Comparison of GiBUU calculations with MiniBooNE pion production data

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GiBUU
The Giessen Boltzmann-Uehling-Uhlenbeck Project

GiBUU model

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GiBUU

The Giessen Boltzmann-Uehling-Uhlenbeck Project

– the semiclassical transport model in couple channels –
simulates the transport of hadrons through nuclear matter
in space and time

GiBUU describes several reactions in resonance and high energy regions,

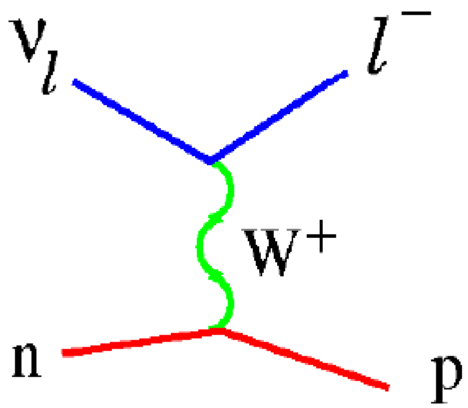
is extensively checked against experimental data for πA, γA, $e^- A$, νA

Aim: many reactions with one microscopic model

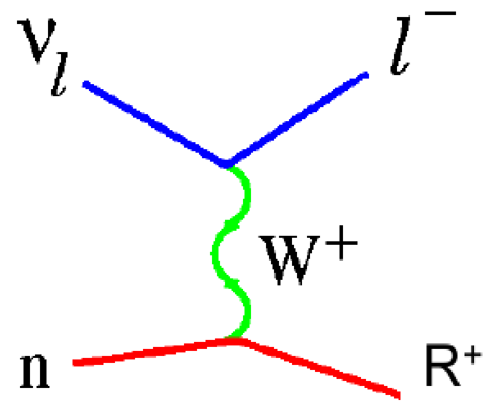
Open source code: http:/gibuu.physik.uni-giessen.de/GuBUU

Primary interactions

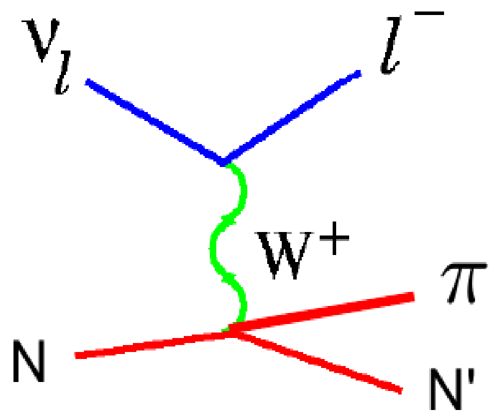
QE



RES

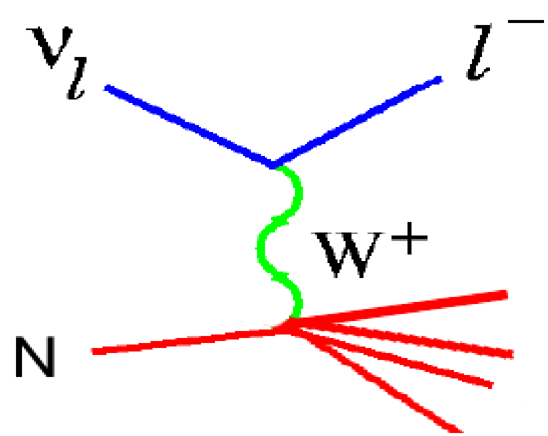


single-π BG



El-m couplings are known for 13 or 19 PDG 3* and 4*

DIS



Input:

parametrization of the elementary xsec

Input: Resonances

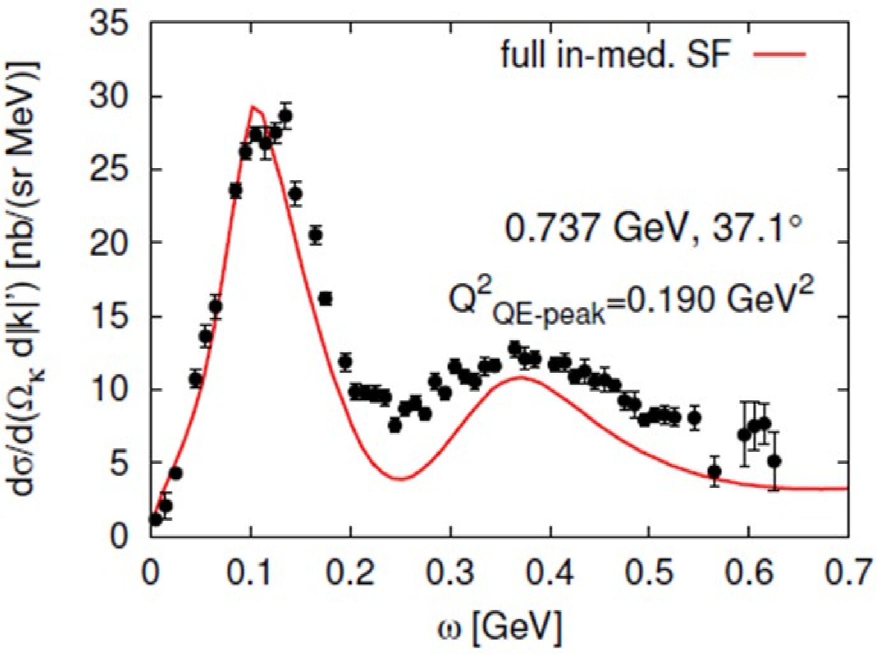
Vector form factors:

- related to el-m for factors, those to helicity amplitudes
- helicity amplitudes are from MAID parameterization

(MAID, Drechsel EPJA 34: Mainz state-of-the art unitary isobar model for pion photo- and electroproduction on the nucleon; based on >70000 data points; it provides the resonance helicity amplitudes, from which el-m transition form factors are derived;)

Inclusive electron scattering on carbon

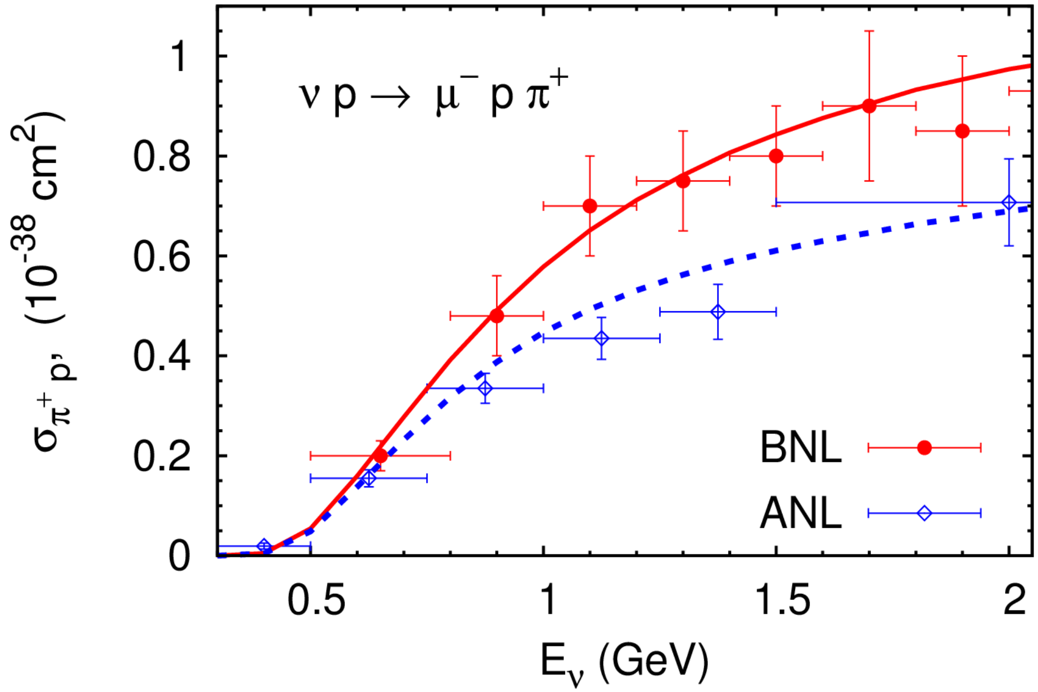
Discreapancy is probably due to many-body:
50% in the dip region
10% at Delta peak



