Preliminary request: Transverse Single-Spin Asymmetry for Single Diffractive Process in $p^{\uparrow} + p$ collisions at $\sqrt{s} = 510$ GeV

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Basic information

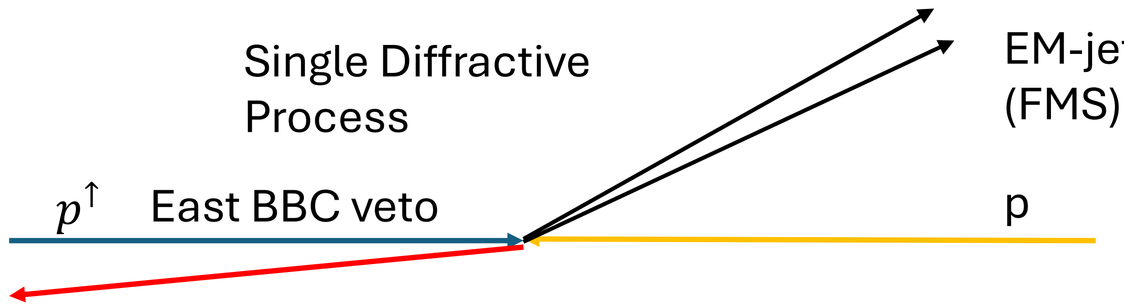
- Title: Transverse Single-Spin Asymmetry for Single Diffractive Process in $p^{\uparrow} + p$ collisions at $\sqrt{s} = 510$ GeV
- PAs: Xilin Liang, Kenneth Barish
- Preliminary request page: https://drupal.star.bnl.gov/STAR/blog/liangxl/Run-17-single-diffractive-EM-jet-preliminary-request

Data set

- Data set: run 17 pp transverse $\sqrt{s} = 510$ GeV ,fms stream
  - (pp500_production_2017)
- Production type: MuDst ; Production tag: P22ib
- STAR library: SL20a
- Triggers for FMS : FMS small board sum, FMS large board sum and FMS-JP
  - Trigger list: FMS-JP0, FMS-JP1, FMS-JP2, FMS-sm-bs1, FMS-sm-bs2, FMS-sm-bs3, FMS-lg- bs1, FMS-lg-bs2, FMS-lg-bs3
  - Trigger veto: FMS-LED
- EM-jet reconstruction: Anti-kT, R<0.7 , FMS point energy > 1 GeV, $p_T > 2$ GeV/c

Single diffractive process (SD)

- **Motivation and goal**: study the A_N for single diffractive process and explore its contribution for large A_N in inclusive processes
- Determine the SD process:
  1. Only 1 proton track on east side RP
  2. No west side RP track requirement
  3. Rapidity gap requirement using east BBC veto
  4. Only 1 FMS EM-jet on the west side



Event selection and corrections for SD process

Details in: 12/4/2024 PWG slide

- **FMS**
  - 9 Triggers, veto on FMS-LED
  - Only 1 EM-jet per event is allowed
  - bit shift, bad / dead / hot channel masking (include fill by fill hot channel masking)
  - Jet reconstruction: StJetMaker2015 , Anti-kT, R<0.7 , FMS point energy > 1 GeV, $p_T > 2$ GeV/c, trigger p_T threshold cut, FMS point as input.

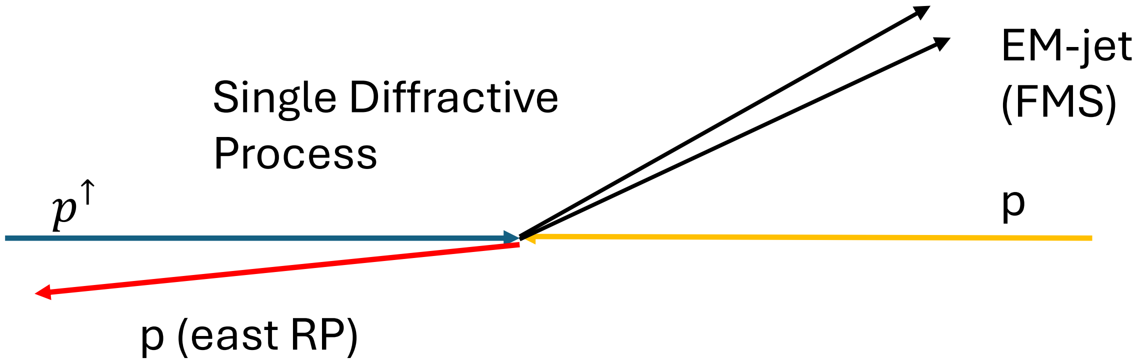
Corrections:
EM-jet energy correction and Underlying Event correction

