FSI group summary

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Comparisons among FSI models (2.2)

- What it is: Is it possible to compare the different FSI models for different particles and momenta independently of neutrino interactions by using particle guns (2.2.1)
- Work goals (2.2.2)
  - Summarize differences in FSI models in different generators independent of their neutrino-nucleus interaction models.
  - Produce hadron scattering type calculations for a specific set of particles (protons and neutrons, pions, K^+) in some well defined initial state (external scattering? placed at a specific point in the nucleus?) on a C, O, Ar, Fe, and at three or four kinetic energies between 100 MeV and 1 GeV.
  - Produce plots that can compare different generator predictions: proton and pion momentum distributions outside the nucleus and multiplicities.

Concilium Tridentinum had 18 years (1545-1563) and we only a week...

What was done?

- Simulations from NEUT, GENIE and NuWro
- Results for
  - pion-carbon/argon reaction and absorption cross section
  - nucleon-carbon/argon/iron reaction and absorption cross section
  - proton transparency (transmission)
  - pion transparency (transmission)

FSI models

NEUT

- for pions based on Oset et al computations with later fit to available pion-nucleus data
- for nucleons Bertini model

GENIE

- hA is an effective model
- hN is a cascade model; Oset et al for pions; Pandharipande-Pieper for nucleons (in-medium modifications)

NuWro

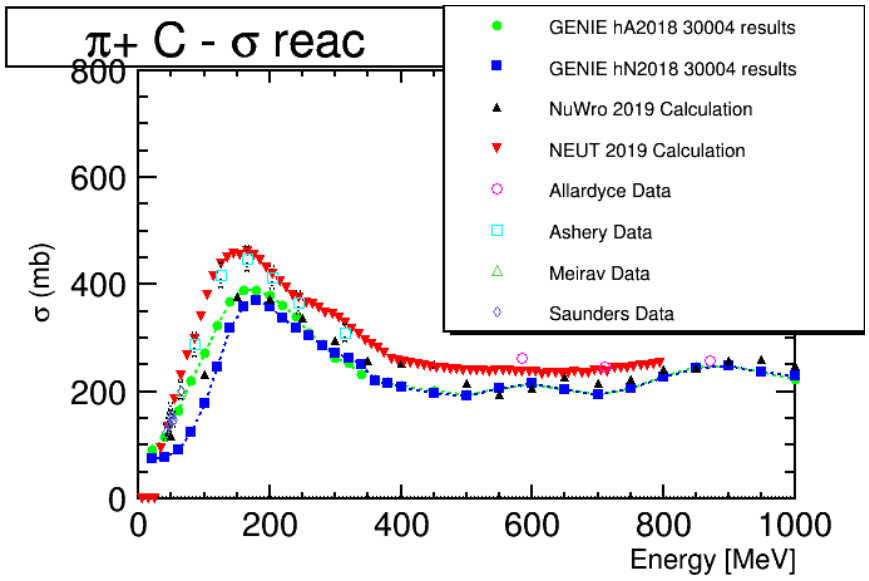
- for pions Oset et al computations
- for nucleons Pandharipande-Pieper and nucleon-nucleon correlation effects (based on K. Niewczas, JTS, arXiv:1902.05618 [hep-ex])

