E03-101: Hard Photodisintegration of a Proton pair

Hall A Collaboration meeting

June 2008

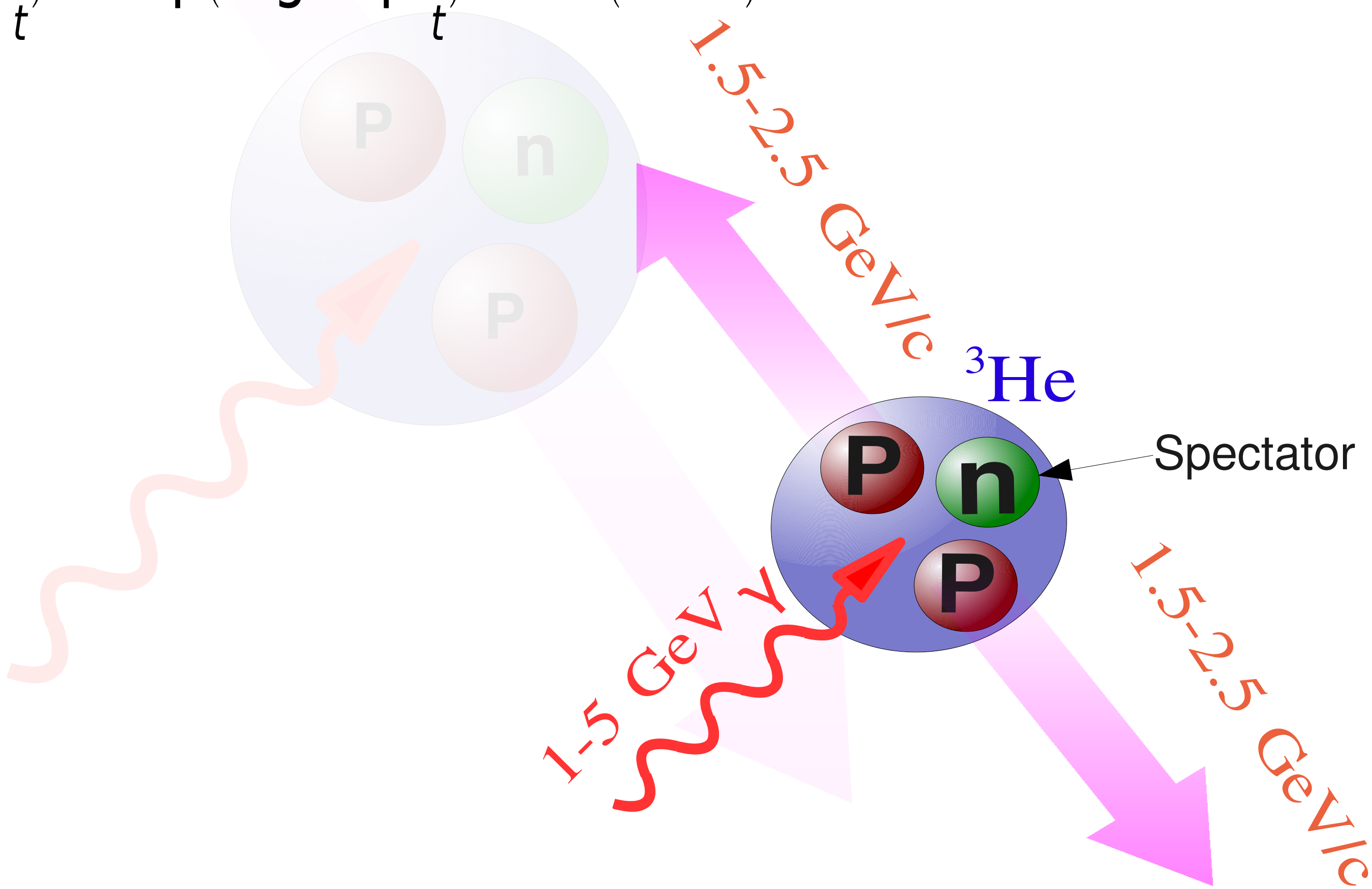
Ishay Pomerantz / Tel Aviv University

Spokespersons: Ron Gilman and Eli Piasetzky

Hard Photodisintegration of a Proton Pair

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

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



Motivation

- For most high energy exclusive process, pQCD predicts correctly the scaling with energy of the cross section, but we seem unable to predict the absolute magnitudes with pQCD. d(γ,p)n is an excellent example.
- Significant effort has been devoted to investigate the hard photodisintegration of the Deuteron.
- For JLab energies, several quark models have been formulated, the breakup of a pp pair will test their validity as a direct continuation of the Deuteron study.

Motivation

- Experimental goals:
  - To determine the mechanism that produce large (1.5-2.5 GeV/c) transverse momentum nucleons.
  - To observe the nature of the transition from meson exchange to quark-gluon dynamics.
  - To verify that scaling work in this process.

The Constituent Counting Rule:

s,t – Mandelstam variables

n_{abcd} – Number of fundamental fields

$$\frac{d\sigma}{dt}(AB \to CD) \propto s^{-(n_a+n_b+n_c+n_d-2)} f(\frac{s}{t})$$

So in our case:

$$\frac{d\sigma}{dt}(\gamma + pp \to p + p) \propto s^{-(1+6+3+3-2)} f(\frac{s}{t}) = s^{-11} f(\frac{s}{t})$$

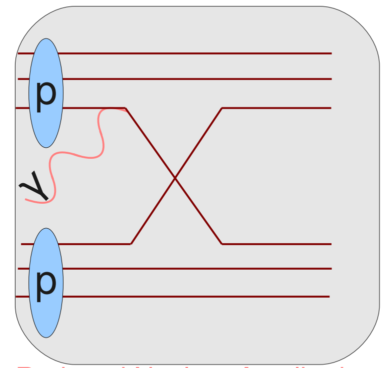
Theory

- Two possible mechanisms can explain the high P_t:

  1)Breaking a transverse compact object

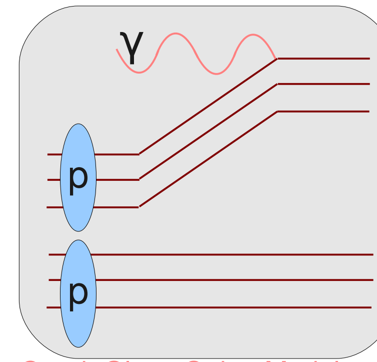
  - The high Pt Results from initial state correlation.
  - A very minute part of the pair wave function.

