Neutrinos from Charm:
Forward production at the LHC and in the atmosphere

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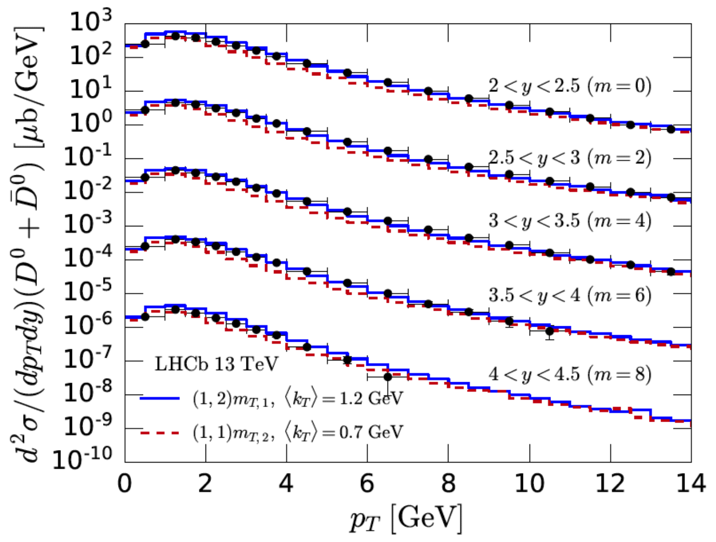
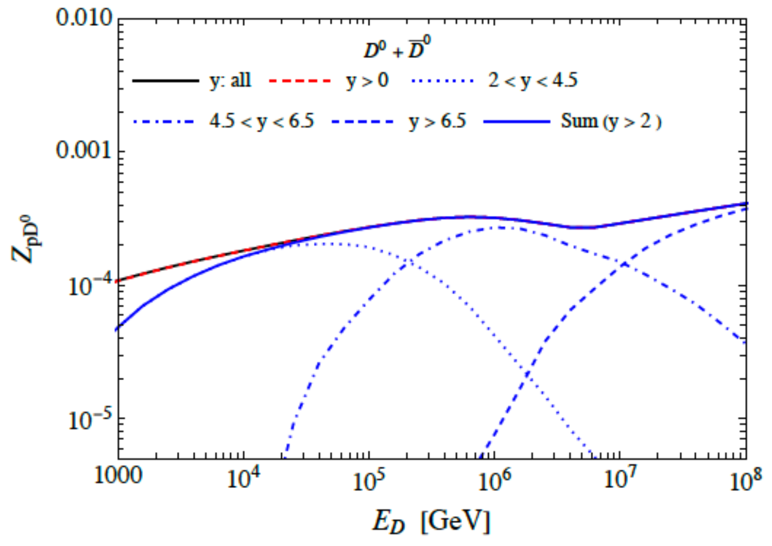
1. Introduction

- Fluxes of neutrinos from heavy flavor decays (prompt neutrinos) have large uncertainty, mainly due to ambiguity of heavy flavor production.
- Prompt neutrinos produced at high energies in the atmosphere is the primary background to astrophysical neutrinos.
- Prompt neutrinos are also produced at the LHC, and expected to be measured by upcoming forward experiments at the LHC [1, 2].
- Measurements of heavy flavor and prompt neutrino at the LHC can improve theoretical predictions of the prompt neutrino flux.
- What we have done in this work:
  - Investigation of kinematic region relevant for prompt atmospheric neutrino flux prediction in terms of collider related variables, $\sqrt{s}$ and y.
  - Impact of PDF at small-x and large-x.

2. Charm meson production



The differential cross sections of $D^0+\bar{D}^0$ production in pp collision at $\sqrt{s}$ = 13 TeV and comparison with the LHCb data [3].

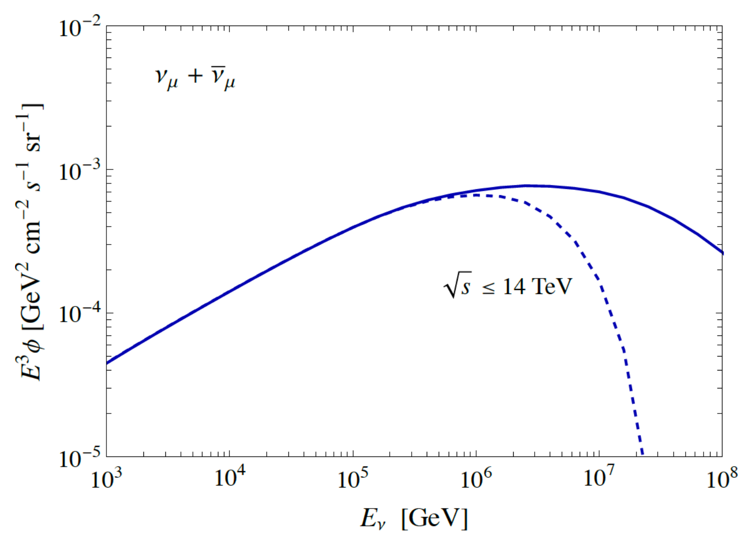


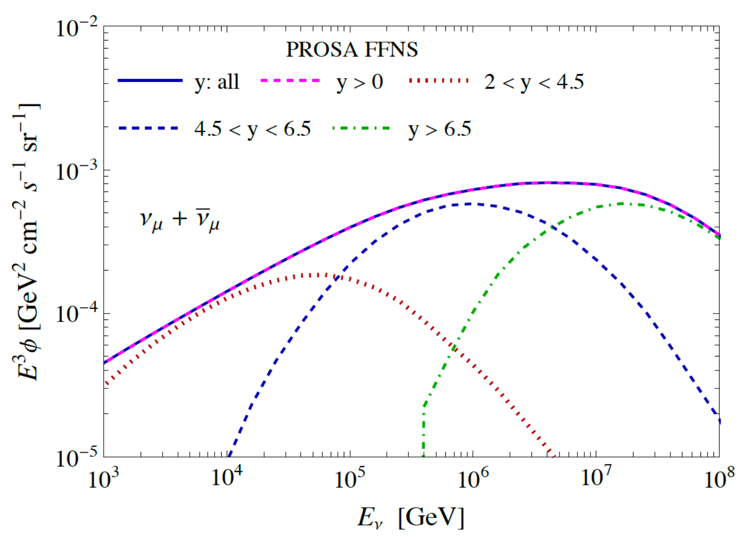
The Z moment for $D^0+\bar{D}^0$ production in p-Air collisions.

