PROBING SOLAR CORE USING NEUTRINOS

I. Lopes, "Probing the Suns inner core using solar neutrinos: Anew diagnostic method," Physical Review D **88**, 045006 (2013).

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PandA @ UNM

OUTLINE

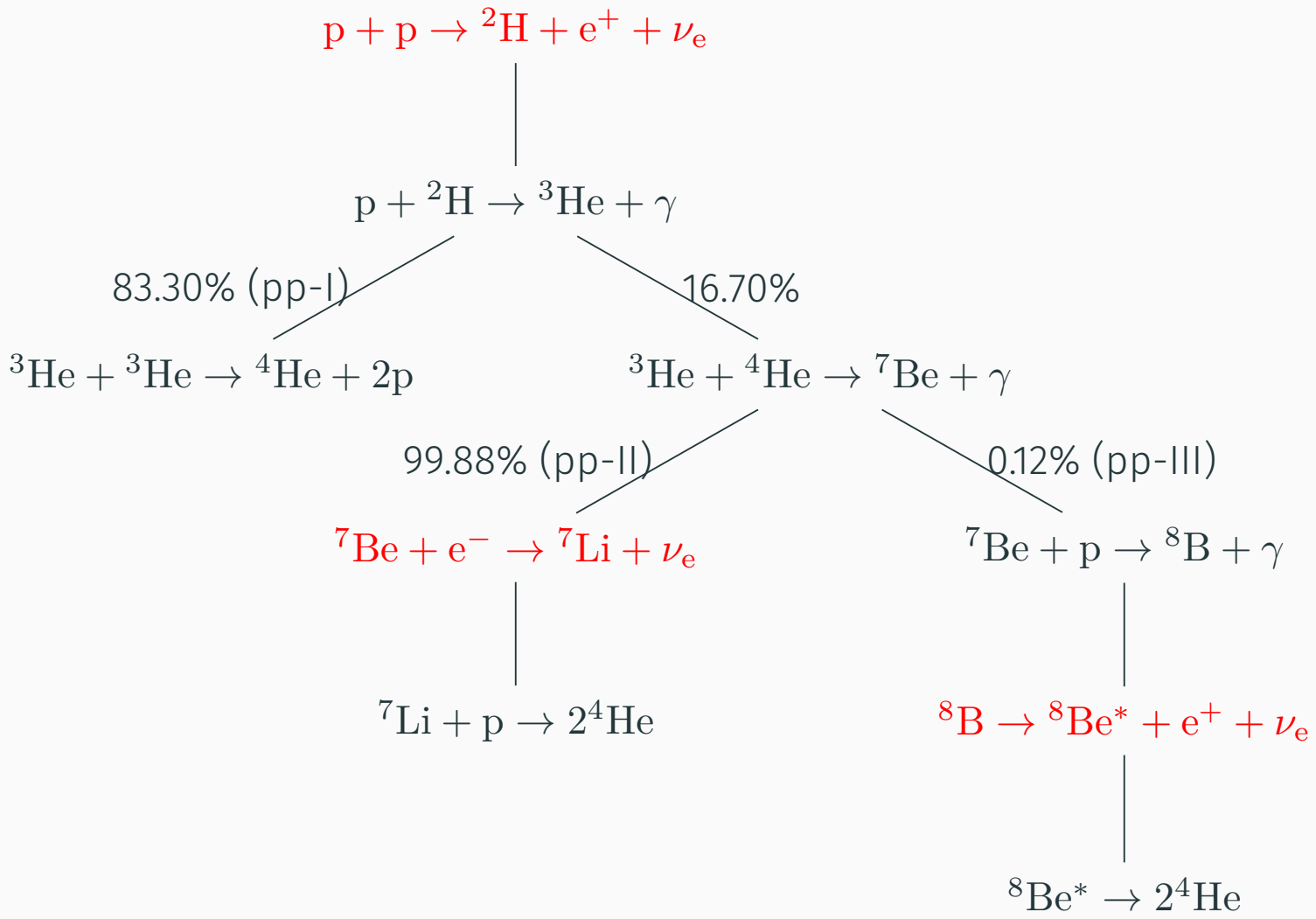
- Stars as Neutrino Factories
- Solar Neutrino Production and Lab Neutrino Production
- Neutrino Spectra
- References

