MPA
MAINZ PHYSICS ACADEMY

mitp Mainz Institute for Theoretical Physics

Asymgenesis

Sascha Weber

JGU Mainz

Based on [2507.10655]
w/ Martin A. Mojahed (JGU Mainz)

Cluster of Excellence Precision Physics, Fundamental Interactions and Structure of Matter
PRISMA

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

JG|U

DESY Theory Workshop 2025 – 25.09.25 – Hamburg

Quick Summary

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Observation $\Omega_B \approx 0.2\,\Omega_{\rm DM}$

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Asymmetric
Dark Matter

[see e.g. Kaplan, Luty, Zurek, 0901.4117]

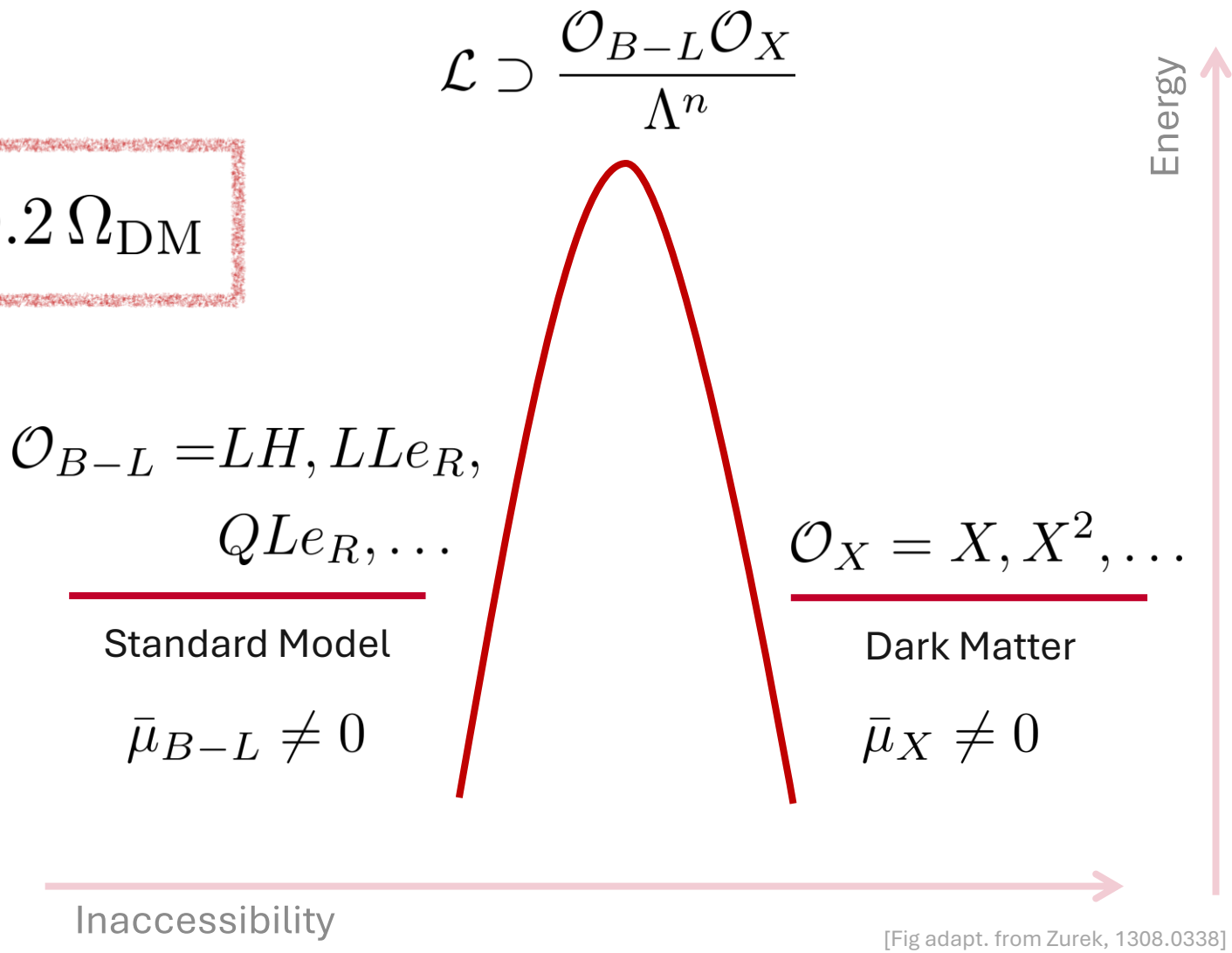
Quick Summary

$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$

Observation $\Omega_B \approx 0.2\,\Omega_{\rm DM}$

Asymmetric Dark Matter

[see e.g. Kaplan, Luty, Zurek, 0901.4117]



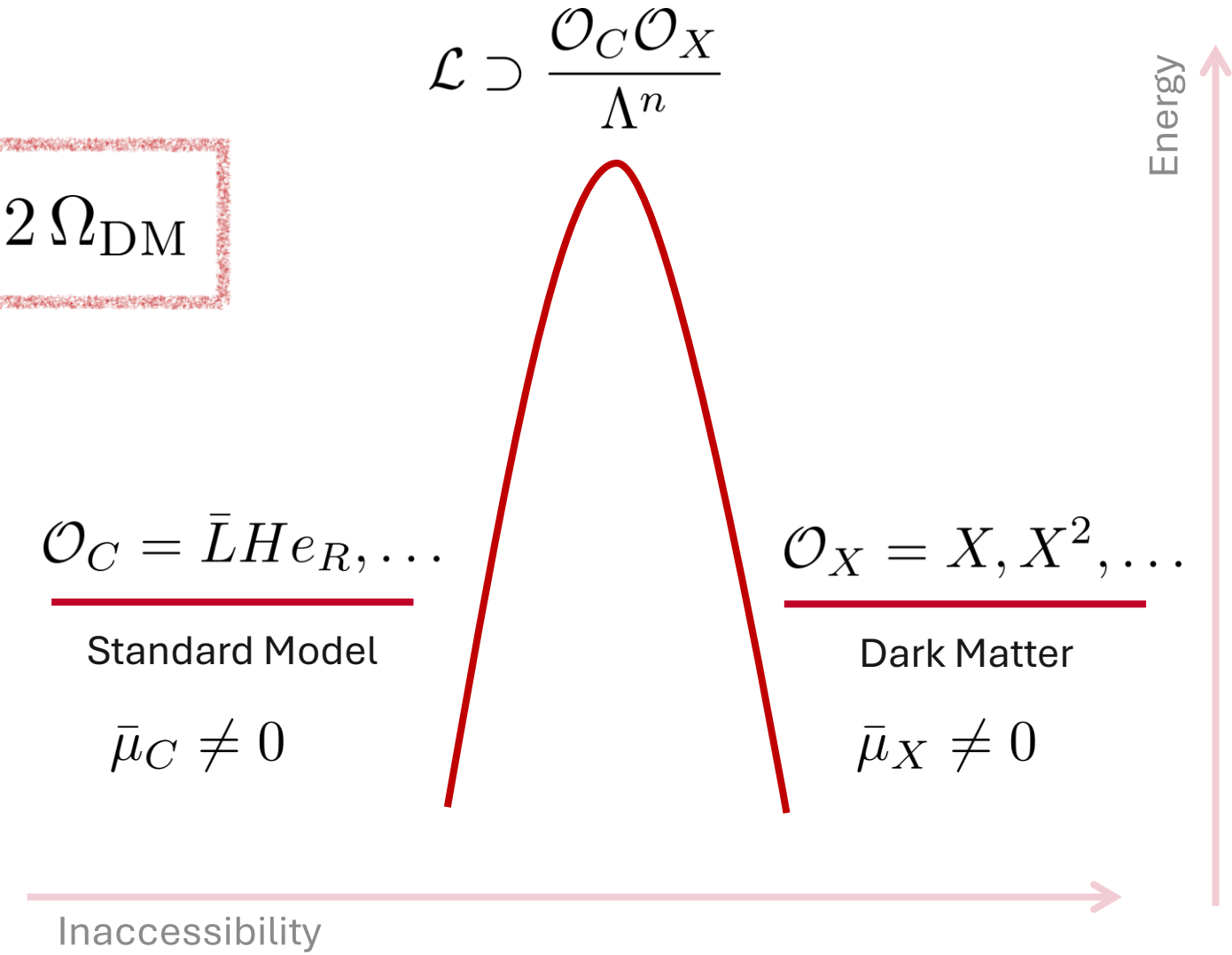
[Fig adapt. from Zurek, 1308.0338]

$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$

Quick Summary: Asymgenesis

[Mojahed, SW, 2507.10655]

Observation $\Omega_B \approx 0.2\,\Omega_{\rm DM}$

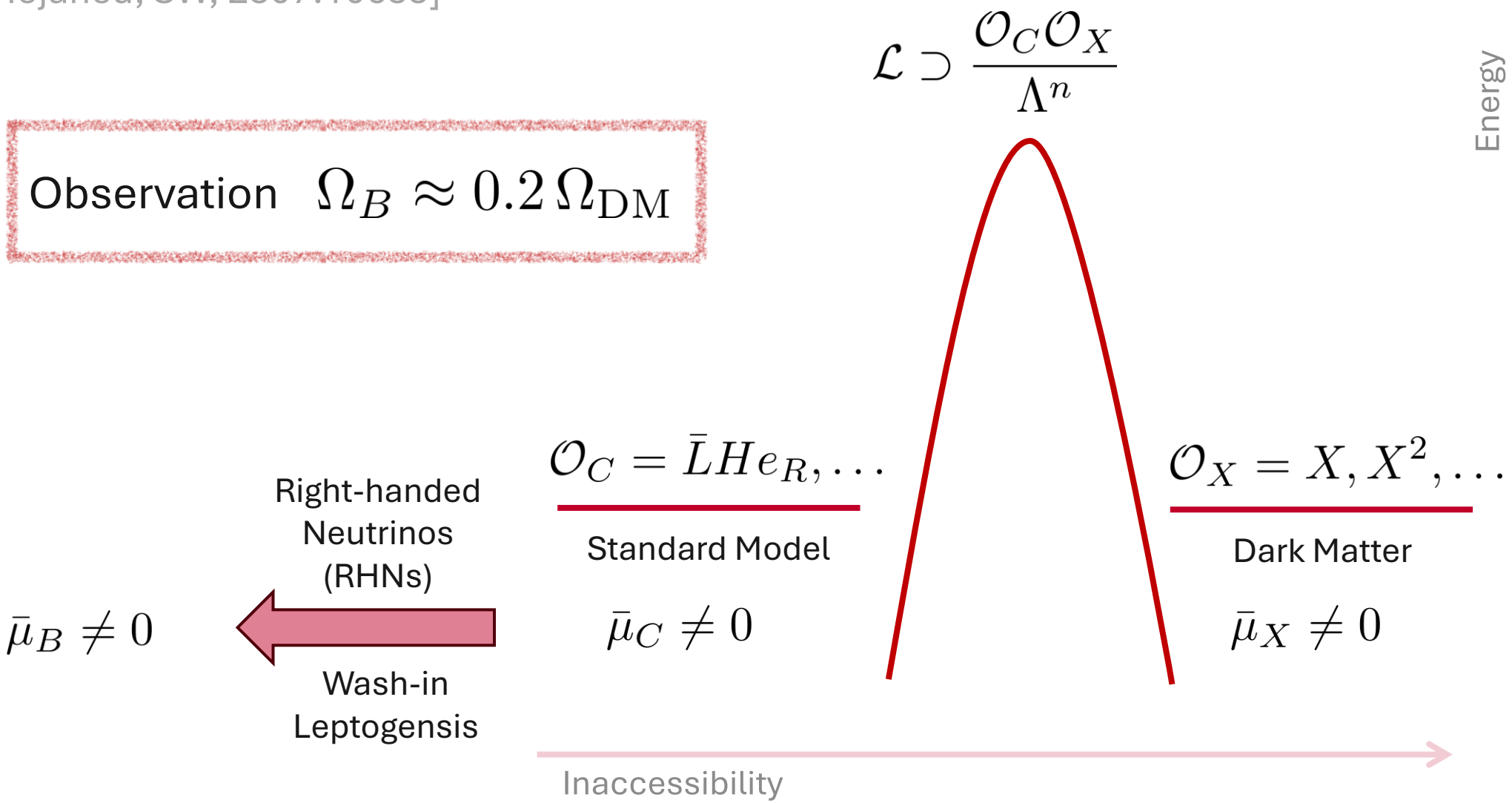


$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$

Quick Summary: Asymgenesis

[Mojahed, SW, 2507.10655]

