

Compatibility of Neutrino Deep Inelastic Scattering Data in a Global Nuclear Parton Density Determination

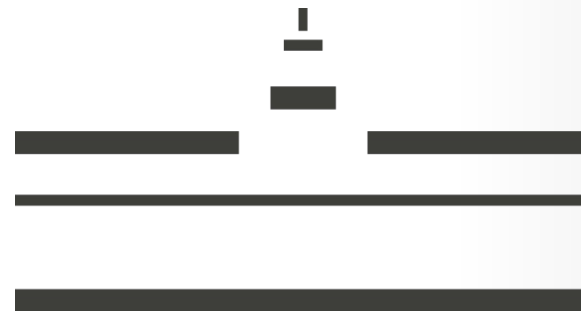
New Directions in Neutrino-Nucleus Scattering
NuSTEC Workshop 2021

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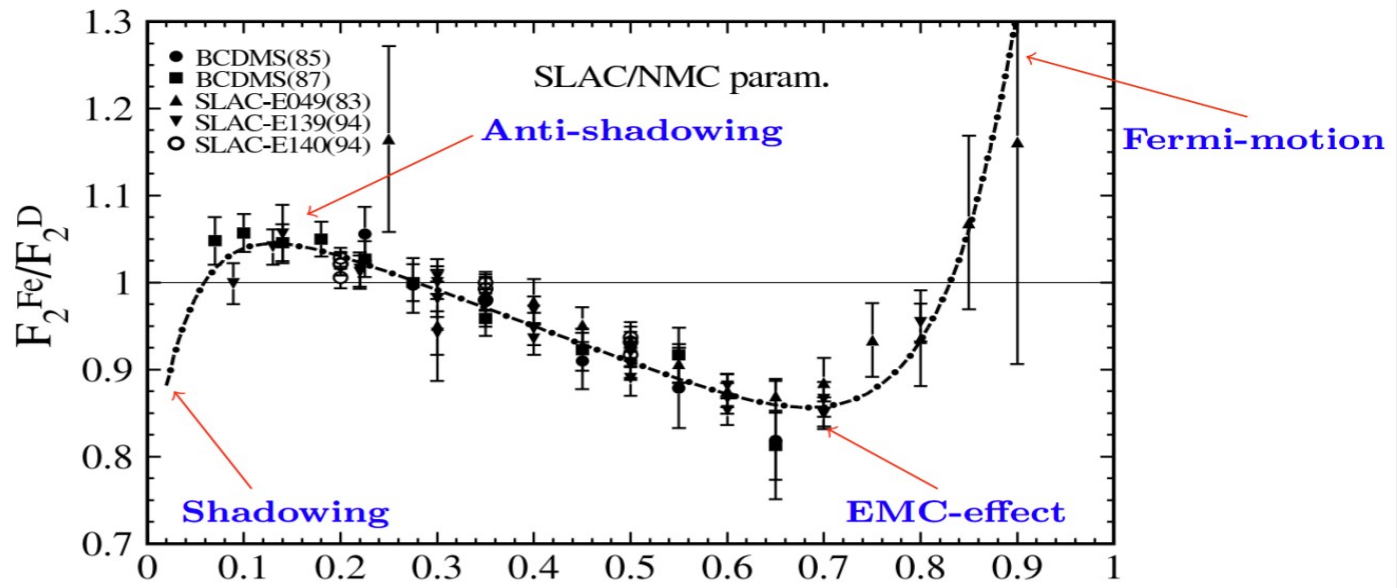
nCTEQ
nuclear parton distribution functions



WWU
MÜNSTER

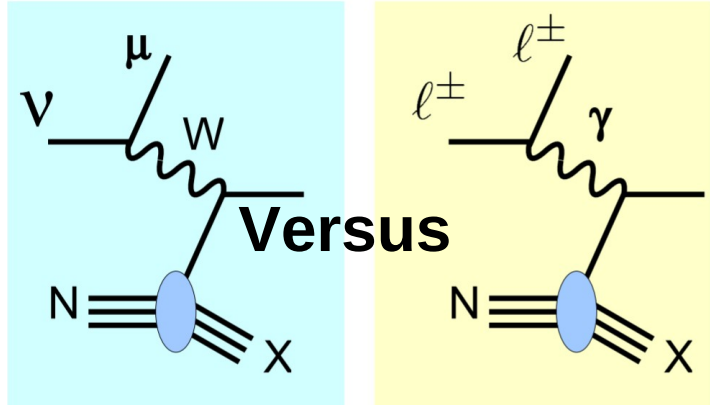
INTRODUCTION : nPDFs

$$AF_2^A \neq ZF_2^p + (A - Z)F_2^n$$



MODEL : Factorization → Universal nPDFs

ISSUE :



