Diffractive EM Jet A_N at FMS with run 17 data preliminary request

Xilin Liang

UC Riverside

Sept. 06, 2023

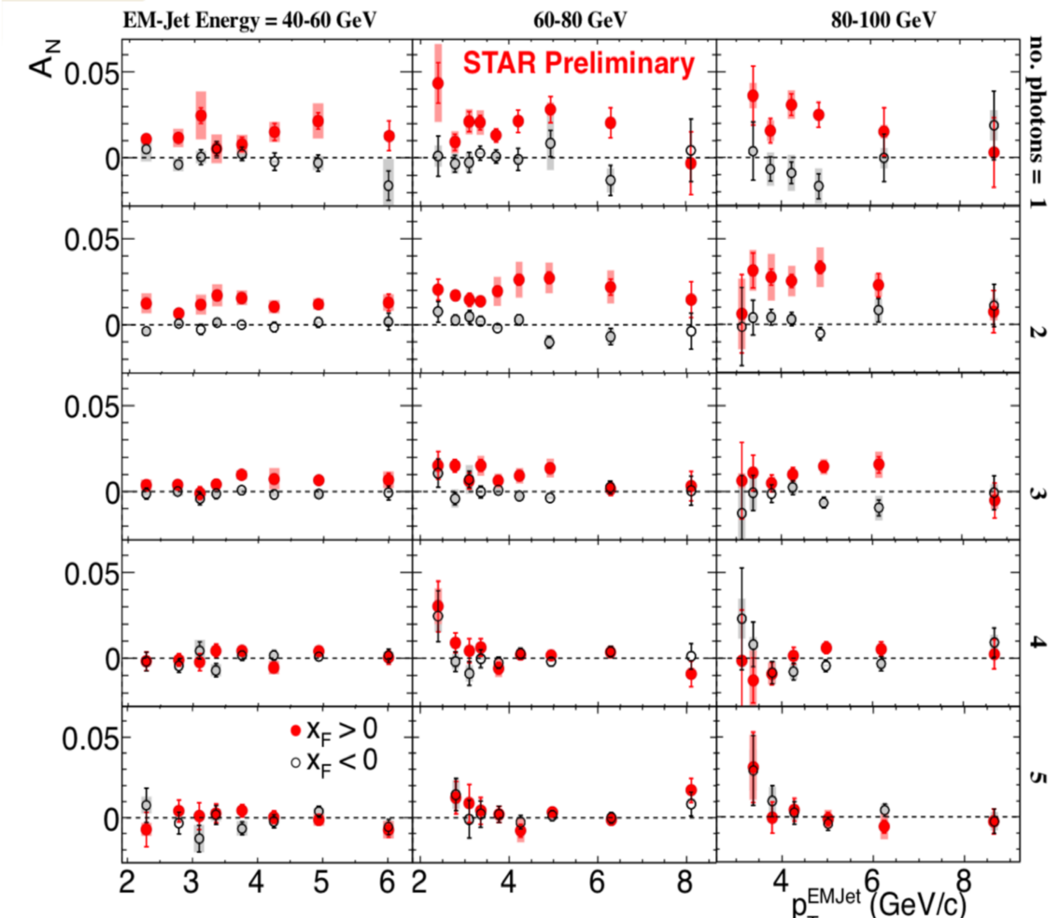
Contact information

- PA: **Xilin Liang**[1], Kenneth Barish[1]
- PA email address: xilin.liang@email.ucr.edu
- Supervisor: Kenneth Barish[1]
- Supervisor email address: kenneth.barish@ucr.edu

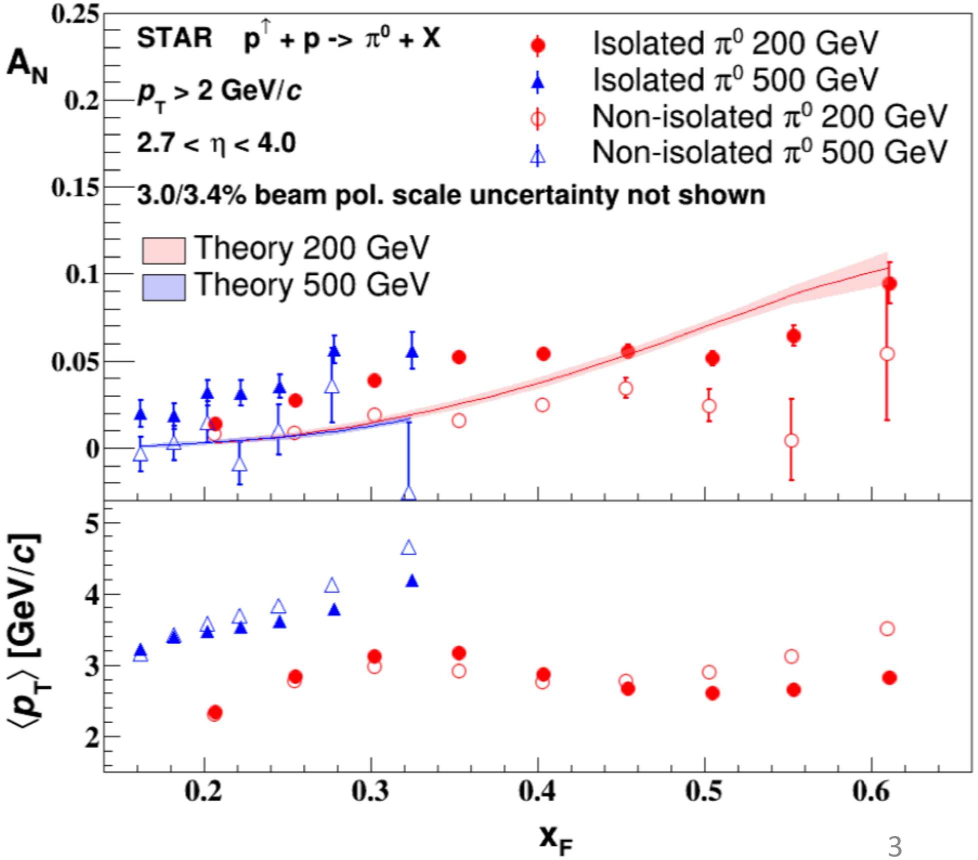
[1] Institution: UC Riverside

Physics motivation

- Diffractive process may play a role to explain large A_N.
  - A_N decreases with Increasing number of photons in EM jets.
  - Isolated π^0 events have larger A_N.



Ref: Mriganka Mondal DIS 2014



Ref: Phys. Rev. D **103**, 092009 (2021)

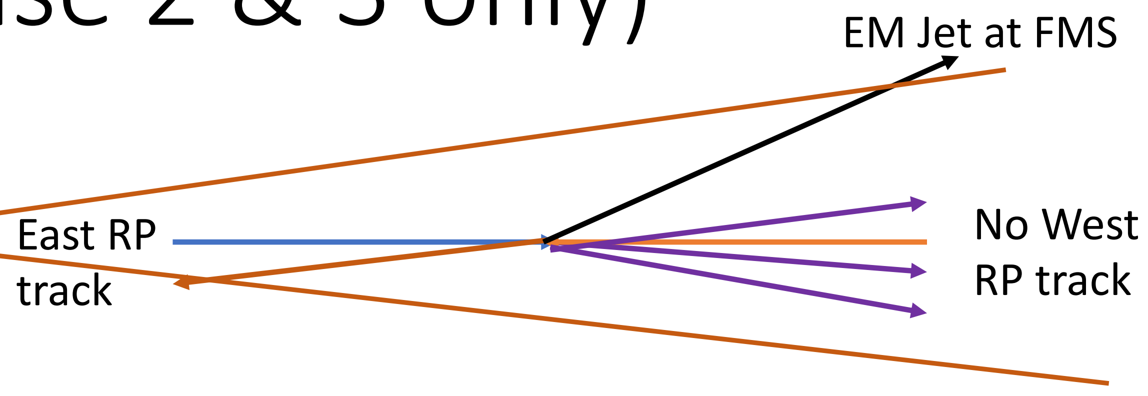
Data set

- 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
- Requirement: Event must contain Roman Pot (RP) information (pp2pp).
  - Already filter out events without RP response. Totally 180 fills.

