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Background Rejection with Neural Network for KamLAND-Zen

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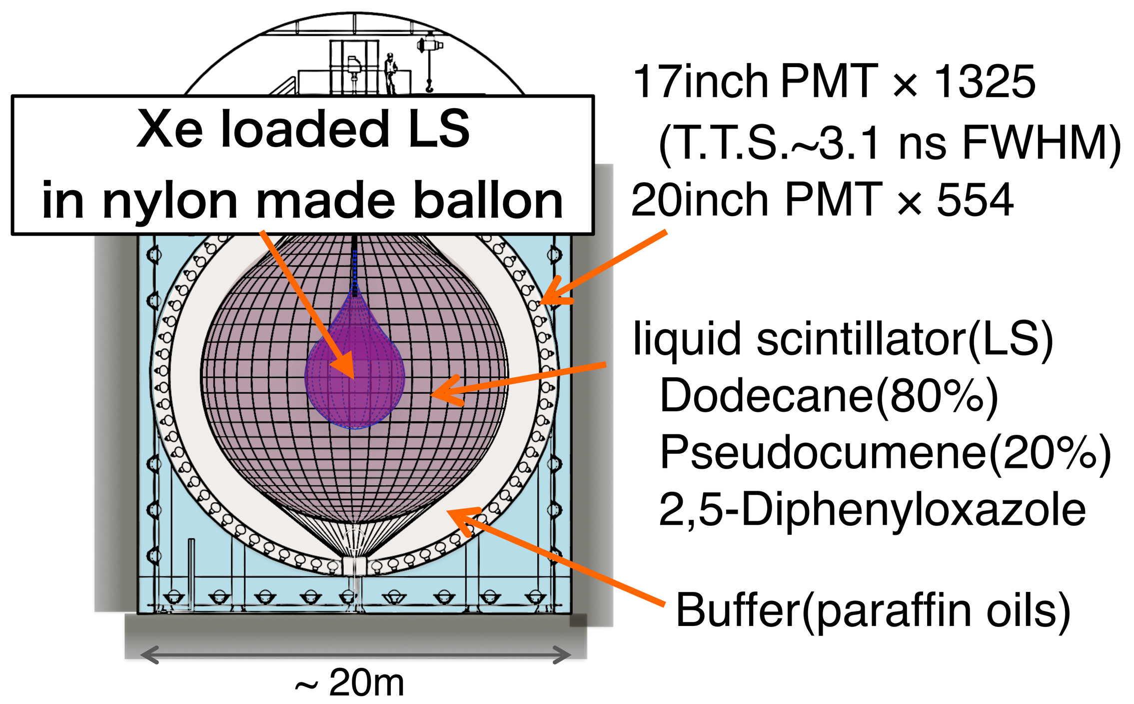
1. KamLAND-Zen

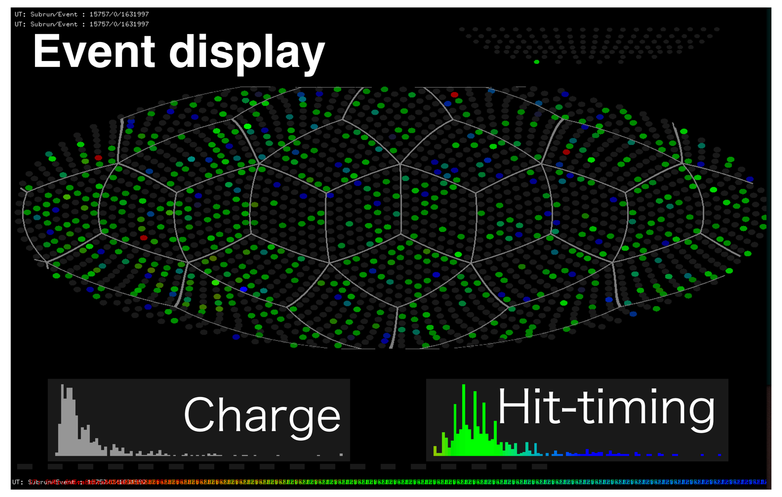
KamLAND-Zen is an experiment searching for **neutrino-less double beta decay (0νββ)** of ^{136}Xe.