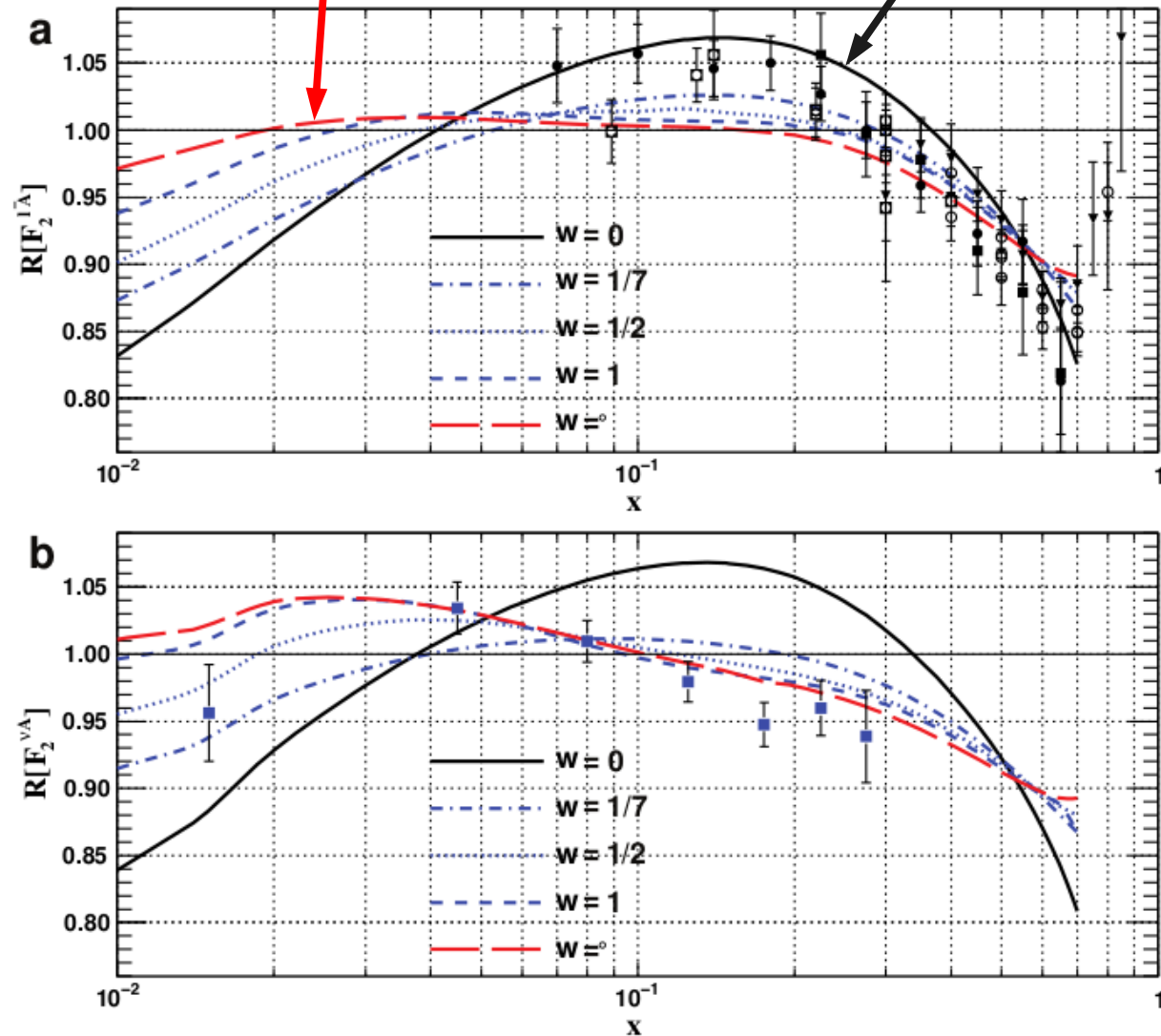
Neutrino DIS Charge Lepton DIS

Different nPDFs?

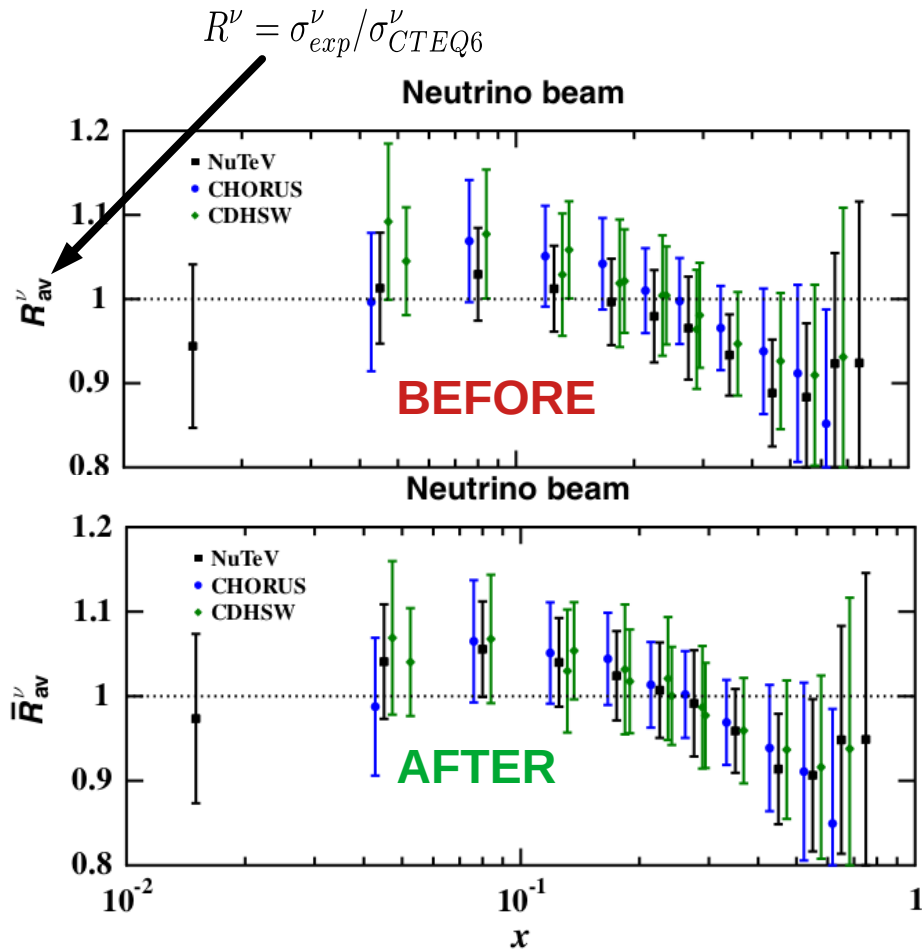
STILL NO CONSENSUS!

