The Hard Photodisintegration of a Proton Pair in ^{3}He Nuclei

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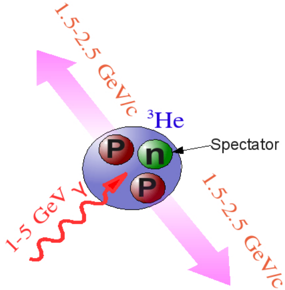
for the Hall A Collaboration

December 15, 2009

The Process

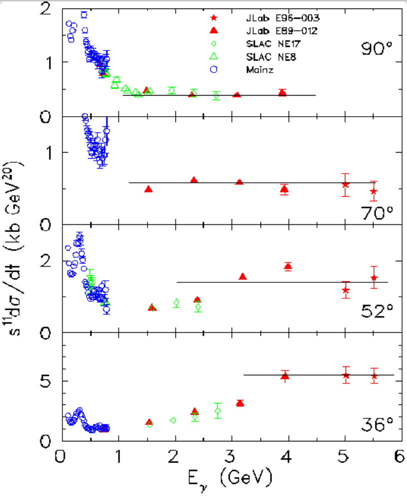
A process in which a high energy photon is absorbed by a proton pair, resulting in two protons with large transverse momenta.

$$\gamma^3\text{He} \longrightarrow p(\text{high } p_t) + p(\text{high } p_t) + \text{n(slow)}.$$



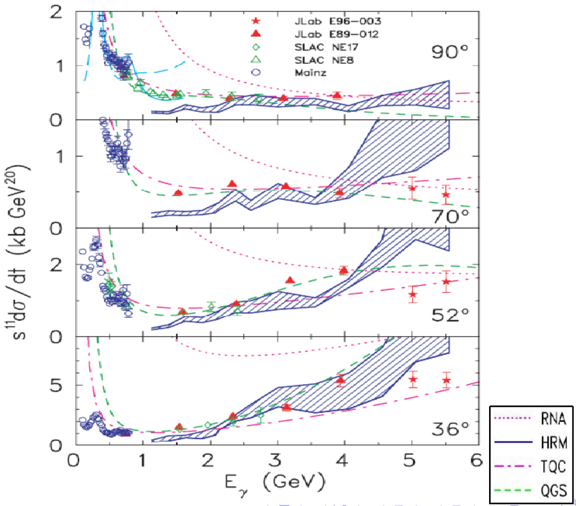
Motivation

- Significant effort has been devoted to investigate the hard photodisintegration of the Deuteron.
- d(γ,p)n cross section scales with s^{-11} at fixed large cm angle, above 1 GeV in photon energy.
- This scaling is predicted by the Constituent Counting Rule.



Motivation

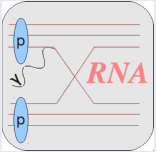
Several quark models, have been formulated, each using very different assumptions to explain the high PT in the scaling regime.



Two possible mechanisms can explain the high PT

1. Breaking a transverse compact object.

- The high PT Results from initial state correlation.
- A very minute part of the pair wave function.



Reduced Nuclear Amplitudes

S.J. Brodsky, J.R. Hiller

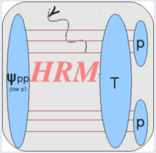
Quark Gluon String Model

V. Yu Grishina et al.

Two possible mechanisms can explain the high PT

2. Hard re-scattering.

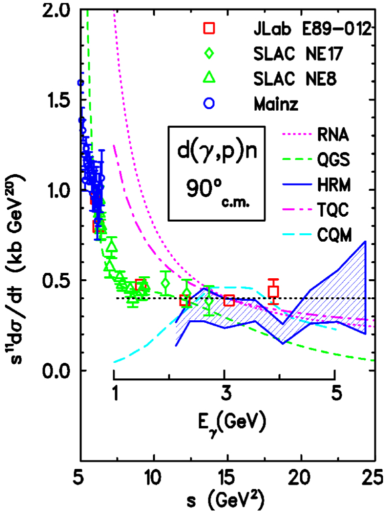
- One proton absorbs the photon, and then interacts with the other member of the pair. The high PT results from this final state interaction.
- Also a rare case (large pp c.m. scattering angle).

