TMU
June 11.98.
New Era

ν ASTROPHYSICS AND ν CONVERSION

MEDIA • EQUATION / PHYSICAL CONDITIONS.

PROFILES • WHEN TRANSITIONS ARE STRONG ?

NEUTRINOS • Neutrino SPECTRA AND MULTI NEUTRINO TRANSITIONS

VACUUM MASS MIXING + MEDIA

1.

MEDIUM

VARIETY OF CONDITIONS

- UNPOLARIZED
- POLARIZED
  MAGNETIZED
- MOVING
- HOT PLASMA.
- ABSORBTION.

EVOLUTION EQUATION

- ν ARE ULTRARELATIVISTIC
- NO SPIN-FLIP
  NO CHANGE OF SPINOR STRUCTURE
- LOWEST ORDER IN $\frac{m_\nu}{E}$
- NO ABSORPTION :

TRANSITIONS IN FLAVOR SPACE
(point-like picture)

- $\nu_f = \begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix} \qquad \nu = \begin{pmatrix} \nu_1 \\ \nu_2 \end{pmatrix}$ MASS EIGENSTATES

$$\boxed{\nu_f = S \nu}$$

$$S = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}$$

- $\nu_i = e^{-i(E_i t - px)}$

$$\dot{\nu}_i = -i E_i \nu_i$$

$$i\dot{\nu}_i = E_i \nu_i$$

$$\boxed{i\dot{\nu}_i \approx \left(k + \frac{m_i^2}{2k}\right)\nu_i}$$

$$i\dot{\nu} = k\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} + \frac{1}{2k}\begin{pmatrix} m_1^2 & 0 \\ 0 & m_2^2 \end{pmatrix}\nu$$

DIAGONAL MATRIX PROPORTIONAL TO $\hat{1}$ CAN BE OMITTED.

$$i\dot{\nu} = \frac{M^2}{2K}\nu \qquad M^2 \equiv \mathrm{diag}(M_1^2, M_2^2) \quad (*)$$

- EQUATION FOR FLAVOR STATES:

$$\nu = S^{-1}(\theta)\,\nu_f$$

INSERT INTO (*)

$$i\, S^{-1}(\theta)\,\dot{\nu}_f = \frac{M^2 S^{-1}}{2K}\nu_f$$

$$i\,\dot{\nu}_f = \frac{S M^2 S^{+}}{2K}\nu_f$$

$$\boxed{i\,\dot{\nu}_f = \frac{M_f^2}{2K}\nu_f}$$

WHERE $M_f \equiv S M S^{+}$ ← MASS MATRIX IN FLAVOR BASIS.

- EXPLICITLY:

$$\frac{1}{4K} S \cdot \begin{pmatrix} -\Delta m^2 & 0 \\ 0 & +\Delta m^2 \end{pmatrix} S^{+} = \frac{\Delta m^2}{4K}\begin{pmatrix} -\cos 2\theta & \sin 2\theta \\ \sin 2\theta & \cos 2\theta \end{pmatrix}$$

$$\hat{H} = \frac{\Delta m^2}{4K}\begin{pmatrix} -\cos 2\theta & \sin 2\theta \\ \sin 2\theta & \cos 2\theta \end{pmatrix}$$

PROPAGATION IN MEDIUM.

$$\boxed{i\dot{\nu} = H\nu}$$

$$H = H_\nu + H_{INT}$$

$$H_\nu = \frac{\Delta m^2}{4k}\begin{pmatrix} -\cos 2\theta & \sin 2\theta \\ \sin 2\theta & \cos 2\theta \end{pmatrix}$$

VACUUM (KINETIC) PART

H_{INT} - INTERACTION PART

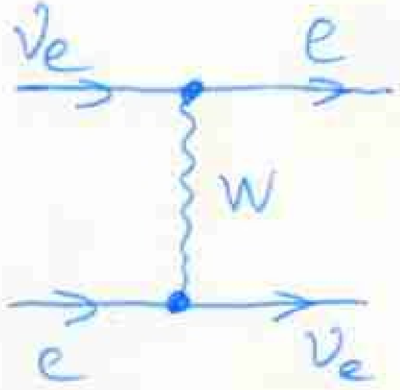
$$\boxed{H_{INT} \equiv V = \langle \Psi | \hat{H}_{INT} | \Psi \rangle}$$

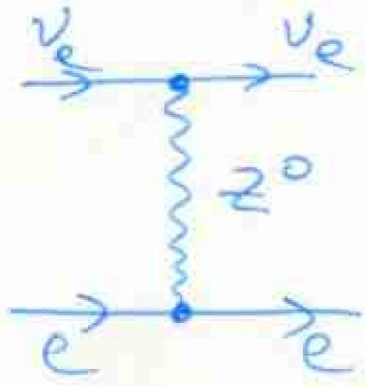
Ψ IS THE WAVE FUNCTION OF SYSTEM NEUTRINO + MEDIUM.

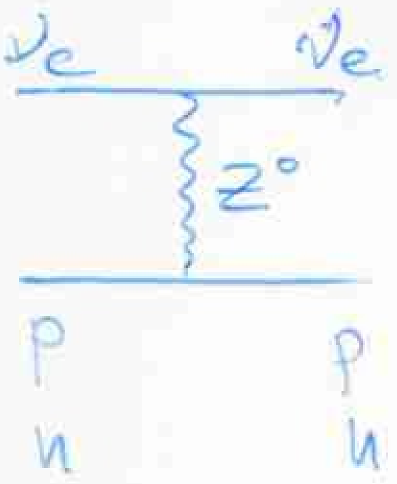
IMAGINARY PART OF V DESCRIBES CREATION (DESTRUCTION) OF NEUTRINO.

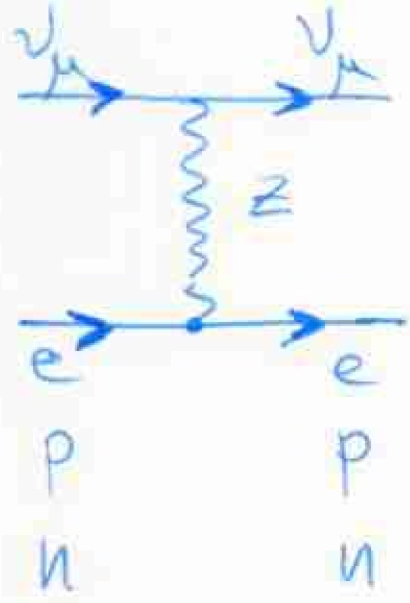
REAL PART = ELASTIC FORWARS SCATTERING.

$$\frac{V_I}{V_R} \sim \frac{\sqrt{s}}{m_W} \lll 1$$ FOR LOW ENERGIES.









THE SAME FOR ν_τ.

HAMILTONIAN

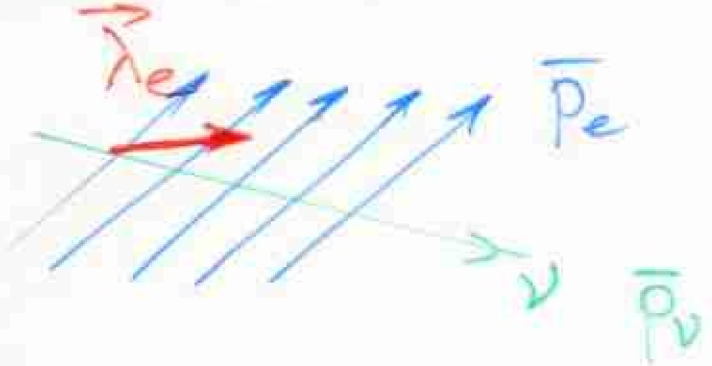
$$\boxed{\hat{H} = \frac{G_F}{\sqrt{2}} \bar{\nu}\gamma^\mu(1-\gamma_5)\nu \times \left[\bar{e}\gamma_\mu(g_V + g_A\gamma_5)e + \bar{p}\gamma_\mu(g_V^p + g_A^p\gamma_5)p + \bar{n}\gamma_\mu(g_V^n + g_A^n\gamma_5)n\right]}$$

G_F IS THE FERMI COUPLING CONSTANT

g_V, g_A – VECTOR AND AXIAL-VECTOR COUPLINGS.

FOR NUCLEONS g_V^N, g_A^N CAN BE CALCULATED USING
QUARK COUPLING + RENORMALIZATION OF THE AXIAL-VECTOR COUPLING

EFFECTS OF SCATTERING ON ELECTRONS:



- $$\boxed{\vec{\lambda}_e \equiv \omega_e^{+} \vec{\sigma}\, \omega_e}$$

VECTOR OF POLARIZATION OF ELECTRONS

ω_e is two-COMPONENT SPINOR

$\vec{p}_e$ IS THE MOMENTUM OF ELECTRONS

- $\dfrac{f(\vec{\lambda}_e, \vec{p}_e)}{(2\pi)^3}$ IS THE DENSITY DISTRIBUTION OF ELECTRONS.

TOTAL NUMBER DENSITY OF ELECTRONS

- $$n_e = \sum_\lambda \int \frac{d^3 p_e}{(2\pi)^3} f(\bar{\lambda}_e \bar{p}_e)$$

MATRIX ELEMENT:

$$\sim \sum_{\lambda} \int \frac{d^3 p_e}{(2\pi)^3} f(\lambda_e \cdot \bar{p}) \cdot \langle e_{p\lambda} | \bar{e} \gamma_\mu (g_V + g_A \gamma_5) | e_{p\lambda} \rangle$$

SOLUTION
OF DIRAC
EQUATION

COLLECTIVE EFFECTS....

Unpolarized MEDIUM

$$\vec{\lambda}_e = 0$$

ONLY VECTOR CURRENT CONTRIBUTES.

$$V(p_e) = \sqrt{2}\, G_F\, g_V\, \frac{f_e(\vec{p})}{(2\pi)^3} \cdot \Big(\underbrace{1}_{J^0} - \underbrace{\frac{\vec{p}_e \cdot \hat{k}_\nu}{E_e}}_{\vec{J}} \Big)$$

$$\hat{k}_\nu \equiv \frac{\vec{p}_\nu}{p_\nu}$$

- NON-RELATIVISTIC ELECTRONS:

J^0_ν

$$\boxed{V = \sqrt{2}\, G_F\, g_V\, n_e}$$

≡ FOR ISOTROPIC DISTRIBUTION. ULTRARELATIVISTIC.

- ULTRA RELATIVISTIC ELECTRONS:

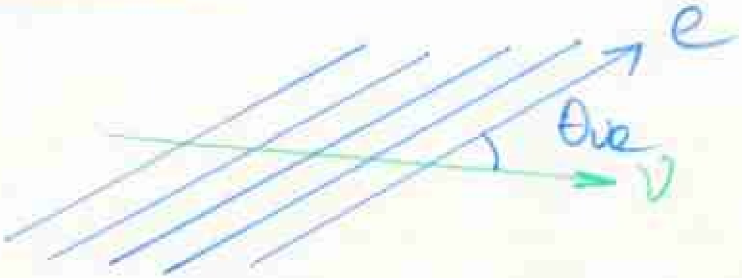
J^0_ν

$\vec{J}_\nu$

$$\boxed{V = \sqrt{2}\, G_F\, g_V \left(1 - \cos\theta_{\nu e}\right) n_e}$$

CONTRIBUTES

n velocity

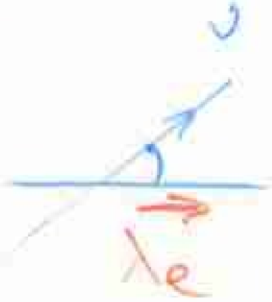


POLARIZED MEDIUM

AXIAL-VECTOR CURRENT CONTRIBUTES:

$\vec{j}_A$

- NON-RELATIVISTIC CASE



$$\boxed{V^A = -\sqrt{2}\, G_F\, g_A\, n_e \left(\hat{k}_\nu \cdot \vec{\lambda}_e\right)}$$

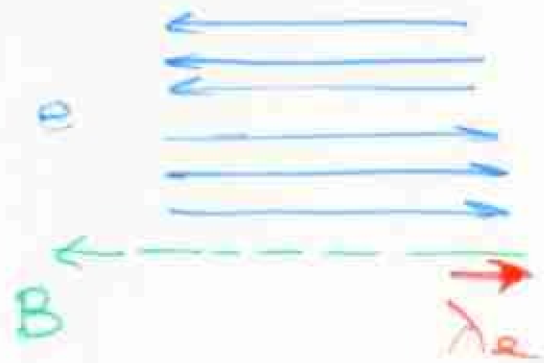
AVERAGE POLARIZATION OF ELECTRONS

- ULTRARELATIVISTIC CASE:

$$\boxed{V^A = \sqrt{2}\, G_F\, g_A \frac{f}{(2\pi)^3} \left(\hat{k}_e \cdot \vec{\lambda}_e\right)\left[1 - \left(\hat{k}_e \cdot \hat{k}_\nu\right)\right]}$$

$$\boxed{\hat{k}_e = \frac{\vec{p}_e}{|\vec{p}_e|}}$$

- MAGNETIZED MEDIUM:



TWO EQUAL ELECTRON FLUXES MOVING IN DIFFERENT DIRECTION (ALONG THE MAGNETIC FIELD) AND POLARIZED AGAINST THE FIELD:

$$\boxed{V^A = -\sqrt{2}\, G_F\, g_A\, n_e \left(\hat{k}_\nu \cdot \vec{\lambda}_e\right)}$$

≡ LOWEST LANDAU LEVEL

AS IN NON-RELATIV. CASE

TOTAL POTENTIAL

$$\boxed{V = \sqrt{2}\, G_F n_e \left[g_V - g_A (\hat{k}_\nu \cdot \vec{\lambda}) \right] + \sqrt{2}\, G_F n_n g_V^n}$$

- ELECTRICALLY NEUTRAL MEDIUM
- NO POLARIZATION OF NUCLEONS
- n_n IS THE NEUTRON CONCENTRATION

- ONLY NC. SCATTERING ON NEUTRONS GIVES CONTRIBUTION:

Nucleon EFFECT:

- UNPOLARIZED $\Rightarrow$ ONLY VECTOR CURRENT.
- NON-RELATIVISTIC $\Rightarrow$ ONLY J^0 ZERO COMPONENT.
- ONLY NC: NO RENORMALIZATION

$\Rightarrow$ CONTRIBUTIONS FROM PROTON AND NC ELECTRON CANCEL EACH OTHER: THEY HAVE OPPOSITE CHARGES

ONLY NEUTRONS CONTRIBUTE

DIFFERENCE OF POTENTIALS:

• REFRACTION

FOR $\boxed{\nu_e \leftrightarrow \nu_\mu}$ - SYSTEM

$\nu_\odot$ SN.

$$V_{e\mu} = \sqrt{2} G_F n_e \left[1 + (\hat{k}_\nu \cdot \vec{\lambda}) \right] \cdot$$
$$= \sqrt{2} G_F n_e \left(1 + \langle \vec{\lambda}_e \rangle \cdot \cos\alpha \right)$$

ONLY CC-SCATTERING ON ELECTRONS CONTRIBUTES.

$$\boxed{\nu_e \to \nu_s}$$

$\nu_\odot$ SN

$$V_{es} = \sqrt{2} G_F n_e \left[\left(1 - \frac{n_n}{2 n_e} \right) + \frac{1}{2} \hat{k}_\nu \cdot \vec{\lambda}_\nu \right]$$

$$\boxed{\nu_\mu \to \nu_s}$$

$$V_{\mu s} = \sqrt{2} G_F \left(- \frac{n_n}{2} \right)$$ + POLARIZATION EFFECT ON ELECTRONS

ATM.

