Search for dark matter at accelerators. NA64 experiment

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Outline

1. Introduction
2. Light dark matter
3. Curent experimental bounds
4. NA64 experiment
5. Conclusions

1.Introduction

A lot of references are contained in:

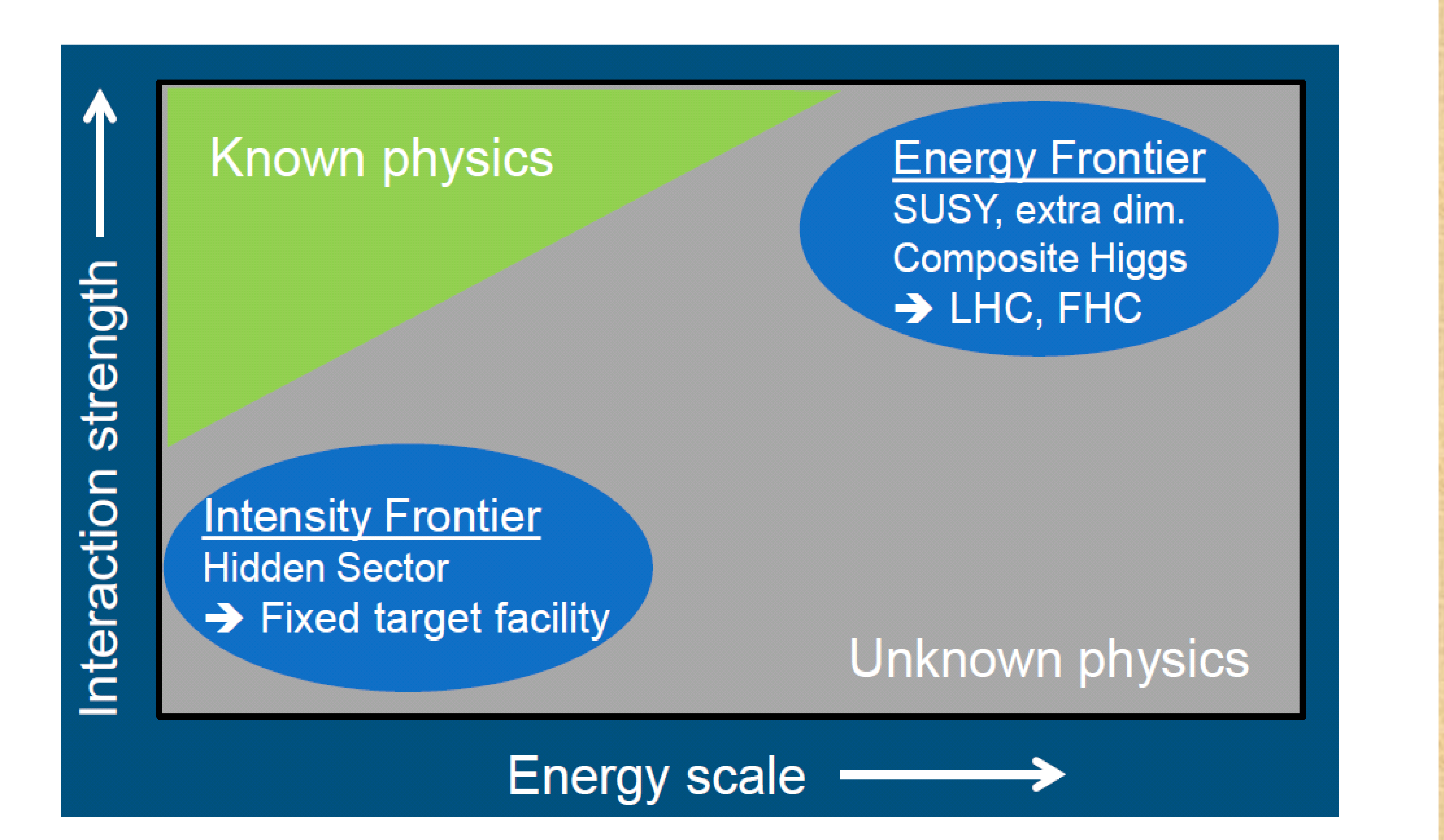
1. J. Alexander et al., arXiv:1608.08632;
2. S.N.Gninenko, N.V.Krasnikov, V.A.Matveev, Phys.Part.Nucl. 51 829 (2020)
3. S.N.Gninenko, N.V.Krasnikov, V.A.Matveev, UFN, 191, N 12, December 2021
5. D.S.Gorbunov, V.A.Rubakov, Introduction to the Theory of early Universe, 2011, Moscow

1.Introduction

Three lines of research in experimental elementary particle physics:

1. High energies → search for new massive particles (CMS and ATLAS mainly)
2. Relatively low energies → search for new relatively light O(10) GeV or less new particles with small coupling constants
3. The measurements with better accuracy

1.Introduction



1.Introduction

Search for new light particles:

1. S = 0 - scalar portal – axions, inflantons, flavons, ...
2. S = ½ - neutrino portal - neutral leptons (sterile neutrino)
3. S =1 - vector portal – light dark vector boson
4. S = 3/2 - gravitino

As a review: arXiv:1504.04855

The main motivation in favor of BSM physics is dark matter

Also probably some hints as:

1. (g-2)-muon anomaly
2. B-semi leptonic decays

DARK MATTER PROBLEM

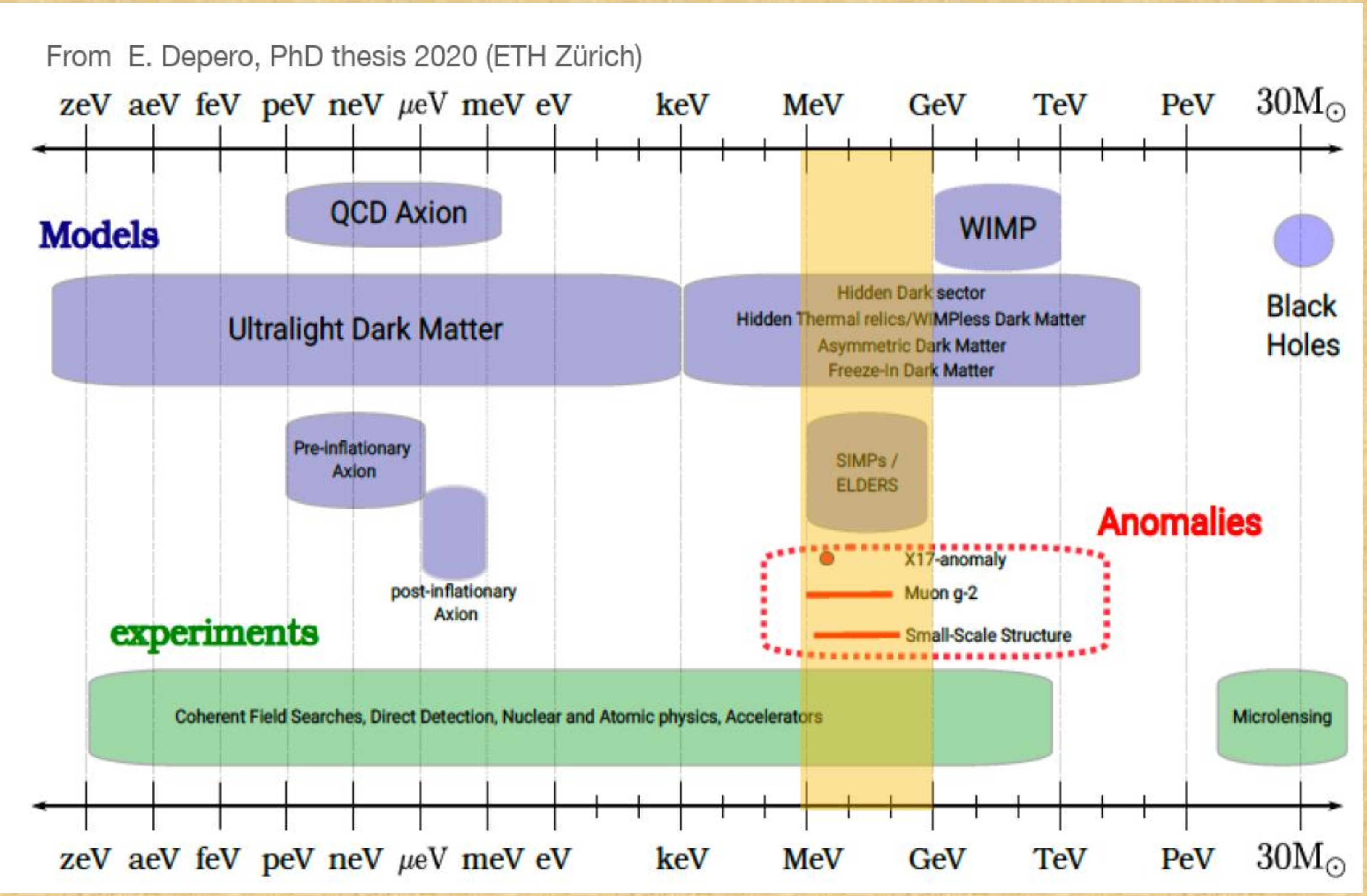
We know that dark matter exists and it is cold (nonrelativistic) or warm

But we don't know:

1. Spin of dark matter particles
2. Mass of dark matter particles

In SUSY with R-parity LSP is gaugino with s = ½ and m = O(100 GeV) as a rule

Dark matter mass range



Dark matter constraints

1. Dark matter is nonrelativistic or warm
2. From PLANCK experiment (CMB bounds) data s-wave annihilation is excluded for dark matter masses

$m_\chi \leq 10$ GeV

2.Light dark matter

It is possible that dark matter particles are relatively light with masses O(1 GeV) or less (C.Boehm, P.Fayet)

To avoid Lee-Weinberg “theorem”

Renormalizable realization – additional interaction connects our world and dark world

The most popular scenario – model with vector messenger dark photon (B.Holdom, L.Okun).

Also models with scalar mediator exist

- **Okun, Holdom (1986)** $\alpha_D = e_D^2/(4\pi)$: new masssive boson A' (dark photon) which has kinetic mixing with ordinary photon ϵ:

$$\mathcal{L} \supset -\frac{1}{4}F_{\mu\nu}^2 + \frac{1}{4}\left(F'_{\mu\nu}\right)^2 + \frac{\epsilon}{2}F_{\mu\nu}F'_{\mu\nu} + +e\bar{\psi}_e\gamma_\mu A^\mu\psi_e + \mathcal{L}_{int}(A' - \mathrm{DM})$$

- Field redefinition $A_\mu \to A_\mu + \epsilon A'_\mu$ to get rid of kinetic mixing between Standard Model (SM) photon A and massive Dark Photon A'
- That implies the effective interaction of DP with electrons $\mathcal{L} \supset e\epsilon \cdot \bar{\psi}_e\gamma^\mu A'_\mu\psi_e$
- Production: A'-bremsstrahlung $e^- N \to e^- N A'$,
- Decays:
  – **Mostly Visible:** $A' \to e^+e^-$, $\mu^+\mu^-$, hadrons, assuming $m_{A'} > 2m_e$, $2m_\mu \ldots$
  – **Mostly Invisible:** $A' \to \chi\chi$ if $m_{A'} > 2m_\chi$ assuming $\alpha_D \sim \alpha_{QED} \gg \epsilon$

The most popular light dark matter model – model with additional U(1) gauge field A' – dark photon model (Holdom, Okun)

Dark photon connects our world and dark matter world due to nonzero kinetic mixing between dark photon and ordinary photon

Also models with (B-L) interaction of light vector Z` boson and (L_μ - L_τ) current are often discussed.

