

Wide Angle Exclusive Neutral Pion Photoproduction

Dipangkar Dutta
Mississippi State
University



**NMS Collaboration
Meeting
Nov 14, 2013**



Motivation

Testing the applicability of QCD in exclusive processes at intermediate energies is one of the key goals of the physics program at JLab



Motivation

Testing the applicability of QCD in exclusive processes at intermediate energies is one of the key goals of the physics program at JLab

- There is consensus that pQCD mechanisms dominate at high energies and small distances
- But there is no agreement on what energy is high enough for pQCD to be completely applicable.



Motivation

Testing the applicability of QCD in exclusive processes at intermediate energies is one of the key goals of the physics program at JLab

- There is consensus that pQCD mechanisms dominate at high energies and small distances
- But there is no agreement on what energy is high enough for pQCD to be completely applicable.

An alternate theoretical framework for exclusive processes at intermediate energies, has been developed over the last decade. This approach advocates the dominance of the handbag mechanism.



Constituent Quark Counting

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

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

s = c.m. energy sq.
 n = # of constituent fields

- First derived based on dimensional analysis (Matveev et al., Brodsky, Farrar,...)
- Confirmed within short distance pQCD framework (Brodsky, LePage)
- Recently, derived from anti-de Sitter/Conformal Field Theory correspondence or string/gauge duality (Polchinski, Strassler)



Constituent Quark Counting

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 sq.
n = # of constituent fields

- First derived based on dimensional analysis (Matveev et al., Brodsky, Farrar,....)
- Confirmed within short distance pQCD framework (Brodsky, LePage)
- Recently, derived from anti-de Sitter/Conformal Field Theory correspondence or string/gauge duality (Polchinski, Strassler)

Many exclusive processes exhibit global scaling behavior

elastic pp scattering @ 90 deg CM angle ($\frac{d\sigma}{dt} \propto s^{-10}$)

deuteron photo-disintegration at large angles ($\frac{d\sigma}{dt} \propto s^{-11}$)

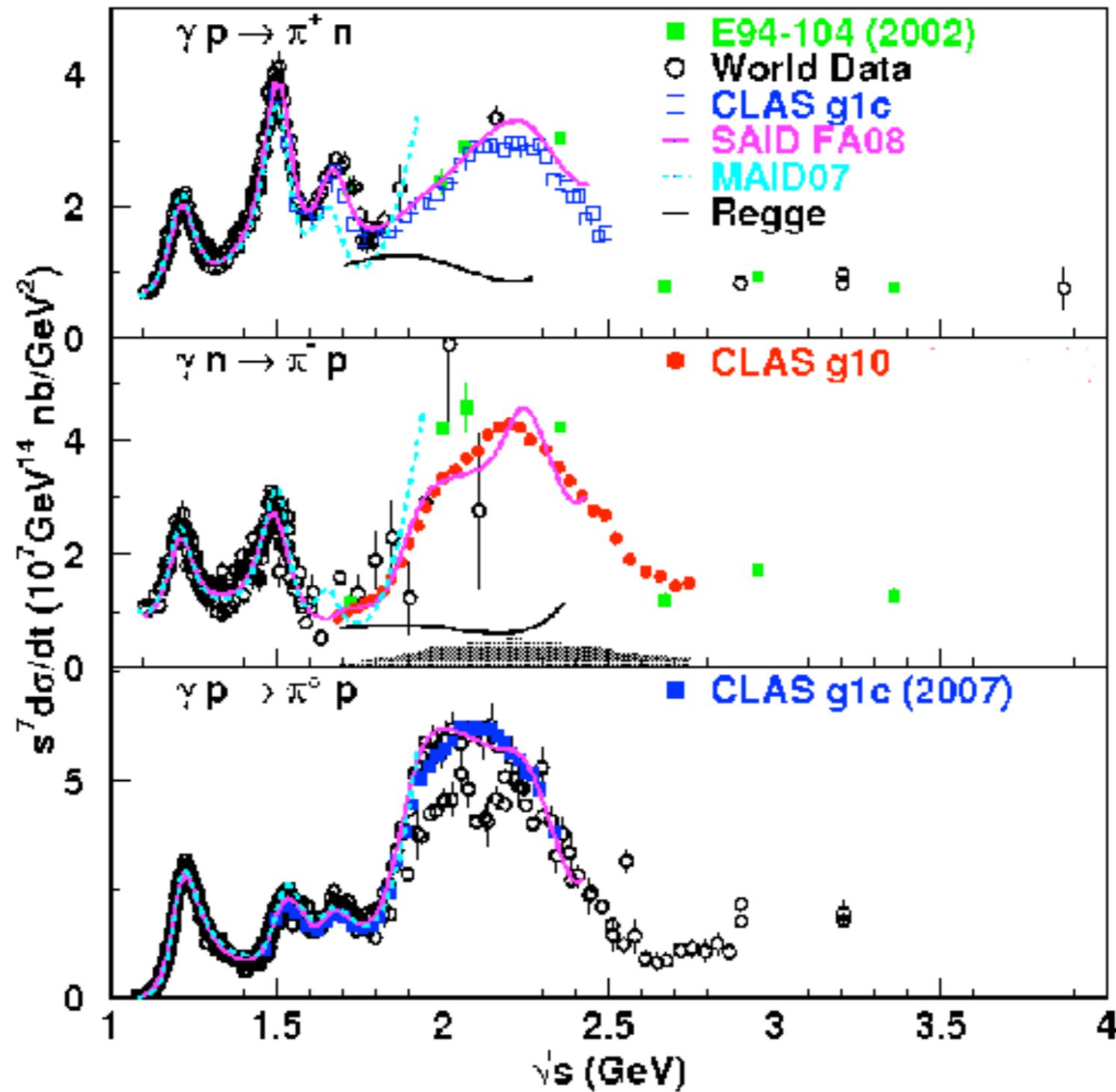
(C. Bochna et al., PRL 81, 4576 (1998), E.C. Schulte, et al., PRL 87, 102302 (2001),
M. Mirazita et al., PRC 70, 014005 (2004), P. Rossi, PRL 94, 012301 (2005)).

