GENIE News

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May 22, 2014

Outline

- The GENIE project
- Current status
- New organization
- On-going developments
- Release plan
- Summary

The GENIE project history

- **2004**: Project started at STFC-RAL, within the MINOS experiment
- **2004-2005**: Development of object-oriented framework using well established software architecture techniques. Extensive code reviews within MINOS.
- **2005-2007**: Development of the first comprehensive set of physics models.
- **August 2007**: First publicly available release **v2.0.0**.
  Physics content in v2.0.0 equivalent with the fortran generator used by MINOS at that time.
- **2007-present**: 12 official releases.
  Numerous physics improvements, software interfaces to allow integrating GENIE with several flux and detector geometry descriptions, numerous tools for systematic error evaluation, validation etc. (see http://releases.genie-mc.org)

GENIE currently used by T2K, NOvA, MINERvA, MicroBooNE, LAr1-ND, LBNE, LAGUNA-LBNO, IceCuBE, OPERA, NESSIE and several others.

A standard reference point for the experimental community: Fully embedded in the MC simulation chain of several experiments. A fully comprehensive model with, out of the box, reasonable agreement with new experimental data.

Main publication (Andreopoulos et al., Nucl.Instrum.Meth. A614 (2010) 87-104) has 130+ citations, about 50 of them in the last year.

GENIE mission statement (abbreviated)

Abbreviated extract from the GENIE Bylaws:

1. The GENIE Collaboration shall provide a state-of-the-art neutrino MC generator for the world experimental neutrino community. GENIE shall simulate **all processes for all neutrino species and nuclear targets, from MeV to PeV energy scales**.
2. The GENIE Collaboration shall provide **electron-nucleus, hadron-nucleus and nucleon decay generators** in the same physics framework as the neutrino-nucleus generator.
3. The GENIE Collaboration shall review critically all relevant theoretical work and experimental data and it shall **synthesize selected physics models and data into a comprehensive and self-consistent picture of neutrino interaction physics.**
4. The GENIE Collaboration shall **curate archives** of the world neutrino scattering data, and a large sample of complementary charged lepton and hadron scattering data, and it shall make those archives available in digital form for the purpose of neutrino interaction **model validation, tuning and systematic error evaluation.**
5. The GENIE Collaboration shall perform **global fits to neutrino, charged-lepton and hadron scattering data and provide global neutrino interaction model tunes.**
6. The GENIE Collaboration shall provide a **complete systematic analysis of its default model.**
7. The GENIE Collaboration shall provide tools to support the full life-cycle of simulation and generator-related analysis tasks.
8. The GENIE Collaboration shall foster closer collaboration between theorists and experimentalists, and it shall organize regular meetings and workshops reaching out to the wider neutrino community.

Default physics model - 1/2

- **Cross-section model**:
  - NCEL: Ahrens model, dipole axial form factor ($M_A = 0.99$ GeV/c^2), strange axial contribution η=0.12.
  - CCQE: Llewellyn-Smith with BBA05 elastic f/f, pseudo-scalar form factor by PCAC, dipole axial form factor ($M_A = 0.99$ GeV/c^2)
  - RES: Rein-Sehgal, 18 resonances with updated parameters, W<1.7 GeV/c^2, ignoring interference, lepton mass only in phase space boundaries, ν_τ corrections due to missing form factors (m=0), dipole vector form factor($M_A = 0.84$ GeV/c^2), dipole axial form factor ($M_A = 1.12$ GeV/c^2)
  - DIS: Bodek-Yang
  - Coherent π: Rein-Sehgal with updated PCAC formula
  - Also QE and DIS charm production, νe elastic, IMD, IMD annihilation
- **Nuclear modelling**: FG with high-momentum tail. Off-shell kinematics.
- **Transition region treatment**: Non-resonance background is extrapolated Bodek-Yang model at W<1.7 GeV/c^2, tuned by a fit to CC inclusive, CC 1π and CC 2π data.

Default physics model - 2/2

- **Neutrino-induced hadronization**
  - Resonances: Phase space decay, all decay channels.
  - DIS/SIS: AGKY - Effective KNO-based "free-nucleon" hadronization at low W, anchored on several pieces of bubble chamber data; Switching gradually (W = 2.3 - 3 GeV/c^2) to PYTHIA at higher W. Non default PYTHIA options (associated production, string energy cuttoff, p_T).
  - DIS charm production: Special hadronization model (charm fragmentation functions + experimentally measured charm fractions, PYTHIA for remnants).
  - SKAT-type formation zone parameterization (DIS only).
- **Intranuclear hadron transport**
  - INTRANUKE/hA: Effective model anchored to h+Fe^{56} data, scaled to all nuclei
  - INTRANUKE/hN: Optional full cascade model

Manpower limitations

Combined core GENIE group effort: Less than 1 FTE/year, for 3-4 last years.

GENIE is falling behind from the state-of-the-art.

These are not in default GENIE. Italicized items have been worked in and are in various stages of completion.

Fundamental Scattering Processes:

Updated nucleon form factors (BBBA07)
Adding ΔS=1 hyperon production
Adding ΔS=1 resonance production
Adding ΔS=1 DIS production
Adding ΔC=1 resonance production
VHE DIS model (NLO cross section construction?)
Updated Bodek-Yang (shallow DIS)
Better ways of combining resonance/shallow-DIS?
GiBUU resonance model
Sato-Lee resonance model
Coherent: PCAC-based (Berger-Sehgal)
Coherent: PCAC-based (Paschos-Schalla)
Coherent: Microscopic (Alvarez-Ruso)
Coherent: Microscopic (Other??)
Coherent: ρ, a_1 production
Diffractive production
Axial-anomaly mediated processes

Hadronization Models:

AGKY model improvements (F/B asymmetry problems)
AGKY model improvements (eta production)
Resonance decay angular distribution fixes
Δ –> Nγ below W=M+m_π threshold
AGKY model improvements (eta production)

Nuclear Physics:

Switching from Bodek-Ritchie/neugen3 treatment of off-shell kinematics to PWIA
Full spectral function implementation
Multi-nucleon scattering mechanisms (MEC et al.)
Short-range correlations
RPA effects
Full hN intranuclear cascade
De-excitation photons for all (or select) nuclei
Nuclear breakup model
Superscaling models

Other:

Tau polarization in cross section calculations
Interfaces to proper tau decay routines (tauola?)
VLE extension
New formation zone parametrizations
Color transparency
Modifications to DIS structure functions in nuclei (e.g. Butkevich)
Radiative corrections for ~1 GeV processes

at least 5 yr of effort
required to get 'up to date'

slide from H.Gallagher, Pittsburgh Generator Workshop

A new generator?

