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GENIE 2.10.0

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DUNE ND PWG

12 November 2015

GENIE Production Release 2.10

- Last production release was 2.8.6, released 14 November, 2014.
- New release 2.10.0 announced today (based on development 2.9.0)
- Model introduction release.
 - Effective Spectral Functions from A. Bodek, E. Christy, B. Coopersmith (EPJC (2014) 74:3091). (B. Coopersmith and A. Bodek, URochester)
 - Very-High Energy extension (5 TeV, working toward PeV) (K. Hoshina, Wisconsin)
 - Inclusive Eta production. (J. Liu, W&M)
 - New Berger-Sehgal resonant pion production model, tuned with MiniBooNE data by J. Nowak. Berger, Sehgal Phys. Rev. D76, 113004 (2007) & Kuzmin, Lyubushkin, Naumov Mod. Phys. Lett. A19 (2004) 2815 (J. Nowak (Lancaster), I. Kakorin (JINR) and S. Dytman)
 - Improved hA FSI model. (S. Dytman and N. Geary)
 - Single Kaon production model by Alam, Simo, Athar, and Vacas (PRD 82, 033001 (2010)). (C. Marshall and M. Nirkko, Rochester and Bern)

GENIE 2.10 Non-physics Changes

- Updates to the flux driver (R. Hatcher):
 - Implemented a GFluxDriverFactory, where flux drivers can self-register and be returned by name.
 - Introduced two common flux interfaces GFluxExposureI and GFluxFileConfigI, allowing GNumIFlux, GSimpleNtpFlux and the external GDk2NuFlux to be used interchangeably. Other flux drivers can start to incorporate these.
 - Renamed gevgen_num1 executable to gevgen_fnal to emphasize its use in FNAL experiments at other beam lines (e.g. DUNE); executable will dynamically pick up GDk2NuFlux flux driver if available (i.e. no longer a build dependence). Flux entries from the input driver will be copied to a branch along side the GHepRecord; flux metadata from all ntuple files will be copied to the output file.
- Event records:
 - Reinstated method in GHepRecord to return the stored KinePhaseSpace_t, allowing records to be fully recreated from elements stored in non-genie formats (R. Hatcher)
 - Note: We updated the XclsTag object with a new field for strange production for one of the new models in 2.10.0. This could impact the ability of some users to read older GENIE files.

GENIE 2.10 Infrastructure Updates

- Other changes in 2.10
 - Numerous updates to the validation packages for new models and some improvements to the old ones.
 - Removed explicit ".so" from `loadlibs.C` so ROOT's library loading mechanism works on Mac OS-X.
 - Message thresholds may now be specified in an ordered list of files for "cascading" settings.
 - New option for using `Geo/GeomVolSelectorRockBox` as a volume delimiter.
 - Changed the numerical integration routines to use GSL (GNU Scientific Library).
 - Required a re-tune of the DIS spline generation settings.
 - Necessary for several new, higher-dimensional models:
 - Single kaon in 2.10
 - Alvarez-Ruso et al, Microscopic Coherent Pion in 2.12

GENIE 2.10 Bug Fixes

- Corrected a sign error in the NC Elastic cross section (L. Alvarez-Ruso, Valencia).
- Small fixes to the Kuzmin-Lyubushkin-Naumov model in the new Berger-Sehgal resonance model (I. Kakorin, INR).
- Fixed a bug in the file handling mechanism for LHAPDF (M. Nirkko, Bern)
- Fixed parameter indexing bug when defining a "box" fiducial volume.
- Bug fix in `Registry::Get()`.
- Bug fix in the settings for `fZmin` and `fZmax` in `Numerical/BLI2D` (R. Gran, Duluth).
- Bug fix in `Max()` and `Min()` in `Numerical/BLI2D` (J. Schwehr, Colorado State).
- Re-weighting bug fix in the Coherent model (NOvA - name?).
- Re-weighting bug in Delta model (weights were not being applied to anything but Delta++) (T. Le, Rutgers and Tufts)
- Re-weighting fix for formation zones.

Many thanks to all!

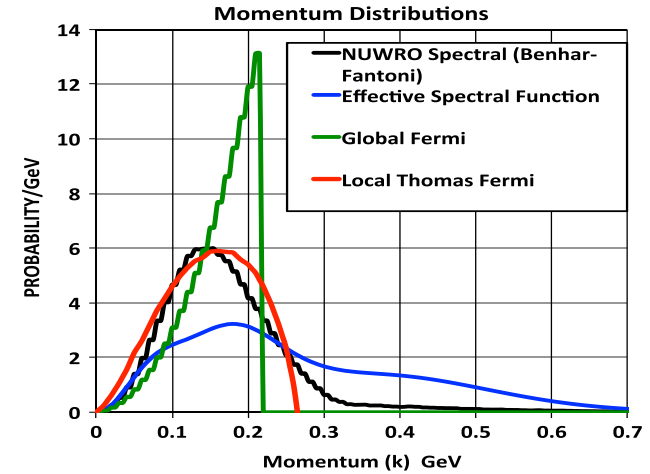
- We would like to officially extend our thanks to everyone who took the time to dig into the code and help find bugs and issues.
- There were many great testers for the 2.9 beta and while we have tried to keep track of everyone's contributions, I'm sure we forgot to mention someone here.
- If you notice an omission, or if an institution is incorrect, etc., please let us know!