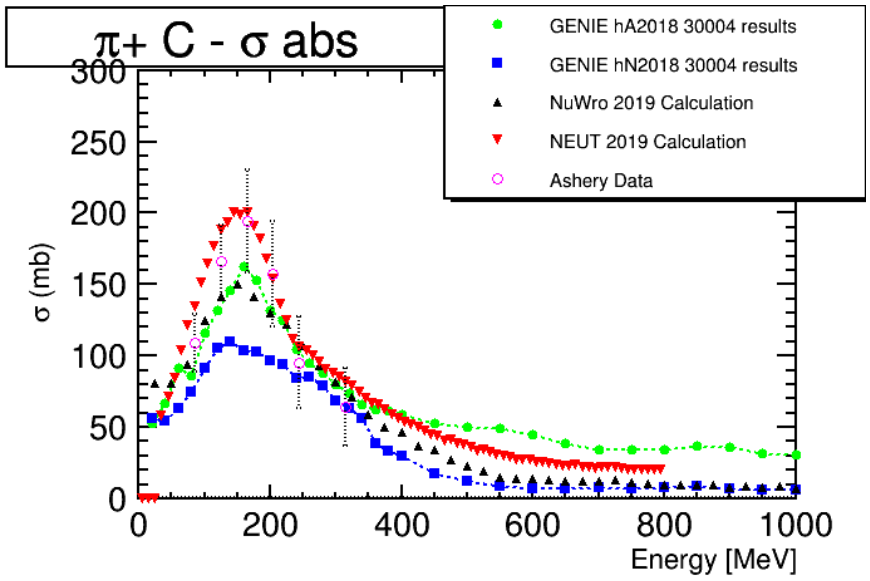
Hadron-nucleus scattering

Strategy:

- A uniform flux of hadrons scatters of nucleus.
- Various final states are conunted
- Knowing nucleus radius cross sections are easily obtained.

