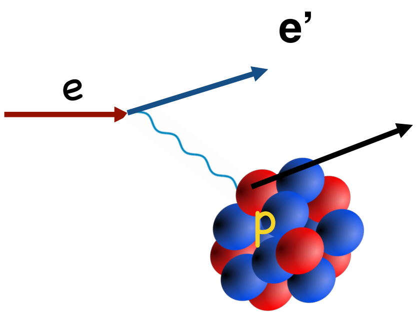
The Isospin Dependence of Short Range Correlations through Inclusive Electron Scattering from ^{40}Ca and ^{48}Ca



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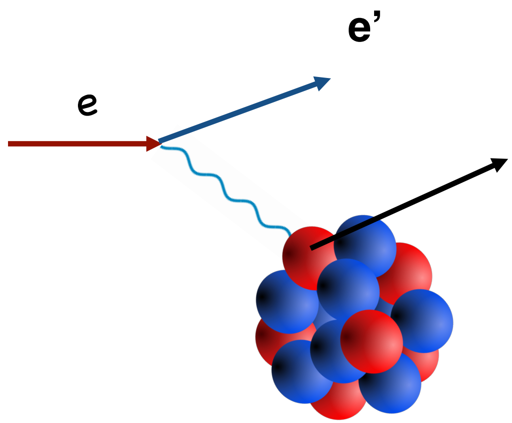
2nd SRC and EMC Workshop
MIT 03/20/2019

Inclusive electron scattering

Kinematic variables:



$\nu = E_0 - E$ → Transfer energy

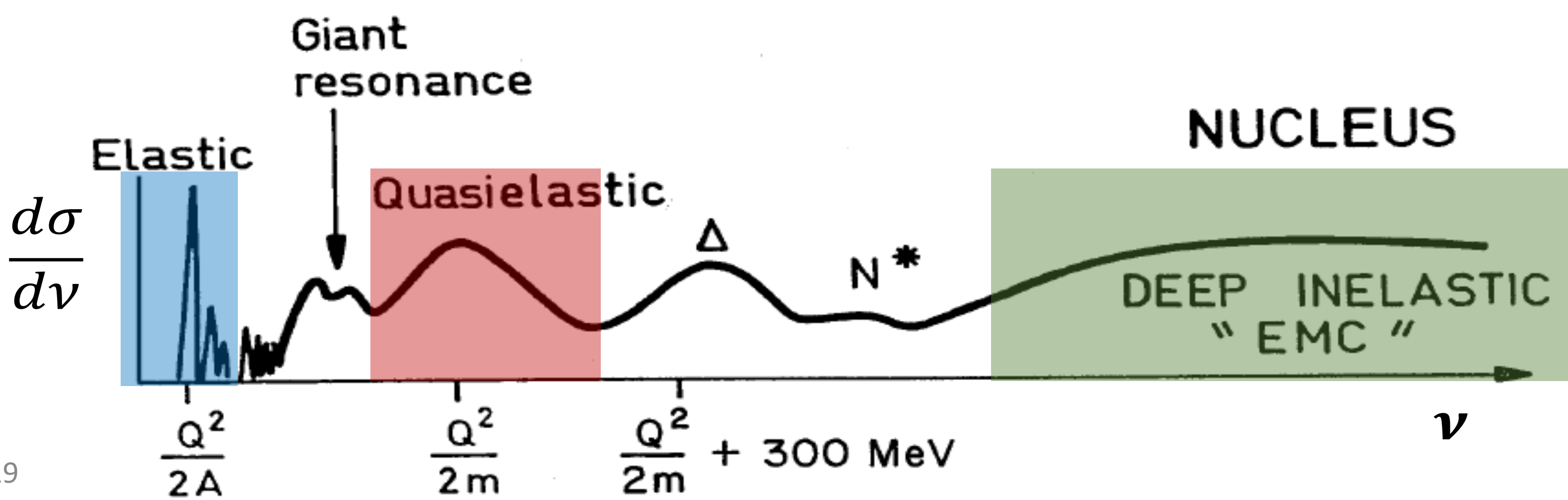
$Q^2 = 4E_0 E \sin^2(\theta/2)$ → 4-momentum transfer squared

$x_{bj} = \frac{Q^2}{2m\nu}$ → Momentum fraction of a nucleon shared by the struck quark.

