SuperScaling Approach (SuSA) and NEUT 1p1h Nieves model

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SuSA principle

- Scaling QE nucleus-neutrino using electron-nucleus data
- Scaling depends on a single quantity: the scaling variable ψ
- Superscaling means the scaling function depends only on the scaling variable and is independent of nuclear species

- SusaV2 detailled in the thesis «Charged-current neutrino interactions with nucleons anf nuclei at intermediate energies » by Guillermo Daniel Megías Vázquez from Sevilla University

Scaling variable

$$\Psi = \frac{1}{\sqrt{\xi_F}} \frac{\lambda - \tau}{\sqrt{(1+\lambda)\tau + \kappa\sqrt{\tau(\tau+1)}}}$$

$$\xi_F = \sqrt{1+\eta_F^2} - 1$$

$$\eta_F = \frac{k_F}{M_N}$$

$$\kappa = q/2M_N$$

$$\lambda = q0/2M_N$$

$$\tau = \kappa^2 - \lambda^2$$

- Depends on transfer momentum (q) and transfer energy (q0)
- nucleon separation Energy (Eshift) has to be removed from transfered energy

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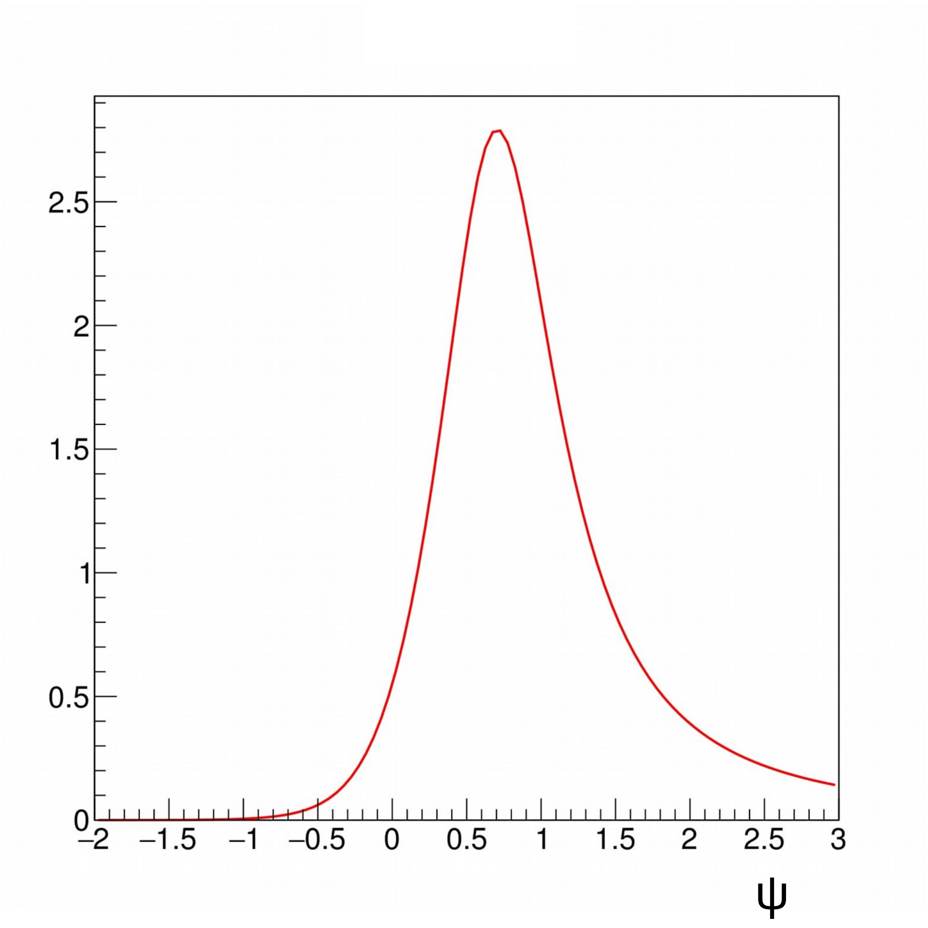
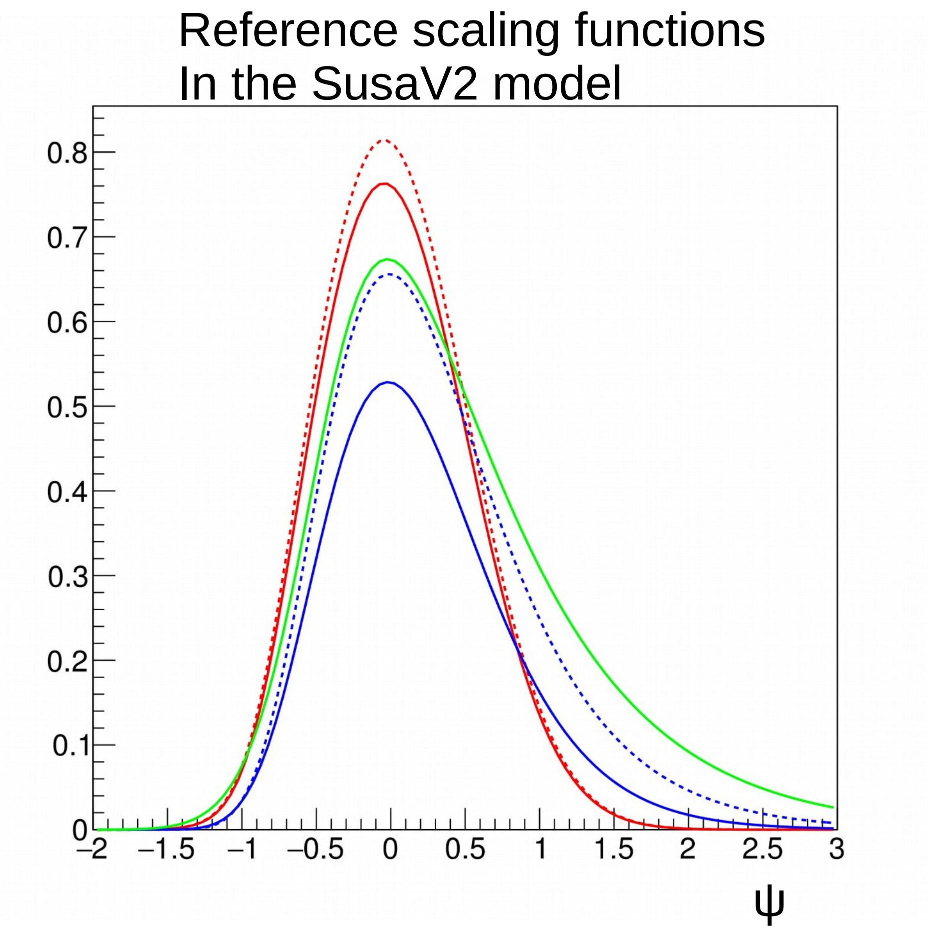
Fermi Momentum