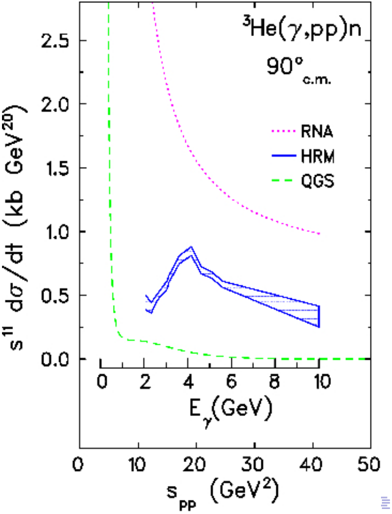


Hard Re-scattering Model

L.L. Frankfurt, G.A Miller, M.M. Sargasian, M.I Strikman

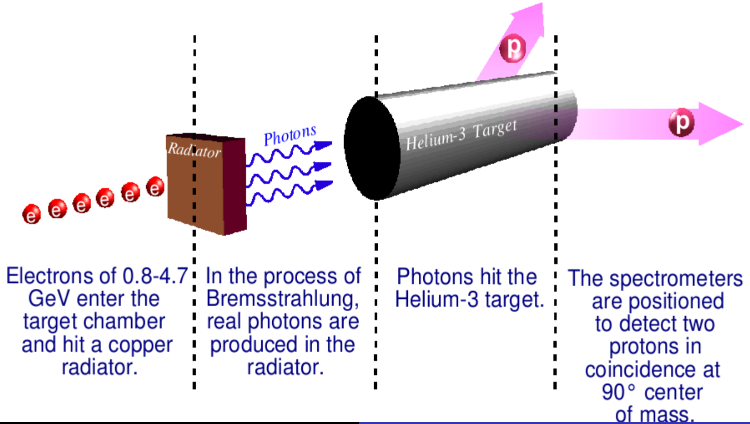
Theoretical predictions





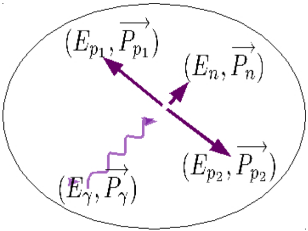
Experimental setup

Technique follows that of I Pomerantz et al, E03-101, submitted to PLB.



Kinematic reconstruction

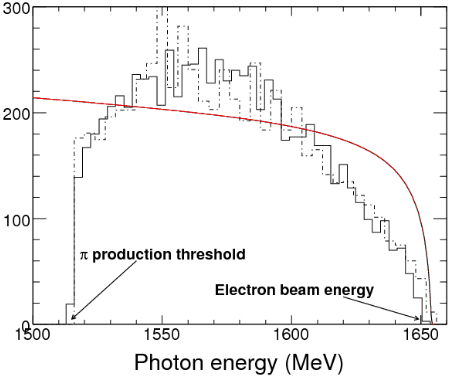
- 6 known variables: $P_1, \phi_1, \theta_1, P_2, \phi_2, \theta_2$.
- 4 unknown variables: $P_n, \phi_n, \theta_n, E_\gamma$.
- 4 constraints of energy and momentum conservation:



$$E_\gamma = E_n + E_1 + E_2$$
$$E_\gamma = P_1 cos\theta_1 + P_2 cos\theta_2 + P_n cos\theta_n$$
$$P_1 sin\phi_1 sin\theta_1 + P_2 sin\phi_2 sin\theta_2 + P_n sin\phi_n sin\theta_n = 0$$
$$P_1 cos\phi_1 sin\theta_1 + P_2 cos\phi_2 sin\theta_2 + P_n cos\phi_n sin\theta_n = 0$$

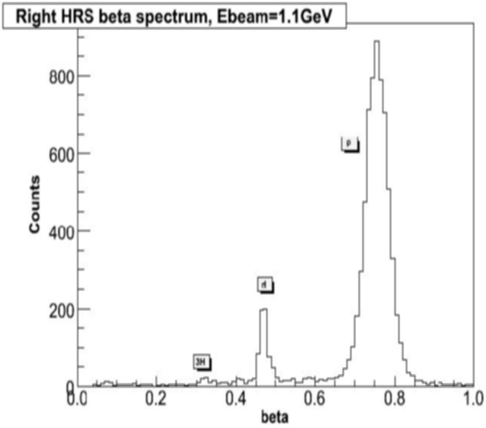
Kinematic reconstruction

- Assuming a two-body process by demanding photon energy of a 140 MeV bin off the tip of the bremsstrahlung spectra.
- Since we extract the photon energy for each event, we care very little about beam parameters.



