Transverse Single Spin Asymmetry (A_N) for Electromagnetic-Jet in FMS

Dataset run 17 p↑ + p collision at √s=510 GeV

Preliminary request

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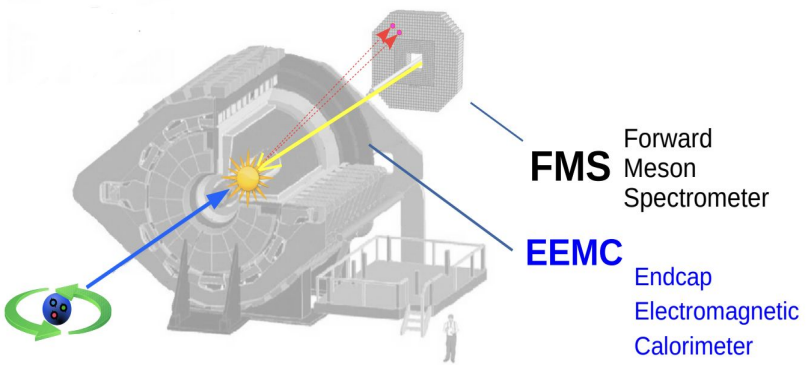
EM-jet A_N ($p\uparrow + p \rightarrow$ EM-jet + X)

Characterize A_N as a function of EM-jet-$p_{T,}$ EM-jet energy, and photon multiplicities



Data Features:

- Data-stream: FMS-stream
- Dataset: Run 17 ($\sqrt{s}$ = 510 GeV pp trans)
- Transversely polarized protons (<P>= 59%)
- Triggers: Small BS, Large BS and FMS-JP trigger
- Calibration from Minghui
- FMS hot channel masking before reconstruction
- Exclude highly bit-shifted FMS channels
- Production tag : P18ic
- STAR Library version: SL20a

EM-jet: Jet reconstructed out of photons only

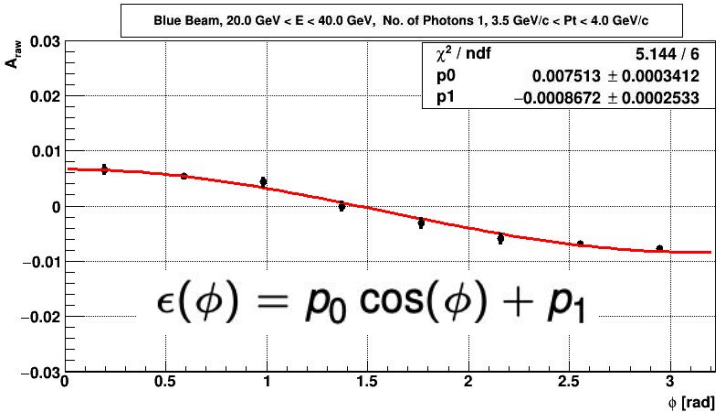
Jet Reconstruction

- Anti-k_T jet clustering algorithm with R= 0.7
- $E\gamma$ > 1.0 GeV
- -80 < z < 80 cm
- Jet p_T > 2.0 GeV/c
- 2.8 < η < 3.8

EM-Jet A_N Extraction

A_N as a function of EM-jet p_T, EM-jet energy, and photon multiplicity

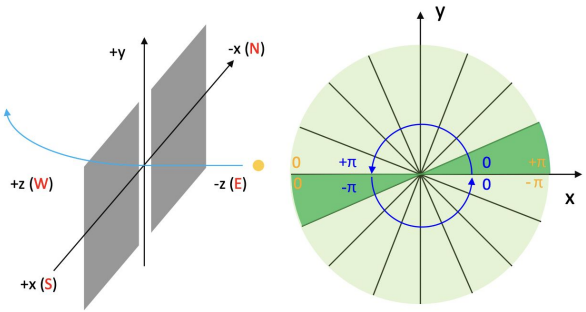
- Energy bins: [0-20] , [20 -40], [40 -60], [60 -80] ,
- and [80 -100] GeV
- 16 equal $\boldsymbol{\phi}$ bins in the range - $\boldsymbol{\pi}$ to $\boldsymbol{\pi}$
- 5 photon multiplicity bins
- Separately for $x_F>0$ and $x_F<0$



- Cross-ratio formula to calculate A_N

$$\epsilon = A_N \times P \times \cos(\phi)$$

$$\epsilon \approx \frac{\sqrt{N_{\phi}^{\uparrow} N_{\phi+\pi}^{\downarrow}} - \sqrt{N_{\phi+\pi}^{\uparrow} N_{\phi}^{\downarrow}}}{\sqrt{N_{\phi}^{\uparrow} N_{\phi+\pi}^{\downarrow}} + \sqrt{N_{\phi+\pi}^{\uparrow} N_{\phi}^{\downarrow}}}$$



Cancels systematics, such as luminosity and detector effects

Electromagnetic-Jet A_N Correction and Uncertainty

- **Polarization Error**

- **Background Uncertainty**
  - **Underlying events**

- **Energy or p_T Corrections and Uncertainties:**
  - Calibration uncertainty
  - Energy or p_T correction
  - Uncertainty due to radiation damage

- **Event Misidentification:**
  - Misidentification of 1, 2 etc photons as other types (2, 1, etc)

