Neutron Spin Structure in the Resonance Region

and

Quark-Hadron Duality

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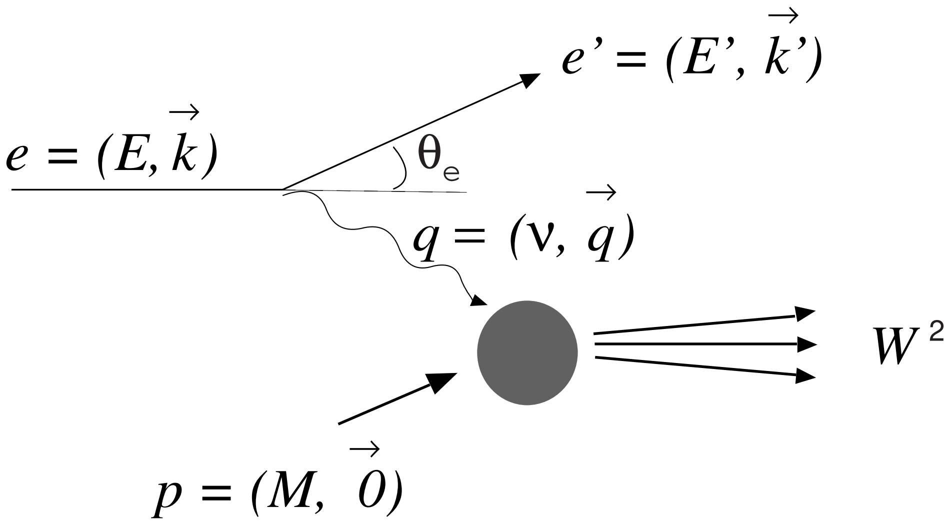
Inclusive Electron Scattering



- 4-momentum transfer of the virtual photon:

$$Q^2 = -q^2 = 4EE' sin^2 \frac{\theta_e}{2}$$

- Invariant mass squared:

$$W^2 = M^2 + 2M\nu - Q^2$$

- Bjorken variable:

$$x = \frac{Q^2}{2M\nu}$$

Structure Functions

Unpolarized case:

$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{Mott}\left[\frac{1}{\nu}F_2(x,Q^2) + \frac{2}{M}F_1(x,Q^2)\tan^2\frac{\theta}{2}\right]$$

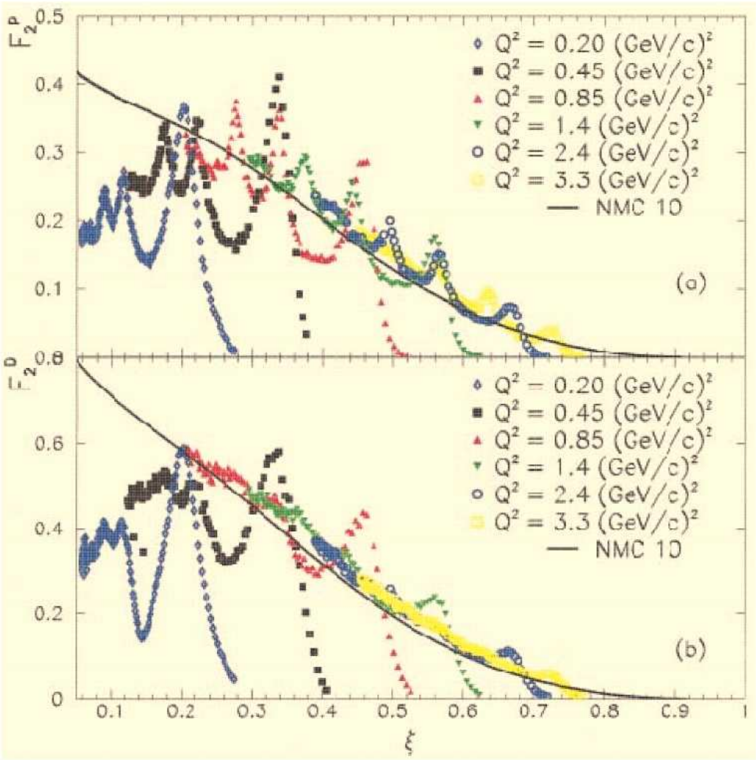
Polarized case:

$$\frac{d^2\sigma_{\uparrow\Uparrow}}{d\Omega dE'} - \frac{d^2\sigma_{\uparrow\Downarrow}}{d\Omega dE'} = \frac{4\alpha^2 E'}{\nu E Q^2}\left[(E + E'\cos\theta)g_1(x,Q^2) - 2Mxg_2(x,Q^2)\right]$$

$$\frac{d^2\sigma_{\uparrow\Rightarrow}}{d\Omega dE'} - \frac{d^2\sigma_{\uparrow\Leftarrow}}{d\Omega dE'} = \frac{4\alpha^2 E'}{\nu E Q^2}\sin\theta\left[g_1(x,Q^2) + \frac{2ME}{\nu}g_2(x,Q^2)\right]$$

