Correlations in Nuclei

Larry Weinstein
Old Dominion University
For the CLAS Collaboration

- Comprehensive Theory Overview
- What are Correlations
- The CLAS Detector
- How to Measure Correlations
- Summary

Comprehensive Theory Overview

Nuclear Theory, circa 1980

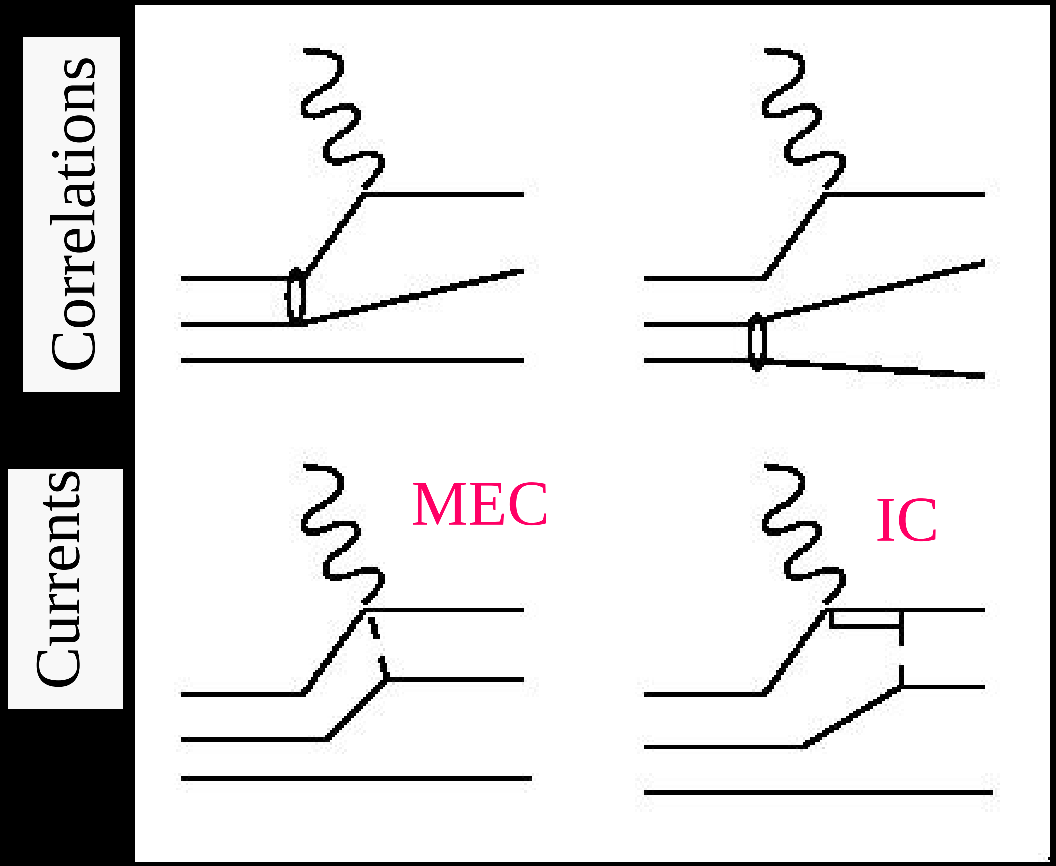
Nuclear Theory - today

What are Correlations?

Average Two Nucleon Properties in the Nuclear Ground State

Responsible for the high momentum part of of the Nuclear WF

Two-body currents are not Correlations



Two body currents strongly enhance the effects of correlations

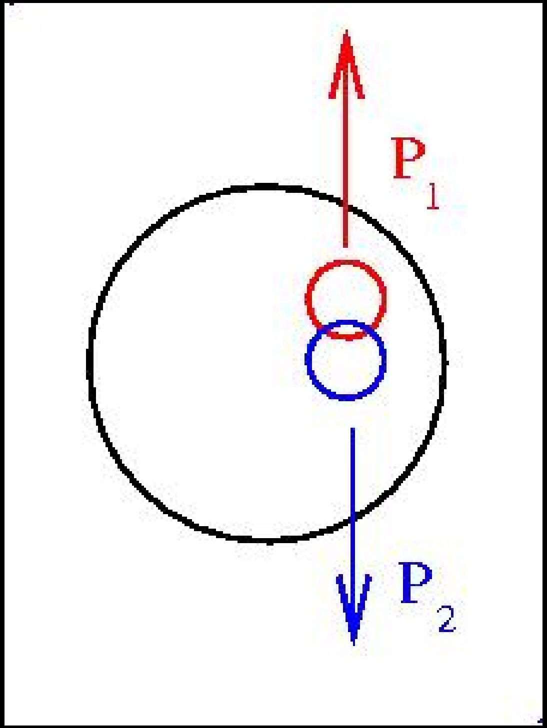
What are Correlations?

Average Two Nucleon Properties in the Nuclear Ground State

Not Two-Body Currents

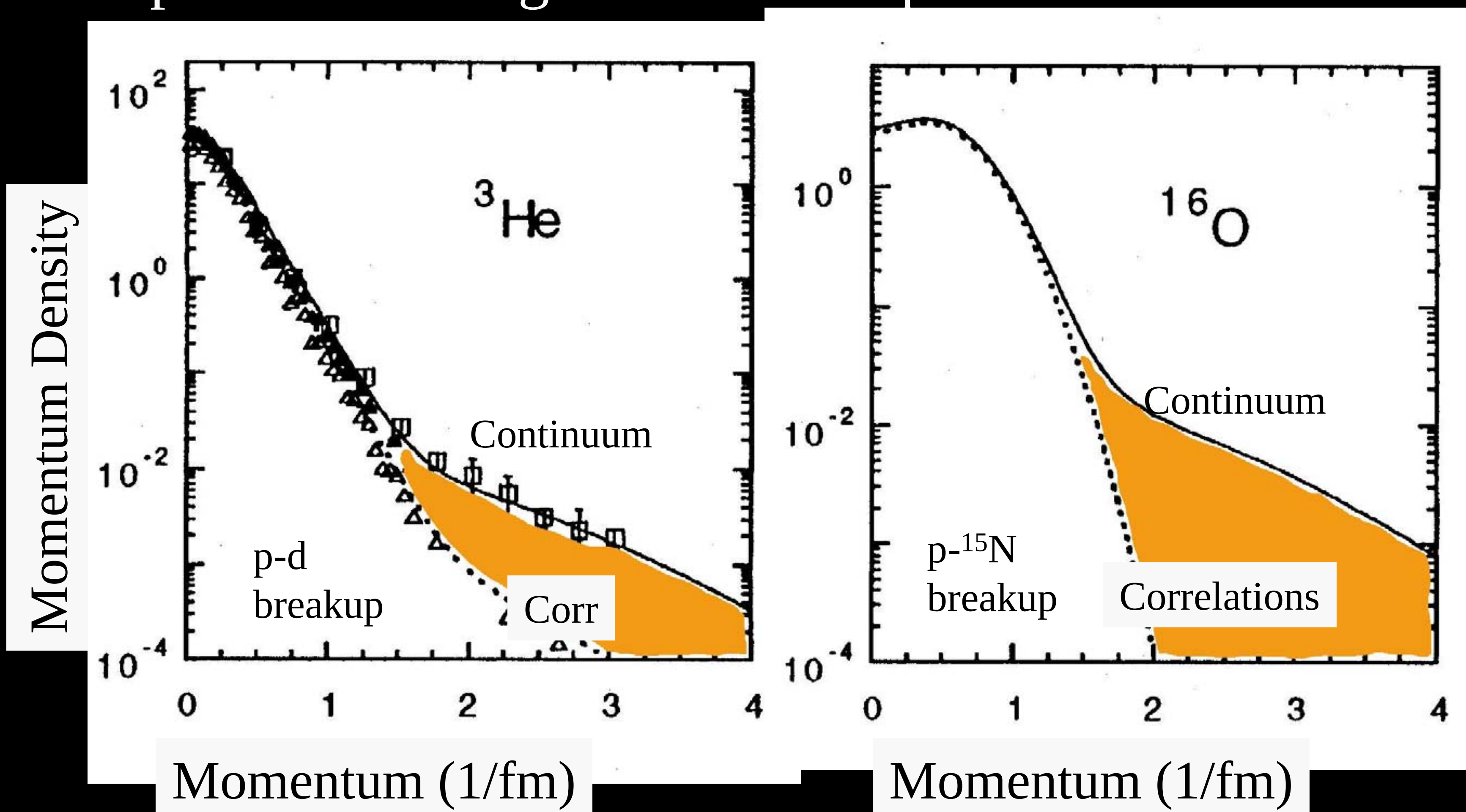
An Experimentalist's Definition:

- A high momentum nucleon whose momentum is balanced by **one** other nucleon
  - NN Pair with
    - Large Relative Momentum
    - Small Total Momentum
- Whatever a theorist says it is



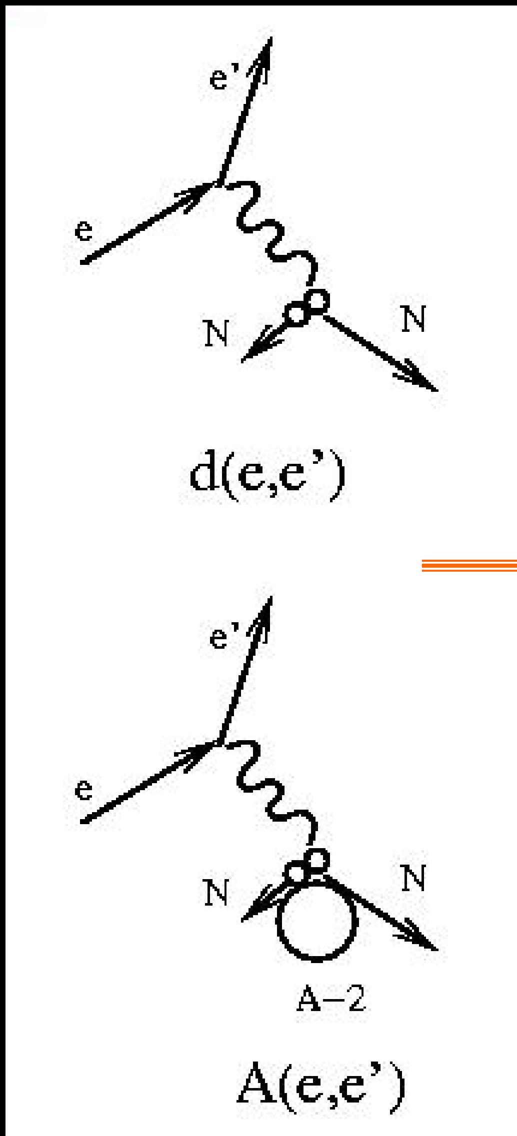
Why are Correlations Interesting?

