

Deuteron Electro-Disintegration at Very High Missing Momenta (E12-10-003)

HALL C WINTER COLLABORATION MEETING

Date: January 21, 2017

Spokespersons: W. Boeglin (FIU) and M Jones (Jlab)

Graduate Student: Carlos Yero (FIU)

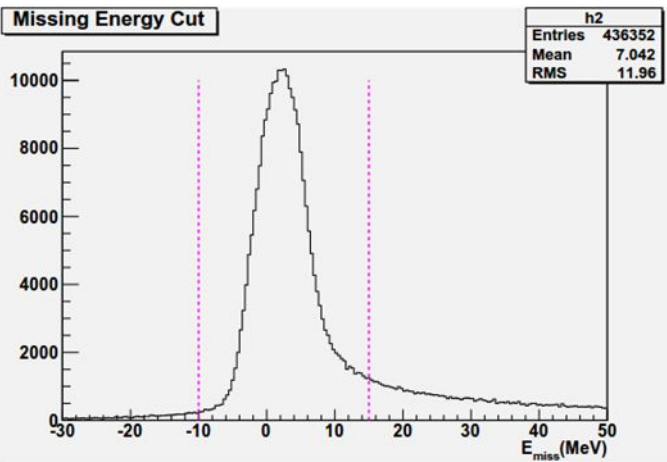
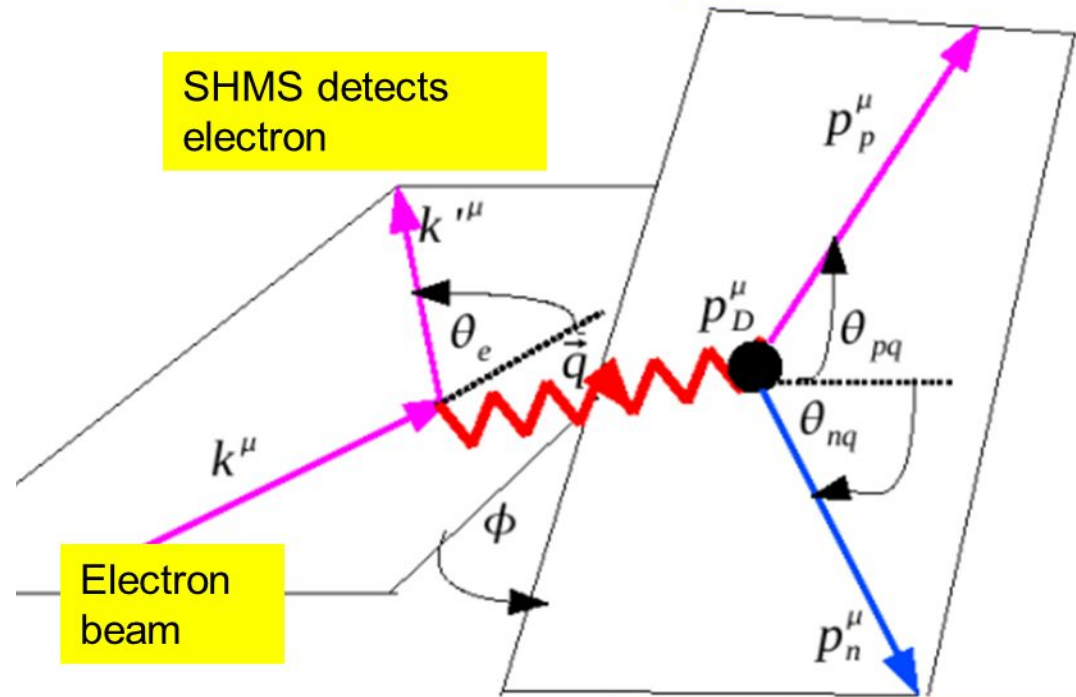
Beam time is 3 PAC days at beam energy of 10.6 GeV

Study the $D(e,e'p)n$ exclusive reaction by using cut on missing energy.