Observation $\Omega_B \approx 0.2\,\Omega_{\rm DM}$



Baryogenesis [Sakharov, Pisma Zh.Eksp.Teor.Fiz. 5 (1967)]

Sakharov conditions
- B violation
- C and CP violation
- Out of equilibrium

Baryogenesis

$\bar{\mu}_B = 0$

Baryogenesis
- B violation
- C and CP violation
- Out of equilibrium

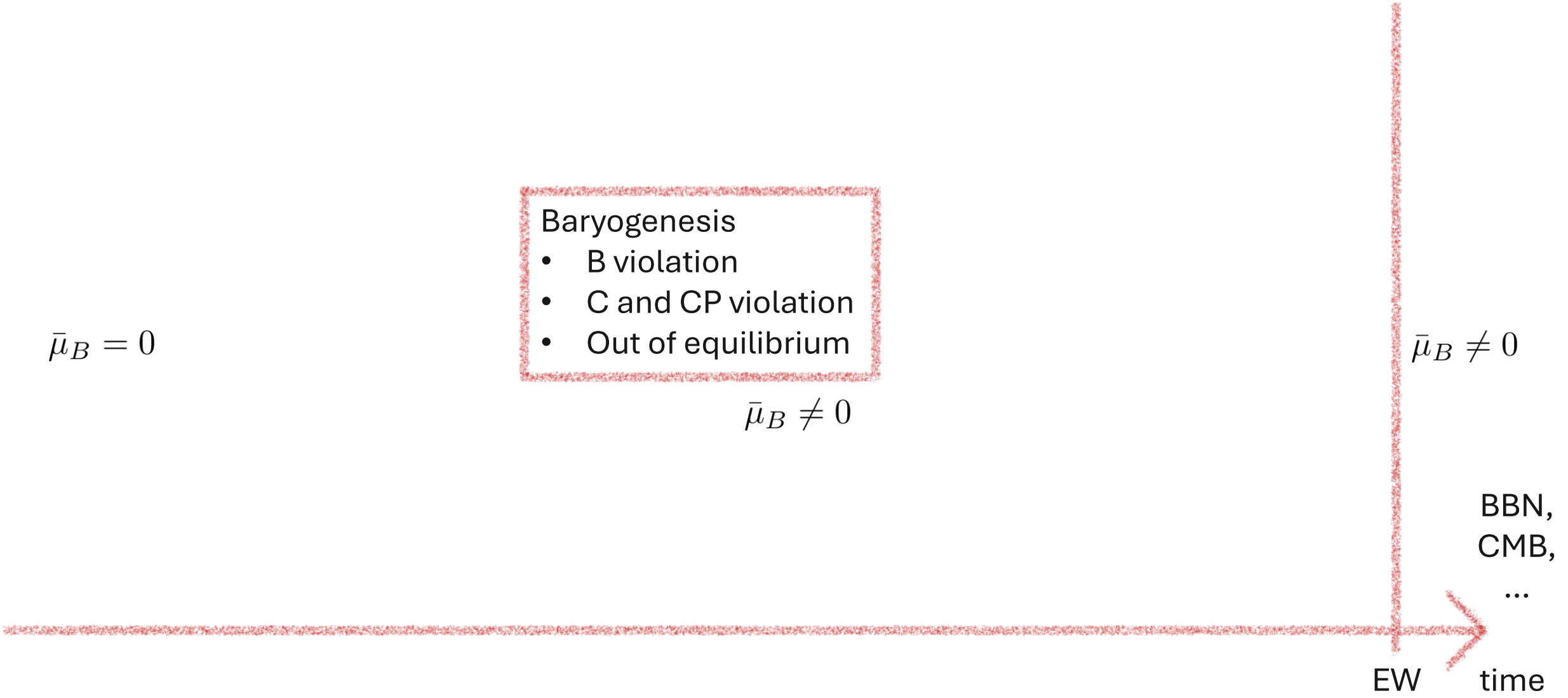
$\bar{\mu}_B \neq 0$

$\bar{\mu}_B \neq 0$

BBN,
CMB,
...

time

Baryogenesis



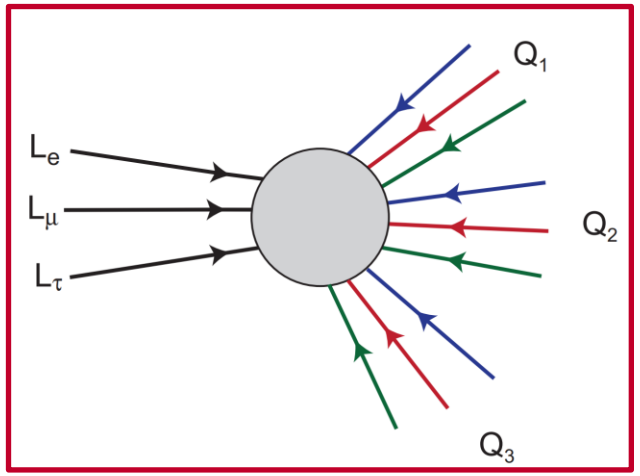
Baryogenesis

$\bar{\mu}_{B\text{-}L} = 0$

Baryogenesis
- B violation
- C and CP violation
- Out of equilibrium

$\bar{\mu}_B \neq 0 \longrightarrow \bar{\mu}_{B\text{-}L} \neq 0,\ \bar{\mu}_{B+L} \neq 0$

[Kuzmin, Rubakov, Shaposhnikov, Phys. Lett. B 155 (1985)]



EW sphalerons

B+L violation (or washout)

[Figure from Nir 2009]

$\bar{\mu}_{B\text{-}L} \neq 0$
$\bar{\mu}_{B+L} = 0$

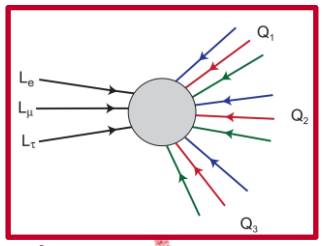
BBN, CMB, ...

EW

time

Baryogenesis

[Nir 2009]



Baryogenesis
- B violation
- C and CP violation
- Out of equilibrium

$\bar{\mu}_{B\text{-}L} = 0$

$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_{B+L} \neq 0$

$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_{B+L} = 0$

BBN,
CMB,
...

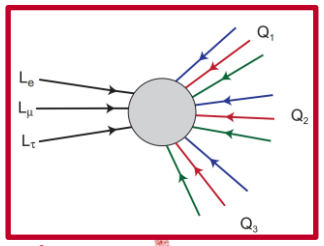
EW

time

Leptogenesis

[M. Fukugita and T. Yanagida, Phys. Lett. B 174 (1986)]

[Nir 2009]



Leptogenesis
- L violation
- C and CP violation
- Out of equilibrium

$\bar{\mu}_{B\text{-}L} = 0$

$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_{B\text{-}L} \neq 0$

BBN, CMB, ...

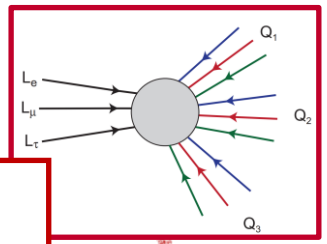
EW

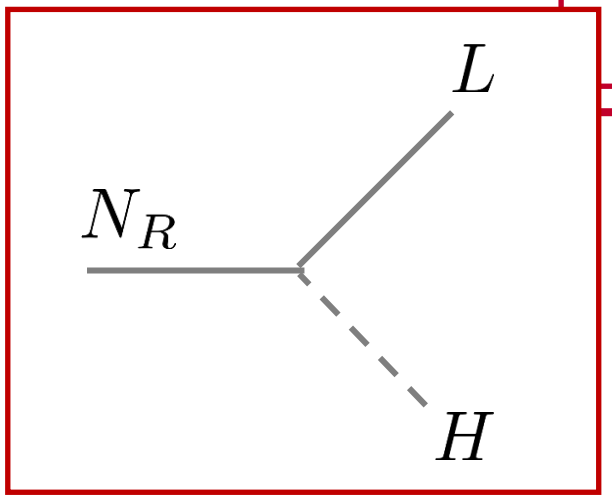
time

Leptogenesis via RHNs

[M. Fukugita and T. Yanagida, Phys. Lett. B 174 (1986)]

[Nir 2009]





RHN sector
- L violation
- C and CP violation
- Out of equilibrium

$\bar{\mu}_{B\text{-}L} = 0$

$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_{B\text{-}L} \neq 0$

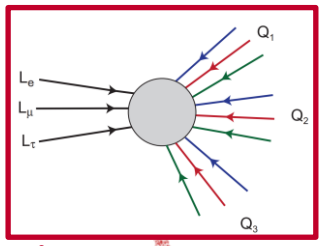
BBN, CMB, ...

EW

time

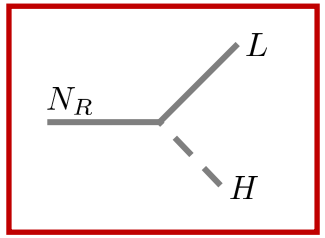
Leptogenesis via RHNs

[Nir 2009]



$\bar{\mu}_{B\text{-}L} = 0$

RHN sector
- L violation
- C and CP violation
- Out of equilibrium



$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_{B\text{-}L} \neq 0$

BBN,
CMB,
...

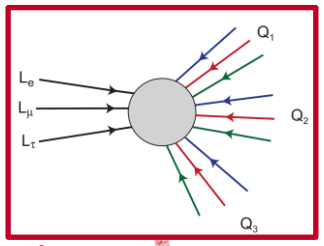
EW

time

Wash-in Leptogenesis (WILG)

[Domcke, Kamada, Mukaida, Schmitz, Yamada, 2011.09347]

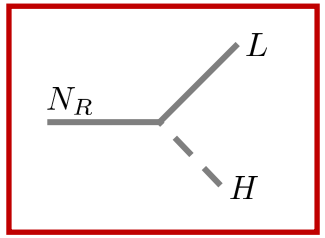
[Nir 2009]



- C and CP violation
- Out of equilibrium

$\bar{\mu}_{B\text{-}L} = 0$

RHN sector
- L violation



$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_{B\text{-}L} \neq 0$

BBN,
CMB,
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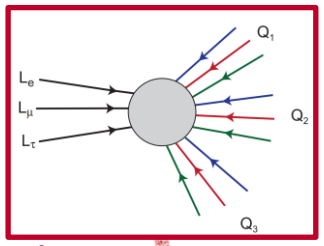
EW

time

Wash-in Leptogenesis (WILG)

[Domcke, Kamada, Mukaida, Schmitz, Yamada, 2011.09347]

[Nir 2009]



"Chargegenesis"

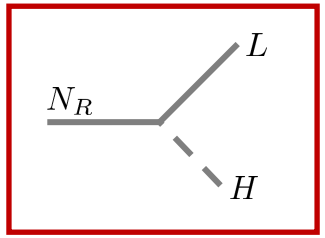
- C and CP violation
- Out of equilibrium

