Low energy radioactivity BG model in Super-Kamiokande detector from SK-IV data

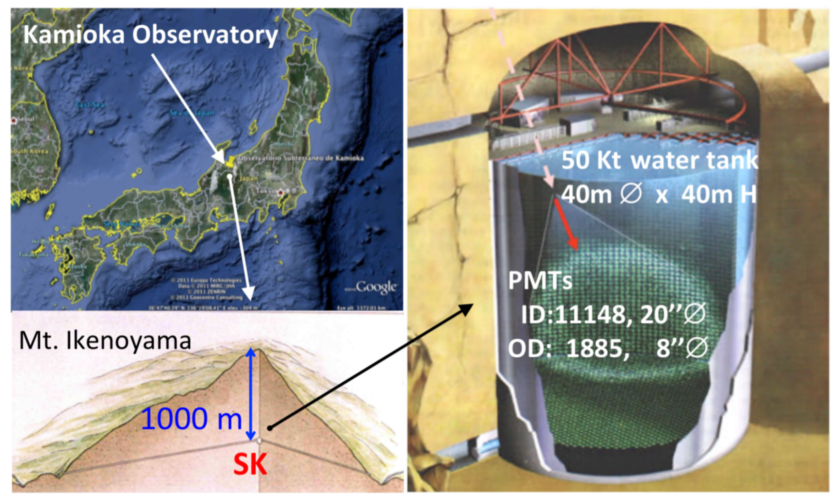
Guillaume Pronost,

on behalf of the Super-Kamiokande Collaboration

Kamioka Observatory, ICRR, The University of Tokyo

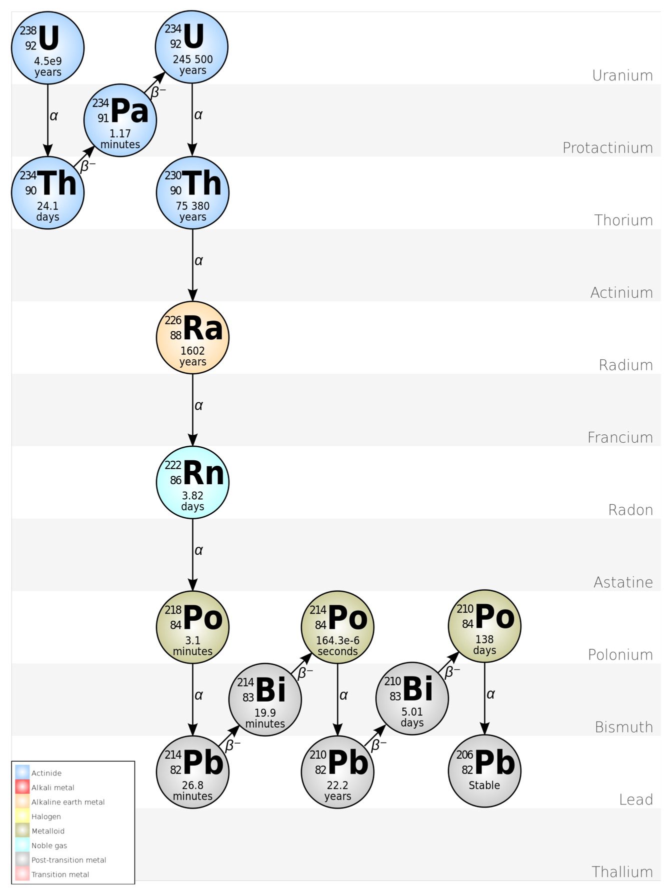
1 Context: Super-Kamiokande experiment

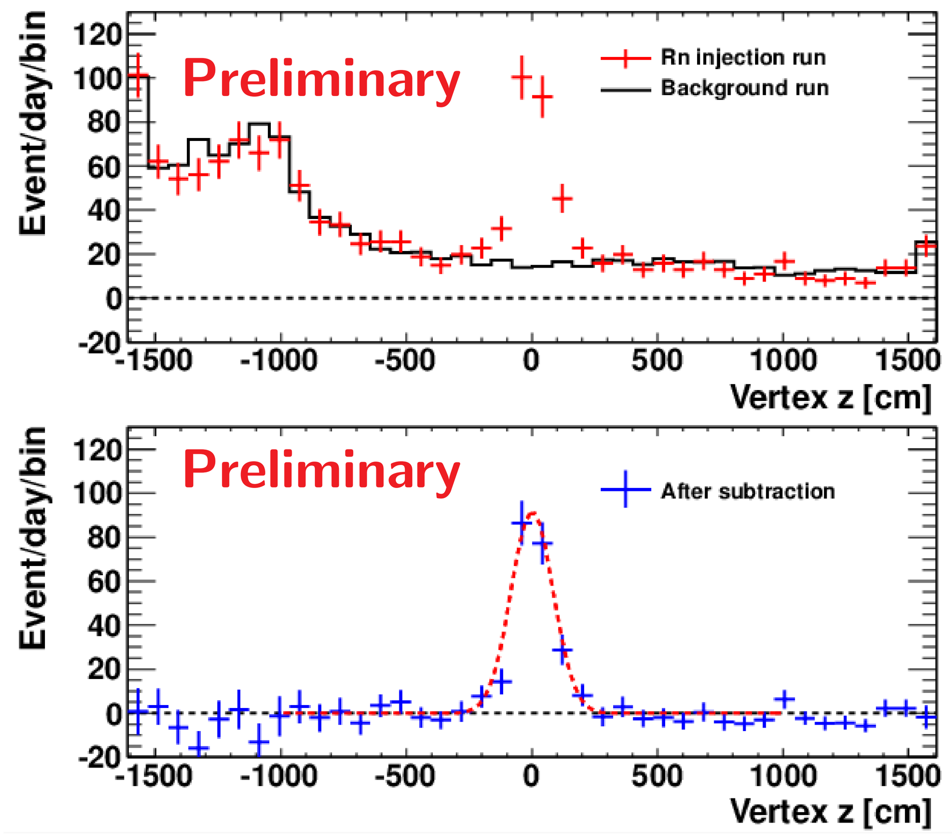
- Super-Kamiokande (SK) is a neutrino experiment located in the Kamioka mine, about 1 km under Mt. Ike (Ikenoyama), in Kamioka-cho (Japan).
- The detector is a 50 ktons water Cerenkov detector and has been operated since 1996. In Summer 2020, it was loaded with 0.01% of Gd, in order to improve the neutron tagging efficiency.
- The Super-Kamiokande Collaboration is working on analysis covering a large part of the neutrino energy spectrum: from MeV (Solar neutrinos, Supernova Relic neutron, etc.) to TeV (atmospheric neutrinos)



2 Radon background

- Radon (^{222}Rn) is one of the dominant backgrounds < 5 MeV in Water Čerenkov detectors.
- In the radon decay chain, ^{214}Bi is likely the main source of background for Water Čerenkov detector's low energy analysis, decaying with the emission of an e^- whose energy can reach up to 3.27 MeV. Due to the energy resolution, such events can affect the full low energy range.
- Rn injection studies in SK allowed to determine that 0.138 ± 0.026 mBq/m^3 of radon were enough to cause 10 evt/day/ktons [1] in the low energy region ($E_{kin} \in [3.5, 5]$ MeV).
- In a Water Čerenkov detector, the sources of radon are mostly the photomultipliers (PMTs) glass and covers which emanate radon, and the pure water itself, whose radon concentration can not be totally reduced.