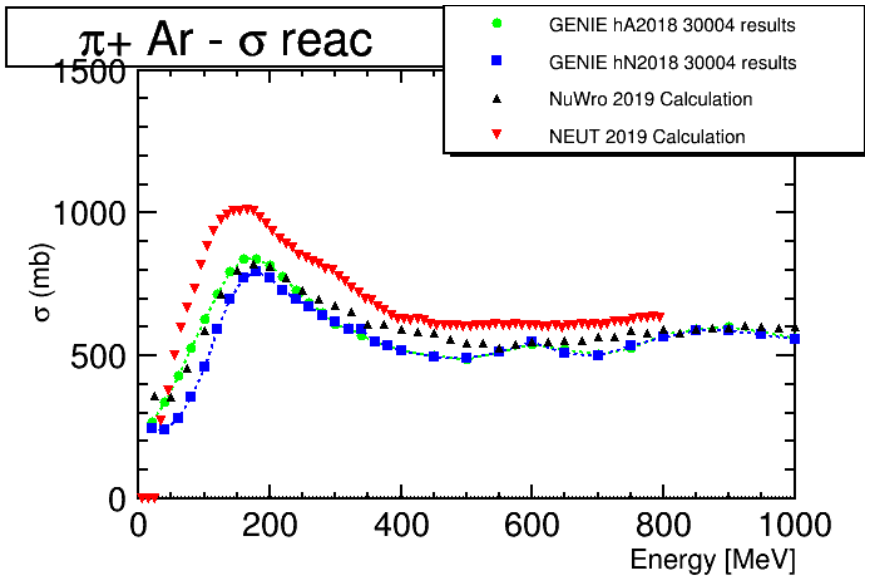
π^+ on carbon

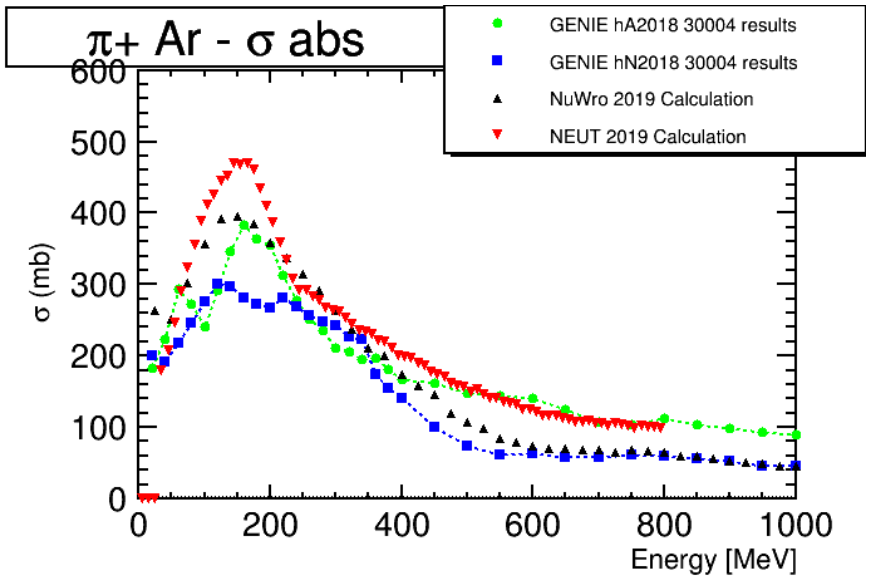




- NEUT reproduces data very well
- For reaction cross section NuWro, GENIE hA and hN agree very well