Dimuon + Chours+ NuTeV vs $l^\pm A + DY$

- **USE** NuTeV's point-by-point correlated systematic uncertainties.
- Different weights w for the neutrino DIS data.
- χ^2 - Hypothesis test : **NO COMPROMISE FIT**
- Ignoring NuTeV correlation seems to lower the tension, but **NOT ENOUGH!**



EPPS



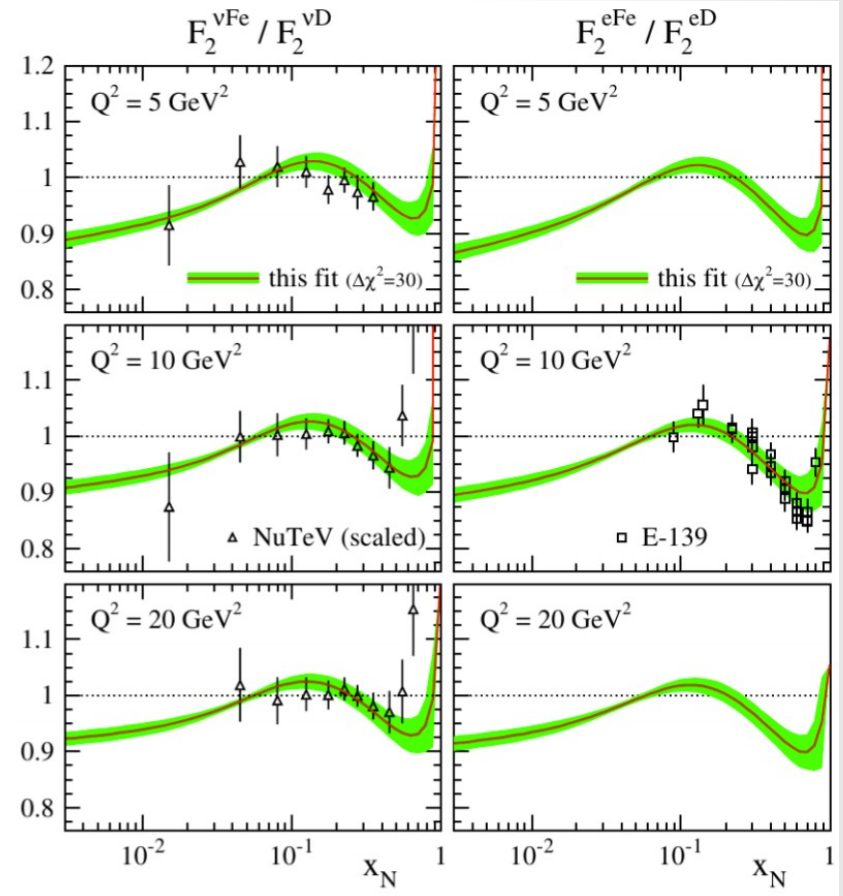
Normalization :

$$\bar{R}^\nu(x, y, E) = \frac{\sigma_{exp}^\nu / I_{exp}^\nu(E)}{\sigma_{CTEQ6}^\nu / I_{CTEQ6}^\nu(E)}$$

Hessian Reweighting $\longrightarrow \Delta\chi^2 < \Delta\chi_{EPS09}^2$

Paukenen & Salgado PRL110(2013)212301

DSSZ



- Global nPDF fit : charge lepton DIS, DY, pion production, and F2,3 NuTeV, Chorus, CDHSW.

- MSTW2008 proton PDF as base --
→ NuTeV is already included.

- Correlation is IGNORED

- NO NOTICEABLE TENSION

de Florian et al Phys.Rev.D85,074028(2012)

OUR ANALYSIS

BASE : nCTEQ15WZdeut

- Data : DIS+ DY+ pion + WZ LHC
- Number of data : 859 pts
- Iso-scalar corrections are undone.
- Deuteron correction :

$$F_2^D \rightarrow F_2^p = F_2^D \times (F_2^p/F_2^D)_{CJ15}$$

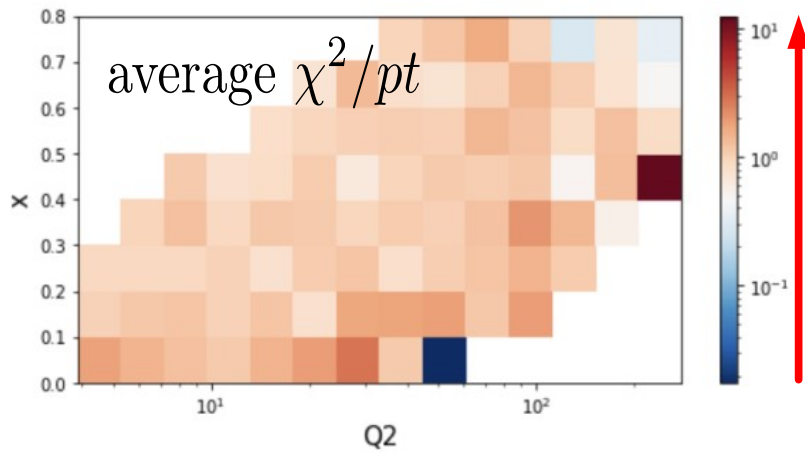
$(F_2^p/F_2^D)_{CJ15}$ taken from (Accardi *et al*
Phys. Rev. D 93 11 (2016) 114017)

DimuNeu

- Data : Dimu CCFR & NuTeV + NuTeV + CDHSW+ Chorus
- Number of data : 4063 pts
- Proper treatment of normalization uncertainty
- CORRELATIONS from NuTeV and Chorus are taken into account!

