

# **Search for light dark matter at accelerators. NA64 experiment**

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# Outline

1. Introduction
2. Search for light dark matter at accelerators
  - a. visible mode
  - b. invisible mode
3. NA64 experiment
4. Conclusions

The main motivation in favor of BSM physics is dark matter

also probably some hints as:

1. (g-2)-muon anomaly
2. proton radius measured for electron and muon atoms
3. B-mesons semi leptonic decays

We know that dark matter exists

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  $s = \frac{1}{2}$  and  $m = O(100 \text{ GeV})$  as a  
rule

3. ....

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

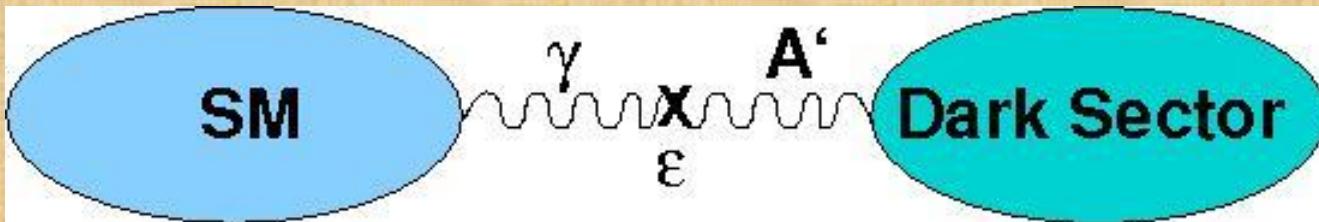
Renormalizable realization – additional interaction connects our world and dark particles world.

The most popular scenario – model with vector messenger (dark photon).

Also models with scalar mediator exist

# An example of dark mediator A`

Holdom'86, earlier work by Okun, ...



- extra  $U(1)$ , new gauge boson  $A'$  (dark or hidden photon, ...)
- $2\Delta L = \epsilon F^{\mu\nu} A'_{\mu\nu}$  - kinetic mixing
- $\gamma$ - $A'$  mixing,  $\epsilon$  - strength of coupling to SM
- $A'$  could be light: e.g.  $M_{A'} \sim \epsilon^{1/2} M_Z$
- new phenomena:  $\gamma$ - $A'$  oscillations, LSW effect,  $A'$  decays, ..
- $A'$  decay modes:  $e^+e^-$ ,  $\mu^+\mu^-$ , hadrons,.. or  $A' \rightarrow$  DM particles,  
i.e.  $A' \rightarrow$  invisible decays

Large literature, >100 papers /few last years, many new theoretical and experimental results

## THERMAL ORIGIN

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

DM density today tells us about annihilation cross-section. Correct DM density corresponds to  $\langle\sigma_{\text{an}}v\rangle \sim 0(1) \text{ pbn}$

So the main features of light dark matter

1. p-wave annihilation(or annihilation  
shuts off before CMB)

2. The annihilation cross-section

$$\langle \sigma_{ann} v \rangle \approx 1 \text{ pbn} \times c$$

As a consequence, crude estimate (E.Izaguirre, et al.,  
Phys.Rev. D91, 094026 (2015)

$$\alpha_D \simeq 0.02 f \left( \frac{10^{-3}}{\epsilon} \right)^2 \left( \frac{m_{A'}}{100 \text{ MeV}} \right)^4 \left( \frac{10 \text{ MeV}}{m_\chi} \right)^2$$

$f = 0(1)$  - fermions,  $f = 0(10)$  - scalars

From the requirement of the absence of  
Landau pole singularity

$$\alpha_D \lesssim 1$$

as a consequence

$$\varepsilon \gtrsim F(m_\chi, m_A)$$

# Two ways of visible A' decay detection

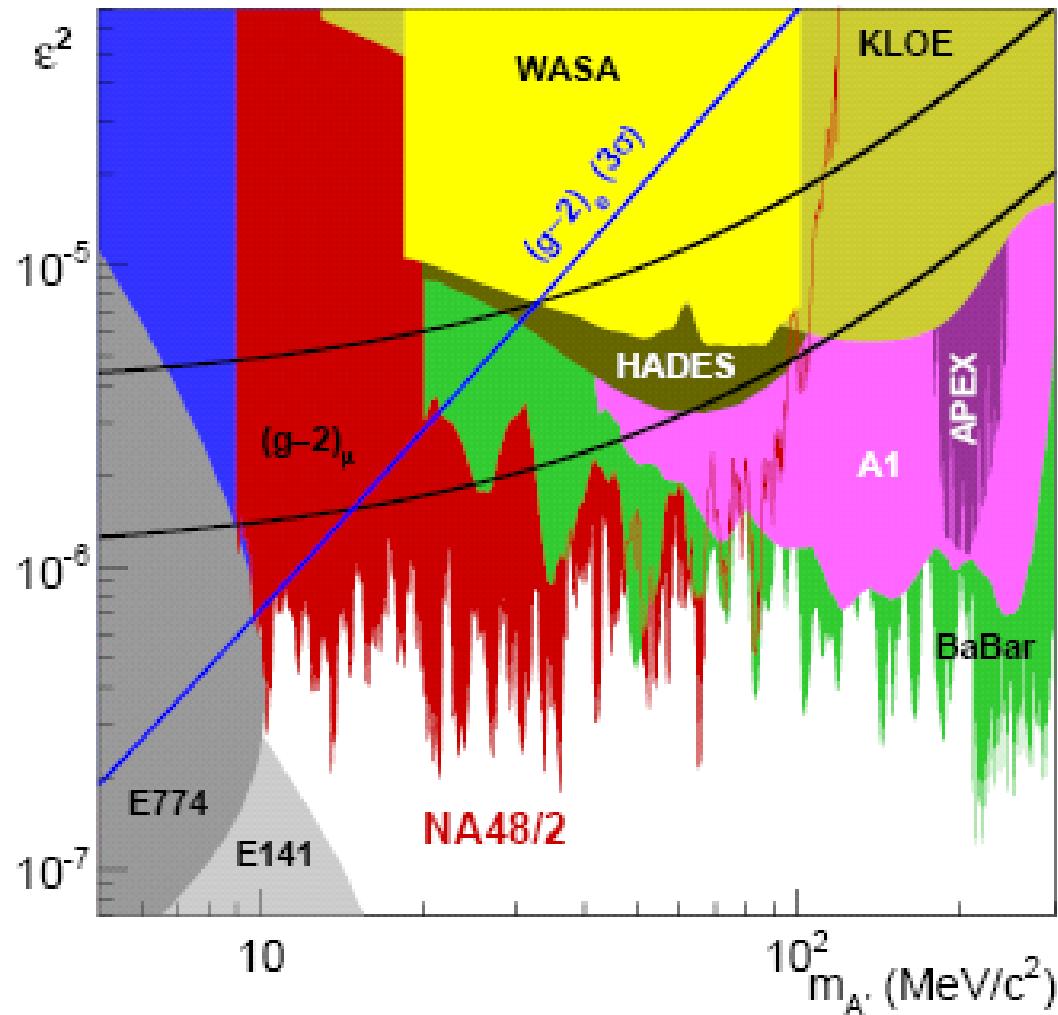
## Visible decays detection

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

## 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  $A^{\gamma}$  decays is excluded.  
Also beam dump experiments(electron beam dump – E137, E774, E141) exclude some regions in  $\varepsilon$

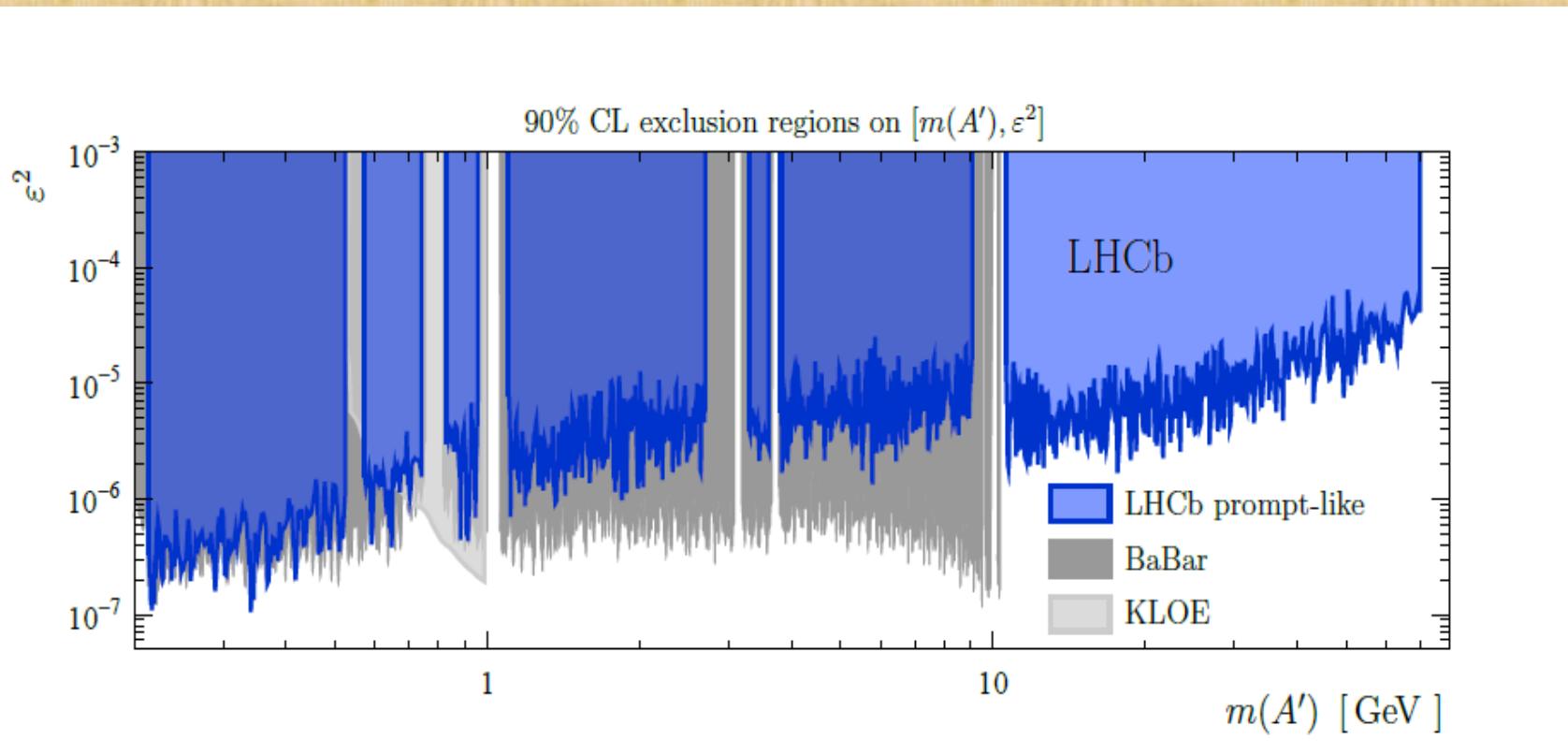
# Current (2017) exclusion plot



# Recent LHCb bounds on visible decays

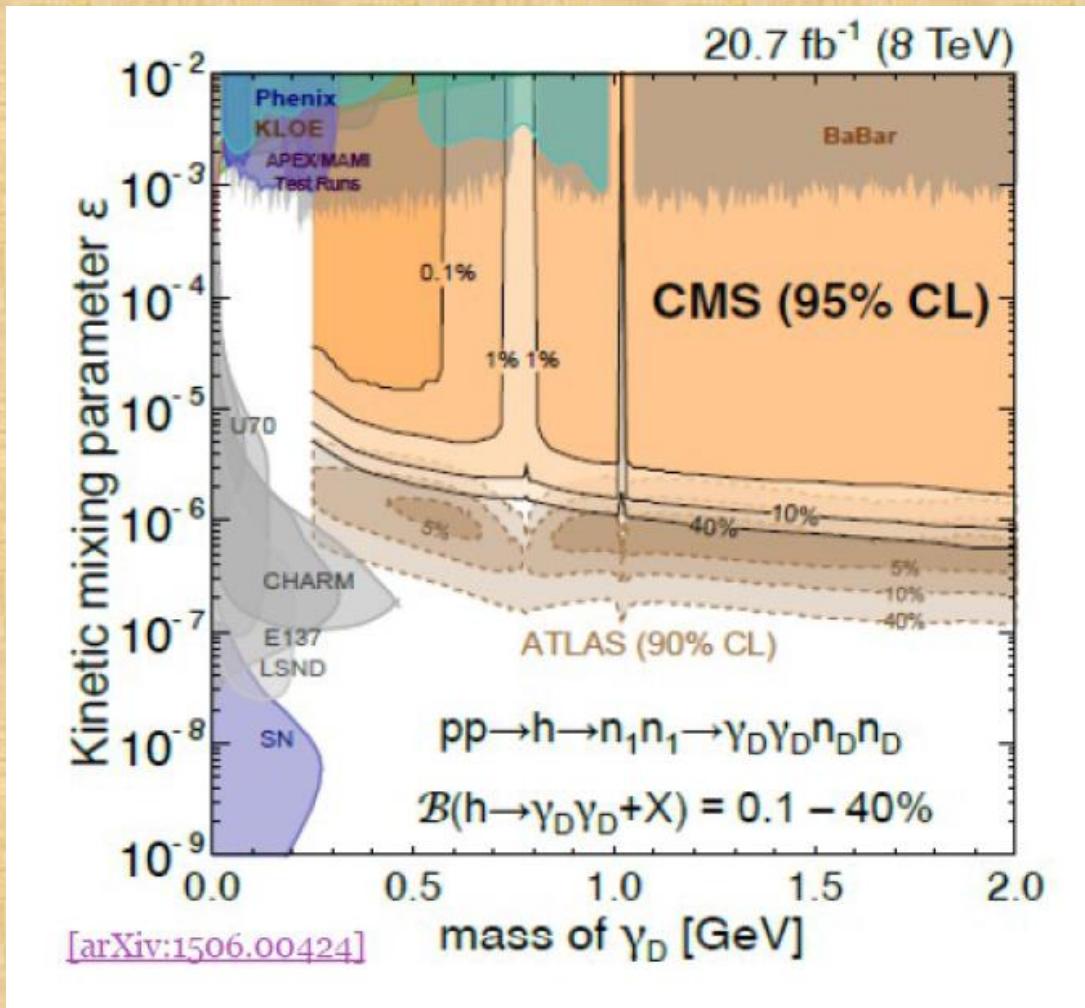
CERN-EP-2017-248

Phys.Rev.Lett. 2018



# CMS and ATLAS visible decays search

CMS-PAS-HIG-16-035, ATLAS-JHEP 02(2016) 062

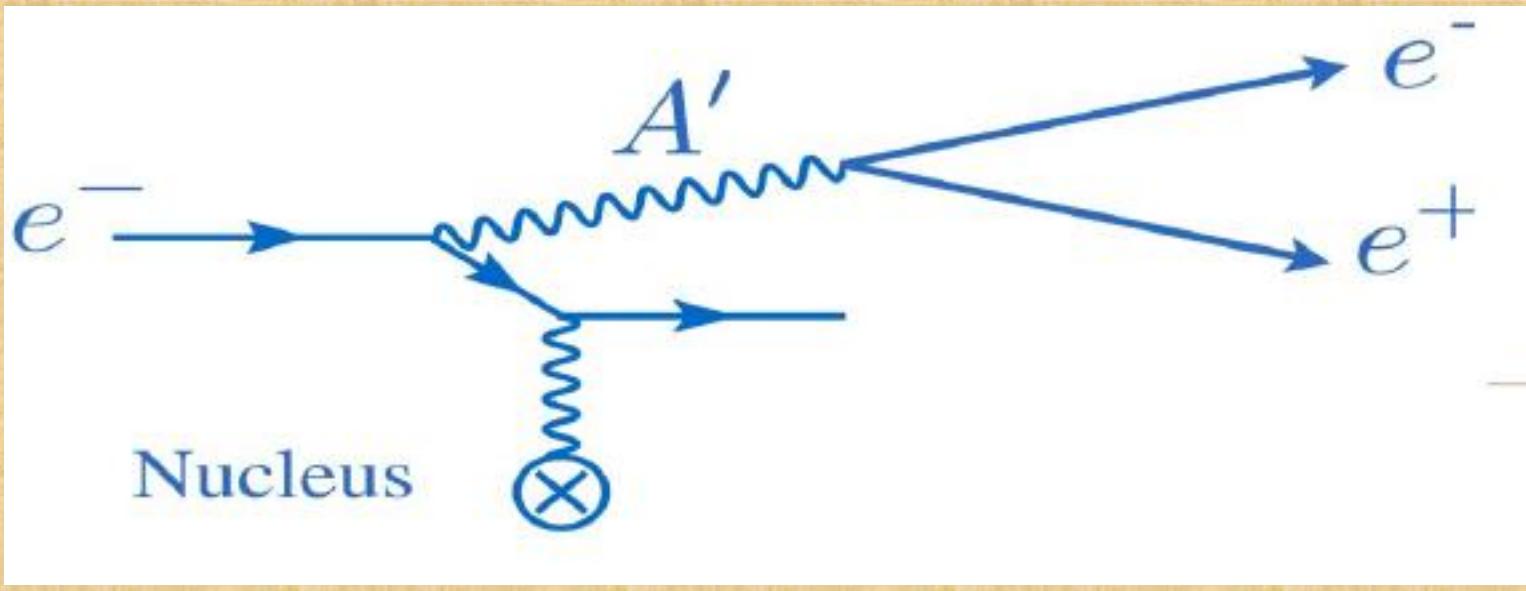


## Future and current visible decays searches

1. APEX at JLab(USA) –prompt decays
2. HPS at JLab – prompt decays
3. NA64 – displaced decays
4. Belle-II 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

