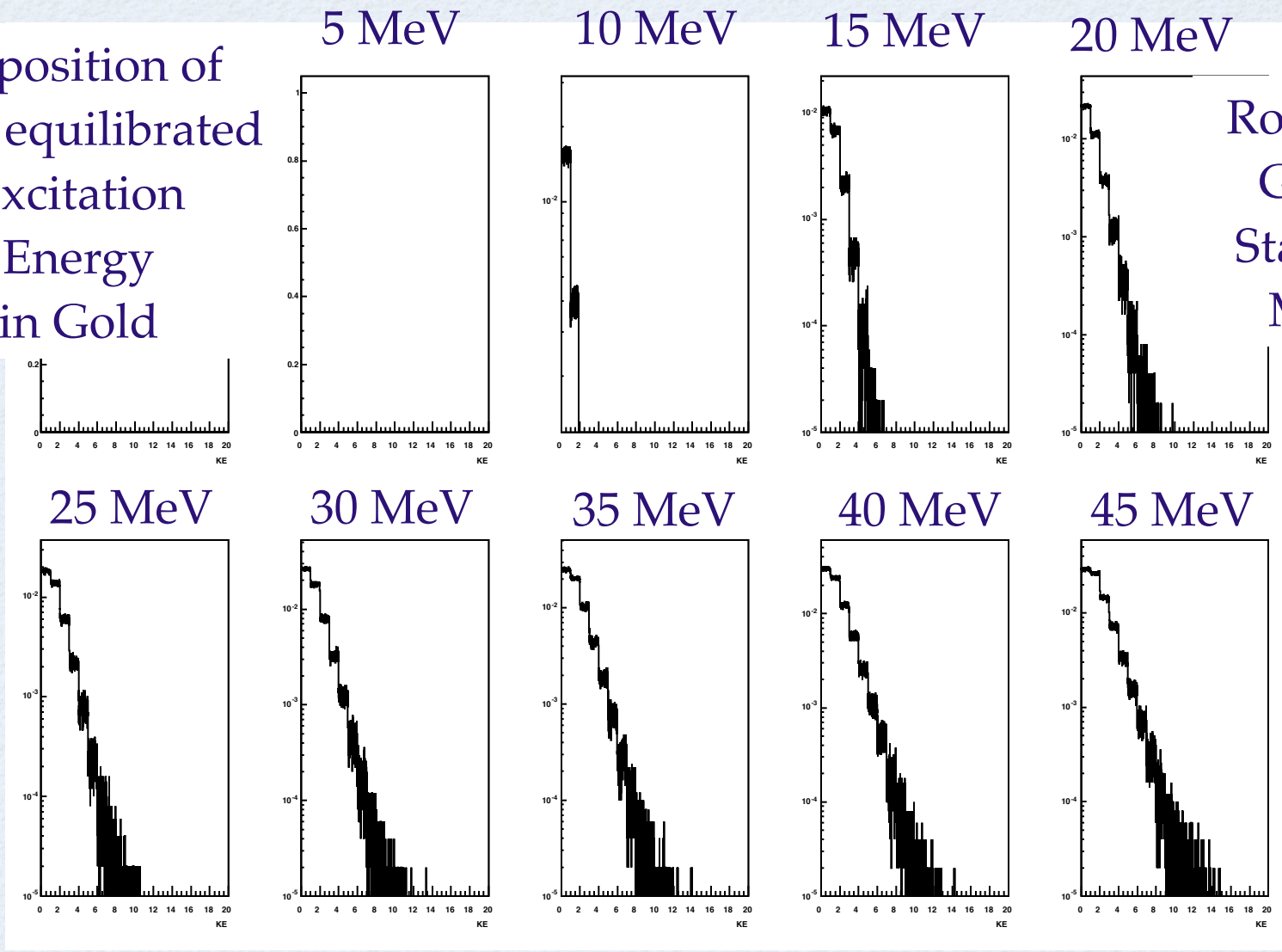
Chasing Nuclear Debris

progress report

H. Kowalski

TF-Meeting 3rd of June 2010

Deposition of fully equilibrated Excitation Energy in Gold



Roy Lacey Gemini Statistical Model

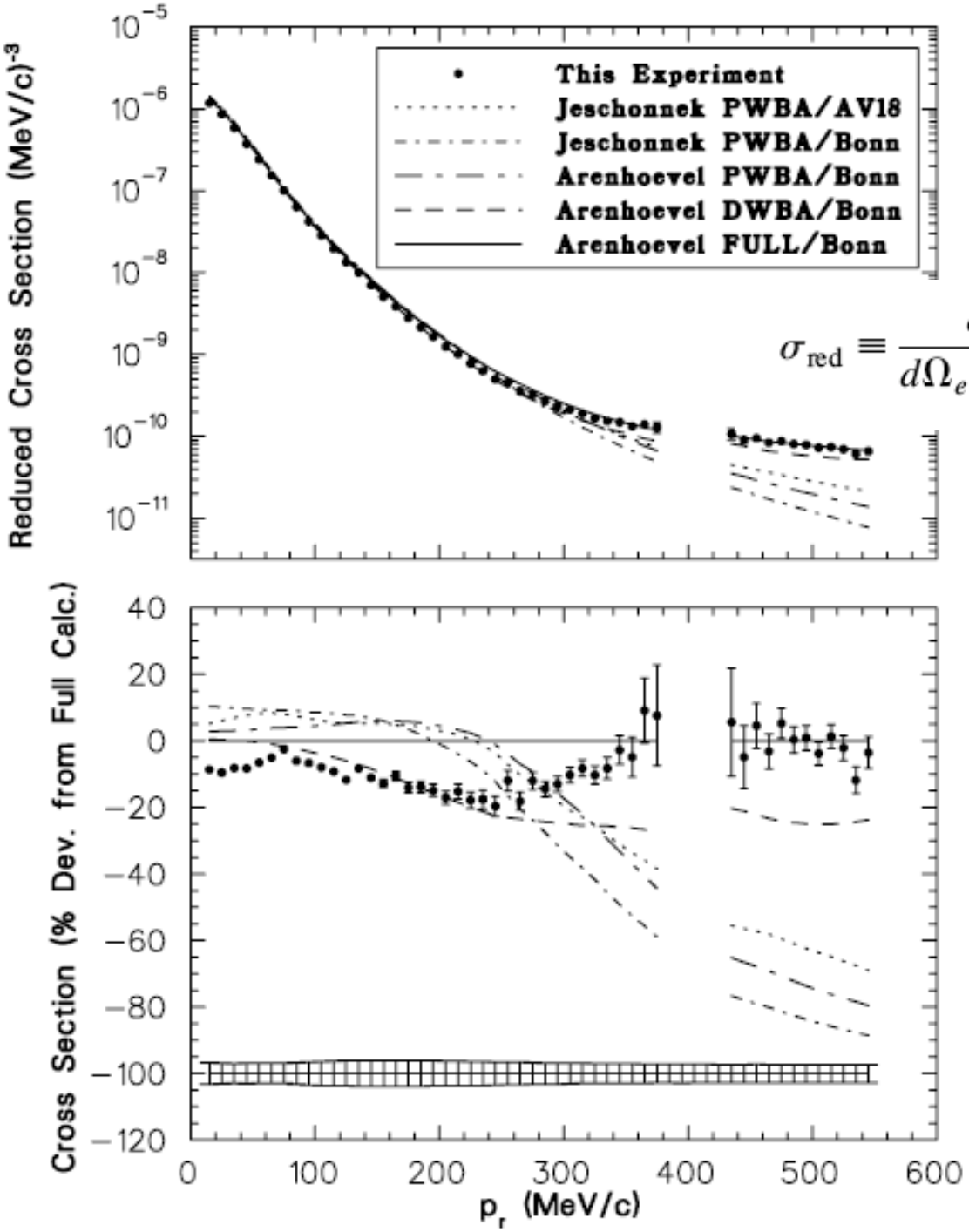
Kinetic E of neutrons in MeV

VOLUME 89, NUMBER 6 PHYSICAL REVIEW LETTERS 5 AUGUST 2002

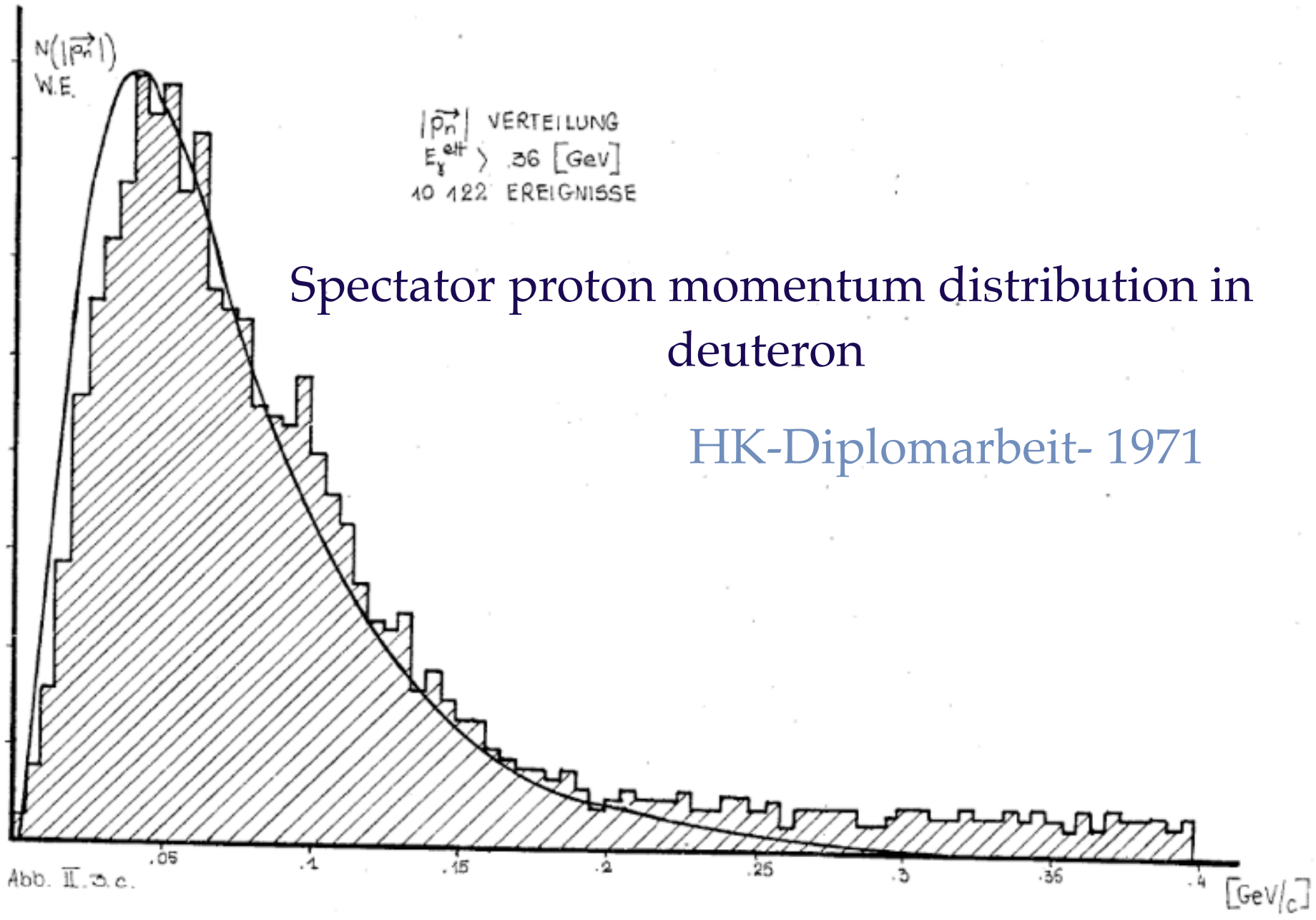
^{2}H$(e, e'p)n$ Reaction at High Recoil Momenta

P. E. Ulmer,[1] K. A. Aniol,[2] H. Arenhövel,[3] J.-P. Chen,[4] E. Chudakov,[4] D. Crovelli,[5] J. M. Finn,[6] K. G. Fissum,[7]

The ^{2}H$(e, e'p)n$ cross section was measured in Hall A of the Thomas Jefferson National Accelerator Facility near the top of the quasielastic peak ($x_{Bj} = 0.964$) at a four-momentum transfer squared, $Q^2 = 0.665$ (GeV/c)^2 ($\omega = 0.368$ GeV, $W = 2.057$ GeV), and for recoil momenta up to 550 MeV/c. The measured cross section deviates by 1–2σ from a state-of-the-art calculation at low recoil momenta. At high recoil momenta the cross section is well described by the same calculation; however, in this region, final-state interactions and interaction currents are predicted to be large, and alternative choices of nucleon-nucleon potential and nucleon current operator may result in significant spread in the calculations.



$$\sigma_{\rm red} \equiv \frac{d^5\sigma}{d\Omega_e d\omega d\Omega_p} \times \frac{1}{f_{\rm rec} K \sigma_{\rm CC1}},$$



