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GENIE 2.10.0

Gabriel Perdue

DUNE ND PWG

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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_numi 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!

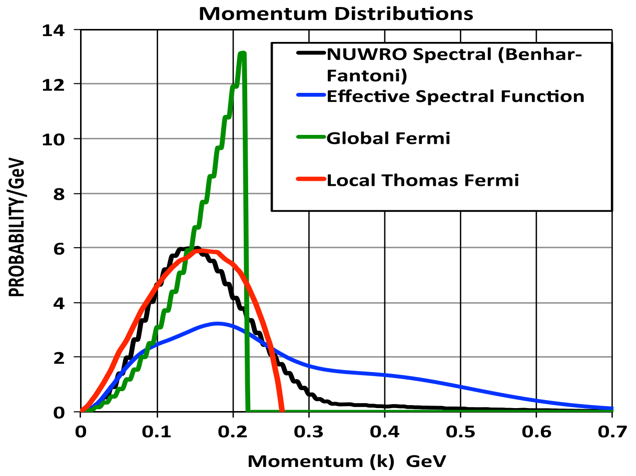
- We would like to officially extend our thanks to everyone who took the time to dig into the code and help find bugs and issues.
- There were many great testers for the 2.9 beta and while we have tried to keep track of everyone's contributions, I'm sure we forgot to mention someone here.
- If you notice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

Comment on systematics

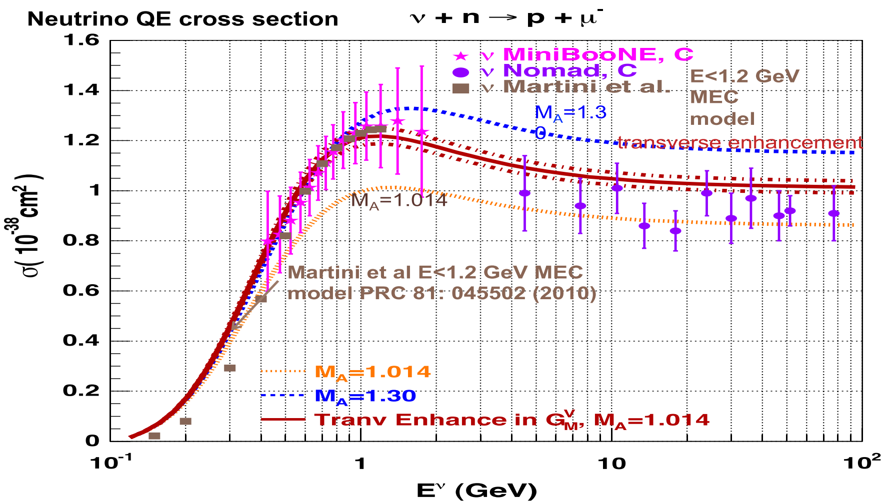
- There are two kinds of changes a user can make to the physics model:
  - reweightable changes
  - non-reweightable changes
- All of the updates for 2.10 involve making non-reweightable changes, so you must re-run events to capture the different physics.
- Even more than that, you must generate new cross section splines for the new models (not if you change the FSI or hadronization models).
  - We, of course, should have done that when making the splines you get from https://www.hepforge.org/archive/genie/data/2.10.0/
    - We'll do this "soon," although some switches (e.g. nuclear model) are not as easy to flip for the purposes of automated spline production.

