Run 17 diffractive EM-jet A_N update

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Outline

- Update on E sum background study
- Diffractive EM-jet A_N for all photon multiplicity EM-jets
- Diffractive EM-jet A_N for 1 or 2 photon multiplicity EM-jets

Motivation

- The E sum spectrum is not behaving well for the signal region. The peak of signal region have a strong dependent with the EM-jet x_F.
- Possible reason: There are still some background events contaminated.
- Therefore, we need to study the background shape using the zerobias events, and subtract the background contribution.
- Zerobias events:
  - Data set: run 17 pp transverse $\sqrt{s} = 510$ GeV ,zerobias stream.
  - About 50% of the zerobias stream files (12k) in dataset are used.

Event selection and corrections

Data set: run 17 pp transverse $\sqrt{s} = 510$ GeV ,fms stream (pp500_production_2017)

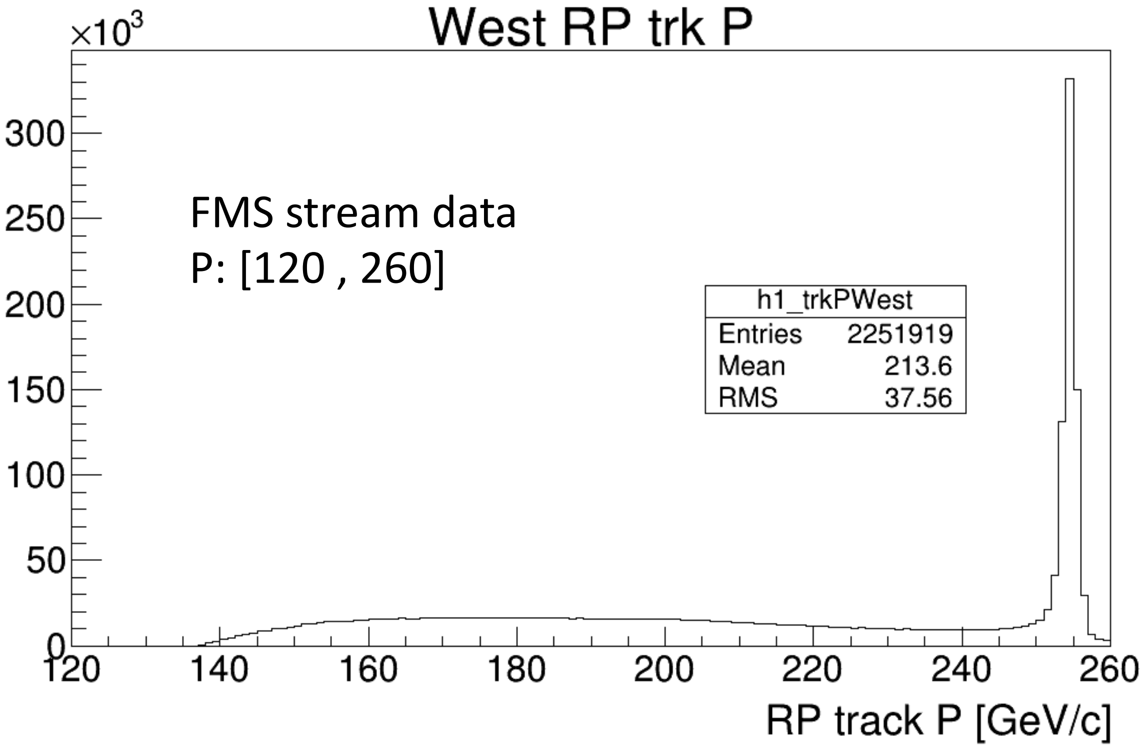
- **FMS**
  - 9 Triggers, veto on FMS-LED
  - bit shift, bad / dead / hot channel masking
  - Jet reconstruction: StJetMaker2015 , Anti-kT, R<0.7 , FMS point energy > 2 GeV, $p_T > 2$ GeV/c, FMS point as input.
  - Only 1 EM-jet per event
- **Only allow acceptable beam polarization (up/down).**
- **Vertex** (Determine vertex z priority according to TPC , VPD, BBC.)
  - Vertex $|z| < 80\ cm$
- **Roman Pot and Diffractive process:**
- Acceptable cases: (in next slide)
  1. Only 1 west RP track + no east RP track
  2. Only 1 east RP track + only 1 west RP track
  - RP track must be good track:
  a) Each track hits 7 or 8 planes
  - $-0.25 < P_X < 0.3$ GeV/c ;
  - $-0.6 < P_Y < -0.4$ GeV/c or $0.3 < P_Y < 0.55$ GeV/c
  - Sum of west RP track energy and all EM Jet energy
- **BBC ADC sum cuts:**
  - small BBC west ADC < 250 and small BBC east ADC > 150

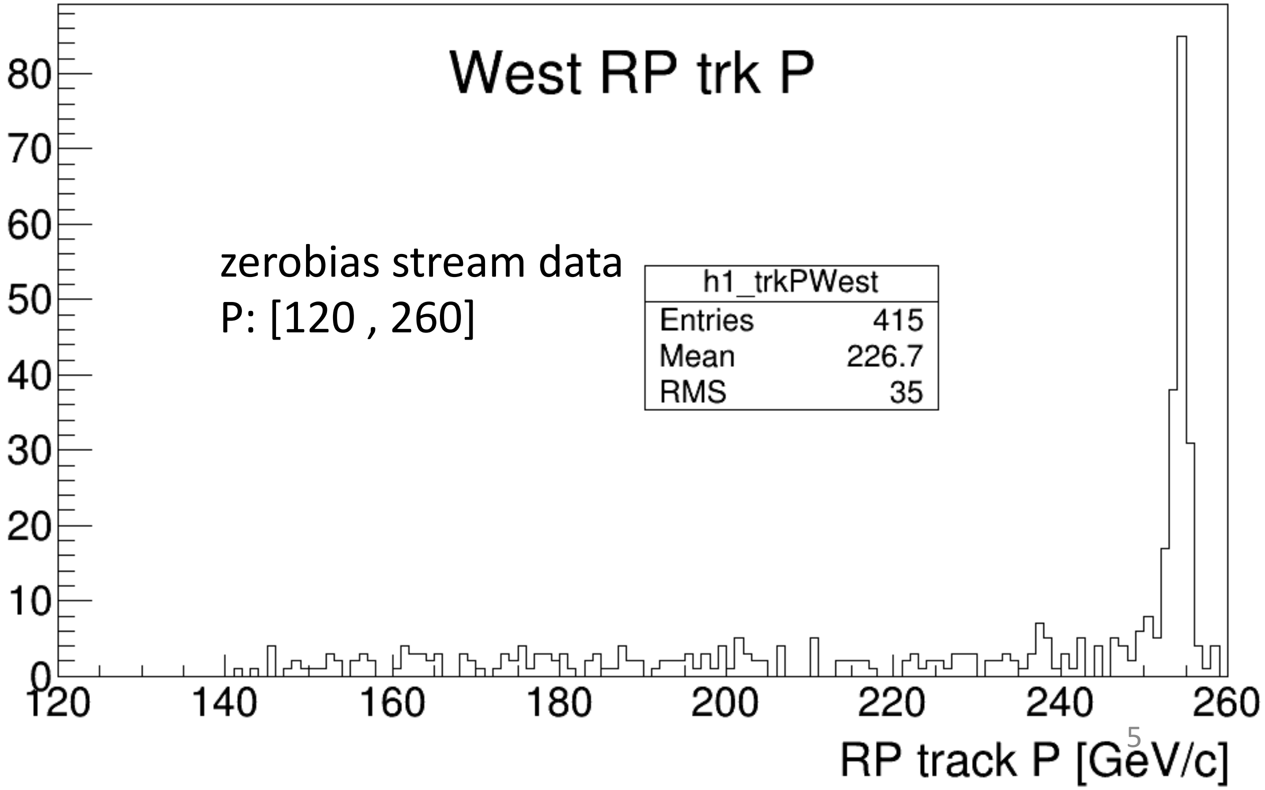
Corrections for EM-jet:
Energy correction and
Underlying Event correction

