Exclusive Pion Photoproduction at 12 GeV.

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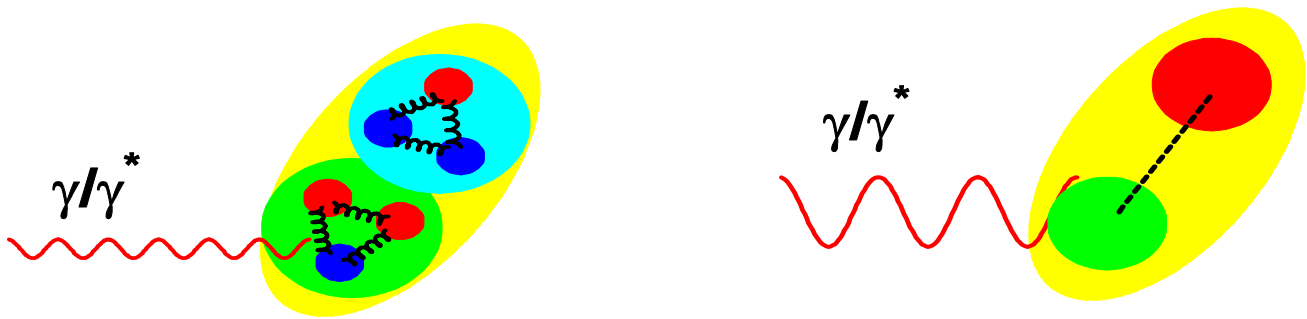
Introduction

Quantum Chromo Dynamics (QCD) with quark-gluon degrees of freedom is very successful at the high energy, perturbative regime.



Nucleon-meson degrees of freedom work better at lower energies.

What Is the Energy Threshold for the Transition?

Exclusive processes (processes with completely determined initial and final states), **are used to study the transition region.**

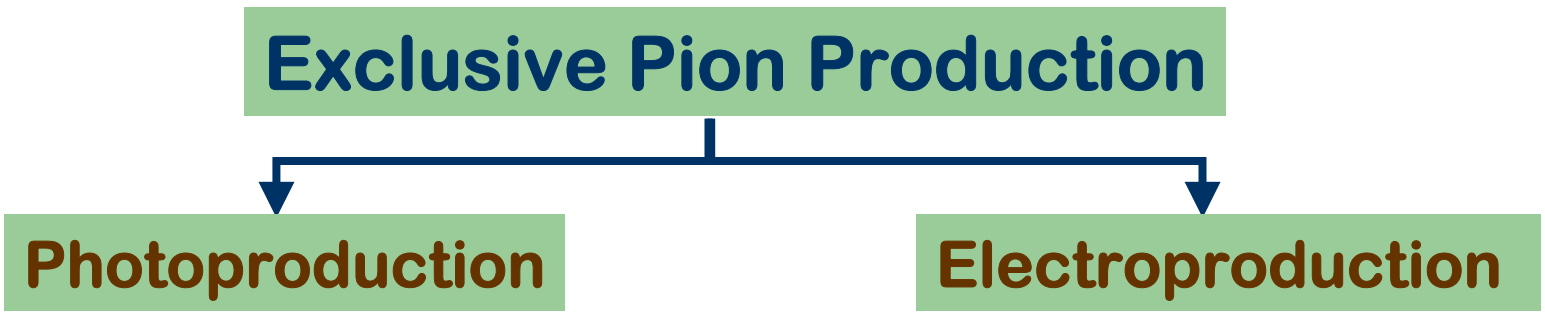
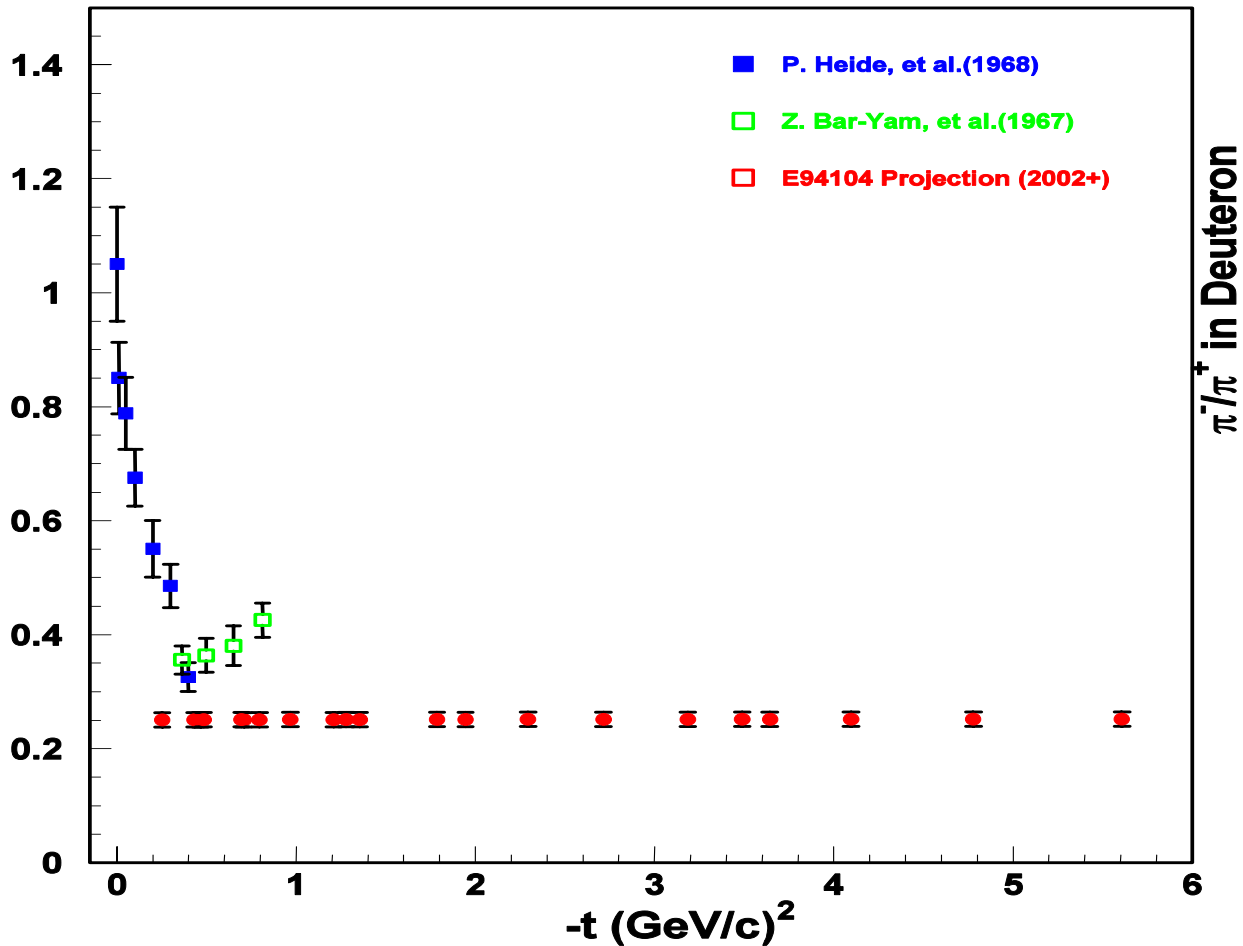


