Beam Normal Single Spin Asymmetry in the N-to- Δ Transition

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for the Q-weak Collaboration

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$$B_{n} = M_{total} \begin{bmatrix} \frac{\epsilon_{reg}}{P} - \sum_{i=1}^{4} B_{bi} f_{bi} \\ \\ 1 - \sum_{i=1}^{4} f_{bi} \end{bmatrix}$$

$$\epsilon_{reg} = \epsilon_{raw} - \sum_{i=1}^{5} \left(\frac{\partial \epsilon_{raw}}{\partial T_{i}} \right) \Delta T_{i}$$

$$M_{total} = M_{RC} M_{Det} M_{O^{2}} M_{\phi}$$

(2)

(3)

(4)

(5)

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 $B_{\rm n} = M_{\rm RC} M_{\rm Det} M_{\rm Q^2} M_{\phi} \left[\frac{\frac{\rm erg}{P} - B_{\rm Al} f_{\rm Al} - B_{\rm BB} f_{\rm BB} - B_{\rm QTor} f_{\rm QTor} - B_{\rm el} f_{\rm el}}{1 - f_{\rm Al} - f_{\rm BB} - f_{\rm QTor} - f_{\rm el}} \right]$

$$B_{\rm n} = M_{\rm kin} \left[\frac{\frac{\epsilon_{\rm reg}}{P} - B_{\rm Al} f_{\rm Al} - B_{\rm BB} f_{\rm BB} - B_{\rm QTor} f_{\rm QTor} - B_{\rm el} f_{\rm el}}{1 - f_{\rm Al} - f_{\rm BB} - f_{\rm QTor} - f_{\rm el}} \right]$$
(6)

$$\frac{\epsilon_{reg}}{P} = \frac{(1 - f_{total})}{M_{bin}} B_n + B_{el} f_{el} + others \tag{7}$$

$$\frac{(1 - f_{total})}{M_{hin}} B_n = \frac{\epsilon_{reg}}{P} - B_{el} f_{el} - others \tag{8}$$

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$$B_{n} = \frac{\frac{\epsilon_{reg}}{P} - B_{Al}f_{Al} - B_{BB}f_{BB} - B_{QTor}f_{QTor} - B_{el}f_{el}}{1 - f_{Al} - f_{BB} - f_{QTor} - f_{el}}$$
(9)

- $\epsilon_{reg} = \epsilon_{reg}^{in} M_{\phi}, \; \epsilon_{reg}^{in}$ is the measured asymmetry
- $B_{Al} = \epsilon_{reg}^{Al} M_{\phi}/P, \ \epsilon_{reg}^{Al} = (\epsilon_{reg}^{DS-Al} + \epsilon_{reg}^{US-Al})/2$
- $ightharpoonup f_{A1}$, measured
- ▶ $B_{BB} = 0 \pm 0.313 \text{ ppm}$, AncELOG 122
- $ightharpoonup f_{BB}$, measured
- \triangleright $B_{Qtor} = 0 \pm 10 \text{ ppm}$
- $ightharpoonup f_{QTor}$, measured
- ▶ $B_{el} = \sqrt{\frac{Q_{in}^2}{Q_{el}^2} B_T^{el}}$, B_T^{el} is Buddhini's final asymmetry. Will change after calculation from Gorchtein. Mark D. has preliminary no. but not finalized yet.
- $ightharpoonup f_{el}$, simulation

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$$B_{n} = M_{RC} M_{Det} M_{Q^{2}} \left[\frac{\frac{\epsilon_{reg}}{P} - B_{Al} f_{Al} - B_{BB} f_{BB} - B_{QTor} f_{QTor} - B_{el} f_{el}}{1 - f_{Al} - f_{BB} - f_{QTor} - f_{el}} \right]$$
(10)

- $\epsilon_{reg} = \epsilon_{reg}^{in} M_{\phi}$, ϵ_{reg}^{in} is the measured asymmetry
- $ightharpoonup f_{Al}$, measured
- \triangleright $B_{BB} = 0$
- $ightharpoonup f_{BB}$, measured
- $ightharpoonup B_{Qtor} = 0$
- $ightharpoonup f_{QTor}$, measured
- ▶ $B_{el} = \sqrt{\frac{Q_{in}^2}{Q_{el}^2} B_T^{el}}$, B_T^{el} is Buddhini's final asymmetry. Will change after calculation from Gorchtein
- $ightharpoonup f_{el}$, simulation
- \triangleright M_{RC} , needs update
- ▶ M_{Det} , needs update
- ▶ M_{Q^2} ?, probably we should change it to M_{θ} as we will be quoting numbers at $\theta = 8.3$ degrees. But need to know the uncertainty on θ .