x_F	E sum cut (this presentation)
0.1 - 0.15	E_{sum} < 260 GeV
0.15 - 0.2	E_{sum} < 260 GeV
0.2 - 0.25	200 < E_{sum} < 280 GeV
0.25 - 0.3	220 < E_{sum} < 280 GeV
0.3 - 0.35	230 < E_{sum} < 300 GeV
0.35 - 0.4	250 < E_{sum} < 300 GeV
0.4 – 0.45	260 < E_{sum} < 320 GeV

Roman Pot track QA for FMS and zerobias data

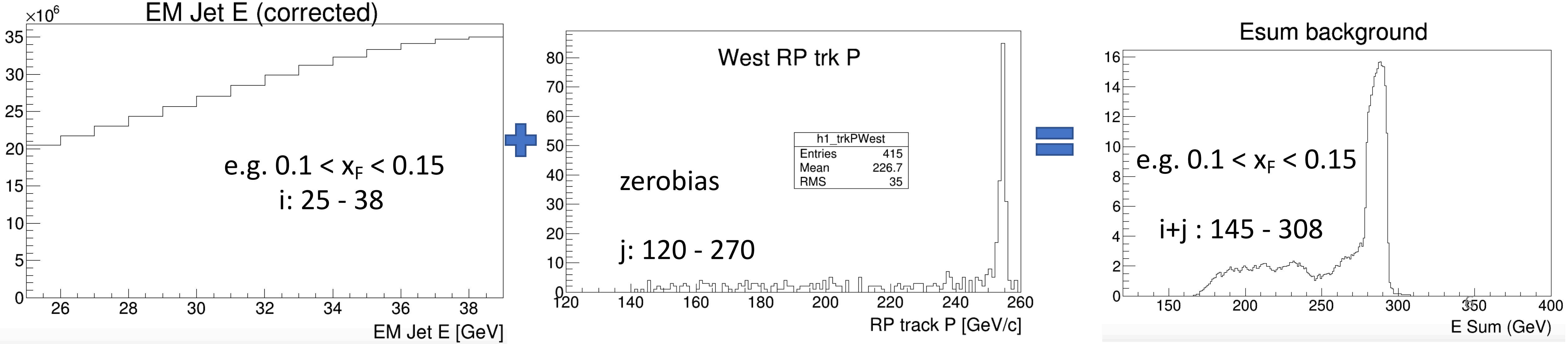
- The Roman Pot track are passing the cut below:
  - Each track hits 7 or 8 planes
  - $-0.25 < P_X < 0.3$ GeV/c ;
  - $-0.6 < P_Y < -0.4$ GeV/c or $0.3 < P_Y < 0.55$ GeV/c
- Apply the same cuts for small BBC west ADC < 250 and small BBC east ADC > 150





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).



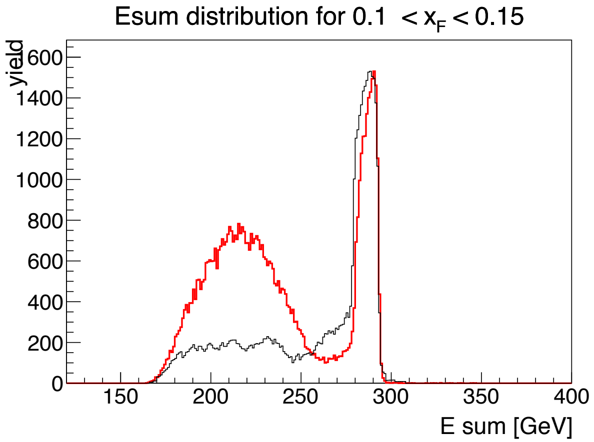
Further explanation for the calculation

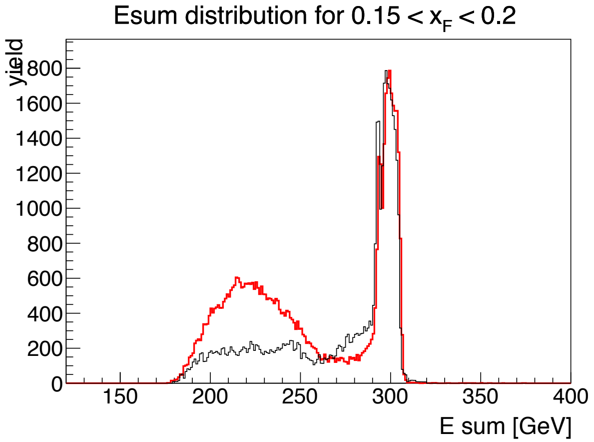
- Calculation: $\boldsymbol{Esum(i+j) = \sum_{i,j} P(i) * n(j)}$
  - i are all possible energies (in 1 GeV bin) for specific x_F range ; j are all possible energies (in 1 GeV bin) for west RP track energy (momentum) in zerobias data.
  - P(i) is the fraction for EM-jet yields in [i,i+1] (GeV) within the specific x_F range .
  - n(j) is the yields in west RP energy (momentum) in [j,j+1] (GeV).
- Example: calculate Esum(250), energy sum for 250 GeV, for $0.1 < x_F < 0.15$
  - $0.1 < x_F < 0.15 \rightarrow 25.5 < E_{jet} < 38.25$ GeV → range of i: [25,38]
  - Esum(250) = $\sum_{i=25}^{38} P(i) * n(250-i)$
  - $= P(25) * n(225) + P(26) * n(224) + \ldots + P(38) * n(212)$
  - $P(i) = \frac{n(EM-jet,i)}{\sum_{i=25}^{38} n(EM-jet,i)}$

