Single pion photoproduction Wide Angle regime: WAPP

Bogdan Wojtsekhowski, Jefferson Lab

The status of the field,

a few slides,
some from 1950s+

Pion Production by Inelastic Scattering of Electrons in Hydrogen*

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High-Energy Physics Laboratory and Department of Physics, Stanford University, Stanford, California
(Received February 27, 1956)

The ratios of the yield of electron-induced to photon-induced pion processes have been measured at an incident energy of 600 Mev. Measurements have been made at energies of 60 and 170 Mev for positive pions.

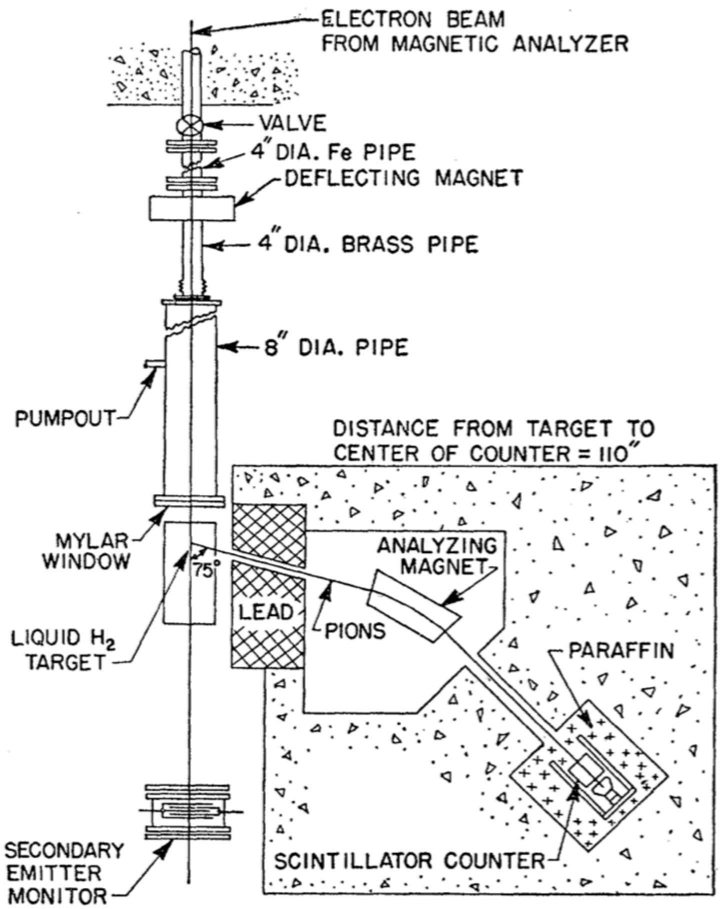

FIG. 3. Meson detection geometry.

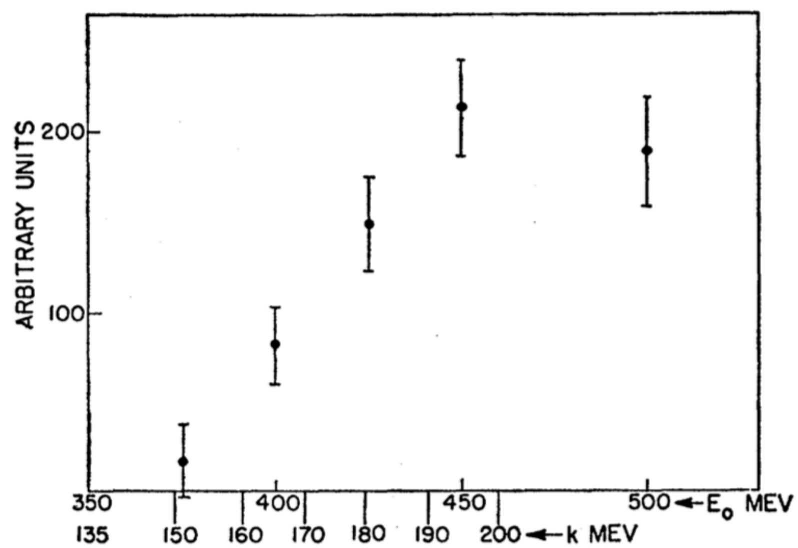

FIG. 5. Excitation function for 170-Mev pions from hydrogen. pion energy uncertainty is estimated from the curve to be ±15 Mev.

PHYSICAL REVIEW D VOLUME 14, NUMBER 3 1 AUGUST 1976

Measurements of exclusive photoproduction processes at large values of t and u from 4 to 7.5 GeV*

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(Received 2 February 1976)

Exclusive photoproduction cross sections have been measured for the processes $\gamma p \to \pi^+ n$, $\gamma p \to \pi^0 p$, $\gamma p \to \pi^- \Delta^{++}$, $\gamma p \to \rho^0 p$, $\gamma p \to K^+ \Lambda$, and $\gamma p \to K^+ \Sigma^0$ at large t and u values at several energies for each process between 4 and 7.5 GeV. These measurements taken together with past data taken at small values of t and u provide complete angular distributions. The data show the usual small t and u peaks and a central region in which the cross section decreases approximately as s^{-7}. The results are discussed within the context of parton or constituent models.

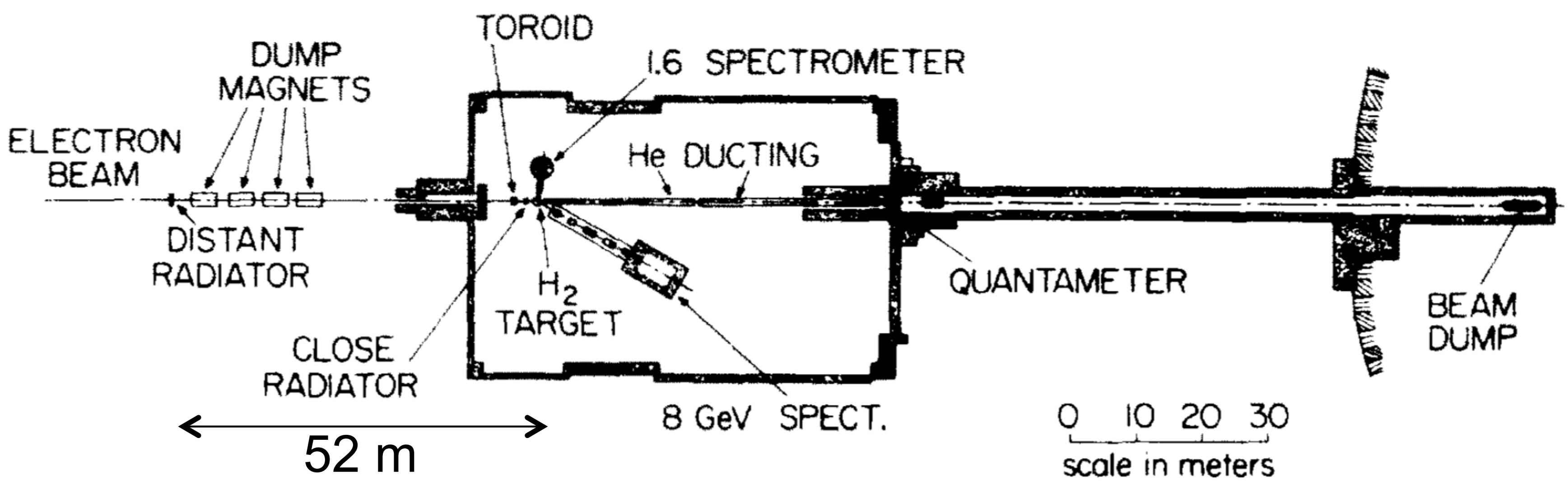


FIG. 1. Plan view of experimental layout.

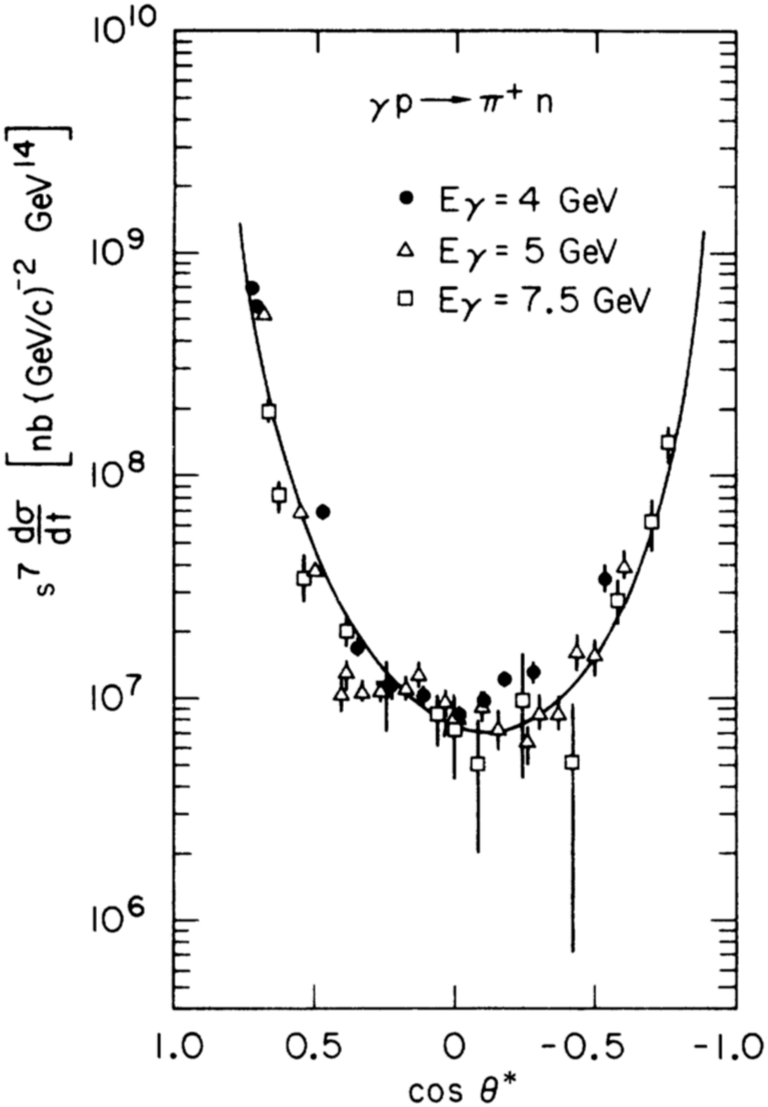


FIG. 6. $s^7 d\sigma/dt$ versus $\cos\theta^*$ for the reaction $\gamma p \rightarrow \pi^+ n$. The solid line shows the empirical function $(1-z)^{-5}(1+z)^{-4}$ where ($z = \cos\theta^*$), which is an empirical fit to the angular distribution.