Project Cost Calculator

Include Logic Code Only

Average Salary (per year) $ 80000 .00

Codebase Size
117,899 lines

Estimated Effort
30 person-years

Estimated Cost
$ 2,394,449 *

*Using the Basic COCOMO Model

I understand that a solution put forward to address the GENIE manpower limitations is to develop a new generator from scratch! An estimate of what is needed to re-develop a modern comprehensive generator from scratch is provided by *ohloh*.

Language Breakdown

Language	Code Lines	Comment Lines	Comment Ratio	Blank Lines	Total Lines	Total Percentage
XML	147,190	2,158	1.4%	21,906	171,254	47.4%
C++	110,463	35,611	24.4%	29,909	175,983	48.7%
Perl	5,532	1,669	23.2%	620	7,821	2.2%
Make	1,895	659	25.8%	655	3,209	0.9%
shell script	1,787	447	20.0%	300	2,534	0.7%
Autoconf	528	0	0.0%	44	572	0.2%
SQL	117	0	0.0%	37	154	0.0%
TeX/LaTeX	36	0	0.0%	6	42	0.0%
Totals	267,548	40,544		53,477	361,569	

Workshop at Fermilab

One of the solutions to the manpower limitations is to engage the wide GENIE user community.

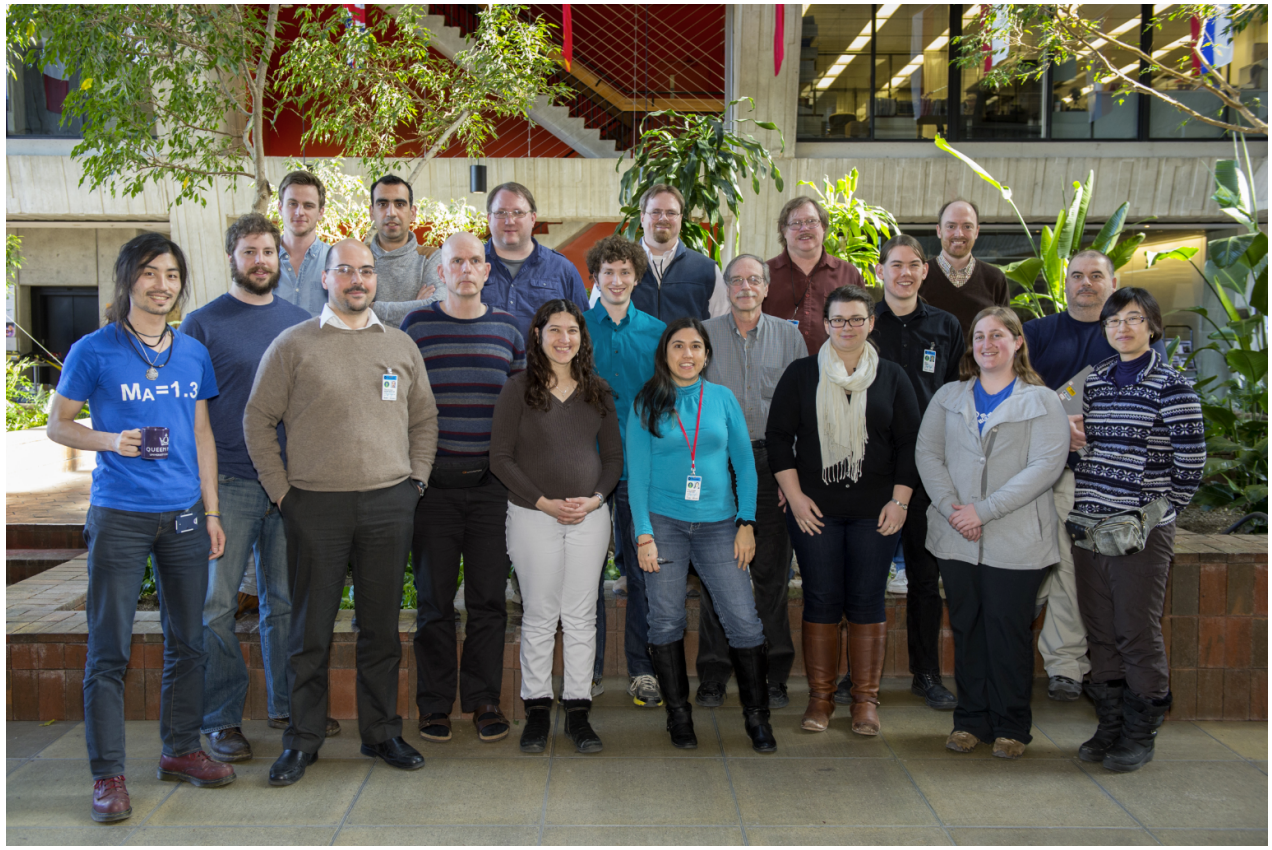
Developers workshop at Fermilab, March 10-14.

Local hosts: Steve Brice and Gabe Perdue.

20 participants from US and Europe. Several experiments represented: LBNE, T2K, MicroBooNE, MINERvA, IceCuBE

Workshop kick-started a series of new developments and continuing collaboration with workshop participants.

The GENIE collaboration shall organize more such workshops in the very near future.



