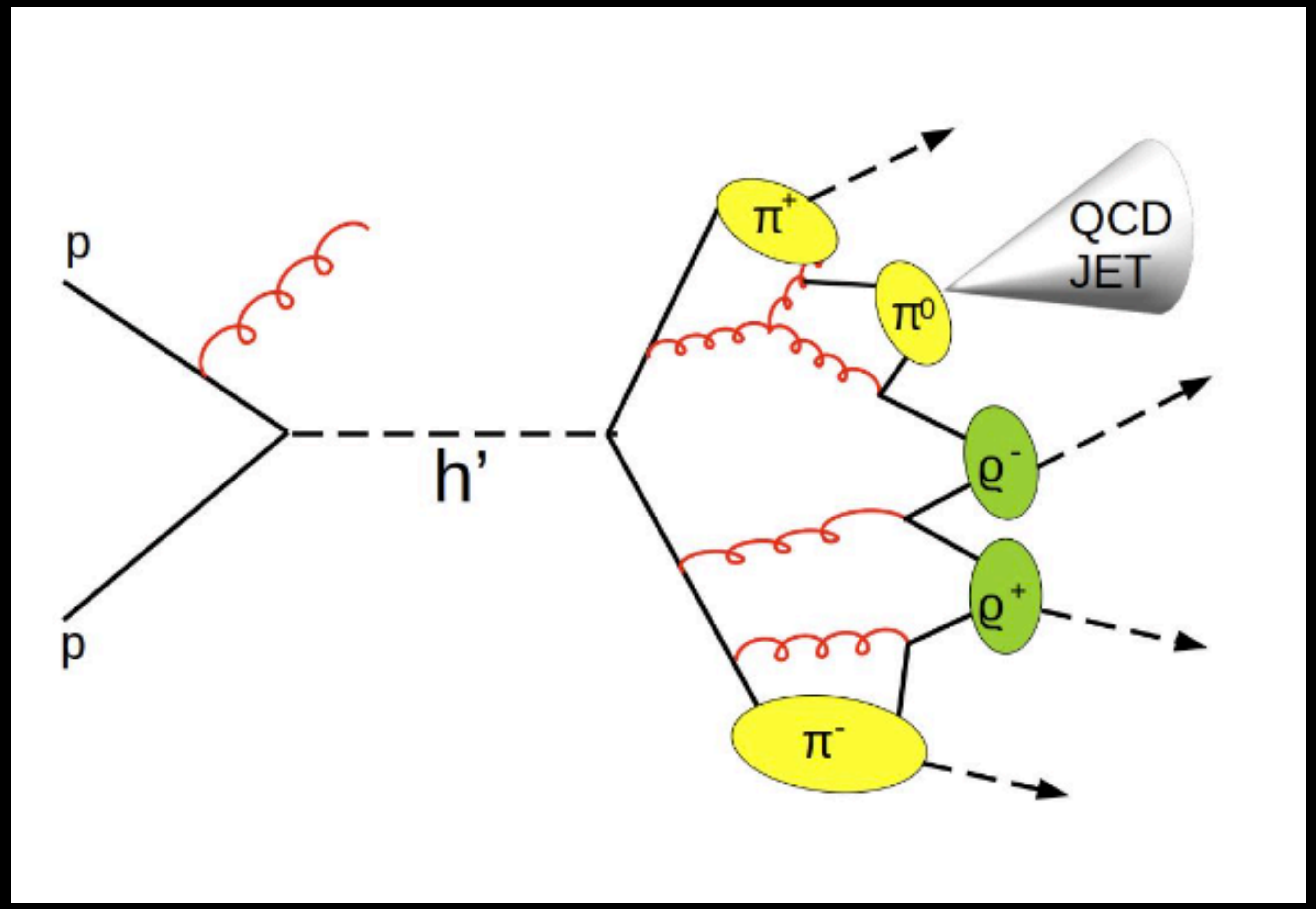
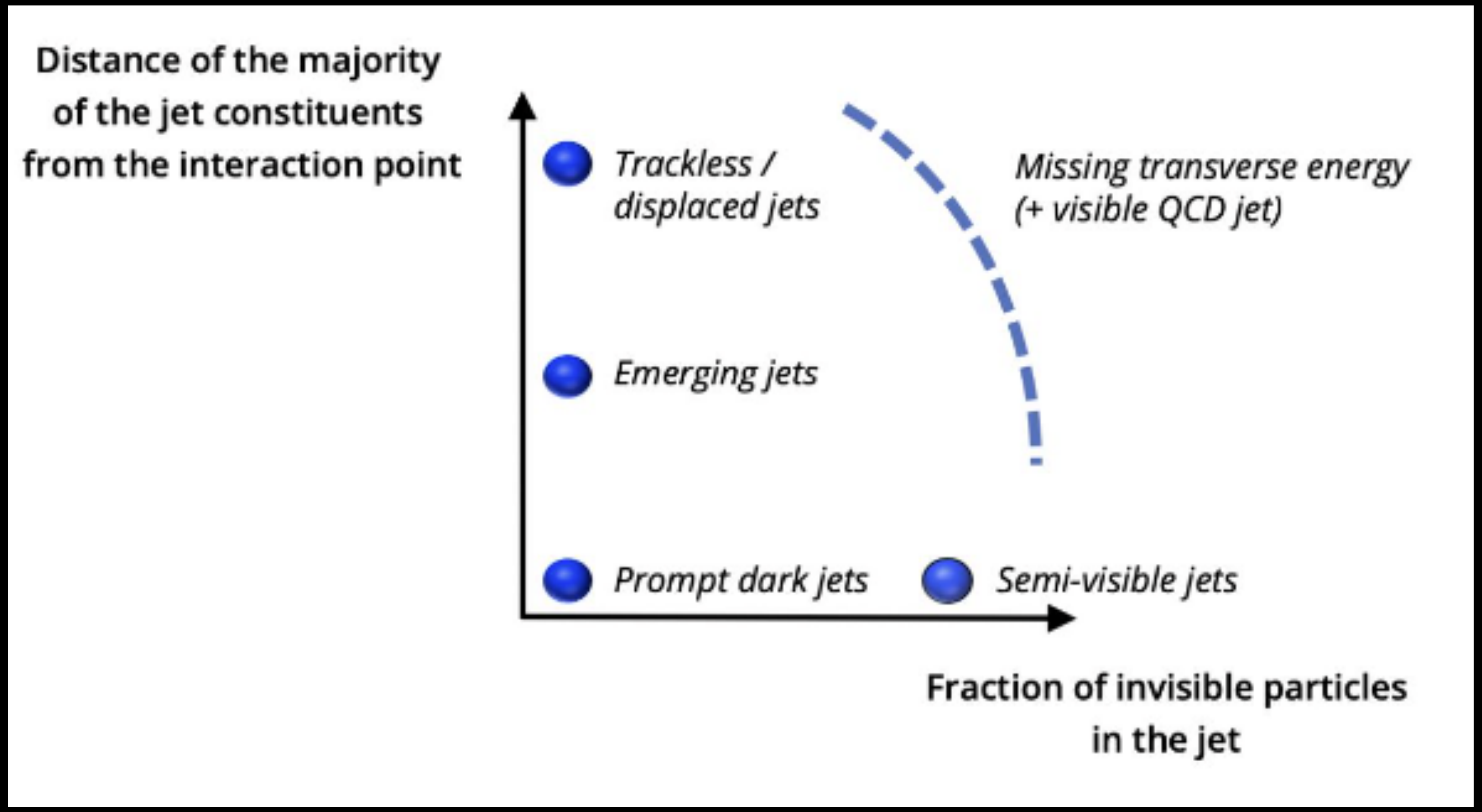
Overview of the dark shower Snowmass project

