

PVDIS with a polarized ³He target

Gordon Cates, Xiaochao Zheng, Yuxiang Zhao SoLID Collaboration meeting (2016-5-7)

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Outline

 Physics of PVDIS with a longitudinally polarized target and unpolarized electron beam

Simulations and expected results

• Discussions

With purely electromagnetic scattering in DIS process
 ➤ F₁^Y, F₂^Y, g₁^Y, g₂^Y

- With purely electromagnetic scattering in DIS process
 ➤ F₁^Y, F₂^Y, g₁^Y, g₂^Y
- Taking into account γ-Z mixing, with parity violation
 Additional interference structure functions: F₁^{γZ}, F₃^{γZ}, g₁^{γZ}, g₅^{γZ}

- With purely electromagnetic scattering in DIS process
 ➤ F₁^Y, F₂^Y, g₁^Y, g₂^Y
- Taking into account γ-Z mixing, with parity violation
 ➤Additional interference structure functions: F₁^{YZ}, F₃^{YZ}, g₁^{YZ}, g₅^{YZ}
- At JLab energy scale, Q²<<M_Z²

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Pol. beam & unpol. Target: A_{beam} =

$$am = \frac{G_F Q^2}{2\sqrt{2}\pi\alpha} \left[g_A^e \frac{F_1^{\gamma Z}}{F_1^{\gamma}} + g_V^e \frac{Y_-}{2Y_+} \frac{F_3^{\gamma Z}}{F_1^{\gamma}}\right]$$

$$g_A^e = -0.5, \quad g_V^e = -0.5 + 2sin^2(\theta_W) \qquad F_1^{\gamma Z} = \sum_f e_{q_f}(g_V)_{q_f}(q_f + \bar{q}_f)$$

$$Y_- = 2y - y^2, \quad Y_+ = y^2 - 2y + 2. \qquad F_3^{\gamma Z} = 2\sum_f e_{q_f}(g_A)_{q_f}(q_f - \bar{q}_f)$$



- With purely electromagnetic scattering in DIS process
 ➤ F₁^Y, F₂^Y, g₁^Y, g₂^Y
- Taking into account γ-Z mixing, with parity violation
 ➢Additional interference structure functions: F₁^{YZ}, F₃^{YZ}, g₁^{YZ}, g₅^{YZ}
- At JLab energy scale, Q²<<M_Z²

Pol. beam & unpol. Target:

$$A_{beam} = \frac{G_F Q^2}{2\sqrt{2}\pi\alpha} [g_A^e \frac{F_1^{\gamma Z}}{F_1^{\gamma}} + g_V^e \frac{Y_-}{2Y_+} \frac{F_3^{\gamma Z}}{F_1^{\gamma}}]$$

$$A_{L} = \frac{G_{F}Q^{2}}{2\sqrt{2}\pi\alpha} [g_{V}^{e} \frac{g_{5}^{\gamma Z}}{F_{1}^{\gamma}} + g_{A}^{e} \frac{Y_{-}}{Y_{+}} \frac{g_{1}^{\gamma Z}}{F_{1}^{\gamma}}]$$

Unpol. beam & pol. Target:

$$A_{L} = \frac{G_{F}Q^{2}}{2\sqrt{2}\pi\alpha} [g_{V}^{e} \frac{g_{5}^{\gamma Z}}{F_{1}^{\gamma}} + g_{A}^{e} \frac{Y_{-}}{Y_{+}} \frac{g_{1}^{\gamma Z}}{F_{1}^{\gamma}}]$$

$$g_{1}^{\gamma Z} = \sum_{f} e_{q_{f}}(g_{V})_{q_{f}}(\Delta q_{f} + \Delta \bar{q}_{f}) \qquad g_{5}^{\gamma Z} = \sum_{f} e_{q_{f}}(g_{A})_{q_{f}}(\Delta q_{f} - \Delta \bar{q}_{f})$$
$$g_{1}^{n,\gamma Z} = \frac{1}{9} \left(\Delta u + \Delta \bar{u} + \Delta c + \Delta \bar{c} + \Delta d + \Delta \bar{d} + \Delta s + \Delta \bar{s} \right) = g_{1}^{p,\gamma Z}$$
$$g_{5}^{n,\gamma Z} = \left[\frac{1}{3} \left(\Delta d_{V} + \Delta s - \Delta \bar{s} \right) + \frac{1}{6} \left(\Delta u_{V} + \Delta c - \Delta \bar{c} \right) \right]$$
$$g_{5}^{p,\gamma Z} = \left[\frac{1}{3} \left(\Delta u_{V} + \Delta c - \Delta \bar{c} \right) + \frac{1}{6} \left(\Delta d_{V} + \Delta s - \Delta \bar{s} \right) \right]$$

