Discussion: day 2

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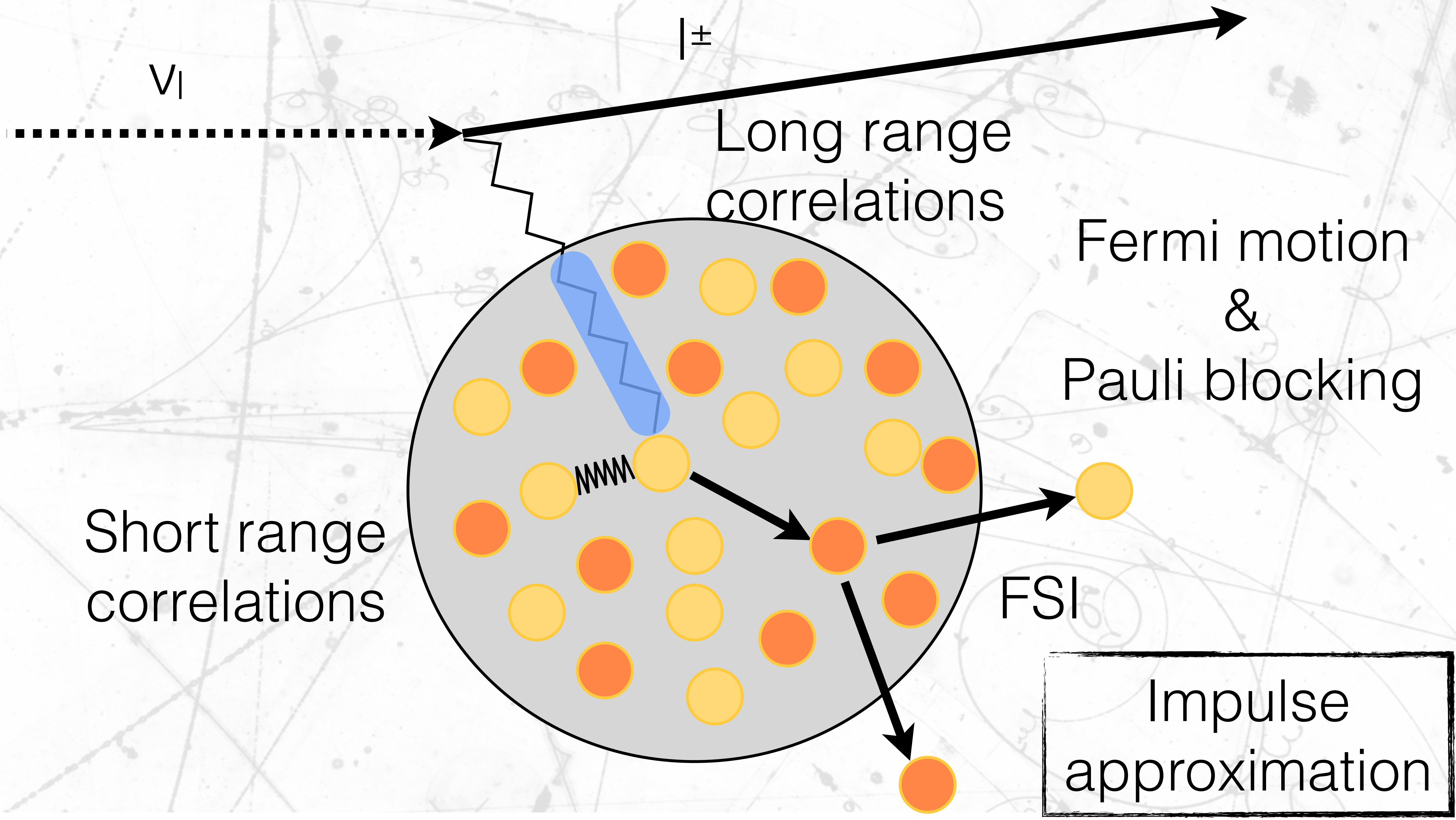
Impulse approximation