- **Only allow acceptable beam polarization (up/down).**
- **Vertex** (Determine vertex z priority according to TPC , VPD, BBC.)
  - Vertex $|z| < 80\ cm$
- **Roman Pot and Single Diffractive process:**
- Acceptable cases:

1. Only 1 east RP track , no requirement on west RP

- RP track must be good track:

a) Each track hits > 6 planes
b) East RP ξ dependent θ_X , θ_Y , P_X and P_Y cuts
c) East RP $0 < \xi < 0.15$



- East Small BBC ADC sum < 80 and East large BBC earliest TDC < 30

Calculate the background fraction for SD

- We use the process with FMS EM-jets and east BBC (RG).
  - All photon multiplicity , 1 or 2 photon multiplicity , 3 or more photon multiplicity
- Calculate the yields for events with EM-jet in different x_F bins.
- Accidental coincidence fraction: 0.37%
  - Estimated from zerobias events

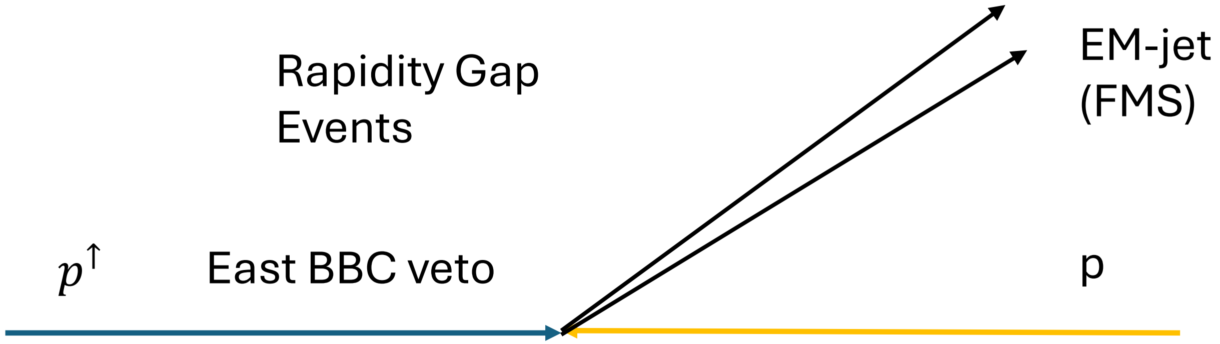
0.37%

$$frac_{bkg} = \frac{n_{AC}}{n_{mea}} = \frac{n_{AC}}{n_{RG}} \times \frac{n_{RG}}{n_{mea}}$$

X_F	$frac_{bkg}$ for all photon multiplicity	$frac_{bkg}$ for 1 , 2 photon multiplicity	$frac_{bkg}$ for 3 or more photon multiplicity
0.1 – 0.15	5.8%	5.8%	5.9%
0.15 – 0.2	5.6%	5.7%	5.6%
0.2 – 0.25	5.5%	5.7%	5.5%
0.25 – 0.3	5.6%	5.7%	5.5%
0.3 – 0.35	5.6%	5.8%	5.6%
0.35 – 0.4	5.6%	5.7%	5.6%

Rapidity gap events (RG)

- Determine the RG process:
  1. Rapidity gap requirement using east BBC veto
  2. No RP track requirement
  3. Only 1 FMS EM-jet on the west side



Event selection and corrections for RG events

- **FMS**

Details in: 12/4/2024 PWG slide

  - 9 Triggers, veto on FMS-LED
  - Only 1 EM-jet per event is allowed
  - bit shift, bad / dead / hot channel masking (include fill by fill hot channel masking)
  - Jet reconstruction: StJetMaker2015 , Anti-kT, R<0.7 , FMS point energy > 1 GeV, $p_T > 2$ GeV/c, trigger p_T threshold cut, FMS point as input.
- **Only allow acceptable beam polarization (up/down).**
- **Vertex** (Determine vertex z priority according to TPC , VPD, BBC.)
  - Vertex $|z| < 80\ cm$
- **No Roman Pot requirement:**
- East Small BBC ADC sum < 80 and East large BBC earliest TDC < 30

Corrections for EM-jets:
EM-jet energy correction and
Underlying Event correction

