Dark Sectors in Event Generators: A Community Framework

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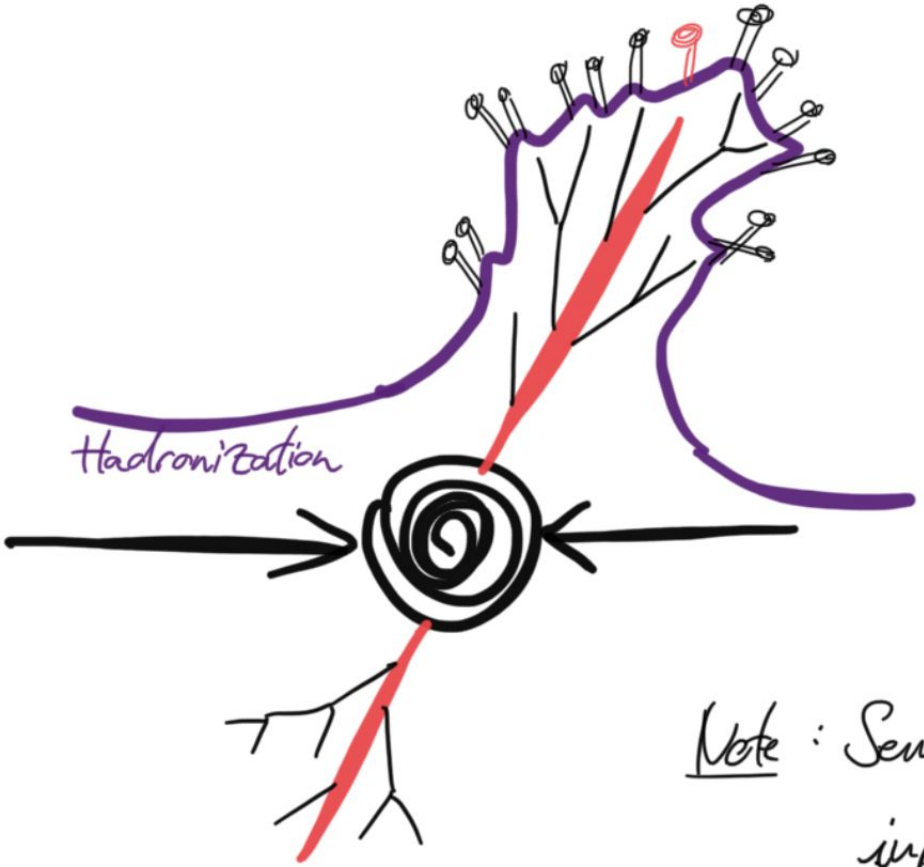
Background

- Pythia(6/8) has a long history of supporting exotic phenomena
- New BSM models are increasingly complex: challenge our thinking on
  - parton showers
  - hadronization
  - “underlying event”
  - decays
- Consistent treatment of all are needed to make meaningful comparisons to SM predictions
- In QCD phenomenology, “interface” problems have been solved by putting different communities in a room and asking them to come to an accord
  - LHE files, SLHA format, LHAPDF

Dark Sector as part of the hard process

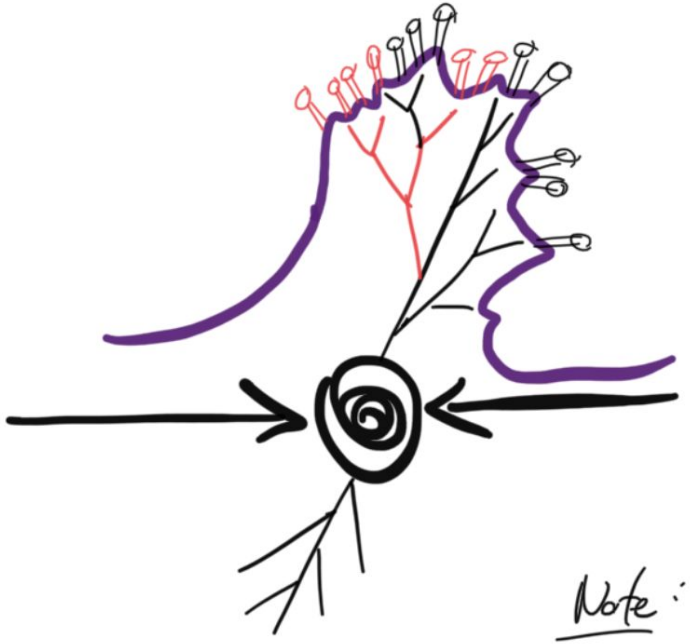


- Dark sector partons in hardest scattering
- SM parton showering (perturbative!)
- Hadronization to few stable dark hadrons.