Comment on systematics

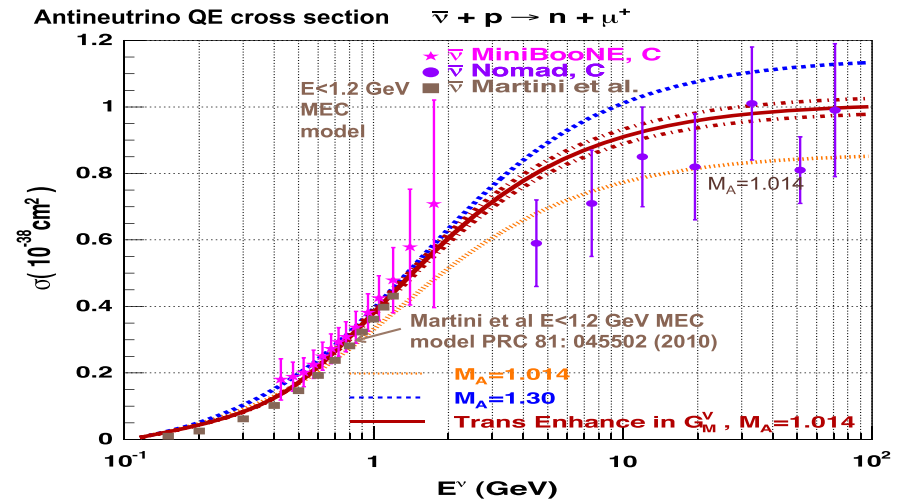
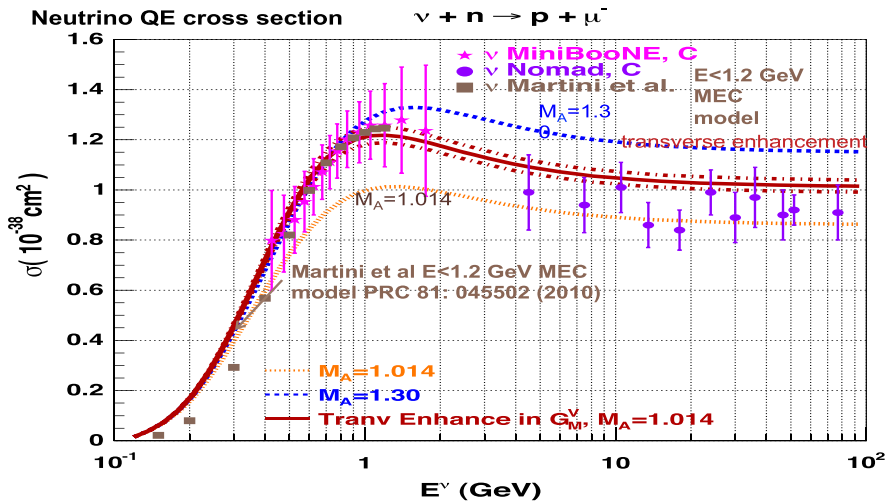
- There are two kinds of changes a user can make to the physics model:
 - reweightable changes
 - non-reweightable changes
- All of the updates for 2.10 involve making non-reweightable changes, so you must re-run events to capture the different physics.
- Even more than that, you must generate new cross section splines for the new models (not if you change the FSI or hadronization models).
 - You can find cross section splines along with documentation on the model changes at our usual spline location:
 - <https://www.hepforge.org/archive/genie/data/2.10.0/>

2.10: Effective Spectral Functions

- The Effective Spectral Function model combines a superscaling formalism together with hadronic energy sharing prescription to form a complete QE model.
 - An eight parameter spectral function is fit to the superscaling function extracted from electron scattering data (plus two parameters for binding energy and 2p2h fraction).
- Implemented by B. Coopersmith (also implemented Transverse Enhancement Model), U. Rochester



