Update and preliminary request for Run 15 single diffractive EM-jet A_N

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Feb. 28, 2024

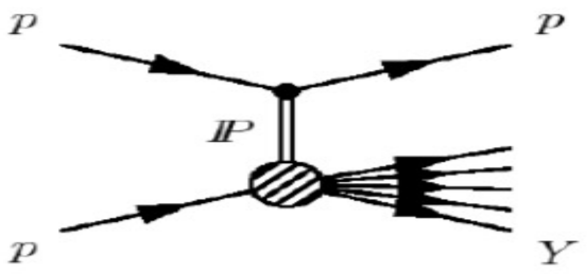
Single diffractive EM-jet A_N using FMS

Motivation and goal: study the A_N for diffractive process and explore its contribution for large A_N in inclusive processes

Determine the single diffractive process:

only 1 proton track on east side RP. No west side RP track requirement. FMS EM-jet on the west side.
Require: small and large BBC east cut

East proton	Rapidity gap	FMS Jet



East RP track

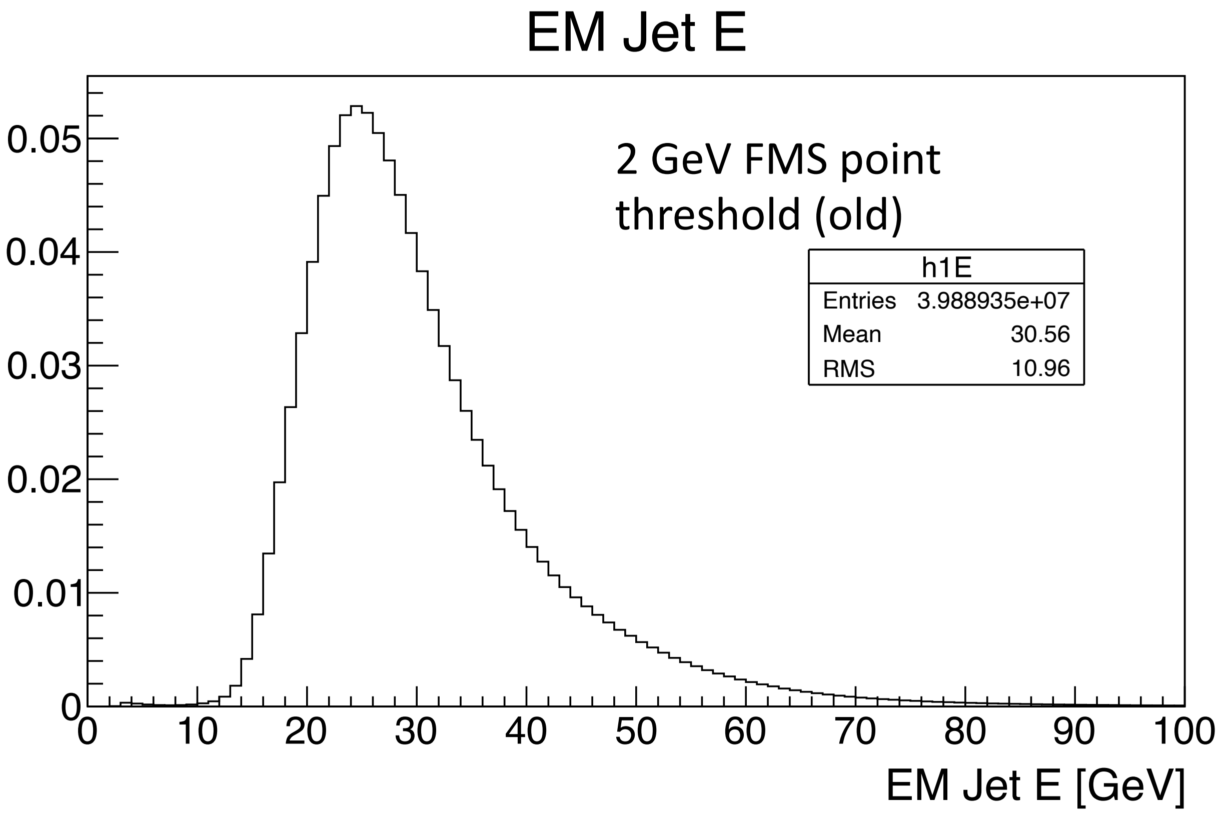
FMS jets

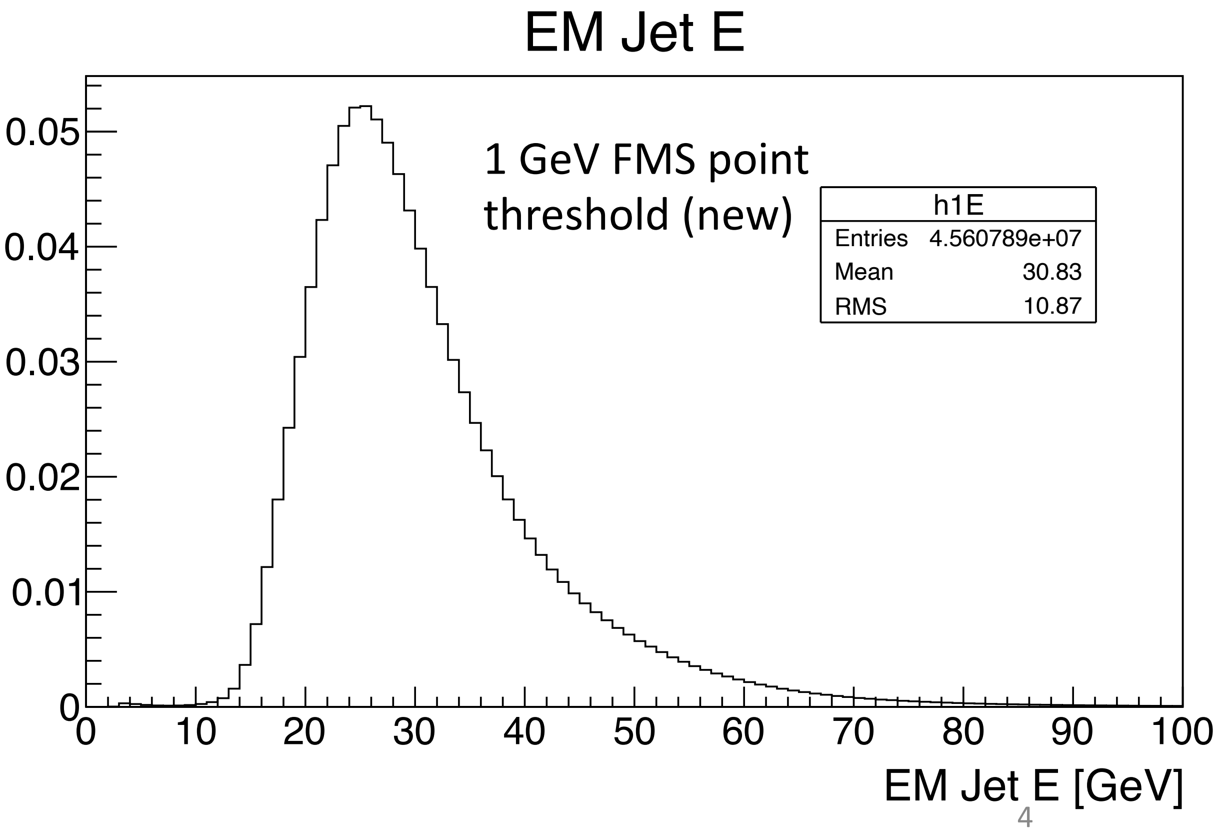
General Information for the data set

- 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.
- The major update for the presentation for today: change the FMS point minimum energy requirement in the jet reconstruction, in order to keep it same as inclusive process.
- EM-jet reconstruction: Anti-k_T algorithm with R=0.7
  - EM-jet: the jet reconstructed using only photons (FMS point)
  - FMS point minimum energy: 1 GeV (to match with inclusive process)

All EM-jet energy distribution

- Compare the EM-jet energy distribution for 2 different FMS point threshold.
  - Both plots are normalized.
  - 1 GeV FMS point threshold will add more EM-jets, but their normalization distribution are not huge different.