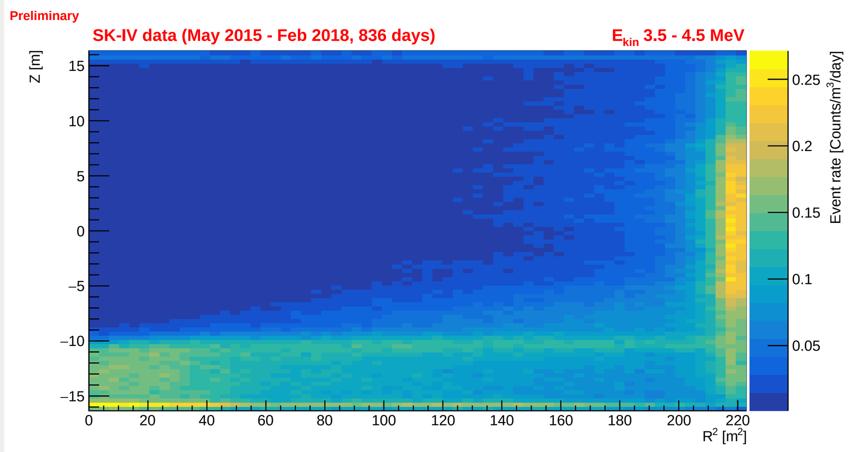


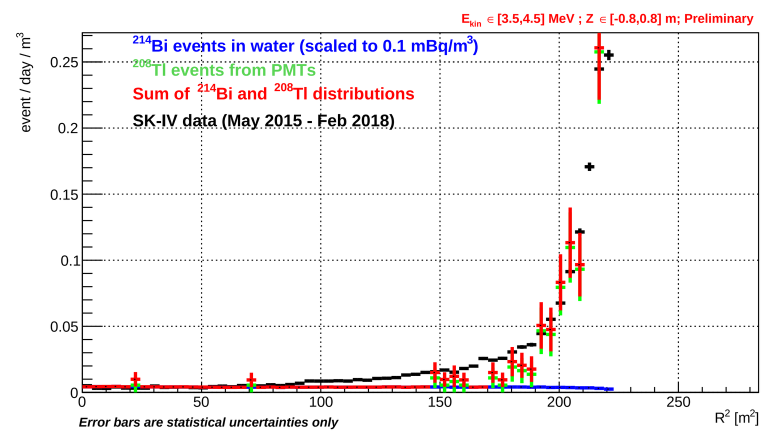


SK Rn injection 2016 study [1]

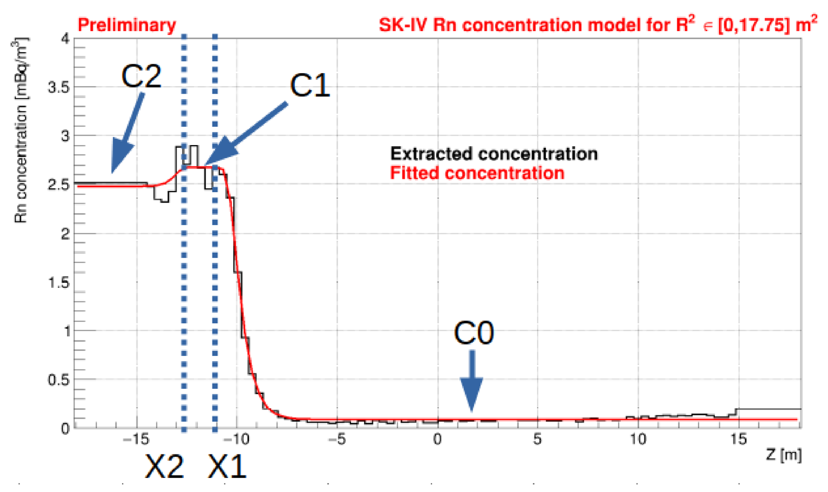
3 Using SK data for radon modelling

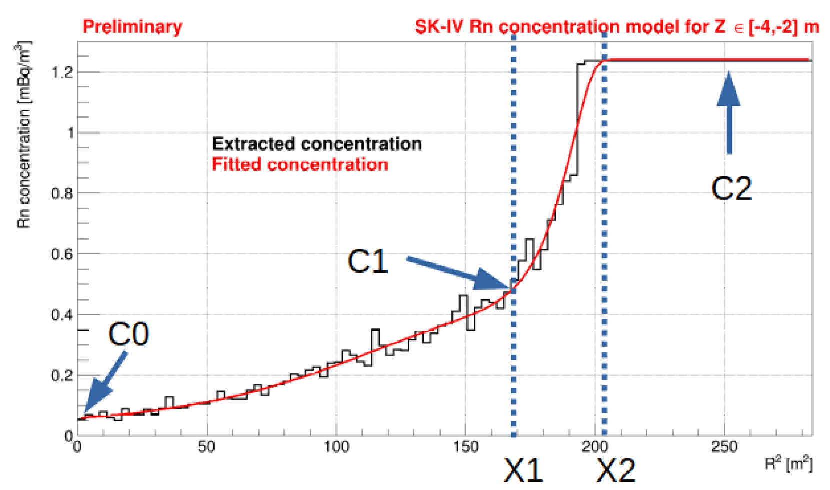
- In order to improve our understanding of the radon background, we can extract radon-like events from the low energy data and derive them to a distribution of the radon concentration in the detector.
- For this studies, we selected the period with the highest trigger efficiency for $E_{kin} \in [3.5, 4]$ MeV in the SK-IV solar data sample.