Quark-Hadron duality

- *Bloom-Gilman duality* was first observed at SLAC in the 70's on spin independent structure functions.
  E.D. Bloom and F.J. Gilman, Phys. Rev. D **4**, 2901 (1971)

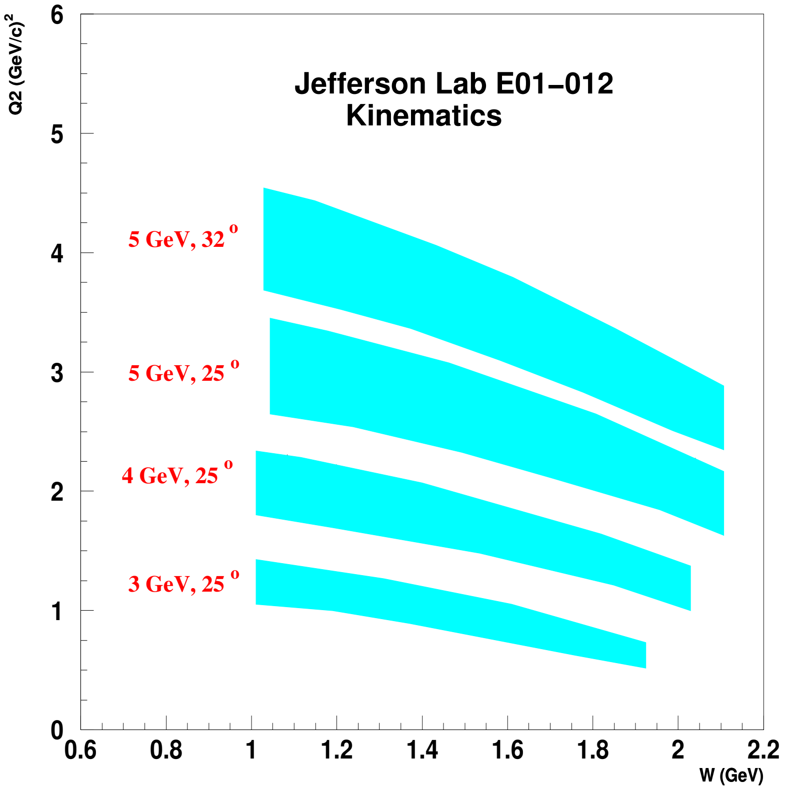


I. Niculescu et al., Phys. Rev. Lett. **85**, 1182 (2000)

- The resonance bumps (low Q^2) average on the scaling curve (higher Q^2).
- Might help us understand the relationship between confinement and asymptotic freedom.

