Flavor (and CP) symmetries beyond fermion masses and mixing

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CERN, Geneva, March 28 , 2017

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Platform

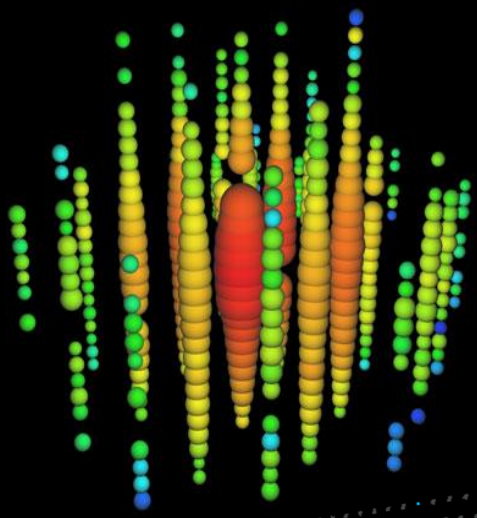
discuss

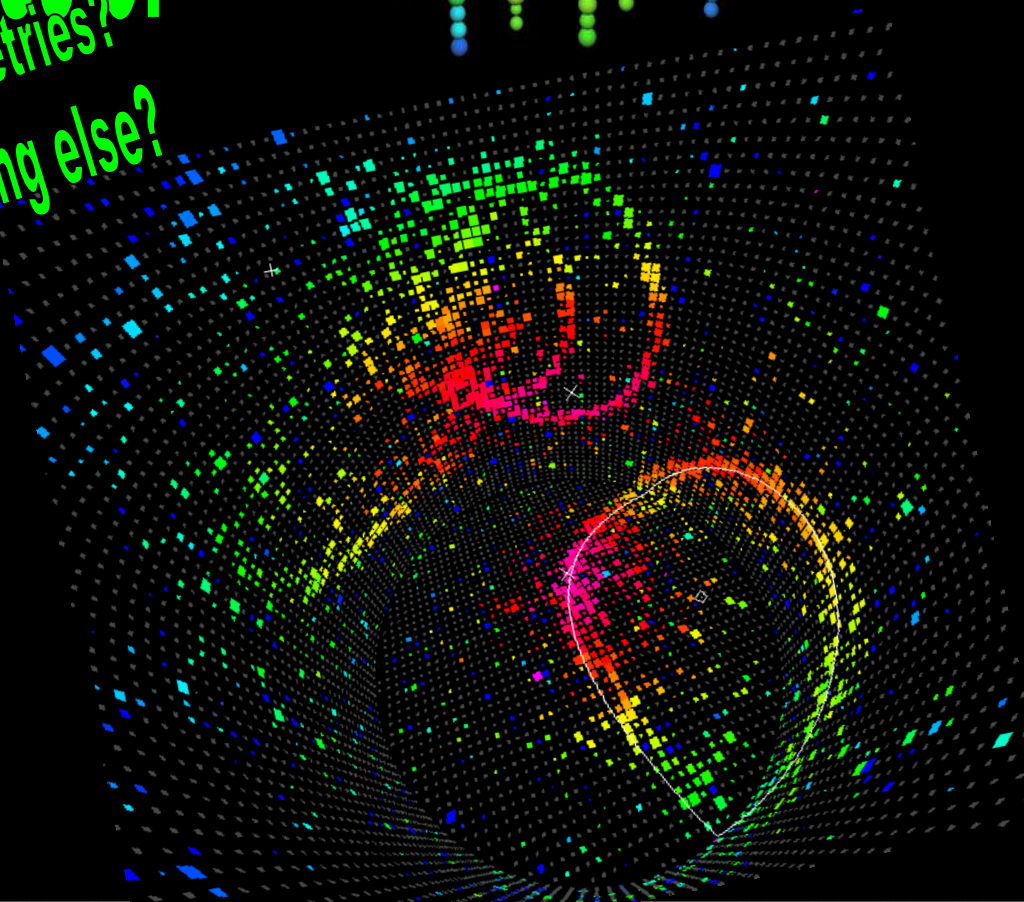
"Signals that could help to decipher the underlying principles of flavor sector"

will they be ever observed?

what is that?

flavor symmetries?
anarchy?
or something else?





in the present situation
ANY signal of new physics
will be relevant!