$y \approx -q/2 + m\upsilon/q$ → Momentum of struck nucleon parallel to q vector

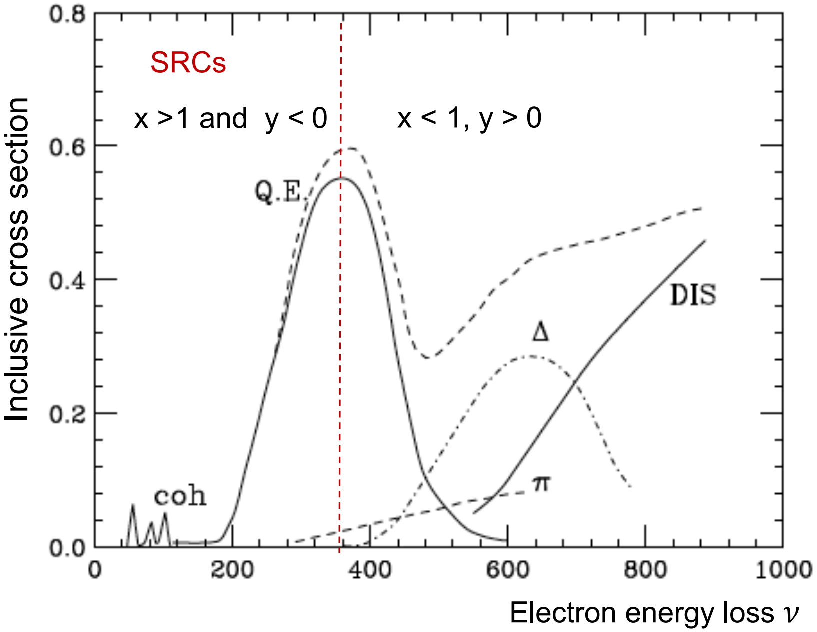
e-p elastic scattering: x = 1, Quasi-elastic scattering x ≈ 1

Motion of nucleon in the nucleus broadens the peak to x~ 1.3



SRCs kinematics

Benhar, Day and SIck, Rev. Mod. Phys. 80 (2008)

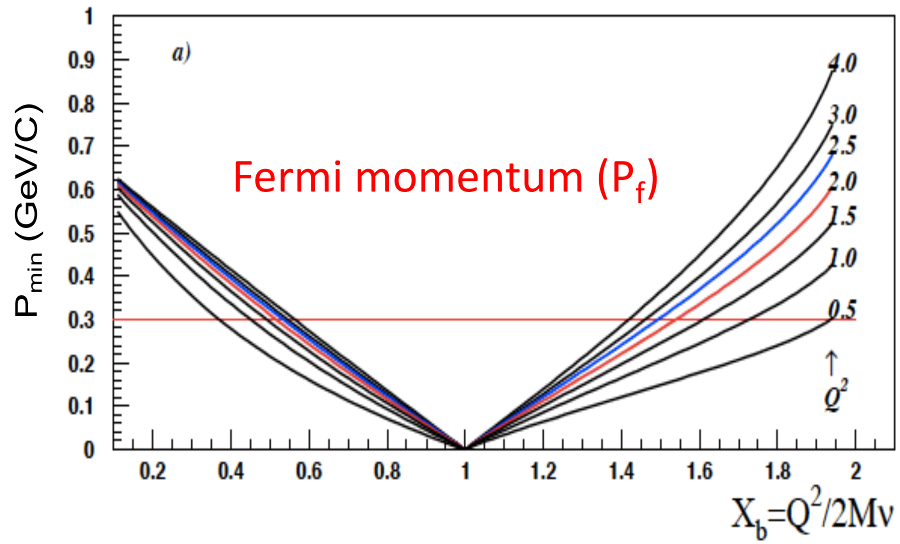


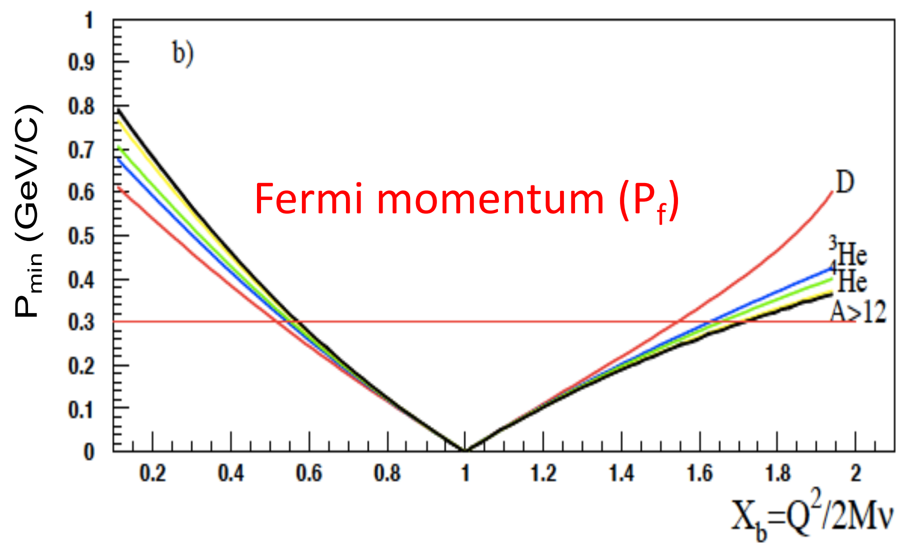
In addition: with x>1.5 and large Q^2 we suppress many effects, ensuring clean "quasi-elastic" scattering on nucleon in a pair.

