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NC gamma, an exclusive channel for neutrino generator

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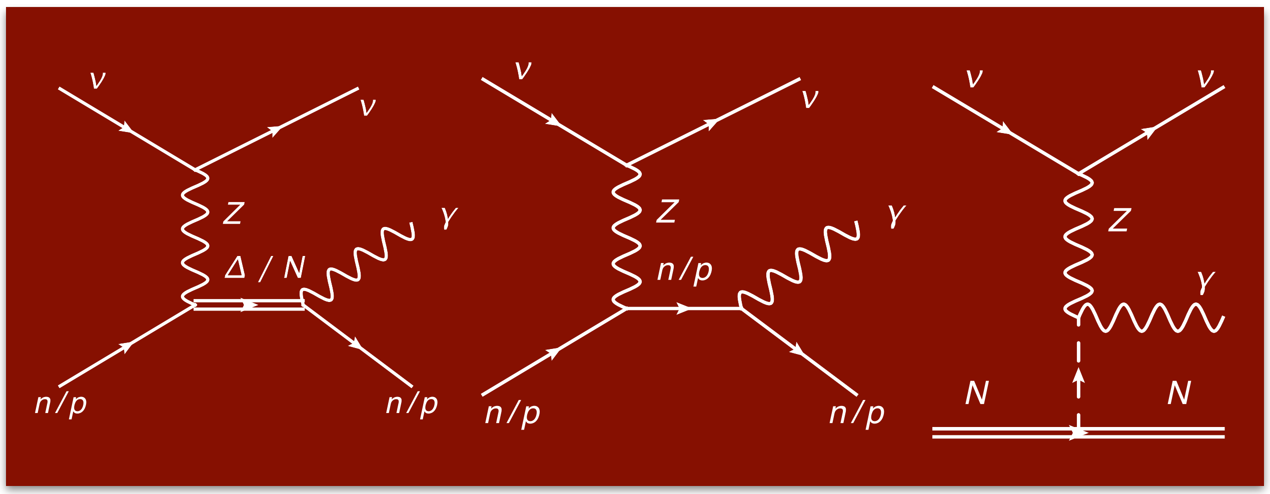
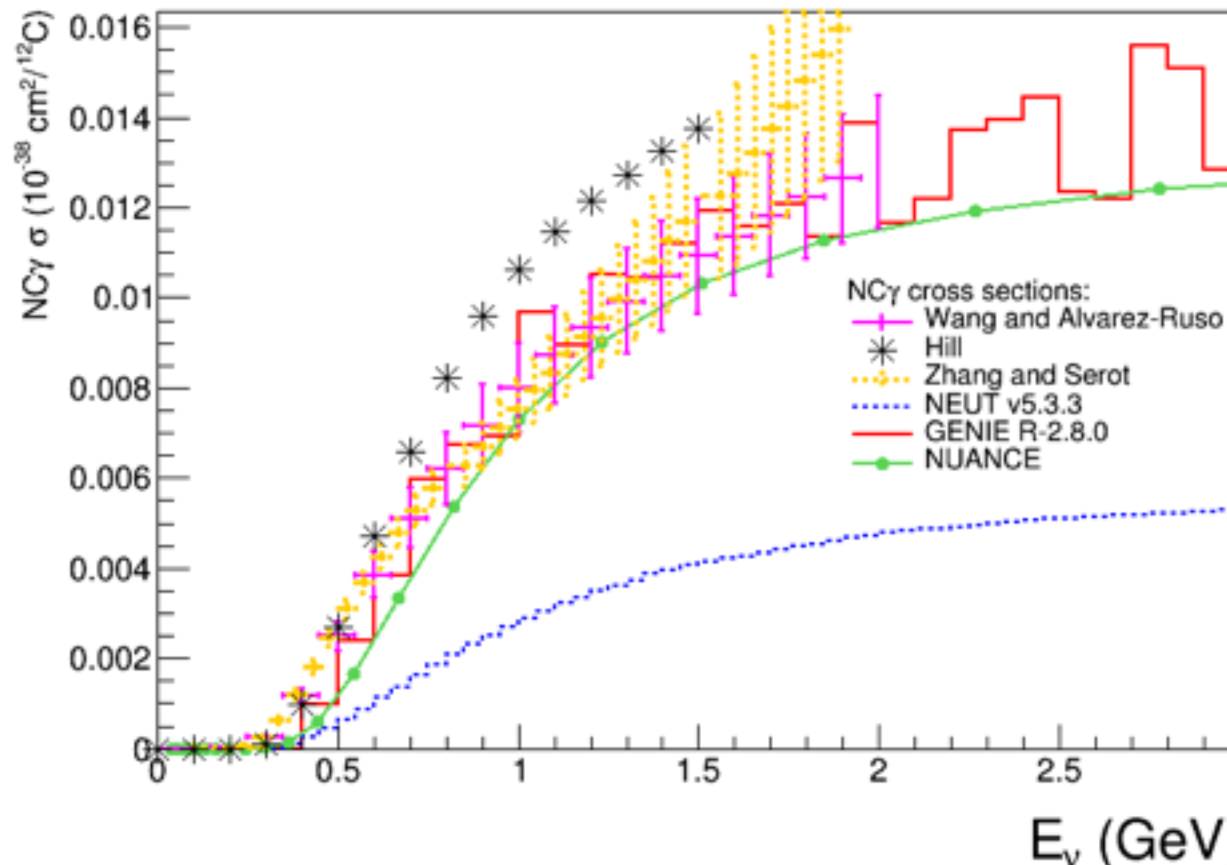
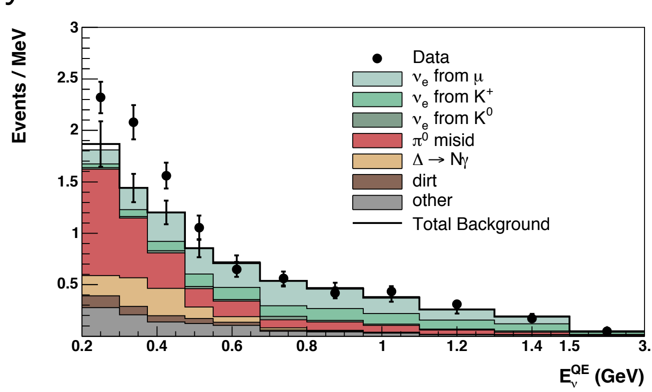
Introduction

