GENIE News

(http://www.genie-mc.org)

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10th Intl Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region
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November 19, 2015

UNIVERSITY OF LIVERPOOL

Science & Technology Facilities Council
Rutherford Appleton Laboratory

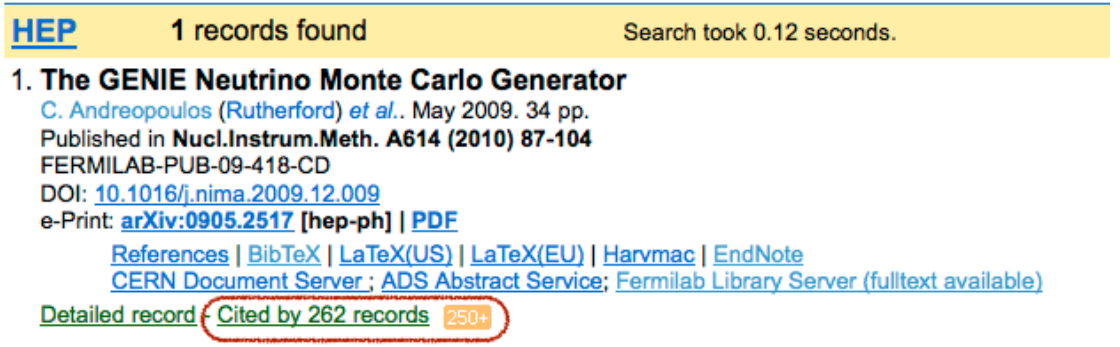
Outline

- The GENIE project
- Organizational news (since NuINT14)
  - *Bylaws*
  - *The Incubator*
  - *New product suite*
- New production release v2.10.0
  - *New models, technical changes, bug-fixes*
  - *Some physics highlights*
- Release roadmap
- Ongoing developments
- Towards a new & re-tuned default model
- Workshops
- Summary

GENIE

About 8 yrs after its first official release, GENIE is the most widely-used Neutrino Monte Carlo generator.

- The main GENIE reference (2010) is now a "famous" paper (250+ citations).
- **Thank you** for this *vote of confidence*.


HEP 1 records found Search took 0.12 seconds.

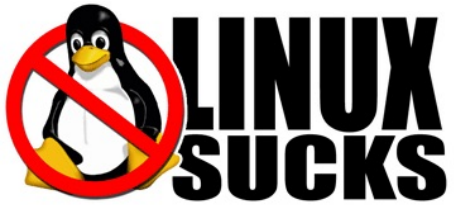
1. **The GENIE Neutrino Monte Carlo Generator**
C. Andreopoulos (Rutherford) *et al.*. May 2009. 34 pp.
Published in **Nucl.Instrum.Meth. A614 (2010) 87-104**
FERMILAB-PUB-09-418-CD
DOI: 10.1016/j.nima.2009.12.009
e-Print: **arXiv:0905.2517 [hep-ph]** | PDF
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
CERN Document Server ; ADS Abstract Service; Fermilab Library Server (fulltext available)
Detailed record - Cited by 262 records 250+

GENIE is popular because:

- On a variety of studies, **for many targets and from MeV to TeV energy scales**, it **performs reasonably well out of the box**.
- Effort was invested to **support generator-related needs of experiments:**
  - Modern software framework
  - Tools and specialised apps to simulate complex experimental setups
  - Tools for a systematic study of the GENIE model
  - Validation, validation, validation

GENIE

GENIE gets the treament of all popular software products: It is tested exhaustively in new situations, and you *love* to point out its weaknesses.



- We are **working very hard to improve it**.
  - Catch-up with best theory
  - Develop new tunes
- Substantial **new manpower** in GENIE Collaboration
  - Significant Fermilab CD involvement since mid-2014
  - 2 new postdocs in US (Tufts, Pitt) with GENIE fractions just starting
  - 2 new postdocs in UK (Liverpool) with GENIE fractions to be hired.
- We are **working hard to engage with our very diverse user base**
  - Developed procedures to engage effectively
  - Several recent new developments were contributed by users

Organizational news

GENIE Bylaws (v1.0)
now **publicly available**
(www.genie-mc.org)

Formalizing the mission of the GENIE Collaboration and **providing a formal framework for its governance**.

Will not attempt to discuss this document much further now.
Please read if you plan to engage with GENIE development.
Feedback is welcome.

Sections:

1. Amendments
2. Licensing and Intellectual Property
3. Mission Statement
4. Governance
5. Advisory Structure
6. Working Groups
7. The Incubator
8. Membership
9. Community Contributions
10. Code Management
11. Service Tasks
12. Publication Policy

The GENIE Incubator

One of the main organizational developments is the *GENIE incubator*.

The *incubator* is where all actual work takes place. It consists of *projects*. Incubator projects are

- in-house development activities, or
- community development efforts

led by the GENIE WG Coordinators and overseen by the GENIE Board.

An incubator project is the **unique route for any physics or software development into a public GENIE release**.

Please get in contact if you have an idea for a new incubator project.

The GENIE group **activelly seek to engage** the community in new projects (and, indeed, I approached several of you in this workshop).

The GENIE Incubator

Incubator projects may include, but not limited to,

- the development of a new physics model,
- the improvement of an existing model,
- a systematic study,
- the tuning of a physics component,
- the development of new tools,
- an upgrade of the framework,
- an improvement of numerical procedure, or
- a documentation improvement.

Public tracking of incubator projects:
http://genie.hepforge.org/load.php?include=incubator

in incubator (24) graduated (5) retired (0)

An incubator projects has **4 phases**:

