Final update for Run 15 diffractive EM-jet A_N (Part 1)

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Outline

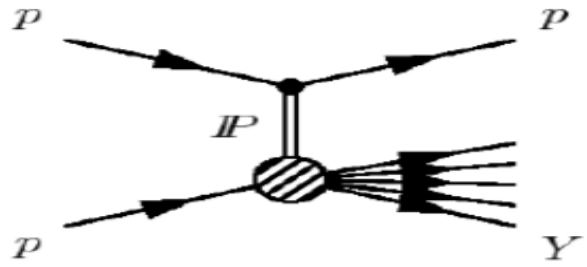
- Update on semi-exclusive process with 1 west RP track
  - Event selection
  - Mix event background from zerobias data
  - Systematic uncertainty
  - A_N measurements
- Update on diffractive process with 1 east RP track (Part 2)
  - Status and plans for studying this diffractive process
- Plans, conclusions and discussion

General Information for the data set

- Data set: run 15 pp transverse $\sqrt{s} = 200$ GeV ,fms stream
  - (production_pp200trans_2015)
- Production type: MuDst ; Production tag: P15ik
- Trigger for FMS : FMS small board sum, FMS large board sum and FMS-JP.
- EM-jet reconstruction: Anti-k_T algorithm with R=0.7
  - EM-jet: the jet reconstructed using only photons (FMS point).
  - Minimum p_T threshold based on trigger threshold

Diffractive process

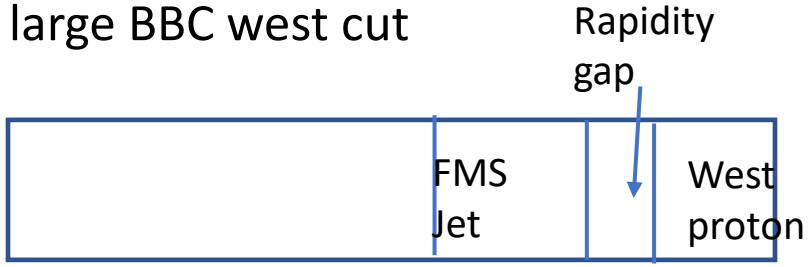
Case 1: (Single diffractive process)
only 1 proton track on east side RP. No west side RP track requirement.
Require: small and large BBC east cut

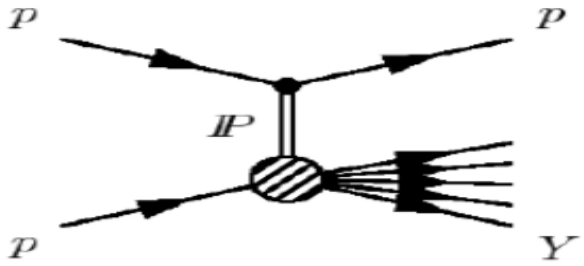


East RP track

FMS jets

Case 2: (semi-exclusive process)
only 1 proton track on west side RP. No requirement on east RP track
Require: small and large BBC west cut



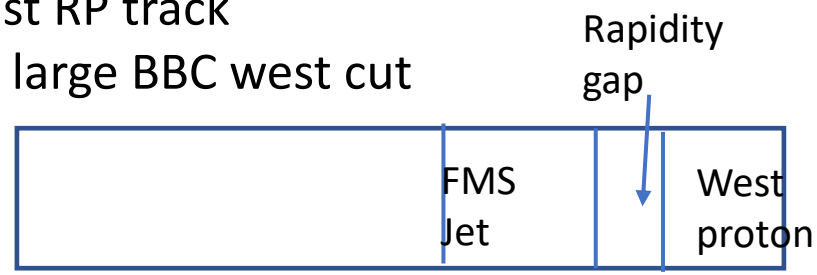


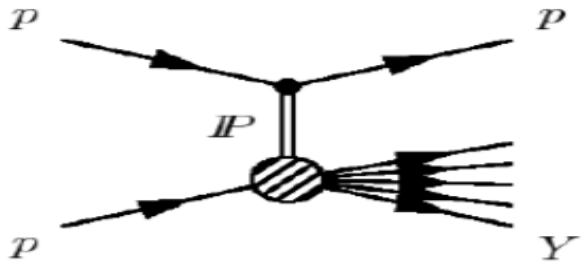
West RP track

FMS jets

Part 1: Semi-exclusive process with 1 west RP track

Case 2: (semi-exclusive process)
only 1 proton track on west side RP. No requirement on east RP track
Require: small and large BBC west cut





West RP track

FMS jets

Outline for studying the RP cuts and BBC cuts

- Here are the idea and steps for considering the cuts for RP and BBC:

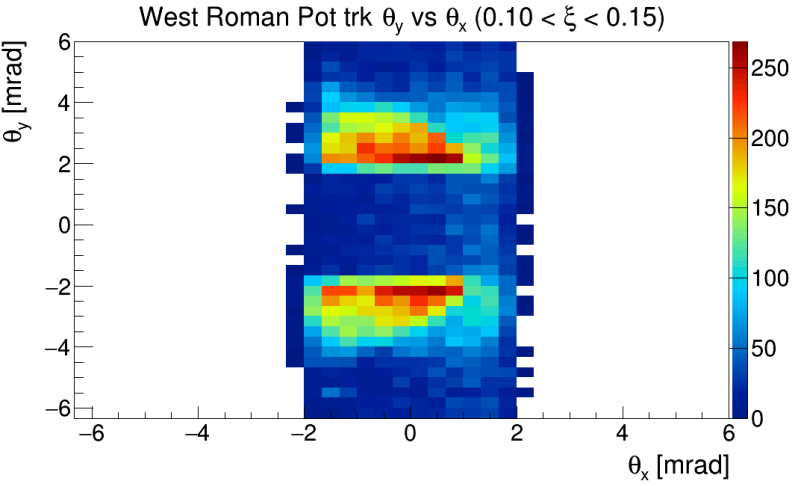
1. Since we reach to the agreement that the low BBC threshold should be applied, we first apply a rough cut on small BBC east or west < 150 . Goal: explore a rough RP P_X , P_Y cuts for different ξ range.
2. Apply the rough RP P_X , P_Y cuts from step 1, study the small BBC east/west ADC distribution and consider further cuts for small BBC cuts.
3. Apply the further cuts for west or east small BBC cuts, study the further RP P_X , P_Y cuts, and θ_X , θ_Y cuts for different ξ range.

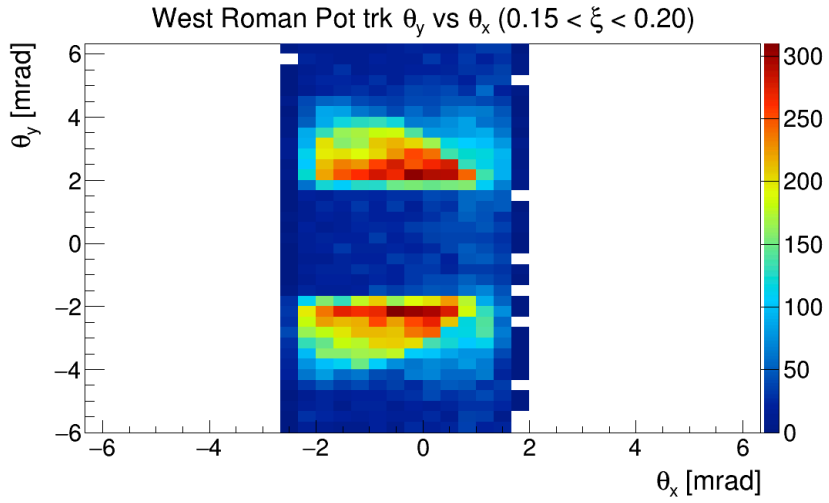
$$\xi = \frac{P_{beam} - P_{RP}}{P_{beam}}$$

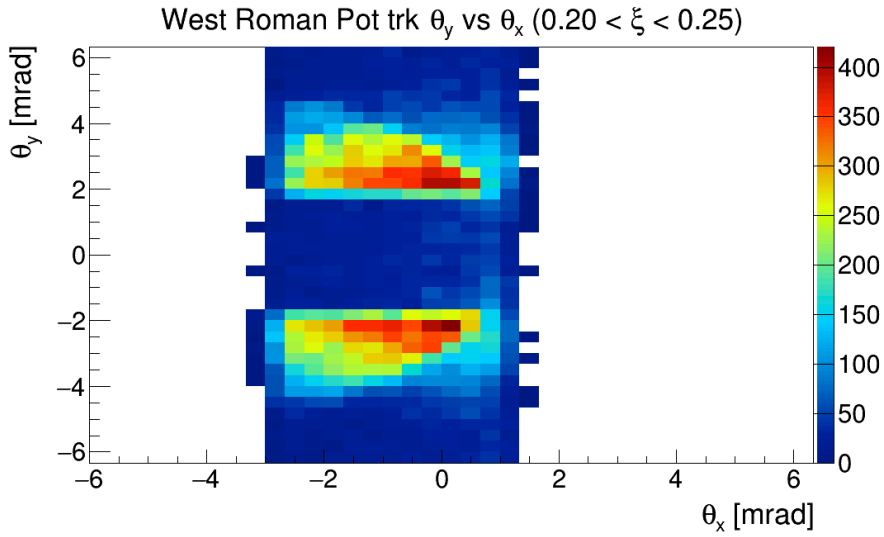
West RP track θ_Y vs θ_X with different ξ ranges

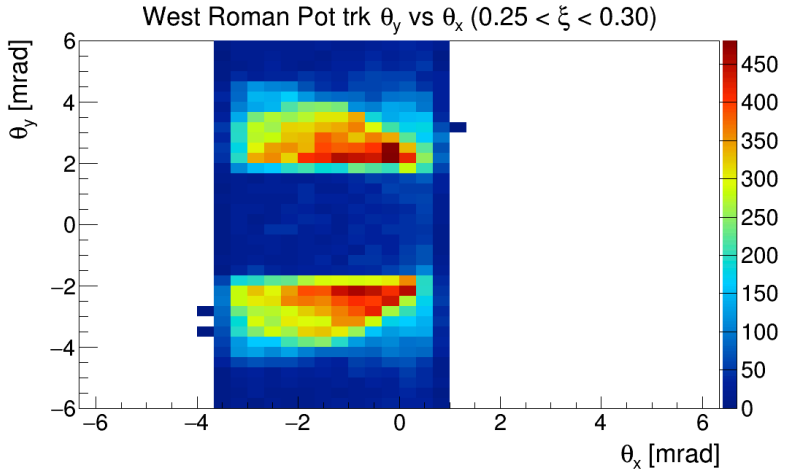
- Cuts applied at this stage: RP track hit at least 7 SSD planes , small BBC west < 150

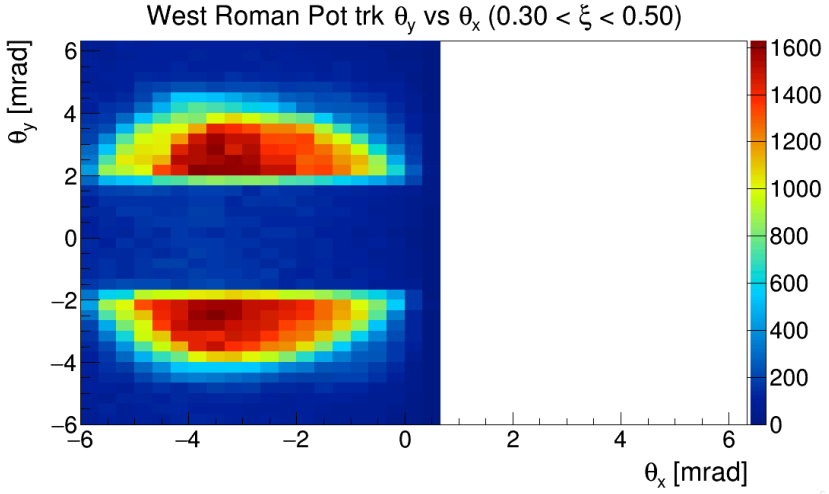
$$(\xi = \frac{P_{beam} - P_{RP}}{P_{beam}})$$

