Snowmass 2021 LoI: Neutrino-induced Shallow- and Deep-Inelastic Scattering

outline

1. Introduction
2. Inelastic processes
3. Quark-Hadron duality
4. DIS in the Nuclear Environment
5. Hadronization
6. Path forward: Theoretical challenges
7. Path forward: Experimental challenges
8. Path forward: Generator challenges
9. White paper plan

This LoI is largely motivated from the SIS workshop we organized in 2018.
https://nustec.fnal.gov/nuSDIS18/

Snowmass 2021 LoI:
Neutrino-induced Shallow- and Deep-Inelastic Scattering

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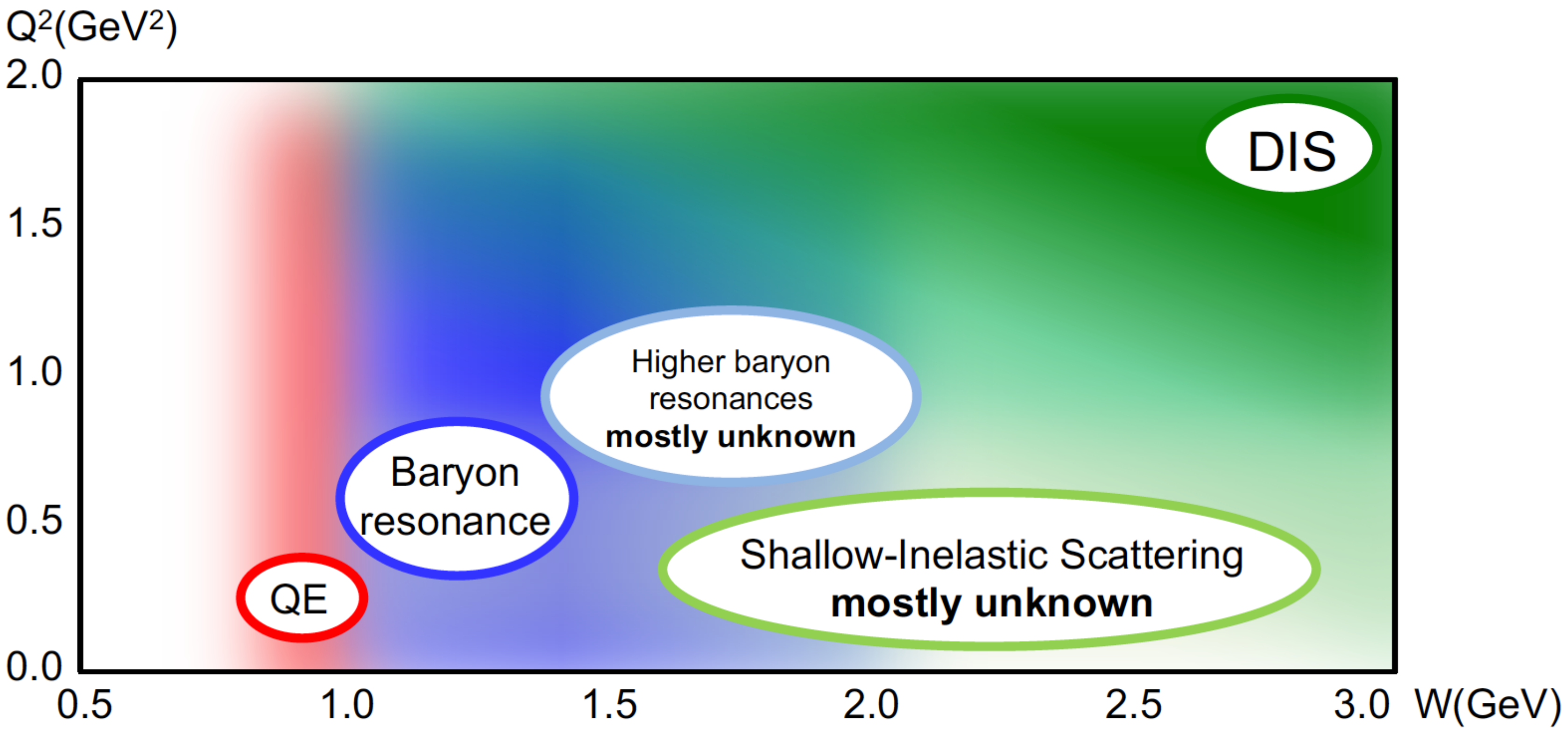
1. Introduction