HMS detects proton

SHMS detects electron

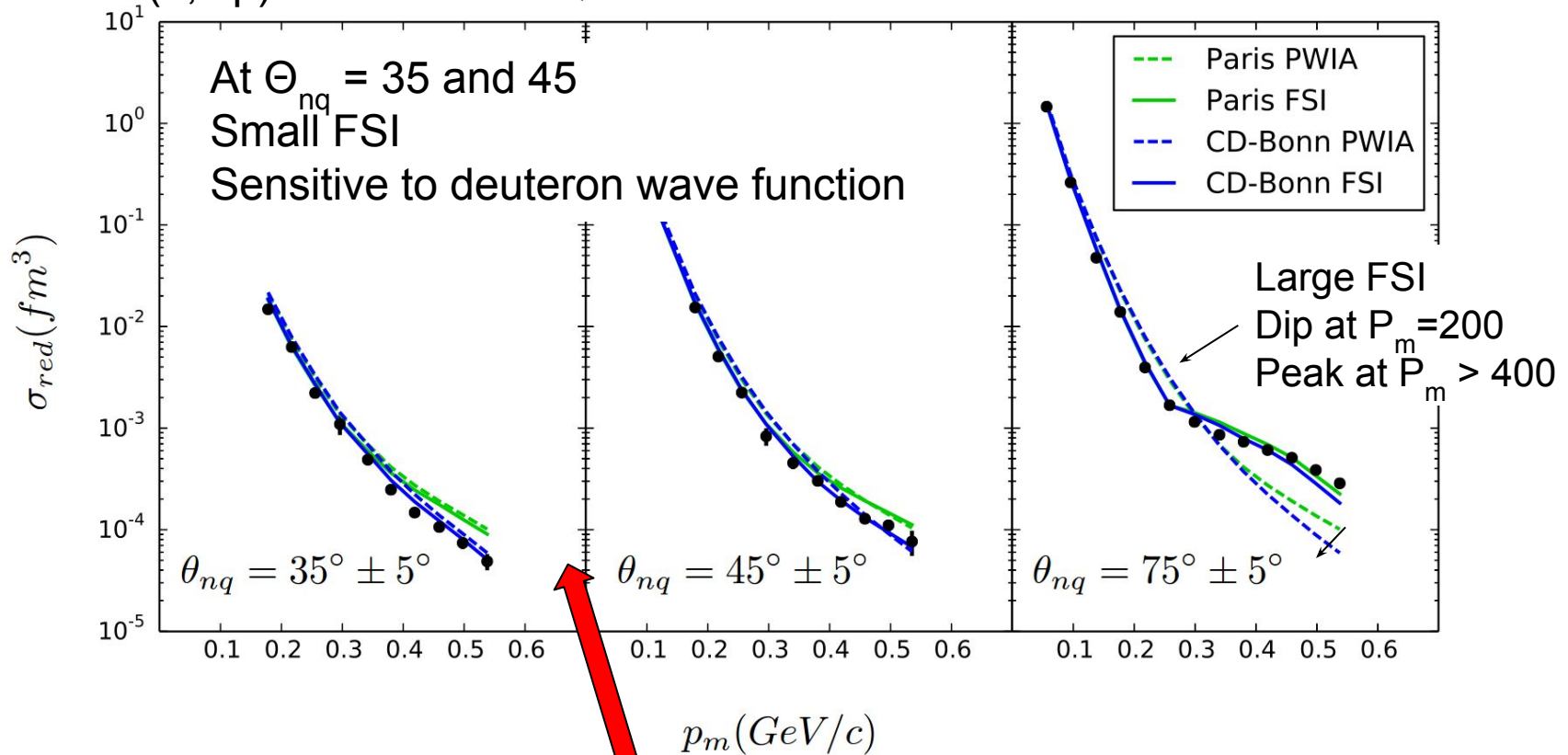
Neutron reconstructed



Previous Hall A experiment

Compare reduced cross section to theoretical calculation of only PWIA, PWIA+FSI with different NN potentials. In PWIA, σ_{red} maps the momentum distribution.

Data for $d(e,e'p)n$ reaction at $Q^2 = 3.25 \text{ GeV}^2$.



New Hall C will focus at $\theta_{nq} \sim 40^\circ$ and $p_m > 500$ at $Q^2 = 4.25$ where the difference to NN potential is larger

