Dark showers:
discussion on detector and software challenges and opportunities

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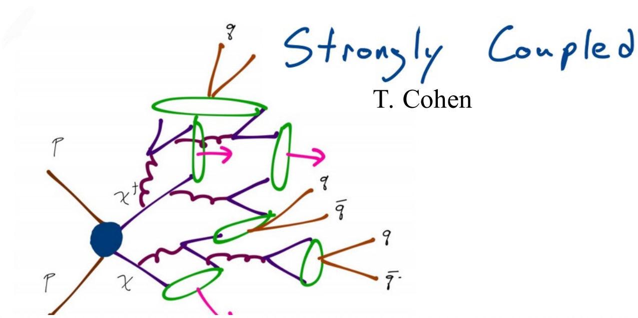
A rich phenomenology

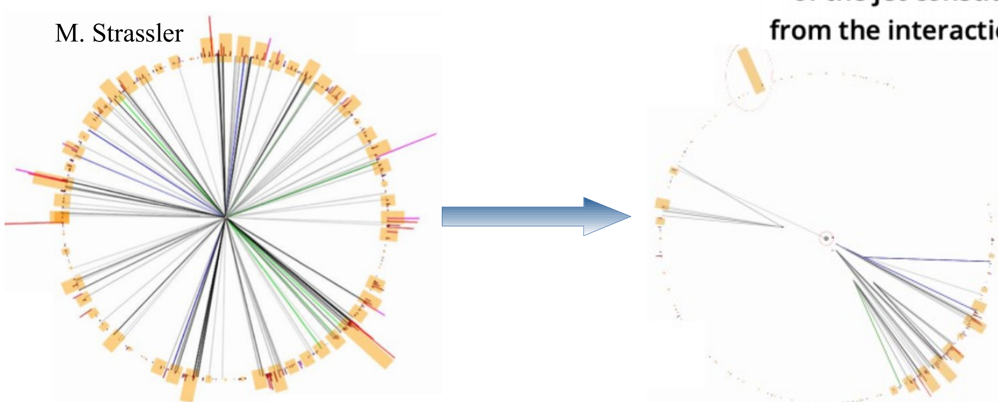
J. Shelton

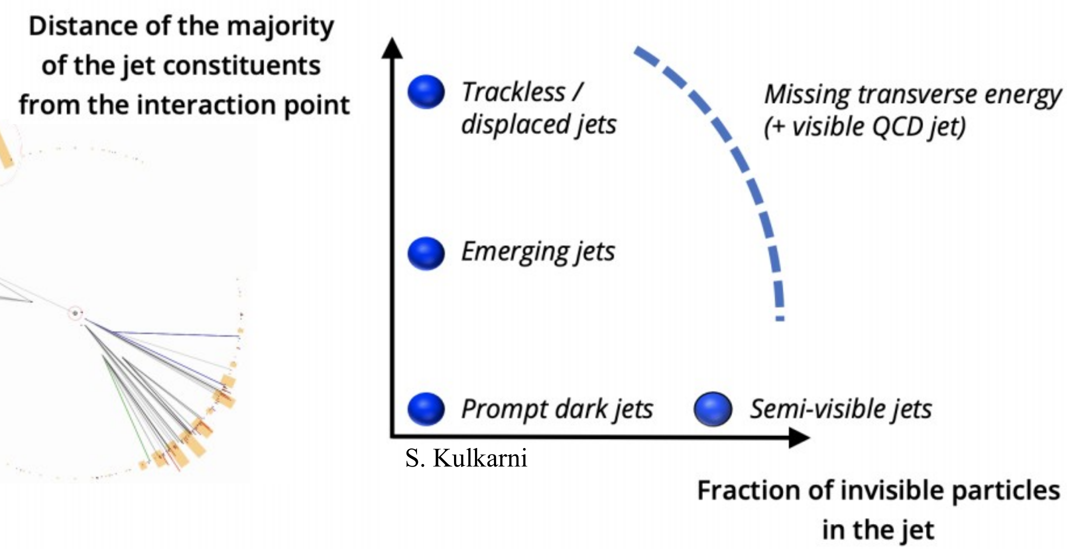
Decay portal	decay operator	features
gluon portal	$aG^{\mu\nu}\tilde{G}_{\mu\nu}$ or $\phi G^{\mu\nu}G_{\mu\nu}$	hadron-rich
photon portal	$aF^{\mu\nu}\tilde{F}_{\mu\nu}$ or $\phi F^{\mu\nu}F_{\mu\nu}$	photon shower
vector portal	$\rho'^{\mu\nu}F_{\mu\nu}$	semi-visible jet
Higgs portal	$\phi H^{\dagger}H$	heavy flavor-rich
dark photon portal	$aF'^{\mu\nu}\tilde{F}'_{\mu\nu} + \epsilon F'^{\mu\nu}F_{\mu\nu}$	hadrons + leptons