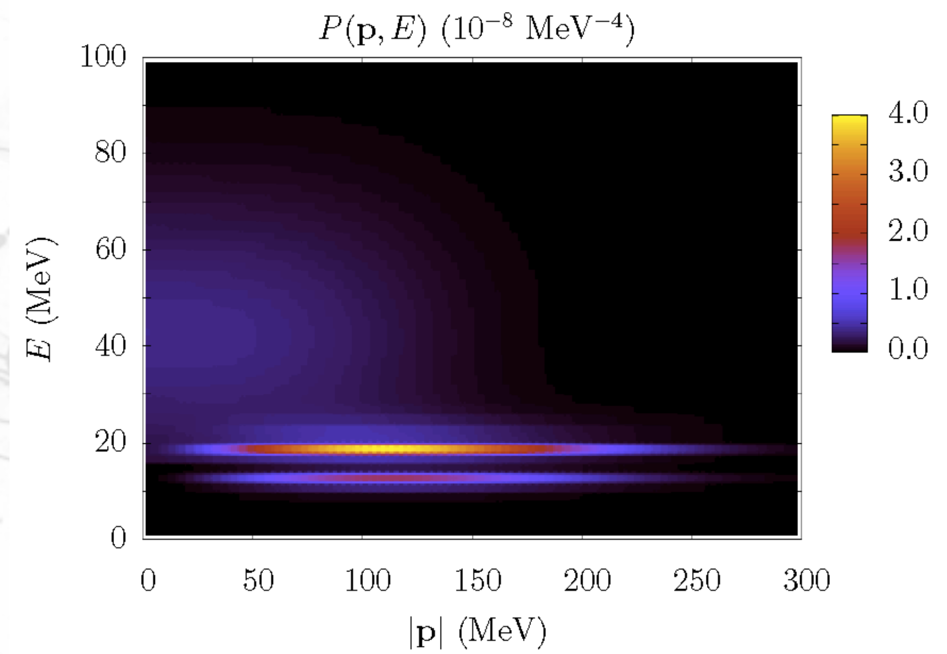


Initial state

- Models implemented:
  - Global Fermi Gas (one free parameter !)
  - Local Fermi Gas (rigid, imposed by nuclear potential)
  - Spectral Function (Rigid)
  - RMF (????)

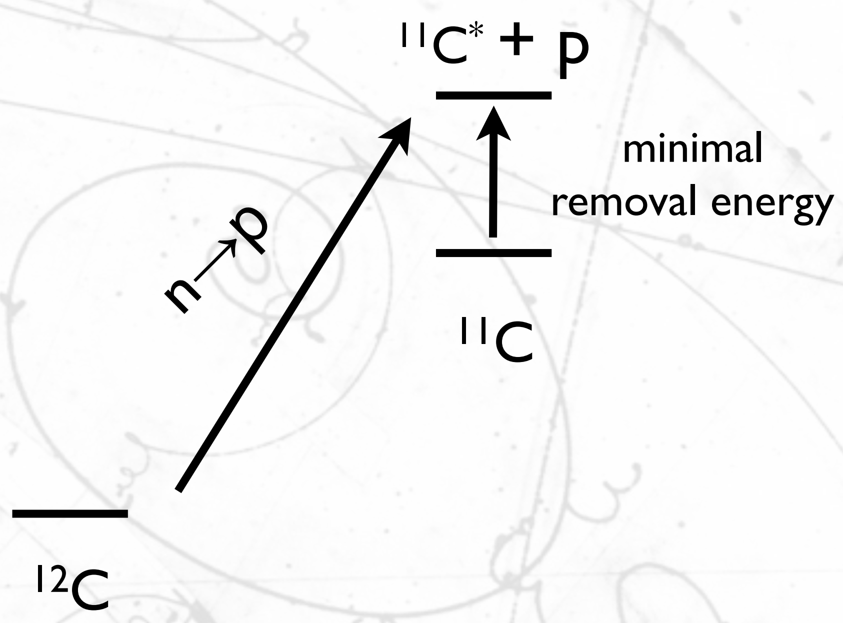
Removal energy

- (As far as I know) for impulse approximation there are 4 ways to implement it:
  - Effective target mass (m→m-E_b)
  - Effective target mass (m→m-E_b) with radial distribution,
  - Dispersion relation (Spectral function).
  - Nuclear removal energy.