- Using MC simulations, we identified a contribution of ^{208}Tl in the borders of the fiducial volume, compatible with the expected ^{232}Th radioactivity from the PMT covers and glass (39 $\sim$ 120 Bq/PMTs)
- To extract the Rn concentration from the data, we divided the detector in different layers (18 over Z-axis, 16 over R^2-axis) and performed a bin-to-bin comparison in each layer between data and a ^{214}Bi MC simulation, assuming all events were due to radon. The region near the border of the Fiducial Volume (FV) was excluded to avoid ^{208}Tl contamination.





- Each distribution was then fitted to obtain a Rn concentration function:

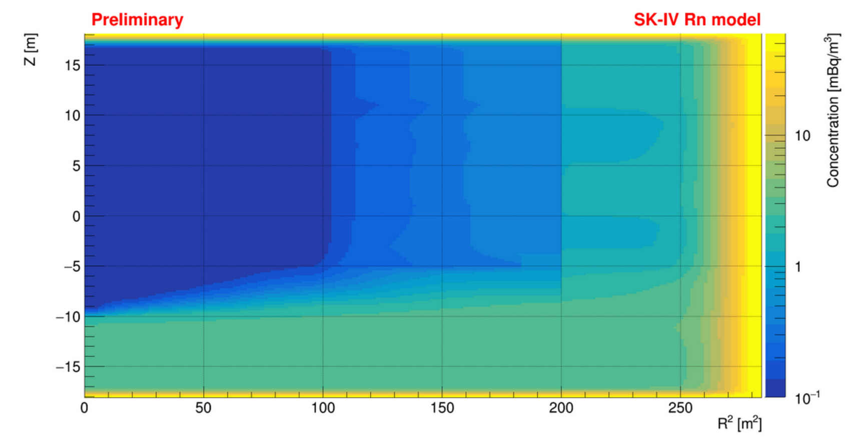
$$f_Z(x) = \begin{cases} C2 + (C1 - C2) * \mathrm{Diff}(x, X2, S2), & \text{if } x < X2 \\ C1, & \text{if } x < X1 \text{ and } x > X2 \\ C0 + (C1 - C0) * \mathrm{Diff}(x, X1, S1), & \text{otherwise} \end{cases}$$

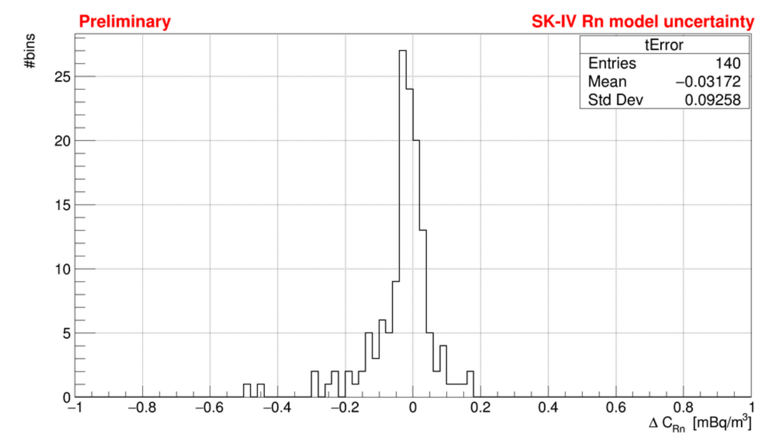
$$f_{R^2}(x) = \begin{cases} C2, & \text{if } x > X2 \\ C1 + (C2 - C1) * \mathrm{Diff}(\sqrt{x}, \sqrt{X2}, S2), & \text{if } x > X1 \text{ and } x < X2 \\ C0 + (C2 - C1) * \mathrm{Diff}(\sqrt{x}, \sqrt{X2}, S2) & \\ \quad + (C1 - C0) * \mathrm{Diff}(\sqrt{x}, \sqrt{X1}, S1), & \text{otherwise} \end{cases}$$

- with C0, C1, C2, X1, X2, S1, and S2 the fit parameters. Diff(x,X,S) is a function representing the radon diffusion in water from X, following a $1/\cosh((x - X) * \sqrt{\lambda_{Rn}/S})$ function [3].

