E03-101: 3He(g,pp)n
Hard pp photodisintegration

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- Introduction – deuteron photo-disintegration review
- ^{3}He - photo-disintegration

Hall A Collaboration Meeting
Jefferson Lab January 2007

Is There a Quark-Hadron Transition in Exclusive Nuclear Reactions?

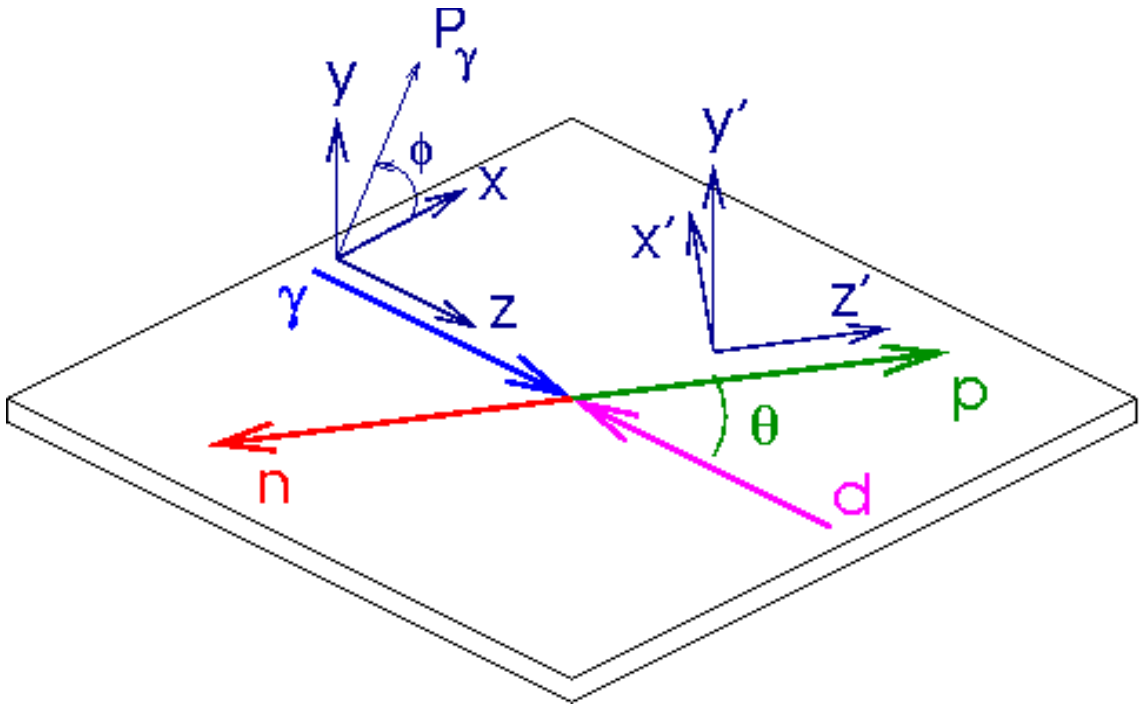
- Numerous studies: d,^{3}He,^{4}He(e,e'), d,^{3}He,^{4}He(e,e'p) in quasi-free kinematics, d(γ,p)n
  - Quark effects typically are subtle: theory based on NN force generally provides good explanation of data, various quark-based models do not help
- Exceptions: d(γ,p)n goes to high -t and high W, and there are several competing quark models

Recent Hall A Photodisintegration

- E00-007: X Jiang
  - Ran Oct 2002, paper distributed to collaboration
  - Angular distribution for recoil polarizations at 2 GeV
- E05-103: J Glister
  - Ran July-Sep 2006
  - Angular distribution for recoil polarizations at 280 – 360 MeV, to see the start of the breakdown in hadronic calculations

Some Observables in d(γ,p)n

- $d\sigma/d\Omega$, Σ, T, $C_{x'}$, p_y, $C_{z'}$



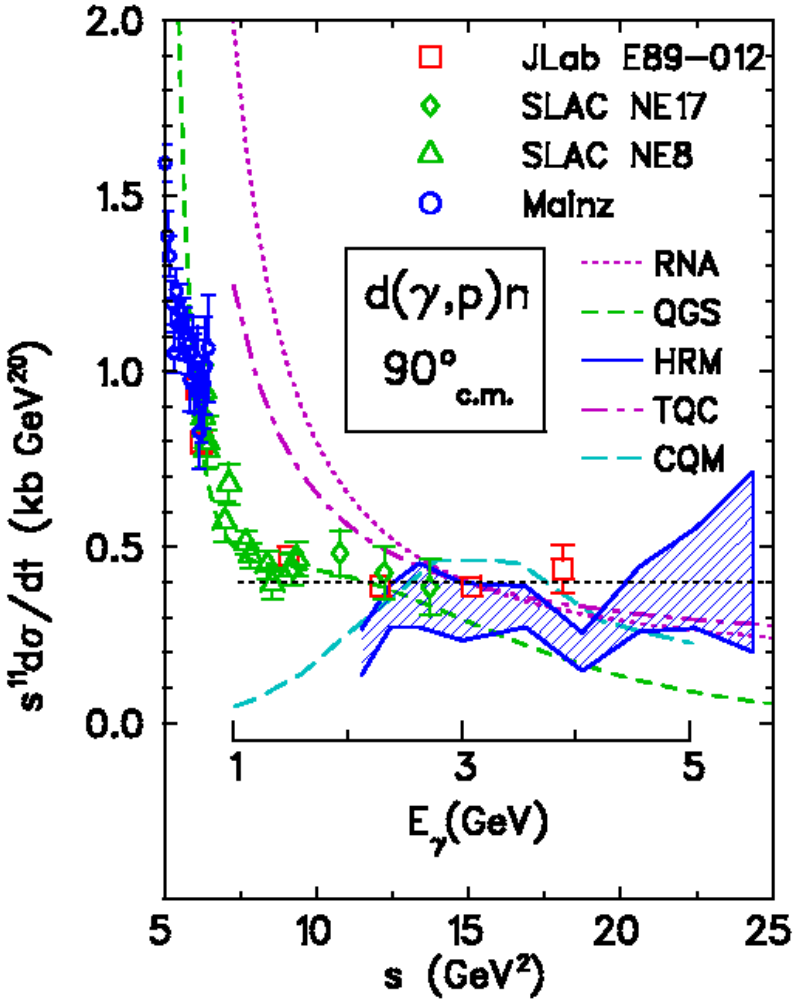
Hard Scattering Regime

- SLAC NE8, NE17
- JLab Hall C E89-012, E96-003
- Yerevan (Σ)
- JLab Hall A E89-019 ($C_{x'}$, p_y, $C_{z'}$), E99-008
- JLab Hall B E93-017
- JLab Hall A E00-007 ($C_{x'}$, p_y, $C_{z'}$) (X. Jiang)
- JLab Hall B: ^{3}He (S. Strauch)

- Does pQCD apply? -> Is there a good quark model? Is there a phase transition?

