

*A brief report on news from SUSY2021:
DARK SHOWERS*

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References

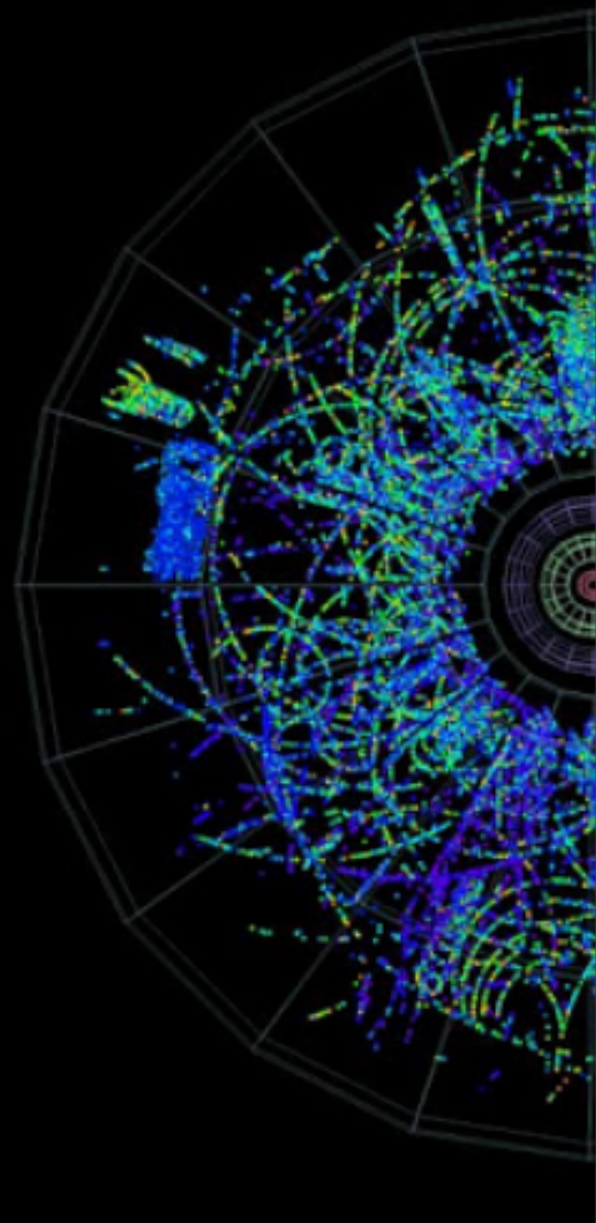
*“EXPLORING FARTHER WITH LONG-LIVED PARTICLES”
J. Shelton*

*SUSY 2021, virtual Beijing
Aug. 25, 2021*

EXPLORING FARTHER WITH LONG-LIVED PARTICLES

Jessie Shelton
UIUC

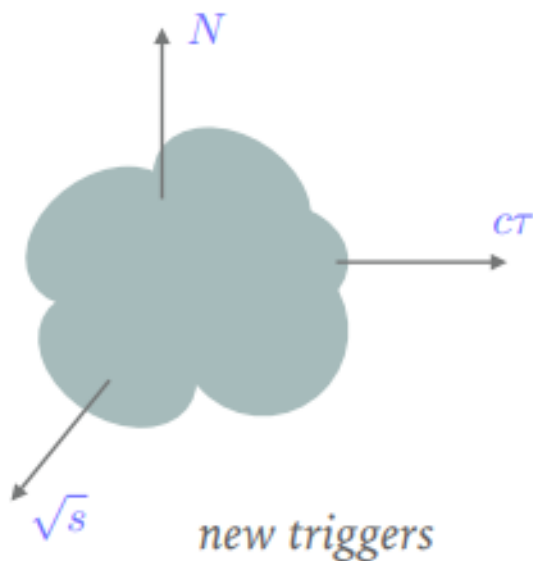
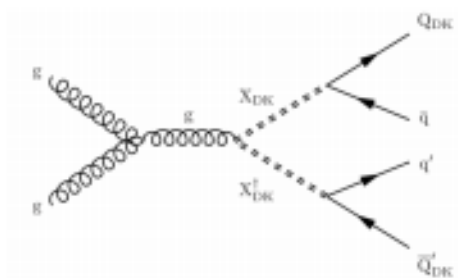
SUSY 2021, virtual Beijing
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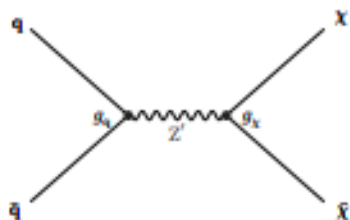
LOOKING FOR LONG-LIVED PARTICLES

- Exciting rapid development in LLP searches!

one; two; many; lots?



*interfaces with
dedicated LLP
detectors*



DARK SHOWERS

- Non-trivial evolution in a hidden sector: **high-multiplicity** final states
 - confining hidden sectors, long cascade decay chains
- Arise naturally in many models:
 - solutions to the **hierarchy problem**

[Chacko, Goh, Harnik; Craig, Katz, Strassler, Sundrum; Craig, Knapen, Longhi, Strassler; Curtin, Verhaaren; ...]

- **dark matter** theories

[Bai, Schwaller; Hochberg, Kuflik, Murayama, Volansky, Wacker; Francis, Hudspith, Lewis, Tulin; ...]

- **generic** possibility for BSM physics

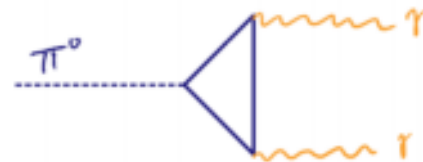
[Strassler, Zurek; Strassler; ...]

