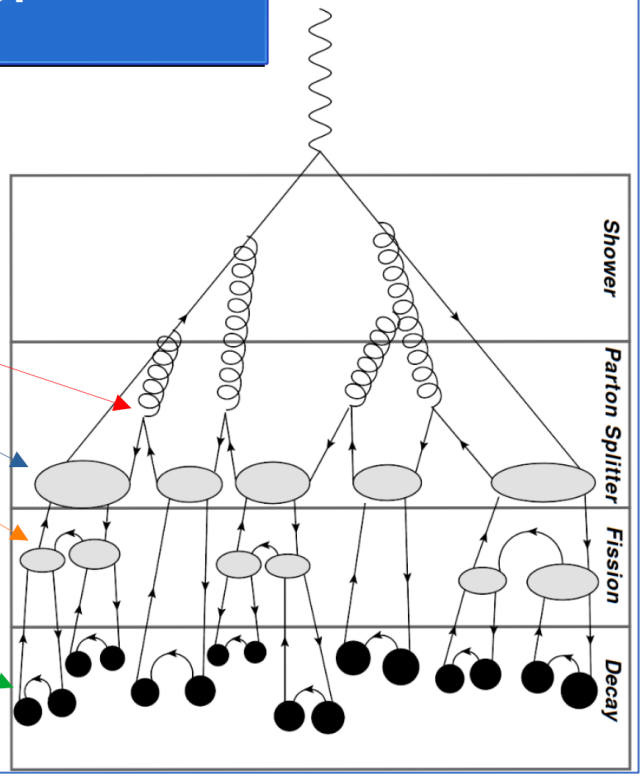
# Why a model with only heavy quarks is hard to simulate

## Cluster Hadronisation Model

*D. Swafford talk*

- Hadronisation is **non-peturbative** => Semi-empirical models, tuned to SM data
- Herwig uses the cluster hadronisation model:
  - Gluons are split into qq pairs
  - Colour connected qq pairs form clusters (representing heavy pseudo-hadrons)
  - Very heavy clusters decay by springing qq pair from vacuum
  - Clusters decay to two hadrons (again by springing qq pair from vacuum) according to phase space and number of available spin-states



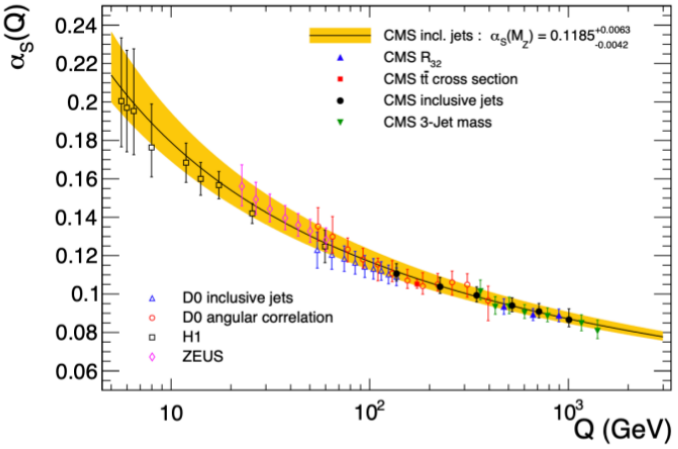



HERWIG hadronization model presumes the presence of light quarks!

So does PYTHIA's Lund String model!

Curtin et al. attempt to modify it to produce glueballs … but no way to test its accuracy

# 2. Expanding the Feasible Region



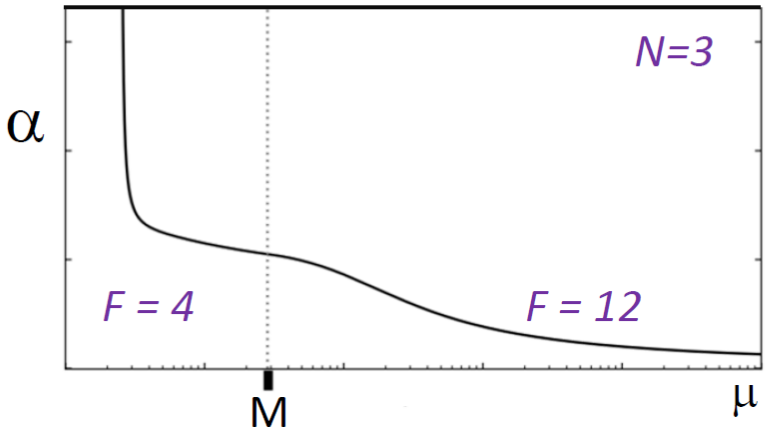

arXiv:1512.05194

**QCD: well-understood**

- Spectrum calculable
- Shower $\alpha_s(\mu)$ determines jet shape
- Hadronization still a black box fit to data