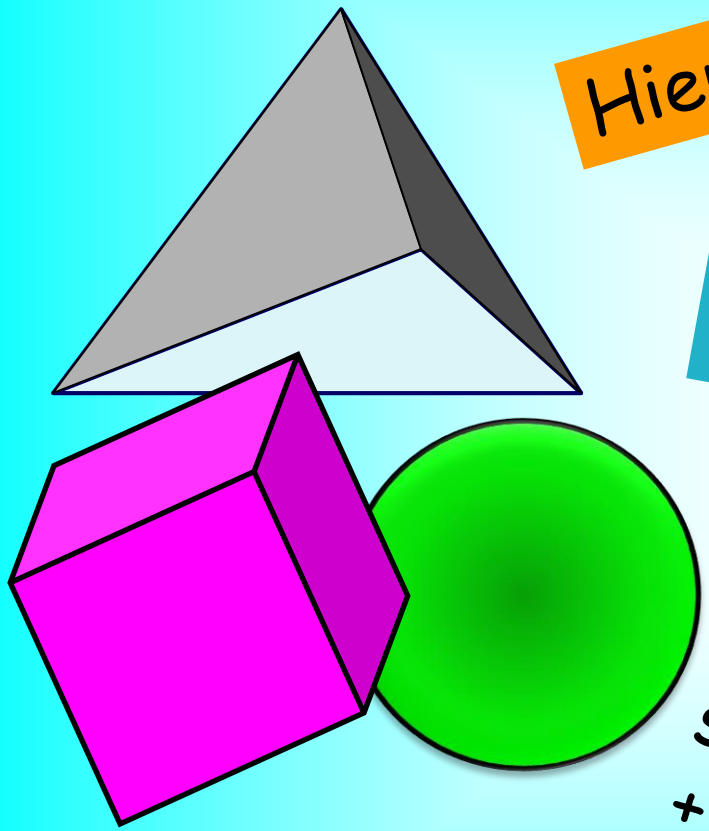
Underlying principles

Hierarchy

Vertical gauge symmetry

Accidental symmetries

Anarchy randomness



Symmetry geometry

Symmetry + anarchy

Starting point

FS: accidental or real?

L. Wolfenstein

P.F. Harrison, D.H. Perkins, W.G. Scott

TBM mixing

$$U_{tbm} = \begin{pmatrix} \sqrt{2/3} & \sqrt{1/3} & 0 \\ -\sqrt{1/6} & \sqrt{1/3} & -\sqrt{1/2} \\ -\sqrt{1/6} & \sqrt{1/3} & \sqrt{1/2} \end{pmatrix}$$

0.15

0.64

0.77

$\sin^2\theta_{12} = 0.30 - 0.31$

$\sin^2\delta_{CP} = -\pi/2$

Accidental, numerology, useful for bookkeeping

Accidental symmetry (still useful)

No relation of mixing with masses (mass ratios)

Not accidental

Lowest order approximation which corresponds to weakly broken (flavor) symmetry of the Lagrangian

with some other physics and structures associated

Discover new physics, particles associated to symmetries

Signals of flavor symmetries

R. Valkas

New processes with known particles

NSI and neutrino oscillations

cLFV:
$\mu \to e + \gamma$
$\mu \to e + e + e$
$\mu \to e$ conv.
$\tau \to e + \gamma$
$\tau \to e + e + \mu$

$H \to \tau + \mu$

Proton decay modes

New particles

Scalars:
- Flavons,
- additional higgses,
- axions

Fermions:
- sterile neutrinos,
- vector-like generations

Gauge bosons
U(1), SU(2), SO(3), SU(3)