Unique linear combinations of the quark polarization
 Never been measured before

³He asymmetry calculations using World PDF fits

$$A_{^{3}\mathrm{He}} = P_n(1 - f_p)A_n + P_pf_pA_p,$$

$$P_n = 0.86^{+0.036}_{-0.02}$$
 and $P_p = -0.028^{+0.009}_{-0.004}$ $f_p = \frac{2\sigma_p}{\sigma_{^3\mathrm{He}}}$

Using LHAPDF6 (Released on Dec 22, 2015)
 □A C++ interface to access both unpolarized and polarized pdfs
 >Pdf sets: <u>https://lhapdf.hepforge.org/pdfsets.html</u>

► Unpolarized pdfs: CT, MRST, MSTW, MMHT, etc

Polarized pdfs: only NNPDF (global data fit up to 2014)





³He asymmetry uncertainty using NNPDF1.1

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-17.7707 -9.74699 -10.5872 -11.9092 -13.2476 -14.6113 -16.063 -17.6345 -19.3814 -21.4823 -24.4167 -29.2273 -37.8016 -53.763 20.6298 22.2202 -11.9053 -9.30398 -10.4399 -11.8601 -13.249 -14.6424 -16.1133 -17.6967 -19.4497 -21.5515 -24.4826 -29.2855 -37.8449 -53.7716 47.1334 -9.73489 -9.00764 -10.3365 -11.8363 -13.2699 -14.6907 -16.1795 -17.7739 -19.532 -21.6339 -24.5611 -29.3563 -37.9015 -53.7944 23.2632 82.1776 -8.72742 -8.8068 -10.2701 -11.8373 -13.3116 -14.758 -16.2638 -17.8684 -19.6306 -21.7316 -24.6544 -29.442 -37.9741 -53.8352 -20.5037 -8.20614 -8.6734 -10.2368 -11.8637 -13.3761 -14.8471 -16.3693 -17.9832 -19.7483 -21.8473 -24.7648 -29.545 -38.0652 -53.8971 32,2805 -13,0995 -7,92532 -8,59186 -10,2352 -11,9175 -13,4668 -14,9619 -16,4999 -18,1223 -19,8889 -21,9843 -24,8957 -29,6686 -38,1789 -53,985 55.4113 -10.9693 -7.78035 -8.55418 -10.2664 -12.0025 -13.5885 -15.1077 -16.6612 -18.291 -20.0576 -22.1477 -25.052 -29.8184 -38.322 -54.1092 225.173 -10.2617 -7.72335 -8.5575 -10.3337 -12.1243 -13.7483 -15.292 -16.8608 -18.4967 -20.2608 -22.3431 -25.2388 -29.9994 -38.5003 -54.2764 -31,487 -10.0734 -7.73324 -8.60367 -10.4437 -12.2921 -13.9563 -15.5256 -17.1093 -18.7493 -20.5079 -22.579 -25.464 -30.2196 -38.7231 -54.4999 -21.064 -10.1245 -7.80472 -8.69986 -10.6077 -12.5197 -14.2278 -15.8241 -17.4222 -19.0635 -20.812 -22.867 -25.7385 -30.4903 -39.0041 -54.7982 -19.303 -10.3252 -7.94581 -8.86048 -10.8438 -12.8284 -14.5861 -16.2112 -17.8224 -19.4603 -21.1916 -23.223 -26.0761 -30.8249 -39.3582 -55.1908 -19.4077 -10.6635 -8.18088 -9.11253 -11.183 -13.2535 -15.0686 -16.7246 -18.3458 -19.9725 -21.6752 -23.6714 -26.4983 -31.2445 -39.8099 -55.7111 -20.23 -11.1858 -8.56335 -9.50644 -11.6798 -13.8553 -15.7386 -17.427 -19.0518 -20.6528 -22.3078 -24.249 -27.0361 -31.7775 -40.3901 -56.3994 -21.6641 -12.0239 -9.20813 -10.1433 -12.4376 -14.7456 -16.7121 -18.4317 -20.0451 -21.5929 -23.1651 -25.0162 -27.738 -32.4665 -41.143 -57.3124 -24.2779 -13.5712 -10.4058 -11.2504 -13.6753 -16.156 -18.2256 -19.9658 -21.5311 -22.9666 -24.3847 -26.0739 -28.672 -33.3539 -42.0949 -58.4749 -30.1614 -17.0046 -12.9851 -13.4523 -15.9589 -18.6639 -20.8553 -22.5699 -23.9858 -25.1642 -26.2644 -27.6297 -29.9681 -34.5078 -43.271 -59.8994