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$$A_{\rm ep} = R_{\rm total} \begin{bmatrix} \frac{A_{\rm msr}}{P} - \sum_{i=1}^{4} A_{\rm bi} f_{\rm bi} \\ \frac{1}{1 - \sum_{i=1}^{4} f_{\rm bi}} \end{bmatrix}$$
(11)

$$A_{\text{msr}} = A_{\text{raw}} + A_T + A_L + A_{\text{reg}} \tag{12}$$

$$R_{\text{total}} = R_{\text{RC}} R_{\text{Det}} R_{\text{Bin}} R_{O^2} \tag{13}$$

$$A_{\rm ep} = R_{\rm RC} R_{\rm Det} R_{\rm Bin} R_{\rm Q^2} \left[\frac{A_{\rm msr}}{P} - A_{\rm Al} f_{\rm Al} - A_{\rm BB} f_{\rm BB} - A_{\rm QTor} f_{\rm QTor} - A_{\rm in} f_{\rm in}}{1 - f_{\rm Al} - f_{\rm BB} - f_{\rm QTor} - f_{\rm el}} \right]$$
(14)

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Q-WEAK FIRST RESULT 2

	Correction	Contr	ibution	
	Value [ppb]	to ΔA	_{ep} [ppb]	
Normalization Factors Applied to A_{raw}				
Beam Polarization 1/P	-21		5	
Kinematics R_{total}	5		9	
Background Dilution $1/(1-f_{total})$	-7		-	
Asymmetry Corrections				
Beam Asymmetries κA_{reg}	-40		13	
Transverse Polarization κA_T	0		5	
Detector Linearity κA_L	0		4	
Backgrounds	$\kappa P f_{\rm bi} A_{\rm bi}$	$\delta(f_{ m bi})$	$\delta(A_{ m bi})$	
Target windows (Al)	-58	4	8	
Beamline scattering (BB)	11	3	23	
Other neutral bkg (QTor)	0	1	<1	
Inelastics (in)	1	1	<1	

Table: Summary of corrections and the associated systematic uncertainty, in parts per billion. The table shows the contributions of normalization factors on A_{raw} , then the properly normalized contributions from other sources. Background correction terms listed here include only $R_{tot}f_iA_i/(1-f_{tot})$ uncertainties in A_{ep} due to dilution fraction and background asymmetry uncertainties are noted separately.

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BEAM NORMAL SINGLE SPIN ASYMMETRY 2

Input parameters				
$5.127 \pm 0.455 \text{ ppm}$ (Det. acpt. corrected)				
0.875 ± 0.009				
0.9938				
Background corrections				
Asymmetry	Dilution	Correction		
(A_{bi})	(f_{bi})	$c_i = \kappa P A_{bi} f_l$		
[ppm]		[ppm]		
9.185 ± 1.279	0.033 ± 0.002	1.364		
2.239 ± 6.843	0.018 ± 0.001	0.180		
0.000 ± 0.200	0.024 ± 0.010	0.000		
-4.885 ± 0.093	0.701 ± 0.070	-13.809		
Other corrections				
1.010 ± 0.004				
0.998 ± 0.001				
1.000 ± 0.012				
	$ \begin{array}{c c} 5.127 \pm 0.455 \text{ p} \\ 0.875 \pm 0.009 \\ 0.9938 \\ \hline \text{ground corrections} \\ \text{Asymmetry} \\ & (A_{bi}) \\ \text{[ppm]} \\ 9.185 \pm 1.279 \\ 2.239 \pm 6.843 \\ 0.000 \pm 0.200 \\ -4.885 \pm 0.093 \\ \hline \text{ther corrections} \\ \hline & 1.010 \pm 0.004 \\ 0.998 \pm 0.001 \\ \hline \end{array} $	$ \begin{array}{c c} 5.127 \pm 0.455 \text{ ppm} & \text{(Det.} \\ 0.875 \pm 0.009 & \\ 0.9938 \\ \hline \text{ground corrections} \\ \hline & \text{Asymmetry} & \text{Dilution} \\ & (A_{bi}) & (f_{bi}) \\ & [\text{ppm}] \\ \hline & 9.185 \pm 1.279 & 0.033 \pm 0.002 \\ 2.239 \pm 6.843 & 0.018 \pm 0.001 \\ 0.000 \pm 0.200 & 0.024 \pm 0.010 \\ -4.885 \pm 0.093 & 0.701 \pm 0.070 \\ \hline \text{ther corrections} \\ \hline & 1.010 \pm 0.004 \\ 0.998 \pm 0.001 \\ \hline \end{array} $		

Table: Summary of input quantities.

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Frame 61

$$A_{ep} = \left[\frac{-G_F Q^2}{4\sqrt{2}\pi\alpha} \right] \left[\frac{\varepsilon G_E^{p\gamma} G_E^{pZ} + \tau G_M^{p\gamma} G_M^{pZ} - (1 - 4\sin^2\theta_W)\varepsilon' G_M^{p\gamma} G_A^{Z}}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right]$$

$$\varepsilon = \frac{1}{1 + 2(1 + \tau)\tan^2\frac{\theta}{2}}, \varepsilon' = \sqrt{\tau (1 + \tau)(1 - \varepsilon^2)}, \tau = \frac{Q^2}{4M}$$
(16)

$$C^{pZ} = (1 + 4\pi i \pi^2 0) C^{p\gamma} = C^{n\gamma} = C^s$$
(17)