Dark matter spin

1. Scalar dark matter
2. Majorana dark matter
3. Pseudo Dirac dark matter

The main assumption – in the early Universe dark matter is in equilibrium with observable matter. At some temperature dark matter decouples.

Observable dark matter density allows to predict the annihilation cross section

The Lagrangian of the dark photon model is the sum of 3 terms

$L = L_{SM} + L_{SM,dark} + L_{dark}$

L_{SM} – the SM Lagrangian

L_{dark} - dark particles Lagrangian

$L_{SM,dark} = -(\varepsilon/2\cos(\theta_W))F'_{\mu\nu}B^{\mu\nu}$

$F'_{\mu\nu} = \partial_\mu A'_\nu - \partial_\nu A'$

$B_{\mu\nu} = \partial_\mu B_\nu - \partial_\nu B_\mu$

B_μ - U(1) gauge field of SM

SU(2)·U(1) – gauge fields

Scalar dark matter χ

$L_{dark,s} = (\partial_\mu \chi - i e_D A'_\mu \chi)^* \cdot (\partial_\mu \chi - i e_D A'_\mu \chi) - m^2_\chi \chi^* \chi - \lambda (\chi^* \chi)^2$

$-(1/4) F'_{\mu\nu} F'^{\mu\nu} + (m^2_{A'}/2) A_\mu' A'^\mu$

It is possible to use Higgs mechanism to create dark photon mass in a gauge invariant way

Also models with Majorana fermion ($\chi = C\chi^*$) are often used

$L_M = (e_D/2) \chi^* \gamma_\mu \gamma_5 \chi A'^\mu$

plus pseudo Dirac model

THERMAL ORIGIN

We assume that in the early Universe dark matter is in equilibrium with the SM matter

As a consequence:

Today DM density tells us about annihilation cross-section. Correct DM density corresponds to $<\sigma_{an} v> \sim 0(1)$ pb

Dark matter annihilation mechanism

Direct annihilation

$\chi\chi^{*} \to e^{+}e^{-}, \ldots$ $(m_{\chi} < m_{A'})$

Secluded annihilation

$\chi\chi^{*} \to A'A'$ $(m_{\chi} > m_{A})$

For dark photon model secluded annihilation is s-wave and for light

dark matter it is excluded . For scalar mediator secluded annihilation is

possible. Here we shall consider direct annihilation

Dark matter dark photon model depends on four unknown parameters

1. Mixing ε

2. Fine coupling constant for dark sector $\alpha_D = e^2_D/4\pi$

3. Dark photon mass $m_{A'}$

4. Dark matter mass m_χ

Thermal origin condition → $<\sigma_{an} v> \sim O(1)$ pbn

As a consequence: 3 independent parameters

$$\varepsilon^2 \alpha_D = F(m_{A'}, m_\chi)$$

To estimate DM density we have to solve Boltzmann equation

$$\frac{dn_d}{dt} + 3H(T)n_d = - < \sigma v_{rel} > (n_d^2 - n_{d,eq}^2)\,.$$

$$n_d(T) = \int \frac{d^3p}{2\pi^3} f_d(p,T)$$

The dark matter relic density can be numerically estimated as

$$\Omega_d h^2 = 8.76 \times 10^{-11} GeV^{-2} [\int_{T_0}^{T_d} (g_*^{1/2} < \sigma v >) \frac{dT}{m_d}]^{-1}$$

In nonrelativistic approximation with $< \sigma v_{rel} >= \sigma_o x_f^{-n}$ one can find that

$$\Omega_{DM} h^2 = 0.1 \Big(\frac{(n+1) x_f^{n+1}}{(g_{*s}/g_*^{1/2})} \Big) \frac{0.876 \cdot 10^{-9} GeV^{-2}}{\sigma_0}$$

$$x_f = c - (n + \frac{1}{2}) \ln(c)\,,$$

$$c = \ln(0.038(n+1) \frac{g}{\sqrt{g_*}} M_{Pl} m_\chi \sigma_0)$$

Here g_*, g_{*s} are the effective relarivistic energy and entropy degrees of freedom and g is an internal number of freedom degree. If DM particles differ from DM antiparticles $\sigma_o = \frac{\sigma_{an}}{2}$.

For s-wave annihilation cross-section with $n = 0$

$$< \sigma v_{rel} >= 7.3 \cdot 10^{-10} GeV^{-2} \cdot \frac{1}{g_{*,av}^{1/2}} (\frac{m_d}{T_d})$$

$$\epsilon^2 \alpha_D = 2 \cdot 10^{-8} GeV^{-2} \frac{(m_{A'}^2 - 4m_\chi^2)^2}{m_\chi^2} \cdot \frac{2c_s}{g_{*,av}^{1/2}}$$

For $m_{A'}=3m_\chi$ we find that dark matter is nonrelativistic:
$(T_D/m_\chi) = (0.1 - 0.05)$ for
$1\ MeV < m_\chi < 1\ GeV$

Scalar dark matter (p-wave)

$$\epsilon^2\alpha_D \sim 10^{-11}\cdot\left(\frac{m_\chi}{MeV}\right)^2$$

for Majorana dark matter additional factor 1/2

For fermion dark matter(s-wave)

$$\epsilon^2\alpha_D \sim 0.4\cdot 10^{-12}\cdot\left(\frac{m_\chi}{MeV}\right)^2$$

From the requirement of the absence of Landau pole singularity(H.Davoudiasl and W.J.Marciano, Phys.Rev. D92 035008 (2015)) upper bound on α_D

The concrete number depends on the Landau pole scale Λ and the model. For instance,

for $\Lambda = 1$ TeV

$\alpha_D \leq$ 0.8(0.2) for scalar(Majorana or pseudo Dirac)

for $\Lambda = M_{PL} = 1.2 \cdot 10^{19}$ GeV

$\alpha_D \leq$ 0.2(0.05) for scalar(Majorana or pseudo Dirac)

2.Search for light dark matter at accelerators

Dark Photon Searches

Production Modes

- Electron-positron annihilation
- Meson Decays
- Drell-Yan (collider or fixed target)
- Bremsstrahlung

Detection Signatures

- Pair resonance
- Beam-dump late decay
- Inclusive missing mass
- Reconstructed displaced vertex

Visible and invisible A' decays

Visible A' decays A' → e^+e^- ,$\mu^+\mu^-$

1. Prompt decays – resonant behavior in invariant mass distribution
2. Displaced decays –long lived A' (NA64 exp.)

Invisible decays

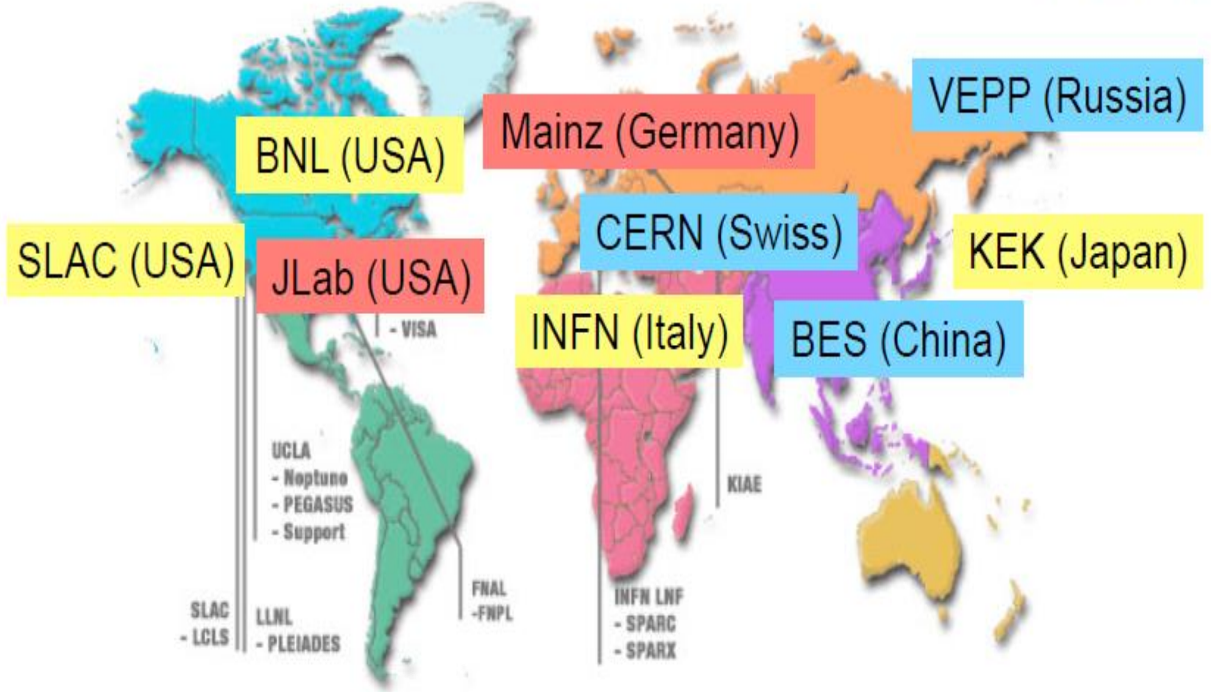
3. Missing momentum(energy) from A' → χχ decays into dark matter particles

Invisible mode detection

1. Beam dump (SHiP, …)
2. Missing mass measurement – resonant distribution (PADME, …)
3. Missing energy measurement (NA64)
4. Missing momentum measurement (LDMX)

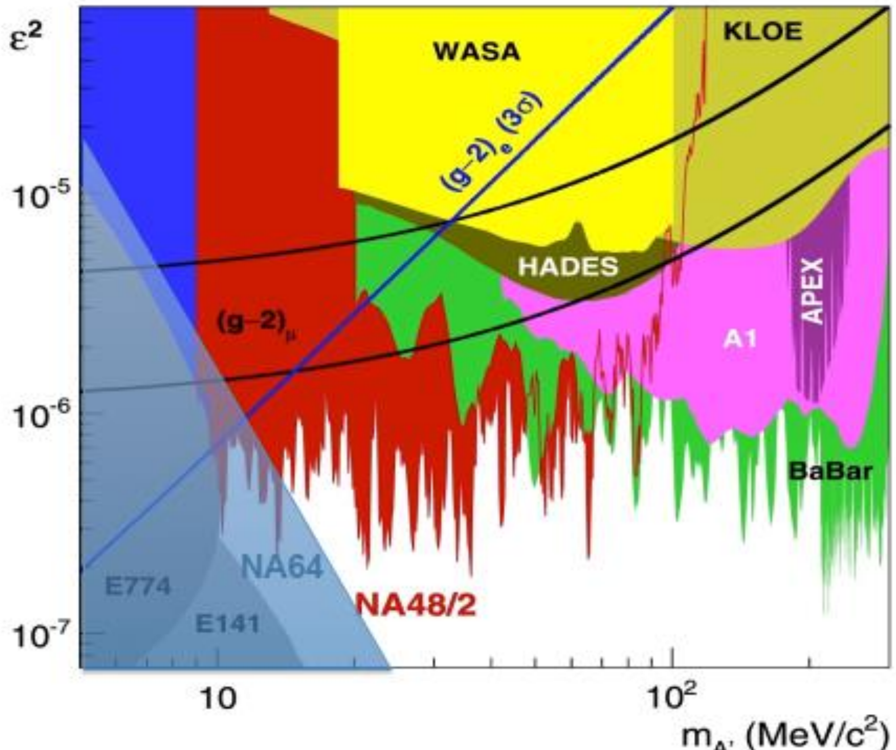
Dark Force searches in the Labs

Many searches for Dark Force in the Labs around the world (ongoing/proposed).



