Precision Measurement of the Isospin Dependence in the 2N and 3N Short Range Correlation Region

* E12-11-112 (x>1 SRC) UPDATE

SHUJIE LI
University of New Hampshire
On behalf of the E12-11-112 Collaboration

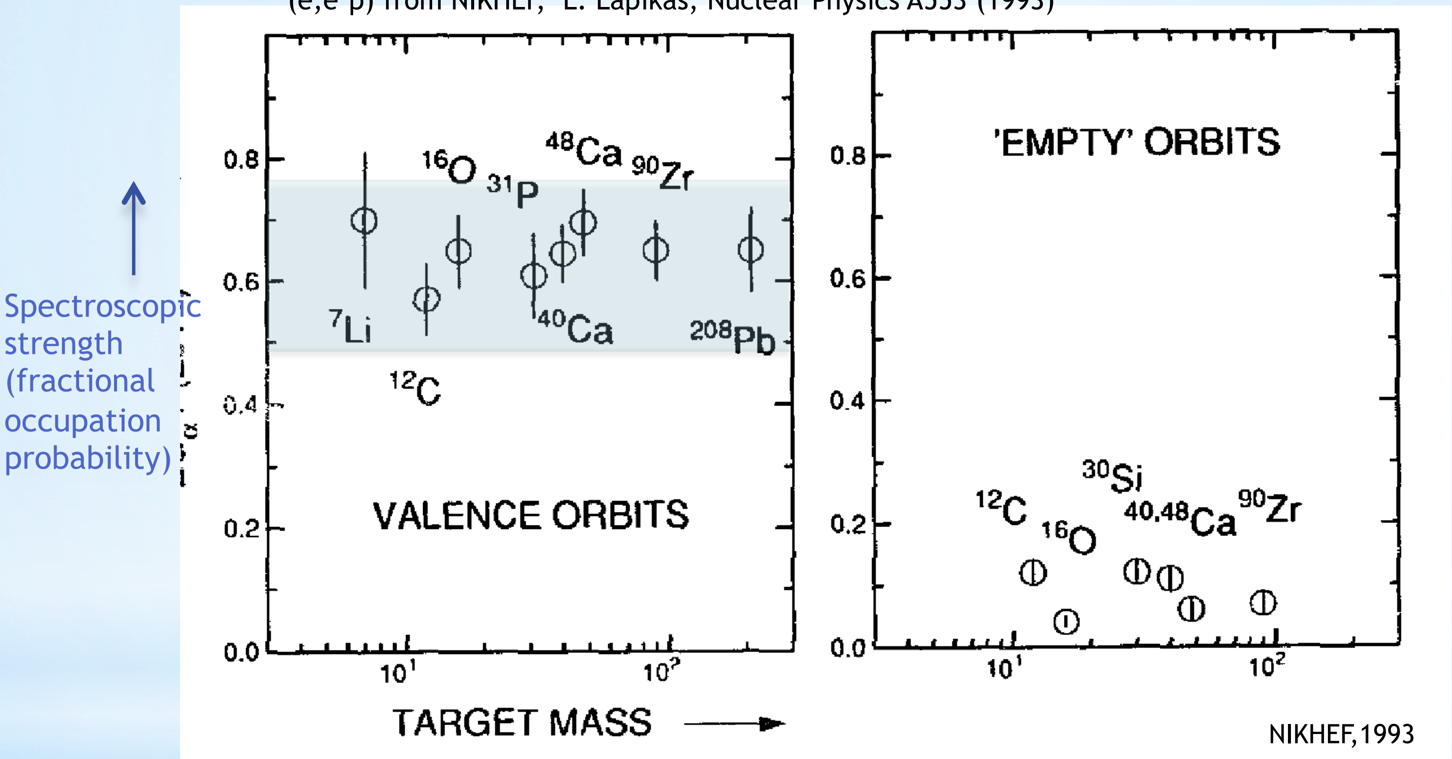
Hall A Collaboration Meeting

01.24.2018

* Short Range Correlation (SRC)

"Missing Strength"

(e,e'p) from NIKHEF, L. Lapikas, Nuclear Physics A553 (1993)



- The closed (valence) orbits are NOT fully occupied, ~30% of strength is missing.
- Nucleons can live in orbits above Fermi level ($k > k_F$)

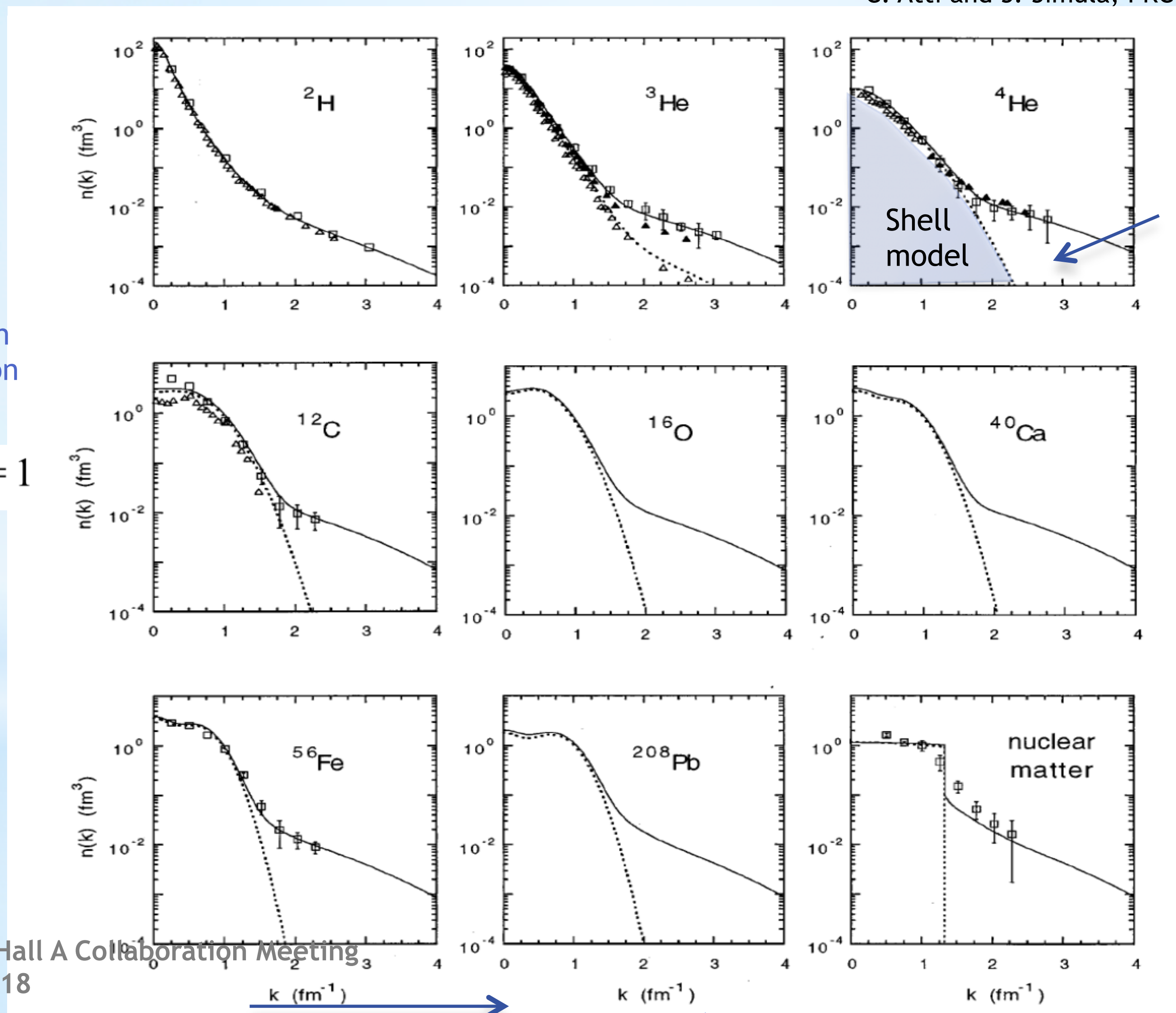
* Short Range Correlation (SRC)

