Physics Beyond Colliders

BSM Working Group: Experimental Context

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Preamble

Big fundamental questions still open today:

Which is the origin of baryogenesis? Which is the nature of Dark Matter?
Which is the origin of neutrino masses and oscillations?

So far the experimental efforts have been concentrated on the discovery of **new particles with masses at (or slightly above) the EW scale** and **sizeable couplings with SM particles**. Other viable possibilities are that the new particles are **below the EW scale and couple very weakly with SM particles** or that they are **at a very high mass scale** so that their effects can only indirectly be observed.

Experimental proposals considered in the BSM WG focus **on low-energy processes that can answer in a complementary way the same fundamental questions of present (or future) high-energy accelerator** facilities and in which **CERN can play a unique role**;

Projects presented at CERN so far (in random order):

SHiP, NA62++, NA64++, KLEVER, IAXO, LSW, EDM

Baryogenesis
(or search for new sources of CP violation)

EDMs as a Window for New Physics

Electric dipole moment: $\frac{1}{2}\overline{\psi}\tilde{F}_{\mu\nu}\sigma^{\mu\nu}\psi$

Only CP-violating interactions induce it:

- search for EDM == search for CP violation, if CPT holds.

It is a precision tool "automatically" as SM (apart from strong CP caveat) does not induce large EDMs. *It is one of the most promising low energy measurements sensitive to the fundamental particle physics*.

Typical energy resolution in modern EDM experiments (eg: neutron EDM):

$$\Delta E \sim 10^{-6}\ \mathrm{Hz} \sim 10^{-21}\ \mathrm{eV}$$

translate to limits to EDM:

$$|d| < \Delta E/\text{Electric Field} \sim 10^{-25}\ \mathrm{e\ cm}$$

Comparing with theoretically inferred scaling:

$$|d| \sim 10^{-2} \times 1\ \mathrm{MeV}/\Lambda^2_{CP}$$

We get sensitivity to:

$$\Lambda_{CP} \sim 1\ \mathrm{TeV}$$

<u>An improvement from 10^{-25} to 10^{-29} would scale up the sensitivity to 100 TeV!</u>

Lines of attack towards an EDM

Free Particles

neutron
muon
deuteron
proton
…

→ particle EDM
→ unique information
→ new insights
→ new techniques
→ challenging technology

Atoms

Hg Xe
Tl
Cs Rb
Ra Rn
Fr …

→ electron EDM
→ nuclear EDM
→ enhancements
→ challenging technology

Electric Dipole Moment
goal:
new source of ~~CP~~

Molecules

→ electron EDM
→ strong enhancements
→ new techniques
→ poor spectroscopic data

BaF , YbF
PbO ,WC
PbF ,ThO
HfF^+,ThF^+
…

Condensed State

→ electron EDM
→ strong enhancements
→ systematics

garnets
$Gd_3Ga_5O_{12}$
$Gd_3Fe_2Fe_3O_{12}$
solid He ?
liquid Xe

Lines of attack towards an EDM

Free Particles

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muon
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Atoms

Hg Xe
Tl
Cs Rb
Ra Rn
Fr …

→ ele… DM
… M
… ts
… ging
technology

Electric

goal:
new source of ~~CP~~

EDMs in hadronic systems is related to θ_{QCD}
→measure of EDM is also a measure of θ_{QCD}

Molecules

→ elec…
→ stron… ents
→ new t… niques
→ poor spectroscopic data

BaF , YbF
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…

Condensed State

garnets
$Gd_3Ga_5O_{12}$
$Gd_3Fe_2Fe_3O_{12}$
solid He ?
liquid Xe

→ electron EDM
→ strong enhancements
→ systematics ??

Current worldwide context

- Electron EDM:
leading experiment is the Harvard/Yale ACME collaboration using ThO polar molecules with an enormous EDM enhancement factor in excited molecular states.

$|d_e| < 8.7 \times 10^{-29}$ e cm (2013 result)

- Proton EDM: (G. E. Harrison et al Phys. Rev. Lett. 22, 1263 (1969)), old experiment using a molecular beam:

$|d_p| < 7 \times 10^{-21}$ e cm

best limit today from 199Hg analysis**: $|d_p| < 5.4\ 10^{-24}$ e cm,** (PRL 91, 212303 (2003))

- Neutron EDM: leading experiment by the nEDM collaboration at PSI.
Many ideas/projects around the world (PSI, ILL, SNS, TRIUMF/Japan, LANL, TUM, > PNPI, …,ESS, ..) :

$|d_n| < 3 \times 10^{-26}$ e cm (90% CL, 2006, 2015 result)

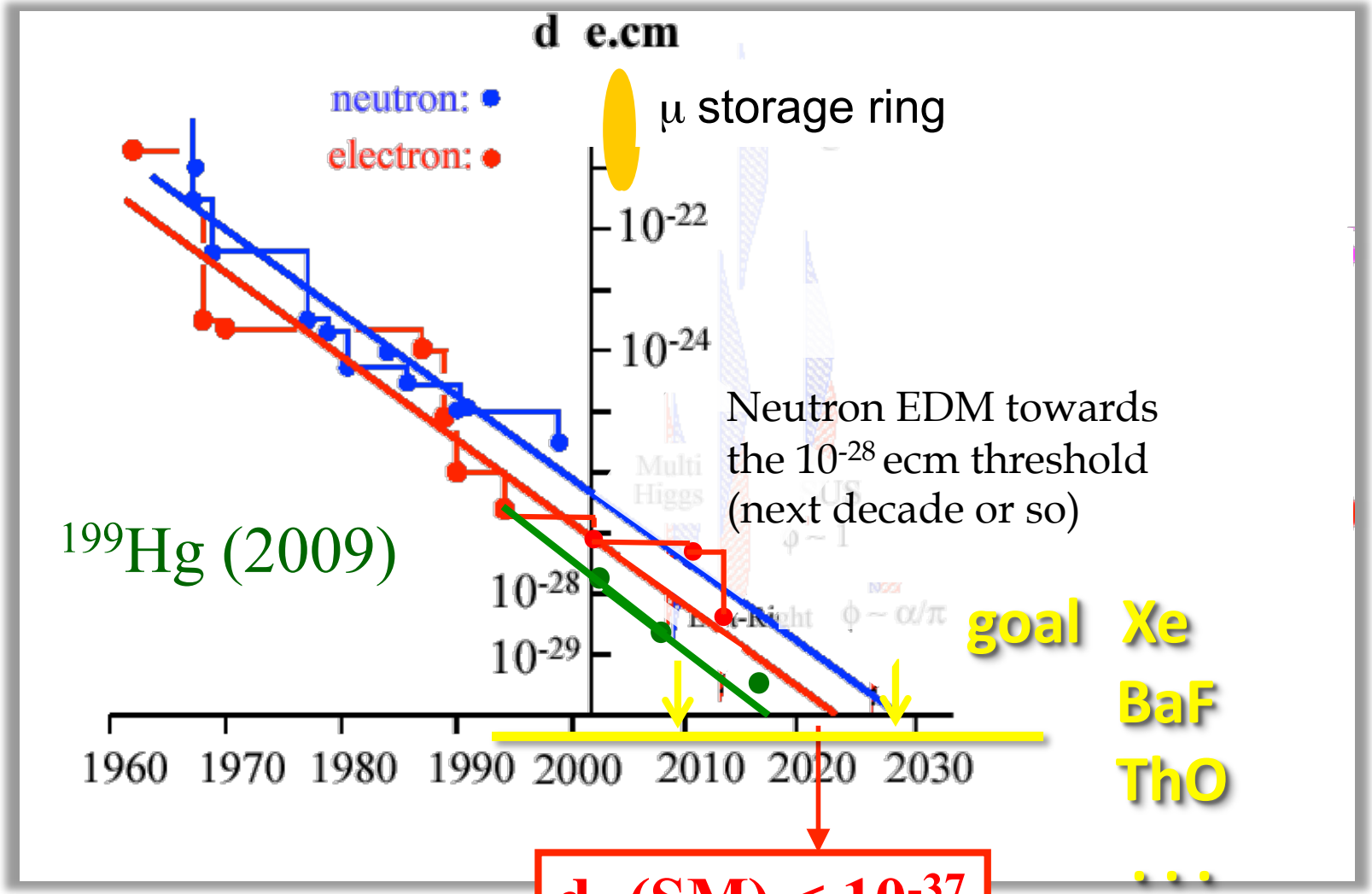
- "Diamagnetic" EDM: World leading experiment uses 199Hg (U Washington, Seattle) : measure of neutron EDMs in a nuclear environment:

$|d_{Hg}| < 7.4 \times 10^{-30}$ e cm (95% CL)

EDM of 129Xe (Mainz, Heidelberg, Groningen, Jülich), using spin polarized noble gas technology could compete with 199Hg on a reasonable time scale.

- Muon EDM: $1.8\ 10^{-19}$ e cm (95% CL) (2009) (Bennett et al., PRD80(2009)052008)

Limit on EDM vs Time

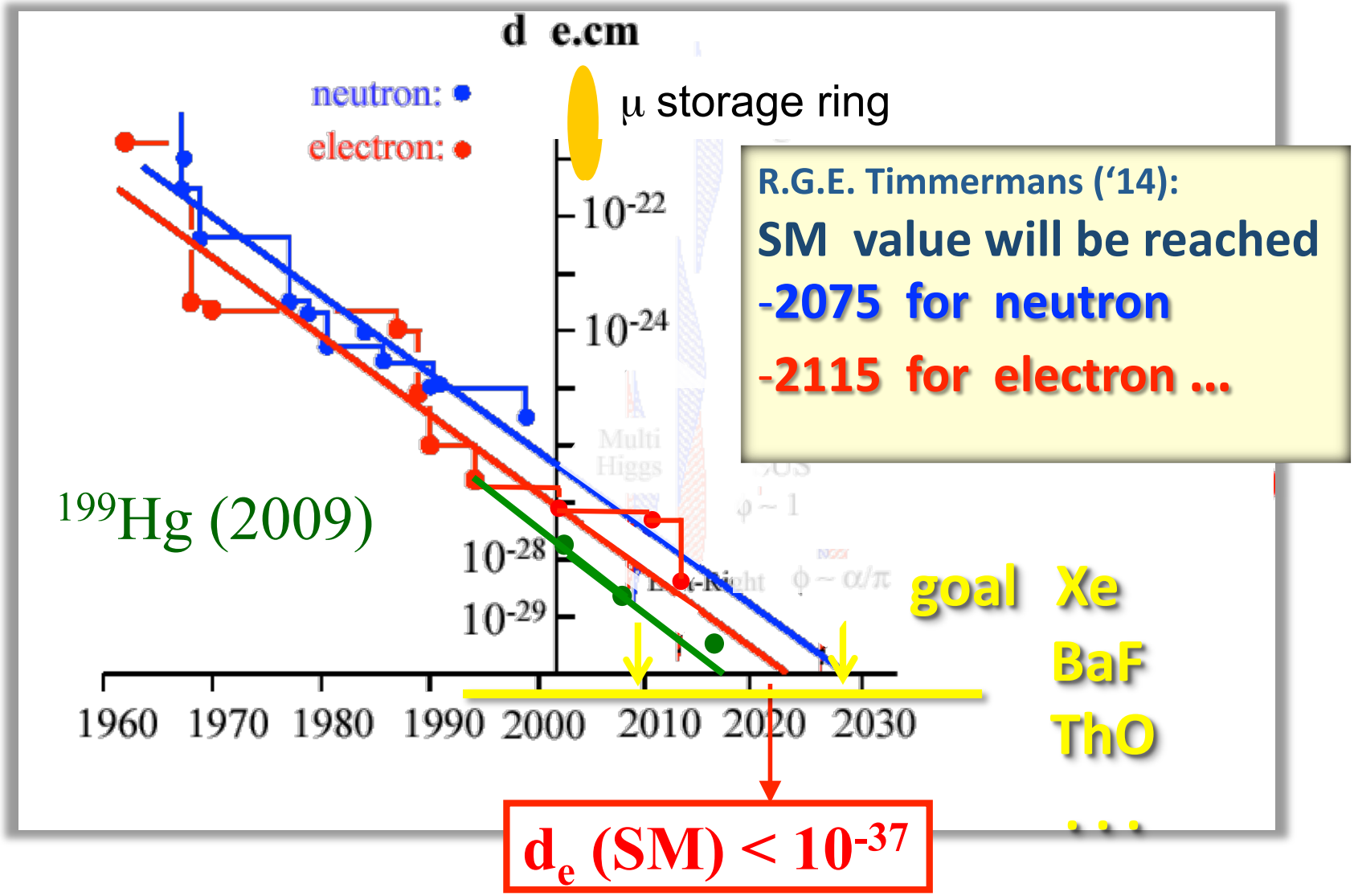


d_e (SM) < 10^{-37}

Hg: *B. Graner et al. PRL 116, 161601 (2016) [Seattle]*

e^- : J. Baron *et al., Science 343, 269 (2014) [Harward, Yale]*

Limit on EDM vs Time



R.G.E. Timmermans ('14):

SM value will be reached

-2075 for neutron

-2115 for electron ...

Hg: *B. Graner et al. PRL 116, 161601 (2016) [Seattle]*

e^- : J. Baron *et al., Science 343, 269 (2014) [Harward, Yale]*

Dedicated experiments to measure EDM at CERN?

Opportunity for CERN to pursue the EDM projects (**proton, deuteron**, and in the future possibly more complicated nuclei). A breakthrough **down to 10^{-29} e cm sensitivity level** has been claimed possible. pEDM is more than an order of magnitude more sensitive than current nEDM plans.

The muon/deuteron/proton etc. ideas to search for EDMs in storage rings is by now ~50 years old. Technology proven in connection with muon g-2, however, not a single experiment to go beyond could be started, yet.

The name of the game is: **systematic uncertainties!**
ex: extremely good control of the external fields over an extended period of time.

The proven part of the technology is some 7 orders of magnitude behind state-of-the-art with other methods. And the forefront is moving: ~10^{-31} e cm can be expected for atoms like 129 Xe (Mainz, Heidelberg, Juelich, Groningen) or 199 Hg (Seattle) within less than a decade.

Extremely challenging (but promising) project.