Visible mode

Summary plot for visible A’ decays



Current experimental bounds

1. The A1 and NA48 collaborations excluded masses between 30 MeV and 300 MeV as muon g-2 anomaly explanation.
2. BaBar collaboration excluded masses between 32 MeV and 10.2 GeV.

So the possibility of g-2 anomaly explanation in the model with visible A` decays is excluded.

Also beam dump experiments(electron beam dump – E137, E774, E141) exclude some regions in ε

Future and current visible decays searches

1. APEX at Jlab(USA) –prompt decays
2. HPS at Jlab – prompt decays
3. NA64 – displaced decays
4. Belle-|| at KEK(Japan) – prompt decays
4. MAGIX at MESA(Germany) –prompt decays
6. SHiP at CERN – displaced decays
7. VEPP3 at BINP(Russia) – prompt decays
8. SeaQuest(FNAL, USA) – dark photon decays into muons

.Invisible decays

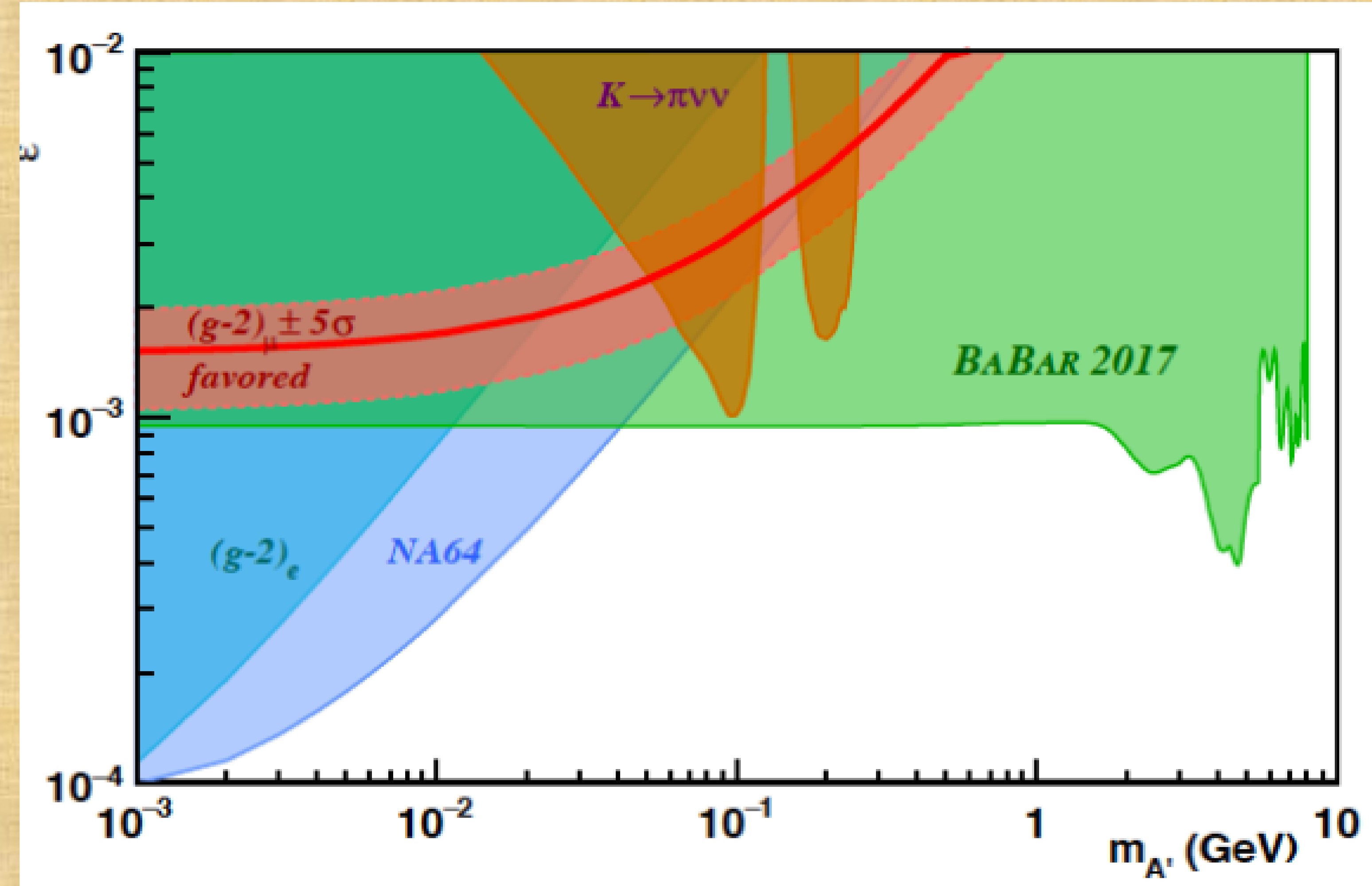
Invisible mode detection

1. Beam dump
2. Missing mass measurement – resonant distribution (PADME)
3. Missing energy measurement (NA64)
4. Missing momentum measurement (LDMX)

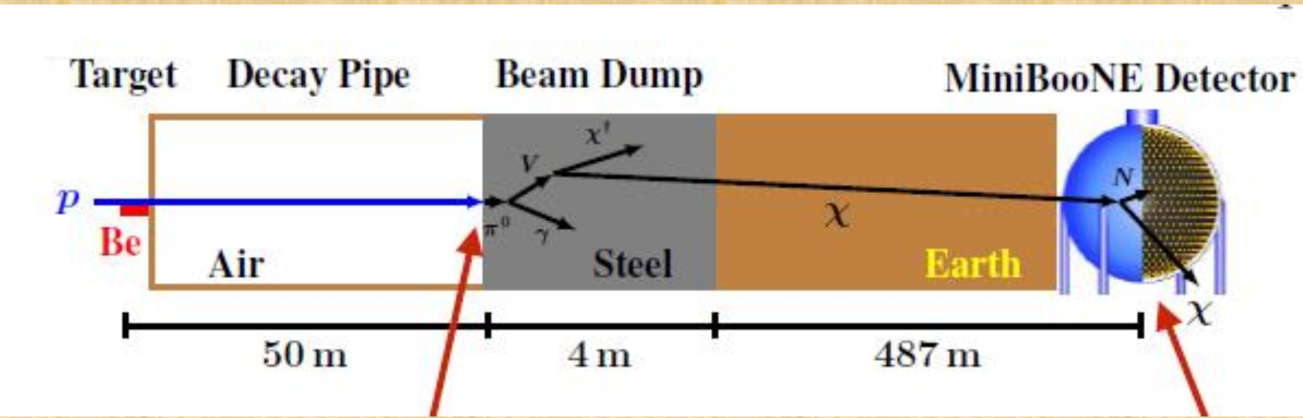
Current and future invisible decays searches

1. NA64 – missing energy searches
2. PADME at LNF(Italy) – missing mass searches
3. VEPP3 at BINP(Russia) – missing mass searches
4. Belle-|| at KEK(Japan) – missing mass searches
5. DarkLight at JLab(USA) – missing mass searches
6. MMAPS at Cornell(USA) – missing mass searches
7. LDMX at SLAC(USA) – missing momentum searches
8. MiniBooNE at FNAL(USA) – proton beam-dump
9. SHiP at CERN – proton beam –dump
10. SBN at FNAL(USA) – proton beam-dump
11. COHERENT at ORNL(USA) – proton beam- dump

Recent experimental results from NA64 and BaBar exclude (g-2) anomaly explanation

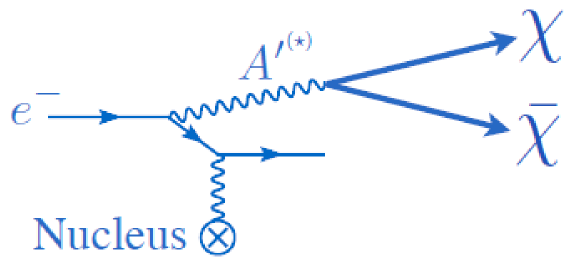


Example of proton beam dump. MiniBooNE



$$\sim \epsilon^4 \alpha_D$$

Missing energy(momentum) reaction NA64 and LDMX



$$\sigma \propto \frac{Z^2 \epsilon^2}{m_{\mathrm{A}'}^2}$$

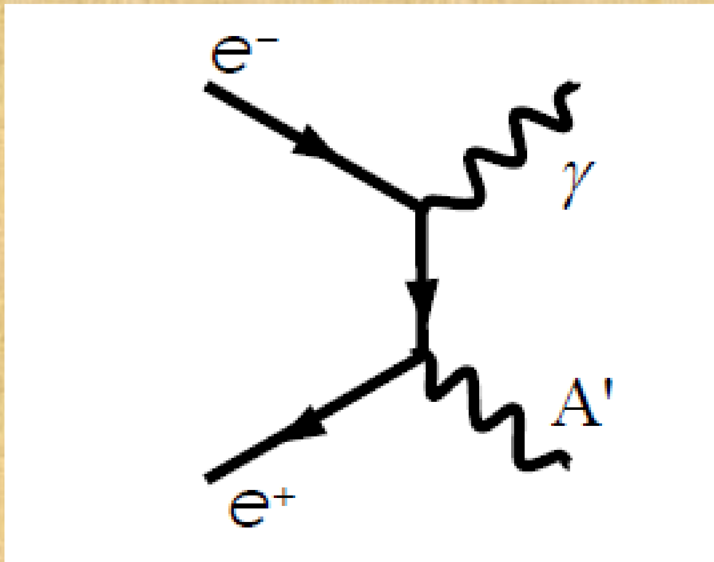
Experiments with missing mass searches

$$e^+ e^- \rightarrow \gamma A'$$

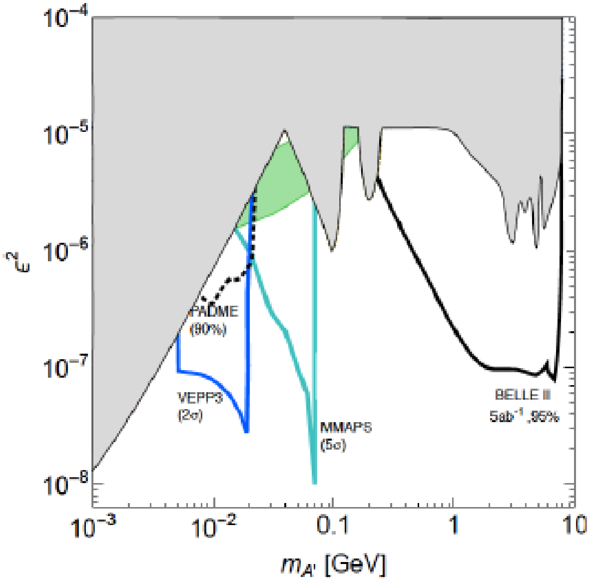
The knowledge of momenta e^+, e^- and γ allows to restore the A' mass – resonant distribution on invariant mass

PADME experiment

Positron Annihilation into Dark Matter Experiment



Dark Photon arXiv:1608.08632v1



Invisible final state A'→χχ

4. NA64 experiment

NA64 - Searches

A´-> invisible A´->

e^+e^-

at SPS CERN

4. NA64 experiment

The NA64 Collaboration(Yu.M.Andreev et al)

