Run 17 diffractive EM-jet A_N analysis
Single diffractive process & rapidity gap events

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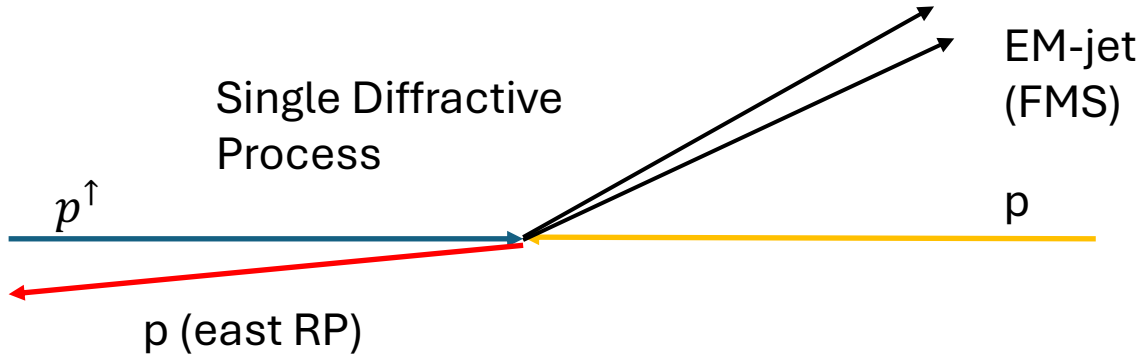
Data set

- 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

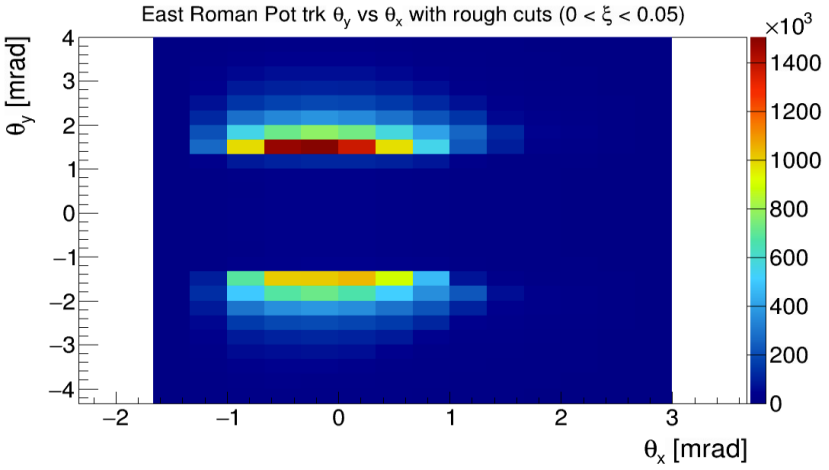
- We use the similar method on studying the event selection criteria for the east RP cuts and east BBC veto cuts.

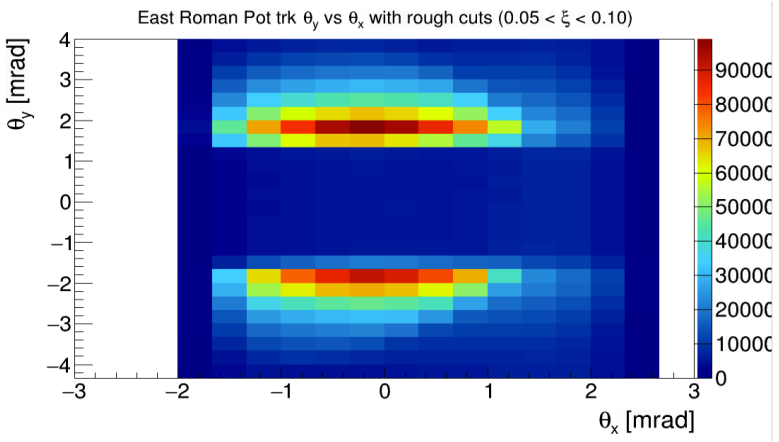


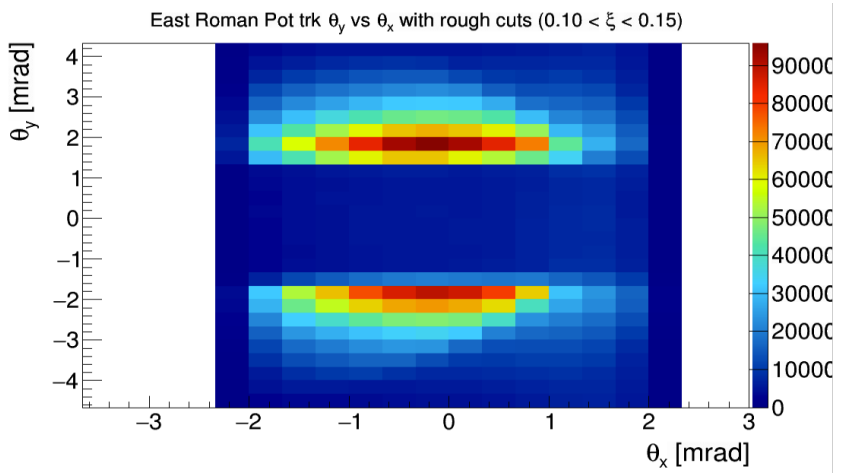
Rough cuts on East RP θ_X and θ_Y

$$\xi = \frac{p_{beam} - P_{RP}}{p_{beam}}$$

- First is to study the rough cuts on East RP θ_X and θ_Y :
  - $1 < |\theta_Y| < 3$
  - For $0.0 < \xi < 0.05$: $-1.5 < \theta_X < 1.5$
  - For $0.05 < \xi < 0.1$: $-1.75 < \theta_X < 2$
  - For $0.1 < \xi < 0.15$: $-2 < \theta_X < 2$

