Source induced backgrounds - Gammas

CeSox collaboration meeting - APC

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February 05th, 2014

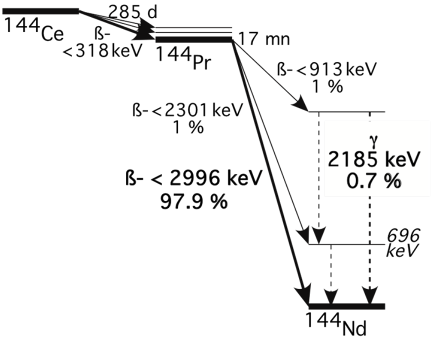
Outline

Introduction

- Study the source induced gamma background
- Gammas are randomly emitted in the source and create accidental background
- Neutrino spectrum below 3 MeV and neutron capture at 2.2 MeV $\rightarrow$ Very sensitive
- Simulations will give exact attenuation and detected energy spectra

^{144}Ce-^{144}Pr source γ emission

- 100 kCi (4 PBq)
- 2 main gammas emitted through ^{144}Pr decay $\rightarrow$ 1.489 and 2.185 MeV
- Respective BR's of 0.3 and 0.7 %
- Focus: 2.185 MeV γ $\rightarrow$ Background for n-H capture at 2.2 MeV
- Also the most energetic, penetrating and frequent γ emission



Outline

Important !

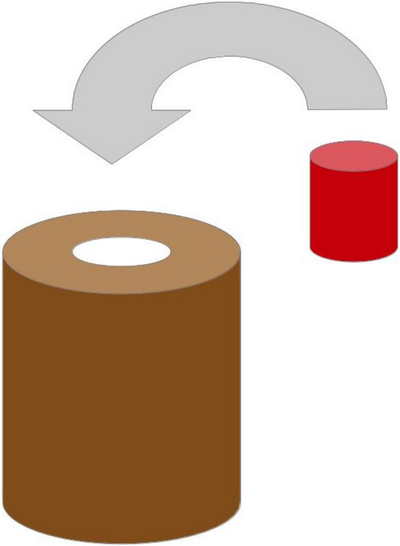
The following simulations are done using the KamLAND simulation package !

The numbers are extrapolated using basic geometry and attenuations calculations

$\rightarrow$ Need to use the full Borexino simulation package

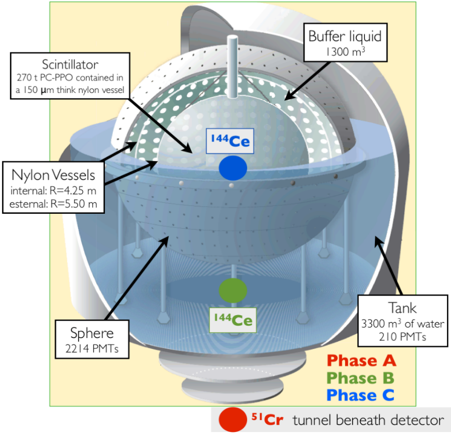
The CeSox Geant4 geometry

- Source
  - Made of CeO_2
  - 70 mm half-height, 70 mm radius
- Shielding
  - Made of tungsten alloy (d = 18.5)
  - Thickness of 16 cm



Simulation setup

- Simulation of CeLAND in water OD (CeSox @ 8.25 m)
- Source center located at 9.3 m from KamLAND center (8.25 m from Borexino center)
- Biological shielding $\rightarrow$ 16 cm thick Densimet185 cylinder
- 2.185 MeV γ's shot isotropically and distributed randomly in the CeO_2 source



Cuts and expectation

- Cuts applied (regular KamLAND $\bar{\nu_e}$ cuts)
  - Prompt energy: $[0.9 - 2.6]\ MeV$
  - Delayed energy: $[1.8 - 2.6]\ MeV$
  - Volume cuts:
    - Fiducial volume $[0 - 6]\ m$
    - $\Delta R < 2\ m$
- We expect an attenuation of 10^{12} after all cuts (for KamLAND)

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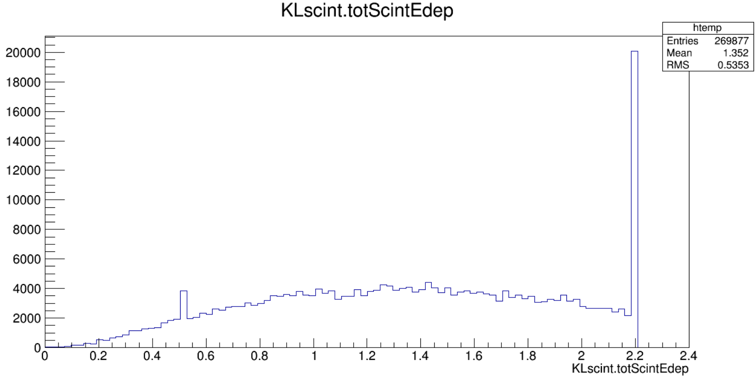
2. CeSox simulation
3. Results
4. Conclusion