Spectator proton momentum distribution in deuteron

HK-Diplomarbeit- 1971

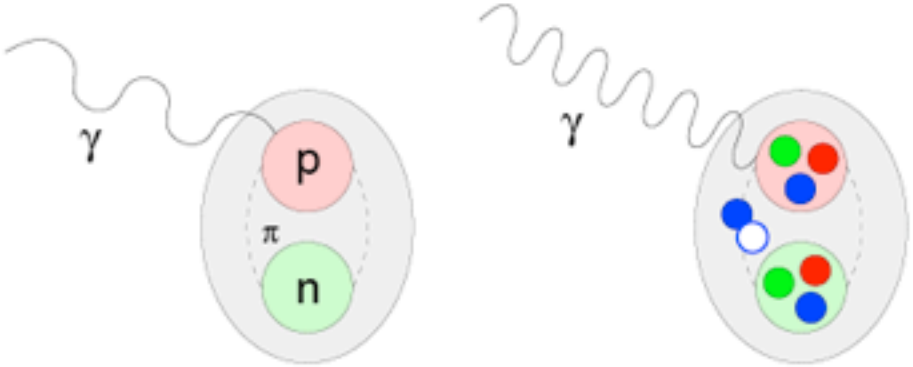
Photodisintegration of ^{2}H, ^{3}He at Intermediate Energies

Steffen Strauch
University of South Carolina

Photonuclear Reactions, GRC — July 30 – August 4, 2006
Tilton School, Tilton, NH

Why Deuteron Photodisintegration?

- Fundamental issue in nuclear physics
  - Whether Quark-Gluon or Meson-Baryon picture governs high $-t$ exclusive reactions.



- Tool: Deuteron photodisintegration
  - Deuteron simplest nucleus
  - Photon probe well understood
  - Large momentum transfer to the constituents

Possible Signatures for QCD Effects

- Cross section obey the constituent counting rules ?

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

  - for the $d(\gamma, p)n$ reaction: $s^{11} d\sigma/dt = \text{const.}$

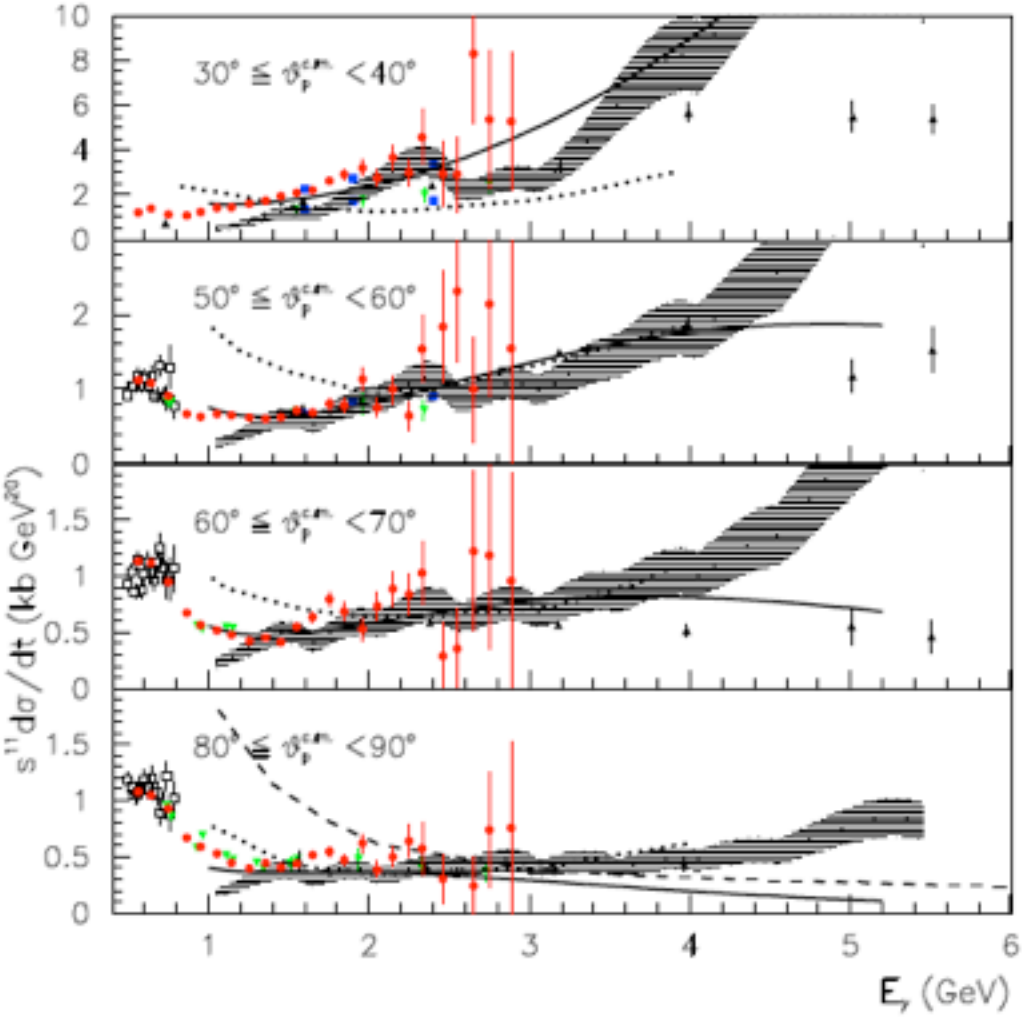
- Hadron helicity conservation satisfied ?