Systematic uncertainty for SD and RG events

- We use Bayesian method for systematic uncertainty study. (ref: arXiv:hep-ex/0207026)
- First of all, for the cuts we choose, varying each individual cut value for calculating the asymmetry. **The first two terms apply for both processes**
  - Small BBC east ADC sum cuts: choose < 60, < 70, <90, <100 for systematic uncertainty
  - Large BBC east earliest TDC cuts: choose =0, < 15, <60, <120 for systematic uncertainty
  - Background (Only for SD events)
- Then, find out the maximum ($A_N(1) \pm \delta(1)$, with statistical uncertainty) , and the minimum ($A_N(2) \pm \delta(2)$, with statistical uncertainty) for the varying cuts as systematic uncertainty.
- If the $\frac{|A_N(1)-A_N(2)|}{\sqrt{|(\delta(1))^2-(\delta(2))^2|}} > 1$ (Barlow check), use the **standard deviation** of all the A_N from varying all the cuts for this systematic term (σ_i), otherwise, the systematic (σ_i), for this term will be assigned 0
- The final systematic will be counted bin by bin (x_F bins) : $\sigma_{summay} = \sqrt{\sum_i (\sigma_i)^2}$

Systematic uncertainty results for SD process

All Photon multiplicity

Blue beam x_F	Small BBC east	Large BBC east	Background	Summary
0.1 – 0.15	0.0017	0	0.0047	0.0050
0.15 – 0.2	0.0016	0.0003	0.0035	0.0039
0.2 - 0.25	0.0013	0.0004	0.0035	0.0037
0.25 - 0.3	0.0009	0.0006	0.0043	0.0044
0.3 – 0.35	0.0008	0.0013	0.0056	0.0058
0.35 – 0.4	0.0028	0.0016	0.0070	0.0077

Yellow beam x_F	Small BBC east	Large BBC east	Background	Summary
0.1 – 0.15	0	0.0006	0.0046	0.0047
0.15 – 0.2	0.0014	0	0.0035	0.0037
0.2 - 0.25	0.0012	0	0.0034	0.0036
0.25 - 0.3	0.0015	0.0006	0.0042	0.0045
0.3 – 0.35	0	0.0013	0.0055	0.0057
0.35 – 0.4	0.0020	0.0021	0.0070	0.0074

1 or 2 Photon multiplicity

Blue beam x_F	Small BBC east	Large BBC east	Background	Summary
0.1 – 0.15	0.0016	0	0.0074	0.0075
0.15 – 0.2	0.0038	0.0006	0.0056	0.0069
0.2 - 0.25	0	0	0.0059	0.0059
0.25 - 0.3	0	0	0.0075	0.0075
0.3 – 0.35	0	0	0.0094	0.0094
0.35 – 0.4	0.0045	0.0020	0.0112	0.0123

Yellow beam x_F	Small BBC east	Large BBC east	Background	Summary
0.1 – 0.15	0.0030	0	0.0073	0.0079
0.15 – 0.2	0.0023	0.0009	0.0055	0.0061
0.2 - 0.25	0.0018	0	0.0058	0.0061
0.25 - 0.3	0.0023	0.0009	0.0074	0.0078
0.3 – 0.35	0.0039	0.0015	0.0093	0.0102
0.35 – 0.4	0.0023	0.0028	0.0111	0.0117

3 or more Photon multiplicity

Blue beam x_F	Small BBC east	Large BBC east	Background	Summary
0.1 – 0.15	0.0027	0	0.0062	0.0067
0.15 – 0.2	0.0013	0	0.0046	0.0048
0.2 - 0.25	0.0020	0.0005	0.0043	0.0048
0.25 - 0.3	0.0016	0.0006	0.0052	0.0055
0.3 – 0.35	0.0011	0.0025	0.0070	0.0075
0.35 – 0.4	0.0060	0.0028	0.0090	0.0112

Yellow beam x_F	Small BBC east	Large BBC east	Background	Summary
0.1 – 0.15	0	0.0007	0.0061	0.0061
0.15 – 0.2	0.0013	0	0.0045	0.0047
0.2 - 0.25	0.0015	0.0004	0.0042	0.0045
0.25 - 0.3	0.0021	0.0005	0.0051	0.0056
0.3 – 0.35	0	0.0013	0.0069	0.0070
0.35 – 0.4	0.0020	0.0017	0.0089	0.0093

Systematic uncertainty results for RG process

All Photon multiplicity

Blue beam x_F	Small BBC east	Large BBC east	Summary
0.1 – 0.15	0	0	0
0.15 – 0.2	0.0004	0.0002	0.0004
0.2 - 0.25	0.0003	0	0.0003
0.25 - 0.3	0.0004	0	0.0004
0.3 – 0.35	0.0003	0	0.0003
0.35 – 0.4	0.0003	0.0004	0.0005