MAGNETIZED MEDIUM.

$$\langle \lambda_e \rangle = -\frac{n_0}{n_e}$$

n_0 - CONCENTRATION OF ELECTRONS IN THE FIRST LANDAU LEVEL

IN STRONGLY <u>DEGENERATE</u> GAS:

$$n_0 = \frac{eB \cdot p_F}{2\pi^2}$$

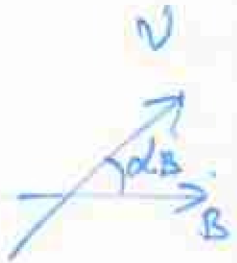
$p_F = \sqrt{\mu^2 - m_e^2}$ is THE FERMI MOMENTUM.

IN THE WEAK FIELD LIMIT: $eB \ll p_F^2$

$$p_F \approx (3\pi^2 n_e)^{1/3}$$

$$\Rightarrow n_0 = \frac{eB}{2}\left(\frac{3n_e}{\pi^4}\right)^{\frac{1}{3}}$$

$$\langle \vec{\lambda}_e \rangle = -\frac{e\vec{B}}{2}\left(\frac{3}{\pi^4}\right)^{1/3} n_e^{-2/3}$$



$$V = \sqrt{2}\, G_F n_e - \frac{G_F eB}{\sqrt{2}}\left(\frac{3n_e}{\pi^4}\right)^{1/3} \cos\alpha_B$$

PULSARS..

"Non-local" corrections:

H_w - four fermionic $\qquad q_w = 0$

Propagator corrections:

$$G_F \to G_F \left[1 + \frac{q_w^2}{m_w^2}\right]$$

$$\frac{1}{m_w^2}$$

$$V = V_0 \left[1 + \frac{q_w^2}{m_w^2}\right]$$

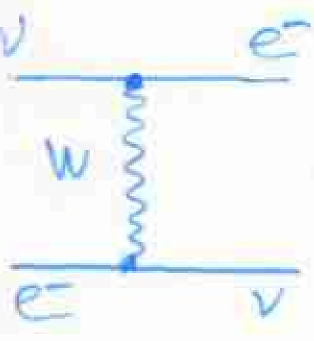
$$-\frac{1}{q^2 - m^2}$$

$$q_w^2 = (p_\nu - p_e)^2$$

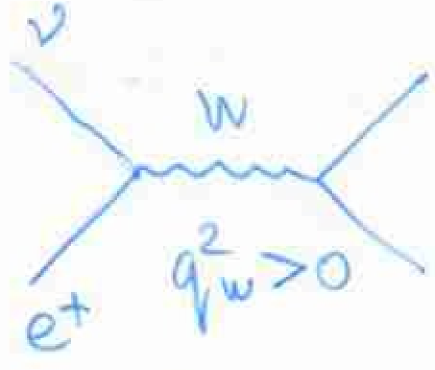
in thermal enviroment $\langle q_w^2 \rangle = \underbrace{A}_{\text{constant}} T^2$.

$$\boxed{V = V_0 \left[1 + \frac{AT^2}{m_w^2}\right]}$$

- Crucial feature: correction has the same sign for scattering on particles and antiparticles:



$q_w^2 < 0$



$q_w^2 > 0$

Early universe

$$V_0 \longrightarrow -V_0$$

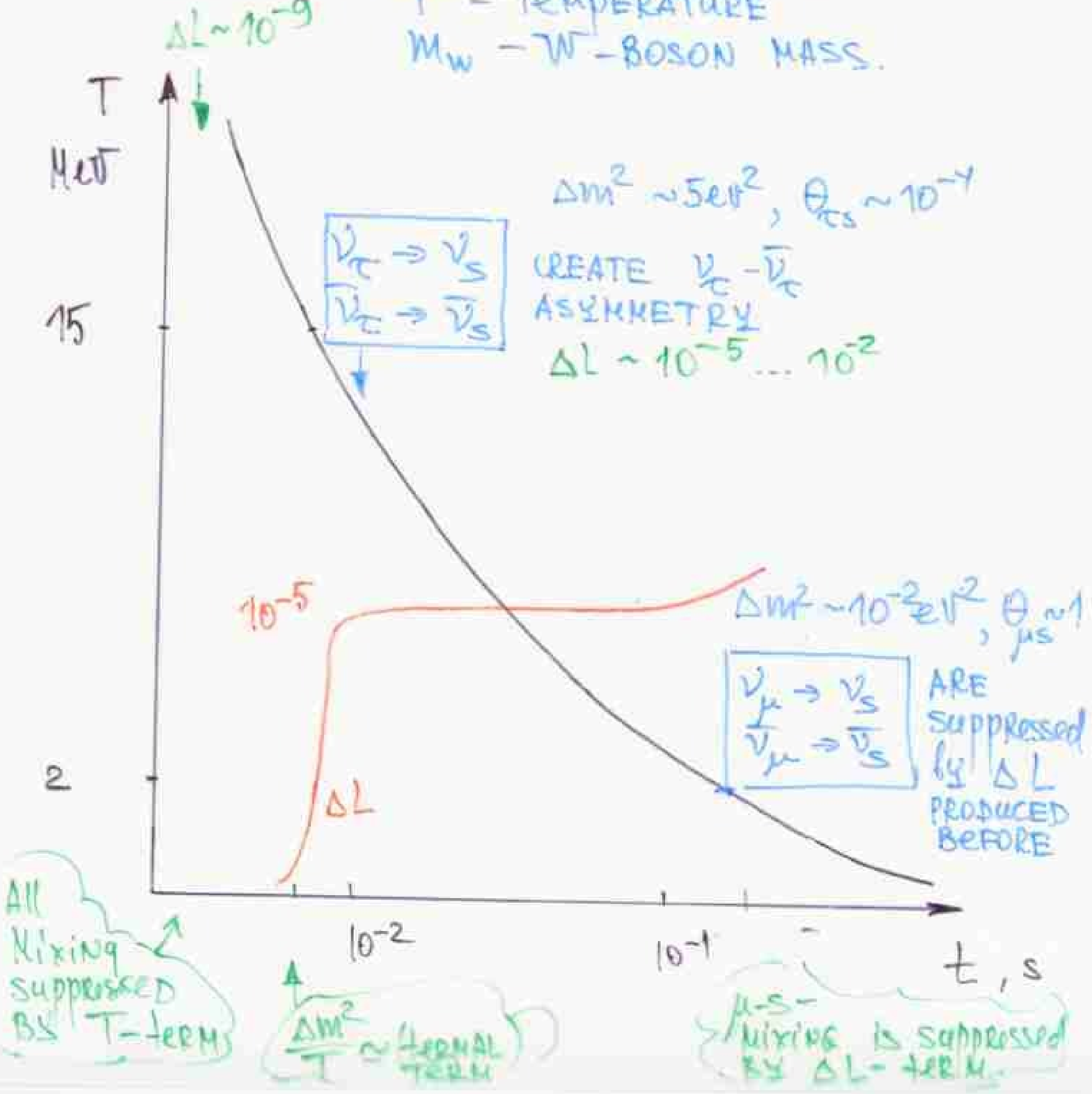
in CP symmetric medium: $V = V_0 \dfrac{AT^2}{m_w^2}$
only temperature correction survives!

Lepton asymmetry and production of sterile neutrinos in the Early Universe.

Foot
Thomson
Volkas

$$\boxed{V = \sqrt{2}\, G_F\, n_\gamma\, \Delta L + \sqrt{2}\, G_F\, n_\gamma \frac{A T^2}{m_W^2}}$$

n_γ – photon density
T – temperature
m_W – W-boson mass.



2. PROFILES

When TRANSITION is STRONG ?

- IMPORTANT FOR ASTROPHYSICAL APPLICATIONS

  - CONSTANT
  - MONOTONIOUSLY DECREASING
  - WITH PERTURBATIONS
  - NOISY.
  - PERIODIC STRUCTURE

EIGENSTATES AND EIGENVALUES.

$$\boxed{i\,\dot{\nu}_f = H\,\nu_f}$$

$\nu_f = \begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix}$, H is in flavor basis.

$H = H(\rho(t))$

QUANTUM MECHANICS:

FOR GIVEN t (INSTANTANEOUS)

- EIGENSTATES OF H : ν_{1m}, ν_{2m}
- EIGENVALUES OF H : E_{1m} E_{2m}

$$H\,\nu_{im} = E_{im}\nu_{im}.$$

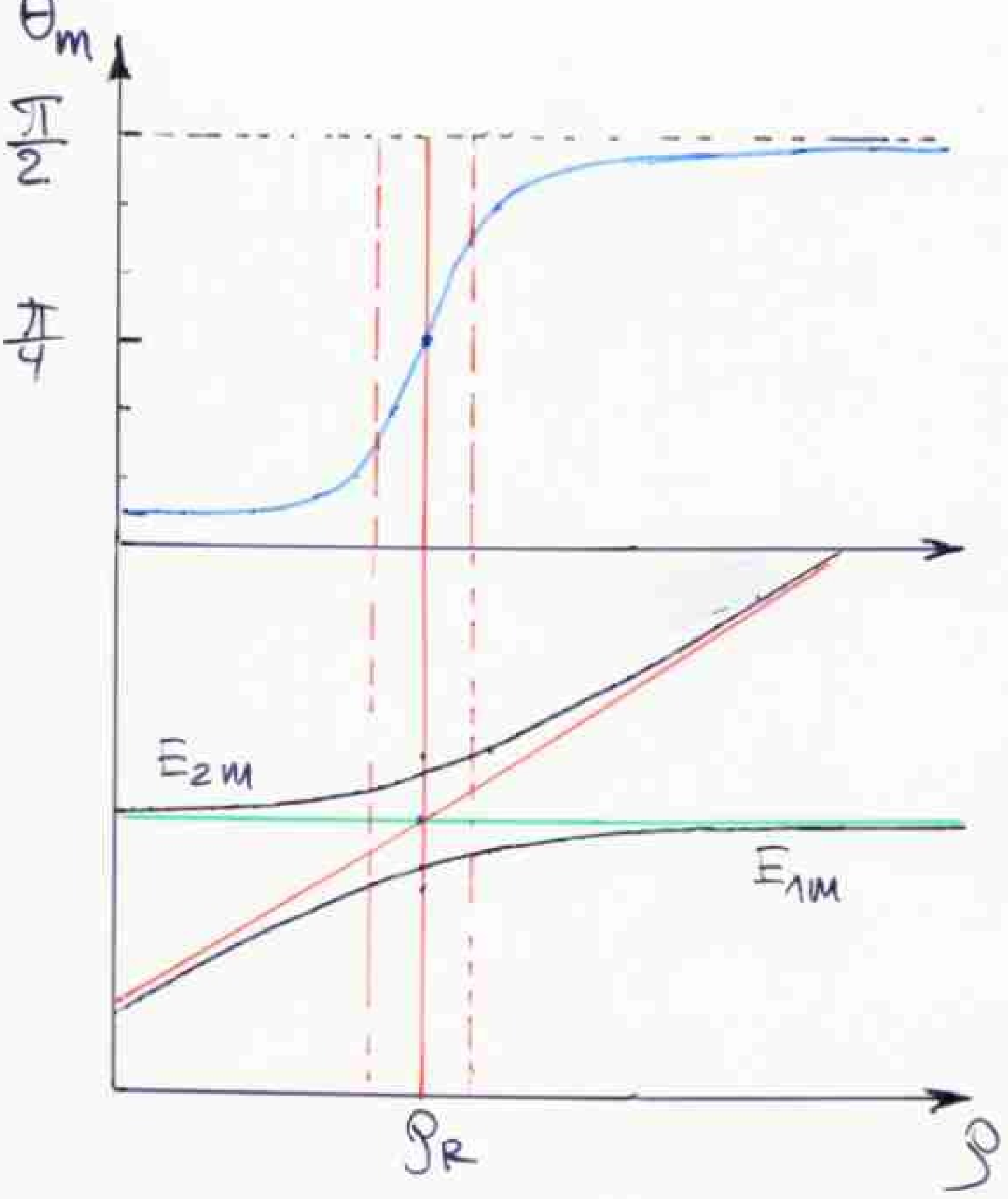
- Explicitly:

$$\nu_{1m} = \cos\theta_m\,\nu_e - \sin\theta_m\,\nu_\mu$$
$$\nu_{2m} = \cos\theta_m\,\nu_\mu + \sin\theta_m\,\nu_e$$

- θ_m is the mixing angle in medium.

$$\nu_f = S(\theta_m)\cdot\nu_m$$

$$\theta_m = \theta_m(\rho, E) \qquad E_{im} = E_{im}(\rho, E)$$



RESONANCE
LAYER.