$$\sum_{\text{final}} \lambda_H = \sum_{\text{initial}} \lambda'_H$$

  - for the $d(\gamma, p)n$ reaction: $p_y \approx C_y \approx C_x(90^\circ) = 0$

S.J. Brodsky and G.R. Farrar, Phys. Rev. Lett **31**, 1153 (1973)
S.J. Bordsky and G.P. Lepage, Phys. Rev. D **24**, 2848 (1981)

Deuteron Photodisintegration at Large Momentum Transfers



- Onset of scaling at $P_T \approx 1.3$ GeV at each angle.
- Indication of quark effects.
- Models: QGS (solid), AMEC (dotted), RNA (dashed), HRM (hashed)

M. Mirazita *et al.*, Phys. Rev. C **70**, 014005 (2004)

Models for Deuteron Photodisintegration

- Reduced Nuclear Amplitude (RNA) Formalism
  - Soft physics described by nucleon form factors.

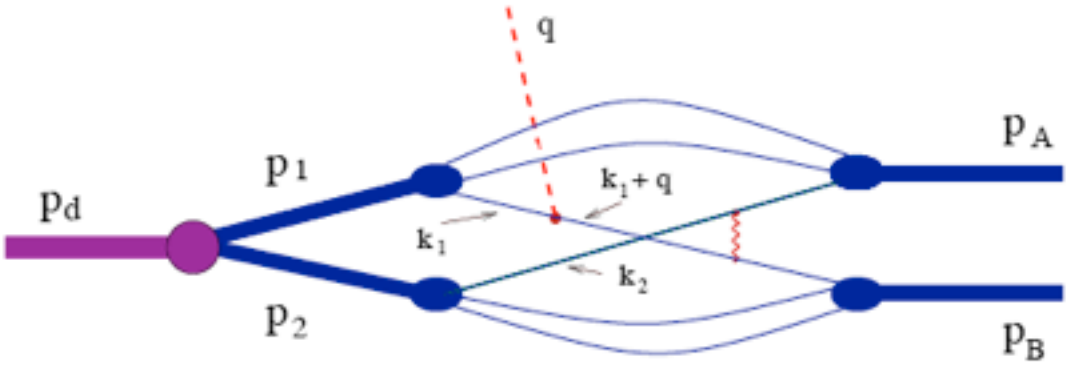
$$\frac{d\sigma}{dt} \sim F_{N_1}^2 F_{N_2}^2 \frac{d\sigma}{dt}\bigg|_{\text{reduced}}$$

  - Reduced amplitudes have scaling properties.
- Two-Quark Coupling (TQC) Model
  - Photon interacts with a pair of quarks being interchanged between the two nucleons
  - Leading kinematic dependencies proportional to nucleon form factors
- Quark-Gluon String (QGS) Model
  - Three-quark exchange with arbitrary number of gluon exchanges
  - Nonlinear Regge trajectories

RNA: S.J. Brodsky, J.R. Hiller, Phys. Rev. C **28**, 475 (1983)
TQC: A. Radyushkin
QGS: Grishina, Kondratyuk, Cassing, Kaidalov, De Sanctis, Rossi, Eur. Phys. J. A **10**, 355 (2001)

Models for Deuteron Photodisintegration

- QCD Hard Rescattering Model (HRM)
  - Photon is absorbed by a quark in one nucleon, followed by a high momentum transfer interaction with a quark of the other nucleon.