D(e,e'p)n Theoretical Support

D(e,e'p)n Kinematics

$$E_{\text{BEAM}} = 11.0 \text{ GeV}$$

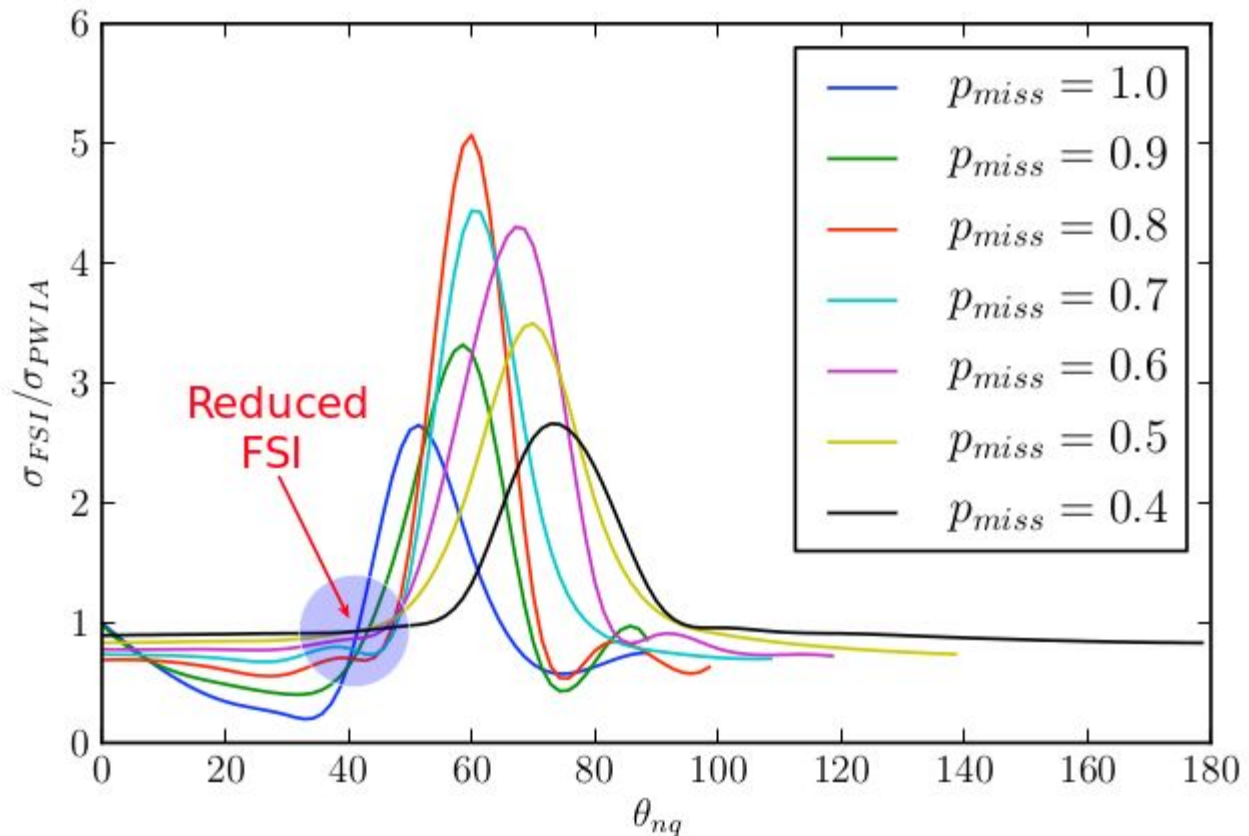
$$Q^2 = 4.25 \text{ (GeV/c)}^2$$

$$x_{\text{Bj}} = 1.35$$

$$p_m = 0.5 - 1.0 \text{ GeV/c}$$

$$\theta_{\text{nq}} = 40^\circ$$

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Int.J.Mod.Phys. E24
(2015) no.03,
1530003



At $\theta_{\text{nq}} \sim 40^\circ$, FSI have weak dependence on p_{miss}

Calculation: M. Sargsian

E12-10-003 Collaboration

Motivation:

- Investigate short range structure of the deuteron (high momentum components)
- Explore a new kinematical region of the 2-nucleon system above $p_m > 500$
- No Deuteron data exist at these kinematics!
- Short range correlation studies cover similar region on missing momenta
- Models are able to reproduce the present data within 20%.
- Signs of a dependence on NN potential at highest missing momentum