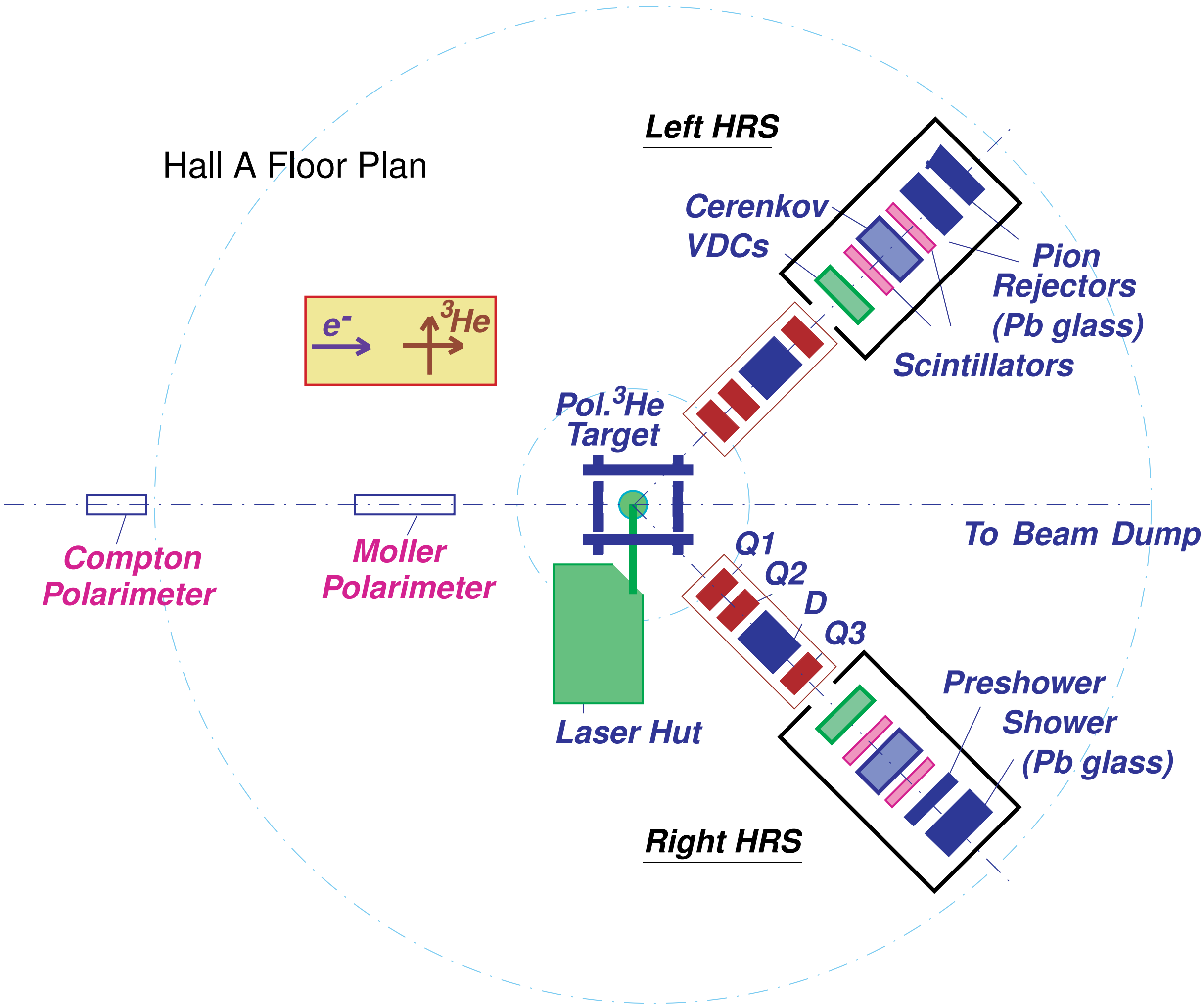
The experiment

- E01-012 measured $g_1^{^3He}$ and $A_1^{^3He}$ in the resonance region up to $Q^2 = 4$ GeV^2.
- Inclusive experiment: $^3\overrightarrow{He}(\vec{e}$,e')X.
- Used *polarized ^3He target* as an *effective polarized neutron*.
- Kinematic coverage from $1 < Q^2 < 4$ (GeV/c)^2 in the resonance region up to W=2 GeV.



The Experimental Setup

- Jefferson Lab *Polarized Electron Beam*.
- The *Polarized ^{3}He Target* System.
- Hall A *High Resolution Spectrometers*.



Extraction of g_1 and A_1

- *Spin structure functions:*

$$g_1 = \frac{F_1}{D'}[A_{\parallel} + tan(\theta/2)A_{\perp}]$$

$$g_2 = \frac{F_1}{D'}\frac{y}{2sin\theta}[\frac{E + E'cos\theta}{E'}A_{\perp} + sin\theta A_{\parallel}]$$

- *Virtual photon asymmetries:*

$$A_{\parallel} = D(A_1 + \eta A_2) \quad \text{and} \quad A_{\perp} = d(A_2 - \xi A_1)$$

Kinematic factors:
$D' = (1-\epsilon)(2-y)/[y(1+\epsilon R)]$
$D = (1 - E'\epsilon/E)/(1+\epsilon R)$
$R(x, Q^2) = \sigma_T/\sigma_L$
$d = D\sqrt{2\epsilon/(1+\epsilon)}$, $\eta = \epsilon\sqrt{Q^2}/(E - E'\epsilon)$, $\xi = \eta(1+\epsilon)/2\epsilon$

Physics asymmetries

$$A_{\parallel,\perp}^{raw} = \frac{\frac{N^-}{Q^-.(1-DT^-)} - \frac{N^+}{Q^+.(1-DT^+)}}{\frac{N^-}{Q^-.(1-DT^-)} + \frac{N^+}{Q^+.(1-DT^+)}}$$

$N^{+(-)}$: the number of events with helicity +(-) passing the cuts (acceptance, PID)

$Q^{+(-)}$: beam charge gated by helicity +(-)

$DT^{+(-)}$: deadtime of the DAQ for helicity +(-)

After correcting for nitrogen dilution, beam and target polarizations, the *physics asymmetry* can be extracted:

$$A_{\parallel,\perp} = \frac{A_{\parallel,\perp}^{raw}}{f_{N_2}.P_{beam}.P_{targ}}$$

