Run 17 diffractive EM-jet A_N update: E sum background study

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Event selection and corrections

- **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 < 550 and small BBC east ADC > 150

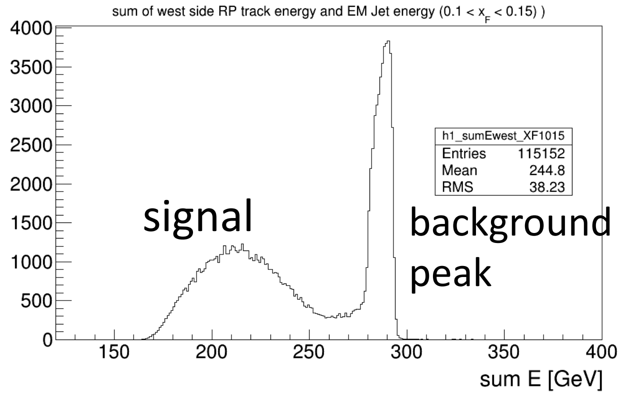
Data set: run 17 pp transverse $\sqrt{s} = 510$ GeV ,fms stream (pp500_production_2017)

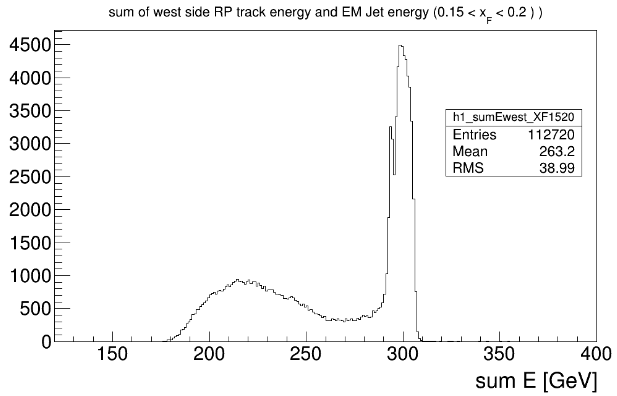
Corrections for EM-jet:
Energy correction and
Underlying Event correction

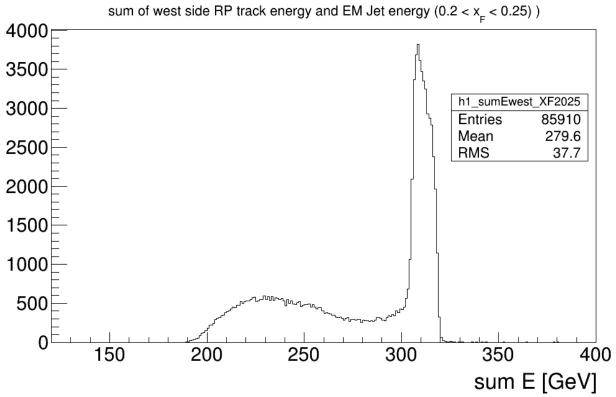
x_F	Old E sum Cut
0.1 - 0.15	E_{sum} < 265 GeV
0.15 - 0.2	E_{sum} < 280 GeV
0.2 - 0.25	E_{sum} < 295 GeV
0.25 - 0.3	E_{sum} < 305 GeV
0.3 - 0.35	E_{sum} < 315 GeV
0.35 - 0.4	E_{sum} < 330 GeV
0.4 – 0.45	E_{sum} < 340 GeV

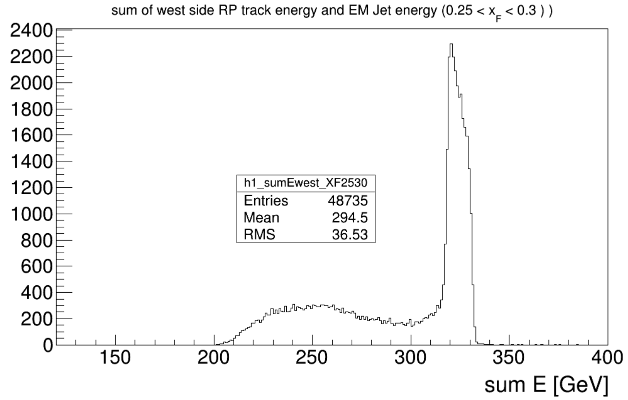
E sum spectrum based on different x_F ranges

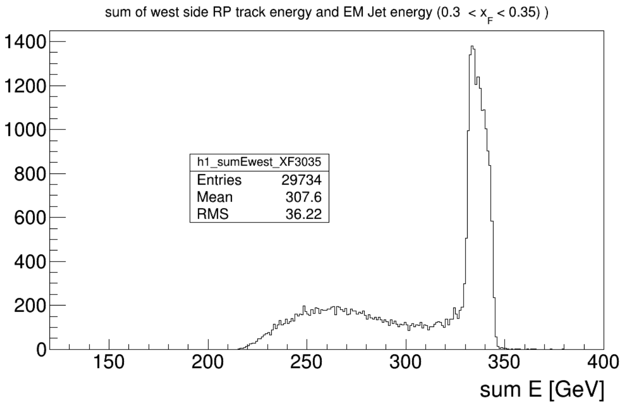
- The peak of signal region shift significantly for different x_F ranges.
  - The peak of signal region is exceeded 255 GeV (beam energy) for higher x_F ranges

