New physics: light and weakly coupled

Maxim Pospelov
Perimeter Institute, Waterloo/University of Victoria, Victoria

INT workshop, 2015

University of Victoria | British Columbia Canada

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

Outline of the talk

1. Introduction. Portals to light new physics. Generalization: UV physics or IR?
2. Snapshots of recent activity with fixed target experiments:
    - A. Vector portal, g-2 discrepancy, and the search for dark photon. Dark Vector coupled to baryons, B-L. Dark scalars.
    - B. New physics for the charge radius.
    - C. Light dark matter via vector portals.
3. Possible future areas of growth: new fixed target/beam dump experiments and proposals. Ultimate intensity frontier experiment.
4. Conclusions

Simple messages in today's talk

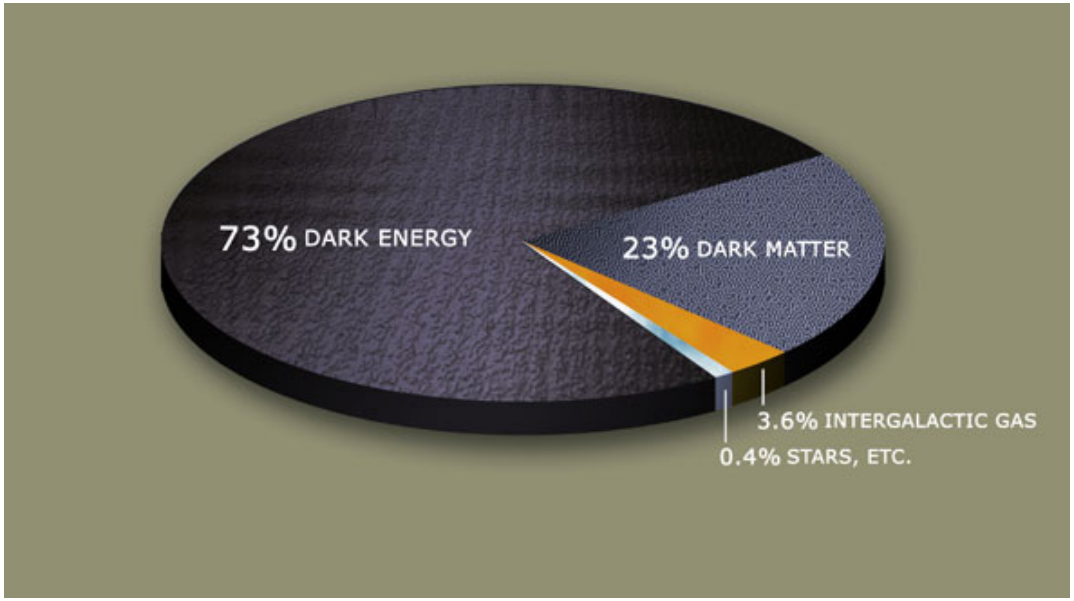
1. *Light weakly coupled new (BSM) physics* is a generic possibility not to be *a priori* discarded.

2. If it does not violate any well-tested symmetry, it can mediate a new interactions that are e.g. *stronger* than some SM interactions.

3. Since 2008, there has been *a revival* of the subject (driven initially by some astrophysics hints), with old data being repurposed, new searches added, and new experiments being set up. There is still considerable room for *new ideas*. This subject is here to stay.

4. If light NP is proposed to "explain away" some anomalies (g-2, muon H Lamb shift), it is often the case that NP model can be tested faster than the true origin of given discrepancy is found.

Big Questions in Physics

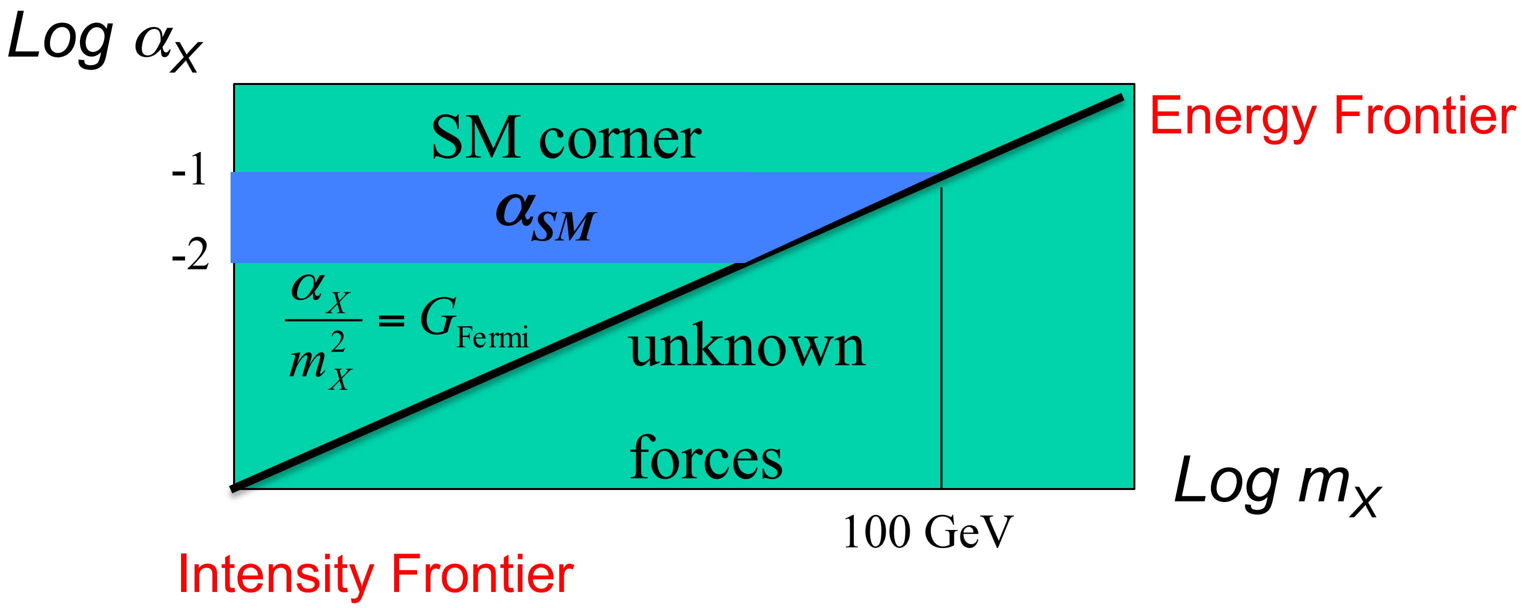


"Missing mass" – what is it?

New particle, new force, …? *Both*? How to find out?

(History lesson: first "dark matter" problem occurred at the nuclear level, and eventually new particles, neutrons, were identified as a source of a "hidden mass" – and of course immediately with the new force of nature, the strong interaction force.)

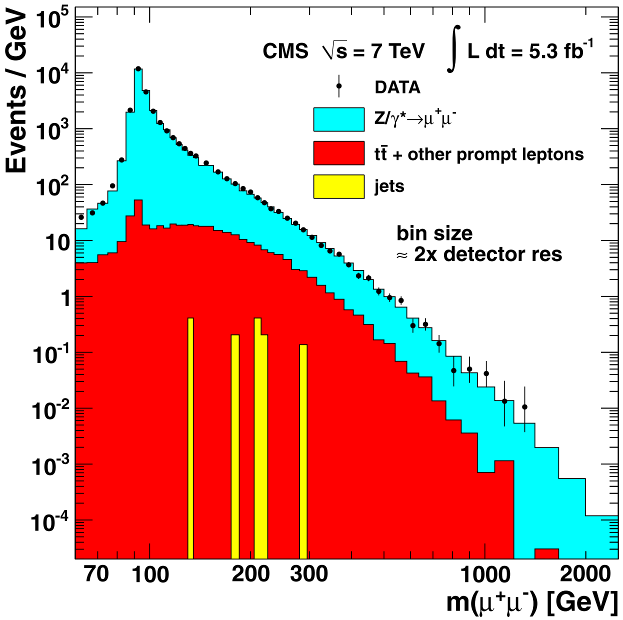
Intensity and Energy Frontiers

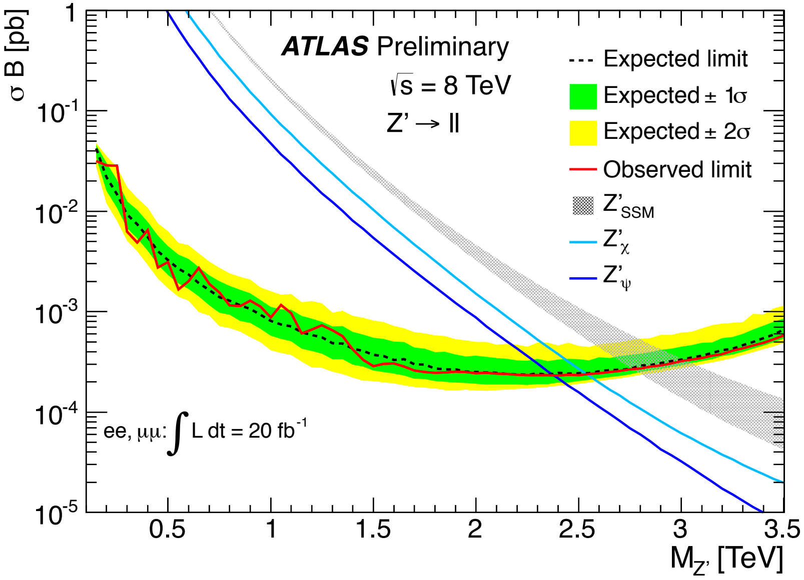


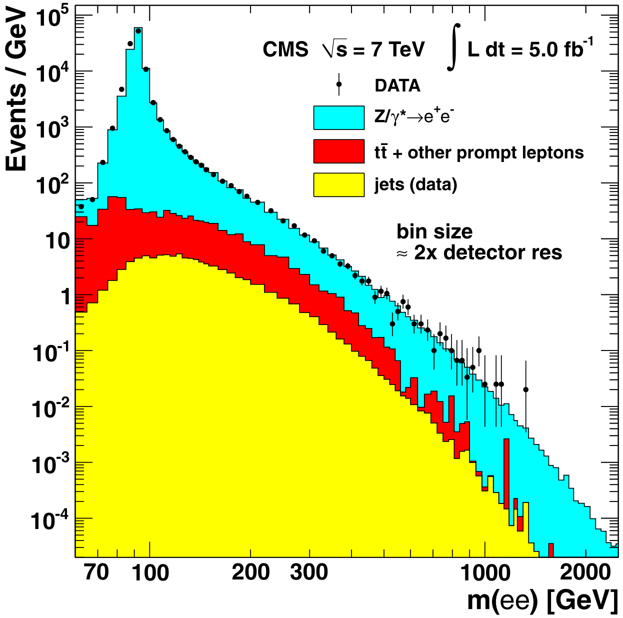
$$V(r) = \frac{\alpha_X}{r}\exp(-r/\lambda_X) = \frac{\alpha_X}{r}\exp(-rm_X) \longrightarrow \text{Amplitude} \approx \frac{\alpha_X}{q^2 + m_X^2}$$

LHC can realistically pick up New Physics with $\alpha_X \sim \alpha_{SM}$, and $m_X \sim$ 1TeV, but may have little success with $\alpha_X \sim 10^{-6}$, and $m_X \sim$ GeV.

No New Physics at high energy thus far (?!)







No hints for any kind of new physics. Strong constraints on SUSY, extra dimensions, technicolor resonances.

Constraints on new *Z'* bosons push the mediator mass into multi-TeV territory.

Hint for $m_{\rho'} \sim 2$ TeV ???

Neutral "portals" to the SM

Let us *classify* possible connections between Dark sector and SM

$H^+H\,(\lambda S^2 + A S)$ Higgs-singlet scalar interactions (scalar portal)

$B_{\mu\nu} V_{\mu\nu}$ "Kinetic mixing" with additional U(1)' group

(becomes a specific example of $J_\mu^i A_\mu$ extension)

LHN neutrino Yukawa coupling, N – RH neutrino

$J_\mu^i A_\mu$ requires gauge invariance and anomaly cancellation

It is very likely that the observed neutrino masses indicate that Nature may have used the *LHN* portal…

Dim>4

$J_\mu^A\ \partial_\mu a/f$ axionic portal

……….

$$\mathcal{L}_{\text{mediation}} = \sum_{k,l,n}^{k+l=n+4} \frac{\mathcal{O}_{\text{med}}^{(k)} \mathcal{O}_{\text{SM}}^{(l)}}{\Lambda^n},$$

Precision frontier: UV physics or IR?

Typical approach: we measure an observable (e.g. $\mu \rightarrow e\,\gamma$, EDM, rare meson decays etc), we perform calculation of the same quantity in the SM, take a difference, and whatever is left is interpreted in terms of physics at a TeV, 10 TeV, XXX TeV scales – *all of them being UV scales*.