Polarization Uncertainty

$$P_{fill} = \sigma(P_0) + \frac{dp}{dt} \cdot \left(\frac{\sum_{run} t_{run} L_{run}}{L_{fill}} - t_0 \right)$$

$$P_{set} = \frac{\sum_{fill} L_{fill} P_{fill}}{\sum_{fill} L_{fill}}$$

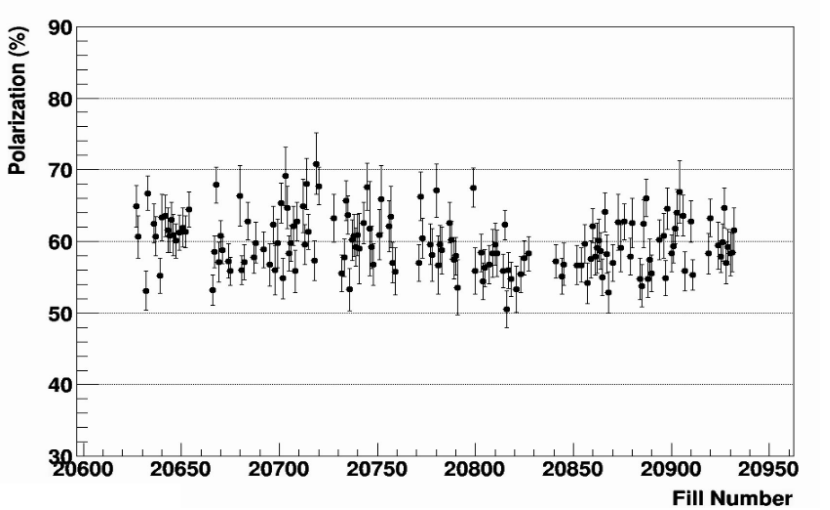
$$\frac{\sigma_{P_{Set}}}{P_{Set}} = \frac{\sigma(scale)}{P} \oplus \sigma_{fill-to-fill} \oplus \frac{\sigma(profile)}{P}$$

$$\frac{\sigma(scale)}{P} = 1.1\ \%$$

$$\frac{\sigma(profile)}{P} = \frac{2.2}{\sqrt{M}}$$

$$\sigma_{fill-to-fill} = \left(\sqrt{1 - \frac{M}{N}} \right) \frac{\sum_{fill} L_{fill} \sigma_{P_{fill}}}{\sum_{fill} L_{fill}}$$

$$\sigma(P_{fill}) = \sigma(P_0) \oplus \sigma \left(\frac{dp}{dt} \right) \cdot \left(\frac{\sum_{run} t_{run} L_{run}}{L_{fill}} - t_0 \right)$$

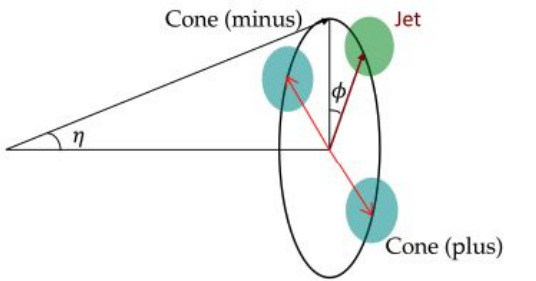


- M = 162
- N = 190
- $\sigma_{\text{fill-to-fill}}$ = 1.08 %
- P_{Set} = 59.94 %
- σ_{PSet} = 1.07 %

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

[2] Z. Chang, Example calculation of fill-to-fill polarization uncertainties

Underlying Event (UE) Correction



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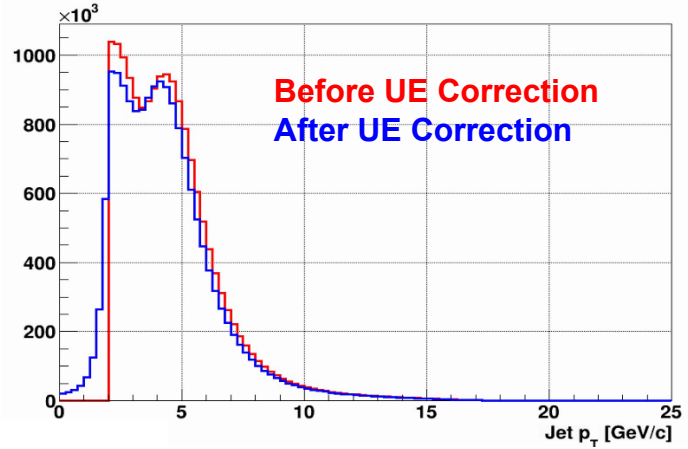
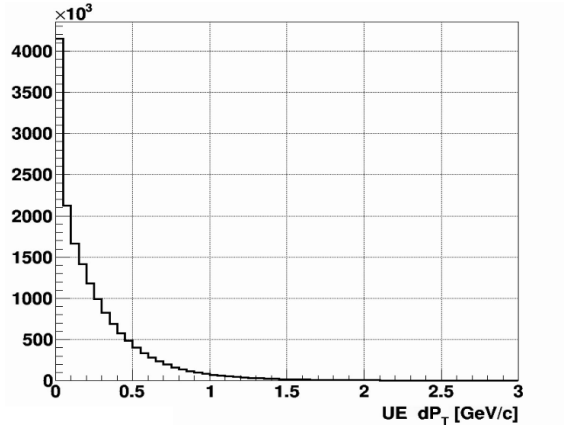


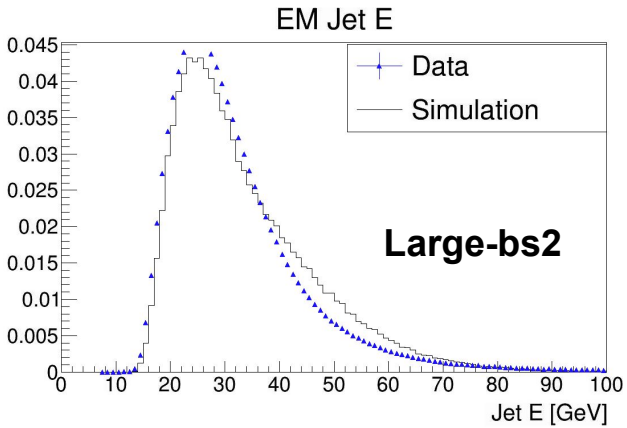


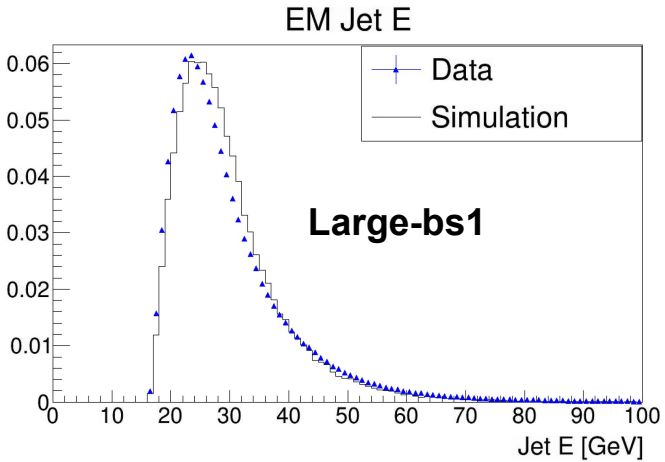
- EM-jet p_T values are corrected for contaminations from underlying events (UE) using off-axis cone method
- Correction to jet p_T, dp_T = underlying Event Density x Area
- Corrected Jet $\mathbf{p_T = p_T - dp_T}$

