The NuSTEC Concept

Neutrino Scattering Theory Experiment Collaboration

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Goals of NuSTEC

- Generators: Coordinate theorist-experimentalist collaborative efforts to improve generator(s):
 - Develop transfer protocols how to get theoretical concepts in form that can be used by generator.
 - ▼ Checking/verifying these implementations (...avoid double counting... etc)
 - ▼ Retire outdated/incorrect procedures...
 - Implications: need <u>at least</u> one member from each generator and one member from every experiment and many/all theorists as members.

Workshops: Organize Community-wide Workshops when needed.

- ▼ Main Conference is the NuInt Workshop here we are.
- Leave frequency of NuInt at 18 months and organize smaller topic-specific workshops such as last year's Pittsburgh generator workshop and December's INT workshop in between NuInts.
- Implication: members of NuSTEC must be ready to devote time to, with community help, organizing and running workshops.

Goals continued

- Training: Organize/Run a neutrino-nucleus scattering physics
 Training Training Program : experimentalists ± few years from Dr.
 - First Training Program in two parts: first last week generator oriented program at Univ. Liverpool and second - theory oriented 18 to 26 October at Fermilab.
 - ▼ Thereafter coordinated with location and 18 month cycle of NuInt? Plans underway for second Training before NuInt15 in Japan.
- Funding: Collaborative funding requests to support the NuSTEC Theory training have been very successful. In addition to the Training, consider NuSTEC postDocs or support of postDocs at member institutions.
- Global Fits: Combine results from multiple experiments <u>not only</u> <u>neutrino</u> - to compare/adjust with a theory/model framework.
 - ▼ Experiment representatives insure results are in form to be included in the fits
 - ▼ Since many measurements are in form of convoluted $\phi(E) \otimes \sigma(E) \otimes \operatorname{Nuc}(E)$ need experiment generator in the fit and flux from each experiment.

Collaboration Structure and Meetings

- Structure: Discuss at upcoming NuSTEC meeting. Keep it simple
 - ▼ A theorist and experimentalist co-spokes and, perhaps, institutional board.
- Collection of individual / group efforts that feed into the generator upgrades and global fits.
- Coherent NuSTEC collaborative effort for
 - ▼ The organization of workshops and the training.
 - ▼ The global fits themselves.
- Meetings:
 - ▼ Frequent smaller project meetings phone/video... as required.
 - ▼ Larger collaborative meetings held in conjunction with workshops and perhaps – training program.
 - ▼ One (?) several day directed NuSTEC collaboration meeting a year to review status of individual projects and global fits. To begin planning the next NuSTEC workshops and training programs.

NuSTEC Training Program - Part 1: Generator-oriented Training

 First Program in two parts: last week generator oriented program at Univ. Liverpool: http://Training.genie-mc.org

Organizing Committee

▼ L. Alvarez Ruso (Valencia), C. Andreopoulos [*] (Liverpool / RAL)

S. Boyd (Warwick), S. Dytman (Pittsburgh), H. Gallagher (Tufts),

J. Morfin (FNAL), J. Nowak (Lancaster), G. Perdue (FNAL),

J. Sobczyk [*] (Wroclaw), M. Wascko (Imperial) [*] co-chairs

▼ Local support: Linda Fielding (Liverpool), Angie Reid (Liverpool)

 The (generator) school will provide a series of lectures covering a broad range of neutrino interaction phenomenology topics focusing on the connections between theory, experiment and MC simulations. The Training will also offer extensive hands-on tutorials of the GENIE and NuWro MC generators.

• We will review this training at following NuSTEC meeting.

NuSTEC Generator Training on MC Generators

Programme

Click on the lecture titles to see the slides (PDF format).		Wed 14	Thu 15	Fri 16
Wed 14 Thu 15 I 08:00 - Registration 08:20 08:20 - Welcome (Andreopoulos) 08:30	Fri 16 13:30 - 15:00	Tutorial 1 (Perdue) GENIE intro - How to configure and run basic applications and analyze the outputs	Tutorial 3 (Perdue) How to extract cross- section information	Tutorial 6 (Perdue) Adding new models: A detailed walk-through
08:30 Lecture T1 Lecture T5 (Alvarez- I - (Andreopoulos) Ruso)	Lecture T9 (Alvarez-Ruso) - Weak coherent meson 15:30	, Mid-afterno	oon refreshements (at	Foresight Centre)
09:20 Neutrino generators & MC Quasielastic neutrino p methods scattering	production 15:30	Tutorial 2 (Golan) NuWro intro - How to	Tutorial 4 (Perdue/Golan)	Tutorial 7 (Perdue) Using fluxes and detector
09:20 - Break 09:30	- 17:00	configure and run basic applications and analyze the outputs	Comparing generator predictions with data	geometries. How to customize GENIE for a complex experimental setup.
09:30 Lecture T2 (Sobczyk) Survey of current 10:20 neutrino MC generators 10:21 Lecture T6 (Sobczyk) Np-Nh contributions to quasielastic-like neutrino scattering	Lecture T10 (Sobczyk) Final state interactions & survey of intranuclear cascade codes 17:15)	Break	experimental setap.
10:20 - Mid-morning refreshements (at Fo 10:45	oresight Centre) 17:15	Lecture E1 (Boyd) Survey of neutrino scattering data	Lecture E2 (Nowak) Electron scattering data and its use in	Lecture E3 (Wascko) Unfolding techniques and model-independent
10:30 Lecture T3 (Alvarez-Ruso) Lecture T7 (Alvarez- Basics of electro-weak Ruso) 11:20 interactions Neutrino production	Tutorial 5 (Andreopoulos) 18:15 Systematics & event re- weighting 18:15		constraining neutrino models	measurements
11:20 of resonances	- 19:30	Discussion/Drinks	Discussion/Drinks	Discussion/Drinks
11:30 Lecture T4 (Alvarez-Ruso) Lecture T8 (Sobczyk)	19:30 -		School dinner	
11:30 The nuclear initial state / Deep inelastic- Basics of many-body12:20 theoryand neutrino-inducedhadronization		Theory 6 MC methods	llanda on tutoris la	Functiment
12:20 - Lunch (at Foresight Cer	ntre)	Theory & MC methods	Hands-on tutorials	Experiment