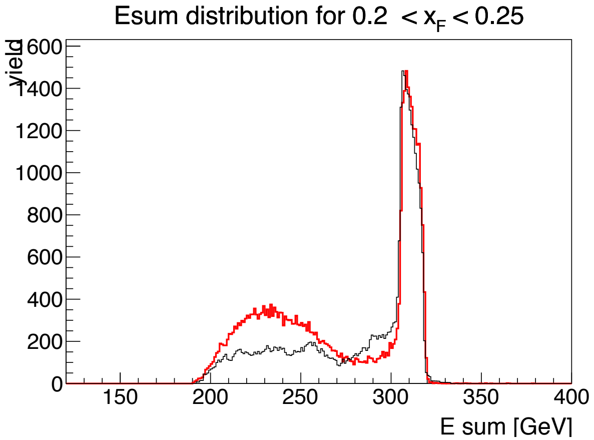
E sum spectrum based on different x_F ranges

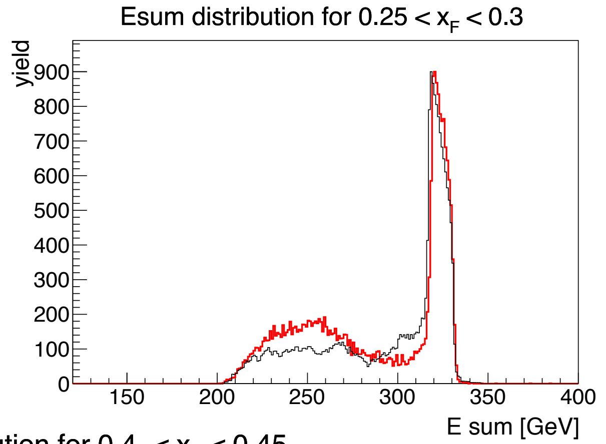
- Data: FMS stream data with <u>east BBC cut and west BBC cut (**<250**)</u>.
- Black curve (Background) is mixed events from zerobias events (scaled to data).
- Red curve is the FMS stream data

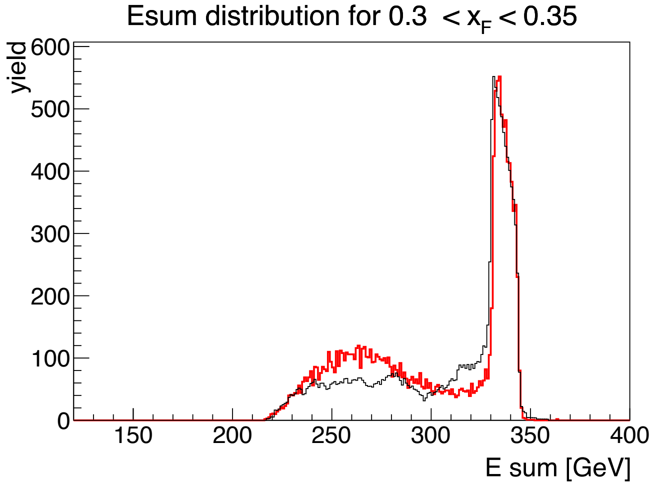
GOOD!

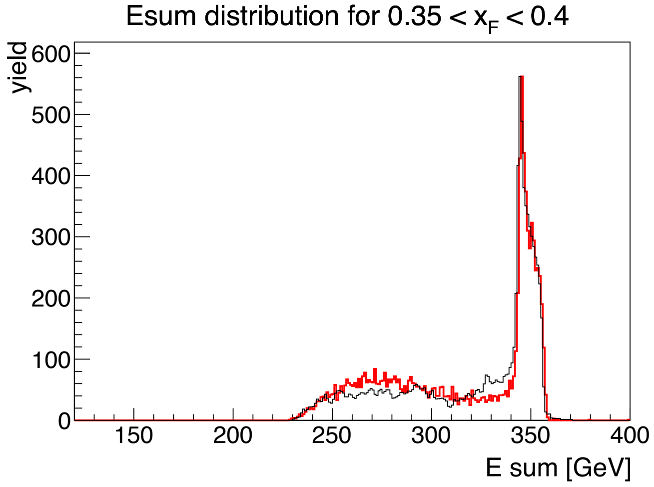


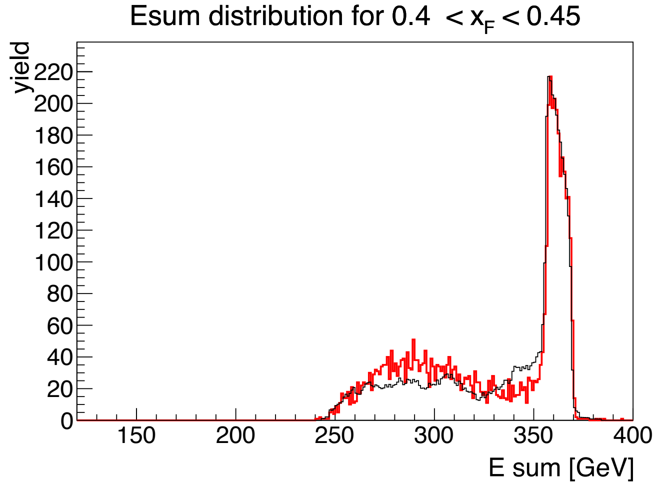












New E sum cut based on the zerobias bkg study

- We choose small BBC West < 250 , which have much higher fraction of signal.
- Apply the new E sum cut based on the regions of **FMS data curve** over the **zerobias curve**

x_F	**Old** E sum Cut
0.1 - 0.15	$E_{sum} < 265$ GeV
0.15 - 0.2	$E_{sum} < 280$ GeV
0.2 - 0.25	$E_{sum} < 295$ GeV
0.25 - 0.3	$E_{sum} < 305$ GeV
0.3 - 0.35	$E_{sum} < 315$ GeV
0.35 - 0.4	$E_{sum} < 330$ GeV
0.4 – 0.45	$E_{sum} < 340$ GeV

x_F	**New** E sum Cut
0.1 - 0.15	$E_{sum} < 260$ GeV
0.15 - 0.2	$E_{sum} < 260$ GeV
0.2 - 0.25	$200 < E_{sum} < 280$ GeV
0.25 - 0.3	$220 < E_{sum} < 280$ GeV
0.3 - 0.35	$230 < E_{sum} < 300$ GeV
0.35 - 0.4	$250 < E_{sum} < 300$ GeV
0.4 – 0.45	$260 < E_{sum} < 320$ GeV

