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Seoul (South Korea)

Neutrino Structure Functions from GeV to EeV Energies

Alfonso Garcia

alfonsogarciasoto@fas.harvard.edu

Neutrino cross sections

- A lot of efforts in the last decades to model high-energy cross sections:
  - Consistent picture for free nucleon predictions -> pQCD

$$\frac{d^2\sigma^{\nu A}(x,Q^2,y)}{dxdy} = \frac{G_F^2 s/2\pi}{\left(1+Q^2/m_W^2\right)^2}\left[(1-y)F_2^{\nu A}(x,Q^2) + y^2 x F_1^{\nu A}(x,Q^2) + y\left(1-\frac{y}{2}\right) x F_3^{\nu A}(x,Q^2)\right]$$

  - Secondary processes also accounted for.

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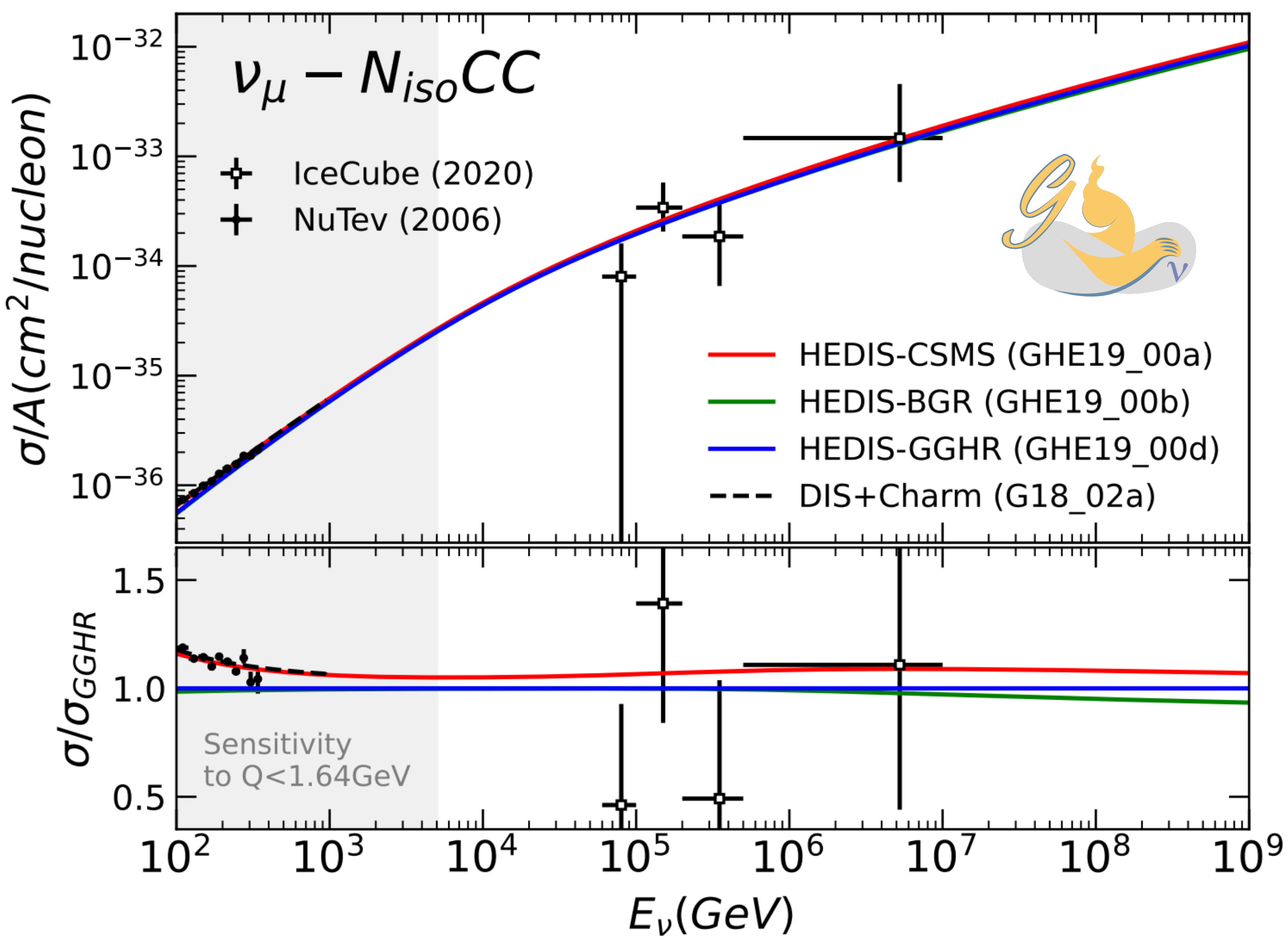