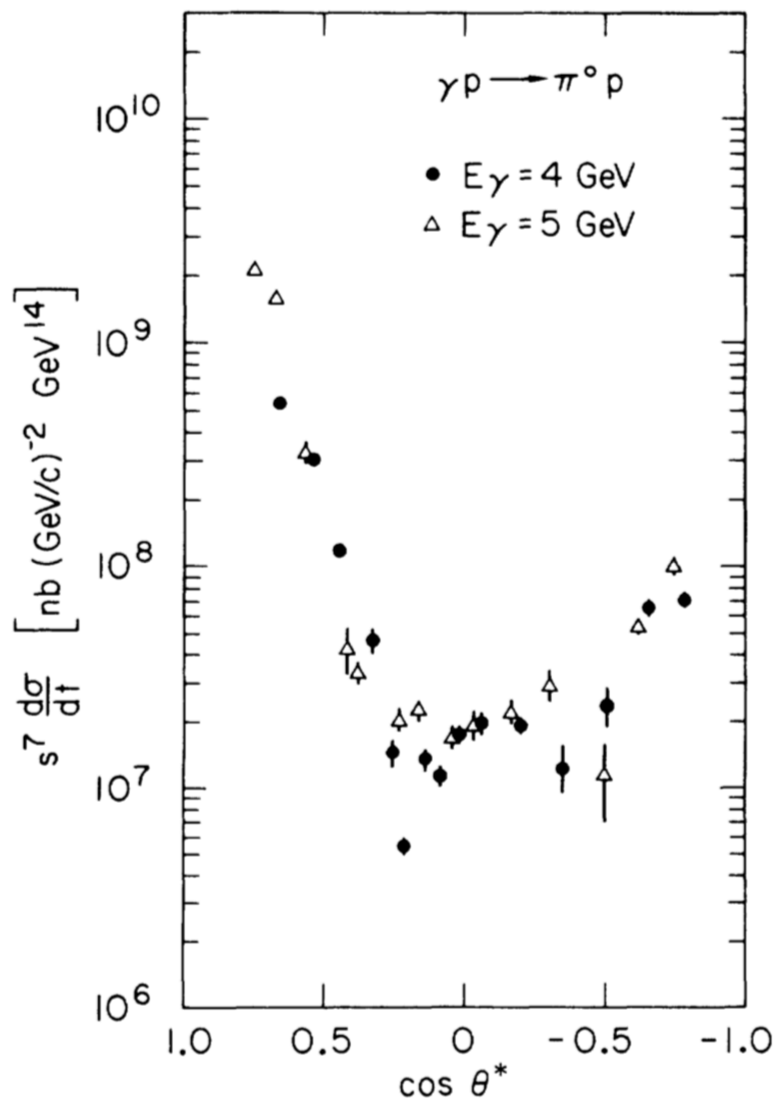


FIG. 9. $s^7 d\sigma/dt$ versus $\cos\theta^*$ for the reaction $\gamma p \rightarrow \pi^0 p$.

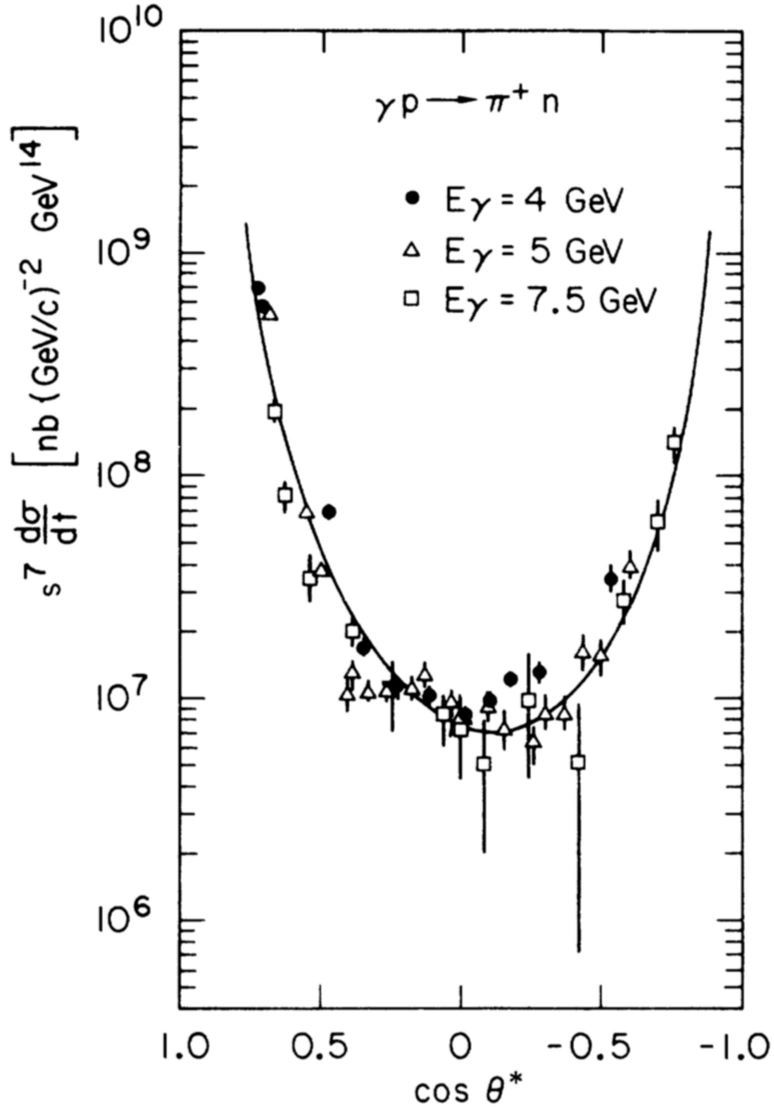


FIG. 6. $s^7 d\sigma/dt$ versus $\cos\theta^*$ for the reaction $\gamma p \to \pi^+ n$. The solid line shows the empirical function $(1-z)^{-5}(1+z)^{-4}$ where ($z = \cos\theta^*$), which is an empirical fit to the angular distribution.