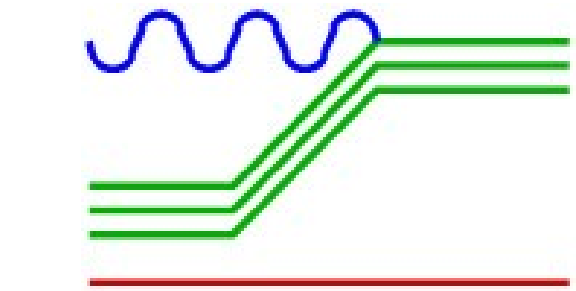
90° Excitation Functions

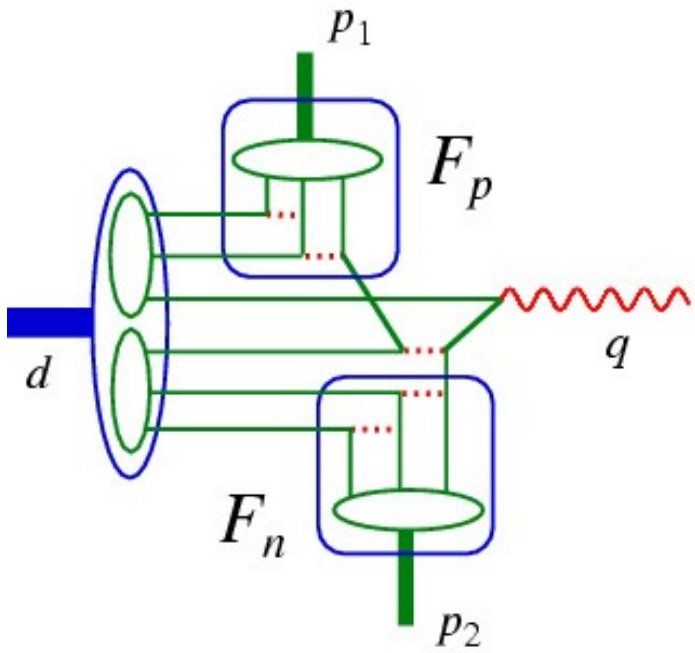
- Cross sections fall by a factor of 30,000 from 1 – 4 GeV, ~following ``expected'' quark scaling, $d\sigma/dt \sim s^{-11}$
- Hadronic theories not satisfactory and not shown
- Most quark models normalized



The Quark Models

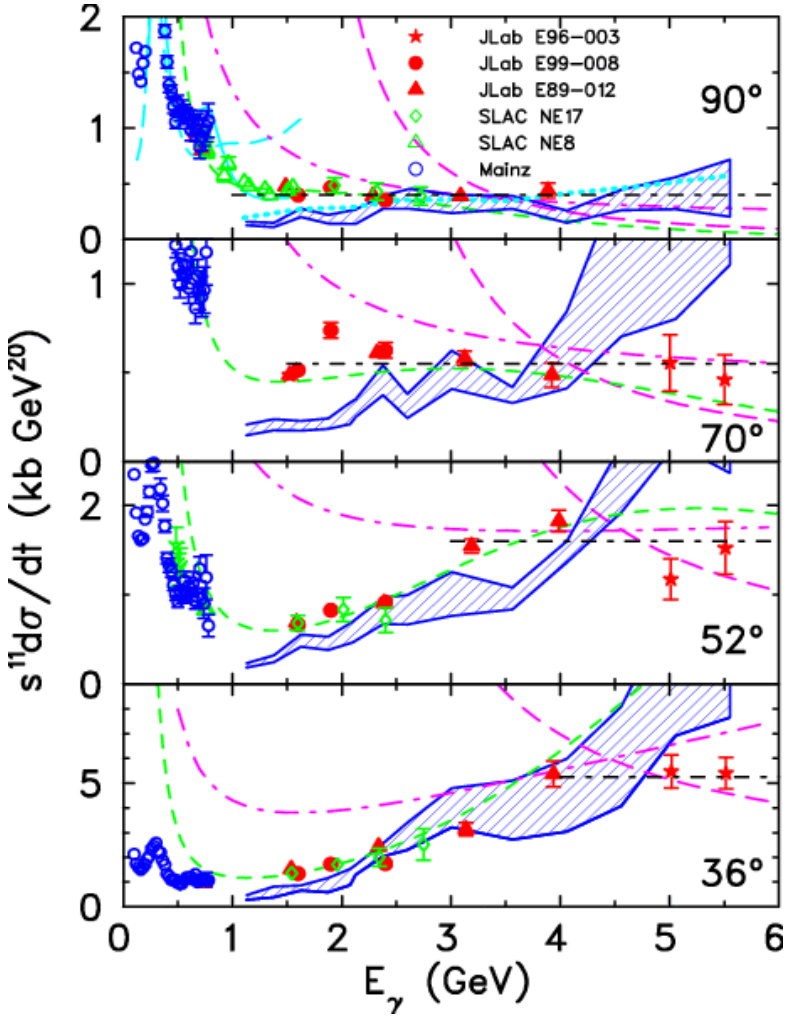
- QGS: Regge phenomenology to evaluate 3-quark exchange, justified by dominance of planar diagrams
- RNA, HRM, TQC, CQM: Photon absorbed and quarks exchanged; might be related to *NN* elastic scattering – all use hard scattering approximations





