Run 17 diffractive EM-jet A_N update and preliminary request

Xilin Liang

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Outline

- Update on statistical uncertainty propagation and results
- Update on systematic uncertainty study
- Update on Run 17 diffractive EM-jet A_N and preliminary request

Questions and suggestions from last week

- 1. Error propagation for signal fraction.
  - Derive the error propagation for signal fraction and calculate the statistical uncertainty for signal fraction (background fraction)
  - Derive the error propagation for A_N (sig)
  - Recalculate the systematic uncertainty for signal fraction.
- 2. Systematic uncertainty for small BBC east
  - Try to get rid of the small BBC east cut (suggested by Carl)
  - Drop the systematic term for small BBC east.

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 < 250 (no small BBC east cut)

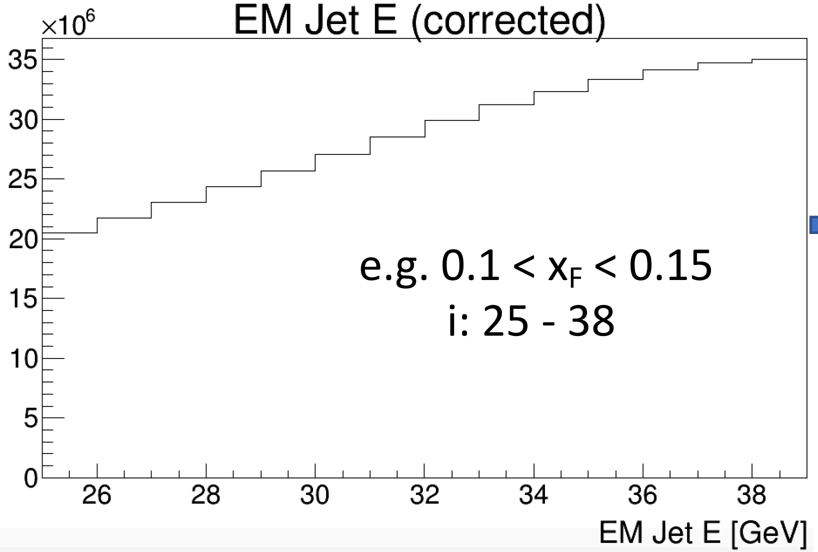
Data set: run 17 pp transverse $\sqrt{s} = 510$ GeV ,fms stream (pp500_production_2017)

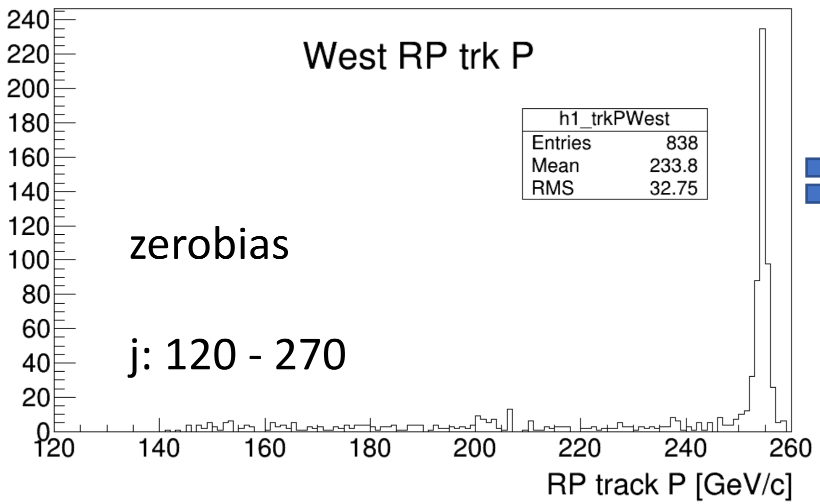
Corrections for EM-jet:
Energy correction and
Underlying Event correction

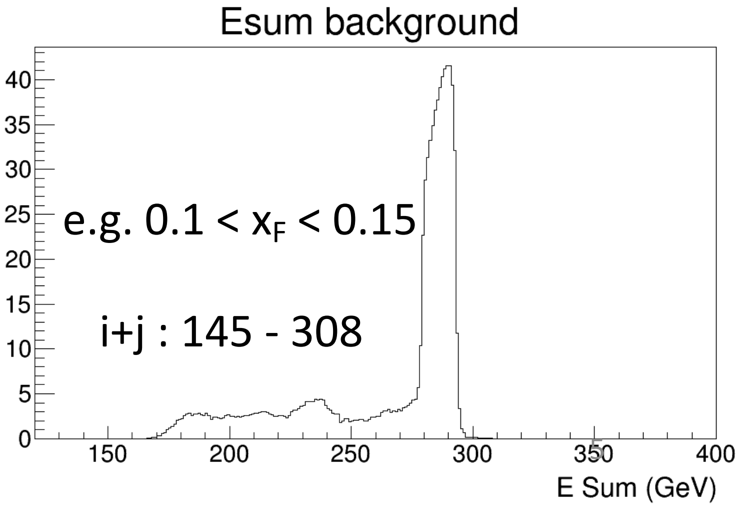
x_F	E sum cut (this presentation)
0.1 - 0.15	E_{sum} < 260 GeV
0.15 - 0.2	E_{sum} < 270 GeV
0.2 - 0.25	E_{sum} < 280 GeV
0.25 - 0.3	220 < E_{sum} < 290 GeV
0.3 - 0.35	230 < E_{sum} < 310 GeV
0.35 - 0.4	240 < E_{sum} < 320 GeV
0.4 – 0.45	260 < E_{sum} < 340 GeV

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).



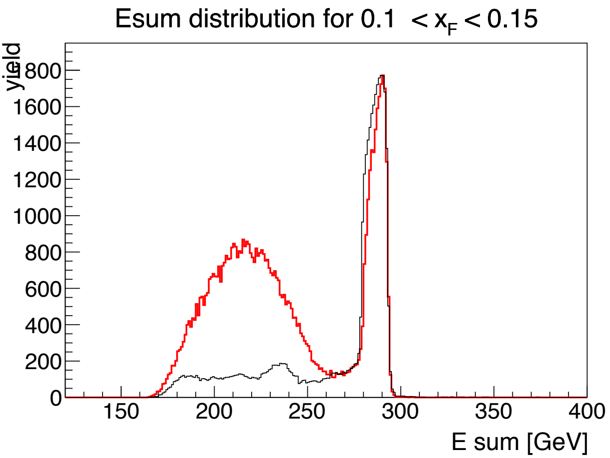


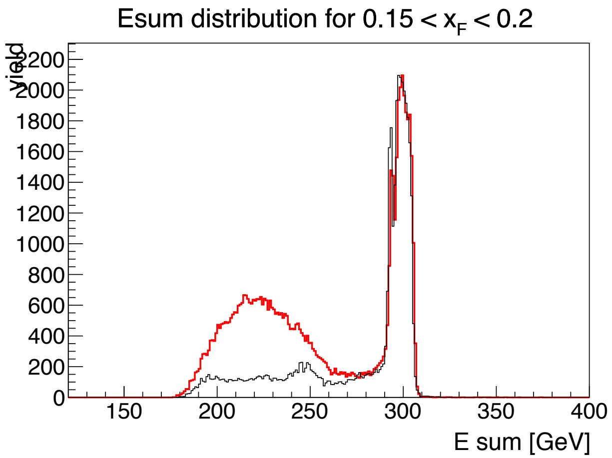


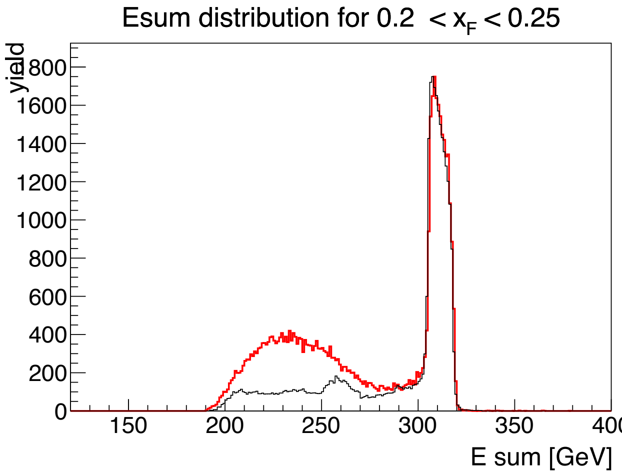
E sum spectrum based on different x_F ranges