Photopion production from nucleon at large angles ($\frac{d\sigma}{dt} \propto s^{-7}$)

(L.Y. Zhu et al., PRL 91, 022003(2003))



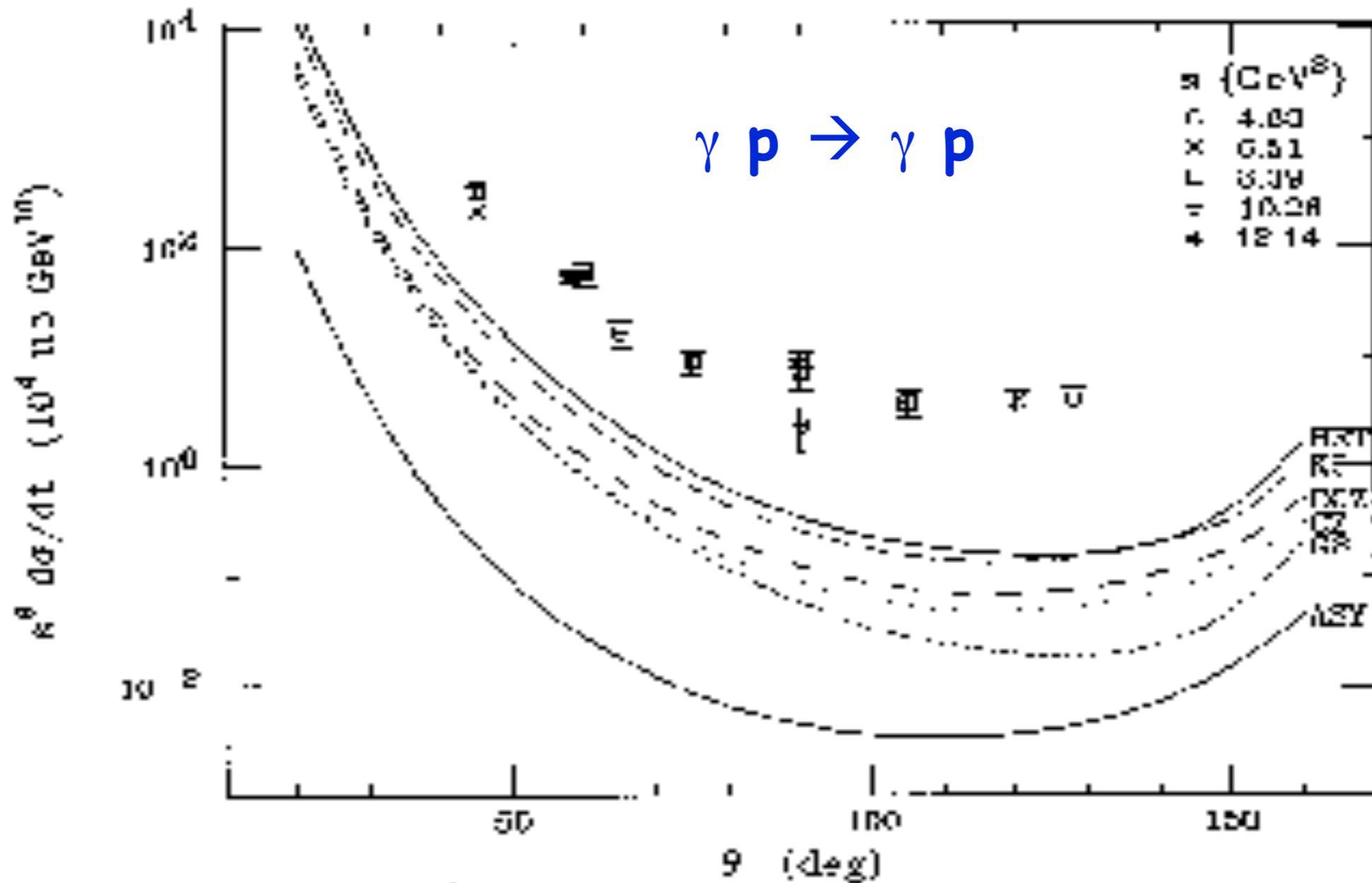
Pion Photoproduction





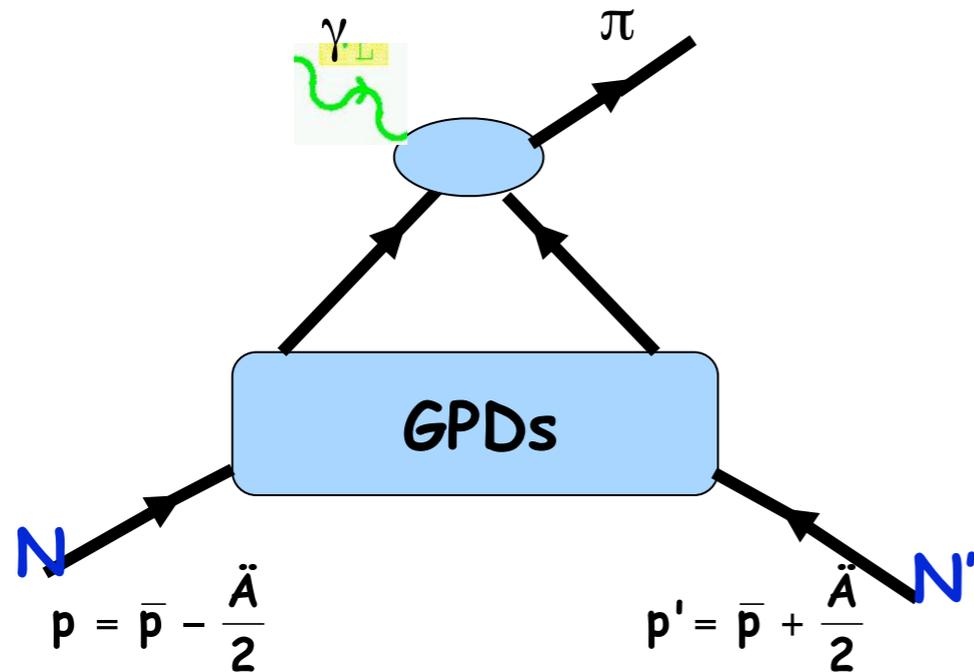
Cross Sections

pQCD based cross-section calculations for exclusive processes such as wide angle Compton scattering are invariably lower than measured values sometime by an order of magnitude.