# APEX,HPS,MAGIX

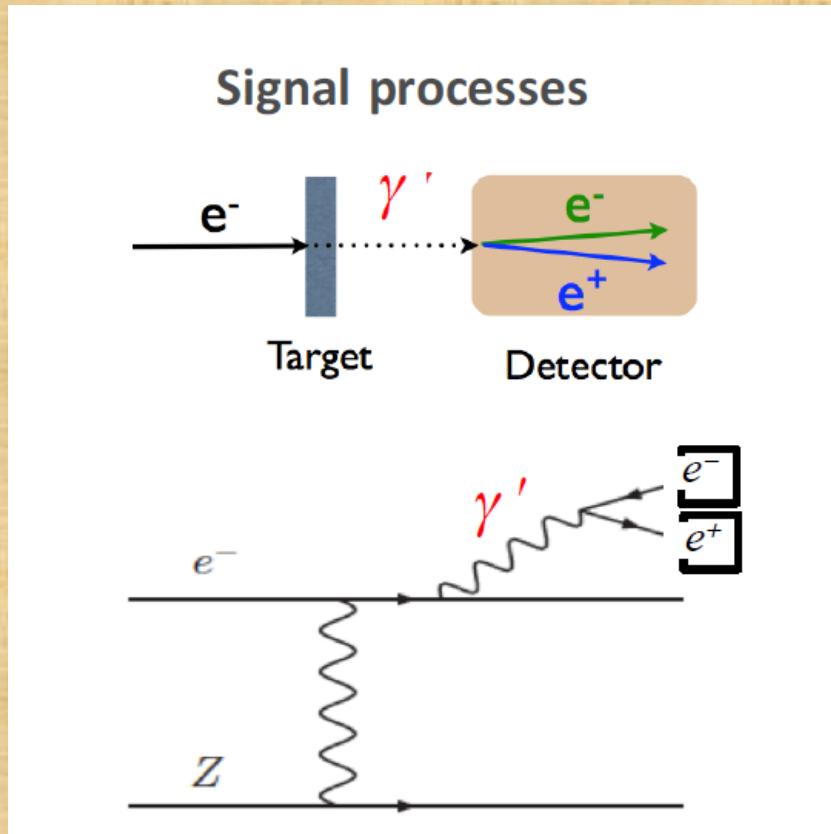
The A' bremsstrahlung production



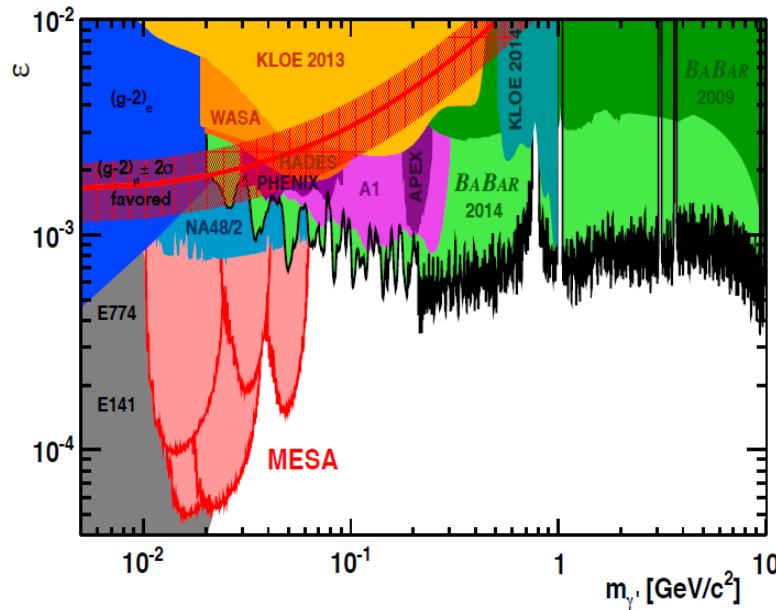
$$\frac{d\sigma(e^- Z \rightarrow e^- Z(A' \rightarrow l^+ l^-))}{d\sigma(e^- Z \rightarrow e^- Z(\gamma^* \rightarrow l^+ l^-))} = \frac{3\pi\epsilon^2}{2N_{eff}\alpha} \frac{m_{A'}}{\delta m}$$

# The MAinz Gas Internal EXperiment

## Experiment scheme



**MAGIX Discovery potential (>2020)**



## APEX(A-prime experiment) (1108.2750) and HPS(Heavy Photon Search) at JLAB(USA)

11 GeV electron beam from CEBAF.

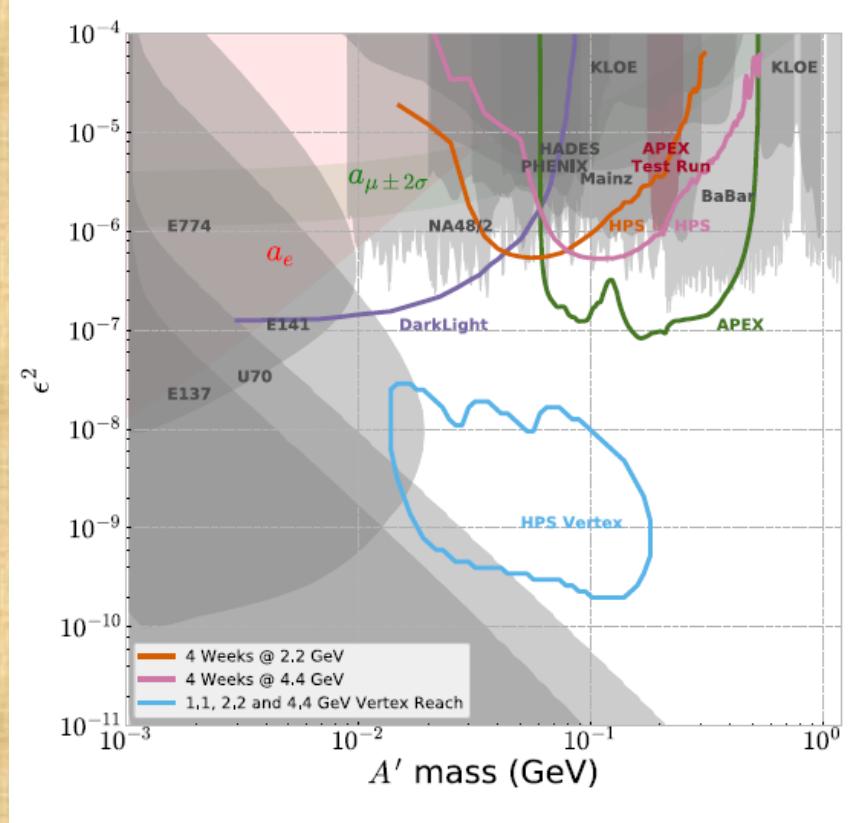
APEX →  $\varepsilon^2 \gtrsim 10^{-7}$  for  $60 < m_{A'} < 550$  MeV

after 2018 (1707.04591)

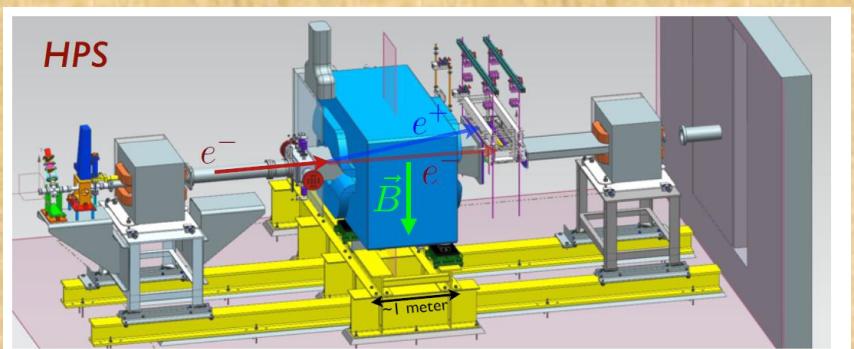
HPS →  $\varepsilon^2 \gtrsim 10^{-6}$  for  $18 < m_{A'} < 500$  MeV

after 2019 (1707.04591)

## APEX and HPS discovery potentials



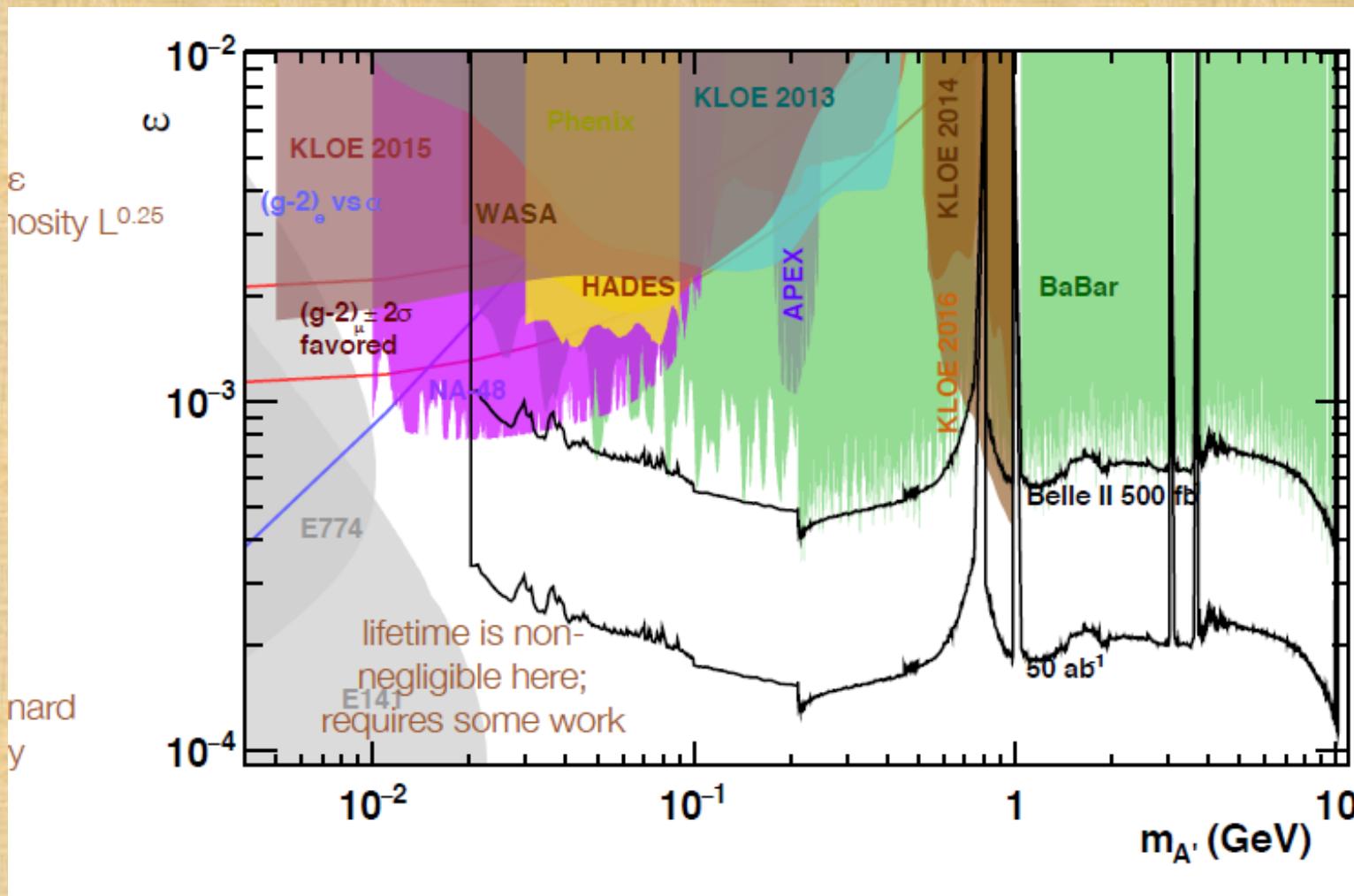
## HPS top view



# DarkLight at Jlab (1412.4717)

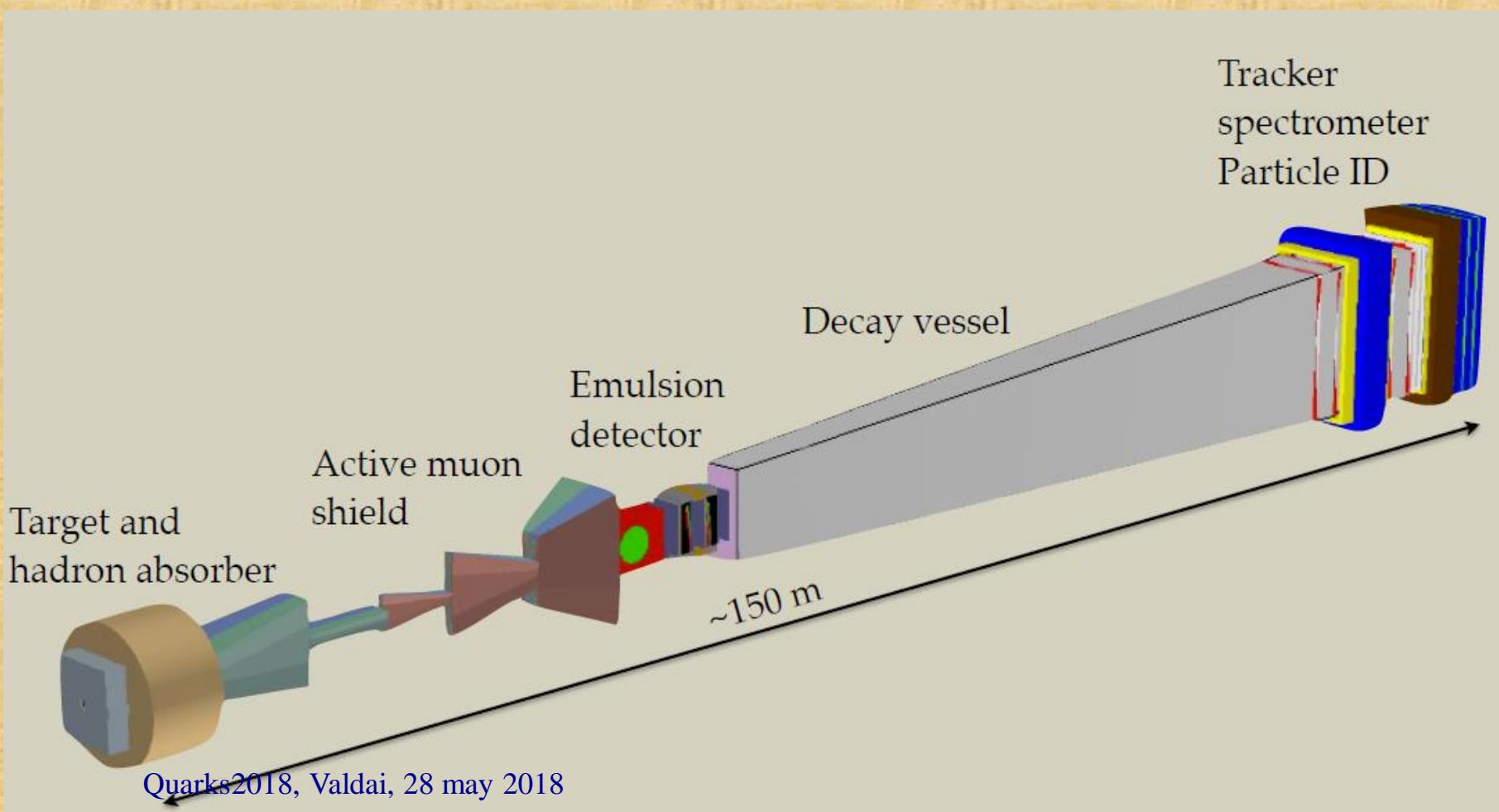
Both visible and invisible decays using the reaction  $pp \rightarrow ppA'$ ,  $A' \rightarrow e^+e^-$  - all visible final states momenta restoration  
LERF accelerator with  $E_e \sim 170$  MeV with high intensity electron beam  
 $\varepsilon^2 \gtrsim 10^{-6}$  for  $10 < m_{A'} < 80$  MeV ( $> 2020$ )