Baryogenesis
(or the strong CP problem → axions)

Axions at a glance

Axion: Pseudo Nambu-Goldstone boson associated with Peccei-Quinn symmetry, a global U(1), introduced to address the strong CP problem
[Pseudo: the $U(1)_{PQ}$ is not exact, and gives a small mass to the axion]

f_a (axion decay constant) = $U(1)_{PQ}$ symmetry breaking scale

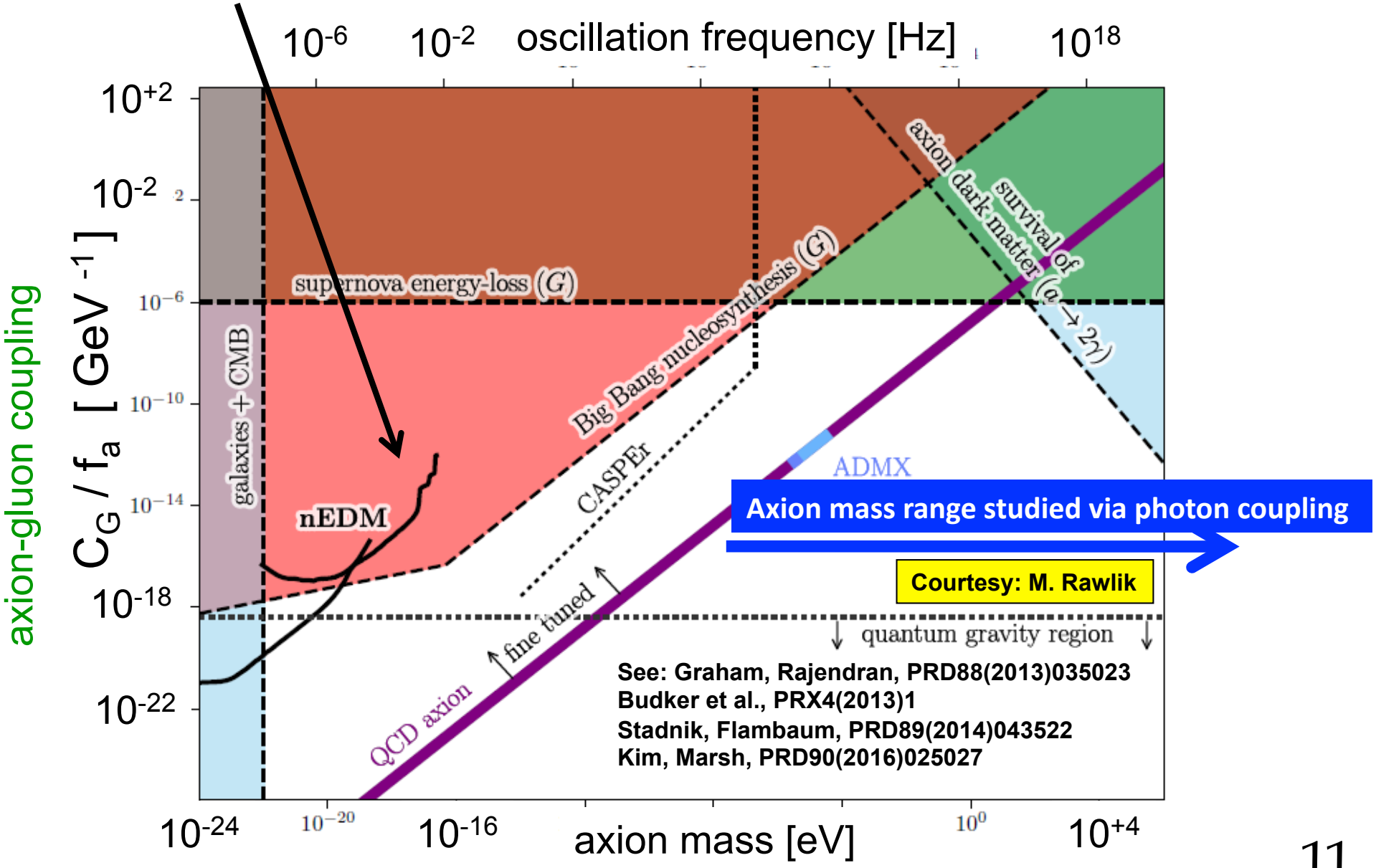
$$m_a \approx 0.5\,\frac{f_\pi m_\pi}{f_a}\,, \quad G_{agg} \approx \frac{1}{2}\frac{\alpha_S}{f_a}\,, \quad G_{a\gamma\gamma} \approx \frac{1}{2}\frac{\alpha_{EM}}{f_a}\,\mathcal{O}(1)$$

Axion coupling is almost determined once its mass is given. $\frac{G_{a\gamma\gamma}}{m_a} \sim \frac{10^{-9}\ \mathrm{GeV}^{-1}}{\mathrm{eV}}$

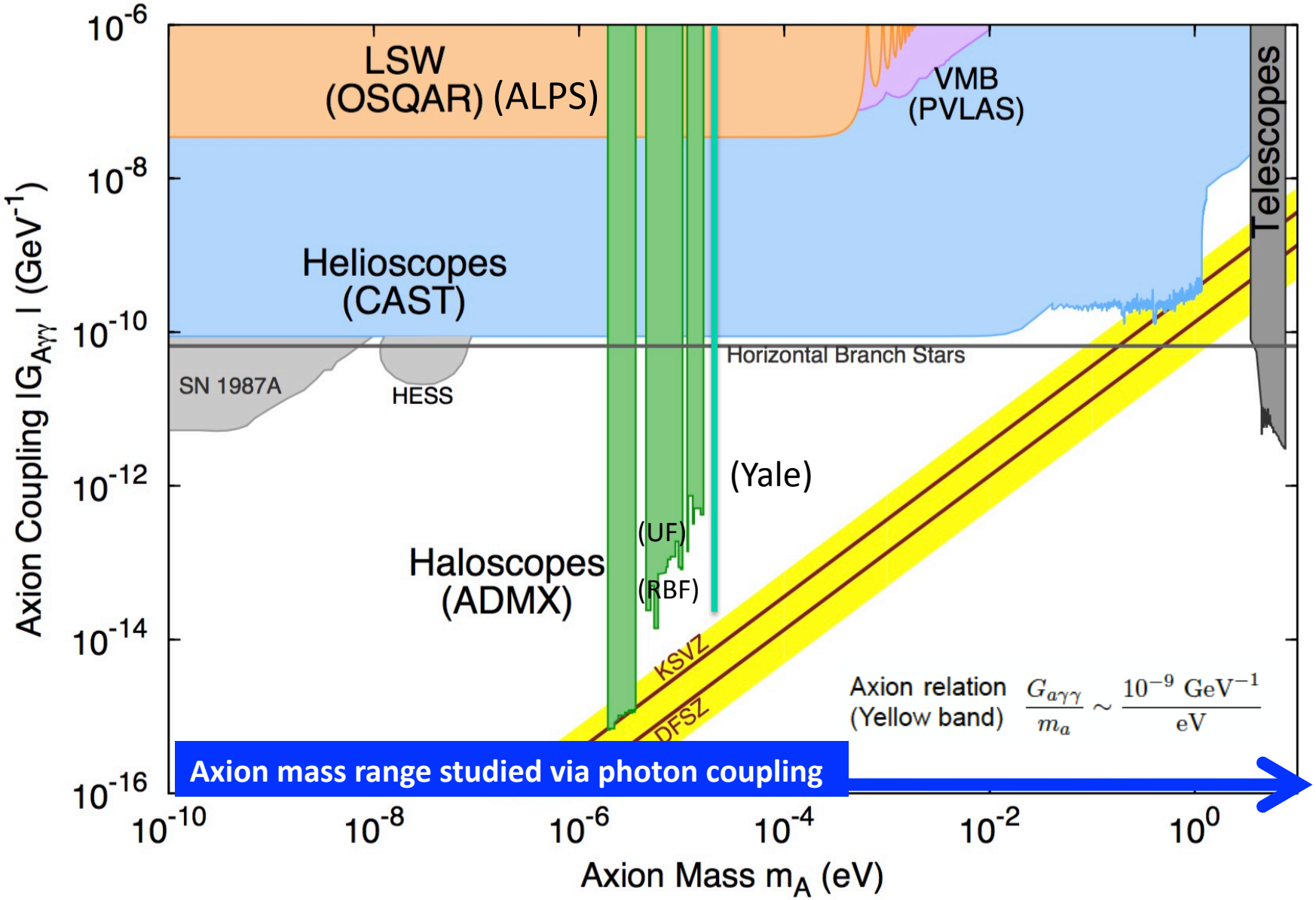
Axon-Like Particle (ALP): a generalized version of the axion (at the cost of original motivation from the strong CP problem). No direct relation between $G_{a\gamma\gamma}$ and m_a.

Courtesy of H.-S. Lee

Oscillating nEDM as a probe for axions/ALPS via gluon-coupling



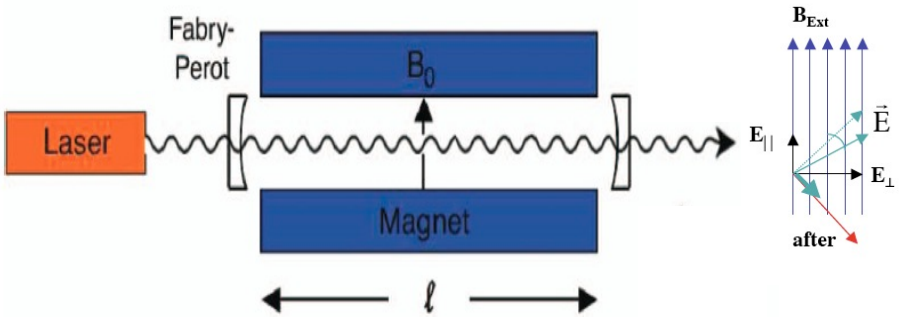
Axion-photon coupling – current exclusion plot



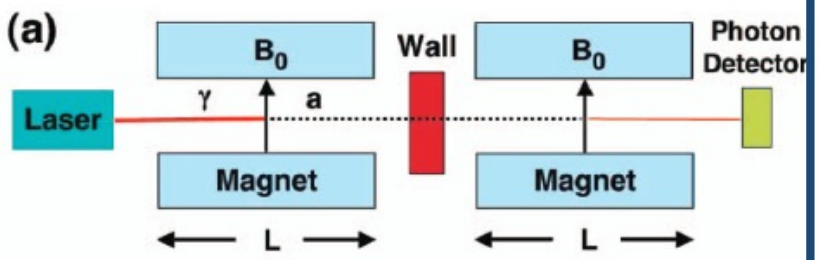
Detecting axions via axion-photon coupling

Production and detection of axions in a terrestrial laboratory

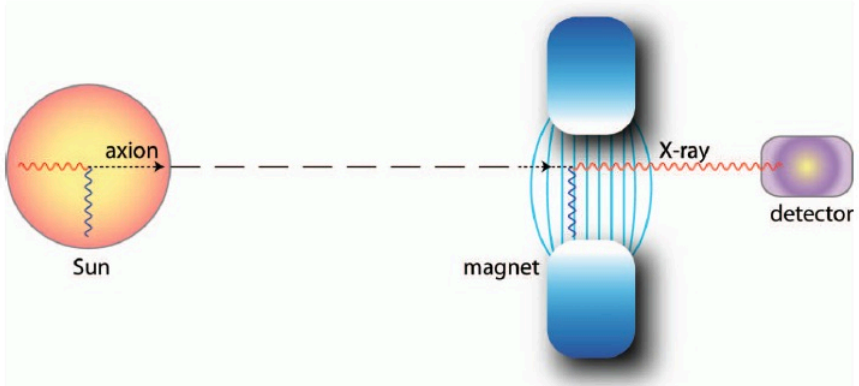
Polarization experiments



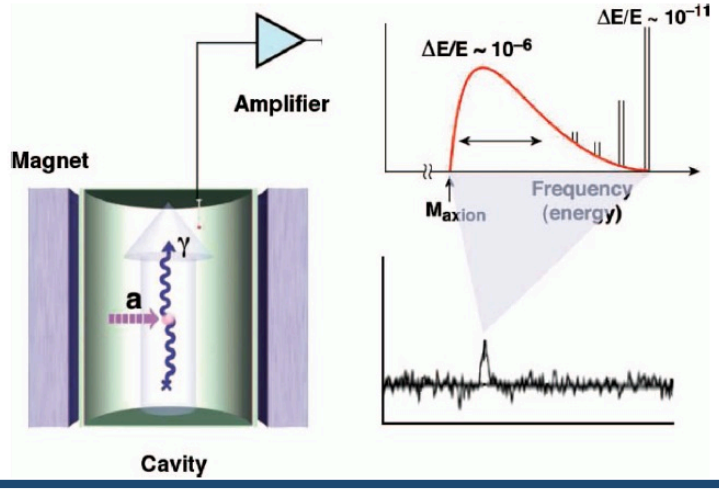
Regeneration experiments



Detection of axions coming from external sources (Sun)- Helioscopes



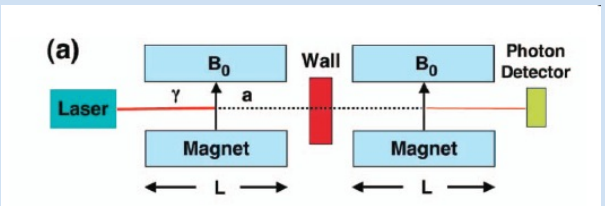
Detection of axions present into the Galactic Halo - Haloscopes

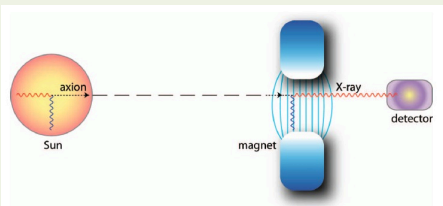


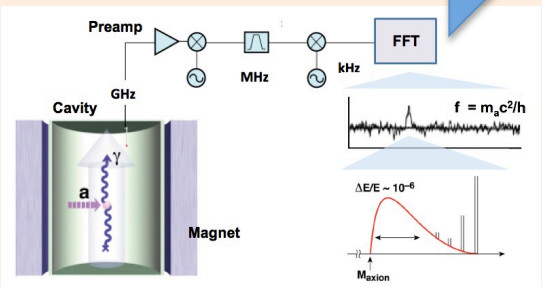
All pictures from: G. Carosi et al, Contemp. Phys. 49, 281 (2008)

Comparison

Lab Experiments	Helioscopes	Haloscopes
Axion Like Particle	ALPS & QCD Axion	ALPS & **QCD Axion**
Wide band experiment	Wide band experiment	Resonance experiment
Optical photons	X rays photons	Microwave photons
Model independent	Model dependent	Strong model dependency
Low axion flux	Medium axion flux	High axion flux
Low sensitivity to alps coupling	Good sensitivity to alps coupling	Reaches KSVZ axion model







Recent experiments (partial list)

Lab Experiments

- regeneration - optical

ALPS, OSQAR –

ALPS II upgrade in progress, expected large sensitivity improvement. ALPS III foreseen

- regeneration - microwave
  - STAX
- polarization

PVLAS, BMV – large improvement of current results difficult

Helioscopes

SUMICO

CAST - presently with best limits, small upgrade possible (?)

