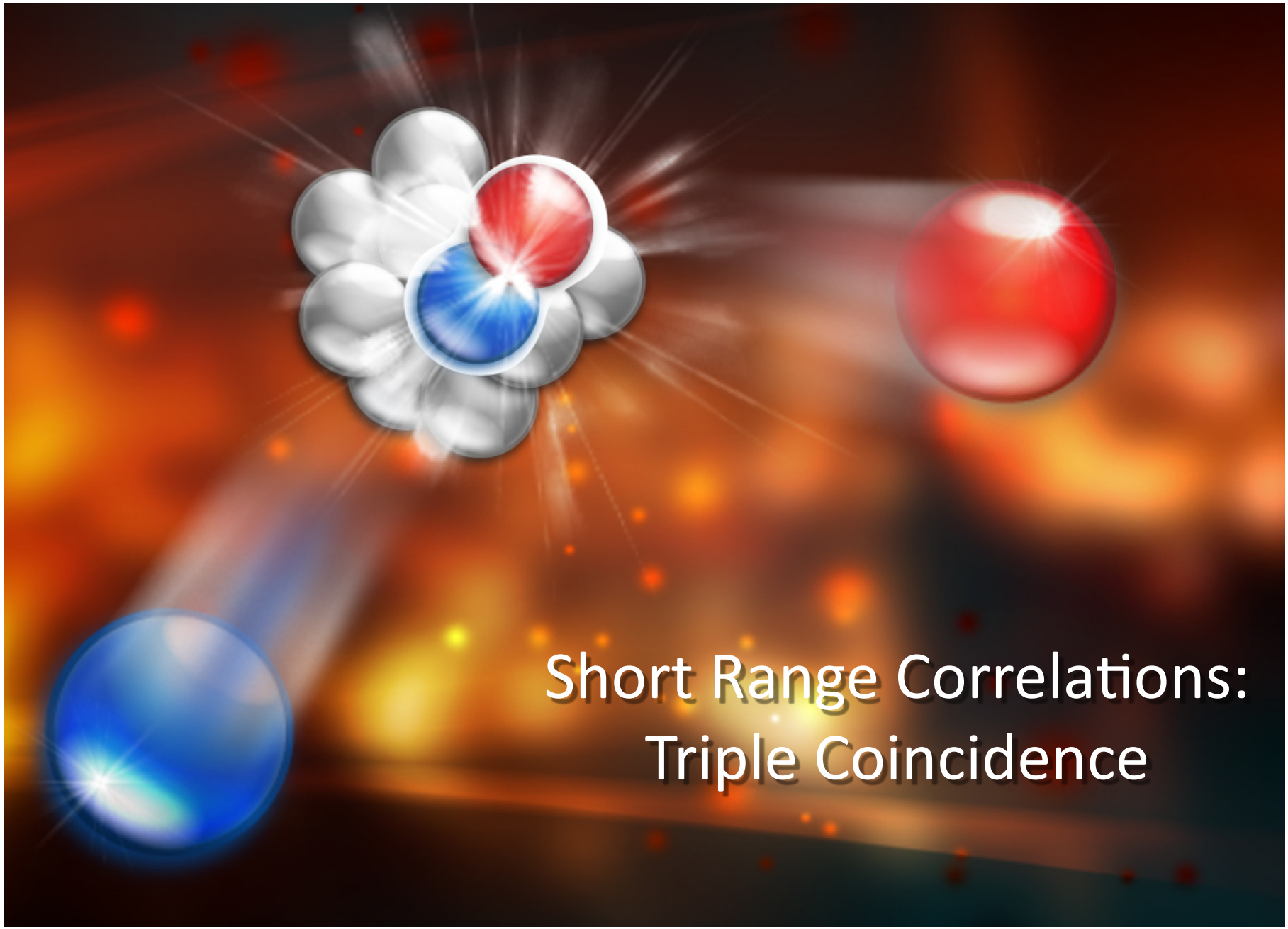


Short Range Correlations: Triple Coincidence

Outline of SRC Talks

- Monday Morning: History & Kinematics
- Monday Afternoon: Jefferson Lab Equipment (Tour after talk!) & Life Of An Experiment
- Tuesday Morning: Recent (e,e') &(e,e'p) Results
- Tuesday Afternoon: Recent (e,e'pN) Results
- Wednesday: Future SRC Experiments

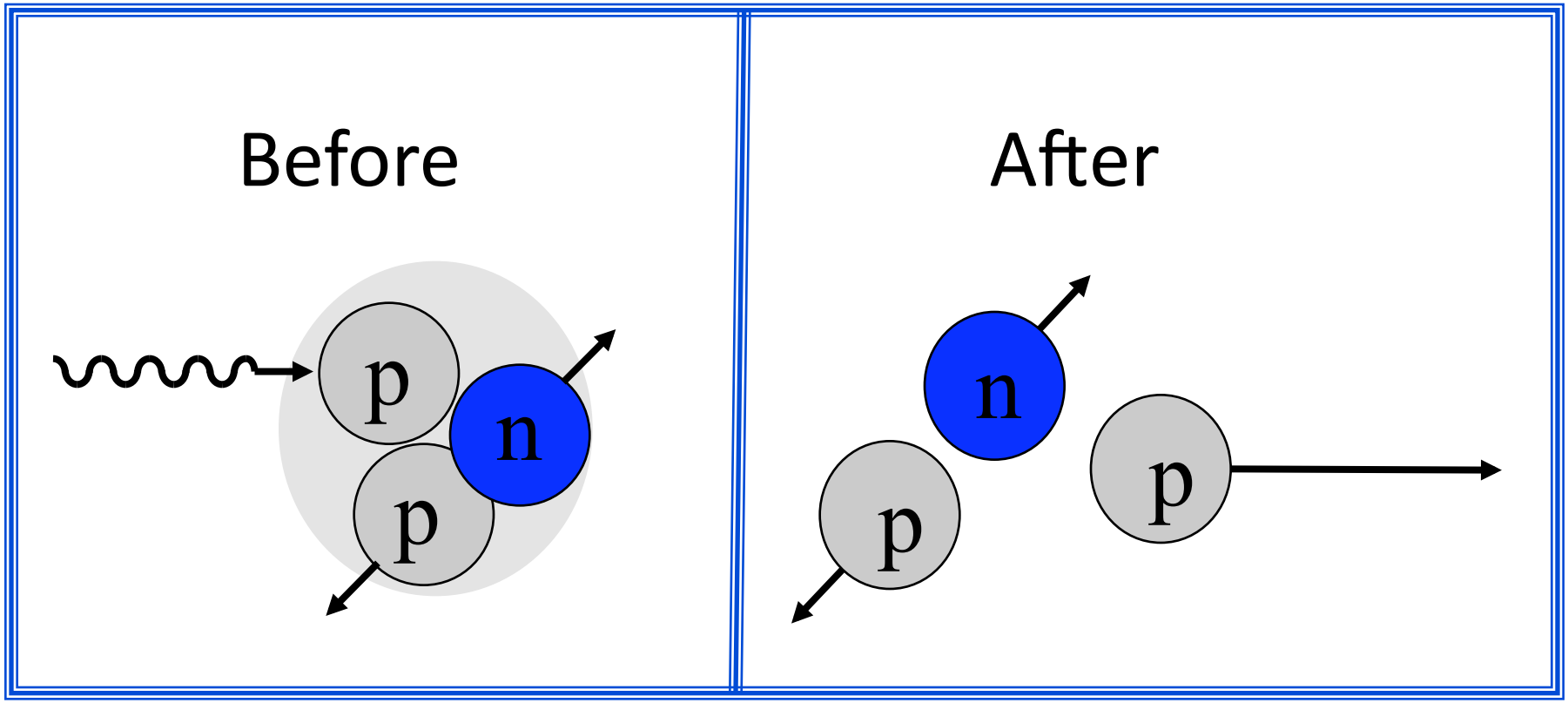
From the (e,e') and (e,e'p), and Results

- 80 +/- 5% single particles moving in an average potential
  - 60 – 70% independent single particle in a shell model potential
  - 10 – 20% shell model long range correlations
- 20 +/- 5% two-nucleon short-range correlations
- Less than 1% multi-nucleon correlations

"A full investigation of two-nucleon correlations would require (e,e'NN) coincidence studies, but these are technically not yet feasible."