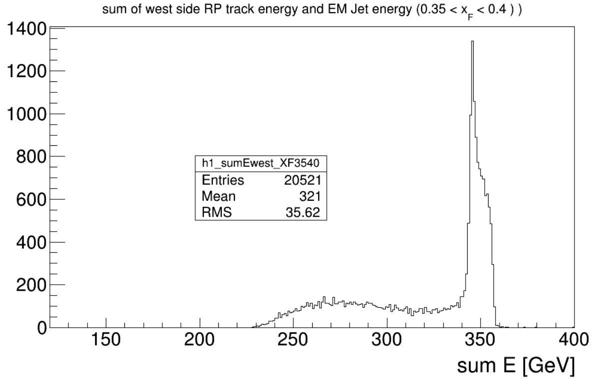


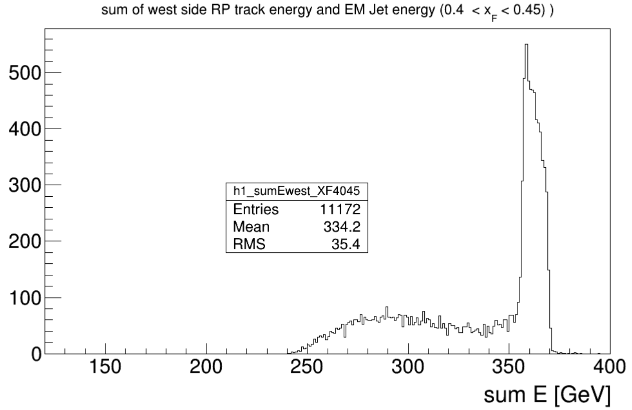










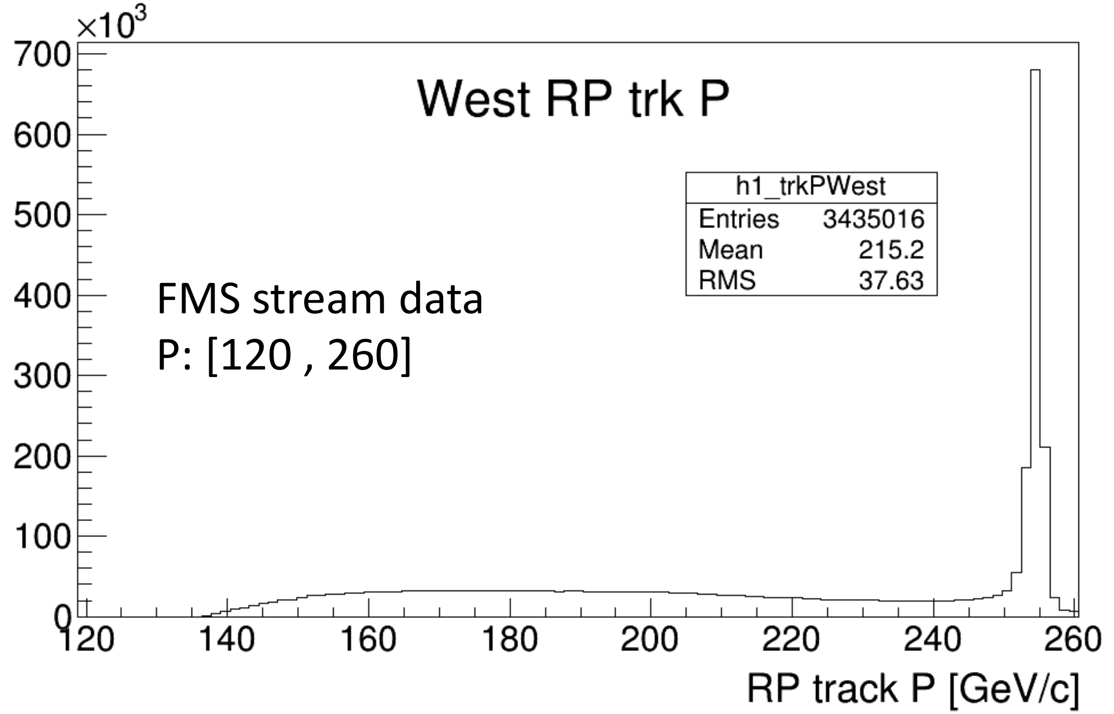


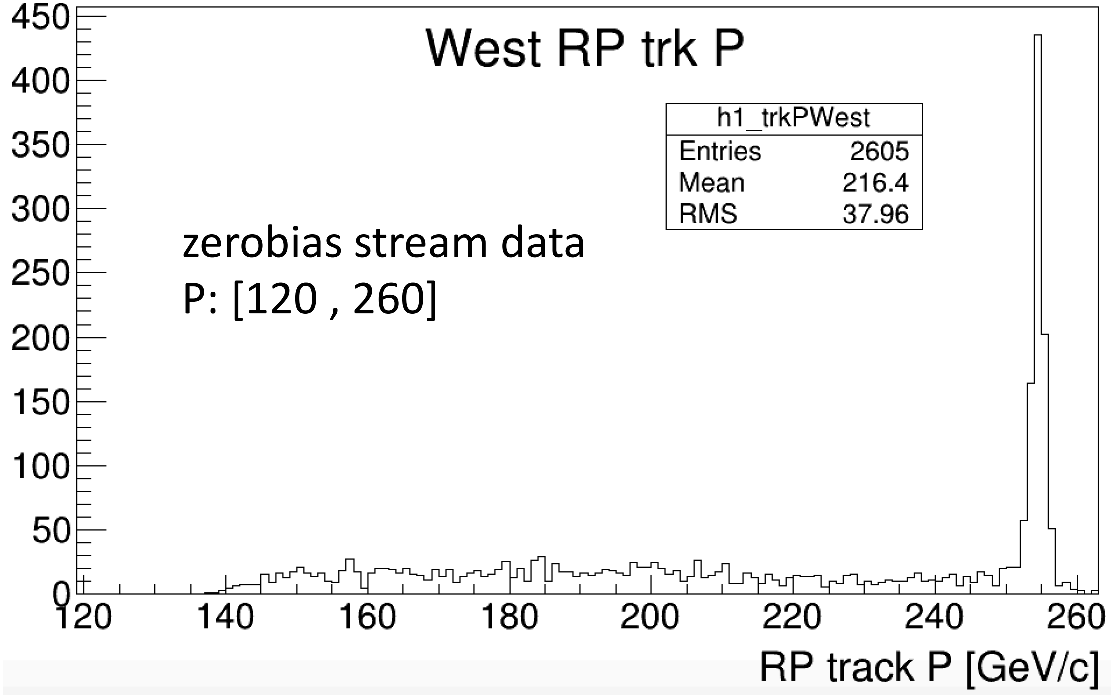
Motivation

- 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.
- 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.

Roman Pot track QA for FMS and zerobias data

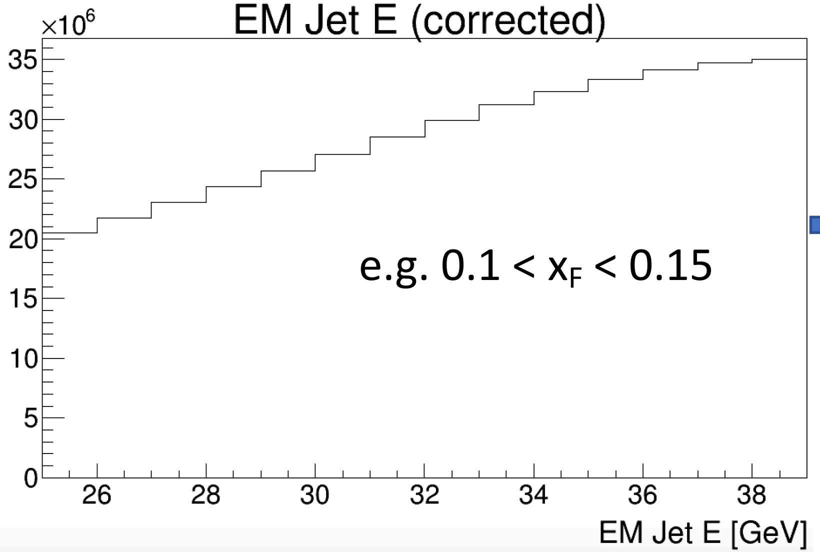
- The Roman Pot track are passing the cut below:
  - Each track hits 7 or 8 planes
  - $-0.25 < P_X < 0.3$ GeV/c ;
  - $-0.6 < P_Y < -0.4$ GeV/c or $0.3 < P_Y < 0.55$ GeV/c
- Compare the west RP track P between FMS stream data and zerobias stream data.