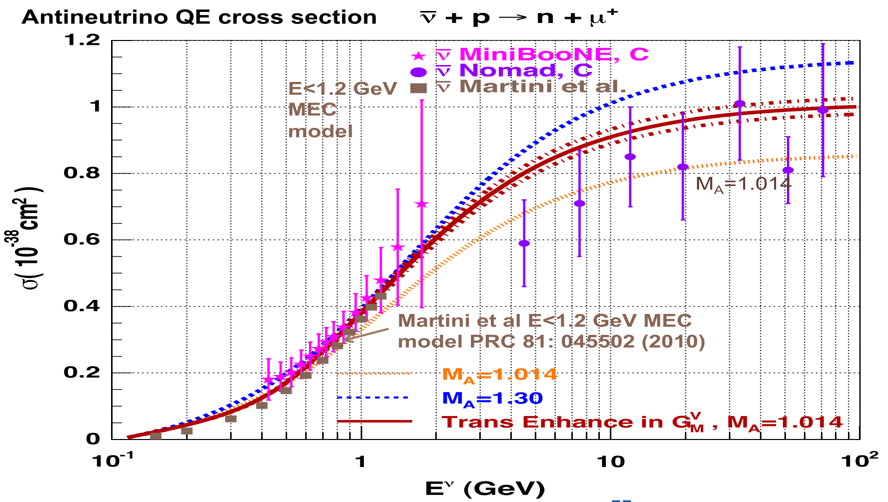
2.10: Effective Spectral Functions

- 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





