CALCULATION OF COALESCEENCE
PARAMETERS IN MONTE CARLO MODELS

Tony Perez
University of Tennessee, Knoxville
RELATIVISTIC HEAVY-ION COLLISIONS

• Large Hadron Collider (LHC)
• Nuclear collisions at near light speed (~ 0.999c)
• Extreme energy densities and temperatures achieved
• Deconfinement of hadrons into parton “soup”
• Quark-Gluon Plasma ($T_C \sim 150$ MeV)
COALESCEENCE MODEL

- Light nuclei formed by nucleons nearby in phase-space
- Small binding energies of $^2\text{H}$, $^3\text{H}$, & $^3\text{He}$ ($< 9$ MeV)
  - Sensitive to
    1. Chemical freeze-out conditions
    2. Dynamics of emitting source
    3. Final-state effects
- Formed during final stage of nuclear collision
IMPLEMENTATION OF MONTE-CARLO SIMULATOR

pp Collision Simulator

Nuclei Formation via Coalescence

Model of Nuclei Production

PYTHIA → Afterburner

5
COALESCENCE MODEL PARAMETER $B_A$

Experimental measure of light nuclei formation probability:

$$ E_i \frac{d^3 N_i}{dp_i^3} = B_A \left( E_p \frac{d^3 N_p}{dp_p^3} \right)^A $$

- Number of formed nuclei
- Number of protons

- Deuteron:
  $$ B_2 \propto \frac{N_d}{N_p^2} $$
  $$ E_d \frac{d^3 N_d}{dp_d^3} = B_2 \left( E_p \frac{d^3 N_p}{dp_p^3} \right)^2 $$

- Triton & He-3:
  $$ E_t \frac{d^3 N_t}{dp_t^3} = B_3 \left( E_p \frac{d^3 N_p}{dp_p^3} \right)^3 $$

$E$: energy, $A$: mass number, $p$: momentum

Source: Phys. Rev. C 93, 024917
For an $M$-nucleon cluster with $Z$ protons in a system of $A$ nucleons

\[
\frac{dN_M}{d^3K} = G(A)(M)Z \frac{1}{A^M} \int \left[ \prod_{i=1}^{Z} f_p(r_i, k_i) \right] \times \left[ \prod_{i=Z+1}^{M} f_n(r_i, k_i) \right] \rho^W(r_{i1}, k_{i1} \ldots r_{iM-1}, k_{iM-1}) \times \delta(K - (k_1 + \ldots + k_M))dr_1dk_1 \ldots dr_Mdk_M
\]

Permutations of combinations of protons & neutrons

Probability of finding proton/neutron within nucleus

Probability of forming a deuteron/triton/He-3 nucleus

Experimental $B_2$ in pp collisions

Source: Production of deuterons, anti-deuterons, anti-triton and anti-$^3$He nuclei in pp collisions $\sqrt{s} = 900$ GeV, 2.76 TeV, and 7 TeV
MODELED $B_3$ PLOT IN $pp$ COLLISIONS

Triton $B_3$ vs. Transverse Momentum

<table>
<thead>
<tr>
<th>$B_3$ Triton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>RMS</td>
</tr>
</tbody>
</table>

Source: Phys. Rev. C 93, 024917
$B_2$ IN Pb-Pb COLLISIONS

**Experimental Deuteron Yield**

**Simulated Deuteron Yield**

Source: Phys. Rev. C 93, 024917
WORKING GROUP

Dr. Christine Nattrass
Dr. Natasha Sharma
Tony Perez
Andy Castro