Input: Resonances

Axial form factors

- dipole ansatz (modified dipole for Delta), related via PCAC
- using neutrino data when possible
- Delta fitted to $p\pi^+$ data (ANL or BNL)



Graczyk et al PRD80, Hernandez et al PRD81 : ANL and BNL are compatable within errors and flux uncertainties. Joint fit of the data.

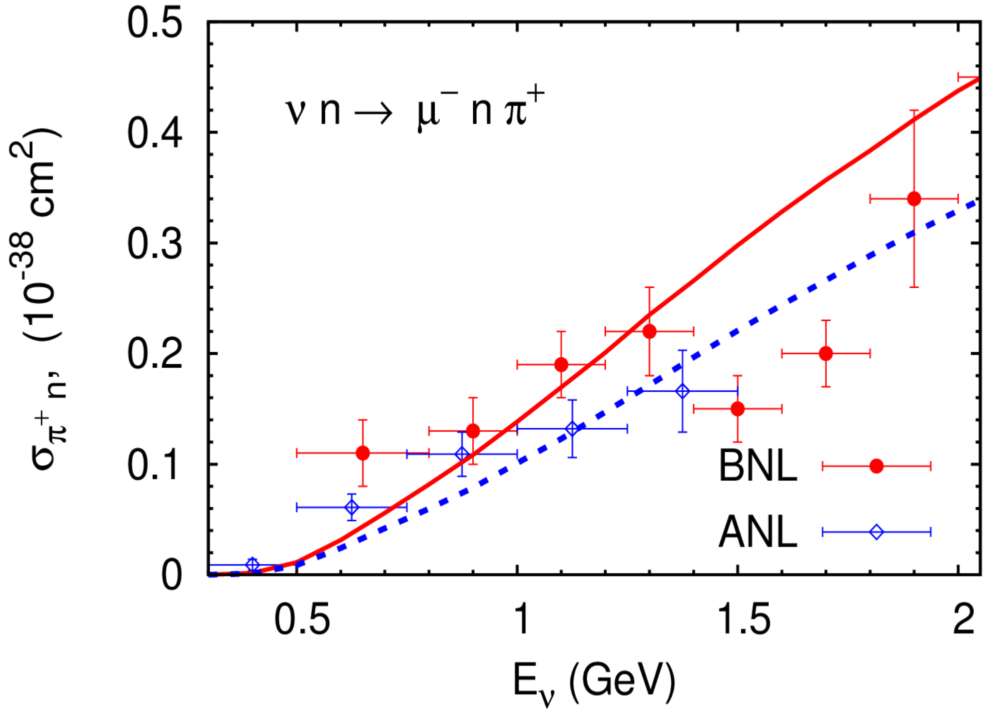
GiBUU: consider **ANL as lower bound** and **BNL as upper bound**