STARS AS NEUTRINO FACTORIES

Reaction	Equation	Boson
Electron emission	${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}X + e^{-} + \bar{\nu}_e$	W
Positron emission	${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}X + e^{+} + \nu_e$	W
Electron capture	${}^{A}_{Z}X + e^{-} \rightarrow {}^{A}_{Z-1}X + \nu_e$	W
Positron capture	${}^{A}_{Z}X + e^{+} \rightarrow {}^{A}_{Z+1}X + \bar{\nu}_e$	W
Electron annihilation	$e^{-} + e^{+} \rightarrow \nu_e + \bar{\nu}_e$	W
Electron annihilation	$e^{-} + e^{+} \rightarrow \nu + \bar{\nu}$	Z
Neutrino capture	${}^{A}_{Z}X + {}^{(-)}_{\nu_e} \rightarrow {}^{A}_{Z\mp1}X + e^{\pm}$	W
$e^{-}\nu$ scattering	$e^{-} + {}^{(-)}_{\nu_e} \rightarrow e^{-} + {}^{(-)}_{\nu_e}$	W
$e^{-}\nu$ scattering	$e^{\pm} + {}^{(-)}_{\nu_e} \rightarrow e^{\pm} + {}^{(-)}_{\nu_e}$	Z
Neutrino scattering	${}^{A}_{Z}X + {}^{(-)}_{\nu} \rightarrow {}^{A}_{Z}X + {}^{(-)}_{\nu}$	Z