RNA



Reduced Nuclear Amplitudes
S.J. Brodsky, J.R. Hiller,Phys. Rev. C 28 (1983) 475

QGS



Quark Gluon String Model
V. Yu Grishina et al. EUR.J.Phys.A10,355(2000)

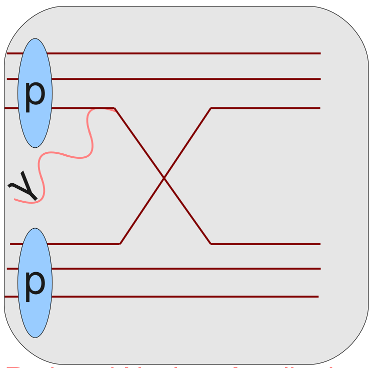
Theory

- Two possible mechanisms can explain the high P_t:

1)Breaking a transverse compact object

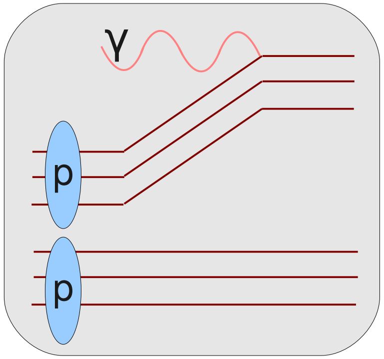
- The high Pt Results from initial state correlation.
- A very minute part of the pair wave function.

RNA



Reduced Nuclear Amplitudes
S.J. Brodsky, J.R. Hiller,Phys. Rev. C 28 (1983) 475

QGS

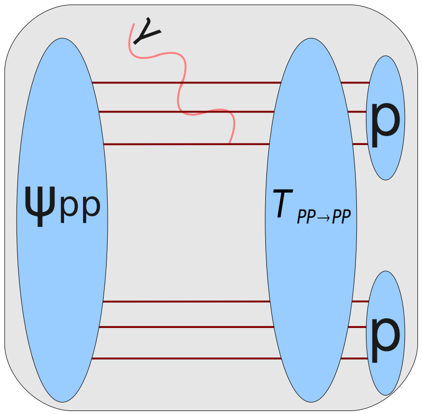


Quark Gluon String Model
V. Yu Grishina et al. EUR.J.Phys.A10,355(2000)

2)Hard re-scattering

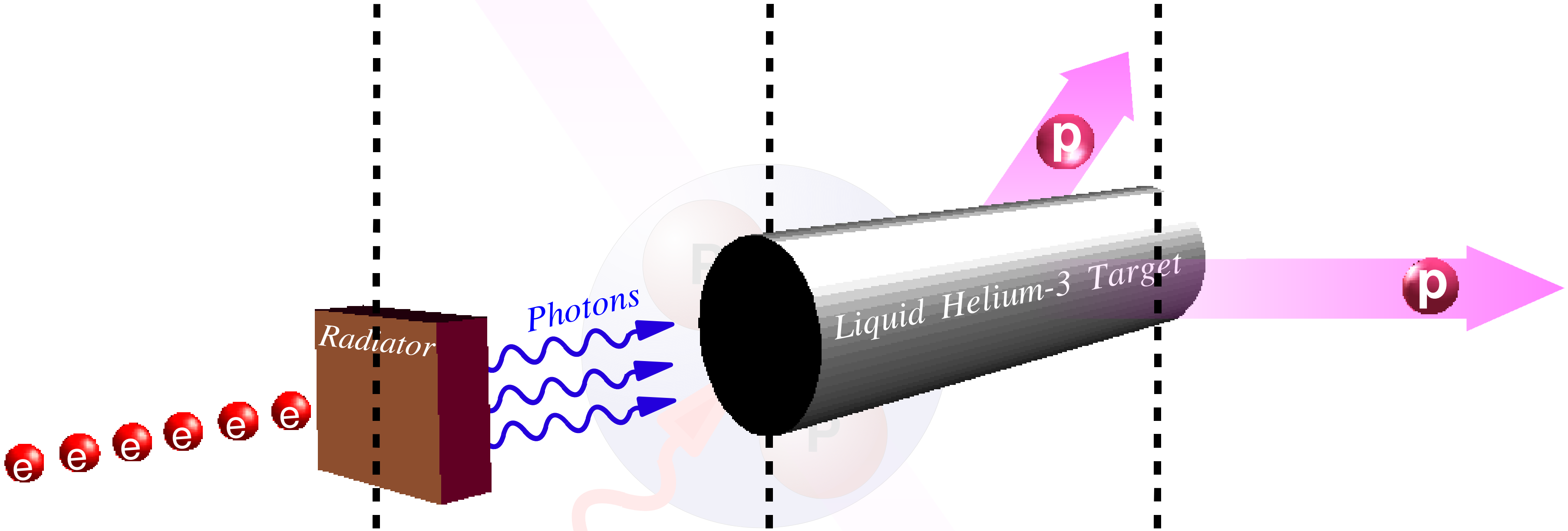
- One proton absorbs the photon, and then interacts with the other member of the pair. The high Pt results from this final state interaction.
- Also a rare case (large pp c.m. scattering angle).

HRM



Hard Re-scattering Model
L.L. Frankfurt, G.A Miller,M.M. Sargasian, M.I Strikman , Phys. Rev. Lett.84,3045(2000)

Experimental setup



Electrons of 0.8-4.7 GeV enter the target chamber and hit a copper radiator.

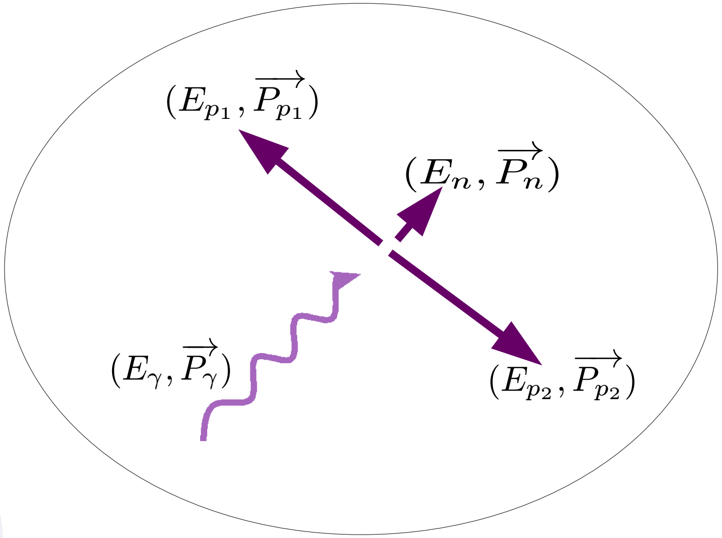
In the process of Bremsstrahlung, real photons are produced in the radiator.

