Transverse Single Spin Asymmetry of Electromagnetic Jets at FMS

Run17 $p^{\uparrow} + p$ Collisions at $\sqrt{s} = 510$ GeV

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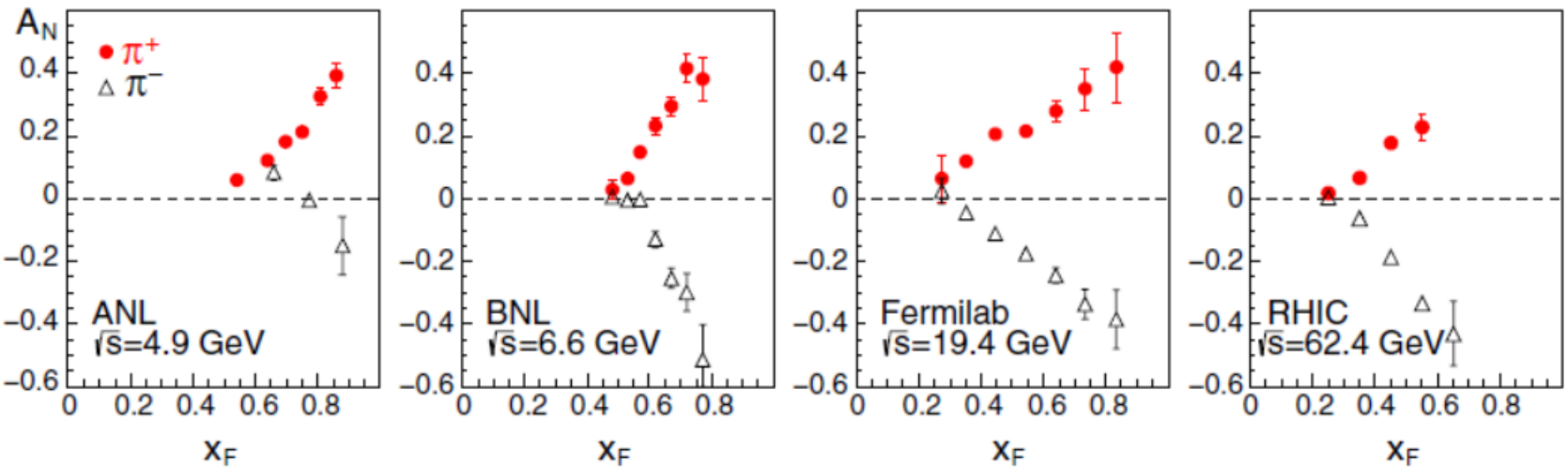
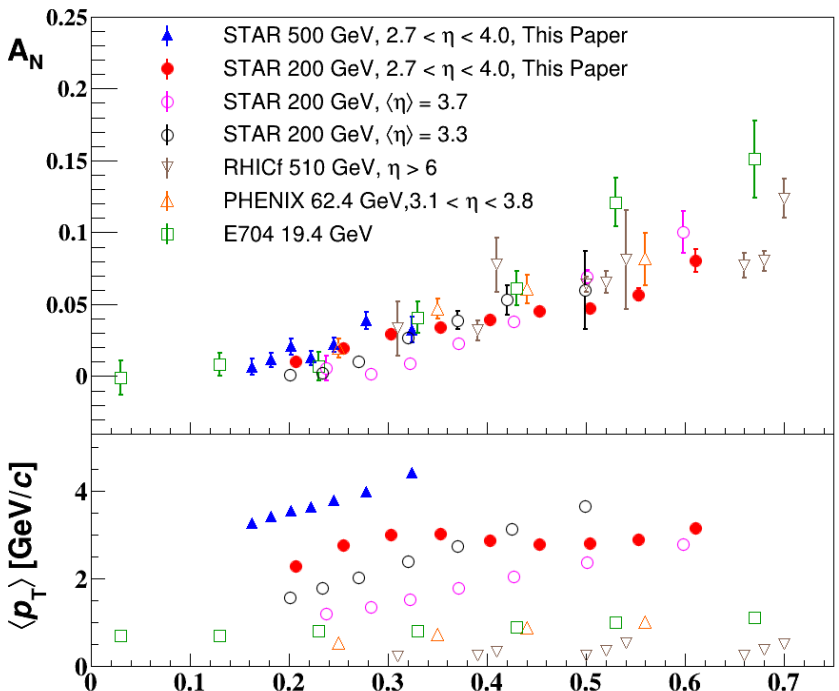
Transverse Single Spin Asymmetry (TSSA/A_N)

