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Measurements of light yield quenching and the ^{14}C content in liquid scintillator of 5 ton prototype of Baksan Large Neutrino Telescope Project

A. Sidorenkov, A. Budzinskaya, A. Fazliakhmetov, B. Lubsandorzhiev, A. Lukanov, D. Nanzanov, N. Ushakov, D. Voronin

Institute for Nuclear Research of the Russian Academy of Sciences

Liquid scintillator of the prototype of BBNT Project

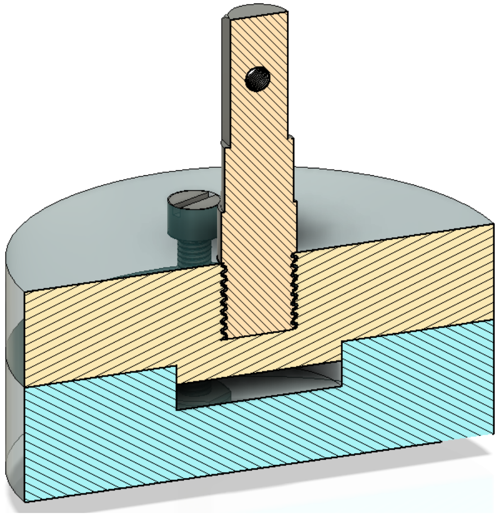
The prototype of BBNT:

- Acrylic sphere with about 400 kg liquid scintillator
- 20 Hamamatsu R7081-100 PMTs (10-inch)
- Water-filled cylindrical polypropylene tank

Liquid scintillator recipe:

- Linear alkylbenzene (LAB) + 2 g/L 2,5-diphenyloxazole (PPO) + 10 mg/L 1,4-bis(2-methylstyryl)benzene (bis-MSB)

Energy calibration



Radioactive sources: ^{241}Am, ^{109}Cd, ^{22}Na, ^{133}Ba, ^{137}Cs, ^{60}Co

Light yield quenching and Birks’ formula

- Many aspects of the output of the scintillation process depends on the energy loss dE/dx of the incident particle

- Heavily ionizing particle (high dE/dx) -> high density of excited and ionized molecule -> high probability of non radiative decay to ground state through their interaction and hence less energy converted into light – ionization quenching

- This effect is phenomenologically captured by the Birks’ formula

Light yield quenching and Birks' formula

- For an ideal scintillator and low ionization density:
  luminescence ∝ energy dissipated in scintillator

$$L = SE$$

or, in differential form

$$\frac{dL}{dx} = S\frac{dE}{dx}$$

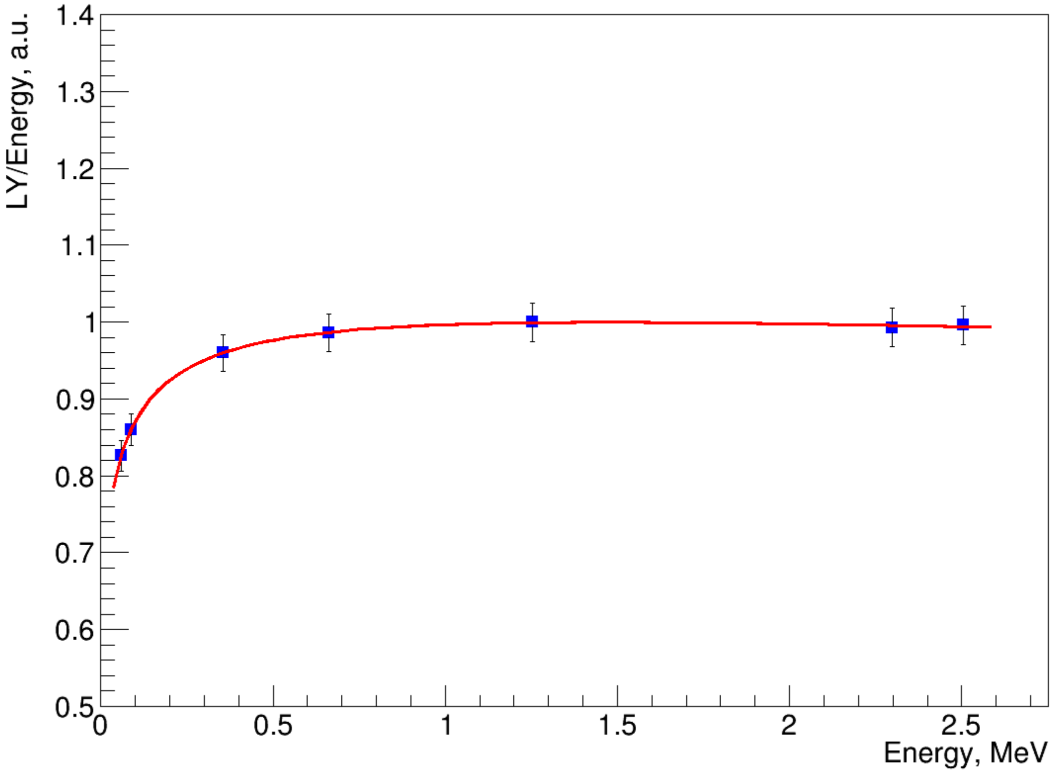
- Assume that a portion of the primary excitation is lost at high ionization density (ionization quenching) and introduce a quenching parameter. Then