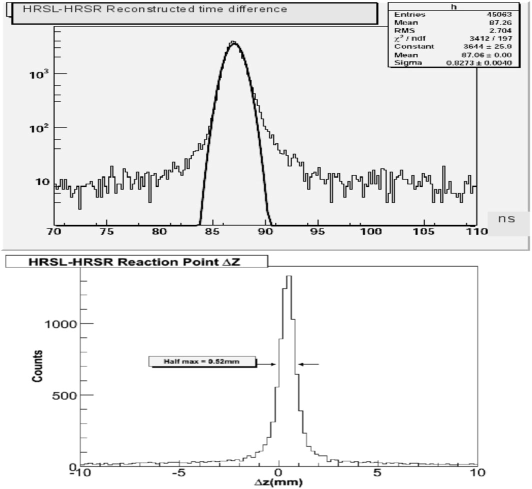
Event selection

- Particle ID.



Event selection

- Particle ID.
- Coincidence time, and reaction point.



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- Particle ID.
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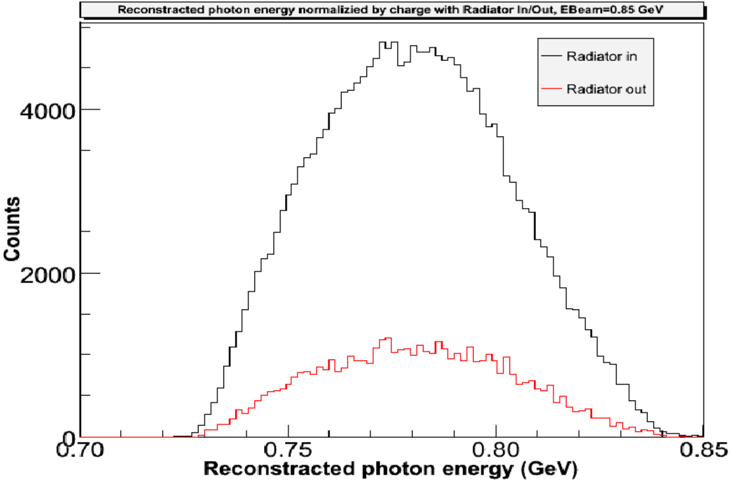
- Phase space cuts on nominal HRSs acceptance.

Event selection

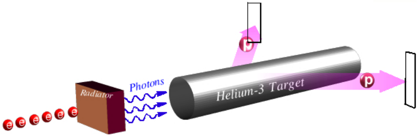
- Particle ID.
- Coincidence time, and reaction point.
- Phase space cuts on nominal HRSs acceptance.
- Cut on an 140MeV bin in photon energy.

Electroproduction background subtraction



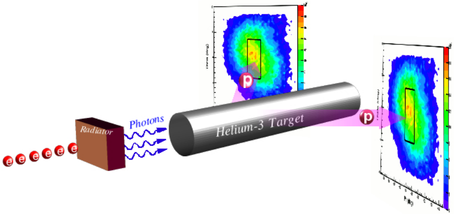
Coincidence efficiency

- The edge of the HRS acceptance is set to detect a pair at rest disintegrated in 90° c.m. from a photon with $E_{\gamma} = E_{Beam}$.

