Radon background model for Hyper-Kamiokande

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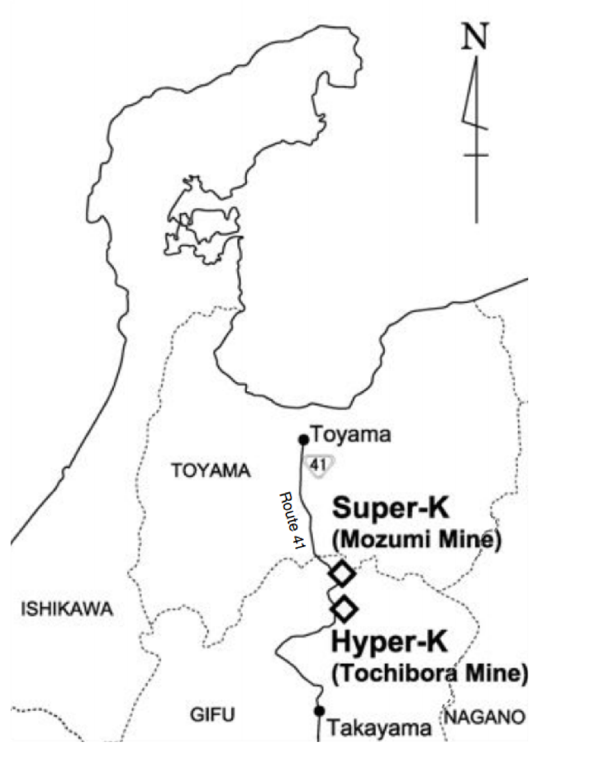
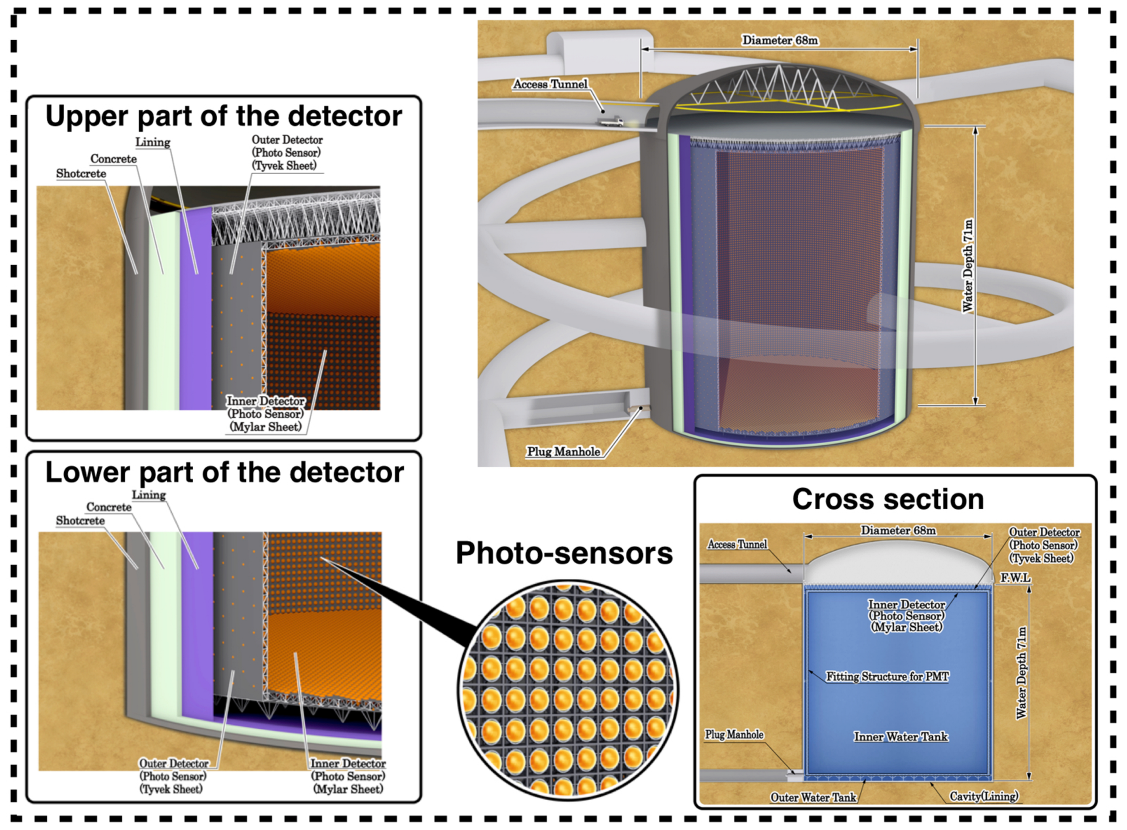
1 Context: Hyper-Kamiokande experiment