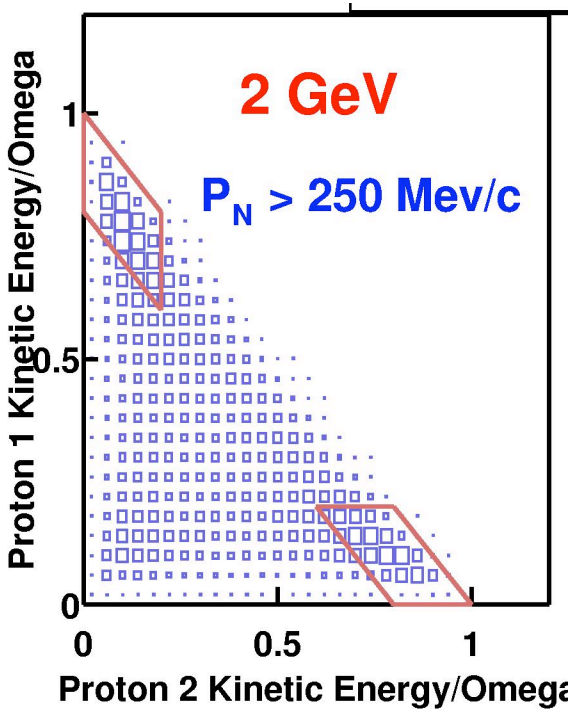
Rolf Ent's Ph.D. Thesis 1989

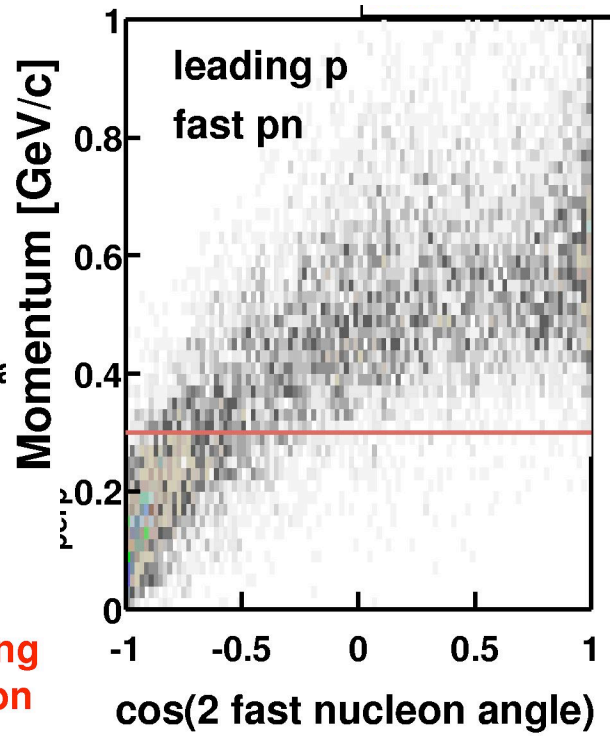
Use CLAS and ^{3}He



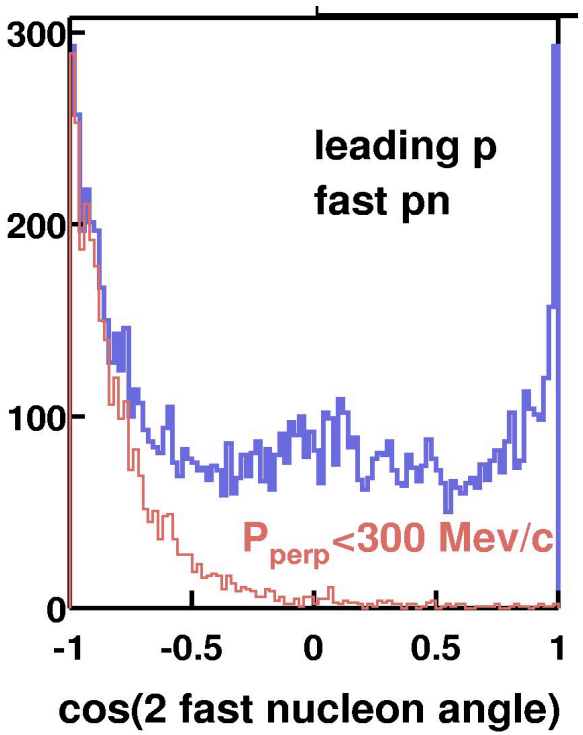
CLAS ^{3}He Data

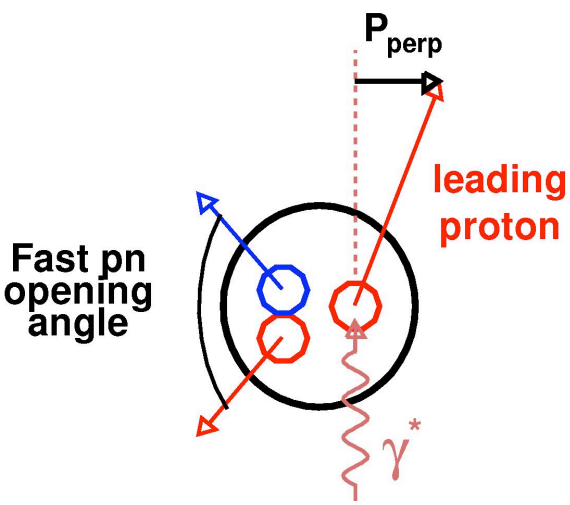
R. Niyazov, Phys. Rev. Lett. **92** (2003) 052303.



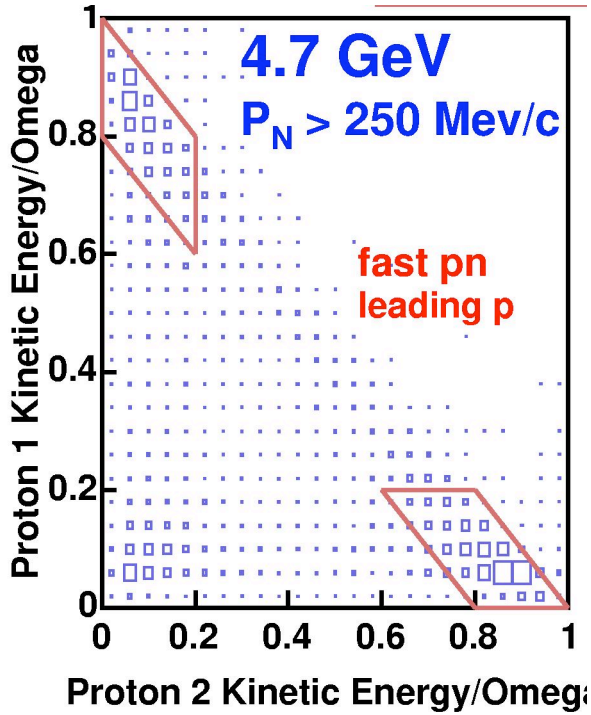


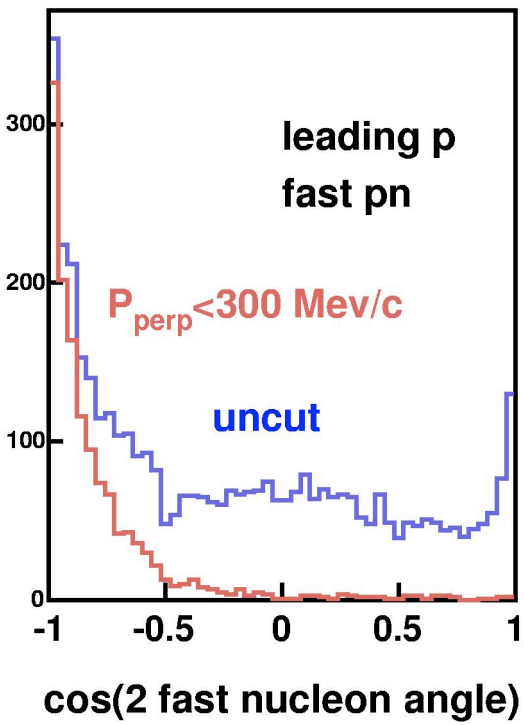
Pair has
back-to-back peak!





Same Experiment, Higher Q^2





Pair has
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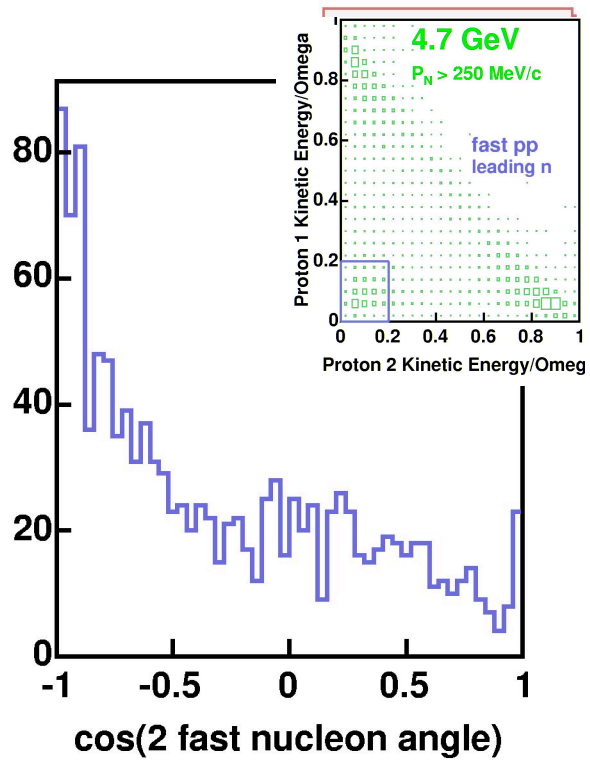
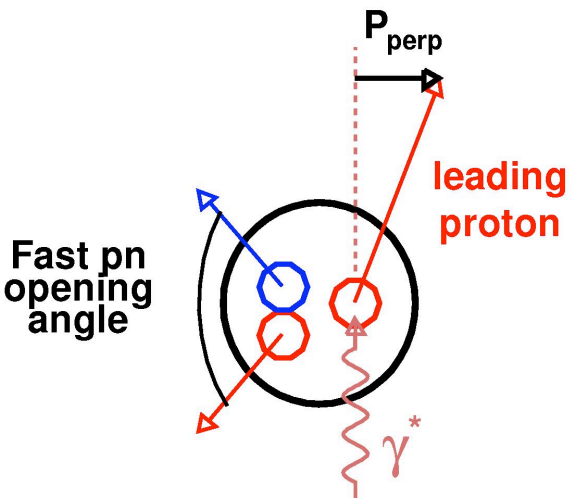
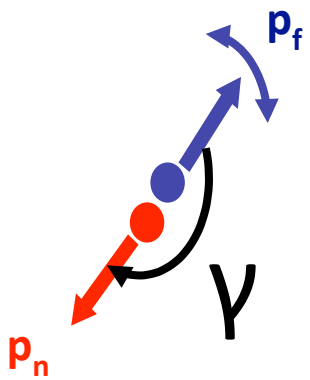