Fraction of signal and background

- All photon multiplicity
- Calculate the fraction of signal and background from the integrating the yield of each the FMS data and zerobias background:
  - N tot = Integral of yield for the **FMS data curve** within new E sum range.
  - N bkg = Integral of yield for the **zerobias data scaled curve** within new E sum range.
  - N sig = N tot – N bkg
  - Frac sig (bkg) = N sig (N bkg) / N tot

xF bin	N tot	N sig	N bkg	Frac sig	Frac bkg
0.1 – 0.15	40690	26240	14450	0.64	0.36
0.15 – 0.2	29861	16890	12971	0.57	0.43
0.2 – 0.25	19412	8242	11169	0.42	0.58
0.25 – 0.3	8511	2865	5646	0.34	0.66
0.3 – 0.35	5774	1769	4005	0.31	0.69
0.35 – 0.4	2936	678	2258	0.23	0.77
0.4 – 0.45	1830	477	1353	0.26	0.74
0.25 – 0.45	19051	5790	13261	0.30	0.70

Calculate the signal A_N result

- Consider the measured A_N contains signal and background.
- $A_N(measured) = frac(bkg) * A_N(bkg) + frac(sig) * A_N(sig)$
- Therefore, $A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$
- The background study apply the background region for E sum cut

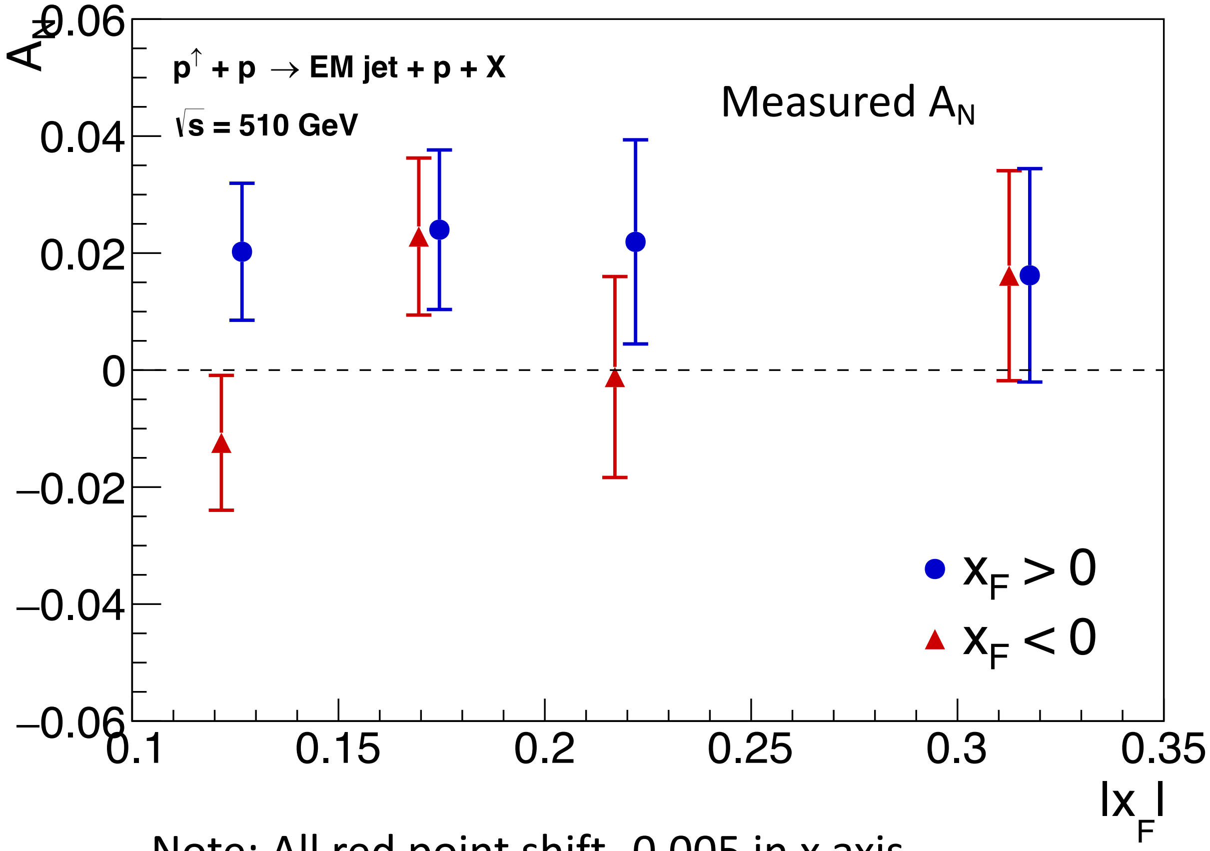
x_F	**New** E sum Cut (measured)
0.1 - 0.15	$E_{sum} < 260$ GeV
0.15 - 0.2	$E_{sum} < 260$ GeV
0.2 - 0.25	$200 < E_{sum} < 280$ GeV
0.25 - 0.3	$220 < E_{sum} < 280$ GeV
0.3 - 0.35	$230 < E_{sum} < 300$ GeV
0.35 - 0.4	$250 < E_{sum} < 300$ GeV
0.4 – 0.45	$260 < E_{sum} < 320$ GeV