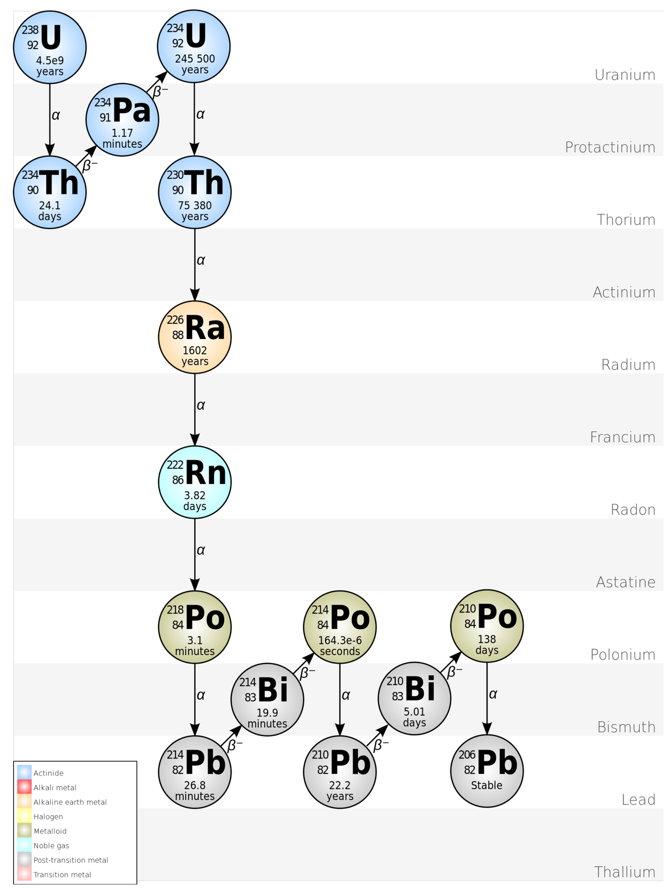
- Hyper-Kamiokande (HK) is the planned successor of the Super-Kamiokande (SK) experiment. It is foreseen to be built 650 m (1750 mwe) under the peak of Nijuugo-yama in the Tochibora mine in Kamioka (Japan).
- HK will be a Water Čerenkov detector, filled with 255 ktons of pure water, with a fiducial volume about 8 times larger than the SK's.
- HK is aiming at the observation of proton decay, atmospheric neutrinos, solar neutrinos, and neutrinos from other astronomical sources like supernovae.
- In order to estimate the physics capabilities of HK, a good understanding of the detector's backgrounds is needed. These backgrounds are expected to be in different rates and shapes than in the SK experiment, due to the different location and detector size.
- In this poster, we focus on one of the dominant backgrounds for the low energy physics: the radon background.