The photons hit the liquid Helium-3 target.

The spectrometers are positioned to detect two protons in coincidence at 90° center of mass.

Analysis

- Kinematic reconstruction:
  - Assuming a two-body process by demanding photon energy of a 140 MeV bin off the tip of the bremsstrahlung spectra.



6 Known variables: $P_1, \phi_1, \theta_1, P_2, \phi_2, \theta_2$

4 Unknown variables: $E_\gamma, P_n, \phi_n, \theta_n$

- Demanding energy conservation: $E_\gamma = E_n + E_1 + E_2$
- Demanding momentum conservation:

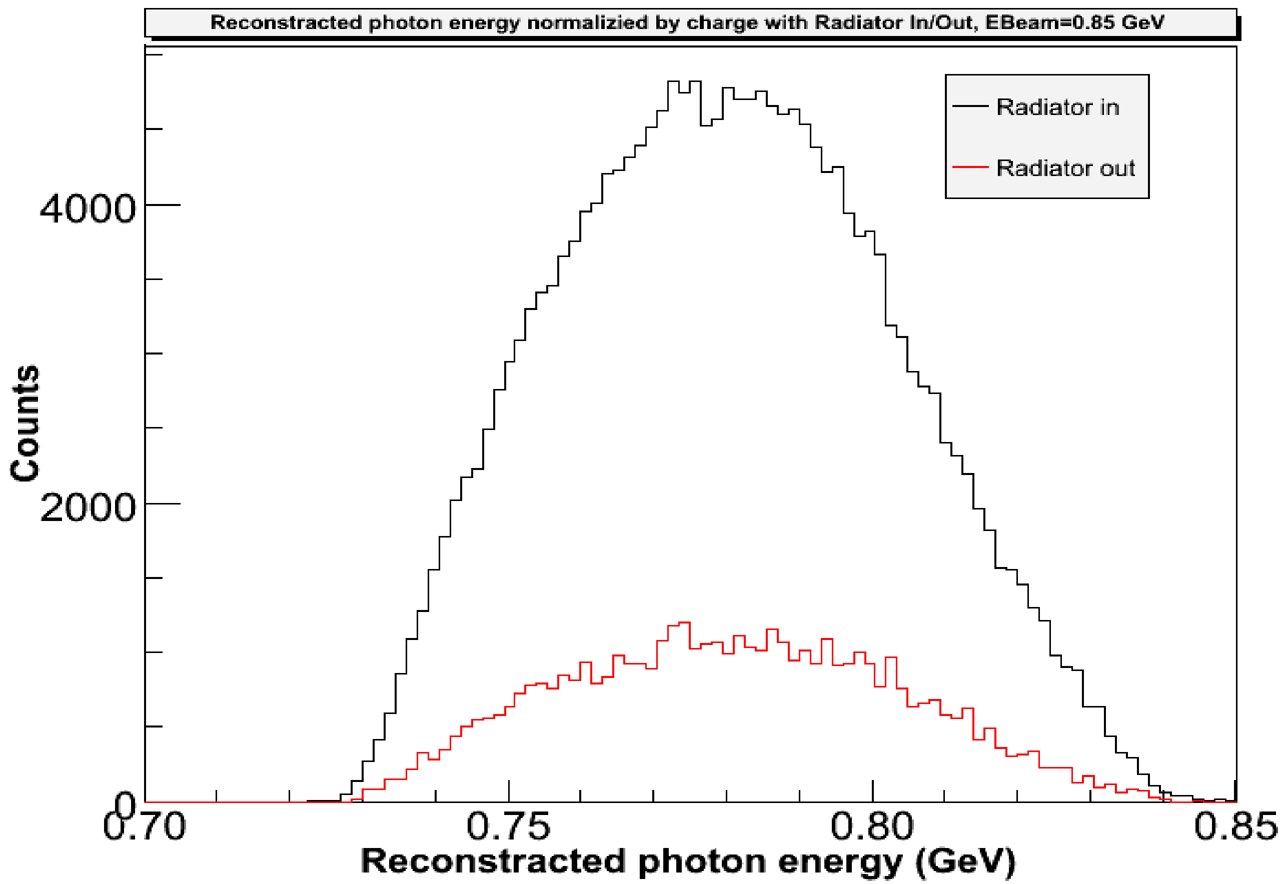
$$E_\gamma = P_1 \cos\theta_1 + P_2 \cos\theta_2 + P_n \cos\theta_n$$

$$P_1 \sin\phi_1 \sin\theta_1 + P_2 \sin\phi_2 \sin\theta_2 + P_n \sin\phi_n \sin\theta_n = 0$$

$$P_1 \cos\phi_1 \sin\theta_1 + P_2 \cos\phi_2 \sin\theta_2 + P_n \cos\phi_n \sin\theta_n = 0$$