More correct approach: Assume that New Physics consist of UV pieces, IR pieces or both,

$$\mathcal{L}_{\rm NP} = \mathcal{L}_{\rm UV} + \mathcal{L}_{\rm IR}.$$

$$\mathcal{L}_{\rm UV} = \sum_{d\geq 5} \frac{1}{\Lambda_{\rm UV}^{d-4}} \mathcal{O}_d. \;\; \mathcal{L}_{\rm IR} = \kappa B^{\mu\nu} V_{\mu\nu} - H^\dagger H (AS + \lambda S^2) - Y_N LHN + \mathcal{L}_{\rm hid}$$

If result for NP is consistent with 0, we can set constraints on both. If it is non-zero: then *more work is required in deciding IR or UV*

UV physics or IR: examples of NP that we know

Neutrino oscillations: We know that new phenomenon exists, and if interpreted as neutrino masses and mixing, is it coming from deep UV, via e. .g Weinberg's operator

$$\mathcal{L}_{\rm NP} \propto (HL)(HL)/\Lambda_{\rm UV} \text{ with } \Lambda_{\rm UV} \gg \langle H \rangle$$

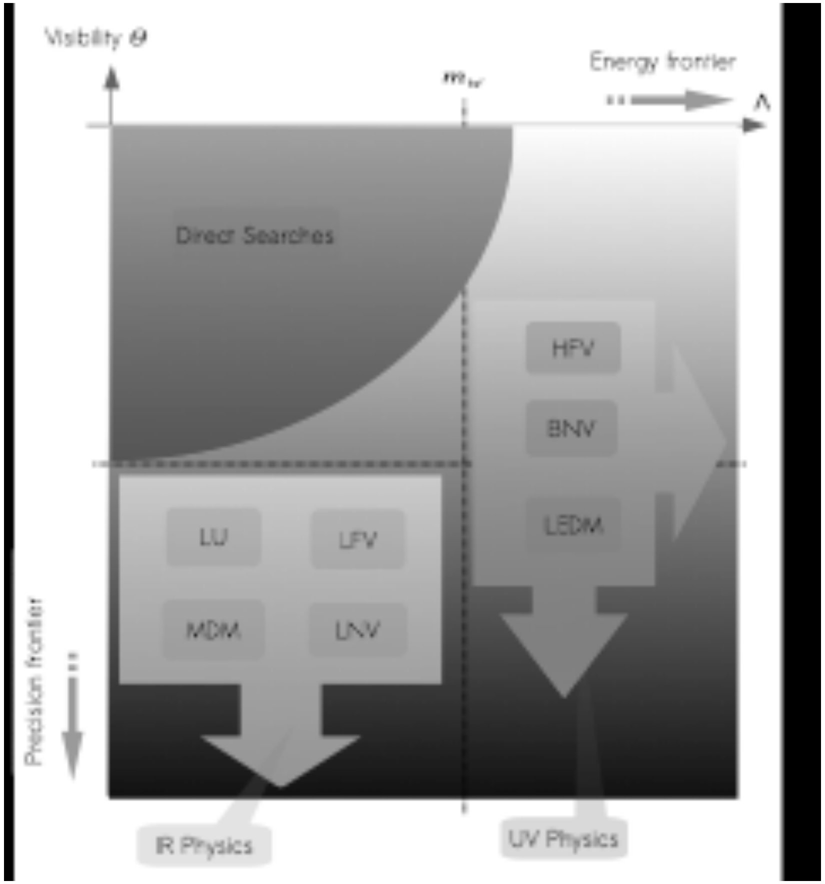
or it is generated by *new IR field*, such as RH component of Dirac neutrinos? *New dedicated experimental efforts are directed in trying to decide between these possibilities.*

Dark matter: 25% of Universe's energy balance is in dark matter: we can set constraints on both. If it is embedded in particle physics, then e.g. neutralinos or axions imply new UV scales.

However, *there are models of DM where NP is completely localized in the IR, and no new scales are necessary*.

New efforts underway both in the UV and IR category.

Mini-analysis



Le Dall, MP, Ritz, 2015

Observable	(A,B) Portals	(C,D) UV-incomplete
LFV	✓	✓
LU	✓	✓
$(g-2)_l$	✓	✓
LNV	✓	✓
LEDMs		✓
HFV		✓
BNV		✓

At current level of experimental accuracy many lepton observables (g-2, LFV, LU) but EDM can be induced by IR physics (e.g. new massive sterile neutrinos below the weak scale).

Quark sector observables would typically require NP at UV scale (except neutron EDM)

Dark photon

(Holdom 1986; earlier paper by Okun')

$$\mathcal{L} = -\frac{1}{4}V_{\mu\nu}^2 - \frac{\kappa}{2}V_{\mu\nu}F^{\mu\nu} + |D_\mu\phi|^2 - V(\phi),$$

This Lagrangian describes an extra U(1)' group (**dark force, hidden photon, secluded gauge boson, shadow boson etc, also known as U-boson, V-boson, A-prime, gamma-prime etc**), attached to the SM via a vector portal (kinetic mixing). Mixing angle κ (also known as ε, η) controls the coupling to the SM. New gauge bosons can be light if the mixing angle is small.

In this talk κ = ε

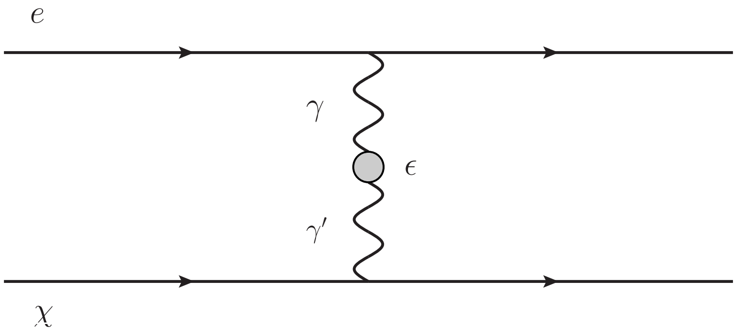
Low-energy content: **Additional massive photon-like vector V**, and possibly a new light Higgs h', both with small couplings.

Model for “mini-charged” particles

$$\mathcal{L} = \mathcal{L}_{\psi,A} + \mathcal{L}_{\chi,A'} - \frac{\epsilon}{2} F_{\mu\nu} F'_{\mu\nu} + \frac{1}{2} m^2_{A'} (A'_\mu)^2.$$

$$\mathcal{L}_{\psi,A} = -\frac{1}{4} F^2_{\mu\nu} + \bar{\psi}[\gamma_\mu(i\partial_\mu - eA_\mu) - m_\psi]\psi$$

$$\mathcal{L}_{\chi,A'} = -\frac{1}{4} (F'_{\mu\nu})^2 + \bar{\chi}[\gamma_\mu(i\partial_\mu - g'A'_\mu) - m_\chi]\chi,$$



- “Effective” charge of the “dark sector” particle χ is Q = e × ε (if momentum scale $q > m_V$). At $q < m_V$ one can say that particle χ has a non-vanishing *EM charge radius*, $r^2_\chi \simeq 6\epsilon m_V^{-2}$.
- Dark photon can “communicate” interaction between SM and dark matter. Very light χ can be possible.

“Non-decoupling” of secluded U(1) Theoretical expectations for masses and mixing

Suppose that the SM particles are not charged under new $U_S(1)$, and communicate with it only via extremely heavy particles of mass scale Λ (however heavy!, e.g. 100000 TeV) charged under the SM $U_Y(1)$ and $U_S(1)$ (B. Holdom, 1986)

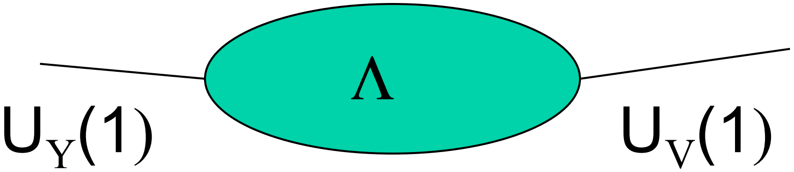


Diagram $U_Y(1)$ $U_V(1)$ does not decouple!

A mixing term is induced, $\kappa F^Y_{\mu\nu} F^S_{\mu\nu}$,

With κ having only the log dependence on mass scale Λ

$\kappa \sim (\alpha\alpha')^{1/2} (3\pi)^{-1} \log(\Lambda_{UV}/\Lambda) \sim 10^{-3}$

$M_V \sim e'\kappa M_{EW}$ (M_Z or TeV) ~ MeV – GeV

This is very “realistic” in terms of experimental sensitivity range of parameters.

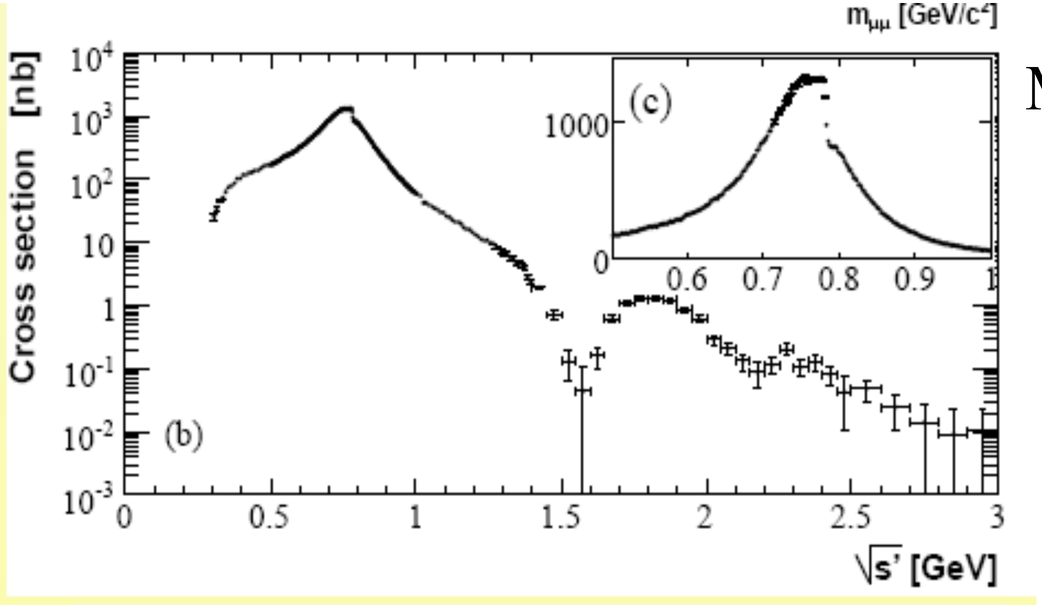
Variations of vector portal: gauged B - L, L_μ - L_τ, baryon number, etc.. symmetries

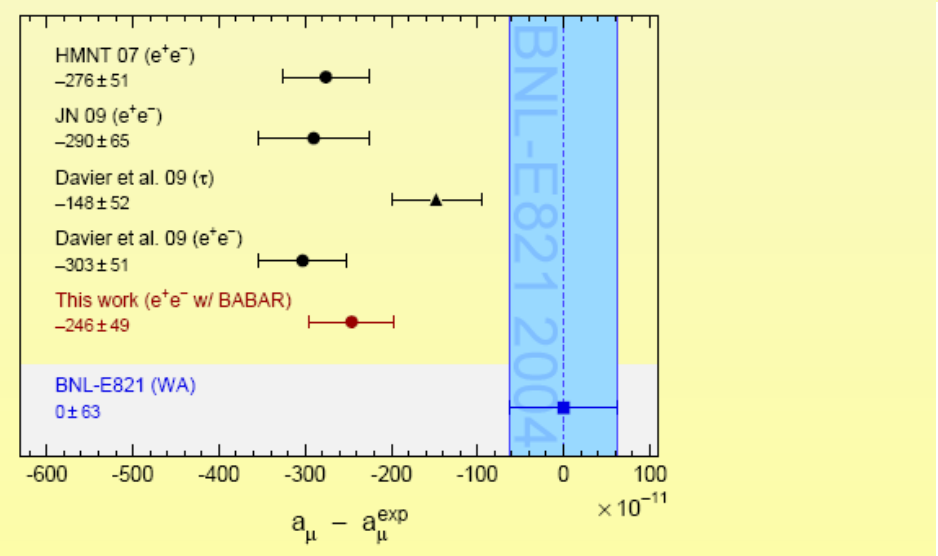
- *Anomaly-free, can be UV complete. (For B, anomaly can be cancelled)*
- A non-zero kinetic mixing will be developed out of RG evolution
- Neutrinos get extra interaction – already constrained!
- L_μ - L_τ is the *least constrained* possibility because neither electrons nor nucleons have extra interactions with neutrinos.

In recent years there has been some increase of experimental activity searching for light particles in MeV-GeV range because of the following speculative motivations.

1. Light New Physics helps to solve some particle physics anomalies (muon g-2,…).
2. 2. It helps to tie some astrophysical anomalies (511 keV excess from the bulge, positron excess above 10 GeV etc) with models of dark matter *without large fine tuning*.

g-2 of muon





✱ Davier et al. arXiv:0906-5443

More than 3 sigma discrepancy for most of the analyses. Possibly a sign of new physics, but some complicated strong interaction dynamics could still be at play.

Supersymmetric models with large-ish *tanβ*; light-ish sleptons, and right sign of μ parameter can account for the discrepancy.