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

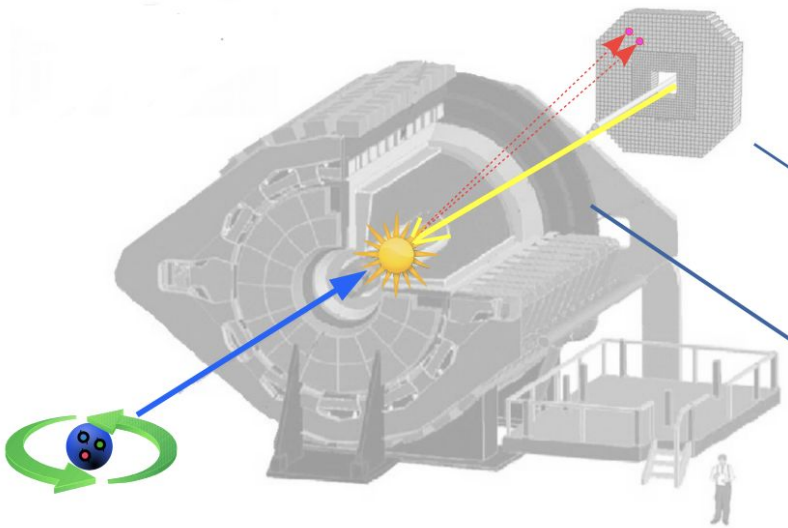


PRD 103, 092009 (2021)



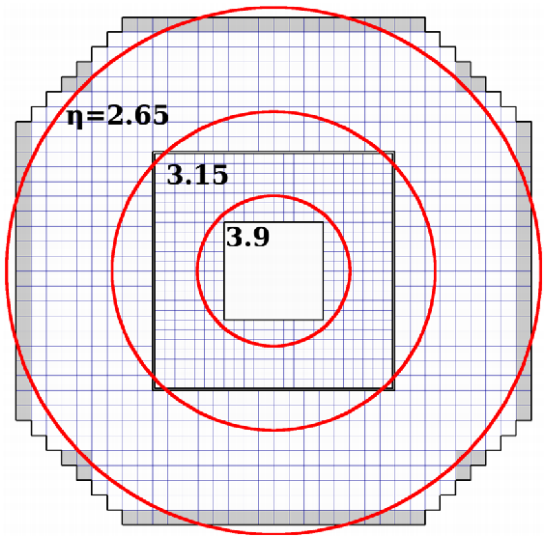
- Explore the potential sources of large A_N observed at forward rapidities
- Characterize A_N in terms of EM-jet p_T, energy and photon multiplicities

