

Emerging Jets Displaced into the Future

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and Daniel Stolarski

arXiv:2112.05690

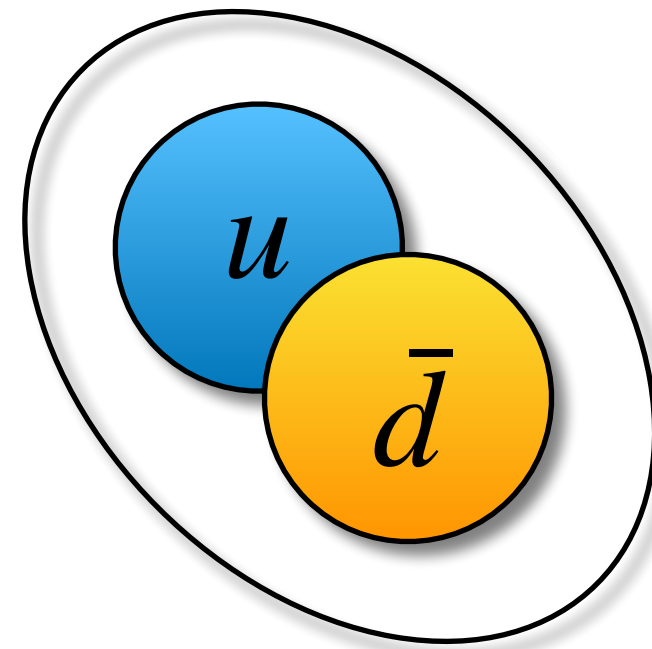
June 1st, LLP 11



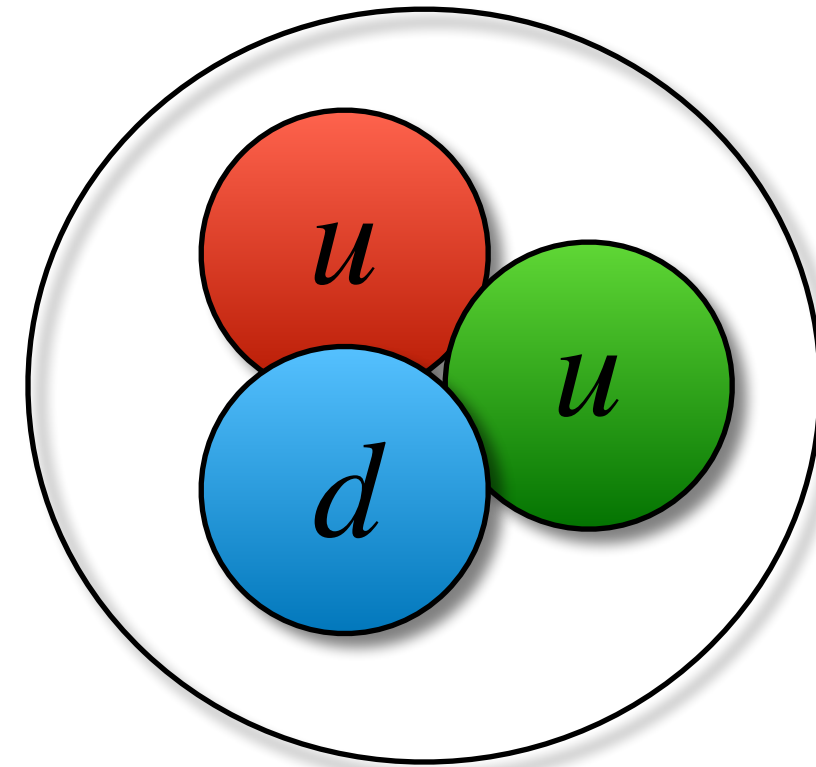
Dark QCD

(Ref: Schwaller et al arXiv:1502.05409)

Mesons:

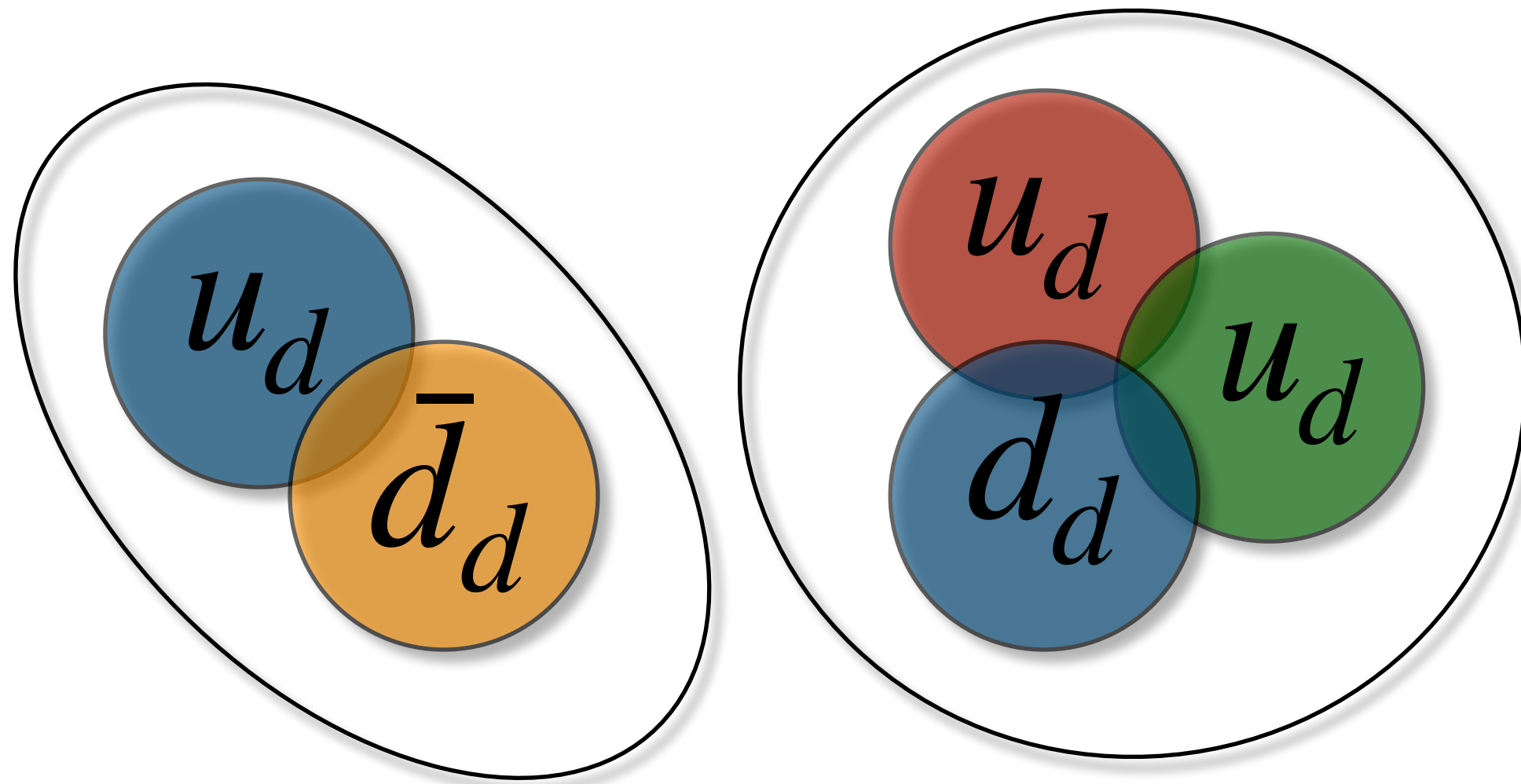


Baryons :



- Dark QCD confines at some QCD-like scale.

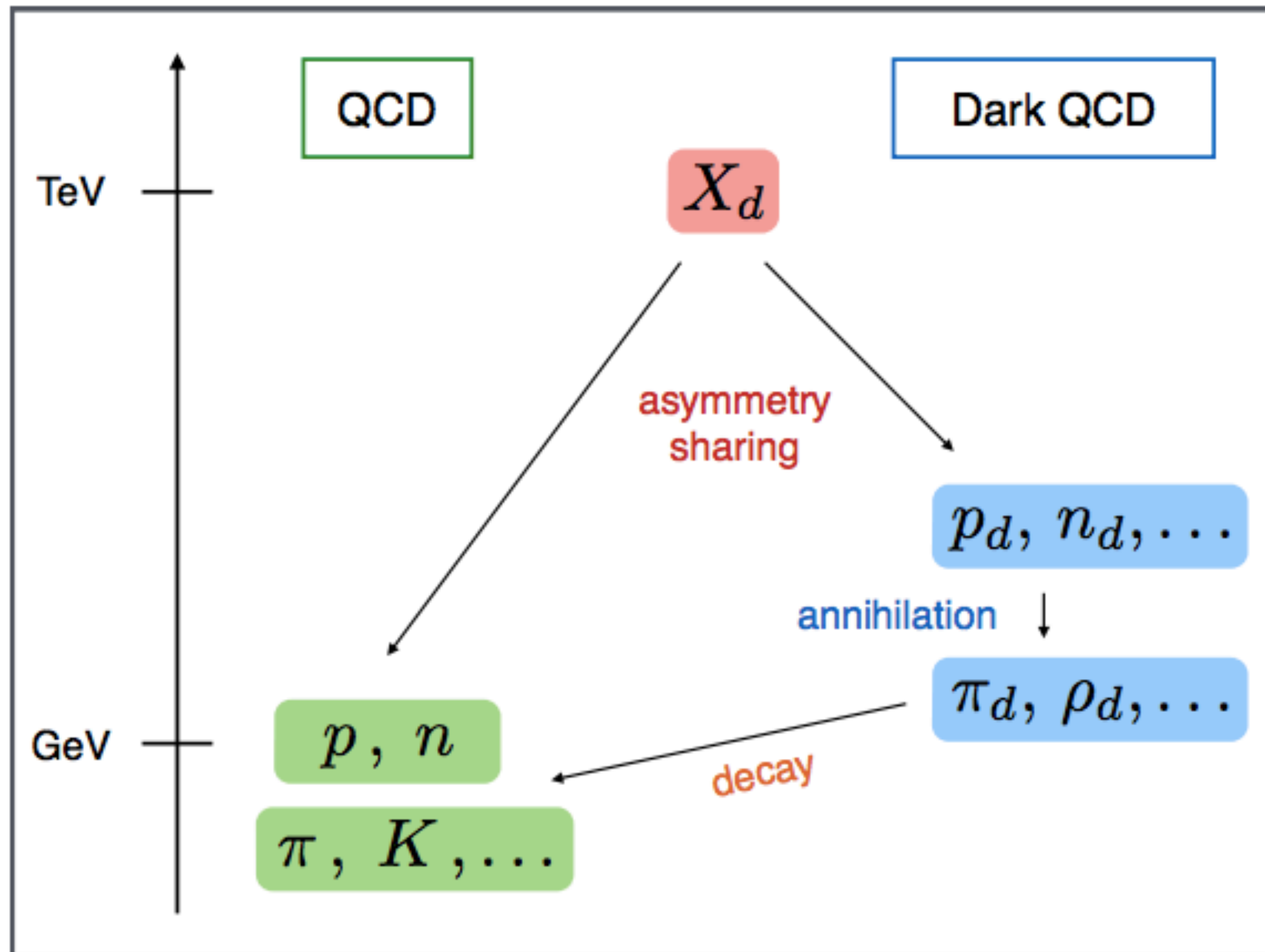
$$SU(3) \times SU(2) \times U(1) \times SU(N_d)$$