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

Outline for studying the RP cuts and BBC cuts

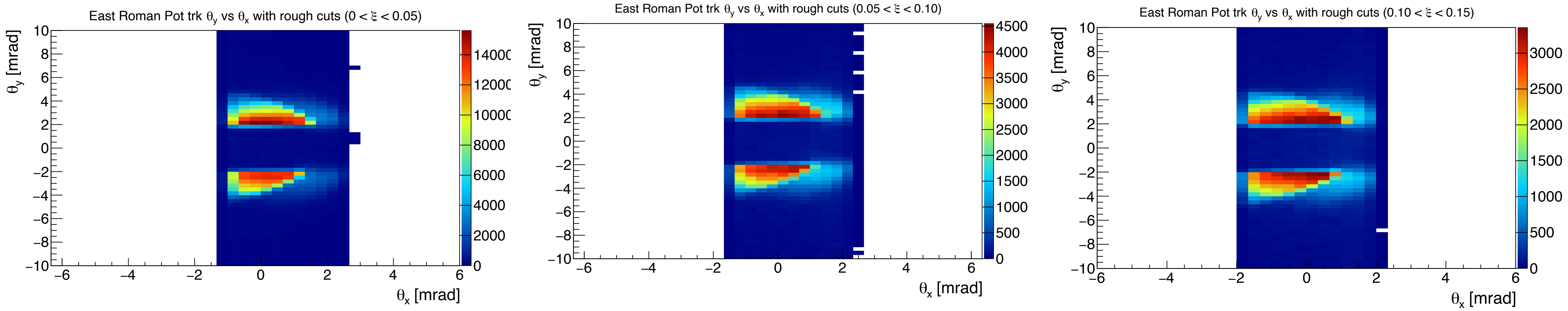
- Here are the idea and steps for considering the cuts for RP and BBC: (Same as the procedures introduced before)

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 < 150 . Goal: explore a **rough east RP $\boldsymbol{\theta_X}$, $\boldsymbol{\theta_Y}$ cuts for different $\boldsymbol{\xi}$ range**.
2. Apply the rough east RP P_X , P_Y cuts from step 1, study the small/large BBC east ADC distribution and consider further cuts for **small/large BBC east cuts**.
3. Apply the further cuts for east small/large BBC cuts, study the **final east RP $\boldsymbol{P_X}$, $\boldsymbol{P_Y}$ cuts, and $\boldsymbol{\theta_X}$, $\boldsymbol{\theta_Y}$ cuts for different $\boldsymbol{\xi}$ range**.

- Note: only east RP track $0 < \xi < 0.15$ are considered for the single diffractive process.

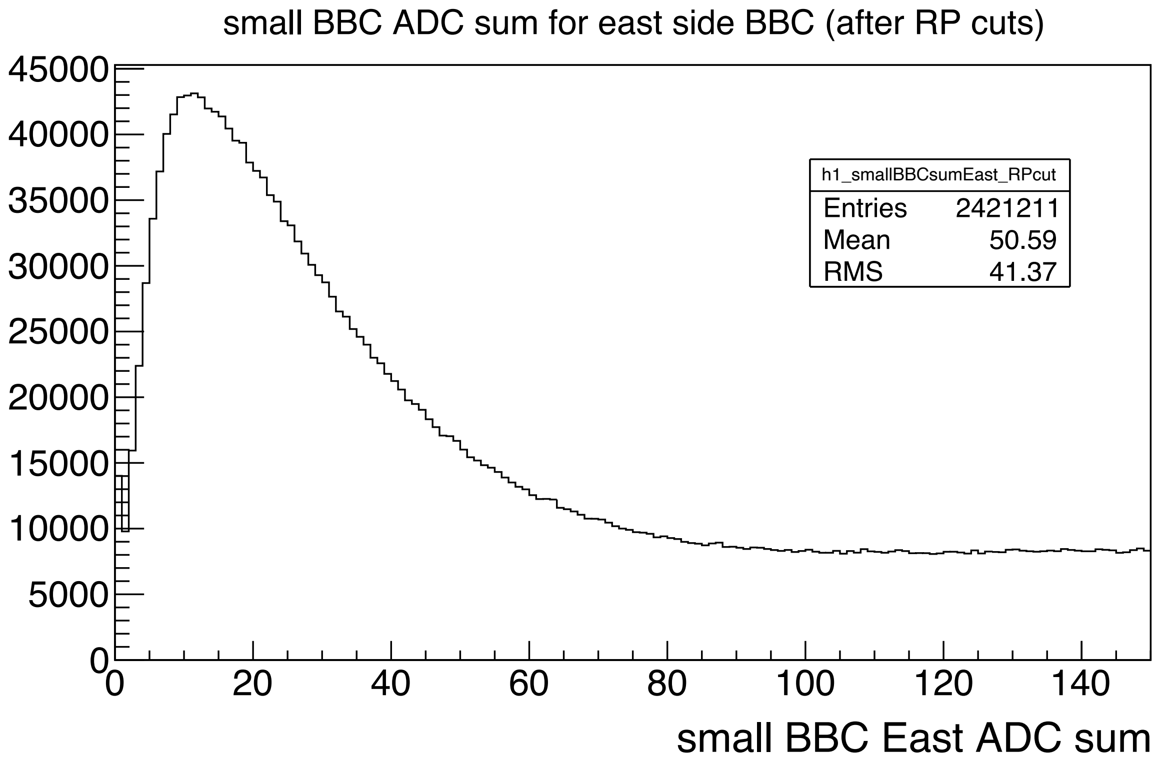
East RP track θ_Y vs θ_X with different ξ ranges

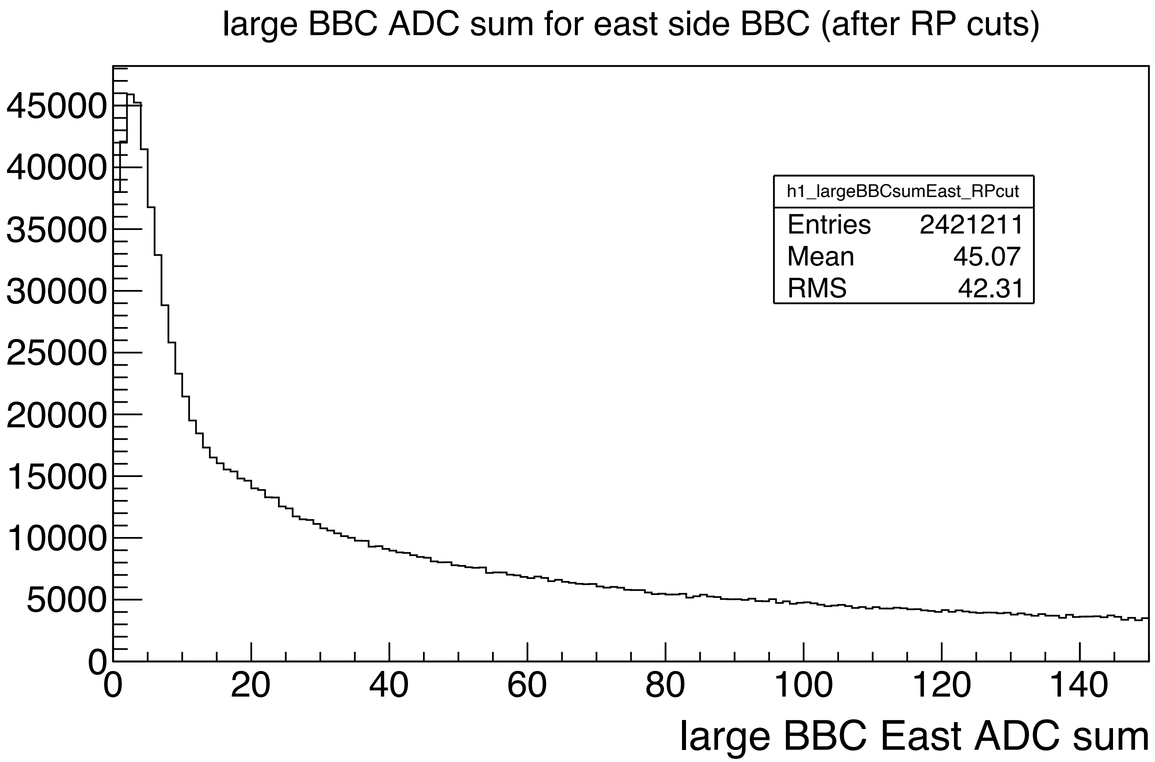
- Cuts applied at this stage: RP track hit at least 7 SSD planes , small BBC east < 150
- We can consider the rough east RP θ_Y cut: $2 < |\theta_Y| < 4\ mrad$ $\left(\xi = \frac{P_{beam} - P_{RP}}{P_{beam}}\right)$
- The rough east RP θ_X cut can be applied with ξ dependent
  - $0.0 < \xi < 0.05$: $-1. < \theta_X < 1.5$ mrad
  - $0.05 < \xi < 0.10$: $-1.25 < \theta_X < 1.25$ mrad
  - $0.10 < \xi < 0.15$: $-1.5 < \theta_X < 1.25$ mrad



East small and large BBC ADC sum after the rough east RP track θ_X and θ_Y cuts

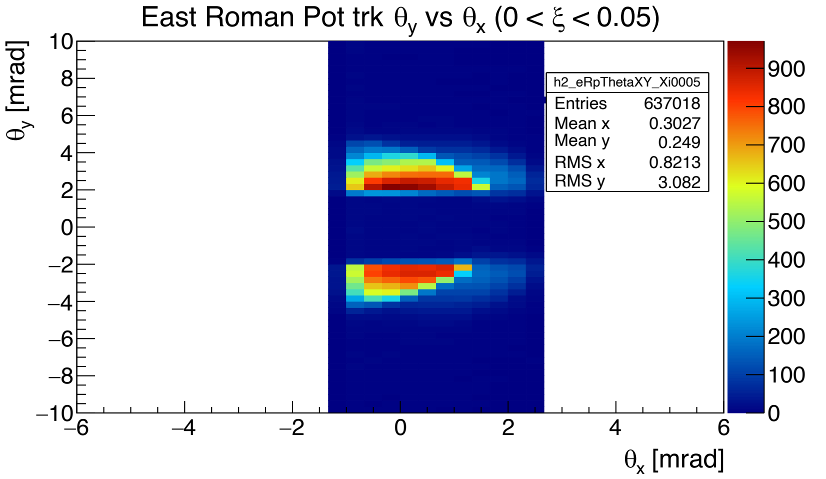
- Temporally apply the rough east RP track θ_X and θ_Y cuts to study the east small and large BBC ADC sum.
- We can consider small BBC east ADC sum < 90 and large BBC east < 80