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-50

-100

-150

-200

³He asymmetry calculations using World PDF fits

0.125 0.175 0.225 0.275 0.325 0.375 0.425 0.475 0.525 0.575 0.625 0.675 0.725 0.775 0.825 0.875 asymmetry uncertainty (%) from DSSV2008: 8.750 (0.0%) 0.0%) 0.0%) 0.0%) 0.0% 0.0%) 5.8% (7.1%)8.8%) (10.9%)(13.6%)(17.2%)(22.3%) Θ. (22.3%) 8.250 0.0%) 0.0% .0% Θ Θ. 0.0% 0.0% 0.0%) 4.8%) 5.8% (7.1%)8.8%) (10.9%)(13.6%)(17.2%)7.750 (0.0%) 0.0%) 0.0%) 0.0%) 0.0%) 0.0%) 4.1%)4.8%) 5.8%) (7.1%)8.8%) (10.9%)(13.6%)(17.3%)(22.4%) 0.0%) (17.3%)7.250 0.0%) 0.0% 0.0%) 0.0%) 0.0% 0.0%) 0.0% 4.1%) 4.8%) 5.8%) (7.1%)8.8%) (10.9%)(13.7%)(22.4%) 6.750 (22.5%) 0.0%) 0.0%) 0.0%) 0.0%) 0.0%) 0.0%) 3.6%) 4.1%4.8%) 5.8%) (7.2%) 8.8%) (11.0%)(13.7%)(17.4%)6.250 (0.0%) 0.0%) 0.0%) 3.3%) 3.6%) (7.2%) 8.9%) (11.0%) (13.8%)(17.4%)(22.6%) 0.0% 0.0% 4.1%) 4.8%) 5.9% 5.750 (22.7%) (0.0%)0.0%) 0.0%) 0.0%) 3.2%) (3.3%)3.6%) 4.1%) 4.9%) 5.9%) (7.2%) 8.9%) (11.0%) (13.8%)(17.5%)5.250 (0.0%) 0.0%) 3.4%) (3.3%)3.6%) (7.2%) 8.9%) (11.1%)(13.9%)(17.6%)(22.8%) 0.0% 3.2%) 4.1%) 4.9%5.9% (17.7%)4.750 0.0%) 0.0%) 0.0%) 3.4%) (3.4%)3.7%) 4.2%) 4.9%)(7.3%) 9.0%) (11.2%)(14.0%)(22.9%) 3.3%) 6.0%) (7.4%) 4.250 3.7%) 4.2%) 9.1%) (11.3%)(17.8%)(23.1%)(0.0%)0.0% 4.0%) 3.5%) 3.3% (3.4%)5.0%) 6.0% (14.1%)3.750 3.6%) 4.3%) (11.4%)(17.9%)(23.3%) (0.0%)0.0%) 4.1%) (3.5%)3.8%) (7.5%)9.2%) (14.2%)3.4%) 5.1%6.1%) 3.250 (0.0%) 5.9%) 4.3%) 3.7%) 3.6%) 3.9% (7.6%) 9.3%) (11.5%)(14.3%)(18.1%)(23.5%)3.5% 5.2%6.2% 4.4% 2.750 (0.0%)6.2%) 4.6%) 4.0%) 3.7%) 3.7%) 4.0% 4.6%) 5.3%) 6.4%) (7.7%)9.5%) (11.7%)(14.6%)(18.4%)(23.8%) 2.250 (11.3%)6.9%) 5.2%) 4.4%) 4.0%) 4.0%) 4.2%) 4.7%5.5%) 6.6%) (7.9%) 9.7%) (11.9%)(14.8%)(18.7%)(24.2%) 1.750 (12.3%)(24.7%) (12.9%)(8.3%) 6.2%) 5.1%) 4.5%) 4.3%) 4.6%) 5.1%) 5.8%) 