Yellow beam x_F	Small BBC east	Large BBC east	Summary
0.1 – 0.15	0	0.0002	0.0002
0.15 – 0.2	0.0004	0	0.0004
0.2 - 0.25	0	0	0
0.25 - 0.3	0.0003	0	0.0003
0.3 – 0.35	0	0	0
0.35 – 0.4	0.0008	0.0001	0.0008

1 or 2 Photon multiplicity

Blue beam x_F	Small BBC east	Large BBC east	Summary
0.1 – 0.15	0.0006	0	0.0006
0.15 – 0.2	0	0	0
0.2 - 0.25	0.0007	0.0003	0.0008
0.25 - 0.3	0.0007	0	0.0007
0.3 – 0.35	0	0.0005	0.0005
0.35 – 0.4	0	0.0006	0.0006

Yellow beam x_F	Small BBC east	Large BBC east	Summary
0.1 – 0.15	0	0.0002	0.0002
0.15 – 0.2	0	0.0003	0.0003
0.2 - 0.25	0	0	0
0.25 - 0.3	0.0008	0	0.0008
0.3 – 0.35	0.0008	0	0.0008
0.35 – 0.4	0.0010	0	0.0010

3 or more Photon multiplicity

Blue beam x_F	Small BBC east	Large BBC east	Summary
0.1 – 0.15	0	0	0
0.15 – 0.2	0.0006	0/0002	0.0006
0.2 - 0.25	0	0.0002	0.0002
0.25 - 0.3	0	0.0002	0.0002
0.3 – 0.35	0.0006	0.004	0.0007
0.35 – 0.4	0	0	0

Yellow beam x_F	Small BBC east	Large BBC east	Summary
0.1 – 0.15	0	0	0
0.15 – 0.2	0.0004	0	0.0004
0.2 - 0.25	0.0003	0	0.0003
0.25 - 0.3	0	0	0
0.3 – 0.35	0	0	0
0.35 – 0.4	0.0007	0	0.0007

Figure 1: Single diffractive EM-jet A_N for the 3 cases of photon multiplicity in $\sqrt{s} = 510$ GeV

- EM-jets with 3 or more photon multiplicity are much more dominant.
- EM-jets with 1 or 2 photon multiplicity have larger A_N than that with 3 or more photon multiplicity.

