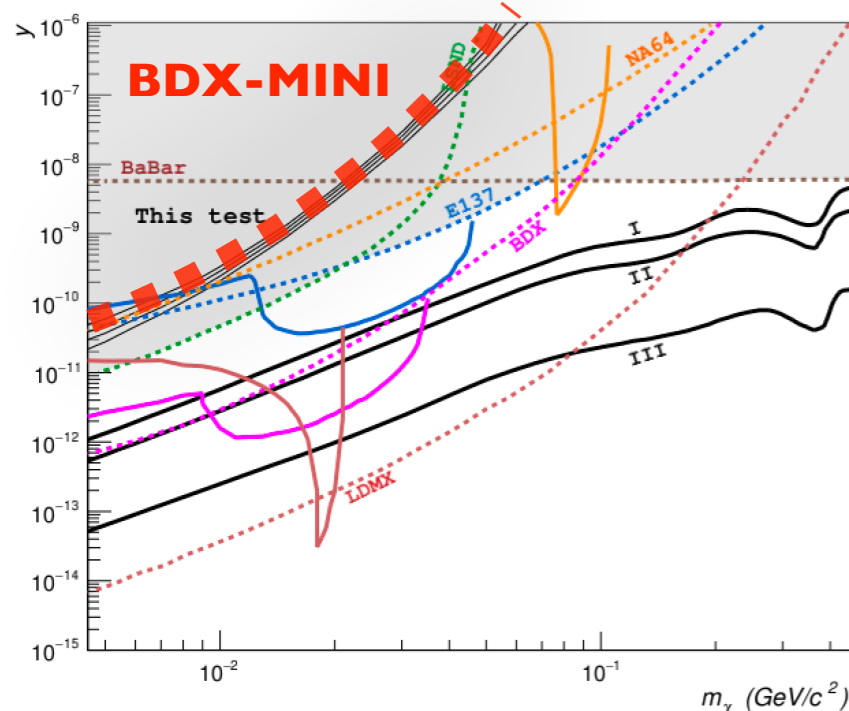
- ★ Cosmic background measured with the BDX detector prototype in CT
- ★ Muon bg: assessed by a dedicated measurement at JLab in spring '18
- ★ Neutrino bg: massive, high stat, FLUKA/GEANT simulations

Good agreement between data and simulations!

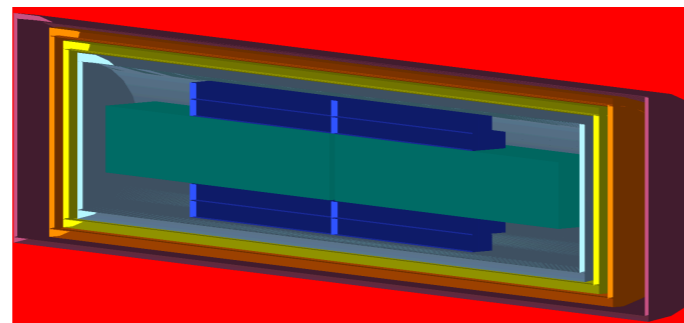
Muon background measurement at JLab



- BDX-MINI fits in BDX-HODO vessel
- 28 PbWO4 PANDA ECal crystals (higher ρ)
- Active vetos (same as BDX), passive W shielding