Dark sector

Dark matter
Dark energy?
Dark photons

B, L - genesis

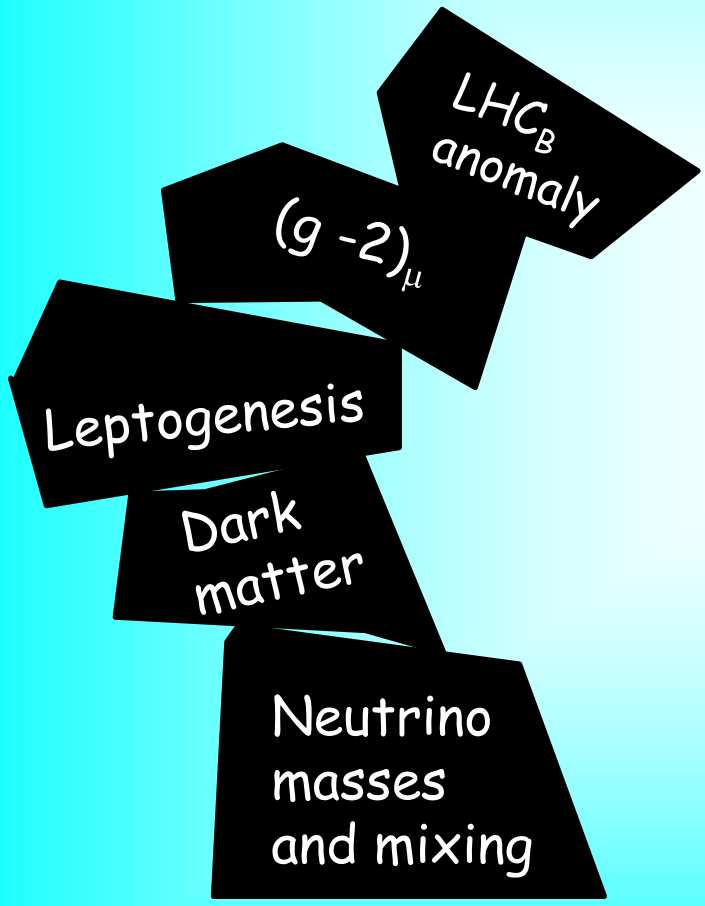
Inflation

Extra dimensions

Compositeness

What else?

Model building



Most of the possible signals are model dependent and scale dependent

If at very high scales -- hopeless? indirect evidences?

predictions which testify for FS ?

Generic consequences?

Minimal model of flavor?

criteria

Models and BSM

Beyond Sensible and Motivated

Signals and signatures

Inverse problem: reconstruct FS from data

Leptogenesis - one number?

Dark matter with mass e.g. 37 GeV

Can we distinguish between symmetry and anarchy?
Identify flavor symmetries?

Two or more channels,
comparison of rates is needed

$H \to \tau + \mu$ $H \to e + \mu$

First discover two or more new processes – then formulate signatures of different underlying flavor physics scenarios

Are we too far from this task?
Too premature,,,,

Chance to discover something new related to lepton mass and mixing? .... scale

Scales of flavor and neutrino mass generation

Residual symmetry approach for explanation of mixing:

No immediate connection to masses

→ Scale of FS is not fixed. RGE?

Some relations appear as a consequence of structure of specific model

Scale of flavor physics Λ_F = breaking of flavor symmetry, e.g. to residual groups in residual symmetry approach?

$\Lambda_F > \Lambda_\nu$?

Natural scales of (Majorana) neutrino mass generation:

$\Lambda_\nu = -\frac{V_{EW}^2}{m_\nu}$	~ $2\ 10^{14}$ GeV	Standard seesaw I
★ $\Lambda_\nu = -\frac{V_{LR}^2}{V_{EW}^2}\, m_\nu$	~ 0.3 keV – 30 MeV	Inverse seesaw L-R symmetry
$\Lambda_\nu = -\frac{V_{GUT}^2}{V_{EW}^2}\, m_\nu$	~ 10^{19} GeV	Double seesaw, GUT- Planck scale physics

Radiative mechanisms - BSM ?

Framework

$$U_{PMNS} = U_{CKM}^{+} U_X$$

From the Dirac matrices of charged leptons and neutrinos

Related to mechanism that explains smallness of neutrino mass

New neutrino structure

Two types of new physics ?

