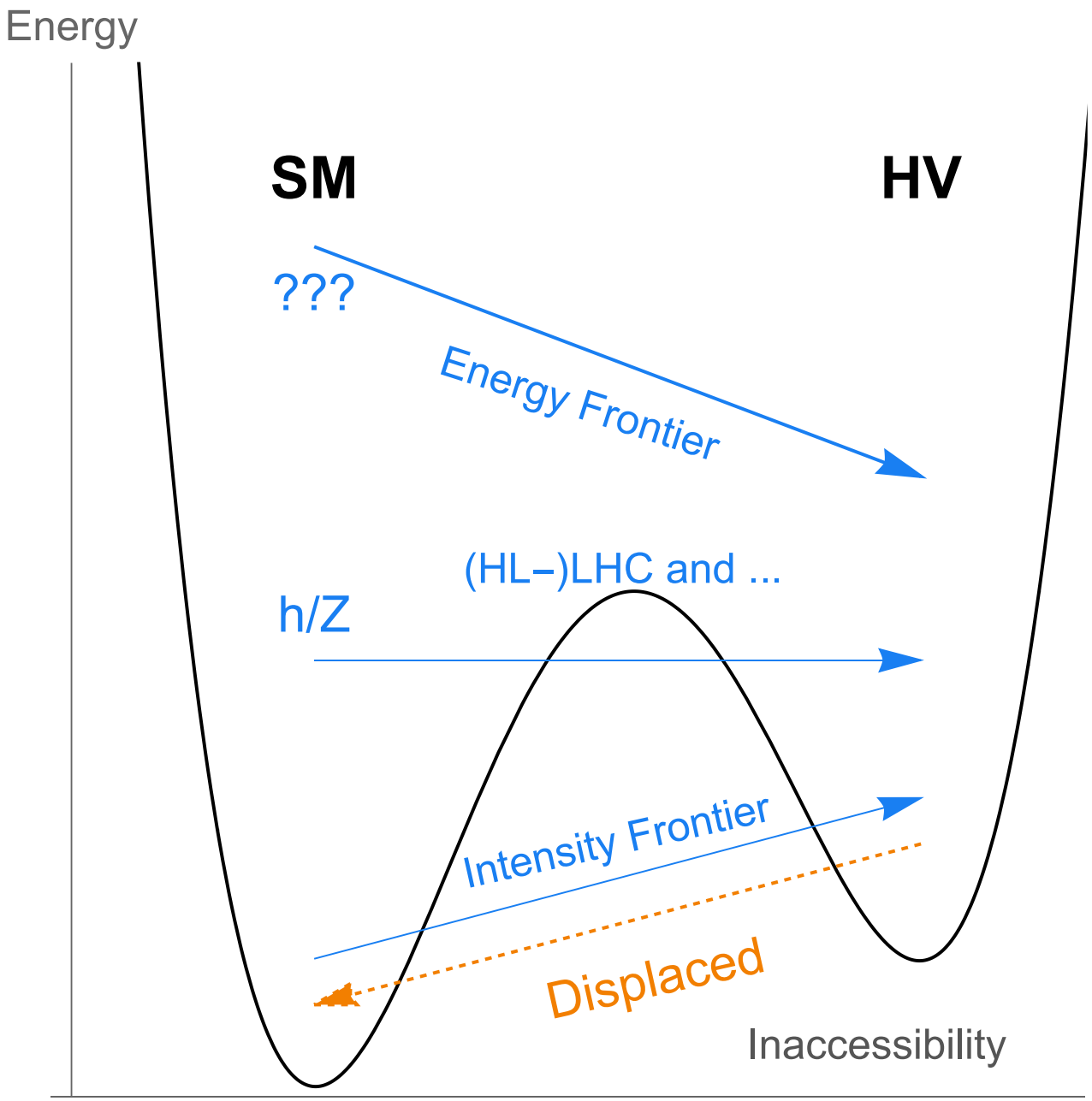
Semi-visible Jet Workshop WG4: Semi-visible Jets with LLPs A Theory Perspective

TH: Hsin-Chia Cheng, **Lingfeng Li**, and Ennio Salvioni

EX: Cristiano Alpigiani, Yi-Mu Chen, Benedikt Maier, Sara Nabili, Long Wang

July 6th, 2022, ETH Zürich



Weakly coupled hidden valley sector.

