Flavoured emerging jets

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A flavoured dark sector

Based on 1803.08080 with Pedro Schwaller

Confining dark sector with $\Lambda_D \sim \mathrm{GeV}$

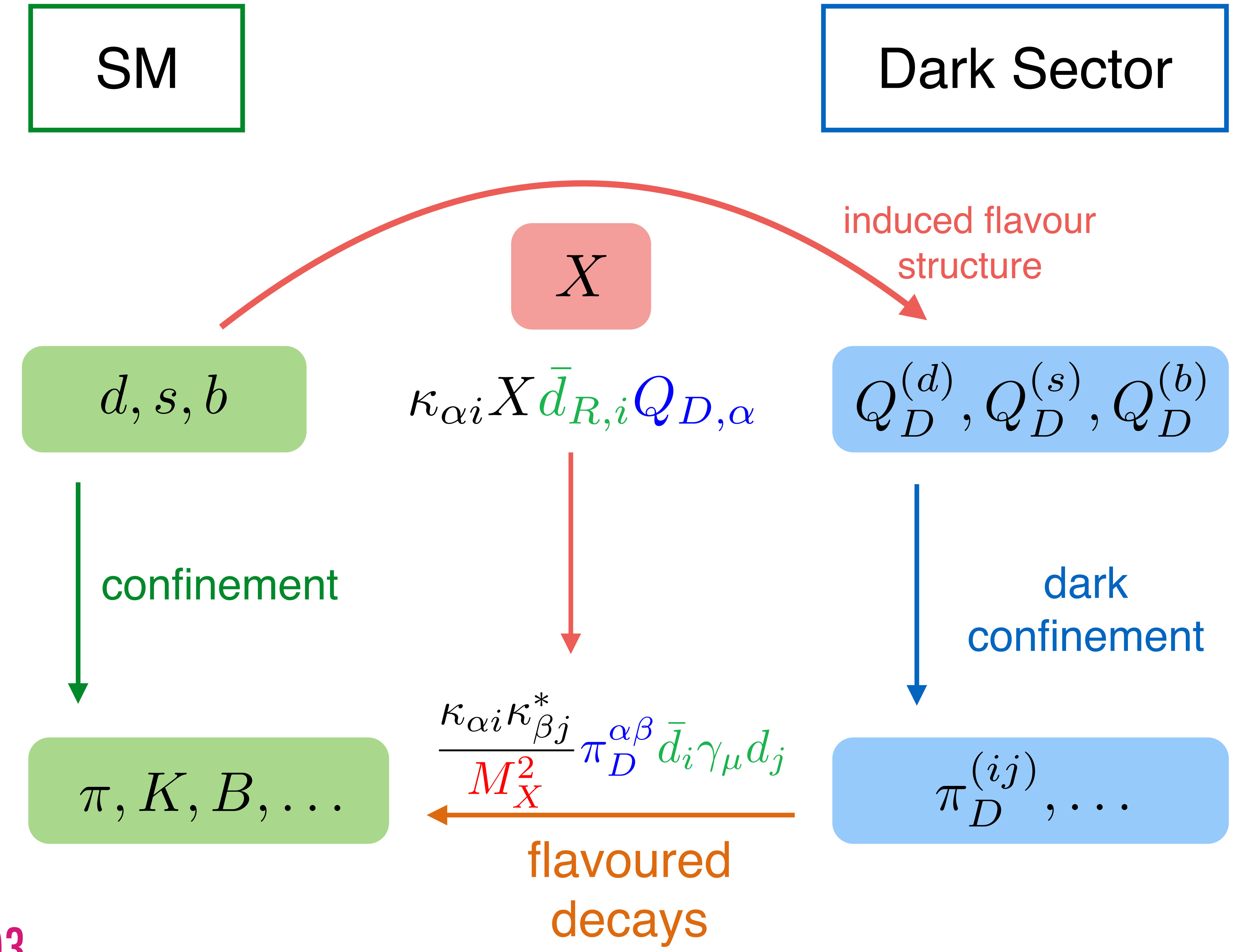
t-channel portal via heavy bifundamental scalar X

$$\kappa_{\alpha i} \bar{d}^i_R Q_\alpha X$$

3×3 coupling matrix

$i = 1,2,3$ quark flavour

$\alpha = 1,2,3$ dark quark flavour



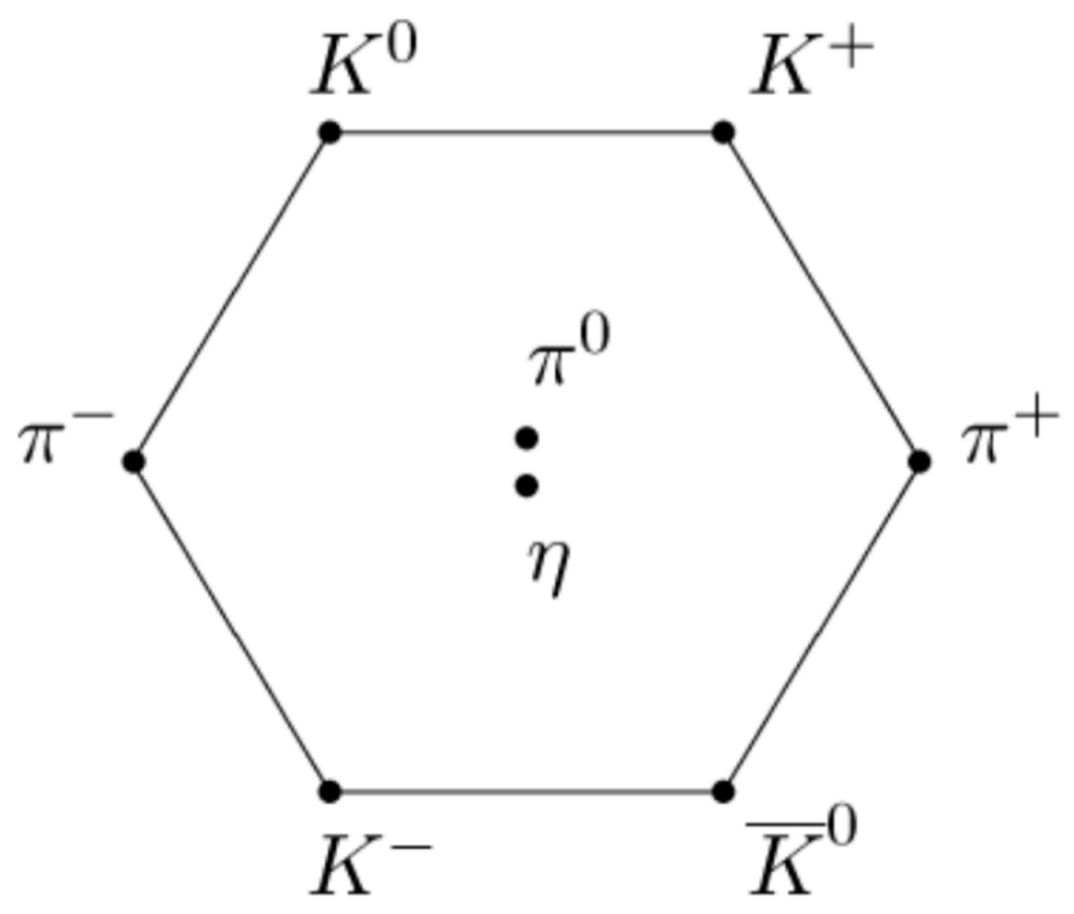
Other choices:

- Coupling to up-type quarks e.g. Carmona, Scherb, Schwaller 2101.07803, see also Yi-Mu Chen's talk yesterday
- $n_f > 3$: stable dark pions see Pedro Schwaller's talk earlier

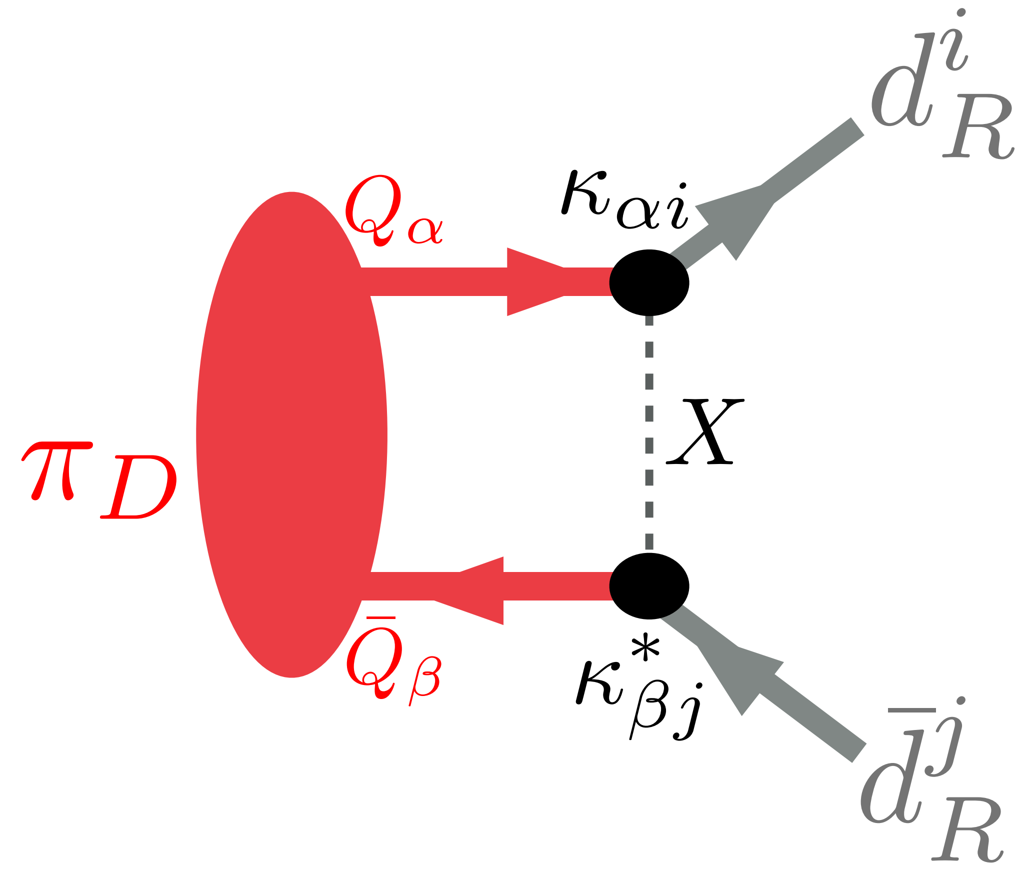
The dark pions

Lightest dark baryon is stable and a dark matter candidate

$$U(3)_{L_{\mathrm{dark}}} \times U(3)_{R_{\mathrm{dark}}} \to SU(3)_{V_{\mathrm{dark}}} \times U(1)_{B_{\mathrm{dark}}} \implies$$ 8 dark pions



