Studies of fast neutrons for design and characterization of neutrino experiments and spallation neutron sources

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Neutron physics is the future of neutrino physics!

Number of neutrons = “hadroness” of the shower
- PID to distinguish shower (multi-ring) topology

\( ^e \text{CC interaction} \)
- Electromagnetic shower
- not many neutrons

\( ^\tau \text{CC interaction} \)
- leptonic shower
- some neutrons

NC interaction
- hadron shower
- many neutrons

Neutron tagging \((n + p \rightarrow d + \gamma, 2.2 \text{ MeV})\)
- SuperK: Captured neutron can be counted
- IceCube: Neutron capture gives late hits
- We need to predict neutron propagation in water or ice.
Neutron physics is the future of neutrino physics!

Beam neutrino-induced neutron measurement
- Data and simulation don’t agree
- Systematic error is underestimated

Neutron capture for astrophysical tau neutrino search
- Promising new PID idea

Physics of fast neutron (>10 MeV) is not well-understand. We perform fast neutron beam test at RAL ISIS ChiPlr beamline to understand this.

Such data will improve precision of neutron simulation in neutrino experiments, improving all science in both water and ice Cherenkov detectors.
RAL ISIS neutron and muon sources

Rutherford Appleton Laboratory (RAL), Oxfordshire
https://www.isis.stfc.ac.uk/Pages/home.aspx
- ISIS target station 2 (TS2)
- ChipIr beamline (fast neutron beamline)
- Co-supervisor, Dr. Carlo Cazzaniga

Using this beamline, fast neutron scattering with water and other elements will be studied.
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ChipIr neutron spectrum

How to select fast neutrons? (activation foil?)
Can we measure multiplicity?
Cross-section function of energy?

→ You will design and perform the experiment.
Then analyze the data and use results in Super-K/Hyper-K/IceCube.
# PhD and experiment timeline

3.5-yr PhD position, 1.5-yr at RAL, active member of Hyper-Kamiokande

Year 1: Stay London to learn particle physics and HyperK simulation
Year 2: Move to RAL, perform the experiment
Year 3: At some point the student comes back to London to write up paper(s) and thesis
Year 4: graduation

The project is hardware oriented. Prior experience in neutron physics (simulation, hardware) is desirable.

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<td>Learning HyperK simulation, and implement and test experimental results in simulation</td>
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<td>Setting up fast neutron measurement at ISIS, and construct simulation</td>
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<td>Test of material of interest for target station components</td>
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<td>Writing peer-reviewed papers and thesis</td>
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Red = high% of time, Yellow = moderate% of time, Green = low% of time
Why join us? Because it’s fun!
The dream boat for neutrino physicists!
(Inside of the Super-Kamiokande detector)

Beam test at Fermilab

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- News about UK astrophysics
https://www.facebook.com/IOPAPP
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“NuSTEC News”
- News about neutrino interaction physics
https://www.facebook.com/nuxsec

Teppei’s recent publications
https://nms.kcl.ac.uk/teppei.katori/#papers
Fermilab beam test (2017)

“Pulse shape particle identification by a single large hemispherical photomultiplier tube”
https://iopscience.iop.org/article/10.1088/1748-0221/15/05/T05002

Shivesh

Beam test at Fermilab

Teppei and DOM (21/01/15)