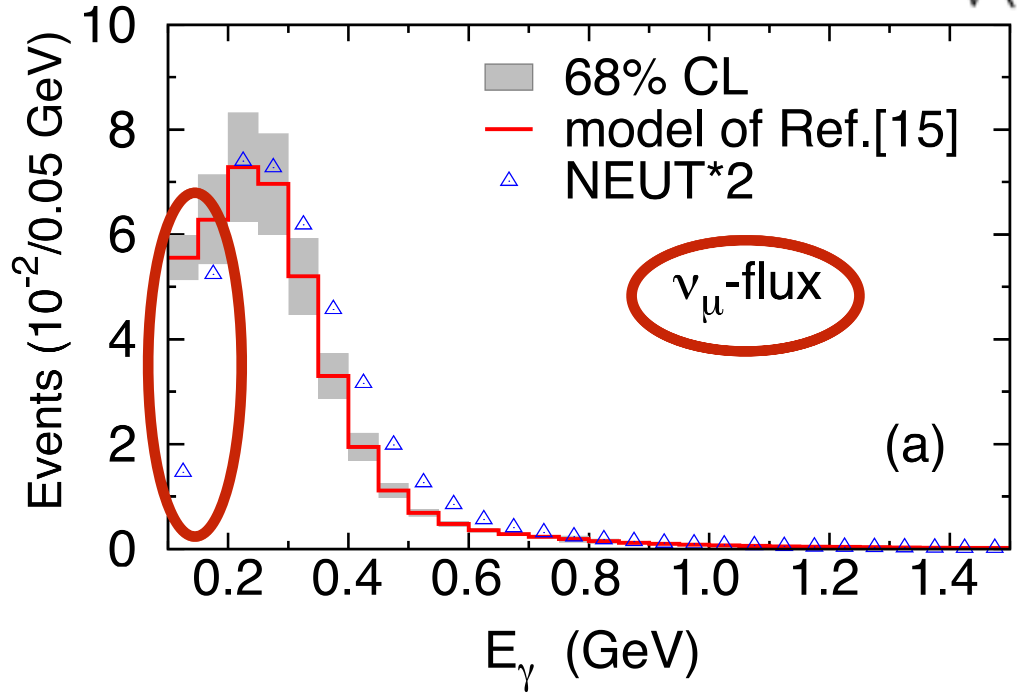
- NC gamma?
  - ➡ Neutrino interacts and creates a single photon