We need to go to high x and Q^2 where P_{min} > P_f where SRCs are dominant.

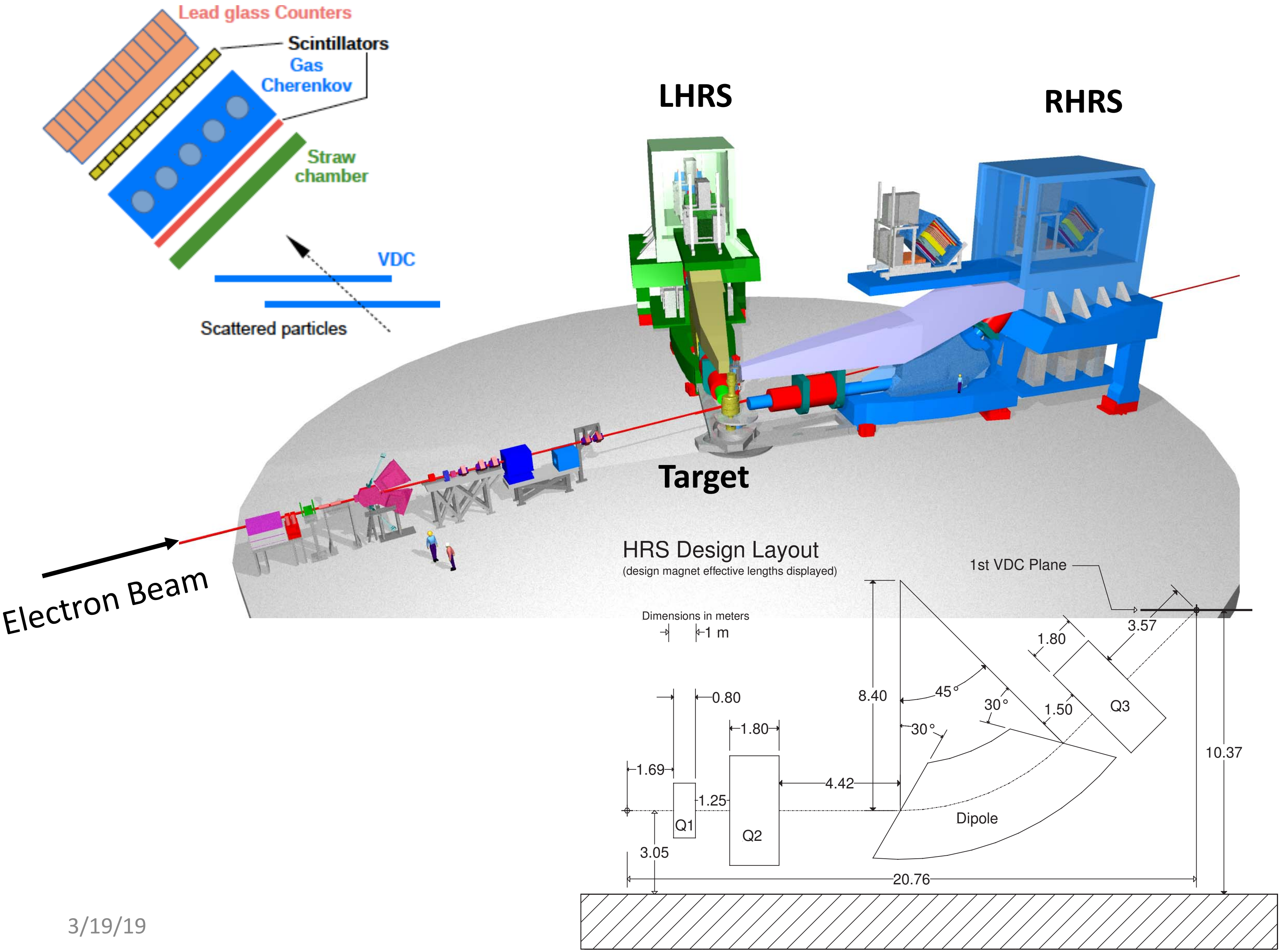
2N-SRCs region: 1<x<2
3N-SRCs region: 2<x<3

