Antiproton Production and Re-absorption in p+A Collisions at the AGS

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Overview

- E910 Experiment
- Centrality in p+A Collisions
- Antiproton Production
  - Beam energy
  - Target Size
  - Centrality
- Re-absorption Cross Section
- Comparison with Antilambda
- What have we learned?
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E910 Spectrometer at the MPS Facility of the AGS

- MPS Magnet
- EOS TPC
- Downstream tracking:
  - MPS Drift Chambers, Wire Chambers
- PID:
  - TPC dE/dx, TOF, Segmented Cherenkov
- Spring 96 Proton Run at AGS
- Be, Cu, Au, U targets
- 6, 12.5, 18 GeV/c Beam Momenta
- O(15) Million Central and MinBias Triggers
MPS Magnet
TOF Wall
TOF Wall
Centrality in E910

- Centrality is defined in terms of the number of projectile collisions $\nu$
- $\nu$ is determined from the number of grey tracks $N_g$
- $N_g$ is defined as the number of slow protons and deuterons

- $\nu = \langle \nu \rangle (N_g)$
Relate $N_\pi$ to $v$

- $0.5 < p < 2.4 \text{ GeV/c}$
- slow neutrons
- $0.25 < p < 1.2 \text{ GeV/c}$
- slow protons

Grey Tracks:

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Grey Tracks
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Grey Tracks

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Grey Tracks

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Physics Goals

- Characterize the centrality of an event by the number projectile collisions

- Antiproton re-absorption
  - system size
  - collision geometry
Antiprotons

Targets: Au, Cu, Be
Beam momenta: 12.3 and 17.5 GeV/c
Measure of $\nu$

To address:
- Production Mechanism
- Re-absorption in the Nucleus
Identification of Antiprotons

PID with TOF

~ 4 million interactions of 17.5 GeV/c p+Au
Antiproton Acceptance

- Acceptance with momentum reconstruction
- Results shown in $y$-$p_T$ coverage shown by solid lines
- Antilambda feeddown estimated $\leq 5\%$
Measured Yields $p+Au$

Comparison at Different Beam Momenta

$p_T < 800$ MeV/c  
$y = [1.0, 2.0]$
Measured Yields 12.3 GeV/c
Comparison of Different Targets

\[ x \times 10^{-3} \]

\[ \frac{dn}{dy} \]

\[ \frac{1}{2m_T} \frac{dn}{dm_T} \]

- \( p + Be \)
- \( p + Cu \)
- \( p + Au \)

\[ p_T < 800 \text{ MeV/c} \]
\[ y = [1.0, 2.0] \]
Inverse Slopes of $m_T$ Distributions

$$\frac{1}{2\pi m_T} \frac{dn}{dm_T} = C_0 e^{-\frac{(m_T - m_0)}{T}}$$

<table>
<thead>
<tr>
<th>Energy (GeV/c)</th>
<th>Target</th>
<th>Slope ($1/\mu$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>p+Au</td>
<td>157 ± 34</td>
</tr>
<tr>
<td>12</td>
<td>p+Au</td>
<td>106 ± 62</td>
</tr>
<tr>
<td>12</td>
<td>p+Cu</td>
<td>108 ± 47</td>
</tr>
<tr>
<td>12</td>
<td>p+Be</td>
<td>86 ± 19</td>
</tr>
</tbody>
</table>
Integrated $dn/dy$ over $y=[1.0, 2.0]$ ($p_T<800$ MeV/c)

- 17.5 GeV/c  p+Au
  $4.61 \pm 0.34 \times 10^{-4}$
- 12.3 GeV/c  p+Au
  $1.39 \pm 0.36 \times 10^{-4}$
- 12.3 GeV/c  p+Cu
  $2.03 \pm 0.37 \times 10^{-4}$
- 12.3 GeV/c  p+Be
  $2.22 \pm 0.42 \times 10^{-4}$

- Increasing yield with beam momentum
- Decreasing yield with target size
Dependence of Yields on Available Kinetic Energy Squared

- Antiproton Yields in p+p data found to increase with 
  \[(KE)^2 = (\sqrt{s} - 4m_p)^2\]  
  (P. Stankus, thesis, 1993.)

- Indicating 3-body final state (instead of 4-body from \((KE)^{3.5}\) dependence)
Comparison with other Experiments

Compare with E802

- Agreement within errors
- Different conclusion
Mean Antiproton Multiplicity as a Function of $\nu$

Assumptions:

- **First collision model**
  
  Dominant antiproton production is in first $p+N$ collision

- **Produced antiprotons follow path of projectile, thus re-absorption depends on $\nu$**

  $\nu$ is a measure of number of mean-free paths antiproton must traverse in nuclear medium

\[
\sigma (p + A \rightarrow \bar{p}) = \sigma (p + p \rightarrow \bar{p}) e^{-\frac{\sigma_{abs}}{\sigma_{pN}} (\nu - 1)}
\]

\[
\frac{\nu - 1}{\sigma_{pN}} = \text{thickness of nucleus seen by antiproton}
\]
Mean Antiproton Multiplicity as a Function of $v$

- Fit to attenuation factor folded with $P_{N_g}(v)$:

$$\sum_v P_{N_g}(v) \sigma(p+p \rightarrow \bar{p}) e^{-C(v-1)}$$

$$C = \frac{\sigma_{abs}}{\sigma_{pN}} = 0.23 \pm 0.09$$

$$\sigma_{abs} = 6.9 \pm 2.7 \text{ mb}$$

(4.0 ± 1.6 mb) in the context of this model!

$\langle p_{lab} \rangle \approx 2.5 \text{ GeV/c}$
Mean Antilambda Multiplicity as a Function of $\nu$

\[ C = \frac{\sigma_{abs}}{\sigma_{pN}} = 0.23 \pm 0.09 \]

\[ \frac{\bar{p}}{\bar{\Lambda}} \]

\[ C = \frac{\sigma_{abs}}{\sigma_{pN}} = 0.22 \pm 0.04 \]
$\Lambda / p$ vs. $\nu$

- $p$ yields for 17.5 GeV/c $p+Au$ as a function of $\nu$

- $\Lambda$ yield for $p+p$

Gazdzicki et al, ZP C71, 55 (1996) extrapolated to $p_{\text{LAB}} = 17.5$ GeV/c

- $p$ yield at $\nu=1$ from E910 12.3 GeV/c $p+Be$ scaled to 17.5 GeV/c

PRELIMINARY
Conclusions

What have we learned about antiproton production and re-absorption?

- Antiproton yield increases with beam momentum
  - 17.5 GeV/c yields $\sim 3.3 \times 12.3$ GeV/c yields
  - Yields can be described with dependence on $\langle KE \rangle$
- Antiproton yield decreases with increasing target size
- Yield in p+Au data is $37 \pm 20\%$ less than p+Be data
Conclusions

- Shapes of $m_T$ distributions indicate effects of reabsorption:
  - Inverse slope smaller for Be than Au
- Yields decrease with increasing $\nu$
- "Effective" annihilation cross section fraction of free annihilation cross section
  - In medium, $\sigma^*_{anni} \sim 1/5 \sigma_{anni}$
- Absorption of $\Lambda$ very similar to $\bar{p}$