Deuteron Photodisintegration: Hall C E96-003 and other experiments

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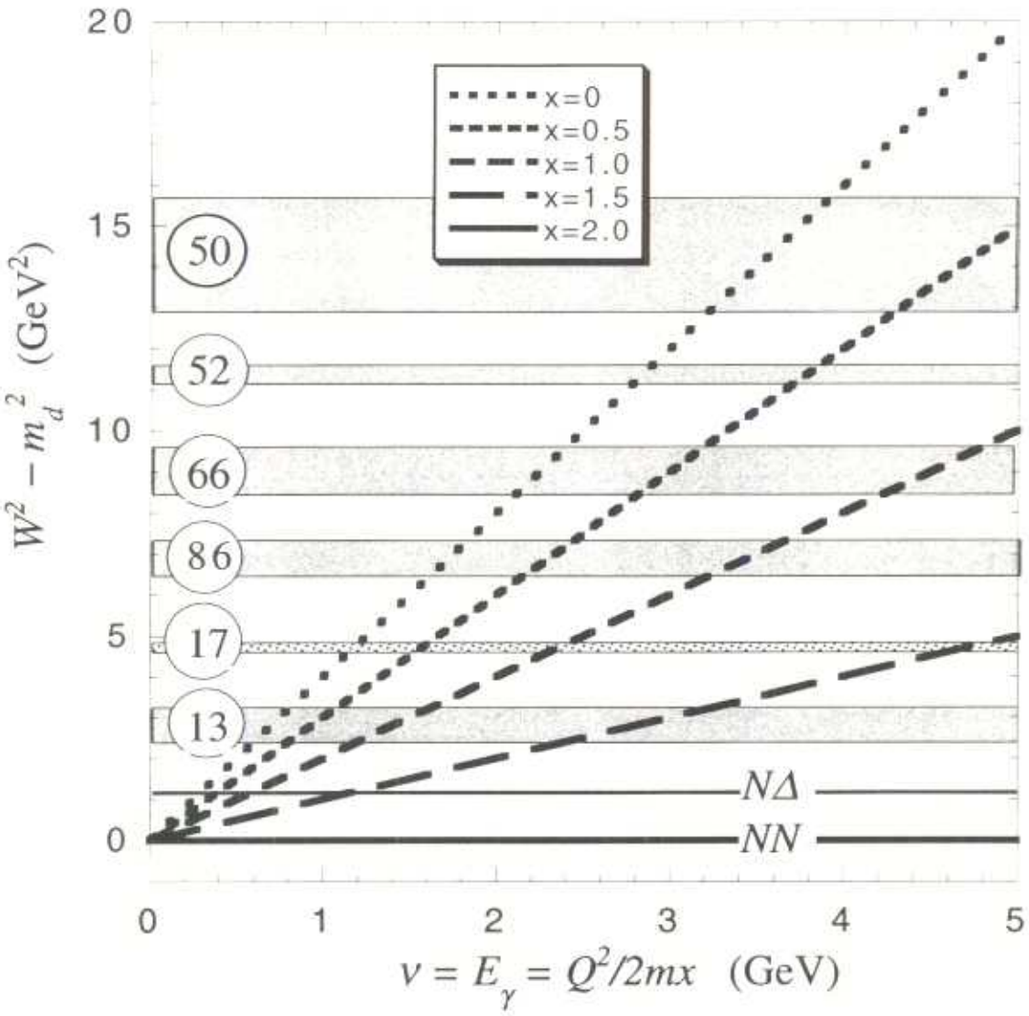
- Motivation
- What We Have Learned
- Future Possibilities

JLab Hall C Meeting

January 11, 2002

Motivation

- Are quarks (e.g., pQCD) needed to explain high energy exclusive reactions?
- Do theories based on meson-baryon degrees of freedom break down at high energies and momentum transfers?
- Quark and hadronic theories provide, *in principle*, equivalent / alternate descriptions of the reaction. If the data are in kinematics for which both theories can be formulated and converge.
- A satisfactory microscopic hadronic model for photodisintegration above 1 GeV appears unlikely in the near future


x=0
x=0.5
x=1.0
x=1.5
x=2.0
50
52
66
86
17
13
NΔ
NN
20
15
10
5
0
0
1
2
3
4
5
$W^2 - m_d^{\ 2}$ (GeV^2)
$\nu = E_\gamma = Q^2/2mx$ (GeV)

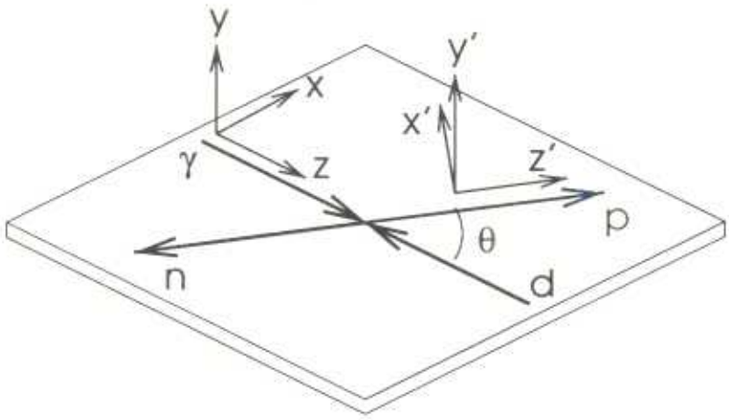
Recent experiments

- Hall C E96-003: cross sections to 5.5 GeV
  E. Schulte *et al*, Phys. Rev. Lett. **87**, 102302 (August 2001)
- Hall A E89-019: recoil polarizations to 2.4 GeV
  K. Wijesooriya *et al*, Phys. Rev. Lett. **86**, 2975 (April 2001).
- Hall A E99-008: more extensive angular distributions
  E. Schulte *et al*, to be published
- Hall B E93-017: cross section angular distributions

