Update and preliminary request for run 17 diffractive EM-jet A_N

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Mar. 15, 2023

Outline

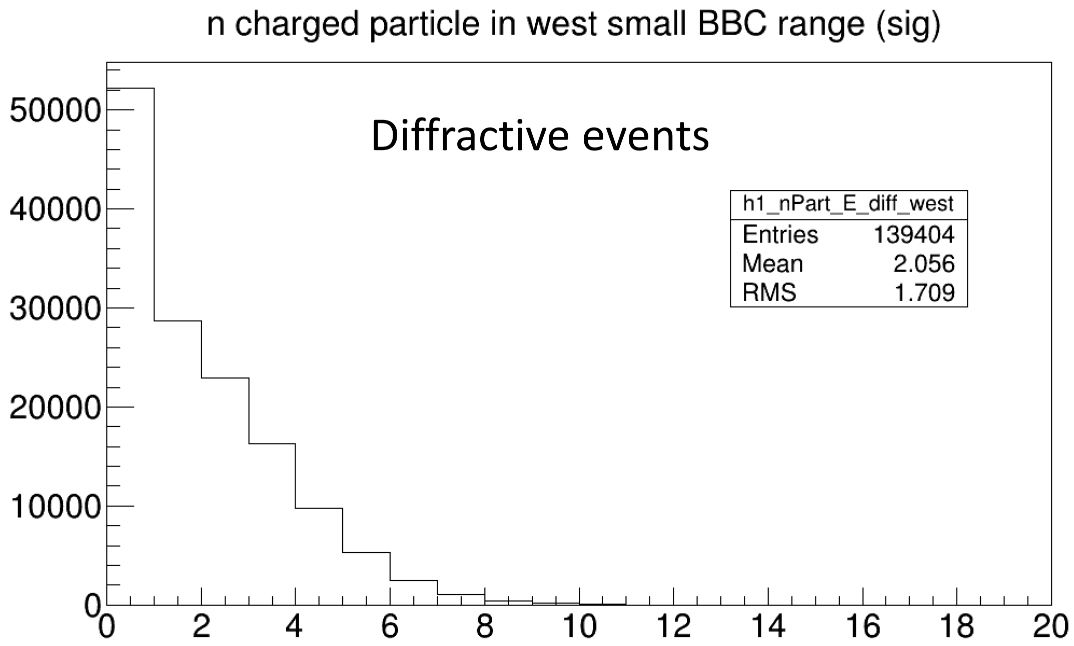
- Update on studying the BBC cuts with simulation
- Preliminary results (plots) for run 17 diffractive EM-jet A_N

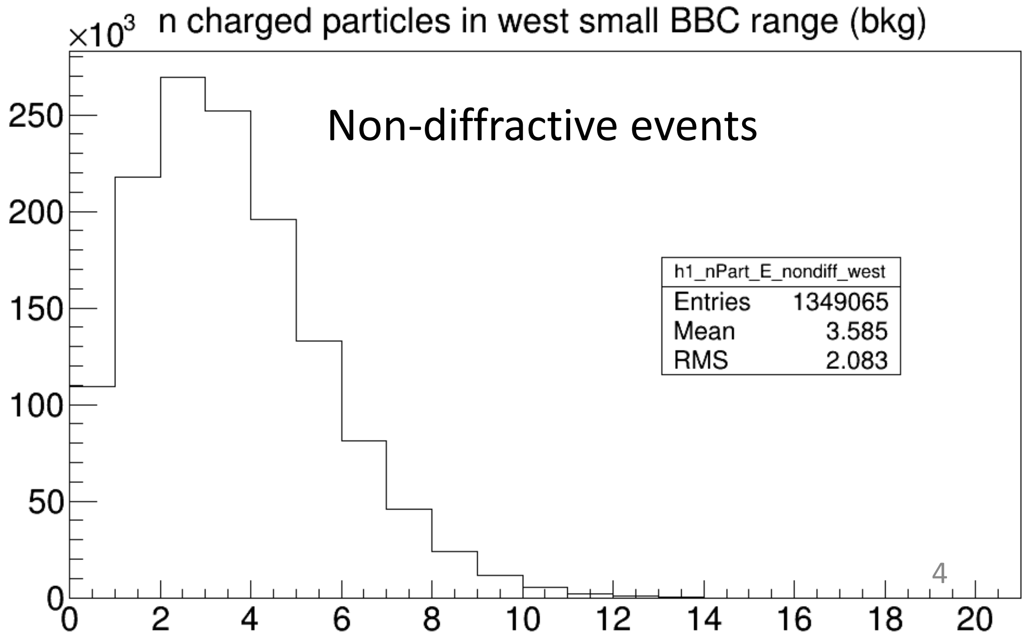
Simulation

- Goal: study the validity for selecting diffractive EM-jet using the BBC cuts.
- Simulation set up: Pythia 8 simulation, hard QCD process
- Cuts for simulation:
  1. Distinguish between diffractive process and non-diffractive process (directly from Pythia 8 output)
  2. Cut on west side proton track (proton track $5.5 < \eta < 7$)
- There are no BBC detector level simulation, so investigate on the final state particle within the BBC coverage
  - According to Akio, the BBC ADC sum can roughly relate to number of charge particle hitting the BBC area.