CKM type new physics

Neutrino new physics

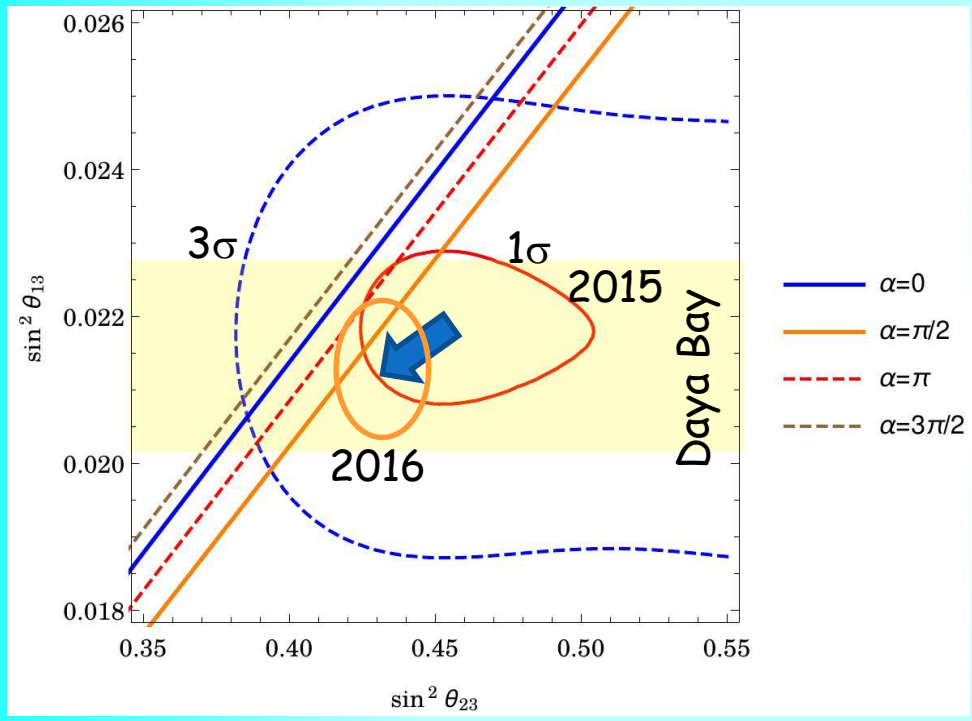
Can be naturally realized in the seesaw type I which after all is the most appealing mechanism of explanation of smallness of neutrino mass

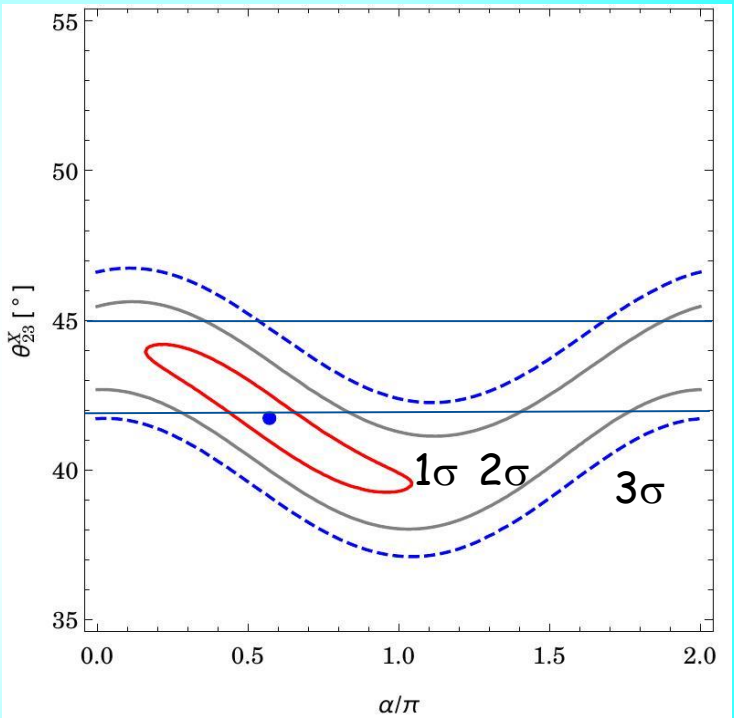
General relation

Normal mass ordering

$$\sin^2\theta_{13} = \sin^2\theta_{23}\,\sin^2\theta_C\,(1 + O(\lambda^2))$$

$$\lambda = \sin\theta_C$$





Dependence of 1-3 mixing on 2-3 mixing for different values of the phase α. Allowed regions from the global fit NuFIT 2015