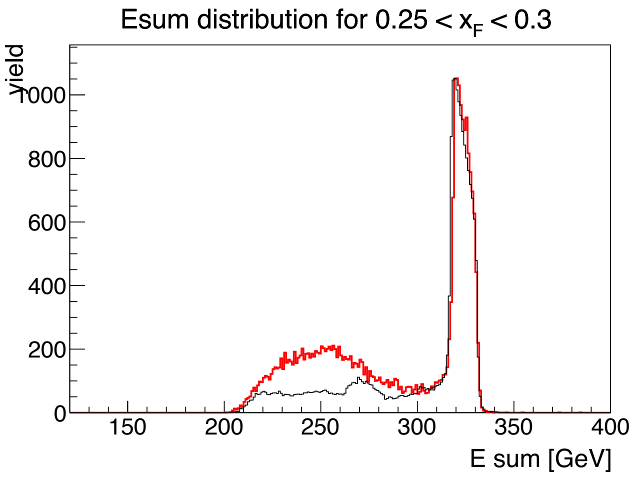
- Data: FMS stream data with **<u>no</u>** <u>east BBC cut</u>, but west BBC cut **<250**.
- <u>All photon multiplicity</u>
- Black curve (Background) is mixed events from zerobias events (scaled to data).
- Red curve is the FMS stream data

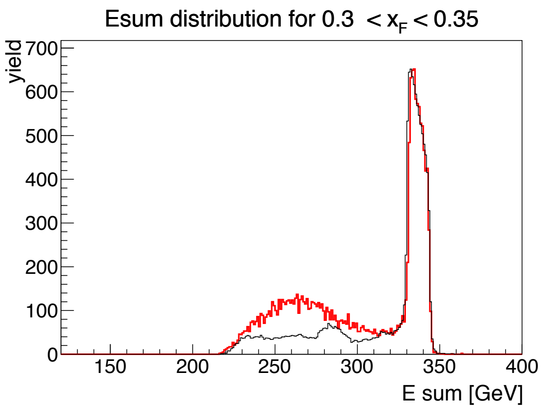
Better!

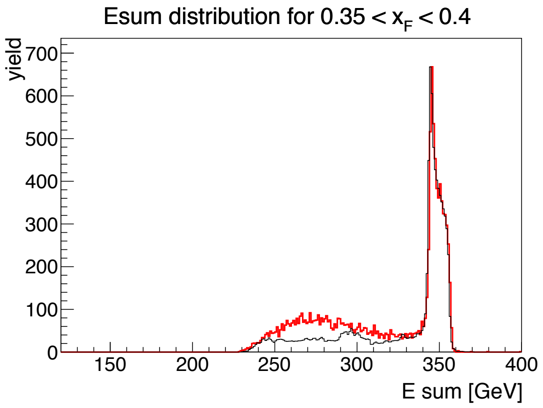


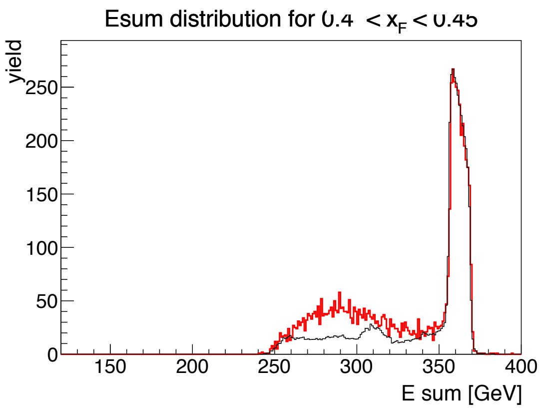








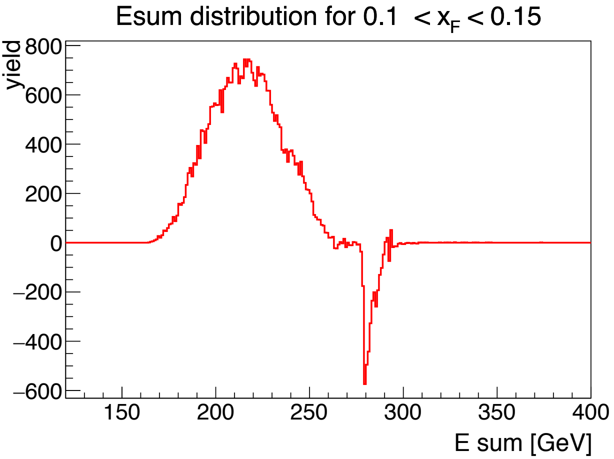


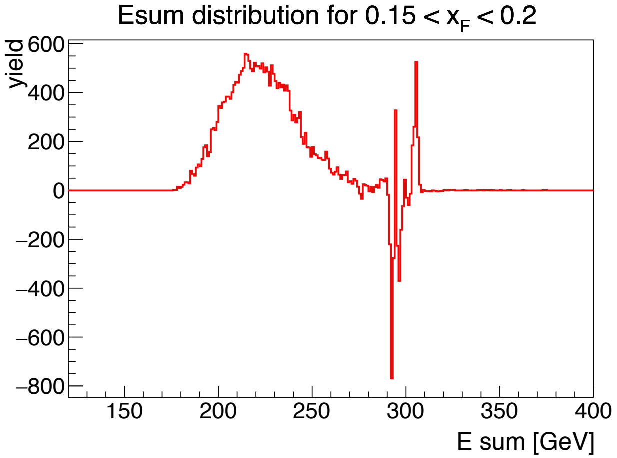


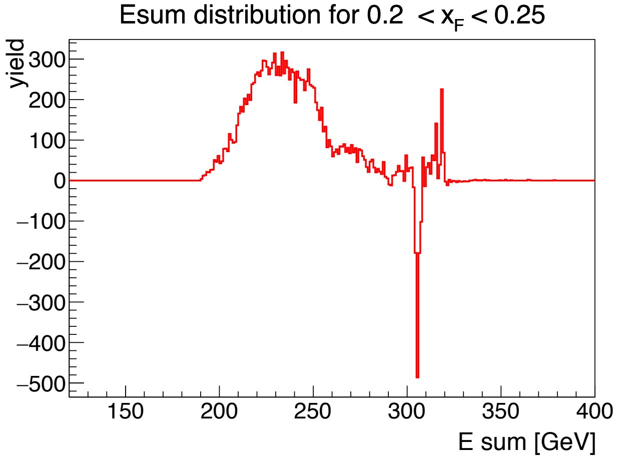
E sum (FMS data – background)