63 Researches from 12 Institutes

NA64 searches:

A´-> invisible, A´-> e^+e^-

at SPS CERN

Plus the use of muon beam

Two main reactions

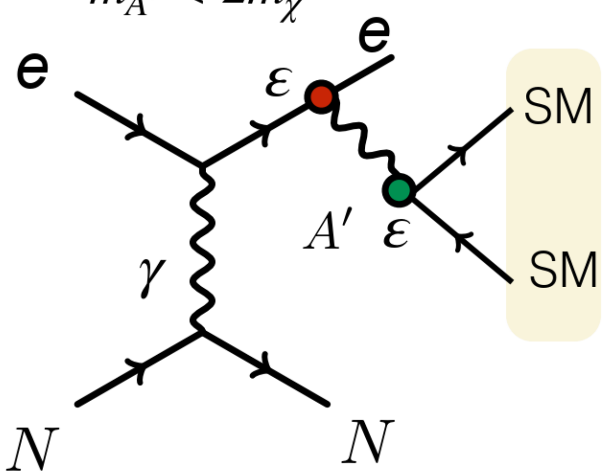
A'

S. Andreas et al., arXiv:1312.3309 (2013)
S. N. Gninenko, Phys. Rev. D 89, 075008 (2014)

Setup:

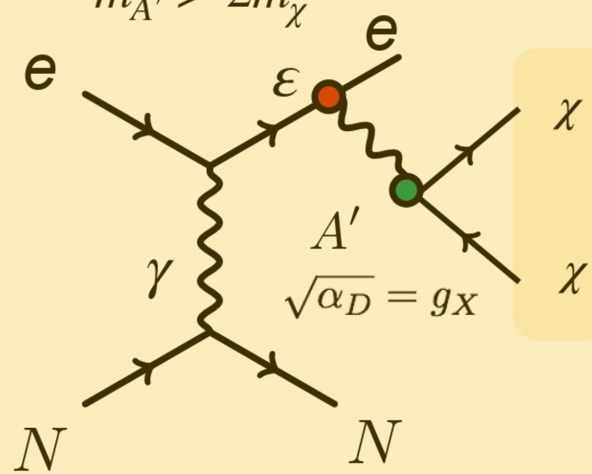
Visible mode

$m_{A'} < 2m_\chi$



Invisible mode

$m_{A'} > 2m_\chi$



Signature:

SM particles pair production

Missing energy

Focus of this talk

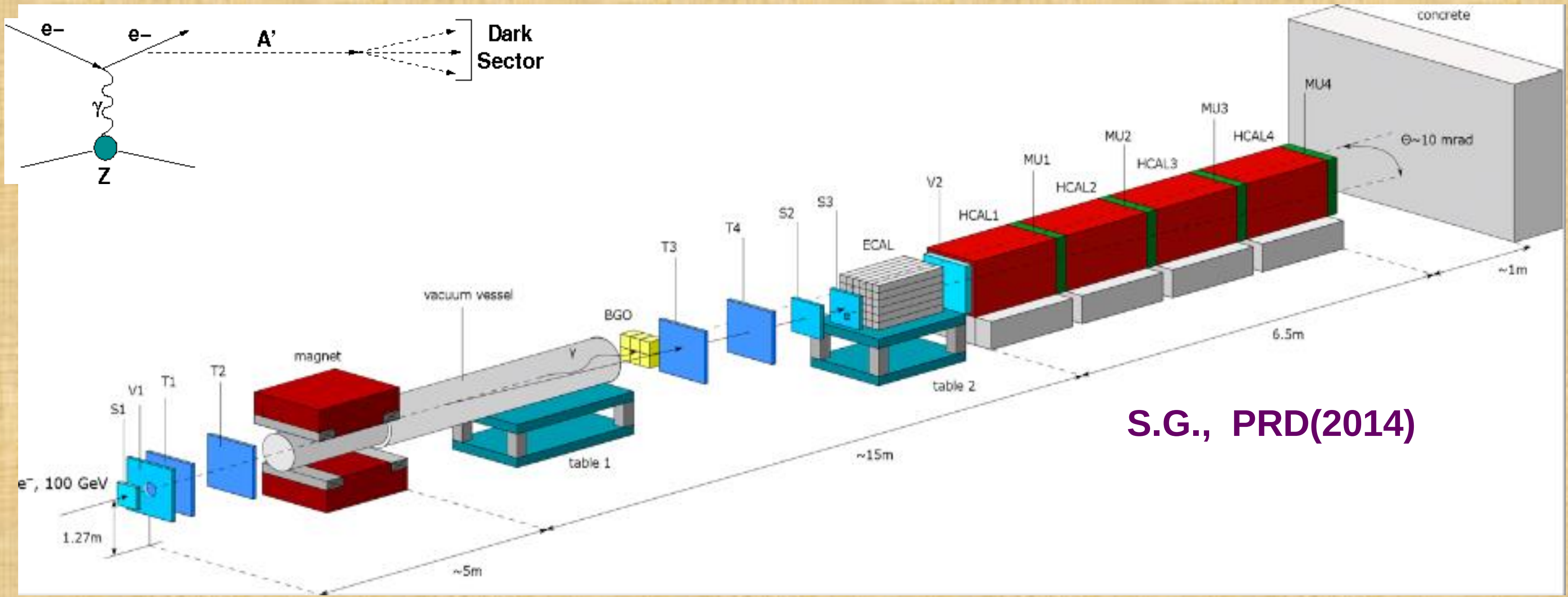
NA64 Research program

Reasearch program: Searches for sub-GeV Z`boson, NHL,… coupled to e, μ, q’s.
New method: Active beam dump combined with missing-energy technique

1. **Beam Purity for Light Dark Matter Search in Beam Dump Experiment**
   D. Banerjee, P. Crivelli, and A. Rubbia (Zurich, ETH)   Adv.High Energy Phys. 2015(2015)105730
2. **On detection of narrow angle e+e- pairs from dark photon decays**
   A.V. Dermenev, S.V. Donskov, S.N. Gninenko, S.B. Kuleshov, V.A. Matveev, V.V. Myalkovskiy, V.D. Peshekhonov, V.A. Poliakov, A.A. Savenkov, V.O. Tikhomirov, I.A.Zhukov
   IEEE Trans.Nucl.Sc. 62 (2015) 3283;
3. **The K_L invisible decays as a probe of new physics**
   S.N. Gninenko and N.V. Krasnikov
   Phys. Rev. D92 (2015) 034009;
4. **Search for invisible decays of π0, η, η', K_S and K_L: A probe of new physics and test using the Bell-Steinberger relation**
   S.N. Gninenko,
   Phys. Rev. D91 (2015) 015004;
5. **Muon g-2 and searches for a new leptophobic sub-GeV dark boson in a missing-energy experiment at CERN**
   S.N. Gninenko, N.V. Krasnikov, V.A. Matveev,
   Phys. Rev. D91 (2015) 095015;
6. **Search for MeV dark photons in a light-shining-through-walls experiment at CERN**
   S.N. Gninenko,
   Phys. Rev. D89 (2014) 075008
7. **The Muon anomalous magnetic moment and a new light gauge boson,**
   S.N. Gninenko and N.V. Krasnikov,
   Phys. Lett. B420 (2000) 9;
8. **Proposal for an Experiment to Search for Light Dark Matter at the SPS**
   S. Andreas, D. Banerjee, S.V. Donskov, P. Crivelli, A. Gardikiotis, S.N. Gninenko, F. Guber et al.,
   arXiv:1312.3309[hep-ex]

search for *A´->invisible* at CERN SPS

Invisible decay of Invisible State!



S.G., PRD(2014)

3 main components :

- clean, mono-energ. 100 GeV e- beam
- e- tagging system: MM tracker + SR
- 4π fully hermetic ECAL+ HCAL

Signature:

- in: 100 GeV e- track
- out: < 50 GeV e-m shower in ECAL
- no energy in the Veto and HCAL
- Sensitivity ~ ε^2


GOLIATH

NA64 dark photon detection

A' – production in ECAL, invisible decay

The A' production in electron nucleus interactions

$eZ \rightarrow eZA'$, $A' \rightarrow$ invisible

Signature: missing energy in ECAL + HCAL

In comparison with initial 100 GeV electron

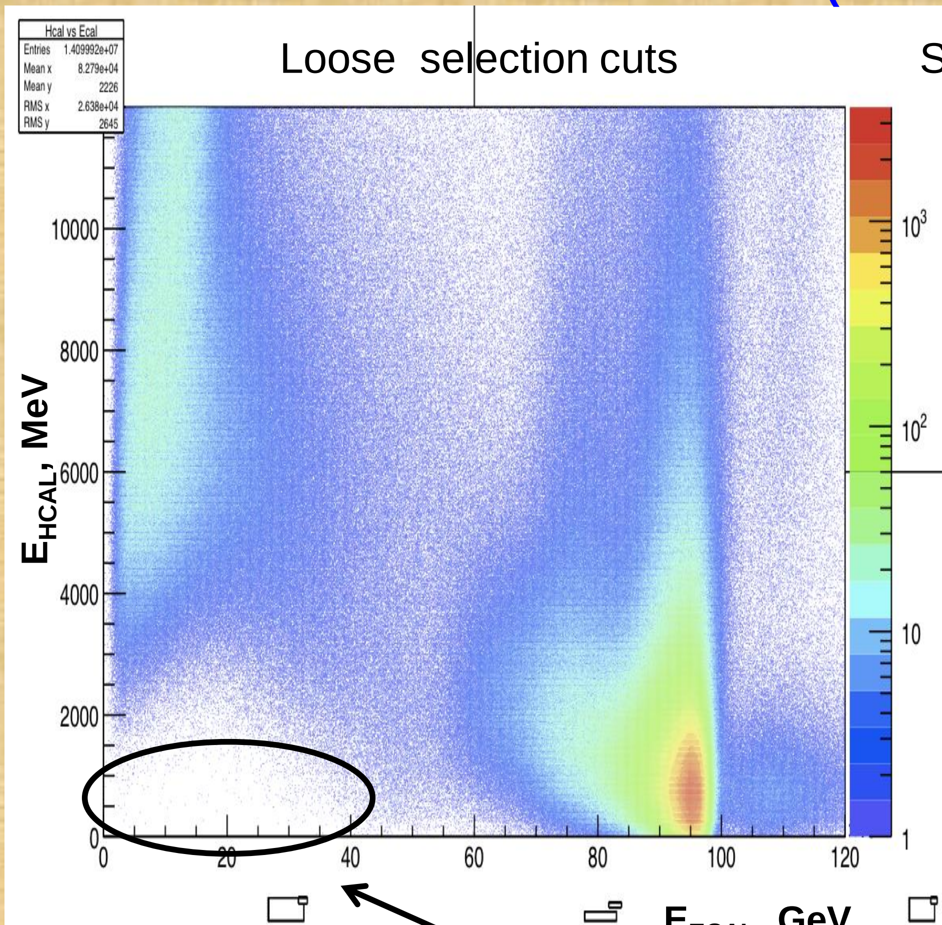
plus no essential activity in HCAL(E_{HCAL}<2 GeV)