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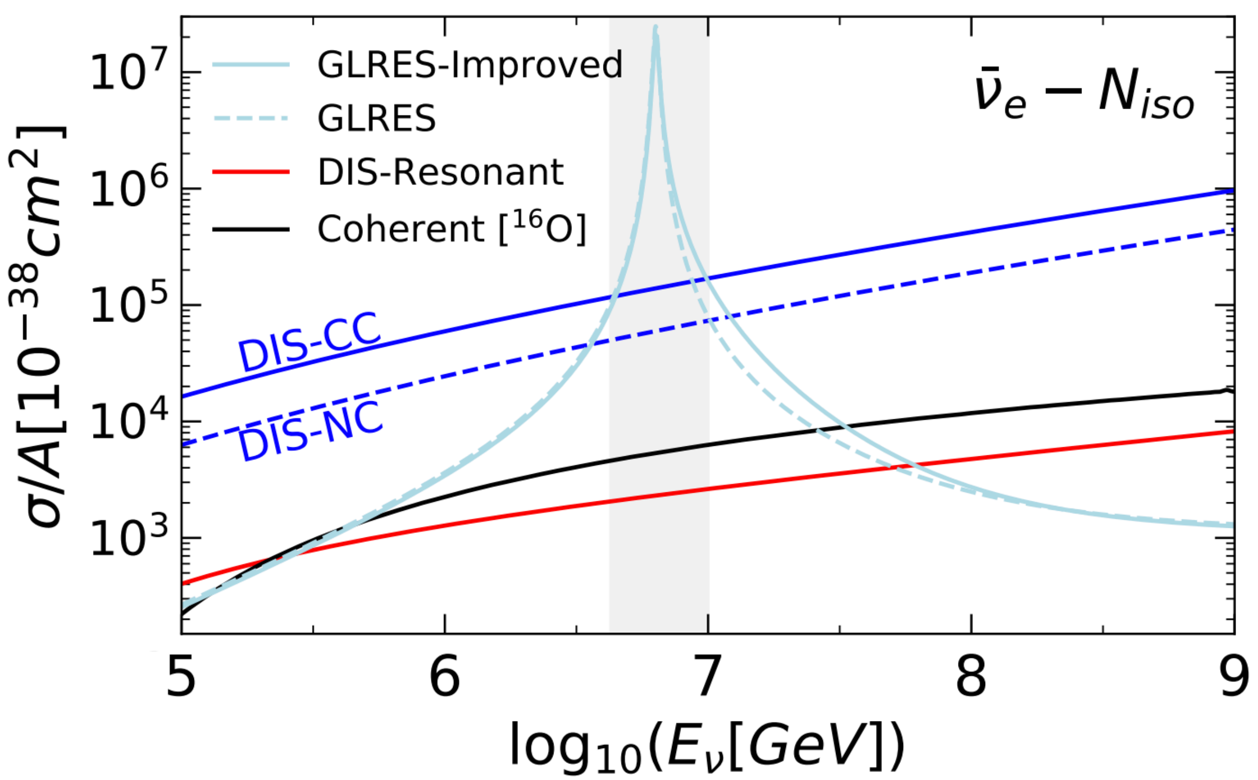
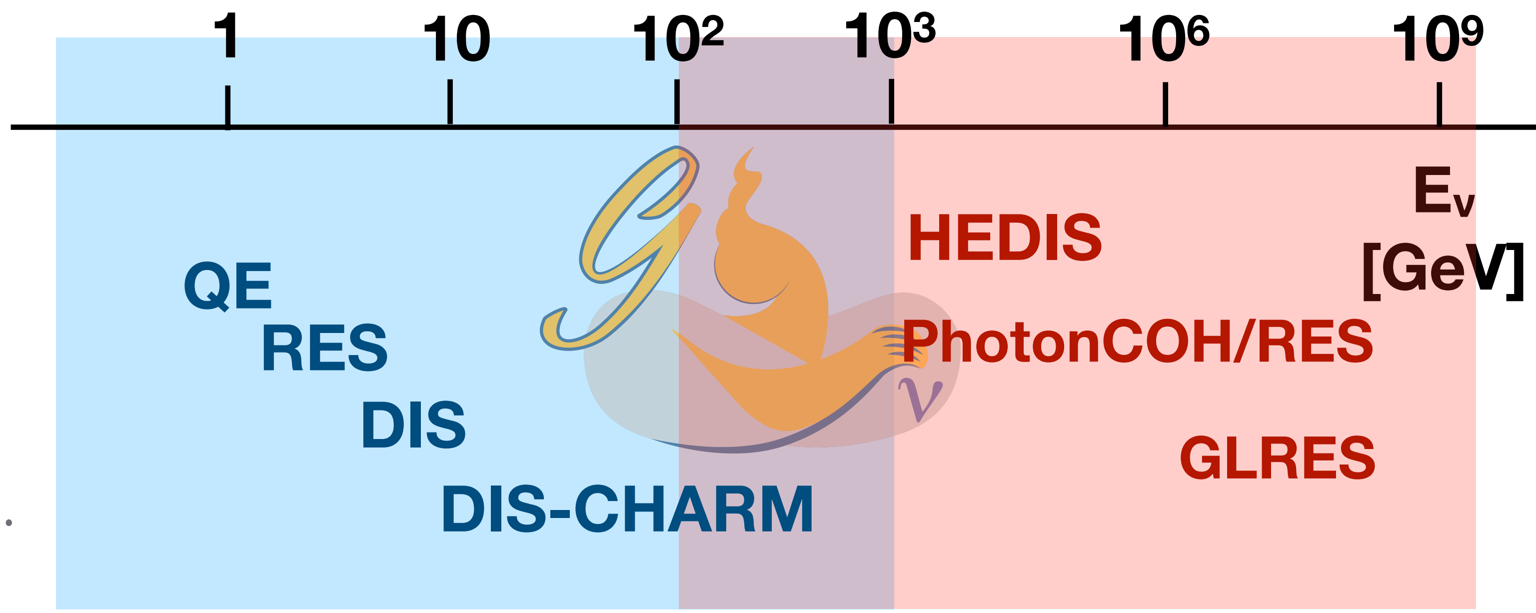
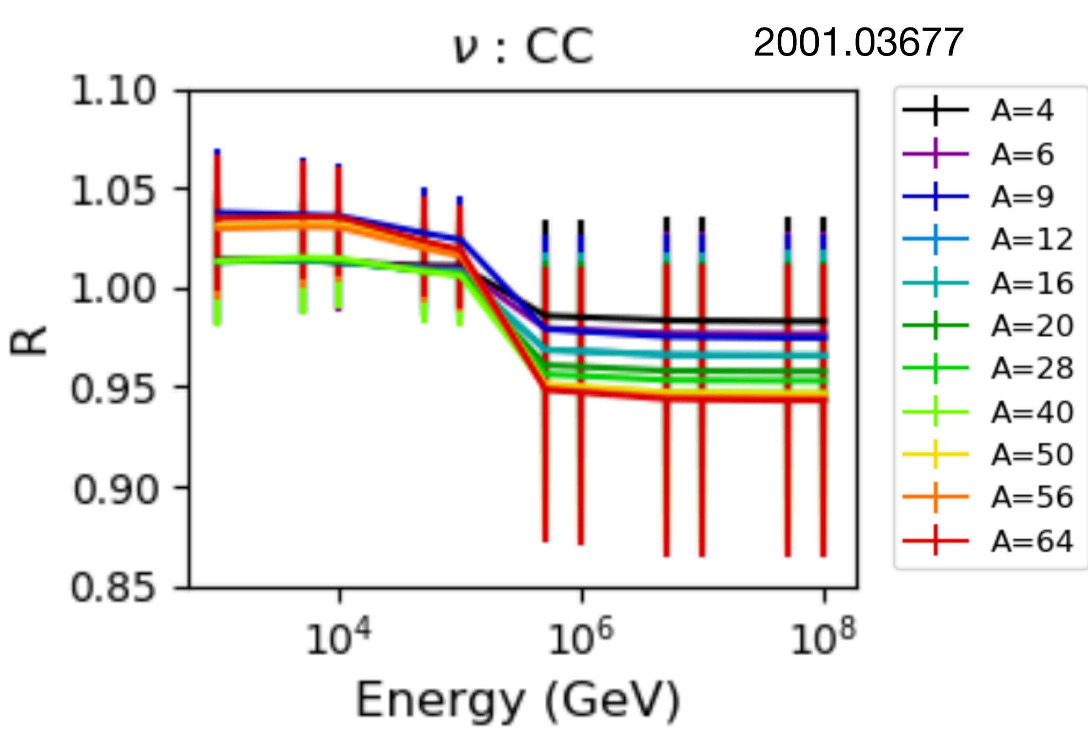


Missing pieces

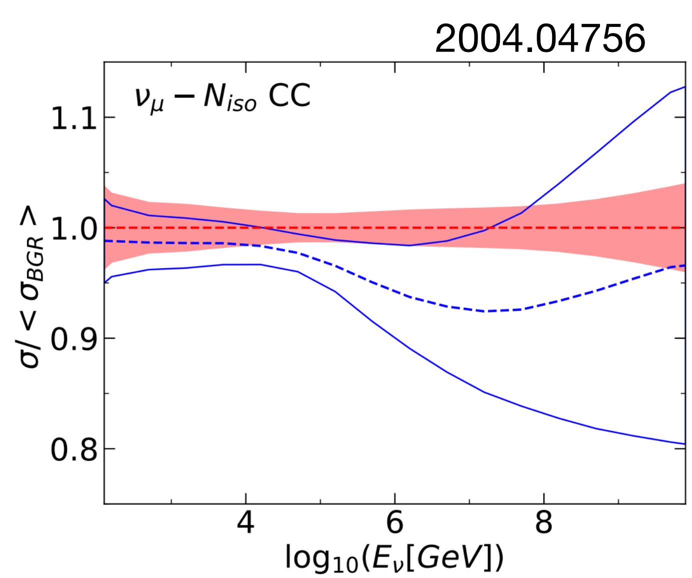


- Two pieces are missing:
  - Transition to pQCD at E<100GeV.
  - Implementation of nuclear effects.