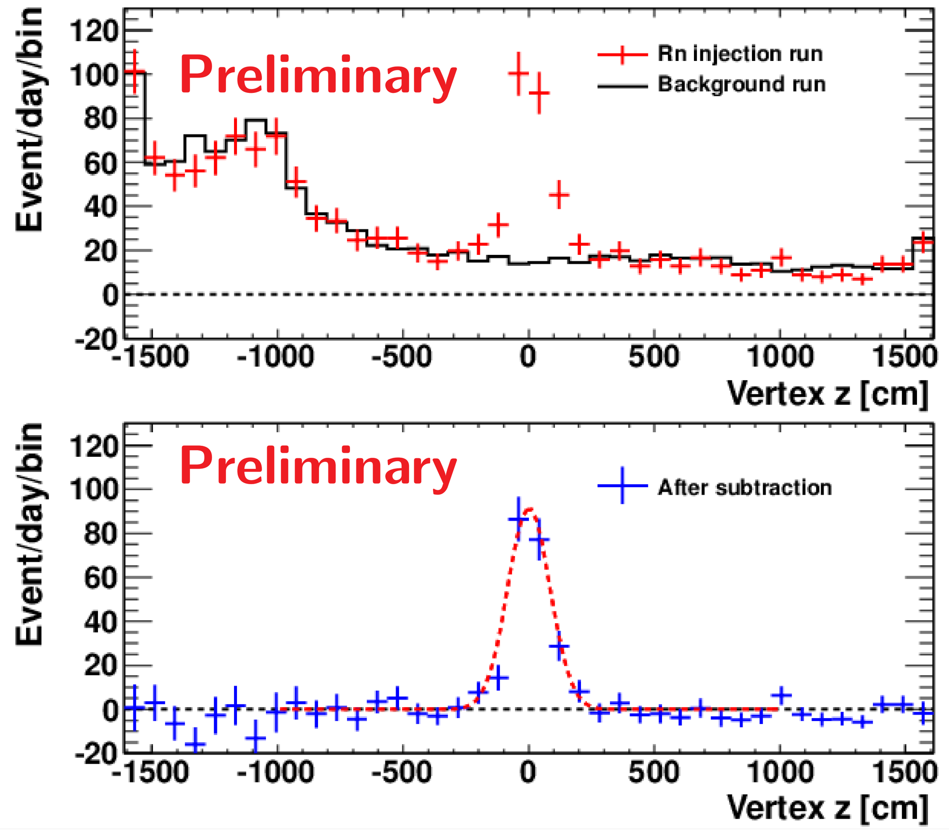




2 Radon background

- 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 most dangerous radio-isotope for Water Čerenkov detector's 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.
- SK made some studies allowing 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 some radon, and the pure water itself, whose radon concentration can't be totally reduced.

