Dimuon production in DIS with charm-mass effects

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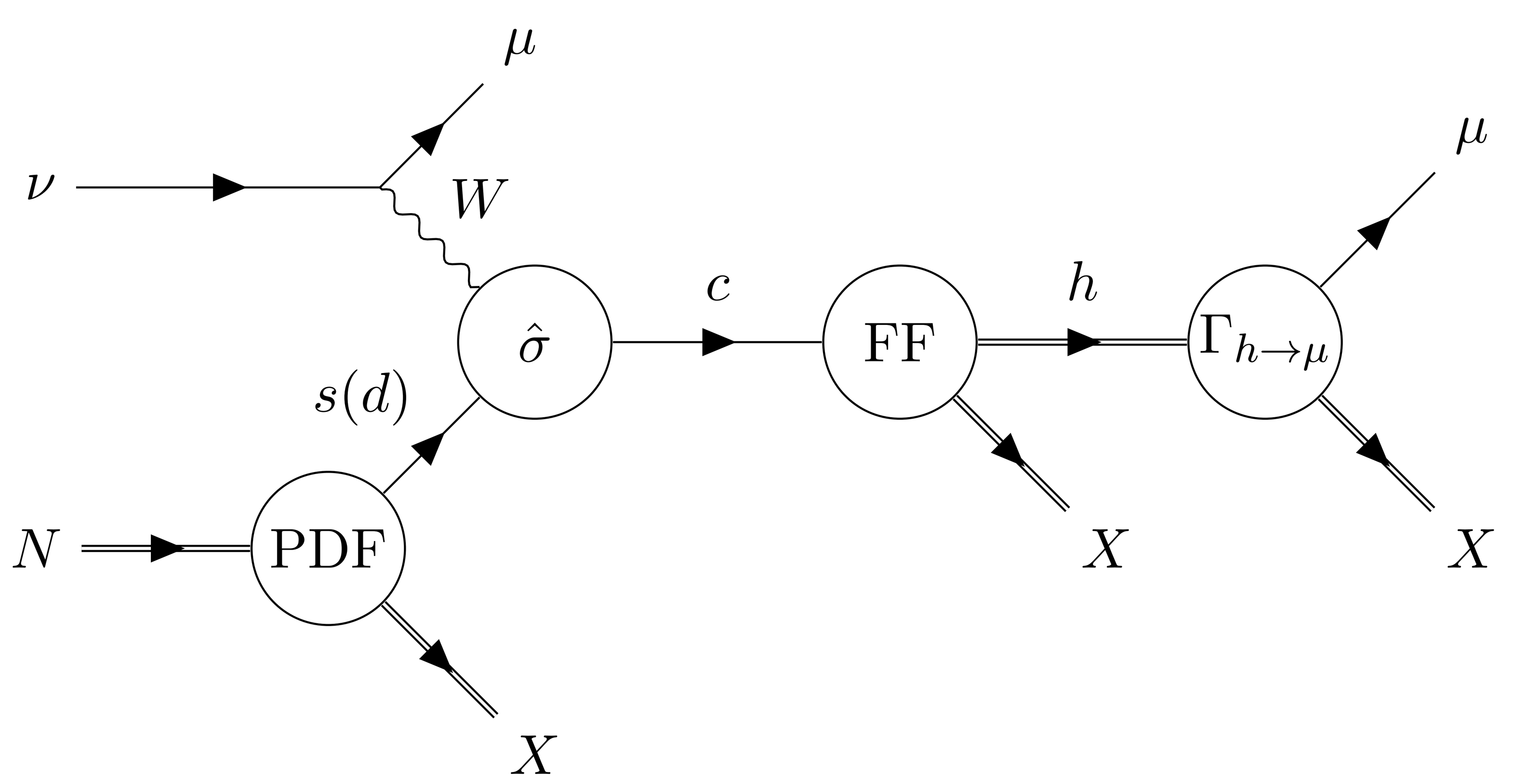
Why study charm-mass effects in $\mu\mu$ production?