DEGREES OF FREEDOM:

$$\boxed{\nu(t) = \cos\theta_a \cdot \nu_{1m} + \sin\theta_a \nu_{2m} e^{i\varphi}}$$

- θ_a DETERMINES ADMIXTURES OF THE EIGENSTATES IN A GIVEN STATE. $\theta_a = \theta_a(t)$

- $\varphi(t)$ IS THE PHASE BETWEEN THE EIGENSTATES (PHASE OF OSCILLATIONS)

$$\varphi(t) = \int_0^t \Delta H \cdot dt' + \varphi_+$$

$\Delta H = H_1 - H_2$ IS THE DIFFERENCE OF EIGENVALUES.

- $$\nu_{1m} = \cos\theta_m \nu_e - \sin\theta_m \nu_\mu$$
$$\nu_{2m} = \cos\theta_m \nu_\mu + \sin\theta_m \nu_e$$

$\theta_m = \theta_m(\rho, E)$ IS THE MIXING ANGLE IN MATTER

DENSITY MATRIX IN FLAVOR SPACE

$$\boxed{i\dot{\nu} = H\nu}$$

$$\nu = \begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix}$$

$$H = \begin{vmatrix} H_d & \frac{1}{2}\bar{H} \\ \frac{1}{2}\bar{H} & 0 \end{vmatrix}$$

$$H_d = -\cos 2\theta \, \frac{\Delta m^2}{2E} + V$$

$$\bar{H} = -\sin 2\theta \, \frac{\Delta m^2}{2E}$$

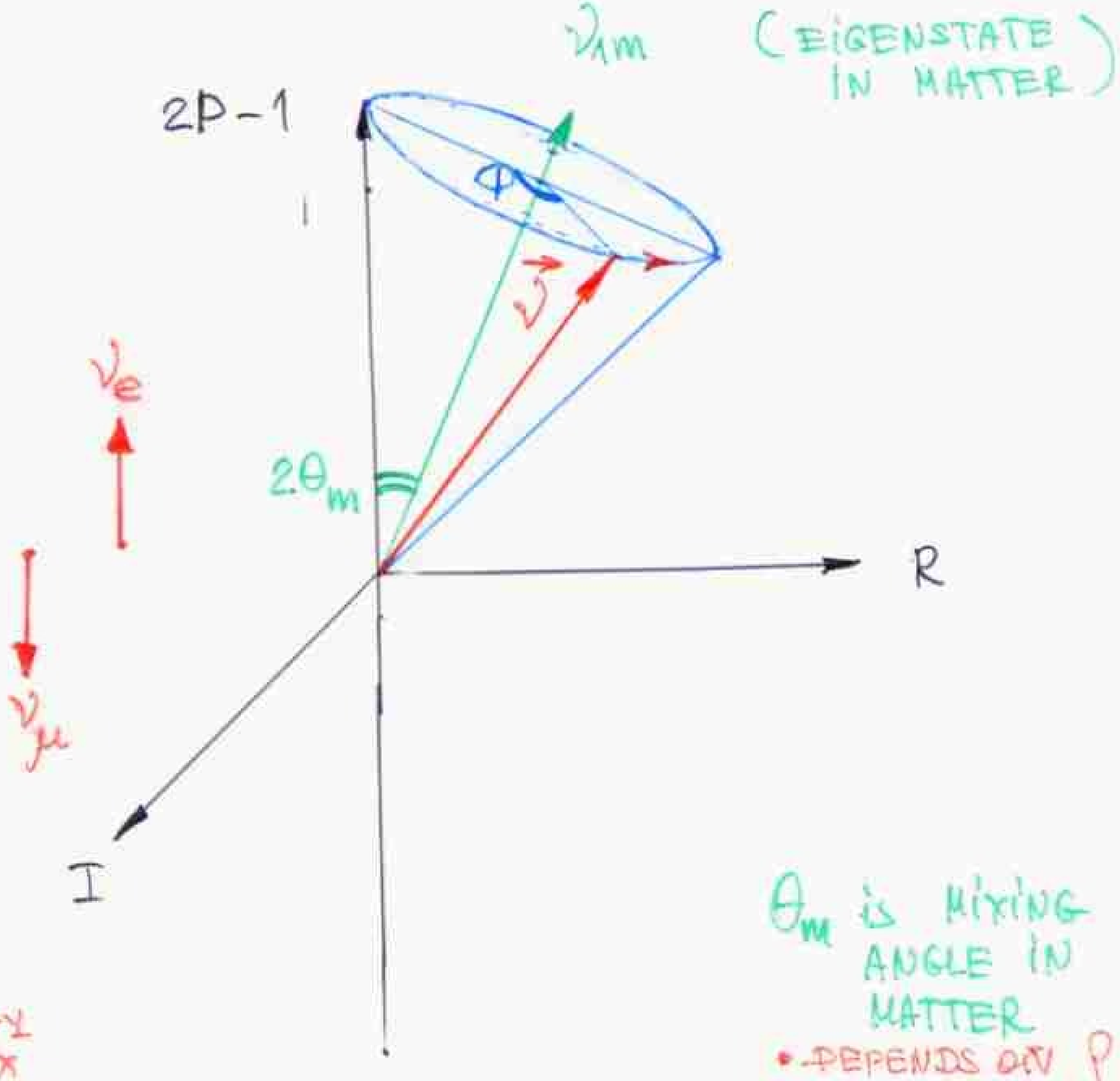
$$\vec{\nu} = \left\{ \mathrm{Re}\, \nu_e^* \nu_\mu \;\; \mathrm{Im}\, \nu_e^* \nu_\mu \,,\; \underbrace{\nu_e^* \nu_e}_{=\rho} - \tfrac{1}{2} \right\}$$

$$\vec{H} = \left\{ \bar{H} \,,\, 0 \,,\, H_d \right\}$$

$$\boxed{\frac{d\vec{\nu}}{dt} = [\vec{H} \times \vec{\nu}]}$$

(ELEMENTS OF DENSITY MATRIX.

Graphic Representation of Oscillations



θ_m is mixing angle in matter
• depends on ρ.

DENSITY MATRIX FORMALISM
=
SPIN IN MAGNETIC FIELD

$$P \equiv |\nu_e|^2$$

$$R = \mathrm{Re}\, \nu_\mu^* \nu_e$$

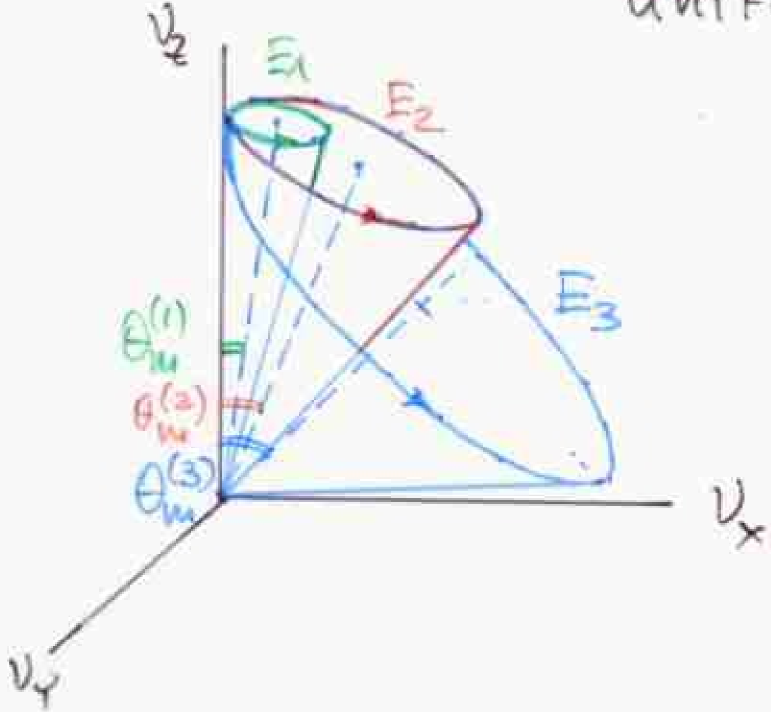
$$I = \mathrm{Im}\, \nu_\mu^* \nu_e$$

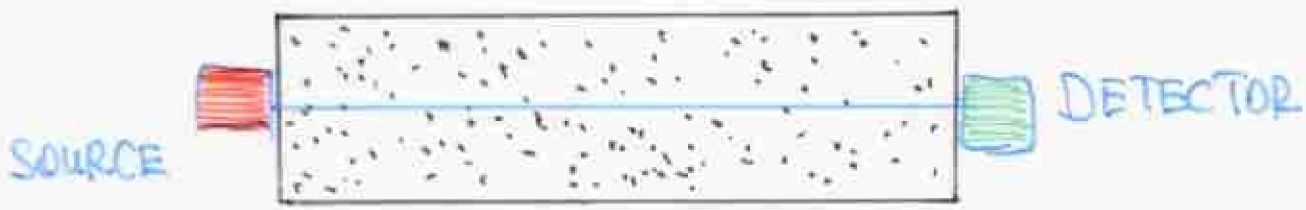
Phase of oscillation

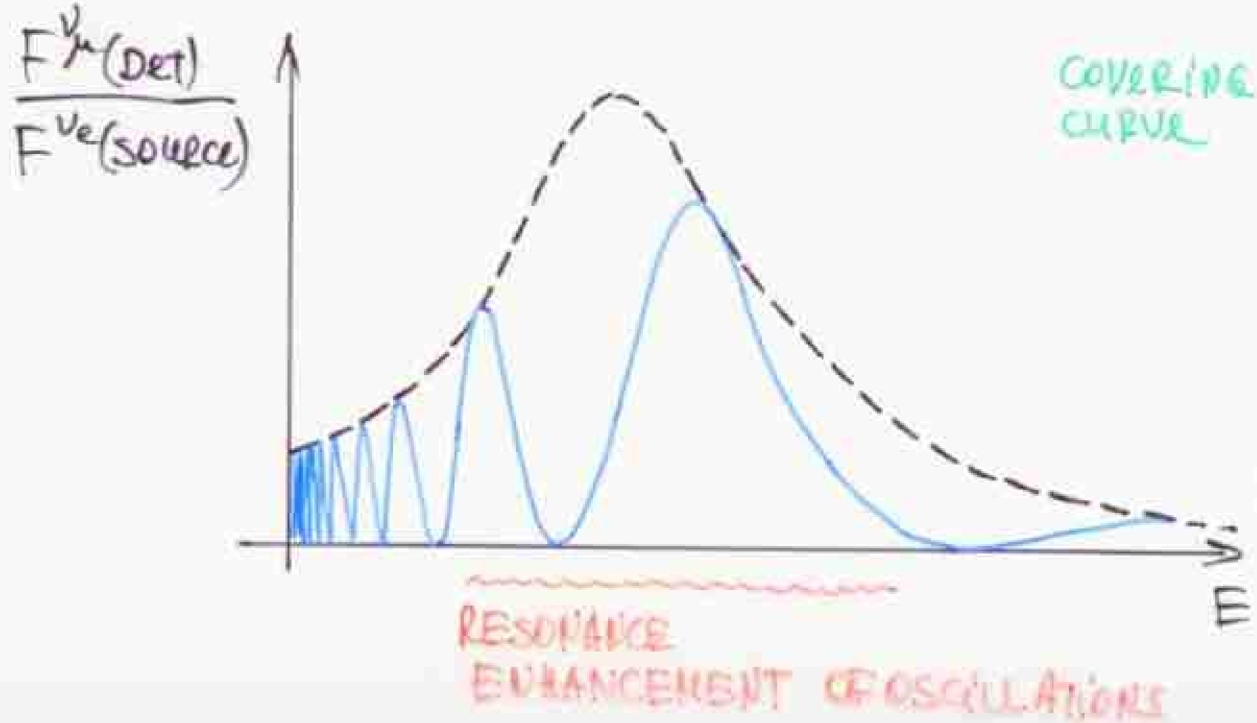
$$\Phi = 2\pi \int \frac{dL}{\ell_m} =$$

$$= \frac{2\pi L}{\ell_m}$$

OSCILLATIONS IN UNIFORM MEDIUM.