The Forward Meson Spectrometer (FMS) at STAR



FMS Forward Meson Spectrometer

EEMC Endcap Electromagnetic Calorimeter



Dataset and Event Selection

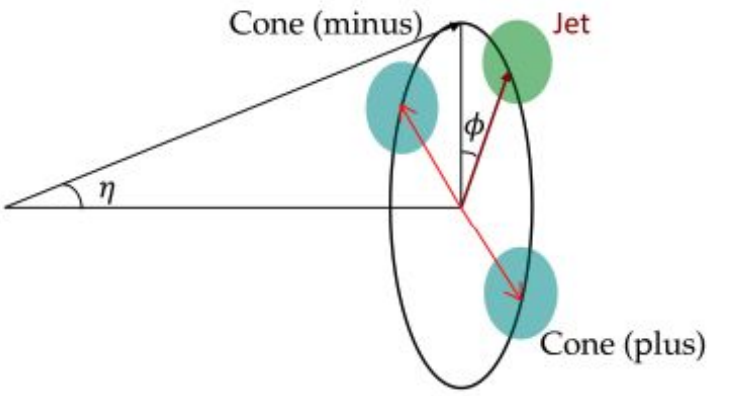
Dataset

- 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

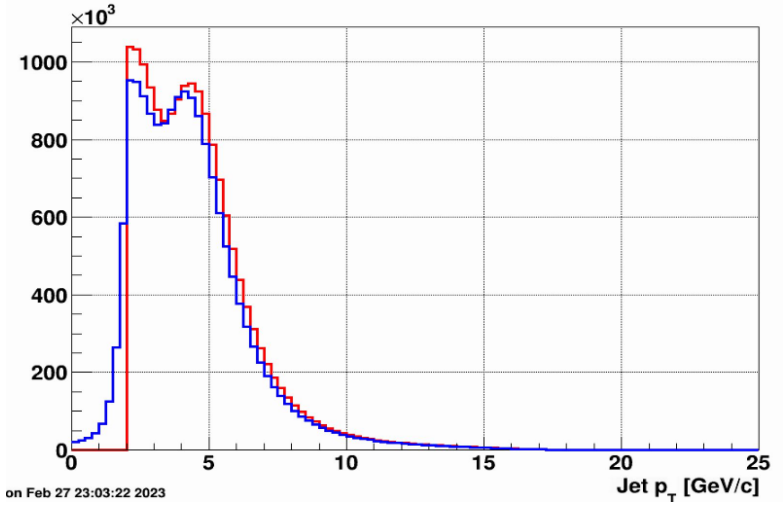
Event Selection

- $|z| \leq 80$ 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

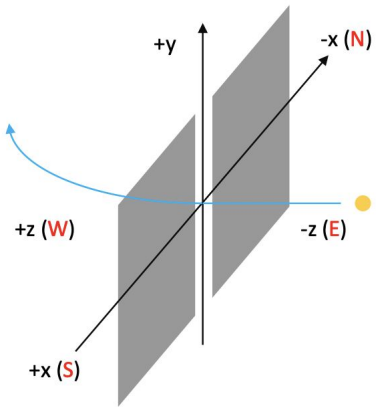


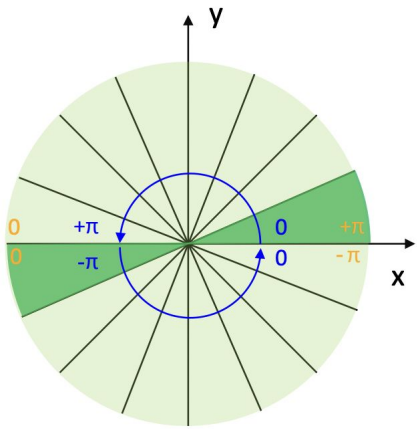
Phys Rev D **91** 112012 (2015), ALICE Collaboration

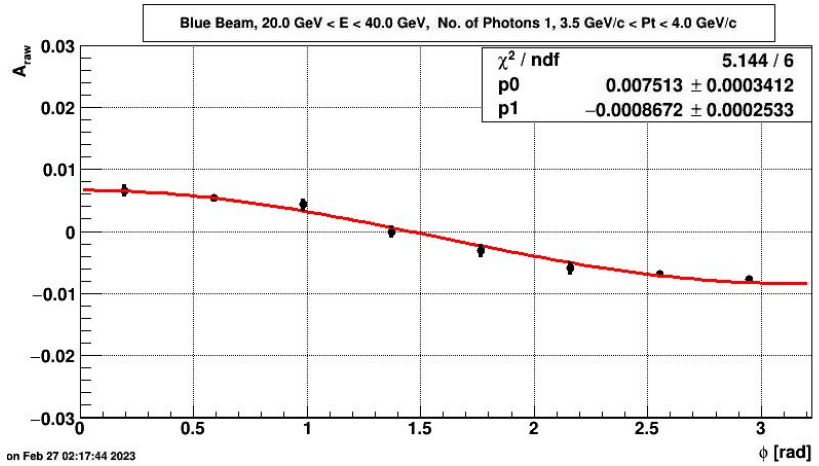


- Off-axis cone method: EM-jet p_T correction for contamination from underlying event (UE)
- dp_T = UE density $\times$ area
- corrected $p_T = p_T - dp_T$