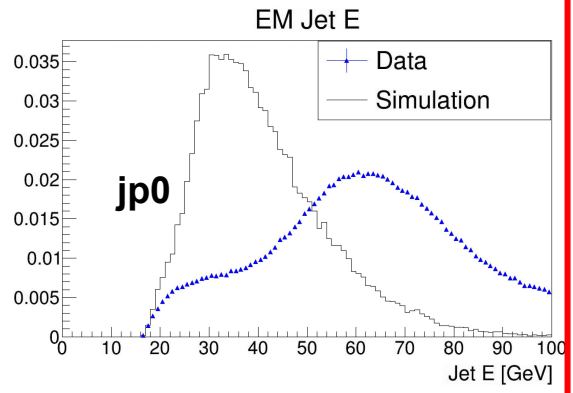
Correction is applied to the presented result

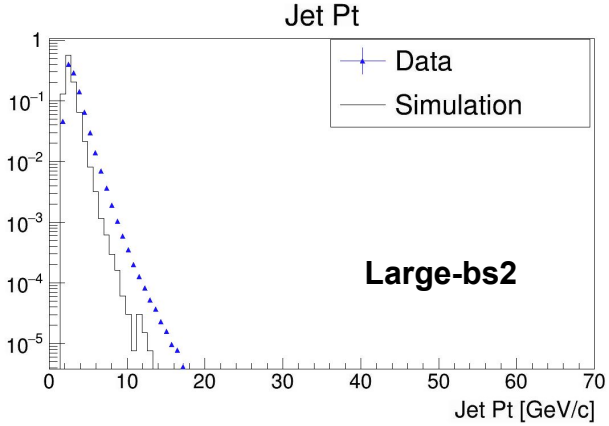
Data vs Simulation

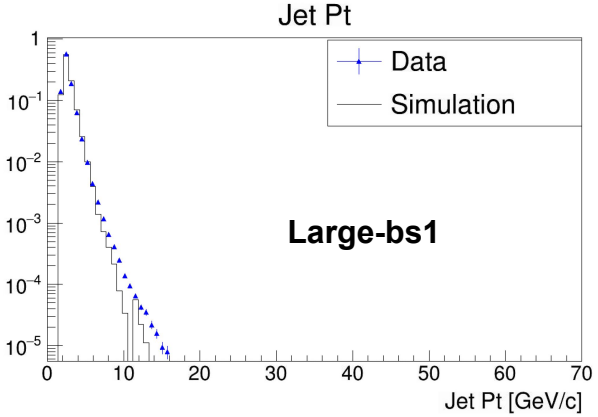
Cut: p_t>2 GeV/c both in sim and data

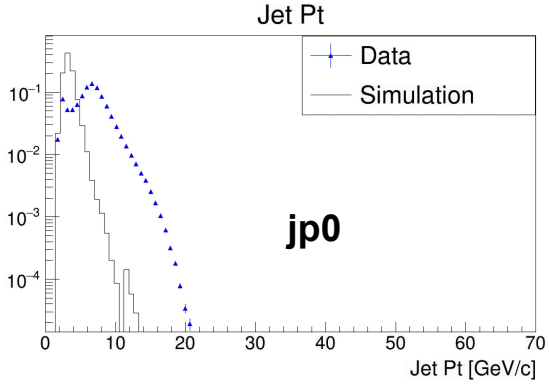






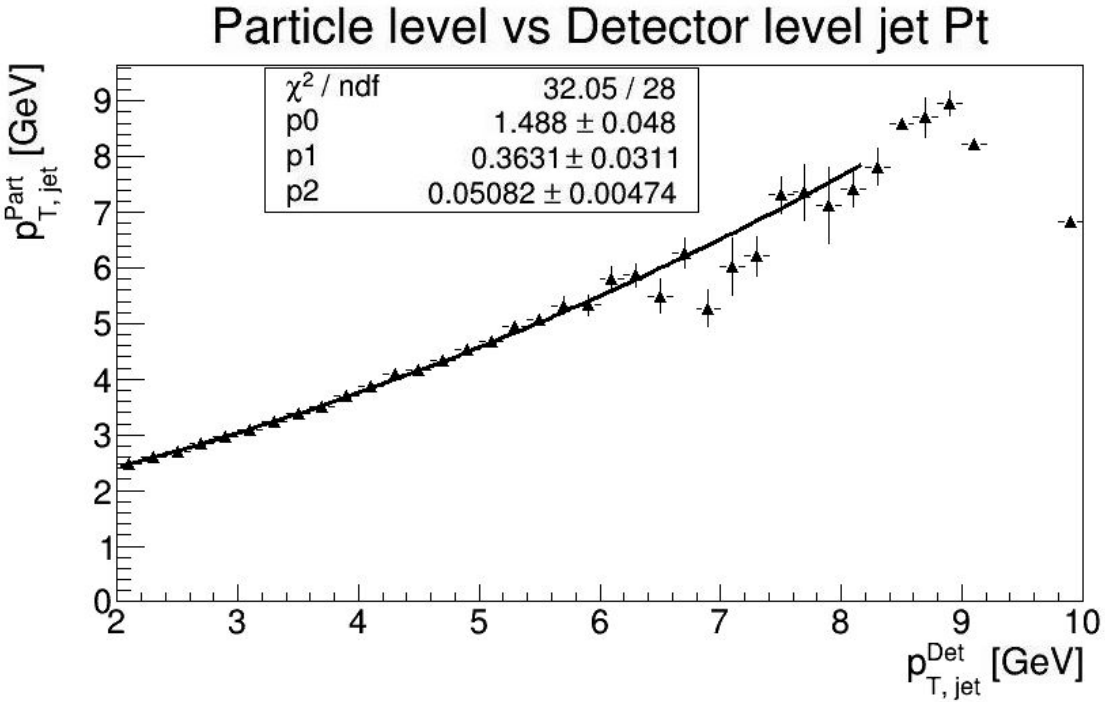


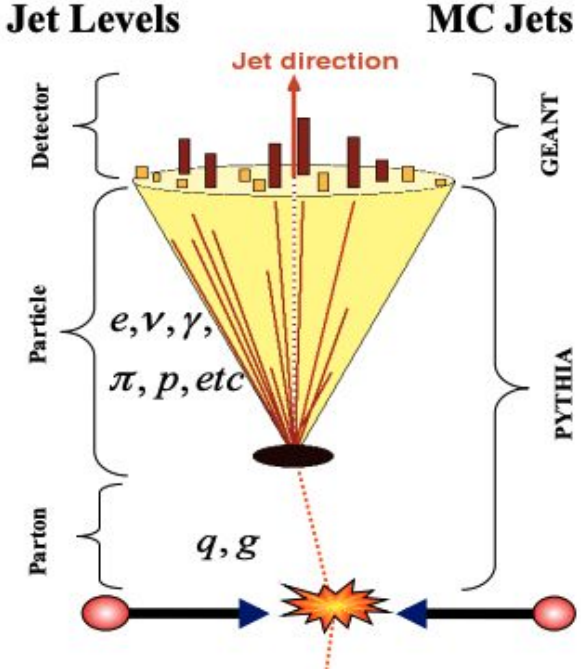




For correction from simulation Jet patch trigger is excluded

