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CeSOX: An experimental test of the sterile neutrino hypothesis with Borexino

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on behalf of the Borexino collaboration

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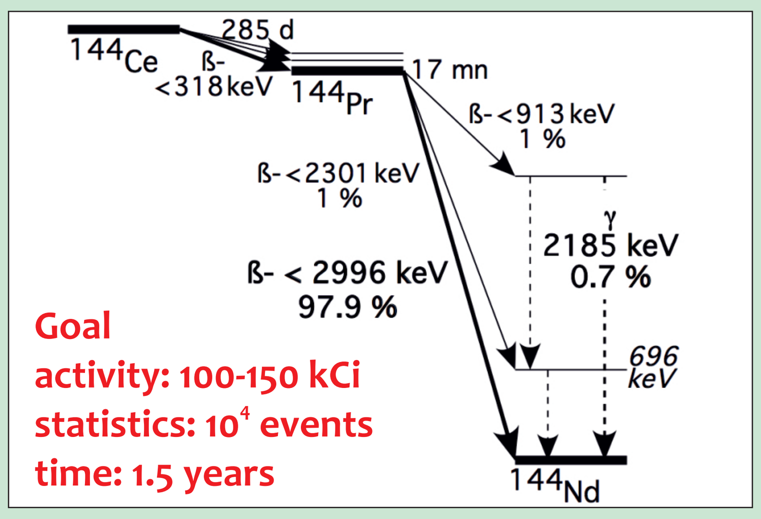
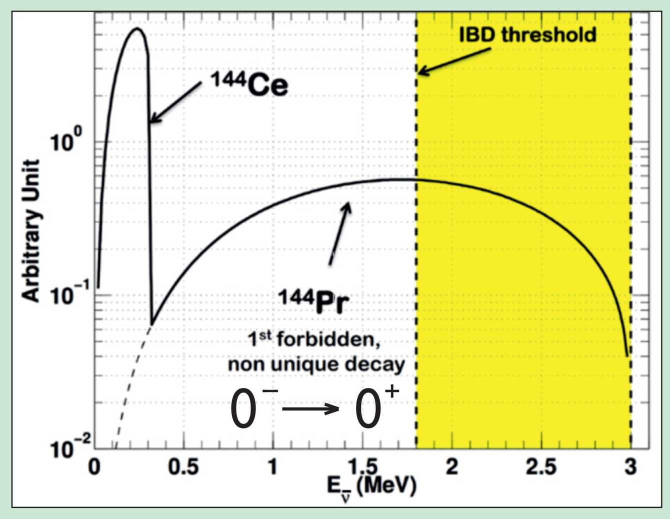
Abstract

The third phase of the Borexino experiment that's referred to as SOX is devoted to test the hypothesis of the existence of one (or more) sterile neutrinos at a short baseline (~5-10 m). The experimental measurement will be made with an artificial sources namely with a 144Ce-144Pr antineutrino source at the first stage (CeSOX) and possibly with a 51Cr neutrino source at the second one. The fixed ^{144}Ce-^{144}Pr sample will be placed beneath the detector in a special pit and the initial activity will be about 100-150 kCi. The start of data taking is scheduled for April 2018. The presentation gives a detailed description of the preparation for the first stage and shows the expected sensitivity.

^{144}Ce-^{144}Pr characteristics





Experimental hints

1) Accelerator anomaly:

LSND [1-4]: Appearance excess of $\bar{\nu}_e$ in a $\bar{\nu}_\mu$ beam at ≈3.8σ

KARMEN [5]: **no signal**

MiniBooNE [6,7]: Appearance excess of $\bar{\nu}_e$ in a $\bar{\nu}_\mu$ beam at ≈2.8σ
Appearance excess of ν_e in a ν_μ beam at ≈3.4σ

2) Gallium anomaly [8-13]:

SAGE [8,9]: calibrations with ^{51}Cr and ^{37}Ar neutrino sources

GALLEX: calibrations with two ^{51}Cr neutrino sources

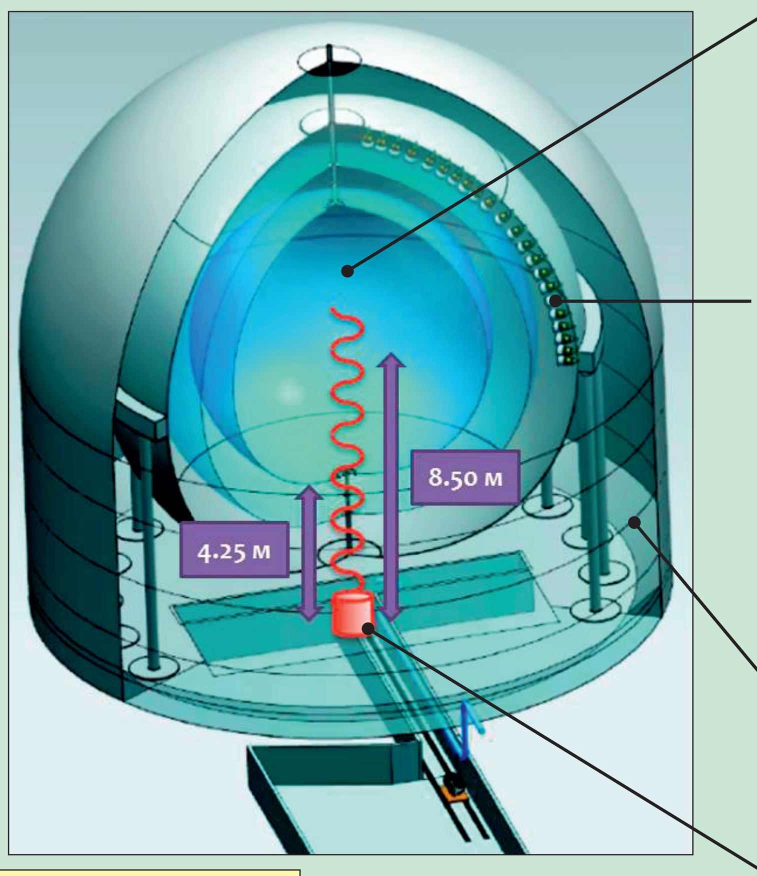
possible ν_e disappearance [14]: <R> = 0,84 ± 0,05, deficit at ≈2.9σ

3) Reactor anomaly [15]:

Re-evaluation of reactor antineutrino spectra results [16,17].
Observed rate deficit in all short-baseline (L = 10 - 100 m) reactor neutrino experiments [14]:
<R> = 0,934±0,024, deficit at ≈2.8σ

The reactor anomaly is strongly weakened by the recent results of Daya Bay [18]

Setup overview



Inner detector:
Scintillator target 278 t PC+PPO (1.5 g/l)
+ 2 buffer layers ~ 1000 m3 PC+DMP (2.0 g/l, light quenching)