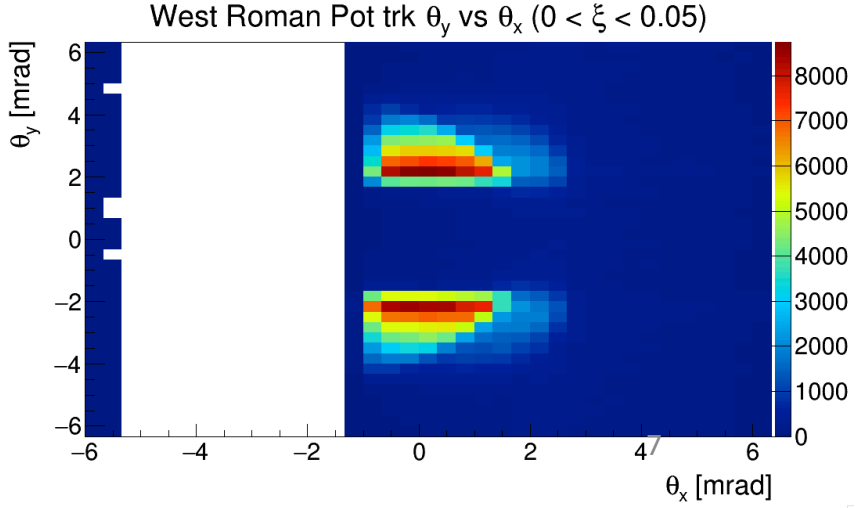










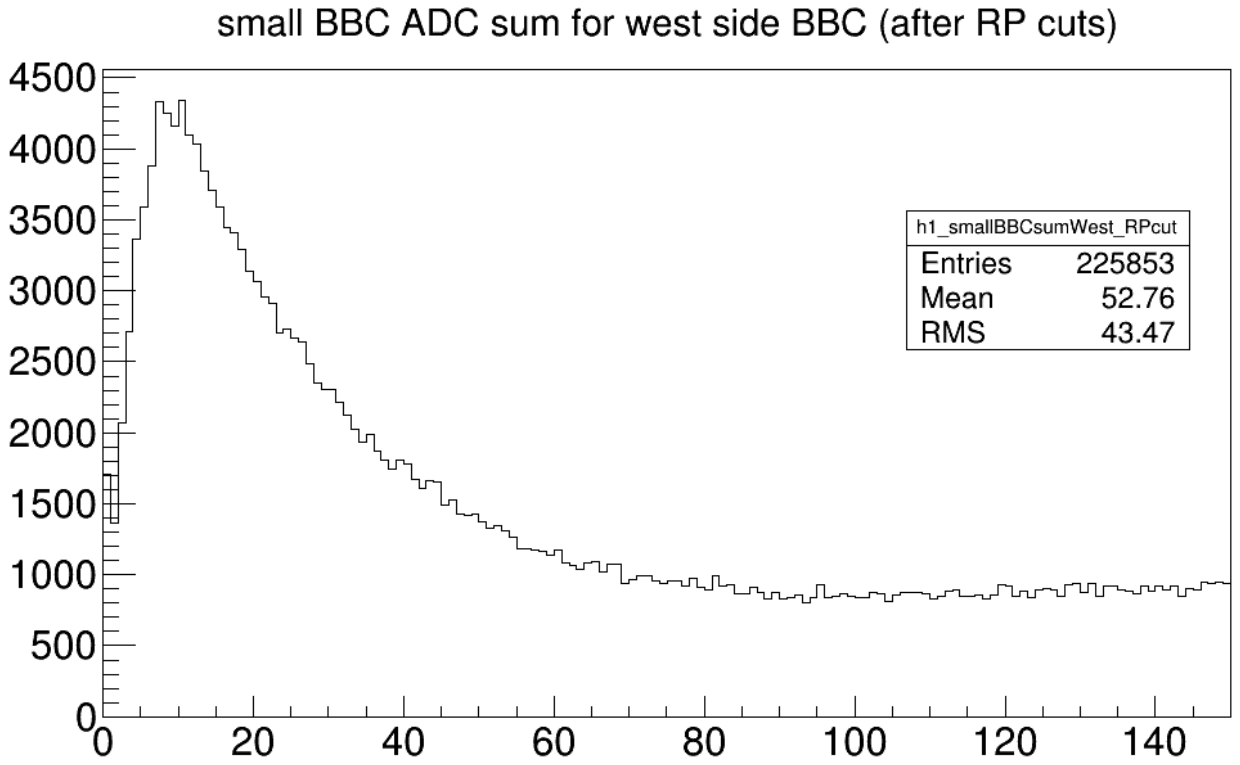


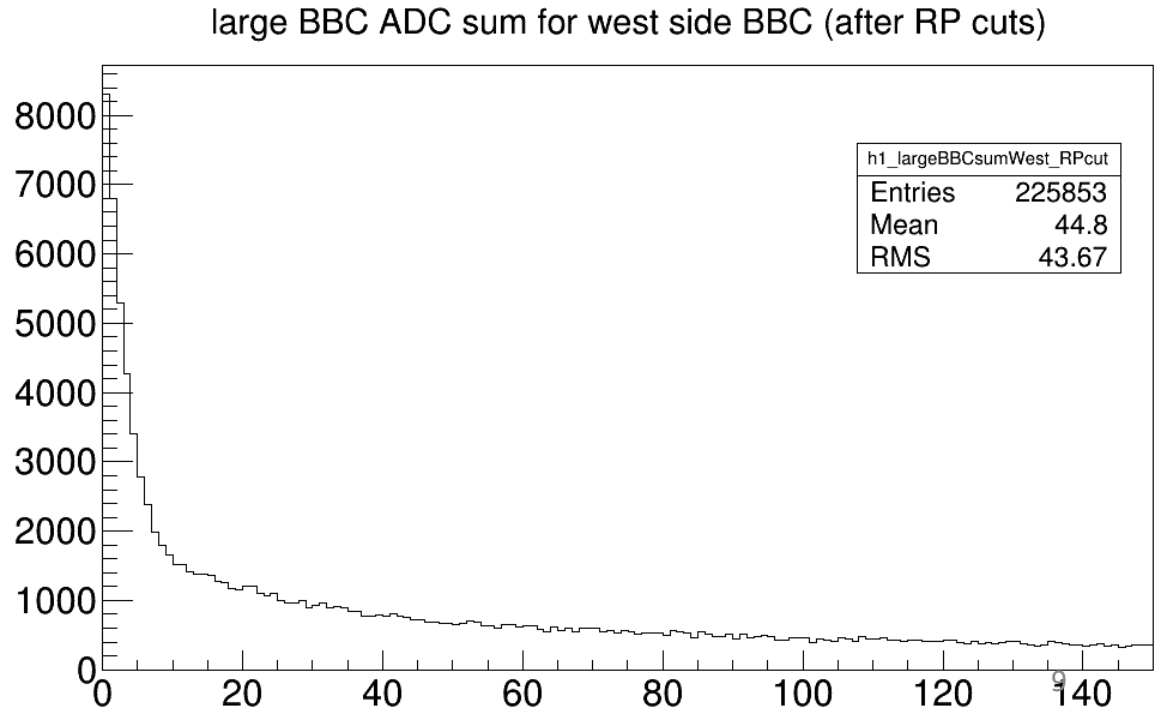
Rough cut on the west RP track θ_X and θ_Y

- Goal: explore the BBC cuts.
- We can consider the west RP θ_Y cut: $1.5 < |\theta_Y| < 4\ mrad$
- The west RP θ_X cut can be applied with ξ dependent
- $0.1 < \xi < 0.15$: $-1.75 < \theta_X < 1.5$ mrad
- $0.15 < \xi < 0.2$: $-2.25 < \theta_X < 1.75$ mrad
- $0.2 < \xi < 0.25$: $-2.5 < \theta_X < 1.5$ mrad
- $0.25 < \xi < 0.3$: $-3 < \theta_X < 0.5$ mrad
- $0.3 < \xi < 0.5$: $-5 < \theta_X < -0.5$ mrad
- Note: these are the rough cuts for west RP track θ_X and θ_Y

West small and large BBC ADC sum after the rough west RP track θ_X and θ_Y cuts

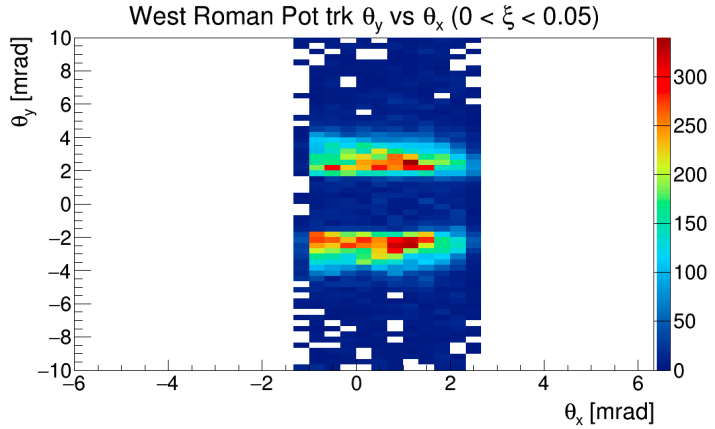
- Temporally apply the rough west RP track θ_X and θ_Y cuts to study the west small and large BBC ADC sum.
- We can consider small BBC west ADC sum < 80 and large BBC west < 60

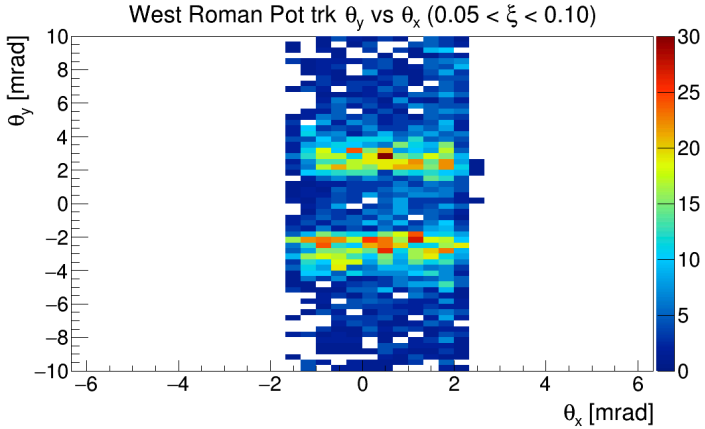


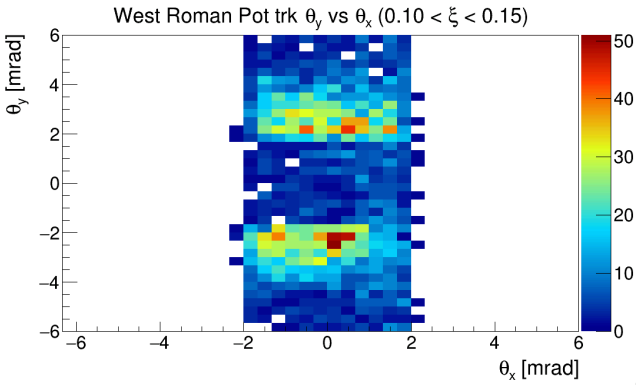


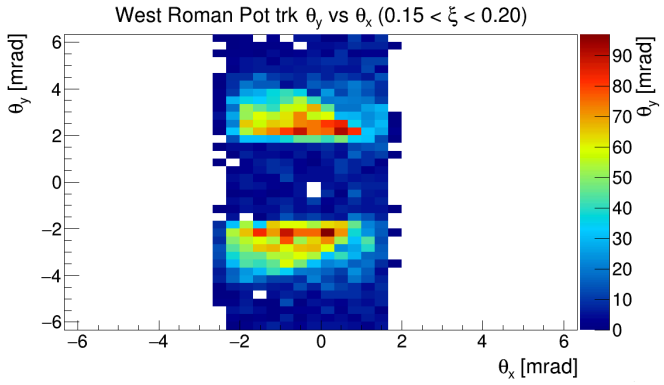
West RP track θ_Y vs θ_X with different ξ ranges

