

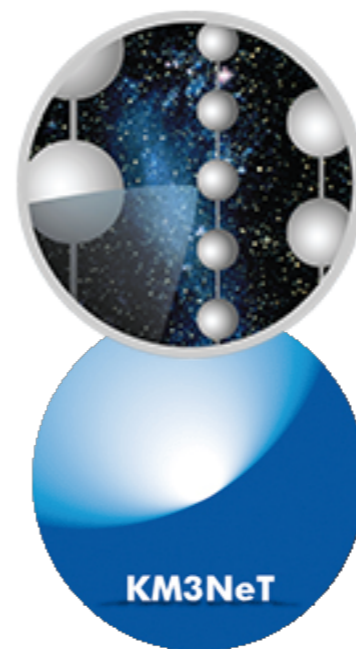
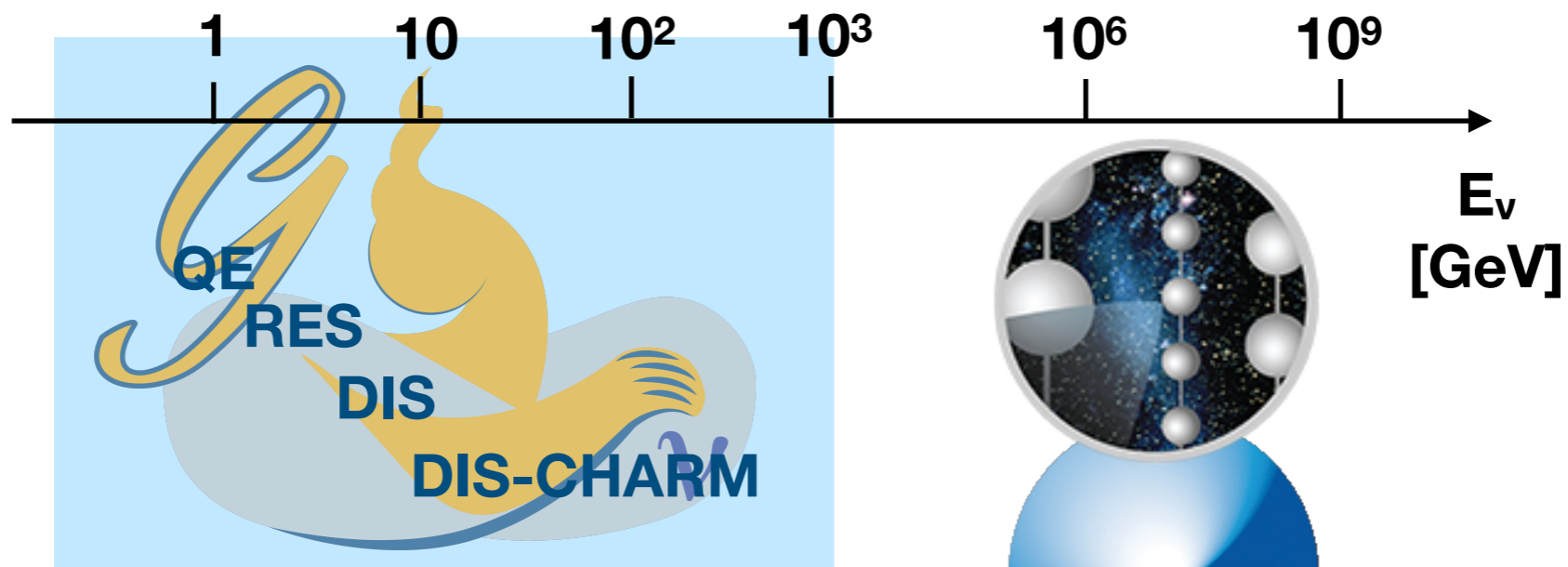
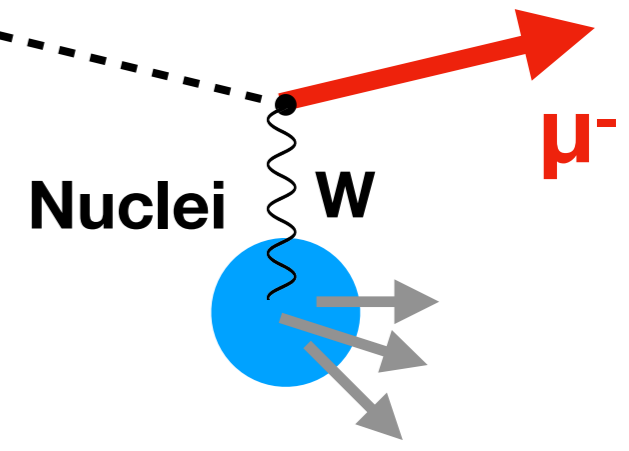
IceDune Workshop

