Subject	**21st Lomonosov Conference**
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Date	2023-08-20 15:06

- 21st_Lomcon_Programme.pdf(~536 KB)

Remove all attachments

Dear Dr. Dubinin,

Please find in attachment the updated conference programme. I would like to ask you to check your name, the title of your talk and also your affiliation as these are indicated in the programme. Some talks have been rescheduled slightly.

Thank you in advance.

Sincerely yours,
Artem Popov
Organizing Committee

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Mixing scenarios, dark matter and lepton universality with three generations of heavy neutral leptons

Lomonosov - 2023

Mikhail Dubinin

work with E. Fedotova, D. Kazarkin

SINP MSU

arXiv: 2206.05186, 2212.11310, 2303.06680, 2308.02240 [hep-ph]

Outline

Extended lepton sector of the SM

Heavy neutral leptons (**HNL**), or Majorana fermions with sterile flavor states, $SU(2)_L \times U(1)_Y$ singlets

$$\mathcal{L} = \mathcal{L}_{SM} + i\overline{\nu}_R \partial_\mu \gamma^\mu \nu_R - \left(F\, \bar{l}_L \nu_R \tilde{H} + \frac{M_M}{2} \overline{\nu^c}_R \nu_R + h.c \right),$$

где $l_L = (\nu_L,\, e_L)^T$ – left SM doublet, ν_R - Majorana flavor states, H – Higgs doublet ($\tilde{H} = i\tau_2 H^*$), F – Yukawa matrix, M_M Majorana mass matrix. After spontaneous symmetry breaking $M_D = F\langle H \rangle = Fv$ ($v = 174$ GeV)

$$\frac{1}{2}(\overline{\nu}_L \overline{\nu^c}_R) \begin{pmatrix} 0 & M_D \\ M_D^T & M_M \end{pmatrix} \begin{pmatrix} \nu_L^c \\ \nu_R \end{pmatrix} + h.c.,$$

For physically interesting scenarios in the seesaw type I models it is needed to combine very small active (standard) neutrino masses $\sim F^2 v^2 / M_M$ with moderately heavy M_{HNL} within the LHC and next colliders energy reach, and not too small mixing $\sim \sqrt{m_\nu / M_{HNL}}$ providing observable signals at the luminosity frontier. This is achieved either by fine-tuning of the mixing matrices in a specific scenarios with additional symmetries, or in the framework of Casas-Ibarra diagonalisation where the mixing can be enhanced. First sort of models gives quasi-Dirac neutrinos processed by the standard calculation technique, which are not fully consistent with the second sort of models not using the "Dirac limit", evaluating with Majorana Feynman rules. Collider studies are performed using socalled "model independent approach"or "phenomenological seesaw type I model"with one generation of HNL and mixing independent of HNL mass.

It is interesting to consider explicit forms of mixing for three HNL generations beyond the "Dirac limit"in view of the available data.

From flavor states to mass states

The full 6×6 mass matrix $\mathcal{M} = \mathcal{U}\mathcal{D}\mathcal{U}^T$, where $\mathcal{U}$ - unitary, $\mathcal{D}$ - diagonal non-negative. Mass and flavor states

$$\begin{pmatrix} \nu_L \\ \nu_R^c \end{pmatrix} = \mathcal{U} P_L \begin{pmatrix} \nu \\ N \end{pmatrix}, \qquad \mathcal{U} = \exp \begin{pmatrix} 0 & \theta \\ -\theta^\dagger & 0 \end{pmatrix} \cdot \begin{pmatrix} U_\nu & 0 \\ 0 & U_N^* \end{pmatrix}$$

$$\begin{aligned} \nu_L &\simeq \left(1 - \frac{1}{2}\theta\theta^\dagger\right) U_\nu P_L \nu + \theta U_N^* P_L N, \\ \nu_R^c &\simeq -\theta^\dagger U_\nu P_L \nu + \left(1 - \frac{1}{2}\theta^\dagger\theta\right) U_N^* P_L N. \end{aligned}$$

Exponent is decomposed in θ - "Casas-Ibarra diagonalization"

NPB 618 (2001) 171 (hep-ph/0103065)

Neutral and charged currents interaction with $W^{\pm}$ and Z

$$\mathcal{L}^{\nu}_{CC} = -\frac{g}{\sqrt{2}}\bar{l}\gamma_{\mu}U_{\text{PMNS}}\,\nu_{i_L}W^{\mu} + h.c. \tag{1a}$$

$$\mathcal{L}^{\nu}_{NC} = \frac{g}{2c_W}\bar{\nu}_{i_L}\gamma_{\mu}U^{\dagger}_{\text{PMNS}}U_{\text{PMNS}}\nu_{j_L}Z^{\mu} + h.c. \tag{1b}$$

$$\mathcal{L}^{N}_{CC} = -\frac{g}{\sqrt{2}}\bar{l}\gamma_{\mu}\theta U^{*}_{N}N_{k_L}W^{\mu} + h.c. \tag{1c}$$

$$\mathcal{L}^{N}_{NC} = -\frac{g}{2c_W}\bar{N}_{i_L}\gamma_{\mu}U^{T}_{N}\theta^{\dagger}\theta U^{*}_{N}N_{j_L}Z^{\mu} + \tag{1d}$$

$$+ \left(-\frac{g}{2c_W}\bar{\nu}_{i_L}\gamma_{\mu}U^{\dagger}_{\text{PMNS}}(I - \frac{1}{2}\theta^{\dagger}\theta)\theta U^{*}_{N}N_{j_L}Z^{\mu} + h.c.\right)$$

HNL mixing with left SM neutrino (active neutrino) is described by $\Theta \equiv \theta U^{*}_{N}$ matrix.

Ambiguity

Solving the diagonalization equations in the $\mathcal{O}(\theta^2)$ order

$$I = \Omega^T \Omega = [-i\sqrt{\hat{m}^{-1}} U_\nu^\dagger M_D U_N^* \sqrt{\hat{M}^{-1}}]^T \cdot [-i\sqrt{\hat{m}^{-1}} U_\nu^\dagger M_D U_N^* \sqrt{\hat{M}^{-1}}],$$

where Ω – arbitrary orthogonal matrix, may include additional parameters to enhance the mixing, U_ν и U_N diagonalize $\nu_{e,\mu,\tau}$ and $N_{1,2,3}$ sectors.

$$\boxed{\Theta = iU_\nu \sqrt{\hat{m}} \Omega \sqrt{\hat{M}^{-1}}}, \text{ где } \hat{m} = diag(m_1, m_2, m_3),\ \hat{M} = diag(M_1, M_2, M_3)$$

PMNS matrix non-unitary: $U_{\text{PMNS}} = \left(1 - \frac{1}{2}\theta^\dagger\theta + \mathcal{O}(\theta^4)\right) U_\nu$

Non-minimal $\mathcal{O}(\theta^3)$ decomposition

Take into account the terms of the order of $\mathcal{O}(\theta M_D)$ when $(\hat{M} = diag(M_1, M_2, M_3))$

$$M_N = U_N^* \hat{M} U_N^\dagger = (\theta^{-1} - \frac{1}{3}\theta^\dagger) M_D = M_M + \theta^\dagger M_D$$

whereas, within $\mathcal{O}(\theta^2)$ approximation for the see-saw mechanism, it is assumed that $M_N = M_M$. For non-minimal decomposition of the **exp** matrix, the condition must be met

$$\Omega^{-1} = \Omega^T + \frac{1}{3}\hat{M}^{-1}(\Omega^{-1})^* \hat{m},$$

which is a condition for the self-consistency of the diagonalization procedure, taking into account the $\mathcal{O}(\theta M_D)$ terms.

Neutrino Minimal Standard Model (νMSM)

In the following νMSM model will be favorable

- explains neutrino oscillation data

	NH	IH
m_1	small	$\sqrt{\Delta m^2_{31}} \simeq 0.049$ eV
m_2	$\sqrt{\lvert\Delta m^2_{21}\rvert} \simeq 0.009$ eV	$\sqrt{\Delta m^2_{32}} \simeq 0.050$ eV
m_3	$\sqrt{\Delta m^2_{31}} \simeq 0.049$ eV	small

- no very distinctive mass scales

- N_1 is the dark matter particle

- baryonic asymmetry is generated by means of $N_2 - -N_3$ oscillations if masses of $N_2 \sim N_3 >> N_1$

T.Asaka, S.Blanchet and M.Shaposhnikov, Phys.Lett. B631 (2005) 151 (hep-ph/0503065)

General cosmological restriction: lifetime

HNL of the first generation – dark matter candidate – does not decay on the cosmological time scale $\tau_{N_1} \geq H_0^{-1} \simeq 4 \times 10^{17}$ sec. The one-loop mediated decay $N \to \gamma, \nu$ can be a distinctive signal with photon energy $E_\gamma = M_1/2$, then the lifetime limit $N_1 \to 3\nu$ is enhanced by astro-gamma observations [1, 2, 3]. In the following $\tau_{N_1} > 10^{25}$ sec.

$$\Gamma\Big(N_1 \to \gamma, \nu\Big) = \frac{9\alpha_{EM} G_F^2 M_1^5}{256\pi^4} \sum_\alpha |\Theta_{\alpha 1}|^2.$$

$$\tau_{N_1} = 3 \times 10^{22} \left(\frac{M_1}{1\ \text{keV}}\right)^{-4} \left(\sum_\alpha \frac{(m_D)_{\alpha 1}}{1\ \text{eV}}\right)^{-1} \text{sec.}$$

Useful variable for Ω-independent observables

$$(m_D)_{\alpha I} = \left| \sum_k \sqrt{m_k}\ U_{\alpha k} \Omega_{kI} \right|^2$$

$$\sum_\alpha (m_D)_{\alpha I} = \left| \sum_k \sqrt{m_k}\ U_{\alpha k} \delta_{k1} \right|^2 = m_1, \quad \sum_\alpha (m_D)_{\alpha I} = \left| \sum_k \sqrt{m_k}\ U_{\alpha k} \delta_{k3} \right|^2 = m_3$$

General cosmological restriction: dark matter energy fraction

Active-sterile neutrino mixing Θ is small and HNL DM particles have never been in thermal equilibrium. Main HNL production source is *Dodelson-Widrow mechanism* [4] of active-sterile neutrino oscillations. In the case of nonresonant production the cosmological energy fraction

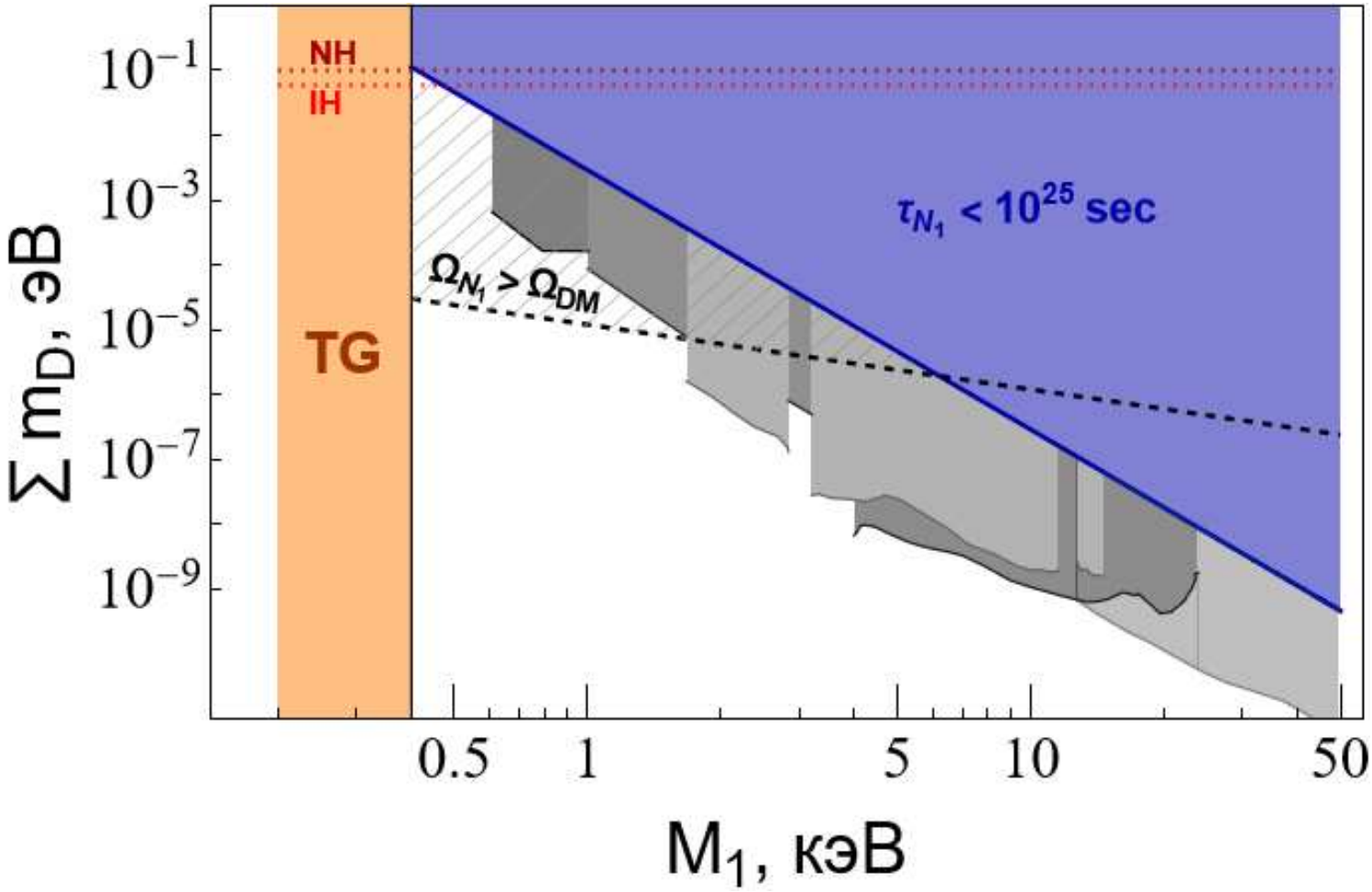
$$\Omega_N h^2 \simeq 0.1 \sum_{I=1}^{3} \sum_{\alpha=e,\nu,\tau} \left(\frac{|\Theta_{\alpha I}|^2}{10^{-8}} \right) \left(\frac{M_I}{1 \text{ keV}} \right)^2 .$$