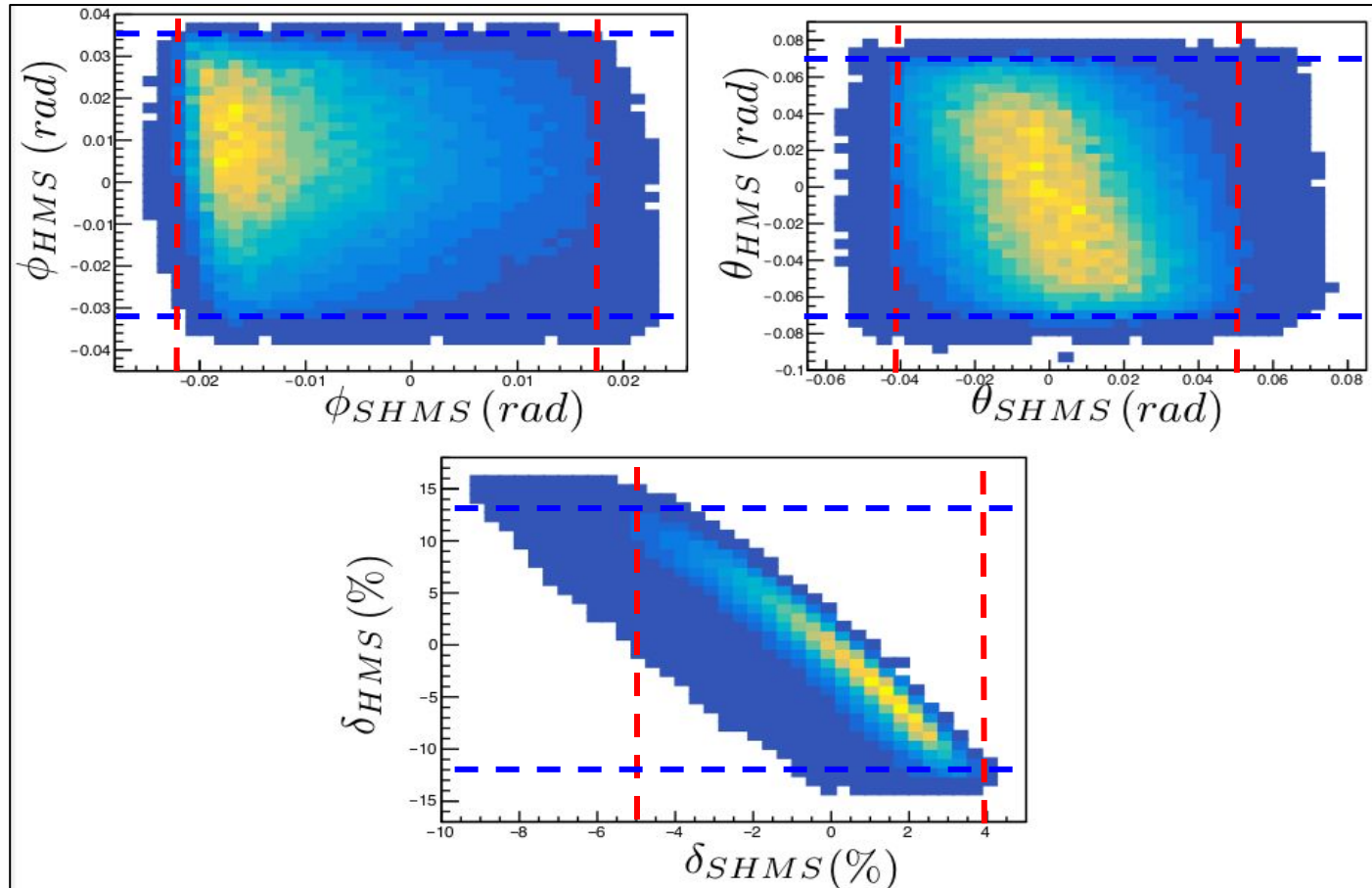
The experiment will:

- Determine cross sections at missing momenta above 0.5 GeV/c
- Measure at well defined kinematic settings at $Q^2 = 4.25$
- Selected kinematics to minimize contributions from FSI
- Selected kinematics to minimize effects of delta excitation

Outline a scaled down version of the experiment for the Hall C commissioning period.

Spectrometer Acceptance Requirements During D(e,e'p)n Commissioning

- D(e,e'p)n will **NOT** use the full SHMS Acceptance
- SIMC kinematic setting: $p_{\text{miss}} = 500 \text{ MeV}$



Kinematics and Beam Time

Beam:

Energy: 10.6 GeV

Current: 70 μ A

Target:

LD₂ (10 cm)

Electron arm *fixed* at:

SHMS at $p_{\text{cen}} = 8.92$ GeV/c

$\theta_e = 12.17^\circ$ $Q^2 = 4.25$ (GeV/c)²

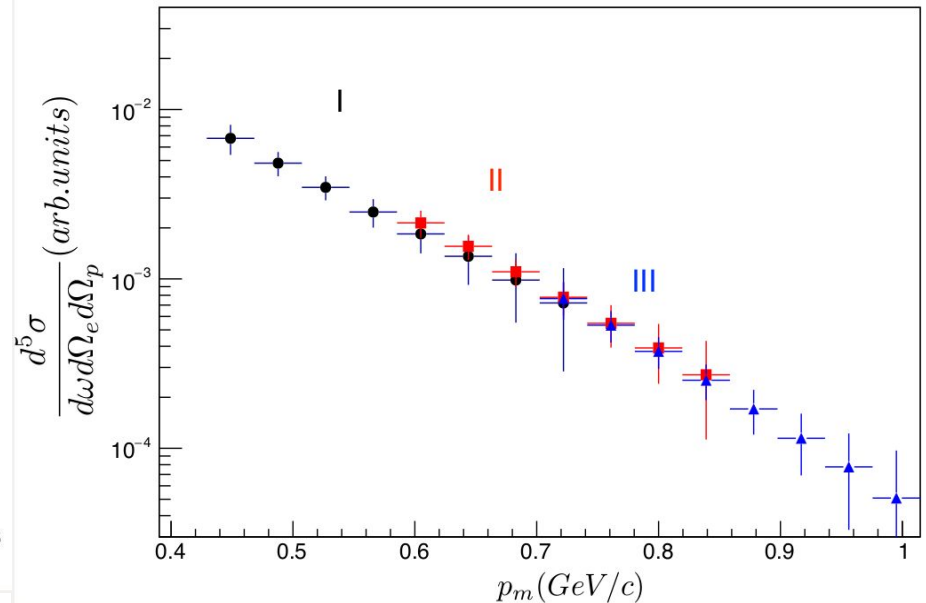
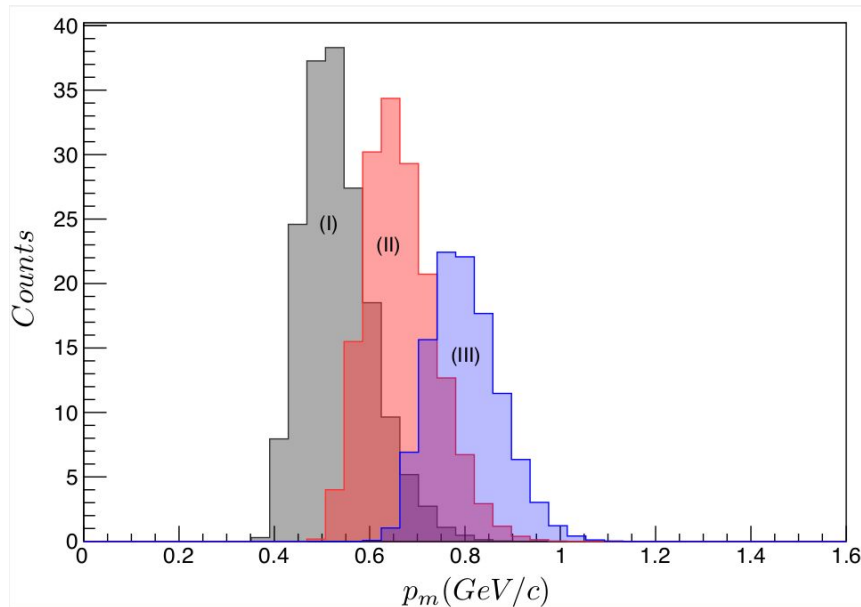
$x = 1.35$ $\theta_{\text{nq}} \sim 40^\circ$

Vary Proton arm to measure :

$p_m = 0.5, 0.65, 0.8$ GeV/c

HMS $2.12 \leq p_{\text{cen}} \leq 2.3$ GeV/c

Angles: $59.6^\circ \geq \theta_p \geq 53.1$



SIMC Results (Radiative Corr.)

- I. $p_m = 0.5$ (GeV/c), beam time 8 hours
- II. $p_m = 0.65$ (GeV/c), beam time 18 hours
- III. $p_m = 0.8$ (GeV/c), beam time 36 hours

Statistical Uncertainties

16.1 %

17.0 %

20.9 %

Calibration Run Kinematics

Beam:

Energy: 10.6 GeV

Current: 70 μ A

Target:

LD₂ (10 cm)

Electron arm *fixed* at:

SHMS at $p_{\text{cen}} = 8.44$ GeV/c

$\theta_e = 12.51^\circ$ $Q^2 = 4.25$ (GeV/c)²

$x = 1.05$ $\theta_{\text{nq}} \sim 59^\circ$

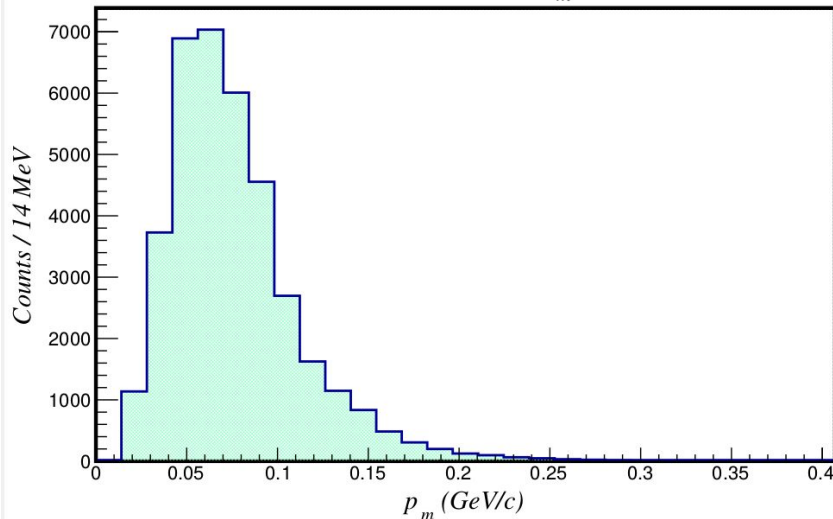
Proton arm to measure:

$p_m = 0.08$ GeV/c

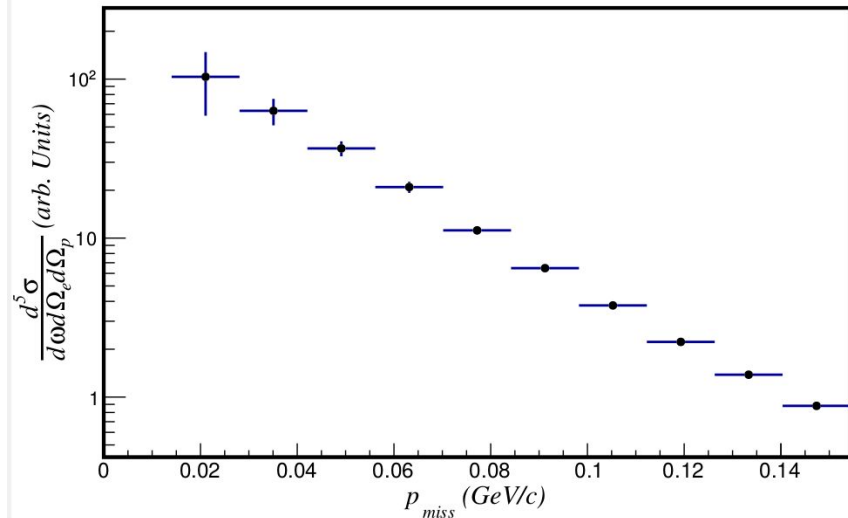
HMS at $p_{\text{cen}} = 2.94$ GeV/c

Angle: $\theta_p = 39.14^\circ$

Missing Momentum Yield, $P_m = 0.08$ GeV



Differential Cross Section, $P_m = 0.08$ GeV



SIMC Results (Radiative Corr.)

$p_m = 0.08 - 0.1$ (GeV/c), beam time 1 hour

Statistical Uncertainty

(1.29 - 1.9) %

- compare to real data at same kinematics for cross-calibration

Yields and Cross-Section Sensitivity to Kinematic Uncertainties

Kinematic Variable	Symbol	Conservative Kinematic Uncertainty	Optimum Kinematics Uncertainty
Beam Energy E_{BEAM}	$\Delta E / E$	1×10^{-3}	5×10^{-4}
Electron Final Momentum \mathbf{k}_f	$\Delta P / P$	1×10^{-3}	5×10^{-4}
Proton Final Momentum \mathbf{P}_f	$\Delta P / P$	1×10^{-3}	5×10^{-4}
Electron Scattering Angle θ_e	$\Delta \theta$	$\mp 1 \text{ mrad}$	$\mp 0.2 \text{ mrad}$
Proton Scattering Angle θ_p	$\Delta \theta$	$\mp 1 \text{ mrad}$	$\mp 0.2 \text{ mrad}$

