Hard photodisintegration of ^{3}He into pp, pn, and pd

(Largely a draft PAC defense as I would give it.)

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Hall A Collaboration Meeting, December 2010

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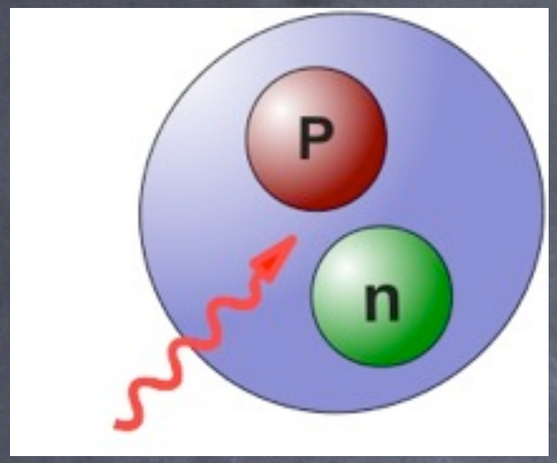
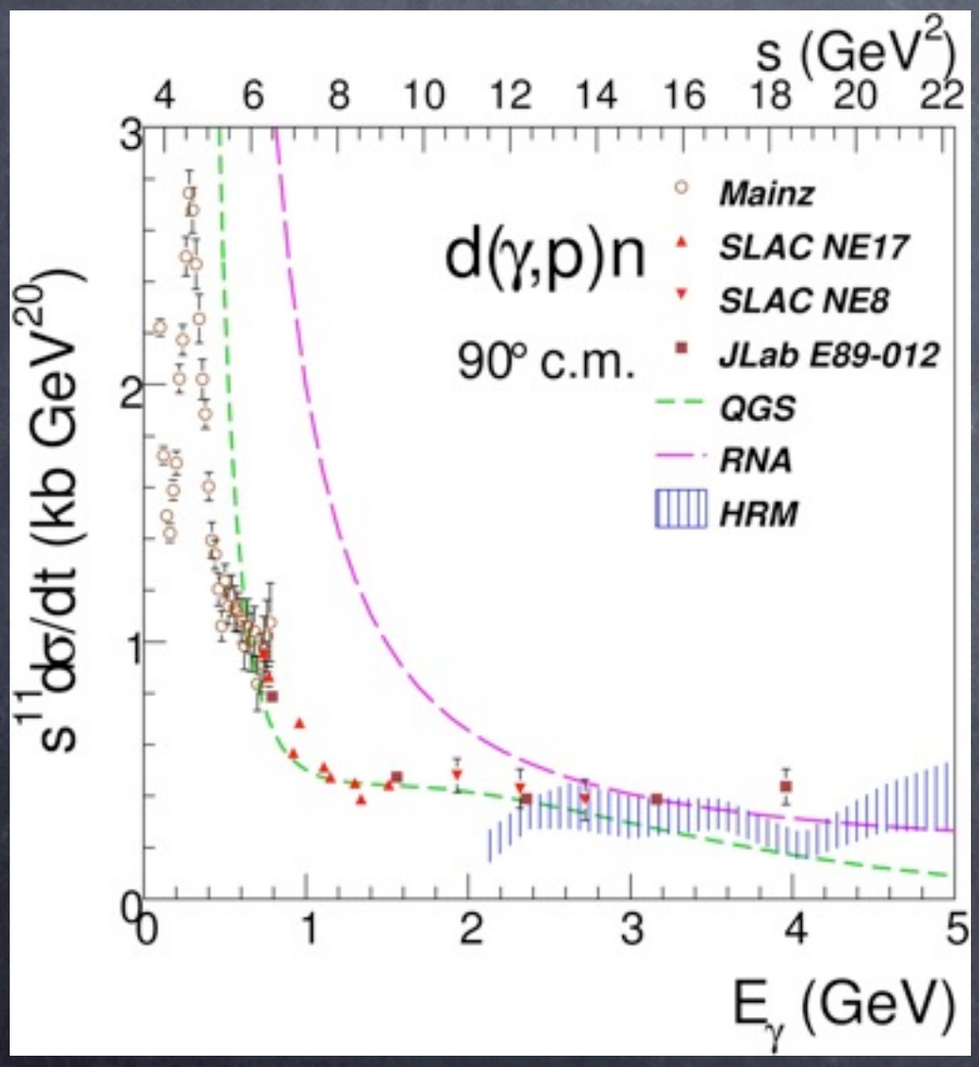
Motivation / Goals

- Establish the underlying dynamics of hard nuclear photodisintegration, leading to:
  - Improved understanding of the NN interaction, and/or
  - Improved understanding of the quark and/or short-range structure of nuclei

- Existing high-energy data largely limited to deuteron photodisintegration
  - Provide complementary data for ^{3}He breakup for better interpretation

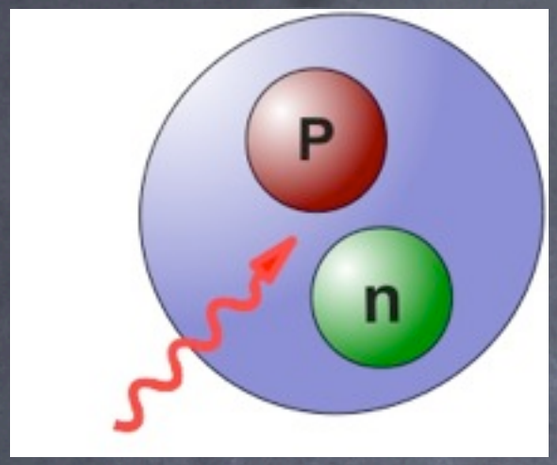
Background: Existing Data for Hard γd→pn