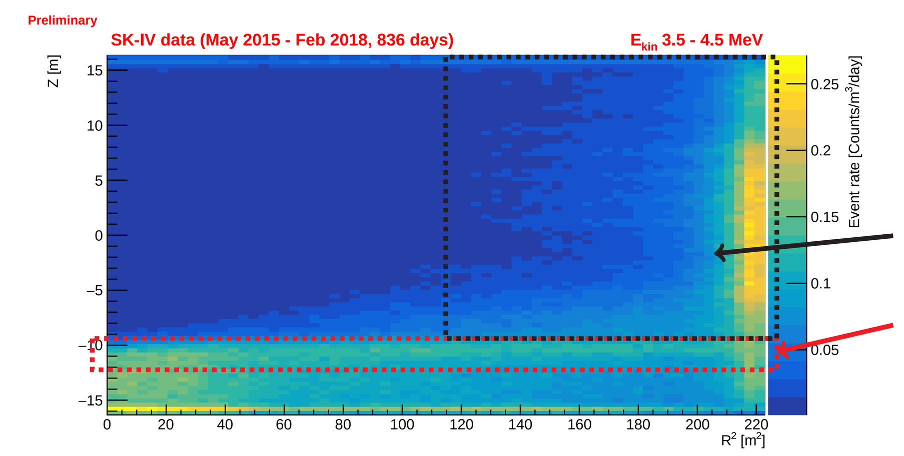




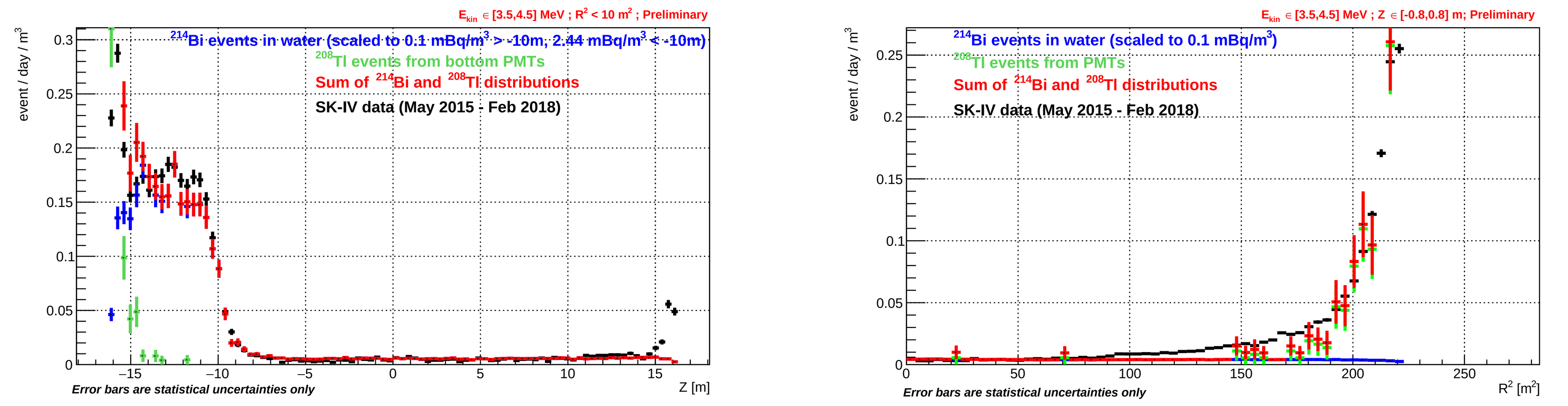
SK Rn injection 2016 study [1]

3 Using SK data for radon modelling

- In order to determine the impact of the radon background on the HK experiment, we want to model the radon distribution in the future detector.
- Radon-like events can be extracted from SK low energy data and derived to a distribution of the radon concentration in the SK detector.
- Thanks to the SK collaboration, we selected the period with the highest trigger efficiency for $E_{kin} \in [3.5, 4]$ MeV in the SK-IV solar data sample.



- Compatibility of the event distribution with the radon BG was tested with ^{214}Bi decays simulated in SK and compared with the data.

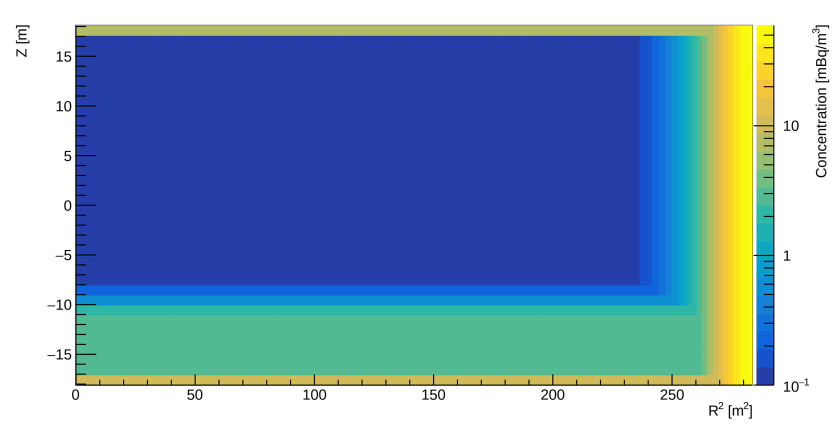


- SK's Rn: < 0.14 mBq/m^3 (Z=0m), 2.44 ± 0.24 mBq/m^3 (Z=-12 m) [2]
- Exponential shape for $Z < -15$m and > 15m and on the R^2 distribution are likely to be due to ^{208}Tl decays in the PMT covers and glass (Preliminary)

