Neutrinos as a Window Beyond the SM

Enrique Fernández-Martínez

HIDDeν
Hunting Invisibles: Dark sectors, Dark matter and Neutrinos

Asymmetry
Essential Asymmetries of Nature

ν and BSM

Adapted from: P. Coloma, L. Koerner, I. Shoemaker and J. Yu Snowmass report
see arXiv:2209.10362 for summary and links to dedicated analyses

ν and BSM

ν masses require BSM physics

See talk by Mikhail Shaposhnikov

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Simplest option to add ν_R to the SM content

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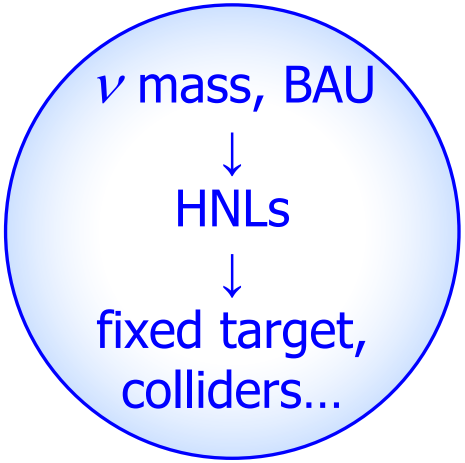

Probed in fixed target including ND of oscillation experiments: NuTeV, T2K, NA62, ProtoDUNE, SHiP, DUNE, ICARUS, SBND, μBooNE…

Or from atmospheric: SK, IceCube, HK ESSνSB, INO-ICAL, KM3NeT-ORCA,…

Also in nuclear decay kinematics: KATRIN/Tristan, HUNTER…

Collider searches: ATLAS, CMS, Faser, Belle II…

See posters by Xaver Stribl, Alexandre Sousa, Kevin Urquia, Matheus Hostert, Julia Book Motzkin

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ν mass, BAU
↓
non-Unitarity
↓
EWPO, flavour
oscillations…

ν mass, BAU
↓
HNLs
↓
fixed target,
colliders…

If they are too heavy to be produced: indirect searches from PMNS non-unitarity: electroweak precision and flavour observables

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Also "zero distance" effect in oscillations: solar, reactors, MINOS/MINOS+, NOνA, T2K, IceCube, HK, ESSνSB, INO-ICAL, KM3NeT-ORCA, DUNE, JUNO, TAO, SUPERCHOOZ/CLOUD…

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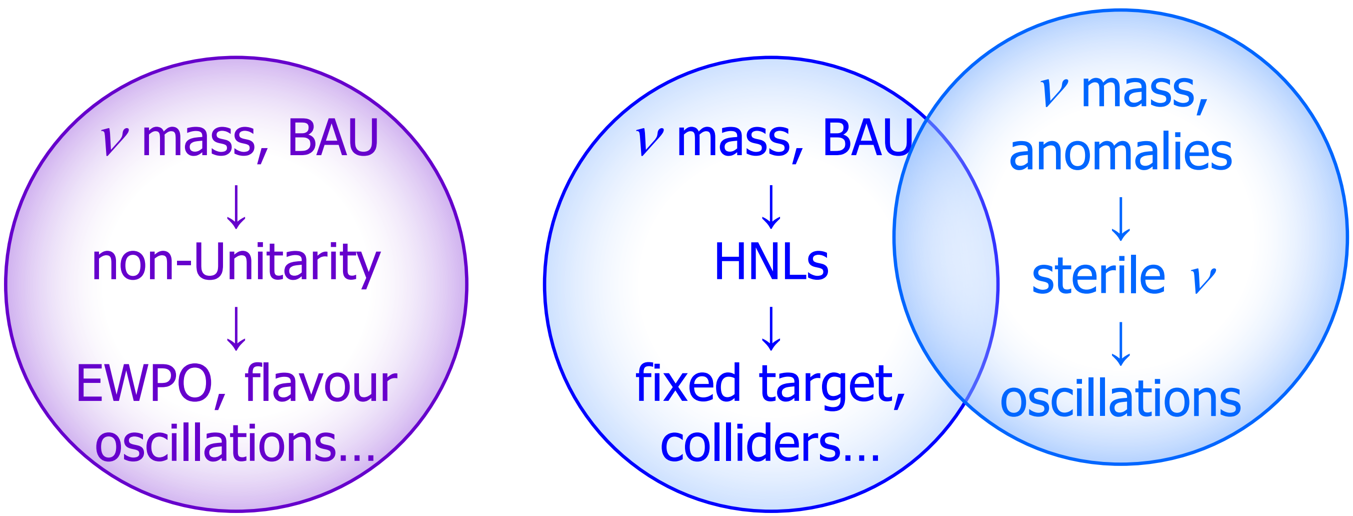

If they are very light they participate in oscillations

See talks at sessions 2,14 and 15 and posters by Alexandre Sousa, Tetiana Kozynets

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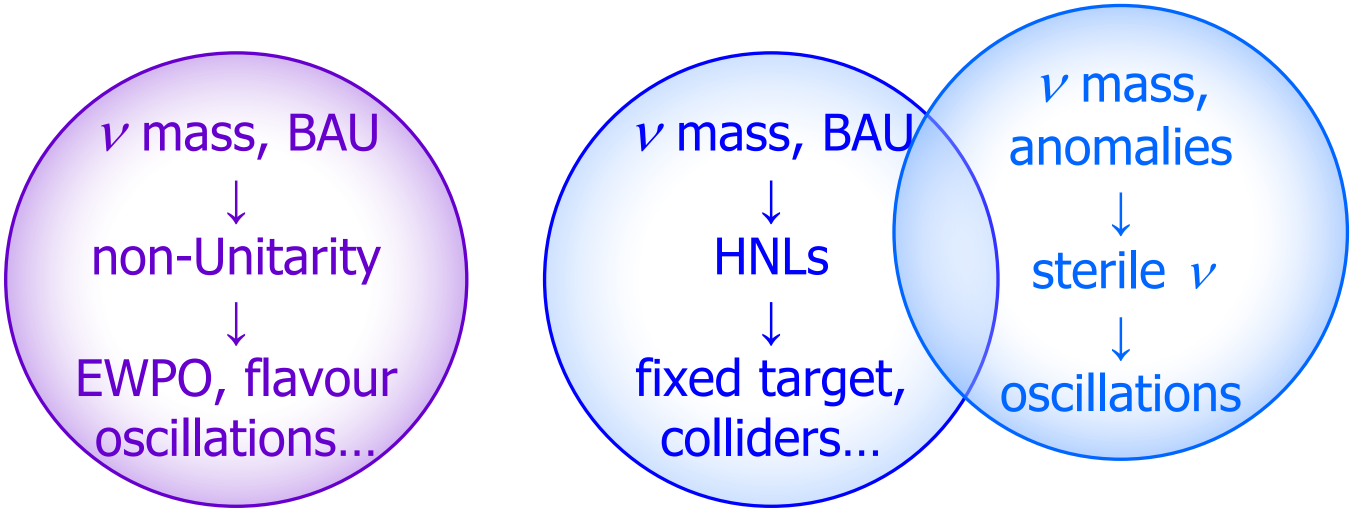

But also "zero distance" effect in averaged-out oscillations: solar, reactors, MINOS/MINOS+, NOνA, T2K, IceCube, HK, ESSνSB, INO-ICAL, KM3NeT-ORCA, DUNE, JUNO, TAO, SUPERCHOOZ, CLOUD…

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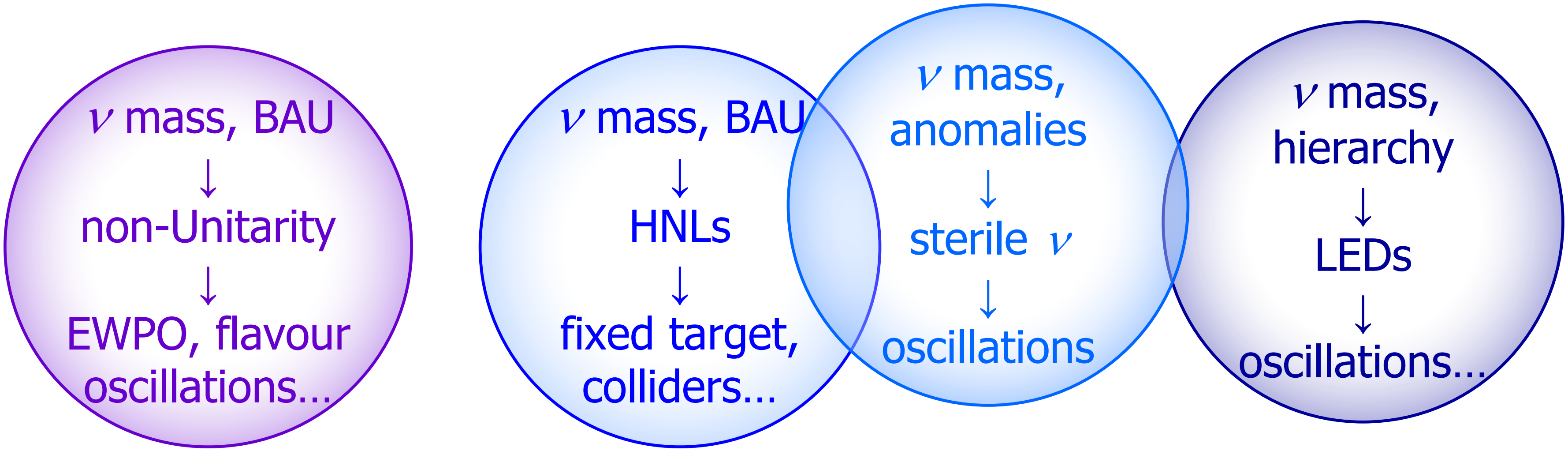
ν and BSM

Possible connections to other open problems: LED may address the hierarchy problem and ν masses



Similar pheno to steriles but with characteristic masses and mixings: solar, reactors, MINOS/MINOS+, NOνA, T2K, IceCube, HK, ESSνSB, INO-ICAL, KM3NeT-ORCA, DUNE, JUNO/TAO, SUPERCHOOZ/CLOUD…

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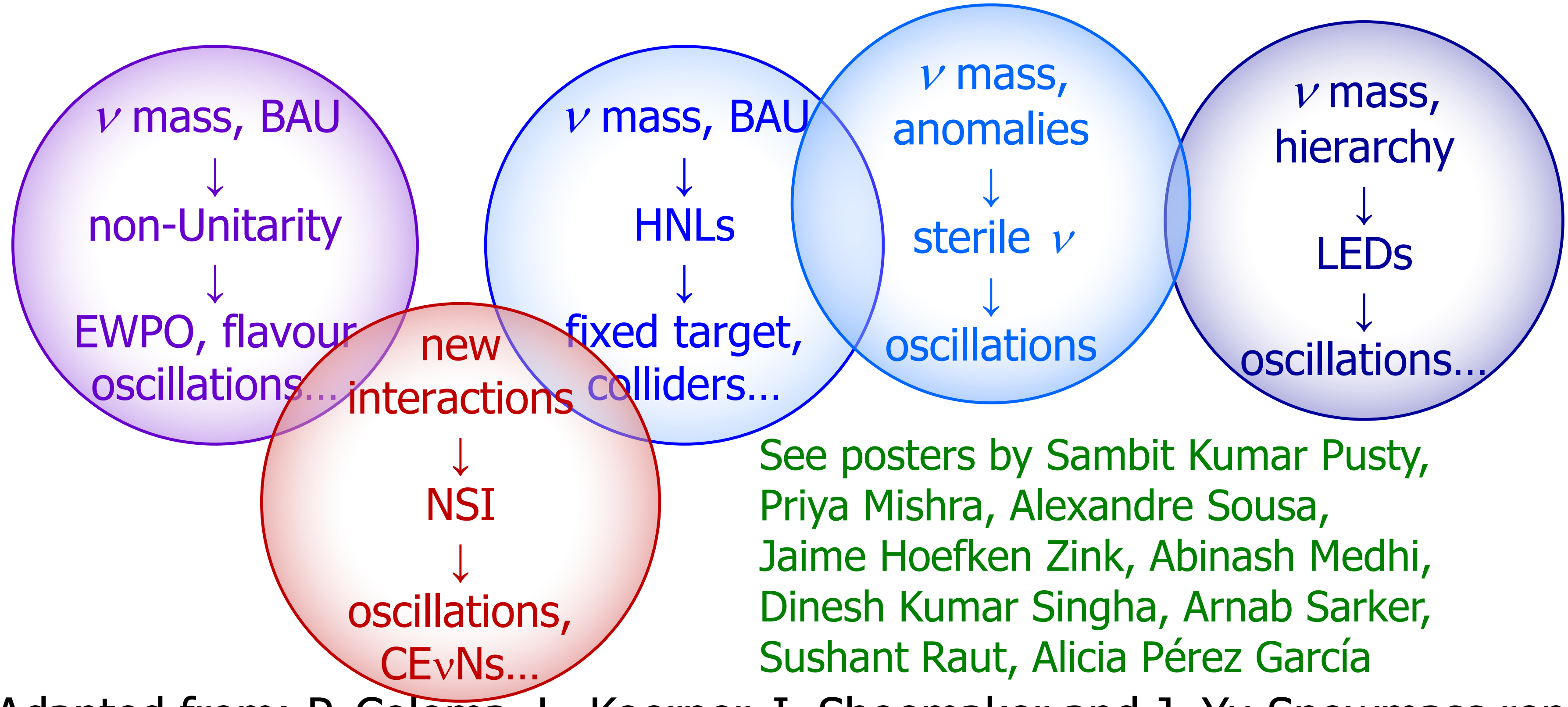
ν and BSM

Also searches for non-standard ν properties:
NSI: affect oscillations solars, MINOS/MINOS+, NOνA, T2K, IceCube, HK, ESSνSB, INO-ICAL, KM3NeT-ORCA, DUNE IsoDAR...
and directly probed through CEνNs: COHERENT, CONNIE, CONUS...