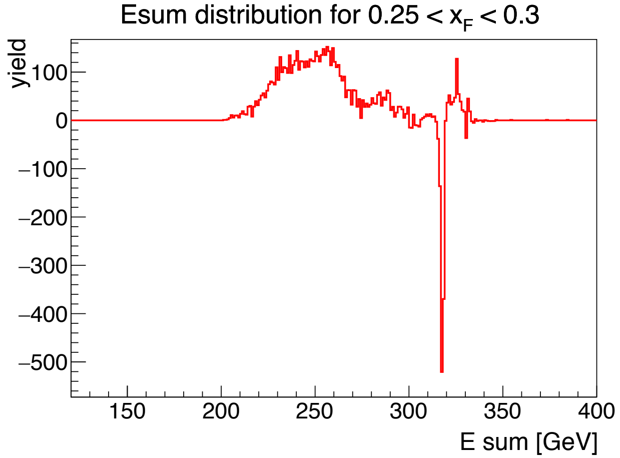
<u>All photon multiplicity</u>

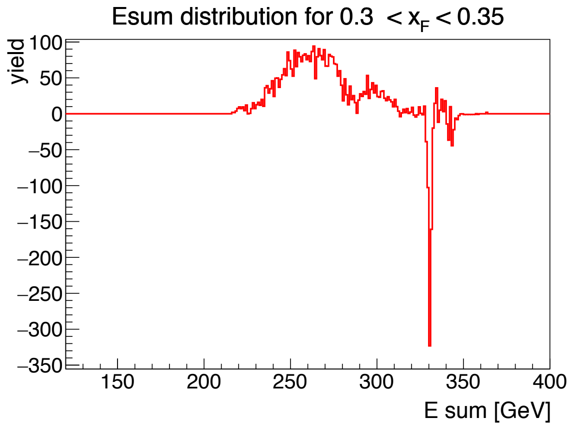
- To be more direct to see the ranges where the FMS data (red curve) over the background (black curve) for each E sum bin, we calculate the yield of FMS data subtracting background.

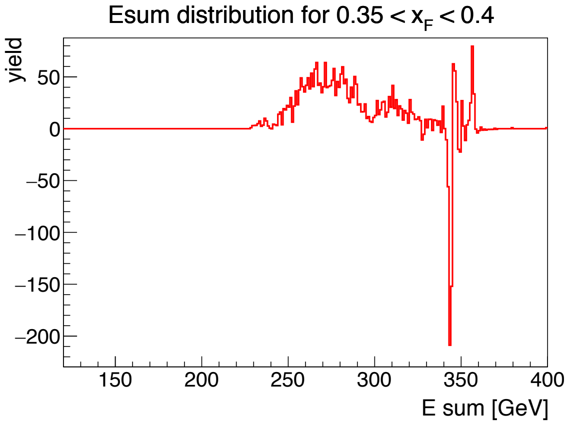


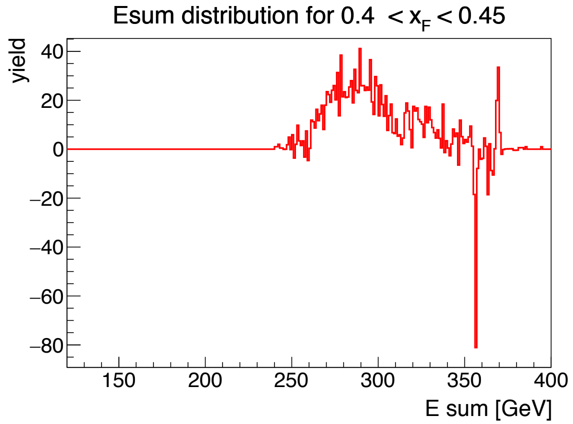












E sum spectrum based on different x_F ranges

- Data: FMS stream data with **no** east BBC cut , but west BBC cut **<250**.
- 1 or 2 photon multiplicity
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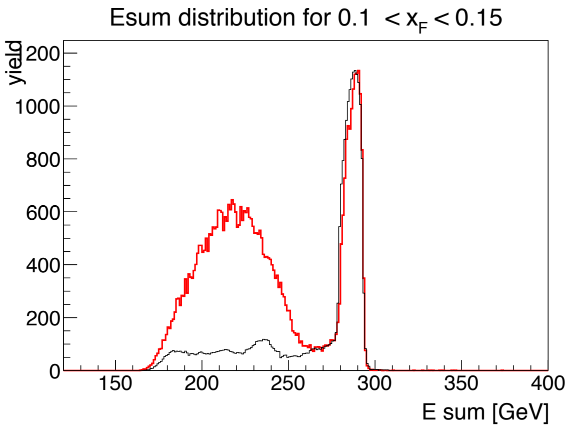

