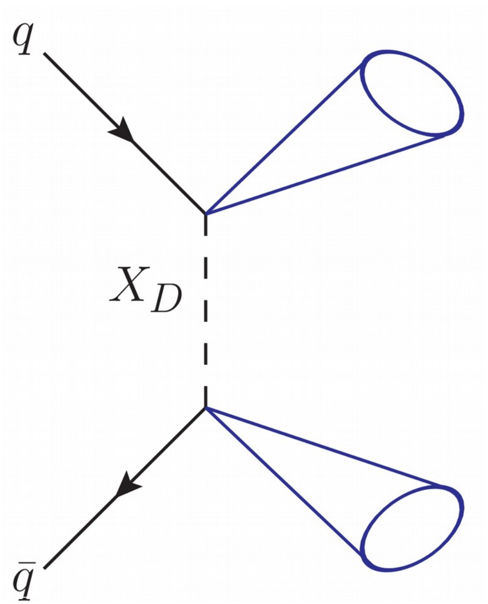
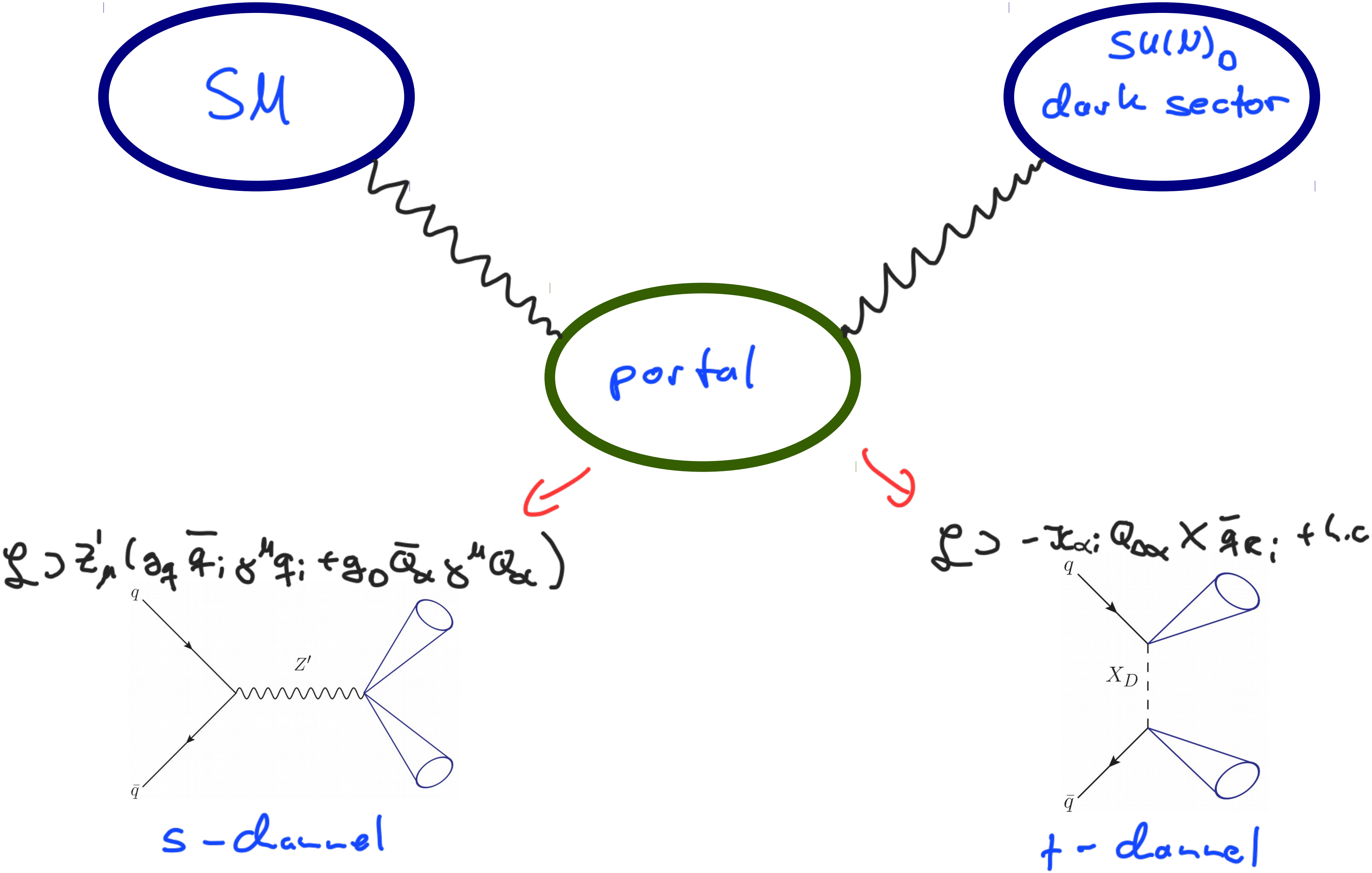
Strongly interacting dark matter pheno at colliders: t-channel mediators