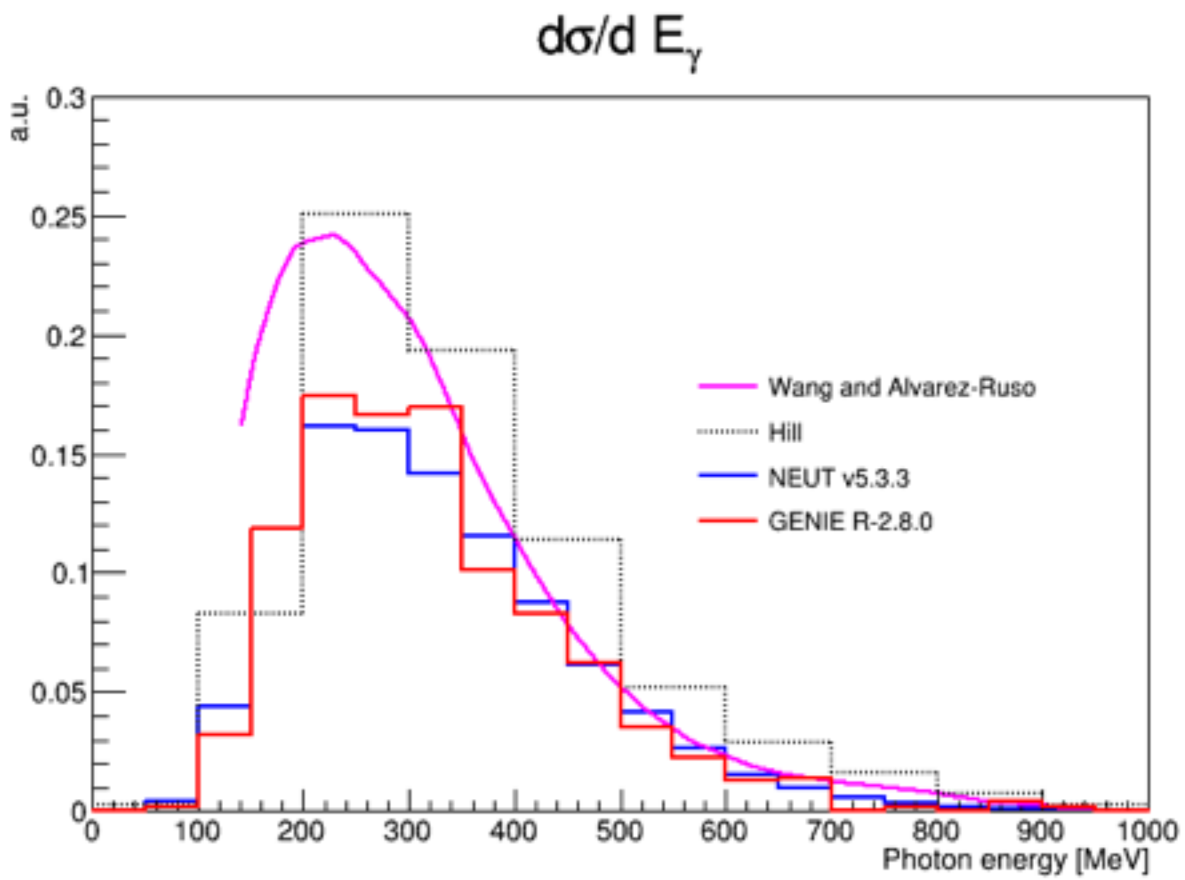
- Why this is important?
  - ➡ Potentially an effect on electron neutrino appearance.