2212 8" PMTs

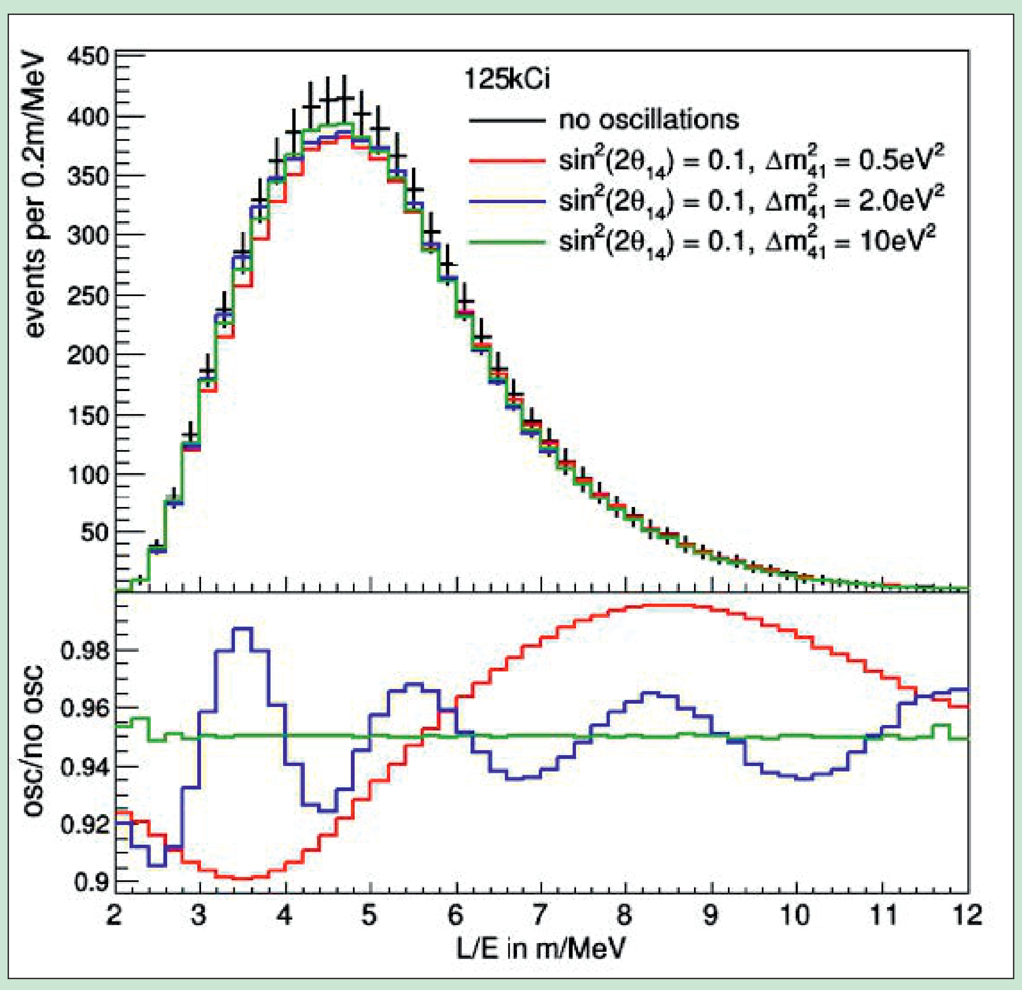
Outer detector:
Water tank - Cherenkov detector
2100 m^3, 208 8" PMTs in water
^{144}Ce-^{144}Pr $\bar{\nu}_e$ source in shielding