$\bar{\mu}_{B\text{-}L} = 0$

$\bar{\mu}_C \neq 0$

RHN sector

- L violation



$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_{B\text{-}L} \neq 0$

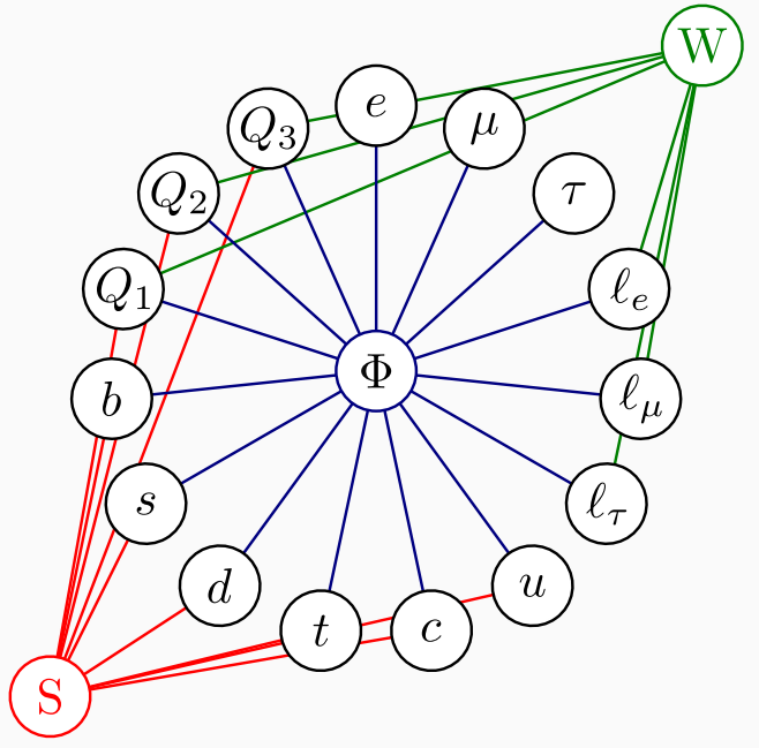
BBN,
CMB,
...

EW

time

What is conserved?

$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$



[Fig. from Kai Schmitz Talk Neutrino Platform Pheno Week 2023]

16 particles
+
12 interactions

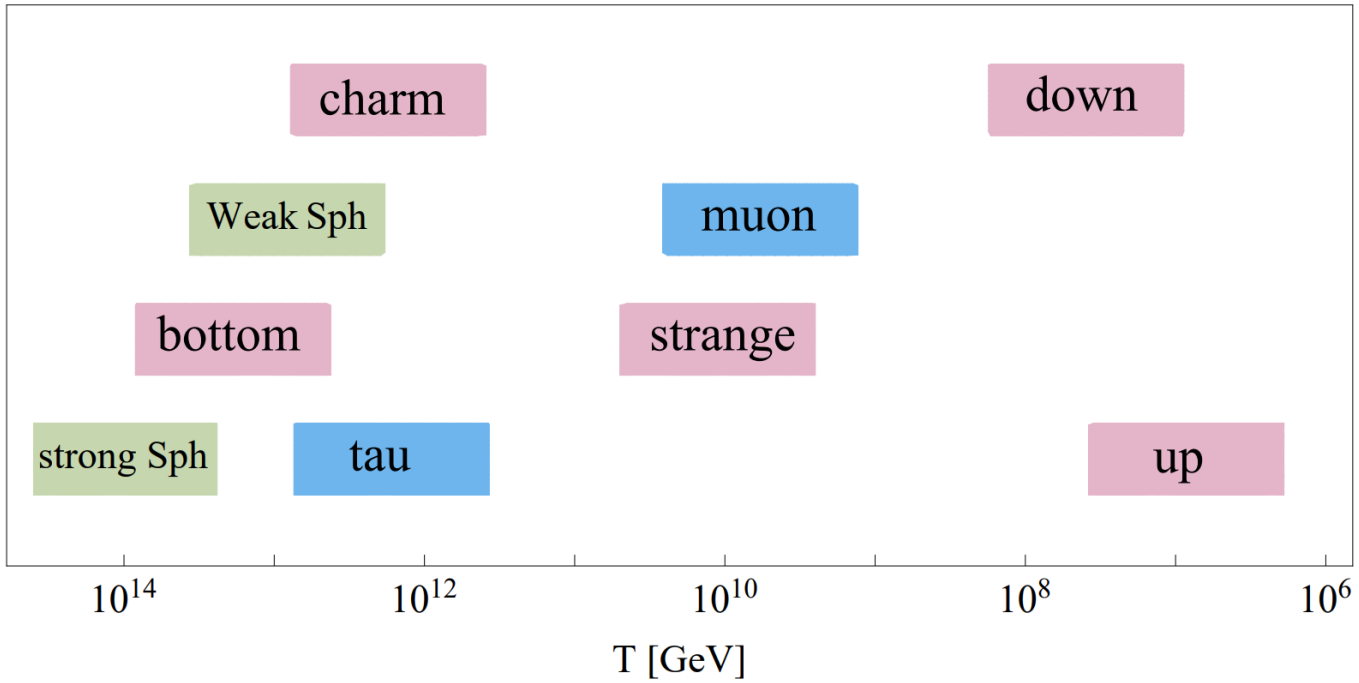
=

4 conserved charges

$$\bar{\mu}_Y$$

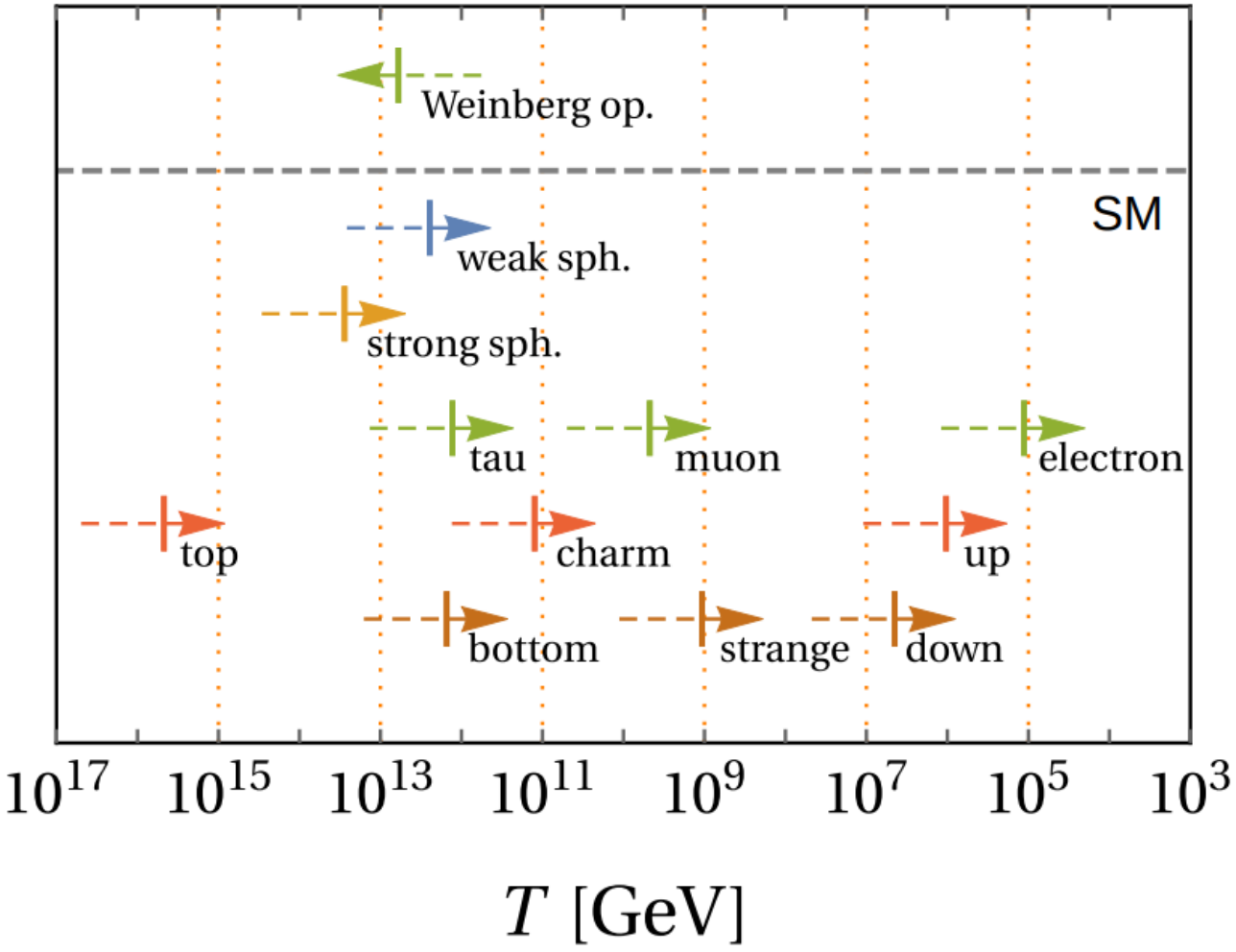
$$\bar{\mu}_{B/3-L_e}, \bar{\mu}_{B/3-L_\mu}, \bar{\mu}_{B/3-L_\tau}$$

Interactions in Equilibrium?

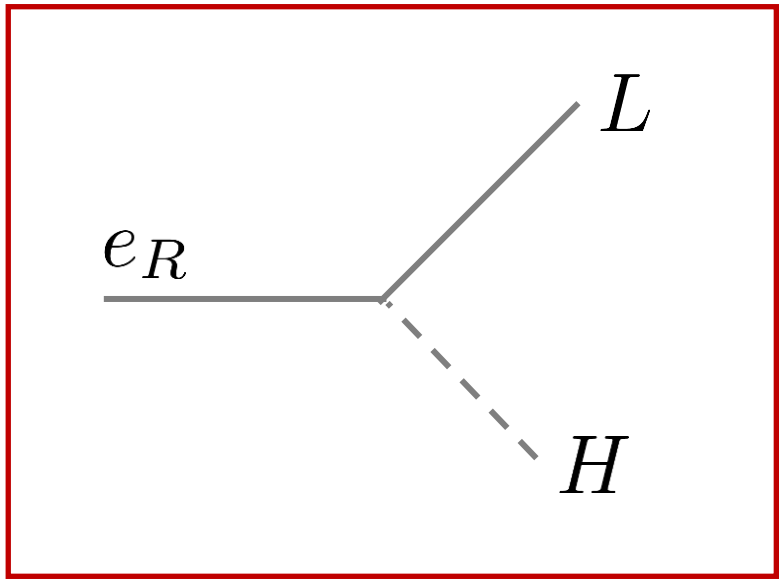


[Garbrecht, Schwaller 1404.2915]

Interactions in Equilibrium?

