RR 00-007

Jefferson Lab PAC 17
January 26 - 28, 2000

PROTON POLARIZATION ANGULAR DISTRIBUTION IN DEUTERON PHOTO-DISINTEGRATION

- An extension of $\vec{\gamma} d \rightarrow \vec{p} n$ measurements of E89-019, motivated by the surprising observation that $P_n \rightarrow 0$
- Request 10 days for angular distribution at ~2 GeV
- General issue: Appropriate model for quark structure of deuteron at high momentum transfer

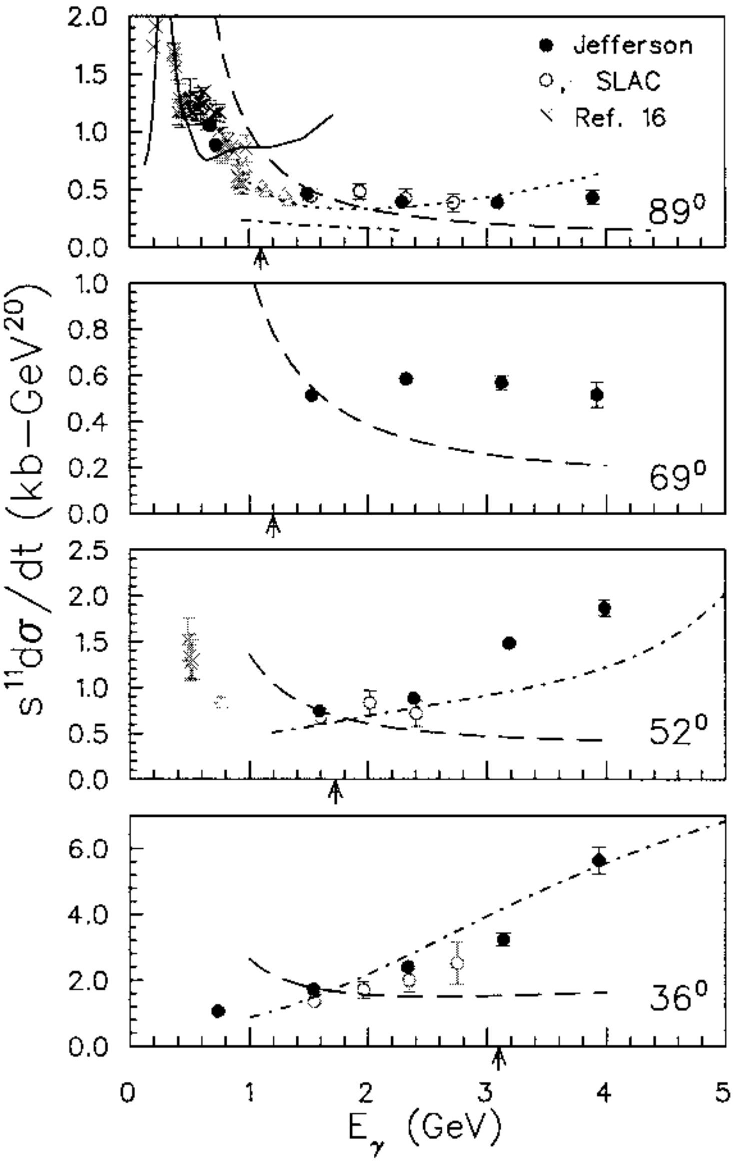


Figure 1: Deuteron photodisintegration data compared to several theories. The cross sections are multiplied by s^{11}, so that quark scaling behavior results in a constant value.