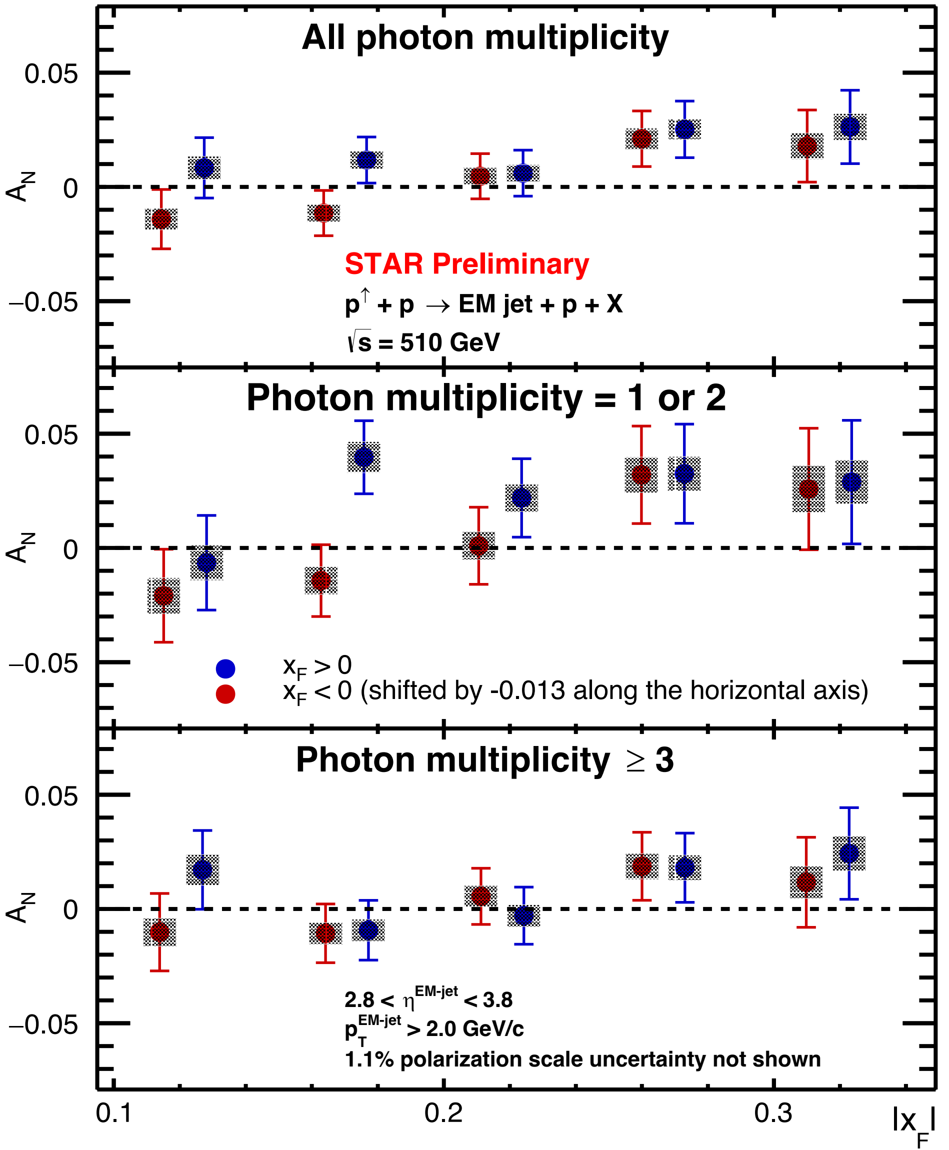


Figure 2: Rapidity gap event EM-jet A_N for the 3 cases of photon multiplicity

- EM-jets with 3 or more photon multiplicity are much more dominant.
- EM-jets with 1 or 2 photon multiplicity have larger A_N than that with 3 or more photon multiplicity.

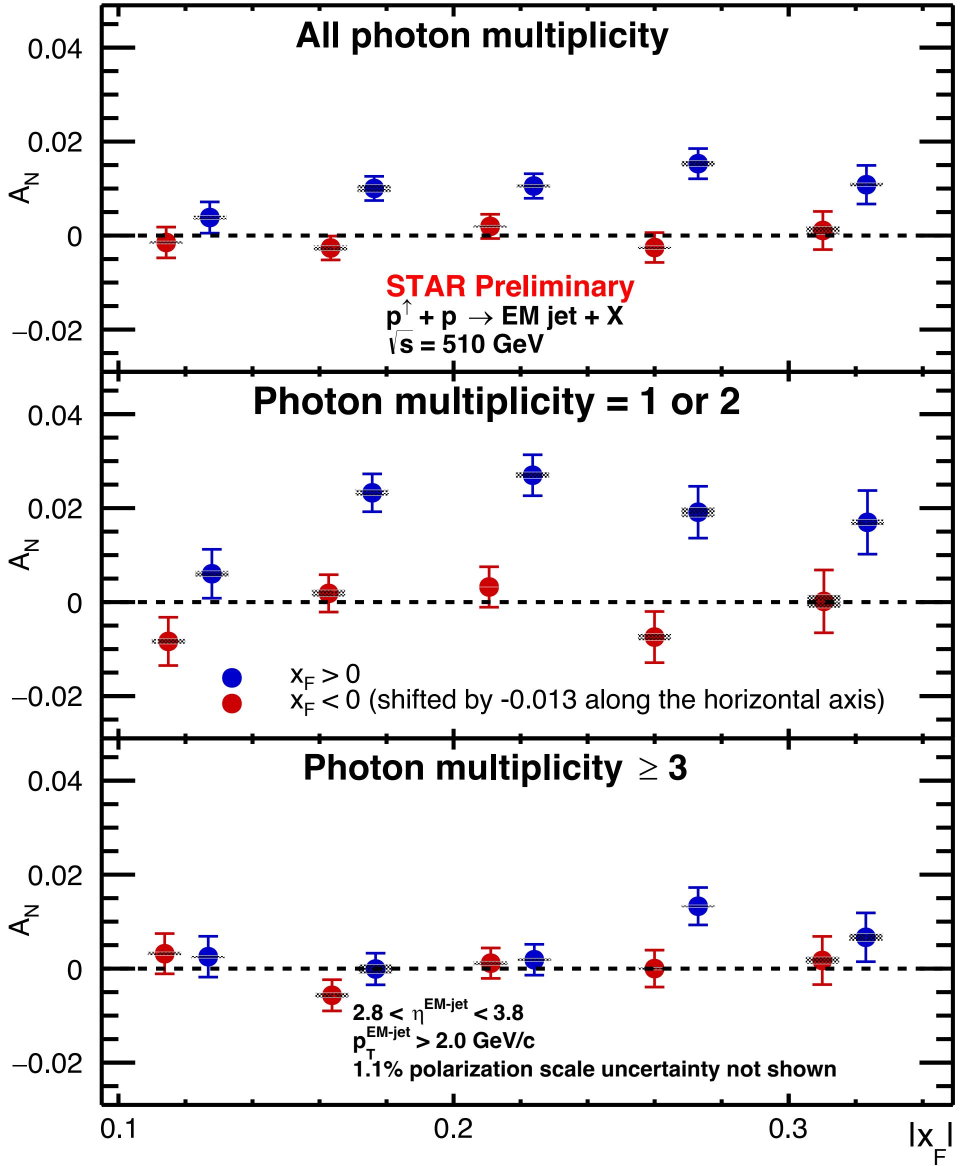


Figure 3: Comparison between inclusive, single diffractive and rapidity gap EM-jet A_N