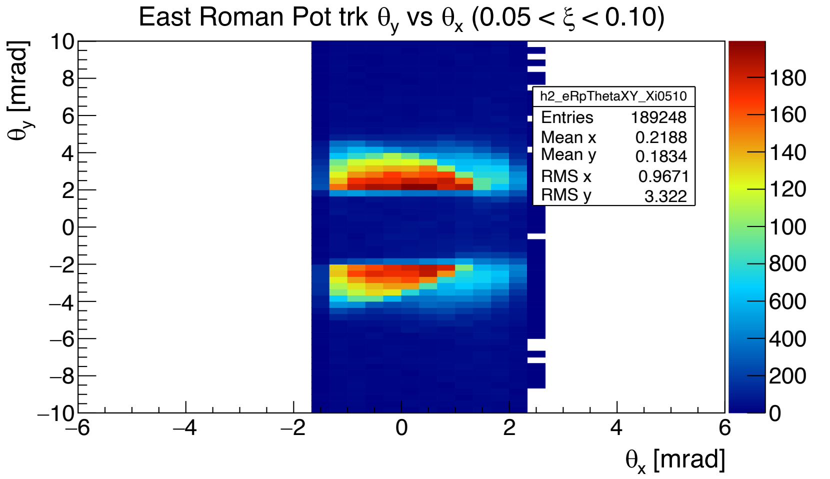


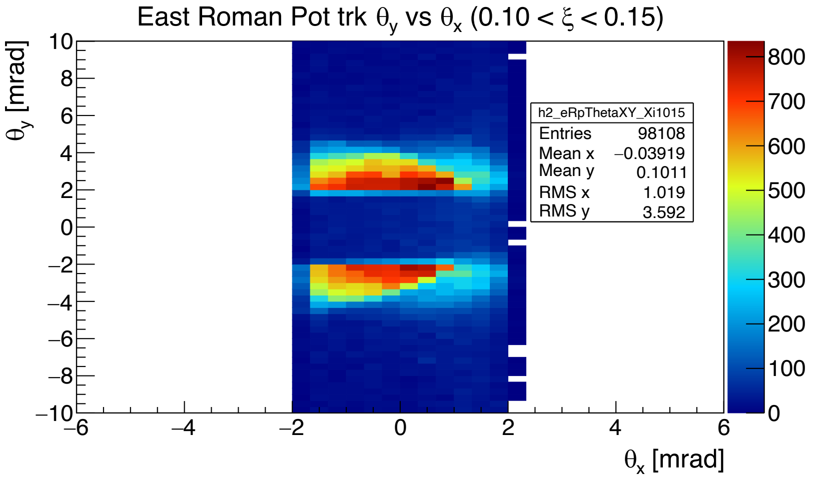


East RP track θ_Y vs θ_X with different ξ ranges

- Cross check after the small/large BBC east cuts
- Cuts applied at this stage: RP track hit at least 7 SSD planes , small BBC east ADC sum < 90 and large BBC east < 80
- The east RP θ_Y cut: $2 < |\theta_Y| < 4\, mrad$
- The east RP θ_X cuts below can be applied with ξ dependent
  - $0.0 < \xi < 0.05$: $-1. < \theta_X < 1.5$ mrad
  - $0.05 < \xi < 0.10$: $-1.25 < \theta_X < 1.25$ mrad
  - $0.10 < \xi < 0.15$: $-1.5 < \theta_X < 1.25$ mrad

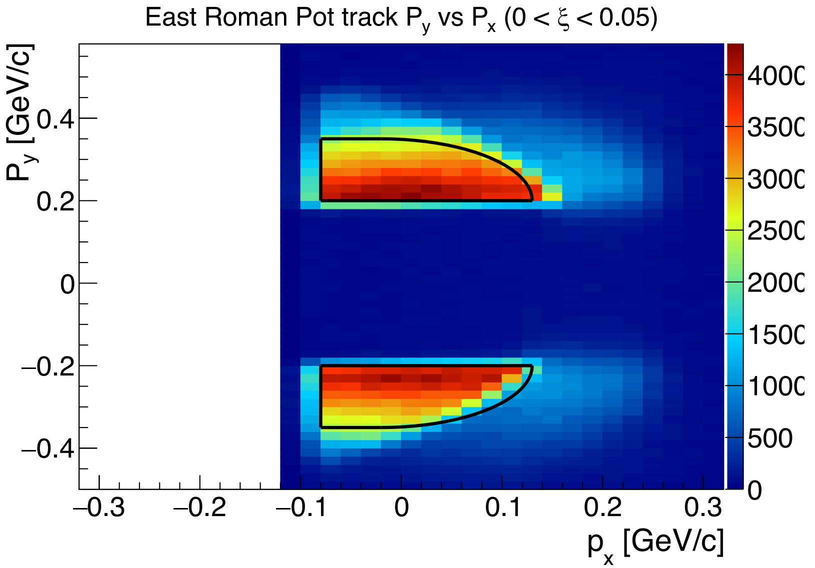


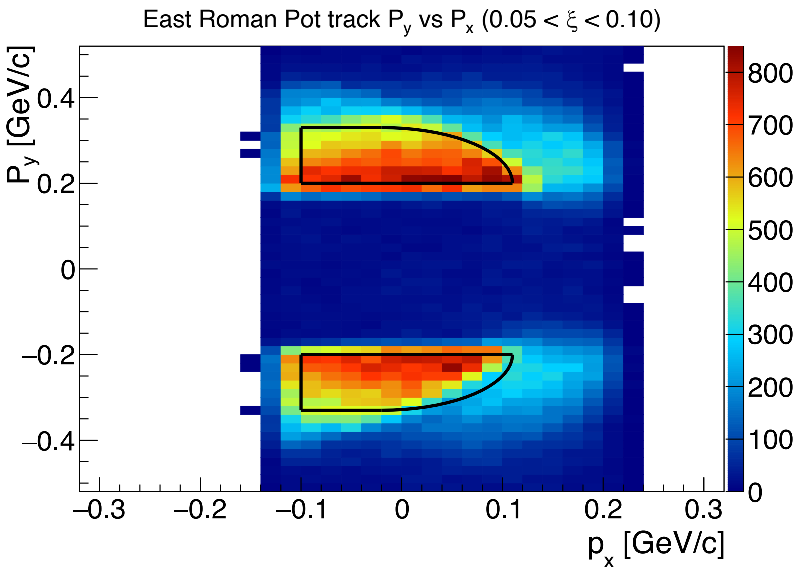


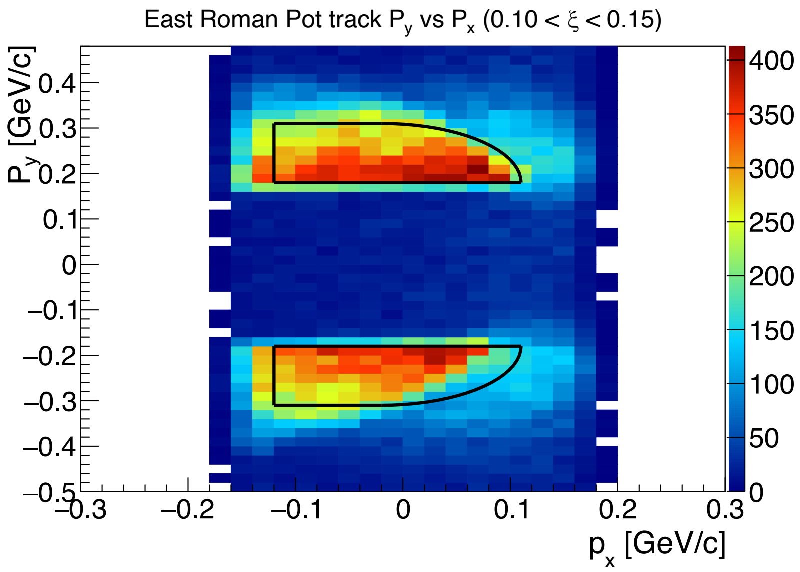


East RP track P_Y vs P_X

- Applying the BBC east small/large ADC sum cuts and east RP θ_X and θ_Y cuts, we check the east RP track P_Y vs P_X distribution.
- Shape of each half: rectangle + quarter circle (black curve)
- List of east RP θ_X and θ_Y cuts:
  - $0.0 < \xi < 0.05$: $(P_X + 0.02)^2 + (|P_Y| - 0.2)^2 < 0.15^2$ or $-0.08 < P_X < -0.02$, and $0.2 < |P_Y| < 0.35$
  - $0.05 < \xi < 0.1$: $(P_X + 0.02)^2 + (|P_Y| - 0.2)^2 < 0.13^2$ or $-0.10 < P_X < -0.02$, and $0.2 < |P_Y| < 0.33$
  - $0.1 < \xi < 0.15$: $(P_X + 0.02)^2 + (|P_Y| - 0.18)^2 < 0.13^2$ or $-0.12 < P_X < -0.02$, and $0.18 < |P_Y| < 0.31$