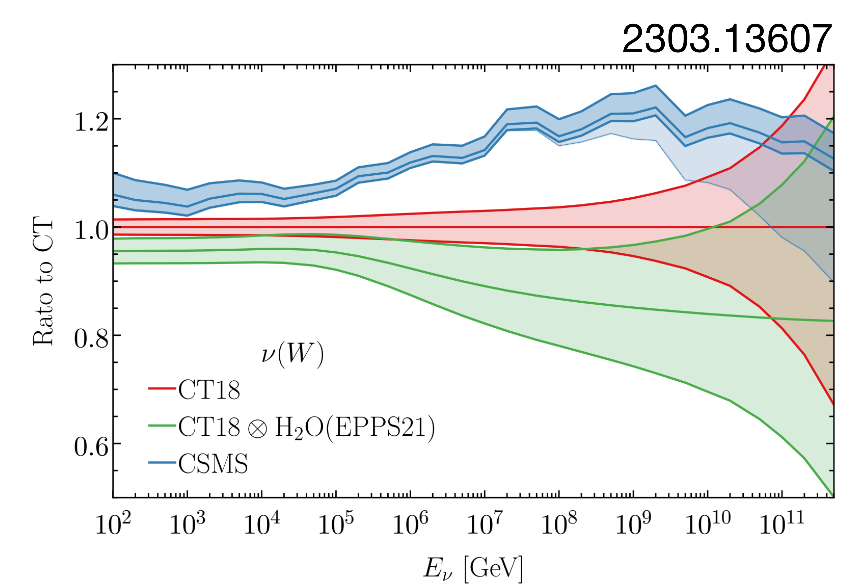
- Multiple studies point to shadowing for heavier targets (large errors).
  - At 1TeV (1PeV) maximal differences are 10% (20%) wrt CSMS.
  - Target dependent.



