# Experimental evidence of neutrinos produced in the CNO fusion cycle in the sun

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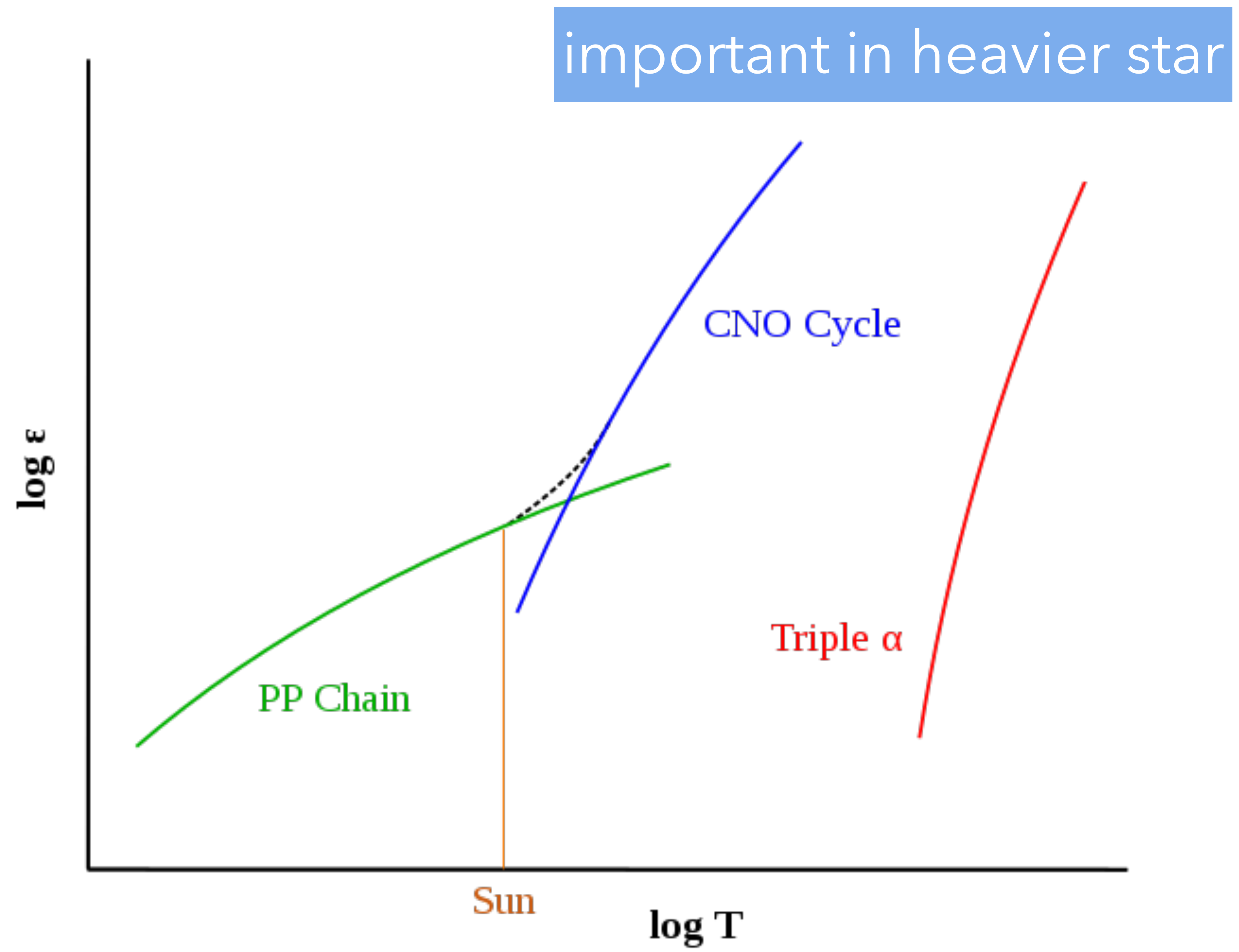
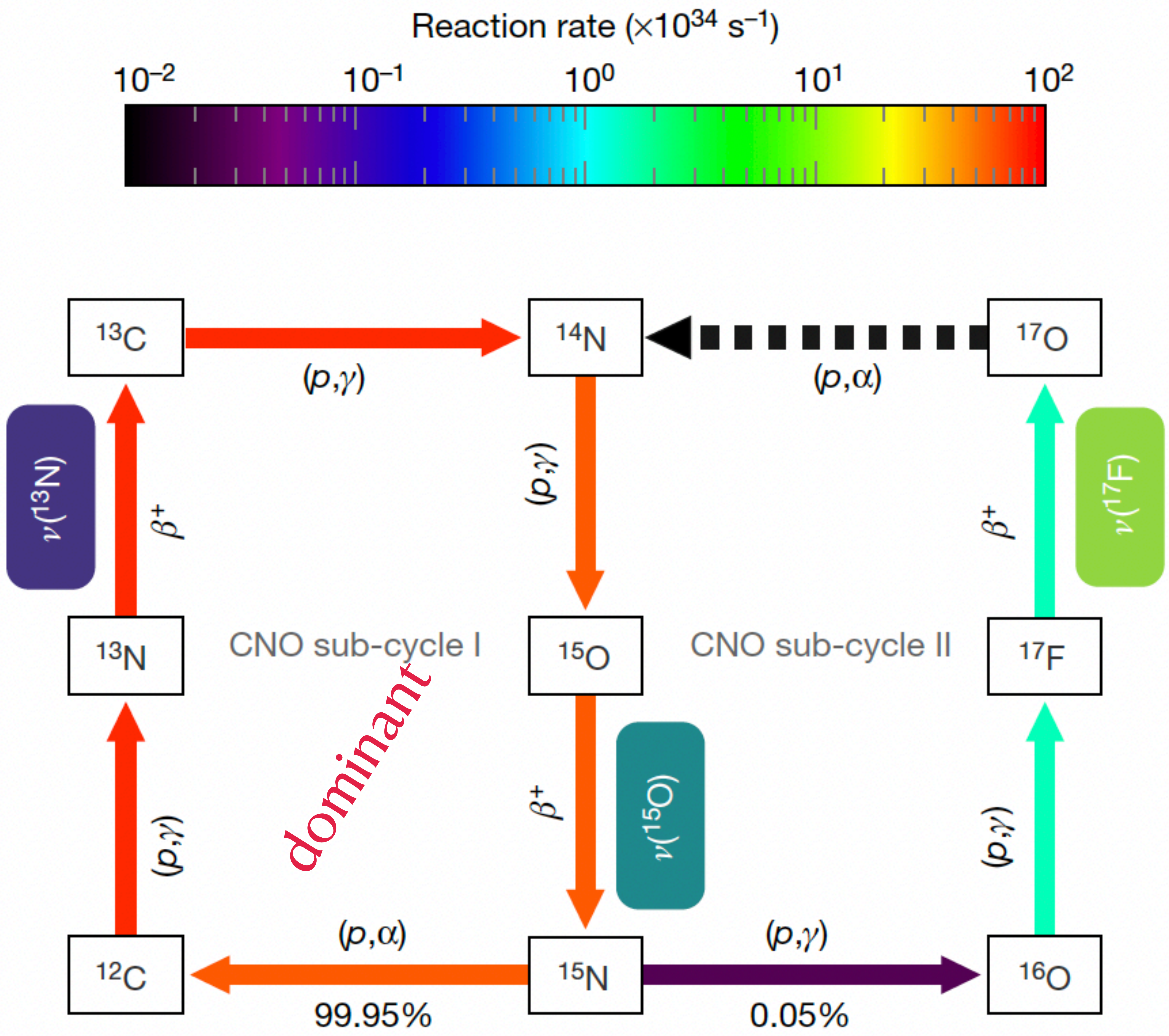
https://doi.org/10.1038/s41586-020-2934-0 The Borexino Collaboration