In particular for N_1 fermions

$$\Omega_{N_1} h^2 \simeq \left(\frac{\sum_\alpha (m_D)_{\alpha 1}}{10^{-4} \text{ эВ}} \right) \left(\frac{M_1}{1\text{keV}} \right) \leq \Omega_{DM} h^2 = 0.12.$$

$$\sum_\alpha (m_D)_{\alpha 1} < \overline{(m_D)}_{\text{DM}} = 10^{-5} \left(\frac{M_1}{1 \text{ keV}} \right)^{-1} \text{ eV}$$

Exclusion contours for N_1 DM particle



Cosmological restrictions on $(m_D)_{\alpha I} = \left| \sum_k \sqrt{m_k}\ U_{\alpha k} \Omega_{kI} \right|^2$ parameter for N_1 DM, summed over flavor index $\alpha = e, \mu, \tau$. Ω-independent plot. Gray regions excluded by satellite experiments XMM, Chandra, HEAO-1, etc recalculated to Σm_D from the data summary in 0811.2385.

Possible Ω forms

- $\Omega = I$ for normal hierarchy (NH) or anti-diagonal orthogonal Ω analogous to $\Omega = I$ for inverse hierarchy (IH);
- $\Omega \in SO(3, \mathbb{R})$ parametrized by Euler angles α_j

$$\Omega = \mathbf{X}_1 \mathbf{Z}_2 \mathbf{X}_3 = \begin{pmatrix} c_2 & -c_3 s_2 & s_2 c_3 \\ c_1 s_2 & c_1 c_2 c_3 - s_1 s_3 & -c_3 s_1 - c_1 c_2 s_3 \\ s_1 s_2 & c_1 s_3 + c_2 c_3 s_1 & c_1 c_3 - c_2 s_1 s_3 \end{pmatrix}$$

- $\Omega \in SO(3, \mathbb{C})$ like above, complex-valued angles $\omega_j = \alpha_j + i\beta_j$.

Surfaces for the real-valued Ω parameters.

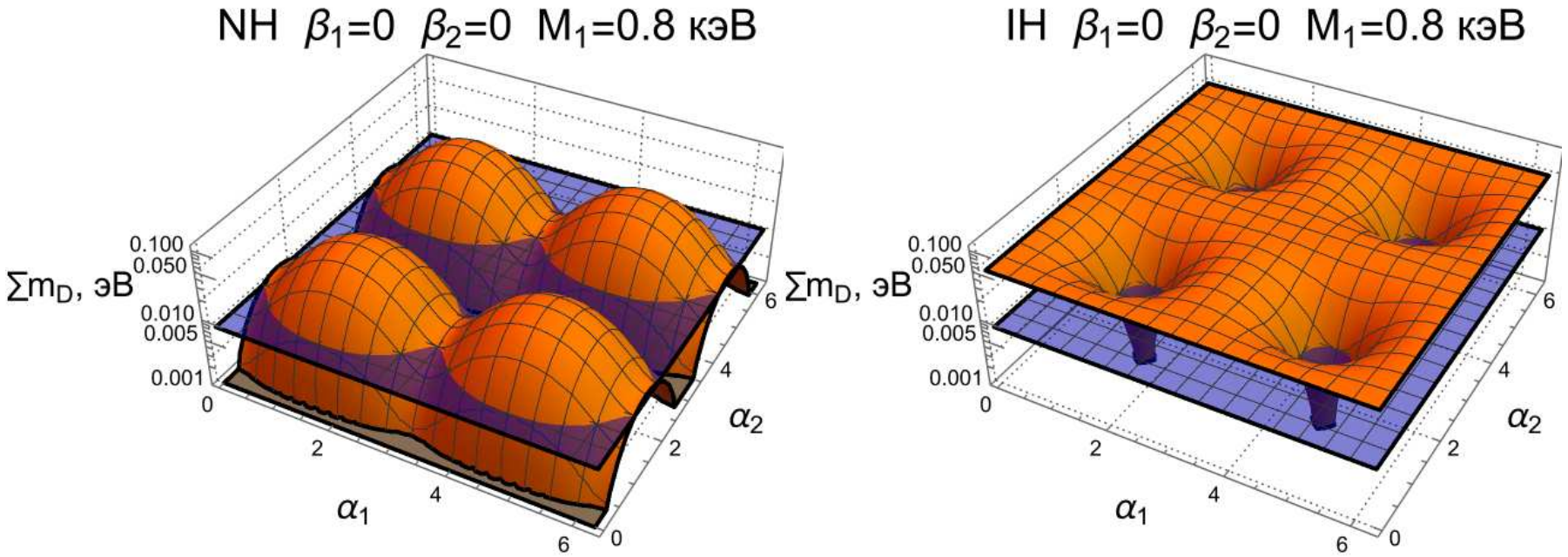


Рис.: Surfaces for $\sum_\alpha (m_D)_{\alpha 1}$ vs α_1 и α_2 for normal hierarchy (left) and inverse hierarchy (right plot). Blue horisontal plane - $\overline{(m_D)}_{\mathrm{X-ray}}$ at $M_1 = 0.8$ keV.

Contours for the real-valued Ω parameters

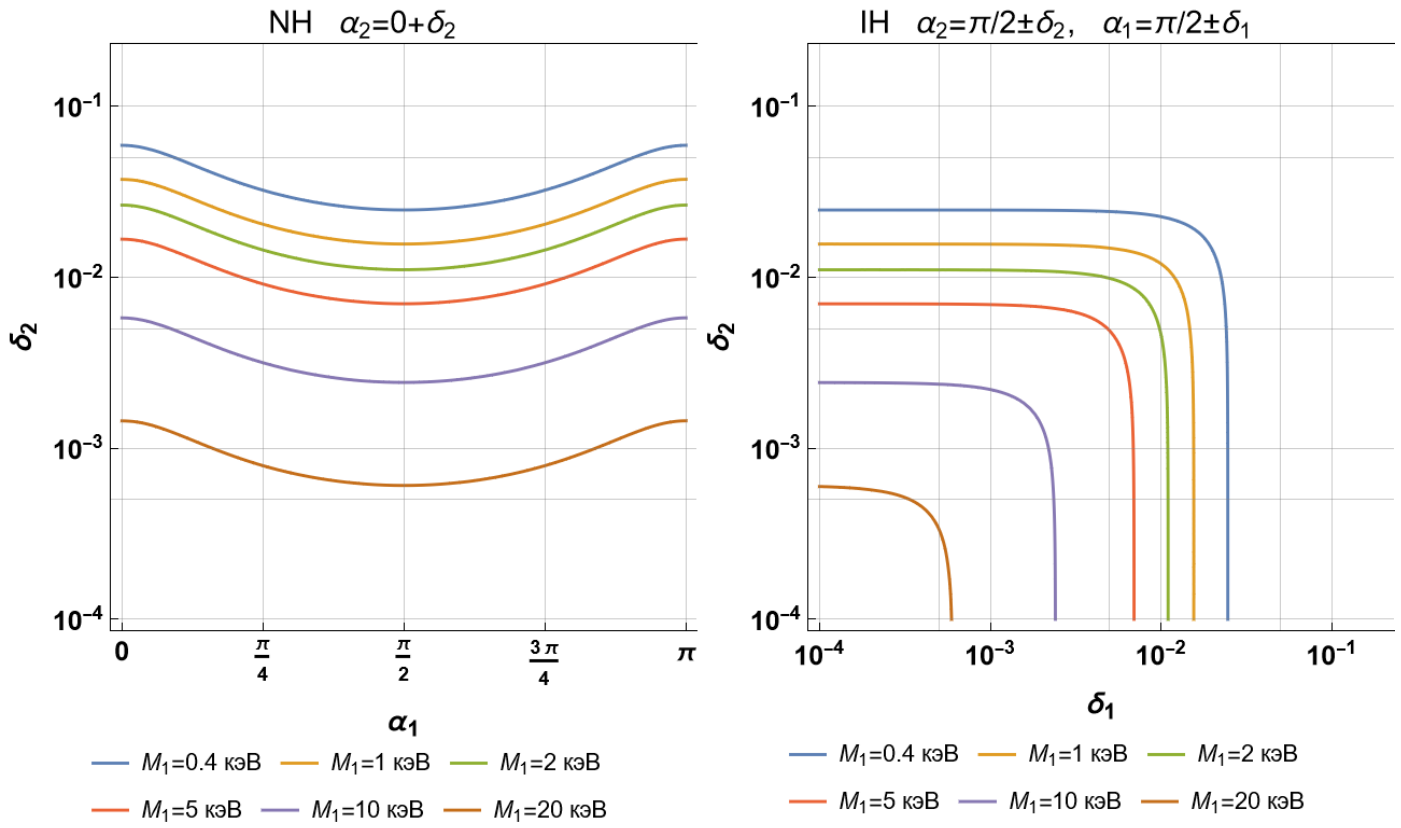


Рис.: Exclusion contours for α_1 и α_2 for various masses M_1 DM. Combination of τ_{N_1} and energy fraction limits is taken. M_1 masses in keV.

Contours for the complex-valued Ω parameters

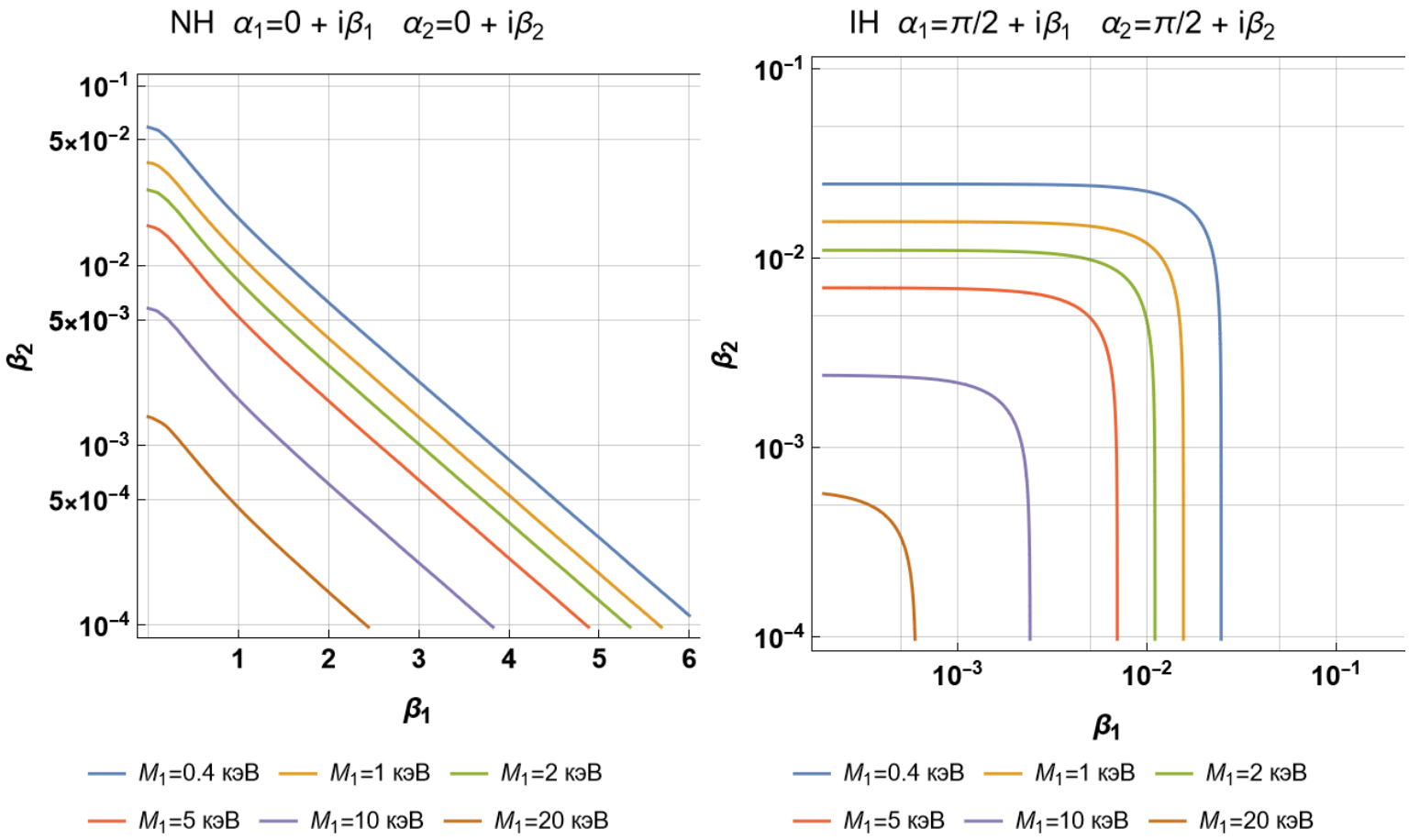


Рис.: Exclusion contours for imaginary parts β_1 and β_2 of Euler angles ω_1 and ω_2 which parametrize Ω at fixed real parts of α_1 and α_2 (NH left plot and IH right plot).