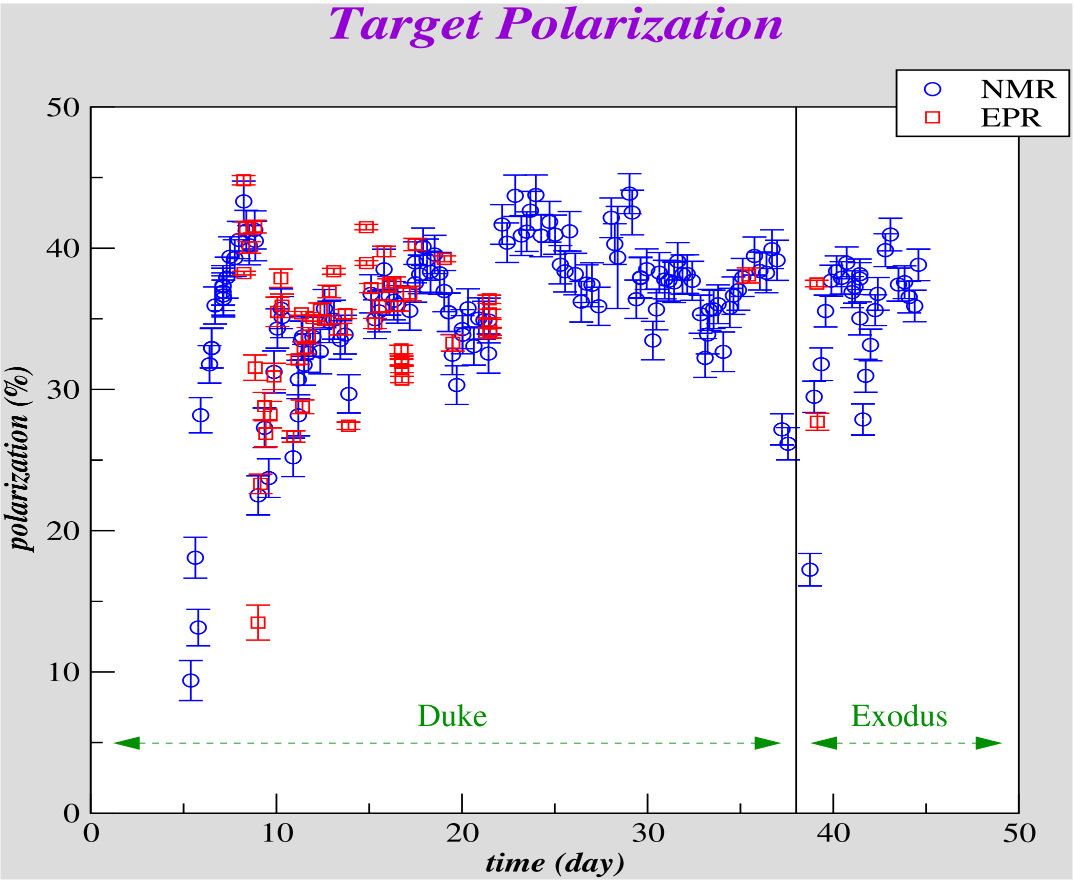
Data analysis

Electron beam (from on-line analysis)

→ Polarization between 70 and 80%.

Target (from on-line analysis)

→ Polarization in beam about 37% in average.