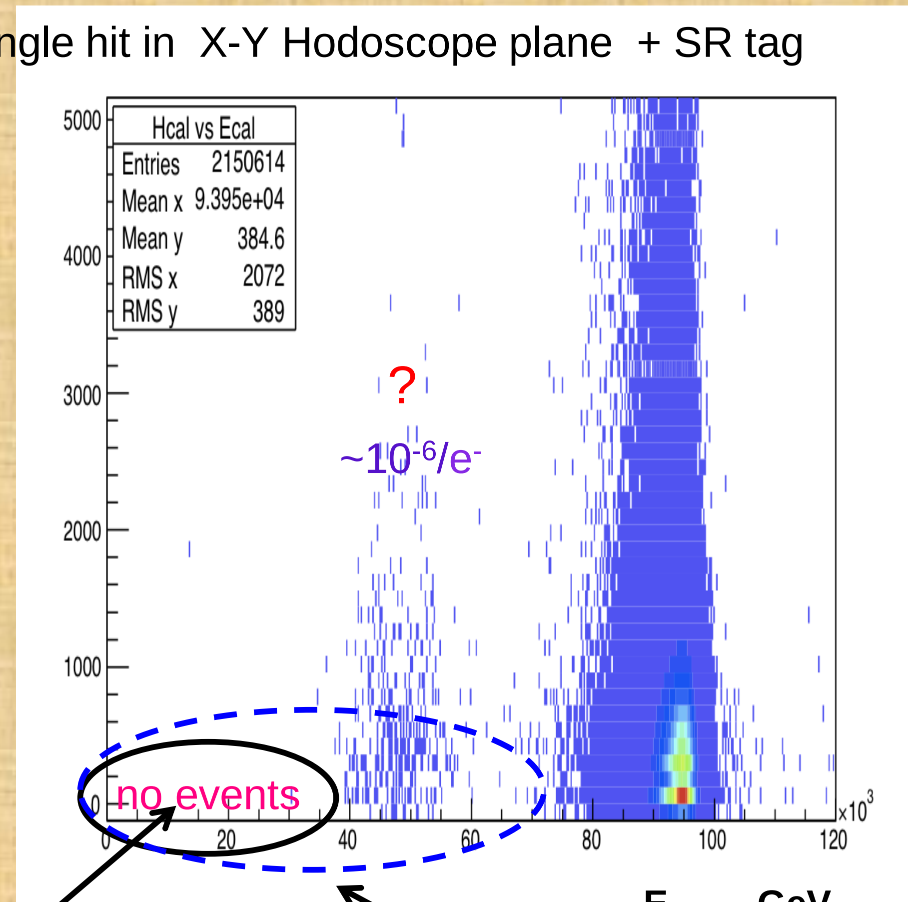
Summary of background sources for A`-> invisible

Source	Expected leve	Comment
Beam contamination		
-π, *p*, μ reactions and punchthroughs,… - e- low energy tail due to bremss., π,μdecays in flight,..	$< 10^{-13}$-10^{-12} ?	Impurity < 1% SR photon tag
Detector		
ECAL+HCAL energy resolution, hermeticity: holes, dead materials, cracks…	$< 10^{-13}$	Full upstream coverage
Physical		
-hadron electroproduction, e.g. eA->neA*, n punchthrough; - WI process: e Z->e Zνν	$< 10^{-13}$ $< 10^{-13}$	~10 mb x nonherm. WI σ estimated. textbook process, first observation?
Total	$< 10^{-12}$ + ?	

A´ signal in $(E_{HCAL}; E_{ECAL})$ plaine

Tr = S0 x S1x PS(>2 GeV) x ECAL(< 95 GeV)



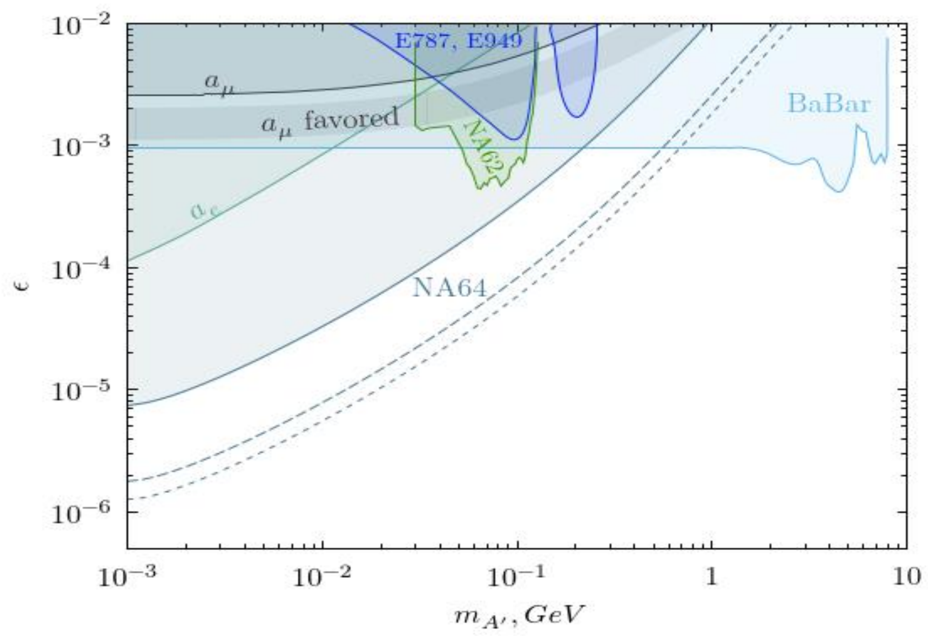


SIGNAL REGION

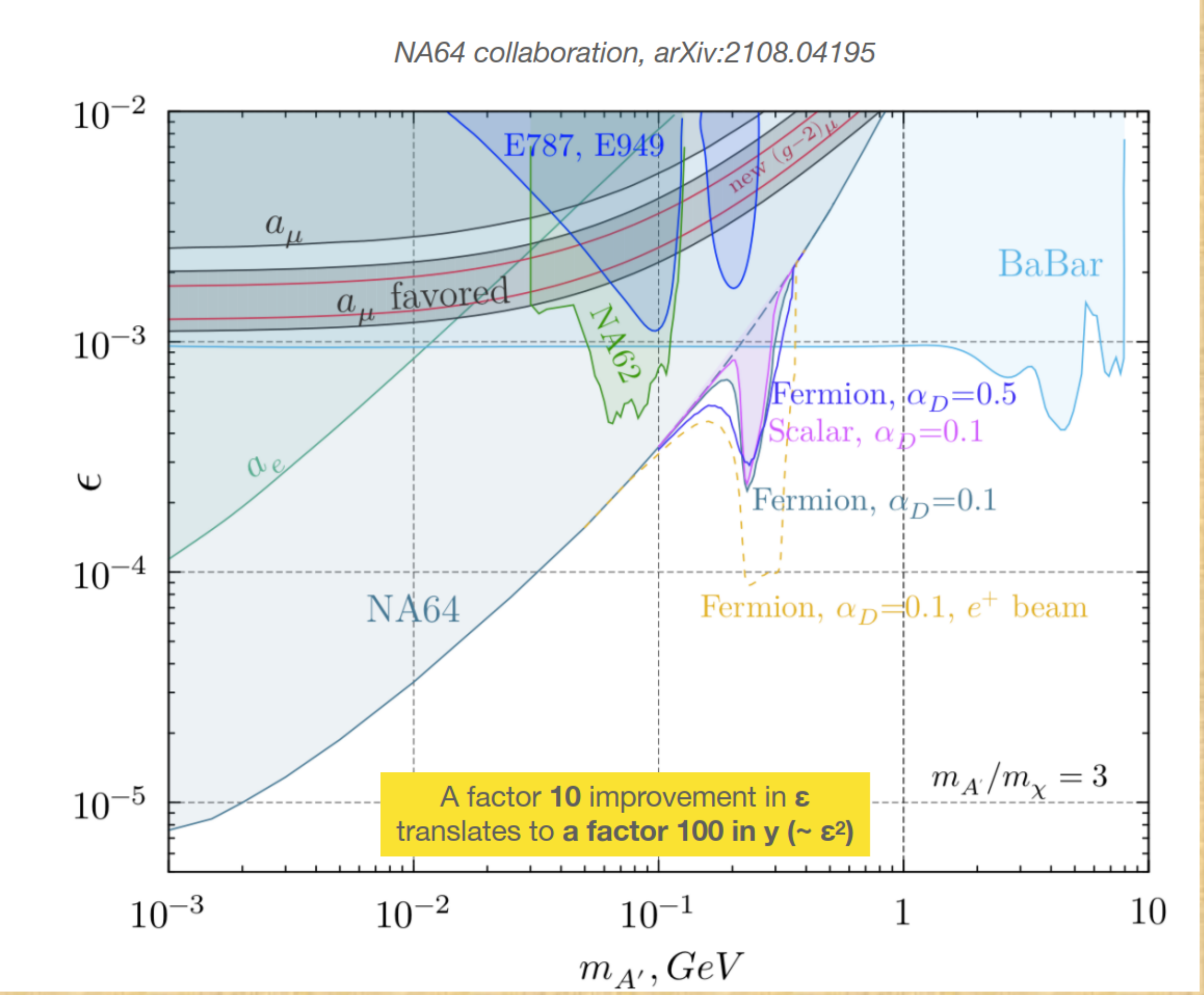
Background $< 10^{-8}/e^-$

Possible extension of signal region

Last NA64 result on ε parameter invisible dark photon decay Phys.Rev.Lett. 123 121801 (2019)



The use of $e^+e^- \rightarrow A'^* \dashrightarrow \chi\chi^*$
Positrons from $eZ \rightarrow eZe^+e^-$