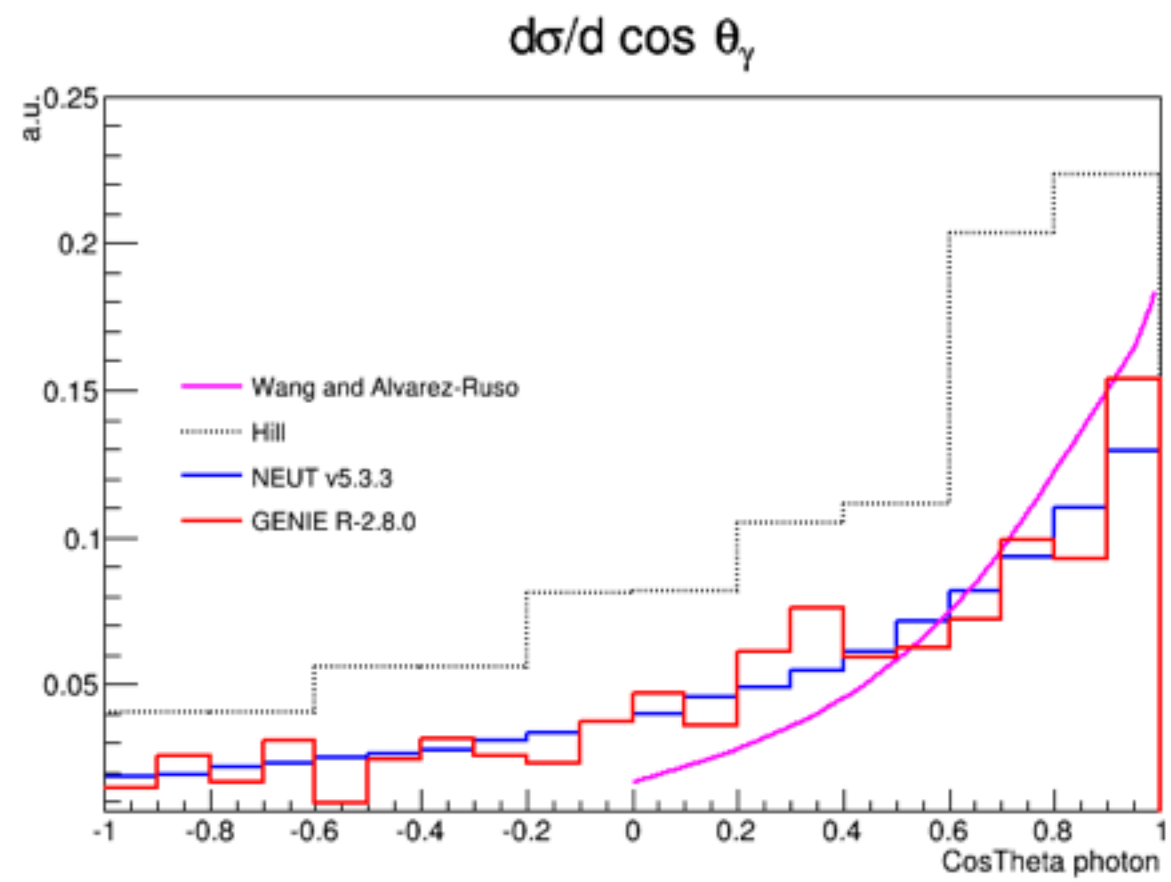




  - ➡ No measurement at next neutrino long baseline experiment energies
  - ➡ Can *hopefully* be seen in liquid Argon detector.

What is available (to me)?