VS

DimuNeu Fit



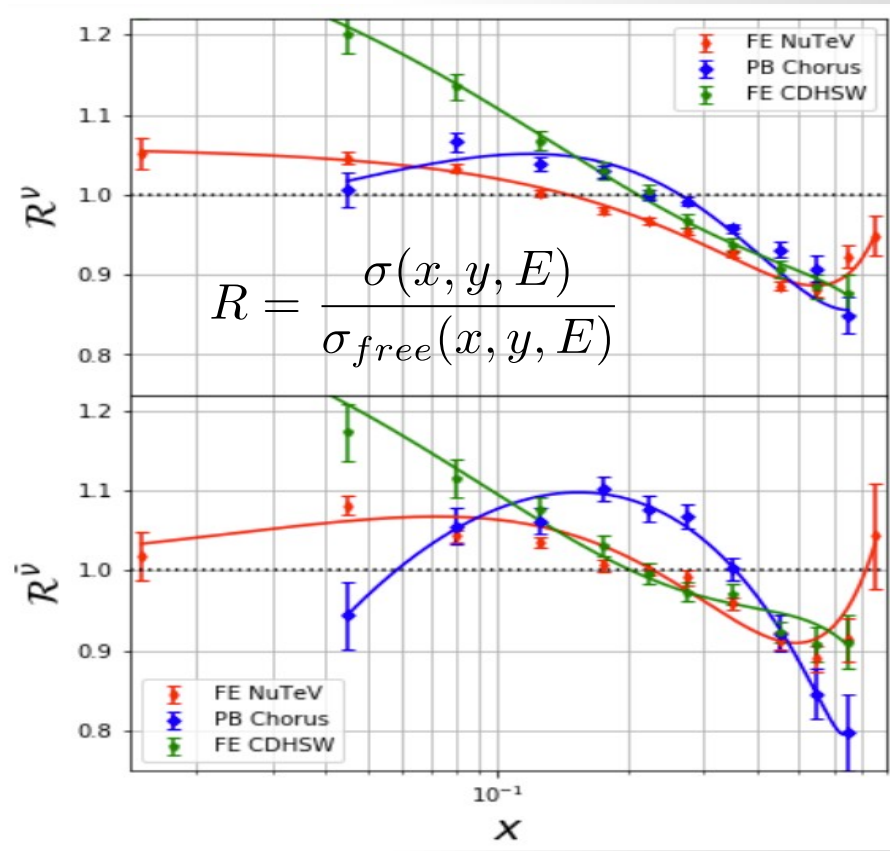
Higher x
better χ^2/pt

x	NuTeV	Chorus	CDHSW	All
0.015	2.51	-	3.85	2.56
0.045	1.37	1.90	1.35	1.44
0.08	1.72	1.24	0.87	1.49
0.125	1.83	1.15	0.48	1.41
0.175	1.30	1.10	0.50	1.07
0.225	1.19	0.90	0.68	1.04
0.275	1.20	1.26	0.73	1.00
0.35	1.40	1.18	0.59	1.16
0.45	1.17	1.23	0.67	1.03
0.55	1.29	1.44	0.61	1.08
0.65	1.04	1.16	0.61	1.02
0.75	1.01	-	-	1.01

- χ^2/pt :
 Dimuon : 1.27
 NuTeV : [1.50, 1.23]
 Chorus : [1.27, 1.09]
 CDHSW : [0.60, 0.72]
 ALL : 1.17

- Higher x --> better agreement.
- TENSION between neutrino data sets at low x !

Weighted Average



Statistical Tests

BASE (S) vs Neutrino (\bar{S})

\bar{S}	$\Delta\chi_S^2$	P -value	Compatible?
CDHSW	49	(6.6e-02, 9.4e-08)	NO
Chorus	6	(0.4199, 0.0568)	YES
NuTeV	58	(0.038, 0.258)	NO
DimuNeu	79	(0.0086, 0.0069)	NO

Compatibility criteria : $\Delta\chi_S^2 \leq 35$ & $P \geq 0.01$

The **BaseChorus** fit seems to describe both the data quite well. But

x	BaseNuTeV	BaseChorus	BaseCDHSW	All
0.015	2.50	-	5.69	3.05
0.045	1.54	1.84	1.67	1.89
0.08	1.78	1.72	0.72	1.55
0.125	1.82	1.07	0.40	1.43
0.175	1.29	1.11	0.47	1.11
0.225	1.20	1.10	0.63	1.04
0.275	1.19	0.84	0.70	0.97
0.35	1.33	1.26	0.51	1.15
0.45	1.19	1.08	0.62	1.01
0.55	1.29	1.14	0.57	1.07
0.65	0.99	1.16	0.58	1.02
0.75	1.01	-	-	1.05

Poor agreement at low x !

- Low x neutrino data disagree with each other and with the **BASE**.
- Incomplete theory?
- What if we cut low x data?