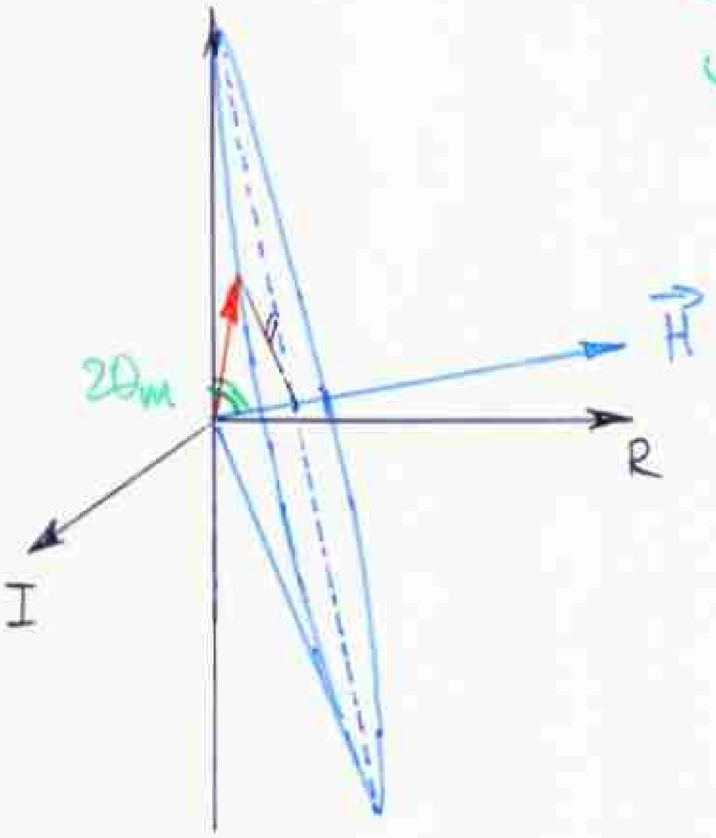




OSCILLATIONS WITH LARGE AMPLITUDE

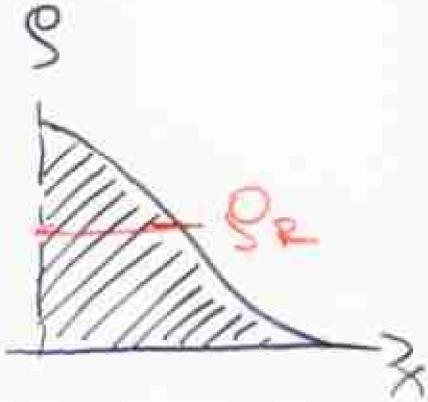
$\theta_m \sim \frac{\pi}{4}$

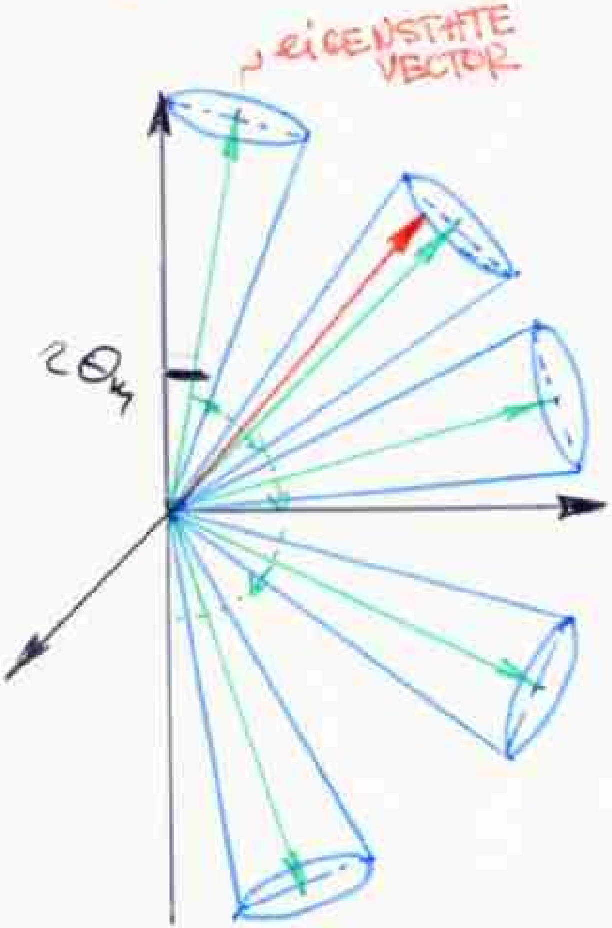
$\varphi \sim \pi$

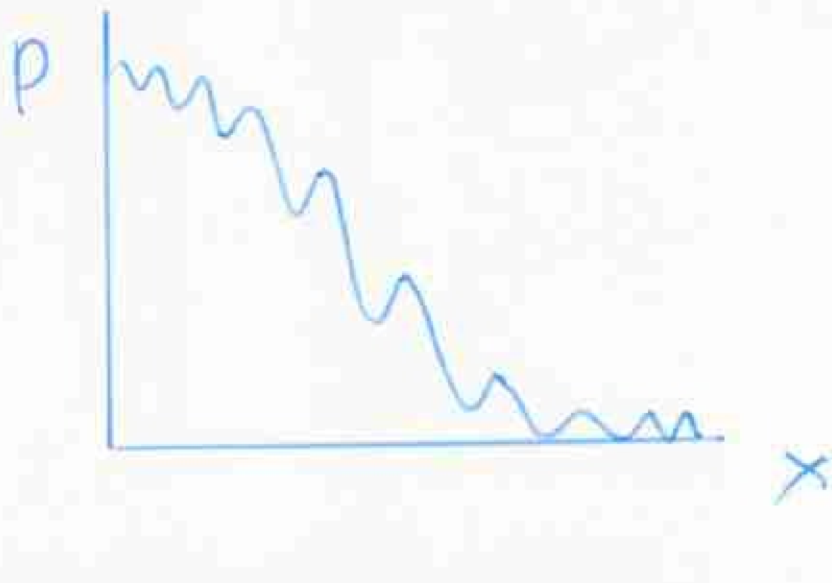


Adiabatic RESONANCE CONVERSION

- NO $\nu_{1m} \leftrightarrow \nu_{2m}$
- $\Theta_a = \text{const.}$

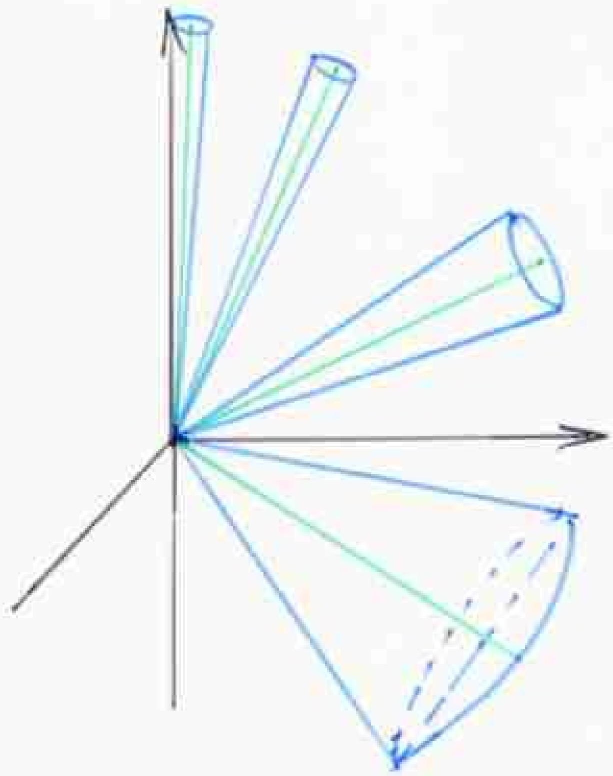






NON-ADIABATIC CONVERSION

- $\nu_{1m} \Leftrightarrow \nu_{2m}$
- θ_a CHANGES.



OSCILLATIONS + INELASTIC COLLISIONS

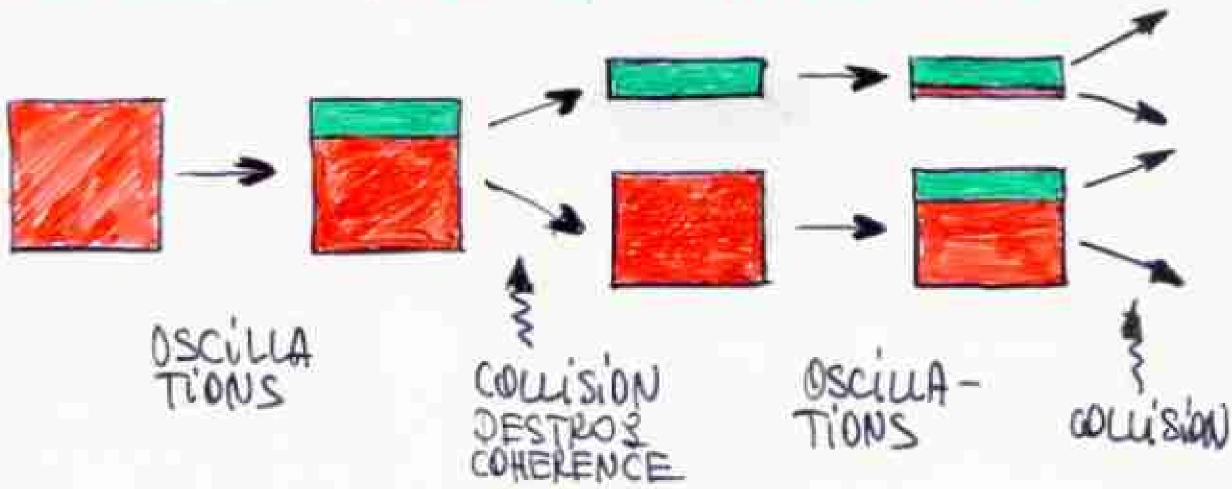
$\ell_0 \ll \ell_{ab}$

$\ell_m \lesssim \ell_0$ (APART FROM RESONANCE REGION)

⇒ OSCILLATIONS BETWEEN INELASTIC COLLISIONS

AVERAGED OSCILLATIONS

COLLISIONS PICK UP FLAVOR STATES

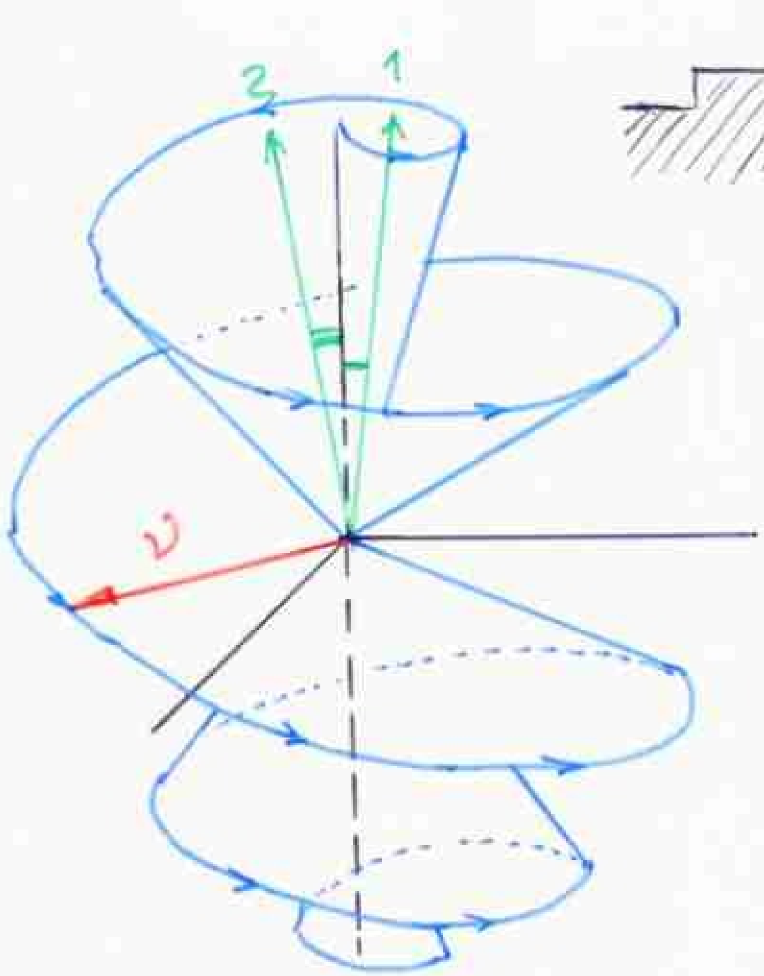


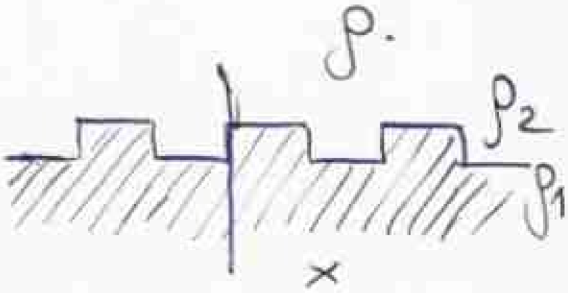
PROCESS HAS STATISTICAL CHARACTER

$$P \to \frac{1}{2}$$

(APPROACHING TD EQUILIBRIUM)