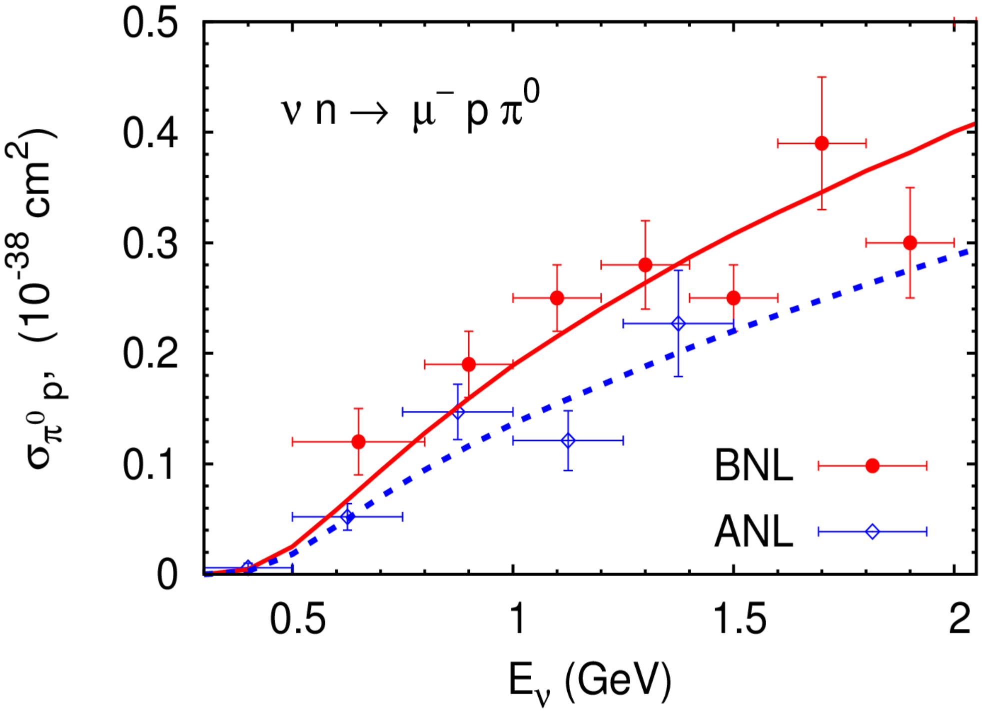
Input: 1-pion background

Phenomenological ansatz

Vector part fitted to MAID results

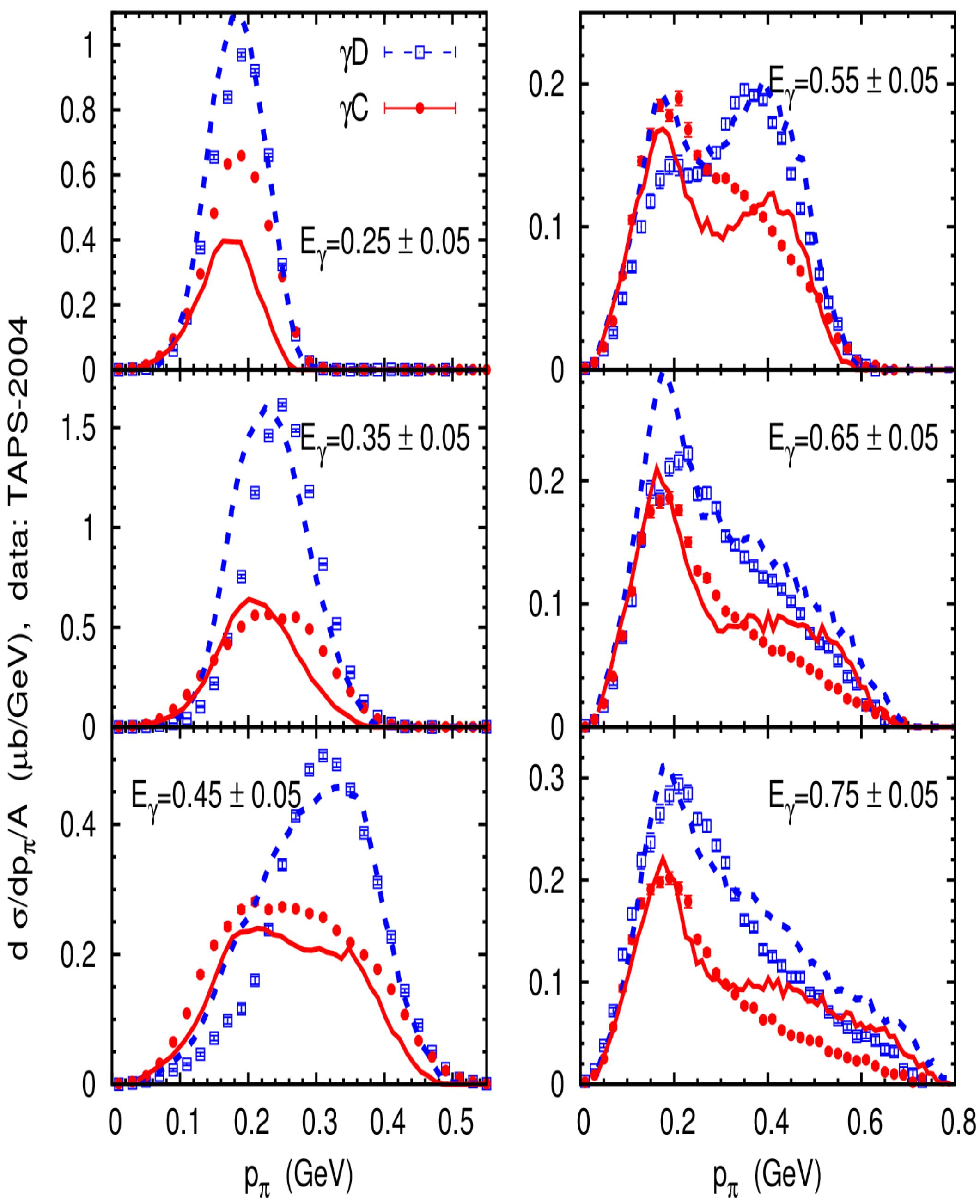
Nonvector part = “axial + vector-axial interferece” is supposed to have the same functional form and then fitted to ANL/BNL data





1-pion bgr + higher RES +DIS

Influence of FSI



Photoproduction of neutral pions

Krusche et al EPJA22 (2004)

rechecked with the current version of GiBUU

Competing processes for Delta:

$\Delta N \to NN$, $\Delta NN \to NNN$

$\Delta \to \pi N$

Competing processes for pion:

$\pi N \to$ R, ωN, ϕN, ΣK, ΛK

$\pi^0 n \leftrightarrow \pi^- p$, $\pi^0 p \leftrightarrow \pi^+ n$

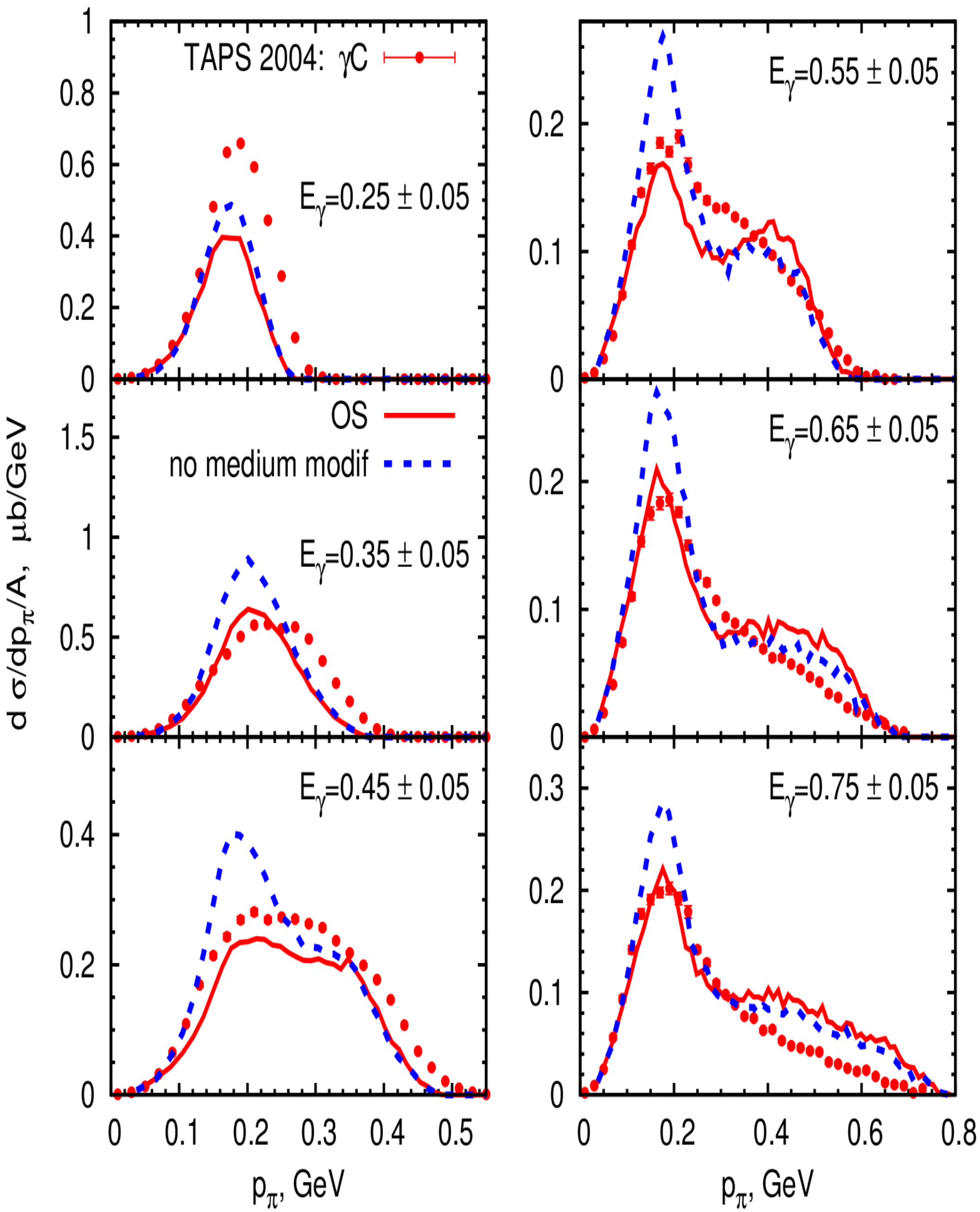
Influence of medium modification

Delta is collison broadened according to Oset-Salsedo (OS) model and thus contains some many-body effects