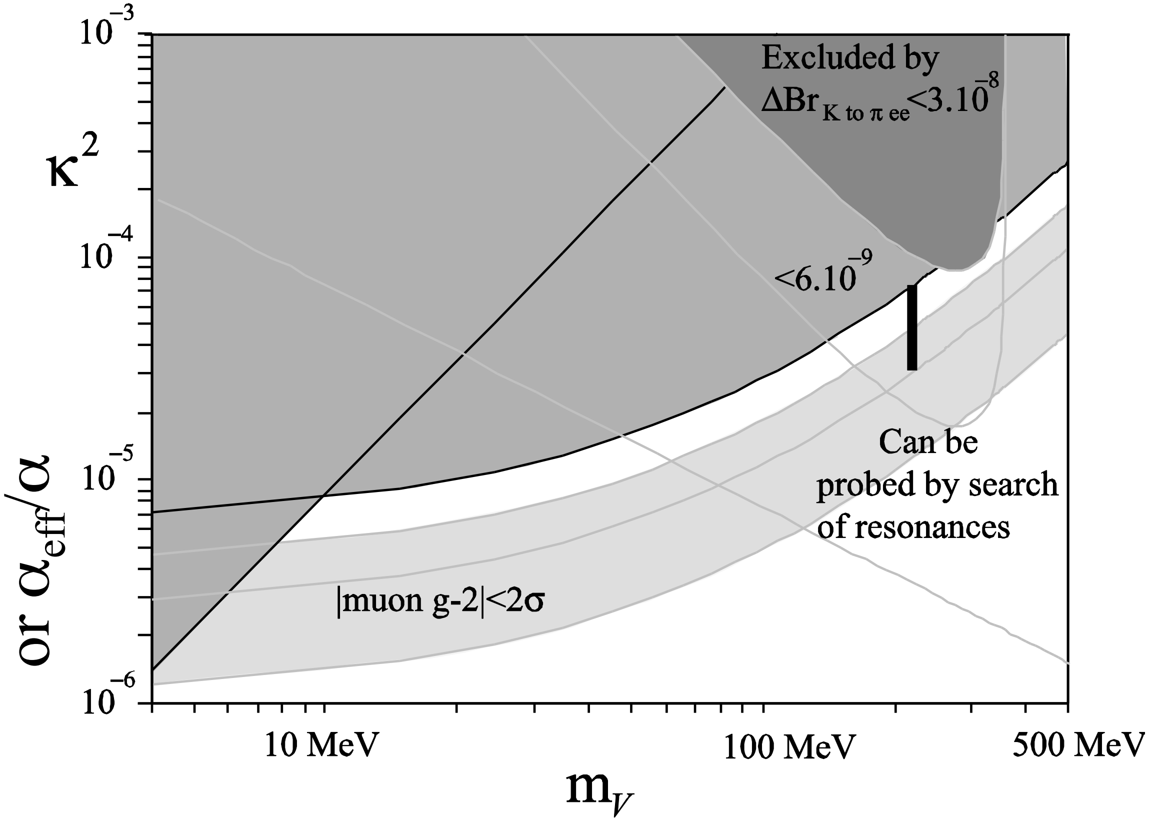
Sub-GeV scale vectors/scalars can also be at play.

g-2 signature of light particles

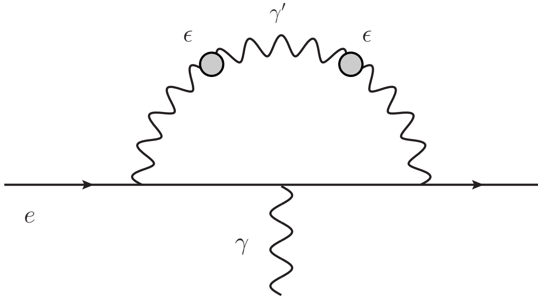
If g-2 discrepancy taken seriously, a new vector force can account for deficit. (Krasnikov, Gninenko; Fayet; Pospelov)

E.g. mixing of order few 0.001 and mass $m_V \sim m_\mu$

This axis is also called ε^2

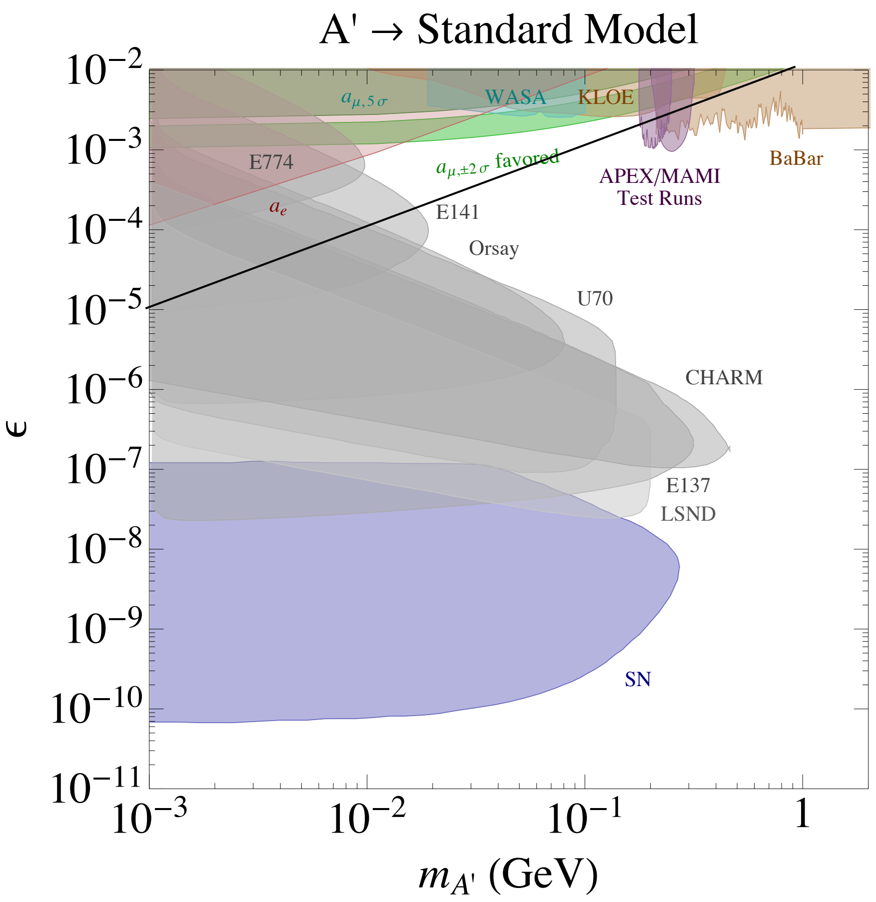


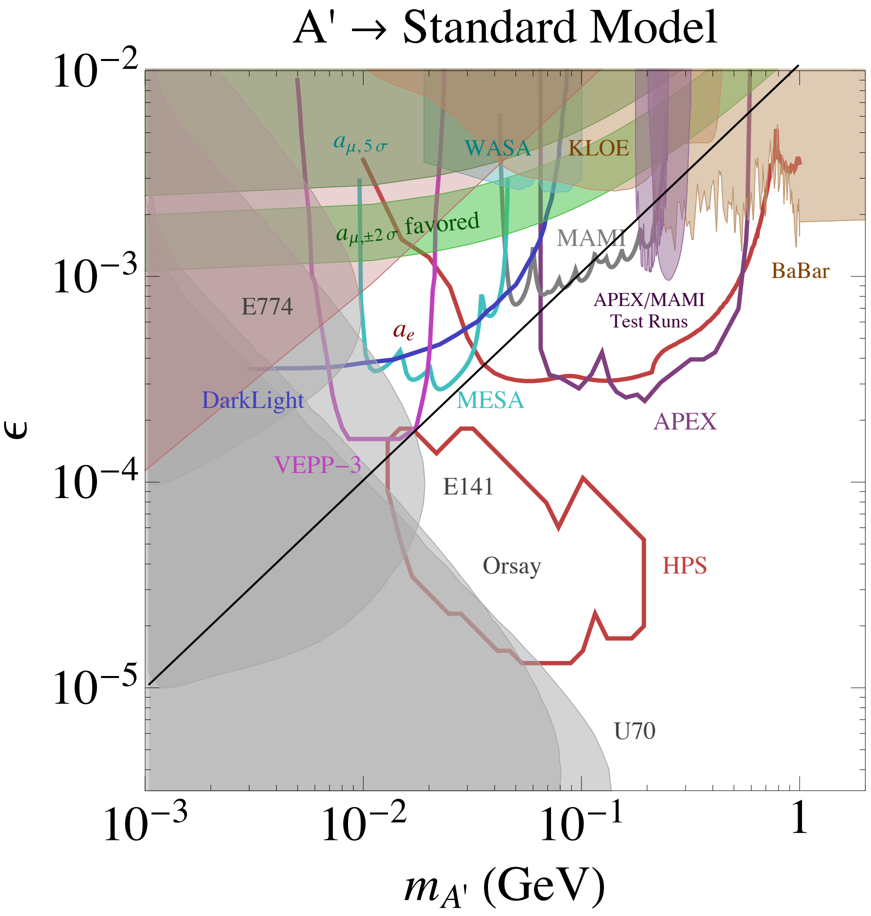
MP, 2008



Since 2008 a lot more of parameter space got constrained

ε-m_V parameter space, Snowmass study, 2013





Dark photon models with mass under 1 GeV, and mixing angles ~ 10^{-3} represent a "window of opportunity" for the high-intensity experiments, and soon the g - 2 ROI will be completely covered. *Gradually, all parameter space in the "SM corner" gets probed/excluded.*

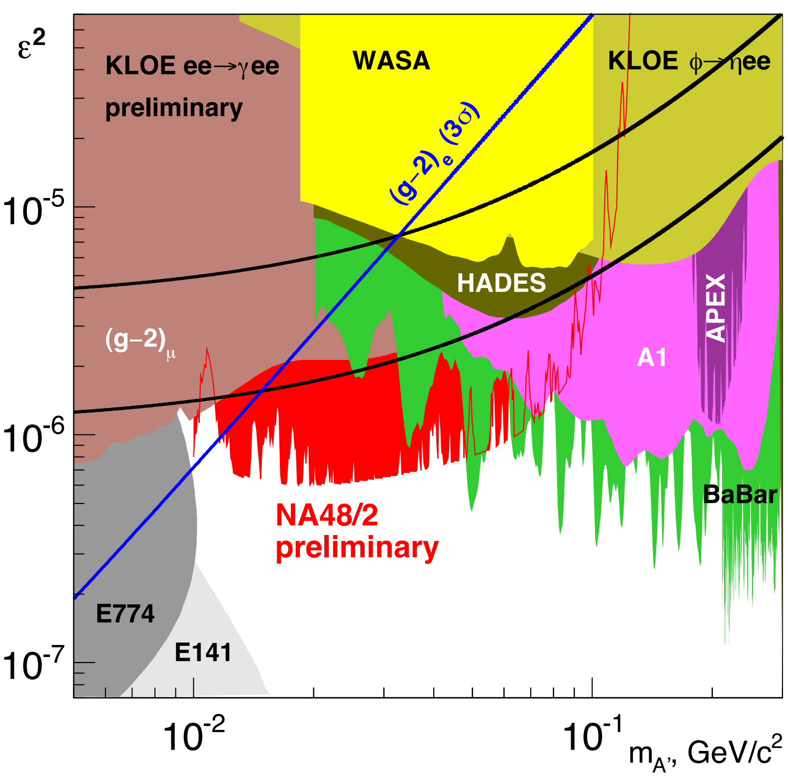
Latest results: A1, Babar, NA48

Signature: “bump” at invariant mass of e^+e^- pairs = $m_{A'}$

Babar: $e^+e^- \rightarrow \gamma V \rightarrow \gamma l^+l^-$

A1(+ APEX): $Z e^- \rightarrow Z e^- V \rightarrow Z e^- e^+e^-$

NA48: $\pi^0 \rightarrow \gamma V \rightarrow \gamma e^+e^-$
Latest results by NA48 exclude the remainder of parameter space relevant for g-2 discrepancy.



Only *less minimal* options for muon g-2 explanation remain:
A. $L_\mu - L_\tau$, B. Dark photons *decaying* to dark state (light dark matter), C. dark scalar (W. Marciano talk)

Signatures of Z’ of L_μ - L_τ

Experimental results on “trident”

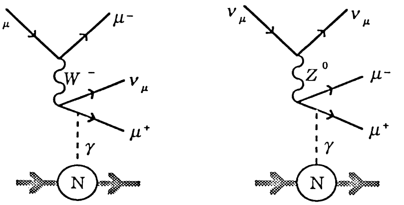
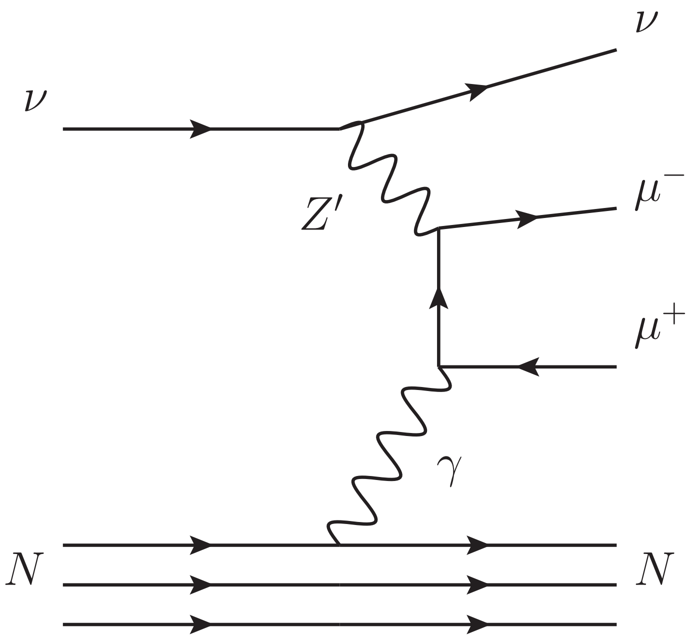
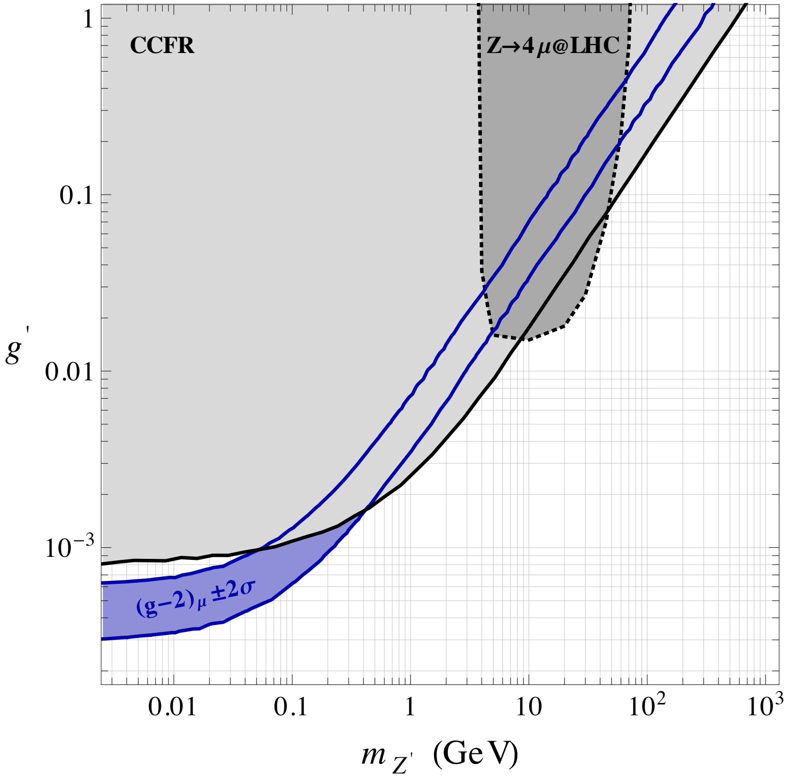