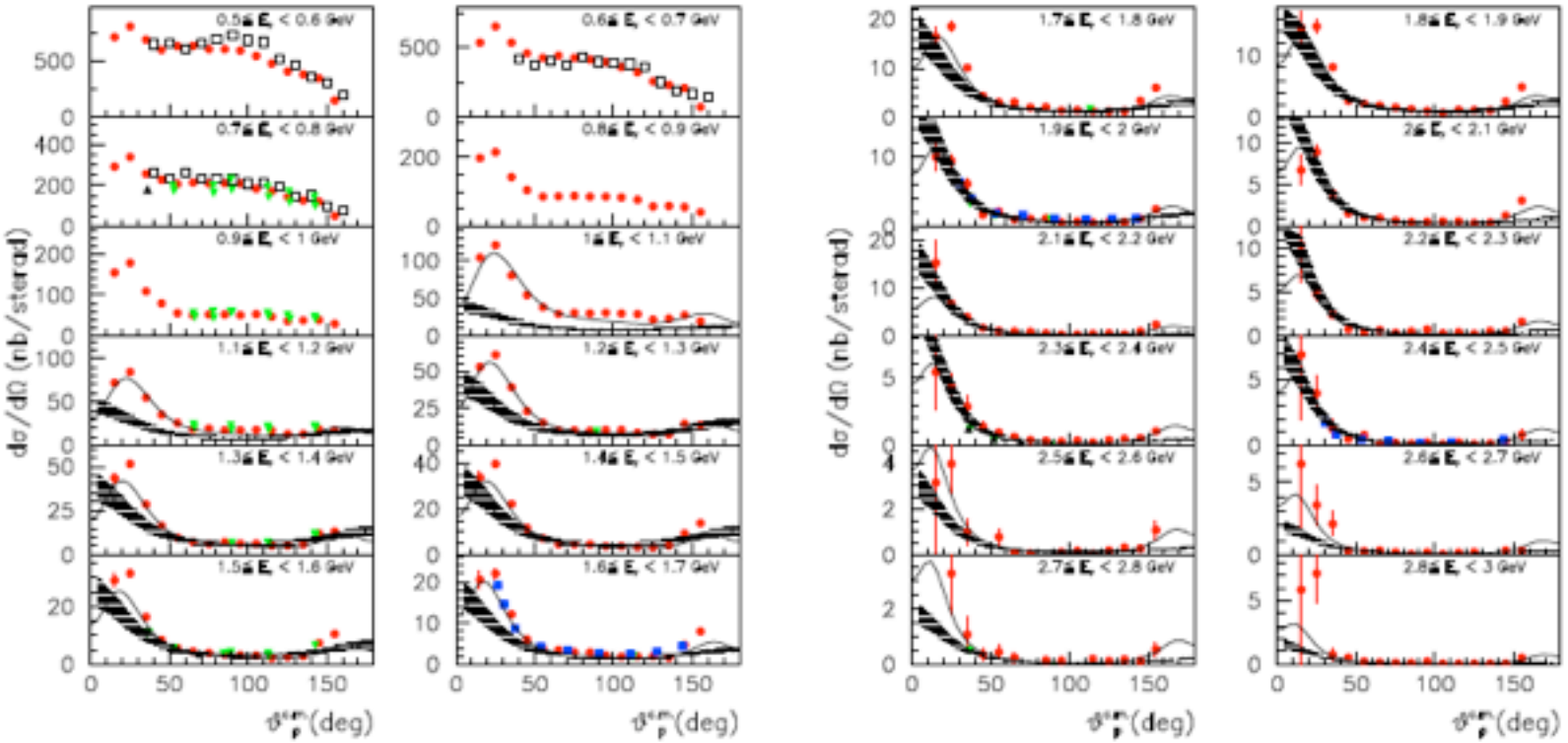


  - Scattering amplitude expressed as convolution of the large-angle pn scattering amplitude, the hard photon–quark interaction vertex, and the low-momentum nuclear wave function.

HRM: L.L. Frankfurt, G.A. Miller, M.M. Sargsian, and M.I. Strikman, Phys. Rev. Lett. **84**, 3045 (2000)

$d(\gamma, p)n$ Angular Distributions

$$0.5\ \text{GeV} < E_\gamma < 3.0\ \text{GeV}$$



- Persistent forward-backward angle asymmetry
- Well described by the nonperturbative Hard Quark Rescattering Mechanism and Quark Gluon String models

M. Mirazita *et al.*, Phys. Rev. C **70**, 014005 (2004)
L.L. Frankfurt, G.A. Miller, M.M. Sargsian, and M.I. Strikman, Phys. Rev. Lett. **84**, 3045 (2000)
L. Kondratyuk et al., Phys. Rev. C **48**, 2491 (1993)

Predictions for $^3\mathrm{He}(\gamma, pp)n$

- Models predict relative cross section

$$R = \frac{\sigma(\gamma\, ^3\mathrm{He} \to pp + n)}{\sigma(\gamma d \to pn)}$$

  - at low energies $R \approx 0.1$
  - at large energies $R \approx 1/3, 2, 4$ (QGS, HRM, RNA)