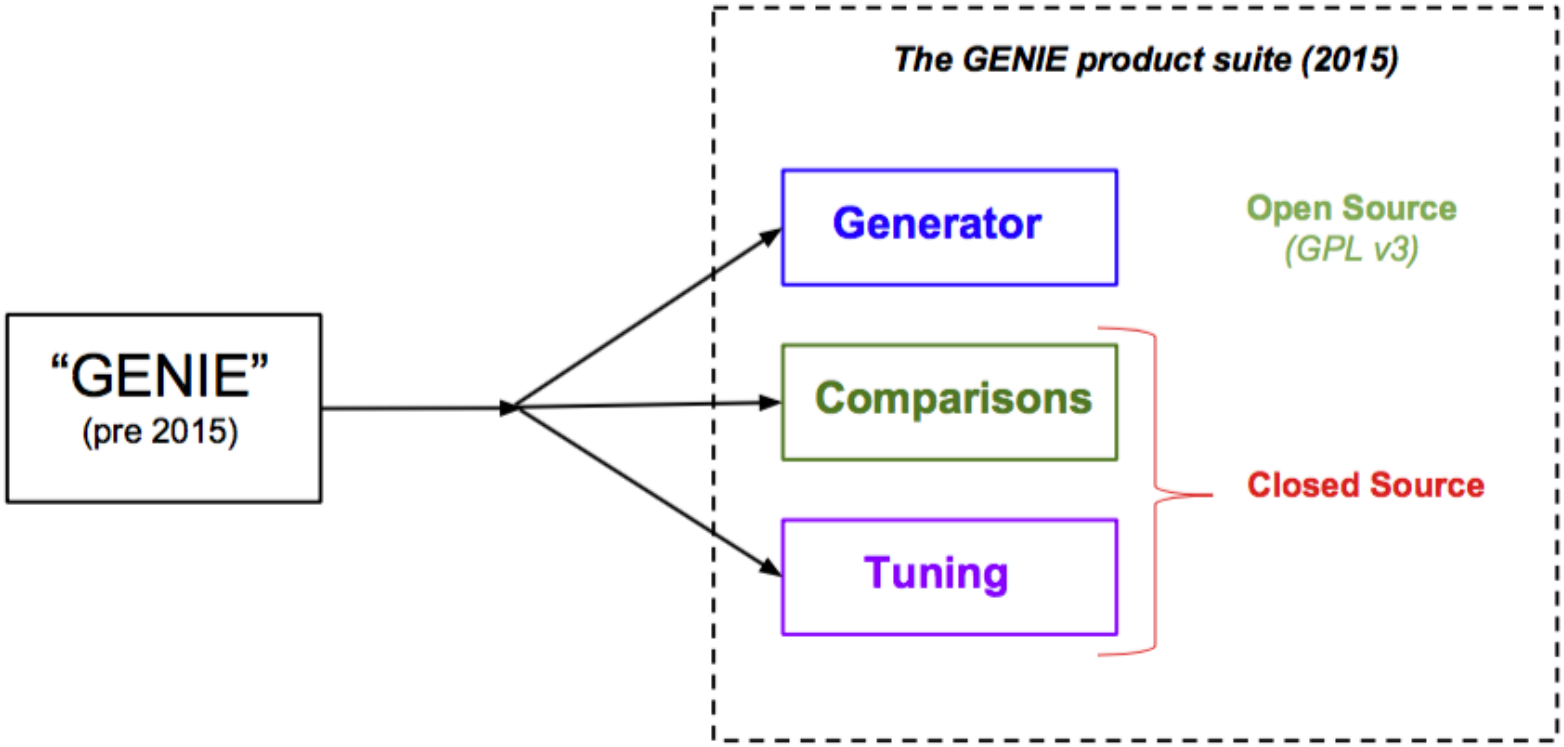
1. **Launch**
2. **Research & Development**
3. **Graduation**
4. **Integration & Deployment**

The procedure is optimized for fast deployment, while maintaining GENIE standards on physics validation, software integration and documentation,

The GENIE **suite of products**

What was known as "GENIE" is now split into **suite of products**.

- Active development of **new products** for the GENIE suite.
- Better separation of the *service* and *proprietary research* components of the GENIE Collaboration work.
  - But actively seeking to engage the community even on closed source products.



The GENIE **suite of products**

- **Generator**:
  1. a modern framework for implementing neutrino event generators,
  2. a well-understood and known comprehensive physics model,
  3. tools to support a systematic analysis of the GENIE physics model, and
  4. tools to support neutrino interaction simulation for realistic experimental setups (flux and geometry drivers, event generation apps)
- **Comparisons**:
  1. extensive curated data archives
     - neutrino, charged-lepton and hadron scattering data
  2. software to produce a data/MC comparisons,
  3. a common framework that facilitates error analysis and tuning, and
  4. event reweighting and tuning hooks
- **Tuning**:
  1. an event generator tuning framework, and
  2. several apps implementing the GENIE tuning strategy.

Improved documentation

We are also improving our documentation and public information on new developments:

- **User and Physics Manual** posted at the arXiv (1510.05494 [hep-ph])
  - To be improved and completed over the next year.
  - Please note: **The NIM A paper is still the primary citation**.
- **Release e-prints** and papers
  - A release note to be posted at the arXiv for each release
    - v2.10.0 e-print by the end of the month
  - Longer journal papers for each new tune
- Setting up an **"official plots" web page**
  - A large collection of data/MC comparisons posted on the web for each physics release

New production version (v2.10.0) - New models

A new production version (**v2.10.0**) was released on **Nov. 2, 2015**.
v2.10.0 is a **model introduction release** (default model/tune unchanged).

- Bodek-Christy-Coopersmith eff. spectral function (EPJC (2014) 74:3091).
  B. Coopersmith and A. Bodek (Rochester)
- Very-High Energy extension (up to 5 TeV, working towards PeV scales)
  K. Hoshina (Wisconsin)
- Inclusive η production.
  J. Liu (W&M)
- Berger-Sehgal resonance model (PRD 76, 113004 (2007))
  J. Nowak (Lancaster) and S. Dytman (Pitt)
- Kuzmin-Lyubushkin-Naumov resonance model (MPL A19 (2004) 2815)
  J. Nowak (Lancaster), I. Kakorin (JINR) and S. Dytman (Pitt)
- Improved INTRANUKE/hA FSI model.
  S. Dytman and N. Geary (Pitt)
- Single K model by Alam, Simo, Athar, and Vacas (PRD 82, 033001 (2010)).
  C. Marshall (Rochester) and M. Nirkko (Bern)

New production version (v2.10.0) - Bug fixes

Noteable (physics or main tool) bug fixes in v2.10.0 (wrt last production release v2.8.6)

- Corrected a sign error in the NC Elastic cross section
  L.Alvarez-Ruso (Valencia)
- Fixed a bug in the file handling mechanism for LHAPDF
  M. Nirkko (Bern)
- Fixed parameter indexing bug when defining a "box" fiducial volume.
- Re-weighting bug fix in the Coherent model.
  unknown hero (NOvA)
- Re-weighting bug in Δ model (weights were applied only to Δ^{++})
  T. Le (Tufts)
- Re-weighting fix for formation zones (T.Golan et al., Phys.Rev. C86 (2012) 015505).