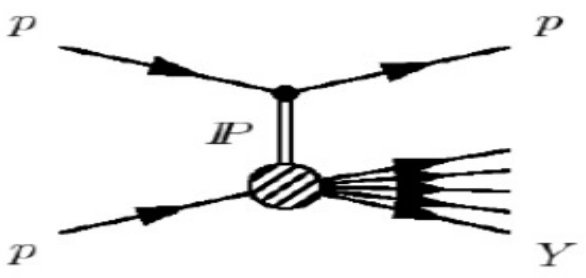


Event selection and corrections

- **FMS**
  - 9 Triggers, veto on FMS-LED
  - Only 1 EM-jet per event is allowed
  - 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 > 1 GeV, $p_T > 2$ GeV/c, trigger p_T threshold cut, FMS point as input.
- **Only allow acceptable beam polarization (up/down).**
- **Vertex** (Determine vertex z priority according to TPC , VPD, BBC.)
  - Vertex $|z| < 80\ cm$

Corrections:
EM-jet energy correction and Underlying Event correction

- **Roman Pot and Single Diffractive process:**



- Acceptable cases:
  1. Only 1 east RP track , no requirement on west RP
  - RP track must be good track:
  a) Each track hits > 6 planes
  b) East RP ξ dependent θ_X , θ_Y , P_X and P_Y cuts
  c) East RP $0 < \xi < 0.15$

- East Large BBC ADC sum < 80 and East Small BBC ADC sum < 90

Background study: FMS EM-jet and BBCE veto (RG)

- The process with FMS EM-jets and BBCE veto are one potential source of the background
  - The east BBC covers a unit of 3 for pseudorapidity gap. We call it RG event set
  - They are a subset of inclusive process
- Same event selections for FMS EM-jets and east BBC as single diffractive process

East Large BBC ADC sum < 80 and East Small BBC ADC sum < 90

- Use this set of events to estimate the background fraction: about 1.8 - 1.9%

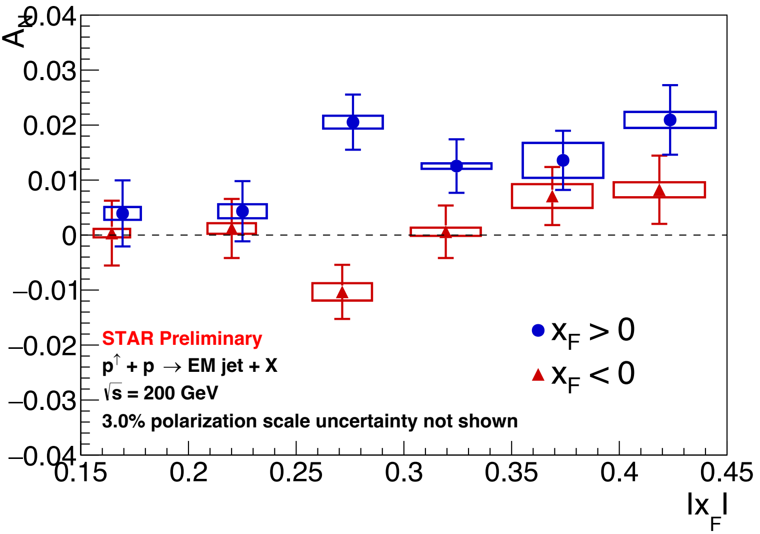
The random coincidence of the single diffractive events in the RG events is 0.2% (zerobias events)

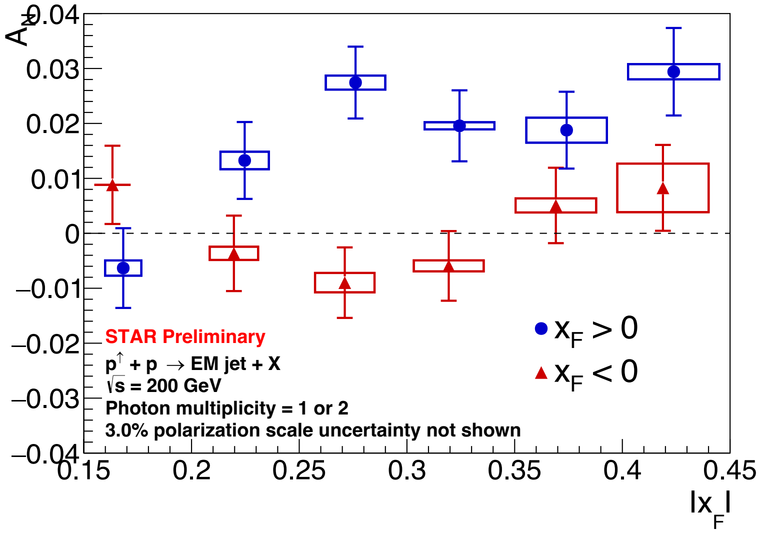
$$frac_{bkg} = \frac{n_{AC}}{n_{mea}} = \frac{n_{AC}}{n_{RG}} \times \frac{n_{RG}}{n_{mea}}$$

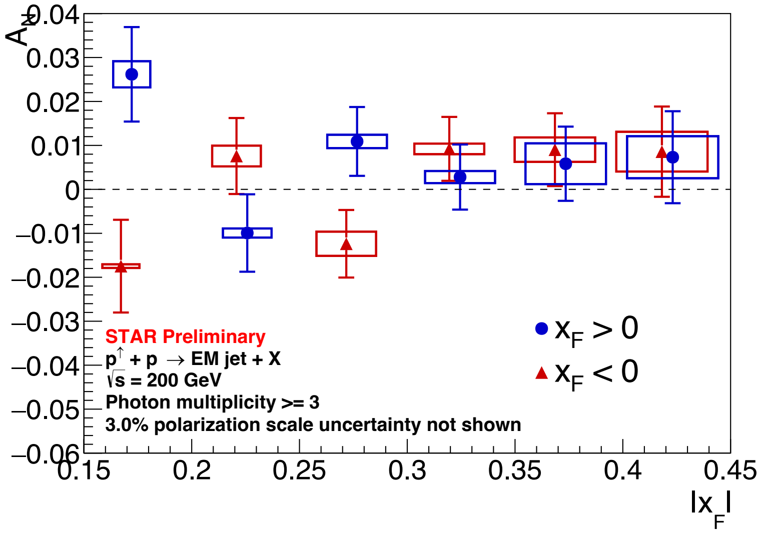
Counting yields of each kinematic bins for RG events and measured FMS events

Discussion: A_N for RG events

- The A_N for EM-jet with RG event study is not the major goal and requirement for the study for single diffractive EM-jet A_N , but it's still interesting and helpful to have it in the analysis and its paper.
- However, there can be some improvements for the RG event study, if we treat it as individual topic.
  - The event selection for BBC east is not optimized.
- The systematic uncertainty includes the small BBC east cut, large BBC east cut, and Ring of Fire.
- Discussion: can the A_N for the RG events release for preliminary? These results are not required and promised to present in DIS2024.





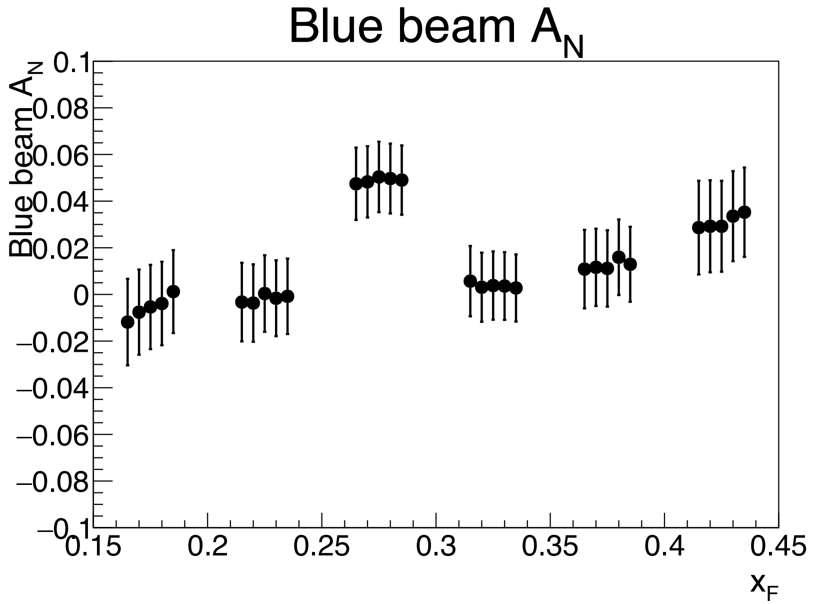


Systematic uncertainty

- 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 east ADC sum cuts: choose < 70, < 80, <100, <110 for systematic uncertainty
  - Large BBC east ADC sum cuts: choose < 60, < 70, <90, <100 for systematic uncertainty
  - Ring of Fire (get rid of small-bs-3 trigger).
  - Background