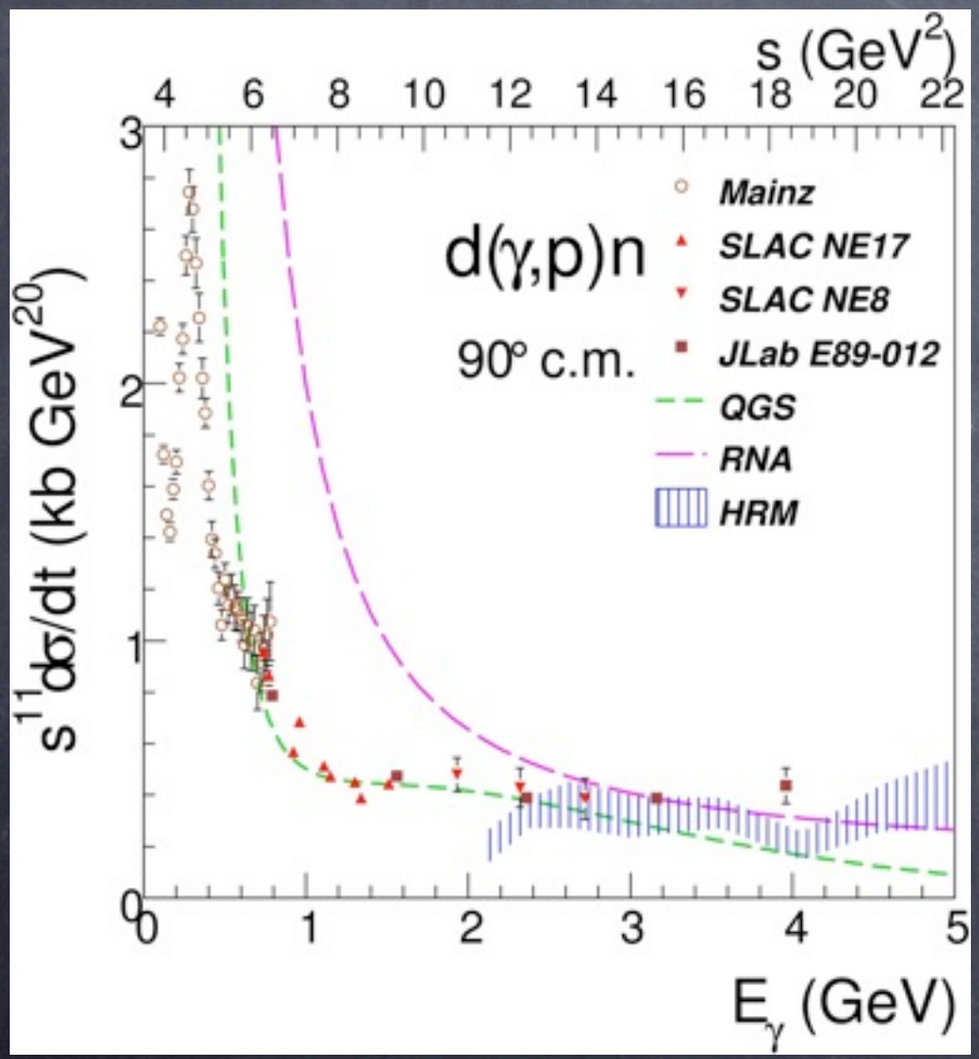




- Example with only θ_{cm} = 90° data
- CLAS: scaling for p_T > 1.3 GeV/c
  - scaling: $d\sigma/dt \approx s^{2-n} = s^{-11}$, with s the cm energy squared, and n the total number of pointlike articles in initial+final states
- Result of dimensional scaling, pQCD, AdS/CFT
- Size of cross sections hard to calculate in pQCD, but reflects short-range quark structure of deuteron

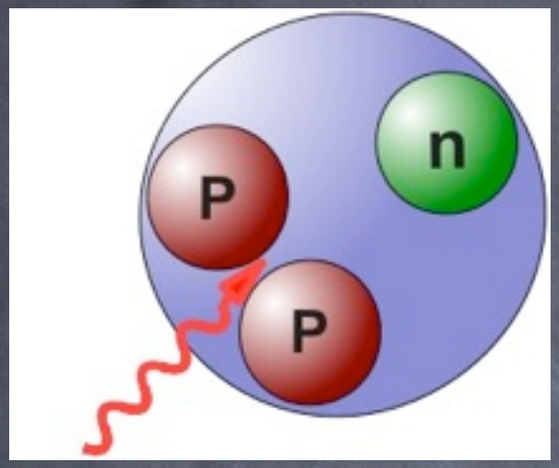
Background: Existing Data for Hard γd→pn

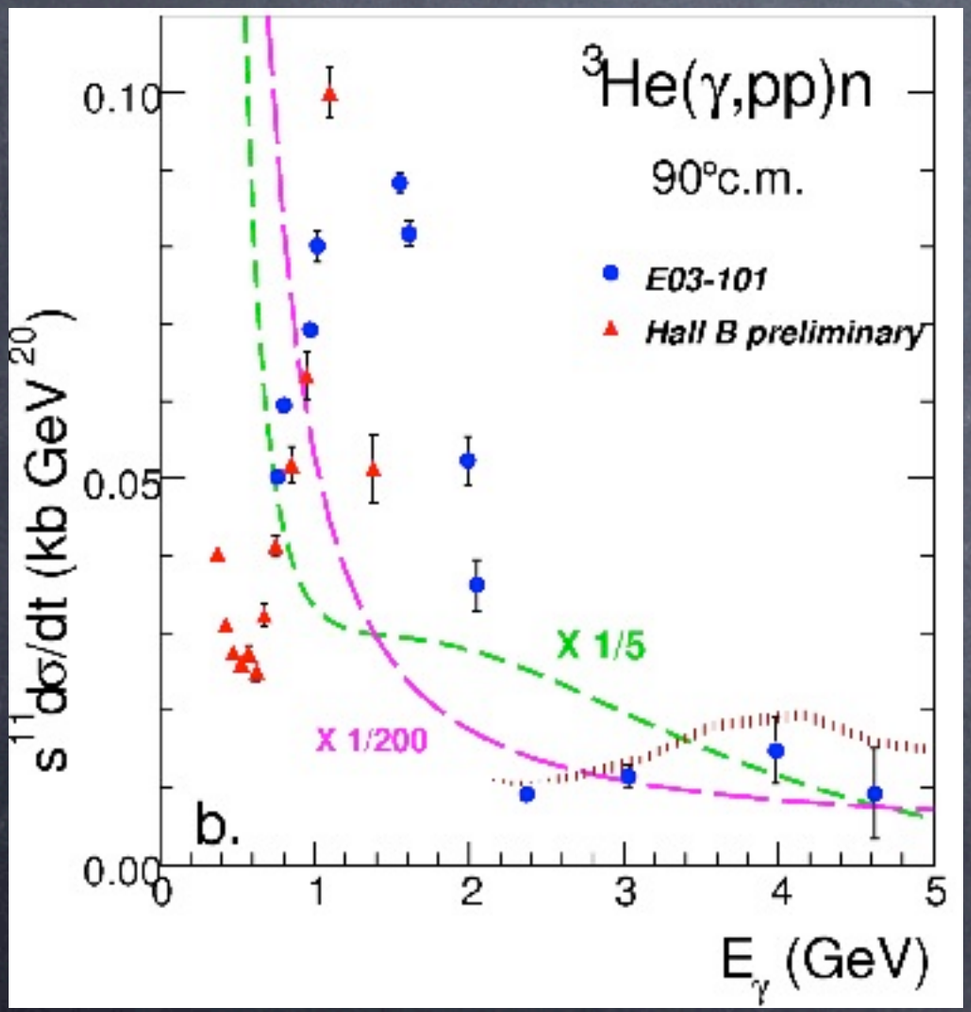




- Nonperturbative approaches:
  - HRM relates photodisintegration to NN elastic scattering, depends on long range deuteron structure
  - QGS uses Regge theory, based on nucleon exchange, usually for low t
  - RNA extends pQCD by including threshold factors

