Transverse Single Spin Asymmetry of Electromagnetic Jets at FMS Run17 p[↑] + p Collisions at $\sqrt{s} = 510$ GeV

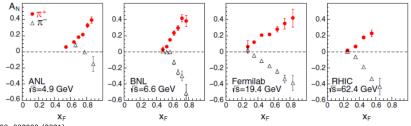
Weibin Zhang

UC Riverside

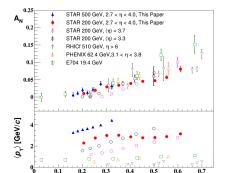
2025-03-12

Transverse Single Spin Asymmetry (TSSA/A_N)

Aidala et al., Rev. Mod. Phys. 85, 655 (2013)

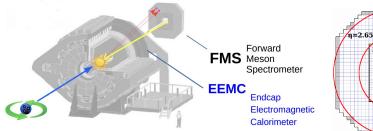


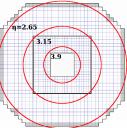
PRD 103, 092009 (2021)



- Explore the potential sources of large A_N observed at forward rapidities
- Characterize A_N in terms of EM-jet p_T, energy and photon multiplicities

The Forward Meson Spectrometer (FMS) at STAR





Dataset and Event Selection

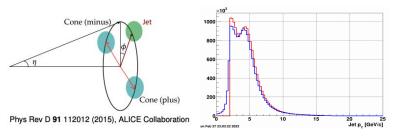
Dataset

- Run 17 (p^{\uparrow} + p, \sqrt{s} = 510 GeV), FMS-stream, P18ic
- 2118 good runs, 1,468,967,819 events
- Triggers: FMS-SM-BS, FMS-LG-BS, FMS-JP

Event Selection

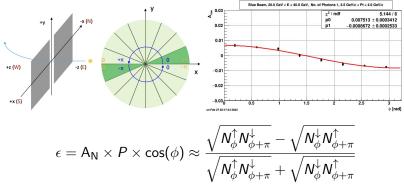
- |z| ≤ 80 cm
- Photon: E > 1 GeV
- Jet: Anti- k_T clustering, R = 0.7, $p_T > 2$ GeV, $2.8 < \eta < 3.8$

Underlying Event p_T Correction



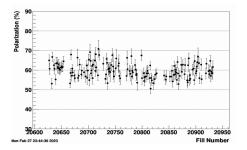
- Off-axis cone method: EM-jet p_T correction for contamination from underlying event (UE)
- $dp_T = UE$ density \times area
- corrected $p_T = p_T dp_T$

A_N Extraction



- 5 equal-width energy bins from 0 to 100 GeV
- 9 p_T bins: [2, 2.5, 3, 3.5, 4, 4.5, 5, 6, 8, 10]
- 10 x_F bins: [0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.6]
- 16 uniform ϕ bins
- 3 photonmultiplicity bins: $n_{\gamma} = 1\&2, 3, 4\&5$

Polarization

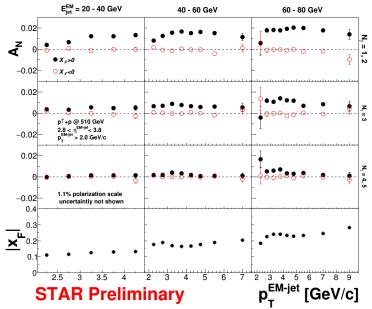


W.B. Schmidke, RHIC Polarization for Run 9-17

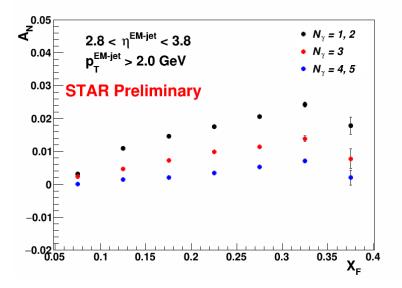
$$\mathcal{P}_{set} = rac{\sum_{i} \mathcal{L}_{i} \cdot \mathcal{P}_{i}}{\sum_{i} \mathcal{L}_{i}}$$
 $\mathcal{P}_{i} = rac{1}{\mathcal{L}_{i}} \int dt \mathcal{L}_{i}(t) P_{i}(t)$
 $= P_{0,i} - rac{\int dt L_{i}(t) t}{\mathcal{L}_{i}} P_{i}^{\prime}$