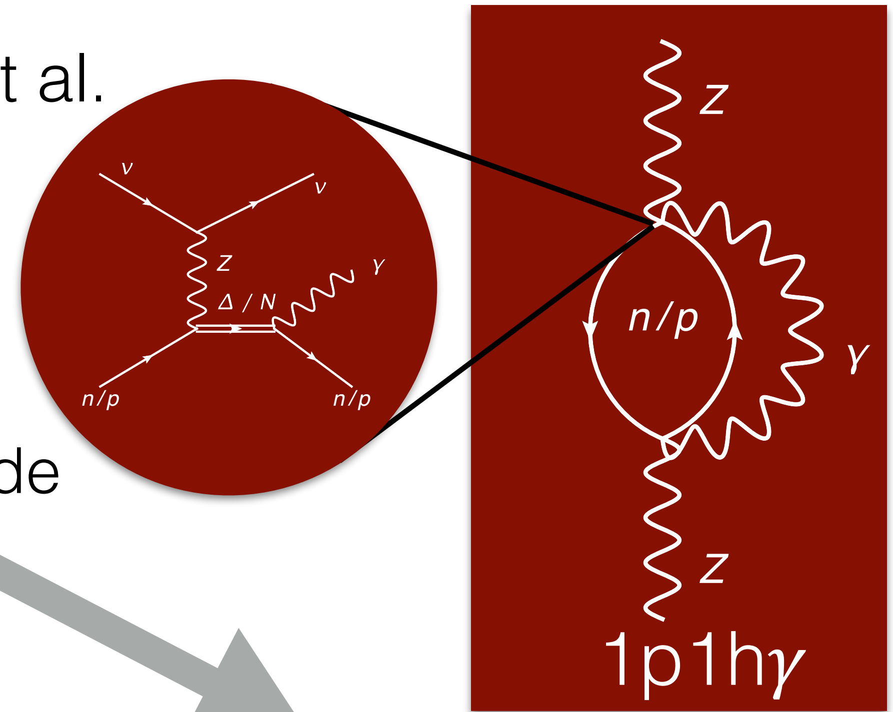


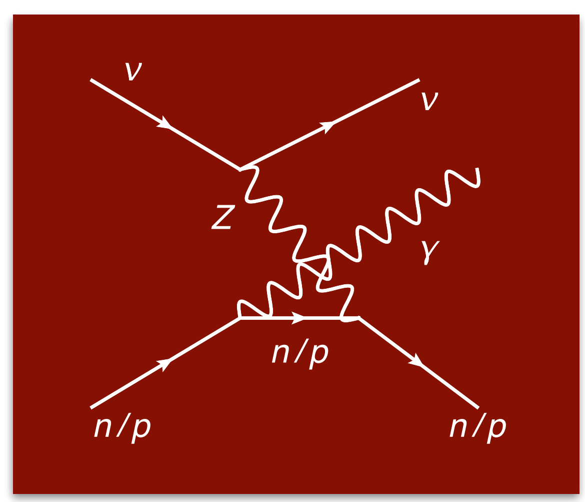
1 GeV muon neutrino on Carbon

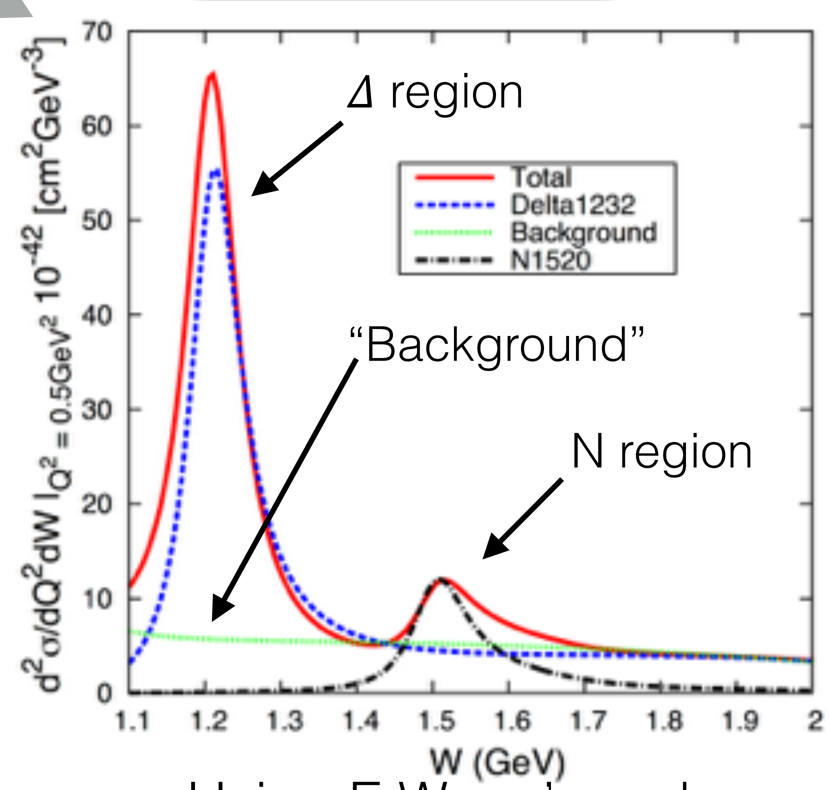
- Shape seems to disagree between model/generator for differential cross sections.

The model

- There are lot of models… We are using Wang et al.
- Few of the features:
  - 1p1hγ Z self-excitations
  - Full treatment of the resonances at the amplitude level: interferences.
  - Polarisations: all the photons are not decaying isotropically in the resonance rest frame.