New production version (v2.10.0) - Technical changes

Noteable technical changes in v2.10.0

- New GSL (GNU Scientific Library) dependency
  - More efficient manipulation of the differential cross-sections of high dimensionality computed by several new models
- Several updates in the flux drivers for Fermilab users
  - A consolidation of various flux simulation output formats used at Fermilab
- A new *unified* event generation app for all Fermilab experiments (in the NuMI, Booster and LBNF beamlines)

For a detailed list see: https://releases.genie-mc.org

https://indico.fnal.gov/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=10677

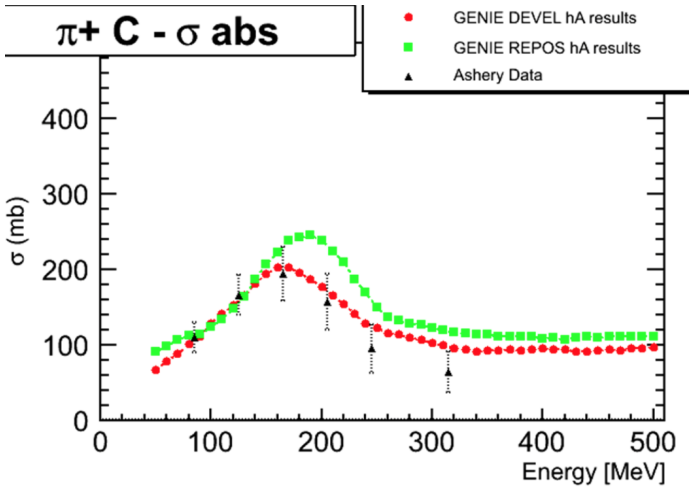
v2.10.0 highlights - Updated *hA* FSI model

Recall that GENIE includes two intranuclear hadron transport models:

- *INTRANUKE/hA*: effective model anchored on data (default)
  - We parameterize a cascade with one *effective* interaction.
  - The model is a) easily re-weightable, and b) in good agreement with data.
- *INTRANUKE/hN*: full INC model (alternative)

Previously hA used data on Fe^{56} and A scaling ($A^{2/3}$ dependence, but this doesn't agree well with data).

- Now including *pi* scattering data for Li^{7}, C^{12}, Al^{27}, Fe^{56}, Nb^{93} and Bi^{209} (less extrapolation needed).
- Now absorption scales as $A^{2/3+0.18}$, charge exchange as $A^{2/3}$, elastic as $A^{2/3+0.25}$, inelastic as $A^{2/3}$, and pion production as $A^{2/3}$ The total cross-section scales as $A^{2/3}$.



Implemented by N. Geary and S. Dytman

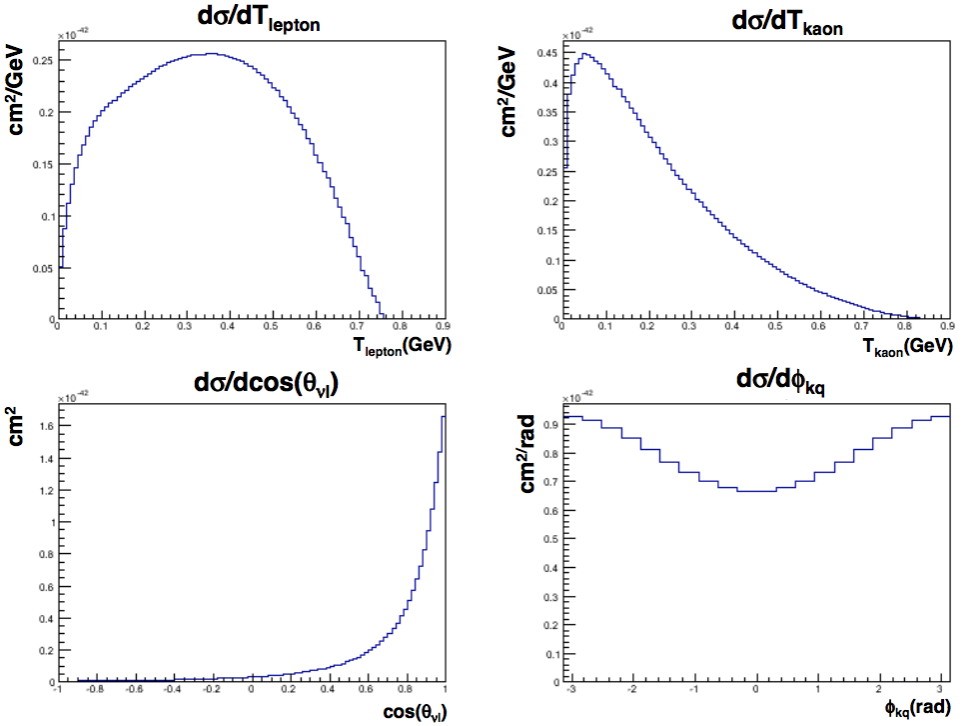
v2.10.0 highlights - Single Kaon production

Single Kaon production:

- $\nu_\ell + p \to \ell^- + K^+ + p$
- $\nu_\ell + n \to \ell^- + K^0 + p$
- $\nu_\ell + n \to \ell^- + K^+ + n$

A new ($\Delta S = 1$) process in GENIE. Previously only associated production ($\Delta S = 0$) was simulated.

Based on the model of Alam, Simo, Athar, and Vacas (PRD 82, 033001 (2010)).

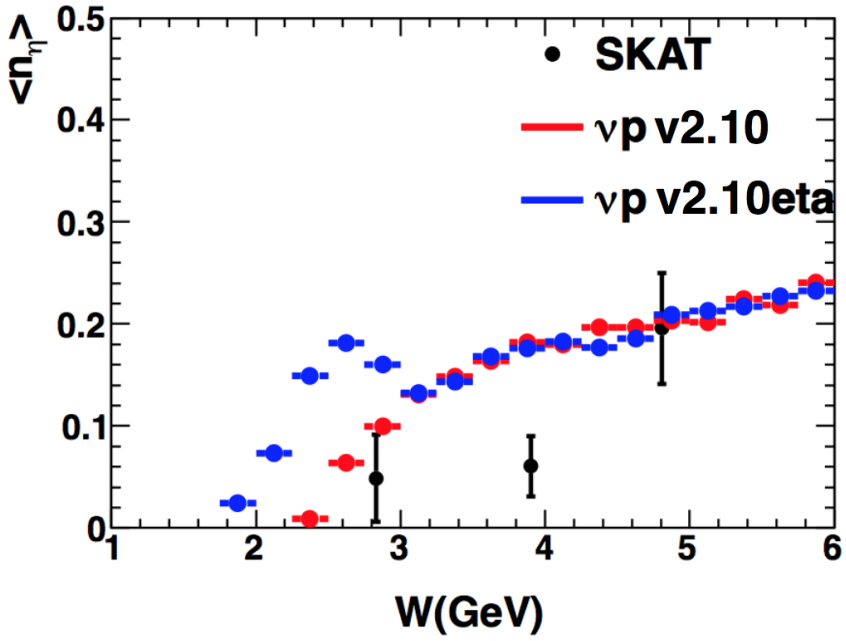


Differential distributions produced in the scattering of 1.5 GeV ν_μ in the channel $\nu_\mu + p \to \mu^- + K^+ + p$

Implemented by C. Marshall and M. Nirkko.

v2.10.0 highlights - η production

- η production important for ν_e appearance as η's have purely electromagnetic decays into photons.
- η's were produced by resonance decays and by the PYTHIA model, but not by the KNO-based part of the AGKY hadronization model.
- Kinematic gap in η production.
- Added option to generate $\eta\eta$ and $\eta\pi^0$ pairs with some probability (untuned).