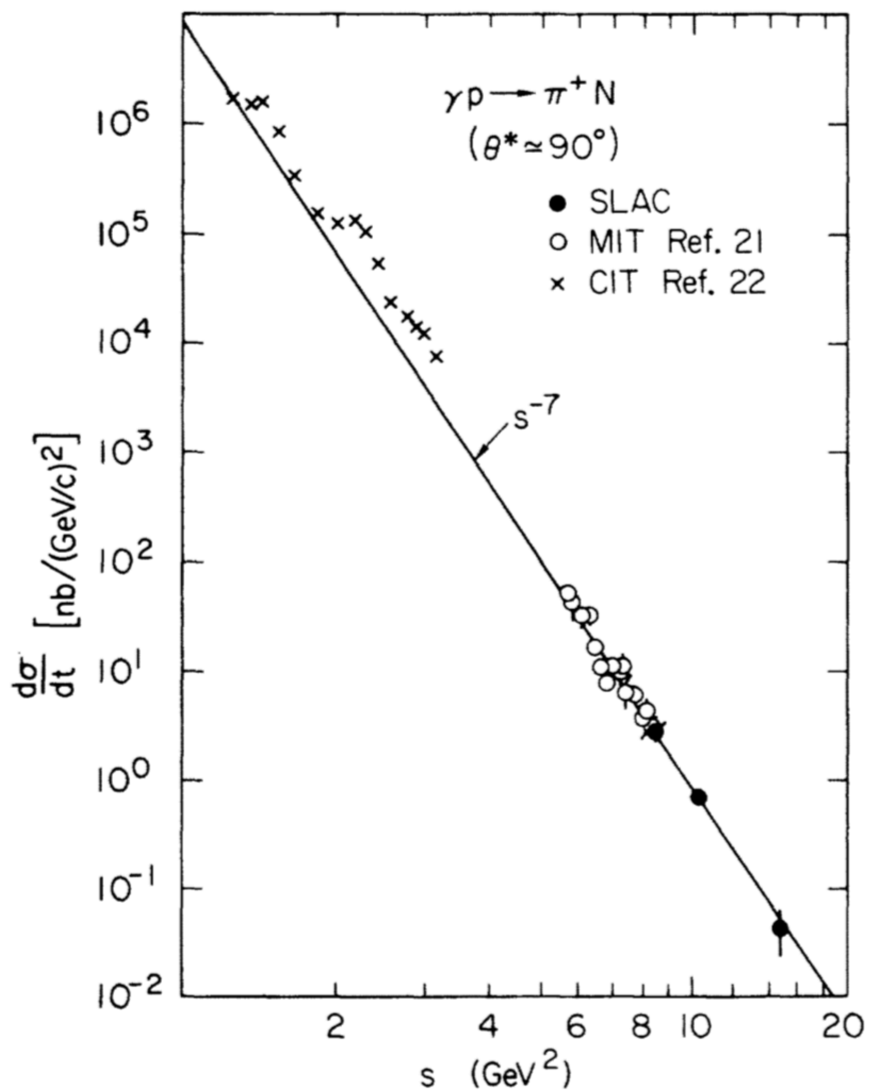


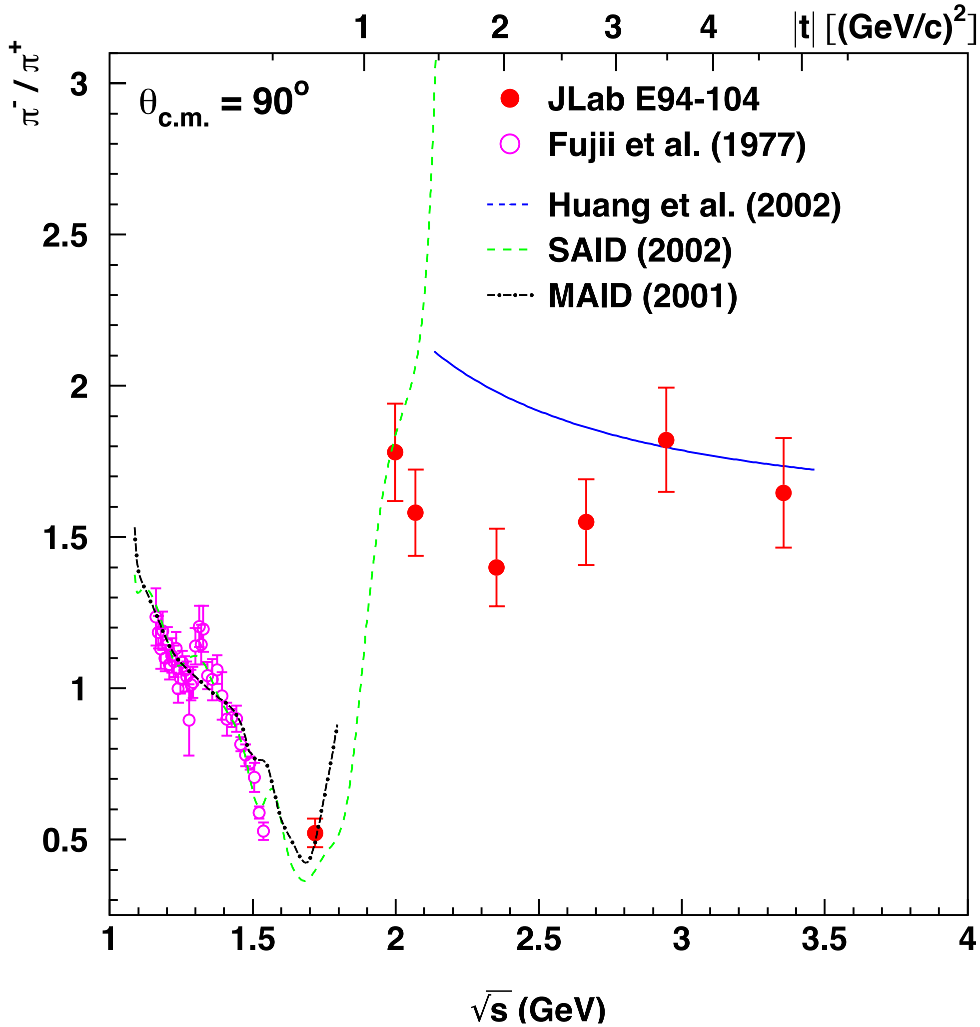
FIG. 20. 90° c.m. values of $d\sigma/dt$ versus s for the process $\gamma p \to \pi^+ n$ from several experiments from E_γ = 700 MeV to E_γ = 7.5 GeV. The solid line shows the function s^{-7} for reference.

PHYSICAL REVIEW C **71**, 044603 (2005)

Cross section measurements of charged pion photoproduction in hydrogen and deuterium from 1.1 to 5.5 GeV

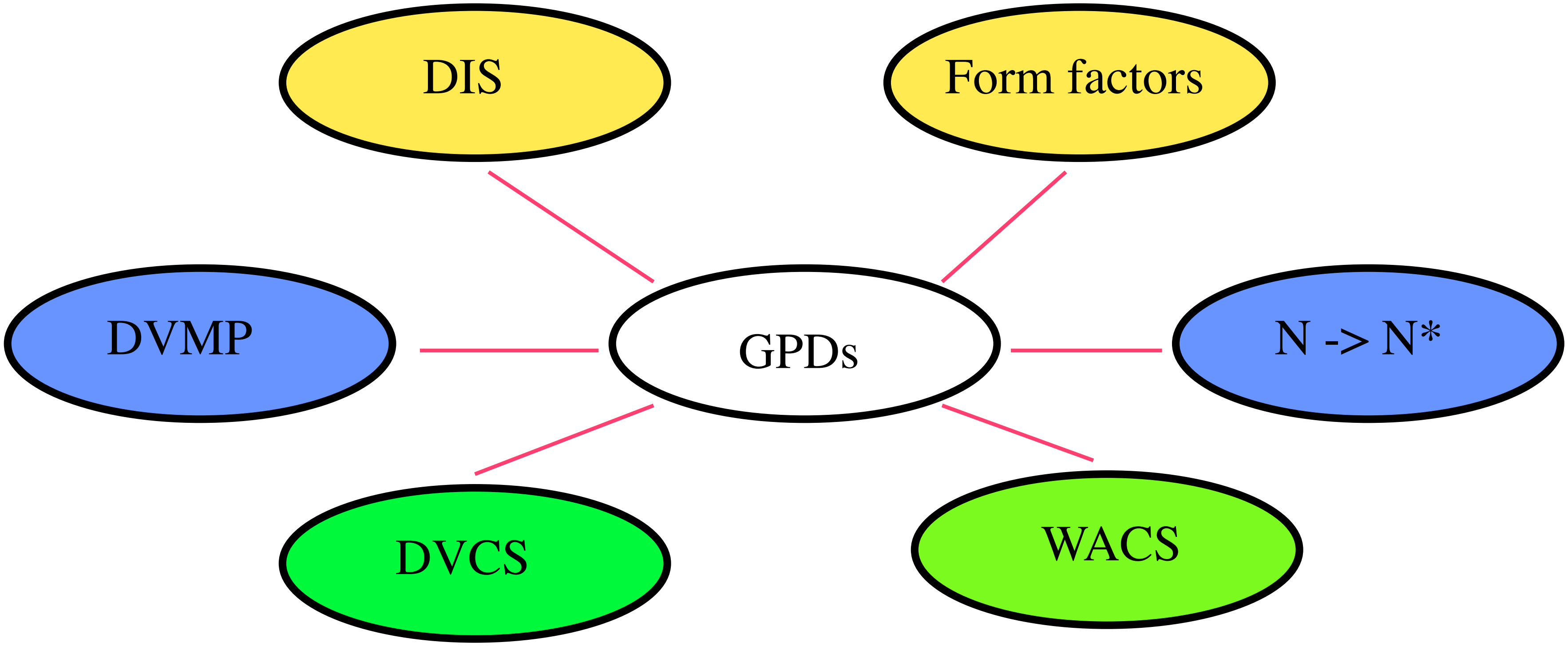
L. Y. Zhu,[1] J. Arrington,[2] T. Averett,[3,4] E. Beise,[5] J. Calarco,[6] T. Chang,[7] J. P. Chen,[4] E. Chudakov,[4] M. Coman,[8] B. Clasie,[1] C. Crawford,[1] S. Dieterich,[9] F. Dohrmann,[2] D. Dutta,[1] K. Fissum,[10] S. Frullani,[11] H. Gao,[1,12] R. Gilman,[4,9] C. Glashausser,[9] J. Gomez,[4] K. Hafidi,[2] O. Hansen,[4] D. W. Higinbotham,[1] R. J. Holt,[2] C. W. de Jager,[4] X. Jiang,[9] E. Kinney,[13] K. Kramer,[3] G. Kumbartzki,[9] J. LeRose,[4] N. Liyanage,[4] D. Mack,[4] P. Markowitz,[8] K. McCormick,[9] D. Meekins,[4] Z.-E. Meziani,[14] R. Michaels,[4] J. Mitchell,[4] S. Nanda,[4] D. Potterveld,[2] R. Ransome,[9] P. E. Reimer,[2] B. Reitz,[4] A. Saha,[4] E. C. Schulte,[2,7] J. Seely,[1] S. Širca,[1] S. Strauch,[9] V. Sulkosky,[3] B. Vlahovic,[15] L. B. Weinstein,[16] K. Wijesooriya,[2] C. Williamson,[1] B. Wojtsekhowski,[4] H. Xiang,[1] F. Xiong,[1] W. Xu,[1] J. Zeng,[17] and X. Zheng[1]
(Jefferson Lab Hall A Collaboration and Jefferson Lab E94-104 Collaboration)

The differential cross sections for the $\gamma n \to \pi^- p$ and the $\gamma p \to \pi^+ n$ processes were measured at Jefferson Lab. The photon energies ranged from 1.1 to 5.5 GeV, corresponding to center-of-mass energies from 1.7 to 3.4 GeV. The pion center-of-mass angles varied from 50° to 110°. The π^- and π^+ photoproduction data both exhibit a global scaling behavior at high energies and high transverse momenta, consistent with the constituent counting rule prediction and the existing π^+ data. The data suggest possible substructure of the scaling behavior, which might be oscillations around the scaling value. The data show an enhancement in the scaled cross section at center-of-mass energy near 2.2 GeV. The differential cross section ratios $[d\sigma/dt(\gamma n \to \pi^- p)/d\sigma/dt(\gamma p \to \pi^+ n)]$ at high energies and high transverse momenta can be described by calculations based on one-hard-gluon-exchange diagrams.