They decay to SM hadrons via the portal interaction



Decay modes of dark pions are determined by the structure of the coupling κ

Flavour structure & implications

Can generally write coupling matrix as

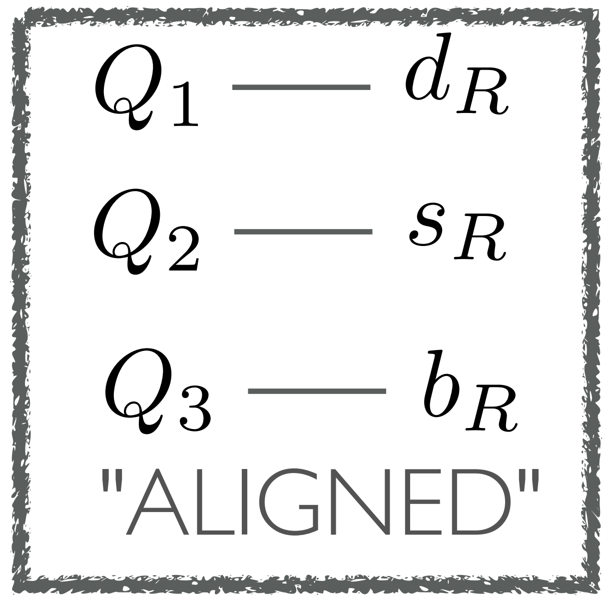
$$\kappa = D\,U$$

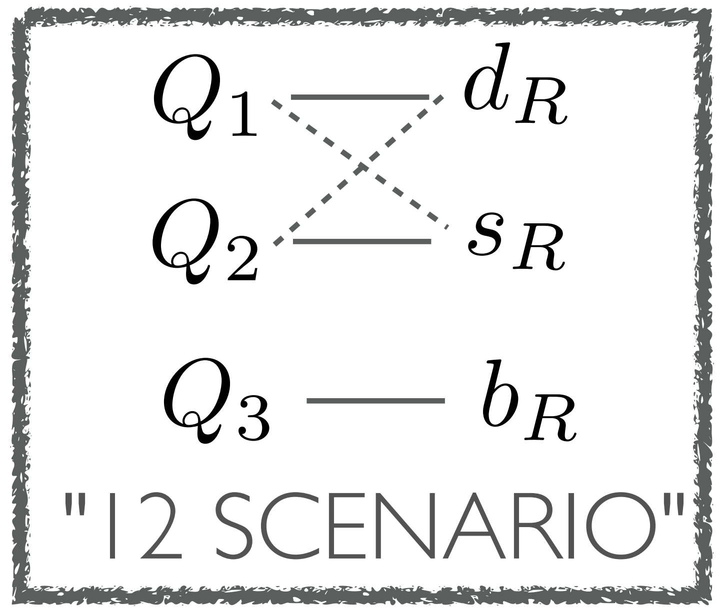
diagonal matrix

$$D = \left(\kappa_0 \cdot \mathbb{1} + \mathrm{diag}(\kappa_1, \kappa_2, -(\kappa_1+\kappa_2))\right)$$

3D rotation matrix, with angles θ_{12}, θ_{13} and θ_{23}

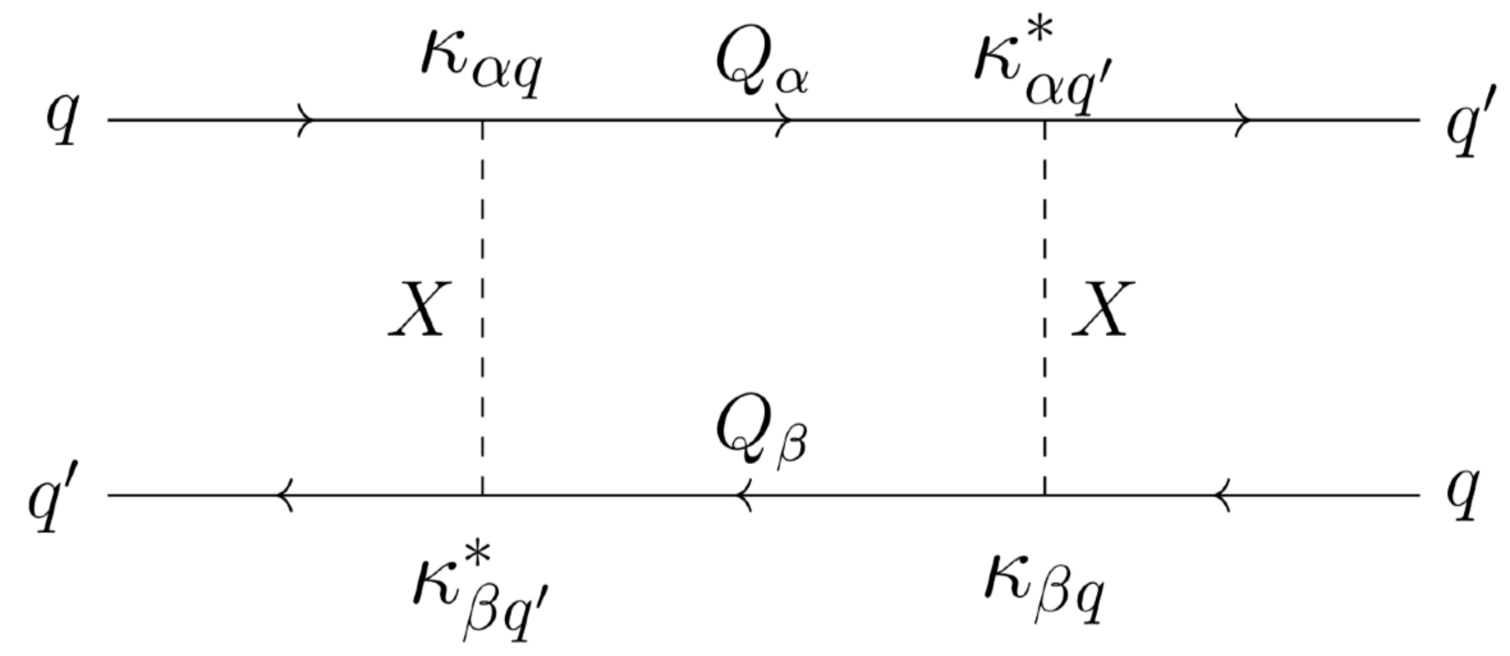
Meson mixing absent in limit where $D \propto 1_{3\times 3}$
"Aligned scenario"