$$G_{E,M}^{pZ} = (1 - 4\sin^2\theta_W)G_{E,M}^{p\gamma} - G_{E,M}^{n\gamma} - G_{E,M}^s$$
 (17)

$$\frac{A_{ep}}{A_0} = \left[\frac{\varepsilon G_E^{p\gamma}(Q_W^p G_E^{p\gamma} - G_E^{n\gamma} - G_E^s) + \tau G_M^{p\gamma}(Q_W^p G_M^{p\gamma} - G_M^{n\gamma} - G_M^s) - (1 - 4\sin^2\theta_W)\varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2}\right]$$

$$(18)$$

$$\frac{A_{ep}}{A_0} = Q_W^p \left[\frac{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{\varepsilon G_E^{p\gamma} G_E^{n\gamma} + \tau G_M^{p\gamma} G_M^{n\gamma}}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] + \left[(-1) \frac{(1 - 4 \sin^2 \theta_W) \varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right]$$

As $\theta \to 0$, $\varepsilon \to 1$, and $\tau \ll 1$

Nuruzzaman [HU] DNP 2013 Q-weak $A_{Q-weak} = \left\lceil \frac{-G_F Q^2}{4\sqrt{2}\pi\alpha} \right\rceil Q_W^p \left\lceil \frac{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right\rceil =$

 $Q_W^p = (1 - 4\sin^2\theta_W)$

Frame 71

$$\begin{split} A_{axial} &= \left[\frac{-G_F Q^2}{4\sqrt{2}\pi\alpha}\right] G_A^e \left[\frac{(1-4\sin^2\theta_W)\varepsilon' G_M^{p\gamma} G_A^Z}{\varepsilon(G_E^{p\gamma})^2 + \tau(G_M^{p\gamma})^2}\right] = \\ A_{ep} &= A_{Q-weak} + A_{hadronic} + A_{axial} = \end{split}$$

$$\frac{A_{ep}}{A_0} = \left[Q_W^p + Q^2 B(Q^2, \theta) \right]$$

$$A_{ep} = \left[\frac{-G_F Q^2}{4\sqrt{2}\pi^2} \right] \left[Q_W^p + B(Q^2, \theta) \right] = A_0 \left[Q_W^p + B(Q^2, \theta) \right]$$

$$A_{ep} = \left[\frac{-G_F Q^2}{4\sqrt{2}\pi\alpha} \right] \left[Q_W^p + Q^2 B(Q^2, \theta) \right] = A_0 \left[Q_W^p + Q^2 B(Q^2, \theta) \right]$$

$$A_{ep} = A_0 \left[Q_W^p + B(Q^2, \theta) \right]$$
$$A_0 = \frac{-G_F Q^2}{\sqrt{2}}$$

$$A_{hadronic} = \left[\frac{-G_F Q^2}{4\sqrt{2}\pi\alpha} \right] Q_W^n \left[\frac{\varepsilon G_E^{p\gamma} G_E^{p\gamma} + \tau G_M^{p\gamma} G_M^{n\gamma}}{\varepsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \right] =$$
(21)

$$\left| \frac{Z}{A} \right| = \tag{22}$$

(24)

(20)

(28)

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Q-weak

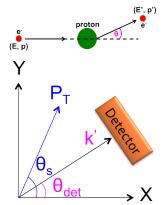
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Measured asymmetry

$$A_{M} = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}} = -B_{n} \vec{P_{T}} \cdot \hat{n} = -B_{n} P_{T} \sin(\phi_{det} - \phi_{s})$$

where $\hat{n} = \frac{\vec{k} \times \vec{k'}}{|\vec{k} \times \vec{k'}|}$ and $\vec{P_T}$ is transverse polarization and B_n is BNSSA.

Measured asymmetry has a small azimuthal dependence.



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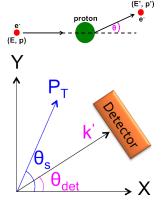
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Measured asymmetry

$$A_{M} = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}} = -B_{n}\vec{P_{T}} \cdot \hat{n} = -B_{n}P_{T}\sin(\phi_{det} - \phi_{s})$$

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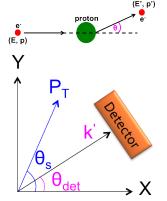
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Measured asymmetry

$$A_{M} = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}} = -B_{n}\vec{P_{T}} \cdot \hat{n} = -B_{n}P_{T}\sin(\phi_{det} - \phi_{s})$$

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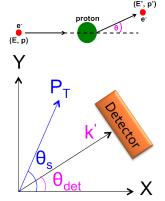
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Measured asymmetry

$$A_{M} = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}} = -B_{n}\vec{P_{T}} \cdot \hat{n} = -B_{n}P_{T}\sin(\phi_{det} - \phi_{s})$$

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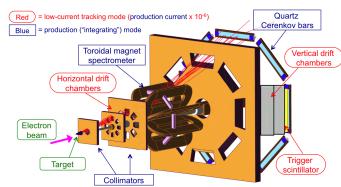
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EXPERIMENTAL APPARATUS

