Reactor Neutrinos in Super-Kamiokande

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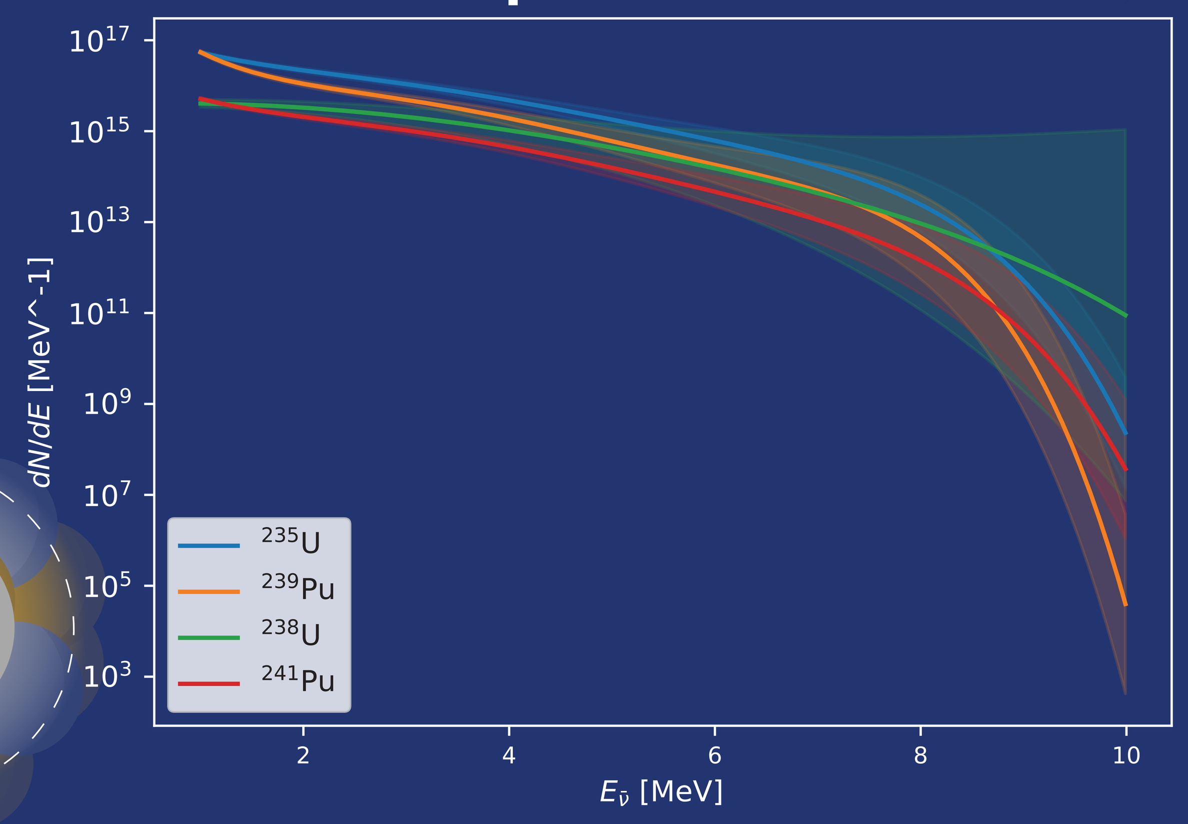
Takahama Produced Spectrum (Simulated)