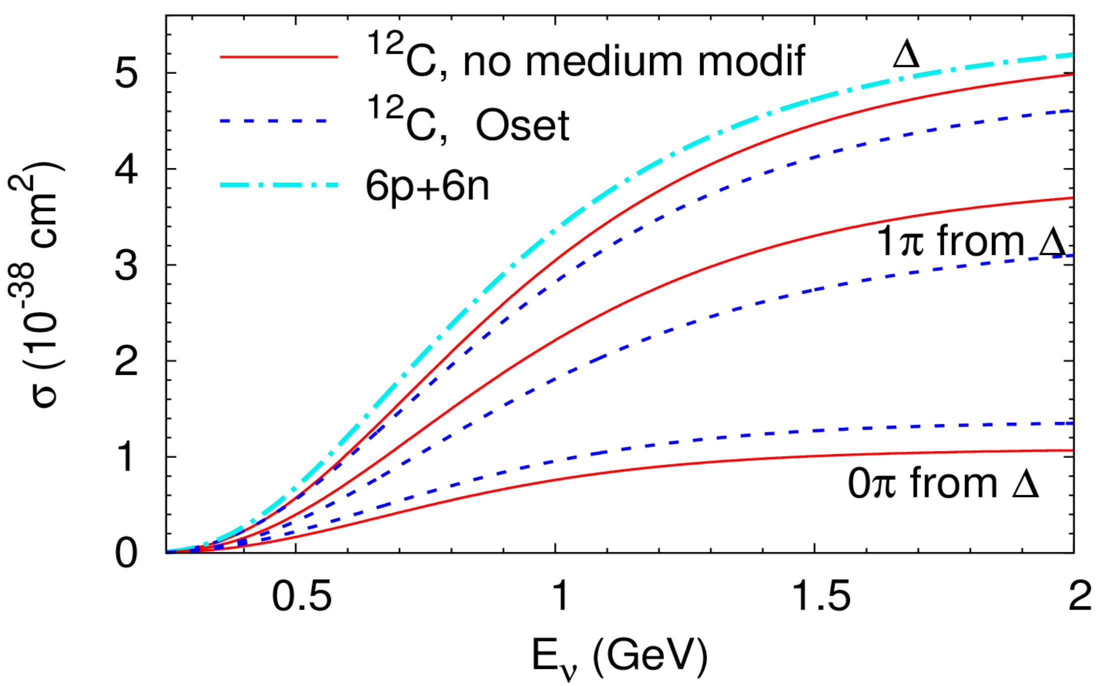
Broadening of the Delta bring the curves down to the data

Exponential time-development of Delta disappearence

$$\frac{dN}{dt} = e^{-\Gamma_{free} t - \Gamma_{collisional} t}$$



Medium modif. for neutrino reactions:



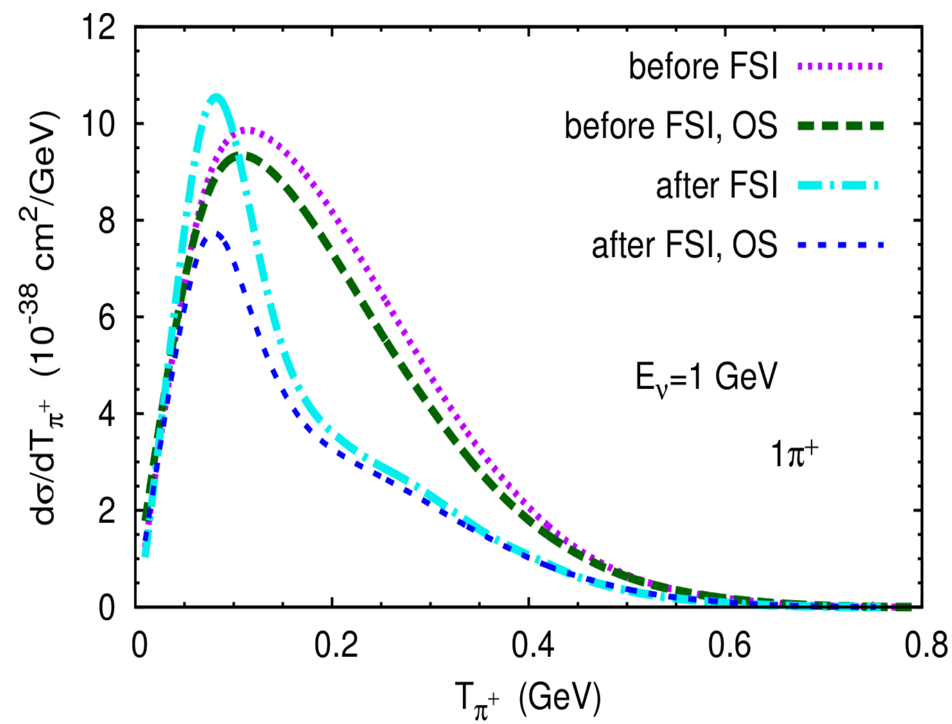
Oset/Salsedo modification:

Delta production – 5-8%

1-pion production -15-20%

0-pion production +20%

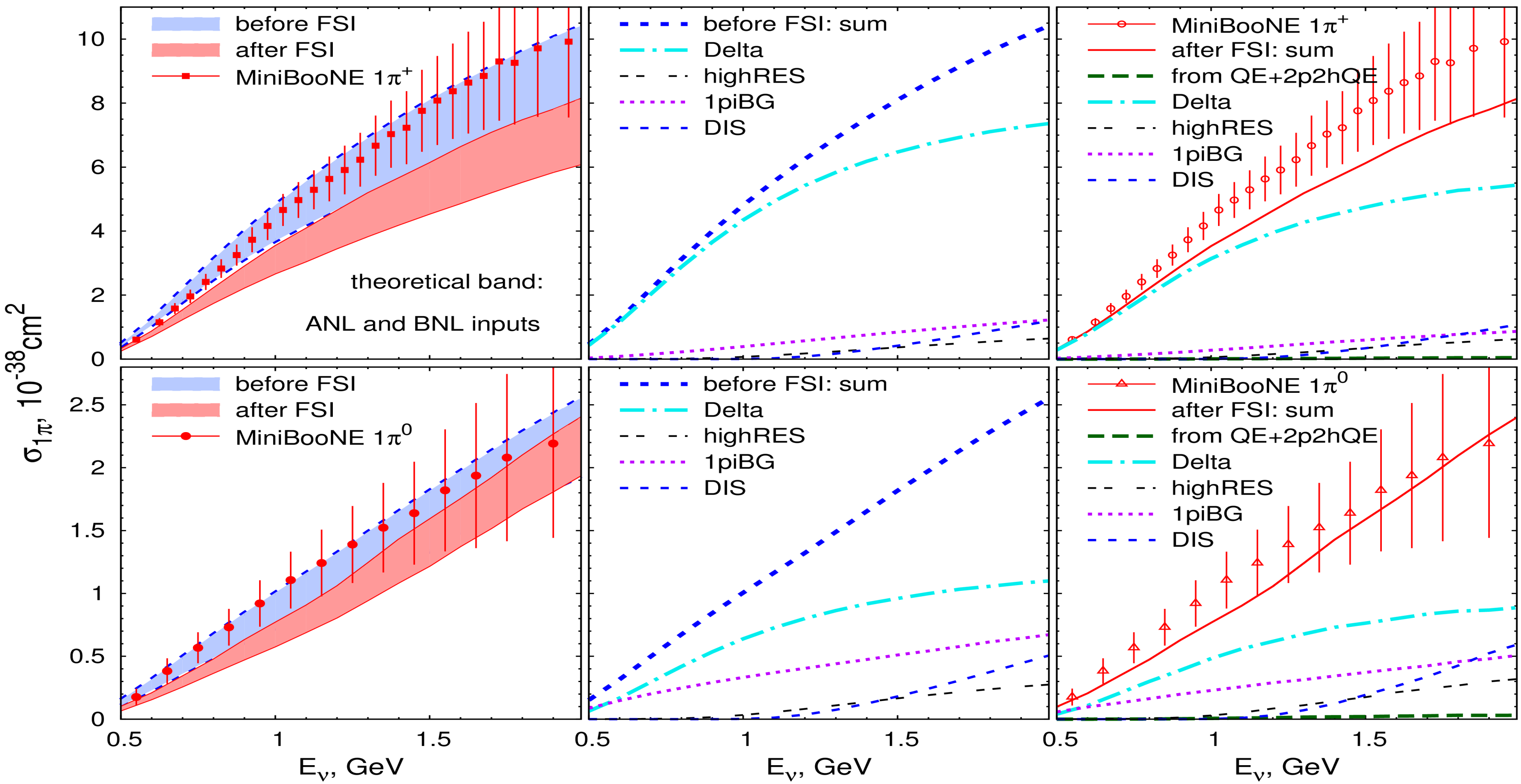
due to increased $\Delta N \rightarrow NN$