See posters by Sambit Kumar Pusty, Priya Mishra, Alexandre Sousa, Jaime Hoefken Zink, Abinash Medhi, Dinesh Kumar Singha, Arnab Sarker, Sushant Raut, Alicia Pérez García

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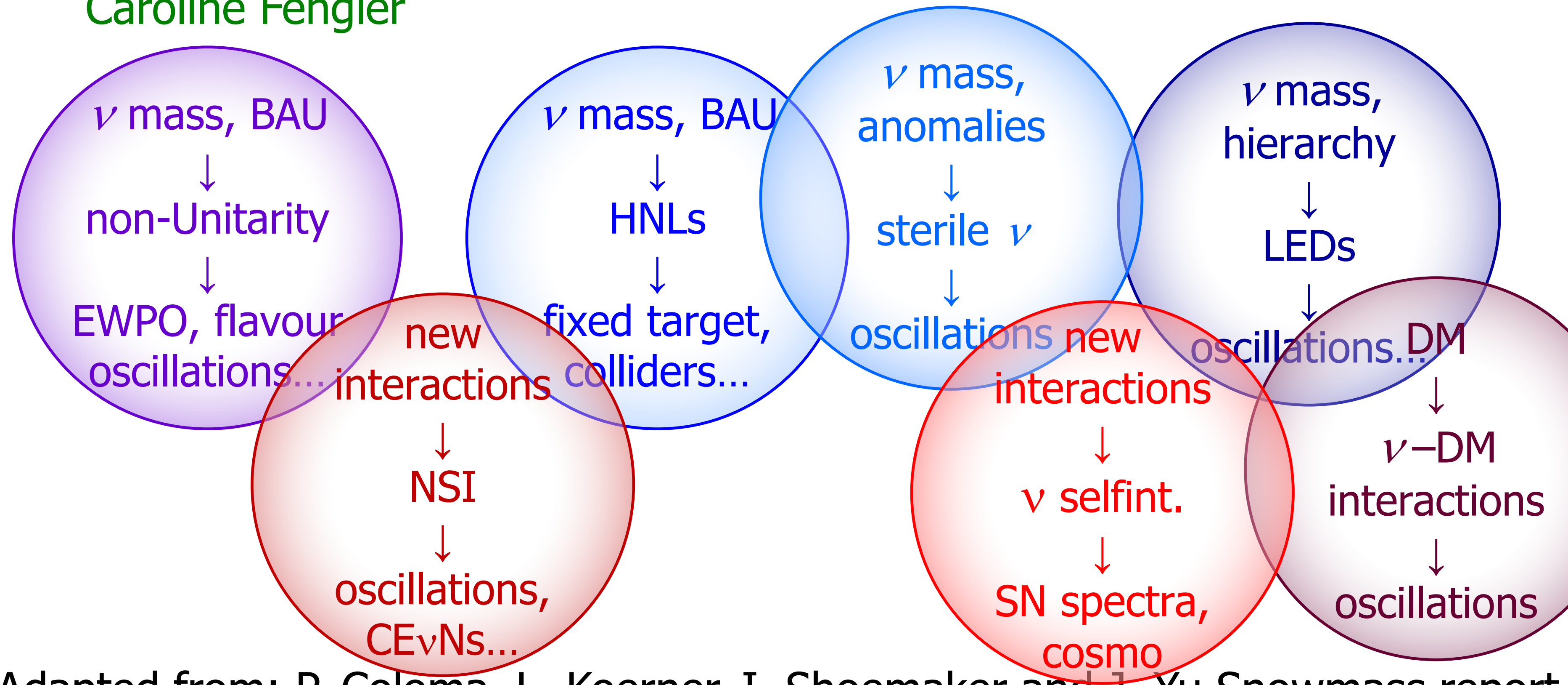
ν and BSM

Also searches for non-standard ν properties:

Longer range forces or interactions with DM → modified matter potentials

Self-interactions → impact cosmological abundance and distort SN fluxes

See talk by Stefano Gariazzo, posters by Diyaselis Delgado, Caroline Fengler



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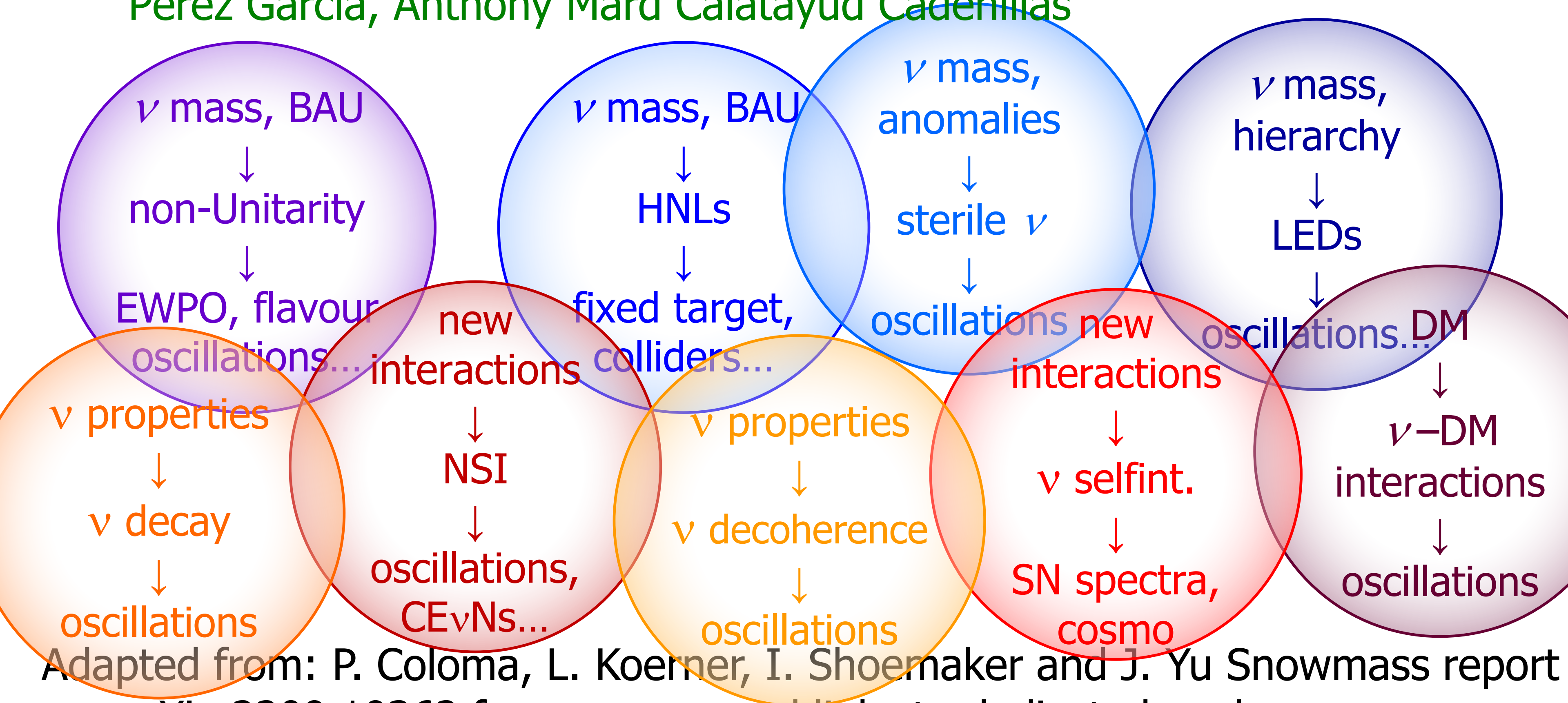
ν and BSM

Also searches for non-standard ν properties:

Neutrino decay or decoherence would also impact oscillations: solar, MINOS/MINOS+, NOνA, T2K, IceCube, HK, ESSνSB, INO-ICAL, KM3NeT-ORCA, DUNE, JUNO,… See posters by Anil Kumar, George Parker, Alicia Pérez García, Anthony Mard Calatayud Cadenillas



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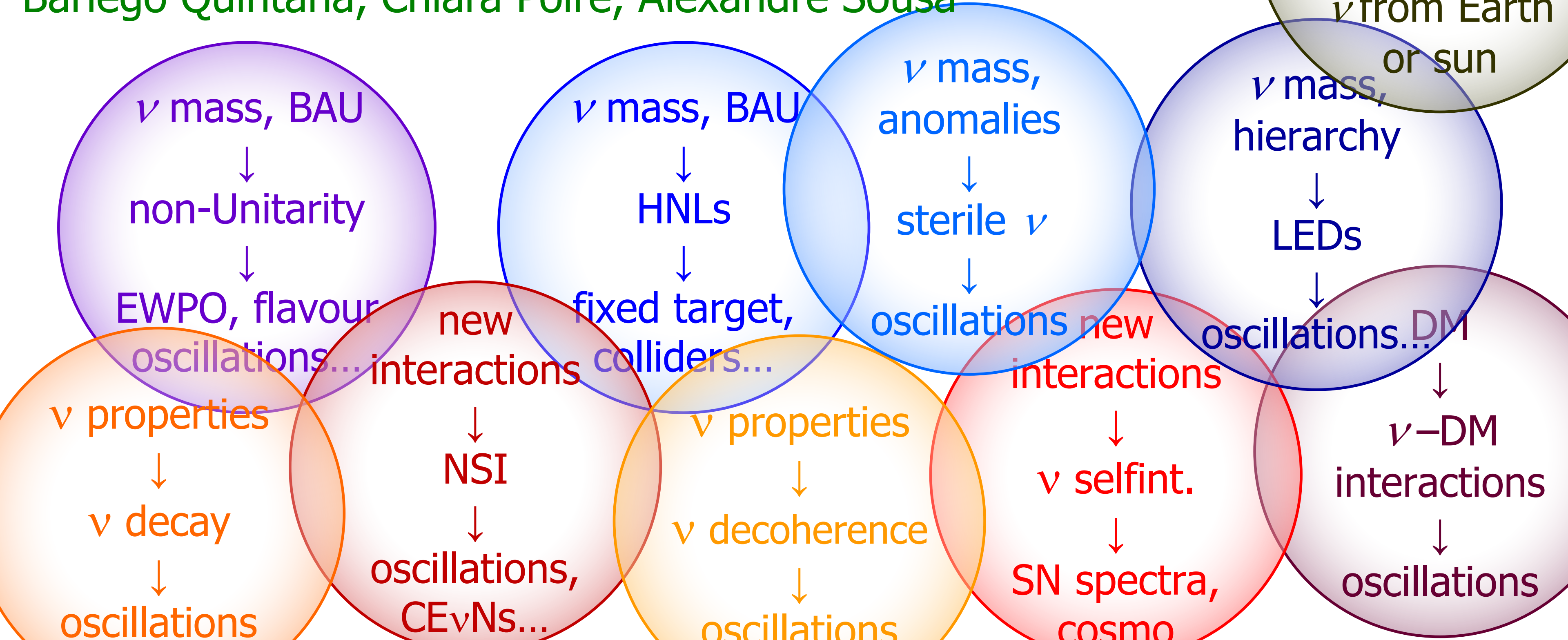
ν and BSM

New dark sectors may be probed with ν facilities:
DM annihilation to ν from Sun SK, IceCube, HK, ESSνSB,…
Accelerated DM with CR scattering with nucleons SK, JUNO, DUNE,… See talk by Laura Baudis and posters by Adriana Bariego Quintana, Chiara Poirè, Alexandre Sousa



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ν and BSM

New dark sectors may be probed with ν facilities: DS like Z′ or millicharged particles produced in fixed target and scattering or decay in ND: HK, ProtoDUNE, SHiP, DUNE, ICARUS, SBND, μBooNE…

new particles ↓ millicharged ↓ fixed targed e scattering

DM ↓ DM → ν ↓ ν from Earth or sun

ν mass, BAU ↓ non-Unitarity ↓ EWPO, flavour oscillations…

ν mass, BAU ↓ HNLs ↓ fixed target, colliders…

ν mass, anomalies ↓ sterile ν ↓ oscillations

ν mass, hierarchy ↓ LEDs ↓ oscillations…

ν properties ↓ ν decay ↓ oscillations

new interactions ↓ NSI ↓ oscillations, CEνNs…

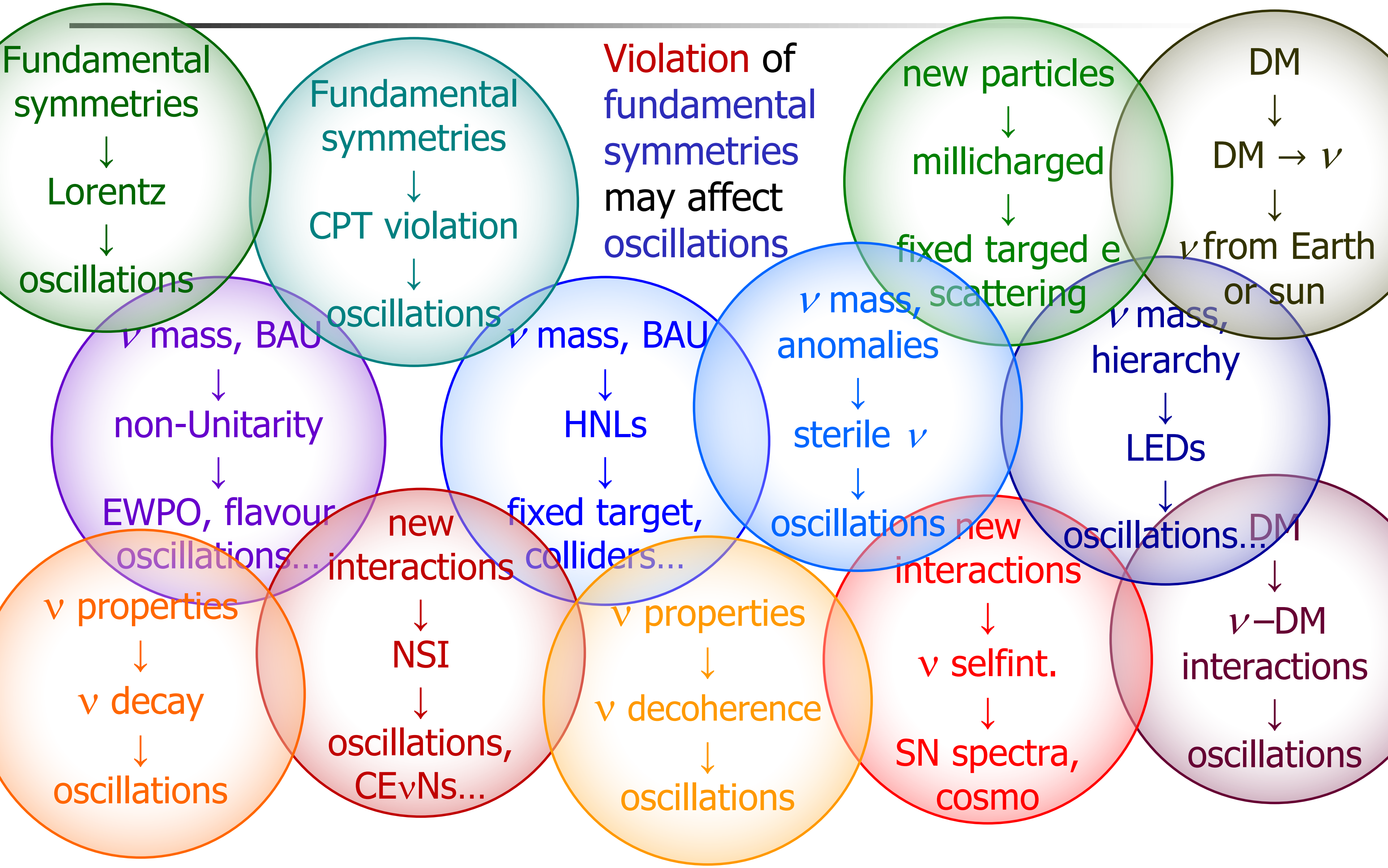
ν properties ↓ ν decoherence ↓ oscillations