# Belle II (>2018) expected bounds for visible decays, 50 ab<sup>-1</sup> (<https://www.belle2.org>)



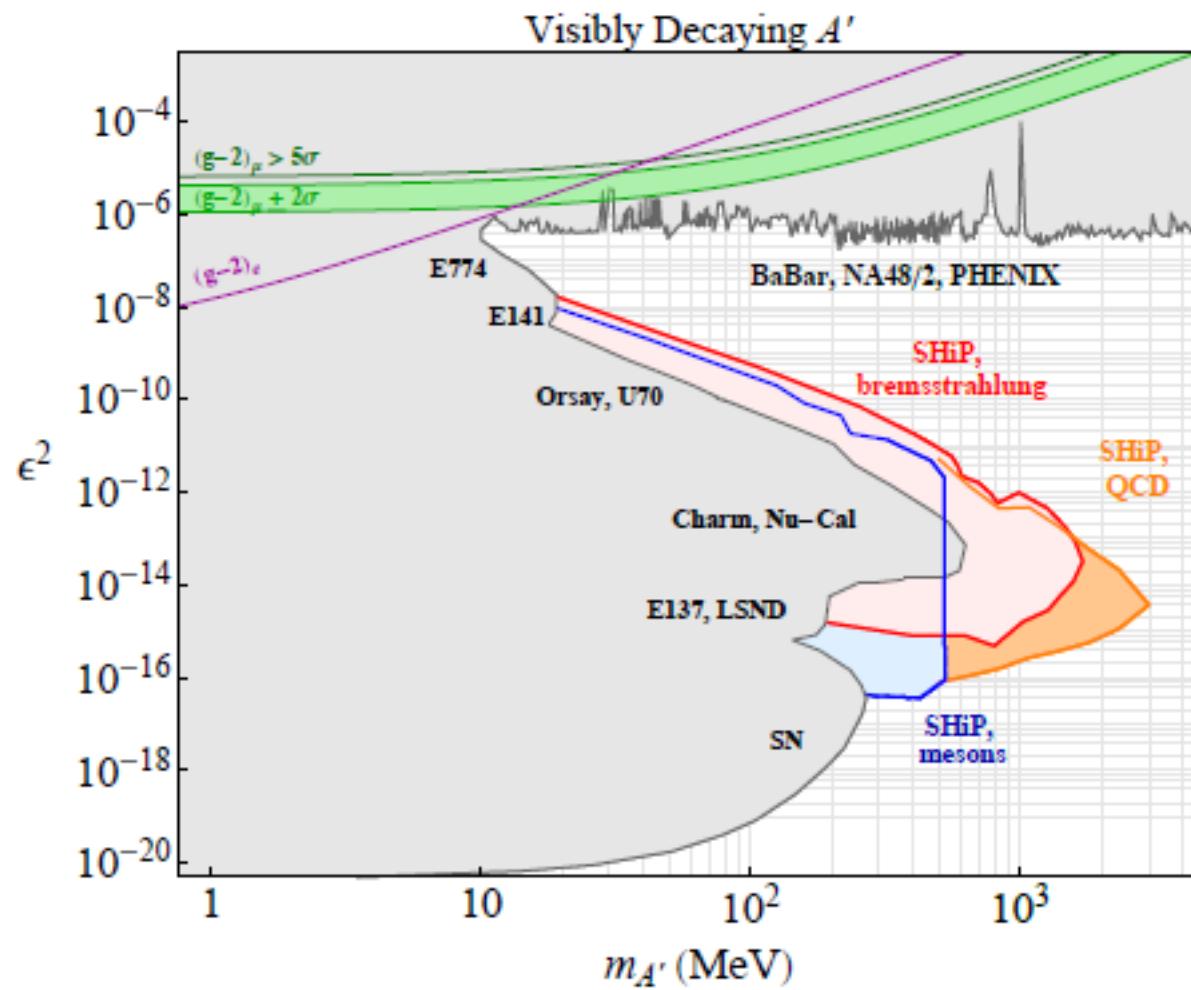
# SHiP (>2026) experiment as an example of displaced decays

*Rep. Prog. Phys.* 79 (2016)  
*arXiv:1504.04855*



# Expected SHiP bounds on visible decays for EPOT = 2\*10<sup>20</sup>

Technical Proposal CERN-SPSC-2015-016



# SeaQuest(FNAL,USA) prompt and displaced muon decay mode search (1707.04591)

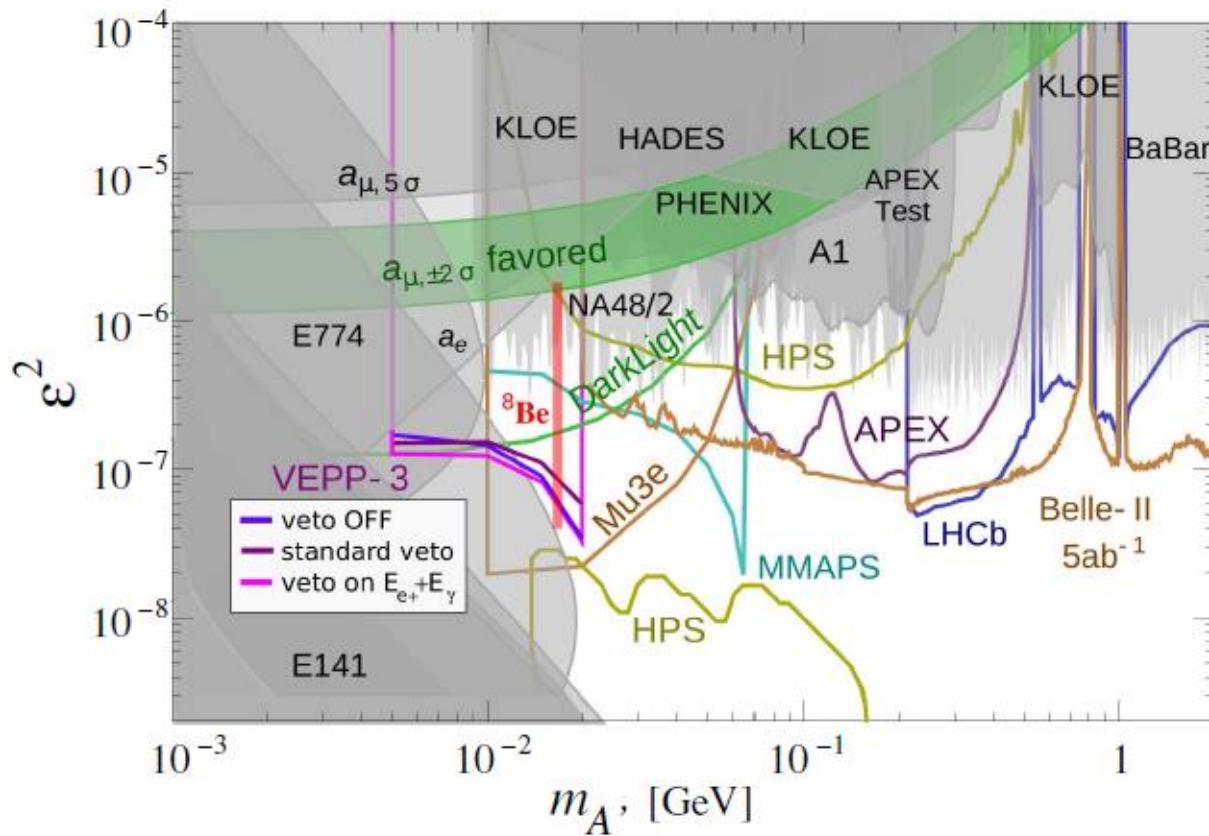


Visible dark photon decay searches at the muon spectrometer at the 120 GeV Main injector beamline at FNAL

$\varepsilon^2 \gtrsim 10^{-8}$  for  $2m_\mu < m_{A'} < 9$  GeV (prompt decays)  
 $\varepsilon^2 \gtrsim 10^{-14} \text{ --- } 10^{-8}$

for  $m_{A'} < 2$  GeV (displaced decays)

# Expected sensitivity for visible decays for $\varepsilon^2$ (J.P.Alexander et al., arXiv:1708.07901) for future experiments



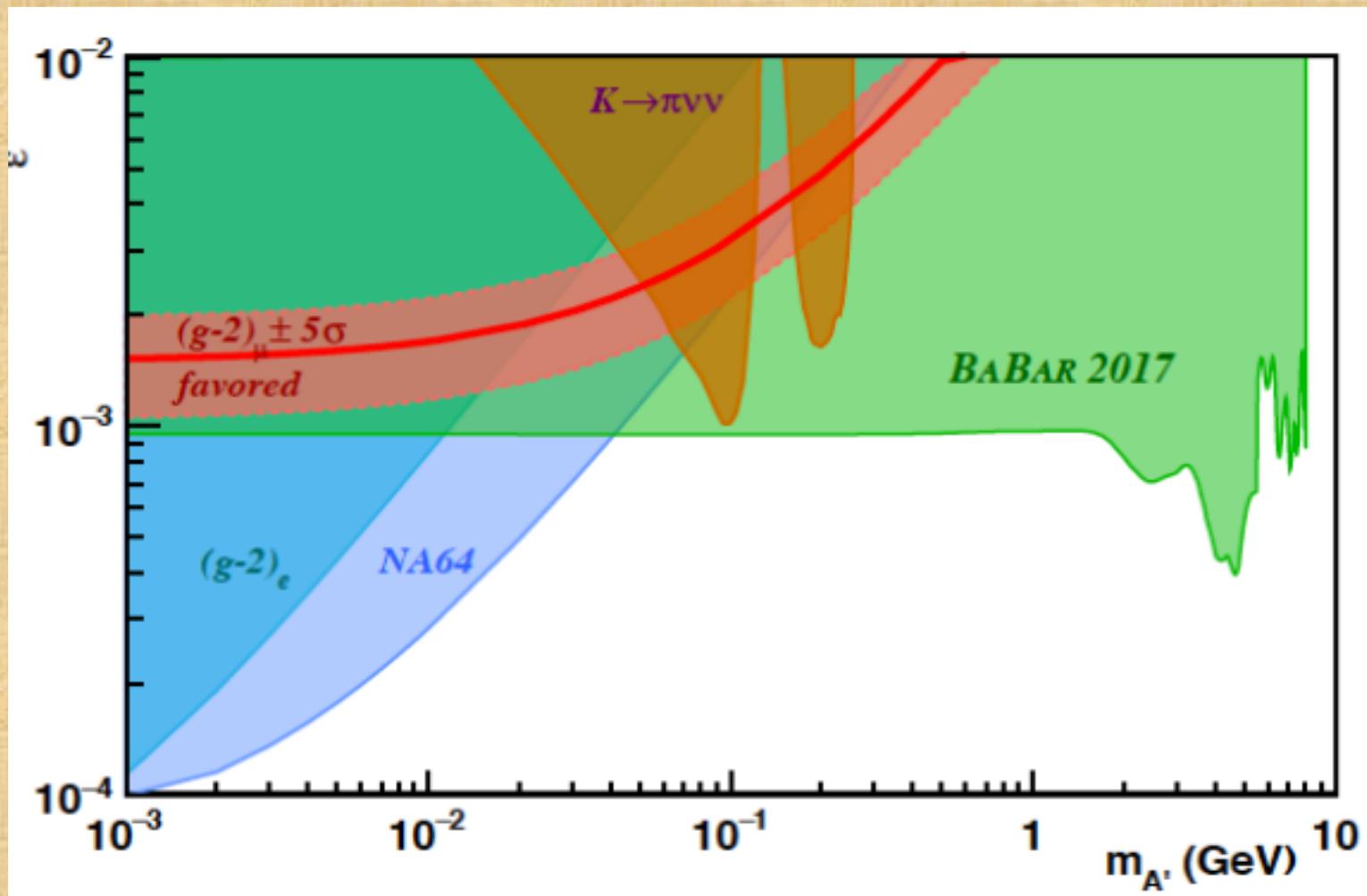
# Invisible mode detection

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

# Current and future invisible decays searches

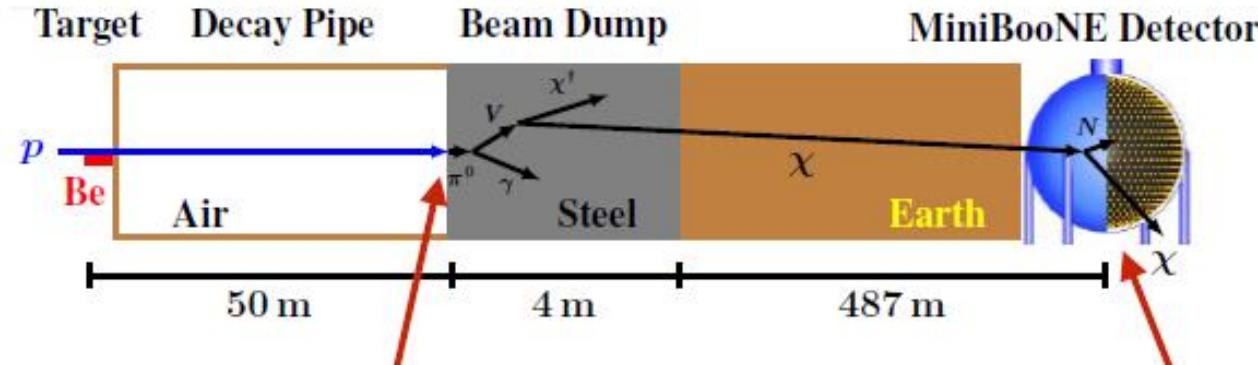
1. NA64 – missing energy searches
2. PADME at LNF(Italy) – missing mass searches
3. VEPP3 at BINP(Russia) – missing mass searches
4. Belle-II at KEK(Japan) – missing mass searches
5. DarkLight at JLab(USA) – missing mass searches
6. MMAPS at Cornell(USA) – missing mass searches
7. LDMX at SLAC(USA) – 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

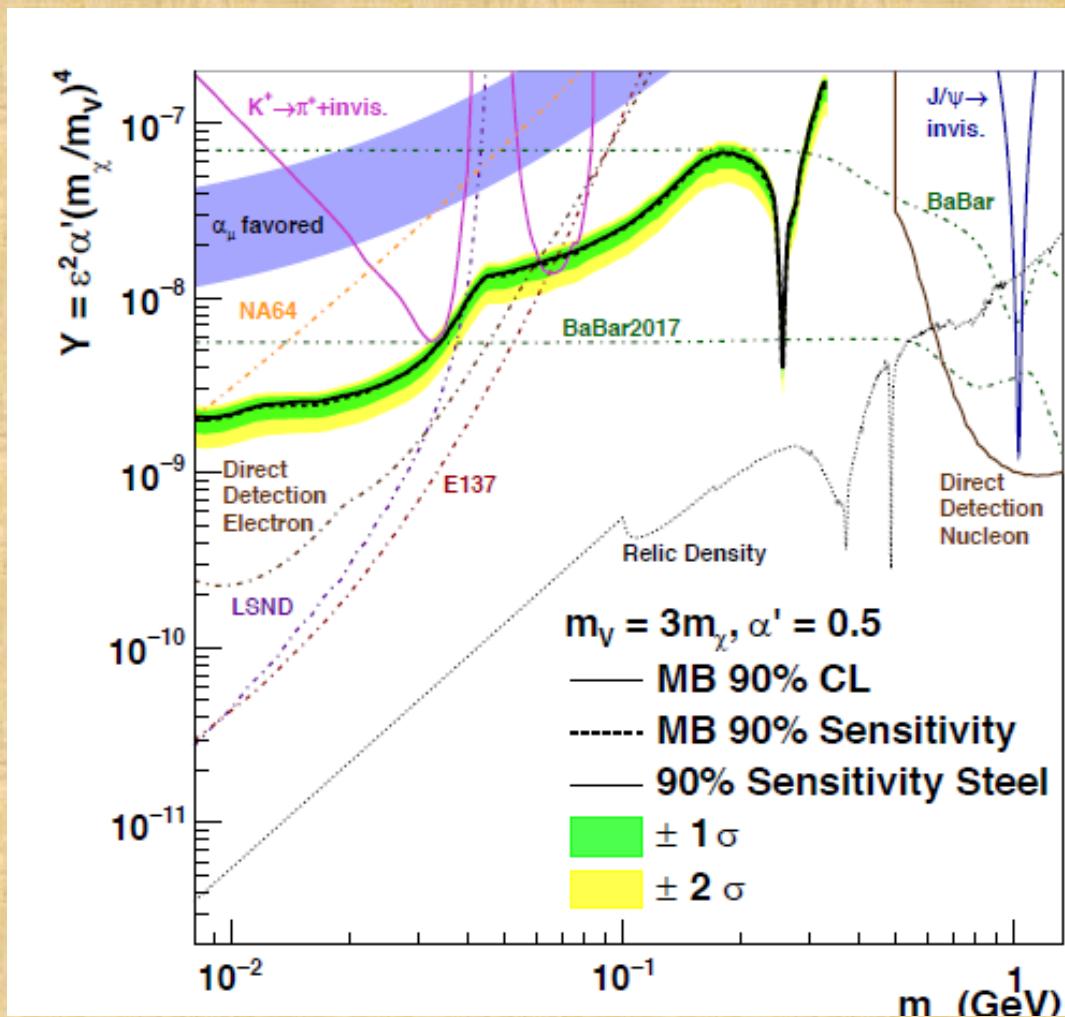
## 1702.02688



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

# Last MiniBooNE bound

## arXiv:1702.02688



# COHERENT experiment

Spallation Neutron Source at Oak Ridge National Laboratory

The main goal – measurement of elastic  
coherent neutrino-nucleus scattering

“CEvNS”:

Coherent Elastic  $\nu$ -Nucleus Scattering:  $\nu A \rightarrow \nu A'$

The first result – arXiv:1708.01294

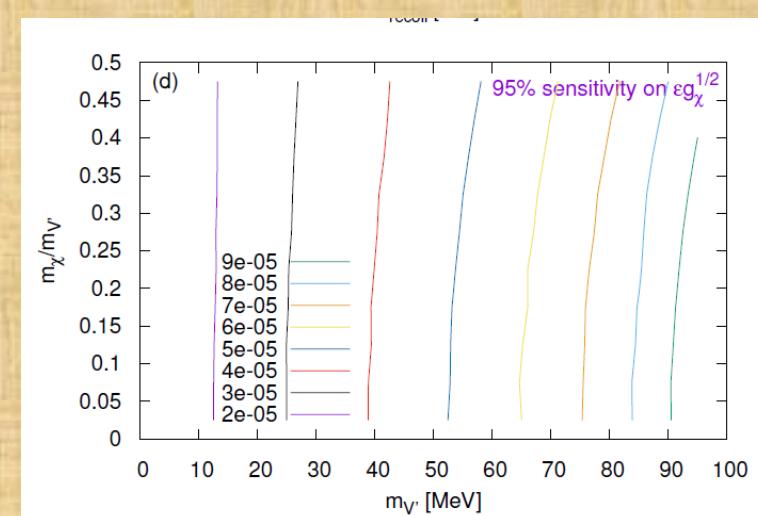
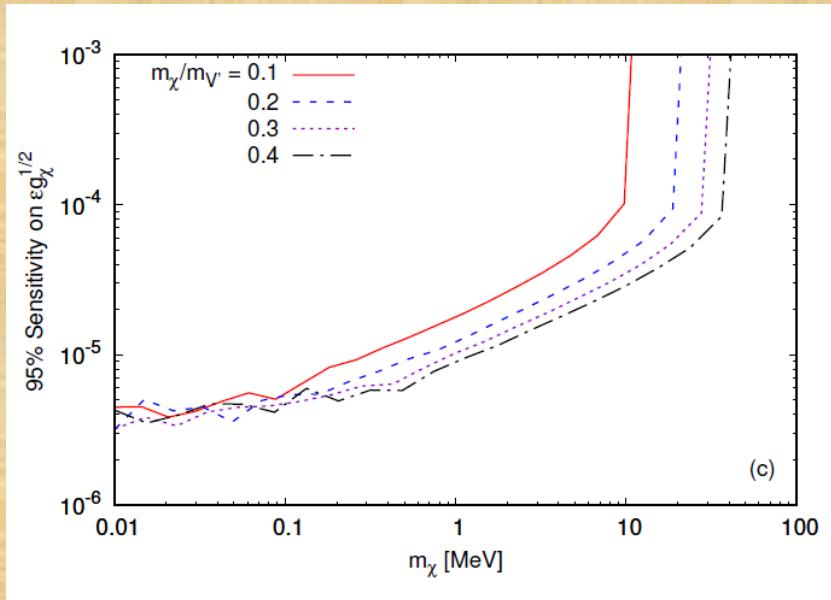
It is possible to extract bounds on  $A'$

S.-F.Ge and I.N.Shoemaker, arXiv:1710.10889

# Extracted bounds on $\varepsilon g_D^{1/2}$ from COHERENT results

**bound on  $\varepsilon g_D^{1/2}$**

$1.76 \times 10^{23}$  protons on target



## Experimental bounds for $L_\mu - L_\tau$ model

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

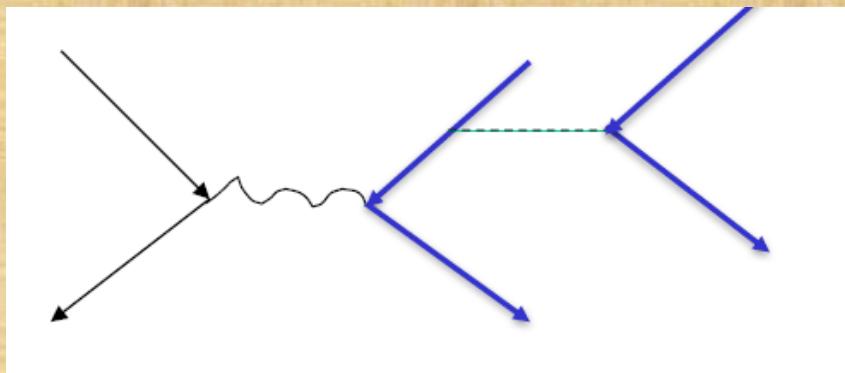
$$L_{Z_\mu} = e_\mu [\bar{\mu} \gamma_\nu \mu + \bar{\nu}_{\mu L} \gamma_\nu \nu_{\mu L} - \bar{\tau} \gamma_\nu \tau - \bar{\nu}_{\tau L} \gamma_\nu \nu_{\tau L}] Z_\mu^\nu$$

For this model the most nontrivial bound (W.Almannsofer et. al) comes from CCFR data on neutrino trident  $\nu_\mu N \rightarrow \nu_\mu N + \mu^+ \mu^-$  production. Masses  $m_{Z_\mu} \geq 400 \text{ MeV}$  are excluded  
New BaBar bound excludes  $m > 214 \text{ MeV}$

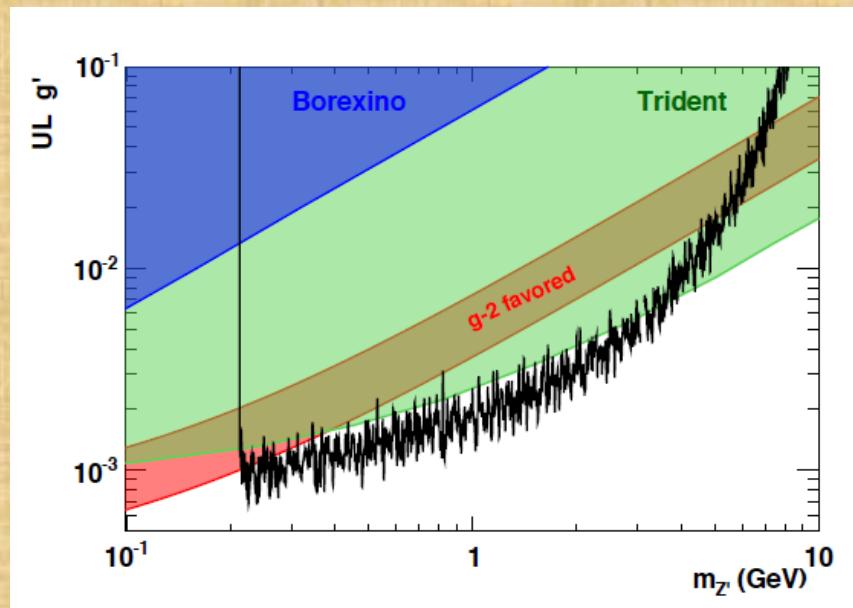
# New BaBar bound

## Phys.Rev.D94,011102(R) (2016)

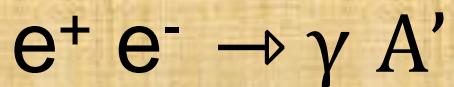
### The main diagram



Only masses <214 MeV survive



# Future experiments missing mass searches

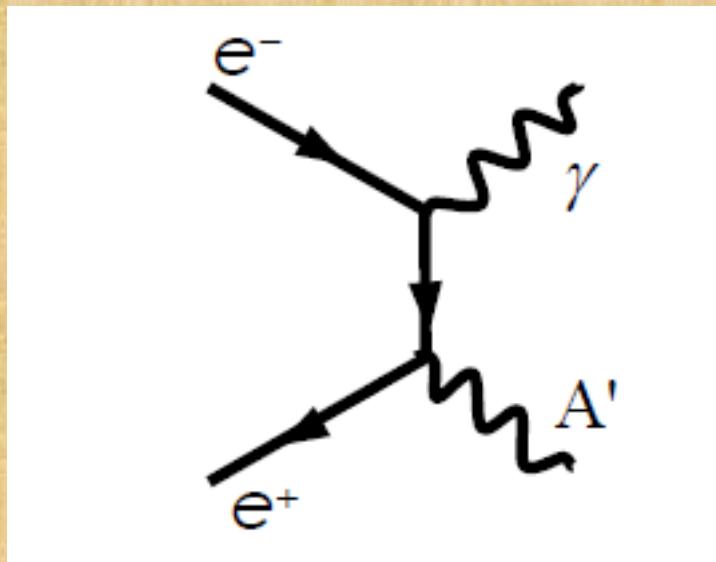


The knowledge of momenta  $e^+$ ,  $e^-$  and  $\gamma$  allows to restore the  $A'$  mass – resonant distribution on invariant mass

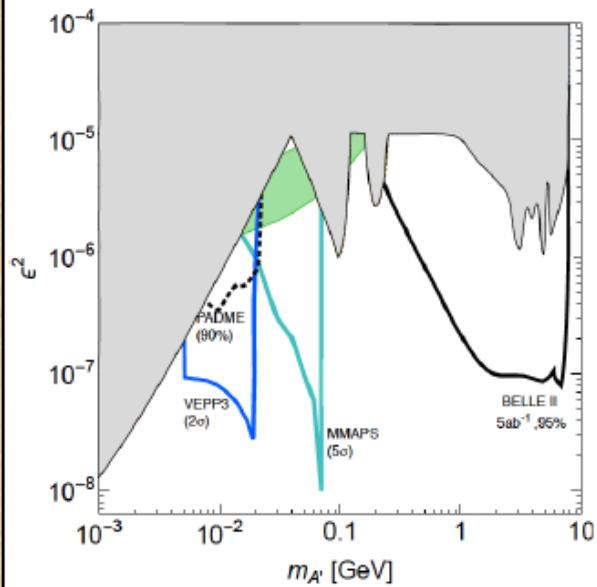
## PADME experiment

# Positron Annihilation into Dark Matter Experiment

positron beam on  
“electron” target



Dark Photon arXiv:1608.08632v1



Invisible final state  $A' \rightarrow \chi\chi$

# Other future missing mass experiments

1. Russia(VEPP3 at BINP, Novosibirsk)  
500 MeV positron beam, dark photon mass limit 22 MeV,  $\varepsilon^2$  limit up to  $10^{-7}$ , >2020  
(1708.07901)
2. USA(Cornell, MMAPS), 6 GeV positron beam  $\varepsilon^2$  limit dark photo  $10^{-6} - 10^{-7}$  at 73 MeV,  
up to

# Beam dump experiments

- a. Electron beam dump
- b. Proton beam dump

# BDX(electron beam dump experiment) at JLAB

Electron( $E_e \sim 12$  GeV) beam experiment  
for the search for light dark matter.

$EOT = 10^{22}$  is assumed. The natural variable

$$y \equiv \epsilon^2 \alpha_D \left( \frac{m_\chi}{m_{A'}} \right)^4$$

# BDX experiment (1607.01390) at JLAB

Beam Dump eXperiment: Light Dark Matter (LDM) direct detection in a  $e^-$  beam, fixed-target setup<sup>1</sup>

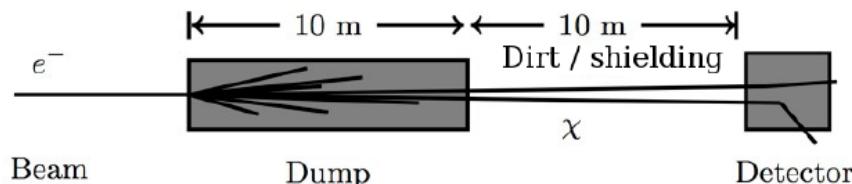
## $\chi$ production

- High-energy, high-intensity  $e^-$  beam impinging on a dump
- $\chi$  particles pair-produced radiatively, through  $A'$  emission

## $\chi$ detection

- Detector placed behind the dump,  $\simeq 20m$
- Neutral-current  $\chi$  scattering on atomic  $e^-$  through  $A'$  exchange, recoil releasing visible energy
- Signal: high-energy EM shower,  $E > .3$  GeV

Number of events scales as:  $N \propto \frac{\alpha_D \varepsilon^4}{m_A^4}$

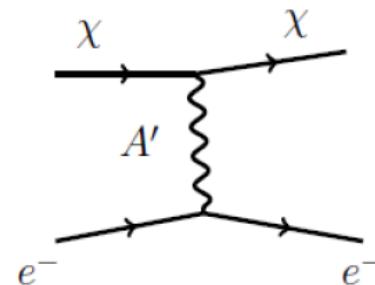
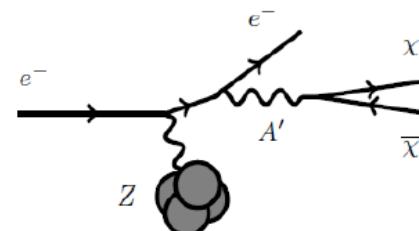


LDM parameters space:

$$M'_A, M_\chi, \varepsilon, \alpha_D$$

$$M'_A \simeq 10 \div 1000 \text{ MeV}$$

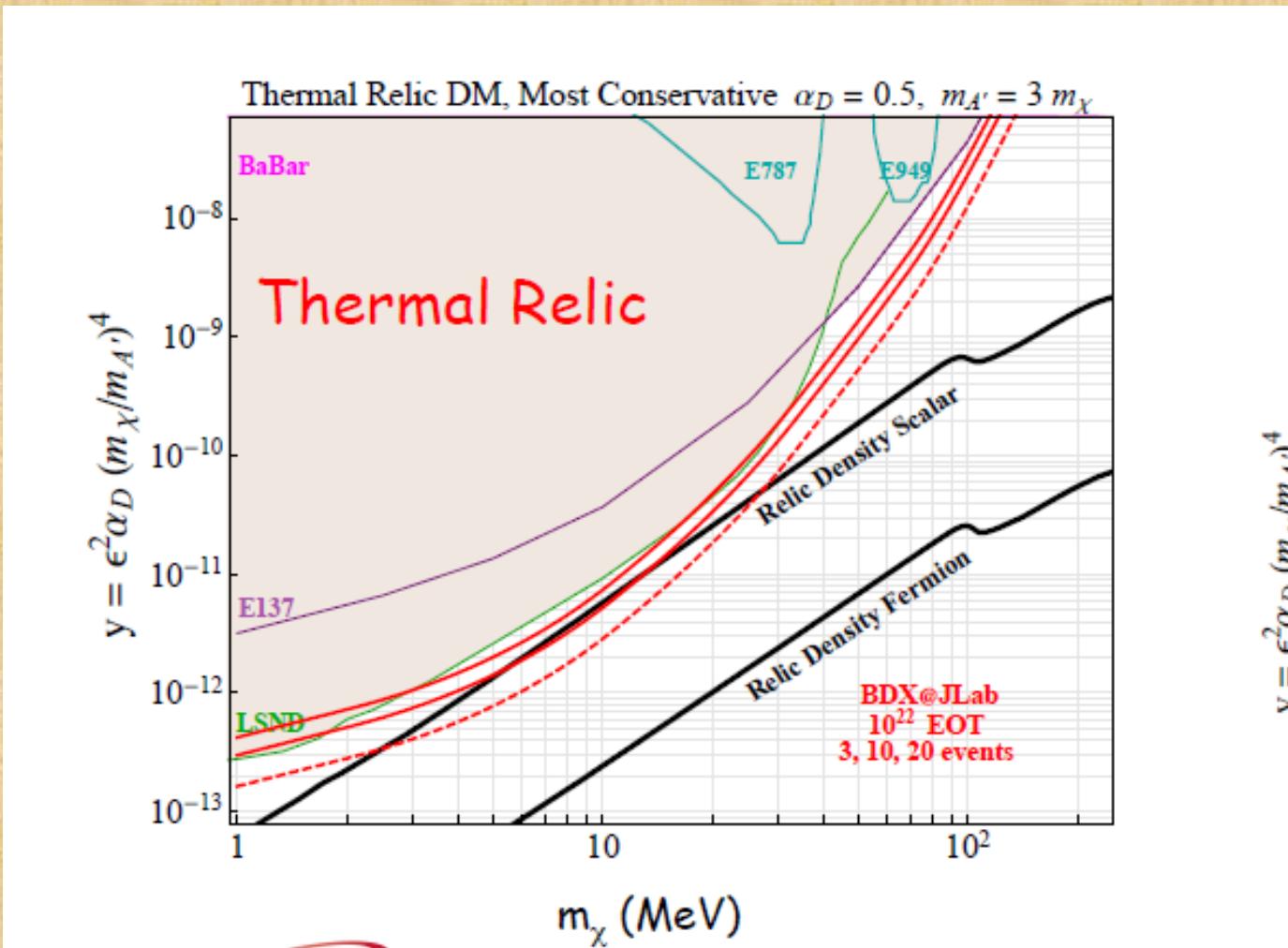
$$M_\chi \simeq 1 \div 100 \text{ MeV}$$



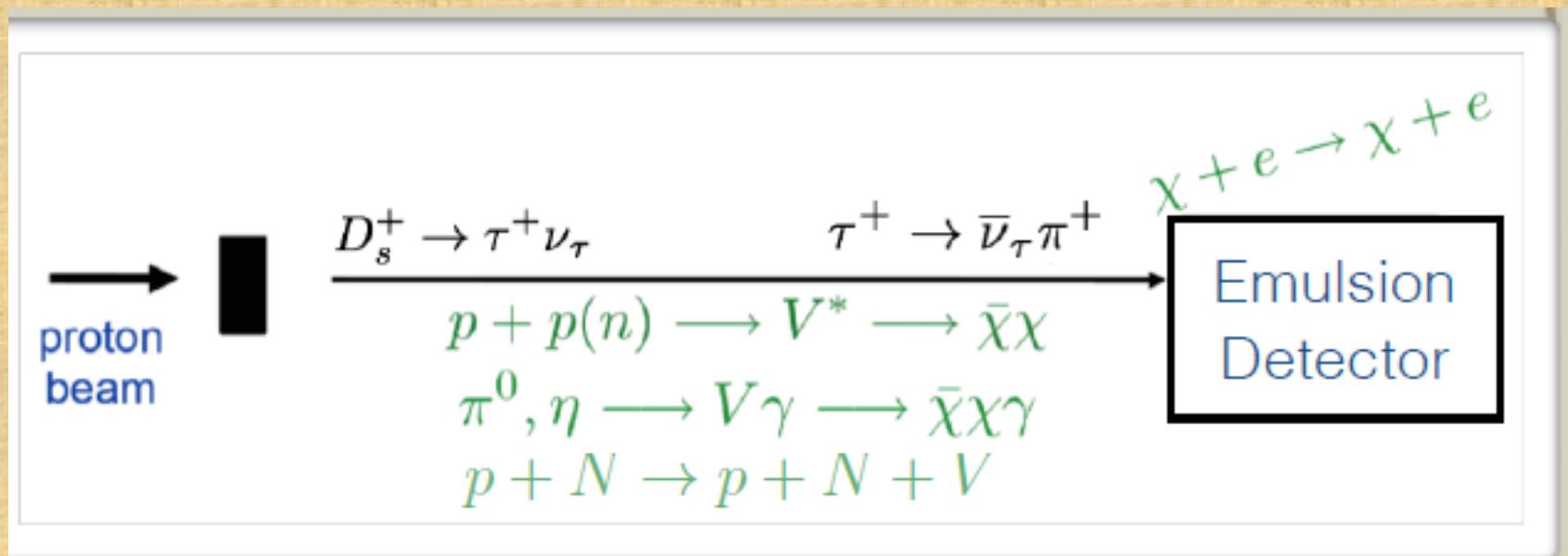
<sup>1</sup>For a comprehensive introduction: E. Izaguirre et al, Phys. Rev. D 88, 114015