p_T correction from simulation





p_T in data is corrected using the fit from simulation

p_T Uncertainty

$$\frac{\sigma_{p_T}}{p_T} = C \oplus G \oplus E$$

C: Calibration Uncertainty (3.5%)

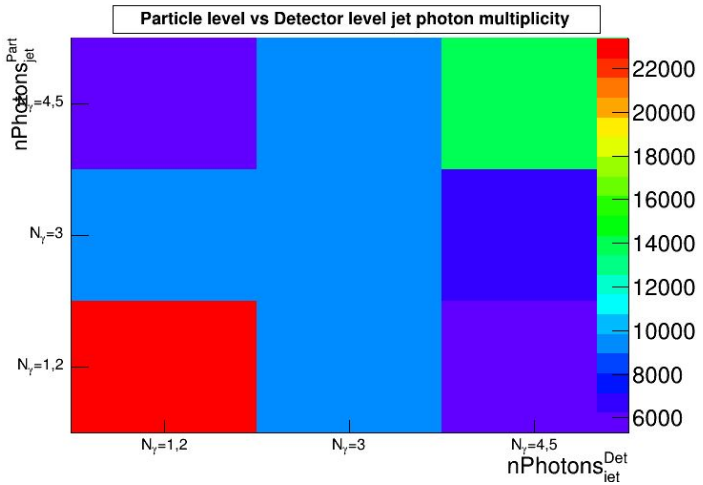
G: Uncertainty from non-linear response and radiation damage (0.5%)

E: Uncertainty from energy resolution and correction (1.5 %)