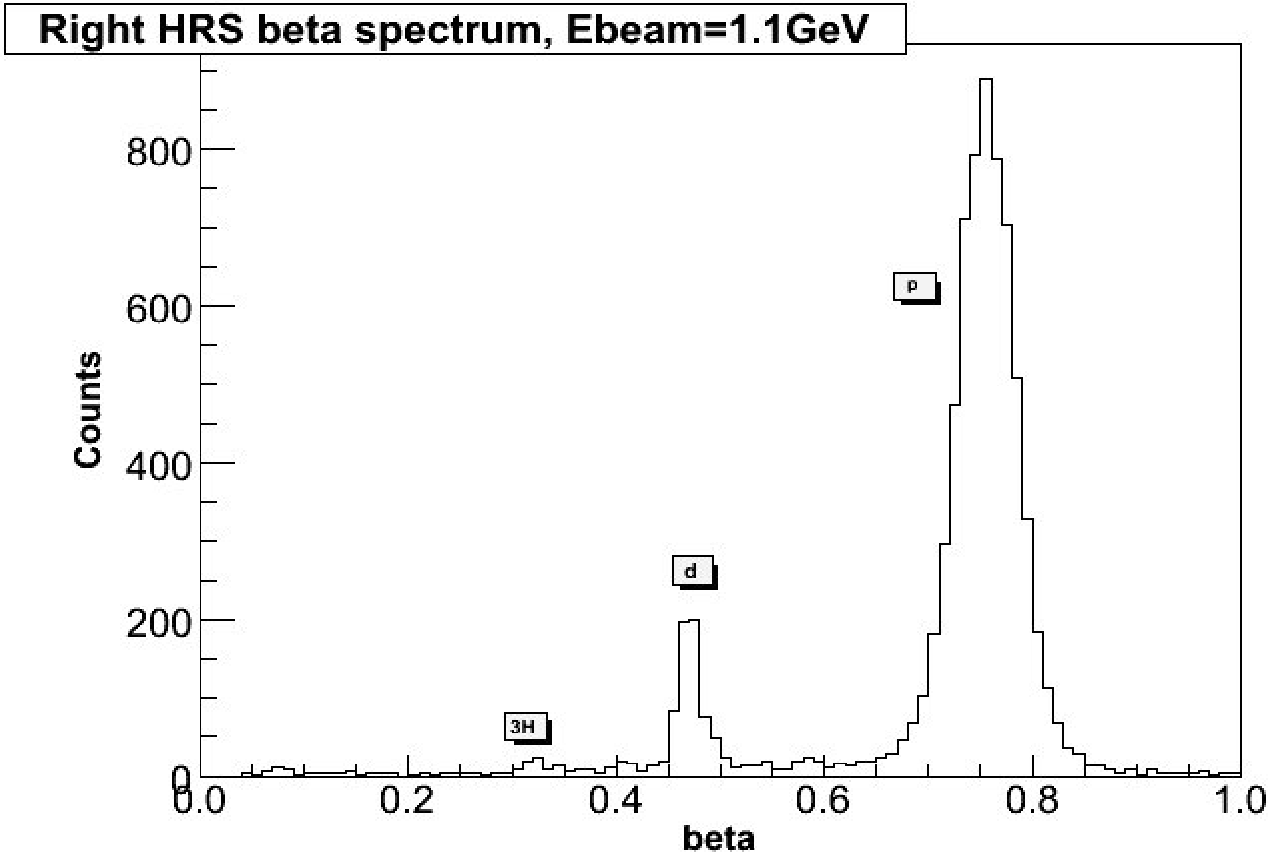
Analysis

- Background subtraction.



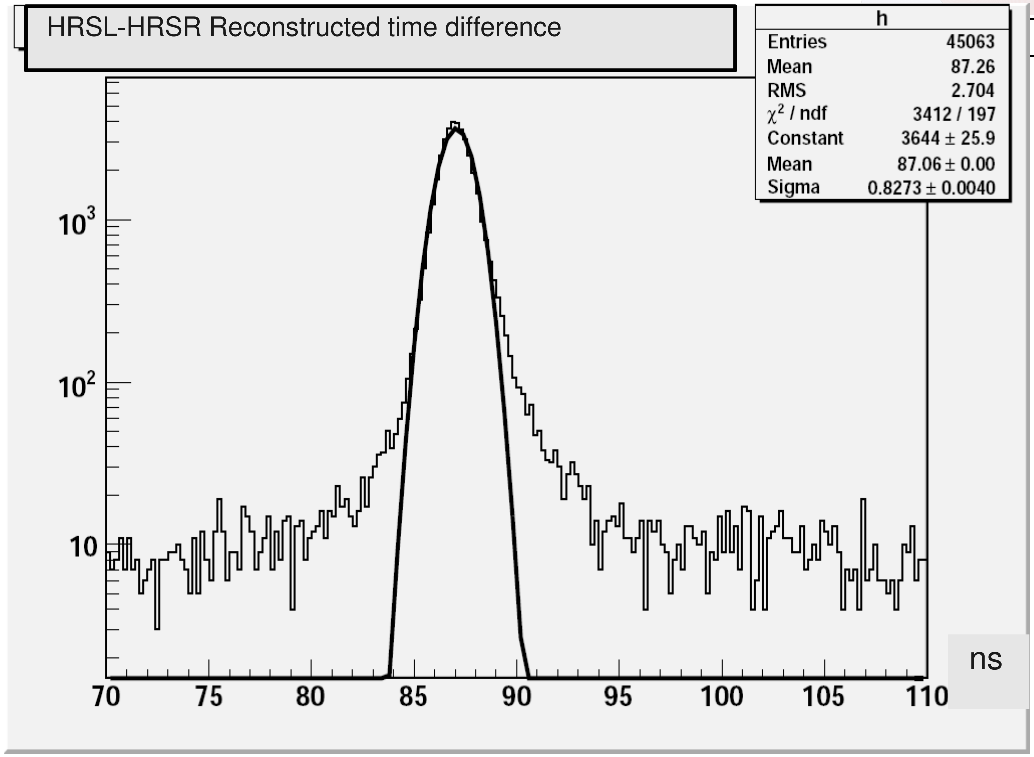
Analysis

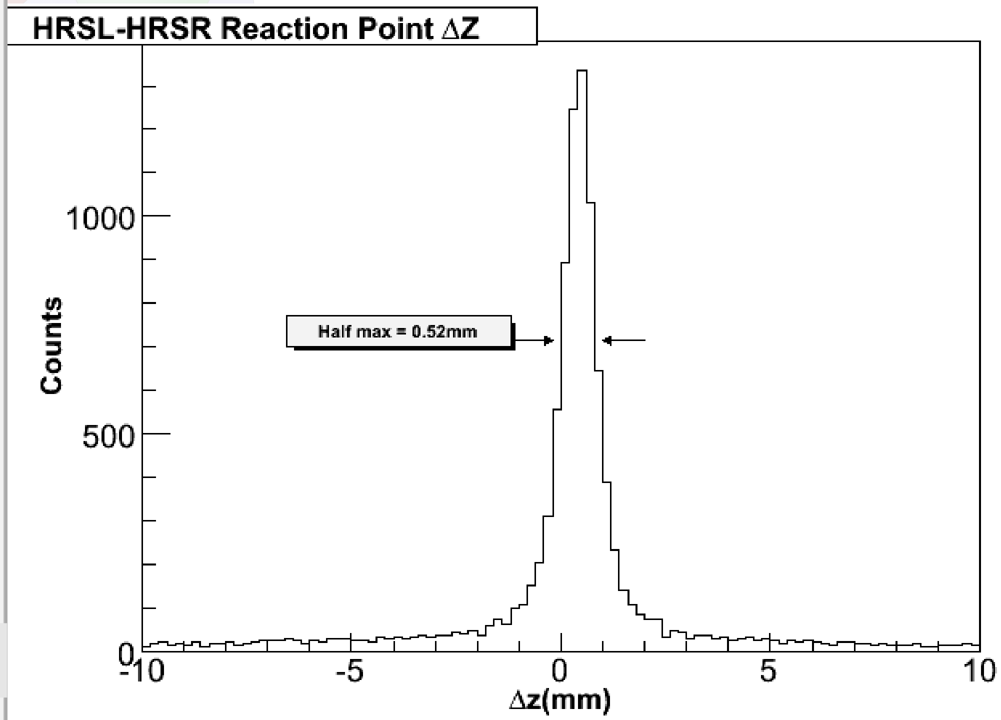
- Event selection:
  - Particle ID.