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Ebeam = 1.155 GeV $(Q^2) \sim 0.025 \text{ (GeV/c)}$ $(\theta) \sim 7.9^{\circ} \pm 3^{\circ}$ $(\theta) \sim 7.9^{\circ} \pm 3^{\circ}$ Current = 180 μΛ Polarization = 89% Target = 34.4 cm LH₂ Cryopower = 2.5 kW Luminosity



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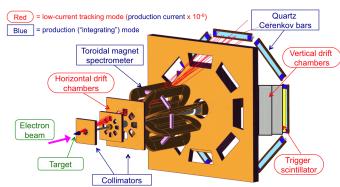
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EXPERIMENTAL APPARATUS

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Ebeam = 1.155 GeV $\langle Q^2 \rangle \sim 0.025 \text{ (GeV/c)}^2 \langle \theta \rangle \sim 7.9^o \pm 3^o$ $\langle \theta \rangle \sim 7.9^o \pm 3^o$ Current = 180 μA Polarization = 89% Target = 34.4 cm LH₂ Cryopower = 2.5 kW Luminosity $2\text{x}1039\text{s}^{-1}\text{cm}^{-2}$



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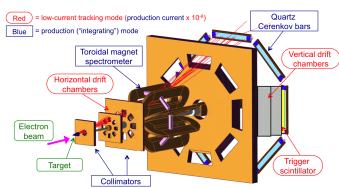
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Ebeam = 1.155 GeV $\langle Q^2 \rangle \sim 0.025 (\text{GeV/c})^2 \langle \theta \rangle \sim 7.9^{\circ} \pm 3^{\circ} \langle \theta \rangle \sim 7.9^{\circ} \pm 3^{\circ} \langle \theta \rangle \sim 7.9^{\circ} \pm 3^{\circ}$ Current = 180 μ A Polarization = 89% Target = 34.4 cm LH₂ Cryopower = 2.5 kW Luminosity $2 \times 10398^{-1} \text{cm}^{-2}$



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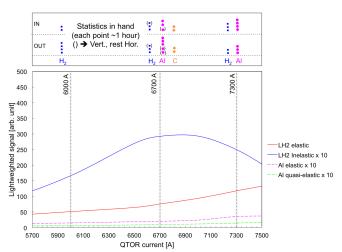
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Transverse N-to- Δ Data Set

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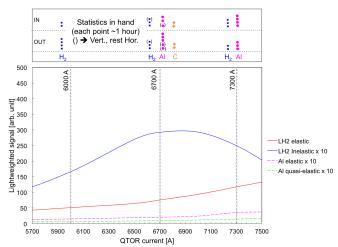
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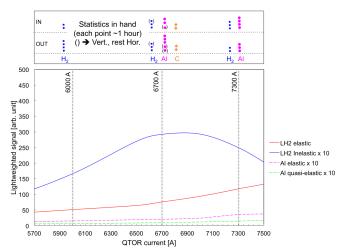
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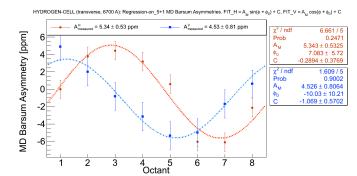


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Transverse Asymmetries for N-to- Δ in Hydrogen

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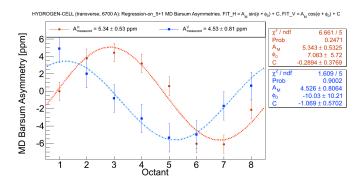


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Transverse Asymmetries for N-to- Δ in Hydrogen

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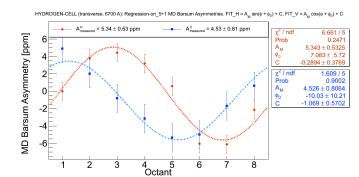
Introduction Basics Methodology Experiment Analysis Results Summary

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Transverse Asymmetries for N-to- Δ in Hydrogen

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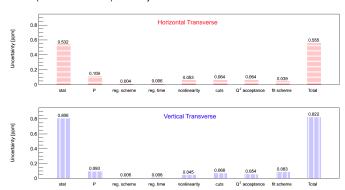
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SUMMARY OF UNCERTAINTIES

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(HYDROGEN-CELL) Summary of Uncertainties for Transverse N-to-Δ



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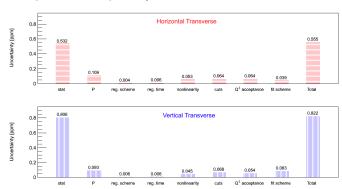
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SUMMARY OF UNCERTAINTIES

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(HYDROGEN-CELL) Summary of Uncertainties for Transverse N-to-Δ



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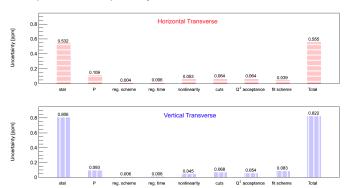
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SUMMARY OF UNCERTAINTIES

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(HYDROGEN-CELL) Summary of Uncertainties for Transverse N-to-Δ



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Transverse N-to- Δ Data Set Transverse Asymmetries for N-to- Δ in Hydroge Summary of Uncertainties