FIG. 1. Feynman diagram showing the neutrino trident production in ν_μ-A scattering via the W and the Z channels.

$$\sigma_{\mathrm{CHARM-II}}/\sigma_{\mathrm{SM}} = 1.58 \pm 0.57\ ,$$
$$\sigma_{\mathrm{CCFR}}/\sigma_{\mathrm{SM}} = 0.82 \pm 0.28\ ,$$
$$\sigma_{\mathrm{NuTeV}}/\sigma_{\mathrm{SM}} = 0.67 \pm 0.27\ .$$

Hypothetical Z’ (any Z’ coupled to L_μ) contributes constructively to cross section. (Almannshofer et al., 2014)





Higgs Portal Models – attaching a singlet S

Quadratic and linear coupling to Higgs is allowed

$$\mathcal{L}_{\text{int}} = (H^\dagger H)(\lambda S^2 + AS) = hv(\lambda S^2 + AS) + \cdots$$

(Linear terms are forbidden if S is charged under dark group)

Integrating out heavy SM Higgs particle, we have

$$\mathcal{L}_{\text{int}} = \mathcal{O}_{\text{SM}}^{(h)} \frac{\lambda S^2 + AS}{m_h^2},$$

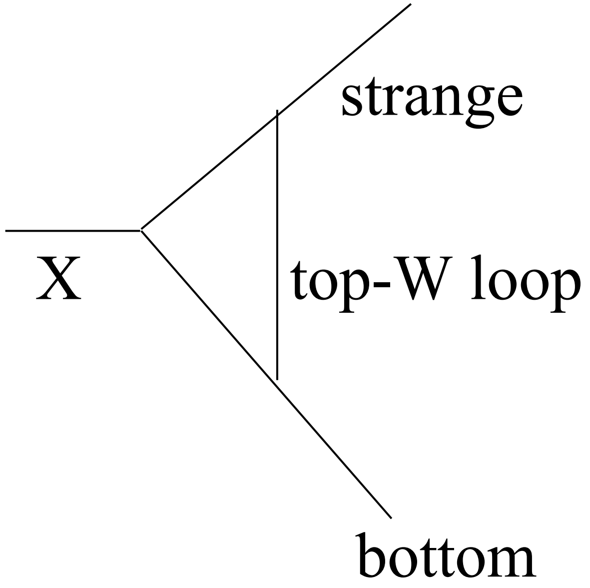
where $\mathcal{O}_{\text{SM}}^{(h)} = \sum_f m_f \bar{f} f + \ldots$

Mass parameter A creates mixing between SM Higgs and S scalar, and the size of the mixing angle $\kappa' \equiv Av/m_h^2$: be as large 0.001-0.01 without creating technical naturalness problem.

One can have a "close relative" of the Higgs, with smaller mass (e.g. GeV) and coupling.

Scalar currents are very different from conserved vector currents

Conserved vector currents are uniquely positioned to avoid very strong flavor constraints. Axial vector portals, Higgs portals are potentially liable to very strong flavor constraints. Consider generic FCNC penguin-type loop correction.



For a conserved vector current, $G_F\, q^2$

For scalar current, $G_F\, m_t^2$

There is extremely strong sensitivity to new scalars, pseudoscalars axial-vectors in rare K and B decays.

Leptonic 2HDM + singlet scalar

Consider 2HDM where one of the Higgses (Φ_1) will mostly couple to leptons, and also mixes with a singlet that is "light" relative to EW scale.

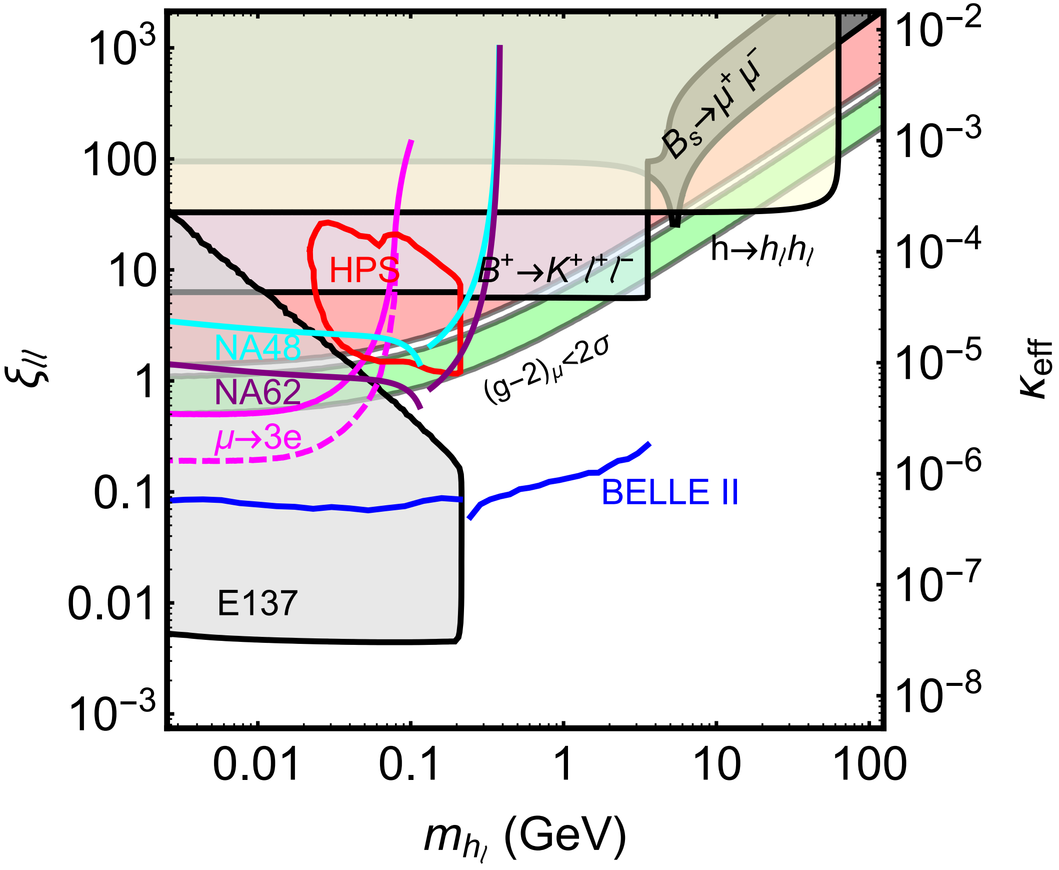
$$
\begin{aligned}
V &= V_{\rm 2HDM} + V_S + V_{\rm portal} \\
V_{\rm 2HDM} &= m_{11}^2 \Phi_1^\dagger \Phi_1 + m_{22}^2 \Phi_2^\dagger \Phi_2 - m_{12}^2 \left(\Phi_1^\dagger \Phi_2 + \Phi_2^\dagger \Phi_1 \right) + \frac{\lambda_1}{2} \left(\Phi_1^\dagger \Phi_1 \right)^2 + \frac{\lambda_2}{2} \left(\Phi_2^\dagger \Phi_2 \right)^2 \\
&\quad + \lambda_3 \left(\Phi_1^\dagger \Phi_1 \right) \left(\Phi_2^\dagger \Phi_2 \right) + \lambda_4 \left(\Phi_1^\dagger \Phi_2 \right) \left(\Phi_2^\dagger \Phi_1 \right) + \frac{\lambda_5}{2} \left[\left(\Phi_1^\dagger \Phi_2 \right)^2 + \left(\Phi_2^\dagger \Phi_2 \right)^2 \right] \\
V_S &= BS + \frac{1}{2} m_0^2 S^2 + \frac{A_S}{2} S^3 + \frac{\lambda_S}{4} S^4 \\
V_{\rm portal} &= S \left[A_{11} \Phi_1^\dagger \Phi_1 + A_{22} \Phi_2^\dagger \Phi_2 + A_{12} \left(\Phi_1^\dagger \Phi_2 + \Phi_2^\dagger \Phi_1 \right) \right]
\end{aligned}
$$

Calling the the lightest scalar particle "h_l", one takes a large tan beta regime, and considers an effective Yukawa interaction,

$$
\begin{aligned}
\mathcal{L}_{\rm Yuk} &= \frac{m_\ell}{v c_\beta} \rho_1 \bar{\ell} \ell + \frac{m_q}{v s_\beta} \rho_2 \bar{q} q \\
&\equiv \frac{m_\ell}{v} \left(\xi_{h\ell\ell} h + \xi_{H\ell\ell} H + \xi_{\ell\ell} h_\ell \right) \bar{\ell} \ell + \frac{m_q}{v} \left(\xi_{hqq} h + \xi_{Hqq} H + \xi_{qq} h_\ell \right) \bar{q} q
\end{aligned}
$$

where it is important that 1. h_l is light, 2. couples mostly to leptons, proportionally to their masses. This leads to an effective "reweighting" of the traditional e-mV parameter space for all effect involving muons.

Constraints on the parameter space



“Effective” mixing angle for electrons

$$\kappa_{\rm eff} \equiv m_e \xi_{\ell\ell}/ev$$

Batell, Lange, McKeen, Pospelov, Ritz, *to appear [eventually]*.

Muon, Kaon decays will bring progress; B-factory signal from the associated ττ + Scalar → ττμμ production will resolutely test the model below ~ 6 GeV.

More discrepancies discovered using muons !

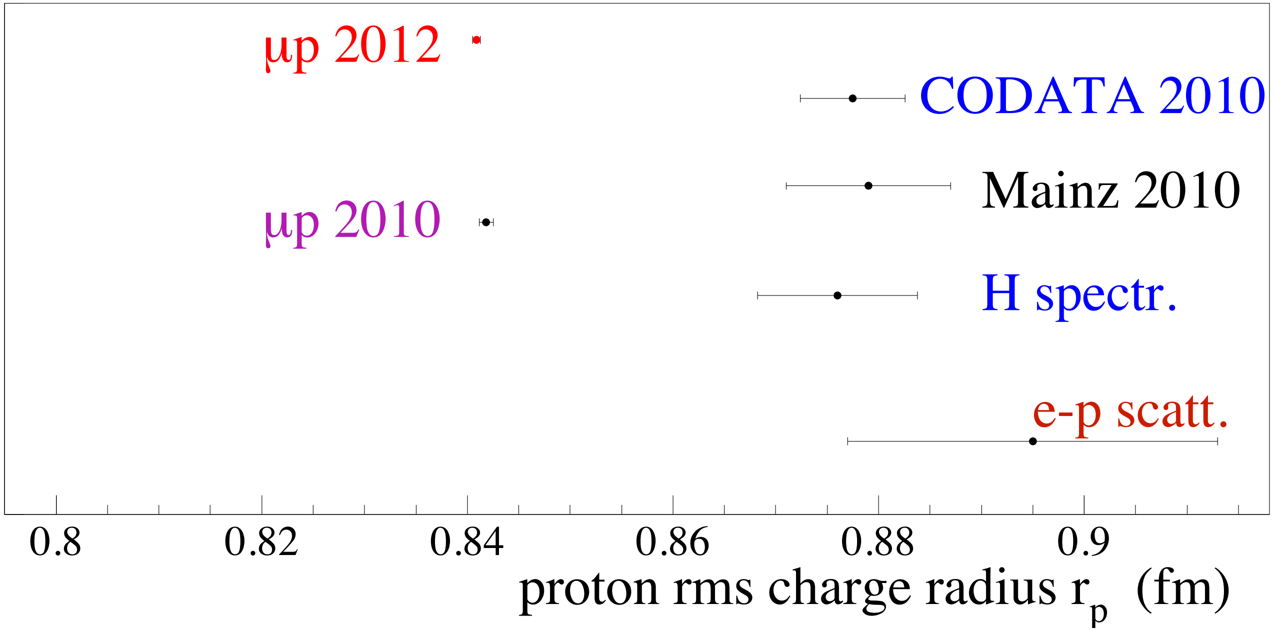
$\nu(2S_{1/2}^{F=1} \rightarrow 2P_{3/2}^{F=2})$ = 49881.88(76) GHz R. Pohl *et al.*, Nature 466, 213 (2010)

49881.35(64) GHz preliminary

$\nu(2S_{1/2}^{F=0} \rightarrow 2P_{3/2}^{F=1})$ = 54611.16(1.04) GHz preliminary

Proton charge radius: r_p = 0.84089 $(26)_\mathrm{exp}$ $(29)_\mathrm{th}$ = 0.84089 (39) fm (prel.)