Analysis

- Event selection:
  - Particle ID.
  - Coincidence time, and reaction point.



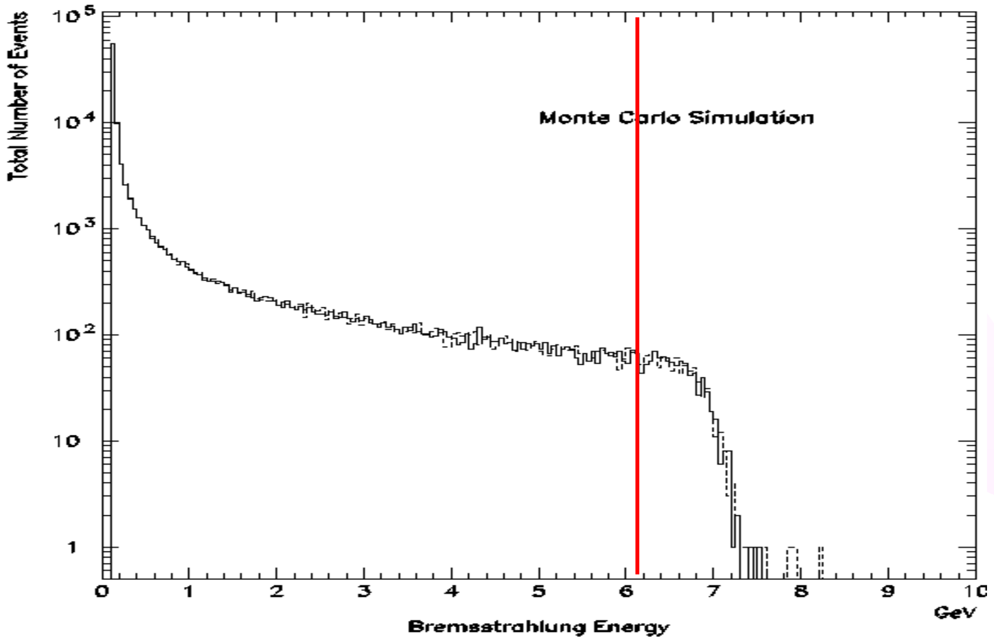


Analysis

- Event selection:
  - Particle ID.
  - Coincidence time, and reaction point.
  - Phase space cuts on nominal HRSs acceptance.

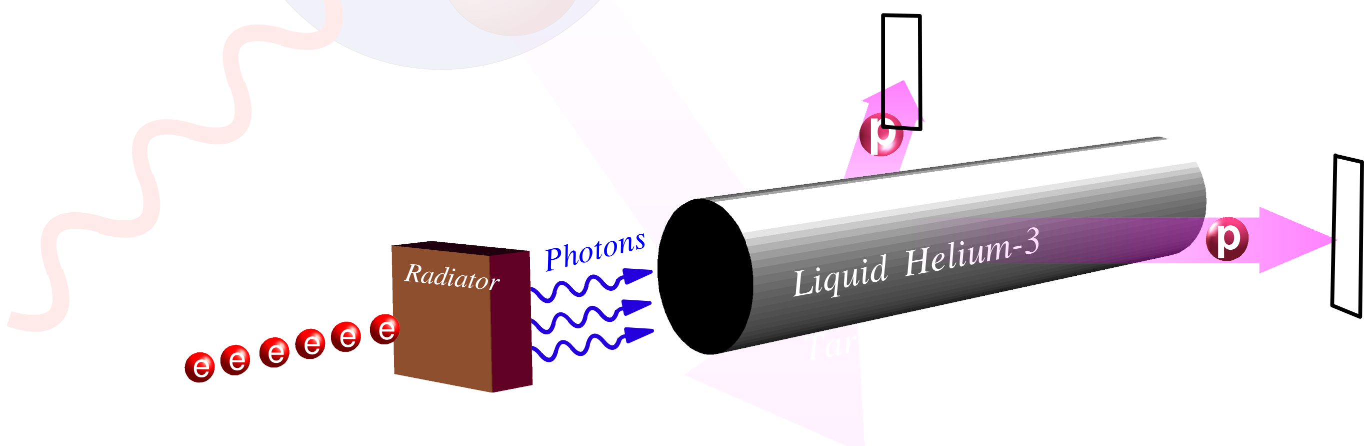
Analysis

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



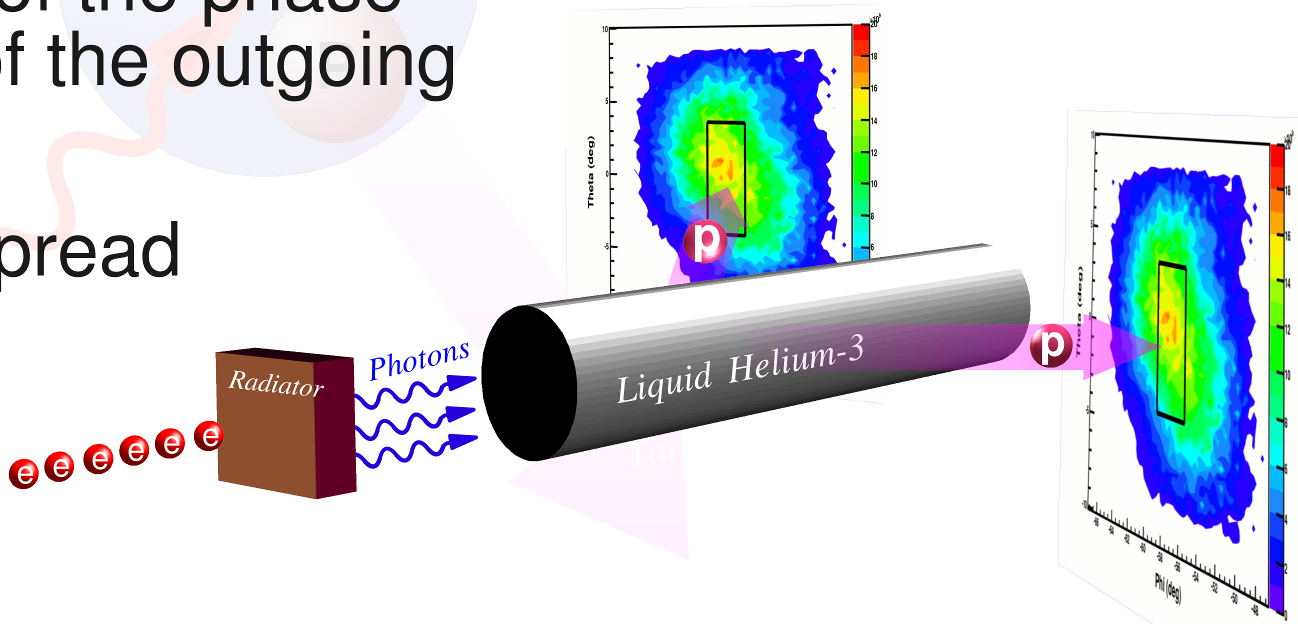
Analysis

- Coincidence efficiency calculation:
  - The edge of the HRS acceptance is set to detect a pair at rest disintegrated in 90^0 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 spread of the phase-space distribution of the outgoing protons.



