Jet Modifications in the RHIC and LHC Era
Wayne State, August 20, 2014

In Medium Hadronization: Hadrons and Jets

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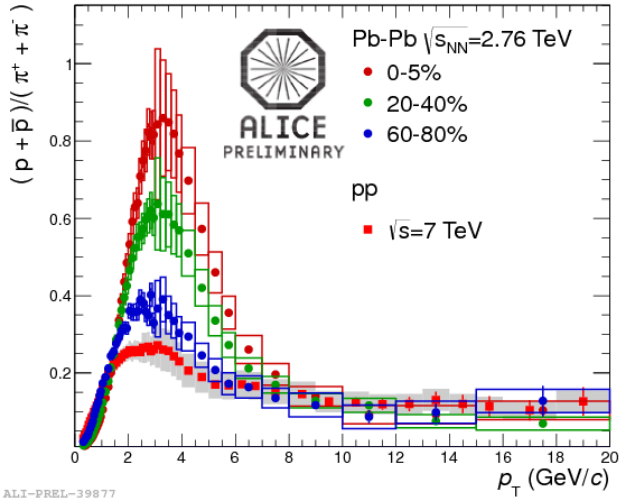
Outline

- Hadronization and in-medium hadronization
- The JET shower recombination module
- How to implement a medium
- Some preliminary results with medium
- Summary

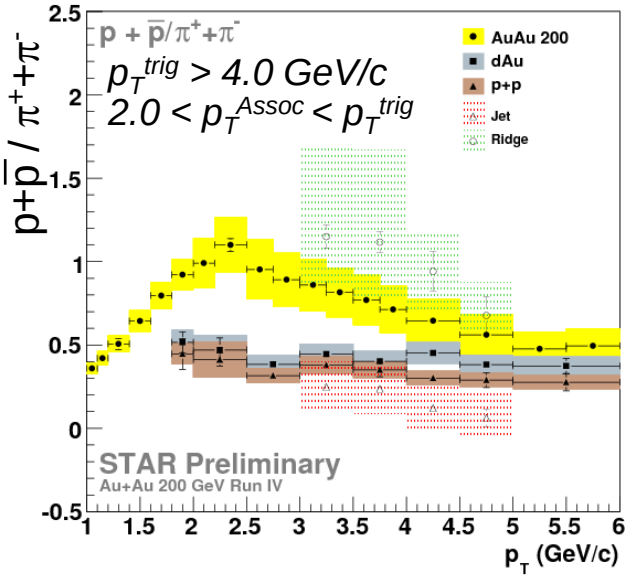
Hadronization Matters

- Example: Hadron chemistry
  - Does the B/M ratio measure phase space occupation?

Can effect be measured directly?
YES

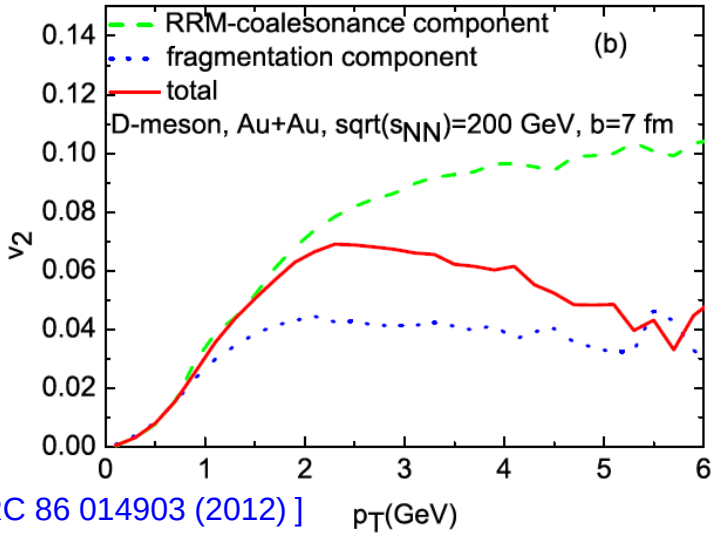


C. Suarez et al, QM08



- Example: Elliptic flow in the heavy quark sector.
  - Hadronization in-medium = additional interaction with the thermal medium.
  - More diffusion/thermalization

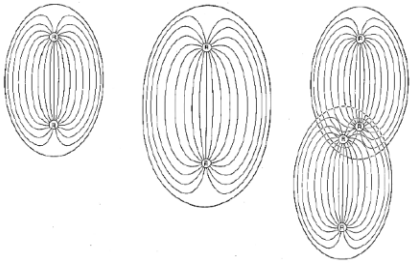
Can effect be measured directly?
DIFFICULT