RESULTS

Extraction of Physics Asymmetry Results

Summary

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EXTRACTING PHYSICS ASYMMETRY

$$egin{aligned} oldsymbol{A_{ep}} &= R_{total} & egin{aligned} & A_M/P - \sum_{i=1}^4 f_i A_i \ & & 1 - \sum_{i=1}^4 f_i \end{aligned}$$

- Polarization
- ▶ Multiplicative corrections $R_{total} = R_{RC}R_{Det}R_{Bin}R_Q$ Radiative correction R_{RC} Detector bias correction R_{Det} Bis centering correction R_{Bin} O^2 correction R_{O^2}
- Background corrections
 Al. window correction $A_{b1} = \text{ppm}$, $f_{b1} = c_{b1} = \text{ppm}$, $f_{b2} = c_{b2} = \text{ppm}$ Beamline background $A_{b2} = \text{ppm}$, $f_{b2} = c_{b2} = \text{ppm}$ Other neutral $A_{b3} = \text{ppm}$, $f_{b3} = c_{b3} = \text{ppm}$ Inelastic correction $A_{b4} = \text{ppm}$, $f_{b4} = c_{b4} = \text{ppm}$

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Extracting Physics Asymmetry

$$A_{ep} = R_{total} \begin{bmatrix} A_M/P - \sum_{i=1}^{4} f_i A_i \\ \frac{1 - \sum_{i=1}^{4} f_i} \end{bmatrix}$$

- Polarization
- ▶ Multiplicative corrections $R_{total} = R_{RC}R_{Det}R_{Bin}R_Q$ Radiative correction R_{RC} Detector bias correction R_{Det} Bis centering correction R_{Bin} O^2 correction R_{O^2}
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Nuruzzaman [HU]

Extracting Physics Asymmetry

$$A_{ep} = R_{total} \begin{bmatrix} A_M/P - \sum_{i=1}^{4} f_i A_i \\ \frac{1}{1 - \sum_{i=1}^{4} f_i} \end{bmatrix}$$

- ▶ Polarization
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EXTRACTING PHYSICS ASYMMETRY

$$A_{ep} = R_{total} \begin{bmatrix} A_M/P - \sum_{i=1}^{4} f_i A_i \\ \frac{1 - \sum_{i=1}^{4} f_i} \end{bmatrix}$$

▶ Polarization

- ▶ Multiplicative corrections $R_{total} = R_{RC}R_{Det}R_{Bin}R_{Q^2}$ Radiative correction R_{RC} Detector bias correction R_{Det} Bis centering correction R_{Bin} Q^2 correction R_{O^2}
- ▶ Background corrections
 Al. window correction $A_{b1} = \text{ppm}$, $f_{b1} = c_{b1} = \text{pp}$ Beamline background $A_{b2} = \text{ppm}$, $f_{b2} = c_{b2} = \text{ppm}$ Other neutral $A_{b3} = \text{ppm}$, $f_{b3} = c_{b3} = \text{ppm}$



Extracting Physics Asymmetry

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- ▶ Polarization
- ▶ Multiplicative corrections $R_{total} = R_{RC}R_{Det}R_{Bin}R_{O^2}$ Radiative correction R_{RC} Detector bias correction R_{Det} Bis centering correction R_{Bin} Q^2 correction R_{Q^2}
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Extracting Physics Asymmetry

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- ▶ Polarization
- ▶ Multiplicative corrections $R_{total} = R_{RC}R_{Det}R_{Bin}R_{O^2}$ Radiative correction R_{RC} Detector bias correction R_{Det} Bis centering correction R_{Bin} Q^2 correction R_{O^2}
- ► Background corrections Al. window correction $A_{b1} = ppm$, $f_{b1} = c_{b1} = ppm$ Beamline background $A_{b2} = ppm$, $f_{b2} = c_{b2} = ppm$ Other neutral $A_{b3} = ppm$, $f_{b3} = c_{b3} = ppm$ Inelastic correction $A_{b4} = ppm$, $f_{b4} = c_{b4} = ppm$



000	000	0	000	0	0
Quantity	Asymmetry [ppm]	Dilution	Cor. $c_i = A_{bi} f_{bi}$	Re	f.
Aluminum window	A_{b1} 8.431 ± 0.985	$f_{b1}0.033 \pm 0.002$	$c_{b1} 0.033 \pm 0.002$	ELOG 451 (.	Analysis)[?]
Beamline scattering	$A_{b2} = 0.000 \pm 0.000$	$ f_{b2}0.033 \pm 0.002 $	$c_{b1} 0.033 \pm 0.002$	DocDB :	1655 [?]

Analysis

 $|f_{b3}0.033 \pm 0.002|c_{b1}0.033 \pm 0.002|$

 $|f_{b4}0.033 \pm 0.002|c_{b1}0.033 \pm 0.002|$

Summary

DocDB 1655 [?]

DocDB 1655 [?]

 0.033 ± 0.002

 f_{b1}

ppm

DocDB 10

Basics

Elastic asymmetry

 A_{b3}

 A_{b4}

Other neutrals

Inelastics

Table: Background correction table.