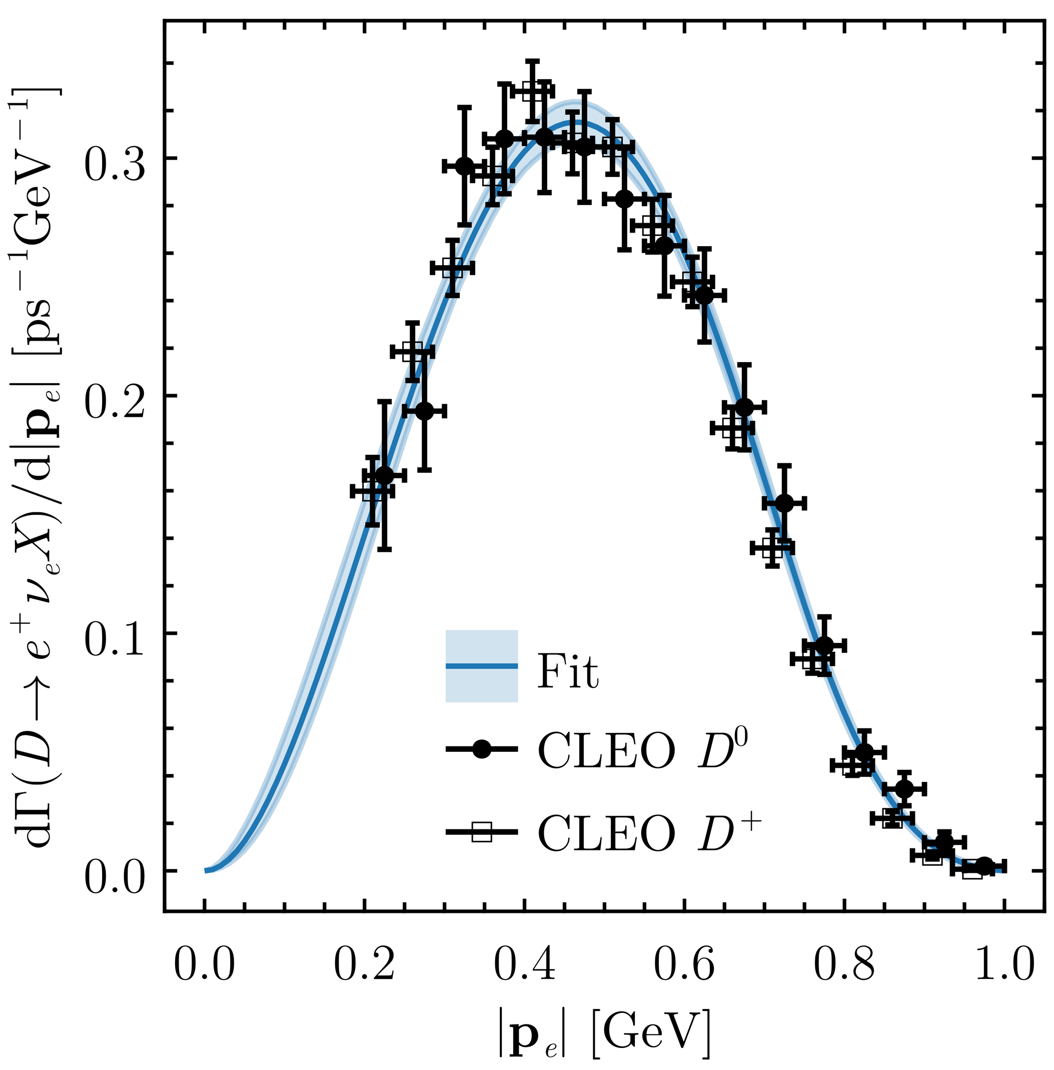
- Dimuon production in neutrino-nucleus collisions provides important constraints for the strange PDF in protons and nuclei
- Second muon comes from the decay of the charmed hadron $\rightarrow$ charm-mass effects important in precision PDF analyses

How do we compute $\mu\mu$ production?



- Semi-inclusive DIS to compute charmed-hadron production
- Fit CLEO data to obtain a "decay function" for the muonic decay

$$\sigma(\mu\mu) = \sum_h \int \mathrm{d}\sigma(\mu h) B_{h\to\mu}(E_\mu^{\mathrm{min}})$$



- SIDIS mass schemes at NLO for charm-mass effects
  - zero-mass (ZM): no mass corrections [1]
  - slow-rescaling (SR): kinematic mass corrections only [1]
  - SACOT-χ: kinematic + matrix-element mass corrections [2]

Why a new calculation?