GENIE-HEDIS

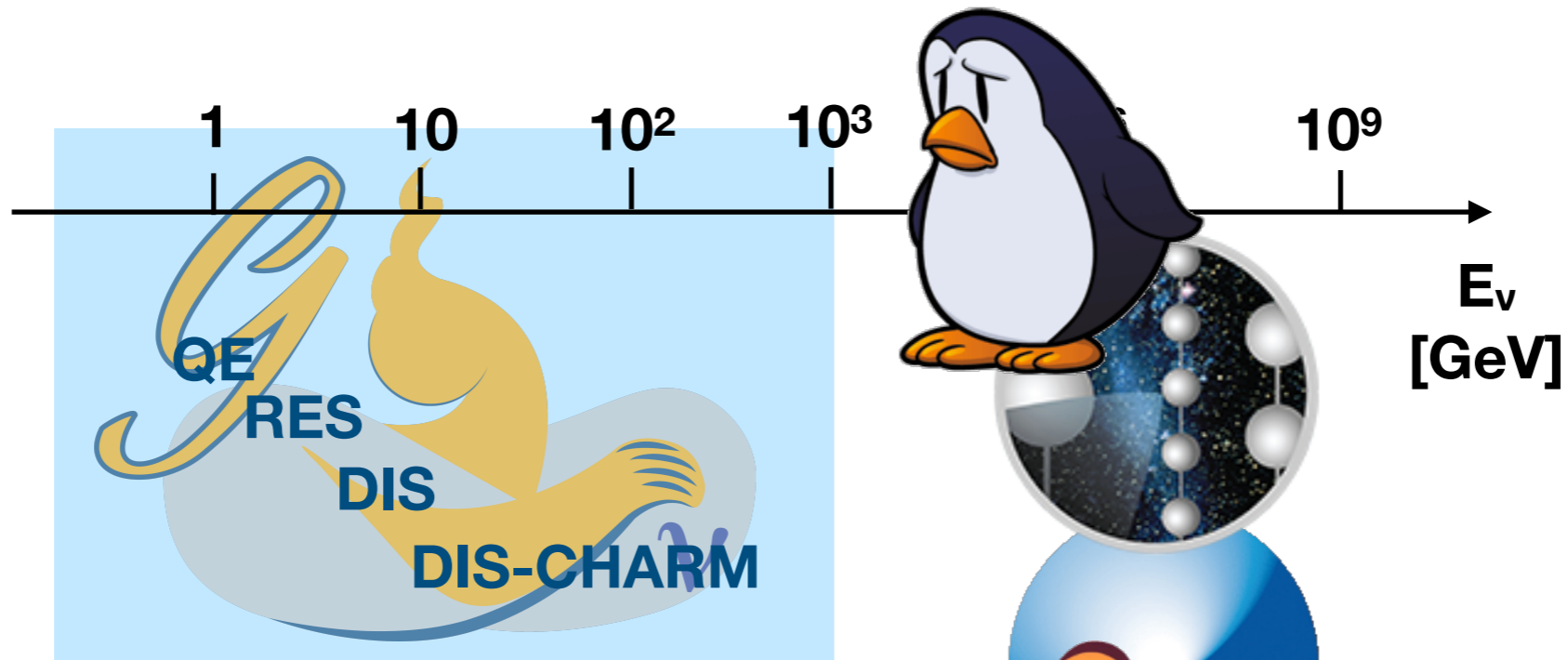
Alfonso Garcia



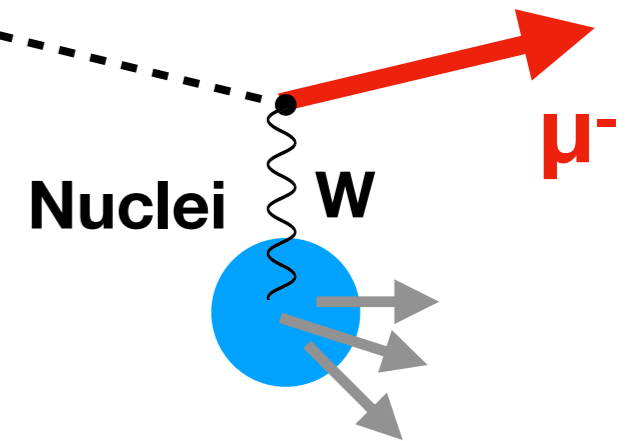
GENIE



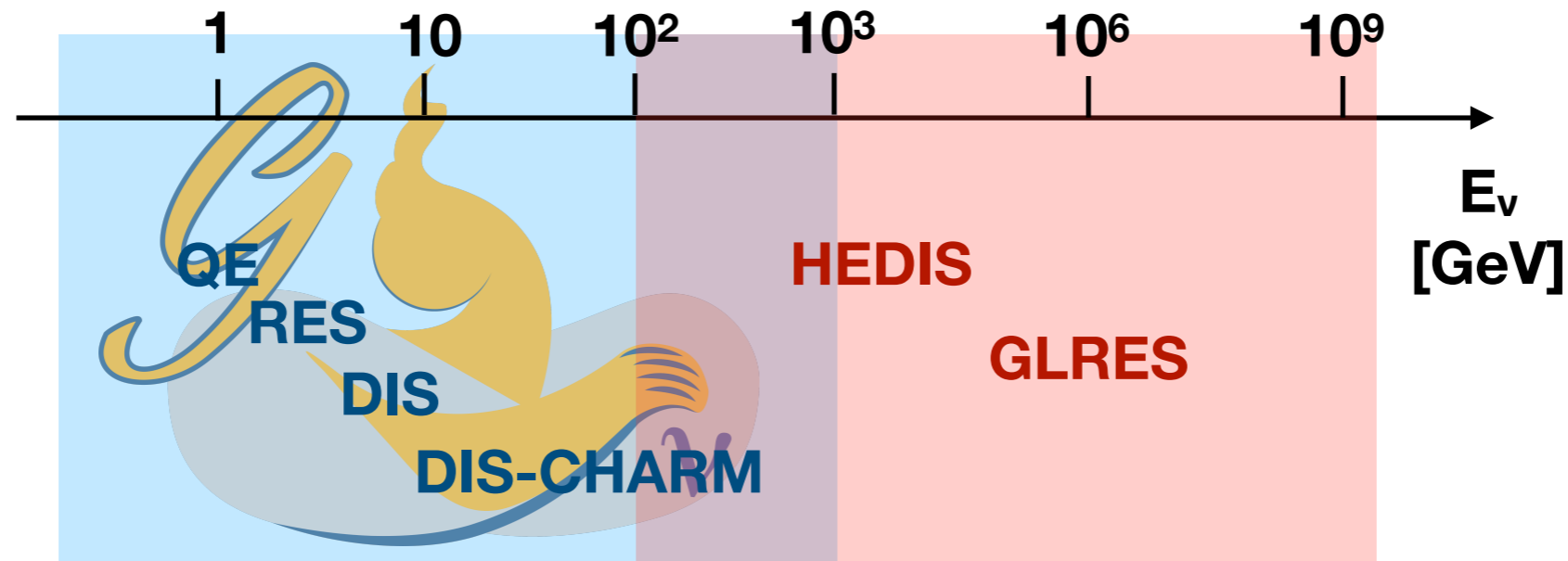
GENIE



GENIE

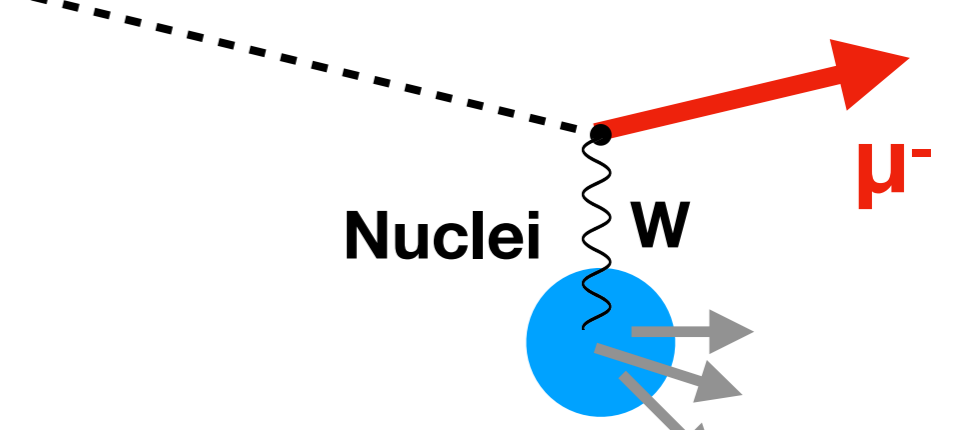


- Current status of GENIE in the high energy regime:
 - DIS based on Bodek-Yang model \rightarrow optimised for low Q^2 .
 - Structure Function = C_{ij} LO \otimes PDF LO (GRV98 $Q^2[0.8, 2 \cdot 10^6]$).
 - Contributions from heavy quarks are not included.



- New extension allows UHE interaction \rightarrow HEDIS
 - Newer PDFs with broader Q^2 phase space.
 - Structure Functions = C_{ij} NLO \otimes PDF NLO.
 - Account for the heavy quark contributions.