Marie-Hélène Genest (LPSC Grenoble) for the project

Aim of the project

- Contribute a whitepaper to the Snowmass process:
  - Phenomenological studies of currently-used LHC jetty benchmarks
    - Could include prompt dark jets, semi-visible jets, emerging jets, SUEP, trackless jets
    - Considering the following questions:
      - Which parameter scans are the most useful in terms of coverage?
      - How model-dependent are our searches and how can we improve?
      - How can we catch more models, at future colliders/HL-LHC?
  - Link to LOI





Practical details & organisation

- Group mailing list: dark-showers-snowmass21@cern.ch
- Group meeting every 3 weeks (indico entry)
  - Anyone encouraged to write their own papers with their studies we will summarize & cite in the common one from this group
  - Presentation of this work / intermediate work in the group
  - Next meeting: Thursday December 9th @ 15h (CERN time)
- Sharing models / code:
  - Gitlab repository (being populated): https://github.com/dark-showers-snowmass21

Meetings so far

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Dark shower simulation tutorial

At the LLP WG workshop last spring

- In collaboration with the LLP WG workshop Introduction to pythia Hidden Valley module and the SUEP simulation tool
- Hands-on exercise in simulating dark showers semi-visible jet and SUEP signal
- Common discussion with theorists about possible limitation of simulation tools
- Docker container/pythia codes/python codes publicly available
- Well attended by over 60 participants
  Link to tutorial material + discussion google doc + recording

HV module: can it do all we want?

- Discussion started in Snowmass meeting (incl. recording)-> ongoing studies
- Matt Strassler's talk : Theory and Simulation Challenges for Hidden Valleys/ Dark Sectors at LLPX (incl. recording)

Summary

- Existing Pythia 8 HV Module covers SU(N) with F degenerate quarks
  - Standard QCD-like showering [or constant-coupling showering]
  - Standard QCD-like hadronization includes only spin-0,1 flavor-adjoint mesons
- But this module does not work for all N, F
  - Many values of N,F have very different spectrum or new showering dynamics
- Even for acceptable N,F
  - not necessarily (yet) working for small quark mass (chiral limit)
  - and definitely not for large quark mass (very different spectrum)
- For LLPs: definitely want
  - The chiral limit (pion lifetimes increase; multiplicity too?)
  - Non-degenerate quarks (cascades, more lifetimes)

Needs work by theorists/tool-developers to assure Pythia 8 HV module is
- made **more robust**
- stable/accurate for **low pion mass**
- extended to **non-degenerate quarks**.