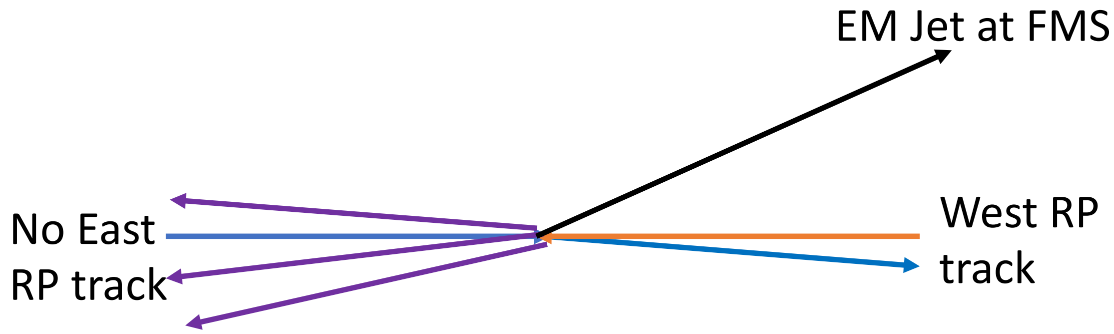
Total number of events from data set sample (with FMS and RP coincidence)	882 M
Total number of events with FMS points	874 M
Total number of events with FMS EM-jets	860 M

Diffractive process (case 2 & 3 only)

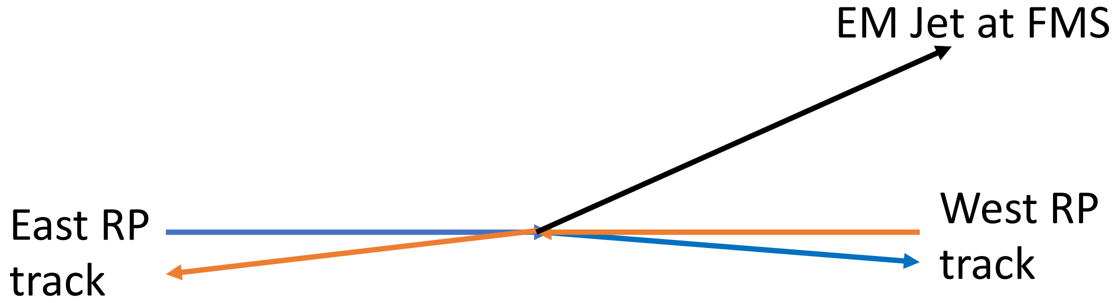
~~Case 1:~~
~~Single diffractive event: we can detect only 1 proton track on east side RP.~~
~~Require: only 1 east side RP track~~



Case 2:
Single diffractive event: we can detect only 1 proton track on west side RP.
Require: sum of west side tracks energy (proton + EM Jet) less than beam energy



Case 3:
Double diffractive event: we can detect 1 proton track on east side RP and 1 proton track on west side RP.
Require: sum of west side tracks energy (proton + EM Jet) less than beam energy



Procedure for data analysis

MuDst files

Trigger selection, FMS bad/hot channel masking, jet reconstruction, event contains at least 1 RP track information

Nano Dst files (keep the physics measurements used for this analysis)

Event selection with vertex cut, RP cuts , FMS EM jet, sum energy cut and BBC cut

Physics measurements and uncertainty study

Cross ratio method for A_N calculation

Systematic uncertainty

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)

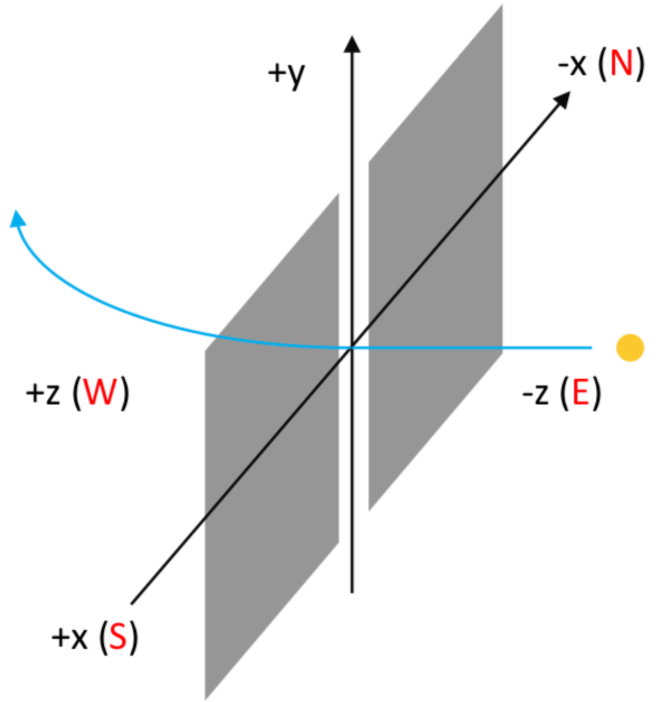
Data set: run 17 pp transverse $\sqrt{s} = 510$ GeV ,fms stream (pp500_production_2017)

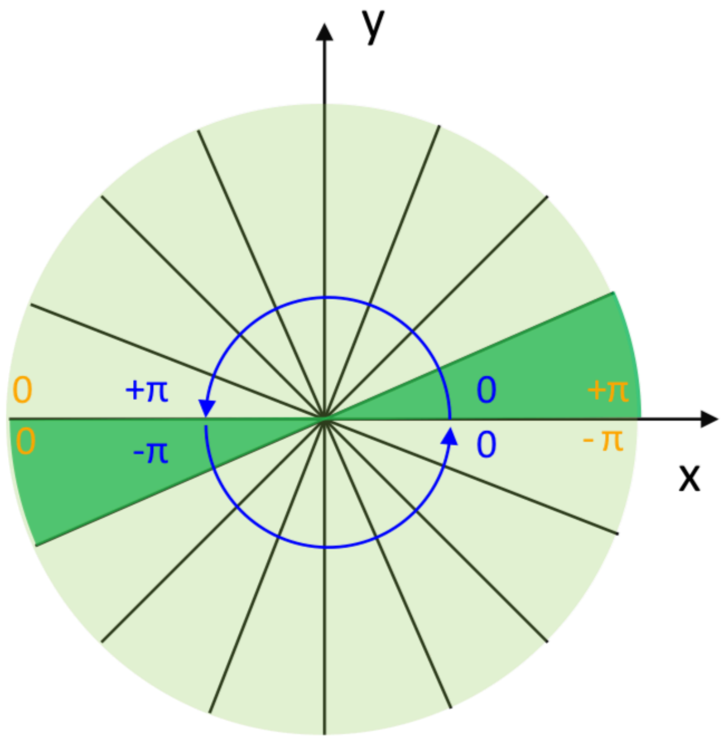
Corrections for EM-jet:
Energy correction and
Underlying Event correction

x_F	E sum cut
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

Transverse single spin asymmetry (A_N) calculation

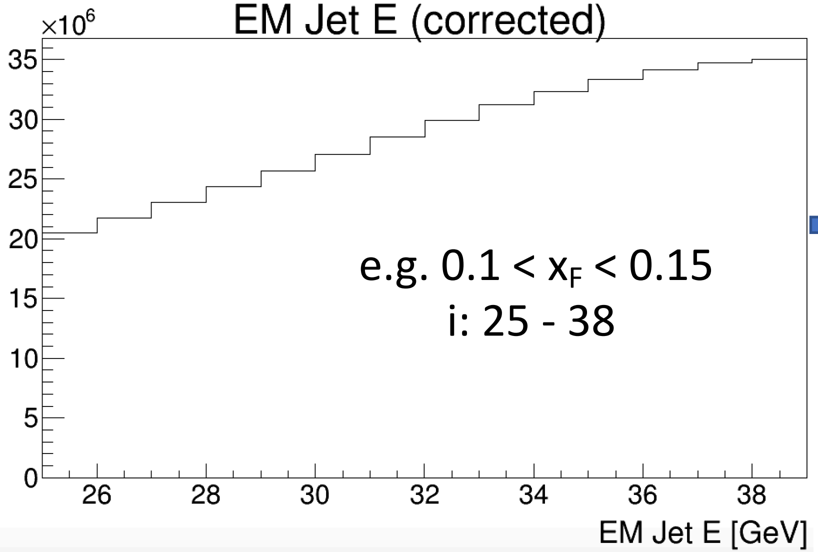
- We use **cross ratio** method to calculate the diffractive EM Jet A_N at FMS.
  - Raw A_N: $\varepsilon = \frac{\sqrt{N^{\uparrow}(\phi)N^{\downarrow}(\phi+\pi)} - \sqrt{N^{\downarrow}(\phi)N^{\uparrow}(\phi+\pi)}}{\sqrt{N^{\uparrow}(\phi)N^{\downarrow}(\phi+\pi)} + \sqrt{N^{\downarrow}(\phi)N^{\uparrow}(\phi+\pi)}} \approx pol * A_N * \cos(\phi)$
  - Plot A_N as a function of X_F. ($x_F = \frac{E_{EM\ jet}}{E_{Beam}}$) , $x_F \in [0.1, 0.45]$
  - Divide full ϕ range [-π , +π] into 16 bins.