**Less QCD-like:** $SU(N)$ with $F \gg 3N$ flavors of quarks

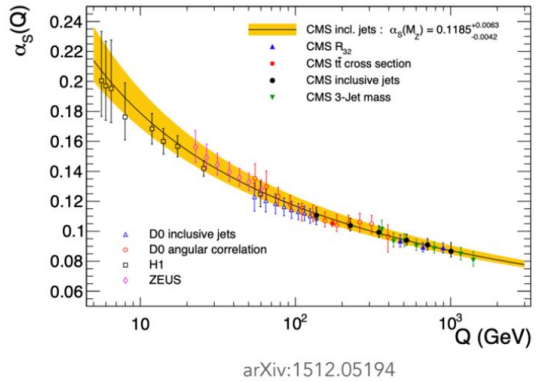
- equal $m_i$: somewhat understood, PYTHIA not ok
- unequal $m_i$ (many large, some small): understood, **PYTHIA soon**




See J. Lockyer's talk

# How can changing the running coupling change the dark jets?

MJS ‘08

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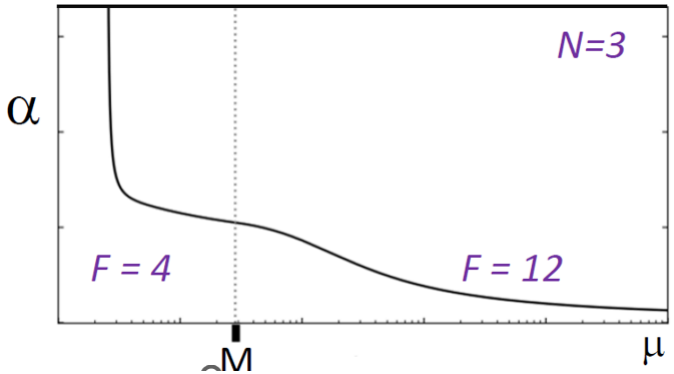
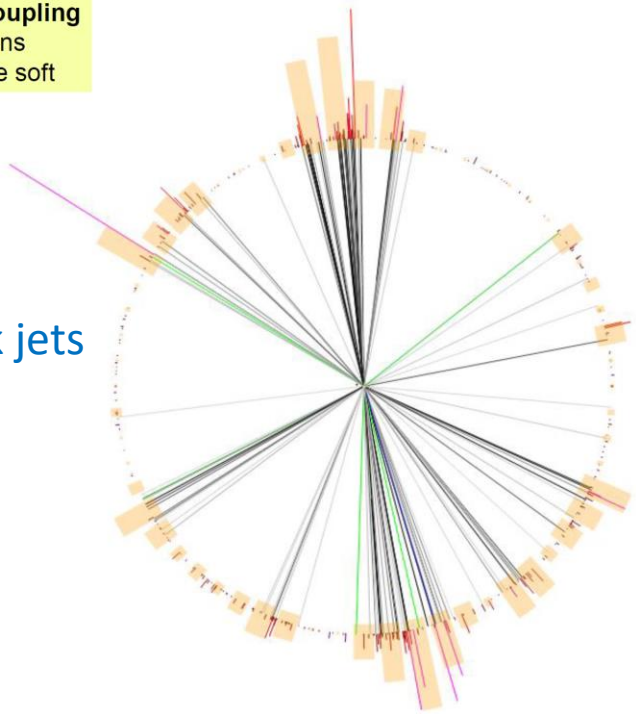