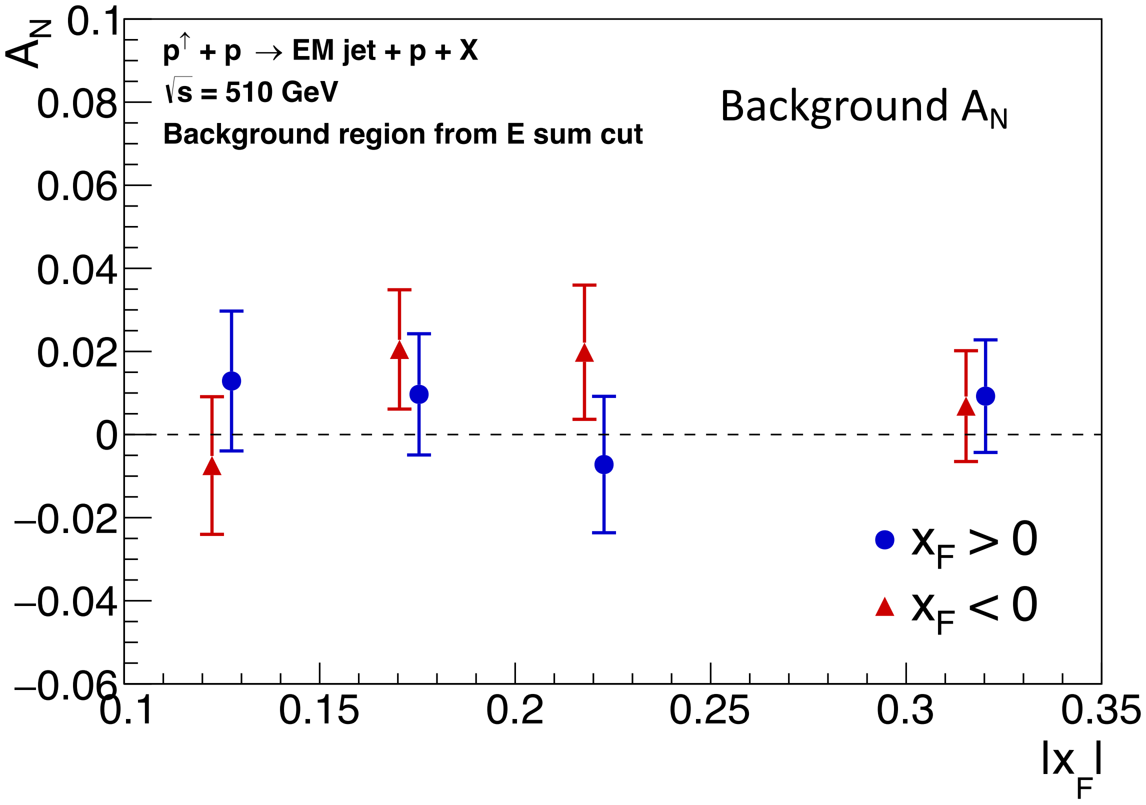
x_F	**Background** E sum Cut
0.1 - 0.15	$E_{sum} > 260$ GeV
0.15 - 0.2	$E_{sum} > 260$ GeV
0.2 - 0.25	$E_{sum} > 280$ GeV
0.25 - 0.3	$E_{sum} > 280$ GeV
0.3 - 0.35	$E_{sum} > 300$ GeV
0.35 - 0.4	$E_{sum} > 300$ GeV
0.4 – 0.45	$E_{sum} > 320$ GeV

Measured A_N and background A_N

EM-jet with all photon multiplicity

$$A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$$





Note: All red point shift -0.005 in x axis.

Systematic uncertainty

- $A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$
- Systematic uncertainty for $A_N(measured)$
  - Small BBC east cut, small BBC west cut, E sum cut
- Systematic uncertainty for $A_N(bkg)$
  - Small BBC east cut, small BBC west cut
- Systematic uncertainty for $frac(sig)$
- Polarization uncertainty

Use 2 methods to estimate the systematic uncertainty for cuts:

1. Estimate the systematic uncertainty by the average A_N difference (from constant fit) from varying the cuts.
2. For a certainty cut (R1), choose an entirely different cut region (R2) to study . Calculate their A_N difference and statistical uncertainty.

$$= \max\{(|A_N(R1) - A_N(R2)| - \sqrt{\sigma_{R1}^2 + \sigma_{R2}^2}), 0\}$$

Systematic uncertainty results ($A_N(measured)$)

- Small BBC west sum

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.0038	0.00084	0.0012	0.025
0.15 – 0.2		0		0
0.2 – 0.25		0		0
0.25 – 0.45		0		0

- Small BBC east sum

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.00083	0	0.00012	0.040
0.15 – 0.2		0		0
0.2 – 0.25		0		0.016
0.25 – 0.45		0		0

- E sum

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.0018	0.00084	0.00059	0.025
0.15 – 0.2		0		0
0.2 – 0.25		0.0054		0
0.25 – 0.45		0		0

$$A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$$

Use the higher value one between 2 methods to assign as systematic uncertainty

Sys(mea)=

$$\sqrt{sys^2_{SBBCW} + sys^2_{SBBCE} + sys^2_{Esum}}/frac(sig)$$

Systematic uncertainty results ($A_N(bkg)$)

- Small BBC west sum

xF (bkg)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.0022	0	0.0017	0
0.15 – 0.2		0		0.0080
0.2 – 0.25		0		0
0.25 – 0.45		0		0

- Small BBC east sum

xF (bkg)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.0038	0.0035	0.0018	0
0.15 – 0.2		0		0
0.2 – 0.25		0		0.060
0.25 – 0.45		0		0.017

$$A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$$

Use the higher value one between 2 methods to assign as systematic uncertainty

Sys(bkg)=

$$\sqrt{sys_{SBBCW}^2 + sys_{SBBCE}^2} * frac(bkg)/frac(sig)$$

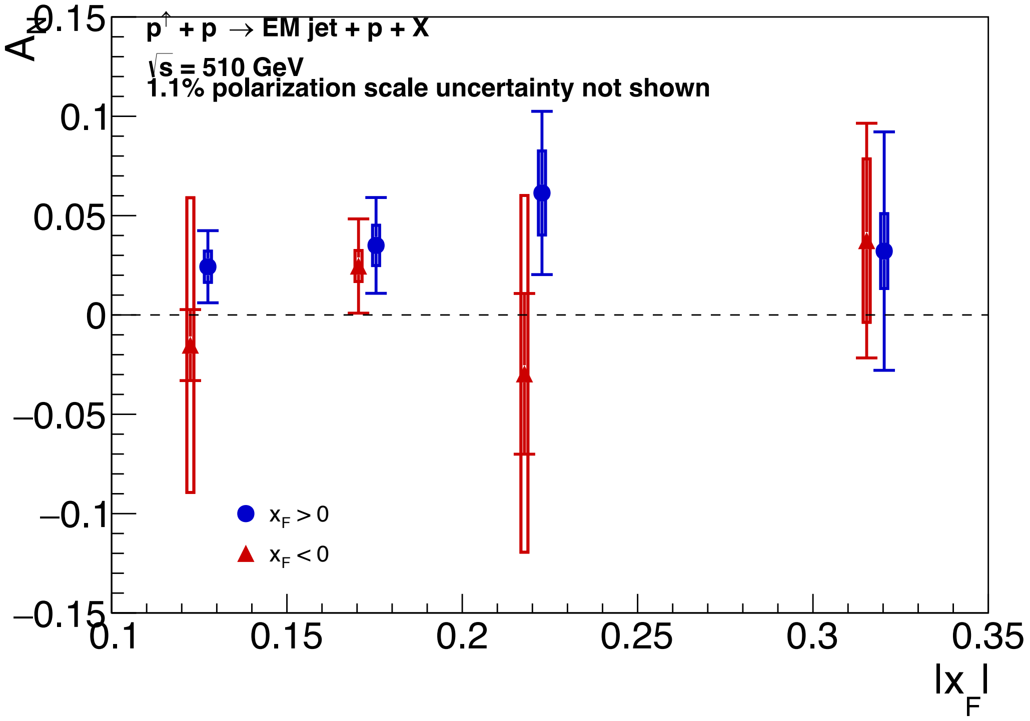
Systematic uncertainty for $frac(sig)$

- For the systematic uncertainty, use west RP track from samples of RP stream to do the mix event for background study for systematic uncertainty.
- Apply the difference of the signal fraction to assign for systematic.