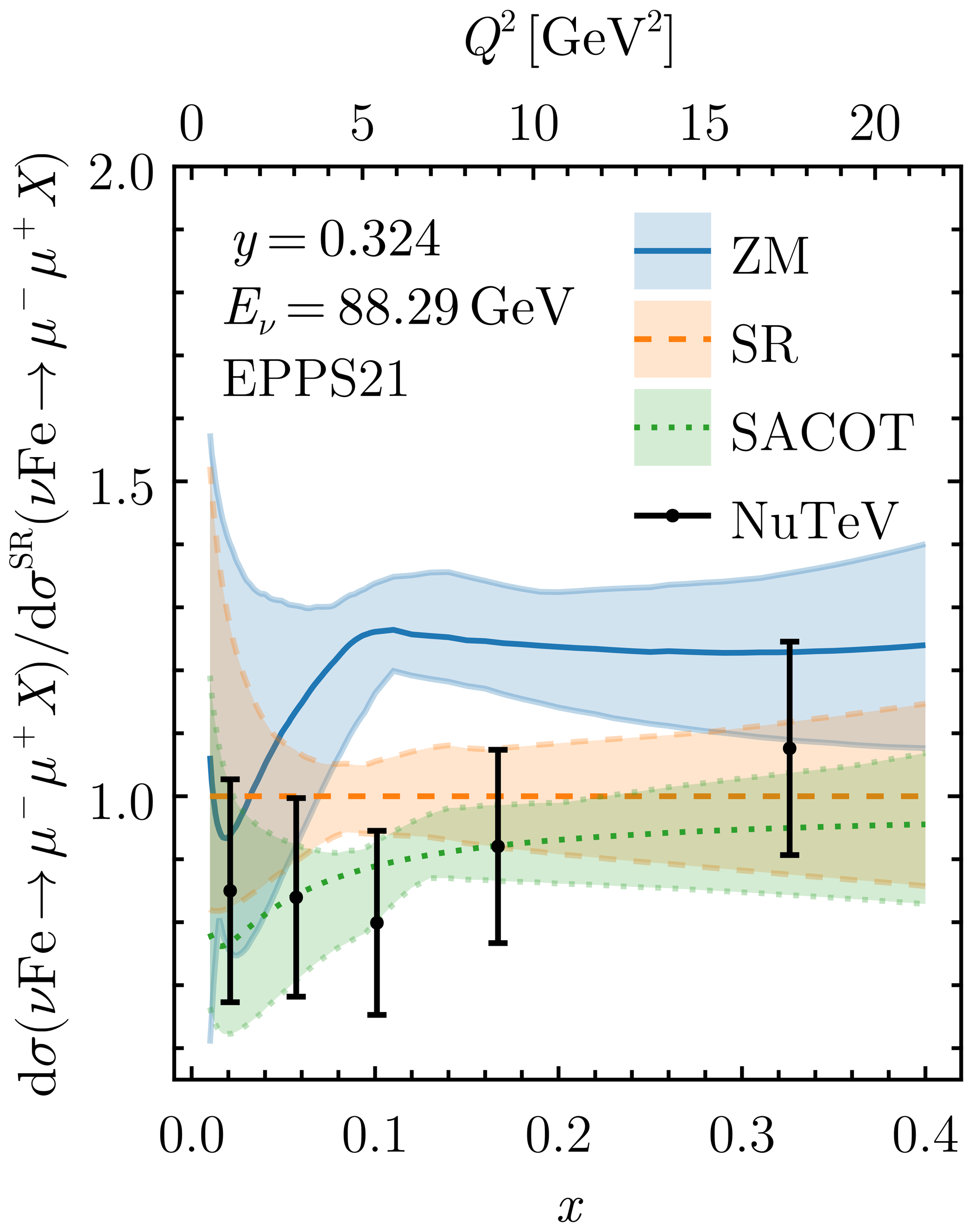
- In typical PDF fits, dimuon production is computed using inclusive charm production as