A_N Extraction



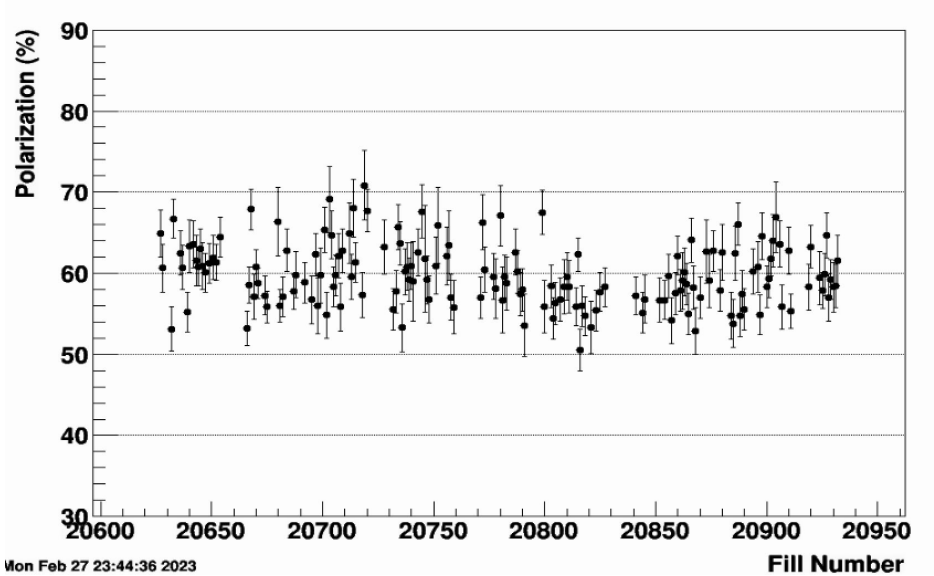




$$\epsilon = A_N \times P \times \cos(\phi) \approx \frac{\sqrt{N_\phi^\uparrow N_{\phi+\pi}^\downarrow} - \sqrt{N_\phi^\downarrow N_{\phi+\pi}^\uparrow}}{\sqrt{N_\phi^\uparrow