xF	West RP track from zerobias stream (analysis) $frac(sig)$	West RP track from RP stream (systematic) $frac(sig)$	Difference
0.1 – 0.15	0.64	0.51	0.13
0.15 – 0.2	0.57	0.40	0.17
0.2 – 0.25	0.42	0.21	0.21
0.25 – 0.45	0.30	0.08	0.22

Signal A_N results for new E sum cut

- A_N results for new E sum cut
- **4 x_F bins.** ([0.1, 0.15], [0.15, 0.2], [0.2, 0.25] , **[0.25, 0.45]**)
- The new E sum cut will reduce huge fraction of events, increasing the statistical uncertainty.



$$A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$$

Constant fit to check n-sigma to be non-zero:

- Blue beam: 0.0317 +/- 0.0145. (2.18 σ)
- Yellow beam: 0.0198 +/- 0.0220. (0.902 σ)

Note: All red point shift -0.005 in x axis.

Study for EM-jet with photon multiplicity 1 or 2

- The event selection for the EM-jet with photon multiplicity 1 or 2 are same as the EM-jet with all photon multiplicity.
  - We study the background shape on the E sum spectrum, and the regions based on the FMS data curve over the background curve are similar. Therefore, we choose the same E sum cuts.
- The method of calculating the signal A_N for EM-jet with photon multiplicity 1 or 2 is same as for all photon multiplicity EM-jets.
  - $A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$
- Same approaches to estimate the systematic uncertainties.

Fraction of signal and background

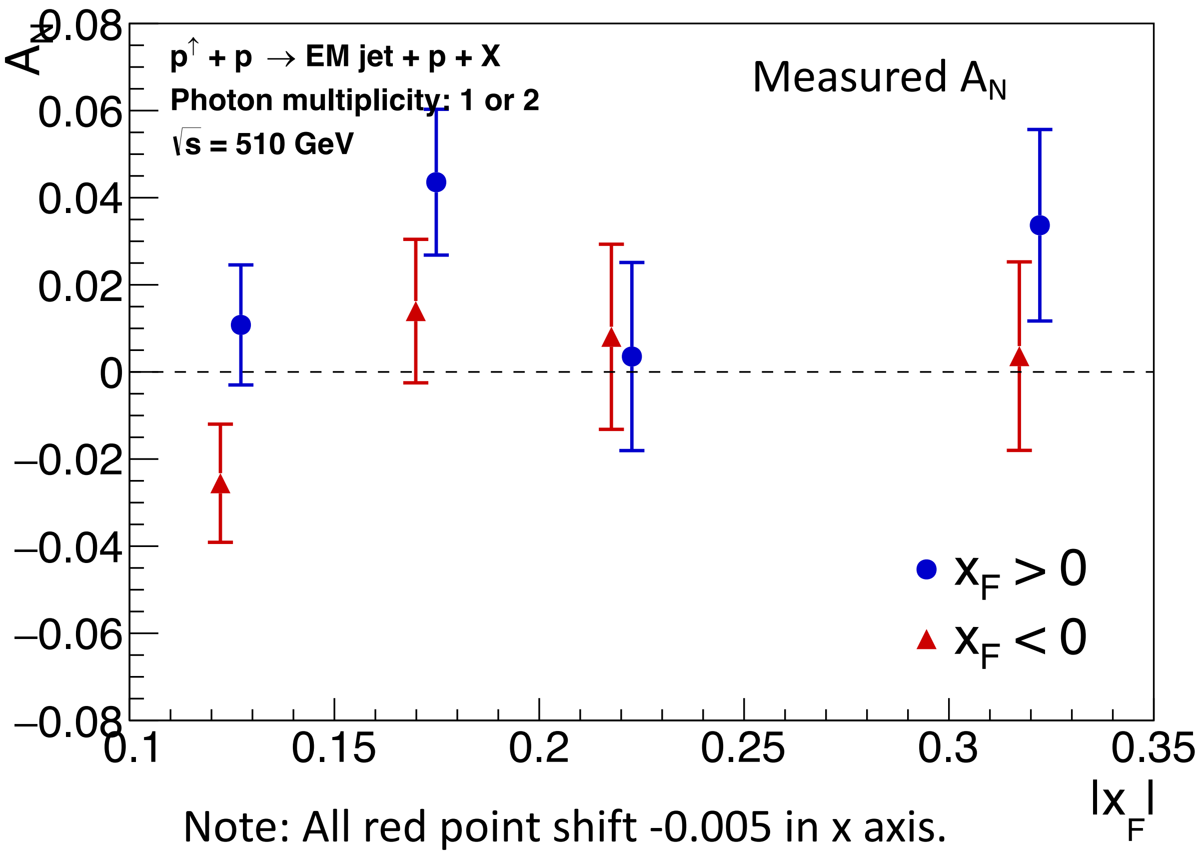
- Photon multiplicity : 1 or 2
- Calculate the fraction of signal and background from the integrating the yield of each the FMS data and zerobias background:
  - N tot = Integral of yield for the **FMS data curve** within new E sum range.
  - N bkg = Integral of yield for the **zerobias data scaled curve** within new E sum range.
  - N sig = N tot – N bkg
  - Frac sig (bkg) = N sig (N bkg) / N tot