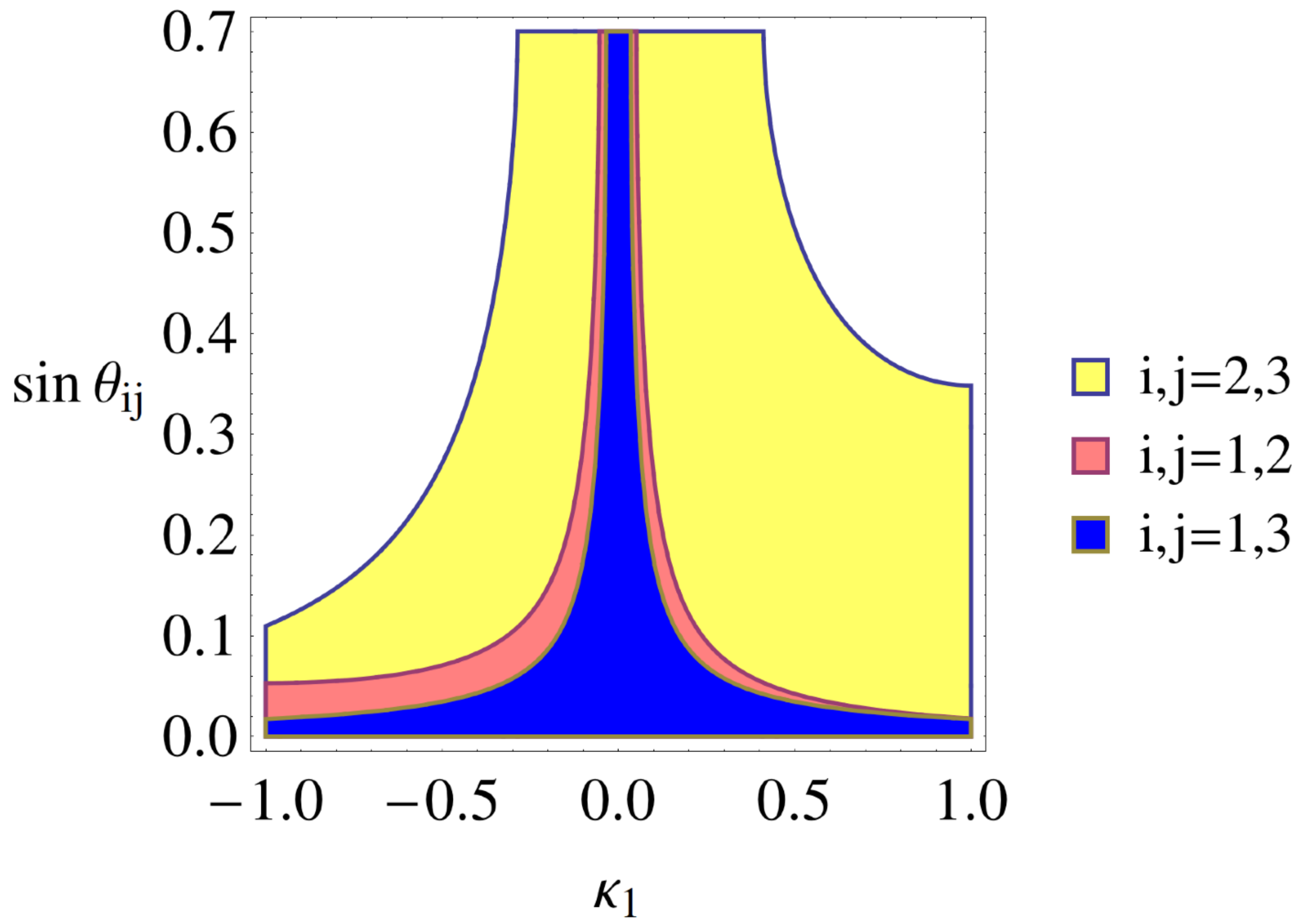




etc

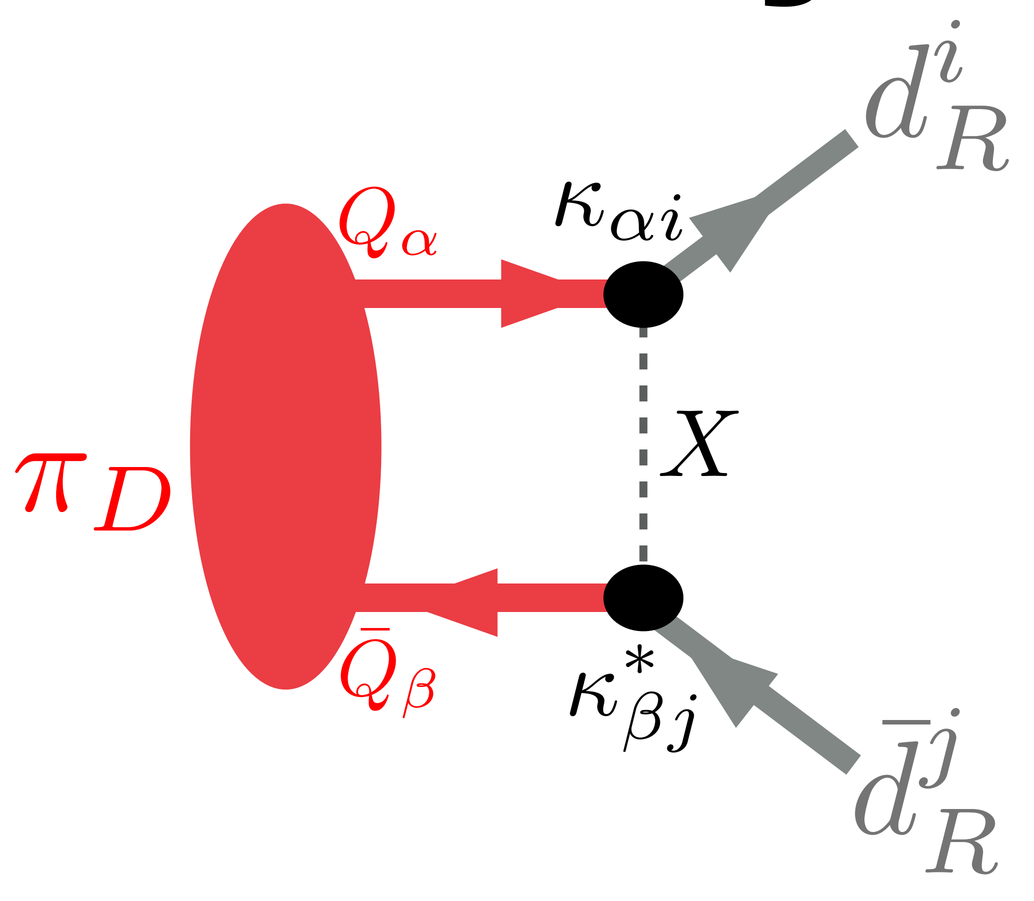
Meson mixing





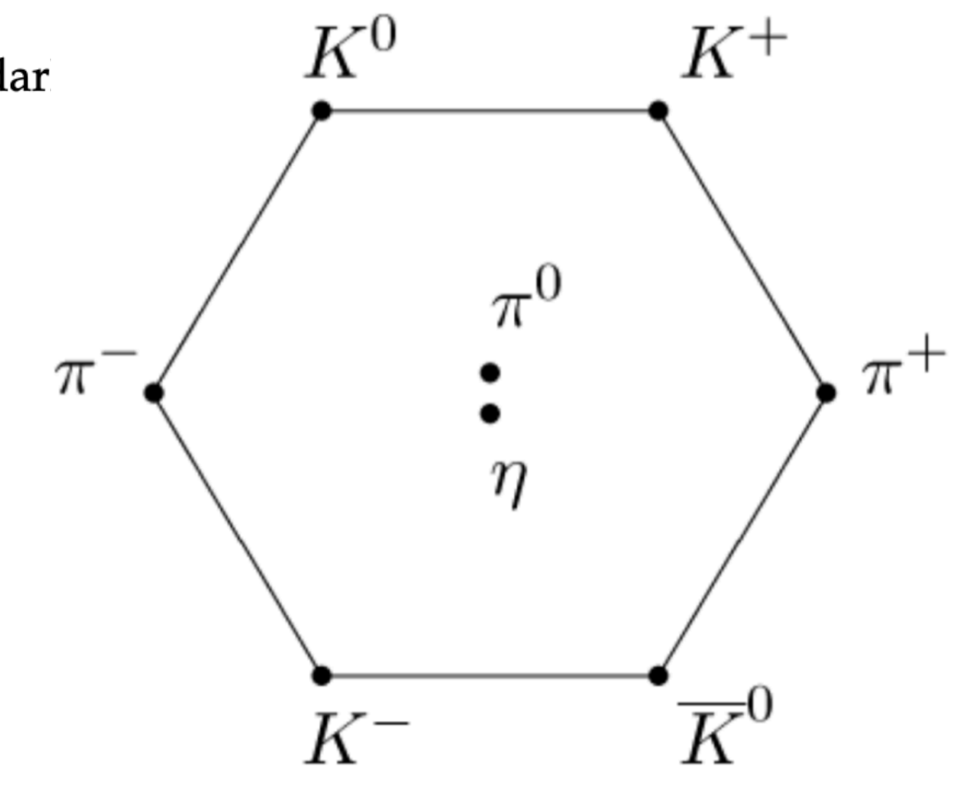
Shaded regions are allowed by meson mixing

Decays of dark pions



$$c\tau^{\alpha\beta}_{\pi_{\text{dark}}} = \frac{8\pi m^4_{X_{\text{dark}}} c\hbar}{N_c m_{\pi_{\text{dark}}} f^2_{\pi_{\text{dark}}} \sum_{i,j} |\kappa_{\alpha i}\kappa^*_{\beta j}|^2 \left(m_i^2 + m_j^2\right) \sqrt{\left(1 - \frac{(m_i+m_j)^2}{m^2_{\pi_{\text{dark}}}}\right)\left(1 - \frac{(m_i-m_j)^2}{m^2_{\pi_{\text{dar}}}}\right)}}$$