N_{\phi+\pi}^\downarrow} + \sqrt{N_\phi^\downarrow N_{\phi+\pi}^\uparrow}}$$

- 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

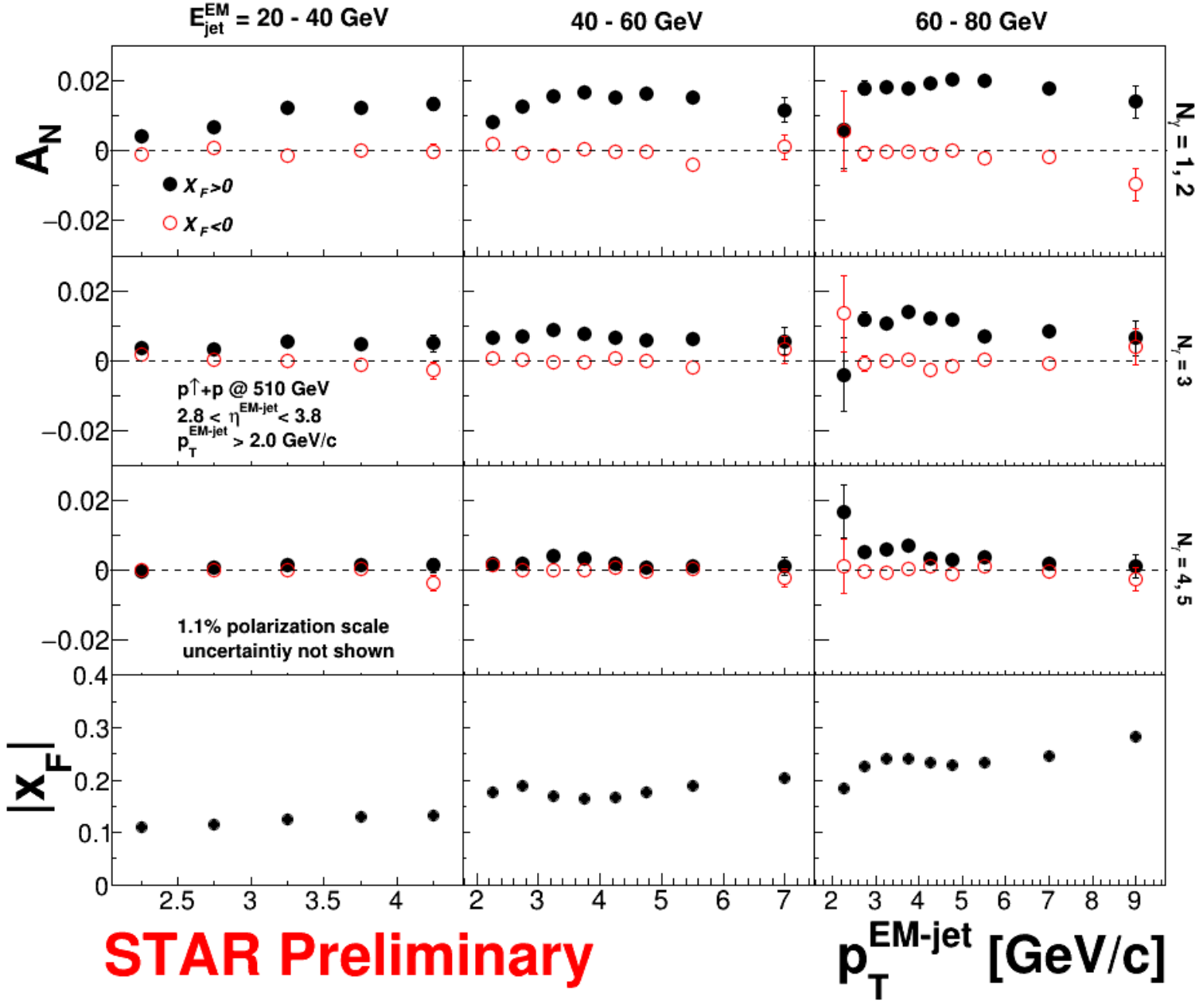
$$\mathcal{P}_{set} = \frac{\sum_i \mathcal{L}_i \cdot \mathcal{P}_i}{\sum_i \mathcal{L}_i}$$