PARAMETRIC CONVERSION

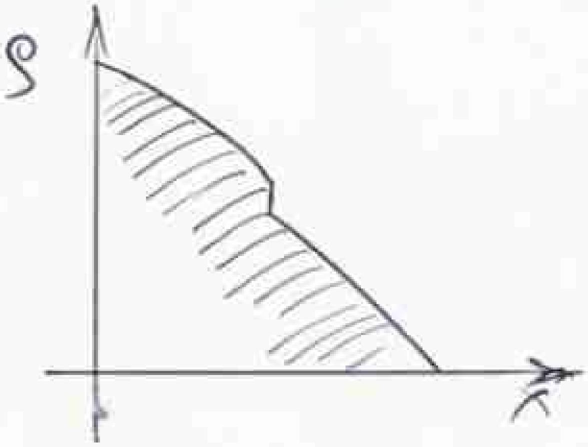




ρ_1 ρ_2
FAR FROM
ρ_R

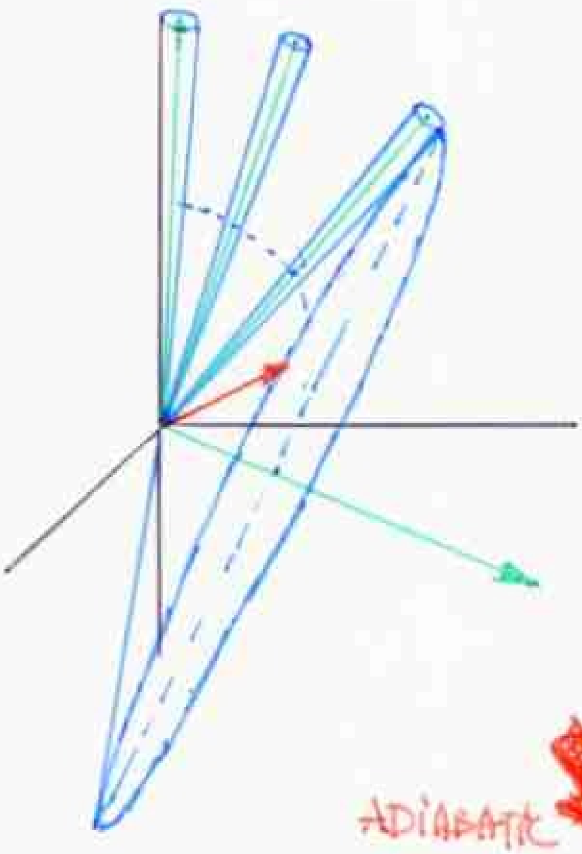
NO LOST
OF
COHERENCE

NON-ADIABATIC PERTURBATIONS



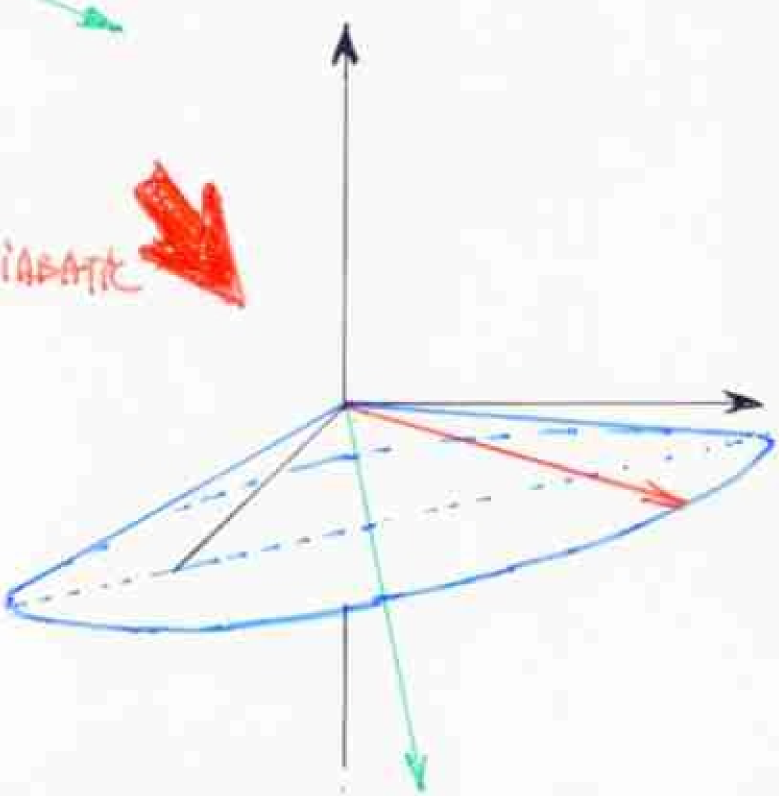
$$\frac{\Delta \rho}{\rho} \sim \sin 2\theta$$

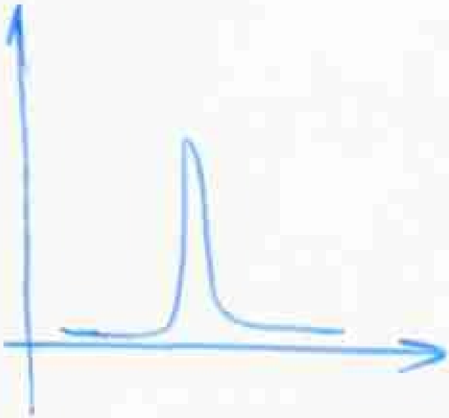
IF PERTURBATION IN RESONANCE LAYER
→ STRONG MODIFICATION.



jump

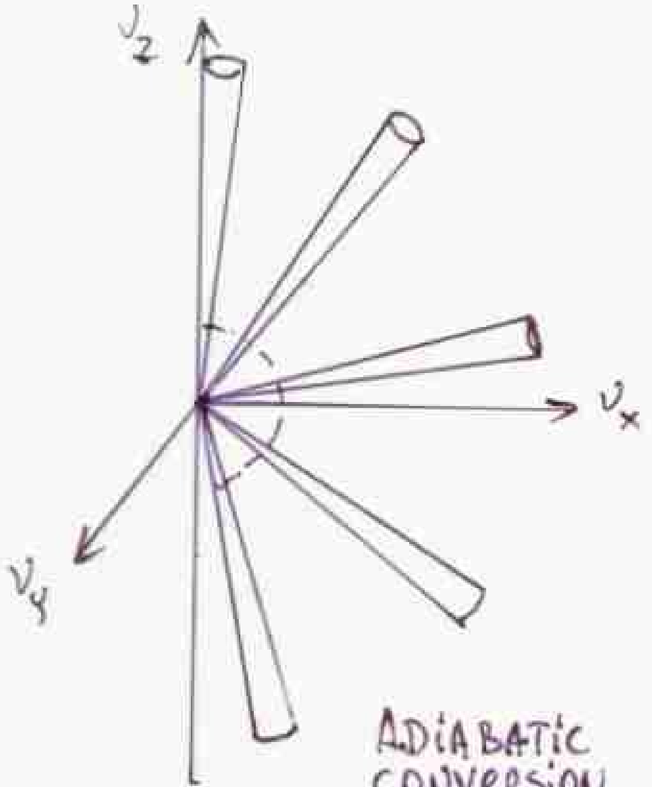
ADIABATIC



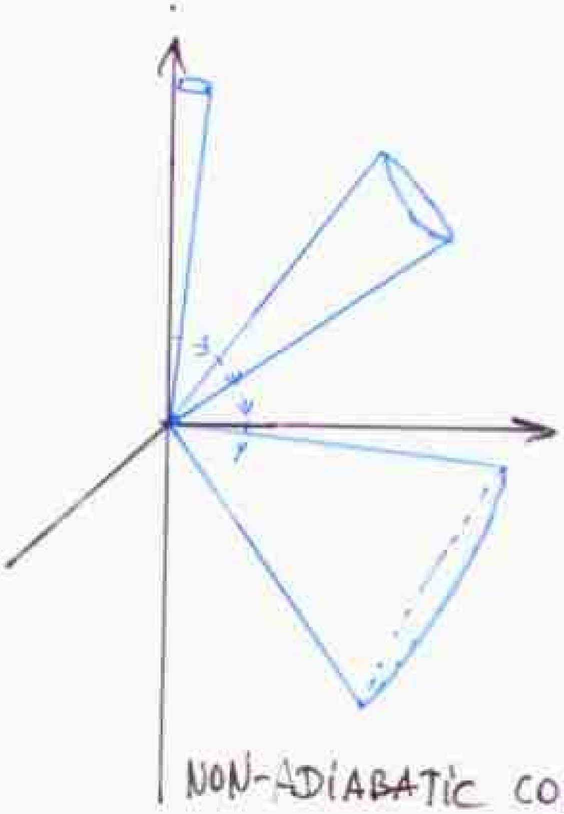


IN NON UNIFORM MEDIUM: $\Theta_m = \Theta_m(\rho(t))$
MIXING IS CHANGING ON THE WAY OF NEUTRINOS $\Longrightarrow$ NEW EFFECTS.

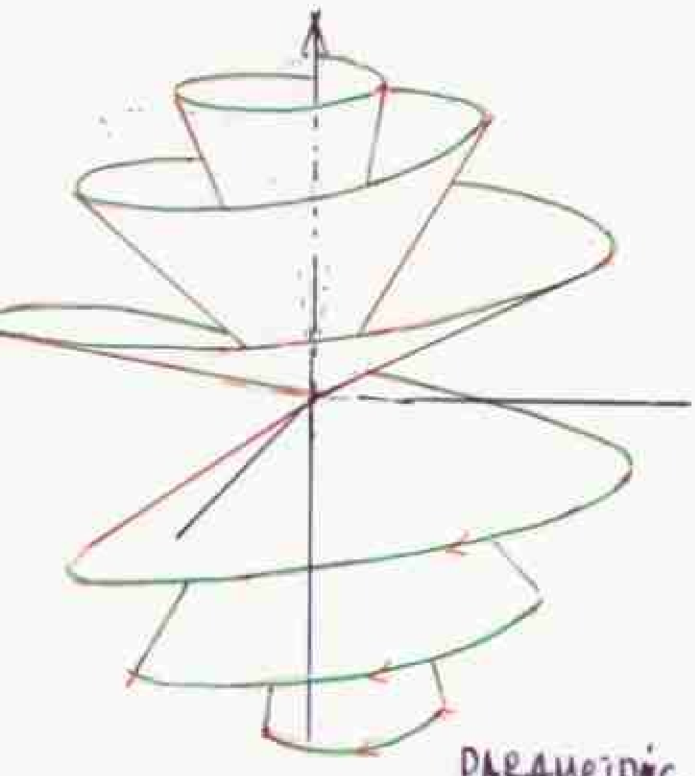
TYPICALLY THERE IS AN INTERPLAY OF OSCILLATIONS AND THESE NEW EFFECTS.



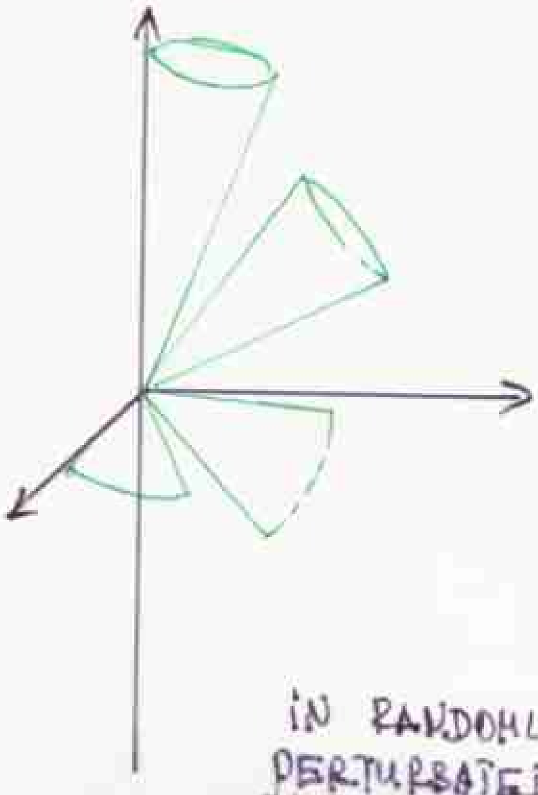
ADIABATIC CONVERSION



NON-ADIABATIC CONVERSION



PARAMETRIC ENHANCEMENT



IN RANDOMLY PERTURBATED DISTRIBUTION

3. NEUTRINOS

Neutrino SPECTRA AND NEUTRINO TRANSITIONS

- 3ν - SCHEMES

DECOUPLING (REDUCTION TO 2ν CASE)

GENERIC 3ν EFFECTS

- SCHEMES WITH STERILE NEUTRINOS.

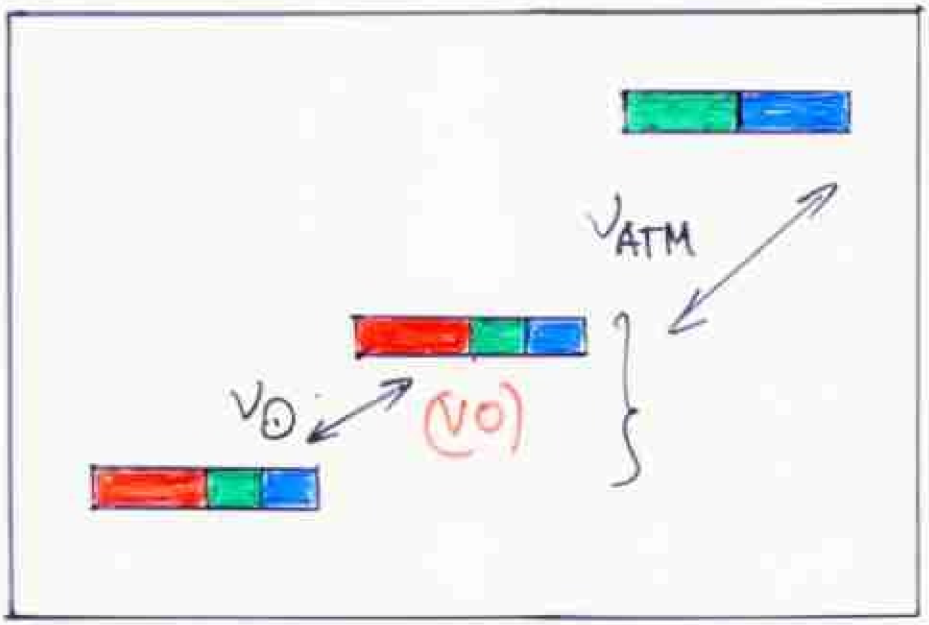
- SN : CAN TEST WHOLE SYSTEM OF LEVELS

NO RESONANCE CONVERSION ?