μp theory: A. Antogini *et al.*, arXiv :1208.2637 (atom-ph)



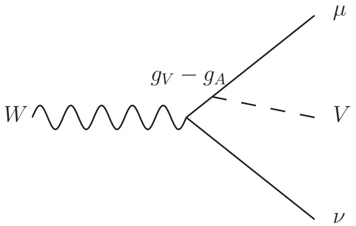
If new physics is responsible for that, it cannot be weak scale, only very light, as r_p will require ~ 10^4 G_F effects…

Muon-specific vector forces

$$\mathcal{L}_{\rm int} = -V_\nu\left[\kappa J_\nu^{\rm em} - \bar\psi_\mu(g_V\gamma_\nu + g_A\gamma_\nu\gamma_5)\psi_\mu\right]$$

$$= -V_\nu\left[e\kappa\bar\psi_p\gamma_\nu\psi_p - e\kappa\bar\psi_e\gamma_\nu\psi_e\right.$$

$$\left.-\bar\psi_\mu((e\kappa + g_V)\gamma_\nu + g_A\gamma_\nu\gamma_5)\psi_\mu + \ldots\right],$$



The problem with this is that it is not SM gauge invariant – sensitivity at high energy (C. Carlson talk) ~ $(\Lambda_{UV}/m_V)^2$. Decay of W is one issue, but there will be lots of trouble with EWP observables, off-shell W-exchange etc. (~ O(1 GeV) mass shifts)

Putting it in the SM representation is the only model solution.

$$\mathcal{L} = -\frac{1}{4}V_{\alpha\beta}^2 + |D_\alpha\phi|^2 + \bar\mu_R i\not{D}\mu_R - \frac{\kappa}{2}V_{\alpha\beta}F^{\alpha\beta} - \mathcal{L}_m$$

Implication: a new parity NC-like parity-violating force for muons, that is *stronger than weak.*

Other possibilities??

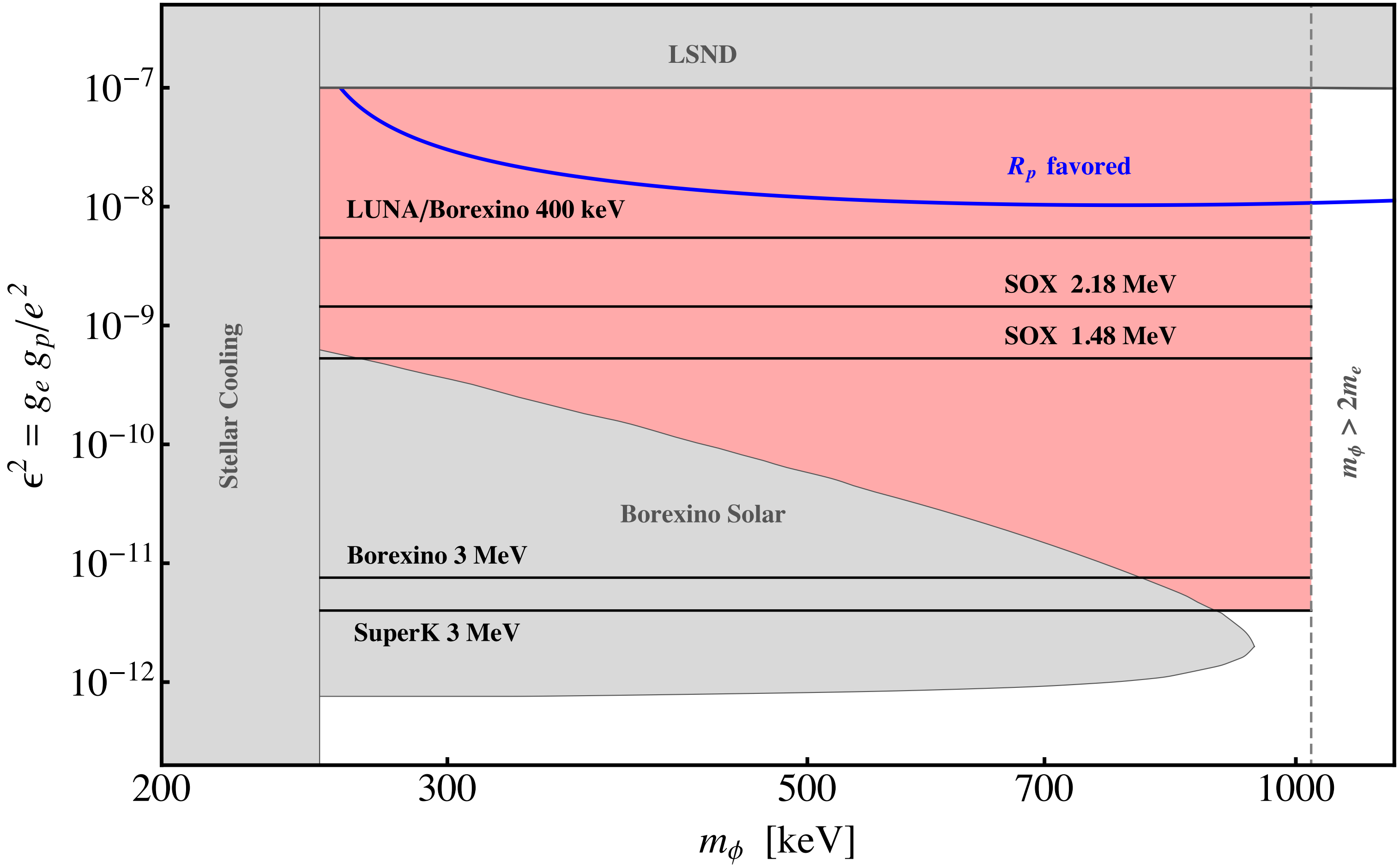
- How about the scalar force – call it *S* – that provides e-p repulsion and fixes r_p discrepancies at least between normal H and μH (Tucker-Smith, Yavin proposal)?

$$\mathcal{L}_\phi = \frac{1}{2}(\partial_\mu\phi)^2 - \frac{1}{2}m_\phi^2\phi^2 + (g_p\bar{p}p + g_e\bar{e}e + g_\mu\bar{\mu}\mu)\phi$$

- Couplings will be very small, and the mass will be small, O(200 keV- 1MeV), $y_e y_p / e^2 \sim - 10^{-8}$.
- This turns out to be somewhat of a blind spot in terms of astro and cosmo constraints. *Issues with UV completion, n scattering*
- Izaguirre, Krnjaic, MP: use small *underground accelerators* coupled with large scale detectors such as *Borexino, Super-K* etc… Up to ~ 20 MeV kinematic reach is available due to nuclear binding. Use $^{19}F + p \rightarrow {}^{16}O(*) + {}^4He$ reaction

Sensitivity to scalar mediator

- ^{16}O de-excitation of 6.05 MeV as a source of scalars
- *r_p relevant region can be fully covered.*



Light WIMPs due to light mediators

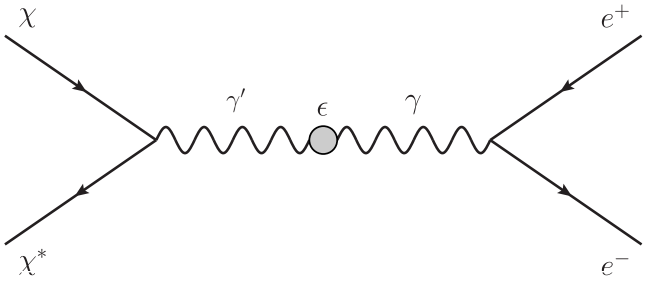
(Boehm, Fayet; MP, Riz, Voloshin …) Light dark matter is not ruled out if one adds a light mediator.

WIMP paradigm: $\sigma_{\rm annih}(v/c) \sim 1 \text{ pbn} \implies \Omega_{\rm DM} \simeq 0.25,$

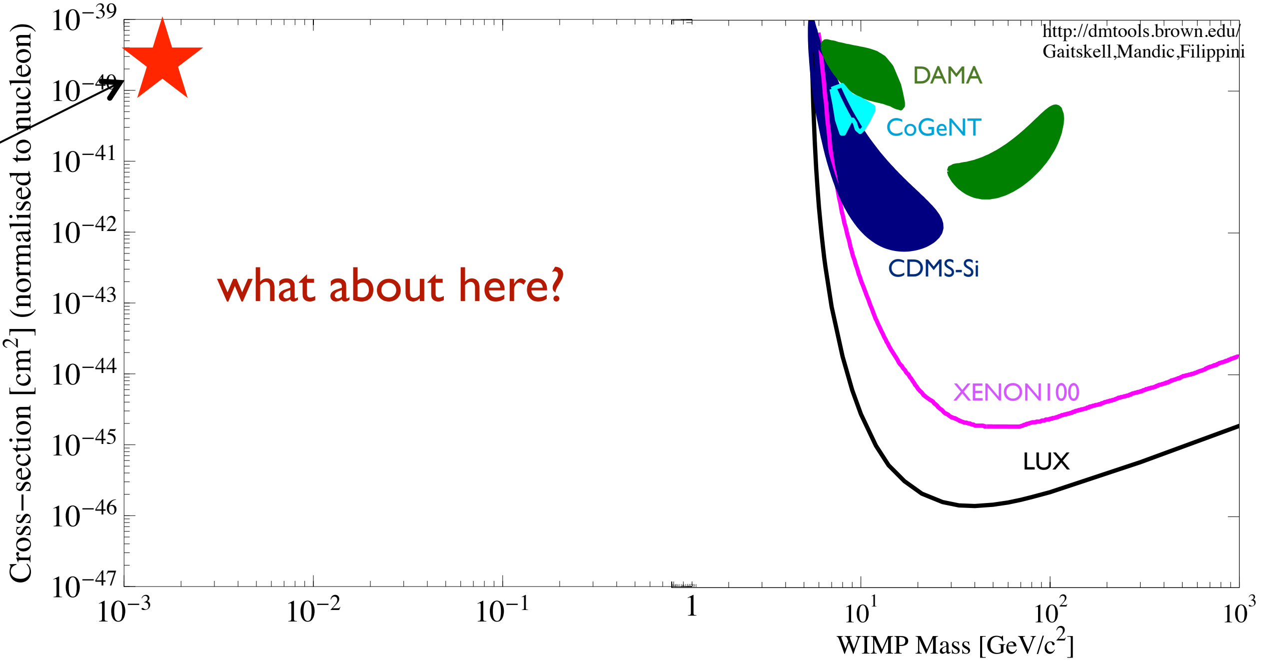
Electroweak mediators lead to the so-called Lee-Weinberg window,

$$\sigma(v/c) \propto \begin{cases} G_F^2 m_\chi^2 & \text{for} \quad m_\chi \ll m_W, \\ 1/m_\chi^2 & \text{for} \quad m_\chi \gg m_W. \end{cases} \implies \text{few GeV} < m_\chi < \text{few TeV}$$

If instead the annihilation occurs via a force carrier with light mass, DM can be as light as ~ MeV (and not ruled out by the CMB if it is a scalar).



Light DM – direct production/detection



511 keV motivated

If WIMP dark matter is coupled to light mediators, the WIMP mass scale can be much lighter than nominal Lee-Weinberg bound,

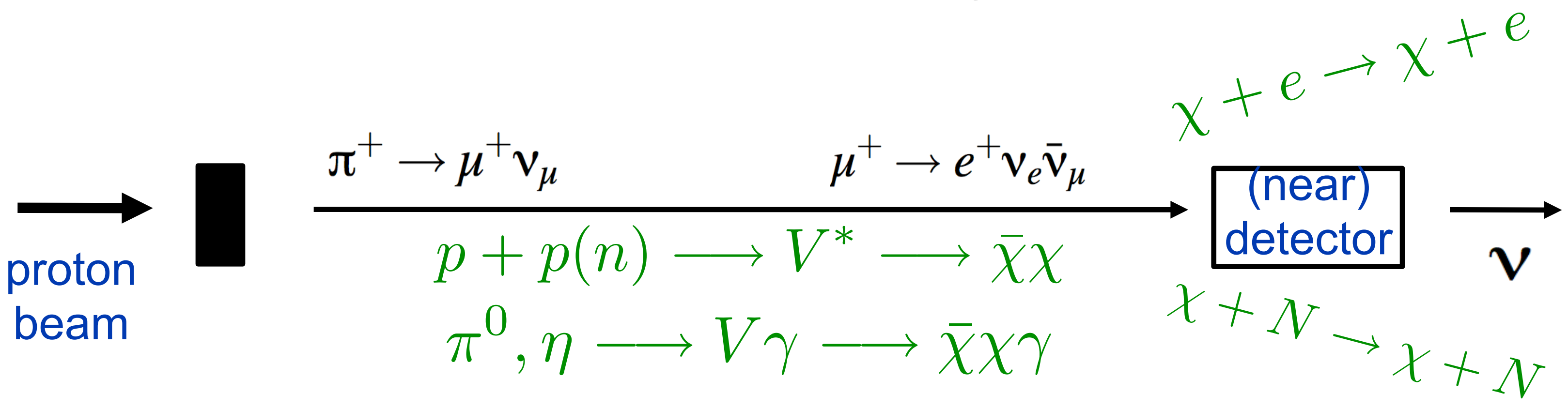
$$\mathcal{L} \supset |D_\mu \chi|^2 - m_\chi^2 |\chi|^2 - \frac{1}{4}(V_{\mu\nu})^2 + +\frac{1}{2} m_V^2 (V_\mu)^2 - \frac{\kappa}{2} V_{\mu\nu} F^{\mu\nu} + \ldots$$

↑
DM

↑
mediation

Fixed target probes - Neutrino Beams

Proposed in Batell, MP, Ritz, 2009. Strongest constraints on MeV DM



$\pi^+ \to \mu^+\nu_\mu$

$\mu^+ \to e^+\nu_e\bar{\nu}_\mu$

$p + p(n) \longrightarrow V^* \longrightarrow \bar{\chi}\chi$

$\pi^0, \eta \longrightarrow V\gamma \longrightarrow \bar{\chi}\chi\gamma$

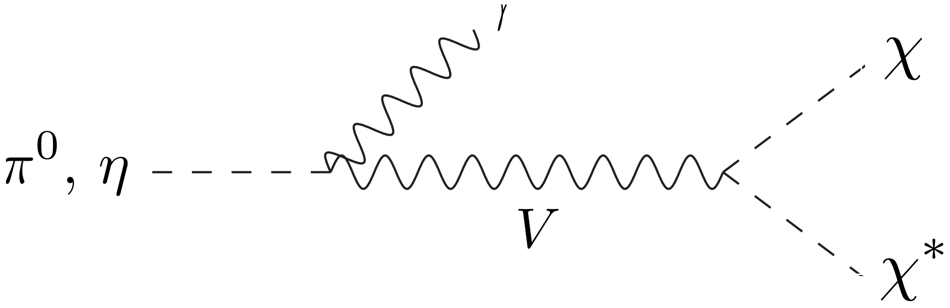
$\chi + e \to \chi + e$

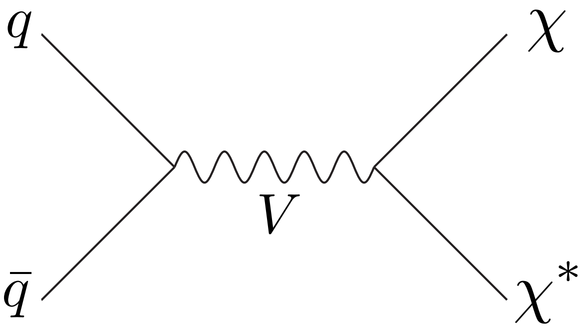
$\chi + N \to \chi + N$

We can use the neutrino (near) detector as a dark matter detector, looking for recoil, but now from a relativistic beam. E.g.