$$\mathcal{P}_i = \frac{1}{\mathcal{L}_i} \int dt \mathcal{L}_i(t) P_i(t)$$

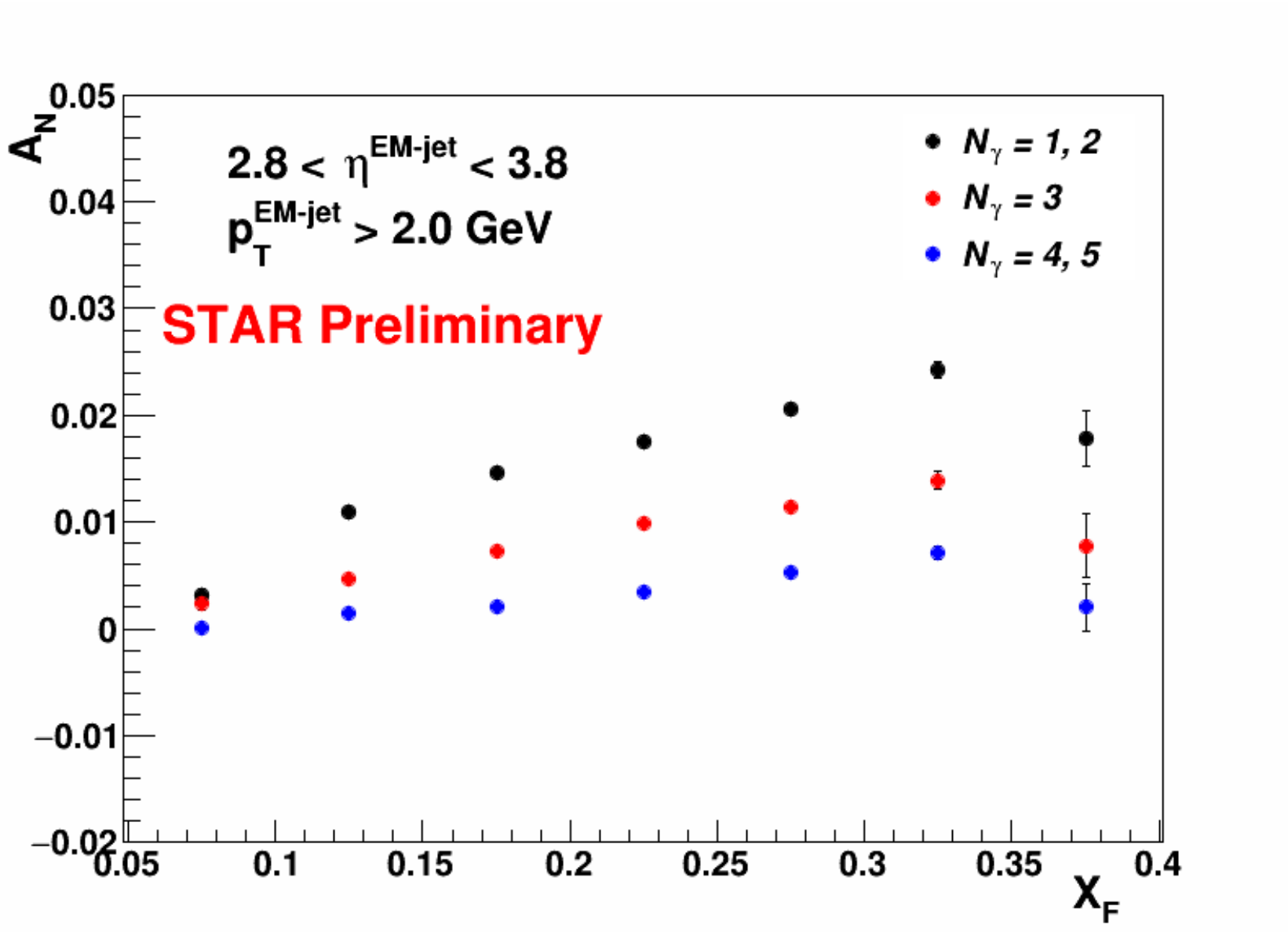
$$= P_{0,i} - \frac{\int dt L_i(t) t}{\mathcal{L}_i} P_i'$$

