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  - Retire outdated/incorrect procedures…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 at least 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 – not only neutrino - 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 $\phi(E) \otimes \sigma(E) \otimes \mathrm{Nuc}(E)$ 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
08:00 - 08:20	Registration		
08:20 - 08:30	Welcome (Andreopoulos)		
08:30 - 09:20	**Lecture T1** (Andreopoulos) *Neutrino generators & MC methods*	**Lecture T5** (Alvarez-Ruso) *Quasielastic neutrino scattering*	**Lecture T9** (Alvarez-Ruso) *Weak coherent meson production*
09:20 - 09:30		Break	
09:30 - 10:20	**Lecture T2** (Sobczyk) *Survey of current neutrino MC generators*	**Lecture T6** (Sobczyk) *Np-Nh contributions to quasielastic-like neutrino scattering*	**Lecture T10** (Sobczyk) *Final state interactions & survey of intranuclear cascade codes*
10:20 - 10:45		**Mid-morning refreshements** (at Foresight Centre)	
10:30 - 11:20	**Lecture T3** (Alvarez-Ruso) *Basics of electro-weak interactions*	**Lecture T7** (Alvarez-Ruso) *Neutrino production of resonances*	**Tutorial 5** (Andreopoulos) *Systematics & event re-weighting*
11:20 - 11:30		Break	
11:30 - 12:20	**Lecture T4** (Alvarez-Ruso) *The nuclear initial state / Basics of many-body theory*	**Lecture T8** (Sobczyk) *Deep inelastic neutrino scattering and neutrino-induced hadronization*	
12:20 -		**Lunch** (at Foresight Centre)	

	Wed 14	Thu 15	Fri 16
13:30			
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*
15:00 - 15:30		**Mid-afternoon refreshements** (at Foresight Centre)	
15:30 - 17:00	**Tutorial 2** (Golan) *NuWro intro - How to configure and run basic applications and analyze the outputs*	**Tutorial 4** (Perdue/Golan) *Comparing generator predictions with data*	**Tutorial 7** (Perdue) *Using fluxes and detector geometries. How to customize GENIE for a complex experimental setup.*
17:00 - 17:15		Break	
17:15 - 18:15	**Lecture E1** (Boyd) *Survey of neutrino scattering data*	**Lecture E2** (Nowak) *Electron scattering data and its use in constraining neutrino models*	**Lecture E3** (Wascko) *Unfolding techniques and model-independent measurements*
- 19:30	Discussion/Drinks	Discussion/Drinks	Discussion/Drinks
19:30 -		**School dinner**	

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 Maria**ni*, **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** 3 hours
  - 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** 4 hours
  - Two- and three-nucleon pion exchange interactions; realistic models of two- and three-nucleon 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) 3 hours
    - » 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) 3 hours
    - » The polarization propagator; RPA approach; RPA equations; many-body diagrams; meson exchange currents and 2p2h terms in general.

NuSTEC Training Program- Part 2: Theory-oriented Training

- Ab initio methods for nuclei 3 hours
  - 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** 3 hours
  - 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.

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; quark-parton 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
  - Fine-grained Sampling detector 2 hours
    - » Experimental technique
    - » Results/capabilities
  - LAr detectors 2 hours
    - » Experimental technique
    - » Results/capabilities
  - Cerenkov vs. fine-grained measurement techniques ½ hour

NuSTEC Collaboration Meeting

- NuSTEQ Les Houches? - development of accords - Tom Feusels
  - Will need these accords to help "facilitate" global fits
- NuSTEC Workshop: np-nh/MEC Effects and Exclusive Channels - 1 year from now?
- Reminder NuSTEC Theory-oriented Training Program
  - 18 – 26 October at Fermilab;
    - **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
- 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?

NuSTEC Generator School at Liverpool

What worked well, what could be improved

Costas Andreopoulos (University of Liverpool & STFC/RAL)

NuSTEC Generator School programme

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NuSTEC Generator School programme

3 very full days (08:30 – 19:30)

- **10 theory lectures** (~10 hrs)
- **7 hand-on tutorials** (~11 hrs)
  - GENIE
  - NuWro
- **3 experimental lectures** (~3 hrs)
  - Broad surveys of neutrino and electron scattering data
  - Unfolding techniques and model-independent measurements

Lectures

Slides available on the web (http://school.genie-mc.org)

I believe all lectures were at about the right level for this school

- Will seek feedback from the students – form in preparation

Theory lectures and tutorials were prepared separately

- Perhaps, in the next school, an attempt can be made to connect those
  - More MC-oriented lectures and more theory-oriented tutorials

- E.g. students could be asked to use the generators to test and confirm statements made in the theory lectures,
  e.g.
  - *relation between CC and NC coherent cross-sections*
  - *KNO scaling*
  - *Ratio of neutral / charge pions in hadron showers*

- That would provide well-motivated tutorial activities and help students remember some of what they heard in the theory lectures

Lectures – A highlight

Morgan came at Liverpool without slides, asking for a blackboard.