- Motivated by antisymmetric dark matter

$$\Lambda_d \sim \mathcal{O}(\text{GeV})$$

Dark QCD and The Hidden Valley



Hidden Valley equipped with its own simplified hadron spectrum.

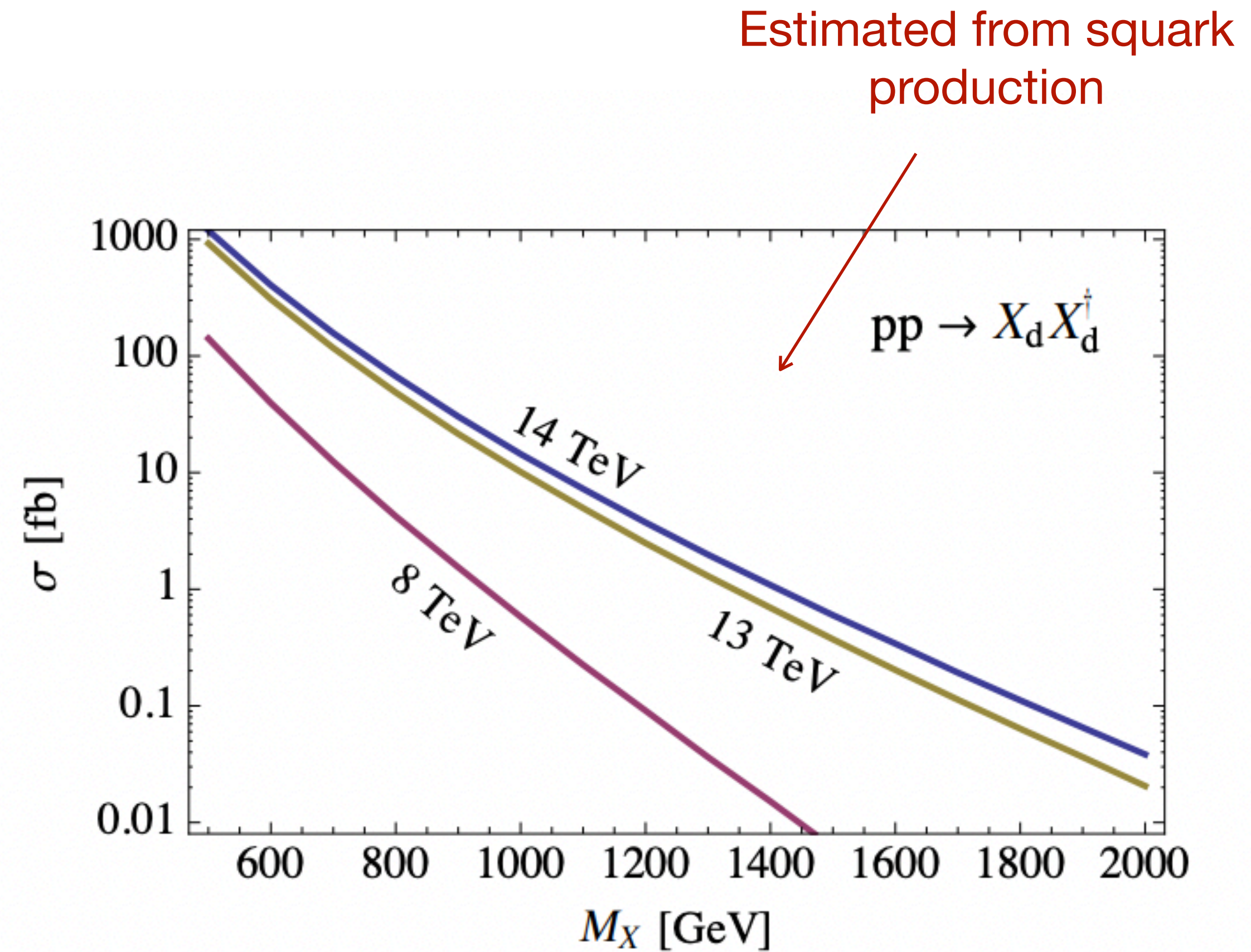
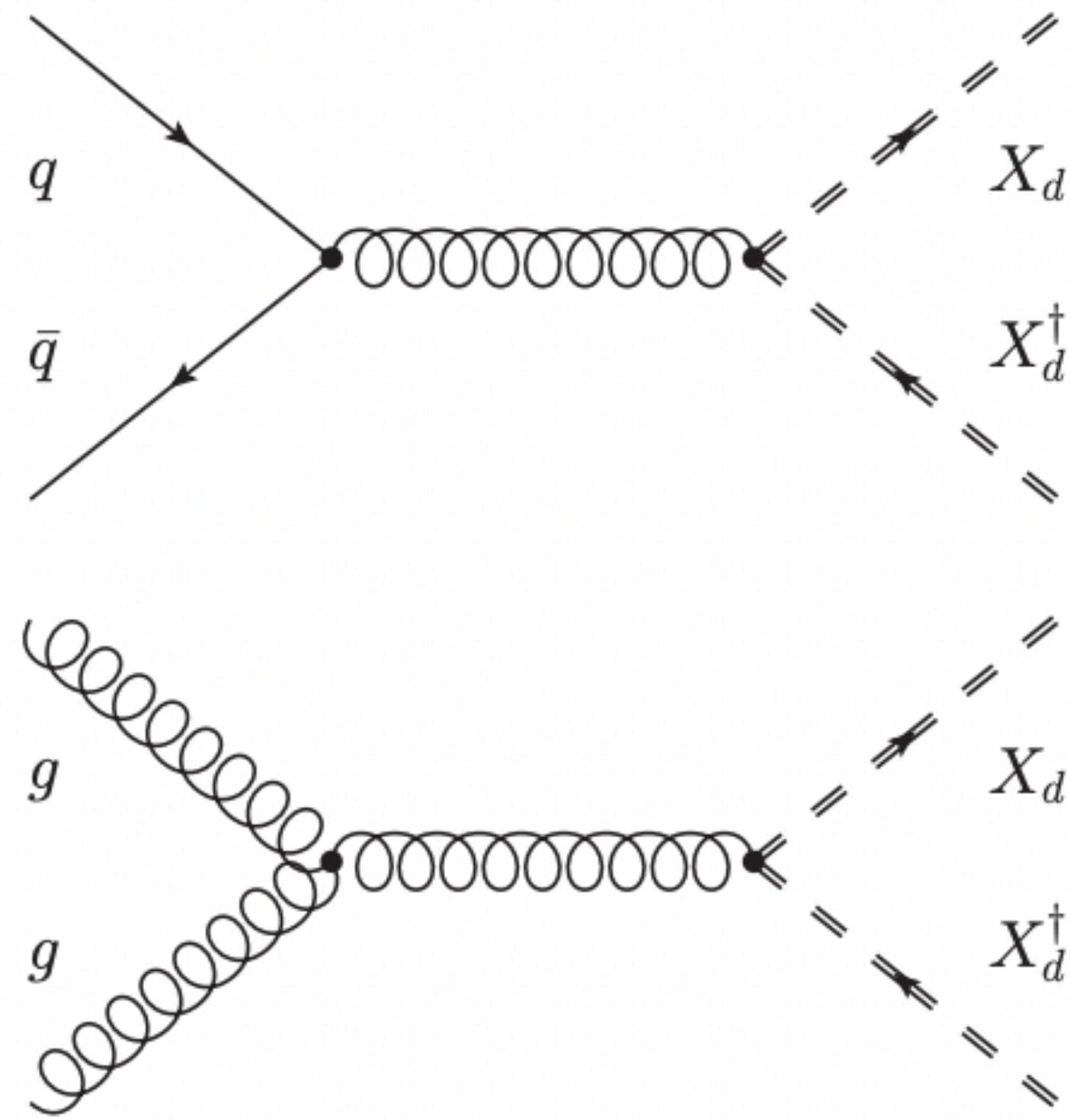
$$(\pi_d, \rho_d, \dots)$$