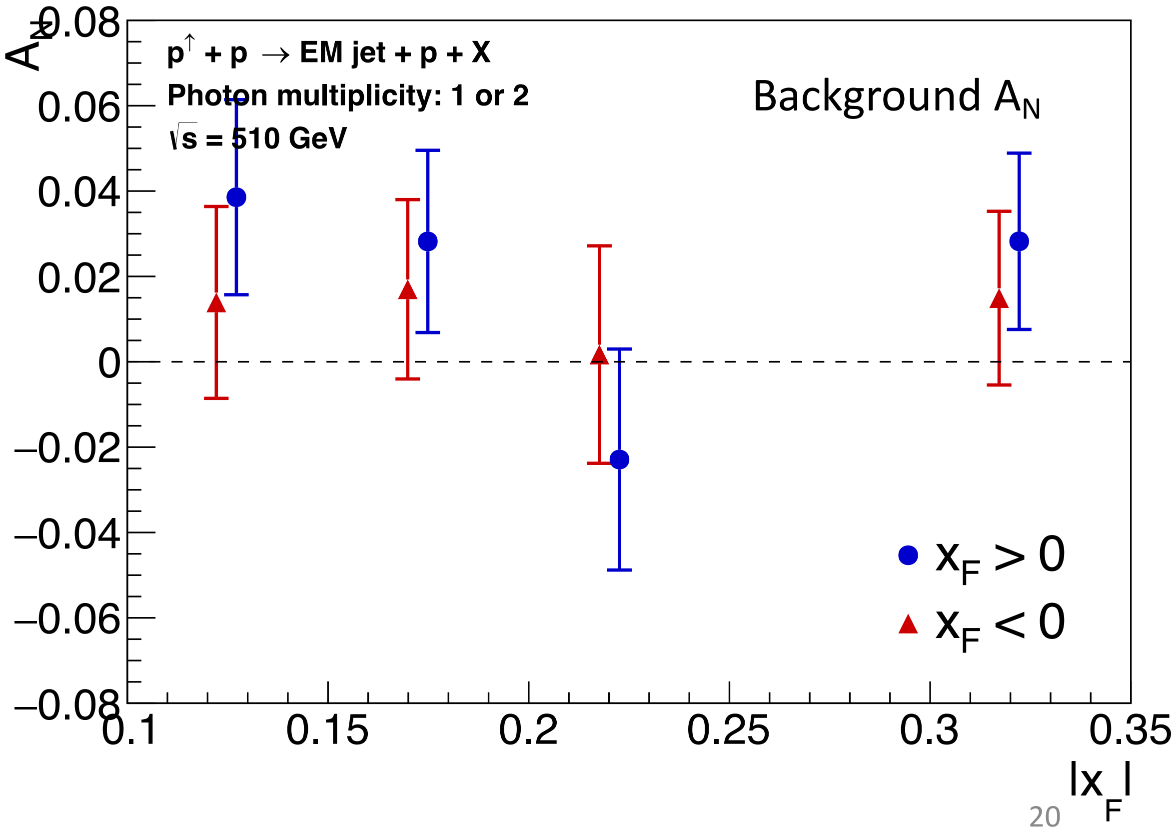
xF bin	N tot	N sig	N bkg	Frac sig	Frac bkg
0.1 – 0.15	29406	20924	8482	0.71	0.29
0.15 – 0.2	19965	13308	6657	0.67	0.33
0.2 – 0.25	12988	7728	5260	0.60	0.40
0.25 – 0.3	5851	3212	2639	0.55	0.45
0.3 – 0.35	4028	1885	2143	0.47	0.53
0.35 – 0.4	2107	825	1283	0.39	0.61
0.4 – 0.45	1275	546	729	0.43	0.57
0.25 – 0.45	13261	6468	6793	0.49	0.51

Measured A_N and background A_N

EM-jet with photon multiplicity 1 or 2

$$A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$$





Note: All red point shift -0.005 in x axis.

Systematic uncertainty results ($A_N(measured)$)

- Small BBC west sum

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.0025	0	0.0013	0.0084
0.15 – 0.2		0.0062		0
0.2 – 0.25		0		0
0.25 – 0.45		0		0

- E sum

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.0011	0.0011	0.00071	0.013
0.15 – 0.2		0		0
0.2 – 0.25		0		0
0.25 – 0.45		0		0

- Small BBC east sum

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.00082	0	0.00031	0.068
0.15 – 0.2		0		0
0.2 – 0.25		0.021		0.0047
0.25 – 0.45		0		0

Use the higher value one between 2 methods to assign as systematic uncertainty

Systematic uncertainty results ($A_N(bkg)$)

- Small BBC west sum

xF (bkg)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.0045	0	0.00074	0.0057
0.15 – 0.2		0		0.0080
0.2 – 0.25		0.012		0
0.25 – 0.45		0		0.00024

- Small BBC east sum

xF (bkg)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.0039	0.030	0.00046	0
0.15 – 0.2		0		0
0.2 – 0.25		0		0.036
0.25 – 0.45		0		0

Use the higher value one between 2 methods to assign as systematic uncertainty

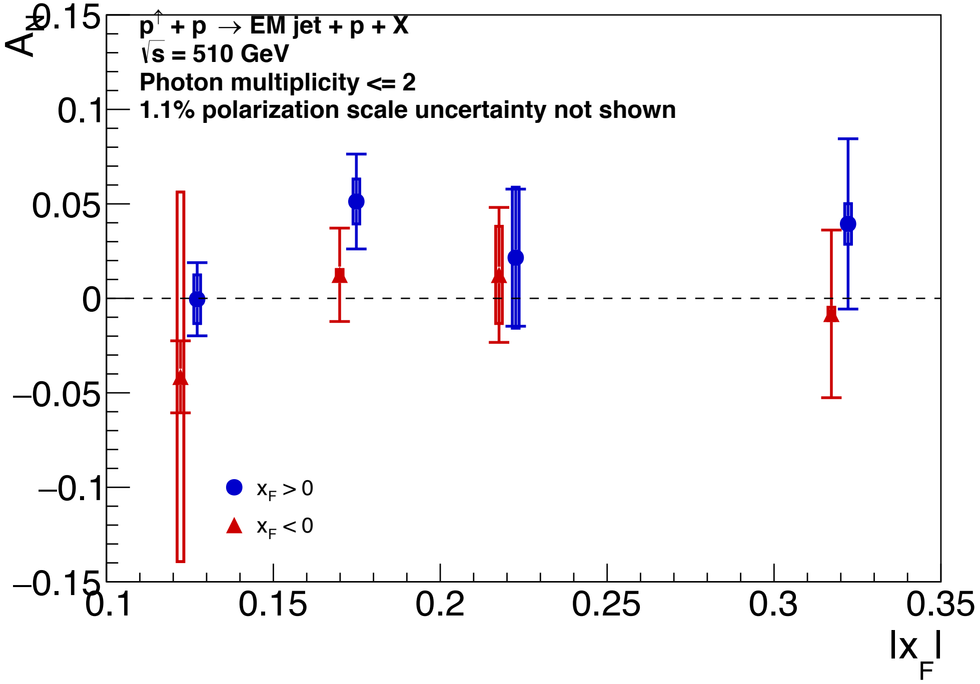
Systematic uncertainty for $frac(sig)$

- For the systematic uncertainty, use west RP track from samples of RP stream to do the mix event for background study for systematic uncertainty.
- Apply the difference of the signal fraction to assign for systematic.

xF	West RP track from zerobias stream (analysis) $frac(sig)$	West RP track from RP stream (systematic) $frac(sig)$	Difference
0.1 – 0.15	0.71	0.60	0.11
0.15 – 0.2	0.67	0.54	0.13
0.2 – 0.25	0.60	0.45	0.15
0.25 – 0.45	0.49	0.32	0.17

Signal A_N results for 1 or 2 photon multi EM-jets

- A_N results for 1 or 2 photon multiplicity EM-jets
- **4 x_F bins.** ([0.1, 0.15], [0.15, 0.2], [0.2, 0.25] , **[0.25, 0.45]**)



$$A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$$

Constant fit to check n-sigma to be non-zero:

- Blue beam: 0.0231 +/- 0.0158. (1.46 σ)
- Yellow beam: 0.0067 +/- 0.019. (0.348 σ)

Note: All red point shift -0.005 in x axis.