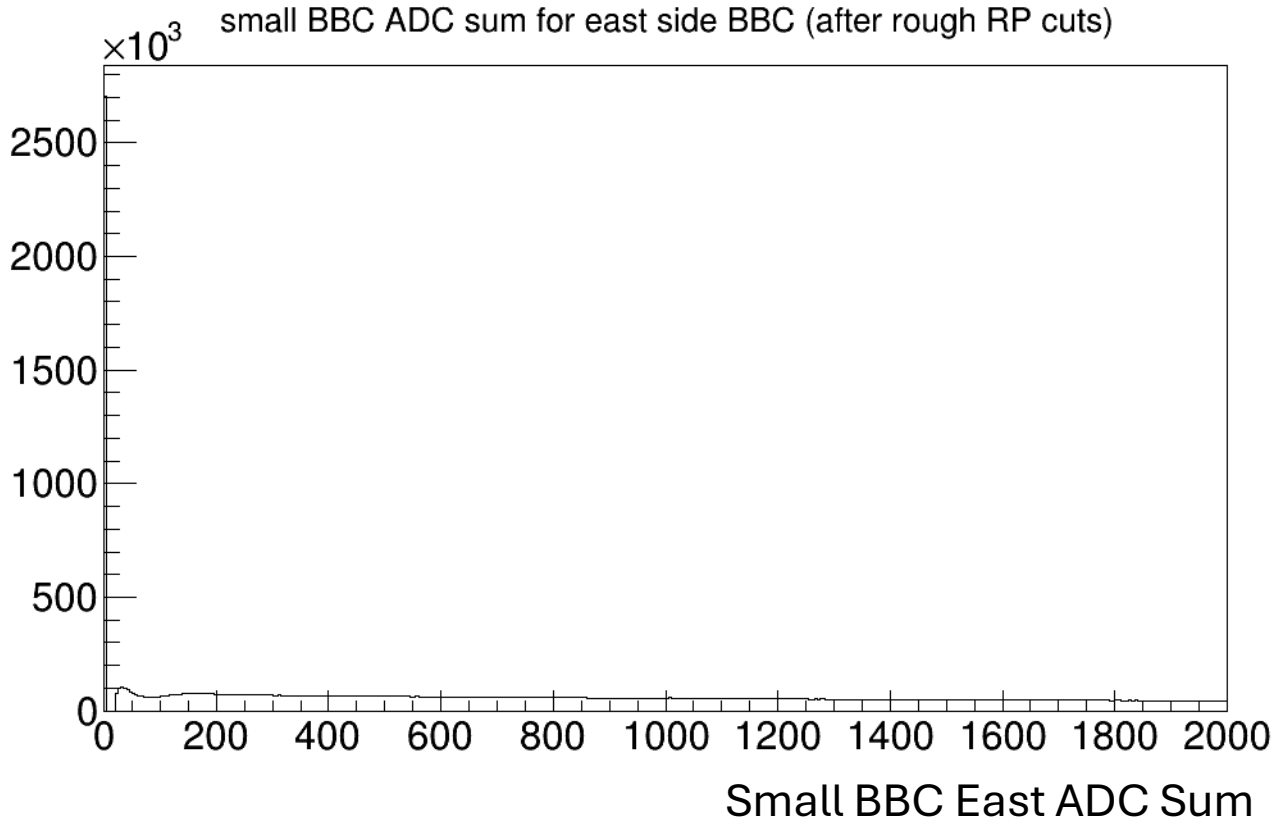






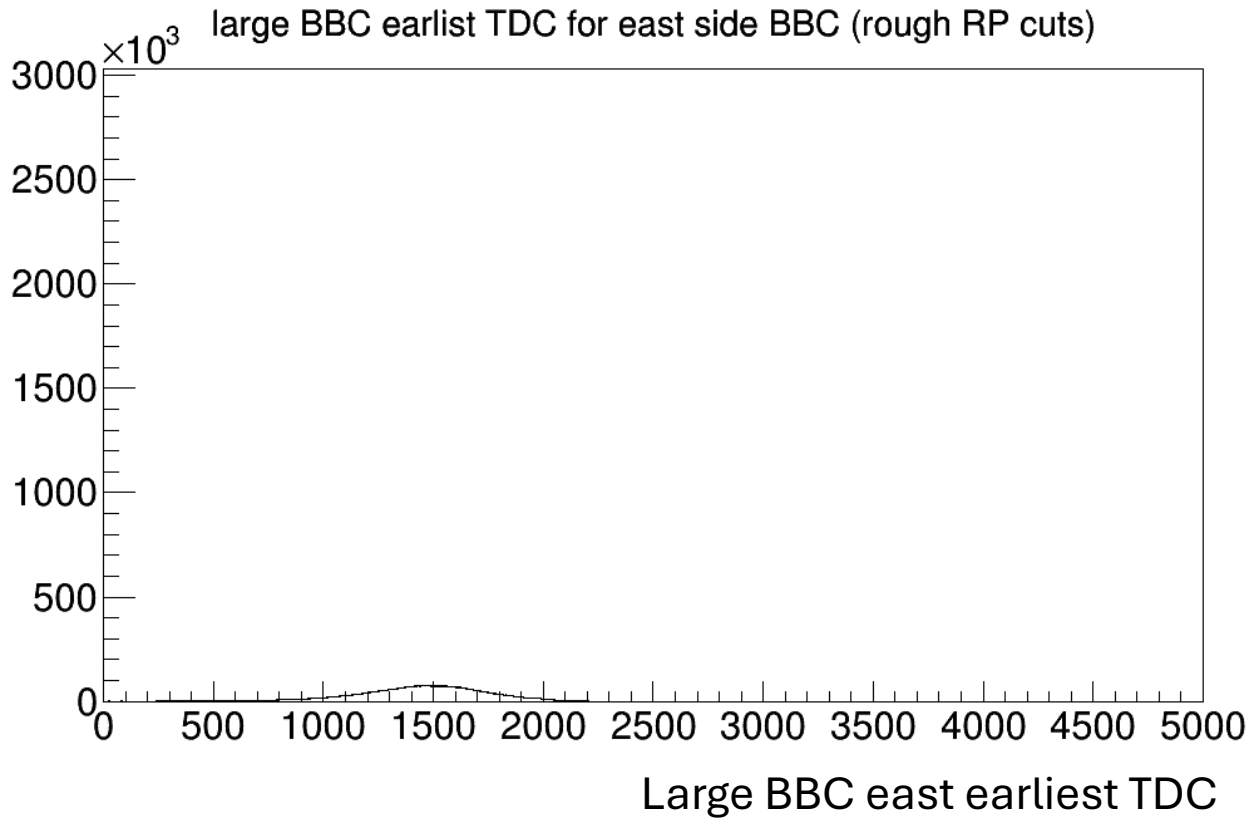
Small BBC East ADC Sum cut

- We apply the rough East RP θ_X and θ_Y cut as well as only 1 east RP track to study the small BBC east ADC sum
- We could consider to have small BBC east ADC sum < 80 for the single diffractive process