Shallow-Inelastic Scattering region

- Q^2 is around less than 1 GeV^2, but W is above pion threshold.
- Baryon resonance, non-resonant meson production, and DIS meet there
- It is responsible to hadron productions, but poorly understood (and modeled)



1. Introduction

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Cross-section model
- Lepton kinematics
- Meson kinematics from baryon resonant models

Hadron production model
- Conservation laws
- Isotropic phase space decay (no model)

FSI model
- Complicated (rough surface to move)

Neutrino experimentalist
- Driving a car with beautiful front wheels, no back wheels, on a rough road.

Current and future experiments claim great exclusive measurements, but we are not ready to simulate exclusive channels.

1. Introduction

LoI was submitted to remind to the community about the situation of the SIS physics (Sec. 2, 3, 4, 5), and we listed few solutions (Sec. 6, 7, 8)

LoI has 8 sections with section leaders. The white paper plan is to form working groups in each section and combine outcomes. (TBA).

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6. Path forward: Theoretical challenges
7. Path forward: Experimental challenges
8. Path forward: Generator challenges

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2. Inelastic processes

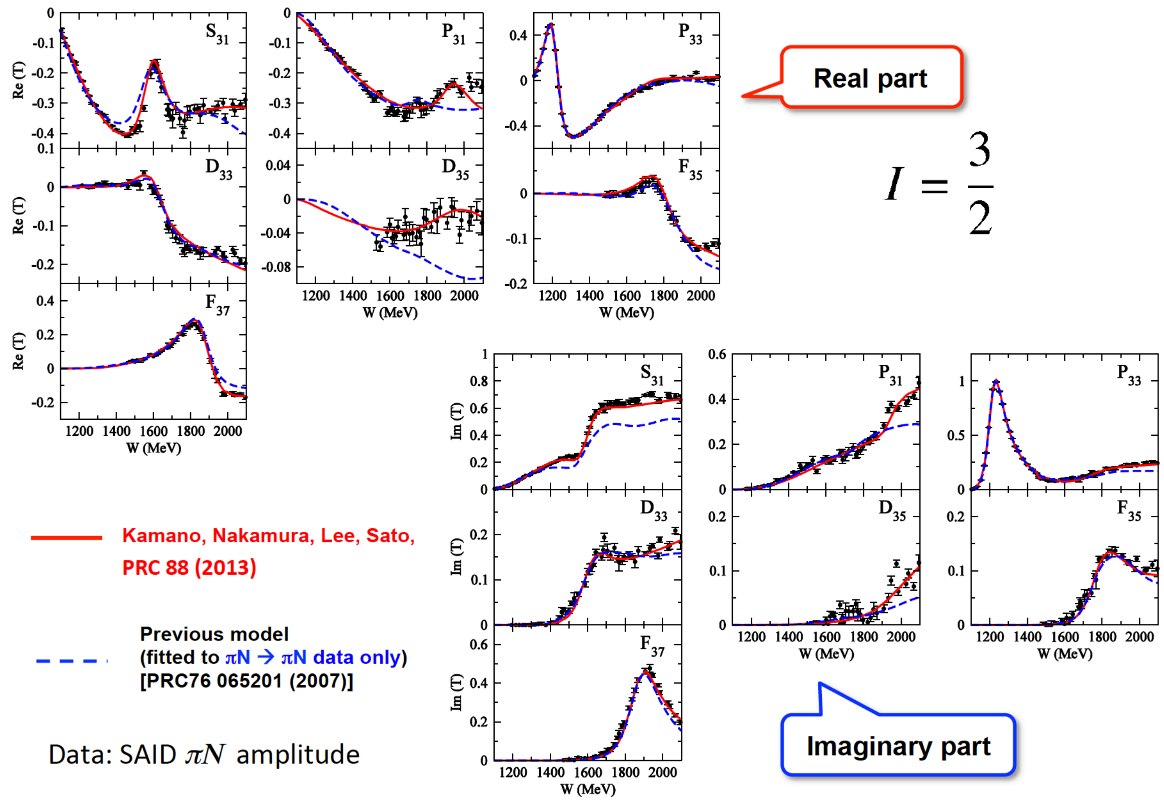
Baryonic meson productions
- Single meson production is already difficult
- Multi-baryon final states are harder
- Several models are proposed
  - Regge theory-based model
  - DCC model
  - GiBUU

Issues: Although eN and πN data provide a lot of inputs, axial form factors are largely unconstrained.