new interactions ↓ ν selfint. ↓ SN spectra, cosmo

DM ↓ ν–DM interactions ↓ oscillations

See posters by Gray Putnam, Daniel Mayer, Austin Schneider, Matheus Hostert

ν and BSM



See posters by Lukas Hennig, Supriya Pan, Alicia Pérez García

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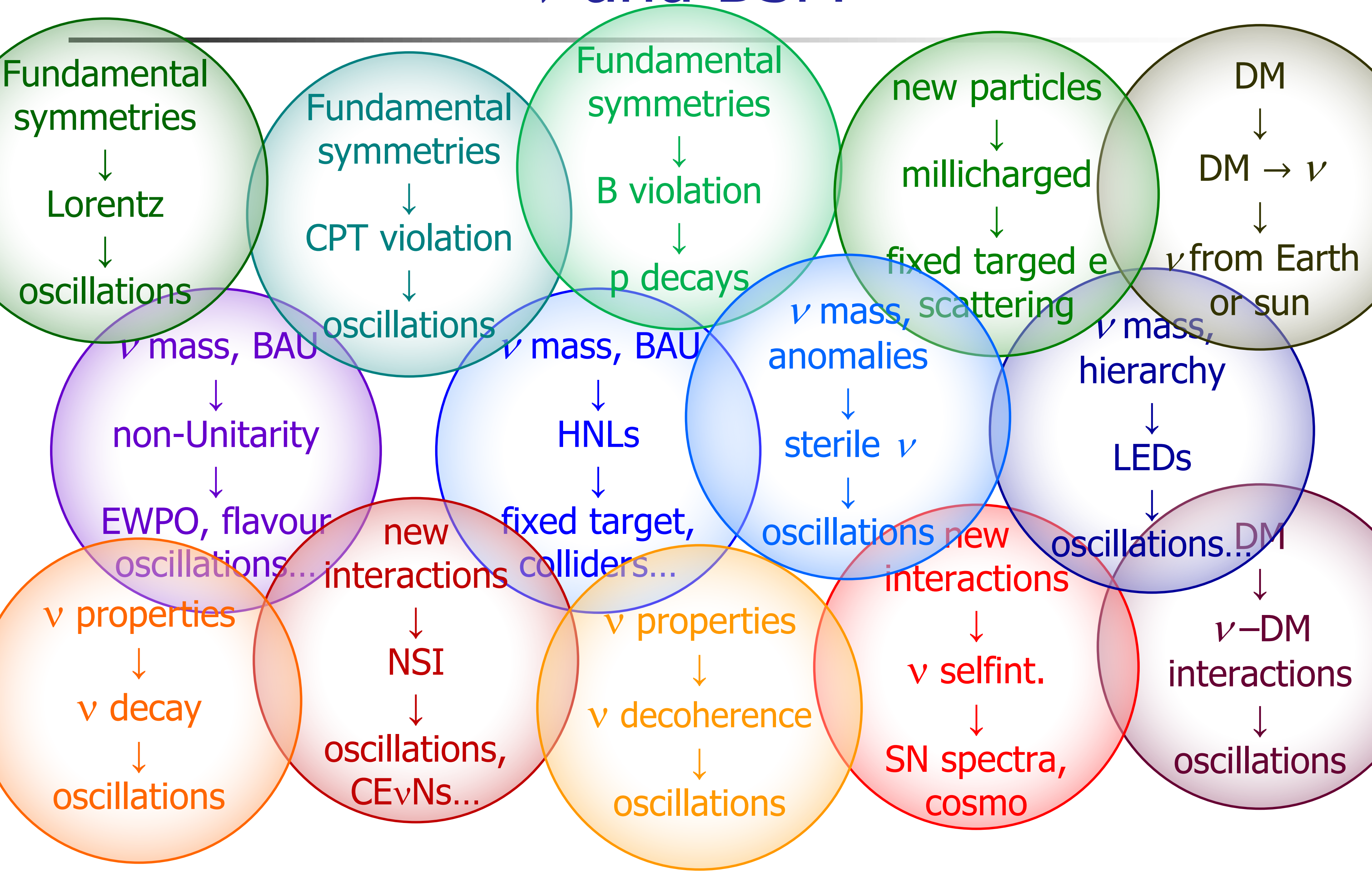

See posters by Natsumi Taniuchi, Joshua Barrow, Daisy Kalra, Roxanne Guenette, Cailian Jiang

ν mass from right-handed neutrinos

Simplest option add ν_R and acquire Dirac masses via Yukawas

$$Y_\nu \bar{\nu}_R \phi \nu_L \xrightarrow[\langle\phi\rangle = \frac{Y_f v}{\sqrt{2}}]{\text{SSB}} \frac{Y_\nu v}{\sqrt{2}} \bar{\nu}_R \nu_L \qquad m_D = \frac{Y_\nu v}{\sqrt{2}}$$

See talk by Mikhail Shaposhnikov

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but a Majorana mass is also allowed…

$$M_N \bar{\nu}_R \nu_R^c$$

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Fermion number violation → Baryogenesis via Leptogenesis

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The first mass scale not related to the EW scale and the Higgs

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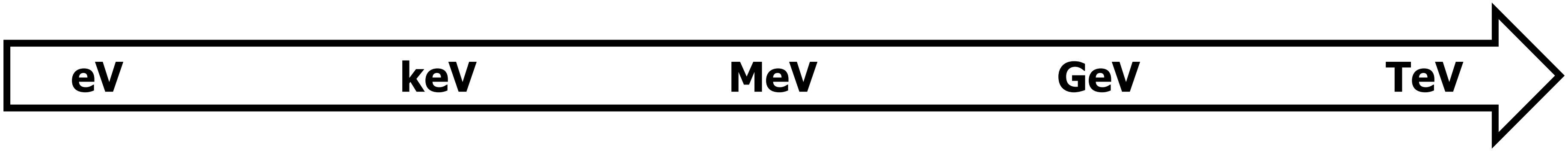
The first mass scale not related to the EW scale and the Higgs

→ To be searched for at experiments!!

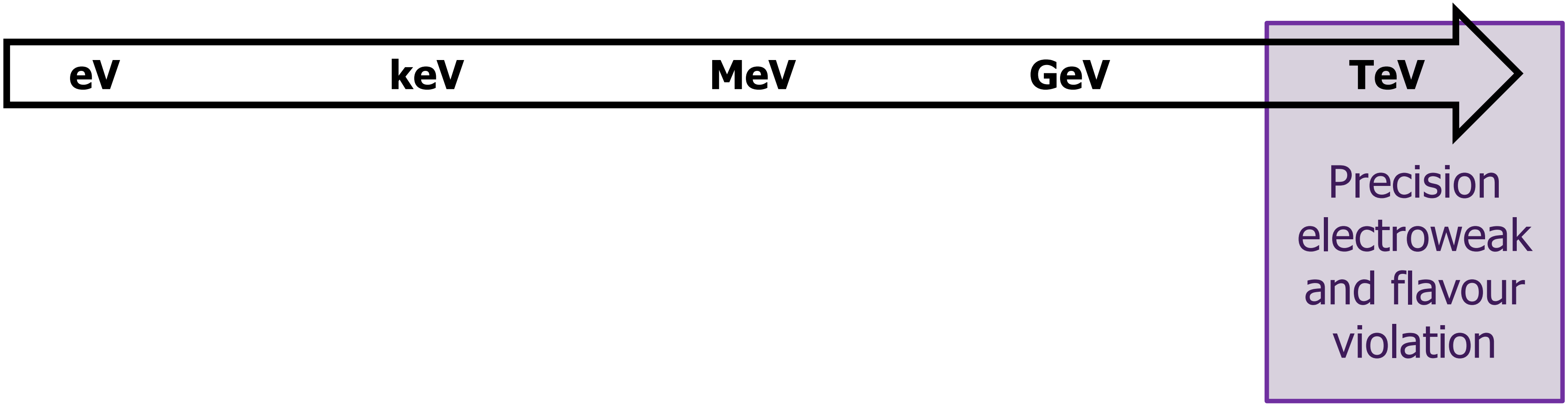
A new physics scale



M_N could be anywhere…

Very different phenomenology at different scales

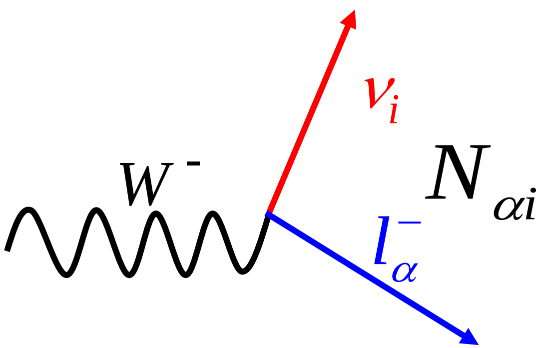
A new physics scale

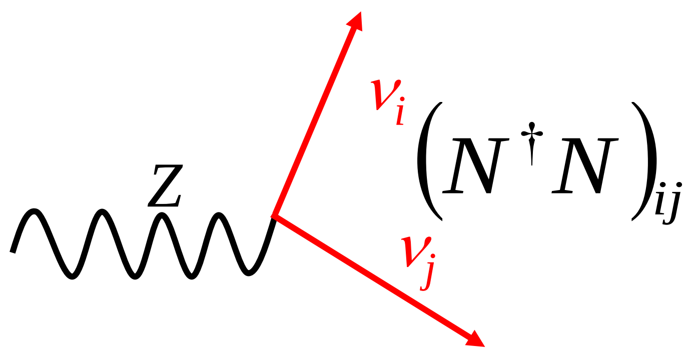


Looking for ν_R: Non-Unitarity

$$U^t \begin{pmatrix} 0 & m_D^t \\ m_D & M_N \end{pmatrix} U \approx \begin{pmatrix} N^t & -\Theta^* \\ \Theta^t & X^t \end{pmatrix} \begin{pmatrix} 0 & m_D^t \\ m_D & M_N \end{pmatrix} \begin{pmatrix} N & \Theta \\ -\Theta^\dagger & X \end{pmatrix} = \begin{pmatrix} m & 0 \\ 0 & M \end{pmatrix}$$

The 3×3 submatrix *N* of active neutrinos will not be unitary





Effects in weak interactions…

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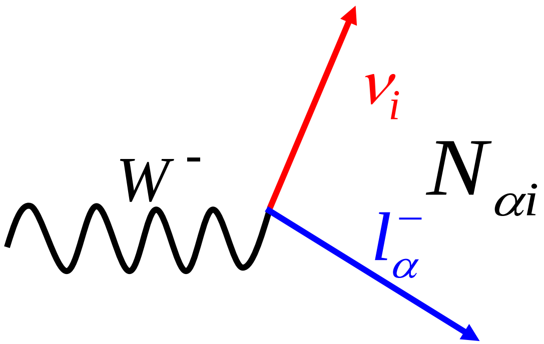

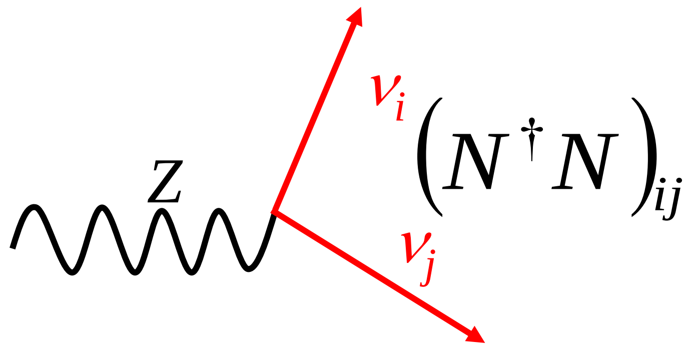

Effects in weak interactions…

When the W and Z are integrated out to obtain the Fermi theory NSI are recovered!

see e.g. M. Blennow, P.Coloma, EFM, J. Hernandez-Garcia and J. Lopez-Pavon arXiv:1609.08637 for the dictionary

Non-unitarity in oscillations

Just replace U by N

$$P_{\alpha\beta}(L) = \sum_{i,j} N_{\beta i} N^*_{\alpha i} N_{\alpha j} N^*_{\beta j} e^{\frac{-\Delta m^2_{ij} L}{2E}}$$

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Careful!! The "zero distance effect" will also be present in the data used to estimate the flux and cross section

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Careful!! The "zero distance effect" will also be present in the data used to estimate the flux and cross section

For instance, if the prediction for $P_{\mu e}$ comes from near detector data on $P_{\mu\mu}$:

$$\hat{P}_{\mu e}(L) = \frac{P_{\mu e}(L)}{P_{\mu\mu}(0)} = \frac{\sum_{i,j} N_{ei} N^*_{\mu i} N_{\mu j} N^*_{ej} e^{\frac{-\Delta m^2_{ij} L}{2E}}}{\left|\left(NN^\dagger\right)_{\mu\mu}\right|^2}$$

M. Blennow, P. Coloma, EFM, J. Hernandez-Garcia and J. Lopez-Pavon arXiv:1609.08637

Non-unitarity in oscillations

Also, no zero distance effect in disappearance channles!!