T. Cohen

M. Strassler





S. Kulkarni

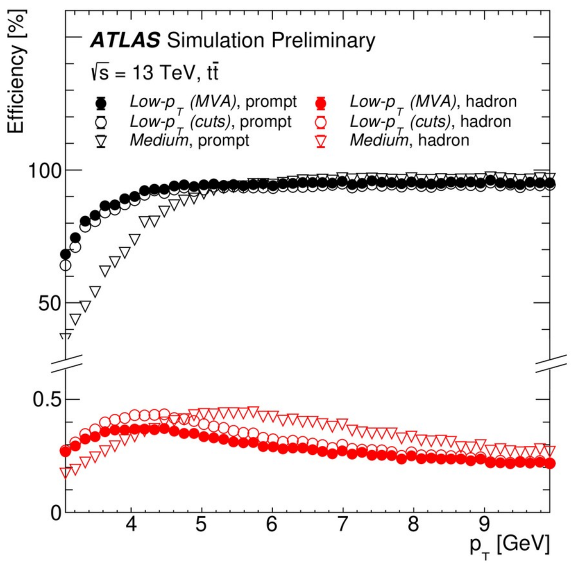
- Reminder:

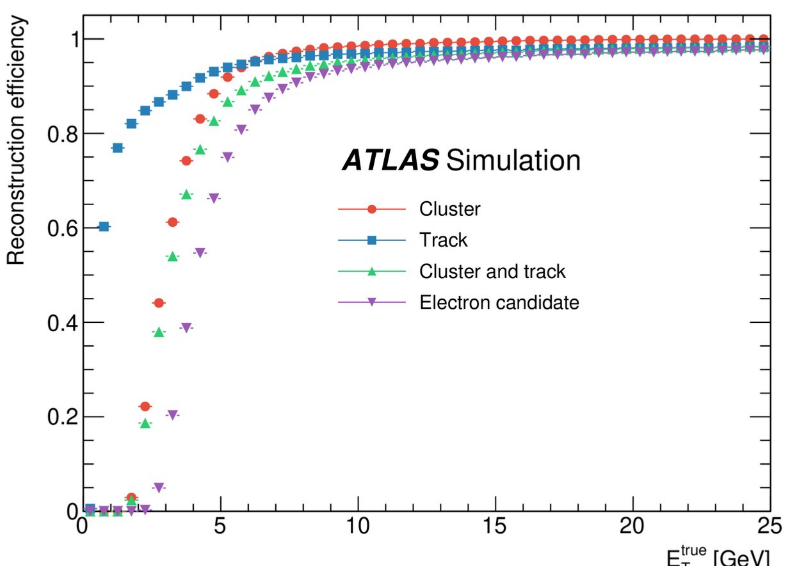
More information/ details available → More complex exp. observables → Striking (no background) signature / More complex analyses

important to learn to walk before we run

Low p_T activity - I

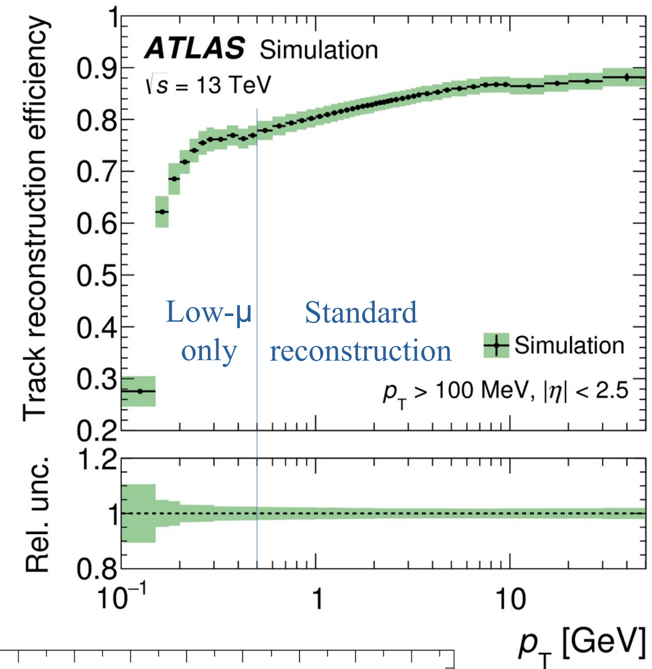
- Lots of information often encoded in low-p_T objects
  — LHC detectors designed to be efficient at high-pT
- Leptons
  — Continuous developments vs low-pT working points
  — Electrons/Muons ID down to few GeV (> ~5 GeV)
  — Compromise: higher fake rate
  — Reaching limit? (e.g. $p_T(\mu)$~3 GeV to get to MS)
  — Harder with higher pile-up (Run 3 and HL-LHC)
    - New Small Wheels in ATLAS to help in the forward region

