Building a systematic primer for the rescattering of heavy flavor hadrons

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Motivation

- Hadronic rescattering affects observables: Momentum spectra and anisotropy [1], quarkonia suppression [2], IMR dilepton yields [3]...
- No agreed-upon theoretical description for interactions of HF hadrons or any *systematic* study on the effects of different assumptions [4]

Theory uncertainties

- How do we determine and model the relevant channels?
- Can we treat resonances as independent and distinct?

Experimental difficulties

- Interaction cross sections with HF not directly measurable
- Lacking data on resonance properties (mass, width) [5]

- Small statistics so far does not constrain incompatible models
- Upcoming "precision era" requires a good handle on the mechanisms
- *Goal*: construct the simplest possible setup resembling a post-hadronization system, and gradually make it more complex

SMASH

Simulating **Ma**ny **S**trongly-interacting **H**adrons

- Evolve hadrons according to the Boltzmann equation [6]

$$p^\mu \partial_\mu f_i(x,p) = C_i^{\text{coll}}[f]$$

- Isotropic and elastic collision term

$$C^i_{2\leftrightarrow 2}[f] = \sum_j \int |\mathbf{p}'_i - \mathbf{p}'_j| \underline{\sigma_{ij}(s)} [f(\mathbf{p}'_i)f(\mathbf{p}'_j) - f(\mathbf{p}_i)f(\mathbf{p}_j)]\, \mathrm{d}^3\mathbf{p}$$

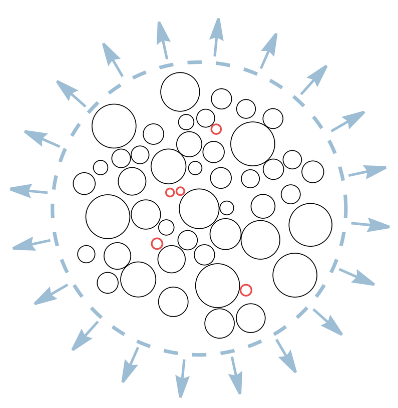
- Cross sections from the Additive Quark Model

$$\underline{\sigma_{AB}} = \sigma_{pp}\frac{n_q^A}{3}\frac{n_q^B}{3}(1-0.4x_s^A)(1-0.4x_s^B)(1-\kappa_c x_c^A)(1-\kappa_c x_c^B)$$

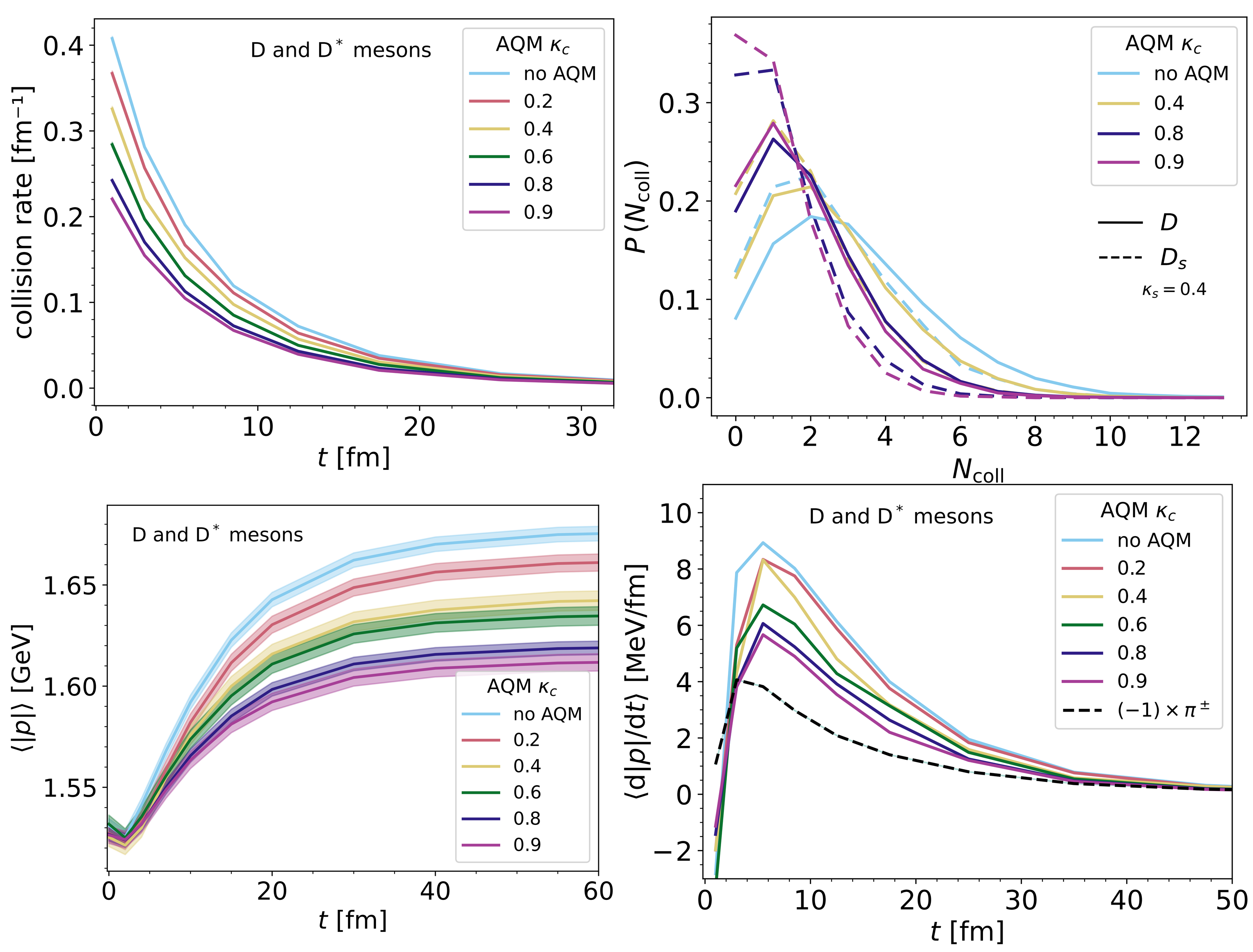
- $\kappa_s = 0.4$ from fitting experimental data, but no established value for κ_c