Particle level simulation to study west BBC cuts

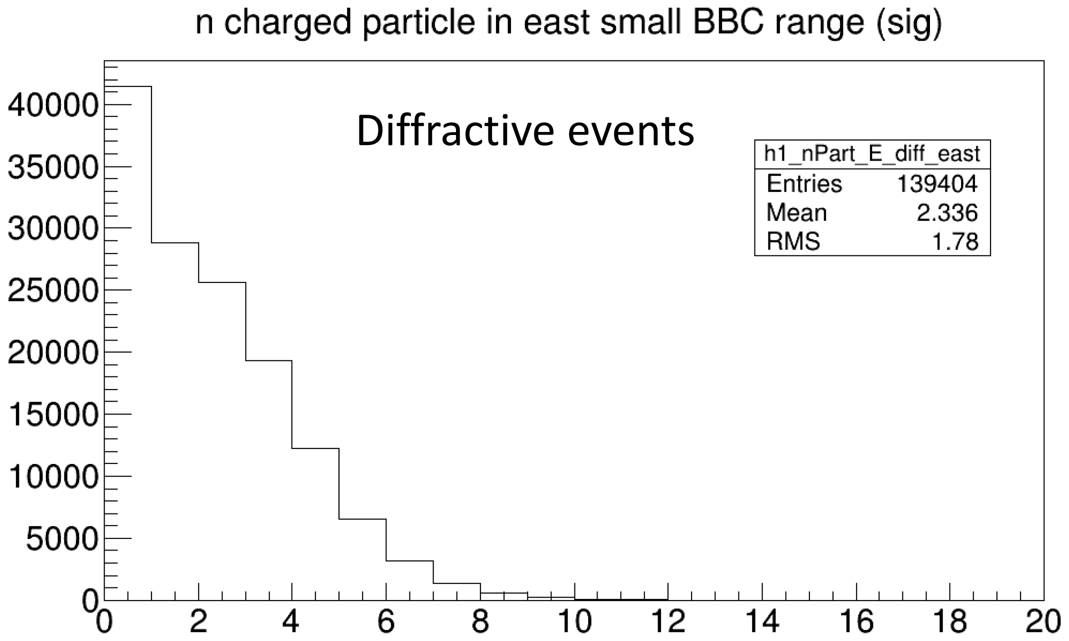
- Consider events only in particle level simulation.
- Investigate the outgoing particle distribution in the small BBC region.
  - Small BBC **west**: $3.5 < \eta < 4.5$
  - Count the number of charged final state particles within such range.
- From the plots, lower number of charged particles for diffractive events is preferred. -> Choosing west small BBC cut with low threshold is OK.

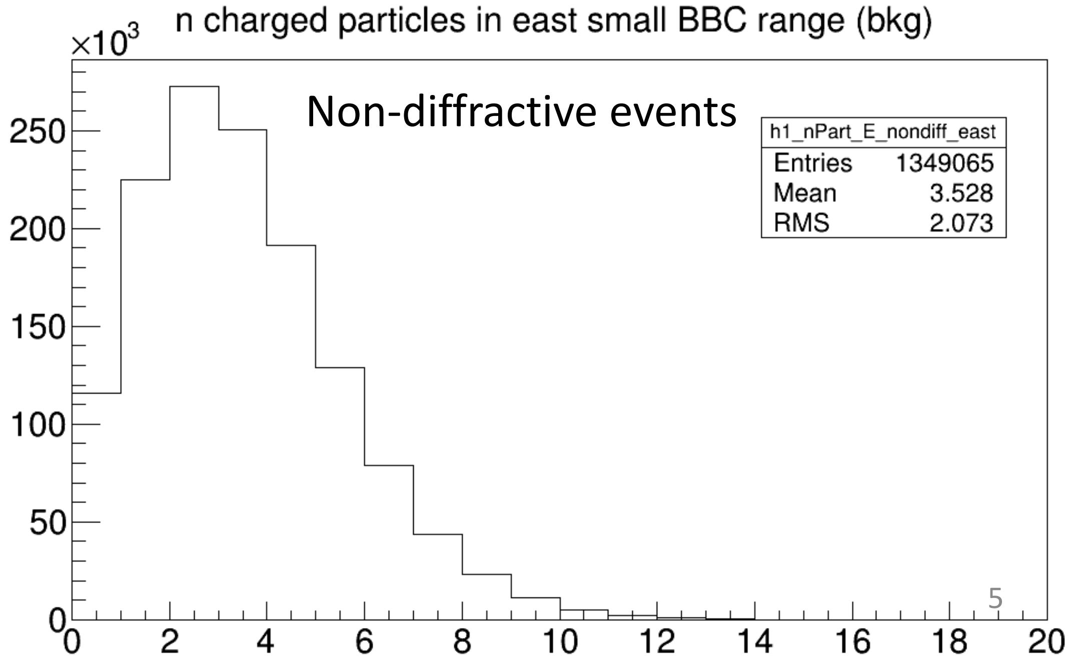




Particle level simulation to study east BBC cuts

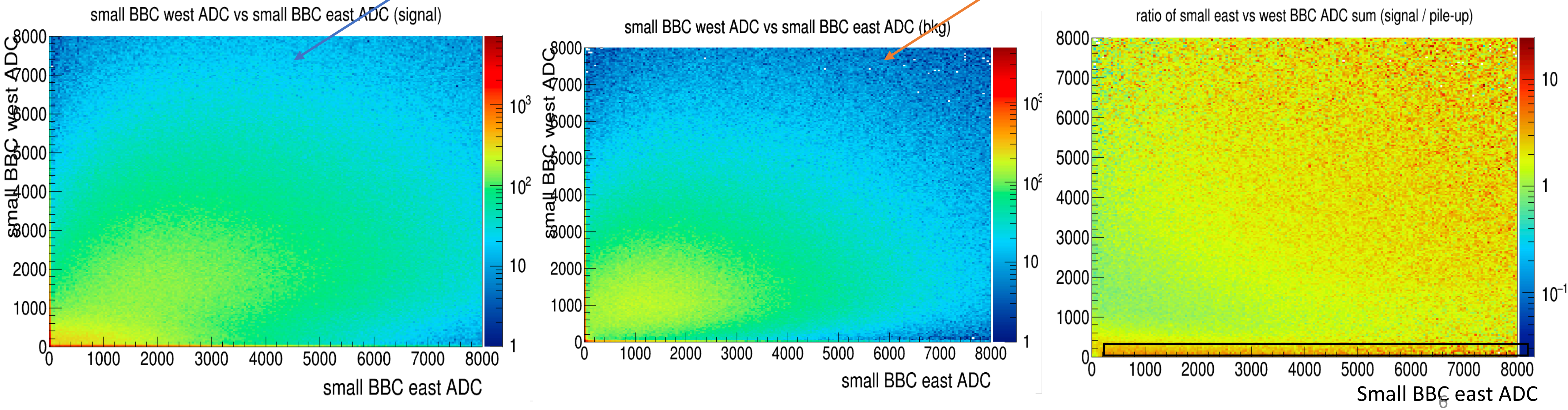
- Consider events only in particle level simulation.
- Investigate the outgoing particle distribution in the small BBC region.
  - Small BBC **east**: $-4.5 < \eta < -3.5$
  - Count the number of charged final state particles within such range.
- From the plots, lower number of charged particles for diffractive events is preferred. -> Choosing east small BBC cut with low threshold is OK.