In the Fermilab newsletter:

http://www.fnal.gov/pub/today/archive/archive_2014/today14-03-20.html

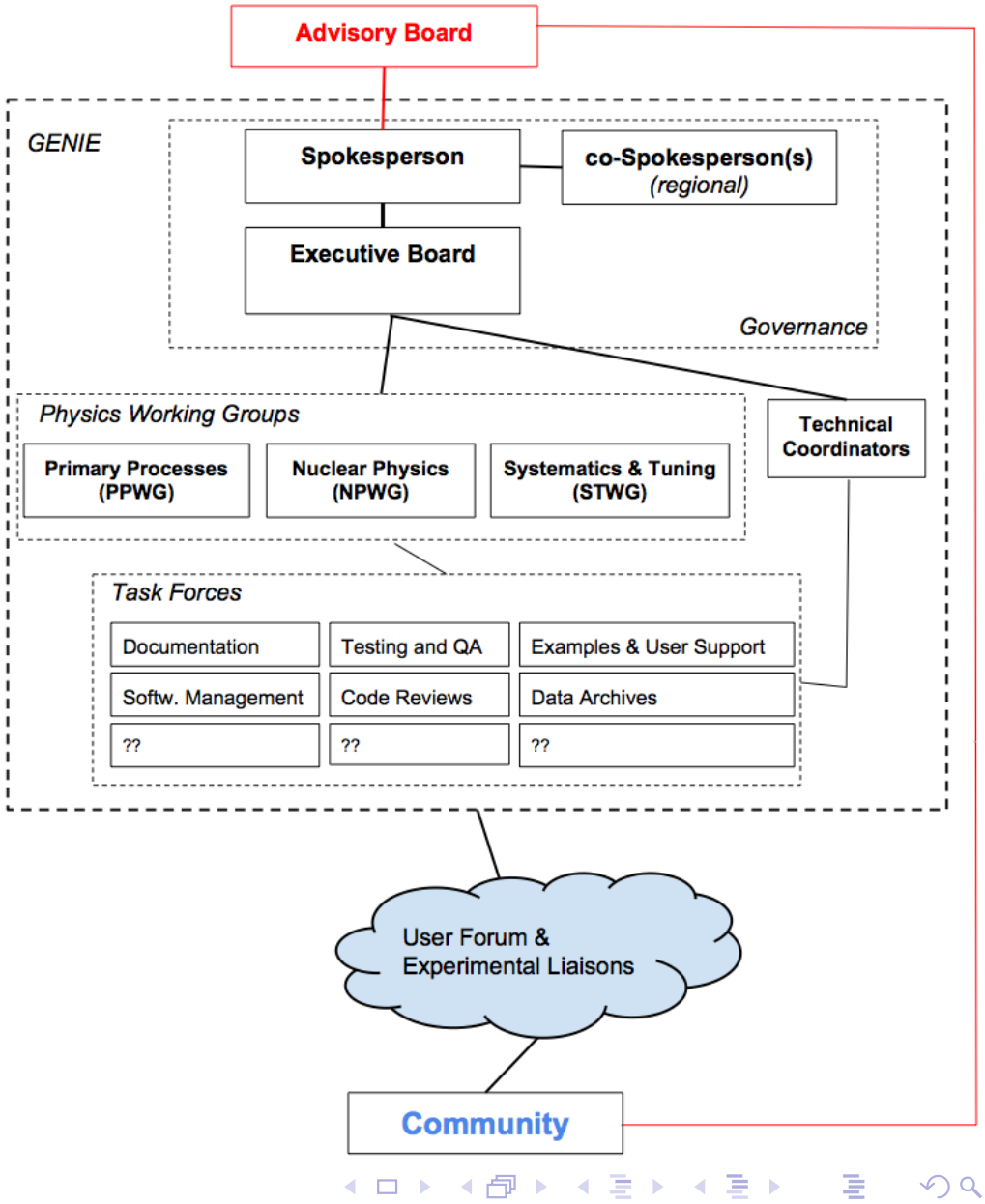
New organization

Along-side opening up GENIE to the community, a new organization structure was adopted to help us grow and manage efficiently a complex project coupled to several experimental efforts.

For the near future we are aiming to a core effort of at least 5 FTE spread amongst a group of $\sim$15 developers.

Strategic expansion (Fermilab CD) and several proposals to DOE, STFC, Horizon-2020 (MSCA-ITN, ERC-CG) and elsewhere to secure funding.

New collaborators welcome!
Participation in the GENIE collaboration implies a significant committment, not only in physics model development but in *all aspects* of generator development, validation, deployment and support. A significant service task contribution, formally agreed in an MOU (STFC Innovations), is expected from GENIE collaborators.



New organization - The role of community

- Most in our community will not want to be full GENIE collaborators.
  - Again, this implies a very significant (service task) contribution to several aspects of the generator besides physics model development.
  - Not unusual. Most collaborations, in one way or another, impose a service task requirement.
- Become a **GENIE contributor** instead!
  - More losely affiliated with GENIE.
  - No formal MOU or service task requirement.
  - Can focus entirely on physics and model building.
  - Possible to co-author GENIE papers wherever appropriate.
  - No role in GENIE organogram
  - Deciding default physics content, global tunes, release schedules etc entirely a responsibility of the GENIE collaboration.
  - No GENIE code releases outside the official distribution channels (MCNET fair academic use guidelines).
- All contributions to GENIE shall be overseen, managed and approved by the GENIE Physics WG coordinators and the Technical co-coordinators.

GENIE at Fermilab

Fermilab an important GENIE partner organization. GENIE a critical tool for the Fermilab Intensity Frontier programme.

A large number of MC validation tools exist in GENIE, but we need to fully automate the validation procedure so as to reduce the *cycle time* to 1 day (currently: ∼week(s), not repeatable). This shall allow GENIE to increase the frequency of fully validated physics relases (currently: every 12-18 months). Using 'Continuous Integration'.

I also expect the Fermilab group to play an important role interfacing GENIE with the Fermilab-based contributors and user community.

Eventually, I would also like to see KEK and CERN assume similar roles in support of the corresponding neutrino programmes.

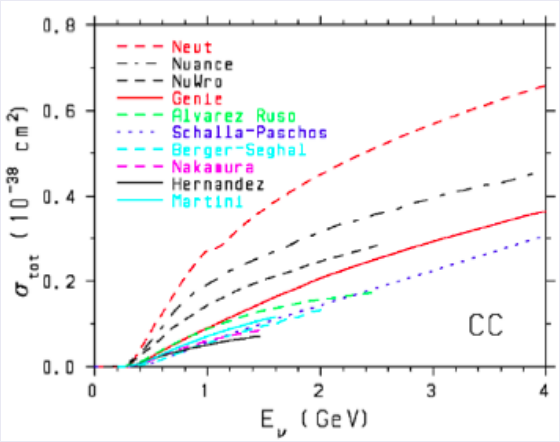
slide from Gabe Perdue (Fermilab)

1. Local work is starting for a fully-automated validation framework.
   - Automated nightly build.
   - Simple nightly validation tests.
   - Weekly "full validation" (production of high statistics samples and comparison to data) for the specified integration branch.
   - Plan to make the automation framework as portable as possible to other institutions. Everyone who wants to needs to be able to set it up.
2. Local working group coalescing.
   - Discussion and planning stage right now.
   - The goal is to partner the core FNAL group with the user community to do effective development.