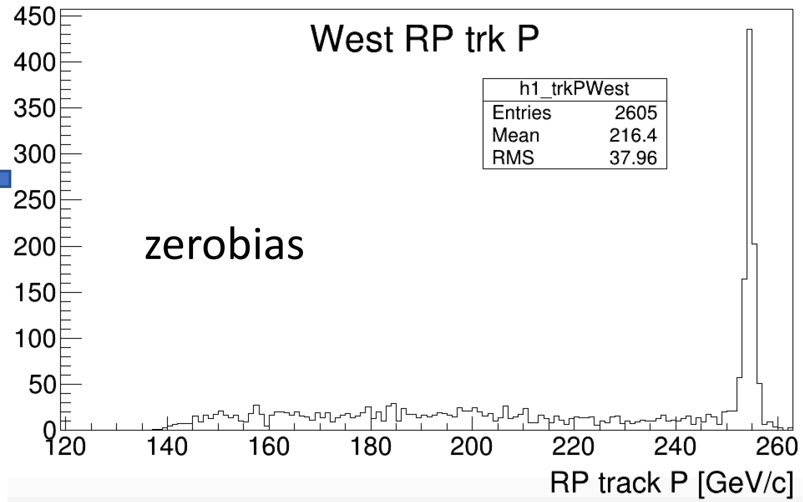


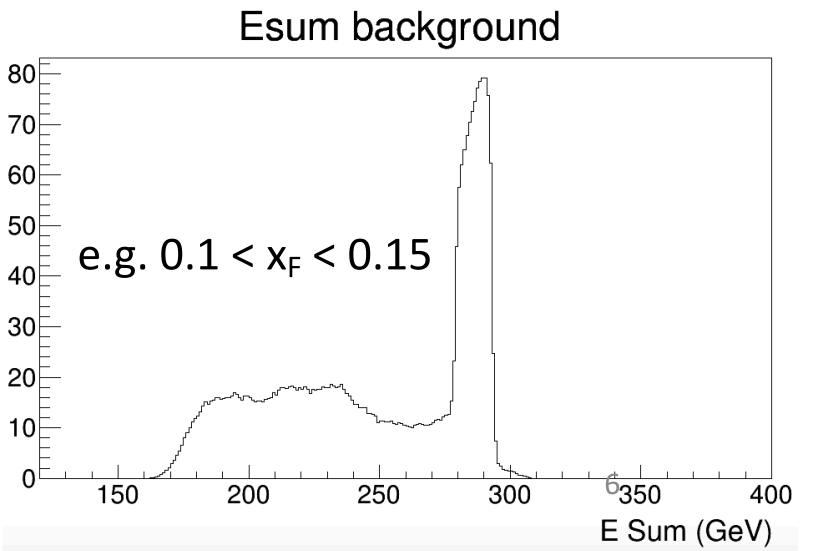


Background study for E sum

- 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: $\boldsymbol{Esum(i+j) = \sum_{i,j} P(i) * n(RP, j)}$, 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(RP,j) is the yields in west RP energy (momentum) in [j,j+1] (GeV).





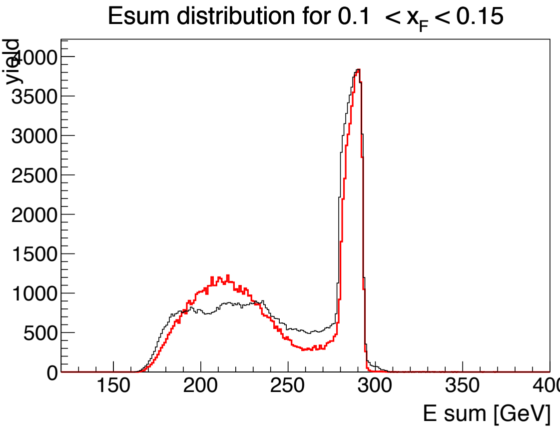


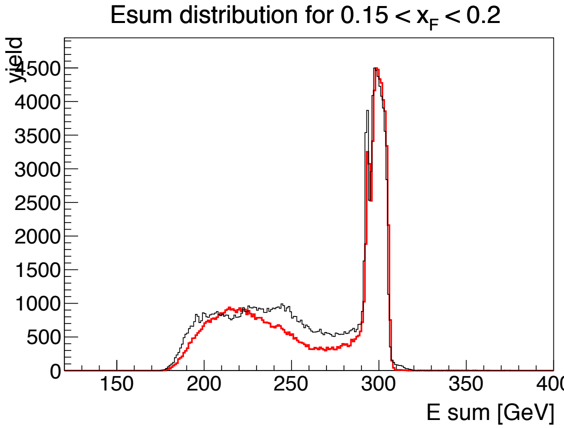
Further explanation for the calculation

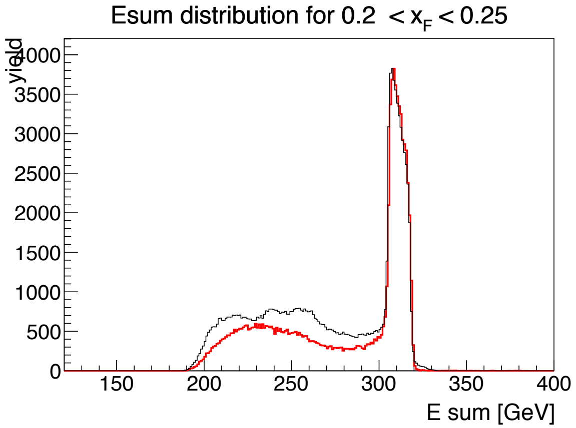
- Calculation: $\boldsymbol{Esum(i+j) = \sum_{i,j} P(i) * n(RP, j)}$
  - i are all possible energies (in 1 GeV bin) for specific x_F range ; j are all possible energies (in 1 GeV bin) for west RP track energy (momentum) in zerobias data.
  - P(i) is the fraction for EM-jet yields in [i,i+1] (GeV) within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

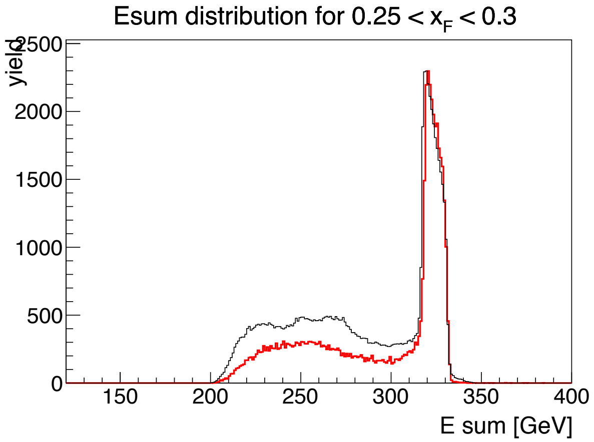
E sum spectrum based on different x_F ranges

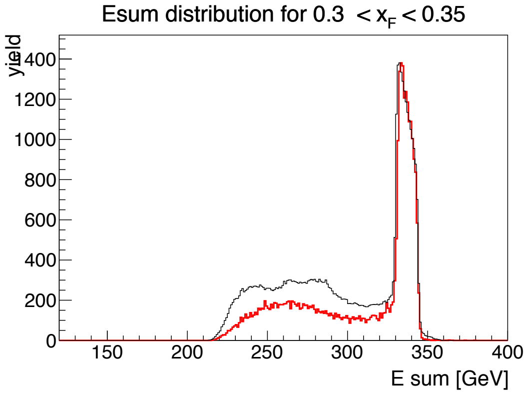
- Data: FMS stream data with <u>east BBC cut and west BBC cut (<550)</u>.
- Black curve (Background) is mixed events from zerobias events (scaled to data).
- Red curve is the FMS stream data