Thermalized sphere

- Simplest possible system to mimic an afterburner
- Late stage thermodynamics of a Pb+Pb collision at $\sqrt{s_{NN}} = 2.76$ TeV



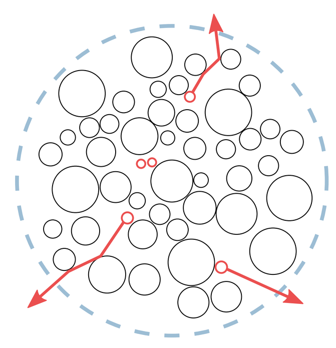
LHC:
- ⋆ Statistical hadronization model: $T = 157$ MeV and $r = 10.9$ fm [7]
- ⋆ Blast wave fit: $u_0 = 0.65$ [8]

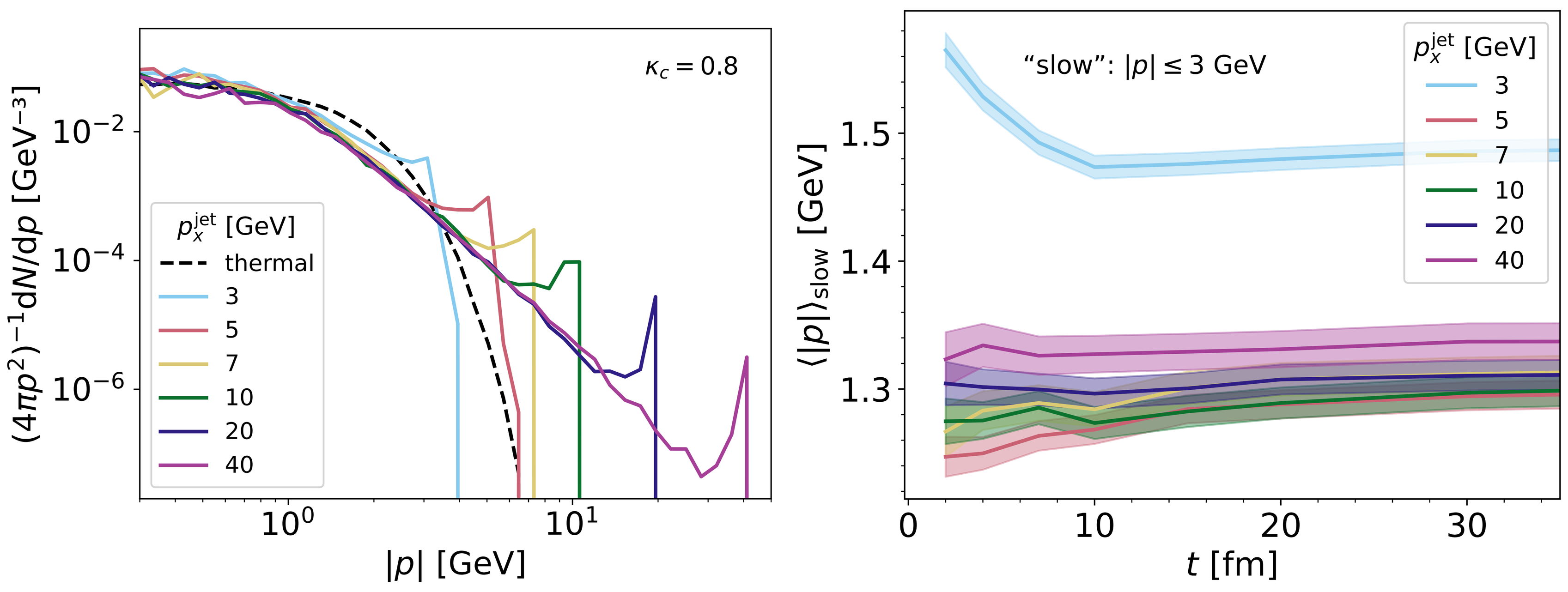


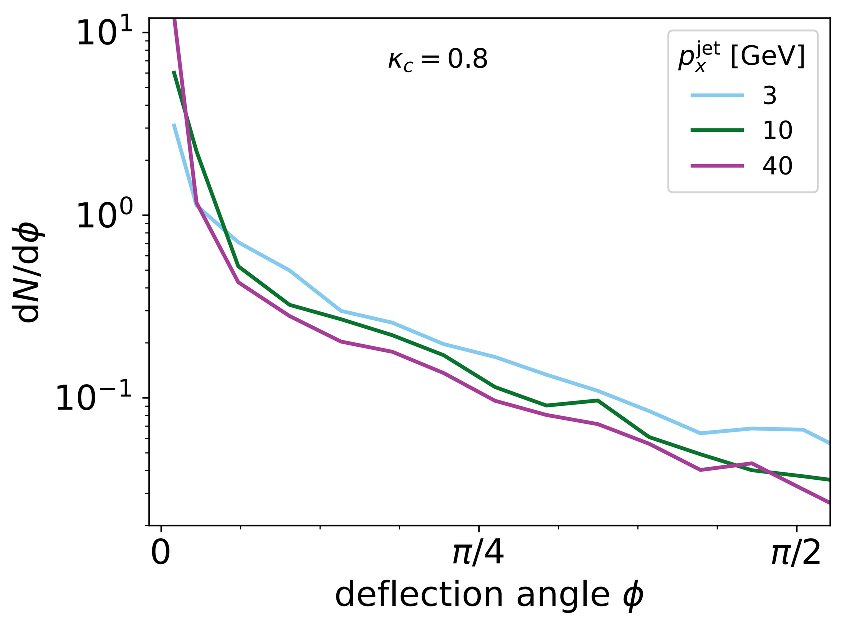
- Kinetic freezeout at $t_{\text{fo}} = 20 \sim 25$ fm after hadronization
- Cross section ∝ interaction rate but t_{fo} is not sensitive
- D mesons pushed faster by lower mass particles (*pion wind*)

"Jets"

- Realistically: HF mostly from hard processes
  - ⋆ Charmed hadrons are faster than (u,d,s) hadrons during rescattering
- Our *jet*: a single D meson scatters elastically without radiating, initially fast in the x-direction







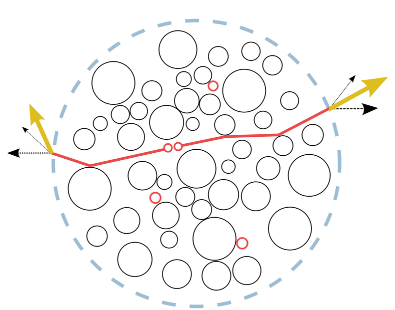
Hint of thermalization

- Rescattered particles from the jet follow an universal curve
- Momentum of *slow* particles insensitive to initial condition