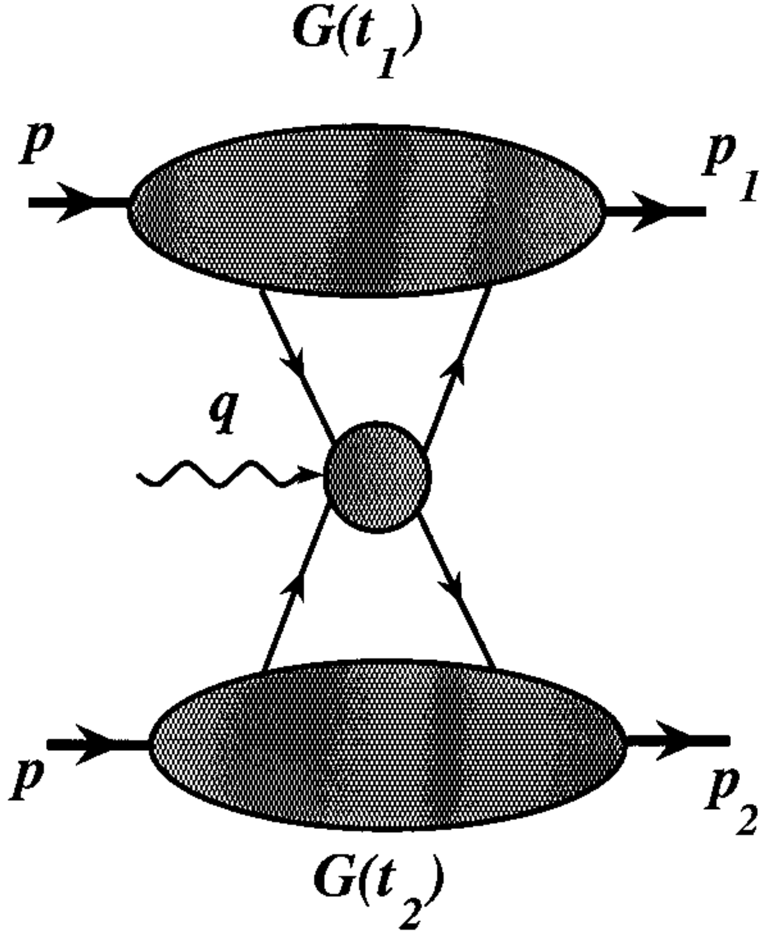
Calculations

Meson-baryon degrees of freedom

- Jean-Marc Laget (below 1 GeV)
- Harry Lee (at 90°_{cm} to 1.6 GeV)
- Kang, Erbs, Pfeil, Rollnik *Bonn* (")
- Nagornyi, Dieperink: Asymptotic Meson Exchange

Quark degrees of freedom

- Brodsky, Farrar, ...: pQCD
- Brodsky, Hiller: reduced nuclear amplitudes
- Kondratyuk, De Sanctis, ...: quark-gluon string model
- Radyushkin: effective double-distribution model
- Frankfurt, Miller, Sargsian, Strikman: QCD rescattering model



