Light Nucleus Production in p+p & d+Au

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Existing Results on $B_2$

$$B_A = \frac{\sigma_A}{[\sigma_N]^A}$$

where the cross-sections are evaluated at same momentum

$$B_A = \frac{d}{p^2}$$

where cross-sections are formed at same $P_T/A$ & $\gamma=0$, $\Delta y=1.0$

deuterons relative to protons is largest in “elementary collisions”...

- factor of $\sim 40$ larger than in A+A according to the trend (blue squares)
- essentially independent of $\sqrt{s_{NN}}$ ... also unlike A+A

where’s the RHIC results?
where does the RHIC data fall?

...we have p+p @ 62, 200, & 500 GeV & d+Au @ 200 GeV

Conventional Wisdom:
- p+p: several strings stretched between 2 hadrons → $B_2 \sim 0.02$
- γ+p: fewer strings → $B_2 \sim 0.01$
- e+e: only one string → $B_2 \sim 0.003$
- A+A: lots of strings, but strong rescattering kills all d’s except those that form very late → $B_2 \sim 0.0003$


Fig. 3a, b. a Possible string breakup process with a $pn$ pair. b Space-time structure of the breakup
Coalescence Afterburner + pure Pythia events.....

define $\Delta p$ - the relative momentum cutoff for p+n pair forming a deuteron ($k = \Delta p/2$)

$\Delta p \sim 120$-$140$ MeV implied by earliest Bevalac A+A results...
(somewhat larger value required to match existing p+p data - see previous pages)

Factor $\sim 10$ differences in $d/p^2$ depending on Pythia subprocess......
Jets and deuteron production....
use Pythia’s PYCELL (simple seeded cone) to find jets....

B2 values hugely increased in Jets... (and also increase with the jet energy?)
Significant spallation backgrounds are well-known.

from ~1999

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

High production rate (relative to p) and low track densities
→ elementary collisions as a test-bed to optimize cuts & background calculations?
Goals:
• learn how to use MuDsts & offline software...
• investigate DCA-type cuts to suppress spallation backgrounds
  track densities are relatively low...
  primary vertex not as precisely defined...
• extract cross-sections and coalescence parameters for d and t production & compare to:
  trends implied by the existing lower-energy data....
  UrQMD or Pythia calculations with coalescence afterburner...
• Include direct Jet-finding & investigate fragment production mechanisms...

Data:

<table>
<thead>
<tr>
<th>Run</th>
<th>Type</th>
<th>$\sqrt{s_{NN}}$ (GeV)</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run-6</td>
<td>p+p</td>
<td>62</td>
<td>4.8 M</td>
</tr>
<tr>
<td>Run-8</td>
<td>p+p</td>
<td>200</td>
<td>36.1 M</td>
</tr>
<tr>
<td>Run-8</td>
<td>d+Au</td>
<td>200</td>
<td>75.8 M</td>
</tr>
</tbody>
</table>

Cuts:
Require that a Primary Vertex was found...
Nfitpts > 15, Nfitpts/Nhitsposs > 0.52, DCAglobal < 1.0cm
Presently, use only TPC dE/dx for PID....

A.S.A.P....
Include PID from the significant TOF coverage in the Run-9 data....
Produce plots for the new $\sqrt{s_{NN}} = 500$ GeV data....
d/d\text{bar} is huge... (spallation in \text{★})

Significant d\text{bar} signal in our p+p and d+Au data.....

Some t\text{bars} and He-3's too...
(hard to see here though)
At present, simply do the PID by “Splitting the differences” of the dE/dx curves....

Momentum cut-offs used:
\[ p \rightarrow 1.0 \text{ GeV} \]
\[ d \rightarrow 1.5 \text{ GeV} \]
\[ t \rightarrow 2.0 \text{ GeV} \]

...fairly crude at the moment
& can be improved
& TOF will help a lot too
Working towards Statistical PID....
reference = pbar

data set=2, ipart=1, ichg=1, all eta
reference = tbar

dataset=2, ipart=3, ichg=1, all eta
Our $d\bar{b}$ B2 is close to that in the lower-energy $p+p$ data: $B_2 \sim 0.02$
Run-8 $d+Au$ 200 GeV

$B_2 \sim 0.01$
Comparison to Pythia -- $p+p$ 62 GeV

$B_2$ vs $P_T/A$ (GeV)

$p+p \sqrt{s_{NN}}=62$ Run-6

$\Delta p=400\text{MeV}$

$\Delta p=100\text{MeV}$

$B_3$ vs $P_T/A$ (GeV)

dbar implies $\Delta p \sim 350 \text{ MeV}$ for $p+p$, 62 GeV
Comparison to Pythia -- p+p 200 GeV

dbar B2 implies $\Delta p \sim 200$ MeV for p+p, 200 GeV
Comparison to UrQMD -- d+Au 200 GeV

dbar B2 implies $\Delta p \sim 200$ MeV for d+Au, 200 GeV
Lots of other DCA plots made - could not find a “magic cut” that brought d/d|b| near ~1......

options:  1. concentrate on dbar and tbar, and give up on d and t....
          2. “standard” P|T|>1 GeV cut...      ...only productive for Run-9 data including TOF PID?
          3. PHENIX simulation method & subtract spallation background.