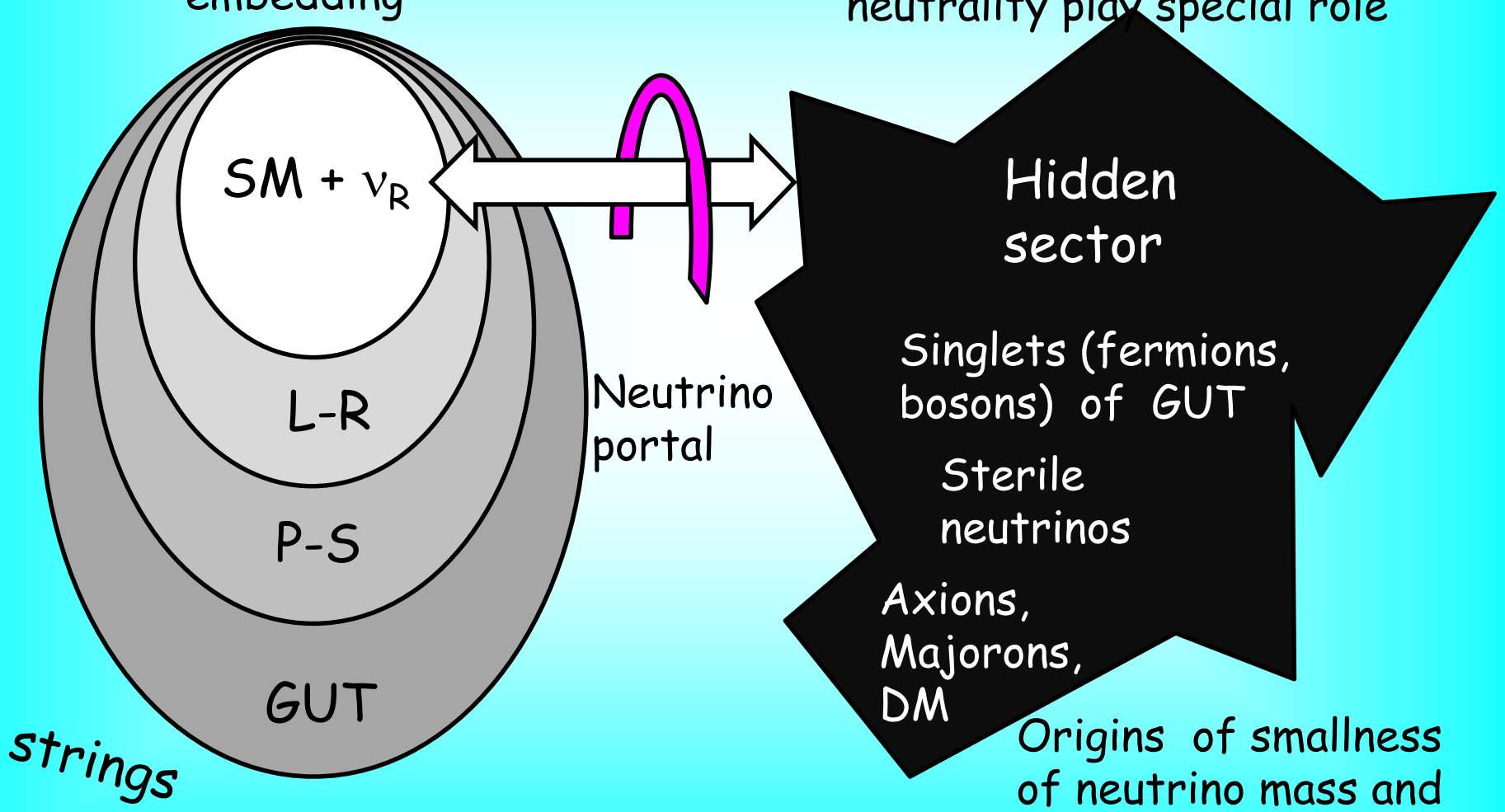
Allowed values of parameters of U_X
Best fit value: $\theta^X_{23} = 42^0$

RGE effect from maximal mixing value at high scale

Setup

S – from the Hidden sector?