- Suppression of the HV-SM interaction:
  avoid high “direct” signal rates at the LHC, B factories and intensity frontier experiments.
- LLP is a natural prediction of HV models.
- Invisible component in semi-visible jets are also LLPs but just with very long lifetimes.

The key elements of a semi-visible jet (hence our criteria for models):

- Must include “invisible” ($c\tau >> m$) components

- Must include “prompt” components:

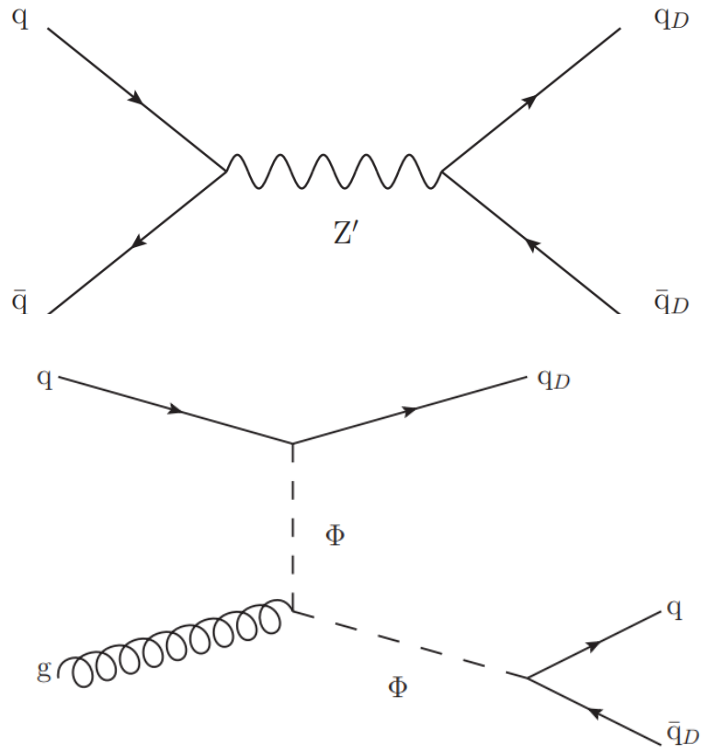
anything with $c\tau < c\tau(\text{charm}) \sim 0.1$ mm works?