$\theta_{c.m.} = 90^o$
JLab E94-104
Fujii et al. (1977)
Huang et al. (2002)
SAID (2002)
MAID (2001)
π^- / π^+
$|t|$ [(GeV/c)^2]
1
2
3
4
0.5
1
1.5
2
2.5
3
1
1.5
2
2.5
3
3.5
4
$\sqrt{s}$ (GeV)

Unification of nucleon structure within GPDs



x ξ t

Signatures of the handbag mechanism in wide-angle photoproduction of pseudoscalar mesons

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Received: 15 September 2003 / Revised version: 2 December 2003 /
Published online: 29 January 2004 –

Abstract. Wide-angle photoproduction of pseudoscalar mesons is investigated under the assumption of dominance of the handbag mechanism, considering both quark helicity flip and non-flip. The partonic subprocess, meson photoproduction off quarks, is analysed with the help of a covariant decomposition of the subprocess amplitudes which is independent of a specific meson generation mechanism. As examples of subprocess dynamics, however, the twist-2 as well as two-particle twist-3 contributions are explicitly calculated. Characteristic features of the handbag approach are discussed in dependence upon the relative magnitudes of the invariant functions. Differential cross sections and spin correlations are predicted to show a characteristic behaviour which allows one to test the underlying assumption of handbag dominance.

$$\frac{\mathrm{d}\sigma(\gamma n \to \pi^- p)}{\mathrm{d}\sigma(\gamma p \to \pi^+ n)} = \left(\frac{e_u s + e_d u}{e_u u + e_d s}\right)^2$$

Signatures of the handbag mechanism in wide-angle photoproduction of pseudoscalar mesons

H.W. Huang[1], R. Jakob[2], P. Kroll[2], K. Passek-Kumerički[3]

[1] Department of Physics, University of Colorado, Boulder, CO 80309-0390, USA
[2] Fachbereich Physik, Universität Wuppertal, 42097 Wuppertal, Germany
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The GPDs model predicts too small cross section

PHYSICAL REVIEW C **98**, 015207 (2018)

Exclusive photoproduction of π^0 up to large values of Mandelstam variables s, t, and u with CLAS

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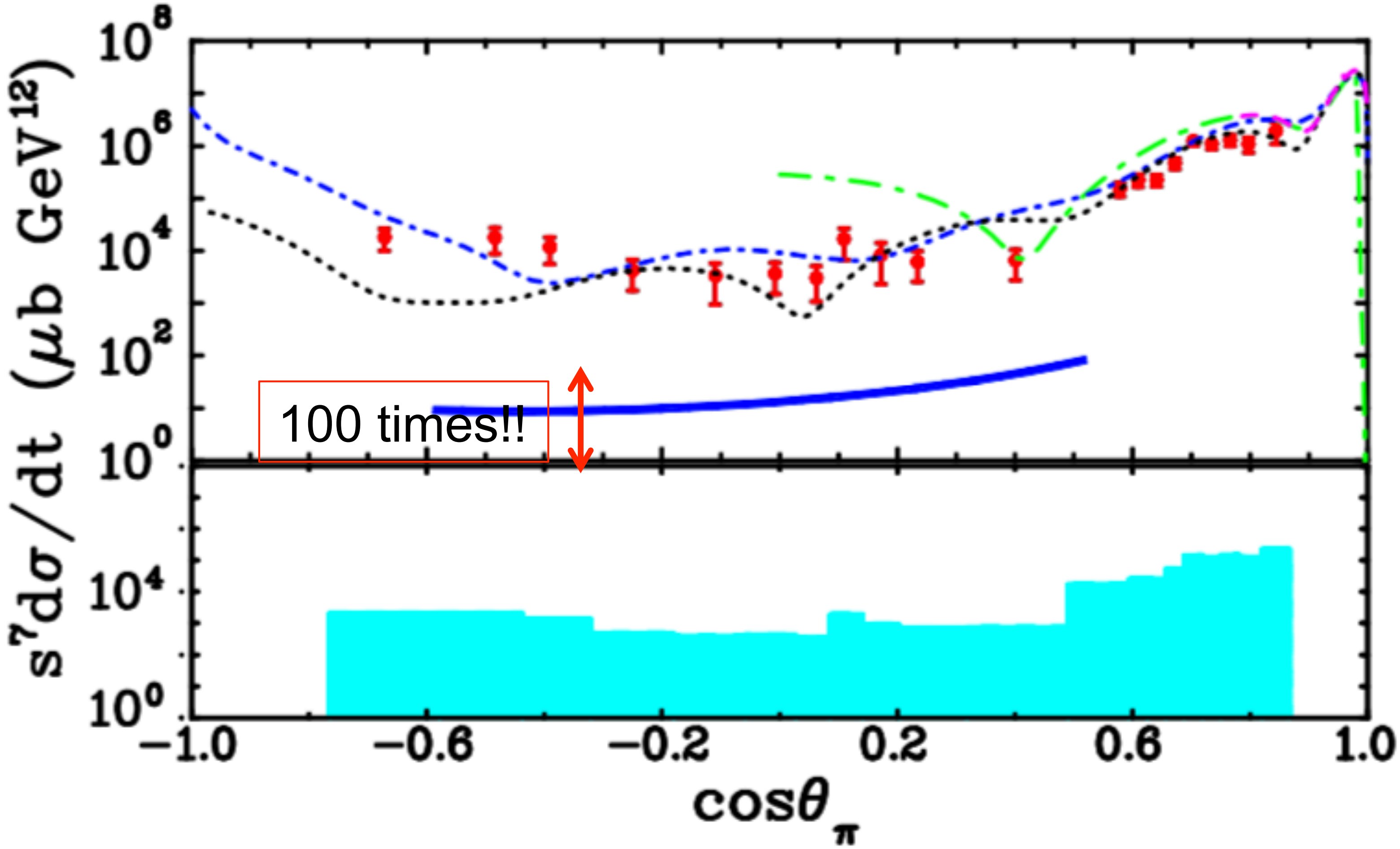


What is the mechanism of scaling?

pQCD

participating in the reaction. If the photon is assumed to be one elementary field, then the prediction for meson photoproduction is

$$\frac{d\sigma}{dt} \sim \frac{1}{s^7} f(\cos\theta^*) .$$

It will be shown that the results of the present experiment are consistent with these predictions in the large-c.m.-angle region.

GPDs

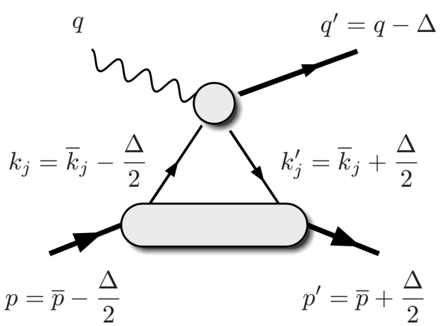


Fig. 1. The handbag diagram for photo- and electroproduction of mesons. The large blob represents a baryon GPD, while the small one stands for meson photo- and electroproduction off partons. The momenta of the various particles are indicated

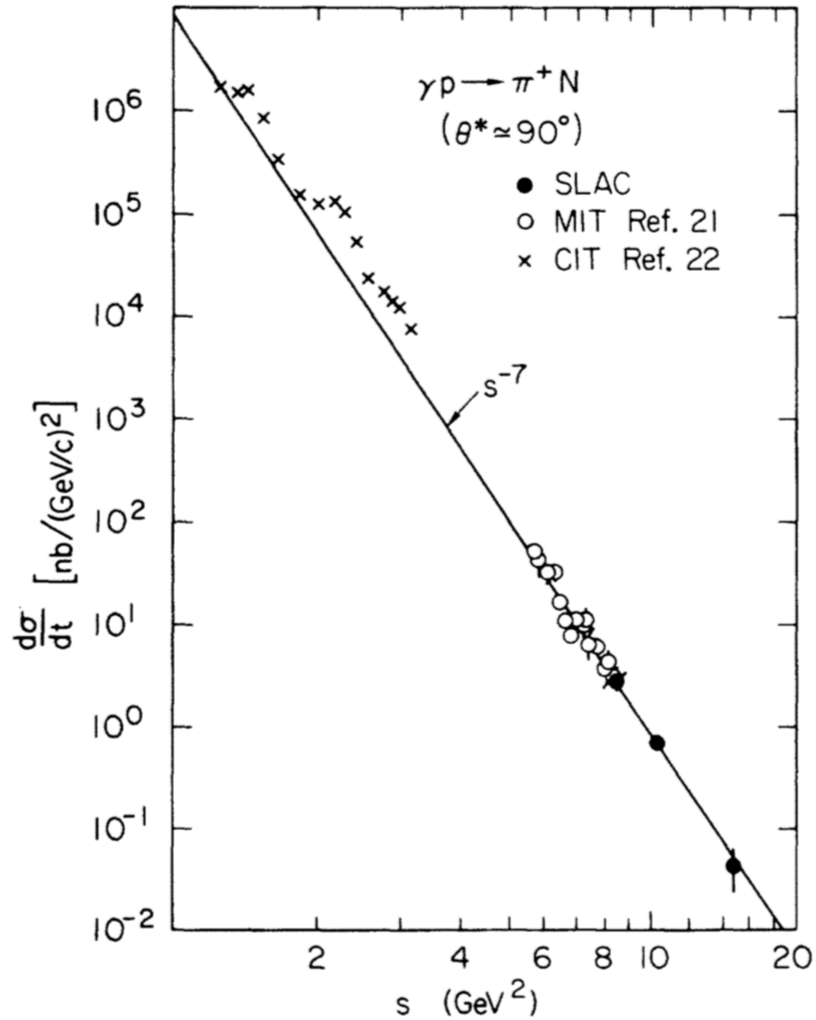
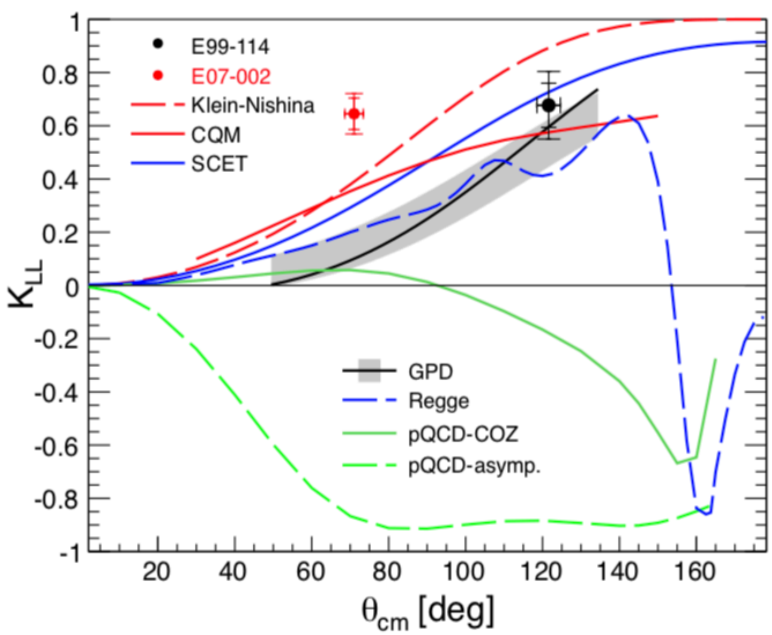