T2K	**MINOS**	**MiniBooNE**
30 GeV protons	120 GeV protons	8.9 GeV protons
(➠ ~5x10^{21} POT)	10^{21} POT	10^{21} POT
280m to on- and off-axis detectors	1km to (~27ton) segmented detector	540m to (~650ton) mineral oil detector

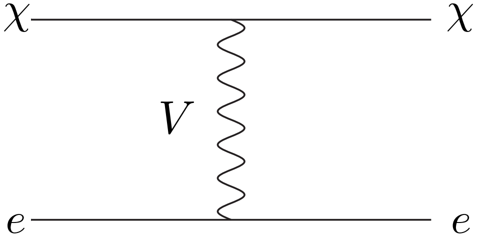
Light DM - trying to force the issue



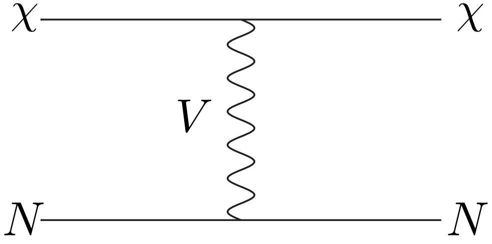


In the detector:

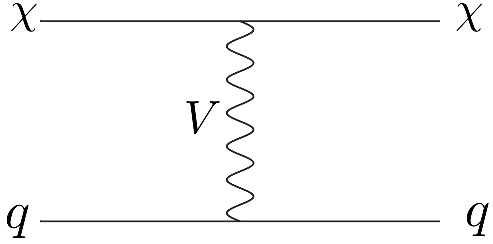
Elastic scattering on electrons



Elastic scattering on nucleons

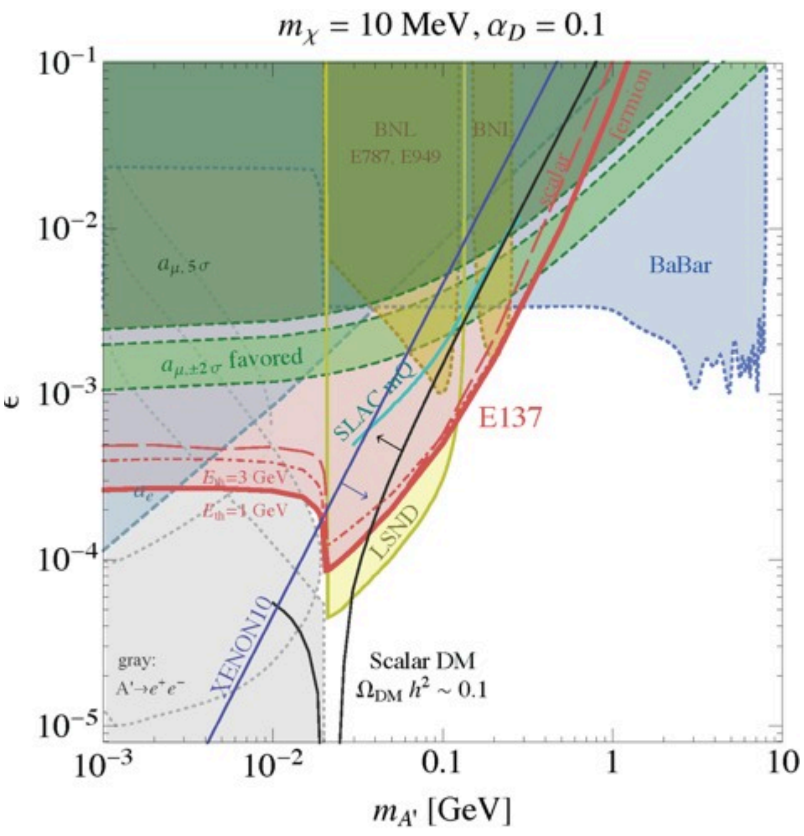


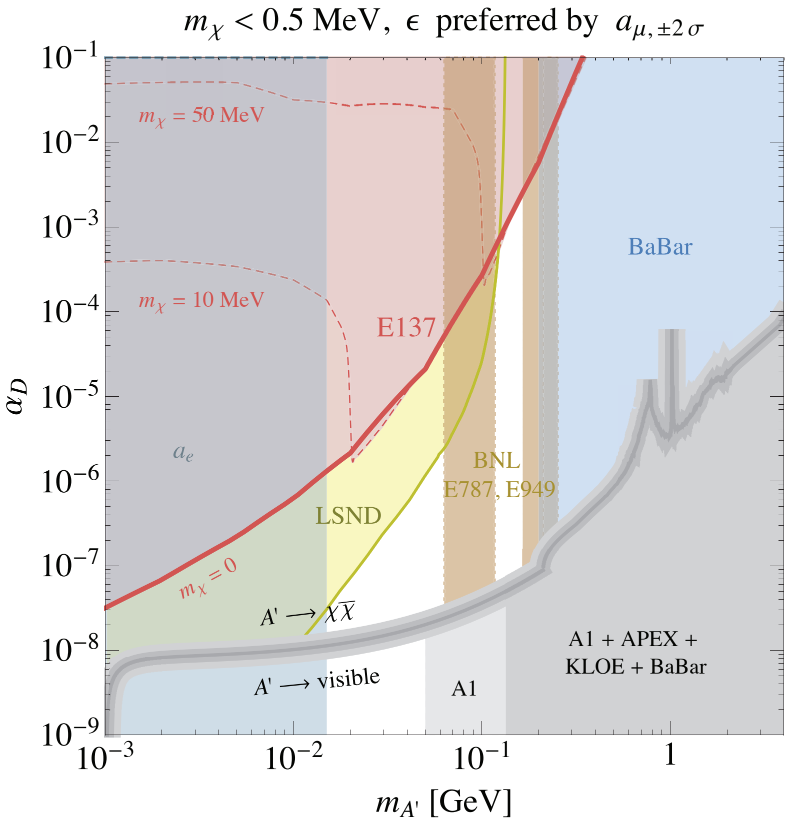
Deep inelastic scattering



Same force that is responsible for depletion of χ to acceptable levels in the early Universe will be responsible for it production at the collision point and subsequent scattering in the detector.

Compilation of current constraints on dark photons decaying to light DM





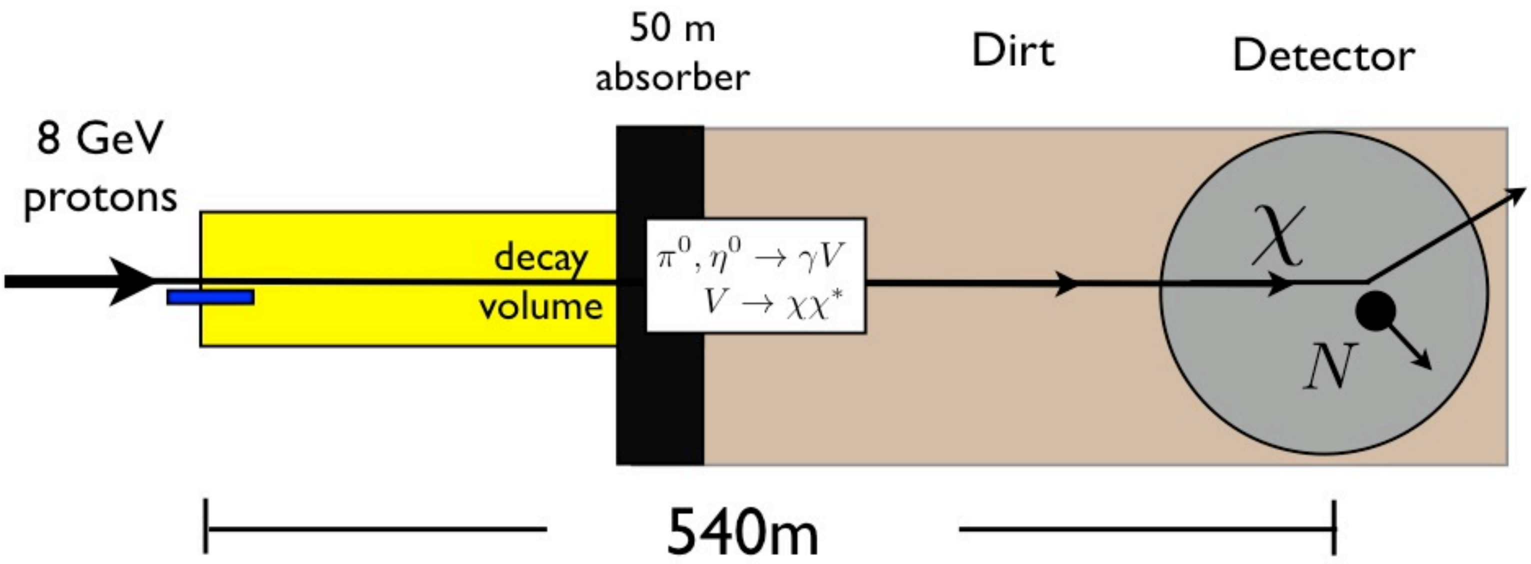
The sensitivity of electron beam dump experiments to light DM is investigated in Izaguirre et al, 2013; Batell, Essig, Surujon, 2014.

On-going and future projects

Fixed Target/beam dump experiments sensitive to

- Dark Photons: HPS, DarkLight, APEX, Mainz, SHiP…
- Light dark matter production + scattering: MiniBoNE, BDX, SHiP…
- Right-handed neutrinos: SHiP
- Missing energy via DM production: NA62 ($K\rightarrow\pi\nu\nu$ mode), positron beam dumps…
- Extra Z’ in neutrino scattering: DUNE near detector (?)

MiniBooNE search for light DM

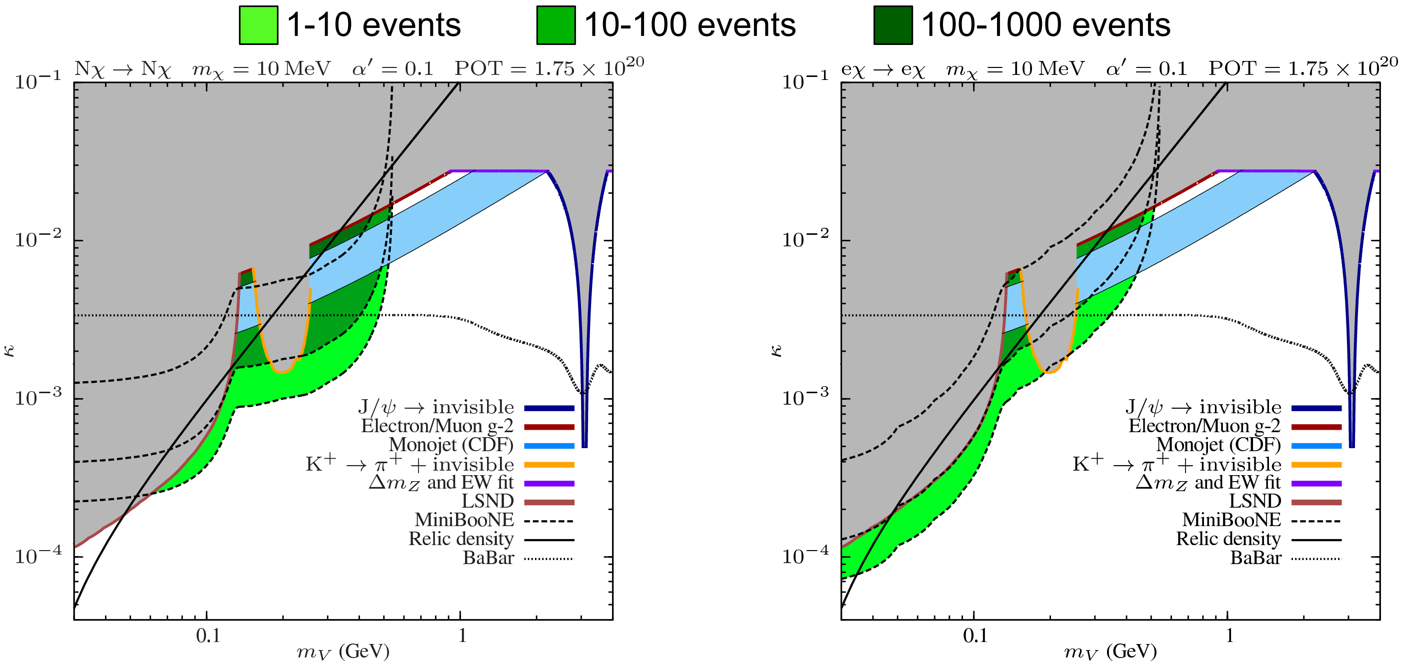


MiniBoone has completed a long run in the beam dump mode, as suggested in [arXiv:1211.2258]

By-passing Be target is crucial for reducing the neutrino background (Richard van de Water et al. …) . Currently, suppression of ν flux ~50.