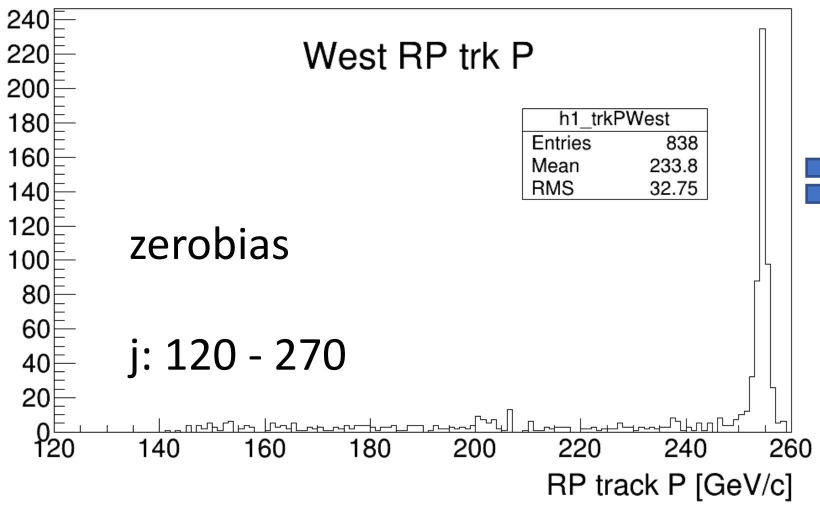


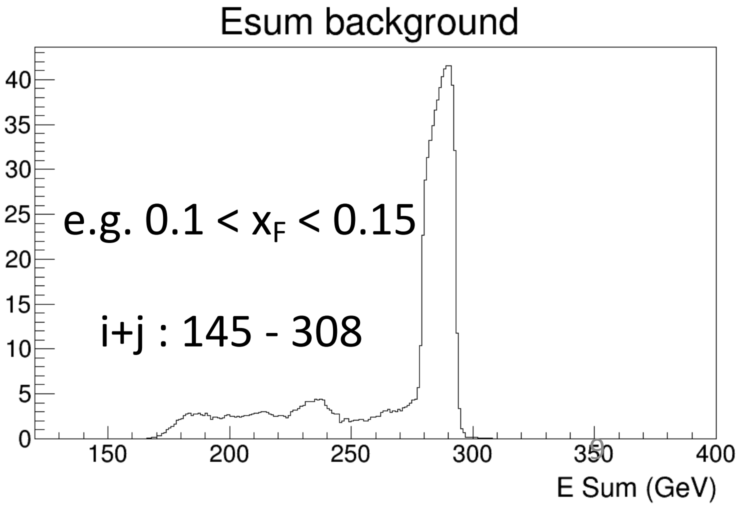


Background study for E sum

- 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: $\boldsymbol{Esum(i+j)} = \sum_{i,j} \boldsymbol{P(i) * n(j)}$, 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).

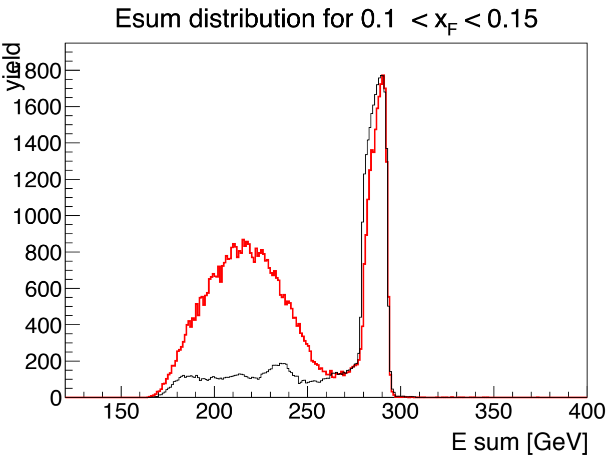


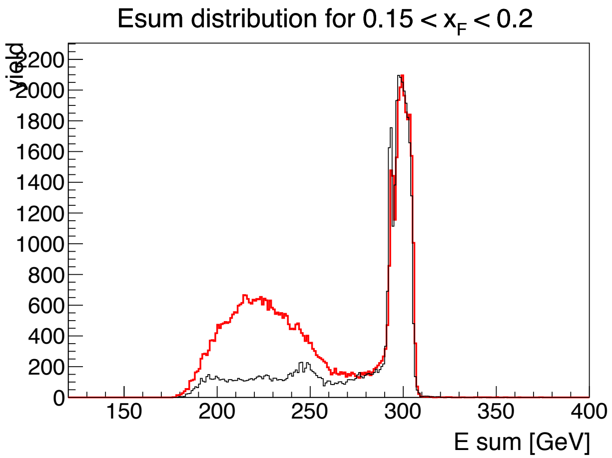


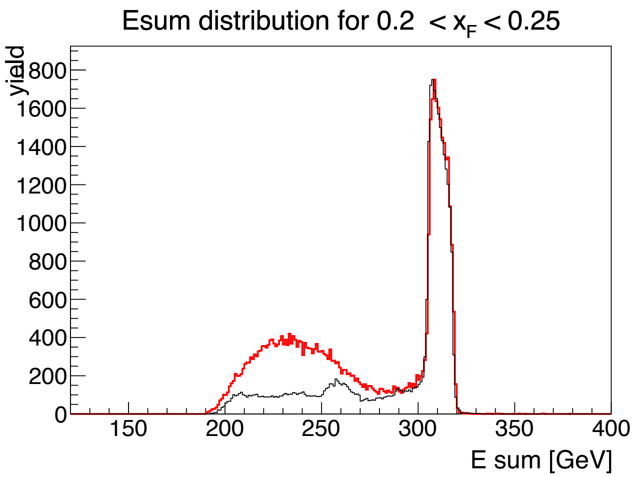


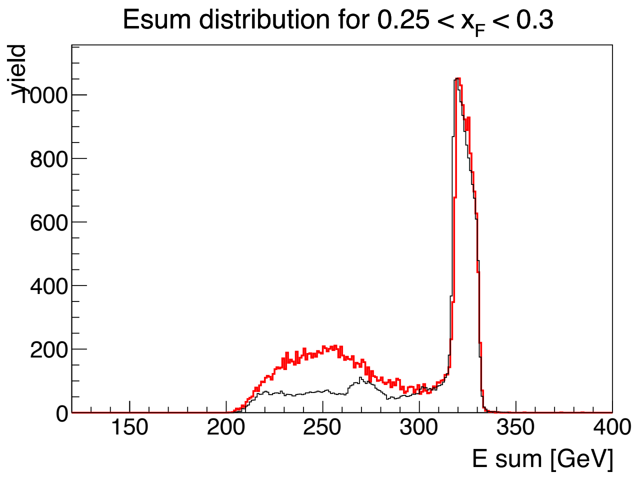
E sum spectrum based on different x_F ranges

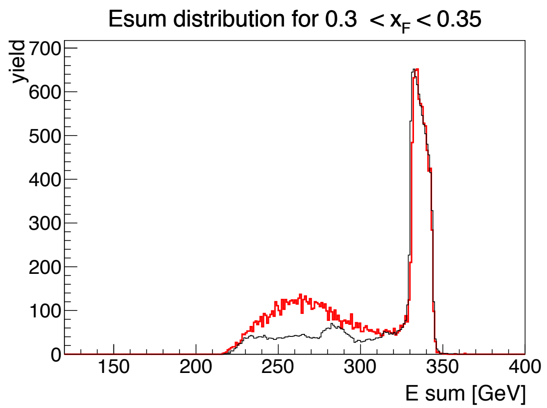
- All photon multiplicity
- Black curve (Background) is mixed events from zerobias events (scaled to data).
- Red curve is the FMS stream data