m, eV

$5 \cdot 10^{-2}$

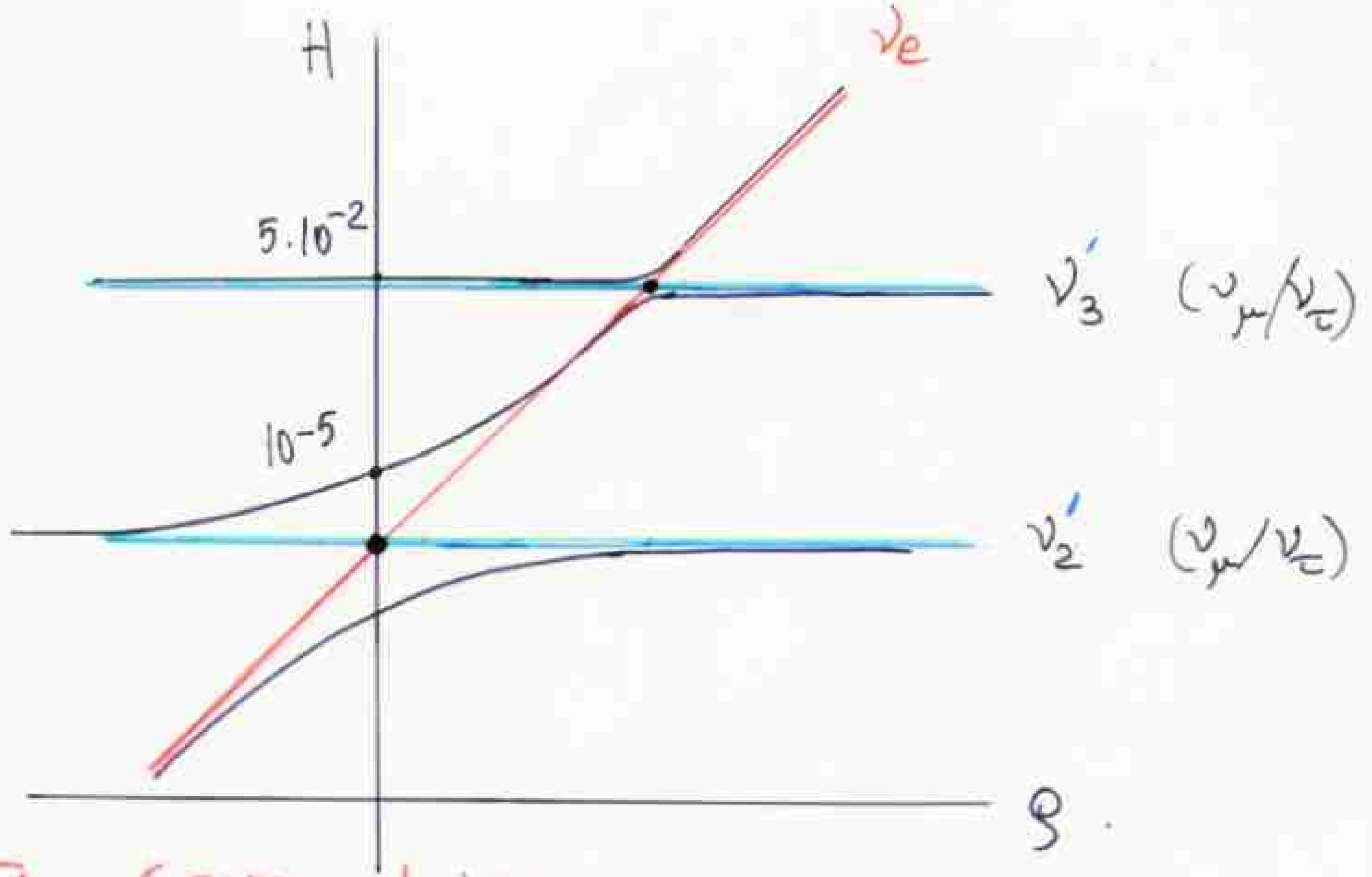
10^{-5}



- $\nu_{\odot}$: MAXIMAL MIXING $\nu_e \to \nu_2$ (ν_μ / ν_τ)
- ν_{ATM} : MAXIMAL MIXING $\nu_\mu \leftrightarrow \nu_\tau$.

$$U = \begin{pmatrix} \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \\ \frac{1}{2} & \frac{1}{2} & -\frac{1}{\sqrt{2}} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{\sqrt{2}} \end{pmatrix}$$

- Fritzsch
- Tanimoto
- Goldhaber
- A.S.

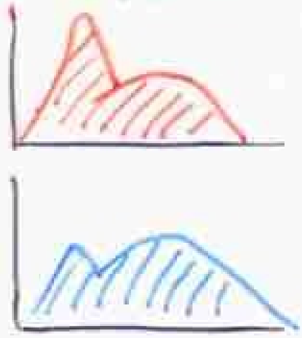


$\bar{\nu}_e$ $\frac{1}{2}$ SOFT + $\frac{1}{2}$ HARD COMPONENT $p \simeq 0.5$.

- $\theta_{e3} \sim \frac{1}{2\sqrt{2}} \frac{m_2^2}{m_3^2} \sim 10^{-7}$ (IN ORIGINAL SCHEME)

$\Rightarrow$ $\nu_e - \nu_3'$ RESONANCE IS INOPERATIVE IN SN.

OSCILLATIONS IN VACUUM $\Rightarrow$

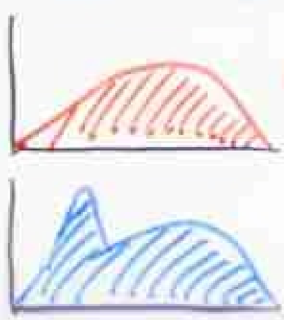


- If there is ν_e-MIXING WITH ν_3 AND $\nu_e - \nu_3'$ IS ADIABATIC:

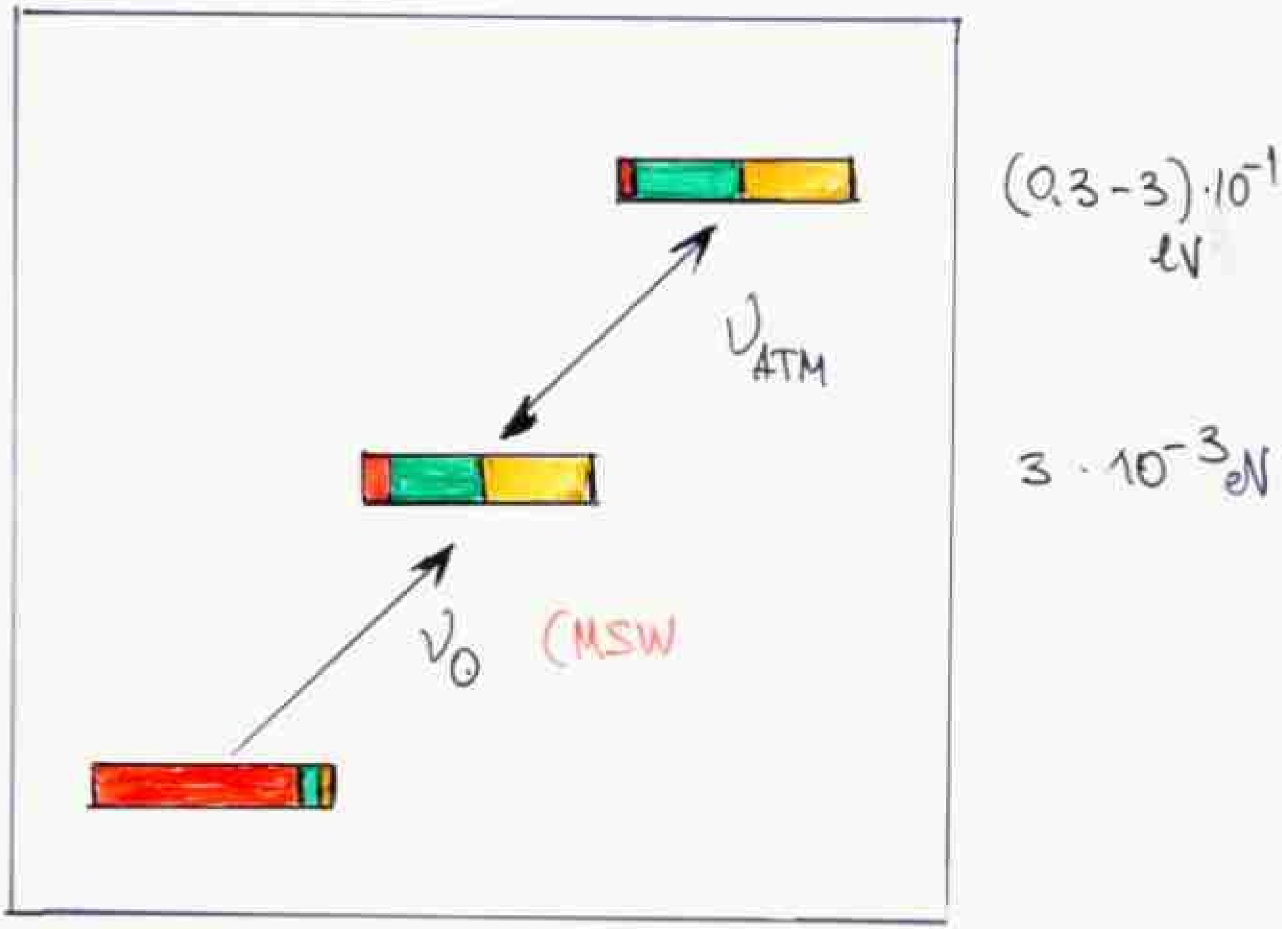
$\nu_e \Rightarrow \nu_3$

$\nu_3' \Rightarrow \nu_2$ $\quad$ $\nu_2' \Rightarrow \nu_1$

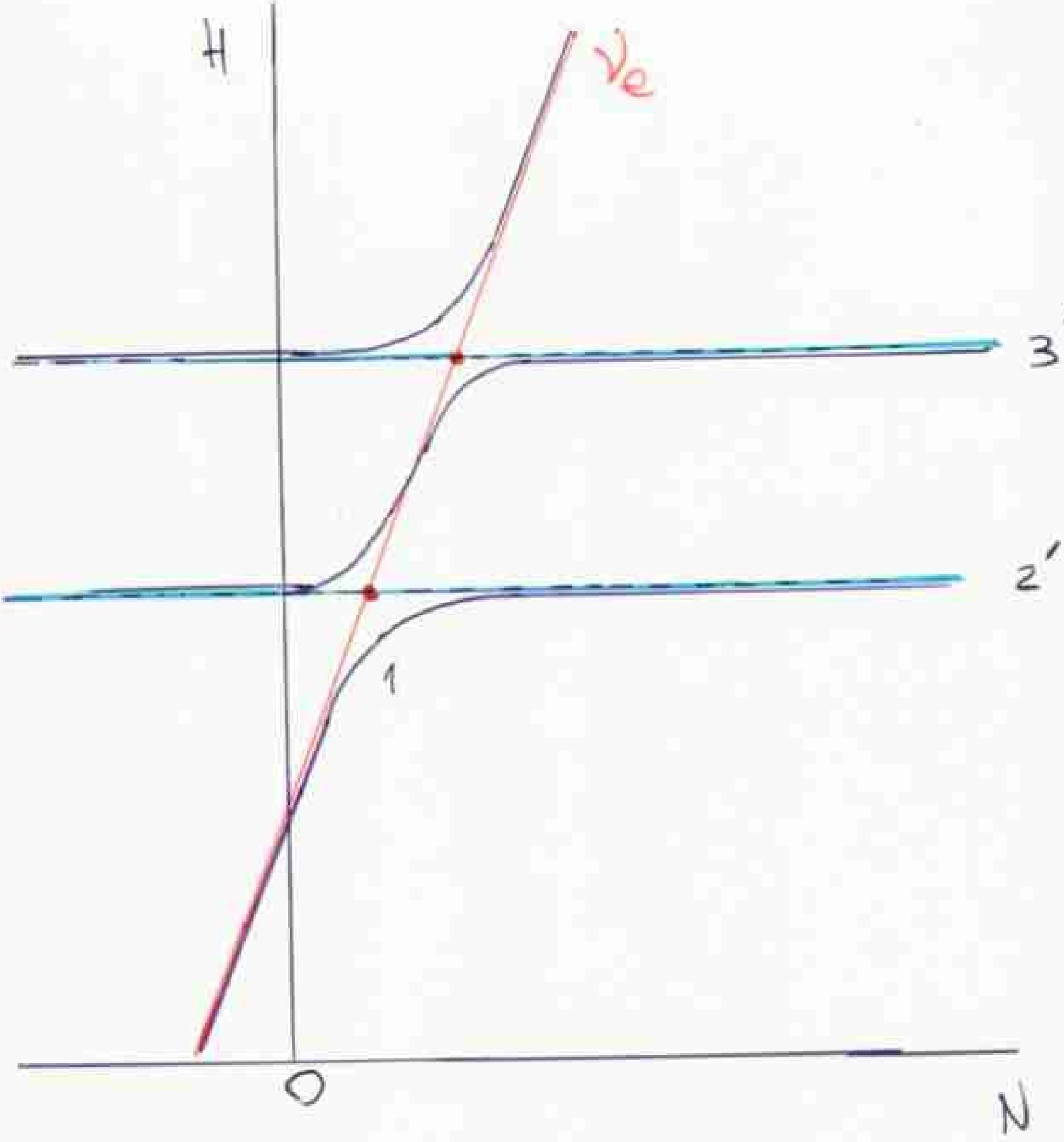
NO NEUTRONIZ. PEAK.



$\nu_{\odot} + \nu_{ATM}$



- NO HDM
- NO LSND.



IF ADIABATIC

!!!