Timing is used (10 MeV dark matter propagates slower than neutrinos) to further reduce backgrounds. First results – this year (2015)

MiBooNE search for DM

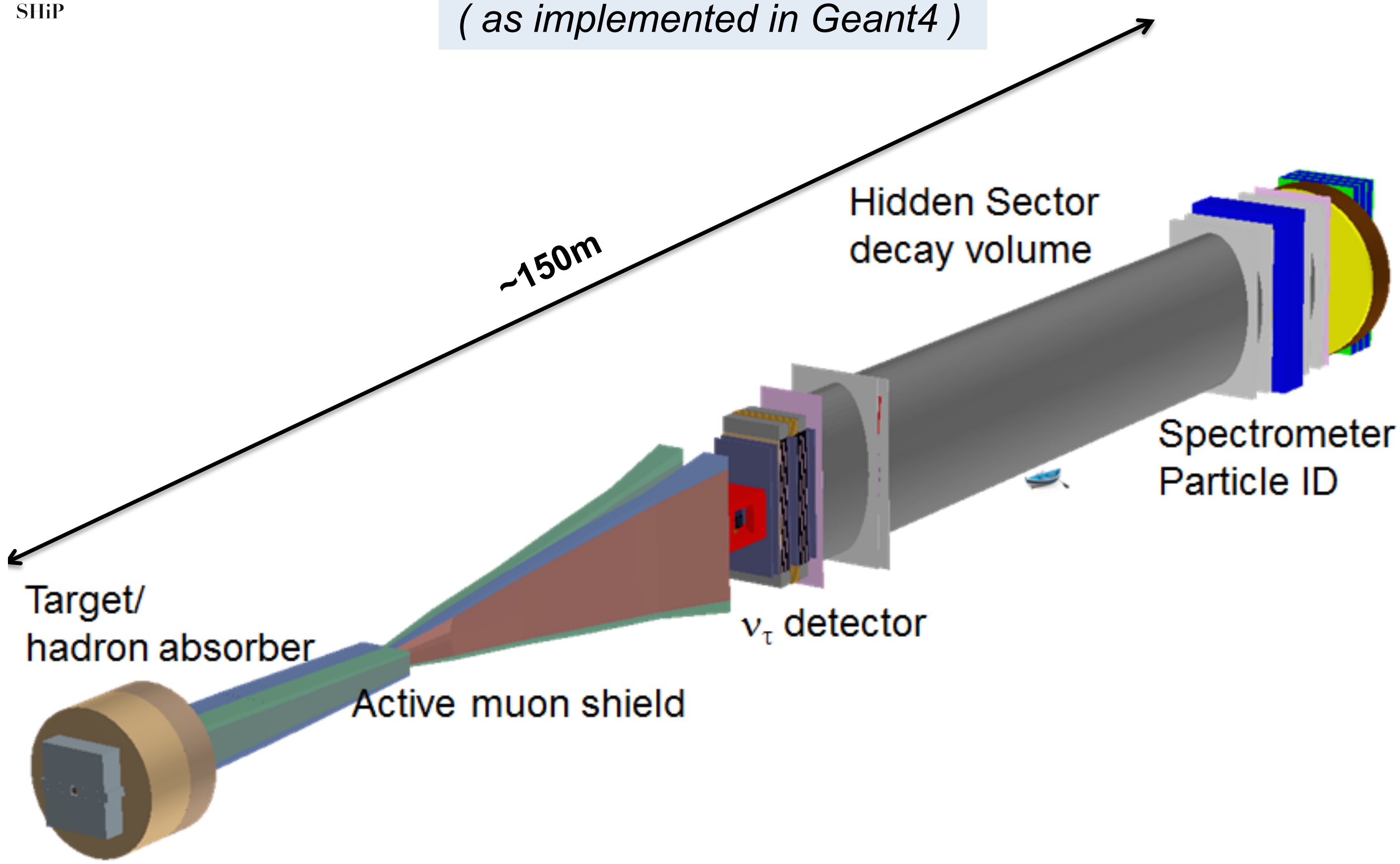


R. Cooper presentation, Camogli workshop on light dark matter, 2015

- MiniBooNE has collected 1.86×10^{20} POT in beam-off-target configuration to search for sub-GeV dark matter
- Beam-off-target suppresses neutrino backgrounds
  → beam uncorrelated backgrounds dominant

Future big project: SHiP project at CERN

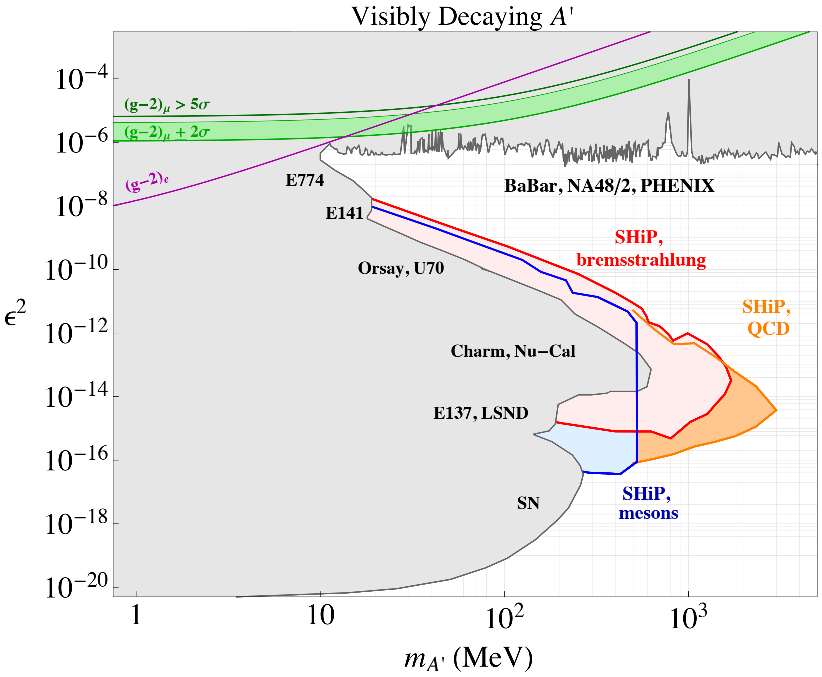
The SHiP experiment
(as implemented in Geant4)

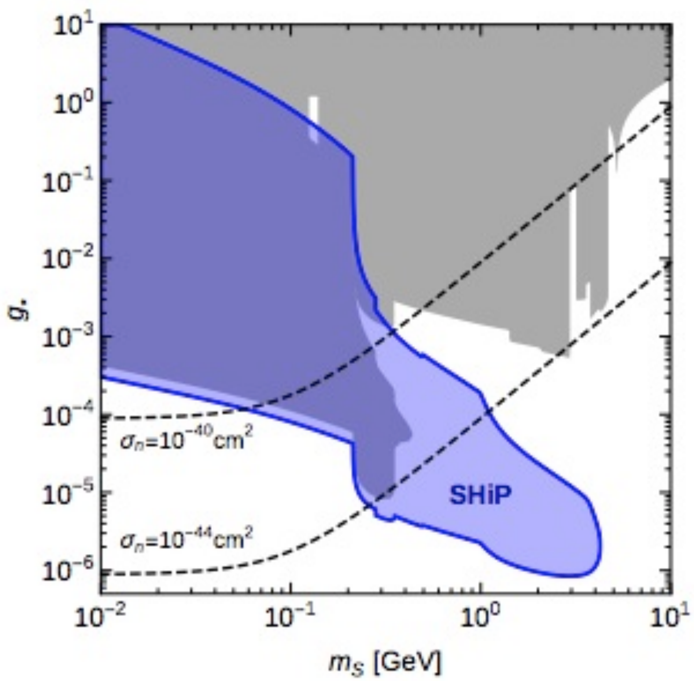


See e.g. A. Golutvin presentation, CERN SHiP symposium, 2015

SHiP sensitivity to vector and scalar portals

- SHiP will collect 2×10^{20} protons of 400 GeV dumped on target
- Sensitivity to dark vectors is via the unflavored meson decays, and through direct production, pp → … V → …… l^+l^-
- Sensitivity to light scalar mixed with Higgs is via B-meson decays, b → s + Scalar → … $\mu^+\mu^-$



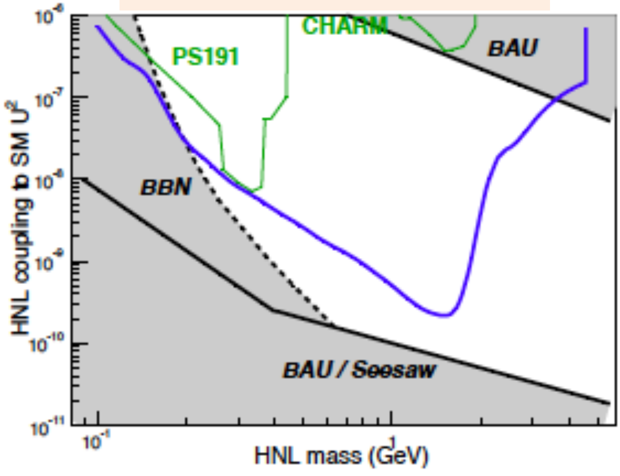


Details can be found in the white paper, 1505.01865, Alekhin et al.

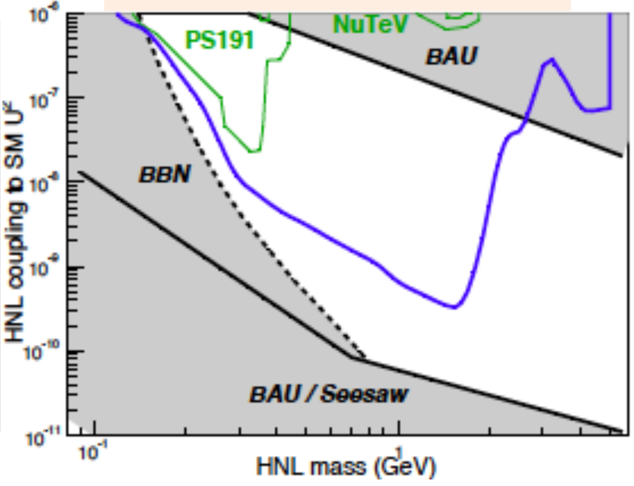
SHiP has unique sensitivity to RH neutrinos

- Production channel is through charm pp → c cbar → N_R. (N_R are often called Heavy Neutral Leptons, or HNL)
- Detection is through their occasional decay via small mixing angle U, with charged states in the final state, e.g. $\pi^+\mu^-$, $\pi^-\mu^+$, etc.
- Decays are slow, so that the sensitivity is proportional to (Mixing angle)^4.

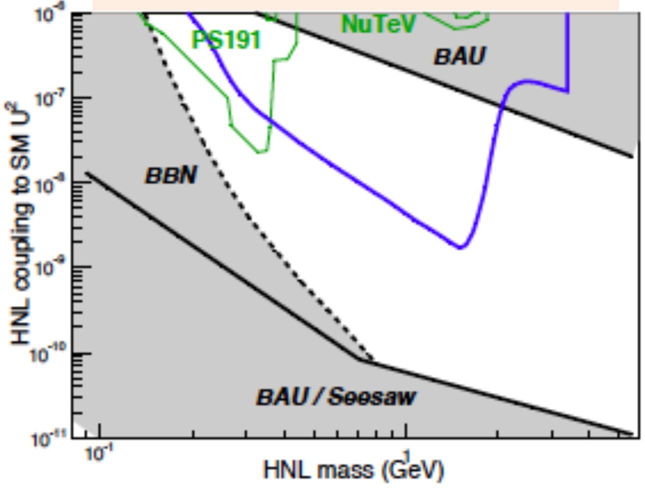
U^2_e: U^2_μ: U^2_τ~52:1:1
Inverted hierarchy



U^2_e: U^2_μ: U^2_τ~1:16:3.8
Normal hierarchy



U^2_e: U^2_μ: U^2_τ~0.061:1:4.3
Normal hierarchy



HNL production can be enhanced in non-minimal models, Batell et al.

Additional physics at SHiP

- Over 10^3 tau neutrino events in the tau neutrino detector

- New measurements of intrinsic strangeness

- Possibly, new constraints on non-standard neutrino properties (magnetic moment); sensitivity to trident production (may be).

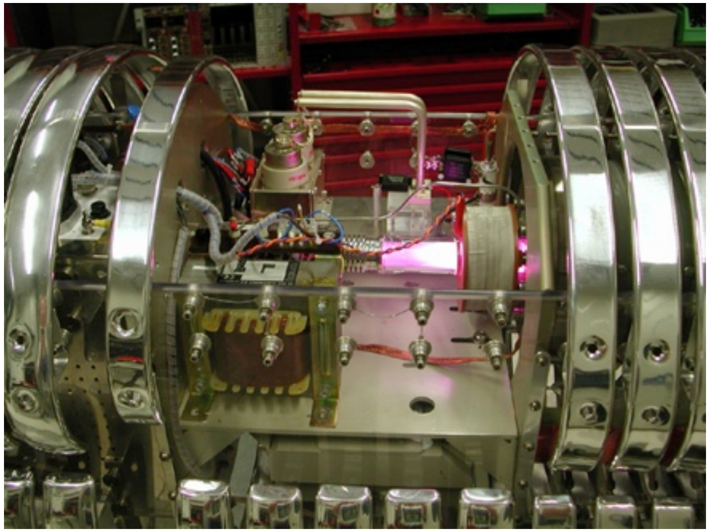
- The sensitivity of SHiP tau neutrino detector to scattering of light dark matter through *light mediators* can be improved, around $m_{mediator} \sim 300$ MeV - 1 GeV.