"Minimal mixing"scenario

"Minimal mixing", does not include redundant unknown parameters reflecting the general properties of constraints in the case of real-valued Ω.

$$\Theta^{(\mathrm{NH})}_{\mathrm{min}} = \begin{pmatrix} iU_{e1}\sqrt{\frac{m_1}{M_1}} & iU_{e2}\sqrt{\frac{m_2}{M_2}} & iU_{e3}\sqrt{\frac{m_3}{M_3}} \\ iU_{\mu 1}\sqrt{\frac{m_1}{M_1}} & iU_{\mu 2}\sqrt{\frac{m_2}{M_2}} & iU_{\mu 3}\sqrt{\frac{m_3}{M_3}} \\ iU_{\tau 1}\sqrt{\frac{m_1}{M_1}} & iU_{\tau 2}\sqrt{\frac{m_2}{M_2}} & iU_{\tau 3}\sqrt{\frac{m_3}{M_3}} \end{pmatrix}, \; \Omega^{(\mathrm{NH})}_{\mathrm{min}} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\Theta^{(\mathrm{IH})}_{\mathrm{min}} = \begin{pmatrix} iU_{e3}\sqrt{\frac{m_3}{M_1}} & iU_{e2}\sqrt{\frac{m_2}{M_2}} & iU_{e1}\sqrt{\frac{m_1}{M_3}} \\ iU_{\mu 3}\sqrt{\frac{m_3}{M_1}} & iU_{\mu 2}\sqrt{\frac{m_2}{M_2}} & iU_{\mu 1}\sqrt{\frac{m_1}{M_3}} \\ iU_{\tau 3}\sqrt{\frac{m_3}{M_1}} & iU_{\tau 2}\sqrt{\frac{m_2}{M_2}} & iU_{\tau 1}\sqrt{\frac{m_1}{M_3}} \end{pmatrix}, \; \Omega^{(\mathrm{IH})}_{\mathrm{min}} = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

"Exponential mixing"scenario

Cosmological restrictions favor block-diagonal Ω and the mass scale $M_1 \sim 1 - 10$ keV.

$$\Omega_{\rm NH} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos(\omega) & -\sin(\omega) \\ 0 & \xi\sin(\omega) & \xi\cos(\omega) \end{pmatrix} \qquad \Omega_{\rm IH} = \begin{pmatrix} 0 & \cos(\omega) & -\sin(\omega) \\ 0 & \xi\sin(\omega) & \xi\cos(\omega) \\ 1 & 0 & 0 \end{pmatrix}$$

with ω complex-valued. Mixing enhancement controlled by $X_\omega = e^{Im(\omega)} \gg 1$, $Im(\omega) > 1$.

Specifically for νMSM second and third generations of *HNL* $M_2 \simeq M_3 \gg M_1$. Quasidegenerate in mass for generation of baryonic asymmetry [5].

Restrictions for νMSM-type model: $N_2 - N_3$ sector

- Accelerator experiments with *missing energy reconstruction* (PIENU, TRIUMPH, KEK, NA62, E949) and *displaced vertices detection* (PS-191, CHARM, NuTeV, DELPHI) in total give upper bounds for the mixing variables ($\alpha = e, \mu, \tau$)

$$U_\alpha^2 = \sum_{I=1}^{3} |\Theta_{\alpha I}|^2 = \begin{cases} \frac{m_1}{M_1}|U_{\alpha 1}|^2 + |\Theta_{\alpha 2}^{(NH)}|^2 + |\Theta_{\alpha 3}^{(NH)}|^2, & \text{NH} \\ \frac{m_3}{M_1}|U_{\alpha 3}|^2 + |\Theta_{\alpha 2}^{(IH)}|^2 + |\Theta_{\alpha 3}^{(IH)}|^2, & \text{IH} \end{cases}$$

- Lifetime restriction for N_2 и N_3, $\tau_N < 0.02$ sec, when there is no overproduction of the light elements ($^4He, ^2H$) in the primary plasma, [6] (socalled primary nucleosynthesis or Big Bang nucleosynthesis, **BBN**). Gives a bound from below on U_α^2.

Perturbative calculations with Majorana fermions

General form

$$\begin{aligned}\mathcal{L} &= \frac{1}{2}\overline{\lambda_a}(i\hat{\partial} - M_a)\lambda_a + \overline{\Psi_b}(i\hat{\partial} - m_b)\Psi_b + \\ &+\frac{1}{2}g^i_{abc}\overline{\lambda_a}\Gamma_i\lambda_b\Phi_c + k^i_{abc}\overline{\lambda_a}\Gamma_i\Psi_b\Phi^*_c + (k^i_{abc})^*\overline{\Psi_a}\Gamma_i\lambda_b\Phi_c + \\ &+h^i_{abc}\Psi_a\Gamma_i\Psi_b\Phi_c,\end{aligned} \tag{2}$$

where λ/Ψ are Majorana/Dirac fermions, Φ - boson.

H.Haber and G.Kane, *The Search for Supersymmetry: Probing Physics Beyond the Standard Model*, Phys.Rept. 117 (1985) 75-263 (general basis)

A.Denner, H.Eck, O.Hahn and J.Kublbeck, *Feynman rules for fermion number violating interactions*, Nucl.Phys.B 387 (1992) 467-481 (fermion flow technique implemented in FeynCalc package)

neutral current interaction

$$\mathcal{L}_{\nu N} = -\frac{g}{2c_w}\left[(U^{\dagger}\Theta)_{iJ}\overline{\nu_i}\gamma^{\mu}P_L N_J + (U^{\dagger}\Theta)^{*}_{iJ}\overline{N_J}\gamma^{\mu}P_L\nu_i\right]Z_{\mu}$$

for Majorana case can be rewritten in the form

$$\overline{N_J}\gamma^{\mu}P_L\nu_i = (\overline{N_J}\gamma^{\mu}P_L\nu_i)^T = (-1)\nu_i^T(\gamma^{\mu}P_L)^T\overline{N_J}^T = (-1)(-\overline{\widetilde{\nu}_i}\,C)(\gamma^{\mu}P_L)$$

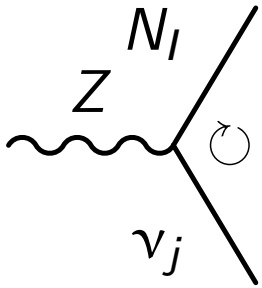
$$= \overline{\widetilde{\nu}_i}\underbrace{C(\gamma^{\mu}P_L)^T C^{-1}}_{=-\gamma^{\mu}P_R}\widetilde{N_J} = \left\{\begin{array}{c}\overline{\widetilde{\nu}_i} = \overline{\nu_i}\\ \widetilde{N_J} = N_J\end{array}\right\} = -\overline{\nu_i}\gamma^{\mu}P_R N_J \quad (3)$$

and

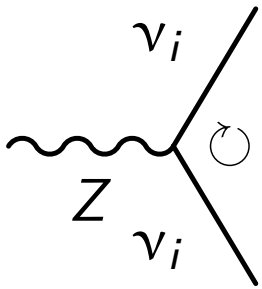
$$\mathcal{L}_{\nu N} = -\frac{g}{2c_w}\overline{\nu_i}\left[(U^{\dagger}\Theta)_{iJ}\gamma^{\mu}P_L - (U^{\dagger}\Theta)^{*}_{iJ}\gamma^{\mu}P_R\right]N_J Z_{\mu}$$

HNL decays: Feynman rules for Majorana fermions

Width calculation for Majorana fermions.



$$-i\frac{g}{2\cos\theta_W}\gamma^\mu\left[(U^\dagger\Theta)^*_{jI}P_L-(U^\dagger\Theta)_{jI}P_R\right]$$



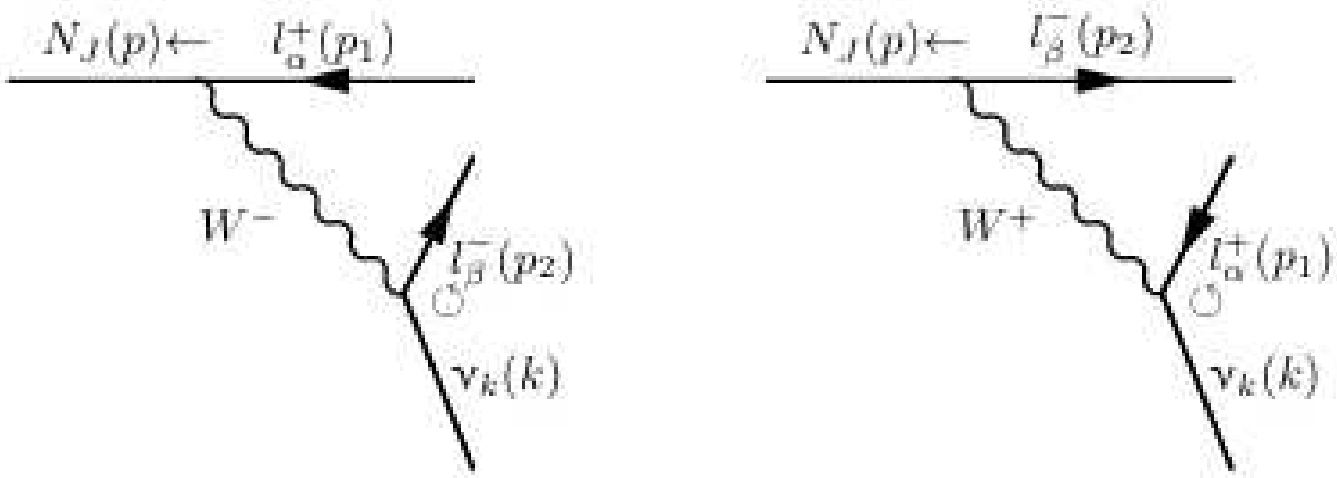
$$-i\frac{g}{2\cos\theta_W}\gamma^\mu(P_L-P_R)=i\frac{g}{2\cos\theta_W}\gamma^\mu\gamma^5$$

Таблица: Sample Feynman rules for Majorana fermions implemented in LanHEP/CompHEP

$$\Gamma_{N_{2,3}}=\Gamma(\to h^\pm+l^\mp)+\Gamma(\to h^0+\nu)+\Gamma(\to l^+l^-\nu),\quad \tau_{N_{2,3}}=\Gamma^{-1}_{N_{2,3}}$$

Majorana case interferences and the "Dirac limit": example

$$N \to l_\alpha^+ l_\beta^- \nu$$



Decay width

$$\Gamma(N_J \to \sum_{k=1}^{3} \nu_k l_\alpha^+ l_\beta^-) = \frac{G_F^2 M_J^5}{192\pi^3} \left(|\Theta_{\alpha J}|^2 + |\Theta_{\beta J}|^2 - \frac{4}{M_J} \sum_{k=1}^{3} m_k Re\{\Theta_{\alpha J} \Theta_{\beta J}^* U_{\beta k}^* U_{\alpha k}\} \right)$$

$e^{Im(\omega)}$ =1100 at ω =7. If $\alpha = \beta$ third interfering diagram with intermediate Z appears.