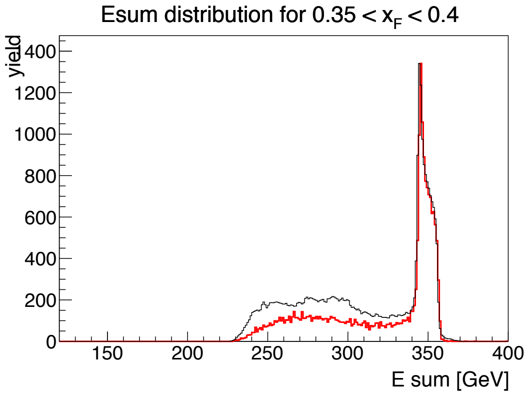


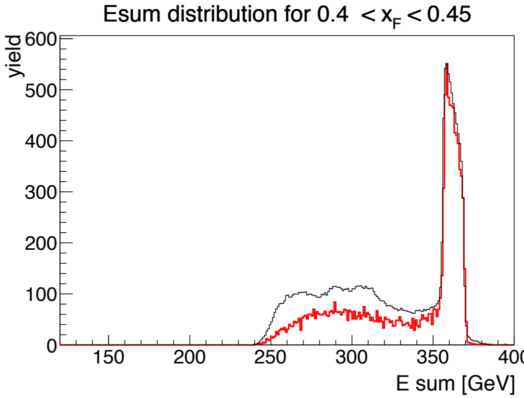






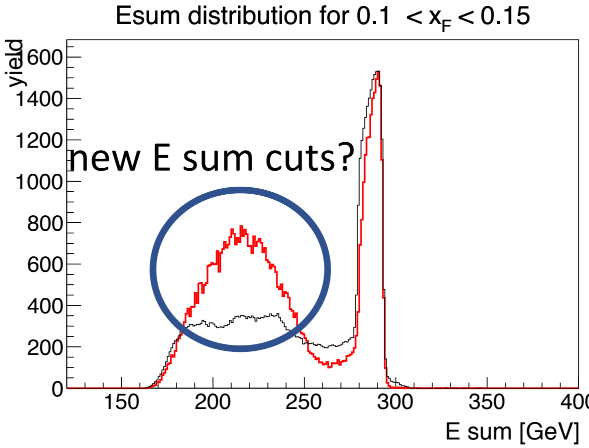


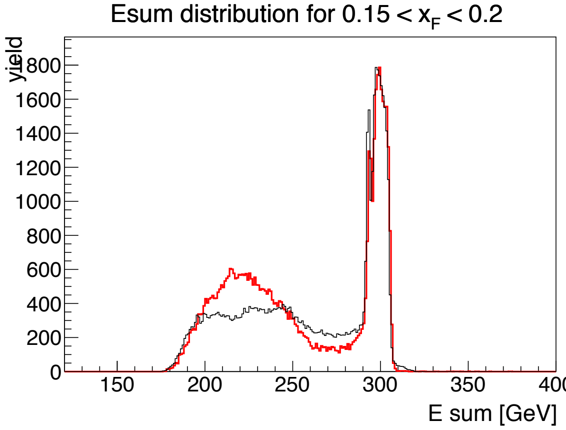


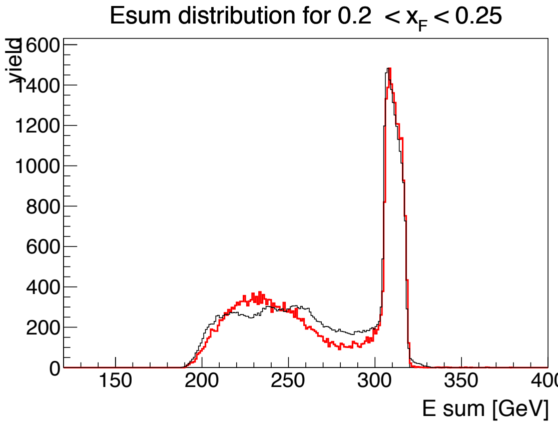


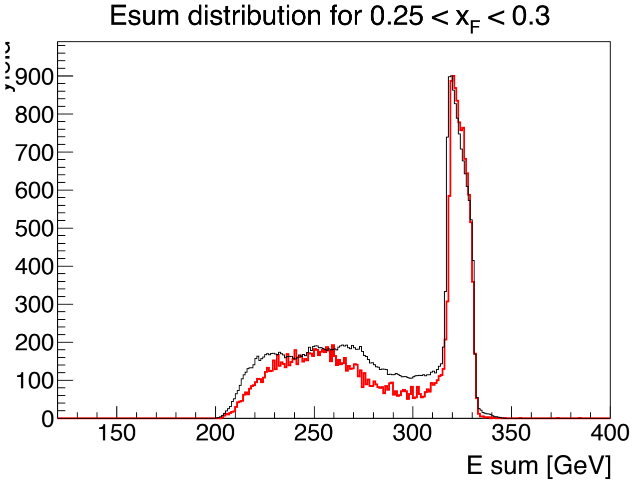
E sum spectrum based on different x_F ranges

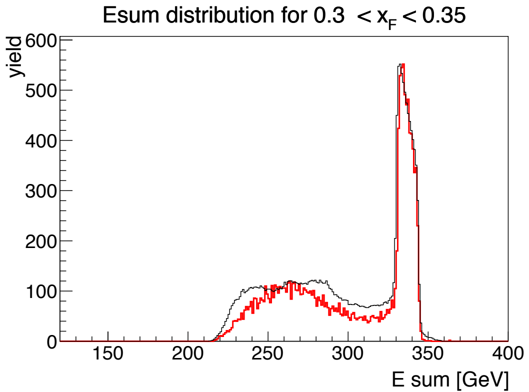
- Data: FMS stream data with east BBC cut and west BBC cut (<250).
- Black curve (Background) is mixed events from zerobias events (scaled to data).
- Red curve is the FMS stream data