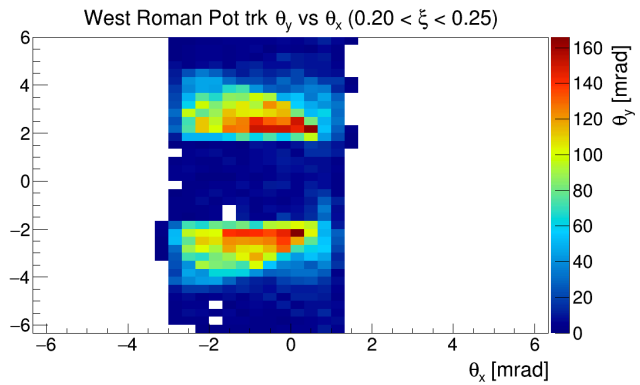
- Apply small BBC west ADC sum < 80 and large west BBC ADC sum < 60 cuts

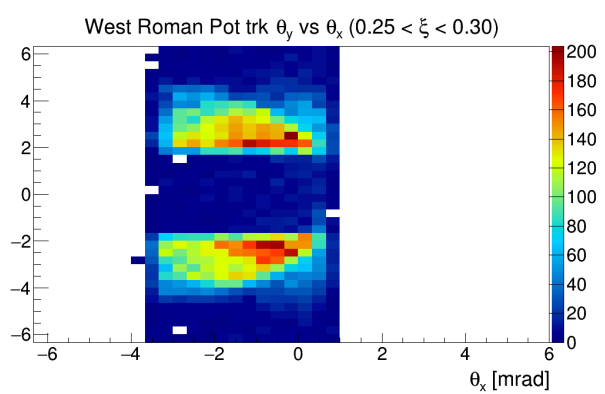


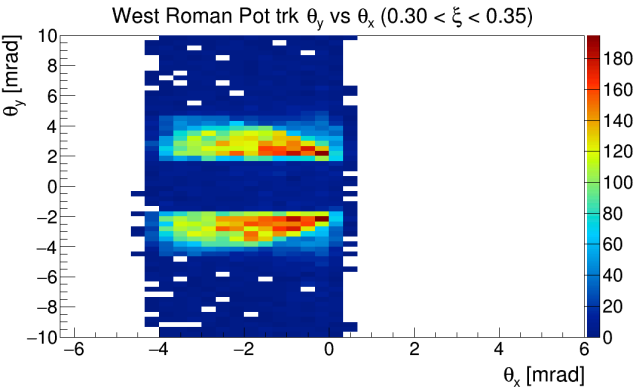


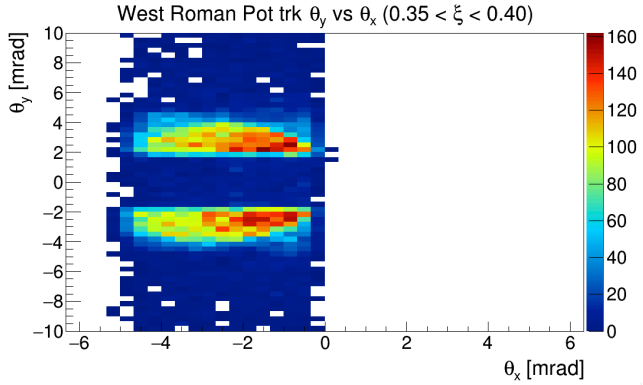


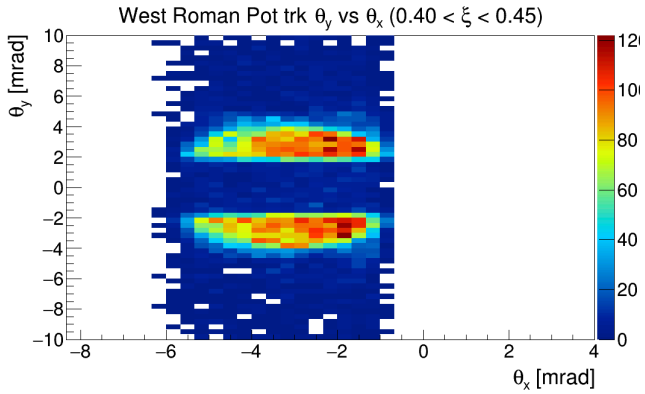










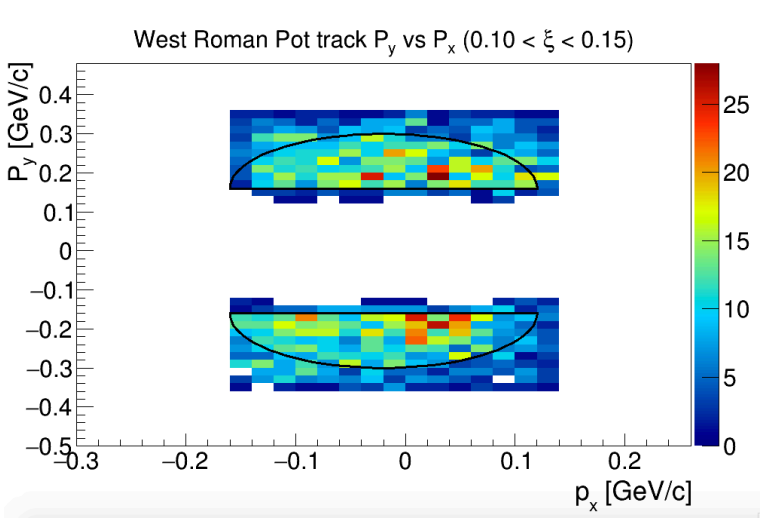


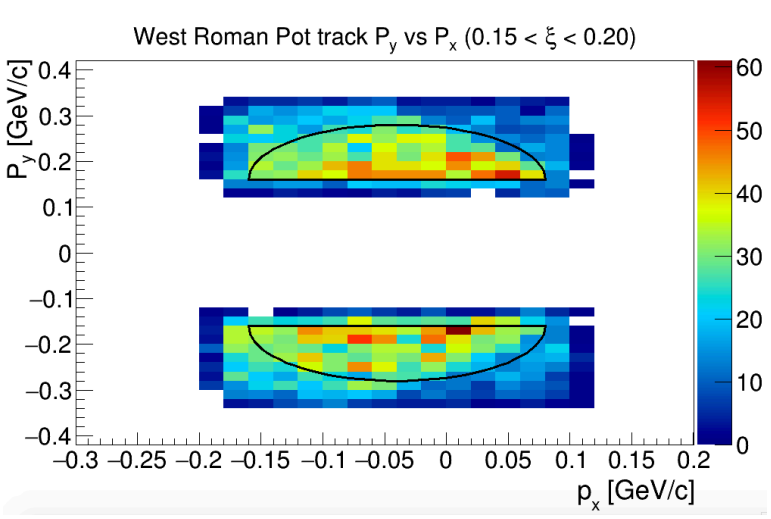
Final cut on the **west** RP track θ_X and θ_Y

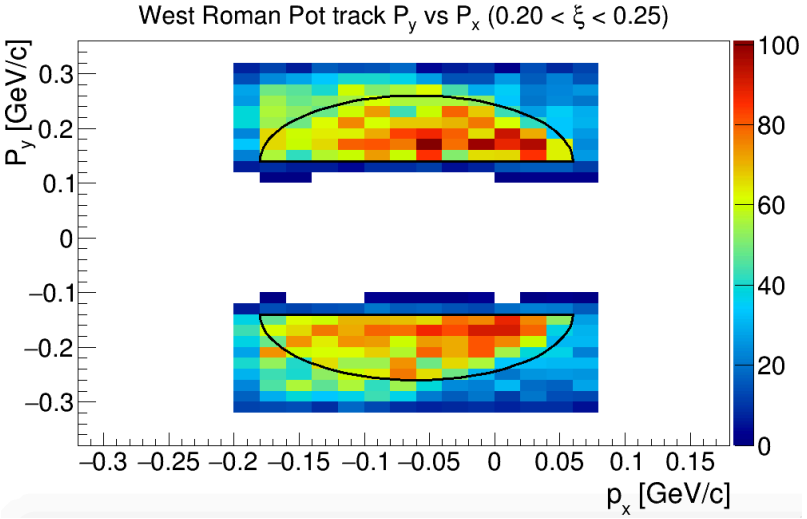
- We apply the BBC cuts: BBC west ADC sum < 80 and large BBC west < 60
- We can consider the west RP θ_Y cut: $1.5 < |\theta_Y| < 4\ mrad$
- The west RP θ_X cut can be applied with ξ dependent
  - $0.0 < \xi < 0.05$: $-1 < \theta_X < 1.5$ mrad
  - $0.05 < \xi < 0.1$: $-1.5 < \theta_X < 1.5$ mrad
  - $0.1 < \xi < 0.15$: $-1.75 < \theta_X < 1.5$ mrad
  - $0.15 < \xi < 0.2$: $-2.25 < \theta_X < 1.25$ mrad
  - $0.2 < \xi < 0.25$: $-2.5 < \theta_X < 1$ mrad
  - $0.25 < \xi < 0.3$: $-3 < \theta_X < 0.5$ mrad
  - $0.3 < \xi < 0.35$: $-3.5 < \theta_X < 0$ mrad
  - $0.35 < \xi < 0.4$: $-4 < \theta_X < -0.5$ mrad
  - $0.4 < \xi < 0.45$: $-5 < \theta_X < -1$ mrad

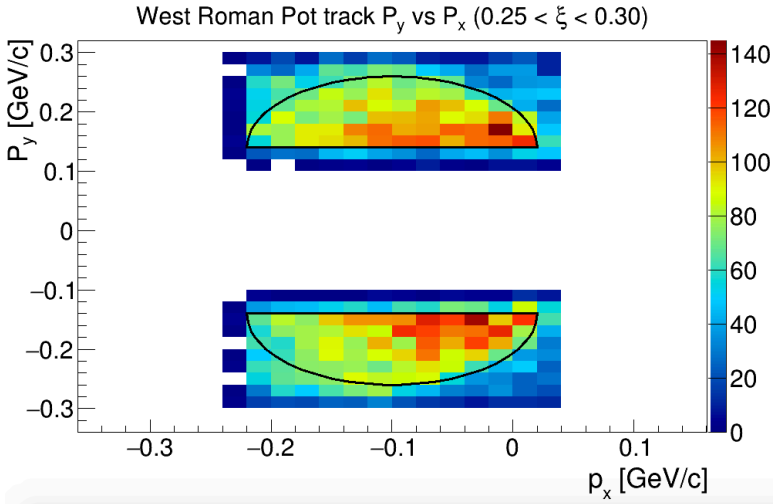
West RP track P_Y vs P_X

- Applying the BBC west small/large ADC sum cuts and RP θ_X and θ_Y cuts, we check the west RP track P_Y vs P_X distribution.