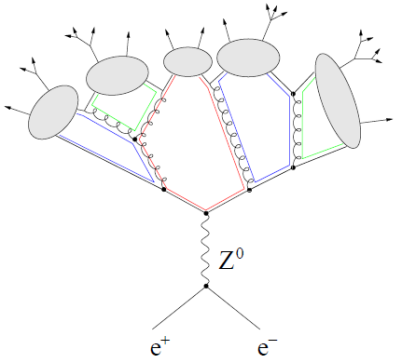
[M He, R J Fries, R Rapp, PRC 86 014903 (2012)]

Hadronization Candidates

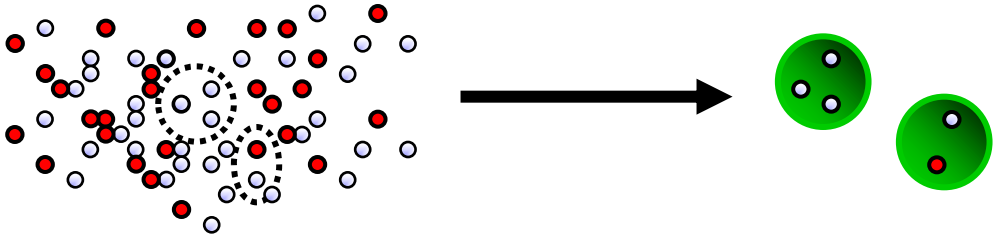
- Lund string fragmentation



- Cluster hadronization

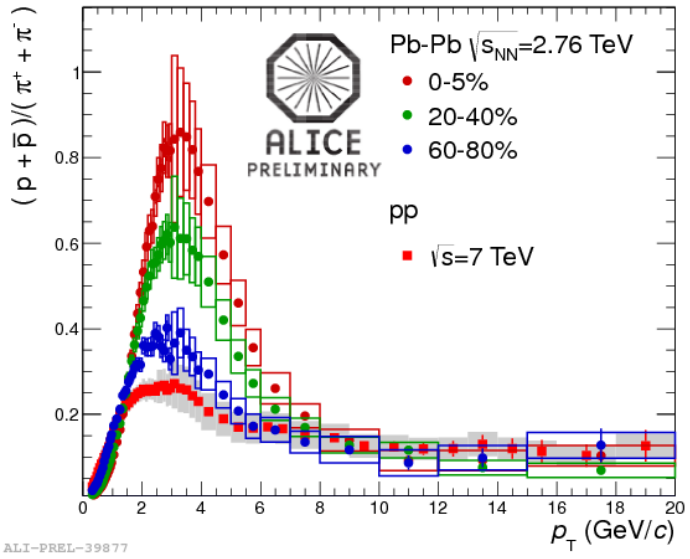


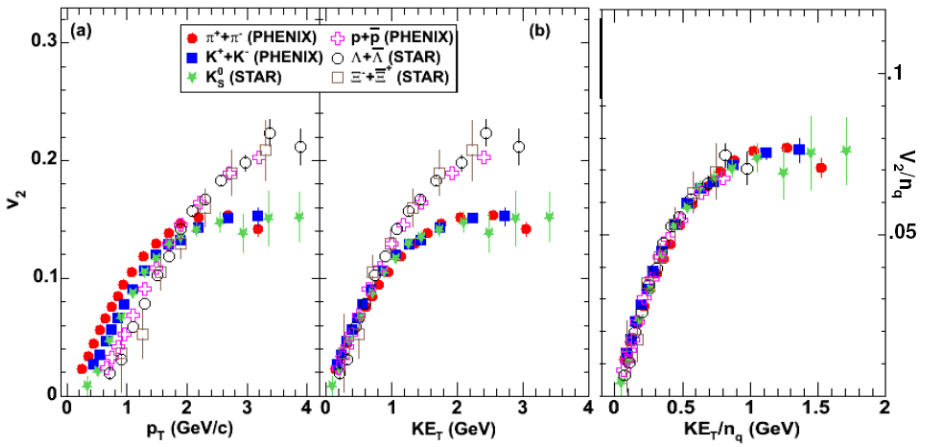
- Jet recombination



Why Quark Recombination?

- Data indicates a dependence of several important observables on the number of valence quarks.





- Quark coalescence models very successful for hadron production at intermediate P_T in HICs.
  - Large baryon/meson ratios
  - Elliptic flow scaling with quark number → QGP signature?