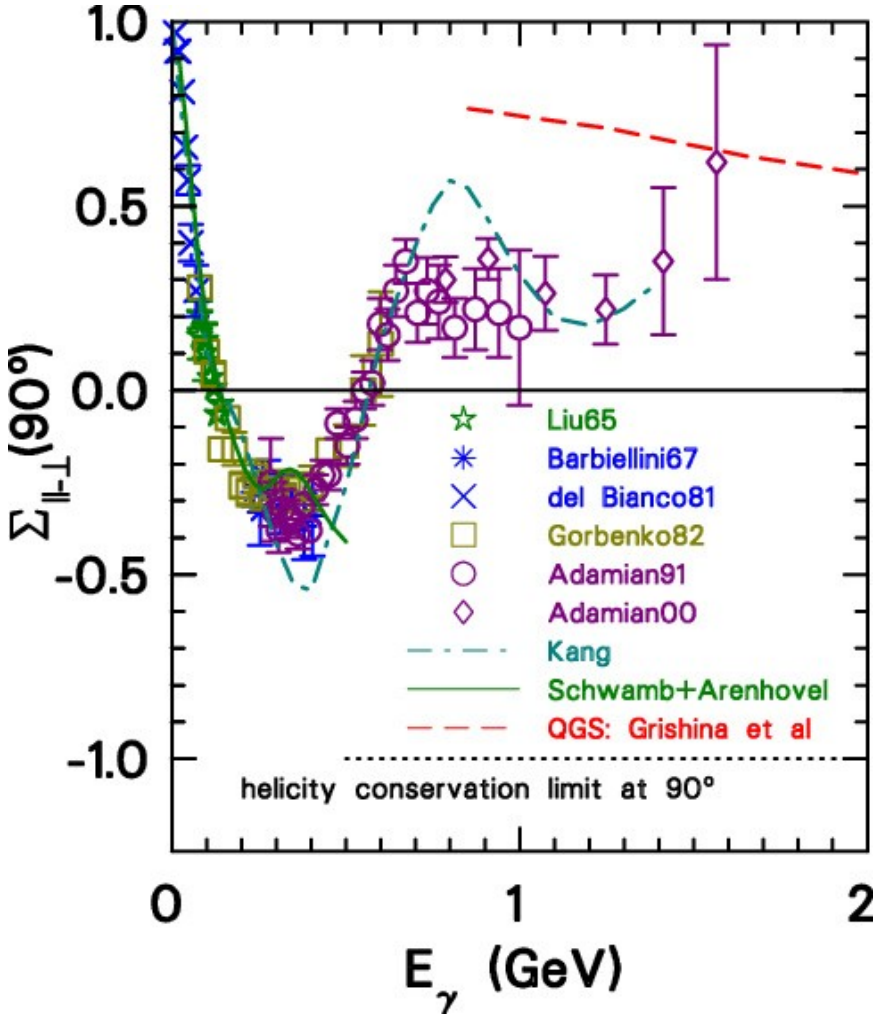
90° Excitation Functions

- Cross sections fall by factor of 1.2×10^6 from 1 – 6 GeV
- The onset of ~quark scaling, $d\sigma/dt \sim s^{-11}$, at each angle corresponds to $p_T \sim 1.1$ GeV: P Rossi et al, PRL 94, 012301 (2005)



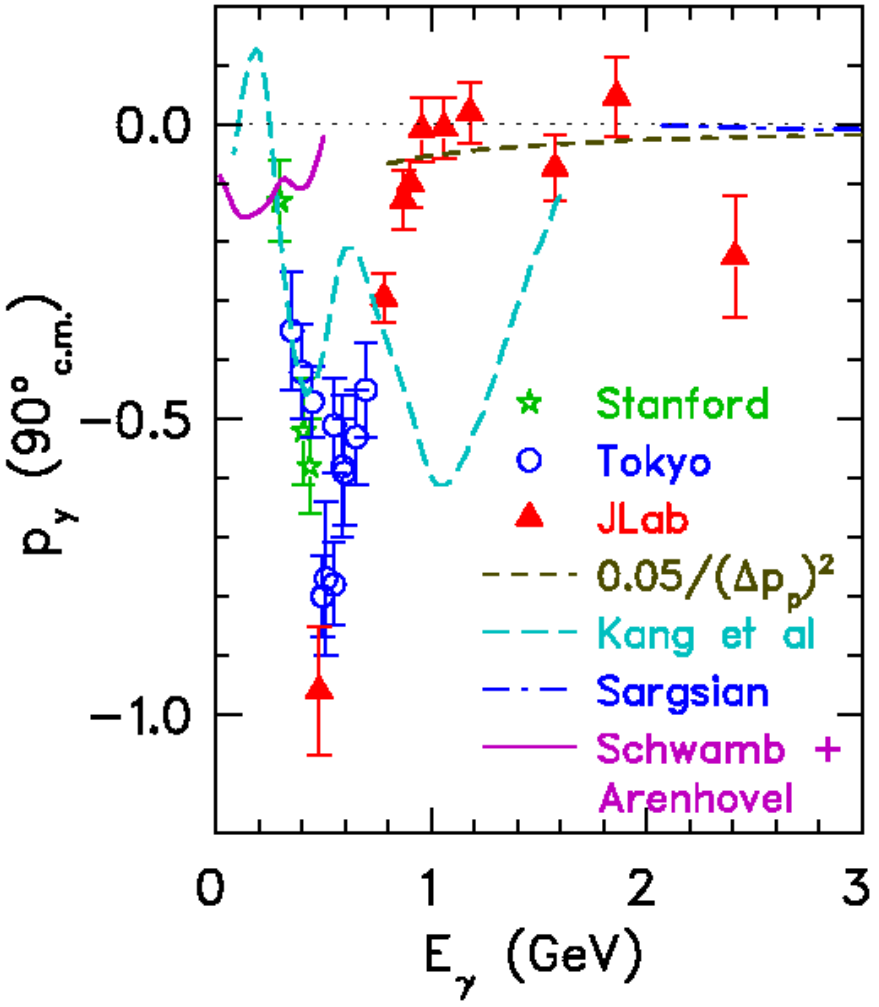
Σ Asymmetry

- HHC - Hadron Helicty Conservation – leads to Σ = -1
- Adamian *et al.* showed Σ heads away from HHC, with increasing energy
- Grishina et al. pointed out iso-vector (scalar) limit is Σ = 1 (-1)



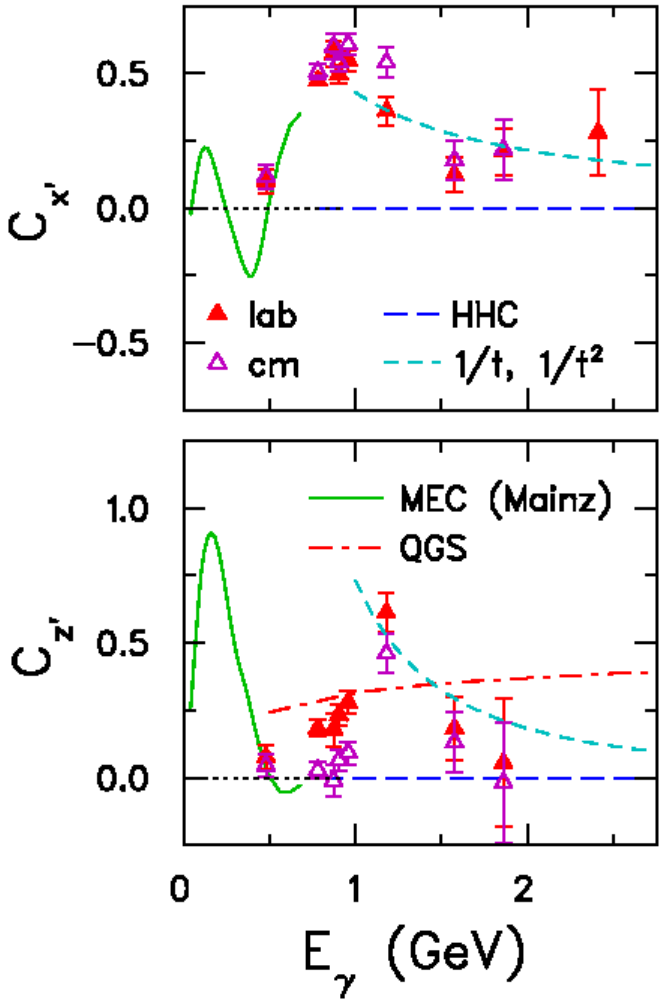
Induced Polarization p_y

- Hadronic prediction, that D_{13} + D_{15} leads to large resonance peak, falsified
- HHC leads to p_y = 0, and p_y vanishes above 1 GeV
- HRM predicts p_y small, <0