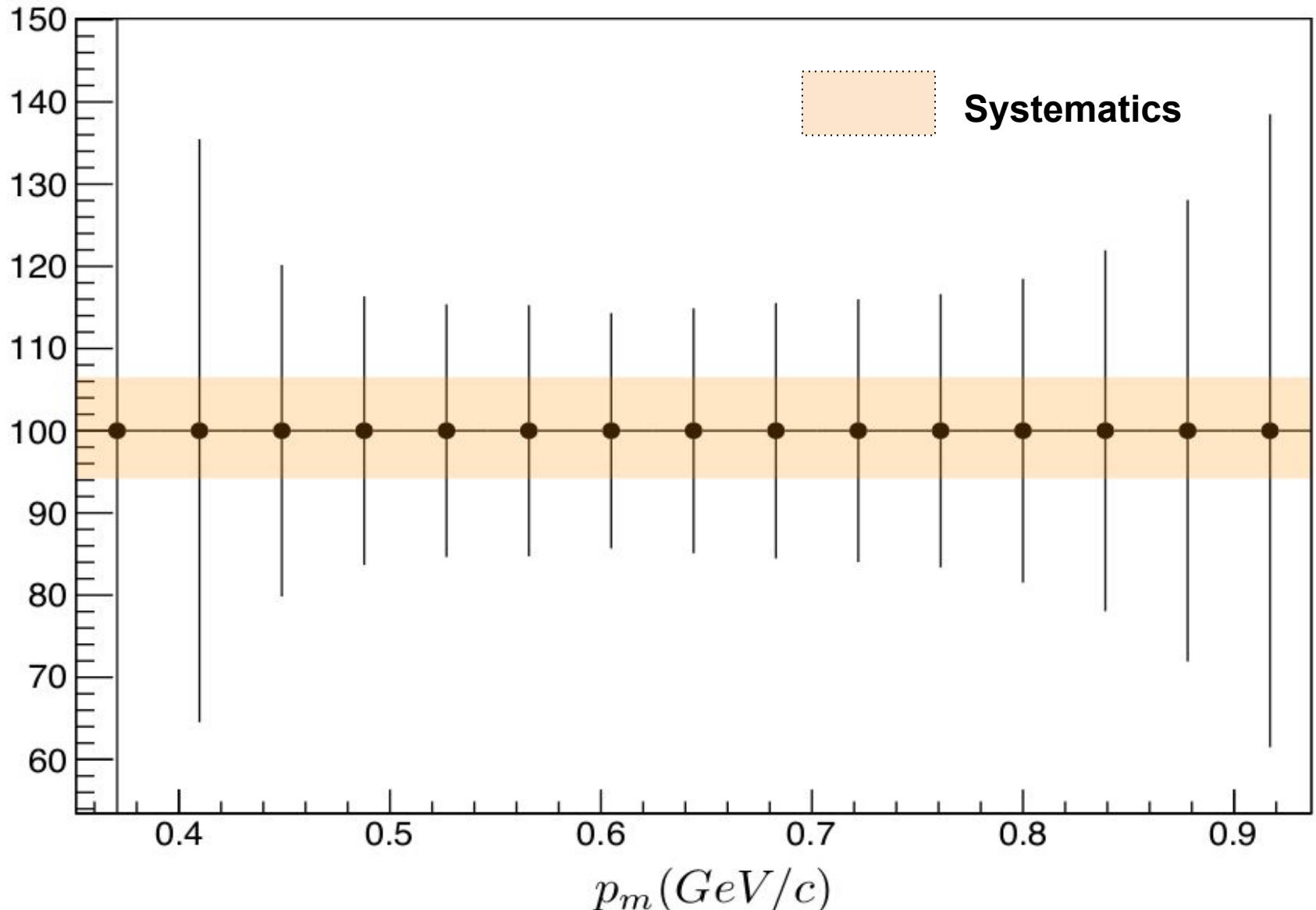
- Investigate small variations of kinematic variables on yields and final cross-section for systematics

Systematics @ $P_{\text{miss}} = 0.80 \text{ GeV}$

$P_{\text{miss}} (\text{GeV}/c)$	Total Error in $d\sigma/d\Omega$ (%)	$E_{\text{INCIDENT}} (\%)$	$E_{\text{FINAL}} (\%)$	$\Delta\theta_e (\%)$	$\Delta\theta_p (\%)$
0.69	7.4	1.1	0.6	7.0	2.2
0.72	7.6	1.2	0.7	7.1	2.3
0.76	7.8	1.2	0.8	7.2	2.5
0.80	8.1	1.3	0.9	7.5	2.7
0.84	8.5	1.3	1.0	7.8	2.9
0.88	9.0	1.4	1.1	8.2	3.1
0.91	9.5	1.5	1.2	8.6	3.4
0.95	10.2	1.6	1.3	9.2	3.7
0.99	11.2	1.8	1.4	10.0	4.1

Expected Relative Errors

Relative Error



Summary

- First meaningful data at very high missing momenta obtainable during commissioning period
- Systematic errors due to uncertainties in kinematic variables are smaller than statistical
- Requirements on initial spectrometer performance realistic
- 3 days of beam time required
- Good opportunity to obtain new early physics results.