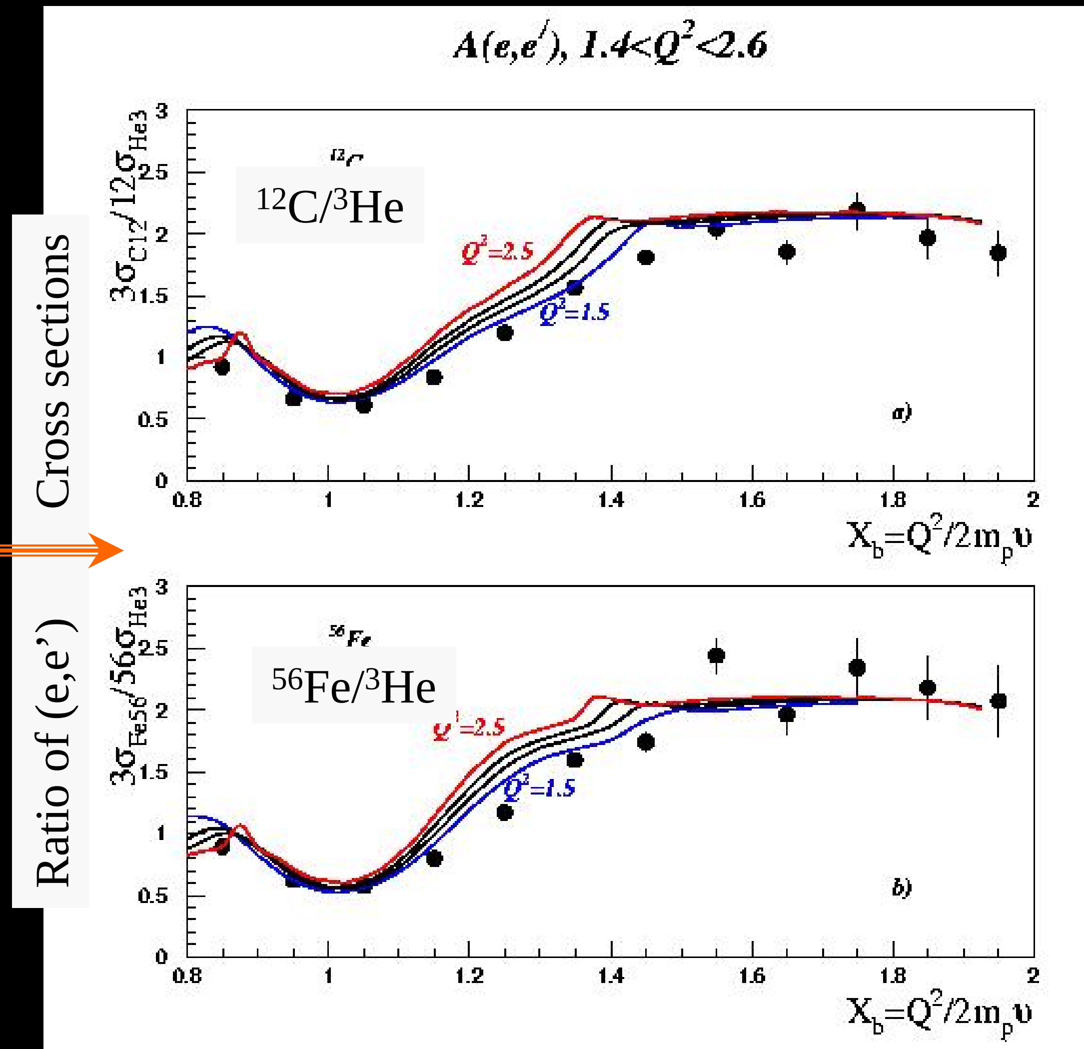
Responsible for high momentum part of Nuclear WF



Ciofi degli Atti, PRC 53 (1996) 1689

Correlations are Universal

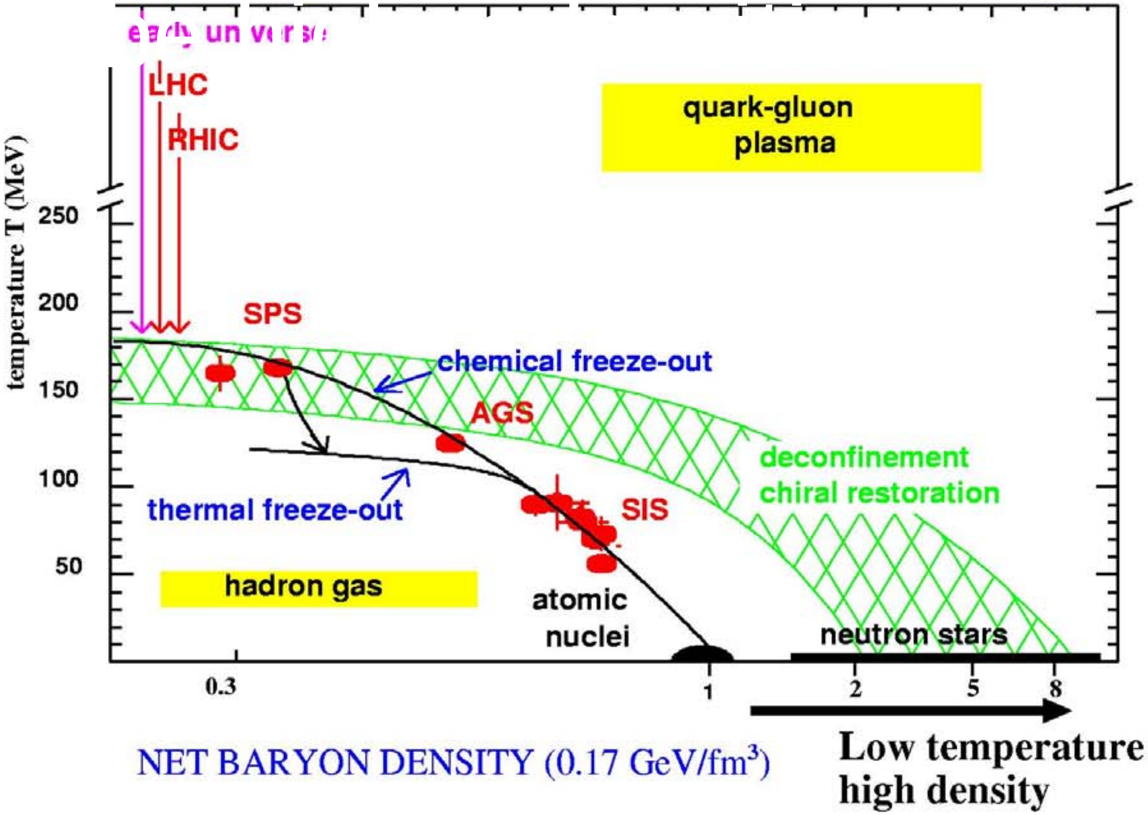




K. Egiyan et al, PRC 68 (2003) 014313

J. Arrington, 2004

~~Crazy~~ New ideas: Probe even higher densities



Average nuclear density is a few times smaller than the critical density

A nucleus is a dynamic system, with local fluctuations in density

These fluctuations provide a small high-density component (short-range correlations)

* This may be origin of EMC effect, medium modifications
* We can try to isolate SRCs to probe high density matter

If SRCs are the source of the EMC effect, why probe nuclei? ***Probe SRCs instead!***

J. Arrington, 2004

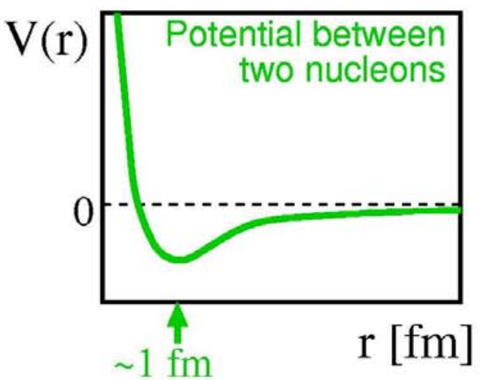
High Density Configurations

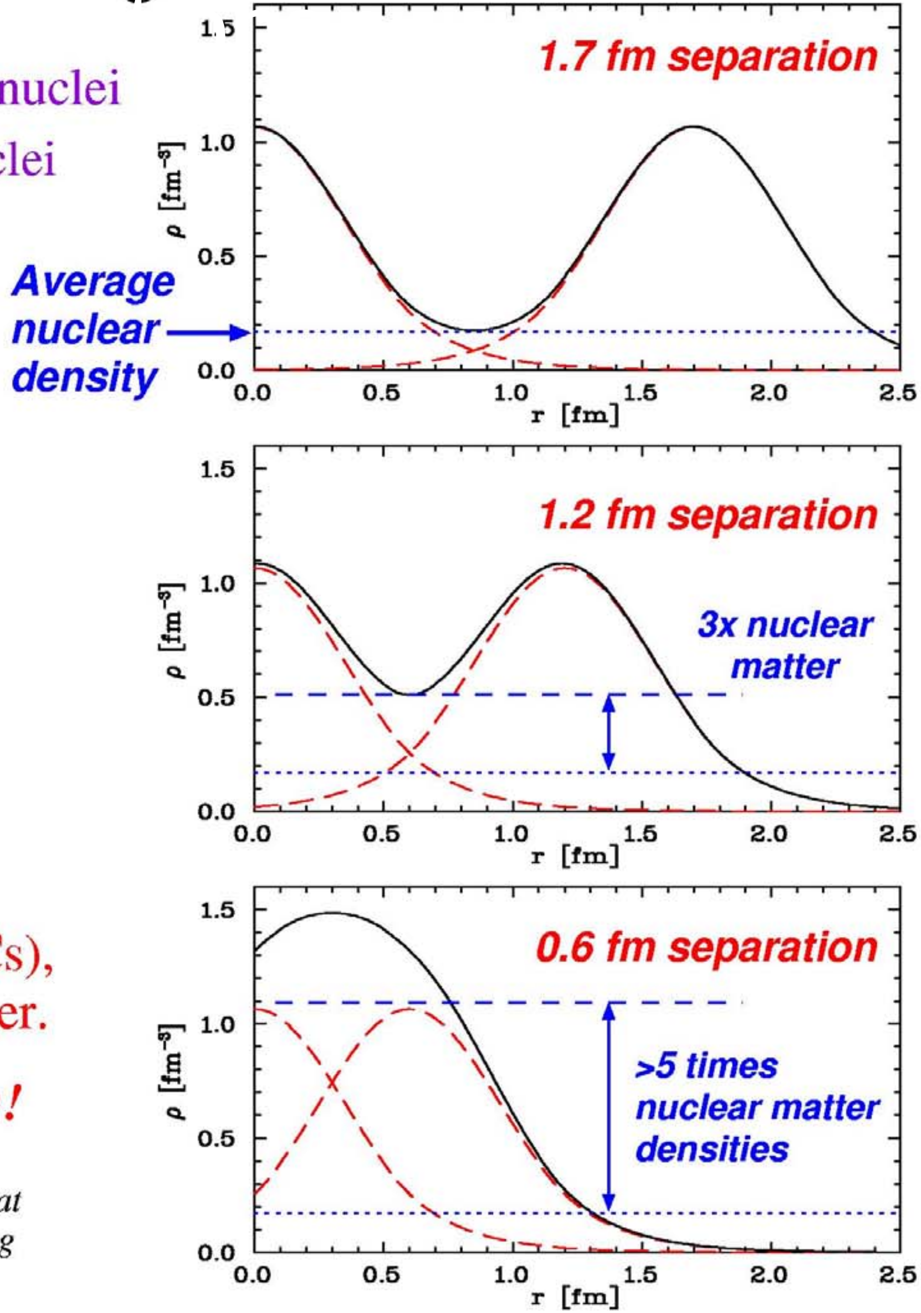
Nucleons are already closely packed in nuclei