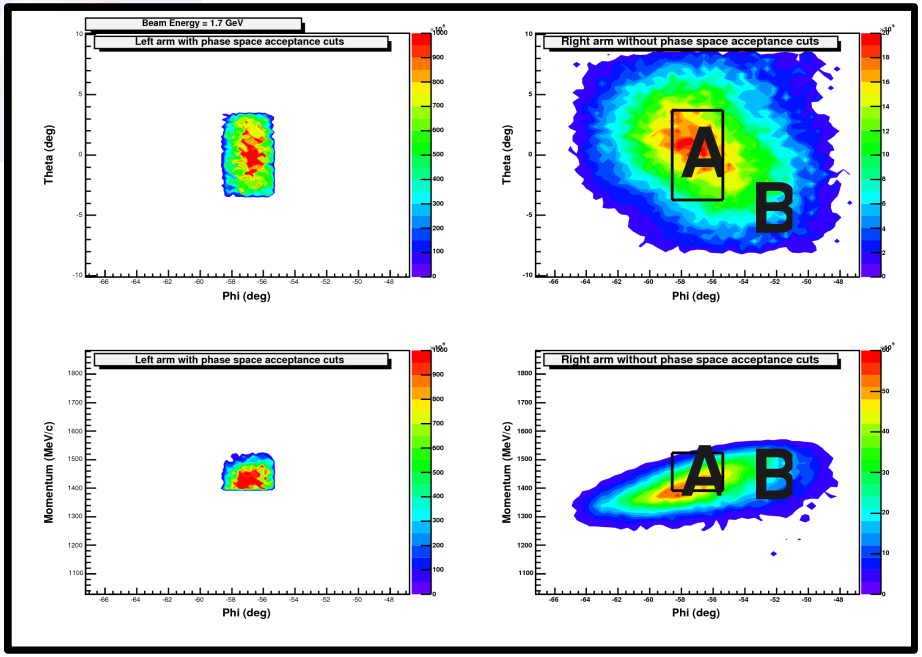
Analysis

- Coincidence efficiency calculation:
  - The edge of the HRS acceptance is set to detect a pair at rest disintegrated in 90^0 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 spread of the phase-space distribution of the outgoing protons.
  - The difficulty: this spread is larger than the spectrometers acceptance.



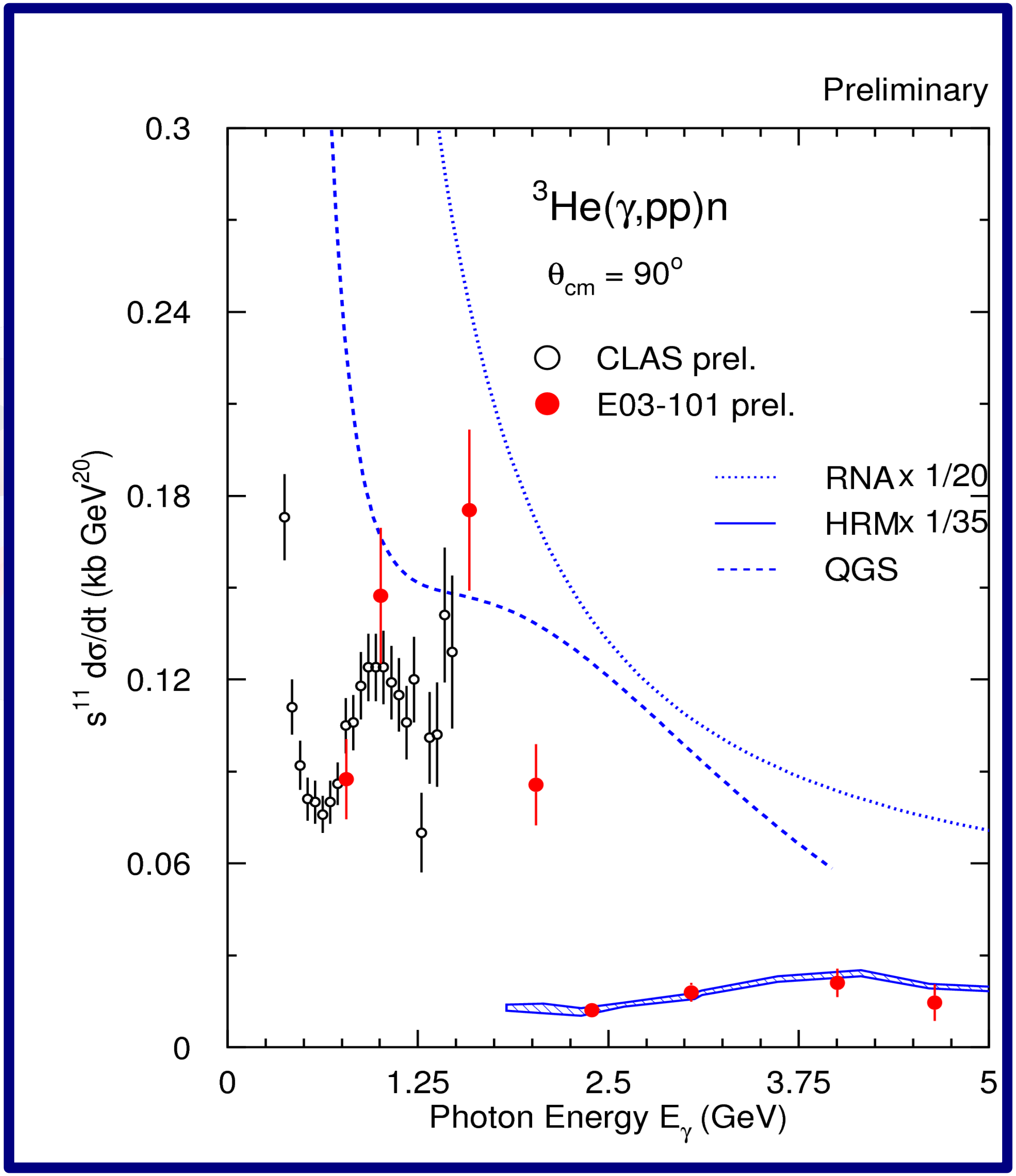
Analysis

- Coincidence efficiency calculation:
  - The solution: taking into account the ”Coincidence efficiency” in the cross section calculation.
  - MCEEP will answer the following question: “if one proton has been detected in one HRS, what is the probability that the other proton will be detected in the other HRS ?”.
  - $f_{coinc} = A/B$