EPPS16



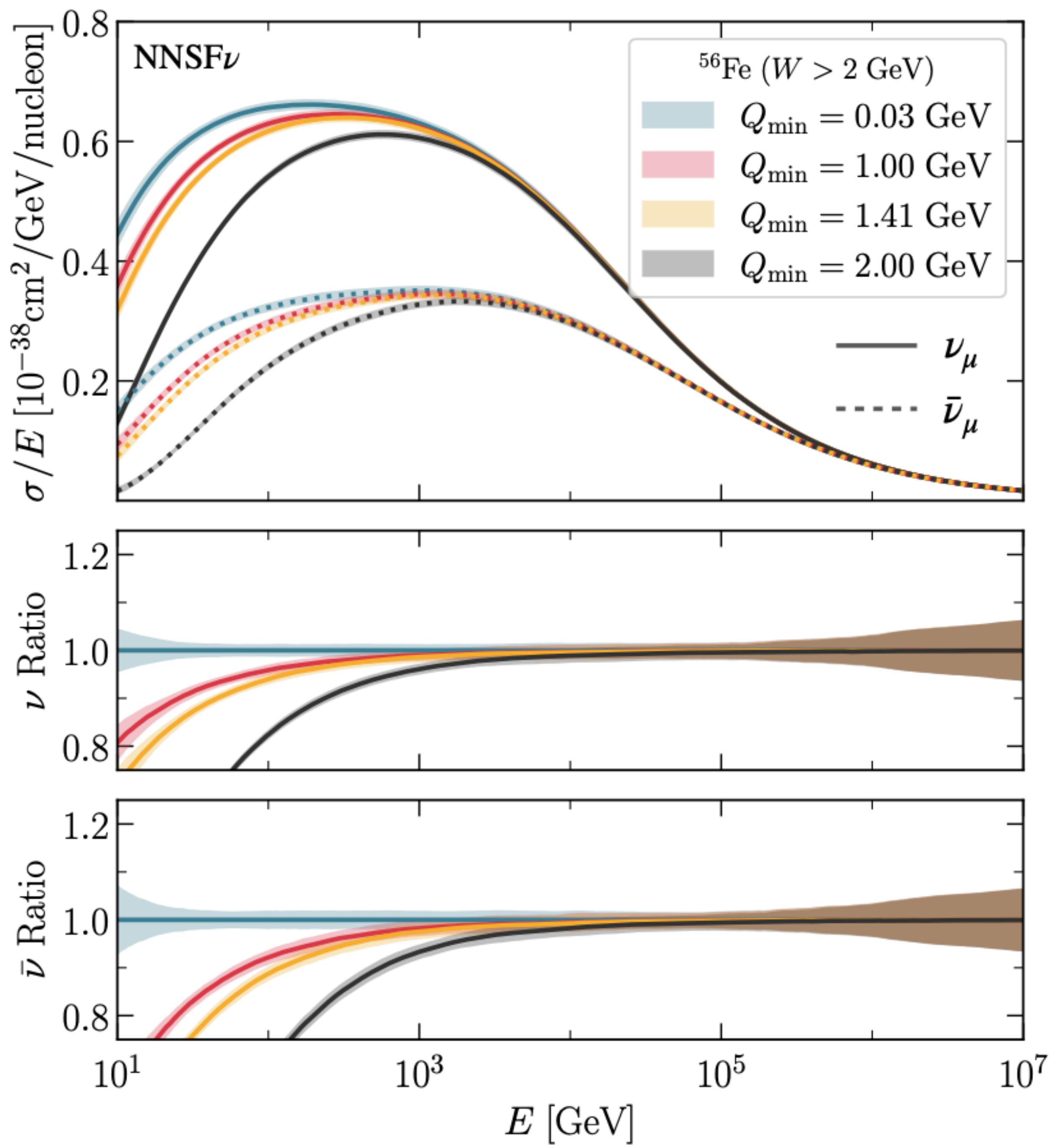
nNNPDF20



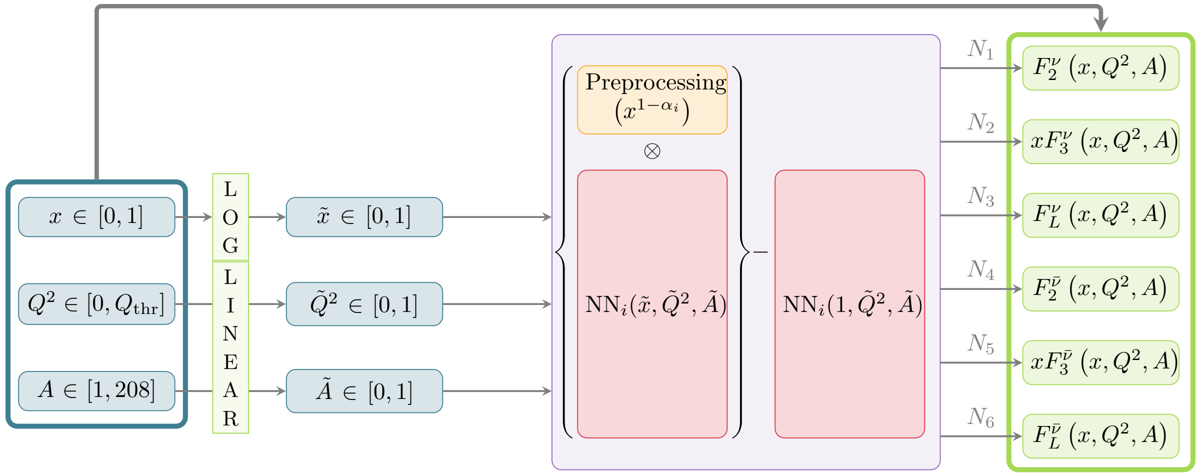
EPPS21

Low–Q^2

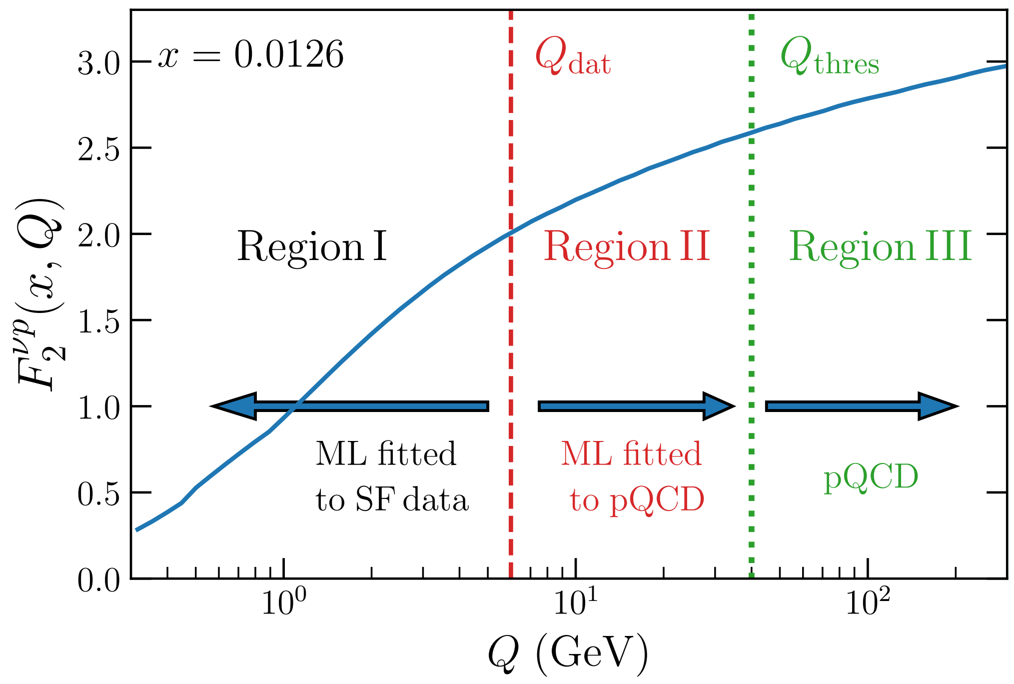
- Q<1GeV contribution 10-20% in the 10-100 GeV region.
  - Non-perturbative QCD required.

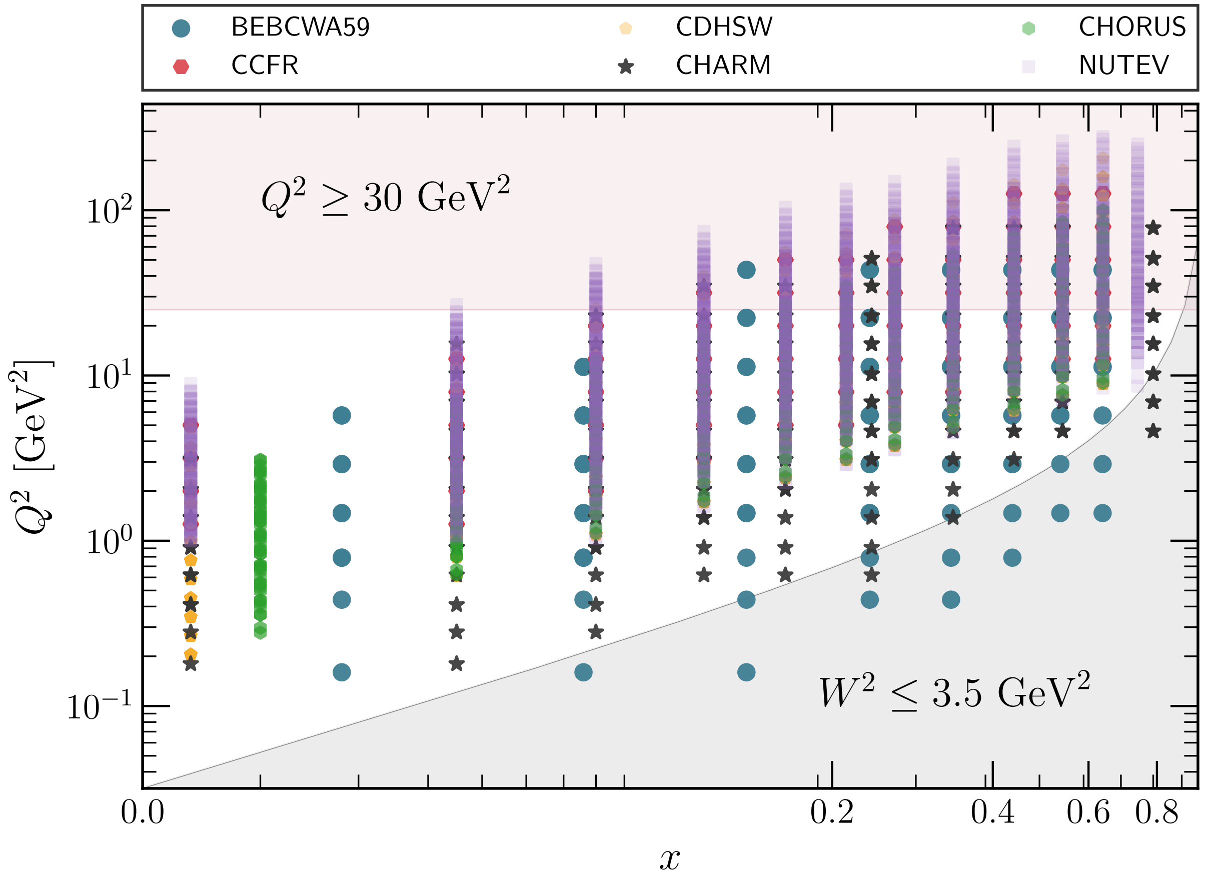


NNSFnu



- Develop a new method to account for non-pQCD terms.
  - Machine learning parametrisation of low Q using neutrino scattering data.
  - High Q region comes from pQCD.
  - Account for nuclear effects.