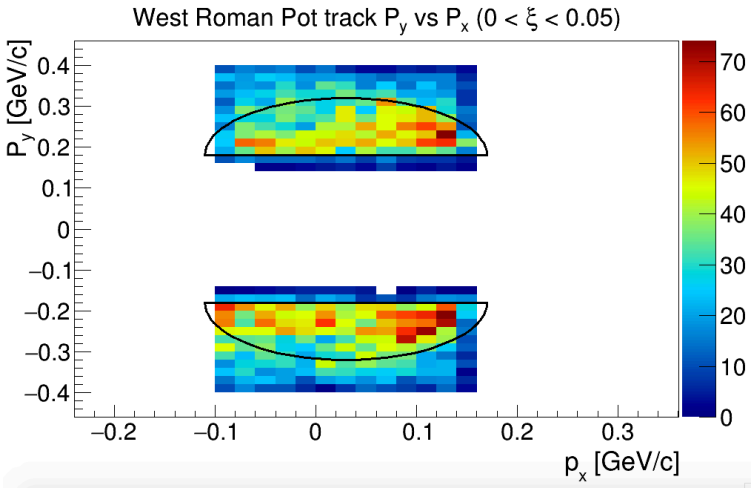


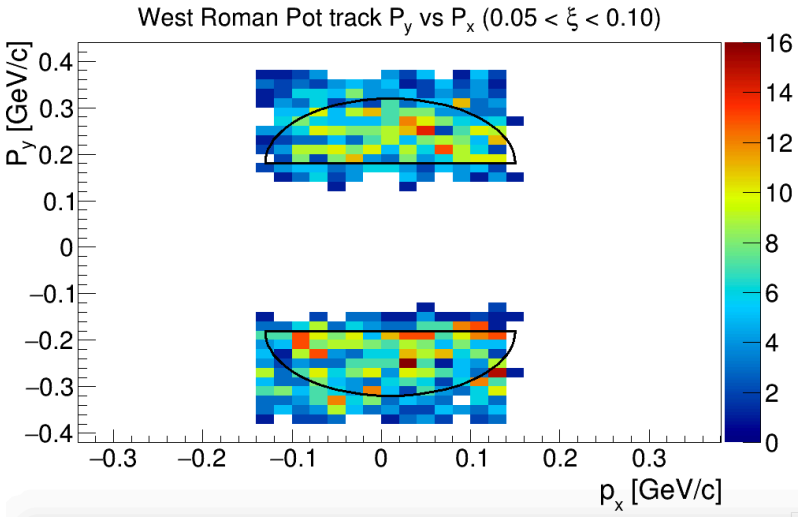


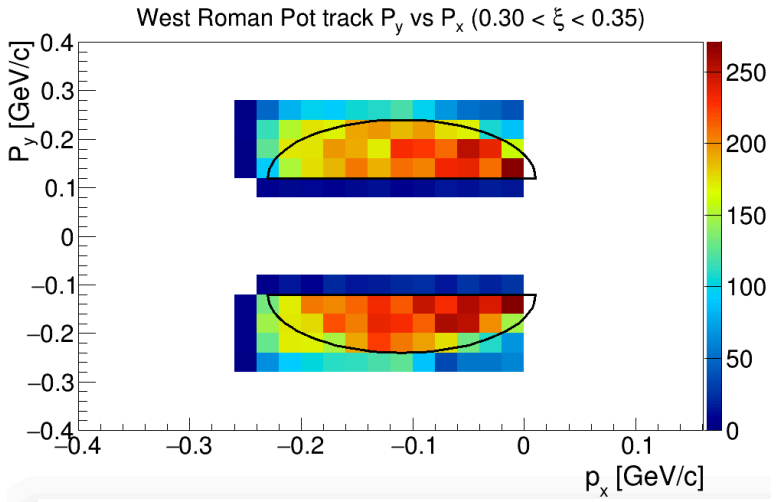
Additional RP track P_X and P_Y cuts are obtained from the semi-circle regions (black curve).

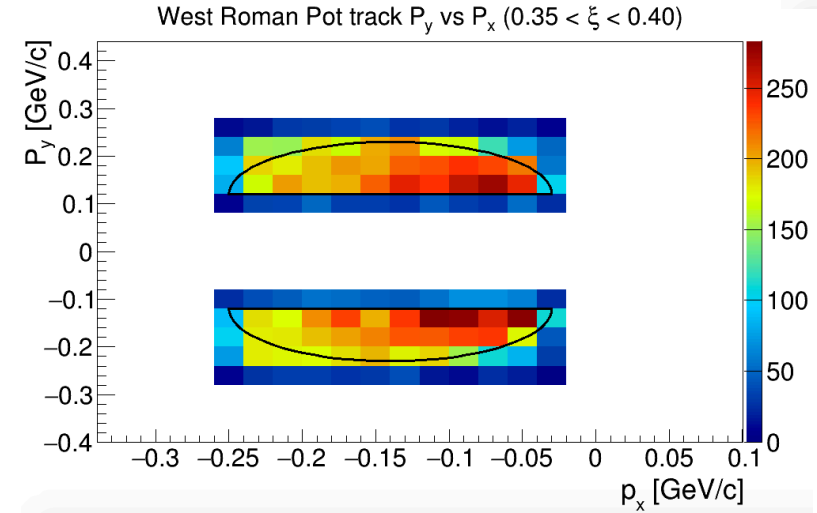
West RP track P_Y vs P_X

- Applying the BBC west small/large ADC sum cuts and RP θ_X and θ_Y cuts, we check the west RP track P_Y vs P_X distribution.

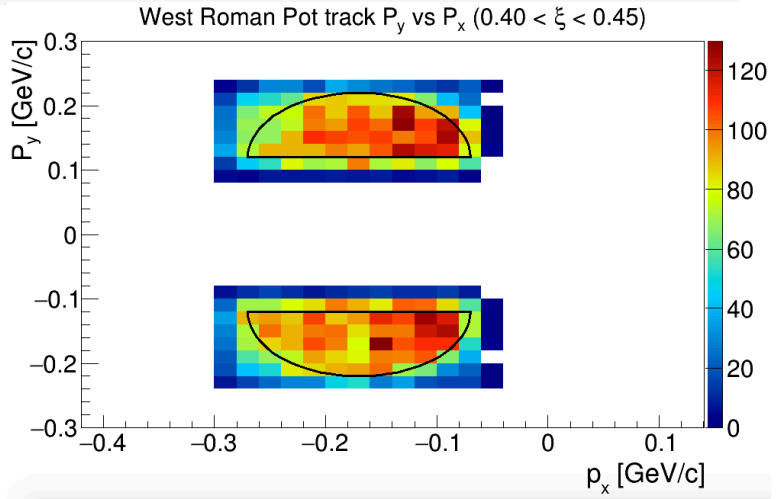








Additional RP track P_X and P_Y cuts are obtained from the semi-circle regions (black curve).



List of **west** RP track P_X and P_Y cuts

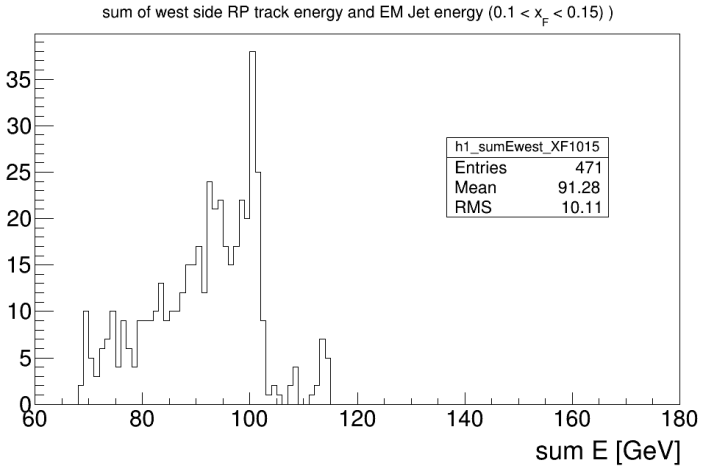
- $0.0 < \xi < 0.05$: $(P_X - 0.03)^2 + (|P_Y| - 0.18)^2 < 0.14^2$ and $0.18 < |P_Y| < 0.32$
- $0.05 < \xi < 0.1$: $(P_X - 0.01)^2 + (|P_Y| - 0.18)^2 < 0.14^2$ and $0.18 < |P_Y| < 0.32$
- $0.1 < \xi < 0.15$: $(P_X + 0.02)^2 + (|P_Y| - 0.16)^2 < 0.14^2$ and $0.16 < |P_Y| < 0.3$
- $0.15 < \xi < 0.2$: $(P_X + 0.04)^2 + (|P_Y| - 0.16)^2 < 0.12^2$ and $0.16 < |P_Y| < 0.28$
- $0.2 < \xi < 0.25$: $(P_X + 0.06)^2 + (|P_Y| - 0.14)^2 < 0.12^2$ and $0.14 < |P_Y| < 0.26$
- $0.25 < \xi < 0.3$: $(P_X + 0.1)^2 + (|P_Y| - 0.14)^2 < 0.12^2$ and $0.14 < |P_Y| < 0.26$
- $0.3 < \xi < 0.35$: $(P_X + 0.11)^2 + (|P_Y| - 0.12)^2 < 0.12^2$ and $0.12 < |P_Y| < 0.24$
- $0.35 < \xi < 0.4$: $(P_X + 0.14)^2 + (|P_Y| - 0.12)^2 < 0.11^2$ and $0.12 < |P_Y| < 0.23$
- $0.4 < \xi < 0.45$: $(P_X + 0.17)^2 + (|P_Y| - 0.12)^2 < 0.1^2$ and $0.12 < |P_Y| < 0.22$

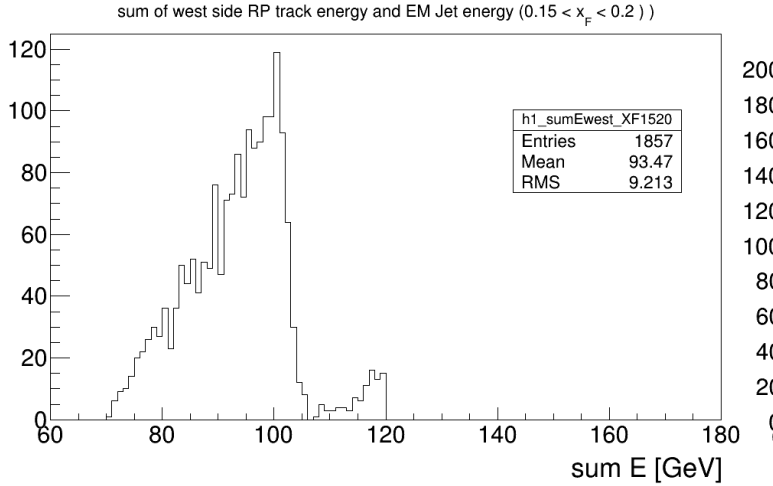
Energy sum plot for case with only 1 west RP track

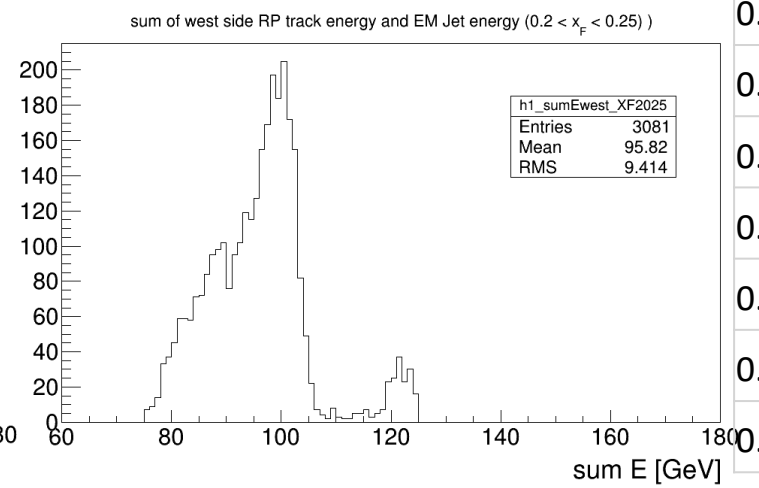
- Energy sum: E(west RP track) + E(EM-jet)
- Applying cuts with west small/large BBC, RP track and FMS EM-jets.