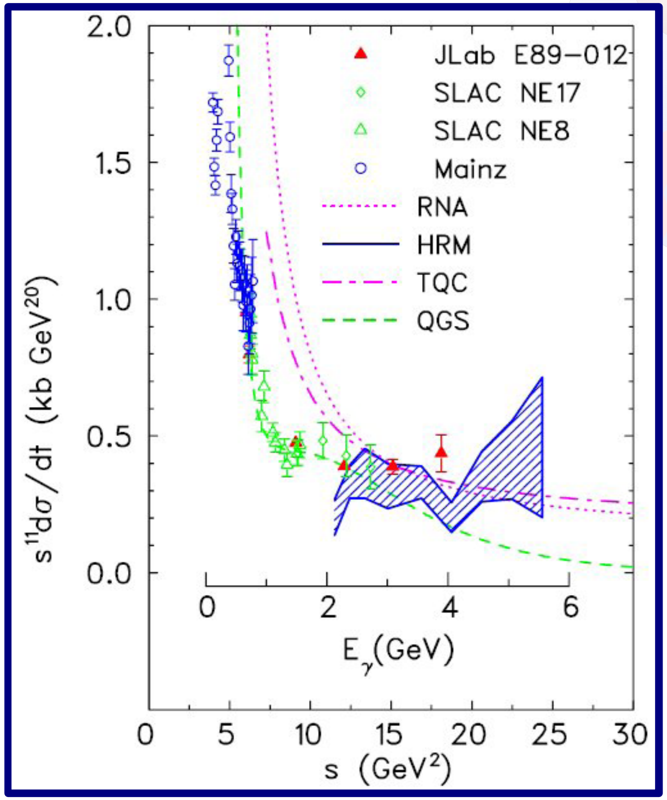
Preliminary results

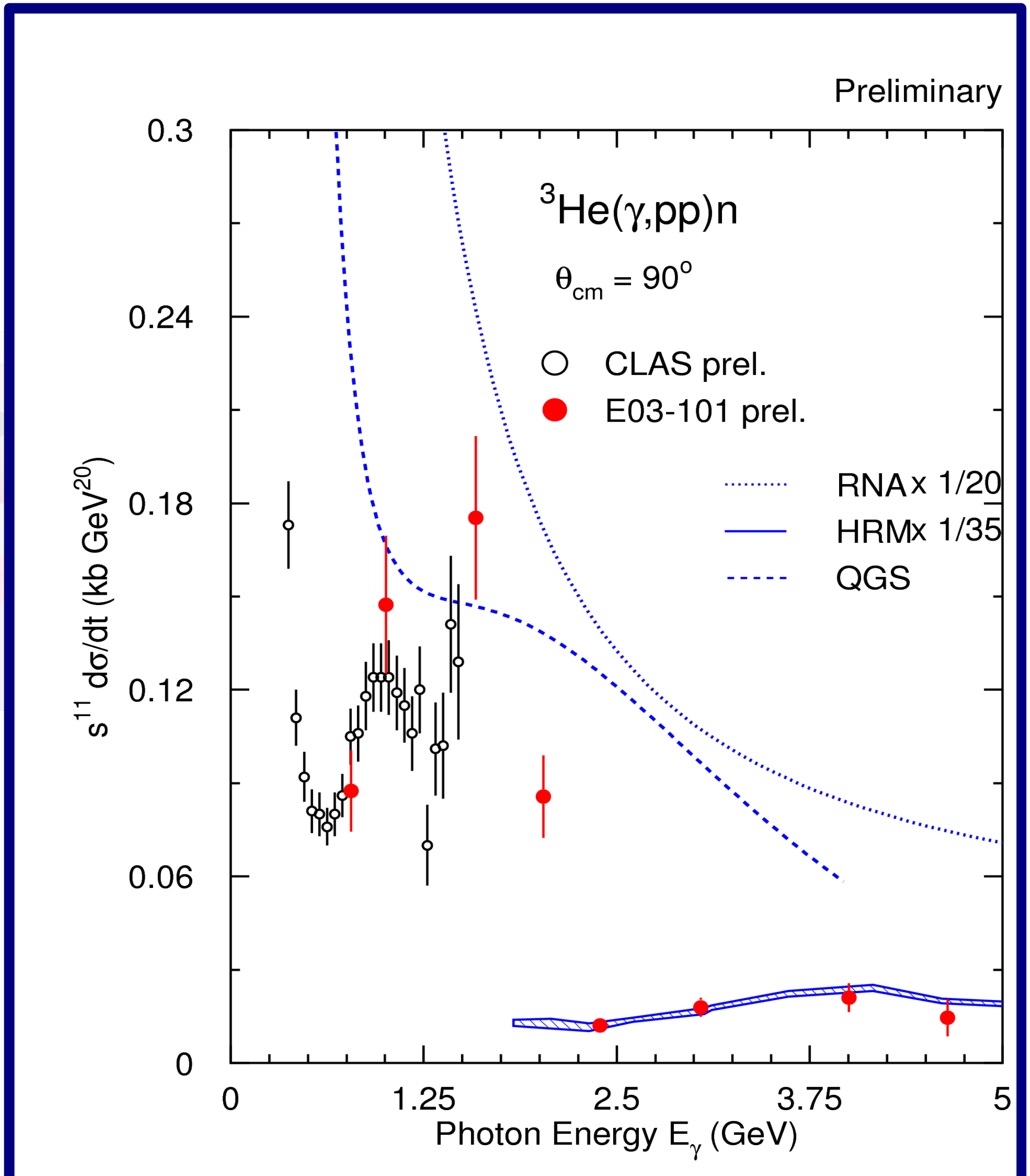
- The cross section presented is scaled with the center of mass energy squared, s, to the 11th power. The preliminary calculated cross section is temporarily normalized to the preliminary CLAS data. The absolute cross section calculation is in progress.



Preliminary results

- Deuteron photodisintegration results shows flat dependence of the scaled cross section on photon energy above 1 GeV. Why does the pp disintegration appear to have structures in this region?