New NA64 limit in comparison with predictions for light dark matter models

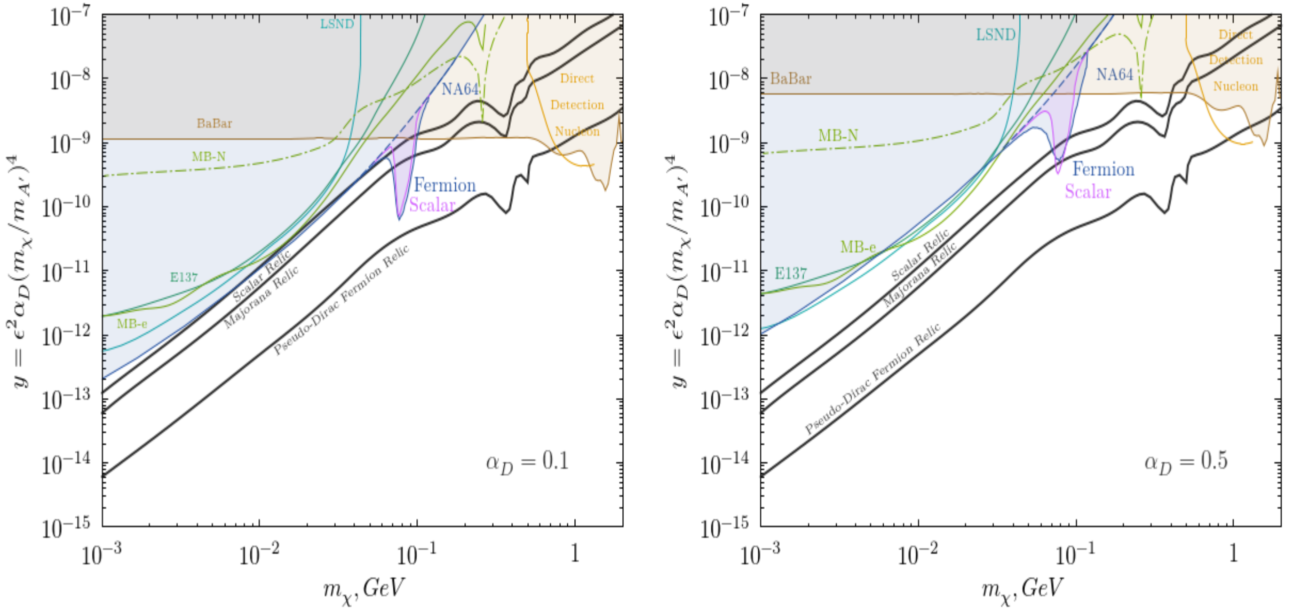
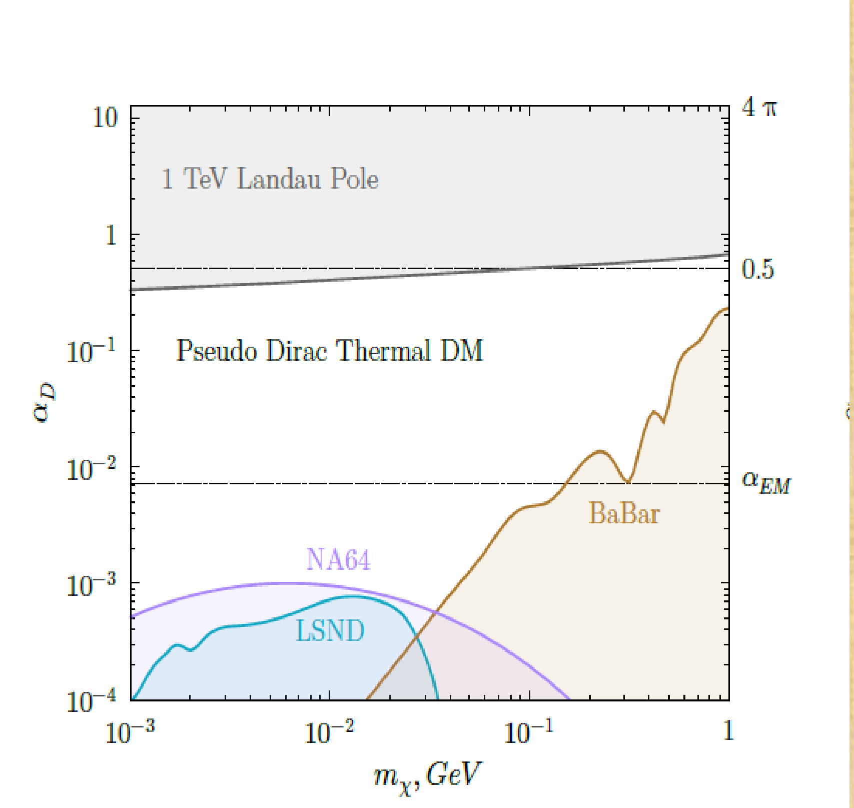


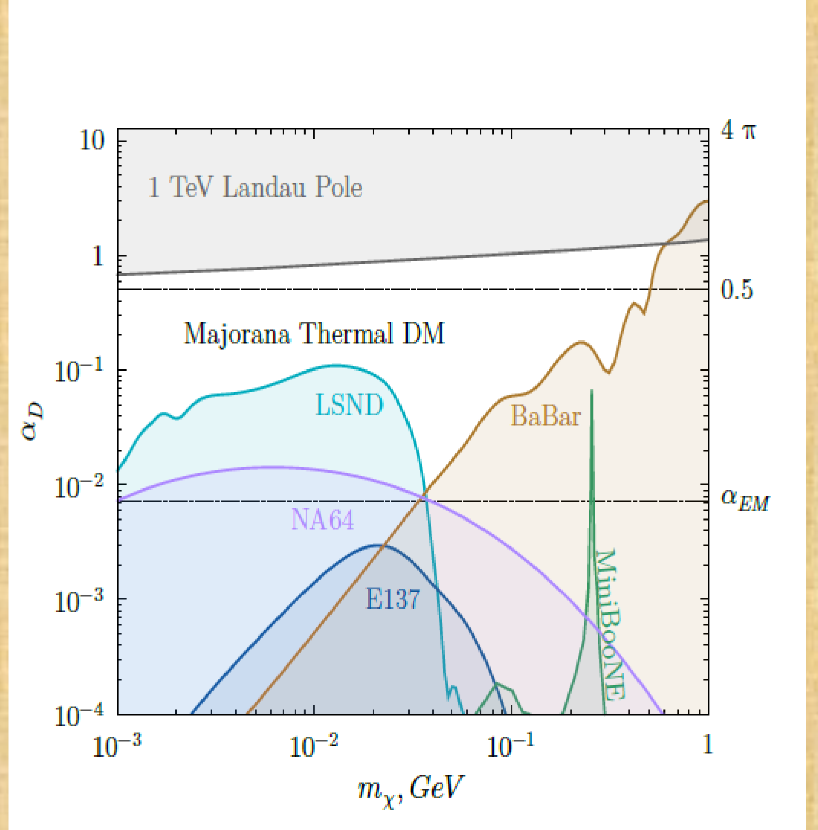
FIG. 4. The new NA64 exclusion limit in the (y, m_χ) plane, including the e^+e^- annihilation process, in the (m_χ, y) plane, for $\alpha_D = 0.1$ (left) and $\alpha_D = 0.5$ (right). The other curves and shaded areas report already-existing limits in the same parameters space from E137 [47], LSND [48, 49], MiniBoone [49], and BaBar [22]. The black lines show the favored parameter combinations for the observed dark matter relic density for different variations of the model.

NA64 bound on α_D

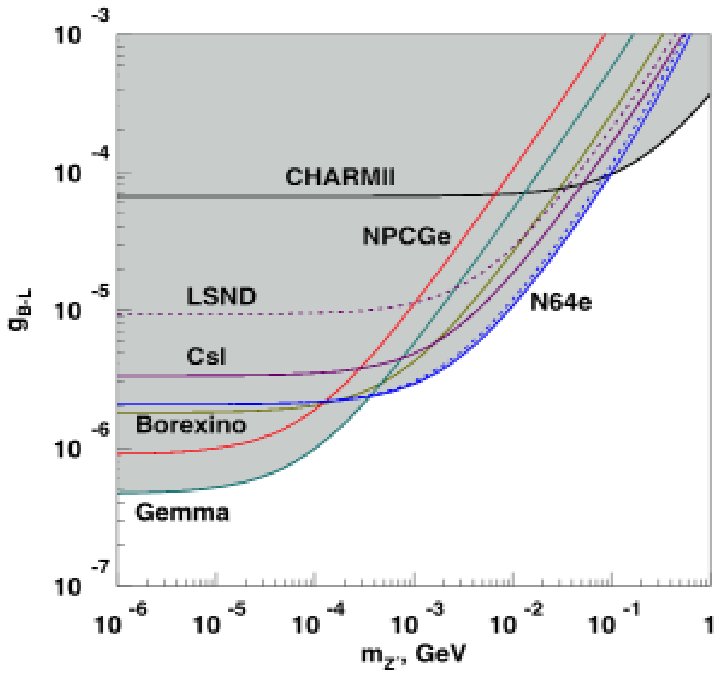
Pseudo Dirac

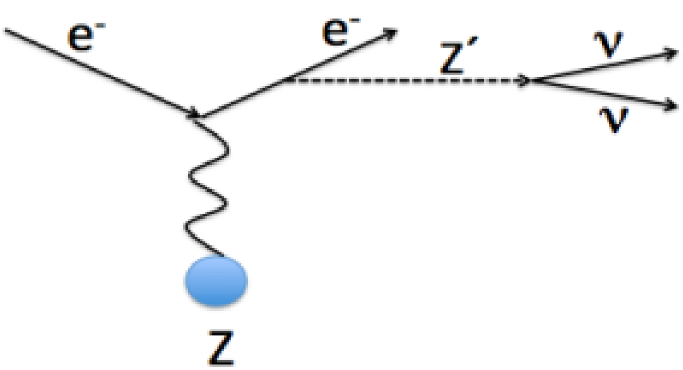


Majorana



Z' boson from B-L scenario: Phys.Rev.Lett. 129 (2022) 16, 161801





$$\mathcal{L} \supset g_{B-L} Z'_\mu \sum_{families} \left[\frac{1}{3} \bar{q} \gamma^\mu q - \bar{l} \gamma^\mu l - \bar{\nu} \gamma^\mu \nu \right]$$

- Mass range of interest $1\,\text{keV} \lesssim m_{Z'} \lesssim 1\,\text{GeV}$
- DATA: 3.2×10^{11} EOT collected during 2016-2018 and 2021 runs
- **NA64 RESULTS more stringent compared to those obtained from neutrino-electron scattering data in the mass range $300\,\text{keV} \lesssim m_{Z'} \lesssim 100\,\text{MeV}$**

Current situation and future plans

2022 august - October electron run

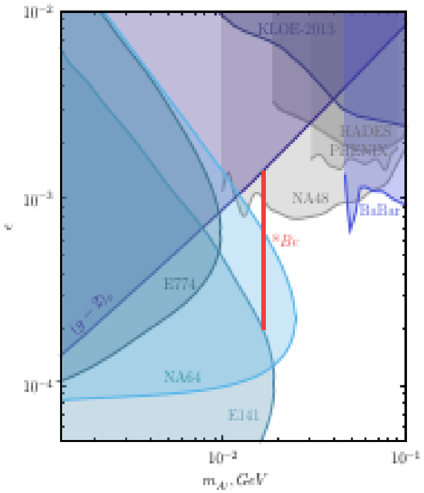
Full statistics - all years $9*10^{11}$ EOT

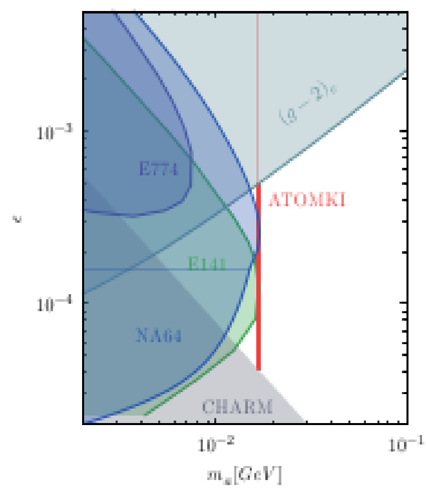
$6*10^{11}$ EOT at 2022

Plans for 2023-2025

Full statistics - $(3 – 5)*10^{12}$ EOT

Visible mode of Dark Photon and ALPs coupled mostly to electrons



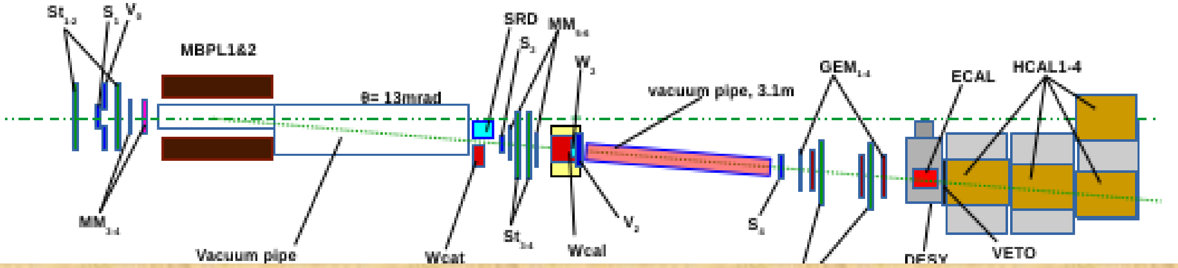


The ATOMKI experiment of (Krasznahorkay et al. 2016) has reported the observation of a 6.8 σ excess of events in the invariant mass distributions of e^+e^- pairs produced in the nuclear transitions of excited $^*Be^8$ and $^*He^4$

This anomaly can be associated with X-boson of $m_X = 16.7$ MeV.