# BDX reach for $10^{22}$ EOT

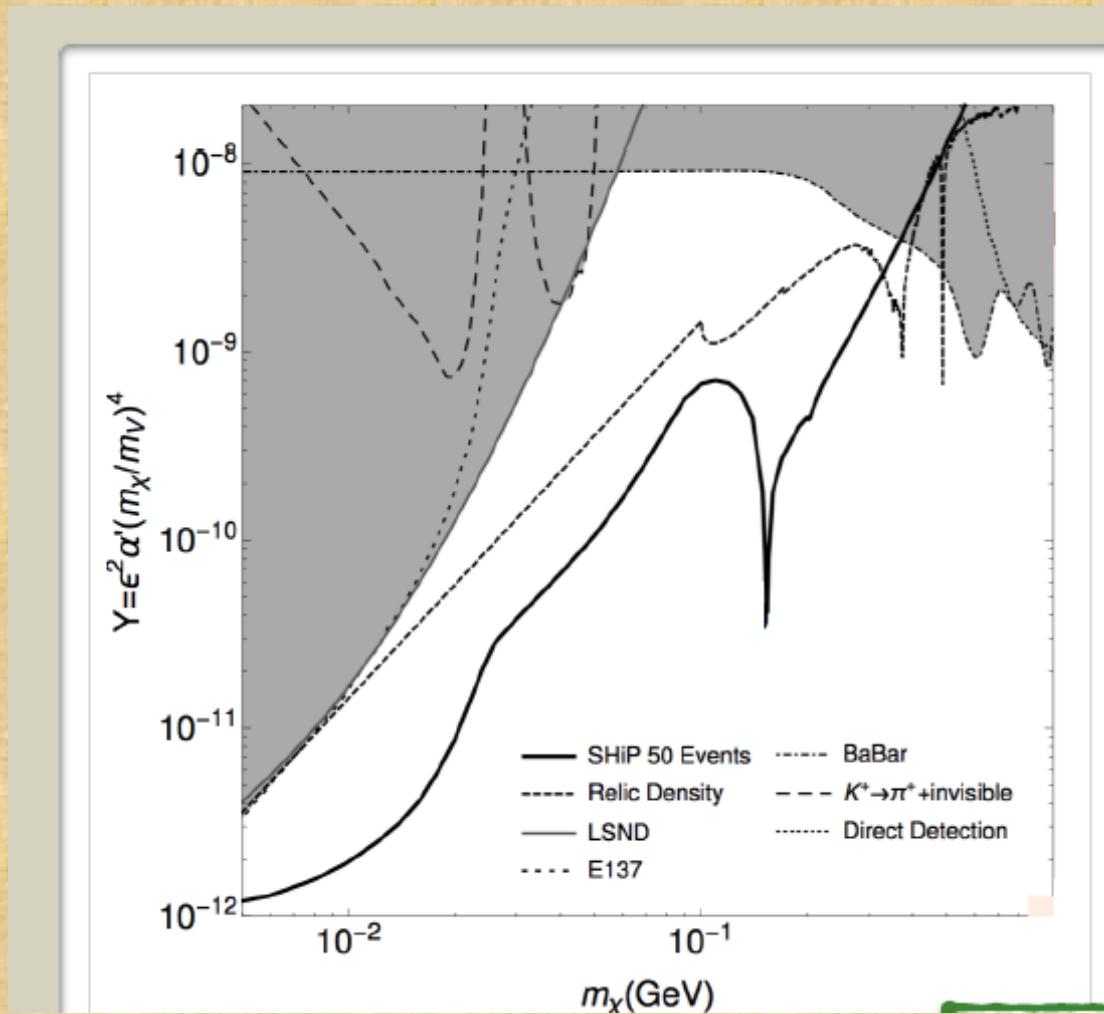
1607.01390



# SHiP experiment can also search for invisible decays



# Expected SHiP sensitivity to invisible decays



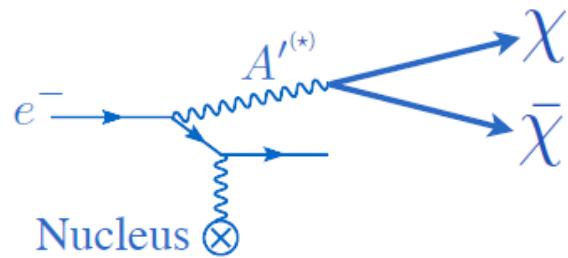
# Future proton beam dumps at FNAL

SBND(Short Base Near Detector)

(1503.01520) -

- factor 10 improvement in signal sensitivity relative to MiniBoone

# Missing energy(momentum) reaction NA64 and LDMX



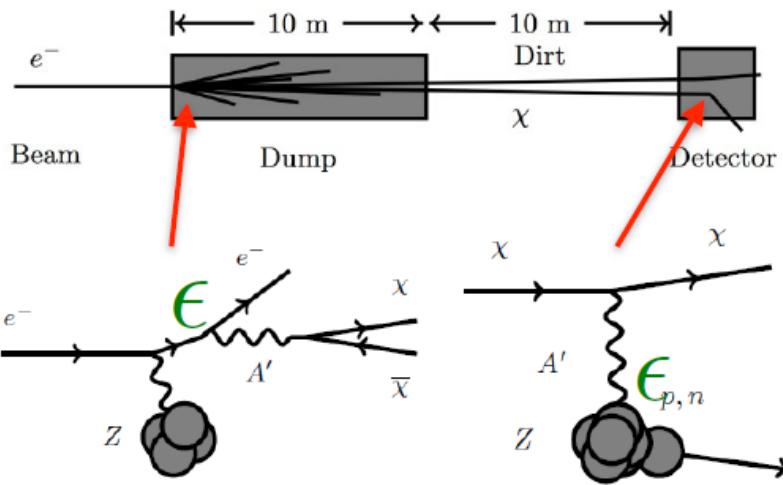
$$\sigma \propto \frac{Z^2 \epsilon^2}{m_{A'}^2}$$

# LDMX(Light Dark Matter eXperiment)

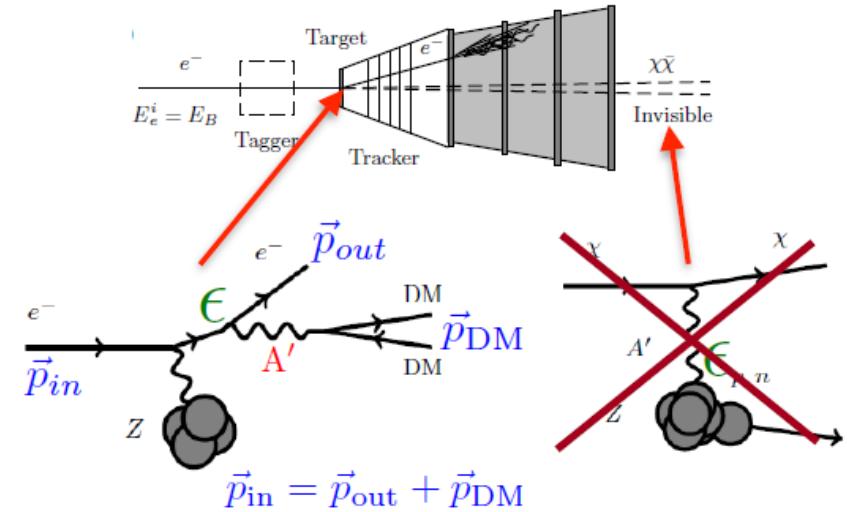
## 1801.07867

Maximize DM detection efficiency

*beam dump*



*missing momentum*



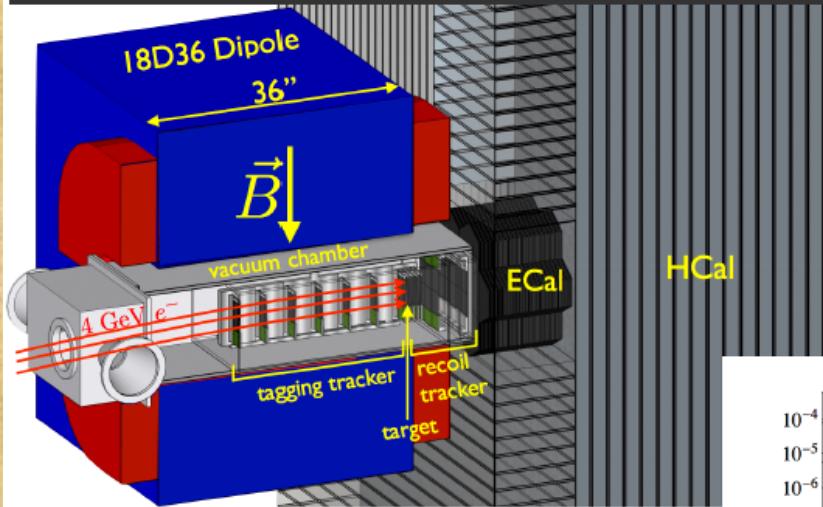
$$N \propto \epsilon^4$$



$$N \propto \epsilon^2(1 - \epsilon^2) \approx \epsilon^2$$

# Example of missing momentum experiment: LDMX

## LDMX: $P_{\text{Miss}}$ experiment

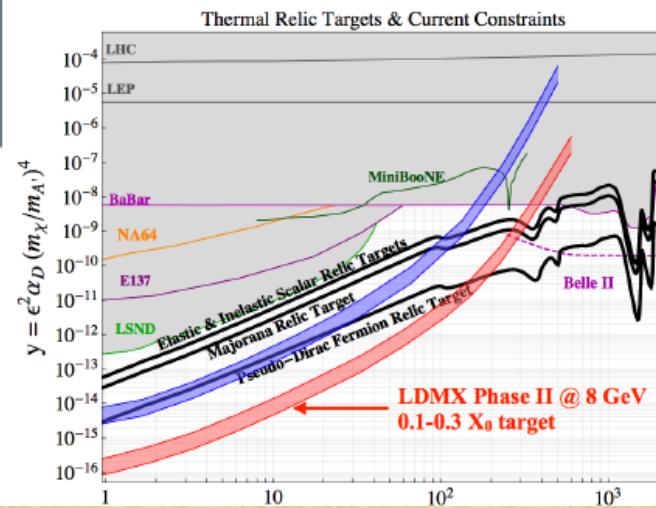


Two-stage approach to LDMX:  
 **$4 \times 10^{14}$  "Phase I"** late 2021  
 **$1 \times 10^{16}$  "Phase II"** late 2023-2024

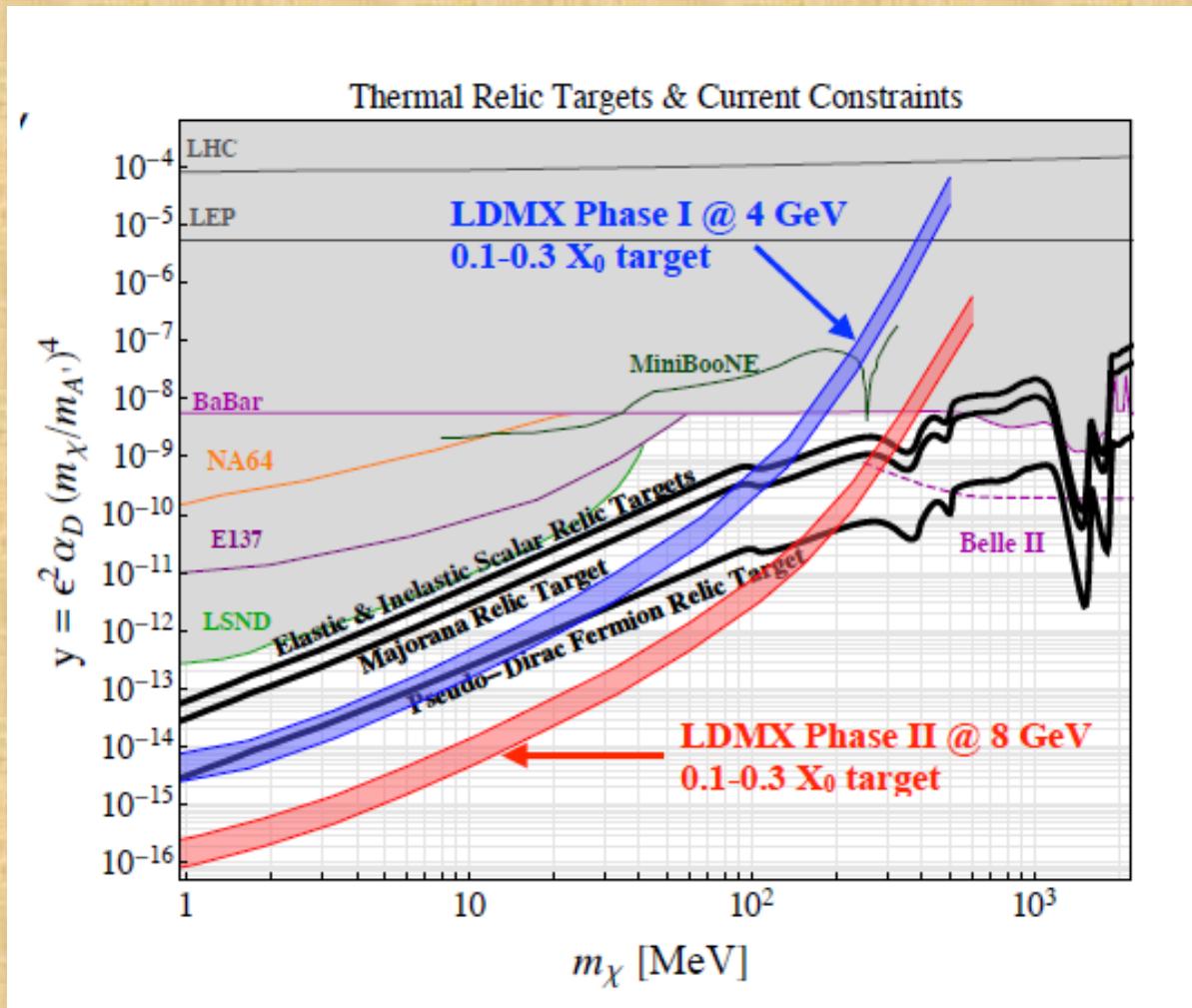
**Beam:** individual tag of  $10^{16}$  incident  $e^-$   
- A low-current, multi-GeV,  $e^-$  beam  
( $10^{16}/\text{year} \approx 1 e^- / 3 \text{ ns}$ ).