$$\mathcal{P}_{set} = 59.94\% \pm 1.07\%$$

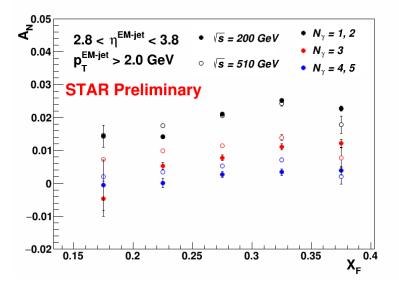
 A_N vs p_T



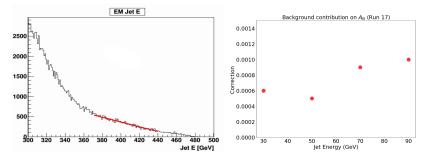
 A_N vs x_F



Run 17 vs 15



Systematic Uncertainty from Unphysical Events



Insignificant contribution from unphysical events

Systematic Uncertainty Due to Miscounting

- Assuming all EM-jets arise from π^0
- From simulation, here is the FMS detection efficiency:

Energy (GeV)	f ₀ (%)	f ₁ (%)	f ₂ (%)	f ₃ (%)
20-40	0.645	44.0055	51.7335	3.3355
40-60	1.012	75.82	21.707	1.2935
60-80	1.325	84.3105	13.382	0.827

• Consider the first order correction:

$$\Delta N_{1,2} = -(f_0 + f_3)N_{1,2} + f_0N_3$$
$$\Delta N_3 = f_3N_{1,2} - (f_0 + f_3)N_3 + f_0N_{4,5}$$
$$\Delta N_{4,5} = f_3N_3 - (f_0 + f_3)N_{4,5}$$

- Modify N by ΔN, the difference in A_N is quoted as corresponding systematic uncertainty
- Negligible systematic uncertainty

Summary

- Run 17 $A_{\sf N}$ (510 GeV) is extracted as functions of $p_{\sf T}$ and $x_{\sf F}$
- A_N increases along x_F , similar trend to Run 15 (200 GeV)
- A_N decreases as EM-jet photon multiplicity increases, EM-jets with high photon multiplicity show little asymmetry
- A_N varies with EM-jet energy

