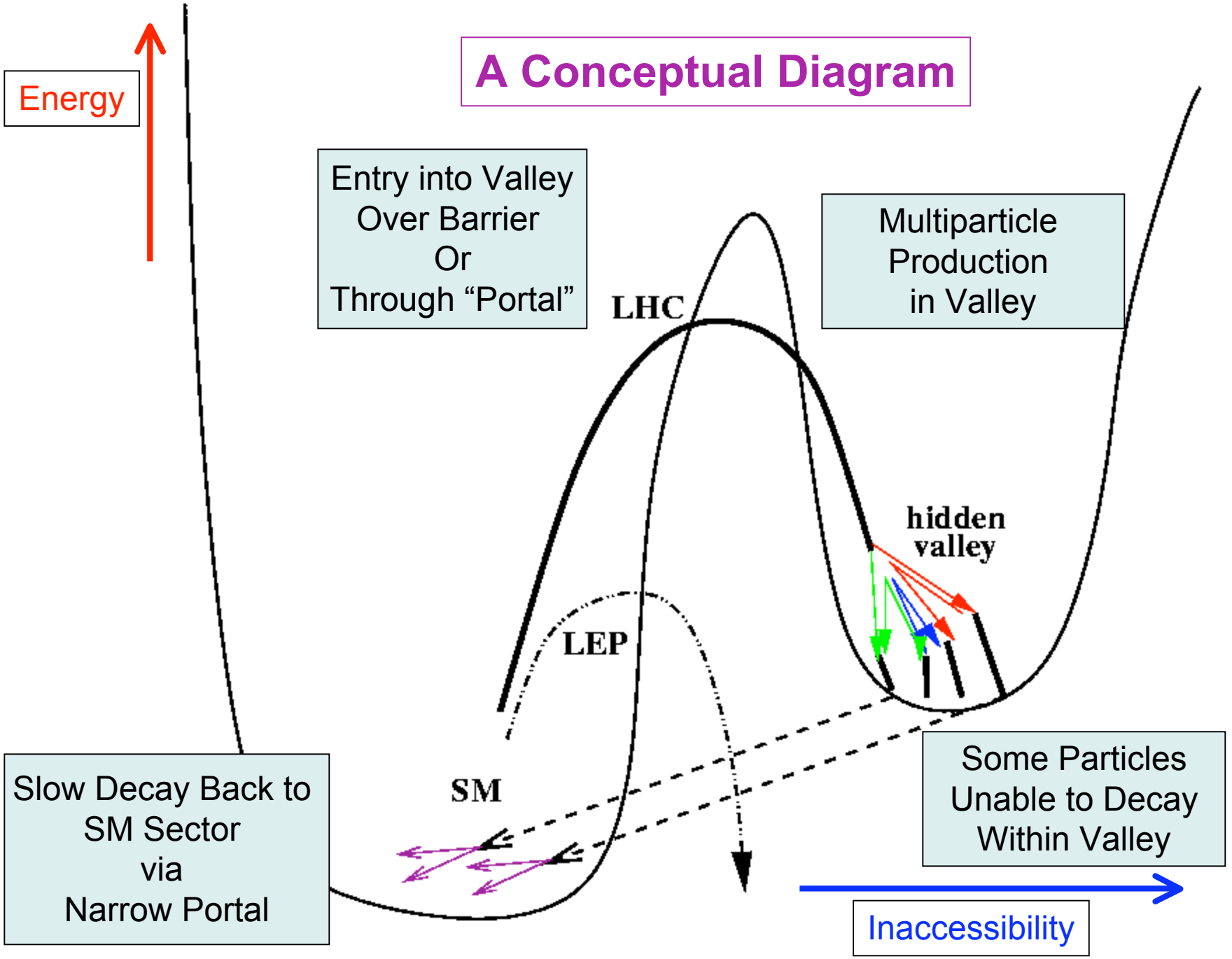
Hidden Valley

Strassler and Zurek 06

- General Scenario (not a “model”)
  - Attach hidden sector with a mass gap to SM
- General Motivation
  - Hidden sectors common in strings, SUSY, ED
  - Natural home for Dark Matter
  - Something seems wrong with minimal SUSY…
- General Predictions (see below)
- Motivation: the general predictions are
  - Different from standard SUSY, ED, etc.
  - Challenging at Hadron Colliders ➔ urgent to consider


A Conceptual Diagram
Energy
Entry into Valley
Over Barrier
Or
Through "Portal"
LHC
Multiparticle
Production
in Valley
hidden
valley
LEP
SM
Slow Decay Back to
SM Sector
via
Narrow Portal
Some Particles
Unable to Decay
Within Valley
Inaccessibility