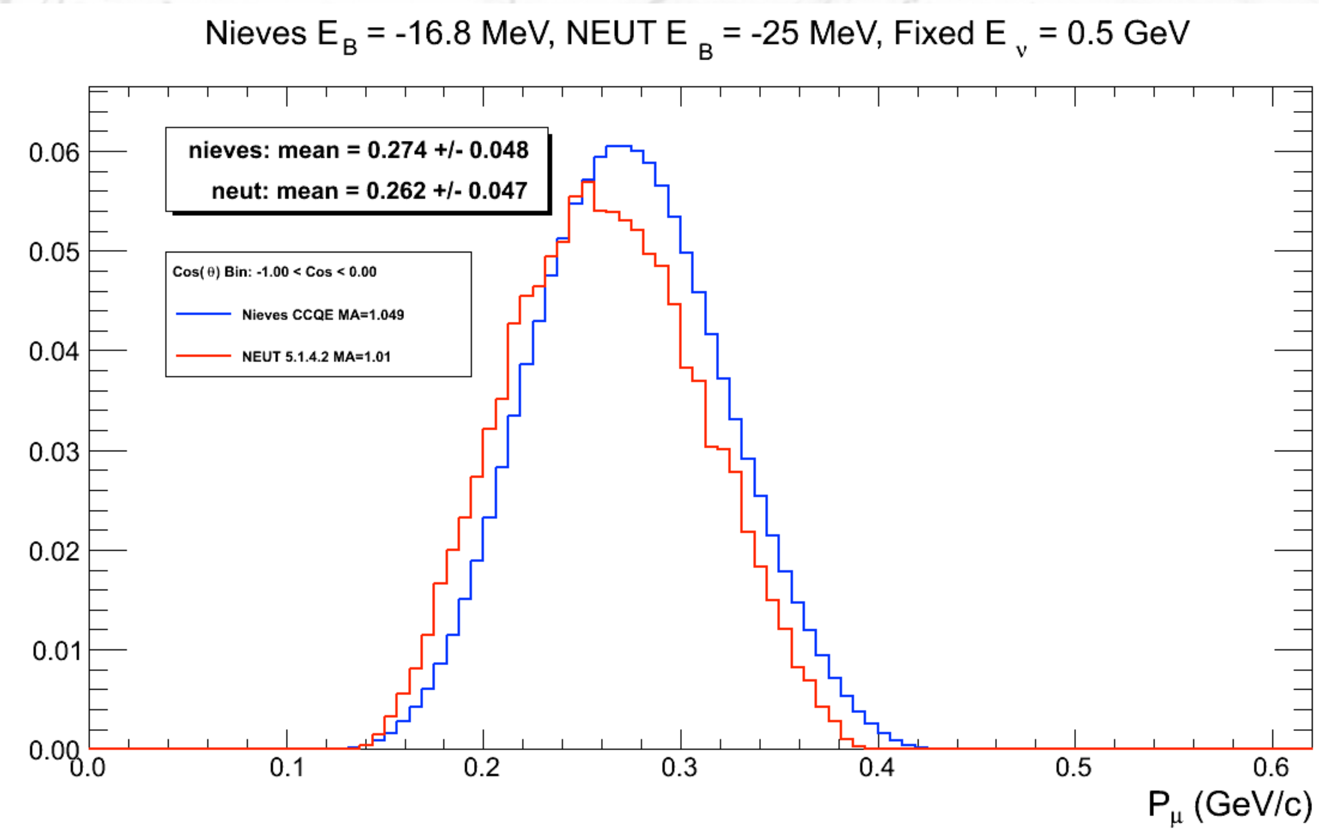
Bind energy is variable because final nuclear states might be excited.

~6 MeV γ in SK



Removal energy

- Effect is visible at T2K energies.
- Since the Bind Energy is not a fixed value (0-10 MeV) this could smear distributions.



Nieves E_b = -16.8 MeV
Neut E_b = -25.0 MeV

Bind energy is a delicate parameter for event re-weight making calculations complicated.

Pauli blocking

- Same for different implementations:
  - Relativistic Fermi gas.
  - Local Fermi gas.
  - Spectral functions
  - "Ab initio" calculations (non impulse approximation).

Remove interactions where $p_p < p_{fermi}$

Is this 100% correct ?