Minimum initial struck nucleon momentum





Experiment E08-014: Hall A Jefferson Lab



Experiment E08-014:

- Measuring the inclusive Cross section
- Isospin dependence of the 2N SRCs using $^{40,48}Ca$
  - Isospin-independence assumption

$$\frac{\sigma_{^{48}\mathrm{Ca}}/48}{\sigma_{^{40}\mathrm{Ca}}/40} = \frac{(20\sigma_p + 28\sigma_n)/48}{(20\sigma_p + 20\sigma_n)/40} \xrightarrow{\sigma_p \sim 3\sigma_n} \sim 0.92$$

  - Isospin-dependence assumption

$$\frac{\sigma_{^{48}\mathrm{Ca}}/48}{\sigma_{^{40}\mathrm{Ca}}/40} \sim 1$$

M. Vanhalst, J. Rycketcbusch, Wim Cosyn Phys. Rev. C86 (2012)
M. Vanhalst, J. Rycketcbusch, Wim Cosyn J. Phys. G. 42 (2015)

^{2}H	1.128	^{40}Ca	1.637
^{4}He	1.327	^{48}Ca	1.629
^{9}Be	1.384	^{56}Fe	1.638
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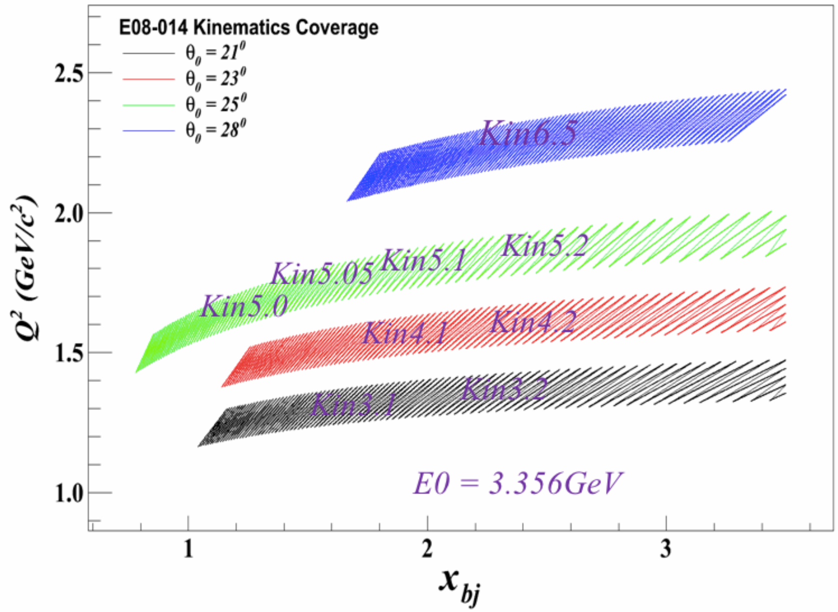


Targets : Cryo targets: LH_2 , ^{3}He, ^{4}He
Solid targets: C12, ^{40}Ca, ^{48}Ca

Beam Energy: E0 = 3.356 GeV
Momentum: Ep: 2.505 - 3.055 GeV
Angle: 21, 23, 25, 28

Q^2 range : 0.8 GeV^2 – 2.8 GeV^2
X_{bj} range: $1<X_{bj}<2$ and $X_{bj} > 2$

Cross Section Extraction Methods

For each bin in ΔE, $\Delta\Omega$, the number of detected electrons is:

$$N^- = L*(d\sigma/d\Omega dE')*(\Delta E' \, \Delta\Omega)*\varepsilon*A(E',\theta)*B + BG$$

Where:

L: Integrated Luminosity (# *of beam electrons**targets/area*)

ε: Total efficiency for detection

$A(E',\theta)$: Acceptance for bin

B : Binning correction

BG: Background events.

Notation:
$(d\sigma/d\Omega dE') = \sigma^{data}$

N- : obtained by applying selection cuts: Tracking, trigger, PID, acceptance

The efficiency corrected electron yield is

$$Y = (N^- - BG)/\varepsilon \quad = \quad L*\sigma^{data}*(\Delta E \, \Delta\Omega)*A(E',\theta)*B$$

For known $A(E',\theta)$, $\sigma^{data} = Y/[(\Delta E \, \Delta\Omega)*A(E',\theta)*B*L]$

1. Acceptance correction method:

$$\sigma^{data} = Y(E',\theta) / [(\Delta E\ \Delta\Omega) * A(E',\theta) * B * L$$

$A(E',\theta)$ is the probability that a particle will make it through the spectrometer and *must be measured or determined from simulation!*

$\Delta\Omega_{eff} = \Delta\Omega * A(E',\theta)$ is the *effective solid angle* or *solid angle acceptance*.