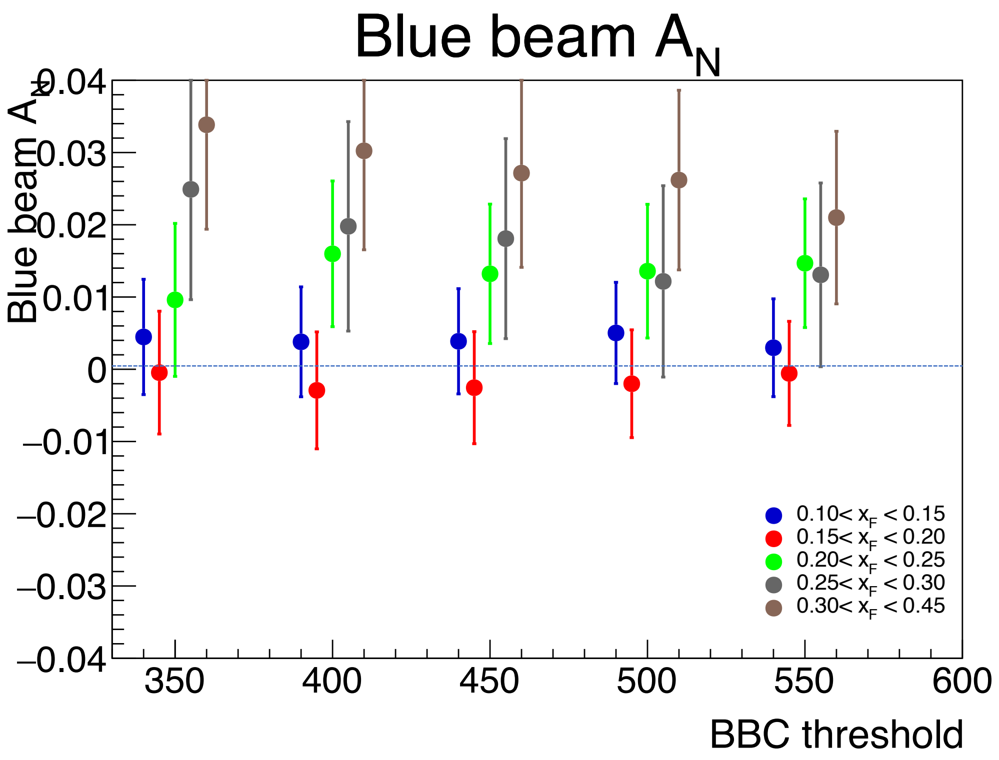
Check small BBC west ADC vs small BBC east ADC

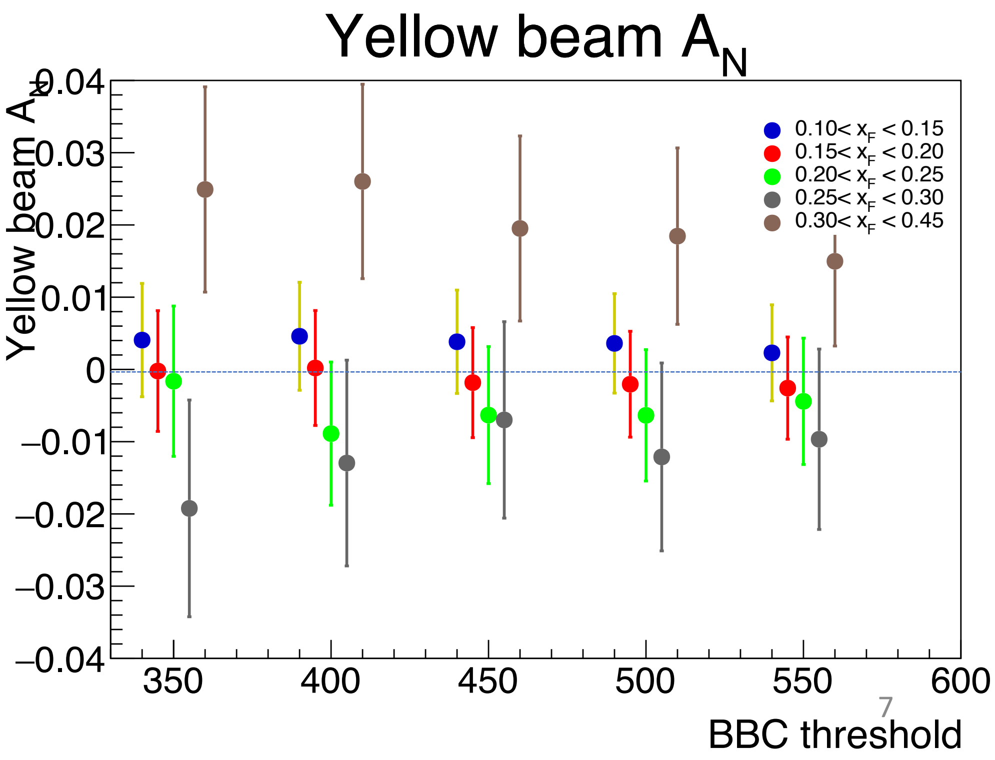
- Consider $E_{sum} < 260$ GeV as signal and $E_{sum} > 260$ GeV as background
  - E_{sum}: sum of FMS EM-jet energy and west RP track energy
- Plot the signal / background ratio
  - Consider cut on small BBC west ADC < 450 ~~and small BBC east ADC > 220~~
  - East small BBC cut seems not figuring out good cuts.



Investigate the A_N for different west BBC cut

- We try on different west BBC cut to see if the results are so converged.
  - List of west BBC max threshold: 350, 400, 450, 500, 550
- Use all photon multiplicity A_N as example.
  - Only A_N central value and statistical uncertainty shown in the plots.