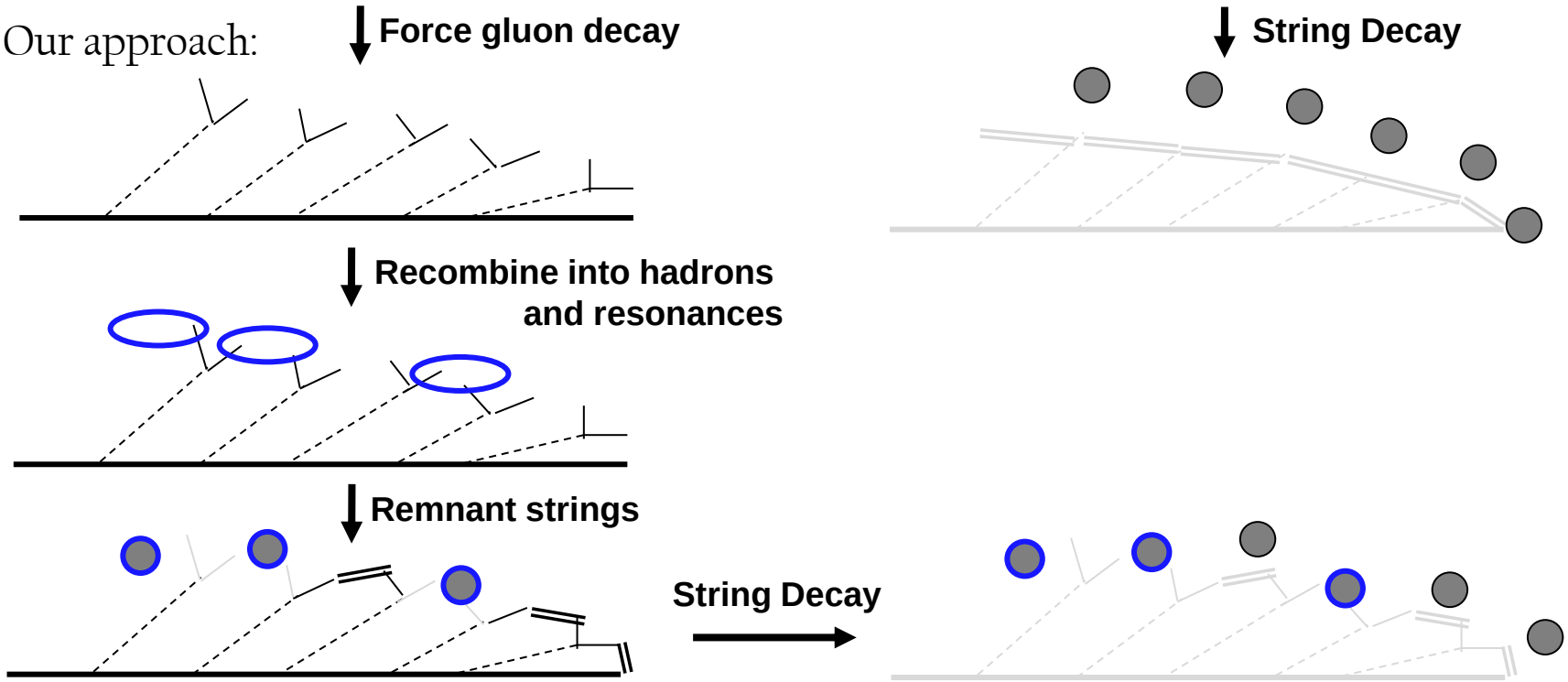
Hadronization Candidates

- No clear strategy how to generalize strings or clusters to in-medium hadronization.
- Recombination did not have a working jet shower implementation. Can one get vacuum fragmentation right?
- Including medium effects then in principle straight forward; good track record.
- JET jet shower recombination module: work in progress (see yesterday's talk)
- This is a project that benefits from feedback from the community.

Summary of JET Recombination

- Standard PYTHIA Lund string fragmentation:

- Our approach:

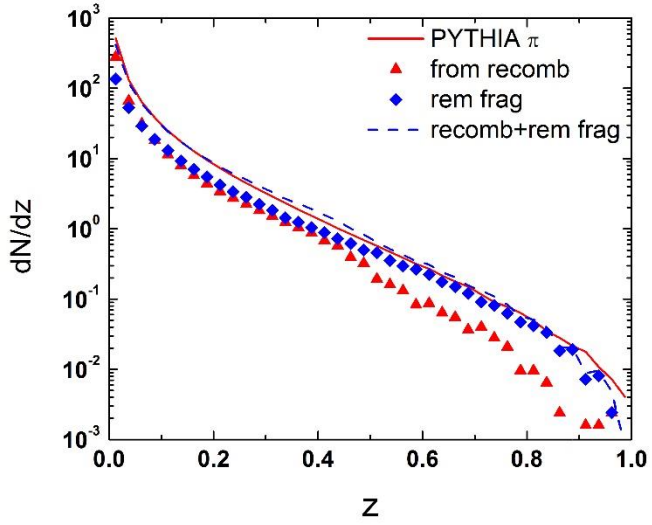


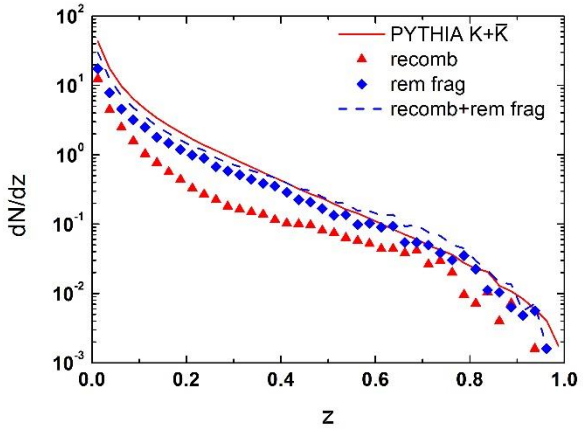
Summary of JET Recombination

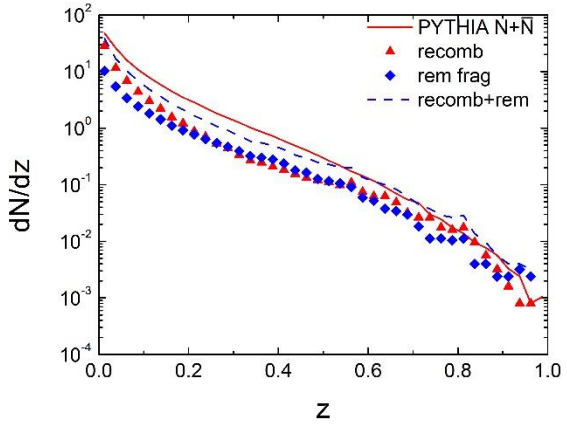
	String	Cluster	Recombination
Gluons	Kinks	Forced decay	Forced decay
Large separation quarks	String breaking	Clusters	String Breaking
Small separation quarks, low mass	Indirectly from string breaking	Clusters	Direct recombination
Small separation quarks, high mass	Indirectly from string breaking	High mass cluster	Resonance

Some Results

- Longitudinal structure: *dN/dz* of stable particles compared to PYTHIA string frag





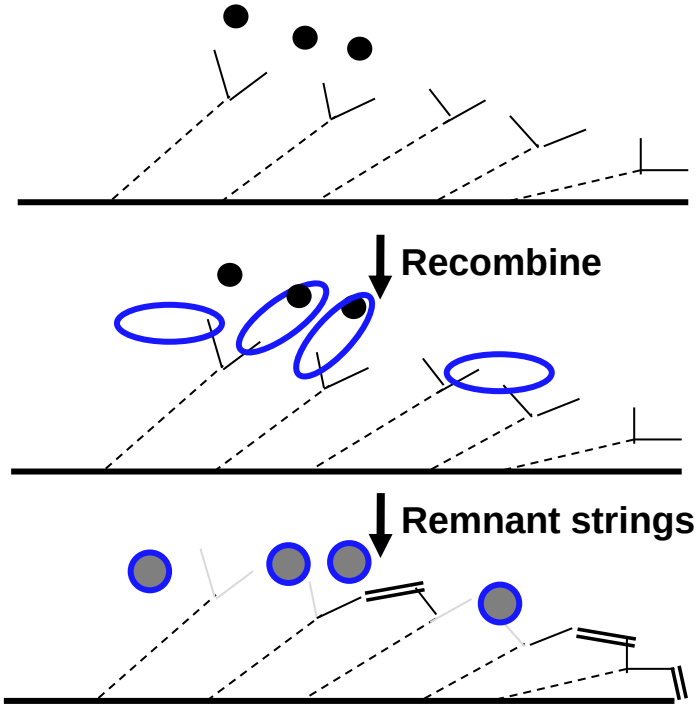


- How to tune parameters?