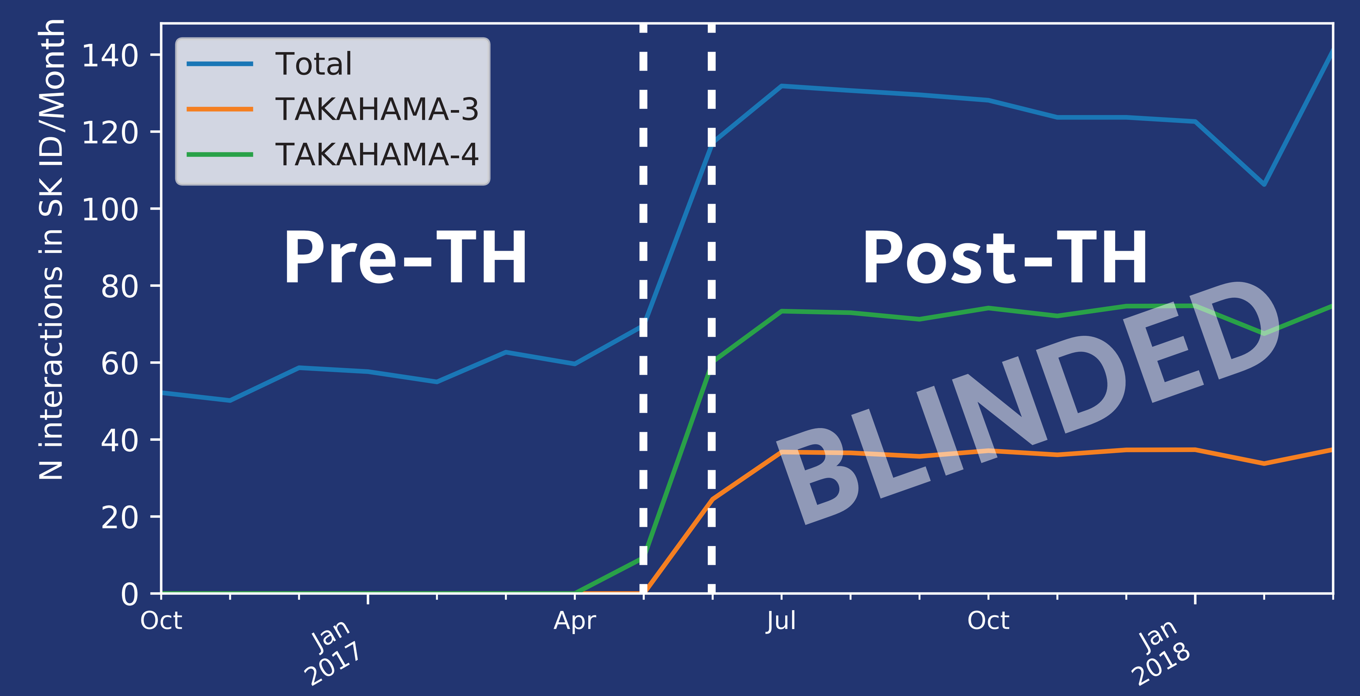


Beta decay of neutron rich fission fragments in nuclear reactors is a huge source of neutrinos, **never before detected in a water Cherenkov detector** due to their low energy.