The Handbag Mechanism



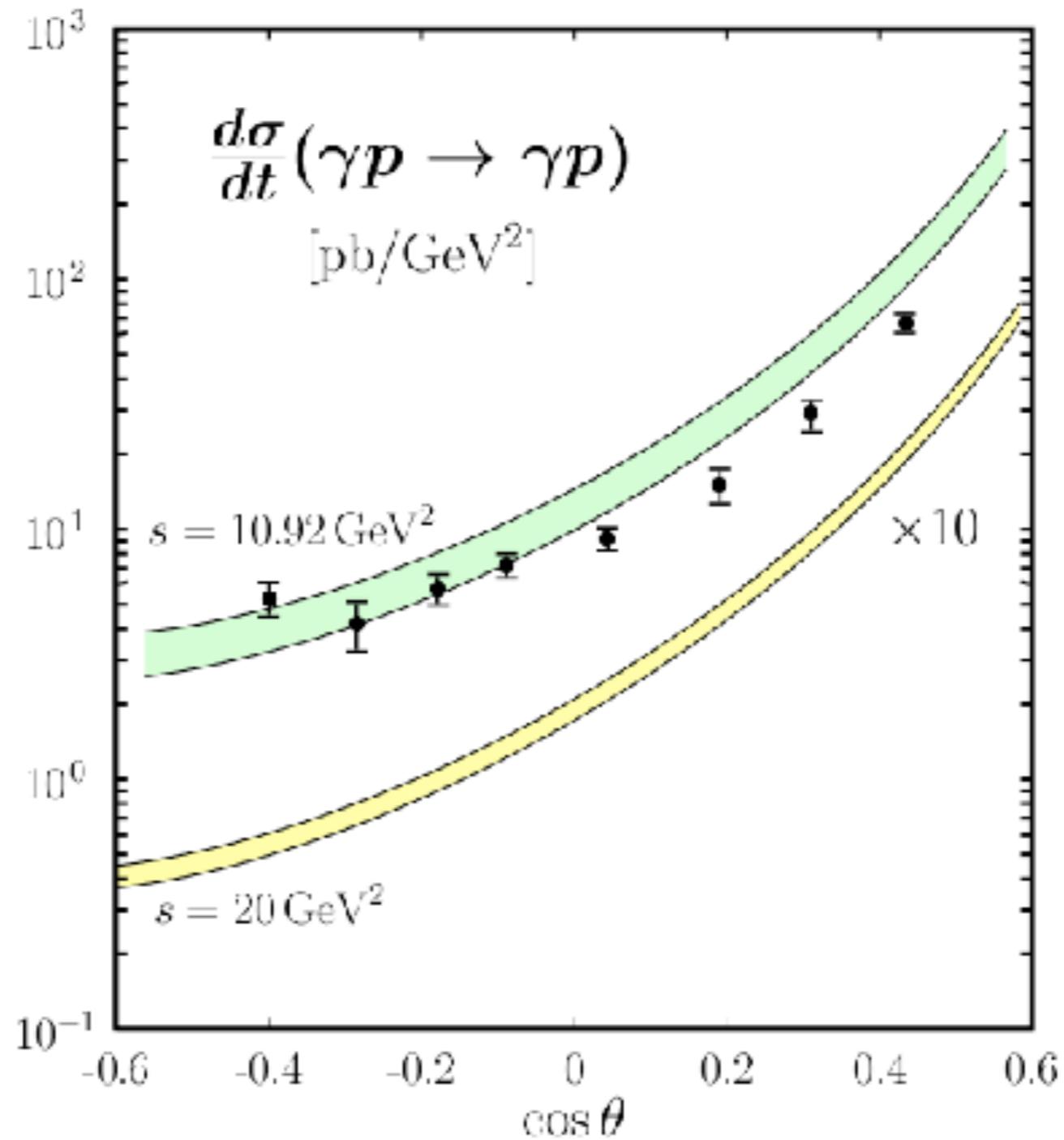
An **alternate framework** assumes the dominance of the handbag mechanism.

The reaction amplitude factorizes into a sub-process involving a hard interaction with a single quark from the incoming and outgoing nucleon ($\gamma q_a \rightarrow \pi q_b$) and GPDs.

Recent DVCS and wide angle Compton scattering results disagree with pQCD predictions but are consistent with the dominance of handbag mechanism.