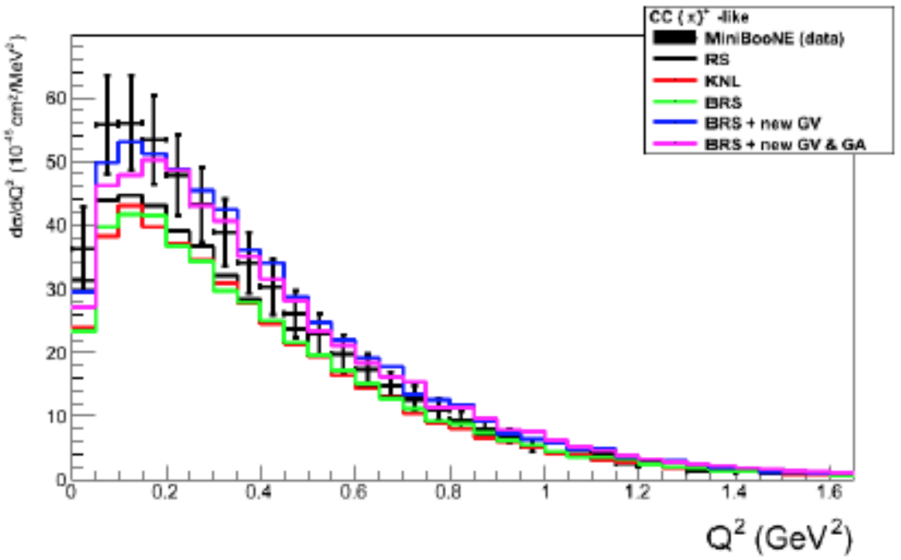
η production rate measurements from the SKAT experiment, compared with the GENIE default prediction (red) and the GENIE prediction with eta production parameters set to large non-zero values (blue).

Implemented by J. Liu.

v2.10.0 highlights - New resonance models

- New resonance models
  - Kuzmin-Lyubushkin-Naumov (KLN) model (MPL A19 (2004)) 2815)
  - Berger-Sehgal (BS) model (PRD 76, 113004 (2007))

- KLN similar to Rein-Sehgal (RS), but includes muon mass effects.
- BS similar to KLN, but includes the pion pole contribution.
- Both models include new vector and axial form factors by the MiniBooNE Collaboration (AIP Conf.Proc. 1189 (2009) 243-248)

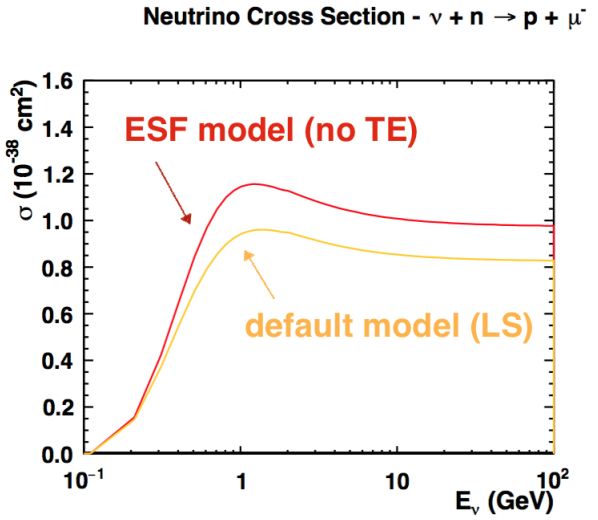


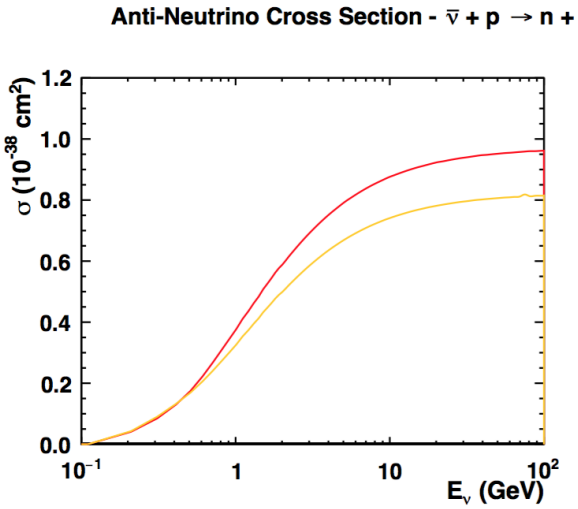
Comparison with MiniBooNE CCπ^+ data. The plot shows the effect of adding the components of the model one at a time.

Implemented by J. Nowak, I. Kakorin and S. Dytman.

v2.10.0 highlights - ESF and TEM models

- Superscaling calculations (PRC 71 (2005) 015501) include FSI effects responsible for an increase of strength in the tail of the differential cross-section distribution and a decrease in the peak. The **Effective Spectral Function (ESF)** model (Bodek, Christy and Coopersmith, EPJC 74 (2014) 3091) included in 2.10.0 is fitted to the superscaling models predictions.
- 2.10.0 also includes the **Transverse Enhancement Model (TEM)** (can be enabled separately within the ESF model) where Q^2 dependent modifications to the elastic proton and neutron magnetic form factors simulate nuclear effects like those expected from MEC.