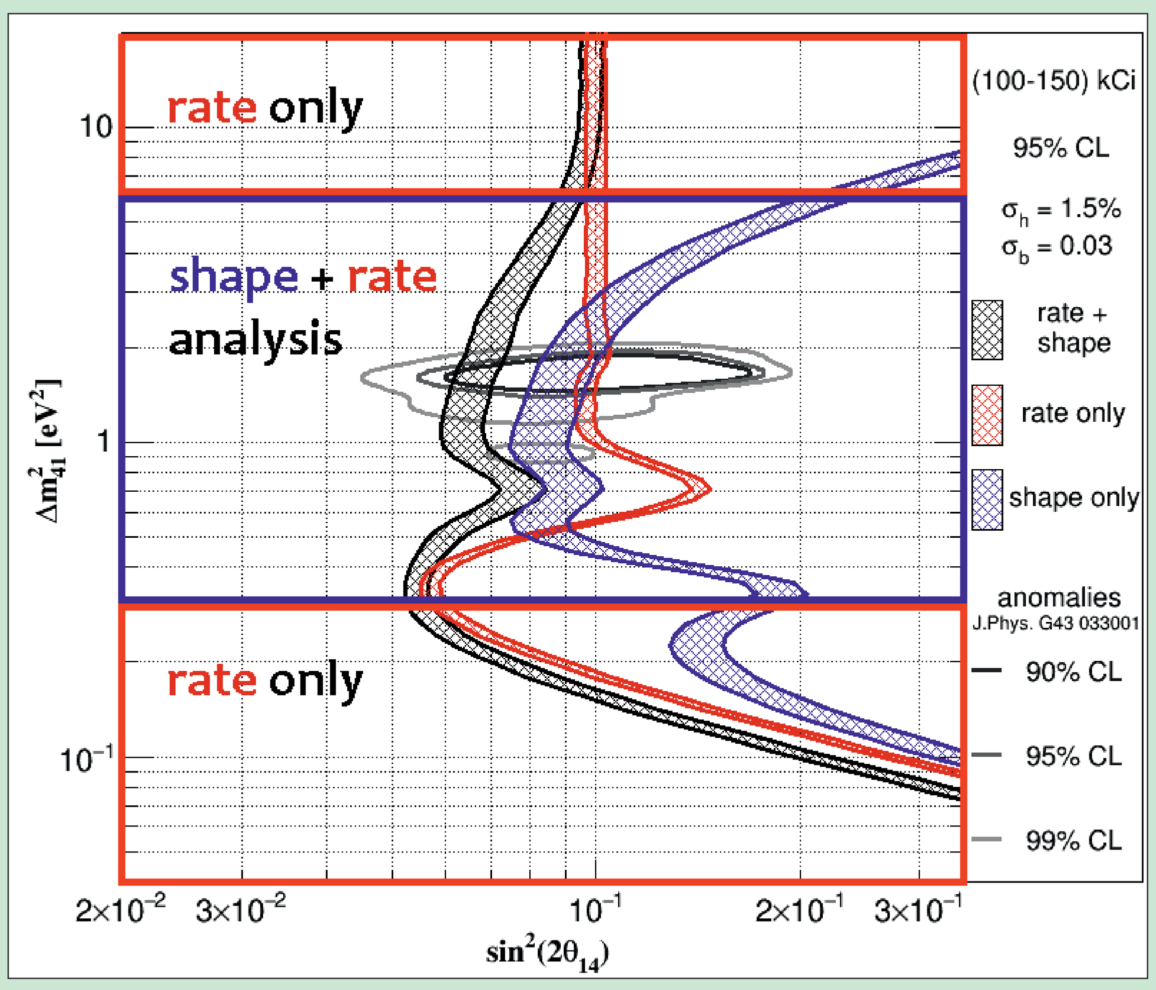
Characteristics of the Borexino detector

- Light yield: ~ 500 p.e./MeV
- Energy resolution: σ_E ~ 5% at 1 MeV
- Spatial resolution: σ_L ~ 10 cm at 1 MeV
- Pulse shape discrimination
- Ultra-high purity of the target
- Fiducial mass: ~ 240 t (increasing possible)
- ^{144}Ce-^{144}Pr $\bar{\nu}_e$ source
- IBD - mostly background free: ~ 15 ev/yr

L/E_ν ~ 1 m/MeV

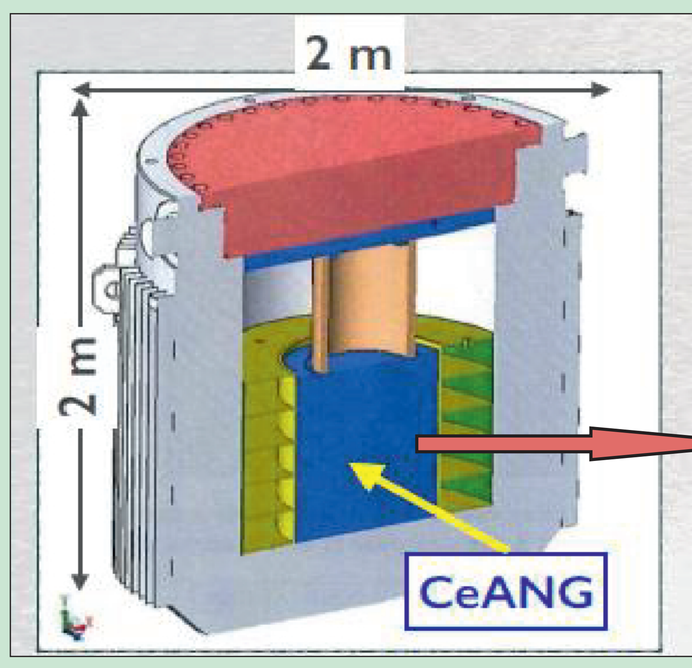
Sensitivity: rate + shape combined analysis