Backup

Systematic Uncertainty Due to Miscounting

0 1 0 0 0.0043462 0.000713175 4.49e-06 0 1 0 1 0.00659133 0.000582593 3.2e-05 0 1 0 3 0.0122909 0.000749464 3.43e-05 0 1 0 4 0.033854 0.000713572 2.139e-05 0 1 1 0 0.00373862 0.000713572 2.139e-05 0 1 1 0.00373862 0.000526262 0.00023039 0 1 1 0.00474225 0.000906421 0.00037478 0 1 2 0.00434961 0.00023934 0.00037478 0 1 2 1 0.00628898 0.000457922 9.567e-05 0 1 2 3 0.00133553 0.00057922 9.567e-05 0 1 2 3 0.00140425 0.0021287 0.500102411 0 2 0 1 0.0155137 0.000642675 <th></th> <th></th> <th></th> <th>-</th> <th></th> <th>-</th> <th></th>				-		-	
0 1 0 2 0.0122909 0.000582593 3.2e-05 0 1 0 3 0.0121544 0.000749464 3.43e-05 0 1 0 4 0.0133854 0.000713572 2.139e-05 0 1 1 0 0.00373862 0.000713572 2.139e-05 0 1 1 0 0.0015451 0.00052645 8.306e-05 0 1 1 2 0.0054019 0.000692662 0.00023669 0 1 1 3 0.00478225 0.000569213 8.4524e-05 0 1 2 0 -0.00133553 0.000569213 8.4524e-05 0 1 2 3 0.00134541 0.000569213 8.4524e-05 0 1 2 3 0.0013353 0.000569213 8.4524e-05 0 1 2 3 0.0013353 0.00065971 1.6e-05 0 1 2 0 <td></td> <td></td> <td></td> <td></td> <td>0.0043462</td> <td>0.000713175</td> <td>4.49e-06</td>					0.0043462	0.000713175	4.49e-06
0 1 0 3 0.0121544 0.000749464 3.43e-05 0 1 0 4 0.013384 0.000749464 3.43e-05 0 1 0 4 0.013384 0.000131457 2.139e-05 0 1 1 0.00315451 0.000552445 8.306e-05 0 1 1 2 0.0054019 0.00055262 0.00020393 0 1 1 3 0.00478225 0.0009064211 0.00037478 0 1 2 0 0.00169597 0.00032034 0.00037478 0 1 2 0 0.00169593 0.000429129 9.557e-05 0 1 2 0 0.0133553 0.00012287 0.00012411 0 0.0018455 1.6e-05 0 0.001255137 0.00012773 4.8e-05 0 2 0 0.01255137 0.000592114 8.02e-05 0 2 0 0.0166897 0.00	0		0		0.00659193	0.000563123	2.381e-05
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0 1 1 0 0.00373862 0.00713572 2.139e-05 0 1 1 0.00313451 0.000552445 8.306e-05 0 1 1 2 0.0054013 0.000552445 8.306e-05 0 1 1 3 0.00478225 0.000906421 0.0005269 0 1 2 0 -0.000169597 0.000569213 8.4524e-05 0 1 2 0 0.00133533 0.00036631 9.557e-05 0 1 2 4 0.00149425 0.00012247 0.0001241 0 2 0 0 0.0025514 0.0007473 4.8e-05 0 2 0 2 0.0125514 0.0007475 4.8e-05 0 2 0 3 0.0166877 0.000592114 8.02e-05 0 2 0 3 0.0166877 0.000793356 0.36e-05 0 2 0 5 0.0164637 <td></td> <td></td> <td></td> <td></td> <td>0.0121544</td> <td>0.000749464</td> <td>3.43e-05</td>					0.0121544	0.000749464	3.43e-05
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0 1 1 3 0.00478225 0.00906421 0.00037478 0 1 2 0 -0.00169597 0.00037478 0.00037478 0 1 2 0 -0.00169597 0.000320934 0.00037478 0 1 2 0 0.0062898 0.000429129 5.576e-05 0 1 2 2 0.00133553 0.00036631 9.752e-05 0 1 2 3 0.00138454 0.00012287 0.000104211 0 2 0 0 0.0022713 0.0015955 1.6e-05 0 2 0 1 0.0155137 0.000592114 8.02e-05 0 2 0 3 0.0166897 0.000592114 8.02e-05 0 2 0 7 0.0116941 0.00173551 4.617e-05 0 2 0 7 0.0166897 0.000639214 4.94e-05 0 2 0 7					0.00315451	0.000552445	8.306e-05