$\nu_e \to \nu_3' \ (\nu_\mu/\nu_\tau)$

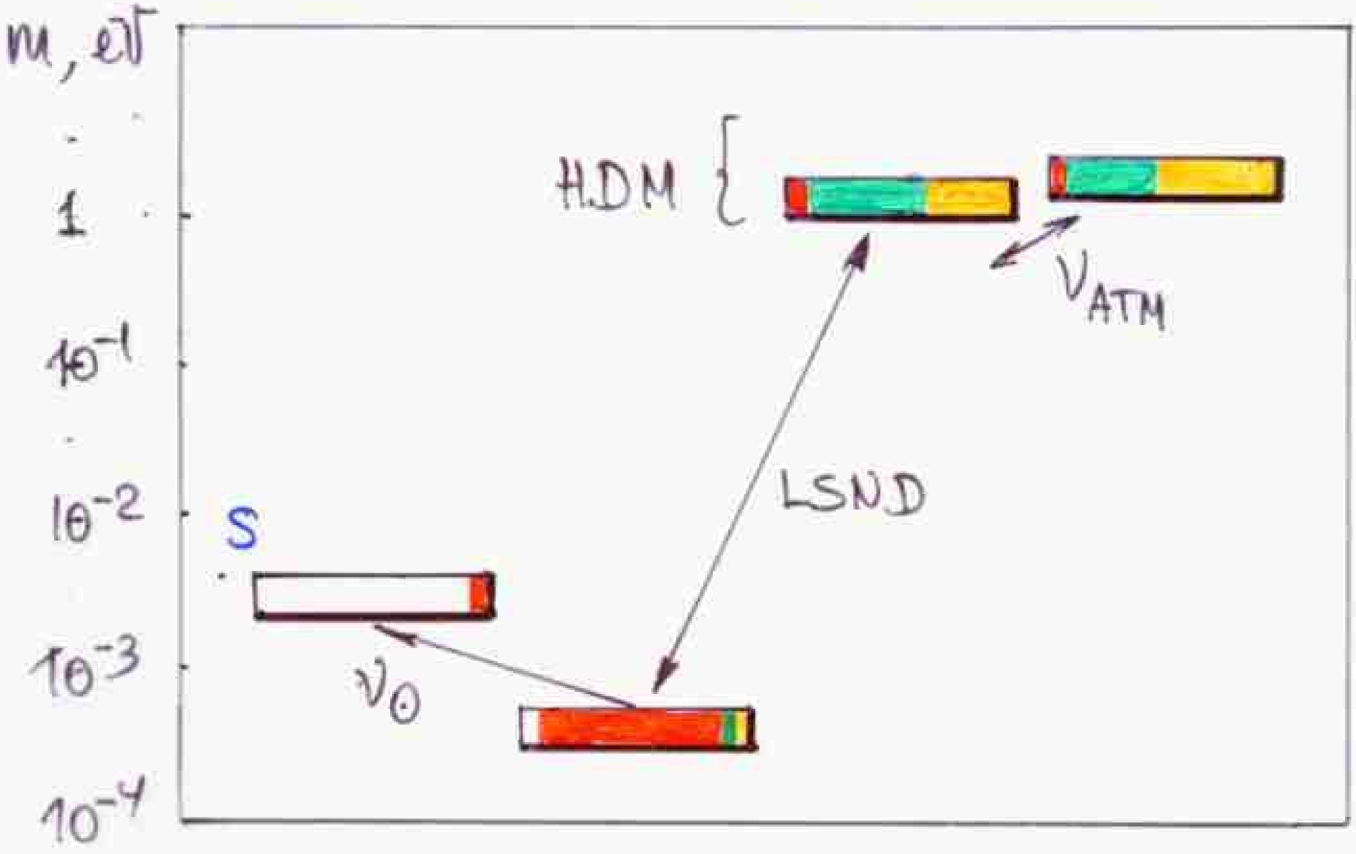
$\nu_3' \to \nu_2$

$\nu_2' \to \nu_e$

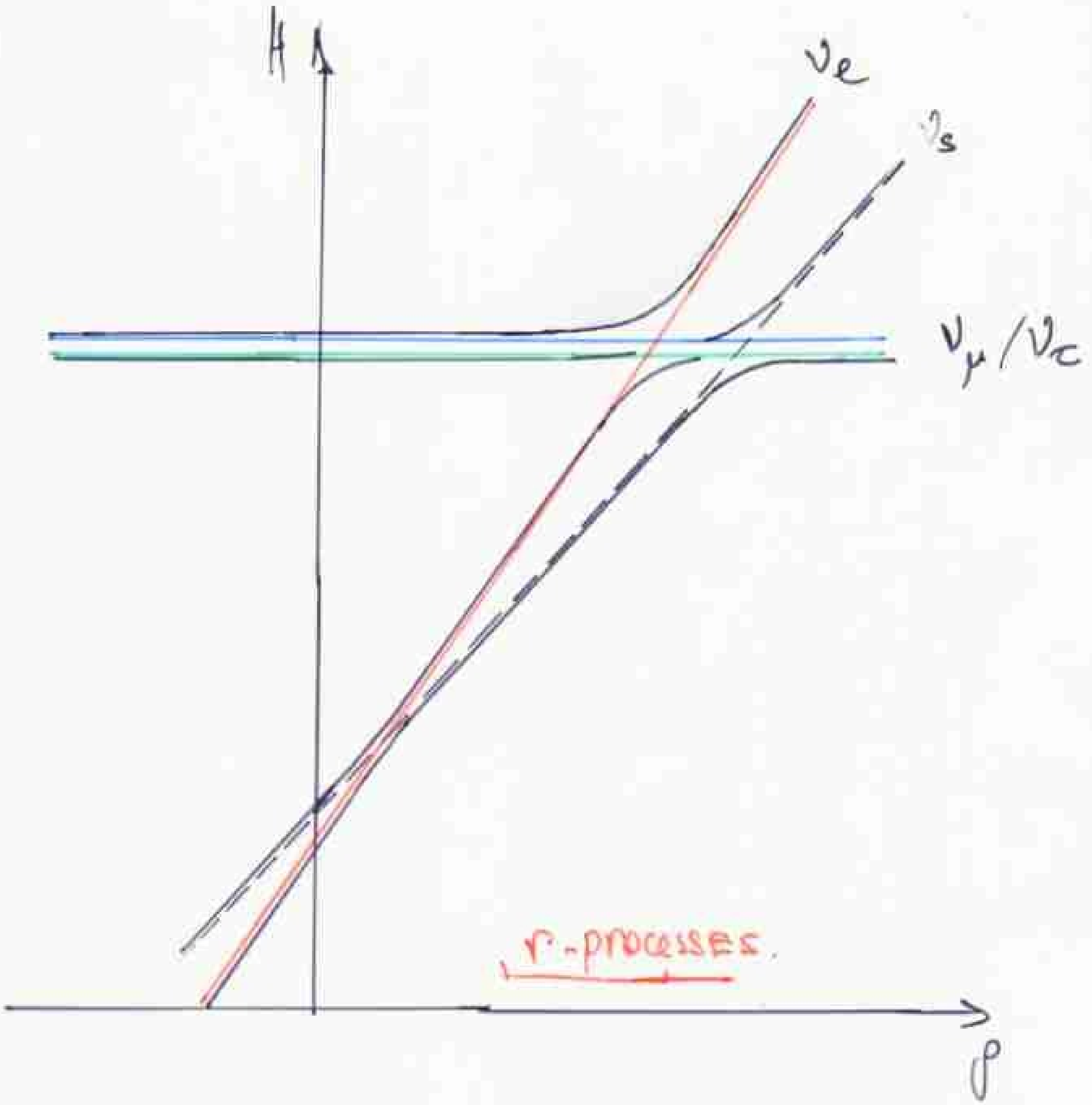
- DISAPEARANCE OF NEUTRONIZATION PEAK.
- HARD ν_e SPECTRUM
- $\left.\begin{array}{l}\nu_\mu \\ \nu_\tau\end{array}\right\}$ BOTH SOFT AND HARD COMPONENTS

$\bar{\nu}$ – UNCHANGED

$\nu_e \to \nu_s$ FOR SOLAR NEUTRINOS.



- $m_s \sim 3 \cdot 10^{-3}$ eV
- SOLAR ν: $\nu_e \to \nu_s$ (SNO)
- CHORUS / NOMAD: $\nu_\mu - \nu_\tau$ – suppressed
  $\nu_e - \nu_\tau$ CAN BE SEEN
- ν-processes ?



$\nu_e \to \nu' (\nu_\mu / \nu_\tau)$

$\nu_\mu \to \nu_s \to \nu_e$

$\nu_\tau \to \nu_e \to \nu_s$

- disappearance of ν_e neutronization peak
- HARD ν_e.
- SOME FLUX OF ν_s

r- processes.

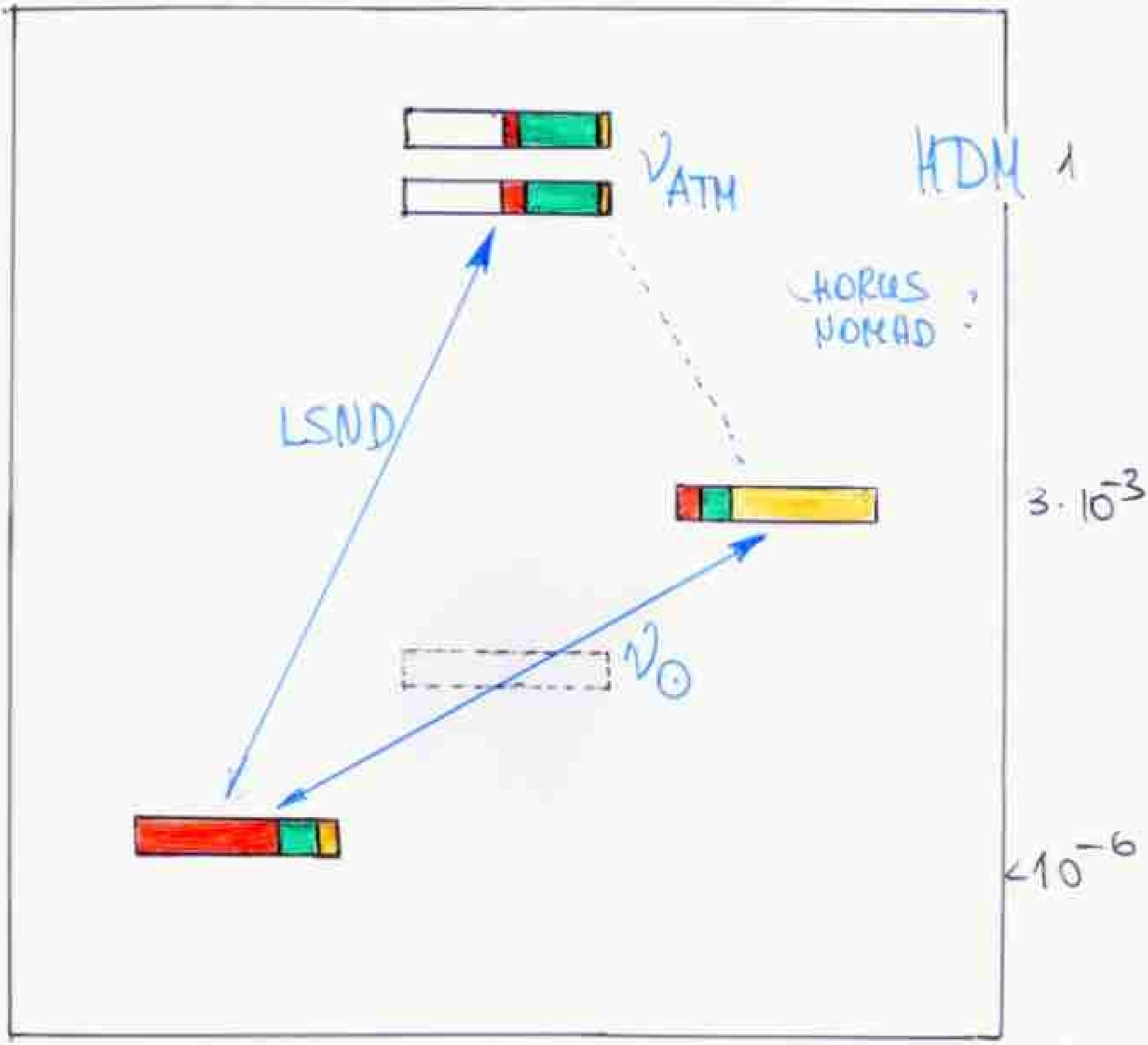
GRAND UNIFICATION

$$m_{\mu s}\, \nu_s^T \nu_\mu + h.c.$$

$m_{\mu s} \sim O(1\ eV)$ $\qquad$ $m_{ss} \ll m_{\mu s}$

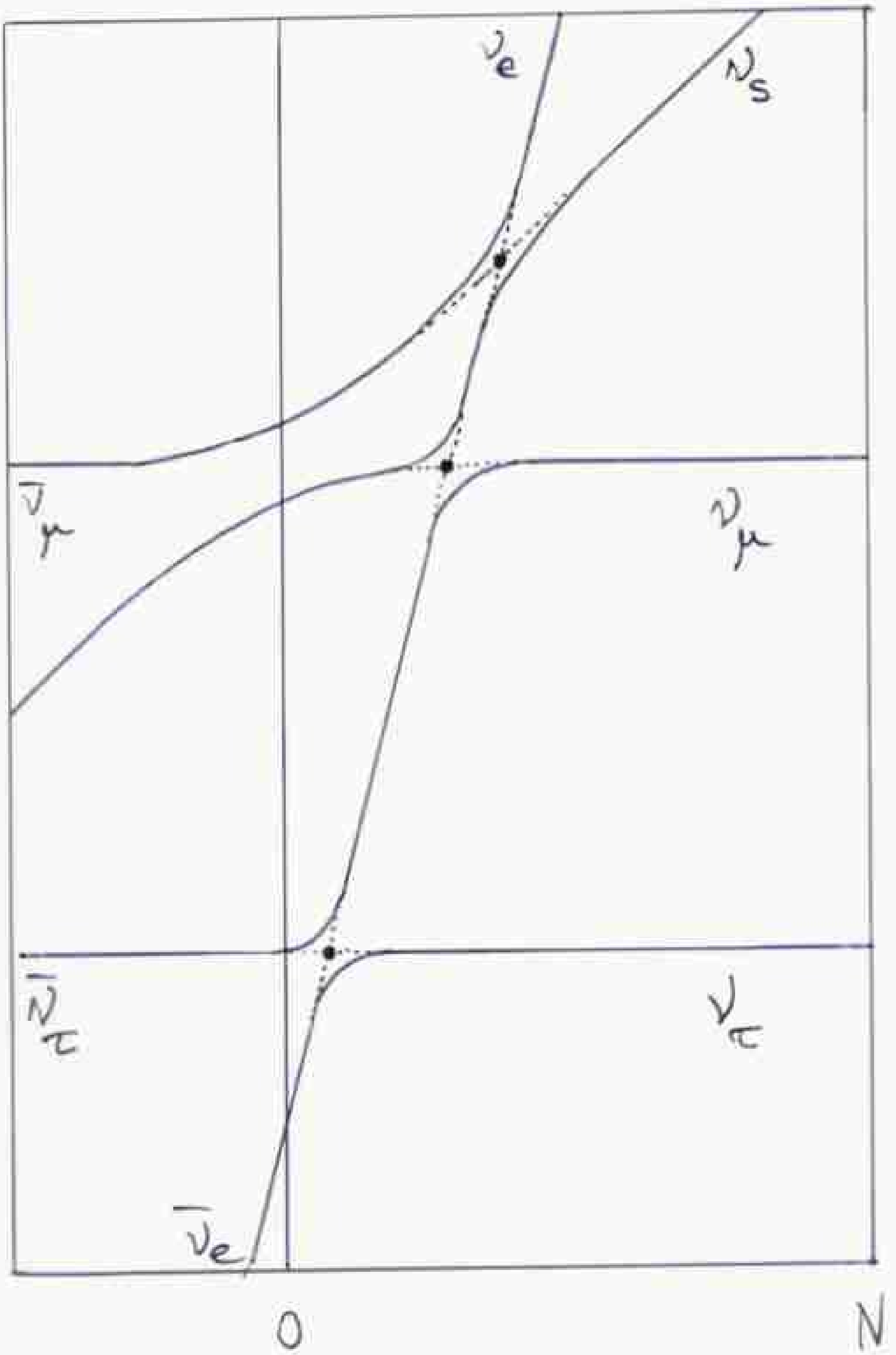
$\nu_\odot : \nu_e \to \nu_\tau$

ORIGIN:
J. Peltoniemi et al RAD
J. CHUN : SINGULAR SEESAW
A. JOSHIPURA: $\cancel{R}$