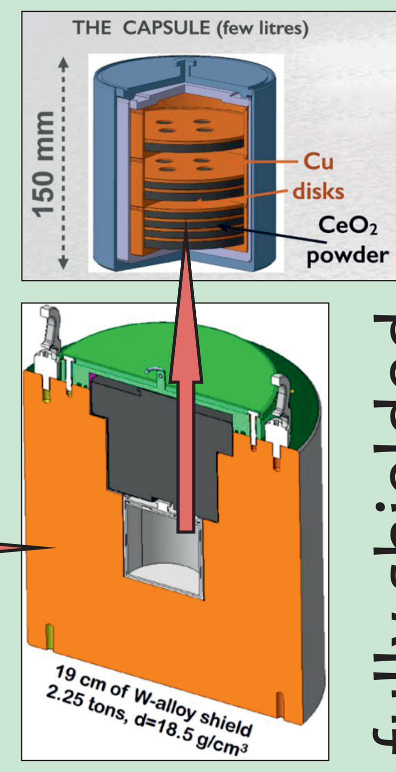




The "shape-analysis" is most powerful for 0.5 eV^2 < Δm^2_{14} < 5.0 eV^2

Source overview





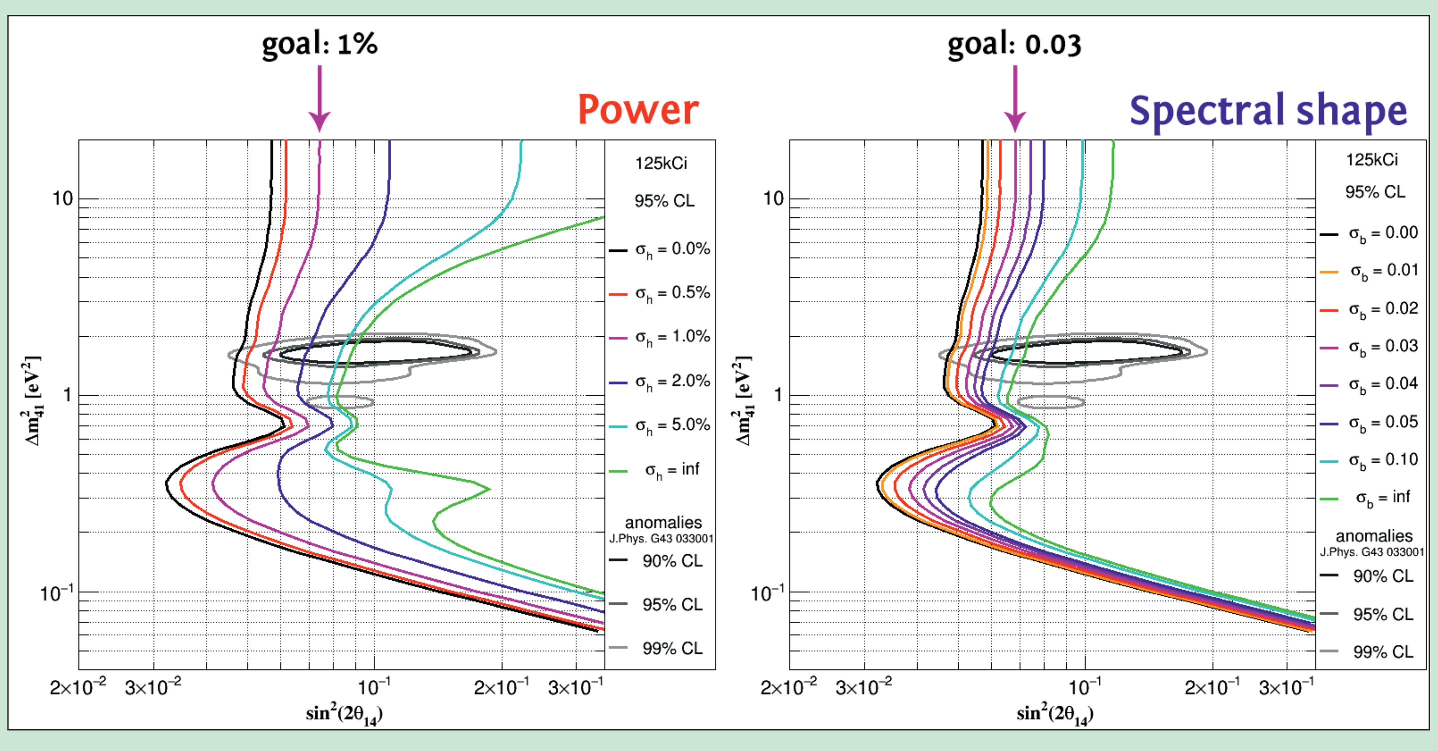
fully shielded

Route:
Mayak > by train > St. Petersburg > by boat > > Le Havre > by truck > Saclay > by truck > LNGS

Time: ~ 3 weeks **Loss of activity:** ~ 5%

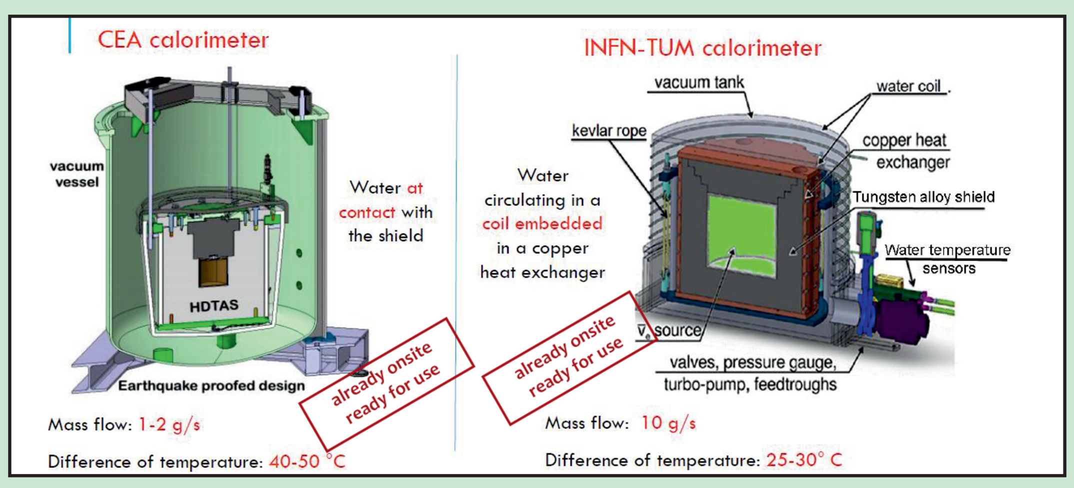
SOX will start data taking in April 2018

Source related systematics



$N(E_\nu, L, t) \sim S_\nu(E_\nu, L, b) \times A(b, t) \sim S_\nu(E_\nu, L, b) \times P(t)/\langle E(b)\rangle$, $S_\nu(E_\nu, L, b)$ - β-spectrum,
b - shape factor, $A(b, t)$ - activity, $P(t)$ - power, $\langle E(b)\rangle$ - mean energy per decay

heat production



Two measurements with different calorimeters

Calorimetric measurement will reach **1% precision or even better**

β-spectrum shape

^{144}Pr -spectrum: **old shape factor measurements differ by 10%**

$N(W) \approx Kp^2(W - W_0)^2F(Z, W)C(Z, W)$, $C(Z, W) = 1 + aW + b/W + cW^2$

4 exp. setups involved: CEA, TUM, PNPI and Kurchatov Institute (Moscow)

detector response

New calibration campaign

1) E and L resolutions, 2) true inner vessel shape, 3) MC tuning, 4) efficiency

Sources: ^{241}Am-^{9}Be+Ni (n), ^{68}Ga-^{68}Ge (e^+), ^{222}Rn+^{14}C (α, β, γ), ^{54}Mn, ^{65}Zn, ^{40}K, ^{85}Sr

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