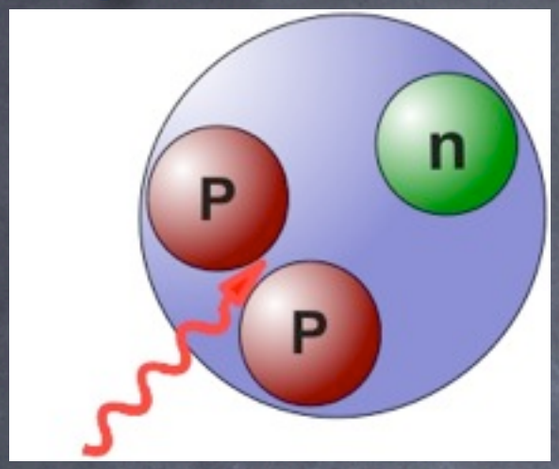
Background: Existing Data for Hard $\gamma\,^3He \rightarrow pp+n_{spectator}$

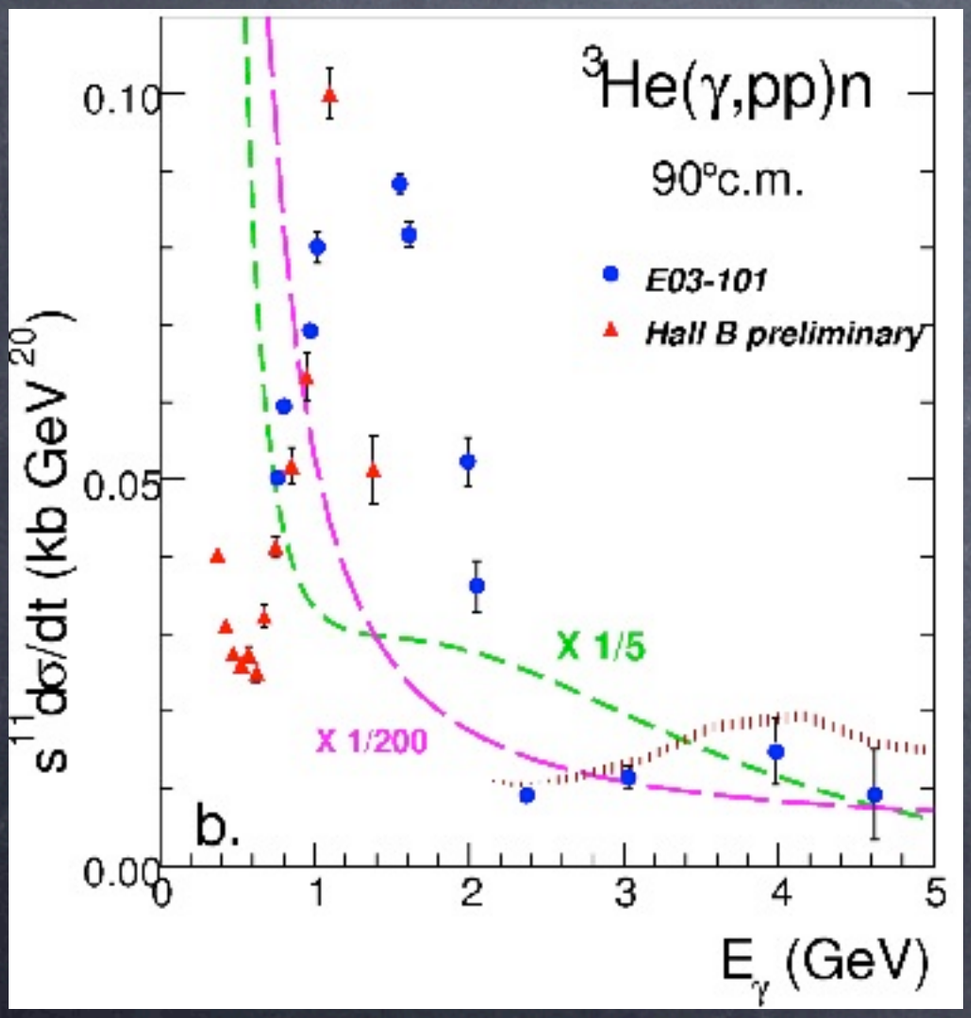




- Idea: test pn disintegration models with complementary pp disintegration data
  - I. Pomerantz et al., PLB 684 (2010)
  - Cross sections much smaller than anticipated before experiment ran
  - Broad resonance structure(s) seen from 1-2 GeV
  - Scaling seen above ≈2 GeV

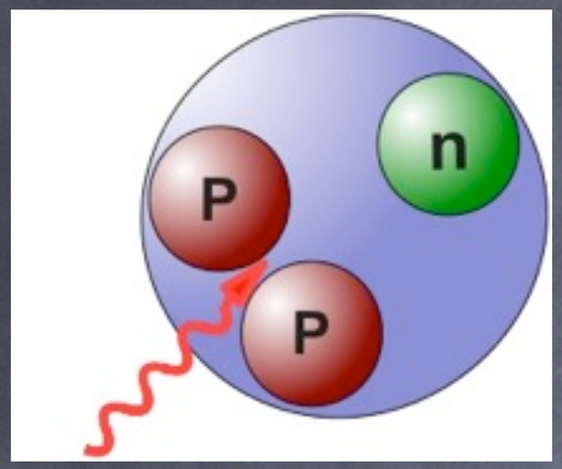
Background: Interpretation for Hard $\gamma^3He \rightarrow pp+n_{spectator}$