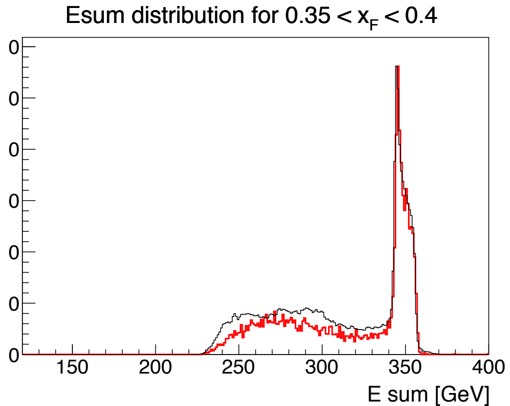


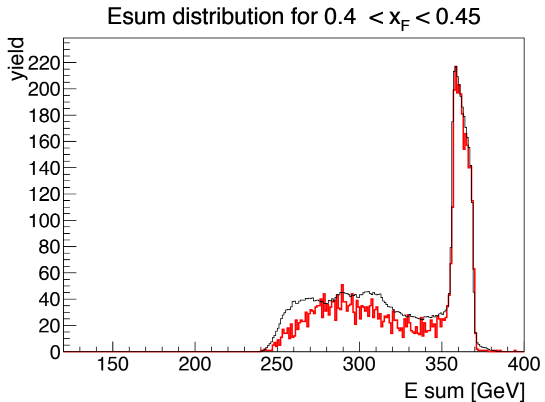






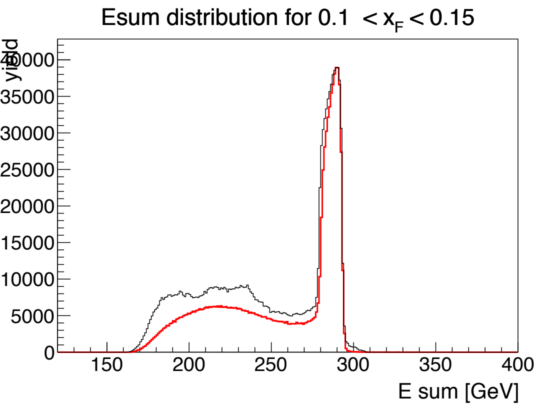


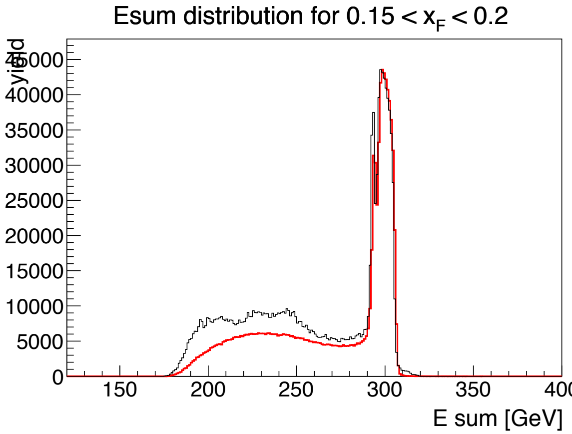


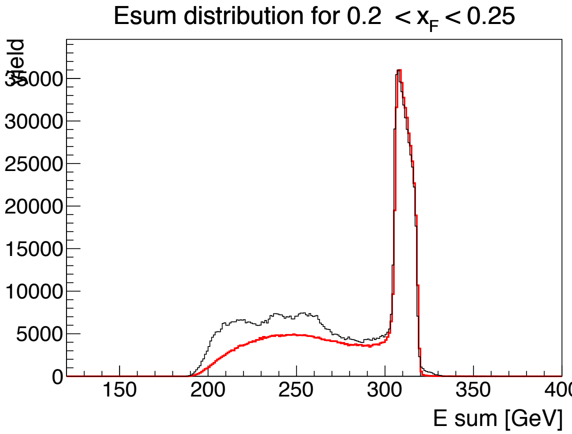


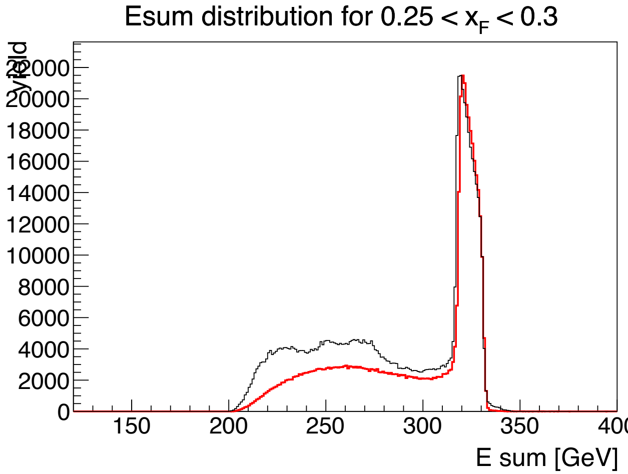
E sum spectrum based on different x_F ranges

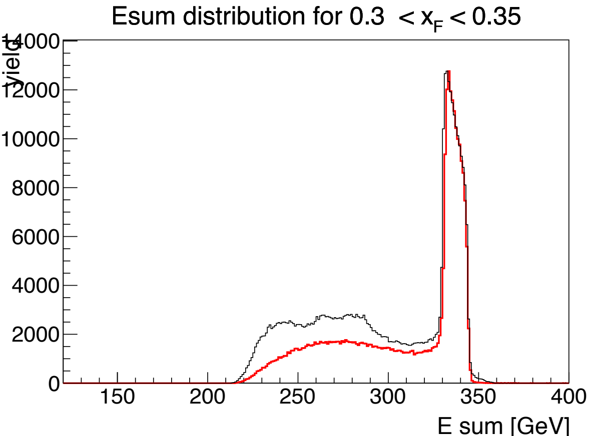
- Data: FMS stream data with no east BBC cut and no west BBC cut.
  - Another way to prove the BBC cuts are needed!
- Black curve (Background) is mixed events from zerobias events (scaled to data).
- Red curve is the FMS stream data

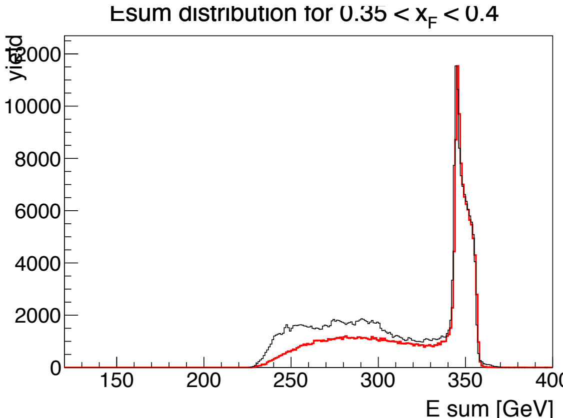


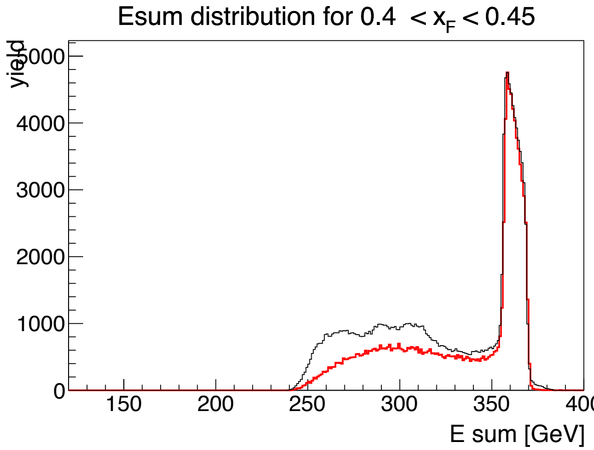












New E sum cut based on the zerobias bkg study

- Although the zerobias background study seems not to provide much information for how to apply additional cuts on E sum, especially for high x_F ranges, we can try to consider to apply additional cuts based on the width for signal over background we have from low x_F ranges.

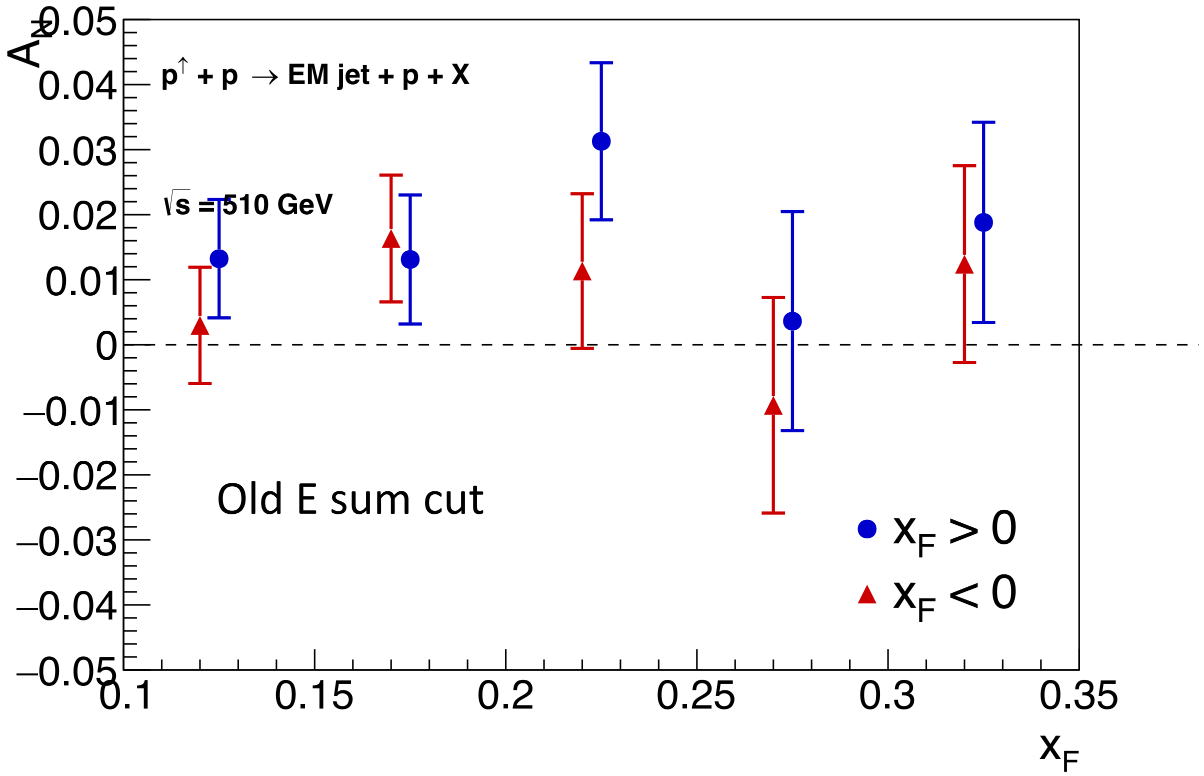
x_F	**Old** E sum Cut
0.1 - 0.15	E_{sum} < 265 GeV
0.15 - 0.2	E_{sum} < 280 GeV
0.2 - 0.25	E_{sum} < 295 GeV
0.25 - 0.3	E_{sum} < 305 GeV
0.3 - 0.35	E_{sum} < 315 GeV
0.35 - 0.4	E_{sum} < 330 GeV
0.4 – 0.45	E_{sum} < 340 GeV