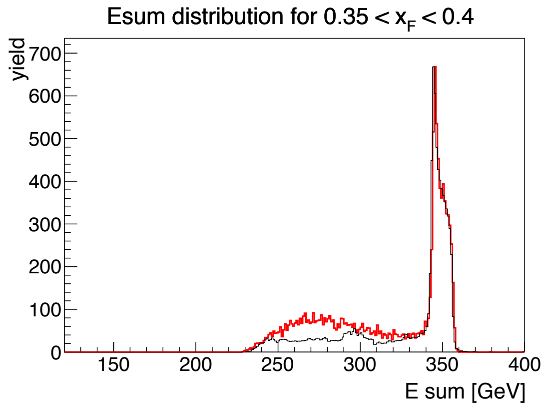


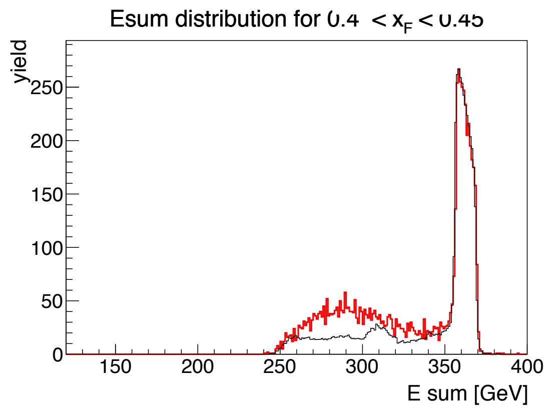






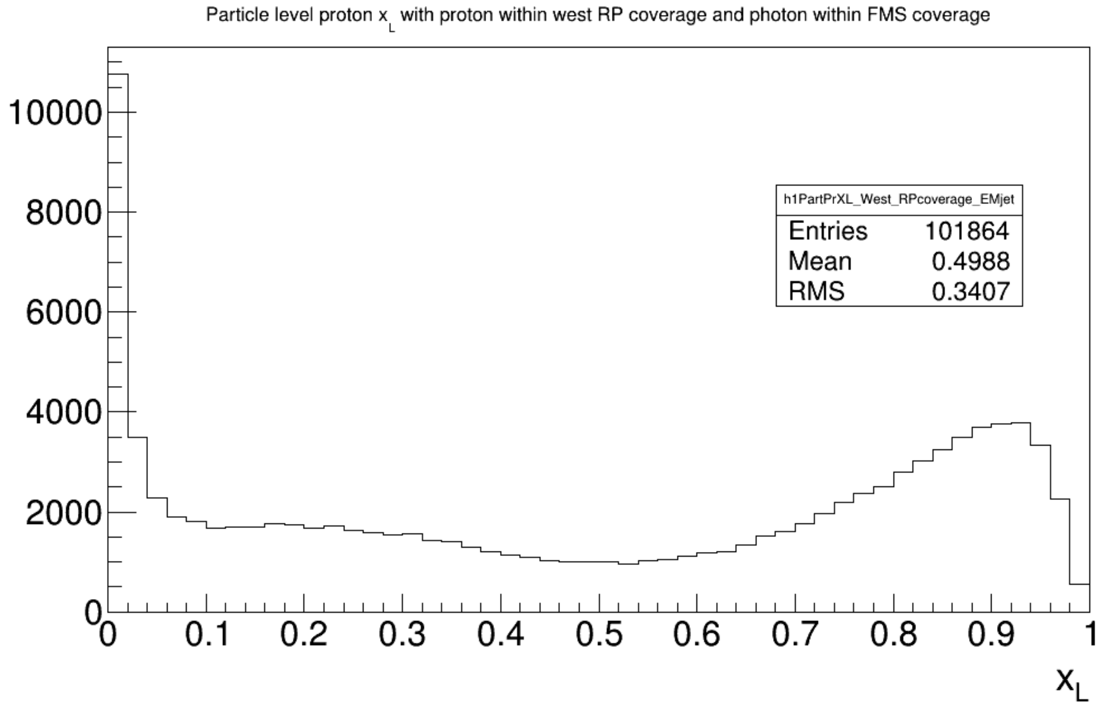






Particle level proton x_L

- Particle level proton x_L with proton within west RP coverage and photon within FMS coverage.
  - $x_L = \frac{E_{proton}}{E_{beam}}$
- In simulation, we can see high x_L is preferred with west RP coverage.
  - (Low x_L can not be detected by RP)



Simulation: 2M hard diffraction simulation events with pp510.

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

- 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

- 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

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

Systematic uncertainty for $frac(sig)$

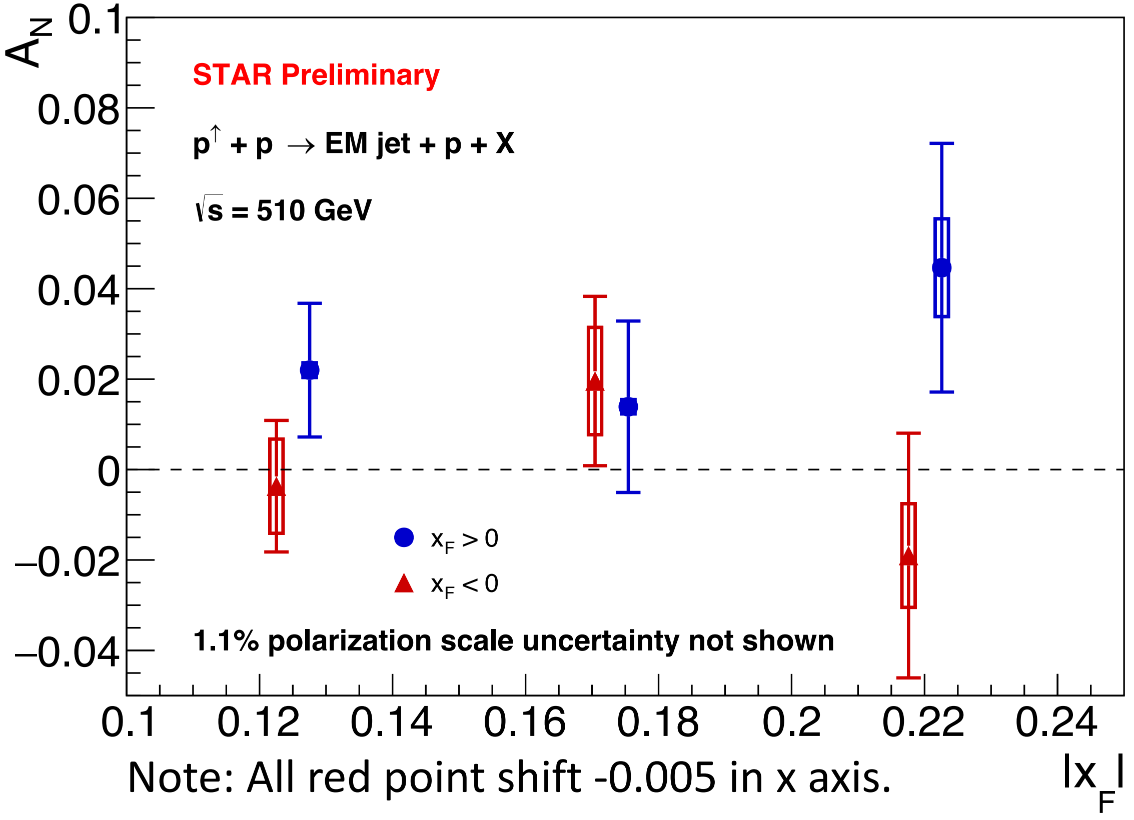
- For the systematic uncertainty, use west RP track from samples of RP stream to do the mix event for background study for systematic uncertainty.
- Apply the difference of the signal fraction to assign for systematic.

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

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

Signal A_N results for all photon multiplicity

- A_N results with 3 x_F bins only
  - **3 x_F bins.** ([0.1, 0.15], [0.15, 0.2], [0.2, 0.25])
- **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.