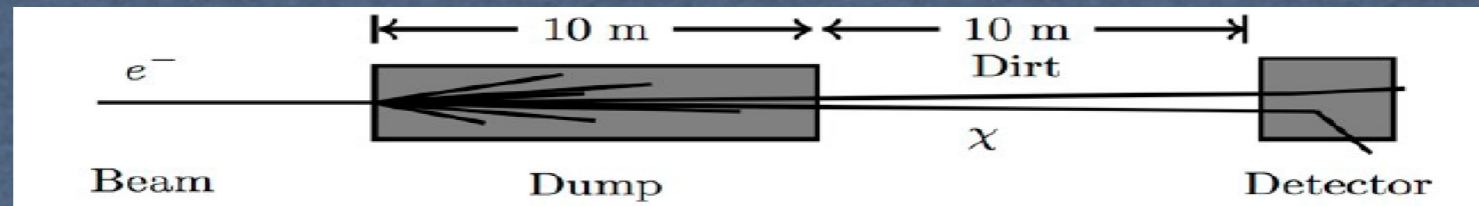


BDX-MINI in 2019

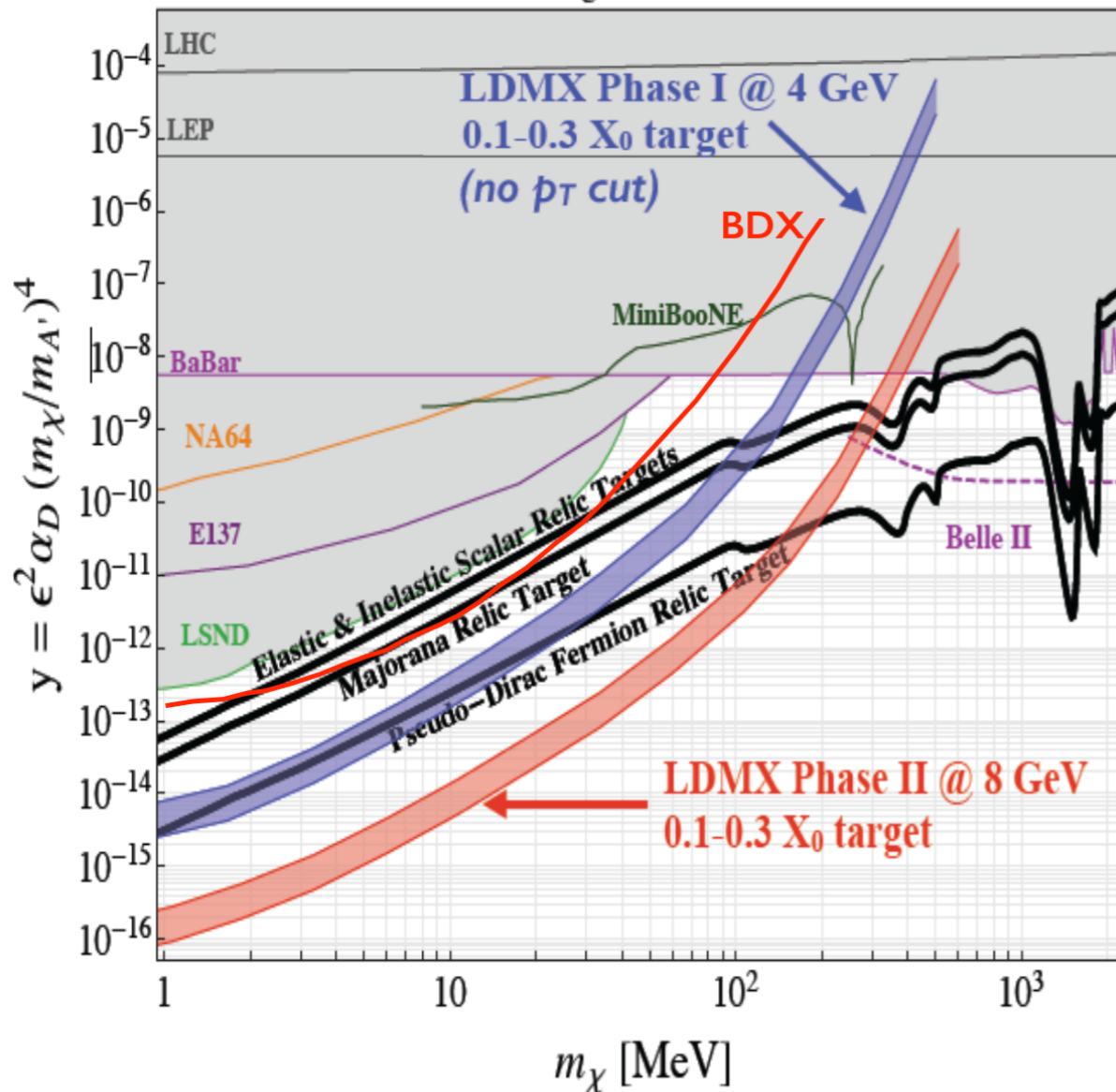


- take advantage of two wells dug for muon tests
- $E_{beam} = 2.2 \text{ GeV}$, 5^{20} EOT expected for 2019, no muons at well locations
- **BDX first physics result!**