6.9%) (8.2%) (10.0%)(15.2%)(19.1%)1.250 (5.1%)(16.7%)(11.4%)8.5%) 6.6%) (5.5%)(5.1%)(5.6%)(6.3%)(7.4%)(8.7%) (10.5%)(12.8%)(15.7%)(19.7%)(25.4%) asymmetry uncertainty (%) among all 4 PDFs: 8.750 0.0%) (11.1%)(51.3%) 0.0%) 0.0%) 0 (7.6%)(15.8%)(22.9%)(33.7%)0.0% 0.0% (15.7%)8.250 0.0%) 0.0% 7.6% (11.0%) (22.7%)(33.5%)(51.0%) 0.0% .0%) 0 0 3 5. 7.750 (22.5%)(33.2%)(50.6%) 0.0%) 0.0% 0.0%) 0.0%) 0.0%) 0.0%) 2.7%) 3.1%) 5.0%) (7.5%) (11.0%) (15.6%)0.0% 7.250 0.0%) 0.0%) 0.0%) 0.0% 2.8%) (7.5%)(10.9%)(15.6%)(22.3%)(33.0%) (50.3%) 0.0% 0.0% 3.0%) 4.9% 6.750 0.0%) 0.0% 0.0%) 0.0%) 0.0%) 3.0%) 2.8%) 3.0%) 4.9% (7.5%) (10.9%)(15.5%)(22.2%)(32.8%)(50.1%) 0.0% 6.250 (10.9%)(15.5%)(22.1%)(32.6%) (49.9%) 0.0%) 0.0% 0.0% 0.0% 3.6%) 3.1% 2.9%) 3.0%) 4.9% (7.5%)(31.9%) 5.750 0.0%) 3.7%) 3.2% (7.3%) (10.6%)(15.2%)(21.7%)(48.9%)0.0%) 0.0%) 0.0%) 3.0%) 2.9%) 4.8% 5.250 (48.0%) 0.0%) 0.0% 0.0%) 3.8%) 3.3% 3.1%) (7.1%) (10.4%)(14.9%)(21.3%)(31.2%)4.8% 2.9%) 4.750 (47.7%) 0.0%) 4.0%) 3.5%) (7.1%)(10.4%)(14.9%)(21.3%)(31.0%) 0.0% 0.0%) 5.0%) 3.3%) 3.0%) 4.7%) 4.6% 4.250 0.0%) 3.6% (7.1%)(10.4%)(14.9%)(21.2%)(30.7%)(47.4%) 0.0%) 5.1%) 4.1%) 3.4%) 3 3.750 0.0%) 4.2%) 3.8%) 3.6%) (7.0%) (10.2%)(14.6%)(20.9%)(30.3%)(46.5%)0.0% 5.6%) 5.3%) 3.4%) 4.6% 4.8% 3.250 (14.3%)(20.4%)(29.5%)(45.0%) 0.0%) 6.5%) 5.8%) 4.4% 4.0% 6.8% (10.0%)3.8% 2.750 (0.0%)(7.0%)6.1%) 4.6%) 4.3% 6.8%) 9.9%) (14.2%)(20.3%)(29.3%)(44.4%) 5.7% 4.1%) 3.9%) 4.5% 2.250 (9.4%)(7.7%)6.6%) 6.0%) 5.0%) 4.7%) 4.5%) 4.3%) 6.7% 9.7%) (13.9%)(19.8%)(28.6%)(43.4%) 5.5% 4.4% 1.750 5.2%) 8.2%) (25.3%) (38.7%) (11.1%)(9.0%)(7.6%)6.7%)6.0%) 5.6%) 4.9%) 4.6%) 4.2%) (5.5%)(11.9%)(17.2%)1.250 (14.9%) (11.7%)(9.6%) (8.2%) (7.2%) (6.5%) (5.9%) (5.5%) (5.0%) (4.6%) (5.3%) (7.8%) (11.4%)(16.6%)(37.6%) (24.5%)

Calculated by Xiaochao Zheng

Δq world data (Δu and Δd)