Model approximating long–distance parts by effective form factors ***G(t)***

QCD rescattering

Frankfurt, Miller, Sargsian, Strikman

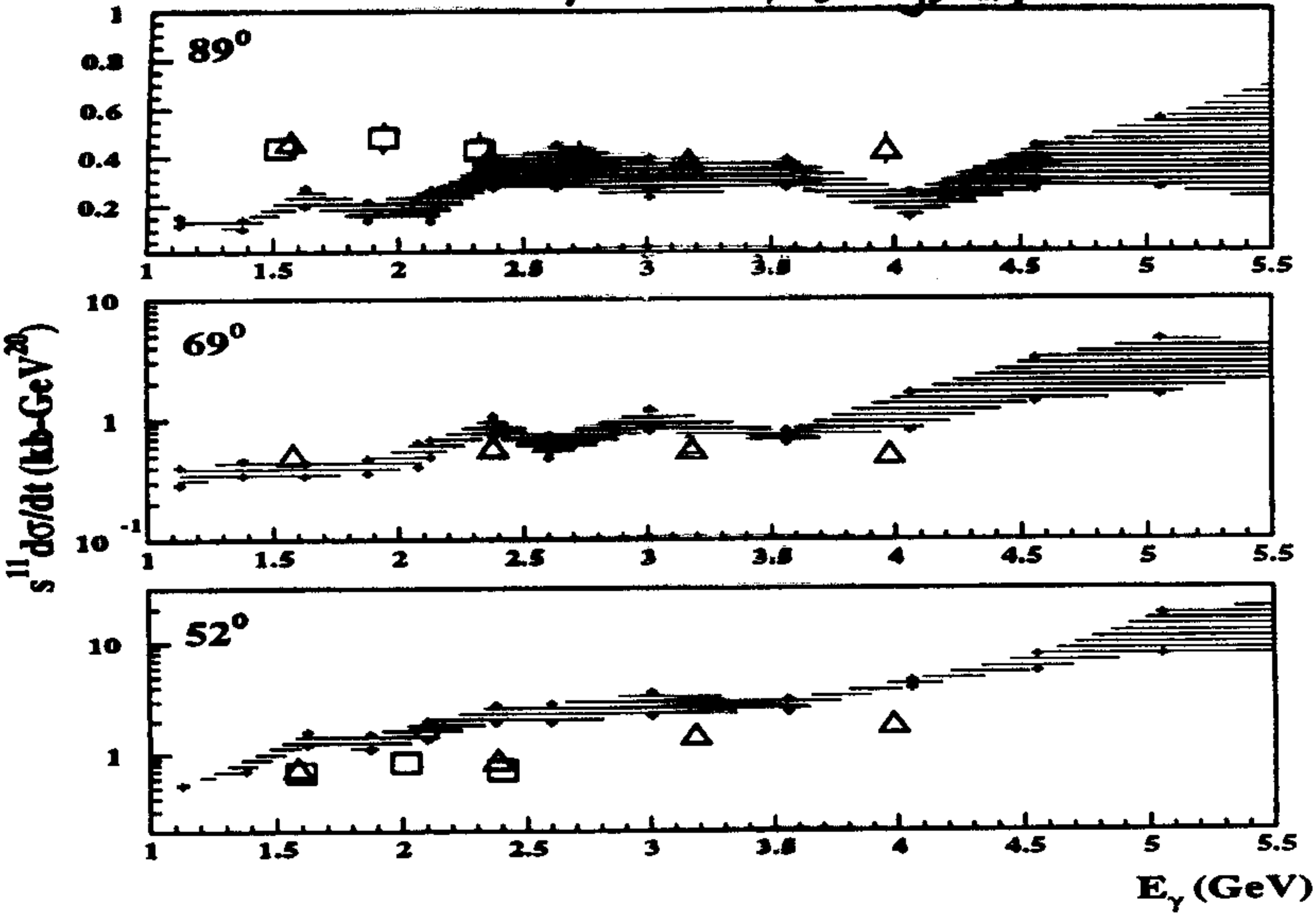


FIG. 2. The scaled differential cross sections as a function of the photon energy, for different values of cm angle. Data are from [1] (triangles) and [3] (squares).

Goal

At higher energies, there is already evidence that some behavior characteristic of hard QCD interactions sets in when photons are used to decompose a deuteron into a neutron and proton. Recent results from SLAC for this reaction ... reveal an energy dependence that agrees well with simple "counting rules" based on the total number of point-like constituents (here, valence quarks and the photon itself) participating in the interaction. **Future experiments at CEBAF will provide crucial information on whether this behavior persists in polarization measurements.** – DOE / NSF Nuclear Science Advisory Committee, in *Nuclear Science: A Long Range Plan* (February, 1996).

It would also be interesting to test the prediction of QCD that the polarization of the nucleon emitted in this reaction goes to zero in the "true" perturbative scaling regime. The polarization at energies below 0.75 GeV, where data do exist, is large. Measuring the polarization in the 1-4 GeV region should provide additional insights into the transition from nucleon to quark behavior. – L. Cardman, TJNAF, *Nuclear Physics News*, Vol. 6, No. 4, page 19, 1996.

Proposal: E89-019

Spokespersons: R. Gilman, R. Holt, and Z.E. Meziani

Title: Measurement of Proton Polarization in the $d(\gamma,p)n$ Reaction

Motivation:

It is proposed to measure proton polarization in the reaction $d(\gamma,p)n$ up to an energy of 2.8 GeV at four angles. The measurements wil improve upon the accuracy of existing low energy data and extend the range in energy by more than a factor of two.

The proposal addresses the issue of the scaling region where perturbative QCD predicts the polarization to vanish. Differential cross section measurements from SLAC experiments NE8 and NE17 indicate that the onset of scaling may occur in this kinematic region.

Measurement and Feasibility:

A Bremsstrahlung photon beam with maximum energies essentially equal to the electron kinetic energy is produced by a radiator some 20 cm upstream of the target. The PAC was satisfied that the experimental technique had been addressed effectively.

Issues:

The PAC views this as an interesting experiment, but notes that, given the abscense of a successful theory for photodisintegration experiments in the range below 2 GeV it is difficult to predict what precision is needed in P_n to differentiate among competing models. **The PAC suggests concentrating on one excitation function at $\theta = 90°$ with a more extensive sample of energies than proposed and deferring angular distribution measurements.**

It seems unlikely that $P_n = 0$ over this energy range, therefore precise data with small errors could serve to stimulate both theoretical efforts to calculate polarizations and differential cross sections in a hadronic picture, and experimental efforts to focus on selective cases of angular distributions.