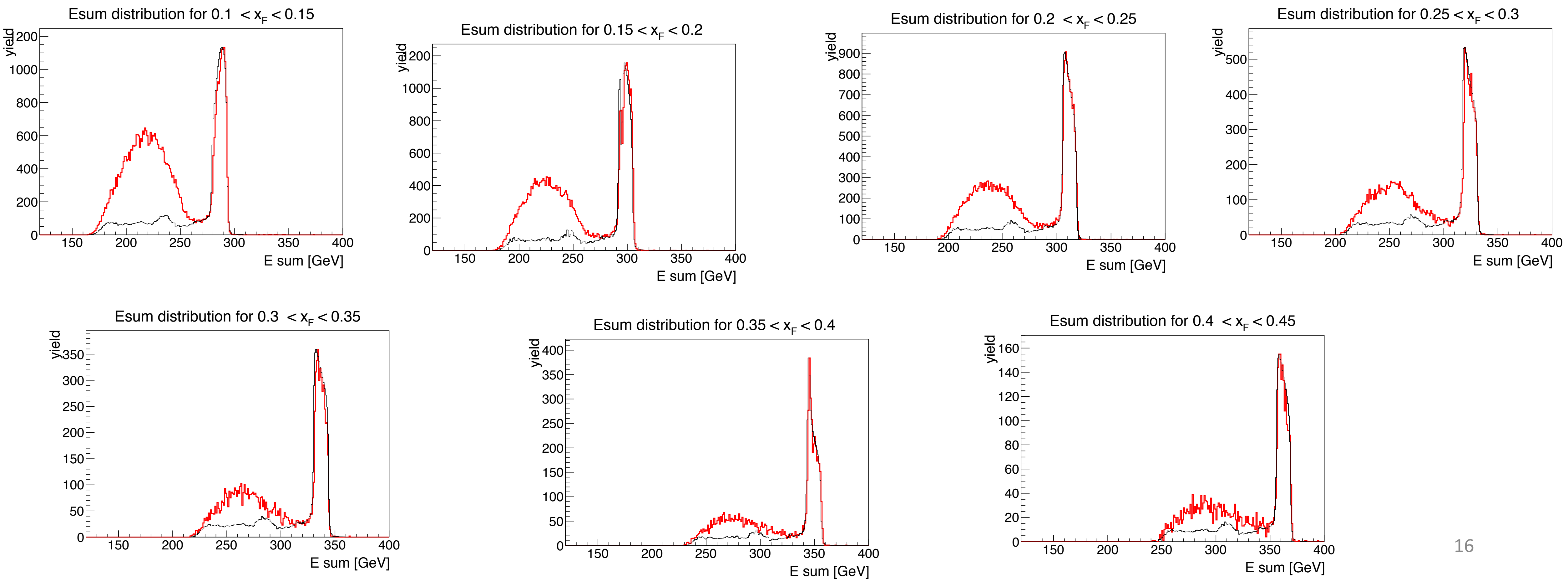
$$A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$$

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

- Blue beam: 0.022 +/- 0.011. (2.05 σ)
- Yellow beam: 0.0010 +/- 0.013. (0.79 σ)

E sum spectrum based on different x_F ranges

- <u>1 or 2 photon multiplicity</u>
- Black curve (Background) is mixed events from zerobias events (scaled to data).
- Red curve is the FMS stream data



Systematic uncertainty results

- 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

- 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

- 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

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

Systematic uncertainty for $frac(sig)$

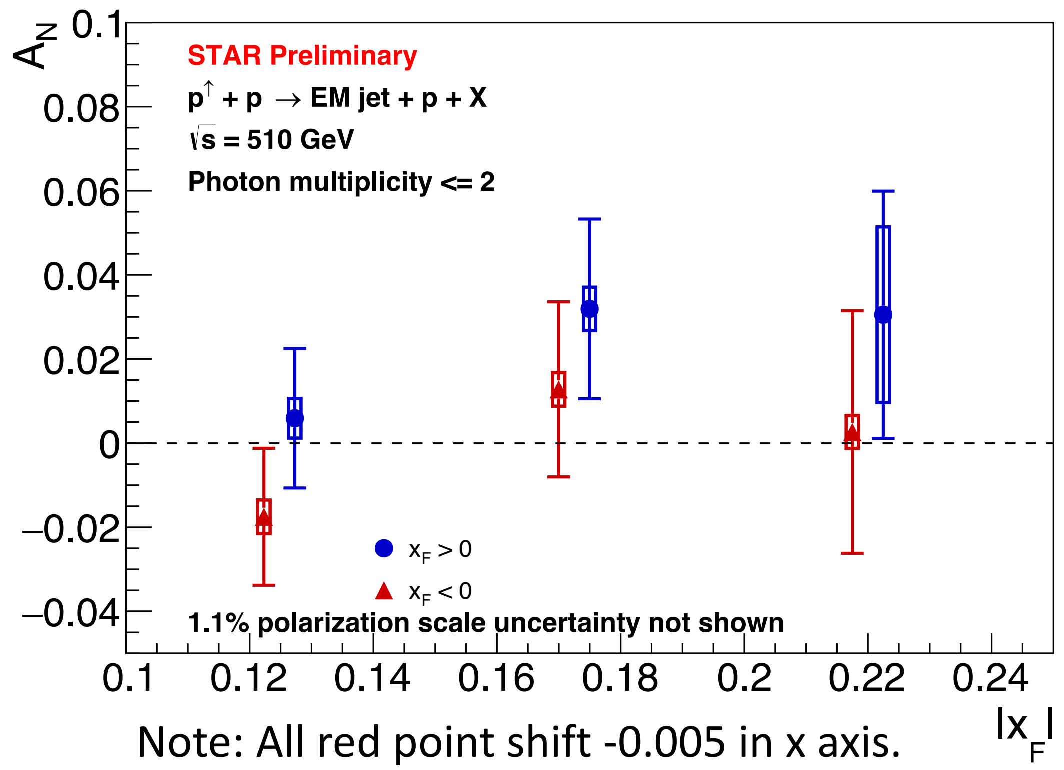
- For the systematic uncertainty, use west RP track from samples of RP stream to do the mix event for background study for systematic uncertainty.
- Apply the difference of the signal fraction to assign for systematic.

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

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

Signal A_N results for **photon multiplicity <= 2**

- A_N results with 3 x_F bins only
  - **3 x_F bins.** ([0.1, 0.15], [0.15, 0.2], [0.2, 0.25])
- **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.

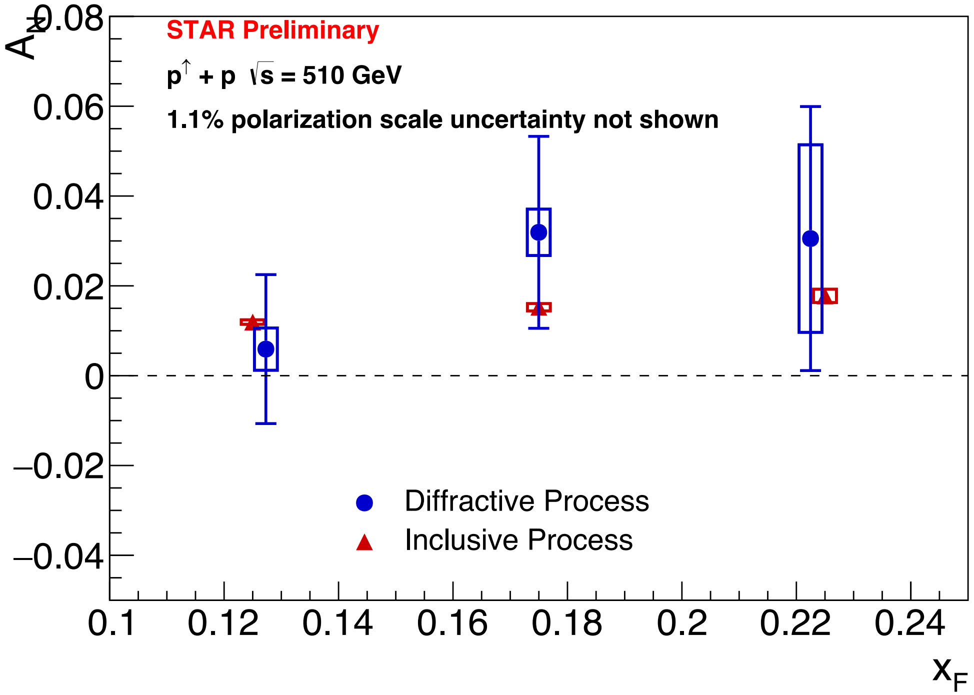
$$A_N(sig) = \frac{A_N(measured) - frac(bkg) * A_N(bkg)}{frac(sig)}$$

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

- Blue beam: 0.018 +/- 0.013. (1.38 σ)
- Yellow beam: -0.0044 +/- 0.012 (0.36 σ)

Comparison between run 17 inclusive and diffractive EM-jet A_N

- Compare the A_N results between inclusive and diffractive process.
  - 1 or 2 photon multiplicity EM-jets are considered.
- Both inclusive and diffractive EM-jet A_N are with the same sign ($A_N > 0$)
- Diffractive process could have some contribution on large A_N for inclusive process at high x_F regions. However, their values are still covered with uncertainties.



