

# Neutrino Production

## From ATLAS IP to FASER

- At  $s = 13$  TeV, the inelastic cross section is approximately,  $\sigma_{inel} 13\text{ TeV} \sim 75$  mb
- For LHC Run 3 (250 fb<sup>-1</sup>), this corresponds to  $\sim 10^{16}$  light particles produced
  - Angular spread of meson decays  $\theta \sim m\pi/E(\text{TeV}) \sim \text{mrad}$

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

# More physics

## FASER physics

- **Light mesons ( $\pi$ ,  $K$ )**  $\rightarrow$  dominate the low-energy  $\nu$  flux: **Precision SM tests:** Cross-sections of  $\nu_e$ ,  $\nu_\mu$ ,  $\nu_\tau$ .
  - High-energy  $\nu$  (TeV scale) come mainly from charm and beauty decays.
  - **Tau neutrinos ( $\nu_\tau$ )** are *almost entirely* from  $D_s \rightarrow \tau \nu_\tau \rightarrow \dots$  chains.
- Testing lepton universality (does  $\nu_\tau$  interact as predicted, same as  $\nu_\mu$ ,  $\nu_e$ ?).
- Study neutrino CC interactions with charm production ( $\nu_s \rightarrow l c$ ) (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  $\rightarrow$  visible signatures (e.g.  $e^+e^-$ ,  $\mu^+\mu^-$ ,  $\gamma\gamma$ )).
- QCD uncertainties
  - Forward production of charm and beauty is **not well measured** by ATLAS/CMS ( $\theta \lesssim 1$  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**.