SOLAR NEUTRINOS AND BOREXINO

STATUS AFTER BOREXINO FINAL RESULTS

Based on: "Status of direct determination of solar neutrino fluxes after Borexino," JHEP 02 (2024), 064

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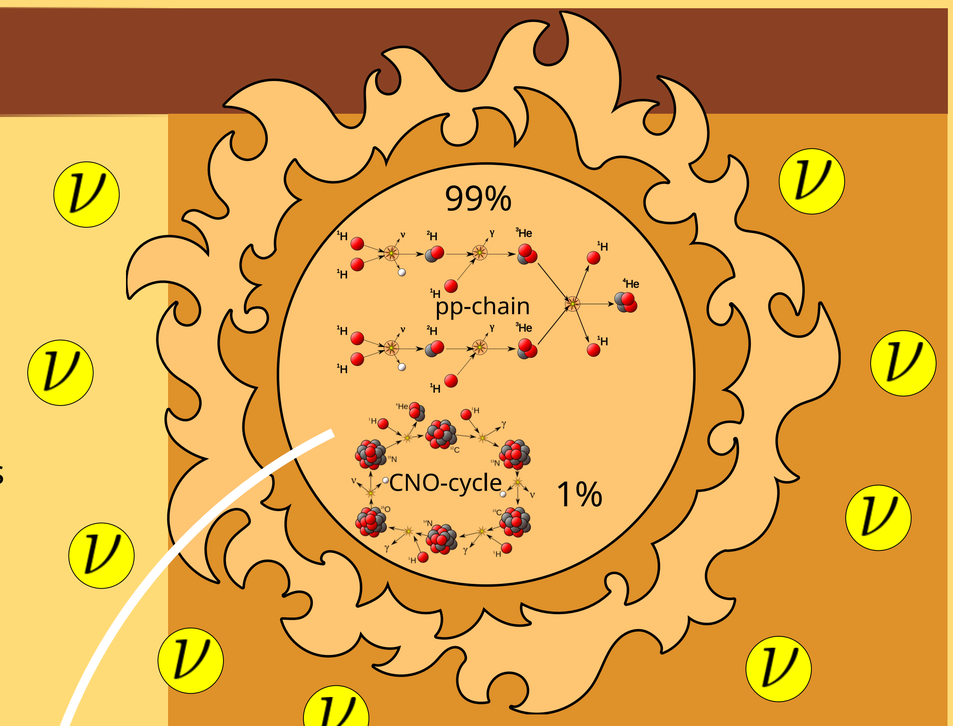
1 GLOBAL ANALYSIS OF SOLAR EXPERIMENTS

Frequentist analysis, include experimental data from Solar and KamLAND:

$$\chi^2_{\rm global}(\vec{\omega}_{\rm flux},\,\vec{\omega}_{\rm osc}) \equiv \chi^2_{\rm solar}(D_{\rm solar}\,|\,\vec{\omega}_{\rm flux},\,\vec{\omega}_{\rm osc}) + \chi^2_{\rm KamLAND}(D_{\rm KamLAND}\,|\,\vec{\omega}_{\rm osc})$$

Inequalities related to nuclear-processes (consistency check)

CNO-analysis without SSM-bias:
We constrained the ratios of individual CNO fluxes with the average of 5 different solar models



NEW DETERMINATIONS OF SOLAR FLUXES:

with Luminosity Constraint*:

$\Phi_{\rm pp} = 5.941^{+0.024}_{-0.023}\,[^{+0.057}_{-0.055}] \times 10^{10}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{^7{\rm Be}} = 4.93^{+0.10}_{-0.08}\,[^{+0.23}_{-0.20}] \times 10^{9}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{\rm pep} = 1.421^{+0.023}_{-0.026}\,[^{+0.058}_{-0.060}] \times 10^{8}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{^{13}{\rm N}} = 3.48^{+0.47}_{-0.40}\,[^{+1.30}_{-1.10}] \times 10^{8}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{^{15}{\rm O}} = 2.53^{+0.34}_{-0.29}\,[^{+0.94}_{-0.80}] \times 10^{8}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{^{17}{\rm F}} = 5.51^{+0.75}_{-0.63}\,[^{+2.06}_{-1.75}] \times 10^{7}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{^8{\rm B}} = 5.20^{+0.10}_{-0.10}\,[^{+0.24}_{-0.24}] \times 10^{6}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{\rm hep} = 3.0^{+0.9}_{-1.0}\,[^{+2.2}_{-2.1}] \times 10^{4}\ {\rm cm}^{-2}\ {\rm s}^{-1}$