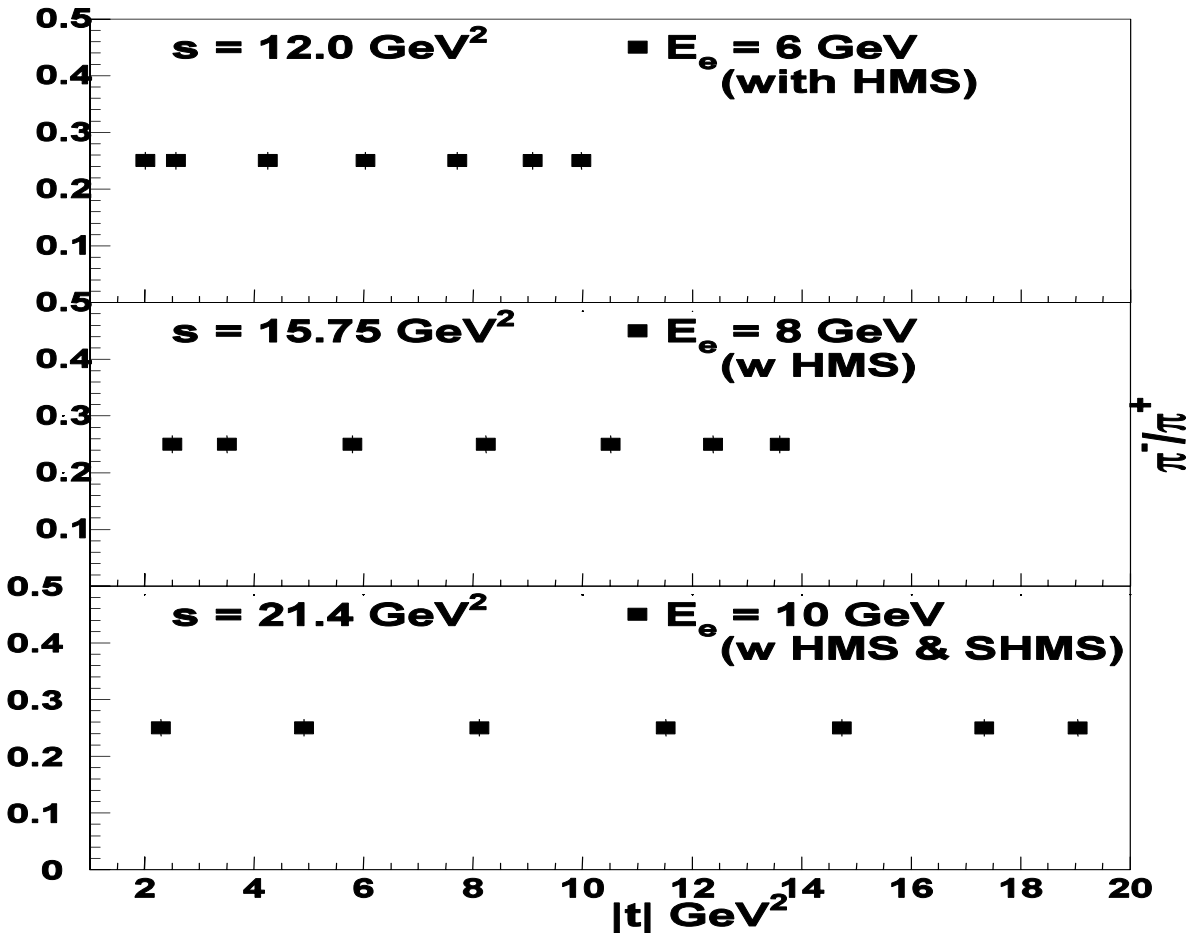
Photo vs Electroproduction

- **Pion Photoproduction**
  - Quark Counting Rule
  - Oscillatory Scaling
  - π^-/π^+ Ratio
  - Nuclear Filtering
- **Pion Electroproduction**
  - Color Transparency
  - GPDs

The π^-/π^+ Ratio



π^-/π^+ Ratio at 12 GeV



The Constituent Quark Counting Rule

Exclusive two body reactions (A+B →C+D) at large momentum transfers should scale as:

$$\frac{d\sigma}{dt} = f(\theta_{CM}) \frac{1}{s^{n-2}}$$

s = c.m. energy

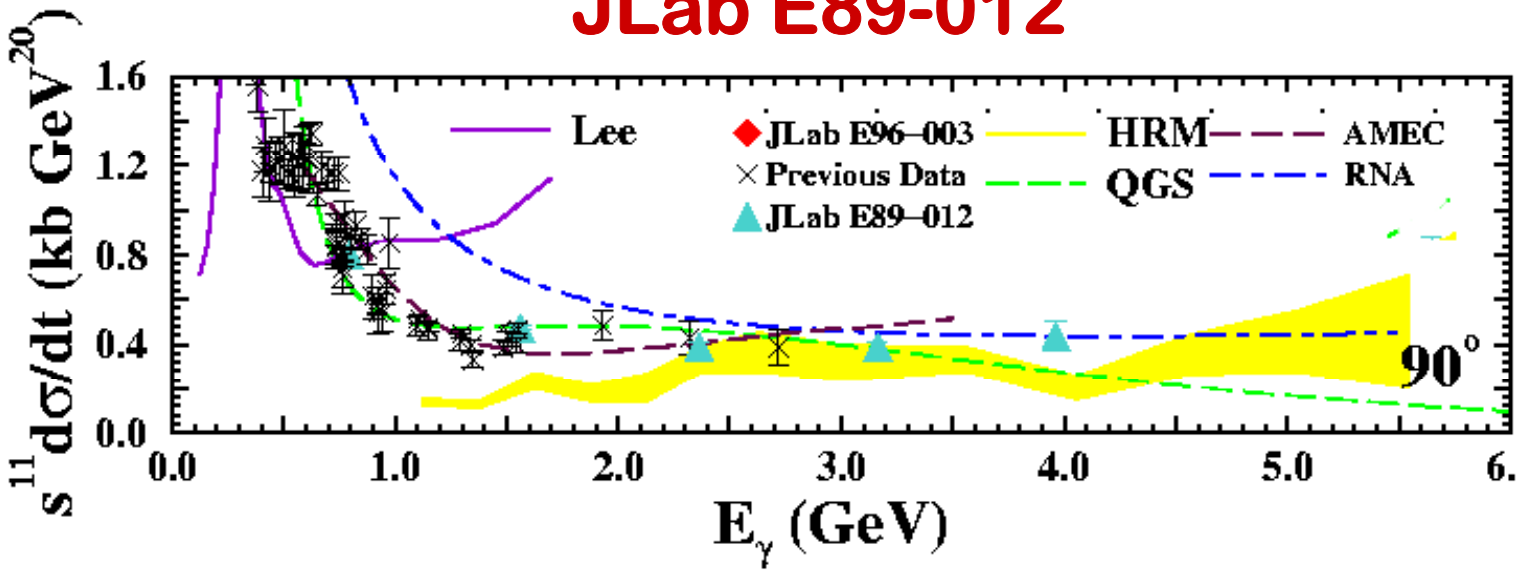
n = # of fields

- First derived based on dimensional analysis (Brodsky, Farrar,….)
- Confirmed within short distance pQCD framework (Brodsky, Le page)
- Many exclusive process seem to exhibit global quark counting rule behavior

Deuteron Photo-disintegration

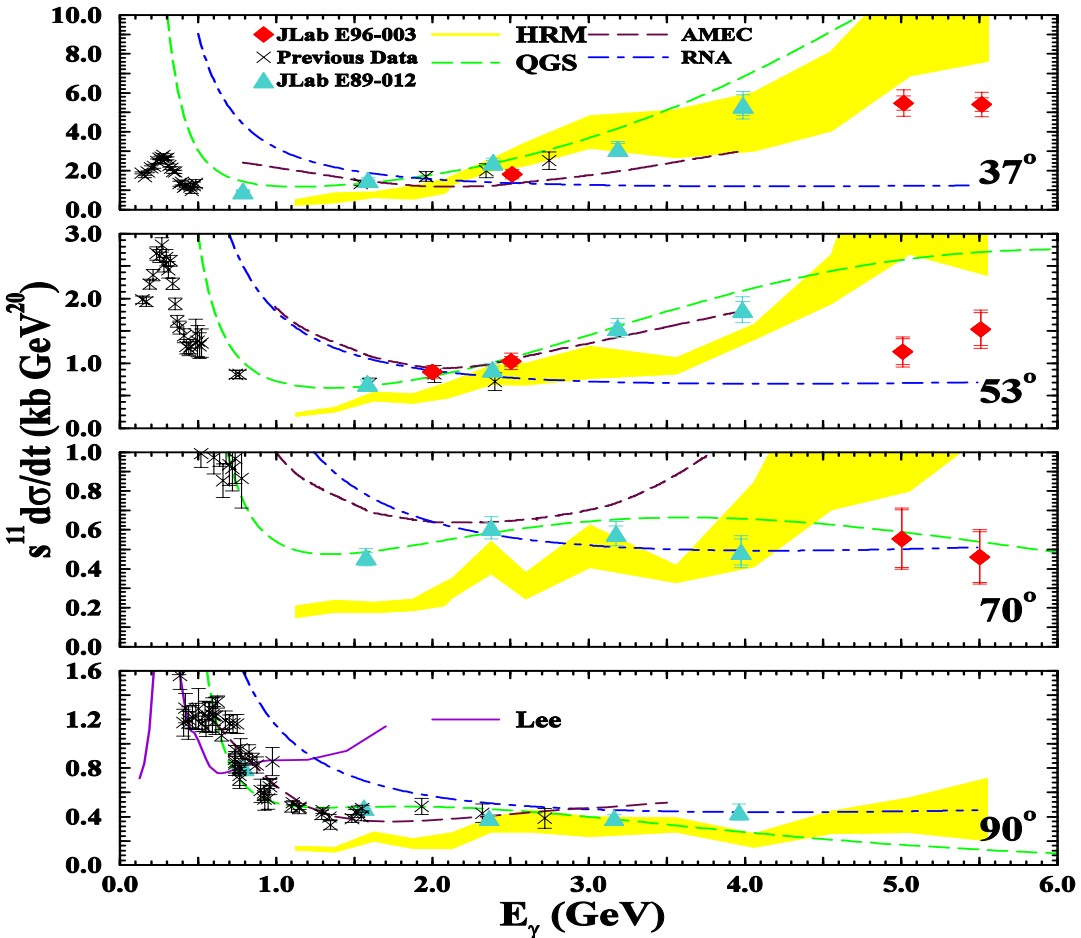
$\gamma + d \rightarrow p + n$ @ 90 deg CM angle