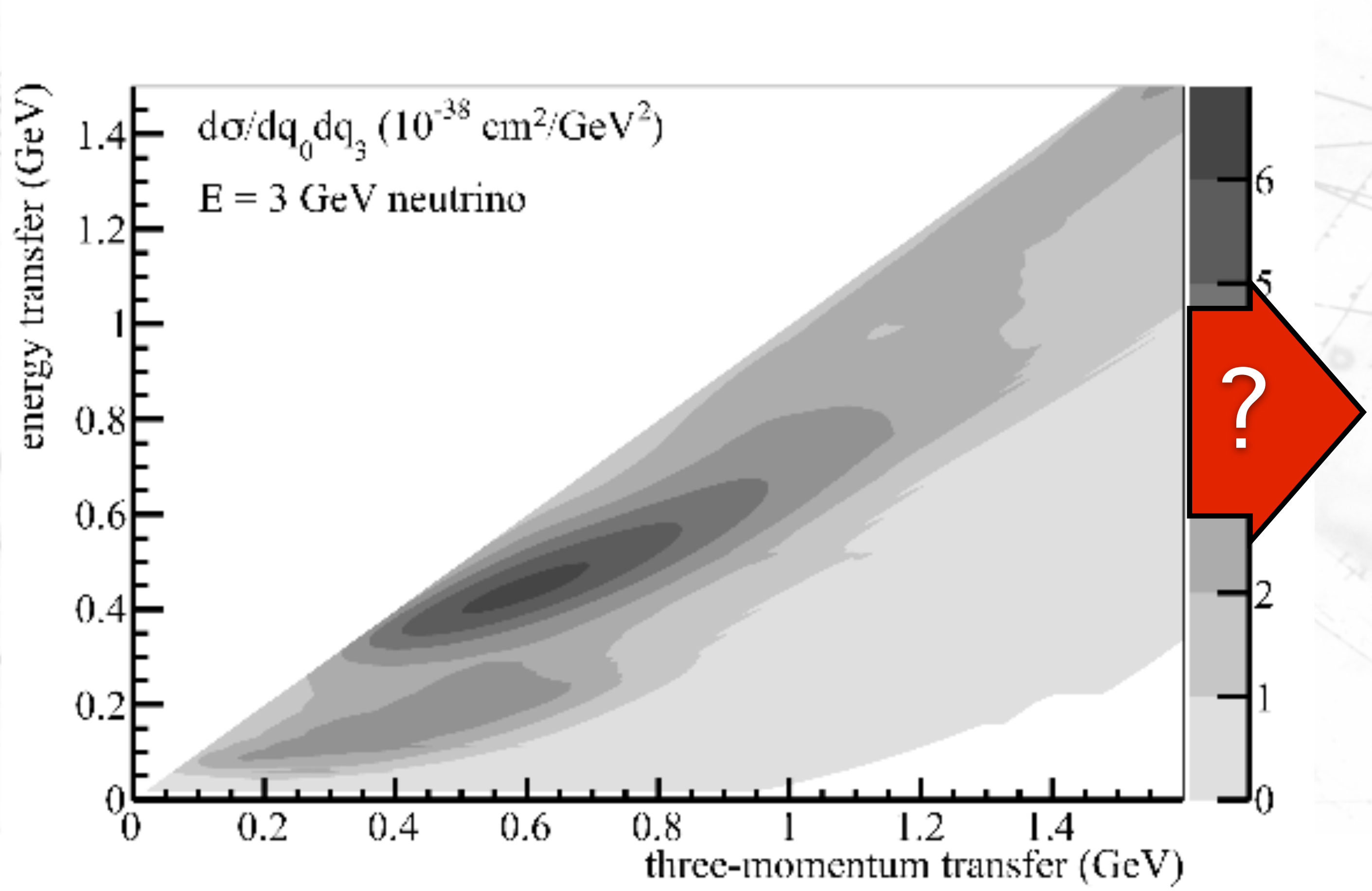
Pauli blocking should be also implemented consistently for the Final State Interactions.

Pauli blocking is delicate to re-weight in case of single Fermi level (RFG).

!

Limit of models

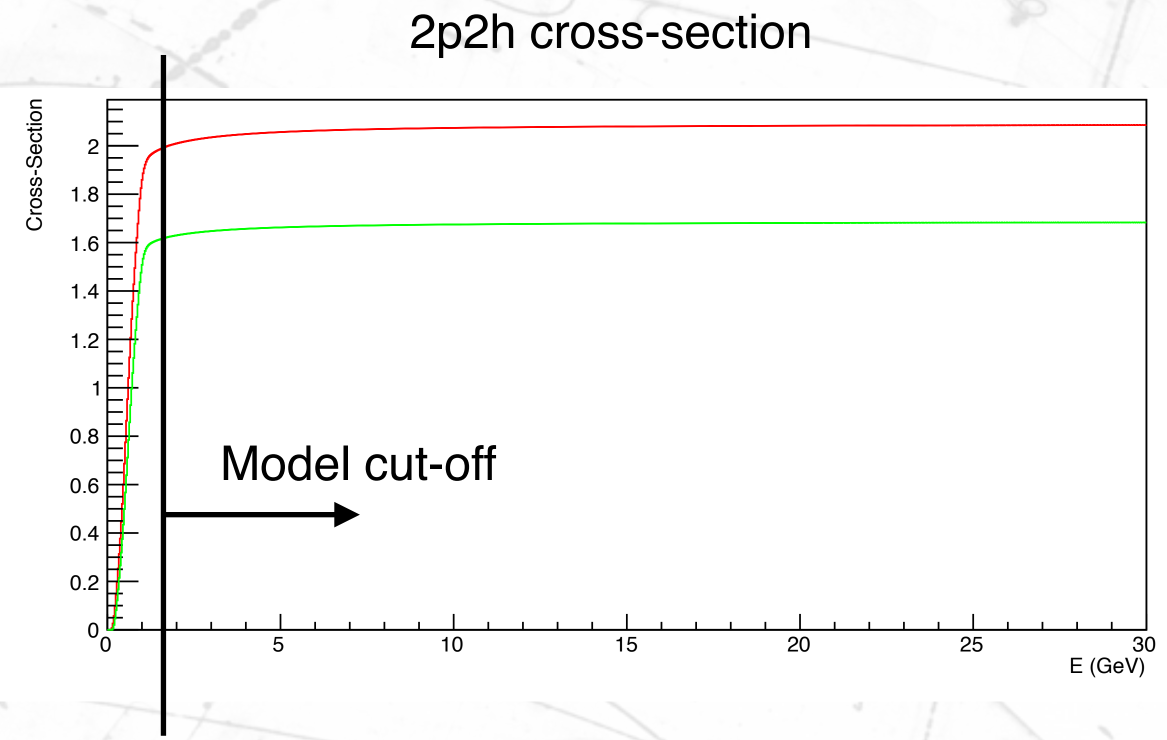
- The validity of the models is normally restricted to some kinematical phase space.
- This is a critical point for broad band beam neutrino MC's.
- One of the most relevant cases now is the 2p2h.