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These are often thought to be the strongest bounds, but the effect cancels (together with the systematics) when using actual data involving ν to predict the unoscillated events

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And data involving neutrinos is always necessary:
If I know π flux from hadroproduction need $\pi \to \mu \nu$ Br
Even if computing from "first principles" need G_F (μ decay) and V_{ud} (β decay)

M. Blennow, P. Coloma, EFM, J. Hernandez-Garcia and J. Lopez-Pavon arXiv:1609.08637

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These are often thought to be the strongest bounds, but the effect cancels (together with the systematics) when using actual data involving ν to predict the unoscillated events

At most, if the prediction comes from a different channel, one may constrain the ratio

$$\frac{\left| \left(N N^\dagger \right)_{\alpha\alpha} \right|^2}{\left| \left(N N^\dagger \right)_{\beta\beta} \right|^2}$$

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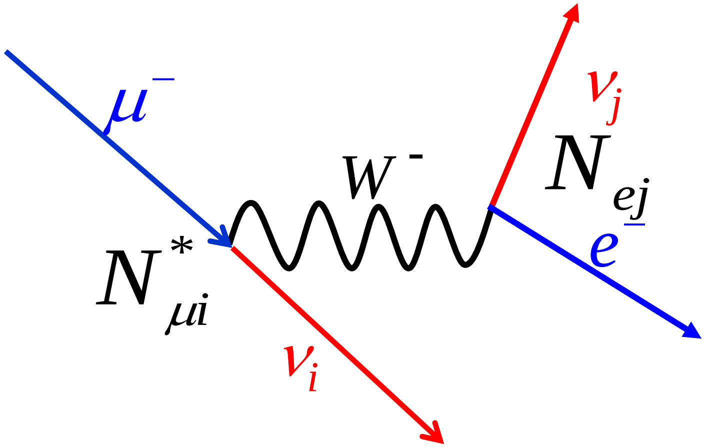
But these are more efficiently constraint from LFU bounds, from instance π decay ratios, no need to also detect the ν…

Non-unitarity beyond oscillations

G_F from μ decay is affected!



$$G_\mu = G_F \left(NN^\dagger\right)_{ee} \left(NN^\dagger\right)_{\mu\mu}$$

Non-unitarity beyond oscillations

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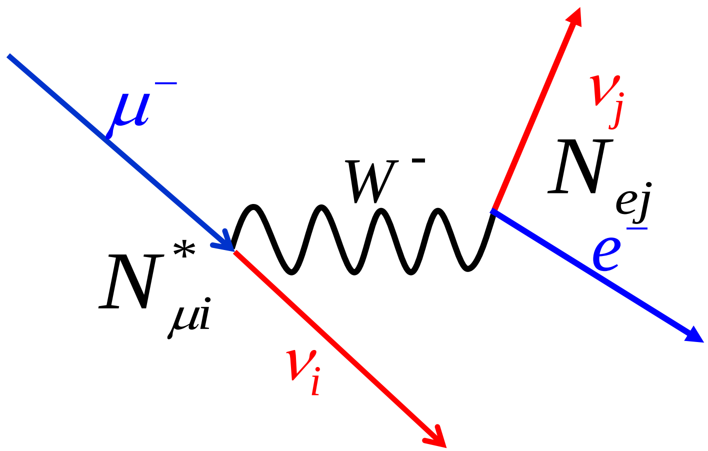

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But this agrees at $\sim 10^{-3}$ with G_F from M_W (modulo CDF), measurents of $\sin\theta_W$ from LEP, Tevatron and LHC and β and K decays

Non-unitarity beyond oscillations

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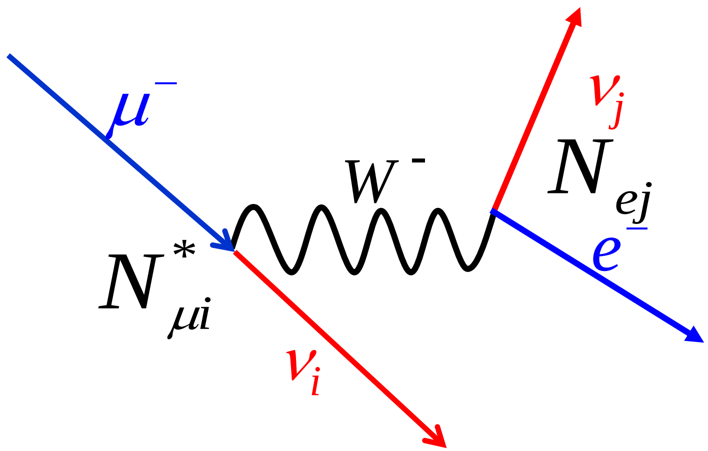

$$G_\mu = G_F \left(NN^\dagger\right)_{ee} \left(NN^\dagger\right)_{\mu\mu}$$

But this agrees at ~10^{-3} with G_F from M_W (modulo CDF), measurents of sinθ_W from LEP, Tevatron and LHC and β and K decays

LFU also strong bounds on ratios:

$$\frac{\left(NN^\dagger\right)_{\alpha\alpha}}{\left(NN^\dagger\right)_{\beta\beta}}$$

From ratios of π, K, and lepton decays

Non-unitarity beyond oscillations

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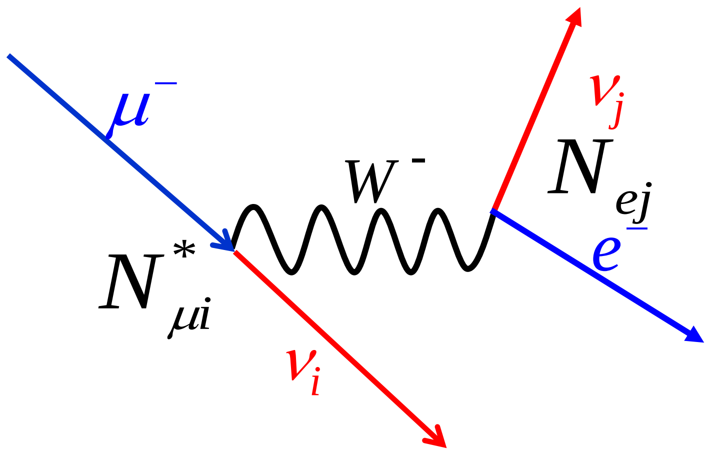

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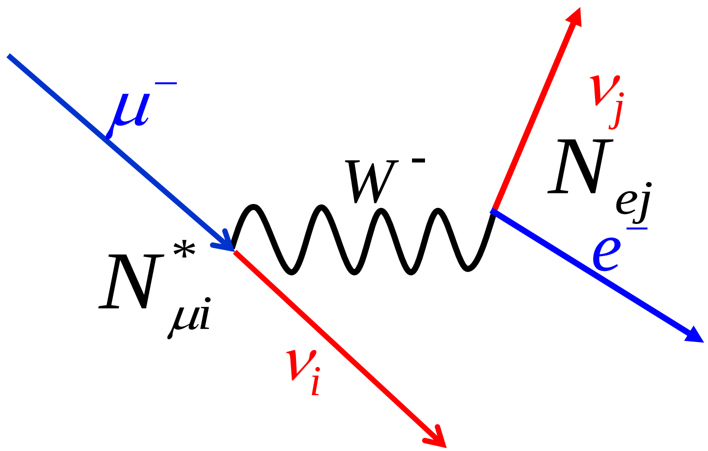
Also the invisible width of the Z since NC are also affected

Non-unitarity beyond oscillations

G_F from μ decay is affected!



$$G_\mu = G_F \left(NN^\dagger\right)_{ee} \left(NN^\dagger\right)_{\mu\mu}$$

But this agrees at $\sim 10^{-3}$ with G_F from M_W (modulo CDF), measurents of $\sin\theta_W$ from LEP, Tevatron and LHC and β and K decays

LFU also strong bounds on ratios:

$$\frac{\left(NN^\dagger\right)_{\alpha\alpha}}{\left(NN^\dagger\right)_{\beta\beta}}$$

From ratios of π, K, and lepton decays

Also the invisible width of the Z since NC are also affected

And LFV processes such as $\mu \rightarrow e\,\gamma$ since the GIM cancellation is lost

Looking for ν_R: Non-Unitarity

Bounds from a global fit to flavour and Electroweak precision data

	"flavor+electroweak" $m >$ EW (2σ limit)
α_{ee}	$[0.081, 1.4] \cdot 10^{-3}$
$\alpha_{\mu\mu}$	$1.4 \cdot 10^{-4}$
$\alpha_{\tau\tau}$	$8.9 \cdot 10^{-4}$
$\lvert\alpha_{\mu e}\rvert$	$6.8 \cdot 10^{-4}$ $(2.4 \cdot 10^{-5})$
$\lvert\alpha_{\tau e}\rvert$	$1.8 \cdot 10^{-3}$
$\lvert\alpha_{\tau\mu}\rvert$	$3.6 \cdot 10^{-4}$

with

$$N = \begin{pmatrix} 1-\alpha_{ee} & 0 & 0 \\ -\alpha_{\mu e} & 1-\alpha_{\mu\mu} & 0 \\ -\alpha_{\tau e} & -\alpha_{\tau\mu} & 1-\alpha_{\tau\tau} \end{pmatrix} U$$

Z.-z. Xing 0709.2220 and 1110.0083.
F. J. Escrihuela, D. V. Forero, O. G. Miranda, M. Tortola, and J. W. F. Valle 1503.08879.

M. Blennow, EFM, J. Hernandez-Garcia, X. Marcano and D. Naredo-Tuero and J. Lopez-Pavon 2306.01040

See also R. E. Shrock 1980, 1981; P. Langaker and D. London 1988; S. M. Bilenky and C. Giunti hep-ph/9211269; E. Nardi, E. Roulet and D. Tommasini hep-ph/9503228; D. Tommasini, G. Barenboim, J. Bernabeu and C. Jarlskog hep-ph/9503228; S. Antusch, C. Biggio, EFM, B. Gavela and J. López Pavón hep-ph/0607020; S. Antusch, J. Baumann and EFM 0807.1003; D. V. Forero, S. Morisi, M. Tortola, and J. W. F. Valle 1107.6009; S. Antusch and O. Fischer 1407.6607; F. J. Escrihuela, D. V. Forero, O. G. Miranda, M. Tortola, and J. W. F. Valle 1503.08879; F.J. Escrihuela, D.V. Forero, O.G. Miranda, M. Tórtola, J.W.F. Valle 1612.07377; EFM, J. Hernandez-Garcia and J. Lopez-Pavon 1605.08774; R. Coy, M. Frigerio, 1812.0316, 2110.09126…

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2 σ preference for mixing with electrons ~0.03

M. Blennow, EFM, J. Hernandez-Garcia, X. Marcano and D. Naredo-Tuero and J. Lopez-Pavon 2306.01040

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Looking for ν_R: Non-Unitarity

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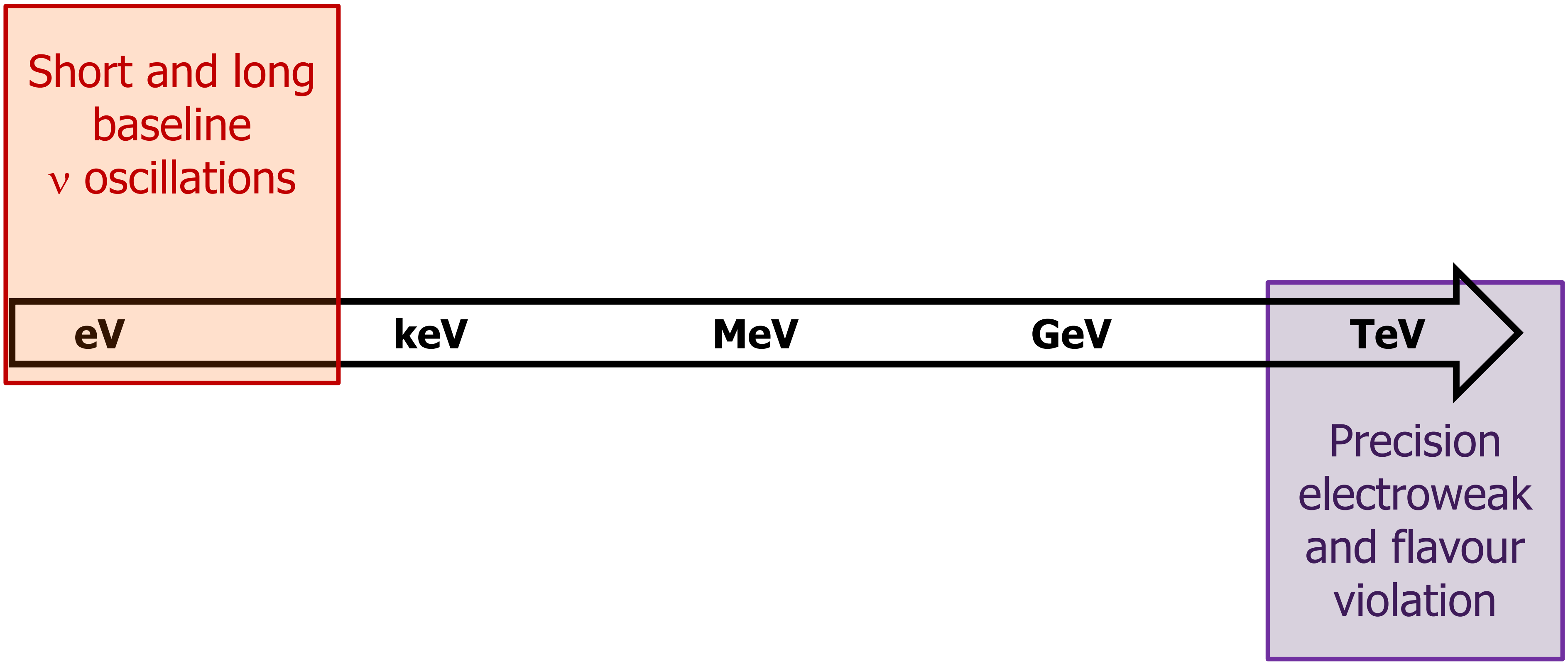
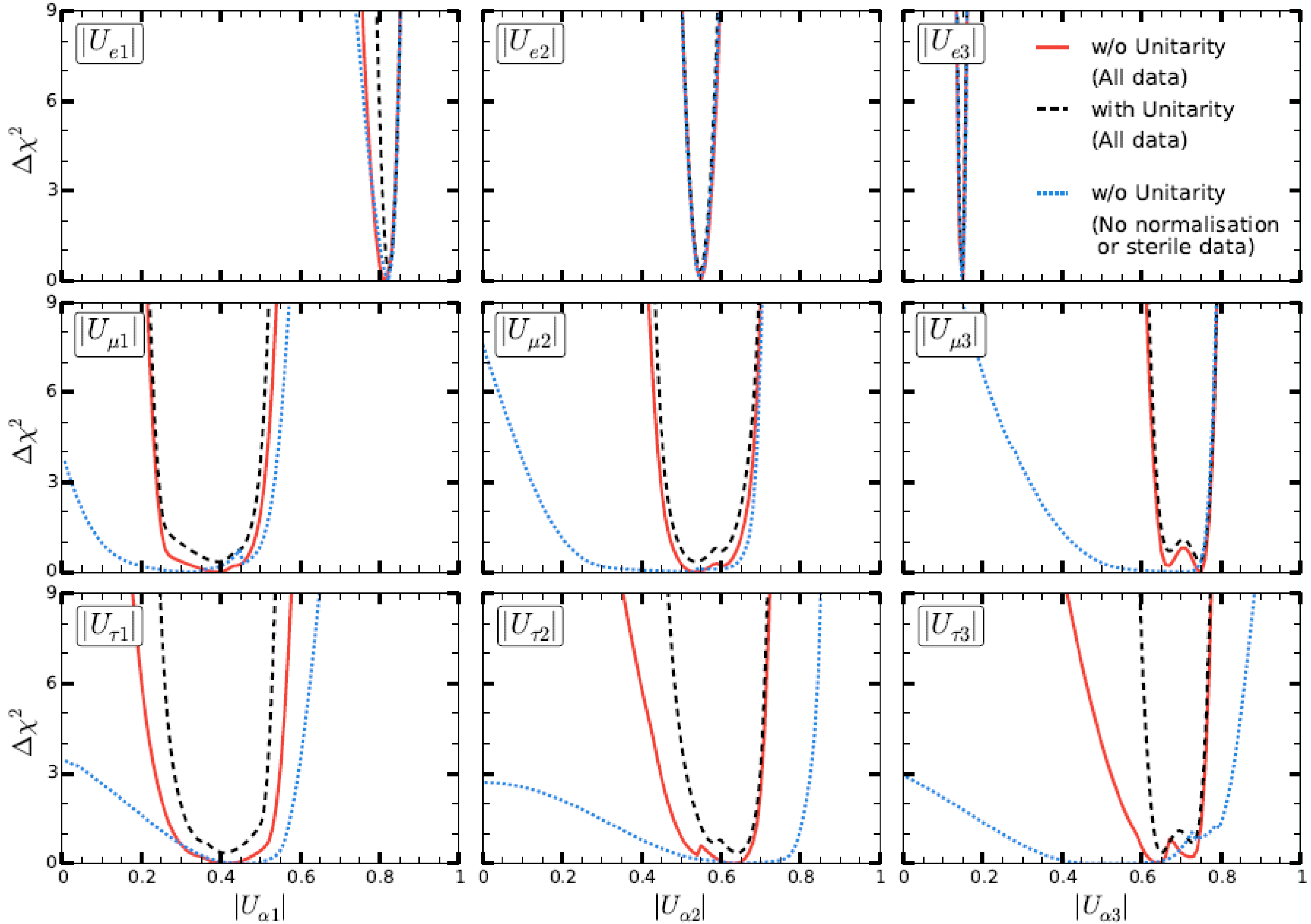
From C. Argüelles et al Snowmass Whitepaper 2203.10811,
M. Blennow, P. Coloma, EFM, J. Hernandez-Garcia and J. Lopez-Pavon 1609.08637
and M. Blennow, EFM, J. Hernandez-Garcia, X. Marcano and D. Naredo-Tuero and J. Lopez-Pavon 2306.01040