Ave. separation ~1.7 fm in heavy nuclei

nucleon charge radius ~ 0.86 fm

Nucleon separation is limited by the short range repulsive core



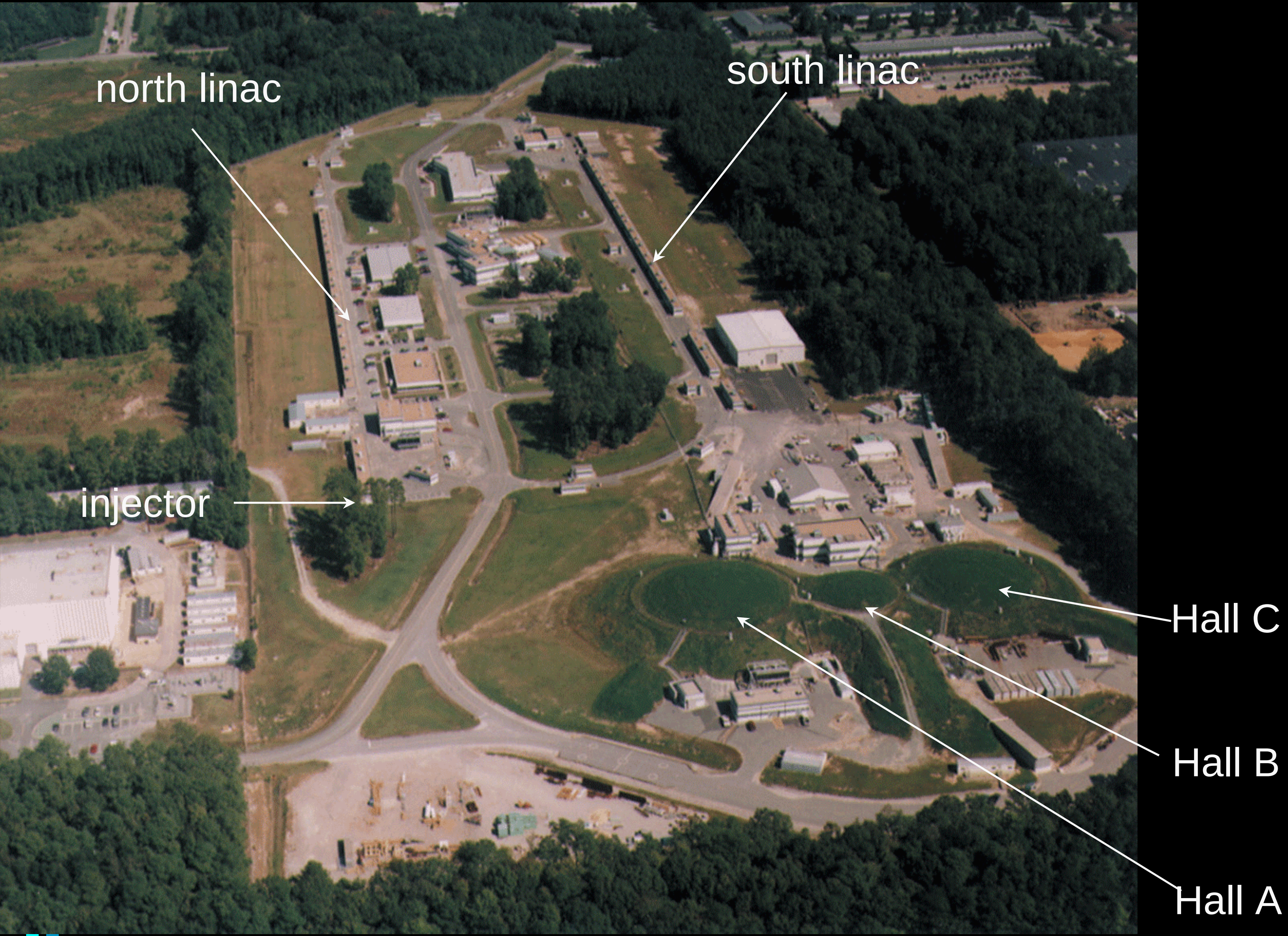


For a 1 fm separation (typical for SRCs), the central density is ~4x nuclear matter.

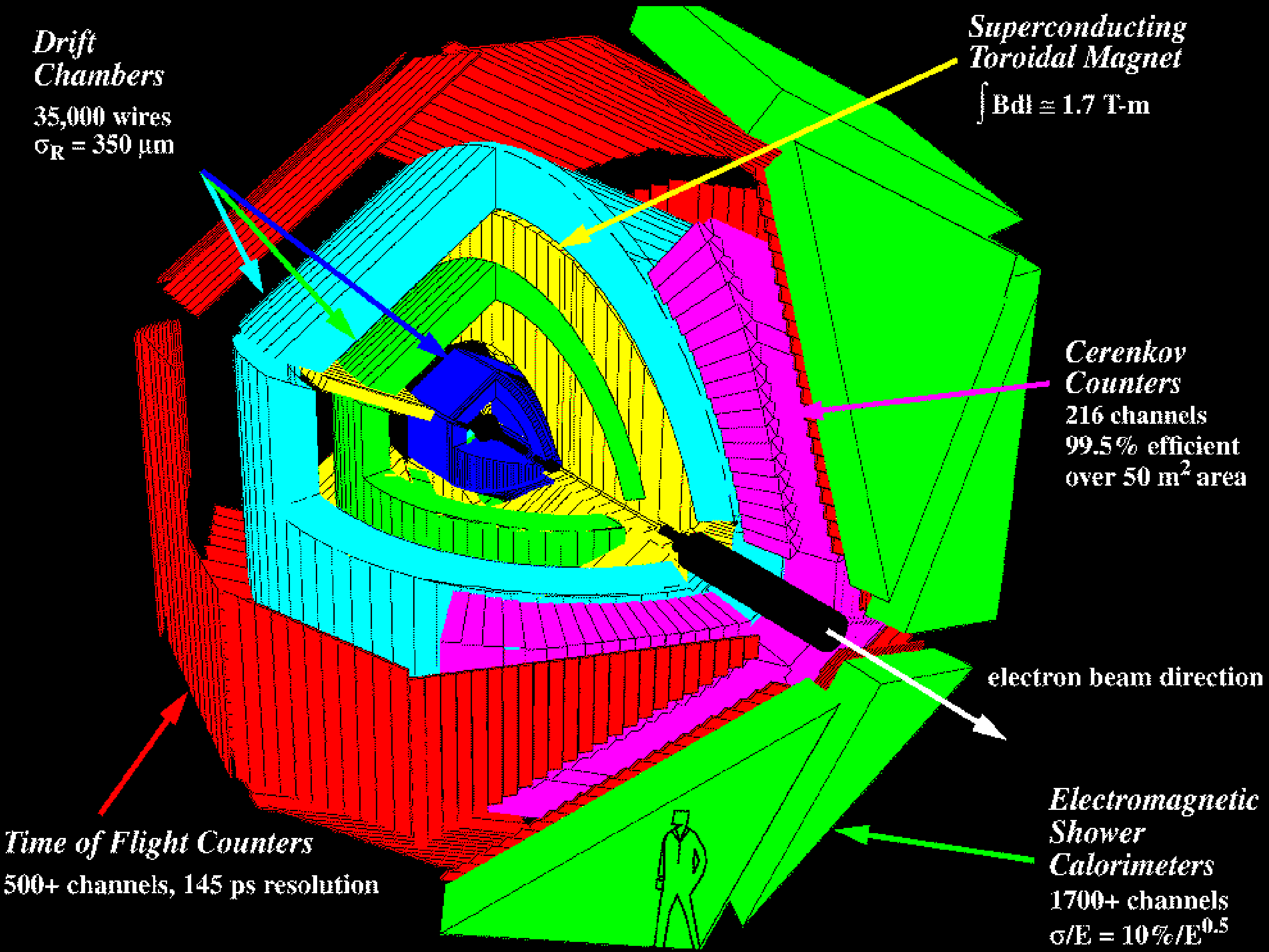
Comparable to neutron star densities!

Warning: portions of the person seated next to you are at neutron star densities and may collapse without warning