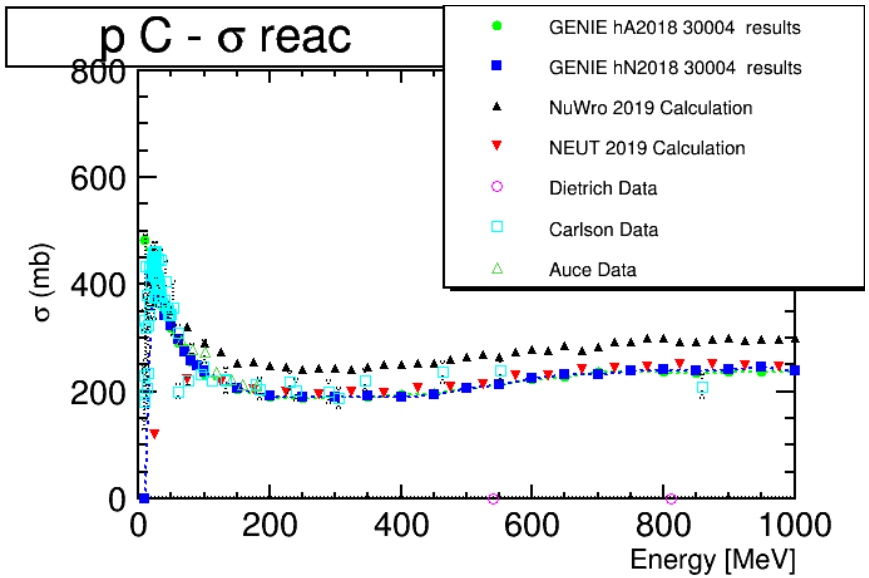
π^+ on argon

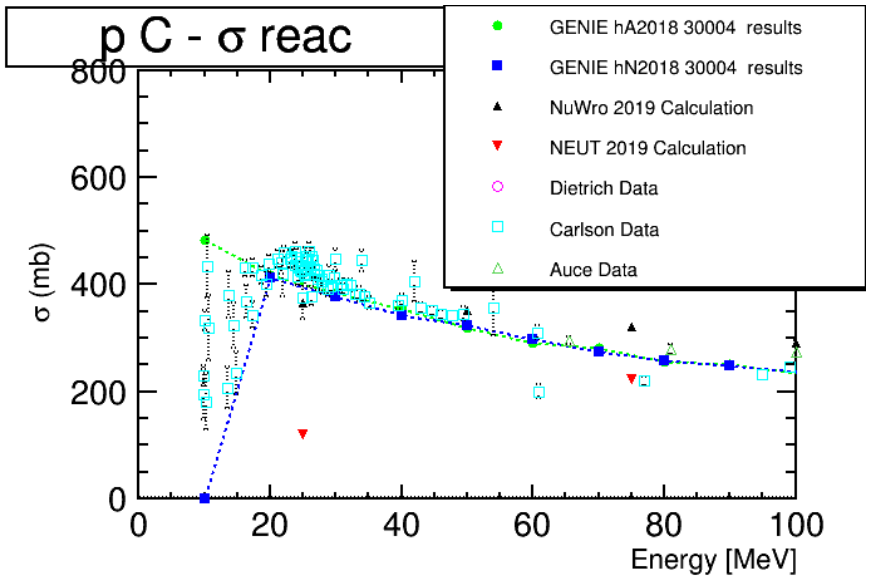




- For pion absorption significant differences between the models.