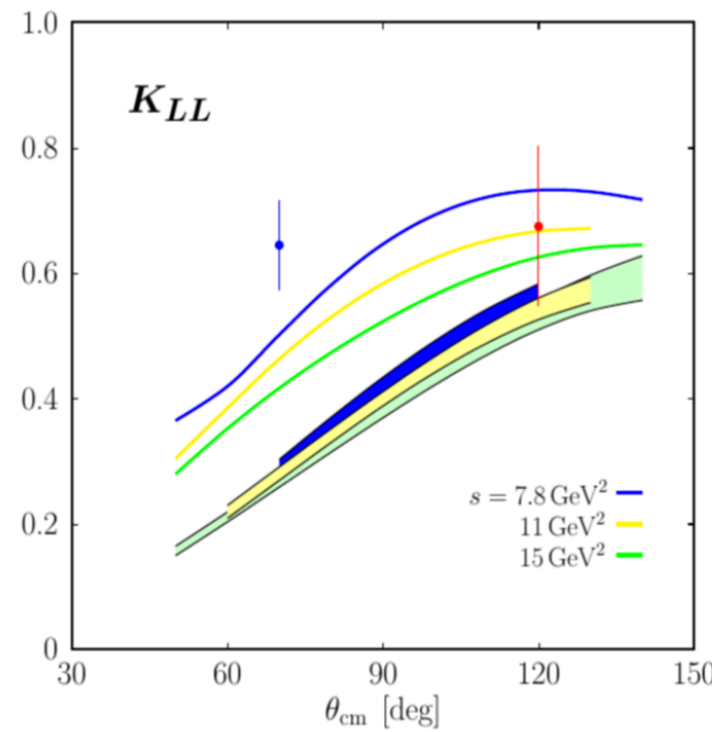
FIG. 20. 90° c.m. values of $d\sigma/dt$ versus s for the process $\gamma p \to \pi^+ n$ from several experiments from E_γ = 700 MeV to E_γ = 7.5 GeV. The solid line shows the function s^{-7} for reference.

Exclusive photon-proton reaction: WACS results are in reasonable agreement with GPDs

Hamilton *et al.* PRL94 (2005)
Fanelli *et al.* PRL115 (2015)

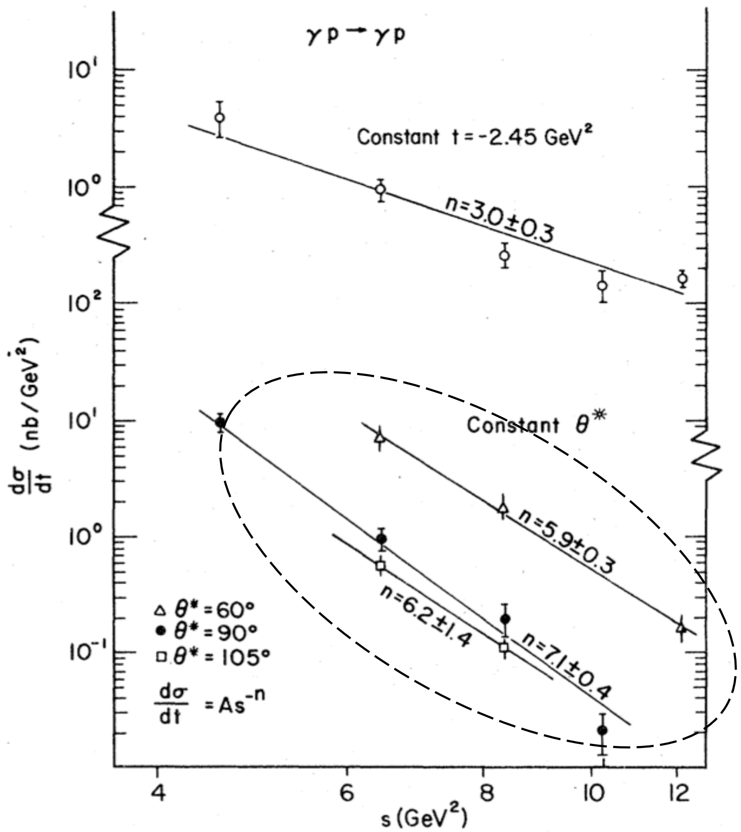


Diehl & Kroll Eur. Phys. J. C73 (2013)
Kroll arXiv:hep-ph/1703.05000 (2017)



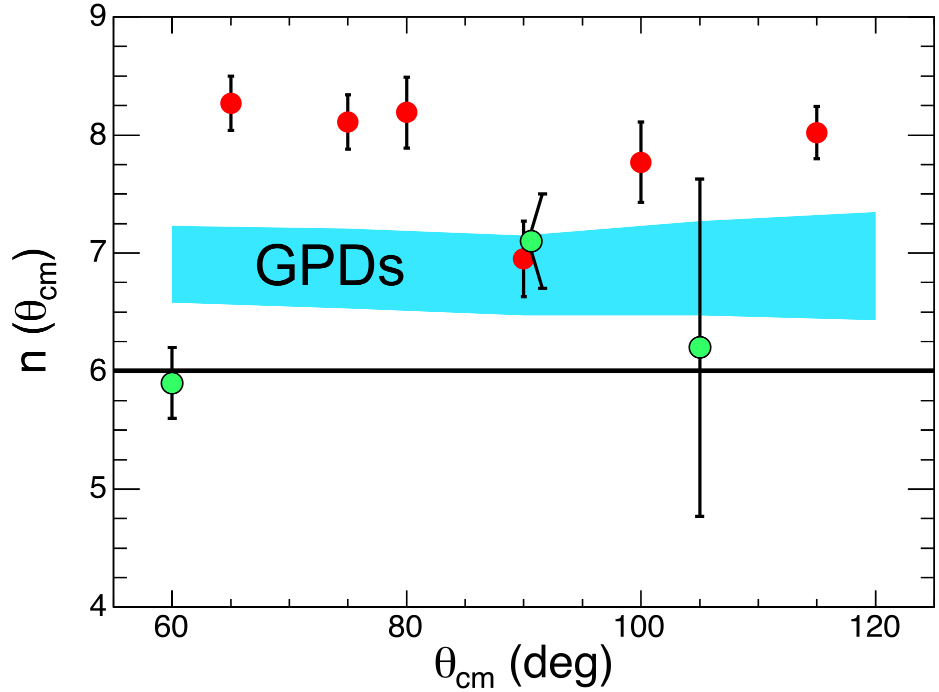
- Results strongly favour leading quark mechanism ($x = 1$).

Exclusive photon-proton reaction: WACS results are in reasonable agreement with GPDs