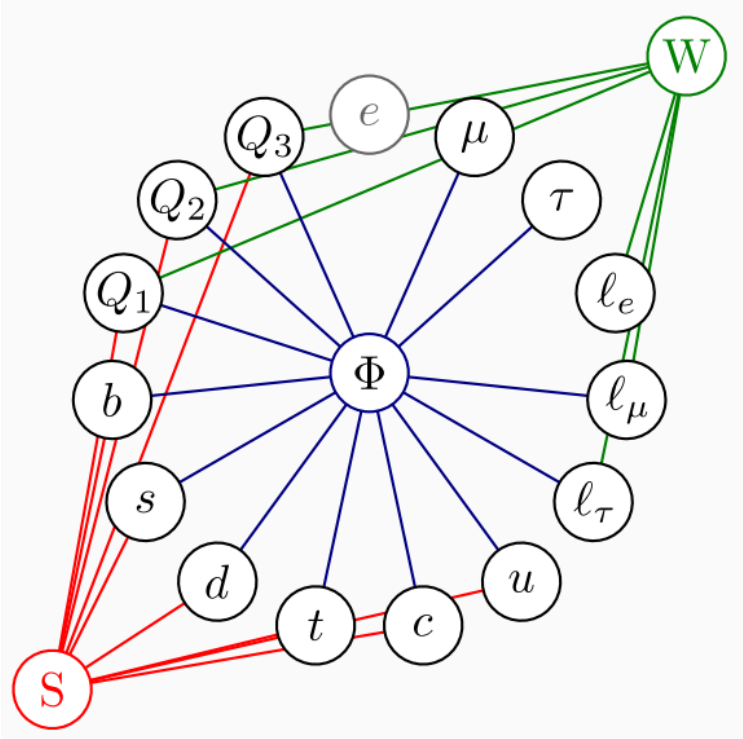


[Domcke, Ema, Mukaida, Yamada, 2006.03148]



Additional Charge

$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$



[Fig. from Kai Schmitz Talk Neutrino Platform Pheno Week 2023]

16 particles
+
11 interactions

=

5 conserved charges

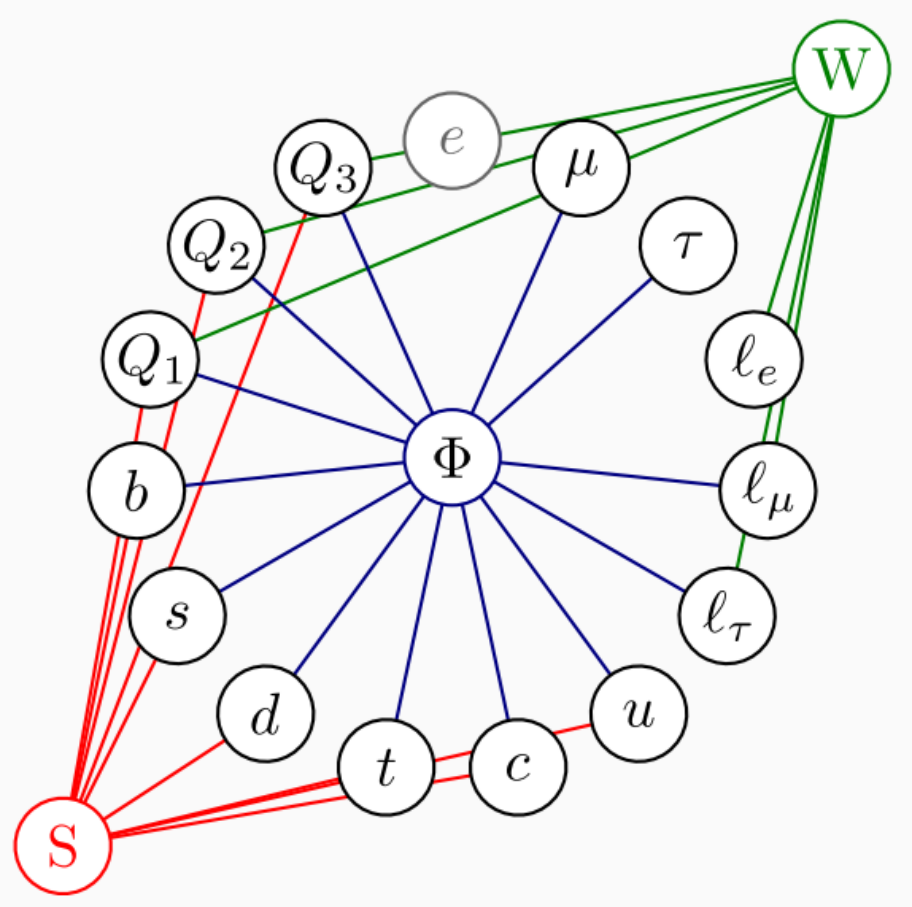
$$\bar{\mu}_Y\,,$$

$$\bar{\mu}_{B/3-L_e}\,,\bar{\mu}_{B/3-L_\mu}\,,\bar{\mu}_{B/3-L_\tau}\,,$$

$$\bar{\mu}_e$$

Charges at high T

$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$



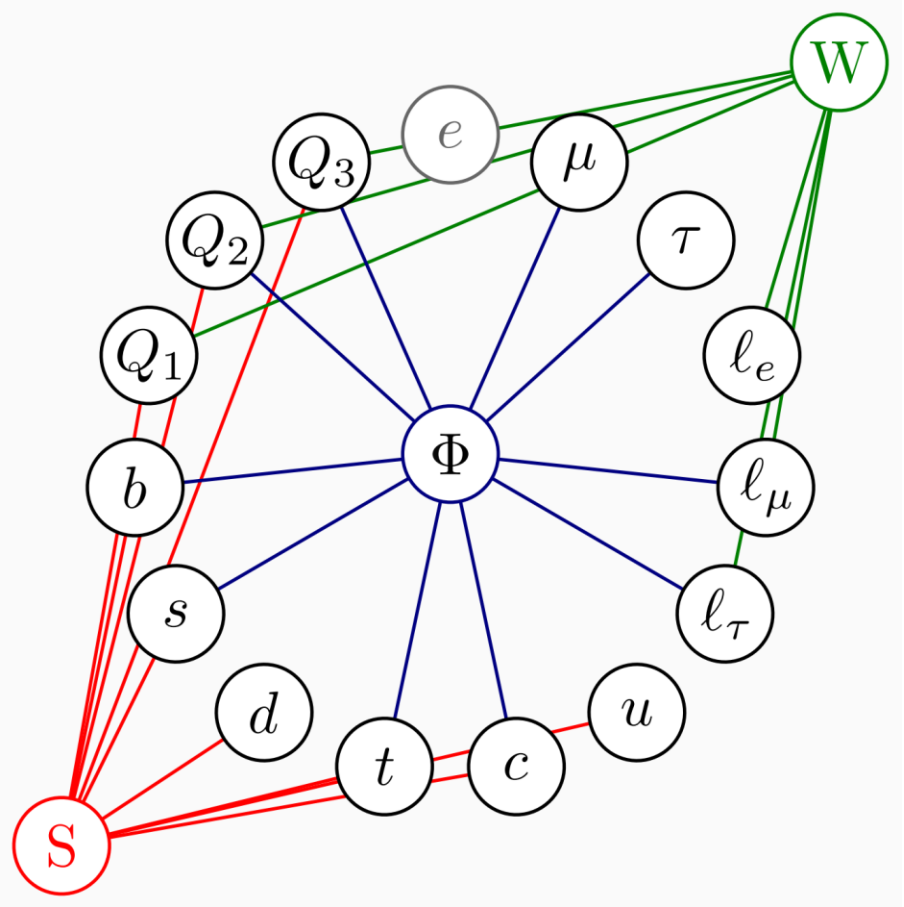
[Fig. from Kai Schmitz Talk Neutrino Platform Pheno Week 2023]

$T \in [10^5, 10^6]$ GeV:

$$\bar{\mu}_Y, \bar{\mu}_{B/3-L_e}, \bar{\mu}_{B/3-L_\mu}, \bar{\mu}_{B/3-L_\tau},$$
$$\bar{\mu}_e$$

Charges at high T

$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$



[Fig. from Kai Schmitz Talk Neutrino Platform Pheno Week 2023]

$T \in [10^6, 10^9]$ GeV:

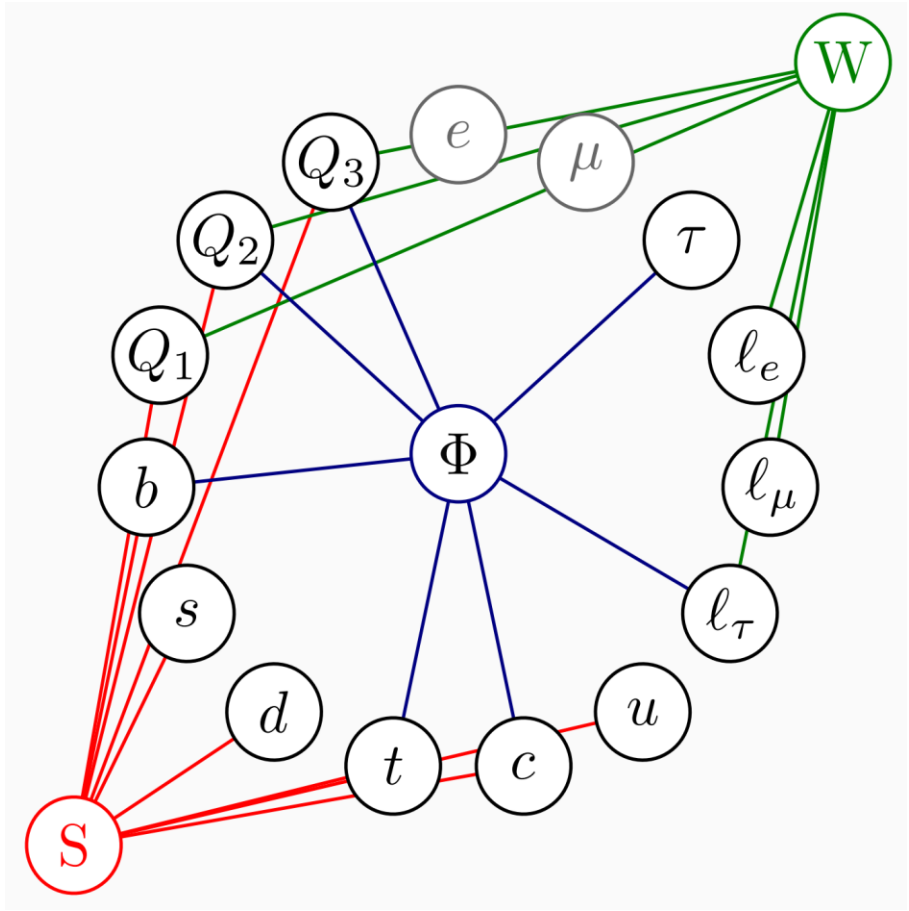
$$\bar{\mu}_Y\,, \bar{\mu}_{B/3-L_e}\,, \bar{\mu}_{B/3-L_\mu}\,, \bar{\mu}_{B/3-L_\tau}\,,$$

$$\bar{\mu}_e$$

$$\bar{\mu}_{2B_1-B_2-B_3}\,, \bar{\mu}_{u-d}$$

Charges at high T

$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$



[Fig. from Kai Schmitz Talk Neutrino Platform Pheno Week 2023]

$T \in [10^9, 10^{11\cdots12}]$ GeV:

$$\bar{\mu}_Y\,,\ \bar{\mu}_{B/3-L_e}\,,\ \bar{\mu}_{B/3-L_\mu}\,,\ \bar{\mu}_{B/3-L_\tau}\,,$$