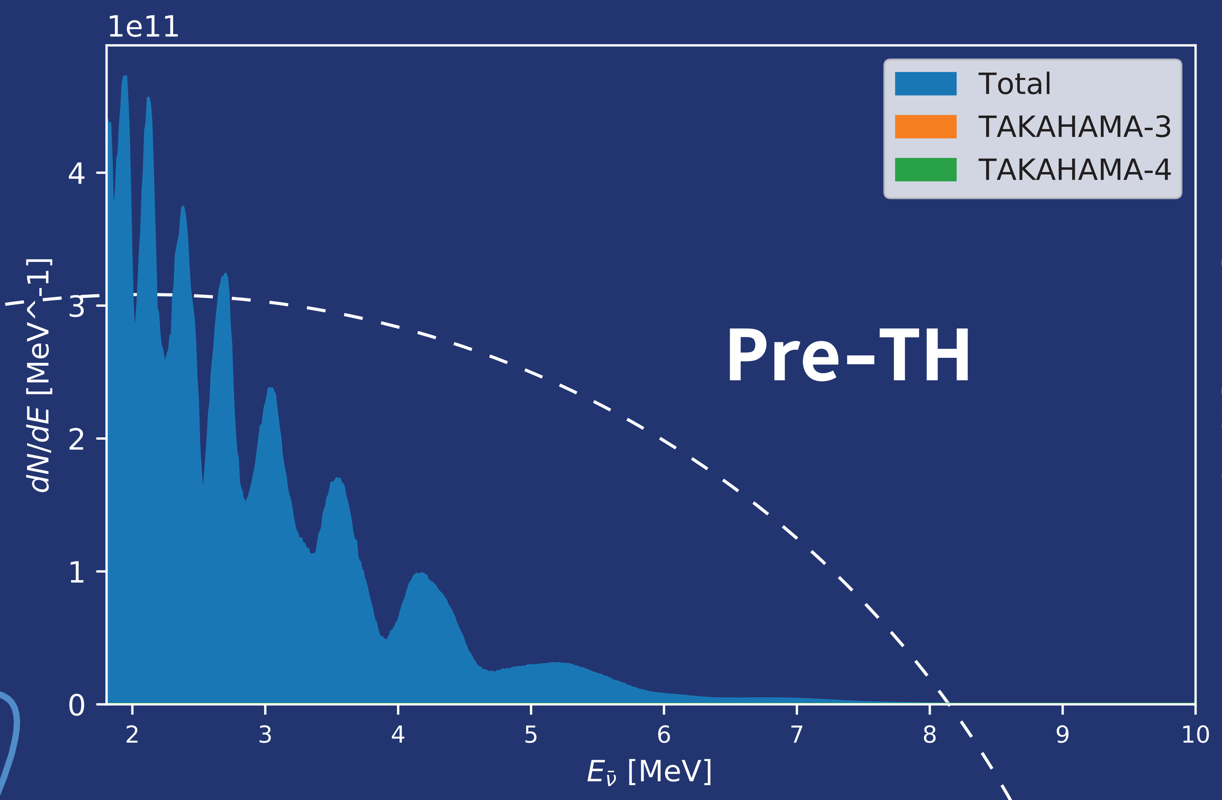
In 2011, all nuclear reactors in Japan were powered down, however in 2017, **Takahama (TH) plant partially restarted**.

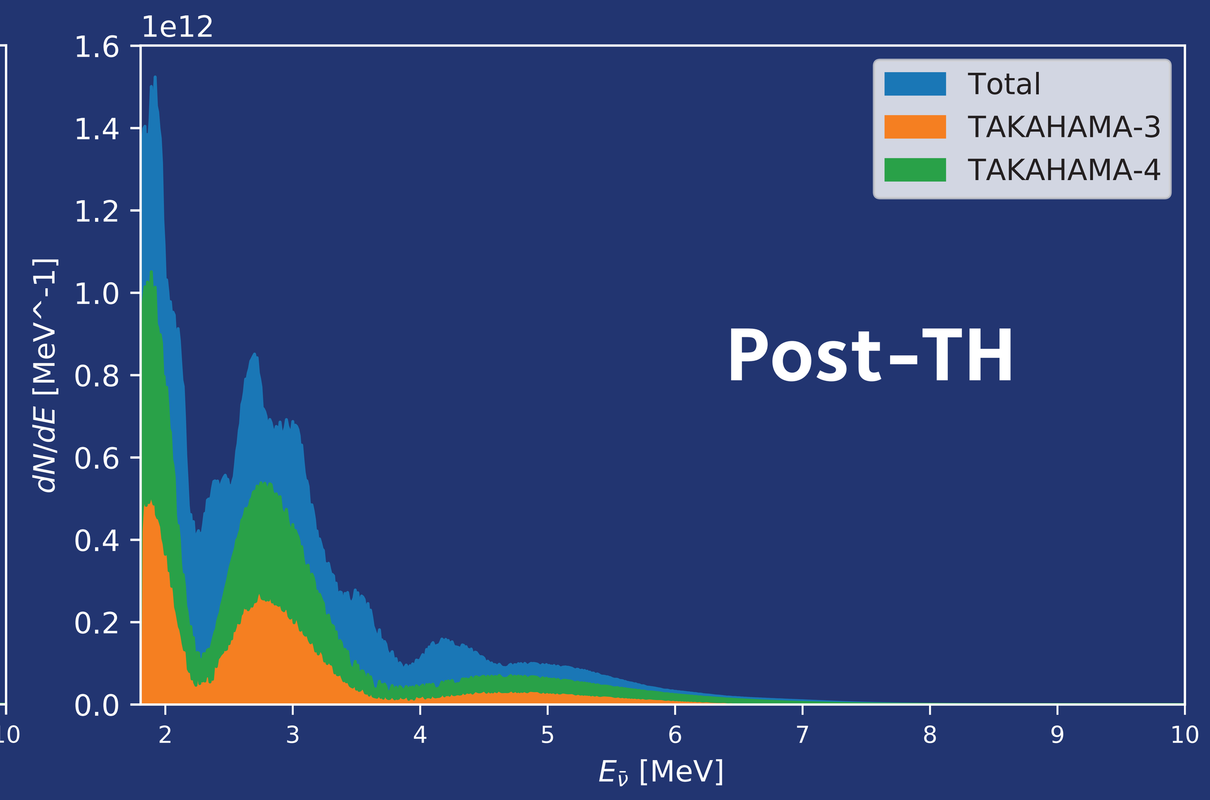
Super-Kamiokande's **Wideband Intelligent Trigger (WIT)**[1] was online in SK-IV data taking period from '16/10->'18/02.