> Lepton number violating process (beyond SM)

> Proof of the **Majorana nature of neutrinos**

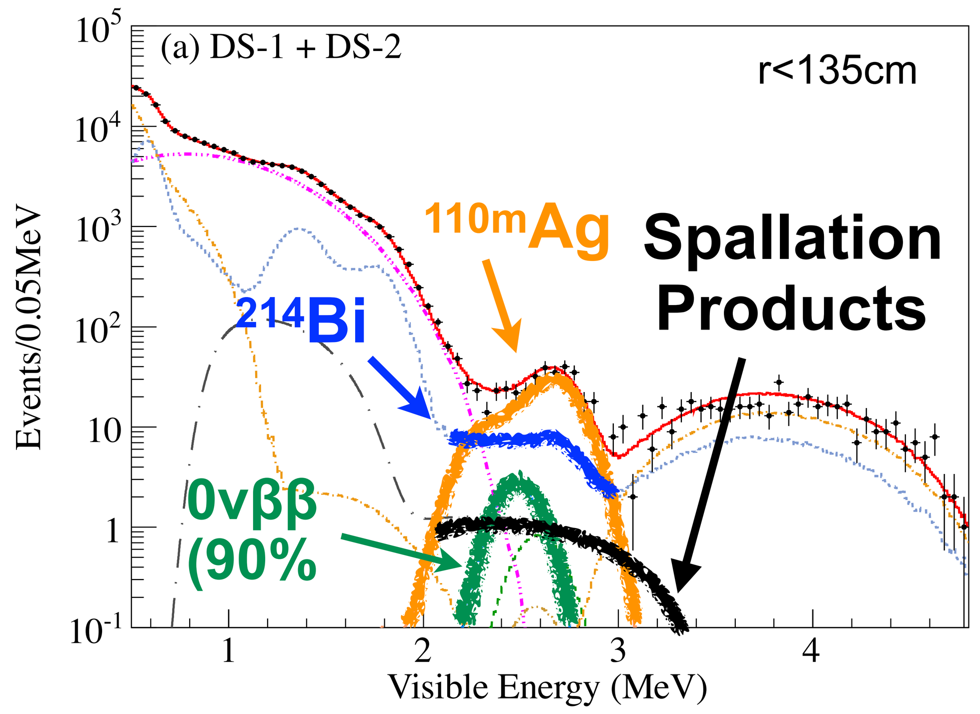
Fig 1.1 : Detector and event display of KamLAND-Zen





Events are reconstructed with hit-timing and charge of PMTs.

Fig 1.2 : Energy spectrum of Zen400 1st Phase



In KamLAND-Zen400[1,2] (the previous phase of KamLAND-Zen), ^{110m}Ag, spallation products, and ^{214}Bi were the dominant backgrounds which limited the sensitivity.

→ The sensitivity can be improved by analytical BG rejection even after finishing data taking.

2. Particle identification for KamLAND-Zen

The dominant backgrounds in KamLAND-Zen experiment are γ-events while 0νββ is pure β-event.

→ **β/γ-particle identification** (PID) is an effective BG rejection.

idea

γ-ray runs longer than β^- in LS.