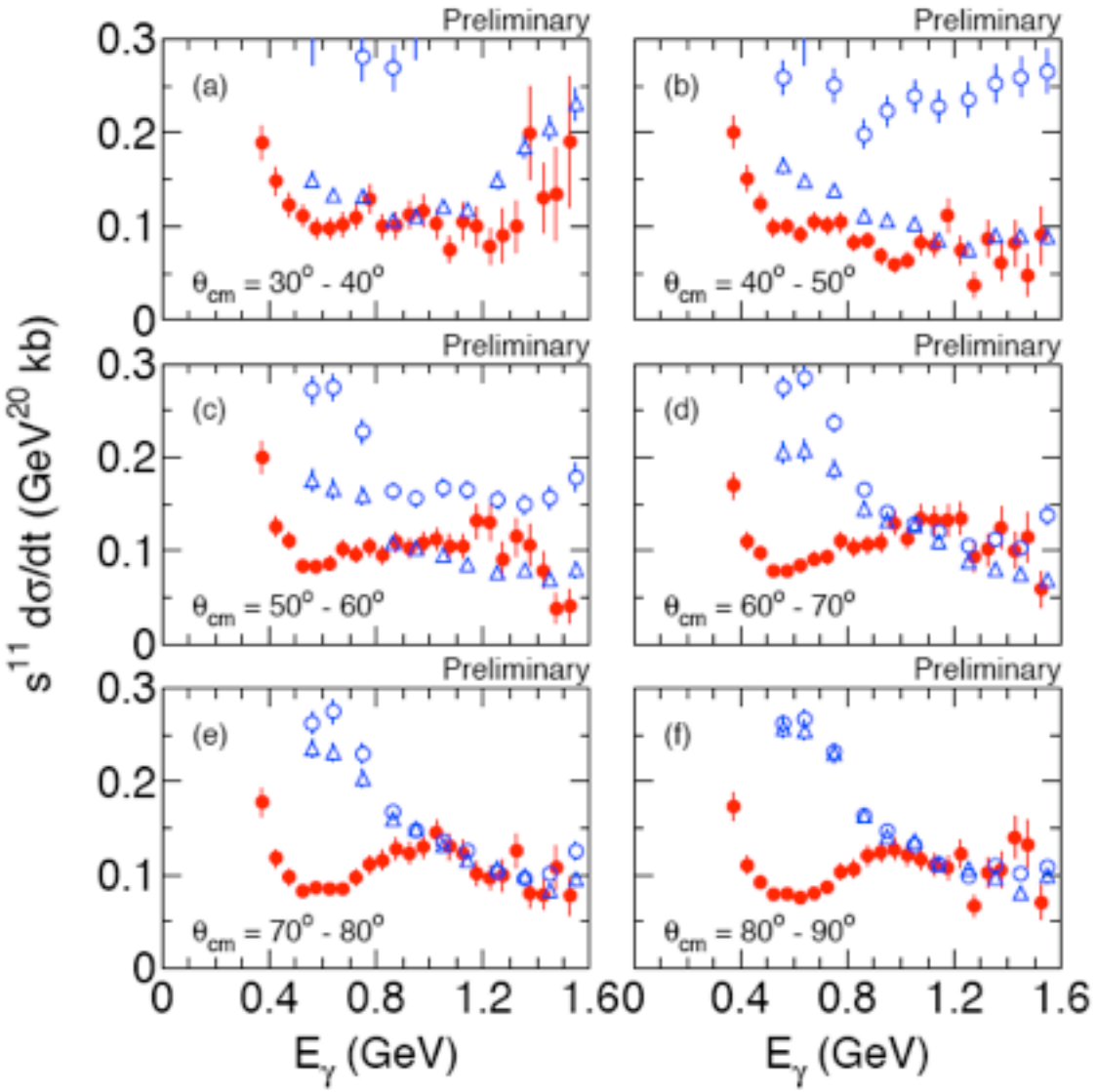
- Scaling of $\gamma\ pp$ cross section

- Test of factorization: oscillations seen in pp scattering will also appear in the $\gamma\ ^3\mathrm{He} \to pp + n$ reaction (HRM)

- Light-cone momentum distribution of the recoil neutron provides an independent test of the underlying dynamics of hard disintegration

S.J. Brodsky *et al.*, Phys. Lett. B **578** 69 (2004)