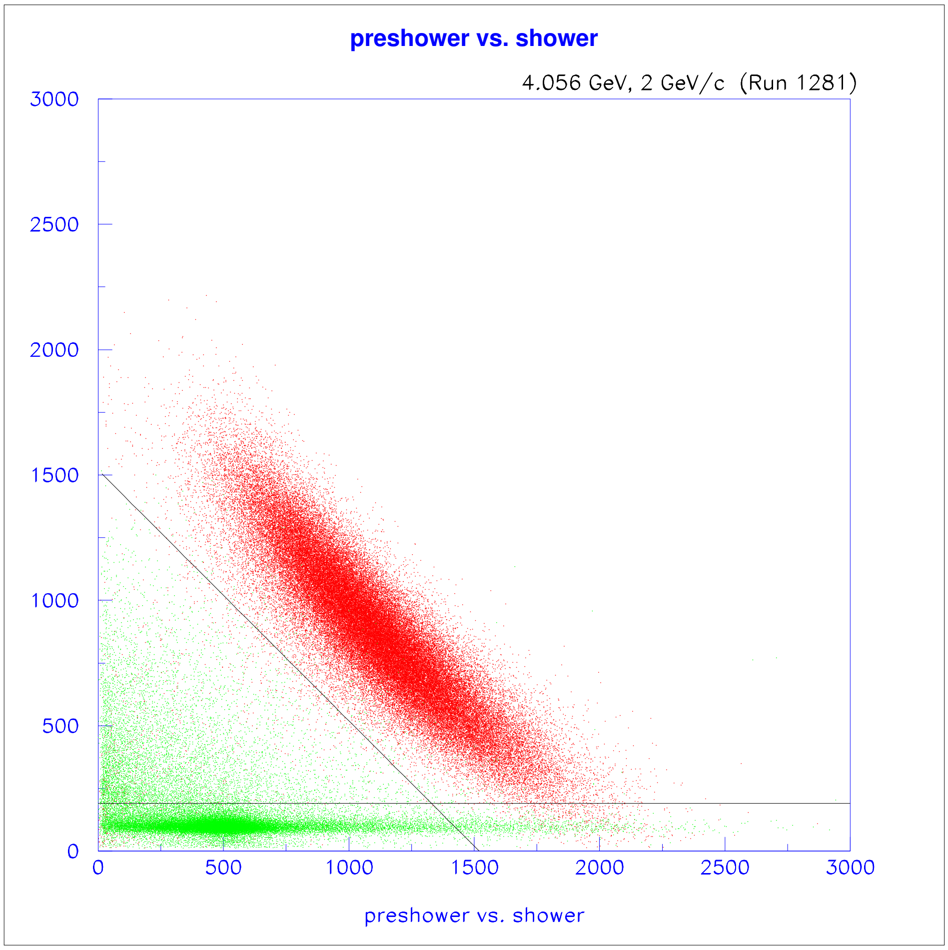


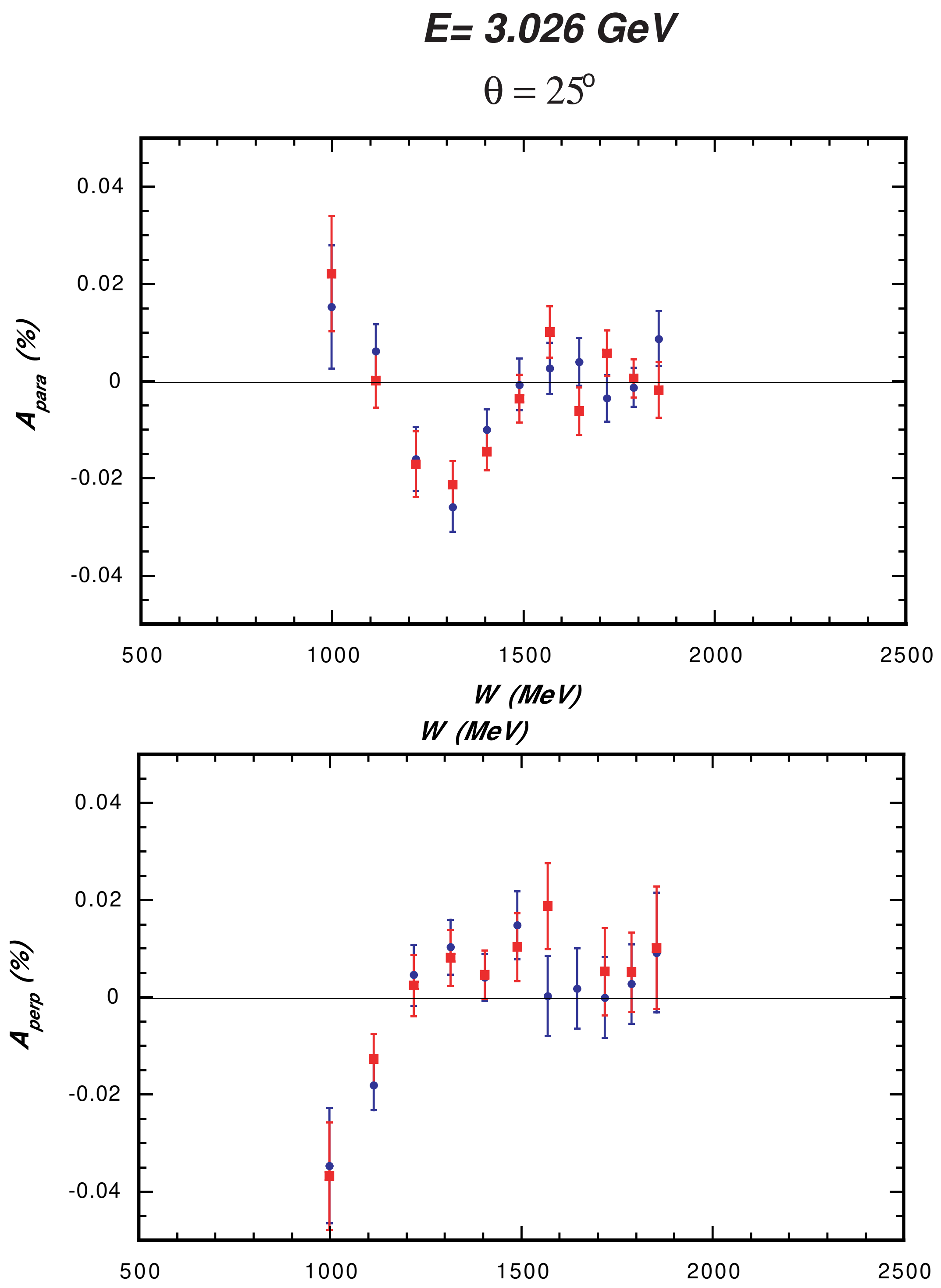
Particle ID analysis

→ After calibration, the Cerenkov