Susa parametrized scaling function



- Obtained from QE electron scaterring and single nucleon scattering.

SusaV2 parametrized scaling function

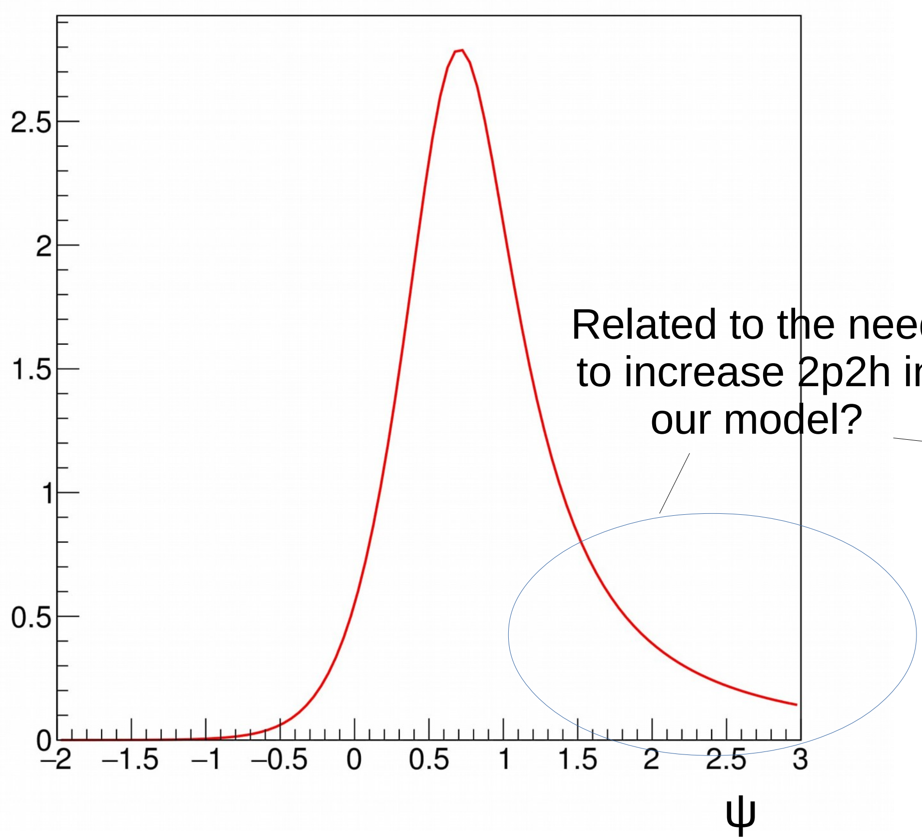


- Combination of :
  - Susa
  - Relativistic Mean Field (RMF)
  - RelativisticPlane Wave Impulse Approximation (RPWIA)
- The 5 scaling functions presented here are linearly combined to have 3 scaling functions two longitudinal and one transverse

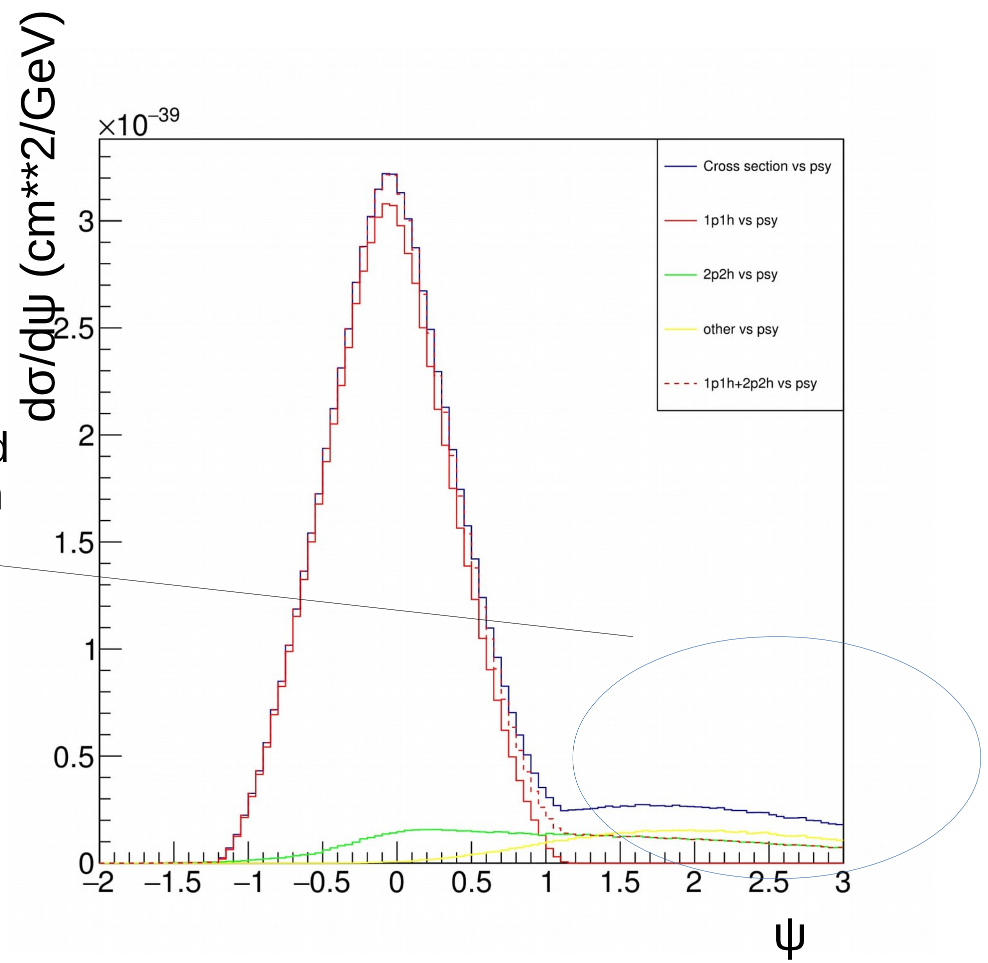
Why testing SuSA?