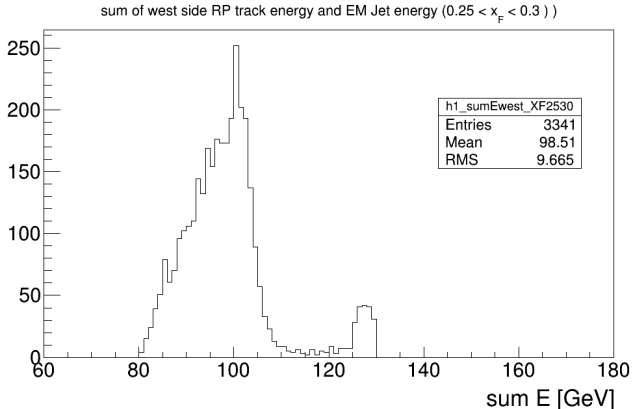
Therefore, we can consider the energy sum cuts below:

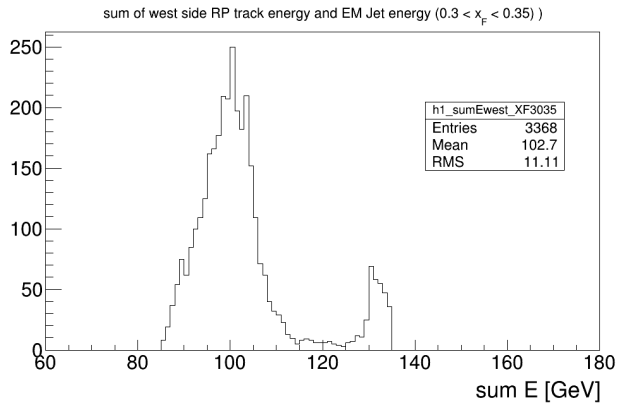
x_F	E sum Cut
0.1 - 0.15	E_{sum} < 105 GeV
0.15 - 0.2	E_{sum} < 105 GeV
0.2 - 0.25	E_{sum} < 110 GeV
0.25 - 0.3	E_{sum} < 110 GeV
0.3 – 0.35	E_{sum} < 115 GeV
0.35 – 0.4	E_{sum} < 115 GeV
0.4 – 0.45	E_{sum} < 120 GeV

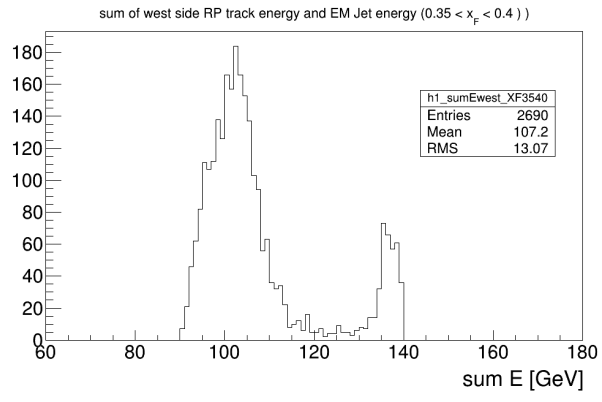


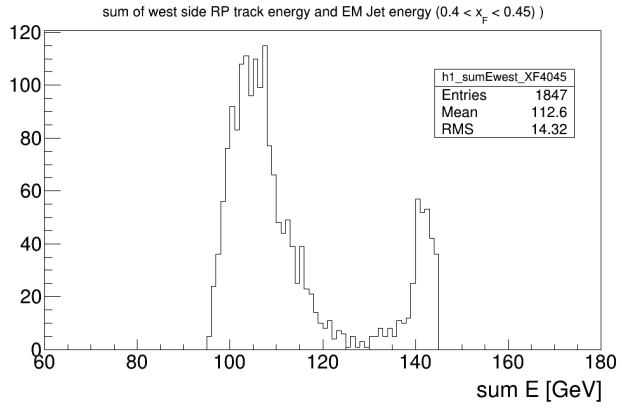






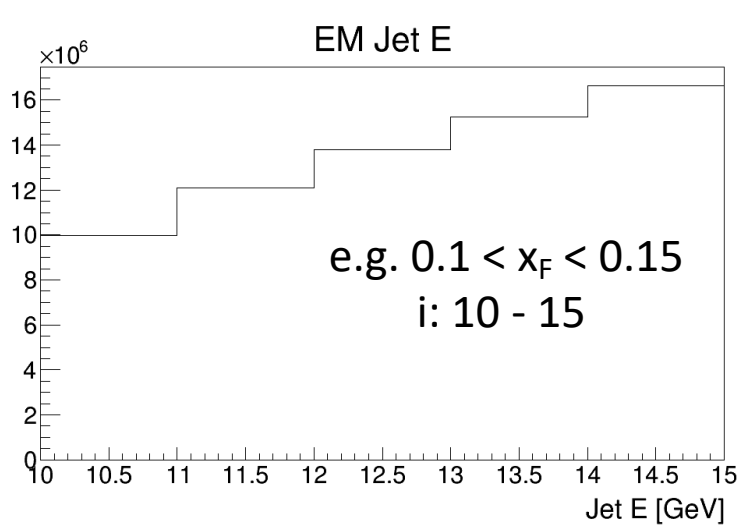


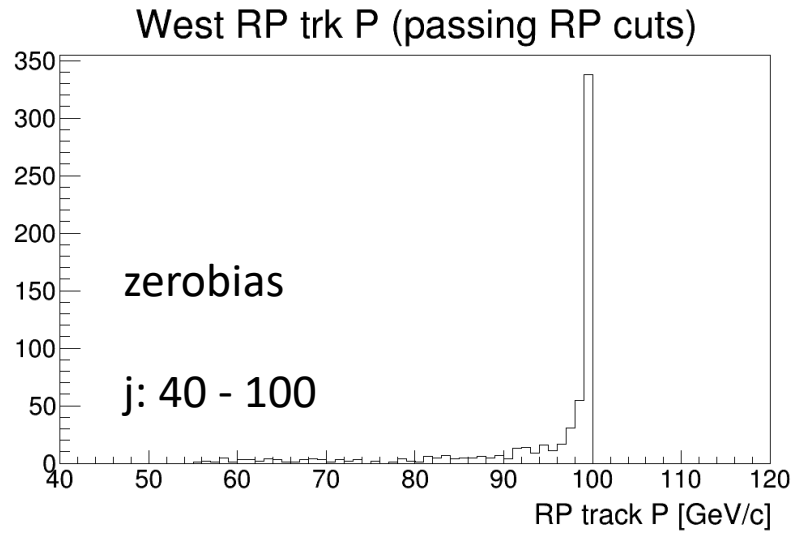


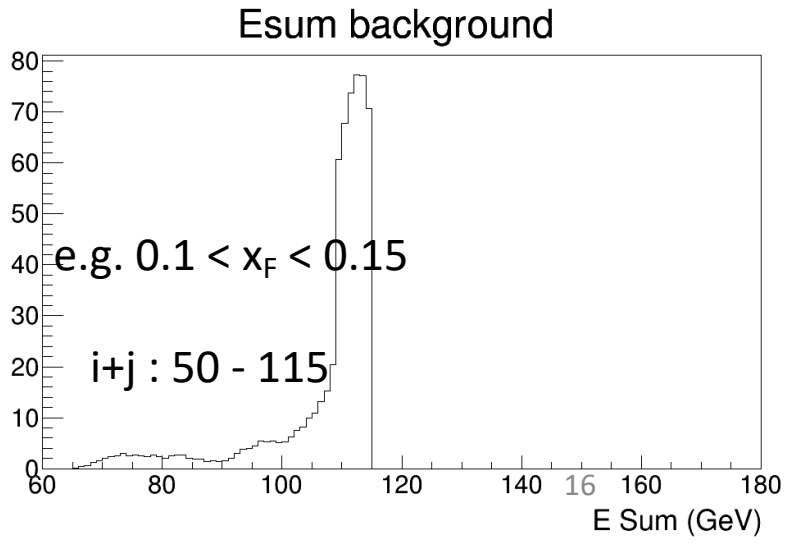


Background study for E sum

- We use zerobias stream events to study the background shape for E sum spectrum for different EM-jet x_F ranges.
  - E sum (**background**)= E(EM-jet from **inclusive process**) + E(west RP from **zerobias**)
- Calculation: $\boldsymbol{Esum(i+j) = \sum_{i,j} P(i) * n(j)}$, i are all possible energies (in 1 GeV bin) for specific x_F range ; j are all possible energies (in 1 GeV bin) for west RP track energy (momentum) in zerobias data.
  - P(i) is the fraction for EM-jet yields in [i,i+1] (GeV) within the specific x_F range .
  - n(j) is the yields in west RP energy (momentum) in [j,j+1] (GeV).

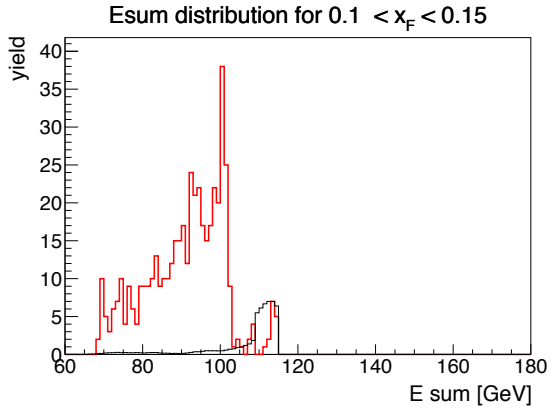


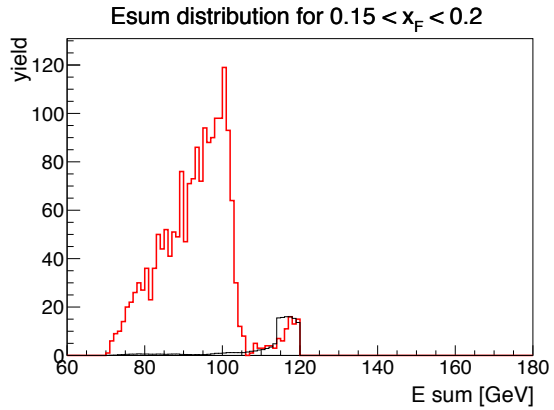


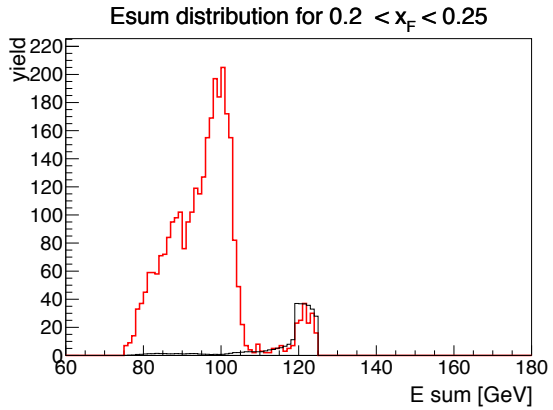


Mix event energy sum study results

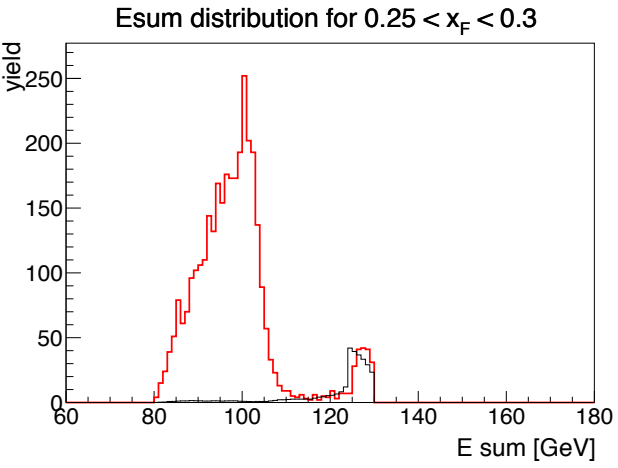
- <u>All photon multiplicity</u>
- **Black** curve (Background) is mixed events from zerobias events (scaled to data in the elastic peak region).
- Red curve is the FMS stream data