Constraining it consistently:

$$m_{Q_d} = \Lambda_d = 2m_{\pi_d} = \frac{1}{2}m_{\rho_d}.$$

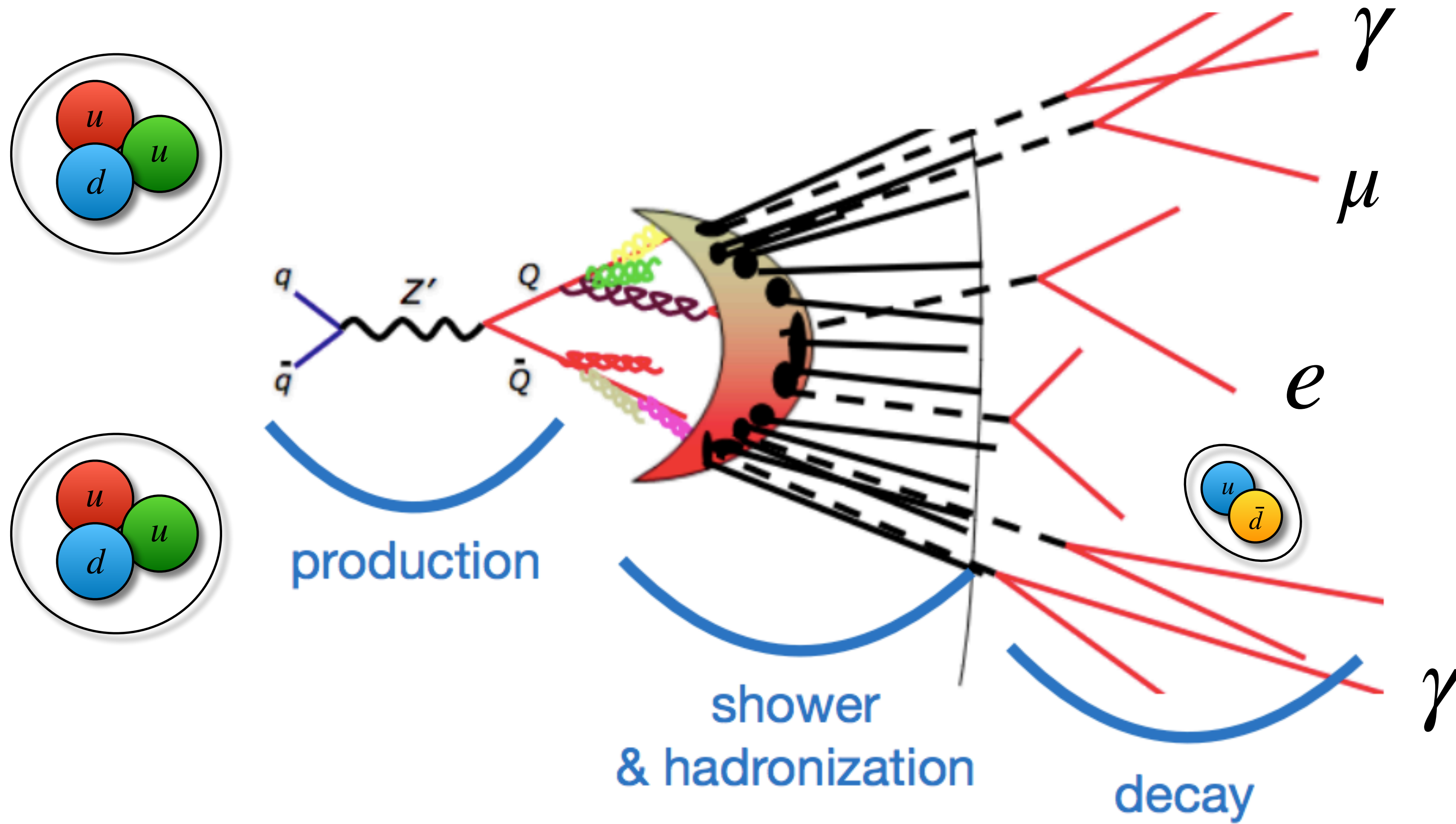
Allowed to decay promptly

Hidden Valley Mediator



Pair production of heavy scalar bifundamental independent of dark coupling.

Dark Parton Showers

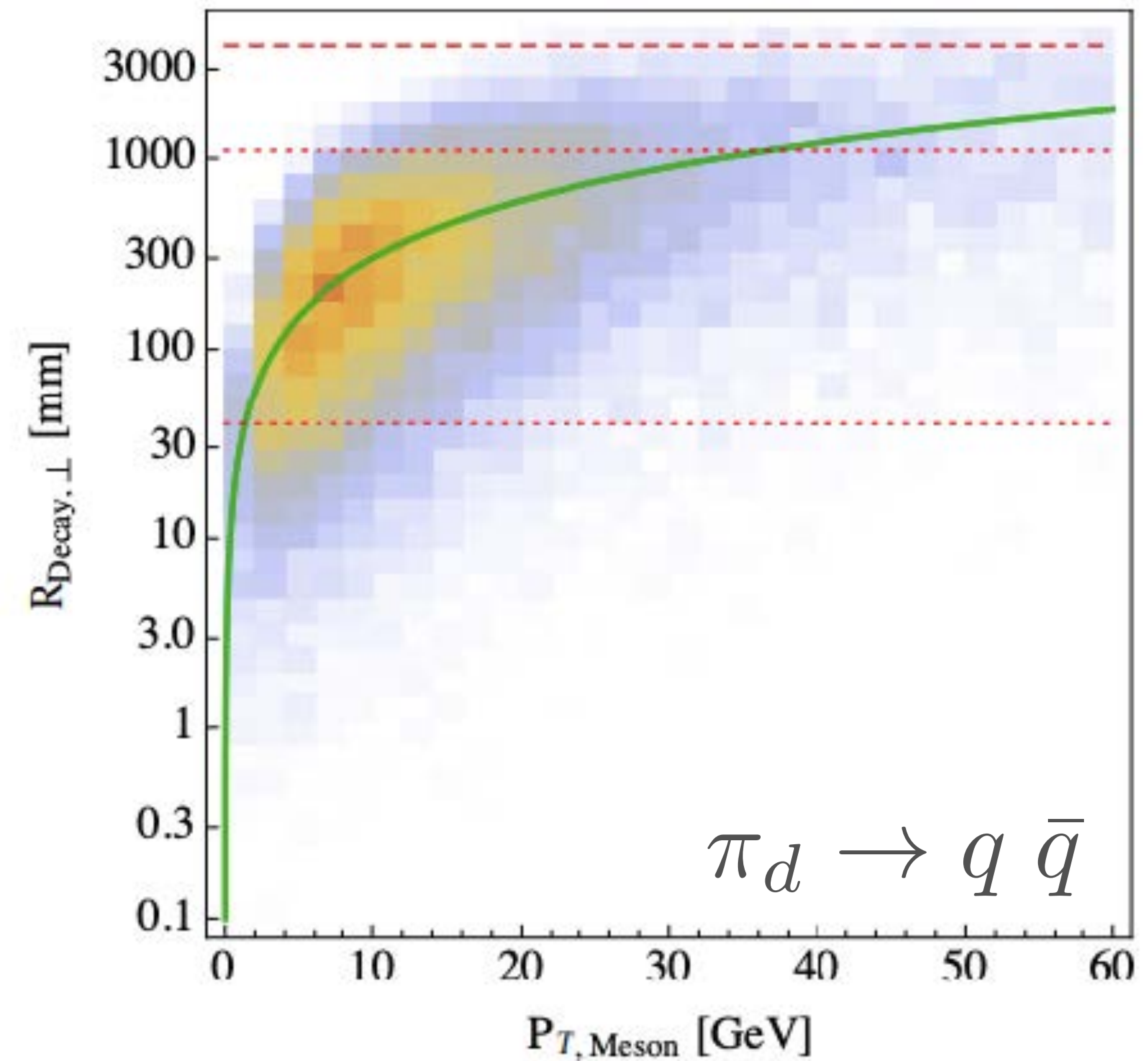
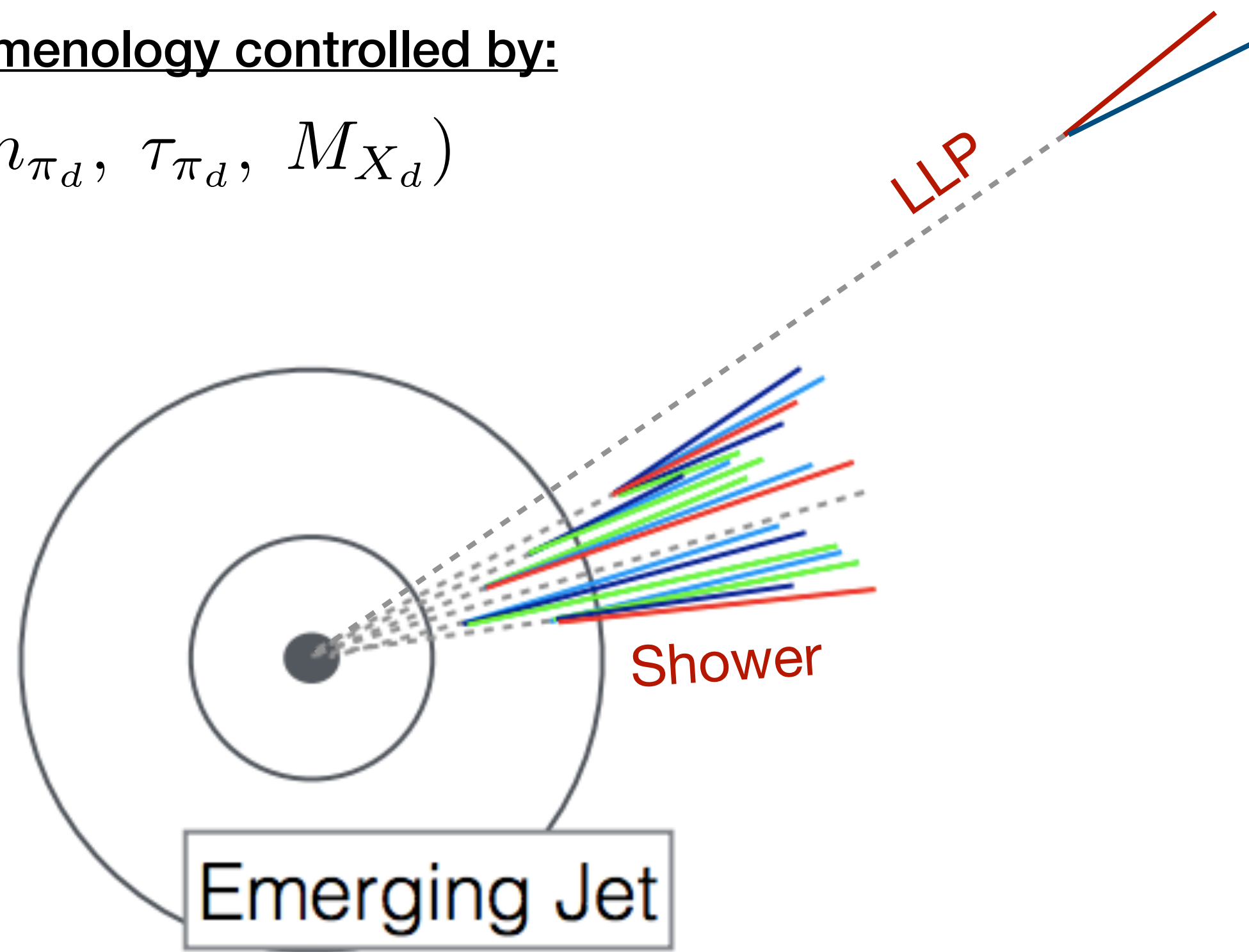