That would have been fine, except that we didn't have a blackboard...

Gave the lecture using a flip-chart.

Actually, that was brilliant!

Students were fully engaged.
They appreciated the slow pace and were not swamped with equations.

One can not learn everything in a few days, but could learn something well.

Future schools **should have more of that**.

Tutorials

I believe they also worked well

- Again, will seek student feedback

Multiple generators? **2 works best.**

- Used GENIE and NuWro (1 experimental and 1 theory generator)
- Covered NuWro basics, used GENIE for most part of the school
- It is not worth using many more generators in a school
  - Installation always an issue (unless school provides computers)
  - Would spent most time covering variations of the basics
- Focussing on one generator allows exploring more generator use cases
  - event generation for complex setups (geometry, flux)
  - systematics and event reweighting
- And having 2 generators allows some physics comparisons

Tutorial activities

We knew from Jan's school at Ladek, that having tutorial activities works well

- Motivation
- Task-oriented learning
- Students work in groups: Peer learning opportunities
- Activities were improvised – Could be further developed in future schools
- Schools before NuINT? Generator comparisons, reporting at NuINT

Lecturers coming up with student tasks

Winners of the school competition with prizes (Liverpool HEP t-shirts)

Venue

The venue fundamentally alters the character of school

Liverpool is a great and bustling city, with a beautiful waterfront and too much to do
→ Too much distraction!

The character of the generator school requires total immersion

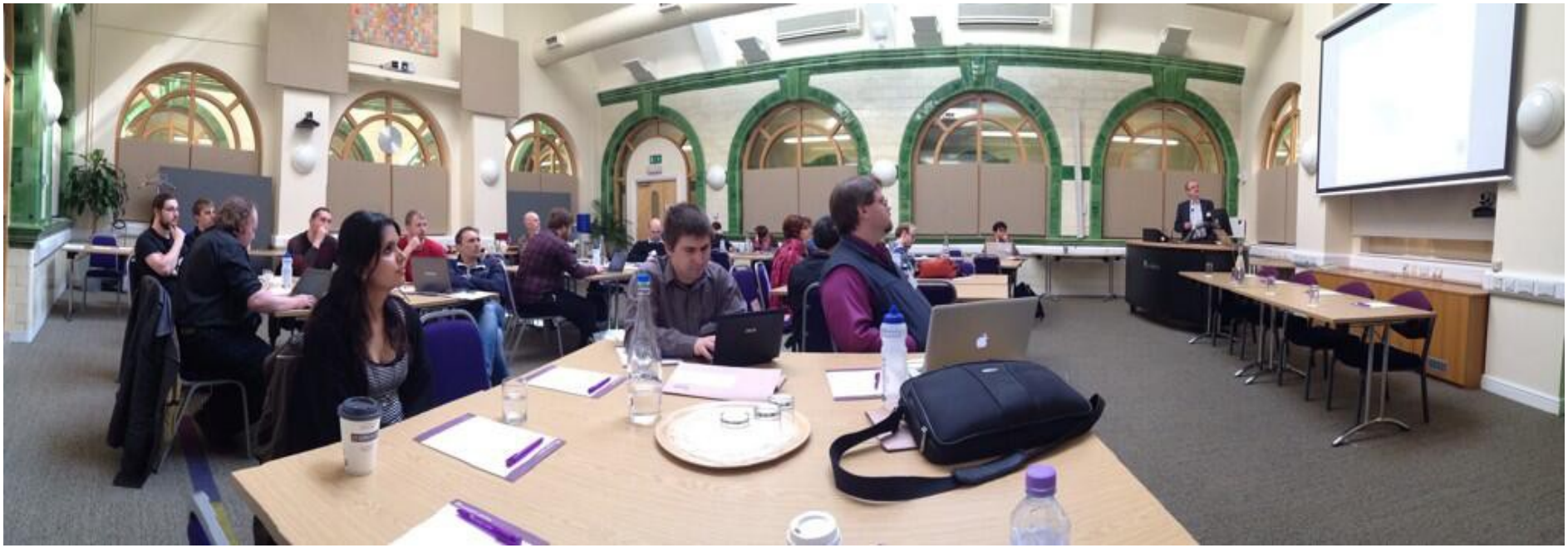
- At Jan's school at Ladek, students were still working on their tutorial activities way past midnight.
- I would organise the next generator school in a more remote place and provide room for students to gather and work in groups.

Participation

Due to the hands-on nature of the generator school, the number of participants was limited to ~30.

Could have a few more, but not many more.

This is a limitation running the generator school along the theory training



Participation

School participation could have been more diverse.
Having the school back-to-back with NuINT did not help much

- Students could not come to NuINT either

Participants were predominantly from Europe (and UK).
School had 1 participant from China, 0 from Japan, 0 from other parts of Asia, 1 from Canada and only 1 from US.

Several potential participants asked for travel support – but none was available