Define two periods:
Pre-TH ('16/10->'17/05) and **Post-TH** ('17/06->'18/02).
Blind post-TH, develop selection on MC, infer baseline, unblind.



Oscillated Spectrum at SK (Simulated)





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5.62 (13.2) events/wk in pre (post)-TH.

Develop sample selection until predicted increase in signal rate is significant over baseline rate in pre-TH .

Unblind, compare measured rate increase with predicted, validate sample.

Developed **"SKReact"** framework for simulating spectrum at SK, including smearing process to estimate reconstructed spectrum.

In sample selection development stage.

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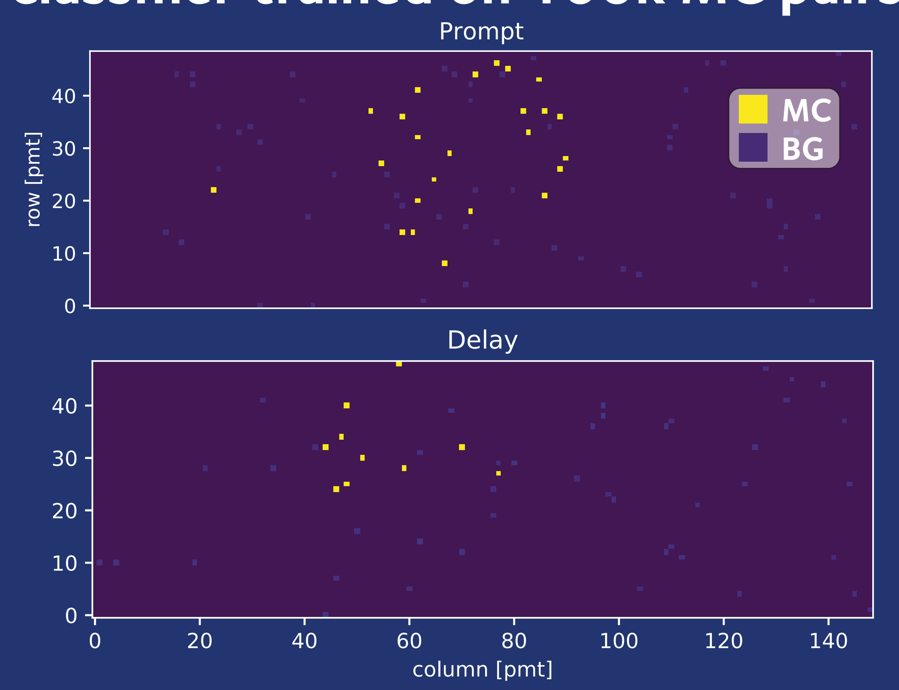
Convolutional Neural Networks (CNNs) can recognise spatially dependent features in images.