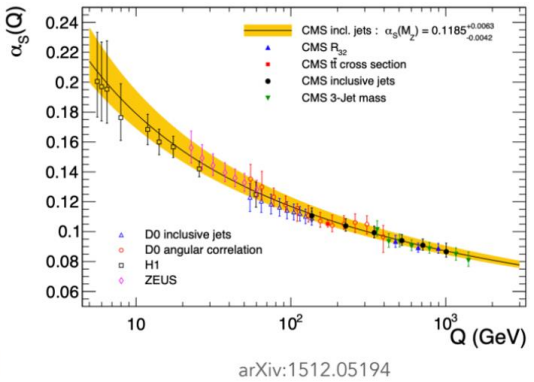
**Running Weak-Coupling**
Many v-hadrons
Some hard, some soft

# How can changing the running coupling change the dark jets?

MJS '08

Normal dark jets



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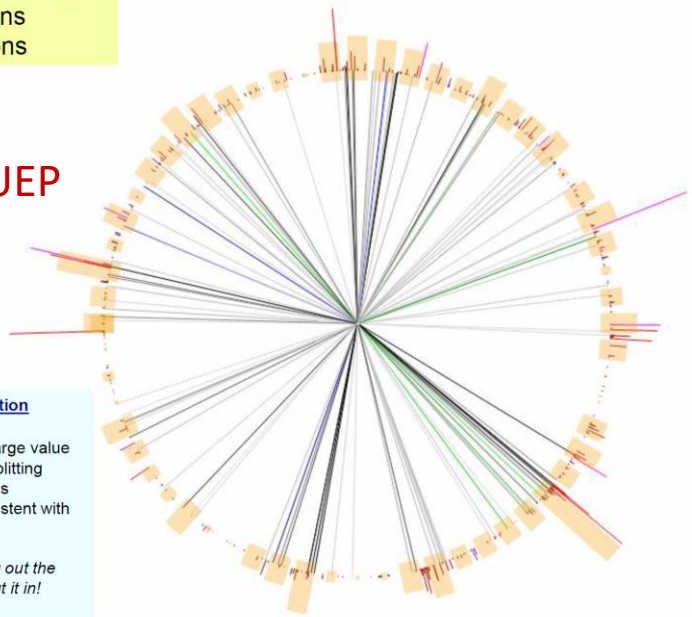
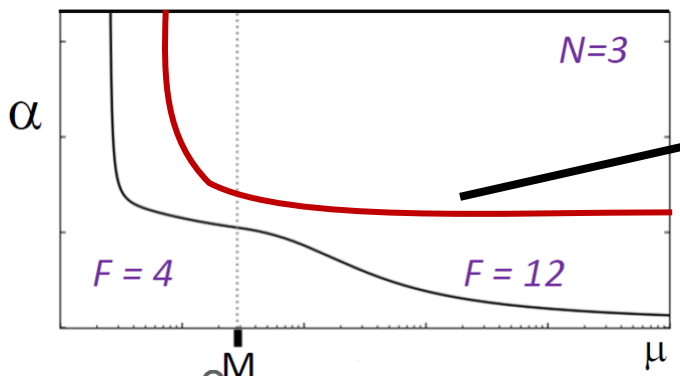
**Strong-Coupling Fixed Point**
**(educated guesswork!)**
More v-hadrons
Softer v-hadrons

