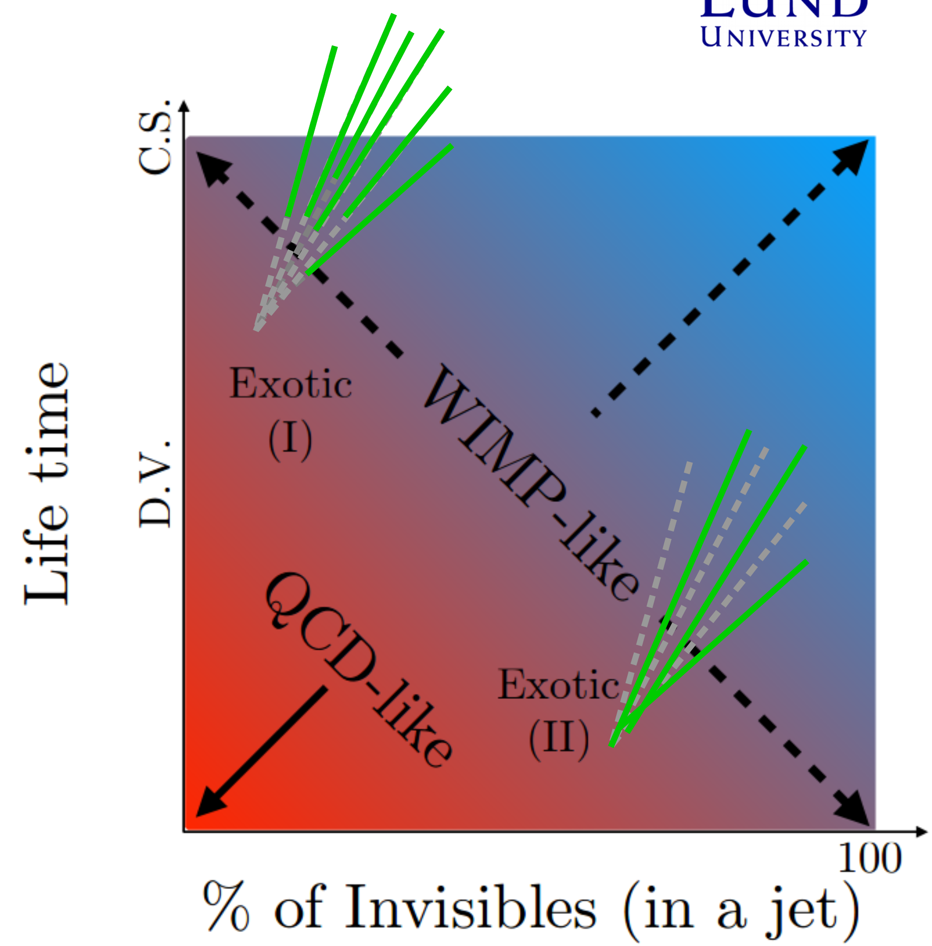
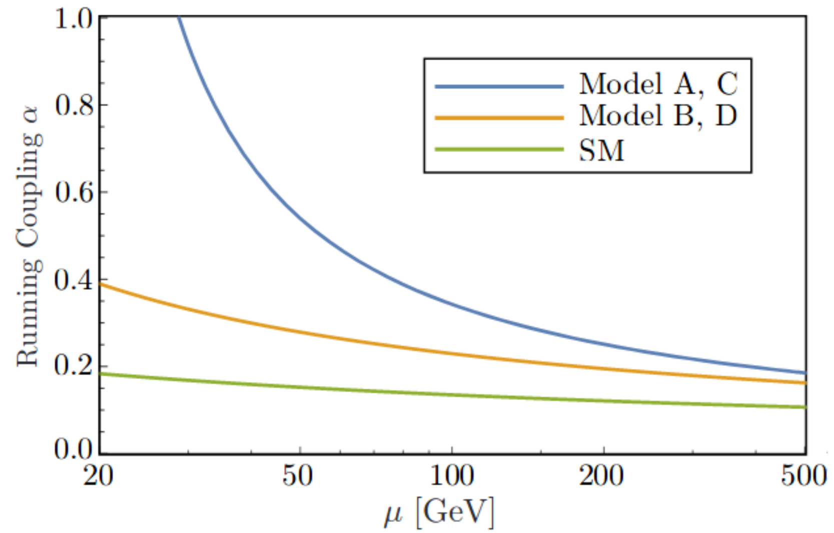
Dark Jets Benchmark Models

- Hidden sector with confinement (“dark QCD”) coupled to SM through a heavy mediator
- Different realisations can lead to very different detector signatures
- Composition of **visible** and **invisible** partons in the jet dependent on parameter choice:
  - Exotic I: Displaced vertices, emerging jets
  - Exotic II: Semi-visible jets
  - **We target SM QCD-like models**
    - With *s*-channel mediator decaying to two dark quarks