Preliminary request plot

Conclusion

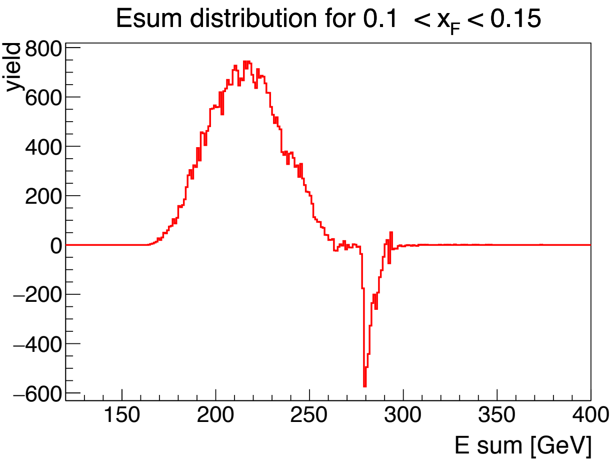
- Run 17 diffractive EM-jet A_N using FMS is at preliminary stage for requesting for preliminary.
- The A_N for run 17 are showing the mostly positive values but close to zero.
- We do not observe the negative sign for A_N, so it's different from run 15 diffractive EM-jet A_N results.

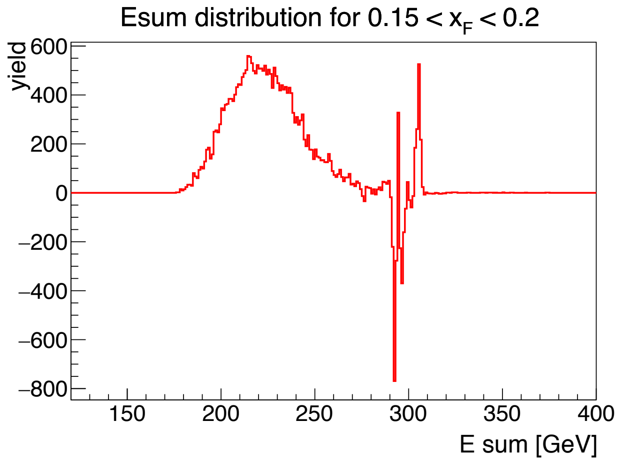
Back up

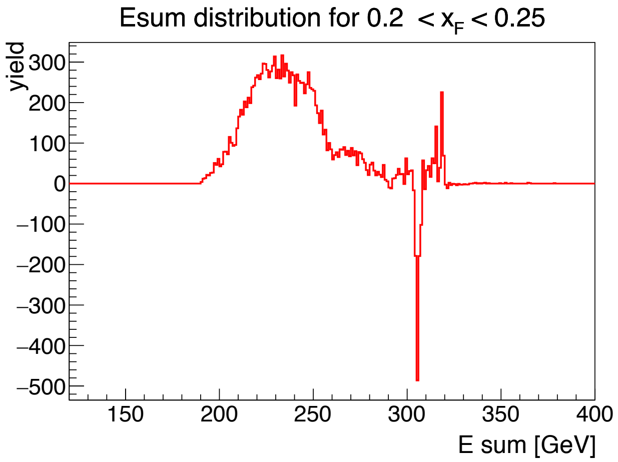
E sum (FMS data – background)

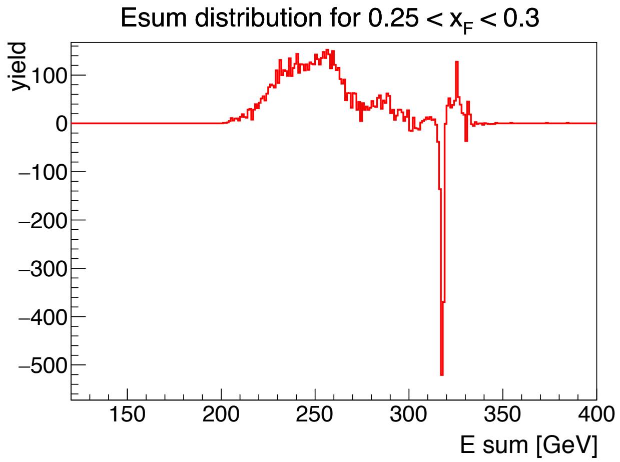
<u>All photon multiplicity</u>

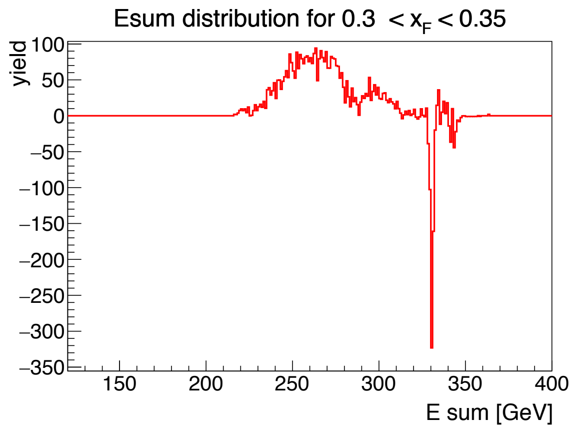
- To be more direct to see the ranges where the FMS data (red curve) over the background (black curve) for each E sum bin, we calculate the yield of FMS data subtracting background.