HEDIS



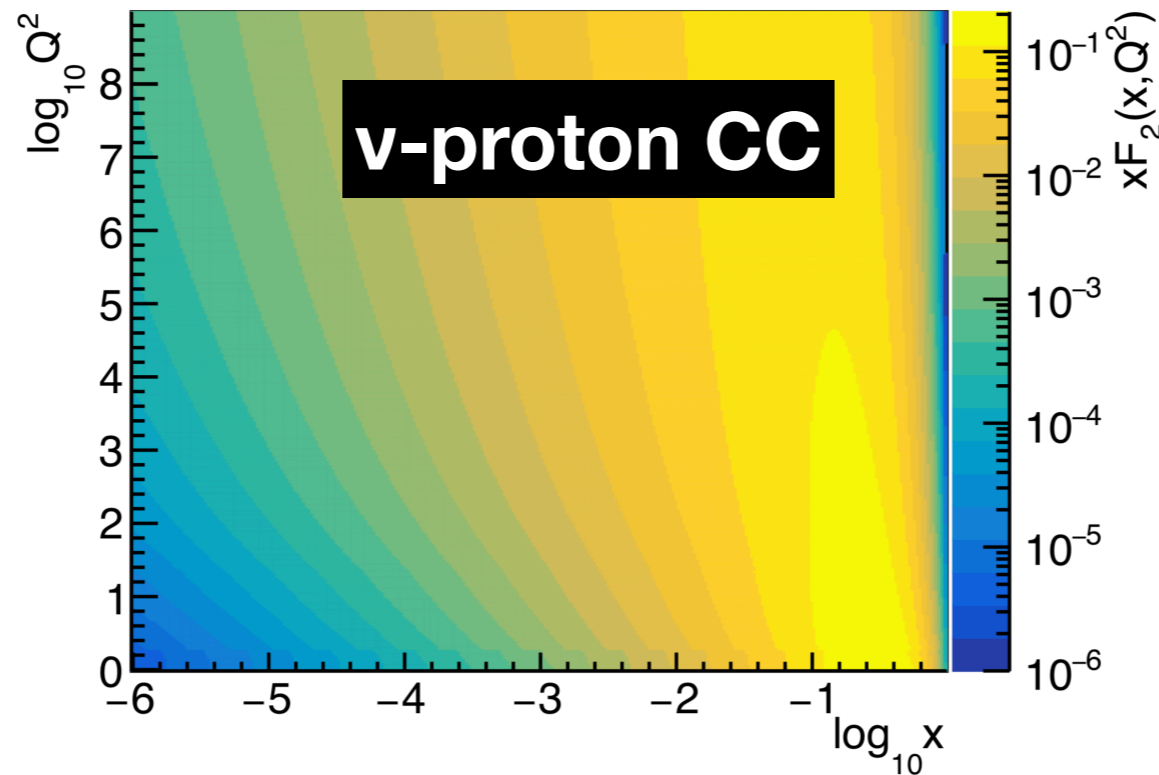
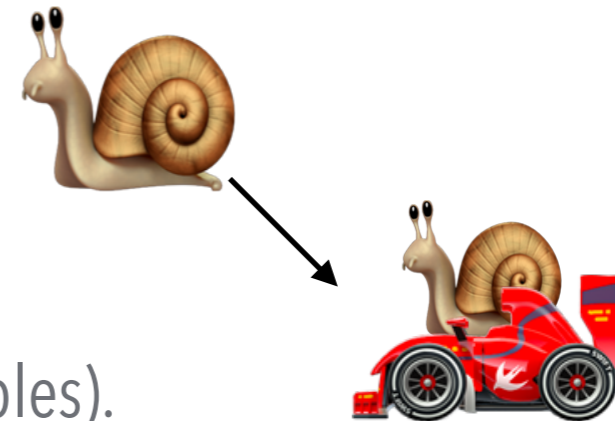
$$\frac{d^2\sigma_{\nu-n}^{CC}}{dx dy} = \frac{G_F^2}{\pi} M_N E_\nu \frac{M_W^4}{(Q^2 + M_W^2)^2} \left[y^2 \frac{x}{2} \mathbf{F}_1(\mathbf{x}, Q^2) + (1 - y) \mathbf{F}_2(\mathbf{x}, Q^2) + y \left(1 - \frac{y^2}{2} \right) \mathbf{F}_3(\mathbf{x}, Q^2) \right]$$

- The key feature:

- Event generation using NLO Structure Functions!!!

- Solution:

- Precomputation of the Structure Functions (lookup tables).