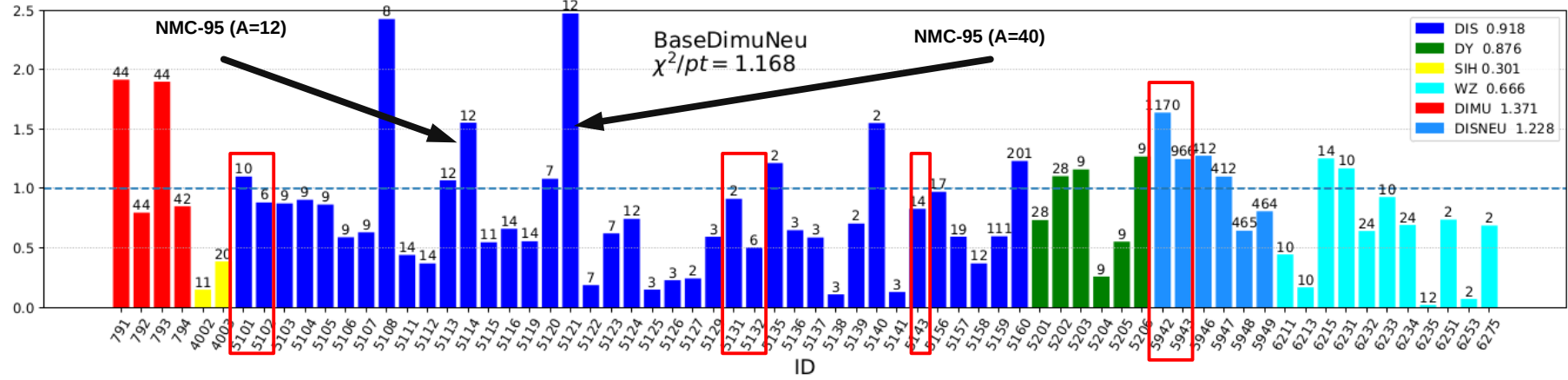
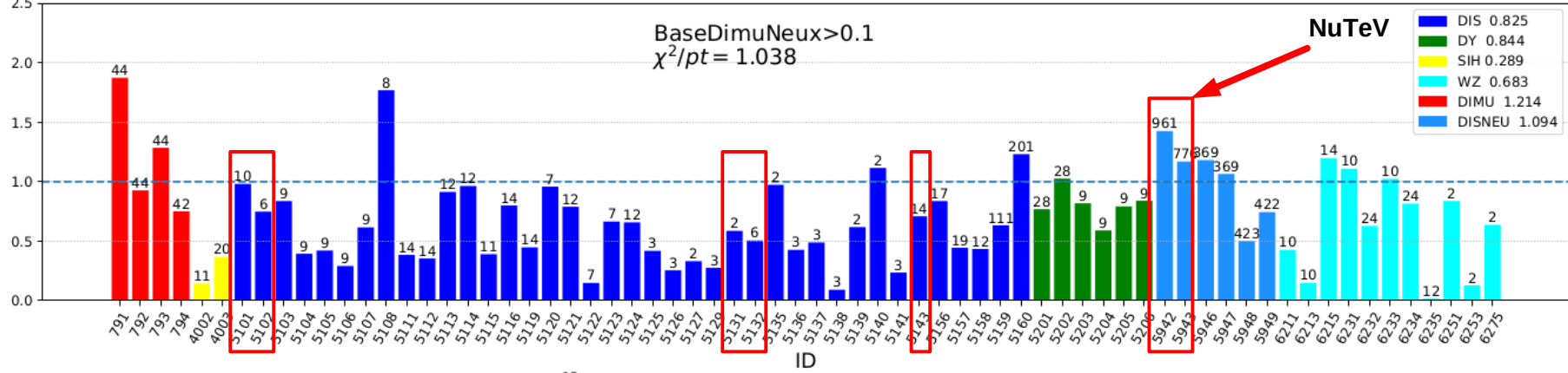
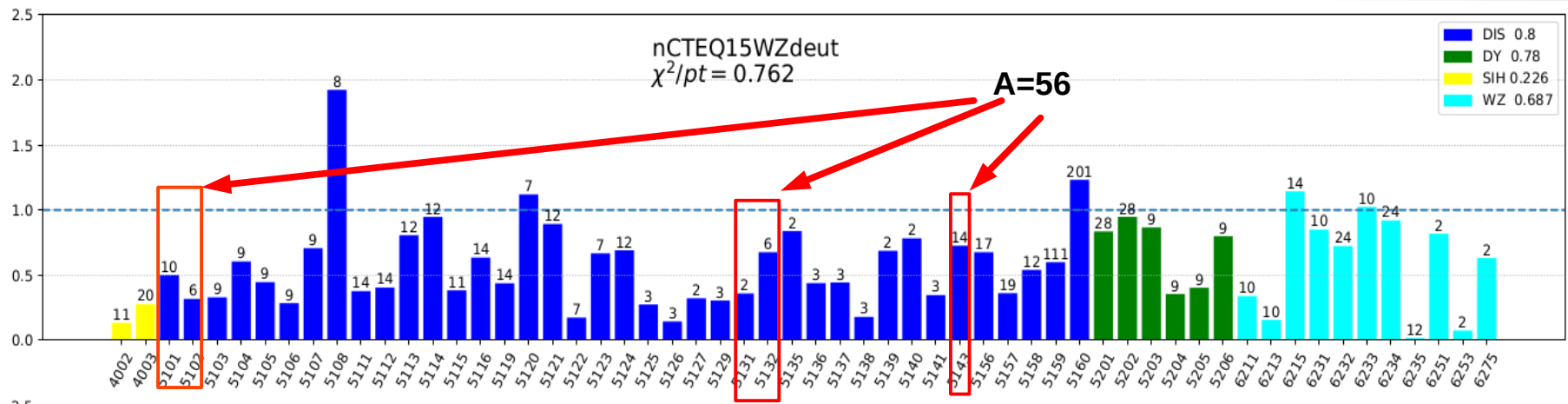
NuTeV : minimal tension at $x \geq 0.175$