IAXO – large scale evolution of CAST

Haloscopes

- Sikivie type – μeV range

ADMX, WISPDMX, CAPP

- Sikivie type – higher masses

ADMX-HF(Yale), ORGAN, ORPHEUS

- Conversion @ surfaces

MADMAX

Sub μeV masses

- axion induced oscillating B

ABRACADABRA, DM Radio

- Axion induced oscillating nEDM

CASPEr – exploit NMR techn.

- Axion electron coupling

QUAX – EPR techniques

Other searches

- Search for axion mediated long range forces

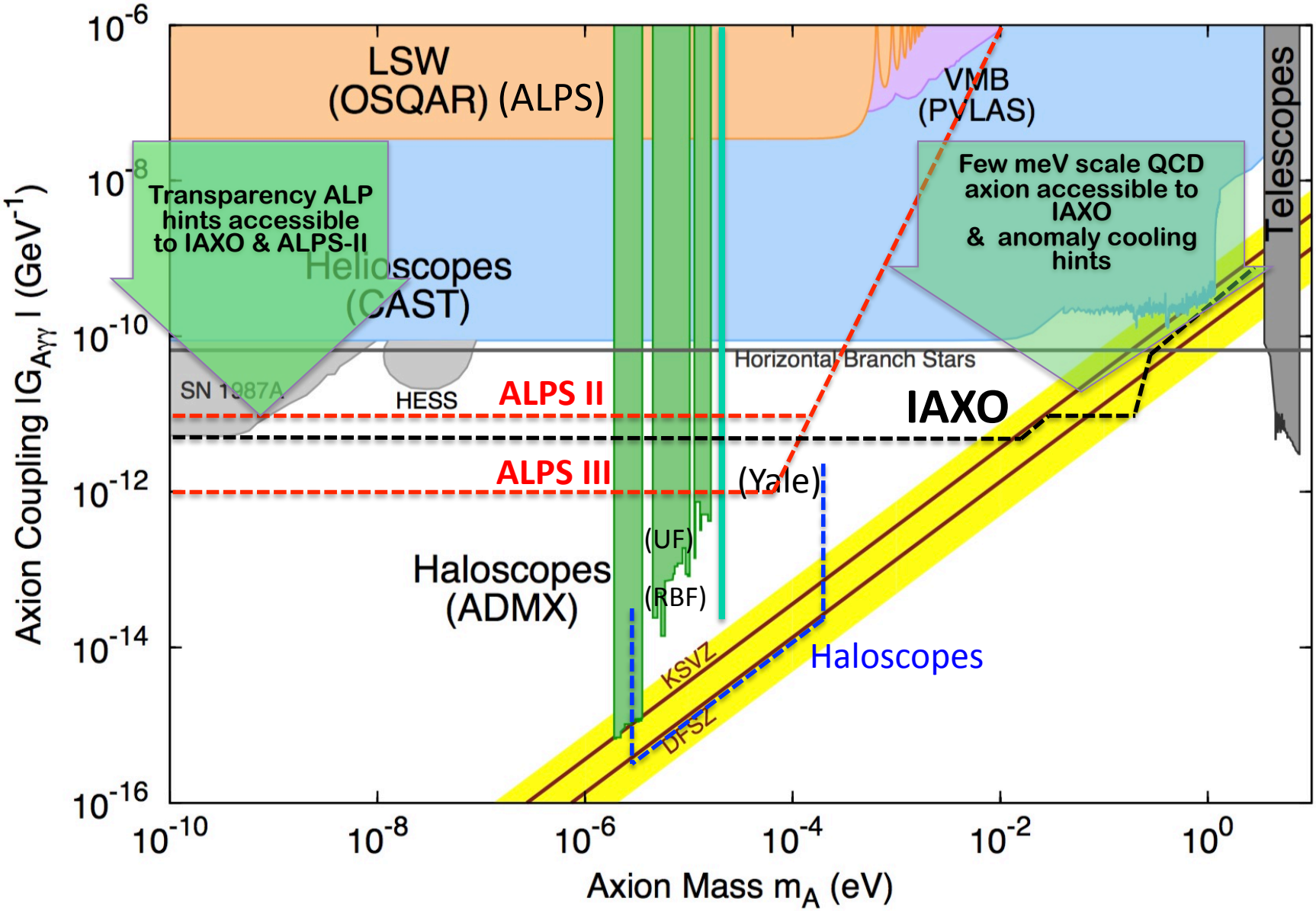
ARIADNE – precision magnetometry, μeV to meV range

Experiments on spin precession in magnetic field, He-3 depolarization

- Search for anomalies in gamma ray astronomy

MAGIC, **HESS,** CTA – Cherenkov telescopes

Coupling to photons – Projected exclusion plot

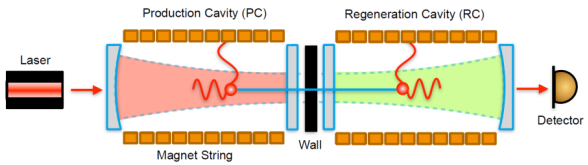


IAXO experiment

- IAXO → legacy of CAST in the "axion helioscope frontier":
- IAXO is unique technique to search part of the axion/ALP parameter space:
  → highly complementary with other efforts in the community
- Good technological synergies with magnet and x-ray optics communities:
  → important role for CERN
- Opportunity for other European centers to host the experiment (DESY?…)
- Additional physics opportunities (generic axion ALP infrastructure)

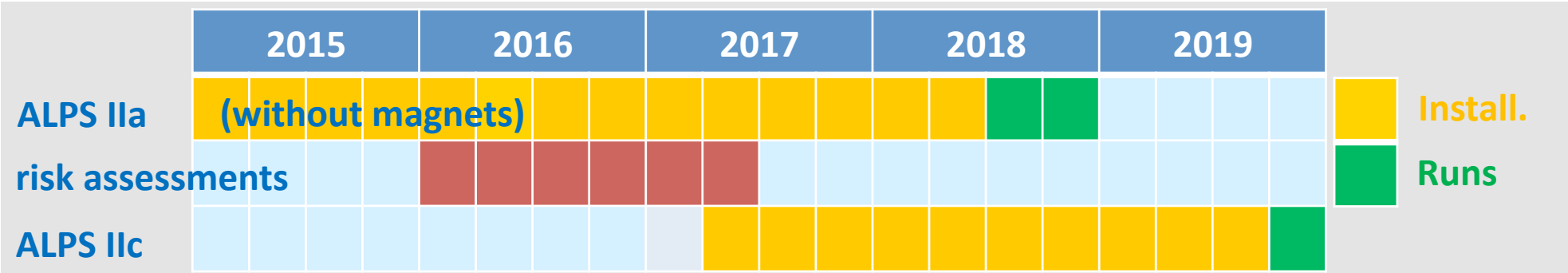
- Project in the TDR phase, roadmap to construction being defined, collaboration getting established; An intermediate stage (mini-IAXO) to test new magnet configuration and provide intermediate physics under consideration as part of TDR.

LSW: ALPS-II and ALPS-III experiments



ALPS-II, almost running

just about to be started in the HERA tunnel:
(uses 20 HERA dipole magnets (5.3 T, 8.8 m magnetic length).



ALPS-III, conceptual idea:

would **dramatically increase the sensitivity for purely laboratory based experiments searching for axion-like particles by combining**

- present day expertise in optics (ALPS II lessons learned from LIGO)
- present day expertise in detectors or very low photon fluxes (ALPS II)

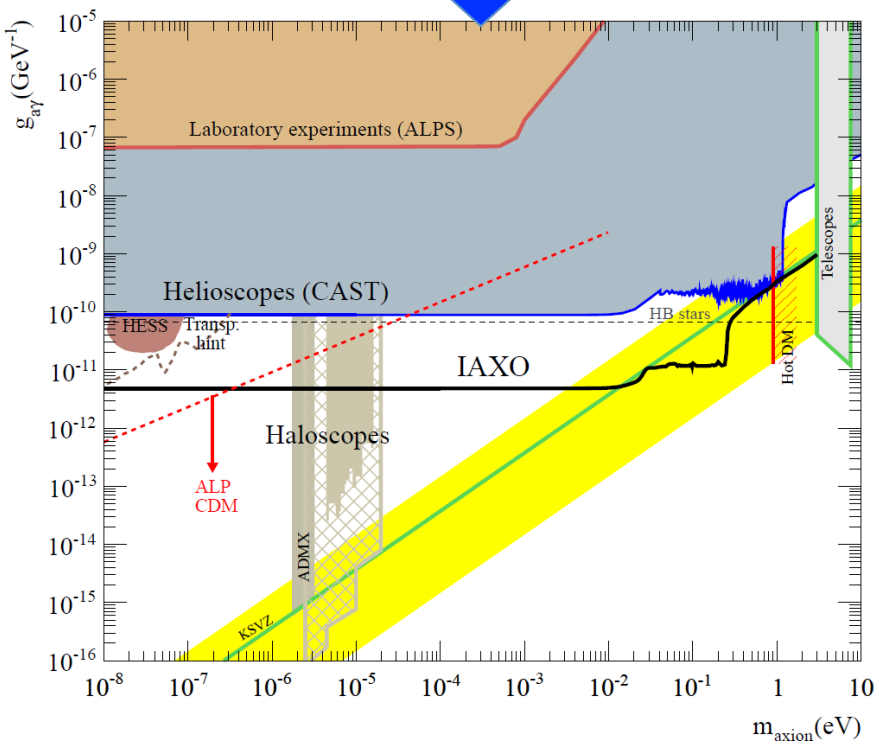
with **new dipole magnets under development at CERN for future accelerators.**

A possible site for ALPS-III could be CERN

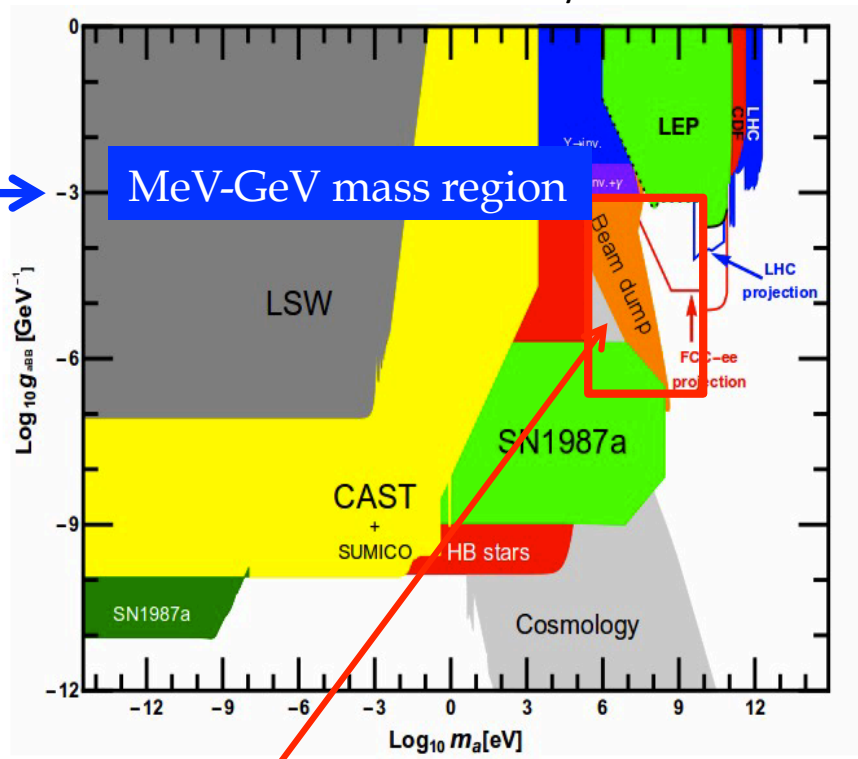
Expanding the ALPS exclusion limits in the "high" mass region