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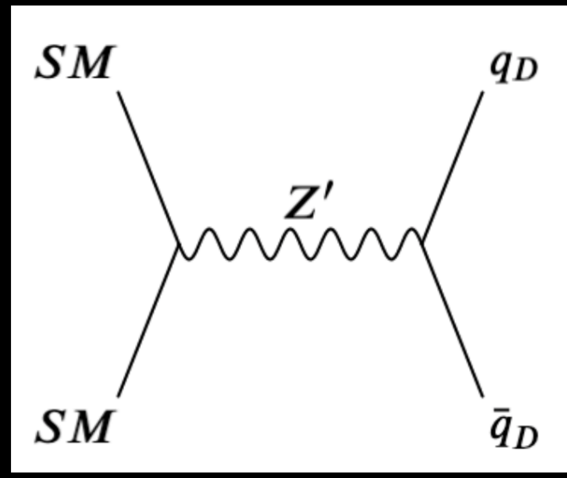
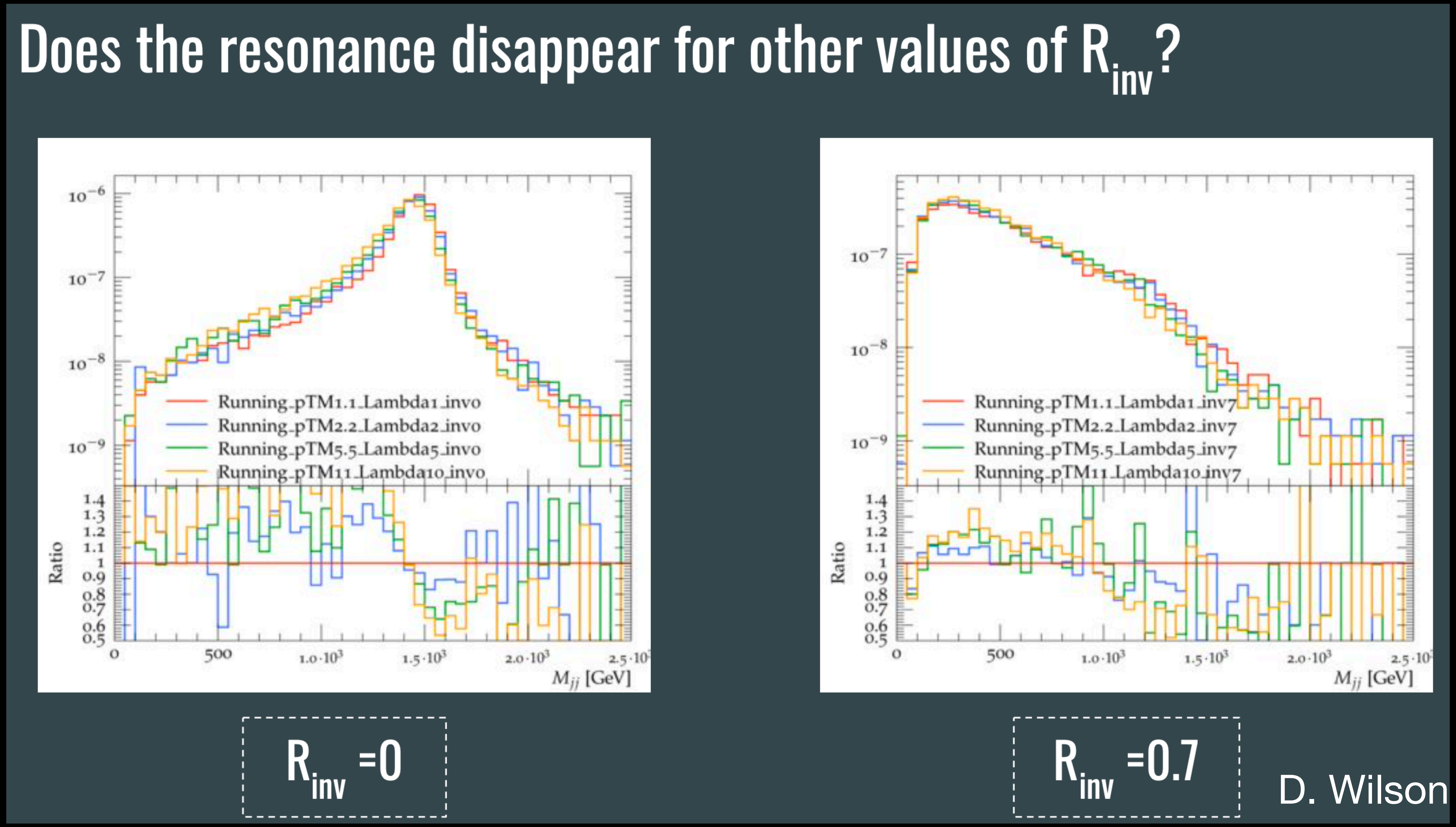
Example of ongoing work

How do dark sector parameters affect collider observables?

- Many studies done in terms of the jet invisible fraction, Rinv, for example:





Example of ongoing work

How do dark sector parameters affect collider observables?

- This links to detector signatures, but how does it relate to the physical dark QCD parameters?
- Study the phenomenology (jet kinematics, radius, tracks, ….) as a function of the physical parameters (number of colours, flavours, masses, confinement scale…)
- But need to be careful:
  - take into account the physical relationships between them
  - produce samples within the validity range of the HV module -
- Samples will be shared when produced