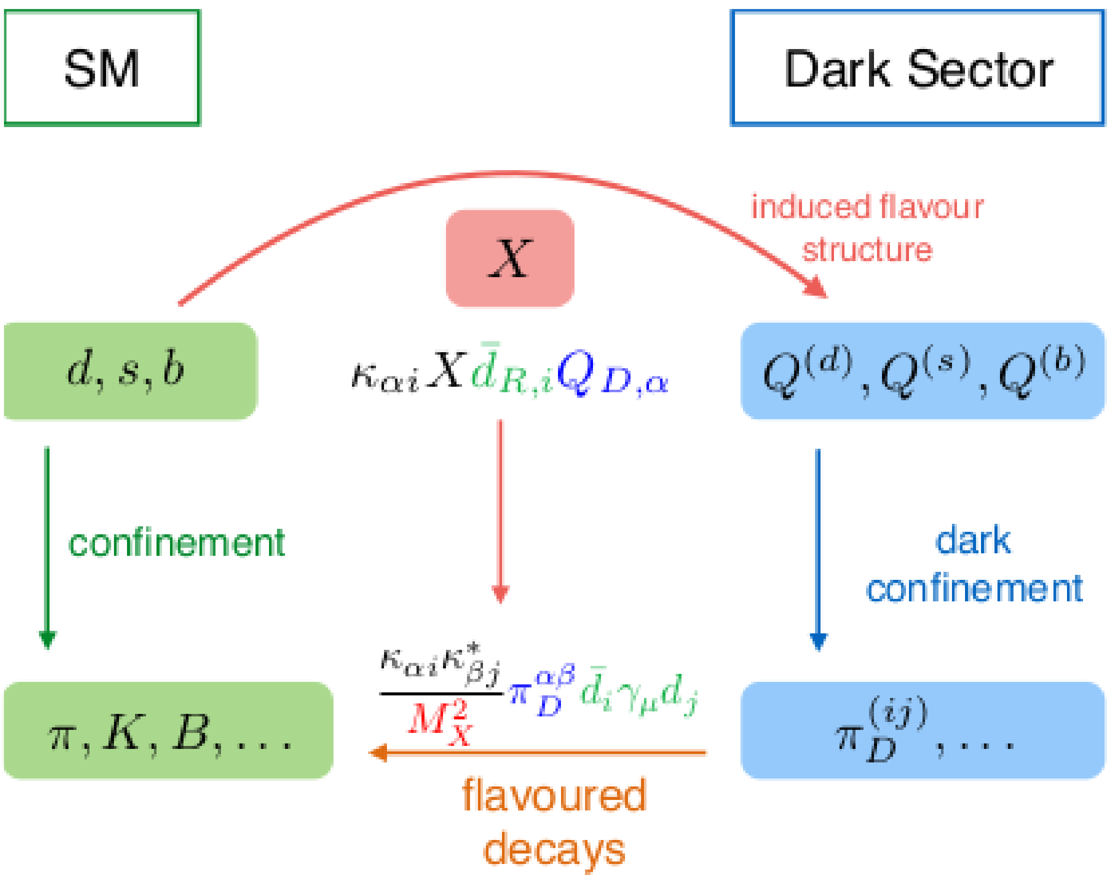
Christiane Scherb (Mainz University)

Dark Showers Snowmass Project Meeting

Based on
Bai, Schwaller, 2013
Schwaller, Stolarski, Weiler, 2015
Renner, Schwaller, 2018
Mies, CS, Schwaller, 2020


SM
SU(N)_D
dark sector
portal
ℒ ⊃ Z'_μ (g_q q̄_i γ^μ q_i + g_D Q̄_α γ^μ Q_α)
q
Z'
q̄
s-channel
ℒ ⊃ -λ_αi Q_α X q̄_i + h.c.
q
X_D
q̄
t-channel

t-channel models



$$\mathcal{L} \supset -\frac{1}{4} G_{D\mu\nu} G_D^{\mu\nu} + i \bar{Q}_D \not{D} Q_D - m_Q \bar{Q}_D Q_D + D_\mu X_D D^\mu X + m_X |X|^2 - \kappa_{\alpha i} Q_{D\alpha} X \bar{q}_{Ri} + h.c.$$

$SU(3)_D$, 3 dark flavours

$q_{Ri} = d_{Ri}$ or u_{Ri}

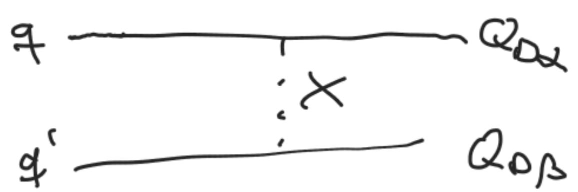
connection to flavour

Yukawa-like coupling

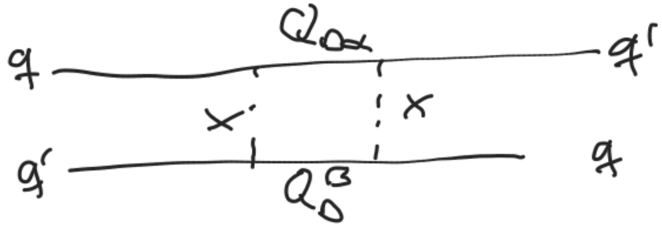
$$\lambda_{ij}\bar{q}_{R_j}X_D Q_{D_{L_i}}$$

constraints from

- exotic meson decays



- neutral meson mixing

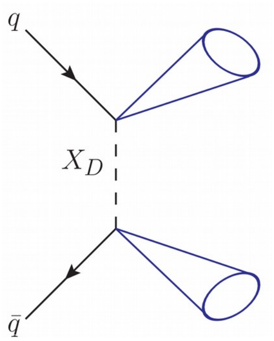


→ couplings to up- and down-type quarks studied

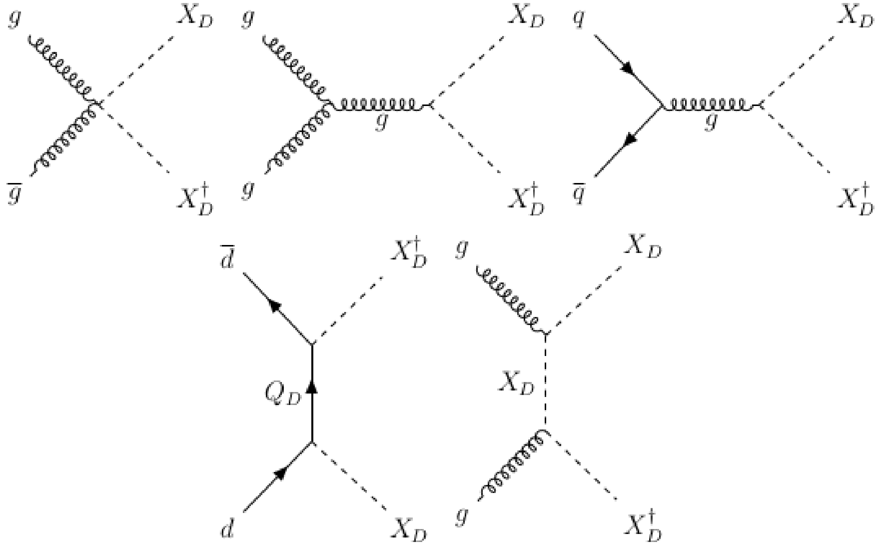
→ collider pheno mostly for couplings to down-type quarks