100 GeV jets

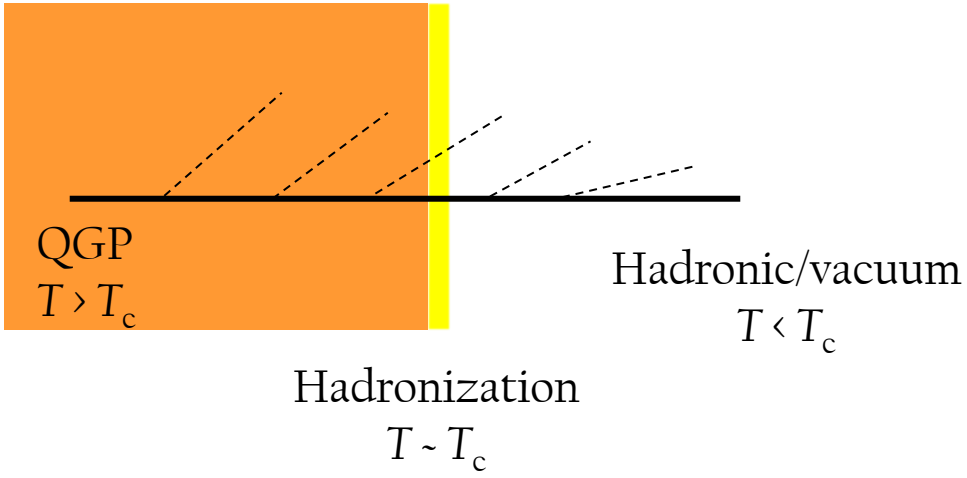
Adding Medium Partons

- Sampling thermal partons from a blastwave models or hydro.
- Allow recombination of shower partons with thermal partons.



Space-Time Picture

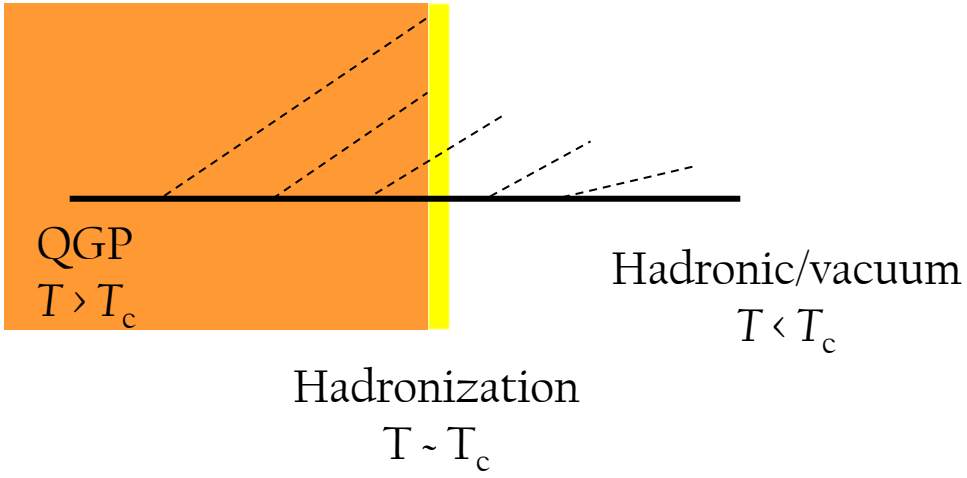
- Space-time picture important.



- Situation not static: $T = T_c$ hypersurface moving.

Space-Time Picture

- Space-time picture important.

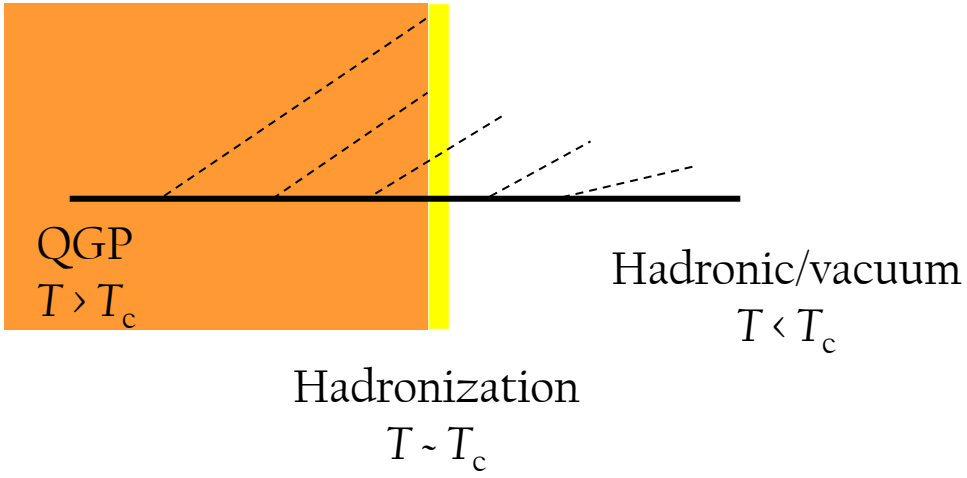


- Situation not static: $T = T_c$ hypersurface moving.

