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

Dataset run 17 p↑ + p collision at $\sqrt{s}$=510 GeV

STAR Collaboration Meeting
Oct 24, 2023

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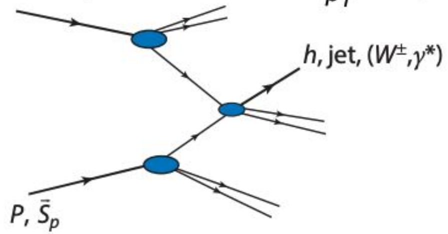
Follow up for the status presented here
My Blog

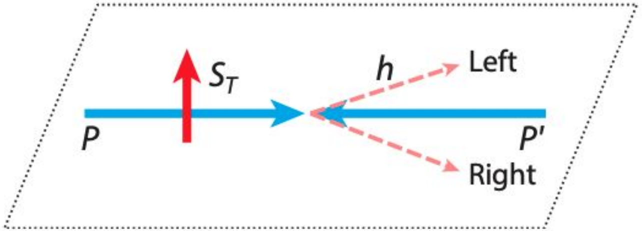
Transverse Single Spin Asymmetry (A_N)

- Unexpected large transverse single-spin asymmetries (A_N) are observed in proton-proton collisions
- pQCD predicts $A_N \sim \frac{m_q}{p_T} \cdot \alpha_S \sim 0.001$

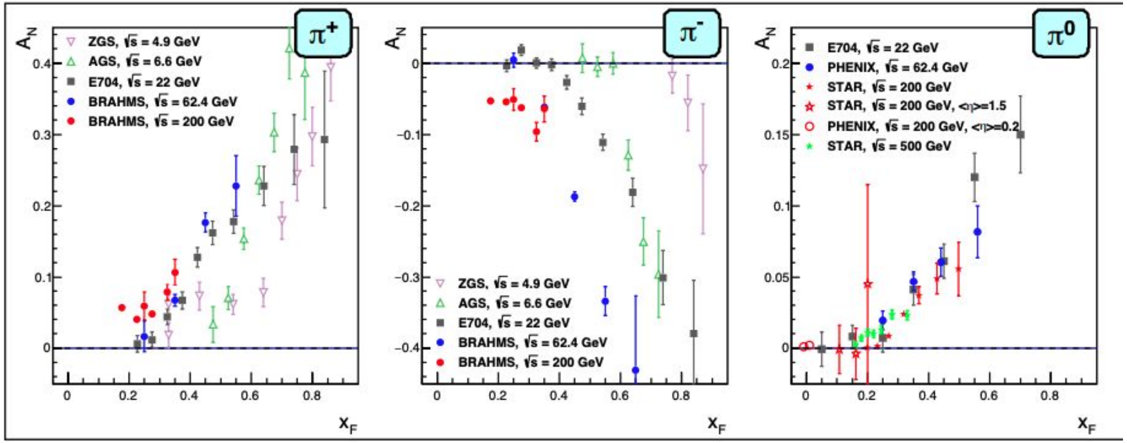
Kane, Pumplin and Repko
PRL 41 1689 (1978)



A_N in $p(S_T) + p \to h + X$



$$A_N = \frac{d\sigma_L - d\sigma_R}{d\sigma_L + d\sigma_R}$$

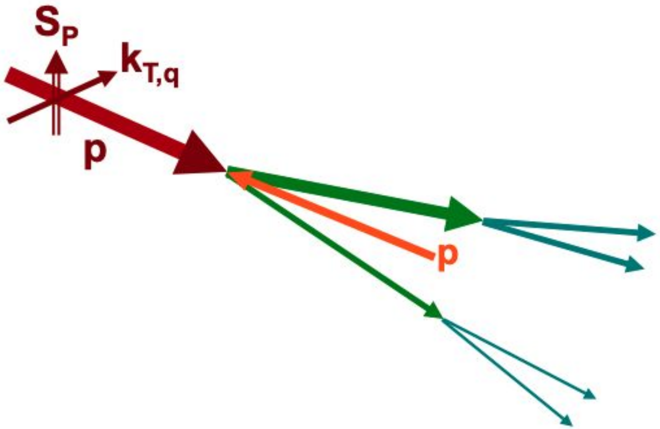


R. D. Klem *et al.*, PRL **36**, 929 (1976)
D.L. Adams *et al.*, PLB **264**, 462 - 466(1991)
I. Arsene *et al.*, PRL **101**, 042001 (2008)