Table: Neutrino related nuclear or leptonic reactions

STARS AS NEUTRINO FACTORIES



STARS AS NEUTRINO FACTORIES

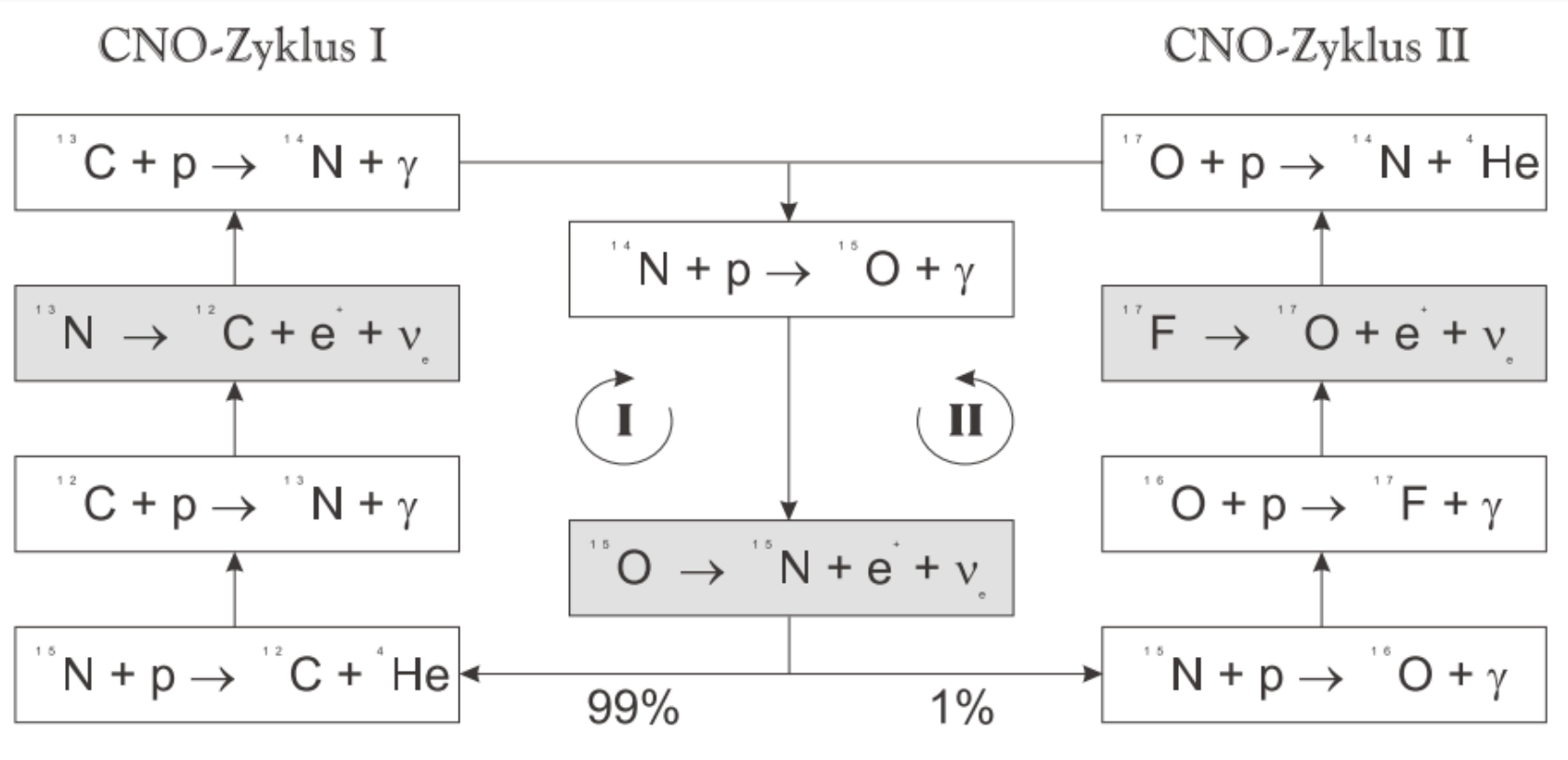


Figure: CNO cycle illustration. Figure taken from wikipedia.