Bodek, Christy, Coopersmith EPJ C (2014) 74:3091



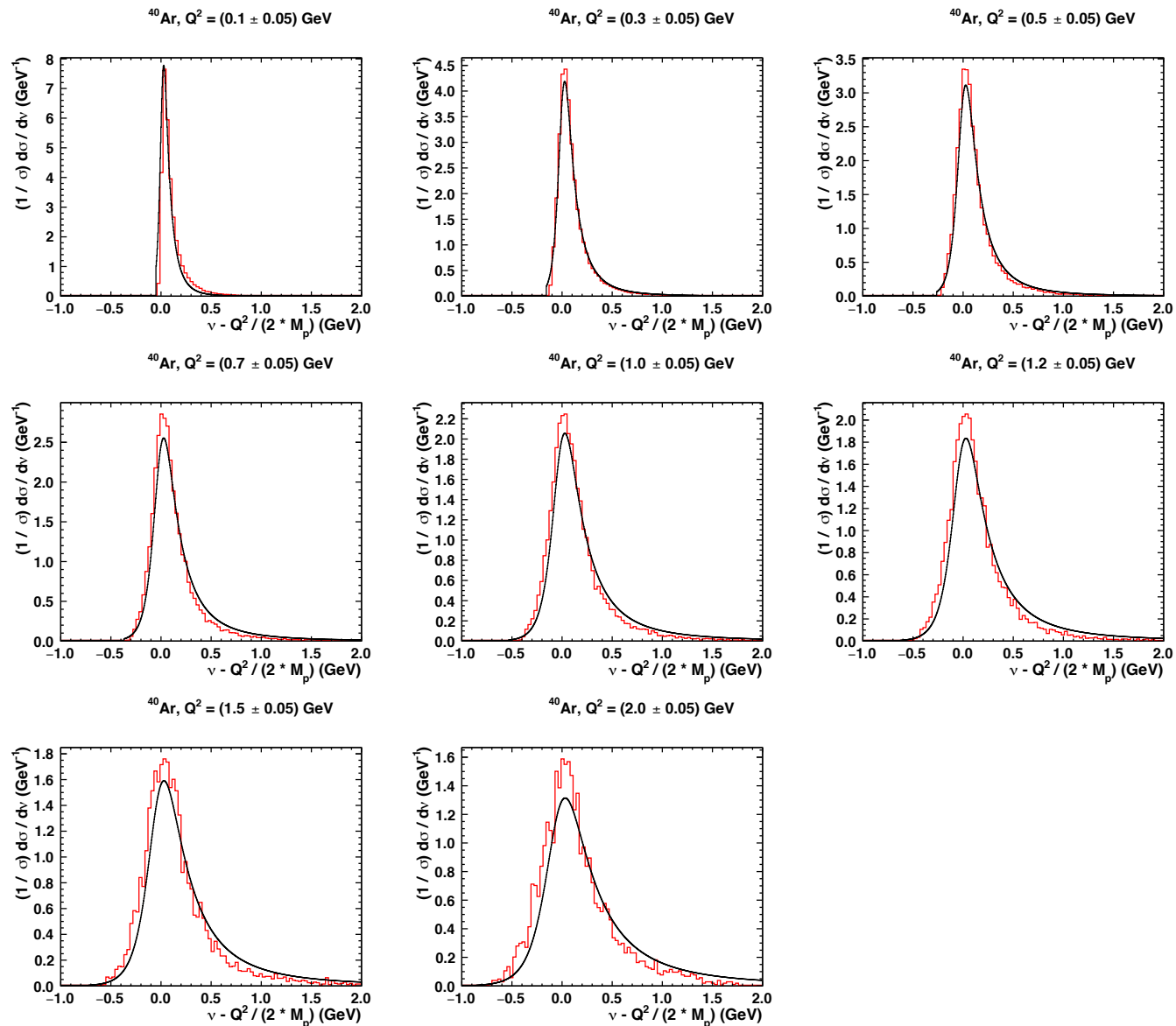


Figure 3: Comparisons between the ψ' superscaling parameter as extracted from electron scattering data [21] (the smooth black curve) as a function of $\nu - Q^2 / (2M_p)$ and the computation produced by GENIE (the red histogram) for different values of Q^2 on Argon-40.

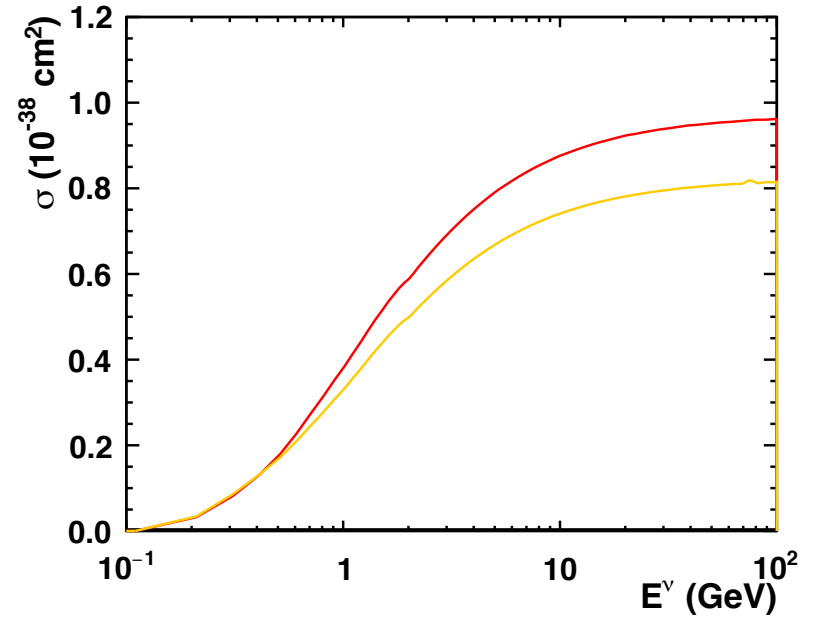
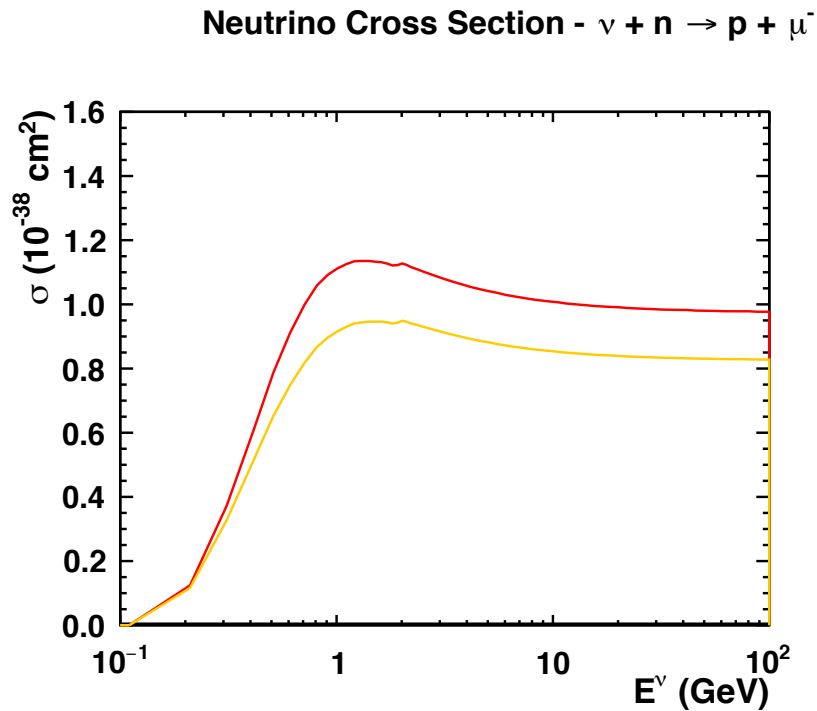


Figure 4: The charged-current quasielastic cross section for neutrinos with the default Llewellyn Smith model in orange and the new Effective Spectral Function model in red.

