NuSTEC (Neutrino Scattering Theory Experiment Collaboration)

Goals and Strategy

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What is NuSTEC?
NuSTEC is defined by what it does!

- NuSTEC promotes the collaboration and coordinates efforts between:
  - Theorists – studying neutrino nucleon/nucleus interactions and related problems
  - Experimentalists – primarily those actively engaged in neutrino nucleus scattering experiments as well as those trying to understand oscillation experiment systematics. However e-A experimentalists contributions are certainly welcome.
  - Generator builders – actively developing/modifying the model of the nucleus as well as the behavior of particles in/out of the nucleus within generators
- The main goal is to improve our understanding of neutrino interactions with nucleons and nuclei and, practically, get that understanding in our event generators.
  - The impact of our main goal will be widespread in both hadron and nuclear physics and directly effect oscillation physics.

NuSTEC is defined by what it does!

How do we do it: workshops

- We promote the exchange of information within our community
- **Workshops**: We coordinate and organize community-wide workshops.
  - NuInt
    - » organized every18 months.
    - » NuSTEC coordinates the organization of NuInts
    - » America-Europe-Asia
    - » Comparison of experimental results and nuclear models via event generators
    - » Highlight open problems
  - Topic-specific
    - » to be held in between NuInts
    - » such as the past Pittsburg and INT workshops and possible workshops on D_2 experiments and multiple-experiment/theorist discussions as well as future INTs
    - » NuSTEC coordinates multiple workshops to avoid date collisions and unwanted duplication

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How do we do it: training programs

- We give back to the community by organizing and running generator and neutrino scattering physics schools/trainings

- **Training**:
  - Long (10-day) schools (see next slide)
    - » Every 2-3(?) years
    - » Fixed location (Fermilab or Deadwood, SD or ??)
    - » Broad theory/experiment program
    - » Example: Nustec Training in Neutrino Nucleus Scattering Physics, October 2014, Fermilab with **85** participants.
  - Short (≤ week) schools
    - » More specific or practical or generator-oriented
    - » Correlated in time and space with NuInt
    - » Example: The Liverpool NuSTEC Nu Generator School associated with NuInt14
    - » Plans for second Short Training program to be held before NuInt15 in Japan.

Nustec Training in Neutrino Nucleus Scattering Physics – Fermilab, October 2014

Electroweak interactions on the nucleon	**3 hours**
Strong and electroweak interactions in nuclei	**4 hours**
The nuclear physics of electron and neutrino scattering in nuclei in the quasielastic regime and beyond	**9 hours**
Pion production	**3 hours**
Exclusive channels and final state interactions	**3 hours**
Inclusive e and ν scattering in the DIS regime	**3 hours**
Impact of uncertainties on neutrino cross sections	**3 hours**
Selected experimental illustrations	**4 hours**

NuSTEC15 – Okayama University

- **Tentative List of Lectures and Lecturers**
- Neutrino Physics and Neutrino Interactions (L. Alvarez-Ruso, IFIC, Spain)
- Basics of Nuclear Theory (potential ,current, symmetry) (A. Lovato, ANL)
- Neutrino Oscillation Experiments (T.Katori, Queen Mary University of London)
- Neutrino-Nucleus Scattering from Elastic to Quasi-Elastic Region (M.Sakuda)
- Quasi-Elastic Scattering in Nuclei (S. K. Singh, AMU, India)
- Pion production from nucleons and nuclei , strange particle production, Deep Inelastic Scattering (M.Sajjad Athar, AMU, India)
- Monte Carlo Event Generator (T.Golan, Rochester/Fermilab)
- Neutrino-Nucleus Scattering Experiments and Detectors (C.Mariani, VTEC)
- Water Cherenkov Detector and Neutrino Physics (Y. Koshio, Okayama)
- Liquid Argon Detector and Neutrino Interactions (F. Cavanna, FNAL)
- Liquid Scintillator Detector and KamLAND Latest Result（J.Shirai, Tohoku）
- Reactor Experiment RENO and RENO-50 (S.B.Kim, Seoul National University)
- MiNERVA and Neutrino Nucleus Interactions (J. Morfin, Fermilab)