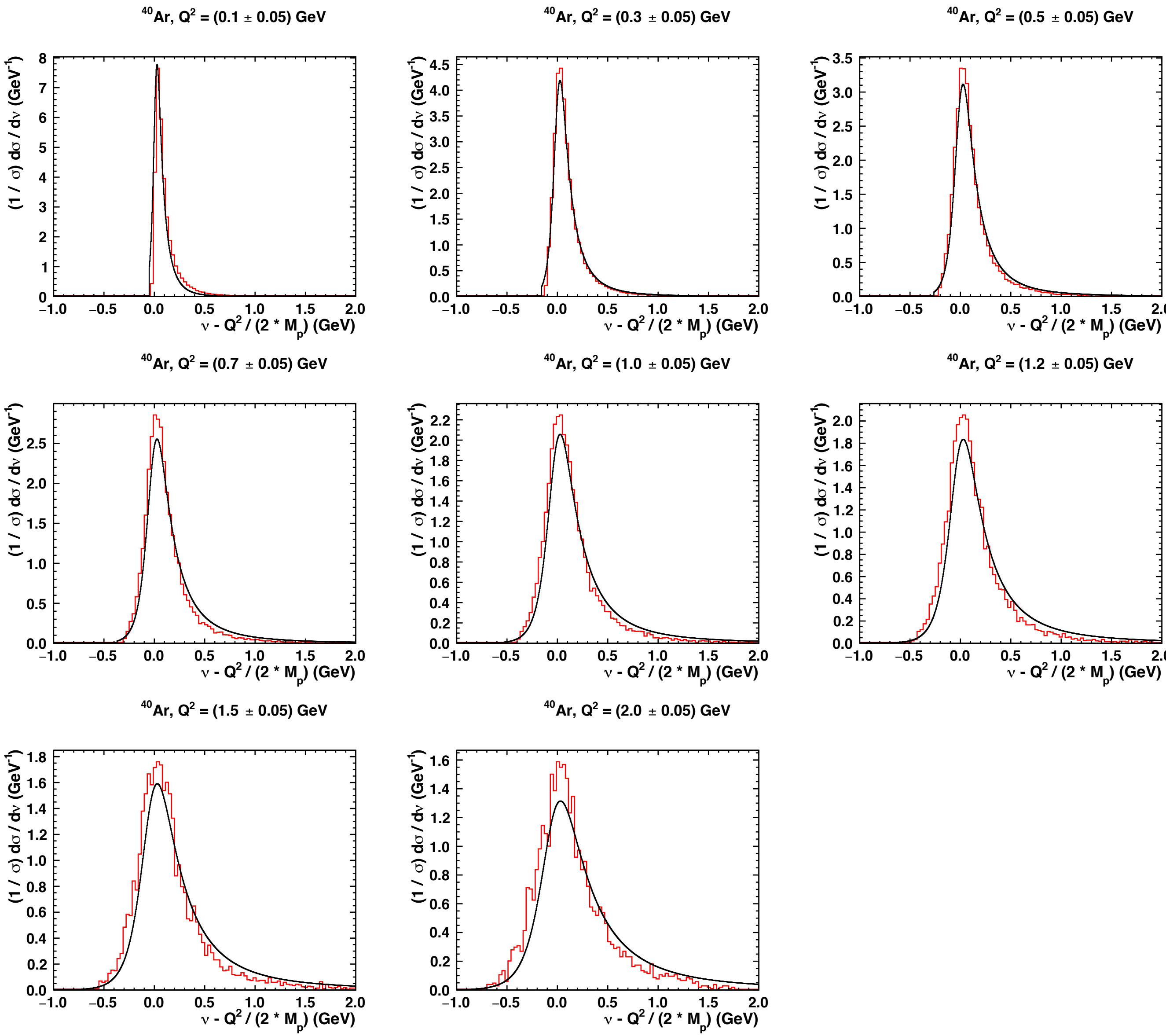
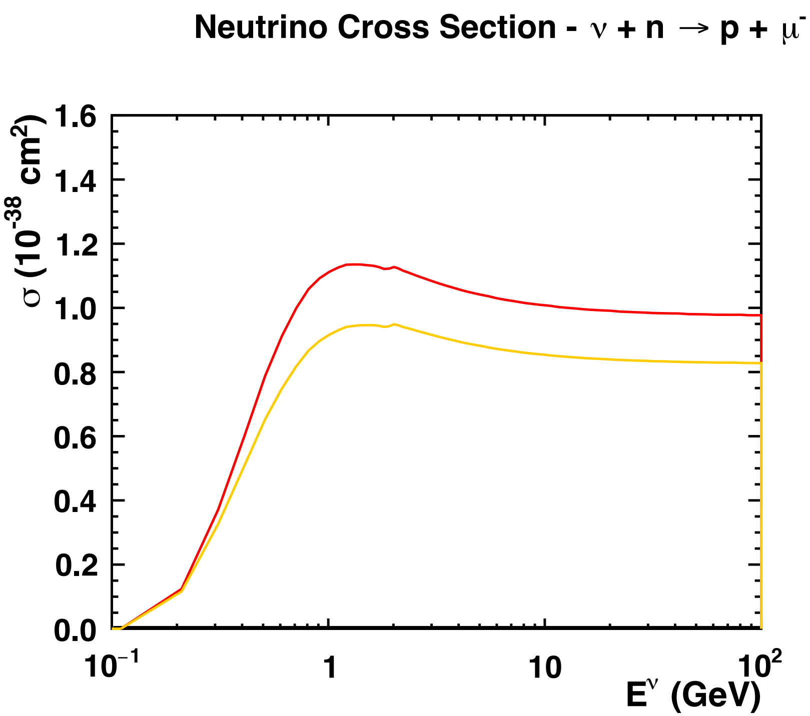