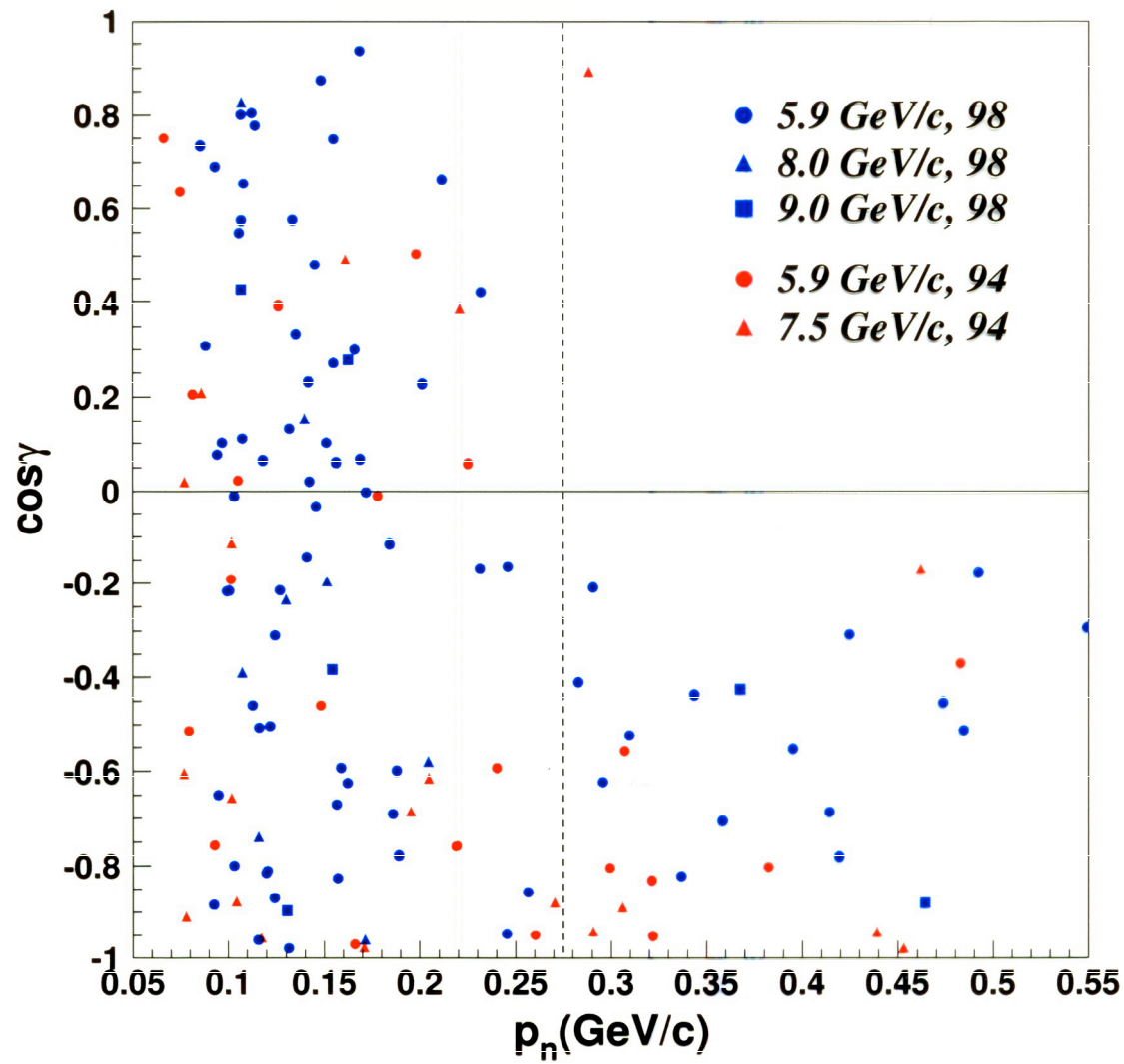


Brookhaven EVA Collaboration Result

A. Tang *et al.*, Phys. Rev. Lett. **90** (2003) 042301.

^{12}C(p,2p+n) Reaction





$p_f = p_1 + p_2 - p_0$

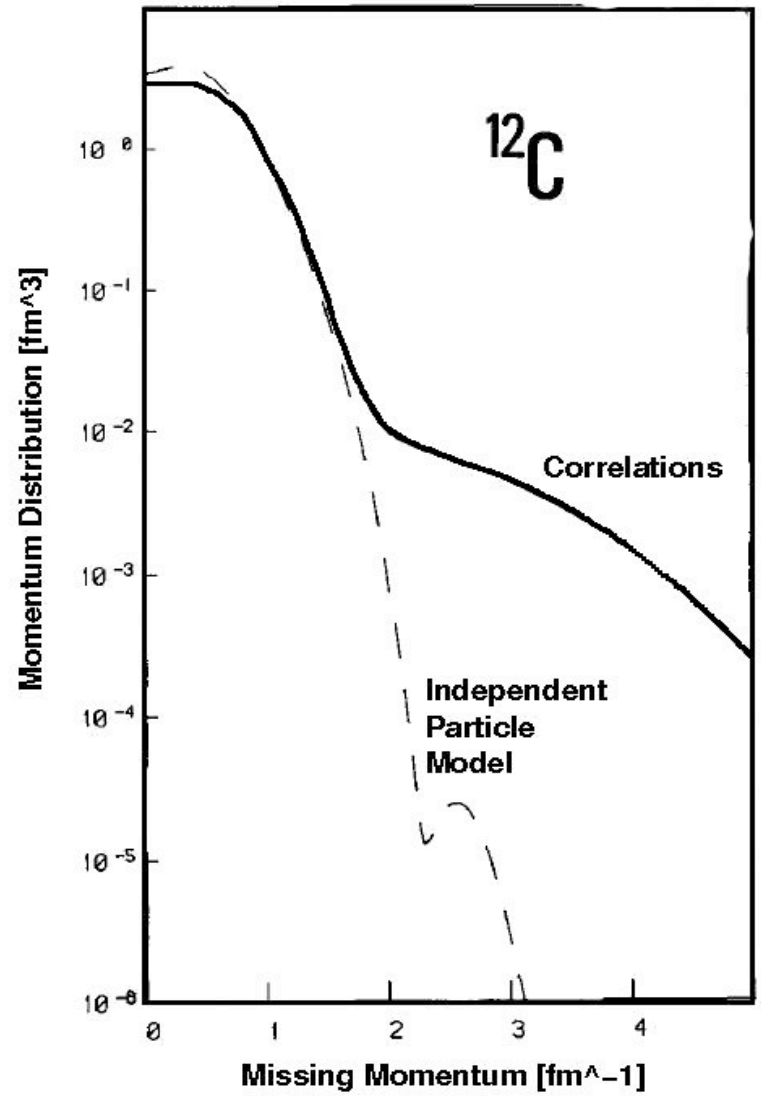
p_0 = incident proton

p1 and p2 are detected

Questions

- What fraction of the momentum distribution is due to 2N-SRC?
- What is the relative momentum between the nucleons in the pair?
- What is the ratio of pp to pn pairs?
- Are these nucleons different from free nucleons (e.g. size)?

Benhar et al., Phys. Lett. **B** 177 (1986) 135.



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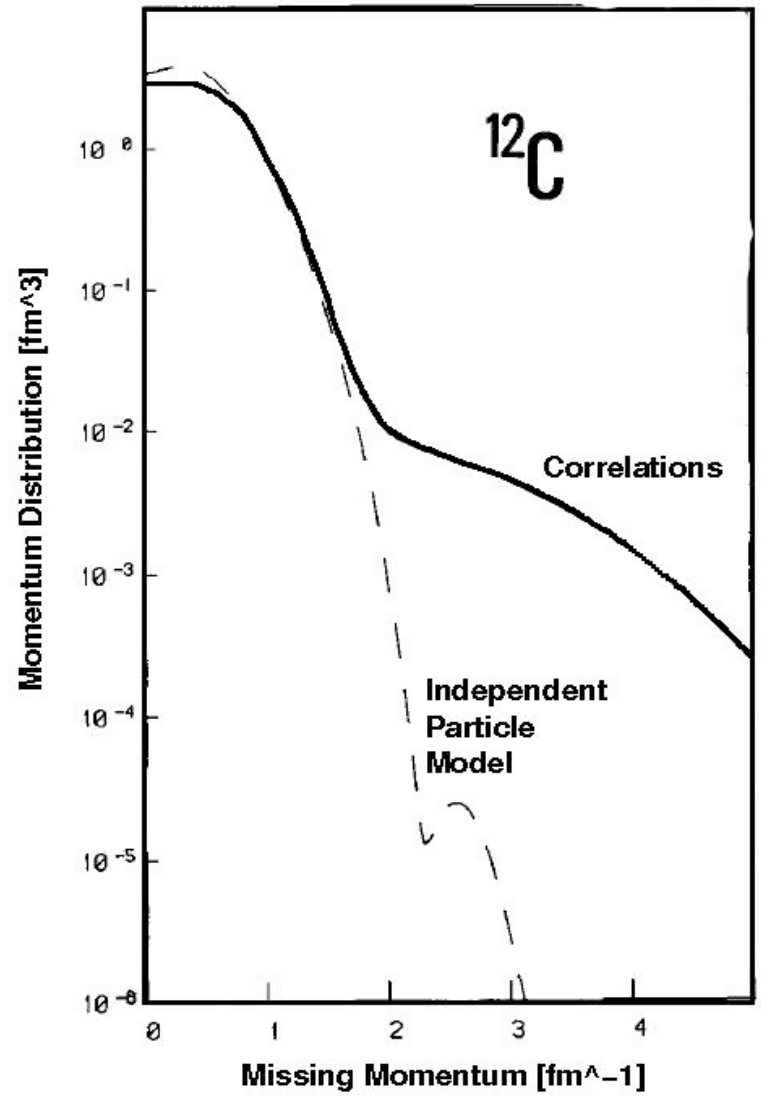
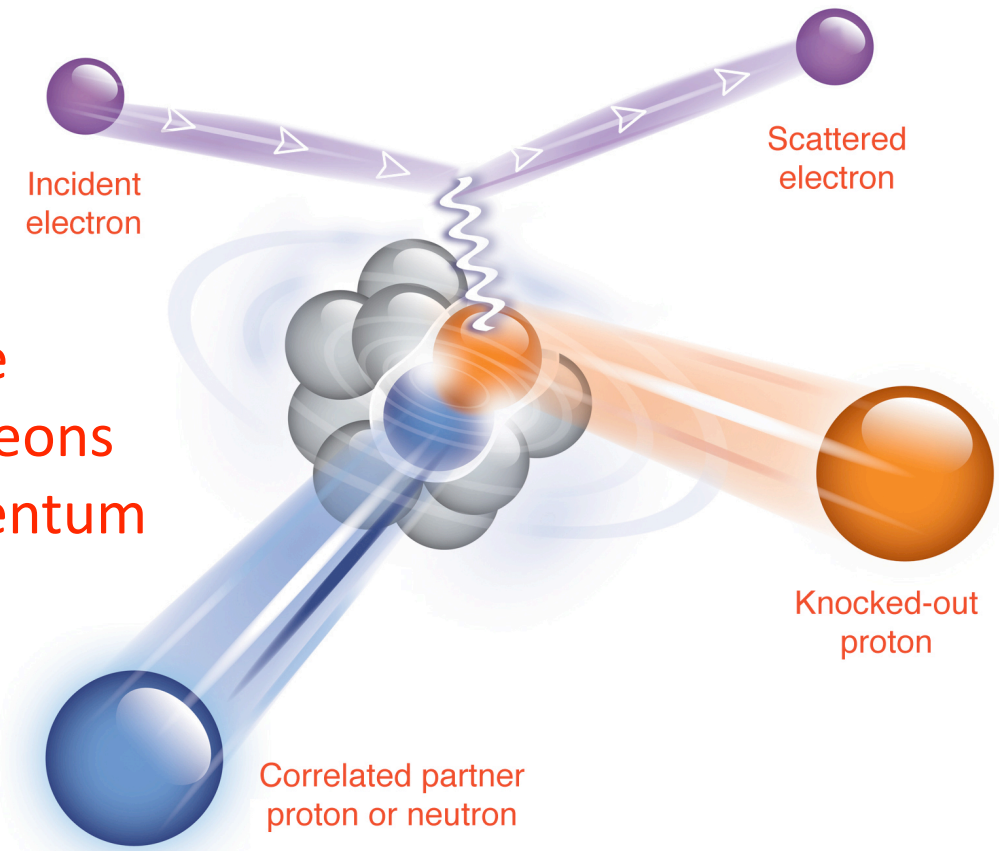