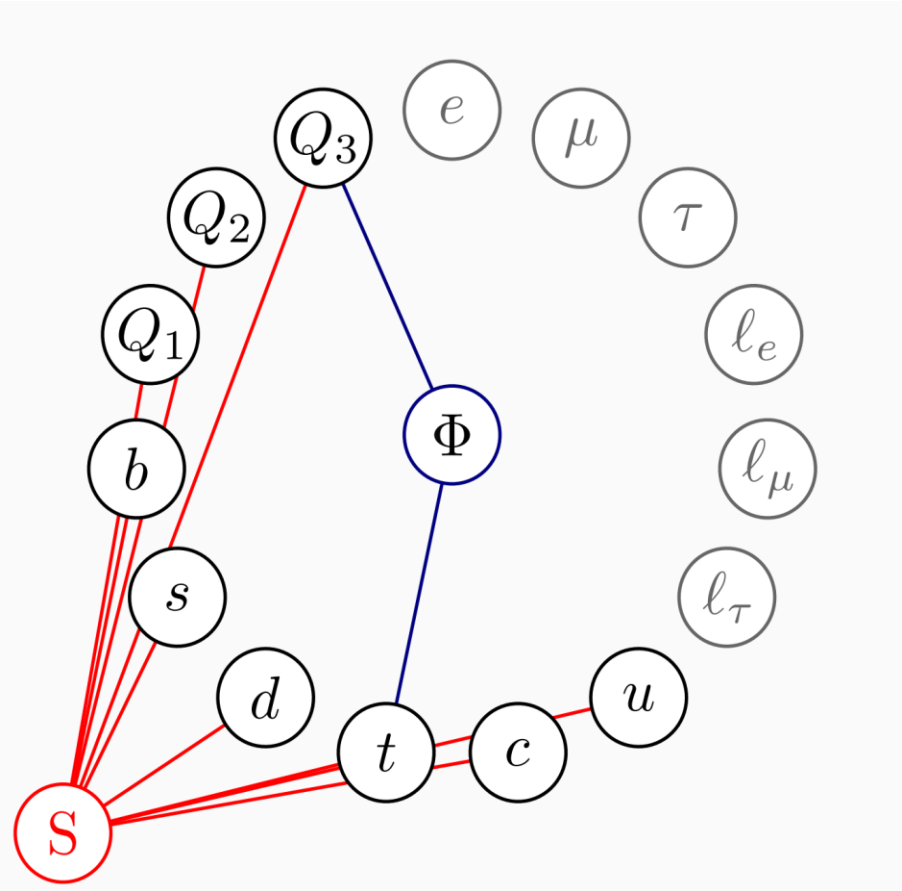
$$\bar{\mu}_e$$

$$\bar{\mu}_{2B_1-B_2-B_3}\,,\ \bar{\mu}_{u-d}$$

$$\bar{\mu}_{d-s}\,,\ \bar{\mu}_{B_1-B_2}\,,\ \mu_\mu$$

Charges at high T

$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$



[Fig. from Kai Schmitz Talk Neutrino Platform Pheno Week 2023]

$T \in [10^{11\cdots12}, 10^{13}]$ GeV:

$$\bar{\mu}_Y, \bar{\mu}_{B/3-L_e}, \bar{\mu}_{B/3-L_\mu}, \bar{\mu}_{B/3-L_\tau},$$

$$\bar{\mu}_e$$

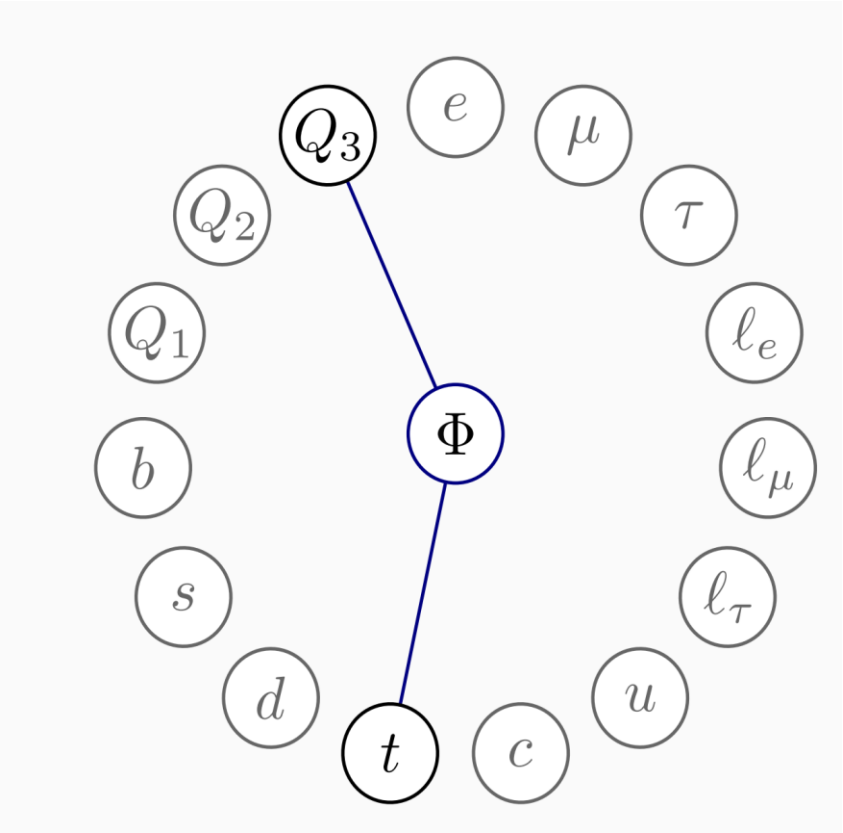
$$\bar{\mu}_{2B_1-B_2-B_3}, \bar{\mu}_{u-d}$$

$$\bar{\mu}_{d-s}, \bar{\mu}_{B_1-B_2}, \mu_\mu,$$

$$\bar{\mu}_{u-c}, \bar{\mu}_\tau, \mu_{d-b}, \mu_B$$

Charges at high T

$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$



[Fig. from Kai Schmitz Talk Neutrino Platform Pheno Week 2023]

$T \in [10^{13}, 10^{15}]$ GeV:

$$\bar{\mu}_Y, \bar{\mu}_{B/3-L_e}, \bar{\mu}_{B/3-L_\mu}, \bar{\mu}_{B/3-L_\tau},$$

$$\bar{\mu}_e$$

$$\bar{\mu}_{2B_1-B_2-B_3}, \bar{\mu}_{u-d}$$

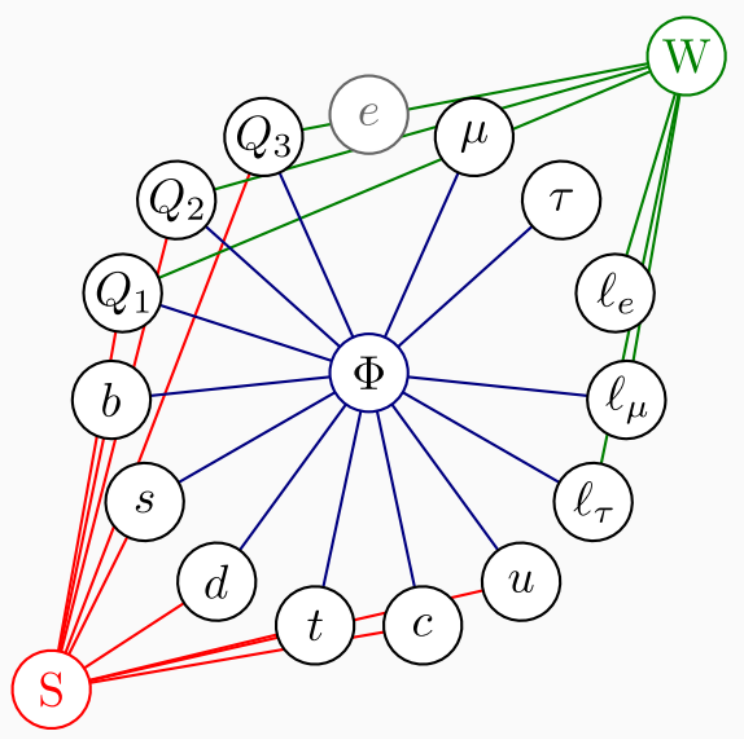
$$\bar{\mu}_{d-s}, \bar{\mu}_{B_1-B_2}, \mu_\mu,$$

$$\bar{\mu}_{u-c}, \bar{\mu}_\tau, \mu_{d-b}, \mu_B$$

$$\bar{\mu}_u$$

Focus on RH electron charge

$$\Omega_i \propto Y_{\Delta i} \propto n_{\Delta i} \propto \bar{\mu}_i$$



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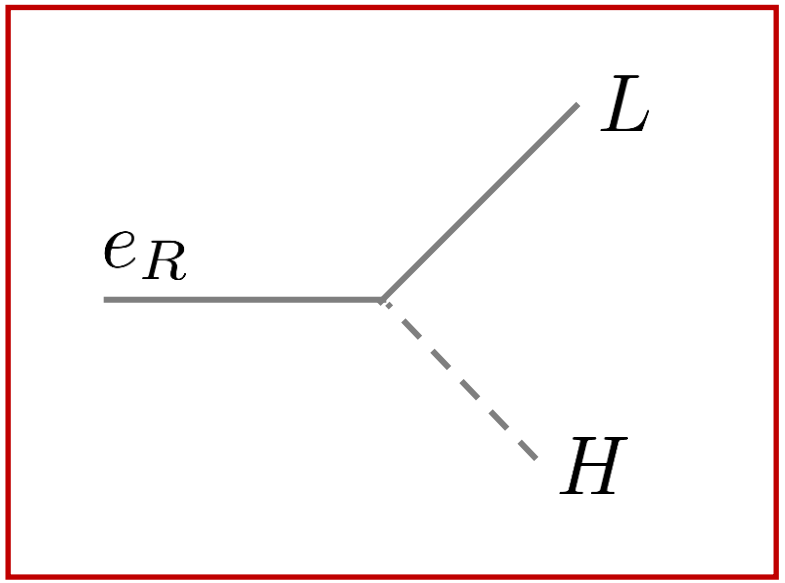
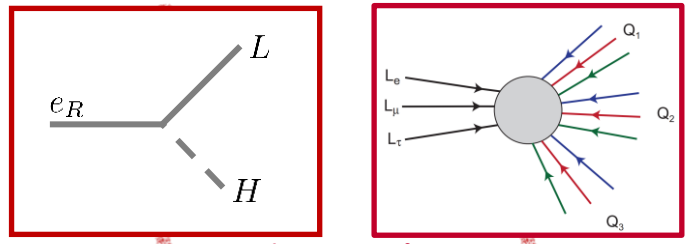


$\bar{\mu}_e$

Wash-in Leptogenesis (WILG)

[Domcke, Kamada, Mukaida, Schmitz, Yamada, 2011.09347]

[Nir 2009]



"Electrogenesis"

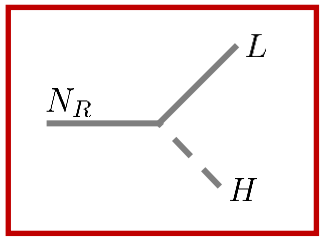
- C and CP violation
- Out of equilibrium

$\bar{\mu}_e \neq 0$
$\bar{\mu}_{B\text{-}L} = 0$

RHN sector

- L violation

→ Wash-in LG



$\bar{\mu}_e \neq 0$
$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_e = 0$
$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_e = 0$
$\bar{\mu}_{B\text{-}L} \neq 0$

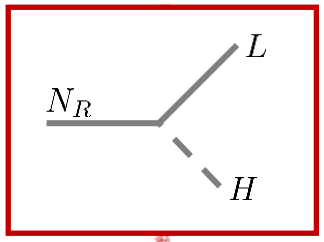
BBN, CMB, ...

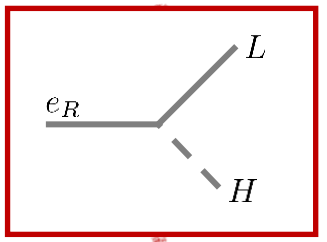
C eq. EW time

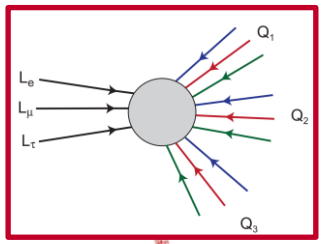
Spectator Leptogenesis

[Domcke, Kamada, Mukaida, Schmitz, Yamada, 2011.09347]

[Nir 2009]







"Electrogenesis"

- C and CP violation
- Out of equilibrium

$\bar{\mu}_e \neq 0$
$\bar{\mu}_{B\text{-}L} = 0$

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BBN,
CMB,
...

WILG

C eq.