2. Yield ratio method

we can simulate Monte Carlo data using a cross section model to obtain

MC: $Y_{MC}(E',\theta) = L * \sigma^{mod} * (\Delta E\ \Delta\Omega) * A_{MC}(E',\theta) * B$

Data $Y = L * \sigma^{data} * (\Delta E\ \Delta\Omega) * A(E',\theta) * B$

Taking the ratio to data and assuming that $A_{MC} = A$ yields

$$\sigma^{data} = \sigma^{mod} * [Y(E',\theta) / Y_{MC}(E',\theta)]$$

Acceptance study using the SAMC

Goal:

- Simulate the experiment using SAMC
- Compare the target reconstruction variables from data to simulation
- Determine the range for acceptance cuts for cross section analysis

Simulation SAMC

Generator : uniformly generate:

- Es : beam energy
- Th_tg_gen : the out-plane angle
- Ph_tg_gen: the in-plane angle
- dp_tg_gen: relative momentum

Transport functions:

- Forward matrix: transport generated event from target to the focal plan and then add the VDC smearing
- Backward matrix: reconstruct event to target

Cross section model: XEMC

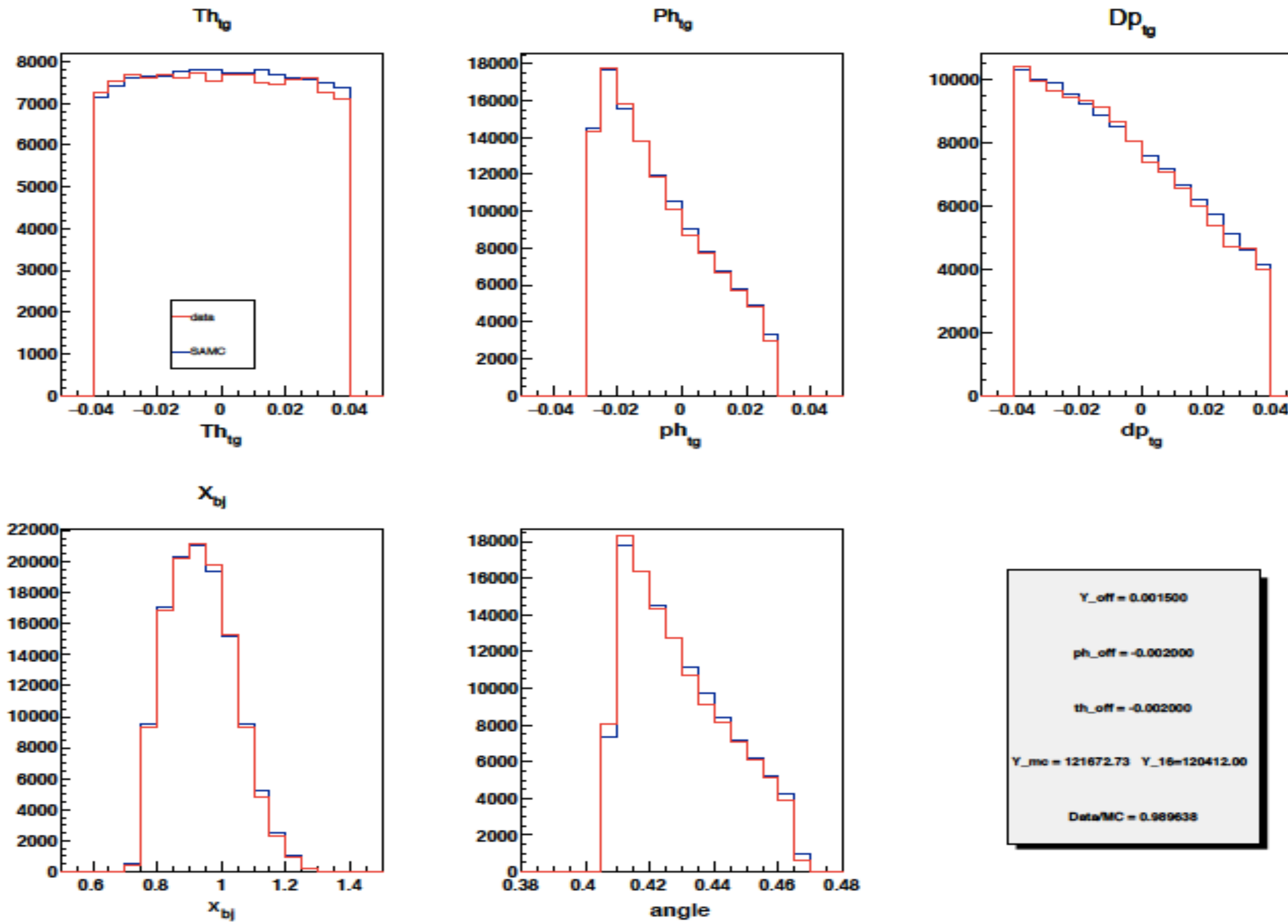
- This cross section model uses the F1F209 for DIS and F(y) for QE, Born = DIS + QE
- The radiative correction was merged in the cross section model
- The simulation output will be weighted by radiative cross section

