

# Update and Plans for Run 15/17 diffractive EM-jet $A_N$ analysis

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UCR

STAR Collaboration Meeting Spin/Cold-QCD Parallel Session

Oct. 24, 2023

# Outline

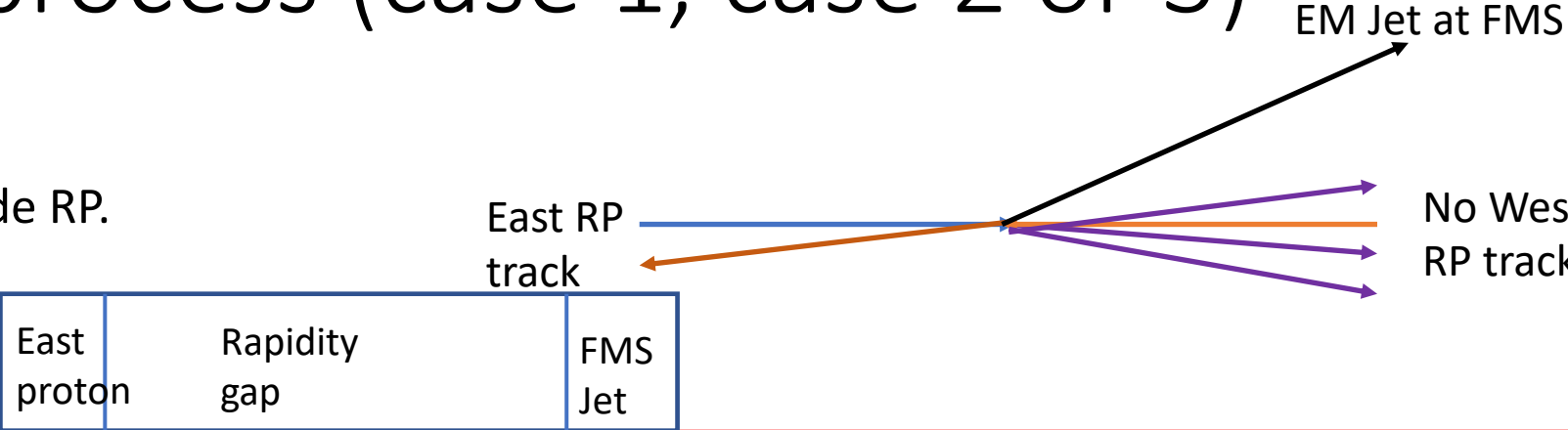
- Discussion with Roman Pot group
- Study for run 17 west RP track cuts
- Plan and status for run 15/17 analyses

# Discussion with Roman Pot (RP) group

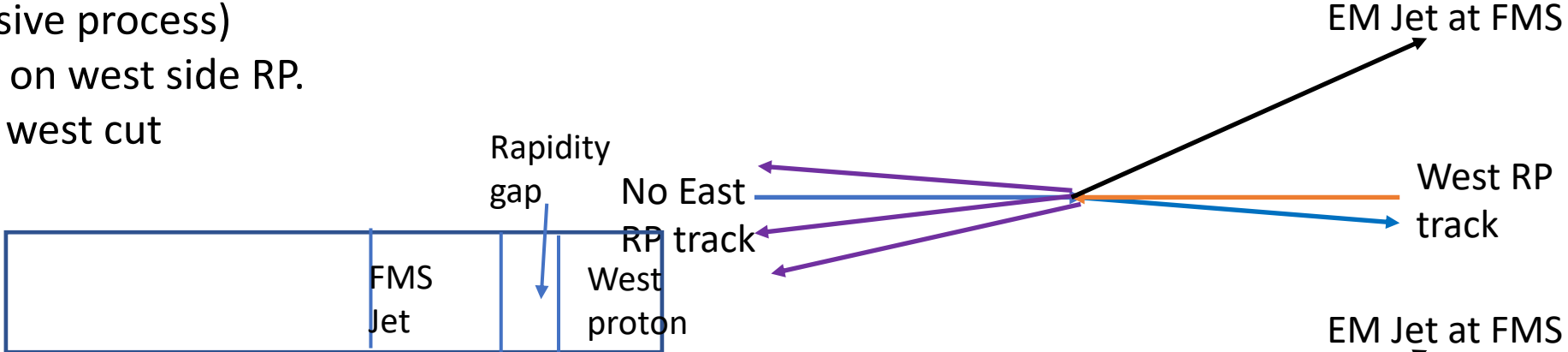
- In mid September, we had a discussion with RP group (Woldek Guryn, Leszek Adamczyk, Tomas Truhlar) for the cuts on RP track and diffractive processes
- Lesson we learned:
  - ✓ The RP track cuts need to be considered properly:
    1. Study RP track  $P_X, P_Y, \theta_X, \theta_Y$  distribution for different RP track  $\xi$  ( $\xi = \frac{P_{beam} - P_{RP}}{P_{beam}}$ )
    2. Consider the RP track  $P_X, P_Y, \theta_X, \theta_Y$  cuts for different RP track  $\xi$
  - Re-consider the case with only 1 east RP track
    1. Study the east RP track cuts
    2. Better to determine the veto on detectors for the presence of rapidity gap