collider phenomenology

1) direct pair-production of dark quarks



2) pair-production of mediator

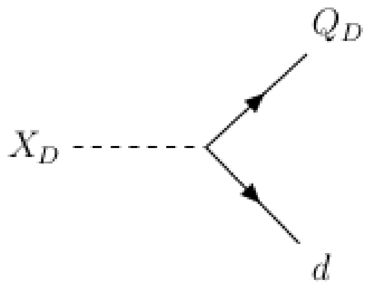


Collider signatures

focus on pair produced mediators coupled to down-type quarks

- production cross-section depends on flavour structure of the model
- each mediator decays to

  a quark and dark quark

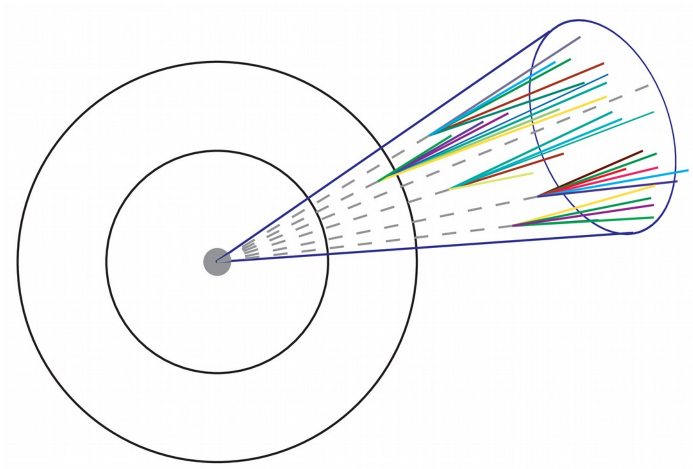
  

  ➔ always two SM jets

  ➔ dark shower, possibly containing stable DM candidate(s)
- signature depends on lightest dark hadron (dark pion) lifetime

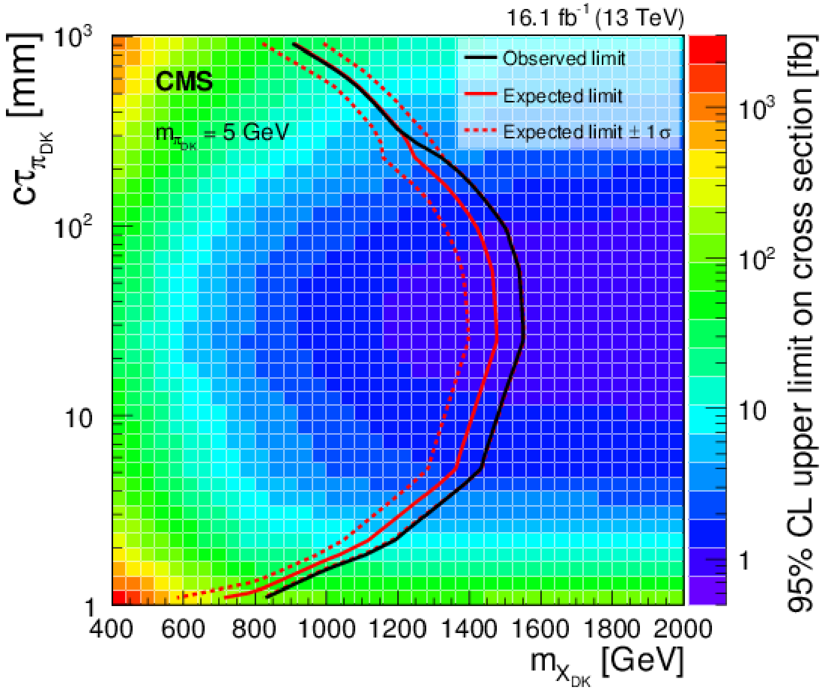
Collider signatures

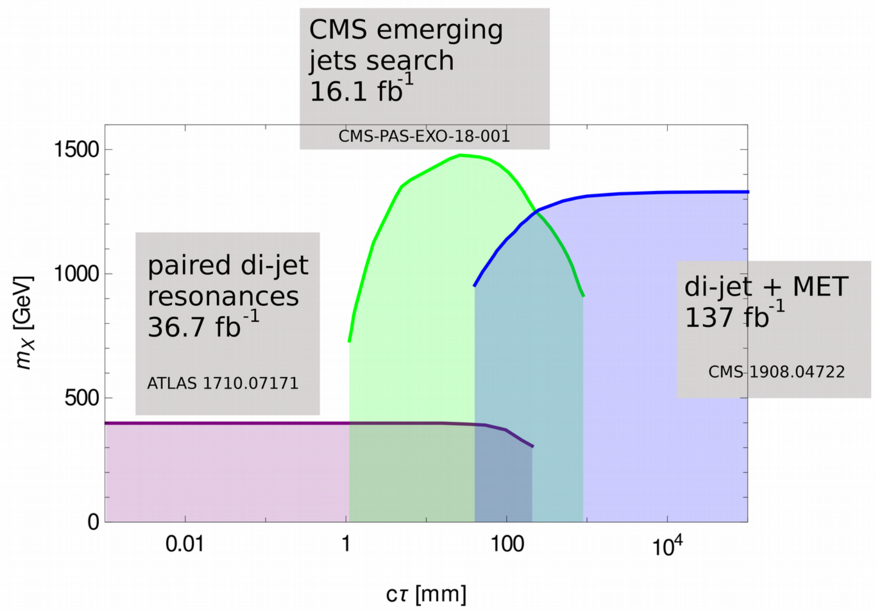
- prompt dark pion decay: paired di-jet resonance
- dark pions stable on collider scales: di-jet + MET
- intermediate lifetimes: emerging jets
  - ➔ few/no tracks in inner detector
  - ➔ dark pions decay at different distances from decay point
  - ➔ MET from DM candidate



