

New View of Particle Physics from Neutrinos and BSM Phenomena

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International Conference on the Physics of the Two Infinities

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Summary of C02 Group from 2018 to 2023

in Grant-in-Aid for Scientific Research on Innovation Areas

“Exploration of Particle Physics and Cosmology with Neutrinos”

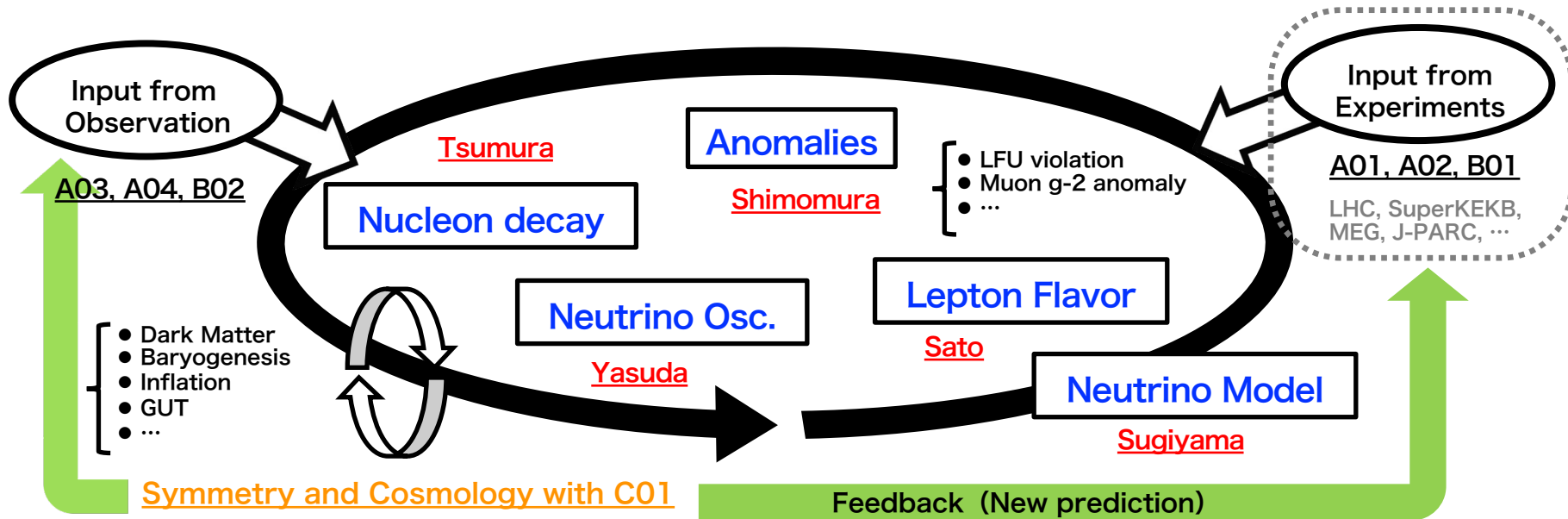
C02 Group

Members

PI : K. Tsumura (Kyushu U.)

Co-PI : O. Yasuda (Tokyo Metropolitan U.), J. Sato (Yokohama National U.),

T. Shimomura (Miyazaki U.), H. Sugiyama (Toyama Prefectural U.)



Goal : Unified description of Two infinities

Particle Physics and Cosmology

C02

C01

Focus Topics of C02

Neutrino Oscillation

Yasuda

- Systematic analysis of ν oscillation
- Discrepancy btw diff. ν osc experiments
- Non Standard Interactions
- Possibility of sterile ν
- ...

Lepton Flavor

Sato

- New LFV process
- High precision LFV prediction
- Quark Flavor violation
- Origin of CP violation
- ...

Neutrino Model

Sugiyama

- Model building
- Systematic classification of models
- ν Mass and Flavor symmetry
- ...

Anomalies

Shimomura

- Muon $g-2$
- Lepton Flavor Universality
- New light particles
- ...

 C02

- Dark Matter
- Baryogenesis
- Inflation
- ...