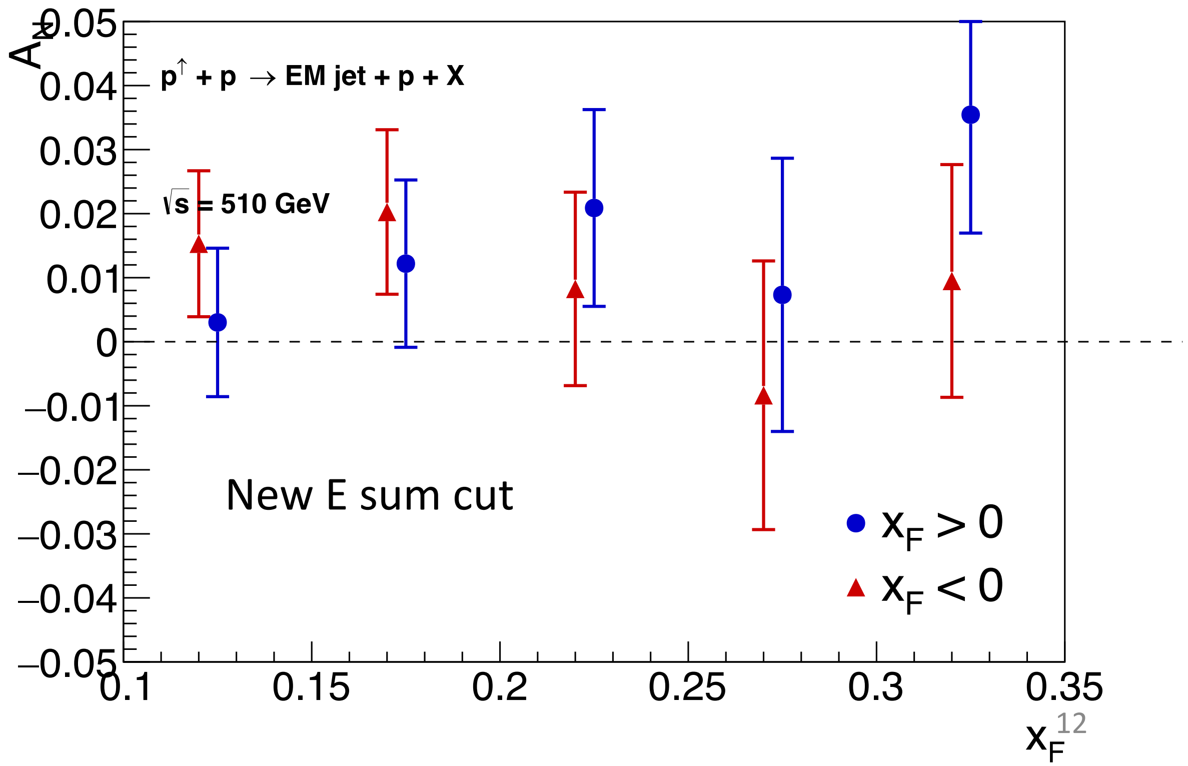
→

x_F	**New** E sum Cut
0.1 - 0.15	190 < E_{sum} < 230 GeV
0.15 - 0.2	200 < E_{sum} < 240 GeV
0.2 - 0.25	205 < E_{sum} < 255 GeV
0.25 - 0.3	225 < E_{sum} < 275 GeV
0.3 - 0.35	235 < E_{sum} < 290 GeV
0.35 - 0.4	240 < E_{sum} < 300 GeV
0.4 – 0.45	260 < E_{sum} < 320 GeV

A_N results for old / new E sum cut

- A_N results for old (left) / new (right) E sum cut
  - The new E sum cut will reduce huge fraction of events, increasing the statistical uncertainty.
  - The A_N for low x_F ranges are even smaller in the central value for changing the E sum cut.
  - The results with old/new cuts are roughly consistent within statistical uncertainty.
- Discussion: should we consider to apply the new set of the E sum cut?





Conclusion and outlook

- The elastic scattering peak matches pretty well.
- However, the scaled background distribution is more than the FMS stream data for high x_F regions in Esum spectrum.
- The A_N for old / new E sum cuts are consistent within statistical uncertainty.
- Next to do: finalize the systematic uncertainty for E sum cut and BBC cuts.
  - Use the two methods (presented in Spin PWG meeting on July 5.) to estimate the systematic uncertainty.

Back up

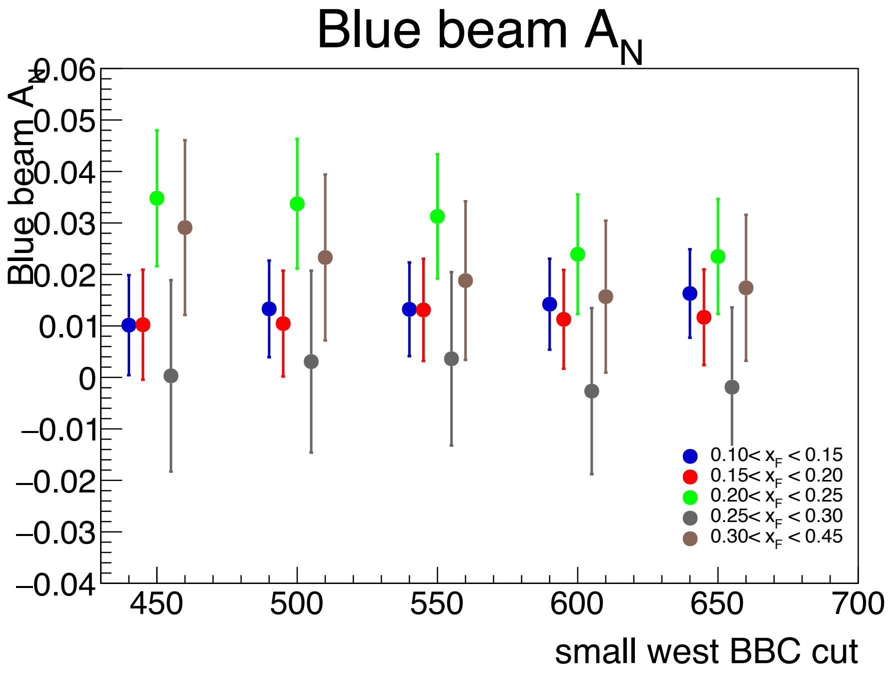
- Methods for systematic uncertainty
  - Presented in Spin PWG meeting on July 5

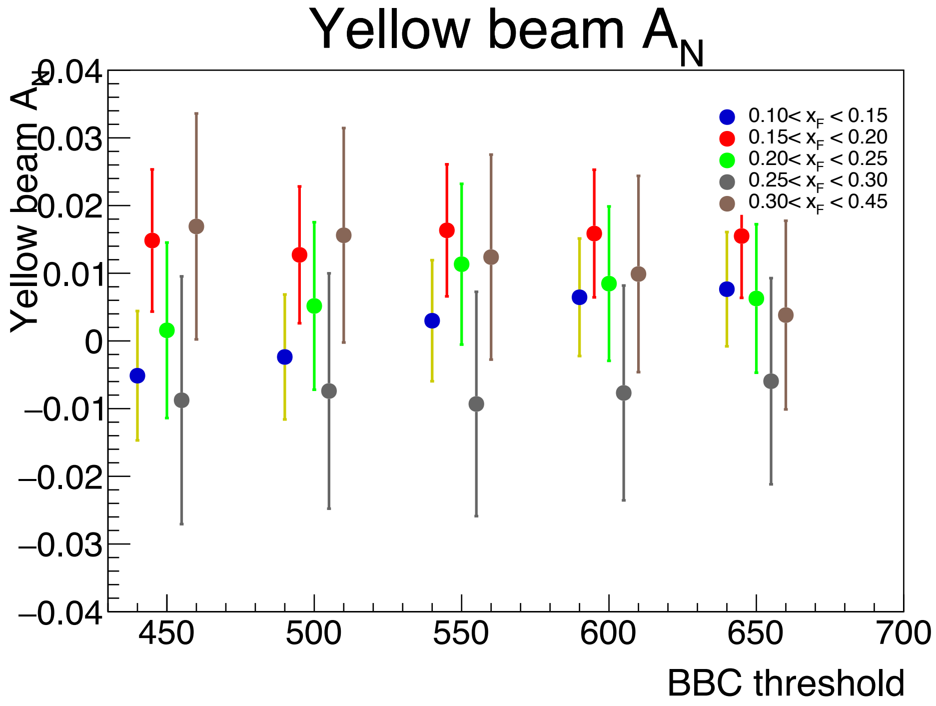
Method 1 (suggested by Oleg)