Shorter decay length to heavier final states

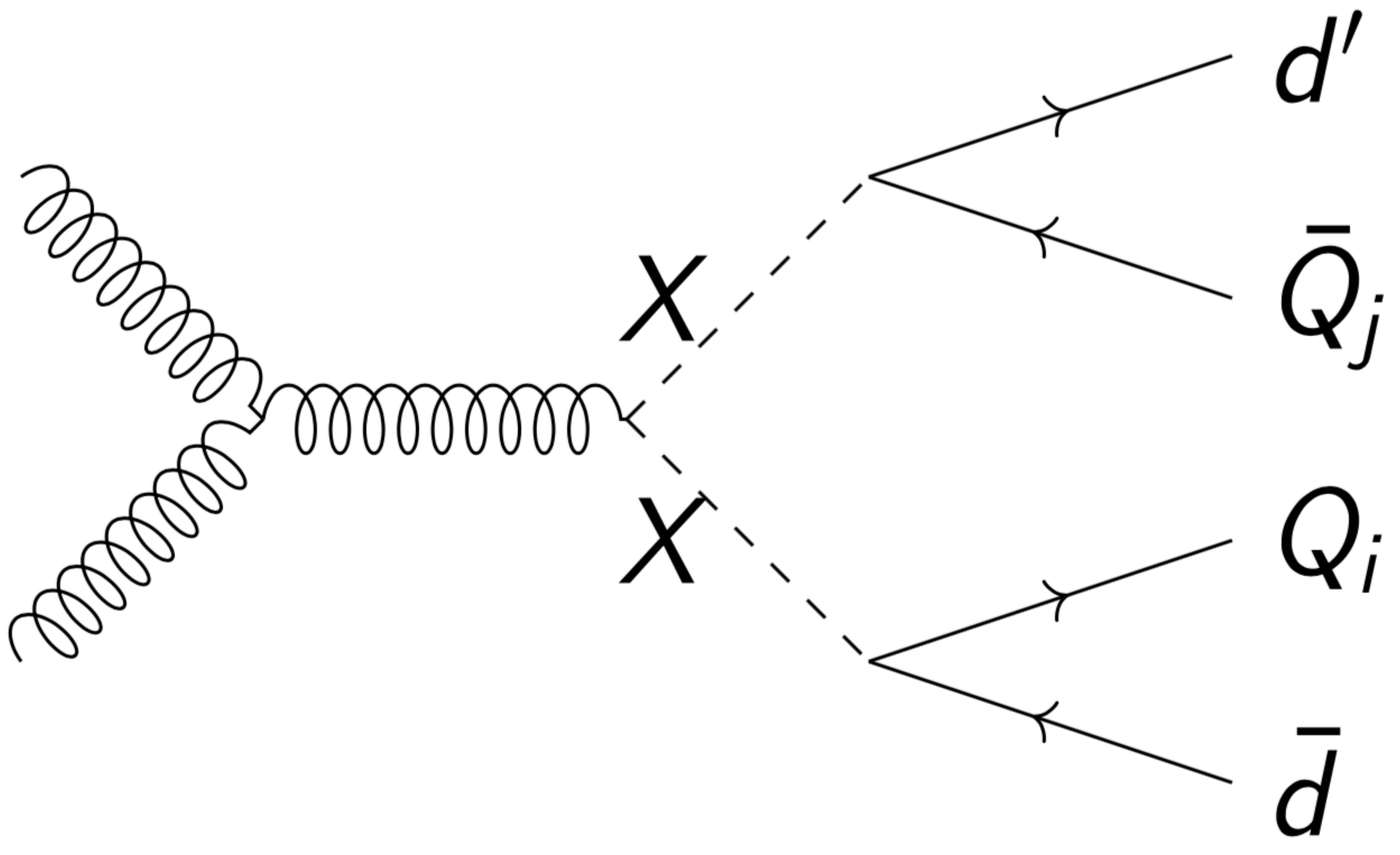


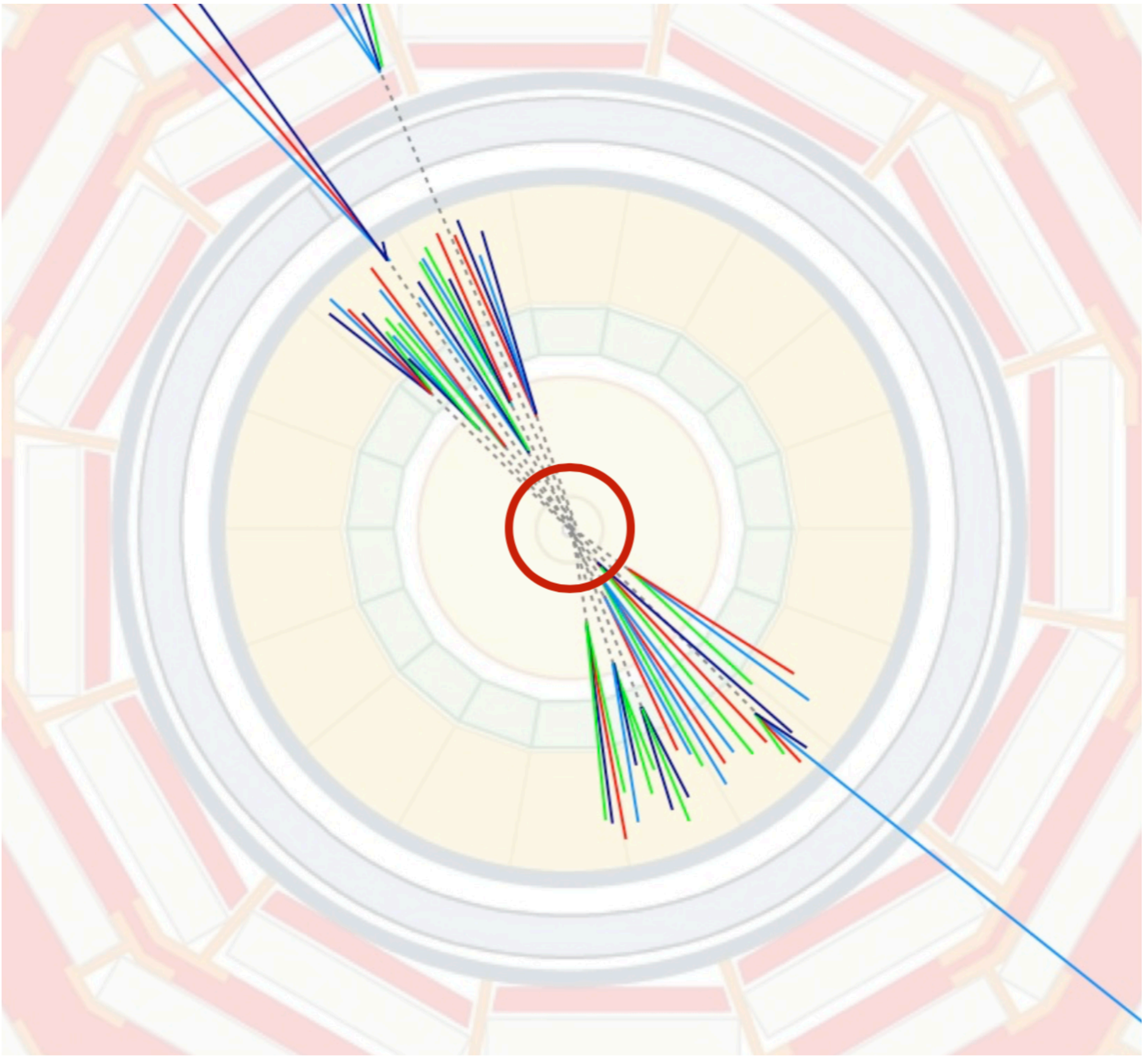
Q_1 — d_R
Q_2 — s_R
Q_3 — b_R
"ALIGNED"

But in aligned scenario, only dark pions with Q_3 charge can decay to b-containing final states