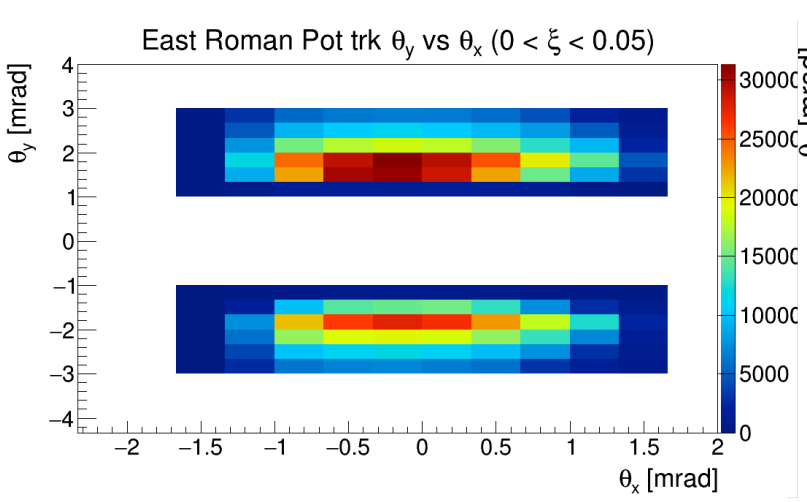
Large BBC east earliest TDC

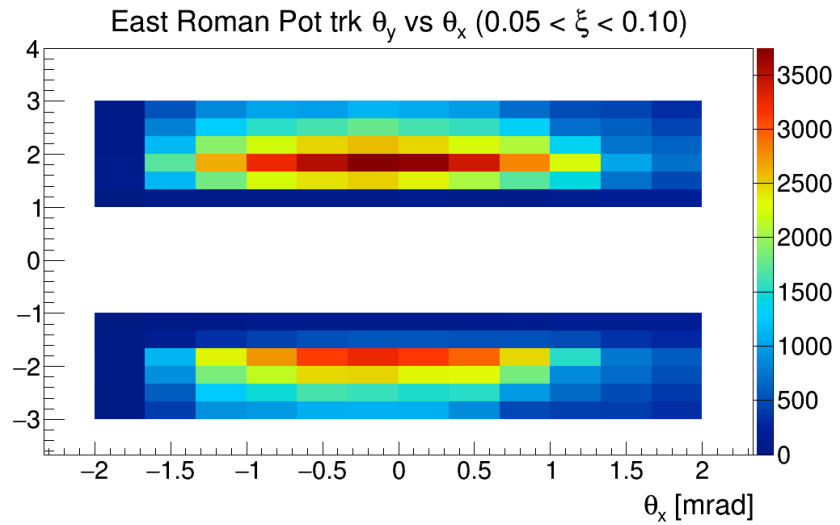
- The large BBC ADC sum is not available for fms stream data, we use large BBC east earliest TDC for the large BBC east veto
  - If large BBC east earliest TDC = 0, there will be no hit on large BBC east region
- If we choose Large BBC east earliest TDC < 30 as no hit on large BBC region, the fraction is about 5.28%

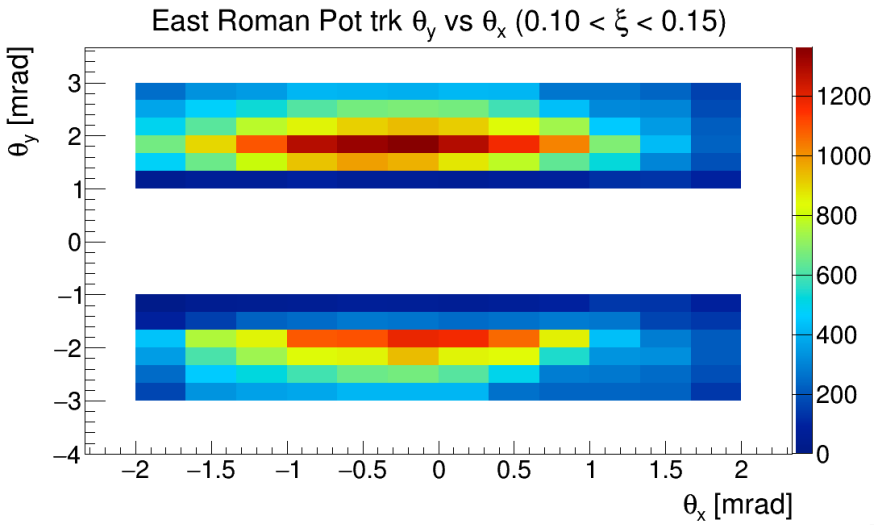


Final cuts on East RP θ_X and θ_Y

- We apply the small BBC east cut, and then check the final cut on East RP θ_X and θ_Y .
  - $1.25 < |\theta_Y| < 3$
  - For $0.0 < \xi < 0.05$: $-1 < \theta_X < 1.25$
  - For $0.05 < \xi < 0.1$: $-1.25 < \theta_X < 1.25$
  - For $0.1 < \xi < 0.0$: $-1.5 < \theta_X < 1.25$