Partial widths of three-particle decays

- $\Gamma(N_I \to \sum_i \nu_i,\nu_j,\nu_j) = \frac{G_F^2 M_I^5}{192\pi^3} \sum_{\alpha=e,\mu,\tau} |\Theta_{\alpha I}|^2$
- $\Gamma(N_I \to \sum_{i=1,2,3} \nu_i \; l_\alpha^+ l_\alpha^-) = \frac{G_F^2 M_I^5}{96\pi^3} \left(\left[\left(\mathcal{C}_1^2+\mathcal{C}_2^2\right) \sum_\beta |\Theta_{\beta I}|^2 + (1-2\mathcal{C}_1)|\Theta_{\alpha I}|^2 \right] \mathcal{F}_1(r) + \right.$

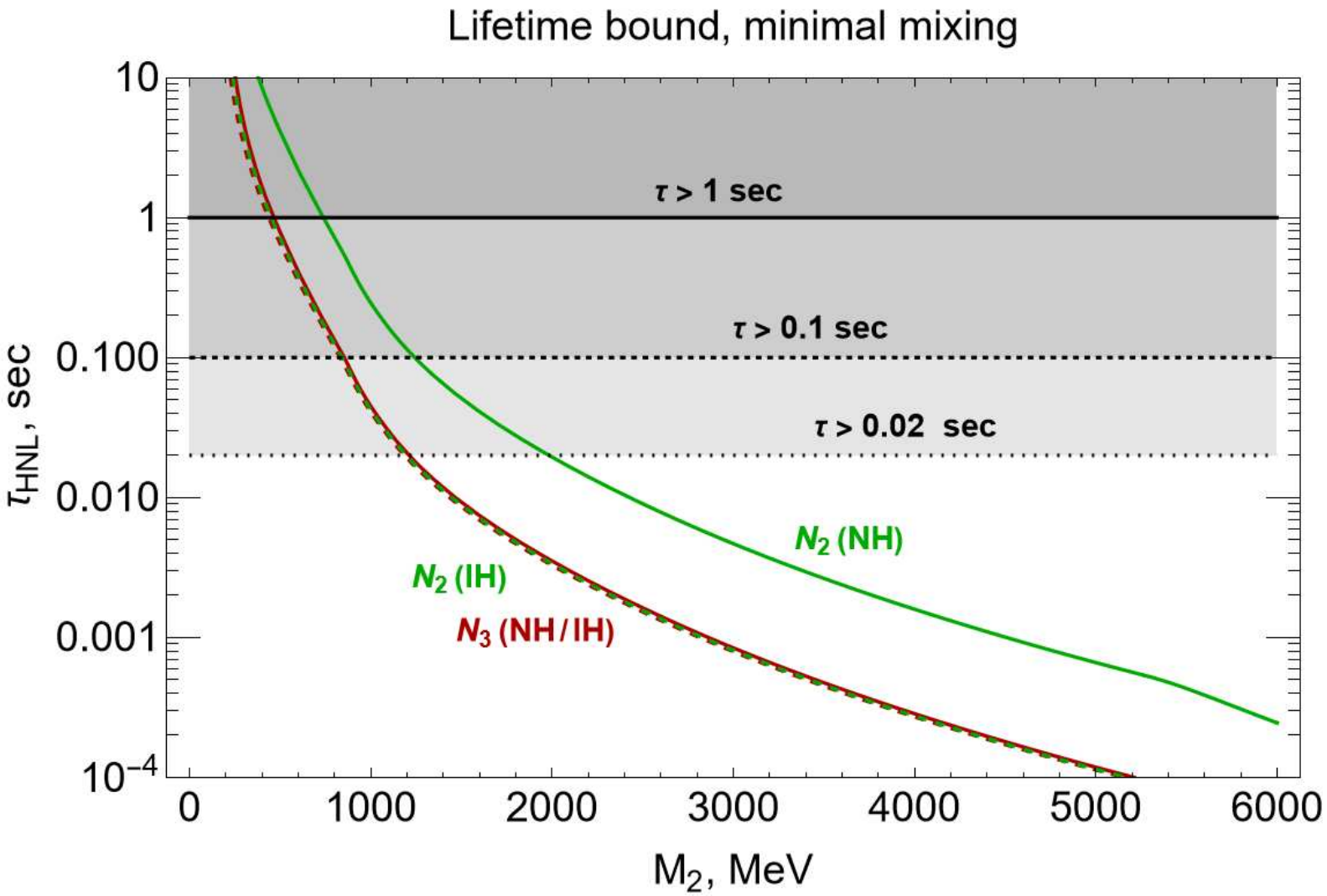
  $\left. + \left[(2\mathcal{C}_1\mathcal{C}_2) \sum_\beta |\Theta_{\beta I}|^2 - 2\mathcal{C}_2^2 |\Theta_{\alpha I}|^2 \right] \mathcal{F}_2(r) \right)$, где $\mathcal{C}_1 = s_W^2 - \frac{1}{2}$, $\mathcal{C}_2 = s_W^2$, $r_\alpha = \frac{m_\alpha^2}{M_I^2}$,

$$\mathcal{F}_1(r) = \left(1-14r-2r^2-12r^3\right)\sqrt{1-4r} + 12r^2\left(1-r^2\right)\ln\left(\frac{1-3r+(1-r)\sqrt{1-4r}}{r(1-\sqrt{1-4r})}\right),$$
$$\mathcal{F}_2(r) = (2r+10r^2-12r^3)\sqrt{1-4r} - (6r^2-12r^3+12r^4)\ln\left(\frac{1-3r+(1-r)\sqrt{1-4r}}{r(1-\sqrt{1-4r})}\right).$$

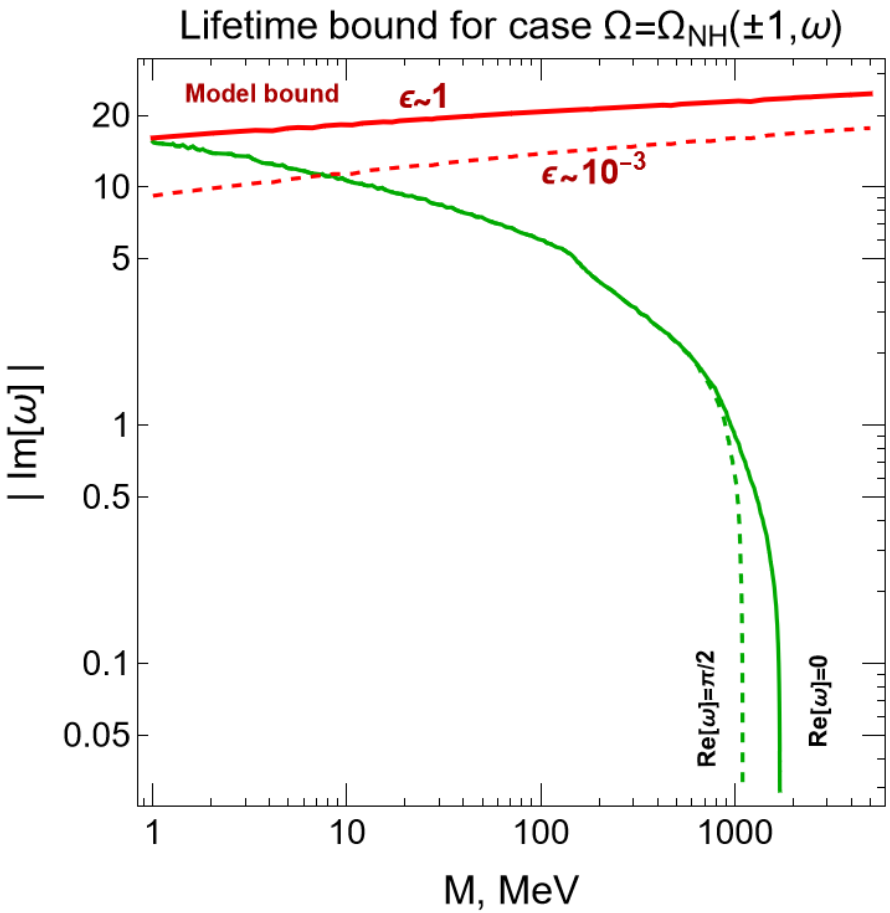
- $\Gamma(N_I \to \sum_{i=1,2,3} \nu_i \; l_{\alpha\neq\beta}^+ l_\beta^-) = \frac{G_F^2 M_I^5}{192\pi^3} \left(|\Theta_{\alpha I}|^2 + |\Theta_{\beta I}|^2\right) \mathcal{G}(r_\alpha, r_\beta)$,

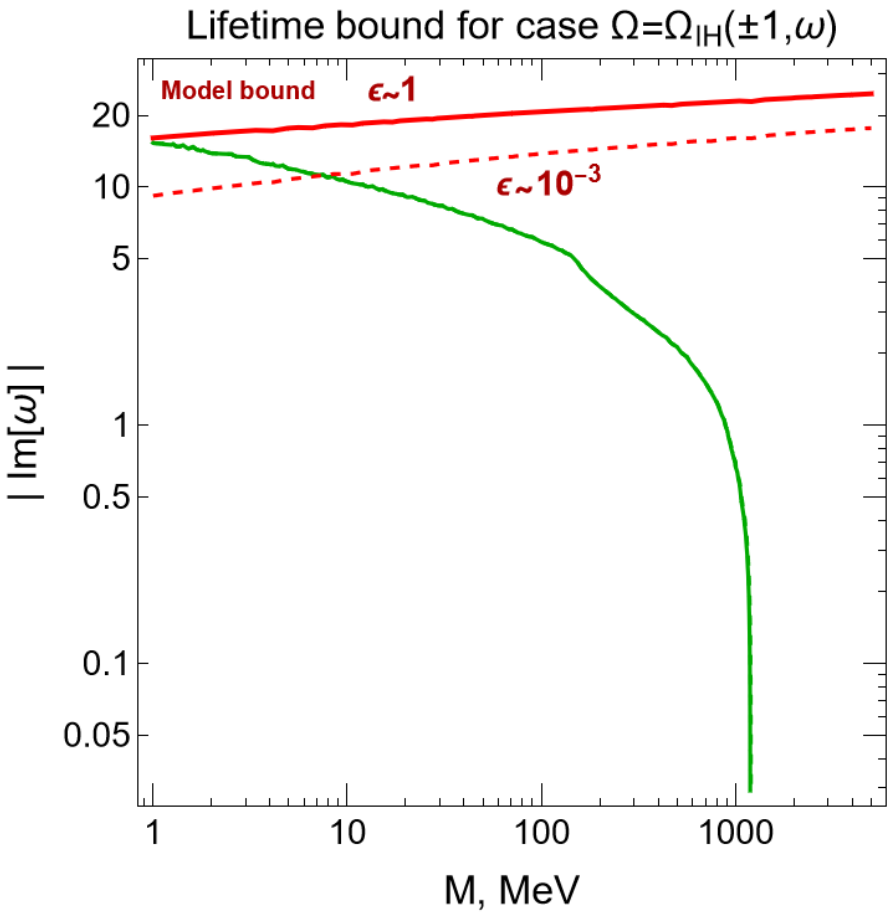
$$\mathcal{G}(x,y) = (1-7x-7x^2+x^3+12xy-7y-7y^2+y^3-7x^2y-7xy^2)R +$$
$$+12(y^2+x^2y^2-2x^2)\ln\left(\frac{1+x-y+R}{2}\right) + 12x^2(1-y^2)\ln\left(\frac{1}{x}\right) +$$
$$+12y^2(1-x^2)\ln\left(\frac{1-x-y+R}{1-x+y-R}\right), \quad R = \lambda^{1/2}(1,x,y)$$