Percentage difference for changing small west BBC ADC cut

Calculate each term by result difference fraction when changing the cuts:

$$difference = \frac{|A_{N,change\ cut} - A_{N,origin}|}{|A_{N,origin}|}$$

- Reference cut: small west BBC ADC sum < 450
- Blue beam

$|x_F|$ range	small west BBC cut 350	small west BBC cut 400	small west BBC cut 500	small west BBC cut 550
0.1 - 0.15	16%	2%	30%	23%
0.15 - 0.2	82%	15%	21%	78%
0.2 - 0.25	27%	21%	3%	11%
0.25 - 0.3	38%	9%	33%	28%
0.3 - 0.45	25%	11%	4%	23%

- Yellow beam

$|x_F|$ range	small west BBC cut 350	small west BBC cut 400	small west BBC cut 500	small west BBC cut 550
0.1 - 0.15	6%	20%	6%	40%
0.15 - 0.2	88%	111%	12%	41%
0.2 - 0.25	74%	41%	1%	30%
0.25 - 0.3	175%	85%	73%	38%
0.3 - 0.45	28%	33%	5%	23%

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, $\boldsymbol{p_T > 2}$ **GeV/c**, FMS point as input.
  - Apply energy correction.
- **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

  $b)$ $-0.5 < p_x < 0.3$ [GeV/c] , $0.25 < |p_y| < 0.4$ [GeV/c]
  - Sum of west RP track energy and all EM Jet energy
- **BBC ADC sum cuts:**
  - **West Small BBC ADC sum < 450**

Corrections:
Energy correction and
Underlying Event correction

x_F	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

Systematic uncertainty (EM-jet with all photon multiplicity)

- Systematic uncertainties for residual background effect mainly come from the cut for selecting signal from background.
  - Energy sum cut: change the energy sum cut to check the uncertainty.
  - Small west BBC ADC sum cut: change 450 to 400
- Polarization uncertainty: 1.1 % (back up)

Calculate each systematic uncertainty by result difference fraction when changing the cuts:

$$uncertainty = \frac{|A_{N,change\ cut} - A_{N,origin}|}{|A_{N,origin}|}$$

x_F	E sum Cut original	E sum Cut systematic
0.1 - 0.15	E_{sum} < 265 GeV	E_{sum} < 255 GeV
0.15 - 0.2	E_{sum} < 280 GeV	E_{sum} < 265 GeV
0.2 - 0.25	E_{sum} < 295 GeV	E_{sum} < 275 GeV
0.25 - 0.3	E_{sum} < 305 GeV	E_{sum} < 290 GeV
0.3 - 0.35	E_{sum} < 315 GeV	E_{sum} < 300 GeV
0.35 - 0.4	E_{sum} < 330 GeV	E_{sum} < 310 GeV
0.4 – 0.45	E_{sum} < 340 GeV	E_{sum} < 320 GeV

Blue beam

x_F range	E_sum	Small BBC	Summary
0.1 – 0.15	5%	2%	5%
0.15 – 0.2	3%	15%	15%
0.2 – 0.25	8%	21%	22%
0.25 – 0.3	15%	9%	17%
0.3 – 0.45	9%	11%	14%

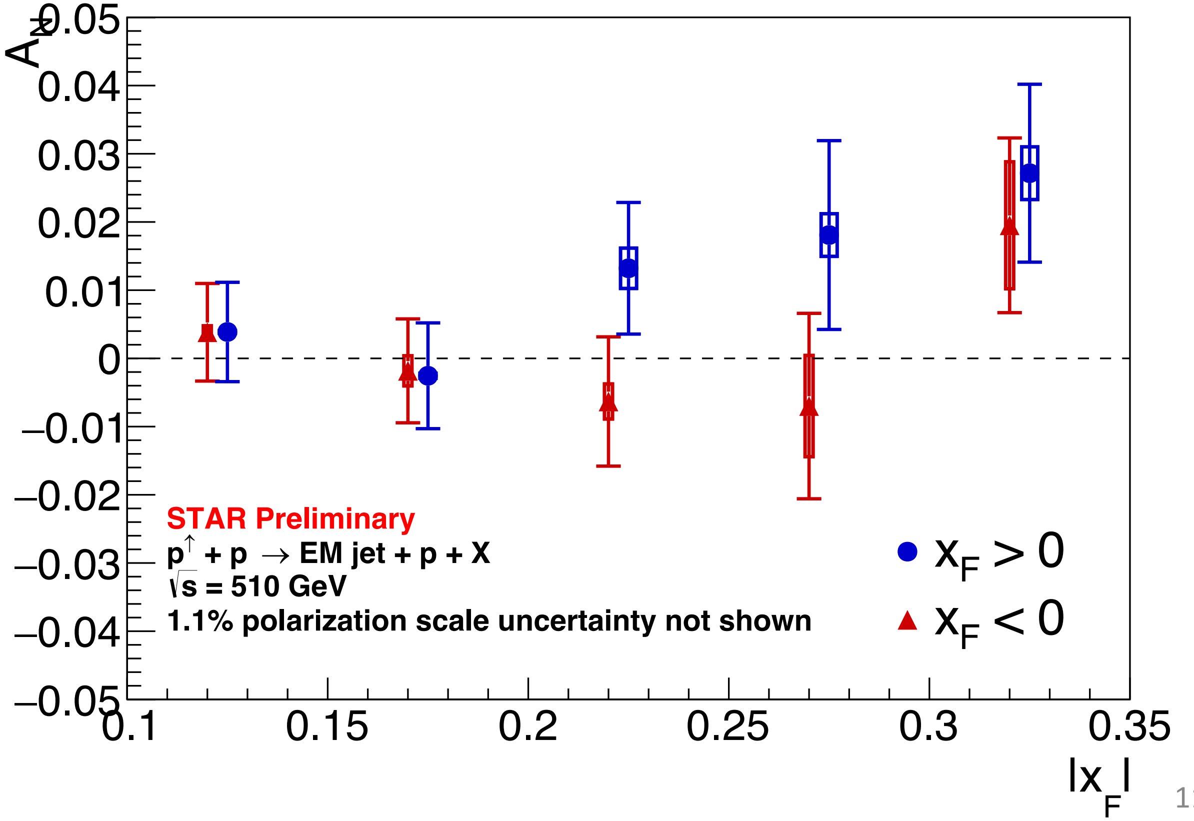
Yellow beam

x_F range	E_sum	Small BBC	Summary
0.1 – 0.15	15%	20%	25%
0.15 – 0.2	49%	111%	121%
0.2 – 0.25	3%	41%	41%
0.25 – 0.3	63%	85%	106%
0.3 – 0.45	34%	33%	48%

