

Measuring the ^{14}C Content in Liquid Scintillators

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^{14}C Measurements

Introduction

- ▶ Measurement of $^{14}\text{C}/^{12}\text{C}$ ratio of several liquid scintillator samples
 - ▶ currently the lowest concentration: $^{14}\text{C}/^{12}\text{C} \sim 2 \times 10^{-18}$
 - ▶ aim to observe $R < 10^{-18}$
- ▶ If calculated from the ^{14}C half life (~ 5700 a) and the age of oil/gas sources,
 - ▶ the ratio $^{14}\text{C}/^{12}\text{C}$ should be $\sim 10^{-21} - 10^{-22}$
 - ▶ contamination from local environment (U, Th, K, ...)
- ▶ Measurements in two laboratories
 - ▶ Baksan Underground Laboratory, Russia, at 4900 mwe
 - ▶ Pyhäsalmi Mine (CallioLab), Finland, at 4000 mwe
 - ▶ \sim similar method, \sim similar shielding
- ▶ Schedule
 - ▶ Baksan – measurements already started (first preliminary results)
 - ▶ Pyhäsalmi – starting still this year

^{14}C Measurements

Motivation

- ▶ Detector development
 - ▶ low-background liquid scintillator detector
- ▶ The decay energy of ^{14}C is small ($Q_\beta=156$ keV)
 - ▶ usually below the threshold
- ▶ If the ^{14}C concentration too large \implies pulses may pile-up
- ▶ In JUNO the upper limit is: $^{14}\text{C}/^{12}\text{C} \sim 10^{-17}$
 - ▶ JUNO (Jiangmen Underground Neutrino Observatory) is a 20 kton LS detector under construction in China for ν mass hierarchy measurements
- ▶ LAB (Linear Alkyl Benzene) is currently the favoured liquid scintillator in large LS detectors
 - ▶ SNO+ (1 kton) in Canada, JUNO (20 kton in China)
 - ▶ ^{14}C concentration of LAB not measured before

^{14}C Measurements

Earlier measurements for $^{14}\text{C}/^{12}\text{C}$

$^{14}\text{C}/^{12}\text{C} (\times 10^{-18})$	Liquid Scintillator	Experiment	[Ref]
(1.94 ± 0.09)	PC+PPO	Borexino CTF	[1]
(9.1 ± 0.4)	PXE+p-Tp+...	Borexino CTF	[2]
(3.98 ± 0.94)	PC-Dodecane+PPO	KamLAND	[3]
(12.6 ± 0.4)	PXE+p-Tp+...	Dedicated setup	[4]

[1] G. Alimonti *et al.*, Physics Letters B 422 (1998) 349

[2] H.O. Back *et al.*, Nuclear Instrum. Methods A 585 (2008) 48

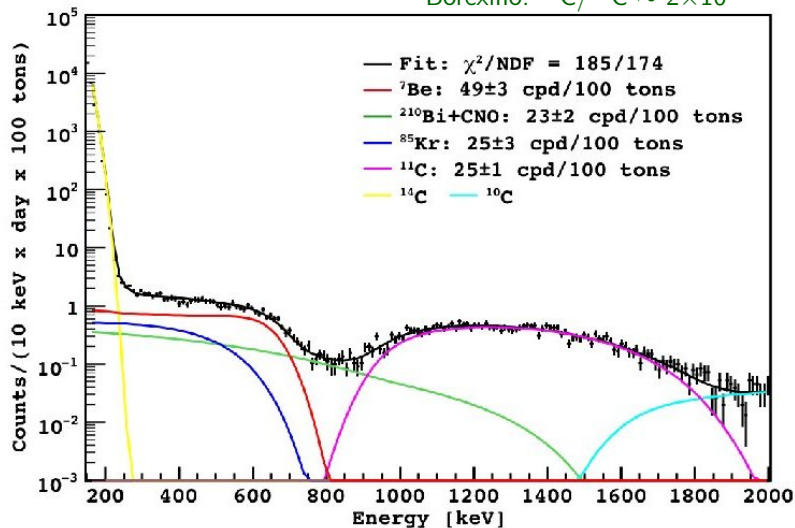
[3] G. Keefer, arXiv:1102.3786

[4] C. Buck *et al.*, Instrum. and Experim. Techniques 55 (2012) 34

^{14}C Measurements

^{14}C background in Borexino

Borexino: $^{14}\text{C}/^{12}\text{C} \sim 2 \times 10^{-18}$



^{14}C Measurements

Baksan – The LAB (Russian)

- ▶ Composition



$\text{C}_{16}\text{H}_{26}$ (0.125), $\text{C}_{17}\text{H}_{28}$ (0.293), $\text{C}_{18}\text{H}_{30}$ (0.315), $\text{C}_{19}\text{H}_{32}$ (0.267)

- ▶ Density 0.856 g/cm^3

- ▶ Light yield $\sim 8000 \text{ photons/MeV}$ (@ $\sim 400 \text{ nm}$)