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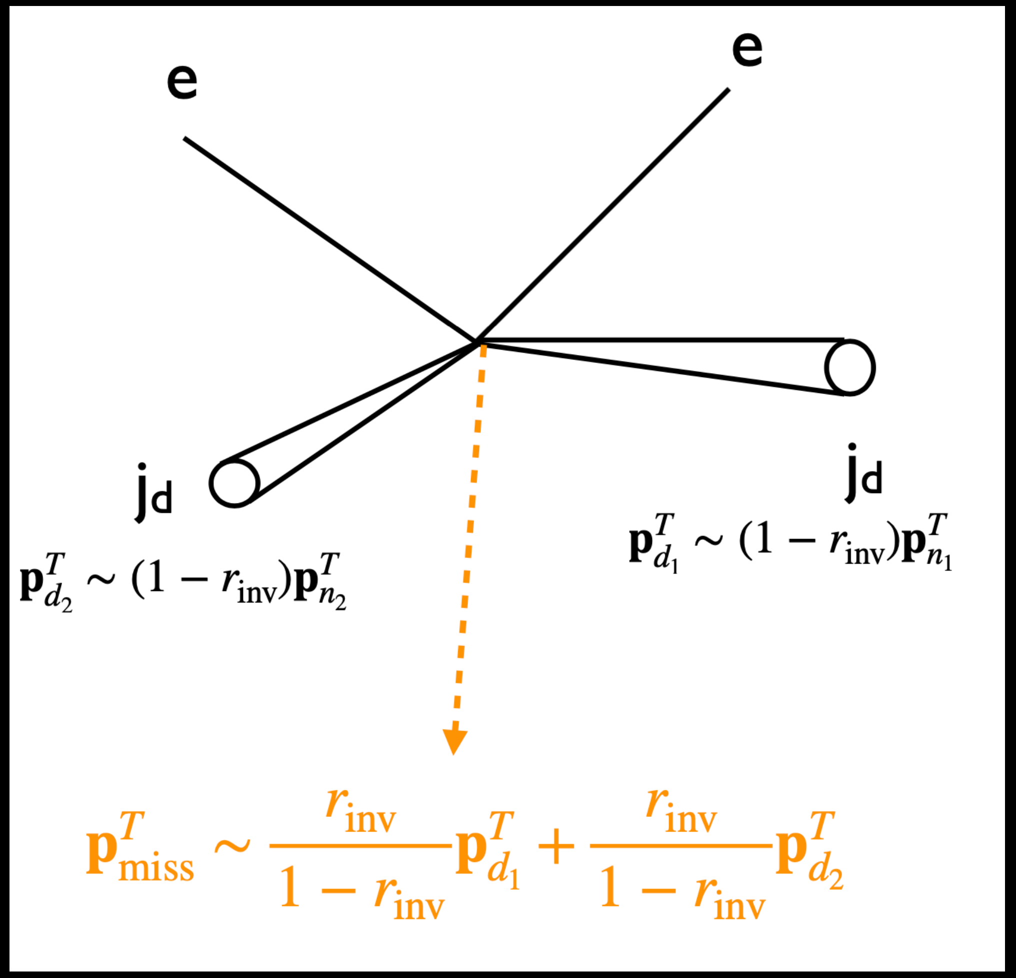
Example of ongoing work

Can we devise event-level variables to identify events?

Paper to be submitted this week!

- If the dark quarks are produced in association with other objects -> can devise some kinematic variables with large discriminating power