Wide Angle Compton Scattering



M.Diehl and P. Kroll, arxiv:1302.4604



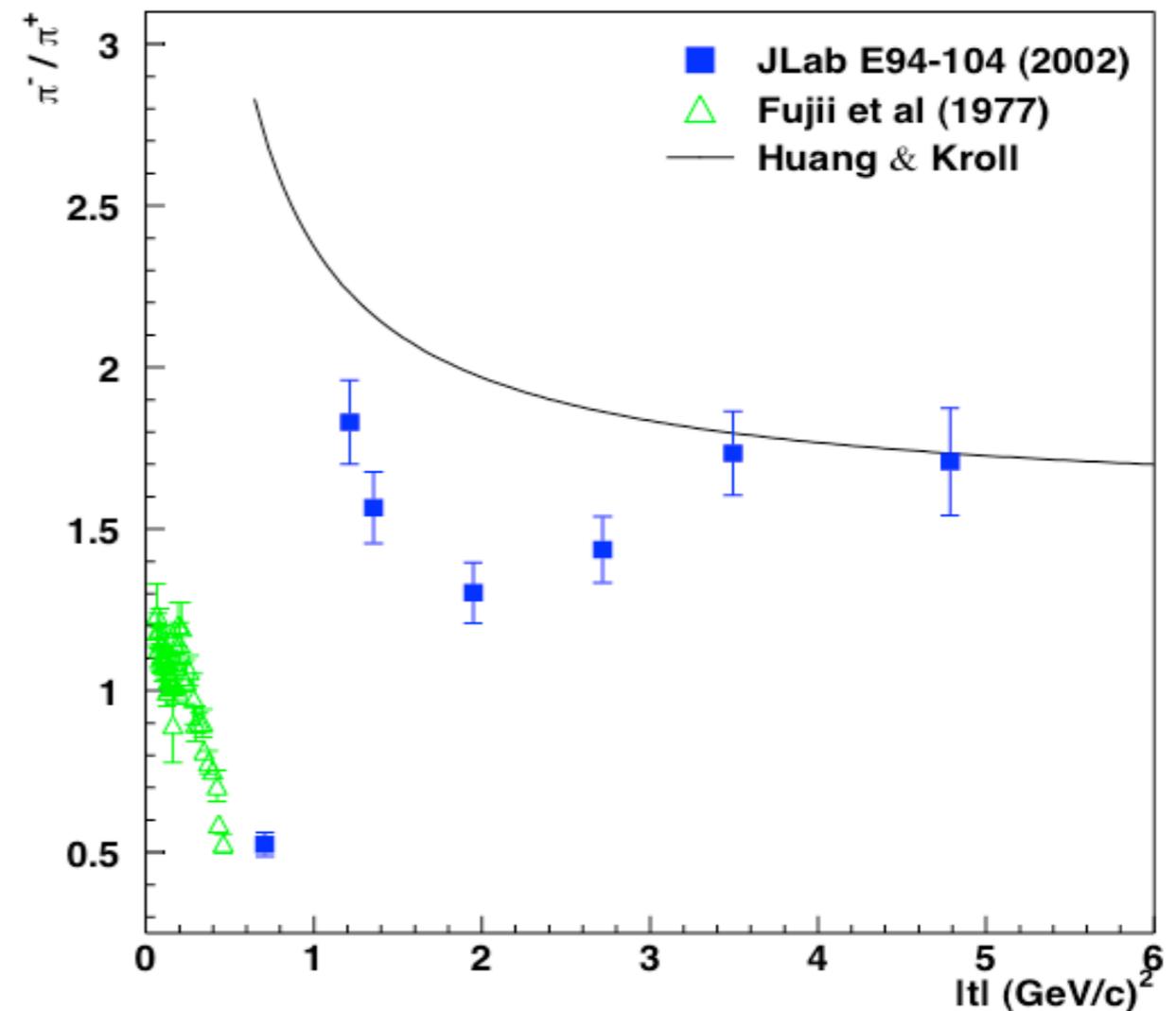
Pion Photoproduction

L.Y. Zhu, PRL 91, 022003 (2003)

Some recent work already looks promising

Calculations in the framework of handbag mechanisms, with factorization into $\gamma q_a \rightarrow \pi q_b$ sub-process and GPDs, show that the GPD part of the contribution cancel in the ratio.

Huang & Kroll, EPJC, 17, 423 (2000),
Huang, Jakob, Kroll & Passek-Kumericki, hep-ph/0309071, Afanasev, Carlson & Wahlquist, PLB 398, 393 (1997).





Pion Photoproduction

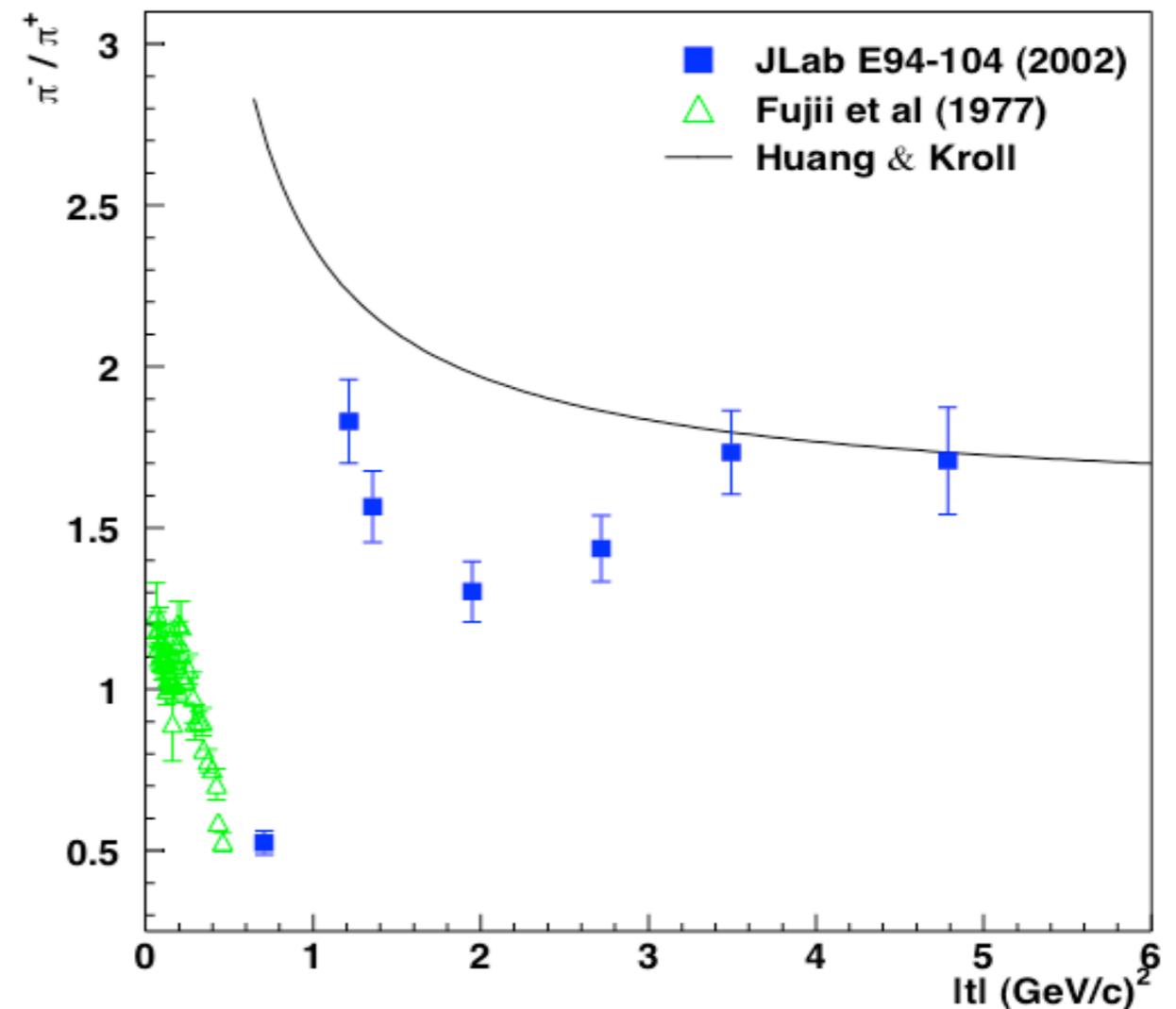
Pion photoproduction is next in complexity to wide angle Compton scattering and should be explored in these models.