Emerging Jets and LLP

$$c\tau_0 = \frac{c\hbar}{\Gamma} \approx 80 \text{ mm} \times \frac{1}{\kappa^4} \times \left(\frac{2 \text{ GeV}}{f_{\pi_d}}\right)^2 \left(\frac{100 \text{ MeV}}{m_{\text{down}}}\right)^2 \left(\frac{2 \text{ GeV}}{m_{\pi_d}}\right) \left(\frac{M_{X_d}}{1 \text{ TeV}}\right)^4$$

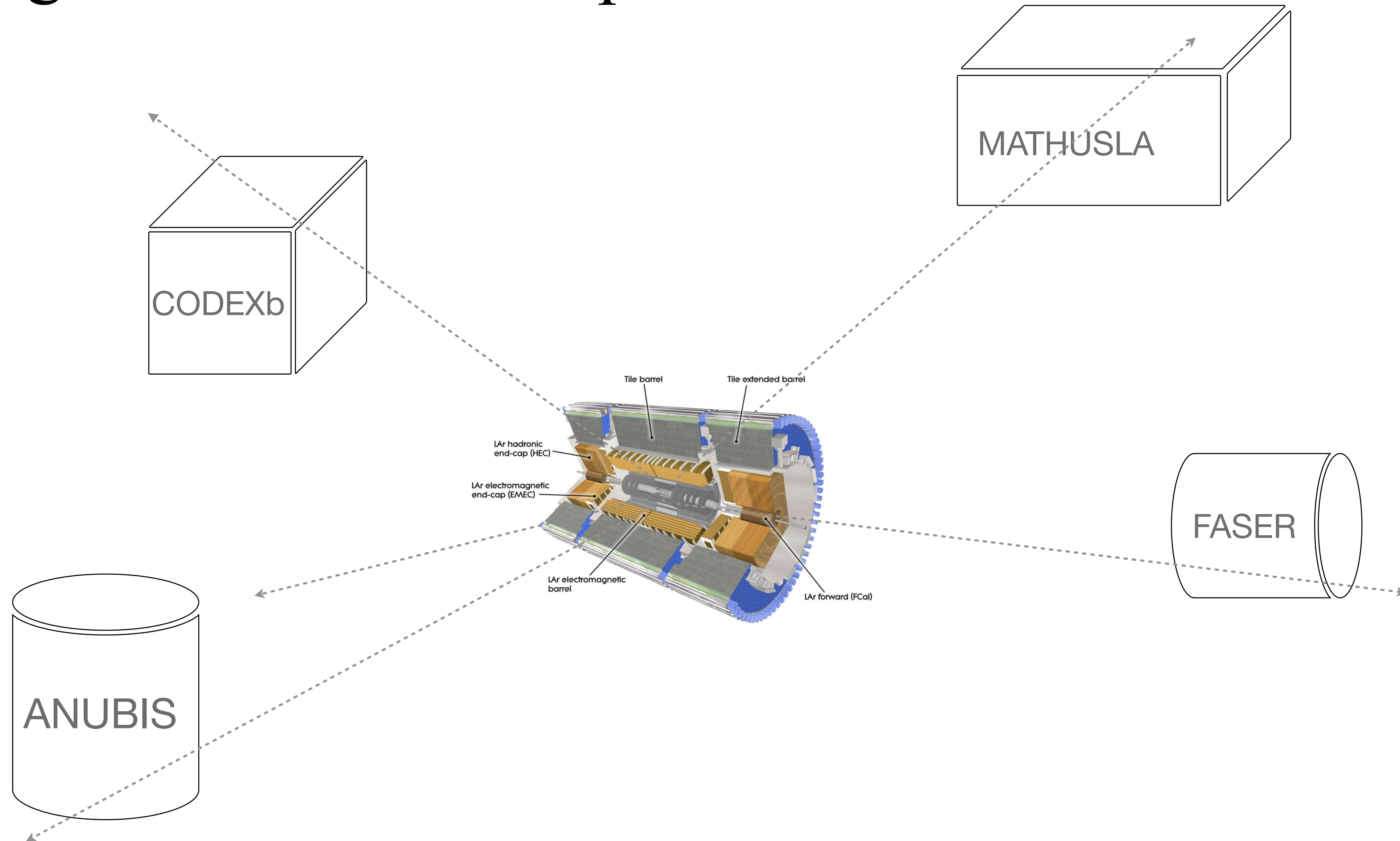
Phenomenology controlled by:

$$(m_{\pi_d}, \tau_{\pi_d}, M_{X_d})$$

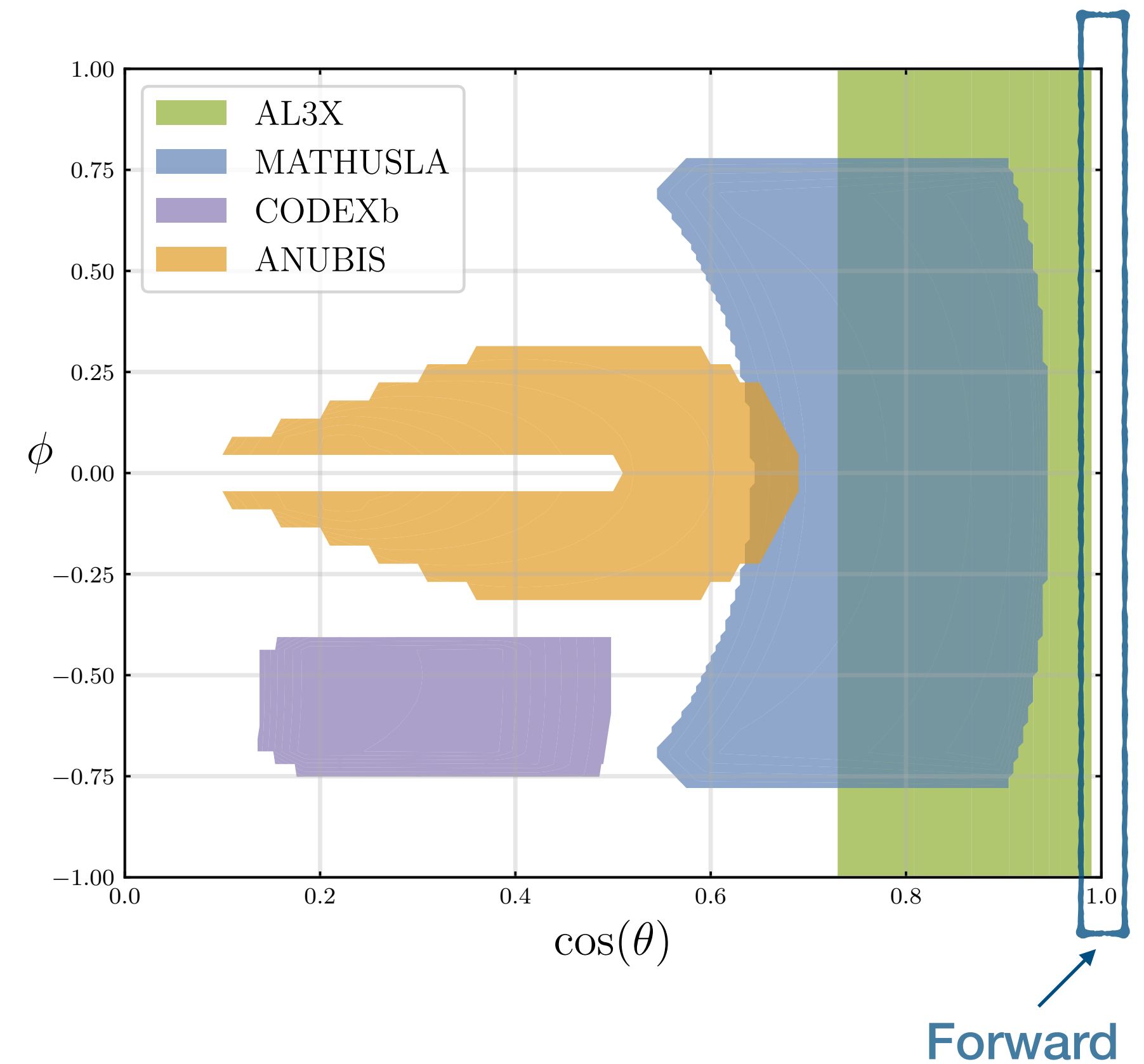
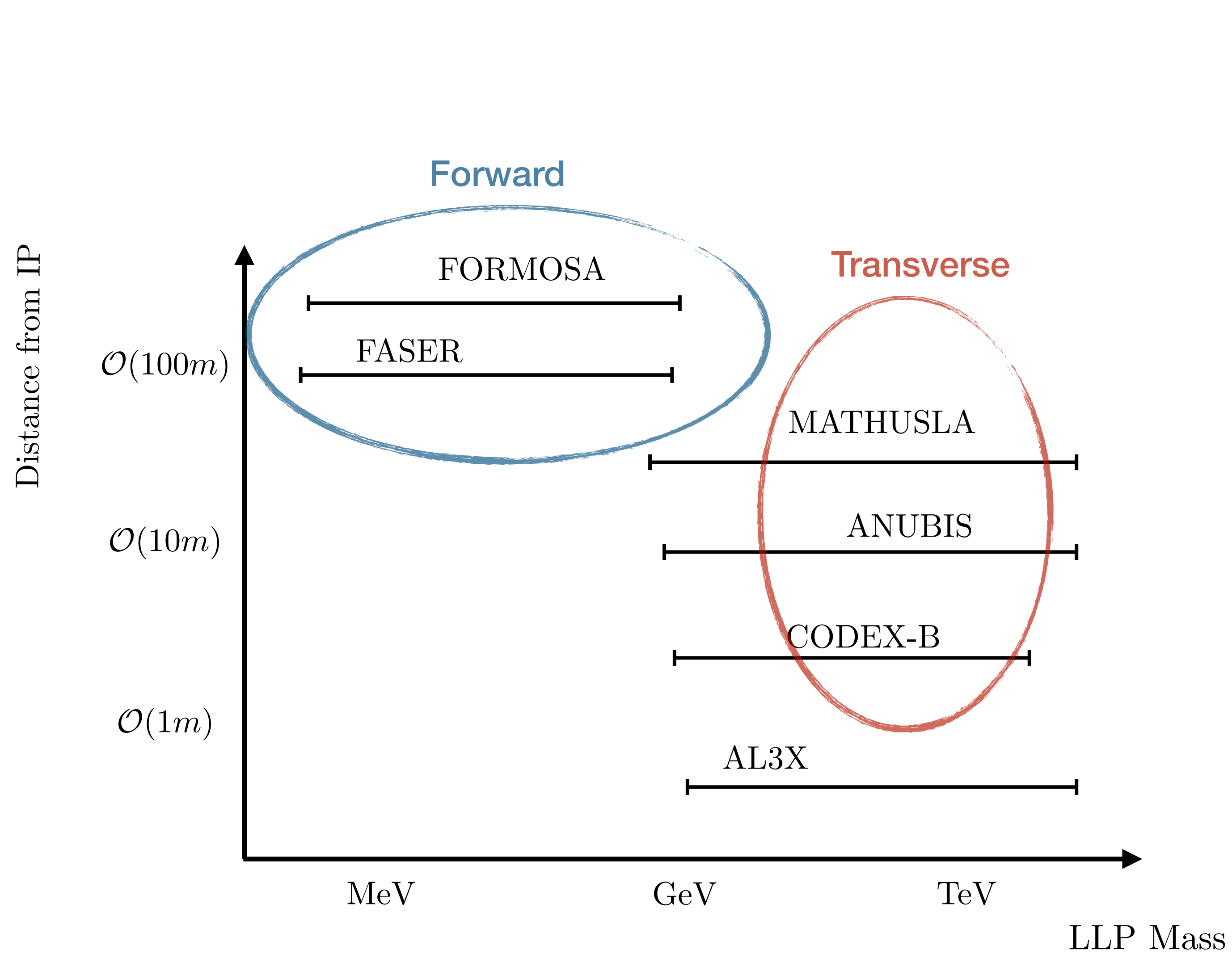