JLab E89-012



C. Bochna *et al.*, PRL **81,** 4576 (1998)

Angular Dependence of Scaling

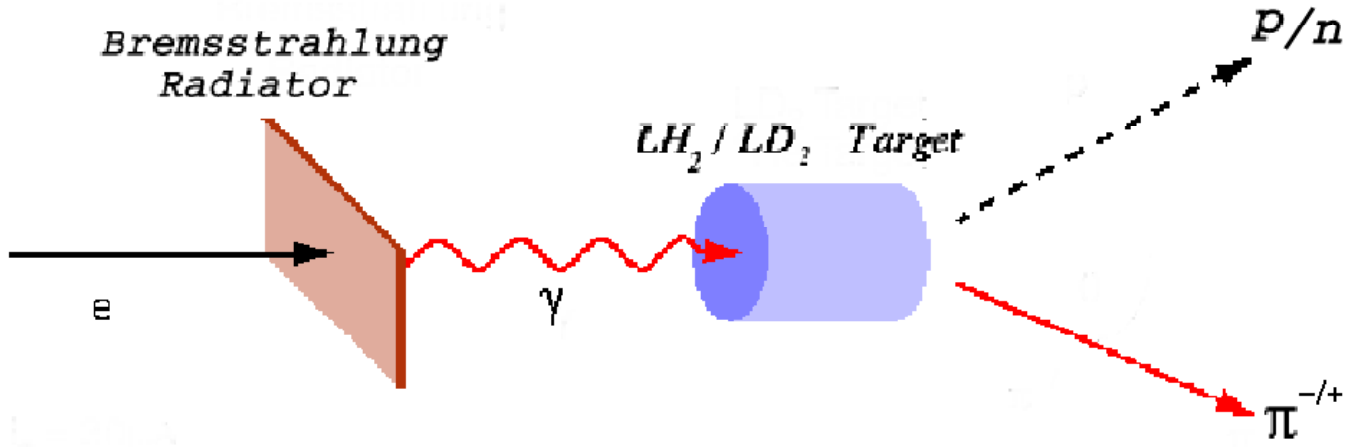


$\gamma + d \rightarrow p + n$

E. C. Schulte *et al.*, PRL 87, 102302, 2001.

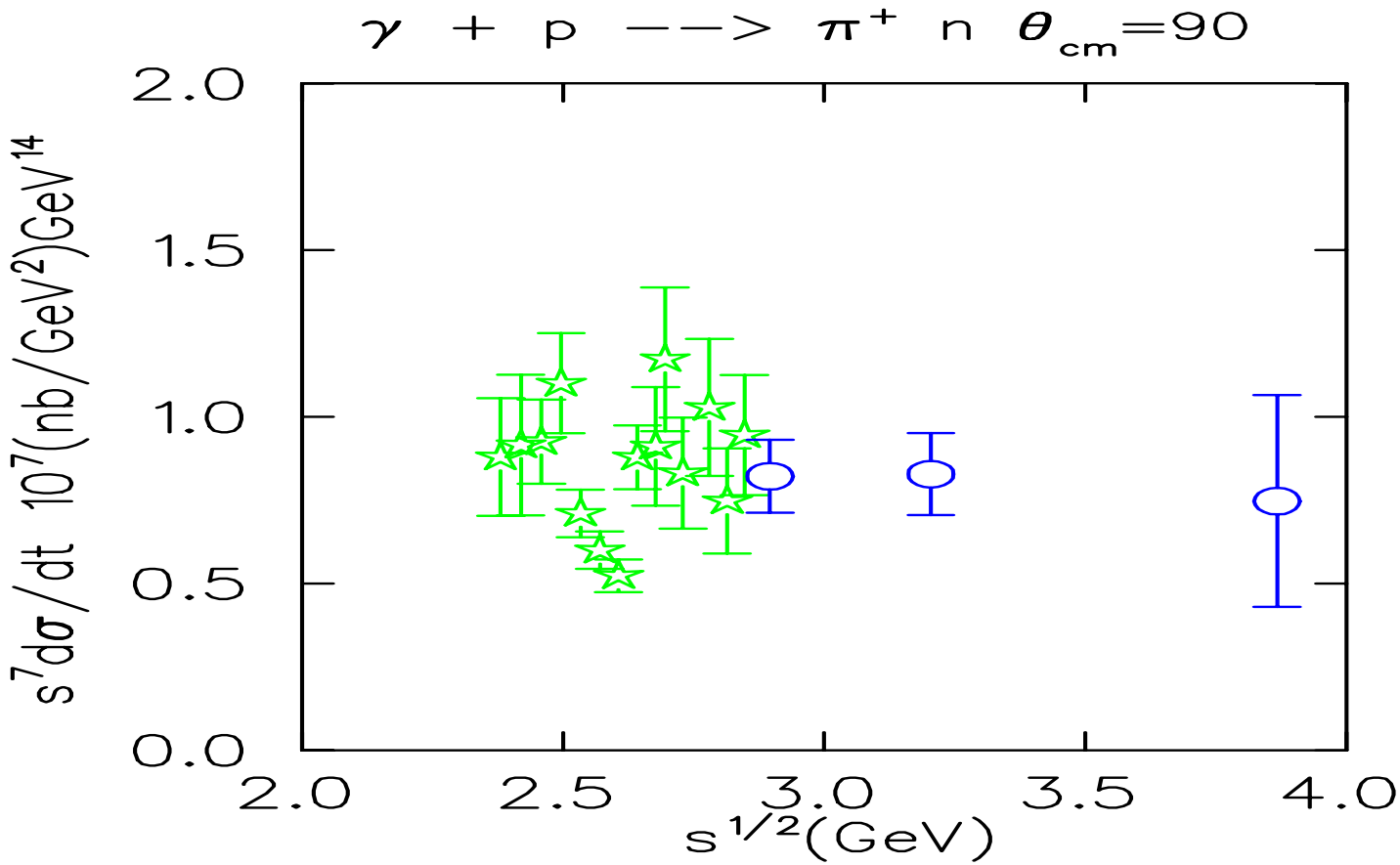
Pion-photoproduction

$\gamma\, p \rightarrow \pi^{+}\, n \;,\; \gamma\, n \rightarrow \pi^{-}\, p$