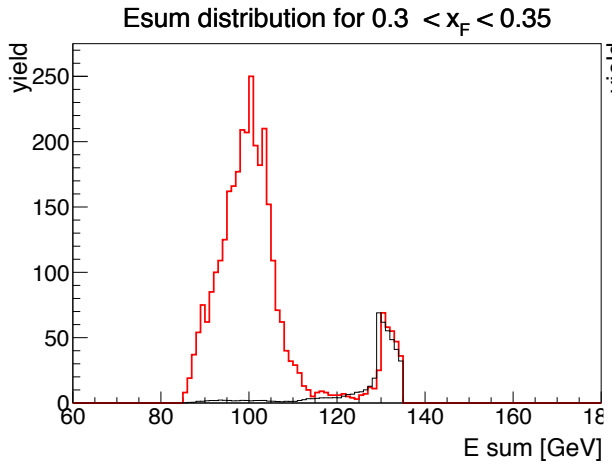


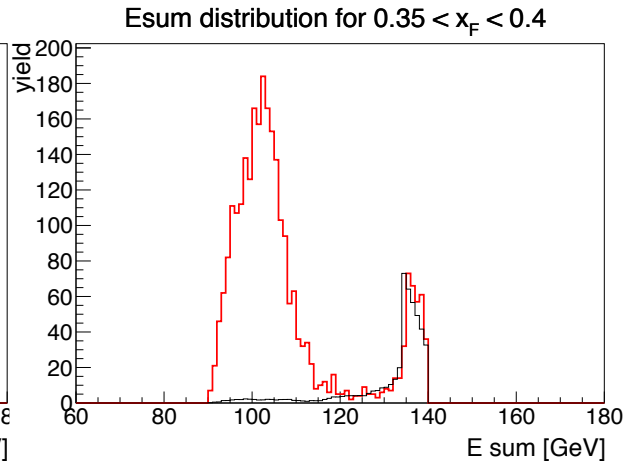


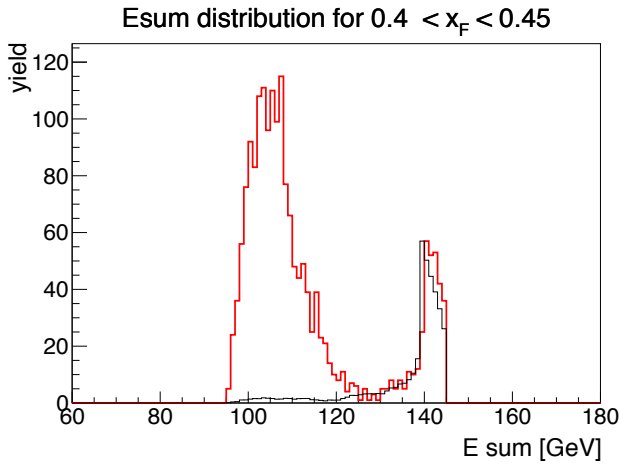


x_F	Signal region	Elastic peak region
0.1 - 0.15	E_{sum} < 105 GeV	E_{sum} > 105 GeV
0.15 - 0.2	E_{sum} < 105 GeV	E_{sum} > 105 GeV
0.2 - 0.25	E_{sum} < 110 GeV	E_{sum} > 110 GeV
0.25 - 0.3	E_{sum} < 110 GeV	E_{sum} > 110 GeV
0.3 - 0.35	E_{sum} < 115 GeV	E_{sum} > 115 GeV
0.35 - 0.4	E_{sum} < 115 GeV	E_{sum} > 115 GeV
0.4 - 0.45	E_{sum} < 120 GeV	E_{sum} > 120 GeV









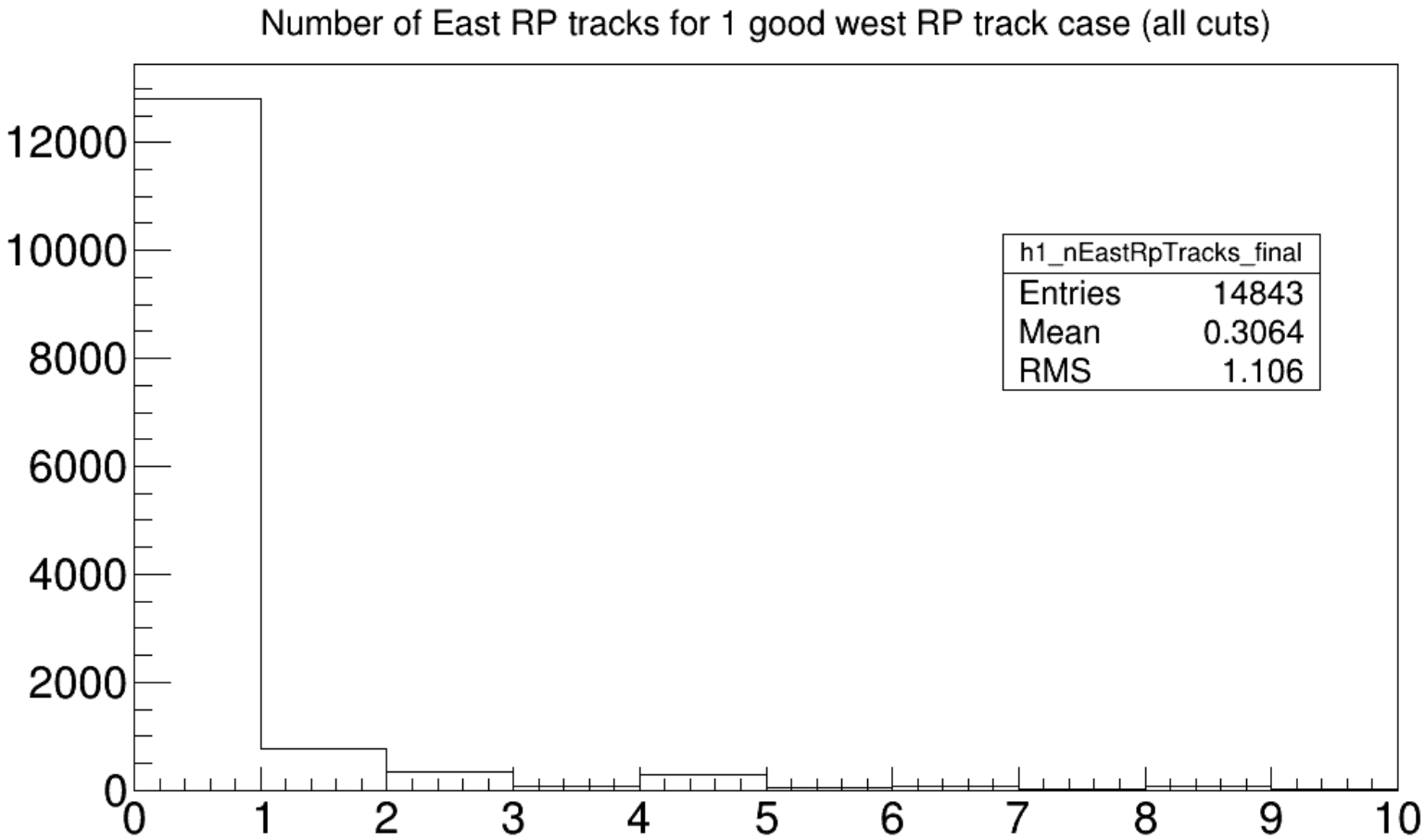
Mix event background study results

- The background from mix event will be counted as systematic uncertainty results.
  - $frac = \frac{Integral\ of\ yields\ in\ signal\ region\ for\ mix\ event\ background}{Intrgral\ of\ yields\ in\ signal\ region\ for\ FMS\ data}$

x_F	Signal region	Frac of background (%)
0.1 - 0.2	E_{sum} < 105 GeV	1.5
0.2 - 0.25	E_{sum} < 110 GeV	1.6
0.25 - 0.3	E_{sum} < 110 GeV	1.1
0.3 – 0.35	E_{sum} < 115 GeV	1.7
0.35 – 0.4	E_{sum} < 115 GeV	1.8
0.4 – 0.45	E_{sum} < 120 GeV	2.1

Number of east RP track for case with only 1 good west RP track

- After all the cuts, about 8.4% of the events are with more than 1 east RP track.



Event selection and corrections

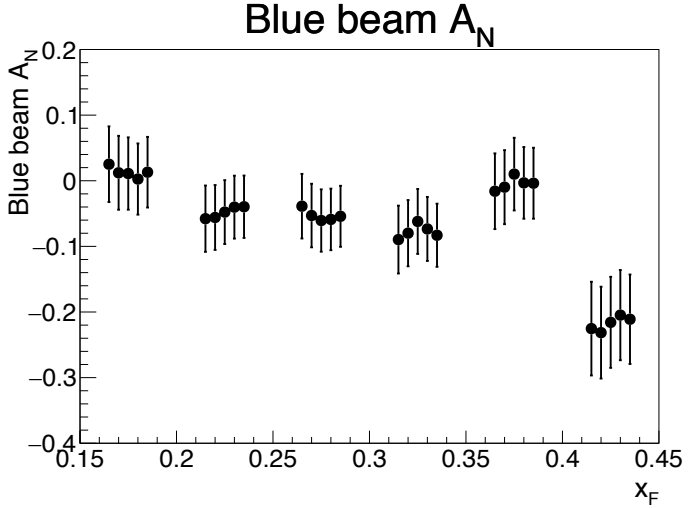
- **FMS**
  - 9 Triggers, veto on FMS-LED
  - bit shift, bad / dead / hot channel masking (include fill by fill hot channel masking)
  - Jet reconstruction: StJetMaker2015 , Anti-kT, R<0.7 , FMS point energy > 2 GeV, $\boldsymbol{p_T > 1}$ **GeV/c, trigger p_T threshold cut**, FMS point as input.
  - Only 1 EM-jet per event allowed
- **Only allow acceptable beam polarization (up/down).**
- **Vertex** (Determine vertex z priority according to TPC , VPD, BBC.)
  - Vertex $|z| < 80\ cm$
- **Roman Pot and Semi-exclusive process:**
- Only 1 west RP track (no restriction on east RP track)
- RP track must be good track:
  a) Each track hits > 6 planes
  b) West RP ξ dependent θ_X , θ_Y , P_X and P_Y cuts
  c) $0 < \xi < 0.45$
  - Sum of west RP track energy and all EM Jet energy (see detail in table)
- West Large BBC ADC sum < 60 and West Small BBC ADC sum < 80

Corrections:
EM-jet energy correction and Underlying Event correction

x_F	E sum Cut
0.1 - 0.15	E_{sum} < 105 GeV
0.15 - 0.2	E_{sum} < 105 GeV
0.2 - 0.25	E_{sum} < 110 GeV
0.25 - 0.3	E_{sum} < 110 GeV
0.3 – 0.35	E_{sum} < 115 GeV
0.35 – 0.4	E_{sum} < 115 GeV
0.4 – 0.45	E_{sum} < 120 GeV

Systematic uncertainty

- 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.
  - Small BBC west ADC sum cuts: choose < 60, < 70, <90, <100 for systematic uncertainty
  - Large BBC west ADC sum cuts: choose < 40, < 50, <70, <80 for systematic uncertainty
  - E sum cut, varying each cut by ±5 , and ±3 GeV, accordingly
  - Ring of Fire (get rid of small-bs-3 trigger)



Example: Small BBC west cuts

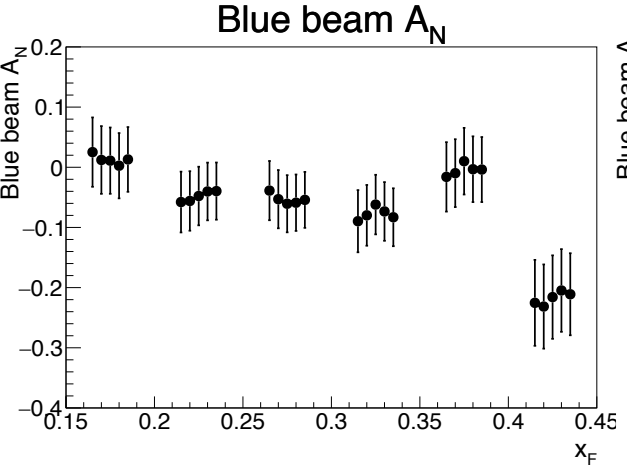
Each x_F set, from left to right:
varying the cuts from original:
-20, -10, 0, +10, +20

x_F	E sum Cut
0.1 - 0.15	E_{sum} < 105 GeV
0.15 - 0.2	E_{sum} < 105 GeV
0.2 - 0.25	E_{sum} < 110 GeV
0.25 - 0.3	E_{sum} < 110 GeV
0.3 – 0.35	E_{sum} < 115 GeV
0.35 – 0.4	E_{sum} < 115 GeV
0.4 – 0.45	E_{sum} < 120 GeV

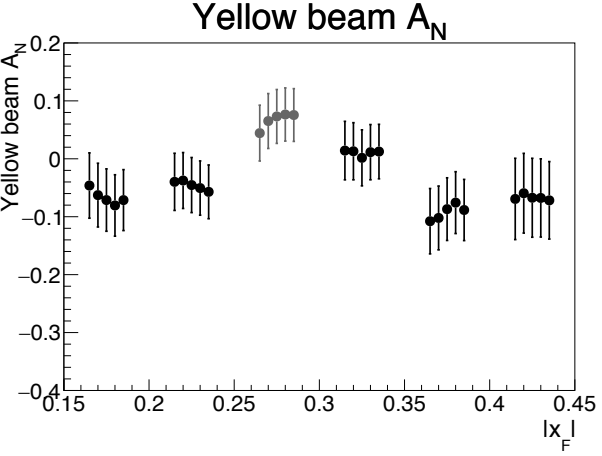
A_N results for varying the cuts (systematic)