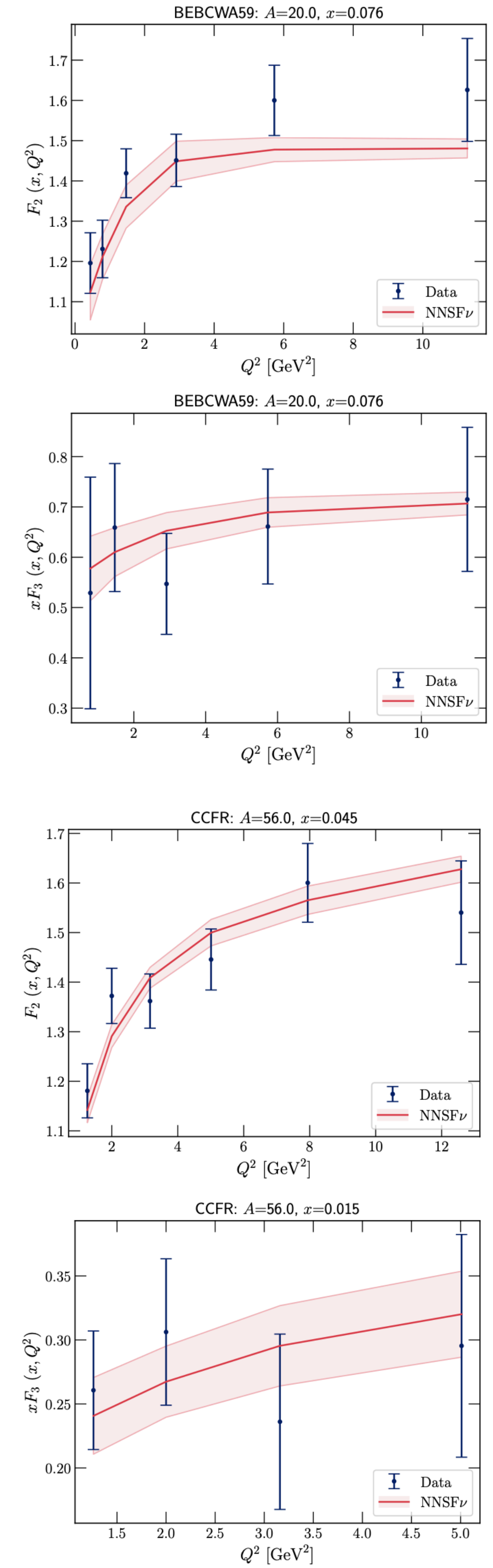




Data-driven

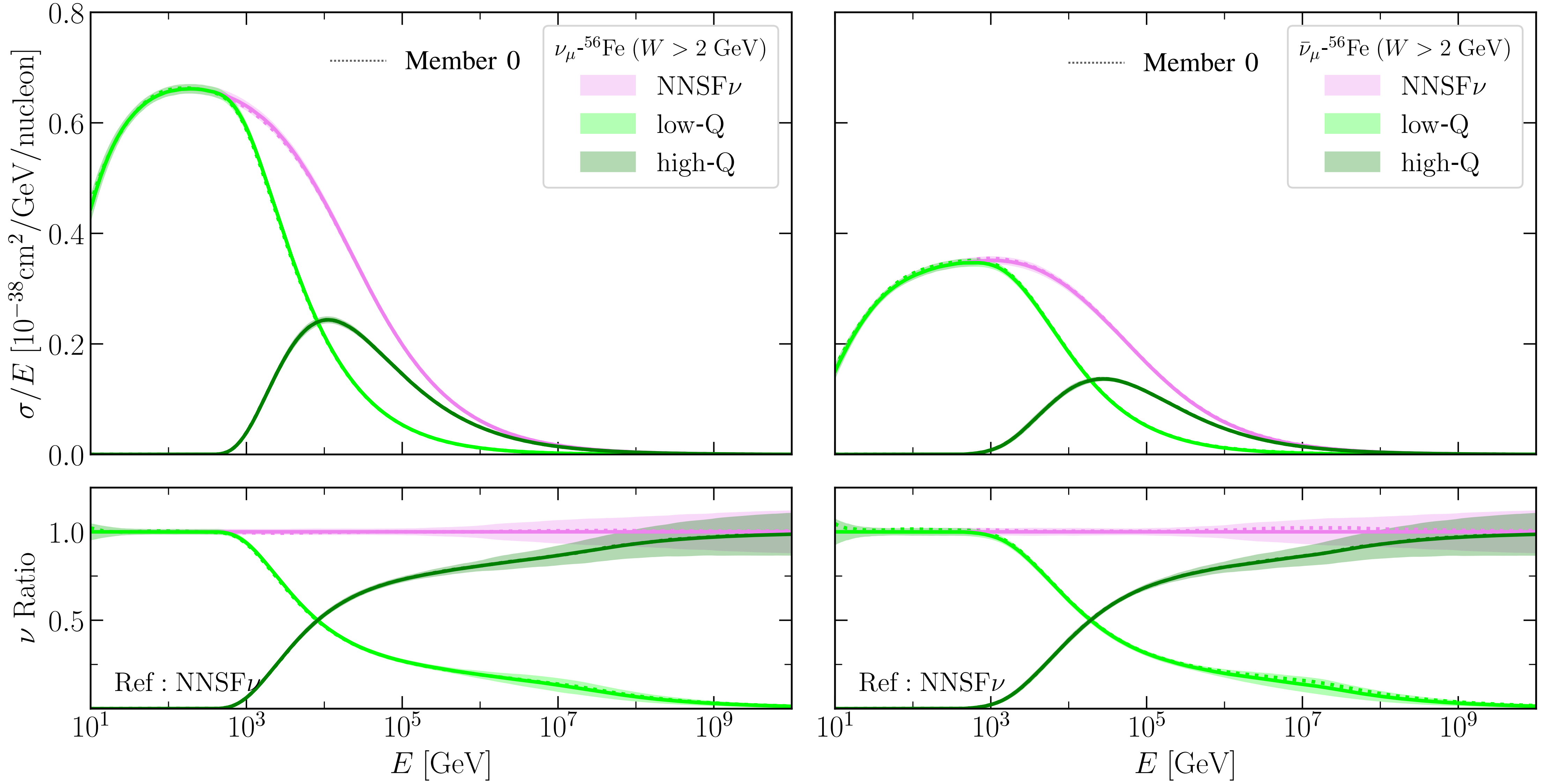
- Data from different targets
  - Differential cross sections when available.