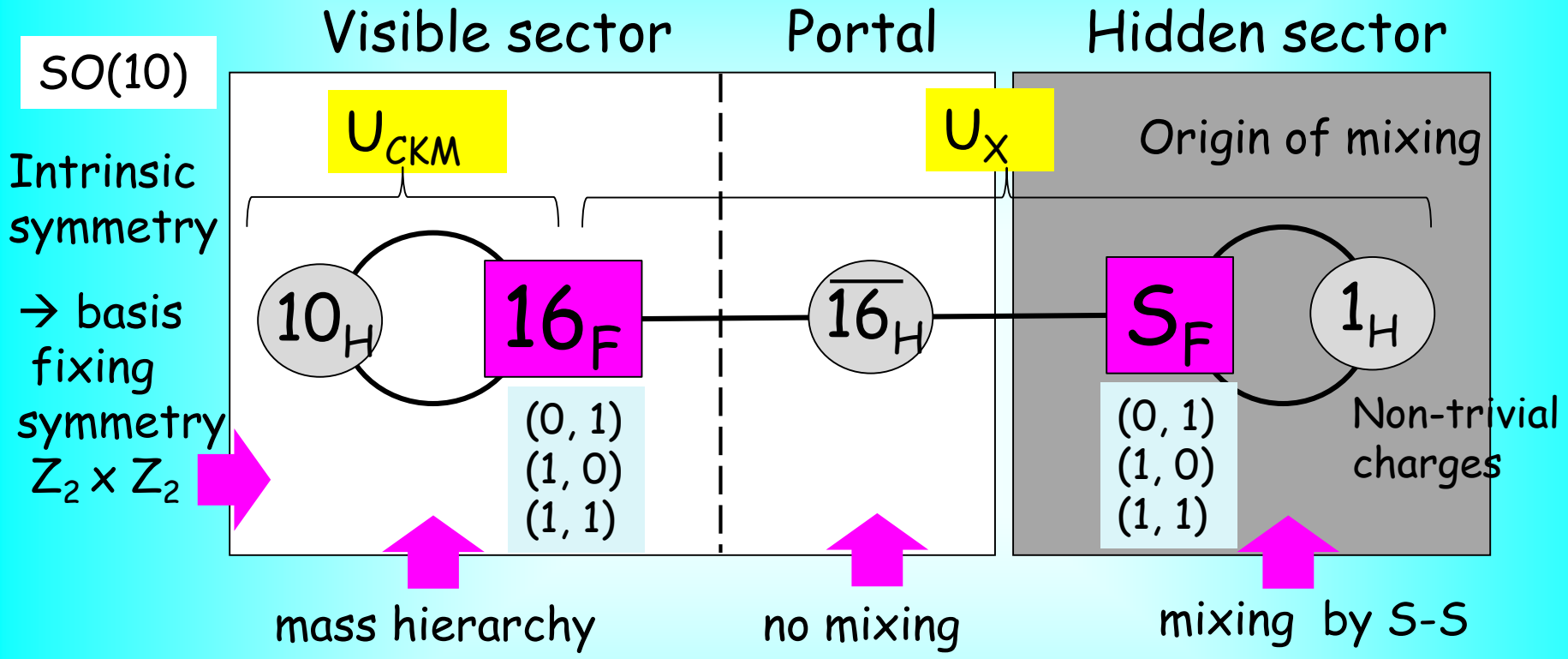
Neutrinos due to neutrality play special role



Origins of smallness of neutrino mass and large (maximal mixing)

Realization scheme

Patrick Ludl, A.S
arXiv:1507.03494 [hep-ph]



CKM mixing - additional structures

$m_D \sim M_D = \text{diag}$

$M_X = d^T M_S d$

Double seesaw

due to non-trivial $Z_2 \times Z_2$ charges of 1_H

M_S ~ non-diagonal, can be further structured by G_{hidden}

Signals of flavor:

Flavons, new fermions, new higgses are at GUT – Planck scale

Nothing should be observed at LHC which is responsible for neutrino masses

If something is observed against (excludes) framework

Proton decay

New elements related to CKM physics

Light sterile neutrinos?

Dark matter

Connections are possible to

Inflation

Leptogenesis

Questions:

Flavor physics: flavor symmetry or something different?
Flavor without symmetry? Accidental symmetries

Scale of flavor physics?
Connection to neutrino mass generation scale?

Generic elements, model independent consequences?

Minimal model of flavor?

Is connection of flavor with DM, axions, inflaton natural? artificial?
How to prove these connections?

Is GUT-Planck scale of flavor physics plausible?

Flavor from hidden sector/symmetries?