"High Momentum Tail"

C. Atti and S. Simula, PRC 53. 1689 (1996)

Momentum Distribution function

$$\int_0^\infty dk\ k^2 n(k) = 1$$



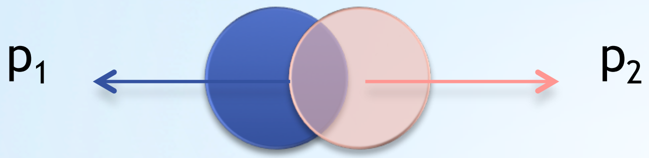
"The main effects of NN correlations is to generate high momentum and high removal energy components"

Momentum k

1 fm^{-1} ~ 200 MeV/c

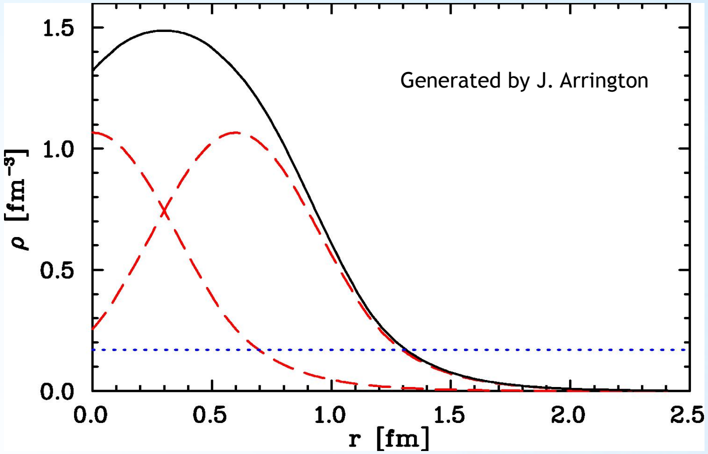
Short Range Correlation (SRC)

"SRC pair"



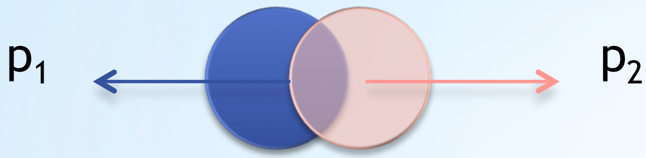
$p_1+p_2 \rightarrow 0$

Large back-to-back momentum ($>k_F$)



Short Range Correlation (SRC)

“SRC pair”



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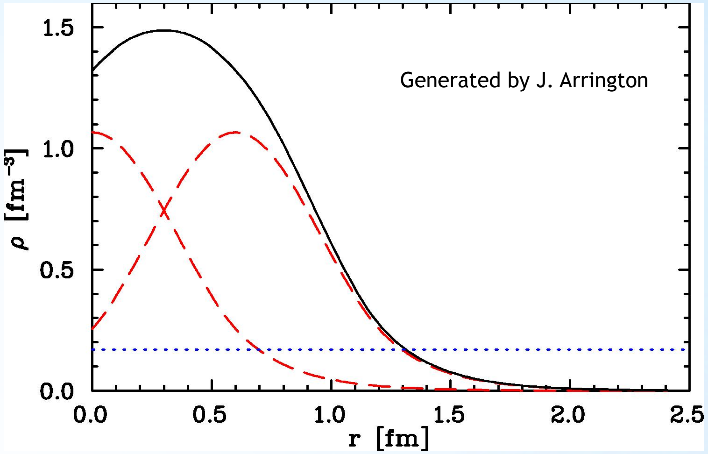
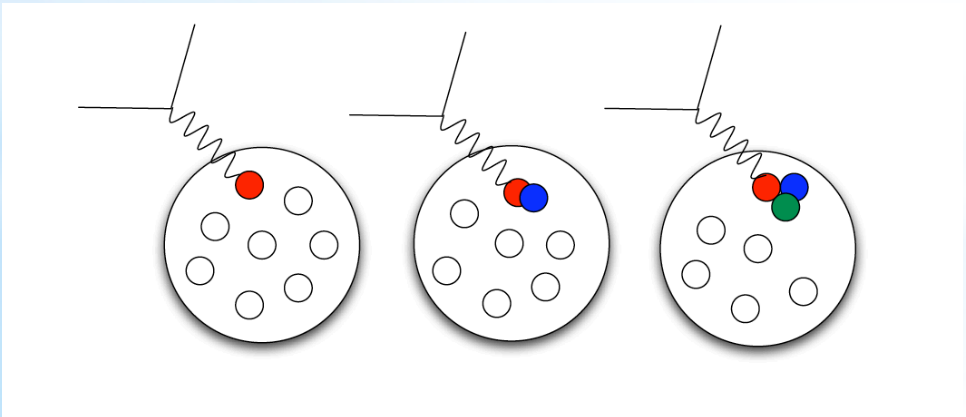
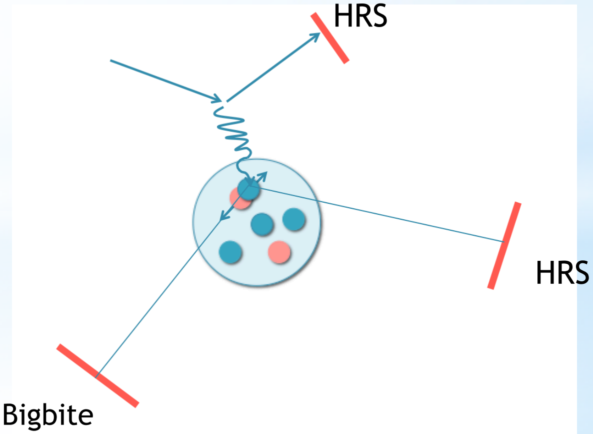