Missing energy/momentum BD experiments



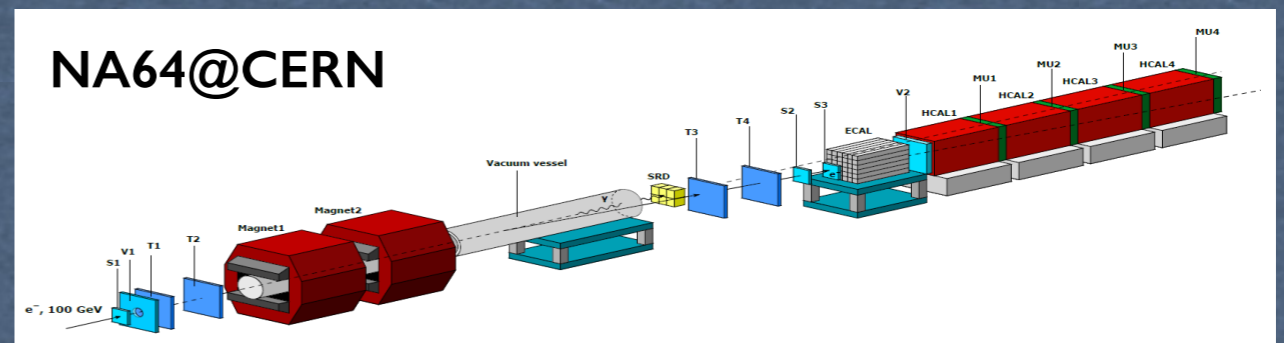
Thermal Relic Targets & Current Constraints



Present ...

- E137 and NA64: null results interpreted as invisible decay search
- No showering effects included