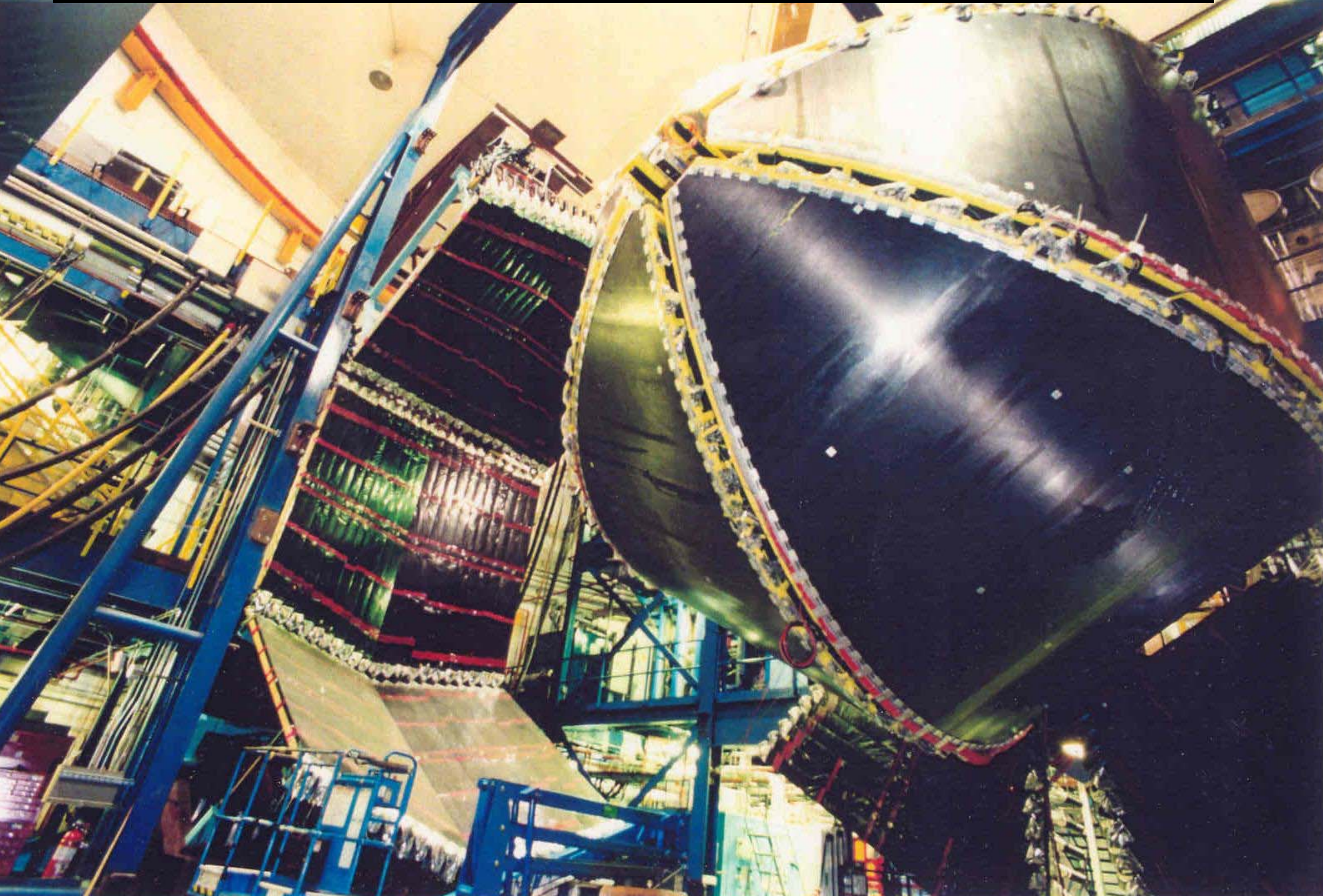
CEBAF Site



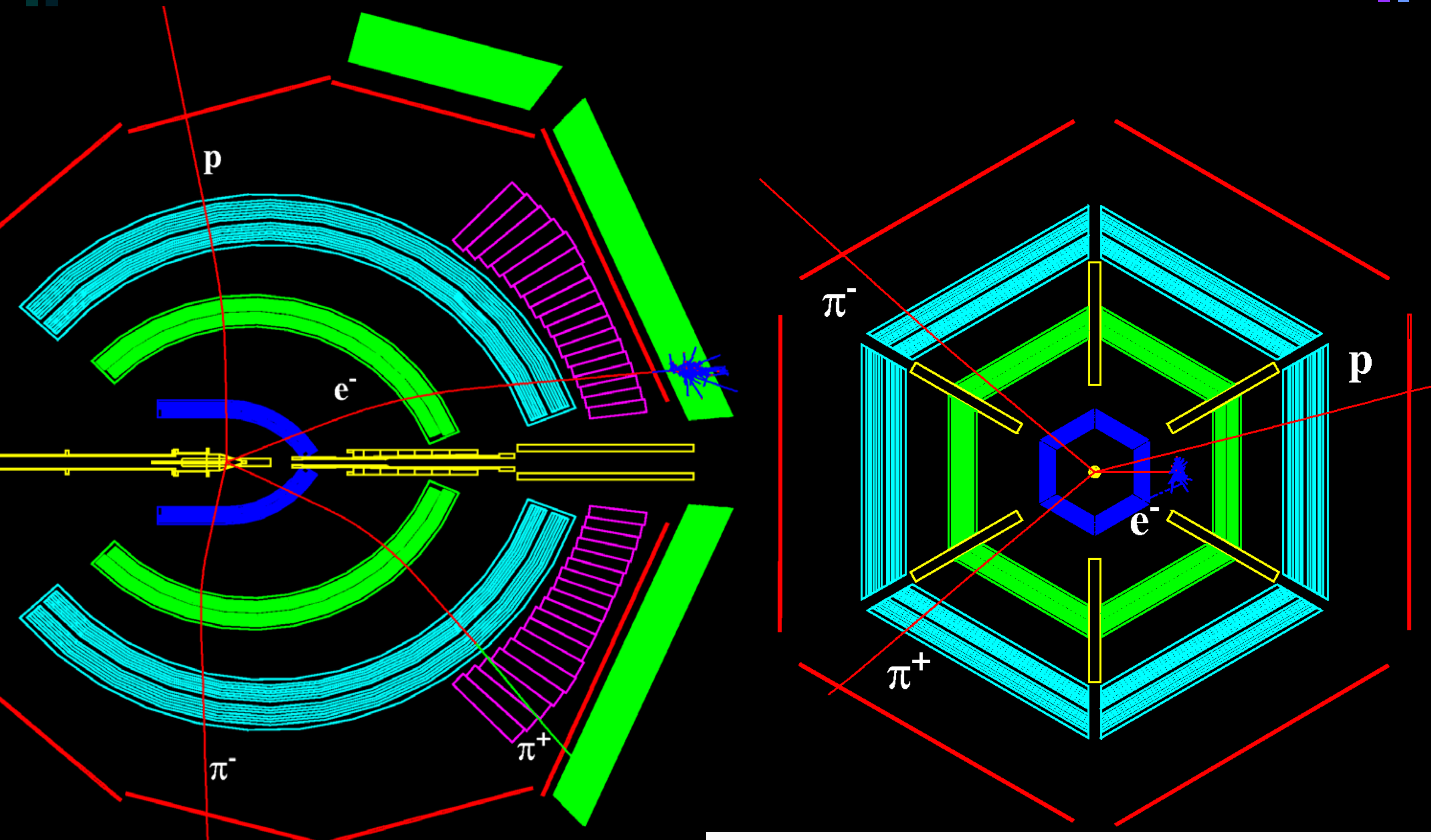
CLAS 3-D View

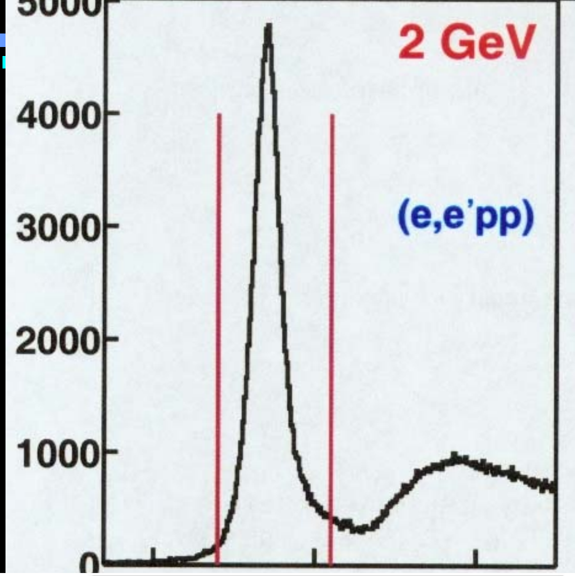

Drift
Chambers
35,000 wires
σ_R = 350 μm
Superconducting
Toroidal Magnet
$\int Bdl \cong 1.7$ T-m
Cerenkov
Counters
216 channels
99.5% efficient
over 50 m^2 area
electron beam direction
Time of Flight Counters
500+ channels, 145 ps resolution
Electromagnetic
Shower
Calorimeters
1700+ channels
$\sigma/E = 10\%/E^{0.5}$

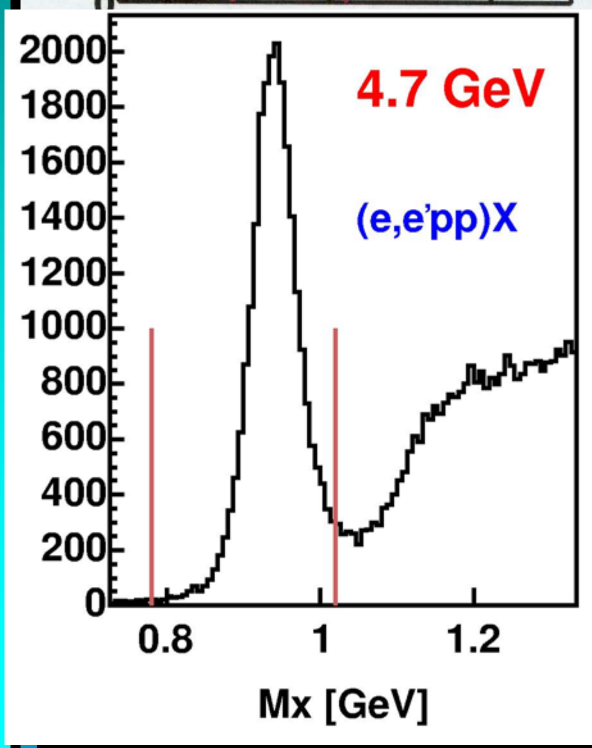
CLAS in Maintenance Position



CLAS Single Event Display



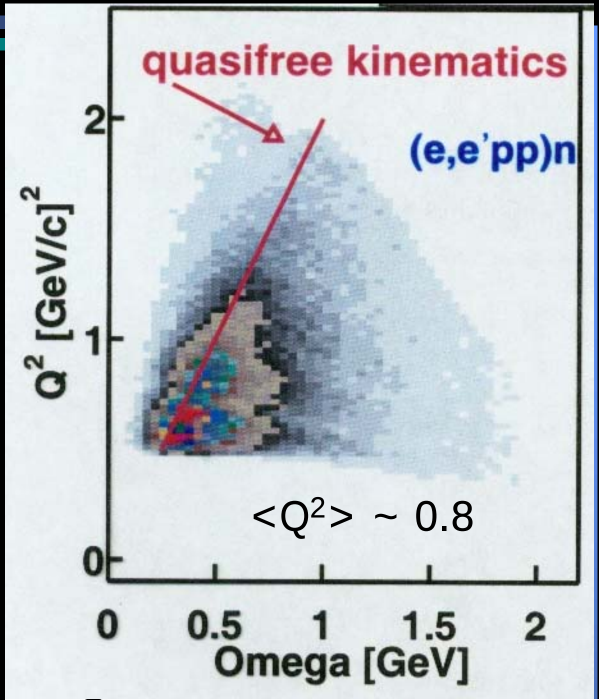


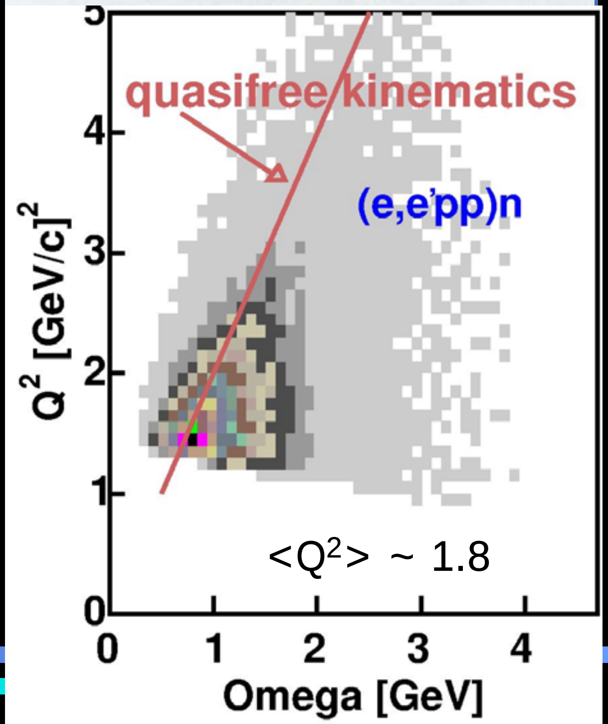


$^3He(e,e'pp)$

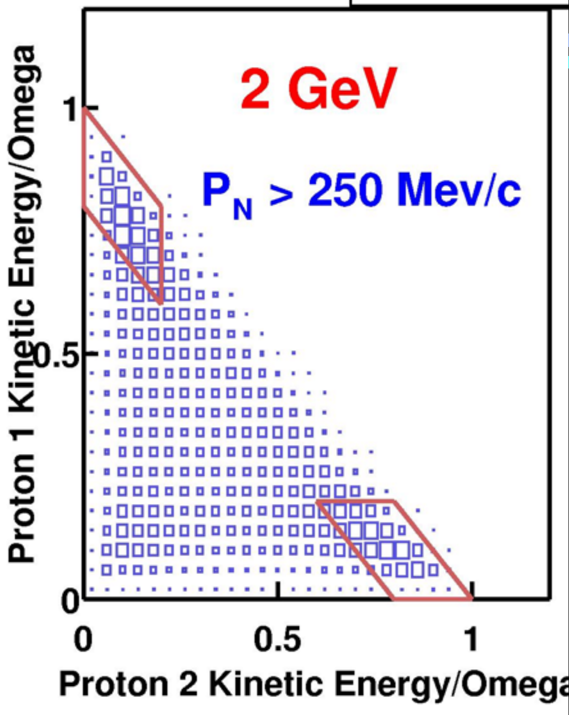
Detect 2 protons, reconstruct the neutron