Intermediate attenuation

- Results after shield only (no OD, no buffer, no geometry effect)
- Energy spectrum of escaping γ's $\rightarrow$

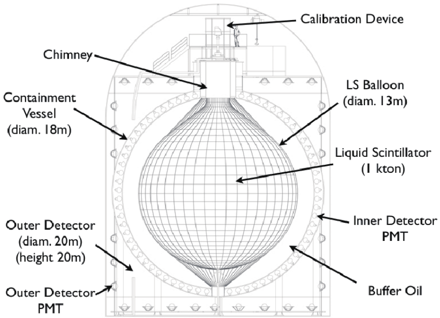


Attenuation: 3×10^5 (no energy cuts)

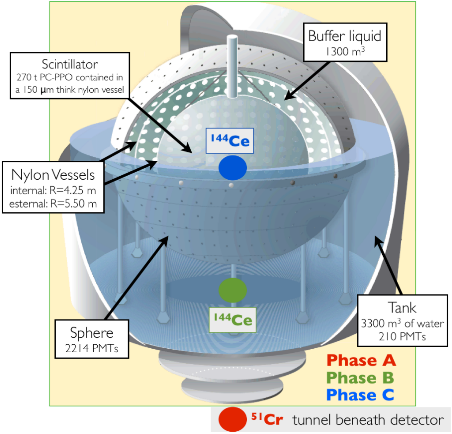
Complete attenuation

- We simulated 1.05×10^{12} gammas
- They went through shield + water + PMT's + buffer
- Out of these gammas:
  - 30 deposited energy in the LS
  - 4 deposited more than 0.9 MeV (prompt)
  - 0 deposited more than 1.8 MeV (delayed)
  - 0 entered the 6 m radius fiducial volume
- Giving an attenuation of:
  - No cuts: 3.5×10^{10} ($R_{singles} = 800\ Hz$)
  - All cuts: $> 1.05 \times 10^{12}$ ($R_{singles} < 27\ Hz$)

KamLAND-Borexino differences



Attenuation = 2.5 m buffer + 0.5 m scintillator (non-fiducial)



Attenuation = 2.6 m buffer + 10 cm steel plate

Results - Borexino

- Solid angle:
  - KamLAND $\rightarrow$ 6 m radius, source @ 9.6 m $\rightarrow \Omega = 0.0977\ sr$
  - Borexino $\rightarrow$ 4.25 m radius, source @ 8.25 m $\rightarrow \Omega = 0.0663\ sr$
- Buffer thickness:
  - Assuming a gamma attenuation length of 20 cm in oil (for 2 MeV gammas)
  - KamLAND $\rightarrow$ 3 m of oil
  - Borexino $\rightarrow$ 2.6 m of oil $\rightarrow$ Two attenuation length missing

Attenuation (no cuts): $7.2 \times 10^9\ (R_{singles} \sim 3.9\ kHz)$
Attenuation (KamLAND cuts): $> 2.01 \times 10^{11}\ (R_{singles} < 140\ Hz)$

Noteworthy

- Time consuming simulations

  $\rightarrow$ "1 s of CeSox" $\sim$ 400 000 simulation hours !

- Design updates: 8.25 m from center + 19 cm W-shield + 10 cm steel plate

  $\rightarrow$ More attenuation expected

  $\rightarrow$ Factor 10 expected from the 3 cm of additional W ($\lambda_{att} = 1.2\ cm$)

  $\rightarrow$ Factor 30 expected from the 10 cm of additional Fe ($\lambda_{att} = 3\ cm$)

Preliminary accidental rates

- Inputs:
  - Activity → 100 kCi
  - Singles rate (no cuts) $\sim\ 4.2\ kHz\ \times\ \frac{1}{10}\ \times\ \frac{1}{30}\ \sim\ 14\ Hz$
  - Prompt/singles ratio: $\epsilon_p = 0.77$, Delayed/singles ratio: $\epsilon_d = 0.26$
  - Coincidence time cut: $\Delta T = 1000\ \mu s$
  - Coincidence volume efficiency: $\frac{\Delta V}{V} = \frac{1}{16}$

- Accidental rate (Hz) $= (R_p\ \times\ \epsilon_p)(R_d\ \times\ \epsilon_d)\ \times\ \Delta T\ \times\ \frac{\Delta V}{V}$

  $$\rightarrow R_{acc}\ =\ 2.5\ mHz\ (210\ evt.d^{-1})$$

Next steps

- Use the complete Borexino Geant4 simulation
- Use biaising techniques to increase simulation speed
- Use another simulation code to cross-check and obtain faster results

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Conclusion

- Expected attenuation seems too low
- Additional 3 cm plate of Densimet might be worth installing
- Statistics are too low to give a definitive answer though
- Stay tuned for the new results with Borexino MC !

Thanks

Thank you for your attention !