 C01

Neucleon decay

Tsumura

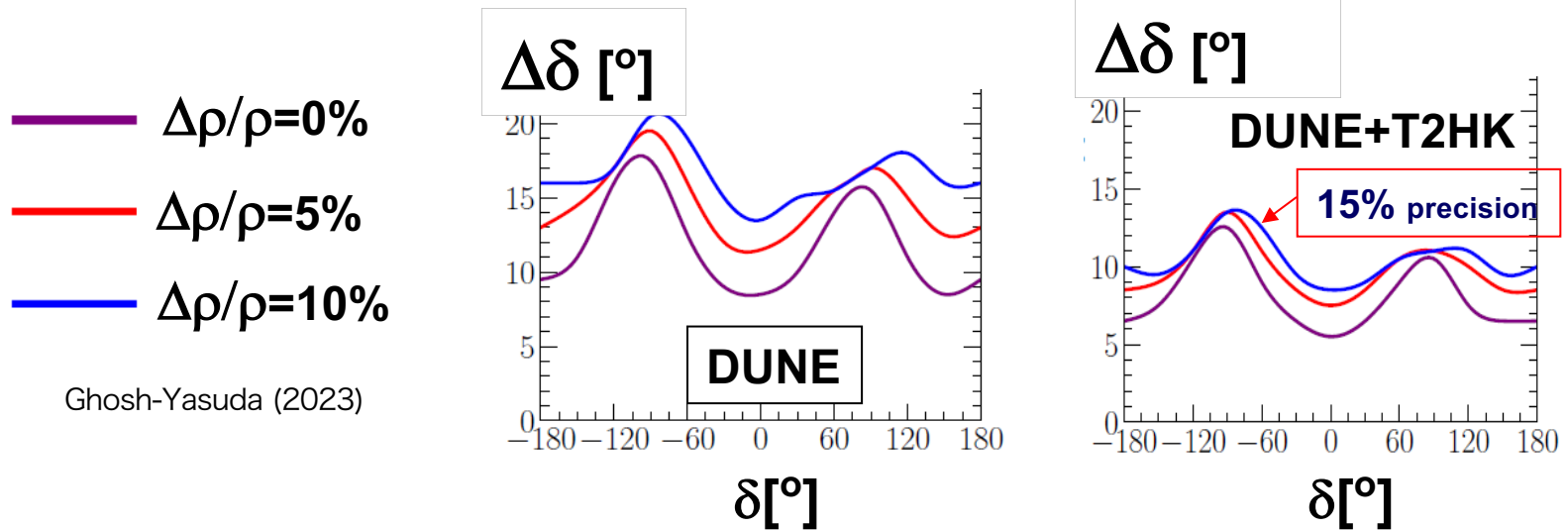
- Model with Baryon number violation
- Model with Lepton number violation
- DM and proton stability
- Grand Unified Theories
- ...

Research Highlights of C02

- Neutrino Oscillation
- Neutrino Mass Model
- Physics of Lepton Flavor
- Feebly Interacting Light Particles
- Dark Matter
- Models with L and B violation

Neutrino Oscillation (O. Yasuda)

- Evaluate the uncertainty on the sensitivity to CP phase at LBL
- Non-negligible Effect from the uncertainty in the matter density of the Earth is found

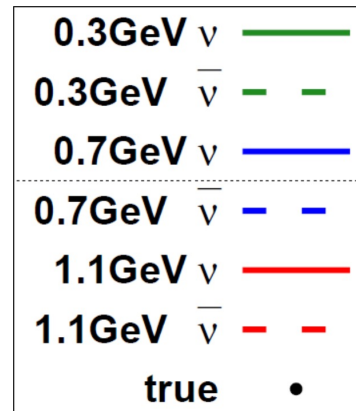


Neutrino Oscillation (O. Yasuda)

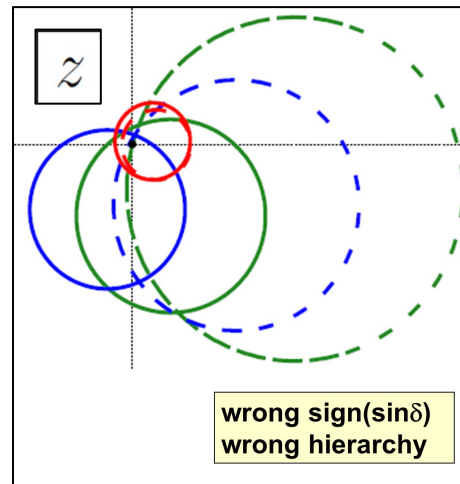
- Resolve parameter degeneracy due to the NSI of neutrinos