 0.000 ± 0.000

 -5.305 ± 0.166

Quantity		Value				Refere
Inelastic measured asymmetry	A_M^{in}	4.789 ± 0.844	ppm			This ana
Polarization	P	0.879 ± 0.018				DocDB 16
Aluminum asymmetry	A_{b1}	8.431 ± 0.985	ppm	f_{b1}	0.033 ± 0.002	This ana
QTOR transport channel	A_{b2}	0.000 ± 0.000	ppm	f_{b1}	0.033 ± 0.002	DocDB 16
Beamline background	A_{b3}	0.000 ± 0.000	ppm	f_{b1}	0.033 ± 0.002	DocDB 16

 -5.305 ± 0.166

Table: Input table.

 A_{b4}

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Transverse Asymmetries for N-to- Δ in Hydroge Summary of Uncertainties

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Extraction of Physics Asymmetry

SUMMARY

Summary

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Summary

Summary

- ▶ The uncertainty in measured N-to- Δ transverse asymmetry is dominated by statistics for in hydrogen. Next largest contribution comes from polarization. Most other systematic uncertainties are under control.
- ▶ A conservative estimate of extracted physics asymmetry using preliminary background asymmetries and dilutions is $A_{PHYS}^{in} = 41.05 \pm 7.90$ ppm. Largest contribution in the uncertainties is from elastic dilution.

To D

- ▶ Beamline background, detector bias correction, radiative correction etc
- ▶ Update dilution factors.
- $\,\blacktriangleright\,$ Quantify impact of these results on the PV N-to- $\!\Delta$ measurement and talk to theoretician for model calculation.

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Summary

Summary

- The uncertainty in measured N-to-Δ transverse asymmetry is dominated by statistics for in hydrogen. Next largest contribution comes from polarization. Most other systematic uncertainties are under control.
- ▶ A conservative estimate of extracted physics asymmetry using preliminary background asymmetries and dilutions is $A_{PHYS}^{in} = 41.05 \pm 7.90$ ppm. Largest contribution in the uncertainties is from elastic dilution.

To Do

- ▶ Beamline background, detector bias correction, radiative correction etc.
- ► Update dilution factors.
- ▶ Quantify impact of these results on the PV N-to- Δ measurement and talk to theoretician for model calculation.

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Backup Slides

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- ► Item A
- ► Item B
 - ► Subitem 1
 - Subitem
 - ► Subtem 2
- ► Item C

- ► Item A
- ► Item B
 - ► Subitem 1
- ► Subtem 2
- ► Item C
- ► Jump to Theorem 36

Table: Table

No.	Ordinary	Blue	Pink	Yellow	Green	RCM		
α =0.05								
H=2	95.0	75.3	75.7	79.5	72.0			
H=3	95.6	87.0	87.3	87.6	85.2			
H=4	95.0	91.6	91.9	90.3	90.2	93.3		
H=5	95.2	93.5	93.7	91.3	91.8	94.3		
H=6	94.9	93.8	94 1	92.6	92.8	94.7		

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Table: Table

No.	Ordinary	Blue	Pink	Yellow	Green	RCM			
	α =0.5								
H=2	95.0	91.4	91.2	79.5	99.9				
H=3	95.6	95.1	95.1	87.6	95.1				
H=4	95.0	94.8	94.8	90.3	93.5	95.5			
H=5	95.2	95.1	95.2	91.3	93.1	95.9			
H=6	94.9	94.8	94.8	92.6	93.4	95.5			

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Table: Table

No.	Ordinary	Blue	Pink	Yellow	Green	RCM
			$\alpha = 0$	0.05		
H=2	95.0	75.3	75.7	79.5	72.0	
H=3	95.6	87.0	87.3	87.6	85.2	
H=4	95.0	91.6	91.9	90.3	90.2	93.3
H=5	95.2	93.5	93.7	91.3	91.8	94.3
H=6	94.9	93.8	94.1	92.6	92.8	94.7
	α =0.5					
H=2	95.0	91.4	91.2	79.5	99.9	
H=3	95.6	95.1	95.1	87.6	95.1	
H=4	95.0	94.8	94.8	90.3	93.5	95.5
H=5	95.2	95.1	95.2	91.3	93.1	95.9
H=6	94.9	94.8	94.8	92.6	93.4	95.5

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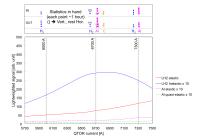


Figure: something

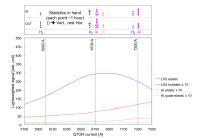


Figure: something



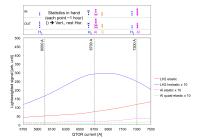


Figure: something

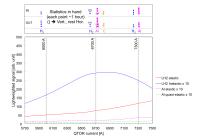
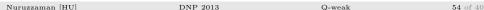


Figure: something



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BACKUP frame

Метнорого

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METHODOLOG

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Some basic formalism about qweak.