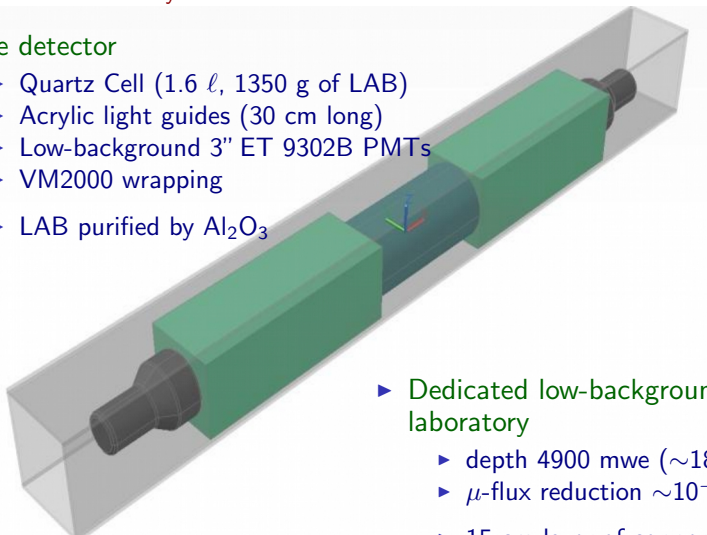
- ▶ PPO 2 g/l

^{14}C Measurements

Baksan – The detector system

► The detector

- Quartz Cell (1.6 ℓ , 1350 g of LAB)
- Acrylic light guides (30 cm long)
- Low-background 3" ET 9302B PMTs
- VM2000 wrapping
- LAB purified by Al_2O_3

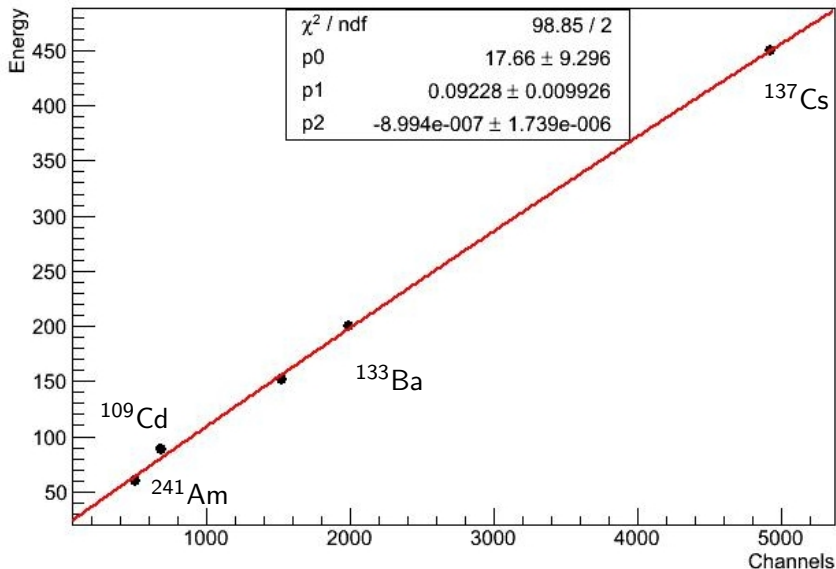


► Dedicated low-background laboratory

- depth 4900 mwe (~ 1800 m)
- μ -flux reduction $\sim 10^{-7}$
- 15 cm layer of copper around the vessel and PMTs

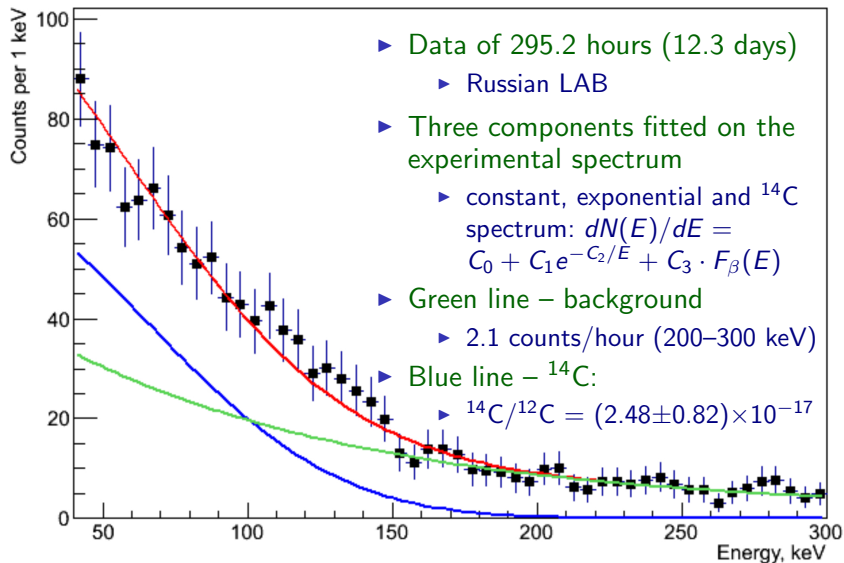
^{14}C Measurements

Baksan – Calibration curve



^{14}C Measurements

Baksan – Data analysis, preliminary (part of the data only)



^{14}C Measurements

Baksan – Conclusions

- ▶ Measurements started in Baksan Underground Laboratory
 - ▶ data analysis of 295.2 hours (12.3 days) resulted in the value of $^{14}\text{C}/^{12}\text{C} = (2.48 \pm 0.82) \times 10^{-17}$
 - ▶ close to the requirement by JUNO
- ▶ First measurement with a small sample of LS confirmed a possibility of ^{14}C -concentration determination using such a small dedicated setup
 - ▶ Dedicated low-background hall at the depth of 4900 mwe
- ▶ Background
 - ▶ quite high, probably from radon (contact with air during the purification of the liquid)
 - ▶ method developed to purify radon
- ▶ Measurements of $^{14}\text{C}/^{12}\text{C}$ ratio starting in Pyhäsalmi Mine