A Conceptual Diagram

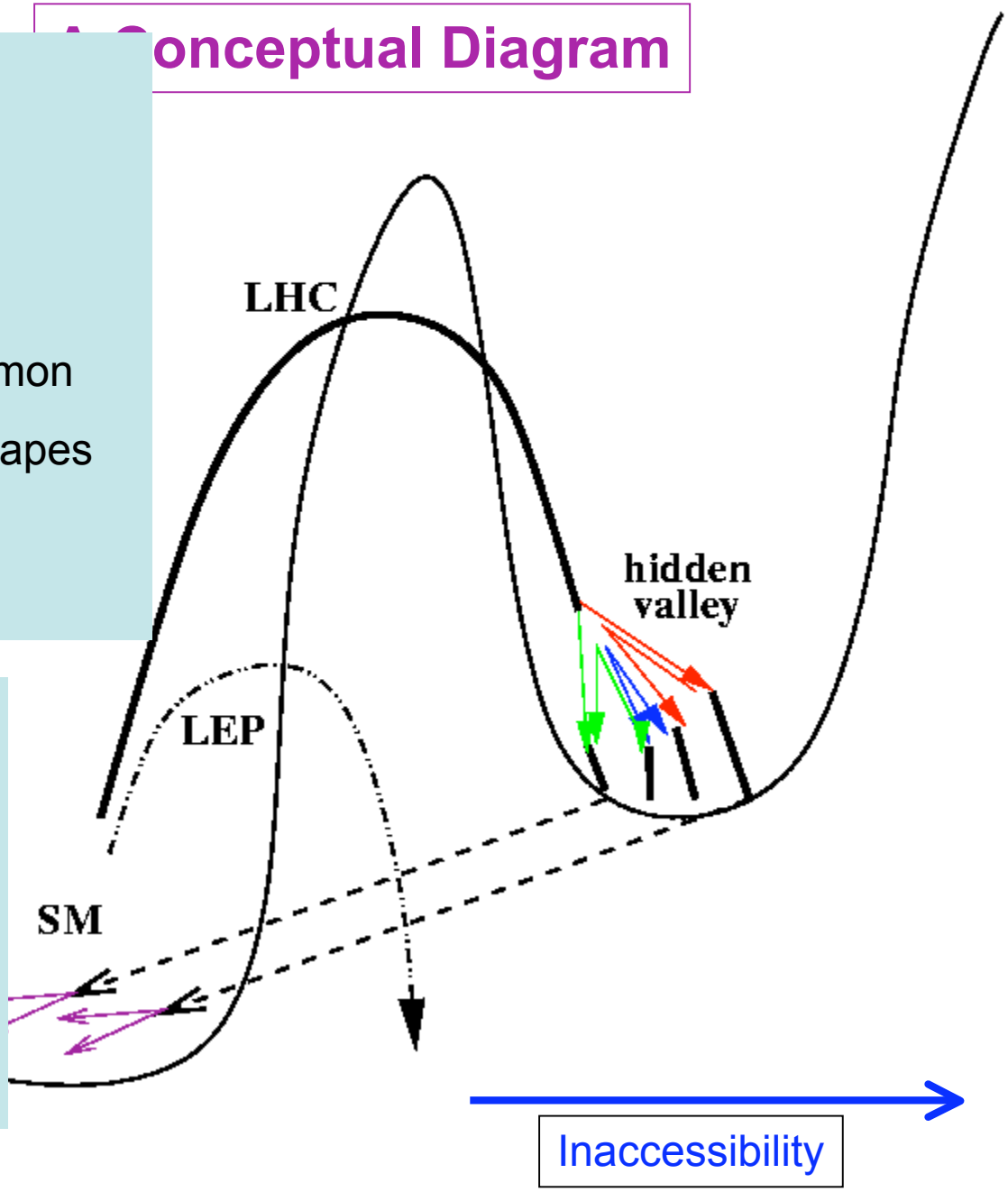
PREDICTIONS MJS+Zurek 2006

1) New Neutral Particles
   often very light!
2) High Multiplicity Events Common
   unusual clustering, event shapes
3) Long Lifetimes Common
   possible displaced vertices

EFFECTS ON

MJS+Zurek 2006, MJS 06,08

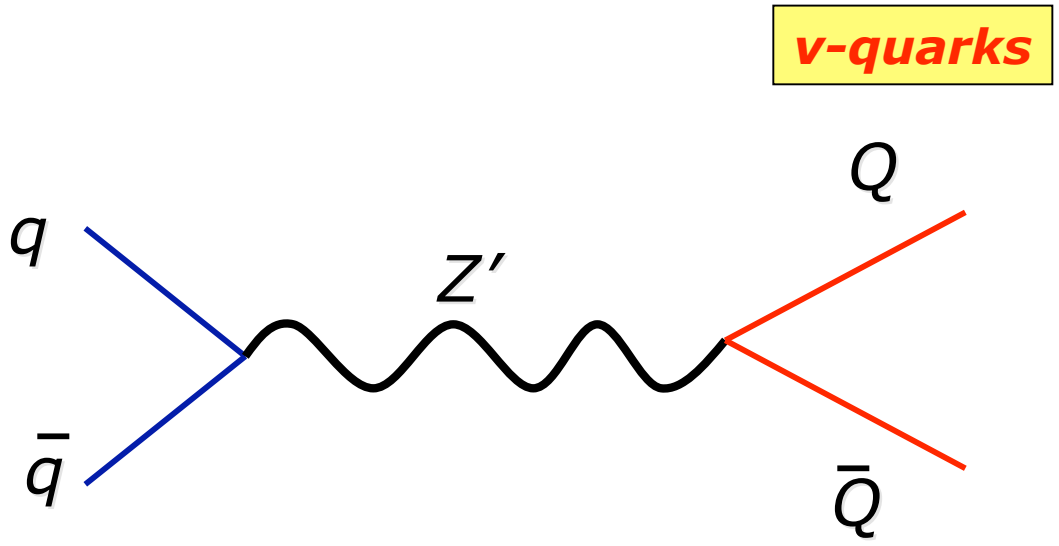
1) H decays
2) LSP/LTP/LKP decays
3) 'unparticles' with mass gap