On-going developments - Highlights

- New PCAC coherent model implementation
- Microscopic coherent model implementation
- Spectral function model implementation
- New Np-Nh model implementation
- New inelastic single Kaon production generator
- FSI model updates
- GENIE-Geant4 integration
- High-energy extension for IceCube

New coherent model (PCAC)



Boyd et al., AIP Conf. Proc. 1189

Large, factor 2, differences in Rein-Sehgal coherent pion production model implementations.
Culprit: Input hadron data.

New model not yet deployed to a public release.

slide from Gabe Perdue (Fermilab)

1. Implemented Berger-Sehgal model at FNAL, with pion cross section lookup courtesy of D. Cherdack at Colorado State.
2. The total cross section reproduces the figure in Berger and Sehgal's paper.
3. Some minor work left (implementation of importance sampling).
4. Available soon as an optional cross section model.

BS "Style"

$$\frac{d\sigma_{\rm el}}{dt} = A_1 e^{-b_1 t}$$

TABLE I. Coefficients A_1, b_1 of Eq. (16).

T_π (GeV)	A_1 (mb/GeV^2)	b_1 (1/GeV^2)
0.076	11 600	116.0
0.080	14 700	109.0
0.100	18 300	89.8
0.148	21 300	91.0
0.162	22 400	89.2
0.226	16 400	80.8
0.486	5730	54.6
0.584	4610	55.2
0.662	4570	58.4
0.776	4930	60.5
0.870	5140	62.2

RS "Style"

$$\frac{d\sigma\,(\pi N \to \pi N)}{dt} = A^2 \frac{d\sigma_{el}}{dt}\Big|_{t=0} e^{-bt} F_{abs}$$

$$\frac{d\sigma_{el}}{dt}\Big|_{t=0} = \frac{1}{16\pi}\left(\frac{\sigma_{tot}^{\pi^+ p} + \sigma_{tot}^{\pi^- p}}{2}\right)^2$$

$$b = \frac{1}{3} R_0^2 A^{2/3}$$

$$F_{abs} = \exp\left(-\frac{9A^{1/3}}{16\pi R_0^2}\sigma_{inel}\right)$$

Microscopic coherent model implementation

Enormous effort by the Warwick group (Daniel Scully, Steve Dennis and Steve Boyd) to implement a microphysical coherent model in GENIE.

Known issues with PCAC models at low energies:

- Because of the $Q^2 \to 0$ limit used to connect, via PCAC, the neutrino cross-section to πA elastic scattering, important angular dependencies are ignored.
- Pion wave-function distortion issue.

slide from Steve Boyd (Warwick)

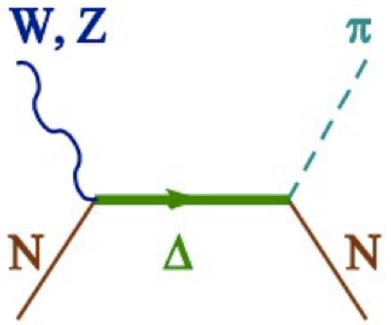
Final nucleus remains in the ground state

Microscopic models :

- Model the $\nu + N \to l\, N\, \pi$ amplitude
- Coherent sum over all nucleons
- Apply medium effects to Δ and distortion to outgoing pion wavefunction

Limited to low energies ($E_\nu < 5$ GeV)

Luis's model (Alvarez-Ruso et al, PRC 75, 76 (2007)) implemented in Genie



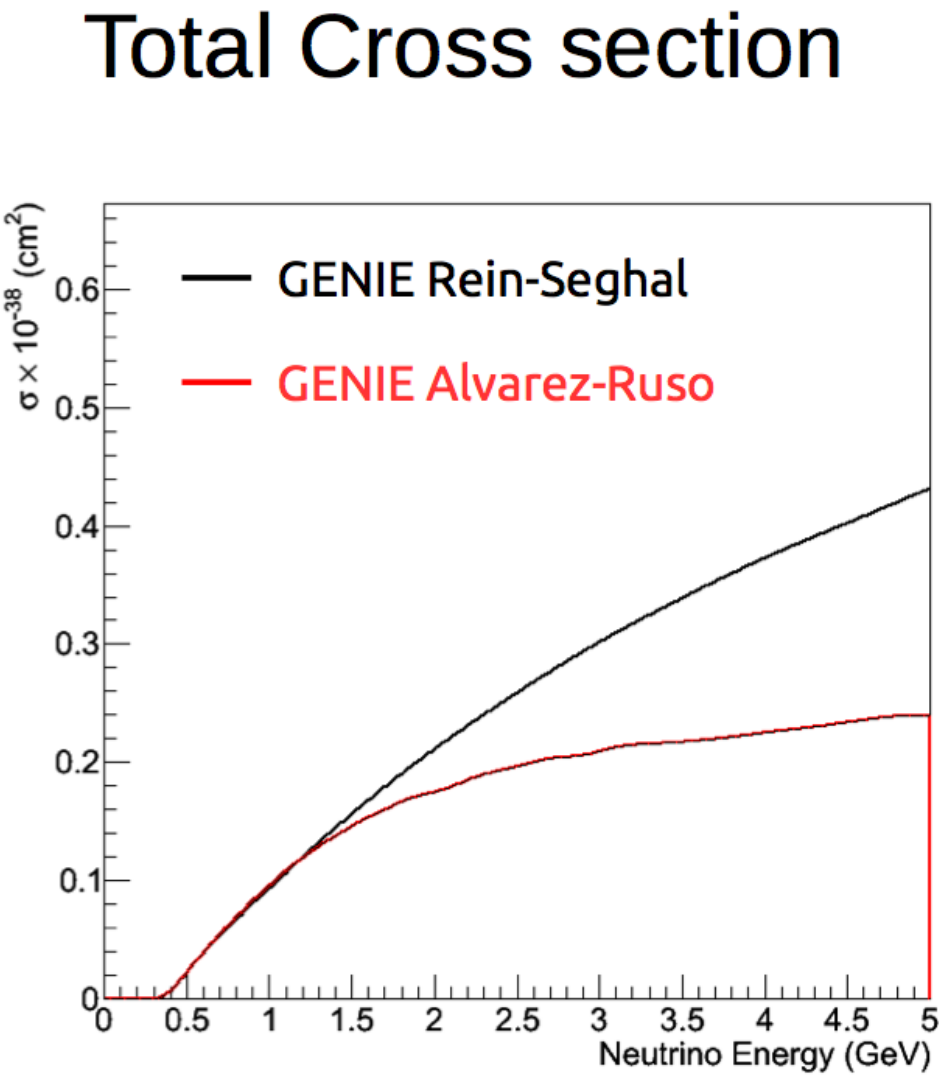
THE UNIVERSITY OF WARWICK

Microscopic coherent model implementation

Cross section model fully implemented in a GENIE development branch.