Figure 3: Comparisons between the ψ' superscaling parameter as extracted from electron scattering data [21] (the smooth black curve) as a function of $\nu - Q^2/(2M_p)$ and the computation produced by GENIE (the red histogram) for different values of Q^2 on Argon-40.



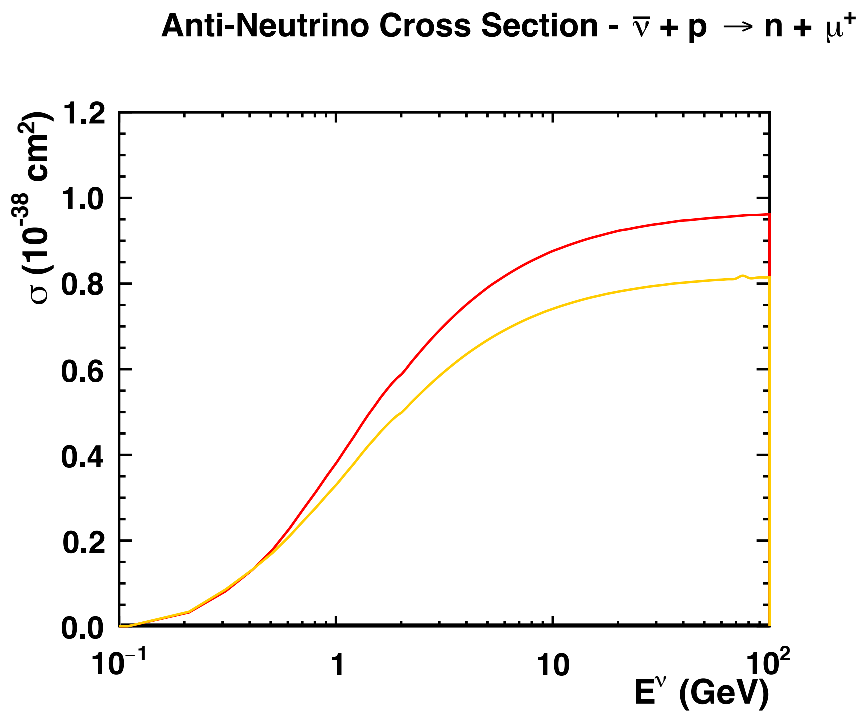


Figure 4: The charged-current quasielastic cross section for neutrinos with the default Llewelyn Smith model in orange and the new Effective Spectral Function model in red.

Activating the effective spectral function

```
 <!--
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  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="UseElFFTransverseEnhancement">  false                          </
param>
  <param type="alg" name="TransverseEnhancement"> genie::TransverseEnhancementFFModel/Default </
param>
<!--
```

Activating the effective spectral function

```
 <!--
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  Nuclear model selection.
  Options:
   - genie::FGMBodekRitchie/Default
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   - genie::EffectiveSF/Default  <- See http://arxiv.org/abs/1405.0583
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  (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::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="UseElFFTransverseEnhancement">  true                          </
param>
  <param type="alg" name="TransverseEnhancement"> genie::TransverseEnhancementFFModel/Default </
param>
<!--
```


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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.

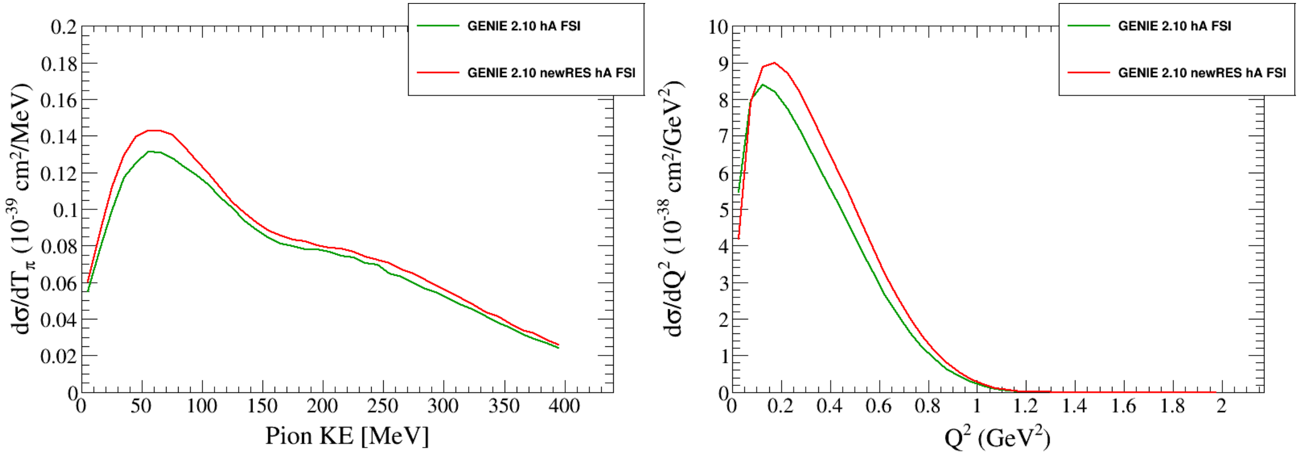


Figure 8: Comparison of new model (Berger-Sehgal with new form factors) with default model.