Huge electron acceptance

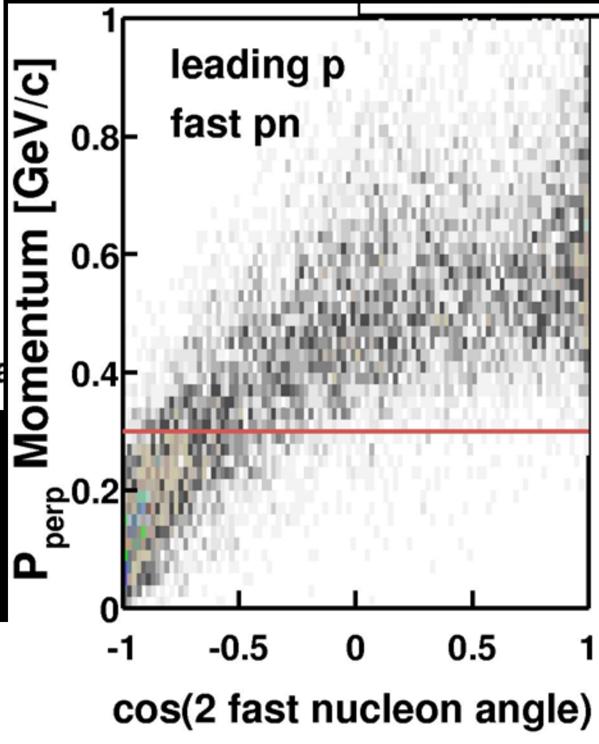




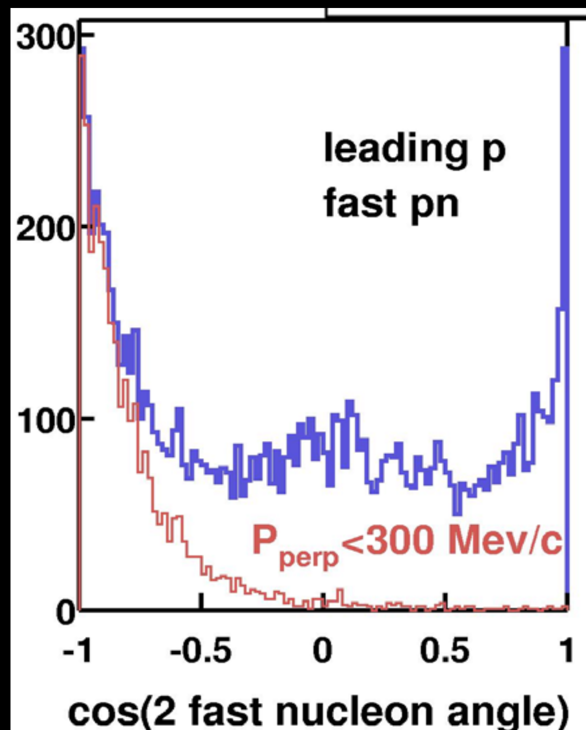
Be vewy, vewy quiet, I'm hunting correlations...

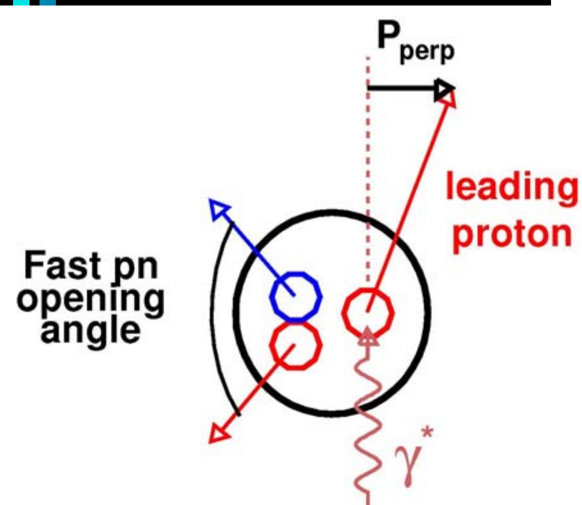


Select peaks
in Dalitz plot



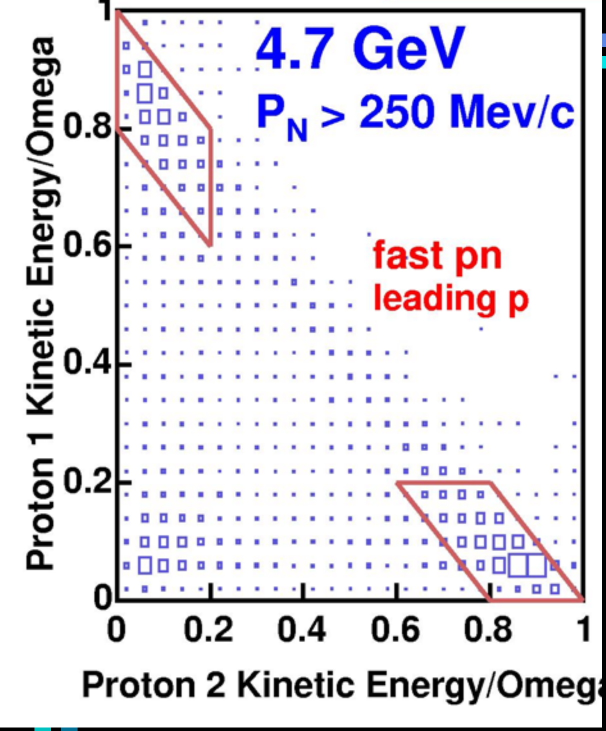
Pair has
back-to-back peak!



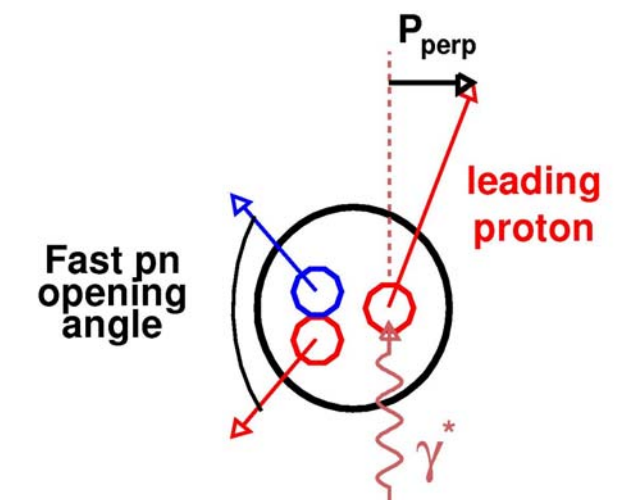


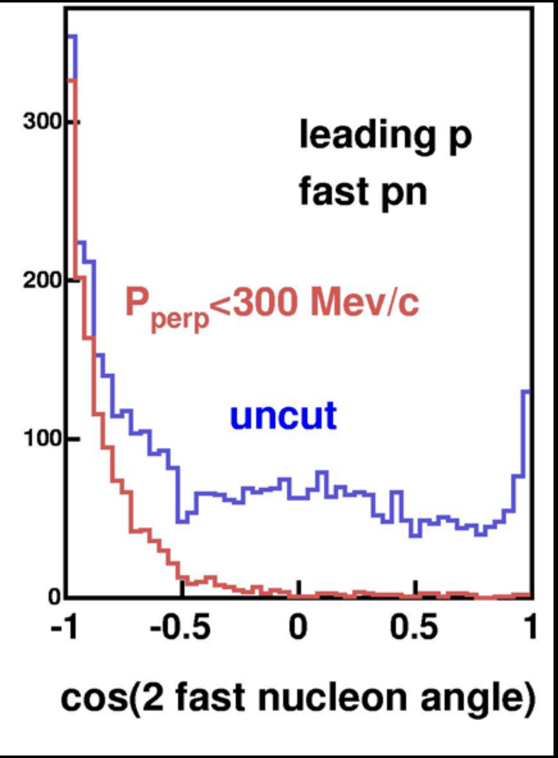
R. Niyazov, PRL92 (2003) 052303

Be vewy, vewy quiet, I'm still hunting correlations...