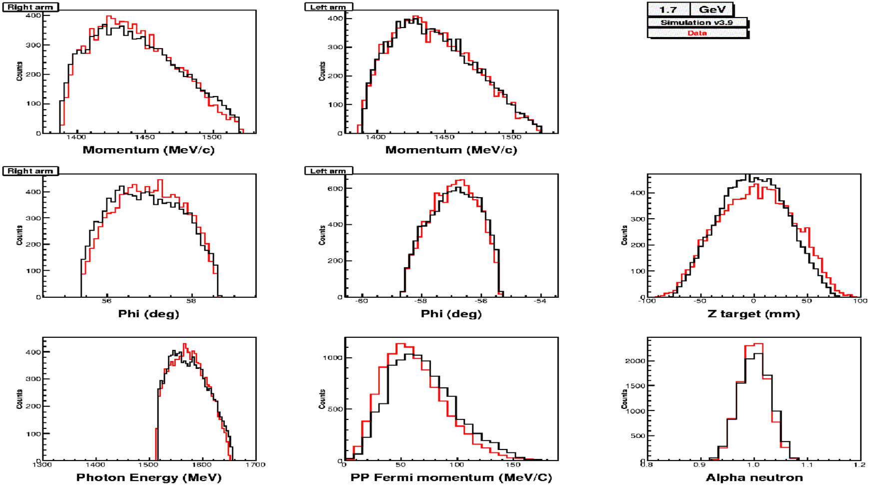


Coincidence efficiency

- The edge of the HRS acceptance is set to detect a pair at rest disintegrated in 90° c.m. from a photon with $E_\gamma = E_{Beam}$.
- The Fermi motion of the proton pair and the different photon energies results in a phase-space spread of the outgoing protons larger than the HRS acceptance.
- To correct the cross section calculation for those missed events, we constructed a MCEEP simulation.

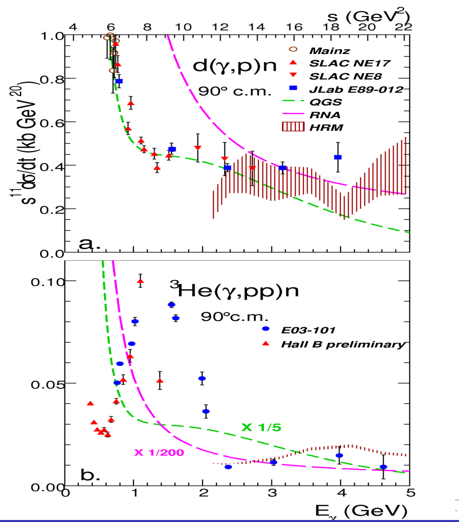


MCEEP results



Results

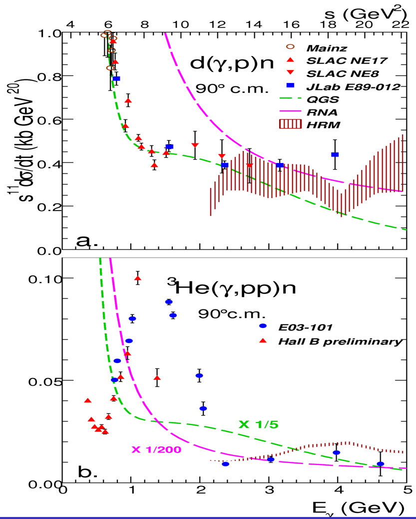
- For $\gamma d \to pn$, scaled cross section falls continuously above Δ resonance, and scaling starts $\sim$ 1 GeV and at $p_T\ > 1.3$ GeV/c.
- For $\gamma pp \to pp$, scaled cross section peaks $\sim$ 1.5 GeV, and scaling starts $\sim$ 2 GeV.



Results

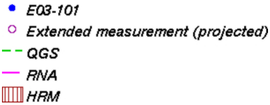
- In the scaling region, the cross section ratio $\sigma(\gamma d)\ /\ \sigma(\gamma pp)\ \sim$ 20, after correcting for measurements only being up to $p_n = 100$ MeV/c.
- HRM explains the low magnitude of the scaled cross section by a cancellation of the opposite sign of the NN helicity amplitudes ϕ_3 and ϕ_4.