Long-Lived Particle Experiments

Experiment
AL3X
ANUBIS
CODEX-b
FASER
FORMOSA
MAPP
MATHUSLA
MilliQan



LLP Experiments



(Inspiration: LLP 10: "Why so many LLP detectors?")

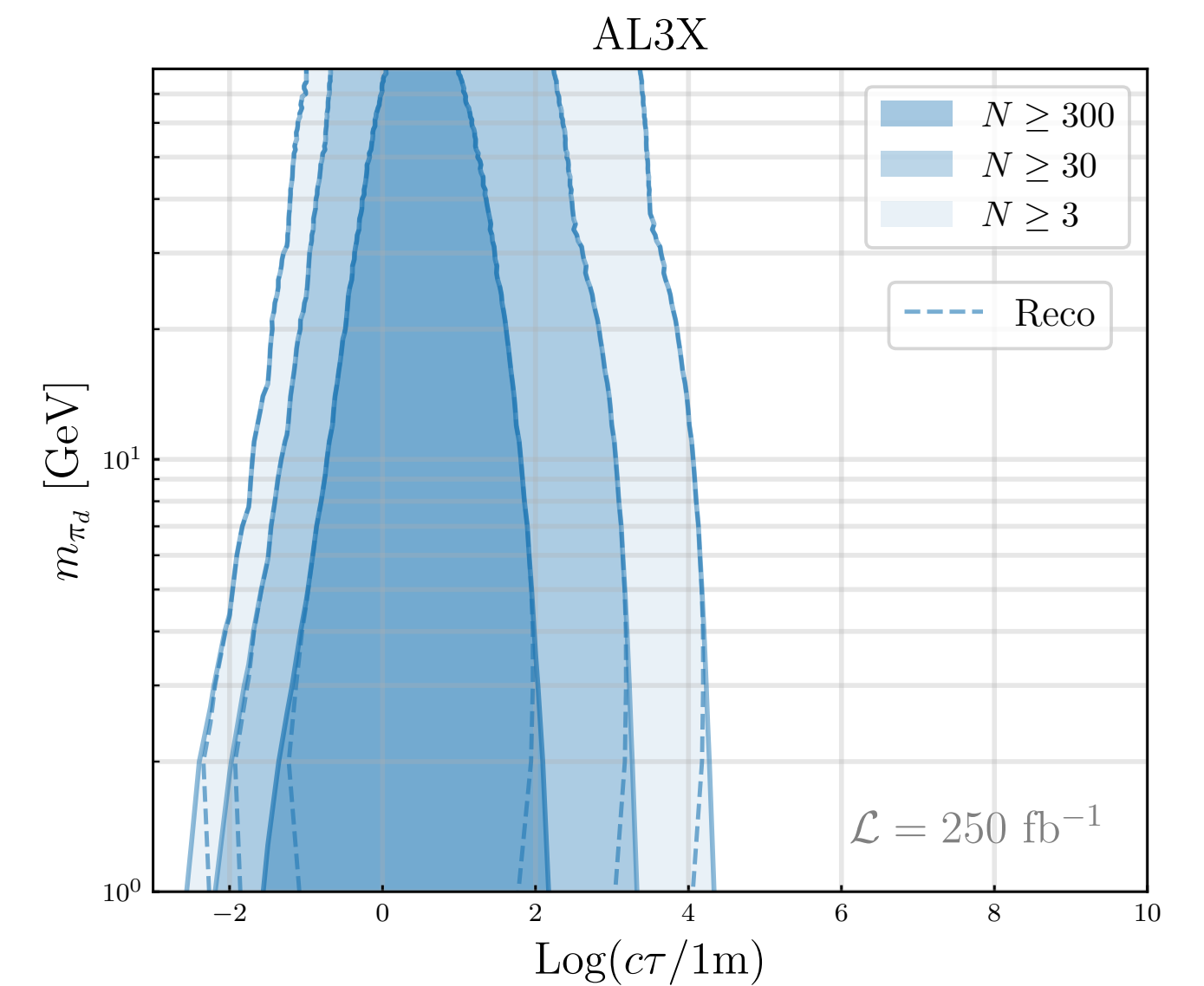
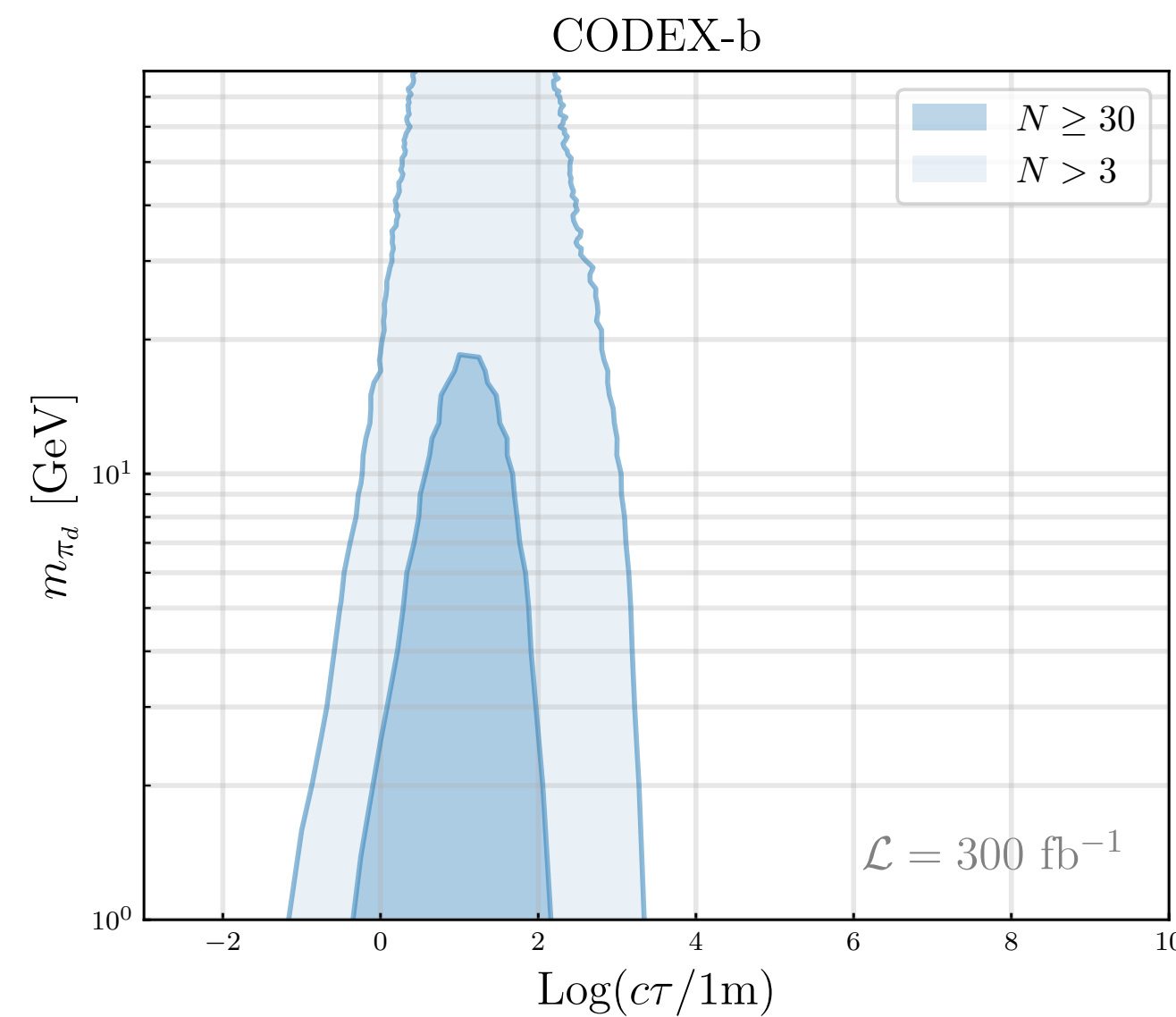
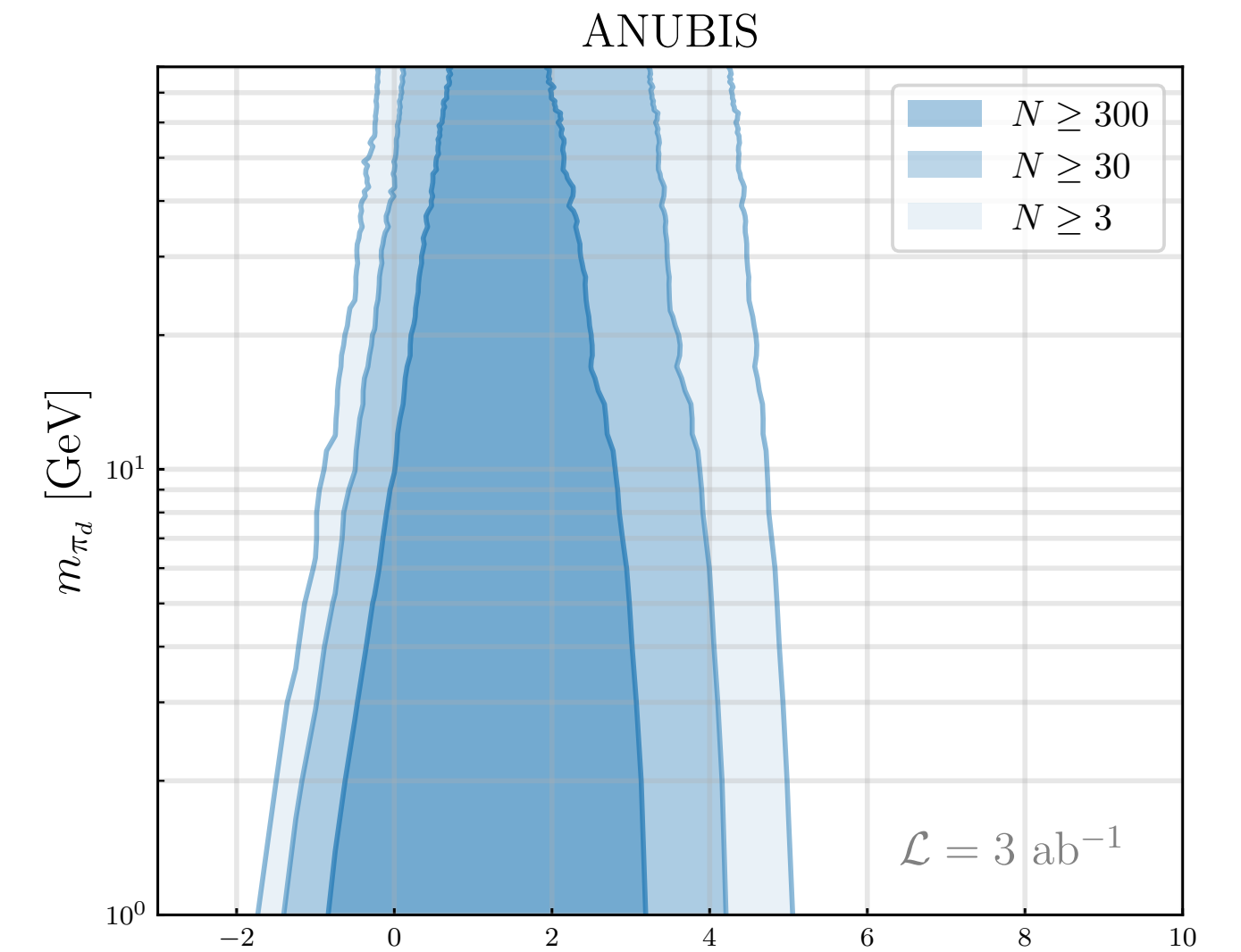