NSI can explain the discrepancy of Δm^2 btw two experiments

→ Combinations of ν -osc & anti- ν -osc / diff. energy runs at T2HK & T2HKK can do the job



Yasuda (2020)



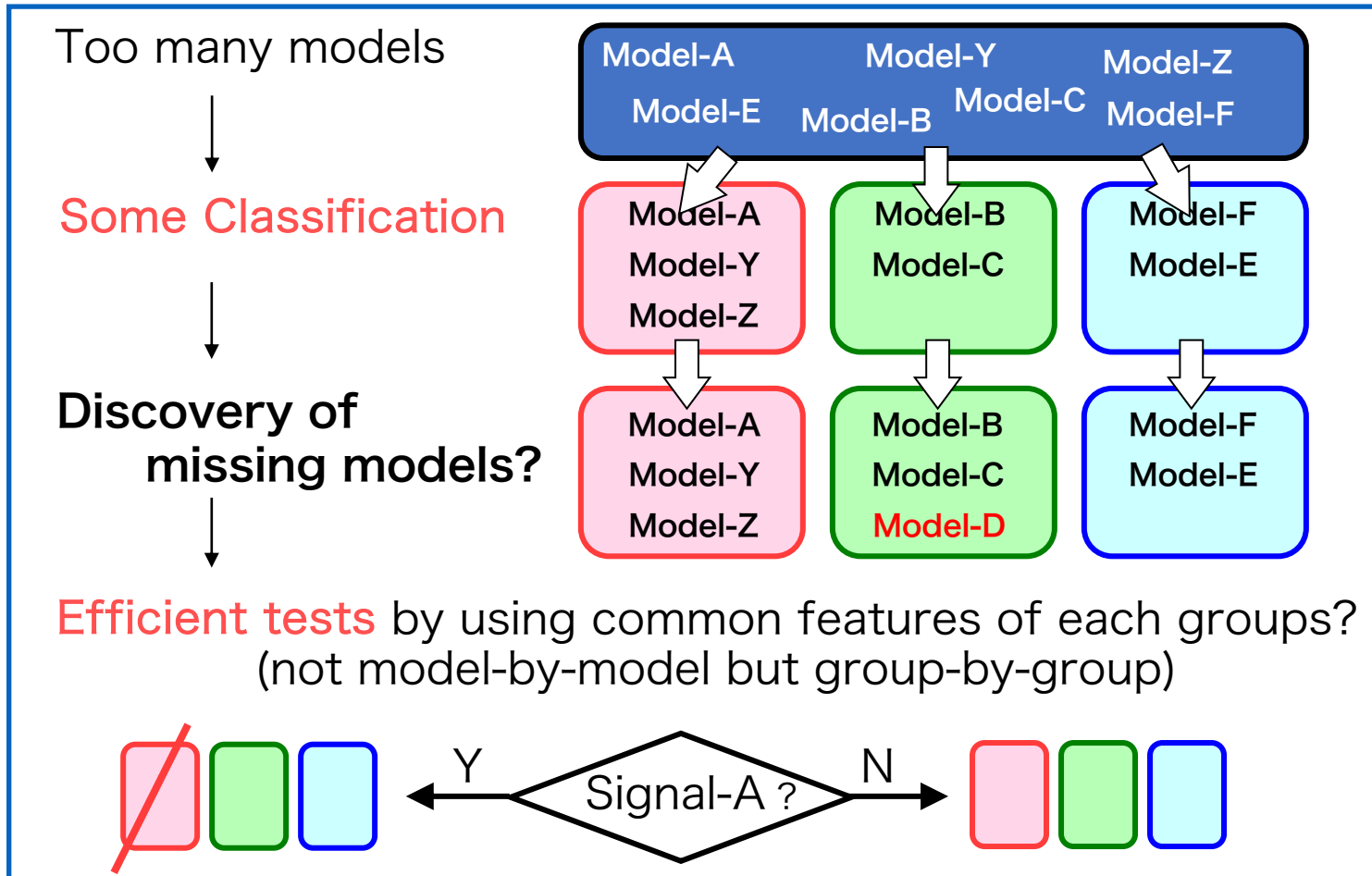
$$z \equiv (AL/2)U_{\tau 3}\epsilon_N$$

Neutrino Mass Model (H. Sugiyama)

$\sim O(10^2-10^3)$

- There are too many models for M_ν

→ Narrow down to the true model (systematic approach)



Neutrino Mass Model (H. Sugiyama)