$$\boxed{\frac{\sigma_{p_T}}{p_T} \sim \mathbf{4\%}}$$

Ref: Run 11 and 15 π^0 A_N Analysis Note by Zhanwen Zhu

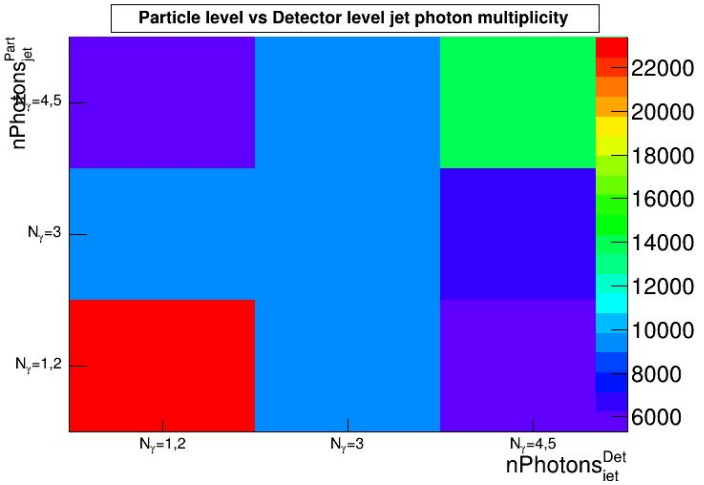
Unfolding for Event Misidentification

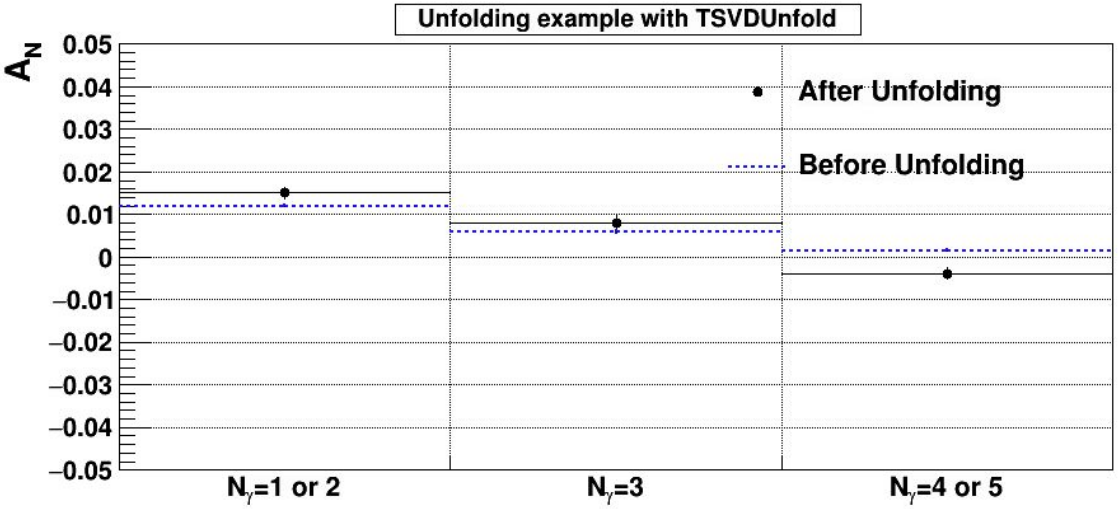


$$\underset{X}{\begin{pmatrix} A_N^{sim}\ (1,\ 2\ \text{photon}) \\ A_N^{sim}\ (3\ \text{photon}) \\ A_N^{sim}(4,\ 5\ \text{photon}) \end{pmatrix}} \underset{A}{=} \underset{Y}{\begin{pmatrix} A_N^{data}\ (1,\ 2\ \text{photon}) \\ A_N^{data}\ (3\ \text{photon}) \\ A_N^{data}(4,\ 5\ \text{photon}) \end{pmatrix}}$$

- Solve a set of five linear equations with 3 variables for each energy and p_T bin using simulation
- Decompose A_N as a linear combination of A^i_N corresponding to n_i photons
- Use SVD for the unfolding procedure (e.g TSVD Unfolding class from ROOT Framework)

Unfolding for Event Misidentification





A_N before unfolding are reported

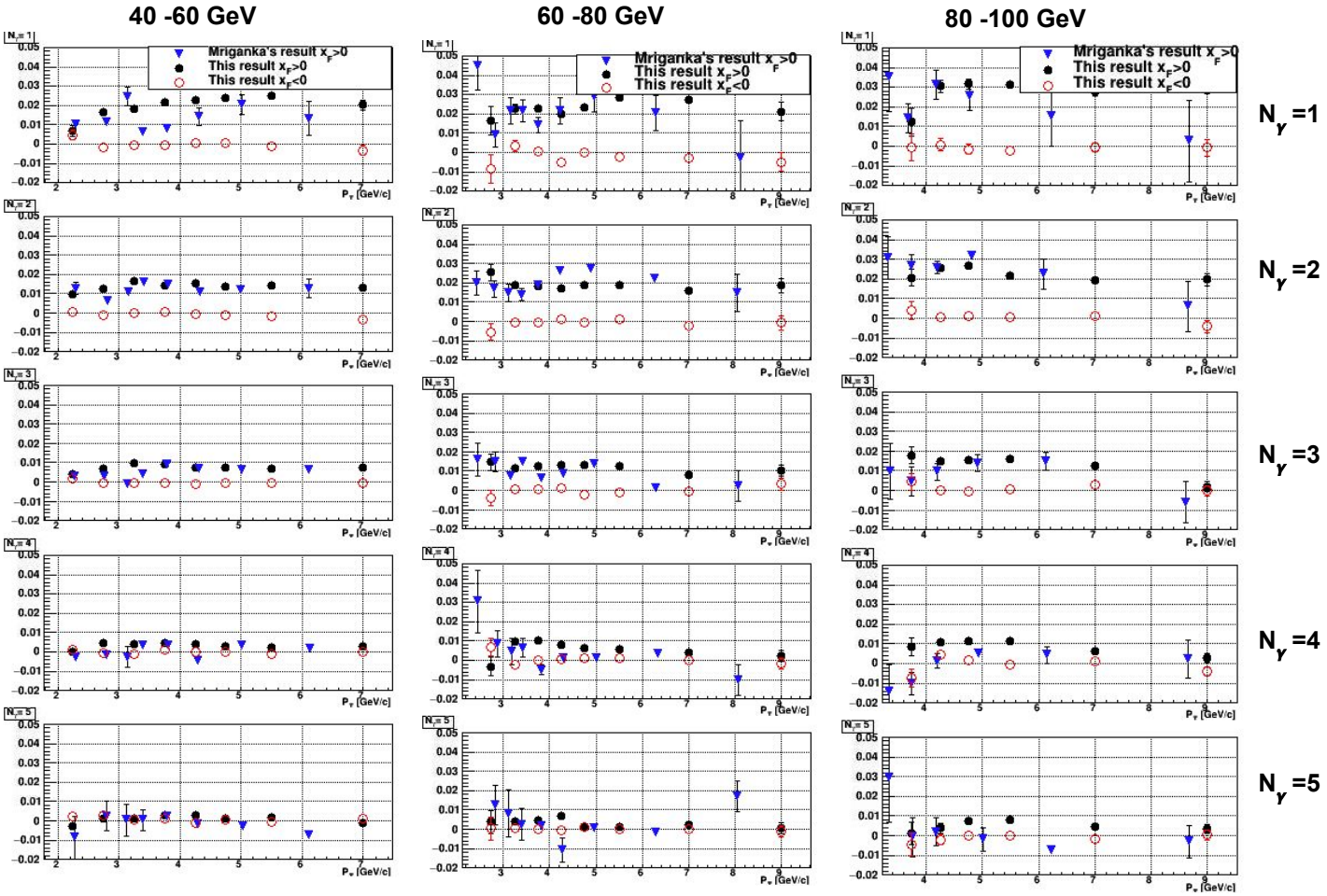
$$\textbf{Systematic Error} = \frac{A_N \text{before Unfolding} - A_N \text{after Unfolding}}{A_N \text{before Unfolding}}$$

Systematic Uncertainty

Uncertainty in	**Source**	**N_γ = 1, 2**	**N_γ = 3**	**N_γ = 4,5**
A_N	Photon Misidentification	20%	15%	20%
A_N	Polarization	1%	1%	1%
p_T	Calibration	4%	4%	4%