# Diffraction process (case 1, case 2 or 3)

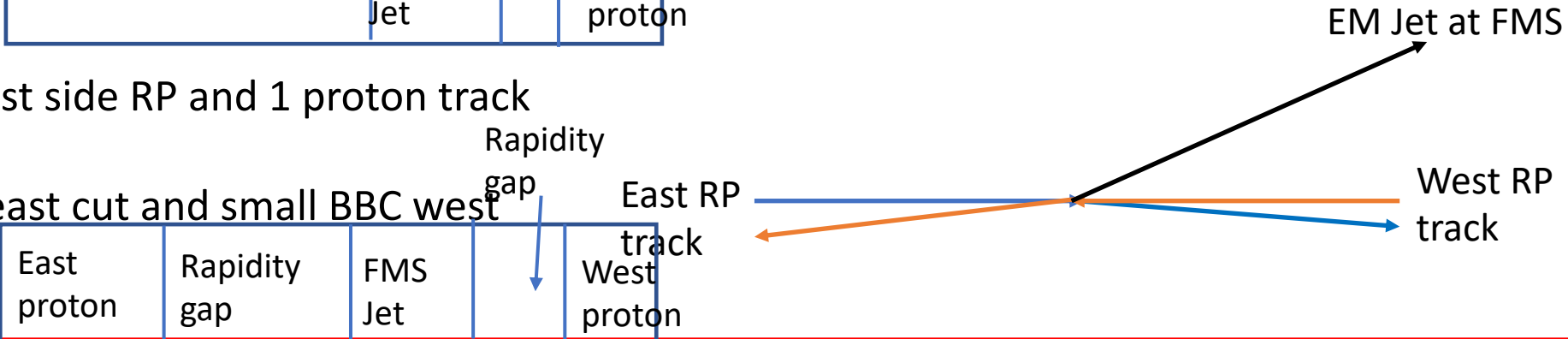
Case 1: (RP group preferred!)  
 only 1 proton track on east side RP.  
**Require:** small BBC east cut



Case 2: (semi-inclusive process)  
 only 1 proton track on west side RP.  
**Require:** small BBC west cut



Case 3:  
 1 proton track on east side RP and 1 proton track  
 on west side RP.  
**Require:** small BBC east cut and small BBC west  
 cut

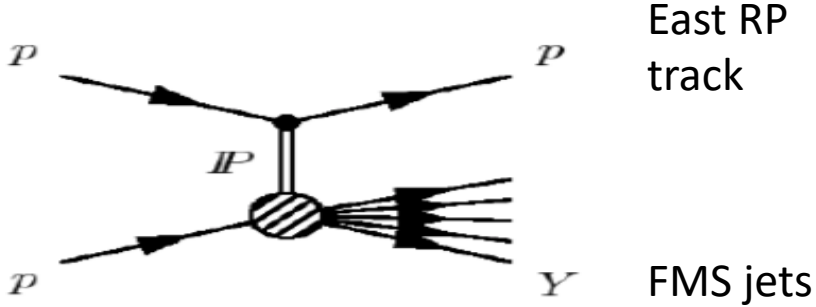


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# Diffraction process (case 1, case 2 or 3)