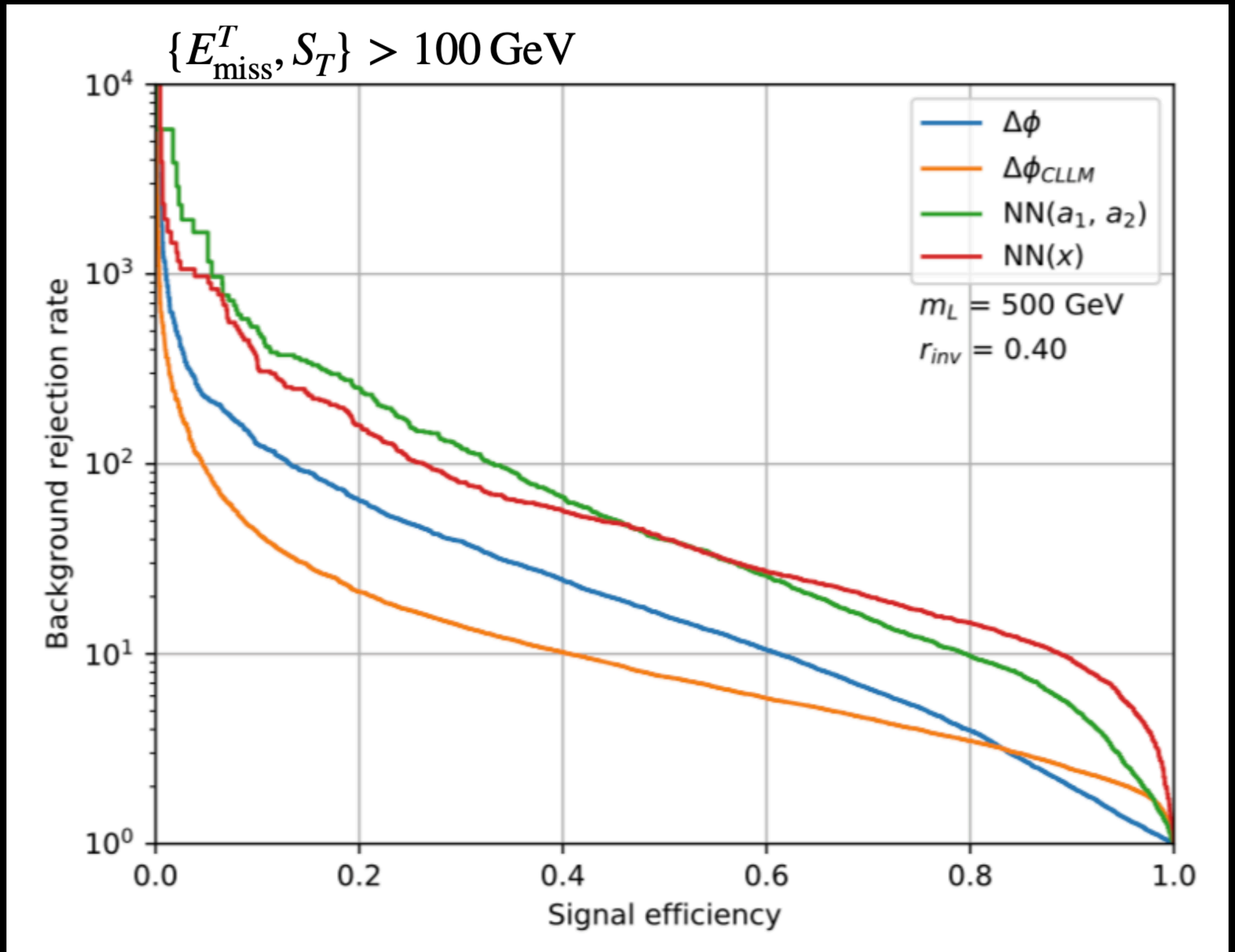


$$a_1 = \frac{|\mathbf{p}^T_{d_2}|^2(\mathbf{p}^T_{d_1} \cdot \mathbf{p}^T_{\rm miss}) - (\mathbf{p}^T_{d_1} \cdot \mathbf{p}^T_{d_2})(\mathbf{p}^T_{d_2} \cdot \mathbf{p}^T_{\rm miss})}{|\mathbf{p}^T_{d_1}|^2|\mathbf{p}^T_{d_2}|^2 - (\mathbf{p}^T_{d_1} \cdot \mathbf{p}^T_{d_2})^2}$$

$$a_2 = \frac{|\mathbf{p}^T_{d_1}|^2(\mathbf{p}^T_{d_2} \cdot \mathbf{p}^T_{\rm miss}) - (\mathbf{p}^T_{d_1} \cdot \mathbf{p}^T_{d_2})(\mathbf{p}^T_{d_1} \cdot \mathbf{p}^T_{\rm miss})}{|\mathbf{p}^T_{d_1}|^2|\mathbf{p}^T_{d_2}|^2 - (\mathbf{p}^T_{d_1} \cdot \mathbf{p}^T_{d_2})^2}$$

$$\Delta\phi = |\phi_{\mathbf{p}^T_D} - \phi_{\mathbf{p}^T_{\rm miss}}|$$

$$\Delta\phi_{CLLM} = \min_{i \le 4}\left\{\left|\phi_{\mathbf{p}^T_{j_i}} - \phi_{\mathbf{p}^T_{\rm miss}}\right|\right\}$$



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Example of ongoing work

What about the Nf=0 case?

`GlueShower:`
Simulating a Pure Gluon Shower for Dark Sector Searches

Conclusions

- Dark showers are a general signature of hidden valley models, motivated by neutral naturalness
  - The zero flavour case being a possible version
- Still many unknowns around the pure-glue hadronisation process
- This work is an attempt at producing a physically motivated tool that can scan the possible range of phenomena, through adjusting internal parameters
  - Outputs are relatively robust to scanning the current parameters
- Intend to publicly release a Python code, `GlueShower`, for the community to use
  - Can run for SU(N), where N can be select values in the range 2 to 12

Contact: caleb.gemmell@mail.utoronto.ca

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Summary

- Good discussions at the meetings, work ongoing on many topics (generation, triggers, observables, …)
- Work to do on the HV module
- You are very welcome to join if you are interested!
- White paper for the spring - should start drafting early 2022