Conclusion and Outlook

- The new set of mix event background study looks better now. It can show obvious peak for signal.
- The background shape could be effected by the limited statistics after the event selection for zerobias events. Therefore, this effect can be considered in the systematic uncertainty
- The signal A_N results subtract the background contribution.
- Next to do: Based on the comments from PWG, improve the results and request for preliminary.
  - Preliminary release for SPIN 23 conference.

Back up

- Methods for systematic uncertainty
  - Presented in Spin PWG meeting on July 5

Method 1 (suggested by Oleg)

- Idea: estimate the systematic uncertainty by the average A_N difference from varying the cuts.
- List of cuts to study: (BBC cuts for example)
  - Small BBC west sum
    - Original cut value: < 250
    - Systematic uncertainty cut value: < 400
  - Small BBC east sum
    - Original cut value: > 150
    - Systematic uncertainty cut value : > 50

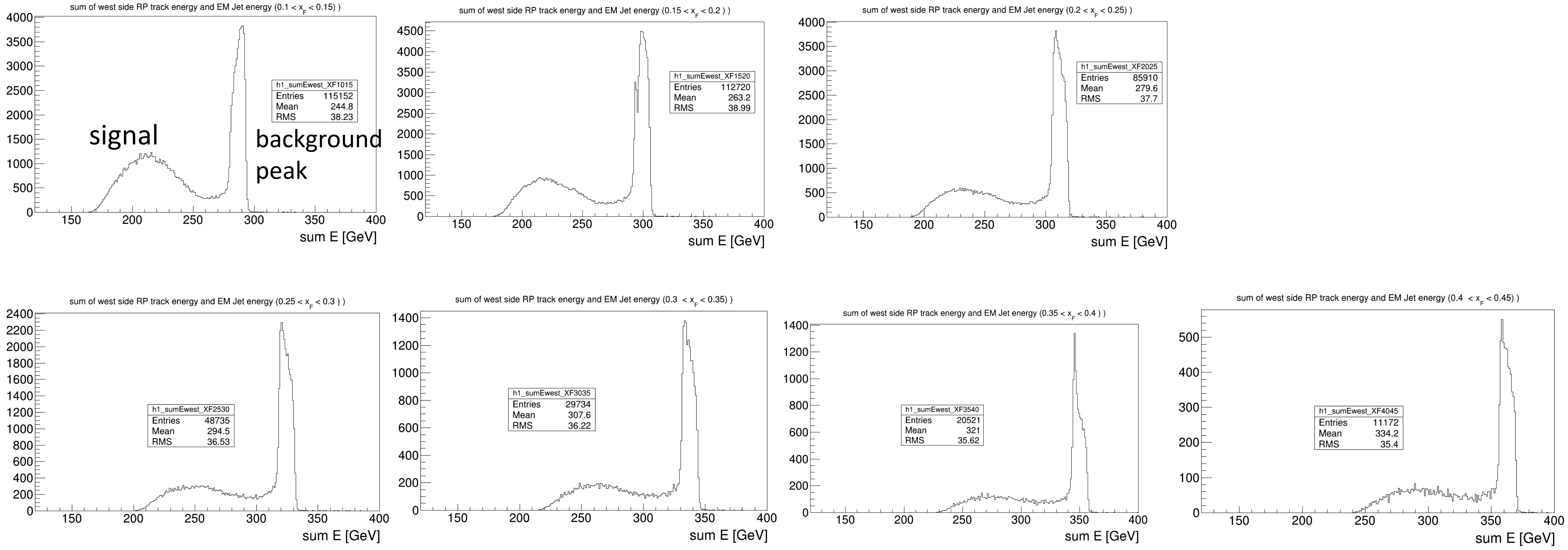
Method 2 (suggested by Carl)

- For a certainty cut, choose an entirely different region (Region 2) from original region (Region 1). Calculate their A_N difference and statistical uncertainty.
- Small BBC west sum (sBBCW):
  - Region 1: sBBCW < 250
  - Region 2: 250 < sBBCW < 550
- Small BBC east sum (sBBCE):
  - Region 1: sBBCE > 150
  - Region 2: sBBCE < 150
- Use the formula below to calculate the systematic uncertainty:

$$Syst = \max\{(|A_N(R1) - A_N(R2)| - \sqrt{\sigma_{R1}^2 + \sigma_{R2}^2}), 0\}$$

E sum spectrum based on different x_F ranges

- The peak of signal region shift significantly for different x_F ranges.
  - The peak of signal region is exceeded 255 GeV (beam energy) for higher x_F ranges



Polarization uncertainty

- $\sigma(P_{set}) = P_{set} \cdot \frac{\sigma(scale)}{P} \oplus \sigma_{set}(fill\ to\ fill) \oplus P_{set} \cdot \frac{\sigma(profile)}{P}$
- $\frac{\sigma(scale)}{P} = 1.1\%$ [1]
- $\frac{\sigma(profile)}{P} = \frac{2.2\%}{\sqrt{M}} = 0.17\ \%$ [1]   M=179, N=190
- $\sigma^2{}_{set}(fill\ to\ fill) = (1 - \frac{M}{N}) \frac{\sum_{fill} L_{fill}{}^2 \sigma^2(P_{fill})}{(\sum_{fill} L_{fill})^2}$
  - $\sigma_{set}(fill\ to\ fill) = 0.06\%$
  - $\sigma(P_{fill}) = \sigma(P_0) \oplus \sigma(\frac{dP}{dt})(\frac{\sum_{run} t_{run} L_{run}}{L_{fill}} - t_0) \oplus \frac{\sigma(fill\ to\ fill)}{P} P_{fill}$ [2]

Close to 0

- so $\sigma(P_{set}) = 1.1\%$

[1] W. B. Schmidke, RHIC polarization for Runs 9-17

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