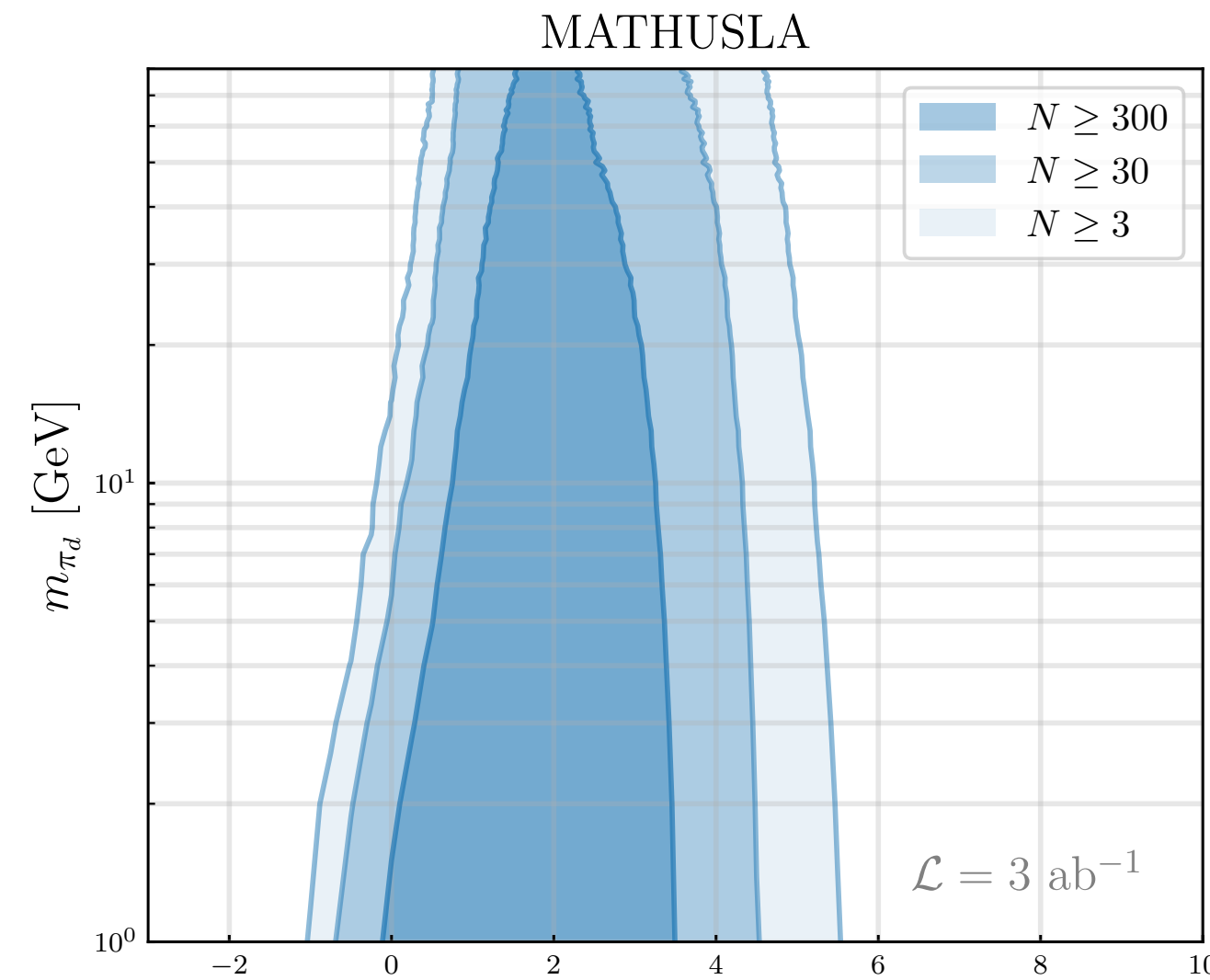
Event Generation and Detector Acceptance

- Simple detector Monte Carlo to estimate dark pion decays.

$$N_{\pi_d}^{dec} = \epsilon \cdot N_{\pi_d}^{prod} \cdot \langle P(\pi_d \text{ in d.r.}) \rangle \cdot \text{BR}(\pi_d \rightarrow \text{signal})$$