Example: Small BBC east cuts

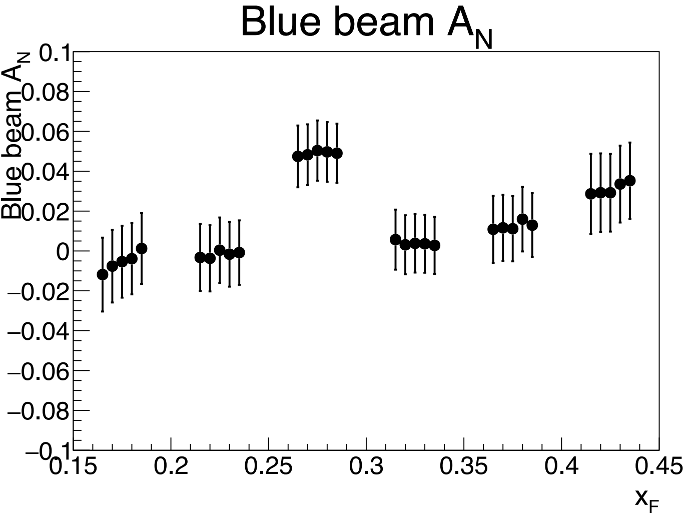
Each x_F set, from left to right: varying the cuts from original: -20, -10, 0, +10, +20



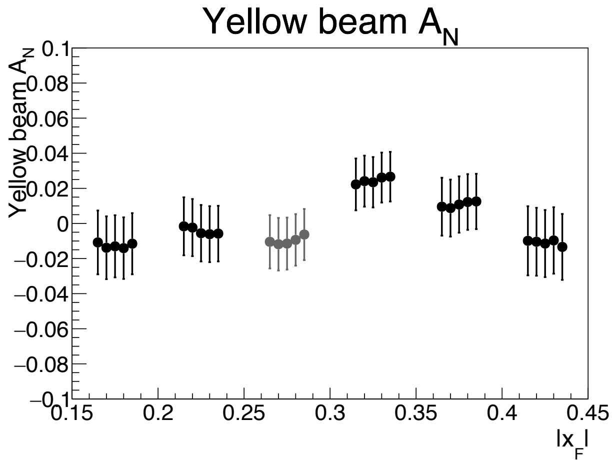
A_N results for varying the cuts (systematic)

All photon multiplicity

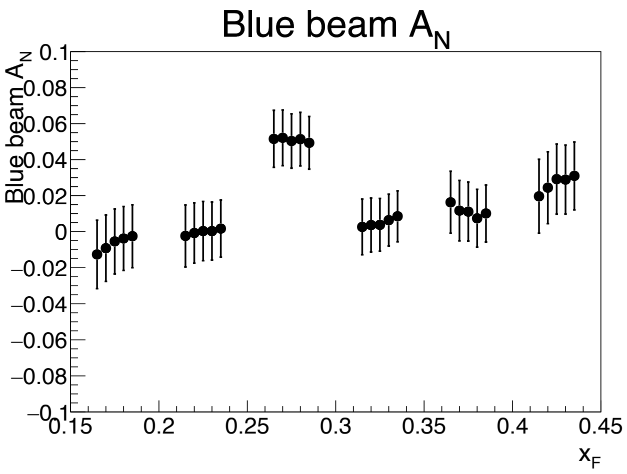
Small BBC east cuts



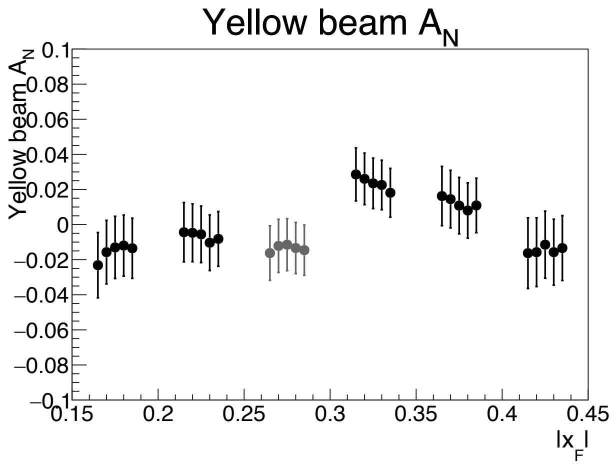
right: varying the cuts from original: -20, -10, 0, +10, +20



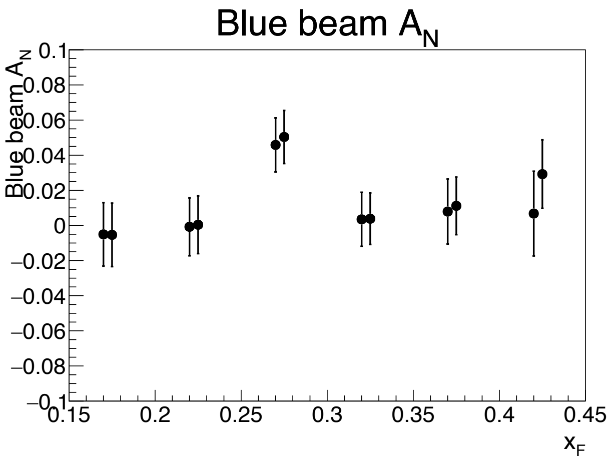
Large BBC east cuts



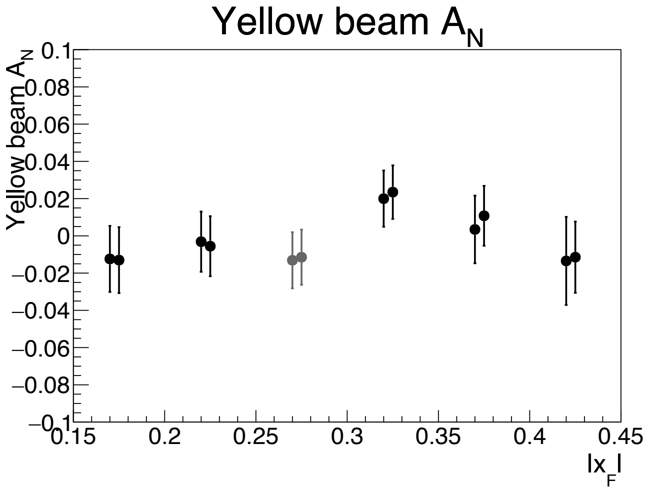
Each x_F set, from left to right: varying the cuts from original: -20, -10, 0, +10, +20



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

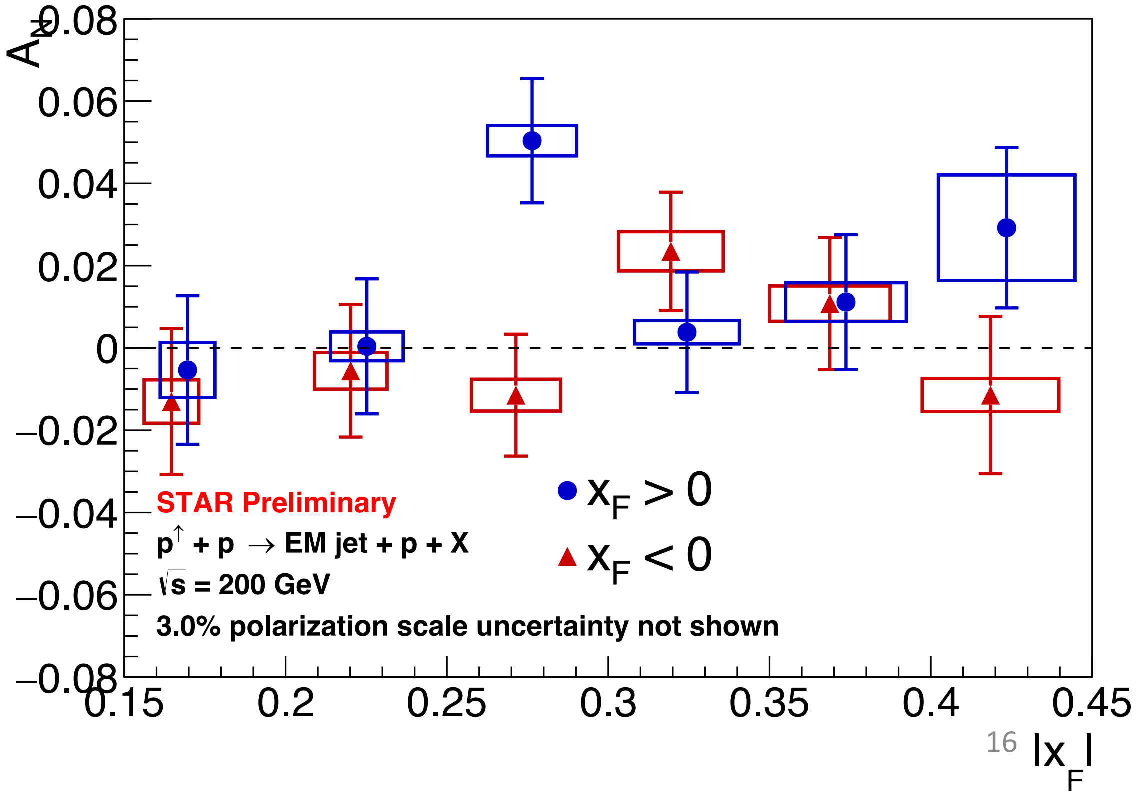
Blue beam x_F	Small BBC east	Large BBC east	Ring of Fire	Background	Summary
0.1 - 0.2	0.0043	0.0037	0	0.0035	0.0067
0.2 - 0.25	0.0015	0	0	0.0032	0.0035
0.25 - 0.3	0	0.0022	0.0029	0.0029	0.0037
0.3 – 0.35	0	0	0	0.0028	0.0028
0.35 – 0.4	0.0018	0.0029	0	0.0032	0.0047
0.4 – 0.45	0.0027	0.0041	0.011	0.0039	0.013