- Comparison between inclusive, single diffractive and rapidity gap EM-jet A_N in run 17
- They are consistent within each other within uncertainty

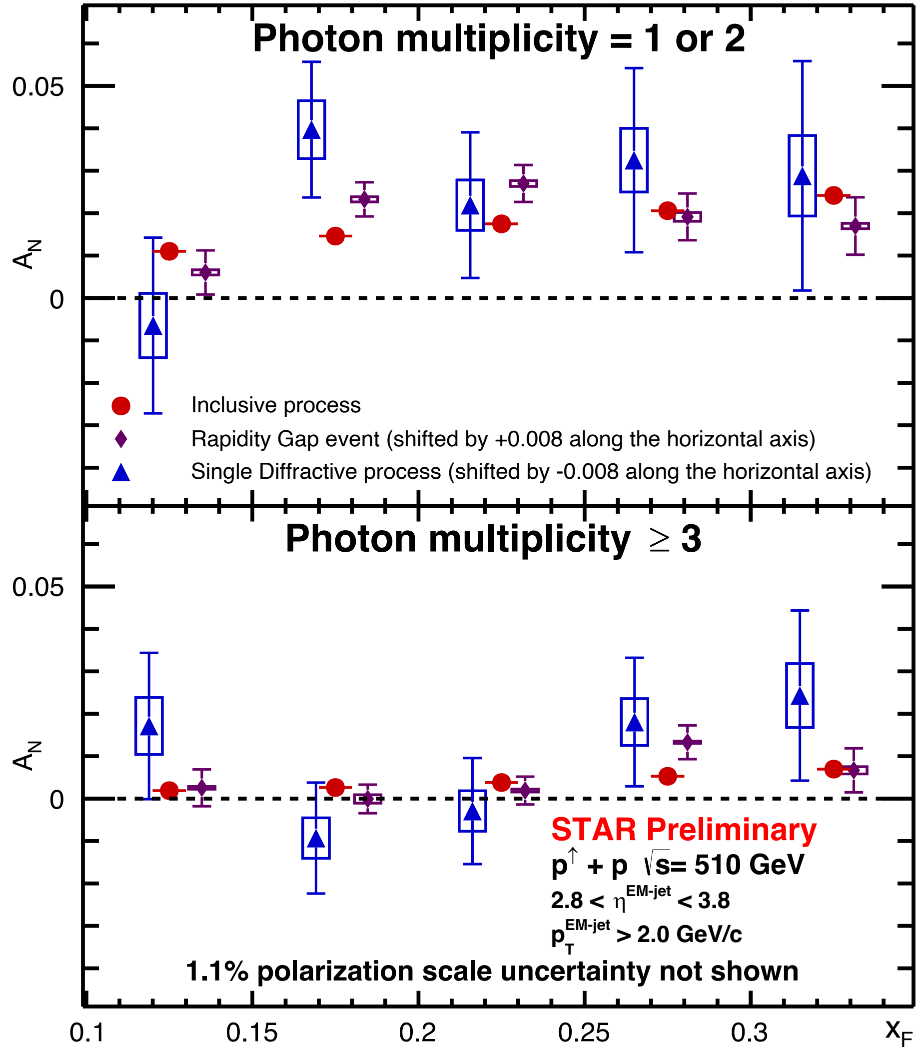


Figure 4: Single diffractive EM-jet A_N for the 3 cases of photon multiplicity in $\sqrt{s} = 200/510$ GeV

- The p+p $\sqrt{s} = 200$ measurement can access to higher x_F, while the p+p $\sqrt{s} = 510$ measurement can access to higher x_F.
- The single diffractive EM-jet A_N for two datasets show consistent within uncertainty.