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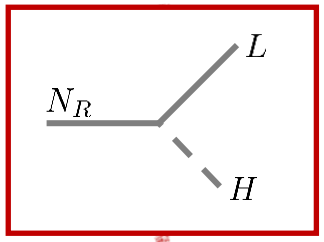
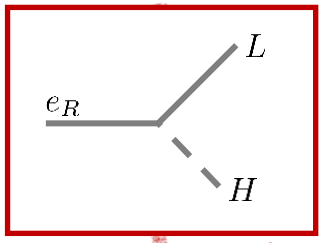
time

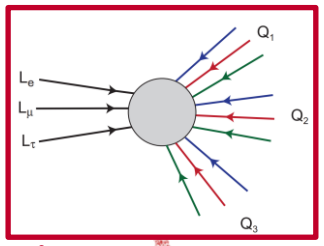
Spectator Leptogenesis

[Domcke, Kamada, Mukaida, Schmitz, Yamada, 2011.09347]





[Nir 2009]



"Chargenesis"

- C and CP violation
- Out of equilibrium

$\bar{\mu}_C \neq 0$
$\bar{\mu}_{B\text{-}L} = 0$

$\bar{\mu}_C \neq 0$
$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_C = 0$
$\bar{\mu}_{B\text{-}L} \neq 0$

$\bar{\mu}_C = 0$
$\bar{\mu}_{B\text{-}L} \neq 0$

BBN,
CMB,
...

WILG

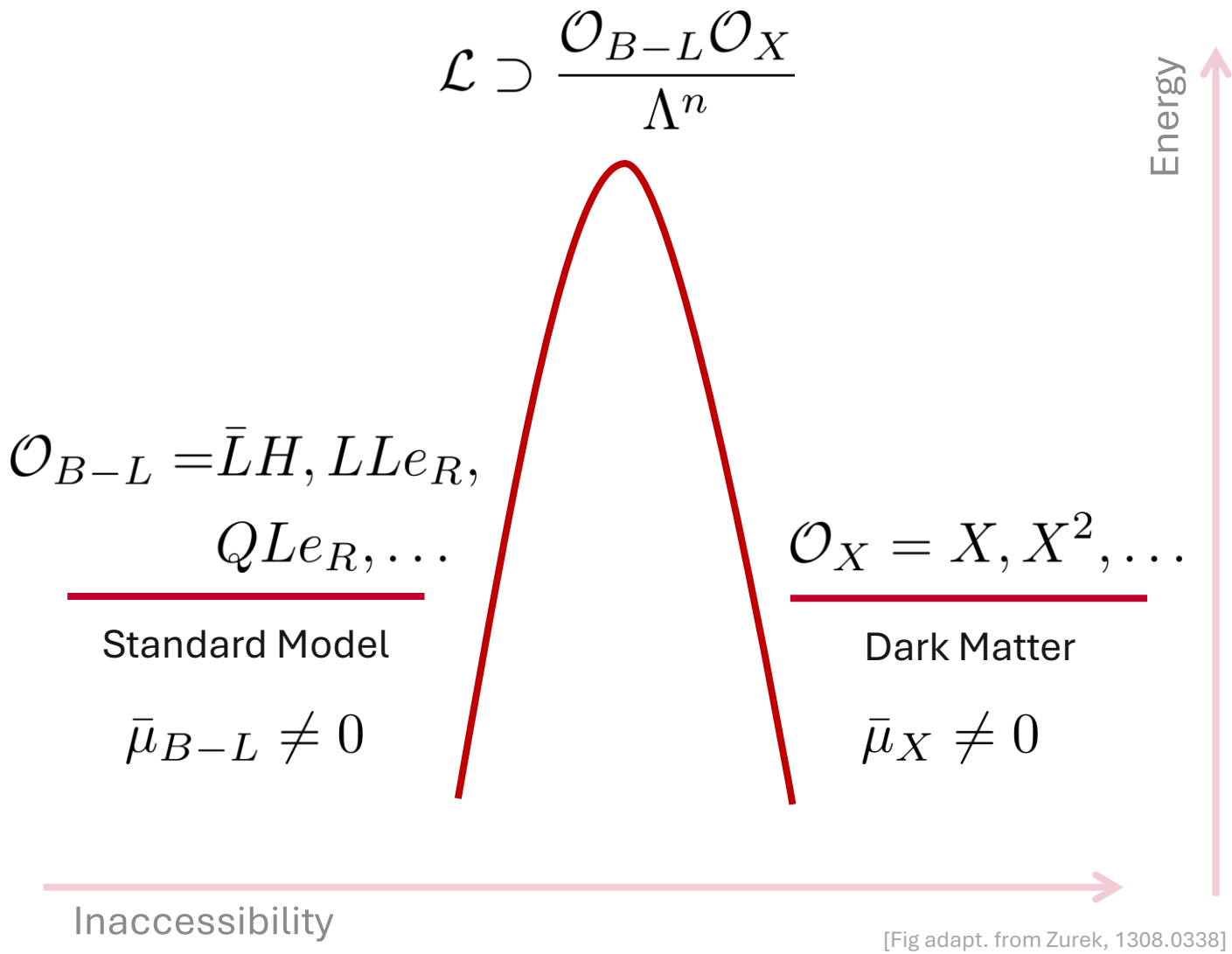
C eq.

EW

time

Asymmetric DM: Double Role

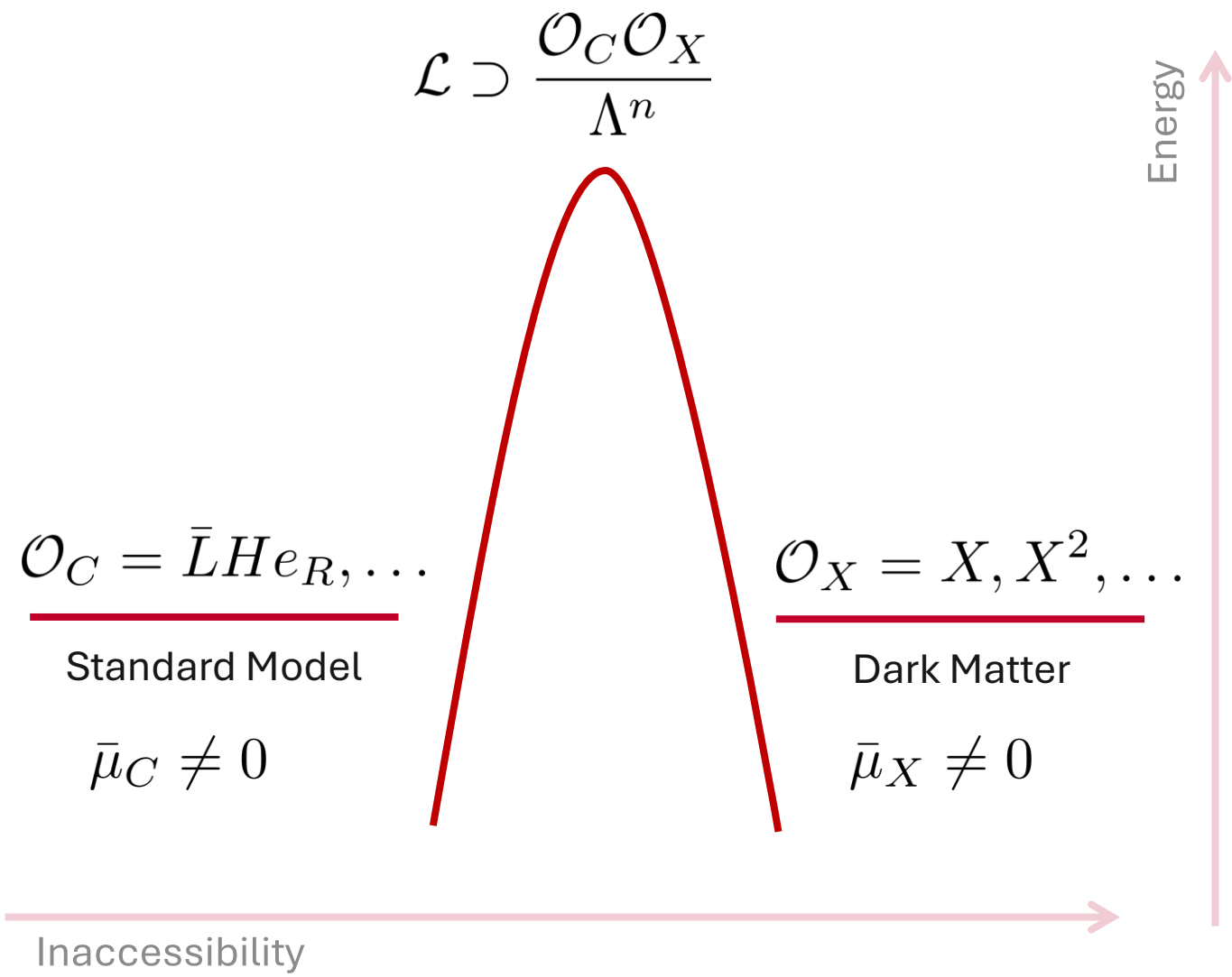
- Violate B-L
- Transfer asymmetry between SM and DM sectors



[Fig adapt. from Zurek, 1308.0338]

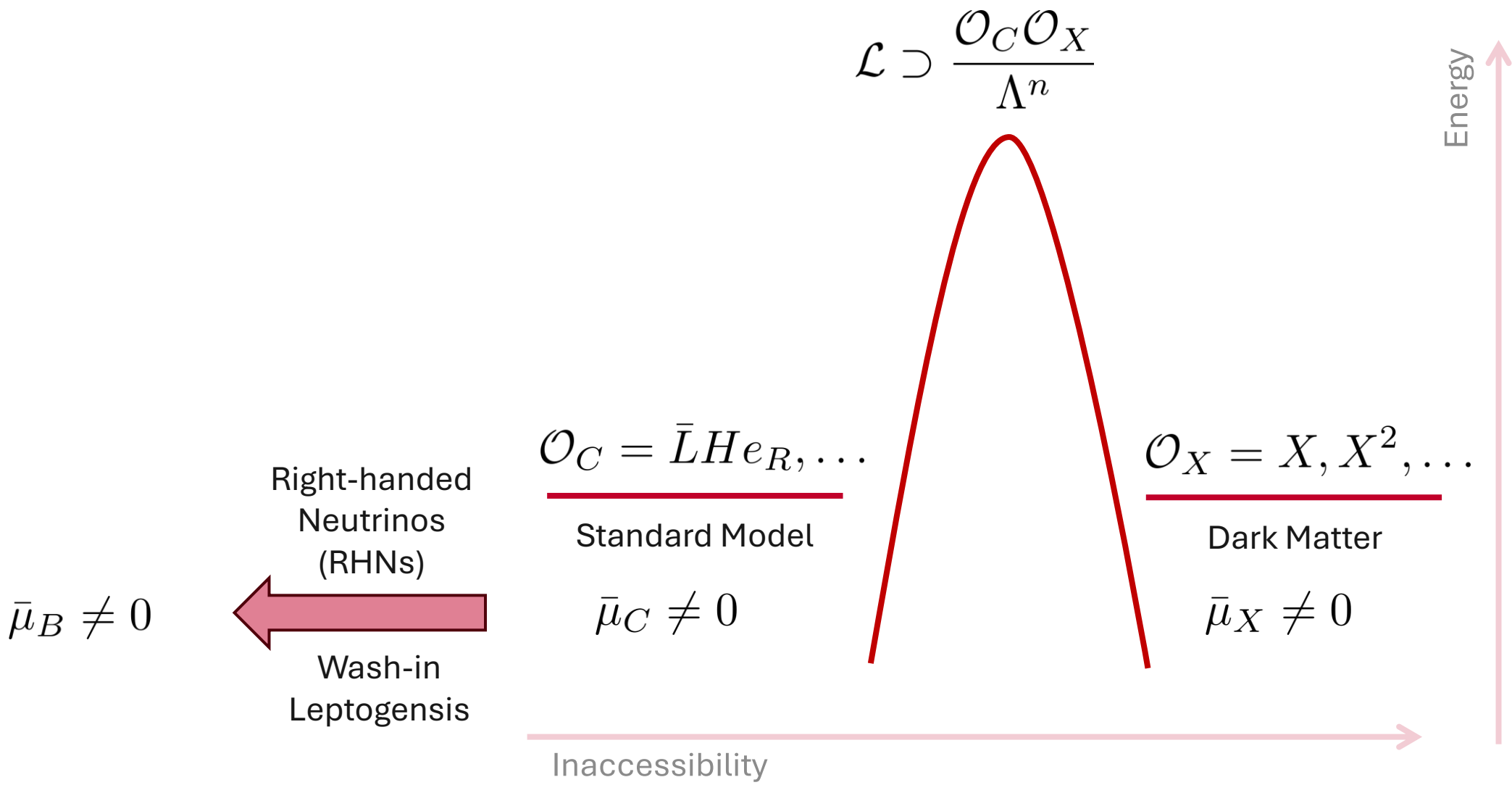
Asymgenesis

[Mojahed, SW, 2507.10655]

