



GENIE AGKYLowW (DIS) Bug Fix

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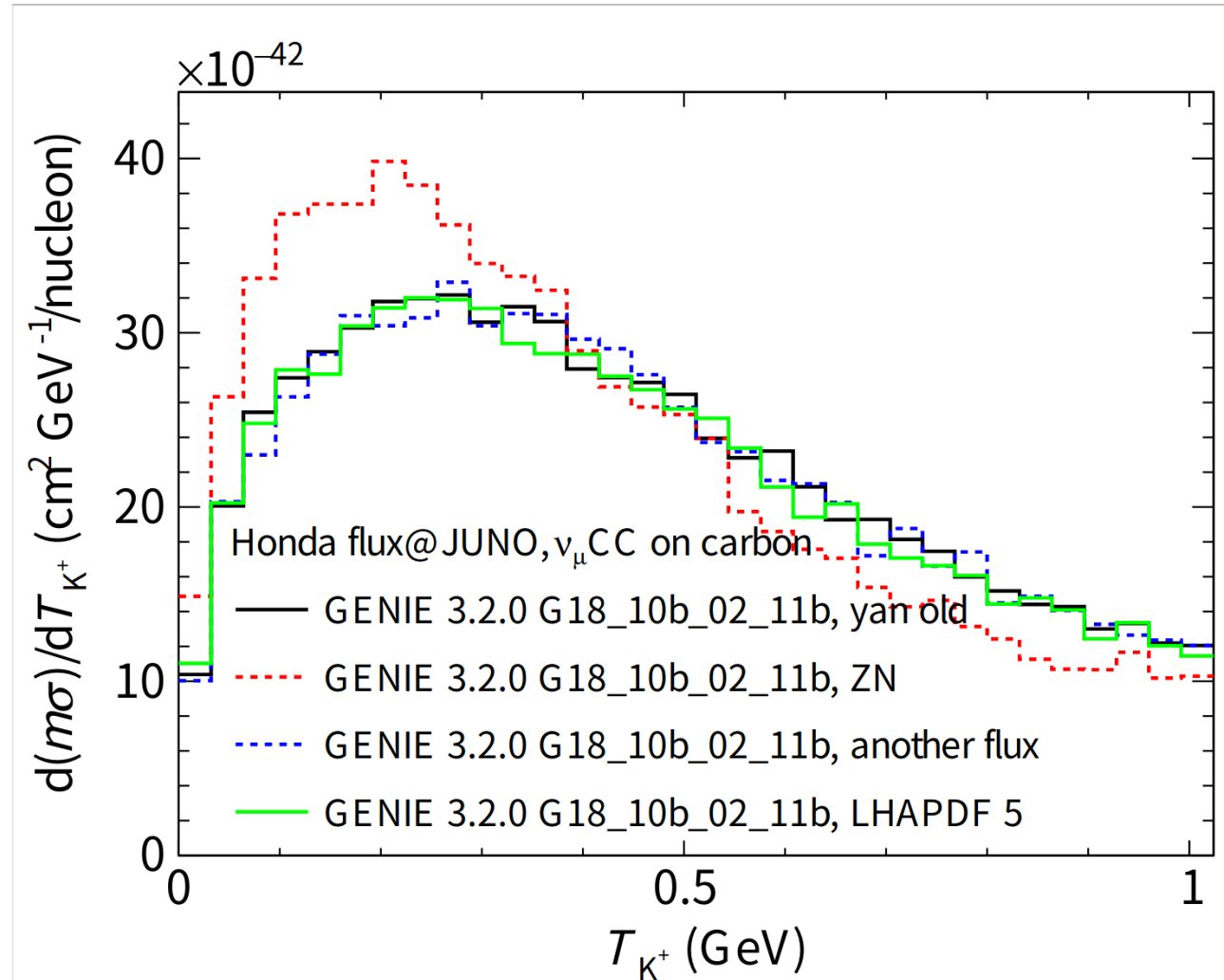
On behalf of JUNO collaboration

16 March 2023

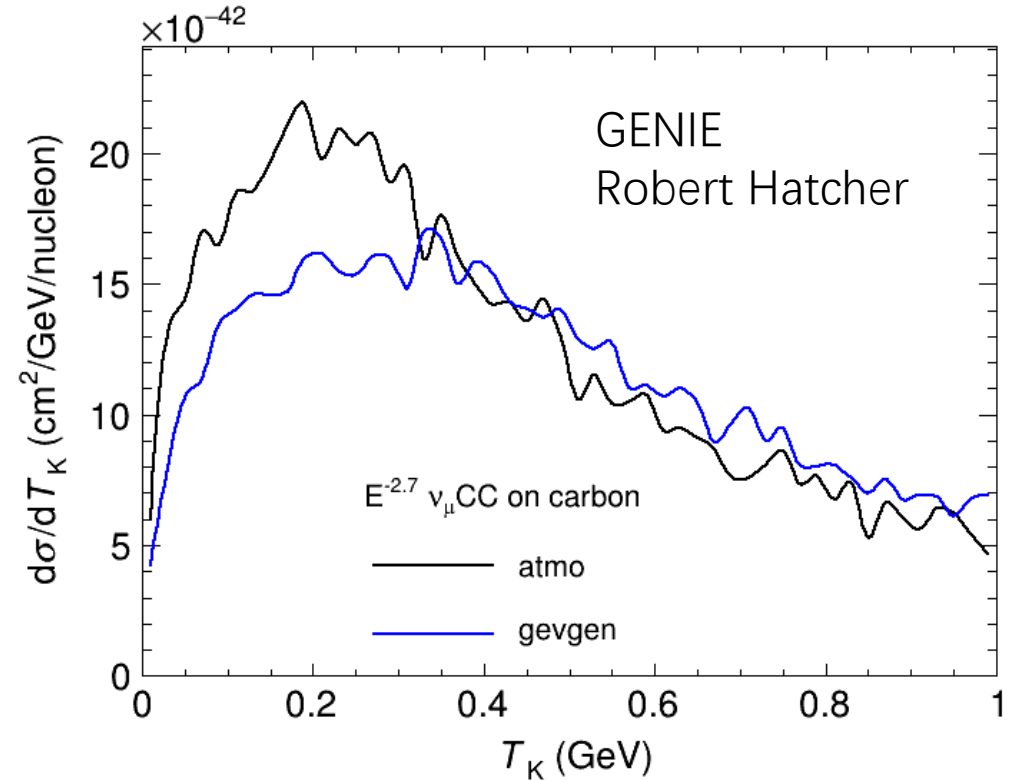
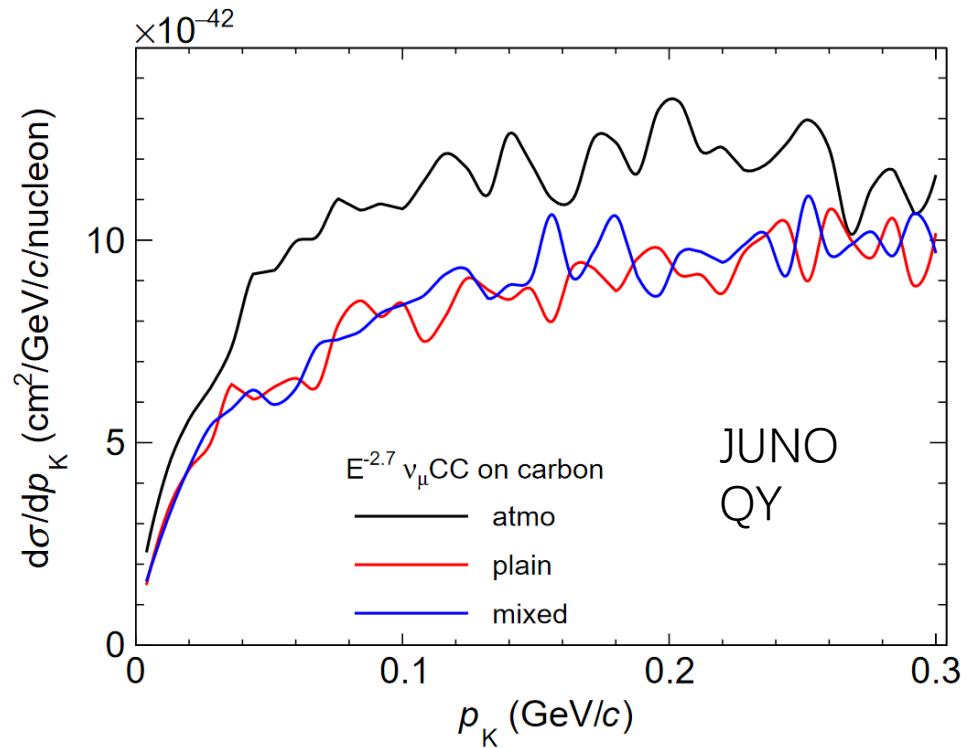
How did it happen?