Dataset	Target	Observable	n_{dat} (cuts)	χ^2_{exp} (wo QCD)	χ^2_{exp} (baseline)
BEBCWA59	Ne	F_2	57 (39)	1.673	2.088
		xF_3	57 (32)	0.842	0.771
CCFR	Fe	F_2	128 (82)	1.902	2.292
		xF_3	128 (82)	0.857	0.946
CDHSW	Fe	$[F_2]$	143 (92)	[6.17]	[5.32]
		$[xF_3]$	143 (100)	[22.9]	[11.7]
		$[F_W]$	130 (95)	[15.9]	[16.4]
		$d\sigma^{\nu}/dxdQ^2$	847 (676)	1.298	1.351
		$d\sigma^{\bar{\nu}}/dxdQ^2$	704 (583)	1.139	1.237
CHARM	$CaCO_3$	F_2	160 (83)	1.368	1.324
		xF_3	160 (61)	0.721	0.850
CHORUS	Pb	$[F_2]$	67 (53)	[63.8]	[38.3]
		$[xF_3]$	67 (53)	[6.881]	[2.904]
		$d\sigma^{\nu}/dxdQ^2$	606 (483)	0.986	1.185
		$d\sigma^{\bar{\nu}}/dxdQ^2$	606 (483)	0.709	0.797
NuTeV	Fe	$[F_2]$	78 (50)	[9.854]	[10.41]
		$[xF_3]$	75 (47)	[6.24]	[3.810]
		$d\sigma^{\nu}/dxdQ^2$	1530 (805)	1.436	1.542
		$d\sigma^{\bar{\nu}}/dxdQ^2$	1344 (775)	1.254	1.311
Total			**6197 (4089)**	**1.187**	**1.287**



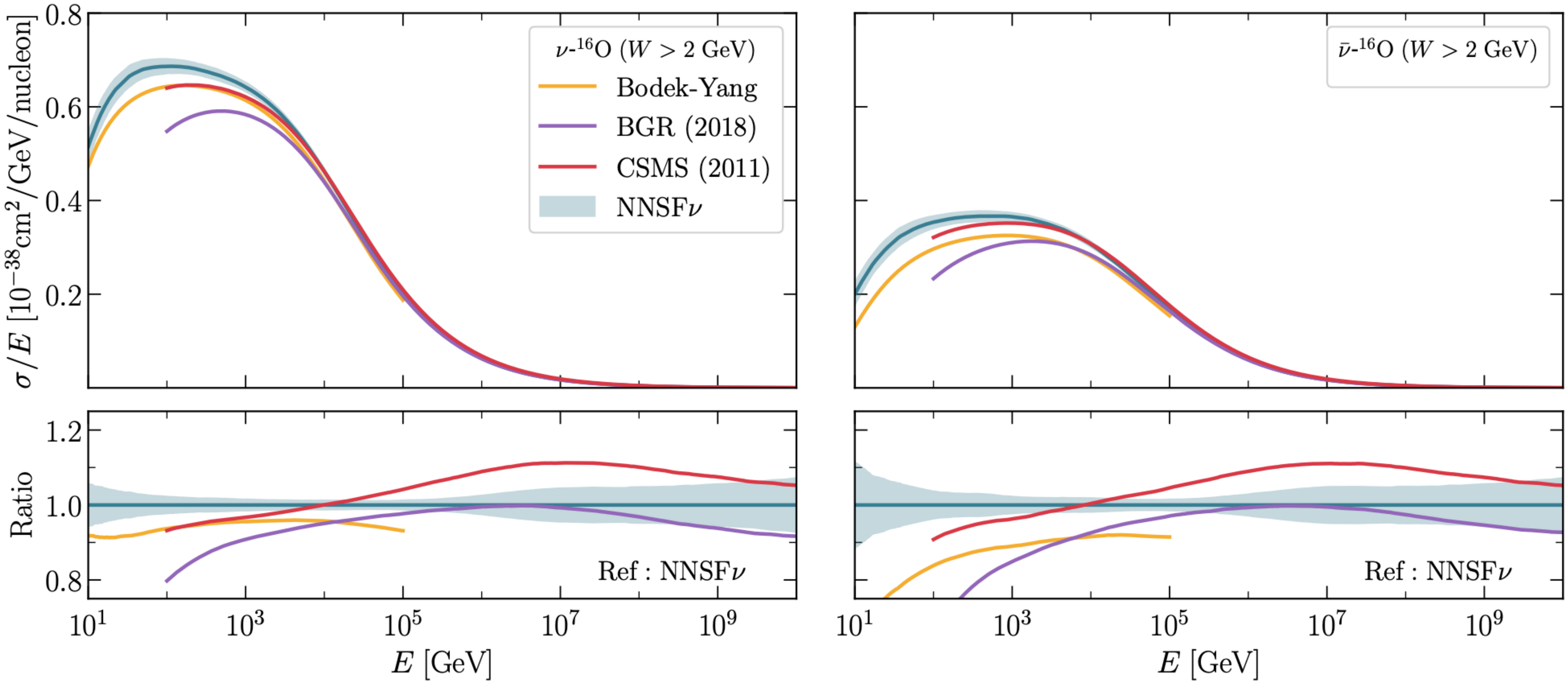
NNSFnu

- Smooth transition from low to high Q!!!