Upshot: different flavours of dark pions can have very different decay lengths

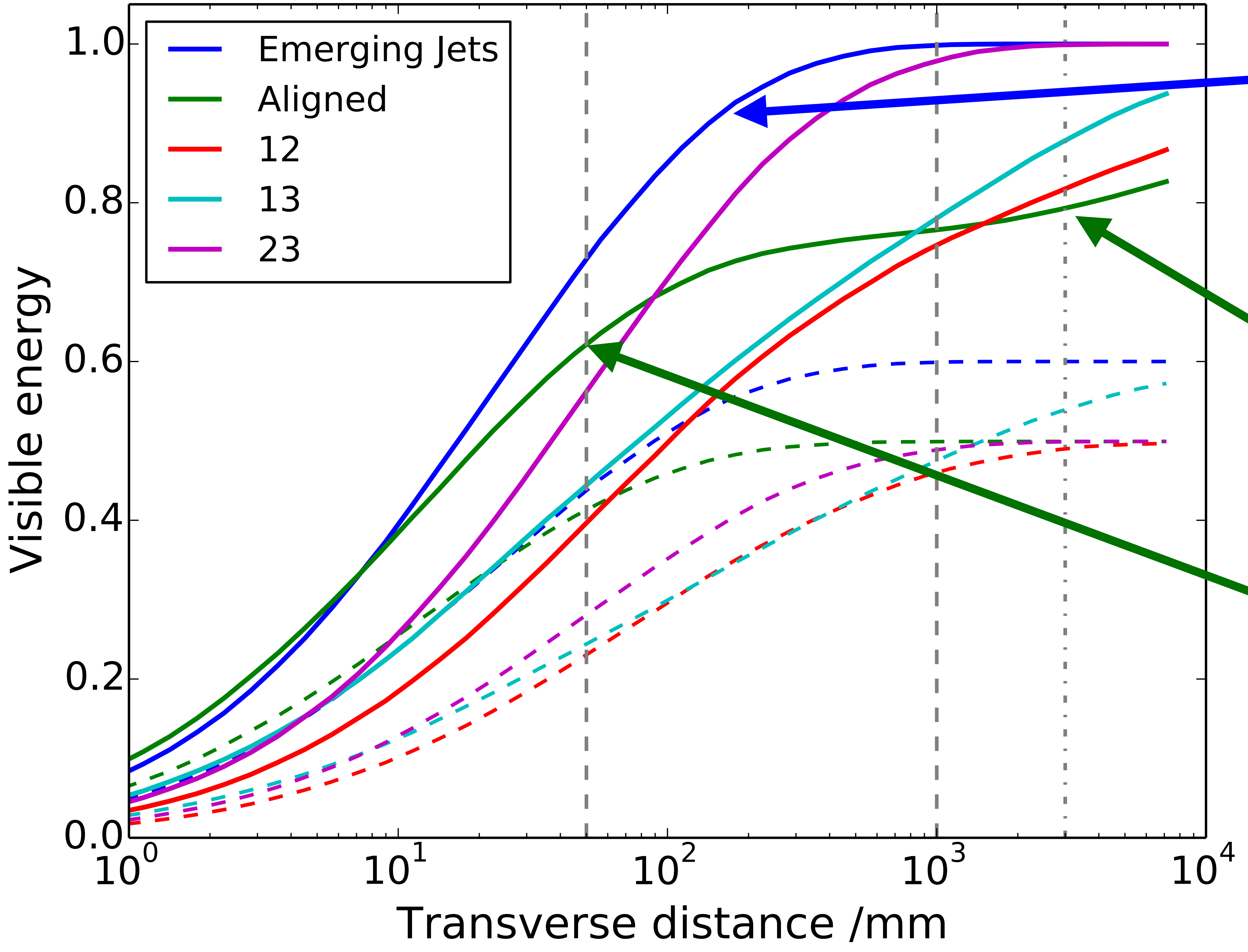
Emerging jets





Dark QCD is flavour symmetric:
Equal numbers of every dark pion are produced in dark jets

Different flavours emerge differently



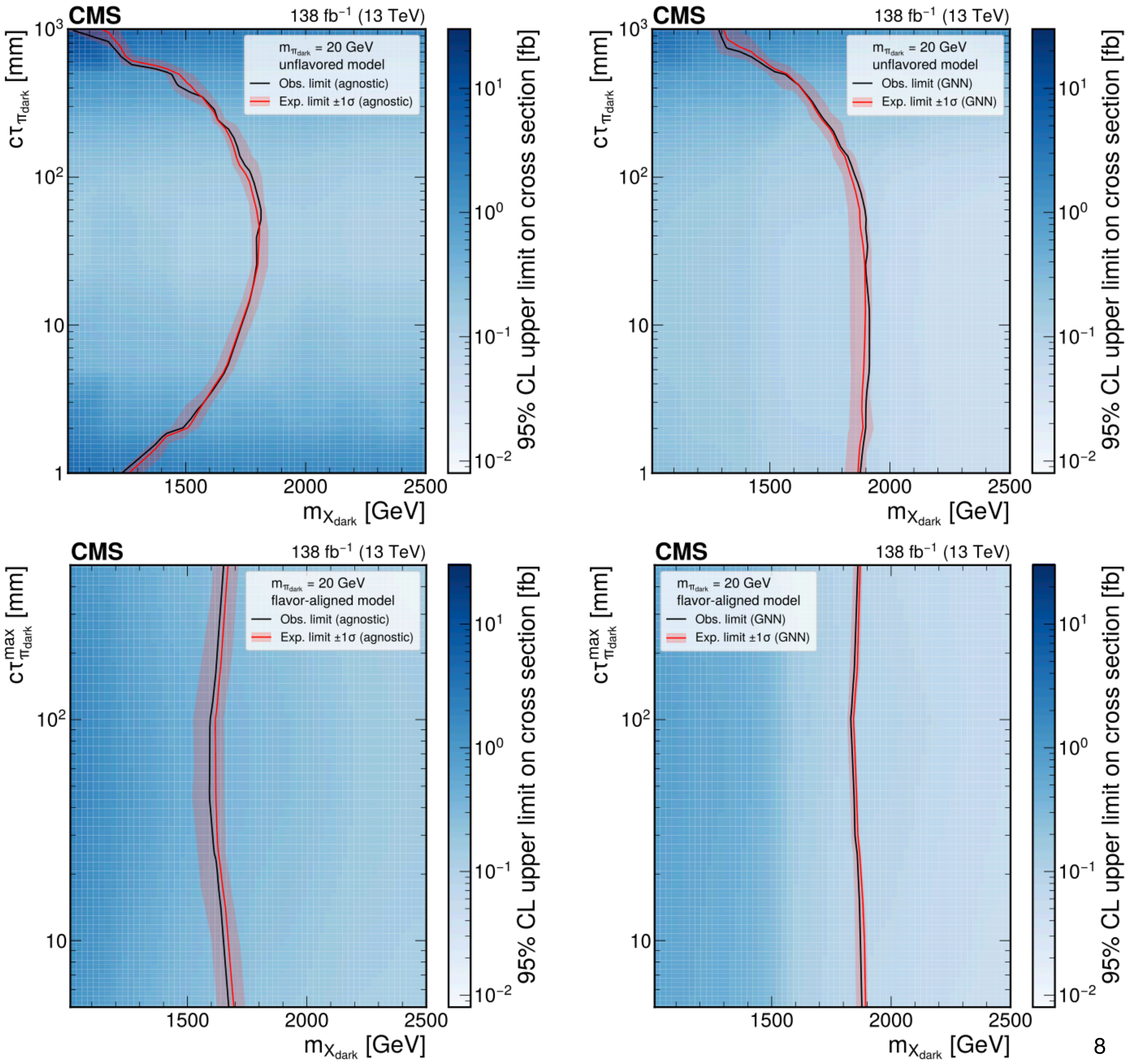
"Emerging jets" scenario: all dark pions have same decay length (by construction)