detectors show a detection efficiency of 99.9%.

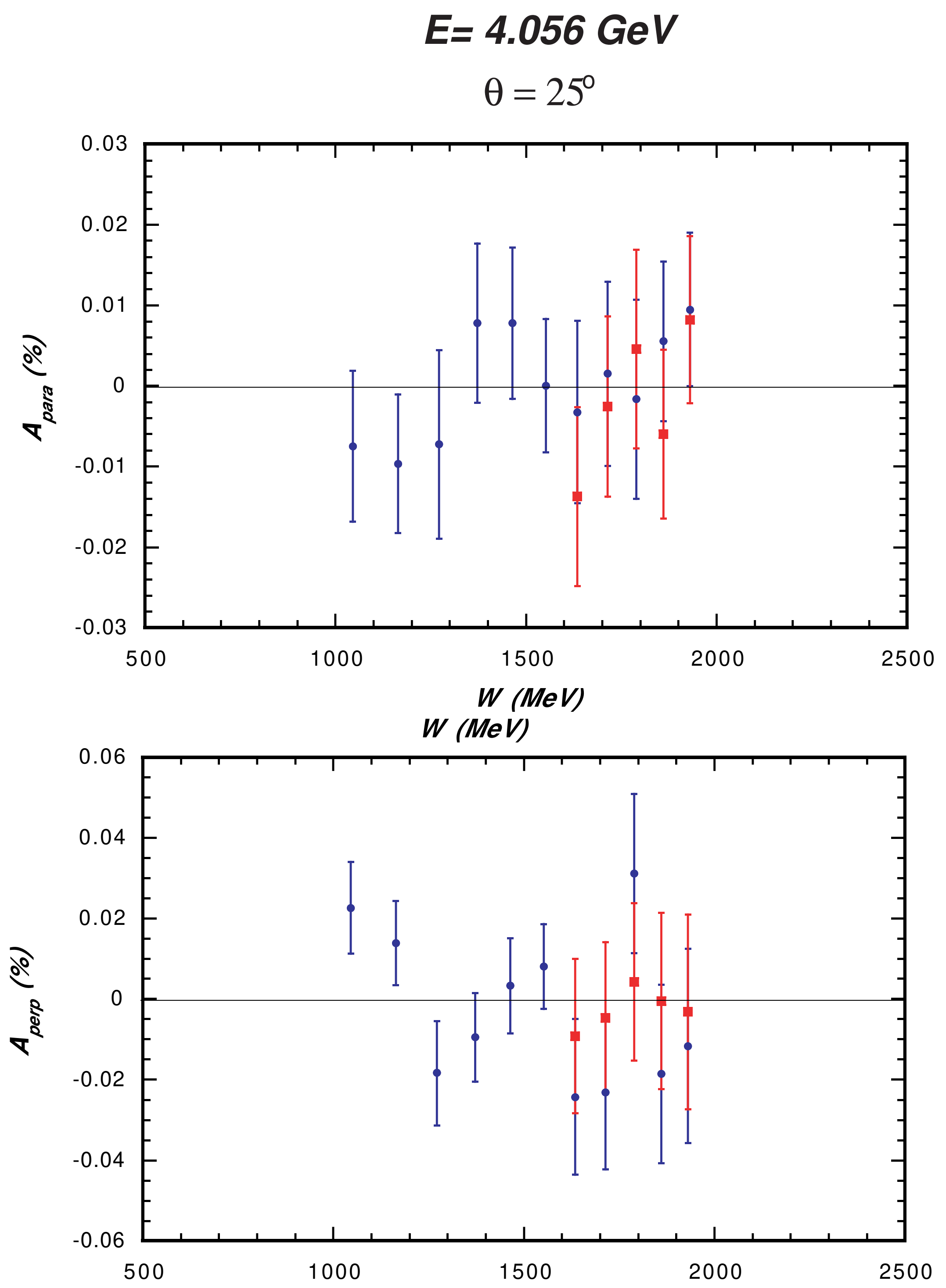
→ Shower detectors had an efficiency better than 99.5%.