courtesy of F. Kahlhoefer

sub-eV mass region

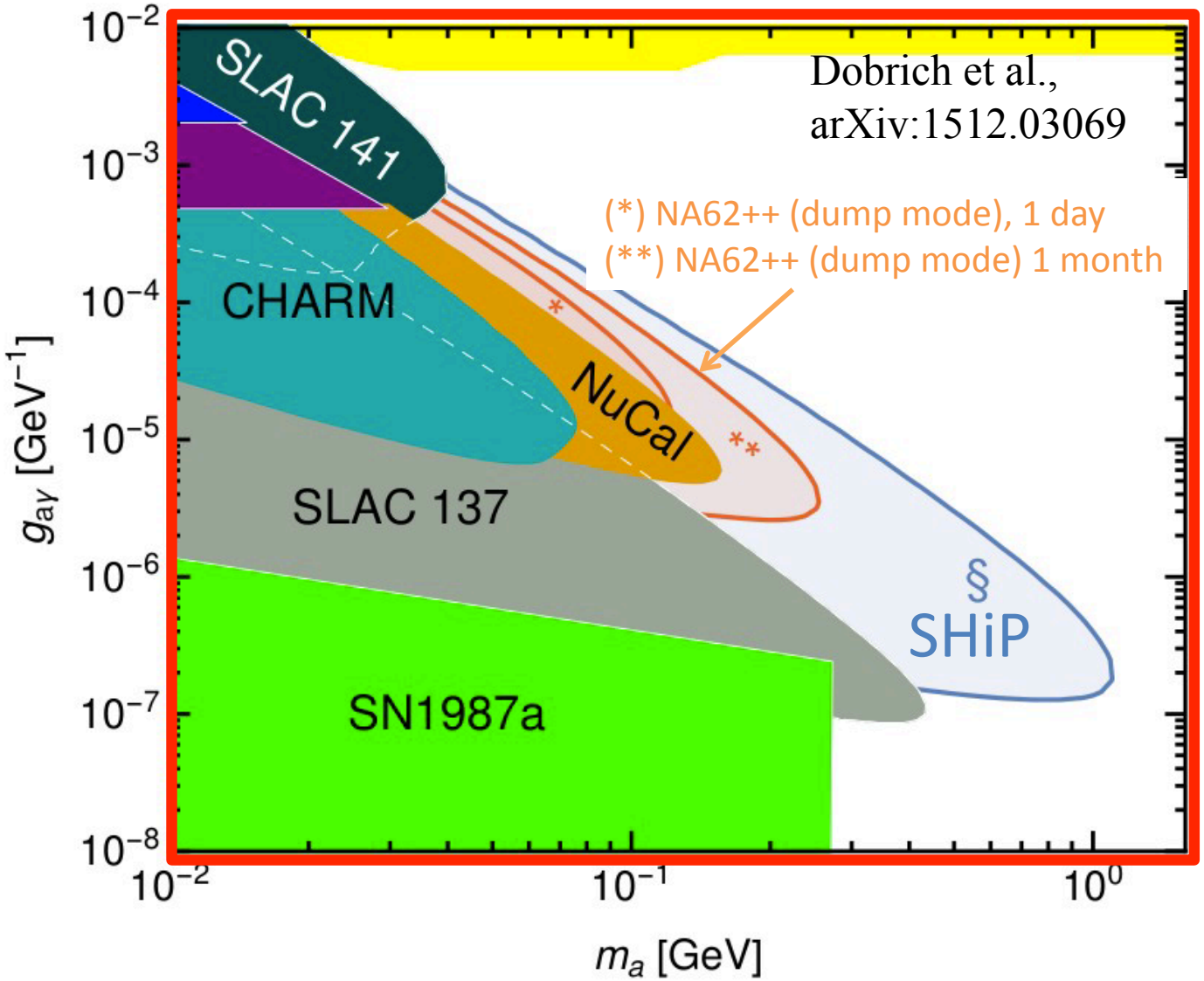


MeV-GeV mass region



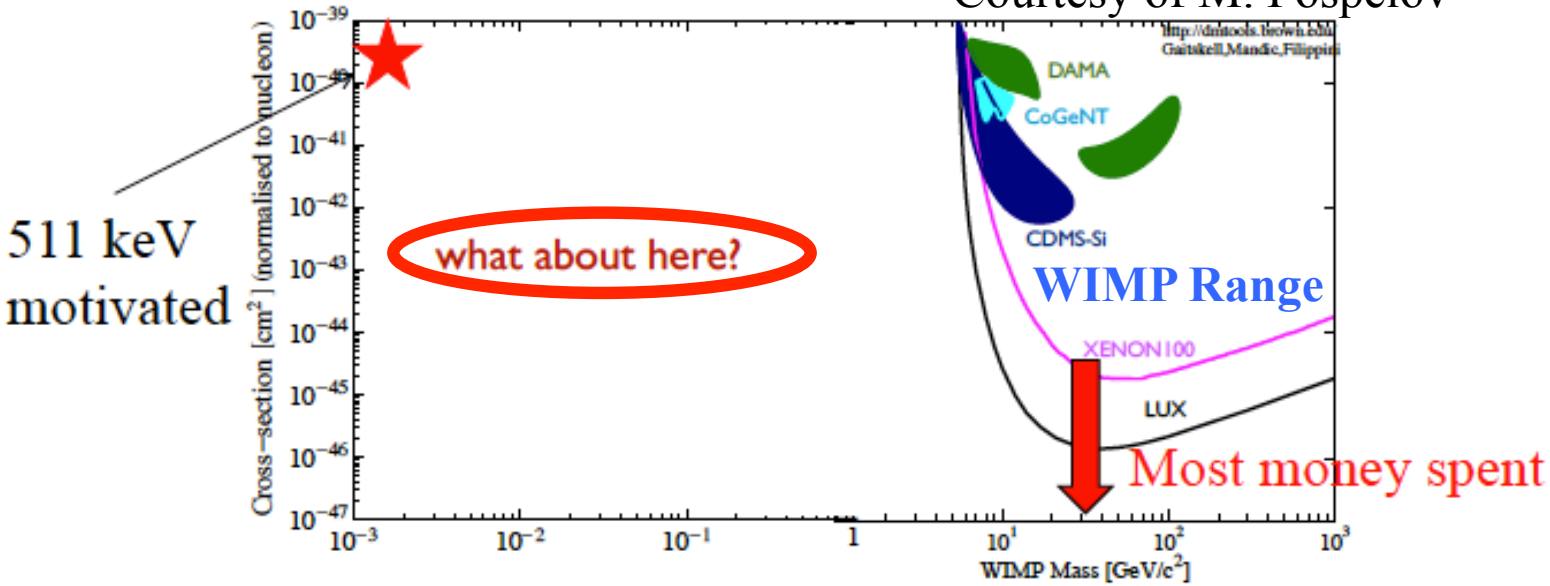
ALPS at (proton) beam dump facilities: GeV-scale ALPs can be produced from the fusion of two coherently emitted photons (Primakoff production)

ALPS contour limit from past and future beam-dump experiments in the "high" mass region (0.1-1.0) GeV)



Light Dark Matter and Light Mediators

Courtesy of M. Pospelov



Light Dark Matter: thermal origin

As universe cools below DM mass, density decreases as exp{-m/T}

- DM interacts with SM to stay in equilibrium
- eventually DM particles can't find each other to annihilate
- and a (minimal) DM abundance is left over the present day.

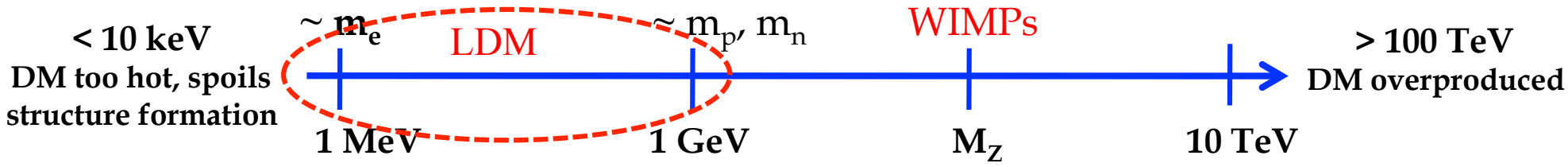
Equilibrium reached easily with a tiny DM-SM coupling.

DM annihilation cross-section necessary to obtain the relic density:

σv (relic) = 3×10^{-26} cm^3/s

The equilibrium can be reached:

- either with traditional WIMP at TeV scale with Z mediator (excluded by current limits)
- or with light DM with light mediator (hence new forces).

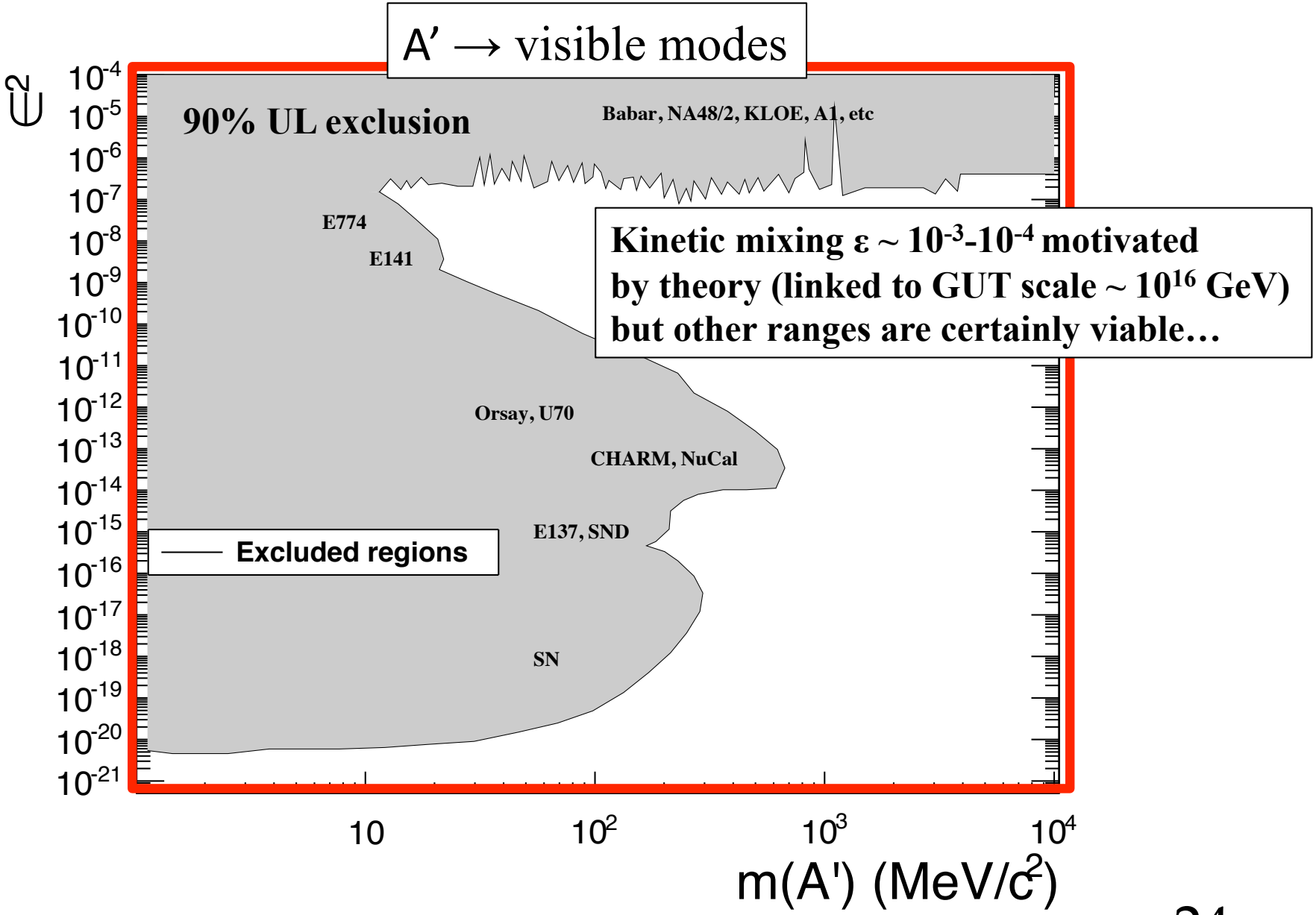


Light mediators must be SM singlet, options limited by SM gauge invariance:

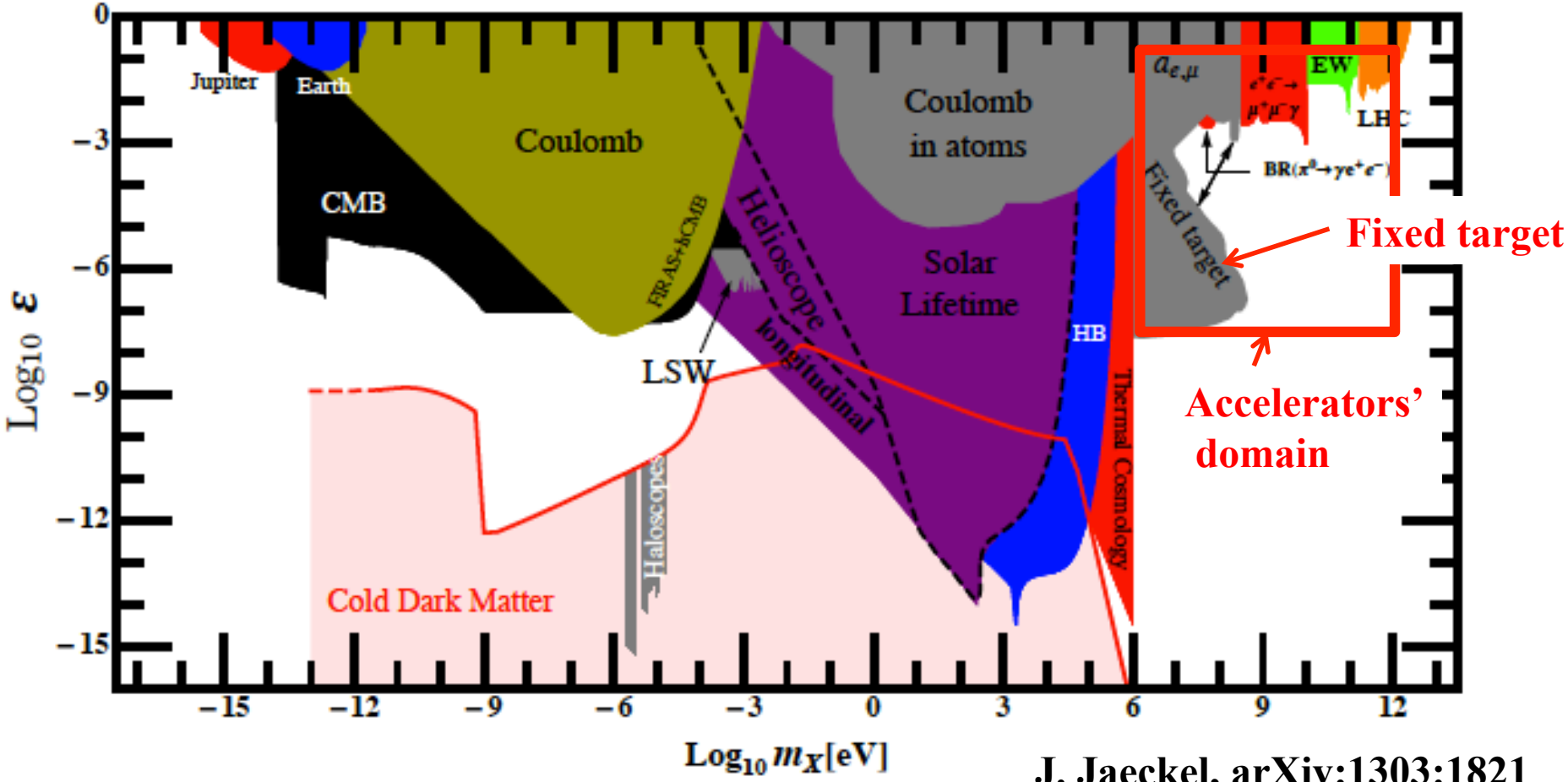
1) Vector Portal; 2) Scalar Portal; 3) Neutrino Portal

Light Dark Matter and Light Mediators: Vector Portal

Vector Portal: Dark Photons in visible modes



Limits on the kinetic mixing of a hidden photon -ordinary photon: expanded scale



J. Jaeckel, arXiv:1303:1821

Vector Portal: a window for light dark matter current and proposed experiments searching for **Dark Photons**