D.L. Adams *et al.*, PLB **261**, 201(1991)
B. I. Abelev *et al.*, PRL **101**, 222001(2008)
A. Adare *et al.*, PRD **90**, 012006 (2014)
E.C. Aschenauer *et al.*, arXiv:1602.03922

Potential Sources for Observed Large A_N

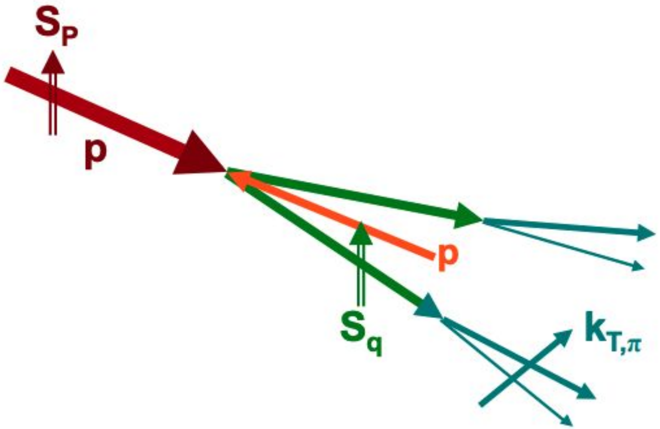
Sivers Mechanism:
Correlation between proton spin and parton k_T



D. Sivers, Phys Rev D **41** (1990) 83; **43** (1991) 261

Signatures: A_N for jets or direct photons, $W^{+/-}$, Z^0, Drell-Yan

Collins Mechanism:
Transversity (quark polarization) ⊗ jet fragmentation asymmetry



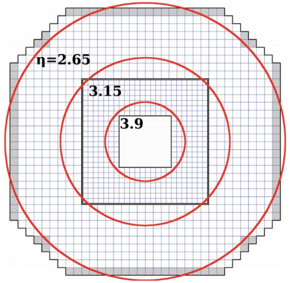
J. Collins, Nucl Phys B **396** (1993) 161

Signatures: Collins effect, Interference fragmentation function (IFF), pion A_N

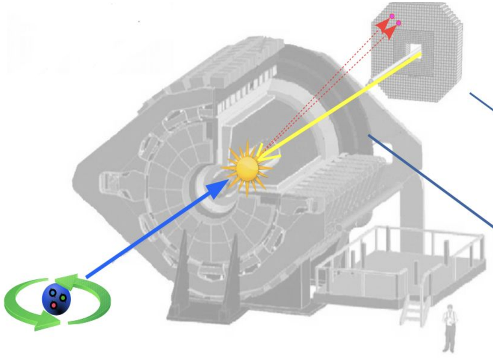
Twist-3:
Quark-gluon / gluon-gluon correlations and fragmentation functions. A source for Sivers function.

J.W. Qiu and G. Sterman, Phys Rev Lett 67 2264 (1991)

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



- Characterize A_N as a function of EM-jet-$p_{T,}$ energy, and photon multiplicities
- Explore the potential sources of large A_N



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, FMS-JP trigger
- Vertex z priority : TPC, VPD, BBC
- 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

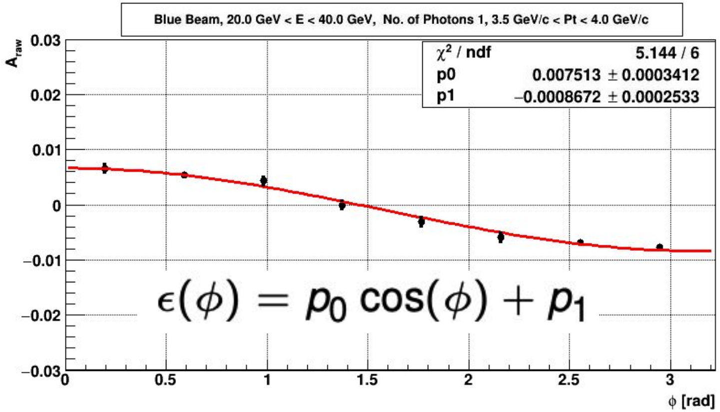
Jet Reconstruction

- 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
- $2.8 < \eta < 3.8$

EM-Jet A_N Extraction

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

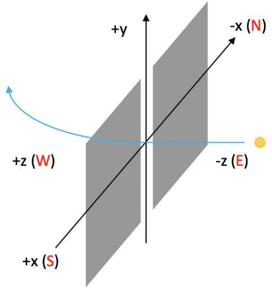
- Energy bins: [0-20] , [20 -40], [40 -60], [60 -80] , and [80 -100] GeV
- 16 equal $\boldsymbol{\phi}$ bins in the range - **π** to **π**
- 3 photon multiplicity bins [n_γ<2, n_γ =3 , and n_γ>4]
- Separately for x_F>0 and x_F<0