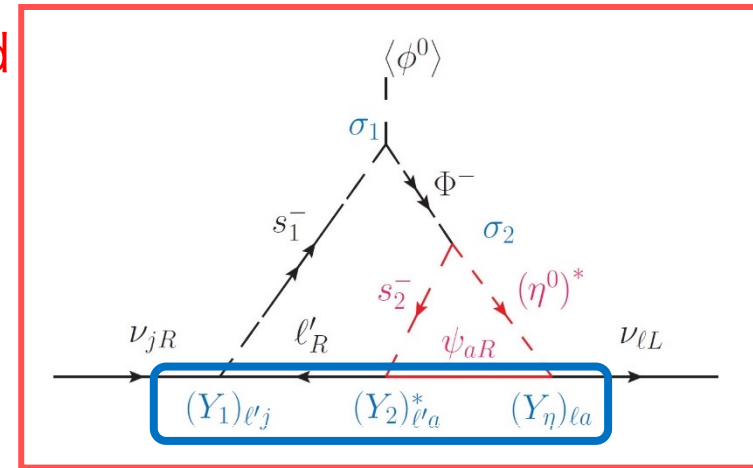
- Example of Classifications

Neutrino mass matrix structure \leftrightarrow combination of Yukawa ints.

→ New Yukawa Combination is found

→ Construct a Concrete Model

- ✓ 2-loop **Dirac neutrino** mass
(naturally light)
- ✓ $\text{Br}(h \rightarrow \bar{\mu}\tau) > \text{Br}(\tau \rightarrow \mu\gamma)$ is possible
(unique feature)



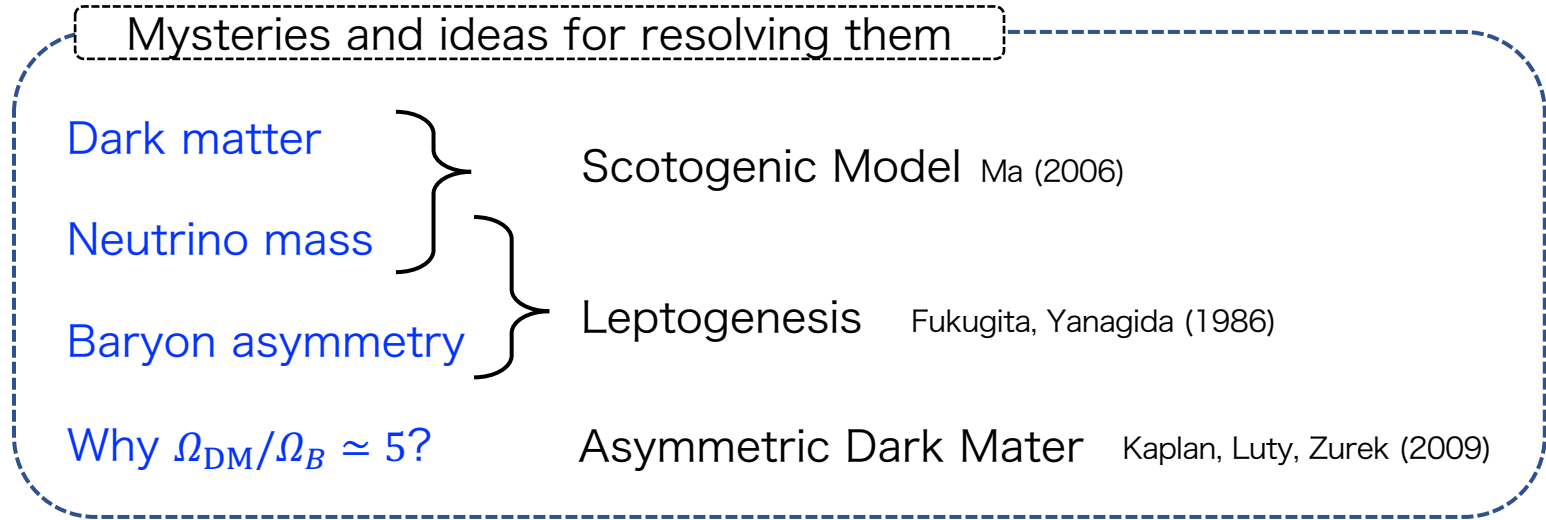
Enomoto-Kanemura-Sakurai-Sugiyama (2019)

- Ongoing : Applications with quark Yukawa ints.