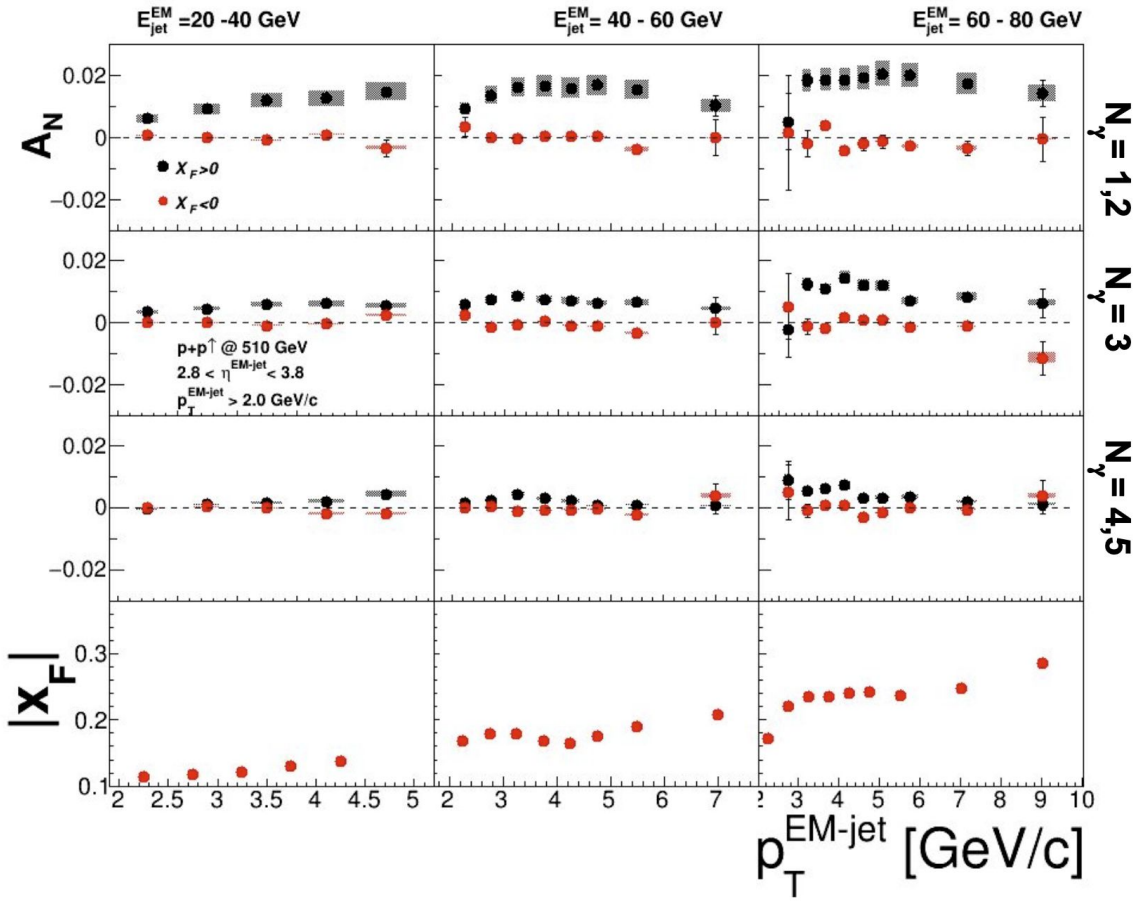
Major source of uncertainty coming from photon misidentification

Comparing with existing results (Run 11 Mriganka Mouli Mondal)



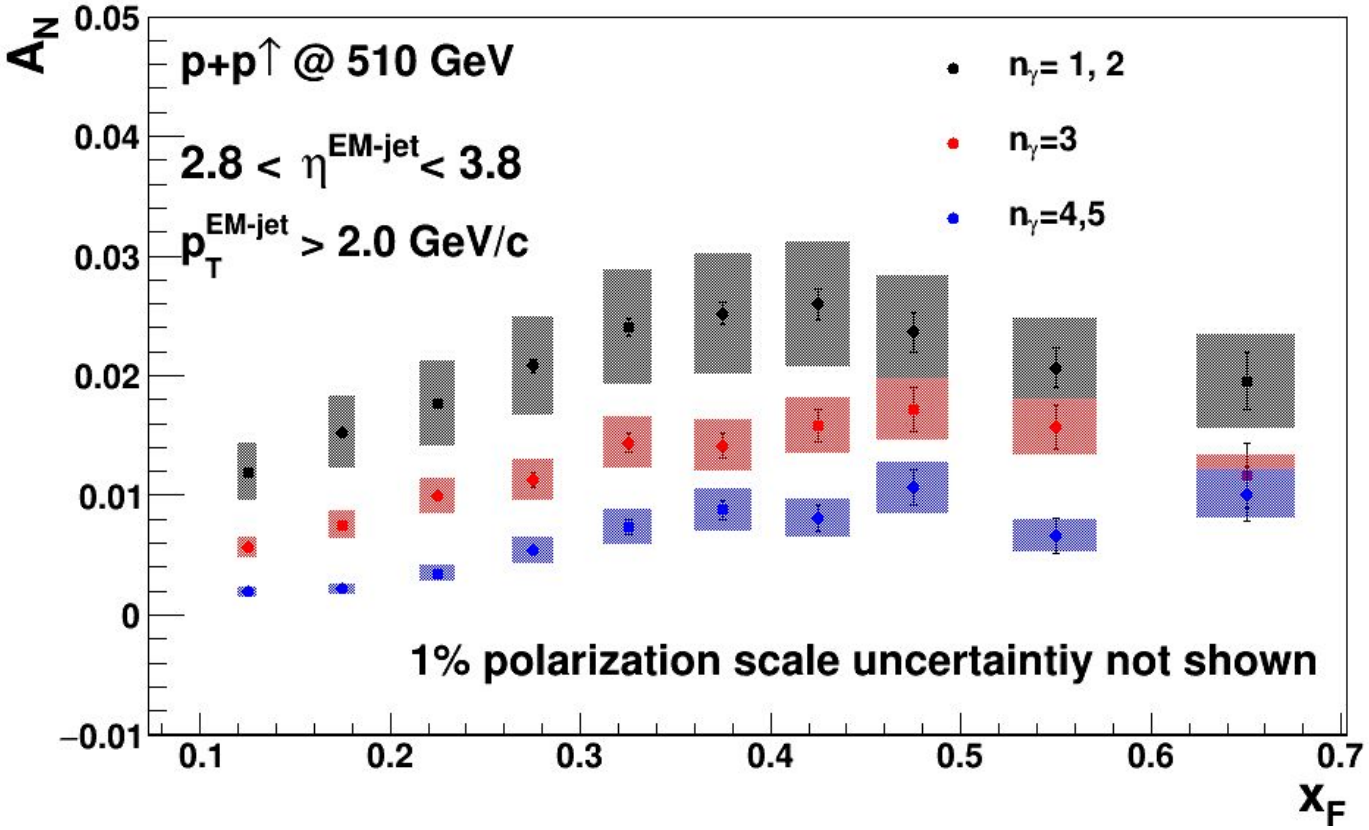
- Different p_T binning
- Consistent with Run 11 data