In our JUNO Neutrino 2022 poster, we studied atmospheric neutrino induced K^+ spectrum
<https://indico.kps.or.kr/event/30/contributions/297/>

- ❑ Discrepancy seen by different analyzers (Jie Cheng, Zhenning Qu, and QY)
- ❑ Traced back to different GENIE (own) tools: gevgen and gevgen_atmo



- ❑ Reported to GENIE <https://github.com/GENIE-MC/Generator/issues/226> (2022-09-30)
- ❑ Confirmed by GENIE expert (2022-10-14)



Development (with approximate dates)

1. Robert Hatcher (GENIE): traced back to different neutrino directions input, as was w/ 3D atmospheric flux (2022-10-24)
2. Used hydrogen instead of carbon (2023-02-18)
 - ✓ Confirmed issue at nucleon (not nuclear) level
3. Looked at different channels:
 - ✓ RES is not affected, problem is in DIS (2023-02-18)
4. Marco Roda (GENIE): Provided a method to run single channel for easier debug (2023-02-19)
5. Robert Hatcher (GENIE): Provided a patch to alter neutrino direction within gevgen (2023-02-21)
6. Guey-Lin Lin (JUNO): Suggested to look at pion (2022-12-08)
 - ✓ Confirmed that pion is also affected (2023-03-01)
7. Looked at muon (2023-03-04)
 - ✓ Muon not affected, only hadronic part affected
8. Guey-Lin Lin (JUNO): Suggested to look at also angular distributions (2023-03-06)
 - ✓ Confirmed that angles (in addition to energy) are also affected
9. Costas Andreopoulos (GENIE): Use same random seed and compare results (2023-03-02)
 - ✓ Powerful debug technique, and finally, traced back to the AGKYLowW model (low-W "DIS") (2023-03-08)







Understanding AGKYLowW

- Andreopoulos-Gallagher-Kehayias-Yang <https://link.springer.com/article/10.1140/epjc/s10052-009-1094-z>

A Hadronization Model for Few-GeV Neutrino Interactions #1

T. Yang (Stanford U., Phys. Dept.), C. Andreopoulos (Rutherford), H. Gallagher (Tufts U.), K. Hoffmann (Tufts U.), P. Kehayias (Tufts U.) (2009)