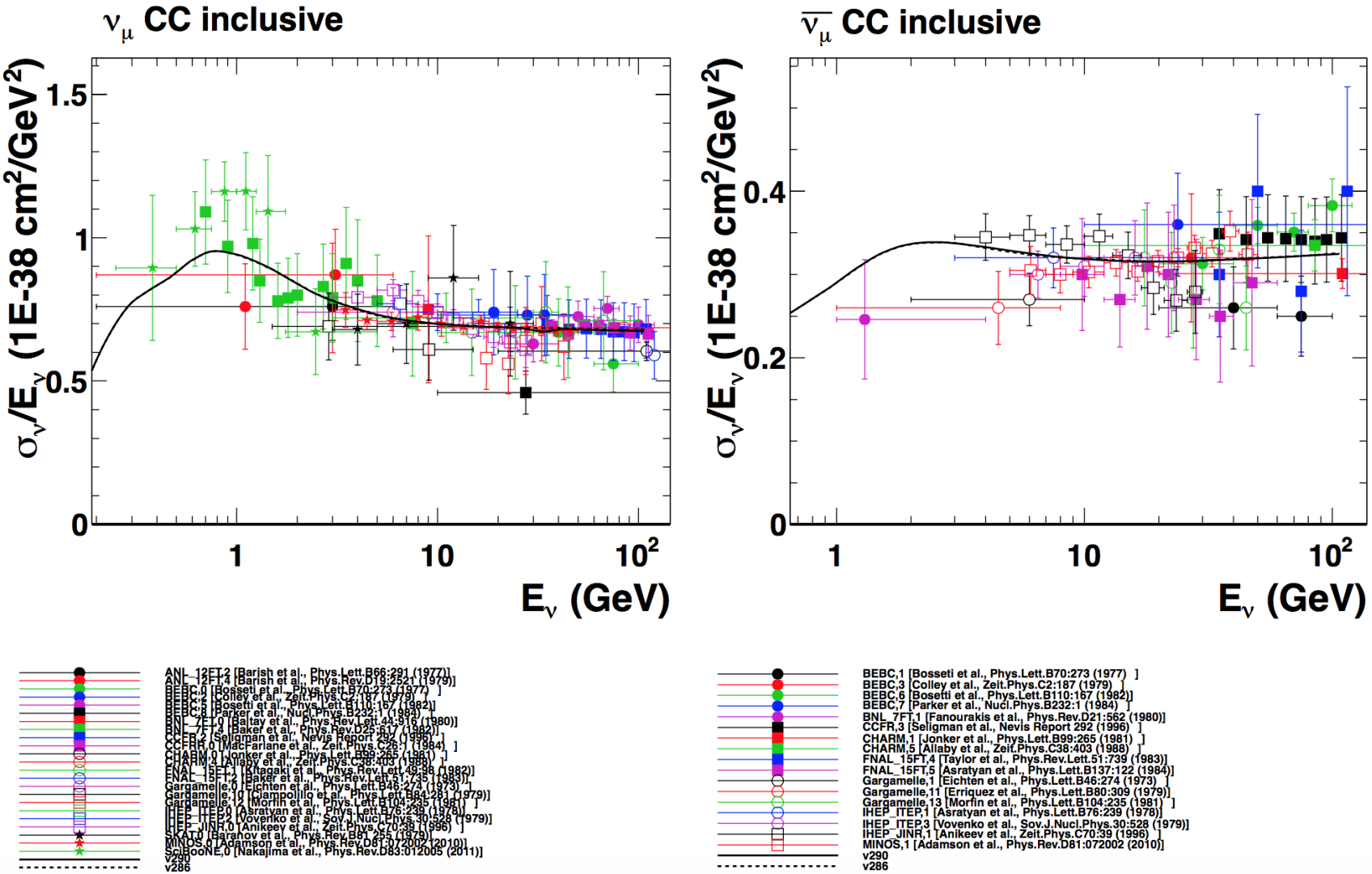




Implemented by B. Coopersmith.

New production version (v2.10.0)

v2.10.0 was a **model introduction release**: New models are optional and the default model was left unchanged.



GENIE release roadmap

Parallel developments towards:

- Release of a new **default physics model / tune**
  (incrementing the major version number vX.Y.Z)
- New **model introduction** releases (leaving default model unchanged)
  (incrementing the minor version number vX.Y.Z), and

Exact timeline uncertain on this instance. A likely scenario:

- **v2.10.0** (now)
- *v2.11.0* (beta model intro release, 2016/Q2)
- **v2.12.0** (official model intro release, soon after v2.11.0)
- **v3.0.0** (new default model / tune, 2016/Q4)
- *v3.1.0* (beta model intro release, 2017)
- **v3.2.0** (official model intro release, soon after v3.1.0)

Of course, revision versions *(incrementing the revision number vX.Y.Z)* **of existing releases** can be prepared and released on a very short timescale, as needed to support the community (e.g fixing bugs found, adding features to support large-scale MC productions).

GENIE release roadmap

Alternative scenarios may unfold.

For example:

- Ongoing physics model developments split over a number of model intro releases (produced at a more rapid succession than usual):
  v2.10.0 (now), *v2.11.0*, **v2.12.0**, *v2.13.0*, **v2.14.0**, *v2.15.0*, **v2.16.0**, **v3.0.0**, ...
- Or, the new / retuned physics model release may be brought forward and released together with newly-introduced model:
  v2.10.0 (now), **v3.0.0**, *v3.1.0*, **v3.2.0**, *v3.3.0*, **v3.4.0**, ...

We know our release roadmap is important for your planning of large scale MC productions (well in advance of summer conferences).

The GENIE Board will the review ongoing developments and priorities and advertise a more **concrete release roadmap by the end of the year**.

Ongoing developments for near-future model intro releases

The following models (or other additions to the GENIE physics) are currently in development*:

- Pais QE Λ production model (Ann. Phys. 63, 361 (1971))
  J. Poage and H. Gallagher (Tufts) $\star\star\star\star\star$
- Berger-Sehgal coherent π production (PRD 79, 053003 (2009))
  G. Perdue (Fermilab), H. Gallagher (Tufts), D. Cherdack (CSU) $\star\star\star\star\star$
- Local Fermi Gas & Nieves-Amaro-Valverde CCQE with RPA (Phys. Rev. C70, 055503 (2004); Phys. Rev. C72,019902 (2005))
  J. Johnston and S. Dytman (Pitt) $\star\star\star\star$
- Valencia 2p-2h model (Phys.Rev. D88, 113007 (2013))
  J. Schwehr (CSU), D.Cherdack (CSU) and R. Gran (UMD) $\star\star\star\star\star$

*The commentary on the stage of development ($\star$: just starting, $\star\star\star\star\star$: nearly complete) is subjective.

Ongoing developments for near-future model intro releases

- Alvarez-Ruso, Geng, Hirenzaki and Vacas microscopic coherent pion production (PRC 75, 055501 (2007); PRC 76, 068501 (2007))
  D.Scully, S. Dennis and S. Boyd (Warwick) ⋆⋆⋆⋆
- Oset, Salcedo and Strottman FSI model (Phys. Lett. B 165, 13 (1985); Nucl. Phys. A 468, 631 (1987).)
  T. Golan (Fermilab and Rochester) ⋆⋆⋆⋆
- Wang, Alvarez-Ruso and Nieves NC 1γ model (PRC 89, 015503 (2014))
  P.Lasorak and T.Katori (QMUL) ⋆⋆
- Benhar et al. spectral function (PR D 72, 053005 (2005)).
  A. Furmanski (Manchester) and M. Jen (VT) ⋆⋆⋆
- Generic structure function interface
  T. Stainer (Liverpool) and R. Petti (SC) ⋆⋆⋆
- Very-high energy DIS model
  K.Mahn, J.Morrison and J.Highnight (MSU) ⋆⋆