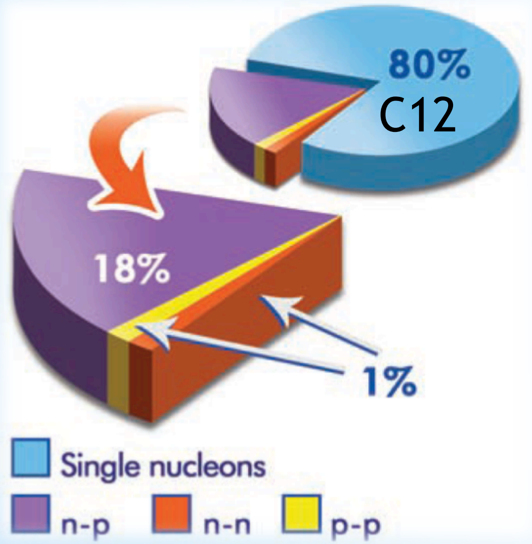
JLAB E01-015



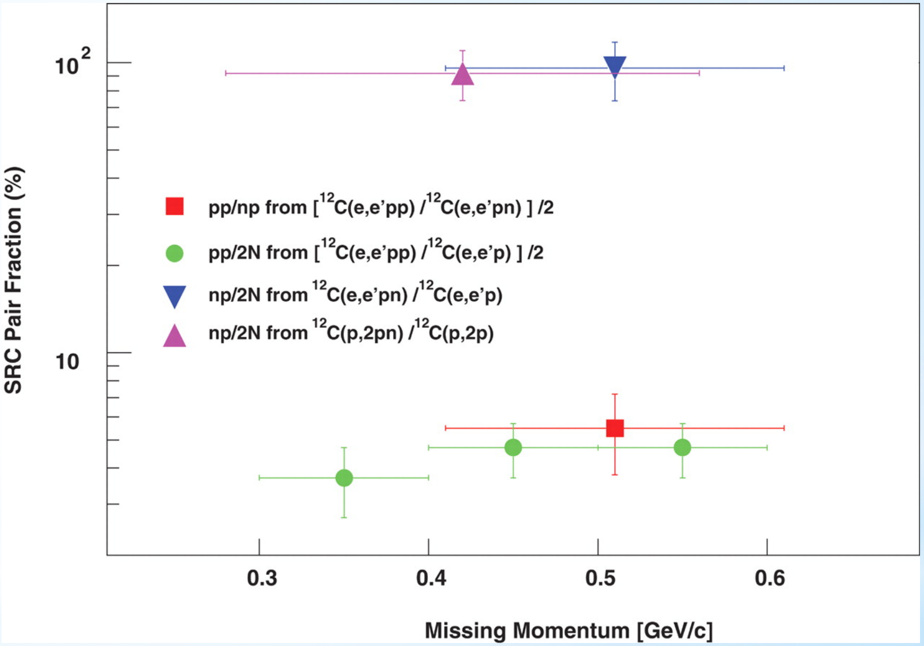
* Short Range Correlation (SRC)

"n-p pair dominance"

Subedi et al, Science 320, 1476 (2008)



Subedi et al, Science 320, 1476 (2008)



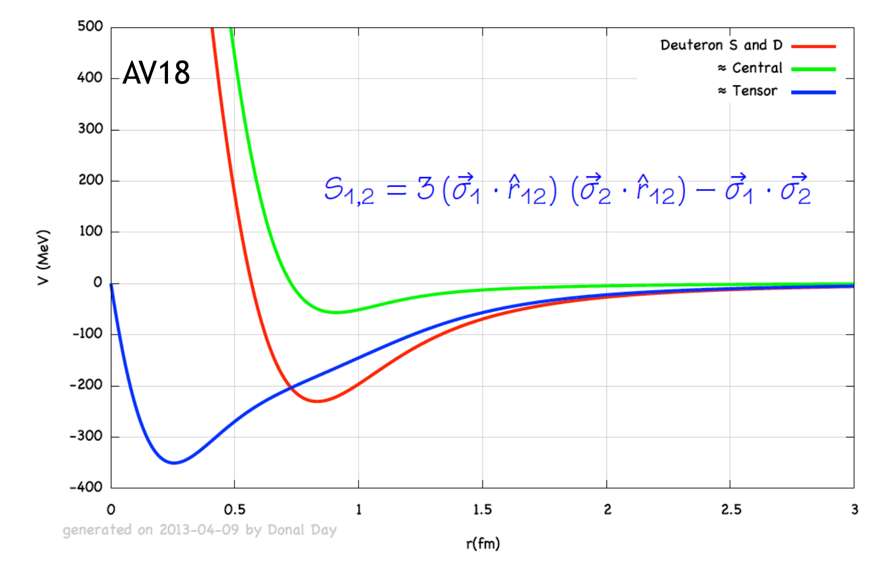
* Short Range Correlation (SRC)

"Isospin Dependence"

NN potential = Repulsive core + tensor part

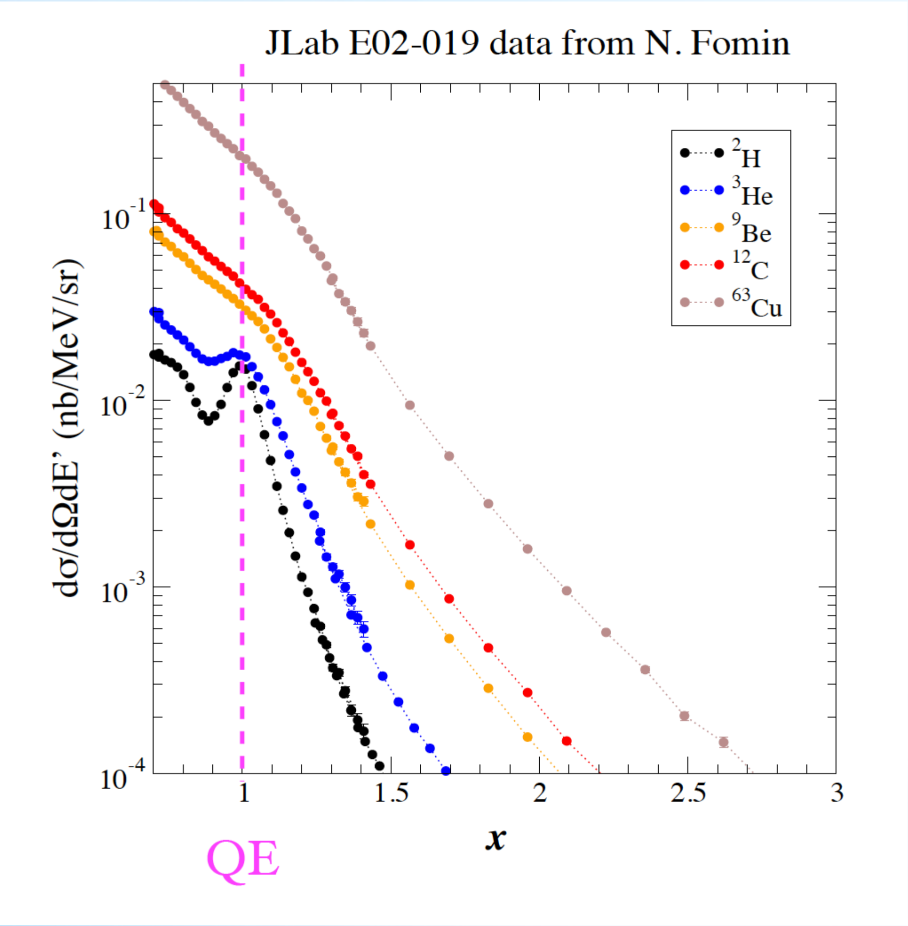
Tensor operator $S_{12} = 2[3\frac{(\vec{S}\cdot\vec{r})^2}{r^2} - \vec{S}^2]$

- T = 1, S = 0 :np, pp, nn pairs. S_{12} = 0, no attractive tensor force
- T = 0, S = 1: Deuteron-like np pair.



* Short Range Correlation (SRC)

"(e,e') at x>1"



* Easy:

Single arm (e,e') measurement.

* Clean:

Detect high momentum nucleons at high x high Q2 with high rates, small final state interaction and meson exchange current.

