Pion production at High $P_T$

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Introduction

• High $P_T$ reactions probe transition region between meson-nucleon and quark-gluon degrees of freedom

• Signature of onset of perturbative regime: constituent counting rule is valid

\[ \frac{d\sigma}{dt} \propto s^{n-2} f(\theta_{CM}) \]

• Helicity conservation: small final state polarization

• High precision data exist from 6 GeV area CLAS and Hall A experiments explored the low energy limit

• Reactions: $\gamma p \rightarrow \pi^+ n$, $\gamma p \rightarrow \pi^0 p$, $(\gamma p \rightarrow \pi^- \Delta^{++})$, $\gamma n \rightarrow \pi^- p$ (requires D target)

• Explore the possibility of extending kinematic region using the GlueX detector
Existing Results

\[ \gamma n \rightarrow \pi^- p \]

\[ \gamma p \rightarrow \pi^+ n \]

\( \theta = 90^\circ \)

\( \theta = 70^\circ \)

\( \theta = 50^\circ \)

\( \sqrt{s} \) (GeV)

\( s \frac{d\sigma}{dt}(10^7 \text{GeV}^4 \text{nb/GeV}^2) \)

L.Y. Zhu et al. PRC 71 (2005) 044603
The upper panel is for the function of FIG. 2: (color online). Scaled di (missing momentum) from this experiment together with a the proton; (b): Reconstructed spectator proton momentum linear function. The arrow indicates the mass squared of the spectator proton fitted with a Gaussian plus.

FIG. 1: (color online). (a): Reconstructed missing mass squared of the spectator proton; and the suggested onset of the CCR scaling energy window of about 300 MeV above this enhancement structure discussed in the text. The prediction from a Regge approach \[32\] (black). Also shown are the results of the SAID FA08 fit has been greatly improved by the CLAS data \[30\]. The drastic fall-off does not give as good a description of the data near the resonance has now been firmly established by the results from this experiment. Also shown are the results of the SAID fit.

W. Chen et al. PRL 103 (2009)
\[ \gamma p \rightarrow \pi^0 p \]
\[ \theta_{CM} = 90^\circ \]


CLAS data: M. Dugger et al. PRC 76 (2007) 025211

O. Bartholomy et al. (CB-ELSA Collaboration) PRL 94 (2005) 012003
Extension in GlueX

• Cross section estimated using scaling and fit to data:

\[ \frac{d\sigma}{dt} = \frac{0.69 f_s}{(1 + \cos \theta_{CM})^4(1 - \cos \theta_{CM})^5} \cdot \left( \frac{s_0}{s} \right)^7 \]

From Zhu et al. PRC 71 (2005), 044603

• Fit to angular distributions of SLAC data
• Reproduces exp. data reasonably well

• Select typical photon rate of $10^7$ photons/s
• 30 cm LH2
• Overall Luminosity: $1.3 \times 10^{31}$
Kinematic coverage

\[
\sqrt{s} \text{ (GeV)} \quad E_{\gamma} \text{ GeV}
\]

\[ \theta_{CM} \quad 60^\circ \quad 70^\circ \quad 80^\circ \quad 90^\circ \]

GlueX
SLAC
JLAB
Large $P_T$ and large $|t|$
Cross Sections / Rates

$\theta_{CM}$

$60^\circ$

$70^\circ$

$80^\circ$

$90^\circ$

$d\sigma/dt n b/(GeV/c)^2$

$R h^{-1}$

$E_\gamma$ GeV

$E_\gamma$ GeV
Beam times for 1000 events

- Small cross sections
- Large amount of beam time needed
- Run parallel to existing and new program (especially on D)
- Polarization degree measurements at lower energies (and larger $\sigma$)
CHAPTER 3. THE GLUEX DETECTOR IN HALL D

The GlueX detector is a complex system designed to study mesons and photons. It consists of several key components:

- **Central Drift Chamber (CDC)**: Measures tracks with polar angles from about 1° to 25°.
- **Forward Drift Chambers (FDC)**: Measures tracks with polar angles from about 11° to 50°.
- **Solenoid** (390 cm long, inner radius 65 cm, outer radius 90 cm): A magnetic field to deflect charged particles.
- **Barrel Calorimeter (BCAL)**: Located inside the solenoid, it is made of scintillating fibers between sheets of lead.
- **Forward Calorimeter (FCAL)**: Located downstream of the time-of-flight wall.
- **Time-of-flight detector**: Records the time charged particles pass through it with about 80 ps accuracy.

The detector is used to measure and reconstruct tracks of charged particles, photons, and mesons. Here are some key features:

- **No forward particles**
- **Pairs of large P_T particles**
- **Special trigger needed**
- **BCAL start counter coincidence**

The diagram illustrates the layout and interactions within the GlueX detector, showing the path of particles and the various detection systems involved.
Summary

• GlueX/Hall D has the potential to significantly increase kinematic range of π production at high $P_T (> 1 \text{ GeV/c})$
• Small cross sections: optimize trigger (for large angles) and PID
• Background needs to be studied
• Hydrogen target data can be taken in parallel to meson spectroscopy program
• Deuteron target opens new possibilities
• High $P_T$ studies for other mesons interesting ($\rho$, $\omega$)
• Polarized photons: new possibilities