All photon multiplicity

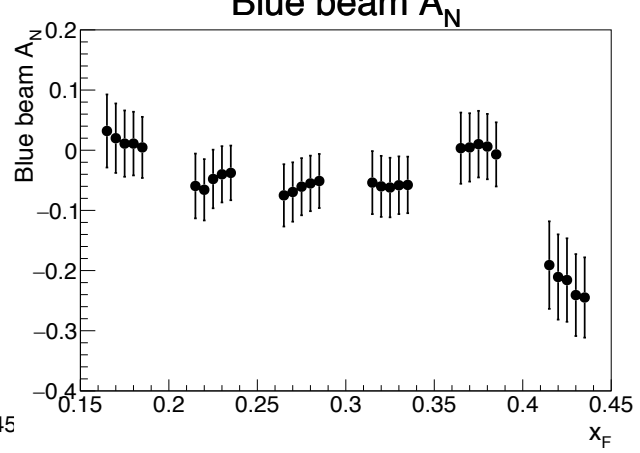
Small BBC west cuts



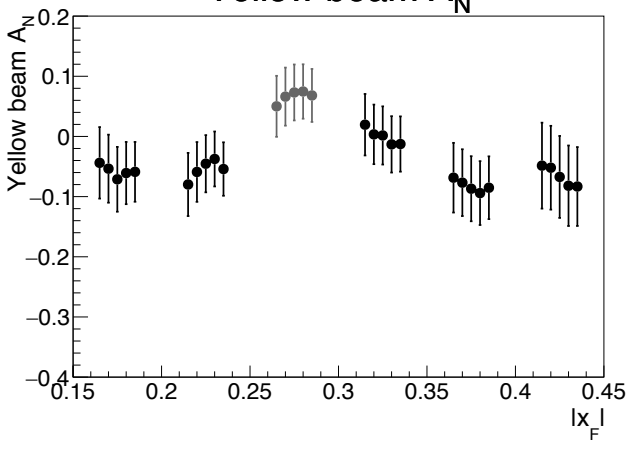
Each x_F set, from left to right: varying the cuts from original: -20, -10, 0, +10, +20



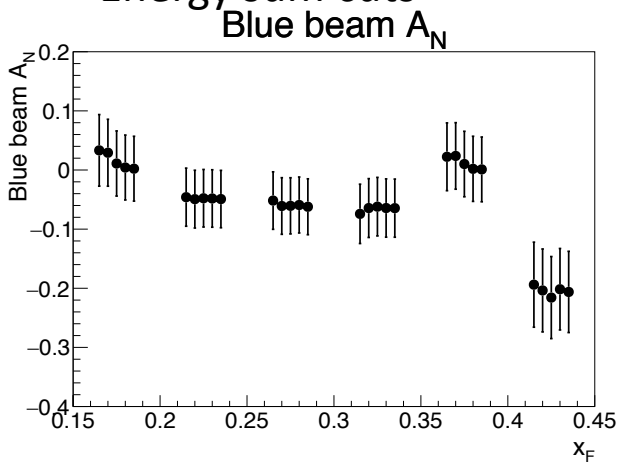
Large BBC west cuts



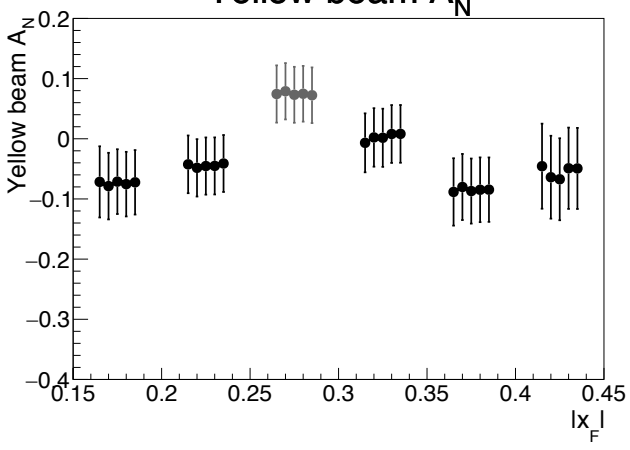
Each x_F set, from left to right: varying the cuts from original: -20, -10, 0, +10, +20



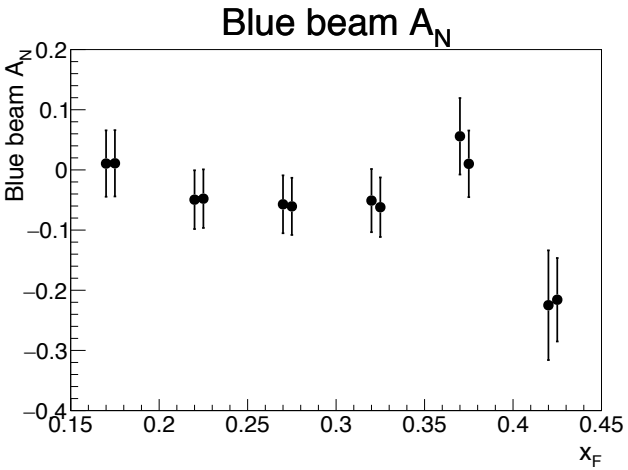
Energy sum cuts



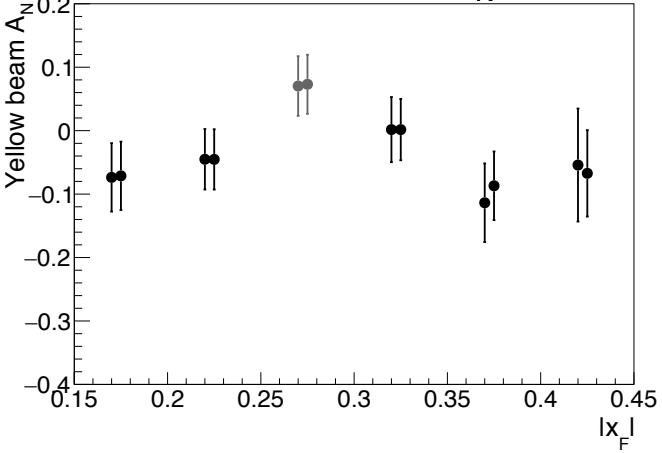
Each x_F set, from left to right: varying the cuts from original: -5, -3, 0, +3, +5 (GeV)



Ring of Fire cuts



Each x_F set, from left to right: Apply Ring of Fire cut, do not apply Ring of Fire cut



Calculating the systematic uncertainty (All photon multiplicity)

- 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 $\frac{|A_N(1)-A_N(2)|}{\sqrt{|(\delta(1))^2-(\delta(2))^2|}} > 1$, 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) : $\sigma_{sys} = \sqrt{\sum_i (\sigma_i)^2}$

Blue beam x_F	Small BBC west	Large BBC west	Energy sum	Ring of Fire	Background	Summary
0.1 - 0.2	0.0072	0	0.013	0	0.00016	0.015
0.2 - 0.25	0.0076	0.011	0	0	0.00074	0.013
0.25 - 0.3	0.0077	0	0	0	0.00063	0.0077
0.3 – 0.35	0.0094	0	0.0043	0	0.0010	0.010
0.35 – 0.4	0.0087	0.0057	0.0097	0.023	0.00018	0.027
0.4 – 0.45	0.0096	0.020	0.0071	0	0.0045	0.024

Yellow beam x_F	Small BBC west	Large BBC west	Energy sum	Ring of Fire	Background	Summary
0.1 - 0.2	0.012	0.0090	0	0	0.0010	0.015
0.2 - 0.25	0.0071	0.014	0.0025	0	0.00070	0.016
0.25 - 0.3	0.012	0.0088	0	0	0.00077	0.015
0.3 – 0.35	0	0.012	0.0054	0	0.000028	0.013
0.35 – 0.4	0.011	0.0088	0	0	0.0015	0.015
0.4 – 0.45	0	0.015	0.0088	0	0.0014	0.017

Calculating the systematic uncertainty (1 or 2 photon multiplicity)

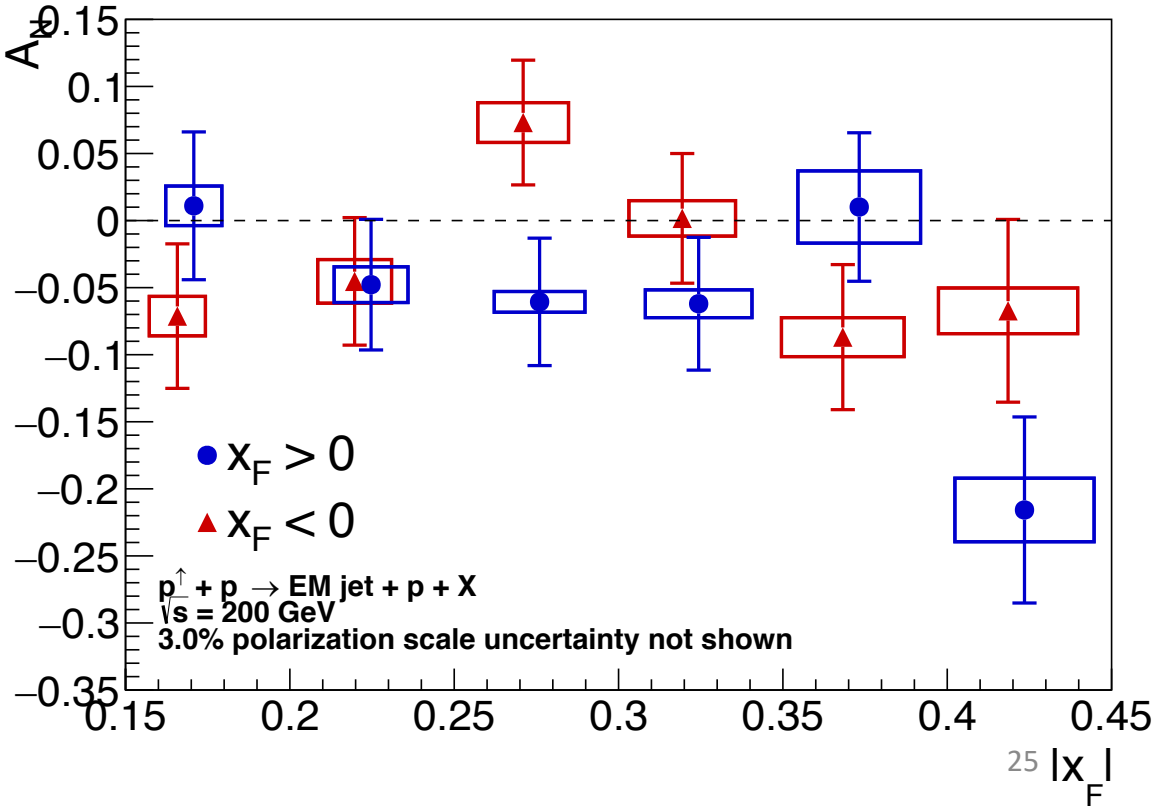
- Then, find out the maximum ($A_N(1) \pm \delta(1)$, with statistical uncertainty) , and the minimum ($A_N(2) \pm \delta(2)$, with statistical uncertainty) for the varying cuts as systematic uncertainty.
- If the $\frac{|A_N(1)-A_N(2)|}{\sqrt{|(\delta(1))^2-(\delta(2))^2|}} > 1$, use the **standard 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) : $\sigma_{sys} = \sqrt{\sum_i (\sigma_i)^2}$

Blue beam x_F	Small BBC west	Large BBC west	Energy sum	Ring of Fire	Background	Summary
0.1 - 0.2	0	0	0.013	0	0.00014	0.013
0.2 - 0.25	0.0091	0.011	0	0	0.00091	0.015
0.25 - 0.3	0.0067	0.010	0.0050	0	0.00068	0.013
0.3 – 0.35	0.010	0	0.0051	0	0.00072	0.012
0.35 – 0.4	0.0069	0.0057	0.0094	0.019	0.000024	0.023
0.4 – 0.45	0.011	0.018	0	0	0.0043	0.022

Yellow beam x_F	Small BBC west	Large BBC west	Energy sum	Ring of Fire	Background	Summary
0.1 - 0.2	0.011	0	0	0	0.00098	0.011
0.2 - 0.25	0.0086	0.010	0.0022	0	0.00078	0.013
0.25 - 0.3	0.010	0	0	0.0030	0.00068	0.011
0.3 – 0.35	0.0064	0.012	0.0044	0	0.000038	0.015
0.35 – 0.4	0.010	0.012	0.0051	0	0.0019	0.017
0.4 – 0.45	0	0.013	0.0093	0	0.0013	0.016