A_N as photon multiplicity

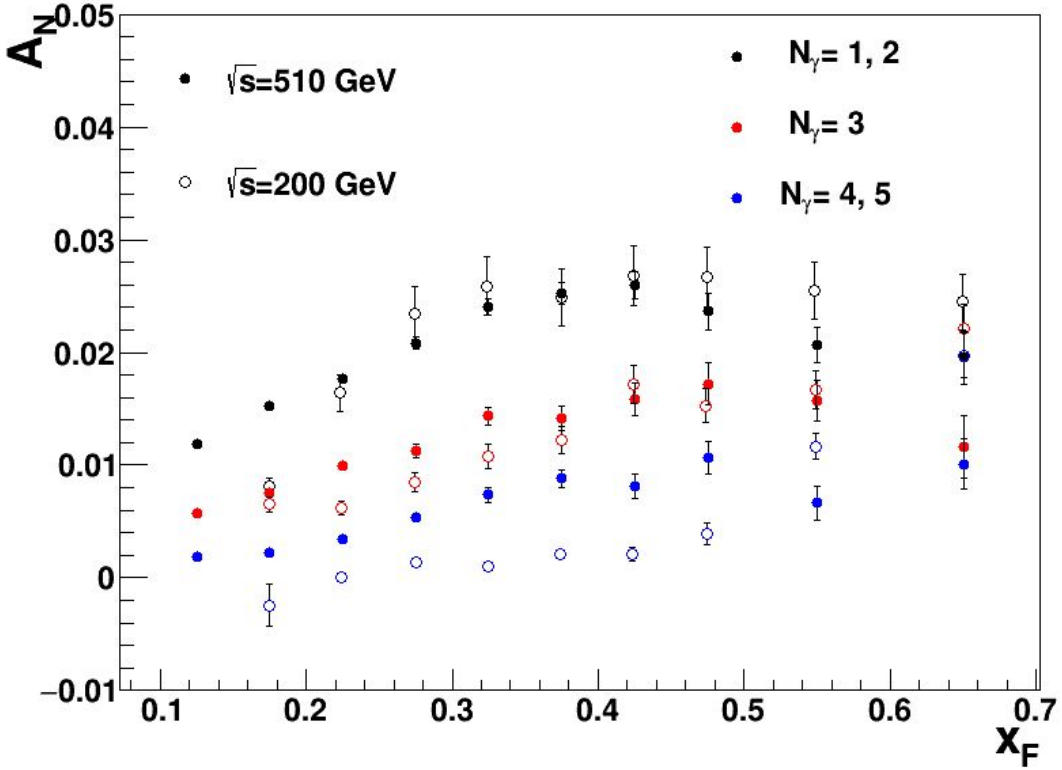


- A_N for 1 or 2 photons, 3 photons, and 4 or 5 photons
- A_N dependence on photon multiplicity
- A_N decreases as complexity increases (larger number of photons in EM-jet)

A_N as photon multiplicity



A_N at different √s and photon multiplicities



L.Kabir p↑ + p @200 GeV

About 15% systematic uncertainty for both run 17 √s =200 GeV and run 15 (√s =200 GeV)