GOAL: to perform invariant mass reconstruction:

- **Increase the length of decay tube to resolve e^+e^- tracks.**
- **More compact WCAL**



Search for axionlike prticles

ALP setup

Benchmark model for ALP and photon coupling:

$$\mathcal{L} \supset -\frac{1}{4} g_{a\gamma\gamma}\, a F_{\mu\nu} \tilde{F}_{\mu\nu} + \frac{1}{2}(\partial_\mu a)^2 - \frac{1}{2} m_a^2 a^2$$

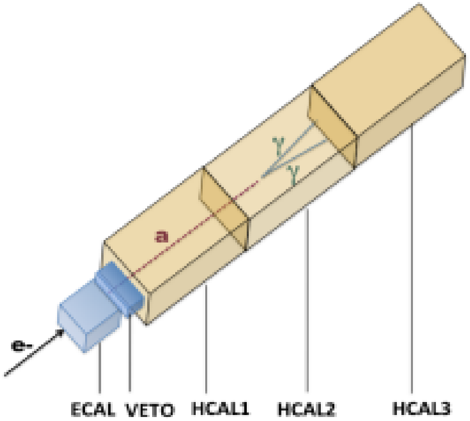
- Primakoff production: $\gamma_{brems.} + N \to a + N$
- followed by decay $a \to \gamma\gamma$
  – in the fiducial volume of NA64 in case of **visible mode setup** .
  – for **invisible mode setup** the ALP decays outside detectors
- Typical decay width

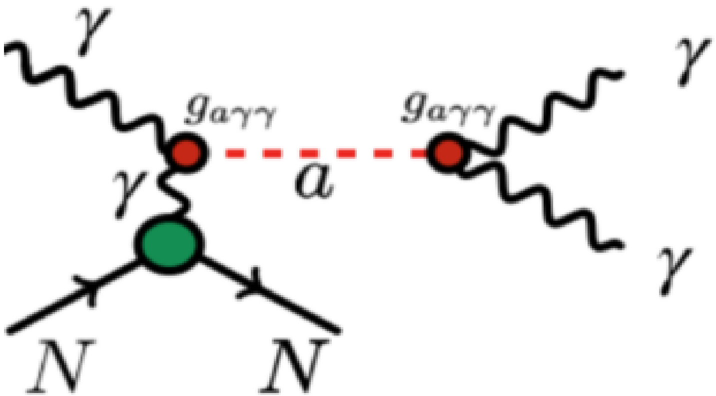
$$\Gamma_{a\to\gamma\gamma} = \frac{g_{a\gamma\gamma}^2 m_a^3}{64\pi}. \qquad (1)$$

- Typical decay length

$$l_a = 4\text{m} \cdot \frac{E_a}{100\ \text{GeV}} \cdot \left(\frac{g_{a\gamma\gamma}}{10^{-4}\ \text{GeV}^{-1}}\right)^{-2} \cdot \left(\frac{m_a}{100\ \text{MeV}}\right)^{-4}. \qquad (2)$$

NA64 semivisible modes: ALPs



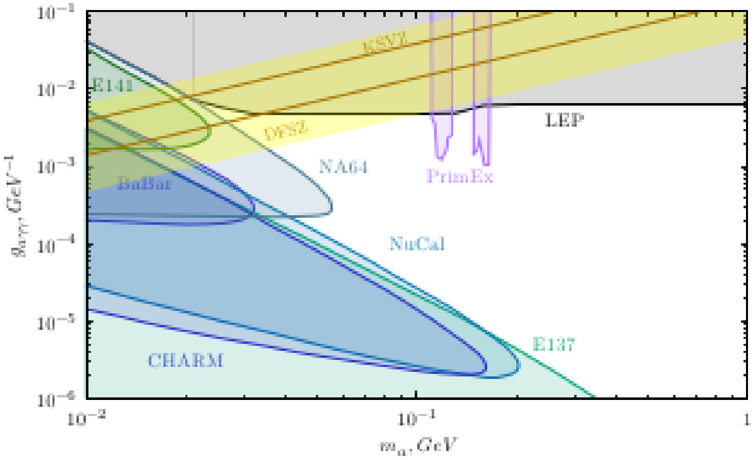


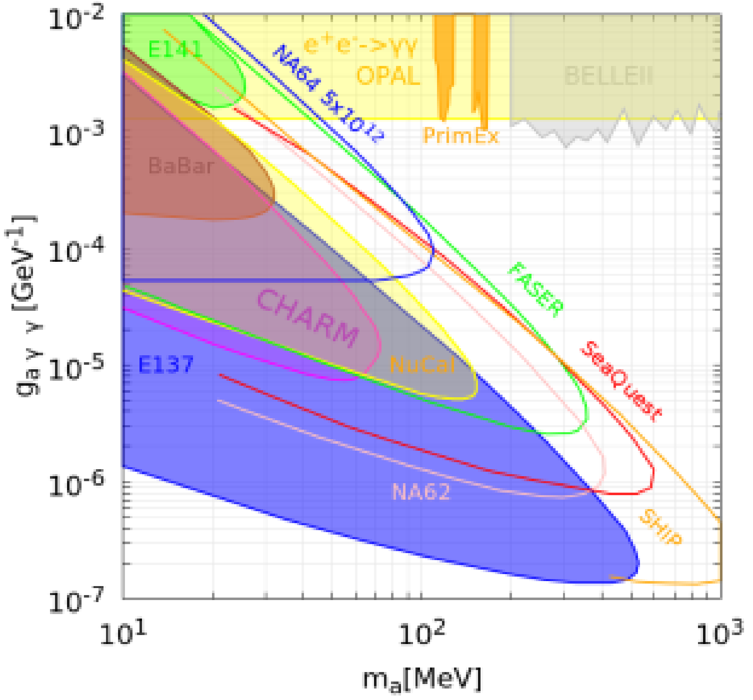
- ALPs predominantly coupled to photons produced via Primakoff effect

$$\mathcal{L} \supset -\frac{1}{4} g_{a\gamma\gamma} a F_{\mu\nu} \tilde{F}_{\mu\nu}$$

- **Signature:**
  - No signal in veto and HCAL1
  - **A: visible decay** into $\gamma\gamma$ on HCAL2 || HCAL3
  - **B: Decays after HCAL3** No activity in HCAL2 and HCAL3

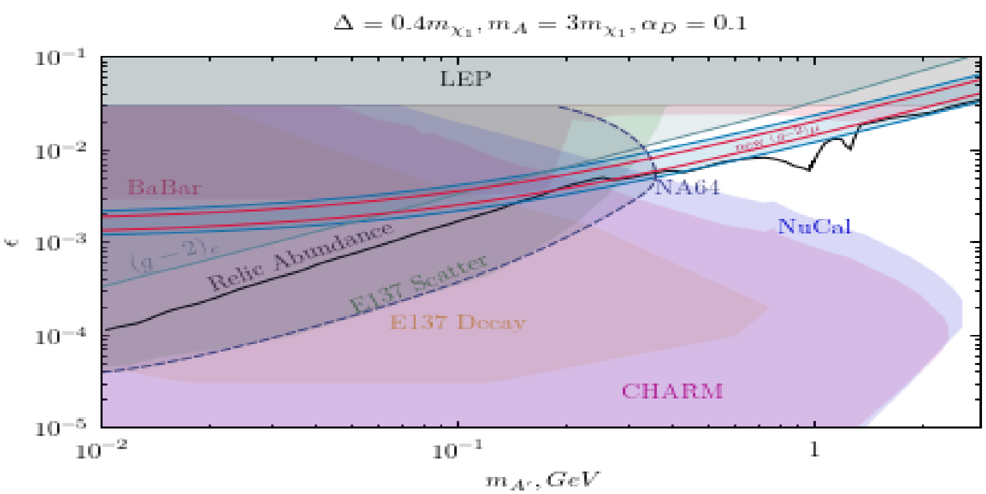
Current limits and projection for ALPs

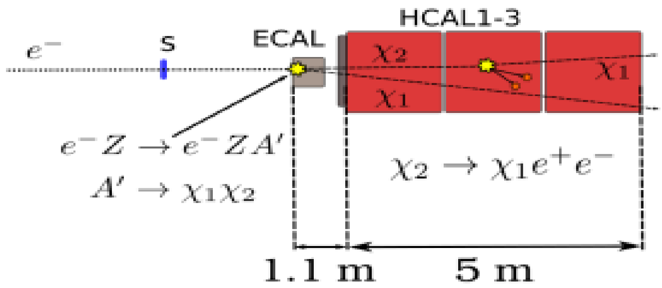




- Left plot is a current limit for $EOT = 2.84 \cdot 10^{11}$ **(PRL, 2020)**
- **Right plot is projected limit for** $EOT = 5 \times 10^{12}$ **(PRD, 2020)**
- **small** $g_{a\gamma\gamma}$ $\rightarrow$ **long-lived ALPs, large** $g_{a\gamma\gamma}$ $\rightarrow$ **short-lived ALPs**
- **Future Plans: to consider invisible decay into DM,**

Semivisible Decay of A' in NA64





- **Signature:** Missing energy + SM particles pair
- **EPJC (2107.02021)**
- **Motivation:** $(g-2)_\mu$ anomaly and Light Dark Matter production

  E. Izaguirre, et al. PRD 96, 055007 (2017)

  G. Mohlabeng, PRD 99, 115001 (2019)

  Y. Tsai, et al., PRL126, 181801 (2021)

The NA64 experiment with muon beam

S.N.Gninenko, N.V.Krasnikov, V.A.Matveev,

Phys.Rev. D91 (2015) 095015

Proposal to look for dark photon at

collisions of CERN SPS muon beams

$$\mu(p) + Z(P) \to Z(P') + \mu(p') + Z_\mu(k)$$

In six years this idea has been realized.