$$A_{ep} = \left[\frac{-G_F Q^2}{4\sqrt{2}\pi\alpha} \right] \left[\frac{\varepsilon G_E^{\gamma} G_E^Z + \tau G_M^{\gamma} G_M^Z - (1 - 4\sin^2\theta_W)\varepsilon' G_M^{\gamma} G_A^Z}{\varepsilon (G_E^{\gamma})^2 + \tau (G_M^{\gamma})^2} \right]$$
(30)

$$\varepsilon = \frac{1}{1 + 2(1+\tau)\tan^2\frac{\theta}{2}}, \varepsilon' = \sqrt{\tau(1+\tau)(1-\varepsilon^2)}, \tau = \frac{Q^2}{4M}$$
 (31)

As $\theta \to 0$, $\varepsilon \to 1$, and $\tau \ll 1$

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$$A_{ep} = \left[\frac{-G_F Q^2}{4\sqrt{2}\pi\alpha}\right] \left[Q_W^p + B(Q^2, \theta)\right] = A_0 \left[Q_W^p + B(Q^2, \theta)\right]$$
 (32)

$$A_{ep} = \left[\frac{-G_F Q^2}{4\sqrt{2}\pi\alpha} \right] \left[Q_W^p + Q^2 B(Q^2, \theta) \right] = A_0 \left[Q_W^p + Q^2 B(Q^2, \theta) \right]$$
(33)

$$A_{ep} = A_0 \left[Q_W^p + B(Q^2, \theta) \right]$$

$$A_0 = \frac{-G_F Q^2}{4\sqrt{2}\pi\alpha}$$
(34)

$$\sigma \approx |M_{EM} + M_{weak}|^2$$

$$\sigma \approx |M_{EM}|^2 + 2M_{EM}^* M_{weak} + |M_{weak}|^2$$

$$\sigma \approx |M_{EM}|^2$$
(35)

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$$A_{ep} = \frac{\sigma_{+} - \sigma_{-}}{\sigma_{+} + \sigma_{-}} \approx \frac{2\Re|M_{EM} \cdot M_{weak}|}{|M_{EM}|^{2}}$$
 (36)

$$A_{msr} = \frac{Y_{+} - Y_{-}}{Y_{+} + Y_{-}} \tag{37}$$

$$A_{msr} - \sum_{i} A_{false}^{i}$$

$$A_{ep} = \frac{1}{p}$$
(38)

$$A_{ep} = \frac{\sigma_{+} - \sigma_{-}}{\sigma_{+} + \sigma_{-}} \approx \frac{|M_{weak}^{PV}|}{|M_{EM}|}$$
(39)

$$A_{ep} \approx \frac{2\Re[M_{EM} \cdot M_{weak}]}{|M_{EM}|^2} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$
(40)

Where $\sigma_+(\sigma_-)$ is the positive (negative) helicity correlated electron-proton scattering cross sections. M_{weak} and M_{EM} are the parity violating and parity conserving electromagnetic scattering amplitudes, respectively

$$Q_W(Z,N) = -2[C_{1u}(2Z+N) + C_{1d}(Z+2N)]$$
(41)

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$$A_{ep} = \frac{\sigma_{+} - \sigma_{-}}{\sigma_{+} + \sigma_{-}} \approx \frac{2\Re|M_{EM} \cdot M_{weak}|}{|M_{EM}|^{2}}$$
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$$A_{msr} = \frac{Y_{+} - Y_{-}}{Y_{+} + Y_{-}} \tag{37}$$

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$$A_{ep} = \frac{\sigma_{+} - \sigma_{-}}{\sigma_{+} + \sigma_{-}} \approx \frac{|M_{weak}^{PV}|}{|M_{EM}|}$$
(39)

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Where $\sigma_+(\sigma_-)$ is the positive (negative) helicity correlated electron-proton scattering cross sections. M_{weak} and M_{EM} are the parity violating and parity conserving electromagnetic scattering amplitudes, respectively

$$Q_W(Z,N) = -2[C_{1u}(2Z+N) + C_{1d}(Z+2N)]$$
(41)

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$$A_{N} = R_{total} \begin{bmatrix} \frac{A_{M}^{in}}{P} - \sum_{i=1}^{4} A_{bi} f_{bi} \\ \\ \frac{1 - \sum_{i=1}^{4} f_{bi}} \end{bmatrix}$$

$$A_{ep} = R_{total} \begin{bmatrix} \frac{A_{msr}}{P} - \sum_{i=1}^{4} A_i f_i \\ \frac{1 - \sum_{i=1}^{4} f_i \end{bmatrix}$$

$$R_{total} = R_{RC}R_{Det}R_{Bin}R_{Q^2}$$

$$A_{msr} = A_{raw} + A_T + A_L + A_{reg}$$

Q-weak

$$A_{ep} = R_{RC}R_{Det}R_{Bin} \left[\frac{\frac{A_{msr}}{P} - A_{b1}f_{b1} - A_{b2}f_{b2} - A_{b3}f_{b3} - A_{b4}f_{b4}}{1 - f_{b1} - f_{b2} - f_{b3} - f_{b4}} \right]$$

$$(dA_{PHYS}^{in})_{A_{M}^{in}} = R_{RC}R_{Det}\frac{dA_{M}^{in}}{P} \left[\frac{1}{1 - f_{b1} - f_{b2} - f_{b2} - f_{b4}} \right]$$

