Results from the Borexino experiment

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On behalf of the Borexino Collaboration

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Borexino is located in the LNGS Underground Laboratory in the mountains of Abruzzo, Italy.

Shielding provided by 1400m of rock:
~3800 m.w.e
The Borexino Detector

Scintillator: 270t PC+PPO

Nylon Vessel: Inner: 4.25m, Outer: 5.50m

Carbon Steel Plates

Stainless Steel Sphere: 2212 PMTs, 1350m³, r=6.85m

Water Tank: 208 PMTs, 2100m³, r=9m
**Expected Spectrum in Borexino**

**Neutrino detection principle:** Electron scattering

\[ \nu + e^- \rightarrow \nu + e^- \]

First real-time measurement down to 200keV. First simultaneous measurement of solar neutrinos from vacuum dominated and matter-enhanced oscillation regions.

**Expected rates:**

- \(^{7}\text{Be} : ~ \sim 50 \text{ c/d/100t}\)
- \(^{8}\text{B} : ~ \sim 0.3 \text{ c/d/100t}\)

Low threshold of 200keV because of high radioactive purity:

- \(^{238}\text{U} : 1.6 \times 10^{-17} \text{ g/g}\)
- \(^{232}\text{Th} : 6.8 \times 10^{-18} \text{ g/g}\)
{\bf $^7$Be Solar Neutrino Flux}

Spectrum of 192 live days

Applied cuts:
- Muons rejected
- 2ms cut after each muon
- Rn daughters vetoed
- FV cut

\begin{itemize}
\item Measured rate: $49\pm3^{\text{stat}}\pm4^{\text{sys}}$ c/d/100t
\item Theoretical rate
  \begin{itemize}
  \item MSW-LMA: $48\pm3$ c/d/100t
  \item no oscillation: $75\pm4$ c/d/100t
  \end{itemize}
\end{itemize}

Hypothesis of no oscillation for $^7$Be solar neutrinos is rejected by the measurement at $4\sigma$. 

Electron recoil spectrum
Calculation of the pp & CNO Fluxes
(Combining the Borexino results with other Experiments)

\[ R_k = \sum_i R_{i,k} f_i P_{ee}^{i,k} \]

\[ f_i = \frac{\Phi_{i,\text{measured}}}{\Phi_{i,\text{predicted}}} \]

- \( R_{i,k} \) = expected rate of source \( i \) for experiment \( k \) at the nominal SSM flux
- \( P_{ee}^{i,k} \) = survival probability for source \( i \) above the threshold for experiment \( k \)
- \( k = \) Homestake, Gallex
- \( i = \) pp, pep, CNO, \(^7\)Be, \(^8\)B

\( f_{\text{B}} = 0.83 \pm 0.07 \), measured by SNO and SuperK
\( f_{\text{B}} = 1.02 \pm 0.10 \) given by the Borexino results

Performing a \( \chi^2 \) based analysis of all neutrino experiments adding the luminosity constraint:

\( f_{\text{pp}} = 1.005^{+0.008}_{-0.020} \) (1\( \sigma \))
\( f_{\text{CNO}} < 3.80 \) (90% C.L.)

This represents the best determination of the pp solar neutrino flux.
**³B Solar Neutrino Flux**

Spectrum of 246 live days measurement.

Cosmogenic background sources:
- Muons
- Muon induced secondaries
- Muon induced radionuclides

Internal background:
- Radon emanation from the nylon vessel
- $^{208}$Tl contamination of the scintillator

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**Graph:**
- Raw spectrum
- After $\mu$-cut
- After FV
- After 5$s$-$\mu$-cut, neutron-cut, $^{10}$C-cut and $^{214}$Bi-cut

**Expected $^{208}$Tl spectrum, taking the light quenching into account**
\(^{8}\text{B} \text{ Solar Neutrino Flux}\)

Measured \(^{8}\text{B} \text{ neutrino rate}:\) 0.26 ± 0.04\(_{\text{stat}}^{\text{sys}}\) ± 0.02\(_{\text{c/d/100t}}^{\text{c/d/100t}}\)\n
Expected rate (SSM and MSW-LMA): 0.27 ± 0.03\(_{\text{c/d/100t}}^{\text{c/d/100t}}\)\n
Non-oscillation excluded at 4.2σ
Assuming the SSM and MSW-LMA solution the measurement of $^7$Be and $^8$B neutrino rate corresponds to:

\[ P_{ee}(^7\text{Be}) = 0.56 \pm 0.10 \]
\[ P_{ee}(^8\text{B}) = 0.35 \pm 0.10 \text{ at the effective energy of 8.6MeV} \]

Measurement is in agreement with the prediction of the MSW-LMA solution for solar neutrinos.
Summary

Achieved so far:
- First real-time measurement of $^7$Be neutrinos
- First real-time measurement of $^8$B neutrinos down to an energy of 2.8MeV using a liquid scintillator
- First simultaneous measurement of solar neutrinos from vacuum dominated and matter-enhanced oscillation regions
- Current best limits for pp- and CNO-neutrinos

In progress:
- Direct measurement of pep- and CNO-neutrinos
- Source calibration to decrease systematic errors

In future:
- Measurement of the solar pp-flux
- Antineutrino observations (geoneutrinos, reactor, from the sun)
- Supernova neutrinos and antineutrinos (joining SNEWS during 2009)