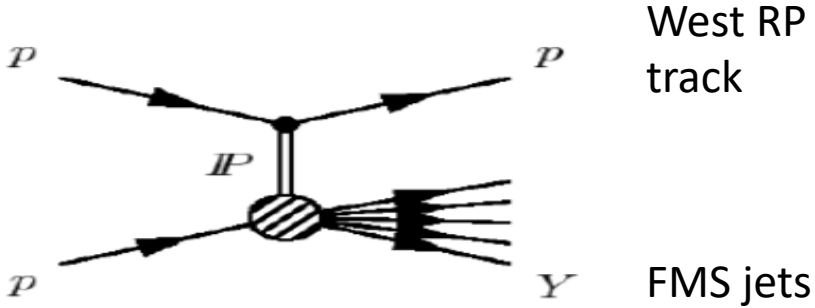
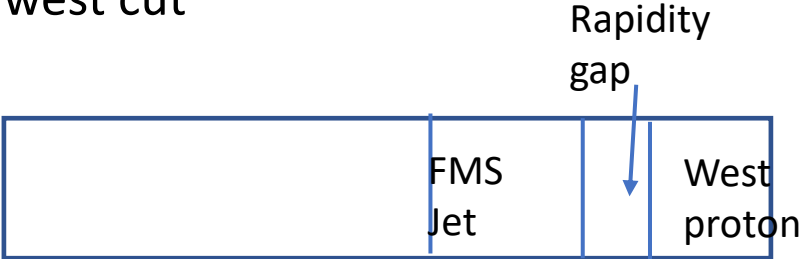
Case 1: (RP group preferred!)  
only 1 proton track on east side RP.

**Require:** small BBC east cut



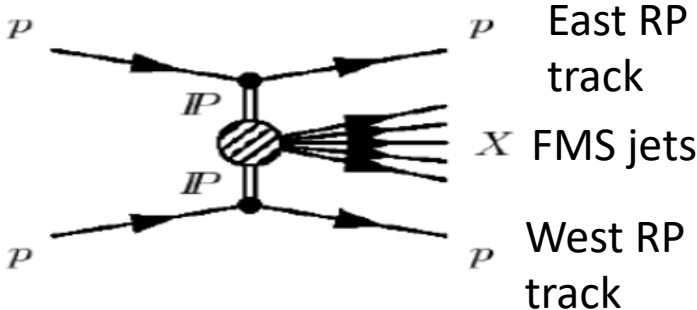
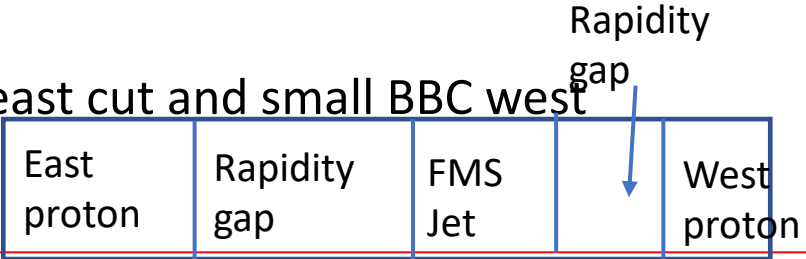
Case 2: (semi-inclusive process)  
only 1 proton track on west side RP.

**Require:** small BBC west cut



Case 3:  
1 proton track on east side RP and 1 proton track on west side RP.

