Neutrino Production

From ATLAS IP to FASER

- At s = 13 TeV, the inelastic cross section is approximately, σ_inel 13 TeV ~ 75 mb
- For LHC Run 3 (250 fb-1), this corresponds to ~10^16 light particles produced
  - Angular spread of meson decays θ ~ $m\pi/E(TeV)$~ mrad

Particle	Decay mode	Branching fraction (approx.)
π^+	$\pi^+ \to \mu^+\nu_\mu$	99.9877%
	$\pi^+ \to e^+\nu_e$	1.23×10^{-4} (helicity suppressed)
K^+	$K^+ \to \mu^+\nu_\mu$	63.56%
	$K^+ \to \pi^0 e^+\nu_e$ (Ke3)	5.07%
D^0	Inclusive semileptonic	$\mathcal{B}(D^0 \to Xe^+\nu_e) \approx 6.46\%$
D^+	Inclusive semileptonic	$\mathcal{B}(D^+ \to Xe^+\nu_e) \approx 16.13\%$
D_s^+	$D_s^+ \to \tau^+\nu_\tau$	5.36%

More physics

FASER physics

- **Light mesons (π, K)** → dominate the low-energy ν flux: **Precision SM tests:** Cross-sections of νe, νμ, ντ.
  - High-energy ν (TeV scale) come mainly from charm and beauty decays.
  - **Tau neutrinos (ντ)** are *almost entirely* from Ds → τντ → … chains.
  - Testing lepton universality (does ντ interact as predicted, same as νμ, νe?).
  - Study neutrino CC interactions with charm production ($\nu s \to lc$) (No charmed hadron has been observed in $\nu_e CC$ interactions)
  - **Long-Lived Particles (LLPs)** are hypothetical particles predicted by many extensions of the Standard Model. (Decay inside a detector like FASER → visible signatures (e.g. e^+e^-, $\mu^+\mu^-$, γγ).
- QCD uncertainties
  - Forward production of charm and beauty is **not well measured** by ATLAS/CMS (θ ≲ 1 mrad), because they don't cover the extreme forward region.
  - Models (PYTHIA, EPOS, SIBYLL, etc.) disagree significantly.
- By measuring neutrino rates and spectra - FASER indirectly constrains **how many charm/beauty hadrons were produced**.