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

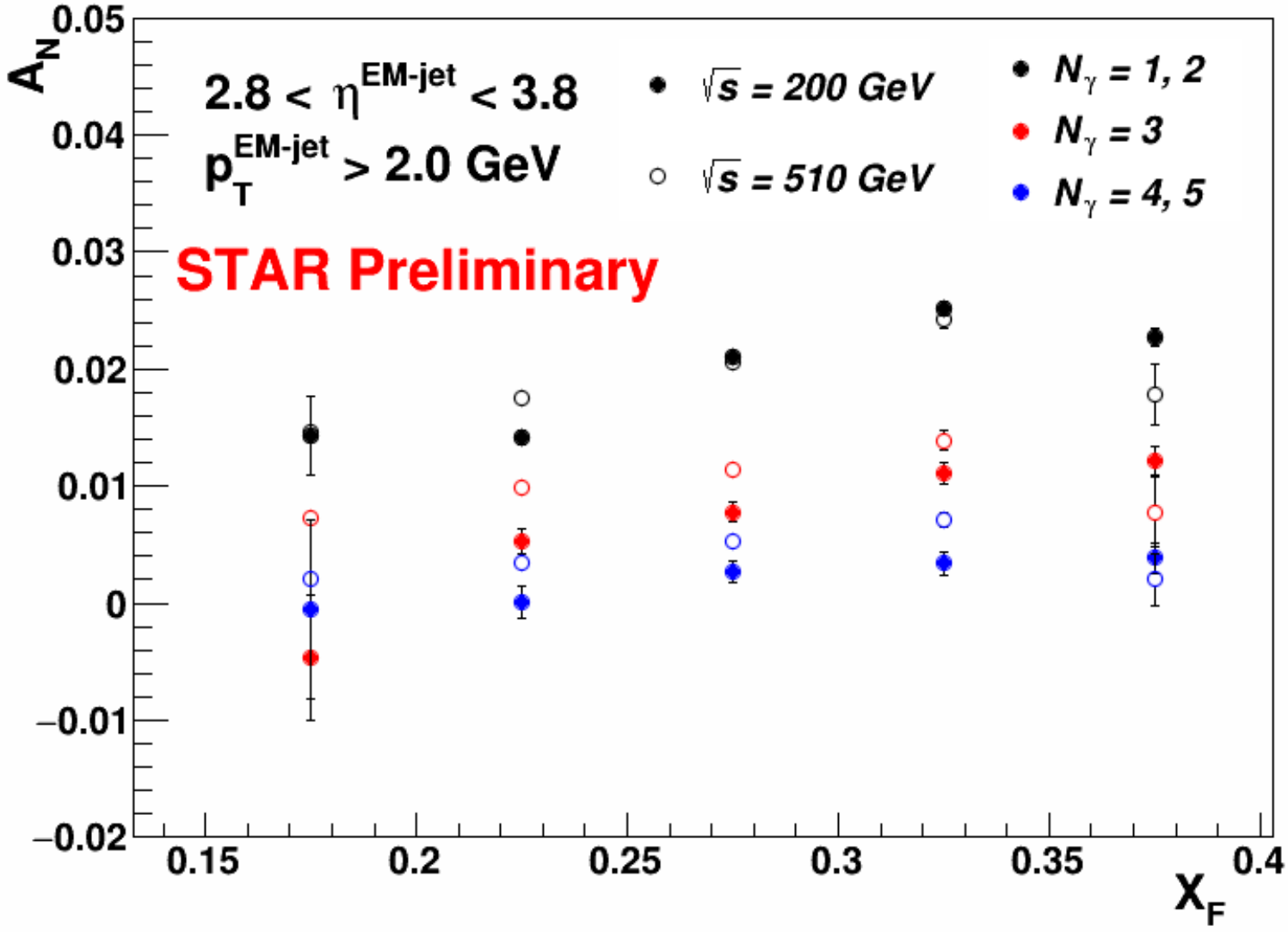
A_N vs p_T


E_{jet}^{EM} = 20 - 40 GeV
40 - 60 GeV
60 - 80 GeV
A_N
$X_F>0$
$X_F<0$
N_γ = 1, 2
N_γ = 3
N_γ = 4, 5
p↑+p @ 510 GeV
2.8 < η^{EM-jet} < 3.8
p_T^{EM-jet} > 2.0 GeV/c
1.1% polarization scale
uncertaintiy not shown
$|X_F|$
STAR Preliminary
p_T^{EM-jet} [GeV/c]