- Hall A E00-007: followup on recoil polarizations "scheduled" for March 2002

- Hall A E01-007: followup on recoil polarizations

Deuteron Spin Observables

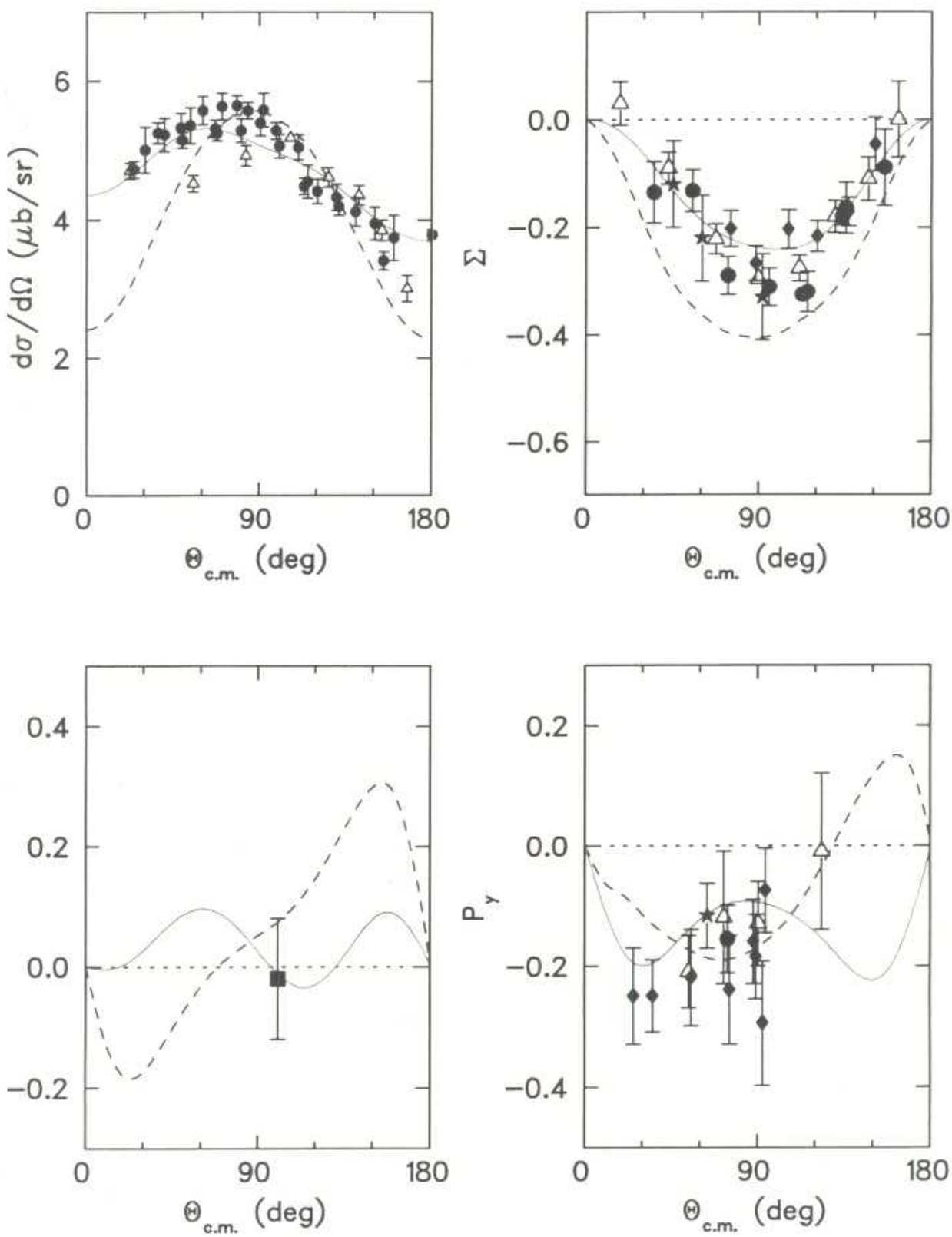


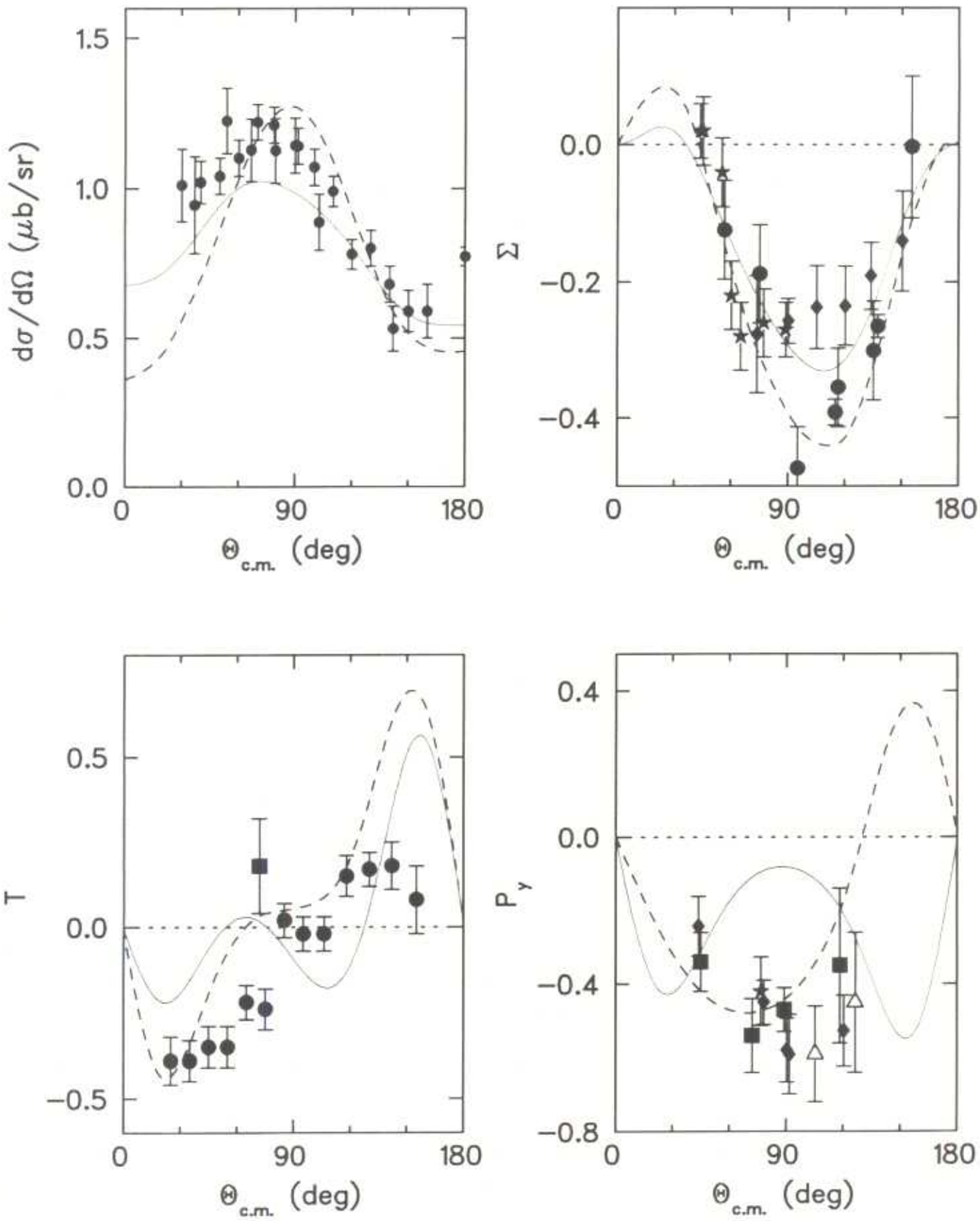
- p_y: induced proton polarization, along $\hat{y}$
- Σ: linearly polarized photon asymmetry, photon polarized along $\hat{y}$ vs. $\hat{x}$
- T: cross section asymmetry, with target vector polarized along $\hat{y}$
- $C_{x'}, C_{z'}$: circularly polarized photon to recoil proton polarization transfer, along $\hat{x}', \hat{z}'$