Searches

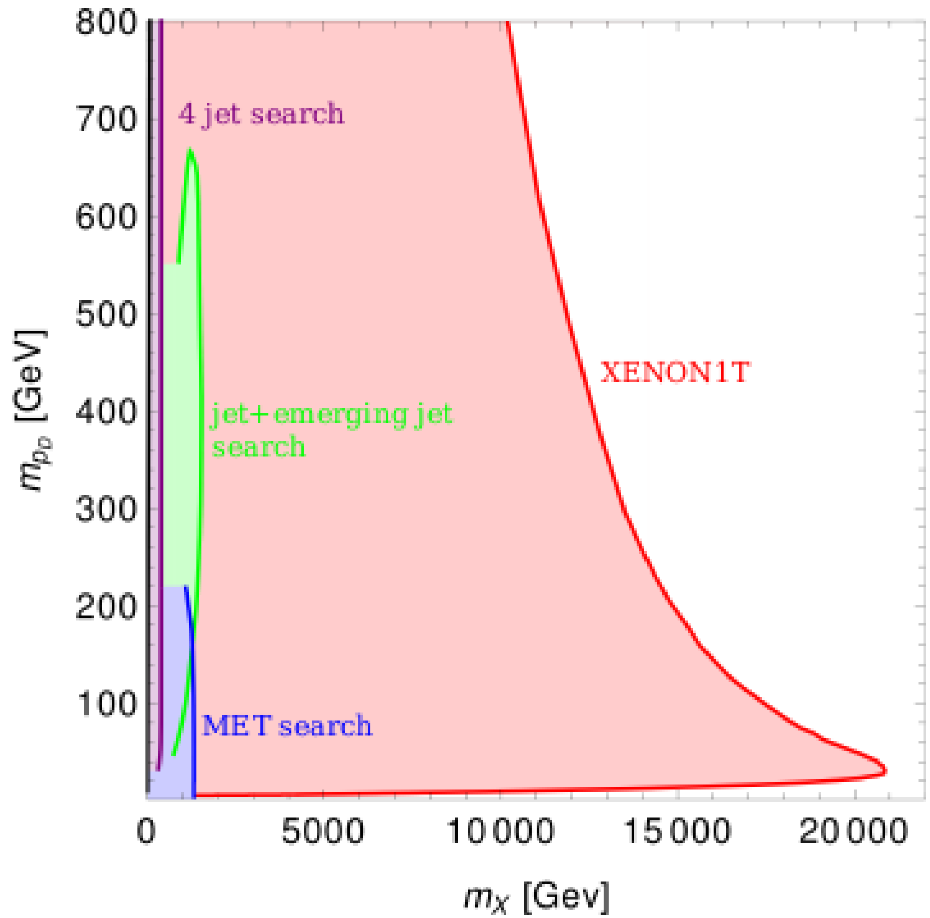
universal π_D lifetime



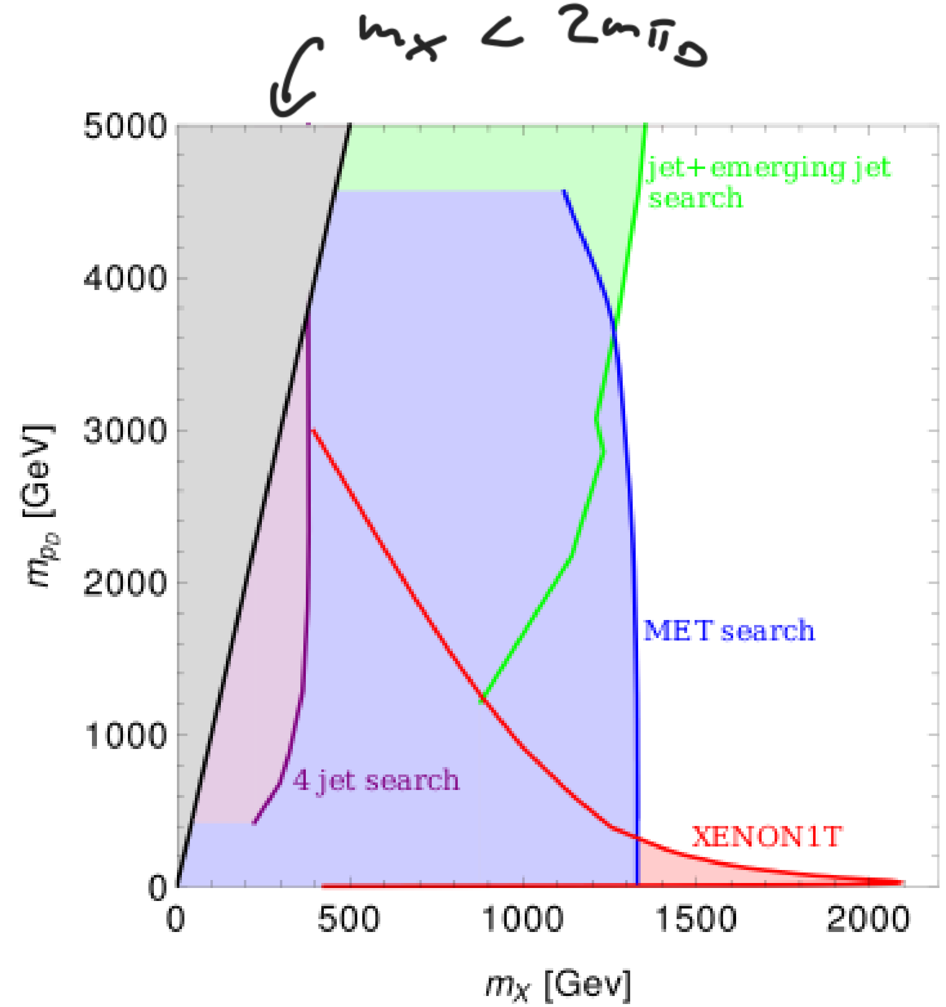


$m_{\pi_D} = 5$ GeV

DM-mass – mediator-mass space



$\lambda_{ii} = 1$

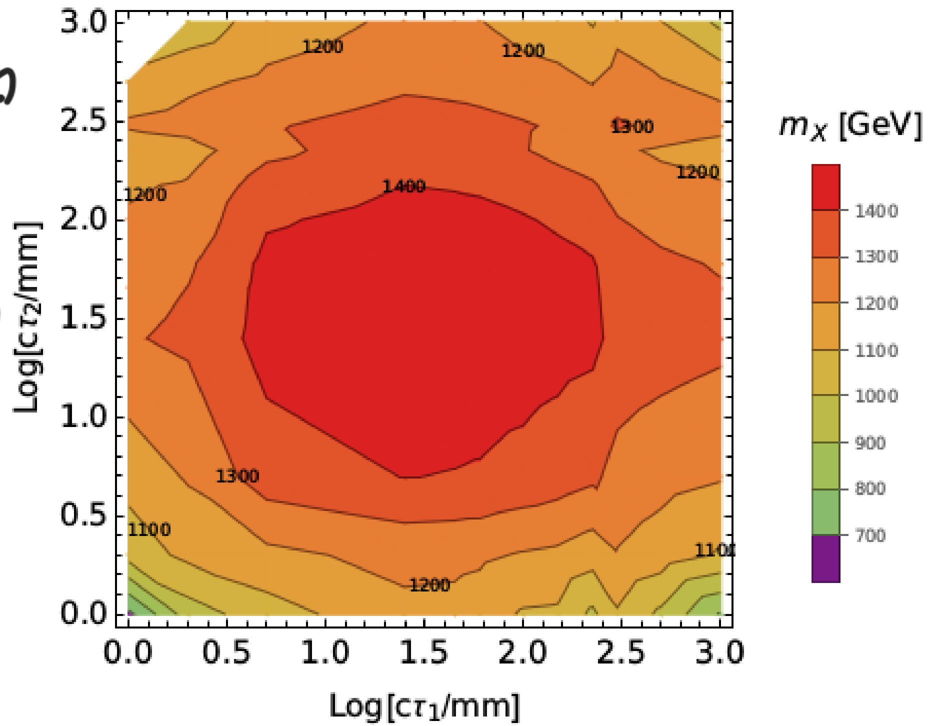


$\lambda_{ii} = 0.1$

$m_{\pi_D} = \frac{1}{10} m_{\rho_D}$

What happens for various dark pion lifetimes?

off-diagonal π_D



diagonal π_D

- sensitivity depends strongly on search implementation