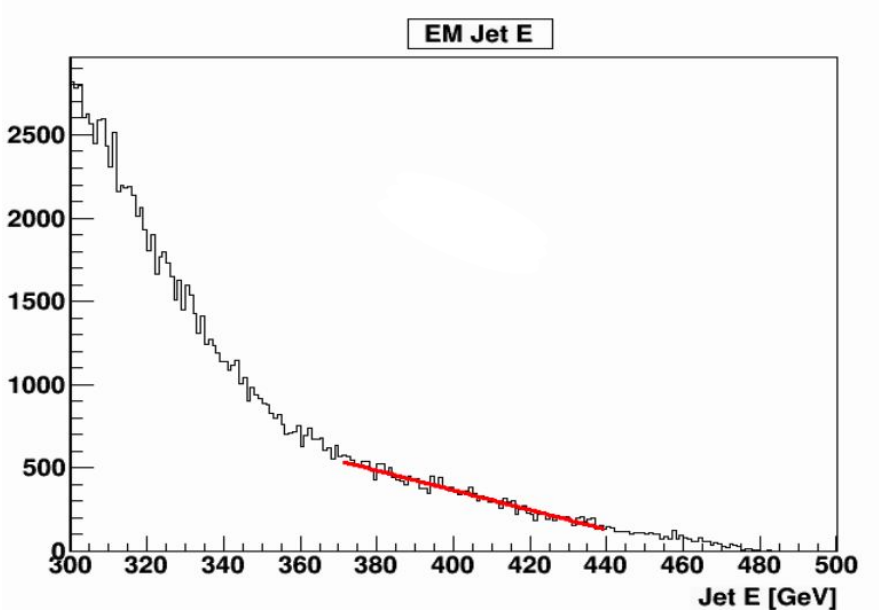
A_N vs x_F

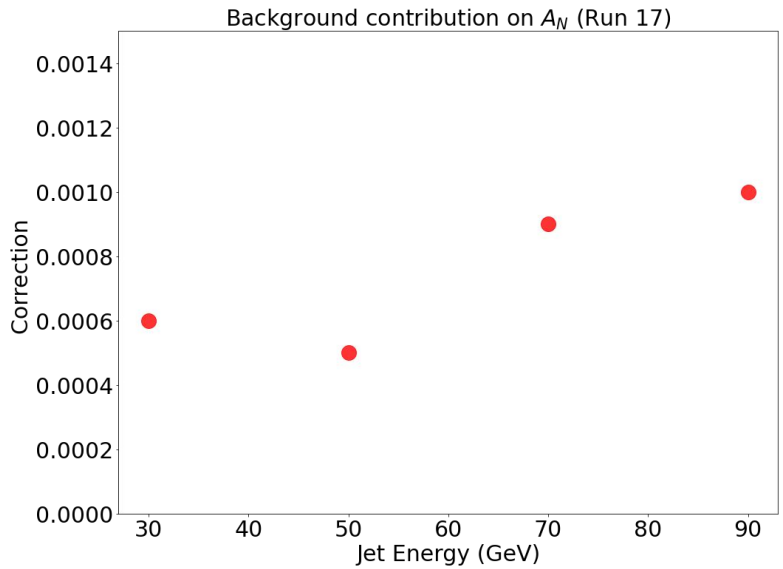

A_N
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
x_F
$2.8 < \eta^{\text{EM-jet}} < 3.8$
$p_T^{\text{EM-jet}} > 2.0$ GeV
STAR Preliminary
$N_\gamma = 1, 2$
$N_\gamma = 3$
$N_\gamma = 4, 5$

Run 17 vs 15


A_N
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
0.15
0.2
0.25
0.3
0.35
0.4
X_F
$2.8 < \eta^{\text{EM-jet}} < 3.8$
$p_T^{\text{EM-jet}} > 2.0$ GeV
$\sqrt{s}$ = 200 GeV
$\sqrt{s}$ = 510 GeV
N_γ = 1, 2
N_γ = 3
N_γ = 4, 5
STAR Preliminary

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:

$$\Delta N_{1,2} = -(f_0 + f_3)N_{1,2} + f_0 N_3$$

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

$$\Delta N_{4,5} = f_3 N_3 - (f_0 + f_3)N_{4,5}$$

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

Summary

- Run 17 A_N (510 GeV) is extracted as functions of p_T and x_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	0.00659193	0.000563123	2.381e-05
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	0.00191457	4.07e-05
0	1	1	0	0.00373862	0.000713572	2.139e-05
0	1	1	1	0.00315451	0.000552445	8.306e-05
0	1	1	2	0.0054019	0.000692862	0.00029039
0	1	1	3	0.00478225	0.000906421	0.00032669
0	1	1	4	0.00494961	0.00230934	0.00037478
0	1	2	0	-0.000169597	0.000569213	8.4524e-05
0	1	2	1	0.000628898	0.000429129	5.0578e-05
0	1	2	2	0.00133553	0.000579922	9.567e-05
0	1	2	3	0.00138484	0.000836631	9.752e-05
0	1	2	4	0.00140425	0.00212287	0.00010241
0	2	0	0	0.00822713	0.00169655	1.6e-05
0	2	0	1	0.0125514	0.0007473	4.8e-05
0	2	0	2	0.0155137	0.000642675	5.74e-05
0	2	0	3	0.0166897	0.000592114	8.02e-05
0	2	0	4	0.0154208	0.000659765	8.36e-05
0	2	0	5	0.0164637	0.000793356	0.0001066
0	2	0	6	0.0151976	0.00101593	9.06e-05
0	2	0	7	0.0116941	0.00348445	4.92e-05
0	2	1	0	0.00640614	0.00175551	4.617e-05
0	2	1	1	0.00688738	0.000826291	1.94e-05
0	2	1	2	0.00880163	0.000698687	3.277e-05
0	2	1	3	0.00763504	0.000638141	6.101e-05
0	2	1	4	0.00651332	0.000688091	3.966e-05
0	2	1	5	0.00583983	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	0.00139586	3.766e-05
0	2	2	1	0.00172635	0.000709154	5.06e-05
0	2	2	2	0.00420422	0.000562852	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	0.000687101	2.845e-05
0	2	2	7	0.00130652	0.0025965	2.502e-05