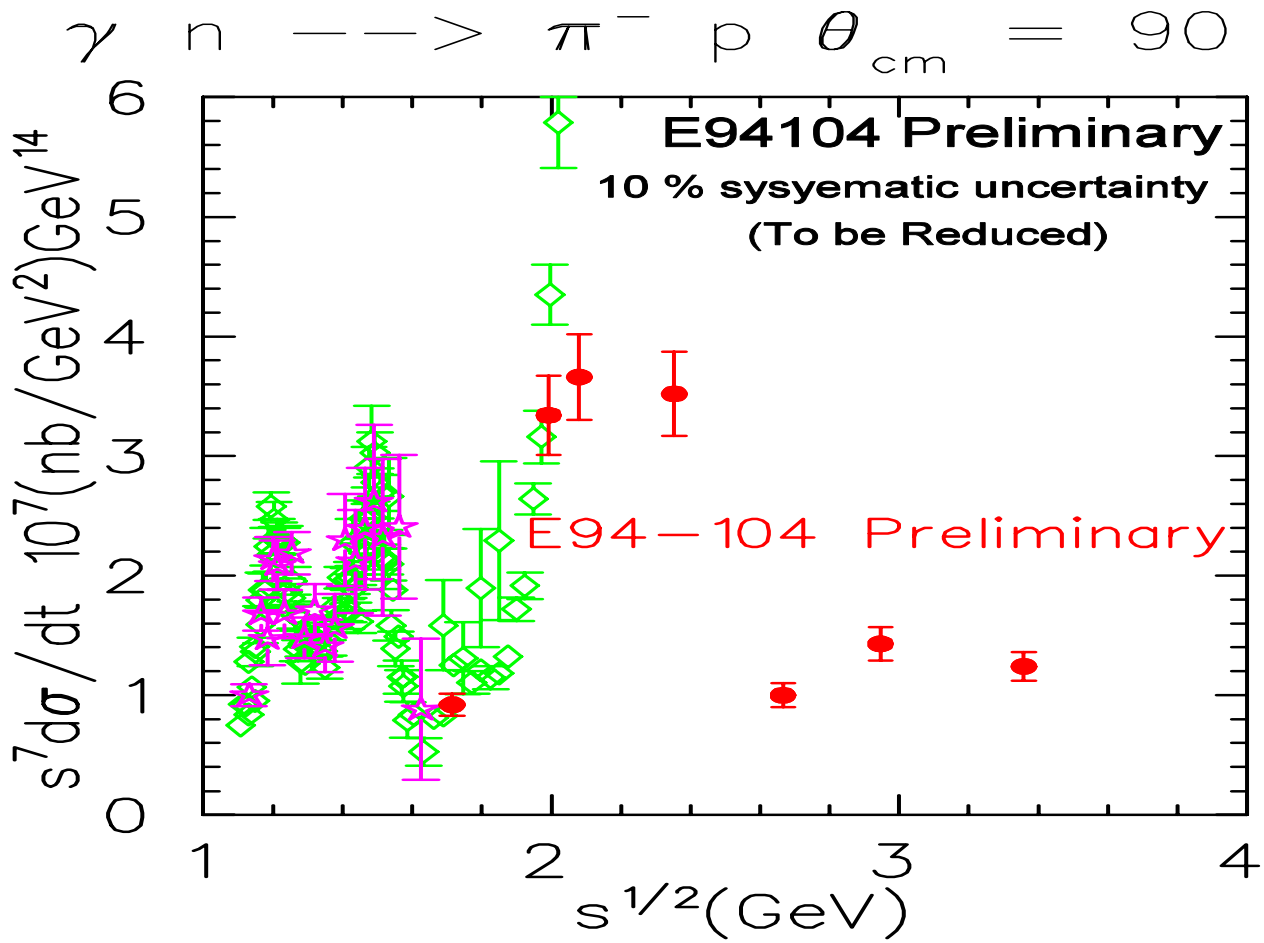


quark counting rule predicts $\frac{d\sigma}{dt} \propto s^{-7}$

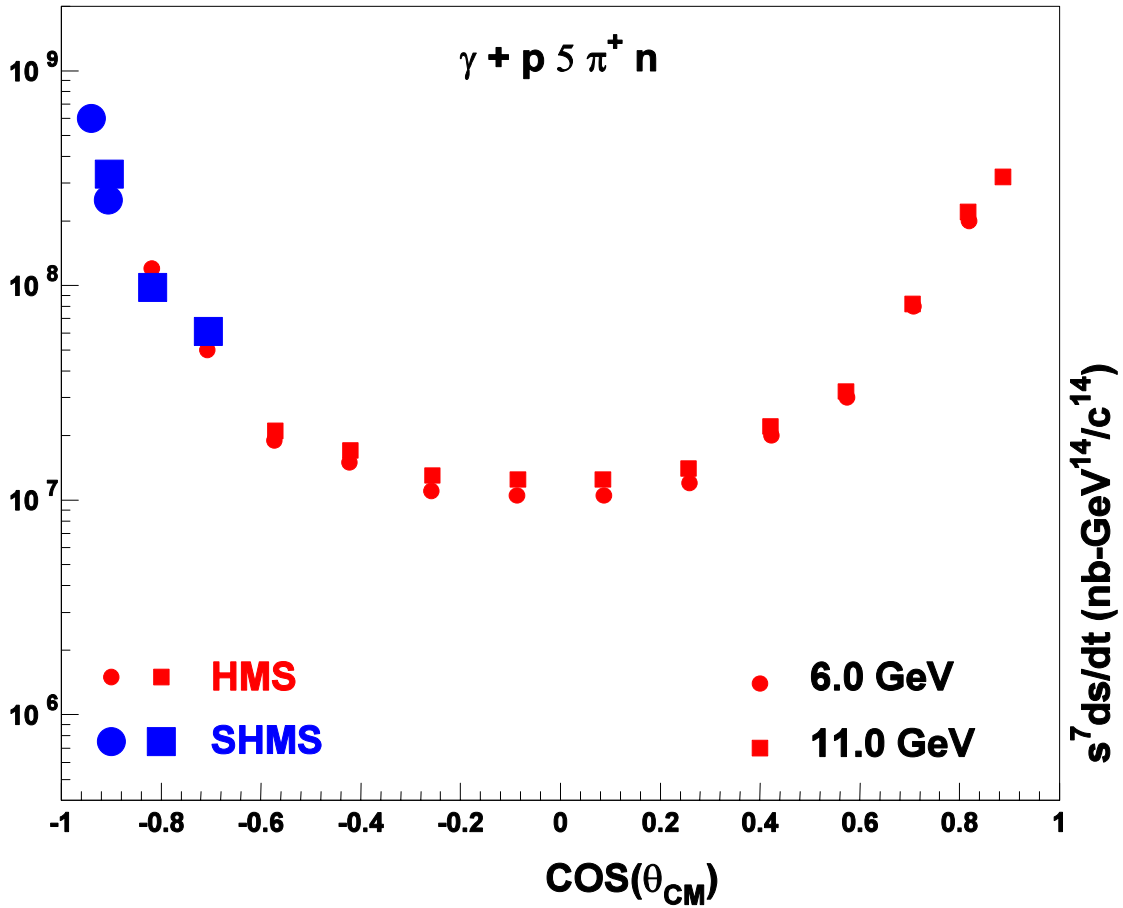
Pion-photoproduction



Pion-photoproduction



Angular Dependence of Scaling

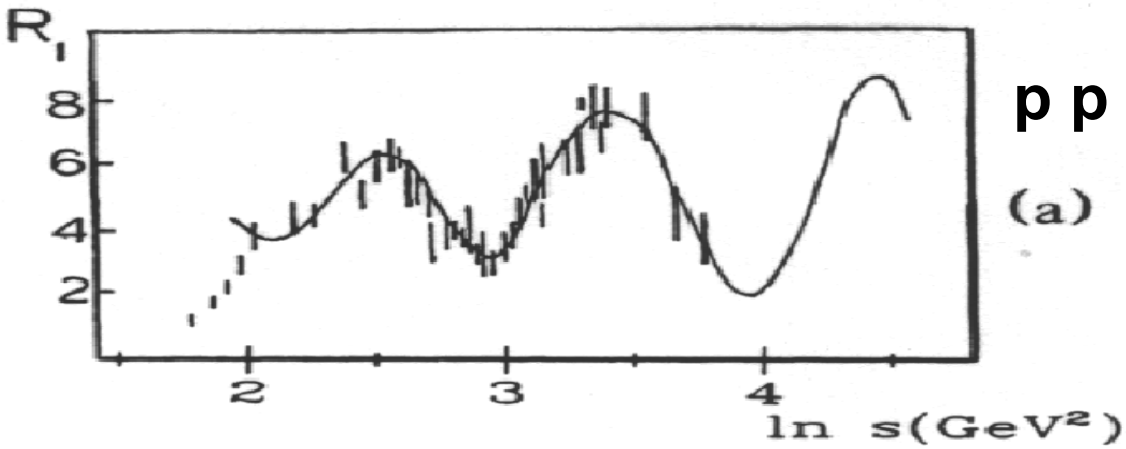


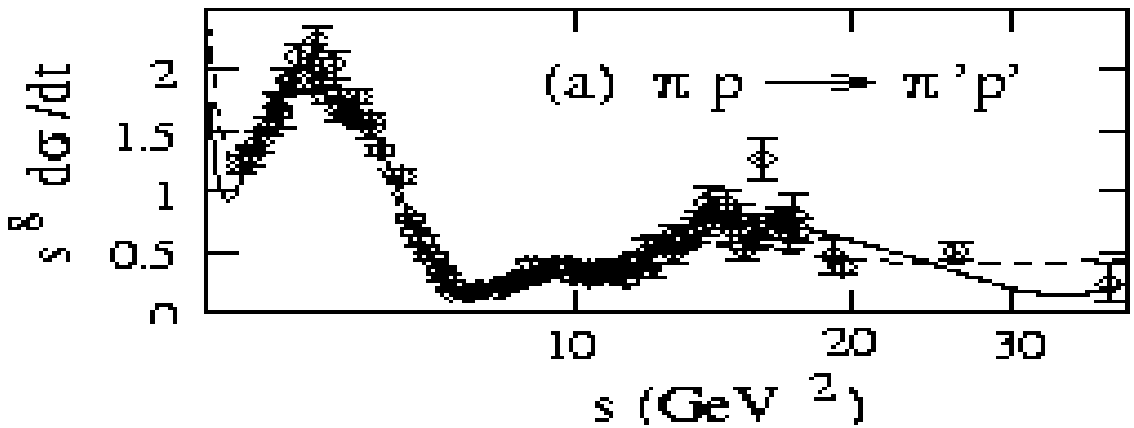
$\gamma\, p \rightarrow \pi^+ n$

Projected