NA64@CERN

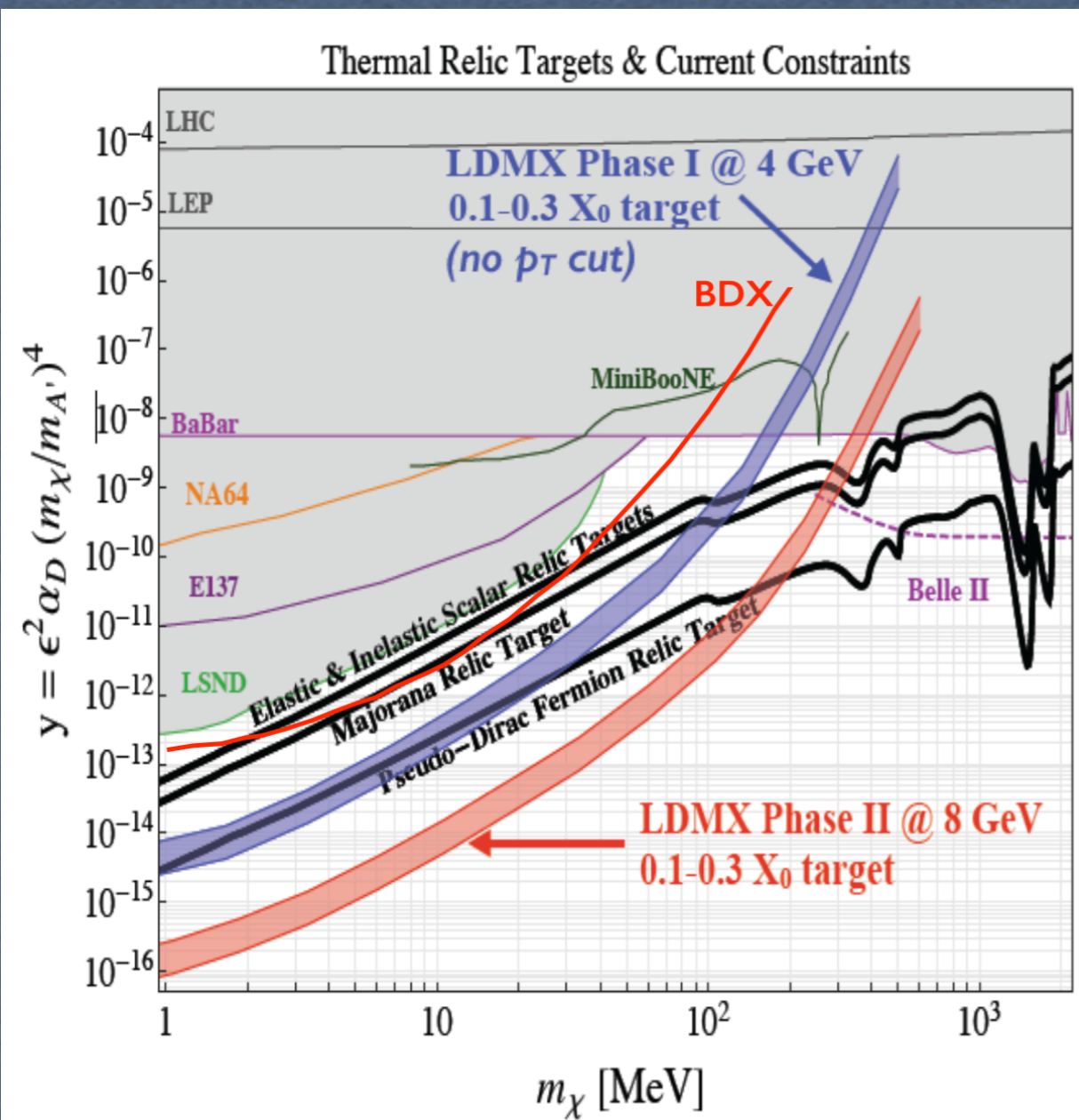
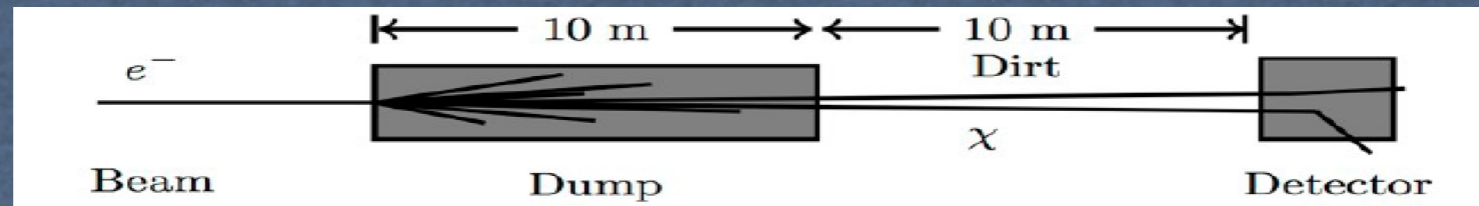


- Active beam-dump experiment
- Missing energy exp ($e Z \rightarrow e Z' A'$ with $A' \rightarrow$ invisible)
- 100 GeV SPS electron beam at SPS
- Active target (calorimeter)
- Exclusion plots based on 3×10^9 EOT