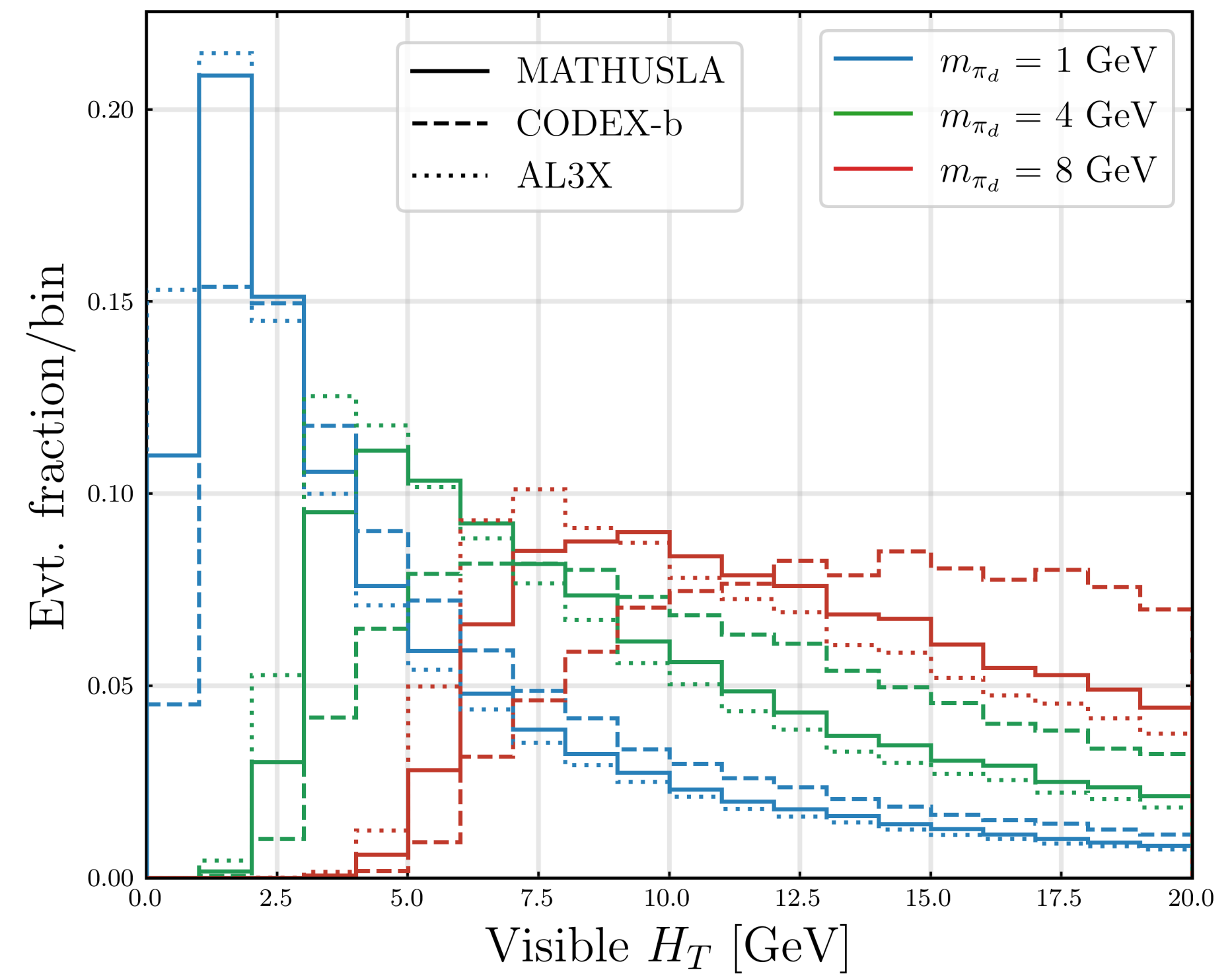
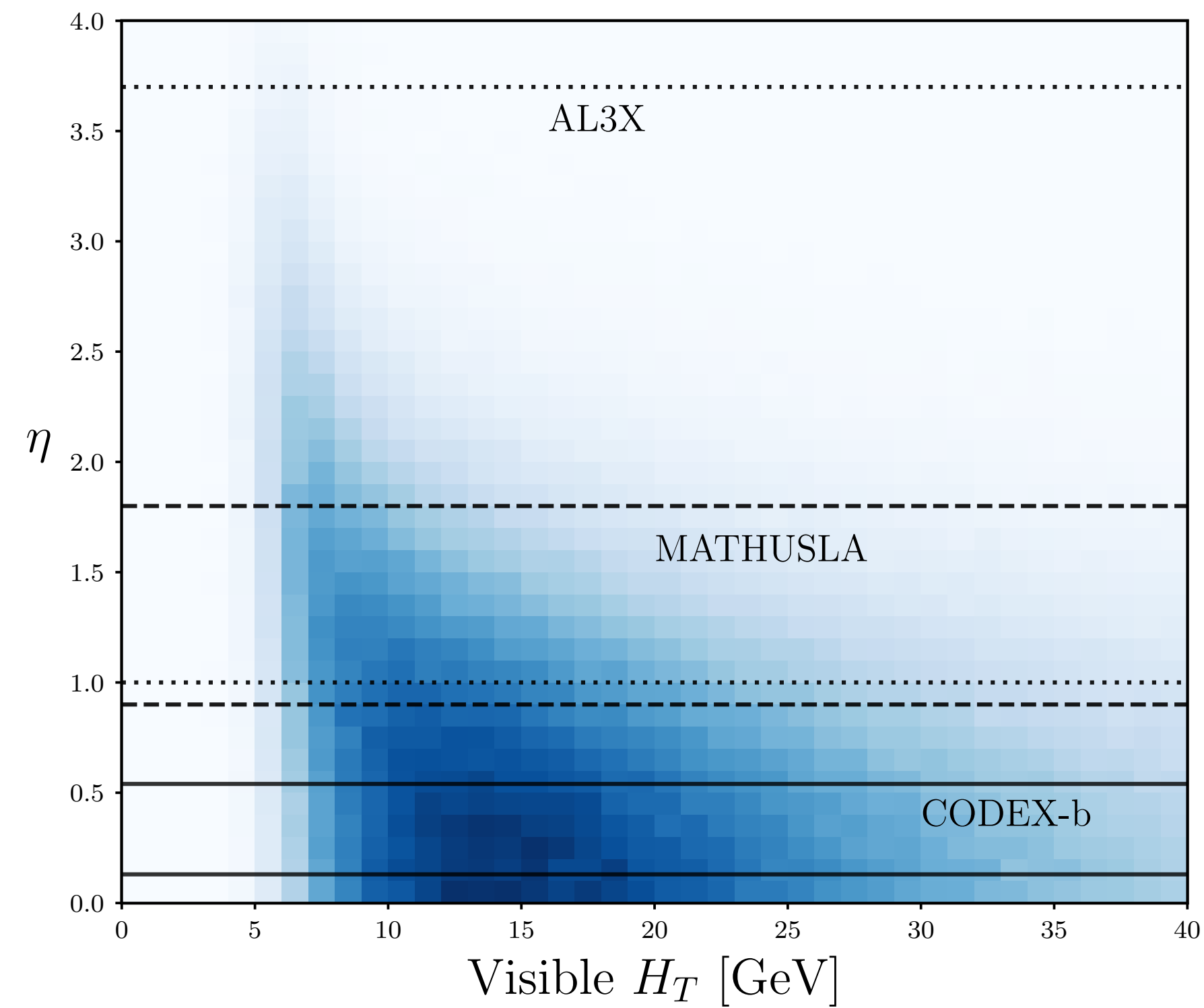
$$P((\pi_d)_i \text{ in d.r.}) = e^{-L_1/\lambda_i} \cdot (1 - e^{-L_2/\lambda_i})$$

- Assuming background free, sensitivities can be representative of the confidence intervals.



Decay Kinematics & Reconstruction

Applying cuts on visible energy & tracks to reduce any background $\pi_d \rightarrow \text{signal}$