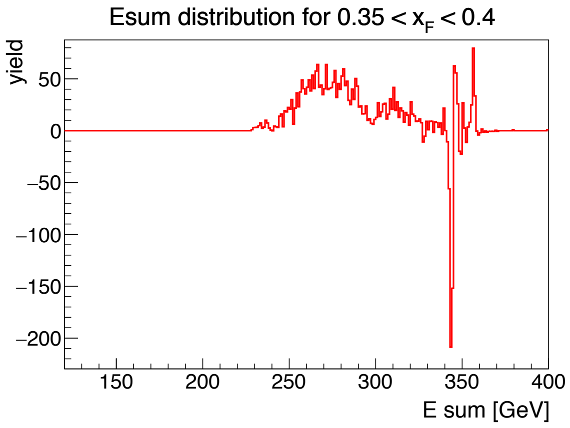


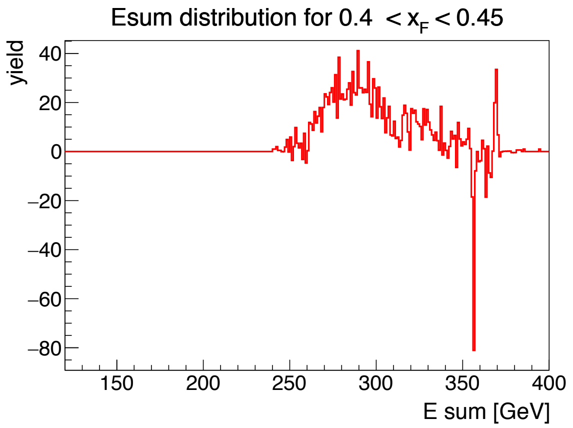








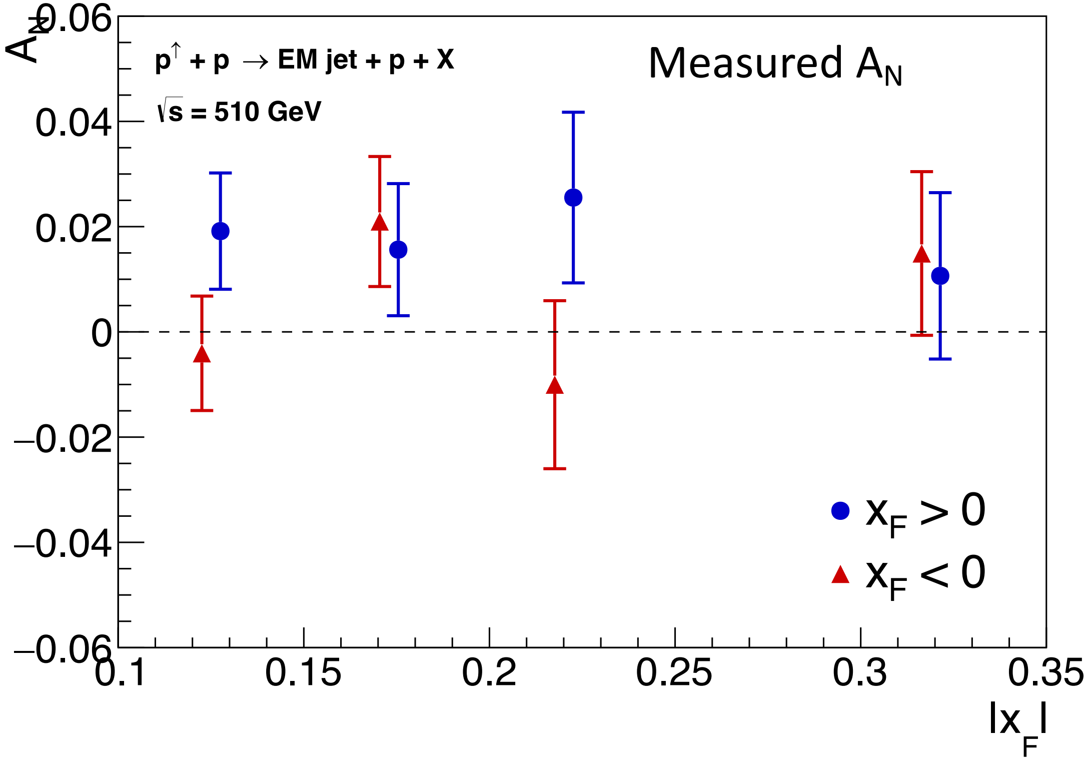


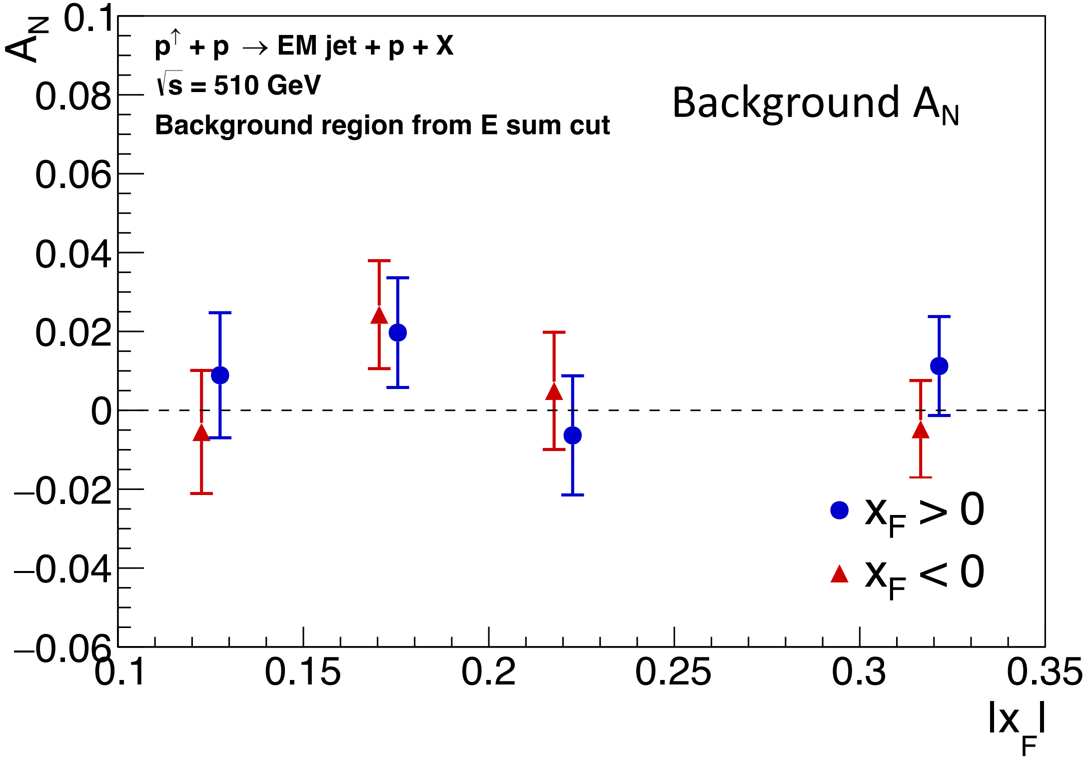


Measured A_N and background A_N

EM-jet with all photon multiplicity

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



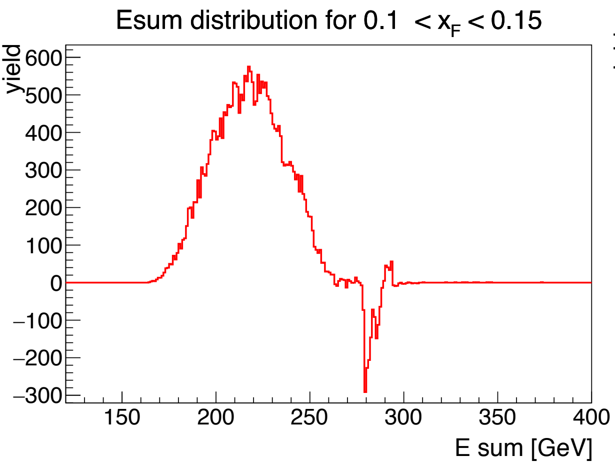


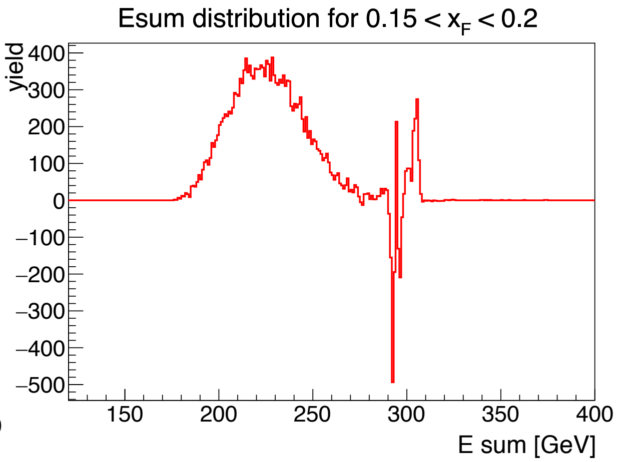
Note: All red point shift -0.005 in x axis.

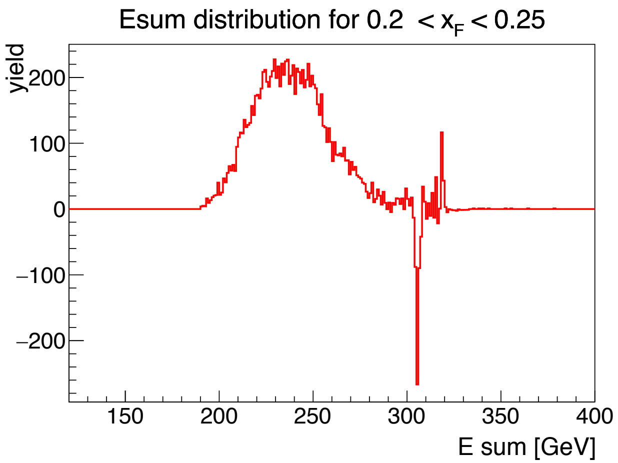
E sum (FMS data – background)

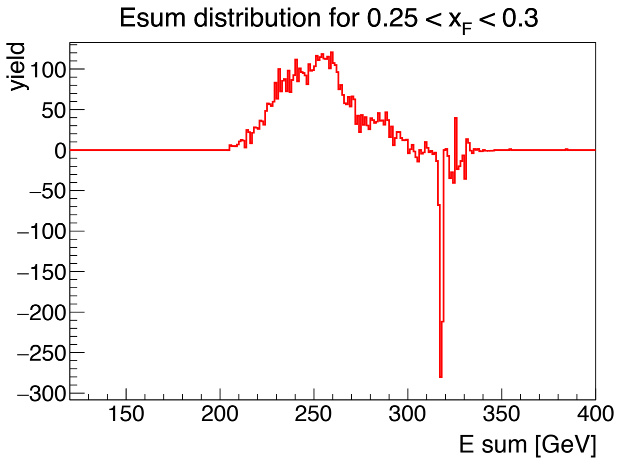
<u>1 or 2 photon multiplicity</u>

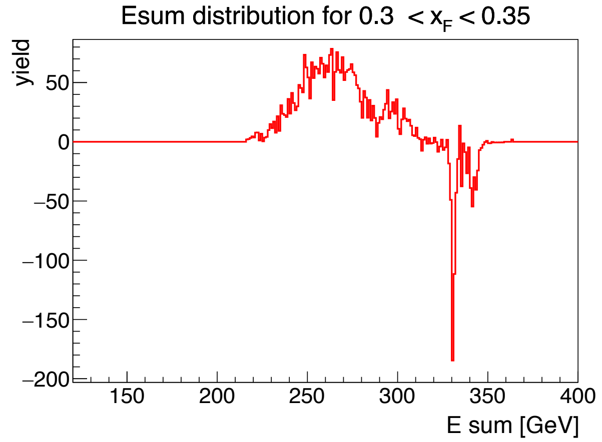
- To be more direct to see the ranges where the FMS data (red curve) over the background (black curve) for each E sum bin, we calculate the yield of FMS data subtracting background.