Activating the effective spectral function

```
<!--
~~~~~
Nuclear model selection.
Options:
- genie::FGMBodekRitchie/Default
- genie::SpectralFunc1d/Default
- genie::EffectiveSF/Default  <- See http://arxiv.org/abs/1405.0583
The 'NuclearModel' option defines the default basic model which should work for any nuclei
(typically a Fermi Gas model with the Bodek-Ritchie NN corellatin tail). Refinements for
specific
nuclei are possible, by specifying the 'NuclearModel@Pdg=10LZZZAAAI' option.
Currently the same nuclear model is forced for all isotopes.

<param type="alg" name="NuclearModel">                genie::EffectiveSF/Default </param>
-->
<param type="alg" name="NuclearModel">                genie::FGMBodekRitchie/Default </param>
<!--
<param type="alg" name="NuclearModel@Pdg=1000060120">  genie::SpectralFunc1d/Default </param>
<param type="alg" name="NuclearModel@Pdg=1000260560">  genie::SpectralFunc1d/Default </param>
-->
<param type="bool" name="IsotopesUseSameNuclearModel"> true </param>

<!-- Option for turning on Transverse Enhancement by Elastic Form Factor adjustment.
See http://arxiv.org/abs/1405.0583 and http://arxiv.org/abs/1106.0340
-->
<param type="bool" name="UseElFFTtransverseEnhancement"> false </
param>
<param type="alg" name="TransverseEnhancement"> genie::TransverseEnhancementFFModel/Default </
param>
<!--
```

Activating the effective spectral function

```
<!--
~~~~~
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- genie::SpectralFunc1d/Default
- genie::EffectiveSF/Default <- See http://arxiv.org/abs/1405.0583
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Currently the same nuclear model is forced for all isotopes.

<param type="alg" name="NuclearModel"> genie::FGMBodekRitchie/Default </param>
-->
<param type="alg" name="NuclearModel"> genie::EffectiveSF/Default </param>
<!--
<param type="alg" name="NuclearModel@Pdg=1000060120"> genie::SpectralFunc1d/Default </param>
<param type="alg" name="NuclearModel@Pdg=1000260560"> genie::SpectralFunc1d/Default </param>
-->
<param type="bool" name="IsotopesUseSameNuclearModel"> true </param>

<!-- Option for turning on Transverse Enhancement by Elastic Form Factor adjustment.
See http://arxiv.org/abs/1405.0583 and http://arxiv.org/abs/1106.0340
-->
<param type="bool" name="UseElFFTtransverseEnhancement"> true </
param>
<param type="alg" name="TransverseEnhancement"> genie::TransverseEnhancementFFModel/Default </
param>
<!--
```

2.10: Berger-Rein-Sehgal Resonant Pion

K. S. Kuzmin, V. V. Lyubushkin, and V. A. Naumov, Mod.Phys.Lett. **A19**, 2919 (2004), hep-ph/0403110.

C. Berger and L. Sehgal, Phys.Rev. **D76**, 113004 (2007), 0709.4378.

- The Berger-Sehgal and Kuzmin-Lyubushkin-Naumov models for N^* resonances are very similar to the default Rein-Sehgal model, but include the effects due to the muon mass.
- BS includes an extra diagram that is not found in KLN.
- Much of the original code for the resonance couplings is untouched.

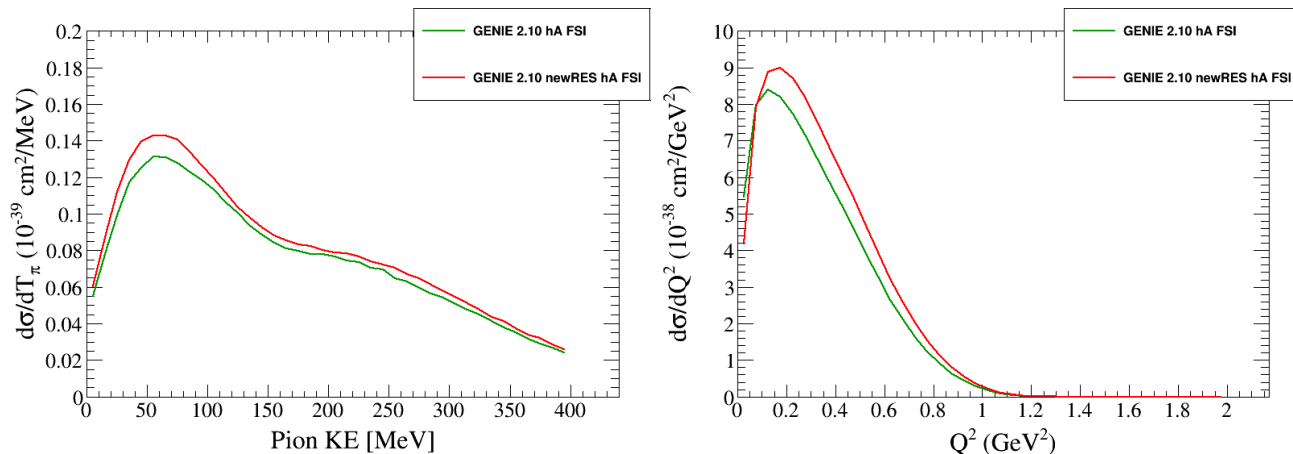


Figure 8: Comparison of new model (Berger-Sehgal with new form factors) with default model.