L.Y. Zhu, PRL 91, 022003 (2003)

Some recent work already looks promising

Calculations in the framework of handbag mechanisms, with factorization into $\gamma q_a \rightarrow \pi q_b$ sub-process and GPDs, show that the GPD part of the contribution cancel in the ratio.

Huang & Kroll, EPJC, 17, 423 (2000),
Huang, Jakob, Kroll & Passek-Kumericki, hep-ph/0309071, Afanasev, Carlson & Wahlquist, PLB 398, 393 (1997).

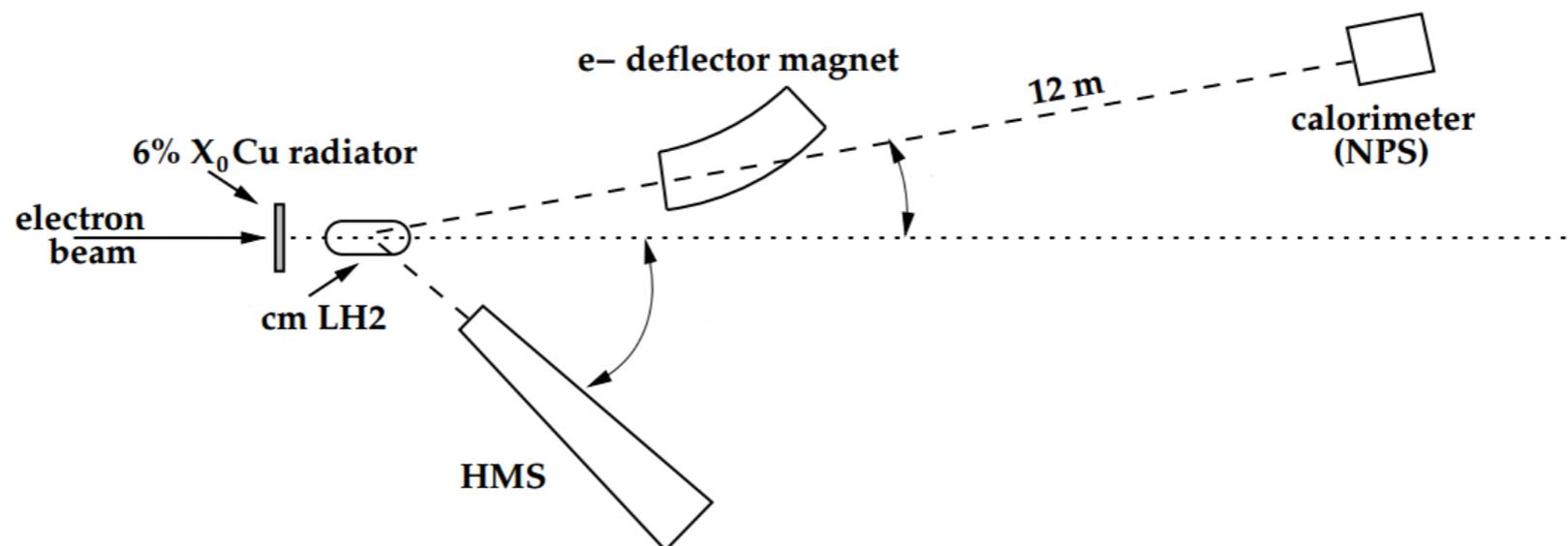




New Proposal

(LOI @ PAC 40)