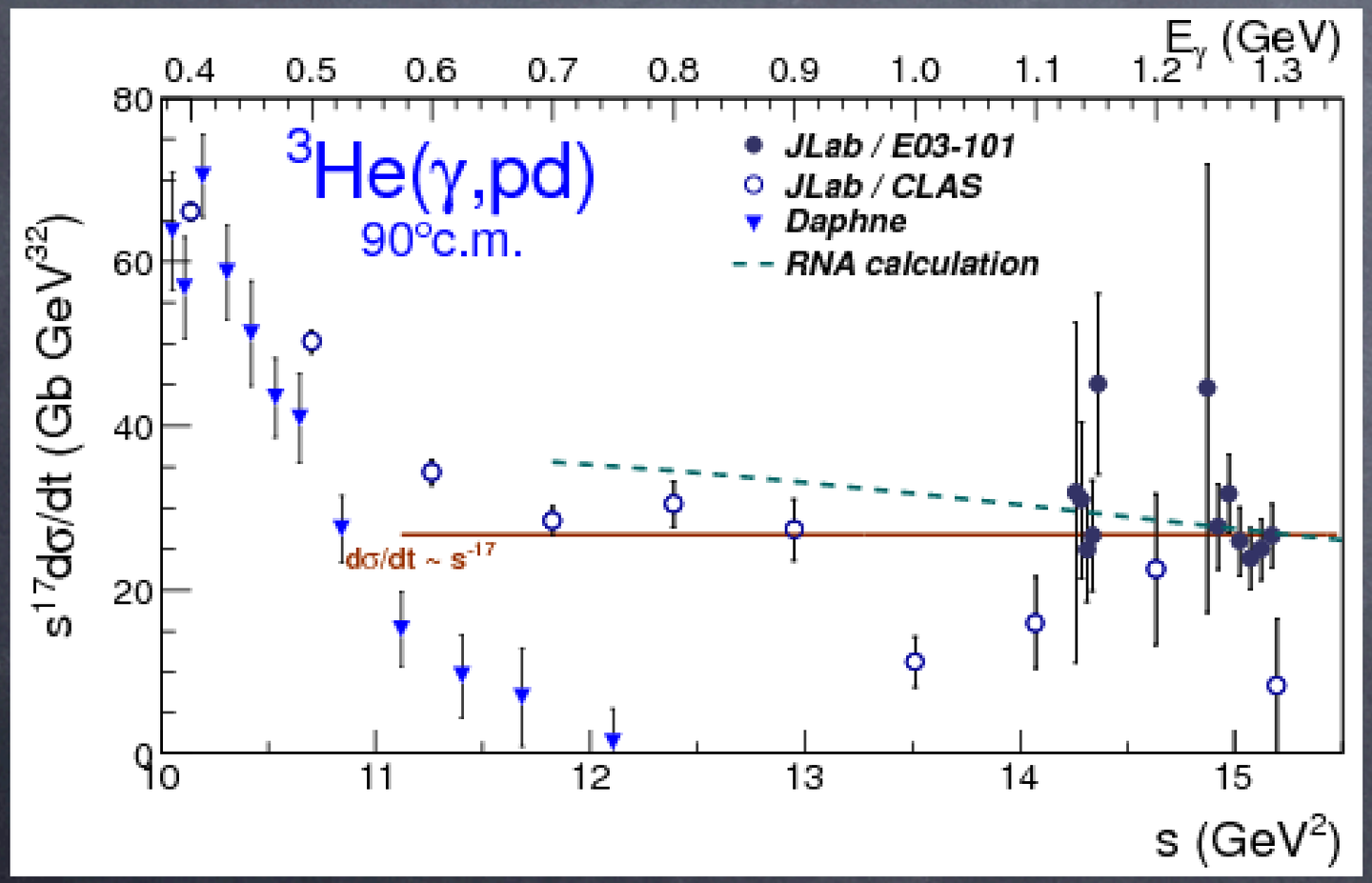


- 1-2 GeV region - $D_{13}+F_{15}+...$ or 3-body mechanisms?
- >2 GeV region: Cross section originally overpredicted by all models (Brodsky et al. Phys Lett B578, 69-77, 2004)
  - HRM: recognized that original estimate neglected that two of the pp amplitudes have opposite signs and cancel
  - RNA/QGS: possible out - if reaction depends on SRC, 300-600 MeV/c nucleons - pn enhanced x20

Background: Existing Data for Hard γ ^{3}He→pd



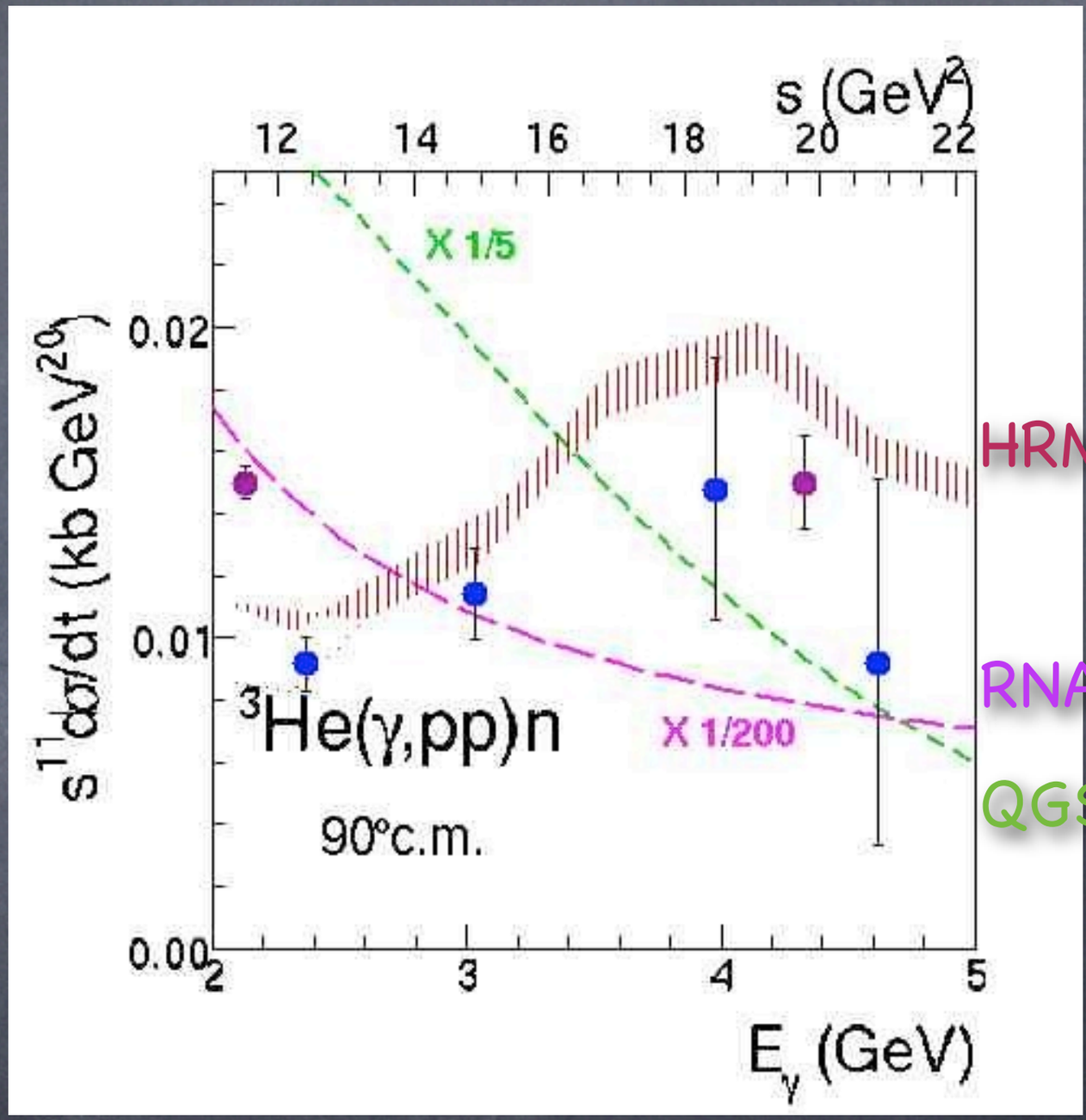
- Hall A E03-101 data final, CLAS data being finalized, joint publication planned
  - ≈ scaling, dσ/dt ≈$s^{-18\pm1}$ vs. s^{-17} for Eγ>0.7 GeV