BBN restriction in the "minimal mixing"scenario



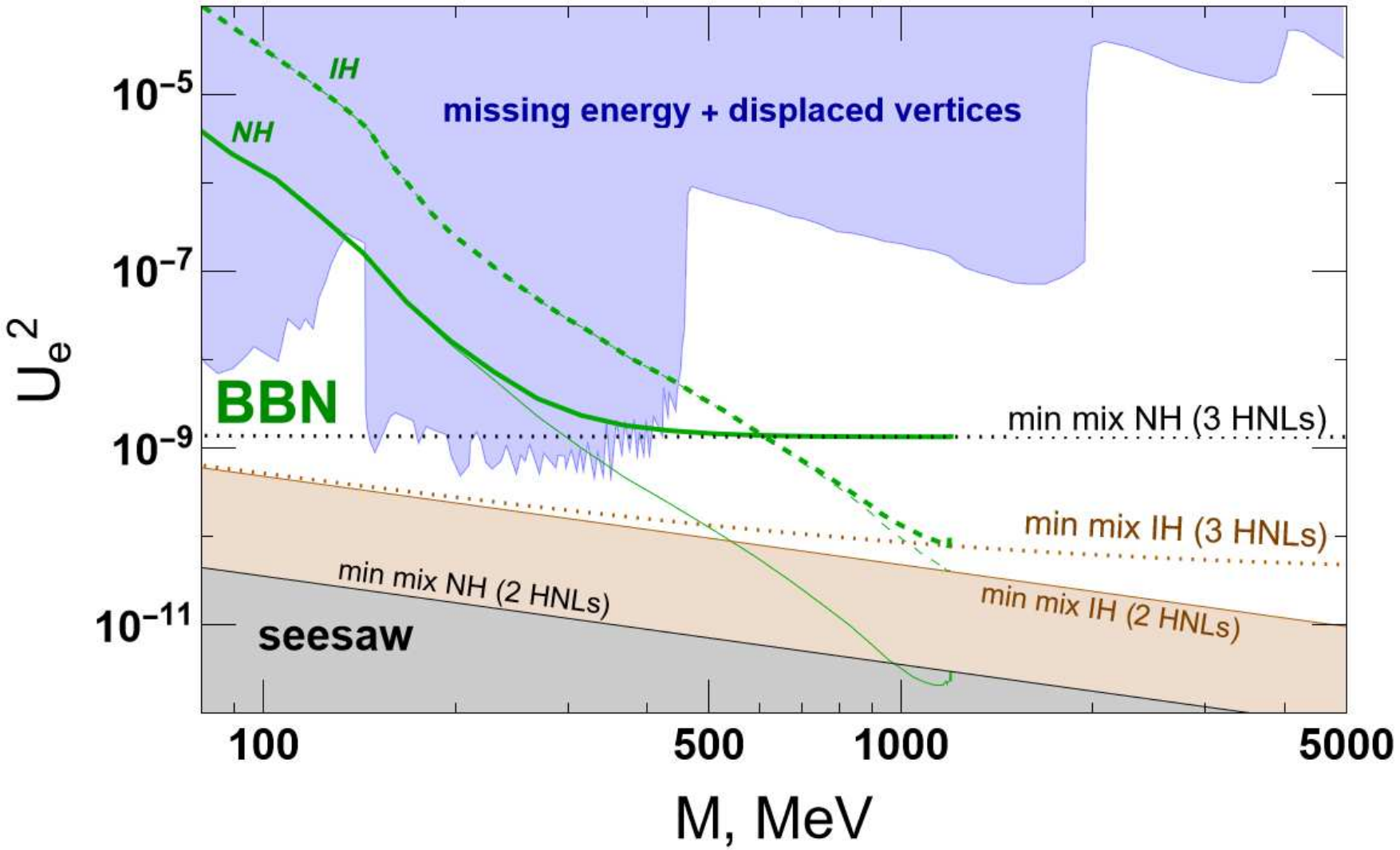
BBN restrictions for ω parameter



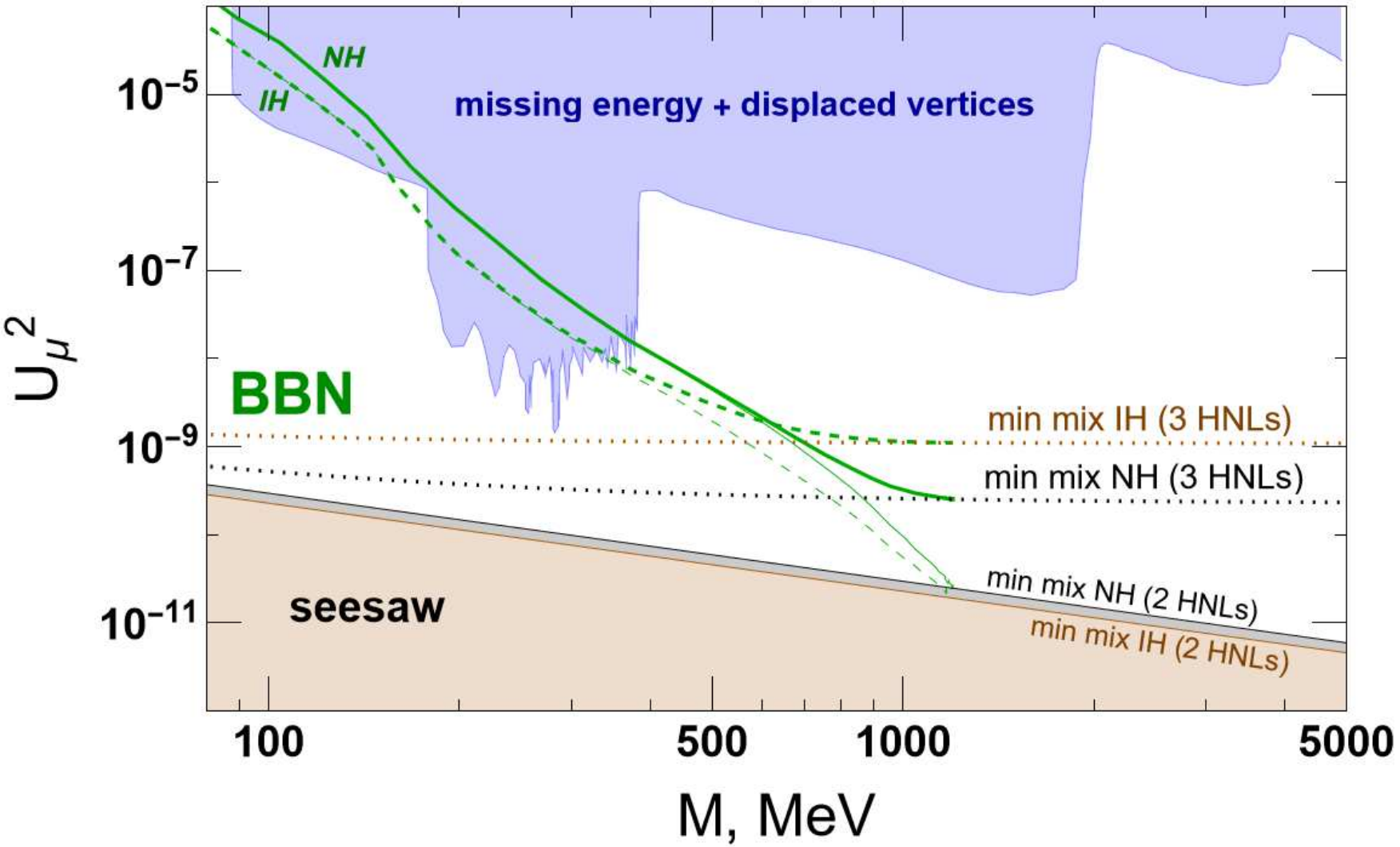


$$\Omega^{-1} = \Omega^T + \frac{1}{3}\hat{M}^{-1}(\Omega^{-1})^* \hat{m}, \quad \text{(up to } \mathcal{O}(M_D\theta) \text{ terms)}$$

Exclusion contours for U_e^2 mixing variable



Exclusion contours for U_μ^2 mixing variable



Parameter of lepton universality violation in the meson decays

The value of lepton universality violation **(LUV)** in meson decays $M = \pi^+, K^+$ is defined as

$$\Delta r_M = \frac{R_M}{R_M^{SM}} - 1, \quad \text{where} \quad R_M = \frac{\Gamma(M \to e\nu) + \Gamma(M \to eN)}{\Gamma(M \to \mu\nu) + \Gamma(M \to \mu N)}$$

to R_M^{SM} only active (SM) neutrino contribute

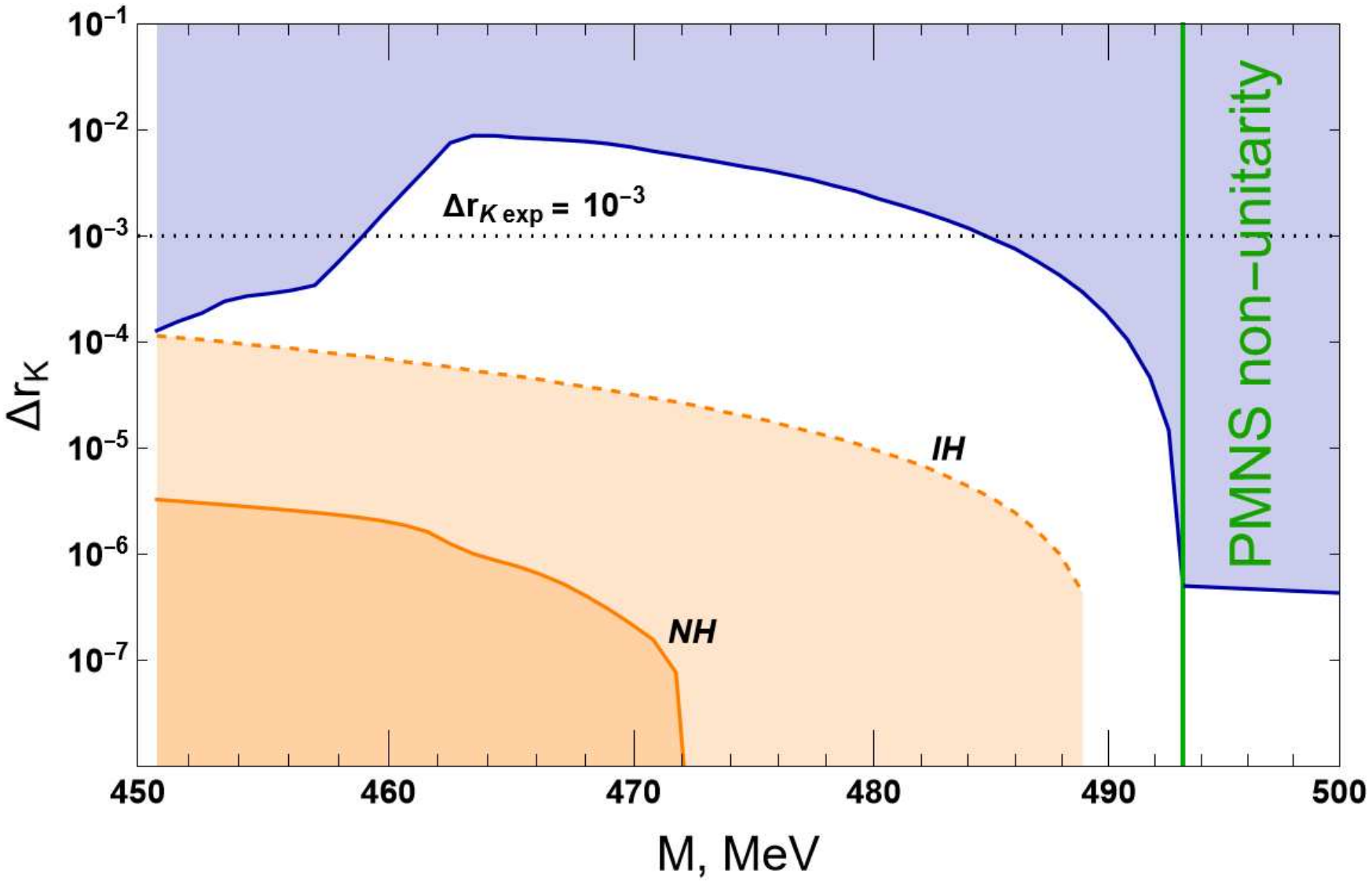
Unitarity condition of the 6×6 matrix $\mathcal{U}$