- 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)

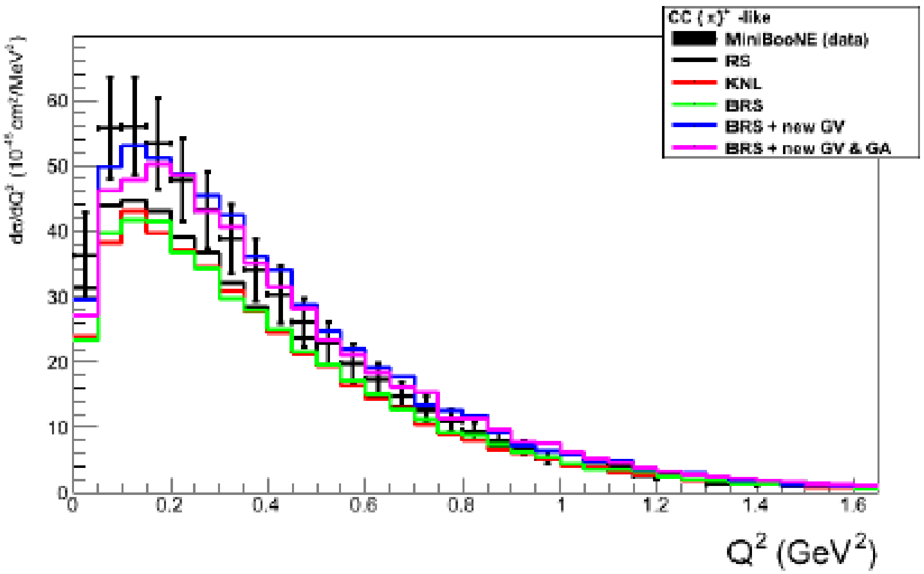


Figure 7: Comparison of new model with MiniBooNE data (J.Nowak).

