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ATLAS

Digestible Dark Dijets
and other Delicacies

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Project Overview

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- **Performance work: In-situ jet calibration**
  - In particular combination of in-situ methods for large-R jets
  - Have done this since QT and been trying to get out of it for a year now
- **Upgrade work: gFEX**
  - An electronics board that will be part of the current upgrade of the ATLAS Level-1 Calorimeter Trigger
  - Lower granularity, but info from full calorimeter available
  - Will improve triggering on
    - heavy, boosted objects
    - Missing transverse energy
    - Interesting heavy ion collisions
  - I work on developing online control software for the board
- **Analysis: Dark dijet resonance search**
  - This is what I will talk about today!

School Recommendations

- **CERN School of Computing**
  - Two weeks in Madrid
  - Thorough introduction to many important concepts in (and outside of) HEP
- **International School of Triggering and Data Acquisition (ISOTDAQ)**
  - Ten day school in Vienna
  - Half lectures / half lab-work (e.g. FPGA-programming 😎)
- **GEANT 4 course**
  - One week here at Lund + project
  - Learn to make a simple mock-up simulation of your favorite detector
- **Nordic Detector School**
  - One week in Copenhagen, one week in Helsinki, project work after
  - Fun, fun, fun
- **Distributed Computing (COMPUTE)**
  - 16 hours lectures/exercises over four weeks + cool project at the end
  - Good ECTS value for work hours

Analysis:
Dark Jet Resonance Search

Motivation: Complex Dark Matter

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- Direct and indirect **WIMP searches have come up empty** so far
- Some cosmological simulations point towards self-interacting dark matter (DM)
  - E.g. composite DM arising from hidden sector with confinement
- Combined with asymmetric DM production, could explain mass and number density of DM and Baryons
- Requires heavy mediator linking hidden sector to visible sector

  → We might be able to **produce and detect dark jets**!

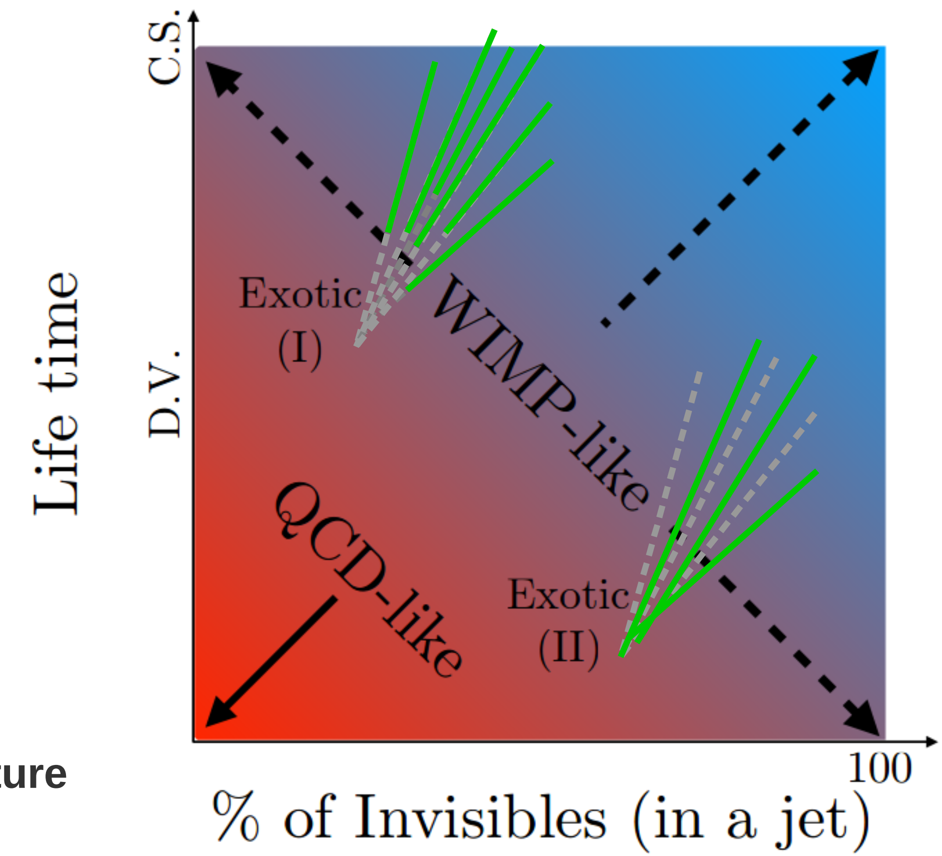
} References in Backup

the Standard Model	Mediator	Dark sector
$\gamma,\ g,\ l,\ q\ \ldots$ $\pi,\ \rho,\ p\ \ldots$	$X,\ Z'\ \ldots$	$\gamma',\ g',\ q'\ \ldots$ $\pi_d,\ \rho_d,\ p_d\ \ldots$
$SU(3) \times SU(2) \times U(1)$		$SU(N)'$ or $SU(N)' \times U(1)'$ or ...