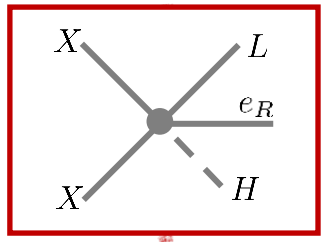


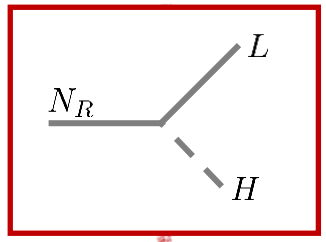
Asymgenesis

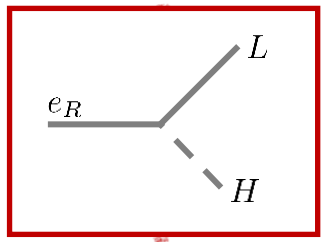
[Mojahed, SW, 2507.10655]



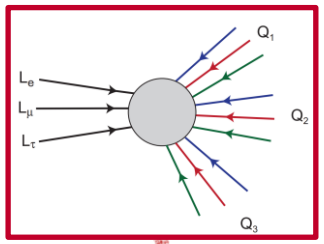
Asymgenesis [Mojahed, SW, 2507.10655]







[Nir 2009]



"Dark Chargenesis"

- C and CP violation
- Out of equilibrium

"Chargenesis"

- C and CP violation
- Out of equilibrium

$\mu_X \neq 0 \quad \mu_C \neq 0$
$\bar{\mu}_{B\text{-}L} = 0$

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BBN,
CMB,
...

Asymgenesis WILG C eq. EW time

Asymgenesis

[Mojahed, SW, 2507.10655]

"Dark Chargenesis"

- C and CP violation
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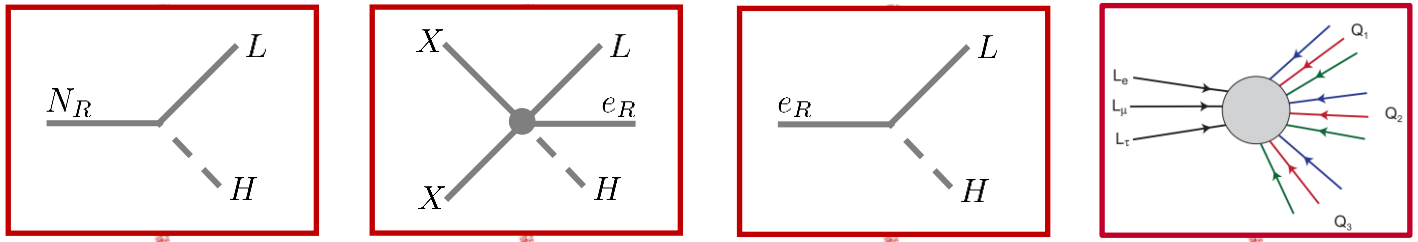

[Nir 2009]

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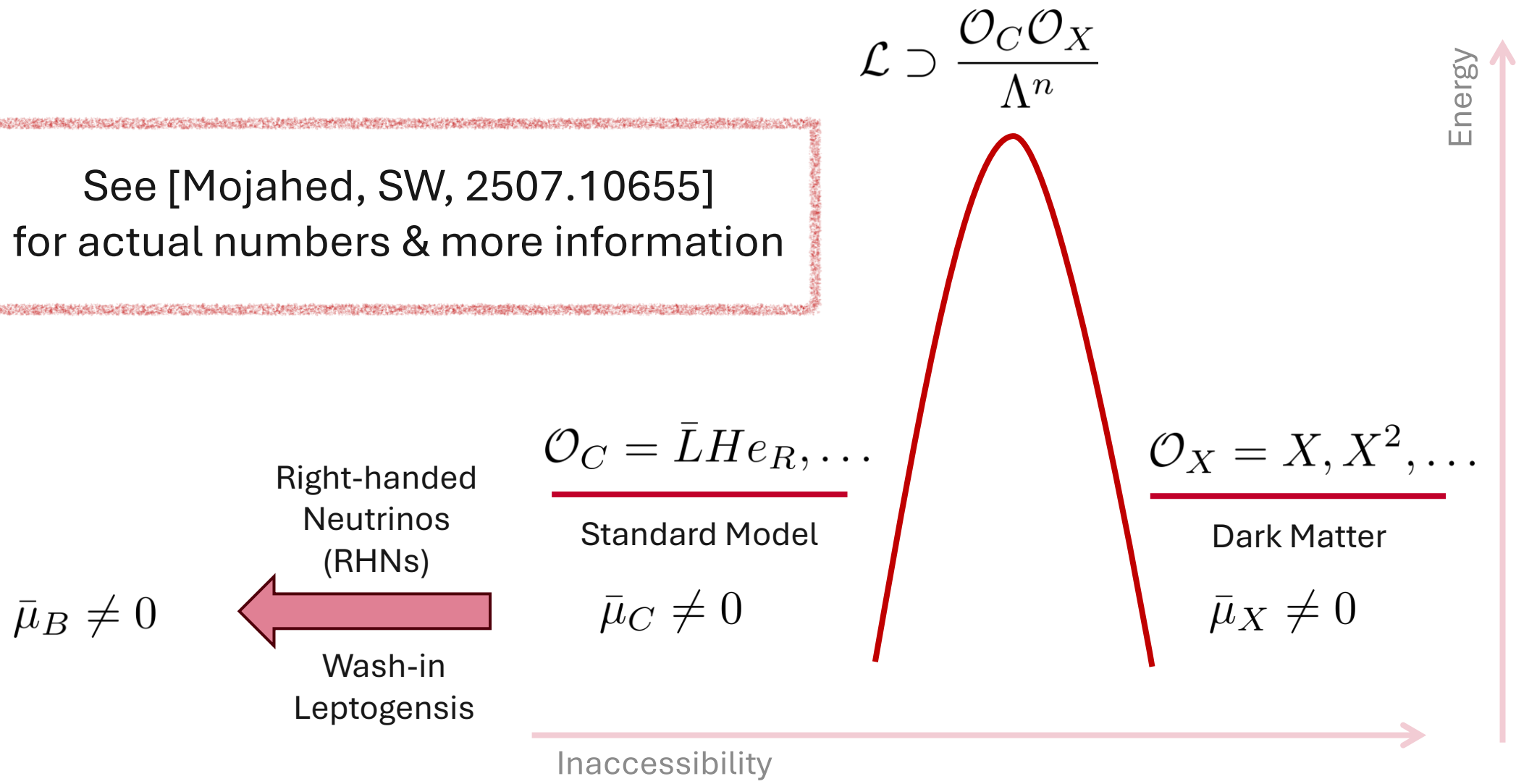
BBN,
CMB,
...