Reconstruction variables comparison

- Optics reconstruction matrix
- Cross section model
- Acceptance model

Data and simulation comparison after every correction

1D reconstruction variables: comparison of Data and simulation: looks pretty good even now with the larger acceptance cuts

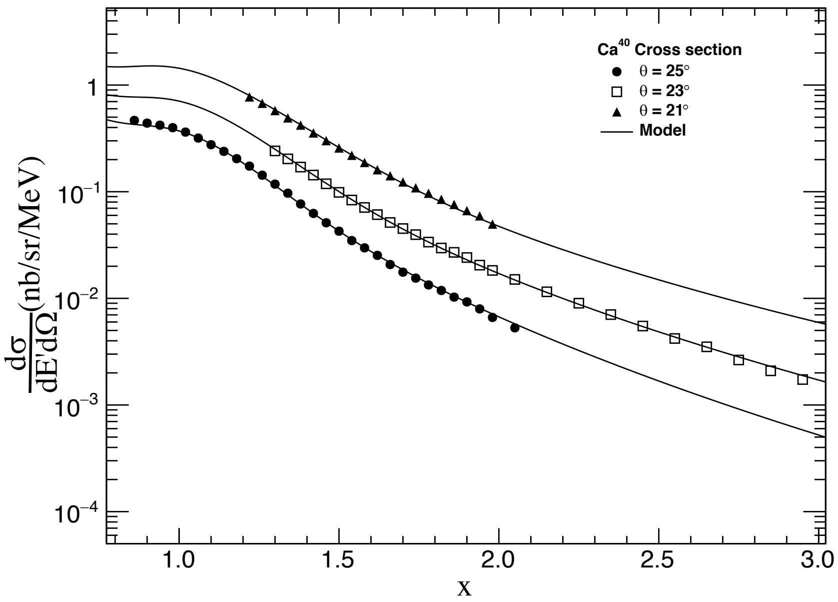


Systematic Uncertainty

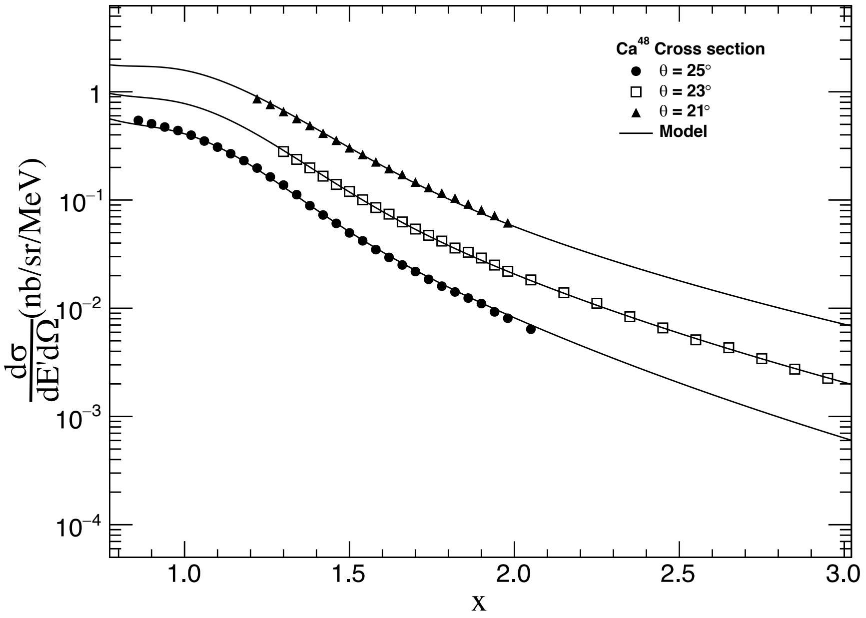
Systematic	$\delta\sigma/\sigma$ (Norm)	$\delta\sigma/\sigma$ (pt-pt)	$\delta R/R$ (Norm)	$\delta R/R$ (pt-pt)
Acceptance dependence	2%	1.5%	-	0.2%
Model dependence	-	0.5%	-	0.5%
Tracking efficiency	1%	0.3%	-	0.2%
Cer efficiency	0.3%	0.1%	-	0.1%
E/p efficiency	0.3%	0.1%	-	0.1%
Target density*	1%	-	1%	-
Beam Charge*	0.5%	-	-	0.5%
radiative correction*	1.5%	-	-	0.5%
Total	2.9%	1.6%	1%	0.9%