SOLAR NEUTRINO PRODUCTION AND LAB NEUTRINO PRODUCTION

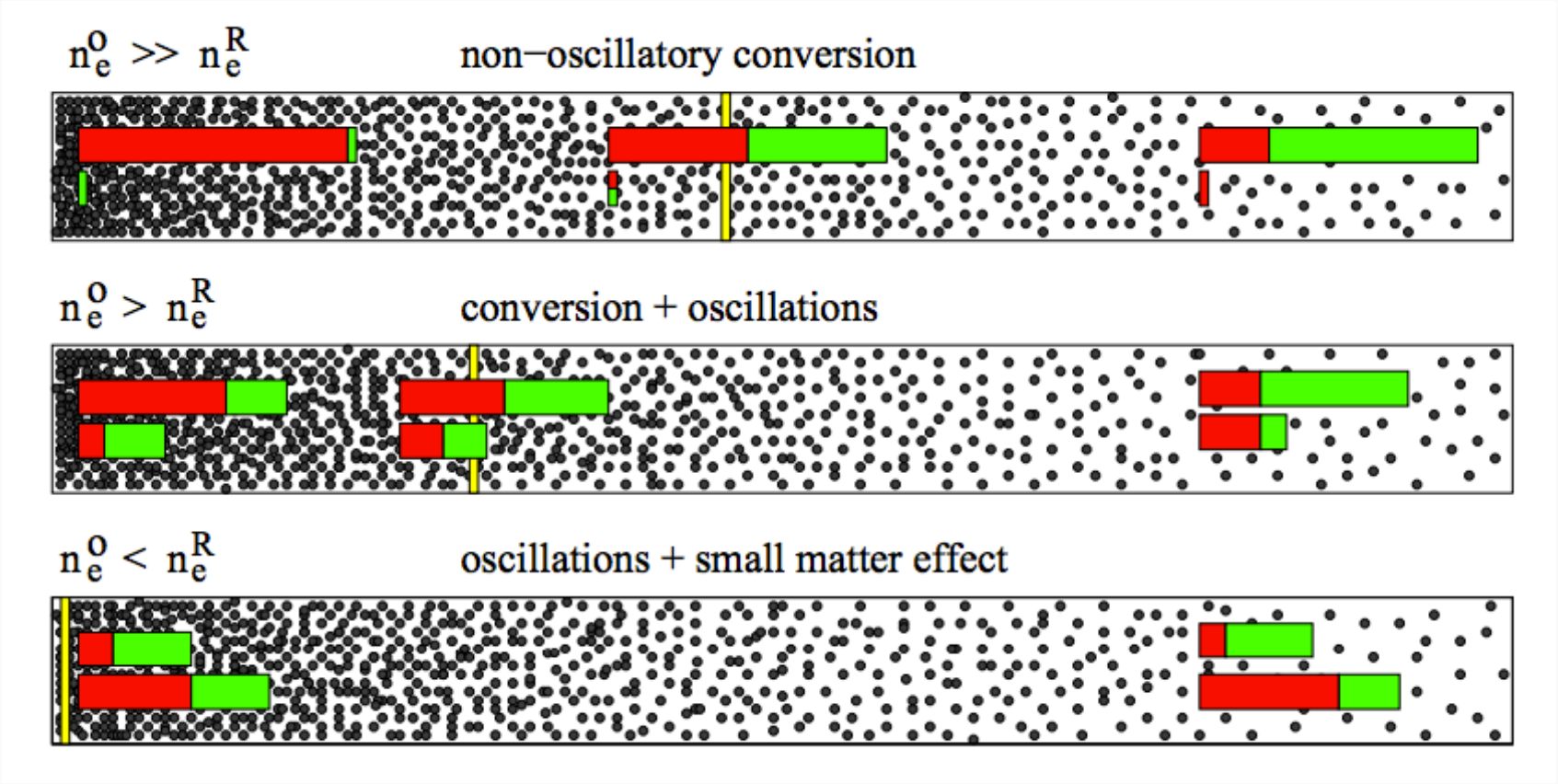


Figure: Flavor mixing of large vacuum mixing angle from a dense region to vacuum. n_e^R is the resonance density. Yellow bar is the resonance point. In each panel, the upper color bar is for heavier eigen-energy while the lower color bar is for the lower eigen-energy. Figure taken from Smirnov.