Solution:
- More neutrino data
- Neutrino H/D data
- Lattice QCD

Nakamura, nuS&DIS2018

Partial wave amplitudes of π N scattering



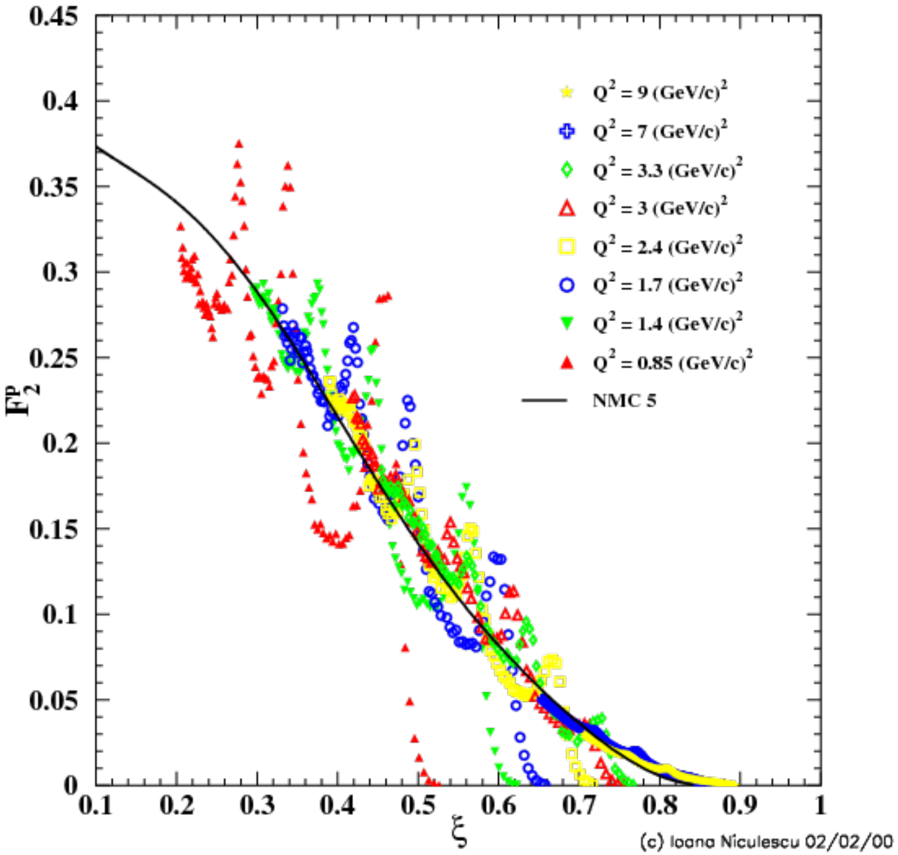
3. Quark-Hadron duality

Nachtmann variable

$$\xi = \frac{2x}{\left(1+\sqrt{1+\frac{4x^2M^2}{Q^2}}\right)}$$

Hadron scattering → quark scattering
- Bjorken scaling is highly violated
- Scaling law in ξ (Nachtmann variable)

Keppel, nuS&DIS2018



Issues: Very interesting topic, but no idea how to model in event-by-event simulation (Bodek-Yang correction)

Solution:
- More neutrino data
- Develop neutrino QH-duality theory
- invent a great model for generator