Dark Jets Benchmark Models

- Four models implemented in Pythia Hidden Valley process
  - **All have larger confinement scales than SM QCD!**
  - Based on arXiv:1712.09279
- Strategy:
  - Select dijet events using **substructure variables**
  - Look for a bump in the dijet invariant mass spectrum



	N_d	n_f	Λ_d (GeV)	$\tilde{m}_{q'}$ (GeV)	m_{π_d} (GeV)	m_{ρ_d} (GeV)	π_d Decay Mode	ρ_d Decay Mode
A	3	2	15	20	10	50	$\pi_d \to c\bar{c}$	$\rho_d \to \pi_d \pi_d$
B	3	6	2	2	2	4.67	$\pi_d \to s\bar{s}$	$\rho_d \to \pi_d \pi_d$
C	3	2	15	20	10	50	$\pi_d \to \gamma'\gamma'$ with $m_{\gamma'} = 4.0$ GeV	$\rho_d \to \pi_d \pi_d$
D	3	6	2	2	2	4.67	$\pi_d \to \gamma'\gamma'$ with $m_{\gamma'} = 0.7$ GeV	$\rho_d \to \pi_d \pi_d$

Decay modes

In all models, Zv → qv qvbar (BR~1.) and qv and qvbar hadronize to piv and rhov with rhov → piv piv (BR=1.)

Model A: piv → c cbar (BR=1.)

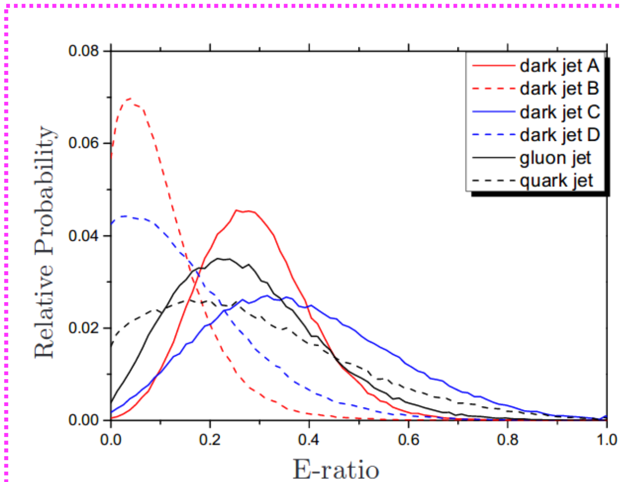
Model B: piv → s sbar (BR=1.)

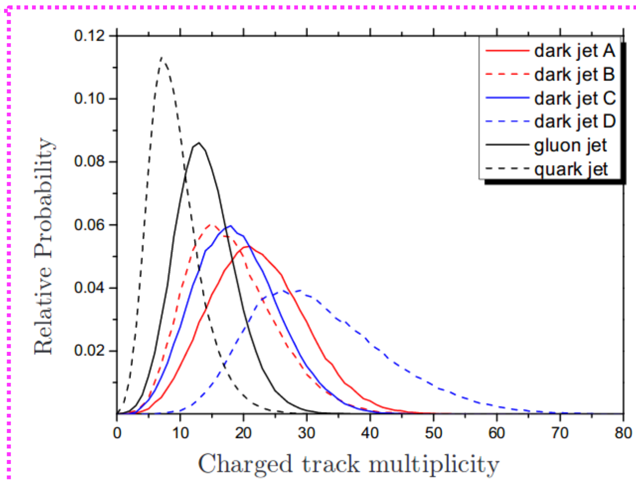
Model C: piv → gammav gammav (BR=1.)
gammav → d dbar (BR=0.22)
u ubar (BR=0.06)
s sbar (BR=0.06)
c cbar (BR=0.22)
e+e- (BR=0.17)
mu+mu- (**BR=0.17**)
tau+tau- (BR=0.10)

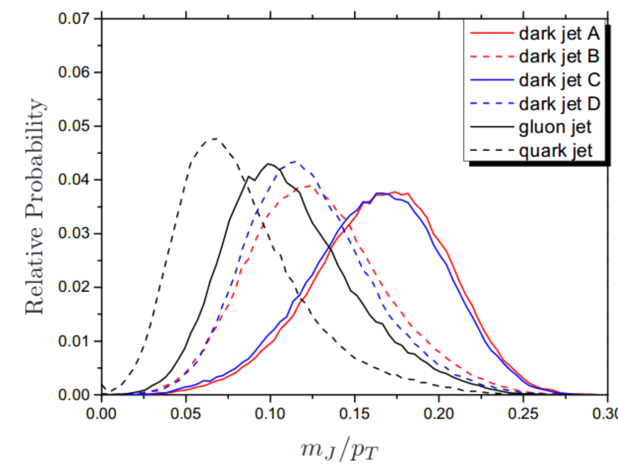
Model D: : piv → gammav gammav (BR=1.)
gammav → e+e- (BR=0.15)
mu+mu- (**BR=0.15**)
pi+pi- (BR=0.70)