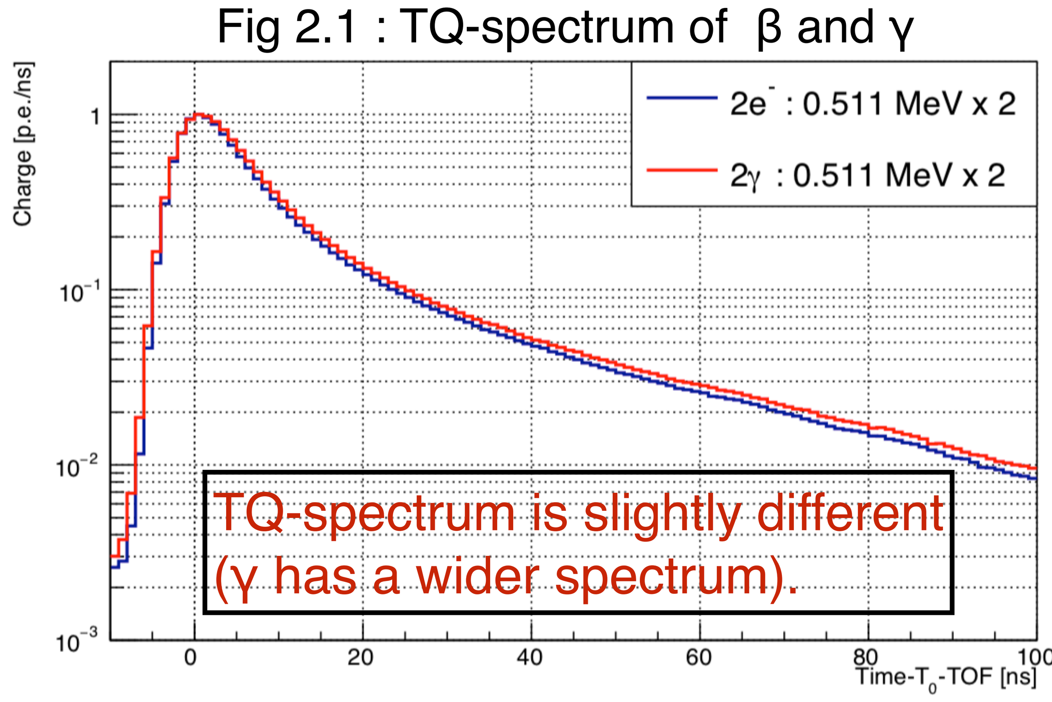
↓

The hit-timing distribution of PMT in γ-ray events spreads.

↓

The shape of hit-timing spectrum changes and is available for PID.

Fig 2.1 : TQ-spectrum of β and γ



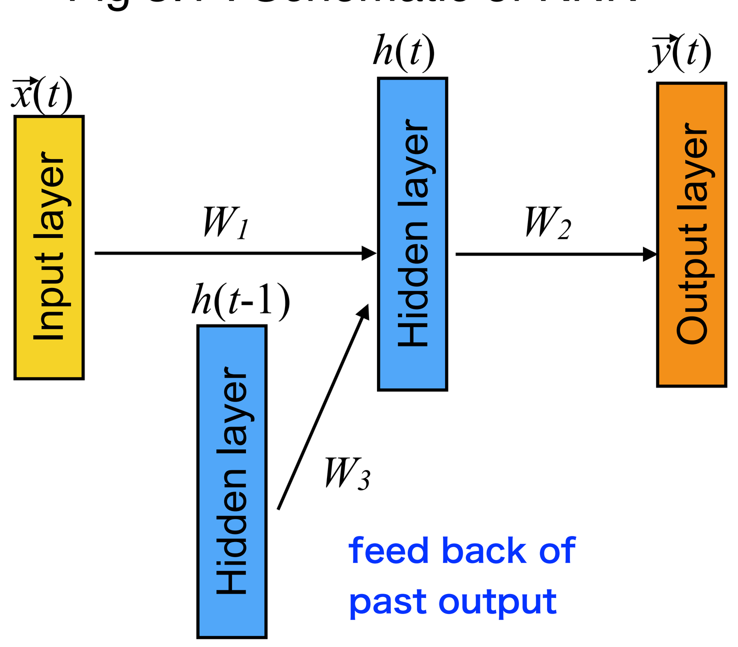
In this study, a neural network which classifies the events into the β and γ classes with the charge weighted hit-timing spectrum (TQ-spectrum) of PMTs is developed.

3. Recurrent Neural Network for Particle ID

Recurrent Neural Network(RNN)

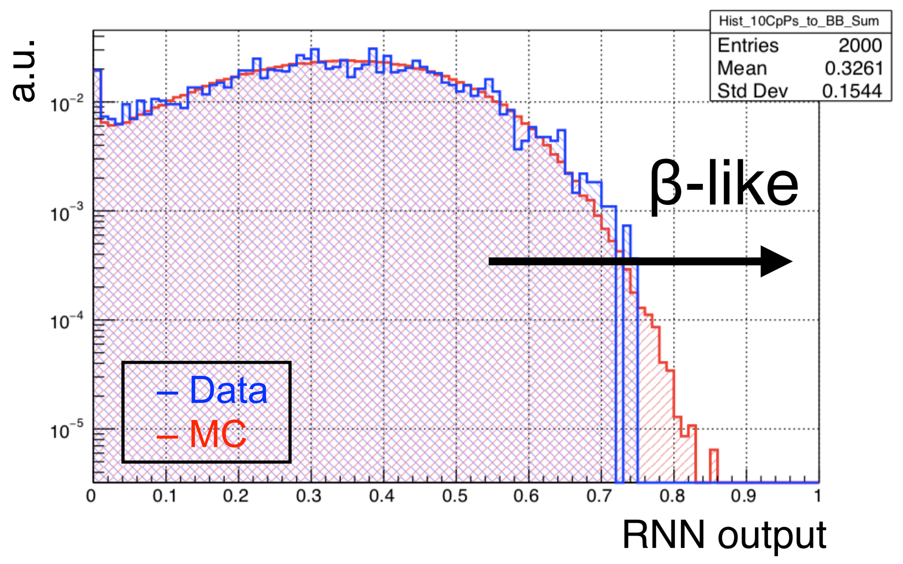
- Computing system composed of artificial neurons and synapses
  - Weight of synapses *W*s are optimized by "training"
  - Used as classifier
- RNN has feed-back loops in hidden layer.
  - Old output is feed back in parameter optimization.
  - Effective to time series data → TQ-spectrum is available.