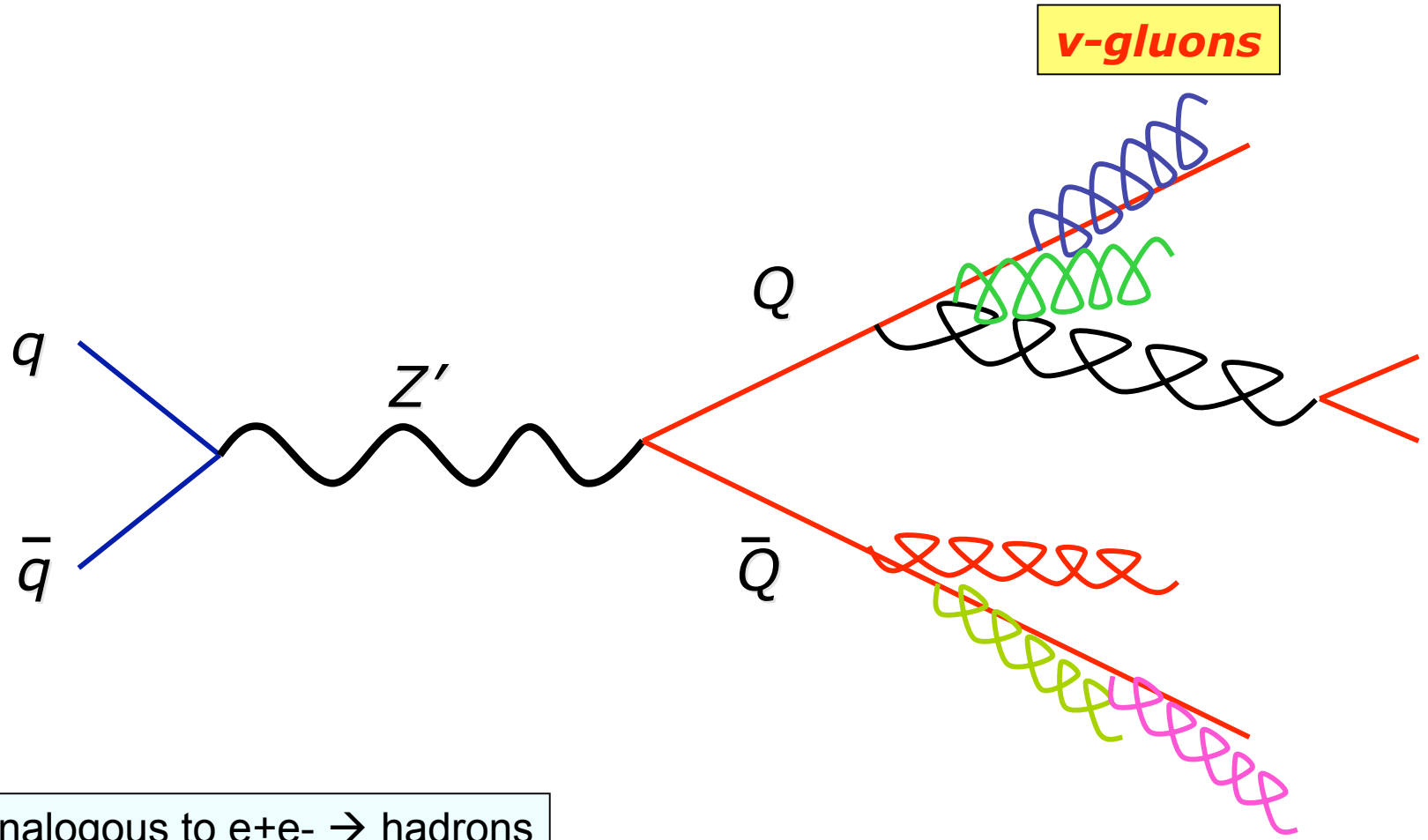
Some Examples:

- Resonance Decay into Hidden Sector
- LSP Decay into Hidden Sector
- CHAMP/R-hadron Radiation into Hidden Sector
- Quirk Annihilation into Hidden Sector