Approaching SUEP






**Crude and uncontrolled simulation**

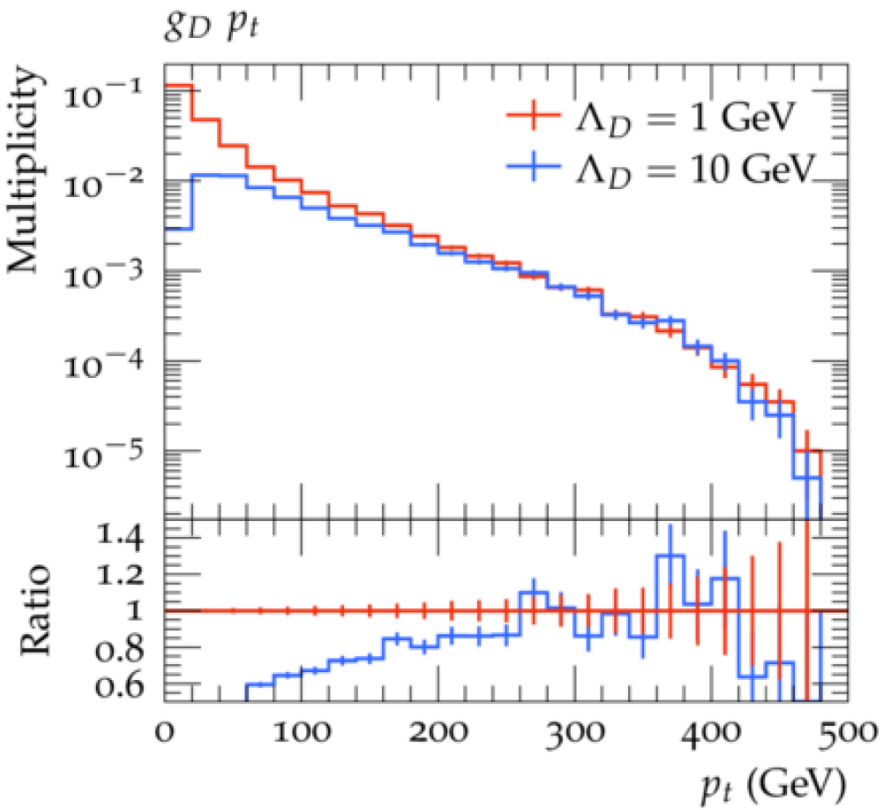
- Fix α in HV Monte Carlo 0.5 at large value
  - This increases collinear splitting
- Check that nothing awful happens
- Check answer is physically consistent with my expectation

*Do not overinterpret! I am getting out the answer that I expect because I put it in!*

# Dark parton shower validation

*D. Swafford talk*

- For testing, generated events with dark photon decaying to only one flavour of dark quark ($q_D^0$), then emissions added by PS
- Shower adds a large number of gluons, especially at lower energies
- Low energy gluons suppressed for $\Lambda_D$ = 10 GeV by shower cut-off



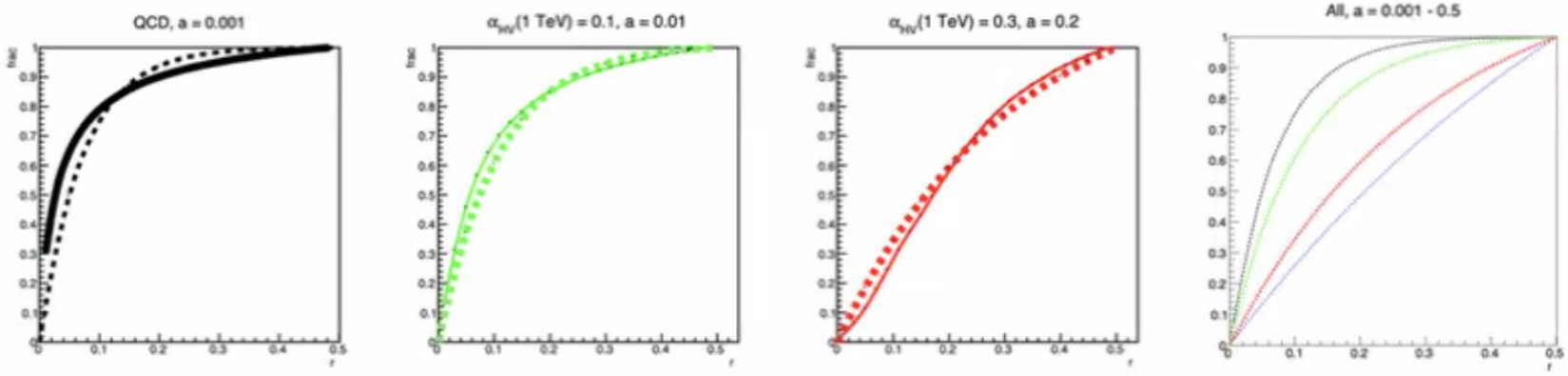
Depends on alpha_s(mu)

*N. Desai talk*

# A bottom-up model for semi-visible jets

- We only care about the visible fraction (1- rinv). Assume one kind of visibly decaying meson
- How does the energy of the dark quark translate into dark hadron jets?

$$f(r) = \frac{1 - a^{2r}}{1 - a^{2r_{\max}}}$$




- Use decay properties (lifetime, decay mode) of pions to make visible signal