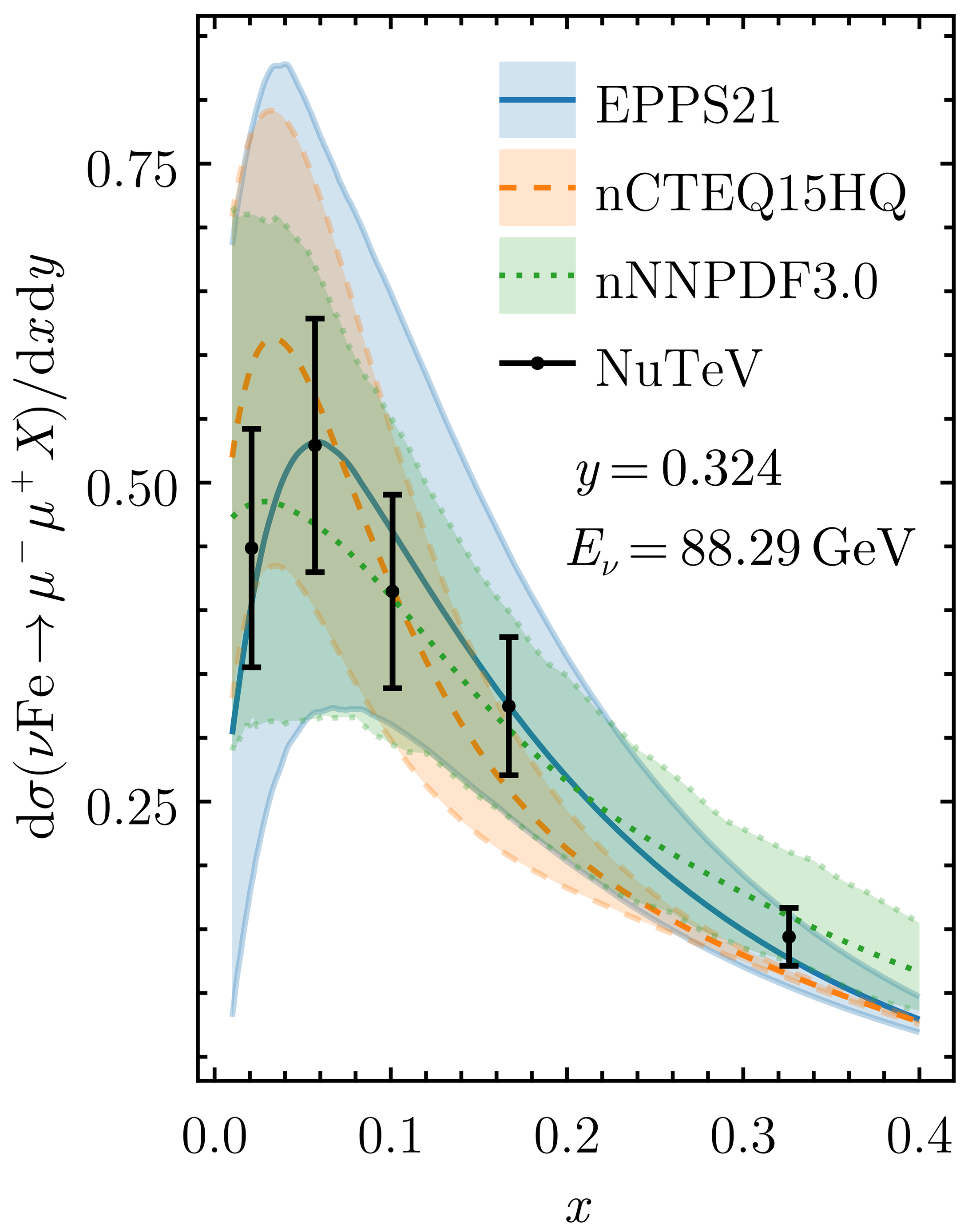
$$\sigma(\mu\mu) = \text{acceptance} \times \text{effective branching fraction} \times \sigma(c\mu)$$

- Acceptance depends on details of the calculation (PDF, variable flavor scheme, perturbative order, ...), but this is usually neglected $\rightarrow$ want an approach where the acceptance is not needed
- Inclusive charm production is not always infrared-safe

What are the effects of charm mass?

- No matrix-element mass corrections at leading order $\rightarrow$ the bulk of mass corrections are kinematical
- Modifications of up to $20\,\%$ in the SACOT-χ scheme $\rightarrow$ inclusion of all mass corrections still important





What did we learn and what's next?

- We obtain good agreement with NuTeV and CCFR dimuon data without depending on the acceptance
- Charm-mass effects are significant at low Q^2, but most impact comes from purely kinematical effects
- Work ongoing for NNLO corrections in the SR scheme

[1] I. Helenius, H. Paukkunen, and S. Yrjänheikki. "Dimuons from neutrino-nucleus collisions in the semi-inclusive DIS approach". In: *JHEP* 09 (2024), p. 043. arXiv: 2405.12677.

[2] H. Paukkunen, I. Helenius, and S. Yrjänheikki. "Improving the description of dimuon production in neutrino-nucleus collisions using the SACOT-χ scheme". In: (June 2025). arXiv: 2506.09492.

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