Resonance decay to v-quarks



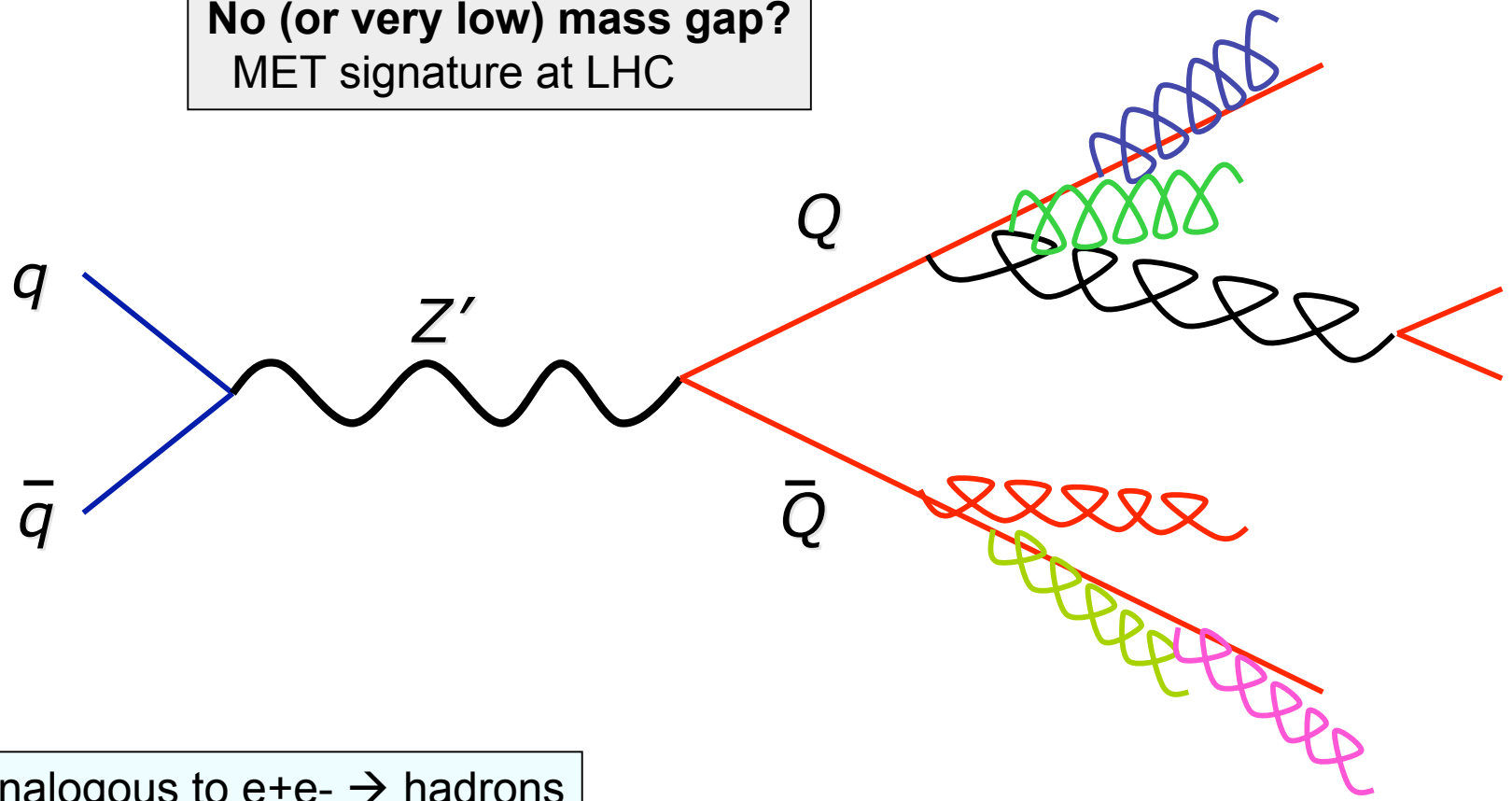
Analogous to e+e- → hadrons



Analogous to e+e- → hadrons

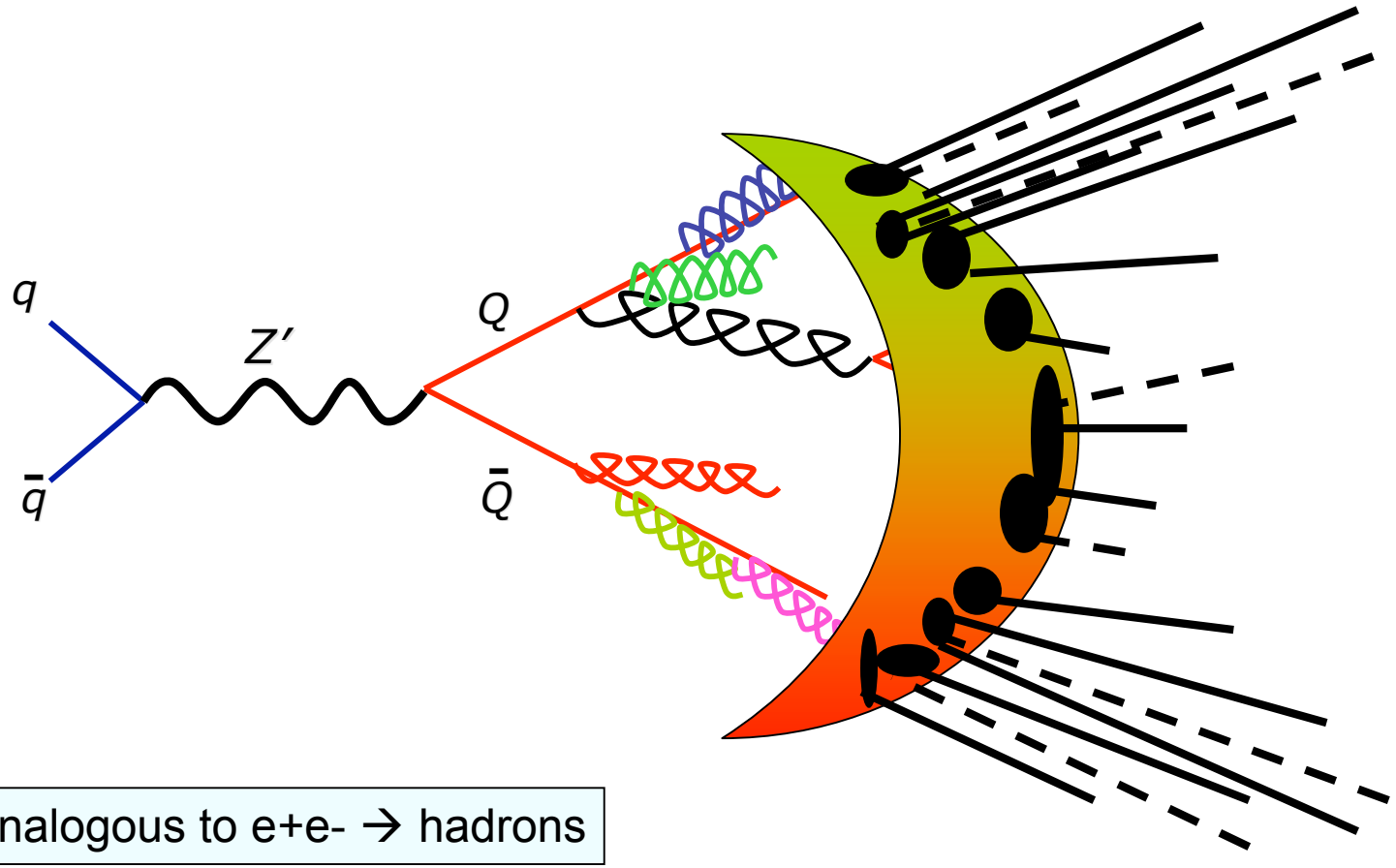
Larger mass gap from Higgsing, Confinement, etc.?
Hidden Valley: Possibly Visible

