Fragments and Antifragments in STAR

Fragments are more sensitive to flow than particles.

effects due to baryonic mean fields?

Relationships between net baryon density and \( \frac{d}{d} \).

Rich information on nucleon sources at freeze-out (FO) via coalescence analyses.

At RHIC:

- \( T \gg B_1 \)
- meson dominated, and
  - net baryon-poor systems
  - non-spherical FO geometries?

- shape of nucleon FO surface  
  complementary to interferometry
- comparison of nucleon and antinucleon FO volumes
- isotopic resolution & \( P_T \)
  dependence \( \rightarrow \) Temperatures, times  
  complementary to spectra and interferometry
- effects on fragment rates from plasma formation?
  \( QGP \rightarrow FO \) later \( \rightarrow \) FO volume larger \( \rightarrow \) fewer d’s?
  what happens to \( d/\bar{d} \) ?!
- FO volumes for pions via scaling vs. \( dN_{chgd}/dy \) or \( dN_{\pi}/dy \)
- with “matched” models \( \rightarrow \) \( v_T \) profiles, \( \rho \) profiles, ...

Do present models imply measurable (anti-)fragment production in central Au+Au at RHIC?

How well can STAR measure (anti-)fragments?
Coalescence: **Empirical, Thermodynamic, Density Matrix, Wigner, Dynamic**

For extraction of source information from *measured* nucleon and fragment distributions, only last two approaches apply at RHIC.

**Wigner approach:**
Mattiello *et al.*, PRL 74, 2180 (1995)

**Dynamic approach:**
Kahana *et al.*, PRC 54, 338 (1996)

For *predicting* fragment production rates in the absence of data, only avenue is “dynamic coalescence”.

**Dynamic Coalescence:**
- don’t approximate phase space density; take it from a model.
- stop the model at time step for which: \( \text{MAX}(E_{ij}^{\text{strong}}) < 2 \text{ MeV} \)
- for each particle in the event, the model gives time, position, and momenta at last strong interaction for each particle.

for every n-p pair per event (or \( \bar{n}-\bar{p} \) pair...)
propagate to common time
calculate \( \Delta X \) and \( \Delta P \) in the 2 particle CM
if \( \text{RAN}() < \text{Prob}(\Delta X, \Delta P) \) → formed a d
→ save composite time, position, momentum
→ remove this p and n from the event.

**Cut-off**
\( \text{Prob}(\Delta X, \Delta P) : \text{Harmonic Oscillator} \)
\( \text{Hulthen Wave Function} \)
Deuterons

→ **0.1 deuterons** per central event per unit rapidity at mid-rapidity

→ **STAR collects >26k deuterons per RHIC day**…
Anti-Deuterons

ANTI DEUTERONS, Au+Au, 100 GeV/N/beam, b<2 fm, RQMD 2.4, wigner coalescence

→ \sim 0.02 \textbf{antideuterons} per central event per unit rapidity at mid-rapidity

→ d/\bar{d} \sim 5 at mid-rapidity…
Nucleon Freeze-out Radii via coalescence arguments

\[
5 \left( R^2 + \frac{\rho_c^2}{2} \right)^{3/2} = \pi^{3/2} \frac{(2S_c + 1)}{(2S_a + 1)(2S_b + 1)} (d^3N_a/d^3p_a)(d^3N_b/d^3p_b)(d^3N_c/d^3p_c) e^{(B_c - B_a - B_b)/T}
\]

where

\((d^3N/d^3p)\) is an invariant cross section (e.g. \(d^2N/2\pi/m_T/\Delta m_T/\Delta y\) or \(d^2N/m/\beta^2/\Delta\beta/\Delta\Omega\))

The cross-sections are evaluated at the same velocity...

Spins are \(S_a, S_b,\) and \(S_c\)  
Binding energies are \(B_a, B_b,\) and \(B_c\)

Temperature is \(T\),  
Fragment finite size correction is \(\rho \rightarrow\) Gaussian radius \(R\) in fm...

\[\text{deuterons, } |y|<0.2\]
\[d_{rqmd24_b1mine_265ev.hst}\]

\[\begin{array}{c|c|c|c}
\text{R (fm)} & \text{Cutoff} & \text{Harmonic} & \text{Hulthen} \\
\hline
\text{Actual} & & & \\
\text{FCM} & & & \\
\end{array}\]

\[\text{antideuterons, } |y|<0.2\]
\[d_{bar_rqmd24_b1mine_265ev.hst}\]

\[\begin{array}{c|c|c|c}
\text{R (fm)} & \text{Cutoff} & \text{Harmonic} & \text{Hulthen} \\
\hline
\text{Actual} & & & \\
\text{FCM} & & & \\
\end{array}\]

Triton prediction using coalescence arguments

\[ n + d \leftrightarrow t \]

\[ R_G^3 \propto \frac{N_n N_d}{N_t} \]

\( N_n \) from RQMD

\( N_d \) from dynamic coalescence

Assume \( R_G \)

*Calculate \( N_t \)*

A \( p + d \leftrightarrow ^3\text{He} \) prediction is also possible in the same way…

\[ \frac{p}{d} \sim 370 \]

\[ \frac{d}{t} > 1150 \]

\[ \frac{p}{d} \sim 370 \]

\[ \frac{d}{t} > 1150 \]

\[ \frac{d}{d} \sim 5 \]

\[ \frac{t}{t} \sim 11 \]

(Au+Au, 100 GeV/N/beam, \( b < 2 \text{fm, RQMD} \))
Fragment measurements in STAR

Track $\langle dE/dx \rangle$ versus momentum from the TPC…

Dynamic range of $dE/dx$ ADCs introduces low-momentum cutoff…
- Normal runs – deuteron $P_T > \sim 0.4$ GeV/c don’t overflow
  - triton $P_T > \sim 0.56$ GeV/c
- Special runs – reduce gas gain and magnetic field…

Significant evaporation backgrounds in $x + \text{Be} \rightarrow \text{d} + X$
- $\sim 0.2$ d/central event (Preliminary) after some cuts…
- Presently studying “d.c.a.” and $P_T$ dependences…

Antideuteron sample necessarily purer…
Larger corrections/backgrounds for particle spectra and ratios
  than for antiparticle spectra and ratios…

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