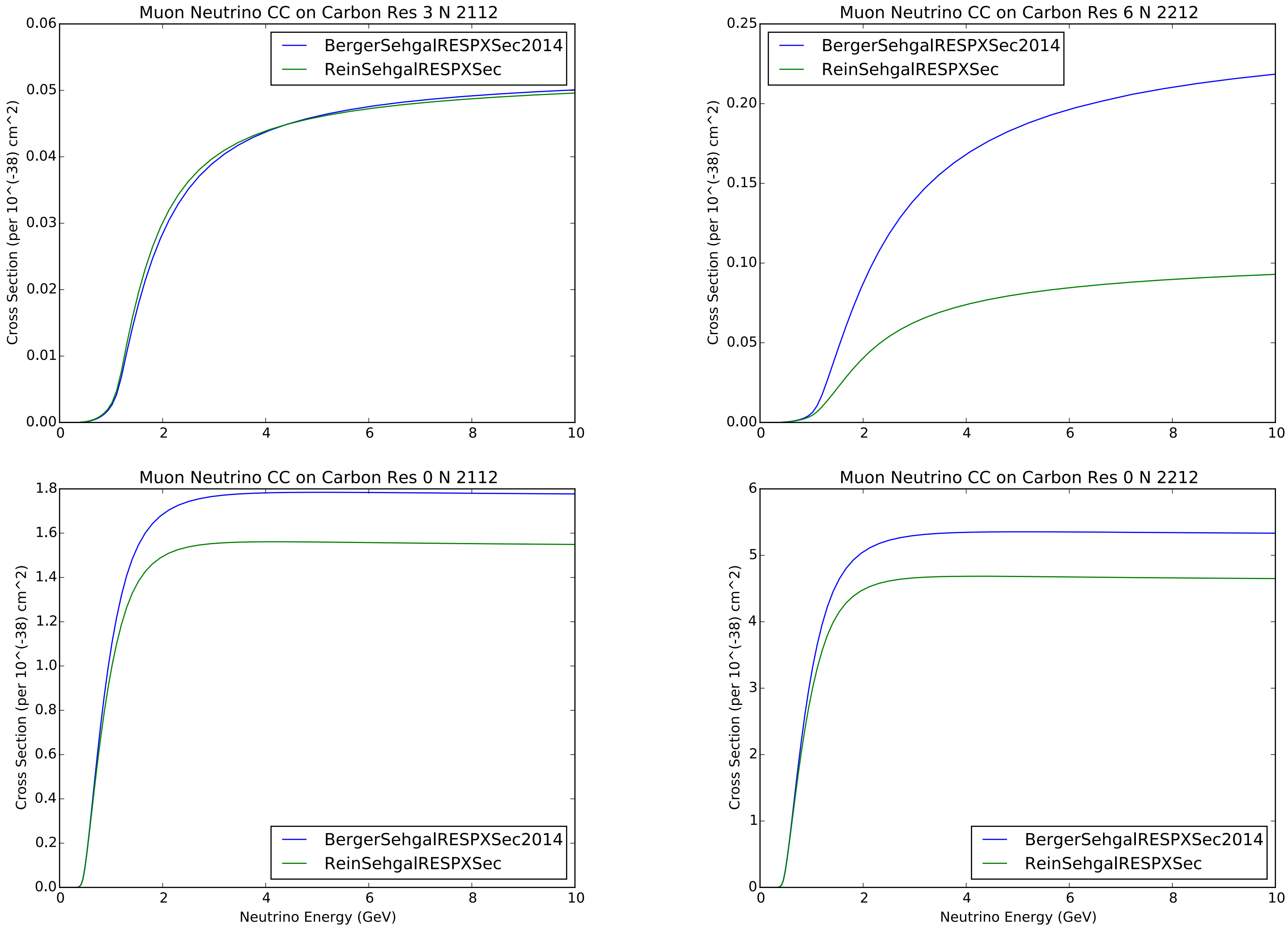
Changing the resonance model

```
  <!-- 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

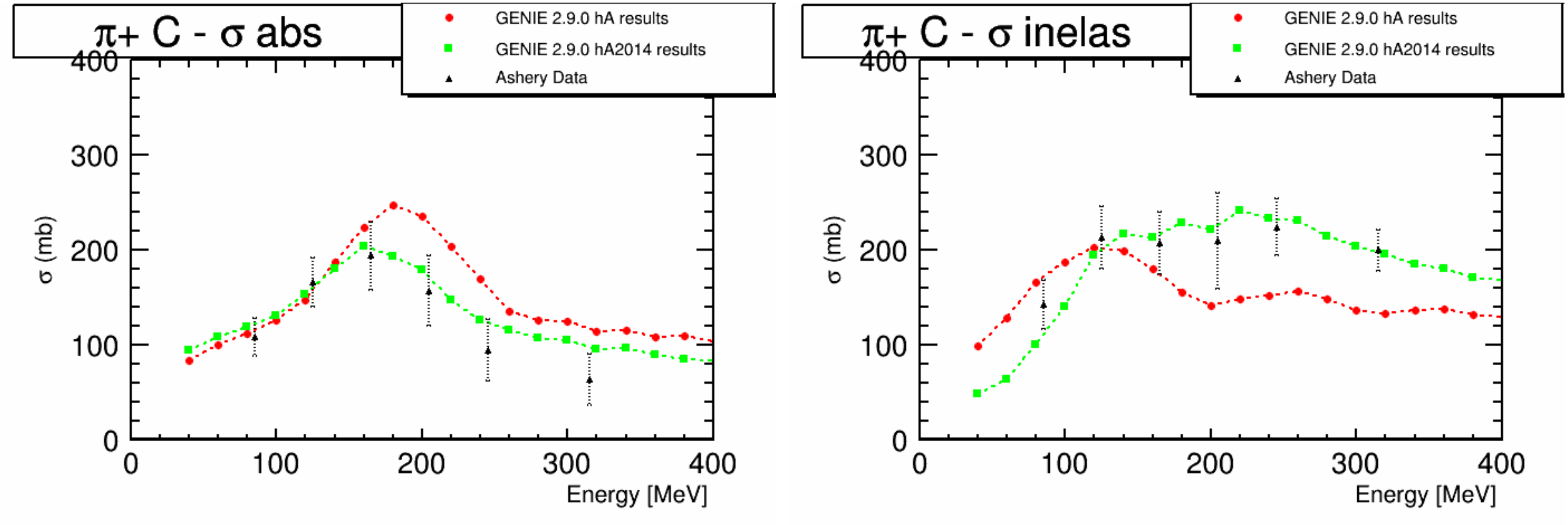


Figure 9: Comparison of new total cross sections for $\pi^{+}C$ for new *hA2014* model with default model *hA*.

Better A dependent performance.

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