(→ efficient tests by $0\nu 2b$, meson decay, LHC phys)

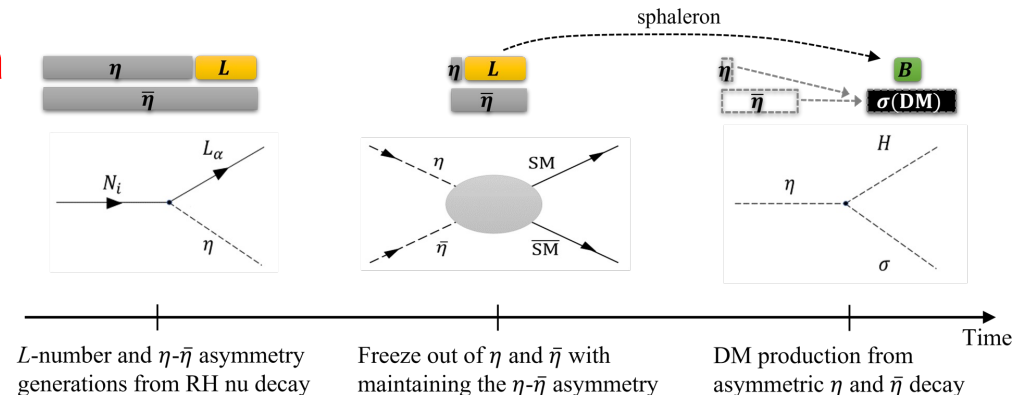
Neutrino Mass Model (J. Sato)

4 mysteries



→ An unified description

- RH neutrinos N_i
- Inert doublet scalar η
- Singlet scalar σ



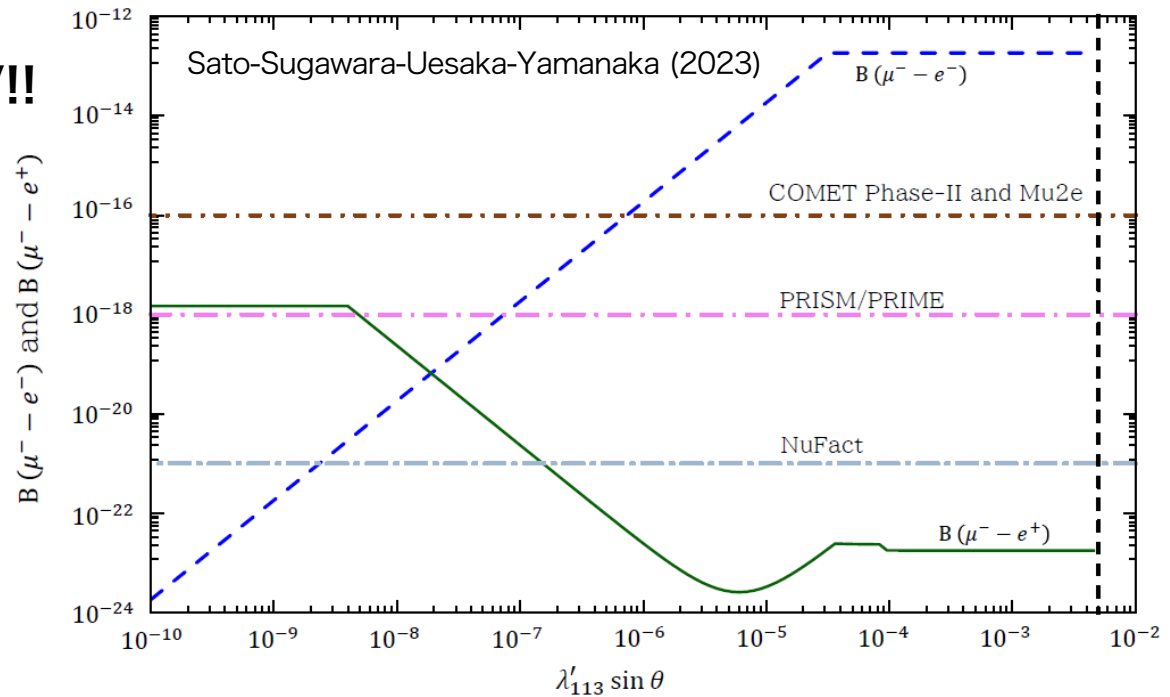
Physics of Lepton Flavor (J. Sato)

- New Physics search using muonic atom

Comparison with $\mu^- \rightarrow e^-$ and $\mu^- \rightarrow e^+$

→ In a certain class of models, LNV process can be larger LFV

Majorana mass is **NOT**
only the source of LNV!!