- Λ_D must be << jet energy for dark shower

T. Cohen, M. Lisanti, H.K. Lou, 1503.00009

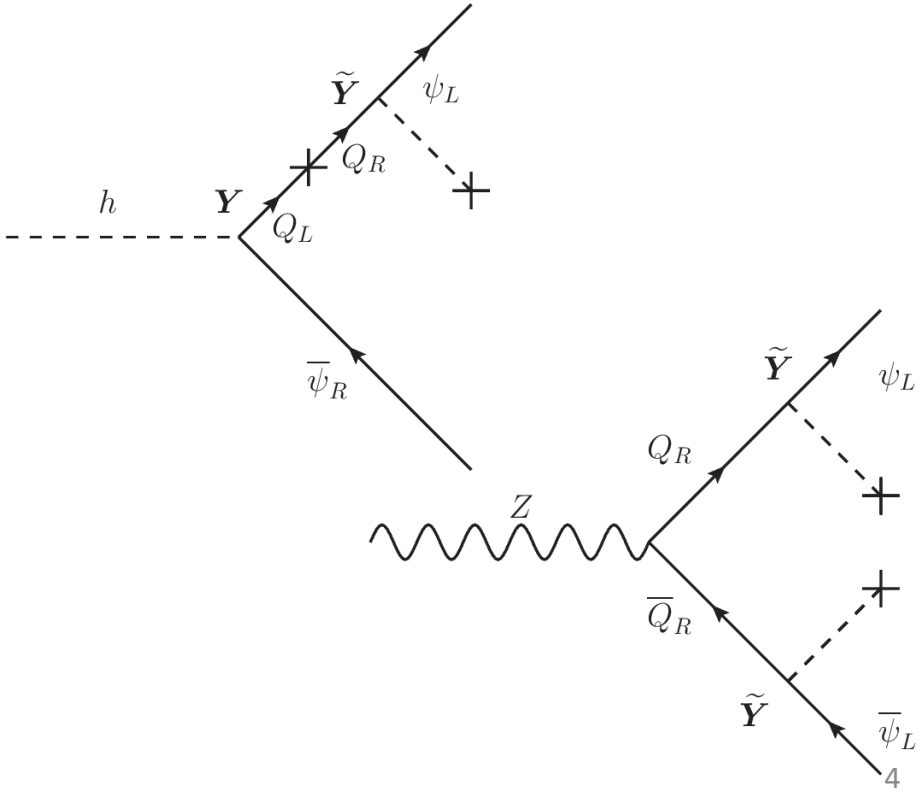
2 Production Scenarios

- Scenario 1: Production with a high kinematic threshold, e.g., a TeV-scale mediator



Dark shower Snowmass report, 2203.09503.

- Scenario 2: Production with no kinematic suppression, e.g., Higgs/Z exotic Decays