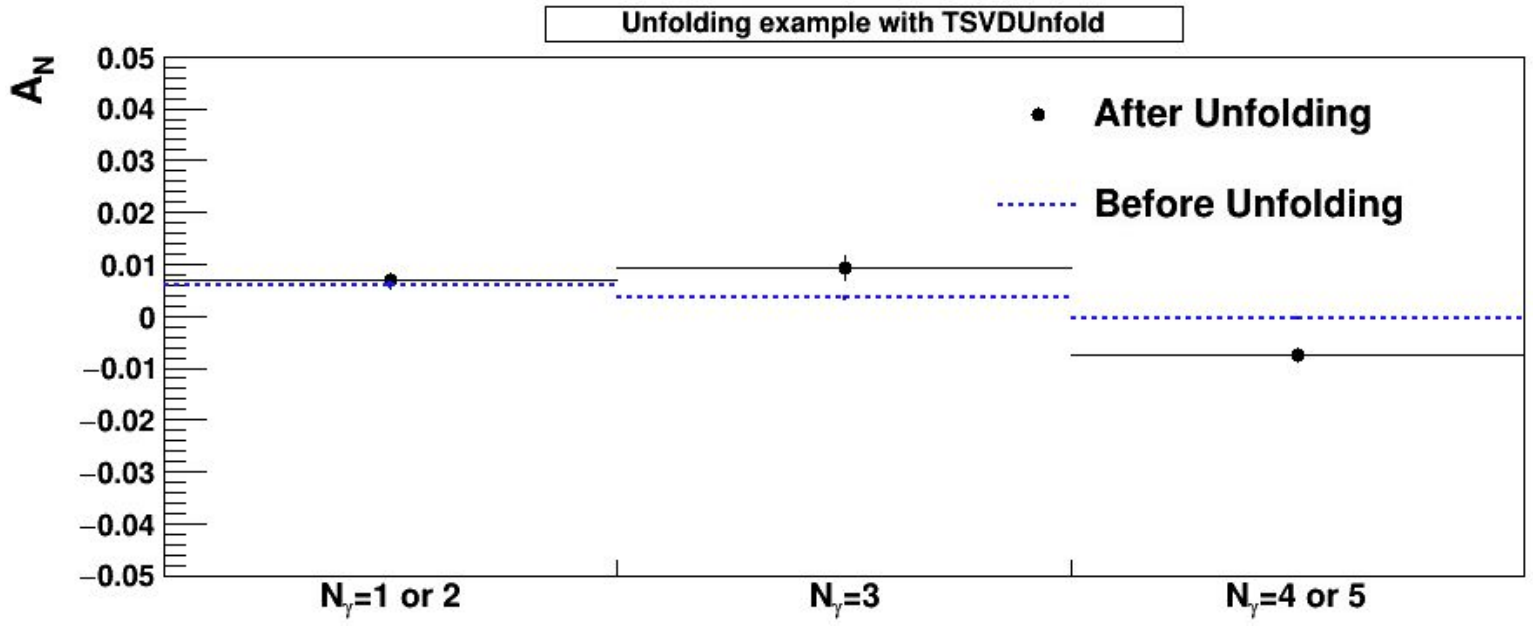
Conclusion

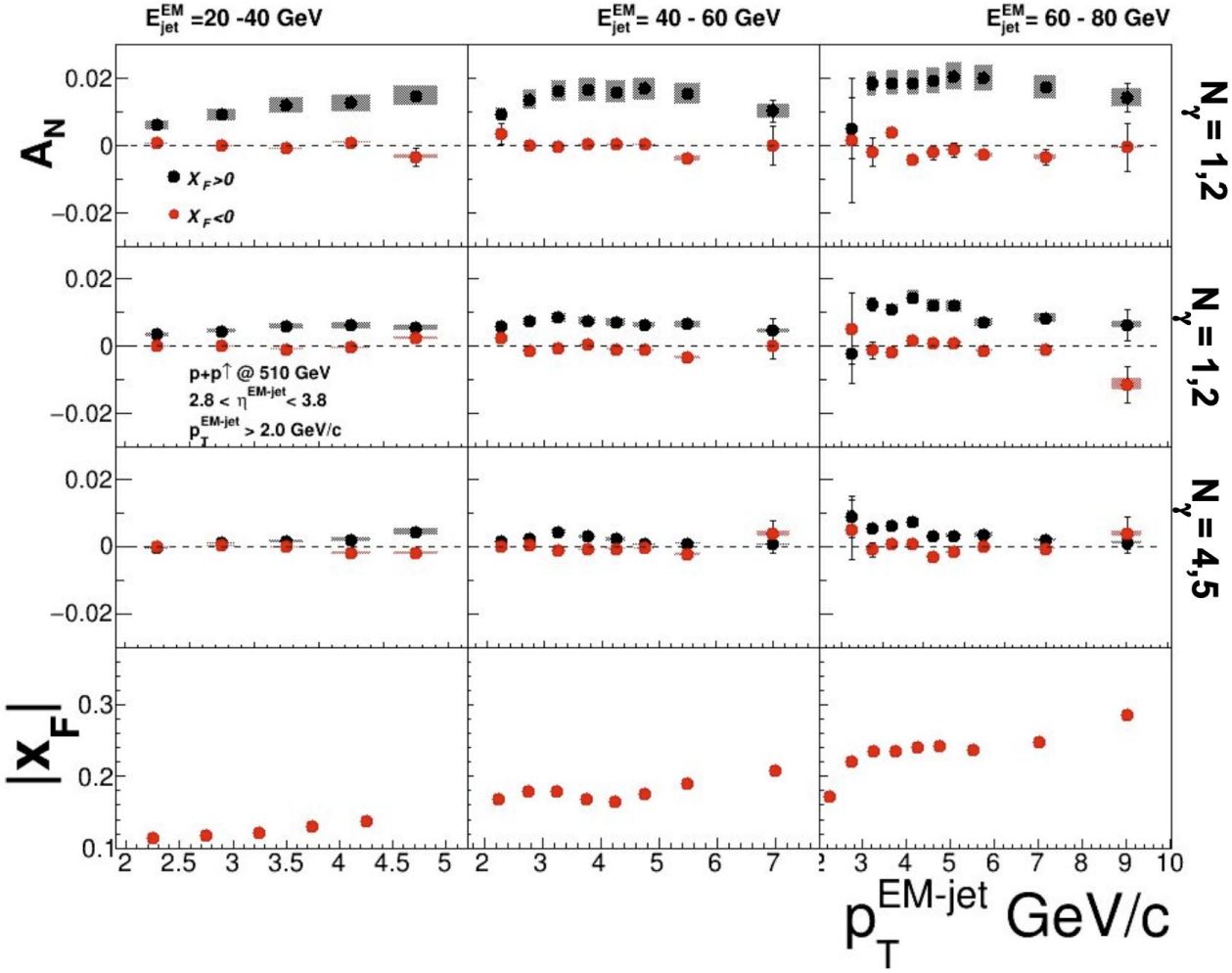
- A_N for EM-jet are extracted using run 17 data set, p↑ + p collision at √s=510 GeV
- A_N are extracted as function of EM-jet p_T, x_F , photon multiplicities for different energies bin
- Extracted A_N are in agreement with similar existing result from run 11 Mriganka Mouli Mondal
- For simulation only board sum trigger are considered for correction
- Correction and systematic are implemented
- A_N shows similar trend as previous results, decreases with higher photon multiplicities
- A_N shows no any dependence with √s

Thanks to STAR cold QCD PWG

Backup

Unfolding for Event Misidentification
First p_t bin




E_{jet}^{EM} =20 -40 GeV
E_{jet}^{EM}= 40 - 60 GeV
E_{jet}^{EM}= 60 - 80 GeV
A_N
X_F>0
X_F<0
p+p↑ @ 510 GeV
2.8 < $\eta^{EM\text{-}jet}$ < 3.8
$p_T^{EM\text{-}jet}$ > 2.0 GeV/c
N_γ = 1,2
N_γ = 1,2
N_γ = 4,5
$|x_F|$
$p_T^{EM\text{-}jet}$ GeV/c