$$Z_{kj}(E) = \int_E^\infty dE' \frac{\phi_k^0(E')}{\phi_k^0(E)} \frac{\lambda_k(E)}{\lambda_k(E')} \frac{dn(k\to j; E', E)}{dE}$$

3. Prompt atmospheric neutrino fluxes

- **Collision energy $\sqrt{s}$ and rapidity y**

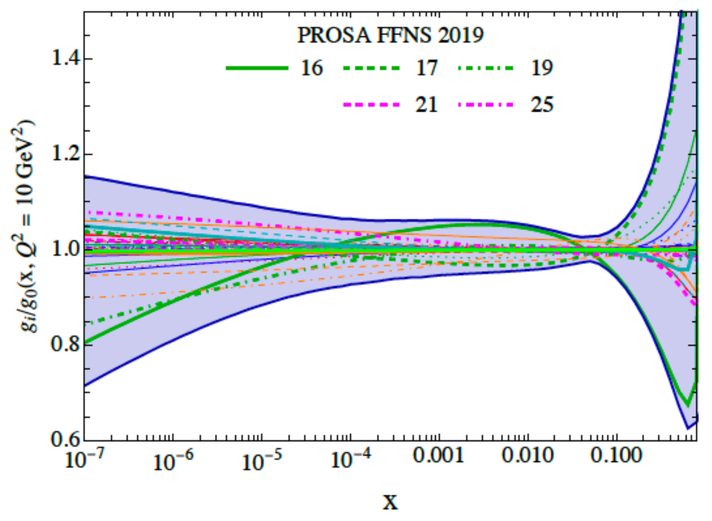




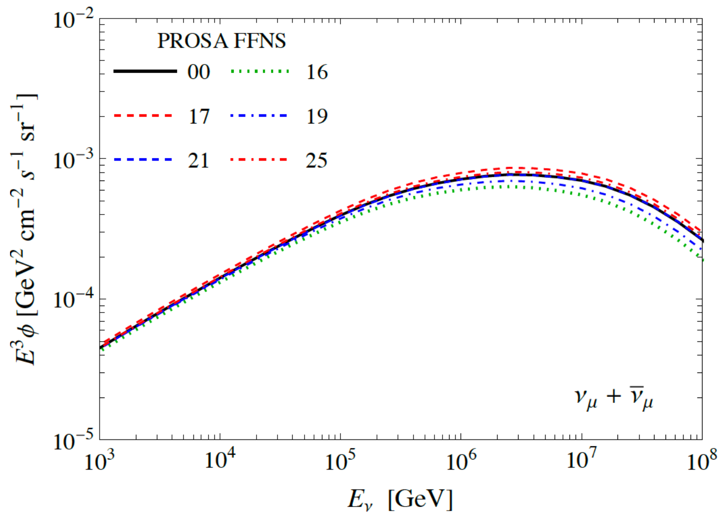
The flux of prompt atmospheric neutrinos evaluated with the collision energy $\sqrt{s}\leq 14$ TeV (left) and from charm mesons produced in different rapidity ranges (right).

- The collision energy $\sqrt{s}=14$ TeV accessible by the LHC corresponds to the lab frame energy $E_p\sim 10^8$ GeV.
- Charm meson production at this energy has contribution to the atmospheric neutrinos at high energies of interest, relevant for probing astrophysical neutrinos.
- At such energies, the most important contribution to the prompt atmospheric neutrinos are from the charm meson produced in 4.5 < y < 6.5.

- **Impact of the small-x and large-x**



The gluon distribution functions of the 40 PROSA FFNS sets [3] normalized to the central set for $Q^2=10$ GeV^2, and their uncertainty



The prompt atmospheric neutrino fluxes evaluated with the maximally deviated PDF sets.

Effect increases with energy in general and it is within 30 % for $E_\nu < 10^8$ GeV.

4. Outlook

- The prompt neutrinos in the few PeV energies, important as background to astrophysical neutrinos, are produced mainly in the rapidity of 4.5 < y < 6.5.
  - Data by measurement exist in y < 4.5.
  - New experiments, FASERν and SND@LHC will probe in $\eta\gtrsim 7$.

  ➡ If forward physics facility (FPF) in future will cover between these rapidity, it will help to improve theoretical prediction of prompt atmospheric neutrino flux.
- The PDF uncertainty is a part of total uncertainty, and it would be constrained by the future forward experiments at the LHC.
- Experimental investigation of charm production and neutrinos in new kinematic regions will guide evaluation of the prompt atmospheric neutrino flux.

References

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[3] R. Aaij et al. [LHCb], JHEP 03 (2016) 159 [erratum: JHEP 09 (2016) 013; erratum: JHEP 05 (2017) 074]
[4] O. Zenaiev et al. [PROSA], JHEP 04 (2020) 118
[5] Weidong Bai, M. Diwan, M. V. Garzelli, Yu Seon Jeong, Fnu Karan Kumar, and M. H. Reno, in preparation (2021).

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