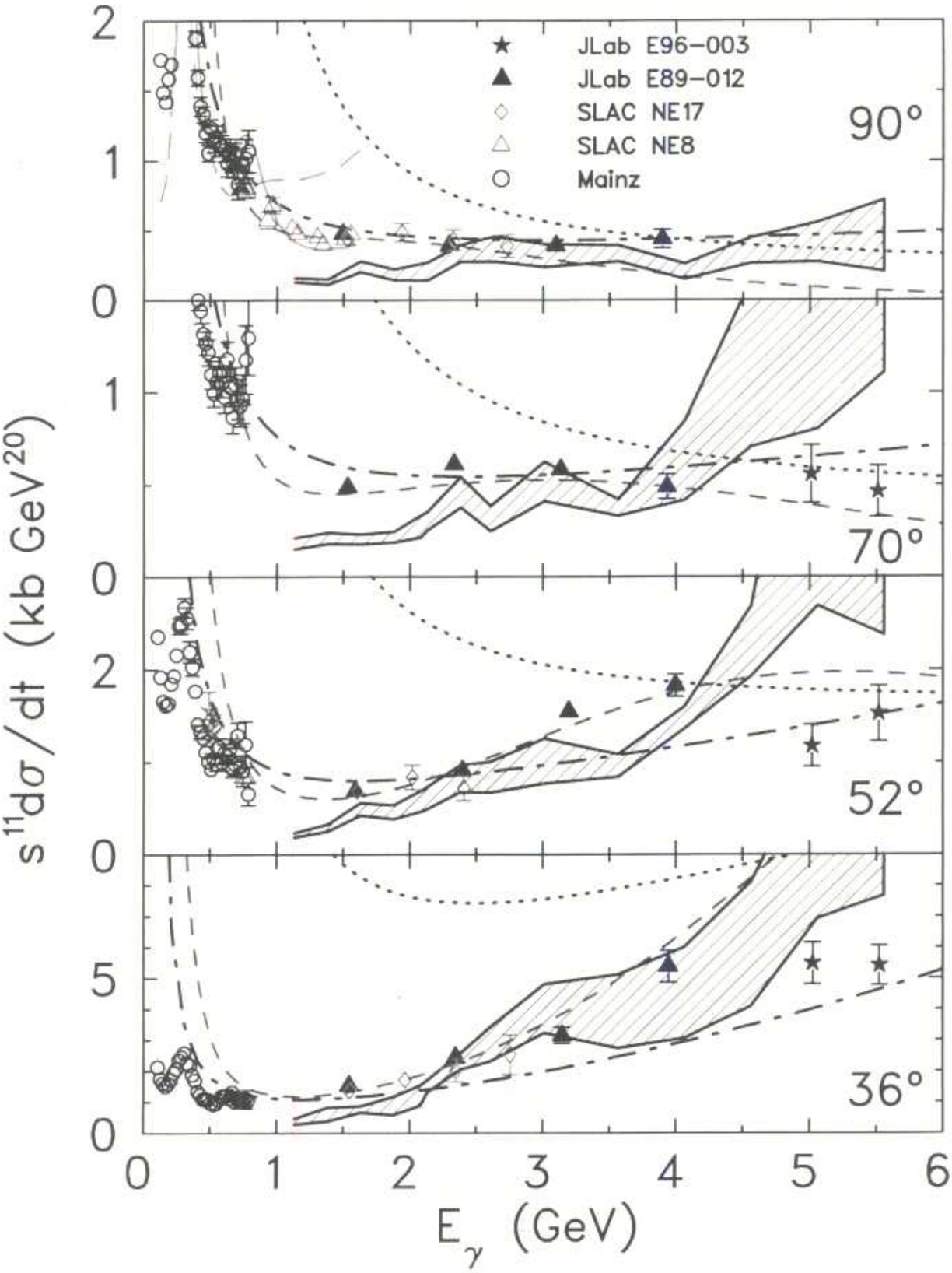
Table 1. Compilation of deuteron photodisintegration polarization observables.