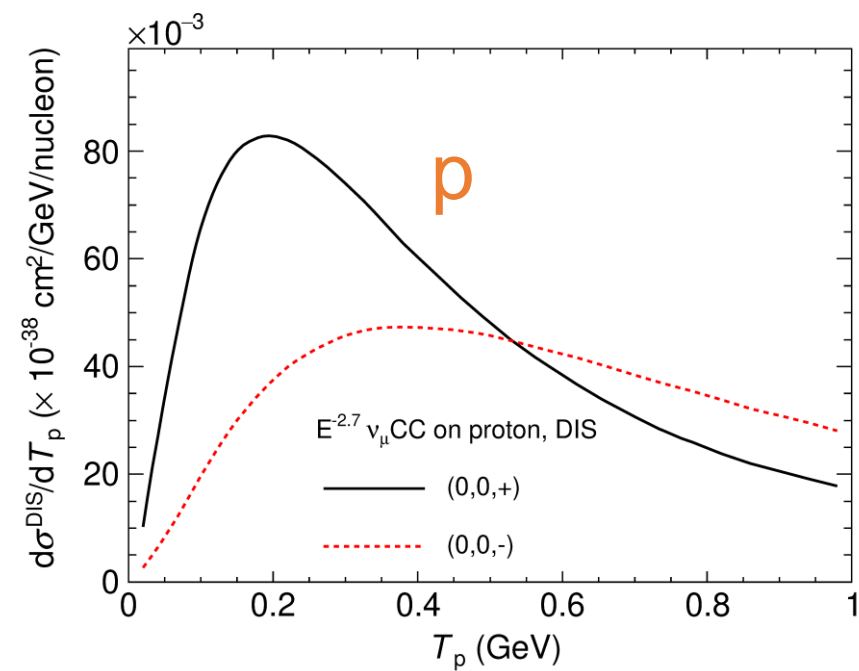
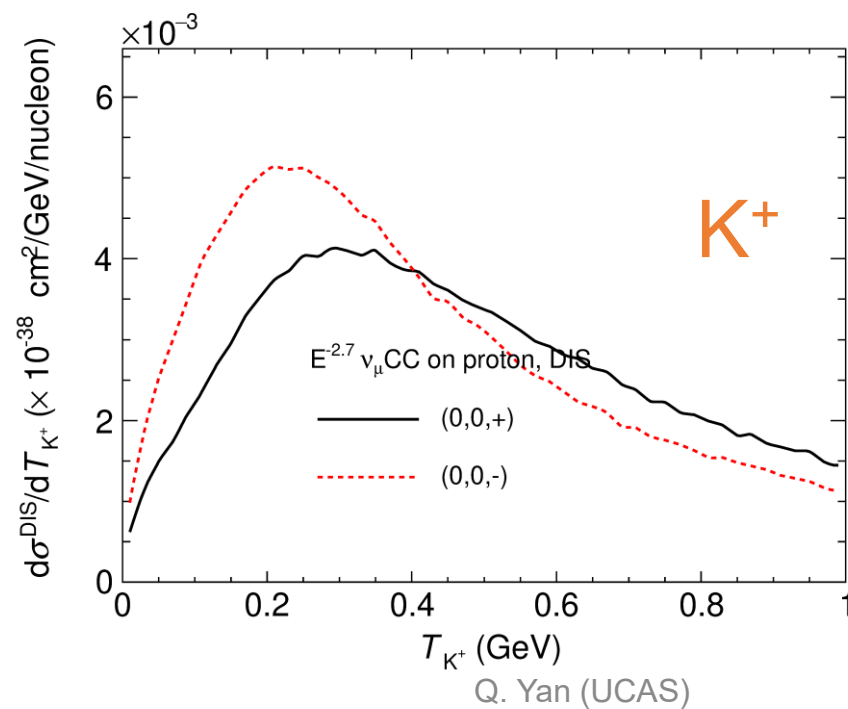
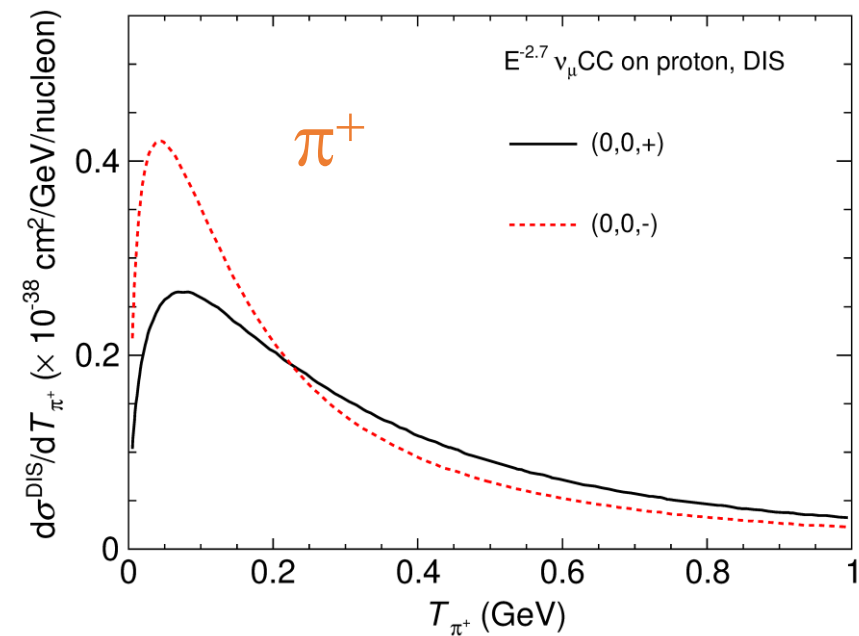
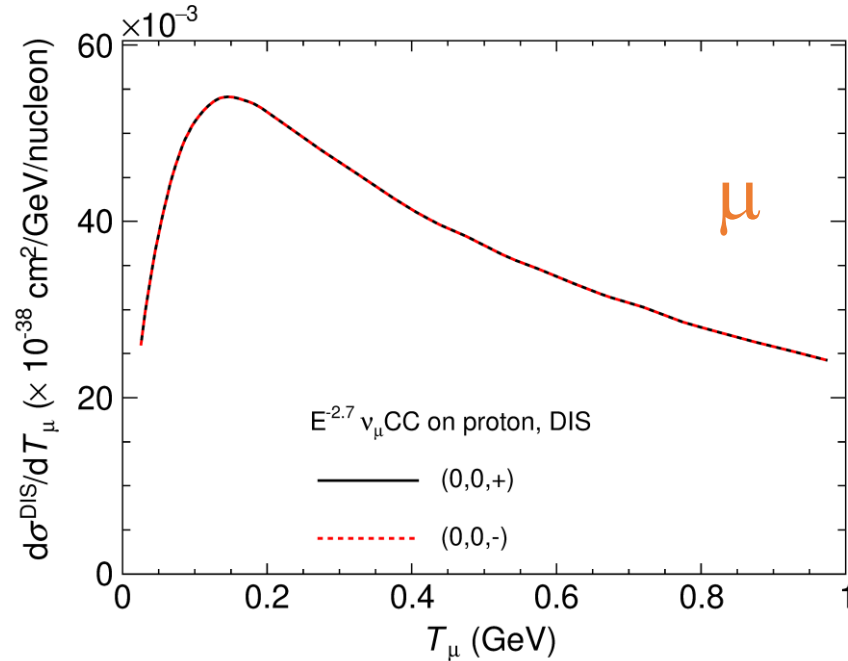
Published in: *Eur.Phys.J.C* 63 (2009) 1-10 • e-Print: 0904.4043 [hep-ph]