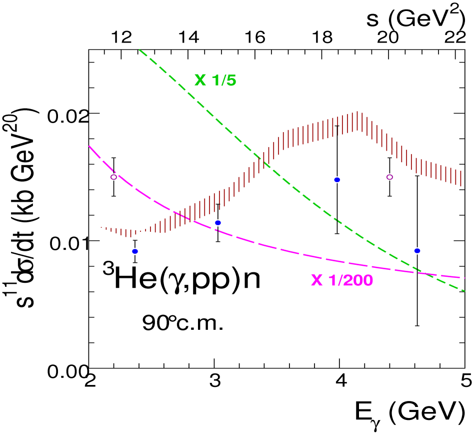
M. M. Sargsian and C. Granados, Phys. Rev. C80, 014612 (2009)



Energy dependence of the cross section

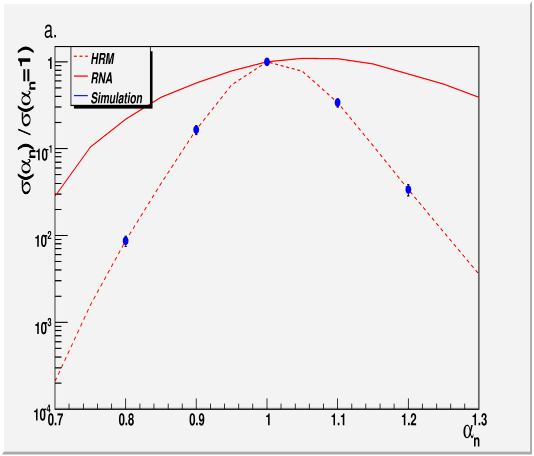
- Two more data points at $E_\gamma = 2.2$ and 4.4 GeV, to look for deviation from constituent counting rules scaling.





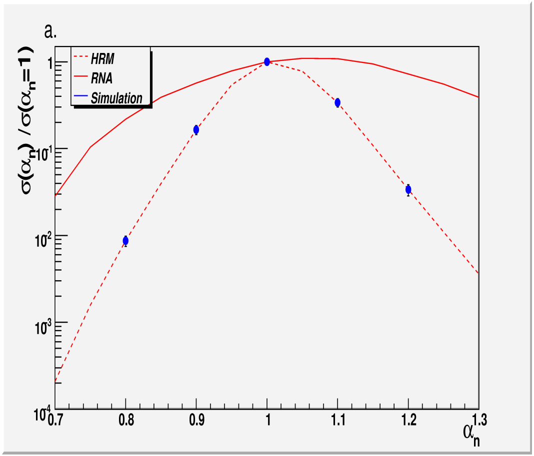
α_n distribution

- The light-cone momentum distribution of the spectator neutron, defined as: $\alpha_n = \frac{E_n - p_n^z}{m_{^3He}/3}$.
- High-energy small-angle final-state rescattering does not change α_n.
- RNA model predicts a much broader distribution of α_n due to selection of large momenta protons from the ^{3}He wave function.



α_n distribution

- We will cover $0.8 < \alpha_n < 1.2$ at 5 kinematics for $E_\gamma = 2.2$ GeV.



Kinematics and expected yields

$E_e \approx E_\gamma$	Tgt	α_n	θ_p	P_p	$s^{11} \frac{d\sigma}{dt}$	rate	time	yield
[GeV]			[deg]	[GeV/c]	[kb GeV^{20}]	[cnt/Hr]	Hr	# evts
2.2	^{3}He	0.8	56.36	1.795	0.001	10	6	54
2.2	^{3}He	0.9	54.42	1.805	0.007	72	2	144
2.2	^{3}He	1.0	52.55	1.808	0.02	210	4	840
2.2	^{3}He	1.1	50.66	1.806	0.004	39	3	117
2.2	^{3}He	1.2	48.76	1.799	0.001	6	8	46
2.2	d	1.0	52.55	1.808	0.4	8400	1	8400
4.4	d	1.0	42.72	2.990	0.4	21	48	1008
4.4	^{3}He	1.0	42.72	2.990	0.01	0.45	222	100

Summary

- We measured hard pp photodisintegration in ^{3}He at $\theta_{c.m.} = 90°$,for $E_\gamma = 0.8$ to 4.7 GeV.
- For $E_\gamma = 1$ - 2 GeV, there are structures in pp system not seen in the pn system.
- For $E_\gamma \; > 2$ GeV, $d\sigma/dt \sim s^{-11}$, but γpp cross section is ~20x smaller than γpn cross section.
- 15 days of beam time will enable us to determine if deviation from constituent counting rules scaling exists, and to measure α_n to determine if initial or final state effect.
- **Looking into adding Hall A neutron detector!**