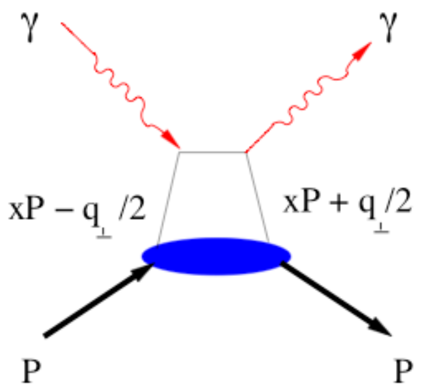


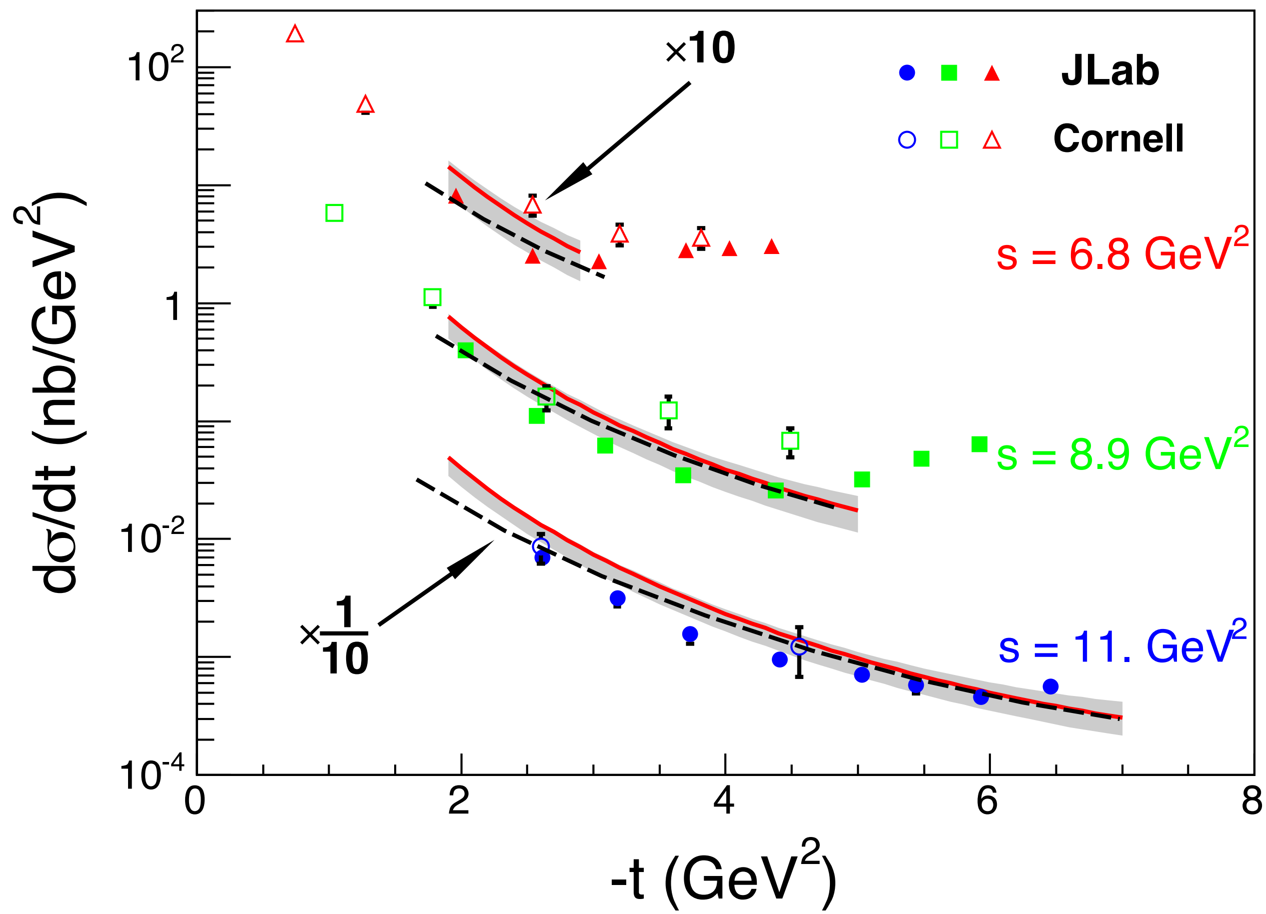
Hard-gluon, n= 6

PRL 98, 152001 (2007)



Exclusive photon-proton reaction: WACS results are in reasonable agreement with GPDs





Need to do the polarization test of a handbag mechanism for exclusive pion production

- A suggestion: A_{LL} vs. K_{LL} , a prediction in the pion photo production, an experiment needs 1% accuracy for A_{LL}

Selection	K_{LL}	K_{LS}
$\mathrm{WACS}_{\text{this experiment}}$	$0.645\pm0.059\pm0.048$	$-0.089\pm0.059\pm0.040$
$\mathrm{WACS}_{\mathrm{E99-114}}$	$0.678\pm0.083\pm0.04$	$0.114\pm0.078\pm0.04$
$\mathrm{Pion}_{\text{this experiment}}$	$\boxed{-0.082\pm0.007}$	-0.296 ± 0.007
$\mathrm{Pion}_{\mathrm{E99-114}}$	$\boxed{0.532\pm0.006}$	0.480 ± 0.006

A first comment from P. Kroll:

Twist-3 would be important for K_{LL} - A_{LL} in the pion photo-production process

Twist-3 contributions to wide-angle photoproduction of pions

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(Received 26 February 2018; published 23 April 2018)

We investigate wide-angle π^0 photoproduction within the handbag approach to twist-3 accuracy. In contrast to earlier work both the 2-particle as well as the 3-particle twist-3 contributions are taken into account. It is shown that both are needed for consistent results that respect gauge invariance and crossing properties. The numerical studies reveal the dominance of the twist-3 contribution. With it fair agreement with the recent CLAS measurement of the π^0 cross section is obtained. We briefly comment also on wide-angle photoproduction of other pseudoscalar mesons.

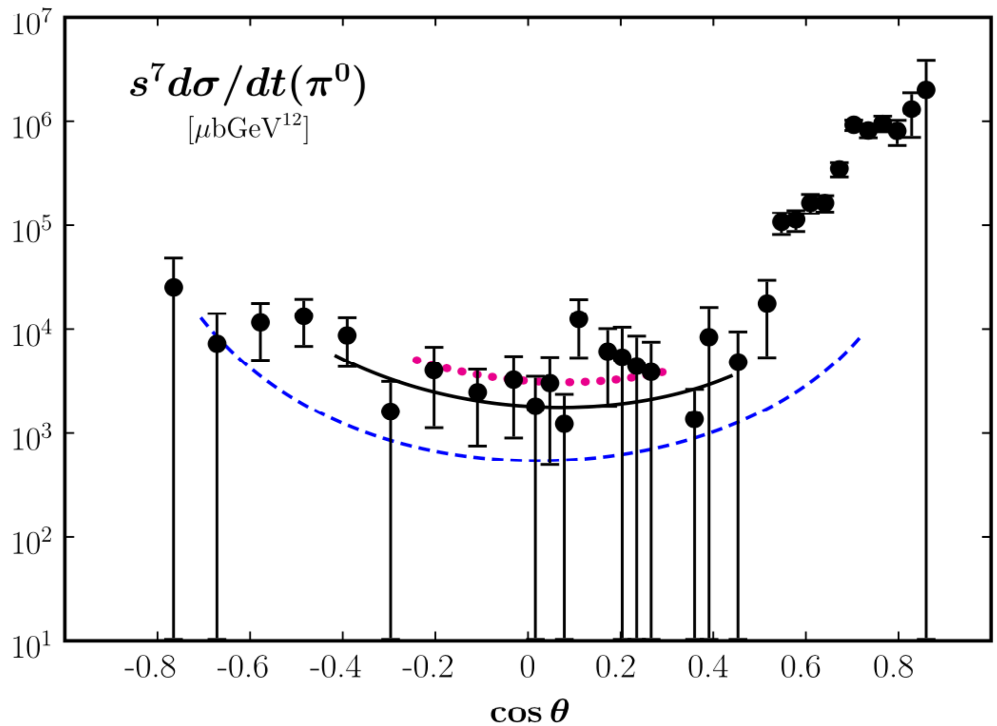
DOI: 10.1103/PhysRevD.97.074023

Twist-3 contributions to wide-angle photoproduction of pions

P. Kroll

Fac ... *rmany*

Theoreti ... *eb, Croatia*



We investigate ... to twist-3 accuracy. In contrast to earli ... utions are taken into account. It is show ... variance and crossing properties. The nu ... With it fair agreement with the recent C ... ly comment also on wide-angle photo|

DOI: 10.1103/PhysI

FIG. 3. Results for the cross section of π^0 photoproduction versus the cosine of the c.m.s. scattering angle, θ. The solid (dashed, dotted) curves represent our results at $s = 11.06(20, 9)$ GeV^2. The data at $s = 11.06$ GeV^2 are taken from CLAS [34]. The cross sections are multiplied by s^7, and the theoretical results are only shown for $-t$ and $-u$ larger than 2.5 GeV^2.

Twist-3 contributions to wide-angle photoproduction of pions

Fa *nany*

Theore *, Croatia*

We investigat… twist-3 accuracy. In contrast to ear… tions are taken into account. It is sho… riance and crossing properties. The n… th it fair agreement with the recent … comment also on wide-angle photo…

DOI: 10.1103/Phys…

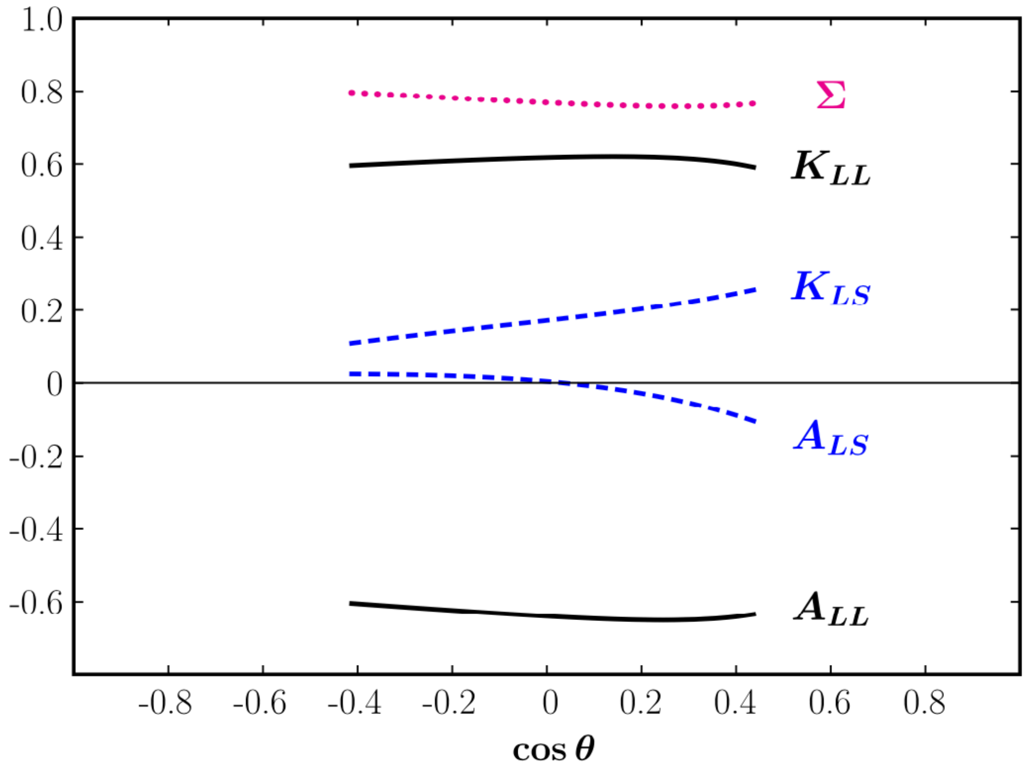


FIG. 4. Predictions for spin observables of π^0 photoproduction at $s = 11.06$ GeV^2. The parametric uncertainty is $\simeq$15% near 90 deg.