Customized (e,e'pN) Measurement

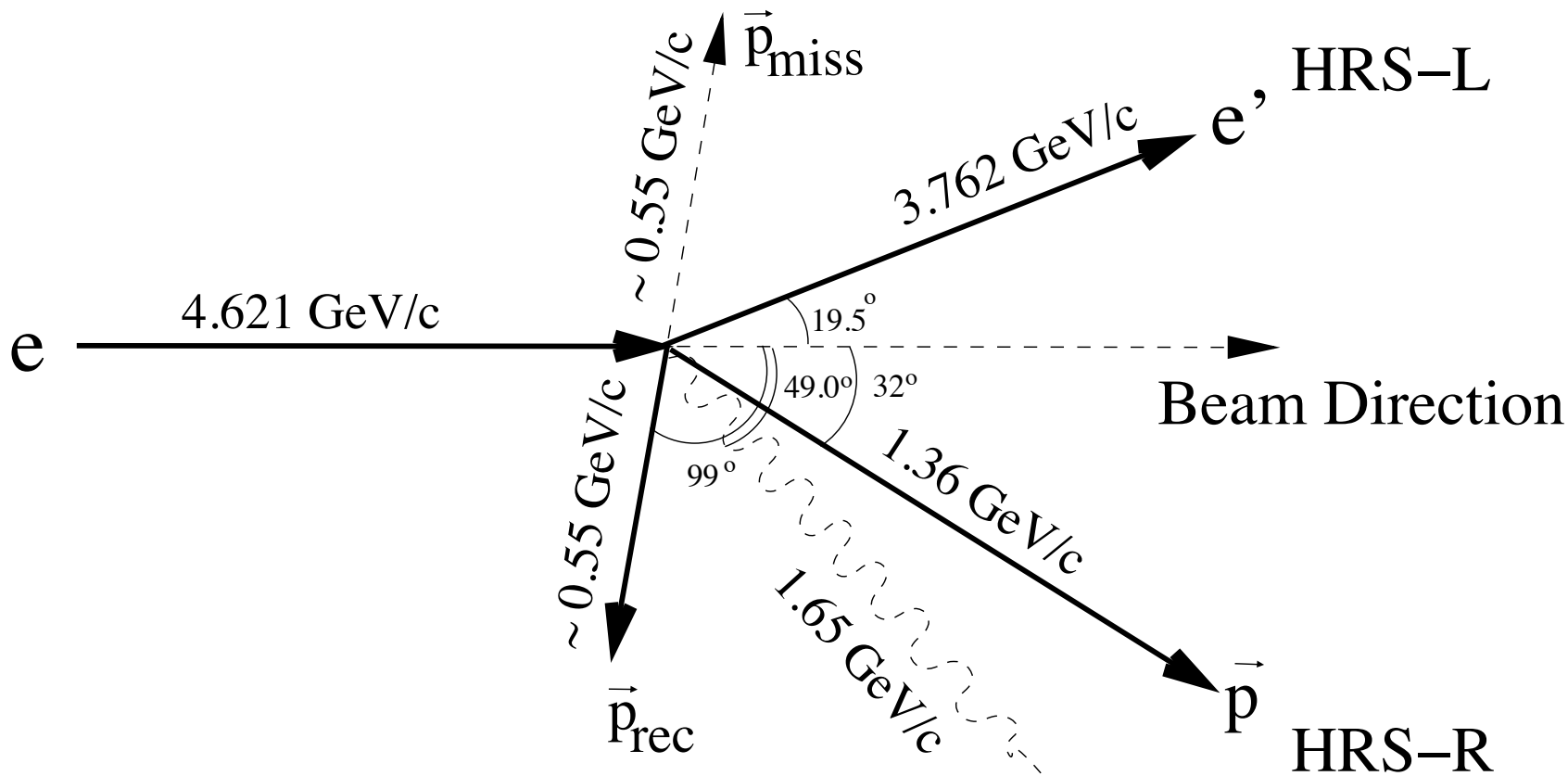
To study nucleon pairs at close proximity and their contributions to the large momentum tail of nucleons in nuclei.

A pair with "large" relative momentum between the nucleons and small center of mass momentum



- high Q2 to minimize MEC
- x>1 to suppress isobar contributions
- anti-parallel kinematics to suppress FSI