$$\sum_{i=1}^{3} |U_{\alpha i}|^2 + \sum_{I=1}^{3} |\Theta_{\alpha I}|^2 = 1$$

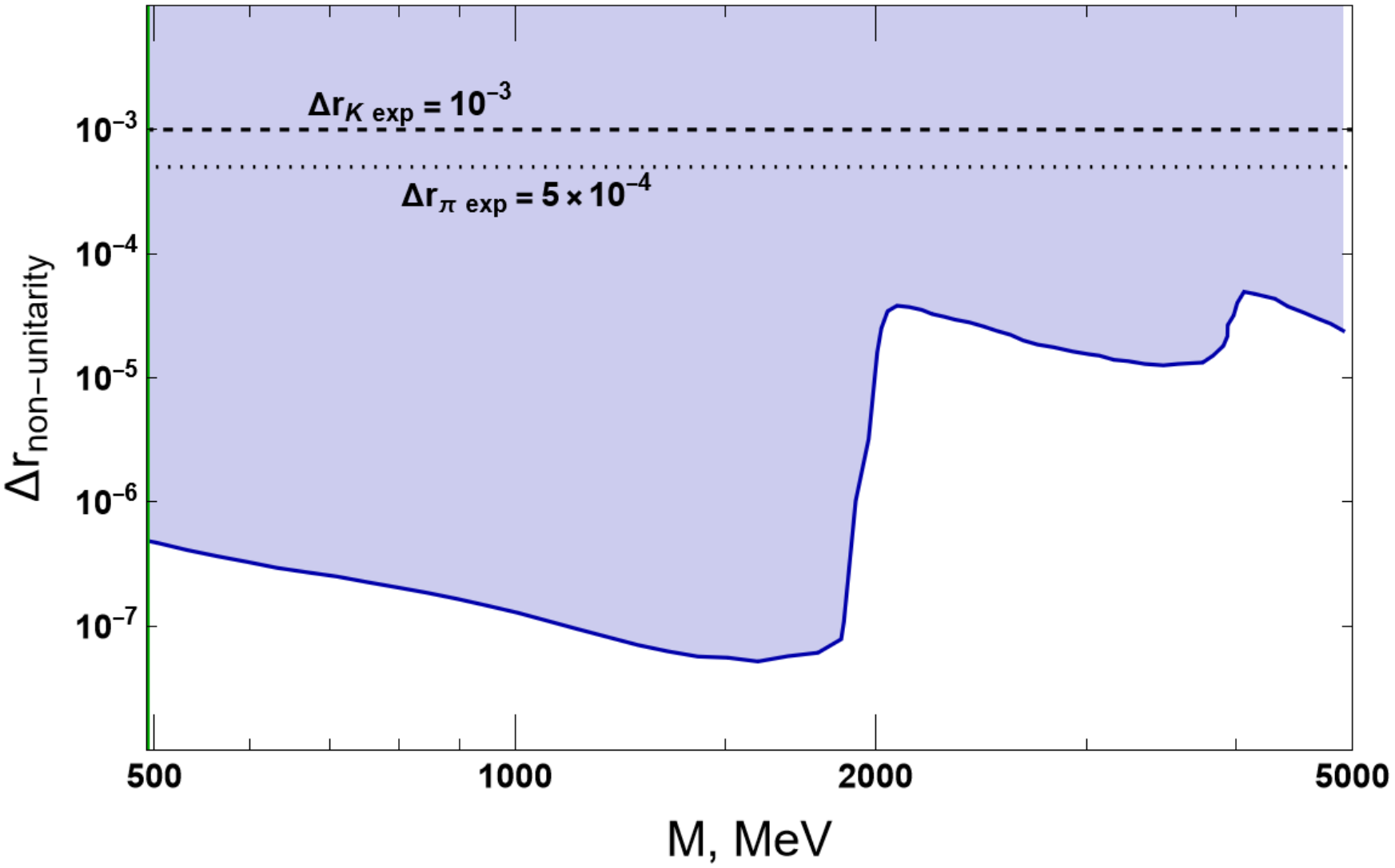
$$\Delta r_M = \frac{1 + \sum_I |\Theta_{eI}|^2 (G_{eI}^M - 1)}{1 + \sum_I |\Theta_{\mu I}|^2 (G_{\mu I}^M - 1)} - 1$$

$$G_{\alpha I}^M = \begin{cases} \frac{\lambda^{1/2}(1, r_I, r_\alpha)\left[r_I + r_\alpha - (r_\alpha - r_I)^2\right]}{r_\alpha (1 - r_\alpha)^2}, & M_I < m_M - m_\alpha \\ 0, & M_I > m_M - m_\alpha \end{cases}$$

Lepton universality violation parameter in K decays



Lepton universality violation parameter in the mass region kinematically closed



Main results (1)

- Limitations on the lifetime and particle density of a light sterile neutrino N_1 of dark matter show that its mass is 0.4 - 40 keV (in the region of mixings experimentally accessible), exponential mixing is favored for enhancements in the $N_2 - N_3$ sector where HNL signals can be amplified by the exponential multiplier $e^{Im(\omega)}$ $\sim$1000 at $\omega = i\times$6-7.
- Consideration of the sector $N_2 - N_3$ for νMSM-like models showed a significant dependence on the mixing component with a light sterile neutrino of dark matter. The model taking into account all three generations significantly raises the lower seesaw bound for mixing parameters at masses $M_{2,3} > 0.5$ GeV.
- In a model with three generations of HNL with the mass of a light active neutrino $m_{1(3)} \sim 10^{-5}$ eV and $M_1 \simeq 5$ keV, BBN the boundary of the mass of HNL $M > 407$ MeV (NH), instead of and $M > 340$ MeV for a model with two HNLs. Thus, taking into account the permissible non-zero values of the mass of a light active neutrino significantly shifts the BBN constraints.
- For LUV, a "window"was found in kaon decays in which the experimental value of $\Delta r_K = (4 \pm 4) \times 10^{-3}$ is exceeded.

Main results (2)

- Careful calculation of the lifetime in conjunction with the accelerator data gives the following acceptable parameter ranges:
  1. 134 MeV $< M <$ 144 MeV for NH – small "window" U_e^2: $1.5 \cdot 10^{-7} < U_e^2 < 2.7 \cdot 10^{-7}$ (Requires a more accurate analysis of experimental data);
  2. 155 MeV $< M <$ 177 MeV for IH: $1,2 \cdot 10^{-6} < U_\mu^2 < 3,5 \cdot 10^{-7}$.
  3. For heavier HNLs that do not fall under the aforementioned ranges, the following boundaries appear from BBN:

$$M > 407 \text{ MeV} \quad \text{for } U_e^2 \text{ with NH}, \qquad M > 452 \text{ MeV} \quad \text{for } U_e^2 \text{ with IH};$$
$$M > 370 \text{ MeV} \quad \text{for } U_\mu^2 \text{ with NH}, \qquad M > 340 \text{ MeV} \quad \text{for } U_\mu^2 \text{ with IH}.$$

  4. For «minimal mixing» the BBN-bound gives an estimate of the minimum HNL mass: $M > 1.2$ GeV for IH and $M > 2$ GeV for NH. For these masses, LUV is determined only by the deviation from unitarity and is an unobservable value of $\mathcal{O}(10^{-11})$.

For HNL signals at collider energies see the talk by A. Drutskoi.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Moscow State University

Faculty of Physics

Dedicated to the 270th Anniversary of Moscow State University and the 90th Anniversary of Faculty of Physics of MSU

TWENTY-FIRST LOMONOSOV CONFERENCE ON ELEMENTARY PARTICLE PHYSICS

Mikhail Lomonosov
1711-1765

Moscow, August 24-30, 2023

Faculty of Physics, Moscow State University
Joint Institute for Nuclear Research
Institute for Nuclear Research Russian Academy of Sciences
Skobeltsyn Institute of Nuclear Research, Moscow State University
Bruno Pontecorvo Neutrino and Astrophysics Laboratory (MSU)

INTERREGIONAL CENTRE FOR ADVANCED STUDIES

Moscow State University

Faculty of Physics

Dedicated to the 110th Anniversary of the birth of Bruno Pontecorvo

Бруно Понтекорво

1913-1993

FIFTEETH INTERNATIONAL SCHOOL on NEUTRINO PHYSICS and ASTROPHYSICS

Moscow, August 25-28, 2023

Faculty of Physics, Moscow State University
Joint Institute for Nuclear Research
Institute for Nuclear Research of Russian Academy of Sciences
Skobeltsyn Institute of Nuclear Research, Moscow State University
Bruno Pontecorvo Neutrino and Astrophysics Laboratory (MSU)

INTERREGIONAL CENTRE FOR ADVANCED STUDIES

TWENTY-FIRST LOMONOSOV CONFERENCE ON ELEMENTARY PARTICLE PHYSICS

Moscow State University, Moscow, August 24-30, 2023

Under the Patronage of the Rector of Moscow State University Victor Sadovnichy

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Programme of the 21st Lomonosov Conference on Elementary Particle Physics
(duration of 25 /20-15/ minutes talks includes 5 /3/ minutes for discussion)
(remote talks are highlighted in blue)

24 August, Thursday

08.00 – 09.00 **Registration** (Hall in front of Central Physics Auditorium, Faculty of Physics, Moscow State University)

09.00 – 09.30 **Opening** (Conference Hall)

Chair: Alexander Studenikin, Chairman of Organizing Committee, MSU

Welcome on behalf of Moscow State University
Vladimir Belokurov, Dean of Faculty of Physics of MSU
Welcome on behalf Joint Institute for Nuclear Research
Grigory Rubtsov, Vice Director of Institute for Nuclear Research RAS
Welcome on behalf of Ministry of Science and Higher Education of Russia

9.30 – 13.20 **MORNING SESSION** (Conference Hall)

09.30 D.Grigoriev (Budker Inst. of Nucl. Phys.) *Status of the COMET experiment* (25 min)
09.55 P.Pakhlov (Higher School of Economics) *Hot topic from Belle and Belle II* (25 min)
10.20 H.B.Li (IHEP, CAS) *Precision hyperon physics at BESIII* (25 min)
10.45 I.Bozovic Jelisavcic (Univ. of Belgrade) *Higgs physics at future e+e- colliders* (25 min)

11.10 – 11.40 Tea break

11.40 A.Starobinsky (Landau Inst.) *Adding baryogenesis to minimal viable inflationary models* (25 min)
12.05 K.Dimopoulos (Lancaster Univ.) *Cosmic inflation and dark energy* (25 min)
12.30 M.Giammarchi (INFN, Milan) *Antimatter gravitation and fundamental laws* (25 min)
12.55 M.Rebelo (Univ. of Lisbon) *Aspects of models with vector-like singlet quarks* (25 min)

13.20 – 15.00 Lunch

15.00 – 18.30 **AFTERNOON SESSION** (Conference Hall)

15.00 W.Wang (Sun Yat-sen Univ.) *The PandaX experiment and its latest results* (25 min)
15.25 S.Gariazzo (INFN, Turin) *Neutrino masses in cosmology* (25 min)
16.50 Sh.Udo (Kanagawa Univ.) *Recent results and status of TA/TALE/TAx4 experiment* (25 min)

16.15 – 16.40 Tea break

16.40 I.Denisenko (JINR) *SPD experiment at JINR* (25 min)
17.05 V.Riabov (NRC «Kurchatov Inst.» - PNPI) *Status and preparations for the first physics with the MPD* (25 min)

17.40 – 23.30 **SPECIAL SESSION** (40^0)
Reception banquet will be held on board of a ship that will stream along the river across the central part of Moscow; the conference buses to the ship will depart from the entrance of the Faculty of Physics at **17.40**

25 August, Friday

The 15th International School on Neutrino Physics and Astrophysics

09.00 – 13.30 **MORNING SESSION** (Conference Hall)

09.00 G.Safronov (INR RAS) *Recent results from the Baikal-GVD neutrino telescope* (25 min)
09.25 D.Akimov (MEPhI) *Worldwide experimental study of CEvNS* (25 min)
09.50 A.Konovalov (Lebedev Phys. Inst.) *Status of COHERENT and new physics opportunities at SNS* (25 min)
10.15 K.Kouzakov (MSU & NCPM) *Status of tritium neutrino experiment in Sarov* (25 min)
10.40 A.Serebrov (NRC "Kurchatov Inst." - PNPI) *The result of the Neutrino-4 experiment, sterile neutrinos, dark matter and the Standard Model* (25 min)

11.05 – 11.35 Tea break

11.35 N.Ushakov (INR RAS) *The Baksan Large Neutrino Telescope: The current status* (25 min)
12.00 I.Drachnev (NRC "Kurchatov Inst." - PNPI) *The latest Borexino results on the CNO neutrino studies* (20 min)
12.20 I.Karpikov (INR RAS) *The indication for 40K geo-antineutrino flux with Borexino phase-III data* (20 min)
12.40 W.Wang (Sun Yat-sen Univ.) *Overview of JUNO experiment* (25 min)
13.05 A.Dolgov (Novosibirsk State Univ. & JINR) *Solution of JWST and HST problems with primordial black holes* (25 min)

13.30 – 15.00 Lunch

15.00 – 16.15 **AFTERNOON SESSION** (Conference Hall)
15.00 E.Yakushev (JINR) *Fundamental physics with reactor neutrinos* (25 min)
15.25 D.Ponomarev (JINR) *Status of the vGeN experiment* (25 min)
15.50 I.Zhitnikov (JINR) *Recent results from the DANSS experiment* (25 min)

16.15 – 16.40 Tea break

SESSION 25.08. A (Neutrino experiment)

16.40 Yu.Kudenko (INR RAS) *Physics with near neutrino detectors of LBL accelerator experiment* (20 min)
17.00 B.Lubsandorgiev (INR RAS) *Low energy neutrino physics with gallium containing scintillators* (20 min)
17.20 D.Moore (Yale Univ.) *Searches for massive neutrinos with mechanical quantum sensors* (20 min)
17.40 R.Samoilov (NRC "Kurchatov Inst." - PNPI) *Preparation of the Neutrino-4+ experiment at the SM-3 reactor* (15 min)
17.55 N.Skrobova (Lebedev Phys. Inst.) *Measurements of the reactor antineutrino energy spectrum dependence on the fuel composition and absolute antineutrino counting rates* (15 min)
18.10 O.Razuvaeva (MEPhI) *The RED-100 results & prospects* (15 min)
18.25 E.Khalikov (SINP MSU) *Recent results from SND@LHC* (15 min)
18.40 A.Majumdar (Indian Inst. of Science Education and Research Bhopal) *Physics implications of Dresden-II reactor data* (10 min)