SOLAR NEUTRINO PRODUCTION AND LAB NEUTRINO PRODUCTION

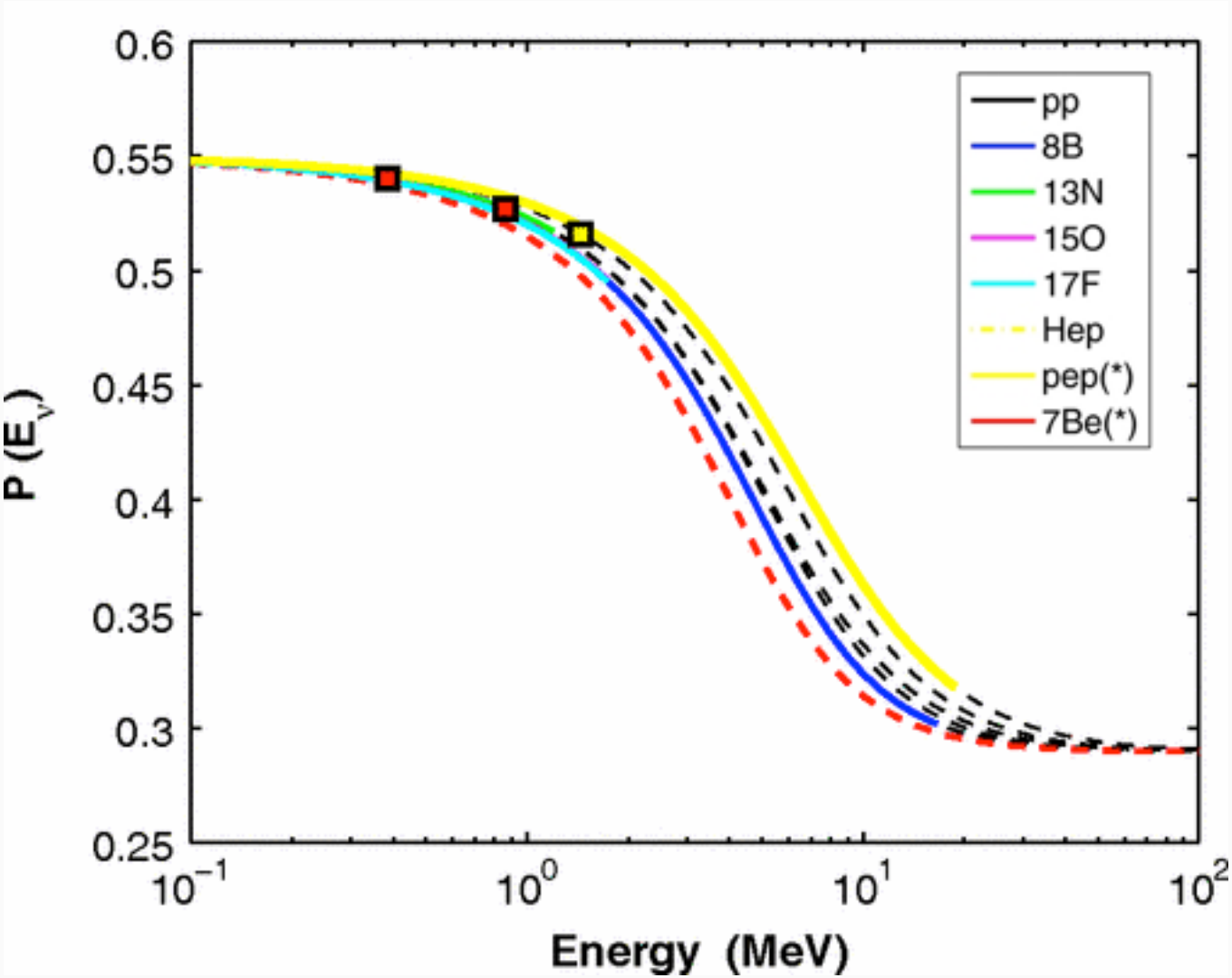


Figure: Neutrino flavor conversion of the Sun. Boxes are from Boroxino experiment measurement.

SOLAR NEUTRINO PRODUCTION AND LAB NEUTRINO PRODUCTION

$$\tau_{EM} \sim 10^{-12}\mathrm{s}\left(\frac{E}{20\mathrm{keV}}\right)^{3/2}\left(\frac{150\mathrm{g}\cdot\mathrm{cm}^{-3}}{\rho}\right), \tag{1}$$

Nuclear Reaction	τ_ν
pp	10^{10} years
$^{7}\mathrm{Be}$	10^{12} years
$^{8}\mathrm{B}$	1 second
$^{13}\mathrm{N}$	10^{3} seconds
$^{15}\mathrm{O}$	10^{2} seconds
$^{17}\mathrm{F}$	10^{2} seconds

Table: Neutrino production characteristic time. Reproduced from Bahcall, 1991.