Not only a limit of the model but also the channels included in the model !

Merging regimes

- Is it possible to merge models with some “smart” transition function ?
- As far as I know there is only one case implemented in our MC’s with limited impact on the predictions:
  - multipion to DIS transition.



Can we use inclusive and semi-inclusive models to complement this regions?

Model consistency

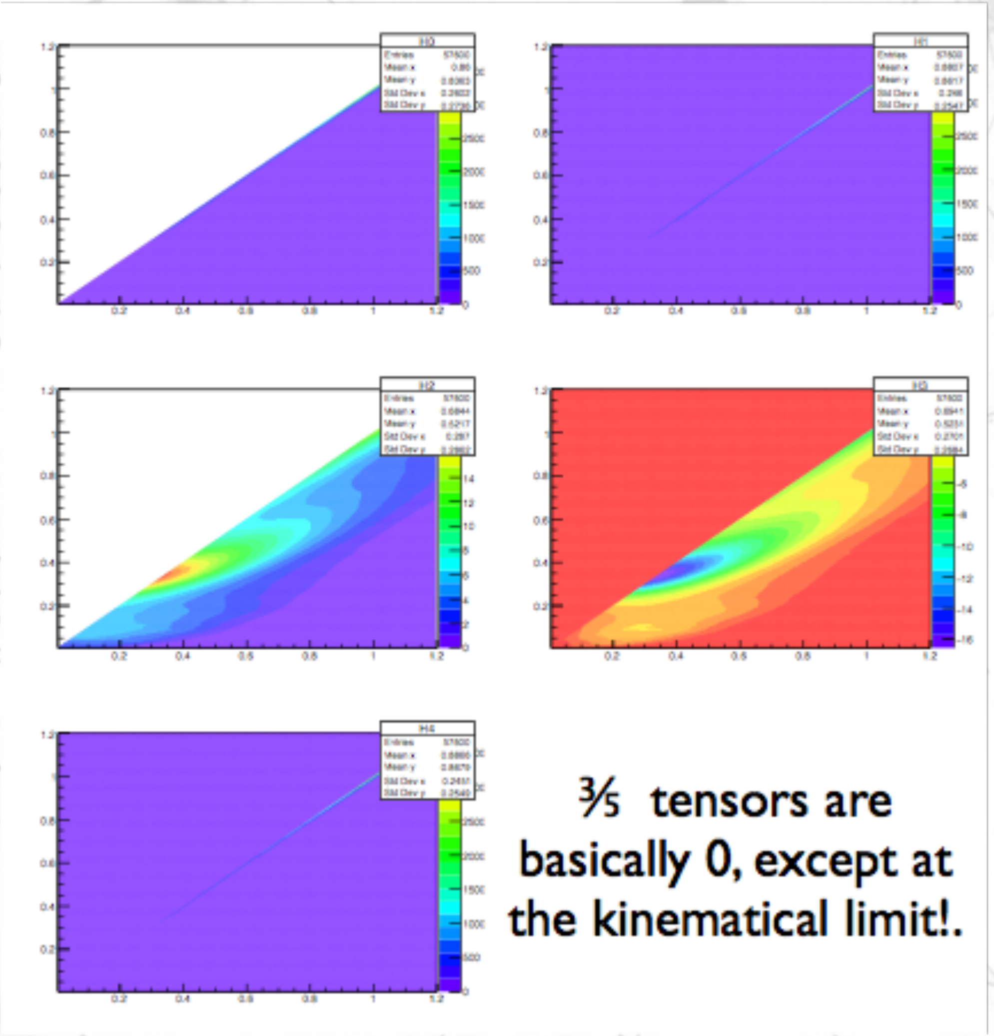
- We always talk about model consistency.
  - But the argument should be given beyond the beauty of the model.
- Model consistency means mainly:
  - avoid double counting.
  - same initial state or final state.
  - common (and correlated) errors associated to the common model (bind energy, FSI, etc…)