Possibilities:

- DASEL@SLAC (4/8 GeV)
- CEBAF@JLab (up to 11 GeV).
- Large beam spot ( $\sim 10 \text{ cm}^2$ )



# LDMX DISCOVERY POTENTIAL



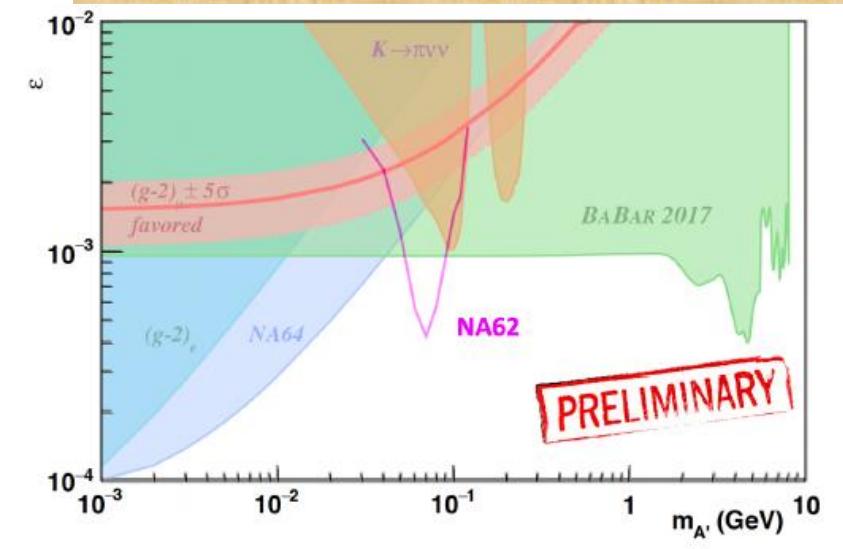
# NA62 future searches of invisible decays (1712.01768)

$$K^\pm \rightarrow \pi^\pm \pi^0 \quad \pi^0 \rightarrow \gamma A' \quad A' \rightarrow \chi\chi$$

Expected limit

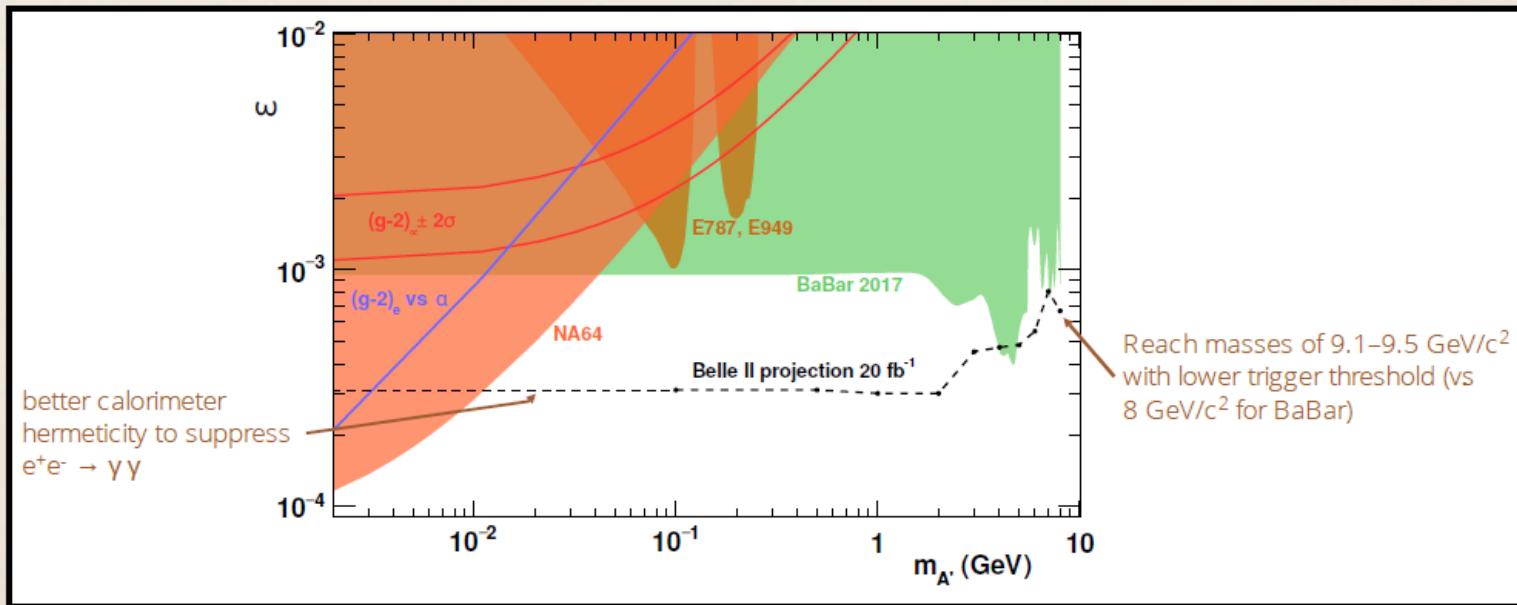
## NA62 is able to investigate dark sector physics in kaon decays

- ◆ Advanced analysis of  $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0 \rightarrow \gamma A' A' \rightarrow \chi\chi$  for invisible  $A'$  decays
- ◆ Decays of  $K^\pm \rightarrow \pi^\pm X \quad X \rightarrow \mu^+\mu^-$  and  $X \rightarrow \chi\chi$
- ◆ Dark sector search in Dump more also very promising ( $A'$ , ALPs HNL)
- ◆ NA62 implemented a dedicated di-lepton trigger for dark sectors



# BELLE II invisible decay potential

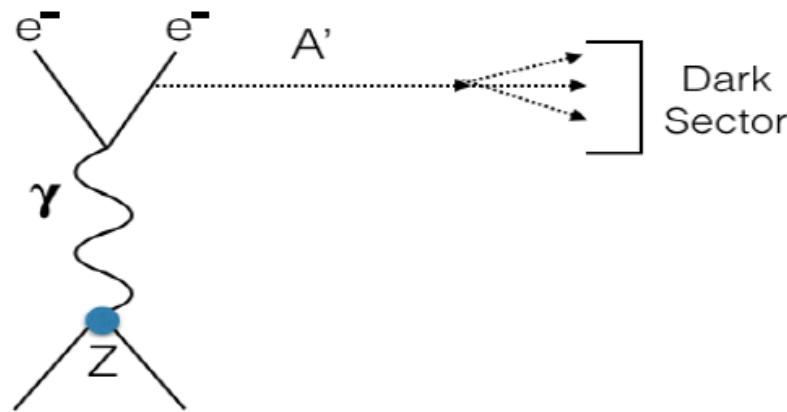
Chris Hearty estimated the BelleII sensitivity for Dark Photon to invisible at U.S. Cosmic Visions: New Ideas in Dark Matter, March 2017



# 3. NA64 experiment

NA64 - Searches  
 $A' \rightarrow invisible$ ,  $A' \rightarrow e^+e^-$   
at SPS CERN

# NA64 Experiment



NA64 is a fixed target experiment combining the active beam dump technique with missing energy measurement searching for invisible decays of massive  $A'$  produced in the reaction  $eZ \rightarrow eZA'$  of electrons scattering off a nuclei ( $A,Z$ ), with a mixing strength  $10^{-5} < \epsilon < 10^{-3}$  and masses  $M_{A'} < 100$  MeV.



# The NA64 Collaboration

D. Banerjee,<sup>11</sup> V. Burtsev,<sup>9</sup> D. Cooke,<sup>11</sup> P. Crivelli,<sup>11</sup> E. Depero,<sup>11</sup> A. V. Dermenev,<sup>4</sup> S. V. Donskov,<sup>8</sup> F. Dubinin,<sup>5</sup> R. R. Dusaev,<sup>9</sup> S. Emmenegger,<sup>11</sup> A. Fabich,<sup>3</sup> V. N. Frolov,<sup>2</sup> A. Gardikiotis,<sup>7</sup> S. N. Glinenko\*,<sup>4</sup> M. Hösgen,<sup>1</sup> V. A. Kachanov,<sup>8</sup> A. E. Karneyeu,<sup>4</sup> B. Ketzer,<sup>1</sup> D. V. Kirpichnikov,<sup>4</sup> M. M. Kirsanov,<sup>4</sup> I. V. Konorov,<sup>5</sup> S. G. Kovalenko,<sup>10</sup> V. A. Kramarenko,<sup>6</sup> L. V. Kravchuk,<sup>4</sup> N. V. Krasnikov,<sup>4</sup> S. V. Kuleshov,<sup>10</sup> V. E. Lyubovitskij,<sup>9</sup> V. Lysan,<sup>2</sup> V. A. Matveev,<sup>2</sup> Yu. V. Mikhailov,<sup>8</sup> V. V. Myalkovskiy,<sup>2</sup> V. D. Peshekhonov†,<sup>2</sup> D. V. Peshekhonov,<sup>2</sup> O. Petuhov,<sup>4</sup> V. A. Polyakov,<sup>8</sup> B. Radics,<sup>11</sup> A. Rubbia,<sup>11</sup> V. D. Samoylenko,<sup>8</sup> V. O. Tikhomirov,<sup>5</sup> D. A. Tlisov,<sup>4</sup> A. N. Toropin,<sup>4</sup> A. Yu. Trifonov,<sup>9</sup> B. Vasilishin,<sup>9</sup> G. Vasquez Arenas,<sup>10</sup> P. Ulloa,<sup>10</sup> K. Zhukov,<sup>5</sup> and K. Zioutas<sup>7</sup>  
(The NA64 Collaboration‡)

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<sup>5</sup>P.N. Lebedev Physics Institute, Moscow, Russia, 119 991 Moscow, Russia

<sup>6</sup>Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia

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<sup>8</sup>State Scientific Center of the Russian Federation Institute for High Energy Physics of National Research Center 'Kurchatov Institute' (IHEP), 142281 Protvino, Russia

<sup>9</sup>Tomsk Polytechnic University, 634050 Tomsk, Russia

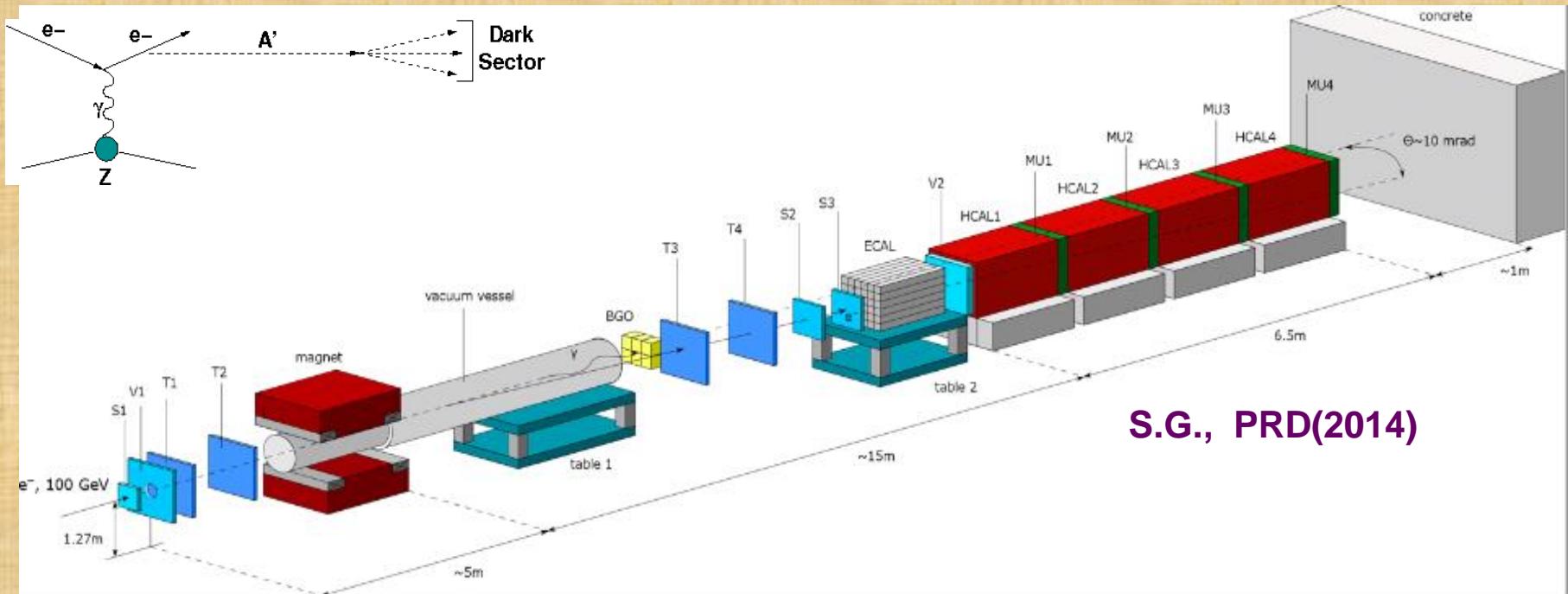
<sup>10</sup>Universidad Técnica Federico Santa María, 2390123 Valparaíso, Chile

<sup>11</sup>ETH Zürich, Institute for Particle Physics, CH-8093 Zürich, Switzerland

## 47 researchers from 12 institutes

# search for $A' \rightarrow \text{invisible}$ 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
- 4 $\pi$  fully hermetic ECAL+ HCAL

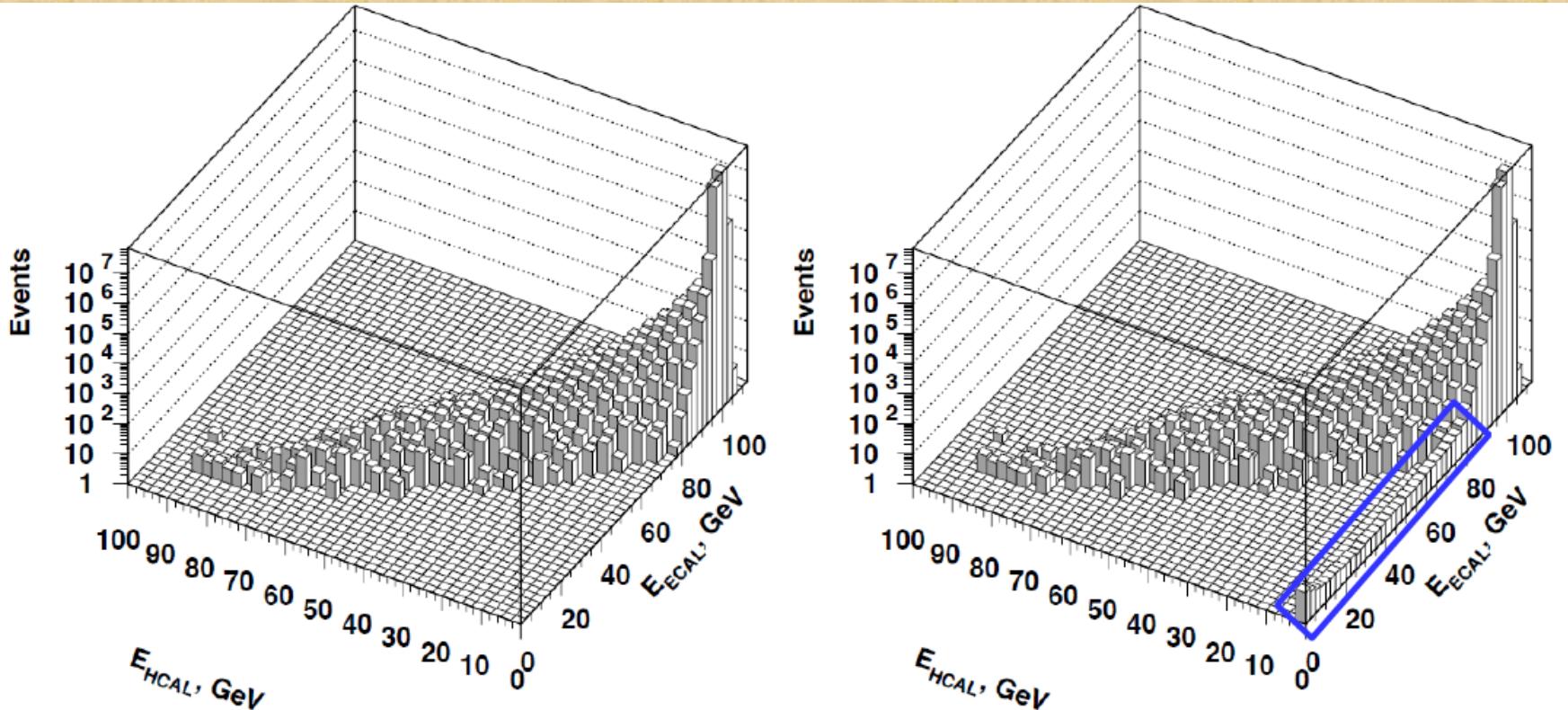
### Signature:

- in: 100 GeV  $e^-$  track
- out: < 50 GeV  $e^-$ - $m$  shower in ECAL
- no energy in the Veto and HCAL
- Sensitivity  $\sim \varepsilon^2$



Quarks2018, Valdai, 28 may 2018

# Active target beam dump concept



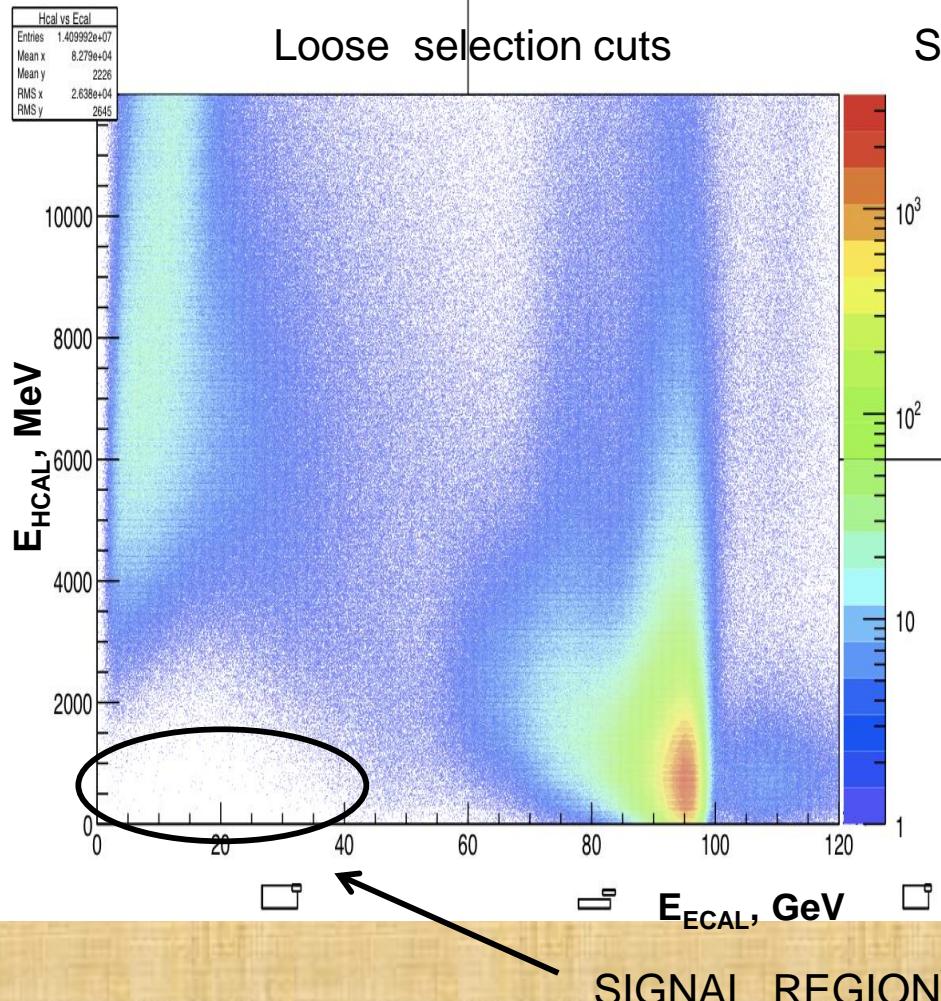
Dark Photon Signature for 100 GeV electron beam:

- Missing energy in ECAL (ECAL threshold < 50 GeV)
- No activity in Veto and HCAL

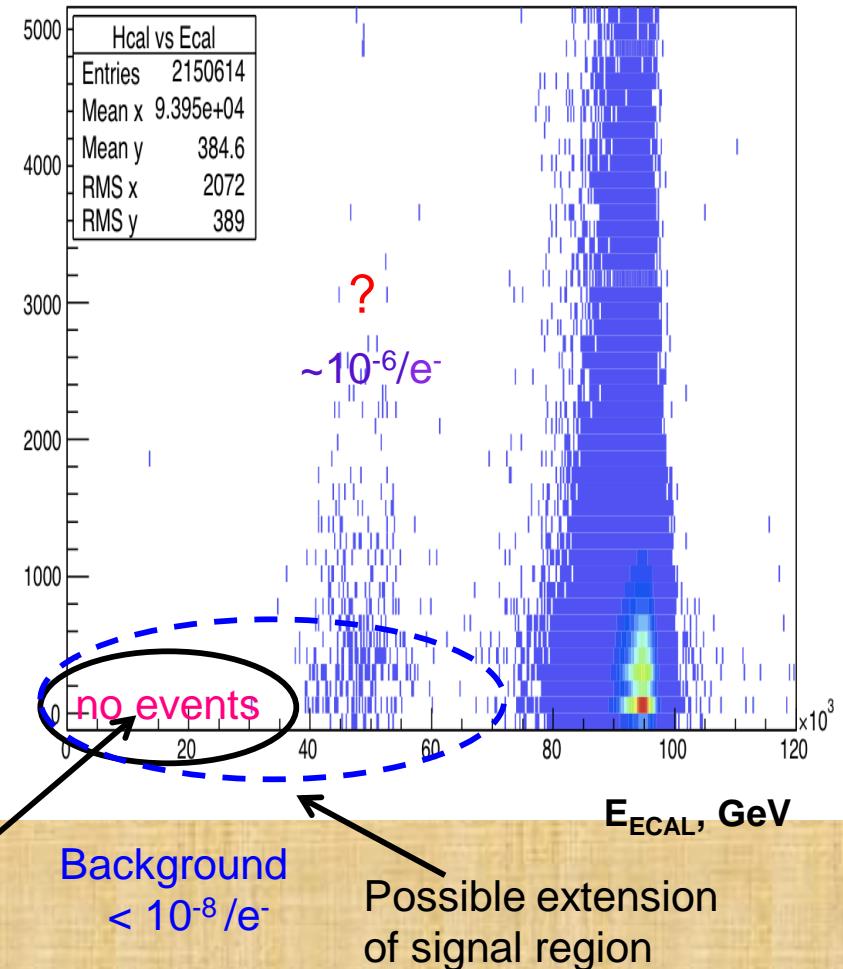
# $A'$ signal in $(E_{HCAL}; E_{ECAL})$ plane

$$Tr = S0 \times S1 \times PS(>2 \text{ GeV}) \times ECAL(< 95 \text{ GeV})$$

Loose selection cuts



Single hit in X-Y Hodoscope plane + SR tag



The NA64 first new result from  
July 2016 run

NA64 Collaboration,  
Phys.Rev.Lett. 118, 011802(2017)

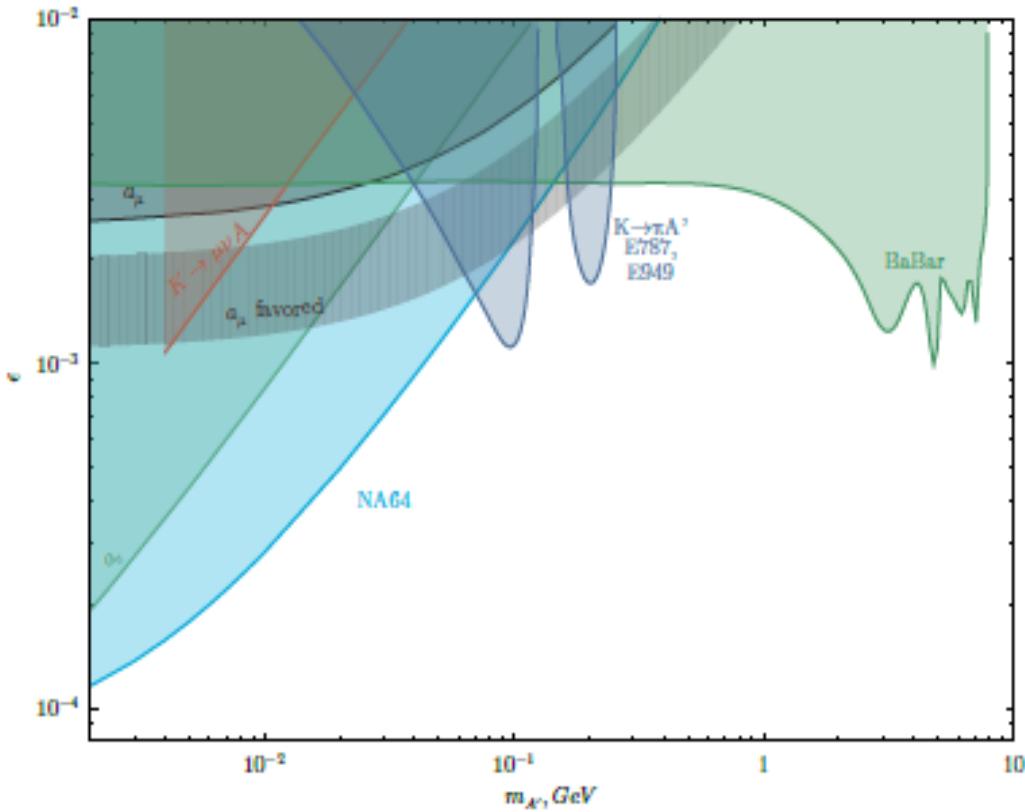
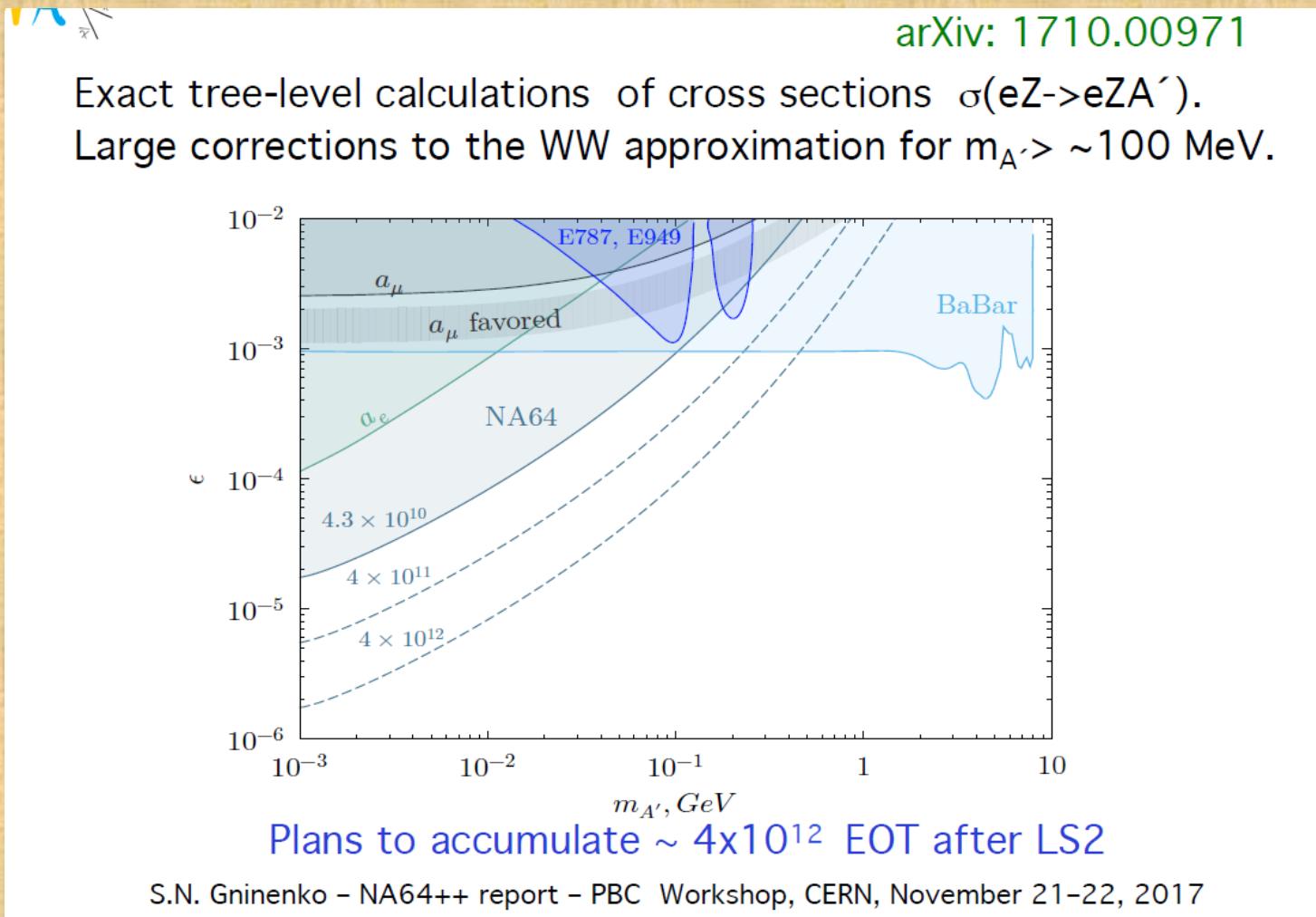


FIG. 3: The NA64 90 % C.L. exclusion region in the  $(m_{A'}, \epsilon)$  plane. Constraints from the BaBar [48, 55], and E787+ E949 experiments [47, 56], as well as muon  $\alpha_\mu$  favored area are also shown. Here,  $\alpha_\mu = \frac{g_\mu - 2}{2}$ . For more limits obtained from indirect searches and planned measurements see e.g. Refs. [5].

# LAST NA64 RESULT

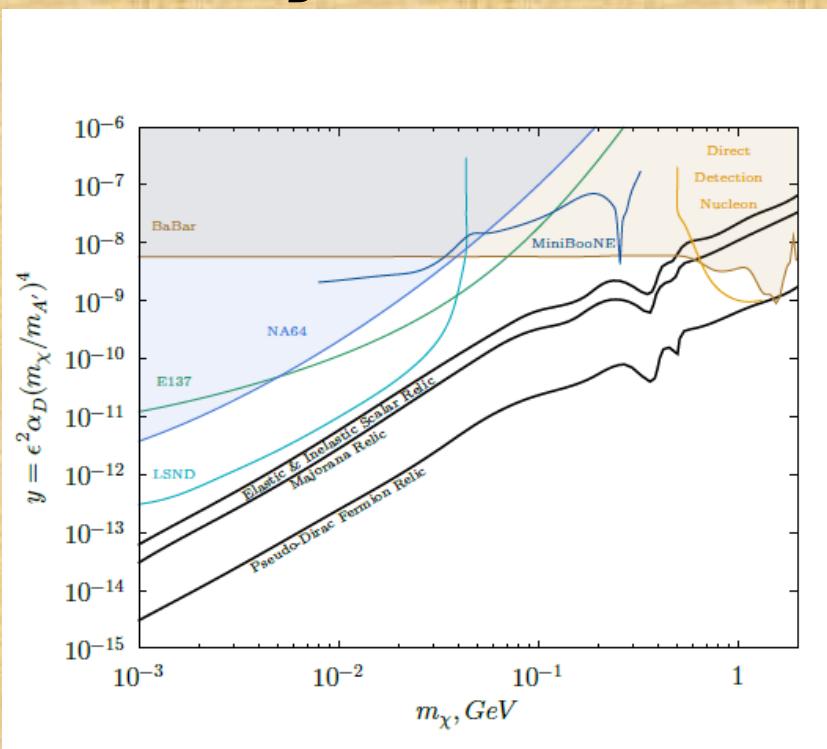
## July + October 2016 run



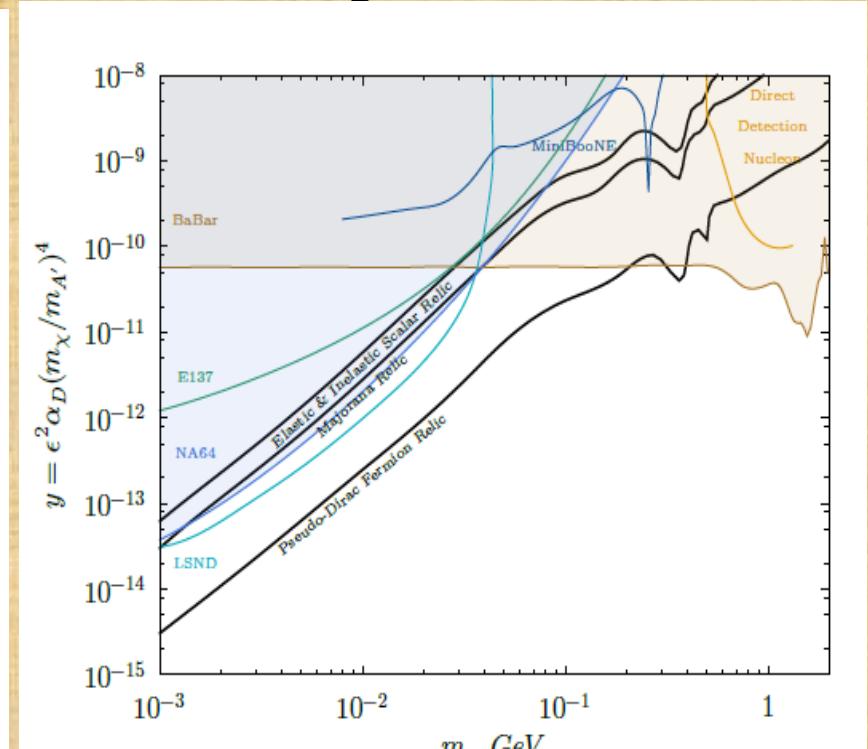
# NA64 bound for

$$y = \epsilon^2 \alpha_D \left( \frac{m_\chi}{m_{A'}} \right)^4$$

$\alpha_D = 0.5$

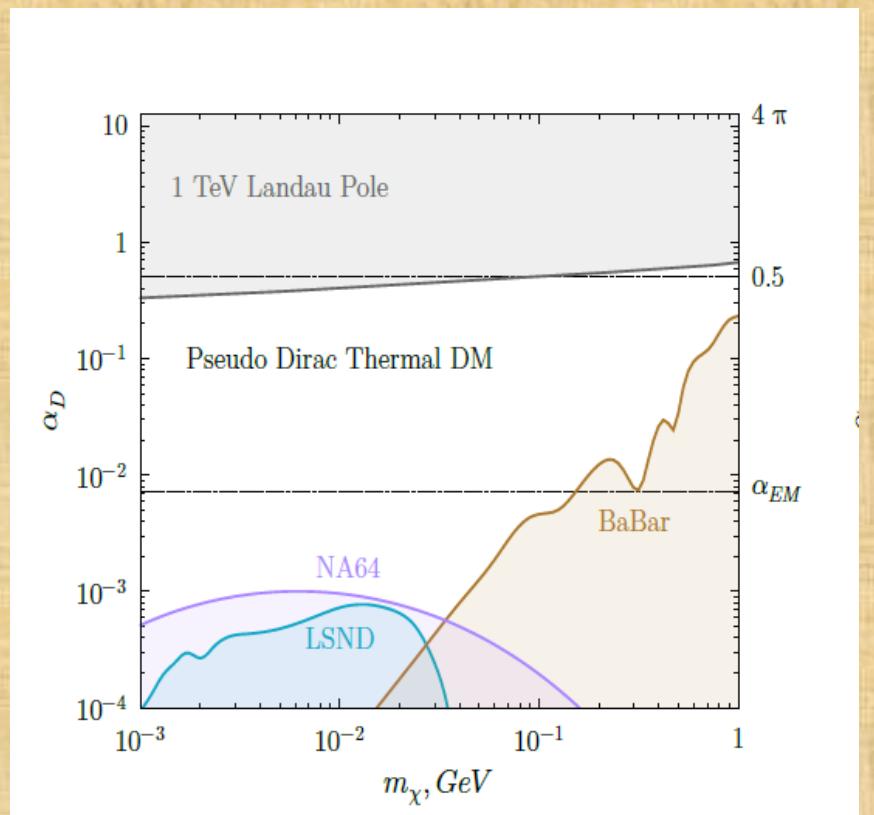


$\alpha_D = 0.005$

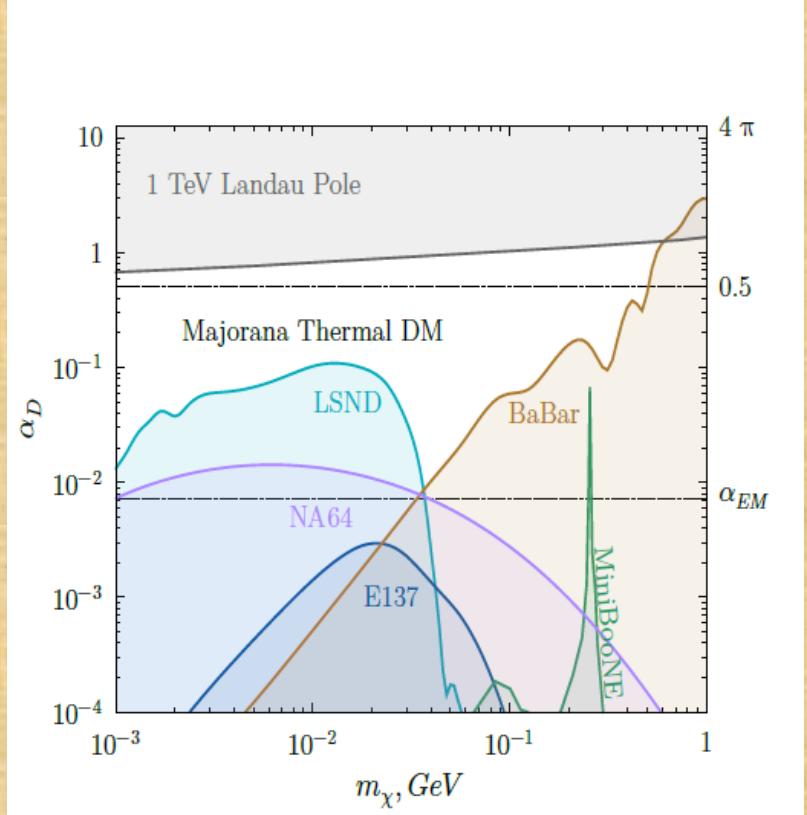


# NA64 bound on $\alpha_D$

## Pseudo Dirac



## Majorana



# Visible decays activity- the check of the ATOMKI experiment

10.