DARK SHOWERS

- Characteristic features of dark shower events:
 - variable and potentially large object multiplicity
 - non-SM-like distributions of energy, flavor
 - often non-isolated final state objects
 - hierarchy of lifetimes
- Long lifetimes arise from hierarchies of scales, small mass splittings, approximate symmetries



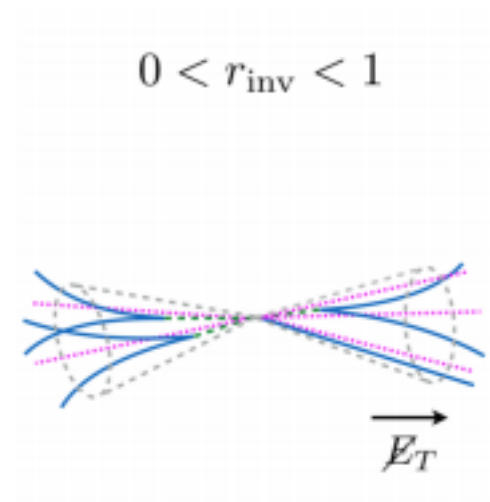
$$\frac{g^2 m_\pi^2}{m_W^2}$$



$$\frac{\alpha m_\pi}{4\pi f_\pi}$$

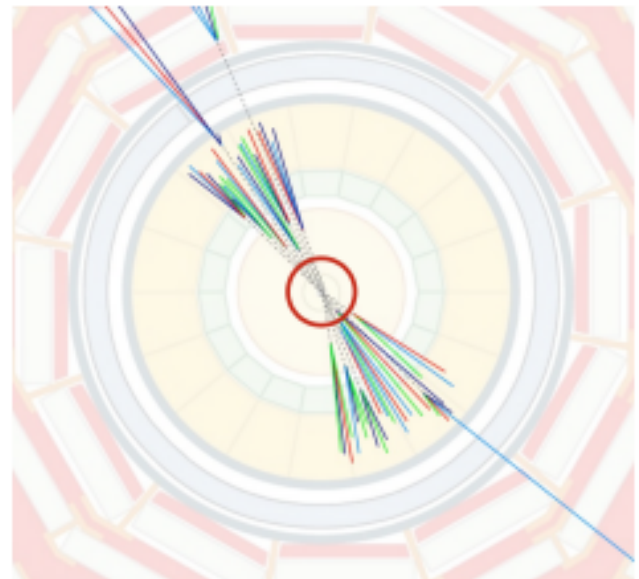
DARK SHOWERS

- Detector-scale lifetimes for at least one species are thus generic
- **Semi-visible jets:** prompt + detector-stable
 - Jetty events, $O(1)$ fraction of particles escape the detector
 - realization: Z' -mediated pair production of dark quarks
 - dark pions: flavor symmetry protects 'charged' pions, lets neutral pion decay



DARK SHOWERS

- Detector-scale lifetimes for at least one species are thus generic
- Emerging jets: displaced
 - Jetty events, lightest dark hadron has detector-scale lifetime
 - realization: pair production of bifundamentals, color charge
 - dark pions decay back to quark pairs



DARK SHOWERS

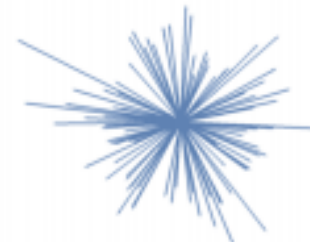
- Detector-scale lifetimes for at least one species are thus generic
- In general, some combination of prompt + displaced + detector-stable

Detector signal is inextricably tied to multiplicity of specific given dark hadron species



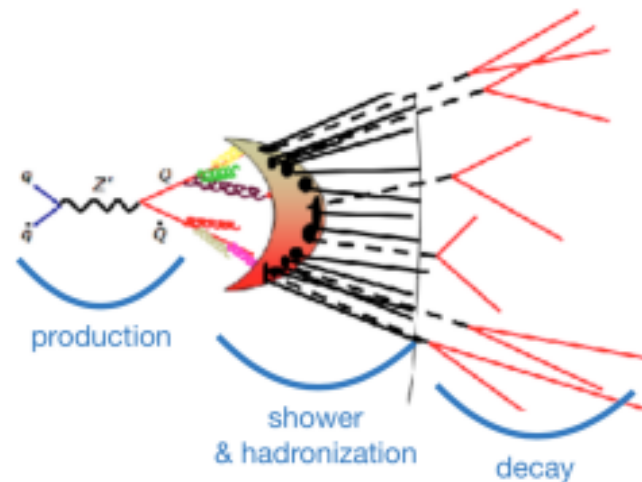
DARK SHOWERS

- and the existence of jets is also an expectation inherited from QCD
- at very large 't Hooft coupling one expects spherical events (sueps)
- at moderate 't Hooft coupling...?



INCLUSIVE SEARCHES FOR DARK SHOWERS

- “(Displaced) dark showers”: $\gtrsim 3$ displaced objects/event
 - Clean signature; enables **inclusive** searches
 - Strategy: use QCD-esque benchmarks, prioritize inclusivity at analysis level
- Components of a dark shower event:
 - production
 - evolution
 - decay



SUMMARY AND CONCLUSIONS

- Exciting developments in long-lived particle searches
 - pushing to lower thresholds
 - looking at longer, shorter lifetimes
 - high-multiplicity final states
- Confining and/or multi-component hidden sectors
 - complicated, variable multiplicity final states
 - well-motivated generic possibility for BSM physics
 - enormous theoretical uncertainties
 - need to develop systematic, inclusive search strategies from clean signatures