- With CLAS data preliminary, not too worried about level of agreement at present
- Likely will need to look more at CLAS vs. DAPHNE - probably DAPHNE issue

Issues to Investigate

- Does $\gamma\,^3He \rightarrow pp+n_{spectator}$ violate scaling, as predicted by HRM?
  - Prediction $s^{11}d\sigma/dt|_{4\ GeV}$ / $s^{11}d\sigma/dt|_{2\ GeV} \approx 2 \pm 10\%$, vs 1
  - vs E03-101 data: $\approx 1.5 \pm 40\%$
- ✓ Confirming the prediction, given the $\gamma d \rightarrow pn$ data, would be strong confirmation of underlying NN elastic scattering dynamics



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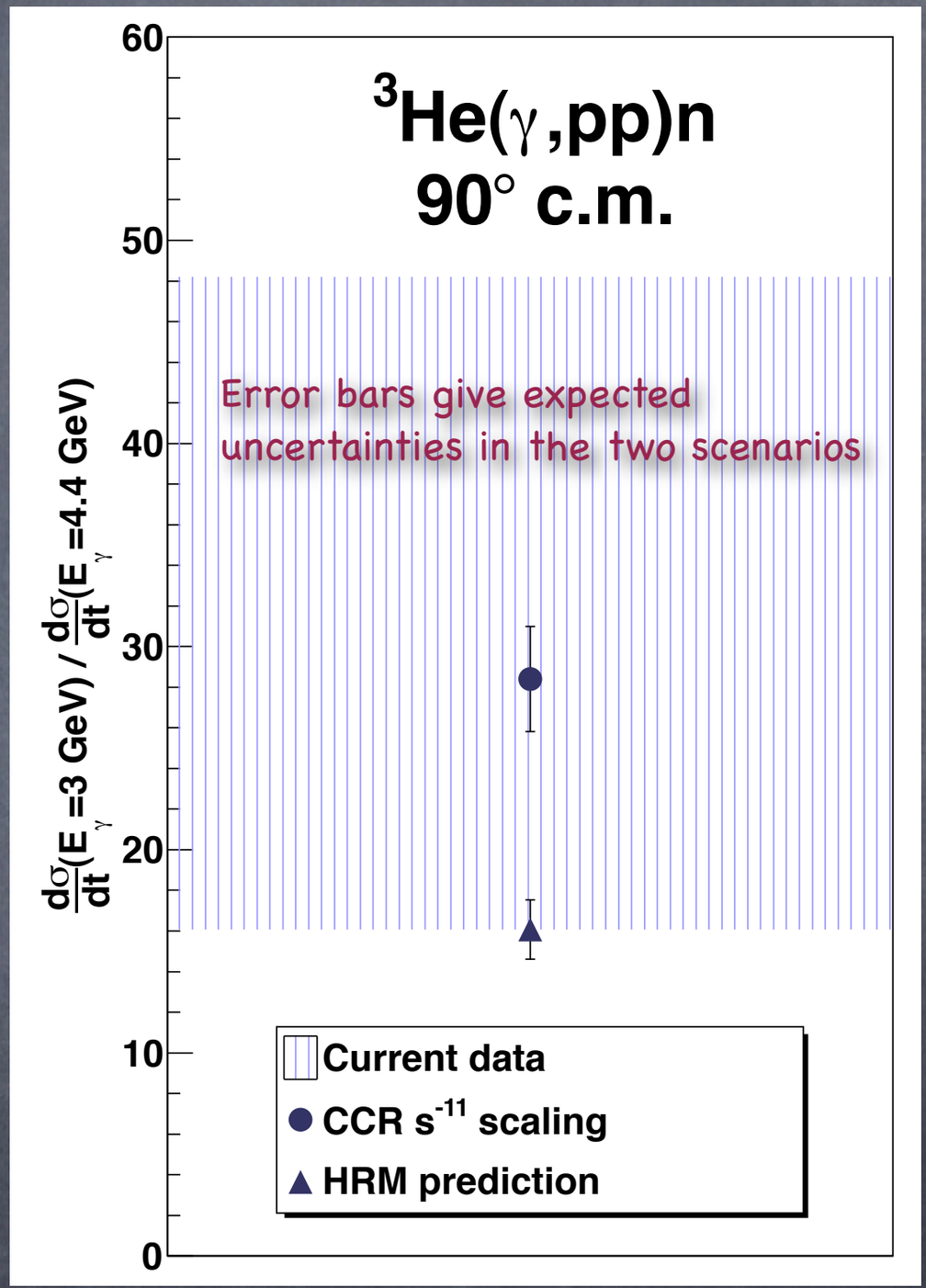
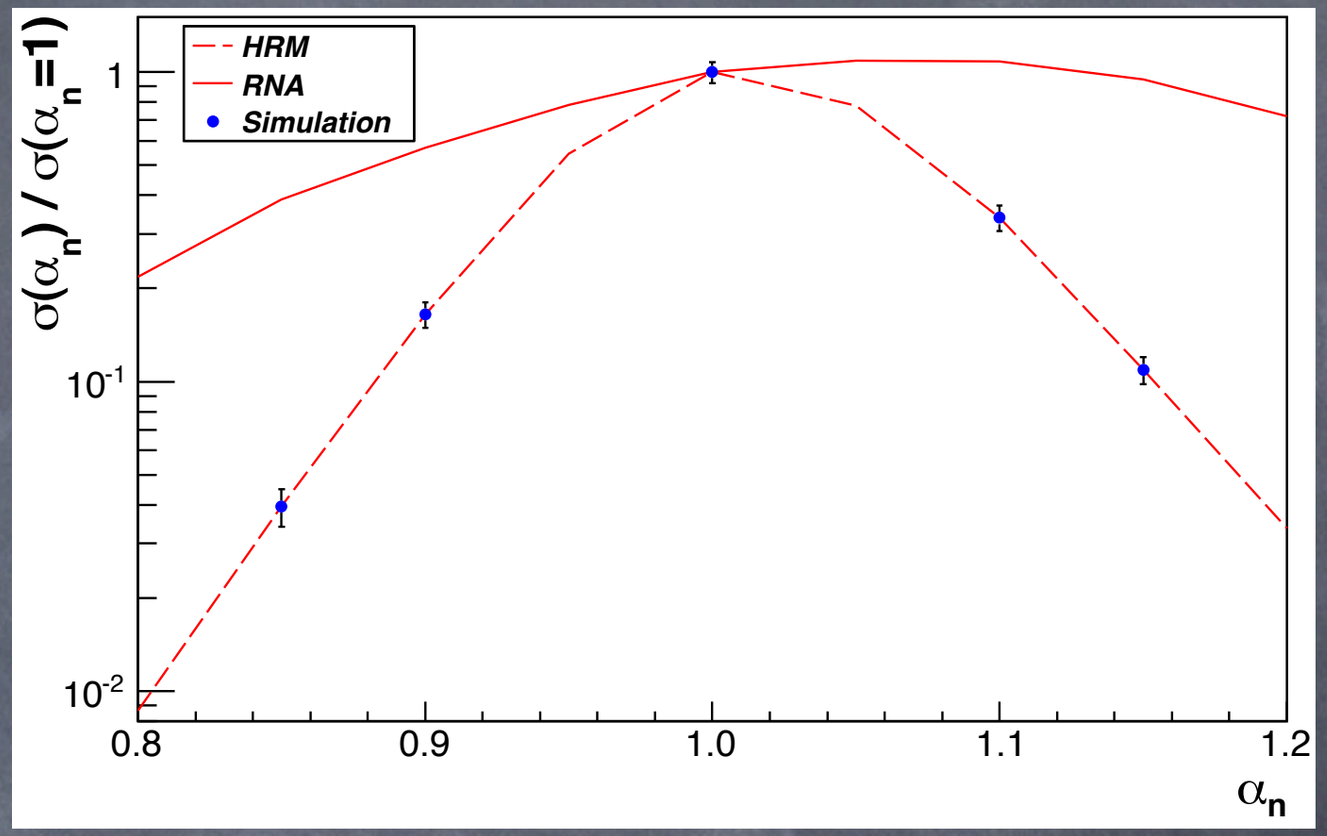