Yellow beam x_F	Small BBC east	Large BBC east	Ring of Fire	Background	Summary
0.1 - 0.2	0	0.0040	0	0.0034	0.0052
0.2 - 0.25	0.0019	0.0023	0.0012	0.0031	0.0045
0.25 - 0.3	0.0020	0.0017	0	0.0028	0.0039
0.3 – 0.35	0.0016	0.0035	0	0.0028	0.0048
0.35 – 0.4	0	0.0029	0	0.0031	0.0043
0.4 – 0.45	0.0014	0	0	0.0038	0.0040

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 2.1 σ to be non-zero.
  - Constant fit: 0.015 ± 0.0070
  - $\chi^2/n.d.f$: 1.61
- Yellow beam A_N is 0.03 σ to be non-zero.
  - Constant fit: 0.0002 ± 0.0068
  - $\chi^2/n.d.f$: 0.87

Preliminary request



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

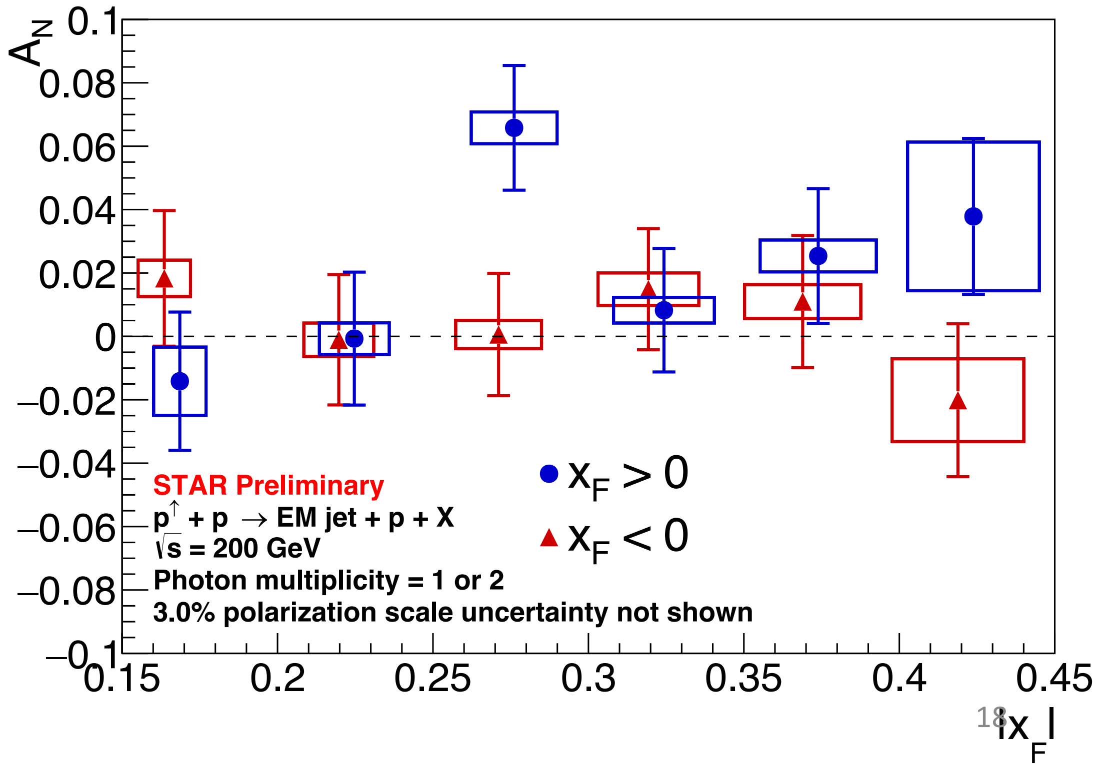
Blue beam x_F	Small BBC east	Large BBC east	Ring of Fire	Background	Summary
0.1 - 0.2	0.0063	0.0077	0	0.0042	0.011
0.2 - 0.25	0.0025	0	0.0015	0.0040	0.0050
0.25 - 0.3	0.0021	0	0.0026	0.0038	0.0050
0.3 – 0.35	0.0015	0	0	0.0038	0.0041
0.35 – 0.4	0.0029	0	0	0.0041	0.0050
0.4 – 0.45	0.0051	0.0064	0.021	0.0049	0.023

Yellow beam x_F	Small BBC east	Large BBC east	Ring of Fire	Background	Summary
0.1 - 0.2	0.0022	0.0033	0	0.0041	0.0057
0.2 - 0.25	0	0.0029	0.0019	0.0039	0.0053
0.25 - 0.3	0.0017	0.0019	0	0.0037	0.0045
0.3 – 0.35	0.0024	0.0026	0	0.0036	0.0051
0.35 – 0.4	0	0.0035	0	0.0040	0.0053
0.4 – 0.45	0.0013	0.0039	0.011	0.0048	0.013

A_N results for 1 or 2 photon multiplicity

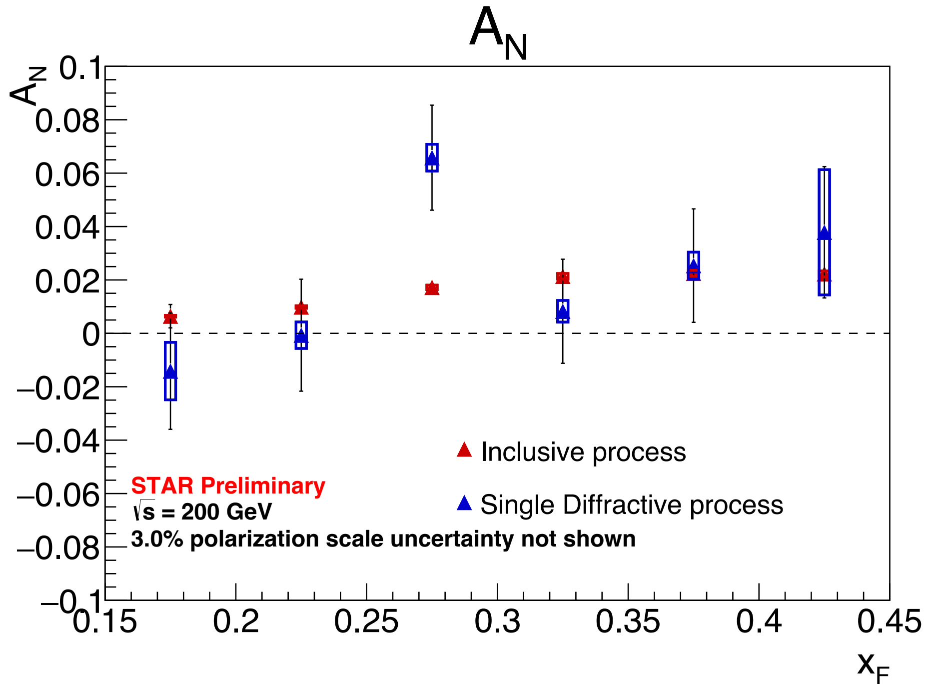
- 6 x_F bins are considered: [0.1, 0.2], [0.2,0.25], [0.25,0.3], [0.3,0.35] , [0.35,0.4], [0.4,0.45]
- 1 or 2 photon multiplicity
- Constant fit is applied to calculate the significance of non-zero
- Blue beam A_N is 2.2 σ to be non-zero.
  - Constant fit: 0.021 ± 0.0092
  - $\chi^2/n.d.f$: 1.73
- Yellow beam A_N is 0.63 σ to be non-zero.
  - Constant fit: 0.0055 ± 0.0088
  - $\chi^2/n.d.f$: 0.33

Preliminary request



Comparison between inclusive process and single diffractive process

- We compare the results between inclusive process and single diffractive process.
  - Both are with EM-jet 1 or 2 photon multiplicity
  - The single diffractive process are tagging 1 east RP track.