All further results are with Oset modification of the Delta

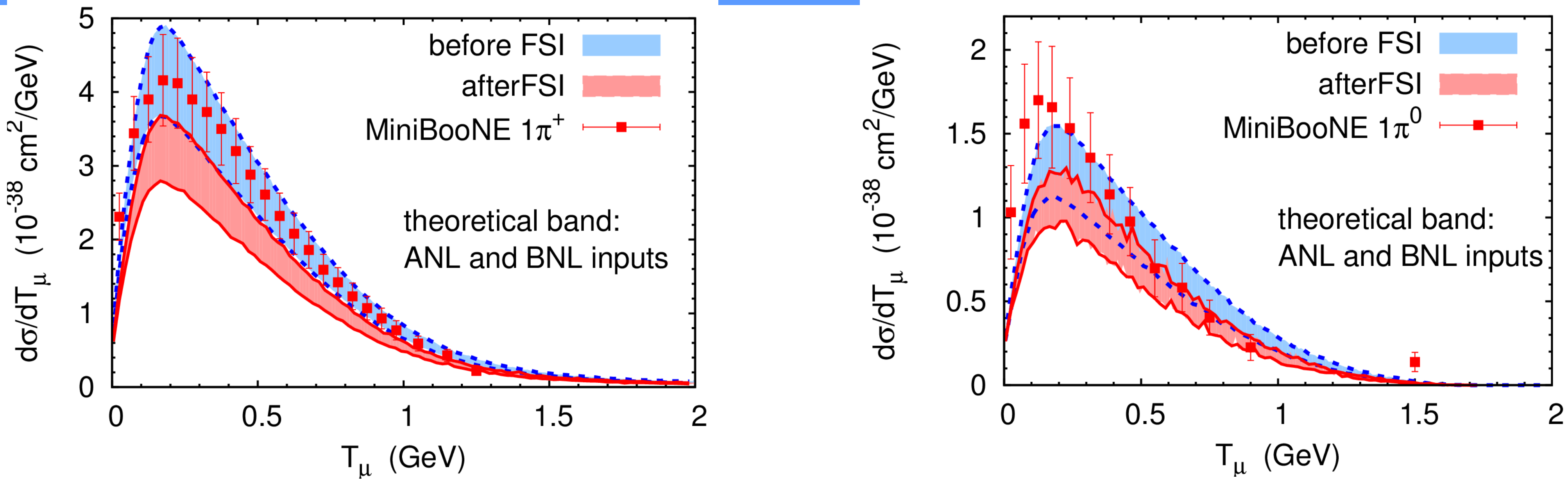
MiniBooNE: origin of 1-pion events

- Delta production and decay
- 1-pion background events



- QE events; outgoing proton rescattered $N\,N \to N\,\Delta \to N\,N\,\pi$
- charge exchange pion rescattering $\pi^+ n \to \pi^0 \; p$

Muon kinetic energy and angle



The shape of the distributions is hardly sensitive to the FSI

The only effect of FSI on muon observables:

- remove events in which the initially produced pion (or Delta) was later on reabsorbed
- bring in events in which the pion was produced only during FSI

! Compare to previously reported results !

Experiment

Charged pion data were averaged over the whole neutrino flux

Neutral pion data were averaged over the flux from 0.5 to 2 GeV
(which constitutes 68% of the whole flux)
(which brings in some model dependence via energy reconstruction)

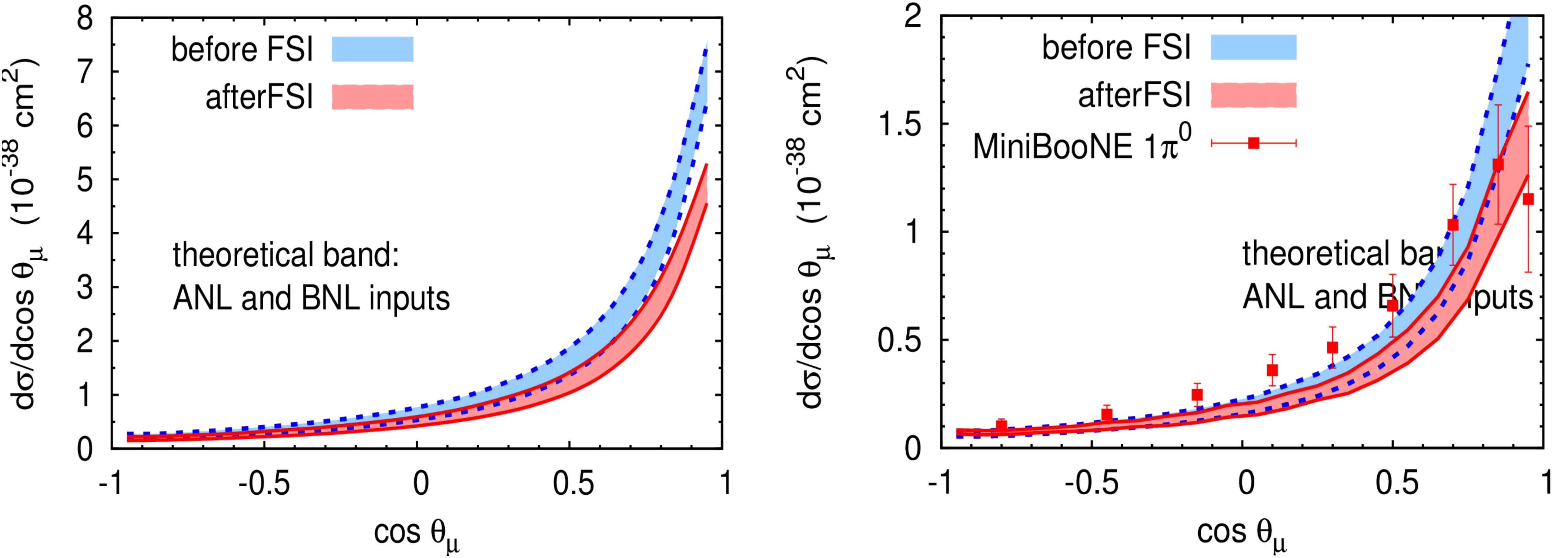
Theory

All our previously published/reported results for neutral pions were averaged over the whole flux, therefore they are too low.