  - In medium effects for the Δ-propagator. (absorption, scattering)
- Complicated! The cross section ultimately will depend on lots of parameters.







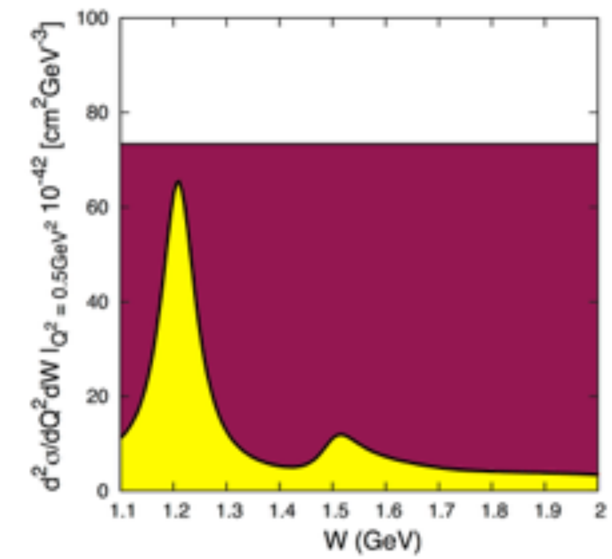
Using E.Wang's code

How to generate neutrino events?

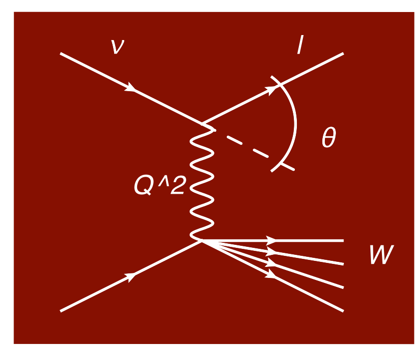
- Usually the neutrino energy and nucleon energy is known (flux and nuclear model)
- For a few of the processes, generators use 2D cross sections → Q^2 and W for given E_ν