**Require:** small BBC east cut and small BBC west cut



**This Slide**

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

# Outline for studying the RP cuts and BBC cuts

- Here are the idea and steps for considering the cuts for RP and BBC:
  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 or west  $< 250$  . Goal: explore a rough RP  $P_X$  ,  $P_Y$  cuts for different  $\xi$  range.
  2. Apply the rough RP  $P_X$  ,  $P_Y$  cuts from step 1, study the small BBC east/west ADC distribution and consider further cuts for small BBC cuts.
  3. Apply the further cuts for west or east small BBC cuts, study the further RP  $P_X$  ,  $P_Y$  cuts, and  $\theta_X$  ,  $\theta_Y$  cuts for different  $\xi$  range.
- This slide focus on the cut on **run 17 west RP track**

# Step 1: **West** RP track $P_x$ , $P_y$ study

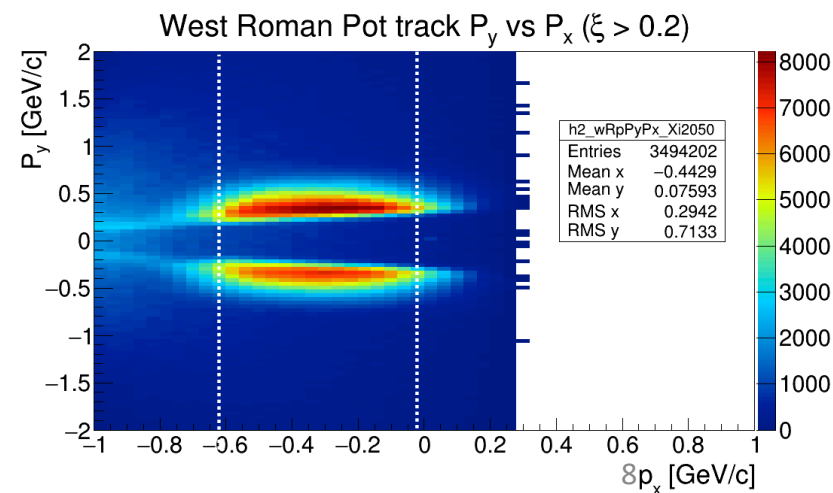
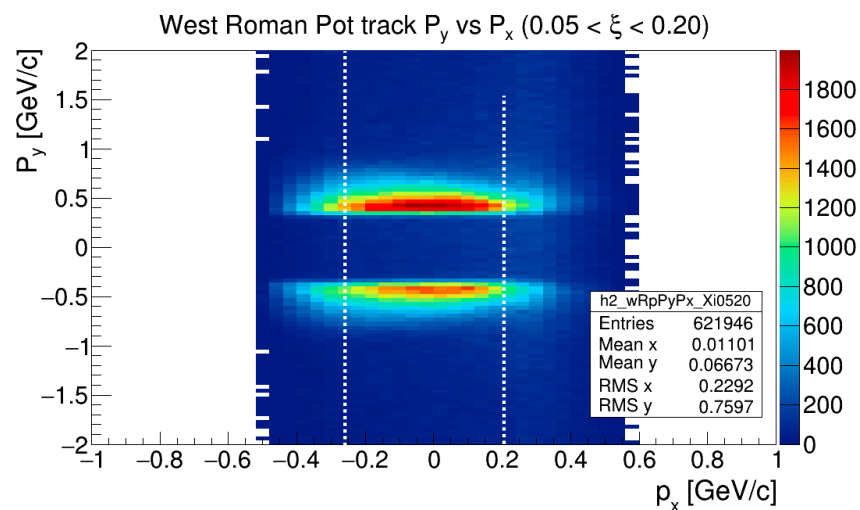
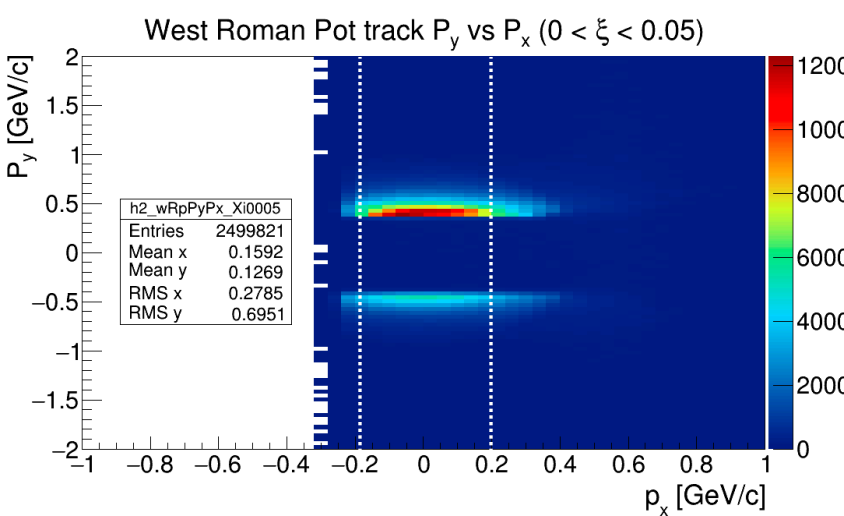
- We require the west RP track to hit at least 7 SSD planes
- Low small BBC ADC sum is preferred. We temporarily assign small BBC west ADC < 250 to study the good west RP track  $P_x$  and  $P_y$  .