Searches for A' → visible states

Name	Where	Source	Intensity	Production mode	Detection mode	Status
Belle-II	Super KEK-B	$e^+e^- \to \Upsilon(3S)$	> 100 fb^{-1} @ $\Upsilon(3S)$	$\Upsilon(3S) \to \gamma A'$	$A' \to e^+e^-, \mu^+\mu^-$	Commis. 2018
Apex	JLAB	e^-, 2 GeV	10^9 EOT (W)	A'-strahlung	$A' \to e^+e^-$	Commis. 2018
HPS	CEBAF12 @ JLAB	e^-,1-2 GeV	10^{14} EOT (W)	A'-strahlung	$A' \to e^+e^-$	Running 2016-20
MAGIX	MESA @ Mainz	e^-, 155 MeV	10^{16} EOT (Xe gas)	A'-strahlung	$A' \to e^+e^-$	Commis. 2020
Mu3e	πE5 line @ PSI	μ^-, 28 MeV	10^{15-16} μ^-	$\mu \to \nu\nu A'$	$A' \to e^+e^-$	Commis. 2017
ATLAS/CMS	LHC @CERN	pp 8, 13 TeV	few fb^{-1}	$H \to 4l + \text{MET}$	$A' \to \mu^+\mu^-$	Running
LHCb	LHC @CERN	pp,13 TeV	15 fb^{-1}	$D^* \to DA'$	$A' \to e^+e^-, \mu^+\mu^-$	Running
NA62	SPS @CERN	p, 400 GeV	2 10^{18} POT	Meson, A'-strahlung	$A' \to e^+e^-, \mu^+\mu^-$	Running -2018
SeaQuest	Main Inj. @ FNAL	p, 120 TeV	1.5	Meson, A'-strahlung	$A' \to \mu^+\mu^-$	Proposed 2017–19
SHiP	SPS @CERN	p, 400 GeV	2 10^{20} POT	Meson, A'-strahlung	$A' \to e^+e^-, \mu^+\mu^-$	Proposed 2026

Searches for A' → Light Dark Matter (invisible states)

Babar	PEP-II @ SLAC	$e^+e^- \to \Upsilon(3S)$	57 fb^{-1}	$\Upsilon(3S) \to \gamma A'$	Single-γ trigger	ICHEP 2016
VEPP-3	VEPP-3 @ Budker Inst.	e^+, 500 MeV	1.5 MHz $\gamma\gamma$	$e^+e^- \to A'\gamma$	detect $\gamma + M_{\text{miss}}$	Proposed
PADME	BTF @ Frascati INFN	e^+, 550 MeV	15 Hz $\gamma\gamma$	$e^+e^- \to A'\gamma$	detect $\gamma + M_{\text{miss}}$	Approved, 2017-19
MMAPS	CESR @ Cornell	e^+, 5.3 GeV	2.2 MHz $\gamma\gamma$	$e^+e^- \to A'\gamma$	detect $\gamma + M_{\text{miss}}$	Not funded
NA64	SPS @ CERN	e^-, 100 GeV	$e^-N \to e^-NA'$	10^9–10^{12} EOT	detect $e^- + E_{\text{miss}}$	Running, 2016-17
LDMX	LCLS-II @ SLAC	e^-, 4 GeV	$e^-N \to e^-NA'$	10^{15}–10^{16} EOT	detect $e^- + E_{\text{miss}}$	Proposed, 2020

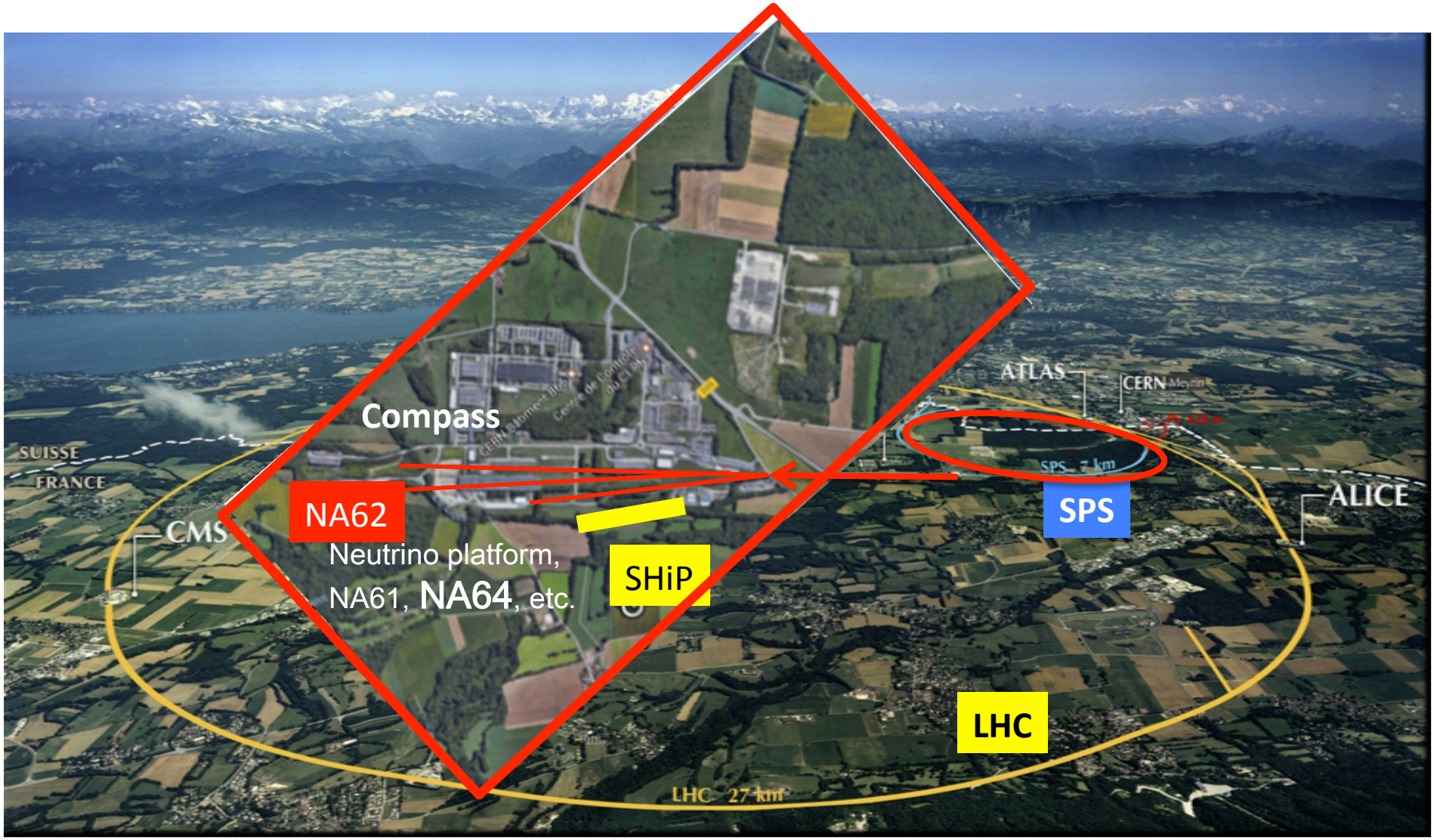
Direct detection of LDM via the process A' → LDM → LDM scattering in the detector

SBND	FNAL	p, 9 GeV	2 10^{20} POT	Meson, A'-strahlung $A' \to \varphi\varphi$	detect ϕ @ 110 m	Under study
T2K	Tokai-Kamioka	p, 30 GeV	10^{21} POT	Meson, A'-strahlung $A' \to \varphi\varphi$	detect ϕ @ 280 m	Running
COHERENT	SNS @ Oak Ridge	p, 1 GeV	10^{23} POT	Meson, A'-strahlung $A' \to \varphi\varphi$	detect ϕ @ 20 m 2°-OA	Proposed
SHiP	SPS @CERN	p, 400 GeV	2 10^{20} POT	Meson, A'-strahlung $A' \to \varphi\varphi$	detect ϕ @ 100 m	Proposed 2026
LBNF	DUNE @FNAL	p, 120 GeV	3 10^{21} POT	Meson, A'-strahlung $A' \to \varphi\varphi$	detect ϕ @ 500 m	Under study 2020

Experiments proposed at CERN: SHiP, NA62++ (proton dump), NA64 (e- dump)

- **SHiP** can search simultaneously for visible decays of DP and direct LDM observation.
- **NA64 & NA62** can search for visible and invisible decays with different methods

Fixed Target Experiments @ CERN



Highest energy proton beam delivered for fixed target experiments in the world

How to search for Hidden Particles in a beam dump?

Light and feebly-interacting particles can be **originated by the decay of beauty, charm and strange hadrons and by photons produced in the interaction of protons with a target**. Their couplings to SM particles are very suppressed leading to expected production rates of 10^{-10} or less. As the charm and beauty cross-sections increase steeply with the energy, **a high-intensity, high-energy proton beam (and secondary beams) is needed to improve over the current results**:

→*To date the world best line to produce high intensity fluxes of beauty and charm hadrons and photons through the interactions of protons on a high-Z target is a 400 GeV/c proton beam line extracted from the CERN SPS*

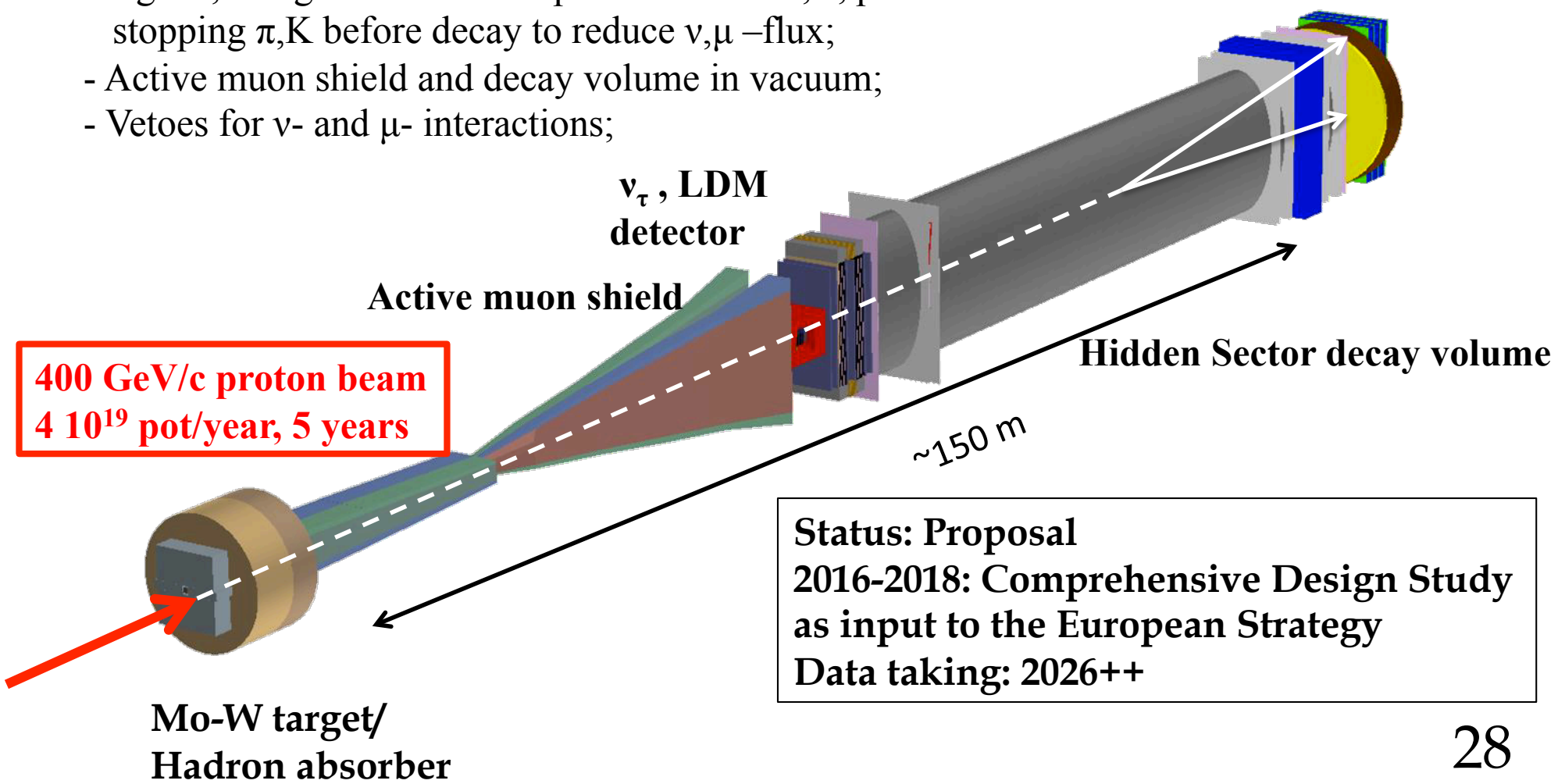
The smallness of the couplings implies that the hidden sector mediators are also very long-lived compared to the bulk of the SM particles:
an HNL with m=1 GeV has $\tau \sim 10^{-5}$ sec and an average flight distance of >10 km at the SPS energies.