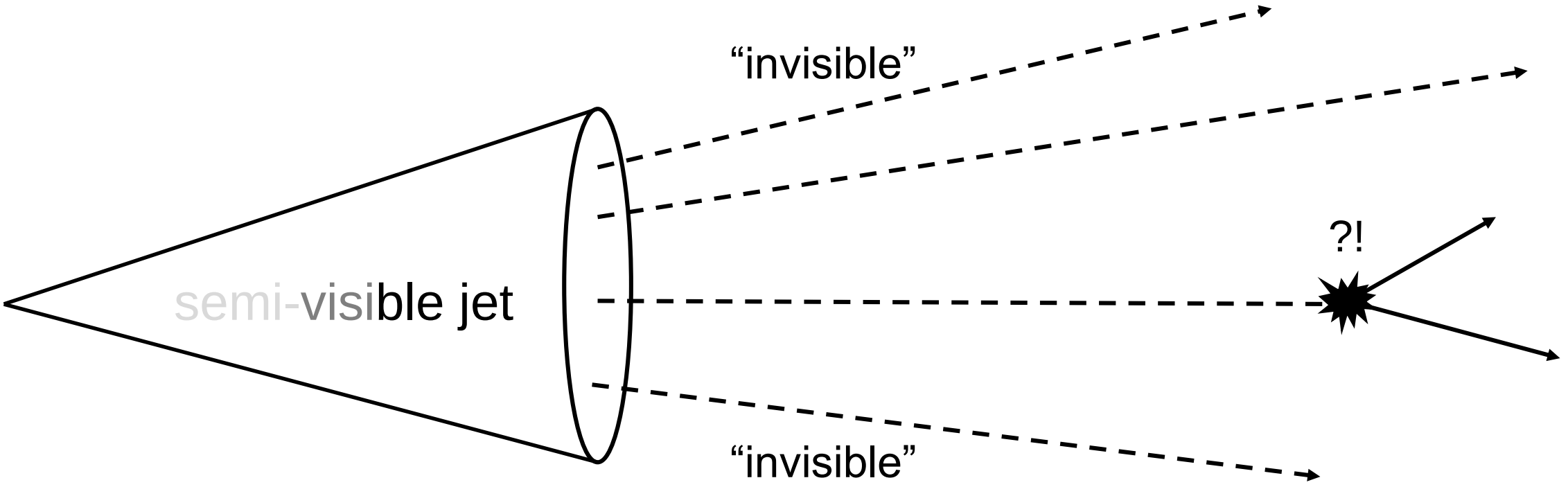


H.C. Cheng, LL, E. Salvioni, 2110.10691

3 LLP Inclusion Scenarios:

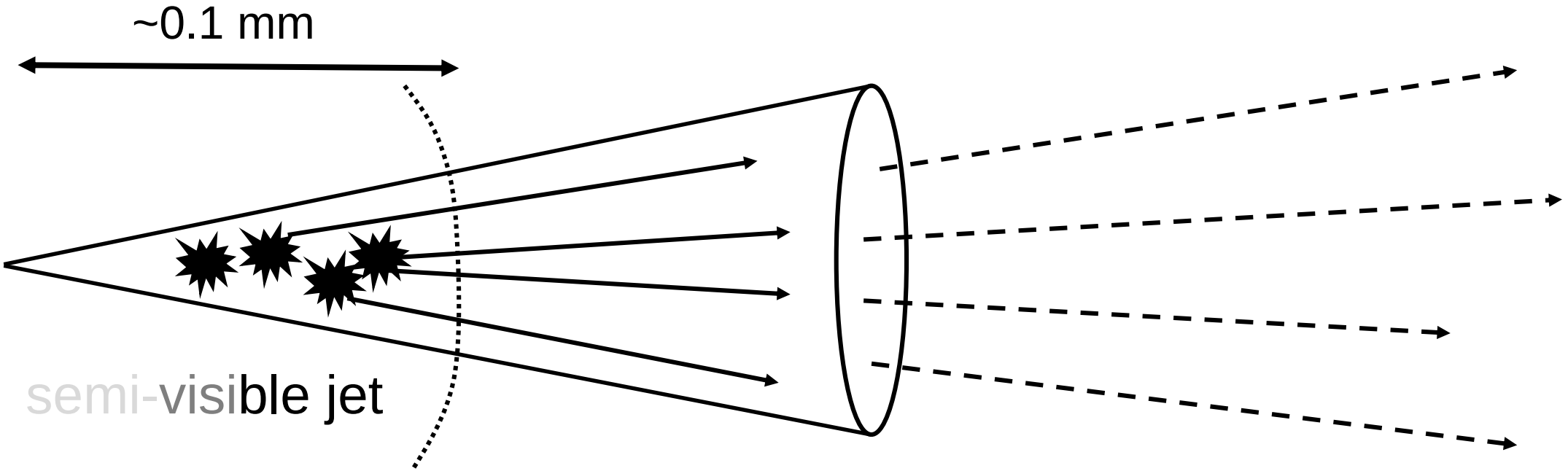
- Scenario 1: Assign a very long (but not infinite) lifetime to the original "missing" components.

  A semi-visible jet and an occasional LLP show up at the far end of the detector (HCAL, Muon System, Far detectors …).



- Scenario 2: Assign a very short but finite lifetime to the original "prompt" components.

A semi-visible jet with a high multiplicity of small impact parameter tracks/vertexes.



- Scenario 3: Add a third component (r_{LLP}) with an arbitrary lifetime.