A new physics scale



The way out: lighter Steriles

For very light (< keV) extra neutrinos the strong constraints from EW and flavour are lost and ν oscillations dominate



S. Parke and M. Ross-Lonergan arXiv:1508.05095

Steriles vs NU

$$U = \begin{pmatrix} N & \Theta \\ -\Theta^{\dagger} & X \end{pmatrix}$$

"Heavy ν" Non-Unitarity

$$P_{\alpha\beta} = \sum_{i,j} N_{\beta i} N^{*}_{\alpha i} N_{\alpha j} N^{*}_{\beta j} e^{\frac{-i\Delta m^2_{ij} L}{2E}}$$

M. Blennow, P. Coloma, EFM, J. Hernandez-Garcia and J. Lopez-Pavon arXiv:1609.08637
C. S. Fong, H. Minakata and H. Nunokawa arXiv:1609.08623

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"Light ν" Steriles

$$P_{\alpha\beta} = \sum_{i,j} N_{\beta i} N^*_{\alpha i} N_{\alpha j} N^*_{\beta j} e^{\frac{-i\Delta m^2_{ij} L}{2E}} + \sum_{I,J} \Theta_{\beta I} \Theta^*_{\alpha I} \Theta_{\alpha J} \Theta^*_{\beta J} e^{\frac{-i\Delta m^2_{IJ} L}{2E}} + \sum_{i,J} N_{\beta i} N^*_{\alpha i} \Theta_{\alpha J} \Theta^*_{\beta J} e^{\frac{-i\Delta m^2_{iJ} L}{2E}}$$

M. Blennow, P. Coloma, EFM, J. Hernandez-Garcia and J. Lopez-Pavon arXiv:1609.08637
C. S. Fong, H. Minakata and H. Nunokawa arXiv:1609.08623

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If $\frac{\Delta m^2_{ij} L}{2E} \gg 1$ oscillations too fast to resolve and only see average effect

M. Blennow, P. Coloma, EFM, J. Hernandez-Garcia and J. Lopez-Pavon 1609.08637
C. S. Fong, H. Minakata and H. Nunokawa 1609.08623

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$$P_{\alpha\beta} = \sum_{i,j} N_{\beta i} N^*_{\alpha i} N_{\alpha j} N^*_{\beta j} e^{\frac{-i\Delta m^2_{ij} L}{2E}} + \sum_{I,J} \Theta_{\beta I} \Theta^*_{\alpha I} \Theta_{\alpha J} \Theta^*_{\beta J} e^{\frac{-i\Delta m^2_{IJ} L}{2E}}$$

At leading order "heavy" non-unitarity and avergaed-out "light" steriles have the same impact in oscillations

M. Blennow, P. Coloma, EFM, J. Hernandez-Garcia and J. Lopez-Pavon arXiv:1609.08637

Steriles vs NU

$$U = \begin{pmatrix} N & \Theta \\ -\Theta^{\dagger} & X \end{pmatrix}$$

"Heavy ν" Non-Unitarity

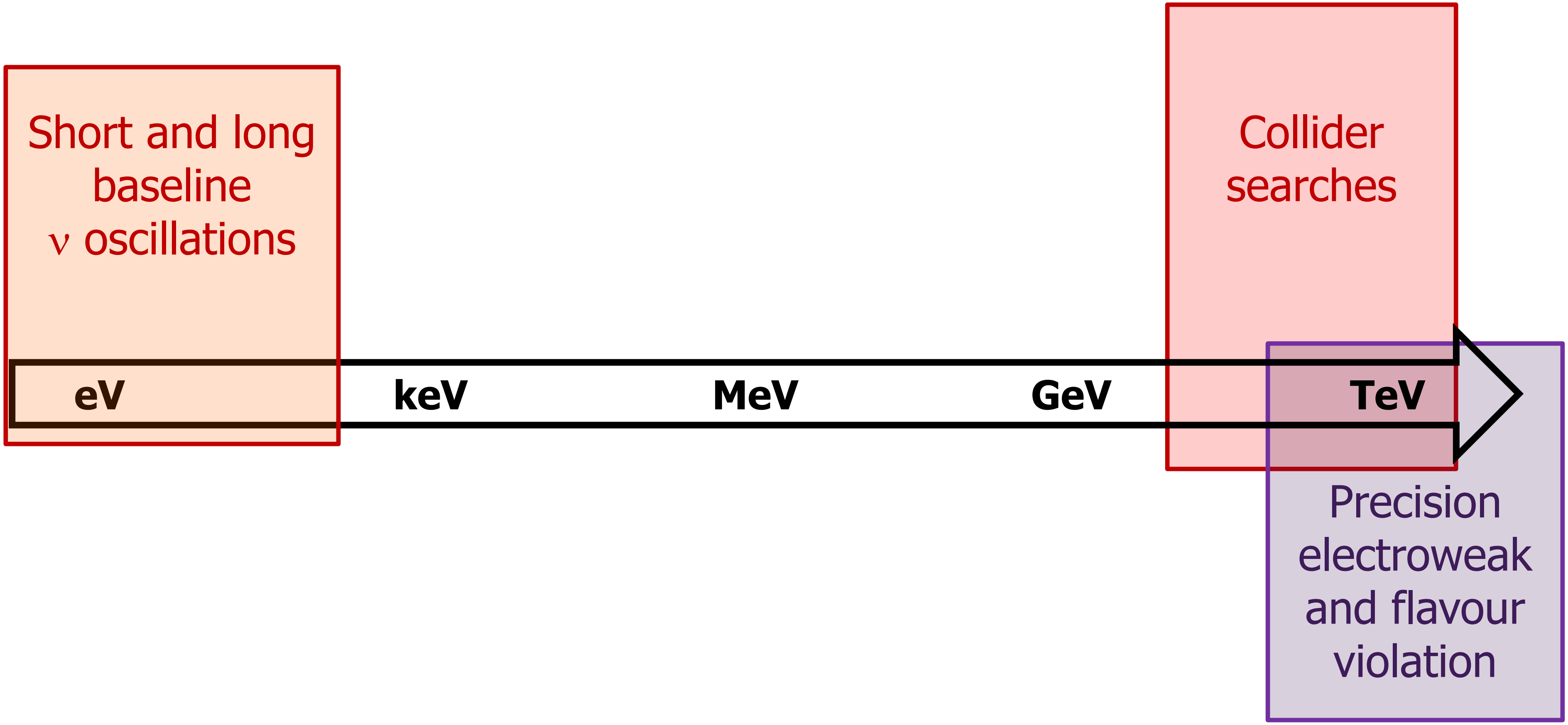
$$P_{\alpha\beta} = \sum_{i,j} N_{\beta i} N^{*}_{\alpha i} N_{\alpha j} N^{*}_{\beta j} e^{\frac{-i\Delta m^2_{ij} L}{2E}}$$

"Light ν" Steriles

$$P_{\alpha\beta} = \sum_{i,j} N_{\beta i} N^{*}_{\alpha i} N_{\alpha j} N^{*}_{\beta j} e^{\frac{-i\Delta m^2_{ij} L}{2E}}$$

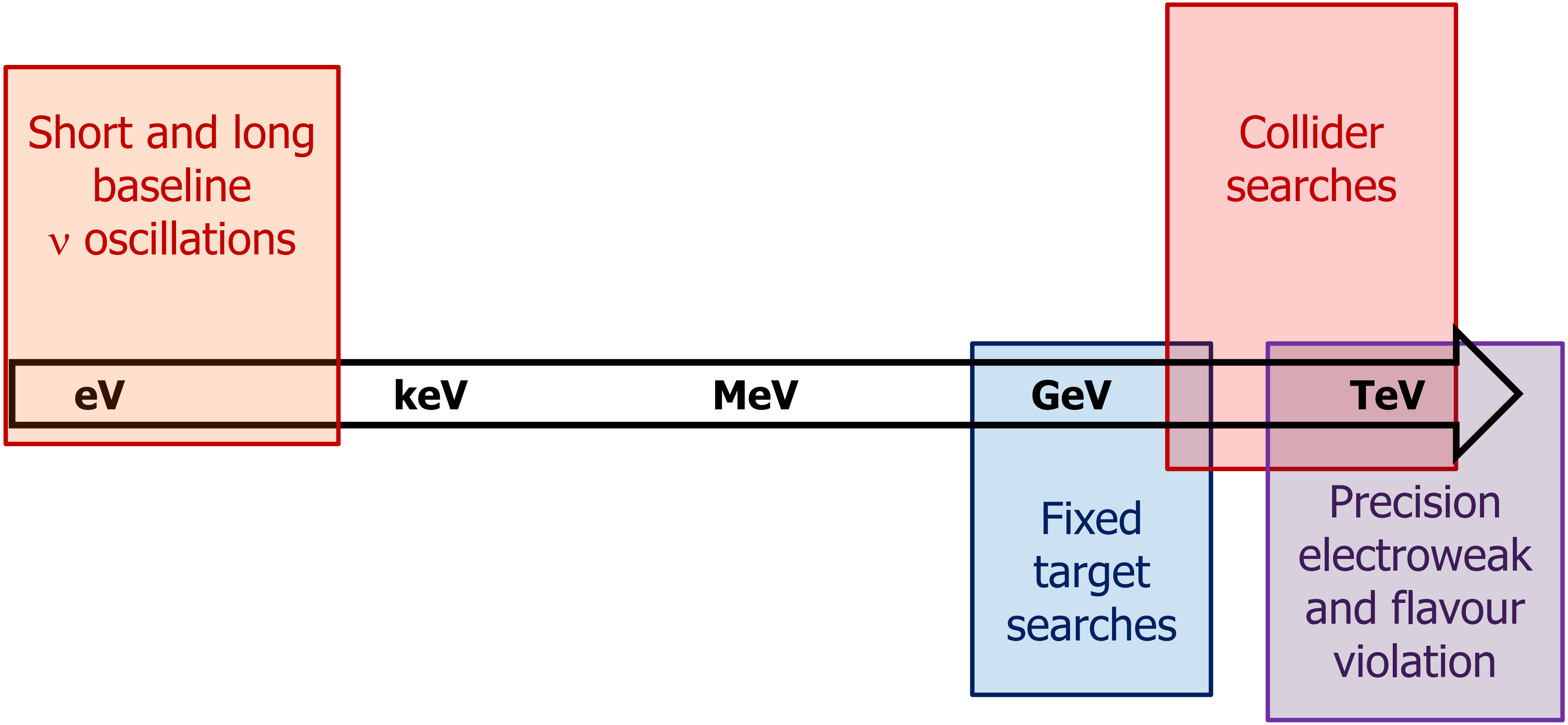
If $\frac{\Delta m^2_{ij} L}{2E} \ll 1$ at the near detector or in the data to estimate the flux and cross section, the zero distance effect is recovered and bounds apply