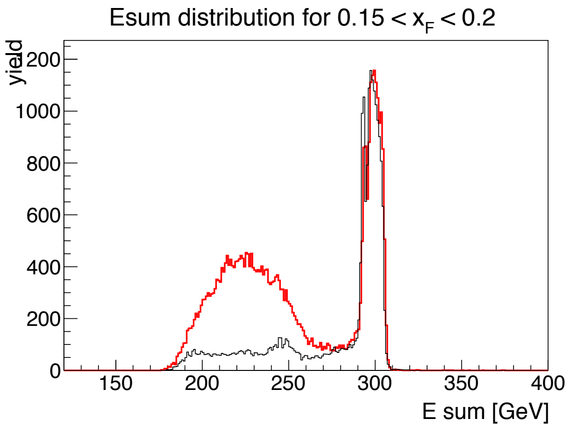

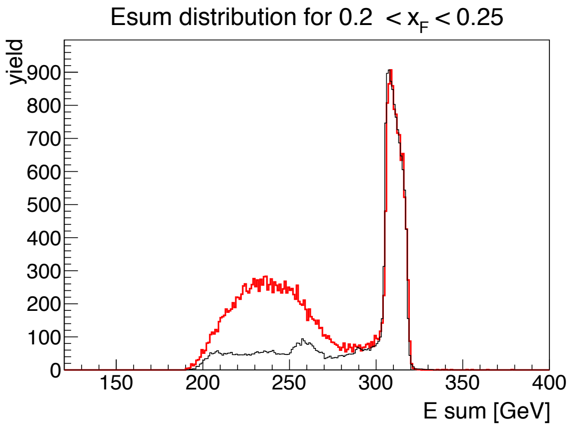

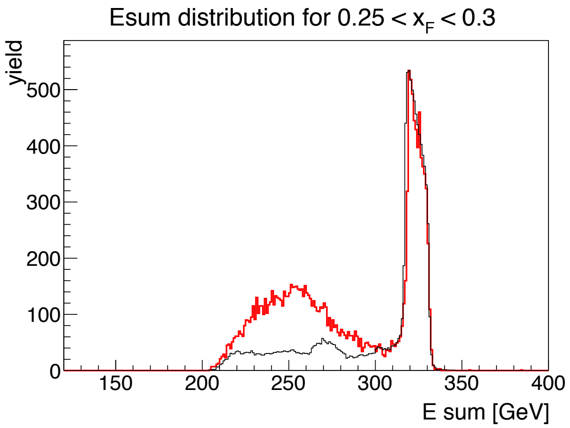

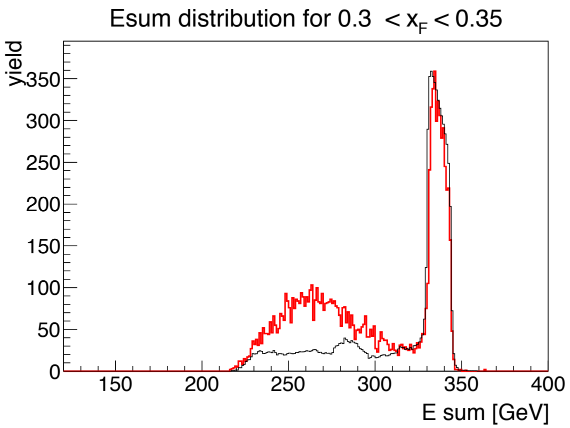

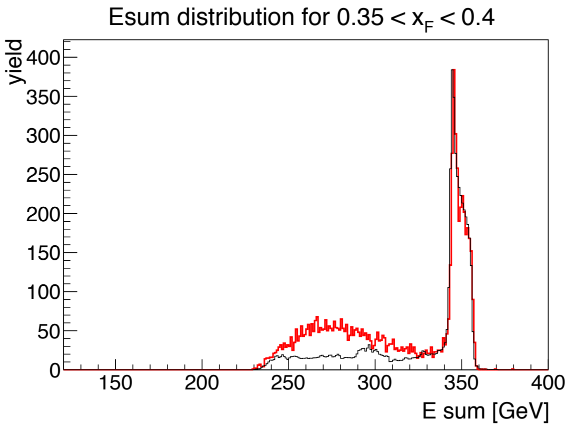

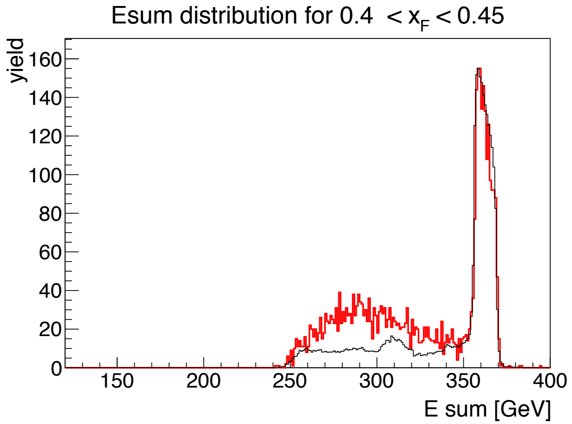

E sum (FMS data – background)

1 or 2 photon multiplicity

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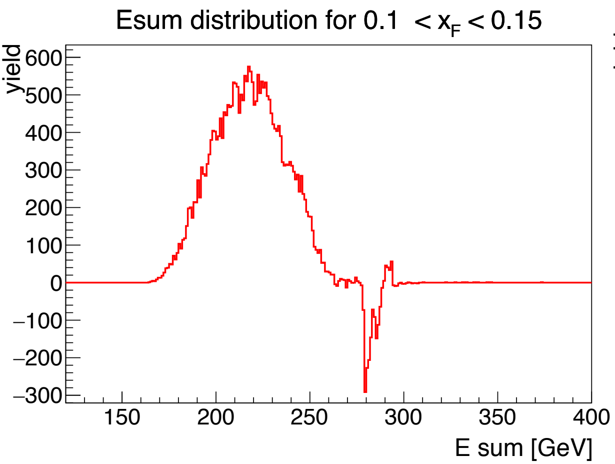
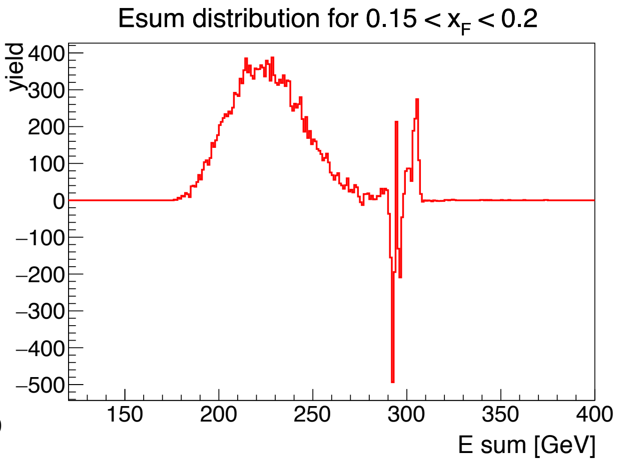
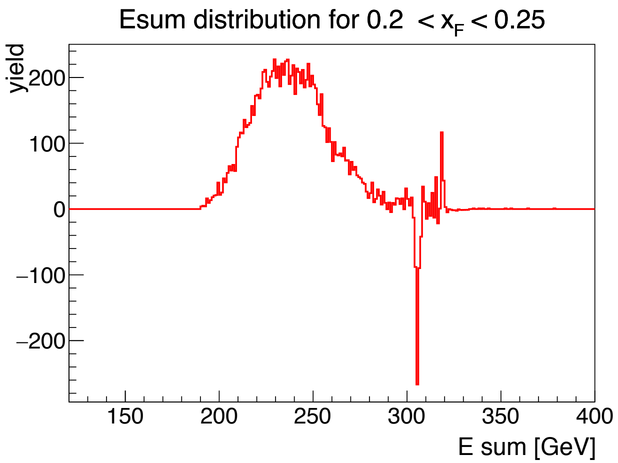
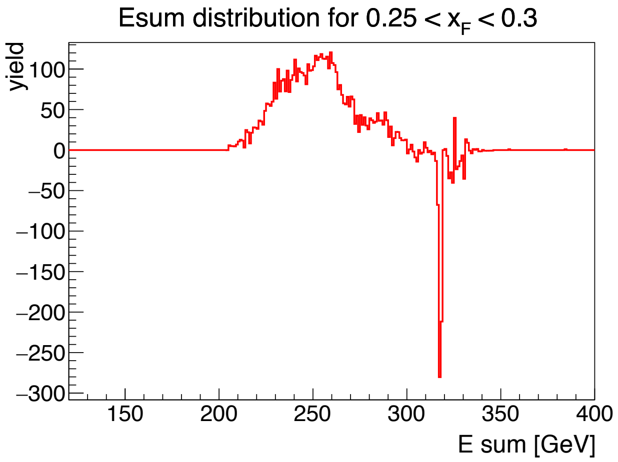
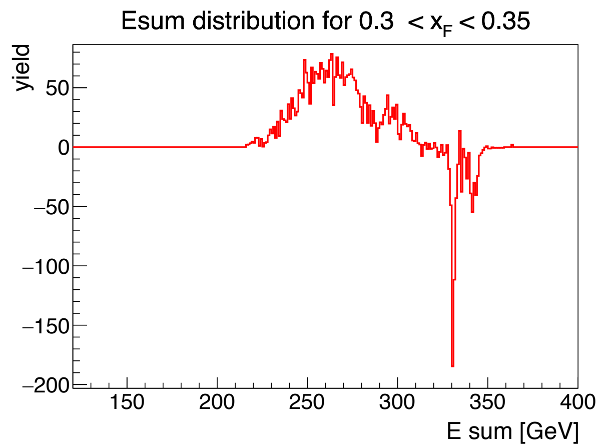
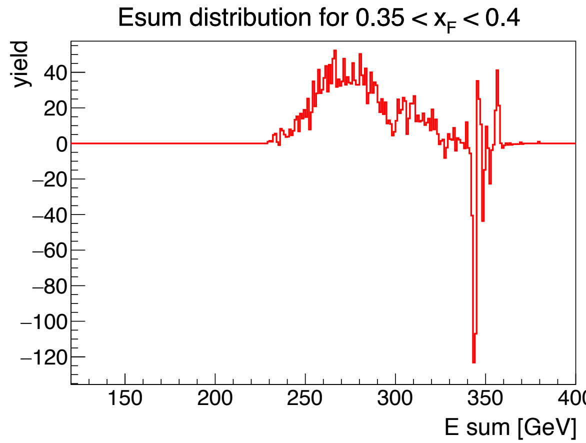