→*The decays to SM particles can optimally be detected only using experiment with decay volume tens of meters long followed by a spectrometer with particle identification capabilities.*

Fixed Target Experiments @ CERN: SHiP

Dedicated experiment to explore Hidden Sector models
with vector, scalar, neutrino, axion-like SM portals (and other):

Strategy: "zero background" experiment as close as possible to target:
- high A,Z target to maximize production of D,B, photons while stopping π,K before decay to reduce ν,μ –flux;
- Active muon shield and decay volume in vacuum;
- Vetoes for ν- and μ- interactions;



Status: Proposal
2016-2018: Comprehensive Design Study as input to the European Strategy
Data taking: 2026++

Fixed Target Experiments @ CERN: SHiP

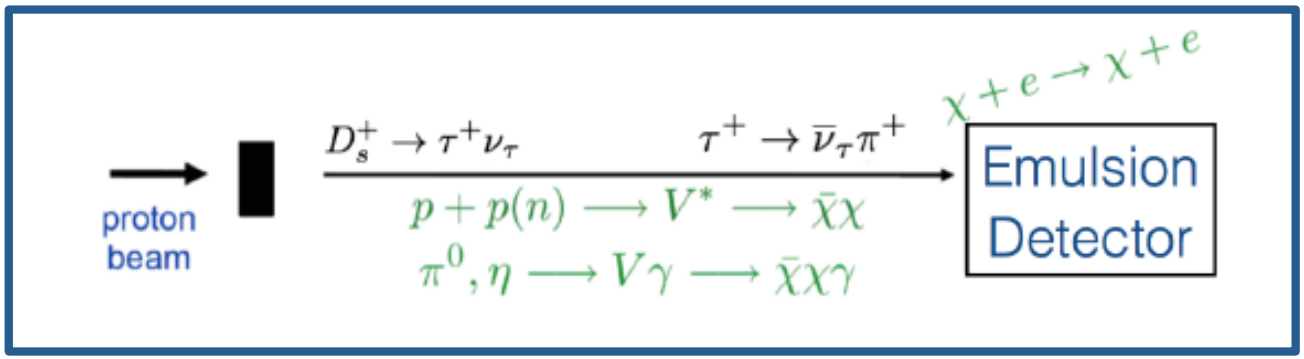
- SHiP is the **only place** to search for Hidden Sector particles in the mass range of up to O(10 GeV) in **zero-background conditions** (powerful muon shield!);

- SHiP is sensitive to a **wide range of final states**, both fully and partially reconstructed with leptons and charged or neutral hadrons in final state:

e.g: Hidden Particle → μ μ ν, K^- l^+ π^0, etc

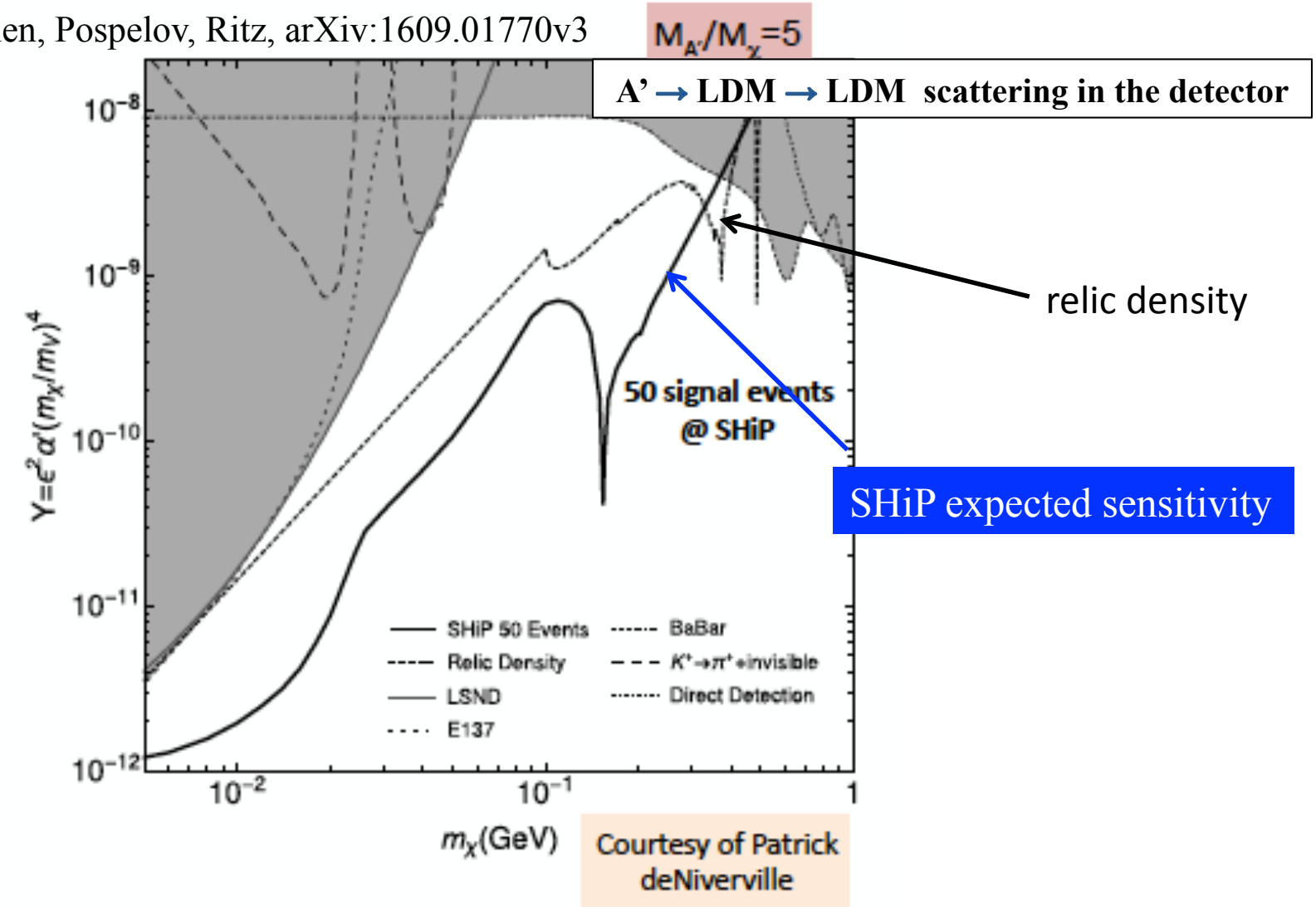
- Spectrometer system to measure momenta and identify vertex, combination of calorimeter and muon systems allow for e/μ and π/μ separation

- Can **simultaneously search for Hidden Particle decays to SM** sector, as well as for the **DM candidate of the Hidden sector** in the region between 10 MeV – 1 GeV where direct searches are less sensitive, via the process:



Dark Photons in invisible modes: direct detection of LDM current and future sensitivities

De Niverville, Chen, Pospelov, Ritz, arXiv:1609.01770v3



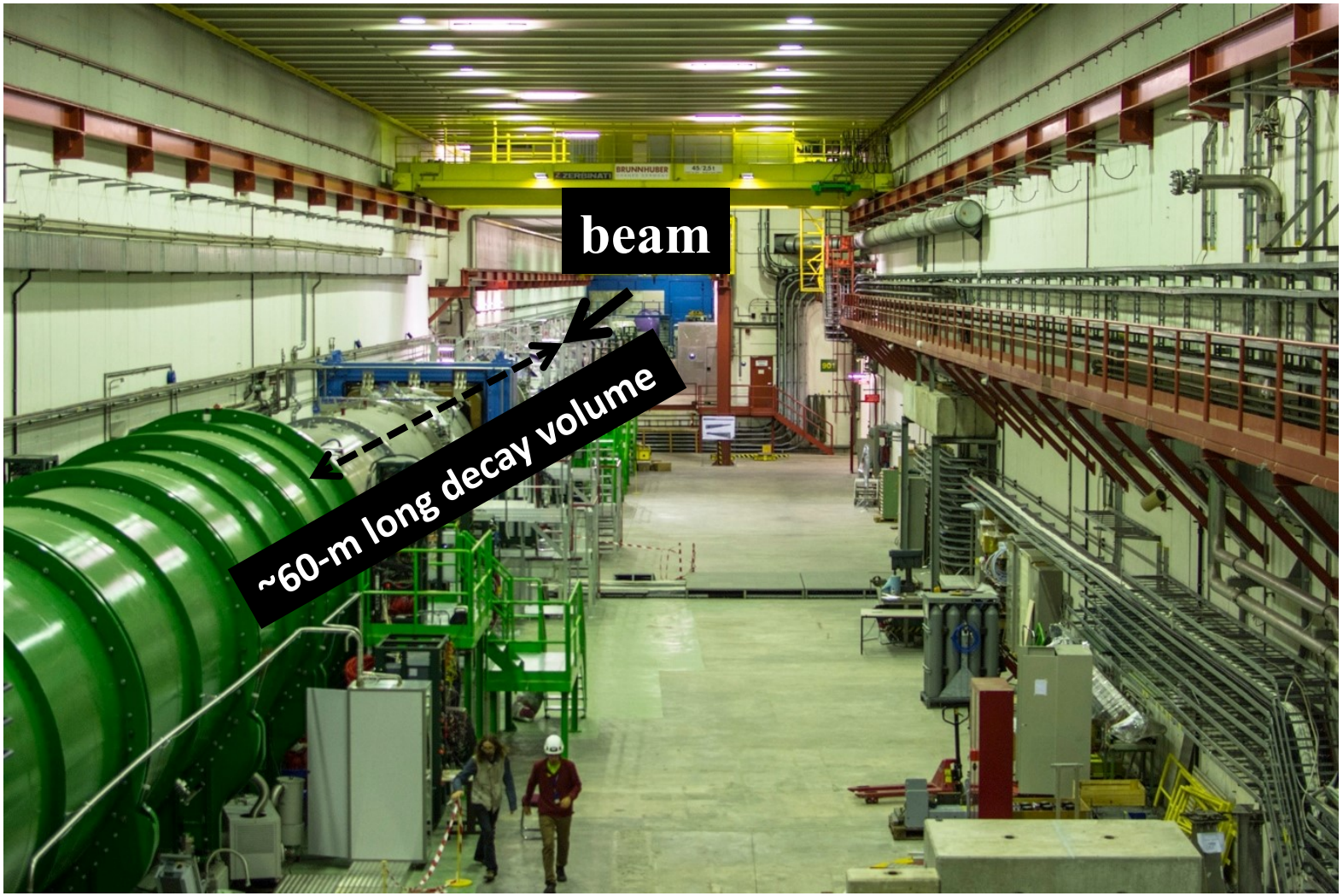
(plot to be updated with recent BaBar & NA64 results)

Fixed Target Experiments @ CERN: NA62

400 GeV proton beam; 10^{12} pot/sec; ~(1-2) 10^{18} pot/year;

Current status: running with a K^+ beam;

goal: measure of BR($K^+ \rightarrow \pi^+ \nu$ anti-ν) with 10% accuracy by 2018



Physics at NA62++ in Run 3

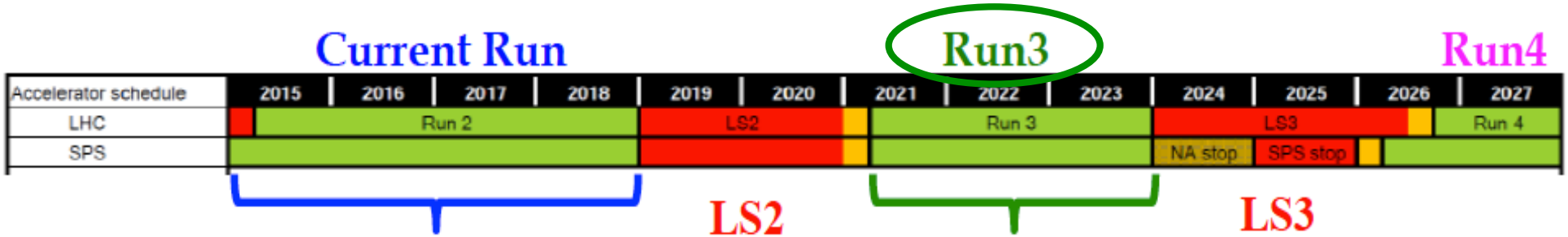
A rich field to be explored during Run3:

1. Present setup for K^+ beam and dedicated triggers: complete LFV/LNV high-sensitivity studies based on K^+/π^0:

   $K^+ \to \pi^+\mu^\pm e^\mp$, $K^+ \to \pi^-\mu^+e^+$, $K^+ \to \pi^-e^+e^+$, $K^+ \to \pi^-\mu^+\mu^+$ (+radiative modes)

   $\pi^0 \to \mu e$, 3γ, 4γ, ee, $eeee$

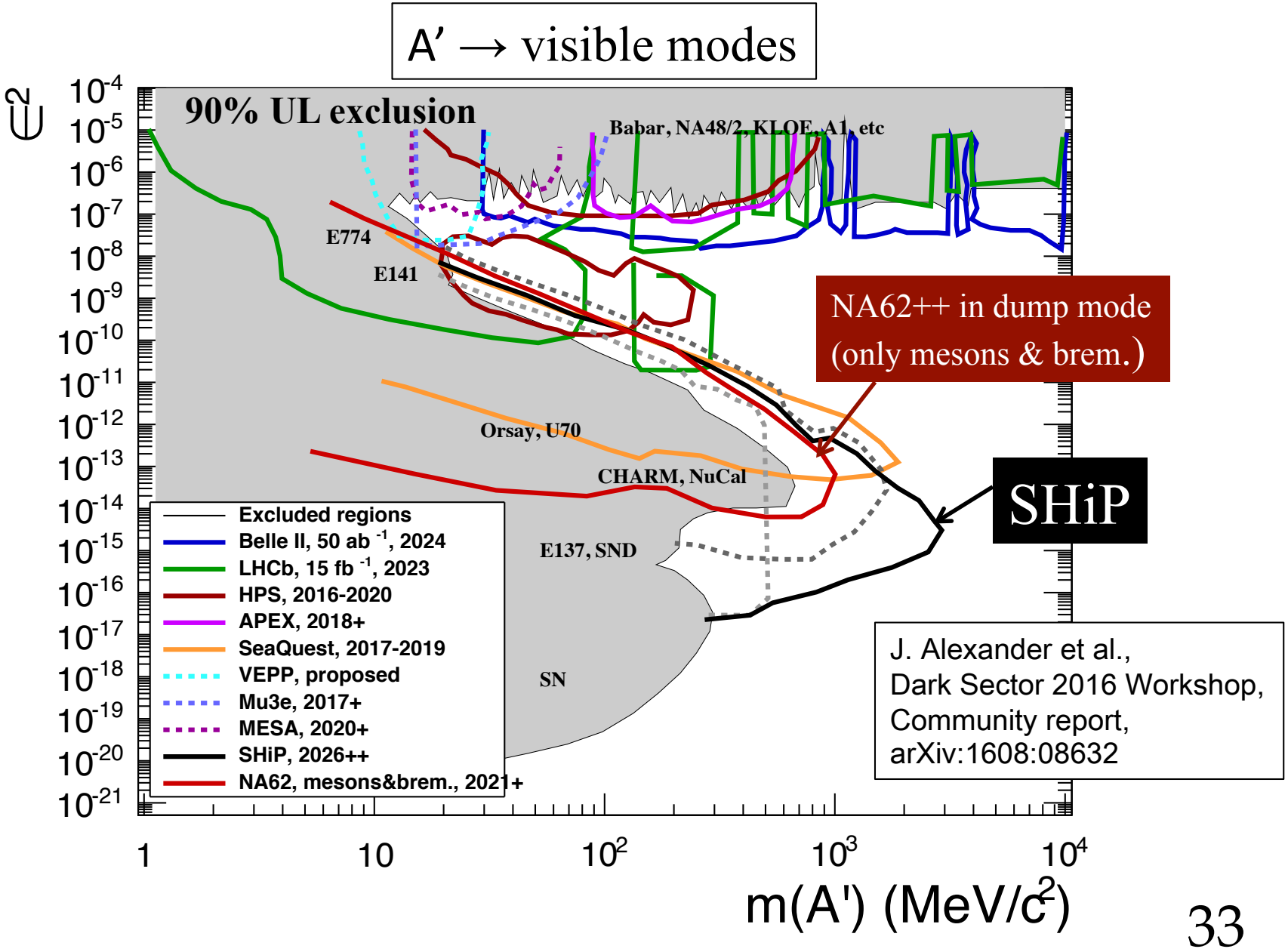
2. Year-long run in **"beam-dump" mode**, new program of NP searches for MeV-GeV mass hidden-sector candidates: **Dark photons, Heavy neutral leptons, Dark Scalars, Axions/ALP's, etc.**