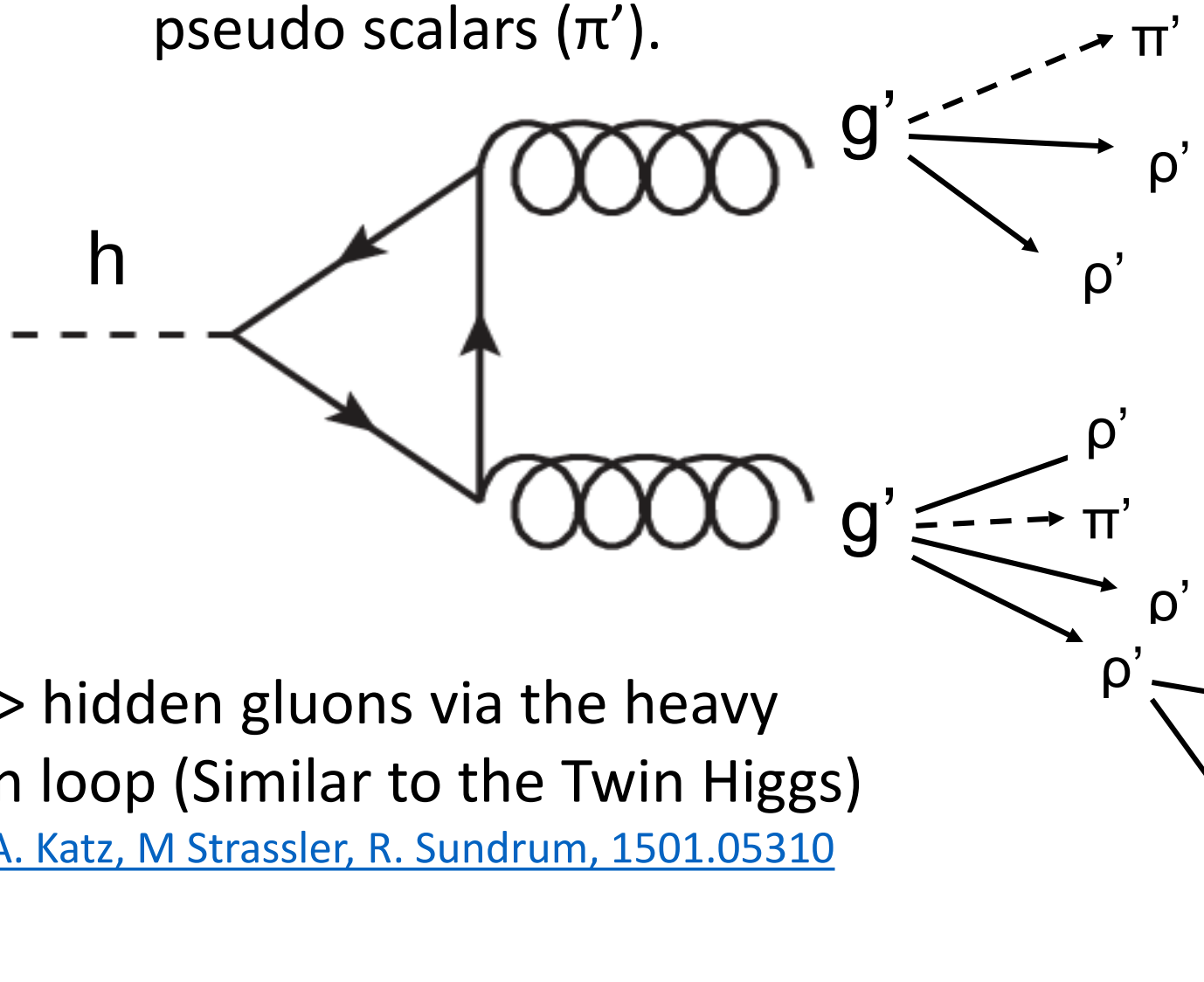
Benchmark 1 Considered

Higgs exotic decays + “prompt” components become LLPs.

- A $SU(N)_{dark}$ confining group with both heavy and light flavors.
- Challenging: low jet energy + small MET -> hard to utilize existing semi-visible jet techniques. Need displaced features for help.
- Light dark hadrons (<~4 GeV), can they be prompt?
- Seems compatible with the WIMP dark matter paradigm [A. Berlin, N. Blinov, S. Gori, P/ Schuster, N. Toro, 1801.05805]. See also talks from Kathryn Zurek and Hugues Beauchesne yesterday.

Dark shower generating light dark hadrons: vectors (ρ’) and pseudo scalars (π’).

π’ pick up very long lifetimes and become the “invisible component”.