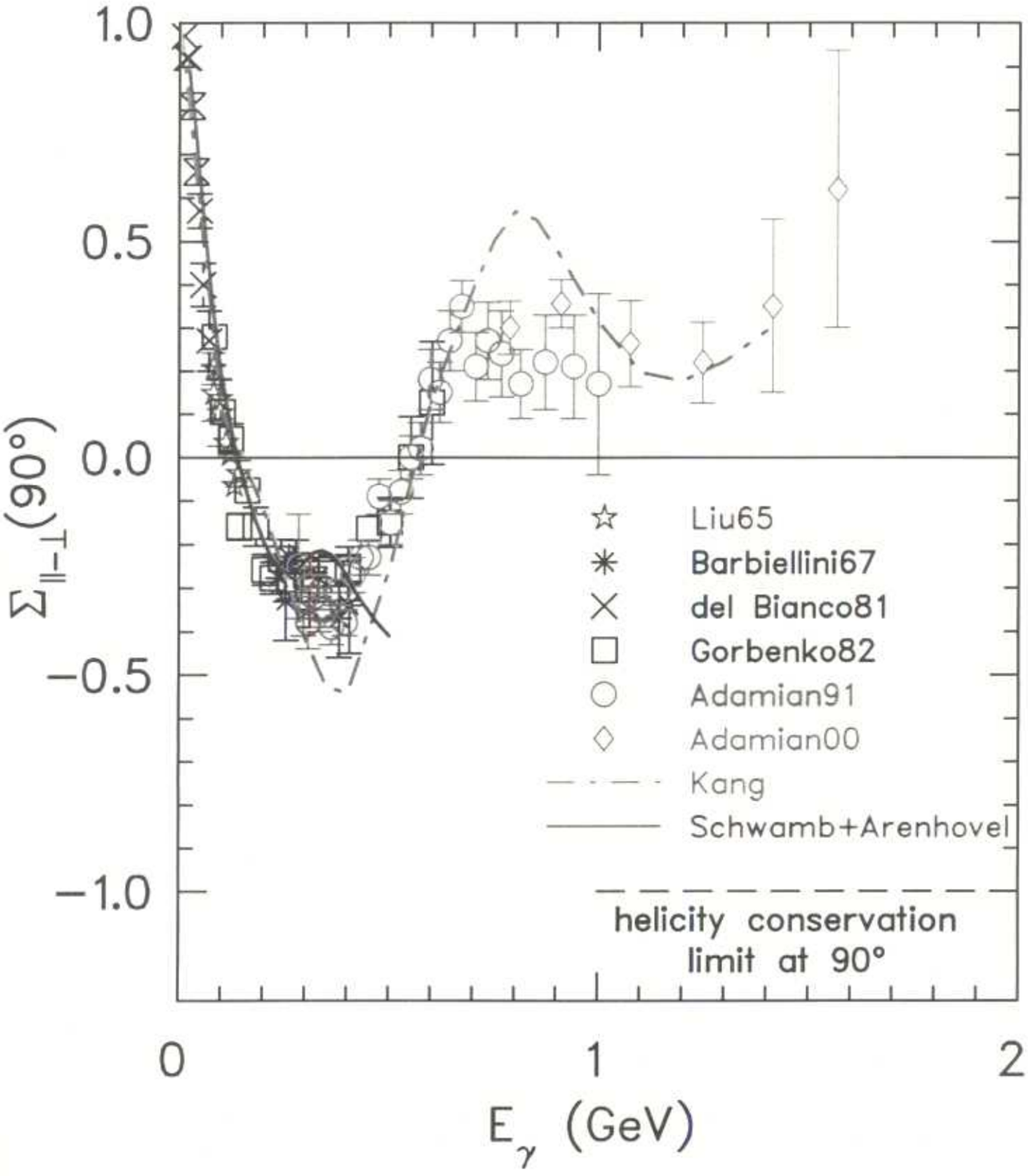
Laboratory	Observable	E (MeV)	$\theta_{cm}(^\circ)$	# of Points	Reference
MIT	p_y	250	49	1	[7]
Livermore	p_y^n	2.75	50 - 136	5	[8]
Zürich	p_y^n	2.75	44, 94	2	[9]
Illinois	p_y^n	12 - 23	148	4	[10]
RPI	p_y^n	12 - 30	90	3	[11]
Purdue	p_y	294	72	1	[12]
Stanford	Σ	80 - 140	45, 90, 135	41	[13, 14]
Livermore	p_y^n	2.75	32 - 152	7	[15]
Frascati	Σ	235 - 404	90	8	[16]
Stanford	p_y	172 - 436	39 - 126	19	[17]
Bonn	p_y	282 - 405	74 - 98	4	[18]
Yale	p_y^n	7 - 30	45, 90	16 (19?)	[19]
Yale	p_y^n	7 - 13	90	3	[20]
Tokyo	p_y	352 - 697	45 - 133	27	[21, 22, 23, 24]
Kharkov	Σ	80 - 600	75 - 150	109	[25, 26, 27, 28]
Frascati	Σ	10 - 69	90	9	[29, 30]
Kharkov	p_y	375 - 700	43, 78, 90, 120	40	[31, 32, 33]
Kharkov	p_y	550 - 1125	90, 120	30	[34, 35, 36]
Yerevan	Σ	400 - 700	45, 55	5	[37]
Tokyo	T	324 - 672	72, 100, 130	24	[38, 39]
Kharkov	p_y, Σ, T_1	300 - 600	75, 90, 120	22,20,20	[40, 41, 42, 43]
Frascati	Σ	20, 29, 39, 61	14 - 165	41	[44, 45]
Bonn	Σ	233 - 818	114, 135	103	[46]
Argonne	p_y^n	6 - 14	90	6	[47]
Kharkov	Σ	40, 50, 60, 70	75, 90	8	[48]
Bonn	T	450, 550, 650	25 - 155	41	[49, 50]
Yerevan	Σ	-	-	-	[51, 53]
Yerevan	Σ	395 - 795	45 - 95	30	[52]
TRIUMPF	A_y^n	180, 270	32 - 144	18	[54, 55]
TRIUMPF	A_y^n	370, 478	45 - 155	45	[56]
Tomsk	Σ	50 - 100	45, 60, 90	13	[57, 58]
Wisconsin	A_y^n	6, 13	90	2	[59]
Novosibirsk	T_{21}	33 - 125	50	4	[60]
Kharkov	p_y	200 - 367	25 - 110	30	[61, 62]
Yerevan	p_y, p_{zz}	306 - 436	65, 75	2×8	[63, 64]
Karlsruhe	A_y^n	19 - 50	61.5, 97.5, 130.5	27	[65]
Yerevan	Σ	284 - 999	45, 60, 75, 95	94	[66]
BNL LEGS	Σ	188 - 314	16 - 162	112	[67, 68, 69]
Novosibirsk	T_{20}, T_{22}	49 - 505	88	2×9	[70]
IUCF	C_{nn}, A_y, A_y^n	183	55 - 100	3×6	[71]
PSI	A_y^n	68	69 - 144	5	[72]
Mainz	Σ	160 - 410	35 - 155	140	[73]
Yerevan	Σ	787 - 1566	90	6	[74]
JLab	$p_y, C_{x'}, C_{z'}$	479 - 2411	90	10,9,8	[75]

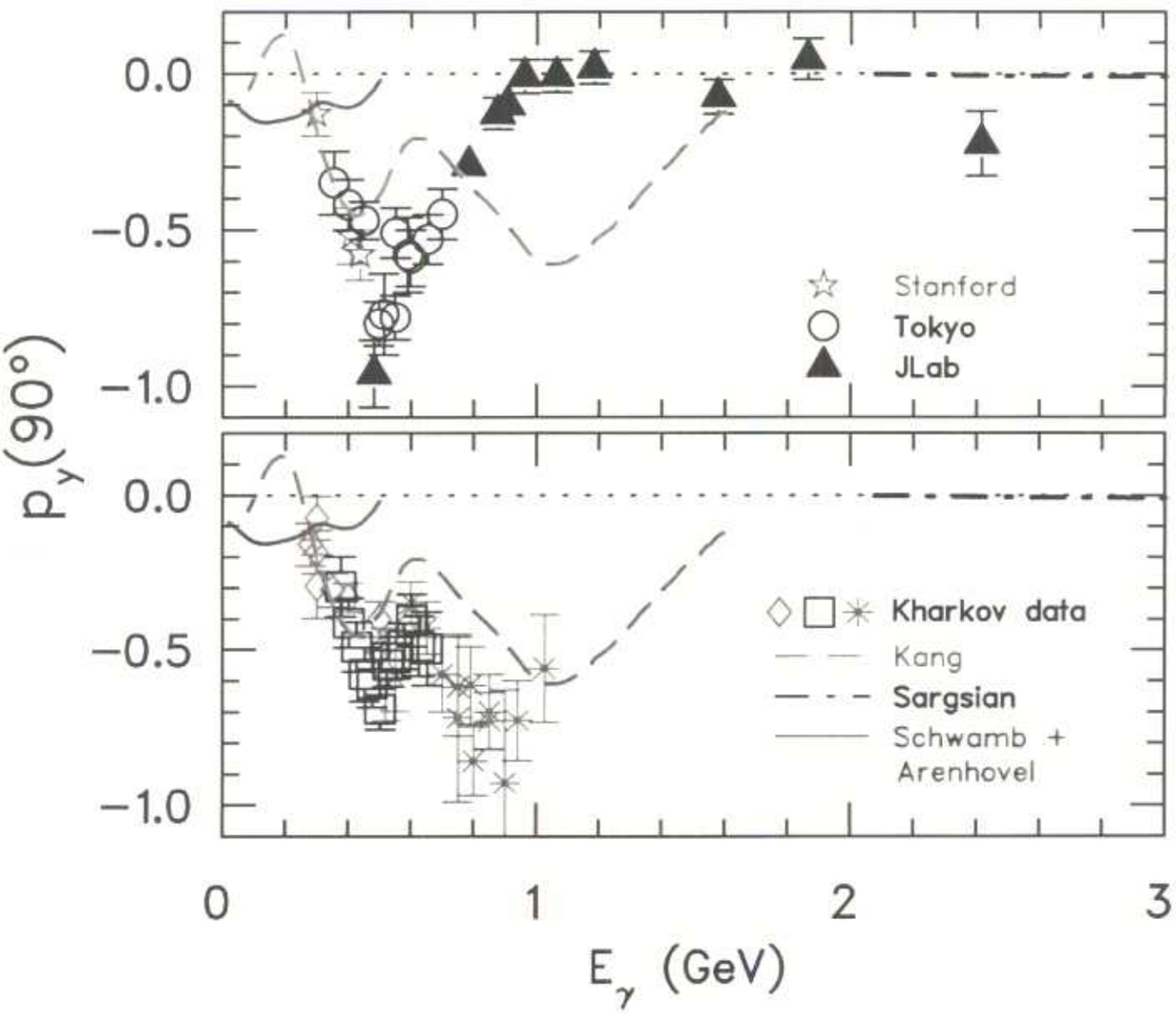
Notes:

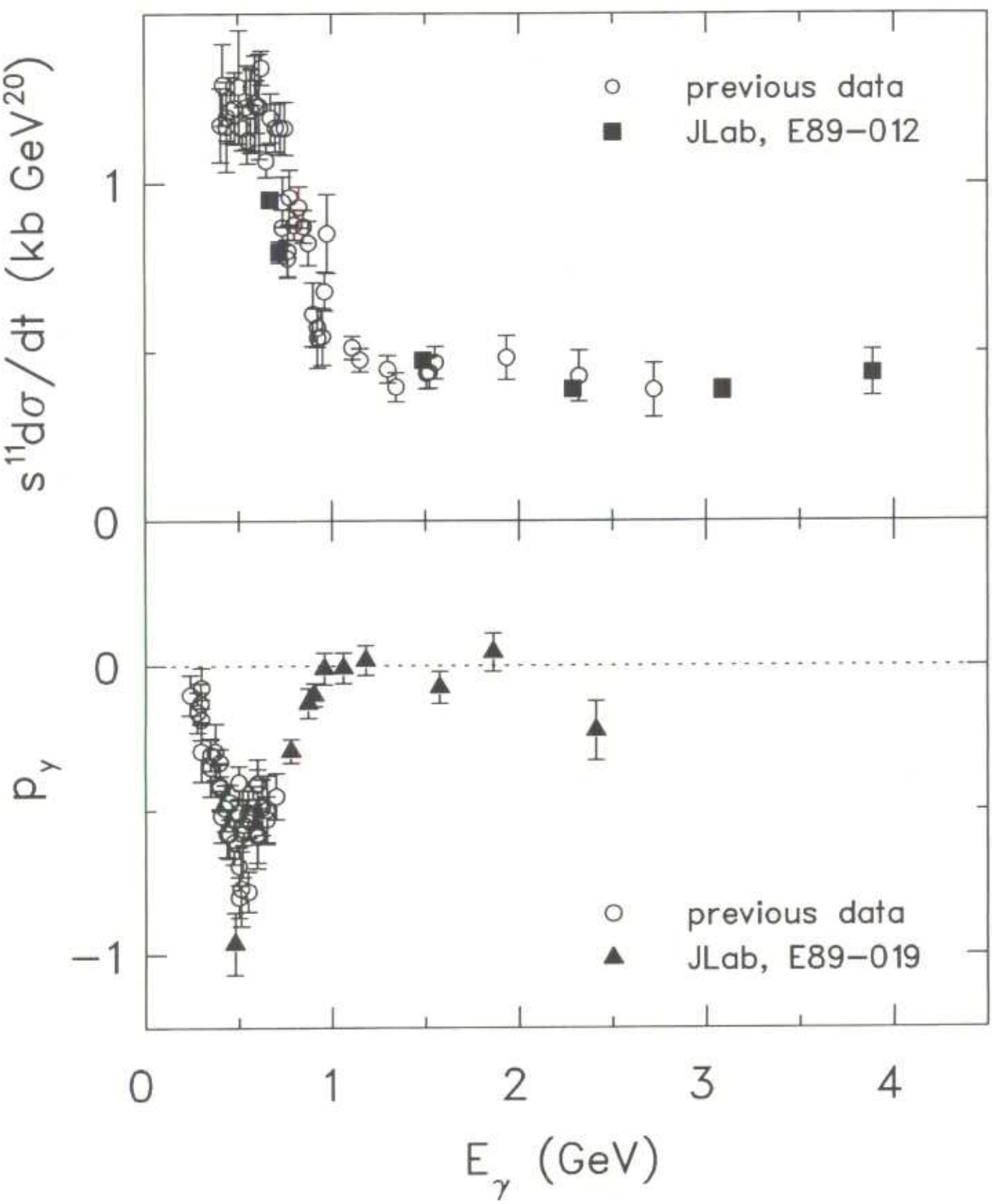

dσ/dΩ (μb/sr)
Σ
T
P_y
$\Theta_{c.m.}$ (deg)
0
90
180
0
2
4
6
0.0
−0.2
−0.4
−0.6
0.4
0.2
0.0
−0.2
0.2
0.0
−0.2
−0.4