- 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: 550
    - Systematic uncertainty cut values: 450, 500, 600, 650
  - Small BBC east sum
    - Original cut value: 150
    - Systematic uncertainty cut values: 90, 120, 180, 210

Study the BBC cuts for systematic uncertainty

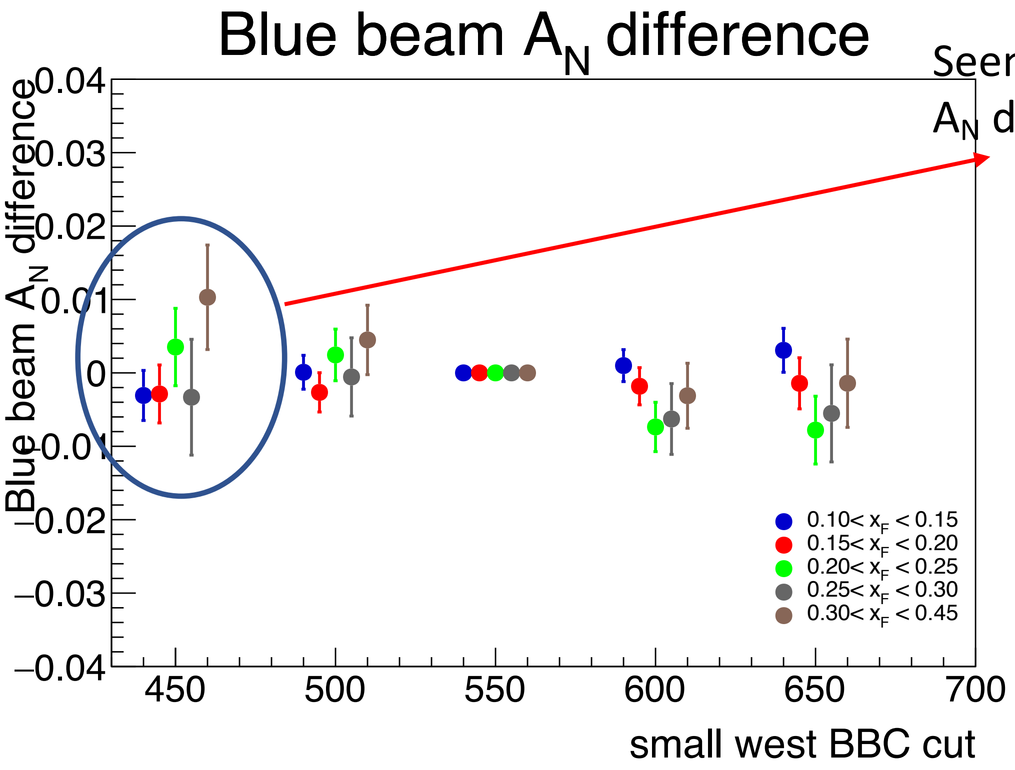
- Small west BBC cut as example:
  - List of small west BBC cut (max): 450, 500, 550, 600, 650
- Left plot show the A_N value for blue beam with statistical uncertainty.
- Right plot show the A_N value for yellow beam with statistical uncertainty.



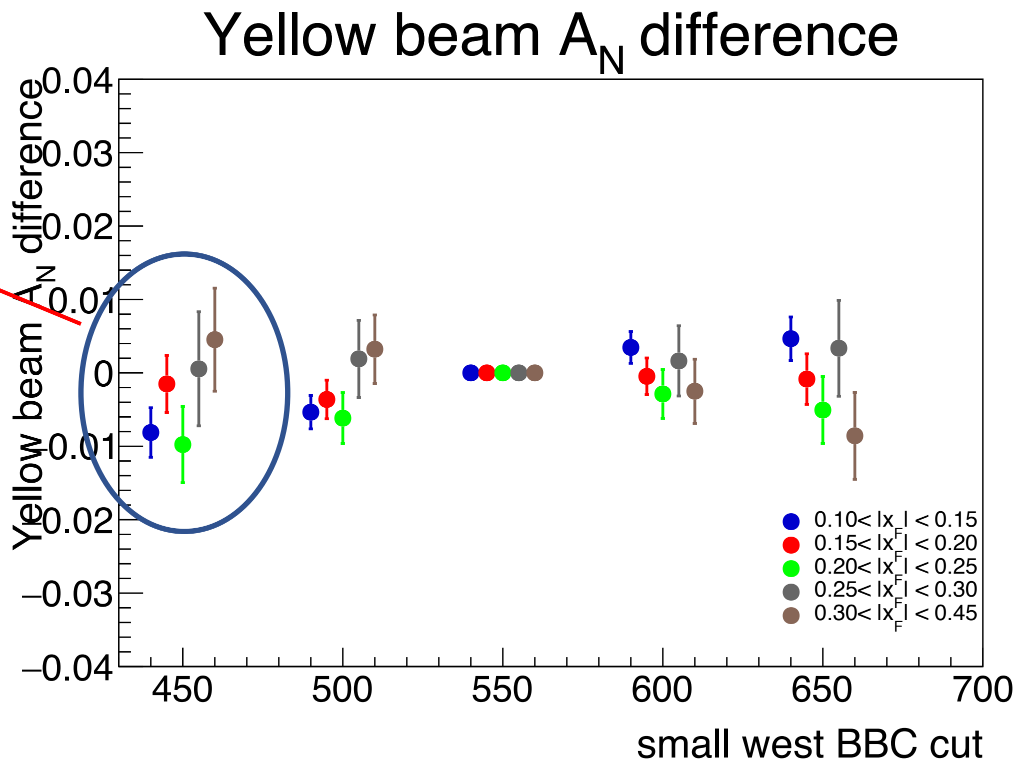


A_N difference for small west BBC ADC sum cut

- Original cut: 550
- Modified cuts for systematic uncertainty study: 450, 500, 600, 650
- A_N difference: A_N (modified) - A_N (original) ,plot A_N difference for different BBC cut
- Error bar: correlated uncertainty