Run 17 FMS diffractive EM-jet A_N results

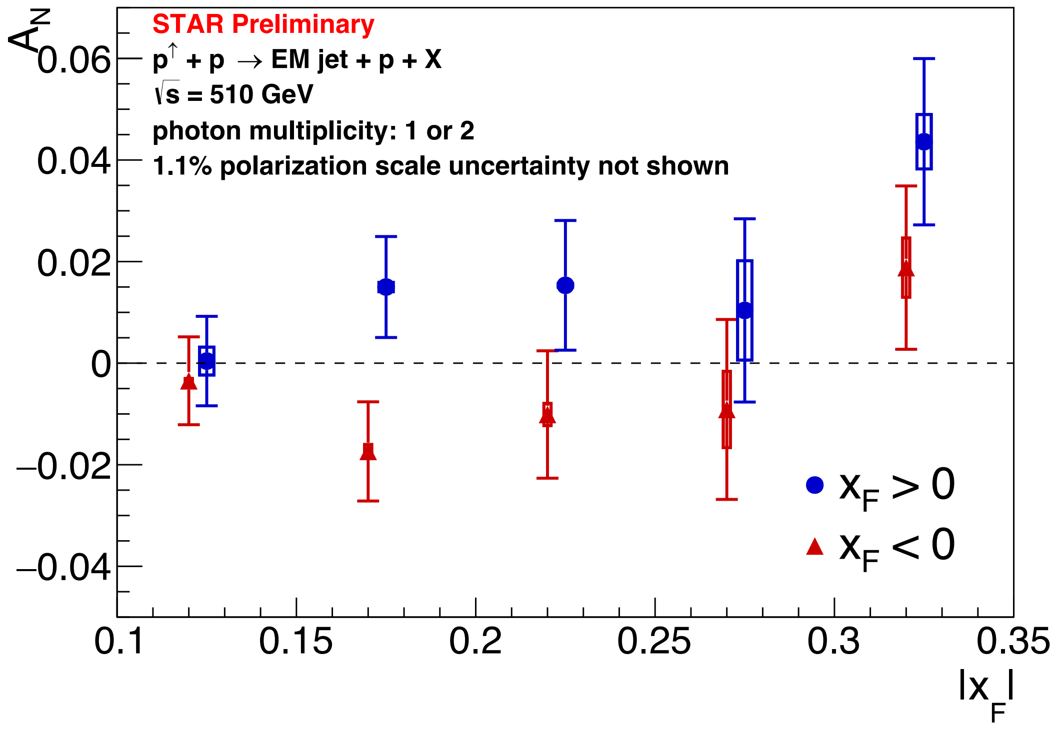
- **EM-jet with all photon multiplicity**
- Cross ratio method is applied to extract the A_N.
- Consider only 5 x_F ranges: [0.1,0.15], [0.15, 0.2], [0.2, 0.25], [0.25, 0.3], [0.3, 0.45]

- They seems to get A_N close to 0 at low x_F ranges, but A_N greater than 0 at high x_F ranges.
- The sign is mostly positive, different from run 15 results.
- Preliminary request plot 1



Run 17 FMS diffractive EM-jet A_N results

- **EM-jet with 1 or 2 photon multiplicity**
- Cross ratio method is applied to extract the A_N.
- Still consider only 5 x_F ranges: [0.1,0.15], [0.15, 0.2], [0.2, 0.25], [0.25, 0.3], [0.3, 0.45]
- The larger A_N values are observed for EM-jet with 1 or 2 photon multiplicity. They are 2.5 σ to be non-zero.
- Preliminary request plot 2



Systematic uncertainty (**EM-jet with 1 or 2 photon multiplicity**)

- Systematic uncertainties for residual background effect mainly come from the cut for selecting signal from background.
  - Energy sum cut: change the energy sum cut to check the uncertainty.
  - Small BBC ADC sum cut: change 450 to 400

Calculate each systematic uncertainty by result difference fraction when changing the cuts:

$$uncertainty = \frac{|A_{N,change\ cut} - A_{N,origin}|}{|A_{N,origin}|}$$

x_F	E sum Cut original	E sum Cut systematic
0.1 - 0.15	E_{sum} < 265 GeV	E_{sum} < 255 GeV
0.15 - 0.2	E_{sum} < 280 GeV	E_{sum} < 265 GeV
0.2 - 0.25	E_{sum} < 295 GeV	E_{sum} < 275 GeV
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0.35 - 0.4	E_{sum} < 330 GeV	E_{sum} < 310 GeV
0.4 – 0.45	E_{sum} < 340 GeV	E_{sum} < 320 GeV

Blue beam

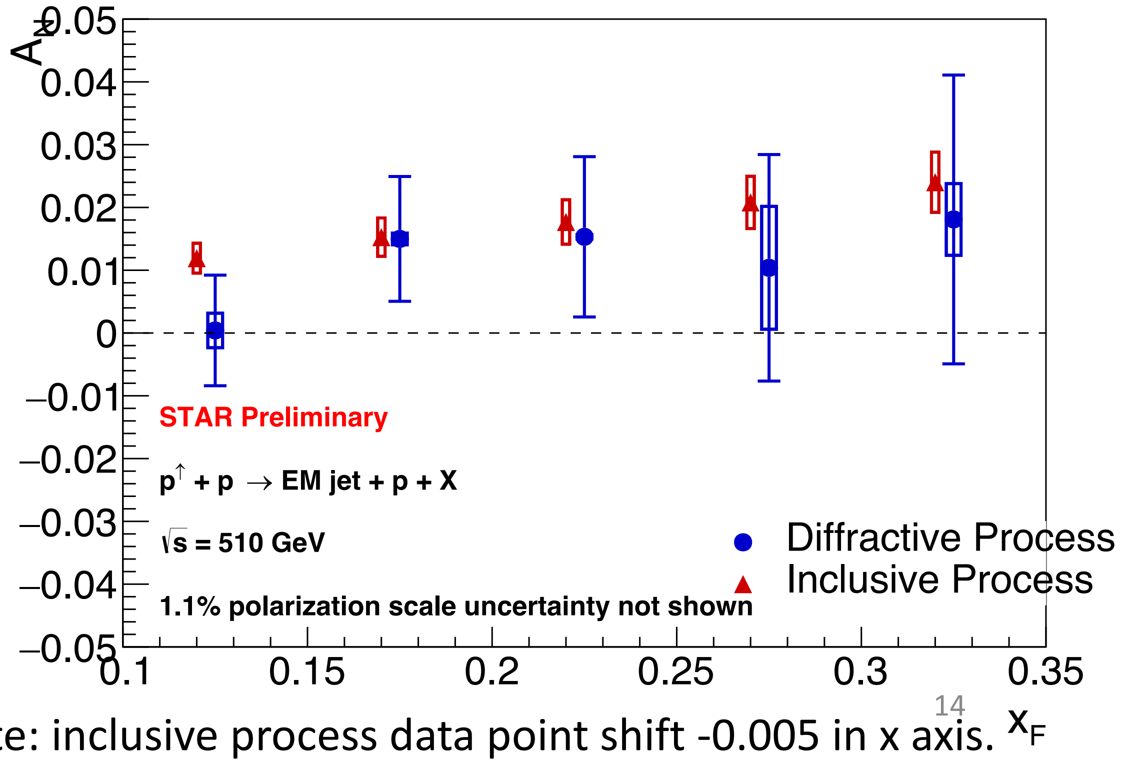
x_F range	E_sum	Small BBC	Summary
0.1 – 0.15	91%	663%	670%
0.15 – 0.2	2%	6%	6%
0.2 – 0.25	1%	2%	2%
0.25 – 0.3	9%	94%	94%
0.3 – 0.45	6%	11%	12%