Ongoing developments for near-future model intro releases

- Kaon FSI improvements
  F. de Maria Blaszczyk (LSU), S. Dytman (Pitt) ⋆⋆⋆⋆
- Bhattacharya, Hill, and Paz QE form factors Z expansion model (PRD 84, 073006)
  A. Meyer (Chicago) ⋆⋆⋆⋆⋆
- Simulation of $n - \bar{n}$ oscillations.
  J. Hewes and G. Karagiorgi (Manchester) ⋆⋆⋆⋆
- Athar, Honda, Kajita, Kasahara and Midorikawa atmospheric neutrino flux, (Phys.Lett. B718, 1375 (2013))
  G. Majumder, A. Ajmi (INO Collab.); R. Hill and T.Katori (QMUL) ⋆⋆⋆
- PYTHIA8 interface (Comput. Phys. Comm. 178 (2008))
  S. Mandalia and T.Katori (QMUL) ⋆⋆
- Event reweighting I/O
  J.Yarba (Fermilab) ⋆⋆⋆⋆⋆

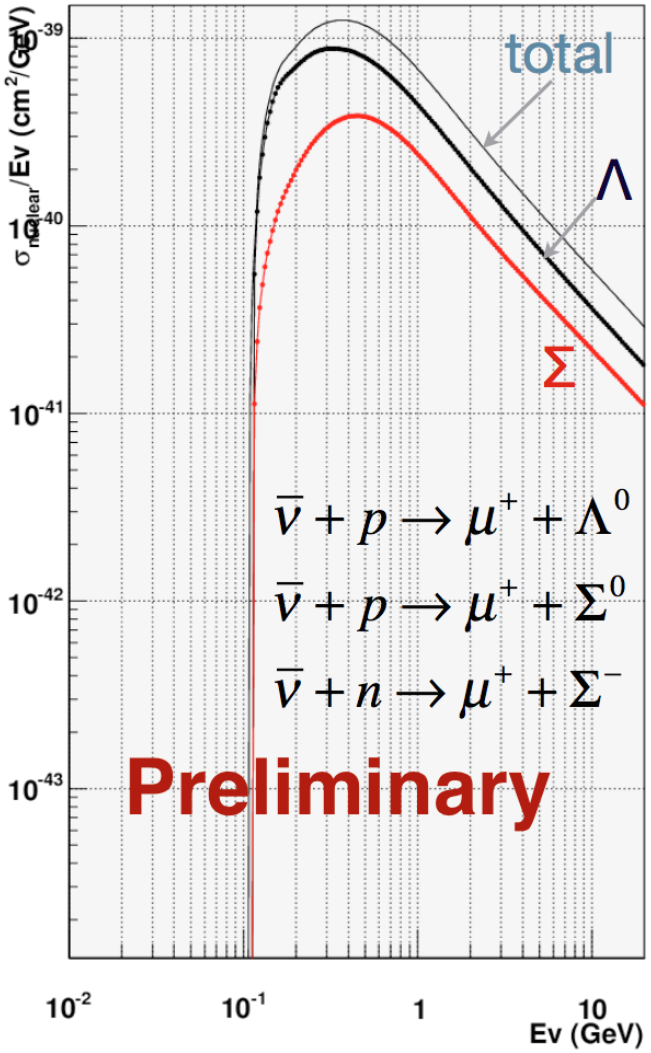
Ongoing devel. highlight - QE Hyperon production

Simulation of three new ΔS=1 channels in GENIE:

- $\bar{\nu}_\ell + p \to \ell^+ + \Lambda^0$
- $\bar{\nu}_\ell + p \to \ell^+ + \Sigma^0$
- $\bar{\nu}_\ell + n \to \ell^+ + \Sigma^-$

Implementing SU(3) model of Pais, Ann. Phys. 63, 361 (1971); Cabibo and Chilton, v136, N6B (1965)

$$\sigma_{\Delta S} \approx tan^2\theta_C \cdot \sigma_{QE} = 0.05\sigma_{QE}$$

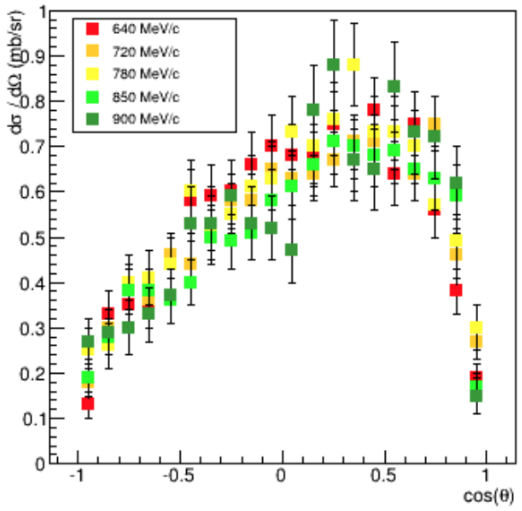


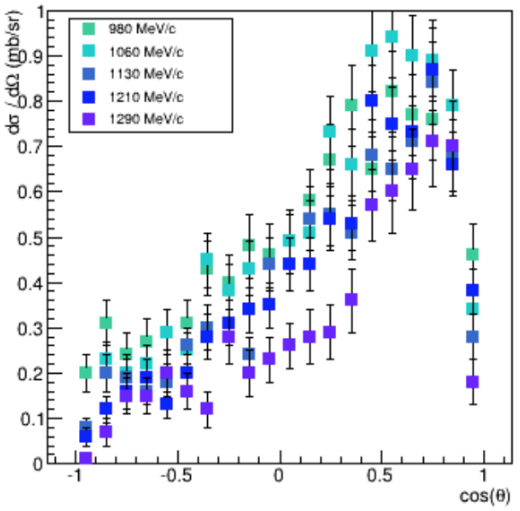
Being implemented by E. Poage, E. Morissey and H. Gallagher.

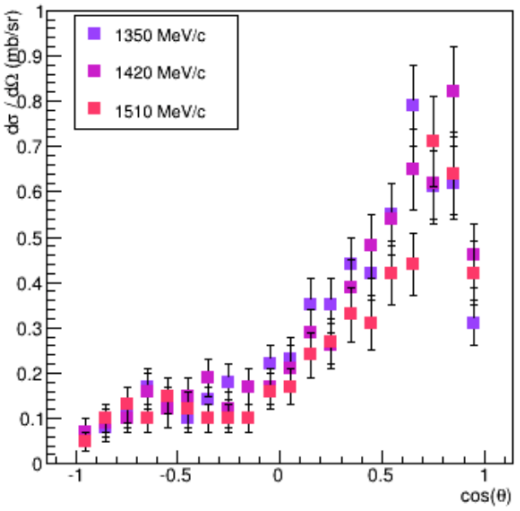
Ongoing devel. highlight - Kaon FSI

- Improvements to the Kaon FSI model, of interest to single-K production and p $\rightarrow \bar{\nu} K^+$ analyses.
- A data-driven extension to INTRANUKE.
- Effort to implement Kaon charge exchange (on a first instance).