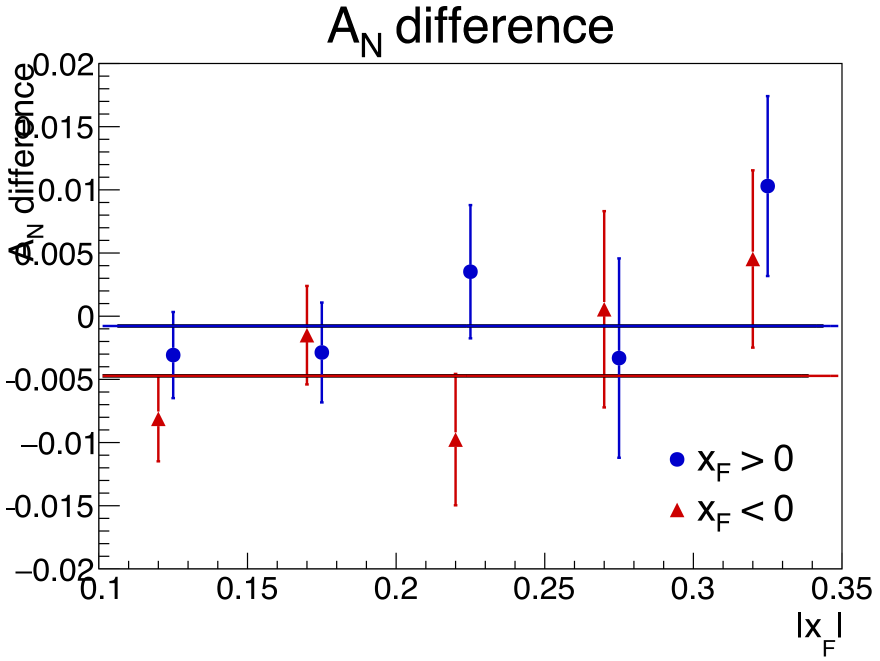


Seems to have largest A_N difference



Estimate the systematic uncertainty from A_N difference

- Extract the A_N difference between small BBC west cut 550 and 450, since they seems to have largest A_N difference .
- Plot A_N difference as function of x_F. Blue points are for blue beam ($x_F > 0$); Red points are for yellow beam ($x_F < 0$)
- Use the constant fit to estimate their average A_N difference from all x_F bins for blue or yellow beam, so to assign it as systematic uncertainty for all x_F bins.
- Fit results:
  - Blue beam: -0.00077
  - Yellow beam: -0.0047
- Therefore, assign uniform syst:
  - Blue beam: 0.00077
  - Yellow beam: 0.0047



Method 2 (suggested by Carl)

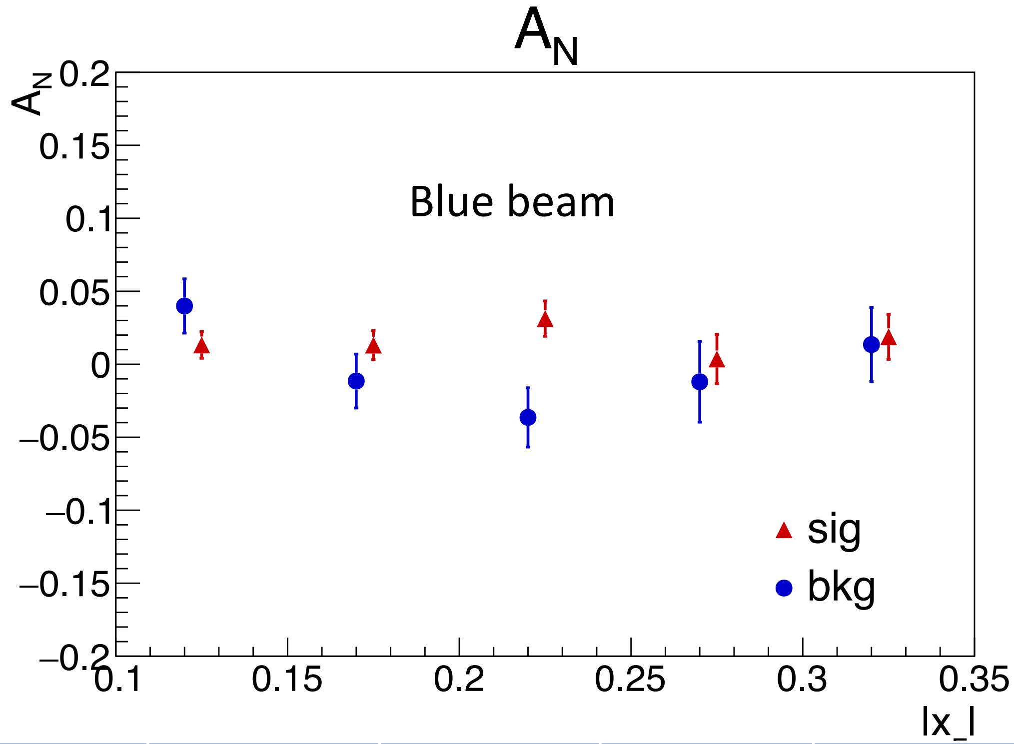
- For a certainty cut, choose an entirely different region from signal for the background. Calculate their A_N difference and statistical uncertainty.
- Small BBC west sum (sBBCW):
  - Signal region: sBBCW < 550
  - Background : 550 < sBBCW < 750
- Small BBC east sum (sBBCE):
  - Signal region: sBBCE > 150
  - Background : 50 < sBBCE < 150
- Use the formula below to calculate the systematic uncertainty:

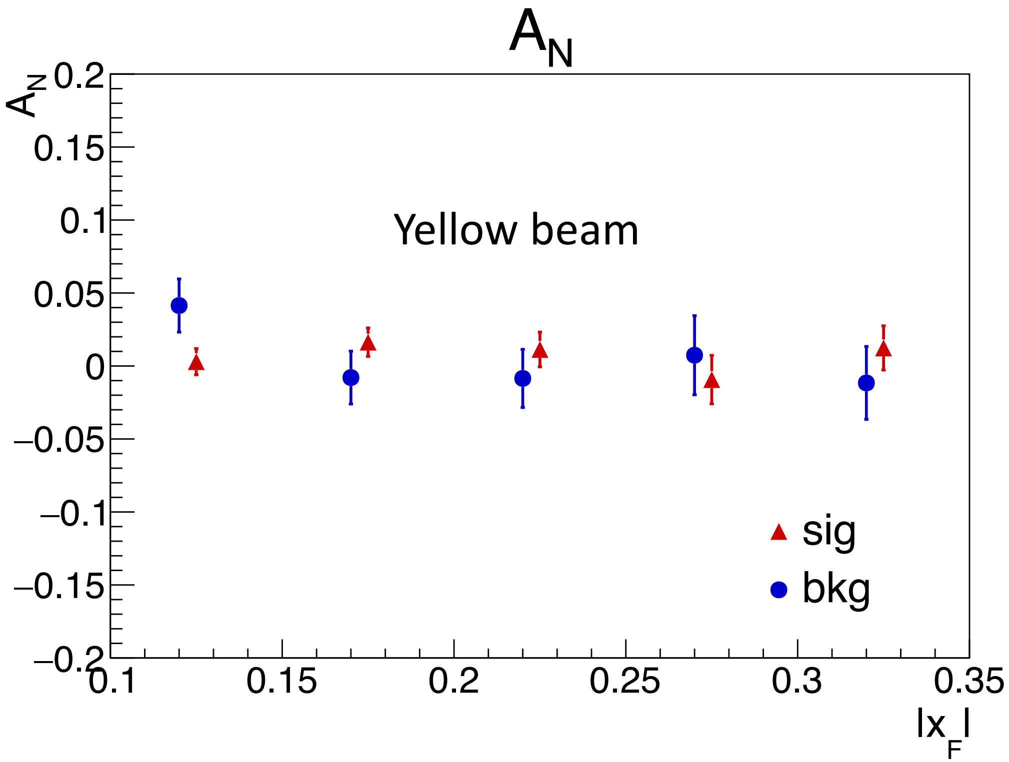
$$Syst = \max\{(|A_N(sig) - A_N(bkg)| - \sqrt{\sigma_{sig}^2 + \sigma_{bkg}^2}), 0\}$$

Systematic uncertainty results for method 2

- Example: Small BBC west ADC:
  - Signal region: sBBCW < 550
  - Background : 550 < sBBCW < 750

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





Blue x_F	0.1 – 0.15	0.15 – 0.2	0.2 – 0.25	0.25 – 0.3	0.3 – 0.45
Syst	0.0061	0.0037	0.044	0	0

Yellow x_F	0.1 – 0.15	0.15 – 0.2	0.2 – 0.25	0.25 – 0.3	0.3 – 0.45
Syst	0.018	0.0037	0	0	0