 pdf  DOI  cite  claim  reference search  113 citations

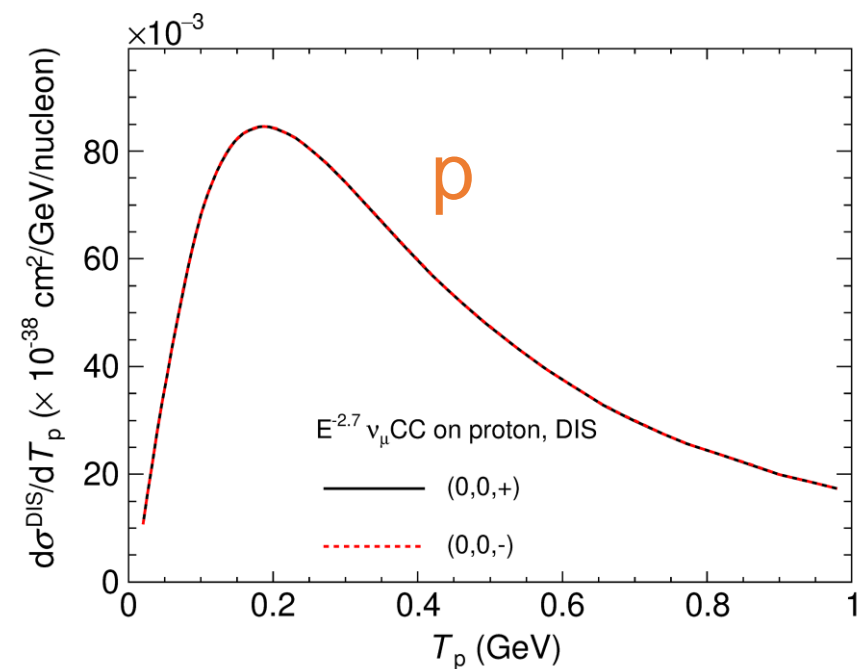
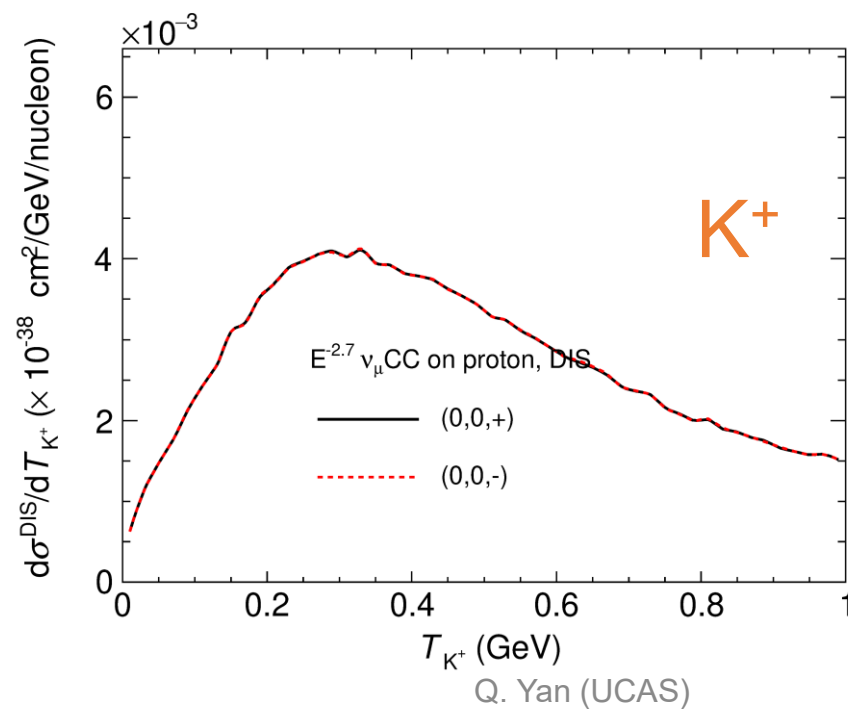
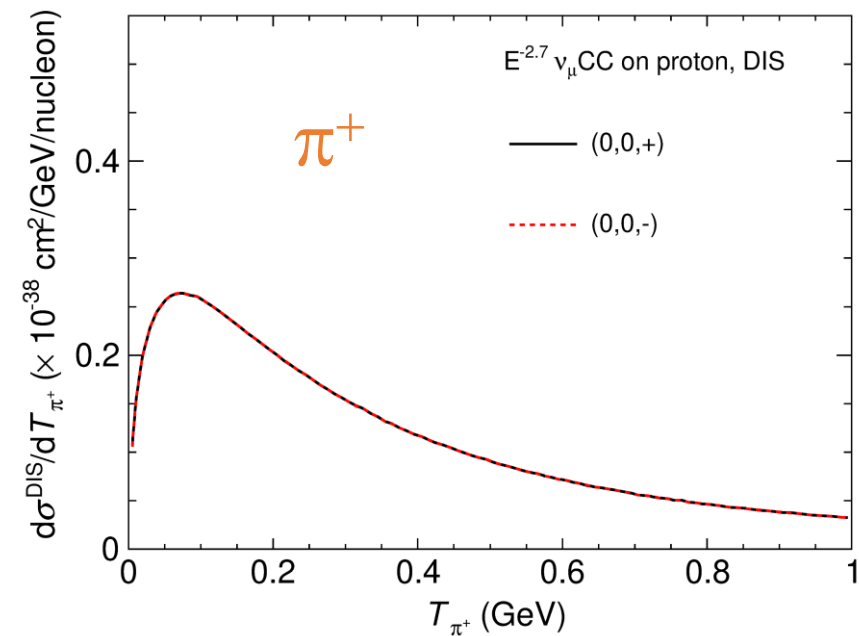
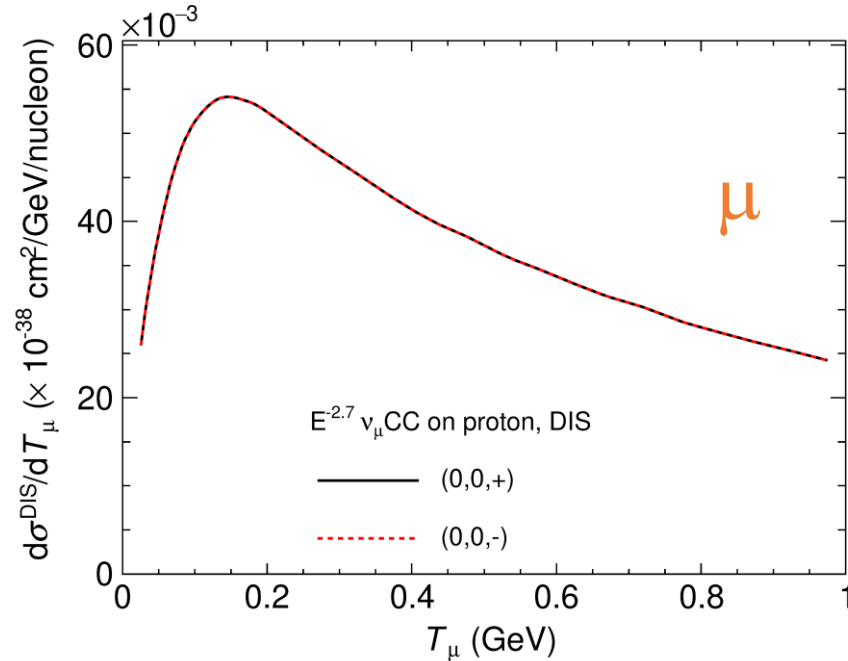
- 3 different frames are involved in DIS event:
 1. LAB frame
 2. CMS frame of hadron system: LAB frame boosted against the motion of hadronic system (axes of Frames 1 and 2 are still parallel)
 3. Hadronizer frame used by AGKY: rotate Frame 2 so that its z^* axis is along the hadronic system motion seen in the LAB frame
- The rotation in Frame 3 is not properly considered in GENIE (fixed in new release 3.4.0)

```
src/Physics/Hadronization/AGKYLowW2019.cxx
@@ -121,7 +121,8 @@ void AGKYLowW2019::ProcessEventRecord(GHepRecord * event) const {
121 121 // retrieve the hadronic blob lorentz boost
122 122 // Because Hadronize() returned particles not in the LAB reference frame
123 123 const TLorentzVector * had_syst = event -> Particle(mom) -> P4() ;
124 - TVector3 boost = had_syst -> BoostVector() ;
124 + TVector3 beta = TVector3(0,0,had_syst->P()/had_syst->E());
125 + TVector3 unitvq = had_syst->Vect().Unit();
125 126
126 127 GHepParticle * neutrino = event->Probe();
127 128 const TLorentzVector & vtx = *(neutrino->X4());
@@ -133,8 +134,8 @@ void AGKYLowW2019::ProcessEventRecord(GHepRecord * event) const {
133 134 int pdgc = particle -> Pdg() ;
134 135
135 136 // bring the particle in the LAB reference frame
136 - particle -> P4() -> Boost( boost ) ;
137 -
137 + particle -> P4() -> Boost( beta);
138 + particle -> P4() -> RotateUz(unitvq);
138 139 // set the proper status according to a number of things:
139 140 // interaction on a nucleus or nucleon, particle type
140 141 GHepStatus_t ist = ( particle -> Status() ==1 ) ? istfin : kIstDISPreFragmHadronicState;
```