Kinematics

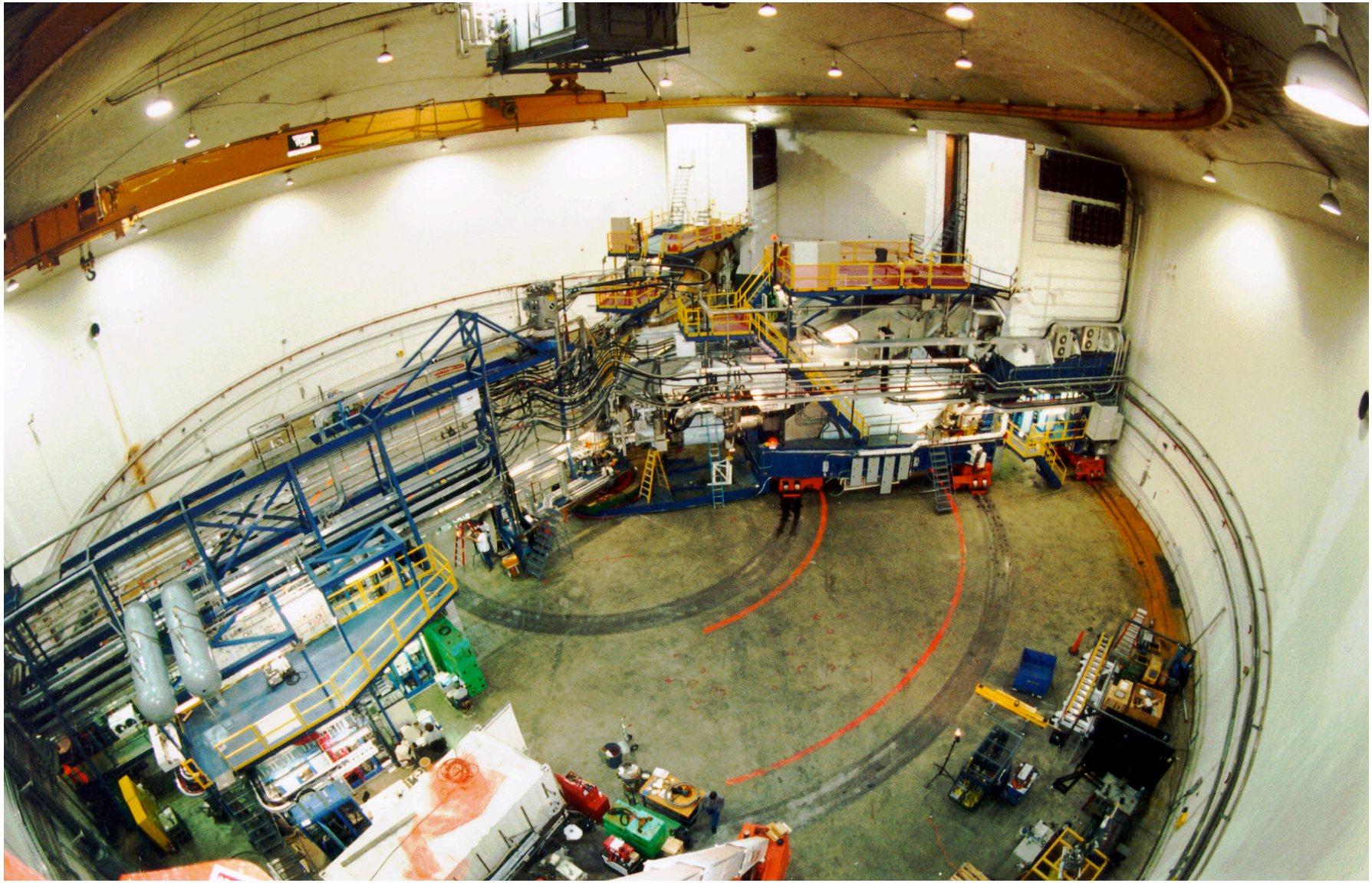


The BigBite Spectrometer

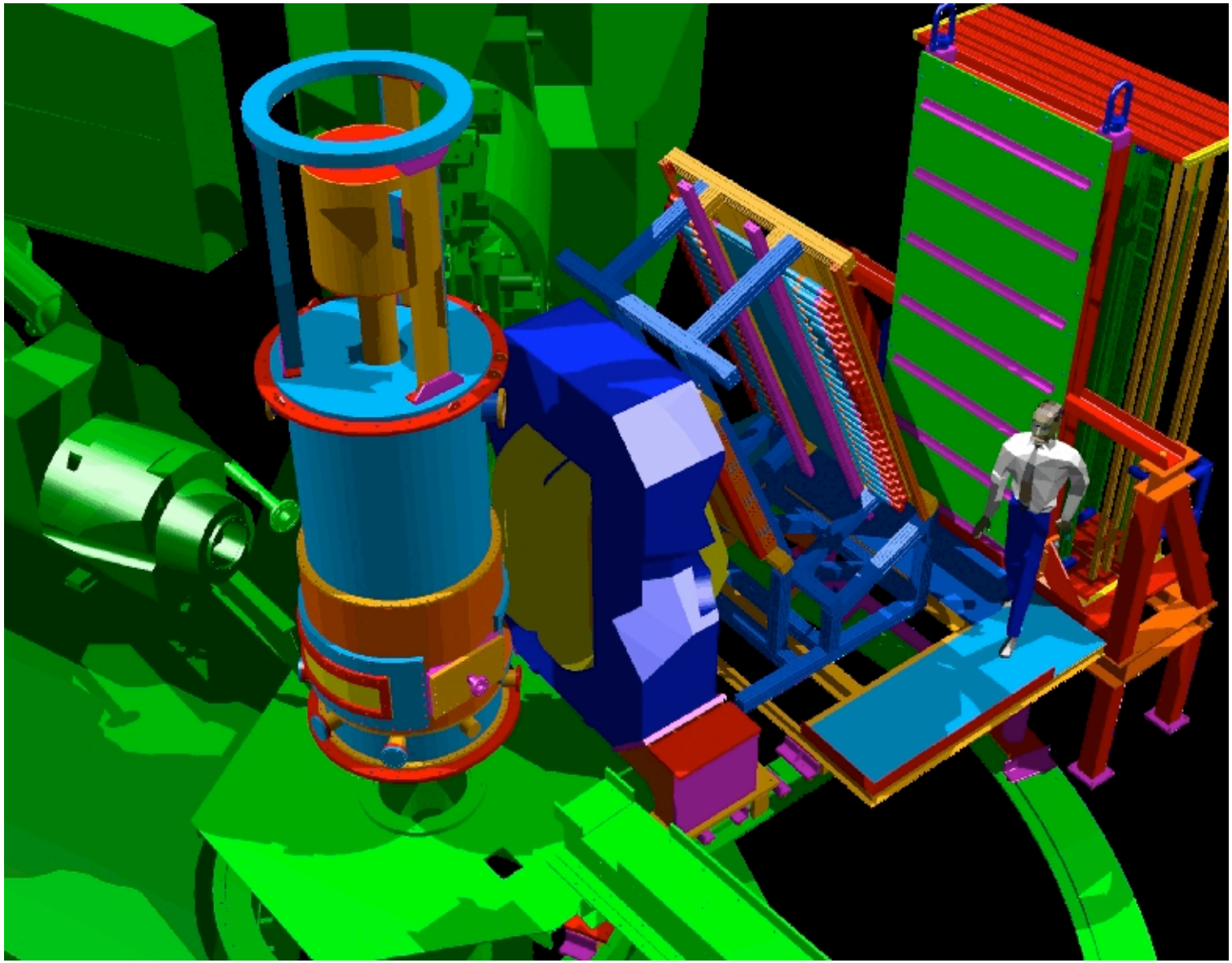
and

Neutron Detector

Jefferson Lab's Hall A



New Equipment

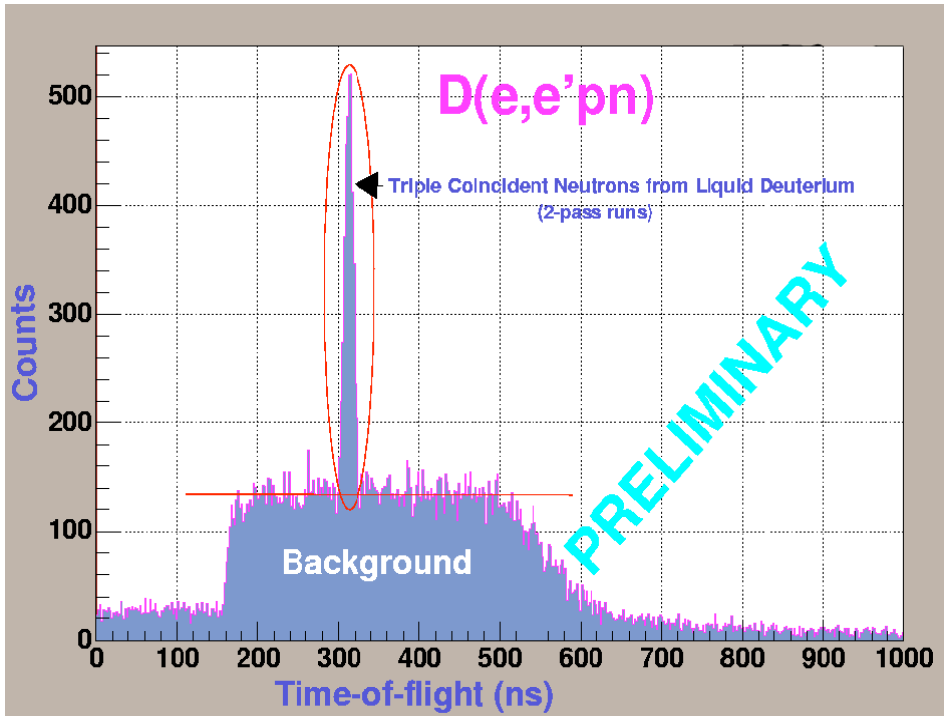


Making BigBite & Neutron Detector

- Jlab from NIKHEF – BigBite Magnet
- Tel Aviv - Auxiliary Plane
- Glasgow - Trigger Plane
- UVa MRI - Scattering Chamber
- Kent State – Most of the Neutron Detectors
- *future Wire Chambers also from UVa MRI*

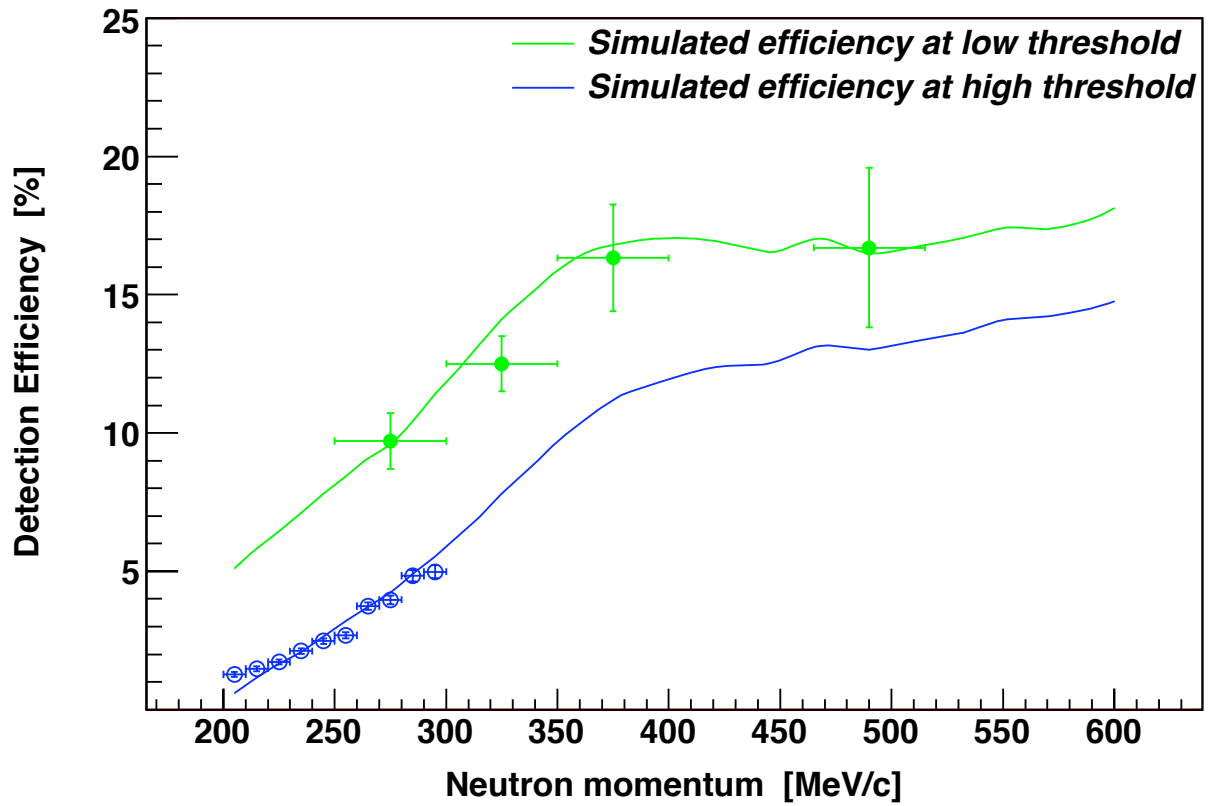
HAND

- Hall A Neutron Detector
- First Neutron Detector in Hall A
- Measuring D(e,e'p) and detecting the neutron, the detector was tested and calibrated.