# CNO fusion cycle

## One of fusion of hydrogen to helium



# Metallicity

*Even a very small fraction of metals is sufficient to alter the behavior of a star completely*

1. as catalysts in the CNO cycle
2. affect the plasma opacity

—> CNO Neutrinos : unique probe of initial condition

- SSM-LZ :
- low metallicity standard solar model
- From spectroscopy

- SSM-HZ:
- high metallicity standard solar model
- From helioseismology

Different physical property

# Neutrino


This is how scientist see the world

# Neutrino

From sun:

400keV-18MeV

$7 \times 10^{10} particles \cdot cm^2 \cdot s^{-1}$

transparent: information of deep solar core

This is how neutrino scientist see the world

# How to detect neutrino?

**only weak interaction**

$$\nu_L + N \to l_L^- + N'$$

$$\bar{\nu}_L + \bar{N} \to l_L^+ + \bar{N}'$$

↓

Cherenkov radiation

1. very large: cross section very small
2. underground: isolate from backgrounds
3. transparent

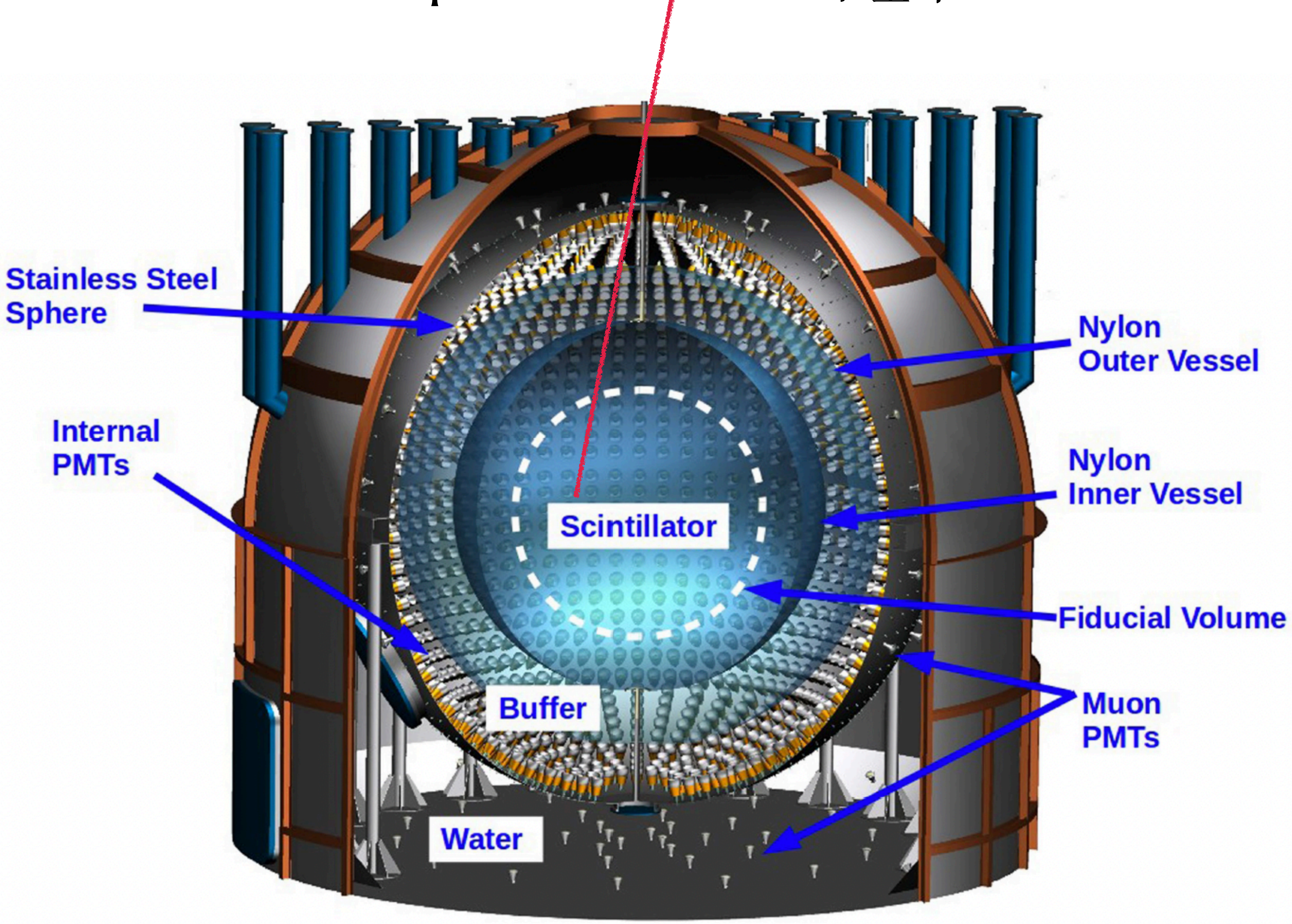
Cherenkov detector: Kamiokande

# Borexino

liquid scintillator detector

- world's most radio-pure liquid scintillator calorimeter
- Measure individual flux neutrino from the sun
- low energy (sub-MeV) solar neutrinos