Double counting

- This is not a “pure” MC issue but a relevant item.
  - How do we ensure that the there is no double counting in our implementation ?
  - Some examples:
    - Multipion vs. DIS
    - Initial state nucleon-nucleon correlation vs. 2 body currents.
    - SF vs. RPA.
- To me this is the main reason to keep consistency across the model.

Hadron Tensors

- The cross-section is a contraction of the Lepton ($L_{\mu\nu}$) and the Hadron tensors ($H^{\mu\nu}$)
- The Hadron tensor is precomputed in an “slow” MC.
- The Hadron tensor can be computed under several conditions:
  - pp or pn final states.
  - with some model ingredients: Δ, non-Δ, interference, ρ propagator, …
- This can be used to understand contributions or to implement re-weights.



Susav2

- Hadron tensor is not the only way to generate final state leptons.
- SusaV2 can be seen as (very) smart parametrisation of 1p1h Relativistic Mean Field.
- This might be a simple way to implement complex physics in Monte Carlos.

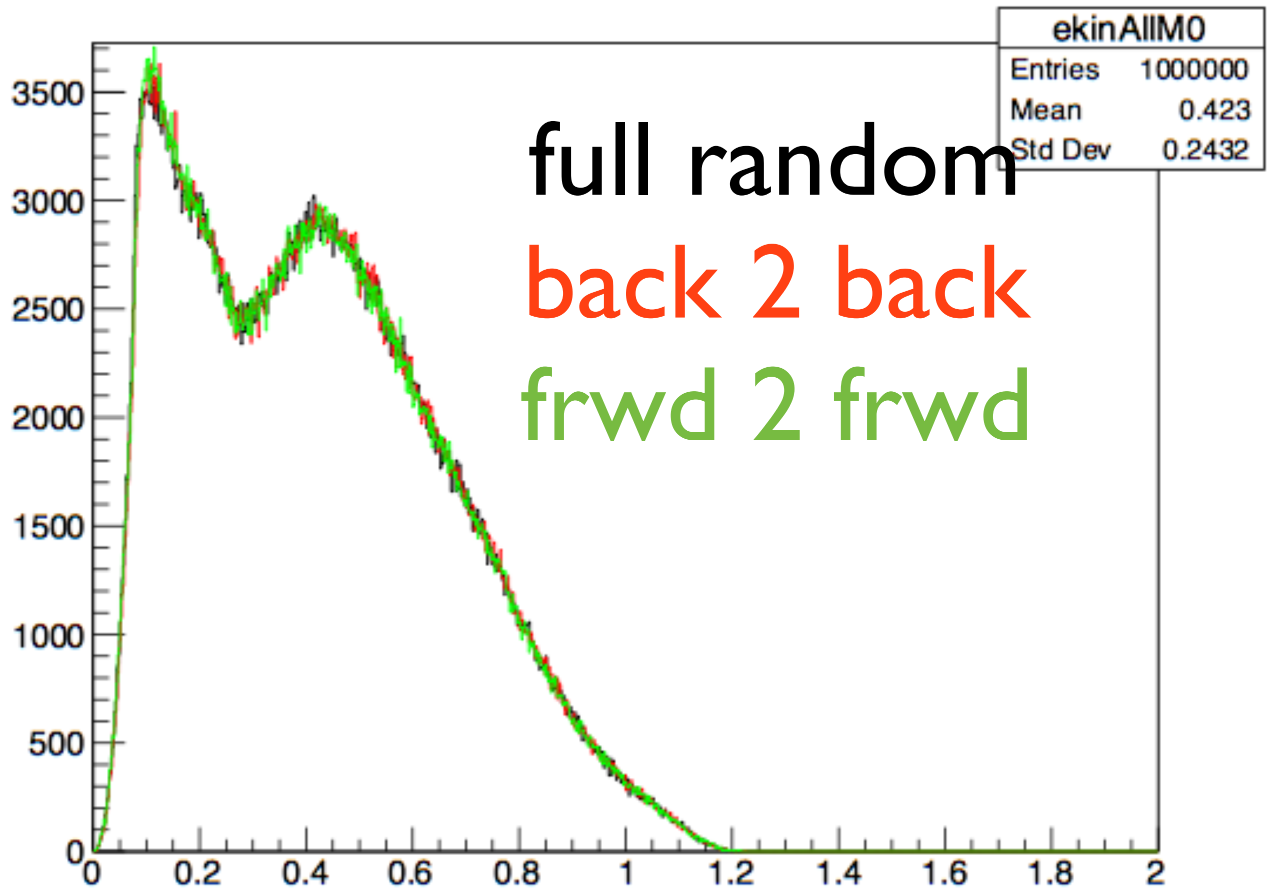
Hadronic states

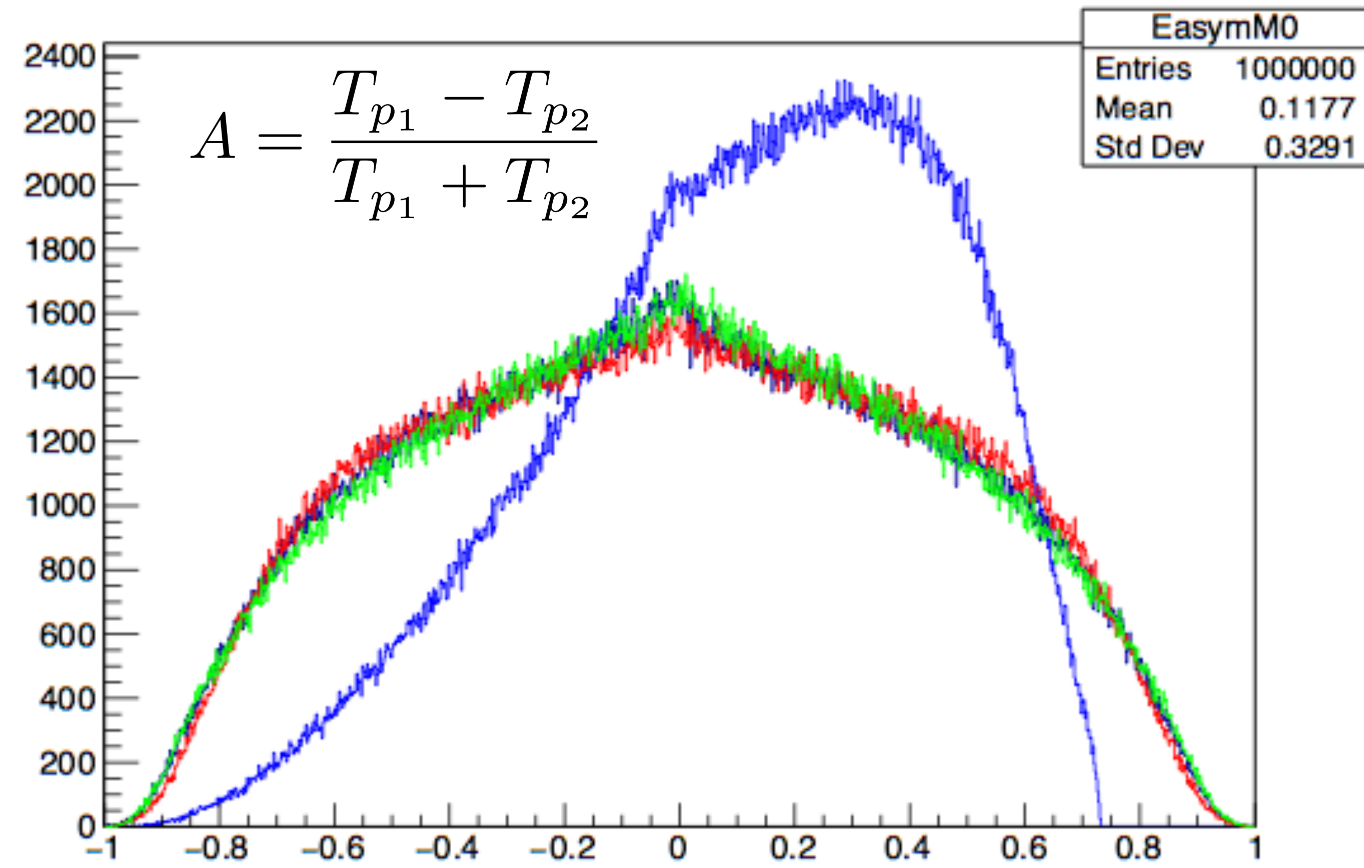
- In both approaches before the hadron kinematics is integrated.
  - We lose information about the hadron kinematics.
- This information is important for current and future experiments.
  - Adding all kinematics might be very “expensive” in term of CPU.
  - We could explore models where we ensure:
    - model consistency (i.e. using same fermi momentum model)
    - energy and momentum balance.
      - this has been implemented in 2p2h models in NuWro and NEUT.