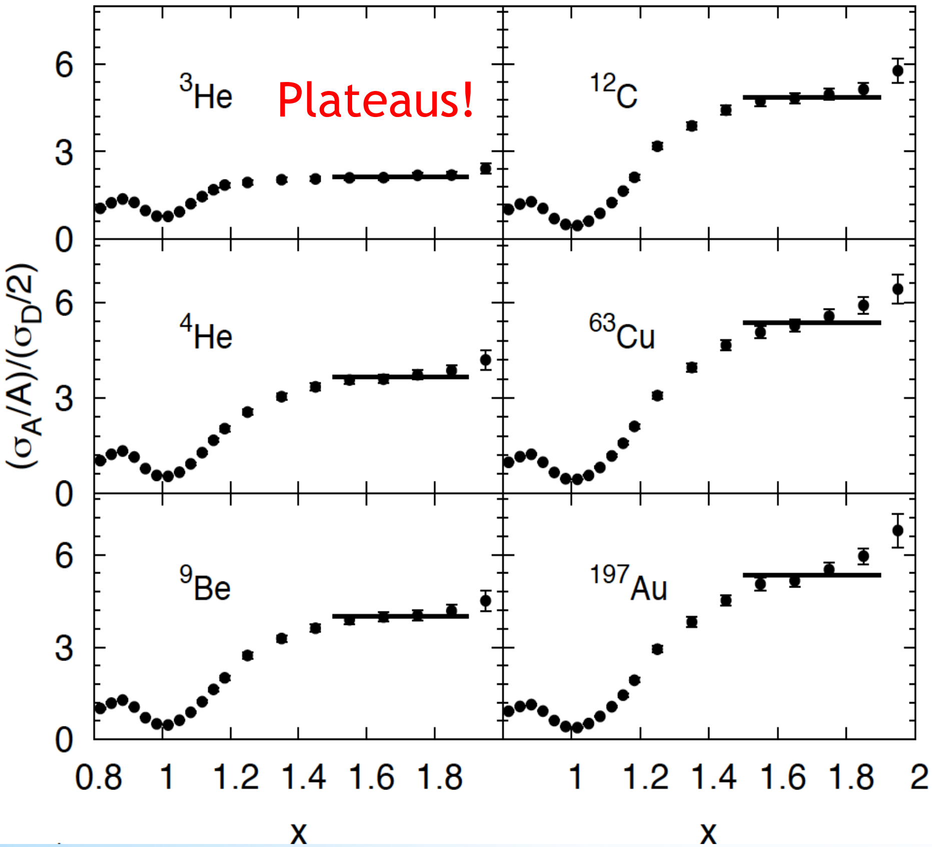
* Precise:

Take ratio of cross sections to cancel systematic uncertainties

* Short Range Correlation (SRC)

"(e,e') at x>1":
Plateau = probability to find Deuteron like SRC pairs in a nucleus

N. Fomin et al., Phys. Rev. Lett. **108** (2012) 092502.



- * Easy:

  Single arm (e,e') measurement.

- * Clean:

  Detect high momentum nucleons at high x high Q2 with high rates, small final state interaction and meson exchange current.

- * Precise:

  Take ratio of cross sections to cancel systematic uncertainties

E12-11-112 x>1 SRC

"Tritium !"
"We take ratios!"

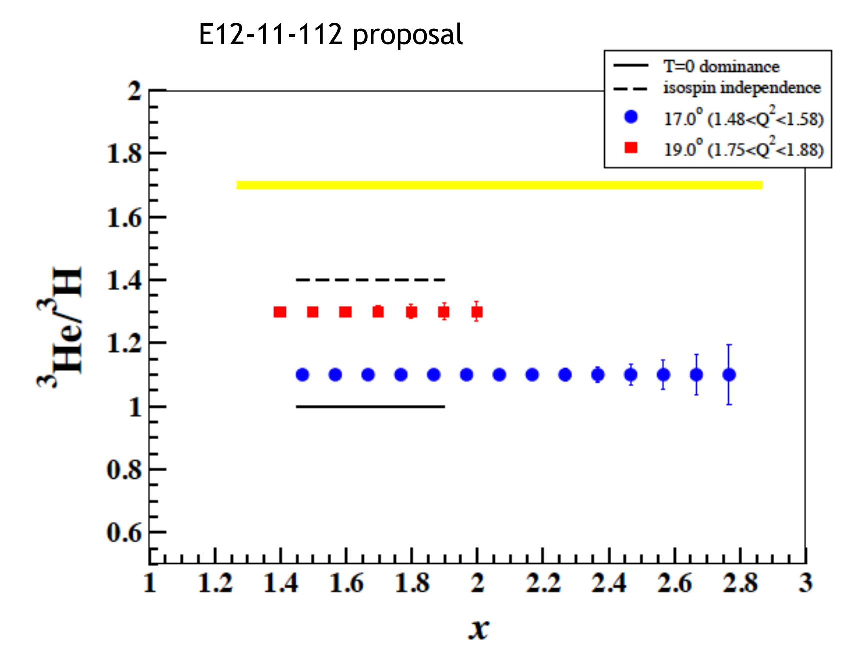
- Goal 1: Check the isospin dependence in 2N SRC at 1<x<2

- np pair dominance:

$$\frac{\sigma_{^3He}}{\sigma_{^3H}} = \frac{\sigma_{np} + \sigma_p}{\sigma_{np} + \sigma_n} \approx \frac{\sigma_{np}}{\sigma_{np}} = 1$$

- No isospin preference

$$\frac{\sigma_{^3He}}{\sigma_{^3H}} = \frac{\sigma_n + 2\sigma_p}{2\sigma_n + \sigma_p} \xrightarrow{\sigma_p \approx 3\sigma_n} 1.4$$

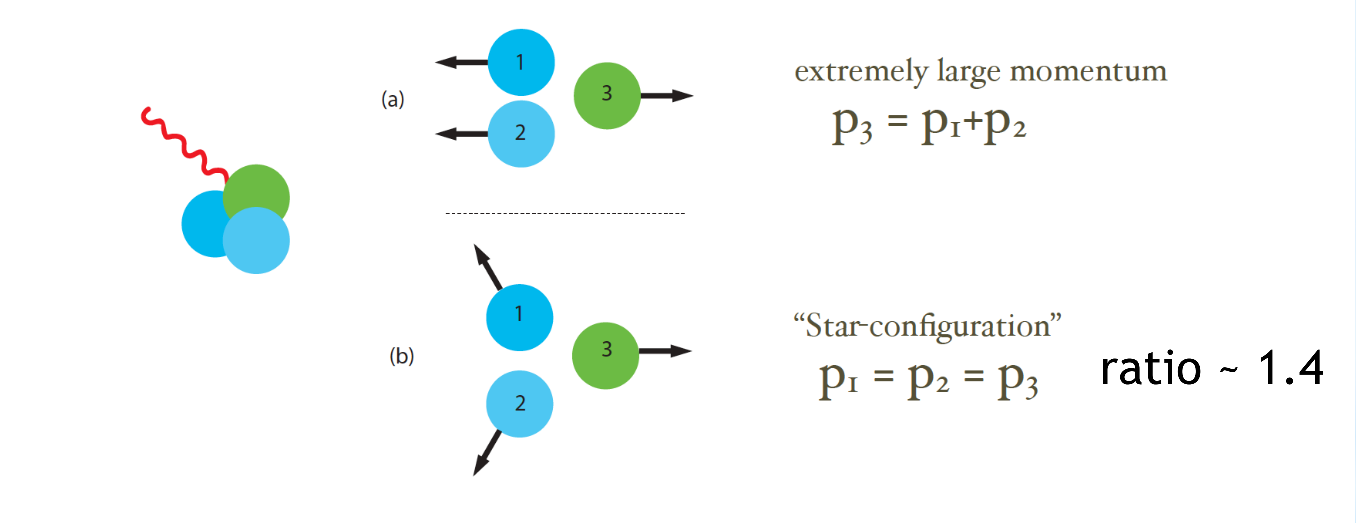


Uncertainty: 1.5% on 3He/3H cross section ratios -> 3.8% on T=1/T=0

E12-11-112 x>1 SRC

"Tritium !"
"We take ratios!"