Manpower:

The manpower is considered adequate.

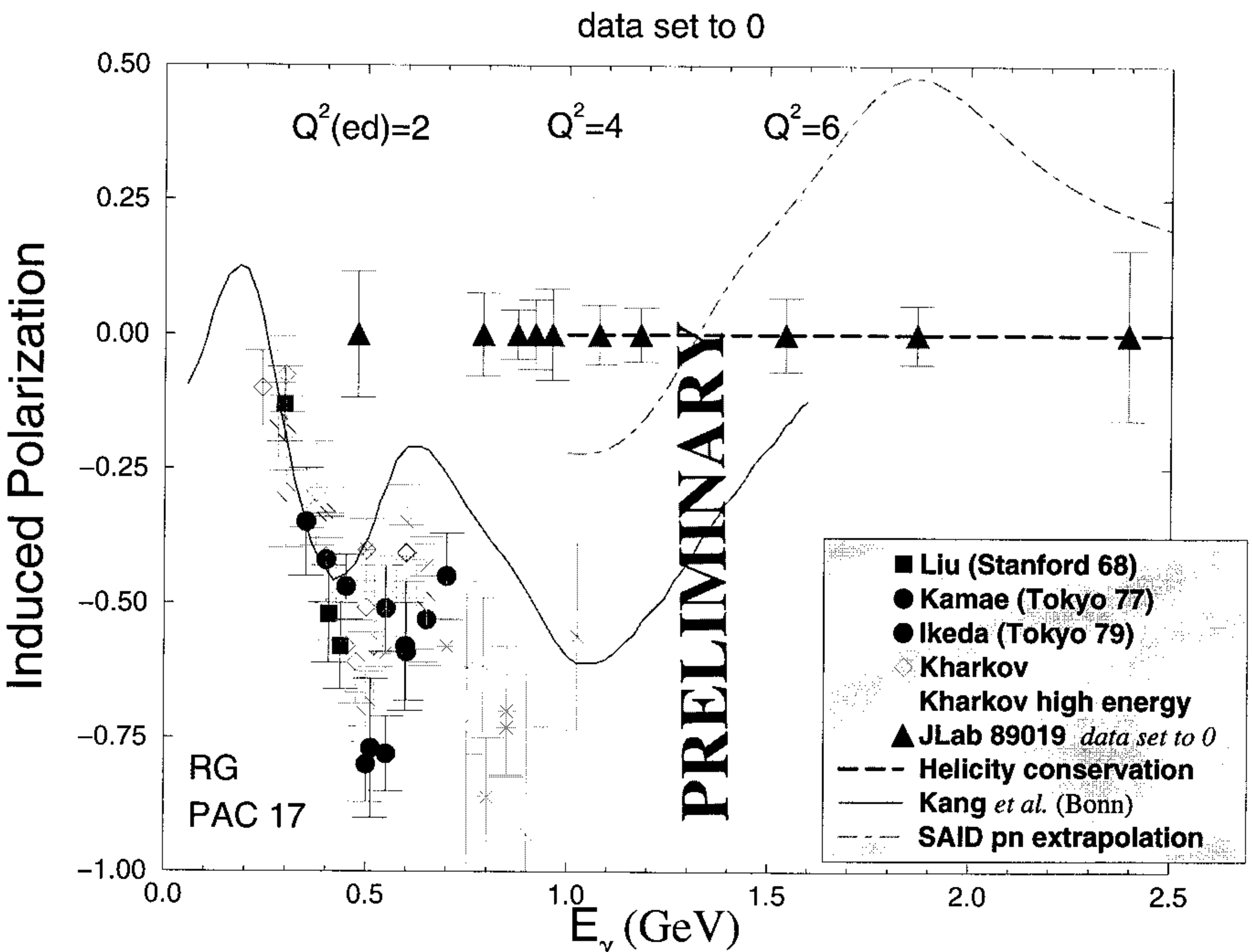
Recommendation:

The PAC recommends an initial beam time allocation of 18 days to permit measurement of an excitation function at 90° cm between 0.8 and 2.4 GeV.