We need to evaluate the “correctness” of this approaches and explore for example others like 1p1h.

Hadron model

- The total energy of hadrons @ the lab is independent of the model for 2p2h.
- The kinematics of each nucleon is not…very relevant for pn or even pp final states.





FSI

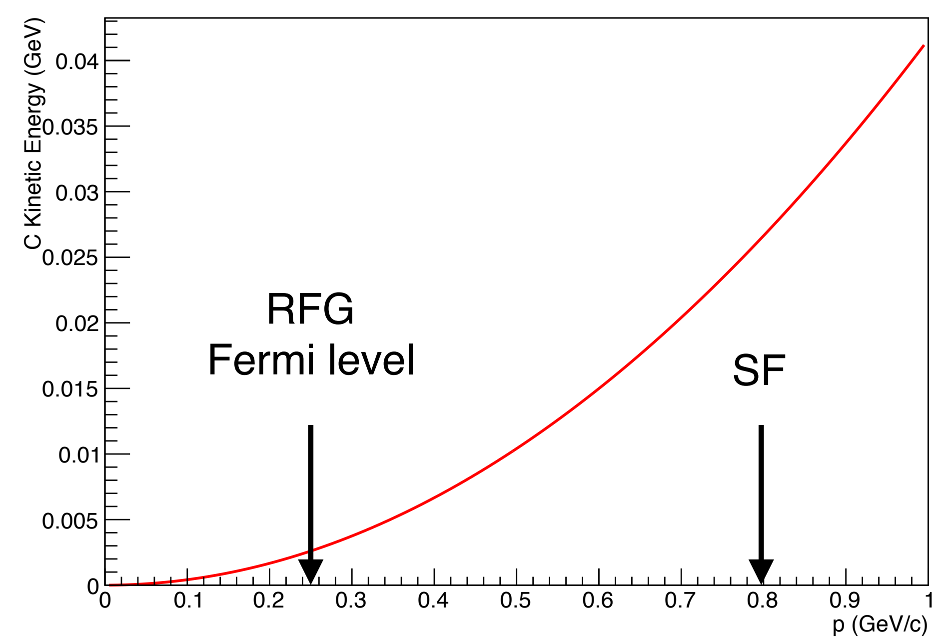
- FSI has been demonstrated to be a critical model for:
  - channel identification.
  - energy measurement.
- Two main models:
  - cascade. (NEUT, NuWro).
    - This one is being tuned by experimental data.
      - One big question is the validity of the experimental πA or pA data to constrain π and proton interaction inside the nucleus.

(e,e’) with hadron measurement is a critical check for these models.

  - transport. (NuWro)

Vertex Activity

- New detector technology (Gas and Liquid TPC's) will require a more precise determination of the activity at the interaction vertex:
  - Low energy nuclear evaporation.
  - Nuclear gamma/alpha de-excitations.
  - Nuclear kinetic energy (also affecting E-p balance)
- Minerva already uses this to derive neutrino energy !



How far are we of this type of implementations?

Sometimes there should be a correlated pair emitted. How?

Are they really needed ?

ν,A vs e,e' models

- Consensus that we need electron scattering.
- Many reasons:
  - Pure modelling (factor the axial component)
  - Relation momentum,energy transfer to final state hadrons.
  - Model of energy reconstruction (factor axial component).
- This is a fundamental development for neutrino MC implementations in the near future.

Other stuff

- Coulomb potential corrections:
  - Nieves model implementation predicts ~5MeV shifts in lepton Energy.
- Electron production bremsstrahlung emission and corrections.
- Missing channels to which we might be sensitive:
  - Single gamma emission.
  - …
- Shallow and Deep inelastic transition.

Impact on experiments to be determined

$\sigma(\nu_\mu)/\sigma(\nu_e)$

Background for oscillations

Calorimetric E recon.

Parameters & errors

- Last but not least: Errors!
  - Models have parameters.
  - Parameters have errors.
- Changing basic parameters of the theory is always far better than funny unphysical re-weights.
  - fundamental parameters allow comparison across experiments.
  - Common language allows broad comparisons.