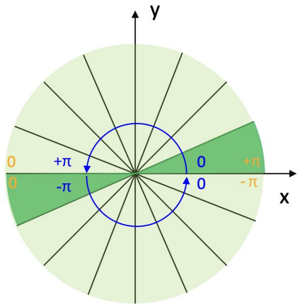


- Cross-ratio formula to calculate A_N

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

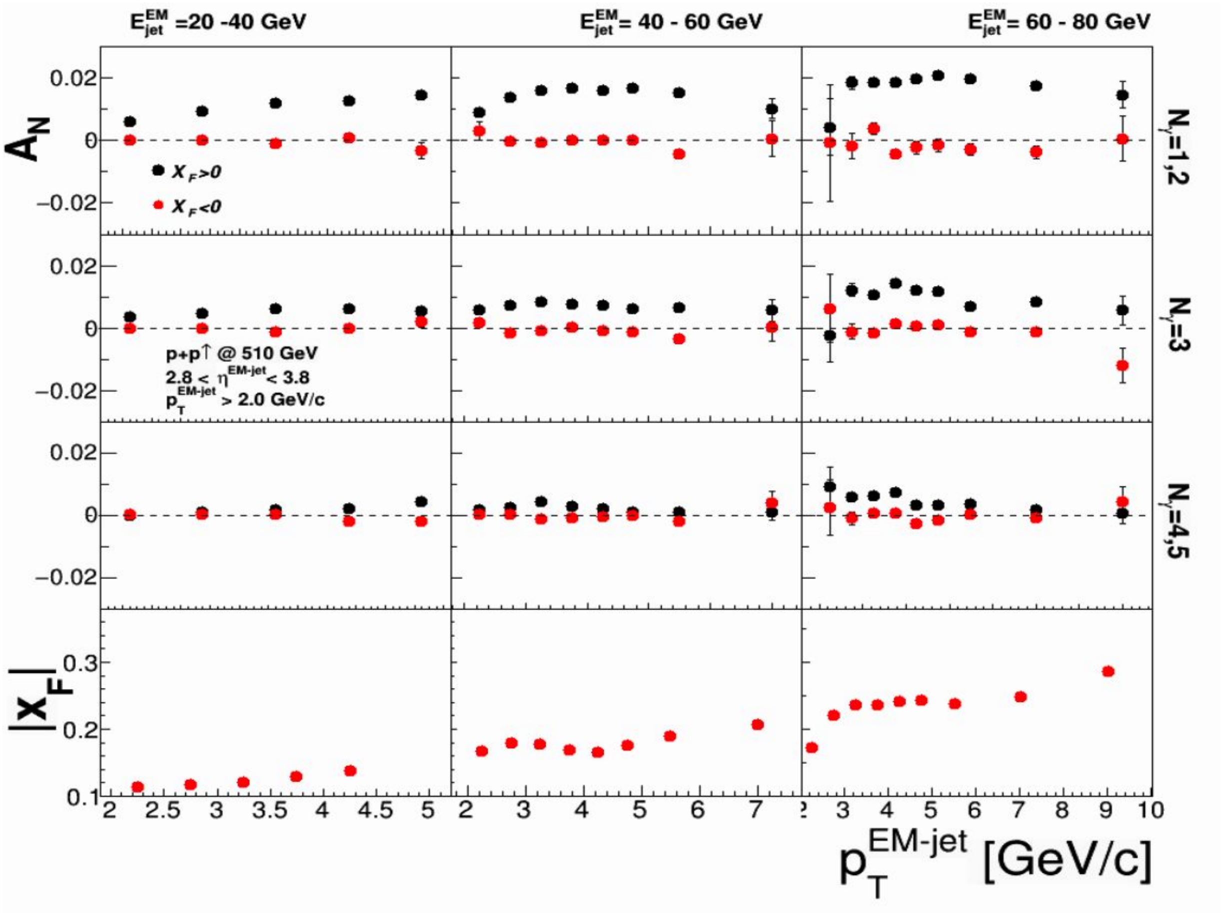
$$\epsilon \approx \frac{\sqrt{N_\phi^\uparrow N_{\phi+\pi}^\downarrow} - \sqrt{N_{\phi+\pi}^\uparrow N_\phi^\downarrow}}{\sqrt{N_\phi^\uparrow N_{\phi+\pi}^\downarrow} + \sqrt{N_{\phi+\pi}^\uparrow N_\phi^\downarrow}}$$