Not yet deployed to a public release.

slide from Steve Boyd (Warwick)



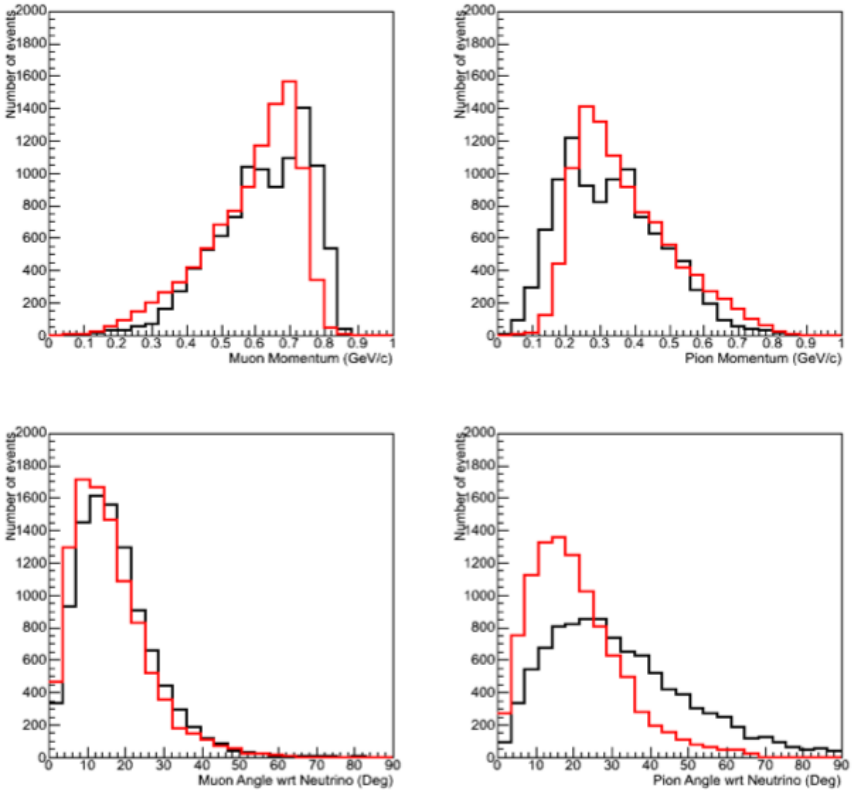
Microscopic coherent model implementation

Coherent event generator using the LAR microphysical model implemented in a GENIE development branch.

Not yet deployed to a public release.

slide from Steve Boyd (Warwick)

Event distributions



CC ν_ν Coherent

E_ν = 1.0 GeV

GENIE Rein-Seghal

GENIE Alvarez-Ruso

THE UNIVERSITY OF WARWICK

Microscopic coherent model implementation

New model factor of 600 slower.

Common theme for GENIE development work this summer:

Upgrade plain kinematical selection in several "slow" models (coherent, spectral function): Metropolis - Hastings or importance sampling.

slide from Steve Boyd (Warwick)

Issues and Plans

- Microscopic model differential cross section is slower than Rein-Seghal but has been optimised – microscopic model has more calculation to do than Rein-Seghal

(64 bit 2.4 GHz Xeon CPU)

Average time to calculate one differential cross section point

Rein-Seghal	Alvarez-Ruso
10 ms	70 ms

Average time to select one event

Rein-Seghal	Alvarez-Ruso
0.2 seconds	120 seconds

- Event selection is currently very inefficient due to the very basic accept-or-reject algorithm used. We are now looking at ways to optimise this : importance sampling, change of variables.

Spectral function nuclear model implementation

A relatively "easy" upgrade. Existed in GENIE for years.
Need to validate this model led to extensive machinery for GENIE comparisons with electron scattering data.

Machinery was "recently" developed but model was not fully validated.

Very significant GENIE effort by Andy Furmanski (Warwick) based on his experience implementing this model in NEUT, and building on work of the NuWro group.

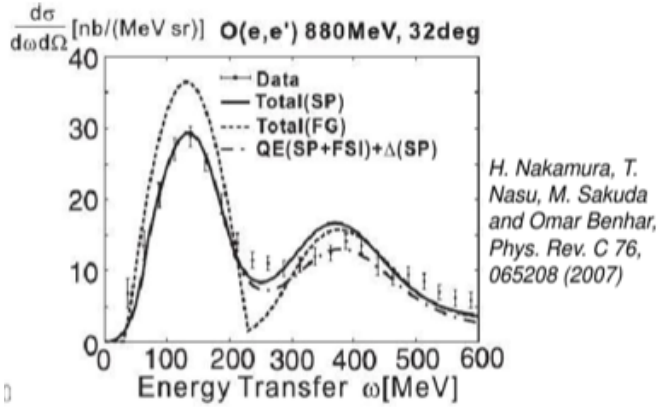
slide from Andy Furmanski (Warwick)

Spectral function model is an alternative to RFG model

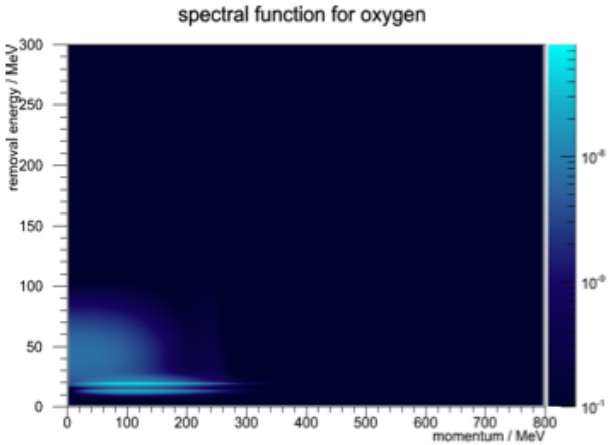
Describes the initial state of the nucleus
- i.e. nucleons initial energy and momentum distribution
- 2D plot in removal energy and momentum
- Long tail comes from correlated pairs of nucleons

Known to provide better agreement with electron scattering data (see plot)

Already implemented in NuWro and NEUT



H. Nakamura, T. Nasu, M. Sakuda and Omar Benhar, Phys. Rev. C 76, 065208 (2007)



Spectral function nuclear model implementation

New spectral function model implemented in a GENIE development branch.