# West Roman Pot track $P_Y$ vs $P_X$

- Plot the west Roman Pot track  $P_Y$  vs  $P_X$  for different  $\xi$

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

- Applying the cut on small BBC west  $< 250$  (just to see more clear  $P_Y$  vs  $P_X$  distribution)
- The distribution for 3 different  $\xi$  ranges are different. Therefore, we should consider different sets of  $P_X$ ,  $P_Y$  cuts for different proton  $\xi$ .





# West Roman Pot track $P_Y$ vs $P_X$

- Plot the west Roman Pot track  $P_Y$  vs  $P_X$  for different  $\xi$

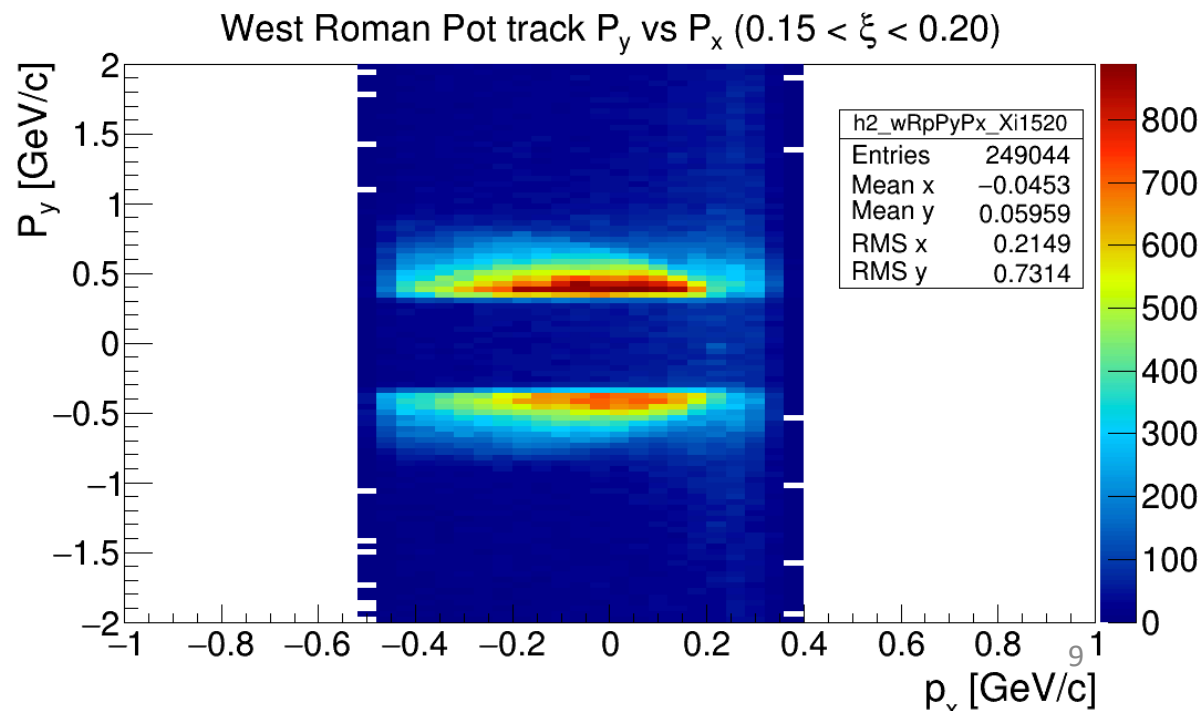
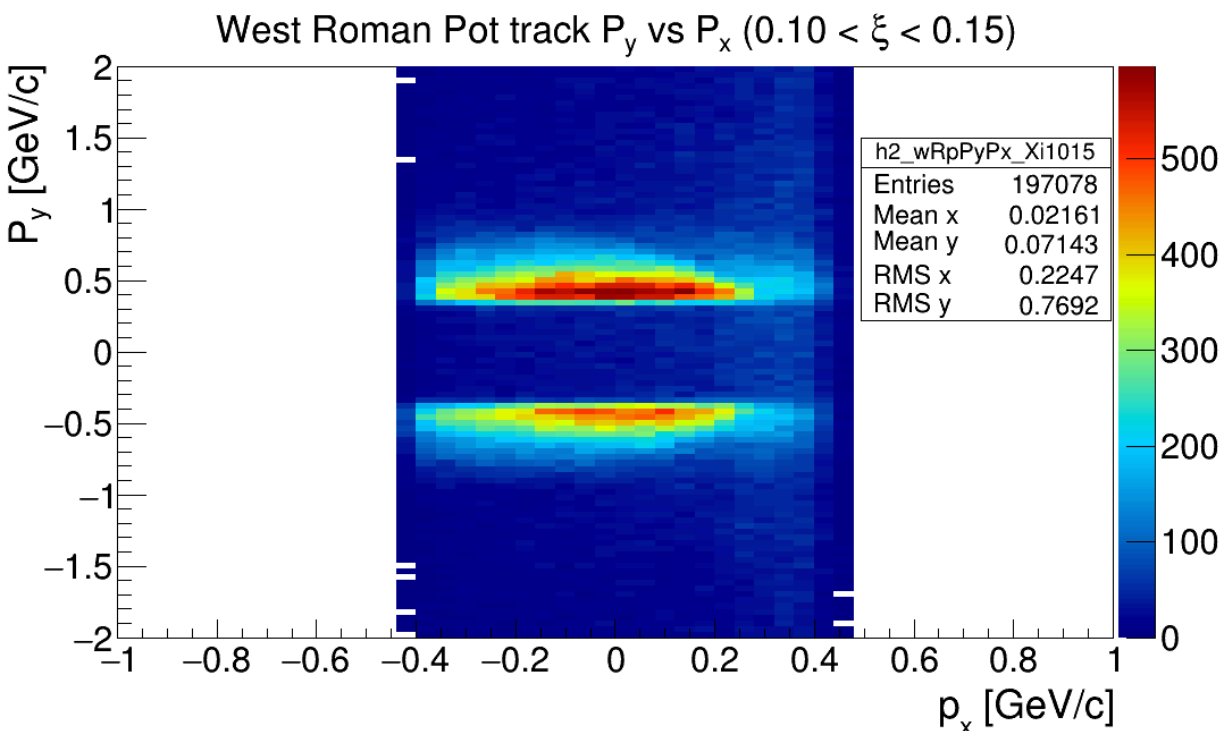
- $\xi = \frac{P_{beam} - P_{RP}}{P_{beam}}$

- Applying the cut on small BBC west  $< 250$  (just to see more clear  $P_Y$  vs  $P_X$  distribution)