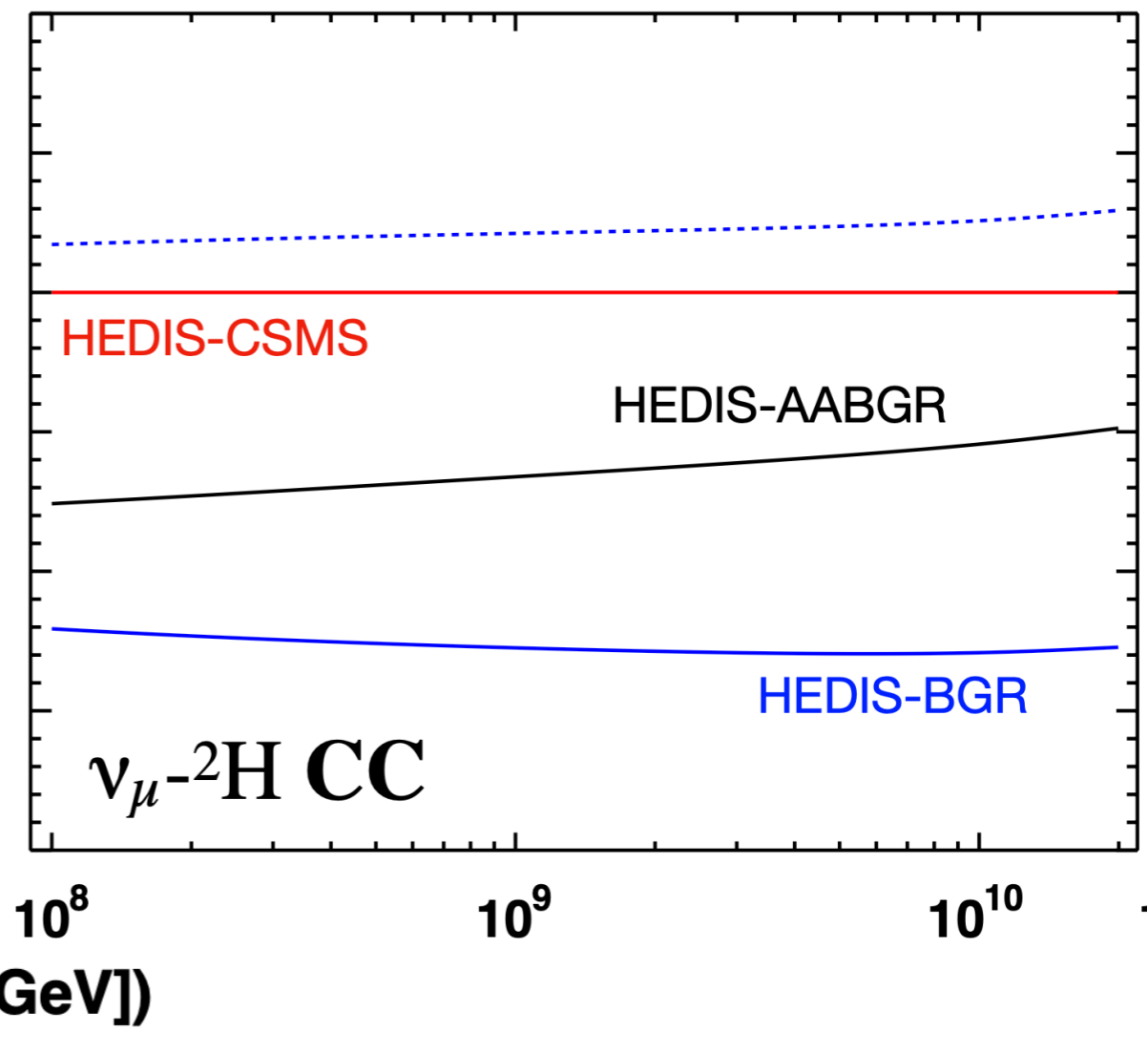
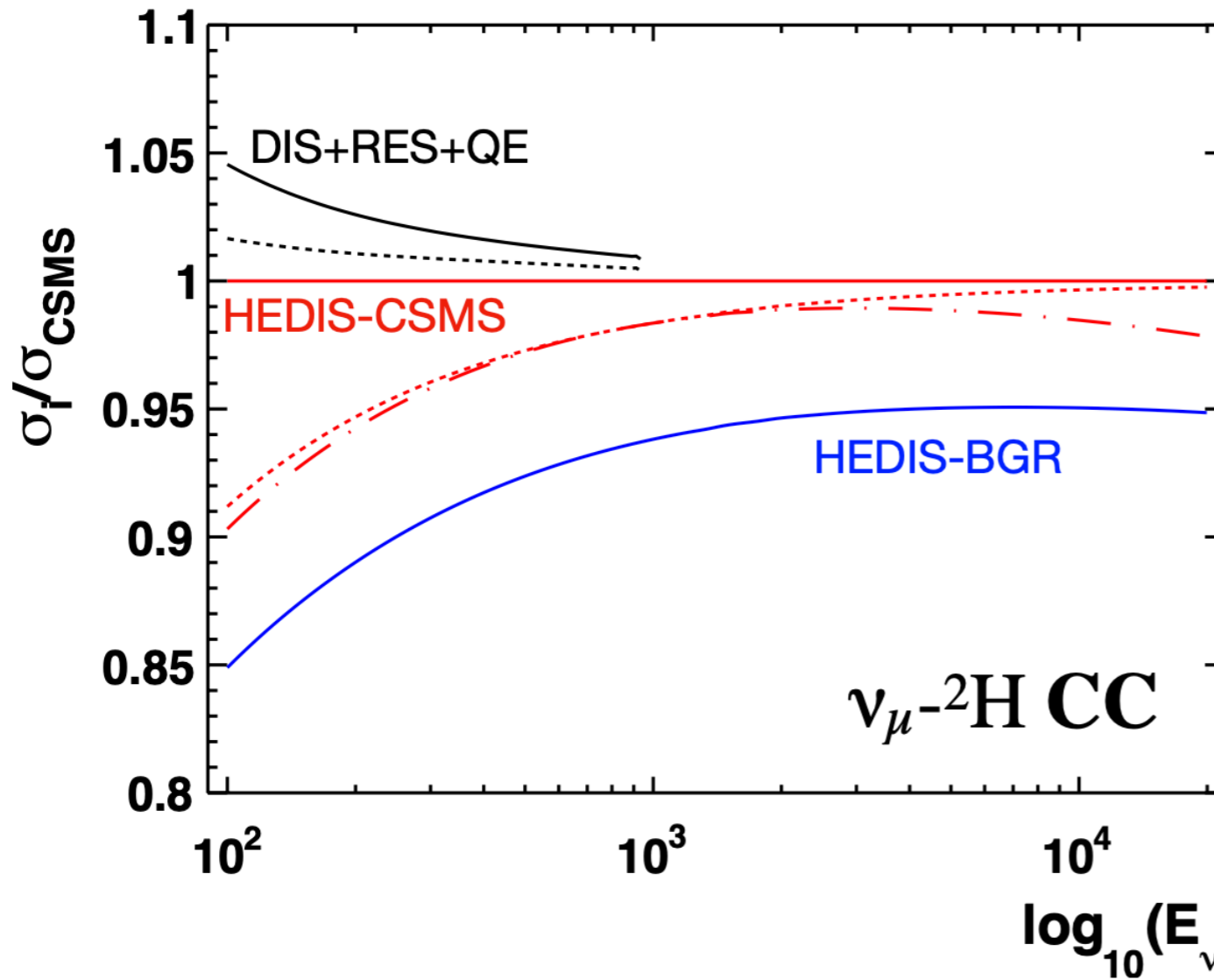