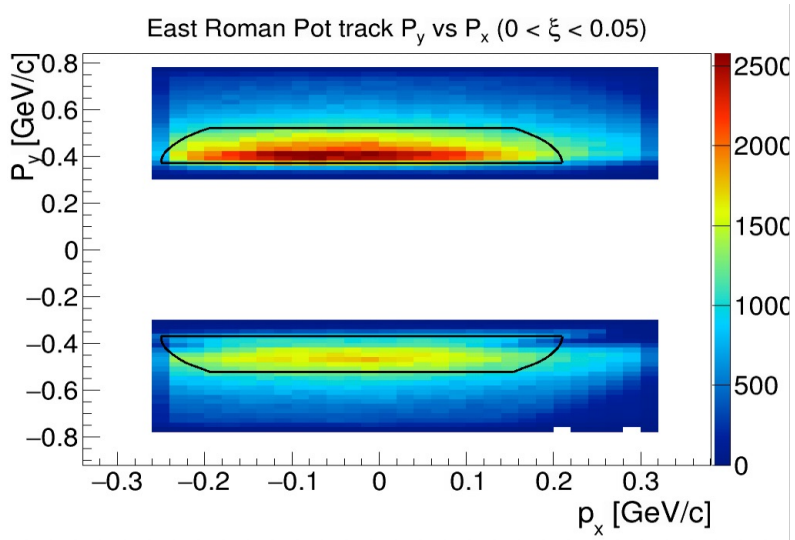


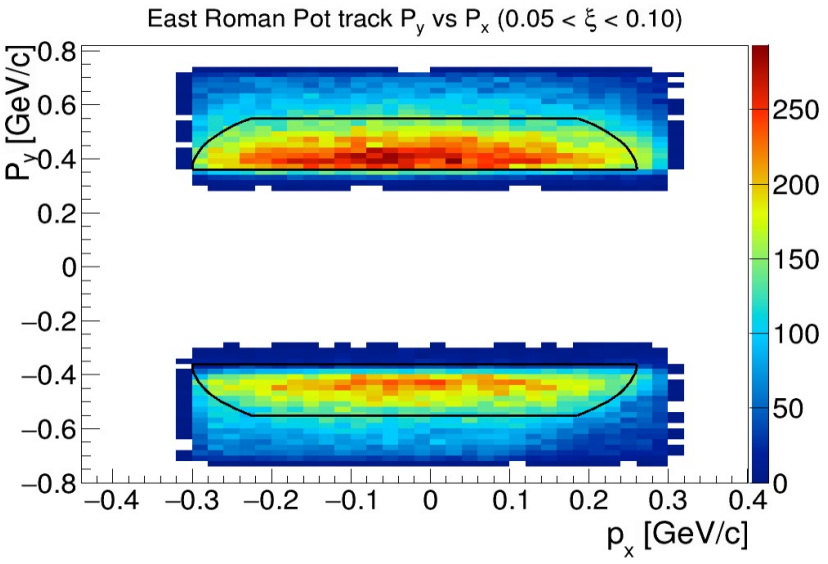


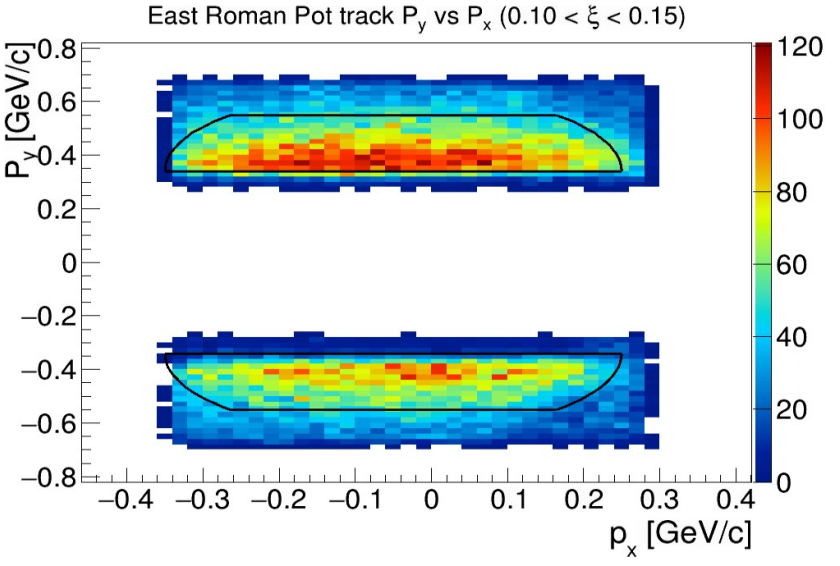


Final cuts on East RP p_X and p_Y

- We also check and apply the final cut on East RP p_X and p_Y :
- For $0.0 < \xi < 0.05$: $(p_X + 0.02)^2 + (|p_Y| - 0.37)^2 < 0.23^2$ and $0.37 < |p_Y| < 0.52$
- For $0.05 < \xi < 0.1$: $(p_X + 0.02)^2 + (|p_Y| - 0.36)^2 < 0.28^2$ and $0.36 < |p_Y| < 0.55$
- For $0.1 < \xi < 0.15$: $(p_X + 0.05)^2 + (|p_Y| - 0.34)^2 < 0.3^2$ and $0.34 < |p_Y| < 0.55$







Event selection and corrections for SD process

- **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.

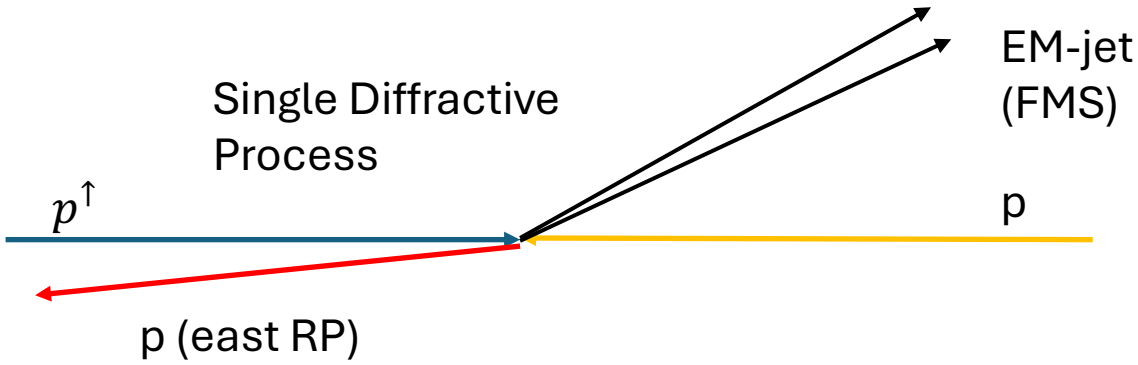
Corrections:
EM-jet energy correction and
Underlying Event correction

- **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

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)

Calculate the background fraction

- 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.

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%

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

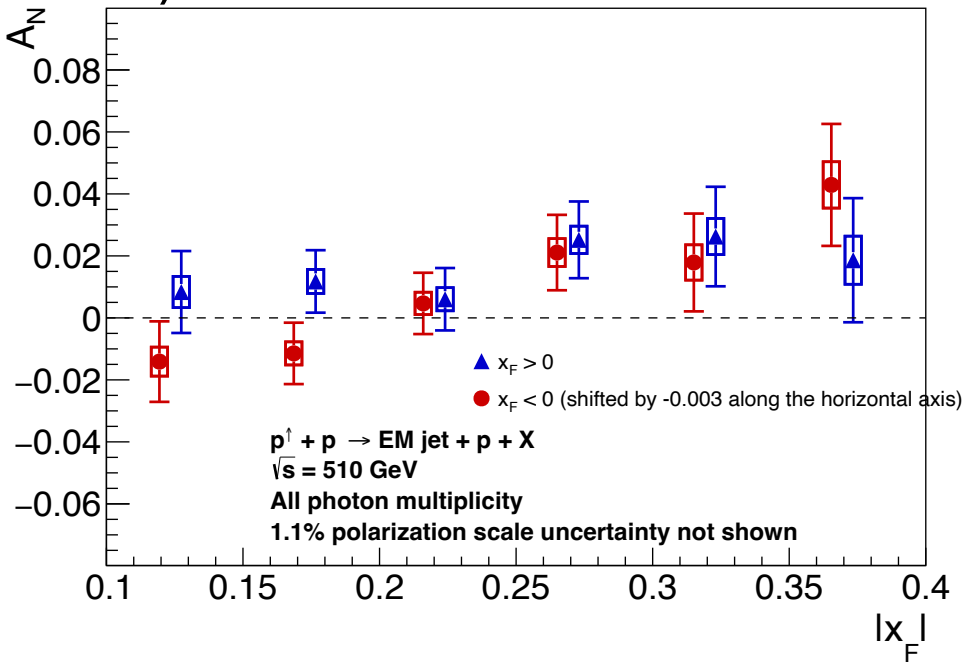
3 or more Photon multiplicity

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

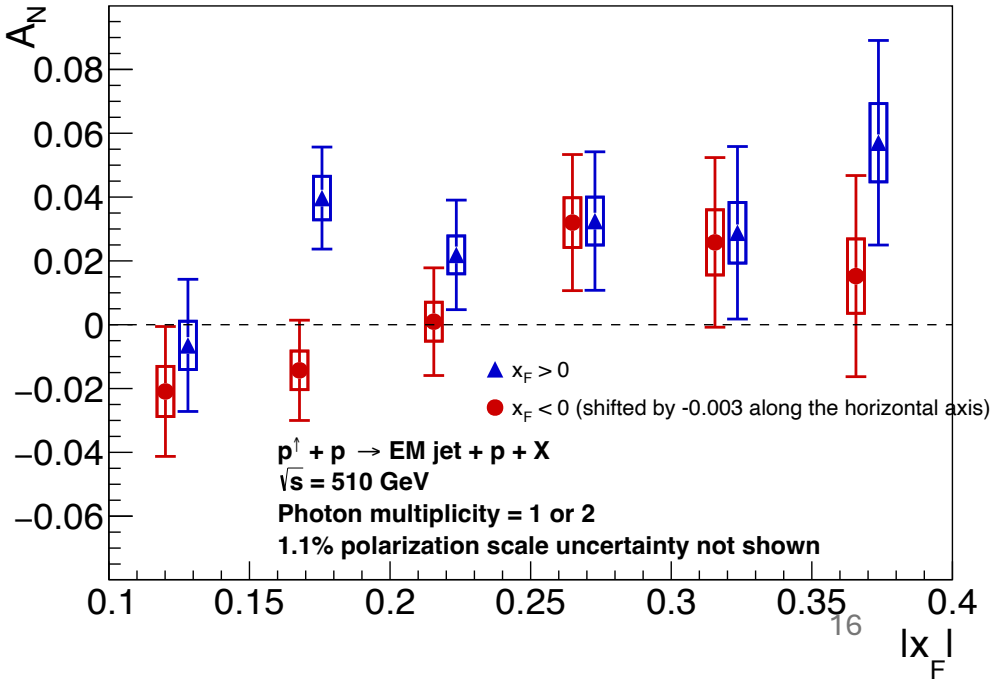
A_N for all photon multiplicity

- 6 x_F bins for EM-jets are used to study the A_N :
  - [0.1, 0.15], [0.15, 0.2] , [0.2, 0.25], [0.25, 0.3] , [0.3, 0.35], [0.35, 0.4]
  - Constant fit are applied for studying the non-zero significance
  - Blue beam A_N : 2.57 σ (0.014 ± 0.0054)
  - Yellow beam A_N : 0.81 σ (0.0043 ± 0.0053)