NA62: $K^+ \to \pi^+ \nu\nu$, LNV/LFV decays, hidden sector searches in K decays

LFV/LNV @ ultimate sensitivity, hidden sector searches (beam dump)

Dark Photons in visible modes: past and future sensitivities



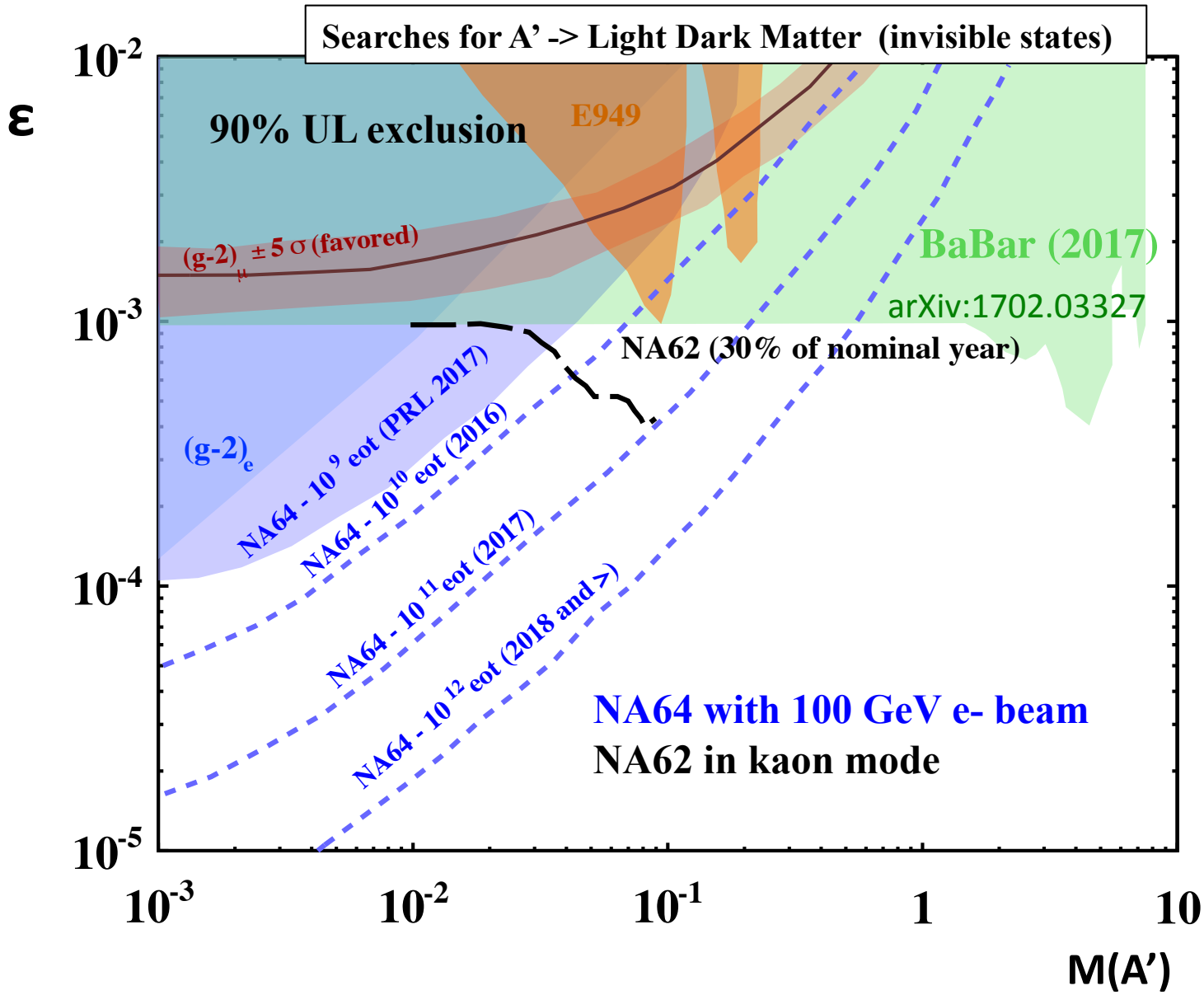
J. Alexander et al.,
Dark Sector 2016 Workshop,
Community report,
arXiv:1608:08632

Fixed Target Experiments @ CERN: NA64

Approved in March'16 for dark photon to invisible searches with 100 GeV e^- beam; electron beam dump, search for missing energy.

Current status: running

Dark Photons in invisible modes: past and future sensitivities



Research program of NA64++

1) Electron beam, 100 GeV

- Search for invisible (e+e-) decays of dark photon $A' \rightarrow$ invisible(e+e-)
- Search for the new boson $X \rightarrow e^+e^-$ from 8Be excess.
- Search for any light particles in active electron beam dump
- Search for millicharged particles

2) Muon beam, 150 GeV

- Search for L_μ-L_τ Z' boson. Could explain the $(g-2)_\mu$ anomaly
- Search for light scalars from dark sector
- Search for $\mu \rightarrow \tau$ conversion (LFV)

3) Pion and kaon beams, 50 GeV

- Search for invisible decays $K_{L,S} \rightarrow \nu\nu$. Complementary to $K_L \rightarrow \pi^0 \nu\nu$, Bell-Steinberger Unitarity, heavy neutrino.
- Search for π^0, η,η' $\rightarrow$ invisible decays, ~ sub-GeV DM

4) Proton beam, 250 –300 GeV

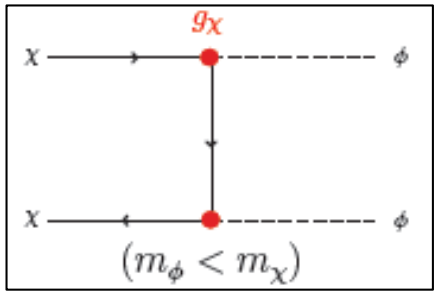
- Search for sub-GeV – GeV range particles coupled to quarks, ~ GeV DM
- Search for axion-like particles

The searches for $A' \rightarrow$ invisible decays, new light states coupled to muon, invisible decays of $K_{L,S}$ and η,η' are highly competitive and could provide the most precise probe of dark sector physics.

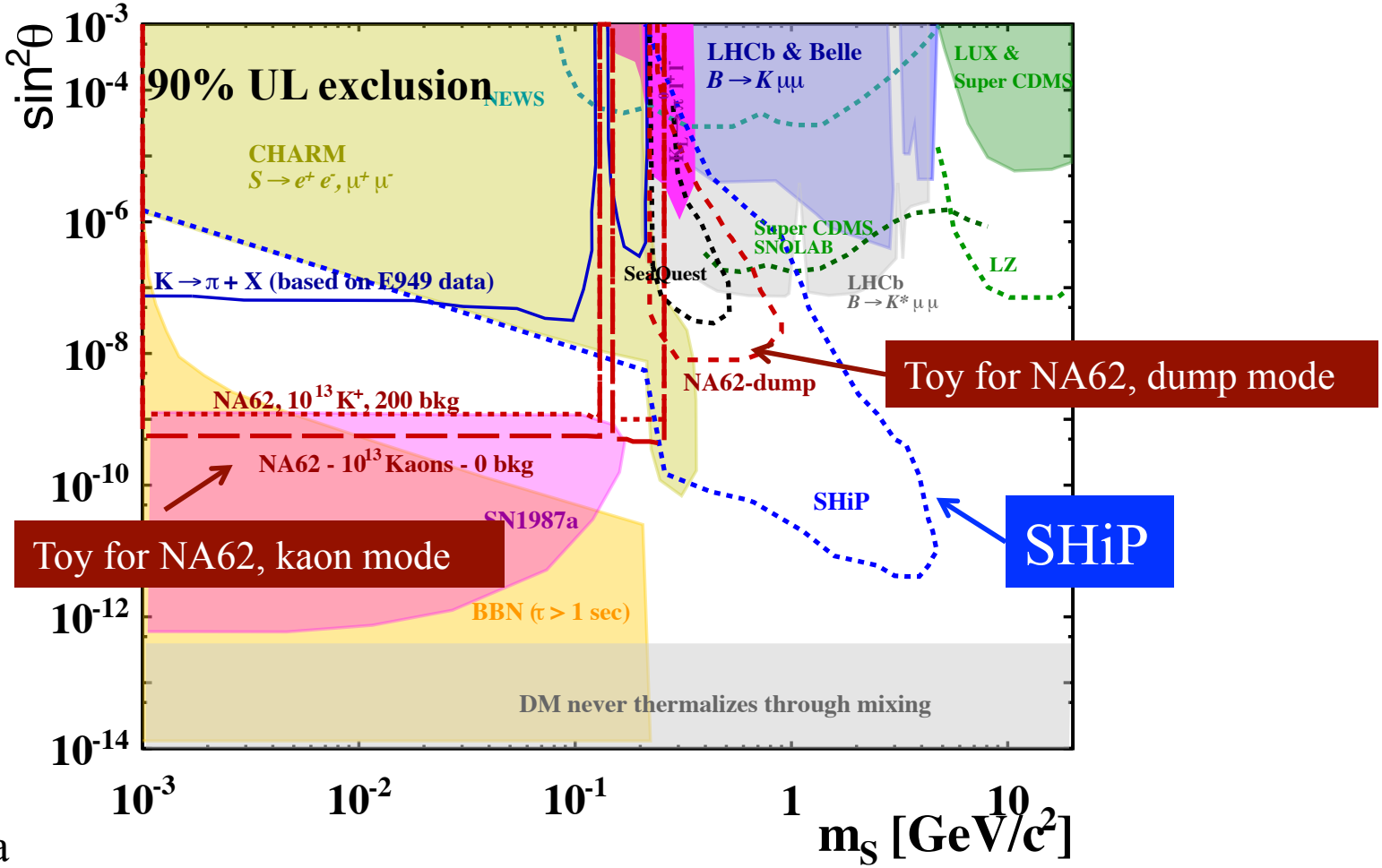
Light Dark Matter and Light Mediators: Scalar Portal

Dark Scalars in visible modes: past and future sensitivities

Secluded annihilation via mediators (only possibility compatible with CMB and rare mesons decays constraints), mediators decay to SM particles



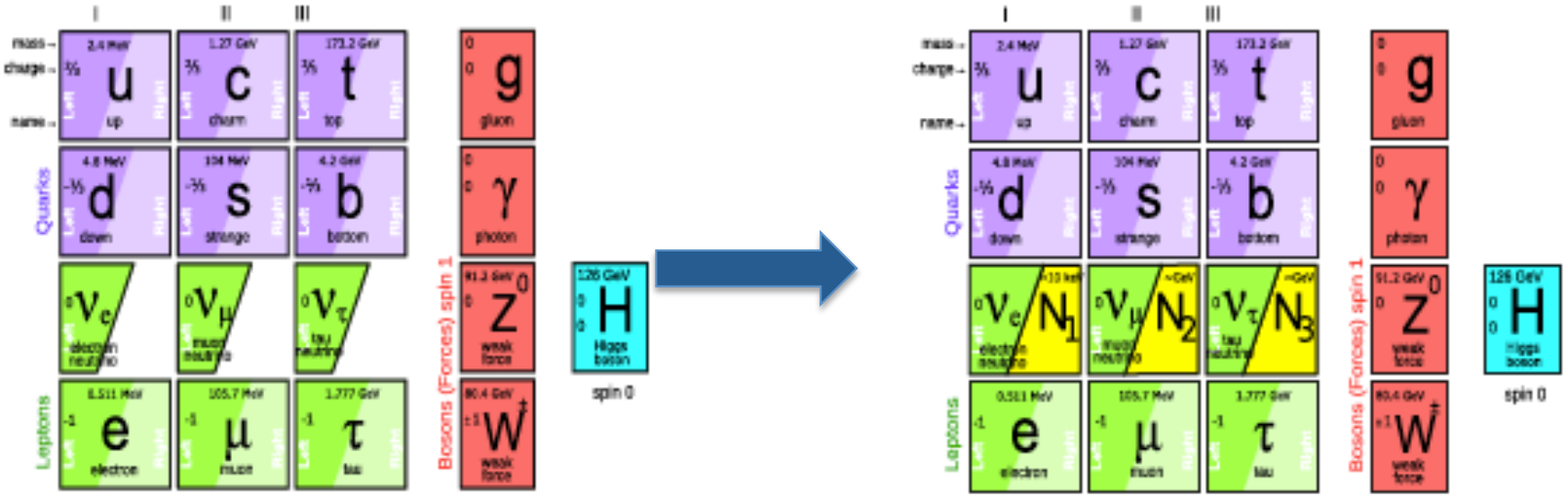
$g_\chi = \sin\theta$



NA64 can search for Dark Scalars in the reaction :
eZ ⟶ eZ S, S⟶ invisible
Results from the 2016 data sample are being finalized.