In the present talk all results are normalized as in experiment

Many thanks to Sam Zeller and Robert Nelson for helpful communication

Muon angle distributions



Experimental point at 0.9-1 is lower than the previous one

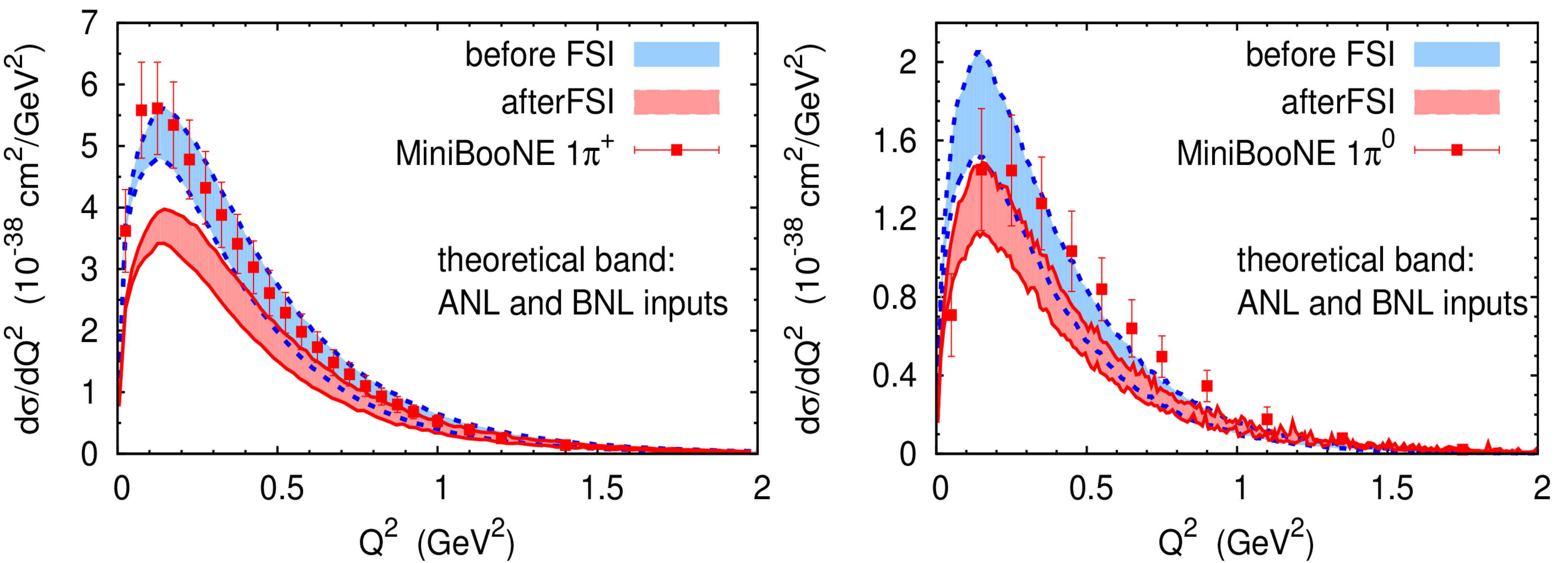
Physical effect?

The range cos θ = 0.9 - 1 corresponds to $\theta = 0^\circ - 25.8^\circ$

Finer binning is needed

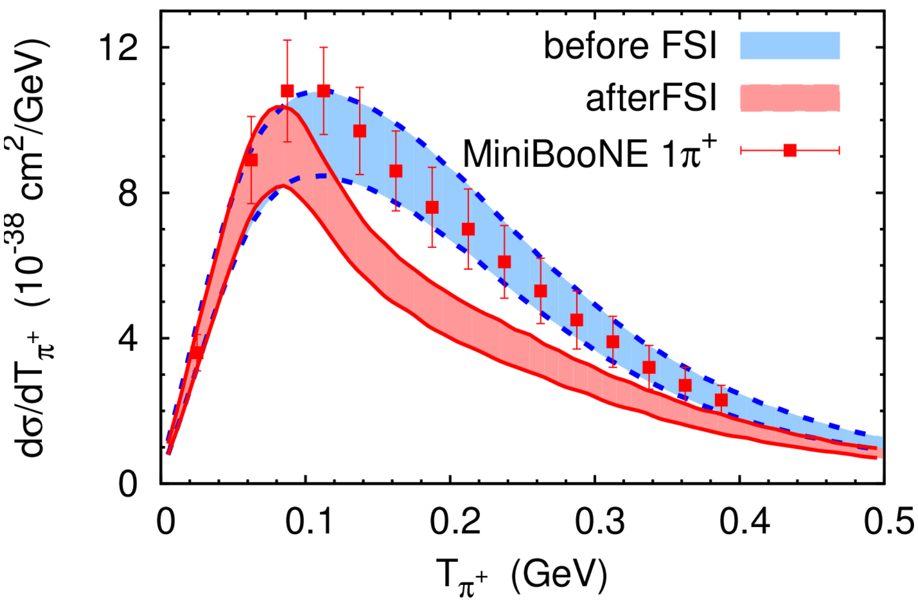
Compare cos θ = 0 - 0.1 corresponds to $\theta = 84.3^\circ - 90^\circ$