Oscillatory Scaling Behavior

$$R_I \propto s^{10} \frac{d\sigma}{dt}$$



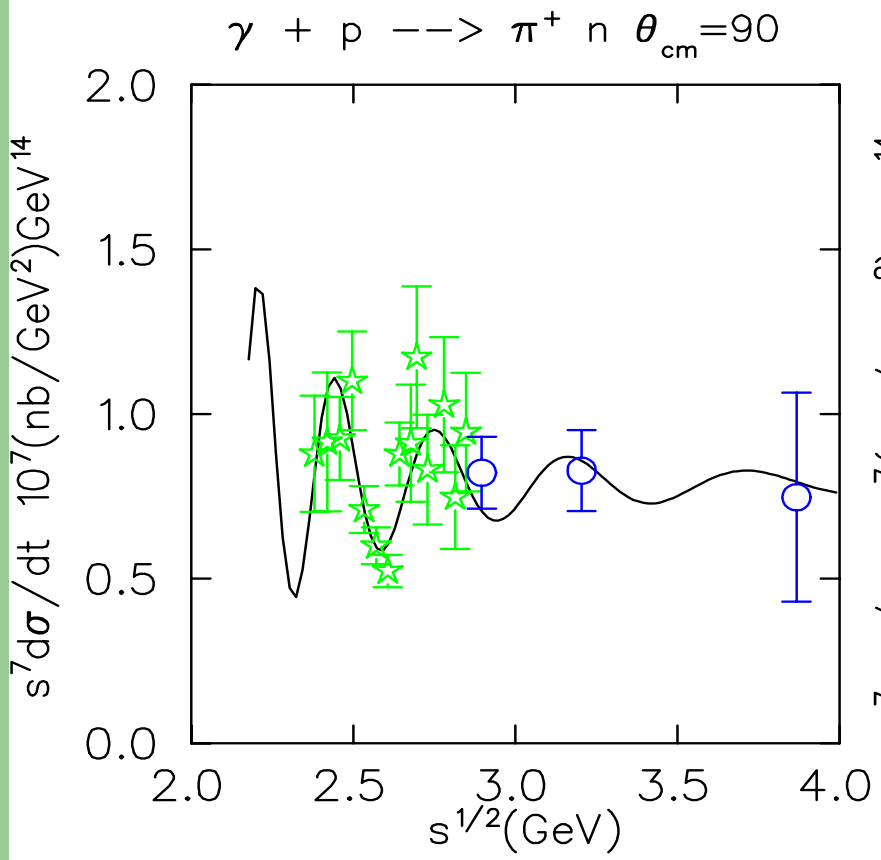


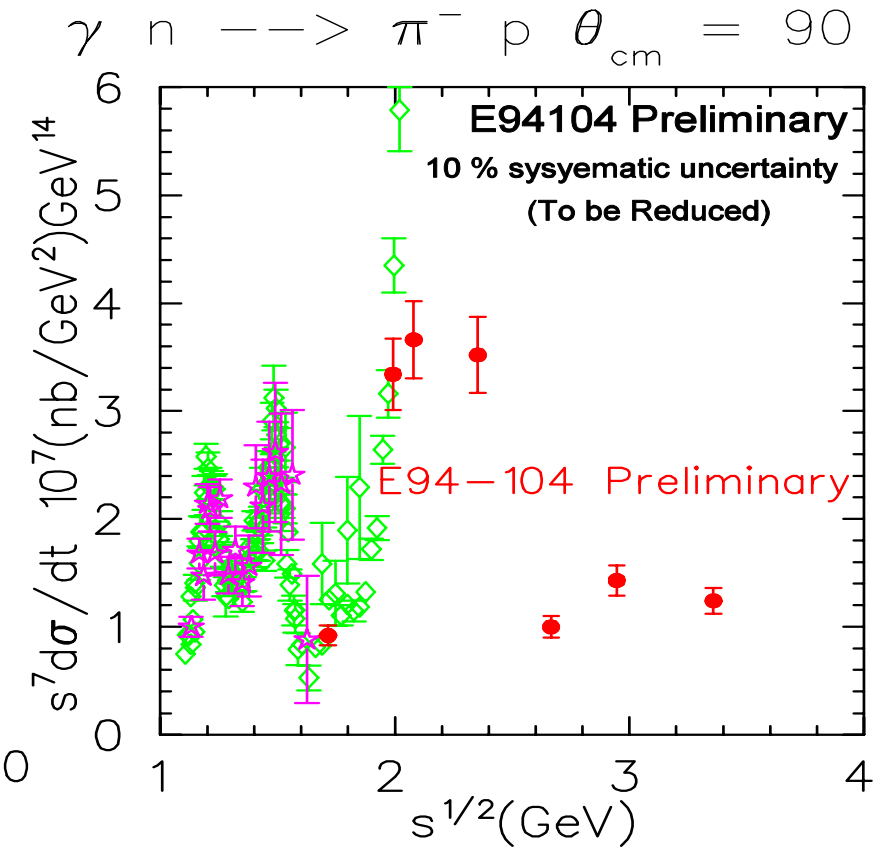
Oscillatory Scaling Behavior

The large spin correlation and oscillations in the scaled cross-section explained as:

- **Resonance state production near the charm threshold (Brodsky, Schmidt , …….).**