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$					0.00138484	0.000836631	9.752e-05
0 2 0 1 0.125514 0.0007473 4.8e-05 0 2 0 2 0.0155137 0.000642675 5.74e-05 0 2 0 3 0.0166897 0.00053765 8.32e-05 0 2 0 4 0.0154208 0.00059765 8.36e-05 0 2 0 5 0.0164637 0.0015335 0.00001066 0 2 0 6 0.0151976 0.000101533 9.06e-05 0 2 0 6 0.0164437 0.0017551 4.617e-05 0 2 1 0.00648014 0.00017551 4.617e-05 0 2 1 0.00680163 0.000638141 6.101e-05 0 2 1 3 0.00763504 0.000638141 6.101e-05 0 2 1 4 0.0051332 0.000638141 3.19e-05 0 2 1 5 0.0056056 0.0013188 <td></td> <td></td> <td></td> <td></td> <td>0.00140425</td> <td>0.00212287</td> <td>0.00010241</td>					0.00140425	0.00212287	0.00010241
0 2 0 2 0.155137 0.00642675 5.74e-05 0 2 0 3 0.0166897 0.000592114 8.02e-05 0 2 0 4 0.0154208 0.000592114 8.02e-05 0 2 0 5 0.0164637 0.000793356 8.36e-05 0 2 0 5 0.016437 0.000793356 9.06e-05 0 2 0 6 0.0151976 0.00148445 4.92e-05 0 2 0 7 0.0116941 0.00348445 4.92e-05 0 2 1 0 0.0680163 0.000692621 1.94e-05 0 2 1 2 0.00863132 0.000680813 3.77re-05 0 2 1 3 0.00533963 0.000608155 3.19e-05 0 2 1 6 0.0060933 0.0013188 8e-06 0 2 2 0 0.01763					0.00822713	0.00169655	1.6e-05
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	0				0.0125514	0.0007473	4.8e-05
0 2 0 4 0.0154208 0.000659765 8.36e-05 0 2 0 5 0.0164637 0.000793356 8.36e-05 0 2 0 5 0.0164637 0.0001793356 8.36e-05 0 2 0 6 0.0151976 0.0011593 9.66e-05 0 2 0 7 0.0116941 0.000348445 4.92e-05 0 2 1 0 0.06486738 0.000526291 1.94e-05 0 2 1 2 0.00880163 0.0006986873 3.277e-05 0 2 1 3 0.00735504 0.0006313141 6.101e-05 0 2 1 4 0.00651332 0.000801555 3.19e-05 0 2 1 6 0.006933 0.00103188 8e-06 0 2 1 7 0.0056056 0.00376494 3.79e-06 0 2 2 0.00172635	0				0.0155137	0.000642675	5.74e-05
0 2 0 5 0.164637 0.000793356 0.0001066 0 2 0 6 0.0151976 0.00101593 9.06e-05 0 2 0 7 0.016941 0.00175551 4.52e-05 0 2 1 0 0.0688738 0.006696873 1.94e-05 0 2 1 2 0.00880163 0.000698687 3.277e-05 0 2 1 2 0.00853983 0.0006038141 6.101e-05 0 2 1 4 0.00533983 0.000801555 3.19e-05 0 2 1 6 0.0056956 0.0013188 8e-06 0 2 1 7 0.0056956 0.00139586 3.766e-05 0 2 2 1 0.00172655 0.000139586 3.766e-05 0 2 2 1 0.00172655 0.000139586 3.766e-05 0 2 2 0.00139225	0				0.0166897	0.000592114	8.02e-05
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$			0	4	0.0154208	0.000659765	8.36e-05