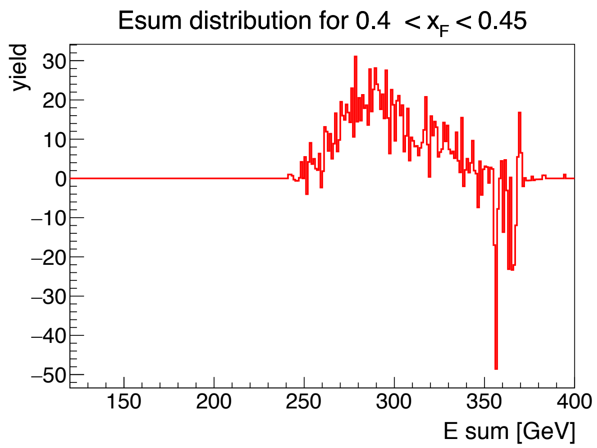












New E sum cut based on the zerobias bkg study

- 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} < 270 GeV
0.2 - 0.25	E_{sum} < 280 GeV
0.25 - 0.3	220 < E_{sum} < 290 GeV
0.3 - 0.35	230 < E_{sum} < 310 GeV
0.35 - 0.4	240 < E_{sum} < 320 GeV
0.4 – 0.45	260 < E_{sum} < 340 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	45637	35747	9890	0.78±0.036	0.22±0.036
0.15 – 0.2	35161	24675	10486	0.70±0.053	0.30±0.053
0.2 – 0.25	22374	13986	8388	0.63±0.064	0.37±0.064
0.25 – 0.3	10655	6006	4649	0.56±0.070	0.44±0.070
0.3 – 0.35	7117	3777	3340	0.53±0.076	0.47±0.076
0.35 – 0.4	4673	2281	2391	0.49±0.090	0.51±0.090
0.4 – 0.45	2595	1302	1293	0.50±0.083	0.50±0.083
0.25 – 0.45	25040	13366	16673	0.53±0.077	0.47±0.077

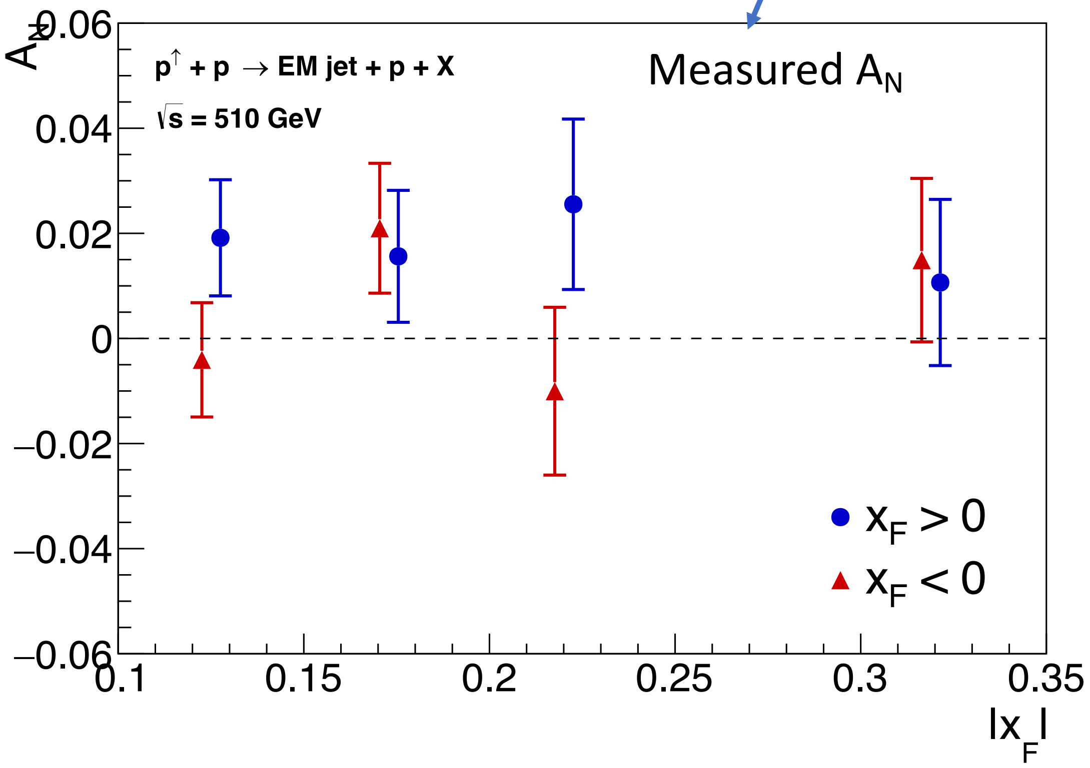
Error propagation for background fraction

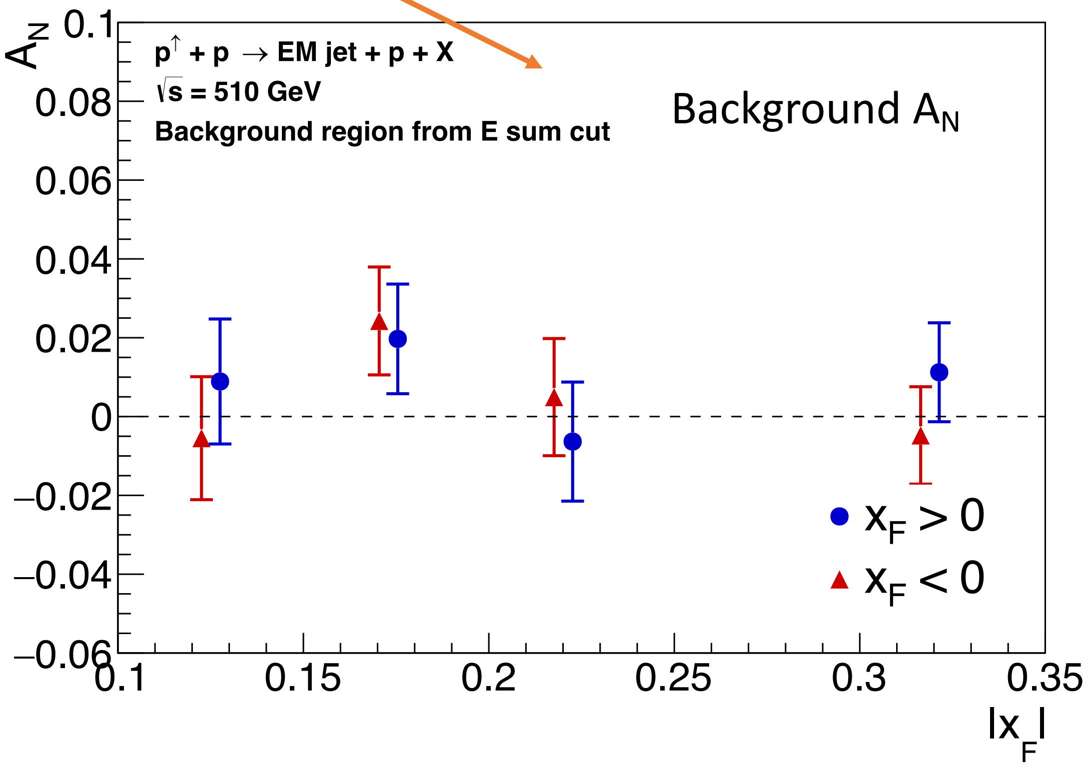
- We start from E sum background shape study: $\mathrm{N}_{Esum}(i+j)=\sum_{i,j} n_{jet}(i)*n_{RP}(j)$
  - $n_{jet}(i)$ is the yield for EM-jet for each energy ; $n_{RP}(j)$ is the yield for west RP (zerobias stream) for each energy
- $\sigma_{N_{Esum}} = \sqrt{\sum_{i,j}[(\frac{\partial y}{\partial n_{jet}(i)})^2\left(\sigma_{n_{RP}(j)}\right)^2+(\frac{\partial y}{\partial n_{RP}(j)})^2\left(\sigma_{n_{jet}(i)}\right)^2]}$
- $= \sqrt{\sum_{i,j}[\left(n_{jet}(i)\right)^2 n_{RP}(j)+(n_{RP}(j))^2 n_{jet}(i)]}$
- Therefore, the count for the background for each energy bin can be expressed by: $n_{Esum}(k)\pm\sigma_{N_{Esum}(k)}$
- $N_{bkg}=scale*\sum_k n_{Esum}(k)$, $\sigma_{N_{bkg}}=scale*\sum_k \sigma_{N_{Esum}}(k)$, where k is each energy with E sum cut.
  - Scale: the scale factor for background shape to FMS data curve.
- Therefore, we get the background fraction: $\frac{N_{bkg}\pm\sigma_{N_{bkg}}}{N_{tot}}$