- **Interference between short distance (Born) and long distance (Landshoff) amplitudes, (Ralston & Pire and Carlson, Myhrer, …….)**

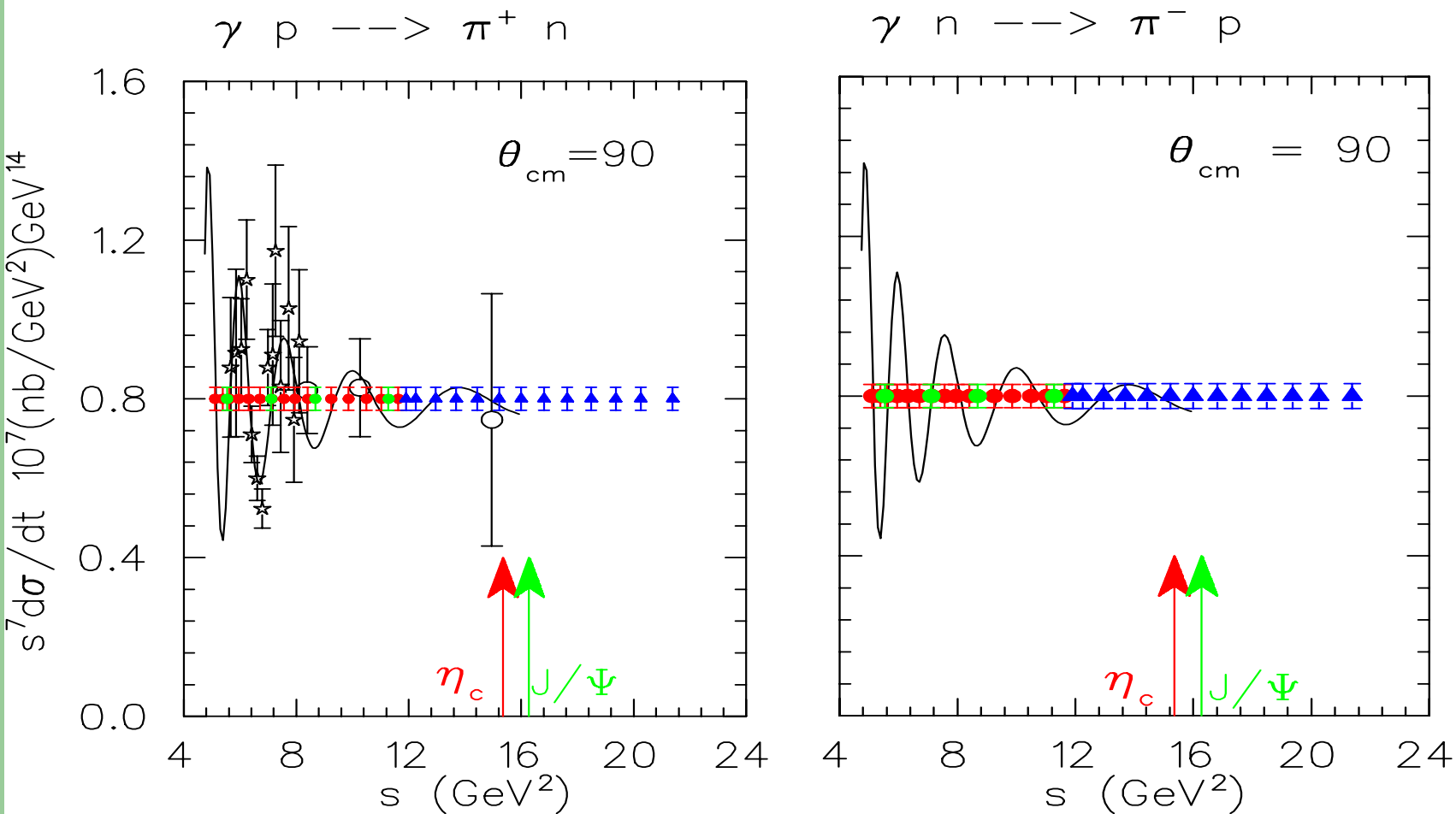
Photo-pion Production





Are oscillations a general feature of QCD ?

Projected Results at 12 GeV



Nuclear Filtering

What happens to the oscillatory scaling behavior in the nuclear medium ?