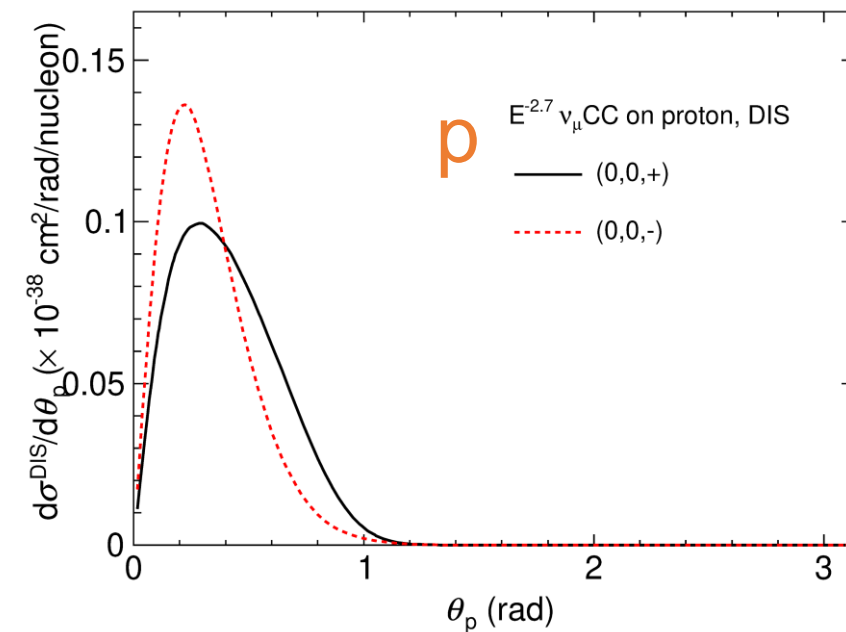
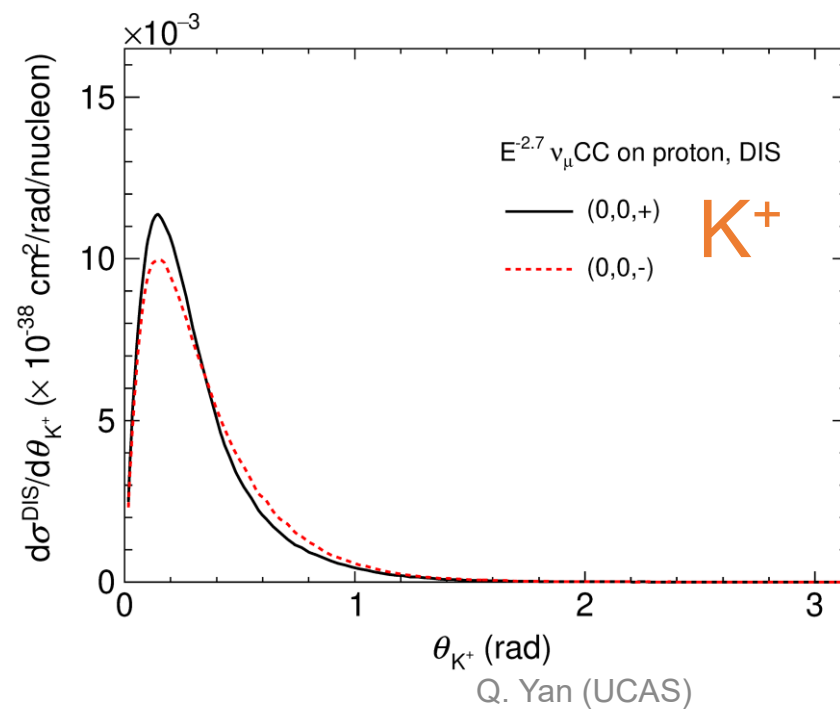
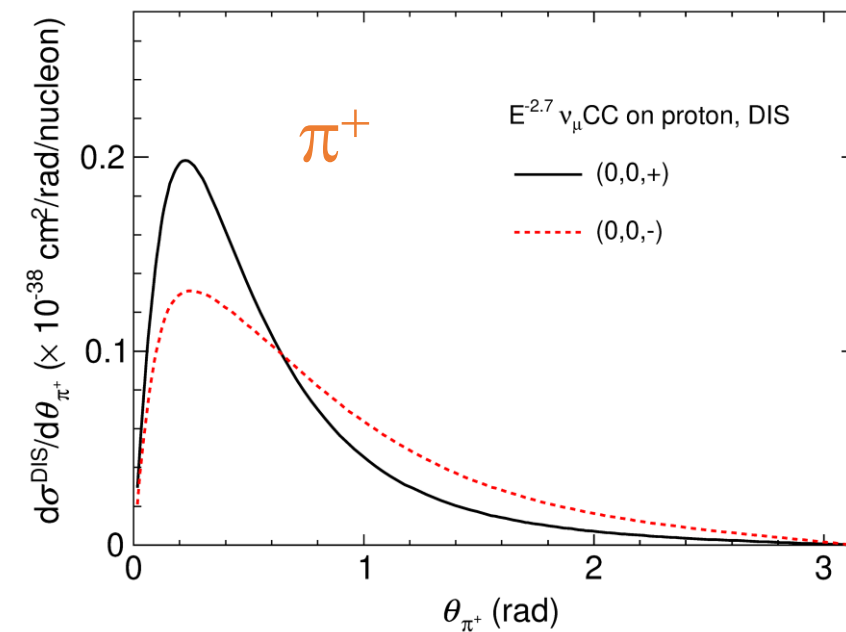
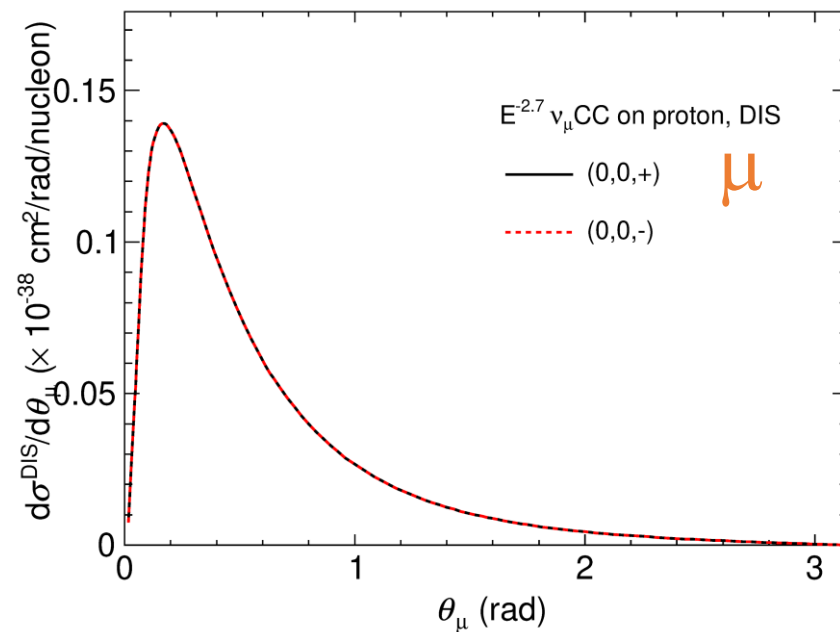
Before fix
particle energy