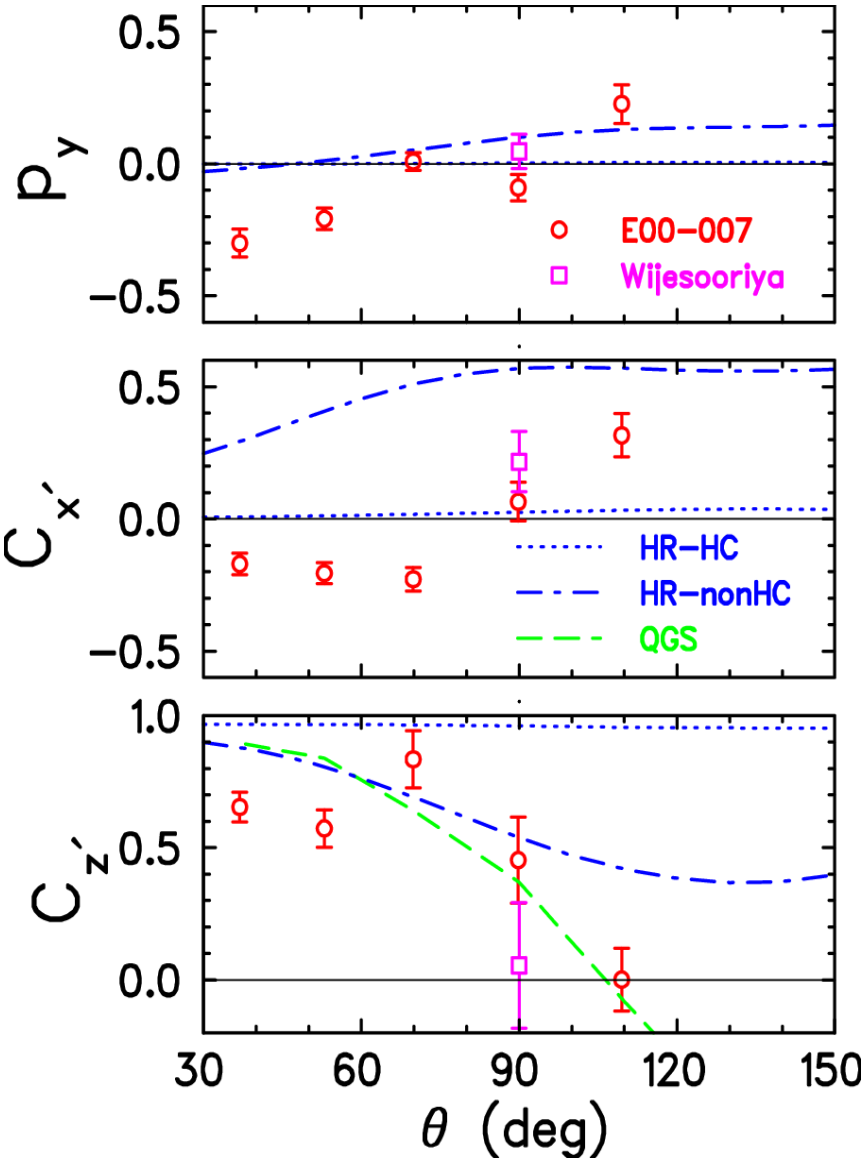
Polarization Transfer

- Schwamb & Arenhövel prediction good at low energies
- $C_{x'}$ small, but not vanishing, so no HHC
- Cannot rule out or strongly support HRM / QGS / approach to HHC



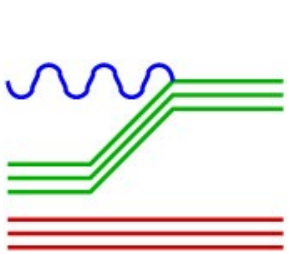
Hall A E00-007: X Jiang et al.

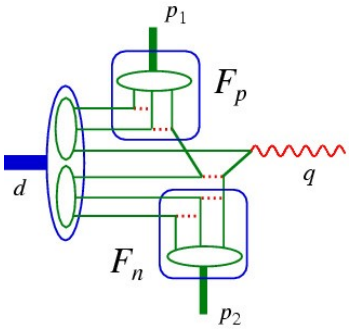
- E_γ ~ 2 GeV
- $C_{z'}$ large at forward angles, like QGS + HR
- $C_{x'}$ and p_y cross 0 near 90°: in HR, if isovector photon dominance, these ≈ φ_5, which vanishes at 90°
- Perhaps similar to Σ?

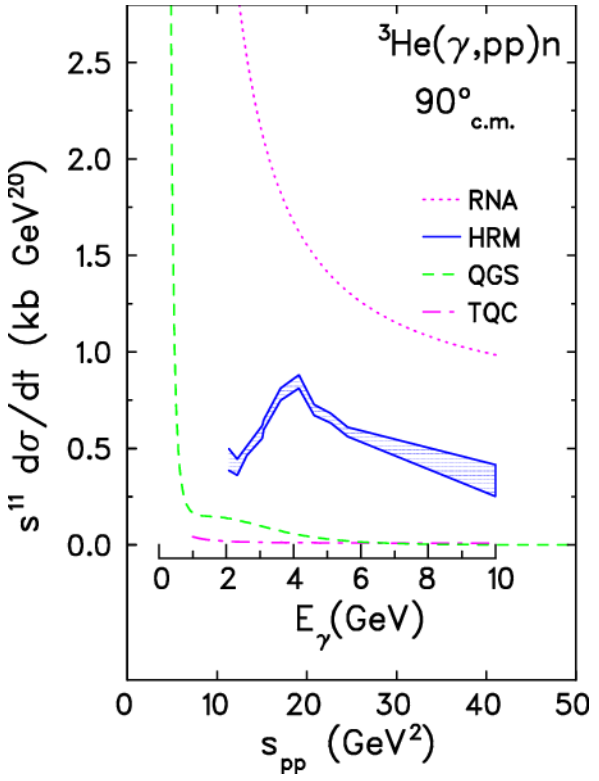


^{3}He (pp) Disintegration

- Brodsky et al, PLB 578, 69 (2003): ratio of pp to pn well determined in theory
- At low energy, σ(γpp) / σ(γpn) ~ 0.1: pp dipole moment vanishes: JM Laget
- Quark models predict larger ratio: slow 2nd order or fast 1st order phase transition?