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(42)

(43)

$$A_N = R_{total} \begin{bmatrix} \frac{A_M^{in}}{P} - \sum_{i=1}^{3} A_{bi} f_{bi} \\ \\ 1 - \sum_{i=1}^{4} f_{bi} \end{bmatrix}$$

$$A_{ep} = R_{total} \begin{bmatrix} \frac{A_{msr}}{P} - \sum_{i=1}^{4} A_i f_i \\ \\ 1 - \sum_{i=1}^{4} f_i \end{bmatrix}$$

$$R_{total} = R_{RC} R_{Det} R_{Bin} R_{Q^2}$$

$$A_{msr} = A_{raw} + A_T + A_L + A_{reg}$$

$$A_{ep} = R_{RC}R_{Det}R_{Bin} \left[\frac{A_{msr}}{P} - A_{b1}f_{b1} - A_{b2}f_{b2} - A_{b3}f_{b3} - A_{b4}f_{b4}}{1 - f_{b1} - f_{b2} - f_{b3} - f_{b4}} \right]$$

$$\left[1 - f_{b1} - f_{b2} - f_{b3} - f_{b4} \right]$$

$$\left(dA_{PHYS}^{in} \right)_{A_{M}^{in}} = R_{RC}R_{Det} \frac{dA_{M}^{in}}{P} \left[\frac{1}{1 - f_{b1} - f_{b2} - f_{b3} - f_{b4}} \right]$$

(42)

(43)

(44)

(45)

(46)

(47)

$$(dA_{PHYS}^{in})_{f_{b1}} = R_{RC}R_{Det}df_{b1} \left[\frac{\frac{A_{M}^{in}}{P} - A_{b1}(1 - f_{b2} - f_{b3} - f_{b4}) - A_{b2}f_{b2} - A_{b3}f_{b3} - A_{b4}f_{b4}}{(1 - f_{b1} - f_{b2} - f_{b3} - f_{b4})^{2}} \right]$$
(53)

$$(dA_{PHYS}^{in})_{f_{b2}} = R_{RC}R_{Det}df_{b2} \left[\frac{\frac{A_{M}^{in}}{P} - A_{b1}f_{b1} - A_{b2}(1 - f_{b1} - f_{b3} - f_{b4}) - A_{b3}f_{b3} - A_{b4}f_{b4}}{(1 - f_{b1} - f_{b2} - f_{b3} - f_{b4})^{2}} \right]$$

$$(54)$$

$$(dA_{PHYS}^{in})_{f_{b3}} = R_{RC}R_{Det}df_{b3} \left[\begin{array}{c} \frac{A_{M}^{in}}{P} - A_{b1}f_{b1} - A_{b2}f_{b2} - A_{b3}(1 - f_{b1} - f_{b2} - f_{b4}) - A_{b4}f_{b4} \\ \\ (1 - f_{b1} - f_{b2} - f_{b3} - f_{b4})^2 \end{array} \right]$$

$$(dA_{PHYS}^{in})_{fb4} = R_{RC}R_{Det}df_{b4} \left[\frac{\frac{A_{M}^{in}}{P} - A_{b1}f_{b1} - A_{b2}f_{b2} - A_{b3}f_{b3} - A_{b4}(1 - f_{b1} - f_{b2} - f_{b3})}{(1 - f_{b1} - f_{b2} - f_{b3} - f_{b4})^{2}} \right]$$
(56)

(55)

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Backup frame

Метнорого

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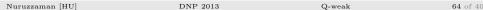
RIGID BODY DYNAMICS

► Coriolis acceleration

$$\vec{a}_p = \vec{a}_o + \frac{^b d^2}{dt^2} \vec{r} + 2 \vec{\omega}_{ib} \times \frac{^b d}{dt} \vec{r} + \frac{\vec{\alpha}_{ib} \times \vec{r}}{} + \vec{\omega}_{ib} \times (\vec{\omega}_{ib} \times \vec{r})$$

- ► Transversal acceleration
- ▶ Centripetal acceleration





RIGID BODY DYNAMICS

► Coriolis acceleration

$$\vec{a}_p = \vec{a}_o + \frac{^bd^2}{dt^2}\vec{r} + \ 2\vec{\omega}_{ib} \times \frac{^bd}{dt}\vec{r} \ + \ \ \frac{\vec{\alpha}_{ib} \times \vec{r}}{\vec{\alpha}_{ib} \times \vec{r}} \ + \ \vec{\omega}_{ib} \times (\vec{\omega}_{ib} \times \vec{r})$$

- ► Transversal acceleration
- ► Centripetal acceleration



RIGID BODY DYNAMICS

► Coriolis acceleration

$$\vec{a}_p = \vec{a}_o + \frac{b_d^2}{dt^2} \vec{r} + \frac{2\vec{\omega}_{ib} \times \frac{b_d}{dt} \vec{r}}{} + \frac{\vec{\alpha}_{ib} \times \vec{r}}{} + \vec{\omega}_{ib} \times (\vec{\omega}_{ib} \times \vec{r})$$

- ► Transversal acceleration
- ► Centripetal acceleration



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