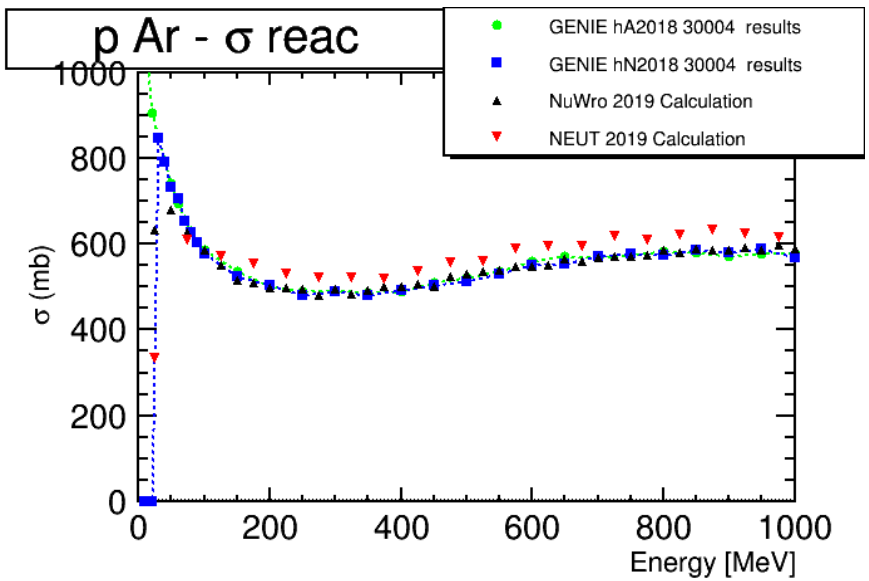
Proton on carbon

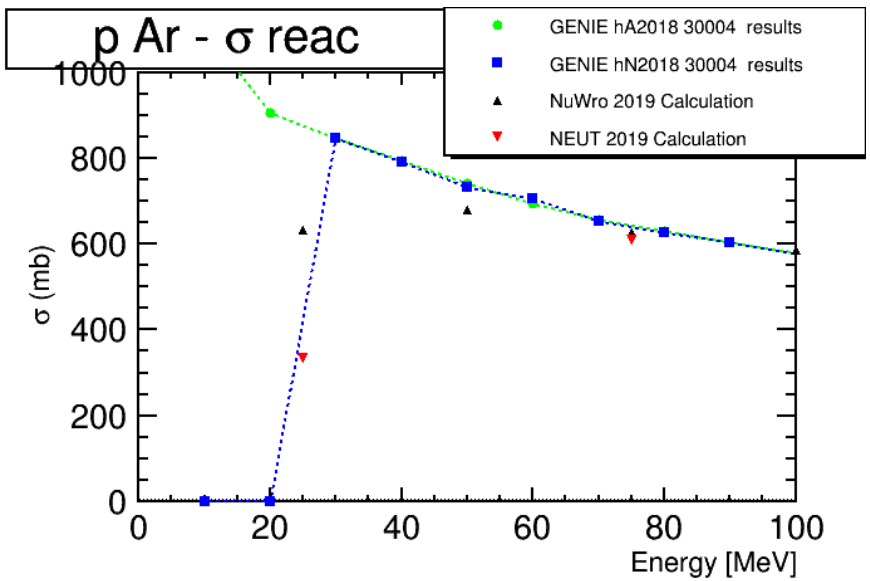




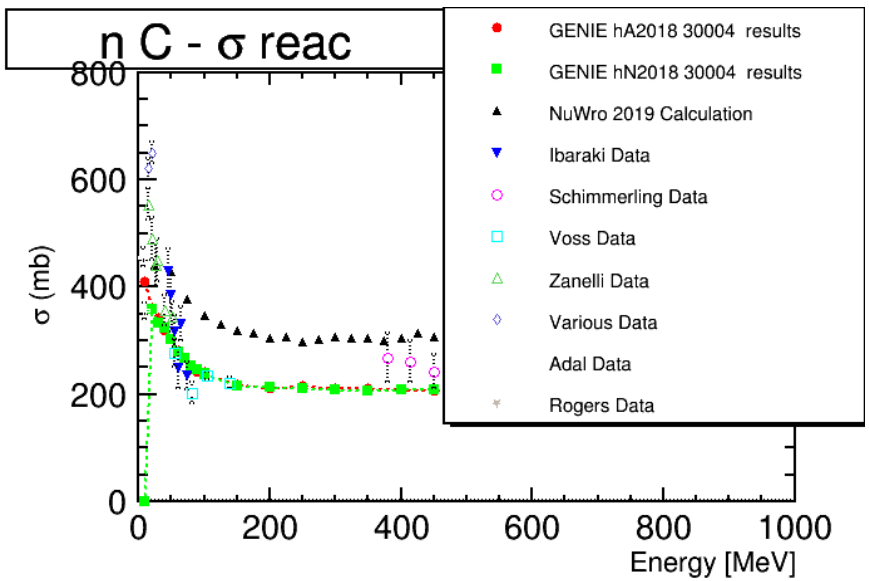
- On the right a region of small kinetic energy shown in more detail.
- At low energies NEUT below the data and other three models agree well