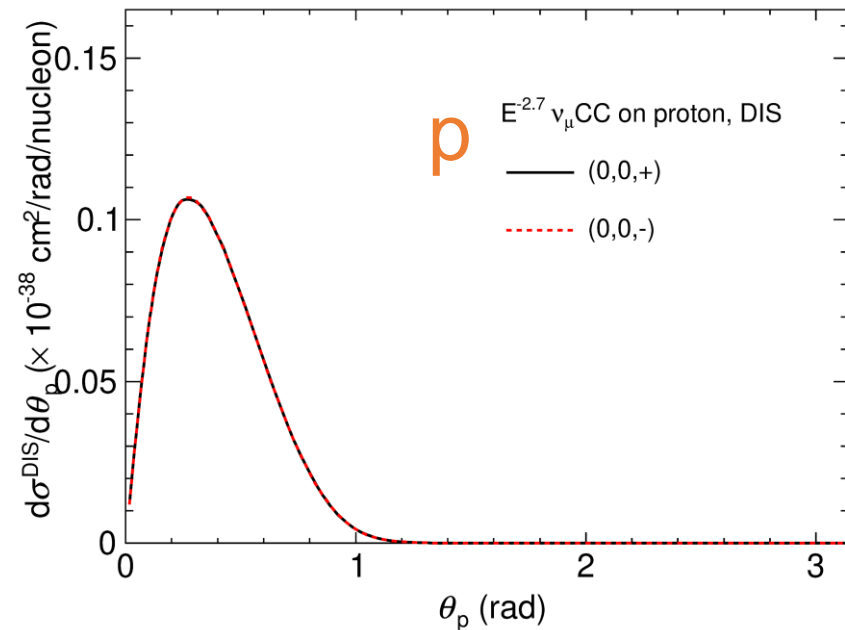
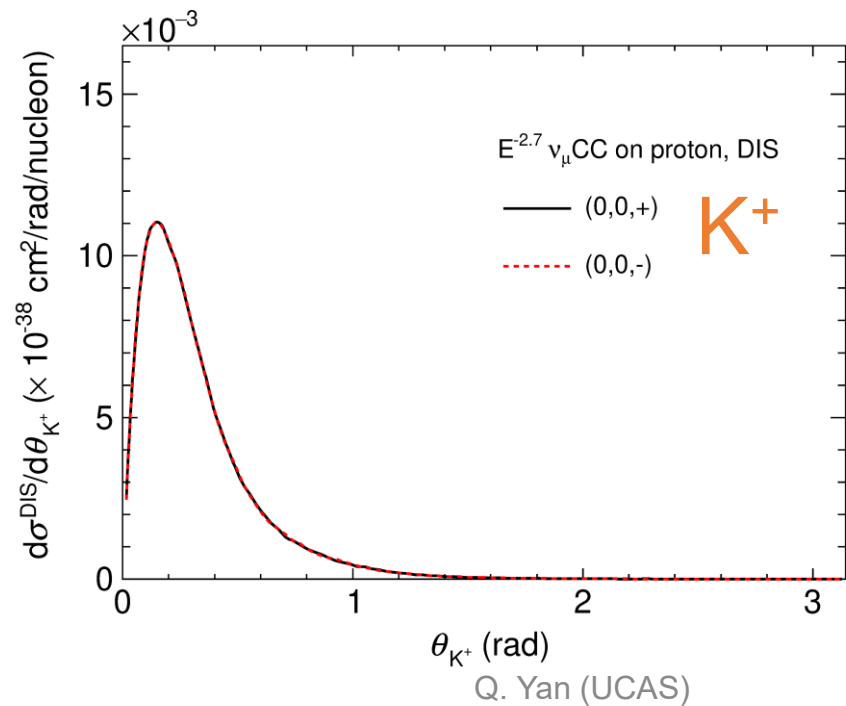
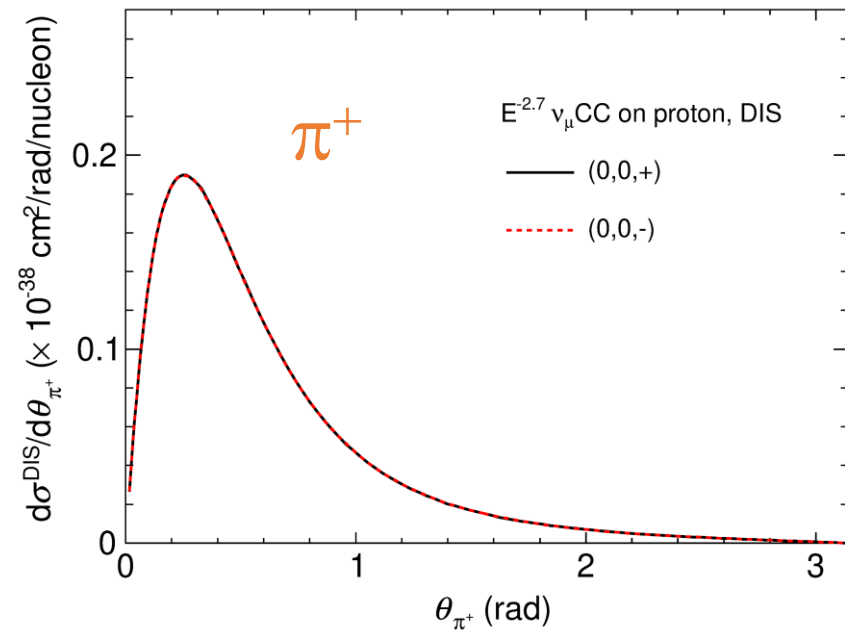
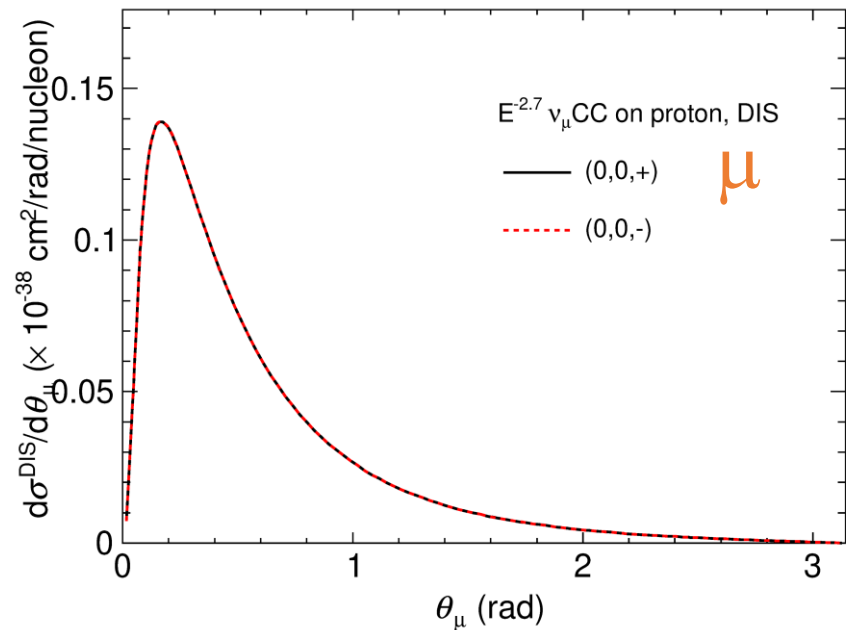
After fix
particle energy