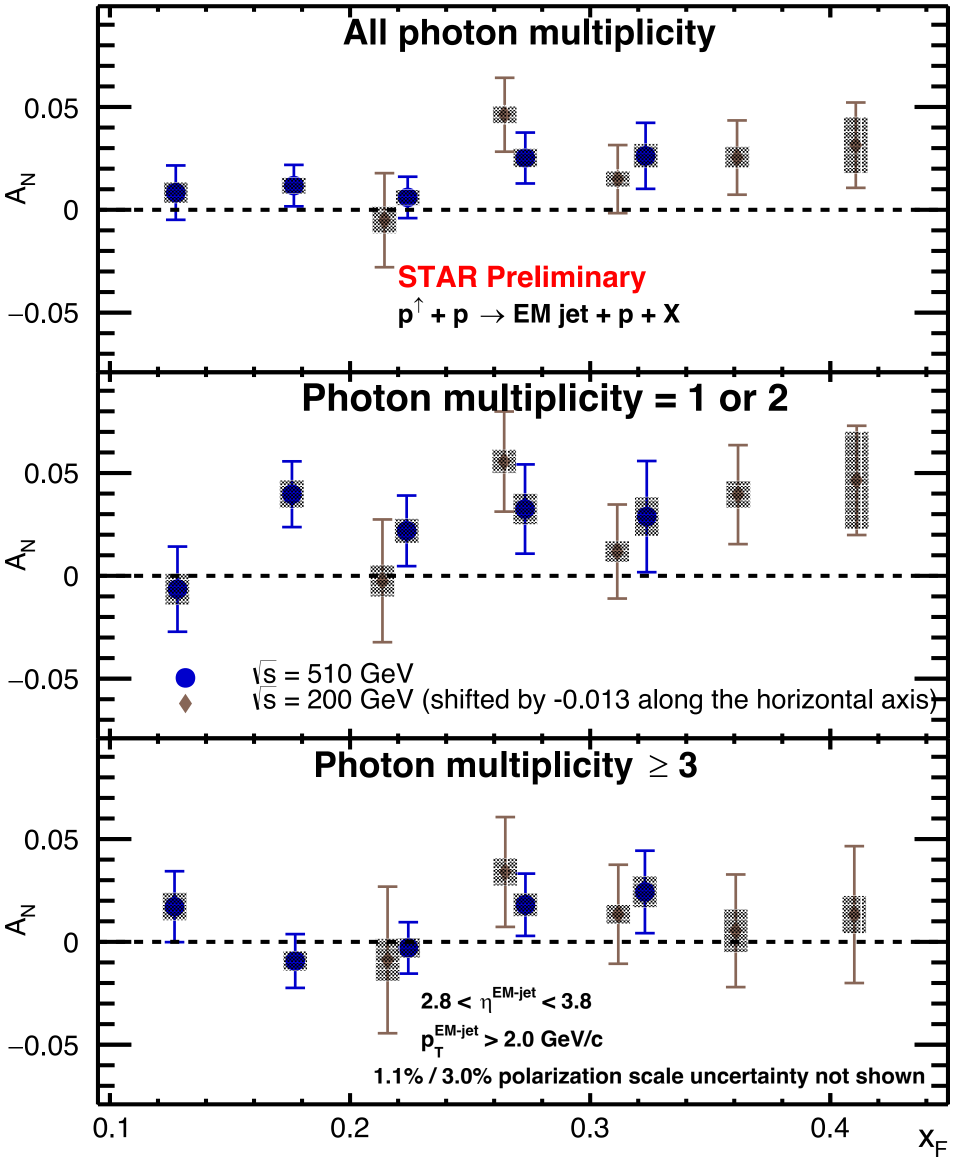
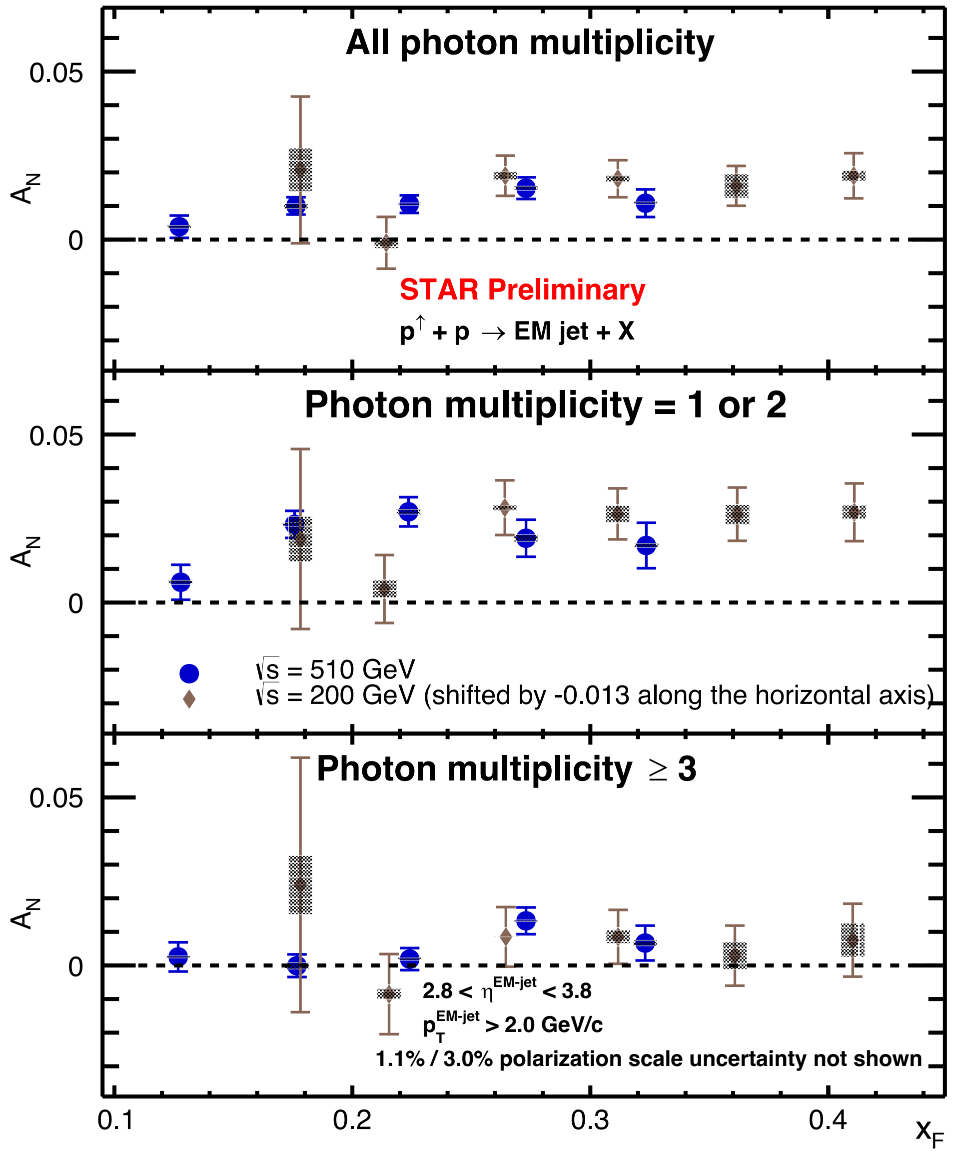