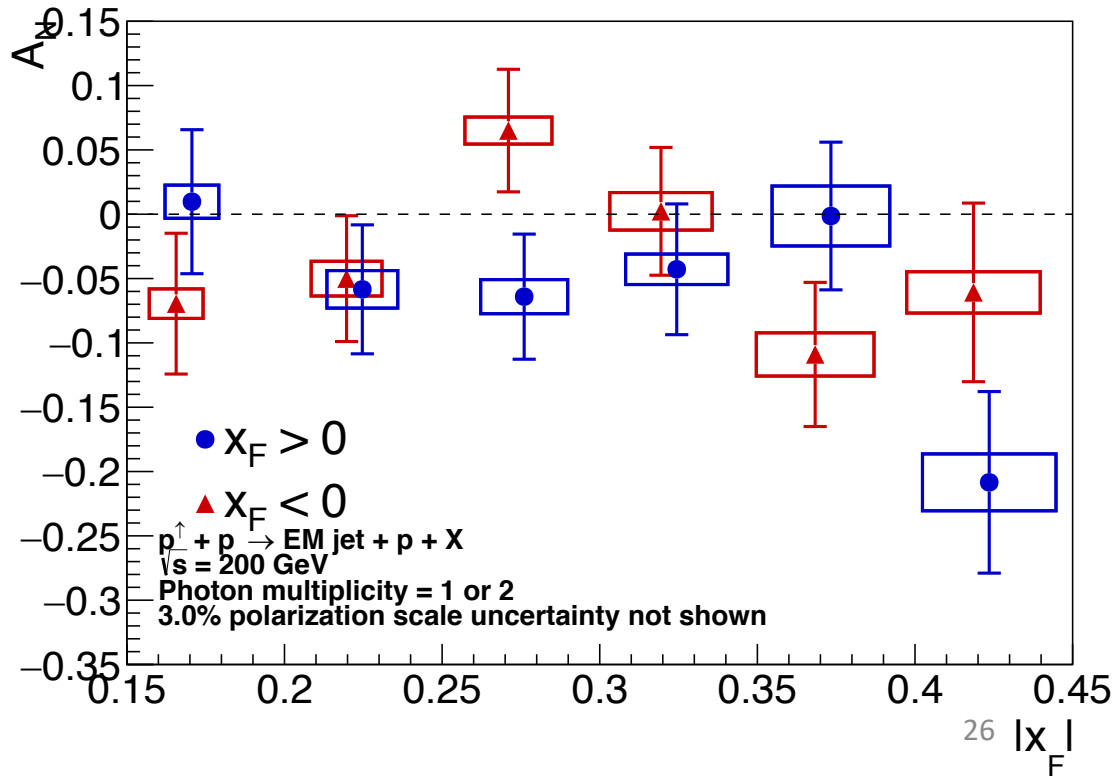
A_N results for all photon multiplicity

- 6 x_F bins are considered: [0.1, 0.2], [0.2,0.25], [0.25,0.3], [0.3,0.35] , [0.35,0.4], [0.4,0.45]
- All photon multiplicity
- Constant fit is applied to calculate the significance of non-zero
- Blue beam A_N is 2.3 σ to be non-zero.
  - Constant fit: -0.052 ± 0.023
  - $\chi^2/n.d.f$: 1.46
- Yellow beam A_N is 1.1 σ to be non-zero.
  - Constant fit: -0.025 ± 0.022
  - $\chi^2/n.d.f$: 1.35



A_N results for 1 or 2 photon multiplicity

- 6 x_F bins are considered: [0.1, 0.2], [0.2,0.25], [0.25,0.3], [0.3,0.35] , [0.35,0.4], [0.4,0.45]
- 1 or 2 photon multiplicity
- Constant fit is applied to calculate the significance of non-zero
- Blue beam A_N is 2.3 σ to be non-zero.
  - Constant fit: -0.052 ± 0.023
  - $\chi^2/n.d.f$: 1.28
- Yellow beam A_N is 1.3 σ to be non-zero.
  - Constant fit: -0.029 ± 0.022
  - $\chi^2/n.d.f$: 1.37



Conclusion for case with only 1 west RP track

- We re-study the west RP track cuts.
- The mix events background from zerobias events shows that there are very few background contaminations in the signal regions.
- Most of the events after the cuts are the events with 1 or 2 multiplicity EM-jets.
- The blue A_N results are mostly negative, which are different from the results in the inclusive EM-jet A_N measurement.
- The results for this semi-exclusive come to conclusion. Anything more studies needed?

Part 2: Diffractive process with 1 east RP track

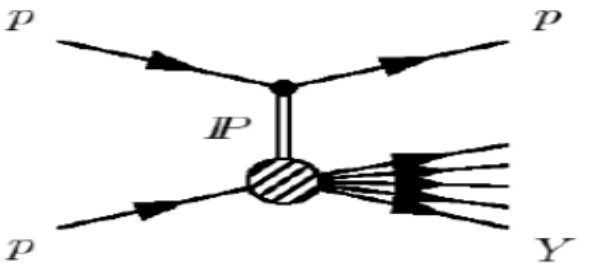
- The studies for this single diffractive process are still in progress.
- Plans for studying the single diffractive process:
  - Event selection: east RP track cuts and east BBC cuts
  - Systematic uncertainty and A_N measurement
  - Background contamination study
- We hope to finish within 2 weeks.

Single diffractive process

only 1 proton track on east side RP. No west side RP track requirement.

Require: small and large BBC east cut

East proton	Rapidity gap	FMS Jet



East RP track

FMS jets

Conclusions and discussion

- We finished the studies for the semi-exclusive process (with only 1 west RP track case). We observe mostly the negative A_N .
- The studies for the single diffractive process (with only 1 east RP track case) are still in progress, hopefully can get done within 2 weeks.
- When we complete analysis for run 15 diffractive EM-jet A_N, we will prepare for paper proposal, hopefully before Christmas.

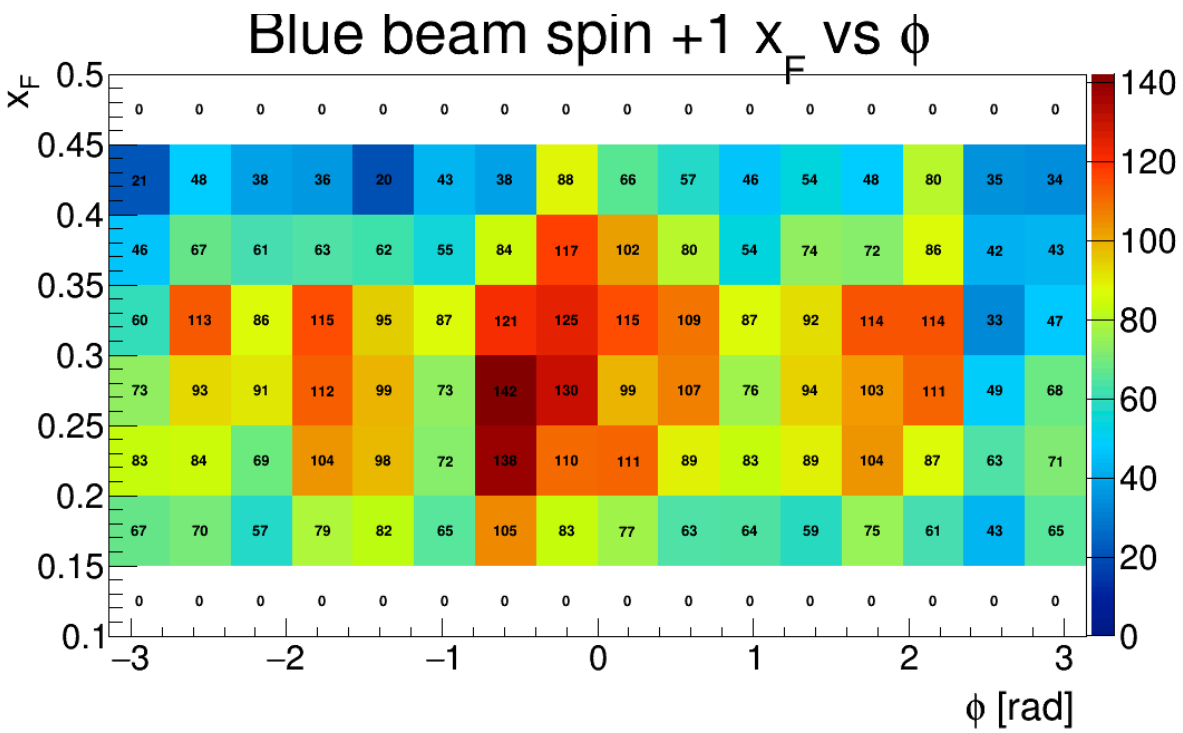
- Discussion: Anything studies needed for the semi-exclusive process study?

Back up

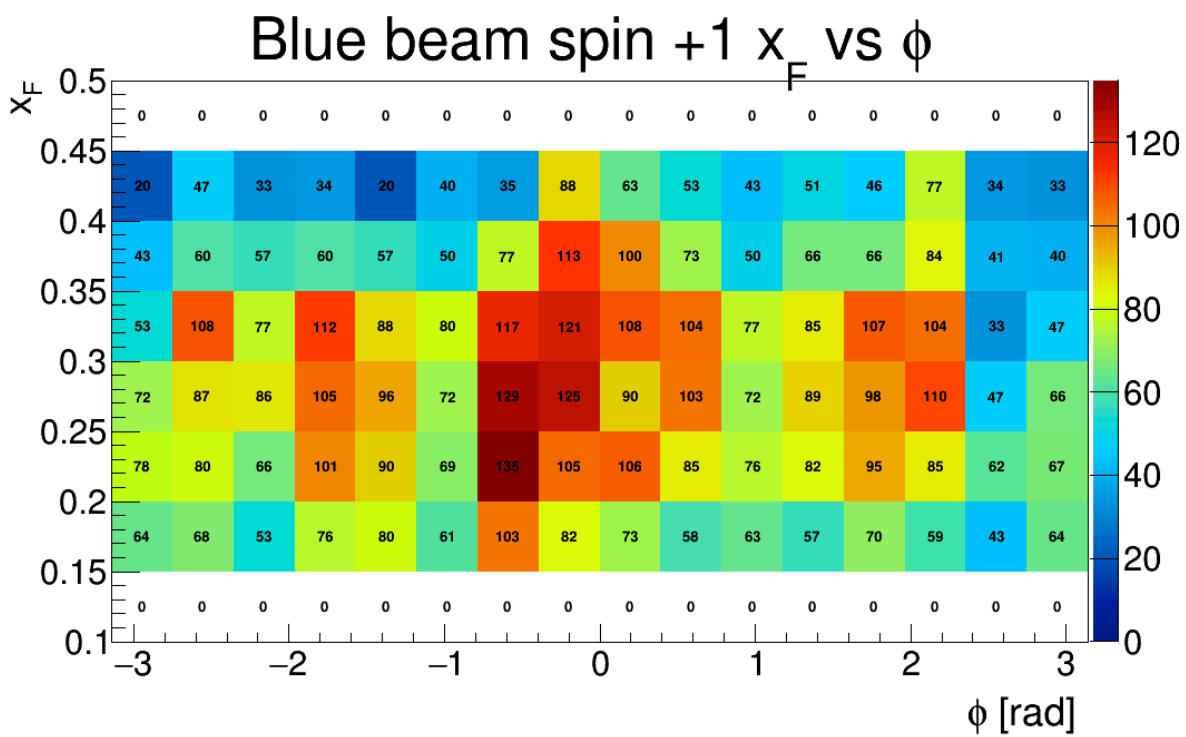
Compare the yields

- Compare the yields for A_N calculations between EM-jets with all photon multiplicity and 1,2 photon multiplicity.
  - They are very close to each other -> Most of the events after all the cuts are with the 1 or 2 photon multiplicity EM-jets.

All photon multiplicity



1 or 2 photon multiplicity



West RP track ξ for the events after all cuts

- We check the west RP track ξ for the events after all the cuts, showing the distribution for different EM-jet x_F region.