- **Goal 2** Probing the possible 3N SRC at 2<x<3
- Isospin structure and momentum sharing scheme(does not rely on cleanly isolating 3N-SRCs)



Isospin independent:

$$\frac{\sigma_{^3He}}{\sigma_{^3H}} = \frac{\sigma_n + 2\sigma_p}{2\sigma_n + \sigma_p} \xrightarrow{\sigma_p \approx 3\sigma_n} 1.4$$

* Precision measurement of the isospin dependence in the 2N and 3N short range correlation region

Spokespersons:

John Arrington (ANL) Donal Day (UVa) Douglas Higinbotham (Jlab)
Patricia Solvignon (UNH) Zhihong Ye (ANL)

PAC38 (2011): A-
Approved for 19 PAC days
HIGH IMPACT

Tritium Experiment Group:

E12-11-103 MARATHON
E12-11-112 x>1 (inclusive SRC)
E12-14-009 Elastic –not scheduled
E12-14-011 e'p (exclusive SRC)
E12-17-003 e'K


Precision measurement of the isospin dependence in the 2N and 3N short range correlation region

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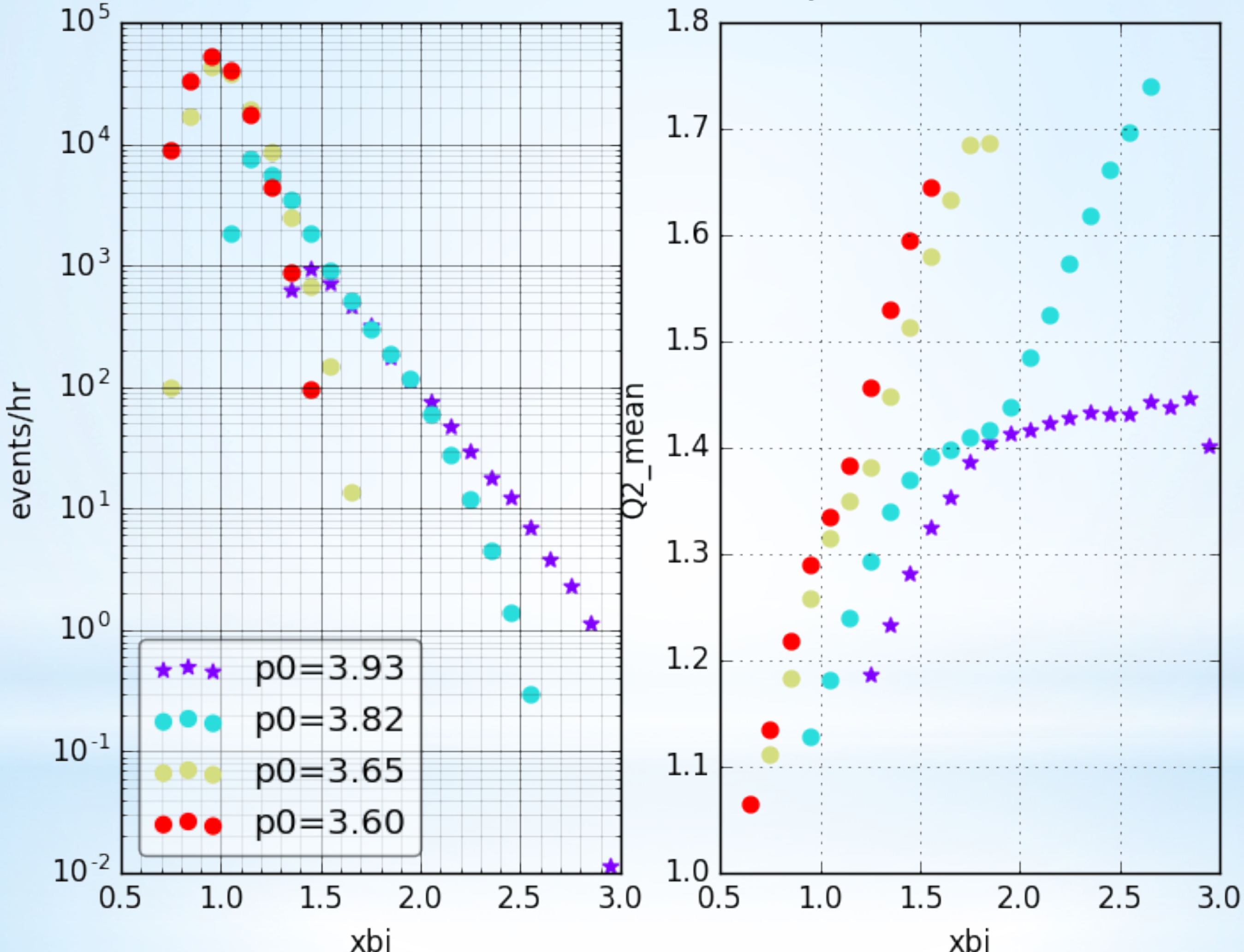
and

The Hall A Collaboration

x>1 Run Plan

"LHRS"

Tritium, 17 degrees



Simulation with single-arm SIMC and XEMC cross section model

* x>1 Run Plan

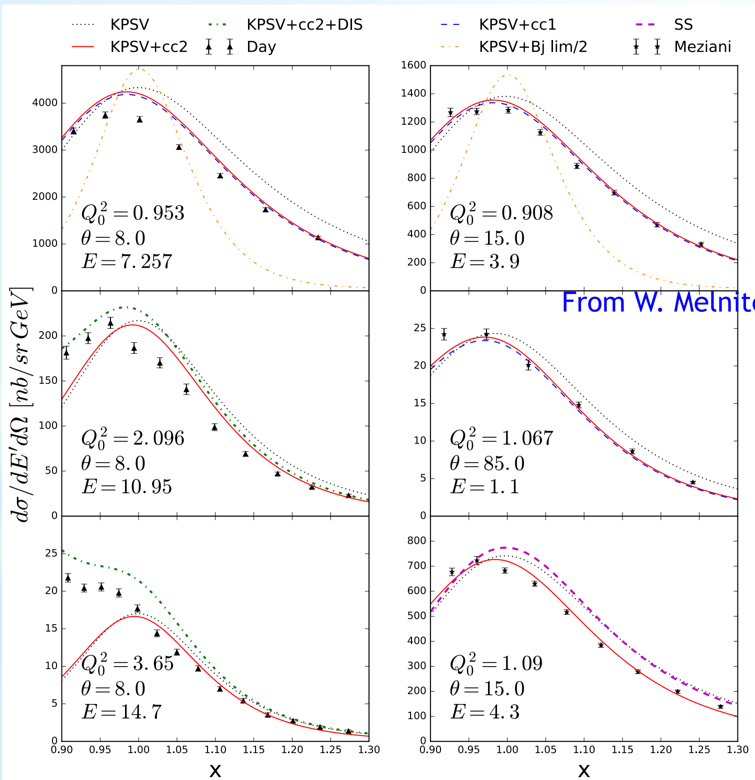
"RHRS"