INTRODUCTION OF $m_{\mu s}$ $\to$ HDM, ν_{ATM}, LSND SIMULTANEOUSLY

SN. GU – SCENARIO



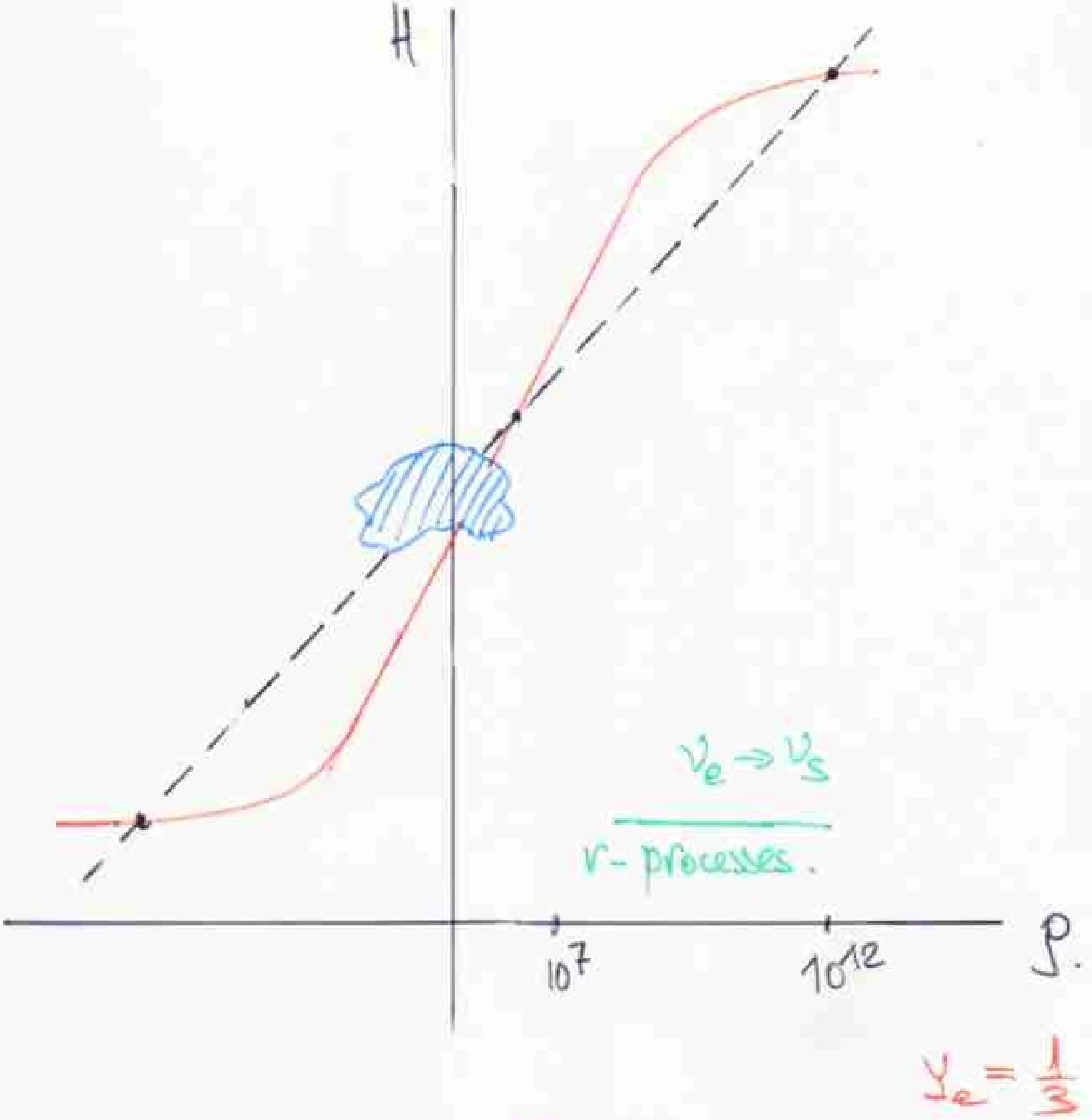
ADIABATIC TRANSITIONS:

$\bar{\nu}_\tau \to \bar{\nu}_s$

$\nu_e \to \nu_\mu / \nu_s$

$\nu_\mu \to \nu_\tau$

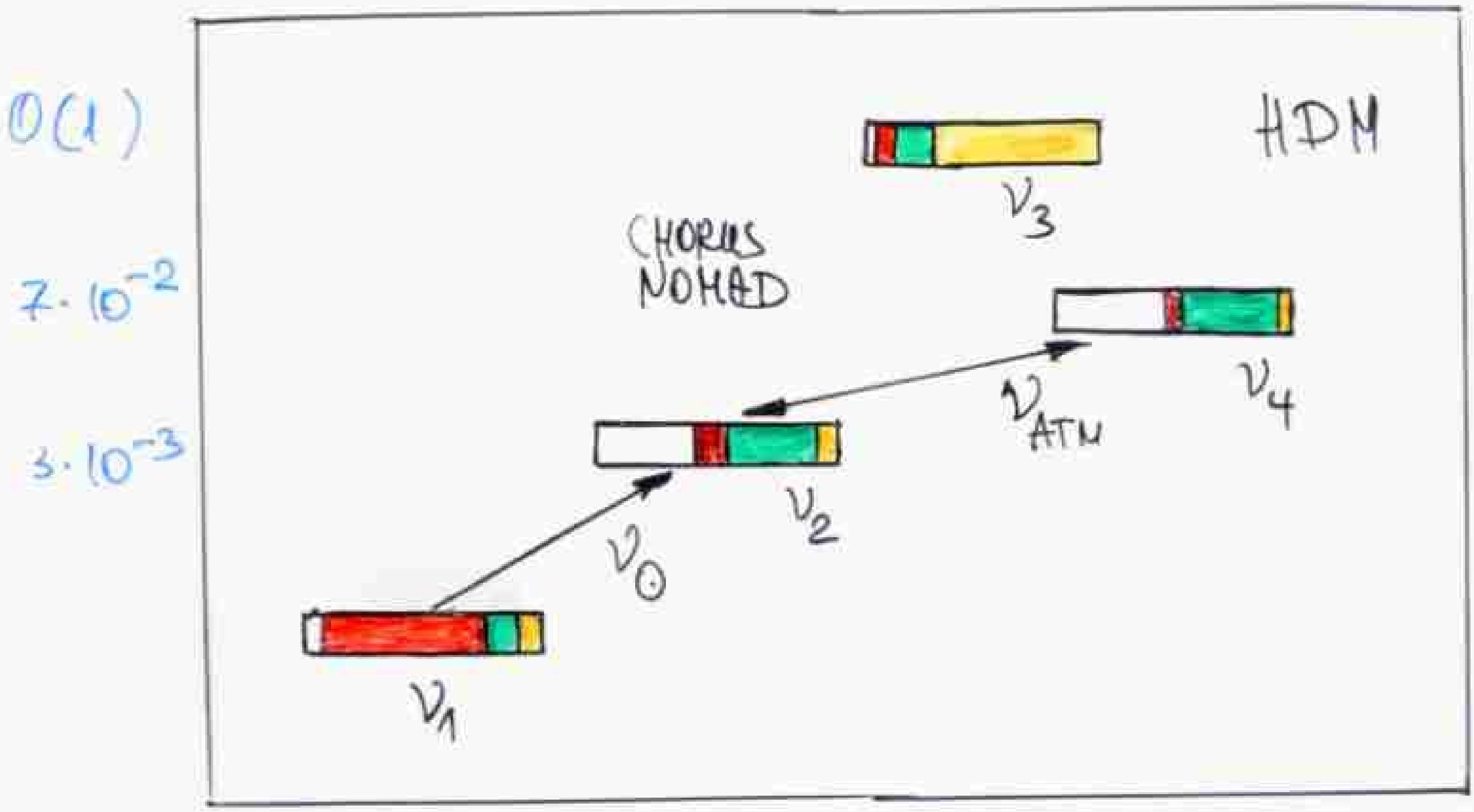
$\nu_\tau \to \nu_e$ HARD ν_e SPECTRUM.



$\bar{\nu}_e$ disappearance ?

LEVEL CROSSING CAN BE ADIABATIC IF $\sin^2\theta_{es} \sim 10^{-3}$

INTERMEDIATE SCALE CASE



$\nu_\odot \quad \nu_e \to \nu_\mu, \ \nu_e \to \nu_s$

$\nu_{ATM} \quad \nu_\mu \to \nu_s$

HDM

LSND – CAN BE ENHANCED IF $m_4 \gtrsim 0.4$ eV

SN

INTERMEDIATE SCALE SCENARIO

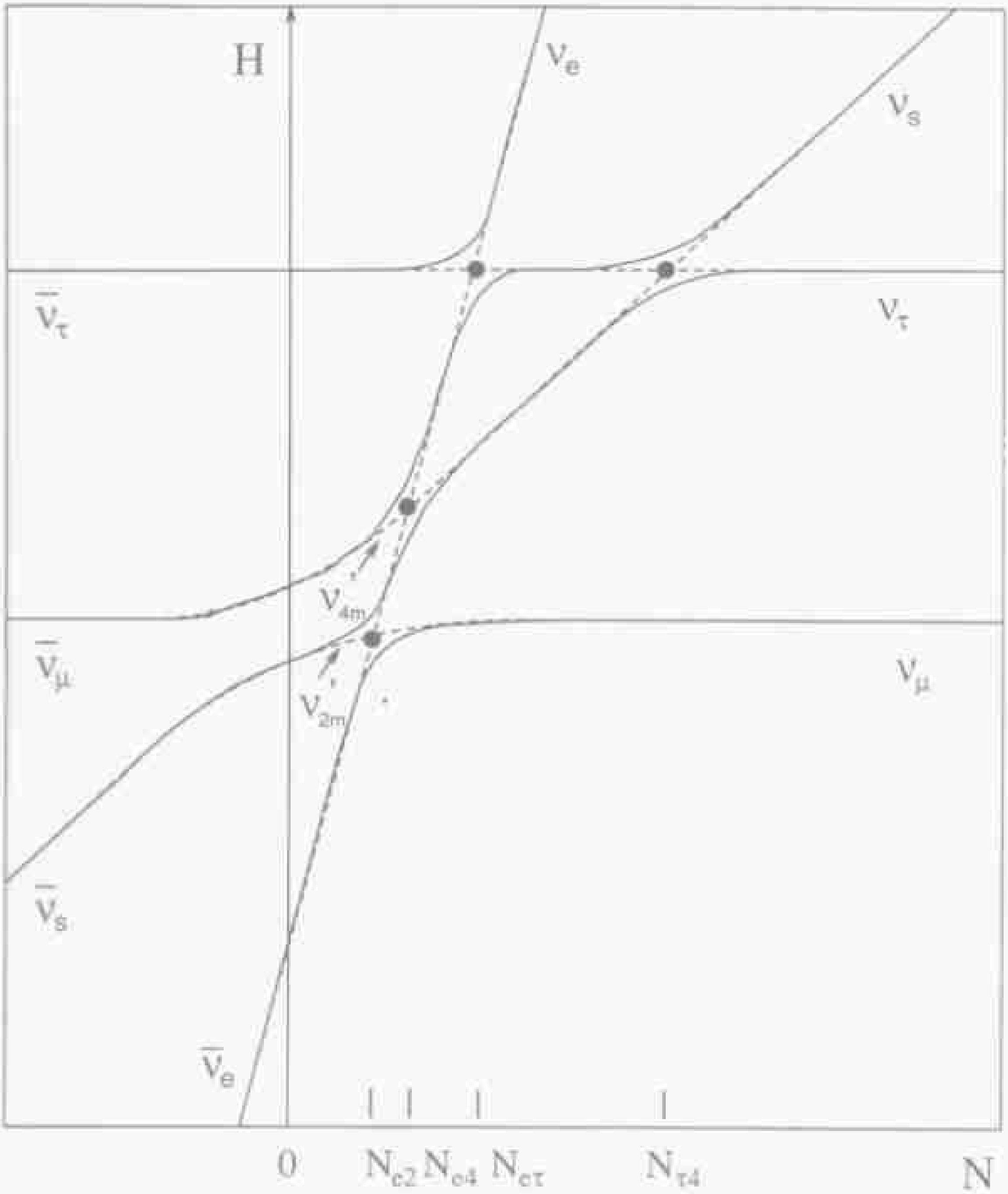


FIG. 5

COMPLETE ADIABATICITY:

$\nu_e \to \nu_\tau$

$\nu_\tau \to \nu_\mu/\nu_s$

$\nu_\mu \to \nu_e$

HARD ν_e SPECTRUM.

IN r-PROCESSES REGION:

ν_τ ν_s ν_μ

NO ν_e !! ENHANCEMENT OF r-PROCESSES.

SUMMARY.

- VARIETY OF PHYSICAL CONDITIONS
- VARIETY OF the EFFECTIVE DENSITY PROFILES.
- STILL VARIETY OF ν- SYSTEMS.

  = VARIETY OF PHENOMENA

SN NEUTRINOS WILL ALLOW TO TEST THE WHOLE MASS SPECTRUM OF NEUTRINOS.