COLLECTIVE FLOW AT SIS ENERGIES WITH A HADRONIC TRANSPORT APPROACH: INFLUENCE OF LIGHT NUCLEI FORMATION AND EQUATION OF STATE


**Directed Flow**

- Observe best agreement with data using hard EoS
- Results are very sensitive to treatment of light Nuclei
- Directed flow well reproduced overall

**Elliptic Flow**

- Elliptic flow signal in general underestimated
- Hard EoS still works best
- Need improved potentials and centrality selection
SMASH

- Effective solution of the relativistic Boltzmann equation
- Hadron degrees of freedom including resonances from Particle Data Group
- Collisions between hadrons according to geometric collision criterion $d_{\text{trans}} < \sqrt{\sigma/\pi}$
- Publicly available at smash-transport.github.io
POTENTIALS AND EQUATIONS OF MOTION

• Simple Skyrme and symmetry potentials, so far, without momentum dependence

• Different equations of state defined by parameter set

\[ U_{Sk} = A \left( \frac{\rho_B}{\rho_0} \right) + B \left( \frac{\rho_B}{\rho_0} \right)^\tau \]

\[ U_{Sym} = \pm 2S_{pot} \frac{\rho_I^3}{\rho_0} \]

<table>
<thead>
<tr>
<th></th>
<th>Soft</th>
<th>Default</th>
<th>Hard</th>
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</thead>
<tbody>
<tr>
<td>( A )</td>
<td>-356 MeV</td>
<td>-209.2 MeV</td>
<td>-124 MeV</td>
</tr>
<tr>
<td>( B )</td>
<td>303 MeV</td>
<td>156.4 MeV</td>
<td>71 MeV</td>
</tr>
<tr>
<td>( \tau )</td>
<td>1.17</td>
<td>1.35</td>
<td>2.0</td>
</tr>
<tr>
<td>( K )</td>
<td>200 MeV</td>
<td>240 MeV</td>
<td>375 MeV</td>
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**LIGHT NUCLEI FORMATION**

### Clustering

- Perform calculation without deuterons and identify light nuclei afterwards
- For each pair of nucleons
  - Look at the distance and momentum difference in their center of mass frame at the time of the latest collision of the two
  - Consider particles as clustered if \( \Delta r < r_0 \) and \( \Delta p < p_0 \)


### Dynamic deuterons

- Deuteron represented as a single particle
- Produced in 3 \( \leftrightarrow \) 2 reactions \( pnN \leftrightarrow dN \) and \( pn\pi \leftrightarrow d\pi \)
- Reactions modelled in two steps via “fake” dibaryon resonance \( pn \leftrightarrow d' \) and \( Nd' \leftrightarrow Nd \)
- Deuterons contribute to densities with baryon number 2 and are affected by potentials


Justin Mohs, Frankfurt University
DEUTERON FLOW

- Flow calculated with deuterons as active degree of freedom
- Reasonable agreement with the data for directed flow with hard EOS
- Elliptic flow would require a softer EoS

Deuterons, Au+Au @ 1.23A GeV 20-30% centrality

Justin Mohs, Frankfurt University