A new physics scale

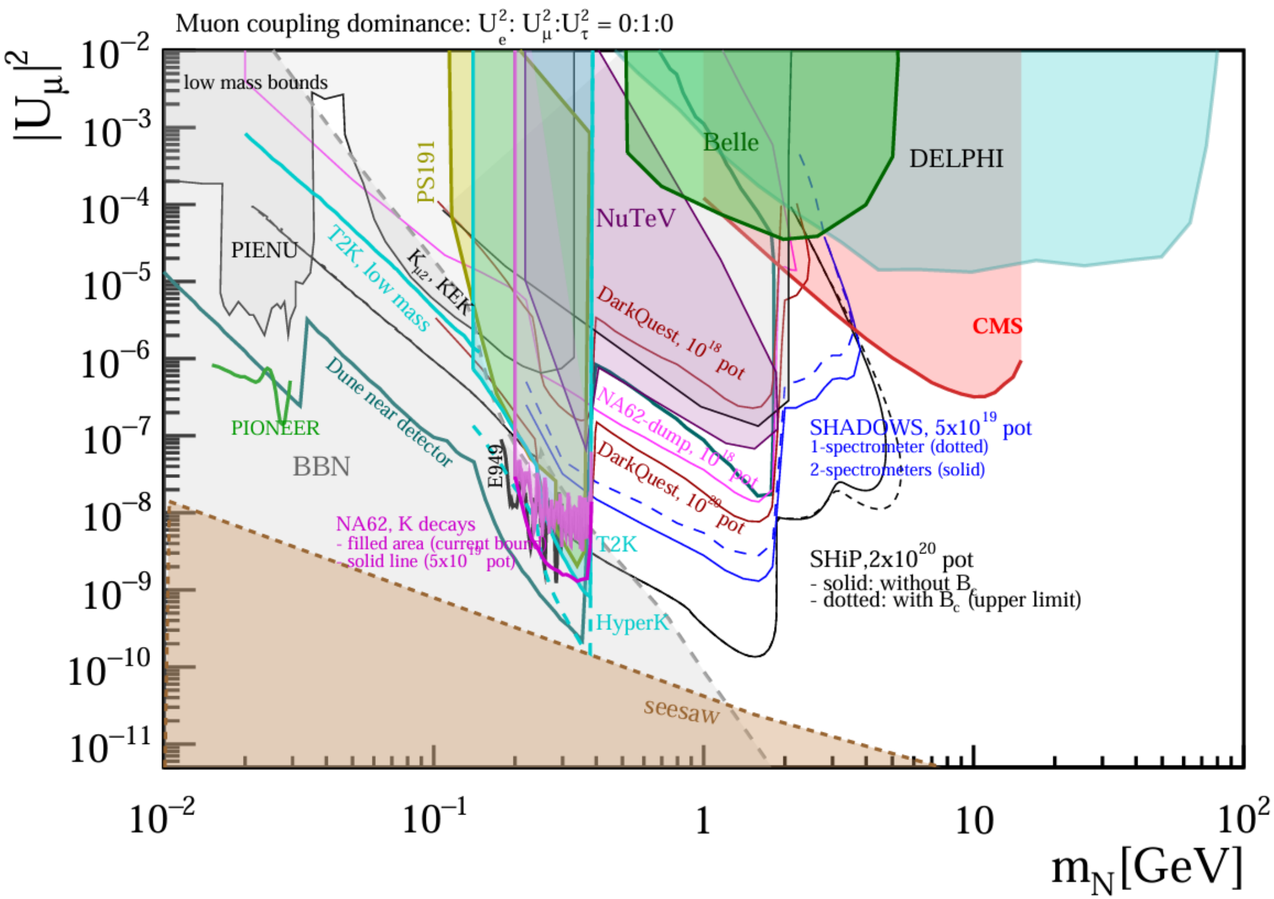


See talk by Albert de Roeck

A new physics scale



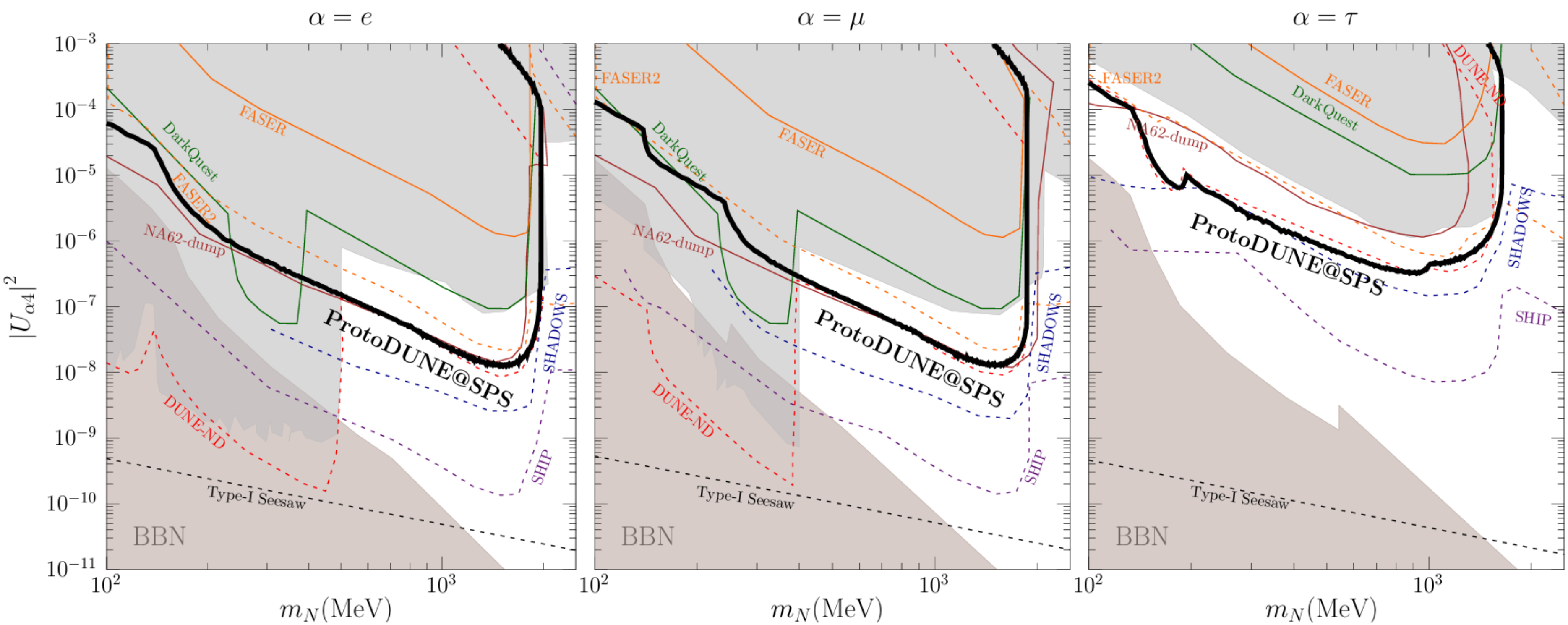
Looking for ν_R: Beam Dumps



A. M. Abdullahi, P. Barham Alzas et al. arXiv:2203.08039

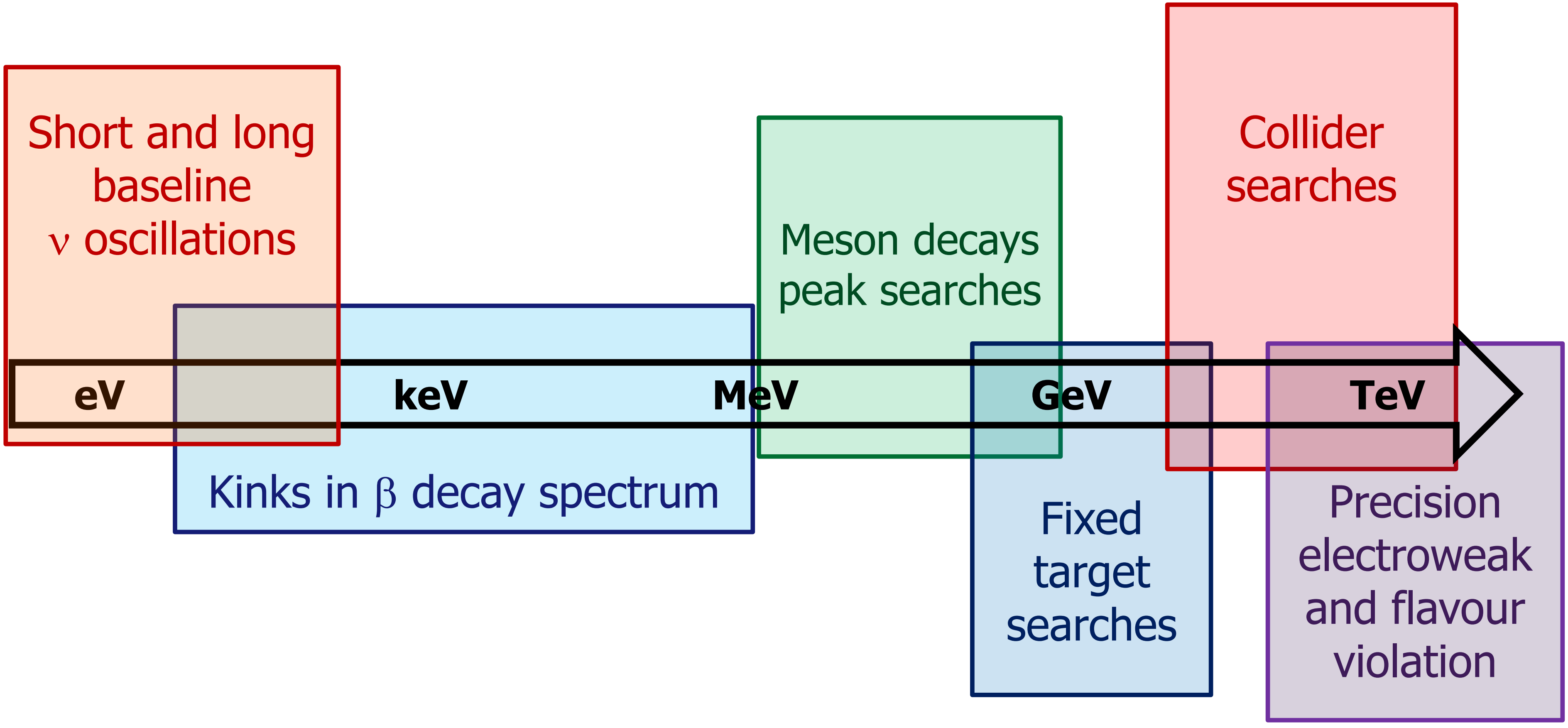
See also P. Coloma, EFM, M. González-López, J. Hernández-García arXiv:2007.03701 for a FeynRules file with interactions between mesons and N_R (HNLs)
and J. L. Feng, A. Hewitt, F. Kling and D. La Rocco 2405.07330 for a python library

Looking for ν_R: Beam Dumps



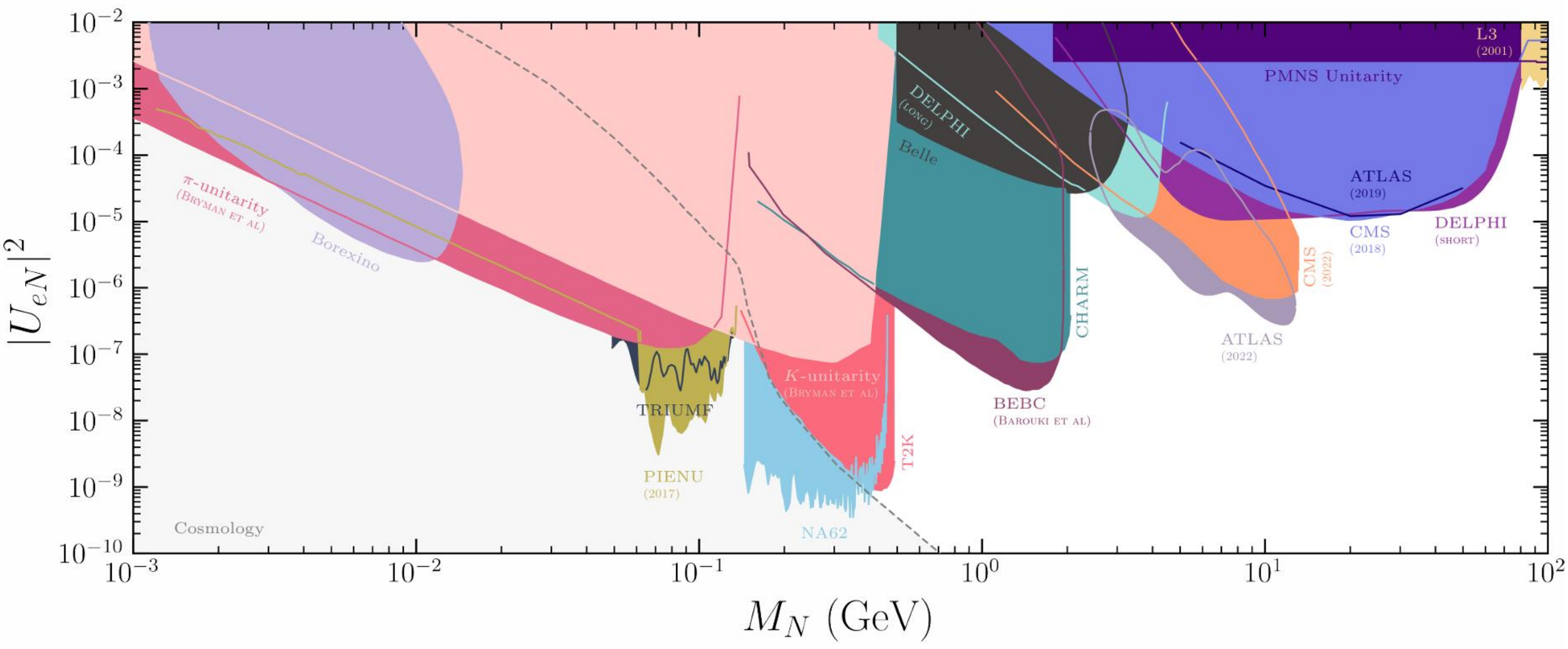
P. Coloma, J. Lopez-Pavon, L. Molina-Bueno and S. Urrea 2304.06765

A new physics scale



Looking for ν_R

All together:



EFM, M. González-López, J. Hernández-García, M. Hostert, J. López-Pavón arXiv:2304.06772
https://github.com/mhostert/Heavy-Neutrino-Limits
See also: P. D. Bolton, F. F. Deppisch and P. S. B. Dev arXiv:1912.03058

Looking for ν_R

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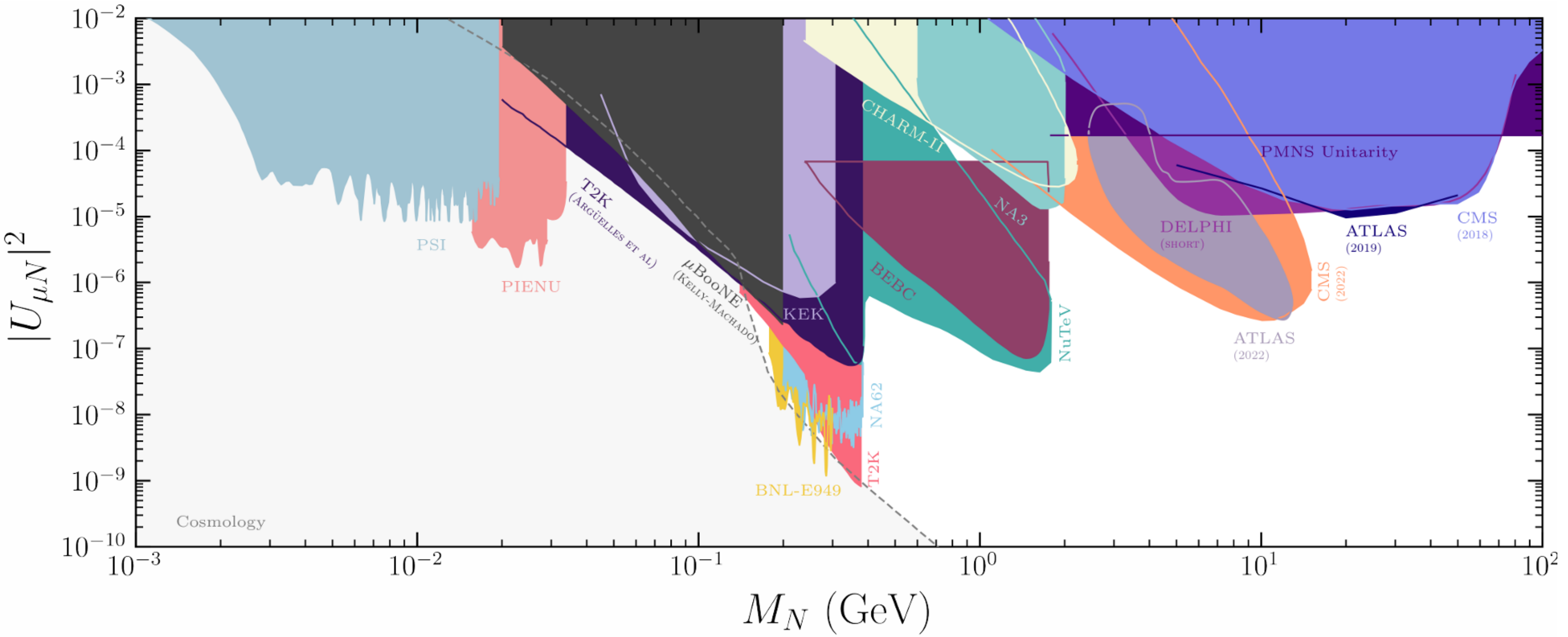

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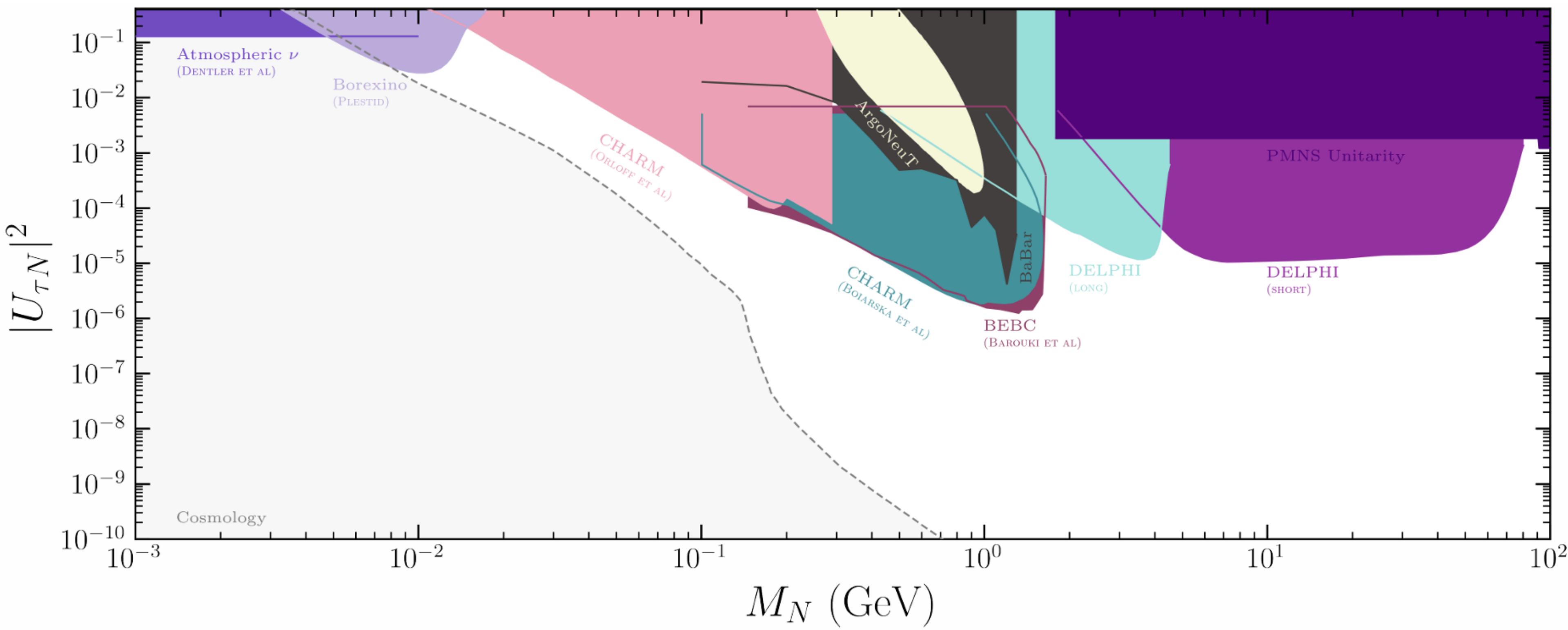

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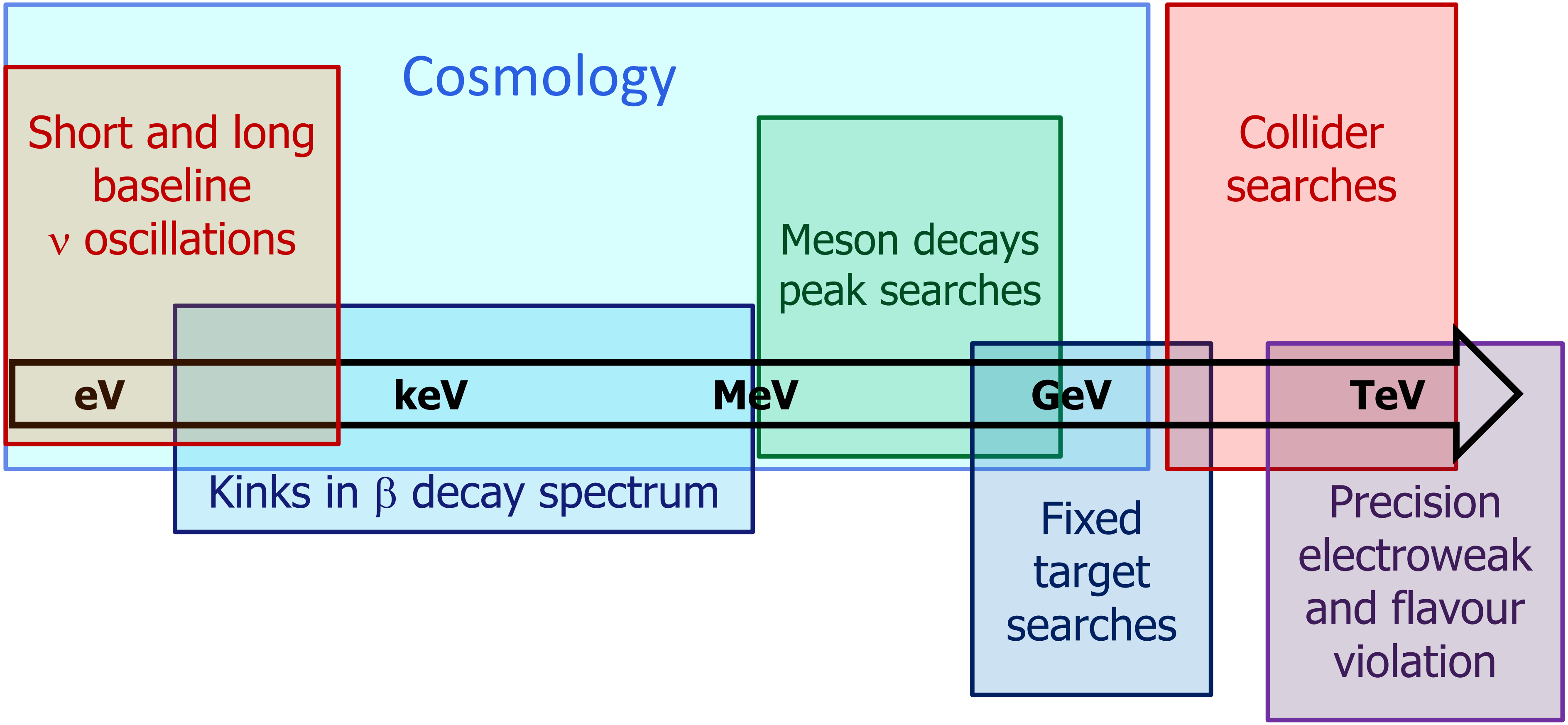
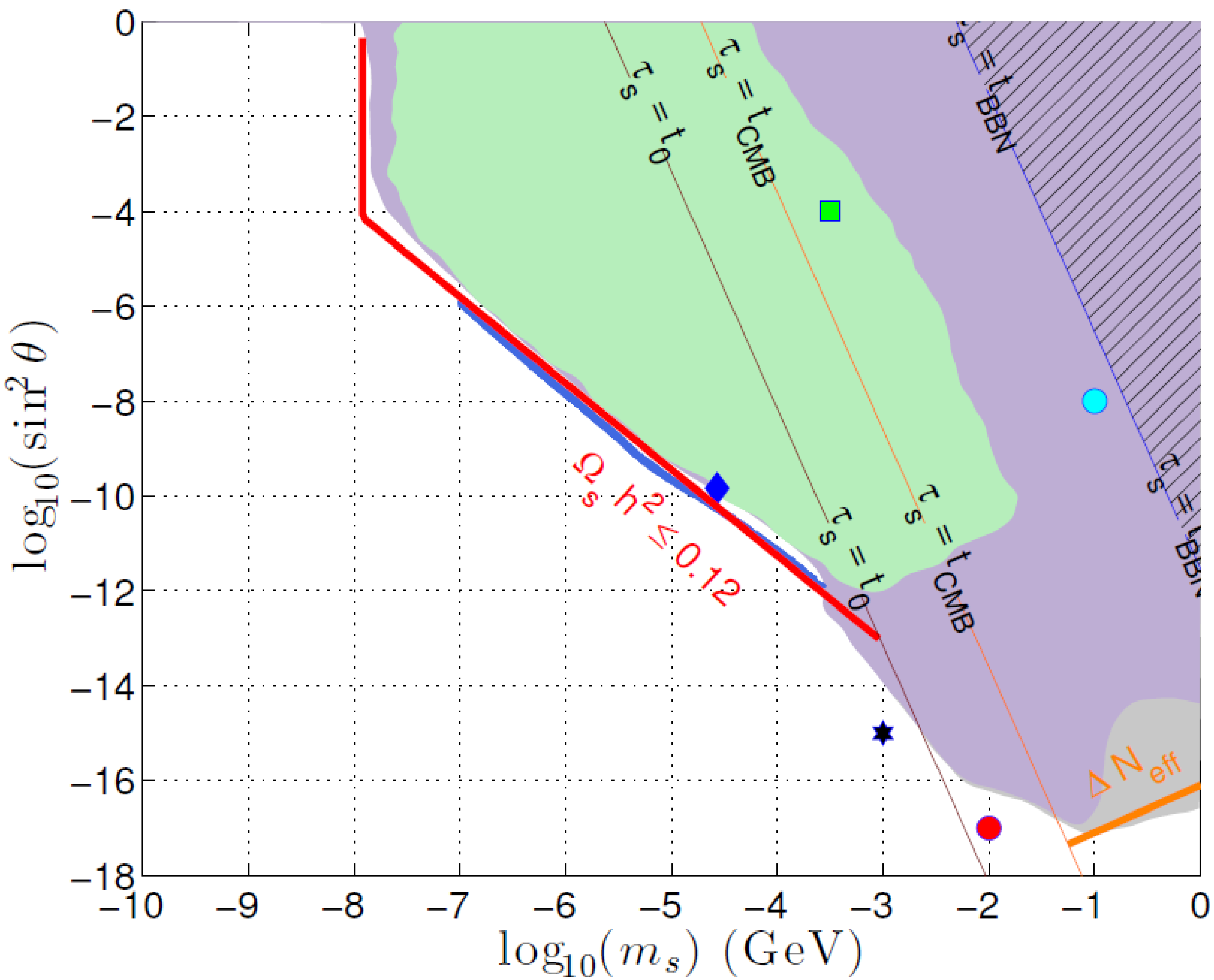