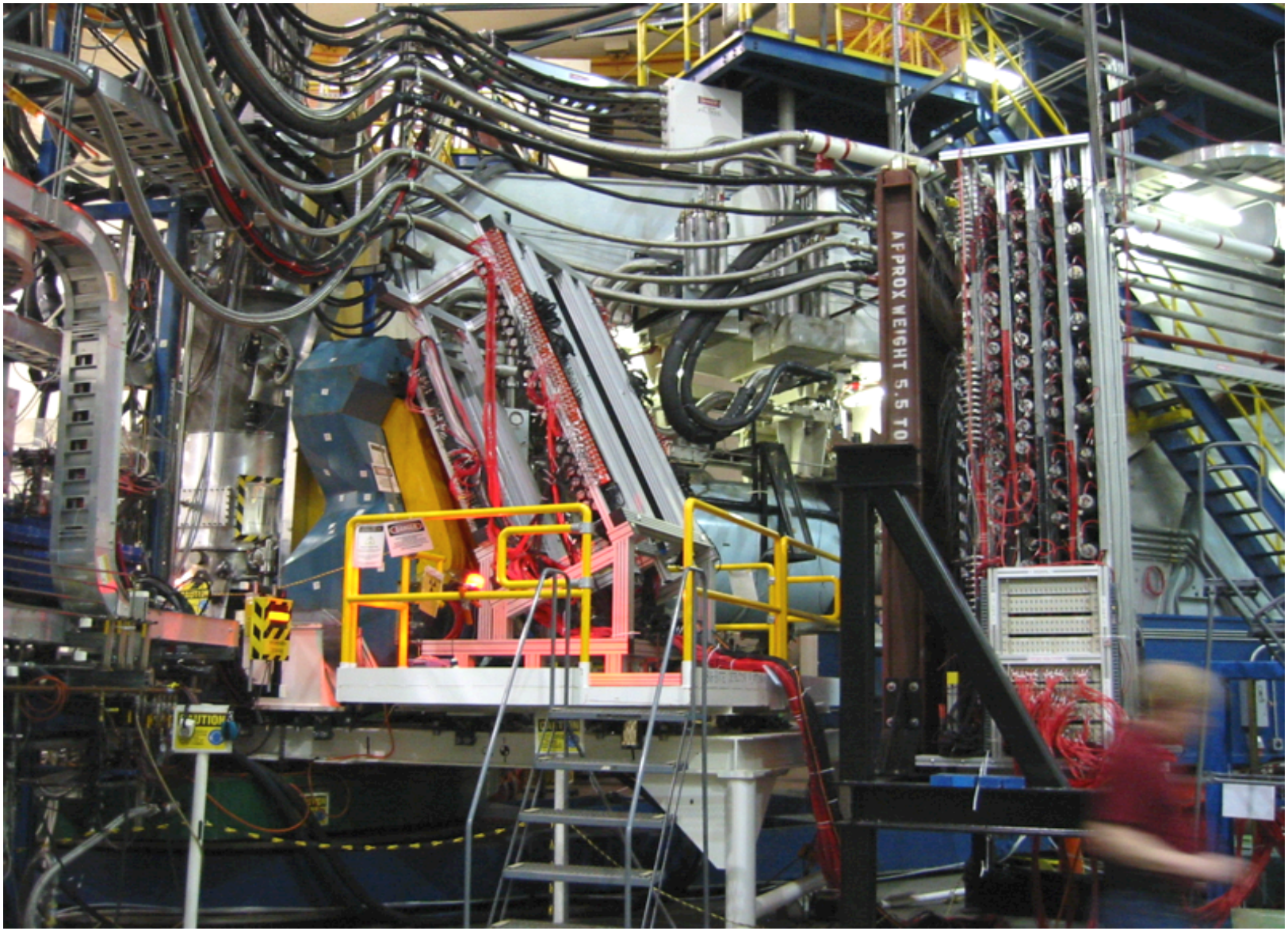


(e,e'n): Absolute Neutron Detector Efficiency

- Used HRS quasi-elastic D(e,e'p)n to tag neutrons
- Tested Result Against Neutron Efficiency Code
  - R. A. Cecil, B. D. Anderson, R. Madey, Nucl. Instrum. Meth. 161 (1979) 430.
  - Blue data using 2.3 GeV beam, Green data with 4.6 GeV beam

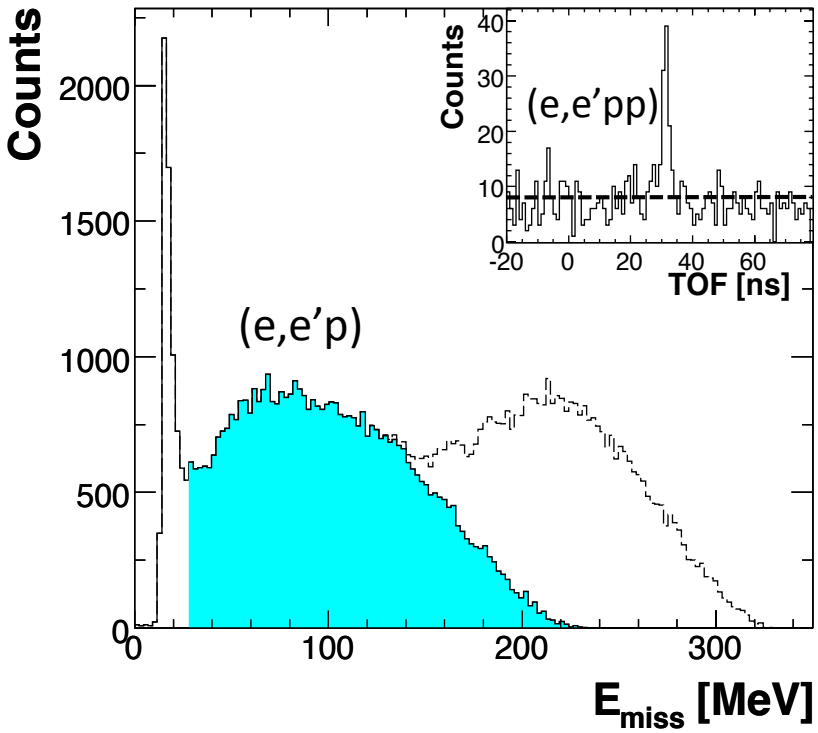


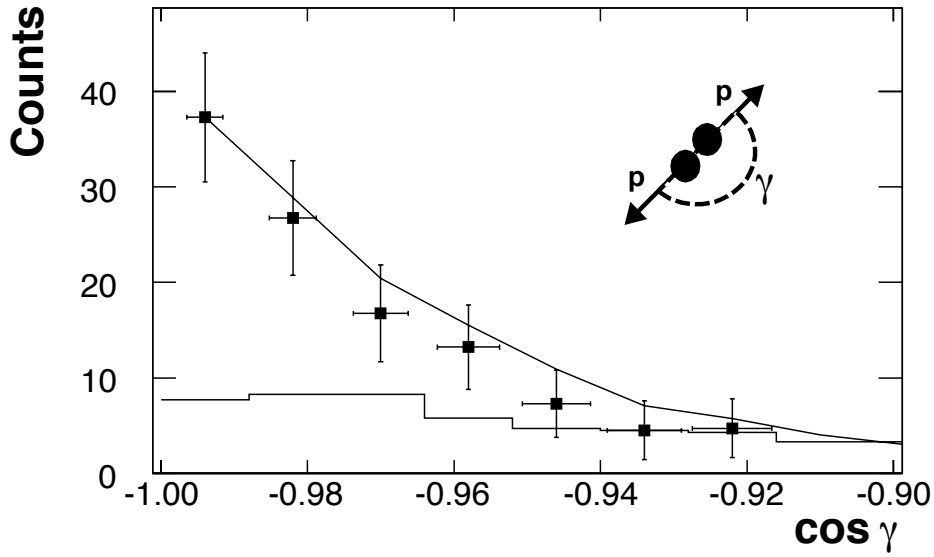
Final Assembly



(e,e'p) & (e,e'pp) Data

R. Shneor *et al*., Phys. Rev. Lett. **99** (2007) 072501.





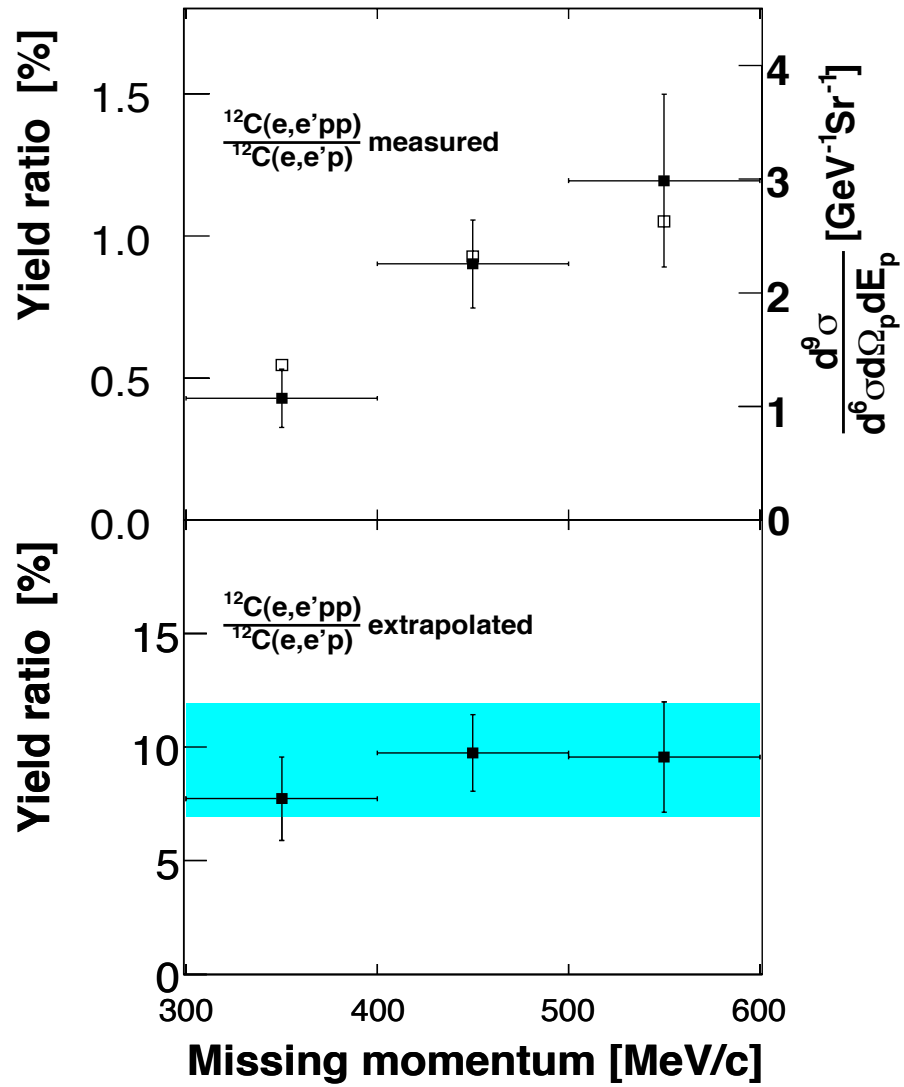
Strong back-to-back correlation!

- $^{12}C(e,e'p)^{11}B$
- Quasi-Elastic Shaded In Blue
- Resonance Even at $x_B>1$

Ratio of $^{12}C(e,e'pp)$ to $^{12}C(e,e'p)$

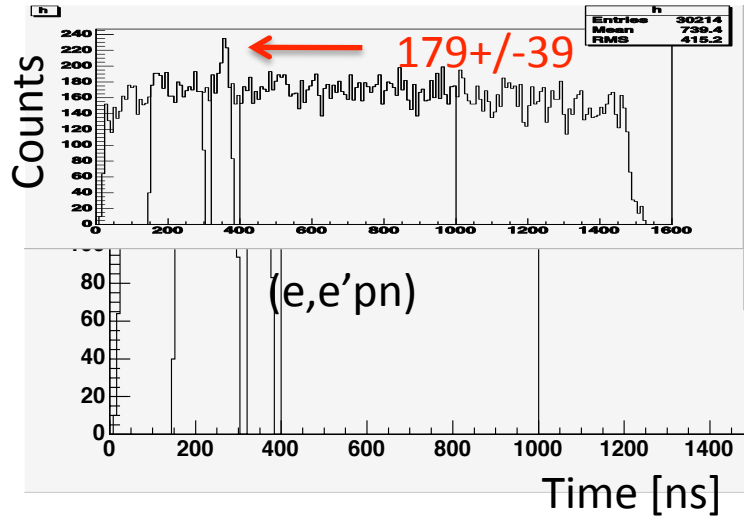
R. Shneor *et al.*, Phys. Rev. Lett. **99** (2007) 072501.