```
<!--

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  Intranuclear rescattering
  Use the HadronTransportEnable option to toggle intranuclear rescattering on/off.
  Also, set the preferred hadron transport model.
  Options include:
   - genie::HAIntranuke/Default
   - genie::HNIntranuke/Default
   - genie::HAIntranuke2014/Default  new 2d spline for piA
   - genie::HNIntranuke2014/Default
  -->
  <param type="bool" name="HadronTransp-Enable"> true </param>
  <!-- <param type="alg"  name="HadronTransp-Model">  genie::HAIntranuke/Default  </param> -->
  <param type="alg"  name="HadronTransp-Model">  genie::HAIntranuke2014/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).

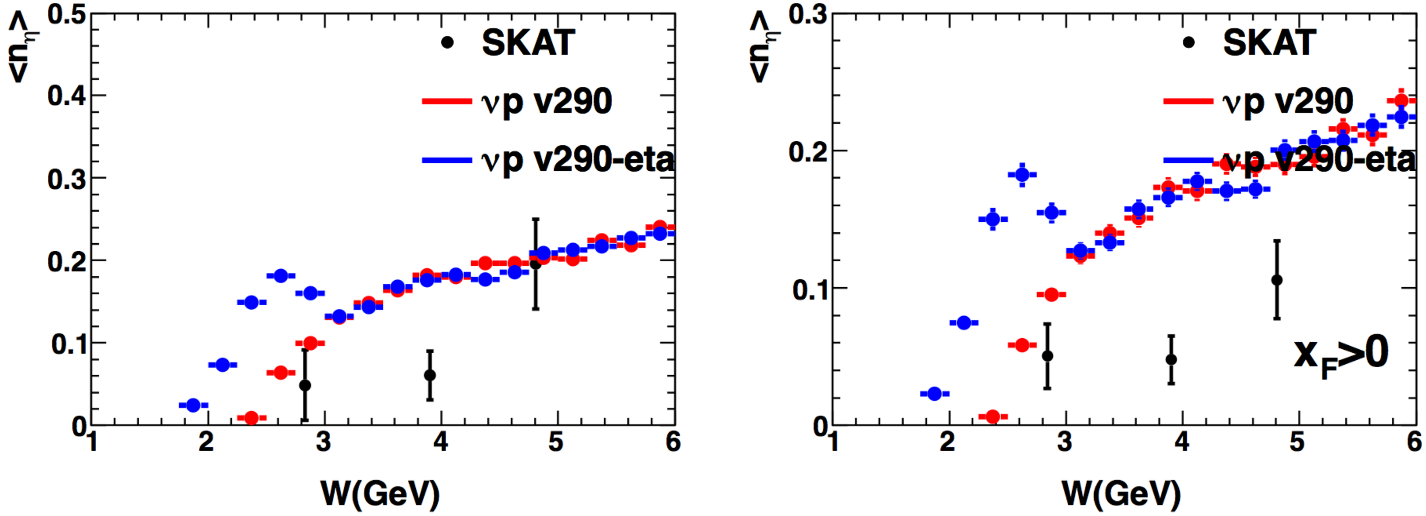
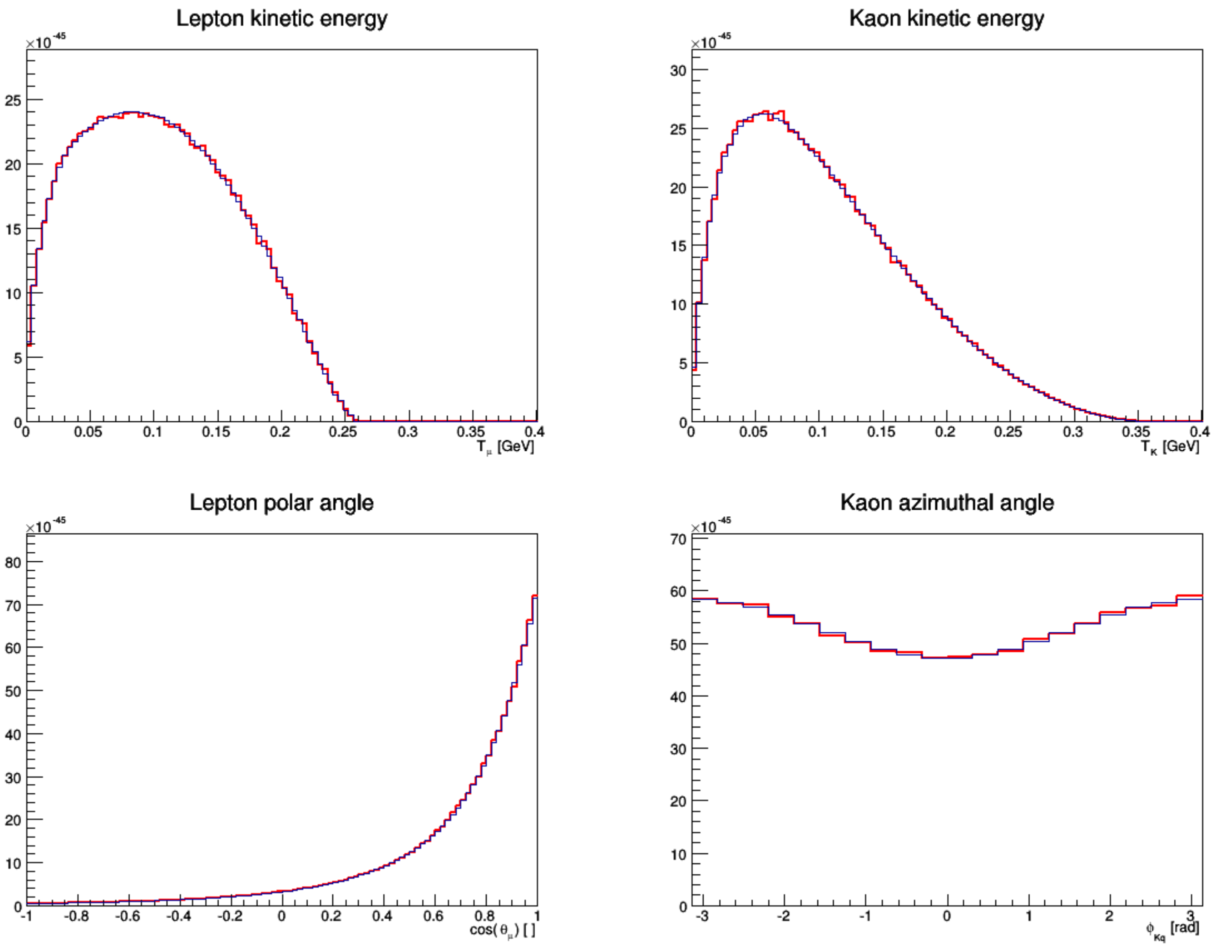


Figure 6: Eta production rate measurements from the SKAT experiment [31], compared with the GENIE default prediction (red) and the GENIE prediction with eta production parameters set to large non-zero values (blue).

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 incorporating all of these models and recent neutrino-nucleus cross section data, plus many tuning and data comparison tools.


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).