Select peaks
in Dalitz plot





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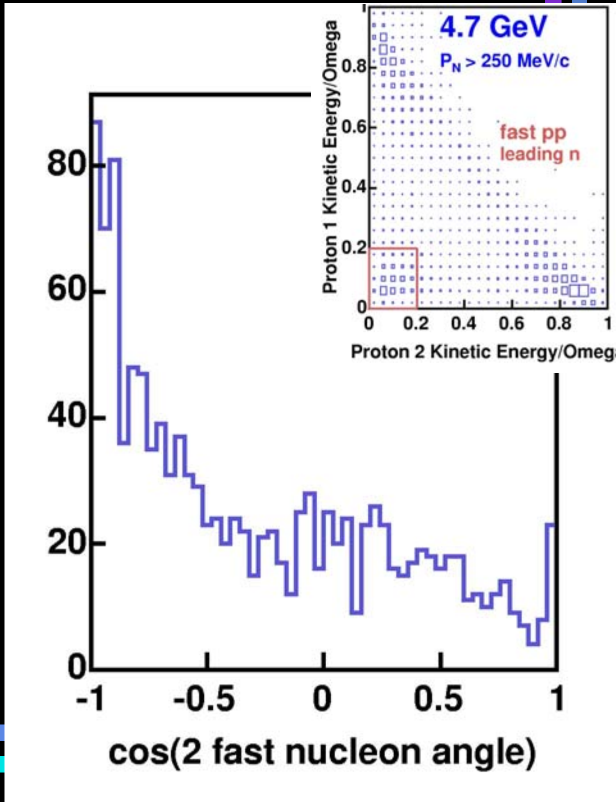
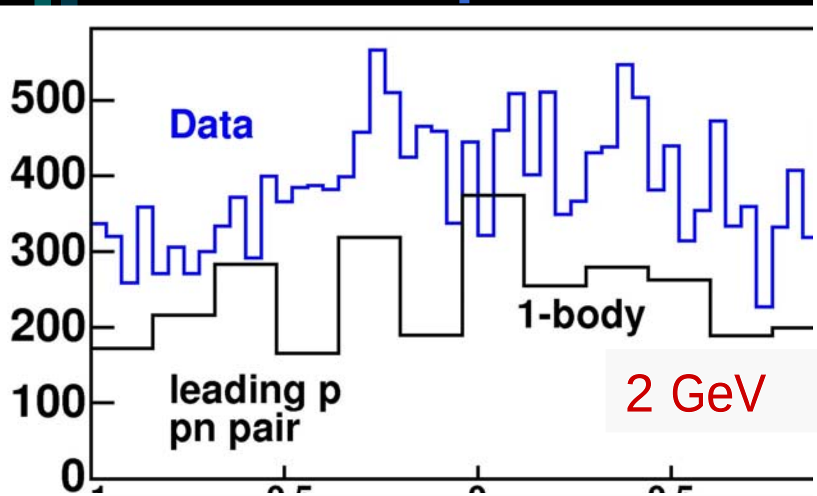
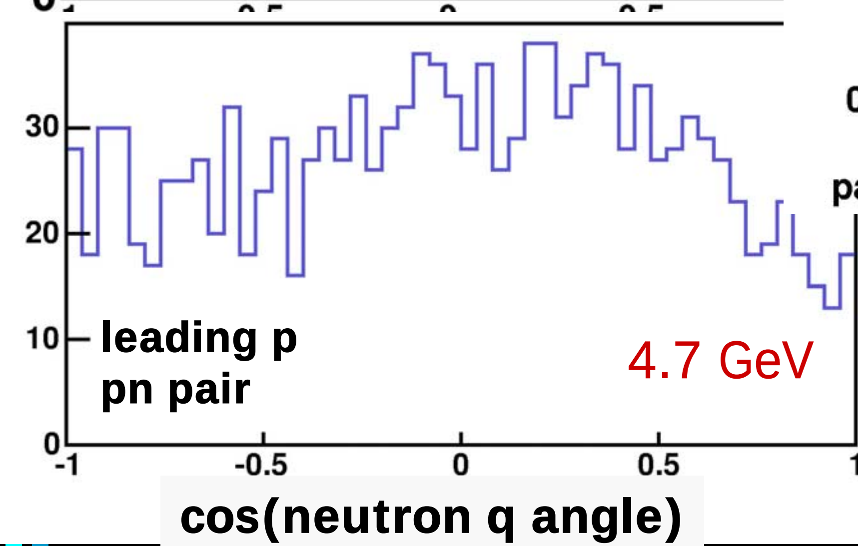
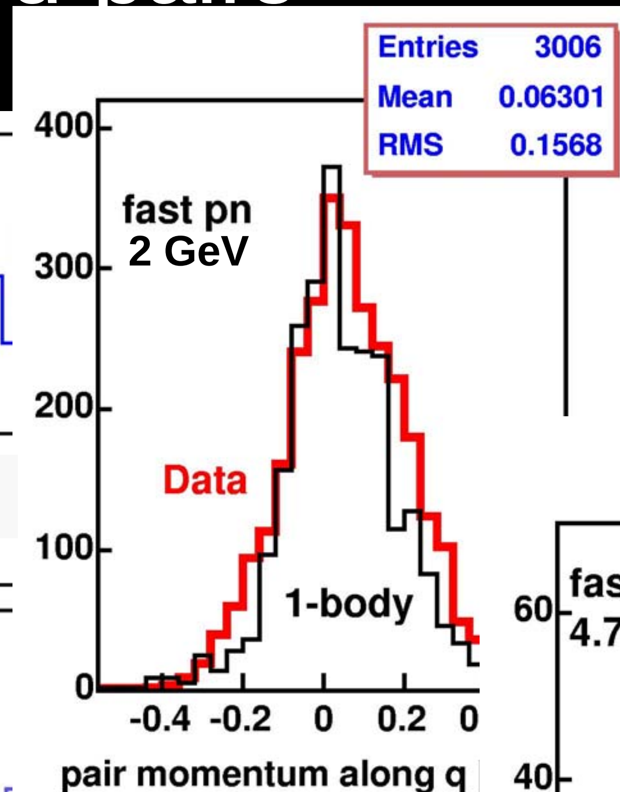


I don't want to get involved: spectator correlated pairs

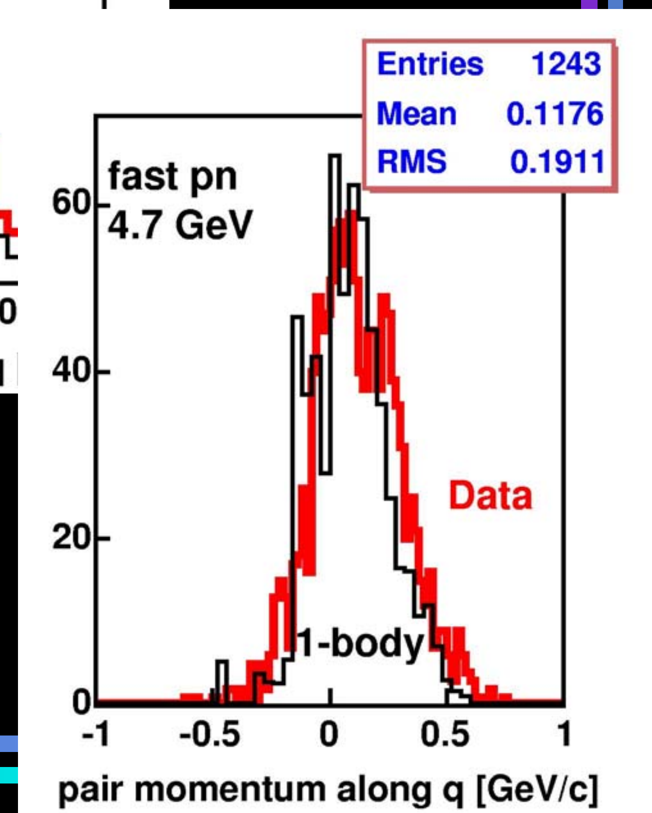
Isotropic!

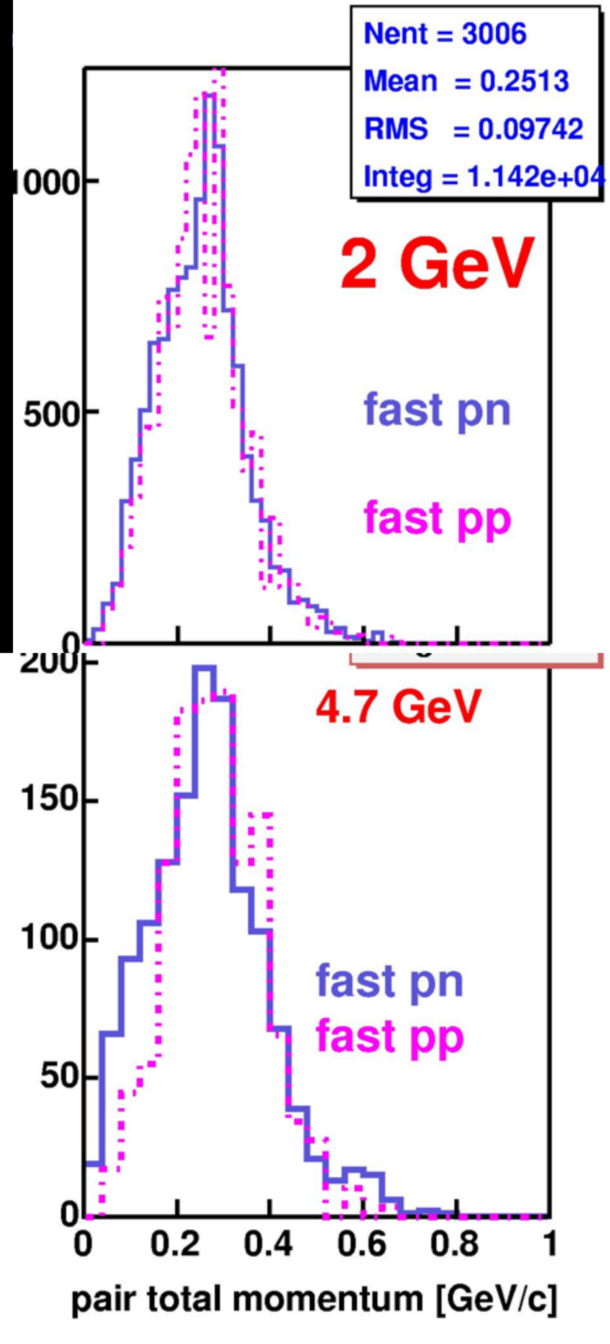






Small forward momentum (described by theory)

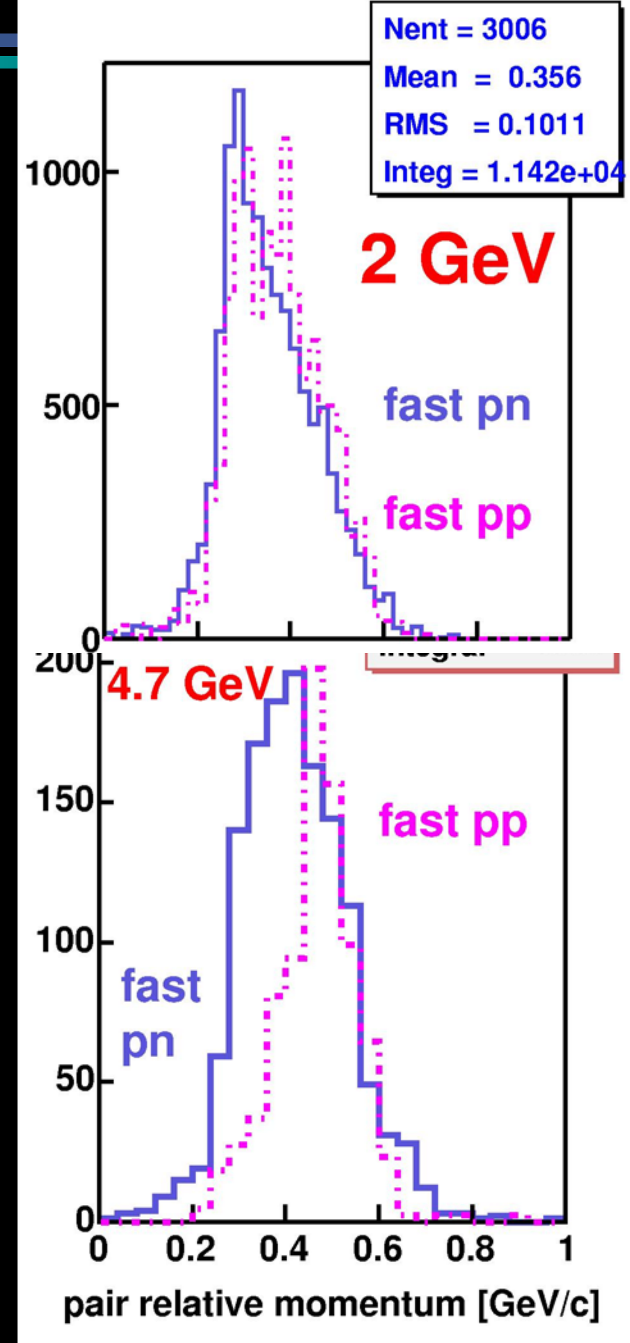




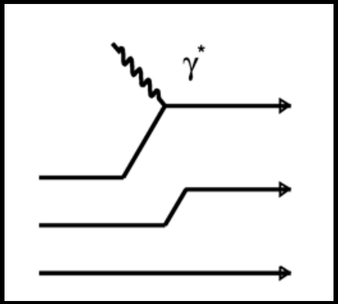
(2 GeV is acceptance corrected)