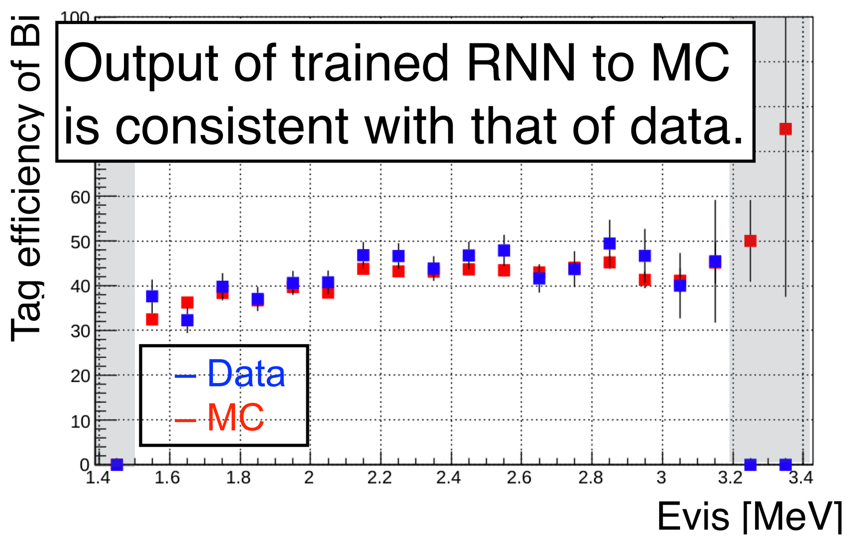
Fig 3.1 : Schematic of RNN



Training and evaluation method

- Make TQ-spectrum with MC where the optical parameters of LS and PMT timing resolution are tuned. RNN is trained with them. ββ and ^{10}C (a kind of spallation products) are used as β,γ-event, respectively.
- The reproducibility of MC is evaluated with delayed coincidence ^{214}Bi.





Developing environment

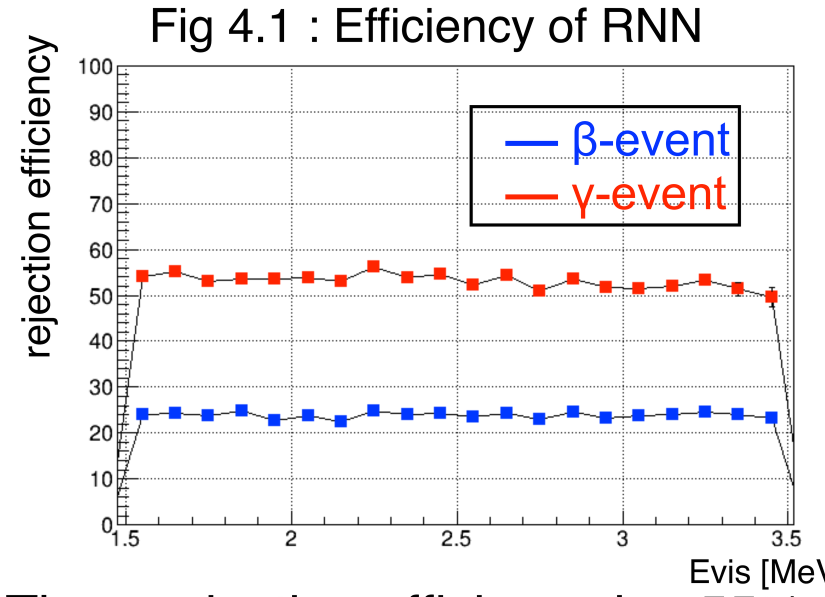
OS	Ubuntu 16.04 LTS
CPU	Intel(R) Core(TM) i7-6700
GPU	NVIDIA-SMI Quadro 620K
Library	tensorflow-gpu 1.14.0 Keras 2.2.4 CuDNN Version7

- The Efficiency is evaluated with MC TQ-spectrum.