... and future BD experiments

- LDMX: missing momentum exp proposed at SLAC-LCLS-II 4 GeV e-beam, (Active beam-dump)
- BDX: beam-dump exp proposed at JLAB 11 GeV e- beam with 10^{22} EOT in 1y run

Missing energy/momentum BD experiments



... but

MissingMomentum vs BeamDump
(disappearance vs appearance)

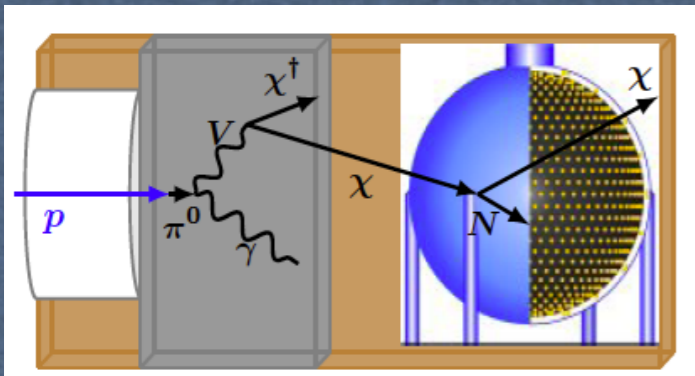
... **more sensitive** in the exclusion plots but **less reliable/convincing** in case of positive finding!

The two experimental approaches are complementary

- ★BDX will reach the ultimate sensitivity of beam dump experiments hitting the irreducible ν bg with a consolidated technology ready-to-go
- ★LDMX presents challenges that if/when overcome will lead the 2nd generation LDM searches experiments

Recent results

MiniBooNE@FERMILAB (Beam-Dump)



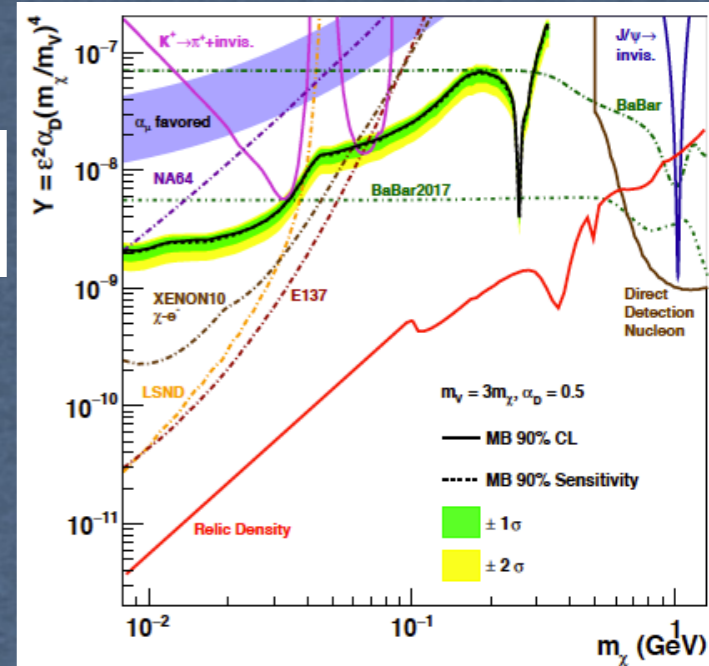
PRL 118, 221803 (2017)

PHYSICAL REVIEW LETTERS

week ending
2 JUNE 2017

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: 2×10^{20} protons on target (POT) per year