Physics of Lepton Flavor (J. Sato)

- Unification of $U(1)_{L\mu-L\tau}$ and SM gauge group

→ Challenge to Grand-Grand Unification Sato (2022)

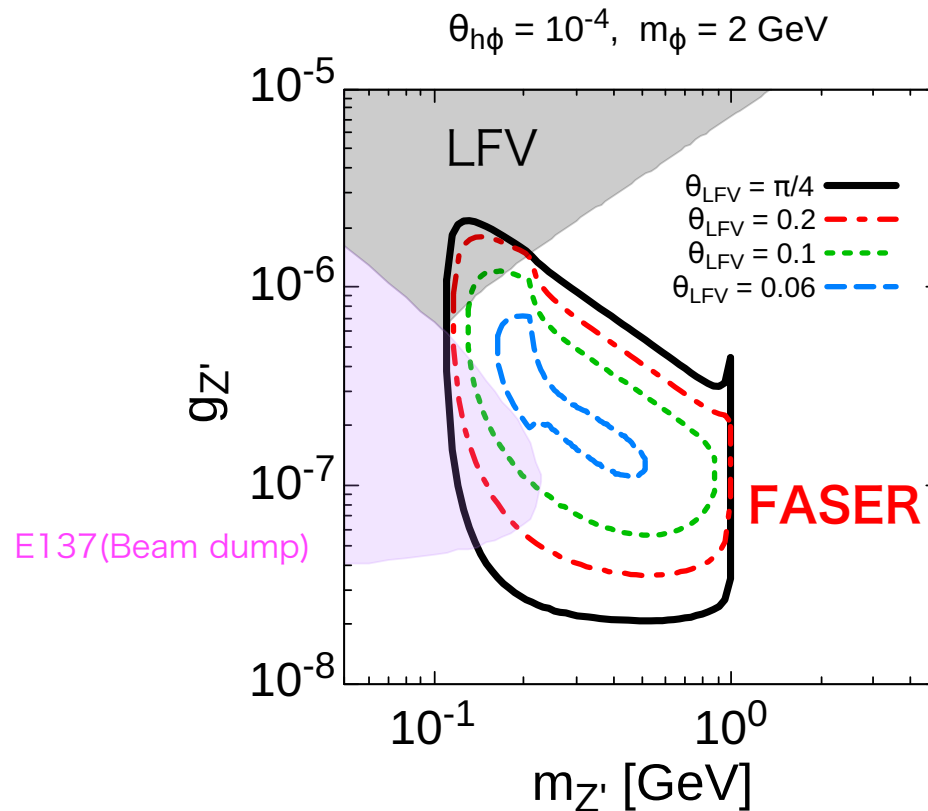
$$\begin{aligned} E_7 &\rightarrow E_6 \times U(1)_1 \rightarrow SU(5) \times SU(2) \times U(1)_1 \times U(1)_2 \\ &\rightarrow SU(5) \times U(1)_1 \times U(1)_2 \times U(1)_{3=\mu-\tau} \end{aligned}$$

Feebly Interacting Light Particles (T. Shimomura)

- Feasibility study of cLFV of light boson at FASER

New physics possibility at low scale (below the EW scale) with feeble ints

→ Sensitivity reach Araki-Asai-Otono-Shimomura-Takubo (2023)