Neutrino Data with $x \leq 0.1$ Cut

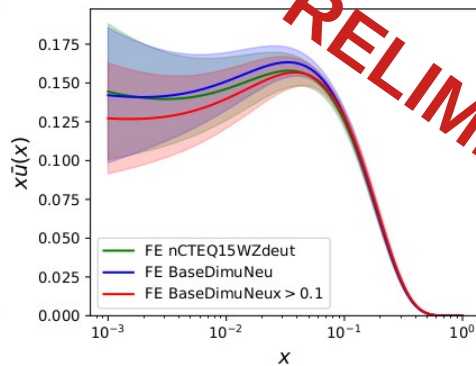
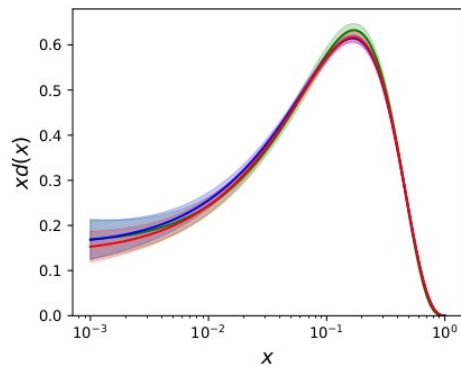
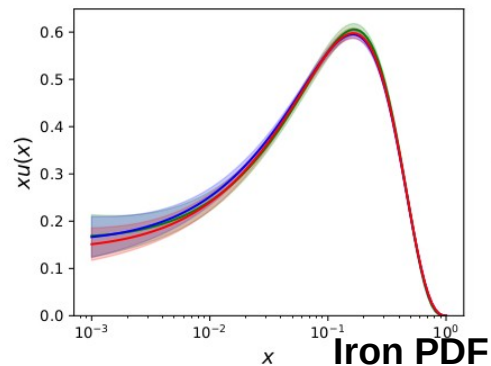
\bar{S}	$\Delta\chi^2_{\bar{S}}$	P -value	Compatible?
CDHSW	19	(0.2737, 0.0376)	YES
Chorus	5	(0.4320, 0.2084)	YES
NuTeV	29	(0.1826, 0.2499)	YES
DimuNeu	23	(0.2346, 0.3522)	YES

The tensions are now gone!

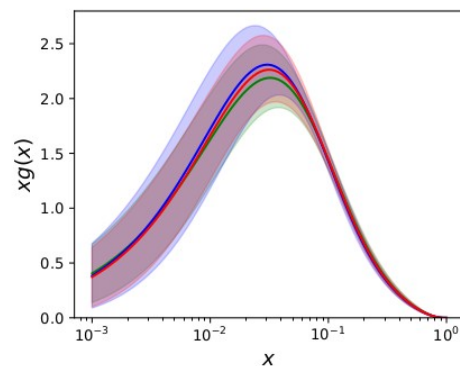
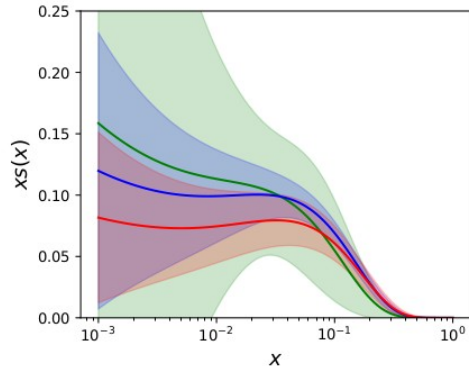
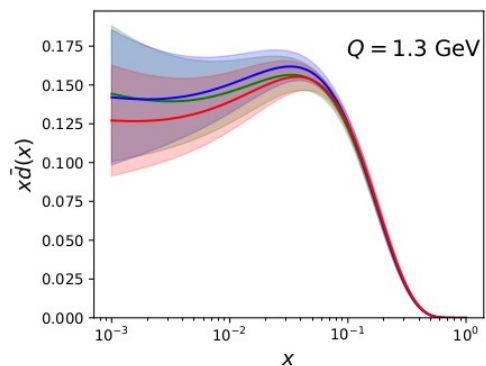
The Combined Fit : BaseDimuNeu vs BaseDimuNeu>0.1



Impact on nPDFs



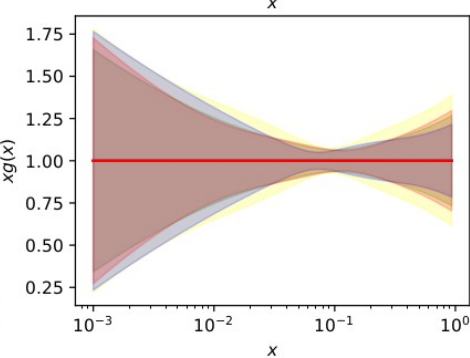
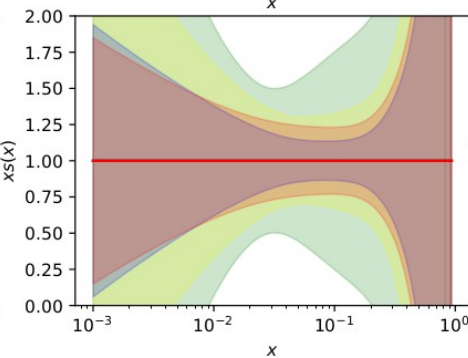
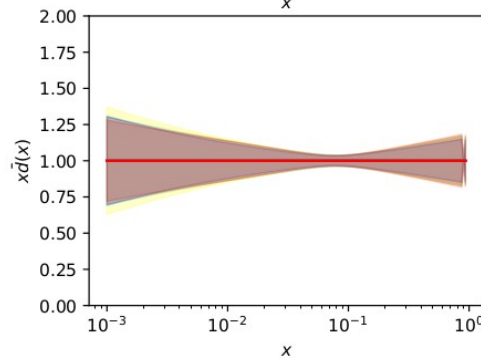
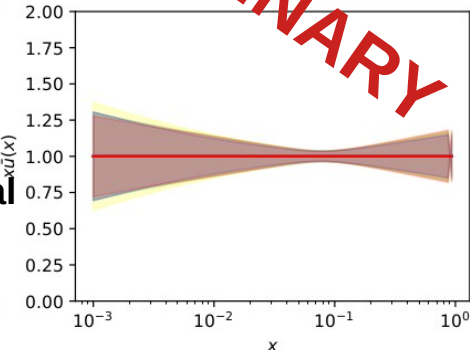
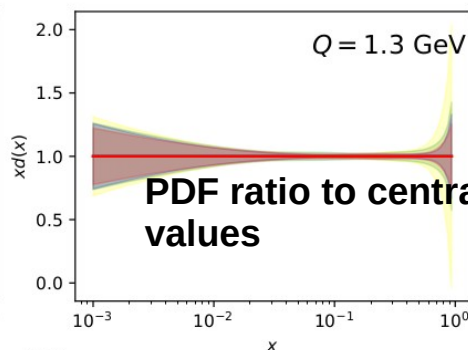
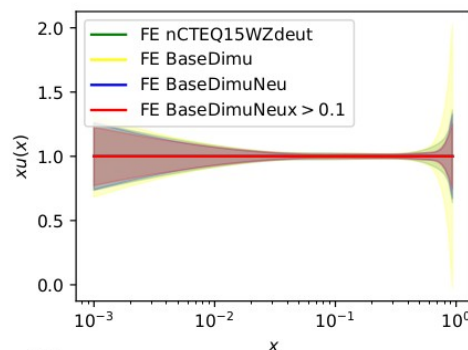
PRELIMINARY