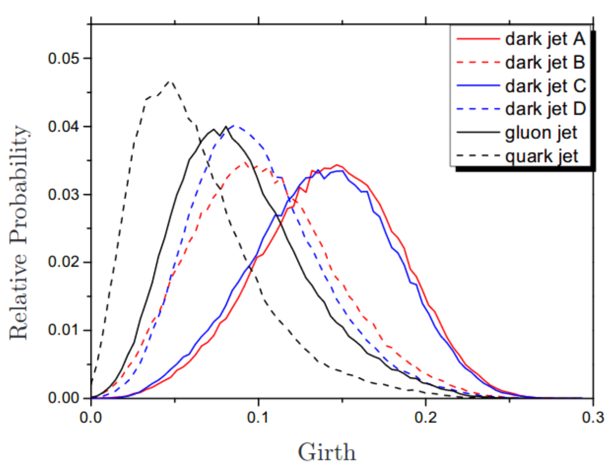
Jet Substructure Variable

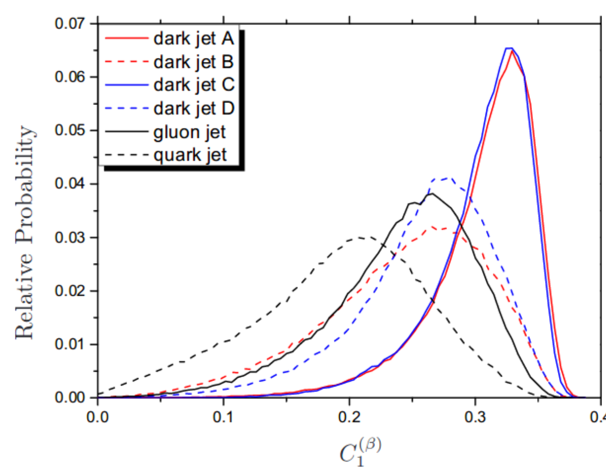
- The paper studies several substructure variables separately and combined in a BDT
- They find the charged track multiplicity (ntrk) to be the strongest discriminating single variable, which we have also found at reco level
- We are basing our event selection on ntrk and E-ratio, for sensitivity on all four models

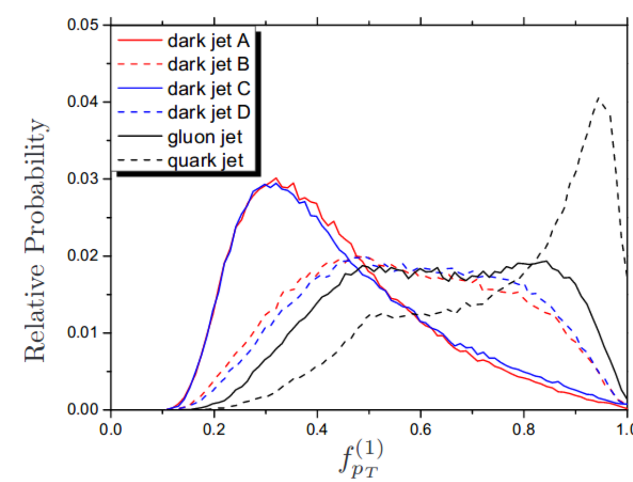












Dijet invariant mass spectrum

- The invariant mass spectrums (m_{jj}) all peak slightly below the resonance mass
- First thought: Missing mass carried by the dark protons
  - O(10%) according to Park and Zhang
- Should be “negligible” and therefore “all dark hadrons are assumed to decay promptly”
  - No sign of stable dark hadrons in the Pythia logs
- However, large muon component (~15%) in jets from model C and D
- Trimming (pile-up mitigation) has a sizable effect on all four models
  - Large fraction of soft components in the dark jets
  - Removing trimming brings m_{jj} peak close to resonance mass for model A and B
- Including the muons as well in the Invariant mass does the rest of the job for model C and D
- Resulting mass peak is slightly broader and below the real mass for model A and C
  - Probably due to the larger coupling

Summary and Outlook

- Four benchmark models implemented in Pythia HV where all dark hadrons decay promptly to SM particles
- Detected signature is very model dependent, but we can target all four with a combination of substructure variables
- The invariant mass distribution is very dependent on jet trimming and on the muon component for two of the models
- So what now?
  - Not an option to remove grooming – we need to get rid of pile-up – but we are considering other pile-up mitigation techniques
  - Adding muon-in-jet corrections might over-complicate analysis for a very model-dependent problem
  - **We would like to understand the impact of having/not having stable dark hadrons in the signal jets**
  - **Next big task is estimating systematic uncertainties**