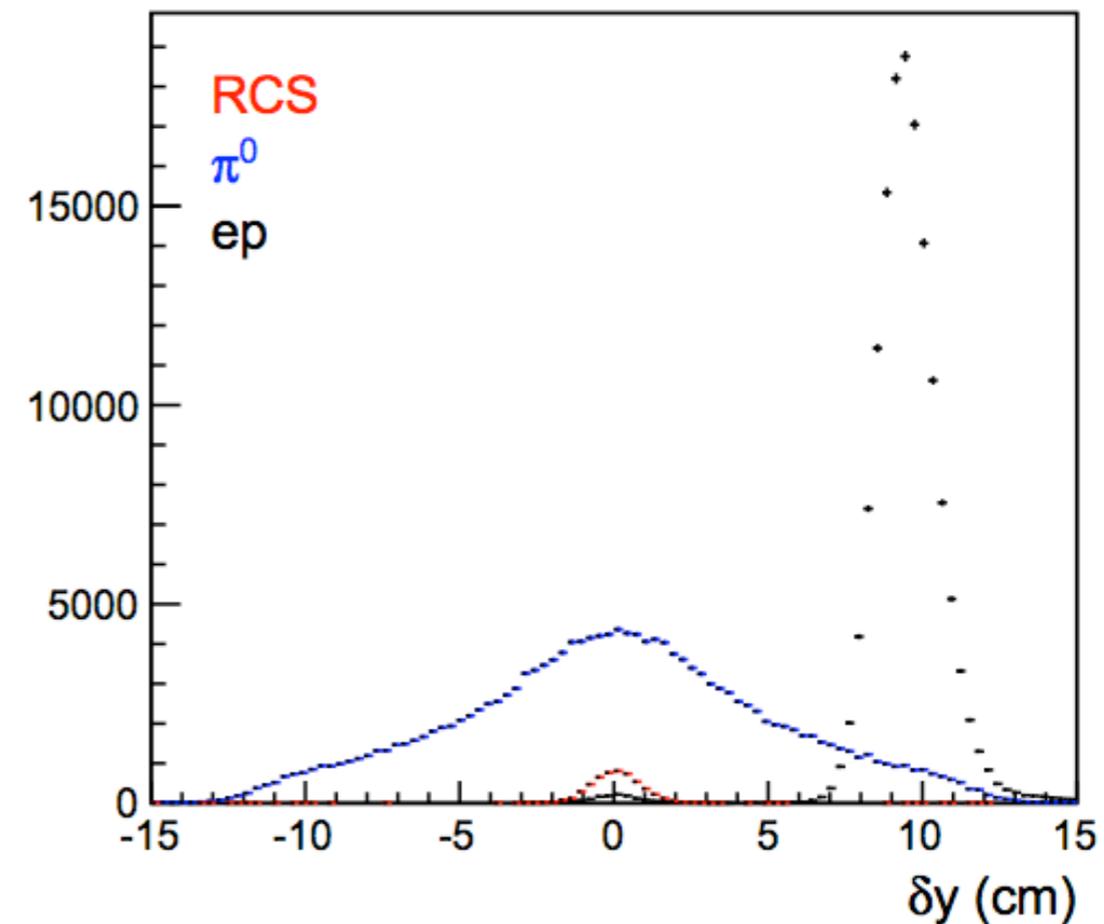
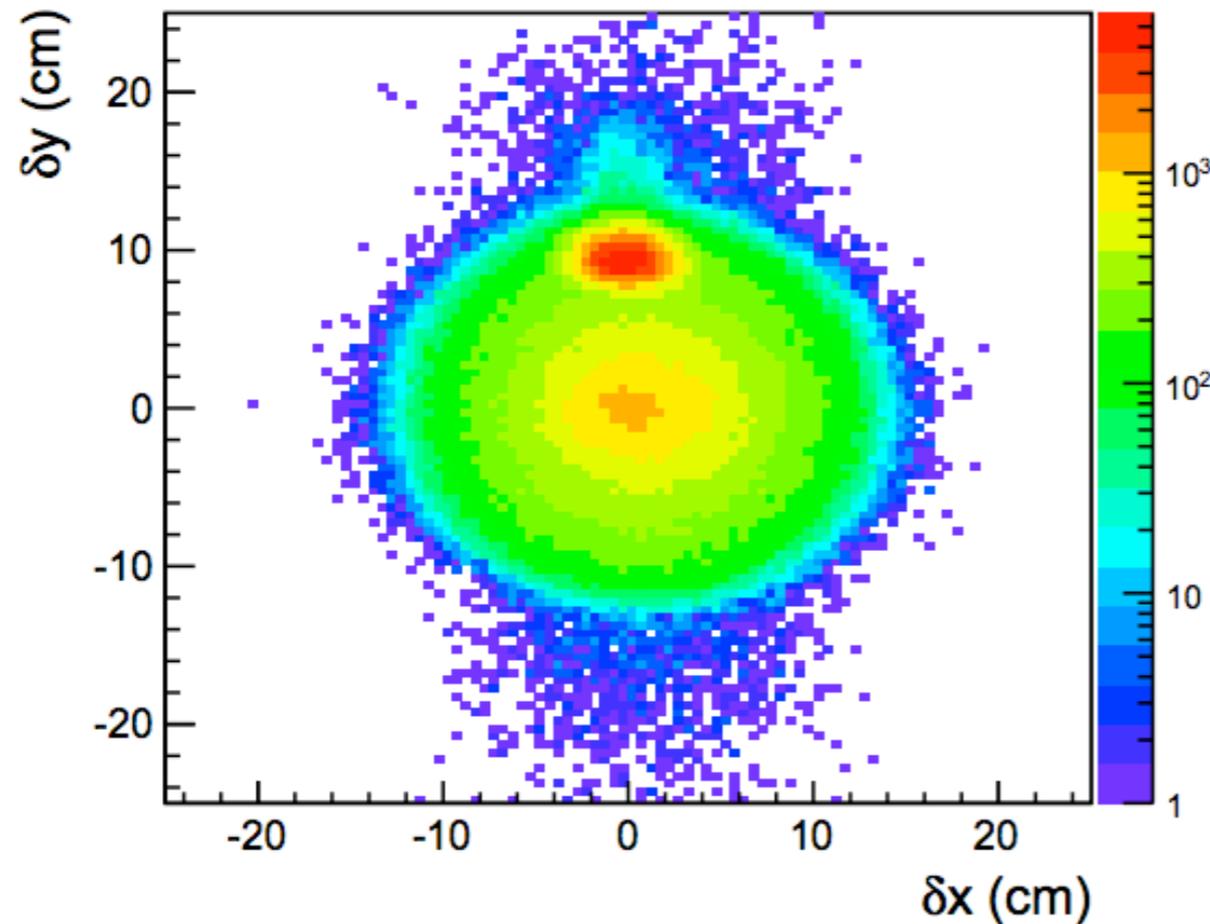
- Detailed investigation of the **angular dependence** of the onset of scaling as observed in deuteron photodisintegration. This will help understand the origins of the scaling behavior.
- Push these measurements to significantly higher **CM energies** beyond **the charm threshold**.
- A successful completion can lead to later experiments that will use a finer scan in center of mass energy to investigate exciting new developments, such as the generalized counting rules.