Yellow beam

x_F range	E_sum	Small BBC	Summary
0.1 – 0.15	11%	7%	13%
0.15 – 0.2	8%	1%	8%
0.2 – 0.25	10%	19%	22%
0.25 – 0.3	52%	64%	82%
0.3 – 0.45	31%	5%	31%

Comparison between run 17 FMS inclusive and diffractive EM-jet A_N results

- We compare run 17 FMS inclusive (done by Bishnu) and diffractive **1 or 2 photon multiplicity** EM-jet A_N results.
- Both results are A_N results as the function of x_F (with exactly same x_F bins [0.1,0.15], [0.15, 0.2], [0.2, 0.25], [0.25, 0.3], [0.3, 0.35])
- Preliminary request plot 3



Note: inclusive process data point shift -0.005 in x axis.

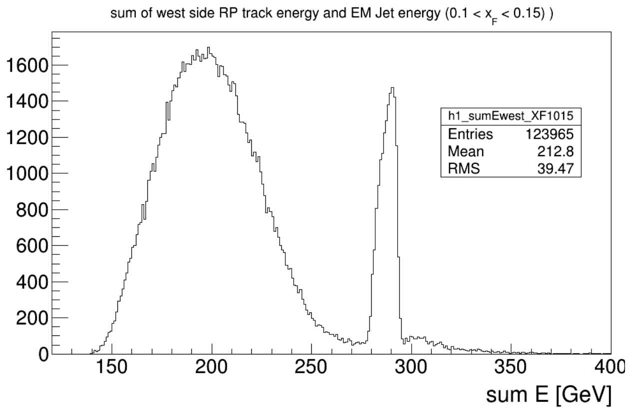
Conclusion

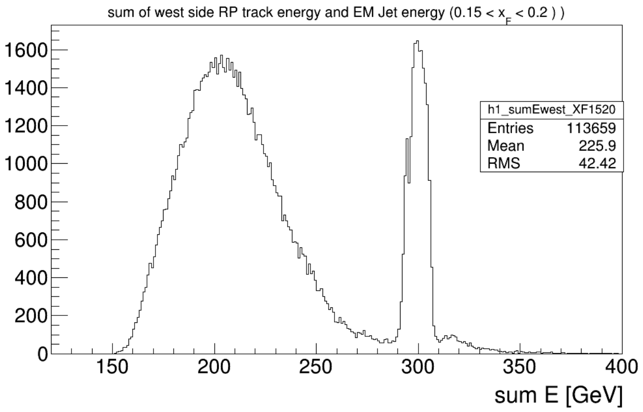
- Particle level simulation shows that the BBC cuts with low threshold can help to maximize the diffractive events.
- Diffractive EM-jet A_N are close to zero at $\sqrt{s}$ = 510 GeV.
- The diffractive process might not contribute to large A_N for inclusive process.
- Outlook:
  - DIS 2023 presentation is ready for review. When preliminary requests for the plots are obtained, we will update to the website.

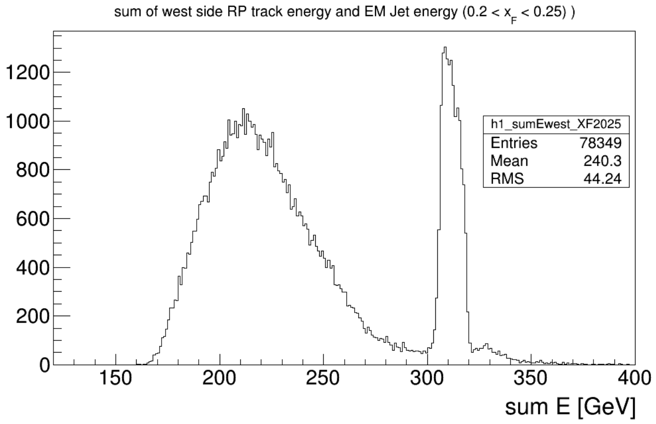
Back up

E sum cuts based on different x_F ranges

- Apply E sum cuts based on signal peak and pile-up peak splitting position.