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.

Error propagation for signal A_N

- $A_N(sig) = \frac{A_N(mea) - frac(bkg) * A_N(bkg)}{frac(sig)} = \frac{A_N(mea) - frac(bkg) * A_N(bkg)}{1 - frac(bkg)}$
- $\sigma^2 = \left(\frac{\partial A_N(sig)}{\partial A_N(mea)}\right)^2 \sigma A_N^2(mea) + \left(\frac{\partial A_N(sig)}{\partial frac(bkg)}\right)^2 \sigma frac^2(bkg) + \left(\frac{\partial A_N(sig)}{\partial A_N(bkg)}\right)^2 \sigma A_N^2(bkg)$
- $= \left(\frac{1}{1 - frac(bkg)}\right)^2 \sigma A_N^2(mea) + \left(\frac{A_N(sig)}{1 - frac(bkg)}\right)^2 \sigma frac^2(bkg) + \left(\frac{frac(bkg)}{1 - frac(bkg)}\right)^2 \sigma A_N^2(bkg)$
- $= \left(\frac{1}{frac(sig)}\right)^2 \sigma A_N^2(mea) + \left(\frac{A_N(sig)}{frac(sig)}\right)^2 \sigma frac^2(bkg) + \left(\frac{frac(bkg)}{frac(sig)}\right)^2 \sigma A_N^2(bkg)$

Systematic uncertainty

- $A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$
- Systematic uncertainty for $A_N(measured)$
  - Small BBC west cut, E sum cut
- Systematic uncertainty for $A_N(bkg)$
  - Small BBC west cut
- Systematic uncertainty for $frac(sig)$
- Polarization uncertainty
  - 1.1%

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 calculation:

$$\sqrt{sys_{A_N(measured)}^2 + sys_{A_N(bkg)}^2 + sys_{frac(bkg)}^2}$$

Systematic uncertainty results

- Small BBC west sum ($A_N(measured)$)

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.00094	0	0.00015	0.010
0.15 – 0.2		0		0
0.2 – 0.25		0		0.011
0.25 – 0.45		0		0.0010

- Small BBC west sum (A_N (bkg))

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.00037	0	0.0025	0
0.15 – 0.2		0		0.012
0.2 – 0.25		0		0
0.25 – 0.45		0		0.00010

- E sum (A_N (measured))

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.00067	0.00067	0.00042	0
0.15 – 0.2		0		0
0.2 – 0.25		0		0.0097
0.25 – 0.45		0		0

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

Systematic uncertainty for $frac(sig)$

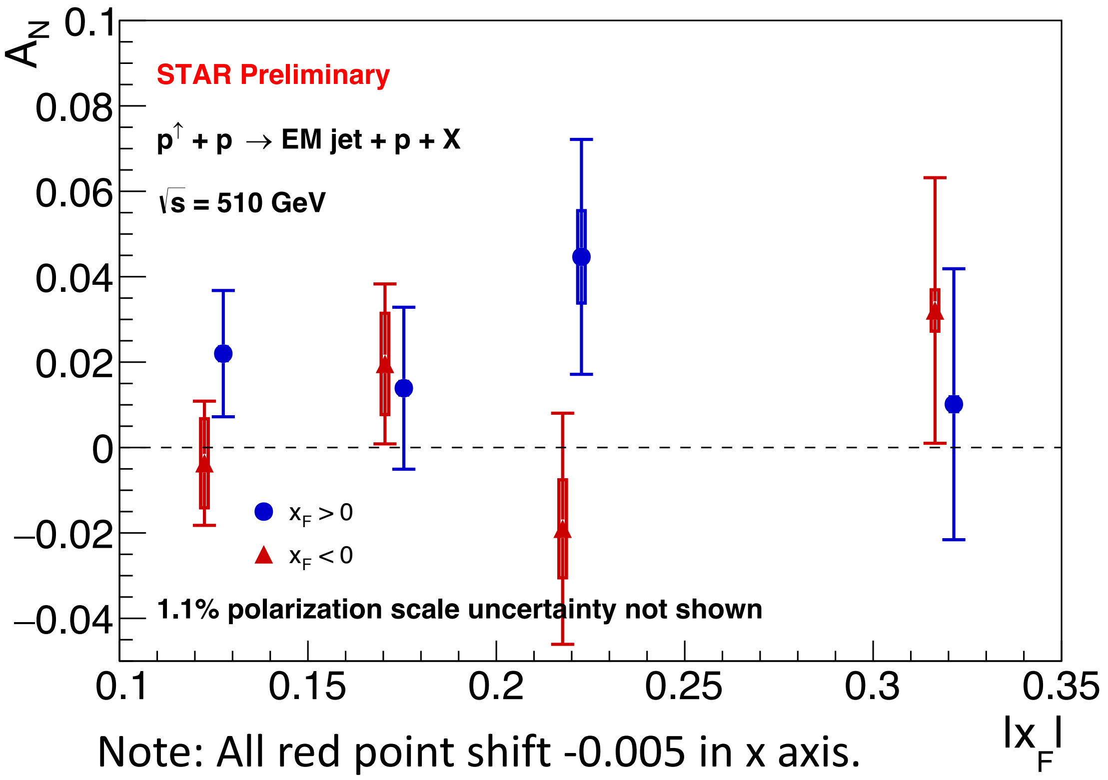
- For the systematic uncertainty, use west RP track from samples of RP stream to do the mix event for background study for systematic uncertainty.
- Apply the difference of the signal fraction to assign for systematic.

xF	West RP track from zerobias stream (analysis) $frac_{ana}(sig)$	West RP track from RP stream (systematic) $frac_{sys}(sig)$	sys
0.1 – 0.15	0.78±0.036	0.89±0.003	0.050
0.15 – 0.2	0.70±0.053	0.87±0.004	0.074
0.2 – 0.25	0.63±0.065	0.85±0.004	0.10
0.25 – 0.45	0.53±0.077	0.80±0.005	0.12

$$sys = \left|frac_{ana}(sig) - frac_{sys}(sig)\right| - \sqrt{(\sigma_{ana}^2 + \sigma_{sys}^2)}$$

Signal A_N results for all photon multiplicity

- 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])**
- **Preliminary plot** request for diffractive EM-jet A_N for all photon multiplicity EM-jets