- SuSA model use semiphenomelogical approach with electron scattering data :
  - use this to compare LFG result to electron scattering data
- See if we can apply the SuSA methodology to our current LFG.
- Explore the possibility of including a SuSA MC model in NEUT.

Direct comparison with LFG CCQE

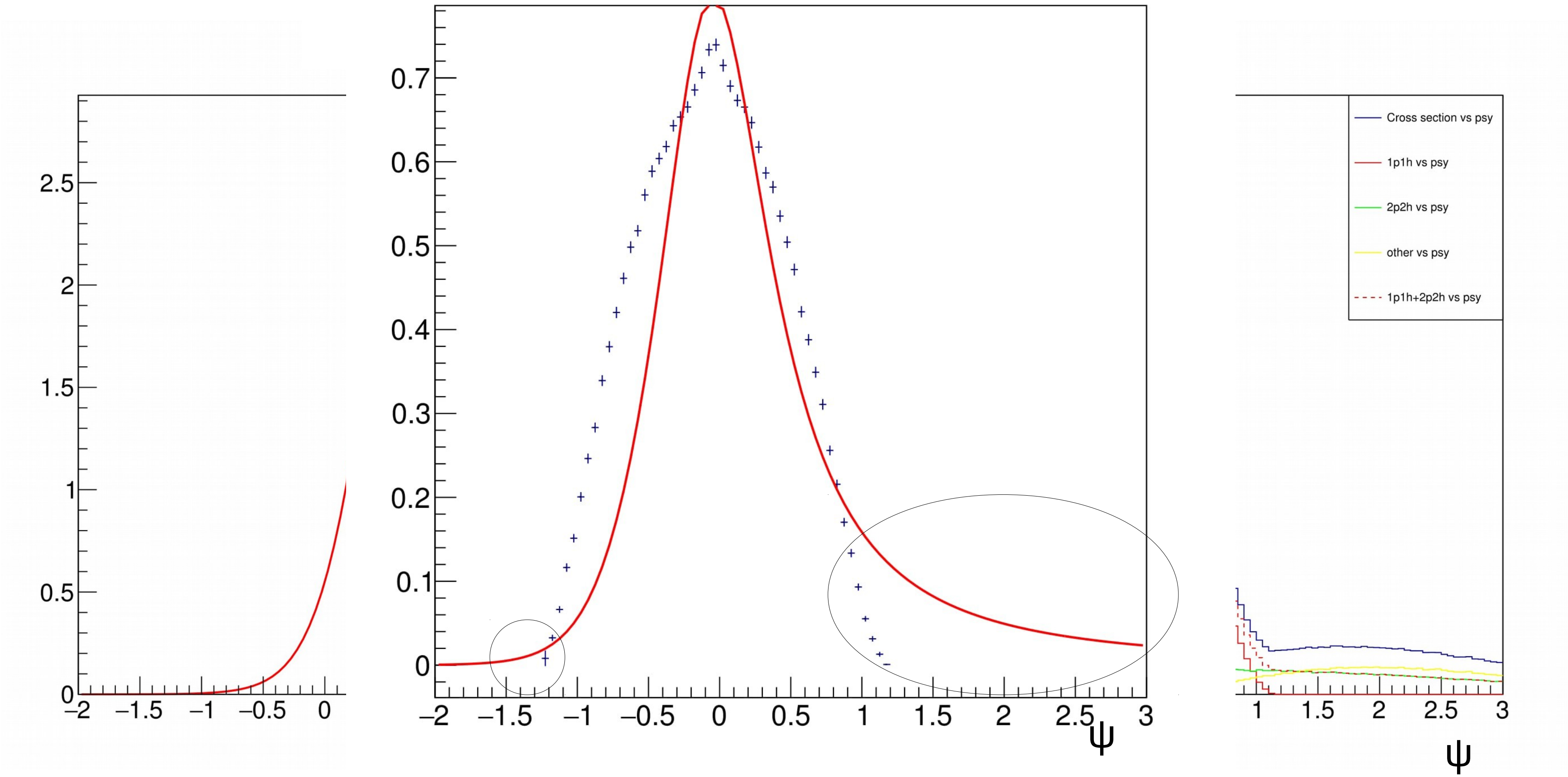


Related to the need to increase 2p2h in our model?