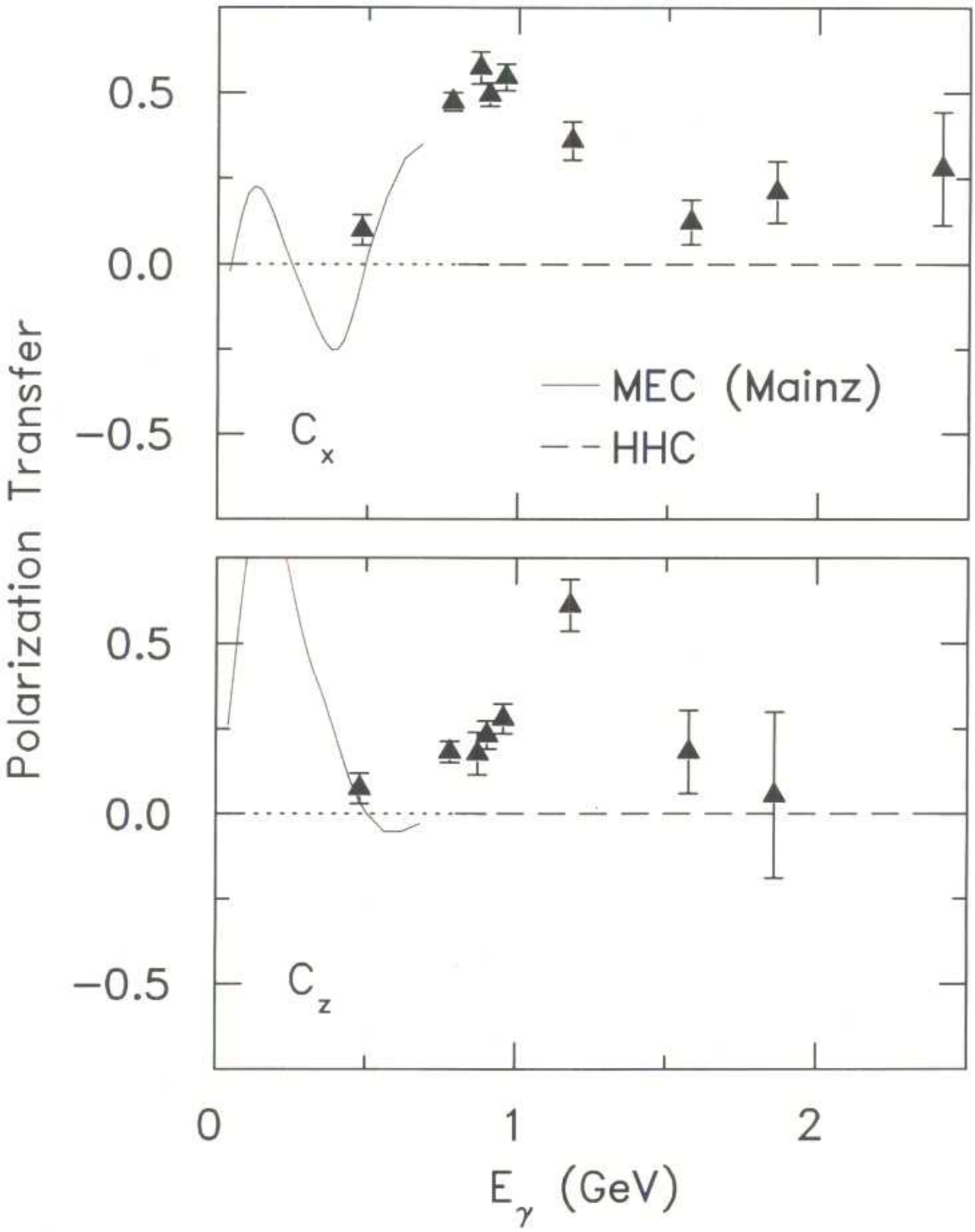

dσ/dΩ (μb/sr)
1.5
1.0
0.5
0.0
0
90
180
Θc.m. (deg)
Σ
0.0
−0.2
−0.4
0
90
180
Θc.m. (deg)
T
0.5
0.0
−0.5
0
90
180
Θc.m. (deg)
Py
0.4
0.0
−0.4
−0.8
0
90
180
Θc.m. (deg)


JLab E96-003
JLab E89-012
SLAC NE17
SLAC NE8
Mainz
90°
70°
52°
36°
$s^{11}d\sigma/dt$ (kb GeV^{20})
E_γ (GeV)

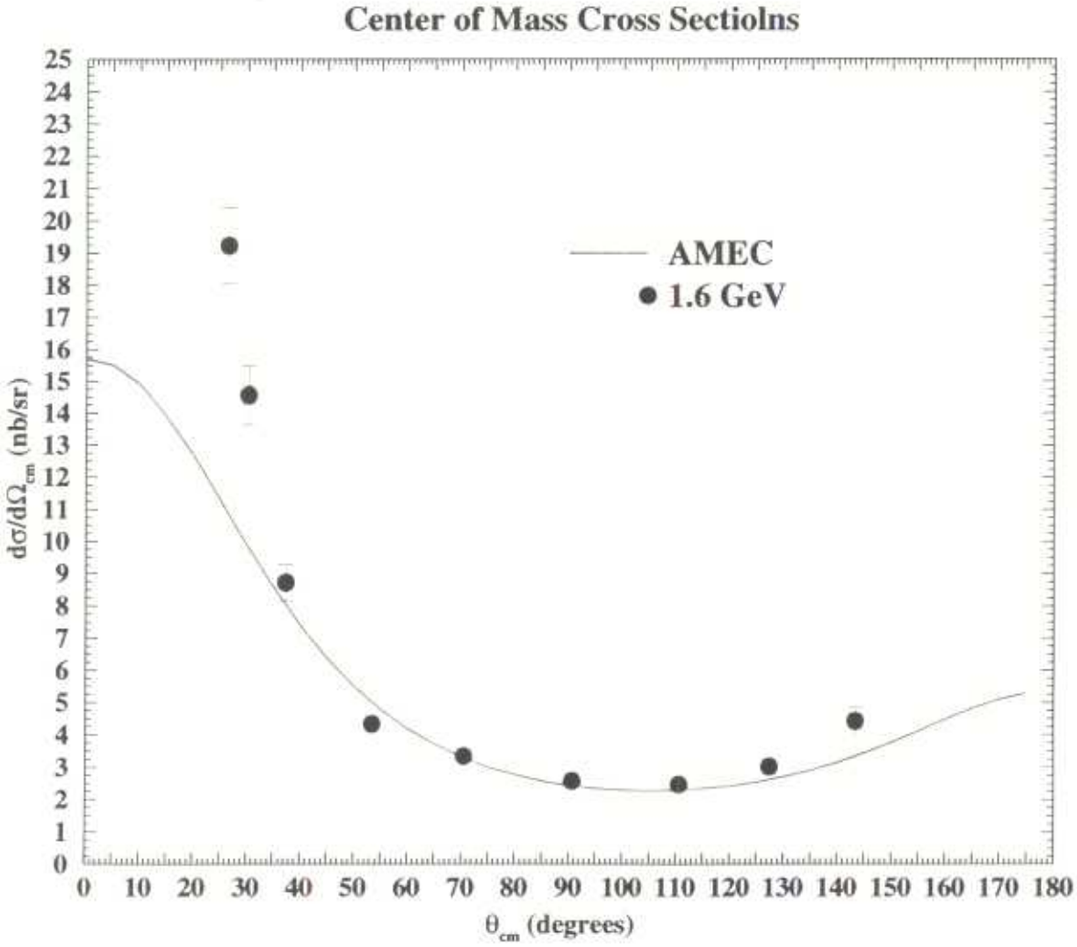

1.0
0.5
0.0
−0.5
−1.0
0
1
2
E_γ (GeV)
$\Sigma_{\parallel-\perp}(90°)$
Liu65
Barbiellini67
del Bianco81
Gorbenko82
Adamian91
Adamian00
Kang
Schwamb+Arenhovel
helicity conservation
limit at 90°


0.0
−0.5
−1.0
$P_y(90°)$
Stanford
Tokyo
JLab
0.0
−0.5
−1.0
Kharkov data
Kang
Sargsian
Schwamb + Arenhovel
0
1
2
3
E_γ (GeV)