Luminosity constraint limits the size of the pp flux

without Luminosity Constraint:

$\Phi_{\rm pp} = 6.19^{+0.45}_{-0.39}\,[^{+1.1}_{-1.0}] \times 10^{10}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{^7{\rm Be}} = 4.95^{+0.11}_{-0.089}\,[^{+0.25}_{-0.22}] \times 10^{9}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{\rm pep} = 1.48^{+0.11}_{-0.09}\,[^{+0.26}_{-0.22}] \times 10^{8}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{^{13}{\rm N}} = 3.32^{+0.53}_{-0.54}\,[^{+1.40}_{-1.24}] \times 10^{8}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{^{15}{\rm O}} = 2.41^{+0.38}_{-0.39}\,[^{+1.02}_{-0.90}] \times 10^{8}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{^{17}{\rm F}} = 5.25^{+0.84}_{-0.85}\,[^{+2.21}_{-1.97}] \times 10^{6}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{^8{\rm B}} = 5.192^{+0.10}_{-0.11}\,[^{+0.26}_{-0.26}] \times 10^{6}\ {\rm cm}^{-2}\ {\rm s}^{-1}$
$\Phi_{\rm hep} = 2.9^{+1.0}_{-0.9}\,[^{+2.4}_{-2.1}] \times 10^{4}\ {\rm cm}^{-2}\ {\rm s}^{-1}$

Oscillation parameters:

$\Delta m^2_{21} = 7\,43^{+0.30}_{-0.30}\,[^{+0.44}_{-0\,49}] \times 10^{-5}{\rm eV}^2$
$\text{and}\ \sin^2\theta_{12} = 0.300^{+0.020}_{-0.017}\,[^{+0.031}_{-0.027}]$

*Constraining the Luminosity infered by neutrinos with the Luminosity infered by spectroscopy

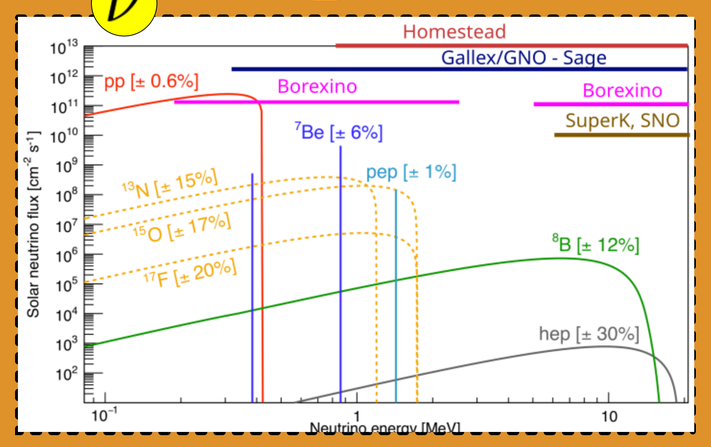
Estimation of nuclear energy generation rate and neutrino

Purely experimental result − no solar model information:

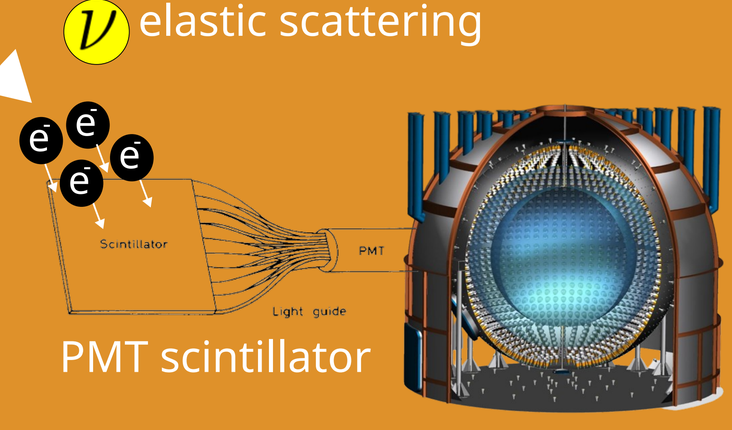
$$\frac{L_{\text{pp-chain}}}{L_\odot} = 1.030^{+0.070}_{-0.061}\,[^{+0.17}_{-0.15}] \quad \text{and} \quad \frac{L_{\rm CNO}}{L_\odot} = 0.0075^{+0.0013}_{-0.0013}\,[^{+0.0030}_{-0.0029}]\,.$$

$$\frac{L_\odot(\text{neutrino-inferred})}{L_\odot} = 1.038^{+0.069}_{-0.060}\,[^{+0.17}_{-0.15}]\,.$$

The $\frac{L_{\rm CNO}}{L_\odot} = 0$ solution is **REJECTED** with almost 8σ!!



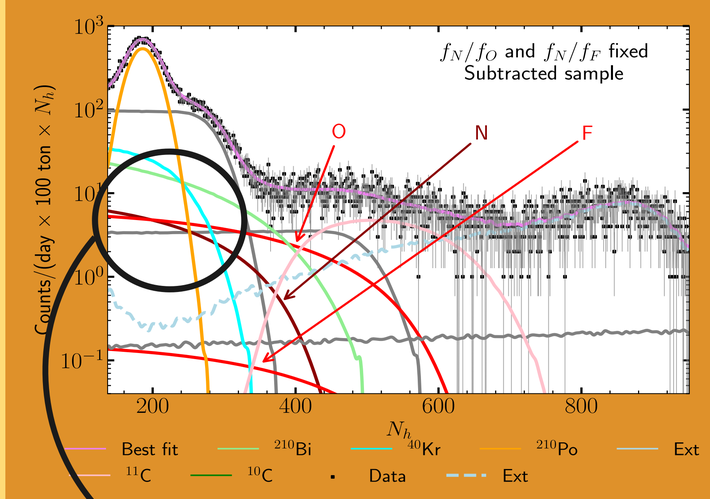
electron-neutrino elastic scattering



PMT scintillator

Borexino

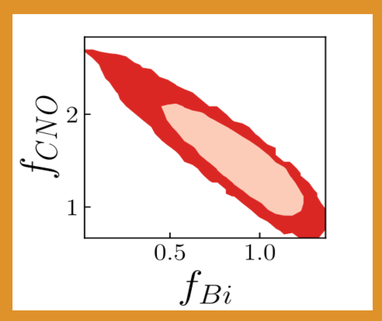
2 FULL SPECTRUM OF BOREXINO



Degenerated in shape:

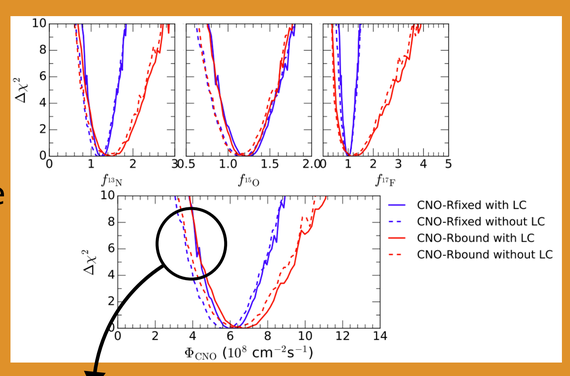
If ^{13}N is free in the fit, bestfit leads to non-realistic zero ^{210}Bi bckg