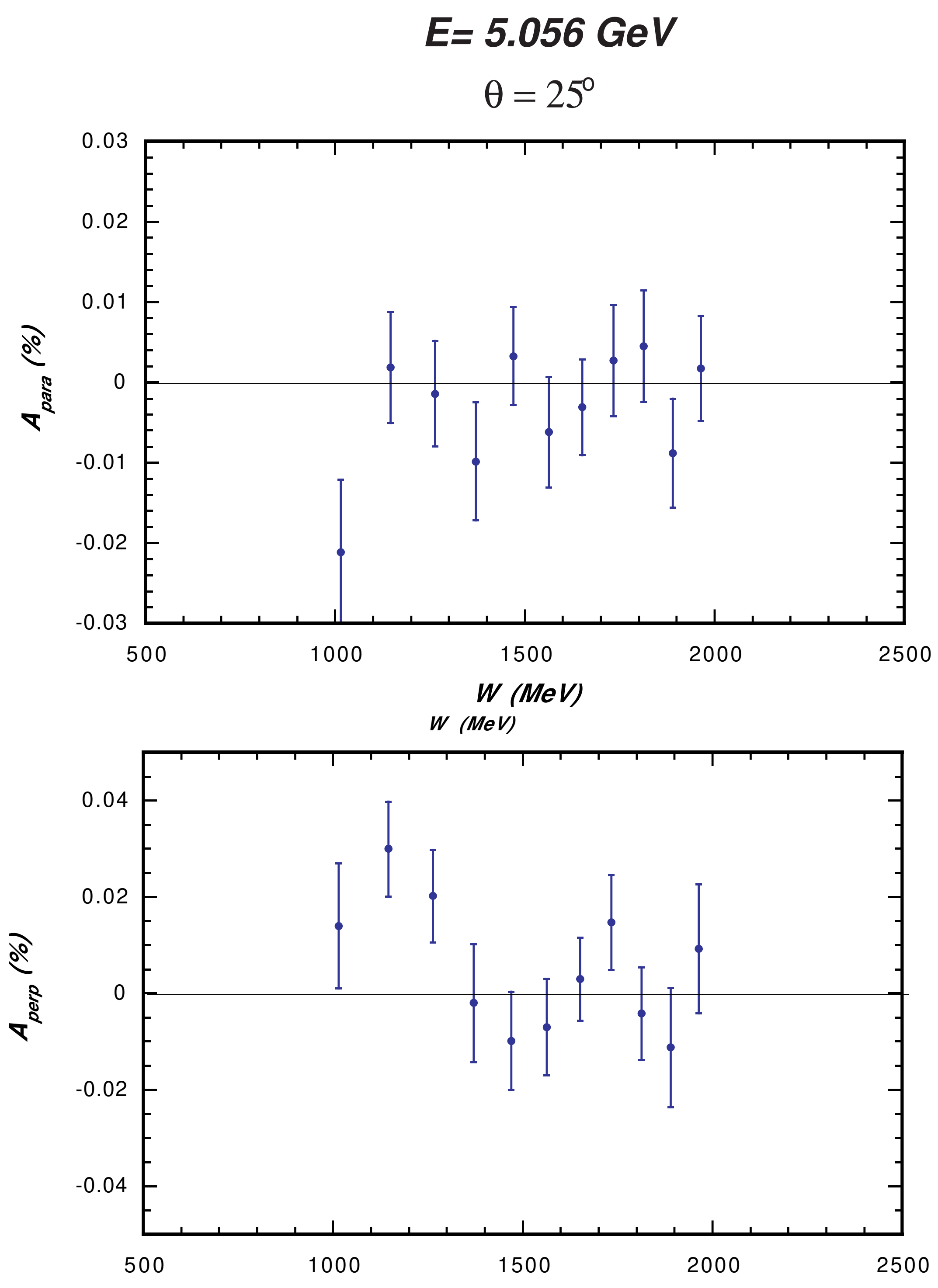
→ Maximum $\pi/e \sim 3$. After PID cut: $\pi/e < 10^{-3}$.