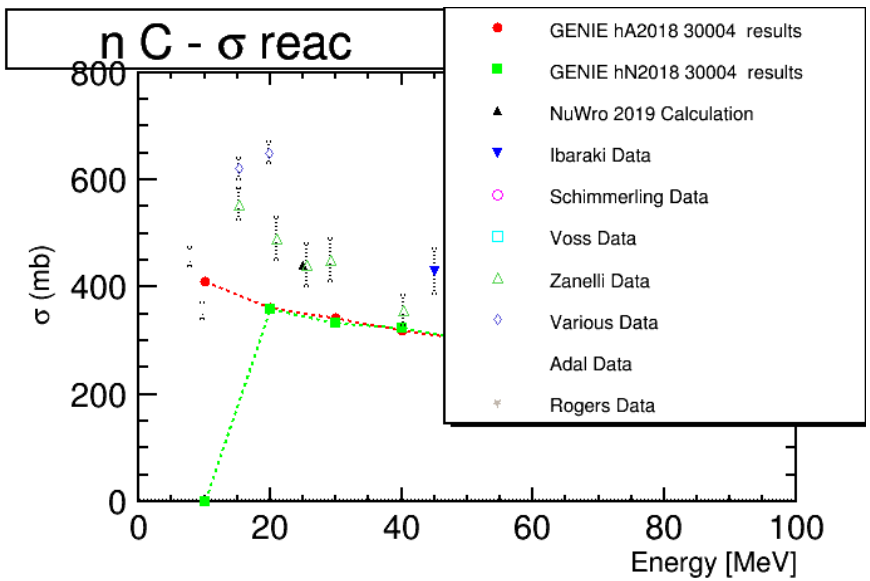
Proton on argon



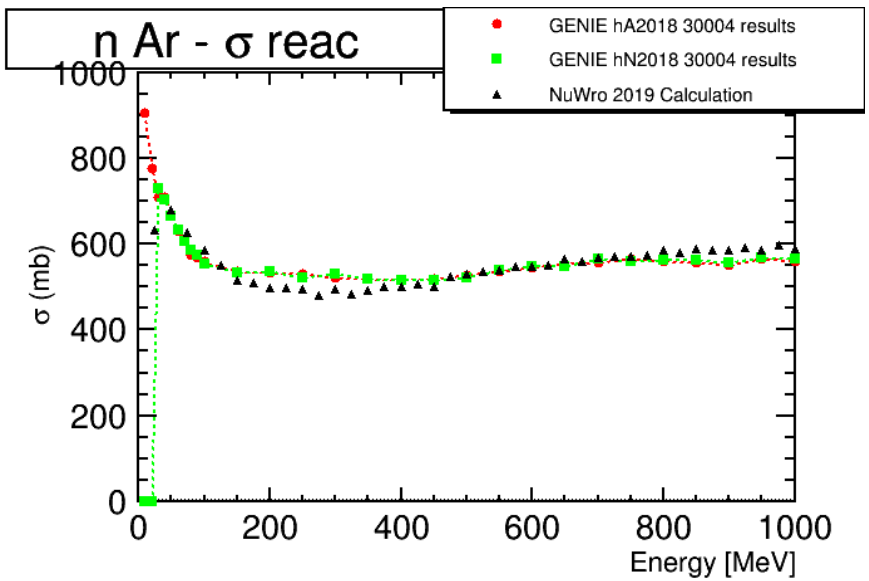


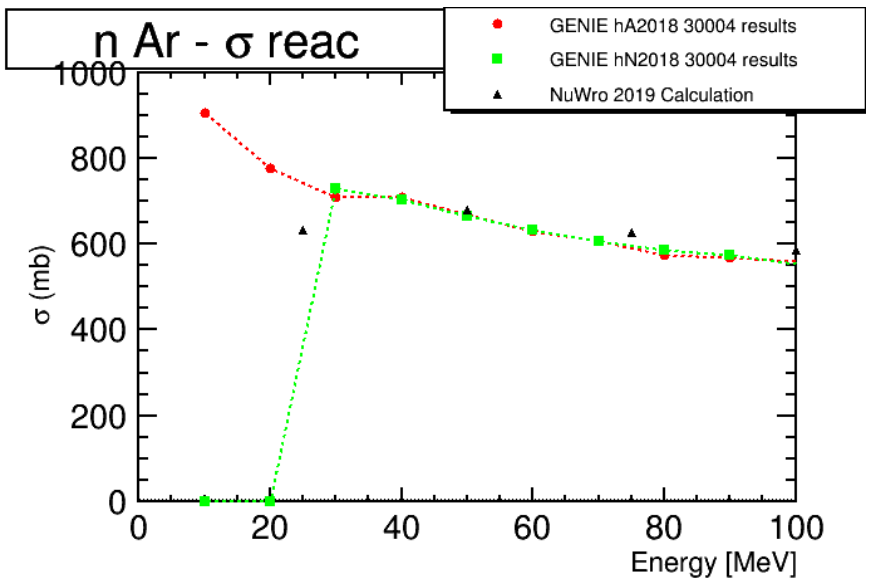
Neutron on carbon





Neutron on argon



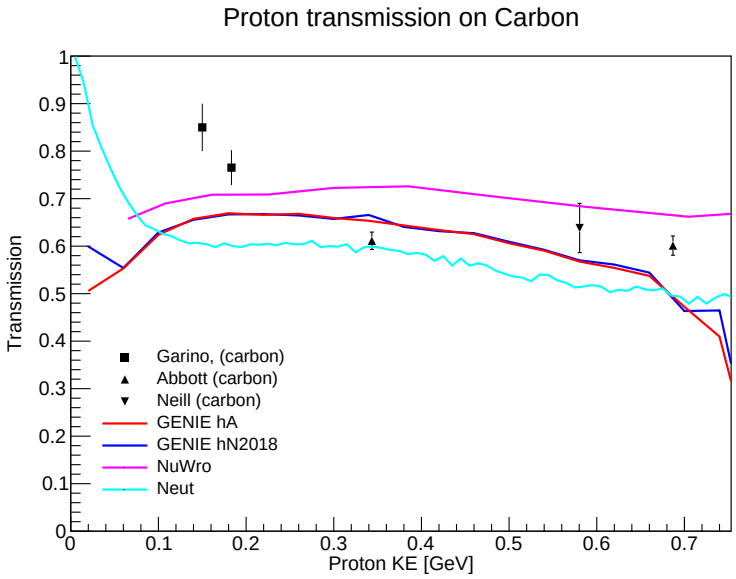


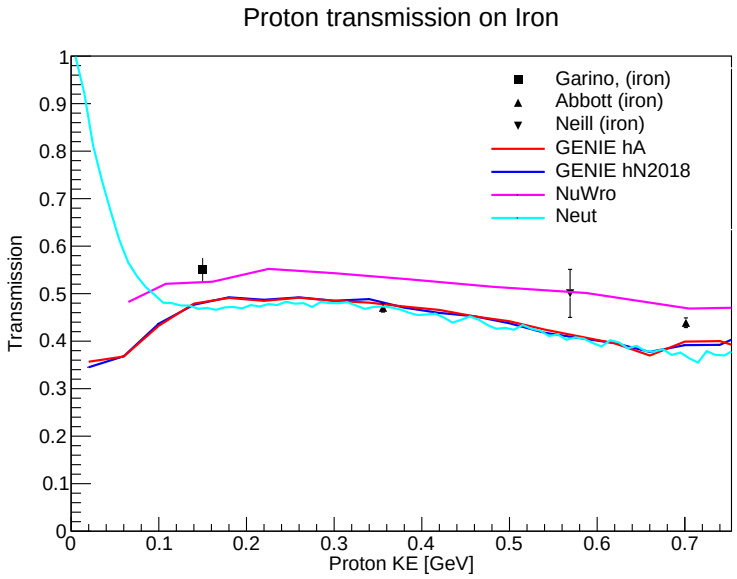
Transparency (transmission)

Strategy:

- A sample of CC events is produced
- Protons before FSI are counted in momentum bins