Issues to Investigate

- What is the α_n distribution in $\gamma\,^3He \rightarrow pp+n_{spectator}$?
  - —HRM from long-range, low-momentum structure vs pQCD from short-range high-momentum structure of nuclei
  - —E03-101 low statistics prevented measuring α_n
  - ✓ α_n provides nearly model-independent check of underlying reaction dynamics



- $\alpha_n = (E_n - p_{zn})/m = \alpha_{3He} + \alpha_\gamma - \alpha_{p1} - \alpha_{p2} = 3 - \alpha_{p1} - \alpha_{p2}$
- α_n is relativistic invariant minimally affected by FSI

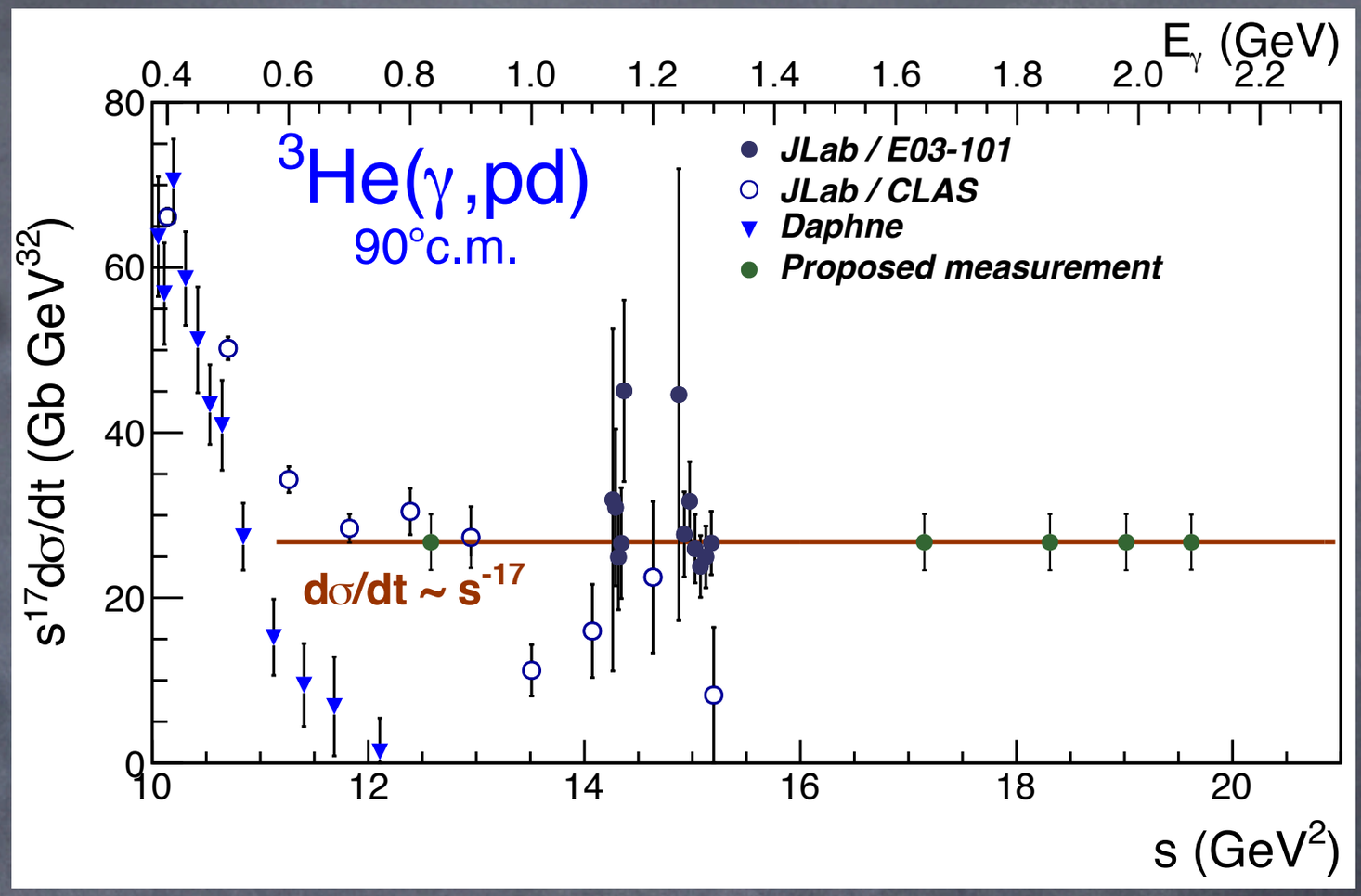
Issues to Investigate

> Is the apparent scaling in $\gamma\,^3He \rightarrow pd$ (A>2!) real?