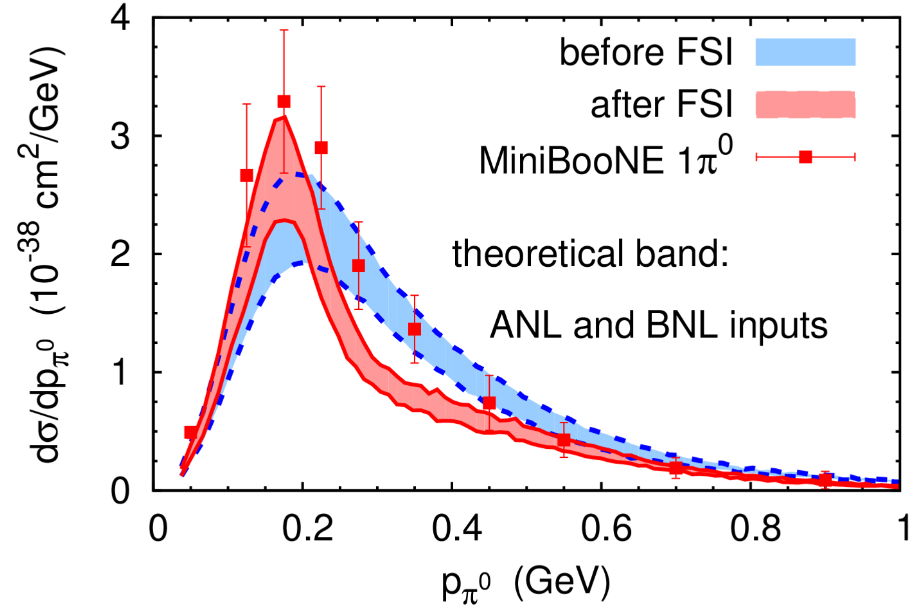
Q^2 distributions



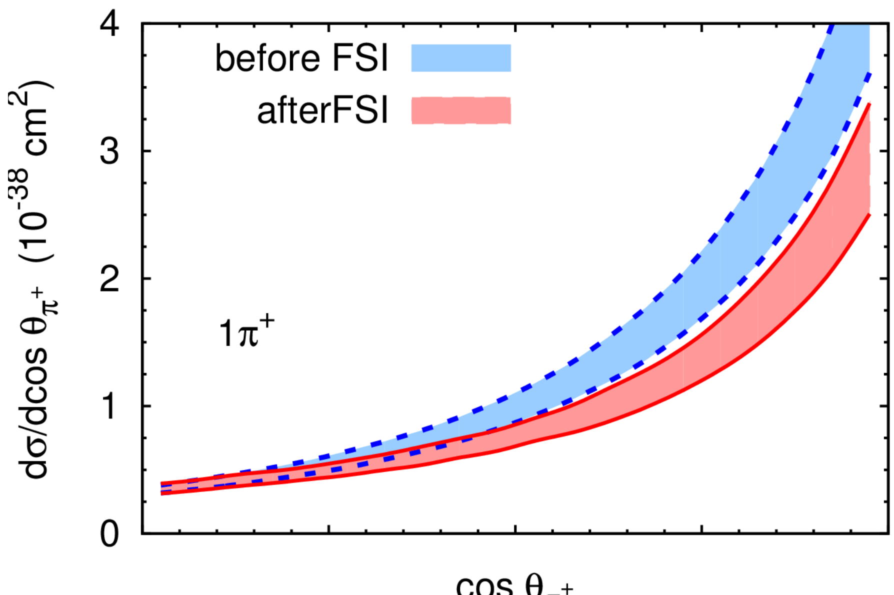
Q^2 has to be reconstructed! Dependence on energy reconstruction

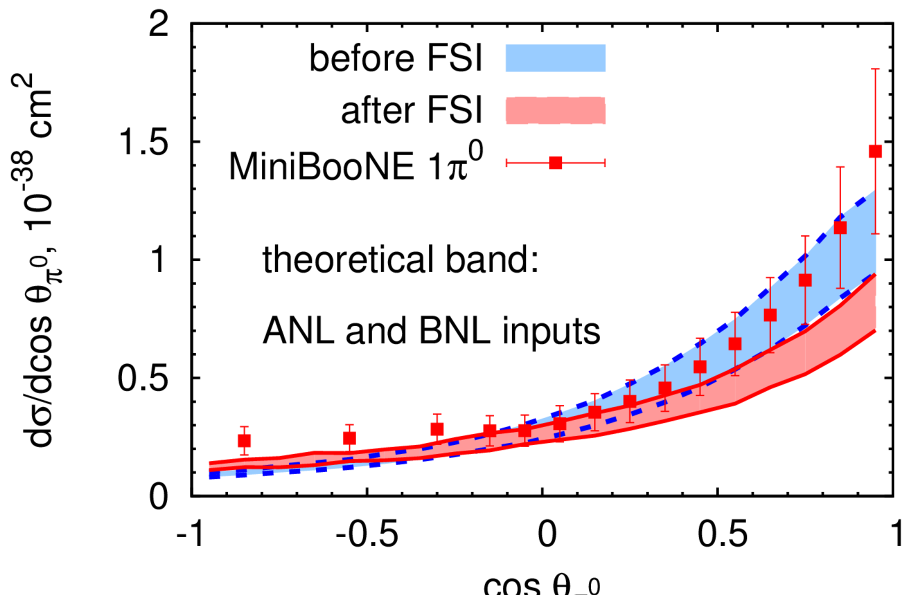
Pion distributions



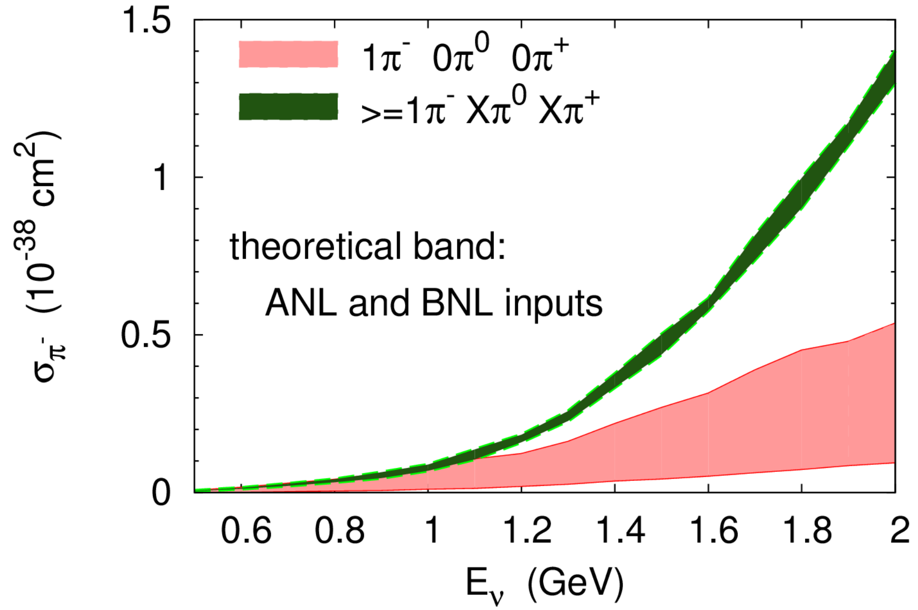


FSI clearly change the shape of the distribution (similar to el-m)