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

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

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

- Blue beam: 0.021 +/- 0.010. (2.05 σ)
- Yellow beam: 0.0053 +/- 0.012. (0.45 σ)

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	33115	26975	6140	0.81±0.031	0.19±0.031
0.15 – 0.2	23640	17940	5700	0.76±0.044	0.24±0.044
0.2 – 0.25	15046	10747	4299	0.71±0.049	0.29±0.049
0.25 – 0.3	7365	4952	2413	0.67±0.052	0.33±0.052
0.3 – 0.35	4962	3060	1902	0.62±0.062	0.38±0.062
0.35 – 0.4	3327	1942	1385	0.58±0.073	0.42±0.073
0.4 – 0.45	1819	1063	756	0.58±0.069	0.42±0.069
0.25 – 0.45	17473	11016	6457	0.63±0.061	0.37±0.061

Measured A_N and background A_N

EM-jet with photon multiplicity 1 or 2

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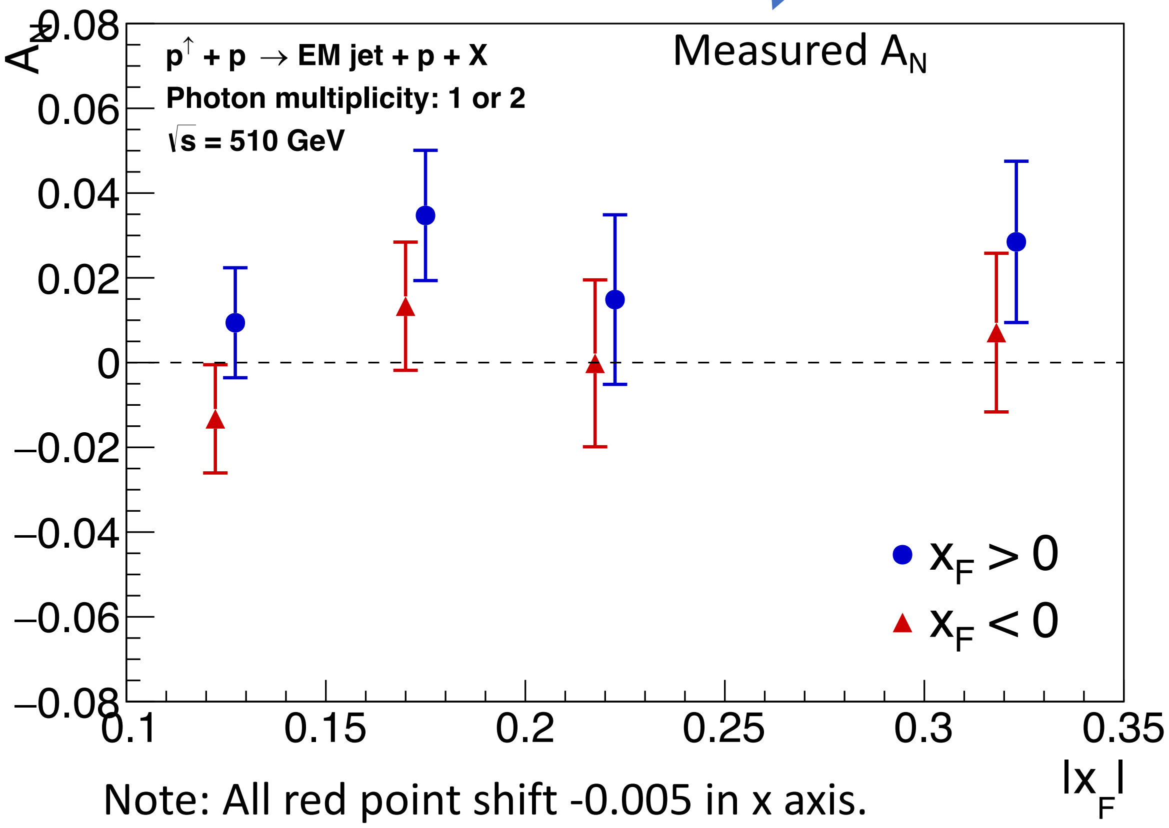

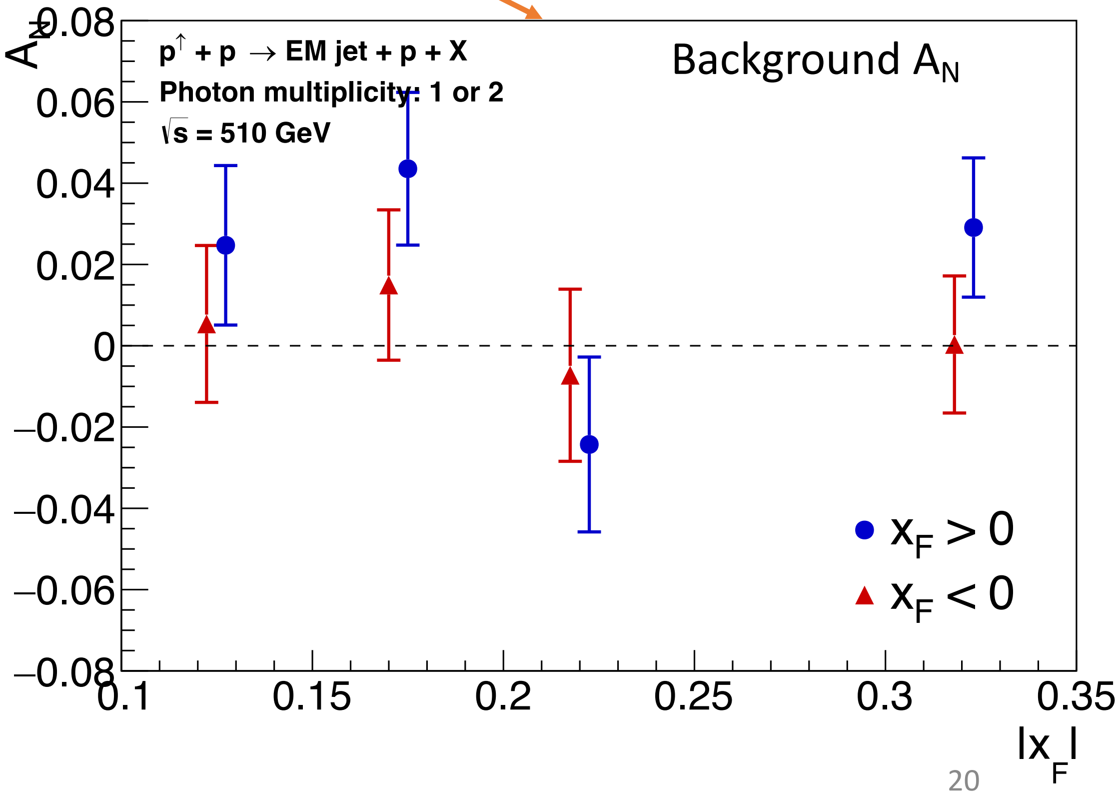

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Systematic uncertainty results

- Small BBC west sum ($A_N(measured)$)

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.00078	0	0.0026	0
0.15 – 0.2		0		0
0.2 – 0.25		0		0
0.25 – 0.45		0		0

- Small BBC west sum (A_N (bkg))

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.0045	0	0.0029	0
0.15 – 0.2		0		0
0.2 – 0.25		0.018		0
0.25 – 0.45		0		0

- E sum (A_N (measured))

xF (measured)	Method 1 Blue beam	Method 2 Blue beam	Method 1 Yellow beam	Method 2 Yellow beam
0.1 – 0.15	0.0010	0	0.00028	0
0.15 – 0.2		0		0
0.2 – 0.25		0.0098		0
0.25 – 0.45		0		0