SESSION 25.08. B (Dilepton production & Photon measurements)

16.40 V.Zykunov (JINR) *Electroweak corrections to dilepton production via photon fusion at LHC* (20 min)
17.00 M.Vysotsky (Lebedev Phys. Inst.) *Lepton pair production in UPC at LHC* (15 min)
17.15 E.Karkaryan (Lebedev Phys. Inst.) *Muon pair production at the LHC with one proton tagging via γγ fusion and γZ fusion* (15 min)
17.30 E.Kasyanova (JINR) *The study of the birth of dimuons in the NA64 experiment* (10 min)
17.40 D.Peresunko (NRC «Kurchatov Inst.») *Real and virtual direct photon measurements with ALICE* (20 min)
18.00 P.Krokovny (Budker Inst. of Nucl. Phys.) *Exotic quarkonium and hadron spectroscopy at Belle II* (15 min)
18.15 N.Burmasov (NRC "Kurchatov Inst." - PNPI) *Results and prospects of two-photon interaction studies with the ALICE experiment at the LHC* (20 min)
18.35 M.Alizada (Baku State Univ.) *Production of prompt photon in bremsstrahlung from quark-gluon plasma at proton-proton collision* (15 min)

SESSION 25.08. C (Dark matter & g-2)

16.40 A.Anokhina (MSU) *NEWSdm experiment to search for the cosmic ray boosted dark matter* (15 min)
16.55 Z.Y. Zhang (Tsinghua Univ.) *Probing dark matter-electron interactions via high-purity germanium detectors from CDEX* (15 min)
17.10 S.Chashin (SINP MSU) *Direct search for low mass dark matter with DarkSide-50* (15 min)
17.25 L.Corona (INFN, Pisa) *Searches for invisible new particles at Belle II* (15 min)
17.40 A.D'yachenko (Petersburg State Transport Univ. & NRC "Kurchatov Inst." - PNPI) *On the issue of detecting dark matter particles* (15 min)
17.55 A.Chaudhuri (Indian Inst. of Technology) *Dark matter production from two evaporating primordial black holes* (15 min)
18.10 A.de Giorgi (Univ. Aut. Madrid, Inst. Theor. Phys.) *The low-scale seesaw solution to the M_W and $(g-2)_\mu$ anomalies* (20 min)
18.30 P.Panda (Univ. of Hyderabad) *Explaining neutrino phenomenology, leptogenesis and $(g-2)_{e,\mu}$ with U(1) symmetries in inverse seesaw framework* (20 min)

19.00 – 22.30 Sight-seeing bus excursion in Moscow

26 August, Saturday

09.00 – 13.35 **MORNING SESSION** (Conference Hall)

09.00 S.Shmatov (JINR) *CMS overview* (25 min)
09.25 A.Furs (INR RAS) *Luminosity determination by ALICE during LHC Run 3* (25 min)
09.50 E.Kryshen (NRC "Kurchatov Inst." - PNPI) *Overview of recent ALICE results* (25 min)
10.15 D.Baigarashev (JINR) *Latest results and precision measurements from the NA62 experiment* (25 min)
10.40 J.Milosevic (Vinča Inst. of Nucl. Science) *Highlights from quark gluon plasma studies in relativistic nuclear collisions* (25 min)
11.05 V.Rekovic (Vinča Inst. of Nucl. Science) *Triggering in the LHC experiments* (25 min)

11.30 – 11.55 Tea break

11.55 K.Han (Shanghai Jiao Tong Univ.) *Progress and status of neutrinoless double beta decay experiments* (25 min)
12.20 S.Fu (Fudan Univ.) *Latest results from the CUORE experiment* (25 min)
12.45 L.Yang (Tsinghua Univ.) *Recent status and prospects of CDEX @CJPL* (25 min)
13.10 M.Dubinin (SINP MSU) *Mixing scenarios, dark matter and lepton universality with three generations of heavy neutral leptons* (25 min)

13.35 – 15.00 Lunch

15.00 – 19.10 **AFTERNOON SESSION** (Conference Hall)
15.00 I.Logashenko (Budker Inst. of Nucl. Phys.) *Measurement of muon g-2 at Fermilab* (25 min)
15.25 G.Fedotovich (Budker Inst. of Nucl. Phys.) *Pion form factor measurement with CMD-3 detector at the electron-positron collider VEPP-2000* (25 min)
15.50 Sh.-P.He (APCTP, Pohang) *Scalar leptoquark and vector-like quark extended models as the explanation of the muon g-2 anomaly* (25 min)
16.15 H.Zhang (Univ. of Science and Technology of China) *R value measurements at BESIII* (20`)

16.35 – 17.00 Tea break

SESSION 26.08. A (Colliders)

17.00 I.Bubanja (Univ. of Montenegro & Université libre de Bruxelles) *Inclusive production of vector bosons in CMS* (15 min)
17.15 N.K.Petrov (MIPT) *New resonances in J/ψJ/ψ mass spectrum at CMS* (15 min)
17.30 E.Solodov (Budker Inst. of Nucl. Phys.) *Study of the e+e- ->hadronic cross sections at the NNbar threshold with CMD-3 detector at VEPP2000 collider* (20 min)
17.50 A.Botov (Budker Inst. of Nucl. Phys.) *Study of the e^+e^- annihilation into hadrons with the SND detector at the VEPP-2000 collider* (15 min)
18.05 N.A.Petrov (Budker Inst. of Nucl. Phys.) *Study of the process $e^+e^- \to K_S K_L$ in the center-of-mass energy range 1.05 − 2.0 GeV with the CMD-3 Detector at VEPP-2000 collide*r (15 min)
18.20 S.Tolmachev (Budker Inst. of Nucl. Phys.) *Study of the $e^+e^- \to \pi^+\pi^-\pi^0$ with the CMD-3 detector at the VEPP-2000* (10 min)
18.30 F.Martynenko (Samara National Research Univ.) *Hadronic light by light contribution to the fine and hyperfine structure of muonic atoms* (15 min)
18.45 D.Prokhorova (Saint-Petersburg State Univ.) *Particle correlations in the model of interacting colour strings for p+p collisions* (10 min)
18.55 N.Pukhaeva (JINR) *Femtoscopy study with BM@N data of NICA* (15 min)

SESSION 26.08. B (Seesaw & *Double beta decay*)

17.00 B.Yu (IHEP) *Sphaleron in the Higgs Triplet Model* (20 min)
17.20 L.Wang (Beijing Normal Univ.) *CDEX-300v: The neutrinoless double beta decay experiment based on 76Ge* (20 min)
17.40 V.Belov (NRC "Kurchatov Inst.") *Searching for Majorana neutrinos with nEXO* (20 min)
18.00 A.Drutskoy (Lebedev Phys. Inst.) *Prospects for heavy Majorana neutrino searches at future lepton colliders* (15 min)
18.15 V.Kornoukhov (MEPhI) *Status and perspectives of the AMoRE experiment* (15 min)

SESSION 26.08. C (Design & Constructions)

17.00 Y.Kambar (JINR) *Straw tubes for the NA64 experiment at CERN* (15 min)
17.15 I.Segal (MEPhI) *Methods for centrality determination in heavy-ion collisions with the BM@N experiment* (15 min)
17.30 N.Karpushkin (INR RAS) *Performance of BM@N forward hadron calorimeter and forward quarz hodoscope in Xe+CsI@3.8 AGeV run* (15 min)
17.45 S.Morozov (INR RAS) *Development of new high granular neutron time-of-flight detector for BM@N experiment* (15 min)
18.00 Y.Wang (Shandong Univ.) *Fabrications and performance test of ECal modules in China for NICA-MPD experiment* (15 min)
18.15 V.Baryshnikov (JINR) *Status of the time-of-flight and ECal particle identification systems of the MPD Experiment at the NICA Collider* (15 min)
18.30 V.Volkov (INR RAS) *Performance of BM@N scintillation wall in Xe+CsI@3.8 AGeV run* (15 min)

19.00-20.00
Conference Hall

The 15th International School on Neutrino Physics and Astrophysics

MOVIE
Dedicated to the 110th Anniversary of Bruno Pontecorvo: “Maksimovich. The Story of Bruno Pontecorvo”
Screenwriter Giuseppe Mussardo
Directed by Diego Cenetiempo

27 August, Sunday

9.00 – 19.00 Bus excursion to Sergiev Posad

28 August, Monday

The 15th International School on Neutrino Physics and Astrophysics

09.00 – 13.40 **MORNING SESSION** (Conference Hall)

09.00 J.Valle (CPPM, Marseille) *Neutrinos: At the dawn of a revolution?* (25 min)
09.25 C.Ternes (INFN, Turin) *Global neutrino oscillation fits and neutrino anomalies* (25 min)
09.50 L.Kolupaeva (JINR) *Current status and future prospects of three-flavor oscillations with accelerator neutrino beams* (25 min)
10.15 M.Dvornikov (IZMIRAN) *Neutrino oscillations in gravitational fields* (25 min)
10.40 D.Gorbunov (INR RAS) *Testing nuMSM with present and next generation experiments* (25 min)

11.05 – 11.30 Tea break

11.30 V.Petrov (NRC "Kurchatov Inst." - IHEP) *Strong interactions in historical perspective: From nuclear structure to multiquarks* (25 min)
11.55 A.Isaev (MSU) *Generalized Bargmann-Wigner construction for massive and massless relativistic fields* (25 min)
12.20 A.Kataev (INR RAS) *The generalized Crewther relation and V-scheme in QCD and theoretical consequences* (20 min)
12.40 K.Stepanyantz (MSU) *Quantum corrections and exact results in supersymmetric theories regularized by higher covariant derivatives* (20 min)
13.00 V.Marachevsky *Chern-Simons boundary layers in the Casimir effect* (20 min)
13.20 N.Raicevic (Univ. of Montenegro) *The impact of intrinsic motion of partons in Drell-Yan production at NLO with the Parton Branching Method* (20 min)

13.40 – 15.00 Lunch

SESSION 28.08. A1 (Neutrino & Astroparticle physics)

15.00 A.Antoshkin (JINR) *Searches for exotic physics in the NOvA experiment* (25 min)
15.25 N.Titov (INR RAS) *Search for heavy sterile neutrinos in the integral mode electron registration* (15 min)
15.40 V.Galkin (MSU) *SPHERE-3: tackling the problem of primary cosmic ray mass composition with a new approach* (20 min)
16.00 M.Amelchakov (MEPhI) *Cosmic-ray anisotropy study by means of detection of muon bundles* (20 min)
16.20 S.Mayburov (Lebedev Phys. Inst.) *Search of periodic and unperiodic variations of nucleus weak decay parameters* (15 min)
16.35 A.Shehada (Chechen State Pedagogical Univ.) *New approach of explaining the missing sources of UHE neutrinos as an effect of approaching Planck length* (10 min)

16.45 – 17.10 Tea break

SESSION 28.08. A2 (QCD & BSM)

17.10 P.Pronin (MSU) *Higher derivative quantum gravity in general parametrization and general gauge conditions* (20 min)
17.30 R.Rogalyov (NRC "Kurchatov Inst." - IHEP) *Net-baryon probability distributions from lattice simulations* (20 min)
17.50 V.Bornyakov (NRC "Kurchatov Inst." - IHEP) *Lattice QCD with N_c=2 at nonzero temperature and quark density* (20 min)

18.10 V.Velizhanin (NRC "Kurchatov Inst." - PNPI) *The anomalous dimension of twist-3 operators in N=4 SYM theory* (15 min)
18.25 V.Shirokova (MSU) *Multiloop calculations of beta-function of N=1 supersymmetric theories, regularized by higher derivatives* (10 min)
18.35 O.Haneychuk (MSU) *Three-loop β-functions and a class of the NSVZ schemes for MSSM obtained with the help of the higher covariant derivative regularization* (10 min)
18.45 A.Aynbund (MIPT) *Supersymmetric proof to count bound state nodes* (10 min)

SESSION 28.08. B1 (Holographic principle & Physics at accelerators. Theory)

15.00 R.Ryutin (NRC "Kurchatov Inst." - IHEP) *Exclusive central diffractive production of hadron pairs in the Regge eikonal model at energies from 30 Gev to 13 TeV* (15 min)
15.15 A.Hajilou (Steklov Mathematical Inst. RAS) *Magnetic catalysis in holographic model with two types of anisotropy for heavy quarks* (10 min)
15.25 P.Slepov (Steklov Mathematical Inst. RAS) *Energy loss for heavy quarks in strong magnetic field* (15 min)
15.40 K.Rannu (Peoples' Friendship Univ. of Russia) *On the role of the z^5 term in the metric strain coefficient for the holographic description of magnetic catalysis in a quark-gluon plasma* (10 min)
15.50 M.Usova (Steklov Mathematical Inst. RAS) *Holographic RG flows for light and heavy quarks models* (10 min)
16.00 V.Schegelsky (NRC "Kurchatov Inst." - PNPI) *The first observation of pion condensate* (20 min)
16.15 V.Kuzminov (INR RAS) *Seasonal changes of the 212Po half-life solar-daily variation parameters* (15 min)