PRELIMINARY

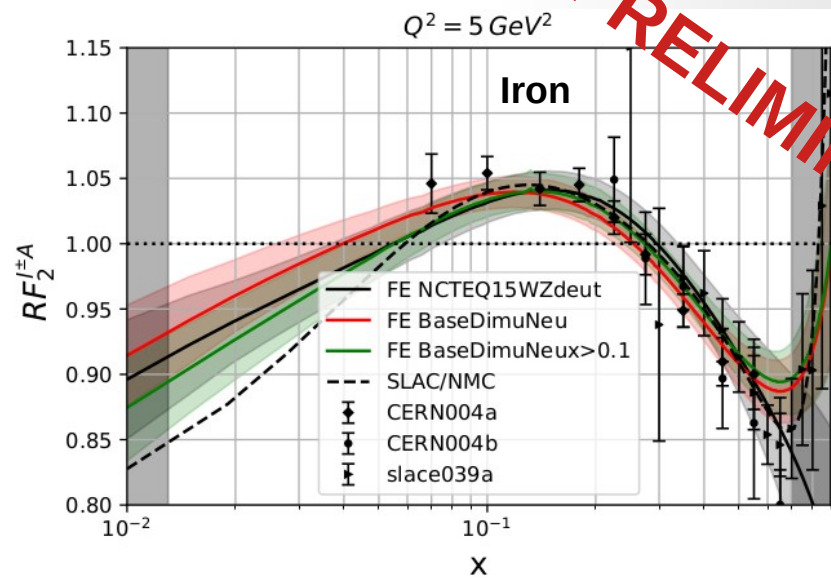
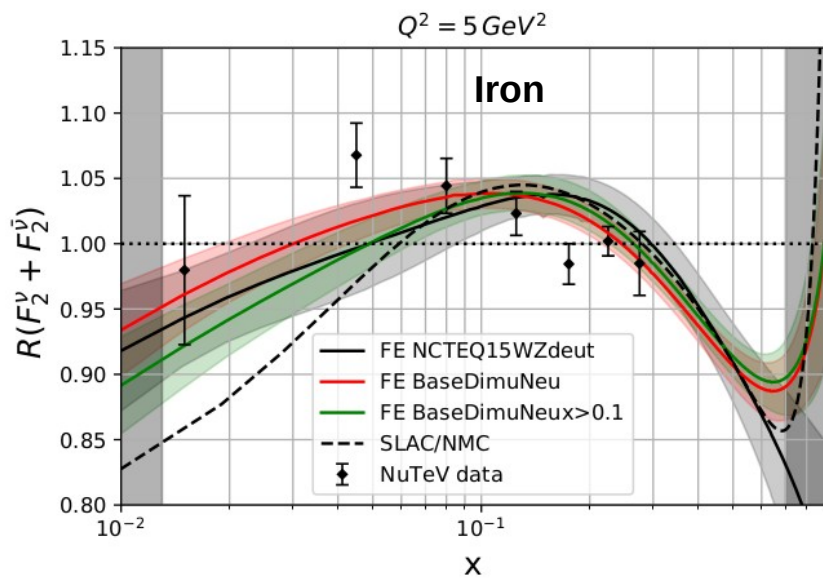
- Including low x neutrino data pulls the strange PDF up.

- Smaller uncertainties as we add more neutrino data.

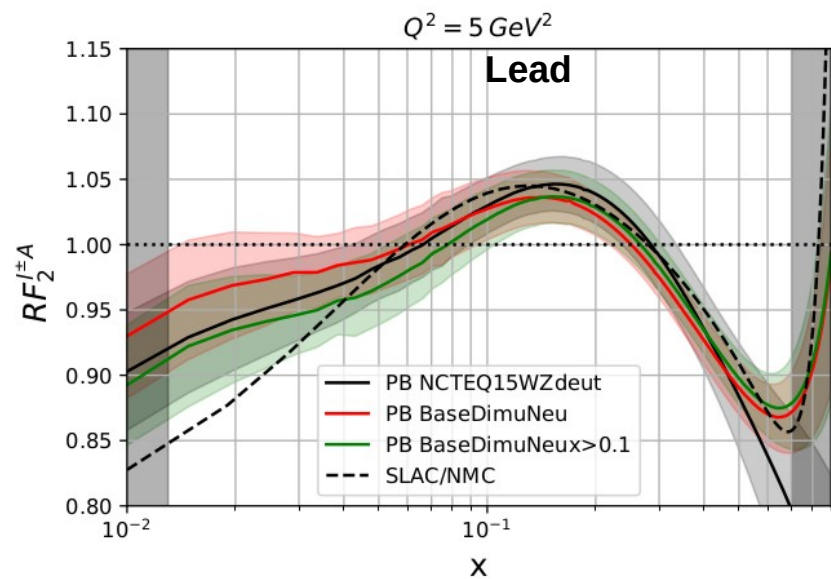
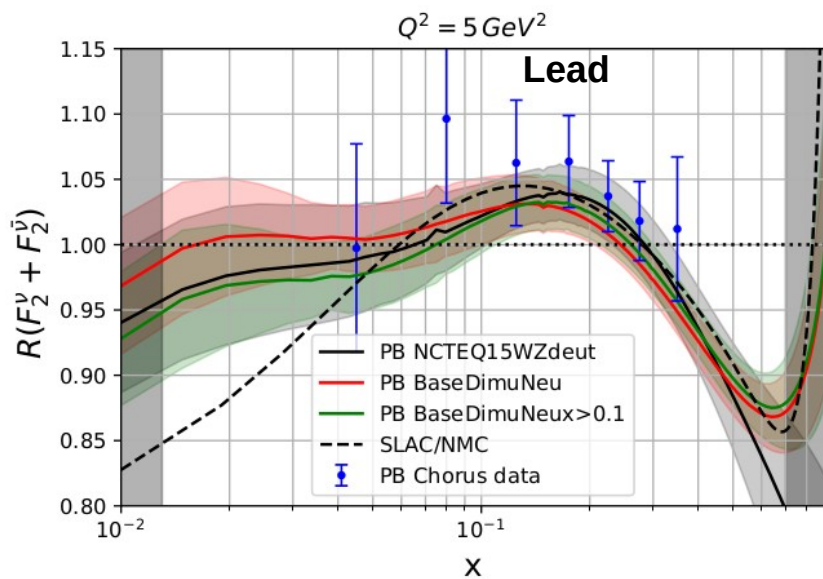