Here E shift applied to ψ is fixed to 20 MeV.
1p1h (red curved on right plot) is limited to ψ <1,2 → Incompatible with the parametrized SuSA scaling function on left plot
This correspond to ψ´ where 2p2h is important

Direct comparison with LFG CCQE

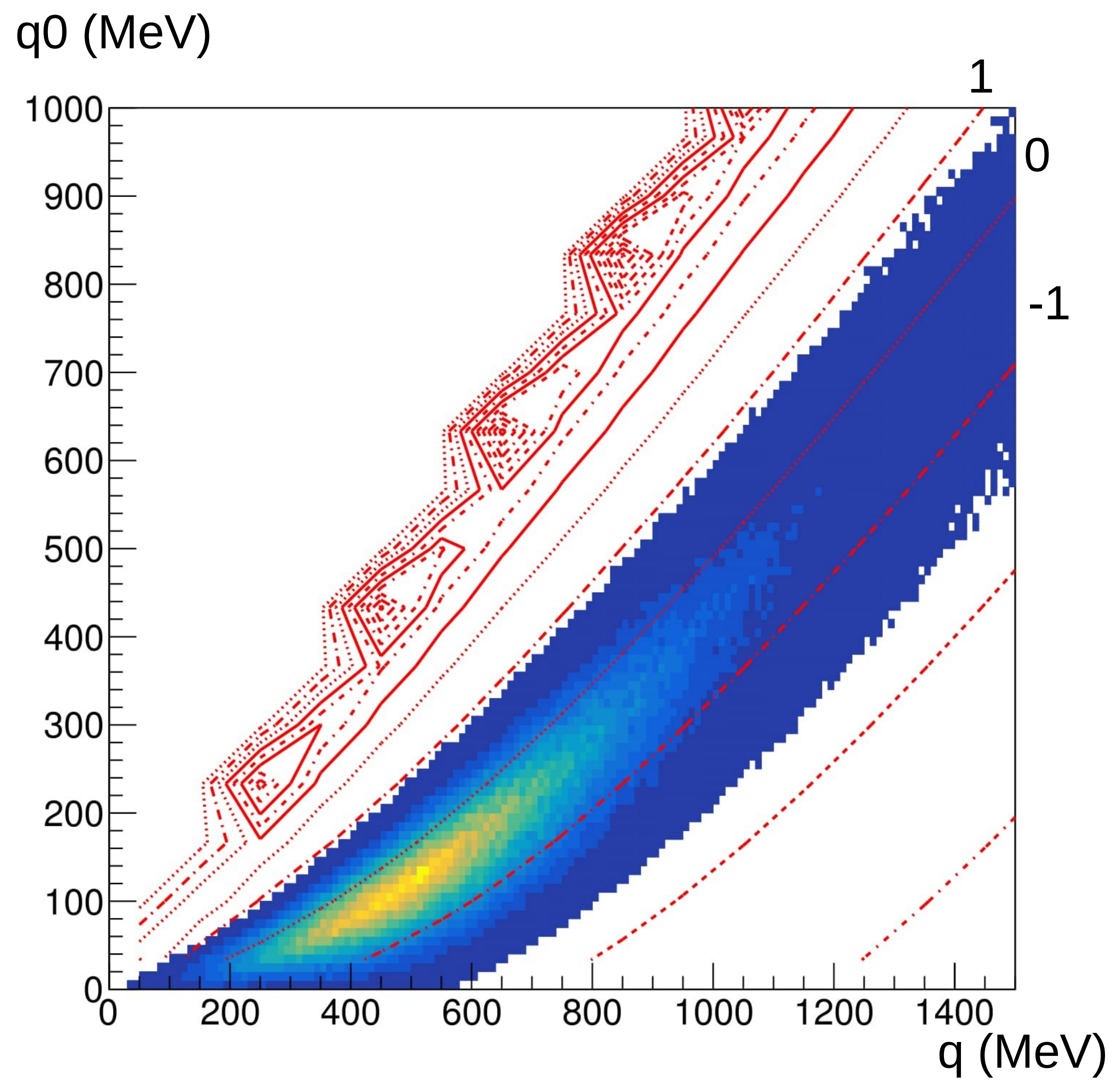