No (or very low) mass gap?
MET signature at LHC

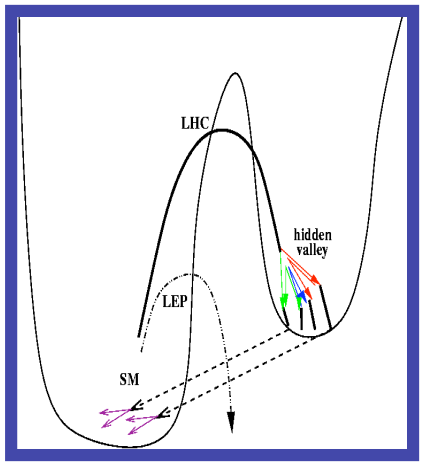


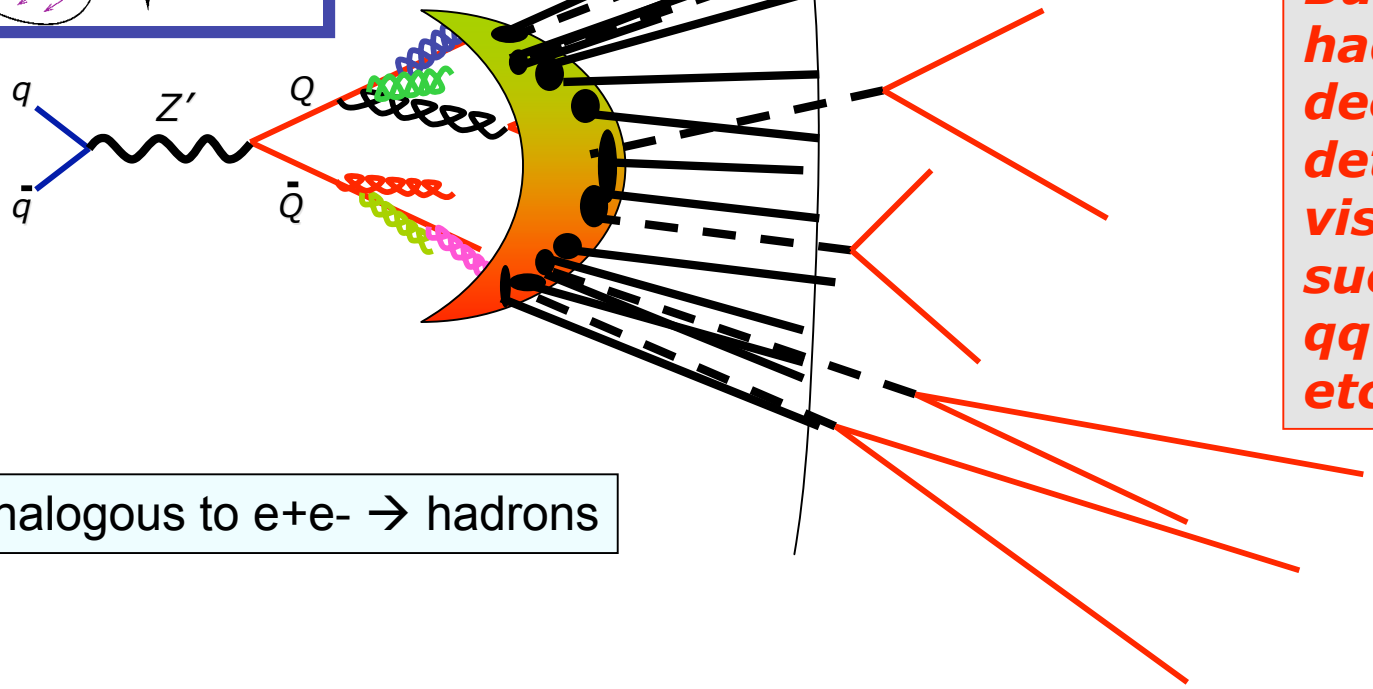
Analogous to e+e- → hadrons

v-hadrons