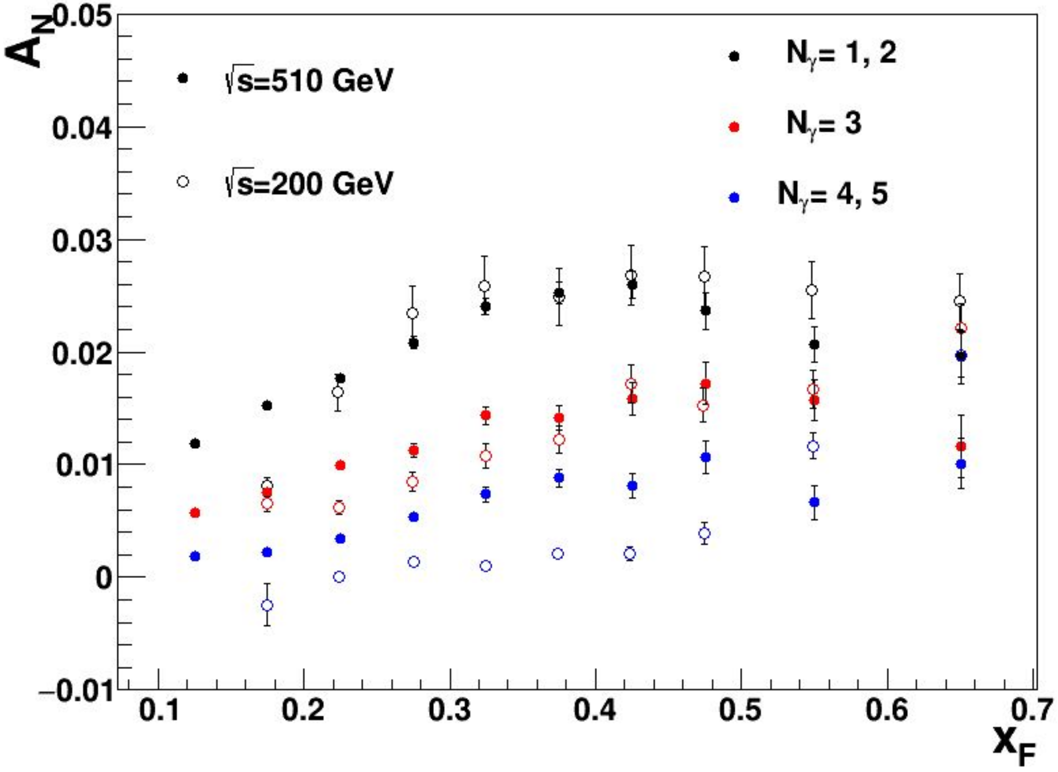
Cancels systematics, such as luminosity and detector effects

EM-Jet A_N at $\sqrt{s}$=510 GeV



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

A_N at different √s and photon multiplicities



L.Kabir p↑ + p @200 GeV

Dependence on √s, especially at lower photon multiplicity

Electromagnetic-Jet A_N Correction and Uncertainty

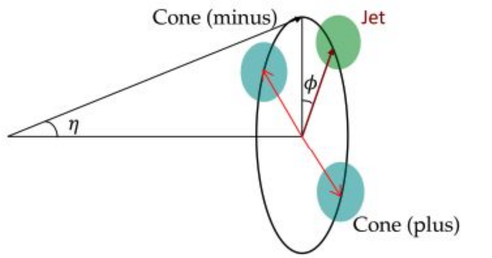
- Underlying event correction, correction in p_T from detector-particle level done

- Polarization Error (~1.1%)
  [1] W.B. Schmidke , RHIC Polarization for Run 9-17
  [2] Z. Chang, Example calculation of fill-to-fill polarization uncertainties