Not yet deployed to a public release.

Need technical changes to fully integrate in the generator and efficiency improvements.

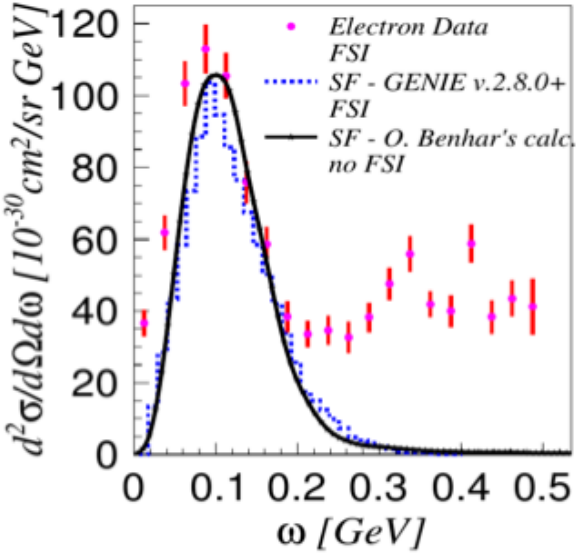
slide from Andy Furmanski (Warwick)

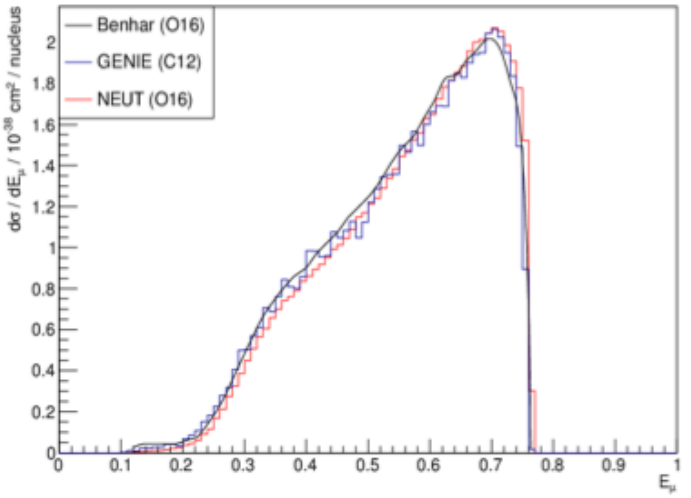
GENIE implementation developed by groups at Warwick and Virginia Tech

Try to re-use as much code from RFG as possible

Current code contains a bug
- Selection of lepton Q2 depends on initial nucleon – uneven sampling
- Has a large effect when using SF model
- Initial fix is in place – good agreement found with O.Benhars calculations (see plots)

Efficiency is now a problem
- Hope to solve in near-future





New Np-Nh model implementation

GENIE has a reasonable home-grown MEC model (presented at the last NuINT).

Not in default mode. Prefereably for systematic studies only.

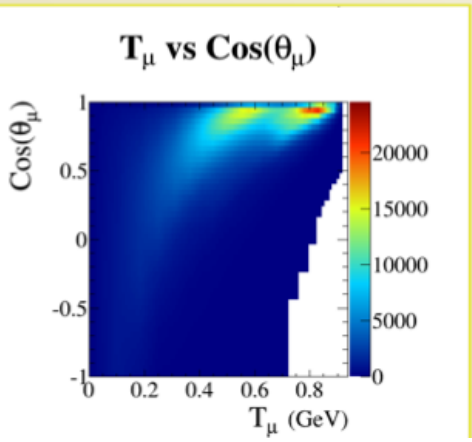
There was a need for a better motivated MEC model.

Work in progress. Not yet deployed to a public release.

slide from Jackie Schwehr (Colorado State)

- Models:
  - Nieves' MEC model: Double differential cross section for outgoing lepton kinematics
  - Sobczyk's Multinucleon ejection model: recipe for outgoing hadron kinematics
- Implementation:
  - Double differential cross section tables sampled for lepton kinematics
  - Remaining transfered four momentum given to the hadron pair
  - Hadrons split momentum evenly and are emitted isotropically
- Current Status:
  - Generator pieces are complete for one target, debugging combination and full generator implementation.
- Future Steps:
  - Full generator completion
  - Cross section table interpolation validation
    - Direct application of Nieves' code without sampling tables
  - Generalizing to all targets and neutrino flavors
  - Full validation

$$\left.\frac{\partial^2\sigma}{\partial T_\mu \, \partial\cos(\theta_\mu)}\right|_{E_\nu}$$