16.45 – 17.10 Tea break

SESSION 28.08. B2 (Physics at accelerators. Theory)

17.10 V.Vechernin (Saint-Petersburg State Univ.) *Cumulative production at central rapidities and large transverse momenta in the quark model of flucton fragmentation* (20 min)
17.30 A.Egorov (NRC "Kurchatov Inst." - PNPI & Peter the Great St. Petersburg Polytec. Univ.) *The next-to-leading approximation of BFKL for dijet production with large rapidity separation between jets at the LHC* (20 min)
17.50 U.Voznaya (JINR) *Electron parton distribution functions* (15 min)
18.05 P.Volkov (MSU) *Neural network techniques for a separation of top pair and single top contributions in tWb final state* (15 min)
18.20 A.Machavariani (JINR) *Relativistic partial wave analysis of inclusive meson production $A+B\to V+X\to 1+2+X$ and determination of the spin quantization axis via the cross sections $A+B\to V+X$* (20 min)

SESSION 28.08. C1 (Mesons)

15.00 M.Sergeev (MEPhI) *Recent CMS results on rare heavy flavour decays* (20 min)
15.20 K.Ivanov (MIPT) *CMS results on heavy flavour spectroscopy and production* (15 min)
15.35 Y.Ji (Shandong Univ.) *Light meson decays at BESIII* (15 min)
15.50 M.Malaev (MIPT & NRC "Kurchatov Inst." - PNPI) *Feasibility studies for the measurements of open heavy-flavor mesons with ALICE-3 at the HL-LHC* (20 min)
16.10 Z.Lei (Univ. of Science and Technology of China) *Light flavor vector mesons between 2 and 3 GeV at BESIII* (20 min)
16.30 I.Ray (IIT Gandhinagar) *Extraction of $|Vub|$ from $B \to \pi lv$* (15 min)

16.45 – 17.10 Tea break

SESSION 28.08. C2 (Mesons and baryons)

17.10 L.Ying (Lanzhou Univ.) *Charmed baryon decays at BESIII* (20 min)
17.30 X.Wang (Lanzhou Univ.) *Hyperon physics at BESIII* (20 min)
17.50 O.Bakina (JINR) *Study of charmonia production in e^+e^- annihilation at center-of-mass energies above 3.81 GeV* (20 min)
18.10 F.Meier (Duke Univ.) *Hadronic B decays at Belle II* (20 min)
18.30 E.Savchenko (MSU & FRC CSC RAS) *Relativistic description of fully heavy tetraquark spectroscopy* (15 min)
18.45 A.Polyarush (INR RAS) *Study of $K^+ \to \pi^0 e^+ \nu\gamma$ decay with OKA setup* (15 min)
19.00 I.Tiurin (NRC "Kurchatov Inst." - IHEP) *$K^+ \to \pi^0 \mu^+ \nu\gamma$ radiative decay: preliminary results from the OKA experiment* (10 min)
19.10 A.Kulik (INR RAS) *Observation of $K^+ \to \pi + \pi^0 \pi^0 \gamma$ decay* (15 min)

29 August, Tuesday

09.00 – 13.35 **MORNING SESSION** (Conference Hall)

09.00 A.Zakharov (NRC "Kurchatov Inst." & BLTP JINR) *Black hole shadows as new tests of general relativity* (25 min)
09.25 D.Levkov (INR RAS & ITMP) *Self-similar growth of axion stars* (25 min)
09.50 D.Galtsov (MSU) *Black hole thermodynamics and S-duality* (25 min)
10.15 E.Arbuzova (Dubna State Univ. & Novosibirsk State Univ.) *High frequency curvature oscillations at gravitational baryogenesis and UHECR emission* (25 min)
10.40 V.Dokuchaev (INR RAS) *Cosmological particle creation in Weyl geometry* (25 min)

11.05 – 11.30 Tea break

11.30 D.Peshekhonov (JINR) *The NA64 experiment - search for hidden sector at CERN SPS* (25 min)
11.55 D.Kirpichnikov (INR RAS) *Current status and prospects of NA64 experiment* (25 min)
12.20 S.Vasina (JINR) *First physics results from the FASER experiment* (20 min)
12.40 P.Jiang (Peking Univ.) *Dark sector and axion-like particle search at BESIII* (20 min)
13.00 M.Savina (JINR) *Dark matter searches at CMS* (20 min)
13.20 I.Aref'eva (Steklov Math. Inst.) *Holography for heavy ions collisions* (25 min)

13.45 – 15.00 Lunch

SESSION 29.08. A1 (Cosmology & Extra-dimensions)

15.00 A.Garat (Univ. of the Republic, Uruguay) *Timelike and spacelike vectors transform into null vectors through local gauge transformations in particle physics* (20 min)
15.20 B.Levchenko (MSU) *Extra dimensions of space and time in the region of deeply inelastic processes* (20 min)
15.40 Y.Grats (MSU) *Casimir interaction of finite-width strings* (15 min)
15.55 P.Spirin (MSU) *Kapteyn type-II series in the synchrotron radiation problem* (15 min)
16.10 A.Reshetnyak (Tomsk State Pedagog. Univ. & Nat. Research Tomsk Polytec. Univ.) *Covariant consistent Lagrangian cubic interaction vertices for irreducible higher spin fields in Minkowski backgrounds* (15 min)
16.25 M.Fil'chenkov (RUDN Univ.) *Quantum cosmology in 3-geometry superspace* (15 min)
16.40 S.Yakimenko (INR RAS) *A way to construct octonion matrices* (10 min)

17.00– 17.25 Tea break

SESSION 29.08. A2 (Theory)

17.25 S.Lebedev (Surgut State Univ.) *Polarization through the elastic scattering in magnetic field* (15 min)
17.40 A.Eskin (Samara National Research Univ.) *Investigation of energy levels of exotic three-particle systems in the variational approach* (15 min)
17.55 A.A.Abd Aljalel (Novosibirsk State Univ.) *Majorana transformation of the Thomas–Fermi equation demystified* (15 min)
18.10 N.Kolomoyets (JINR) *Correlations of the velocities and of the vorticities for nucleons and pions in PHSD model* (15 min)
18.25 V.Maslov (INR RAS & ITMP & MSU) *Analytic description of large scalar oscillons* (10 min)
18.35 R.Shindin (JINR) *Bessel and Spin* (15 min)
18.50 D.Tsousis (Univ. of Patras) *Search of periodic and unperiodic variations of nucleus weak decay parameters* (10 min)

SESSION 29.08. C1 (Heavy ion collisions)

15.00 S.Petrushanko (MSU) *Latest results on heavy-ion physics with the CMS detector* (20 min)
15.20 D.Myagkov (MSU) *Azimuthal anisotropy in Xe–Xe and Pb–Pb collisions with the Monte-Carlo model HYDJET++ and the CMS detector at the energies of the LHC* (10 min)
15.30 U.Dmitrieva (INR RAS) *Studies of electromagnetic dissociation of ^{208}Pb in ALICE experiment at the LHC* (15 min)
15.45 M.Tokarev (JINR) *Statistical properties of fractal entropy of K_S^0-meson production in Au+Au collisions at RHIC* (20 min)
16.05 A.Shabanov (INR RAS) *Measurement of π^0 yield in Ag+Ag collisions at 1.23 A GeV beam energy* (20 min)
16.25 M.Abed (Tomsk Polytech. Univ.) *The effect of the non-Gaussian tail population on the electromagnetic beam-beam interaction between colliding beams in RHIC* (15 min)
16.40 D.Larionova (Saint-Petersburg State Univ.) *PHENIX highlights* (20 min)

17.00 – 17.25 Tea break

SESSION 29.08. C2 (Heavy ion collisions)

17.25 P.Parfenov (MEPhI) *Anisotropic flow and its scaling properties at Nuclotron-NICA energies* (15 min)
17.40 E.Bannikov (St.Petersburg Polytech. Univ.) *Measurements of π^0 elliptic flow in Cu+Au collisions* (20 min)
18.00 V.Troshin (MEPhI) *Performance of FFD detector for anisotropic flow analysis with the MPD experiment* (15 min)
18.15 M.Mamaev (MEPhI) *On the proton directed and elliptic flow in the few-GeV heavy ion collisions with BM@N* (20 min)
18.35 N.Abdulameer (Univ. of Debrecen) *Centrality dependence of direct γ and π0 production in d+Au collisions* (10 min)
18.45 A.Pashkov (LLC Digitizer) *Recording electronics for particle physics: The data collection, digitization and processing* (10 min)
18.55 I.Bredikhin (LLC Digitizer) *Development of a software and hardware complex for the search and identification of gamma-emitting nuclides based on machine learning* (10 min)

30 August, Wednesday

09.00 – 13.35 **MORNING SESSION** (Conference Hall)

09.00 C.Vayenas (Univ. of Patras) *Hadronization via gravitational confinement of fast neutrinos: mechanics at fm distances* (25 min)
09.25 V.Braguta (JINR) Influence of relativistic rotation on QCD properties (25 min)
09.50 O.Kodolova (MSU) *QCD physics with CMS detector* (25 min)
10.15 Y.Kharlov (NRC "Kurchatov Inst." - IHEP) *Overview of QCD studies in ALICE at LHC* (25 min)
10.40 Y.Zhang (Univ. of Science and Technology of China) *Light QCD exotics at BESIII* (25 min)

11.05 – 11.30 Tea break

ROUND TABLE DISCUSSION
"Frontiers in Particle Physics"
(Conference Hall)

11.30 D.Meloni (Rome Univ.) *Modular symmetries and the flavor problem* (25 min)
11.55 R.Mohanta (Univ. of Hyderabad) *Flavour anomalies, light dark matter and rare B decays with missing energy in* $L_\mu - L_\tau$ *model* (25 min)
12.20 T.Roy (TATA Inst. of Fundamental Research) *ALPS physics* (25 min)
12.45 A.Fedynitch (Inst. of Physics, Academia Sinica & Tokyo Univ.) *Progress in high-energy neutrino flux calculations* (25 min)
13.10 V.Neznamov (RFNC-VNIIEF) *Quantum electrodynamics with empty fermion vacuum without "sea" of states with negative energies and with opposite signs of mass summands in Dirac equations for particles and antiparticles: Possibilities of experimental verification* (25 min)

13.35 – 15.00 Lunch

15.00 Q.Liu (Univ. of CAS) *The progress of Super Tau Charm Facility in China* (25 min)
15.25 I.Logashenko (Budker Inst. of Nucl. Phys.) *The progress of Super Charm Tau Factory in Russia* (25 min)
15.50 S.Gertsenberger (JINR) *Lepton flavor violation study in the NA64 experiment* (20 min)
16.10 R.Chistov (Lebedev Phys.Inst.) *Searches for lepton flavor universality violation at CMS* (20 min)
16.30 C.Schwanda (IHEP, Austria) *Semileptonic decays and tests of lepton flavour universality at Belle II* (20 min)

Closing of the 21st Lomonosov Conference on Elementary Particle Physics

SPECIAL SESSION (40^0)

POSTER Session

M.Ostashova (SAI MSU) *Fractal properties of the stellar medium in the solar neighborhood based on GAIA DR2 data*

A.Budzinskaya (INR RAS) *Stages of simulation of the prototypes of the Baksan Large Neutrino telescope*

V.Ashikhmin (INR RAS) *Background and Signal Simulation for cluster detection in the LVD*

A.Soheilbeigi Bazgir (Jan Kochanowski Univ.in Kielce) *Imprints of clustering in multiplicity fluctuations*

A.Purtova (MSU) *The influence of neutrino quantum decoherence on collective neutrino oscillations*

A.Popov *(MSU) Wave packet treatment of neutrino flavour and spin oscillations in galactic and extragalactic magnetic fields*

E.Kovalevskaia (MSU) *Electromagnetic effects in deep inelastic neutrino-proton scattering*

A.Nikolaeva (MSU) *Propagation and oscillations of cosmic neutrinos in a stochastic magnetic field*

F.Lazarev (MSU) *Elastic neutrino-nucleon scattering: The effects of neutrino electromagnetic properties and polarization*

N.Dolganov (MSU) *Neutrino oscillations in external environment*

A.Grigoriev (MIPT) *Neutrino spin states in moving matter and the effect of neutrino spin light*

A.Lichkunov (MSU) *Neutrino oscillation accounting for interaction with axion-like particles*

M.Vyalkov (MSU) *Quantum decoherence of neutrino mass states due to neutrino interaction with an external environment*

S.Sedov (Sarov State Phys. Techn. Inst.) *Analog of Weyl meson as analog of the dark photon*