- vetoes on prompt tracks could reduce sensitivity, if one dark pion decays nearly prompt

$n_{\text{dark flavours}} = 3$

Conclusion/Outlook

- (t-channel) dark sectors feature interesting pheno
- many signatures still unexplored:
  - up-flavoured dark sectors

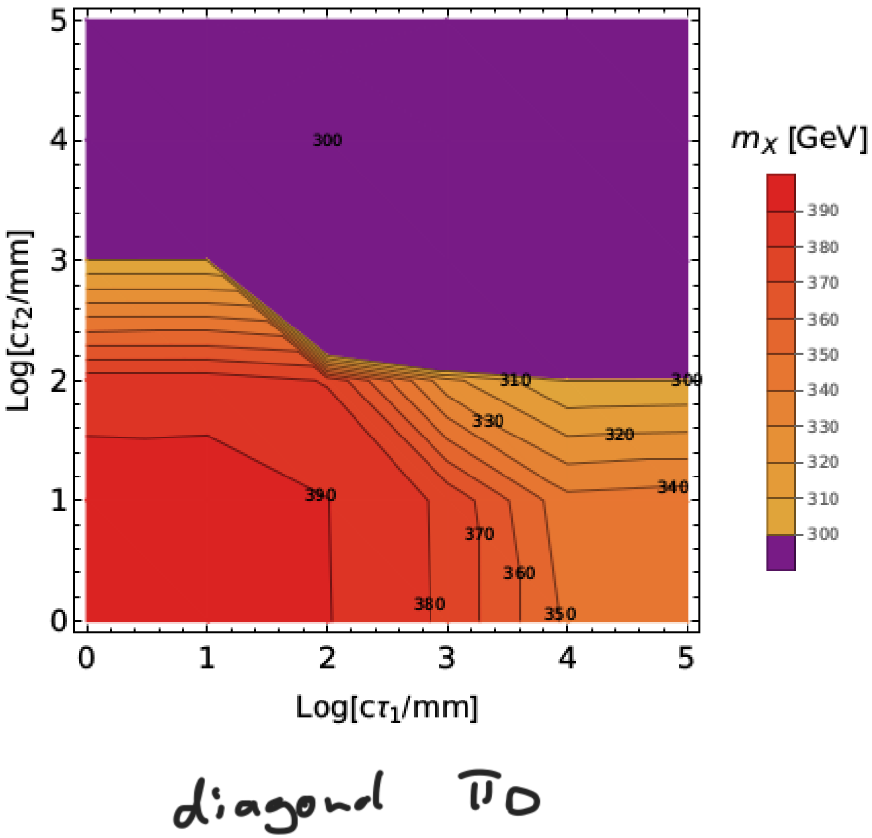
    ➔ dark showers from top decays possible
  - several dark pion species → new Pythia version
  - models with several mediators
  - ...