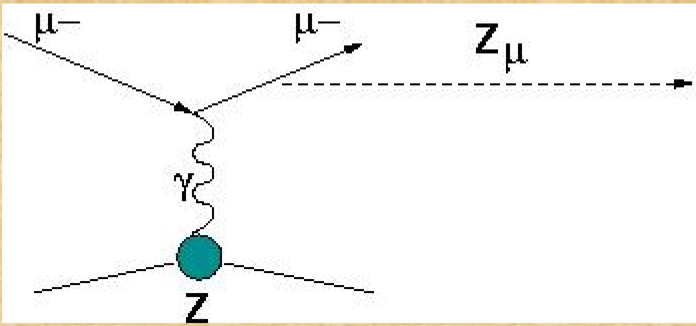
The first muon test run at CERN in November 2021 → $5*10^9$ MOT

Current situation and future plans

After 2021 and 2022 test runs statistics – $5*10^{10}$

Future plans: have statistics at least $5*10^{12}$ MOT

The NA64 experiment at CERN with muon beam



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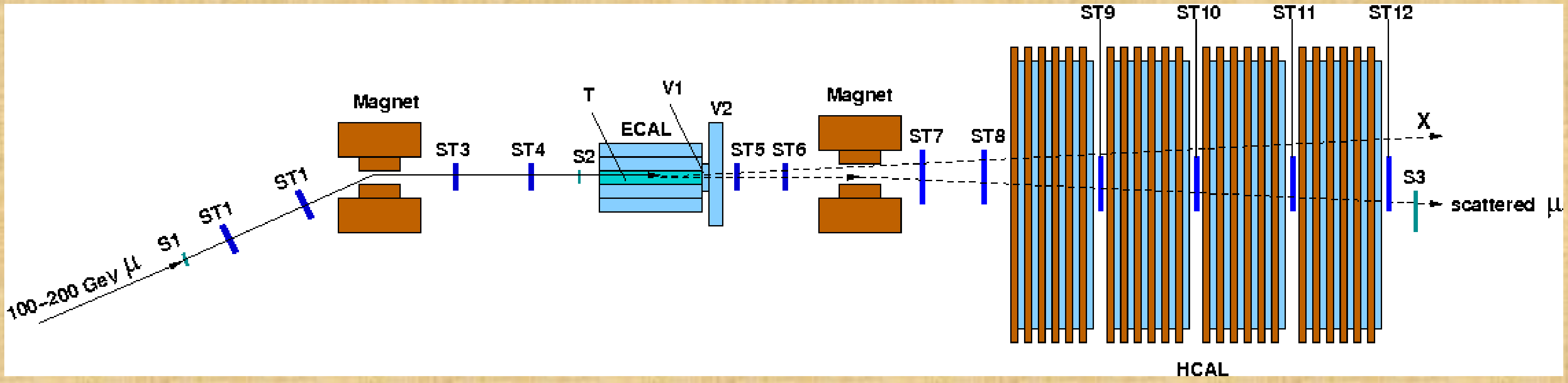
Schematic illustration of the setup to search for dark boson



NA64 at CERN SPS with muon beam

Coming muon produces dark boson at the target. Dark boson decays into neutrino or light dark matter and escapes the detection. So the signature is imbalance in energy for incoming and outcoming muons without big activity in HCAL and ECAL

Motivation for the muon beam use

There is possibility that new boson Z_μ interacts only with $L_\mu - L_\tau$ current

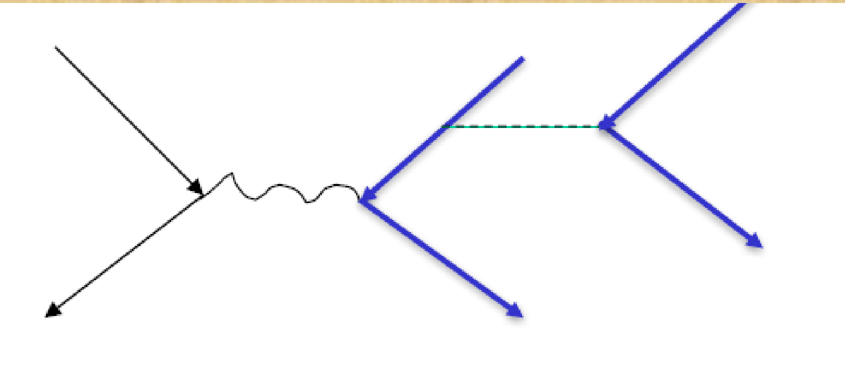
$$L_{Z_\mu} = e_\mu [\bar{\mu}\gamma_\nu \mu + \bar{\nu}_{\mu L}\gamma_\nu \nu_{\mu L} - \bar{\tau}\gamma_\nu \tau - \bar{\nu}_{\tau L}\gamma_\nu \nu_{\tau L}] Z_\mu^\nu$$

For this model the most nontrivial bound (W.Almannsofer et. al) comes from CCFR data on neutrino trident $\nu_\mu N \to \nu_\mu N + \mu^+ \mu^-$ production. Masses $m_{Z_\mu} \geq 400\ MeV$ are excluded

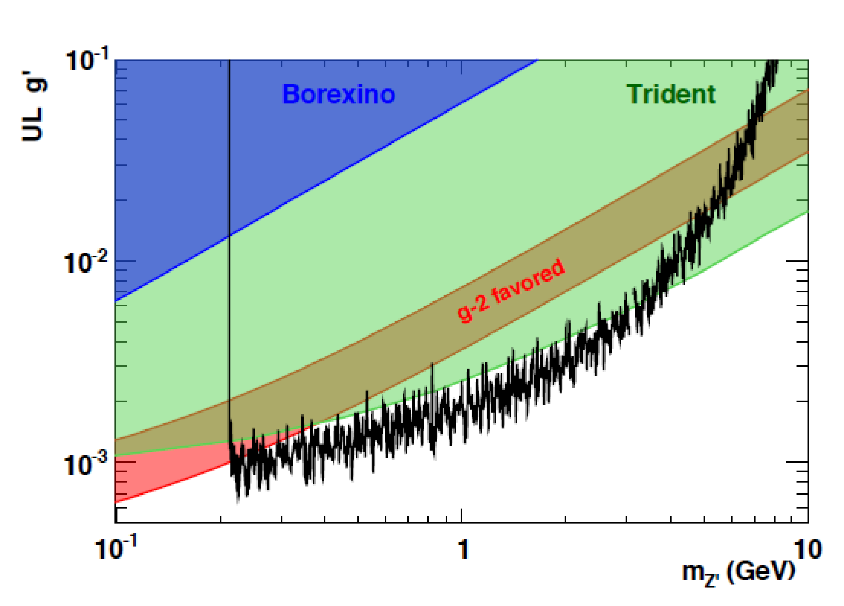
New BaBaR bound excludes m > 214 MeV

BaBar bound
Phys.Rev.D94,011102(R) (2016)

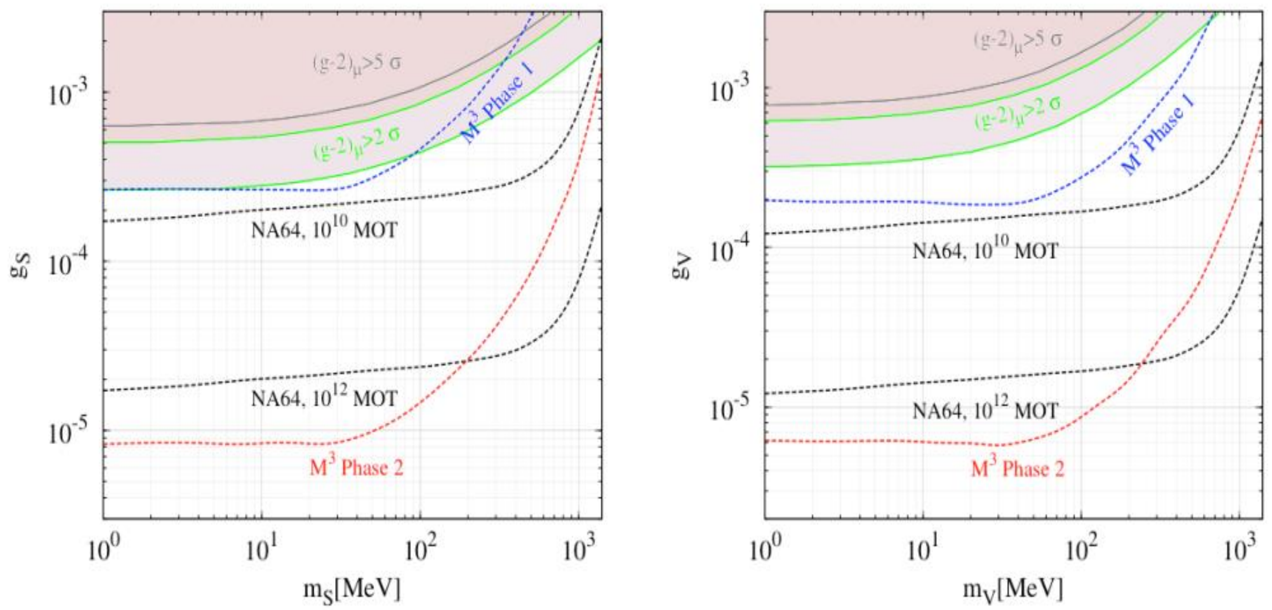
The main diagram



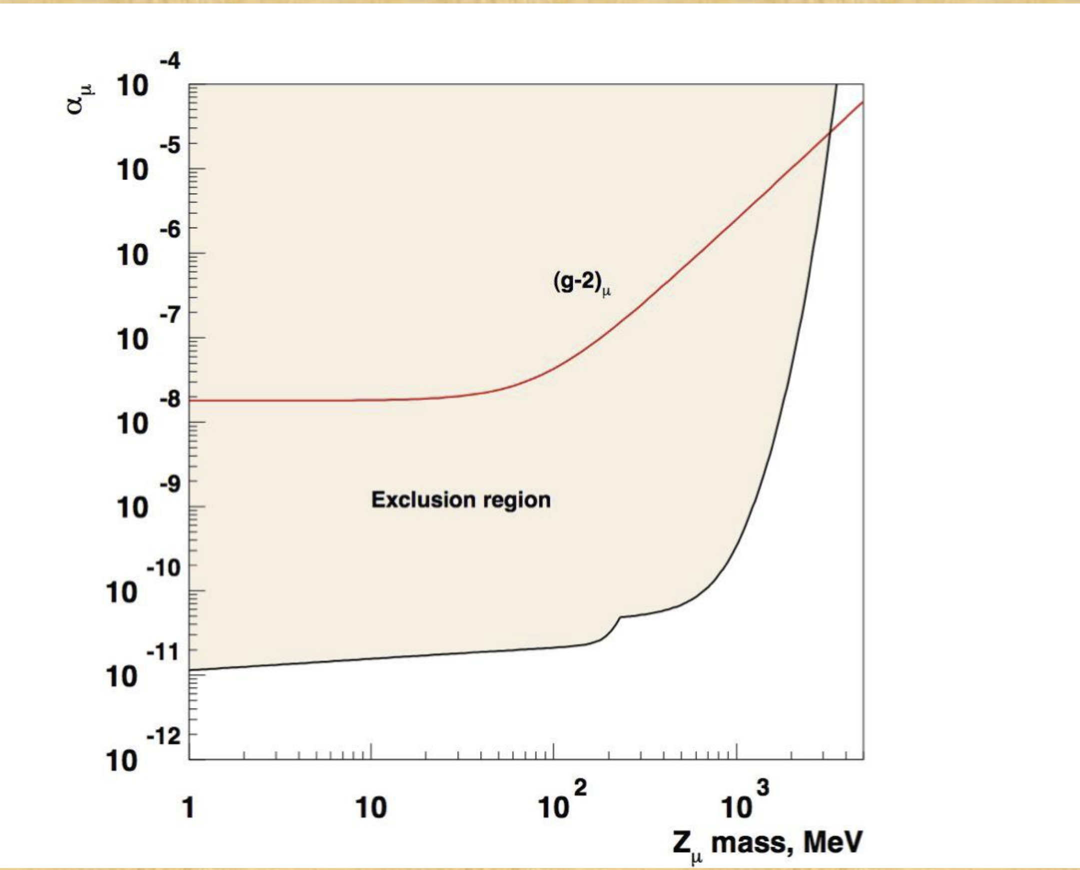
Only masses <214 MeV survive



NA64 discovery potential for experiment with muon beam



Expected sensitivity for 10^{12} muons on target



4.Conclusions

1. Light dark matter – good alternative to SUSY and other dark mtter models (axions, sterile neutrino, …)
2. Dark photon model is the simplest realization
3. Dark photon model predicts mixing interesting for experimental search
4. NA64 with future statistics $5 \cdot 10^{12}$ EOT will be able to test the most interesting models
5. NA64μ has good perspectives to test L_{μ}-L_{τ} model

Thank you!

Additional slides