NuSTEC Training Program- Part 2: Theory-oriented Training

- ◆ Theory oriented part 18 26 October at Fermilab.
 - Applications opening within the next week or two.
- CTEQ Style Total immersion with close student lecturer contact
 - Day consists of 4 1-hour lectures, 1.5 hour recitationin the eveningwhen day's lecturers field questions from assembled students, close with nightcap
- Local hotel contracted: housing and facility for recitation / nightcap.
 - ▼ Registration Fee: \$650 for hotel, breakfast and lunch, bus, coffee breaks....
 - ▼ Registration Fee: not needing hotel \$250
- Good community support: financial support from Jefferson Lab, Fermilab, CERN, NSF, DOE and Virginia Tech.

Organizing Committee

- Luis Alvarez Ruso*, Constantinos Andreopoulos, Omar Benhar, Yoshinari Hayato, Teppei Katori, Camillo Mariani*, Jorge G. Morfín*, Ulrich Mosel, Ornella Palamara, Makoto Sakuda, Rocco Schiavilla, Jan Sobczyk, Martin Tzanov, Sam Zeller *co-chairs
- ▼ Cynthia Sazama and Suzanne Weber from the Fermilab Conference Office.

NuSTEC Training Program- Part 2: Theory-oriented Training – 32 hours

Electroweak interactions on the nucleon

▼ Electromagnetic interactions; V-A and current-current theories of weak interactions; CVC and PCAC; single-nucleon matrix elements of the electroweak current and associated form factors; parametrizations and sources of experimental information about electromagnetic and weak form factors.

Strong and electroweak interactions in nuclei

v Two- and three-nucleon pion exchange interactions; realistic models of two- and threenucleon interactions; short-range structure of nuclei and nuclear correlations; momentum distributions of nucleons and nucleon pairs in nuclei; spectral functions; two- and many-body components in the nuclear electroweak current.

The nuclear physics of electron and neutrino scattering in nuclei in the quasielastic regime and beyond 9 hours

- Approximate methods for nuclei (I)
 - » Shell model; relativistic Fermi gas model (success and limitations); relativistic mean field. Phenomenological description of inclusive neutrino scattering based on scaling/superscaling.
- Approximate methods for nuclei (II)
 - » The polarization propagator; RPA approach; RPA equations; many-body diagrams; meson 8 exchange currents and 2p2h terms in general.

3 hours

4 hours

3 hours

3 hours

NuSTEC Training Program- Part 2: Theory-oriented Training

Ab initio methods for nuclei

» A selection from: variational and Green's function Monte Carlo methods, no-core shell model, coupled-cluster method, auxiliary-field Monte Carlo methods. Ab initio descriptions of inclusive scattering: i) integral transform methods (Euclidean and Lorentz transform techniques), ii) self- consistent Green's function methods.

Pion production

QCD (chiral symmetry) constraints to pion pion production at threshold. The role of the Delta(1232) resonance in pion photon and electroproduction. Electroweak excitation of baryon resonances. Transition form factors. Unitarization. Watson theorem. Single pion production, diffractive off a nucleon and coherent off a nucleus. Other meson production channels (kaon, 2 pions, associated strangeness, etc).

Exclusive channels and final state interactions 3 hours

 Transport and cascade approaches to the description of the exclusive final state; pions in nuclei: propagation and absorption; formation time; baryon resonances in the nuclear medium. Nucleon propagation in nuclei. Entanglement between quasielastic and inelastic processes.

3 hours

9

3 hours

NuSTEC Training Program- Part 2: Theory-oriented Training

• Inclusive e and ν scattering in the DIS regime 3 hours

 General analysis of deep inelastic scattering (DIS); Bjorken scaling; quarkparton model; DGLAP equations; nuclear effects in DIS; shadowing; extraction of parton distribution functions; duality.

Impact of uncertainties on neutrino cross sections 3 hours

 Impact of uncertainties in neutrino cross sections on the determination of oscillation parameters; potential for CP violation discovery; role of the near detector. Experimental example: the T2K analysis.

Selected experimental illustrations

4.5 hours

10

 Fine-grained Sampling detector 	2 hours
» Experimental technique	
» Results/capabilities	
▼ LAr detectors	2 hours
» Experimental technique	
» Results/capabilities	
Cerenkov vs. fine-grained measurement techniques	¹ /2 hour

NuSTEC Collaboration Meeting

- Structure of NuSTEC Jorge
 - ▼ One theorist & one experimentalist co-spokes: 2 year alternating appointments
 - ▼ Institutional Board? More?
 - General NuSTEC collaboration need theorists and generator gurus. Ask for volunteers with awareness of obligations to organize workshops....
 - Door is open with an example goal of 20 30 collaborators being optimal for CTEQ activities.
- Review of past week's NuSTEC Generator Training Costas
 - ▼ What worked well anything need adjusting
 - Could we combine the generator oriented with the theory oriented training?
- NuSTEQ Les Houches? development of accords Tom Feusels
 - ▼ Will need these accords to help "facilitate" global fits