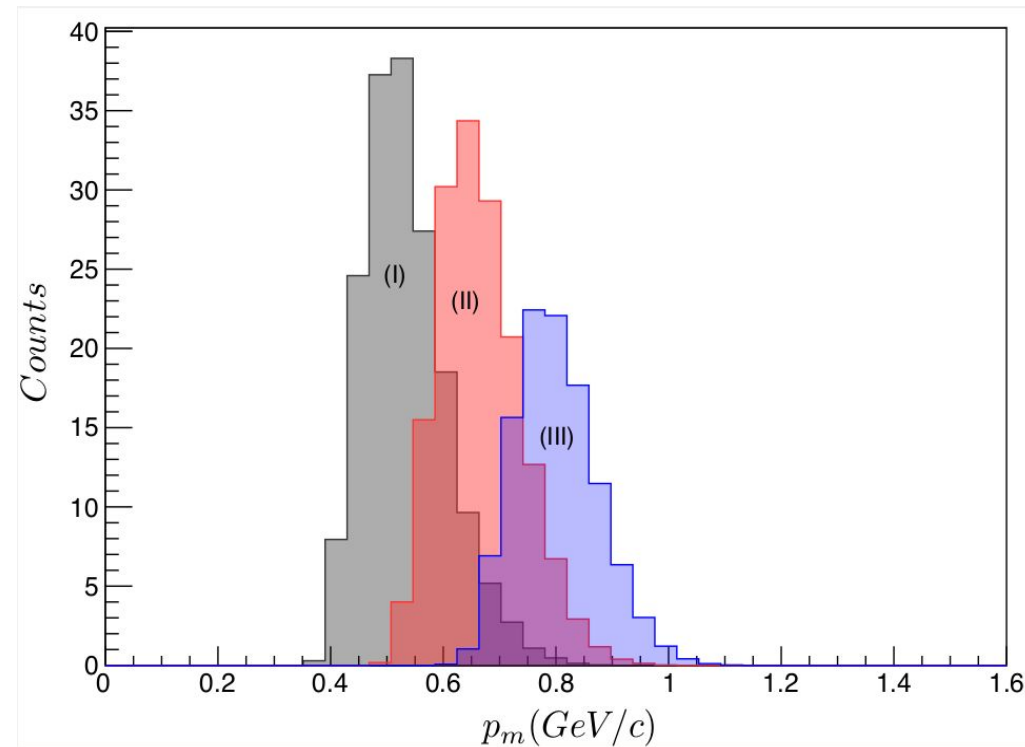
Acknowledgements

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BACKUP SLIDES

Cuts Applied to Extract Yield



Kinematic Cuts:

$$-10 \text{ MeV} \leq E_{\text{miss}} \leq 25 \text{ MeV}$$

$$35^\circ < \theta_{\text{nq}} < 45^\circ$$

$$1.30 < x_{\text{Bj}} < 1.40$$

$$3.1 \leq Q^2 \leq 5.2$$

Solid Angle Cuts:

e-arm $|dx/dz)_{\text{target}}| = |\theta_{\text{target}}| \leq 0.05 \text{ rad}$

(SHMS) $|dy/dz)_{\text{target}}| = |\phi_{\text{target}}| \leq 0.025 \text{ rad}$

p-arm $|dx/dz)_{\text{target}}| = |\theta_{\text{target}}| \leq 0.08 \text{ rad}$

(HMS) $|dy/dz)_{\text{target}}| = |\phi_{\text{target}}| \leq 0.035 \text{ rad}$

Momentum Acceptance Cuts:

e-arm $-8\% \leq \delta_e \leq 4\%$

(SHMS)

p-arm $-15\% \leq \delta_p \leq 15\%$

(HMS)

Systematics @ $P_{\text{miss}} = 0.5 \text{ GeV}$

- Systematics governed by electron scattering angle θ_e

$P_{\text{miss}} (\text{GeV/c})$	Total Error in $d\sigma/d\Omega$ (%)	$E_{\text{INCIDENT}} (\%)$	$E_{\text{FINAL}} (\%)$	$\Delta\theta_e (\%)$	$\Delta\theta_p (\%)$
0.41	8.1	1.4	0.3	7.7	1.9
0.45	7.3	1.2	0.3	6.9	1.8
0.49	6.8	1.1	0.4	6.4	1.8
0.53	6.6	1.0	0.5	6.2	1.8
0.56	6.5	1.0	0.5	6.1	1.9
0.60	6.6	1.0	0.6	6.1	2.0
0.64	6.7	1.0	0.7	6.2	2.1
0.68	6.9	1.0	0.7	6.3	2.2
0.72	7.4	1.1	0.8	6.6	2.4

Systematics @ $P_{\text{miss}} = 0.65 \text{ GeV}$

$P_{\text{miss}} (\text{GeV}/c)$	Total Error in $d\sigma/d\Omega$ (%)	$E_{\text{INCIDENT}} (\%)$	$E_{\text{FINAL}} (\%)$	$\Delta\theta_e (\%)$	$\Delta\theta_p (\%)$
0.53	7.0	1.1	0.4	6.6	1.7
0.57	6.8	1.1	0.5	6.4	1.8
0.61	6.8	1.0	0.6	6.4	2.0
0.64	6.8	1.0	0.6	6.4	2.1
0.68	7.0	1.1	0.7	6.5	2.2
0.72	7.3	1.1	0.8	6.7	2.4
0.76	7.5	1.1	0.9	6.9	2.6
0.80	7.9	1.2	0.9	7.2	2.7
0.84	8.3	1.3	1.0	7.5	2.9