4. DIS in the Nuclear Environment

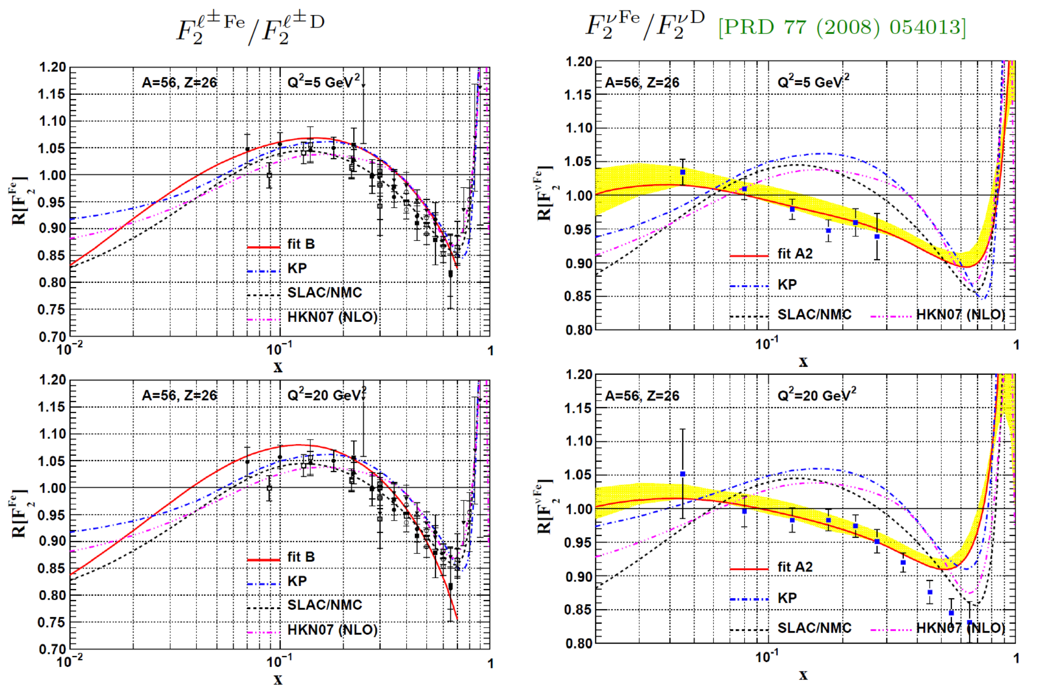
Nuclear-dependent PDF
- Correction for PDF
- Available for NLO

Kushina, nuS&DIS2018

Issues: nPDFs from charged lepton data cannot describe neutrino DIS data

Solution:
- More neutrino data
- Develop neutrino nPDF

nPDFs from charged-lepton DIS data [PRD 80 (2009) 094004]



5. Hadronization

Real Frankenstein model

- Definition of DIS is different in generators
- Very difficult to make continuous curves

Issues: We don't know even we are right or wrong

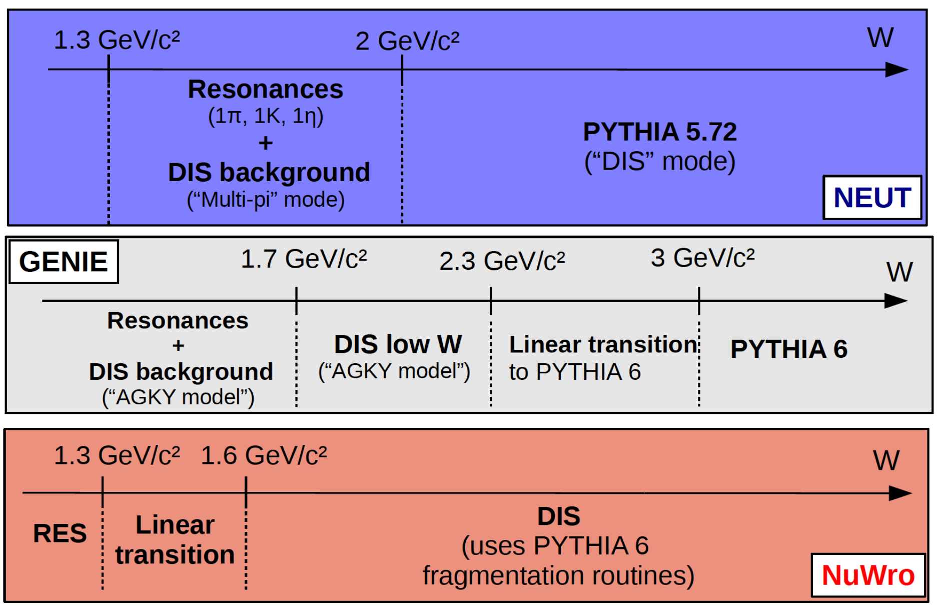
Solution:

- More neutrino data
- More electron exclusive data
- invent a great model for generator

Bronner, nuS&DIS2018

SIS/DIS region in the generators

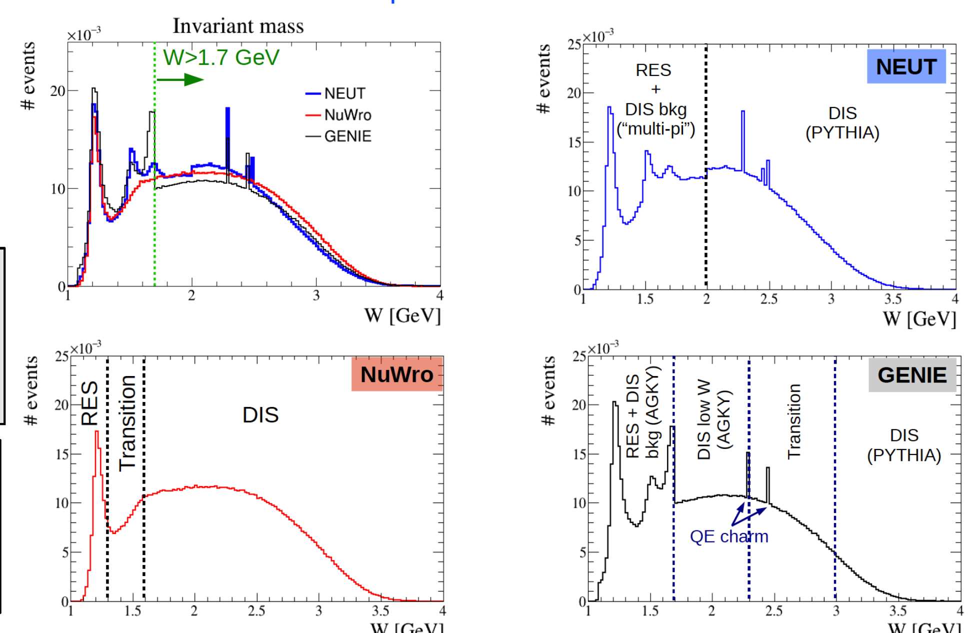
4



Invariant mass distribution

ν_μ on Fe, E_ν=6.0 GeV

5



6. Path forward: Theoretical challenges

Theoretical challenges

- Use all data (electron, neutrino, nucleon and nucleus targets) to improve various models
- Theoretical error estimation
- Lattice QCD input
- Neutrino QH-duality model
- Neutrino nPDF

7. Path forward: Experimental challenges

Theoretical challenges

- Use all data (electron, neutrino, nucleon and nucleus targets) to improve various models
- Theoretical error estimation
- Lattice QCD input
- Neutrino QH-duality model
- Neutrino nPDF

Experimental challenges

- Neutrino H/D experiment (Richard Hill)
- Electron-nucleus scattering experiments (Adi Askenazi)
- Neutrino-nucleus scattering experiments

8. Path forward: Generator challenges

Theoretical challenges

- Use all data (electron, neutrino, nucleon and nucleus targets) to improve various models
- Theoretical error estimation
- Lattice QCD input
- Neutrino QH-duality model
- Neutrino nPDF

Experimental challenges

- Neutrino H/D experiment (Richard Hill)
- Electron-nucleus scattering experiments (Adi Askenazi)
- Neutrino-nucleus scattering experiments (many experimental LoIs)

Generator challenges (Steven Gardiner)

Except theoretical challenges, all sections overlap with other LoIs.

Conclusion

Neutrino Shallow inelastic scattering region is theoretically very interesting region
- Higher baryonic resonance
- Quark-Hadron duality
- Nuclear-dependent PDF

Neutrino hadron productions (exclusive channels) are not easy to measure.

Hadron final state multiplicity and kinematics are not easy to simulate, also not easy to check it's right or wrong.

Snowmass 2021 LoI: Neutrino-induced Shallow- and Deep-Inelastic Scattering
https://arxiv.org/abs/2009.04285

Workshop of Neutrino Shallow- and Deep-Iinelastic Scattering (2018)
https://nustec.fnal.gov/nuSDIS18/
https://arxiv.org/abs/1907.13252

Thank you for your attention!