HEDIS

- Very flexible! -> Users can choose from a list of models.

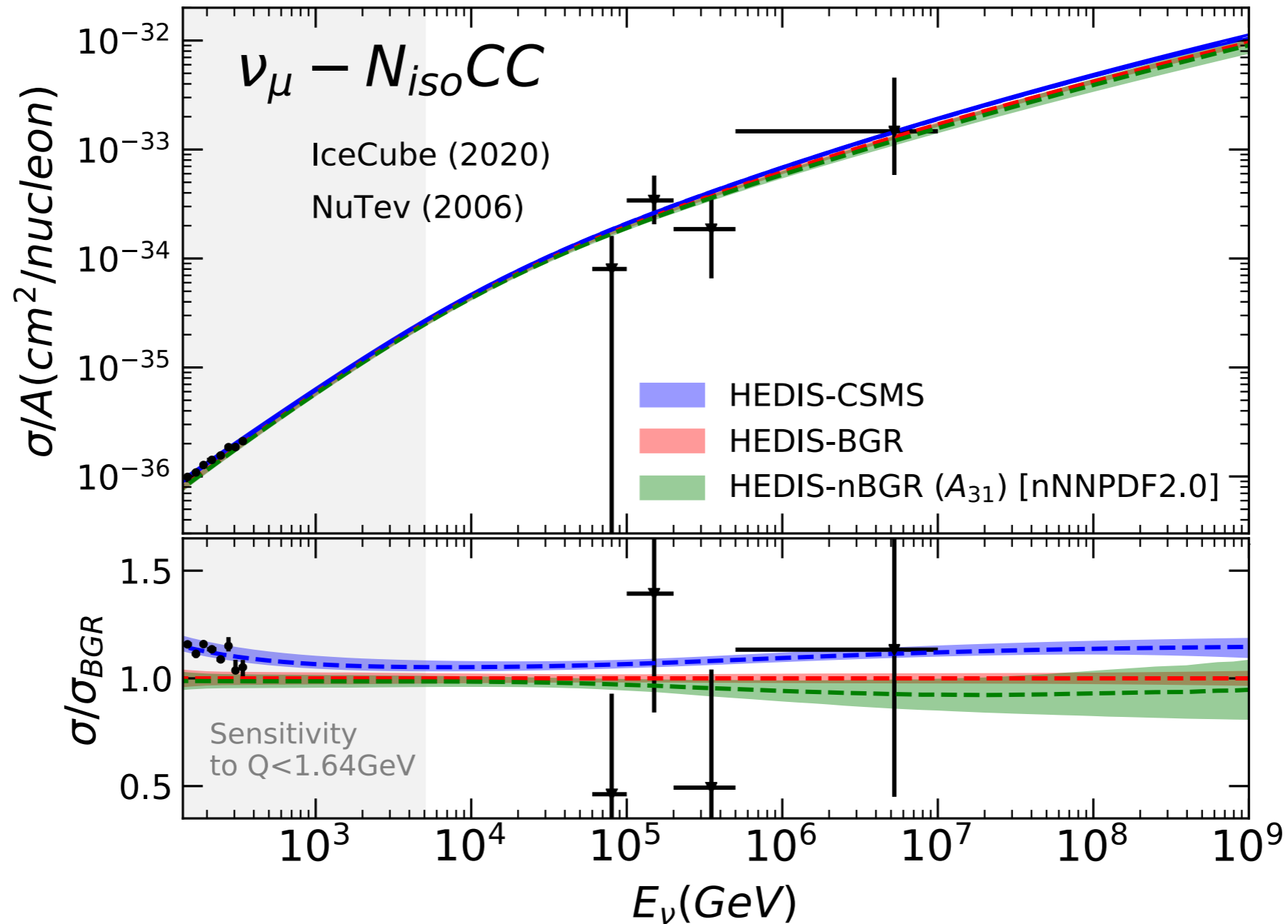
	PDF	SCHEME	Q_0 (GeV)
	HERAPDF15	ZM-VFNS	1.00
	HERAPDF15	ZM-VFNS	1.64
	HERAPDF15	FONLL	1.64
	NNPDF31	FONLL	1.64
	GRV98lo	Bodek-Yang	0.89