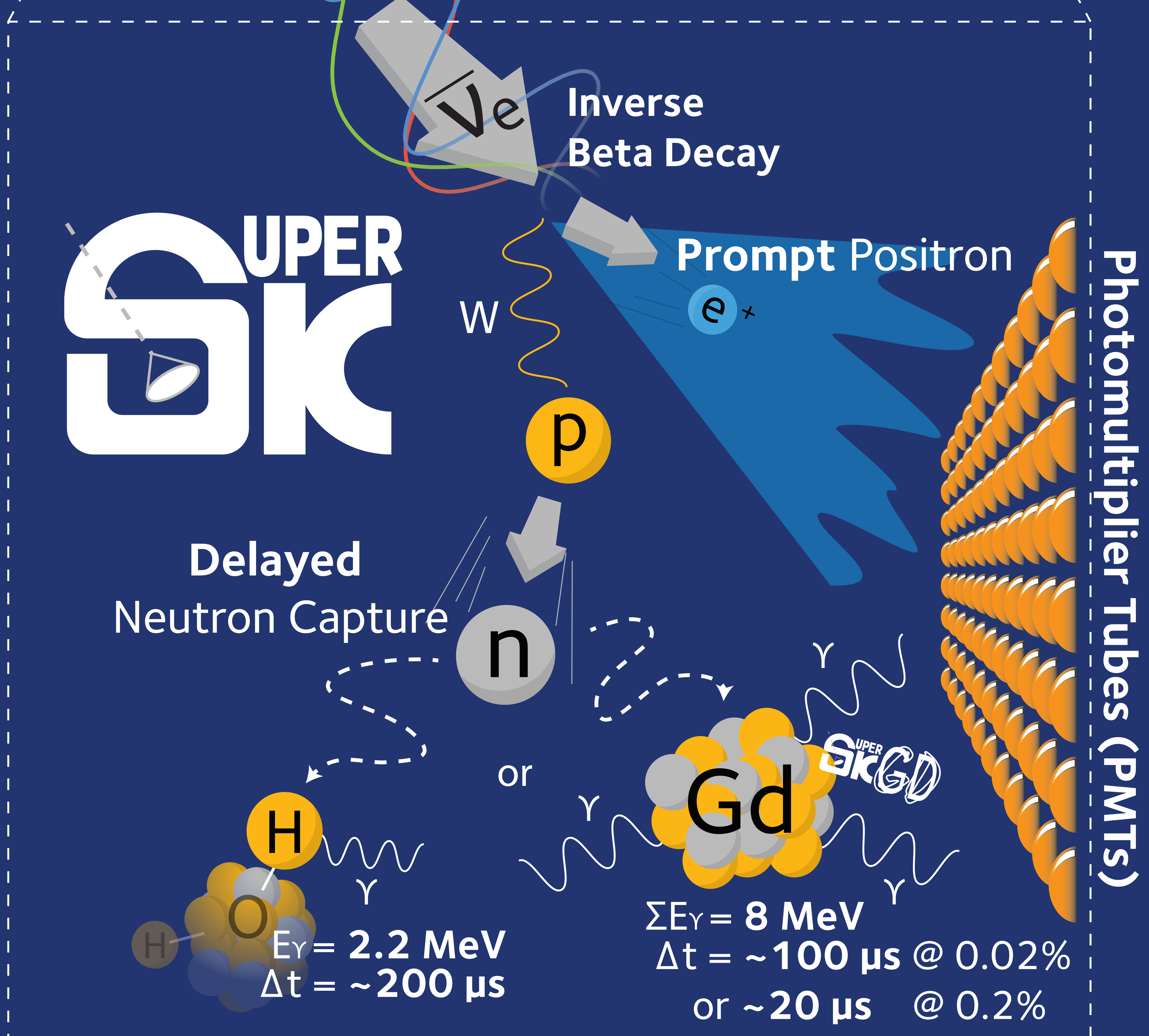
Time information of PMT hits on wall of SK cylinder can be used as input for a CNN for event classification/reconstruction.