Anticorrelation between CNO and ^{210}Bi bckg



Collaboration set upper bound for ^{210}Bi bckg – R(^{210}Bi) ≤ 11.5±1.3 cpd per 100t (hep-ex:2006.15115)

Alternative for each CNO free:
Let the individual fluxes free, within a range that encompass five different SSM's and rejects non-realistic bckg

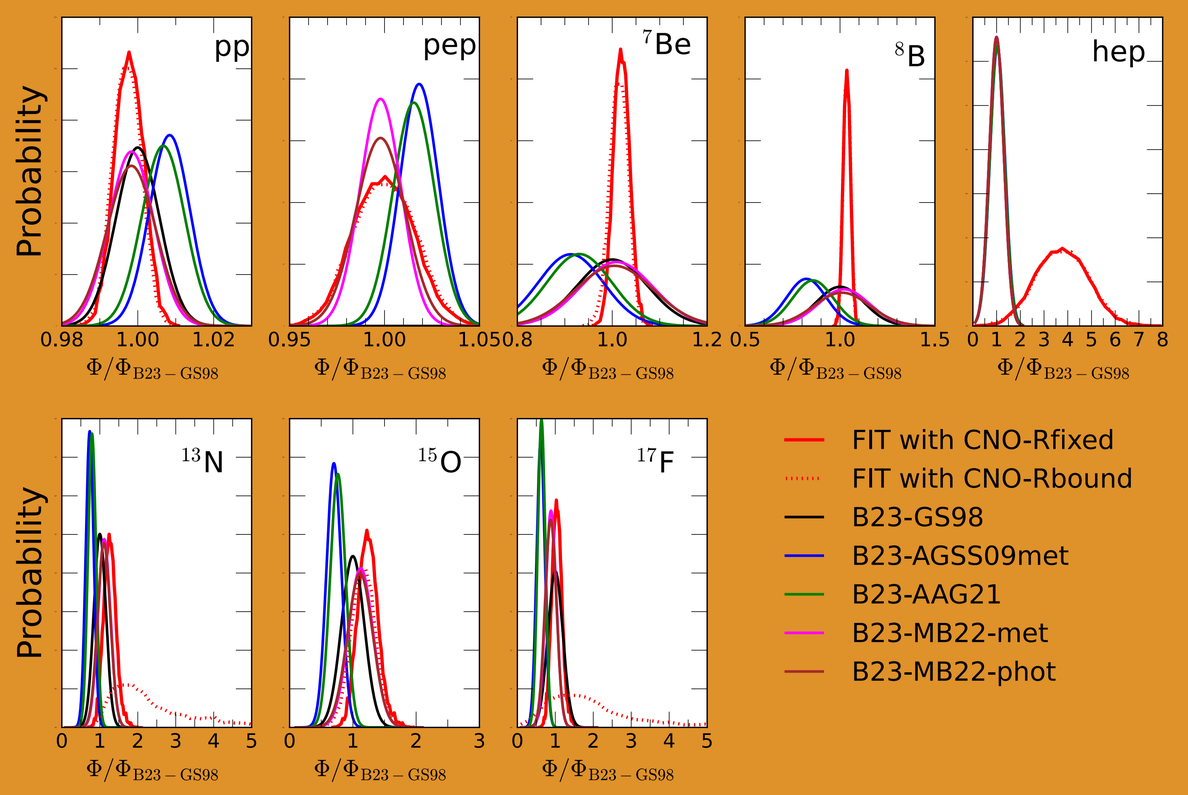


SMALL VALUES OF $\Phi^{\rm CNO}$ ARE STRONGLY REJECTED BY ALL APPROACHES!!

3 NEW STATUS OF SSM's

Marginalized one-dimensional probability distributions for the best determined solar fluxes in our analysis as compared to the predictions for the five SSMs

Herrera, Y. and Serenelli,https://doi.org/10.5281/zenodo.10174172



THE FIT HAS A PREFERENCE FOR HIGH-Z FOR ALL FLUXES!!