- Protons after FSI are counted in momentum bins if they do not suffer from any interaction.
- Ratios give transparency as a function of proton momentum.

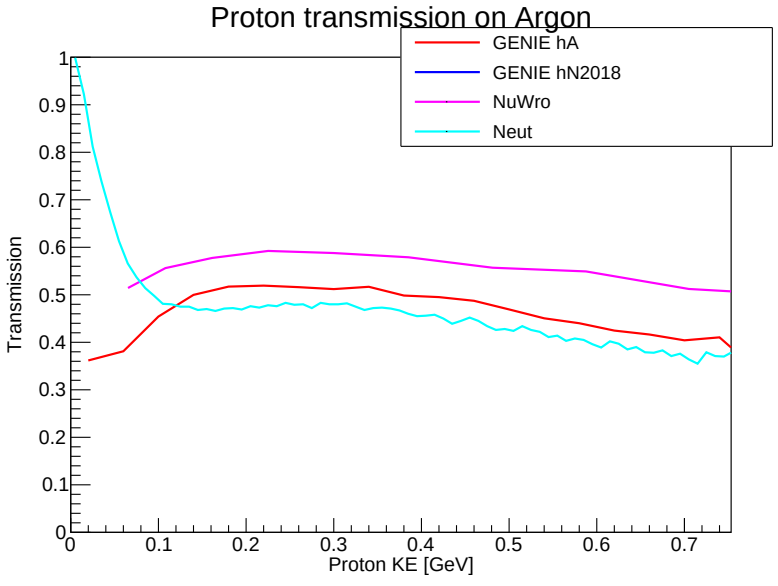
Proton transparency/transmission





- A reasonable agreement between four modela apart from a region of low kinetic energy.
  - In medium modification of NN cross sections is necessary here.