- Jet shower partons born into QGP need to either propagate to the surface or be absorbed by the medium.
- How this is handled will depend strongly on the shower MC.
- Hadronization will only be applied to partons at or below T_c.

Space-Time Picture

- Space-time picture important.



- There is a range, say e.g. T = 155-175 MeV, during which recombination can happen.
- This translates to a finite thickness of the critical hypersurface.
- This should be a physical quantity but it's not necessarily a known quantity.

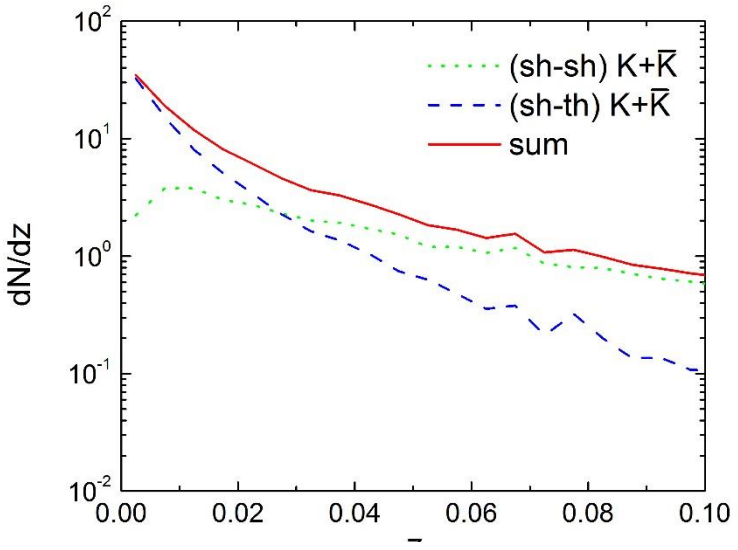
Space-Time Picture

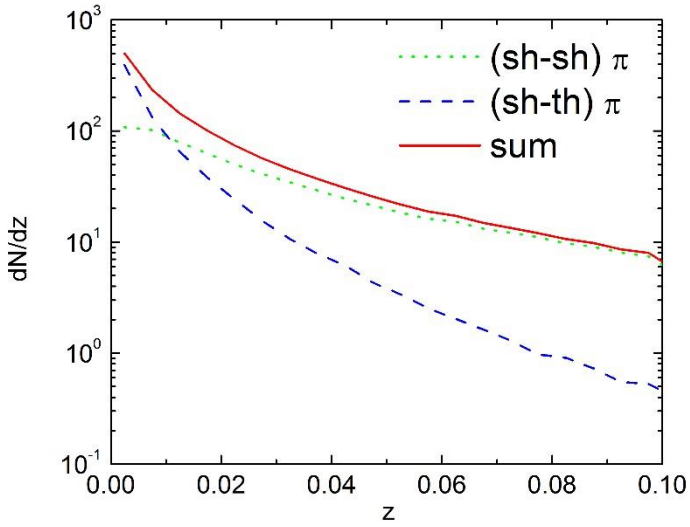
- Eventually this space-time picture will be determined from the underlying hydro event.

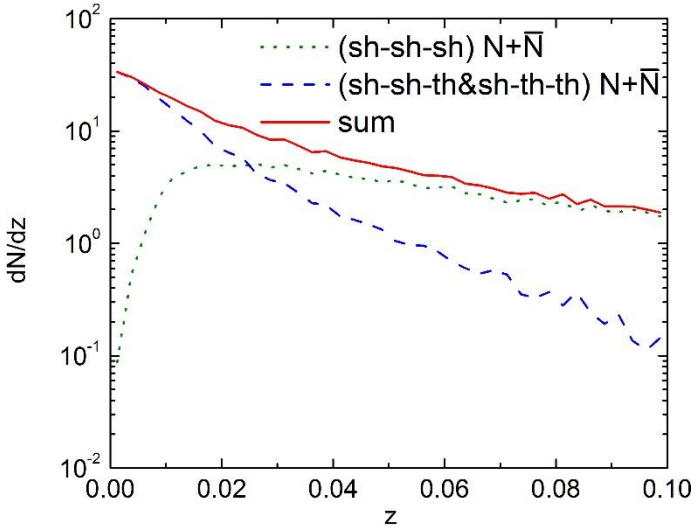
- Here: a few very preliminary results for shower born 1 fm inside a static QGP phase. Thickness of the critical hypersurface is another fermi.