Motivation: Bench Mark Scenarios

- Different hidden sector models 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: A fraction of dark mesons in a jet are stable and fraction decays promptly to Standard model particles

arXiv:1712.09279

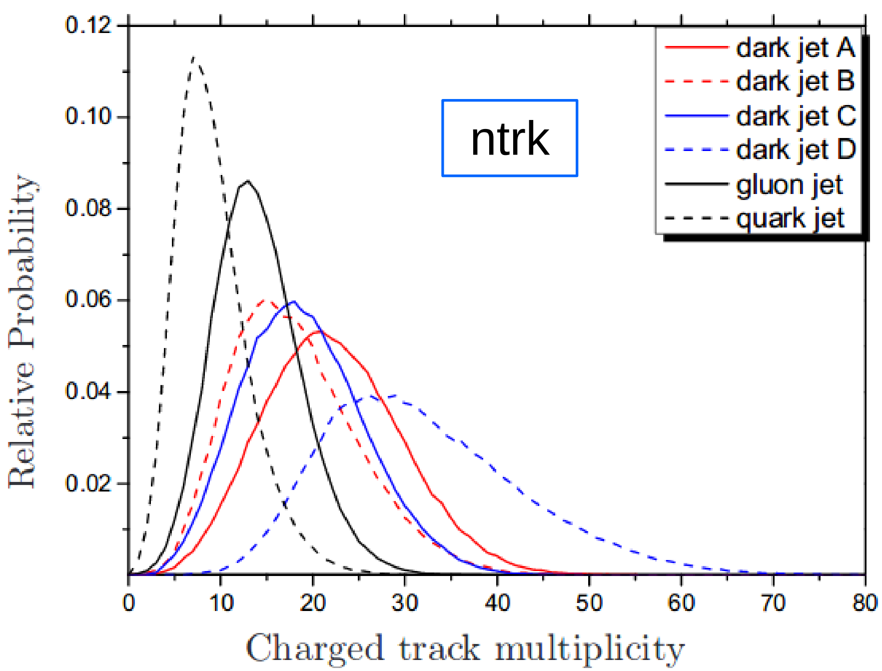


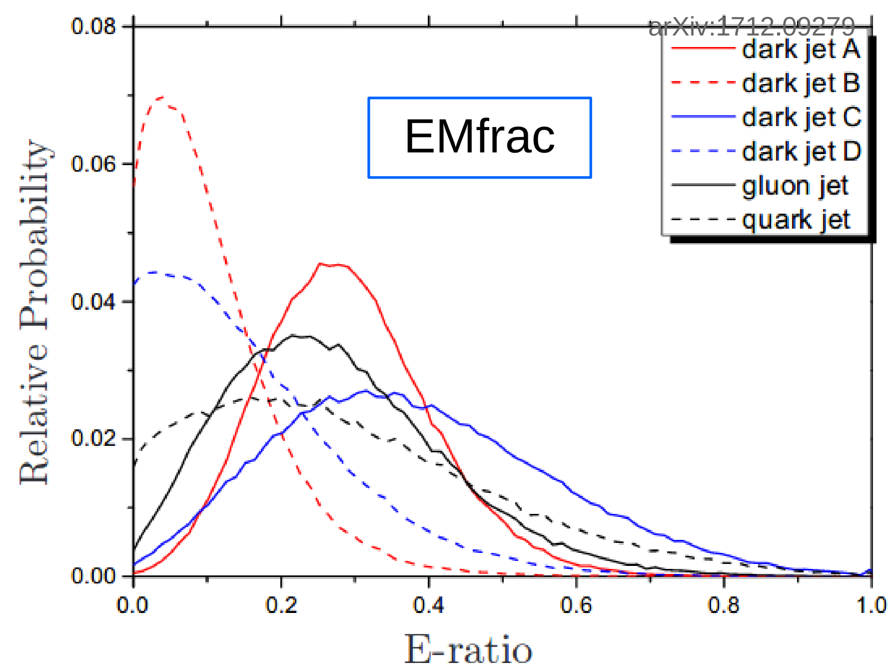
- **We target Exotic II like models:**
  - Idea: Look for dijet resonance using **substructure**
  - Based on arXiv:1712.09279
- Four models implemented in Pythia Hidden Valley process
  - Parameters chosen to be representative of different types of DM
  - Details in backup