Measurement:

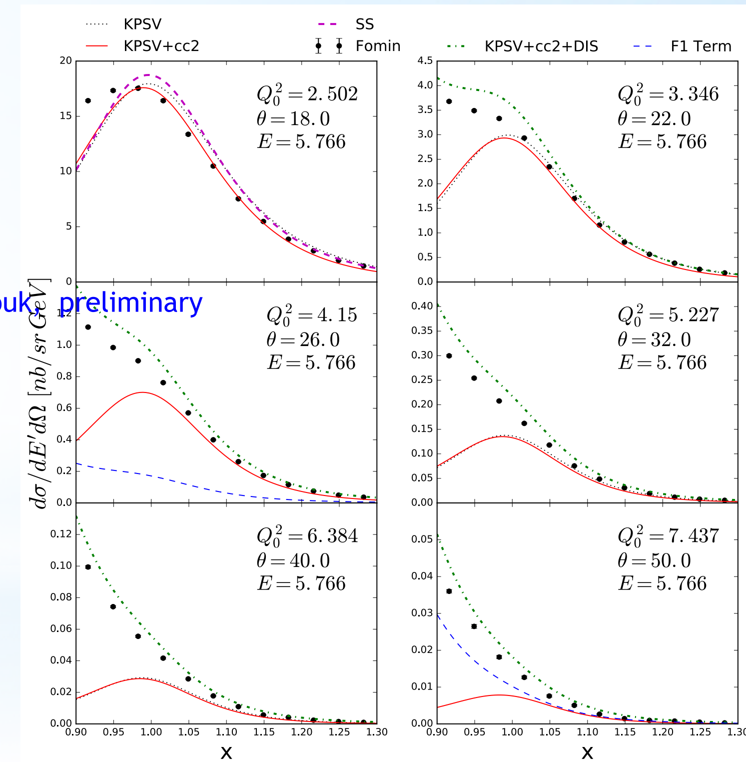
QE cross section at 3H, 3He from Q^2=2 to 3 GeV^2

Goal:

Test 3H and 3He nuclear smearing and off-shell correction models



From W. Melnitchouk, preliminary



A.J. Tropiano, J.J. Ethier, W. Melnitchouk, N. Sato, in preparation (2018).

* Beam?

"Patience is a virtue"

Achilles and the Tortoise ➔ Tritium students and the schedule

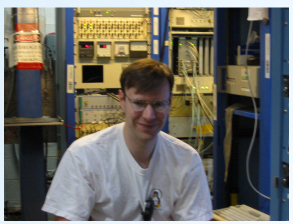
12.15.2017

1999

* Beam?

"Patience is a virtue"

Achilles and the Tortoise ➔ Tritium students and the schedule

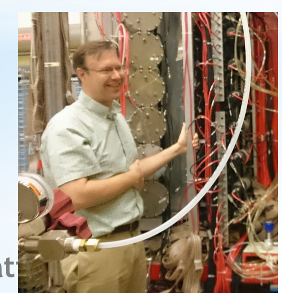


2005

2016

1999

2014



2017

12.15.2017

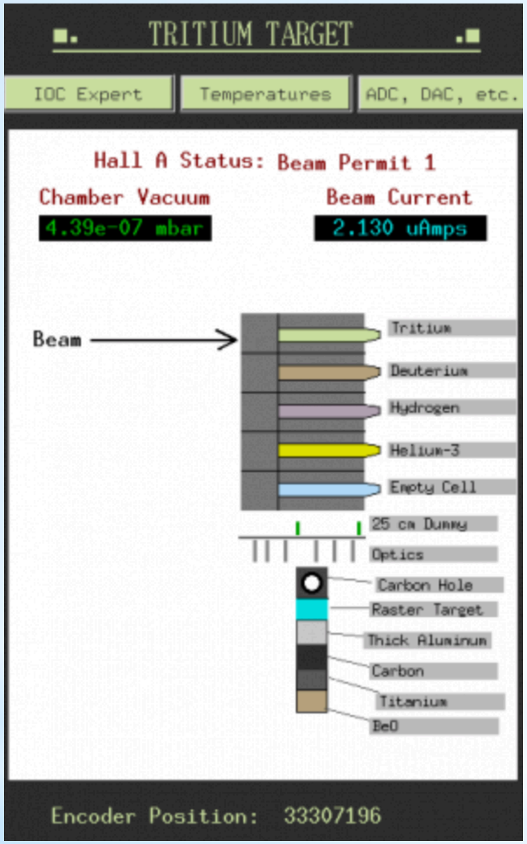
* Tritium Awesome!

"Patience is a virtue"

Achilles and the Tortoise → Tritium students and the schedule

* Beam!

BEAM ON TRITIUM !!!

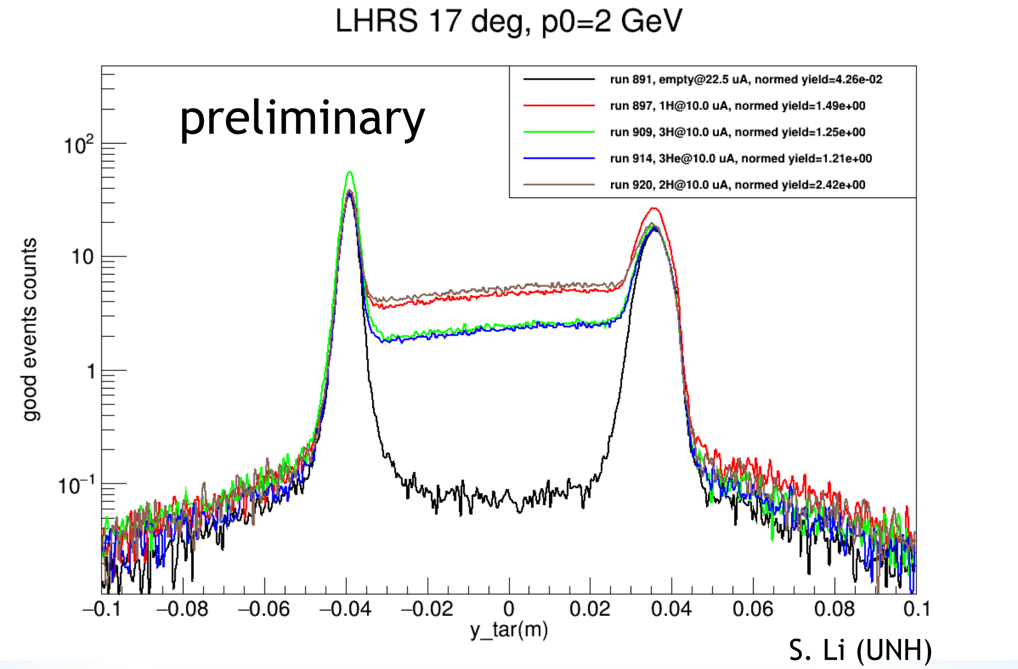


12.15.2017

* x>1 Run Schedule:

December 2017:

1. Tritium commissioning (12.13 – 12.15):
   1. BPM, BCM calibration
   2. LHRS checkout (17 degree)
   3. LHRS sieve runs (1 pass beam, standard Q1 tuning)
   4. Endcap contamination (~4%)



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    1. BPM, BCM calibration
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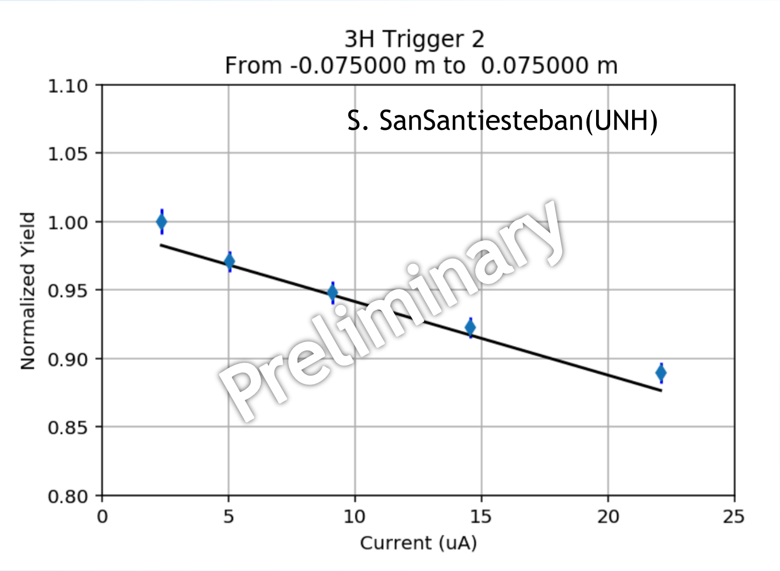
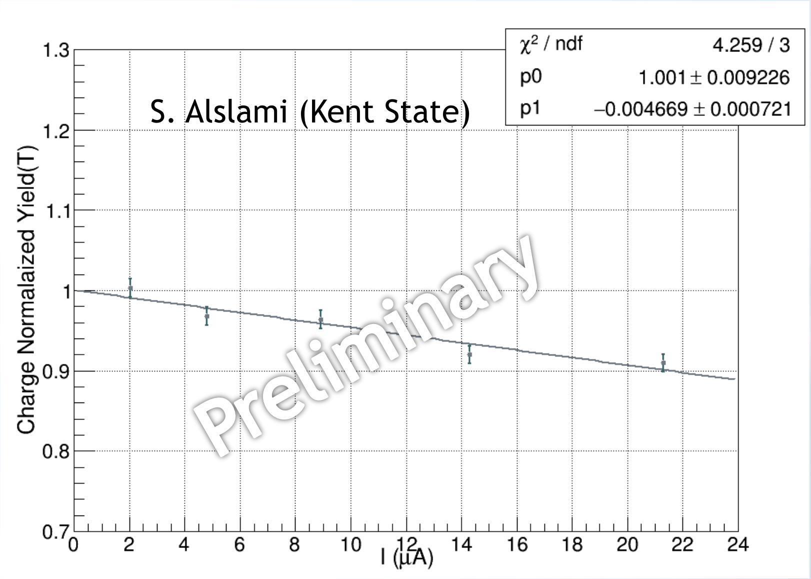
    4. Endcap contamination
    5. Target boiling study (In progress, 8-12% boiling at 22.5 uA)





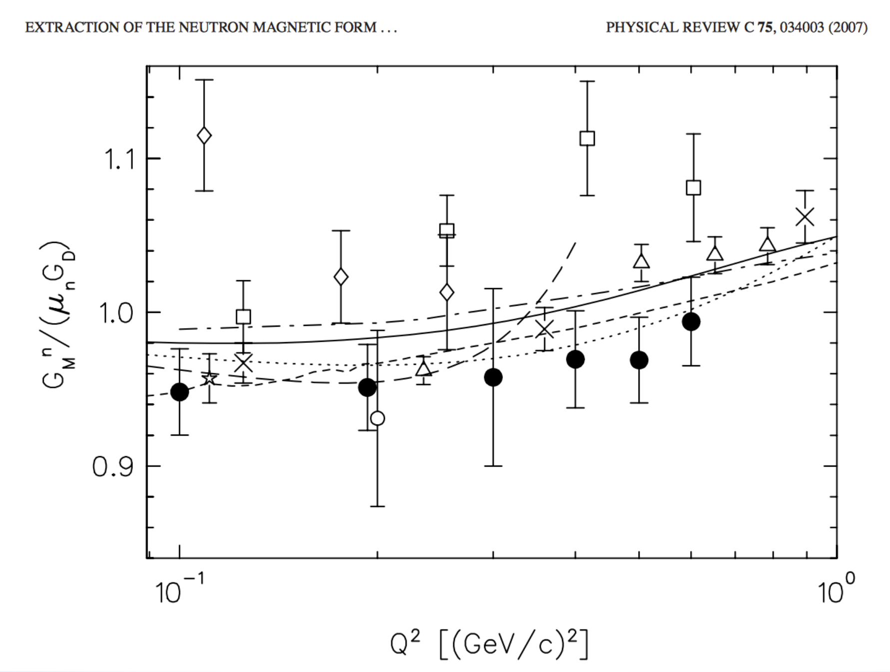
x>1 Run Schedule:

December 2017:

No SRC physics since 2 pass beam was not available

2.Production runs with 2.2 GeV beam(12.16):
Quasi-elastic 2H,3H,3He data,
and elastic 1H data at Q2=0.4, 0.6 GeV2

- Data under quality check. Planned analysis:
  3He/3H cross section ratio➔ GMn



* x>1 Run Schedule:

December 2017:

No SRC physics since 2 pass beam was not available

3. Target position issue (12.16):
   - ➔9 am: beam centering position changed
   - ➔10 am: missed part of multifoil
   - ➔ 11 am to 20 pm: beam centering failed
   - ➔ 21pm: missed multifoil completely, done

Follow-up Re: Follow-up Re: Hall A Lifter Issues

Lognumber 3508343. Submitted by meekins on Tue, 01/02/2018 - 01:13.

Last updated on Tue, 01/02/2018 - 01:20

Logbooks:	HALOG TARGETLOG
Tags:	Hall A Tritium
References:	3508342 - Follow-up Re: Hall A Lifter Issues

cause of lifter failure was a spun shaft coupler see figure 1

x>1 Run Schedule:

December 2017 (mostly commissioning)

March 2018: 4 days
October 2018: 30 days

TODO:

1. finish QE measurement at low Q2 with 1 pass beam
2. Take 2N SRC data on 2H, 3H, 3He at 1<x<2
3. Take 3N SRC data at x>2

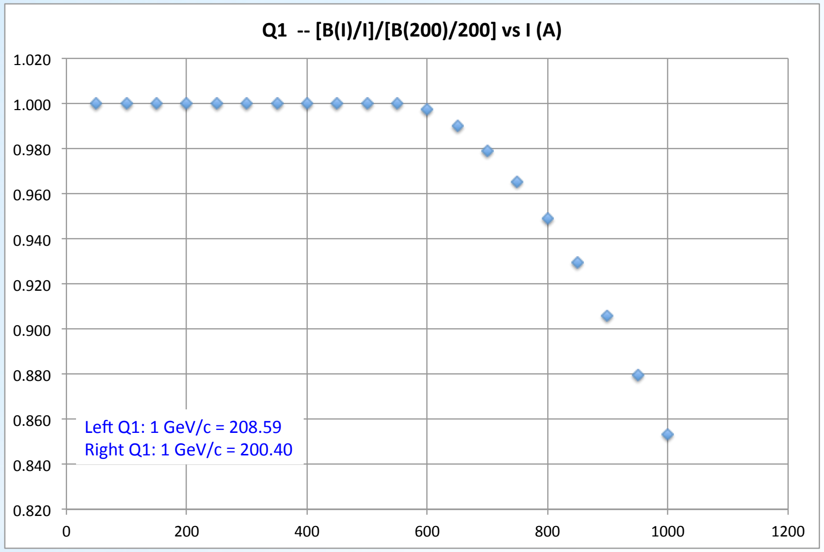
Issues:

Q1 saturation
2 pass beam
Right arm dipole (works now!)