4 Radon model

- The Rn model is then defined with the interpolation of each f_Z and f_{R^2} Rn concentration functions.

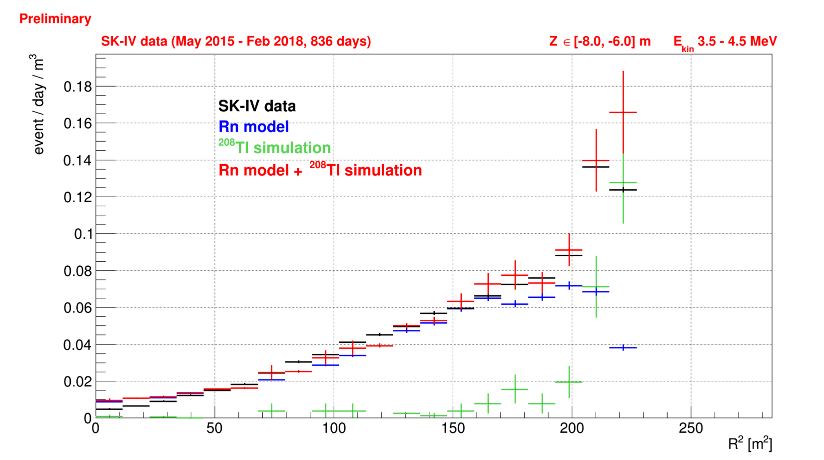


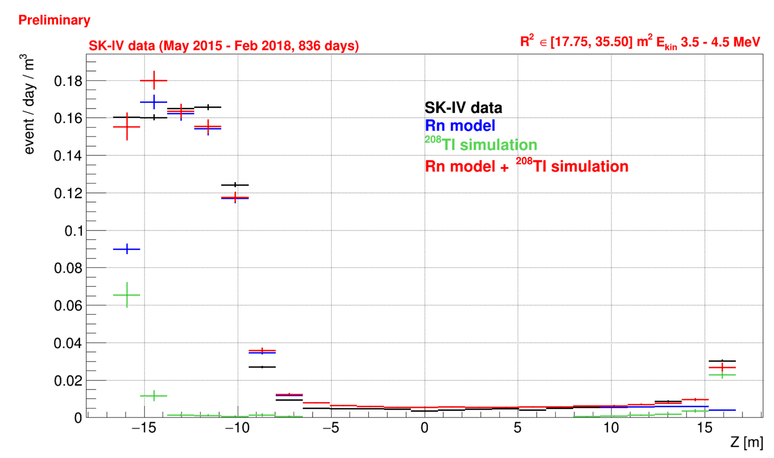


- The model uncertainty was estimated with a ^{214}Bi MC simulation and data as: ~ 0.1 mBq/m^3. The uncertainty map indicate an underestimation of the event rate in the convection front of the detector (Z~ -10m).

5 ^{208}Tl BG

- In order to improve and test the Rn model, we simulate ^{208}Tl decay from the PMT covers and glass with a large stastics.
- Relatively good agreement between data and Rn model + ^{208}Tl simulation
- However in some regions (above convection front and in the borders of the FV) we have hints of misestimation of the Rn concentration by the model





6 Conclusions and Perspectives

- We developed a first modelisation of the Radon concentration in SK detector using SK-IV data.
- This model allow to determine the Rn concentration with a precision of ± 0.1 mBq/m^3.
- Relatively good agreement between data and the BG simulations (Rn and ^{208}Tl) has been found, despite some misestimation in the borders of the FV. The Rn modelisation could be improved in these regions.
- Uncertainty of the Rn model is likely overestimated, and needs to be recomputed taking into account the ^{208}Tl BG.
- This study can allow us to improve our understanding of the low energy BG affecting SK analysis.

Poster presented at **ICRC 2021**, Online

[1] Y. Nakano, 2017 J. Phys.: Conf. Ser. 888 012191 [2] Y. Nakano et al., arXiv:1910.03823 [3] Syahrir et al., Proceedings of the 11th International Congress of the International Radiation Protection Association (Jan 2004)

科研費 KAKENHI

Supported by KAKENHI Grant-in-Aid for Scientific Research on Innovative Areas 26104008