2 GeV
vs
4.7 GeV

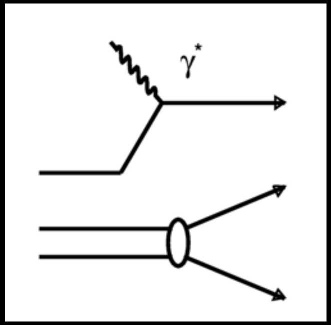
pp and pn have different scales



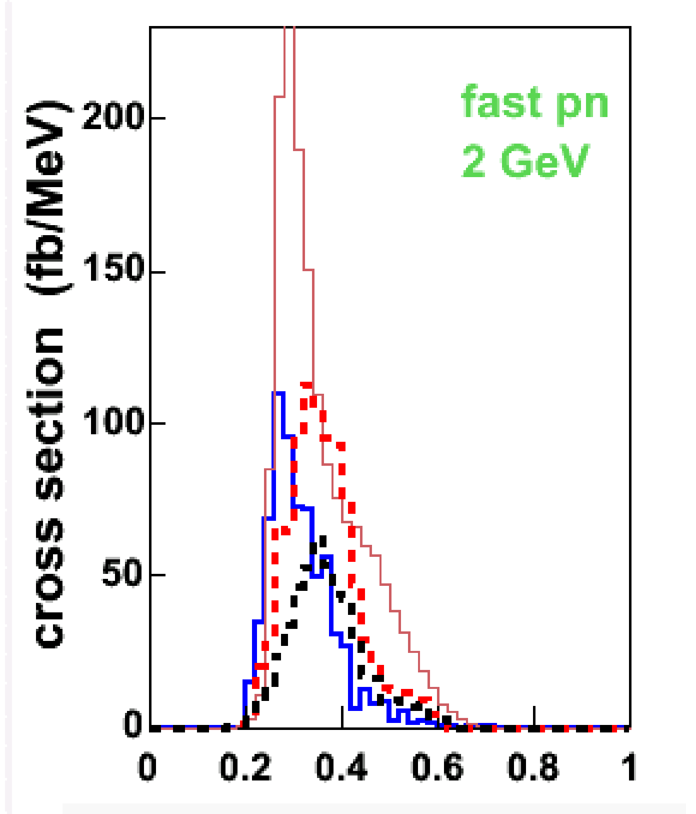
Theory Comparison



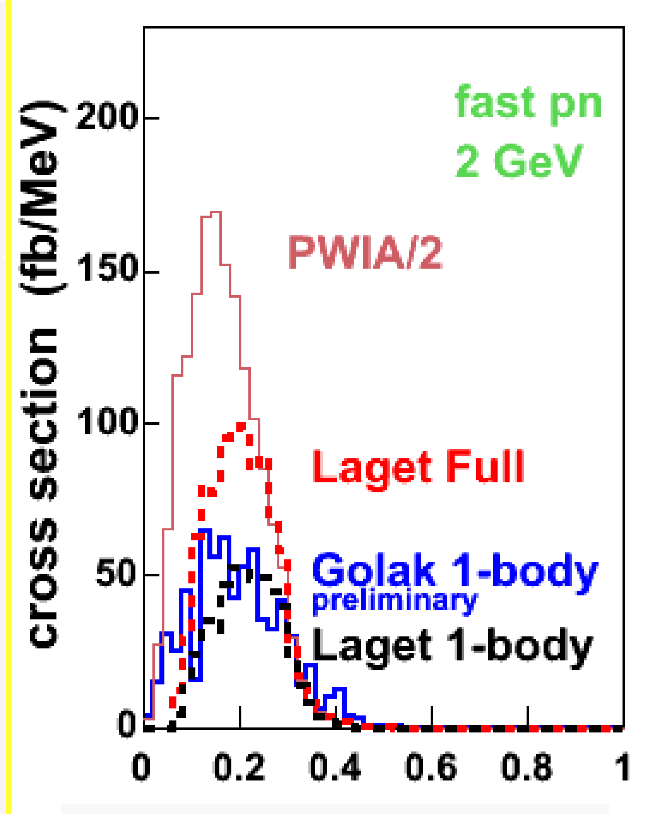
PWIA



Pair distortion



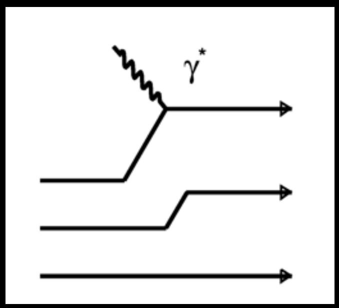
Pair Relative Momentum



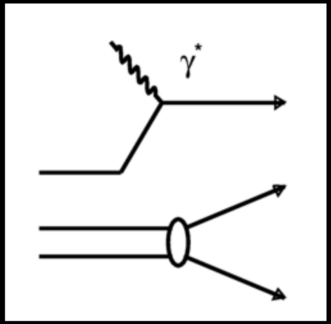
Pair Total Momentum

1-body = PWIA + pair distortion

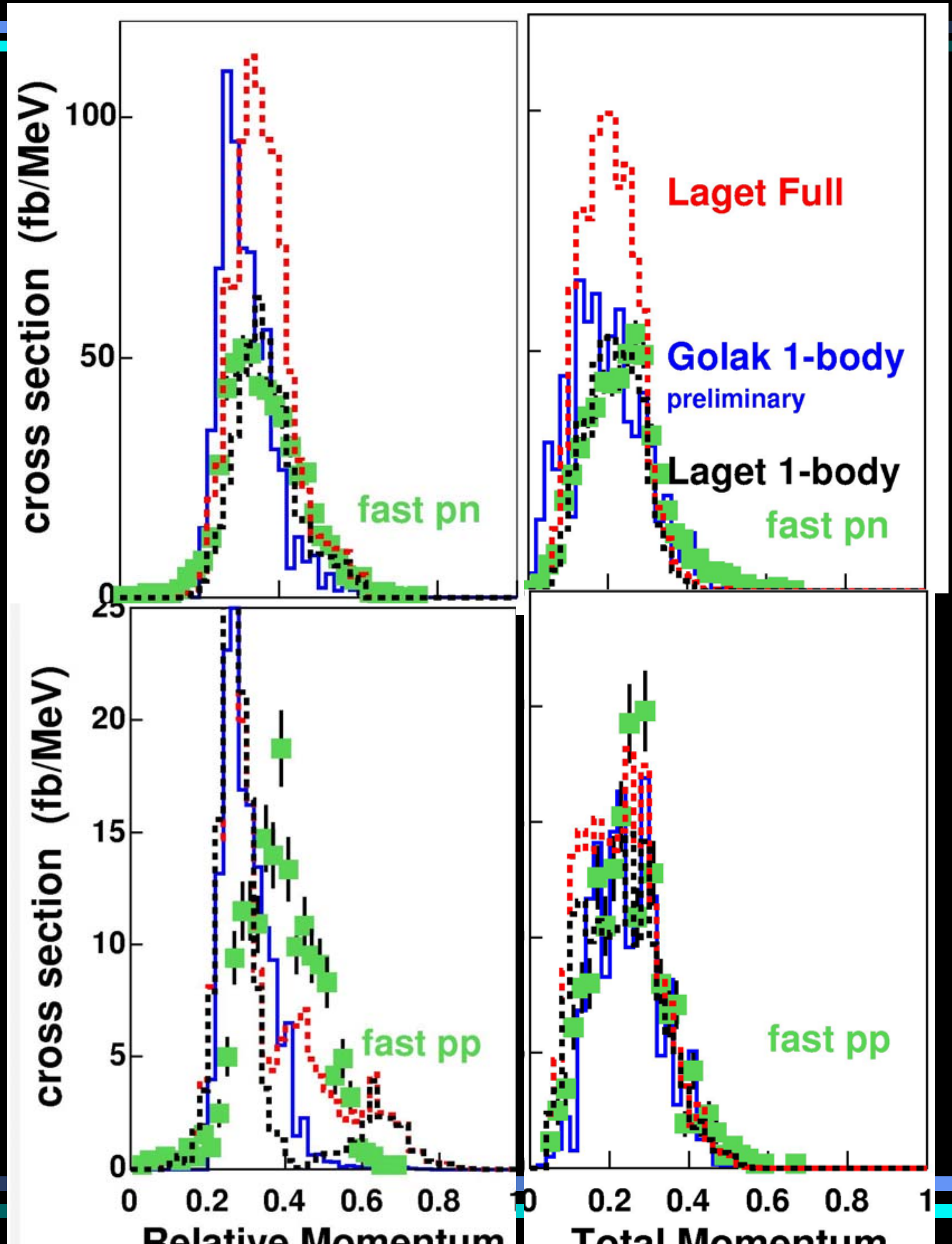
2 GeV Results



PWIA



Pair distortion

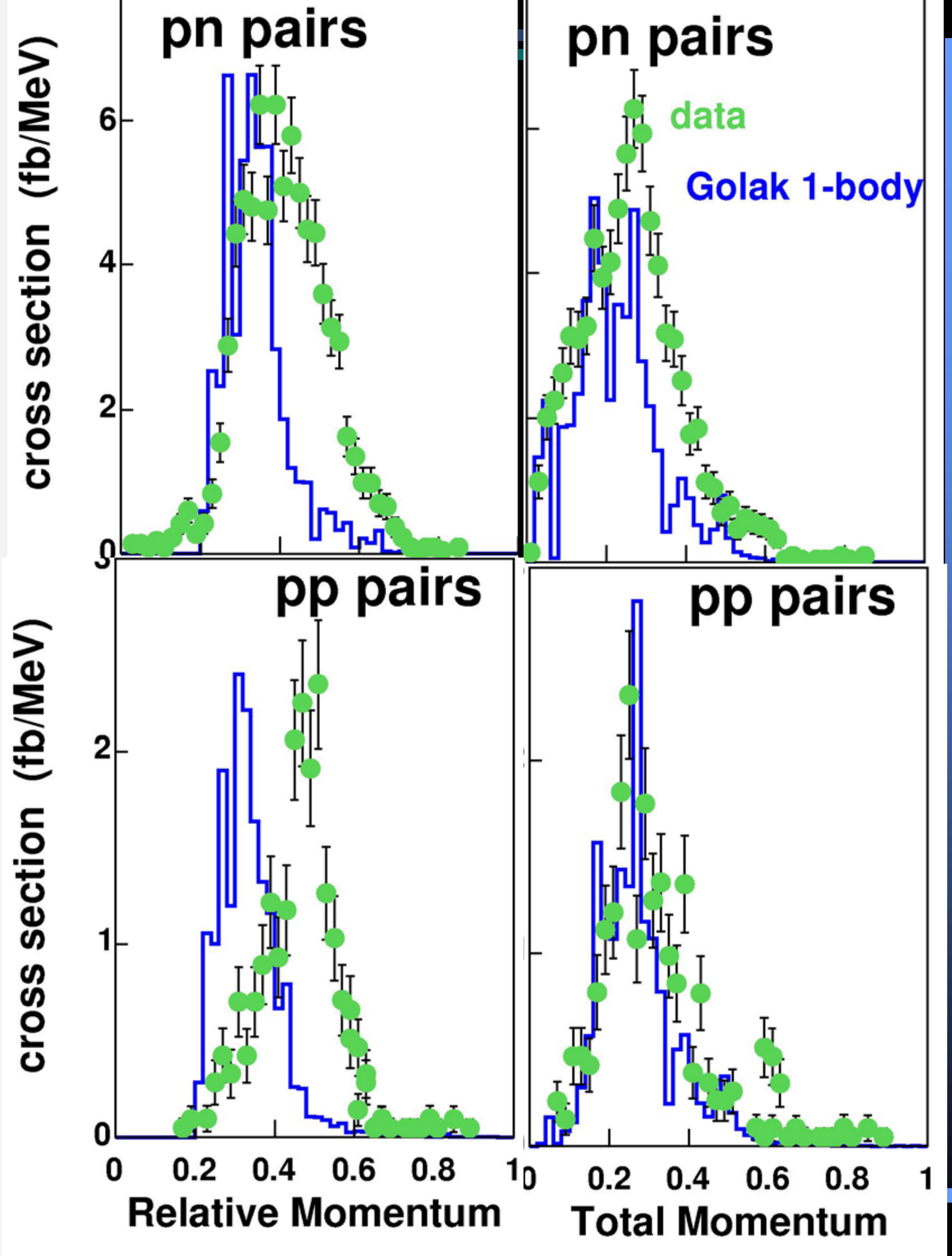


4.7 GeV Results (Golak)

Total cross-sections: data = 1-body!

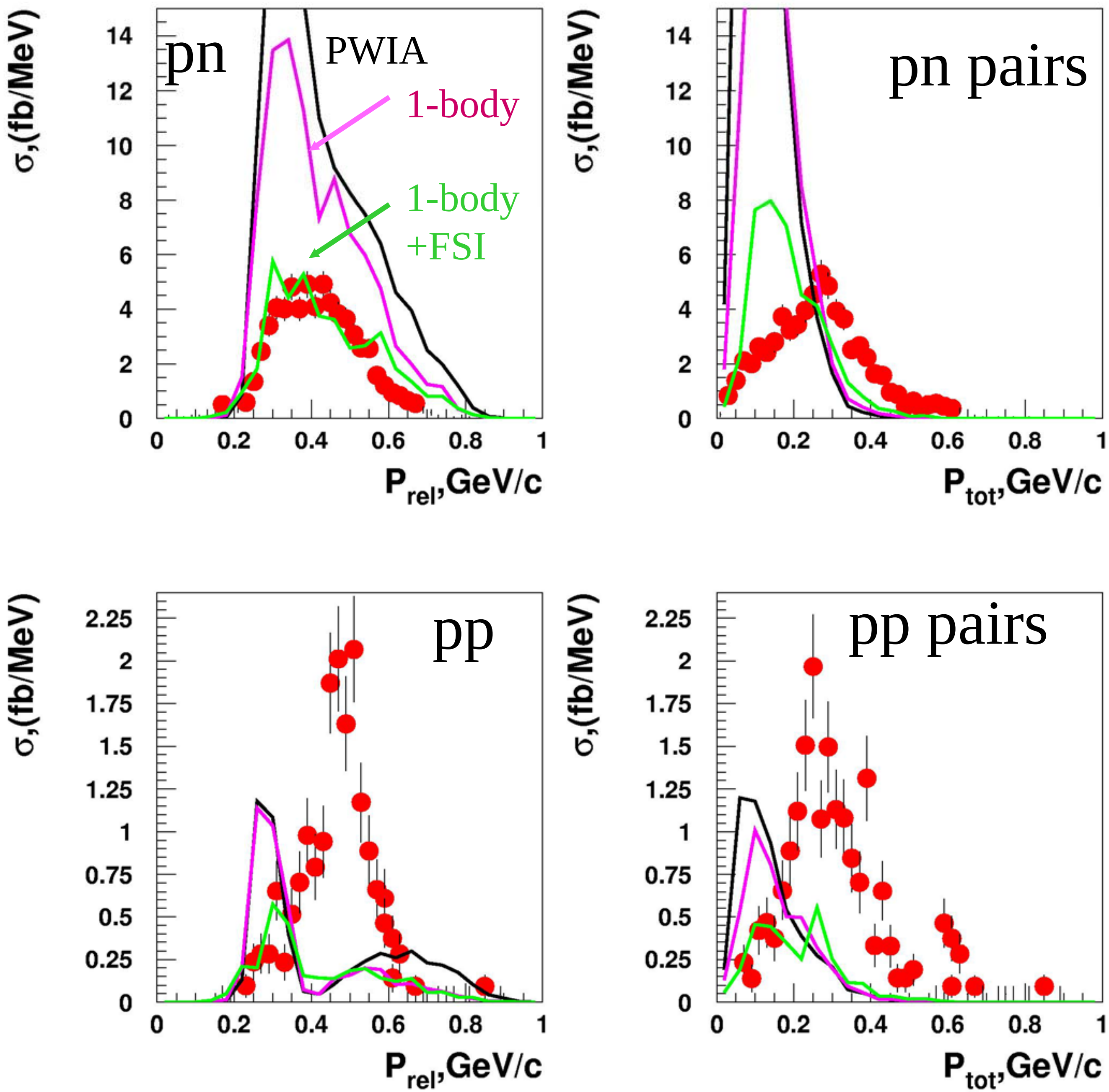
Same Q^2 dependence!

Data: H. Baghdasaryan



4.7 GeV Results (Misak)

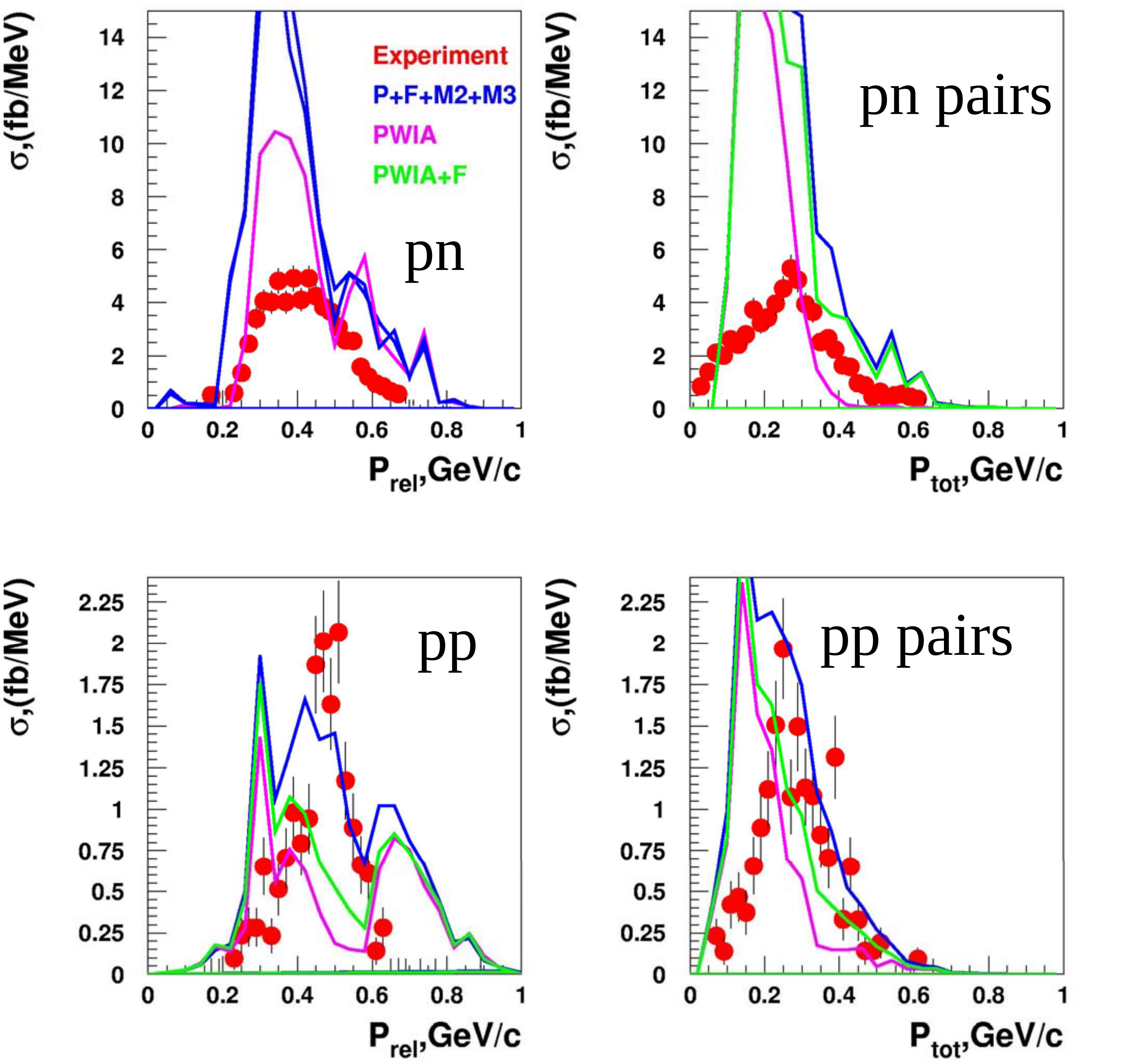
Misak calculations



4.7 GeV Results (Laget)

Laget calculations

`PWIA' = 1-body
F = FSI
M = MEC



3He(e,e'pp)n Summary

- Analysis - follow the peaks:
  - p_N > 250 MeV/c
  - Corners of Dalitz plots (T1, T2 < 0.2*nu)
  - $P_{leading}$(perp) < 300 MeV/c (reduce leading N FSI)
- Results:
  - NN pair is back-to-back
  - Small p_{total} along q
  - isotropic
  - Sigma pp/pn same as PWIA
  - Well described by Golak PWIA + pair distortion
    - Magnitude
    - Q^2 dependence
  - FSI and MEC not needed
- **We have measured distorted correlated pairs!**

How to study correlated pairs:

- Should we hit the correlated pair?
  - No! Need to understand
    - MEC (interferes VERY constructively w/SRC)
    - FSI of struck nucleon
  - Yes! Misak, Laget, Claudio ...
- Should we study spectator pairs?
  - No! Need to understand
    - Pair distortion (a factor of 10)
  - Yes! Golak
- CLAS has both sets of data!