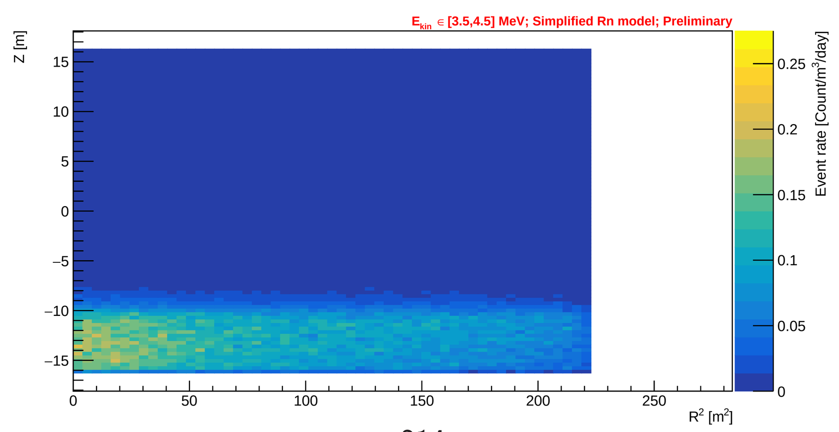
Note: The ^{208}Tl simulation is for illustration only, some bias could not be corrected due to low statistics obtained with the simulation (1 event selected / 10^7 simulated ^{208}Tl decays)

4 Simplified radon model

- Using the results from the radon (^{214}Bi) simulation, we derived a simplified model of the radon distribution in the SK detector. In a first approximation, we assumed the radon distribution is constant over R^2
- We also assumed the radon concentration at the borders of the Inner Detector (ID) volume is only due to the PMT emanation (~ 30 mBq/m^3).



Simplified Rn model



Model output (^{214}Bi simulation)

- Below CoFr, the simulation seems to reproduce the behavior of SK-IV data.

5 Going to big volume (Scaling to HK)

- Scaling the Rn model to the HK volume is not straightforward, we need to consider how the convection front (CoFr) will change.
- Two scenarios are considered: (**A**) a relative scaling (the convection front will be at -19.5m (31% of the fiducial volume height)), or (**B**) an absolute scaling (the convection front will be at -25.3m (8.1m from the ID bottom border)).
- Rn diffusion in water, following 1/cosh(x) [3], should be the same in SK and HK.

Detector/ Model	Rn concentration in the fiducial vol.	Rn concentration in the ID vol.
SK	**0.5** mBq/m^3	3.4 mBq/m^3
HK 20% photocoverage (A)	**0.5** mBq/m^3	1.3 mBq/m^3
HK 20% photocoverage (B)	**0.3** mBq/m^3	1.1 mBq/m^3
HK 40% photocoverage (A)	**0.5** mBq/m^3	2.1 mBq/m^3
HK 40% photocoverage (B)	**0.3** mBq/m^3	1.9 mBq/m^3

Preliminary

6 Summary and perspectives

- The model results depend mainly on the position of the convection front. Stopping the water convection early is critical to reduce the radon concentration.
- A detailed knowledge and understanding of the behavior of the convection front is needed to have realistic modelling of the radon distribution (studies are on-going). For example, the simplification of a constant radon concentration distribution over R^2 is likely oversimplifying for this feature of the water flow.
- The development of this radon model will allow to simulate the radon-induced background in the detector. This will be useful to estimate the impact of this background on the future HK low energy analysis.

Poster presented at **Neutrino 2020**, 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)

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