Background in RCS

courtesy of RCS collaboration



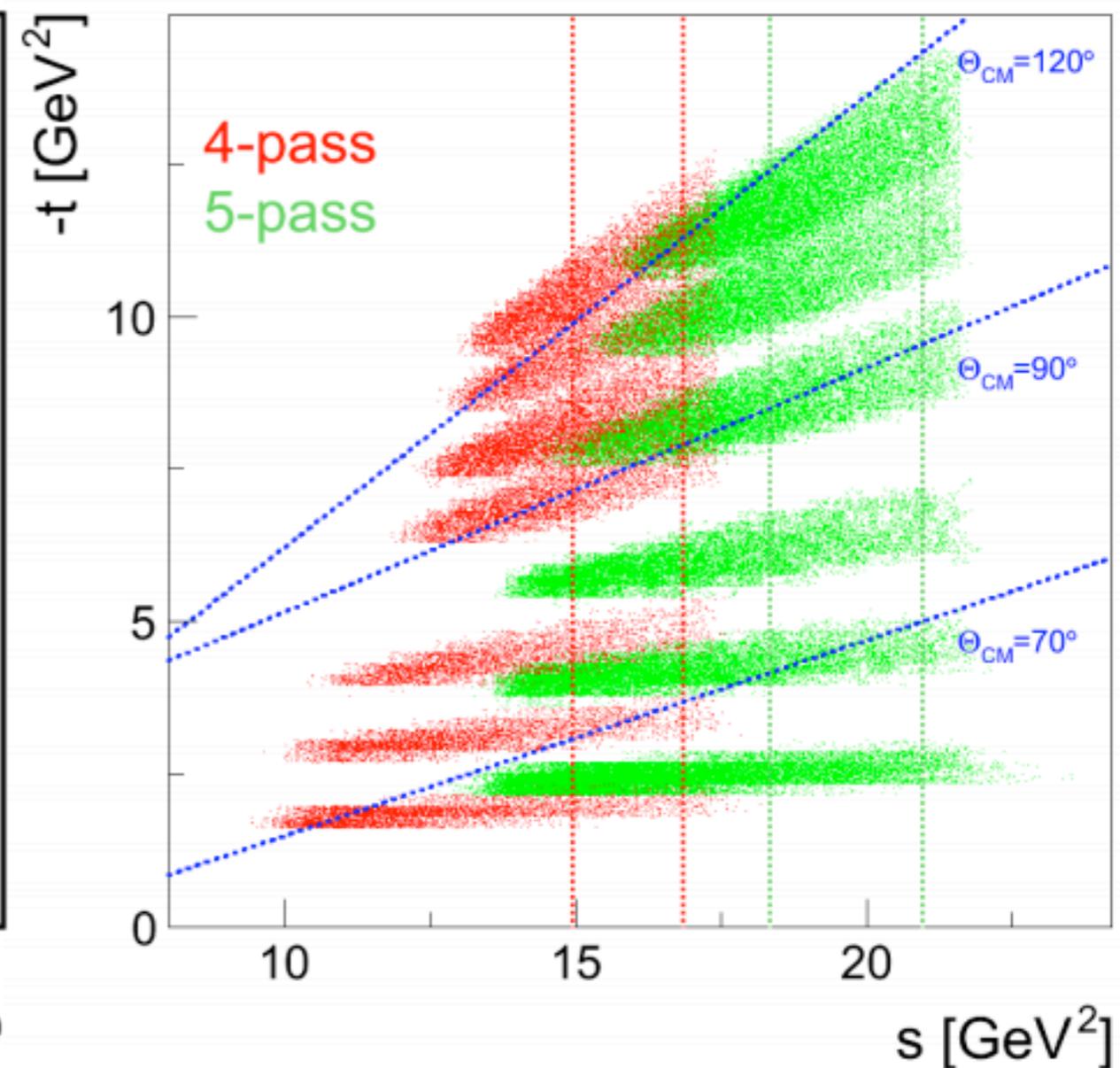
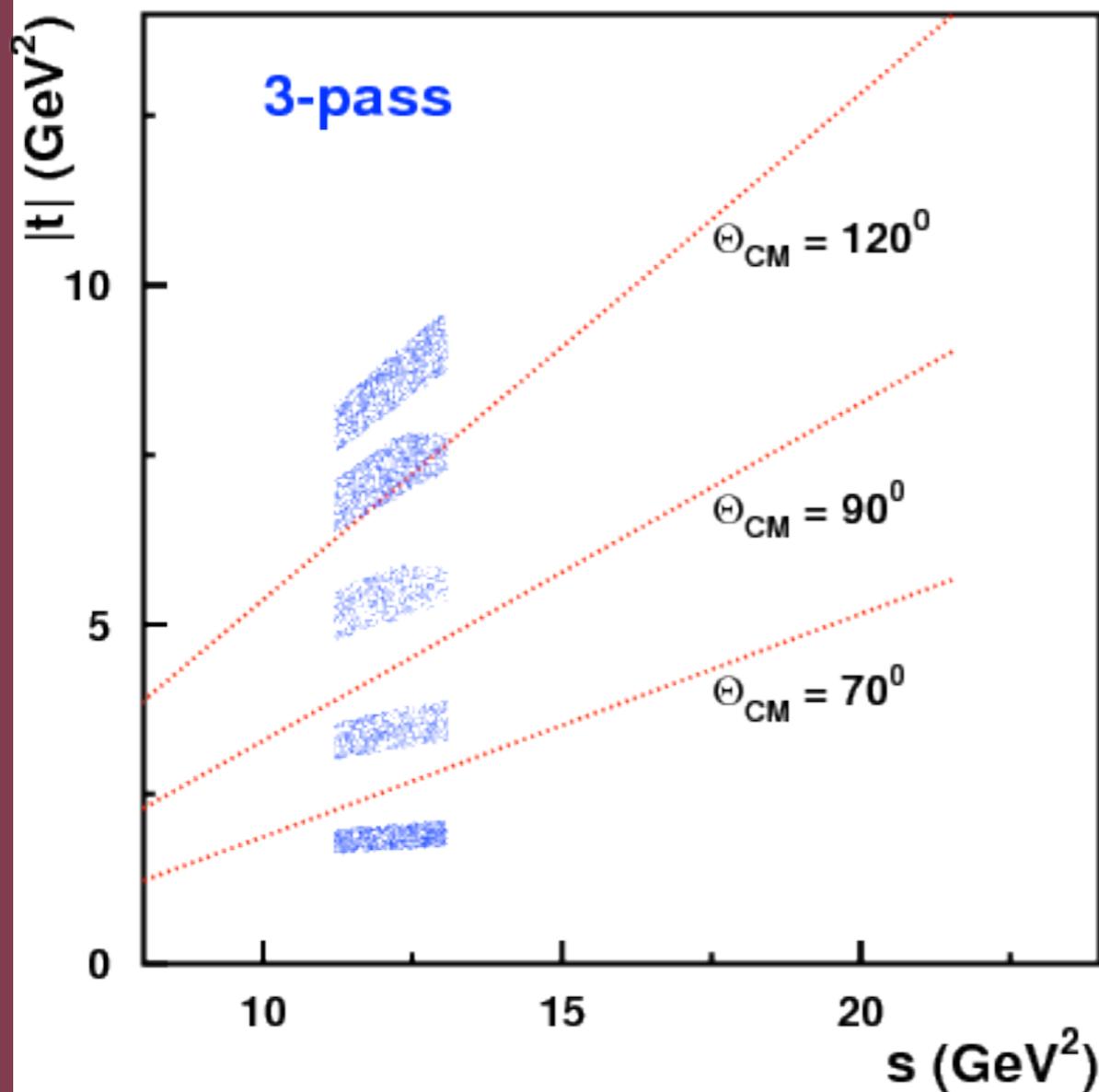
RCS experiment expects $< 8\%$ systematic uncertainties in the extraction of the Compton cross section. Therefore one should be able to extract the neutral pion cross section to a similar precision.