Signal Selection Strategy

- Charged track multiplicity *ntrk* is strongest discriminating variable for a most models
  - Not true for all though – depends on coupling constant and decay time
- No upper limits exist on cross section, coupling, sensitivity
- Two signal regions:
  - **SR1:** High sensitivity, very pure, based on strict *ntrk* cut
  - **SR2:** More inclusive, less sensitive based on softer cuts on *ntrk* and *Emfrac*

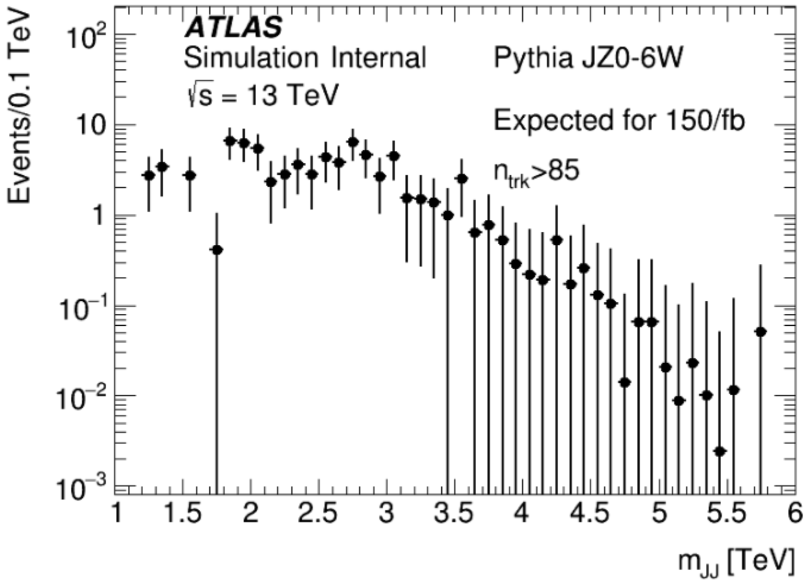
Generator-level results, no detector simulation:

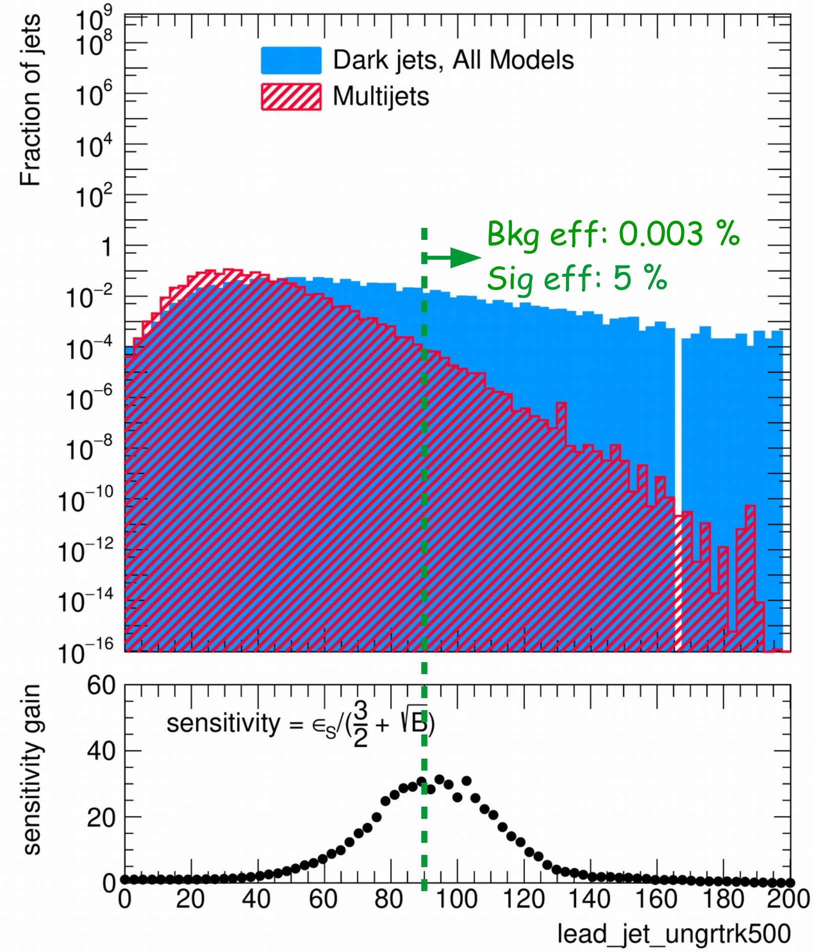




Signal Region 1: Challenge

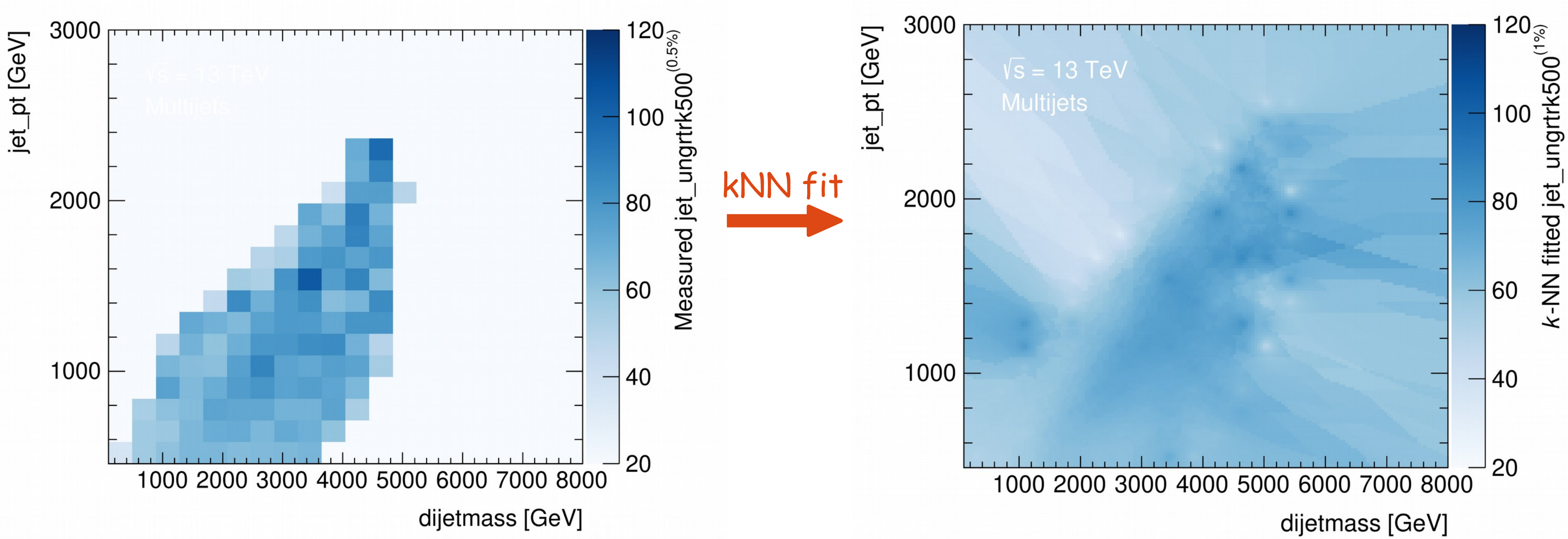
- Best sensitivity for a range of models obtained with very strict cut
- Strict *ntrk* cut significantly sculpts the background dijet mass spectrum
- Solution: Decorrelate *ntrk* from dijet mass!





Signal Region 1: Decorrelation method

- ”kNN method” decorrelates a discriminating variable from other variables
  - Described and tested in for *W*-tagging in ATL-PHYS-PUB-2017-004
- Pinciple:
  - Choose a substructure variable with good clissification power (here *ntrk*)
  - Decide on a fixed background single jet efficiency (0.5%, giving a signal eff. of 30%)
  - Evaluate the cut value on *ntrk* that gives desired bkg. eff. in bins of p_T and m_{jj}
  - Fit the distribution using the *k-nearest neighbours* (kNN) algorithm
  - For each jet, the new decorrelated observable is computed as $ntrk^{kNN} = ntrk - ntrk^{(0.5\%)}$
- Here $ntrk^{kNN}$ is defined from data in a control region with signal efficiency ~ 0.4 %