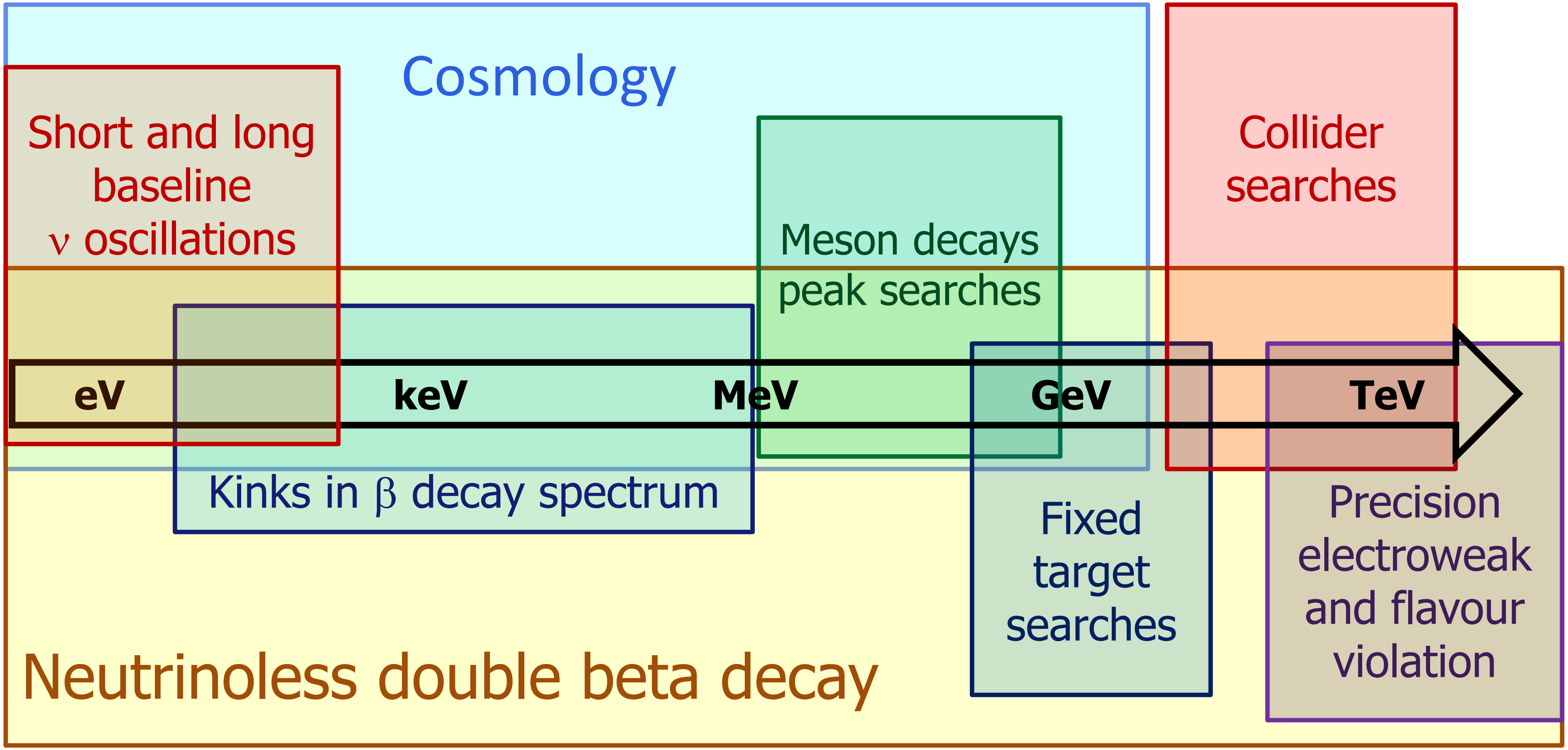
See talks by Maria Archidiacono and Stefano Gariazzo

Cosmology



A. C Vincent, EFM, P. Hernandez, M. Lattanzi and O. Mena arXiv:1408.1956
See also K. Langhoff, N. J. Outmezguine, and N. L. Rodd arXiv:2209.06216

A new physics scale

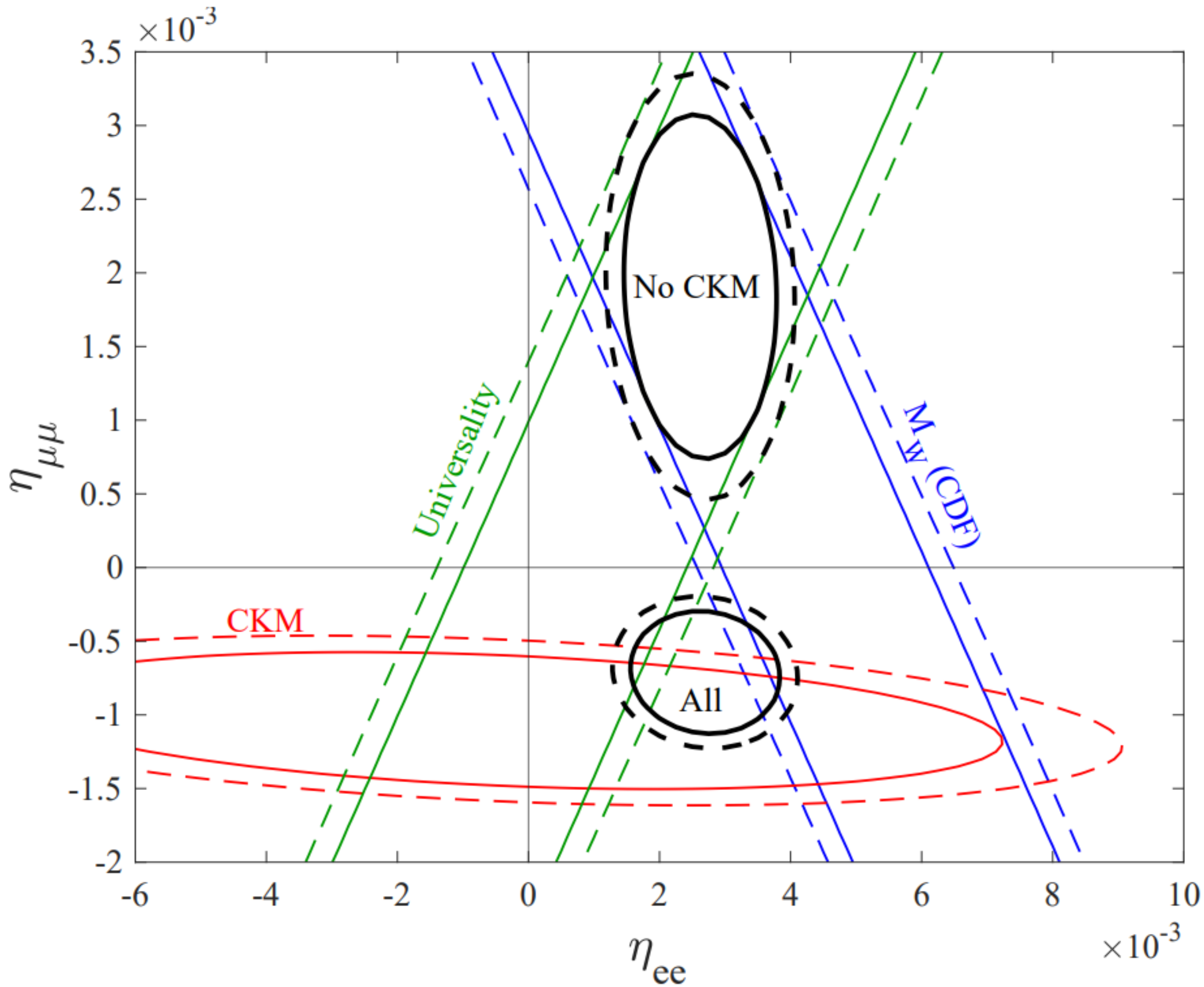


See talks in Sesion 6

Conclusions

- Neutrino masses and mixings imply new BSM physics
- The simplest extension, right-handed neutrinos, already imply a lot of new phenomenology to search for:
  - Non-unitarity, searches at colliders, fixed targets, cosmology, $0\nu\beta\beta$,…
- Also offers conexions to other open problems of the SM
  - Baryogenesis, Dark Matter, Flavour puzzle...
- Neutrino detectors can also probe for other BSM physics
- Neutrino physics is an excellent window BSM!!

Non-unitarity and M_W from CDF



M. Blennow, P. Coloma, EFM, M-González-Lopez 2204.04559
M. Blennow, EFM, J. Hernandez-Garcia, X. Marcano and D. Naredo-Tuero and J. Lopez-Pavon 2306.01040

Looking for ν_R: Non-Unitarity

It has become common to call them:

"Indirect" or "charged leptons" "Direct" or "neutrinos"

	"flavor+electroweak" $m >$ EW (2σ limit)	Oscillations (from zero distance effects in disappearance, 90%)
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From C. Argüelles et al Snowmass Whitepaper arXiv:2203.10811
and M. Blennow, EFM, J. Hernandez-Garcia, X. Marcano and D. Naredo-Tuero
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Looking for ν_R: Non-Unitarity

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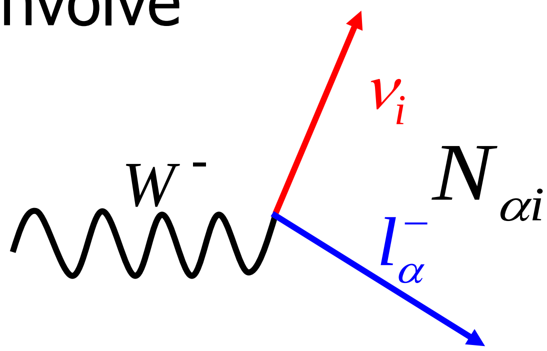
But they all involve



Looking for ν_R: Non-Unitarity

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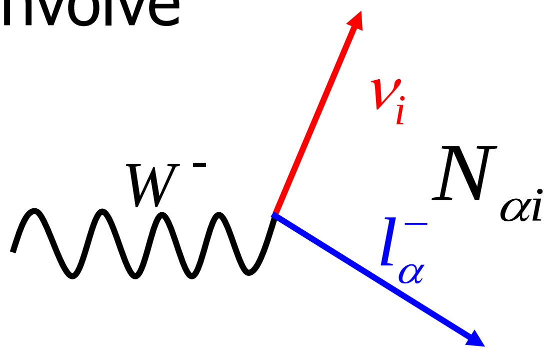

it's where the sensitivity comes from…

So they are all equally "direct" and they all have a neutrino and a charged lepton…

Looking for ν_R: Non-Unitarity

Which one is more robust/model-independent?

"Indirect" or "charged leptons"

"Direct" or "neutrinos"

Looking for ν_R: Non-Unitarity

Which one is more robust/model-independent?

"Indirect" or "charged leptons"

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↓

Introducing an NSI operator with u and d quarks the zero distance effect could be cancelled

Looking for ν_R: Non-Unitarity

Which one is more robust/model-independent?

"Indirect" or "charged leptons"

"Direct" or "neutrinos"

Introducing an NSI operator with u and d quarks the zero distance effect could be cancelled

They also come from zero-distance effect…

Looking for ν_R: Non-Unitarity

Which one is more robust/model-independent?

"Indirect" or "charged leptons"

G_F from μ decay compared to from M_W, measurements of $\sin\theta_w$ at different energies (Moller, colliders) and β and K decays. Very different physics! Not easy to cancel all…

"Direct" or "neutrinos"

Introducing an NSI operator with u and d quarks the zero distance effect could be cancelled

They also induce a zero-distance effect…

But the "neutrino" bounds are often assumed to be more robust… why??

ν mass from right-handed neutrinos

All SM fermions acquire Dirac masses via Yukawa couplings

$$Y_f \bar{f}_R \phi f_L \xrightarrow[\langle\phi\rangle = \frac{Y_f v}{\sqrt{2}}]{\text{SSB}} \frac{Y_f v}{\sqrt{2}} \bar{f}_R f_L \qquad m_D = \frac{Y_f v}{\sqrt{2}}$$

Simplest option add N_R: a Majorana mass is also allowed

$$M_N \overline{N}_R N_R^c$$

$$m_\nu = \begin{pmatrix} 0 & m_D^t \\ m_D & M_N \end{pmatrix} \longrightarrow U^t \begin{pmatrix} 0 & m_D^t \\ m_D & M_N \end{pmatrix} U = \begin{pmatrix} m & 0 \\ 0 & M \end{pmatrix}$$

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If $M_N \gg m_D$ then $M \approx M_N$ and $m \approx m_D^t M_N^{-1} m_D \rightarrow$ lightness of ν

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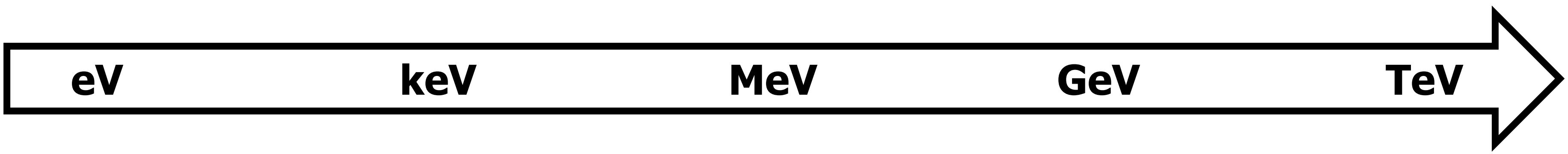
A new physics scale

But a very high M_N worsens the Higgs hierarchy problem

Lightness of ν masses could also come naturally from an approximate symmetry (B-L)



M_N could be anywhere…

A new physics scale

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A new physics scale

But a very high M_N worsens the Higgs hierarchy problem

Lightness of ν masses could also come naturally from an approximate symmetry (B-L)

$$m_D \bar{N}_R \nu_L + M_N \bar{N}_R N_L$$

$$\begin{pmatrix} 0 & m_D^t & 0 \\ m_D & 0 & M_N \\ 0 & M_N & 0 \end{pmatrix}$$

So that $m_\nu = 0$ even if $\Theta \approx m_D^\dagger M_N^{-1}$ is large

A new physics scale

But a very high M_N worsens the Higgs hierarchy problem

Lightness of ν masses could also come naturally from an approximate symmetry (B-L)

$$m_D \bar{N}_R \nu_L + M_N \bar{N}_R N_L + \mu \bar{N}_L^c N_L$$

$$\begin{pmatrix} 0 & m_D^t & 0 \\ m_D & 0 & M_N \\ 0 & M_N & \mu \end{pmatrix}$$

"inverse Seesaw"

R. Mohapatra and J. Valle 1986

Small $m_\nu \approx \mu \frac{m_D^2}{M_N^2}$ even if $\Theta \approx m_D^\dagger M_N^{-1}$ is large and M_N low

Funding

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PID2019-108892RB-100
PID2022-137127NB-100
CEX2020-001007-S
860881-HiDDeN
101086085-ASYMMETRY