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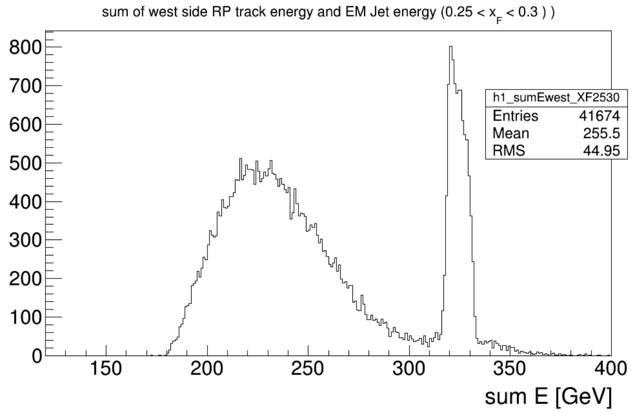
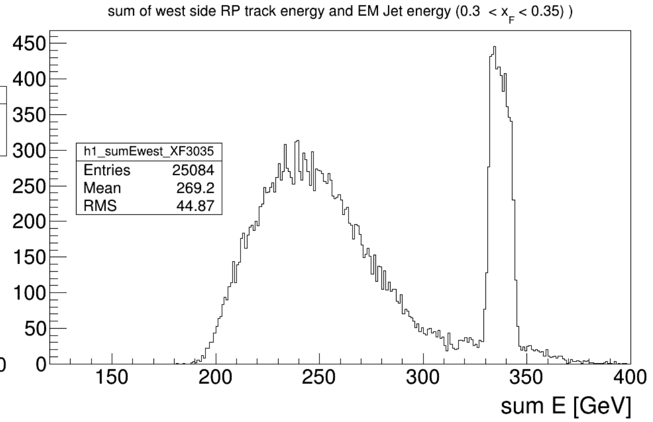
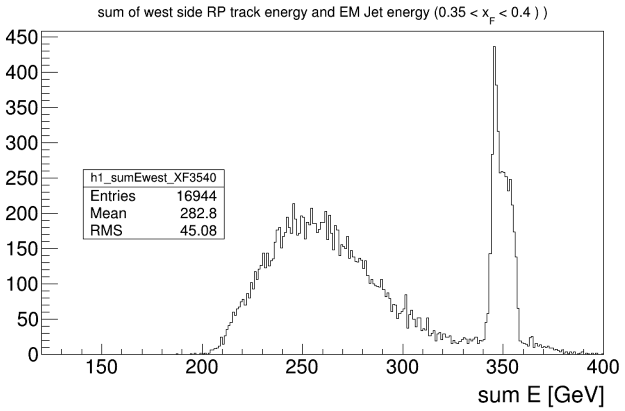
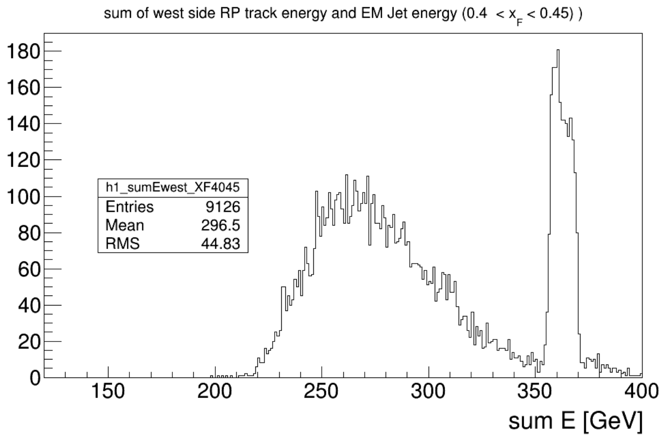








Polarization uncertainty

- $\sigma(P_{set}) = P_{set} \cdot \frac{\sigma(scale)}{P} \oplus \sigma_{set}(fill\ to\ fill) \oplus P_{set} \cdot \frac{\sigma(profile)}{P}$
- $\frac{\sigma(scale)}{P} = 1.1\%$ [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