Think of R-hadron production from SUSY

Note: Semi-simple to extend through LHEF input, SLHA...

Dark Sector in showers

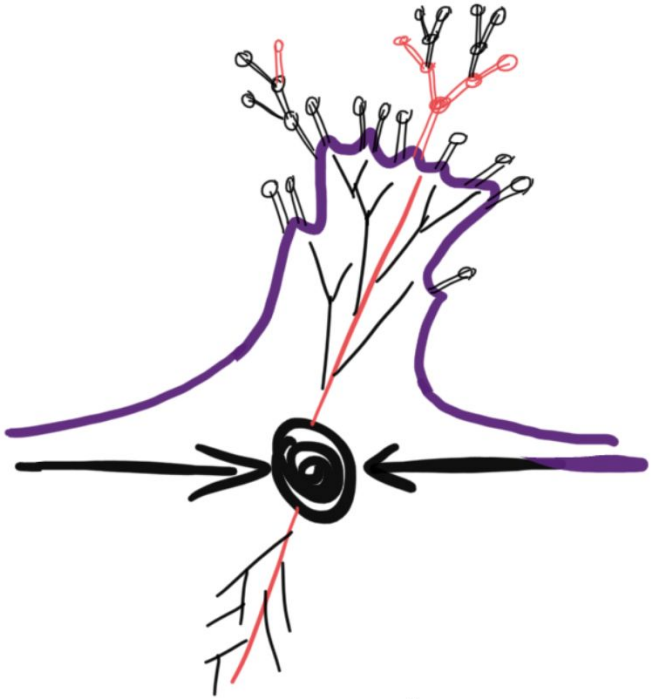


- Hard SM process
- Dark sector partons or "messengers" contribute to jet evolution (may be oscillate between dark & visible)
- Hadronization produces stable dark hadrons.

Note: Requires dedicated implementation (some configuration possible)

Note: Hard production & shower production can happily mix

Dark Hadron decays



- Dark sector production by any means (e.g. in hard scattering, showers)
- Hadronization produces unstable dark hadrons ⇒ Possibly long decay chains
- Or some SM hadron decays include small branching fraction to dark sector

Note: Requires dedicated implementation, both in hadronization and decay.

What do we need for dark showers?

- Is a generic shower module feasible?
  - a representative list of splitting kernels (mostly for QCD but some for QED) with ME corrections already exist in Pythia8 (more in DIRE plugin)
  - behavior of coupling drives the MC sampling
  - can reweight shower with MG plugins
- How many mechanisms of dark showers do we need?
- This assumes we make the same approximations currently in EGs
  - factorization into hard/shower/soft-nonperturbative, no explicit tracking of spin, no color at the amplitude level
- Is interference between SM and Dark sector ever important?
  - not if widths are small
- Not much to say about handling exotic ME calculations with exotic showers
  - not entirely worked out for the SM!

What do we need for dark hadronization?

- Let's assume the string model can handle anything (customizable string parameters for exotic models)
- Further, let's assume you have the dark sector hadron spectrum
  - handled using SLHA interface + some external package
- Need to specify fragmentation functions
  - (blob) -> (blob-hadron) + (blob remnant) OR (blob) -> (blob-hadron) + (SM remnant)
  - This looks like a decay specification in SLHA -- can we come up with a new BLOCK?
- What about junctions/strange color(meta-color) configurations?

Other considerations

- How do we communicate information to GEANT?
  - some common language would be useful
  - is it enough to share an SLHA file? How to synch event generator information with that in the detector simulation (usually at different stages of computing pipeline)
  - extensions to HepMC?
- How to prioritize implementations (or can we make it generic enough?)
- At a next-generation facility with a next-generation detector, what sort of dark sector phenomena can be probed?
- Tim mentioned uncertainty estimates
  - First, we don't even have a good methodology for the SM.
  - For the parton shower (in Pythia), we calculate a weight for how the shower would change based on change of scales, breakdown of soft-collinear approximation, etc., and this could be extended to the HV shower