Light nuclei & Jets  

Plot proton & deuteron cross-sections and B2 values separately for
• events in which no Jet was found...
• tracks not associated with a Jet...
• tracks associated with a Jet...

```cpp
StppAnaPars* anapars = new StppAnaPars();
anapars->setFlagMin(0); // track->flag() > 0
anapars->setNhits(12); // track->nHitsFit()>12
anapars->setCutPtMin(0.2); // track->pt() > 0.2
anapars->setAbsEtaMax(2.0); // abs(track->eta())<2.0
anapars->setJetPtMin(3.5);
anapars->setJetEtaMax(100.0);
anapars->setJetEtaMin(0);
anapars->setJetNmin(0);
//
//---- Setup the cone finder for measured particles
StConePars* cpars = new StConePars();
cpars->setGridSpacing(105, -3.0, 3.0, 120, -pi, pi);
cpars->setConeRadius(0.7);
cpars->setSeedEtMin(0.5);
cpars->setAssocEtMin(0.1);
cpars->setSplitFraction(0.5);
cpars->setPerformMinimization(true);
cpars->setAddMidpoints(true);
cpars->setRequireStableMidpoints(true);
cpars->setDoSplitMerge(true);
cpars->setDebug(false);
```
Some Raw Counts.....

<table>
<thead>
<tr>
<th></th>
<th>p+p 62 GeV Run-6</th>
<th>d+Au 200 GeV Run-8</th>
<th>p+p 200 GeV Run-8</th>
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<tbody>
<tr>
<td>Nev all</td>
<td>4.75121e+06</td>
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<td>3.61101e+07</td>
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<tr>
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<td>2.16753e+07</td>
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<tr>
<td>Nev J1</td>
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<td>8.63504e+06</td>
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<tr>
<td>Nev J2</td>
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<td>1.10162e+07</td>
<td>4.30746e+06</td>
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<tr>
<td>Nev J E6 MR</td>
<td>302</td>
<td>393</td>
<td>244</td>
</tr>
</tbody>
</table>
Cross-sections -- p+p, 200 GeV

NJ, J1ue, J2ue are very similar. J1as & J2as are different!

Particle and antiparticle cross-sections “meet” above $P_T \sim 1$ GeV

Pbar & dbar cross-sections considerably harder for in-jet compared to not in-jet
B2 & B3 -- p+p, 200 GeV

no jets not associated associated

d NJ DCA cut d J1ue DCA cut d J2ue DCA cut d J1as DCA cut d J2as DCA cut

t NJ DCA cut t J1ue DCA cut t J2ue DCA cut t J1as DCA cut t J2as DCA cut

B2 & B3 significantly larger for particles associated with Jets
antiparticle B2 and B3 essentially flat for increasing $P_T/A$
B2 for jet-associated particles gated on Jet Energy -- p+p 200 GeV

Here - “All Jets” and d/p² formed for y=0 & Δy=1.0

B2 increases with jet-energy (also suggested by Pythia)
B2 for jet-associated particles gated on Jet Energy -- d+Au 200 GeV
Here - “All Jets” and d/p^2 formed for y=0 & Δy=1.0
Summary

simple first attempt at light nucleus analysis for p+p and d+Au data (Runs 6 & 8)

looking forward to analyzing the Run-9 data

• significant TOF coverage
• 500 GeV data

Preliminary results:

• Significant dbar signal in the p+p and d+Au data, some tbars too.

  evt-avg dbar B2 in 200 GeV p+p  = ~0.02.... (consistent with lower energy p+p data)
  evt-avg dbar B2 in 200 GeV d+Au  = ~0.01....

• Need corrections, but results consistent with Models & Δp~200 MeV so far (reasonable)

• σ for pbar and dbar in No Jet events similar to that in Jet events but not associated w/ a Jet

• σ for pbar and dbar associated with a Jet are different (and harder with P_T)

• Significant increase in B2 for jet-associated particles compared to “UE” particles
  suggested by pythia

To-Do List

• Respin MuDsts (include more vtx information and retry investigation of spallation BGs)
• continue to contribute to TOF calibrations & get onto Run-9 data w/ TOF PID A.S.A.P....
• better simulations (use gstar and “real” jetfinders on simulated events)...
• + your suggestions!

Thanks in advance for your comments...