Signal Region 1: Results (preliminary)

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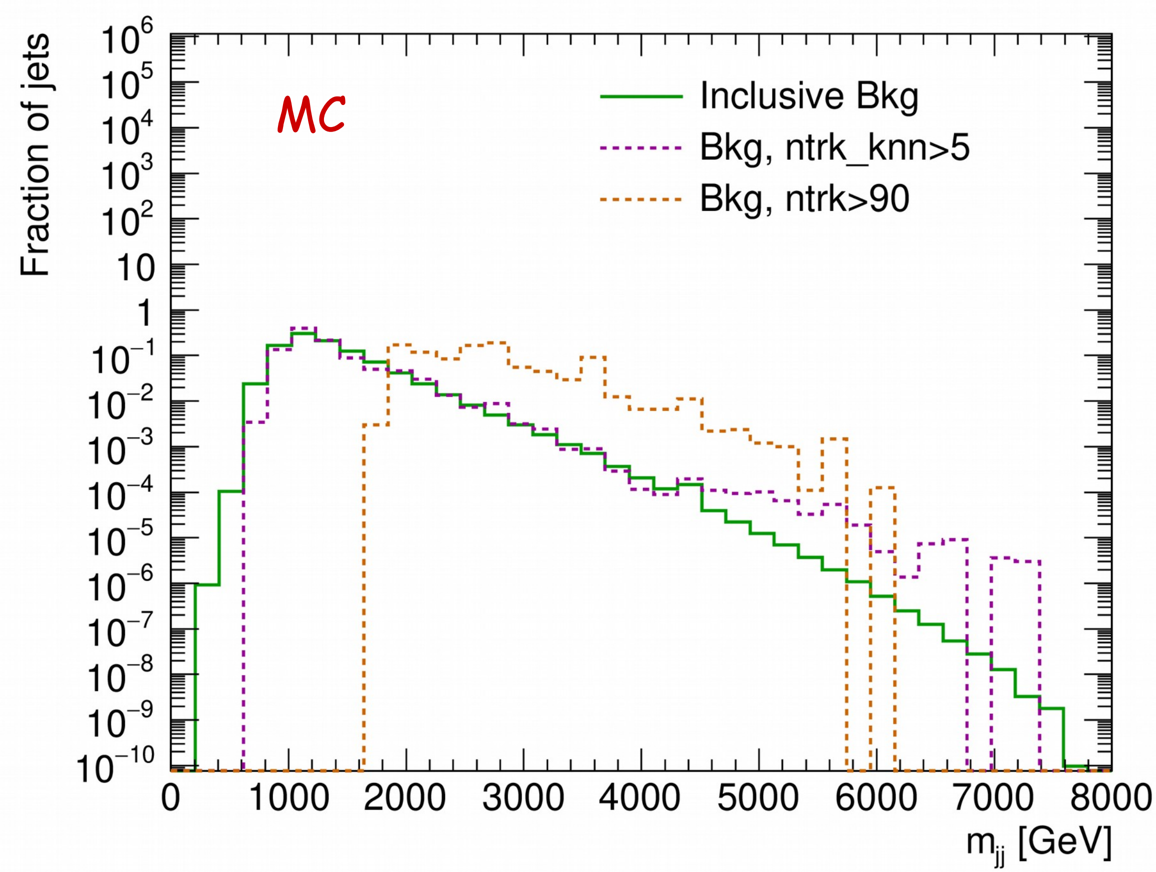
- Gives a smoothly falling spectrum up to ~4 TeV in MC
- Breaks down at higher mjj because of too low statistics in data sample
- Cut: Leading and sub-leading jet *ntrk*^{kNN} > 5
  - Background efficiency: 0.008 %
  - Signal efficiency (all tested models): 25 %



Conclusion and Plans

- **Loads of uncovered phase space in hidden sector models**
  - We can probe part of it by searching for dark jet
  - Many fun challenges for jet substructure fans
- **Analysis to-do list:**
  - Evaluate systematics
  - Optimise background fit
  - Validate with signal injection
- **Other plans:**
  - Write gFEX software
  - Write thesis

Backup

- Table of benchmark models

arXiv:1712.09279

	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	$\rho_d \to \pi_d \pi_d$

Backup

- Sensitivity distribution of *ntrk*^{kNN}
- Cut at peak sensitivity does not leave enough background events to fit