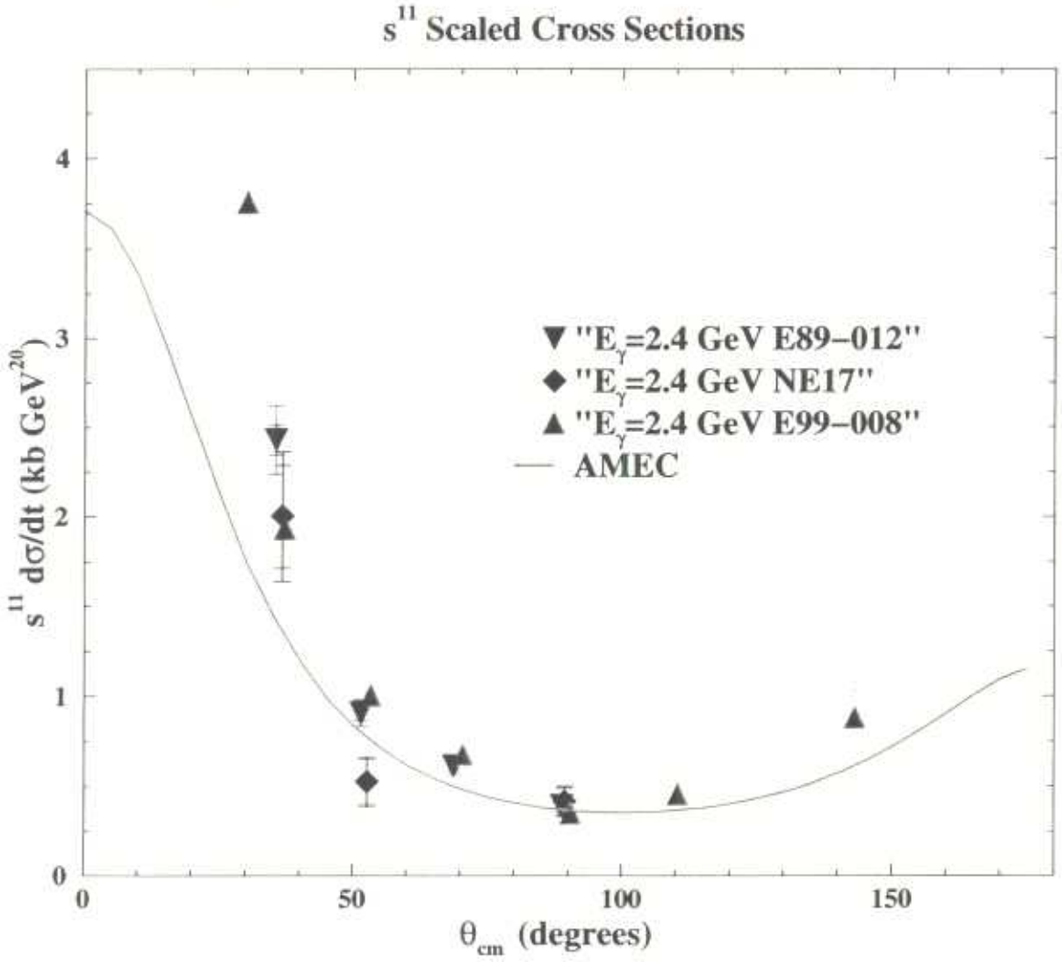

γd → pn (Θcm = 90°)
s11dσ/dt (kb GeV20)
previous data
JLab, E89-012
1
0
0
Py
previous data
JLab, E89-019
−1
0
1
2
3
4
Eγ (GeV)


0.5
0.0
−0.5
Polarization Transfer
MEC (Mainz)
HHC
C_x
C_z
0
1
2
E_γ (GeV)