4. Result

The rejection efficiency is evaluated energy by energy with 0.1 MeV bin.

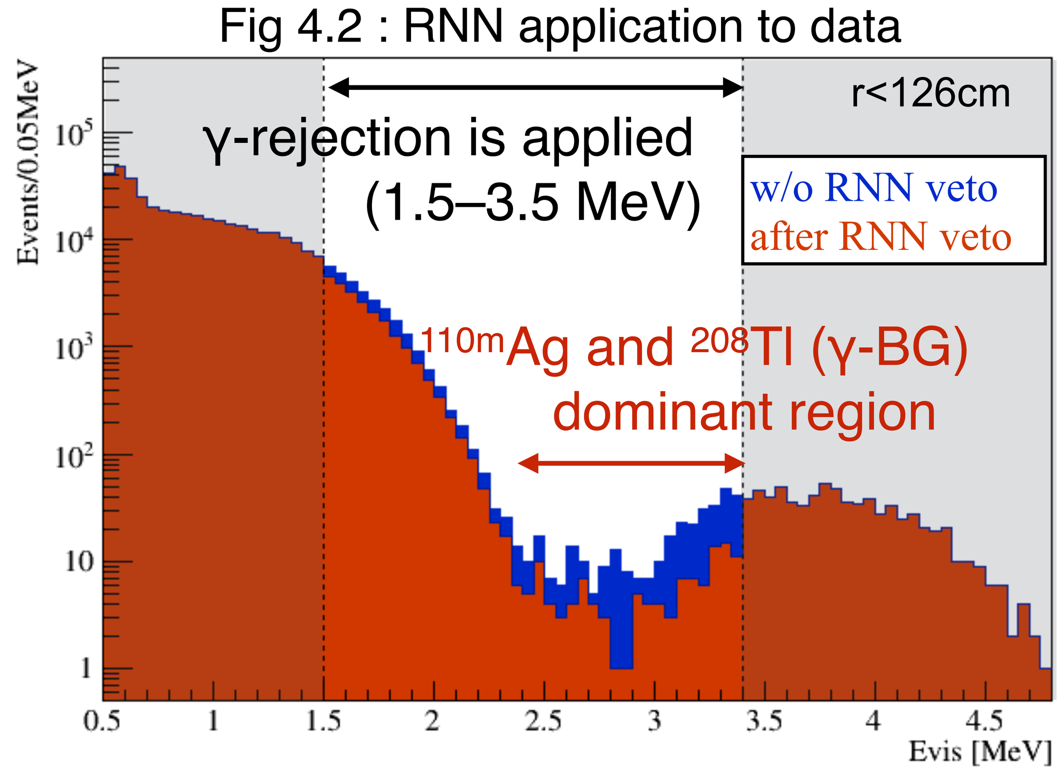
Fig 4.1 : Efficiency of RNN



The γ rejection efficiency is ~55% with β inefficiency of less than 25%.

→ it can be expected that the sensitivity of Zen400 will be improved about 10%.

Fig 4.2 : RNN application to data



γ rejection is applied to the data of Zen400 1st Phase. # of events decrease as expected.

Prospect

- To improve the efficiency by utilizing the PMT hit pattern in addition to the TQ-spectrum.
- 0νββ search with this background rejection method.

5. Summary

- β/γ-PID method with RNN is developed for KamLAND-Zen.
- It reject ~55% of γ-backgrounds with ~25% 0νββ inefficiency.
- Zen400 analysis with γ-rejection will be done in near future.

References

[1] A. Gando *et al.* Phys. Rev. C **85**, 045504
[2] A. Gando *et al.* Phys. Rev. Lett. **117**, 082503

Acknowledgment

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