0 2 0 7 0.0116941 0.00348445 4.922-05 0 2 1 0 0.00640614 0.00175551 4.617e-055 0 2 1 1 0.00688738 0.000696677 3.277e-05 0 2 1 2 0.00880163 0.000696667 3.277e-05 0 2 1 3 0.00753504 0.000688091 3.966e-05 0 2 1 4 0.00651332 0.0006081355 3.19e-05 0 2 1 6 0.006933 0.00103188 8e-06 0 2 1 7 0.0056056 0.00376494 3.79e-06 0 2 2 0 0.00172635 0.00079154 5.06e-05 0 2 2 0.00420422 0.000562523 3.512e-05 0 2 2 3 0.00139255 0.000459154 3.51e-05 0 2 2 3 0.00159154 <td></td> <td></td> <td></td> <td></td> <td>0.0164637</td> <td>0.000793356</td> <td>0.0001066</td>					0.0164637	0.000793356	0.0001066
0 2 1 0 0.06646614 0.00175551 4.617e-05 0 2 1 1 0.00688738 0.000826291 1.94e-05 0 2 1 2 0.006880163 0.000638141 6.101e-05 0 2 1 3 0.00763504 0.000638141 6.101e-05 0 2 1 4 0.0651332 0.0006080155 3.96e-05 0 2 1 5 0.00563983 0.000801555 3.19e-06 0 2 1 6 0.0066033 0.0013158 8e-06 0 2 2 0 0.00184856 0.00139566 3.766e-05 0 2 2 1 0.00156956 0.00076494 3.79e-06 0 2 2 1 0.00176555 0.00076494 3.79e-06 0 2 2 0.00176525 0.00075154 5.06e-05 0 2 2 0.00420422 0.000	0				0.0151976	0.00101593	9.06e-05
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0 2 1 2 0.00880163 0.006058667 3.277e-05 0 2 1 3 0.00763504 0.00608141 6.101e-05 0 2 1 4 0.00631332 0.0006038091 3.966e-05 0 2 1 5 0.00533983 0.000801555 3.19e-05 0 2 1 6 0.060933 0.0013188 8e-06 0 2 1 7 0.0056056 0.001376494 3.79e-06 0 2 2 0 0.00172655 0.00079154 5.06e-05 0 2 2 3 0.0013025 0.00052852 3.912e-05 0 2 2 3 0.00139254 3.51e-05 0 2 2 4 0.00154514 3.51e-05 0 2 2 4 0.00154524 0.000547966 3.182e-05 0 2 2 6 0.000154524 0.000547965301					0.00640614	0.00175551	4.617e-05
0 2 1 3 0.00763504 0.000638141 6.101e-05 0 2 1 4 0.00651332 0.000638141 6.101e-05 0 2 1 5 0.00583903 0.0006801555 3.19e-05 0 2 1 6 0.00605330 0.0013128 8e-06 0 2 1 7 0.0056056 0.00376434 3.79e-06 0 2 2 0 0.00184858 0.00139566 3.766e-05 0 2 2 1 0.001726357 0.0005625252 3.912e-05 0 2 2 3 0.003190257 0.00649194 3.51e-05 0 2 2 4 0.00194161 0.000506089 3.189e-05 0 2 2 6 0.000785246 0.000547906 3.1162e-05 0 2 2 6 0.0017453 0.0005479101 2.645e-05					0.00688738	0.000826291	1.94e-05
0 2 1 4 0.00651332 0.000688091 3.966e-05 0 2 1 5 0.00583963 0.000801555 3.19e-05 0 2 1 6 0.005033963 0.00103188 8e-06 0 2 1 7 0.0056056 0.001376494 3.79e-06 0 2 2 0 0.00172635 0.000376494 3.766e-05 0 2 2 1 0.00172635 0.00079154 5.06e-05 0 2 2 3 0.00131022 0.000562852 3.912e-05 0 2 2 3 0.00131025 0.000560893 3.189e-05 0 2 2 4 0.00194161 0.000560893 3.189e-05 0 2 2 5 0.000785246 0.000567906 3.1162e-05 0 2 2 6 0.00174153 0.00056791201 2.845e-05	0				0.00880163	0.000698687	3.277e-05