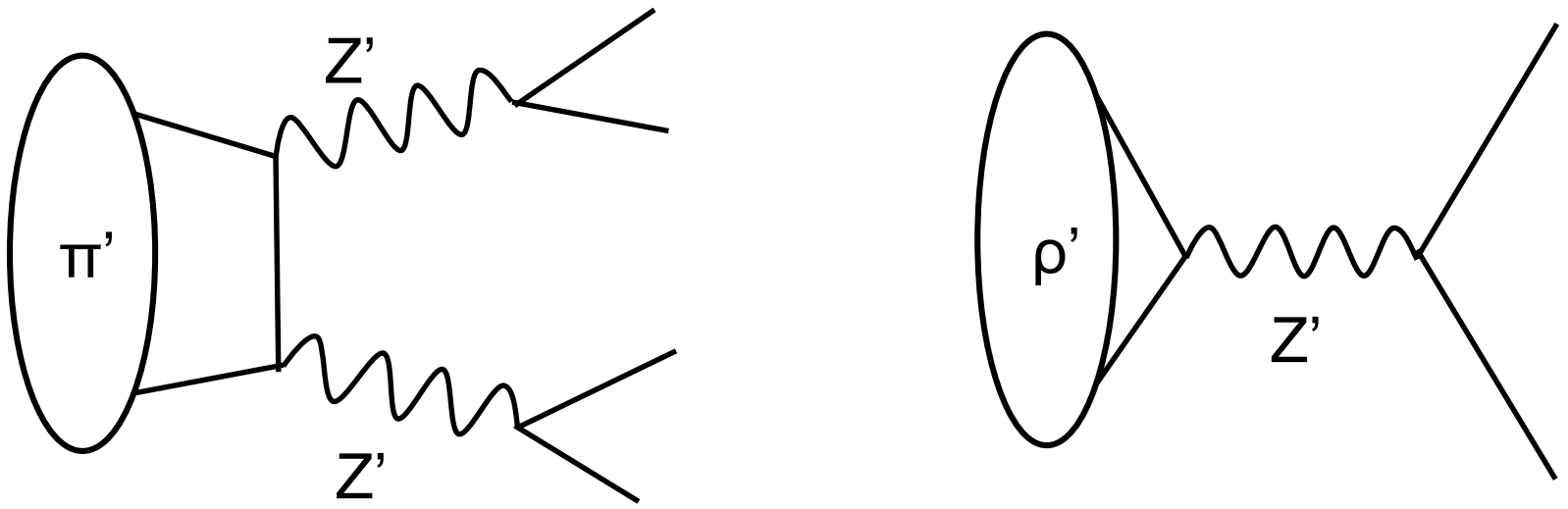
ρ’ are heavier than π’. If $m_{\rho'} < 2\, m_{\pi'}$, ρ’ decay back to SM rather than 2 π’

Higgs -> hidden gluons via the heavy fermion loop (Similar to the Twin Higgs)

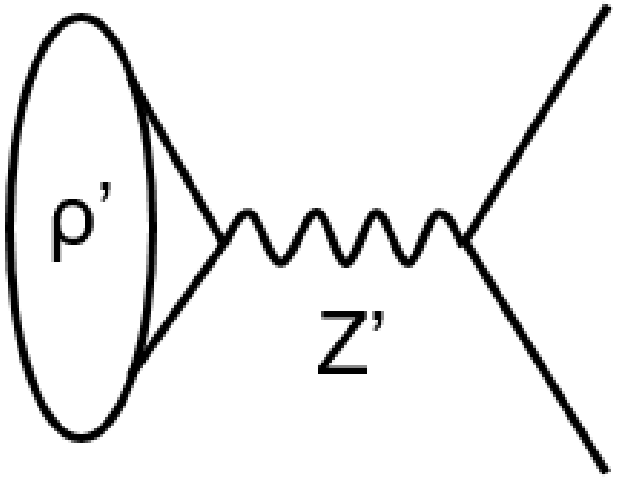
N. Craig, A. Katz, M Strassler, R. Sundrum, 1501.05310

Dark hadrons decay via mixing with a $U(1)_{Dark}$ vector boson (Z').