pseudocumene 三甲基苯

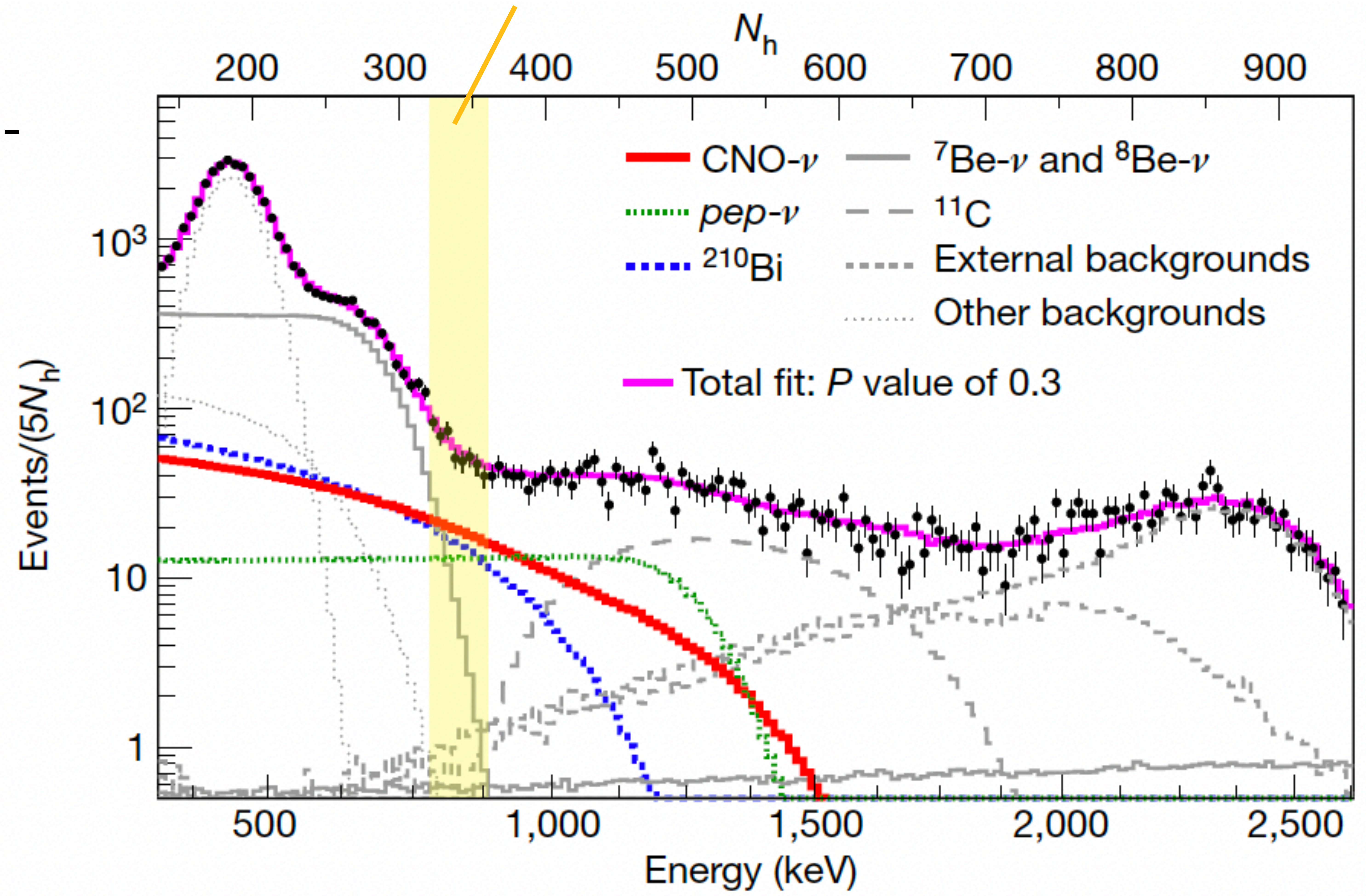


# Main challenge

- Neutrinos from the CNO cycle: 0 - 1740keV
- *pep* $- \nu$: constrained by solar luminosity
- Bi challenge:

1. The low polonium field
2. Spatial uniformity and time stability of Bi

largest signal to noise

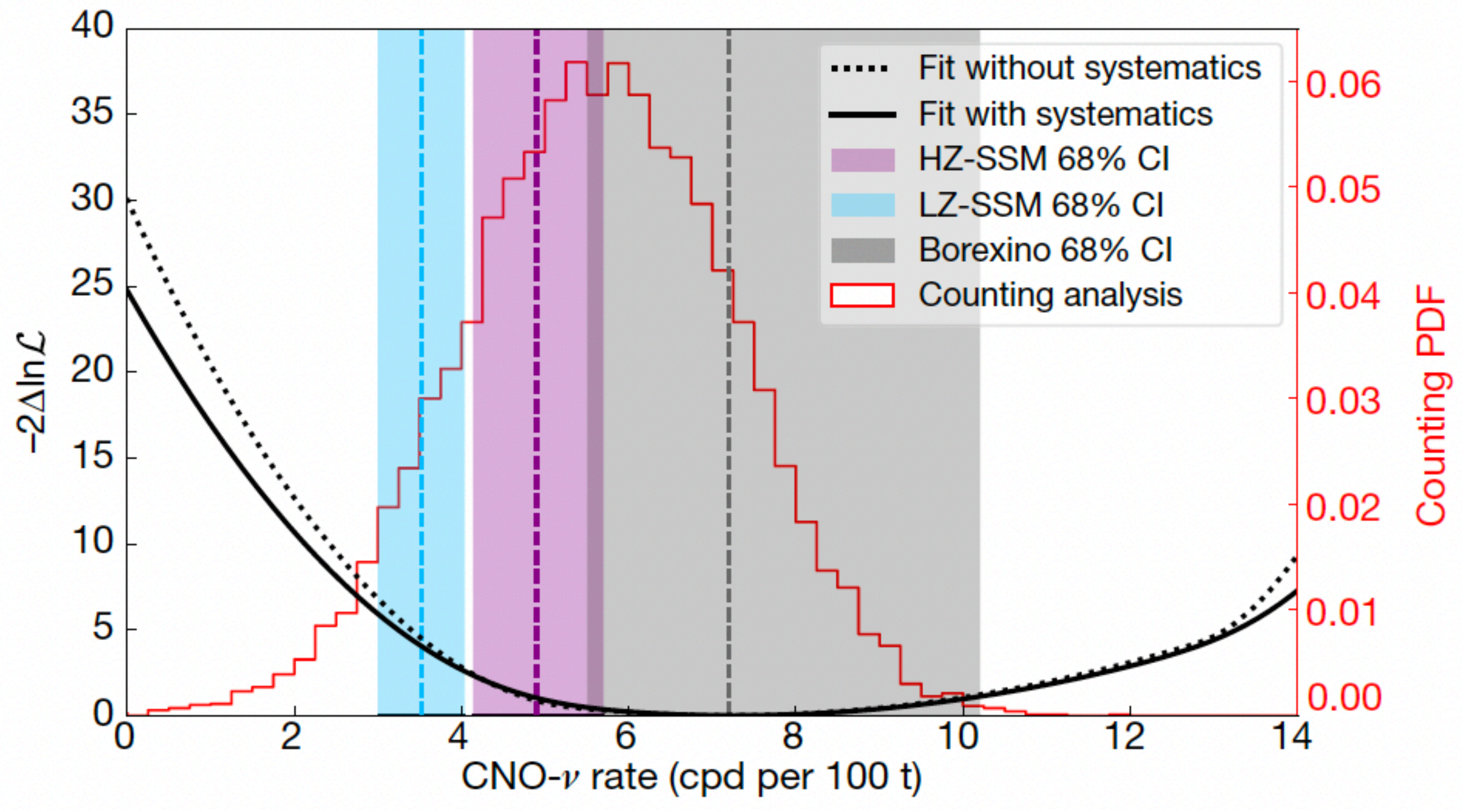


# Strategy

- Setup: thermal insulation, low polonium field, spatial uniformity and time stability of Bi
- June 2016 to February 2020 (Borexino Phase-III) : 320keV-2640keV
- CNO neutrinos are disentangled from residual backgrounds using a multivariate analysis:
  - Spilt data into three-fold-coincidence (TFC)-subtracted spectrum and TFC-tagged spectrum
  - frequentist hypothesis test

# Results & Conclusion

1. CNO neutrino of sun: $7.0^{+3.0}_{-2.0} \times 10^{8} cm^{-2} s^{-1}$
2. cannot distinguish between SSM-HZ and SSM-LZ



# It’s really a breakthrough for solar and stellar physics

# Summary

- CNO fusion is more important at heavier stars
- relative contribution of CNO fusion in the sun~1%
- Metallicity is critical to solar standard model
- Neutrinos only take part in weak interaction, provide information of deep solar core

# Thank you !

# Questions

- Is it possible that the neutrino detected are not from sun ?
- Since the detection cannot distinguish two theories, what can we do to distinguish them further?
- How far we are from neutrino astronomy?
- Will other neutrino detectors detect this signal in the future?
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