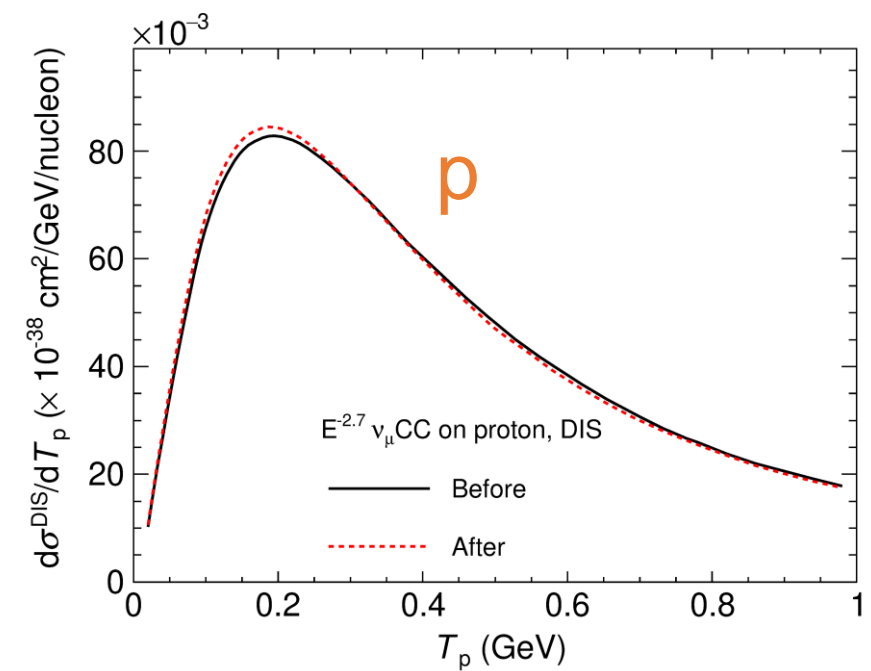
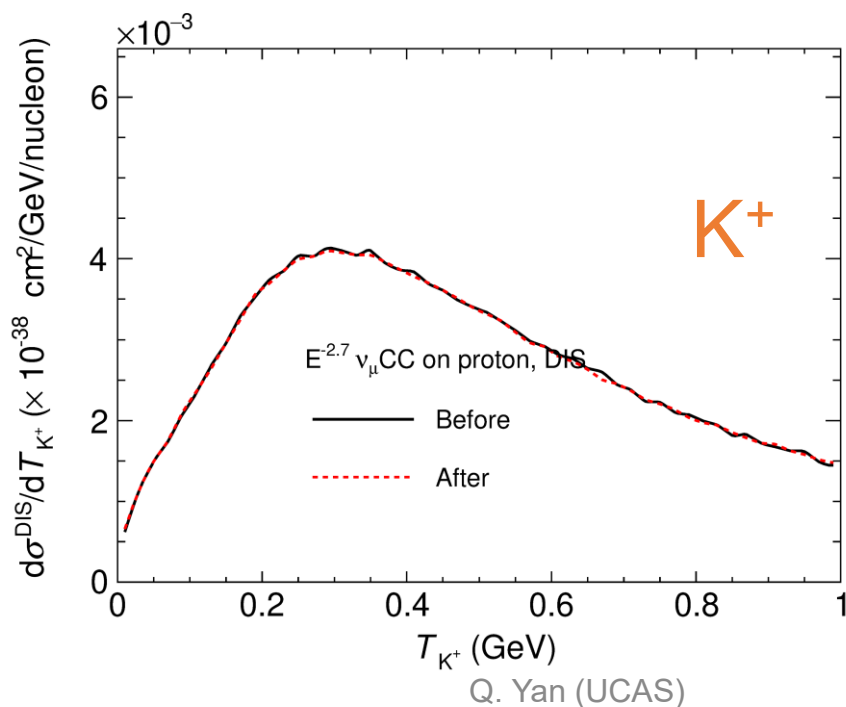
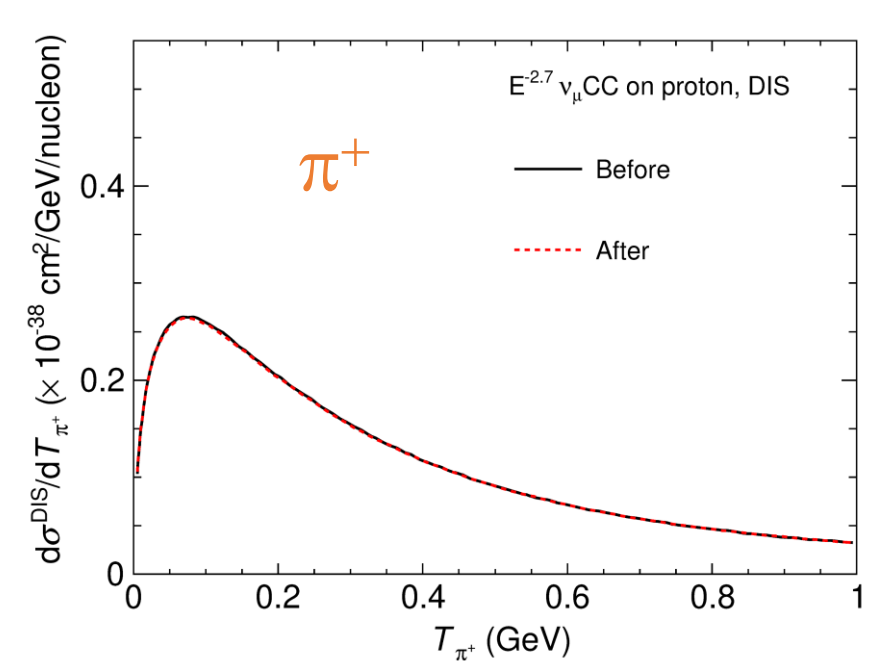
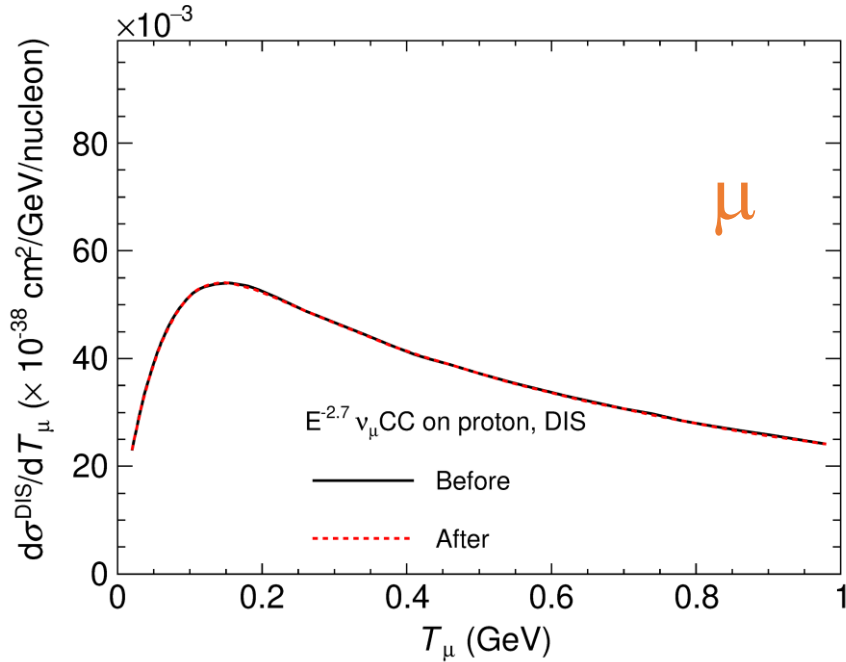
Before fix
particle angle