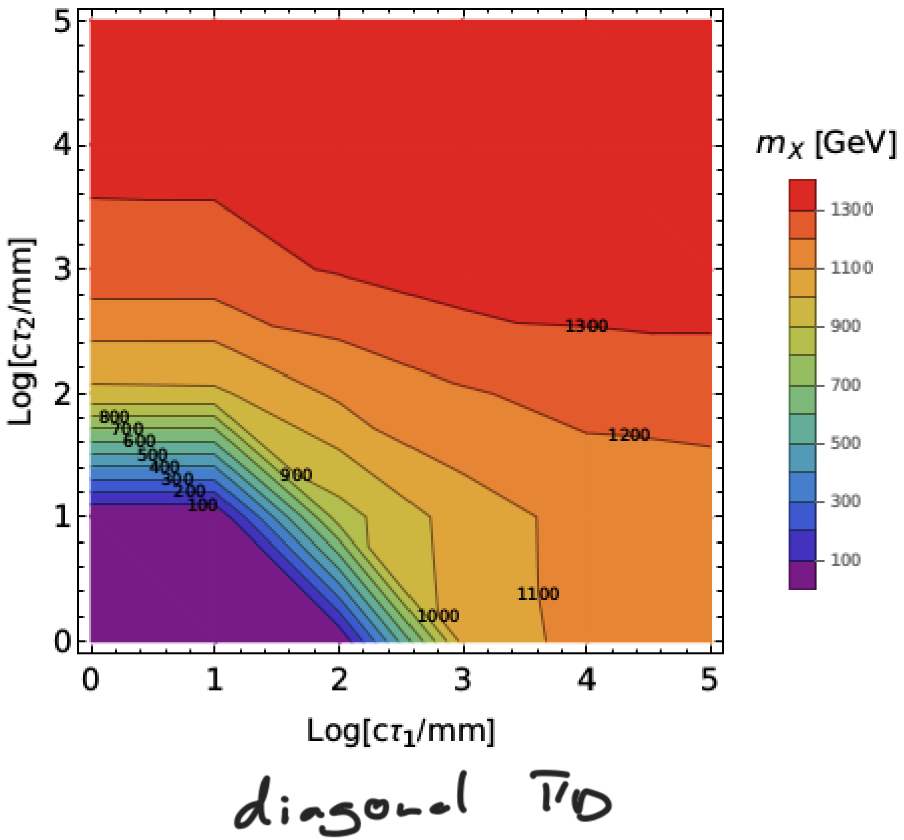
Back-up

What happens for various dark pion lifetimes?

paired di-jet

di-jet +MET





off-diagonal πD

Adding flavour

- rare meson decays (depending on flavour structure)
- fixed target/forward physics facility
- direct detection

$\kappa_{\alpha i} = UDU$

$D = \mathrm{diag}(\kappa_0+\kappa_1, \kappa_0+\kappa_2, \kappa_0-\kappa_1-\kappa_2)$