SOLAR NEUTRINO PRODUCTION AND LAB NEUTRINO PRODUCTION

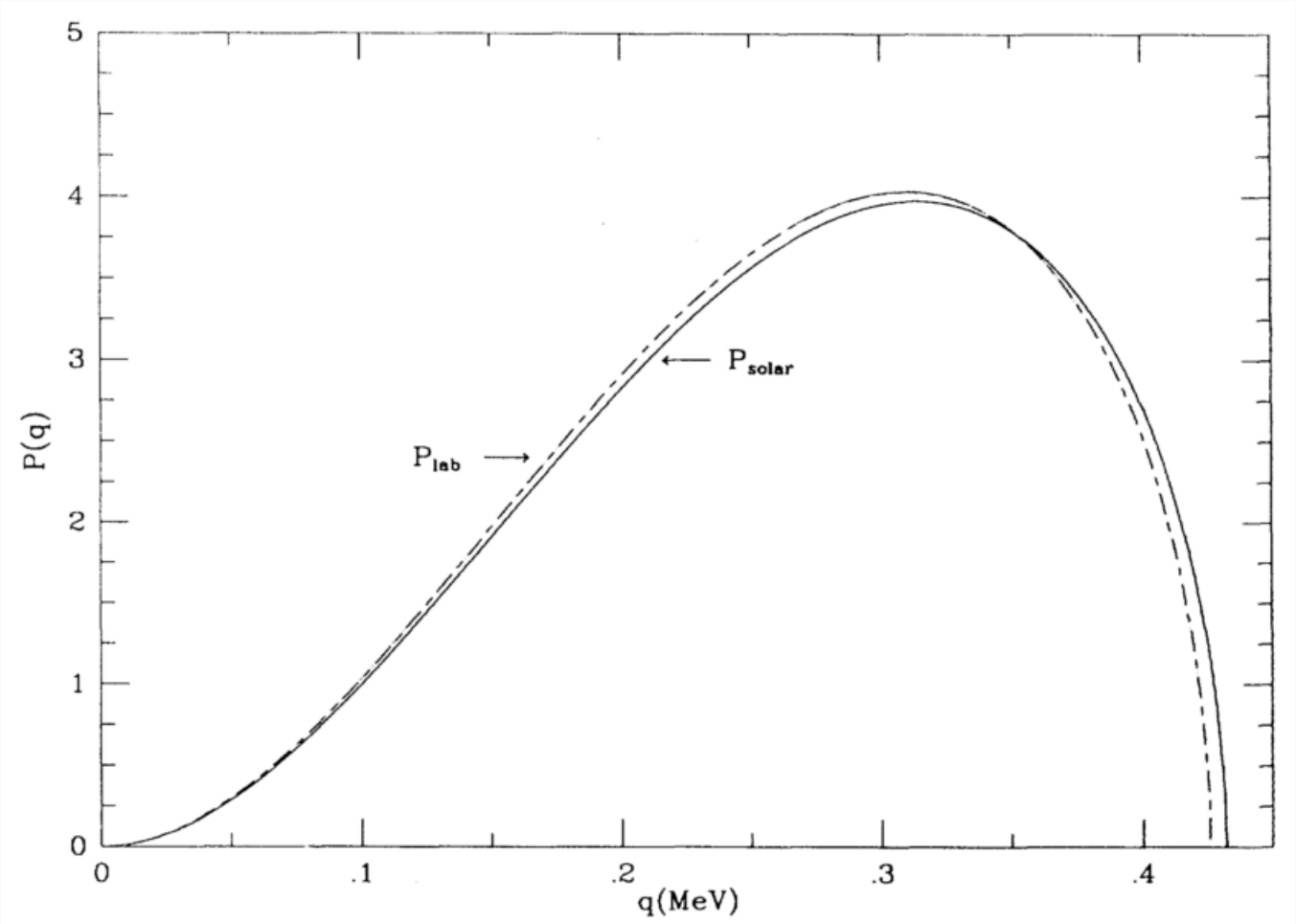


Figure: Comparison of pp reaction neutrino spectrum in the lab experiments and predicted solar spectrum. The correction is very small.