NA64@CERN Missing Energy

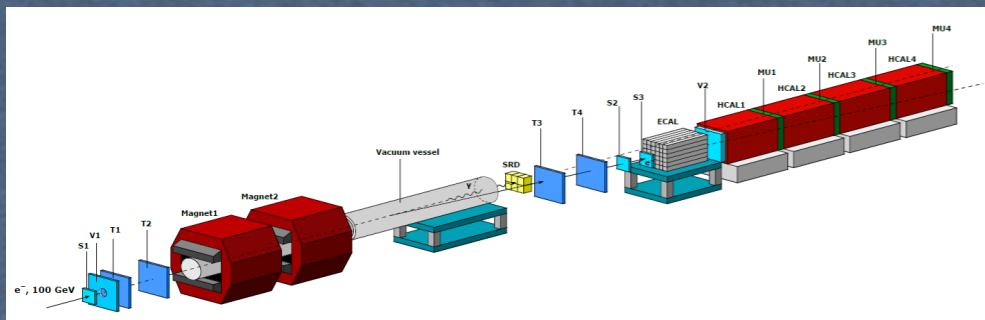
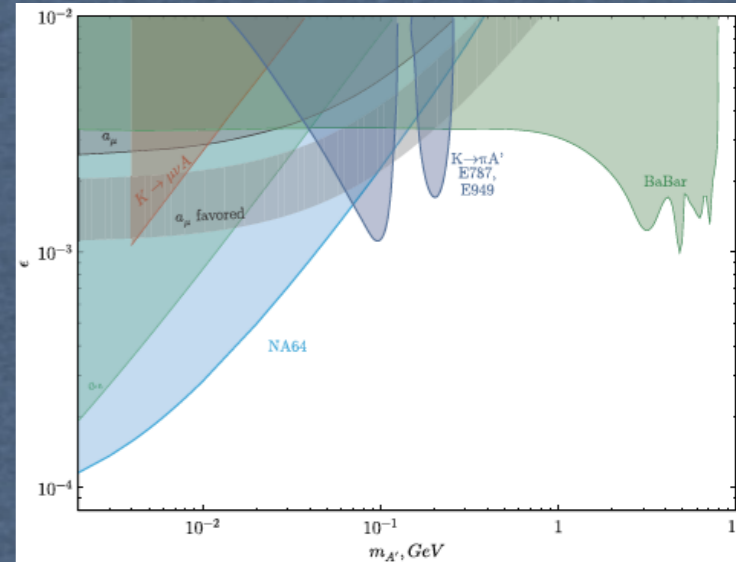
PRL 118, 011802 (2017)

PHYSICAL REVIEW LETTERS

week ending
6 JANUARY 2017

Search for Invisible Decays of Sub-GeV Dark Photons in Missing-Energy Events at the CERN SPS

- Missing energy exp ($e Z \rightarrow e Z' A'$ with $A' \rightarrow$ invisible)
- 100 GeV SPS electron beam at SPS
- Active target (calorimeter)
- Exclusion plots based on 3×10^9 EOT



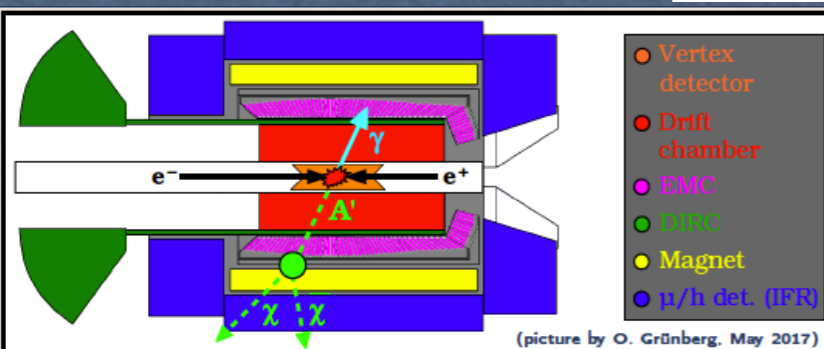
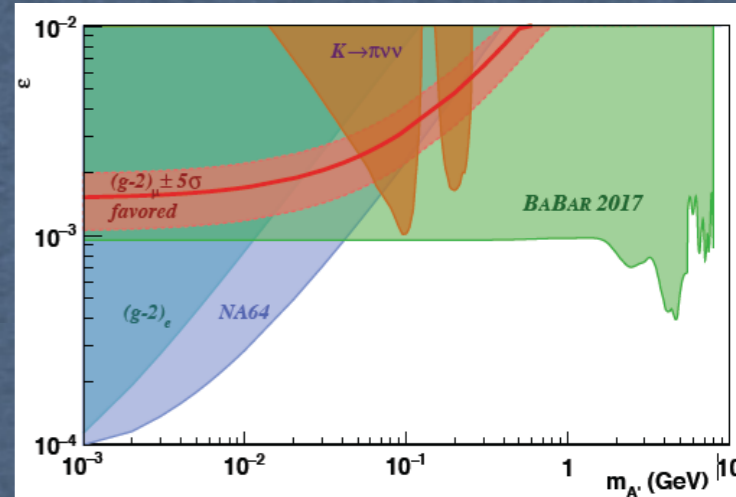
BaBar@SLAC e+e- collider