Aligned scenario: dark pions which can't decay to b-containing final states emerge later

Aligned scenario: dark pions which can decay to b-containing final states emerge first

CMS search

2403.01556



Top plots: "unflavored model", all dark quarks couple only to down quarks

Bottom plots: aligned scenario

Summary

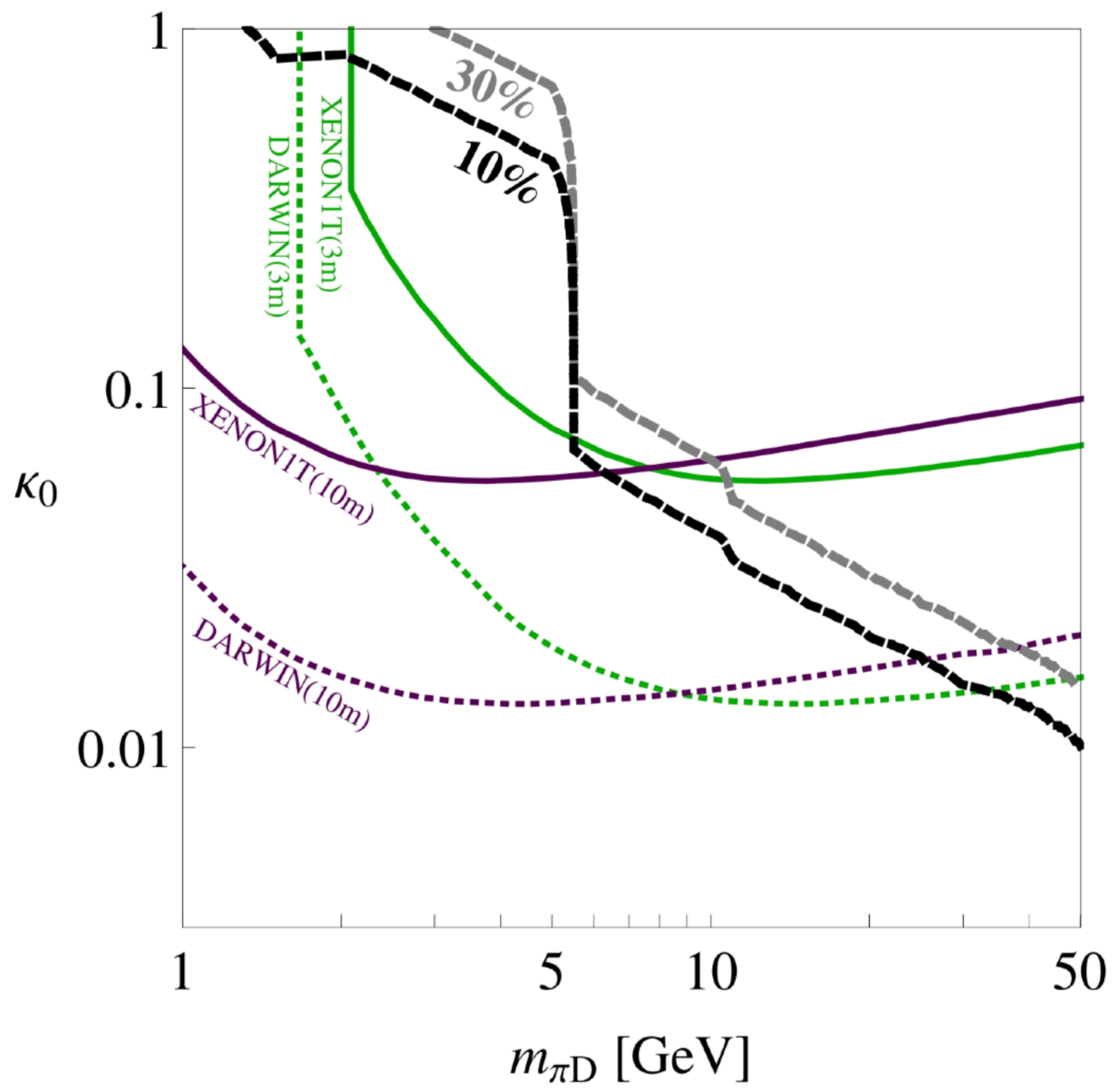
Dark sector models with a t-channel mediator to the SM often carry flavour structure

If such a dark sector confines, the dark pions have flavour-specific couplings

These affect the decay modes and lifetimes of the dark pions

Expect more than one length scale within an emerging jet, and heavier flavours emerge first

Backup



$$\kappa = \kappa_0 \mathbb{1}_{3\times 3} \qquad m_X = 1 \text{ TeV}$$

Above black (grey) line:
10% (30%) of energy in dark jets will emerge within 1m transverse distance

DM direct detection constraints imply dark pions should be heavier than about 10 GeV for "emerging jets"-like behaviour