— Existing high energy data over limited range, E03-101 not optimized for pd

— Apparent scaling at small E_γ and p_T, but big s

— A number of high-energy exclusive reactions exhibit ≈scaling: not known why (if it is not pQCD)



✓ Better determining onset of scaling gives another point in trying to understand why reactions scale or not, and more insight into 3-body effects

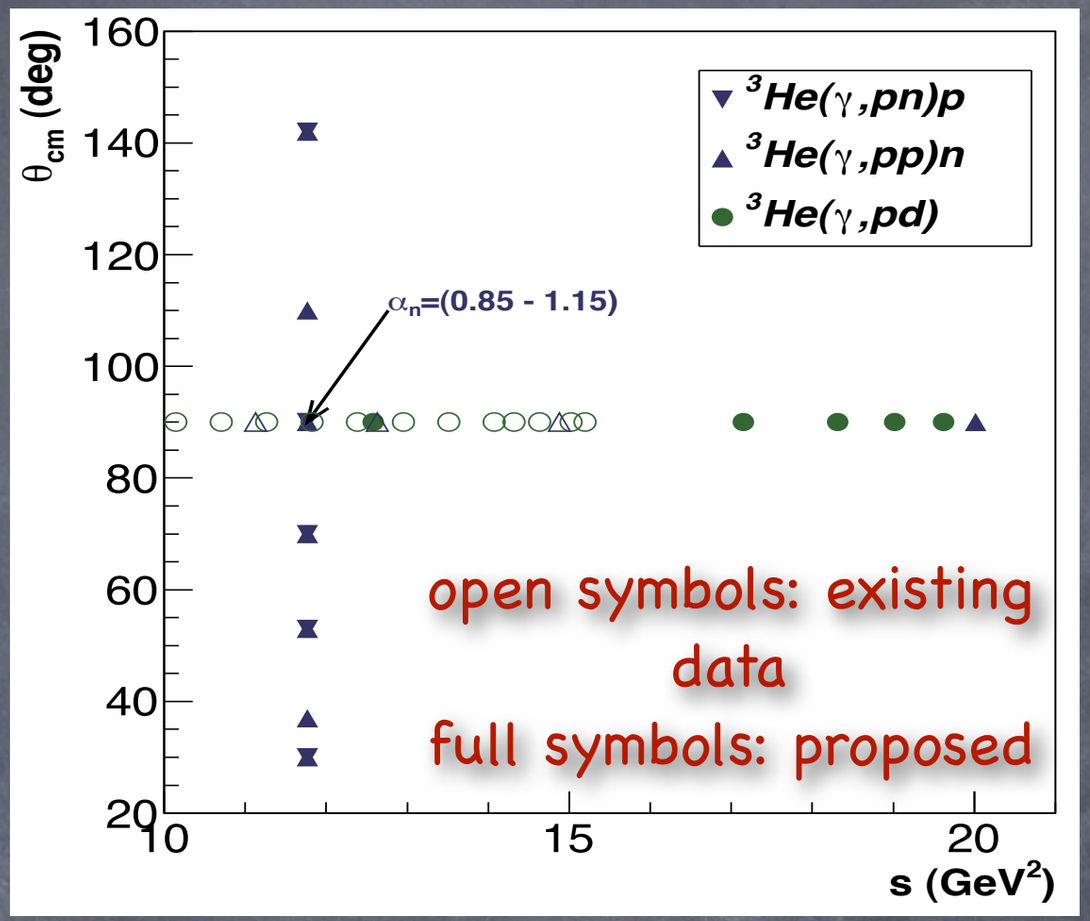
Issues to Investigate

> Why the ratio of scaling

$\sigma_{pn} : \sigma_{pp} : \sigma_{pd} \approx 20 : 1 : 1/4$?

— Two inputs to the calculations: dynamics and nuclear structure

✓ Measure $\gamma\,^3He \rightarrow pn + p_{spectator}$ to compare all reactions on 3He, and pn from d vs. ^3He, to be sure the nuclear structure is under control



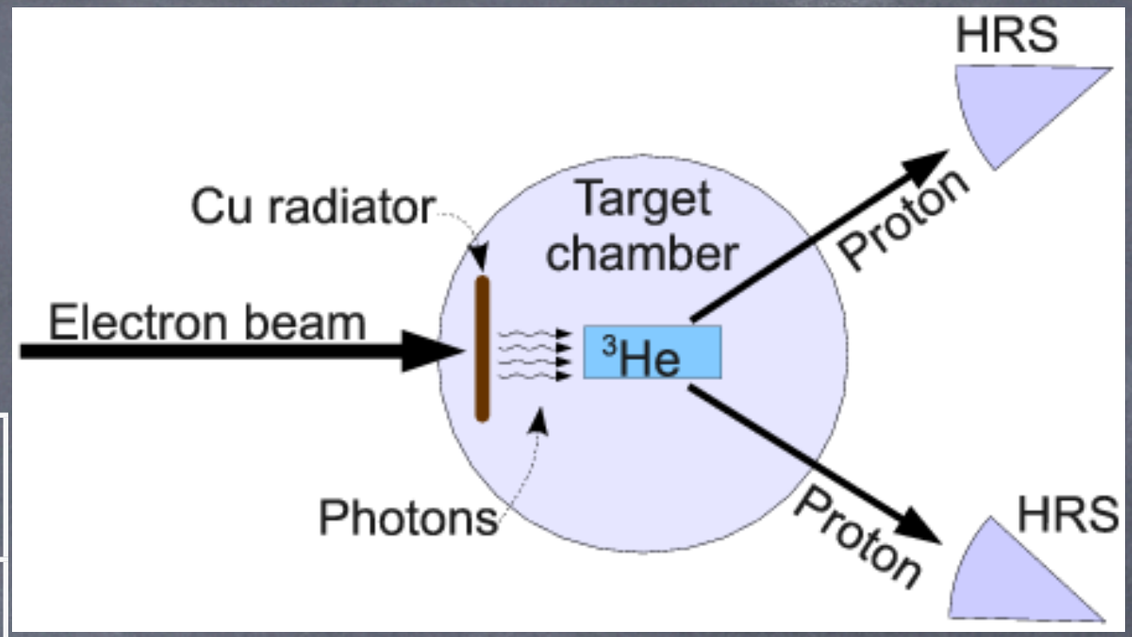
✓ Tests 3-body mechanisms in $\gamma\,^3He \rightarrow pp + n_{spectator}$ for E_γ = 1 - 2 GeV