BABAR-PUB-17/001
SLAC-PUB-16923

arXiv:1702.03327v1 [hep-ex] 10 Feb 2017

Search for invisible decays of a dark photon produced in e^+e^- collisions at BABAR

- Missing mass exp ($e^- e^+ \rightarrow \gamma A'$ with $A' \rightarrow$ invisible)
- Mono-photon trigger
- Exclusion plots based on ~ 50 fb⁻¹



Status and perspectives

Dark Matter Basic Research Needs Workshop

15-18 October 2018
Gaithersburg Marriott Washingtonian Center
US/Eastern timezone

U.S. Cosmic Visions: New Ideas in Dark Matter

23-25 March 2017 Stamp Student Union, University of Maryland, College Park
US/Eastern timezone

"To respond to the 2014 P5 report recommendations in the search for dark matter particles and maintaining a diversity of project scales in our program, the DOE Office of High Energy Physics (HEP) is interested in identifying new, small projects for dark matter searches in areas of parameter space (i.e. mass ranges or types of particles) not currently being (or on track to be) explored. HEP is asking for community input in the spring 2017 timeframe in order to plan the program forward. Input is requested on the possibilities for small (the whole project is ~\$10 million or less) dark matter projects in unexplored parameter space. A community workshop, followed by a White Paper would be a good path to provide the input needed. We encourage you to collect information from the community, including theorists and experimentalists involved in non-accelerator



Experiment	Lab	Production	Detection	Vertex	Mass(MeV)	Mass Res. (MeV)	Beam	Ebeam (GeV)	Ibeam or Lumi	Machine	Ist Run	Next Run
APEX	JLab	e-brem	l^+l^-	no	65 – 600	0.5%	e^-	1.1–4.5	150 μ A	CEBAF(A)	2010	2018
A1	Mainz	e-brem	e^+e^-	no	40 – 300	?	e^-	0.2–0.9	140 μ A	MAMI	2011	-
HPS	JLab	e-brem	e^+e^-	yes	20 – 200	1–2	e^-	1–6	50–500 nA	CEBAF(B)	2015	2018
DarkLight	JLab	e-brem	e^+e^-	no	< 80	?	e^-	0.1	10 mA	LERF	2016	2018
MAGIX	Mainz	e-brem	e^+e^-	no	10 – 60	?	e^-	0.155	1 mA	MESA	2020	-
NA64	CERN	e-brem	e^+e^-	no	1 – 50	?	e^-	100	2×10^{11} EOT/yr	SPS	2017	2022
Super-HPS	SLAC	e-brem	vis	yes	< 500	?	e^-	4 – 8	1 μ A	DASEL	?	?
(TBD)	Cornell	e-brem	e^+e^-	?	< 100	?	e^-	0.1-0.3	100 mA	CBETA	?	?
VEPP3	Budker	annih	invis	no	5 – 22	1	e^+	0.500	$10^{33} \text{ cm}^{-2} \text{ s}^{-1}$	VEPP3	2019	?
PADME	Frascati	annih	invis	no	1 – 24	2 – 5	e^+	0.550	$\leq 10^{14} e^+ \text{ OT/y}$	Linac	2018	?
MMAPS	Cornell	annih	invis	no	20 – 78	1 – 6	e^+	6.0	$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$	Synchr	?	?
KLOE 2	Frascati	several	vis/invis	no	< 1.1 GeV	1.5	e^+e^-	0.51	$2 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$	DAΦNE	2014	-
Belle II	KEK	several	vis/invis	no	$\lesssim 10 \text{ GeV}$	1 – 5	e^+e^-	4×7	$1 \sim 10 \text{ ab}^{-1} / \text{y}$	Super-KEKB	2018	-
SeaQuest	FNAL	several	$\mu^+\mu^-$	yes	$\lesssim 10 \text{ GeV}$	3 – 6%	p	120	10^{18} POT/y	MI	2017	2020
SHIP	CERN	several	vis	yes	$\lesssim 10 \text{ GeV}$	1 – 2	p	400	$2 \times 10^{20} \text{ POT/5y}$	SPS	2026	-
LHCb	CERN	several	l^+l^-	yes	$\lesssim 40 \text{ GeV}$	~ 4	pp	6500	$\sim 10 \text{ fb}^{-1} / \text{y}$	LHC	2010	2015