Shift of the function + Normalisation
Lack of low and high ψ value for LFG CCQE

ψ(q0,q)

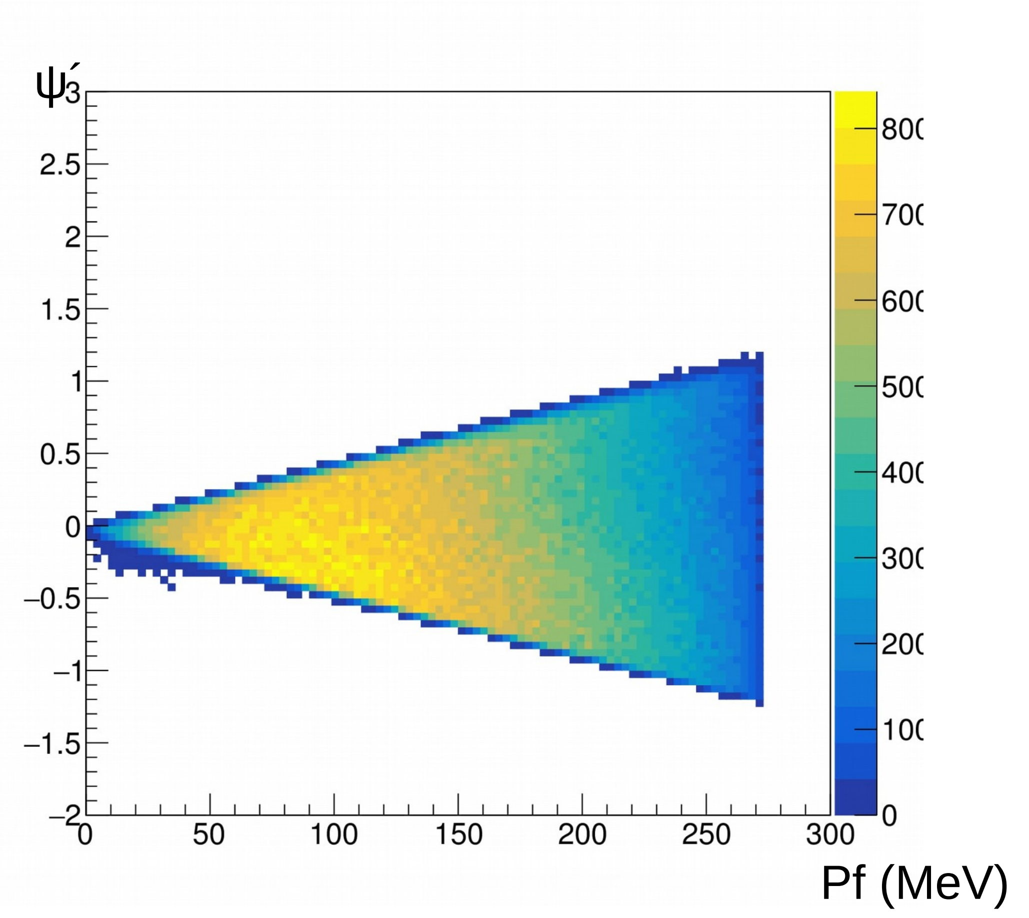
- Red line ψ´ value
- Nieves CCQE cross section

- Transfer energy and transfer momentum allowed by our model are in the zone where ψ' is between ~-1,5 and 1