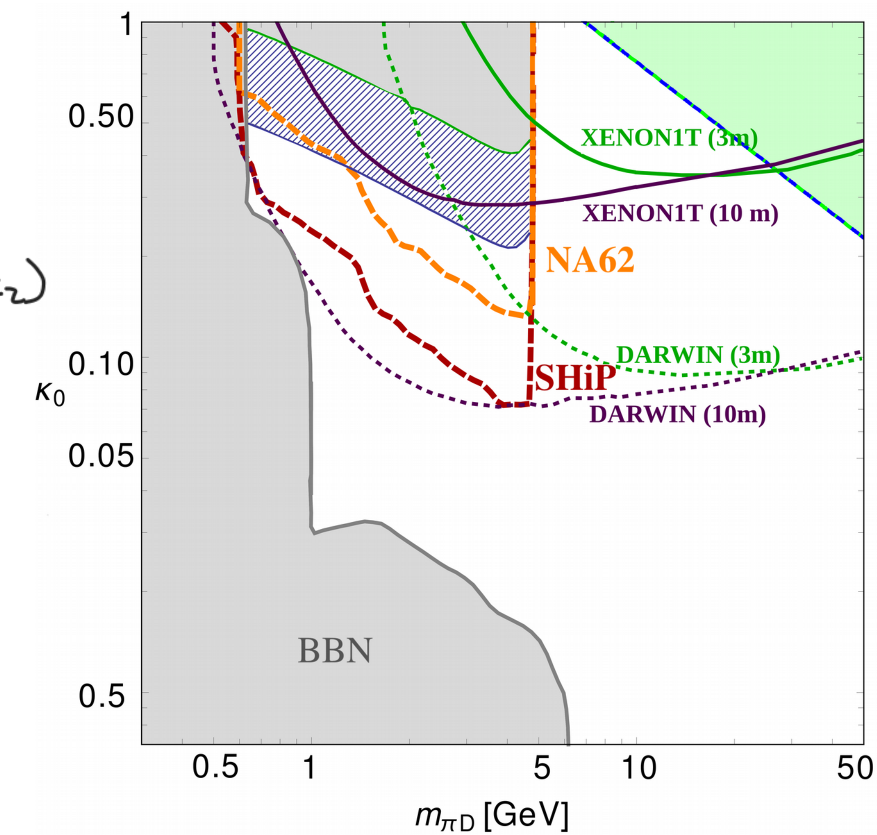
$\kappa_1 = \frac{1}{4}\kappa_0$

$\kappa_2 = 0$

$\theta_{12} = \theta_{23} = 0$

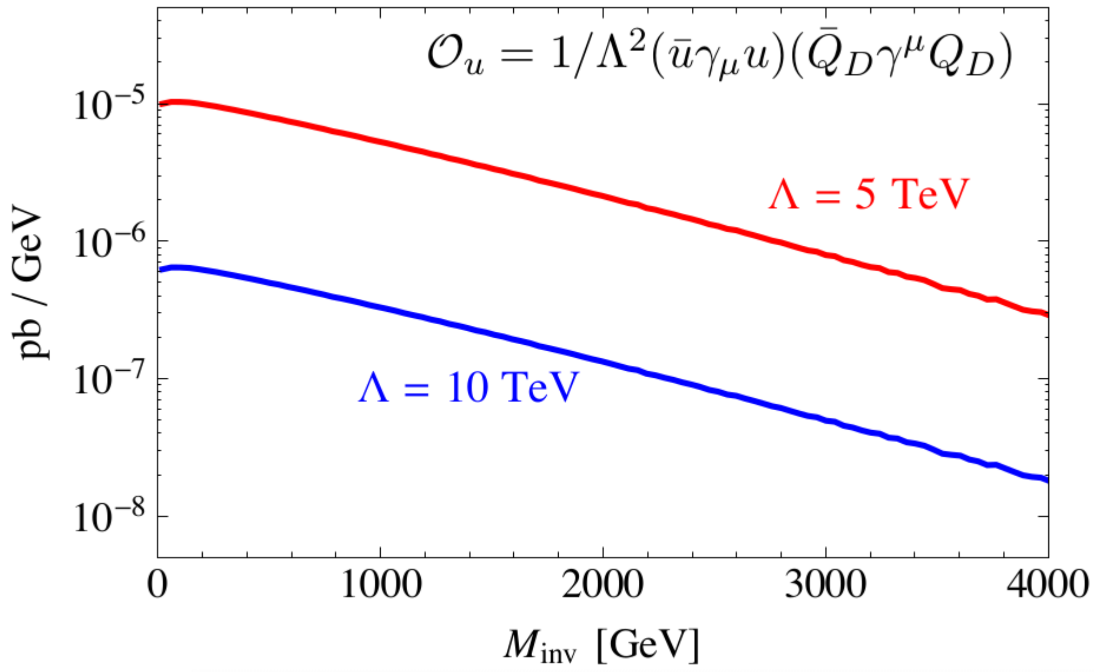
$\sin\theta_{13} = 0{,}05$

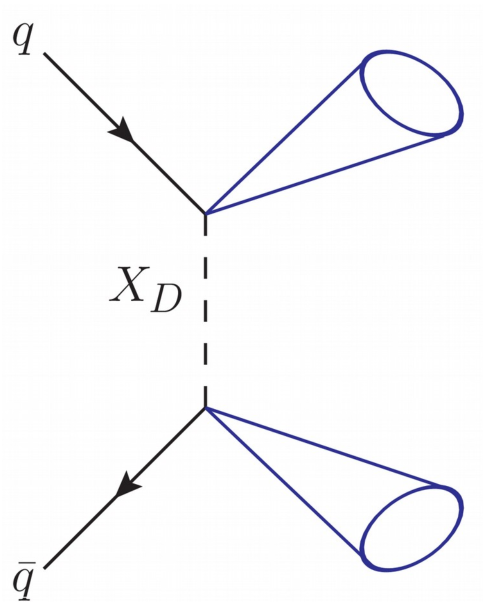
$m_X = 1{,}55$ TeV



direct production prospect

off-shell production

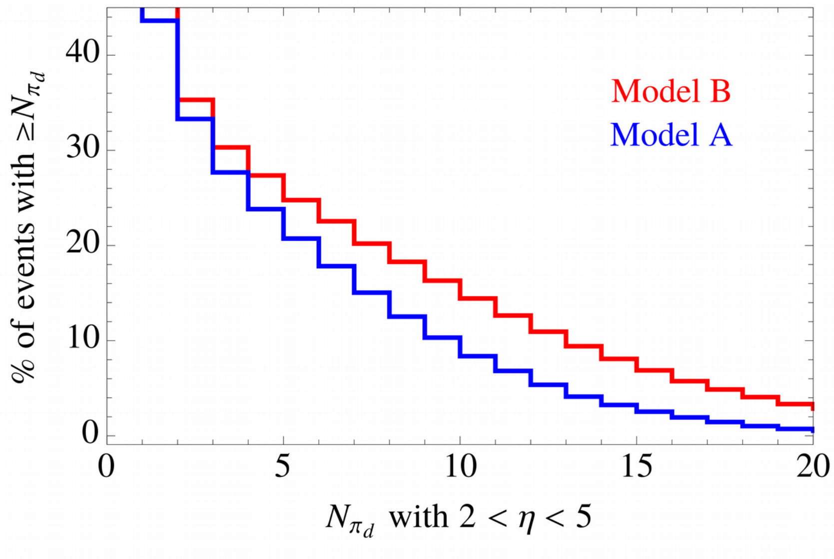




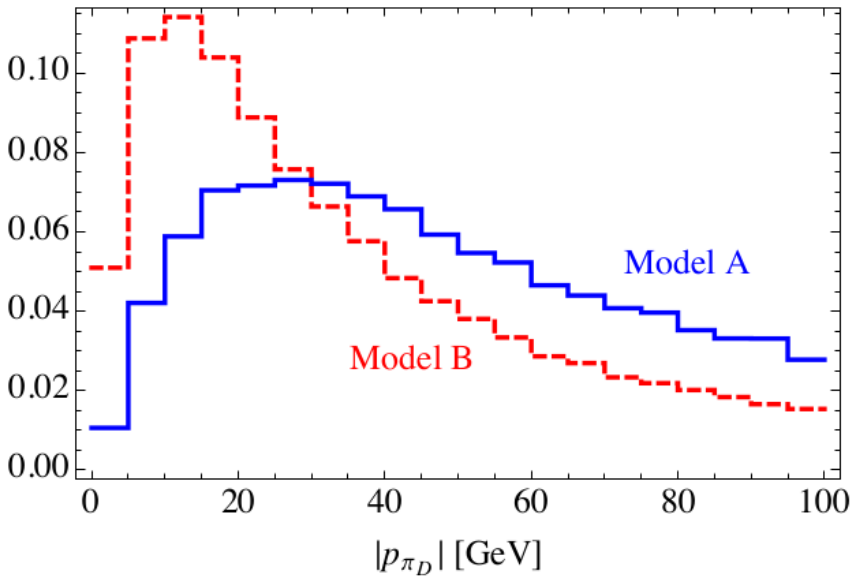
total rate: $$\sigma(pp \to \bar{Q}_D Q_D) \approx 8.2\ \text{pb} \times \left(\frac{\text{TeV}}{\Lambda}\right)^4 \times N_d \times N_F$$