$$\frac{dL}{dx} = \frac{S\frac{dE}{dx}}{1 + kB\frac{dE}{dx}}$$

- For smaller dE/dx this yield the luminescence yield postulated above.
- For large dE/dx the specific luminescence saturates.

$$\frac{dL}{dx} = \frac{S}{kB} = const$$

Birks parameter determination



The value of the Birks parameter kB was obtained fitting with the relative total light yield equation. The scintillation efficiency S was assumed to be 1.

$$L(E) = \int_0^E \frac{S\,\mathrm{d}E}{1 + kB\,\frac{\mathrm{d}E}{\mathrm{d}x}}$$

$$L'(E) = \frac{L(E)}{E}\,,$$

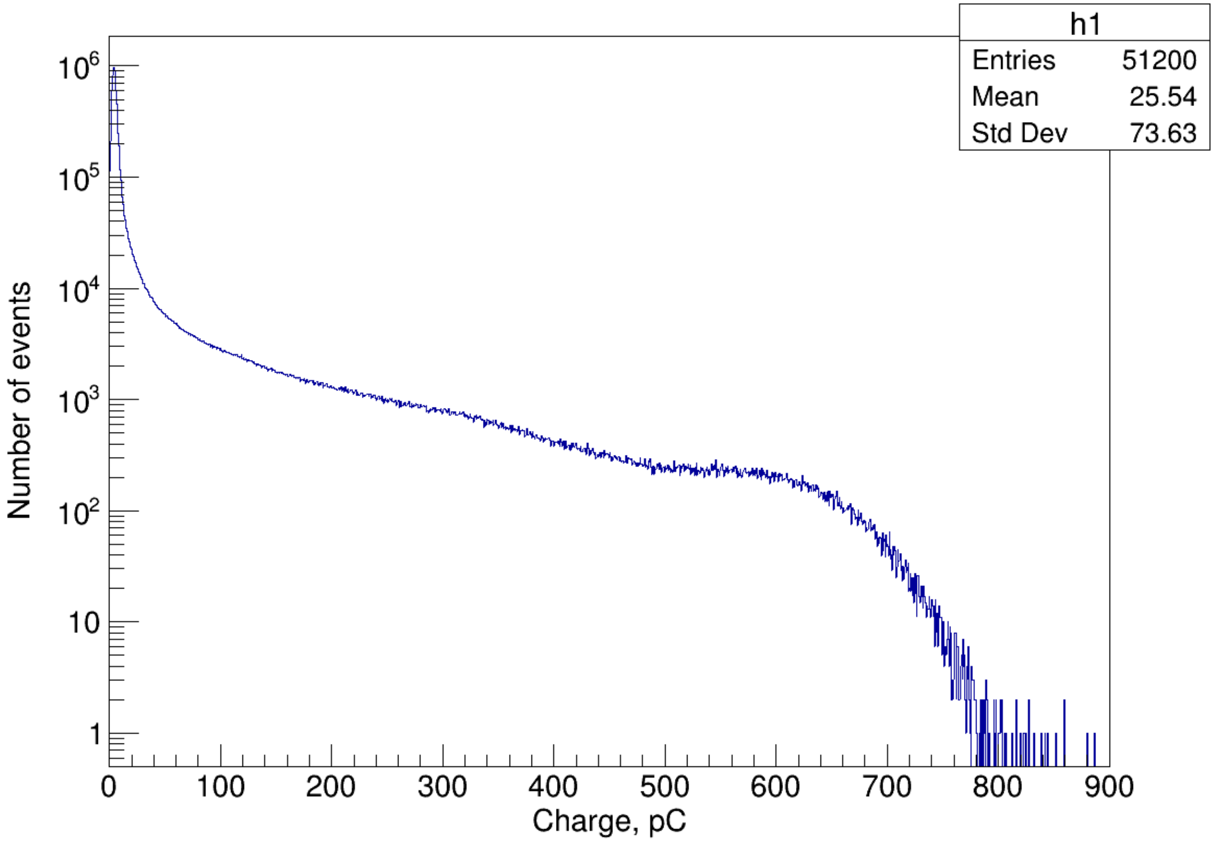
$$S = 1.$$

kB=0.016 ± 0.001 g MeV^{-1} cm^{-2}

Measurements of ^{14}C content

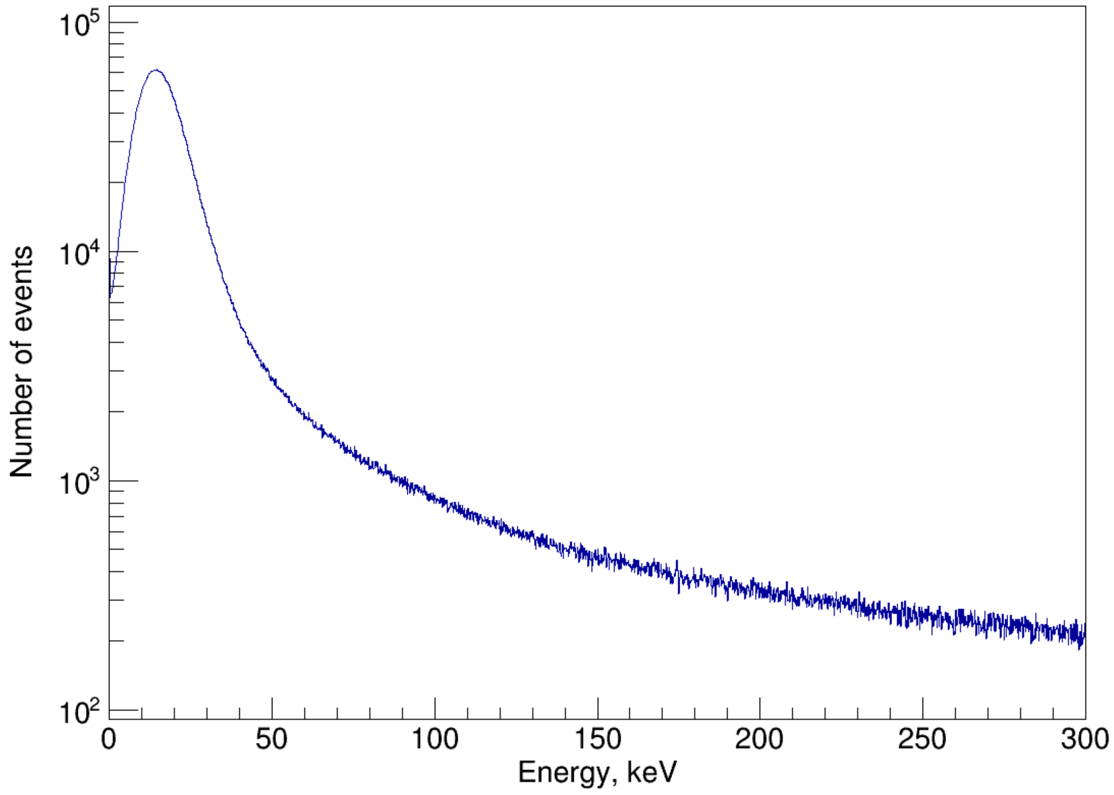
- The decay energy of ^{14}C is small (Q_β=156 keV)
- If the ^{14}C concentration too large $\Rightarrow$ pulses may pile-up
- Currently the lowest concentration: $^{14}C/^{12}C \sim 2 \times 10^{-18}$ (Borexino)
- In JUNO the expected upper limit is: $^{14}C/^{12}C \sim 10^{-17}$

Measurements of ^{14}C content



The background energy spectrum measured using the prototype of BBNT

Measurements of ^{14}C content



Threshold < 50 keV
The upper limit of ^{14}C content in the LAB-based scintillator of the 0.5 ton prototype was estimated:
$^{14}C/^{12}C \sim < 7\times 10^{-16}$ (preliminary)

Conclusion

- Based on the results of the calibration of the prototype detector, the Birks parameter was calculated: kB=0.016 ± 0.001 g MeV^{-1} cm^{-2}
- A preliminary estimation of the ^{14}C content in the scintillator prototype was carried out: $^{14}C/^{12}C \sim 7\times 10^{-16}$
- Further studies on the ^{14}C content are planned after background reduction and repeat calibrations of the detector.