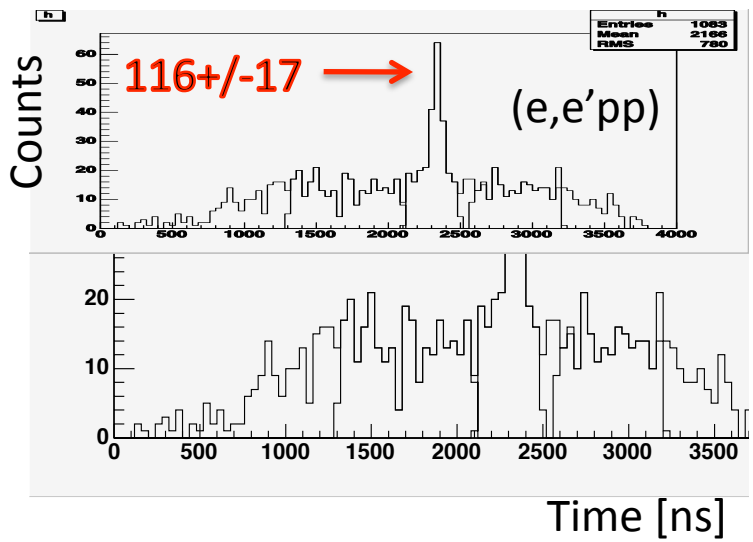
- Top plot shows the raw measured ratio
- Bottom plot shows the extrapolated where the finite acceptance of BigBite and pair center of mass motion has been taken into account.
- Determined pair cm motion to be 136+/-20 MeV/c and blue band indication two-sigma around this value.
- Note Brookhaven found 143+/-17 MeV/c



Ratio of np-SRC/pp-SRC

R. Subedi et al., Science **320**, 1476 (2008); published online 29 May 2008 (10.1126/science.1156675)





Corrected for detection efficiency:

$$\frac{^{12}C(e,e'pn)}{^{12}C(e,e'pp)} = 8.2 \pm 2.2$$

Corrected for SCX (using Glauber):

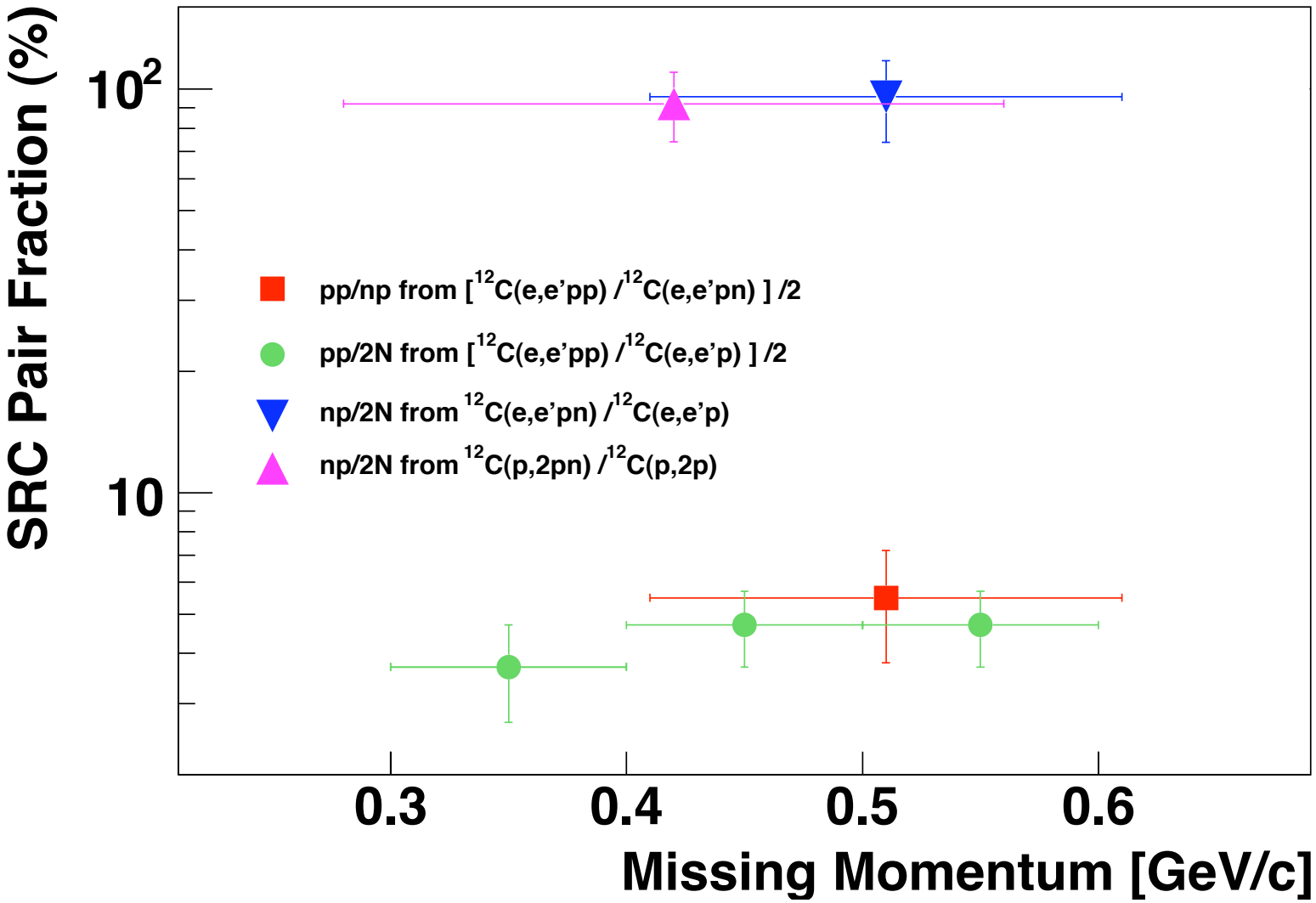
$$\frac{^{12}C(e,e'pn)}{^{12}C(e,e'pp)} = 9.1 \pm 2.5$$

In Carbon:

$$\frac{np-SRC}{pp-SRC} = 18.2 \pm 5$$

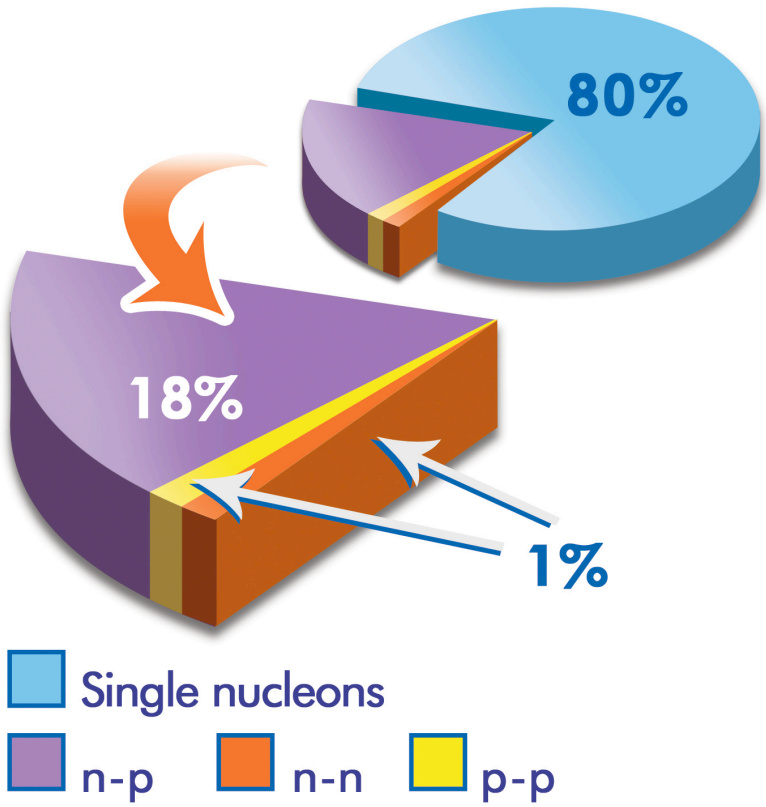
SRC Pair Factions

R. Subedi *et al.*, Science **320**, 1476 (2008), published online 29 May 2008 (0.1126/science.1156675).

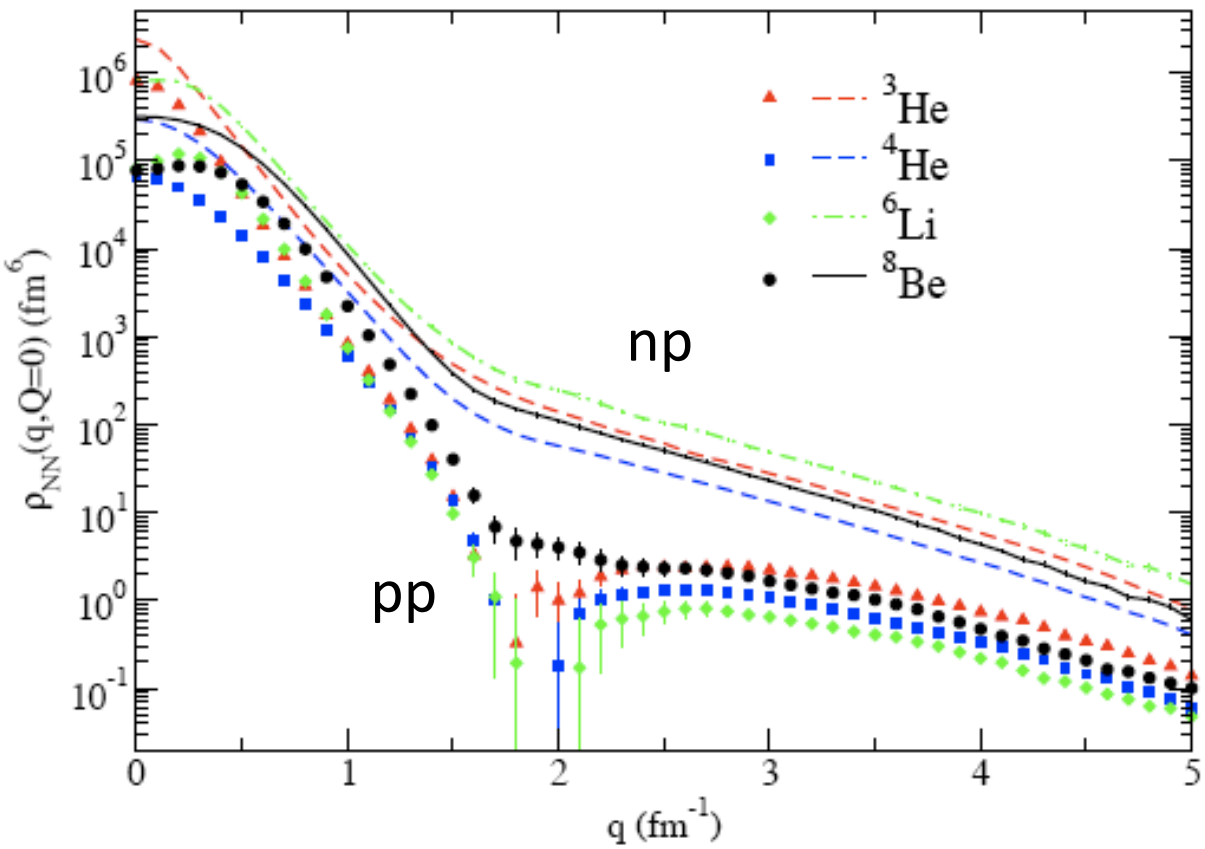


From the (e,e'), (e,e'p), and (e,e'pN) Results

- 80 +/- 5% single particles moving in an average potential
  - 60 – 70% independent single particle in a shell model potential
  - 10 – 20% shell model long range correlations
- 20 +/- 5% two-nucleon short-range correlations
  - 18% np pairs
  - 1% np pairs
  - 1% nn pairs (from isospin symmetry)
- Less than 1% multi-nucleon correlations

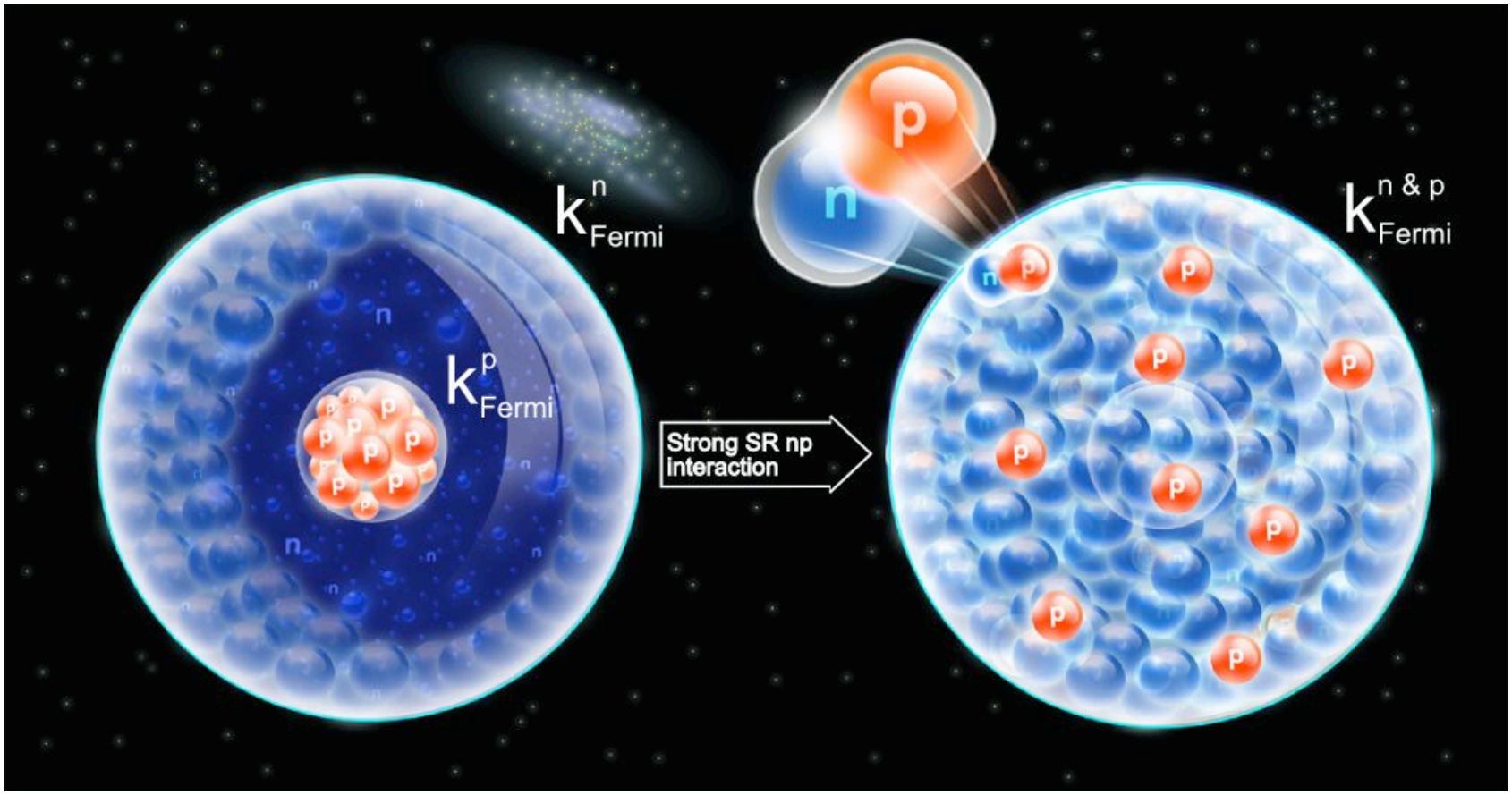


Importance of Tensor Correlations



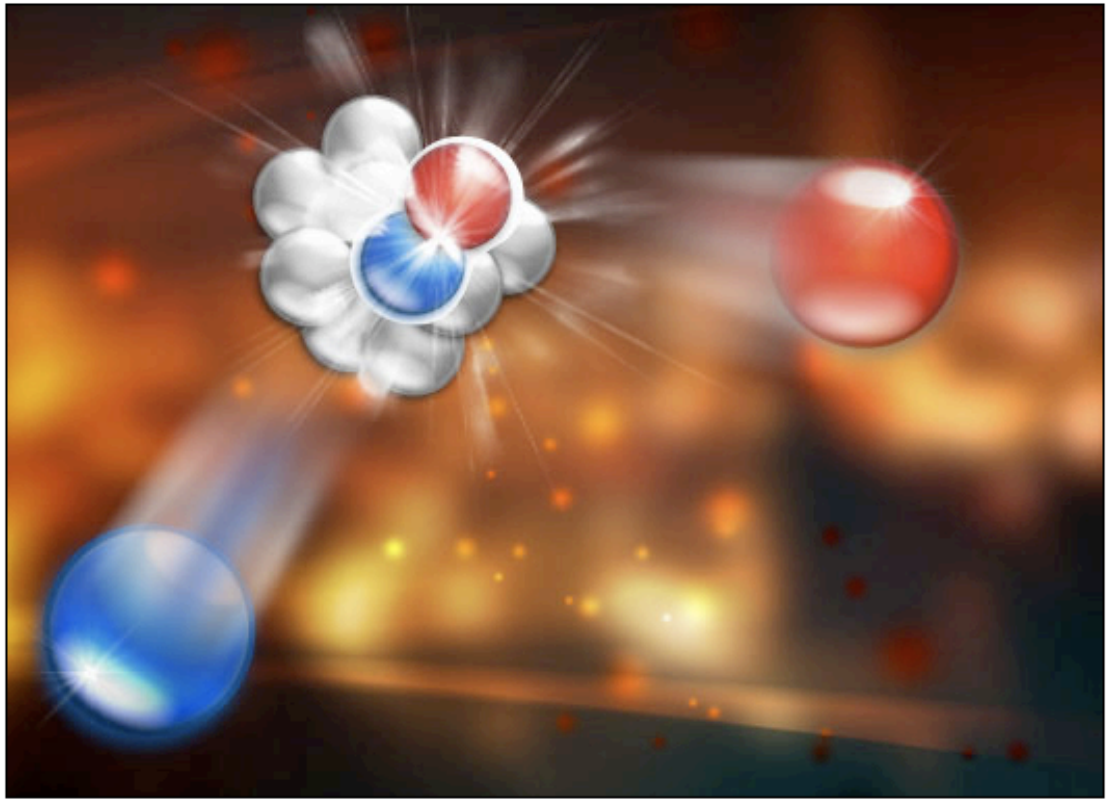
- R. Schiavilla et al., Phys. Rev. Lett. 98 (2007) 132501.
- M. Sargsian et al., Phys. Rev. C (2005) 044615.
- M. Alvioli, C. Ciofi degli Atti, and H. Morita, arXiv:0709.3989.

Implications for Neutron Stars



- At the core of neutron stars, most accepted models assume :~95% neutrons, ~5% protons
- Neglecting the np-SRC interactions, one can assume two separate Fermi gases
- Since np interaction is large compared to nn, n gas heats the p gas
- This could effect the upper limit on mass of neutron and allow the neutrons in the star decay

Public Relations (They are here to help you!)



Nuclear Pairs -Like children playing a game of tag, some protons and neutrons link up briefly inside the nucleus of the atom and then rapidly split apart. These pairings have now been quantified in the first simultaneous measurement of such pairings and their constituents. The result was published in *Science* Express on May 29. Graphic: Joanna Griffin

- Physics Today
  - SRC News Story In July
- CERN Courier
  - SRC News Story in July
  - SRC Feature Article Fall
- Nuclear Physics News
  - I am your correspondent!

YOUR Experiment or Theory should be publicized too!

Work on explaining your work to others and

let public relations know your result is coming!

BigBite Experiments

Completed

- E01-015: SRC (^{12}C)
  - Complete March 2005
  - Phys. Rev. Lett. **99** (2007) 072501
  - Science (10.1126/science.1156675)
- E02-013: Gen at High Q^2
  - Completed May 2006
  - Preliminary Results Available
- E04-007: Threshold pi^0
  - Completed May 2008
- E04-007: Low Q GEp/GMp
  - Completed June 2007

Upcoming

- E06-010: Transversity
  - Scheduled Oct. 2008
- E07-13: Transverse Single Spin
  - Parasitic to Transversity
- E06-014: d2n
  - Early 2009
- E08-005: Transverse QE (e,e'n)
- E05-102: QE ^{3}He(e,e'd)
- E07-006: SRC (^{4}He)
- E12-06-122: A1n

Green = Electron Package Experiment & Blue = Hadron Package Experiment