Results in a Semi-Realistic Setup

- Modification of low-z spectra for 100 GeV jets by presence of a medium at hadronization.
- Showers: PYTHIA vacuum showers.
- Point of origin 1 fm inside the QGP

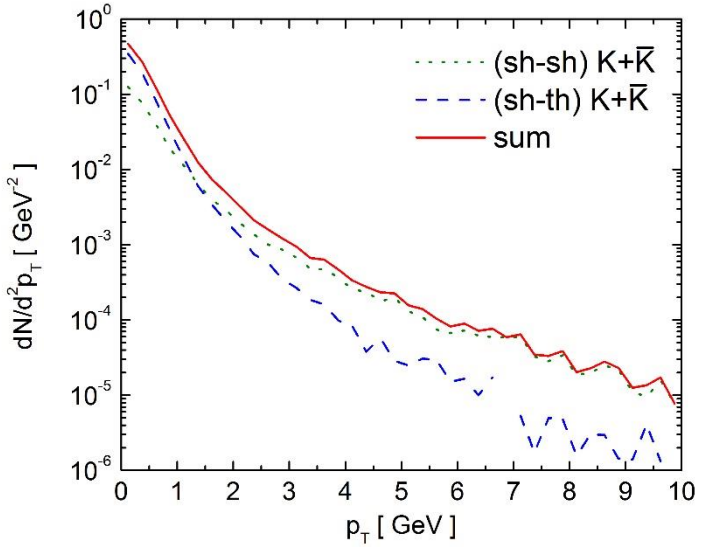


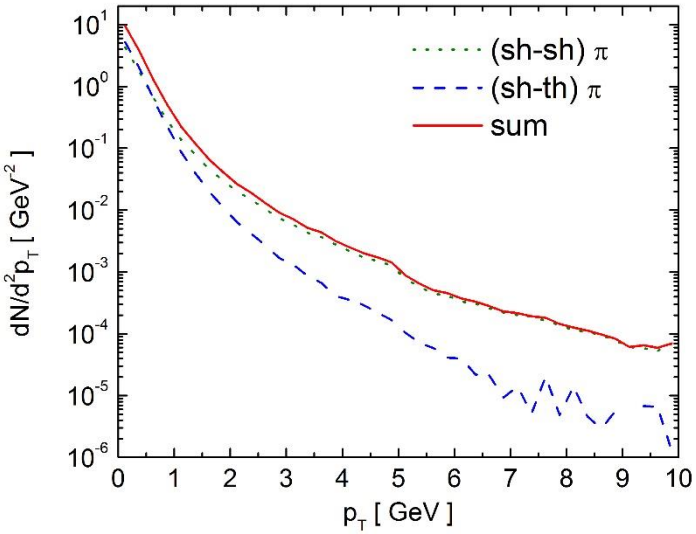


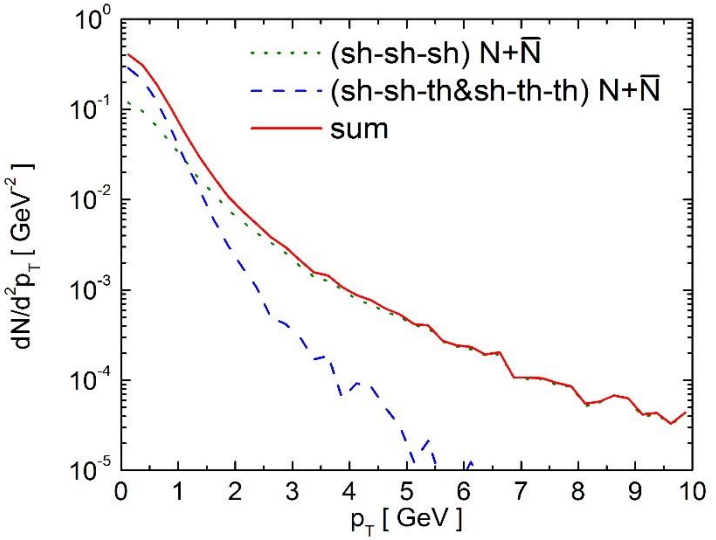


Results in a Semi-Realistic Setup

- Modification of P_T-spectra (all z) for 100 GeV jets by presence of a medium at hadronization.
- Showers: PYTHIA vacuum showers.
- Point of origin 1 fm inside the QGP