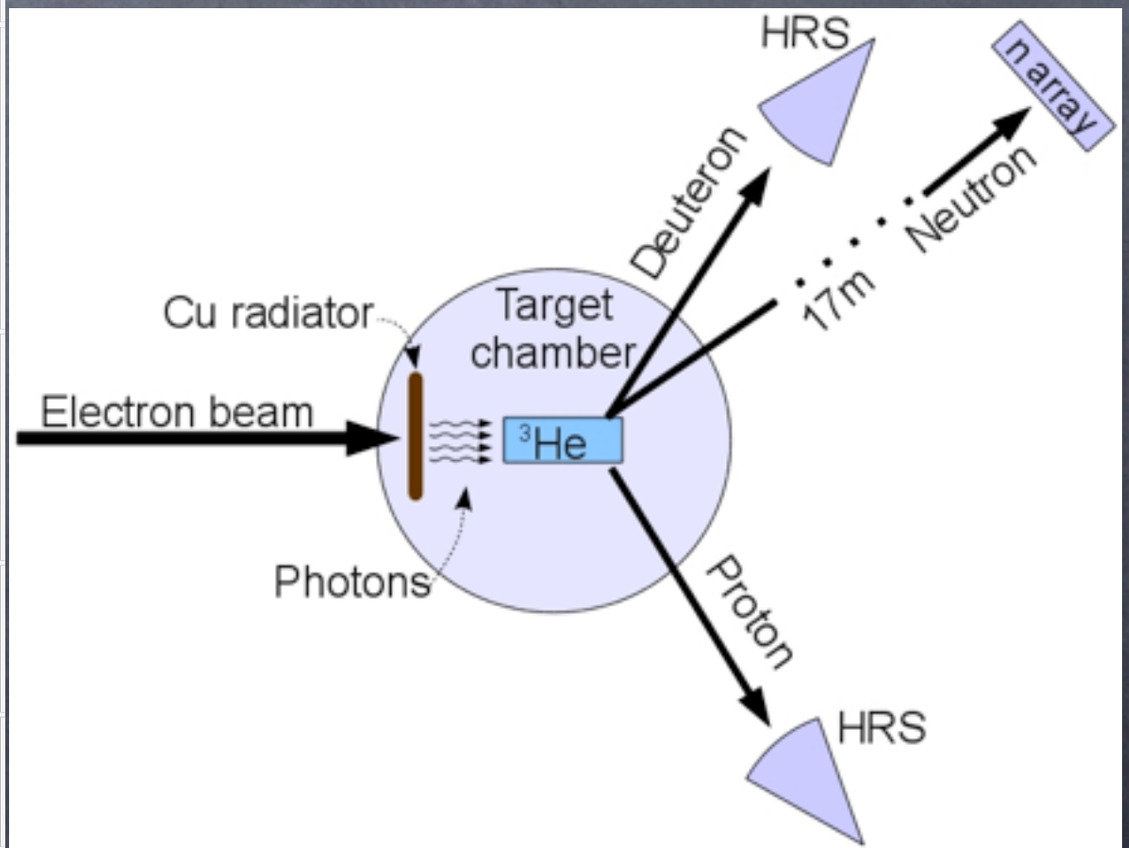
✓ More generally E_γ, θ dependence check nuclear effects in γNN

Experimental Overview

- $\gamma\,^3He \rightarrow pp + n_{spectator}$, $pn + p_{spectator}$, pd
- largely standard Hall A photon experiment

Measurement	Time (days)
Setup/Checkout	1
2.2 GeV $\gamma\,^3He$, 15 kinematics, 5 HAND settings	6
γd calibration, + 2 target changes, 1 energy change	2
4.4 GeV $\gamma\,^3He$	10
TOTAL	**19**





Kinematics Settings

Kin	Ee (GeV)	Target	FS	θ HRS p	θ HRS p or d	θ HAND n
1	2.2	3He	p d+n	105.43	39.34	19.88
2	2.2	3He	pp	49.71	49.71	
3	2.2	3He	pp	54.42	54.42	
4	2.2	3He	p d+n	52.54	69.13	52.53
5	2.2	3He	pp	50.66	50.66	
6	2.2	3He	pp	15.56	117.68	
7	2.2	3He	pp	19.34	106.84	
8	2.2	3He	p d+n	38.71	82.77	69.02
9	2.2	3He	pp	52.54	52.53	
10	2.2	3He	pp	28.33	86.30	
11	2.2	3He	p d+n	28.33	97.27	86.30
12	2.2	3He	pp	38.71	69.02	
13	2.2	3He	p d+n	15.56	124.30	117.68
14	2.2	3He	pp	55.38	55.38	
15	2.2	d	pn cal	52.54		52.53
16	4.4	d	pn cal	42.72		42.72
17	4.4	3He	pp	42.72	42.72	

- HAND rate vs threshold & efficiency discussed in proposal
- HAND always forward of HRS
- momenta ≈ 1 - 3 GeV/c
- optimized pd kinematics, rate 100x E03-101 rate

Summary

- Request 19 days to measure $\gamma^3He \rightarrow pp+n_{spectator}$, $pn+p_{spectator}$, pd
- Largely standard Hall A photon experiment

> Does $\gamma^3He \rightarrow pp+n_{spectator}$ violate scaling, as predicted by HRM?

✓ Tests relation to NN elastic scattering

> What is the α_n distribution in $\gamma^3He \rightarrow pp+n_{spectator}$?

✓ Tests long vs short range underlying dynamics

> Is the apparent scaling in $\gamma^3He \rightarrow pd$ (A>2!) real?

✓ Tests whether A>2 system scales

> Why the ratio of scaling $\sigma_{pn} : \sigma_{pp} : \sigma_{pd} \approx 20 : 1 : 1/4$?

✓ σ_{pn} from ^3He tests nuclear structure inputs, 3 body and other nuclear effects

Note, not for PAC defense

> Bogdan's challenge: can we run with more open Bigbite / SBS / HC to increase solid angles and statistics?

✓ Lots of angle settings at 2.2 GeV, so only use SBS at 4.4 GeV

SBS cannot be p/d arm - neutrons go through magnet iron - but could be p arm.

— For singles, reconstruction uncertainty dominated by $\delta\theta$, as long as $\delta p \leq 10^{-3}$. For coincidence, likely $\delta p \approx 10^{-2}$ OK; it needs study

— HRS provides low backgrounds & high data quality. Our luminosities are high and we need to consider this as well.

Might also make sense to use hadron calorimeter instead of HAND

Note, not for PAC defense

- Bogdan's challenge: can we run with more open Bigbite / SBS / HC to incre
  - ✓ Lots of … 4 GeV
  - SBS co… iron – but could …
  - — For sin… , as long as δp ≤ 10… study
  - — HRS pr… luminositie…
- Might also make sense to use hadron calorimeter instead of HAND

We need to evaluate these suggestions more and consider whether to make changes before the PAC.

Installation of SBS (+BB?) for 10 days probably does not make sense.

Using HC instead of HAND probably about same effort.