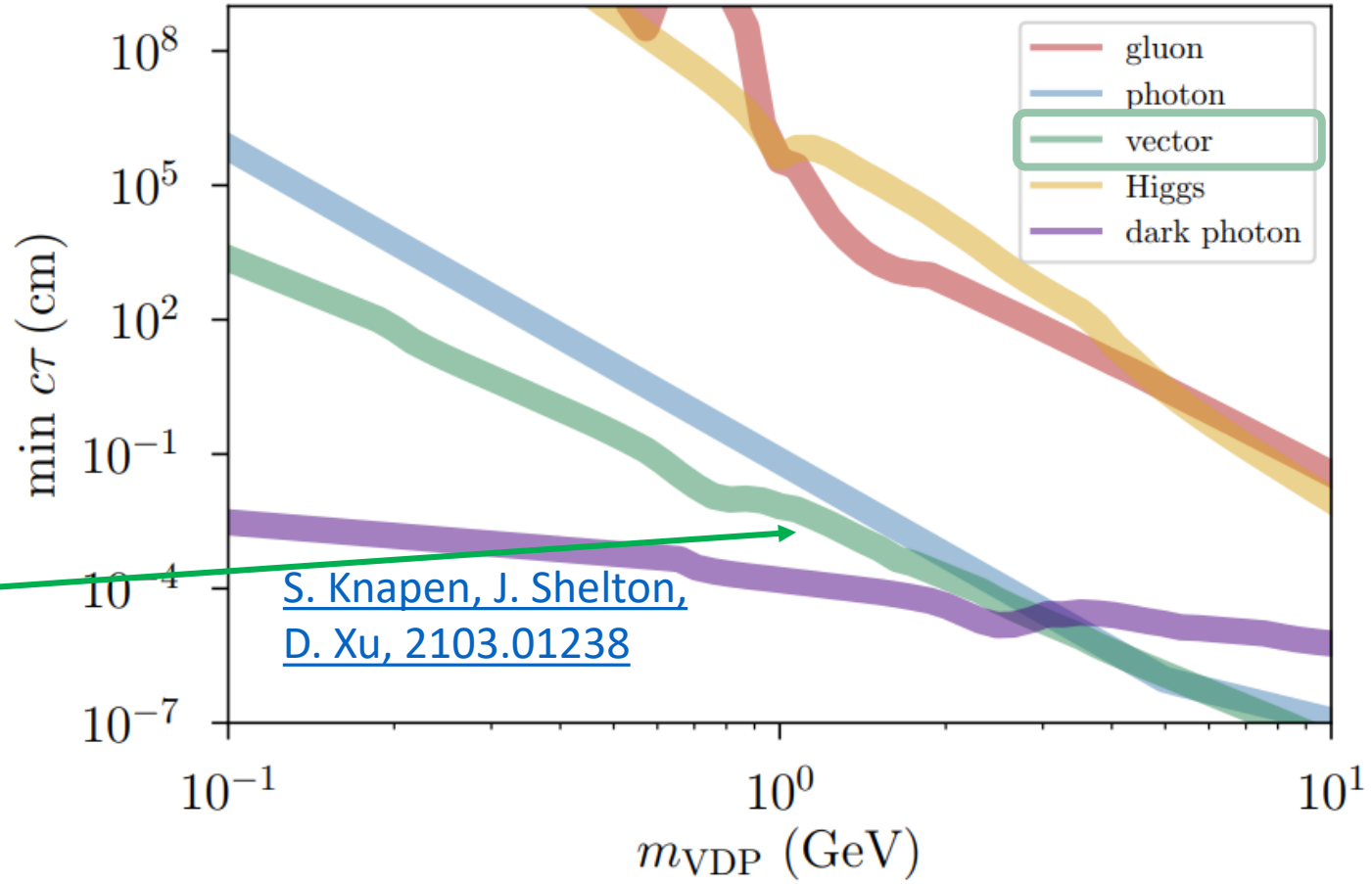
A simple approach: Z' kinematically mixes with the hypercharge by ε.



- In the vanilla model, dark π's decay via the $U(1)_{Dark}$ anomaly, can be very long-lived: the transverse Z' cannot mix with π' directly.
- Dark ρ's decay mostly to hadrons without clear resonances.
  1. But still chances decaying to e^+e^- and $\mu^+\mu^-$: connection to WG5
  2. Decaying to cc and bb: connection to WG3



Minimum lifetime with different portals



S. Knapen, J. Shelton, D. Xu, 2103.01238

➢Dark ρ' width $\sim \alpha_D \alpha_{EM} m_{Z'}^{-4} \Lambda^5 \varepsilon^2$.

➢For $m_{Z'}$~20 GeV (away from B-factory bounds) and $\varepsilon \sim 10^{-2}$, a 2 GeV ρ' has lifetime < 0.1 mm.

➢For production scenario 1 with a TeV-scale threshold, heavier dark hadrons are possible, and making things prompt is easier.