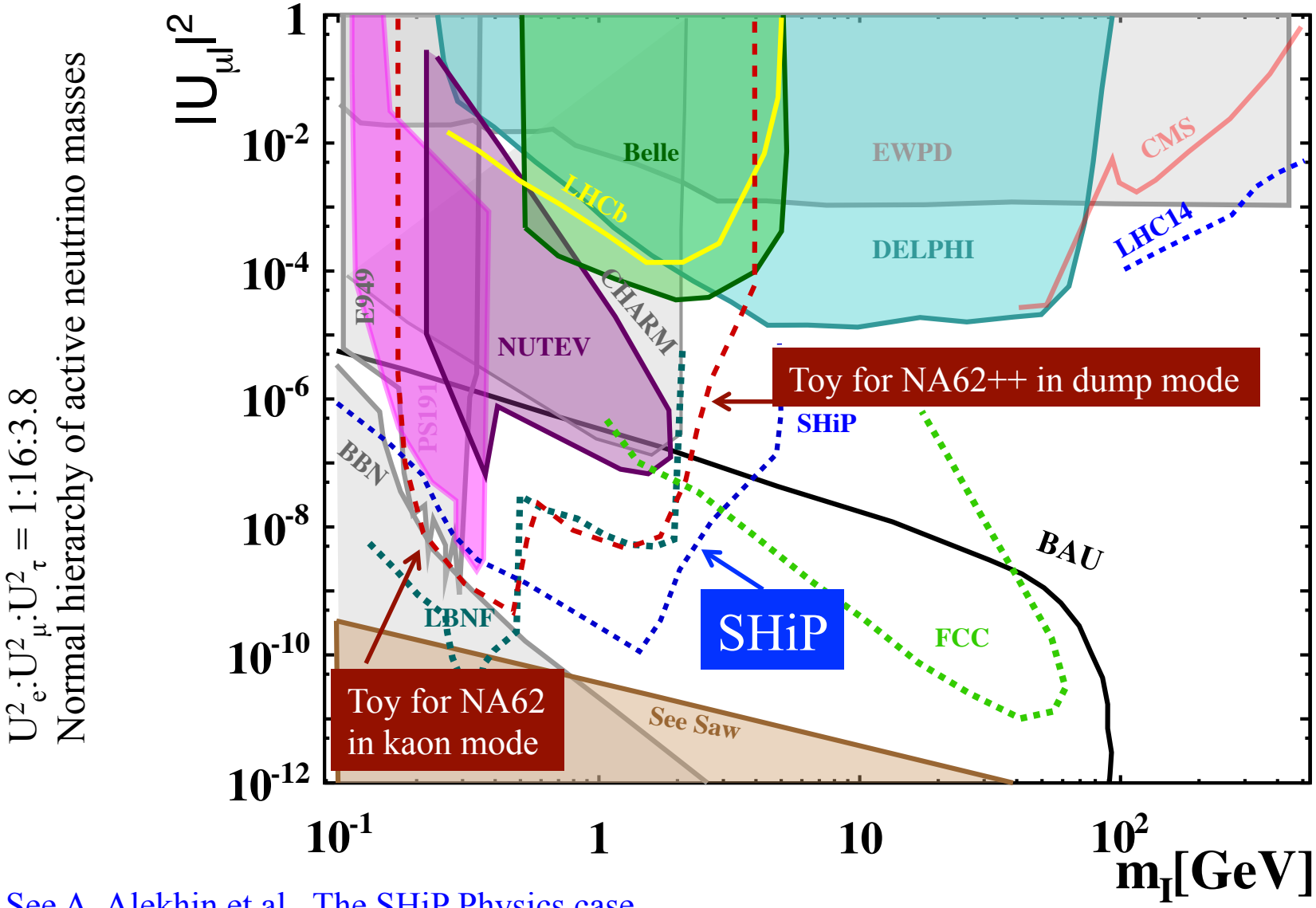
See G. Krnjaic, arXiv:1512.04119v1, and references therein

Baryogenesis (through leptogenesis), Light Dark Matter and origin of neutrino masses and oscillations: the neutrino portal



Eg: νMSM (M. Shaposhnikov et al.):
N_1 keV cold-DM candidate; CP-violating resonant oscillations between N_2 and N_3 produce sufficient lepton asymmetry that then transforms in baryon asymmetry

Heavy Neutral Leptons: past and future sensitivities



See A. Alekhin et al., The SHiP Physics case, arXiv:1504.04855 and references therein

NB: 1 SHiP year ~ 500 NA62 years

Rare mesons decays as a probe for New Physics

$K \to \pi\nu\bar{\nu}$: an overview

Extremely rare decays with rates very precisely predicted in SM:

	SM predicted rates*	Experimental status
$K^+ \to \pi^+\nu\bar{\nu}$	BR = (8.4 ± 1.0) × 10^{-11}	7 evts from BNL787 BR to 10% from **NA62** by 2018
$K_L \to \pi^0\nu\bar{\nu}$	BR = (3.4 ± 0.6) × 10^{-11}	Only limits at present **KOTO** (JPARC): ~few SM events by 2021

New physics affects K^+ and K_L differently

Measurements of both can discriminate among NP scenarios

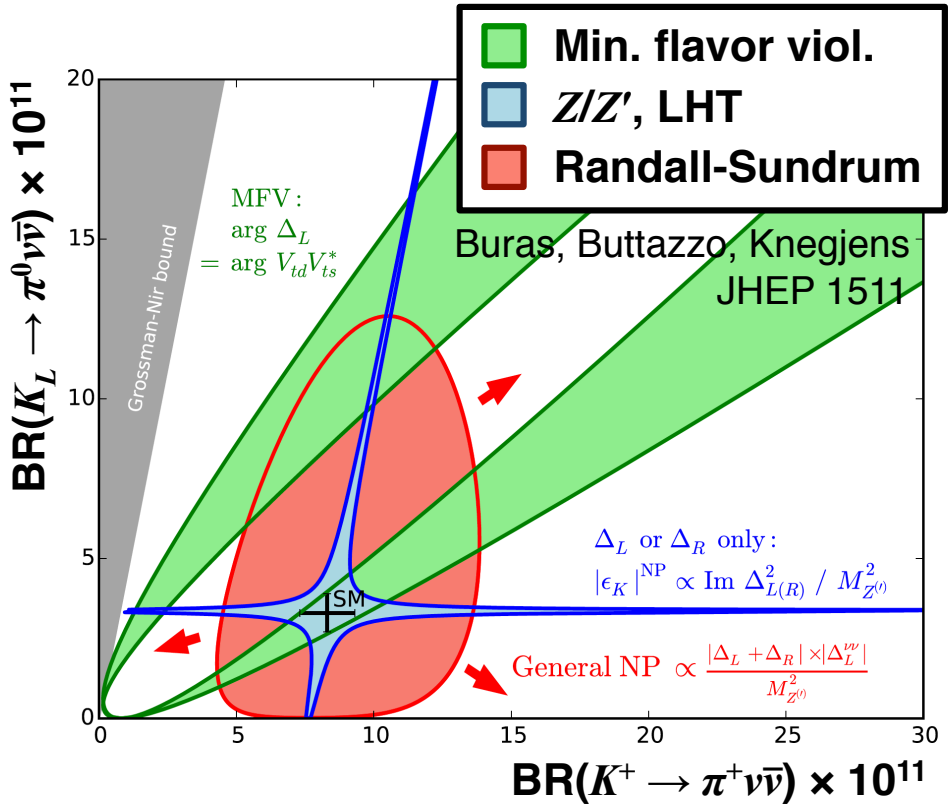
***K_LEVER* sensitivity**

5 years starting Run 4

60 SM $K_L \to \pi^0\nu\bar{\nu}$ events

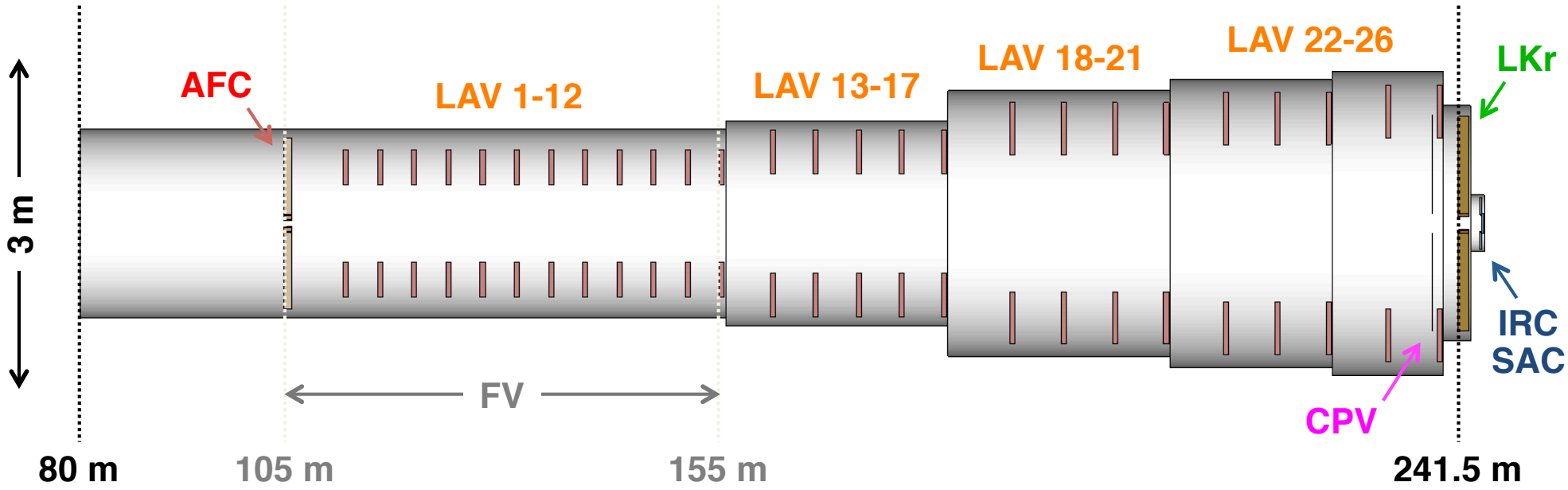
S/B ~ 1

BR($K_L \to \pi^0\nu\nu$) ≃ 20%



Buras et al, JHEP 1511*

K_LEVER, an experiment to measure $K_L \to \pi^0 \bar{\nu}\nu$



For 60 SM events, need:

5×10^{19} pot

E.g. 2×10^{13} ppp/16.8 s × 5 yrs

$\langle p_K \rangle$ **= 70 GeV** for decays in FV

Photons from $K_L \to \pi^0\pi^0$ boosted forward for easier vetoing

Much higher energy than KOTO: Complementary approach

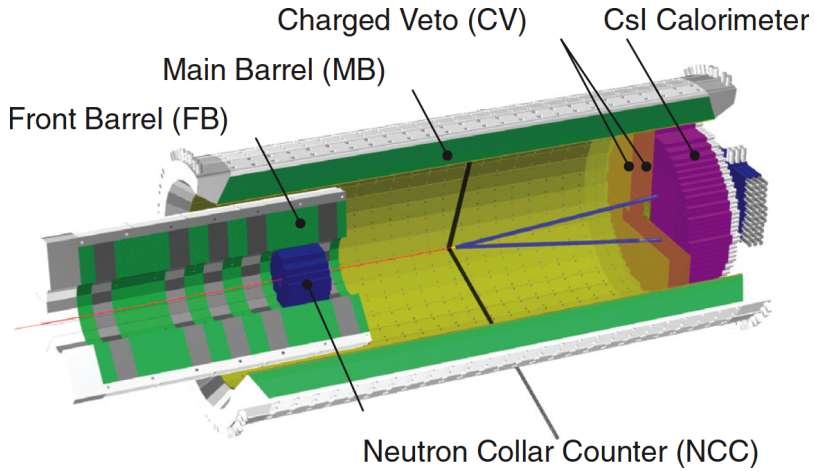
Main detector/veto systems:

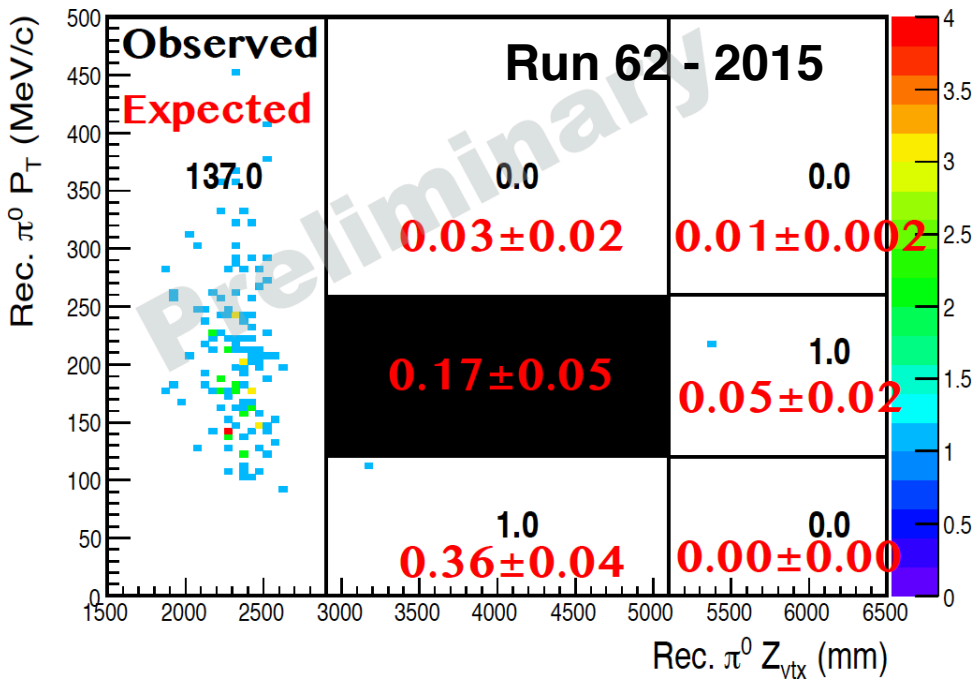
AFC	Active final collimator/upstream veto
LAV1-26	Large-angle vetoes (26 stations)
LKr	NA48 liquid-krypton calorimeter
IRC/SAC	Small-angle vetoes
CPV	Charged-particle veto

Main competitor: $K_L \rightarrow \pi^0 \nu\nu$ at J-PARC

Primary beam: 30 GeV p

$\langle p_K \rangle$ = 2.1 GeV





Current status:

- Reached **42 kW** of slow-extracted beam power in 2015
- Preliminary results: 10% of 2015 data (signal box not unblinded yet)

  SES = 5.9×10^{-9}, exp. bkg: 0.17
- **Expect to reach SM sensitivity by 2021**

KOTO step-2 upgrade:

- strong intention to **upgrade to o(100) events sensitivity** (but **no proposal yet**…)
- explore machine (**>100 kW**) and detector upgrades to increase sensitivity;
- **Indicative time scale for data taking: 2025++**

Conclusions

Experimental proposals considered in the BSM WG focus **on low-energy processes that can answer in a complementary way the same fundamental questions of present (or future) high-energy accelerator** facilities;

Projects presented at CERN so far:

- **SHiP, NA62++, NA64++, KLEVER, IAXO, LSW, EDM**

cover a **wealth of highly-justified physics cases** where **CERN can play a leading and unique role.**

The aim of the BSM WG in the coming two years will be to analyse in detail the proposals and understand how they are placed in the world-wide physics landscape.

….We are beginning a two-year journey…

Thank you for your attention !