Our recent Hall A measurements

- E89-019 (Gilman, Holt, Meziani *et al.*)
  - recoil proton polarization for $\theta_{\rm cm} = 90°$, $E_\gamma = 0.5 \rightarrow 2.5$ GeV
  - first *direct* test of helicity conservation in high-energy photo-reaction
- E99-008 (Gilman, Holt, Meziani *et al.*)
  - complete angular distributions, $\theta_{\rm cm} = 30° \rightarrow 143°$ at 1.6, 1.9, 2.4 GeV
  - test of forward-backward cross-section ratio
  - analysis in progress

E89–019: $\gamma d \rightarrow pn$ at 90^{o}_{cm}



The gray Q^2 markers

For $\gamma d \to pn$ at $E_\gamma = 535$ MeV and $\theta_{cm} = 90°$, the proton and neutron have 3-momentum about 756 MeV/c in the lab system.
For $ed \to ed$ elastic scattering at $Q^2 = 2$ GeV^2, the deuteron lab 3-momentum is 1512 MeV/c $= 2\times 756$ MeV/c.

Measurement systematics

- A_C calibrated with $\vec{e}p \rightarrow e\vec{p}$
  - good agreement with previous A_C, $\mu G_e^p/G_m^p$ data
  - two points have lower A_C due to thicker carbon
  - increases our polarizations $\approx$ 10 %
- false asymmetries calibrated with $\vec{e}p \rightarrow e\vec{p}$
  - $P_n = 0$ if one-photon exchange
  - $\approx$ independent of p, but dependent on δ
  - Using different measured false asymmetries moves 1.9 GeV datum with $\sigma = \pm$ 0.01 - 0.02
  - Two different alignment + tracking algorithyms differ by <0.01; analyzing with third method
- Backgrounds measured and subtracted
  - $P_n(ed) \approx P_n(\gamma d)$, about 1/3 rate
  - $P_n(\gamma Al) \approx 0$, about 10% rate
- spin transport uses simple-dipole approximation
  - full spin transport later
  - insensitive, especially a higher energies, as all P_i small, and spin transport favorable

- **Summary**
  - Confident in our preliminary results
  - Expecting generally $\Delta P_{n\text{systematic}} < 0.05$
  - Suspect problem with old Kharkov data

Implications / Observations

- Most of us did not correctly anticipate nature.
- Assertion: quark physics turns on by ≈ 1 GeV.
- Either helicity is conserved *or* amplitudes are real.
- C_x *probably* indicates amplitudes are real, but helicity is almost conserved.
- Compelling case to measure highest energy angular distribution, and improved C_x to higher energies. The latter is not currently technically feasible.

Difficult to understand these data in meson-baryon models

- Most complete calculation from Bonn:
  - π, ρ, η exchange
  - All well established resonances with $m < 2$ GeV and $J \leq 5/2$
- Resonances introduce large imaginary amplitudes $\rightarrow$ $P_n \neq 0$.
- Cannot get $P_n = 0$, unless ...
  - Bonn gets angle dependence wrong (node at 90°_{cm}), or
  - resonance couplings strongly reduced in nuclei, or
  - $P_n \rightarrow 0$ in sum of *all* resonances
- Model without resonances or final-state interactions can work (Nagornyi), but, can we take them seriously for polarizations?