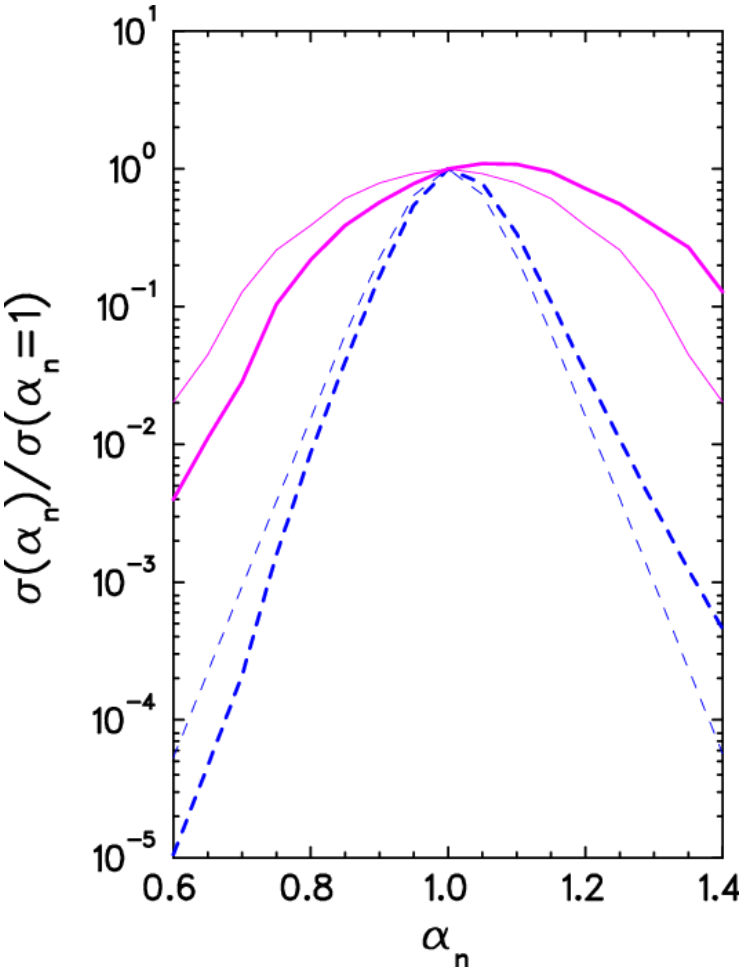






^3He (pp) α_n Distribution

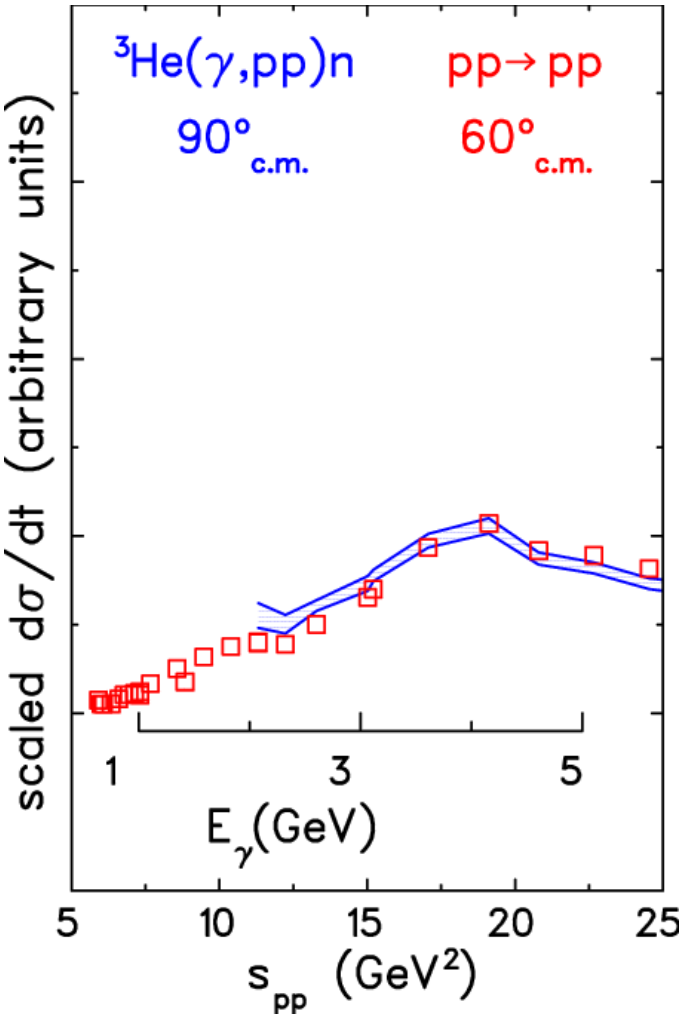
- Light cone momentum fraction, $\alpha = (E-p_z)/m$, is conserved:
  $\alpha_\gamma+\alpha_{He}=0+3=\alpha_{p1}+\alpha_{p2}+\alpha_n$
- Soft FSI "do not" affect α, so α_n reflects neutron spectator wave function
- RNA short range/broad, HRM long range/narrow