LHCb prospect

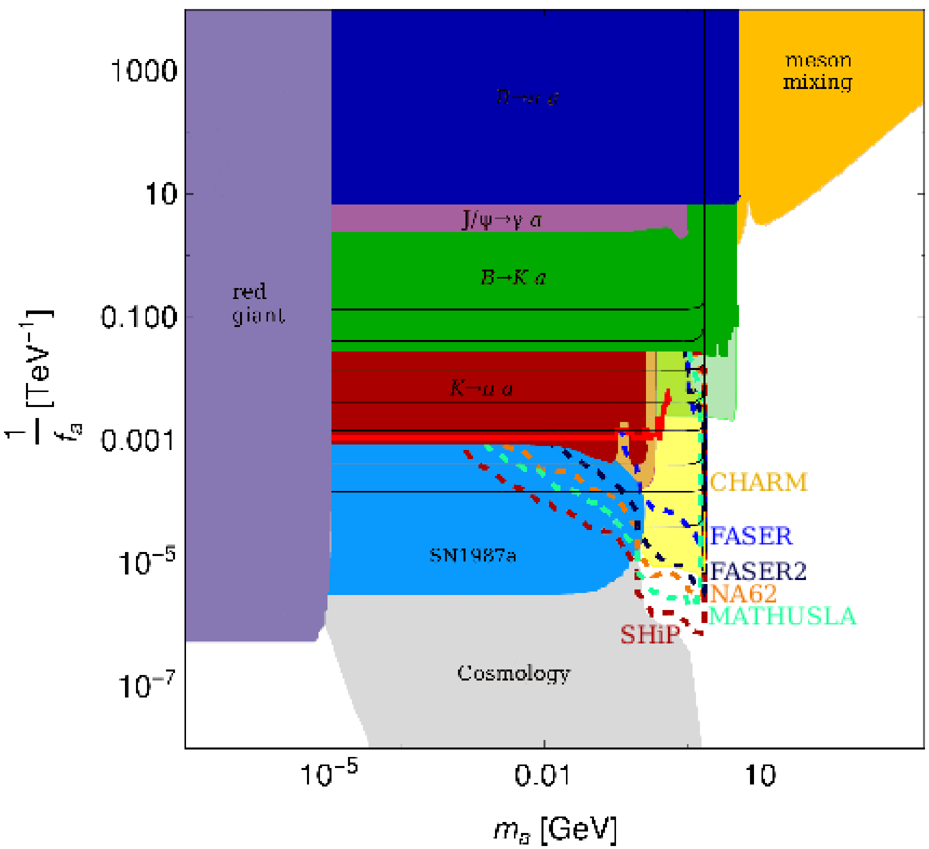
fraction of all signal events with N dark pions

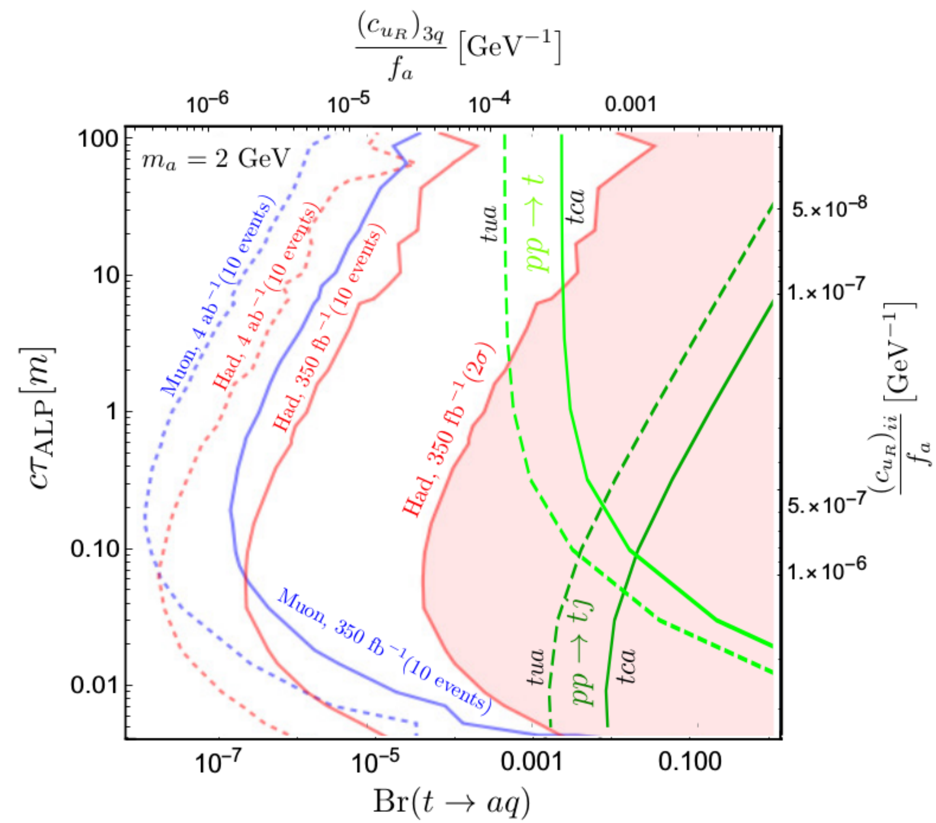


momentum (not pT) distribution of dark pions



up-sector prospects





general ACP $a = \pi_D^8$ $\rightarrow$ $m_a = m_{\pi_D}$

$$\frac{1}{f_a} = \frac{f_{\pi_D}}{m_X^2}$$