PRELIMINARY

RF2 Predictions



PRELIMINARY



Summary

- **Tension at low x ($x \leq 0.1$) among neutrino data sets.**
- **Tension at low x ($x \leq 0.1$) between individual neutrino data sets and the Base.**
- **Low x cut \longrightarrow agreement with the Base.**
- **Still need to understand why tensions occurs at low x .**

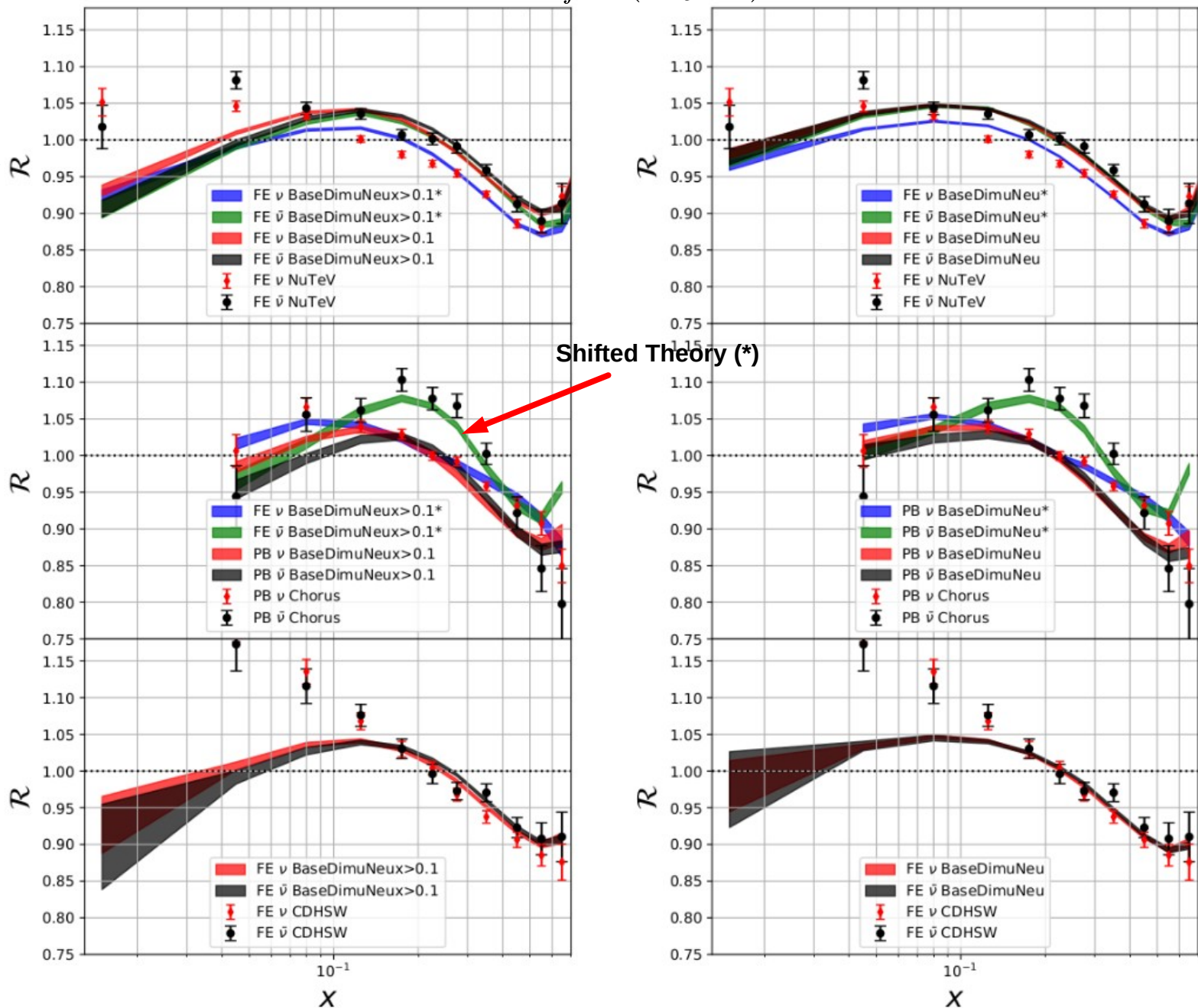
Thank you

Data – Theory Comparison

$$R = \frac{\sigma(x, y, E)}{\sigma_{free}(x, y, E)}$$

Weighted average over E and y

$$w_i = \left(\sum_j \frac{1}{(\Delta R_j)^2} \right)^{-1} \frac{1}{(\Delta R_i)^2}$$



Milder shadowing if low x neutrino data is included.