Therefore, we can consider the rough cuts for RP track:

$$-0.3 < P_X < 0.2 \text{ GeV/c}; -0.6 < P_Y < -0.35 \text{ GeV/c or}$$

$$0.3 < P_Y < 0.55 \text{ GeV/c}$$

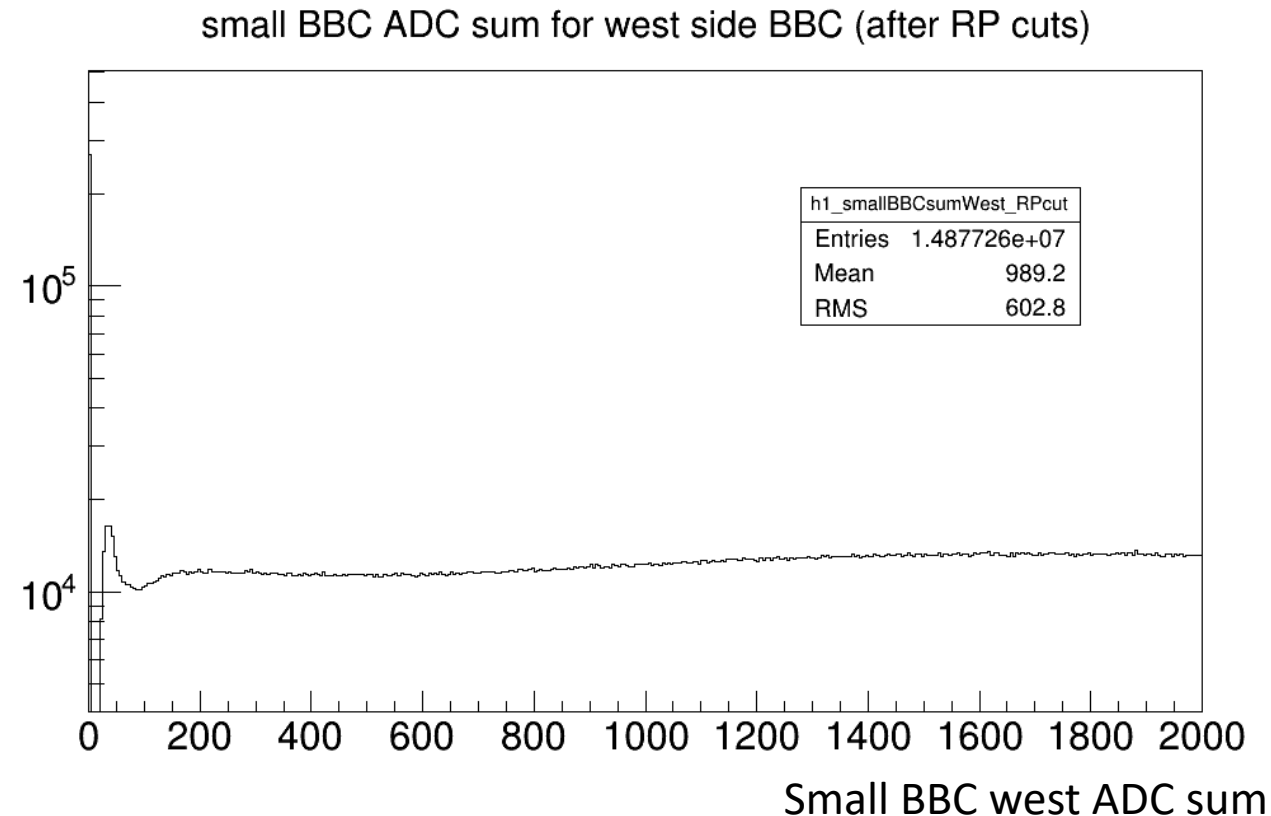


## Step 2: explore the BBC cuts

- Based on the study for RP  $P_X$  and  $P_Y$  distribution, we can first use the cut for RP track below (rough cuts, not the final cuts):
- The RP (west) track must hit at least 7 SSD planes.
- Rough west RP track  $P_X$  and  $P_Y$  cut, depending on  $\xi$ :
  - $0.1 < \xi < 0.2$ :  $-0.3 < P_X < 0.2$  GeV/c ;  $-0.6 < P_Y < -0.35$  GeV/c or  $0.3 < P_Y < 0.55$  GeV/c
  - $0.2 < \xi < 0.3$ :  $-0.3 < P_X < 0.15$  GeV/c ;  $-0.5 < P_Y < -0.3$  GeV/c or  $0.3 < P_Y < 0.5$  GeV/c
  - $0.3 < \xi < 0.5$ :  $-0.6 < P_X < 0$  GeV/c ;  $-0.5 < P_Y < -0.3$  GeV/c or  $0.2 < P_Y < 0.5$  GeV/c (if needed)