Figure 5: Rapidity Gap EM-jet A_N for the 3 cases of photon multiplicity in $\sqrt{s} = 200/510$ GeV

- The p+p $\sqrt{s} = 200$ measurement can access to higher x_F, while the p+p $\sqrt{s} = 510$ measurement can access to higher x_F.
- The rapidity gap EM-jet A_N for two datasets show consistent within uncertainty.



Conclusion

- We have the preliminary request for EM-jet A_N for run 17 single diffractive process and rapidity gap event.
- EM-jets with 1 or 2 photon multiplicity have larger A_N than that with 3 or more photon multiplicity for both processes.
- EM-jets with 3 or more photon multiplicity are much more dominant at higher center-of-mass collisions.
- The single diffractive and rapidity gap EM-jet A_N for two datasets show consistent within uncertainty.
- inclusive, single diffractive and rapidity gap EM-jet A_N are consistent within each other within uncertainty

Back up

Background study: zerobias stream

- Motivation: study the fraction of east RP coincident rate as accidental coincidence (multiple collision event).
- Data production and stream : **pp500_production_2017 , st_zerobias_adc**
- Production tag: P22ib
- The BBC east cuts are same as FMS data (small and large BBC east cuts)
- Event distribution:
  - Total N events: 3,075,560
  - 1,496,422 events (49%) are with small and large BBC east cuts
  - **11,446 events (0.37%) contain 1 east good RP track and with BBC east cuts**
- Therefore, about 0.37% of the events are the accidental coincidences, and should be the same rate for every process.

Background study: Estimate the Accidental coincidence

- **A**ccidental **C**oincidence (AC) (multiple collision event) are coming from the situation that the FMS EM-jets and the east RP tracks are not correlated, i.e. the FMS EM-jets and the east RP tracks are coming from multiple collisions.
- The random coincidence of the single diffractive events in the RG events is 0.37%
- Background fraction:

$$frac_{bkg} = \frac{n_{AC}}{n_{mea}} = \frac{n_{AC}}{n_{RG}} \times \frac{n_{RG}}{n_{mea}}$$

Need to be measured

n_{AC} number of accidental events in the analysis
n_{mea} is the number of events counted after the event selection for the analysis (FMS EM-jet + East RP + East BBC veto)