K^+n charge exchange data built into the simulation:



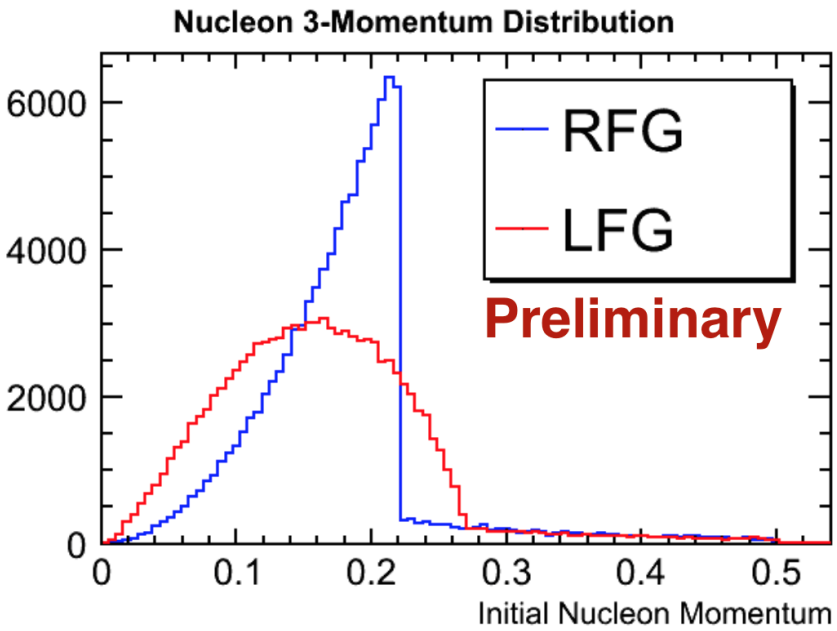


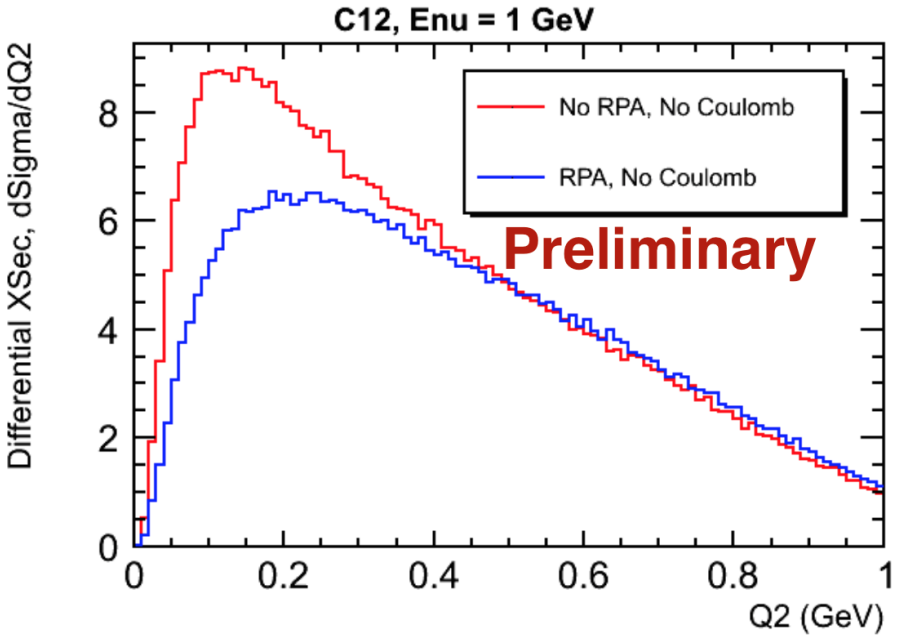


Being implemented by F. de Maria Blaszczyk

Ongoing devel. highlight - Nieves et al CCQE with RPA

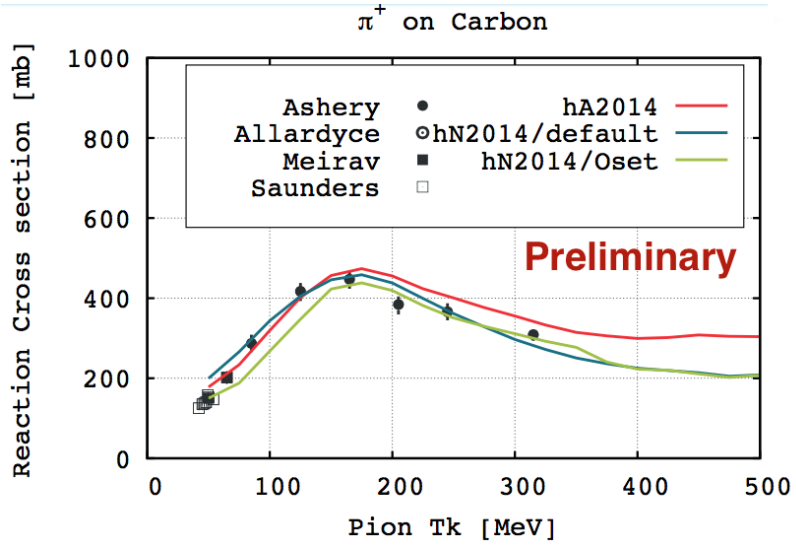
Implementing a local Fermi Gas model and J. Nieves, J. E. Amaro, M. Valverde, PRC 79, 055503 (2004) CCQE model with RPA

