Standard model of HIC needs to be extended to finite baryon densities. In this work we

- Present a new LEXUS based initial state model
- Use a new crossover equation of state
- Calculate departure functions using a quasiparticle model at finite baryon densities
- Use these new developments to do a baseline calculation for observables at RHIC BES energies
LEXUS Based Initial State Model

- LEXUS linearly extrapolates nucleon-nucleon collision data to nucleus-nucleus collision \[\text{Jeon and Kapusta (1997)}\]
- Nucleons are sampled from WS distribution, Lorentz contracted and do binary collisions
- Probability of momentum loss in a binary collision is
  \[P(y_{\text{loss}}) = \frac{\cosh(2y_0 - y_{\text{loss}})}{\sinh(2y_0) - \sinh(y_0)}\]
- Overall normalization is fixed
Hydrodynamics with Crossover Equation of State

- Matching of equation of state between QGP and HRG is done using a switching function

\[ P(t, \mu) = S(T, \mu) P_{QGP}(T, \mu) + [1 - S(T, \mu)] P_{HRG}(T, \mu) \]

- No critical point in this calculation

- MUSIC was dynamically initialized using the energy-momentum and baryon density deposition from our initial state

\[ \partial_{\nu} T^{\mu\nu} = T^{\mu} \]

\[ \partial_{\mu} J^{\mu} = J \]

Albright, Kapusta and Young (2015)

Schenke, Jeon and Gale (2010), Denicol, Gale, Jeon, Monnai, Shen and Schenke (2018)
Departure Functions

- Departure functions account for non-equilibrium corrections at freezeout
  \[ f_a = f_a^{eq} (1 + \phi_a) \]
  \[ \phi_a = -A_a \partial_\rho u^\rho - B_a \rho_a^\rho D_\nu \left( \frac{\mu_B}{T} \right) + C_a \rho_a^\mu \rho_a^\nu \left( D_\mu u_\nu + D_\nu u_\mu + \frac{2}{3} \Delta_{\mu\nu} \partial_\rho u^\rho \right) \]

- Worked in the relaxation time approximation with \( \tau_a(E_a) = \tau'E_a \)

- For shear correction, we get \( C_a = \frac{\eta}{2T^2w} \) where \( \tau' = \frac{\eta}{2T^2w} \)

- We can calculate the thermal conductivity and associated departure function
  \[ \lambda = \tau' T^2 \left[ \left( \frac{s}{n_B} \right)^2 \chi_{\mu\mu} - 2 \left( \frac{s}{n_B} \right) \chi_{T\mu} + \chi_{TT} \right] \]
  \[ B_a = \tau' \left( b_a - \frac{n_B}{w} E_a \right) - b(T, \mu_B) \]

\[ b = \frac{\tau'T}{w^2} \left[ Ts(T\chi_{T\mu} + \mu_B \chi_{\mu\mu}) - Tn_B(T\chi_{TT} + \mu_B \chi_{T\mu}) - n_Bw \right] \]

where we have susceptibilities

\[ \chi_{xy} = \frac{\partial^2 P(T, \mu)}{\partial x \partial y} \]

Albright and Kapusta (2016)
Chakraborty and Kapusta (2017)
Results

- Better agreement with data for pion than for proton. No initial flow, hadronic afterburner or bulk viscosity.
- Neutron to proton conversion will also enhance proton yield.
- Better agreement with data for lower energy than higher energies (not shown here).
Results

- A new baseline calculation for RHIC-BES energies using a LEXUS based initial state, a crossover EOS without critical point and departure functions at finite baryon densities
- **Next step:** Include critical point and a first order phase transition

<table>
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<tr>
<th>Energy</th>
<th>7.7 GeV</th>
<th>11.5 GeV</th>
<th>14.5 GeV</th>
<th>62.4 GeV</th>
<th>200 GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>η/s</td>
<td>0.14</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
</tr>
</tbody>
</table>

- Pion v2 is shown here
- Larger value of η/s was needed for 7.7 GeV collisions
- Inclusion of pre-hydro flow may require a larger η/s

See Joe Kapusta's talk, Session T03, Tue 10:10