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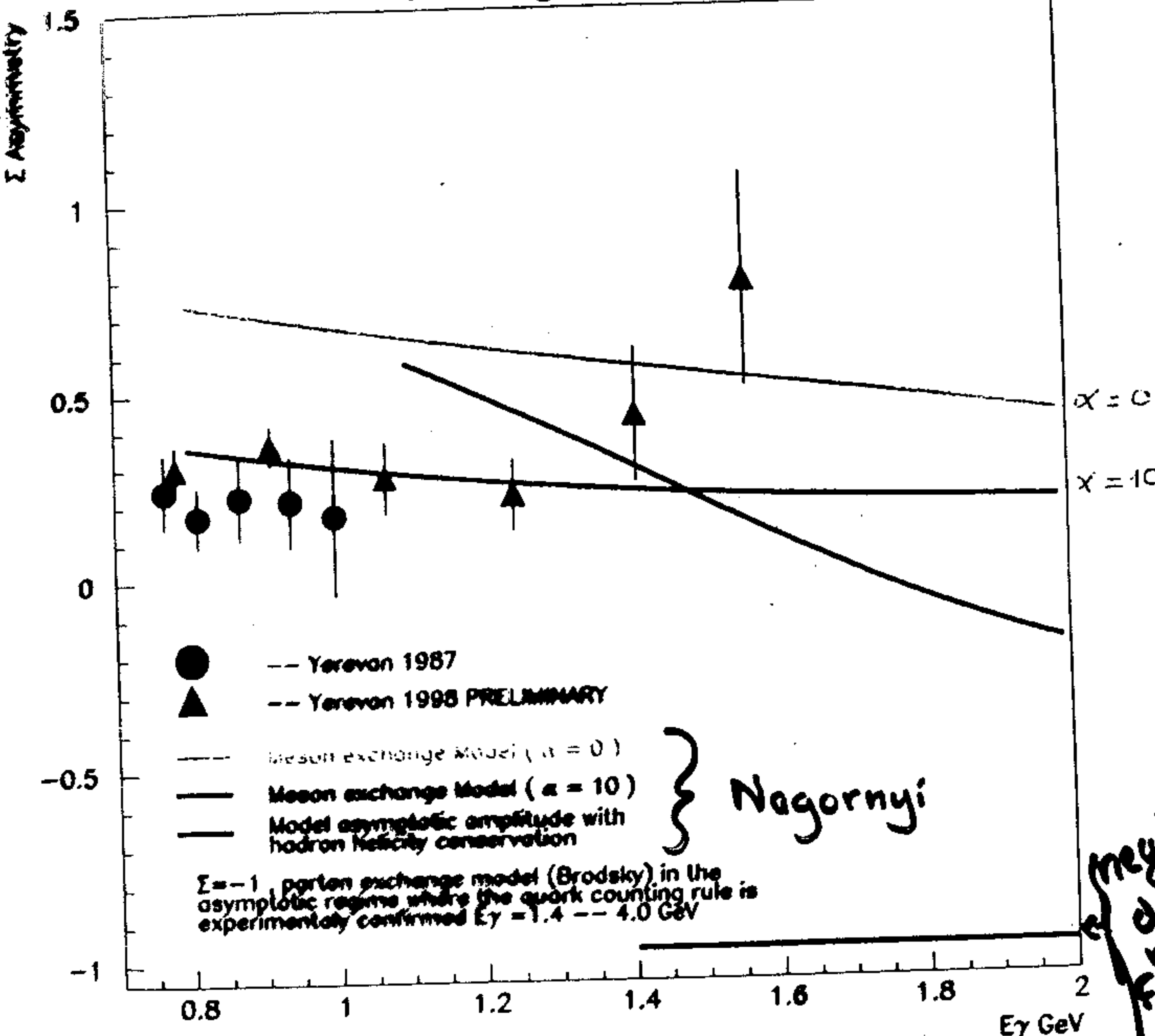

neglect d-state near 90°
$F_{3+} = F_{3-}$
$F_{5+} = F_{5-}$
F's rea

Fig.3 The dependence of the cross section asymmetry Σ from E_γ for θ_p=90° in the cms. Curves for the asymptotic regime and calculated in different models [7].

Additional thoughts on why $P_n \rightarrow 0$

- P_n drops with momentum transfer, as in Guidal, Laget, Vanderhaegen Regge-theory photo-meson calculations.
- pp elastic scattering and Λ production well known for HHC-violating polarizations at large E, $-t \Rightarrow$ point-photon coupling suppresses Landshoff mechanism / orbital angular momentum effects.
- Gluons in reaction mechanism lead to imaginary parts to amplitude $\rightarrow$ no gluons.
- Skewed partons: soft overlap with no gluons. Real amplitudes, followed by helicity conservation at higher momentum transfer.

Available polarization calculations

Meson-baryon degrees of freedom

a.) Laget: below 1 GeV

b.) Lee: no, but ...

c.) Bonn: up to 1.6 GeV

d.) Nagornyi, Dieperink: requested, interested, but ...

quark degrees of freedom

a.) Brodsky / pQCD: $P = C_x = 0$, C_z model dependent

b.) Brodsky / RNA: similar to quark exchange (?)

c.) Kondratyuk ... quark-gluon string model: underway

d.) Radyushkin double-distribution model: requested

e.) Frankfurt/Miller/Strikman/Sargsian ... QCD rescattering model: underway

Note: Glauber calculation of FSI induced polarization by Sabine Jeschonnek in progress?

Why measure an angular distribution?