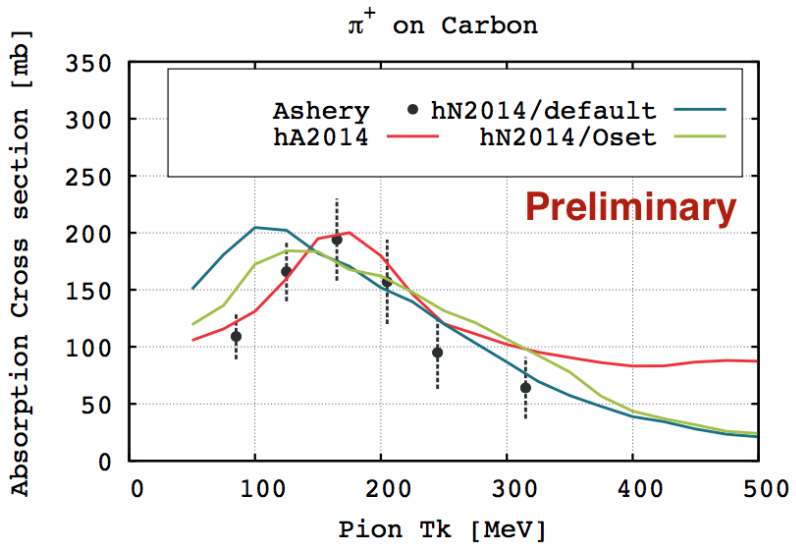




Being implemented by J. Johnston and S. Dytman

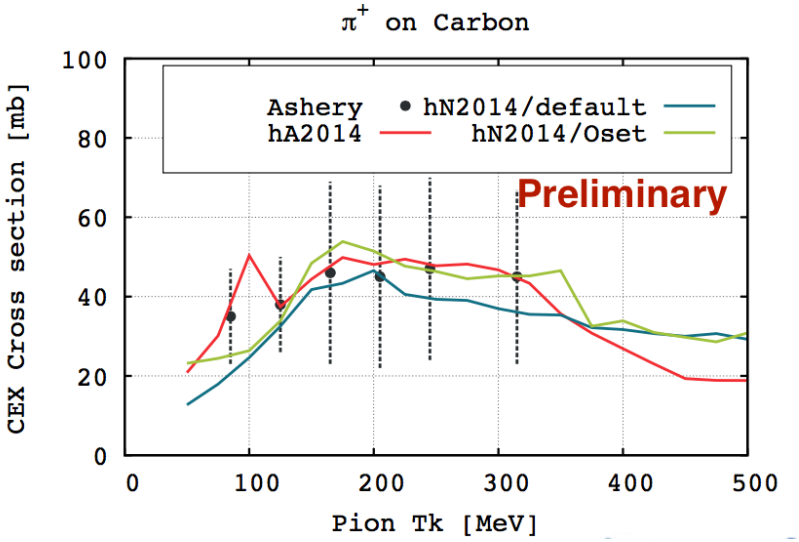
Ongoing devel. highlight - Oset FSI





A 3rd intranuclear cascade model option in GENIE.

Implementing E. Oset et al, Nucl. Phys. A484 (1998) 557-592; E. Oset et al, Nucl. Phys. A468 (1987) 631 within the INTRANUKE/hN framework.



Being implemented by T. Golan

Towards a new / retuned default physics model

GENIE provides a very **well-established platform** (integrated with all experimental frameworks) **to implement neutrino interaction models**.

The core GENIE group:

- **oversees several such projects**,
- has little *own* stake/ preference on the models themselves, and
- exercises its experience on large scale simulations and delivery to experiments to **guarantee the integrity and validity of simulations**.

The above is a **"service" component** of the GENIE Collaboration work.

A longer-term goal of the GENIE Collaboration is to synthesize its models, tools and large collections of curated data archives to provide

- **global analyses of scattering data**, and
- **tunes implemented and distributed through its popular generator**.

This long-term GENIE goal is **starting to materialize**.

Status of the Comparisons package

GENIE includes a large collection of **data acrhives** and **comparisons**. Our comparisons are being moved over to a new framework **linked to a new well-developed Tuning framework** (derived from VALOR).

Dataset	Dataset implemented	Prediction implemented	Comp. tool exists	Comp. in (new) tuning fmwk
$\sigma_\nu, d\sigma_\nu$ (all MiniBooNE)	⋆⋆⋆⋆⋆	⋆⋆⋆⋆		✓
$\sigma_\nu, d\sigma_\nu$ (all MINERvA)	⋆⋆⋆⋆	⋆⋆⋆⋆		✓
$\sigma_\nu, d\sigma_\nu$ (all T2K)	⋆⋆⋆⋆⋆	⋆		✓
$\sigma_\nu, d\sigma_\nu$ (other recent)	⋆⋆⋆	⋆⋆⋆	✓	
$\sigma_\nu, d\sigma_\nu$ (bubble chamber)	⋆⋆⋆⋆⋆	⋆⋆⋆⋆⋆	✓	
F_2, xF_3	⋆⋆⋆⋆⋆	⋆⋆⋆⋆⋆	✓	
$\ell N, \ell A$ hadronics (ν expts.)	⋆⋆⋆⋆	⋆⋆⋆⋆	✓	
$\ell N, \ell A$ hadronics (e, μ expts)	⋆⋆	⋆	✓	
e^- QE (D.Day's dbase)	⋆⋆⋆⋆⋆	⋆⋆⋆⋆⋆	✓	
$e^- p$ resonance (S.Wood's dbase)	⋆⋆⋆⋆⋆	⋆⋆⋆⋆⋆	✓	
pA (various observables)	⋆⋆⋆⋆⋆	⋆⋆⋆⋆⋆	✓	
πA (various observables)	⋆⋆⋆⋆⋆	⋆⋆⋆⋆⋆	✓	
KA (various observables)	⋆⋆⋆⋆⋆	⋆⋆⋆⋆⋆	✓	

Status of the Tuning package and plans

Status:

- Core fitting package and utilities available and well-tested ✓
  - Code adapted from the proprietary **VALOR** oscillation fit framework used for several T2K analyses since 2010
- Event reweighting functionallity for near-term tuning needs ✓
- *ReweightIO* functionallity for improved CPU-efficiency ✓
- Tuning interfaced to event reweighting ✓
- Tuning interfaced to Data/MC comparisons✓

Plans:

- Will embark on first re-tuning exercises once all MiniBooNE, MINERvA, T2K and bubble chamber cross-section data/MC comparisons are brought over to the new framework ($\sim$ 3 months).

The exact scope of the physics model re-tune for GENIE v3.0.0 to be decided by the GENIE Board in the near future.

Upcoming workshops

We plan a series of events to advance this work, collaborate with thers and disseminate our results:

- **GENIE session at CETUP*16**
  Deadwood South Dakota, near the SURF.
  - GENIE-centric hands-on workshop

- **Workshop on Global Analyses of Neutrino Scattering Data**
  Institute of Particle Physics Phenomenology, Univ. of Durham, UK
  - Intl' workshop, non-GENIE-centric
  - Possibly back-to-back with **Neutrino 2016** held in London.

Details for both events to be worked out over the next few months.

Summary

- Several **organization changes since NuINT14**
  - Leading to enhanced collaboration in GENIE-led projects, and optimised for faster deployment of well-validated, integrated and documented developments
- **Model intro release v2.10.0** was made available on Nov 2nd. Credits:

M. Alam[1], C. Andreopoulos[2,3], M. Athar[1], A. Bodek[4], E. Christy[5], B. Coopersmith[4], S. Dennis[6], S. Dytman[7], H. Gallagher[8], N. Geary[7], T. Golan[4,9], R. Hatcher[9], K. Hoshina[10], J. Liu[11], C. Marshall[4], J. Morrison[12], M. Nirkko[13], J. Nowak[14], G. N. Perdue[9], and J. Yarba[9]

- Several ongoing developments
  - **Model intro release 2.12.0 possible in spring 2016.**
- Ongoing efforts towards producing a new default comprehensive model with a new tune
  - **Aiming for new major production release (3.0.0) in 2016**.