SOLAR NEUTRINO PRODUCTION AND LAB NEUTRINO PRODUCTION

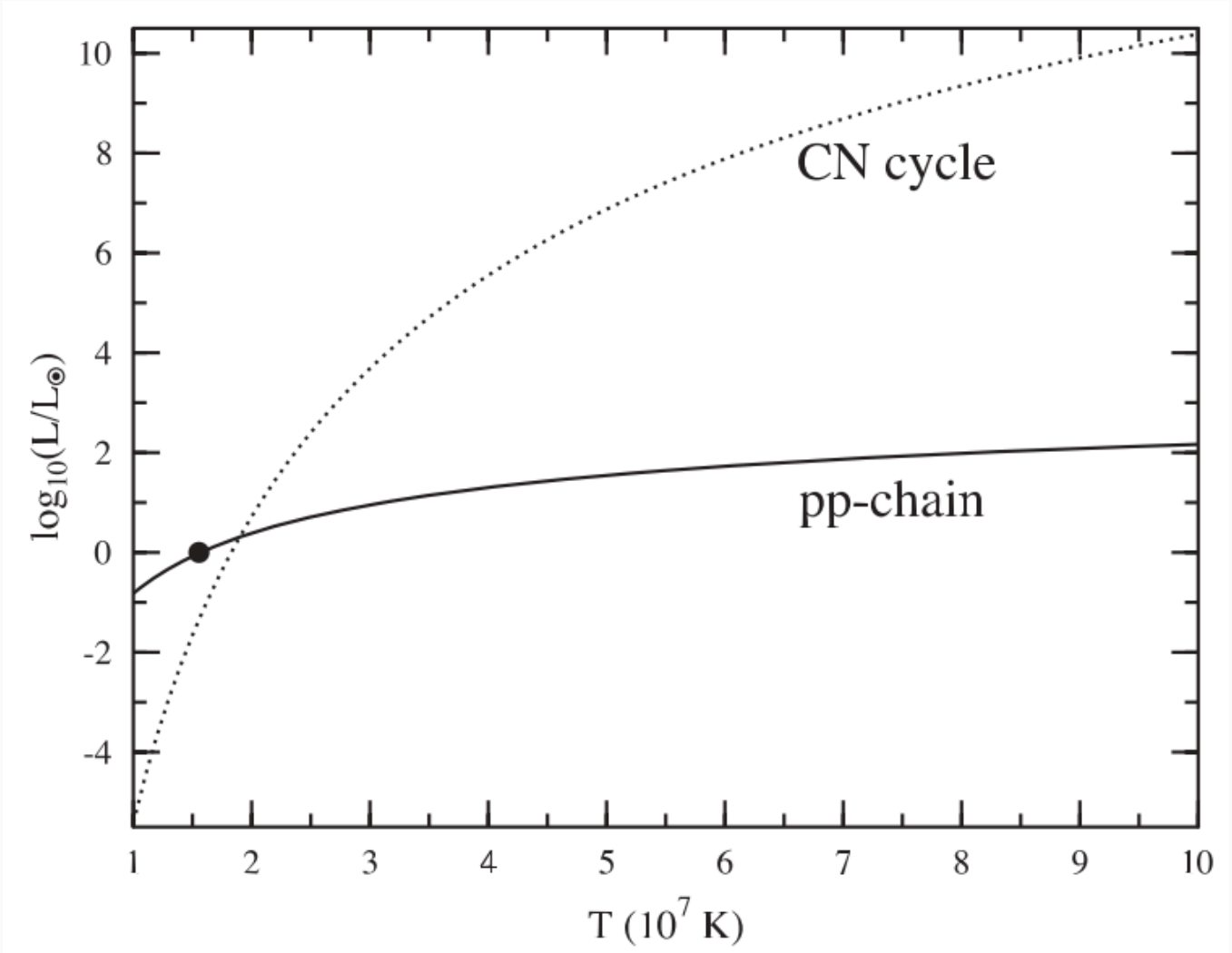


Figure: The contribution to the luminosity by pp chain and CNO cycle as a function of temperature. The black dot is at the solar core temperature. $L_\odot$ is solar luminosity.