In Fig. 4 we show predictions on the spin-dependent observables for π^0 photoproduction. One sees that A_{LL} and K_{LL} are large in absolute value and almost mirror symmetrical. The observables A_{LS} and K_{LS} are small in

How to do such an experiment?

A good case for pi- from a neutron

$$\text{ALL from } {}^3\vec{H}e(e, e'\pi^- \, p)e\,p\,p$$

$$\text{KLL from } D(e, e'\pi^- \, \vec{p})e\,p$$

SBS and BB as in the GEn experiment
(a two-arm detector)

July, 29 2019

Spin effects in wide-angle photoproduction of negatively charged pions

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Private Communication

The spin observables for $\gamma n \to \pi^- p$ are evaluated with twist-2 and the complete twist-3 contributions as described in [1] for π^0 photoproduction. The results are shown in the plot. The subprocess amplitudes from [1] are generalized to the case of charged pions. Its 2-particle twist-3 part were already given in [2]. The twist-2 and twist-3 pion wave functions are the same as those used in [1]. The flavor form factors are also the same as in [1] but they now contribute to π^--production in the combination is only seen for small $-u$. For small $-t$, on the other hand, one rather sees the trend to the twist-2 behavior

$$A_{LL} = K_{LL} \tag{3}$$

with small absolute values.

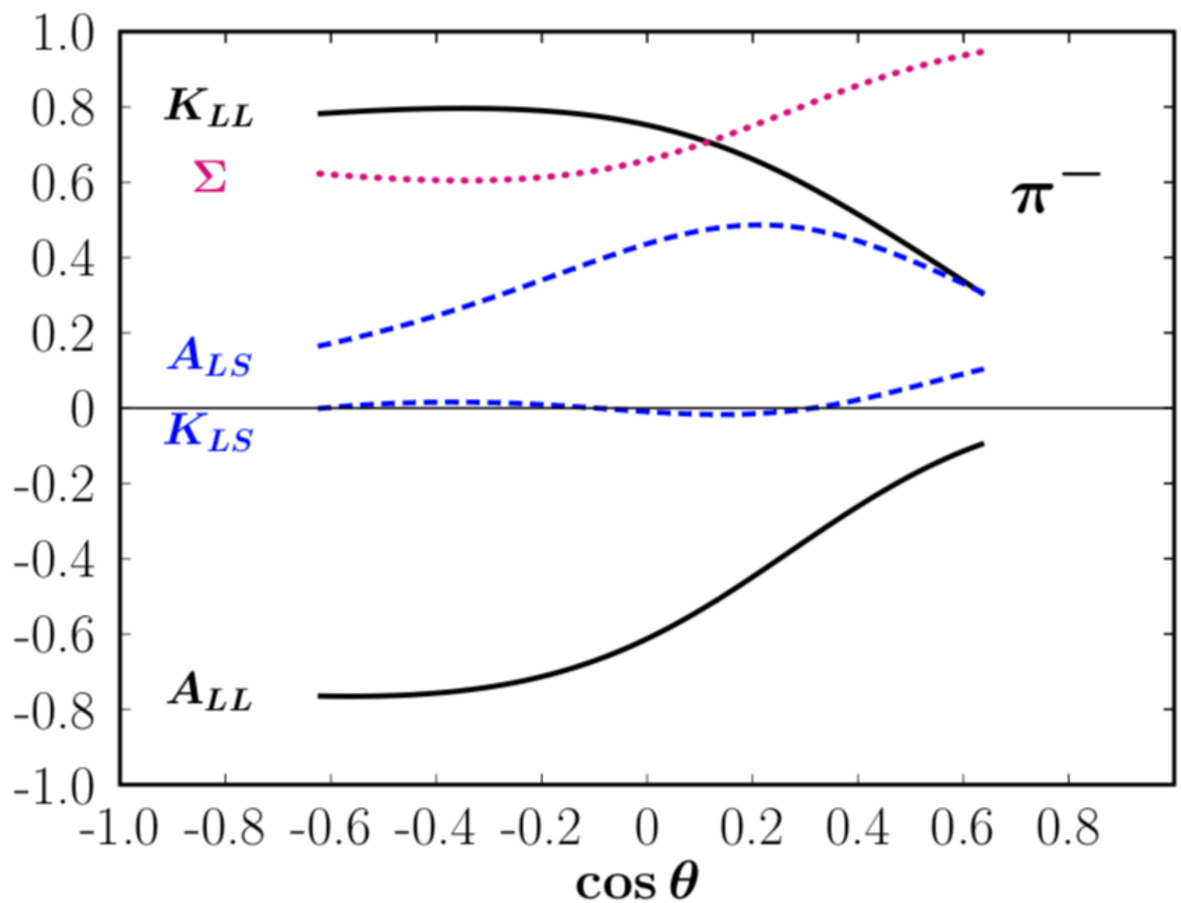
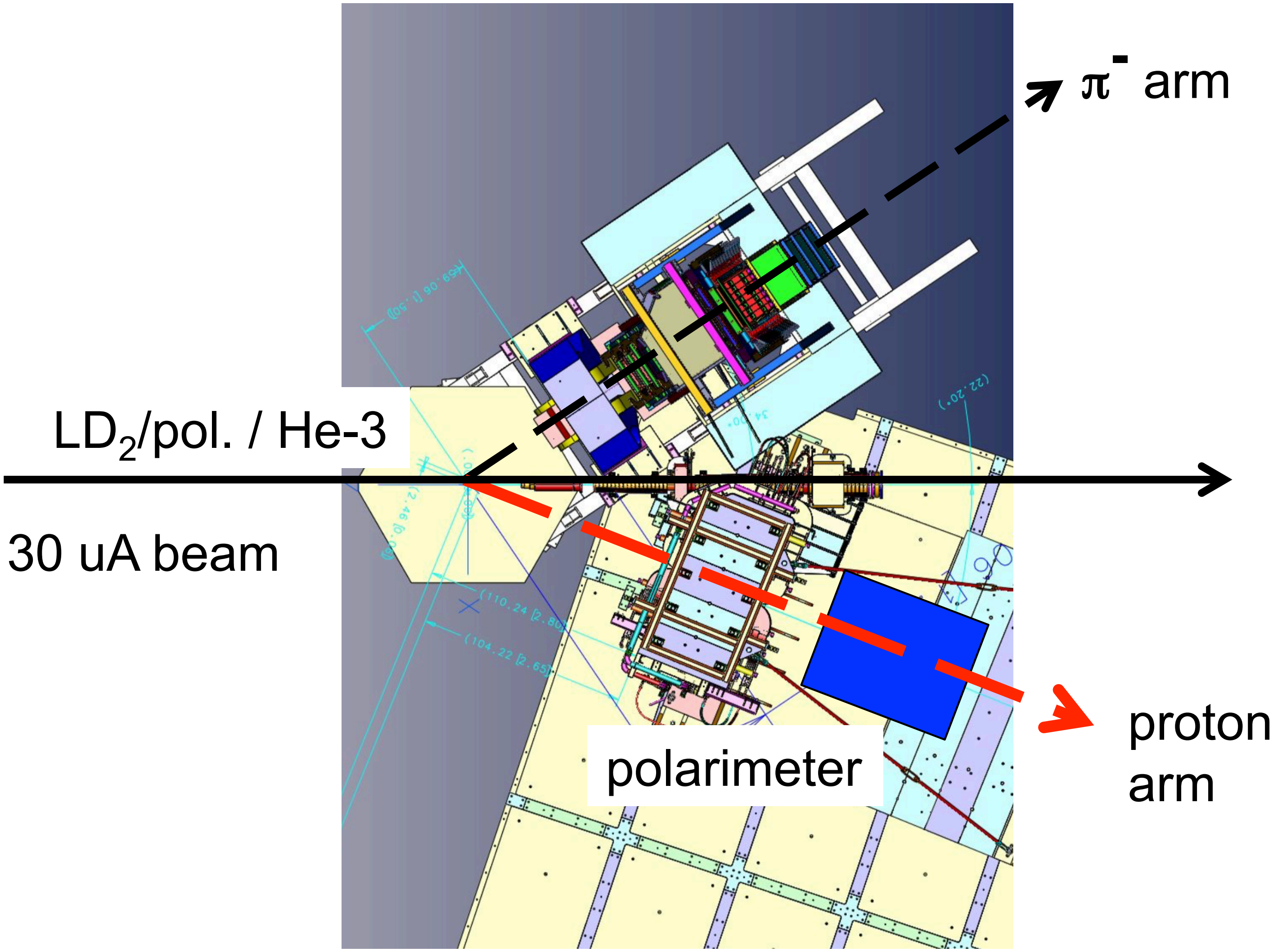
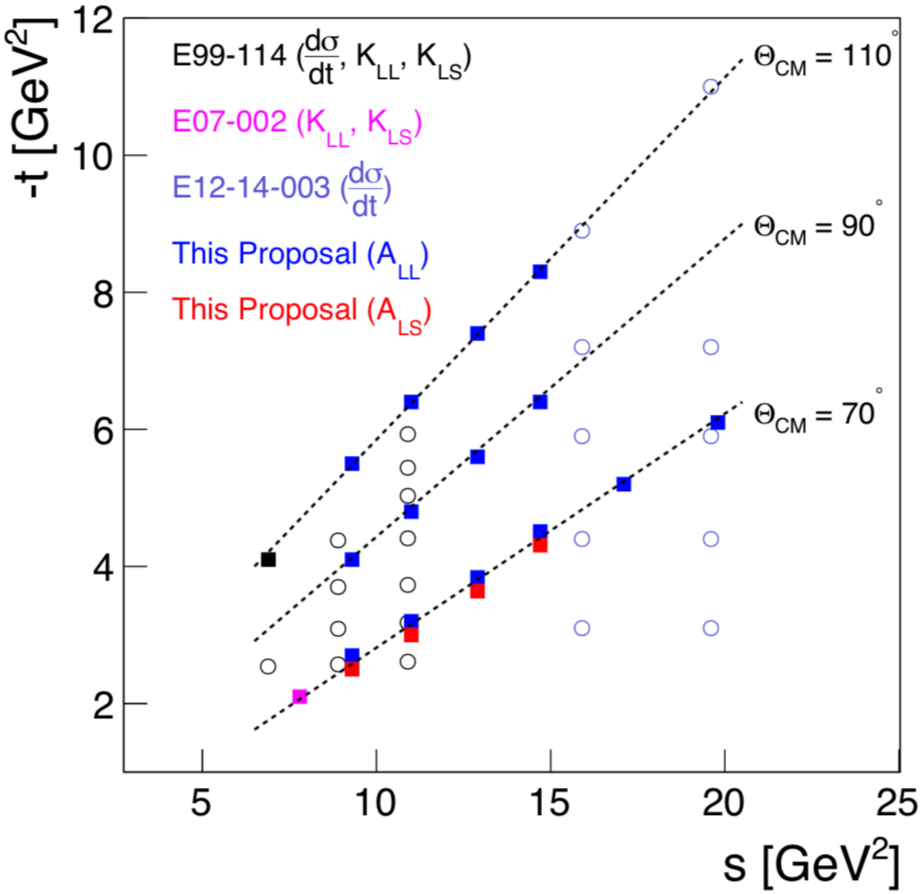