Previous study

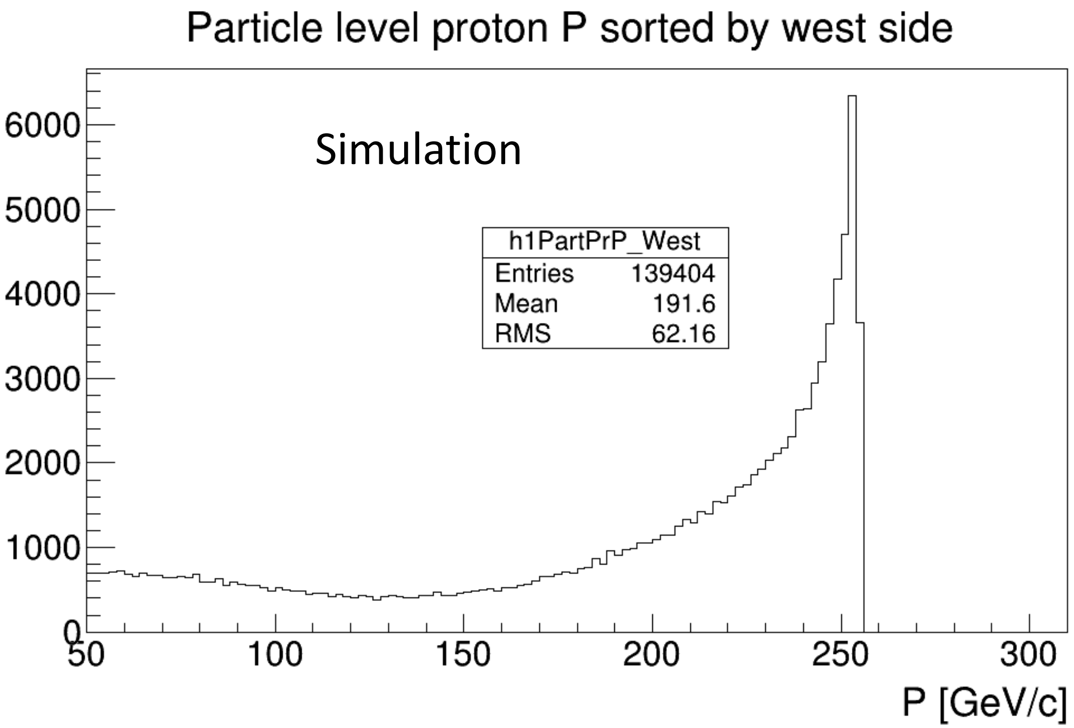
- Mar. 8 PWG meeting

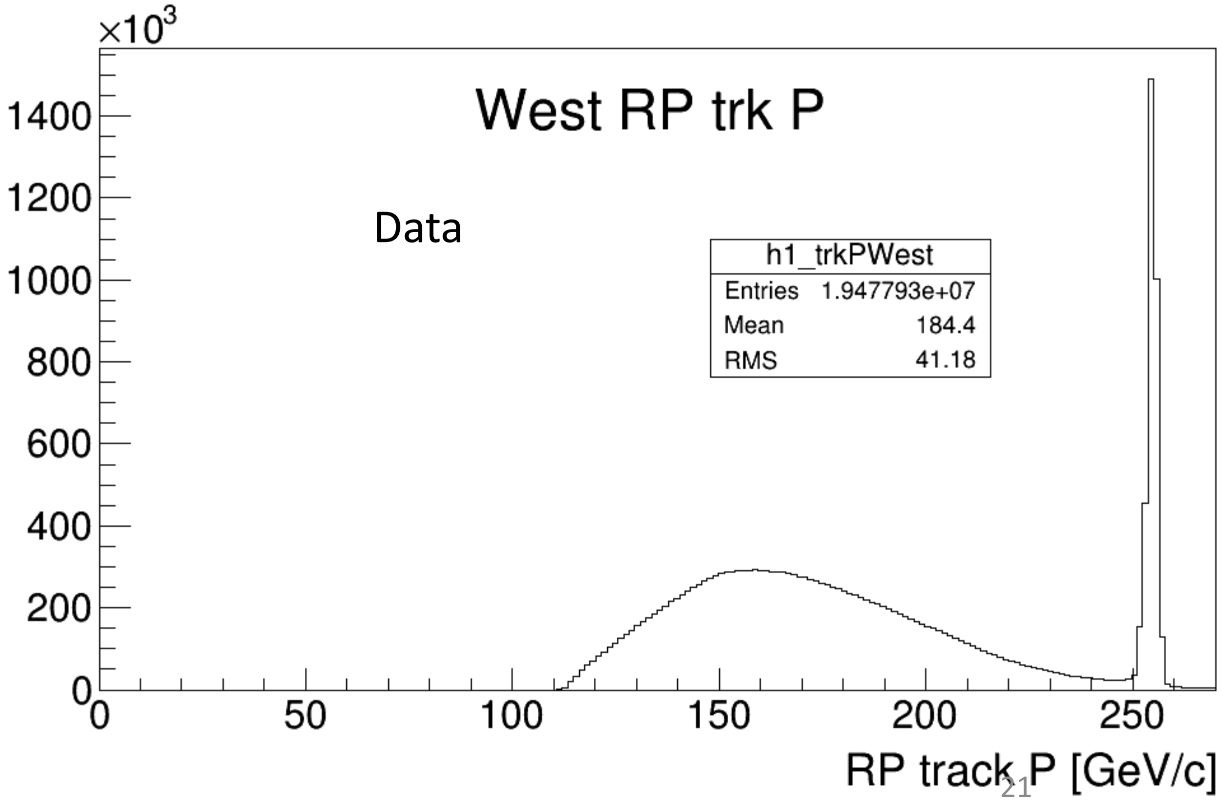
Roman Pot track update

- We discuss with Tomas Truhlar (RP group, LFSUPC PWG), who applies run 17 pp 510 GeV with RP:
  1. It’s better to apply cut on: RP track hits 3 out of 4 planes for each RP package. -> decide to change my RP track cut on hitting at least 7 RP planes.
  2. RP track momentum are still not measuring well.
  3. Detector level simulation for RP for run 17 is still developing. They will apply the simulation to study the detector efficiency.

Simulation for diffractive processes

- Consider hard diffraction in Pythia8 simulation.
  - Only in particle level simulation. The detector level simulation is still developing by Roman Pot group.
- RP track momentum for data look not match well with particle level simulation.

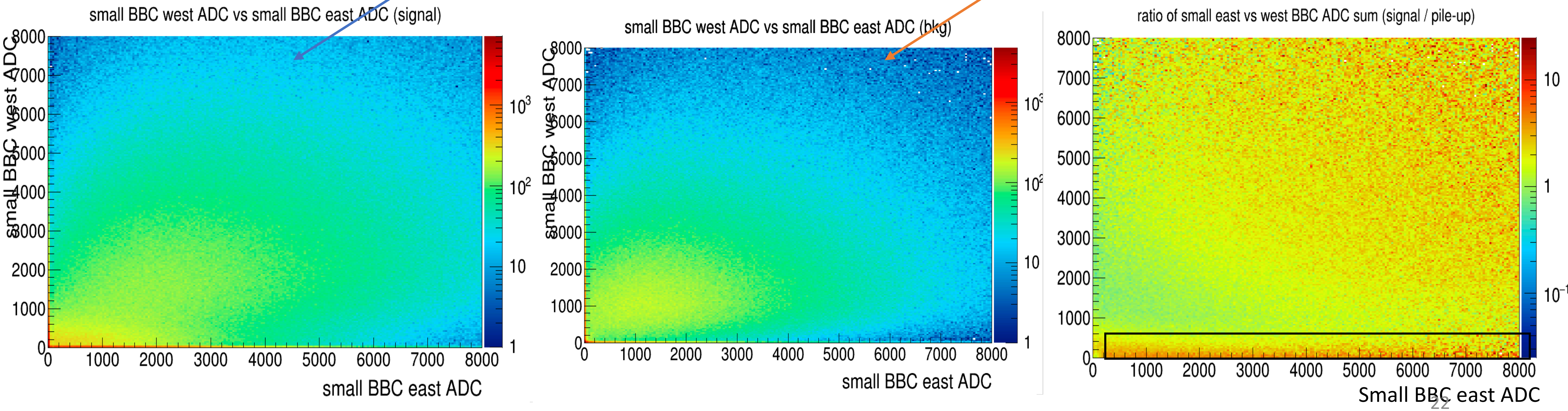




Check small BBC west ADC vs small BBC east ADC

Was presented in Mar.8 PWG meeting. East BBC cut is not used!

- Consider E_{sum} < 260 GeV as signal and E_{sum} > 260 GeV as background
  - E_{sum}: sum of FMS EM-jet energy and west RP track energy
- Plot the signal / background ratio
  - Consider cut on small BBC west ADC < 450 and small BBC east ADC > 220



Investigate the A_N for different west BBC cut

- We try on different west BBC cut to see if the results are so converged.
  - List of west BBC max threshold: 350, 400, 450, 500, 550
  - Fix east BBC cut: East small BBC sum > 220
- Use all photon multiplicity A_N as example.
  - Only A_N central value and statistical uncertainty shown in the plots.