If nuclear models are not the correct physics, quark physics is needed for $E_\gamma \geq 1$ GeV.

Since $P_n(90^\circ_{cm}) = 0$, $C_x(90^\circ_{cm})$ is small, it is important to see the angle / $-t$ variation of these as well, to better constrain developing theories.

As quark models are valid at large energy / momentum transfer, measuring an angular distribution at the highest feasible energy gives the largest angular range for which these models may work.

We check P_n,$C_x(70^\circ_{cm})$, for which cross sections also approximately scale, vs. forward angle behavior.

Having measured $P_n(90^\circ_{cm}) = 0$, it is important to measure the approach to 0.

Since calculations are not yet ready, some ideas about $P_n(\theta)$:

- Is polarization uniformly 0?
- Is polarization ≈ 0 where cross sections scale?
- Is there a node in the polarization at 90°_{cm}?
- Does polarization decrease smoothly with momentum transfer?

Table 1: Kinematics, etc., at 2 GeV

θ_{cm} (deg)	θ_{lab} (deg)	p_p (GeV/c)	p_T (GeV/c)	$-t$ $(\text{GeV/c})^2$	ΔP / ΔC_x / ΔC_z (absolute)	time (days)
37	20.1	2.35	0.8	0.4	0.05 / 0.06 / 0.09	2.
53	29.4	2.19	1.1	1.0	0.05 / 0.07 / 0.16	1.5
70	40.1	1.96	1.3	1.7	0.05 / 0.07 / -	1.5
90	54.3	1.65	1.3	2.7	0.05 / 0.07 / 0.24	2.
110	71.2	1.34	1.3	3.8	0.06 / 0.05 / 0.09	2.

+ 1 day at 4 GeV for calibrations

$\Rightarrow$ 10 days total

Proposal # PR-00-007 **Hall:** A

Title: Proton Polarization Angular Distribution in the $d(\gamma,p)$ Reaction

Contact person: R. Gilman (Rutgers)

Beam time:

Beam days requested: 10

Tune-up time included in request: 0

			Basic Equipment
Beam parameters:			
	Energy:	2.0, 4.0 GeV	yes
	Current:	30 μA	yes
	Polarization:	75 %	yes
Targets:			
	Nuclei:	liquid ^2H, Cu, Al	yes
	Rastering:	no	yes
Spectrometers:			
	HRSE	standard setup	yes
	HRSH	standard setup, incl. FPP	yes

Special requirements: bremsstrahlung radiator
polyethylene analyzer in FPP

Comments:

1. The polyethylene analyzer will not be a standard component of the FPP and will require a non-negligible amount of time and manpower to install. probably not

Theory review

The observation that induced polarizations in deuteron photodisintegration at 90° vanish at 2 GeV is surprising. Whether due to the onset of perturbative QCD scaling, or some other physics, measurements at other angles will be very useful in defining the mechanism behind this simple behaviour.

BEAM REQUIREMENTS LIST

JLab Proposal No.: ______________________ Date: ______________

Hall: A Anticipated Run Date: 2001 PAC Approved Days: __________

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E-mail: gilman@jlab.org

Hall Liaison: ______________________

List all combinations of anticipated targets and beam conditions required to execute the experiment. (This list will form the primary basis for the Radiation Safety Assessment Document (RSAD) calculations that must be performed for each experiment.)

Condition No.	Beam Energy (MeV)	Mean Beam Current (μA)	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Material Thickness (mg/cm²)	Est. Beam-On Time for Cond. No. (hours)
(1)	~2000	30	70-80% polarized	Cu	774	~~100~~ → 108
				Al	50	
				D	2430	
(2)	~2000	30	"	Cu	774	~~50~~ → 45
				Al	50	
				H	1050	
(3)	~2000	30	"	Al	50	~~50~~ → 45
				D	2430	
(4)	~2000	30	"	Al	50	~~20~~ → 18
				H	1050	
(5)	~4000	30	"	Al	50	24
				H	1050	

The beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. E_{Linac} = 800 MeV, i.e., available E_{Beam} are 800, 1600, 2400, 3200, and 4000 MeV. Other energies should be arranged with the Hall Leader before listing.

Proposal Summary

- 10 days for $\approx$2 GeV $\vec{\gamma} d \to \vec{p} n$ angular distribution
- Determine $P_n, C_x(\theta)$
- Highest feasible energy