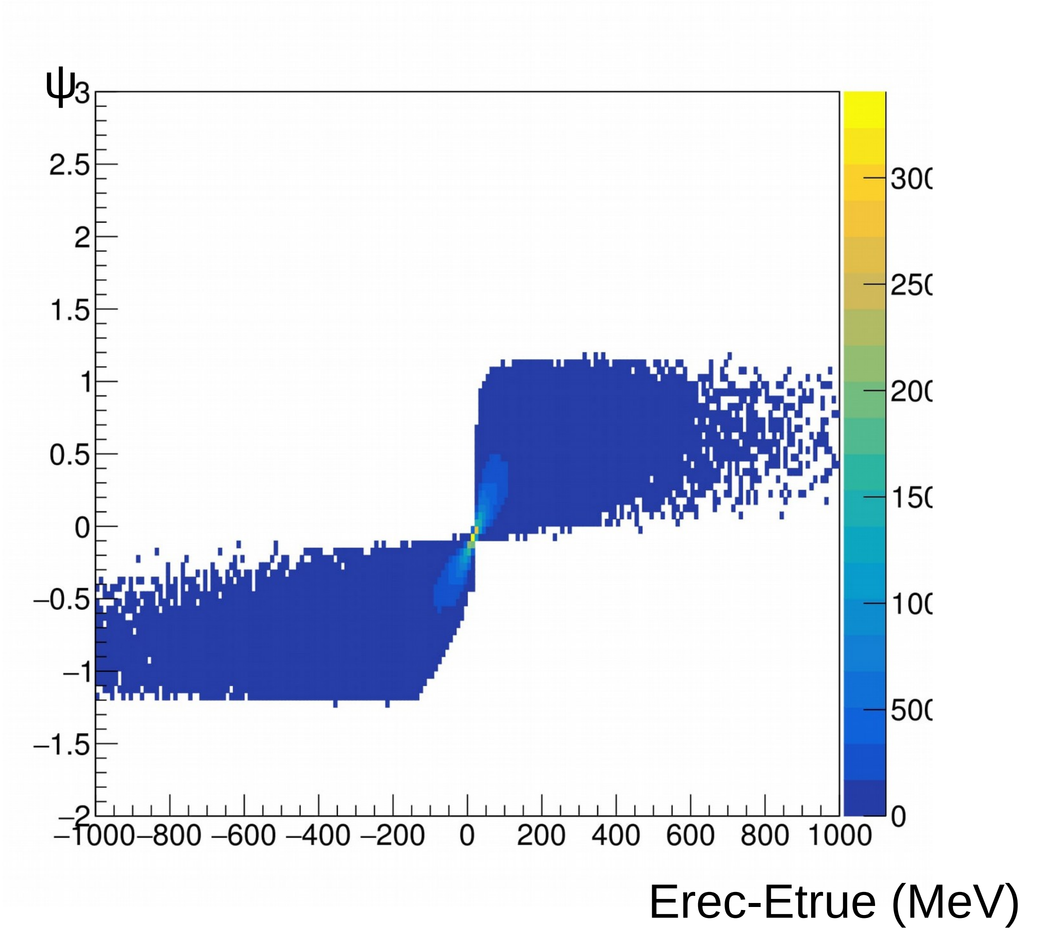
Reason for lack of high ψ' ?

- Scaling variable depending fermi momentum
- Lack of high ψ' tail → limited Fermi Momentum
- But LFG Model restrict Fermi momentum



Effect on reconstructed energy

- Scaling variable vs Reconstructed neutrino energy - true neutrino energy
- Scaling variable affect energy reconstruction
- Could be predicted due to relation between this variable and fermi momentum



Monte Carlo from SUSA

Obtained from Susa papers.

$$\frac{d\sigma^{SUSA}(E_\nu)}{dE_\mu d\cos\theta_\mu} = \boxed{\frac{d\sigma^{RFG}(E_\nu)}{dE_\mu d\cos\theta_\mu}} \boxed{f^{SUSA}(\psi'(E_\nu, E_\mu, \theta_\mu))}$$

This can be obtained from NEUT increasing the Fermi level to large values (500 MeV/c)

This approach will allow us to have a full kinematics of the hadron component.

Need to understand how to include the Pauli blocking.

Conclusion

- First comparison between SuSA and LFG model made
- Potential loss of CCQE cross section in our LFG model for high value of the scaling varaible => for event where transfer energy contribution is higher (for a fix transfer momentum)
- Scaling variable value linked Fermi momentum