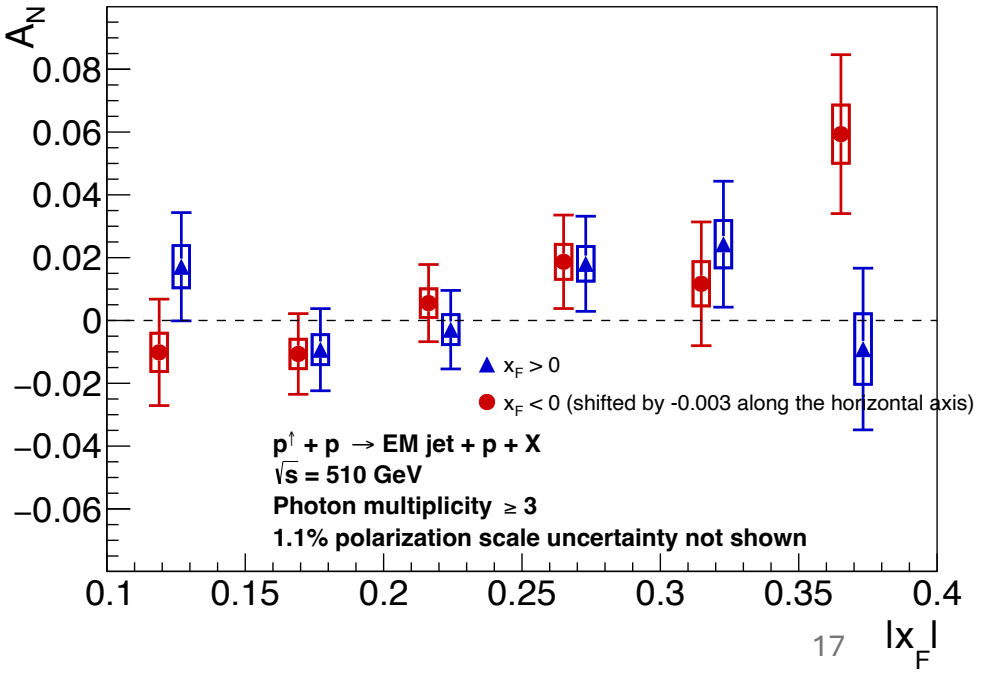
A_N for 1 or 2 photon multiplicity

- 6 x_F bins for EM-jets are used to study the A_N :
  - [0.1, 0.15], [0.15, 0.2] , [0.2, 0.25], [0.25, 0.3] , [0.3, 0.35], [0.35, 0.4]
- Constant fit are applied for studying the non-zero significance
  - Blue beam A_N : 2.96 σ (0.027 ± 0.0090)
  - Yellow beam A_N : 0.14 σ (0.0012 ± 0.0088)



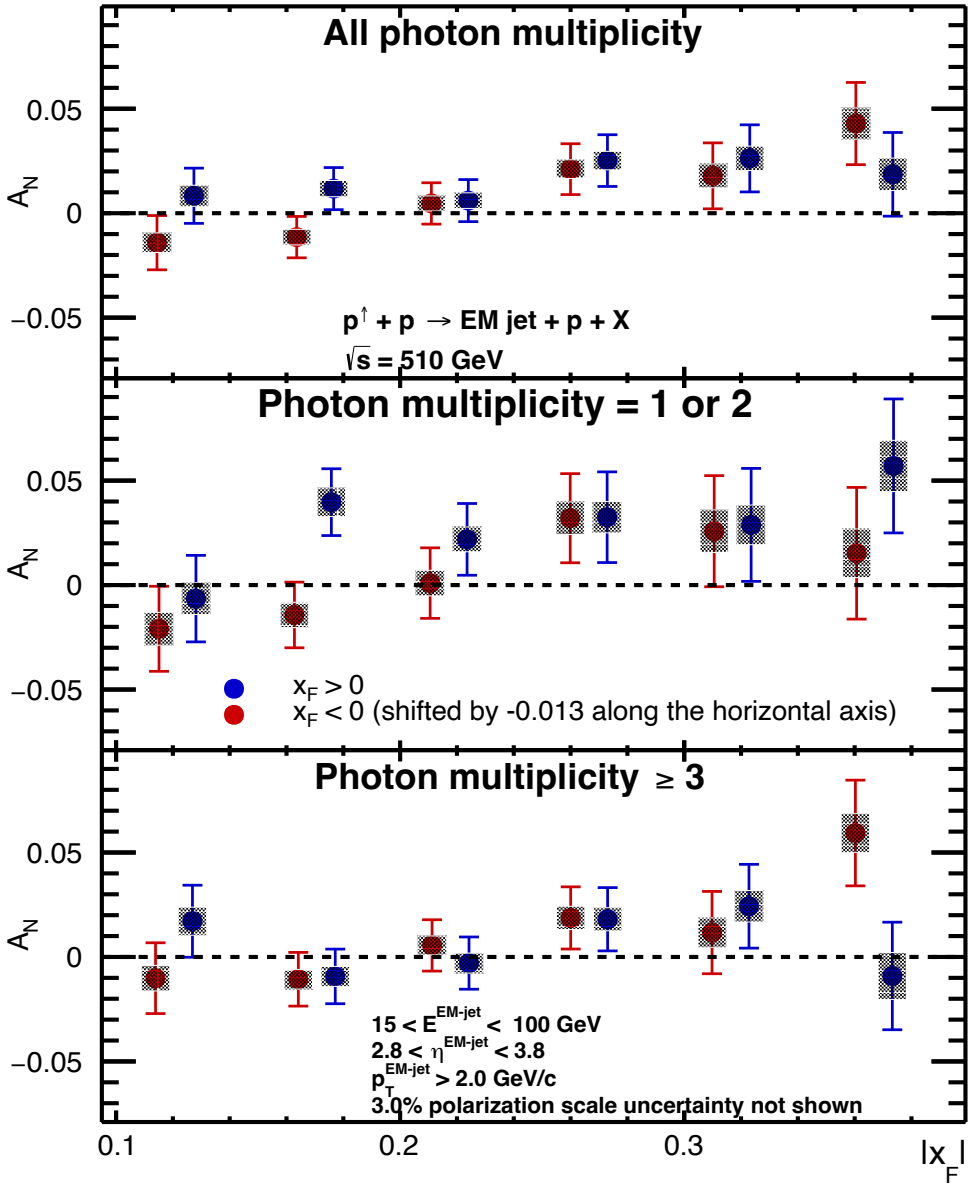
A_N for 3 or more photon multiplicity

- 6 x_F bins for EM-jets are used to study the A_N :
  - [0.1, 0.15], [0.15, 0.2] , [0.2, 0.25], [0.25, 0.3] , [0.3, 0.35], [0.35, 0.4]
- Constant fit are applied for studying the non-zero significance
  - Blue beam A_N : 0.67 σ (0.0046 ± 0.0069)
  - Yellow beam A_N : 0.85 σ (0.0058 ± 0.0068)

