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

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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

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

\[
U_{Sk} = A \left( \frac{\rho_B}{\rho_0} \right) + B \left( \frac{\rho_B}{\rho_0} \right)^\tau \\
U_{Sym} = \pm 2S_{pot} \frac{\rho_{I_3}}{\rho_0}
\]

|     | Soft    | Default | Hard    |
|-----|---------|---------|---------|
| \(A\) | -356 MeV | -209.2 MeV | -124 MeV |
| \(B\) | 303 MeV  | 156.4 MeV  | 71 MeV   |
| \(\tau\) | 1.17    | 1.35    | 2.0     |
| \(K\)  | 200 MeV  | 240 MeV  | 375 MeV |
**LIGHT NUCLEI FORMATION**

- **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

- **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 $\Delta p < p_0$

Zhu et al. Phys.Rev.C 92 (2015), Sombun et al. Phys.Rev.C 99 (2019)

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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