Analogous to e+e- → hadrons



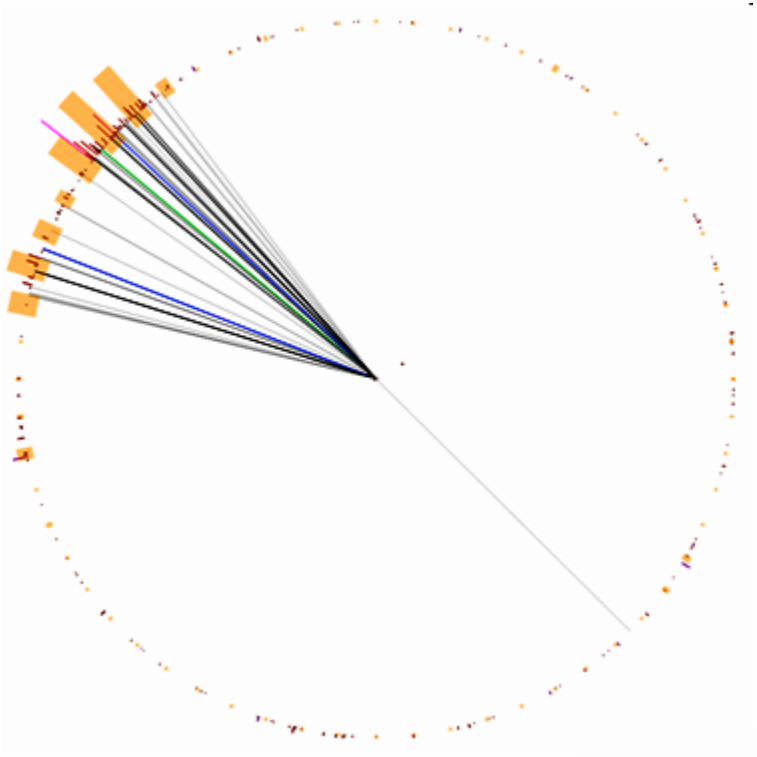


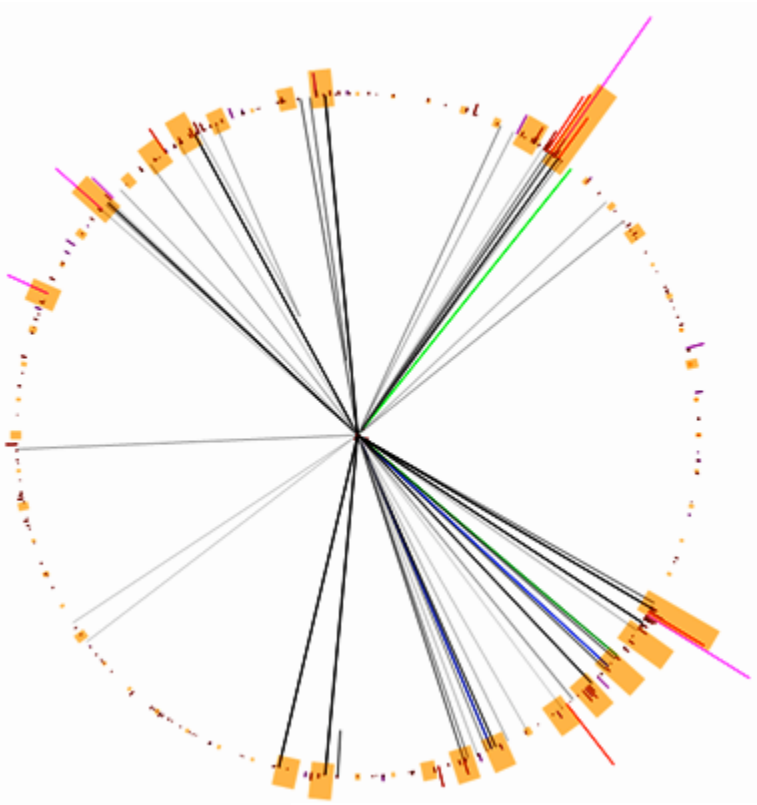
Some v-hadrons may be (meta)stable and therefore invisible