- Work in MiniBooNE also improved the form factors which have remained unchanged in the Rein-Sehgal resonance model.
- These are also included with parameters (`minibooneGV` and `minibooneGA` for new vector and axial form factors) in UserPhysicsOptions.xml.
- Figure shows the effect of adding the components of the model one at a time. (This uses the same code as in the GENIE validations.)
- S. Dytman, J. Nowak (Lancaster), I. Kakorin (JINR)

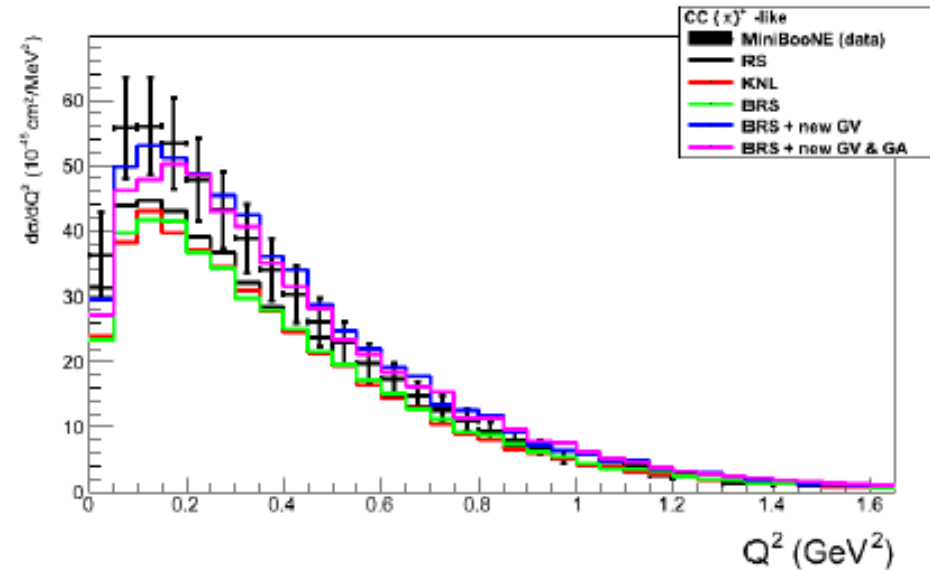


Figure 7: Comparison of new model with MiniBooNE data (J.Nowak).

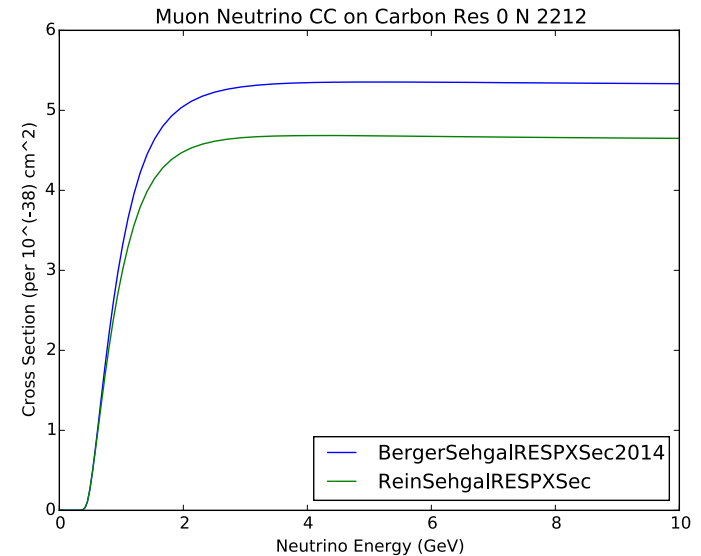
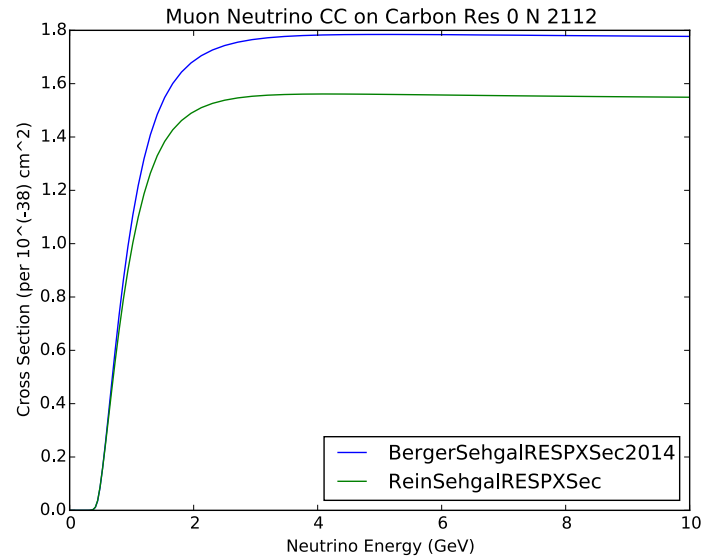
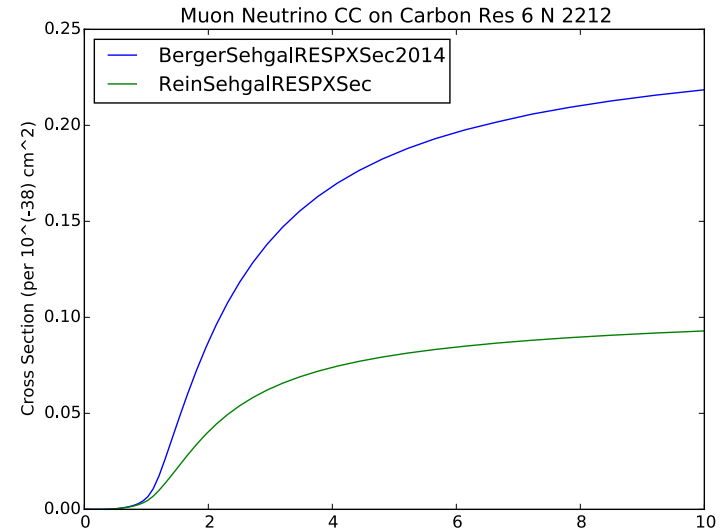
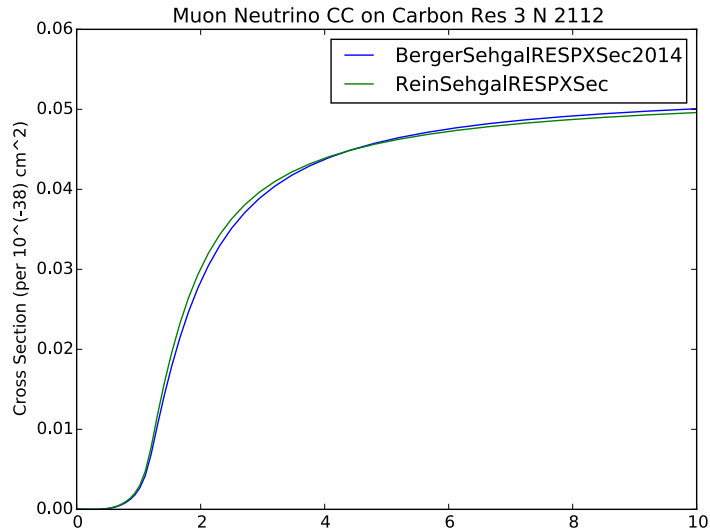
Changing the resonance model

```
<!-- New Berger-Sehgal resonance model w/MiniBooNE tune... -->
<!--
<param type="alg" name="XSecModel@genie::EventGenerator/RES-CC">
genie::BergerSehgalRESPXSec2014/Default </param>
<param type="alg" name="XSecModel@genie::EventGenerator/RES-NC">
genie::BergerSehgalRESPXSec2014/Default </param>
<param type="alg" name="XSecModel@genie::EventGenerator/RES-EM">
genie::BergerSehgalRESPXSec2014/Default </param>
-->

<!-- New Kuzmin-Lyubushkin-Naumov resonance model w/MiniBooNE tune... -->
<!--
<param type="alg" name="XSecModel@genie::EventGenerator/RES-CC">
genie::KuzminLyubushkinNaumovRESPXSec2014/Default </param>
<param type="alg" name="XSecModel@genie::EventGenerator/RES-NC">
genie::KuzminLyubushkinNaumovRESPXSec2014/Default </param>
<param type="alg" name="XSecModel@genie::EventGenerator/RES-EM">
genie::KuzminLyubushkinNaumovRESPXSec2014/Default </param>
-->

<param type="alg" name="XSecModel@genie::EventGenerator/RES-CC">
genie::ReinSehgalRESPXSec/Default </param>
<param type="alg" name="XSecModel@genie::EventGenerator/RES-NC">
genie::ReinSehgalRESPXSec/Default </param>
<param type="alg" name="XSecModel@genie::EventGenerator/RES-EM">
genie::ReinSehgalRESPXSec/Default </param>
```

