

Neutrino Production

From ATLAS IP to FASER

- At $s = 13$ TeV, the inelastic cross section is approximately, $\sigma_{inel} 13\text{ TeV} \sim 75\text{ mb}$
- For LHC Run 3 (250 fb⁻¹), 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.)
π^+	$\pi^+ \rightarrow \mu^+ \nu_\mu$	99.9877%
	$\pi^+ \rightarrow e^+ \nu_e$	1.23×10^{-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 (π , K)** \rightarrow dominate the low-energy ν flux: **Precision SM tests:** Cross-sections of ν_e , ν_μ , ν_τ .
 - High-energy ν (TeV scale) come mainly from charm and beauty decays.
 - **Tau neutrinos (ν_τ)** are *almost entirely* from $D_s \rightarrow \tau \nu_\tau \rightarrow \dots$ chains.
- Testing lepton universality (does ν_τ interact as predicted, same as ν_μ , ν_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**.