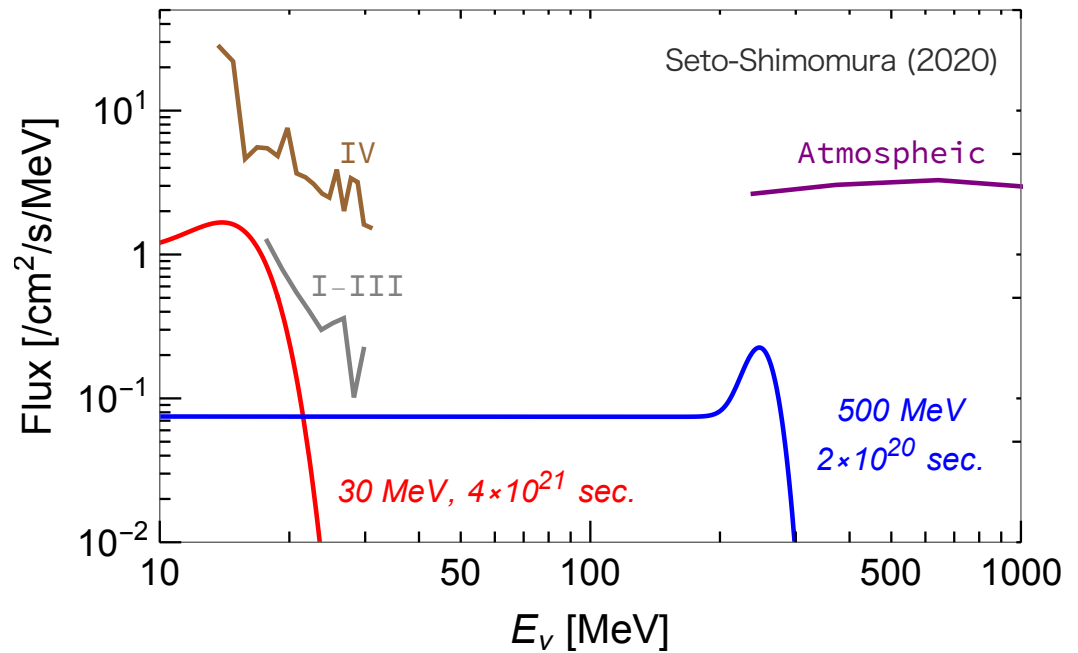


Dark Matter (T. Shimomura)

- Revisit Sterile ν Dark Matter

→ $\nu_s (\rightarrow \nu Z_{B-L})$ decay is observable at ν telescope (SK) !!

$$Z_{B-L} \rightarrow \nu \bar{\nu}$$



→ Overlooked DM production mode is found Eijima-Seto-Shimomura (2022)

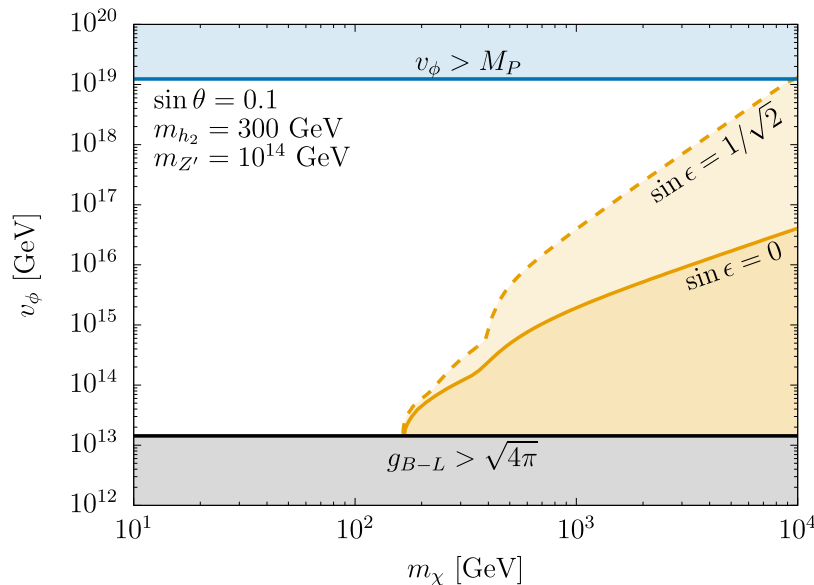
via Inverse Z_{B-L} decay

Dark Matter (K. Tsumura)

- **Origin of pseudo-NGB Dark Matter**

pNGB-DM is a natural framework to suppress the DM-nucleon scattering cross section against severe constraint from DM direct detection