	PDF	SCHEME	Q_0 (GeV)
	HERAPDF15	ZM-VFNS	1.00
	NNPDF31	FONLL	1.64
	NNPDF31	ZM-VFNS	1.64
	NNPDF31	FFNS	1.64



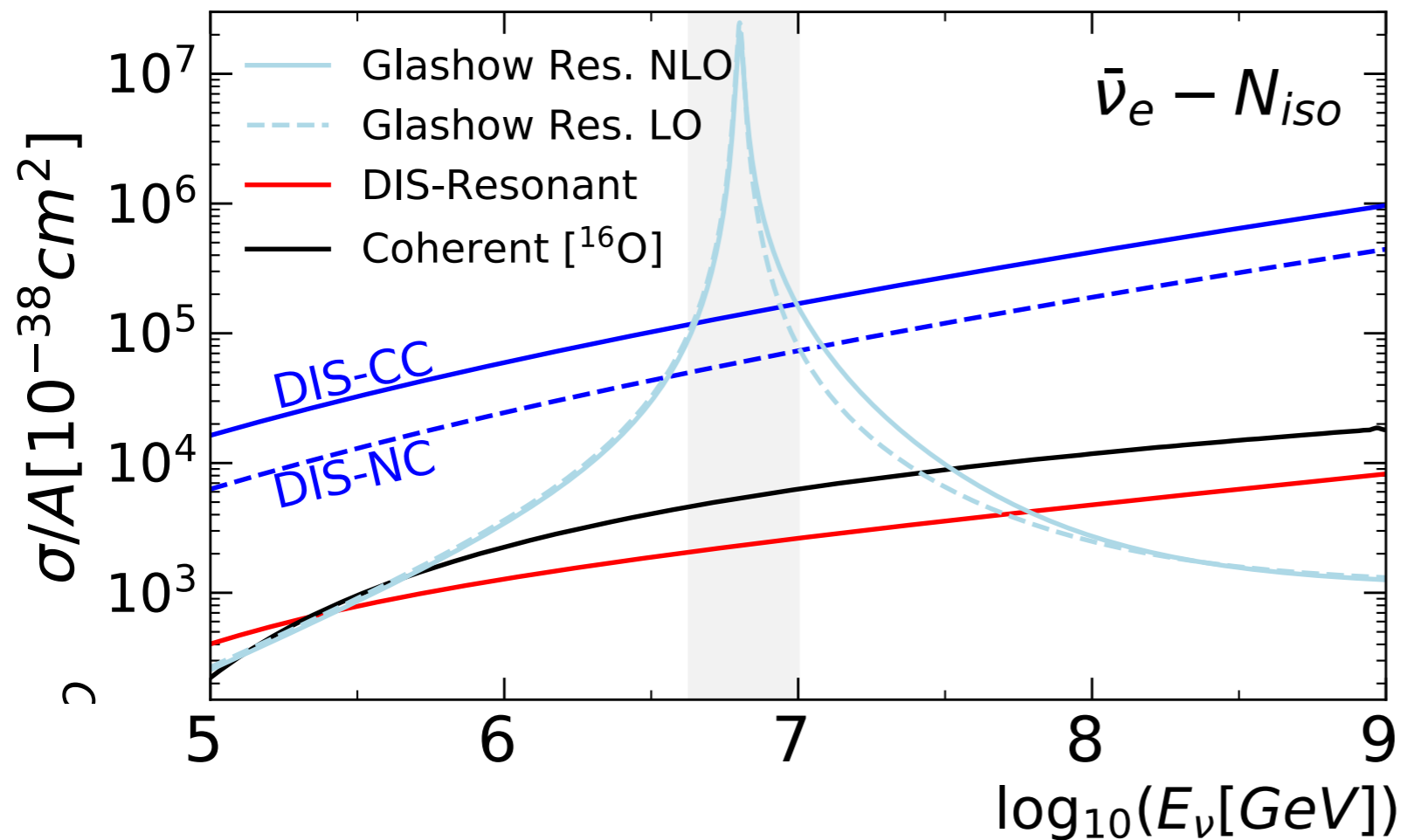
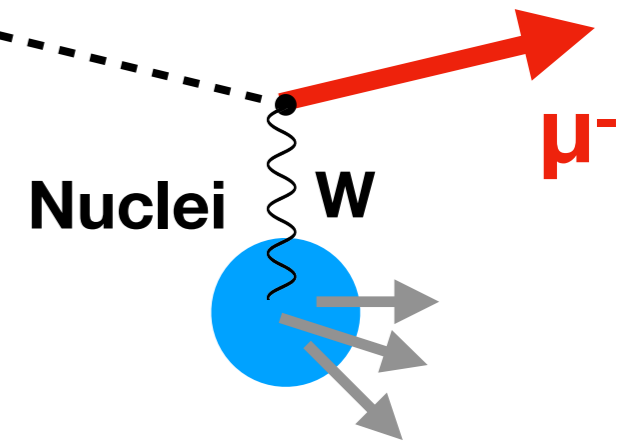
HEDIS

- Uncertainties associated with nucleon PDFs.
- Nuclear corrections.



HEDIS+GLRES

- Extension to more "exotic" channels has been implemented.



Deep inelastic scattering off quarks and gluons.

Scattering on atomic electrons via the Glashow resonance.