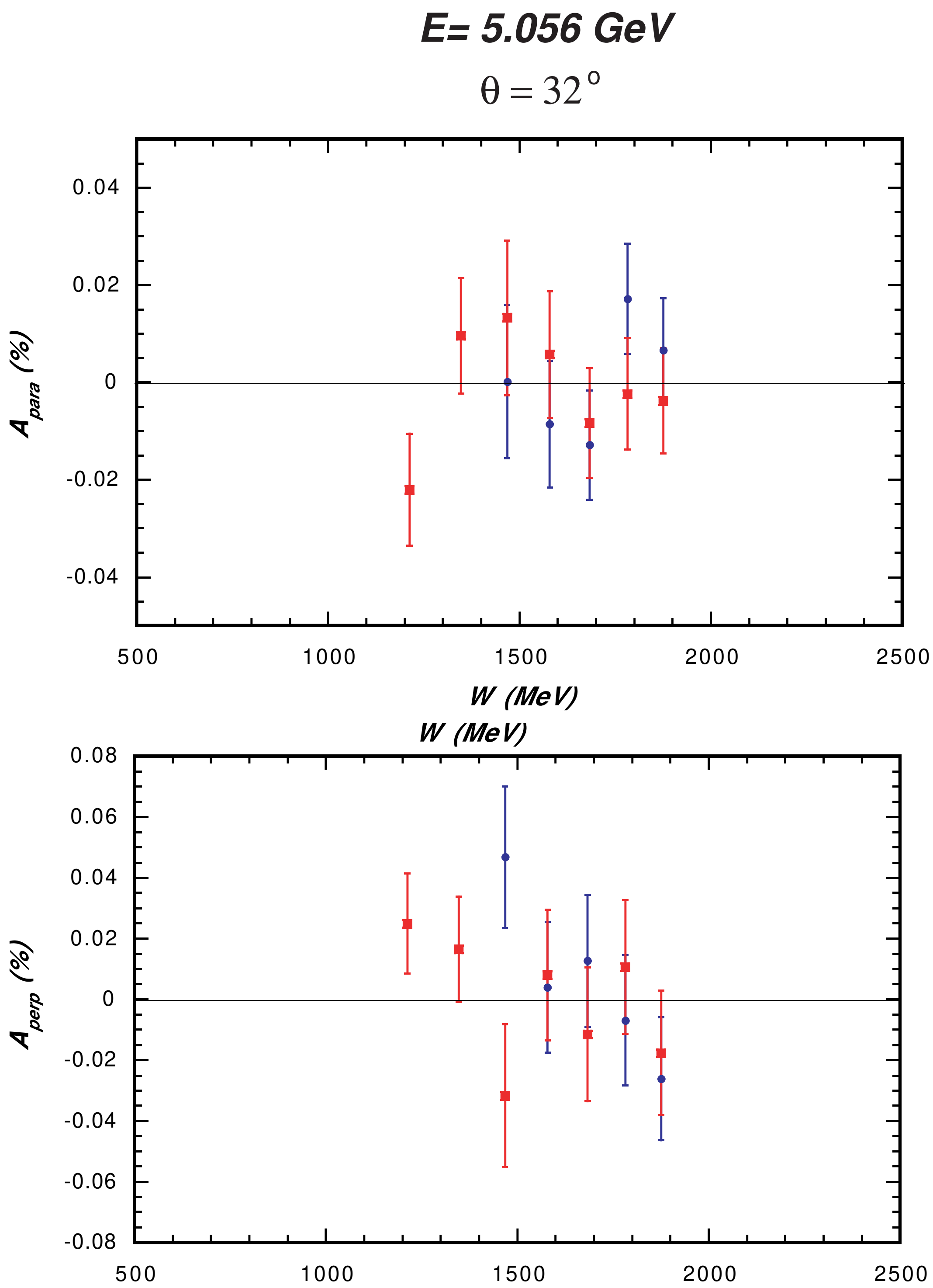


E= 3.026 GeV
θ = 25°
0.04
0.02
0
-0.02
-0.04
A_{para} (%)
500
1000
1500
2000
2500
W (MeV)
W (MeV)
0.04
0.02
0
-0.02
-0.04
A_{perp} (%)
500
1000
1500
2000
2500


E= 4.056 GeV
θ = 25°
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
A_para (%)
500
1000
1500
2000
2500
W (MeV)
W (MeV)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
A_perp (%)
500
1000
1500
2000
2500



E= 5.056 GeV
θ = 25°
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
A_para (%)
500
1000
1500
2000
2500
W (MeV)
W (MeV)
0.04
0.02
0
-0.02
-0.04
A_perp (%)
500
1000
1500
2000
2500


E= 5.056 GeV
θ = 32°
A_para (%)
0.04
0.02
0
-0.02
-0.04
500
1000
1500
2000
2500
W (MeV)
W (MeV)
A_perp (%)
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
500
1000
1500
2000
2500

Future

- → Target analysis.
- → Elastic analysis.
- → Extract asymmetries.
- → Extract cross-sections.
- → Radiative Corrections.
- → Extract g_1^n and A_1^n.