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

Systematic uncertainty for $frac(sig)$

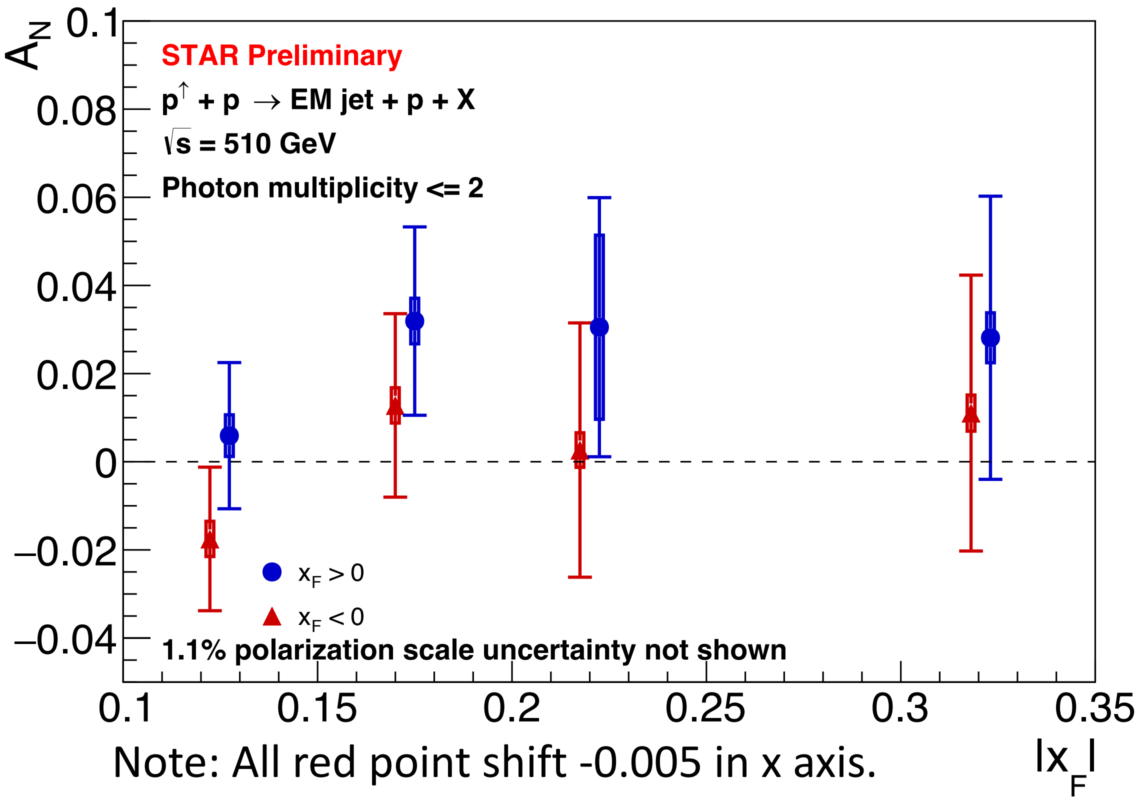
- For the systematic uncertainty, use west RP track from samples of RP stream to do the mix event for background study for systematic uncertainty.
- Apply the difference of the signal fraction to assign for systematic.

xF	West RP track from zerobias stream (analysis) $frac_{ana}(sig)$	West RP track from RP stream (systematic) $frac_{sys}(sig)$	sys
0.1 – 0.15	0.81±0.031	0.89±0.0027	0.046
0.15 – 0.2	0.76±0.044	0.87±0.0036	0.066
0.2 – 0.25	0.71±0.049	0.85±0.0040	0.090
0.25 – 0.45	0.63±0.061	0.80±0.0050	0.11

$$sys = |frac_{ana}(sig) - frac_{sys}(sig)| - \sqrt{(\sigma_{ana}^2 + \sigma_{sys}^2)}$$

Signal A_N results for photon multiplicity <= 2

- 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]**)
- **Preliminary plot** request for diffractive EM-jet A_N for 1 or 2 photon multiplicity EM-jets



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

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

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

- Blue beam: 0.019 +/- 0.011. (1.6 σ)
- Yellow beam: 0.0025 +/- 0.011 (0.22 σ)

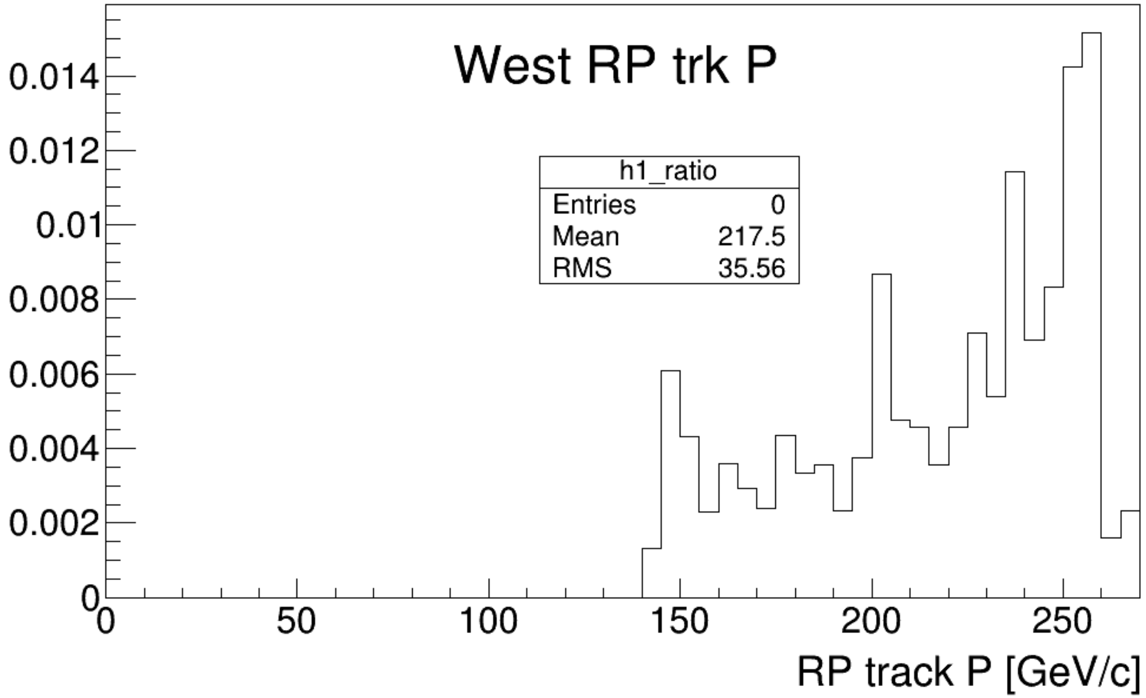
Conclusion and outlook

- Small BBC east sum cuts are not needed, and the E sum plots with background estimation study looks good.
- The diffractive EM-jet A_N for all photon multiplicity, and, 1 or 2 photon multiplicity EM-jets are calculated.
- The systematic uncertainty looks more reasonable now.
- Request for preliminary for the A_N result plots.
  - Preliminary request slide in the same title of my talk in PWG meeting
- Next to do: compare with inclusive EM-jet A_N results and generate the plots for SPIN 23 conference.
  - 1 or 2 photon multiplicity EM-jet A_N for inclusive/diffractive processes.

Back up

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
- Ratio of yield of zerobias west RP to FMS stream west RP. (Rebin(5))



E sum spectrum based on different x_F ranges

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