Berger-Sehgal appears to have a higher total X-Sec



2.10: Updated hA Model (FSI Model) - hA2014

- Recall that in hA mode we parameterize a cascade with one effective interaction.
 - Easily re-weightable.
 - Good agreement with data.
- Previously we used data on iron and $f(A)$ scaling.
 - Now including Li-7, C-12, Al-27, Fe-56, Nb-93, Bi-209
- Previously, all cross sections for different "fates" had an $A^{2/3}$ dependence - but this doesn't agree with data.
 - Now absorption scales as $A^{2/3+0.18}$, charge exchange as $A^{2/3}$, elastic as $A^{2/3 + 0.25}$, inelastic like $A^{2/3}$, pion production as $A^{2/3}$
 - Total cross section scales as $A^{2/3}$ (used to convert a fate cross section to a fraction)
- Implemented by N. Geary and S. Dytman

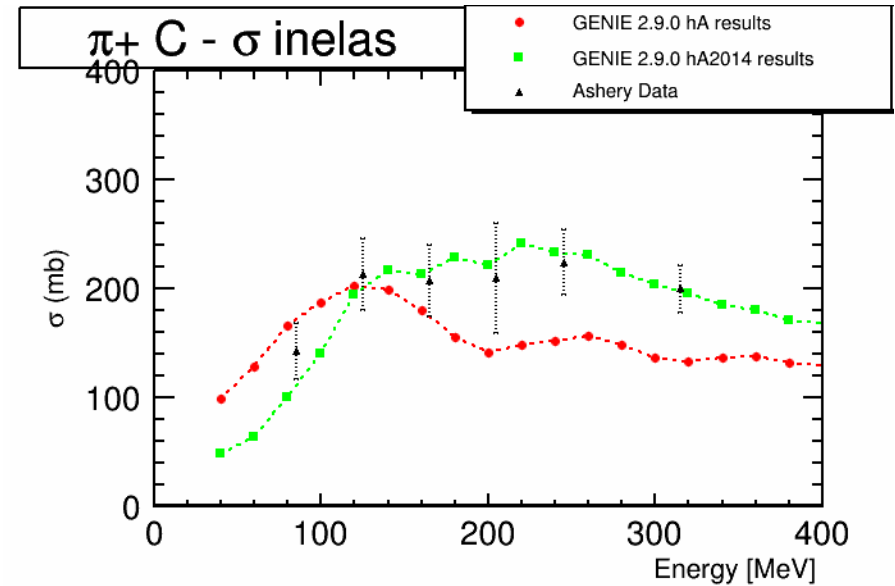
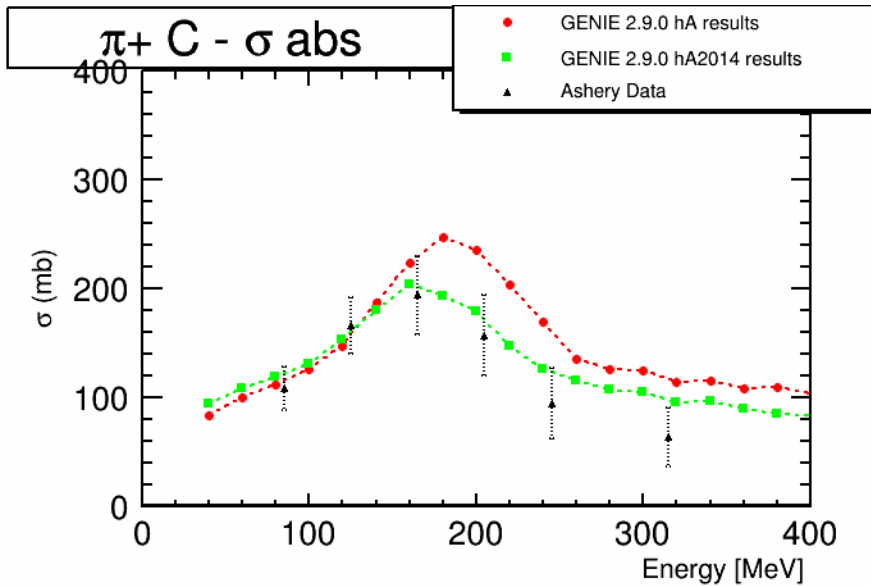