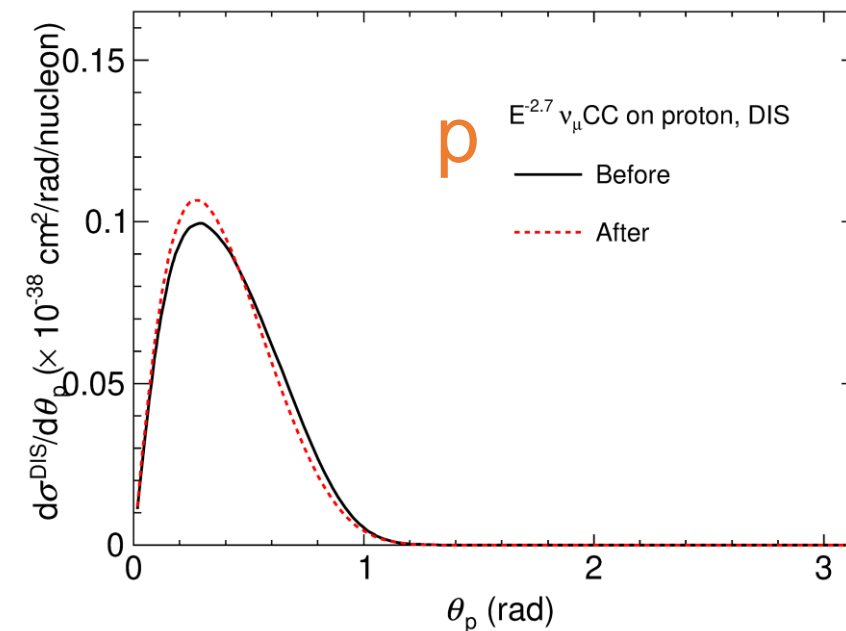
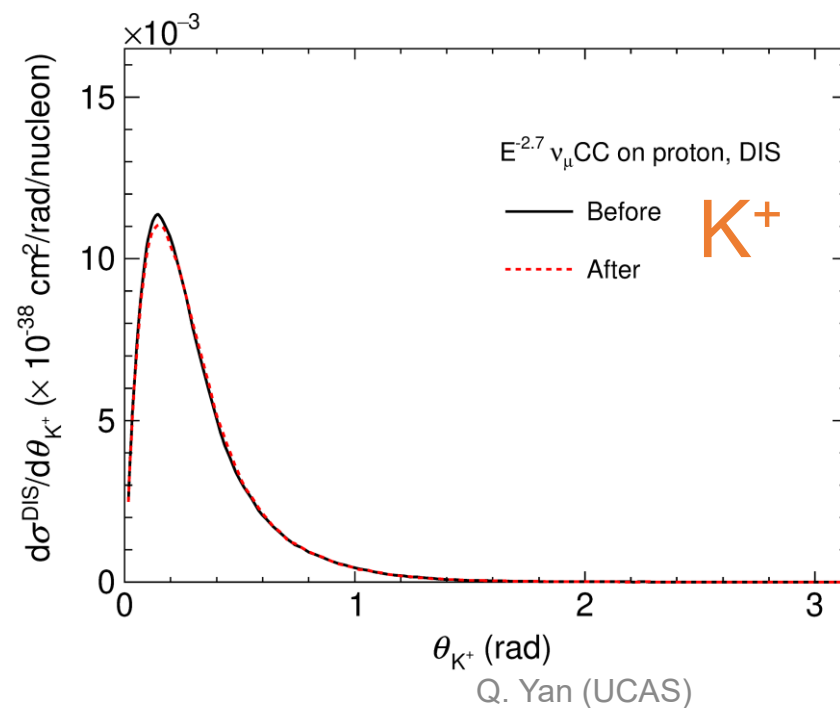
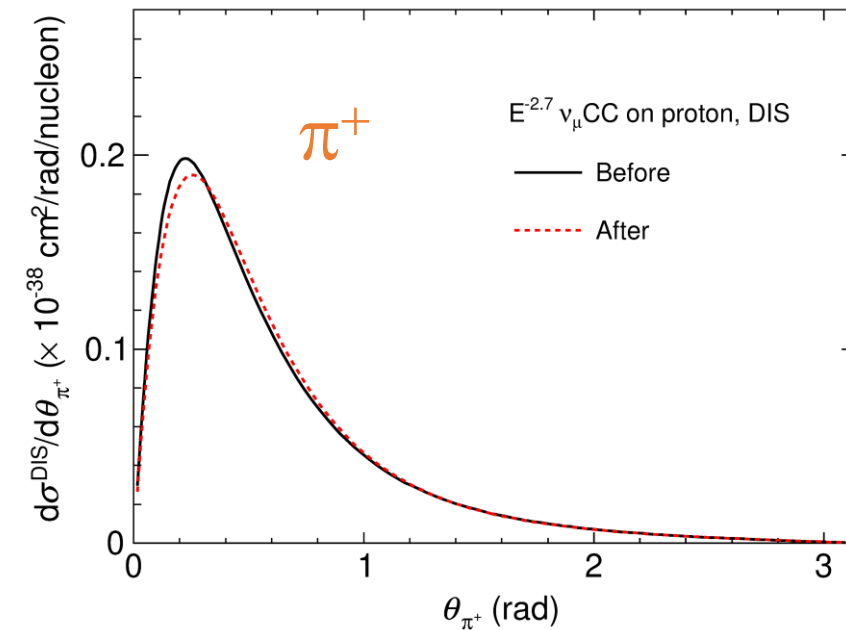
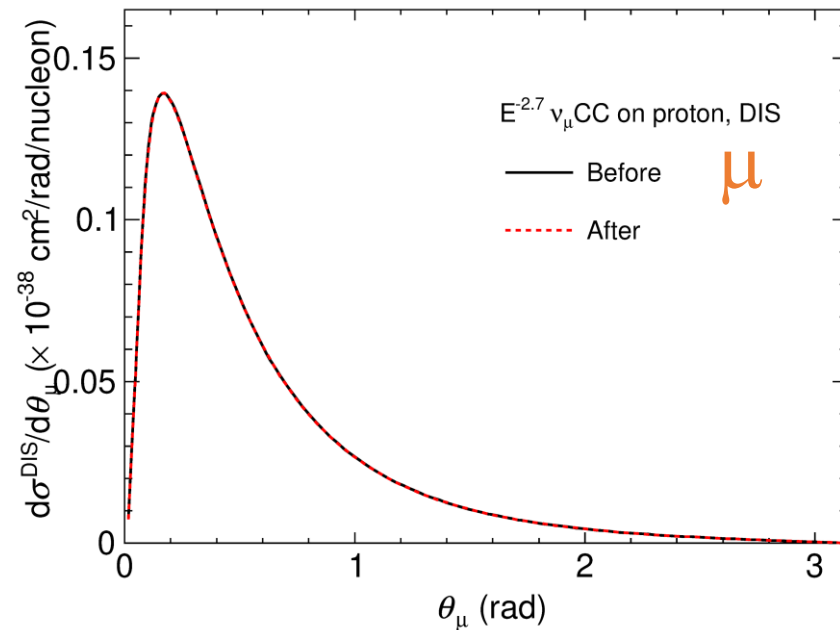
After fix
particle angle



(0,0,+) flux
direct compare
energy



(0,0,+) flux
direct compare
angle



Summary

- Bug in AGKYLowW model of GENIE fixed
 - ❑ Significant impact when neutrino not along +z axis
 - ❑ Slight change if neutrino along +z axis
- Any DIS (in fact, SIS) heavy atmospheric neutrino simulation needs to update to GENIE v3.4.0

Version: 3.4.0

Tag: R-3_04_00, Released: 10 March 2023, Status: *pro*

Improvements over 3.2.2

(Important contributions by non-GENIE authors are especially acknowledged in the text below)

New and/or updated physics models:

- Addition of a spectral function-like approach for binding energies. *Contribution by Steven Dolan and Laura Munteanu* . [\[GENIE pull request #249\]](#).

New comprehensive model configurations and tunes:

- Added CMC desired by SBN and DUNE experiments: AR23_20i_00_000. [\[Readme file\]](#).

Beyond Standard model:

- Addition of Beam-produced Heavy Neutral Leptons. *Contribution by John Plows (Oxford)* . [\[GENIE pull request #223\]](#).

Other improvements / bug fixes:

- Fix in HAItranuke about random number generation. [\[GENIE pull request #241\]](#).
- Fix in the hadronisation rotation. *Contribution by Qiyu Yan* . [\[GENIE pull request #264\]](#).

<http://releases.genie-mc.org/>