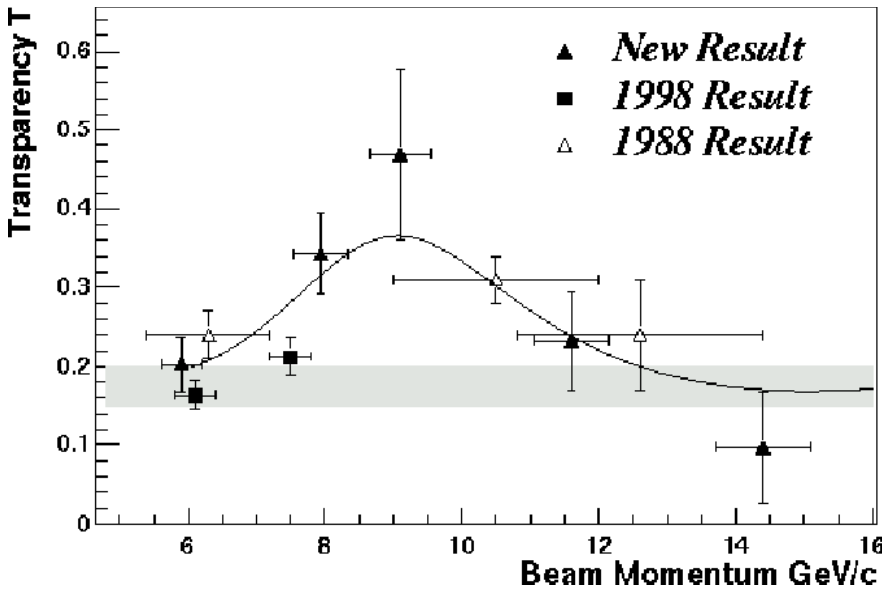
- It has been suggested that they are damped out because the long distance amplitude is suppressed in the nuclear medium.

- This is called " Nuclear Filtering."

- This implies there should be oscillations in nuclear transparency 180^{o} out-of-phase with the oscillations in the free cross-section.

Transparency in A(p,2p) Processes

$$p + {}^{A}N_{Z} \rightarrow p + p + X \quad @\,BNL$$

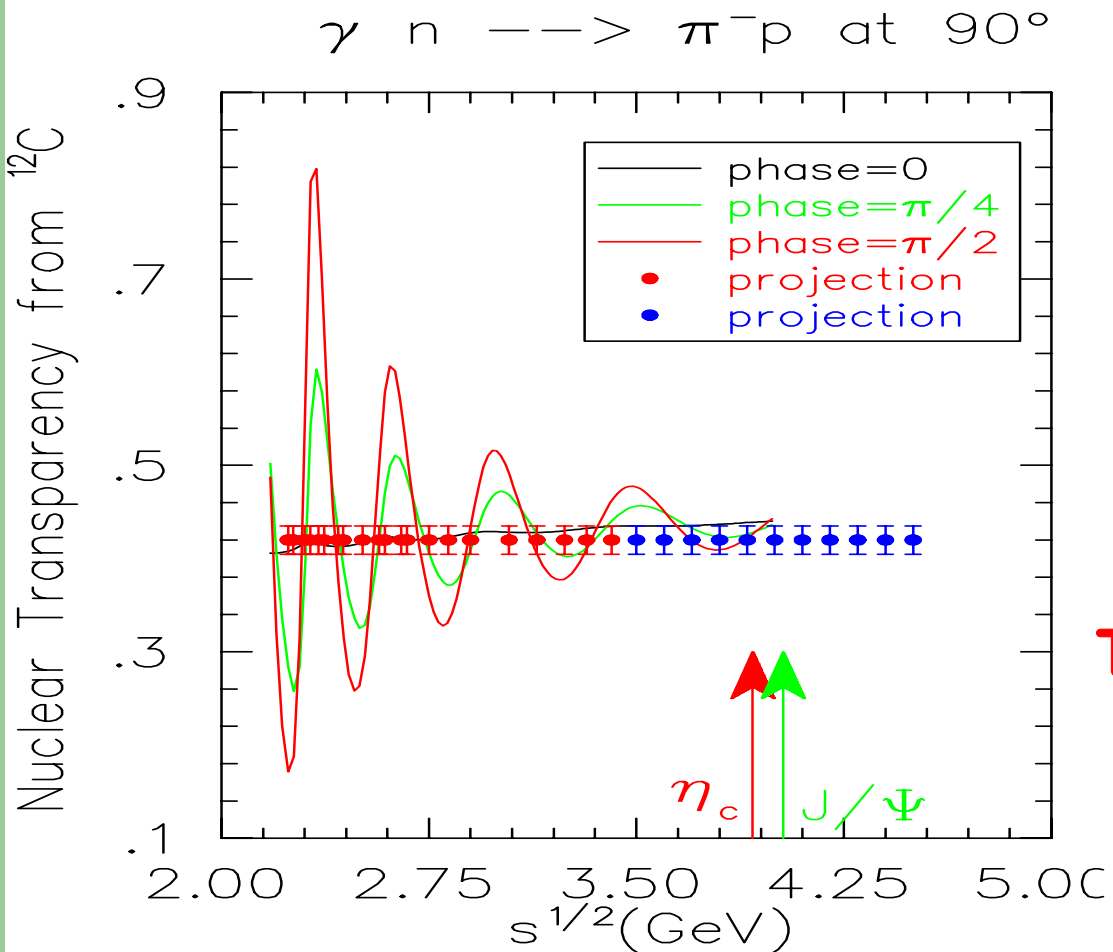


Shaded band is from a conventional nuclear physics calculation

Solid line is fit to 1/oscillation in p-p scattering data

- BNL results explained in terms of Nuclear Filtering (Ralston & Pire)
- In terms of charm resonance states (Brodsky & Le page).

Photo-pion Transparency in ^{12}C



$$\gamma + {}^{12}C \rightarrow \pi^- + p + X$$

$$T \approx \frac{\gamma + {}^{12}C \rightarrow \pi^- + p + X}{\gamma + n \rightarrow \pi^- + p}$$

Detector Requirements

e / π separation :

HMS : 0.6 - 6.0 GeV
SHMS : 7.0 - 10.5 GeV

π / K / p separation :

HMS : 0.6 - 6.0 GeV
SHMS : 3.5 - 6.5 GeV

Summary

- Pion photoproduction can be used to study scaling, both the oscillatory behavior and the angular dependence can be measured.

- The π^-/π^+ ratio can be measured to high t.

- Pion photoproduction from nuclear targets can be used to confirm the nuclear filter idea.

- Electro and photoproduction of pions can be used to study color transparency.