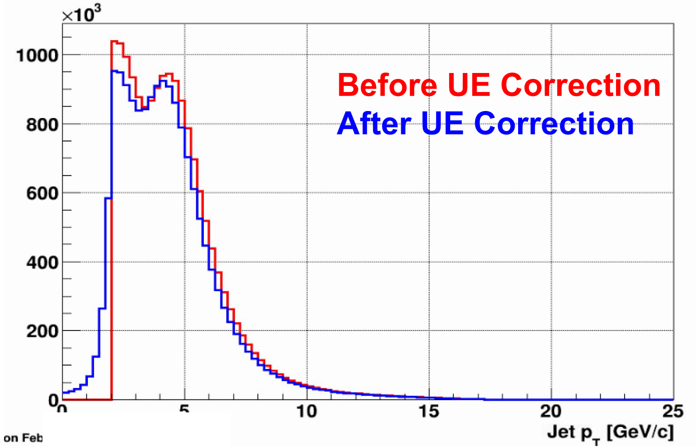
- Energy or p_T Corrections and Uncertainties (~4%):
  - Calibration uncertainty (3.5%)
  - Energy or p_T correction (0.5%)
  - Uncertainty due to radiation damage (1.5%)

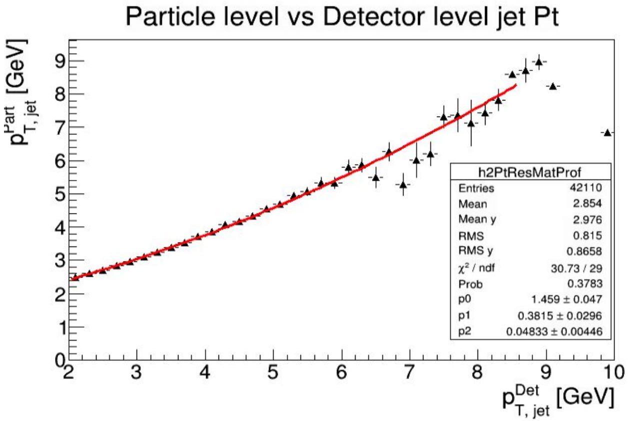
- Systematic on A_N (ongoing)
  - Contamination from unphysical events in A_N energy bin (Zhiwen's analysis note)