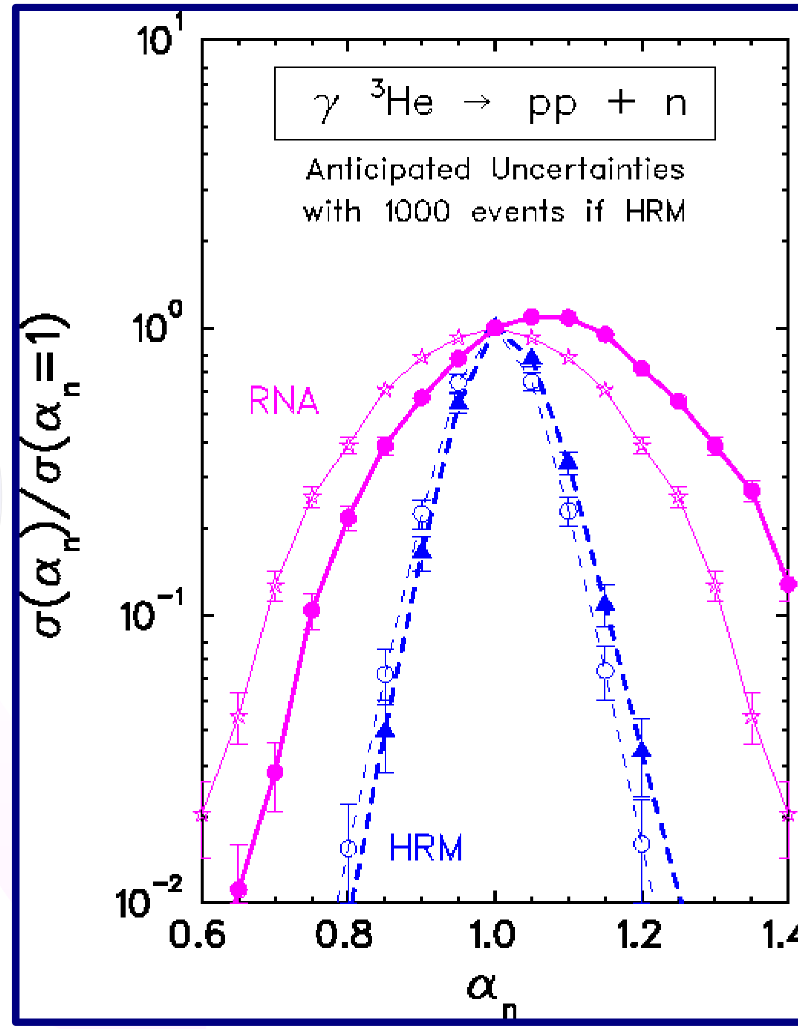


Outlook

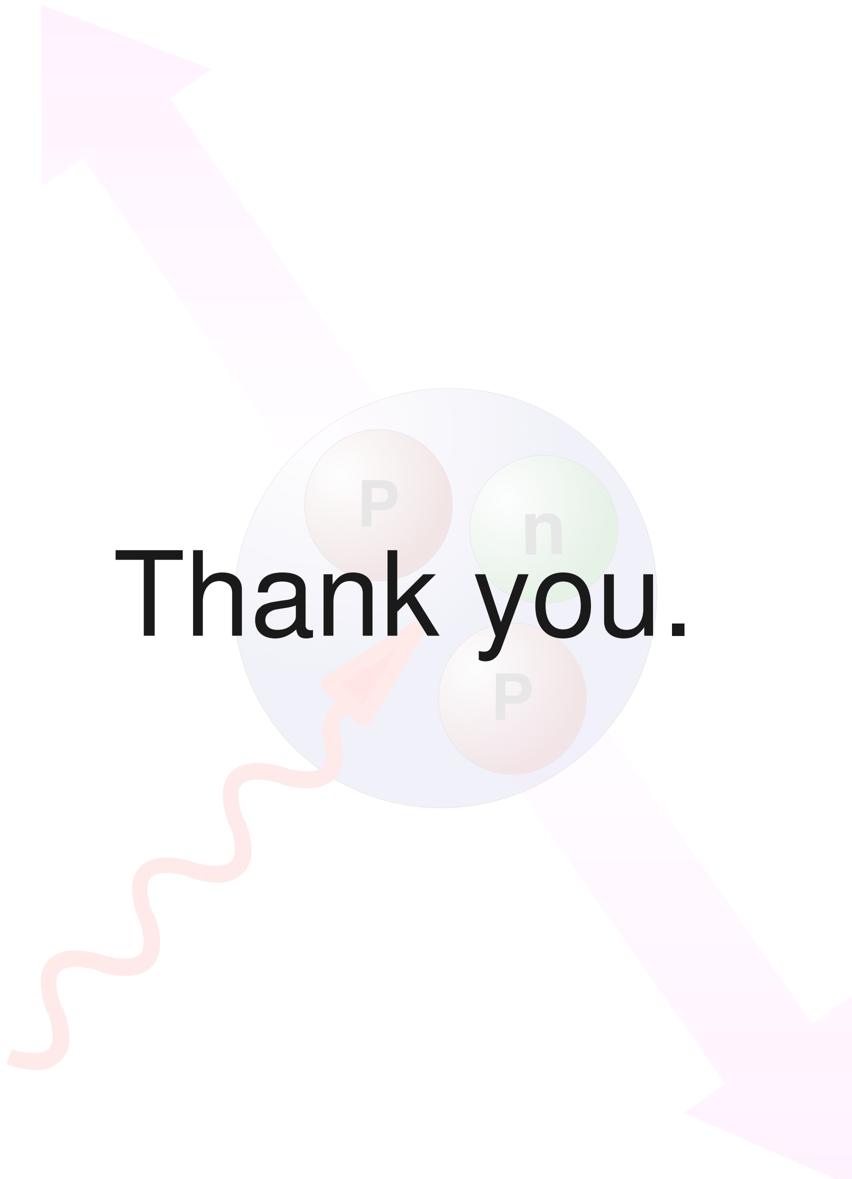
- Absolute normalization of the cross section will be complete in the next few weeks.
- We next plan to look at the light-cone momentum distribution of the neutron:

$$\alpha_n \equiv A\frac{E^n - P_z^n}{E^A - P_z^A} \approx \frac{E^n - P_z^n}{m_n} \approx \frac{E^n - P_z^n}{m_{^3He}/3}$$

The figure shows how the α_n distribution is broader if the reaction dynamics are short-distance (RNA) vs long distance (HRM).



- Final results are expected by the end of the year.



Thank you.