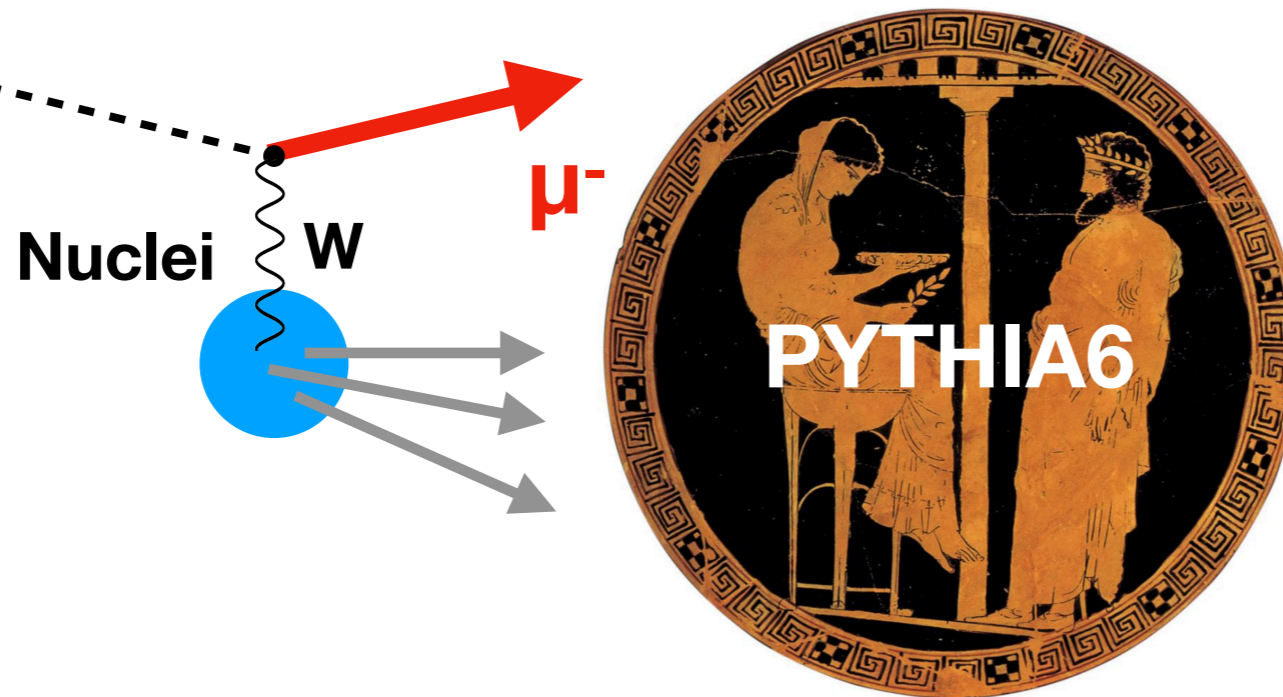
(In)elastic scattering off the photon field of nucleons.

Coherent scattering off the photon field of nuclei.

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HEDIS+GLRES

- These extensions were designed not only to compute neutrino cross sections but also to simulate neutrino HE interactions.
 - Differential cross section to extract kinematics of outgoing lepton.
 - What about the hadronic shower?
 - Detailed simulation of all the hadrons (including heavy quarks).
 - User can choose which particles are relevant for tracking.



```
+eta E=2243.06
|   +-gamma E=1083.88
|   \-gamma E=1159.18
+-rho+ E=542.988
|   +-pi+ E=159.131
|   \-pi0 E=383.856
|           +-gamma E=243.584
|           \-gamma E=140.273
+-pi- E=9.73694
+-pi0 E=5.21542
|   +-gamma E=1.08007
|   \-gamma E=4.13535
+-omega E=3.59776
|   +-gamma E=0.0816192
|   \-pi0 E=3.51614
|           +-gamma E=3.20452
|           \-gamma E=0.311622
\ -Delta+ E=2.49298
   +-proton E=2.00807
   \-pi0 E=0.484947
       +-gamma E=0.0471374
       \-gamma E=0.437831
```

Summary

- **HEDIS:** <https://github.com/GENIE-MC/Generator>
 - Already available in next GENIE repository (master branch).
 - DIS cross section using NLO pQCD expressions.
 - Hadronization including heavy quarks.
- Feedback from different experiments and theoreticians will be very valuable.
- Look into the future:
 - Couple NLO matrix elements to NLO parton showering (using PYTHIA8?).
 - Treatment of of very low x for UHE neutrino cross sections (dipole?).

HOWTO

- **Install:** <https://genie-docdb.pp.rl.ac.uk/DocDB/0000/000002/006/man.pdf>

- Create structure function tables:

```
gmkhedissf --tune GHE19_00b_00_000
```

- Create cross section splines:

```
gmkspl -p 14 -t 1000010010 -n 200 -e 1e10 --event-generator-list HEDIS  
--tune GHE19_00b_00_000 -o test.xml
```

- Generate events for a given energy:

```
gevgen -p 14 -t 1000010010 -e 500 -n 10000 --cross-sections test.xml  
--event-generator-list HEDIS --tune GHE19_00b_00_000
```