- Model-independent check of long vs short range dynamics

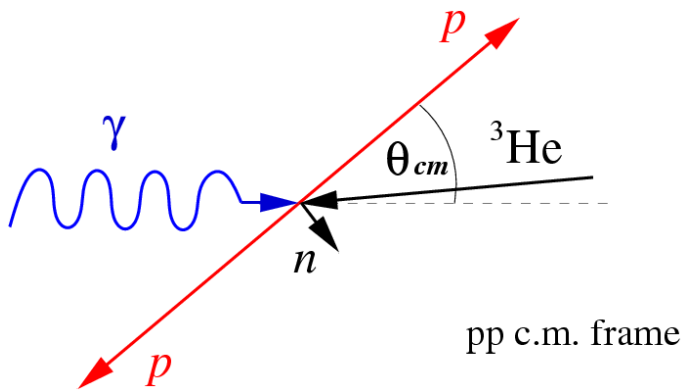
^{3}He (pp) Oscillations

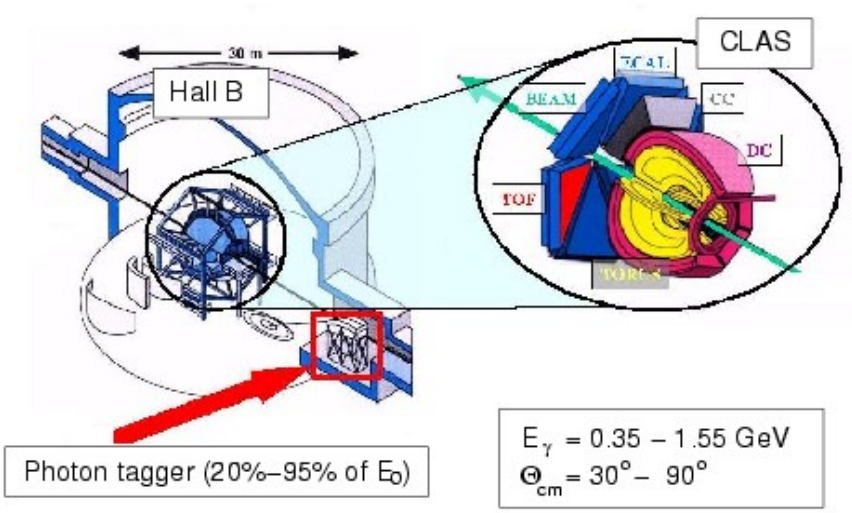
- Prominent oscillations in pp cross section, as opposed to flatter pn cross section, reflected in oscillations in γpp, as opposed to flatter energy dependence in γd?
- To match s and t, compare 60° pp to 90° γpp



^{3}He(γ,pp)n Measured!

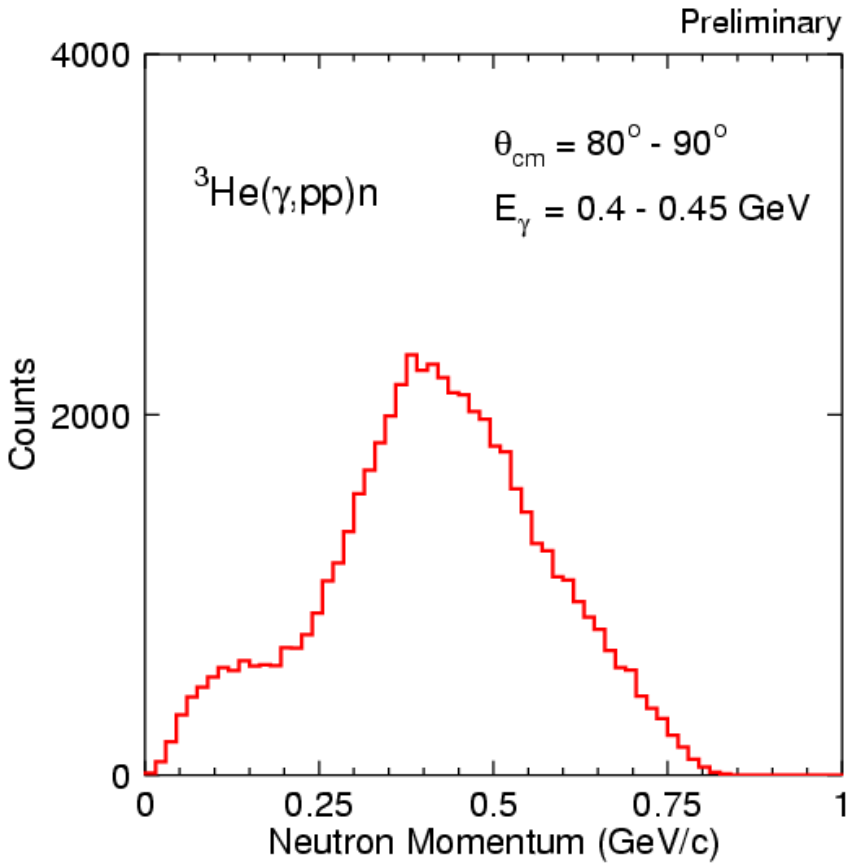
- Hall B experiment, analyzed by S. Strauch, GWU (now SC)
- PRELIMINARY

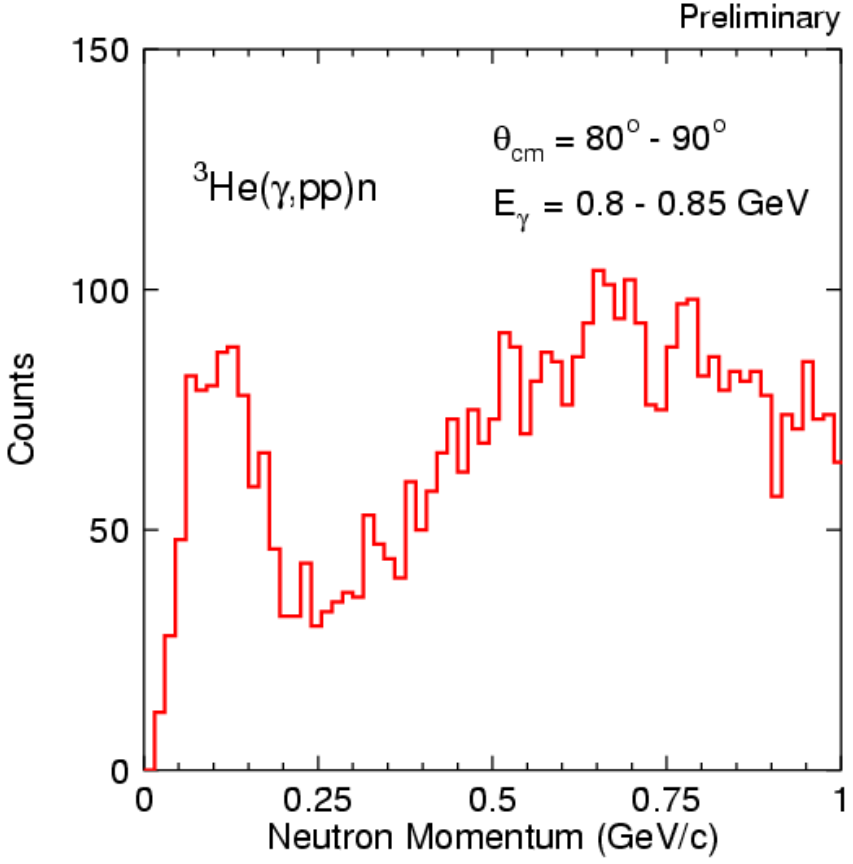




^{3}He(γ,pp)n Neutron Spectator?