Underlying Event (UE) Correction and particle-detector level correction



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

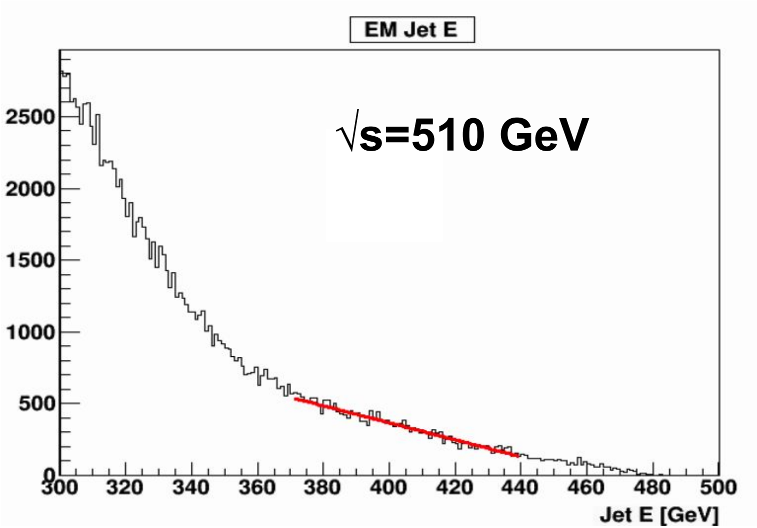


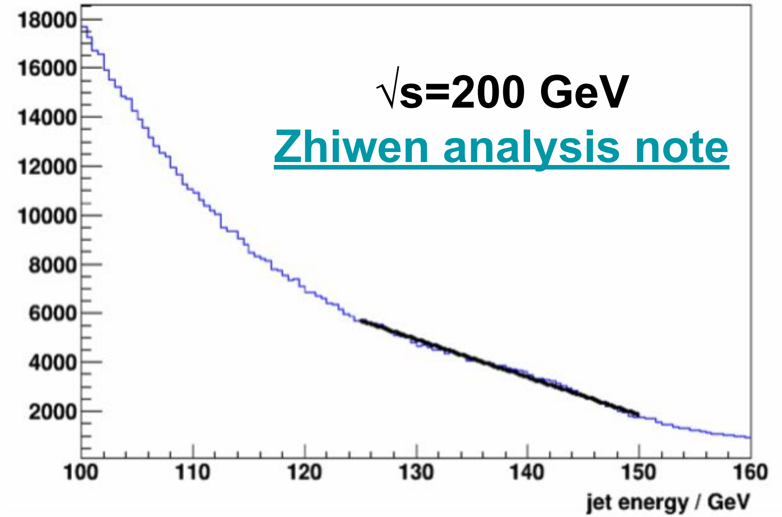


- Underlying event is a part of a jet but not from the parton fragmentation could be secondary scattering
- EM-jet p_T values are corrected for contaminations from underlying events (UE) using off-axis cone method
- Correction to jet p_T, dp_T = underlying Event Density x Area
- Corrected Jet $\mathbf{p_T = p_T - dp_T}$

Correction is applied to the presented result

Correction from Unphysical events





- Unphysical events, events with Jet E larger than beam energy
- Contamination from unphysical events is extrapolated to A_N energy bin for systematic on A_N

Conclusion

- A_N for EM-jet are extracted using run 17 data set, p↑ + p collision at $\sqrt{s}$=510 GeV

- A_N are extracted as function of EM-jet p_T, x_F , photon multiplicities for different energies bin

- Data is corrected with underlying events correction and
- A_N shows similar trend as previous results, decreases with higher photon multiplicities
- A_N shows larger dependence with center of mass energy at higher photon multiplicities
- A_N systematic is underway

Backup

Polarization Uncertainty

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

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

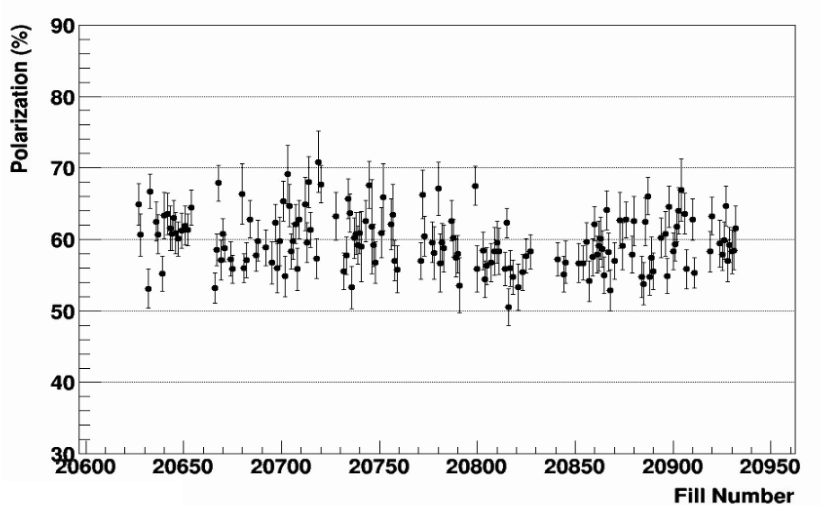
$$\frac{\sigma_{P_{Set}}}{P_{Set}} = \frac{\sigma(scale)}{P} \oplus \sigma_{fill-to-fill} \oplus \frac{\sigma(profile)}{P}$$