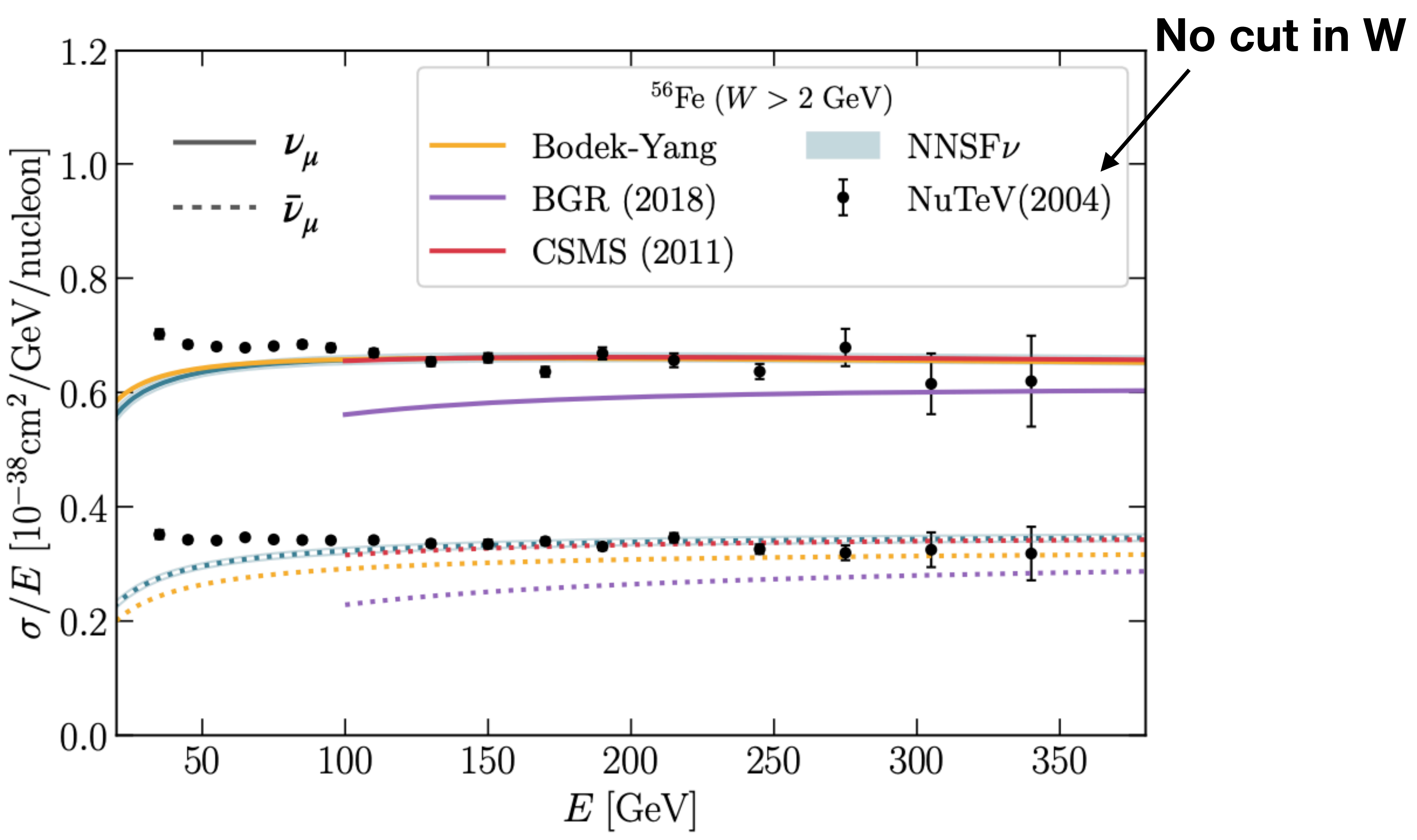
Neutrino–Oxygen

- Main points:
  - Differences with respect to BY for antineutrinos (already observed with CSMS).
  - Nuclear effects are relatively small for Oxygen.



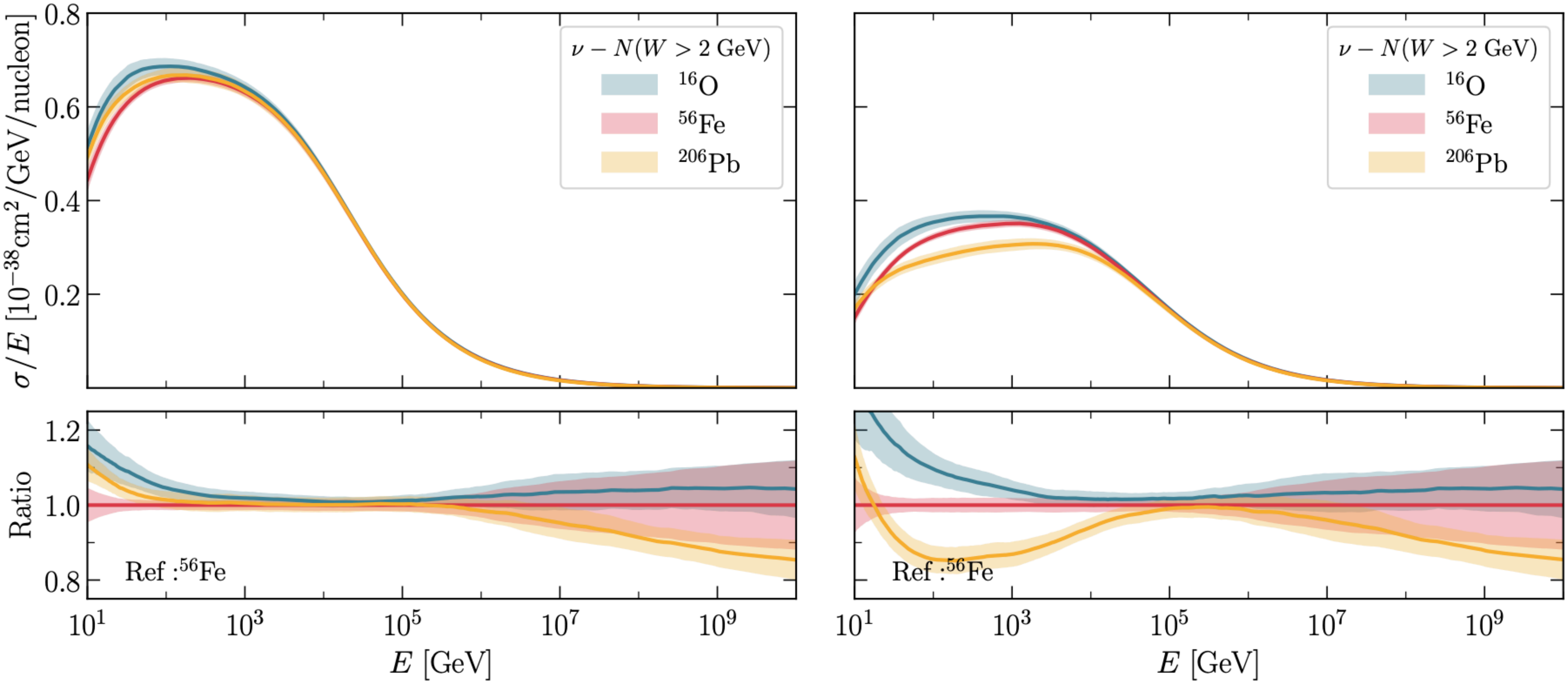
Neutrino–Iron

- Good agreement with NuTeV data:



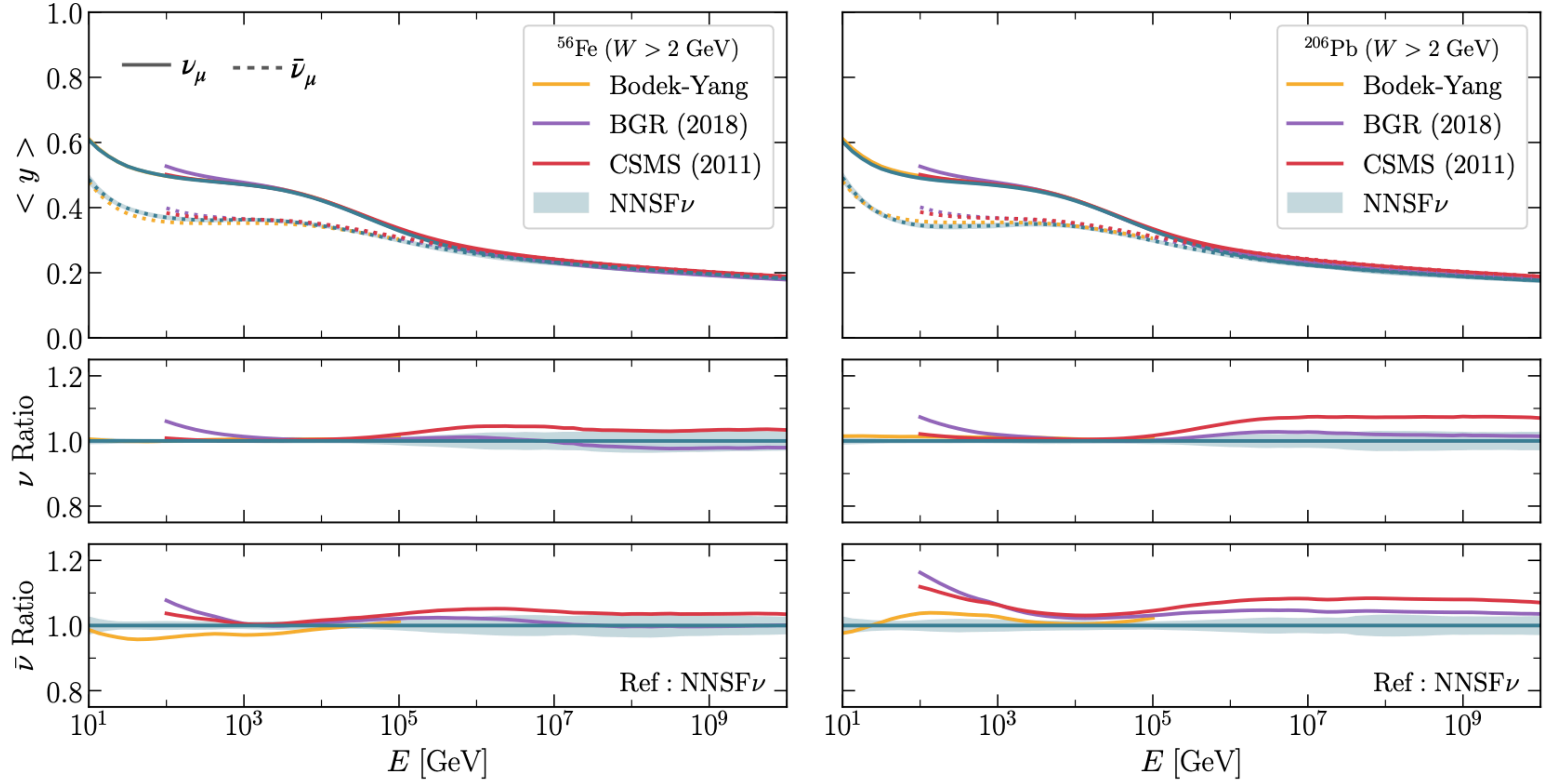
Other targets

- Critical effect in the GeV regime for antineutrinos.



Inelasticity

- Good agreement for average inelasticity.
- Nuclear uncertainties remain small.



Conclusion

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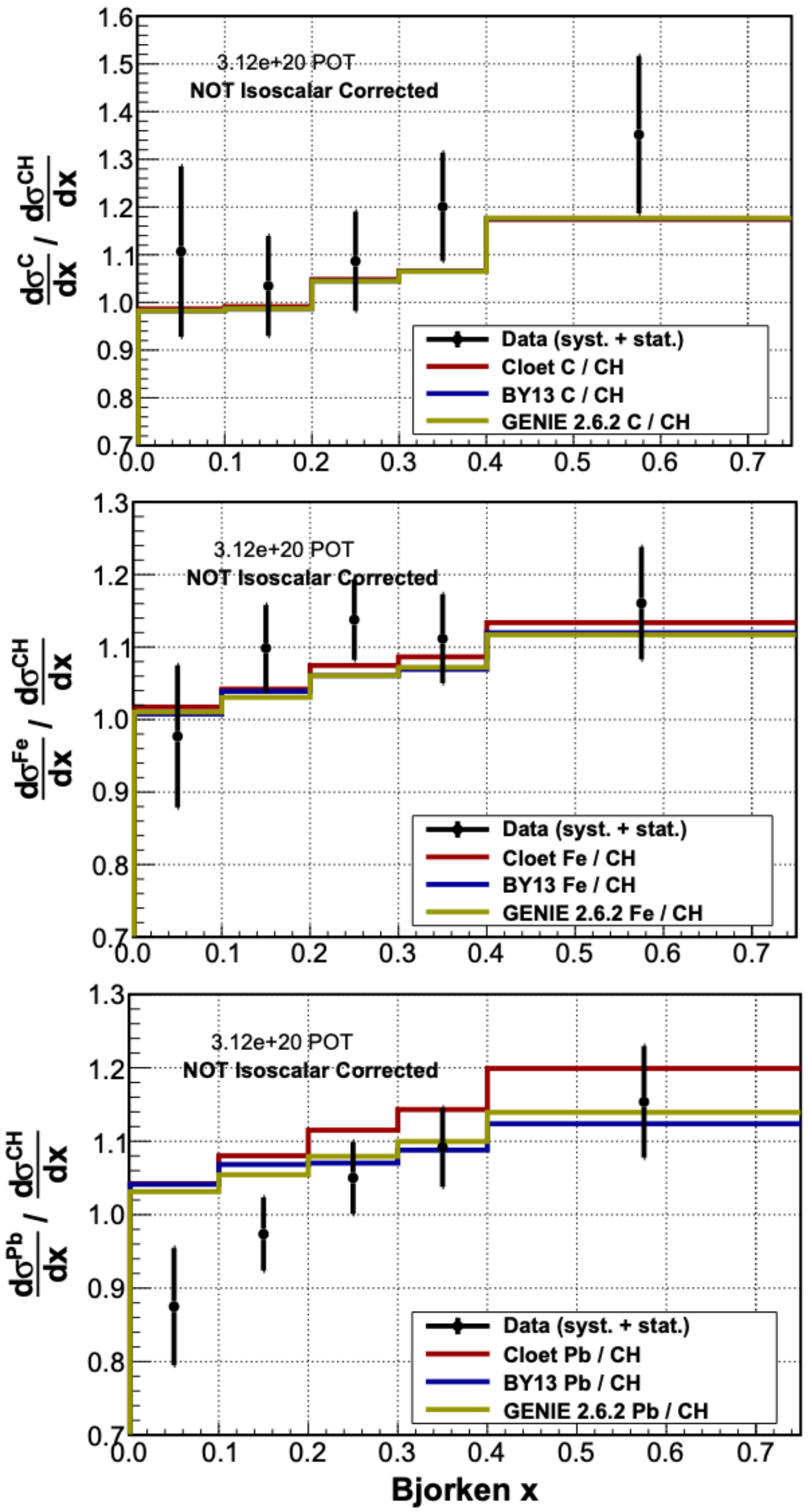

- New method to extract inclusive structure functions.
  - Propagated uncertainties.
- Next steps:
  - Implementation in GENIE underway.
  - Look at Minerva data!
- More details can be found: **JHEP 05 (2023) 149**


Thanks

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