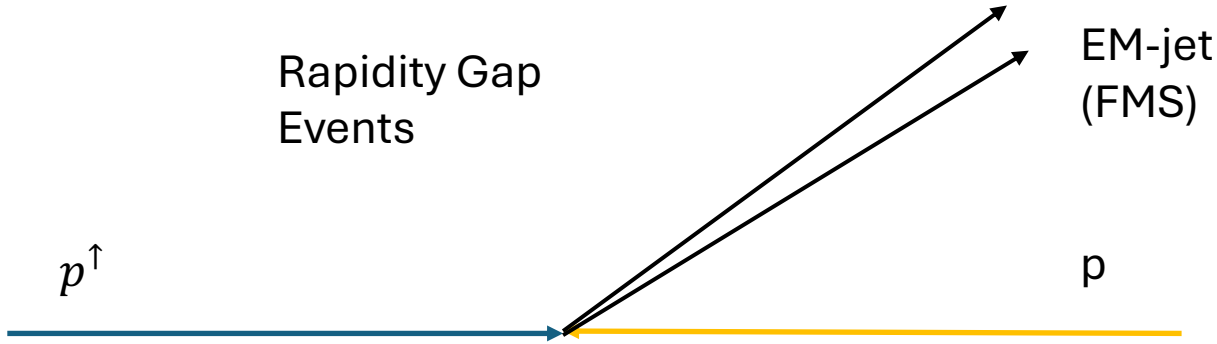


Compare the single diffractive EM-jet A_N for the 3 cases of photon multiplicity

- 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.



Rapidity gap events



Event selection and corrections for RG events

- **FMS**
  - 9 Triggers, veto on FMS-LED
  - Only 1 EM-jet per event is allowed
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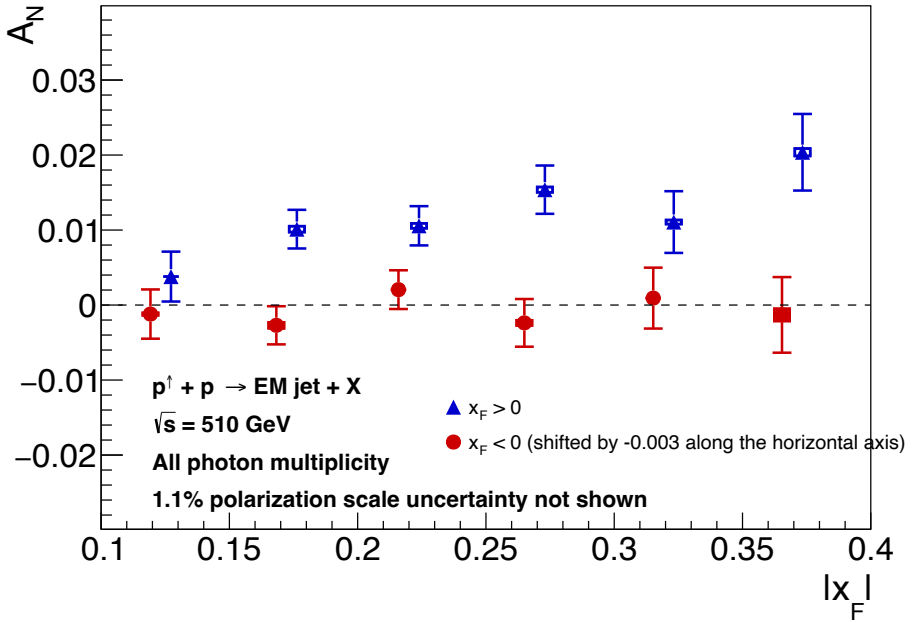
  - Jet reconstruction: StJetMaker2015 , Anti-kT, R<0.7 , FMS point energy > 1 GeV, $p_T > 2$ GeV/c, trigger p_T threshold cut, FMS point as input.
- **Only allow acceptable beam polarization (up/down).**
- **Vertex** (Determine vertex z priority according to TPC , VPD, BBC.)
  - Vertex $|z| < 80\ cm$
- **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

A_N for all photon multiplicity

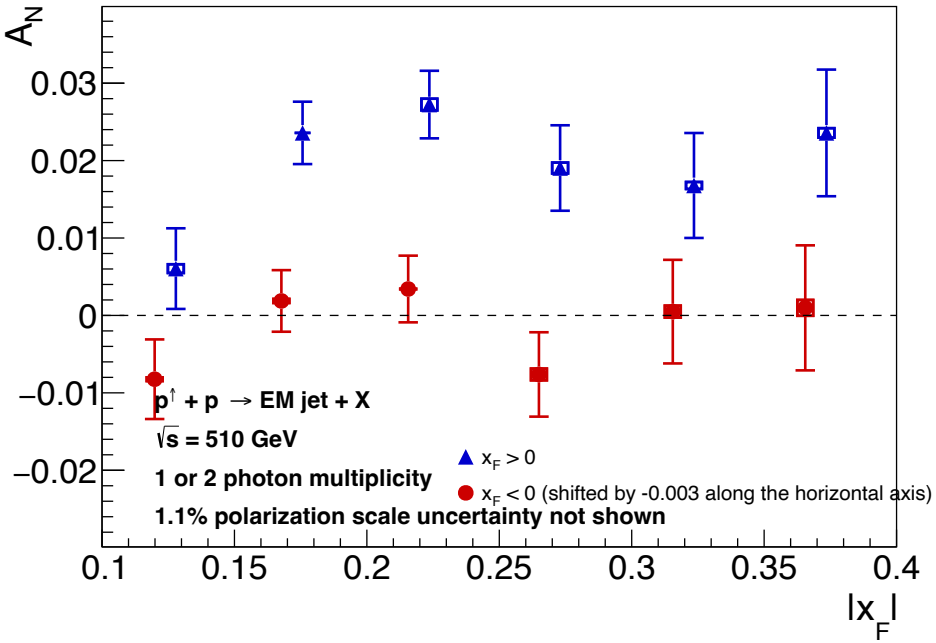
- 6 x_F bins for EM-jets are used to study the A_N :
  - [0.1, 0.15], [0.15, 0.2] , [0.2, 0.25], [0.25, 0.3] , [0.3, 0.35], [0.35, 0.4]
- Constant fit are applied for studying the non-zero significance
  - Blue beam A_N : 8.24 σ (0.011 ± 0.0013)
  - Yellow beam A_N : 0.57 σ (-0.00007 ± 0.0013)
- This shows similar size as single diffractive processes