Proton transparency/transmission (cont.)

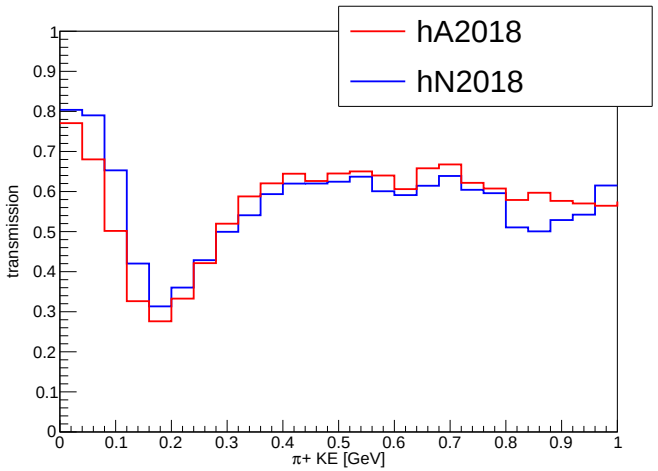


A warning: precise comparison with experimental data on the previous slide is subtle

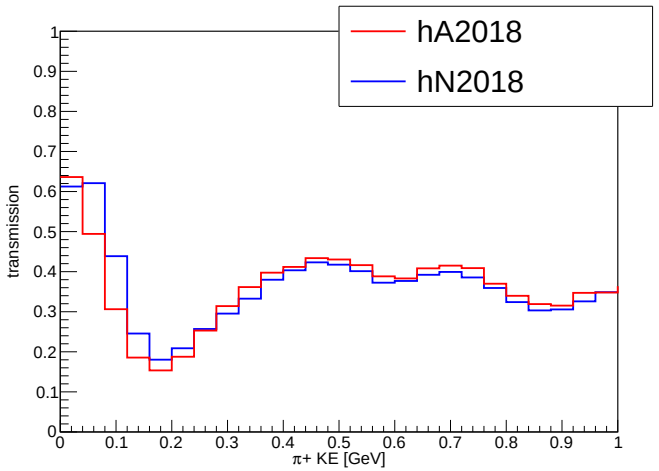
- Monte Carlo transparency was computed, but experimentally soft interaction cannot be distinguished from "no interaction"
- In CC scattering on carbon proton propagates through nucleus of 6 protons and 5 neutrons
- In EM scattering proton propagates through a nucleus of 5 protons and 6 neutrons.
- At proton momentum of $\sim$ 800 MeV/c proton-neutron cross section is $\sim$ 35 mb and proton-proton cross section is $\sim$ 25 mb
- CC transparency is slightly bigger than EM transparency (3% effect)

Pion transparency/transmission

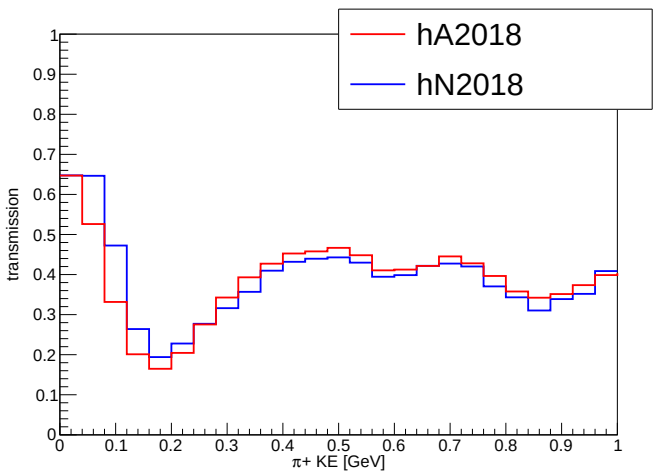
carbon



iron



argon



Conclusions

FSI group did a lot of useful comparisons.