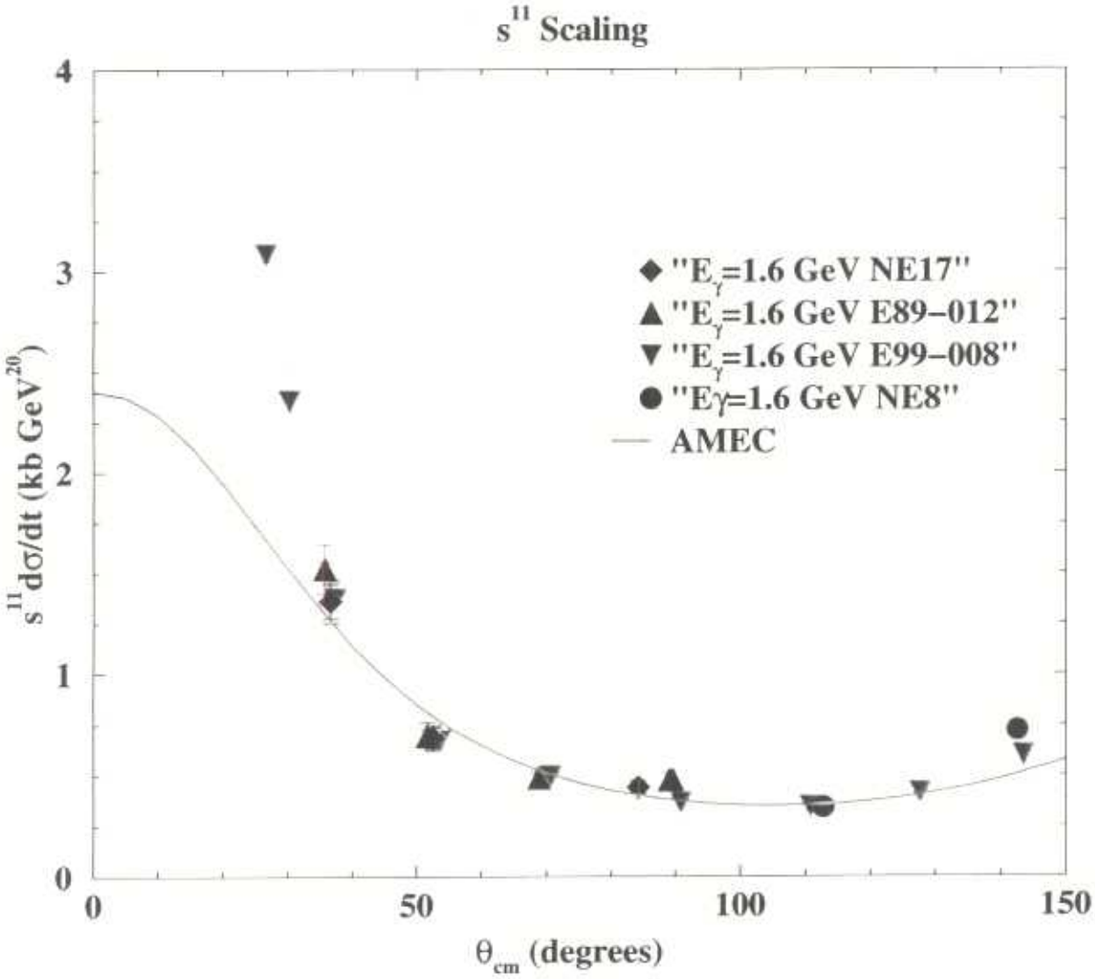
E_b=1670 MeV Angular Distribution



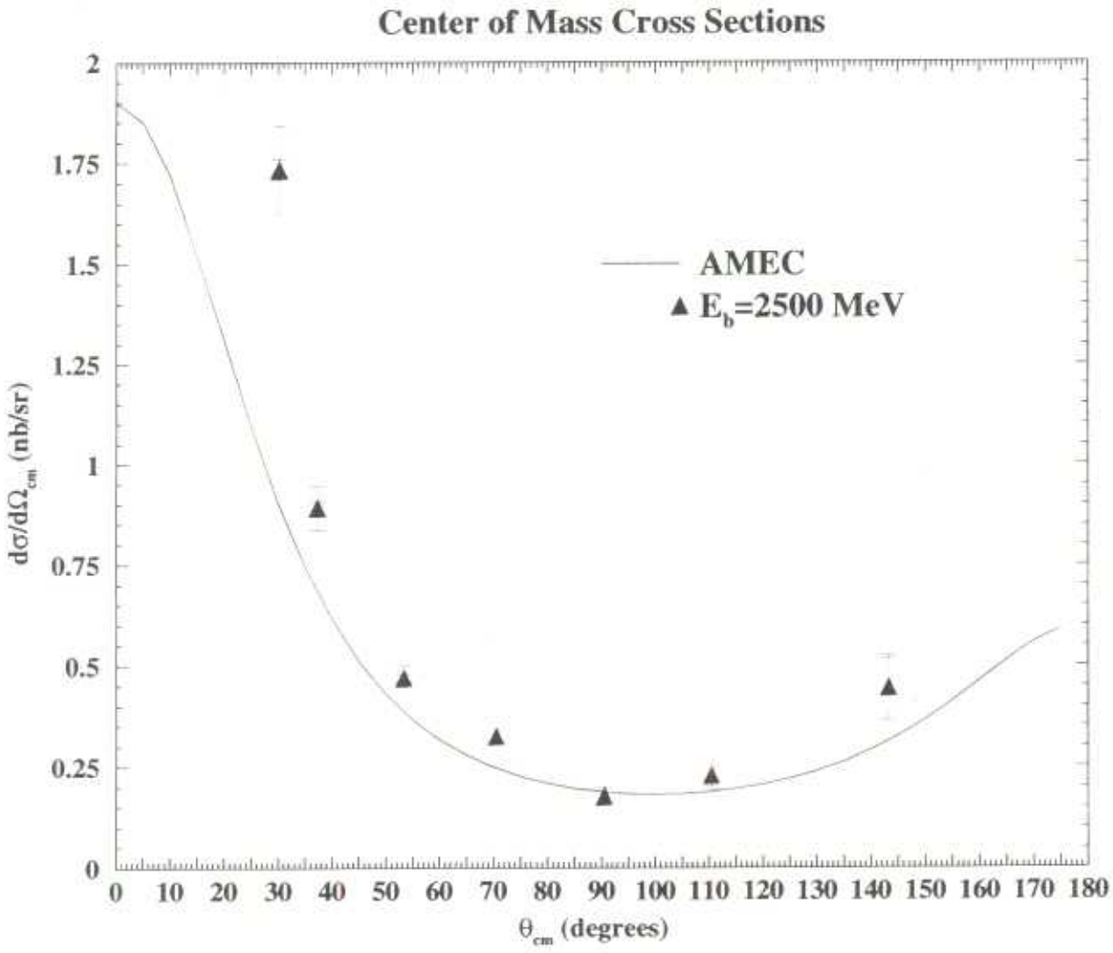
E_b=2500 MeV Angular Distributions



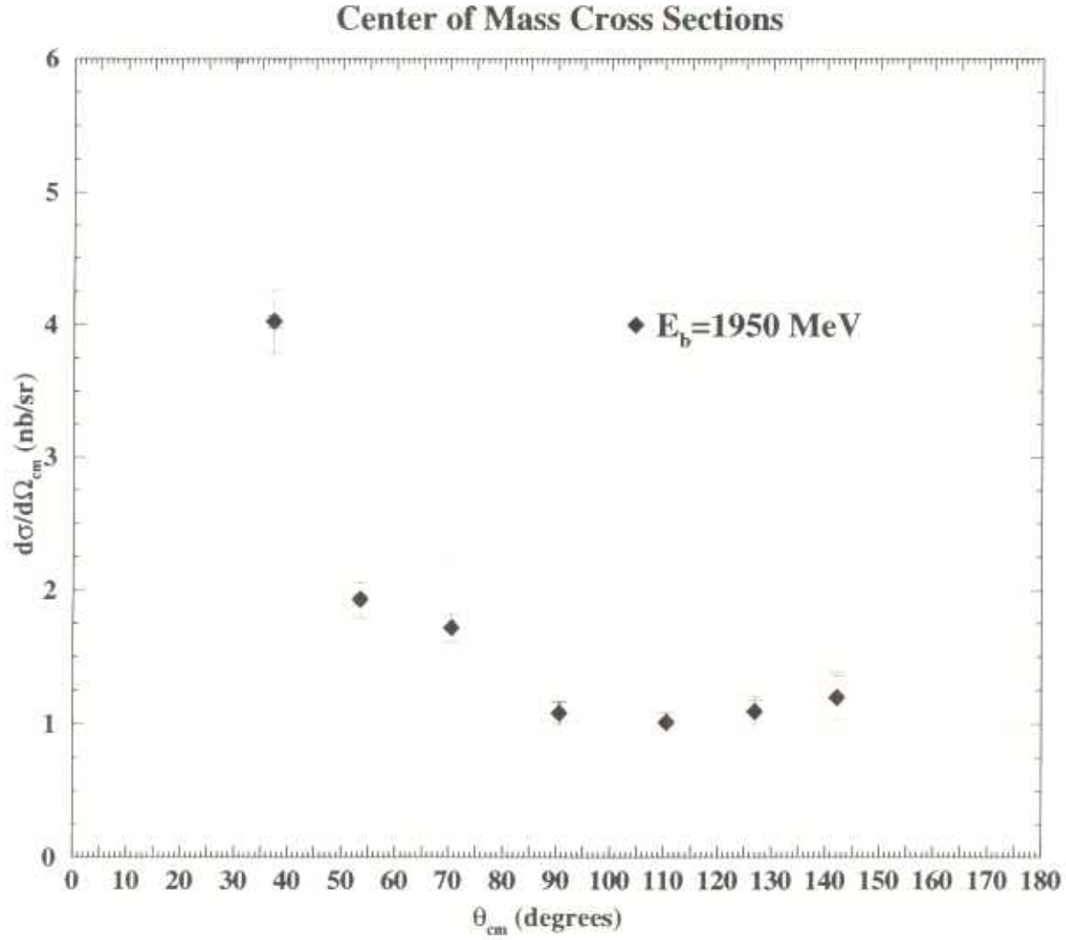
E_b=1670 MeV Angular Distribution



E_b=2500 MeV Angular Distributions



E_b=1950 MeV Angular Distribution



Future Possibilities

- The low energy polarization data base could use improvement - only Σ is in good shape. Not a JLab experiment.

- Hall B could improve high energy Σ database dramatically

- When polarimeter is in HMS for G_{E_p} extension . . . it may be sensible to consider photodisintegration polarizations in Hall C

- When the 12 GeV upgrade is complete and MAD is built in Hall A . . . polarizations up to 4 GeV and cross sections up to 7-8 GeV might be possible.

Summary

- Modern meson baryon theories (Schwamb and Arenhövel) work well, even for polarizations . . . up to 300 - 400 MeV. Imaginary interferences are more troublesome.

- Several "effective" quark models (Kondratyuk quark gluon string model, Sargsian QCD rescattering model) are promising, but not sufficiently well tested

- $\approx$scaling seen a but not hadronic helicity conservation; no compelling need for pQCD explanation