A_N for 1 or 2 photon multiplicity

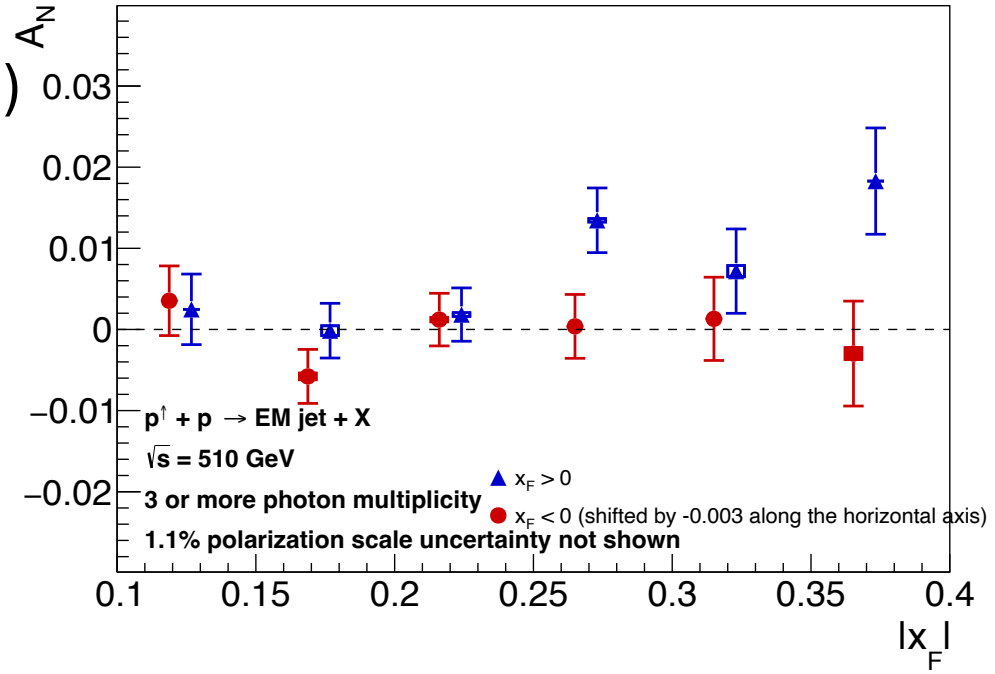
- 6 x_F bins for EM-jets are used to study the A_N :
  - [0.1, 0.15], [0.15, 0.2] , [0.2, 0.25], [0.25, 0.3] , [0.3, 0.35], [0.35, 0.4]
- Constant fit are applied for studying the non-zero significance
  - Blue beam A_N : 9.41 σ (0.020 ± 0.0021)
  - Yellow beam A_N : 0.50 σ (-0.0010 ± 0.0021)

- The A_N for 1 or 2 photon multiplicity in the rapidity gap events is much smaller than that in the single diffractive process



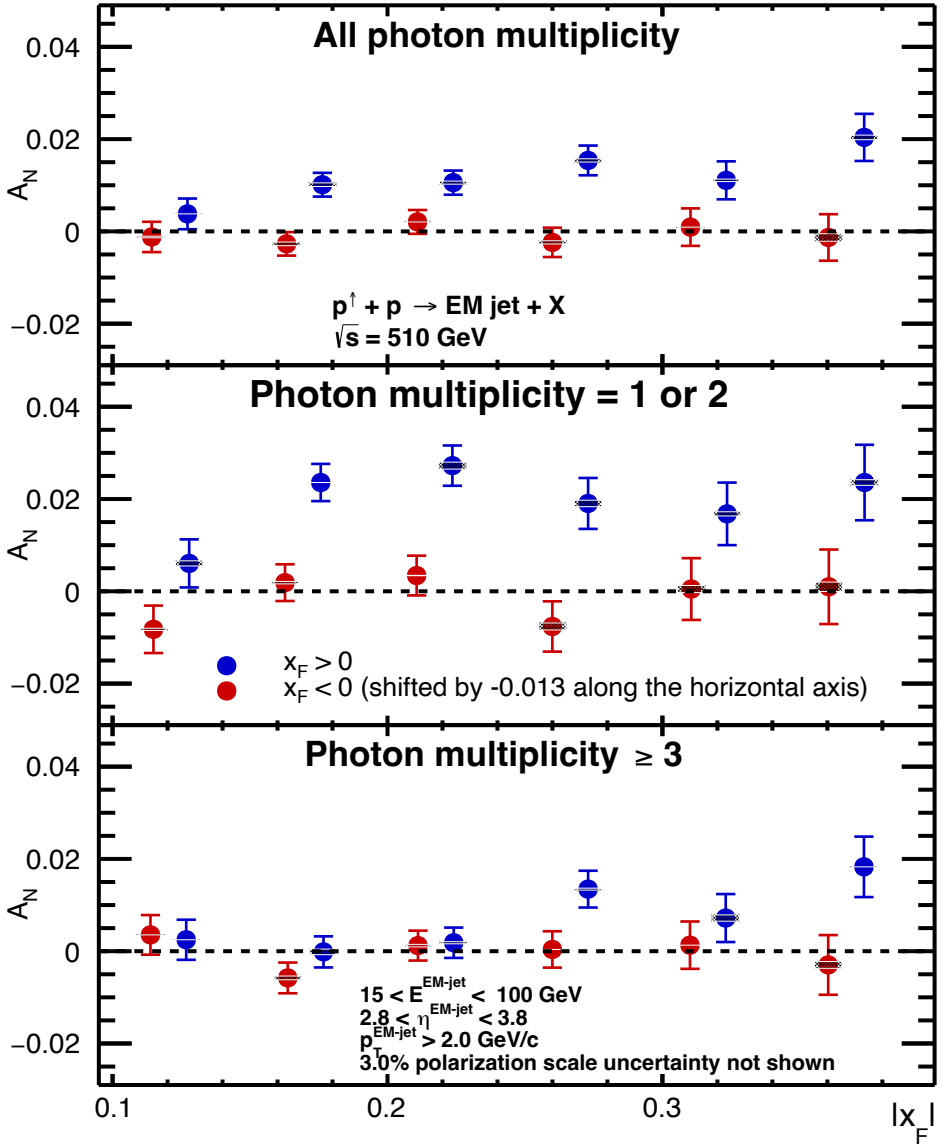
A_N for 3 or more photon multiplicity

- 6 x_F bins for EM-jets are used to study the A_N :
  - [0.1, 0.15], [0.15, 0.2] , [0.2, 0.25], [0.25, 0.3] , [0.3, 0.35], [0.35, 0.4]
- Constant fit are applied for studying the non-zero significance
  - Blue beam A_N : 3.06 σ (0.0052 ± 0.0017)
  - Yellow beam A_N : 0.34 σ (-0.00056 ± 0.0017)



Compare the 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.