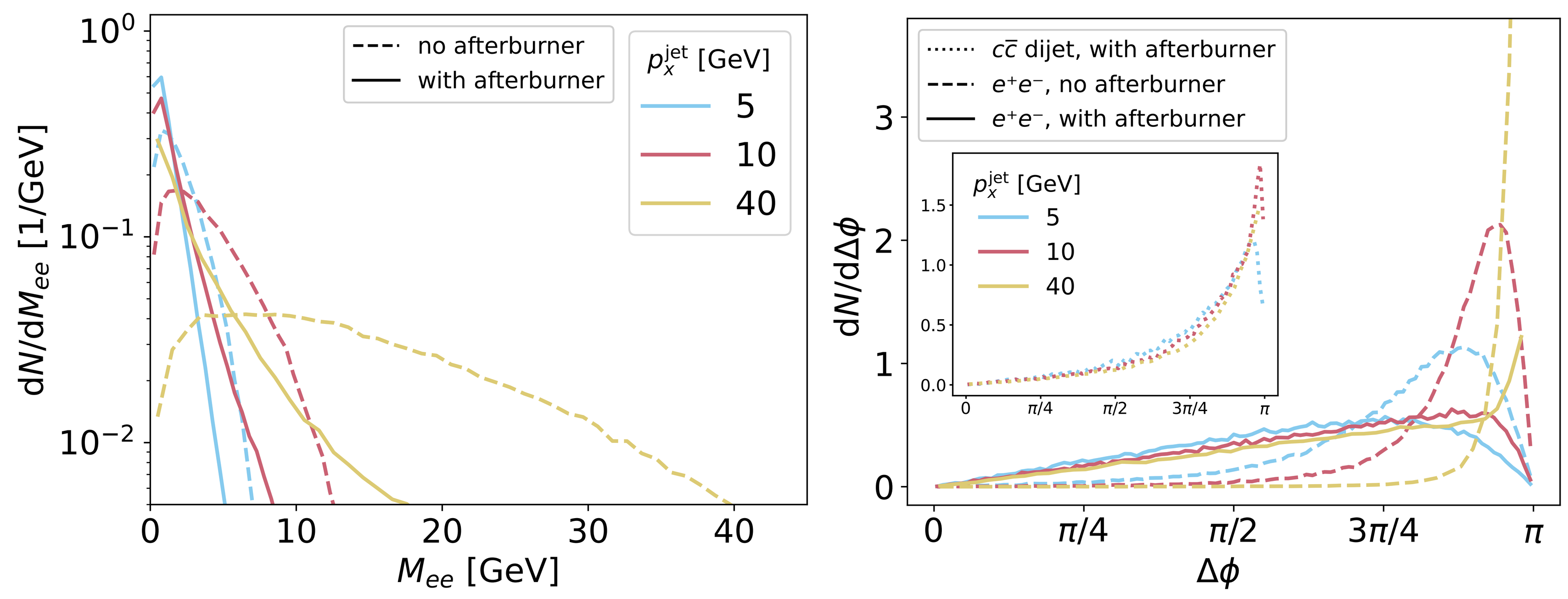
- Most momentum is lost $\langle|p|\rangle \sim 0.55\, p_x^{\text{jet}}$, but rescattered particles are little deflected
- Slower jets more likely to be deflected to larger angles

Dileptons

- IMR ($1.2 < M_{ee} < 3$ GeV): large background from semileptonic decays of correlated HF pairs



- Main decay channels $\begin{cases} D^+ \to \bar{K}^0 e^+ \nu_e & 8.72\% \\ D^+ \to \bar{K}^*(892)^0 e^+ \nu_e & 5.40\% \end{cases}$
- Back-to-back D^+D^- jets



- Independent Dalitz decays
  - ⋆ Indirect dilepton
  - ⋆ Large spread in M_{ee}
- Rescattering: D mesons lose energy to hadronic medium
  - ⋆ Available phase space shrinks
  - ⋆ Lower M_{ee} enhanced
- Vacuum: distribution of opening angle sensitive to jet momentum
- Afterburner: decorrelate D^+D^-
  - ⋆ Small dependence on initial jet
  - ⋆ Distinguishable around $\Delta\phi \approx \pi$
  - ⋆ Resulting leptons are hard to trace back for reconstruction

Further complexities

- Inelastic interactions via resonances
- Dependence on sphere assumptions
- Charmonia depletion $[J/\Psi(+N) \to D\bar{D}(+N)]$
- Distribute jet in phase space
- Whether a jet picks up momentum anisotropy from the medium
- Form factors and polarized dileptons

References

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