Δq world data ($\Delta ubar$ and $\Delta dbar$)



Δq world data (Δs and Δg)



Asymmetry contribution from g1gz

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G1gz dominates the asymmetry (> 90%)

Simulations using GEMC

• Beam current: 60 μA (2nd stage of target upgrade plan)

• 3He target requirements:

✓ Length: 60cm (2nd stage of target upgrade plan)

✓ Polarization: 60%

✓ Density: 12 amg X 12

• Beam time: 200 days

Goal at ~10% precision on the ³He asymmetry measurement

Projections of the asymmetry measurement



Figure-of-merit (A*A*rate) for SIDIS configuration



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dA/A projections using SIDIS configuration



dA/A projections for large angle data only



dA/A projections for forward angle data only



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Trigger rate

• Follow closely with SIDIS electron trigger design

► Large angle electron rate: 2.2 MHz

➢ Forward angle electron rate: 11.2MHz

- Large angle detector is sufficient to reach ~10% measurement
 - With 30 sectors, trigger rate is 73KHz/sector

- Forward angle
 - Can put tight trigger cut to lower down trigger rate
 - Bonus for our measurement

Conclusions and discussions

 With proposed luminosity and beam time, we can access a new structure function g1gz at ~10% level in x<0.5 region

>Only large angle data in SIDIS configuration is sufficient

• Provide a linear combination of $\Delta u + \Delta d + \Delta s$ with even weight

➢ In g1-gamma structure function, ∆d is only 1/4 of ∆u
 ➢ Inclusive electron detection, without complication of fragmentation or hadronic processes

• We will further investigate the impact of our new data to the world polarized PDF fit

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Backups

³He asymmetry calculations using DSSV2008

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	DSSV2008	:															
		0.125	0.175	0.225	0.275	0.325	0.375	0.425	0.475	0.525	0.575	0.625	0.675	0.725	0.775	0.825	0.875
	8.750	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-56.96	-55.93	-54.47	-52.66	-50.42	-47.56	-43.57
	8.250	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-51.99	-51.28	-50.15	-48.72	-47.03	-45.01	-42.45	-38.89
	7.750	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-46.94	-46.55	-45.68	-44.52	-43.17	-41.63	-39.83	-37.56	-34.43
	7.250	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-41.82	-41.16	-40.22	-39.10	-37.87	-36.50	-34.91	-32.94	-30.20
	6.750	0.00	0.00	0.00	0.00	0.00	0.00	-37.12	-36.69	-35.91	-34.97	-33.95	-32.85	-31.66	-30.28	-28.58	-26.21
Q^2	6.250	0.00	0.00	0.00	0.00	0.00	-32.53	-32.33	-31.71	-30.91	-30.04	-29.14	-28.19	-27.18	-26.01	-24.57	-22.54
- •	5.750	0.00	0.00	0.00	0.00	-27.94	-28.12	-27.65	-26.98	-26.24	-25.48	-24.73	-23.95	-23.12	-22.17	-20.98	-19.28
	5.250	0.00	0.00	0.00	-23.29	-23.98	-23.73	-23.16	-22.52	-21.88	-21.26	-20.65	-20.03	-19.37	-18.60	-17.64	-16.23
	4.750	0.00	0.00	0.00	-19.91	-19.95	-19.52	-18.96	-18.41	-17.89	-17.39	-16.92	-16.44	-15.92	-15.33	-14.56	-13.41
	4.250	0.00	0.00	-15.83	-16.33	-16.05	-15.59	-15.11	-14.68	-14.28	-13.91	-13.56	-13.20	-12.81	-12.36	-11.75	-10.84
	3.750	0.00	0.00	-12.83	-12.80	-12.45	-12.07	-11.70	-11.39	-11.11	-10.86	-10.62	-10.37	-10.10	-9.77	-9.32	-8.62
	3.250	0.00	-9.32	-9.74	-9.55	-9.26	-8.98	-8.74	-8.54	-8.37	-8.22	-8.07	-7.92	-7.74	-7.52	-7.21	-6.71
	2.750	0.00	-6.84	-6.89	-6.72	-6.52	-6.36	-6.22	-6.12	-6.03	-5.95	-5.87	-5.78	-5.68	-5.54	-5.33	-4.98
	2.250	-4.06	-4.49	-4.48	-4.38	-4.29	-4.22	-4.16	-4.12	-4.09	-4.06	-4.04	-4.00	-3.96	-3.88	-3.75	-3.52
	1.750	-2.38	-2.57	-2.59	-2.57	-2.55	-2.54	-2.54	-2.55	-2.56	-2.57	-2.58	-2.58	-2.57	-2.54	-2.48	-2.35
	1.250	-1.09	-1.21	-1.25	-1.27	-1.29	-1.32	-1.34	-1.37	-1.40	-1.42	-1.45	-1.47	-1.48	-1.48	-1.46	-1.40

