Systematic Effects in Detector Simulations

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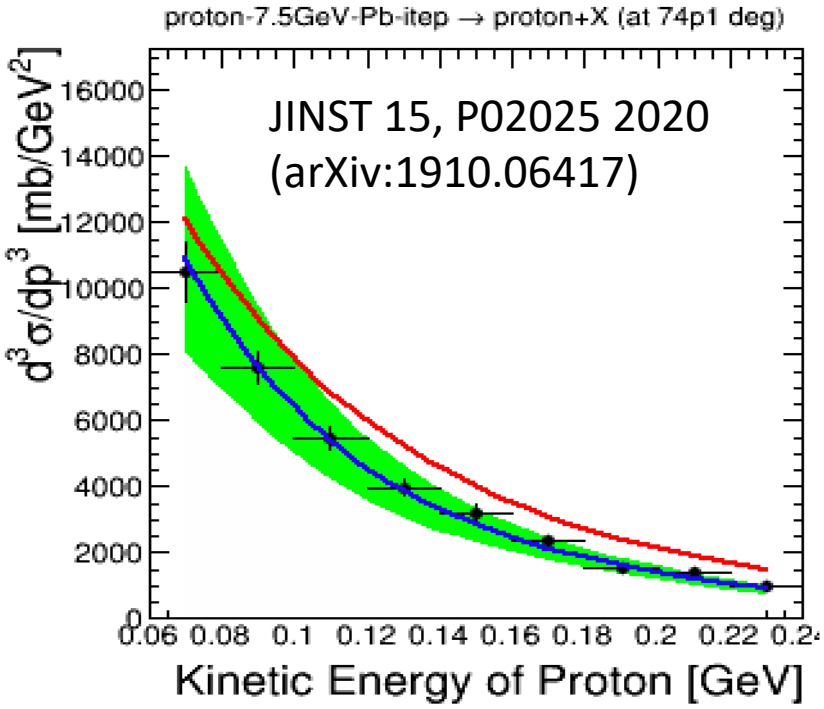
- Uncertainties in experimental results come from various sources, including but not limited to event generation, detector simulation, reconstruction, etc.
- Detector simulation toolkits, e.g. Geant4, simulate particles passing through and interacting with matter by employing a collection of models that cover a wide range of interactions types and energies
  - Model: set of rules/algorithms aiming to describe/simulate physics processes/events; includes **hypotheses** and **parameters**
  - All models have room for what we do not know:

    "Reality" = Prediction + Δstat + Δparams + Δmodel
- The challenge: what uncertainties are associated with the models and how they translate into simulated observables

Systematic Effects in Detector Simulations (II)

- In recent releases, Geant4 extended configuration interfaces to several physics models, including hadronic ones
- This opens possibilities to extract optimal values of parameters and to determine their uncertainties and ranges, using (e.g. thin target) data and tuning tools
  - E.g. Professor tuning toolkit https://professor.hepforge.org
- One can estimate the uncertainties of Geant4 predictions using tuned parameters, their uncertainties and correlations



Data from Yu.D.Bayukov et al., Preprint ITEP-148-1983 are compared with default Geant4 Bertini model simulation (v4.10.4) and the global Professor fit; green band is uncertainty propagated from the fit results

Systematic Effects in Detector Simulation (III)

- Significant steps have been made by e.g. Geant4 collaboration towards understanding uncertainties in the simulated results, but a number of challenges remain, including:
  - Models involved in detector simulation typically rely on **many** parameters; estimating their uncertainties and correlations among them through fitting techniques requires FTE's and CPU
    - Only a fraction of Geant4 model parameters has been explored so far
  - Simulating thin target data (i.e. single interaction) and estimating uncertainties is CPU expensive already. Propagating such knowledge to the full-scale detector simulation, e.g. hadronic showers, etc., is very computationally demanding
- Further exploration of efficient methods to estimate uncertainties in simulated results is needed (this may include other tuning techniques if/where applicable)