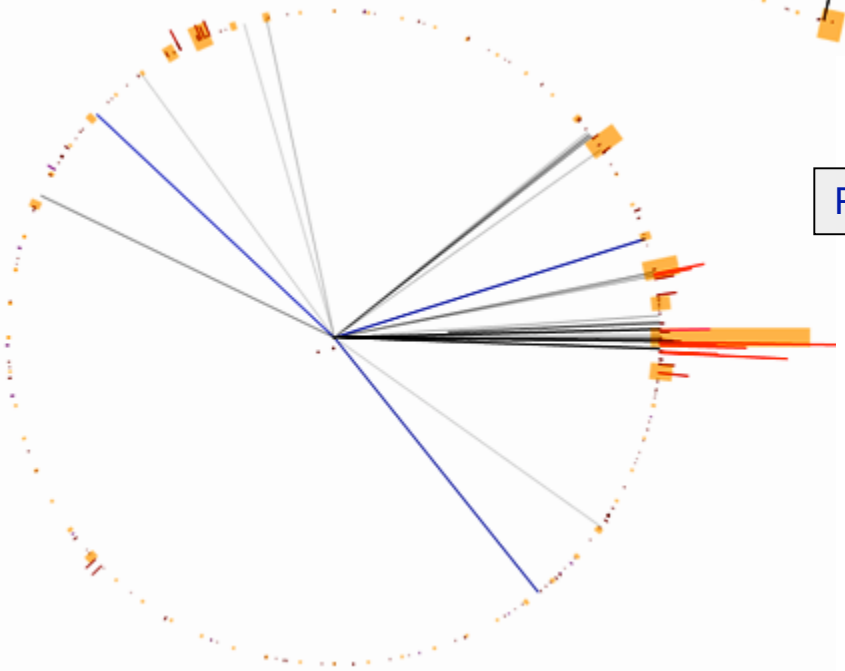
v-hadrons

But some v-hadrons may decay in the detector to visible particles, such as bb pairs, qq pairs, leptons etc.

Analogous to e+e- → hadrons



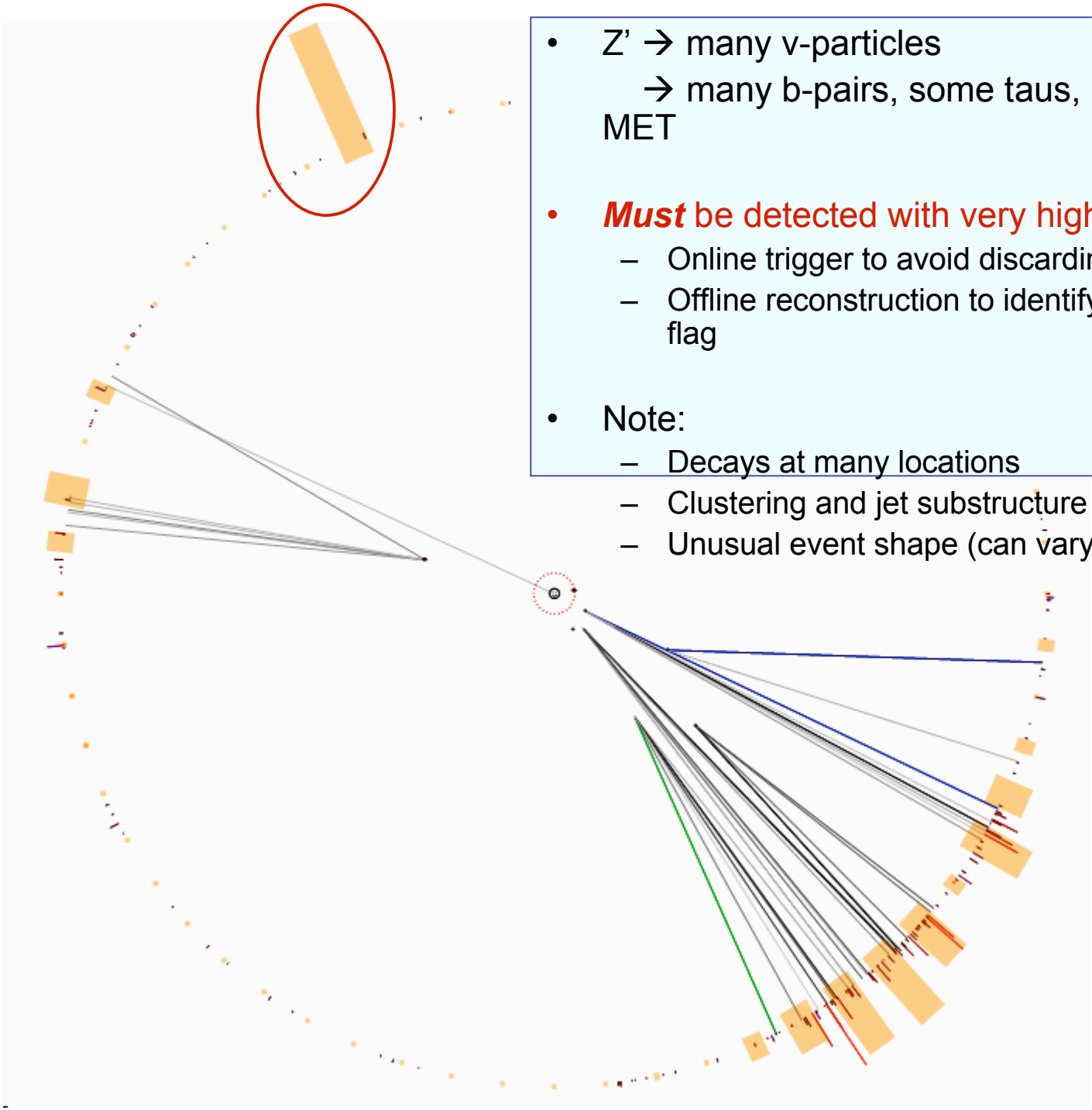




Z' → v-hadrons
Average: 8 b's
Max: 22 b's

Prompt decays: MJS 08

Z' mass = 3.2 TeV
v-pi mass = 50 GeV
Flavor-off-diagonal
v-pions stable



- Z' → many v-particles
  → many b-pairs, some taus, some MET
- ***Must*** be detected with very high efficiency
  - Online trigger to avoid discarding
  - Offline reconstruction to identify or at least flag
- Note:
  - Decays at many locations
  - Clustering and jet substructure
  - Unusual event shape (can vary widely!)