Additional Kinematics

pi0 needs additional 3 pass beam

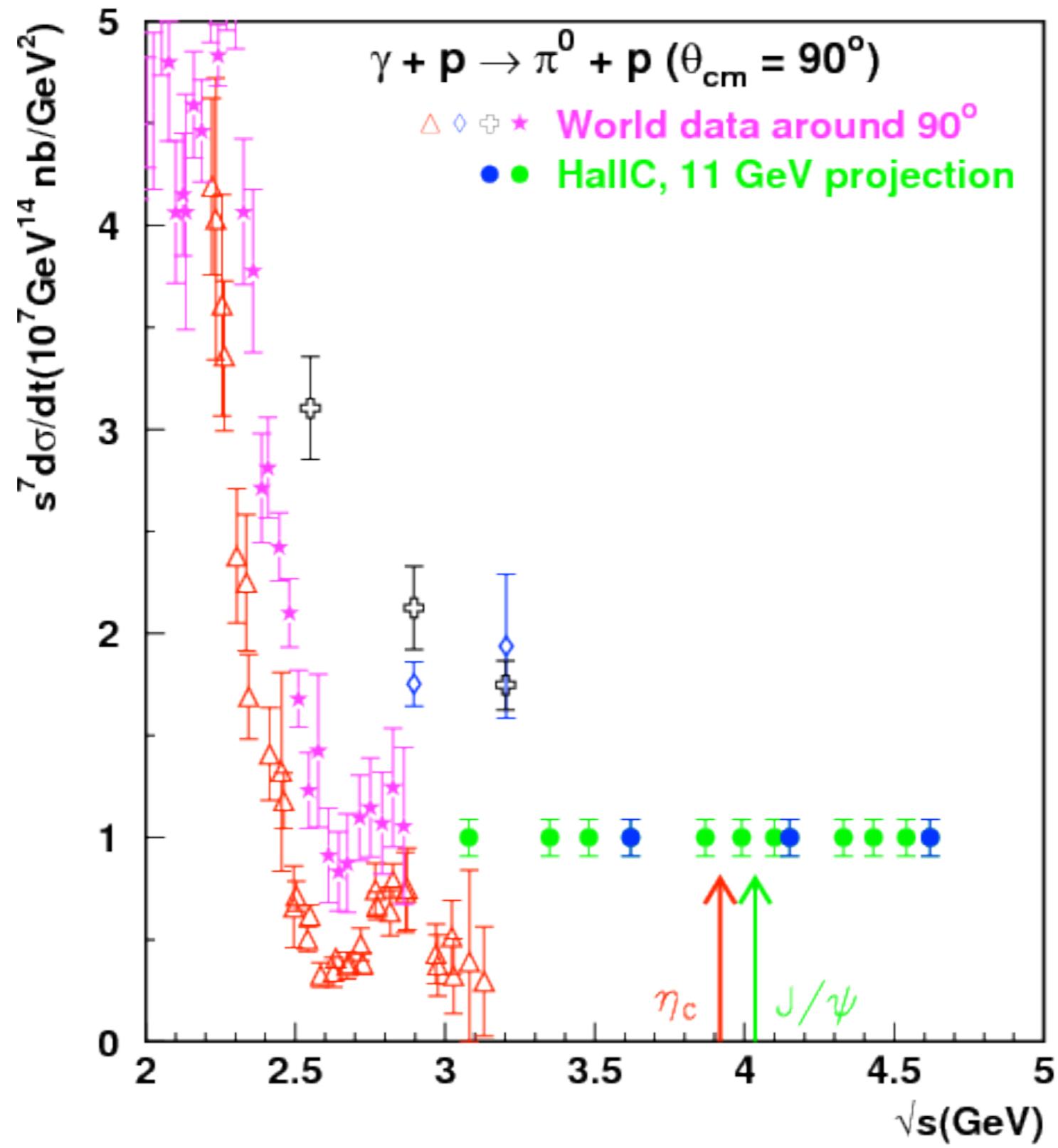
RCS needs only 4 and 5 pass beams



Range in s and $-t$ as defined by the HMS acceptance



Projected Results





Next Steps

- **Geant4 + SimC simulation of the 3-pass kinematics**
- **Careful estimation of systematic uncertainties in extracting the neutral pion cross section by detecting a single photon in coincidence with the proton.**
- **Coordinate with RCS collaboration for PAC41 proposal**
- **Participate in the building of the NPS detector**



Summary

$\gamma + p \rightarrow \pi^0 + p$ process is one of the simplest exclusive processes to investigate the transition from the nucleon-meson degrees of freedom to the quark-gluon degrees of freedom

The 11 GeV beam will allow:

- 1. Detailed investigation of the angular dependent scaling onset as observed in the deuteron photodisintegration process and to understand the origin of scaling behavior.
- 2. Tests of generalized quark counting rule prediction and to investigate indirectly the effect of quark orbital angular momentum.
- 3. Search for oscillatory scaling behavior as shown in the proton-proton elastic scattering data and was suggested possibly by the E94-104 results
- 4. Test predictions of the origin of such oscillatory scaling behavior if observed because the 11 GeV photon beam will allow for the crossing of the charm production threshold.
- 5. Test GPD based calculations as they become available. Confirm the recent success of GPD model calculation in describing WCS.