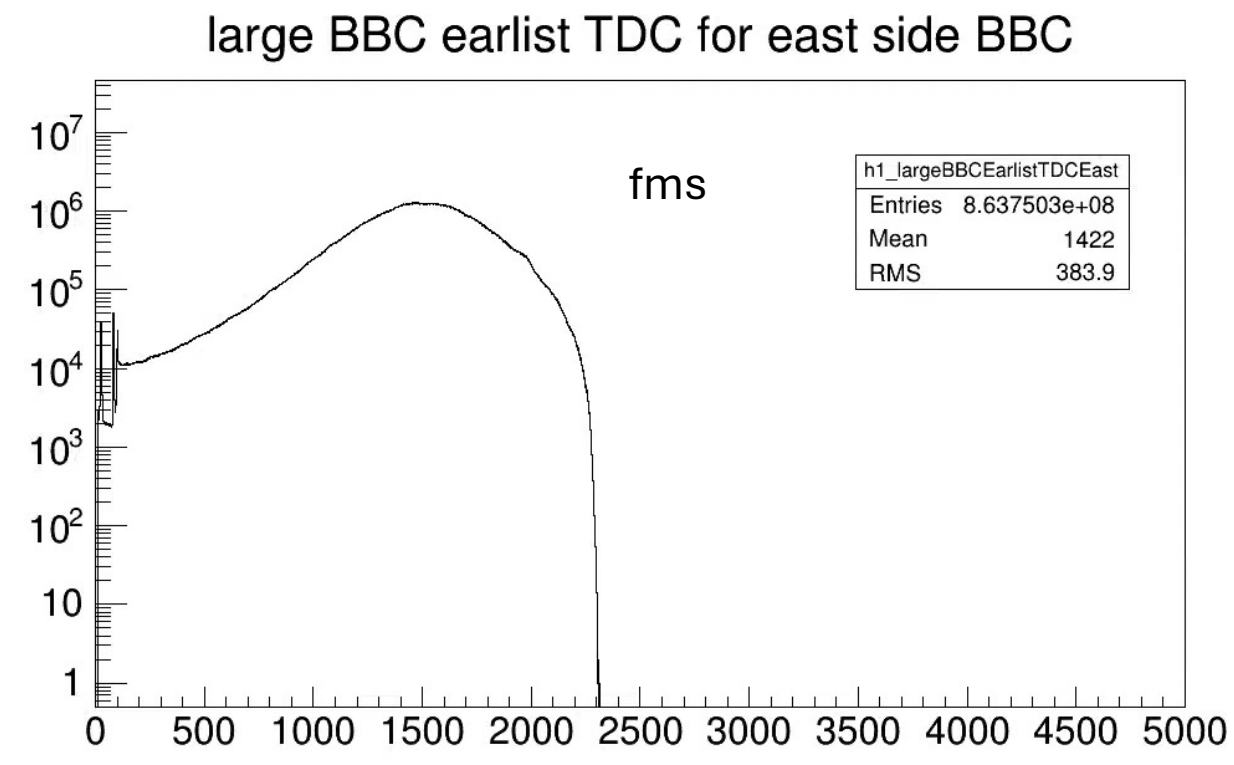
Conclusion

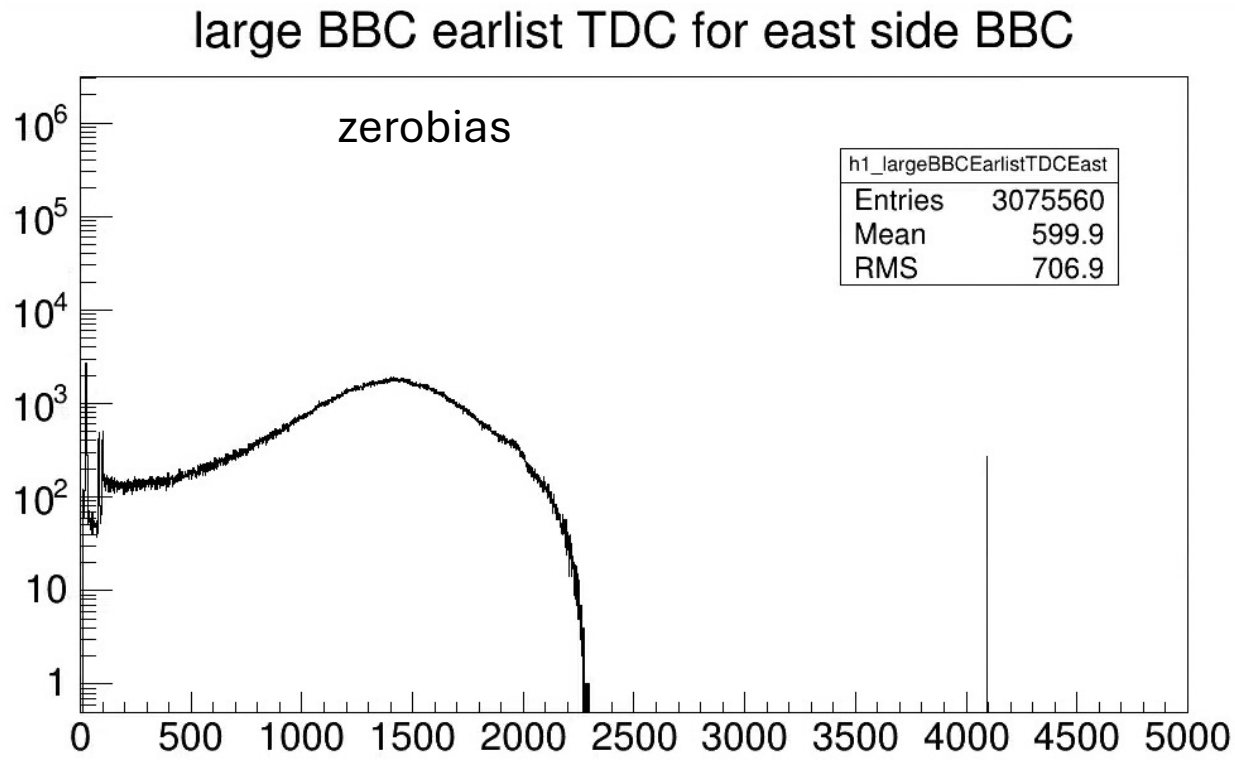
- We have the first study for EM-jet A_N for run 17 single diffractive process and rapidity gap event.
- EM-jets with 1 or 2 photon multiplicity have larger A_N than that with 3 or more photon multiplicity for both processes.
- EM-jets with 3 or more photon multiplicity are much more dominant at higher center-of-mass collisions.

Backup

Compare east BBC large earliest TDC

- We compare east BBC large earliest TDC for fms stream data and zerobias stream data
- We can allow resolution for east BBC large earliest TDC close to 0 for large BBC east veto.





Trigger dependent EM-jet p_T cuts

- For the EM-jets at FMS, they are required to satisfy minimum 2GeV/c on p_T
- In addition, they are required to satisfy the Trigger dependent EM-jet p_T cuts:

Trigger name	Run < 18074023	18074023 <= Run < 18122023	Run >= 18122023
FMS-JP0	1.60 GeV/c	7.58 GeV/c	7.58 GeV/c
FMS-JP1	3.00 GeV/c	3.00 GeV/c	3.00 GeV/c
FMS-JP2	4.48 GeV/c	4.48 GeV/c	4.48 GeV/c
FMS-small-BS-1	1.00 GeV/c	1.00 GeV/c	1.30 GeV/c
FMS-small-BS-2	2.00 GeV/c	2.00 GeV/c	2.38 GeV/c
FMS-small-BS-3	2.38 GeV/c	2.38 GeV/c	3.80 GeV/c
FMS-large-BS-1	1.00 GeV/c	1.00 GeV/c	1.30 GeV/c
FMS-large-BS-2	1.70 GeV/c	1.70 GeV/c	2.40 GeV/c
FMS-large-BS-3	3.04 GeV/c	3.04 GeV/c	4.58 GeV/c

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

EM-jet mean energy and p_T per run

- For most of the runs, the mean energy and p_T per run look fine. Only a few runs are showing abnormal mean energy and p_T (either too high or too low)