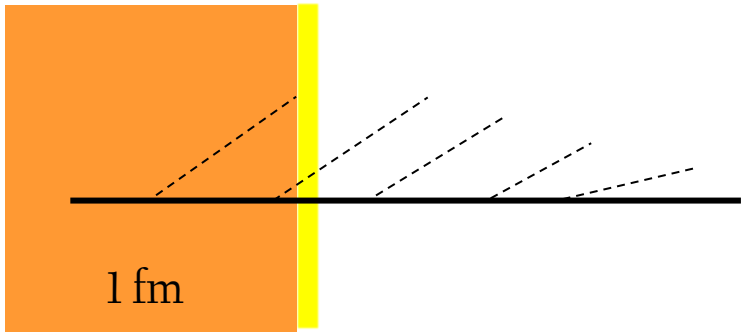


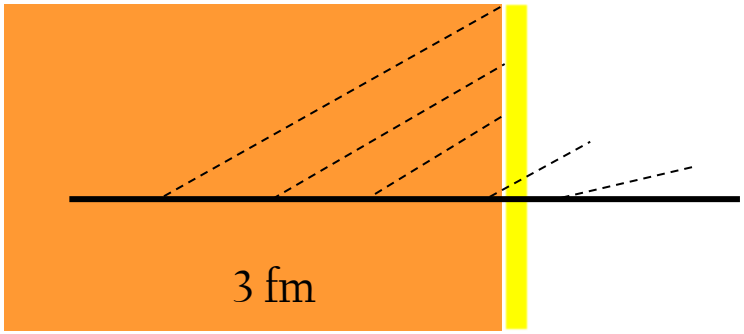


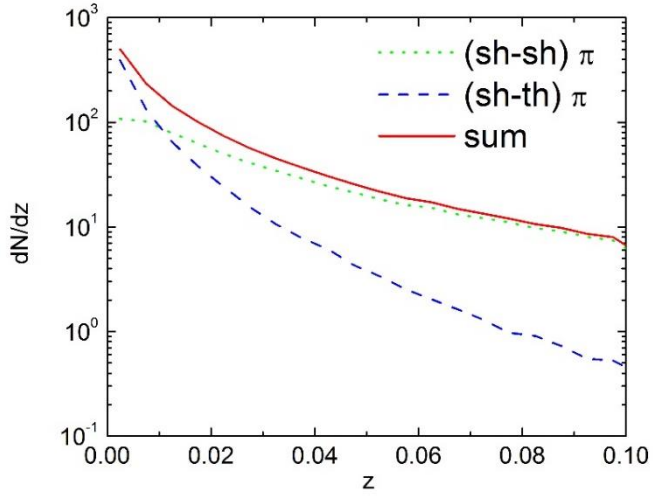


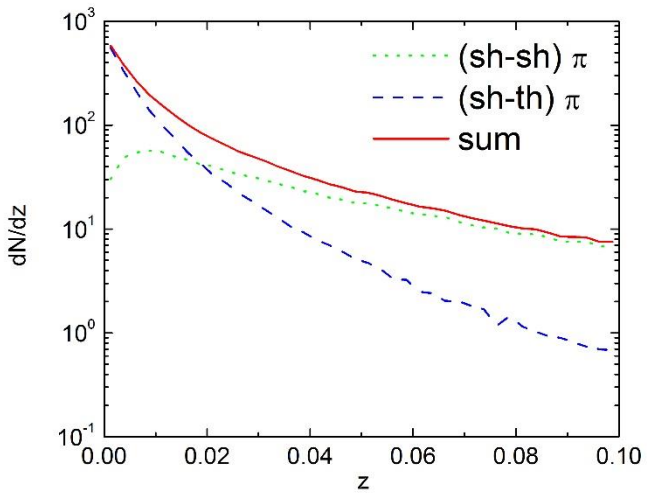
Varying the Point of Origin (Preliminary)

- Modification of z-spectra for 100 GeV jets by presence of a medium at hadronization.









- Trade some sh-sh to sh-th but almost no change in overall spectrum.

How will Hadronization Matter?

- We need to get the physics of in-medium hadronization at least approximately right in simulations.
  - No effect? Fine, but we needed to check.
  - Large effects? Fine!! We need to look into the physics more closely. Explore parameter space.

- Generally: in-medium hadronization is just another layer of interaction with the medium
  - Energy and momentum exchange with the medium.
  - In principle interaction continues in the hadronic phase!

- Hadrons: hadronization will only affect small and intermediate momentum hadrons.
  - Chemistry effects: should be measurable; expect increased baryon/meson ratio
  - Momentum diffusion/broadening: size of the effect needs to be studied in simulations, maybe hard to distinguish from other sources of diffusion/broadening.

How will Hadronization Matter?

- Inclusive jets: hadronization effects suppressed by design.
  - No access to chemistry
  - Diffusion/broadening can contribute to in-cone/out-of-cone effects.
- Jet-hadron correlations/fragmentation functions: most promising to see hadronization effects.
  - Both hadrochemistry and momentum redistribution.
- None of this has been investigated on the MC level.
- JET MCs should be able to do that within a year.