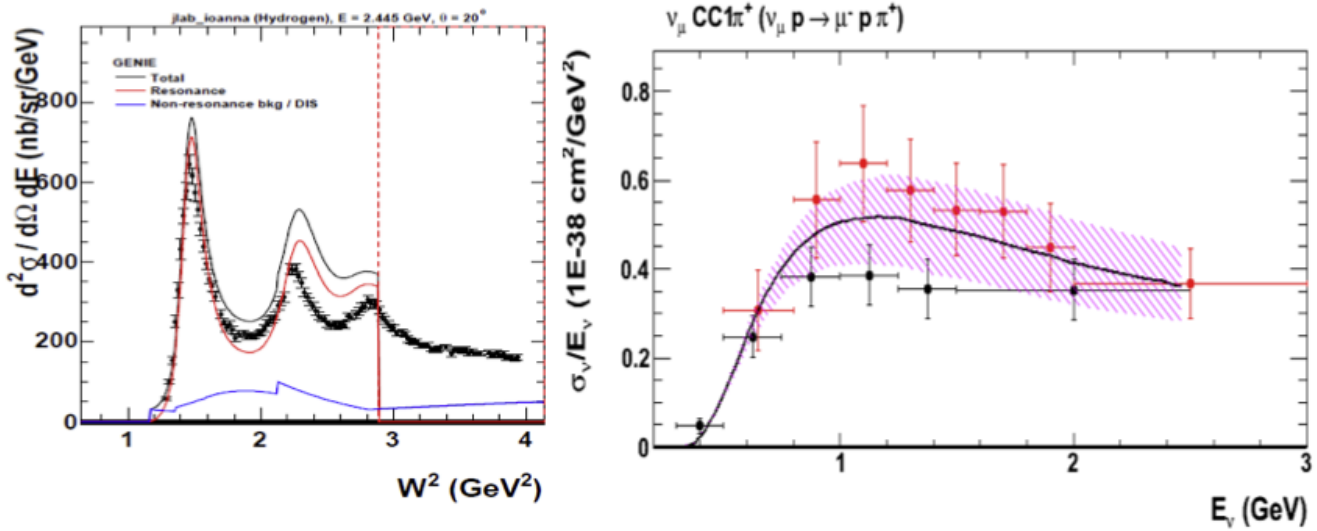


Resonance production model updates

Work in progress.
Not yet deployed to a public release.

slide from Steve Dytman (Pittsburgh)

- v2.8.0 is updated Rein-Sehgal – not same as 1981 paper



- Work underway (see talk by S. Dytman)
  - validation with (e,e') – tools in place
  - vector couplings from MAID (Alvarez-Ruso, Dytman)
  - include lepton mass (Novak)
  - updated non-resonant processes (Alvarez-Ruso, Dytman)

New inelastic single Kaon event generator

Atmospheric neutrino Single Kaon production also an important background for proton decay searches via the p $\rightarrow \bar{\nu} + K^+$ channel (current limit: $\sim 0.4 \times 10^{34}$ yrs).

Unique physics-driver detector requirements from nucleon decay searches. This work important for LBNE, LBNO,... optimization studies.

Important effort by C.Marshall (Rochester) and M.Nirkko (Bern) to include a single Kaon event generator.

slide from Chris Marshall (Rochester) and Martti Nirkko (Bern)

Need for single kaon production

- Planned cross section measurements of kaon production by T2K and MINERvA suffer from lack of single kaon production, such as $\nu_\mu\, p \rightarrow \mu^-\, K^+\, p$
- Dominant at $E_\nu < 1.5$ GeV due to lower threshold
- Model of Alam *et al.* predicts full final state three-particle kinematics

PHYSICAL REVIEW D **82,** 033001 (2010)

Weak kaon production off the nucleon

M. Rafi Alam,[1] I. Ruiz Simo,[2] M. Sajjad Athar,[1] and M. J. Vicente Vacas[2]
[1]*Department of Physics, Aligarh Muslim University, Aligarh-202 002, India*
[2]*Departamento de Física Teórica and IFIC, Centro Mixto Universidad de Valencia-CSIC, Institutos de Investigación de Paterna, E-46071 Valencia, Spain*
(Received 4 May 2010; published 4 August 2010)

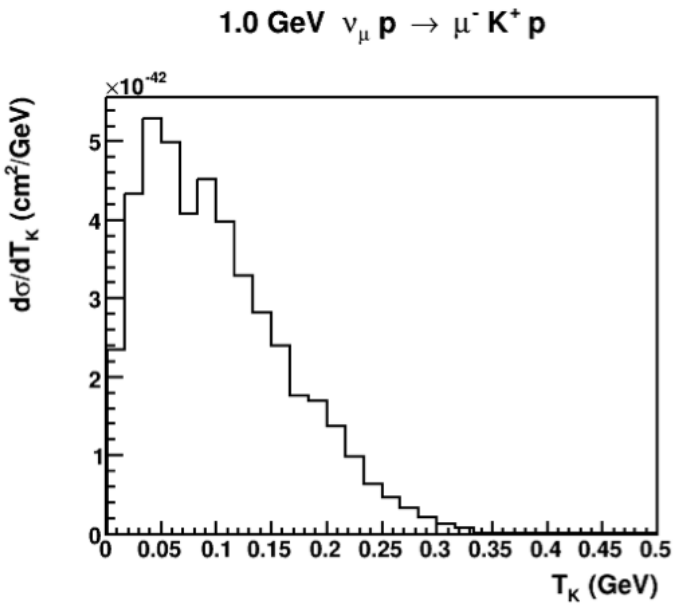
New inelastic single Kaon event generator

Work in progress. Not yet deployed to a public release.

Associated production already included in GENIE. Plans to also include associated production model by the same authors (Athar et al.), probably in combination with own model.

slide from Chris Marshall (Rochester) and Martti Nirkko (Bern)

Status



- Implemented in GENIE by Chris Marshall and Martti Nirkko
- Work began at Fermilab in March
- Neutrino reactions almost done
- Plan to include antineutrinos and hope to finish in a few months

FSI updates: Kaon rescattering

A full evaluation of Kaon backgrounds to nucleon decay searches, and neutrino-induced Kaon production cross-section measurements also require consideration of Kaon rescattering effects.

An effort by F.Blaszczyk to extend the cascade model, having it anchored to additional Kaon data.

Work in progress. Not yet deployed to a public release.

slide from Flor Blaszczyk (LSU)

- GENIE hadron transport only considers elastic scattering data for positive kaons, otherwise kaons are treated as pions in hA routine.

  → K^+ and K^- are very different: different channels, different cross-sections...

- **Goal:** Include all possible channels with available data, use calculations if no other choice.

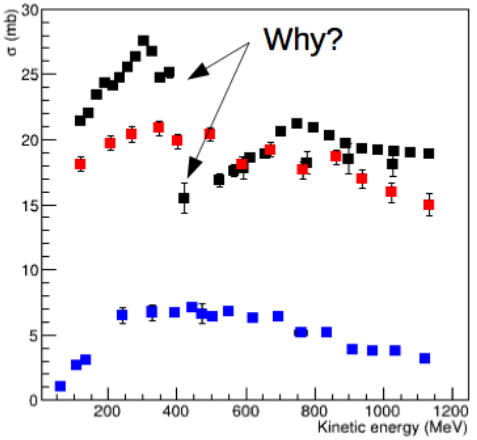
  i.e. $K^+p \rightarrow K\pi N$, $K^+n \rightarrow K^0p$ ...

- **Challenge:** available data on free nucleons mainly... old and incomplete.