WILG | Asymgenesis | C eq. | EW | time

~~Quick~~ Summary: Asymgenesis

See [Mojahed, SW, 2507.10655]
for actual numbers & more information

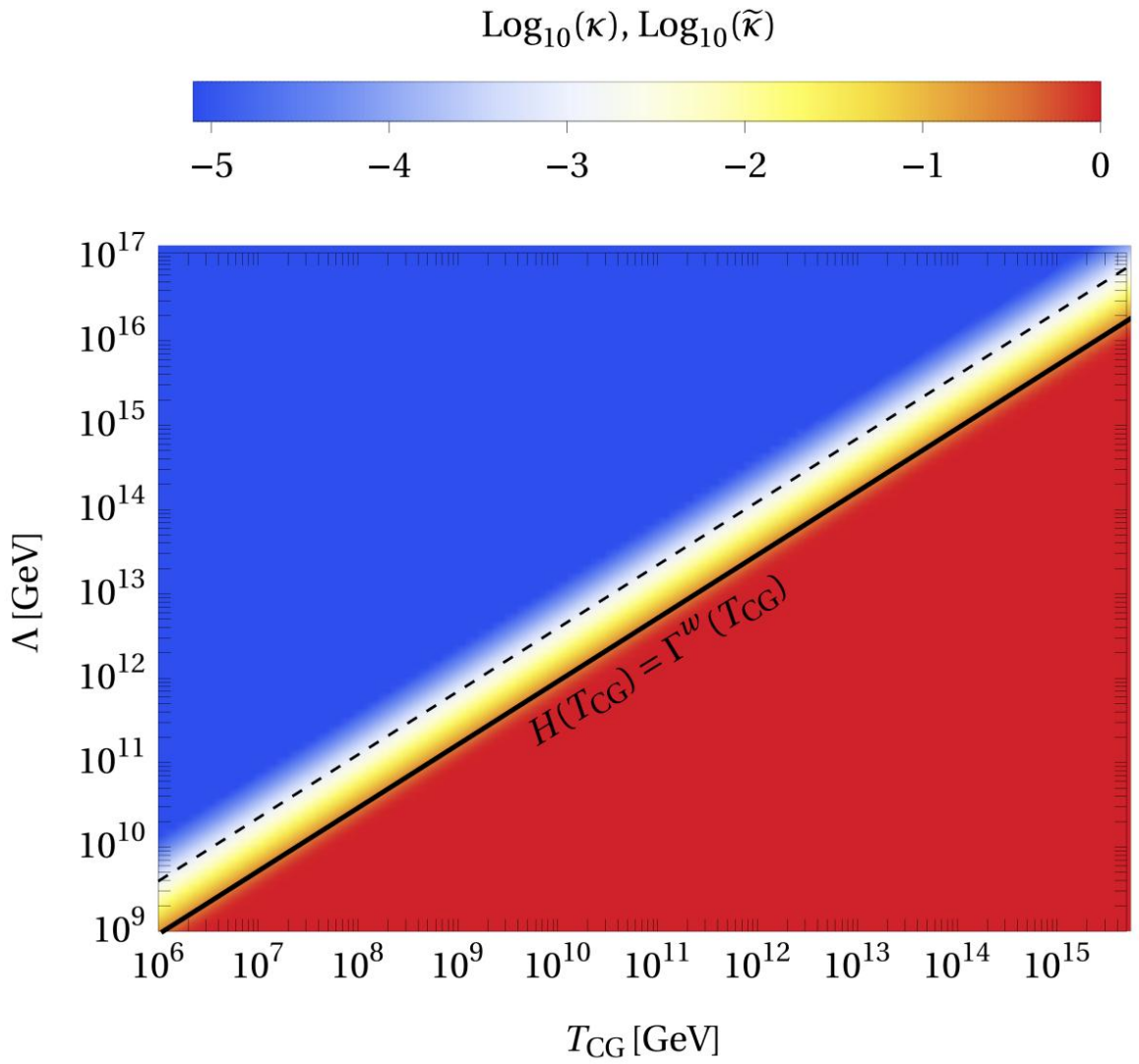


Backup

$T_{\rm dec}$	Index α	$\bar{\mu}_{Xe}$ $(\bar{\mu}_e)$ $\bar{\mu}_{2B_1-B_2-B_3}$ $\bar{\mu}_{u-d}$ $\bar{\mu}_{d-s}$	$\bar{\mu}_{B_1-B_2}$ $\bar{\mu}_{\mu}$ $\bar{\mu}_{u-c}$ $\bar{\mu}_{\tau}$	$\bar{\mu}_{d-b}$ $\bar{\mu}_{B}$ $\bar{\mu}_{u}$ $\bar{\mu}_{\Delta_\perp}$	$\bar{\mu}_{\Delta_\alpha}$
(i)	e,μ,τ (e,μ,τ)	$\frac{-3p^2}{22+10p^2}$ $(\frac{-3}{10})$, $\frac{-711}{1422+481p^2}$ ✗ (✗),✗ ✗ (✗),✗ ✗ (✗),✗	✗ (✗),✗ ✗ (✗),✗ ✗ (✗),✗ ✗ (✗),✗	✗ (✗),✗ ✗ (✗),✗ ✗ (✗),✗ ✗ (✗),✗	$\frac{[-185,52,52]}{1422+481p^2}$
(ii)	e,μ,τ (e,μ,τ)	$\frac{-3p^2}{38+17p^2}$ $\left(\frac{-3}{17}\right)$, $\frac{-1071}{2142+716p^2}$ 0 (0), 0 $\frac{-16-7p^2}{38+17p^2}$ $\left(\frac{-7}{17}\right)$, $\frac{45}{2142+716p^2}$ ✗ (✗),✗	✗ (✗),✗ ✗ (✗),✗ ✗ (✗),✗ ✗ (✗),✗	✗ (✗),✗ ✗ (✗),✗ ✗ (✗),✗ ✗ (✗),✗	$\frac{[-265,92,92]}{2142+716p^2}$
(iii)	e,μ,τ $(\parallel_\tau,\tau)$	$\frac{-3p^2}{62+27p^2}$ $\left(\frac{142-225P_\tau}{247}\right)$, $\frac{-1779}{3558+1178p^2}$ 0 (0),0 $\frac{-6(7+3p^2)}{62+27p^2}$ $\left(\frac{-123}{247}\right)$, $\frac{135}{3558+1178p^2}$ $\frac{-4(7+3p^2)}{62+27p^2}$ $\left(\frac{-82}{247}\right)$, $\frac{45}{1779+589p^2}$	$\frac{21+9p^2}{62+27p^2}$ $\left(\frac{123}{494}\right)$, $\frac{-135}{7116+2356p^2}$ $\frac{-3(2+p^2)}{62+27p^2}$ $\left(\frac{142-225P_\tau}{247}\right)$, $\frac{-6}{1779+589p^2}$ ✗ (✗),✗ ✗(✗),✗	✗(✗),✗ ✗(✗),✗ ✗(✗),✗ ✗ $\left(\frac{225}{247}\right)$,✗	$\frac{[-421,168,172]}{3558+1178p^2}$
(iv)	$e,\parallel_e$ $(\parallel)$	$\frac{-9p^2}{102+37p^2}$ $\left(\frac{-23P+7}{30}\right)$, $\frac{-38}{76+23p^2}$ $\frac{12(3+p^2)}{102+37p^2}$ $\left(\frac{1}{5}\right)$, $\frac{-3}{76+23p^2}$ $\frac{-36(3+p^2)}{102+37p^2}$ $\left(\frac{-3}{5}\right)$, $\frac{9}{76+23p^2}$ $\frac{-10(3+p^2)}{102+37p^2}$ $\left(\frac{-1}{6}\right)$, $\frac{5}{152+46p^2}$	$\frac{-18(3+p^2)}{102+37p^2}$ $\left(\frac{-3}{10}\right)$, $\frac{9}{152+46p^2}$ $\frac{42+p^2(14-23P_e)-60P_e}{102+37p^2}$ $\left(\frac{-23P+7}{30}\right)$, $\frac{-7}{152+46p^2}$ $\frac{18(3+p^2)}{102+37p^2}$ $\left(\frac{3}{10}\right)$, $\frac{-9}{152+46p^2}$ $\frac{42+p^2(14-23P_e)-60P_e}{102+37p^2}$ $\left(\frac{-23P+7}{30}\right)$, $\frac{-7}{152+46p^2}$	$\frac{-16(3+p^2)}{102+37p^2}$ $\left(\frac{-4}{15}\right)$, $\frac{4}{76+23p^2}$ $\frac{120+46p^2}{306+111p^2}$ $\left(\frac{23}{90}\right)$, $\frac{23/6}{76+23p^2}$ ✗ (✗),✗ $\frac{60+23p^2}{102+37p^2}$ $\left(\frac{23}{30}\right)$, $\frac{7}{152+46p^2}$	$\frac{[-16,7]}{152+46p^2}$
(v)	$e,\parallel_e$ $(\parallel)$	$\frac{-p^2}{14+5p^2}$ $\left(\frac{-3P+1}{4}\right)$, $\frac{-5}{10+3p^2}$ $\frac{4(3+p^2)}{42+15p^2}$ $\left(\frac{1}{6}\right)$, $\frac{-1}{30+9p^2}$ $\frac{-20(3+p^2)}{42+15p^2}$ $\left(\frac{-5}{6}\right)$, $\frac{5}{30+9p^2}$ $\frac{-2(3+p^2)}{14+5p^2}$ $\left(\frac{-1}{4}\right)$, $\frac{1}{20+6p^2}$	$\frac{-2(3+p^2)}{14+5p^2}$ $\left(\frac{-1}{4}\right)$, $\frac{1}{20+6p^2}$ $\frac{6+p^2(2-3P_e)-8P_e}{14+5p^2}$ $\left(\frac{-3P+1}{4}\right)$, $\frac{-1}{20+6p^2}$ $\frac{2(3+p^2)}{14+5p^2}$ $\left(\frac{1}{4}\right)$, $\frac{-1}{20+6p^2}$ $\frac{6+p^2(2-3P_e)-8P_e}{14+5p^2}$ $\left(\frac{-3P+1}{4}\right)$, $\frac{-1}{20+6p^2}$	$\frac{-8(3+p^2)}{42+15p^2}$ $\left(\frac{-1}{3}\right)$, $\frac{2}{30+9p^2}$ $\frac{10+4p^2}{42+15p^2}$ $\left(\frac{1}{6}\right)$, $\frac{2}{30+9p^2}$ $\frac{8(3+p^2)}{42+15p^2}$ $\left(\frac{1}{3}\right)$, $\frac{-2}{30+9p^2}$ $\frac{8+3p^2}{14+5p^2}$ $\left(\frac{3}{4}\right)$, $\frac{1}{20+6p^2}$	$\frac{[-2,1]}{20+6p^2}$

$$\frac{q_{B-L}^{\rm win}}{s} = \sum_{C\neq\Delta_\alpha} x_C \frac{q_C}{s}\bigg|_{T_{B-L}}, \qquad \frac{q_X}{s} = 2p\sum_C y_C \frac{q_C}{s}\bigg|_{T_{\rm eq}},$$

[Mojahed, SW, 2507.10655]



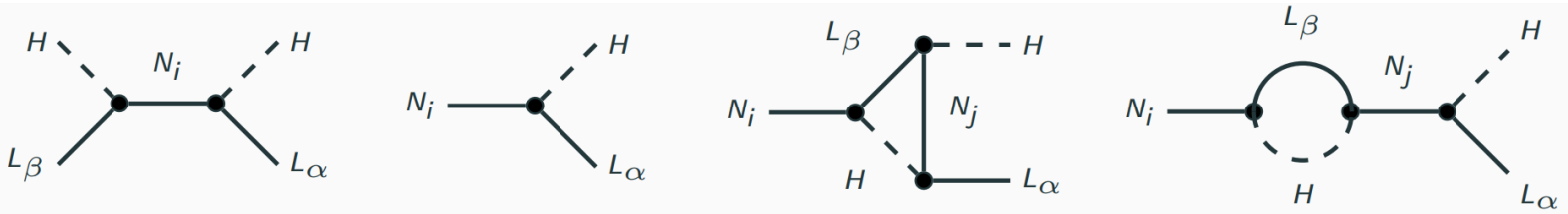
$$Y_{\Delta X}^{\mathrm{end}} = \kappa(z')\, Y_{\Delta X}^{\mathrm{eq}}(z'),$$

$$Y_{\Delta e}^{\mathrm{end}} = \tilde{\kappa}(z')\, Y_{\Delta e}^{\mathrm{eq}}(z'),$$

[Mojahed, SW, 2507.10655]

$$
\begin{pmatrix}
\mu_e \\ \mu_\mu \\ \mu_\tau \\ \mu_{\ell_e} \\ \mu_{\ell_\mu} \\ \mu_{\ell_\tau} \\ \mu_u \\ \mu_c \\ \mu_t \\ \mu_d \\ \mu_s \\ \mu_b \\ \mu_{Q_1} \\ \mu_{Q_2} \\ \mu_{Q_3} \\ \mu_\Phi
\end{pmatrix}
=
\begin{pmatrix}
-185/711 & 52/711 & 52/711 \\
52/711 & -185/711 & 52/711 \\
52/711 & 52/711 & -185/711 \\
-221/711 & 16/711 & 16/711 \\
16/711 & -221/711 & 16/711 \\
16/711 & 16/711 & -211/711 \\
-5/237 & -5/237 & -5/237 \\
-5/237 & -5/237 & -5/237 \\
-5/237 & -5/237 & -5/237 \\
19/237 & 19/237 & 19/237 \\
19/237 & 19/237 & 19/237 \\
19/237 & 19/237 & 19/237 \\
7/237 & 7/237 & 7/237 \\
7/237 & 7/237 & 7/237 \\
7/237 & 7/237 & 7/237 \\
-4/79 & -4/79 & -4/79
\end{pmatrix}
\begin{pmatrix}
\bar{\mu}_{\Delta_e} \\ \bar{\mu}_{\Delta_\mu} \\ \bar{\mu}_{\Delta_\tau}
\end{pmatrix}
$$

[Kai Schmitz Talk Neutrino Platform Pheno Week 2023]



Boltzmann equation for leptogenesis via N_1 right-handed neutrino decays:

$$-\left(\partial_t + 3H\right) q_{\Delta_\alpha} = \varepsilon_{1\alpha}\Gamma_1\left(n_{N_1} - n_{N_1}^{\rm eq}\right) - \sum_\beta \gamma_{\alpha\beta}^{\rm w}\,\frac{\mu_{\ell_\beta} + \mu_\Phi}{T}$$

$$\begin{pmatrix} \mu_{\ell_e} + \mu_\Phi \\ \mu_{\ell_\mu} + \mu_\Phi \\ \mu_{\ell_\tau} + \mu_\Phi \end{pmatrix} = - \begin{pmatrix} 257/711 & 20/711 & 20/711 \\ 20/711 & 257/711 & 20/711 \\ 20/711 & 20/711 & 257/711 \end{pmatrix} \begin{pmatrix} \bar{\mu}_{\Delta_e} \\ \bar{\mu}_{\Delta_\mu} \\ \bar{\mu}_{\Delta_\tau} \end{pmatrix}$$

[Kai Schmitz Talk Neutrino Platform Pheno Week 2023]

$$\begin{pmatrix} \mu_{\ell_e} + \mu_\Phi \\ \mu_{\ell_\mu} + \mu_\Phi \\ \mu_{\ell_\tau} + \mu_\Phi \end{pmatrix} =$$

$$- \begin{pmatrix} 6/13 & 0 & 0 \\ 0 & 41/111 & 4/111 \\ 0 & 4/111 & 41/111 \end{pmatrix} \begin{pmatrix} \bar{\mu}_{\Delta_e} \\ \bar{\mu}_{\Delta_\mu} \\ \bar{\mu}_{\Delta_\tau} \end{pmatrix} + \begin{pmatrix} -5/13 \\ 4/37 \\ 4/37 \end{pmatrix} \bar{\mu}_e$$

[Kai Schmitz Talk Neutrino Platform Pheno Week 2023]