Figure 1: Predictions for spin observables of π^- photoproduction at $s = 15\ \mathrm{GeV}^2$. Predictions are only shown for $-t$ and $-u$ larger than $2.5\ \mathrm{GeV}^2$.

Layout for the proposed experiments



The pi-0 ALL experiment – E12-17-009



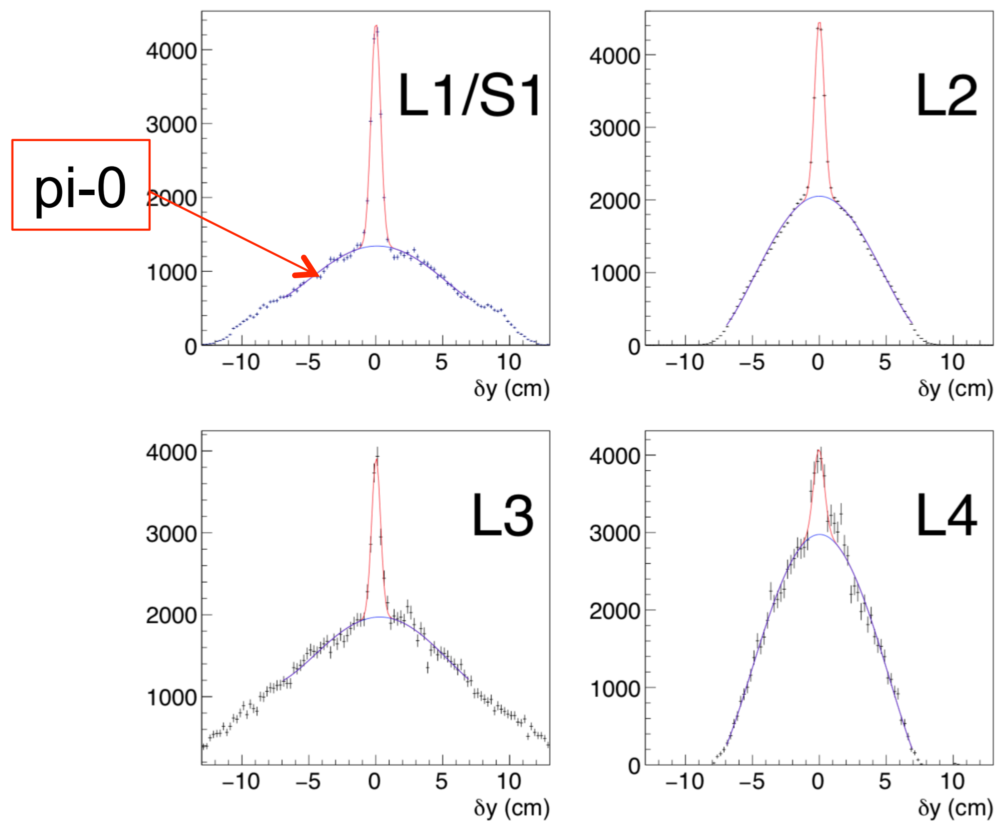


Figure 2: Subtraction of background events for one bin in each kinematic setting (the distributions of L1 and S1 will be very similar). The WACS events are shown in red, while the background is shown in blue.

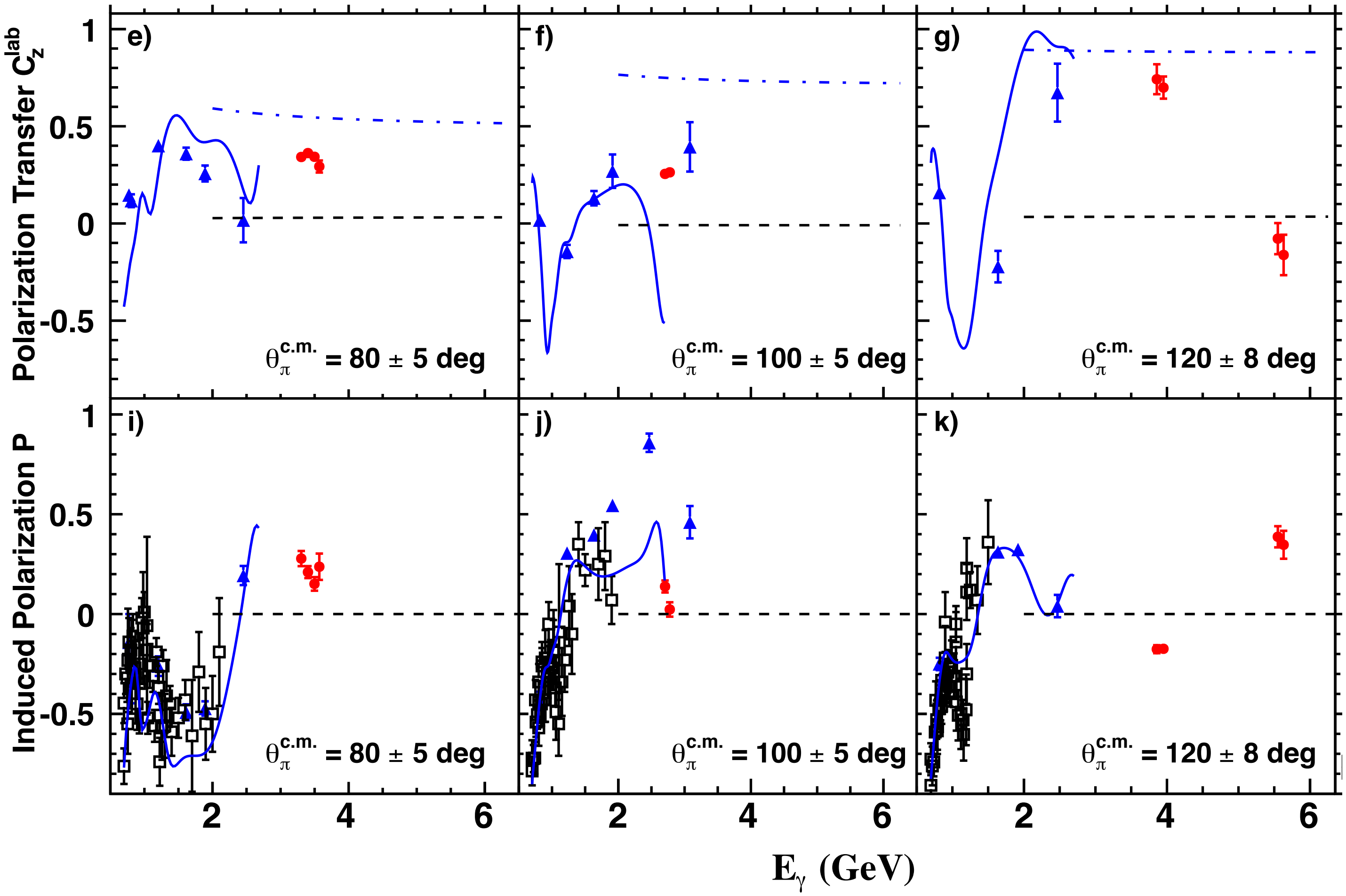
Polarization components in π^0 photoproduction at photon energies up to 5.6 GeV

W. Luo,[1] E. J. Brash,[2,3] R. Gilman,[3,4] M. K. Jones,[3] M. Meziane,[5] L. Pentchev,[5] C. F. Perdrisat,[5] A. J. R. Puckett,[6,7] V. Punjabi,[8] F. R. Wesselmann,[8] A. Ahmidouch,[9] I. Albayrak,[10] K. A. Aniol,[11] J. Arrington,[12] A. Asaturyan,[13] O. Ates,[10] H. Baghdasaryan,[14] F. Benmokhtar,[15] W. Bertozzi,[6] L. Bimbot,[16] P. Bosted,[3] W. Boeglin,[17] C. Butuceanu,[18] P. Carter,[2] S. Chernenko,[19] M. E. Christy,[10] M. Commisso,[14] J. C. Cornejo,[11] S. Covrig,[3] S. Danagoulian,[9] A. Daniel,[20] A. Davidenko,[21] D. Day,[14] S. Dhamija,[17] D. Dutta,[22] R. Ent,[3] S.

KLL =

the data from GEP-3

higher energy in GEp/SBS



Unification within GPDs