$$\frac{\partial^2 \sigma}{\partial W \partial Q^2}$$

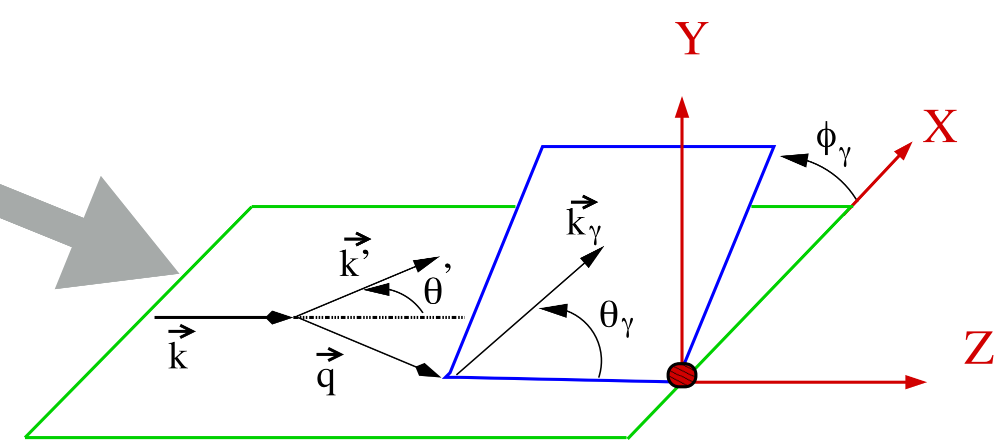
- You use a "rejection method" to choose these 2 variables simultaneously.



- Using energy conservation, one can get the outgoing lepton:
  - Energy
  - cos(θ)



- For the hadronic part, only the energy is know…
  - One has to throw the variable (angle between the scattering plane and outgoing photon…)



- How can we fit the model describe before without loosing physics?

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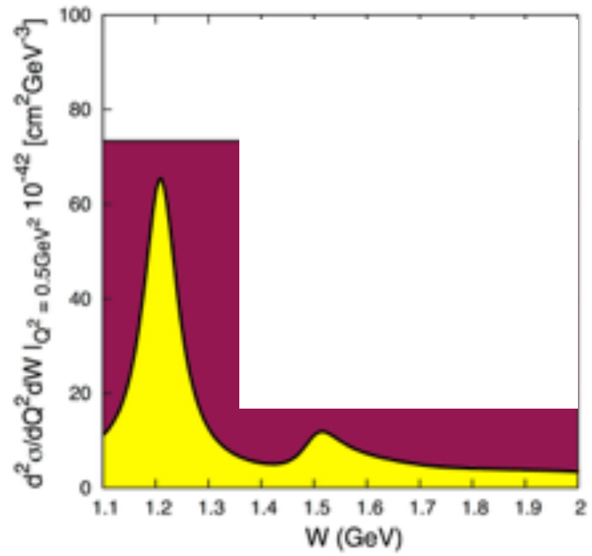
The basic idea

- Increasing the dimensionality of the problem to parametrise the effect one wants to model.

$$\frac{\partial\sigma}{\partial W \partial Q^2 \partial \ldots}$$

- The problem: The rejection method will take very long time (T^Dim)… Slows the event generation.
- There are few ways:
  - "Precalculate" the cross section if the cross is long to calculate and store it:
    - Generator becomes heavy
    - Complicated to extend to different targets
    - Error estimation (shape) is almost impossible to get
  - Importance sampling
    - Intelligent rejection method



In case of NC gamma

- We are not interested in the outgoing neutrino.
- One can keep Q information (direction, magnitude) using (assuming E_ν and p_{nucl} are known)
  - Q^2 and W → Resonant process
  - Bjorken x and y → Deep inelastic scattering
  - $\cos(\theta_{lep})$ and p_{lep} → CC interaction
- Photon information:
  - $\cos(\theta)$ and $\cos(\varphi)$ → 2 angular variables since the resonance is polarised, the decay is not isotropic.
  - The photon energy come from energy conservation on the hadronic mass frame
- Note: this is still a simplification, some of the effects depend on local nuclear density…

Conclusion

- The NC gamma channel is important as long as we have not seen it or properly sized.
- The predictions from modern generators and theorists were compared.
- The methods to include new exclusive channels was explained.
- Implementing properly this kind of channel in the generators becomes more and more important as differences between models are subtle. The time is for precision!

Thank you for your attention

Ref

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