SOLAR NEUTRINO PRODUCTION AND LAB NEUTRINO PRODUCTION

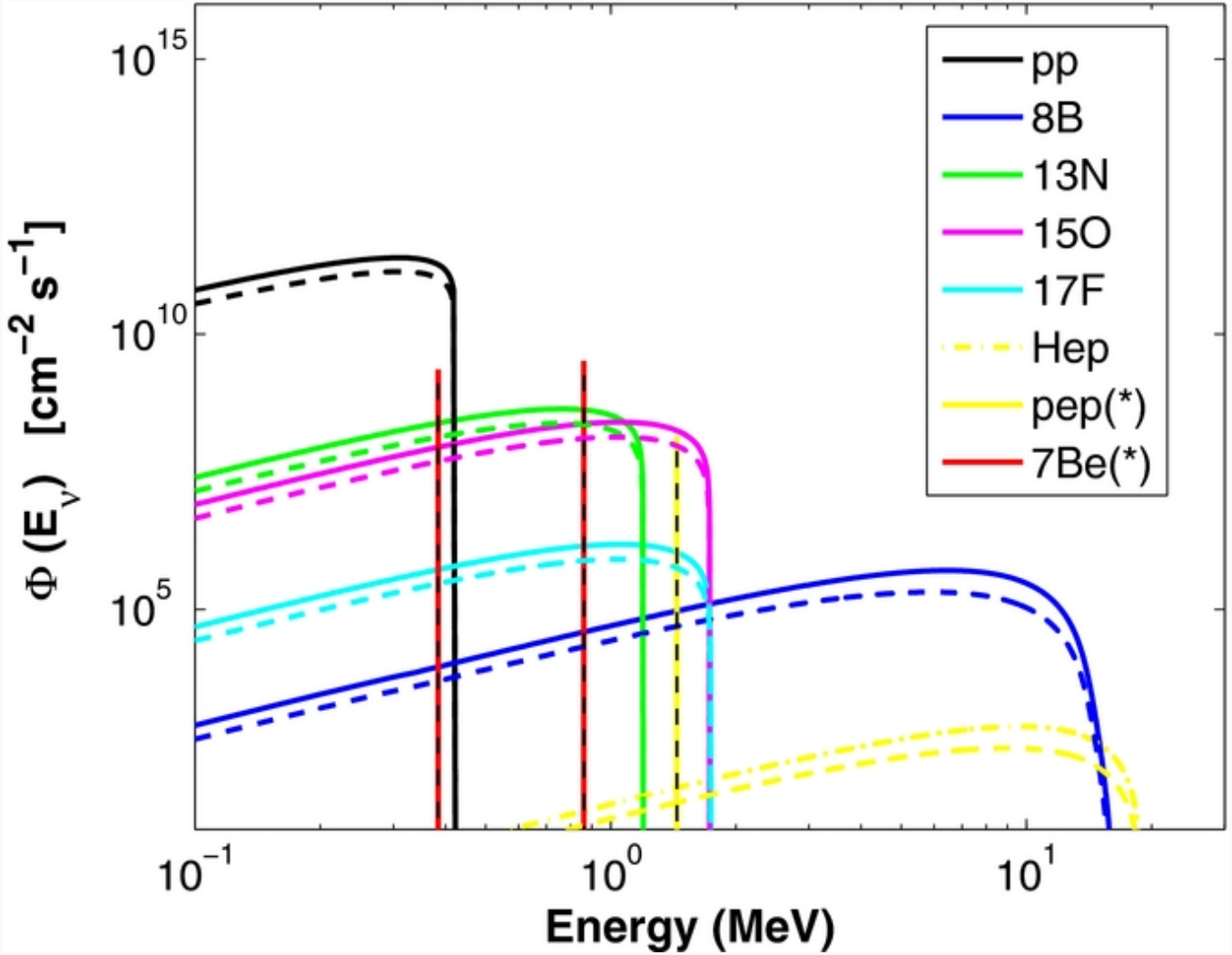


Figure: Solar neutrino spectra with flavor conversion. Solid lines are spectra without flavor conversion while the dashed lines are spectra with flavor conversion. The difference comes from the neutrino mixing. Figure taken

REFERENCES

1. I. Lopes, ”Probing the Suns inner core using solar neutrinos: Anew diagnostic method,” Physical Review D **88**, 045006 (2013).
2. E. Adelberger and a. Garcia, ”Solar fusion cross sections. II. Thepp chain and CNO cycles,” Reviews of Modern Physics 83(2011),arXiv:arXiv:1004.2318v3.

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