0 2 1 5 0.09533983 0.000801555 3.19e-05 0 2 1 6 0.0060933 0.00103188 8e-06 0 2 1 7 0.0056056 0.00376494 3.79e-06 0 2 2 0 0.00184858 0.00139566 3.766e-05 0 2 2 1 0.00172635 0.000754943 3.51e-05 0 2 2 2 0.00420422 0.000562552 3.912e-05 0 2 2 3 0.00319025 0.00045194 3.51e-05 0 2 2 4 0.00194161 0.000506089 3.189e-05 0 2 2 6 0.000785246 0.000547906 3.1162e-05 0 2 2 6 0.00174534 0.000547301 2.845e-05	0				0.00763504	0.000638141	6.101e-05
0 2 1 6 0.0060933 0.00103188 8e-06 0 2 1 7 0.0056056 0.00376494 3.79e-06 0 2 2 0 0.00184858 0.00139566 3.766e-05 0 2 2 1 0.00172635 0.000709154 5.06e-05 0 2 2 2 0.001319025 0.000709154 3.51e-05 0 2 2 3 0.00319025 0.000652852 3.912e-05 0 2 2 3 0.0013914151 0.000506089 3.139e-05 0 2 2 4 0.00194161 0.000506089 3.189e-05 0 2 2 6 0.001453 0.000547906 3.1162e-05 0 2 2 6 0.001453 0.000547906 3.1162e-05					0.00651332	0.000688091	3.966e-05
0 2 1 7 0.0056056 0.00376494 3.79e-06 0 2 2 0 0.00184858 0.00139586 3.766e-05 0 2 2 1 0.00172635 0.00079154 5.06e-05 0 2 2 2 0.00172635 0.000562852 3.912e-05 0 2 2 3 0.00319025 0.00045194 3.51e-05 0 2 2 4 0.00194161 0.000566089 3.189e-05 0 2 2 5 0.000785246 0.000547906 3.1162e-055 0 2 2 6 0.001785246 0.0005479101 2.845e-05 0 2 2 6 0.0017453 0.00057101 2.845e-05					0.00583983	0.000801555	3.19e-05
0 2 2 0 0.00184858 0.00139586 3.766e-05 0 2 2 1 0.00172635 0.000709154 5.06e-05 0 2 2 2 0.0042422 0.0045512 3.912e-05 0 2 2 3 0.00319025 0.000495194 3.51e-05 0 2 2 4 0.00194161 0.000506089 3.189e-05 0 2 2 5 0.000785246 0.000547906 3.1162e-05 0 2 2 6 0.0011453 0.0006787101 2.845e-05					0.0060933	0.00103188	8e-06
0 2 2 1 0.00172635 0.000709154 5.06e-05 0 2 2 0.00420422 0.000562852 3.912e-05 0 2 2 3 0.0013025 0.000562852 3.912e-05 0 2 2 3 0.00139025 0.000566089 3.189e-05 0 2 2 4 0.001914161 0.000566089 3.189e-05 0 2 2 5 0.000785246 0.000547906 3.1162e-05 0 2 2 6 0.0011453 0.000673701 2.845e-05					0.0056056	0.00376494	3.79e-06
0 2 2 0.00420422 0.000562852 3.912e-05 0 2 2 3 0.00319025 0.00495194 3.51e-05 0 2 2 4 0.00194161 0.000506089 3.189e-05 0 2 2 5 0.000785246 0.000547906 3.1162e-05 0 2 2 6 0.00174534 0.00067701 2.645e-05							3.766e-05
0 2 2 3 0.00319025 0.000495194 3.51e-05 0 2 2 4 0.00194161 0.000506089 3.189e-05 0 2 2 5 0.000785246 0.000547906 3.1162e-05 0 2 2 6 0.0011453 0.000674701 2.845e-05					0.00172635		5.06e-05
0 2 2 4 0.00194161 0.000506089 3.189e-05 0 2 2 5 0.000785246 0.000547906 3.1162e-05 0 2 2 6 0.0011453 0.000657101 2.845e-05					0.00420422	0.000562852	
0 2 2 5 0.000785246 0.000547906 3.1162e-05 0 2 2 6 0.0011453 0.000687101 2.845e-05					0.00319025	0.000495194	3.51e-05
0 2 2 6 0.0011453 0.000687101 2.845e-05							
					0.000785246	0.000547906	3.1162e-05
0 2 2 7 0.00130652 0.0025965 2.502e-05						0.000687101	2.845e-05
	0	2	2	7	0.00130652	0.0025965	2.502e-05