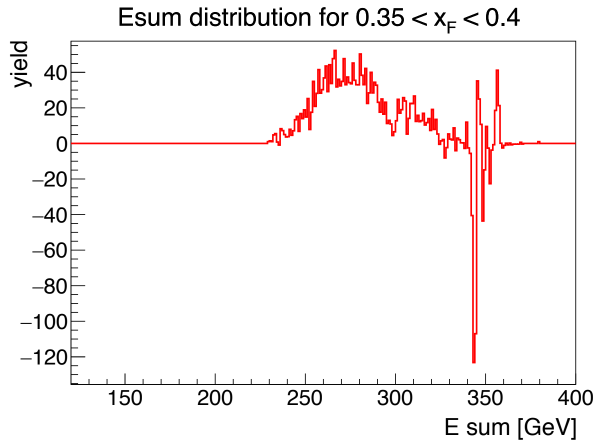


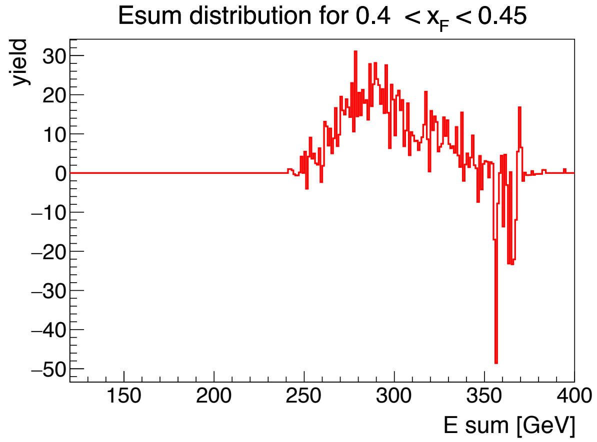








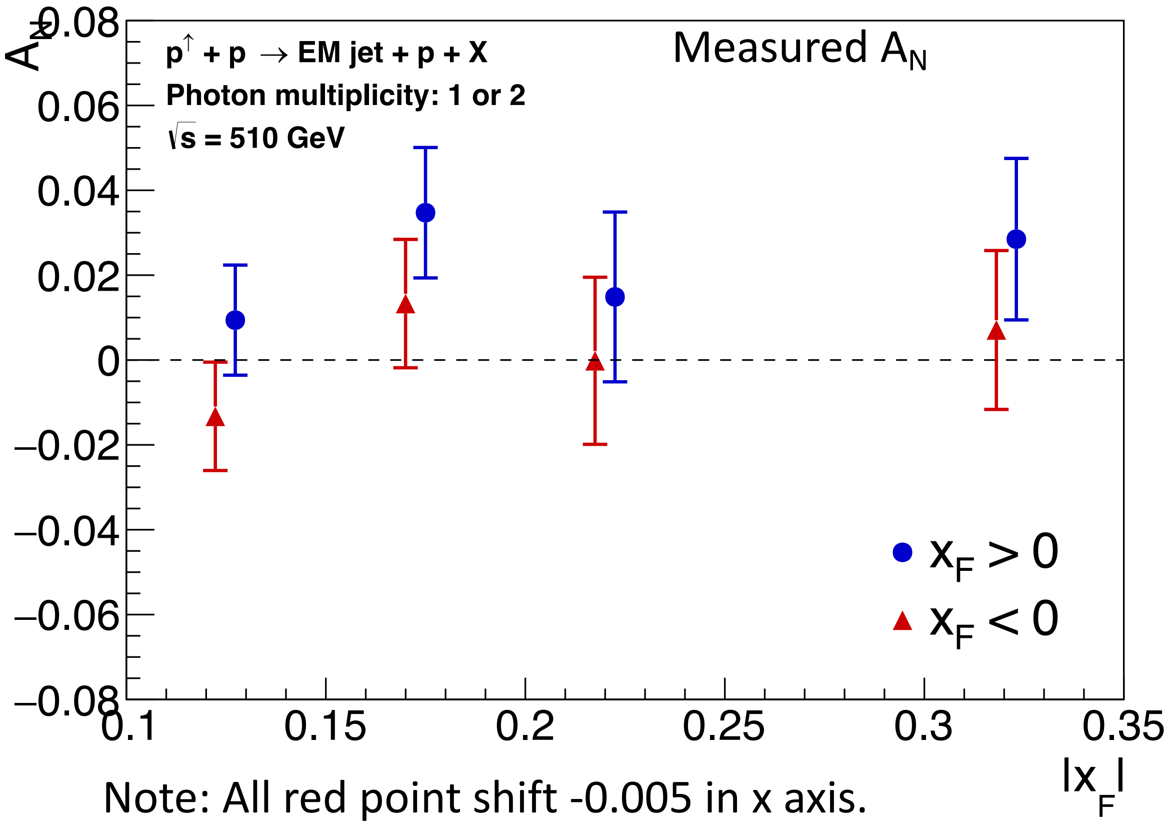


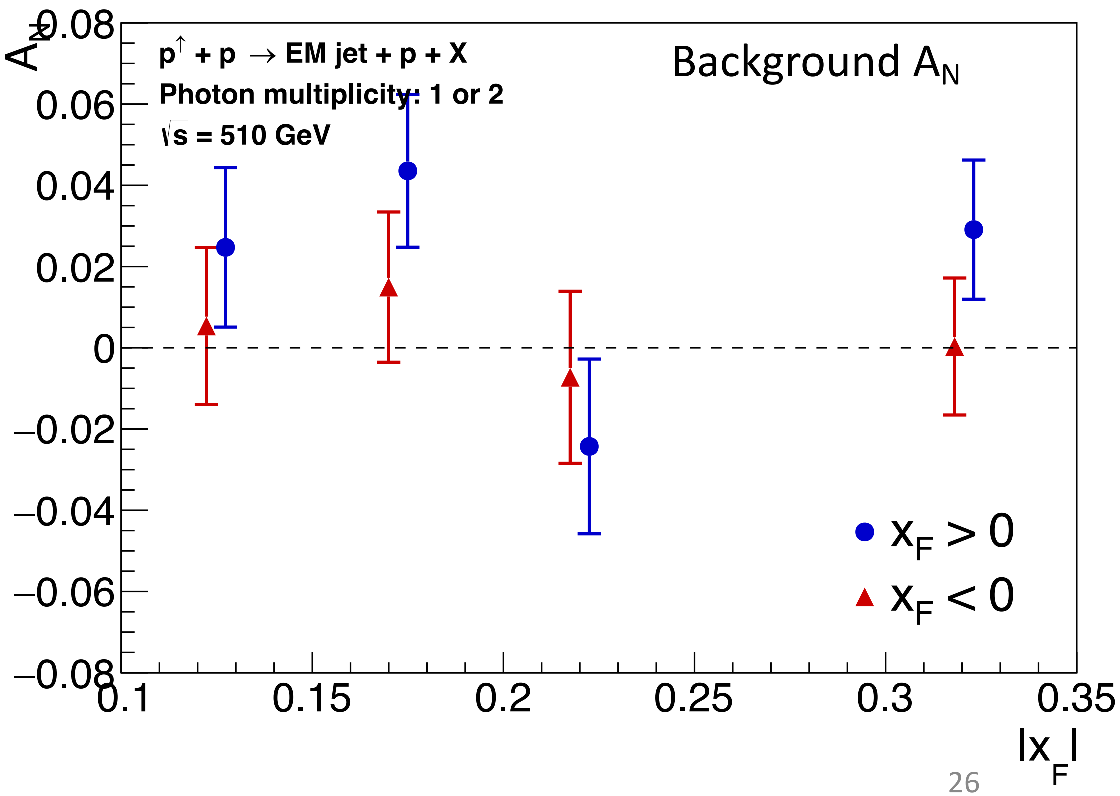


Measured A_N and background A_N

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.