Figure 9: Comparison of new total cross sections for $\pi^+ C$ for new *hA2014* model with default model *hA*.

Better A dependent performance.

Shift to lower energy due to increased inelastics, more pions due to decreased (effectively) absorption.

Activate hA2014

```
<!--
```

Intranuclear rescattering

Use the HadronTransportEnable option to toggle intranuclear rescattering on/off. Also, set the preferred hadron transport model.

Options include:

- genie::HAIIntranuke/Default
- genie::HNIIntranuke/Default
- genie::HAIIntranuke2014/Default new 2d spline for piA
- genie::HNIIntranuke2014/Default

```
-->  
<param type="bool" name="HadronTransp-Enable"> true </param>
```

```
<!-- <param type="alg" name="HadronTransp-Model"> genie::HAIIntranuke/Default </param> -->
```

```
<param type="alg" name="HadronTransp-Model"> genie::HAIIntranuke2014/Default </param>
```

2.10 Eta Production

- Eta mesons, like pi0s, have purely electromagnetic decays into photons and can therefore mimic electron neutrino appearance.
- For this reason, their simulation is important for oscillation experiments.
- Prior to this GENIE release, eta mesons were produced through two mechanisms, the decay of baryon resonances, and Pythia fragmentation.
- The result is a kinematic gap over which eta mesons are not produced - non-resonant inelastic events with invariant masses too low to be fragmented by Pythia.
- These events are handled by the KNO-based part of the AGKY model.
- In this model, mesons are produced in pairs with a net charge of zero, according to probabilities assigned via the `KNO-Prob*` values in UserPhysicsOptions.xml.
- Two new values have been added in this release, `KNO-ProbPi0Eta` and `KNO-ProbPi0Eta`.
- The ability to create eta mesons over all values of W makes possible background studies for oscillation experiments.

2.10 Eta Production

- Both are currently set to zero in 2.10.0, but we expect that they will be tuned to non-zero values in the next GENIE physics release.
- Implemented by J. Liu (W&M).