Calculated by Xiaochao Zheng

Asymmetry comparison between DSSV08 and NNPDF



Figure-of-merit numbers in (x,Q2) grid

		_ ` _	_													
8.75	0	0	0	0	0	0	0	0	0	0.565	4.2	4.62	3.23	1.87	0.972	0.438
8.25	0	0	0	0	0	0	0	0	0.566	6.02	7.1	5.09	3.14	1.81	0.951	0.456
7.75	0	0	0	0	0	0	0	0.4	7.61	10	7.48	4.73	3.04	1.83	1.05	0.494
7.25	0	0	0	0	0	0	0.152	8.79	13.6	10.2	7.03	5.01	3.3	1.98	1.05	0.482
6.75	0	0	0	0	0	0	8.32	18	13.7	10.4	7.7	5.31	3.32	1.82	0.952	0.436
6.25	0	0	0	0	0	6.54	22.1	18.2	14.7	11.2	7.89	4.79	2.91	1.62	0.851	0.387
5.75	0	0	0	0	3.18	24.8	23.9	20.6	15.2	10.3	6.63	4.26	2.36	1.27	0.682	0.313
5.25	0	0	0	0.473	24.2	30.7	26.9	19.3	13.2	8.35	5.25	3.34	2.13	1.25	0.652	0.299
4.75	0	0	0	17	37	33.7	24	15.6	10.4	7.16	4.87	3.07	1.85	1.08	0.554	0.243
4.25	0	0	6.65	40.8	40	27.7	19.2	13.6	9.14	5.91	3.79	2.32	1.43	0.817	0.429	0.192
3.75	0	0.469	34.9	45.2	32	23.2	15.3	10.1	6.73	4.38	2.84	1.8	1.1	0.636	0.327	0.145
3.25	0	16.1	46.3	36.2	25	16.4	10.8	7.19	4.8	3.22	2.06	1.33	0.816	0.473	0.246	0.11
2.75	2	38.4	35.8	24.7	16.5	11	7.43	4.98	3.33	2.21	1.46	0.967	0.62	0.358	0.186	0.082
2.25	14.8	30.1	22.2	15.6	10.8	7.41	5.1	3.46	2.31	1.58	1.06	0.702	0.442	0.257	0.135	0.062
1.75	16	16.3	13.4	9.81	6.85	4.66	3.19	2.12	1.4	0.947	0.626	0.405	0.257	0.145	0.0768	0.036
1.25	7.31	5.63	3.18	1.64	0.781	0.364	0.174	0.0983	0.0537	0.0265	0.0127	0.00547	0.00228	0.00107	0.00030)5 5
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- With purely electromagnetic scattering in DIS process
 ➤ F₁^Y, F₂^Y, g₁^Y, g₂^Y
- Taking into account γ-Z mixing, with parity violation
 ➤Additional interference structure functions: F₁^{YZ}, F₃^{YZ}, g₁^{YZ}, g₅^{YZ}
- At JLab energy scale, Q²<<M_z²

Pol. beam & unpol. Target:
$$A_{beam} = \frac{G_F Q^2}{2\sqrt{2}\pi\alpha} [g_A^e \frac{F_1^{\gamma Z}}{F_1^{\gamma}} + g_V^e \frac{Y_-}{2Y_+} \frac{F_3^{\gamma Z}}{F_1^{\gamma}}]$$

Unpol. beam & pol. Target: $A_L = \frac{G_F Q^2}{2\sqrt{2}\pi\alpha} [g_V^e \frac{g_5^{\gamma Z}}{F_1^{\gamma}} + g_A^e \frac{Y_-}{Y_+} \frac{g_1^{\gamma Z}}{F_1^{\gamma}}]$