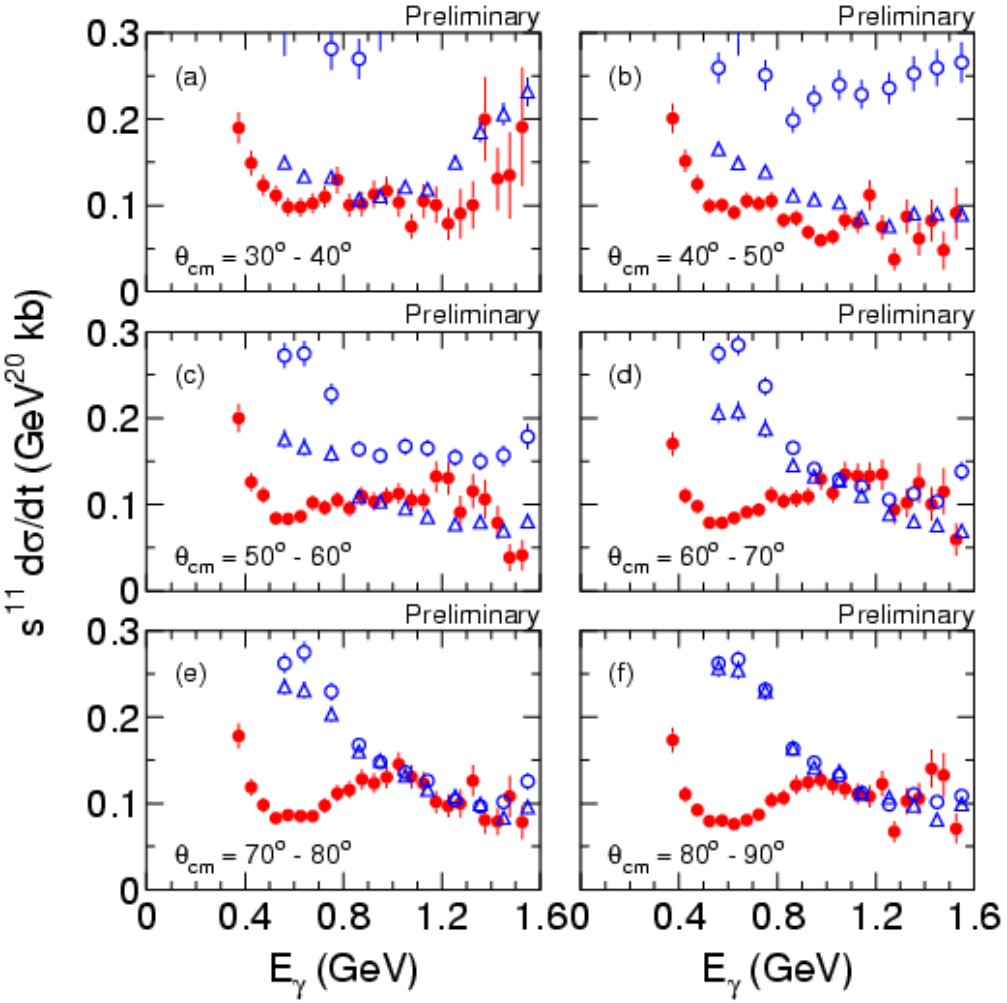
- Is the neutron a spectator? Cut at 0.1 – 0.25 GeV/c





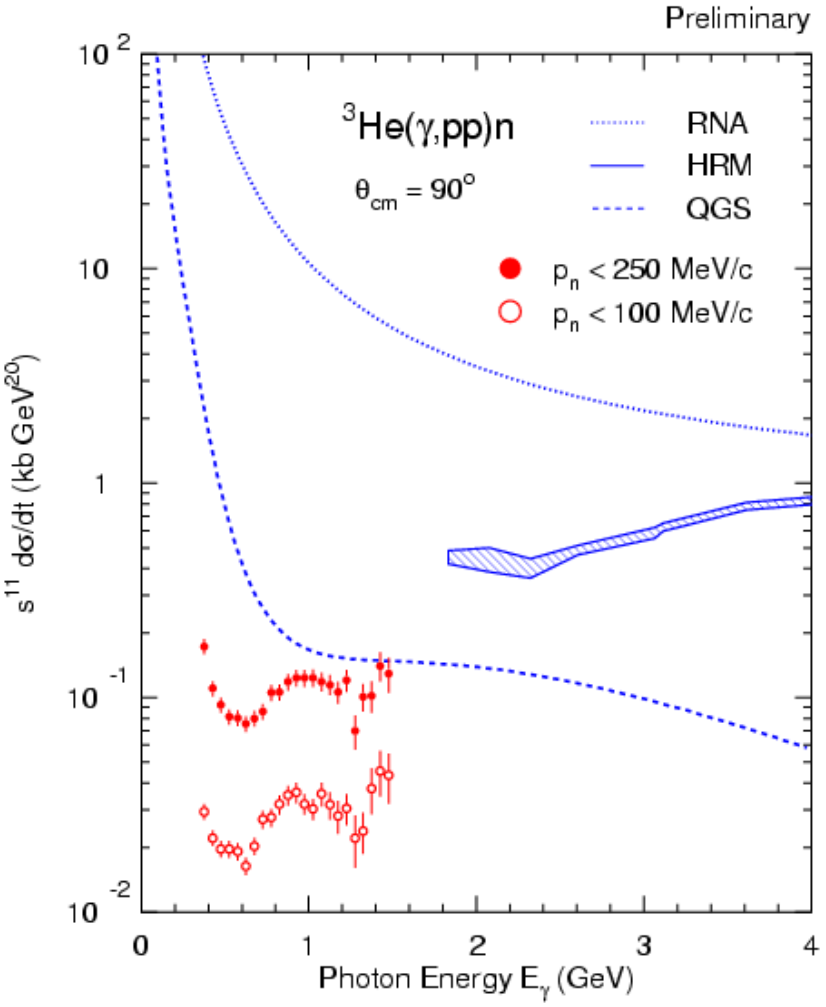
^{3}He(γ,pp)n Cross Sections

- Red: "γpp->pp", symmetric about 90°
- Blue: γd->pn x $\frac{1}{4}$, asymmetric about 90°
- Cross sections for γpp like back-angle γd, near 1 GeV