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How do we do it: addressing open problems

- We address open problems, identified at workshops, by promoting collaborative efforts; theorist ←→ experimentalist/theorists….
- **Defining the Problem**
  - Understand the measurements
  - Model building, calculations
  - Experiment-theory-generator comparisons
  - Generator development
- **Collaborative effort follow-up meetings**
  - Self-organized mainly phone meetings
- **There have been multiple ideas discussed at this NuFact that could easily become a NuSTEC projects:**

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How do we do it: Example Open Problems that need to be addressed

- **Pion production problems:**
  - Do the MINERvA and MiniBooNE pion kinematic distributions disagree? Are they comparable?
  - What is needed to make a complete and correct 1pi model? How does it compare with MB, MINERvA, T2K, and LAr?
  - Do transport models (GiBUU) predict similar pion kinematic behavior as a phenomenological (GENIE) vs. cascade models (NuWro, NEUT). If not, does that indicate that our cascade models are incomplete?
  - What do these different models predict vs. target material? Can we use multiple datasets to constrain or better understand this, or is it too complicated by unknown axial components in 1pi?
  - Are additional neutrino measurements on deuterium needed for pion production and what are the prospects for this?

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How do we do it: Example Open Problems that need to be addressed

- **CCQE problems:**
  - How well do proton kinematics and multiplicity agree with MC generator models?
  - Do we have an experimental handle on neutron multiplicity? How well can we associate those to the vertex?
  - How does one study multinucleon correlation independently from final state effects? Is there additional electron scattering data that can give us more information about the effects we see with neutrinos?
  - What is needed to make a complete and correct QE model? How does it compare with MB, Nomad, MINERvA, T2K, and LAr?
  - Is the axial vector form factor dipole or not? How well can we determine that experimentally? Does it matter for future experiments?

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How do we do it: Example Open Problems that need to be addressed

- **CC inclusive:**
  - Are there more direct comparisons that can be made between neutrino and electron inclusive scattering?
  - What is the most direct way to compare between neutrino experiments? Through the inclusive channel?
  - Is there any missing physics in present DIS models? For example as observed from recent Minerva nuclear target ratio data?
  - What are the prospects for measuring multi-pion final states and does it matter for future experiments?
  - How well do we know electron neutrino cross section?

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How do we do it: NuSTEC and Generators

- How can NuSTEC contribute to generator development?
  - Bringing theorists and generator developers into contact
  - Providing a forum to discuss generator development priorities
  - Working out and suggesting efficient solutions
  - Addressing consistency, allowed parameter range and double-counting issues
  - Discussing validation strategies using different sets of data

NuSTEC and Global fits

- Right – we need to consider this carefully

NuSTEC Structure

- We try to keep the structure less rigid by initially forming a NuSTEC Board
- Board
  - Theorists (all willing to join)
  - Experimentalists
  - Representatives of Event Generators
- Meeting of the NuSTEC Board – as of a phone meeting this morning it looks like 8-9 October are the favored meeting dates.

The NuSTEC Board

Theorists

- Luis Alvarez Ruso
- Sajjad Athar
- Maria Barbaro
- Omar Benhar
- Natalie Jachowicz
- Marco Martini
- Toru Sato
- Rocco Schiavilla
- Jan Sobczyk (also nuWRO)

Experimentalists

- Steve Brice
- Yoshinari Hayato (also NEUT)
- Teppei Katori
- Kendall Mahn
- Camillo Mariani
- Mark Messier
- Jorge G. Morfin
- Ornella Palamara
- Gabe Perdue (also GENIE)
- Makoto Sakuda
- Federico Sanchez
- Sam Zeller
- DUNE representative - coming soon