Production

Higgs-Induced Masses

Cascade Decays

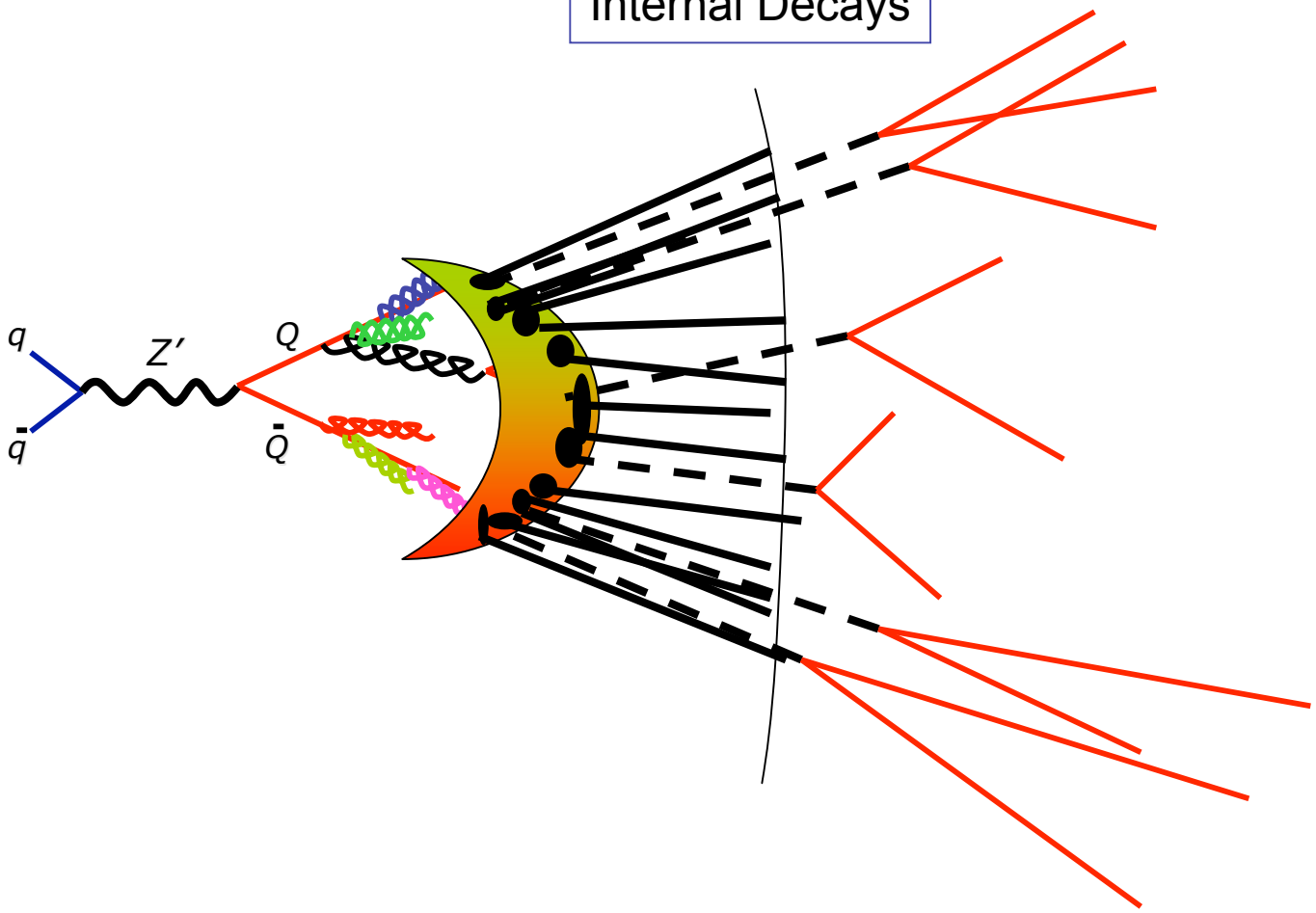
Parton Shower

OR

Decays to Standard Model

Hadronization

Internal Decays



Challenges

- We can simulate with certainty only
  - Perturbative effects
  - QCD-like non-perturbative effects
  - Lattice-computable effects

  - Definition: perturbation theory is expansion in the ‘t Hooft coupling $\alpha_h N_h / \pi$
    - If the ‘t Hooft coupling is small, pert theory ok
    - If it is large, it’s not – even for production/parton shower

Other Cases

- New Electrically Charged or Colored particle carrying hidden charges
  - Pair production with SM rates
  - Unbound
    - Radiation (hard, collinear and soft) (visible or not)
  - Bound (quirks)
    - Relaxation contribution to underlying event
    - Relaxation/Annihilation to valley glueballs