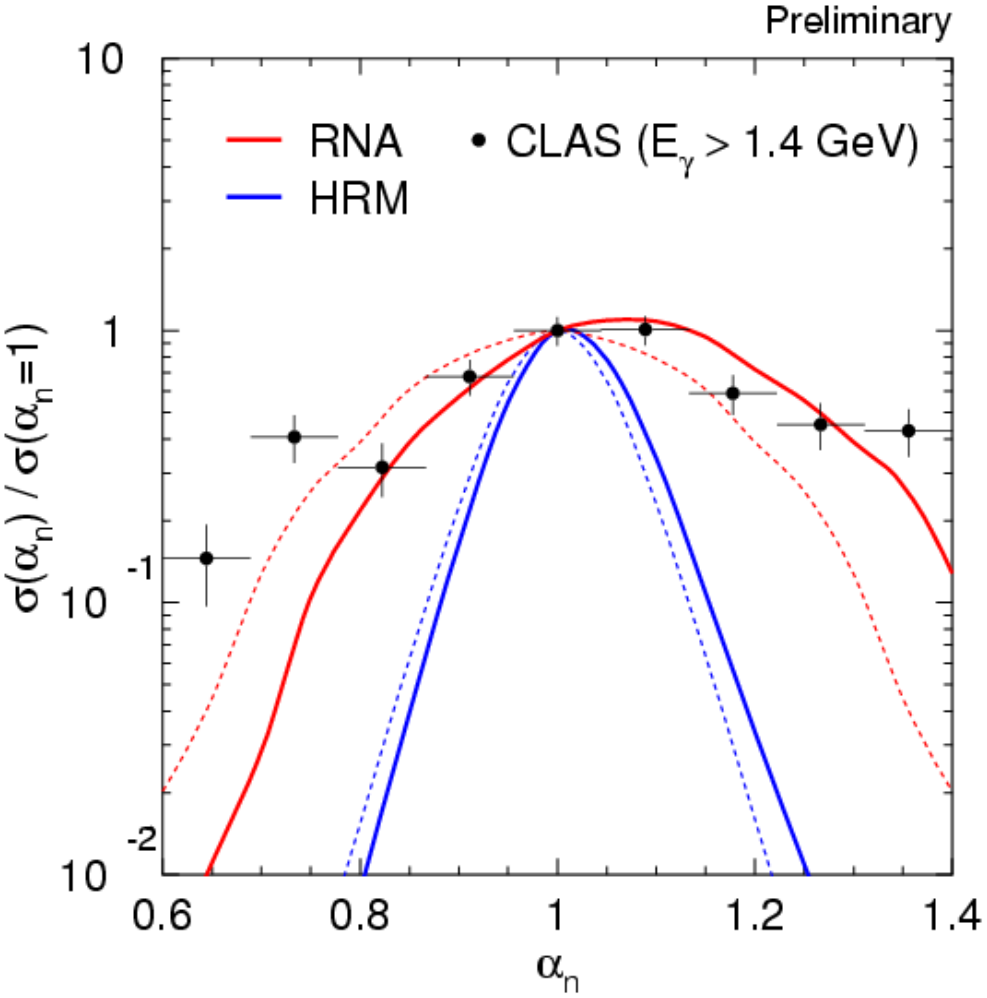
^{3}He(γ,pp)n Cross Sections

- Theory has 100 MeV/c cut
- Data small compared to γd, 10 – 25 % as large
- Scaling of σ by E_γ ~ 1.3 GeV in γd, p_y vanished by ~ 1 GeV, $C_{x',z'}$ slowly vanishing => I would expect a transition by 1 or 1.3 GeV
- Hint of a phase transition starting at 1.4 GeV -or- perhaps QGS or TQC is the right approach?



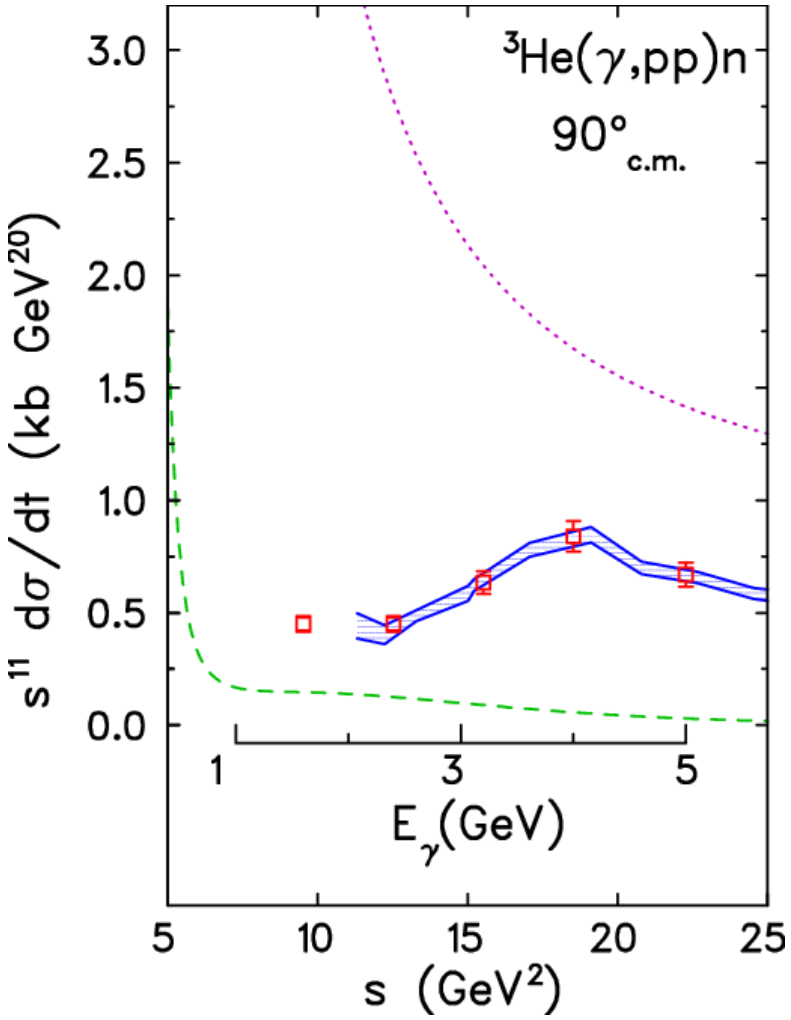
$^3He(\gamma,pp)n$ a_n Distribution

- Hard distribution from short-range physics, evidence for TQC?
- 1 GeV/c nucleons in c.m. are too low in energy: lots of rescattering broadens distribution



^{3}He(γ,pp)n: Hall A E03-101

- Can cleanly distinguish 1/10, 1/4, … x deuteron disintegration cross section vs "phase transition"
- Scheduled for June (December?) 2007



Summary

- Hadronic d.o.f. describe few-body elastic and QF scattering well; going to high Q^2 is insufficient to guarantee large quark effects
- We know lots of details in γd -> pn – it is clear that detailed models like those used at low energy do not, and cannot, work – but the underlying quark dynamics is unclear
- ^{3}He photo-disintegration might sort out if any of the existing quark models represents the underlying physics