Predictions for π^-

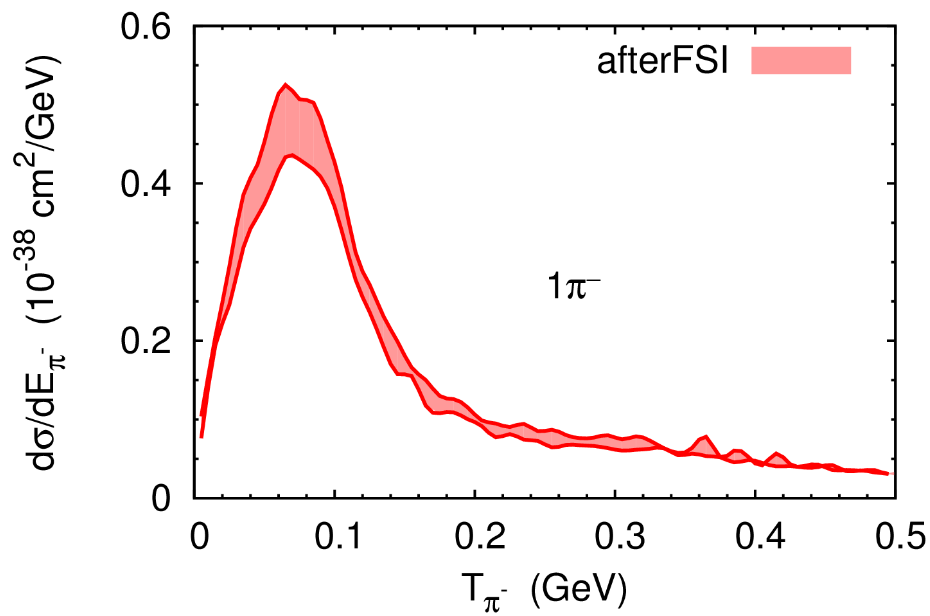


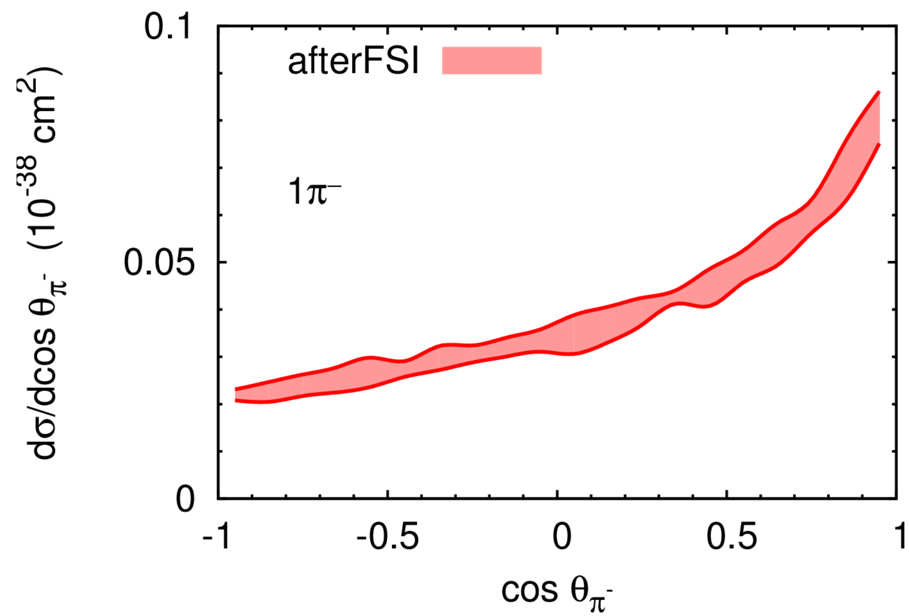
Created nearly only during FSI

Good test for pion dynamics

Significantly less forward peaked than $1\pi^+$ and $1\pi^0$

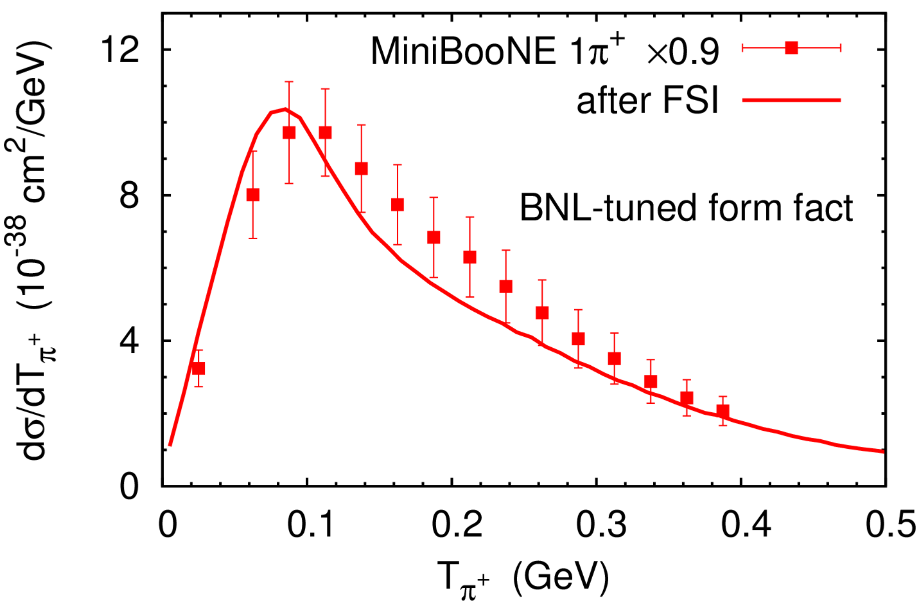
20 times lower than $1\pi^+$ but should be visible in MiniBooNE

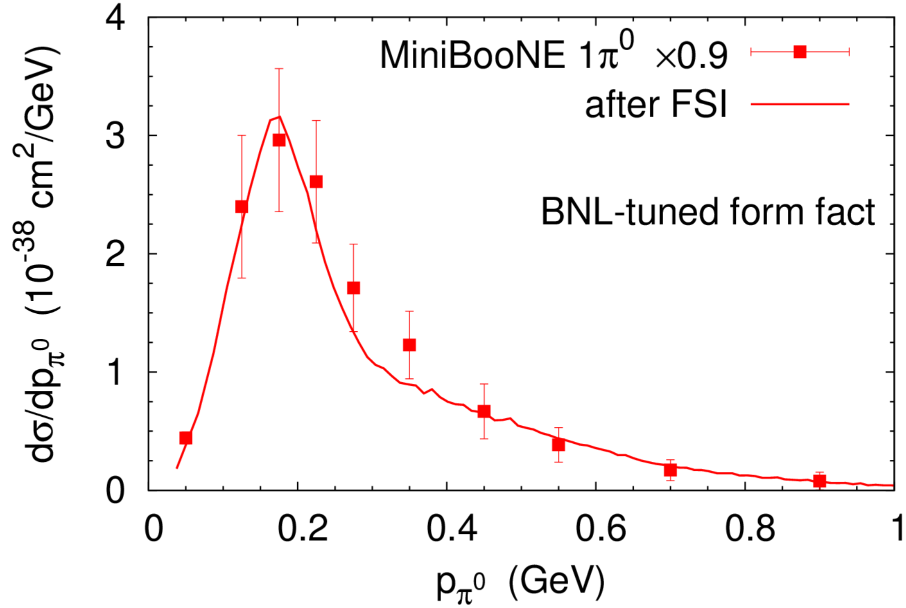




Theory/data discrepancy?

Using 10% flux uncertainty





Many-body mechanism for pion production?

For QE-like scattering $\nu NN \to \mu NN$ relevant above dip region

Similarly $\nu NN \to \mu N\Delta$ should be relevant 300 MeV higher.

A theoretical challenge to separate them from successive scattering in a transport description

Conclusions

- All processes (QE, Delta, highRES, 1-pi bgr, DIS) contribute
- Strong dependence of theoretical results on elementary xsec
- Dependence of theoretical results on medium Delta properties
- New measurements on elementary targets (H,D) needed
- If BNL data describe the elementary xsec correctly, many-body effects could amount to 10-20% at most
- If ANL data describe the elementary xsec correctly, many-body effects could amount up to 40%