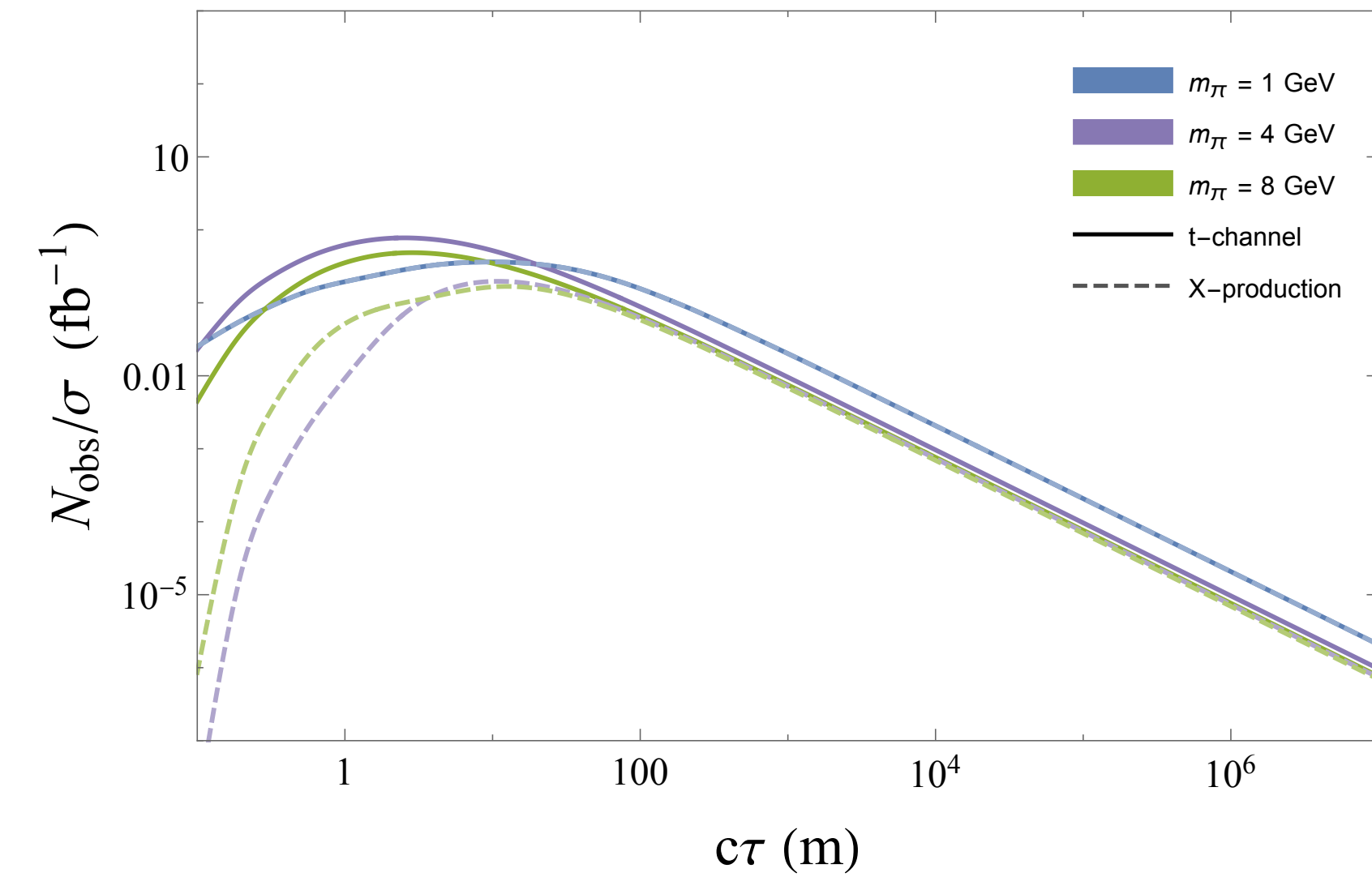
Forward Detectors and t-channel

t-channel exchange is enhanced in the forward direction, where pair production is limited.

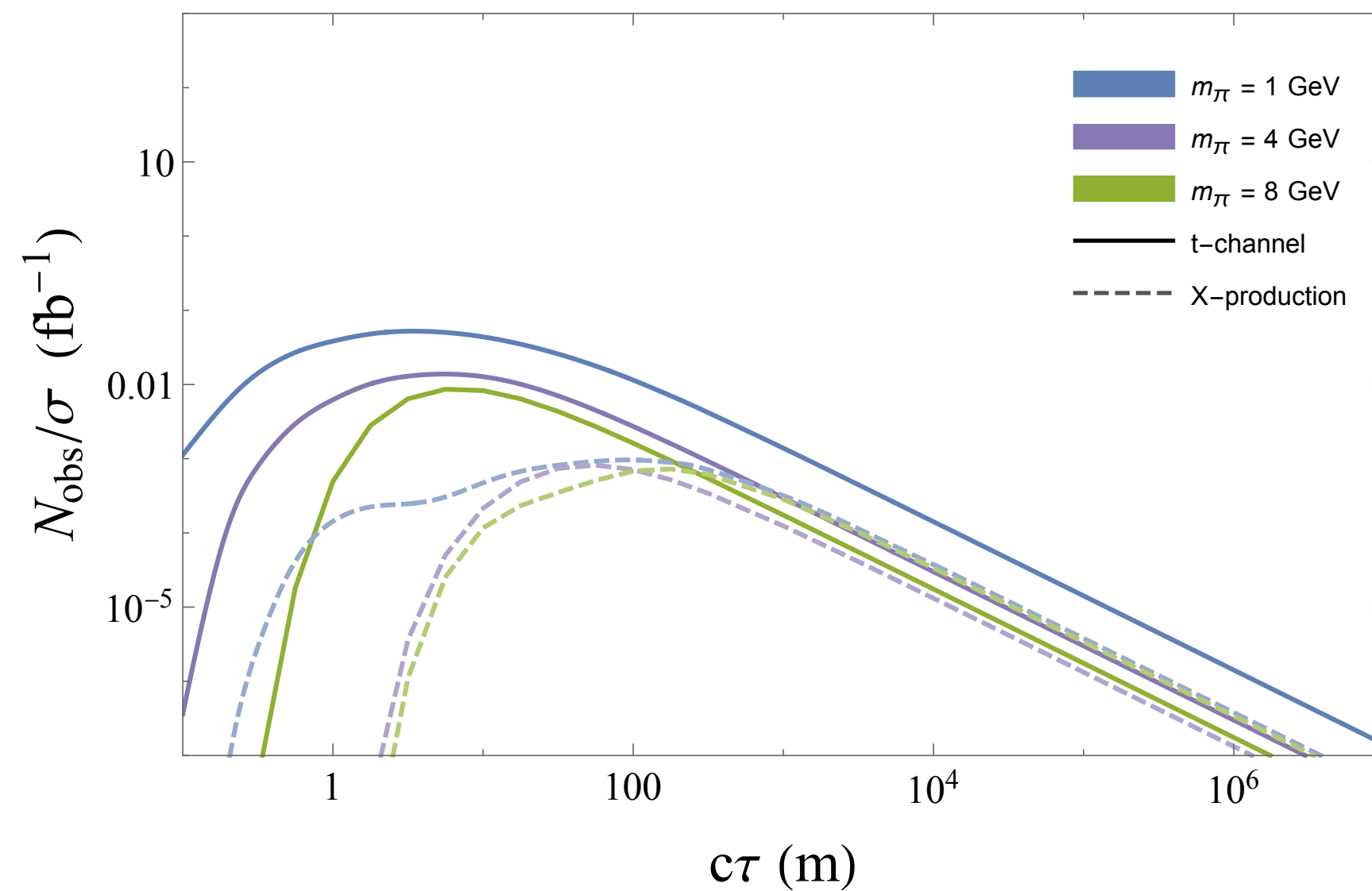
t-channel production not independent of dark coupling



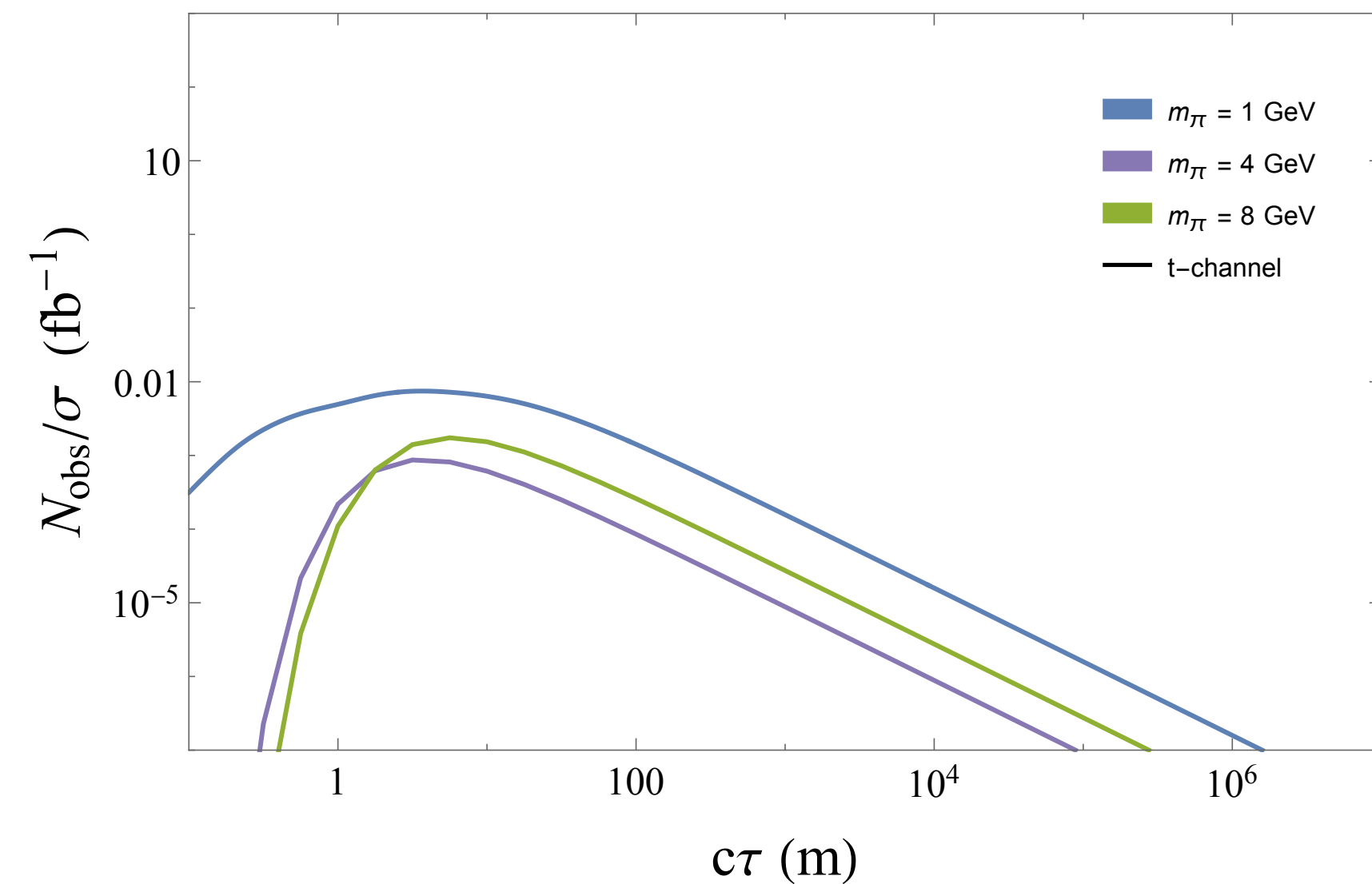
MAPP Detector Acceptance, $M_X = 1$ TeV



FASER Detector Acceptance, $M_X = 1$ TeV



FORMOSA Detector Acceptance, $M_X = 1$ TeV



Summary

- Emerging Jets (EJ) produce novel shower signatures in the low lifetime regime and mimic traditional LLP signatures at higher lifetimes, which can be probed at the various LLP experiments
- Transverse detectors are more sensitive to EJ from pair production.
- Sensitivities are enhanced in the forward region but production is dependent on the dark QCD coupling.
- Visible decay products of the dark pion LLPs can add more complexity in the tagging stage.

Questions?