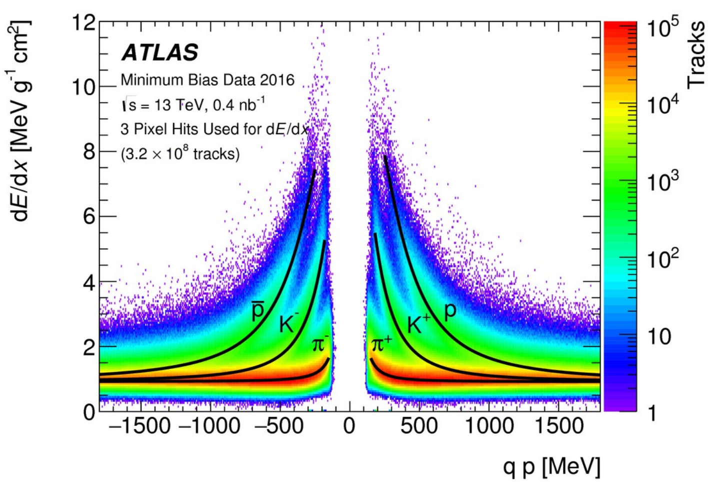


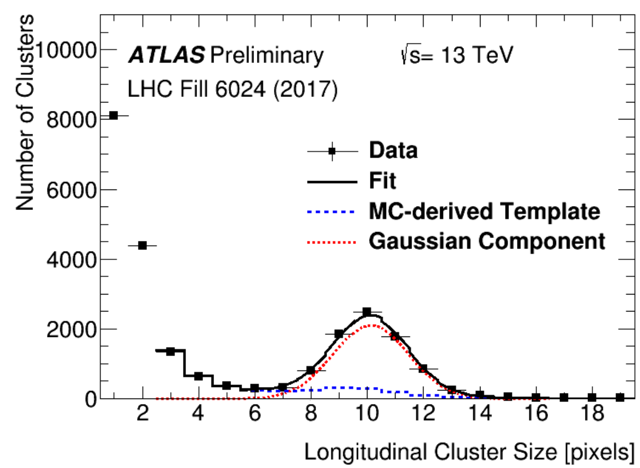


Low p_T activity - II

- Charged particles: inner tracker tracks
  - Large combinatorics, CPU time / disk space limit minimum p_T (compromise)
  - Several dedicated reconstruction setups (been, being and to be) developed need some "pre-selection" of interesting data
  - Synergy in pushing boundaries of what we can reconstruct and maintain flexibility in running custom reconstruction algorithms
- dE/dx, cluster shapes aid to tracking or stand-alone





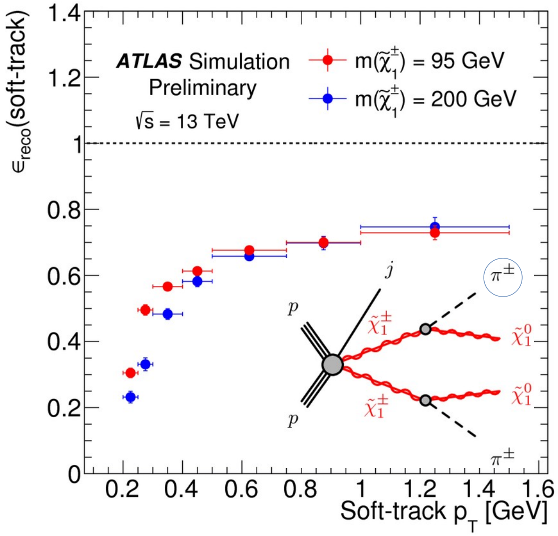


e.g. separating clusters on the outer modules of IBL coming from the IP

Displaced Vertices

- Wish to relax cuts on track multiplicity / m(DV) / ...
  — Suppress higher background with other handles: large multiplicity, other prompt activity, … ?