→ **Unified description of the Small M_V & Long-lived DM**



← DM (meta)stability requires high scale
= Scale of RH neutrino

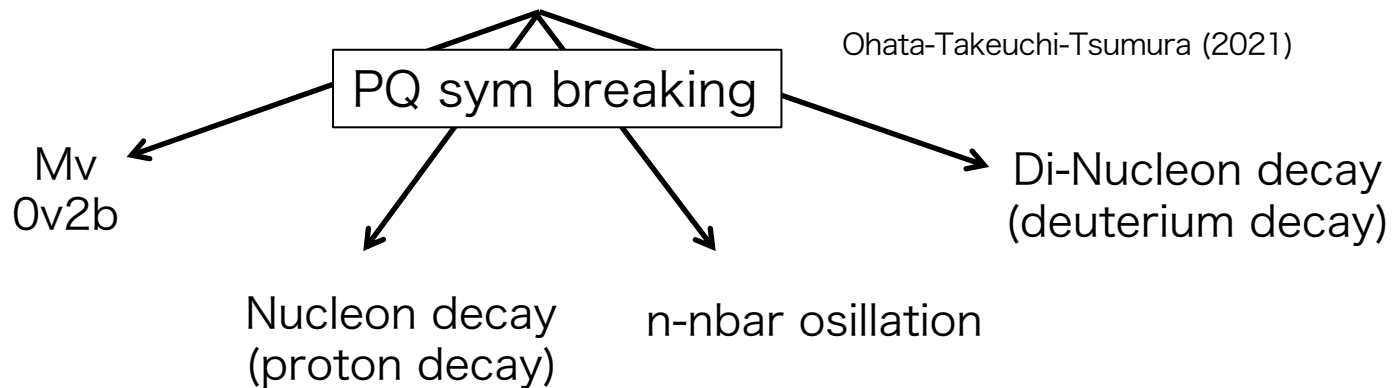
Models with L and B violation (K. Tsumura)

- L/B violation from Non-GUT / RPV-SUSY

→ Construct models from Peccei-Quinn symmetry

PQ sym is known as a solution to strong CP problem

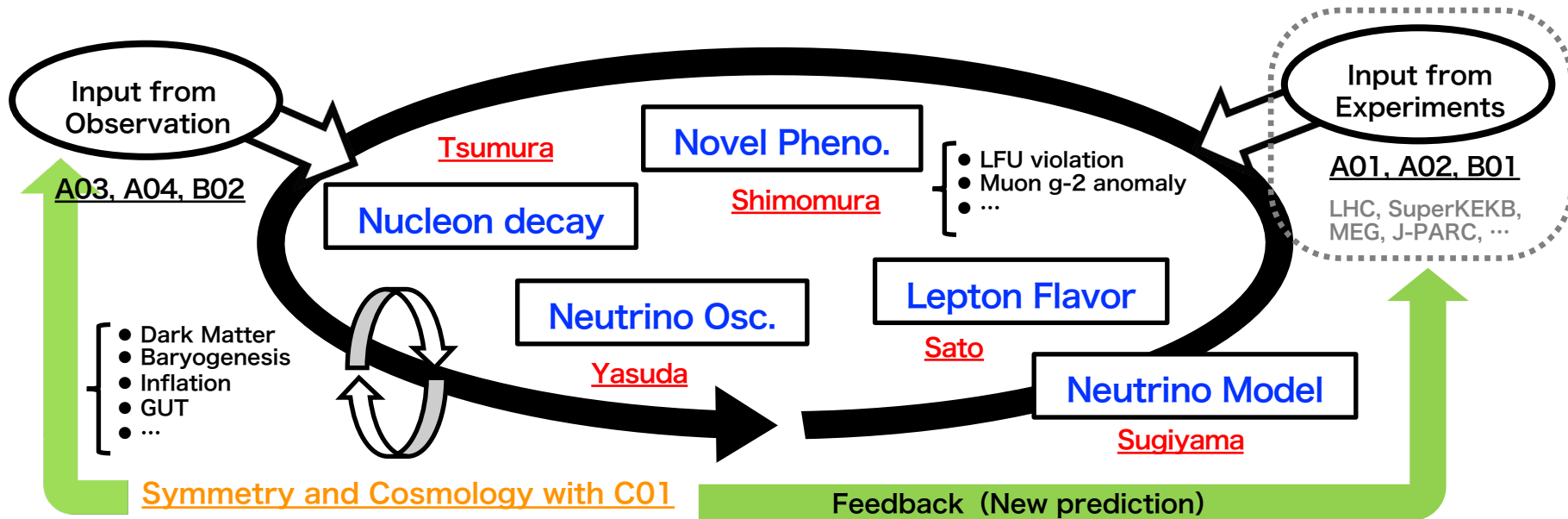
Proposal : $PQ = c_B B + c_L L$



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- Neutrino Oscillation
- Neutrino Mass Model
- Physics of Lepton Flavor
- Feebly Interacting Light Particles
- Dark Matter
- Models with L and B violation
- etc.