- **Plan:**
  - Implement existing data into hN routine, specially at low energy (proton decay studies)

    →*currently implementing charge exchange.*
  - Validate.

K^+ n dominant cross-sections



Charge exchange / elastic:
N.Slater et al., Phys.Rev.Lett. 7, 378 (1961)
G.Giacomelli et al., NP B37 (1972)
Hirata et al., Nucl.Phys. B30 (1971)

Total:
Kaon-nucleon total xsec,Phys.Rev. D2 (1970)
A compilation of K'N reactions, PDG (1969)

FSI updates

Work in progress. Not yet deployed to a public release.

slide from Steve Dytman (Pittsburgh)

- Default FSI is hA (simulate hadron-nucleus in a single, reweightable step)
- Use hN (Intranuclear cascade) as a guide
- hA improvements underway
  - Improve absorption model (Ransome)
  - Use existing data at all A for reaction choices (Geary, Dytman)
  - Improve K-nucleus model (Dytman) (final states from better data)
  - Improve Proton-nucleus at low energy (Betancourt)
- hN improvements underway
  - Add medium corrections in Delta formation (?)
  - Add kaon interaction (de Maria Blaszczyk)

GENIE-Geant4 interface

- A closer integration of GENIE and Geant4?
- Discussion between GENIE and Geant4 collaboration management and SLAC and Fermilab representatives (Asai, Wright, Perdue, Elvira, Andreopoulos).
- Run Geant4 from within GENIE **and** GENIE from within Geant4. Development of interfaces.
- May have important ramifications for the experimental simulation chains.
- Potential to address concerns of precision experiments
  - e.g. unification of hadronic rescattering simulations within the target nucleus (GENIE) and outside the target nucleus (Geant4).
- Expect progress over the next few months embedding the Geant4 cascade in GENIE (Andreopoulos, Perdue + RA/student from the GENIE side)

High-energy extension

GENIE mission to extend down to MeV energy scales (solar, reactor, DAR fluxes) and up to ultra high energy scales (neutrino telescopes). Some early work(e.g. Glashow resonance, IBD)

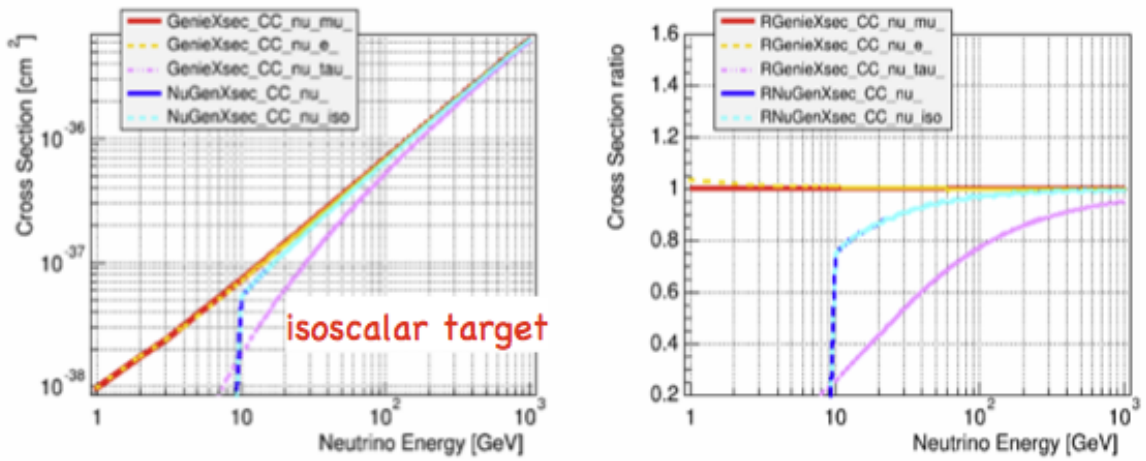
Interest from IceCuBE as with more densely instrumented regions (DeepCore, PINGU) threshold is in the few-GeV region, well within the current GENIE validatity range.

Effort by K.Hoshina (Wisconsin), J.Koskinen (NBI), K.Clark (Toronto) to extend GENIE validity in higher energies.

Kotoyo Hoshina (Wisconsin)

HE extension for IceCube

- Motivation
  - Support wider energy range for IceCube / DeepCore detector
  - For mass production, we need to control random number generator
- New features
  - Set own TRandom3 before running the GENIE program
  - Extend energy limit up to 1 TeV
- Next : detailed study around 1GeV ~ 10 GeV for PINGU



Other developments

- Effective spectral functions (B.Coopersmith, A.Bodek et al.).
- Radiative Δ decays below the pion production threshold (A.Shukraft).
- Formation zone modelling (A.Hatzikoutelis).
- Upgrade of the hadronization validation tools (J.Yarba).
- Initial thoughts about standardized generator/theory interfaces (S.Mrenna, T.Stainer, H.Gallagher, C.Andreopoulos).
- Coherence length and associated reweighting method (G.Christodoulou).
- Extra FSI systematics in GENIE reweighting package (N.Grant and D.Cherdack).
- Hadronization systematics in GENIE reweighting package - Exact method (A.Norrick, N.Meyer).
- Hadronization systematics in GENIE reweighting package - Covariance matrix method (C.Andreopoulos).
- Automated validation (G.Perdue, J.Yarba, C.Andreopoulos).
- Global fitting (C.Andreopoulos, N.Grant, others).
- Experimental interface upgrades (several)
- ...

Plans for future releases

Latest production release: **v2.8.0**

A revision version (**v2.8.2**) should be available by the end of June.

- A bug-fix in R/S coherent model (pion cross-section table interpolation)
- A couple of minor bug-fixes in INTRANUKE (no physics)
- Minor updates in T2K interface, and J-PARC and NuMI fluxes
- ...

New revision version (**v2.8.4**) later this year to include new systematic analysis and reweighting tools used for LBNx detector optimization studies.

A new major version (**v2.10.0** or **v3.0.0**) to include several of the developments mentioned here. Time-line currently unknown (several months to a year seems a realistic goal).

Summary

- GENIE a very well-established and valuable tool for the global experimental neutrino community.
- GENIE fulfills part of its mission but is severely manpower limited
- Now clearly a very exciting time for GENIE
  - New collaboration structure, new ways to work together, several meetings and workshops
  - Strategic expansion, new people, invigorated effort
  - Expect to increase GENIE manpower significantly over the next year.
  - Many new physics developments already in progress

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