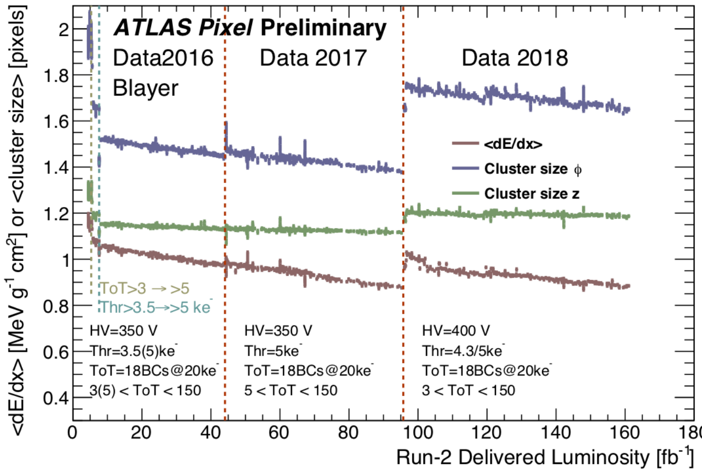
- … and track p_T!
  — Soft-displaced activity seems hard, but not impossible:
    - e.g. disappearing track dev →
    - Need some sort of "seed" to focus reconstruction, e.g. a DV



- Larger pile-up → larger combinatorics
  — Need aggressive R&D to use at the best upcoming luminosity

Inner Tracker hits

- Need high-level observables to compute early on in reconstruction
  - Many ideas around, from tagging DVs to SUEP, etc..
- Several challenges:
  - Large non-uniform response out-of-the-box: operational conditions, radiation damage
  - Challenge to simulate (esp. Background processes) properly, but not entirely hopeless either with sophisticated models
  - Designing a data-driven strategy as important as a new observable



- "Cleaning" requirements and additional information to increase purity
  - e.g. similar ideas based on e.g. shapes
  - Dedicated triggers to measure backgrounds
    - e.g. afterglow through non-filled bunches

- These effects will be even more severe in Run 3 and HL-LHC
  - New tracker for HL-LHC needed to sustain harsh conditions, but these effects will still play a major role

DV in Calo/MS

- Displaced jets in Calo and MS rely on isolated activity discrimination
  - Needed to suppress backgrounds
  - e.g. can't easily relax to gain sensitivity to "emerging" jets scenarios
- More and more sophisticated beam-background suppression techniques based on shape analyses in the calorimeter
- One could aim for a combined ID+Calo+MS analysis searching for "aligned" decays (e.g. from emerging jets)
  - Complies with "you relax something, you require something else"
  - Not obvious if it covers new parameter space a-priori

- Ability to trigger on both signatures is a huge plus
  - aim to maintain capability for HL-LHC
  - Important to maintain ability to control beam-induced backgrounds (isolated/unpaired bunches at HL-LHC not obvious)

Trigger and Flexibility in dataset

- Improvements at trigger-level expected in Run 3 and then HL-LHC, e.g.
  - Better calo-segmentation
  - Ability for more complex trigger primitives
  - Tracking with improved rate and algorithms
    - some sort of calo/muon seed needed
  - ...

- Often needs for "auxiliary" handles in the events to trigger, e.g.
  - e.g. associated production or VBF, or other characteristics of the event

And if things just get "too hard"?

- Think of a different data(set)
  - Dedicated low pile-up runs with special triggers
    - e.g. ~pb^{-1} of data with μ~2 for W mass studies already available
    - Flexibility in defining our priorities for next Run and the future
  - Heavy-Ion (quite some interest recently for e.g. UPC)
- Think of a different data analysis path
  - Trigger-level analysis is a great example, hopefully more to come!

Concluding thoughts

- Looking ahead, Run 3 and HL-LHC will pose significant challenges in terms of trigger, data-processing and reconstruction
  - However, upgrades will help coping with those challenges
- A key element will be, in my opinion, flexibility in implementing different ideas to tackle a large variety of signatures
  - Need to also spend time to think how to achieve such a flexibility
  - Many nice examples recently, more in the works, more ideas I'm sure will come as well
- Still in the infancy of exploring these signatures from the experimental point of view; every new analysis is an opportunity for a better understanding of common backgrounds and detector effects as well