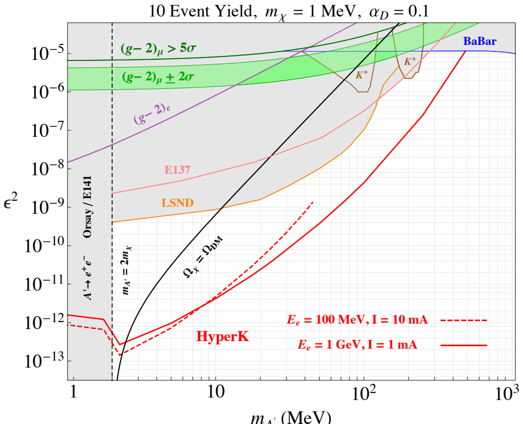
Details can be found in the white paper, 1505.01865, Alekhin et al.

See also a proposal for less powerful but quicker and cheaper version at Fermilab, Gardner et al, 1509.0050, in experiment SeaQuest.

More coverage of dark sector using underground accelerators and neutrino detectors

with Eder Izaguirre and Gordan Krnjaic, 2015



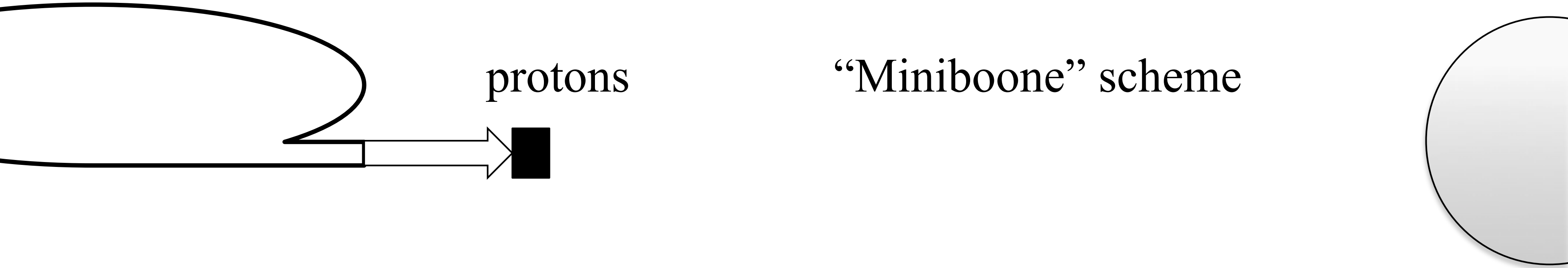


Borexino, Kamland, SNO+, SuperK, JUNO, Hyper-K (?) …

LUNA, DIANA,…,
1 e-linac for calibration

Three schemes to search for light DM

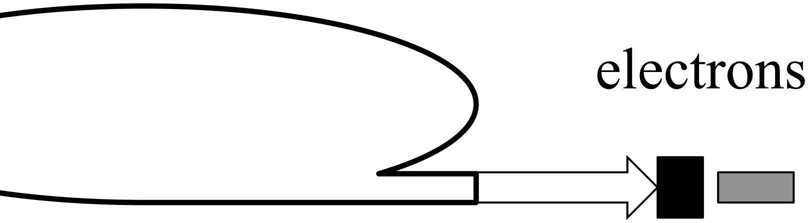
1. Proton beam dump, large neutrino detector, near surface, 0.5 km



protons

“Miniboone” scheme

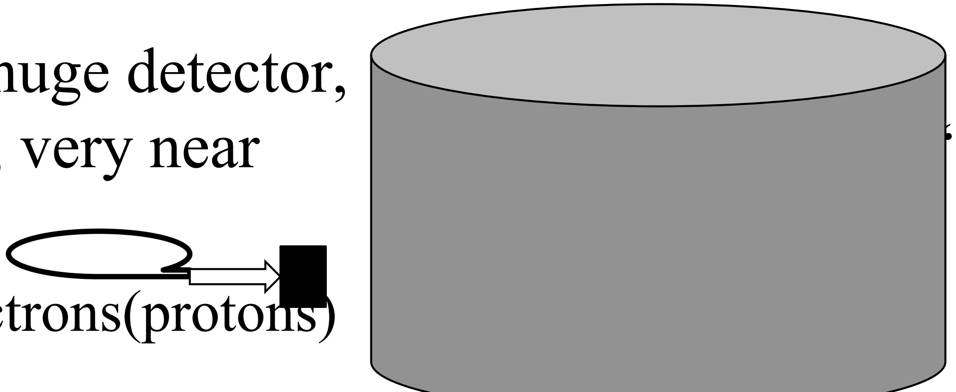
2. Electron beam dump, small-ish detector, very near beam dump



electrons

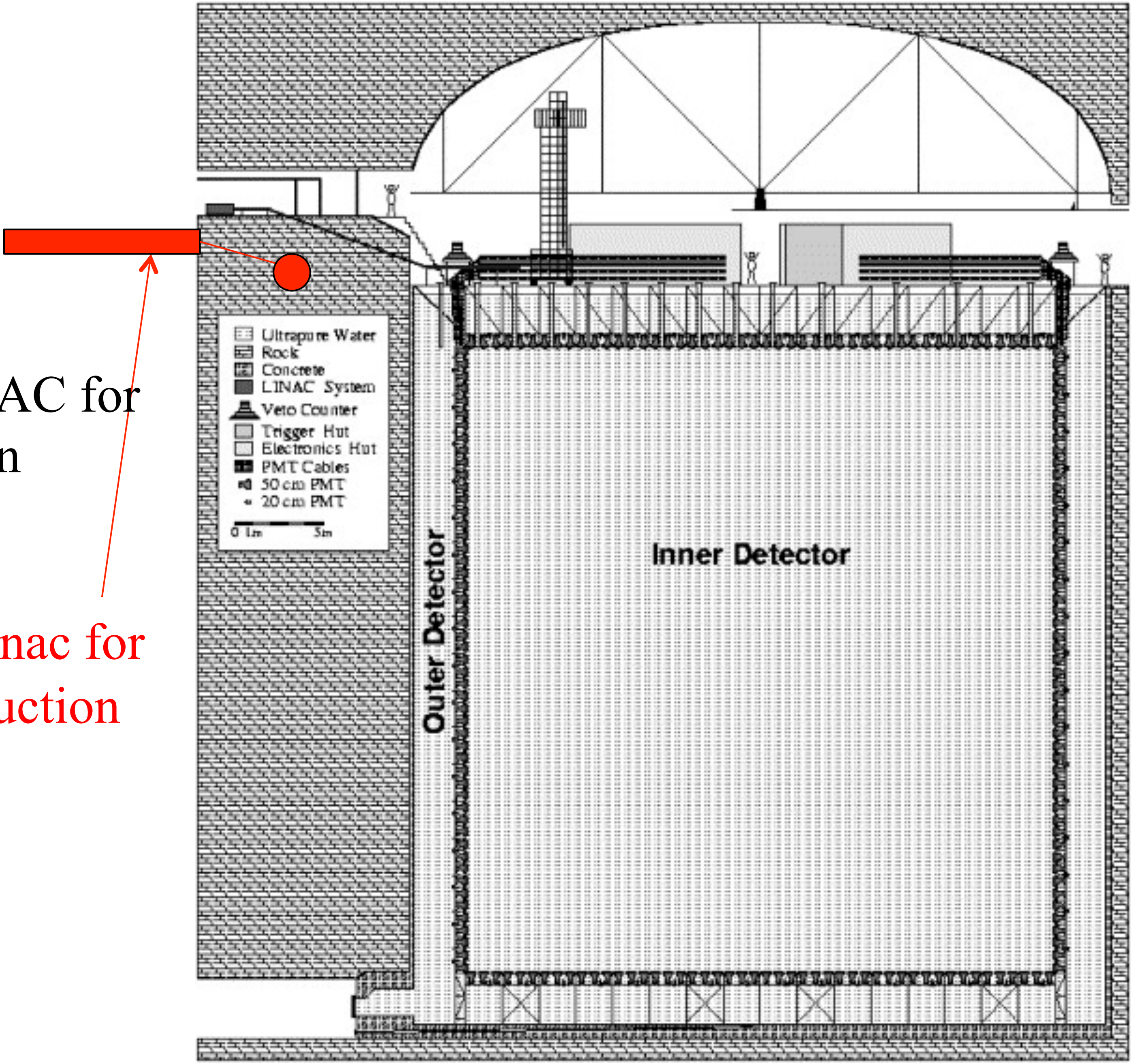
“BDX scheme”

3. Electron beam dump, huge detector, *deep underground*, very near beam dump



Electrons(protons)

“DM-SK”

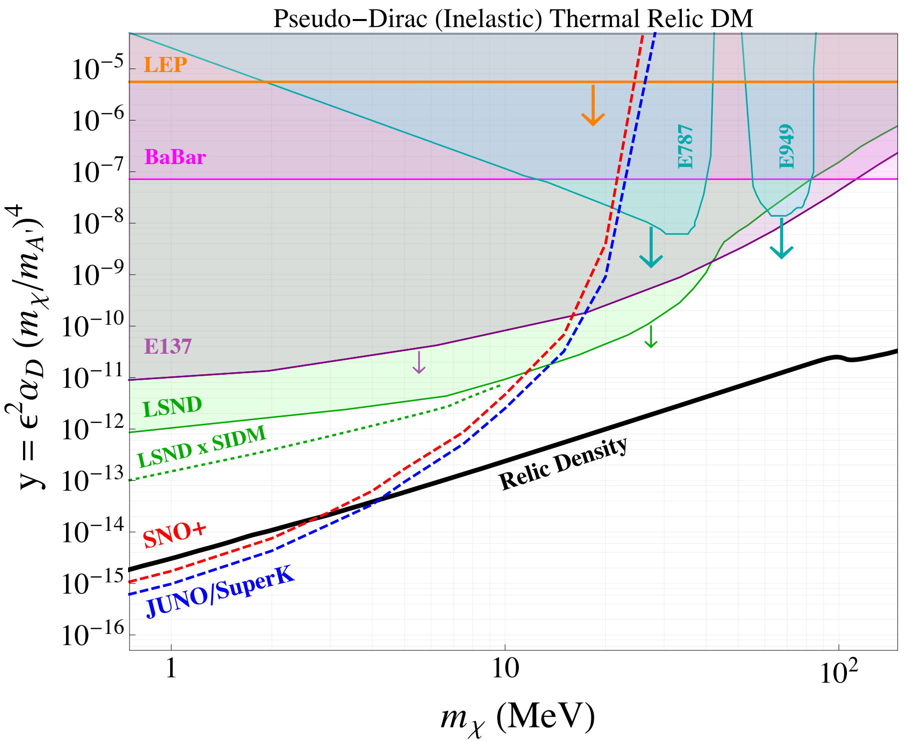


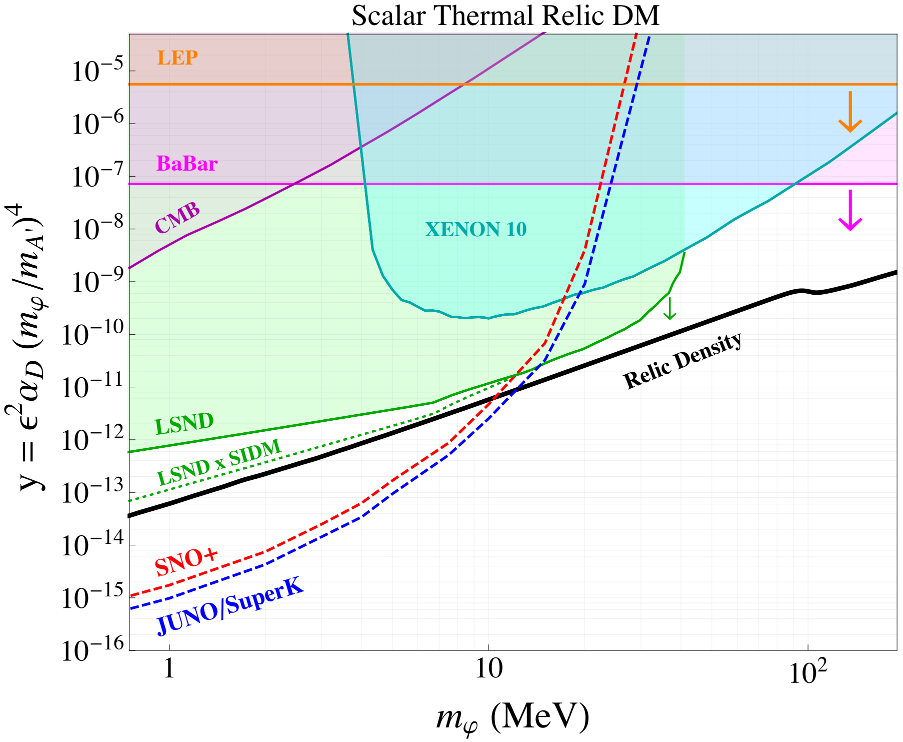
Tiny LINAC for calibration

+

Bigger Linac for DM production

Sensitivity to light DM





One will significantly advance sensitivity to light DM in the sub-100 MeV mass range. Assuming 10^{24} 100 MeV electrons on target

Izaguirre, Krnjaic, MP, 1507.02681

Conclusions

1. Light New Physics (not-so-large masses, tiny couplings) is a generic possibility. Some models (dark photon, scalar coupled Higgs portal) are quite natural, and can be searched for in fixed target experiments.
2. Concerted effort in “dark photon” case rules out minimal model as a cause of g-2 discrepancy. Other possibilities remain.
3. Currently, light dark matter via production & scattering can is being searched for at MiniBoone. HPS is taking data.
4. Future: more experimental possibilities. Watch out for the SHiP project (the only one where all types of portals will be probed)! There is a big potential for increasing sensitivity by placing medium energy linacs next to large underground ν detectors