Differential Cross Section $s^{11} d\sigma / dt$

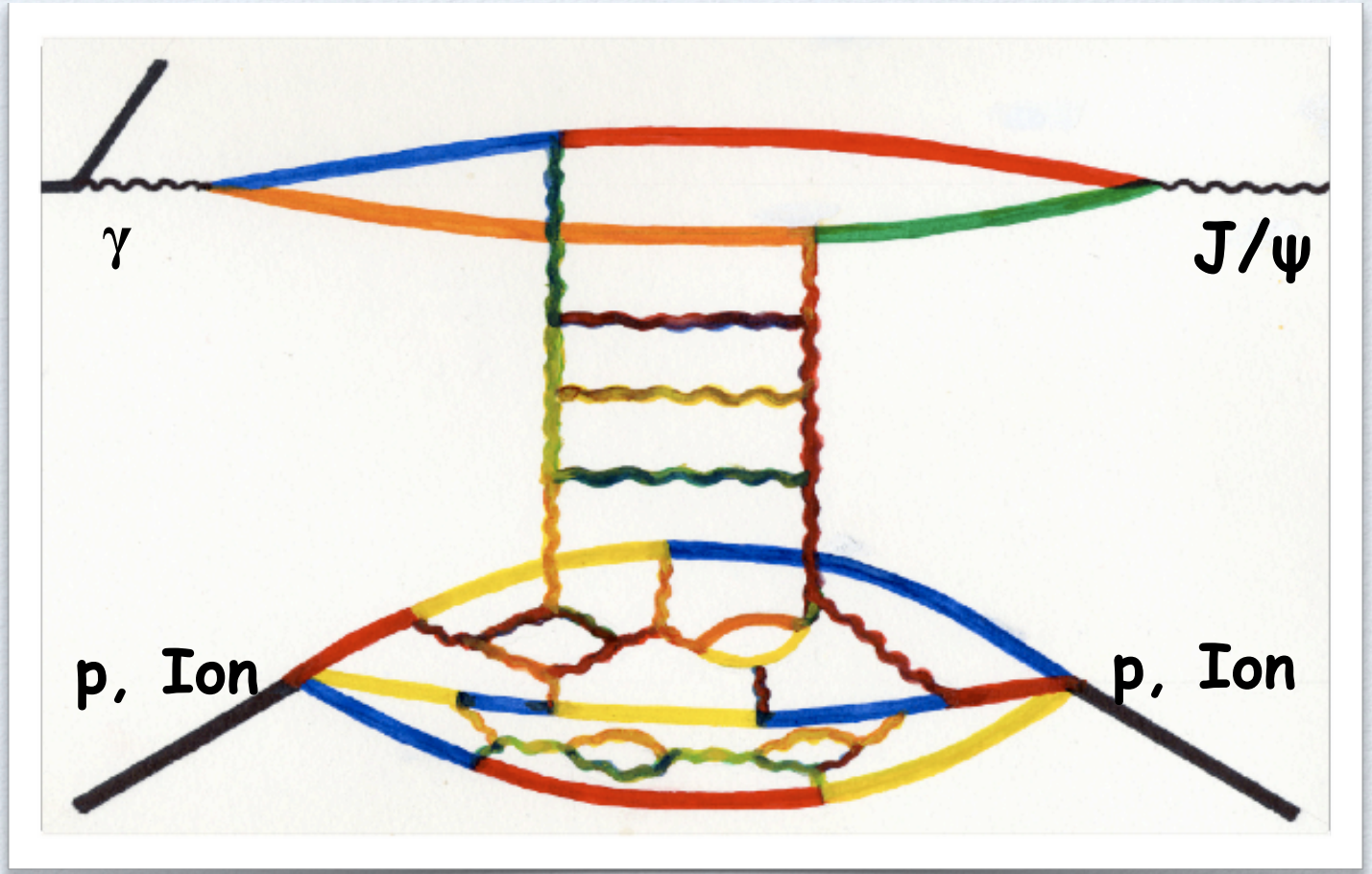


- Cross section scales approximately as s^{-11}
- $\gamma\ pp \rightarrow p + p$ symmetric about $90°$
- Scaled deuteron photodisintegration $(\times \frac{1}{4})$:
  ◯ forward,
  △ backward angles

Mirazita *et al.*, Phys. Rev. C **70**, 014005 (2004)

Summary

- pn-pair photodisintegration
  - Cross sections in good agreement with scaling once $p_T \geq 1.3$ GeV/c
  - Polarization-transfer data inconsistent with HHC
  - Meson-Baryon model starts to disagree with p_y data at $E_\gamma \approx 0.3$ GeV
  - E05-103: Measurement of a systematic set of high precision polarization data underway
- pp-pair photodisintegration
  - $\gamma\,^3\mathrm{He} \rightarrow pp + n$ as a tool to study hard nuclear reactions
  - CLAS data on $^3\mathrm{He}(\gamma, pp)n$ show $\sigma_{pp} \ll \sigma_{pn}$ up to $E_\gamma = 1.55$ GeV
  - E03-101 will provide cross sections and angular distributions for energies up to $E_\gamma = 5$ GeV


γ
J/ψ
p, Ion
p, Ion