Reactor positrons and neutron capture on hydrogen produce very little information (~10 PMT hits each).

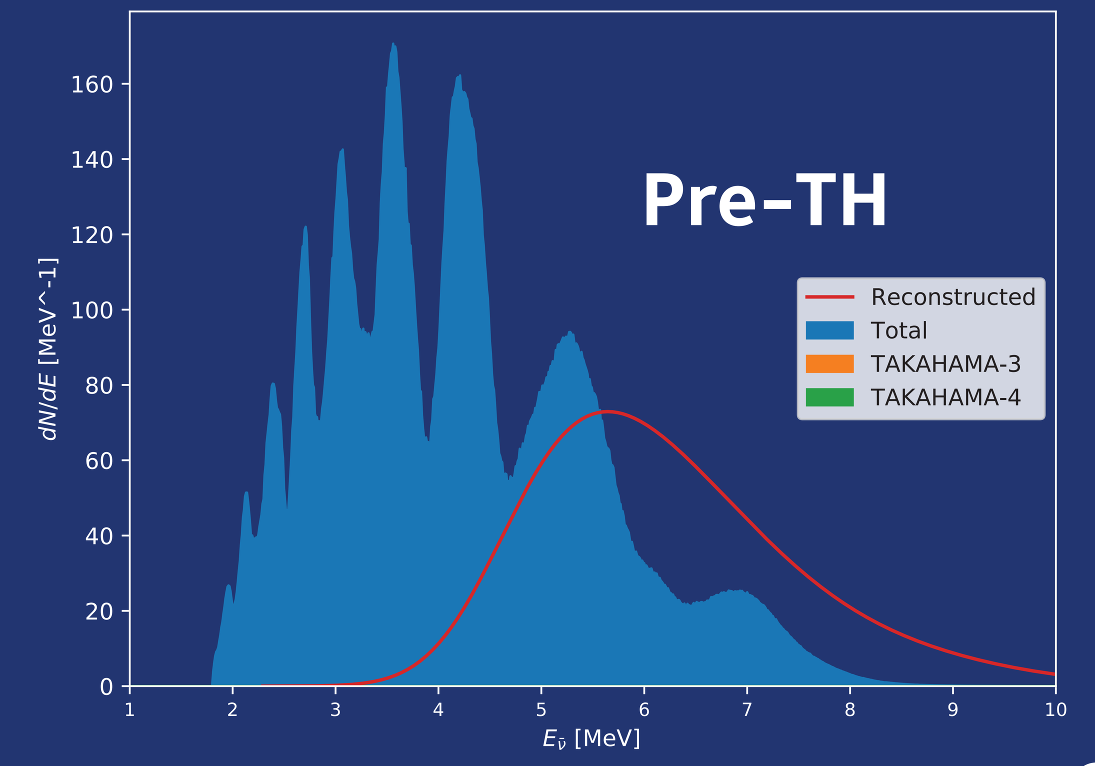
IBD neutron travels ~cm before capture, within SK's spatial resolution. Can treat positron and neutron as same vertex and overlay SK wall "images" as two-channel input for the CNN.