WORKSHOP ON DARK SECTORS 2016

ISOLA D'ELBA

ids for light dark matter | accelerators | Dark forces searches | detection and cosmology | n and experimental techniques |

The existence of dark matter directly suggests new physics beyond the Standard Model. In the past 5 years, an international program of new experiments has expanded dark sector searches to include new forces and matter at the GeV-scale and below, motivated by both data and theory. While this program has made impressive progress, there are considerable challenges that must be overcome to fully explore the most viable dark sector scenarios. The goal of this workshop is to tackle these challenges, finding solutions to problems of principle and technology that are currently limiting our ability to fully explore light dark matter, dark photons, and other dark sector physics interacting with familiar matter.

SLAC National Accelerator Laboratory

Organizing Committee:
Rouven Essig (Stony Brook)
Matt Graham (SLAC)
John Jaros (SLAC)
Tim Nelson (SLAC)
Philip Schuster (SLAC)
Natalia Toro (SLAC)

www-conf.slac.stanford.edu/darksect

Light Dark Matter search @ Accelerators

SLAC NATIONAL ACCELERATOR LABORATORY

LDMA-2015 International workshop Camogli, Italy June 24-26 2015

Local Organizing Committee:
M. Battaglieri (INFN-Genova)
A. Caldeano (INFN-Genova)
D'Angelo (Università Roma Tor Vergata)
M. De Nappi (INFN-Catania)
R. De Vita (INFN-Genova)
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International Advisory Committee:
J. Alexander (Cornell University)
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N. Randazzo (INFN-Catania)
E. Scapellato (INFN-Bologna)
P. Schuster (Perimeter Institute)
C. Sinelli (Columbia University)
S. Stapanian (Jefferson Lab)
M. Taub (Università di Genova)

website: <http://ldma2015.gsi.infn.it> email: ldma2015@gsi.infn.it

Dark Sectors 2016 Workshop arXiv:1608.08632



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
- * Extensive experimental plans at high intensity e-facility: JLab, LNF, Cornell, Mainz, SLAC (+ p beam at FNAL and CERN)
- * A new generation of dedicated and optimised experiments at high intensity frontier will test the relic (light) dark matter scenario
- * Jefferson Lab is the world-leader facility for present and near-future LDM searches: APEX, HPS, DarkLight, BDX (and possibly e^+ annihilation and LDMX)
- * Significant interests from funding agencies (DOE/NSF) and labs (CERN and JLab) to run small scale experiments with a great discovery potential
- * Discovery or decisive tests of simplest scenarios will possible in the next ~5-8 years!