**${}^8\text{Be}^*$  anomaly: a new light X boson?**

PRL 116, 042501 (2016) PHYSICAL REVIEW LETTERS week ending 29 JANUARY 2016

**Observation of Anomalous Internal Pair Creation in  ${}^8\text{Be}$ : A Possible Indication of a Light, Neutral Boson**

A. J. Krasznahorkay,\* M. Csatló, L. Csige, Z. Gács, J. Gulyás, M. Hunyadi, I. Kuti, B. M. Nyakó, L. Stuhl, J. Timár, T. G. Tomyi, and Zs. Vajta  
Institute for Nuclear Research, Hungarian Academy of Sciences (MTA Atomki), P.O. Box 51, H-4001 Debrecen, Hungary

T. J. Ketel  
Nikhef National Institute for Subatomic Physics, Science Park 105, 1098 XG Amsterdam, Netherlands

A. Krasznahorkay  
CERN, CH-1211 Geneva 23, Switzerland and Institute for Nuclear Research, Hungarian Academy of Sciences (MTA Atomki), P.O. Box 51, H-4001 Debrecen, Hungary  
(Received 7 April 2015, published 26 January 2016)

**Feng et al, 2016**

$p^+ \rightarrow {}^7\text{Li} \rightarrow {}^8\text{Be}^*$

${}^8\text{Be}^*$  decays into  $e^+$ ,  $e^-$ , and  $X$ .  $X$  decays into  $e^+$  and  $e^-$ .

$2 \times 10^{-4} < \varepsilon_e < 1.4 \times 10^{-3}$

S.N. Gninenco – NA64 Status Report, SPSC Open Meeting, CERN, June 20-21, 2017

${}^7\text{Li}(p, \gamma){}^8\text{Be}, M_X = 16.7 \text{ MeV}$

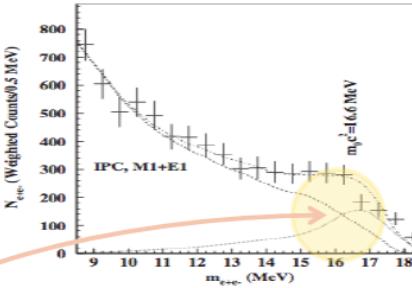
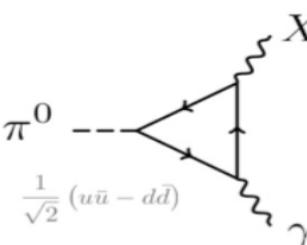


FIG. 5. Invariant mass distribution derived for the 18.15 MeV transition in  ${}^8\text{Be}$ .

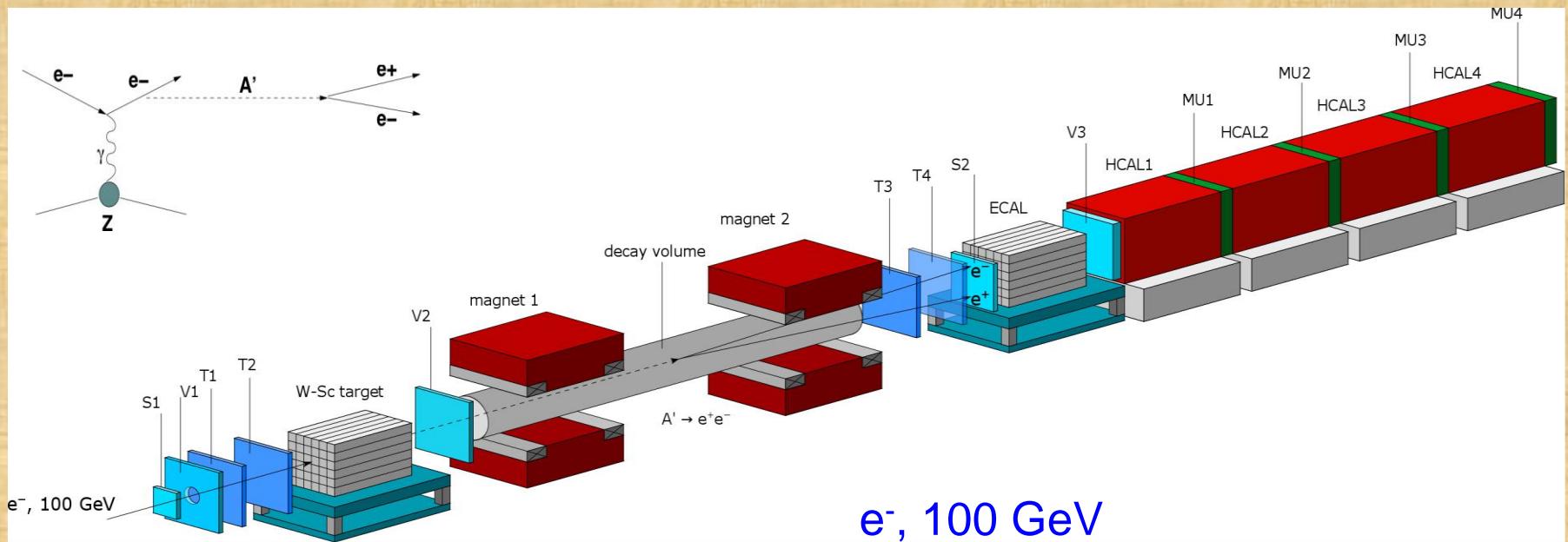
X cannot be A' due to constraints from  $\pi^0 \rightarrow X\gamma$  decay:



$$\Gamma(\pi^0 \rightarrow X\gamma) \sim (\varepsilon_u q_u - \varepsilon_d q_d)^2 \sim 0$$

if  $2\varepsilon_u = -\varepsilon_d \rightarrow$  protophobic X

# Search for $A' \rightarrow e^+e^-$



- $A'$  decay outside W-Sc ECAL1
- $10^{-14} < \tau_{A'} < 10^{-10} \text{ s}$ ,  $\sigma_{A'}/\sigma_\gamma < 10^{-13}-10^{-9}$
- Signature: two separated e-m showers from a single  $e^-$

$$S = \overline{\text{ECAL1} \times \text{S1} \times \text{S2} \times \text{ECAL2} \times \text{V1} \times \text{V2} \times \text{HCAL}}$$

- $E_1 < E_0$ , and  $E_0 = E_1 + E_2$
- $\theta_{e^+e^-}$  is small to be resolved

# Visible decays. New NA64 result-October 2017 run with $4.5 \times 10^{14}$ EOT

ALLOWED REGION,

J.Feng et al., Phys.Rev.Lett., 117, 071803  
(2016)

$$10^{-4} \lesssim \epsilon_e \lesssim 10^{-3}$$

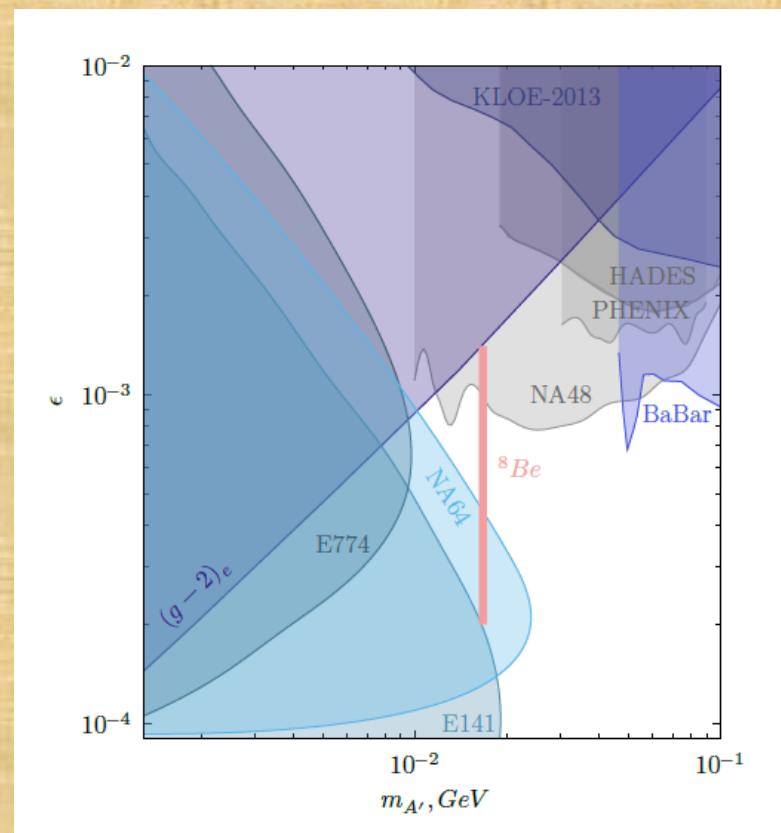
The part of this region is excluded , **namely:**

$$1.3 \times 10^{-4} \lesssim \epsilon_e \lesssim 4.2 \times 10^{-4}$$

for

$$n_{EOT} = 5.4 \times 10^{10} \text{ EOT}$$

**New NA64 result:**  
**arXiv:1803.07748**



# The NA64 experiment with muon beam

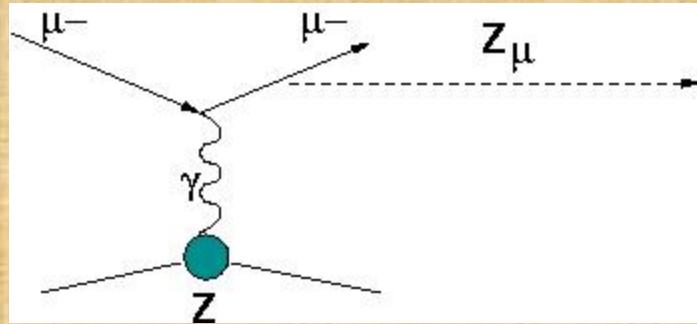
S.Gninenko, N.Krasnikov and V.Matveev,

Phys.Rev. D91(2015)095015

Proposal to look for dark photon at  
collisions of  
CERN SPS muon beams

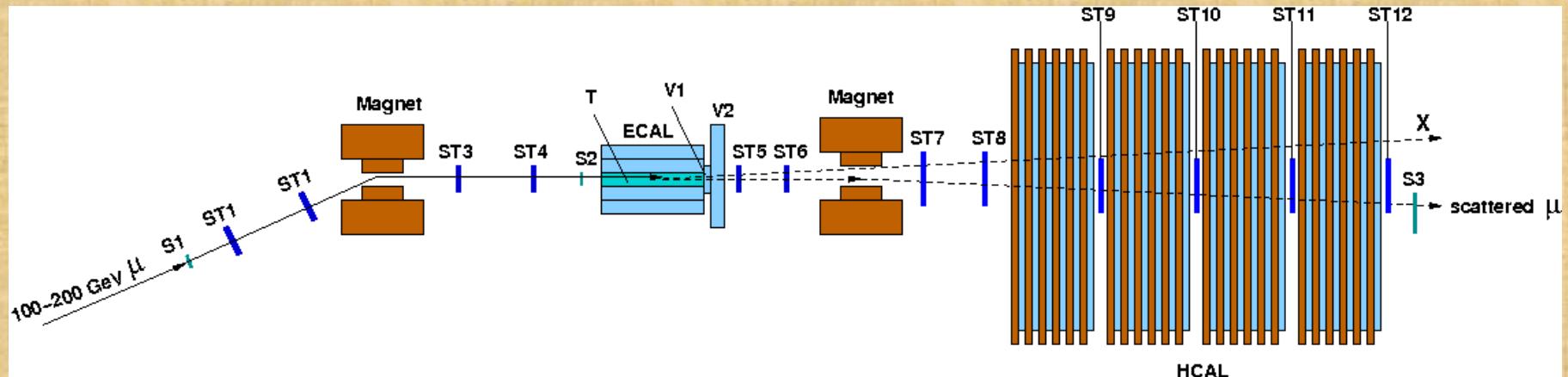
$$\mu(p) + Z(P) \rightarrow Z(P') + \mu(p') + Z_\mu(k)$$

# The NA64 experiment at CERN with muon beam



T

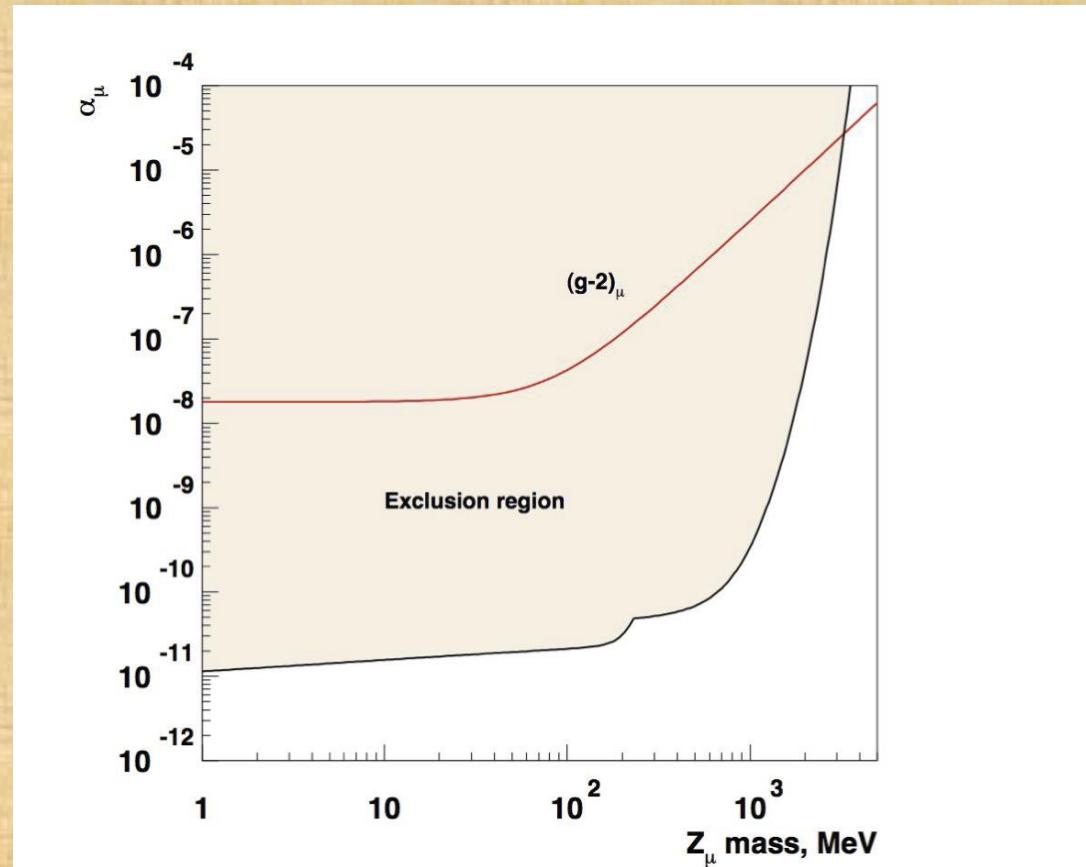
# Schematic illustration of the setup to search for dark boson



# 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 outgoing muons without big activity in HCAL and ECAL

# Expected sensitivity for $10^{12}$ muons on target



## 4. Conclusions

Light dark matter?

To be or not to be?

That's the question!

I believe(hope) the answer (positive? or negative?)

will be known in 10-12 years.

Thank You for your attention.