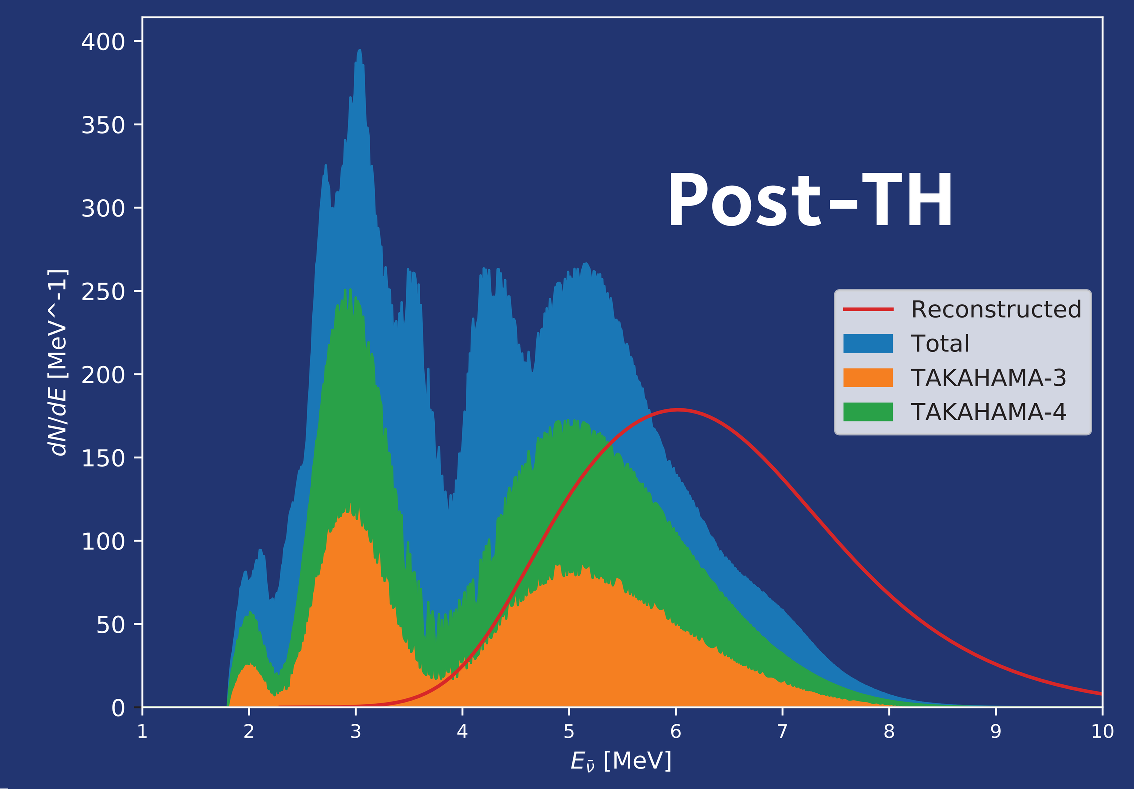
WatChMaL group developing various machine learning techniques specific to water Cherenkov detectors. **Currently investigating CNN IBD signal/noise classifier trained on 100k MC pairs.**





Interacted Spectrum in SK + Reconstructed Spectrum (Simulated)





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Reactor neutrinos are relatively low energy ~a few MeV and interact via **inverse beta decay (IBD)**, producing a positron and a neutron. Positron energy ≈ Neutrino energy - (m_n - m_p), very little Cherenkov light produced. Radioactive decay is major background.

Neutron eventually captures on hydrogen (in water), producing 2.2 MeV photon, also producing few PMT hits. **SK-Gd**[2] plans to combat this by adding 0.02% gadolinium sulphate by mass to SK's water. Neutron capture on Gd produces 8 MeV photon, much easier to isolate from background.

Standard SK-IV solar analysis cuts insufficient, developing further and investigating more novel, machine learning based approach (left).

Conclusion

SK has access to reactor off/on data thanks to Takahama plant partial restart. Currently blinding post-restart data, developing sample selection. SK-IV solar cuts not effective, developing further. Also investigating machine learning event classification, specifically convolutional neural networks.

[1] - Giada Carminati et al. 'The new Wide-band Solar Neutrino Trigger for Super-Kamiokande'. doi: https://doi.org/10.1016/j.phpro.2014.12.068.
[2] - John F. Beacom and Mark R. Vagins. 'GADZOOKS! Antineutrino Spectroscopy with Large Water Cerenkov Detectors'. doi: https://doi.org/10.1103/PhysRevLett.93.171101.