Preliminary request

Calculating the systematic uncertainty (3 or more photon multiplicity)

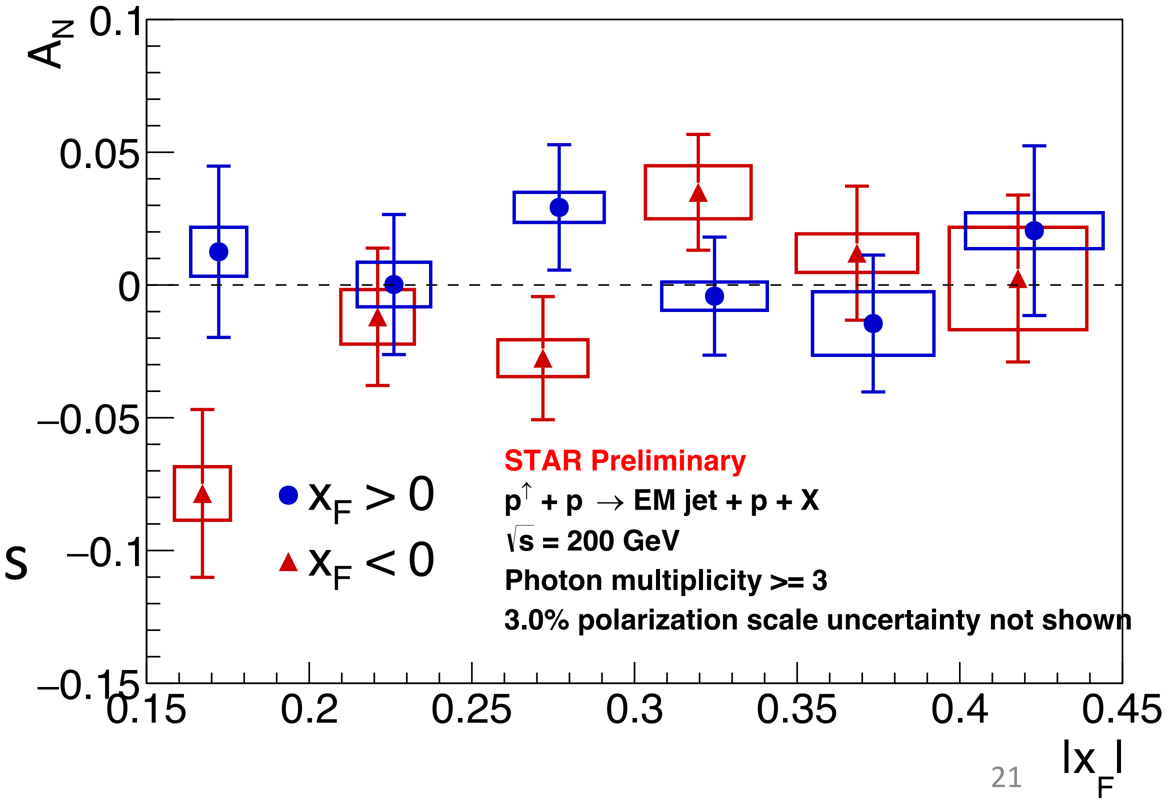
- Then, find out the maximum ($A_N(1) \pm \delta(1)$, with statistical uncertainty) , and the minimum ($A_N(2) \pm \delta(2)$, with statistical uncertainty) for the varying cuts as systematic uncertainty.
- If the $\frac{|A_N(1)-A_N(2)|}{\sqrt{|(\delta(1))^2-(\delta(2))^2|}} > 1$ (Barlow check), use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

Blue beam x_F	Small BBC east	Large BBC east	Ring of Fire	Background	Summary
0.1 - 0.2	0.0038	0.0057	0	0.0061	0.0092
0.2 - 0.25	0.0015	0.0065	0	0.0051	0.0084
0.25 - 0.3	0.0020	0.0027	0	0.0045	0.0056
0.3 – 0.35	0	0.0032	0	0.0043	0.0053
0.35 – 0.4	0.0017	0.0047	0.0096	0.0050	0.012
0.4 – 0.45	0.0025	0	0	0.0063	0.0068

Yellow beam x_F	Small BBC east	Large BBC east	Ring of Fire	Background	Summary
0.1 - 0.2	0	0.0080	0.00095	0.0061	0.010
0.2 - 0.25	0.0050	0.0075	0	0.0050	0.010
0.25 - 0.3	0.0029	0.0022	0.0038	0.0045	0.0069
0.3 – 0.35	0.0033	0.0072	0.0044	0.0042	0.010
0.35 – 0.4	0.0033	0.0042	0	0.0049	0.0073
0.4 – 0.45	0	0	0.018	0.0062	0.019

A_N results for 3 or more 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]
- 3 or more photon multiplicity
- Constant fit is applied to calculate the significance of non-zero
- Blue beam A_N is 0.61 σ to be non-zero.
  - Constant fit: 0.0068 ± 0.011
  - $\chi^2/n.d.f$: 0.38
- Yellow beam A_N is 0.61 σ to be non-zero.
  - Constant fit: -0.0069 ± 0.011
  - $\chi^2/n.d.f$: 1.81
- We are preparing the comparison plot for the case with 3 or more photon multiplicities



Preliminary request

Conclusion

- When applying the 1 GeV FMS point energy threshold, more EM-jets are found for the events (about 10% more totally)
- The event selections for east BBC and east RP are the same, since the distributions look similar as before.
- The asymmetry looks roughly similar as for the events before (2 GeV FMS point energy threshold)
- The EM-jet A_N for single diffractive process does not provide strong evidence that the diffractive process can contribute to large A_N for inclusive process
- We request for preliminary for EM-jet A_N for single diffractive process. These results will target on DIS2024.

Back up

Background study: zerobias stream

- Motivation: study the fraction of east RP coincident rate as accidental coincidence (multiple collision event)
- Data production and stream : **production_pp200trans_2015 , st_zerobias_adc**
- Production tag: P16id
- The BBC east cuts are same as FMS data
- Event distribution:
    - Total N events: 724,485
    - **423,983 events (58.5%) with BBCE veto (f_{noacci})**
    - 2524 events (0.35%) contain 1 east good RP track (no BBC east cuts)
    - **1407 events (0.20%) contain 1 east good RP track (with BBC east cuts)**
    - 78 events (0.012%) contain 1 east good RP track and 1 west good RP track
- Therefore, about 0.2% of the events are the accidental coincidences, and should be the same rate for every process

Estimate the Accidental coincidence for background

- **A**ccidental **C**oincidence (AC) (multiple collision event) are coming from the situation that the FMS EM-jets and the east RP tracks are not correlated, i.e. the FMS EM-jets and the east RP tracks are coming from multiple collisions
- The random coincidence of the single diffractive events in the RG events is 0.2%
- Background fraction:

$$frac_{bkg} = \frac{n_{AC}}{n_{mea}} = \frac{n_{AC}}{n_{RG}} \times \frac{n_{RG}}{n_{mea}}$$

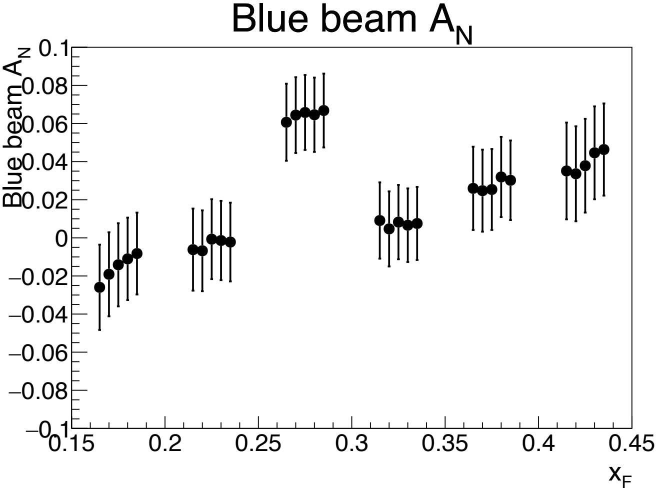
The fraction of AC events for measured FMS events are about 1.8% - 1.9%, their effects are assigned to systematic uncertainty

Need to be measured by counting yields of each kinematic bins for RG events and measured FMS events

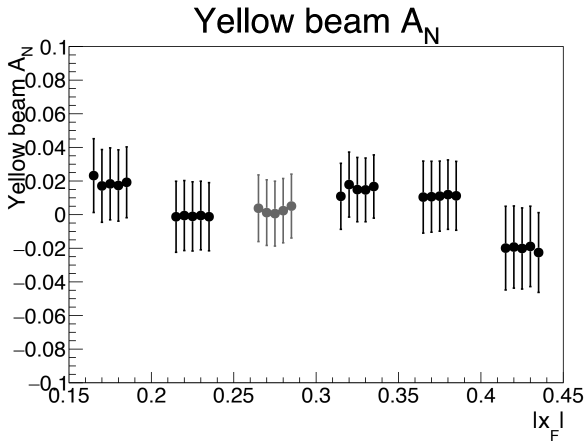
A_N results for varying the cuts (systematic)