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

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

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

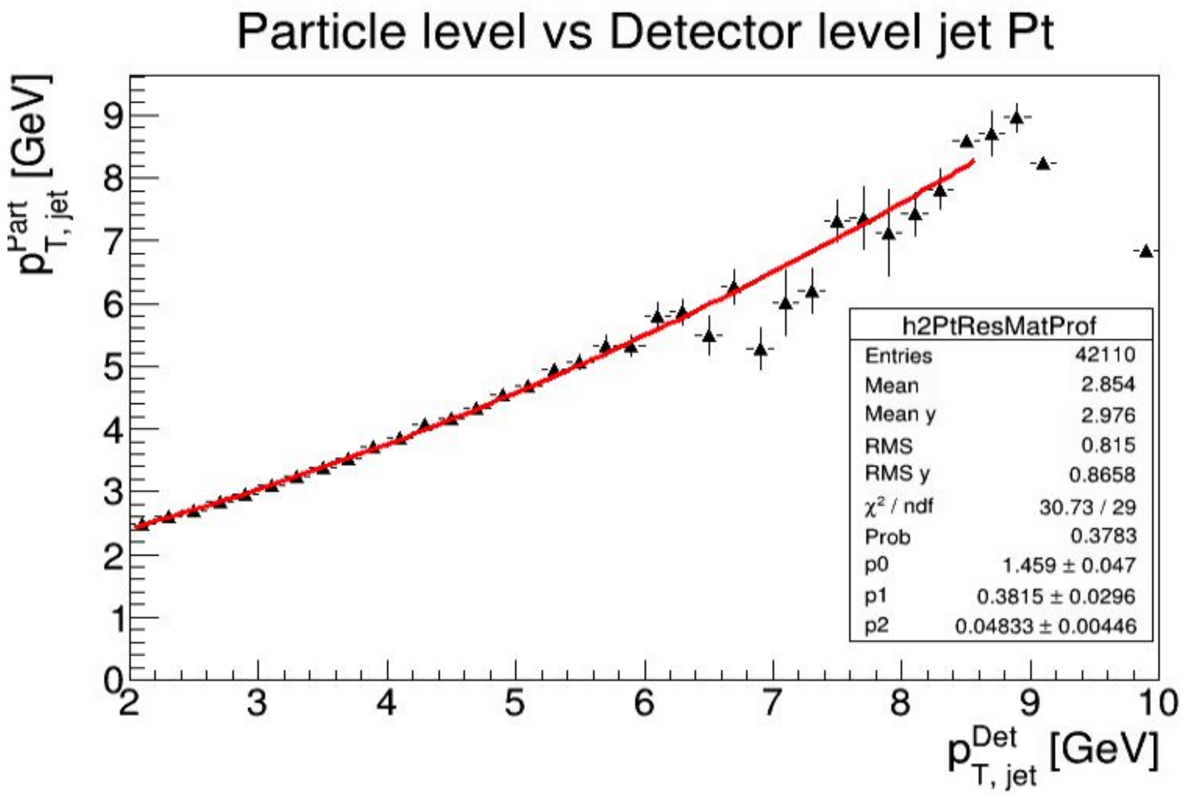
$$\sigma(P_{fill}) = \sigma(P_0) \oplus \sigma \left(\frac{dp}{dt} \right) \cdot \left(\frac{\sum_{run} t_{run} L_{run}}{L_{fill}} - t_0 \right)$$



- M = 162
- N = 190
- $\sigma_{\text{fill-to-fill}}$ = 0.05 %
- 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

Detector to particle level correction (p_T)



Correction is applied to the presented result

Polarization Uncertainty

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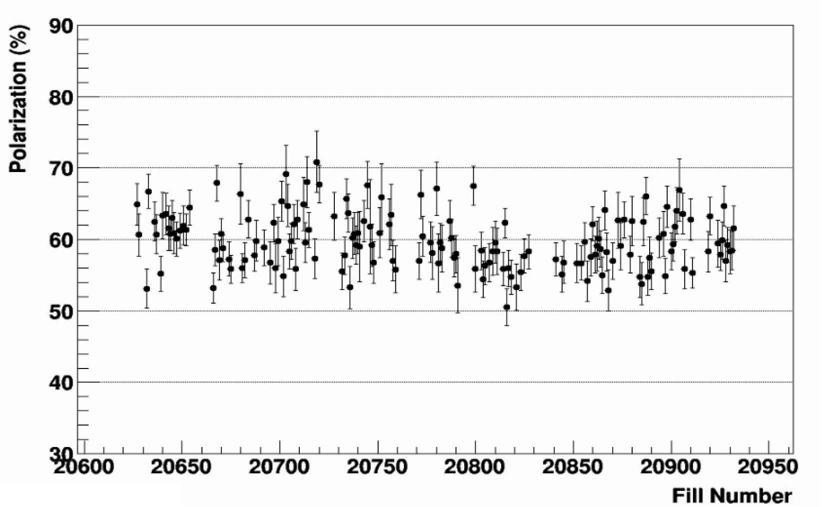

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[2] Z. Chang, Example calculation of fill-to-fill polarization uncertainties

Comparison with existing results (Run 11, √s=500 GeV Mriganka Mouli Mondal)