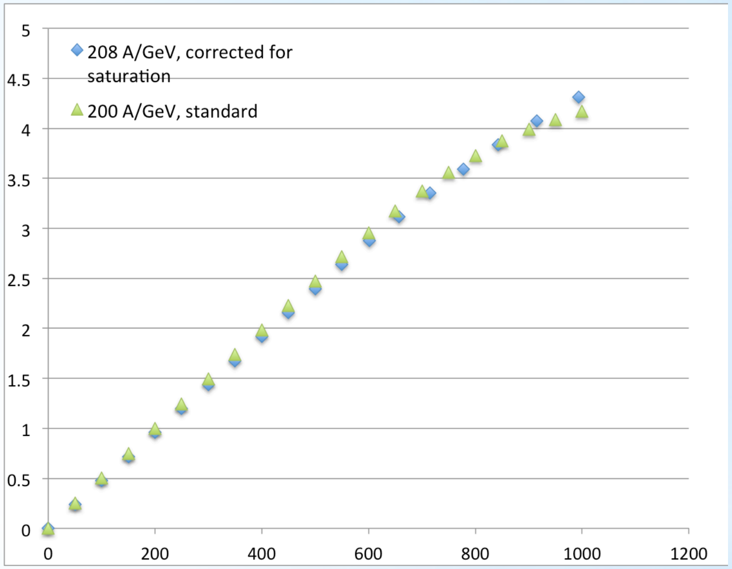
* x>1 Issues:

"Q1 saturation"
"Q1 power supply has a hard limit of 800 A (to be fixed in the summer)"

Hall probe mesured field strength, Generated by J. Gomez



LHRS Q1 current settings from J. Gomez

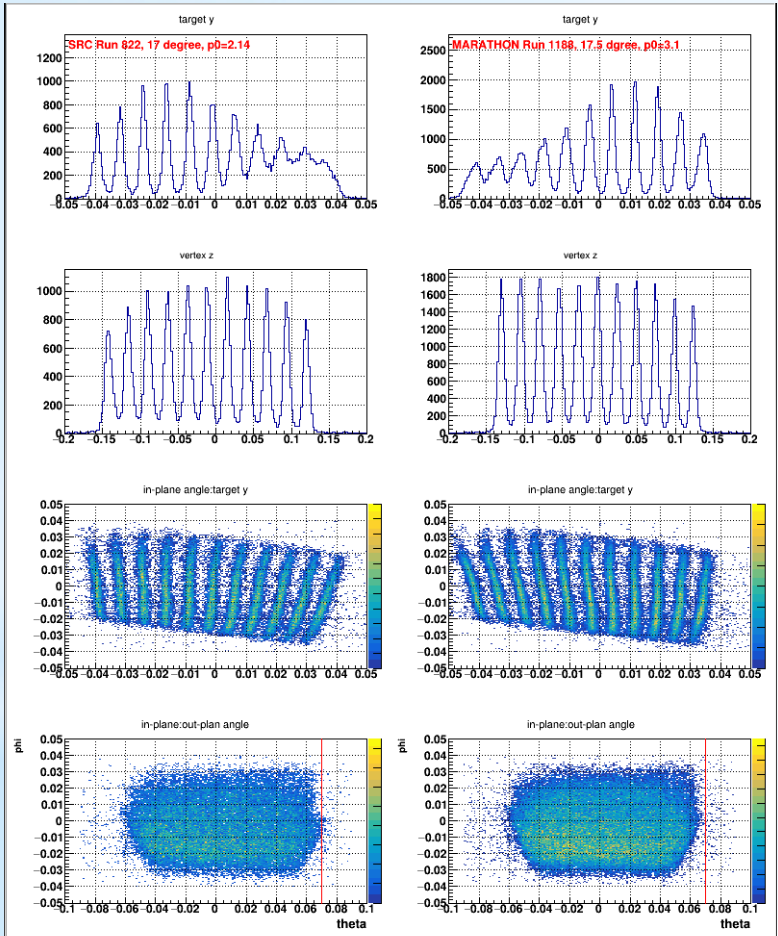


Solution 1: take GMp Q1 tuning (208 A/GeV) with a current correction at p0>3GeV.
The correction factor is provided by GMp data and MC simulation
Solution 2: take standard tuning (200 A/GeV)

* Either way requires optics check at every high momentum setting

* x>1 Issues:

"Q1 saturation"
Optics check from December x>1 (200A/GeV) and MARATHON (208A/GeV) with GMp optics



Plan:

1. December run: calibrate optics from sieve data we took.
2. Future x>1 run: take sieve data at each LHRS setting

*Thank you!

* Thanks to Tritium collaboration, target group, GMp collaboration, MCC …

In memory of Patricia Solvignon

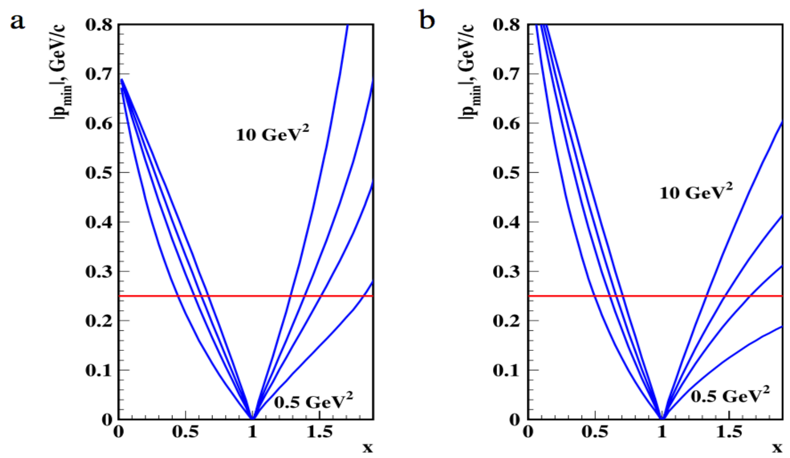


Fig. 3. The minimum momentum for scattering from a nucleon in deuterium (left) and gold (right) as a function of x and Q^2 for quasi-elastic $\gamma+2N \rightarrow N+N$ scattering for Q^2 values of 0.5, 1.5, 3, and 10 GeV^2. For heavy nuclei, the minimum momentum for a given x and Q^2 value is somewhat smaller, as the heavier recoil system requires less kinetic energy to balance the momentum of the struck nucleon. This, combined with the larger Fermi momentum for heavy nuclei, means that slightly higher x or Q^2 values are required to fully suppress scattering from nucleons associated with the mean-field structure.
Source: Figure adapted from Ref. [44].