Results: Extracted absolute cross section

Ca^{40}:



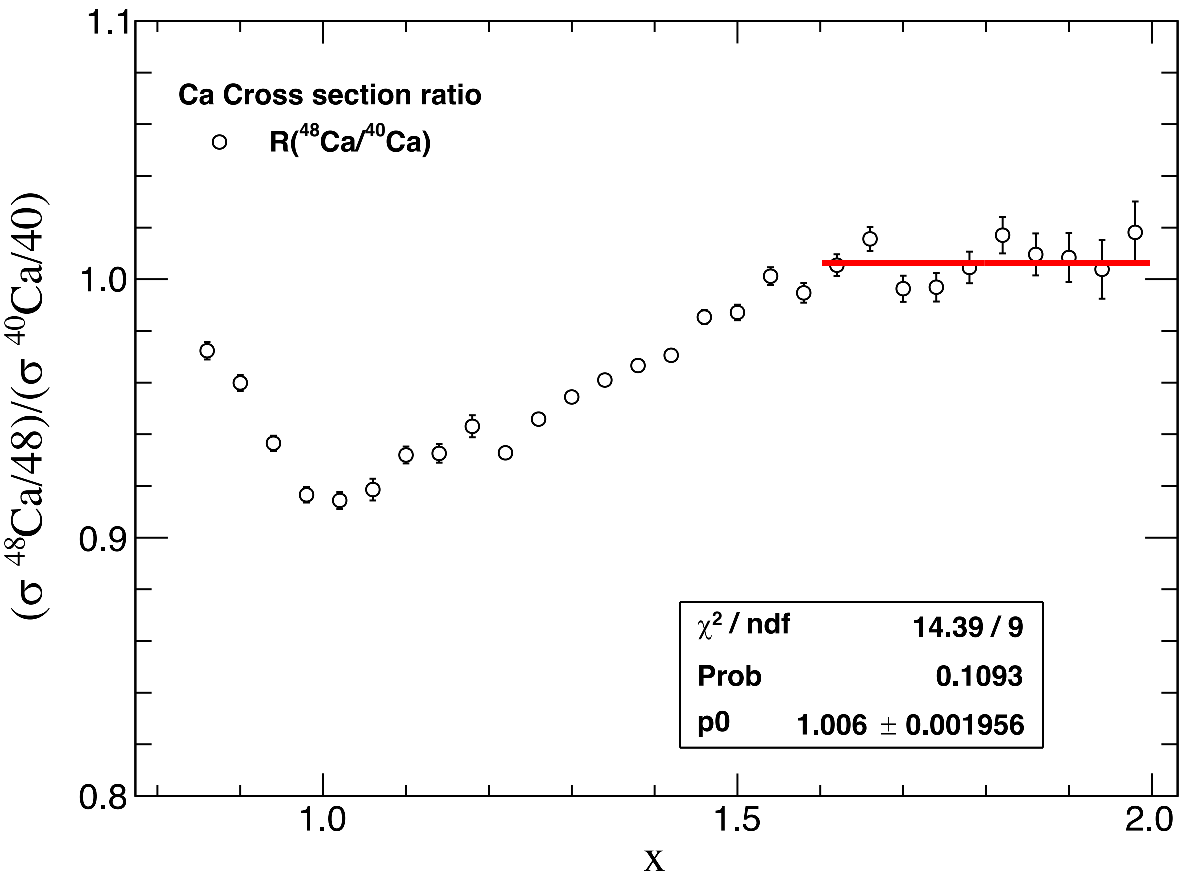
Ca48



Uncertainty: Norm ~2.9%

Uncertainty: point-to-point ~ 1.6%

Cross section ratio per nucleon

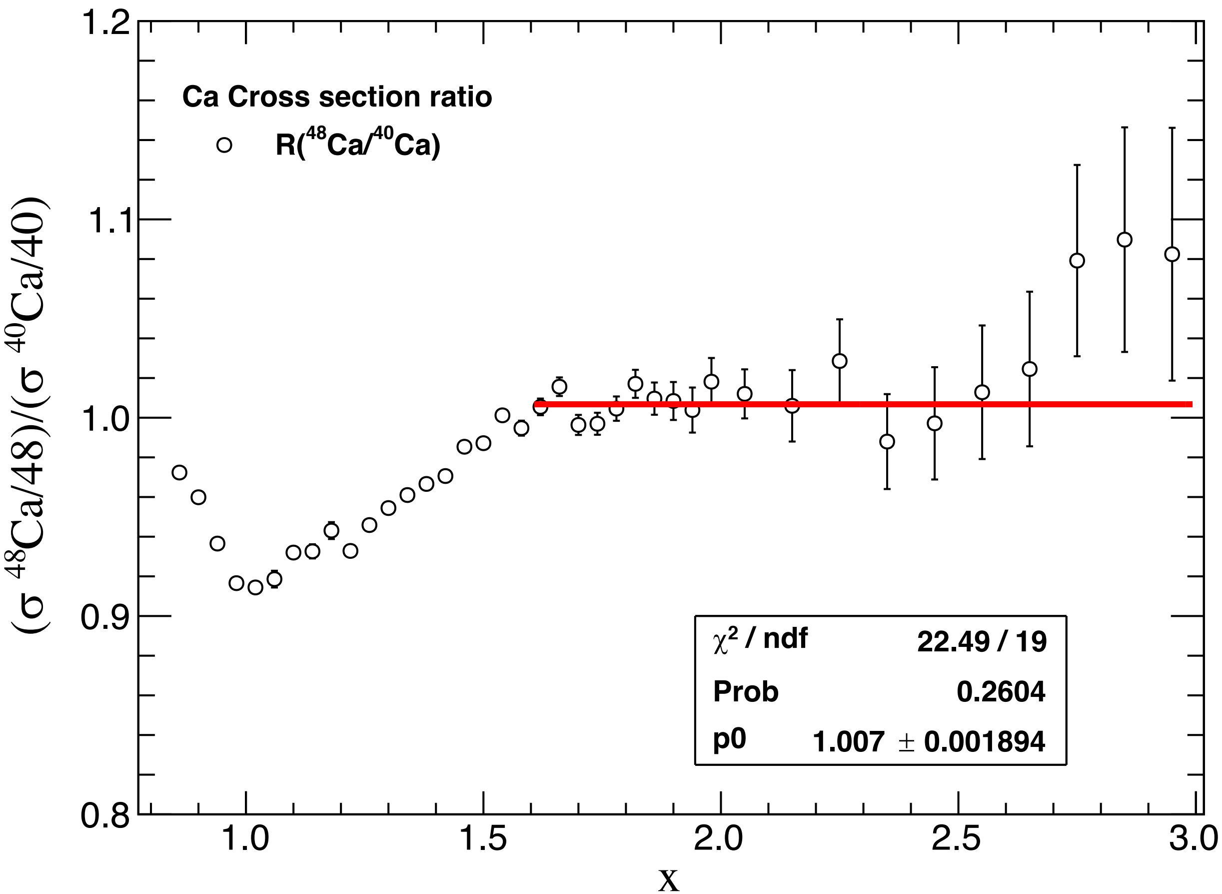


R = 1.006 +/- 0.002

Uncertainty: norm: 1%

Uncertainty: point-to-point: 0.9%

Cross section ratio per nucleon



Discussion

1. Cross section ratio per nucleon is close to **1** compared to the is isospin independent assumption **0.92.**

Evidence of the isospin dependence from inclusive scattering

M. Vanhalst, J. Rycketcbusch, Wim Cosyn Phys. Rev. C86 (2012)
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$$a_2(^{40}\mathrm{Ca}) = \frac{\sigma^{40}\mathrm{Ca}/40}{\sigma^{2}\mathrm{D}/2} = \frac{(1.637-1)}{(1.128-1)} = 4.97$$

$$a_2(^{48}\mathrm{Ca}) = \frac{\sigma^{48}\mathrm{Ca}/48}{\sigma^{2}\mathrm{D}/2} = \frac{(1.629-1)}{(1.128-1)} = 4.92$$

$$\frac{\sigma^{48}\mathrm{Ca}/48}{\sigma^{40}\mathrm{Ca}/40} = 4.92/4.97 = 0.989$$

Thank you