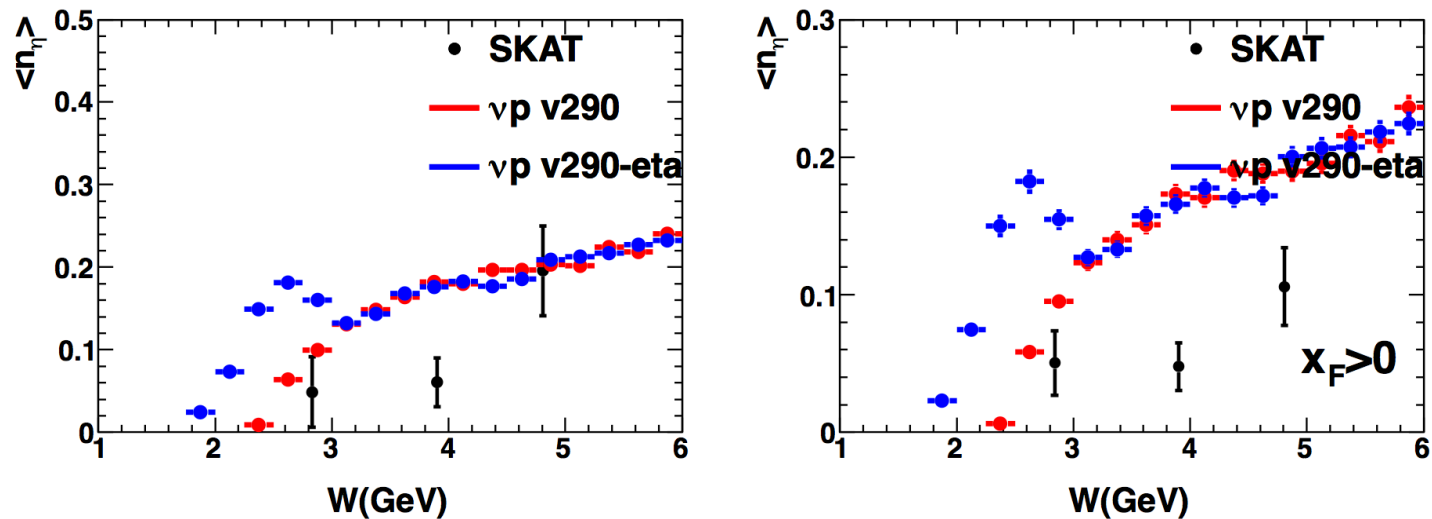
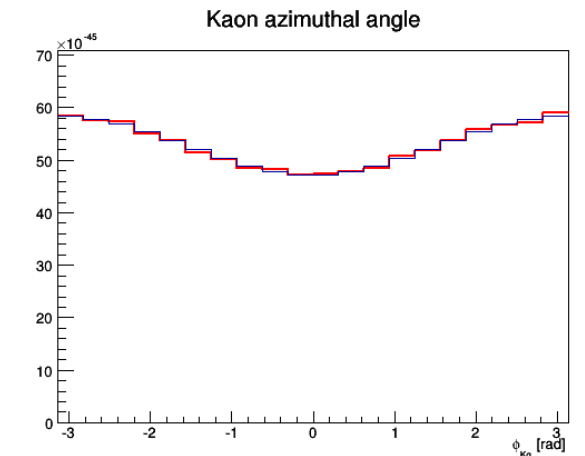
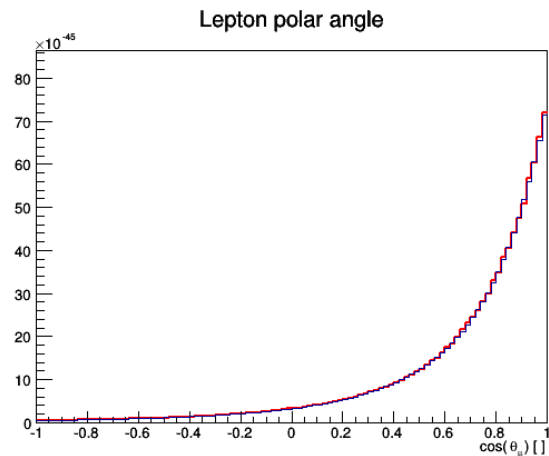
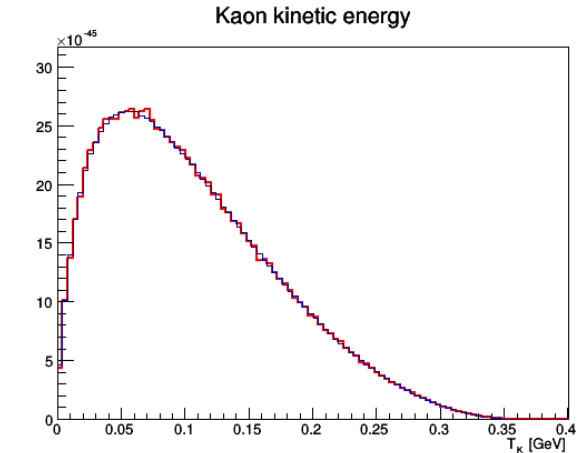
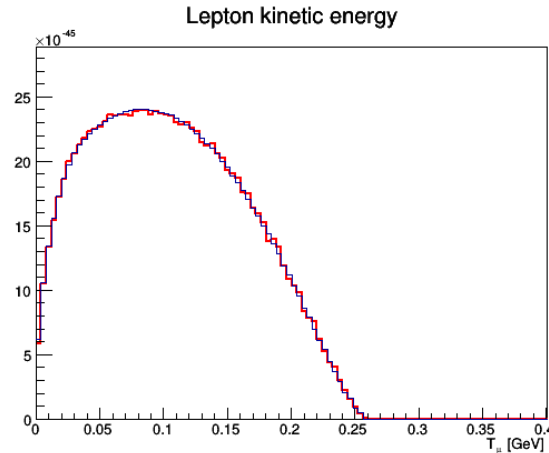


Figure 6: Eta production rate measurements from the SKAT experiment [31], compared with the GENIE default prediction (red) and the GENIE prediction with eta production parameters set to large non-zero values (blue).

2.10: Single Kaon Production

- Alam, Simo, Athar, and Vacas (PRD 82, 033001 (2010)).
- Implemented by C. Marshall and M. Nirkko (Rochester, Bern)

Blue histograms are from the a 4D integral based on the original paper and the red are from the GENIE implementation.



GENIE Release Roadmap: 2.12

- GENIE 2.12.0 - likely Spring 2016
 - Model introduction release (some tweaks to default models)
 - QEL Lambda production (J. Poage and H. Gallagher)
 - Berger-Sehgal coherent pion production (PRD 79, 053003 (2009)) (G. Perdue, H. Gallagher, D. Cherdack)
 - Local Fermi Gas & Nieves et al CCQE with RPA (J. Johnston and S. Dytman)
 - Valencia Model Meson Exchange-Currents (J. Schwer and R. Gran)
 - Alvarez-Ruso et al microscopic coherent pion production (PRC 75, 055501 (2007) and PRC 76, 068501 (2007)) (S. Dennis and S. Boyd)
 - Oset FSI model (T. Golan)
 - Kaon FSI (F. de Maria Blaszczyk, S. Dytman)
 - Z expansion of QEL form factor (Hill et al, PRD 84, 073006) (A. Meyer)
 - Benhar Spectral Functions (C. Mariani, M. Jen, and A. Furmanski)
 - Ambitious to get it all... (and I may have forgotten something)
- GENIE 3.0 - likely late 2016
 - New default physics tune.
- Actively discussing alternative roadmaps in GENIE to try to make some models available sooner (along with some updates to the default model).



Thank you!

Other Misc. Announcements

- Physics and Users Manual now on the arXiv:
 - <http://arxiv.org/abs/1510.05494>
- 2.10 arXiv E-print coming soon (many figures from that document used here).