1 or 2 photon multiplicity

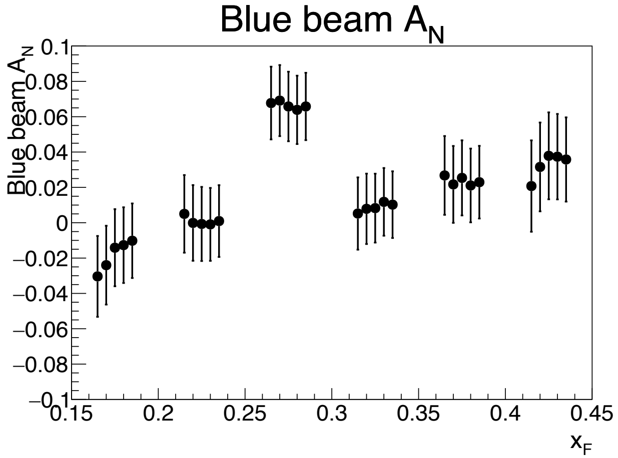
Small BBC east cuts



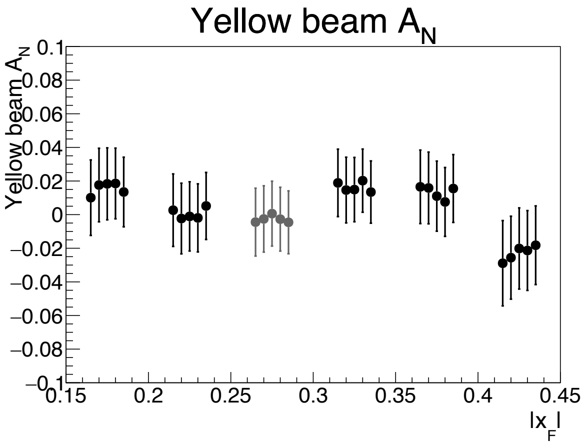
Each x_F set, from left to right: varying the cuts from original: -20, -10, 0, +10, +20



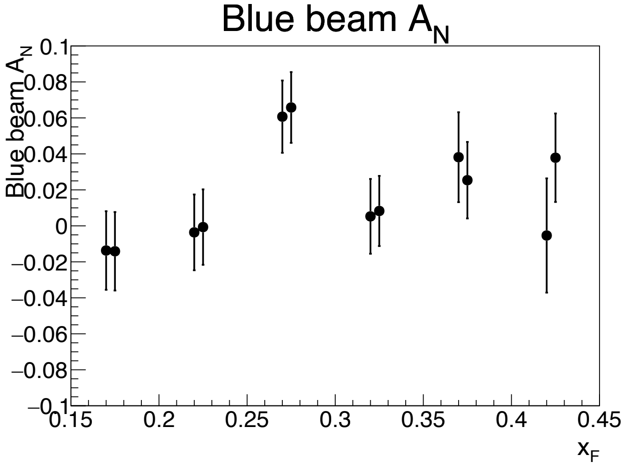
Large BBC east cuts



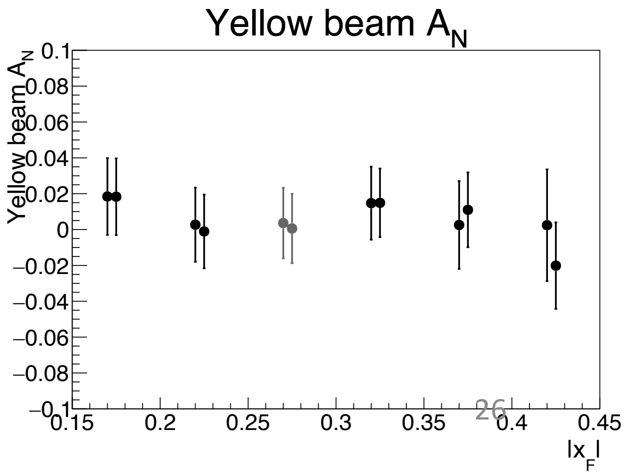
Each x_F set, from left to right: varying the cuts from original: -20, -10, 0, +10, +20



Ring of Fire cuts



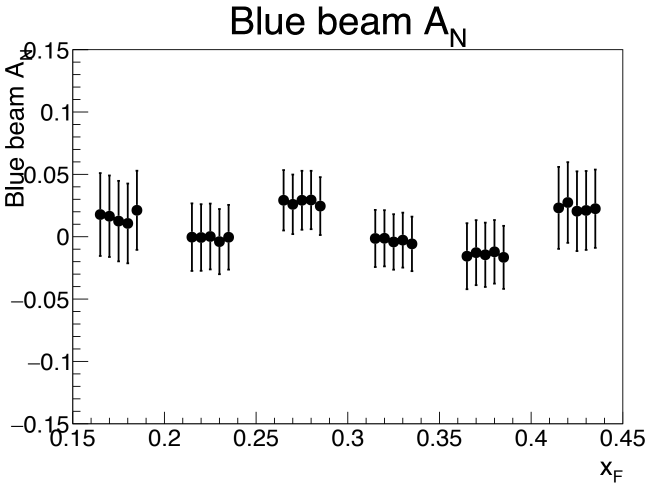
Each x_F set, from left to right: Apply Ring of Fire cut, do not apply Ring of Fire cut



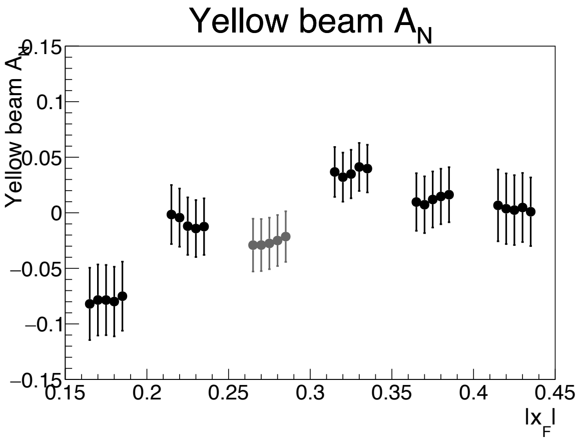
A_N results for varying the cuts (systematic)

3 or more photon multiplicity

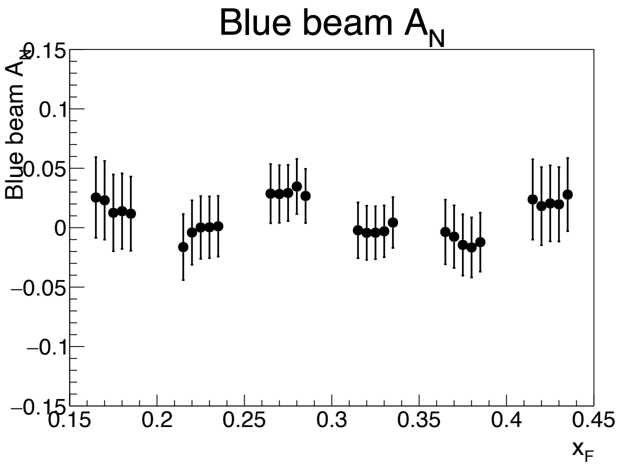
Small BBC east cuts



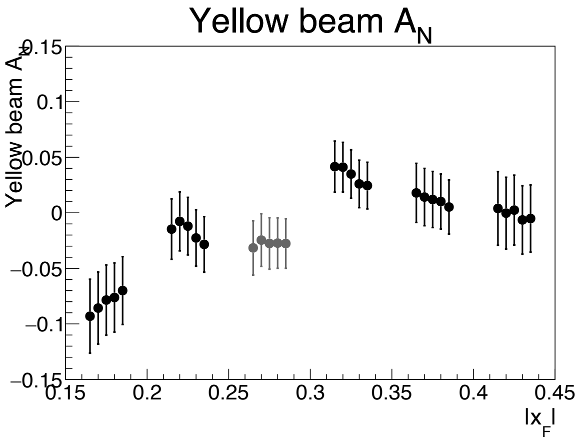
Each x_F set, from left to right: varying the cuts from original: -20, -10, 0, +10, +20



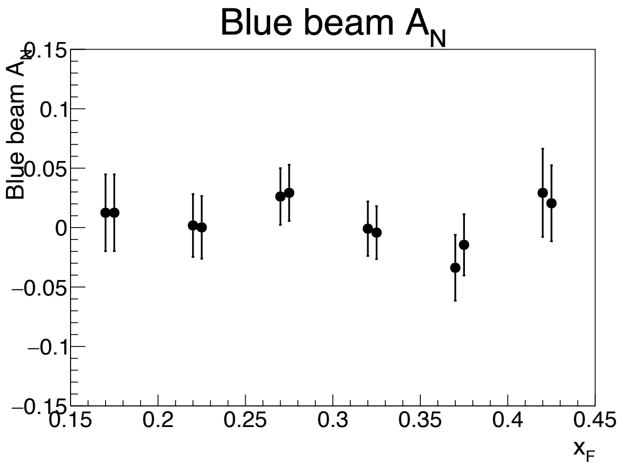
Large BBC east cuts



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



Ring of Fire cuts



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