# Step 2: Study on small BBC west ADC sum

- The small BBC west plot only counts the events with the west RP track passing the RP cut with corresponding  $\xi$  and west RP track  $0.1 < \xi < 0.5$ .
  - Consider cuts: small BBC west  $< 80$
- Large BBC west ADC sum are all 0, so we are not able to apply the large BBC west cut.



## Step 3: study the further RP cuts

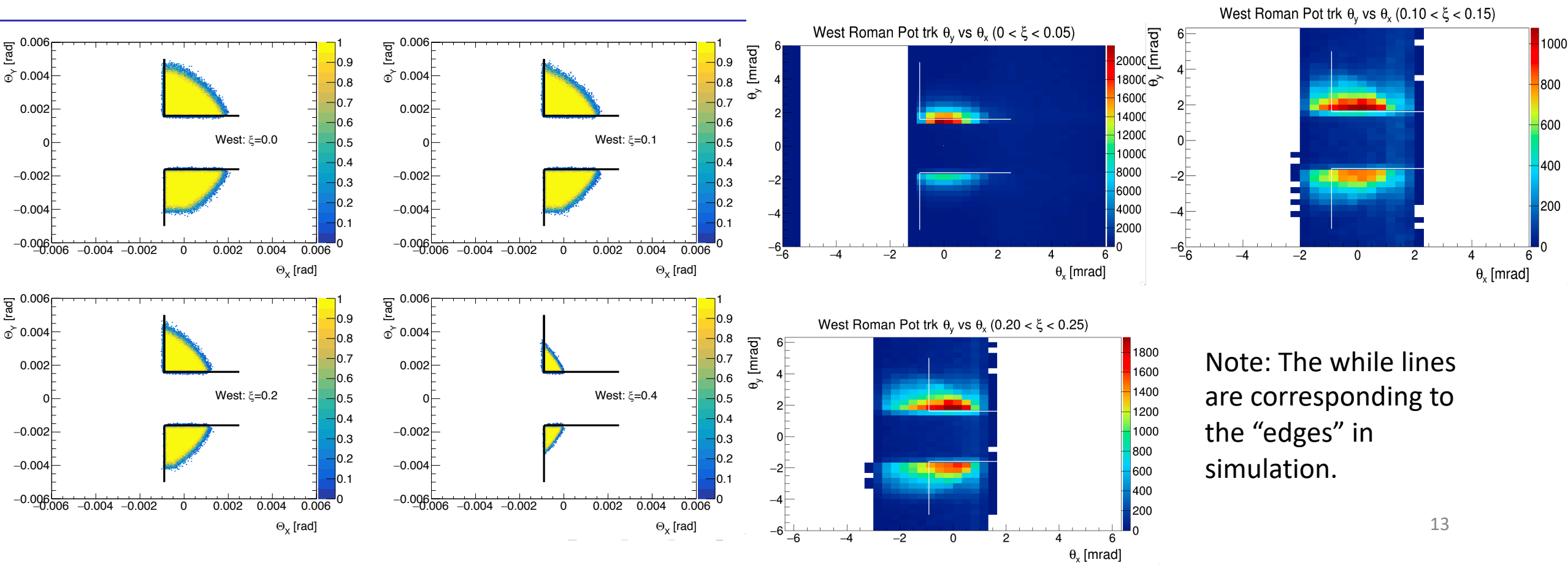
- To study west RP track cuts, we apply cut on small BBC west  $< 80$

# Data and simulation comparison for West RP track $\theta_Y$ vs $\theta_X$

- The simulation for **RP geometric acceptance** is studied by Leszek.
- Black lines (left 2×2 plots) are their tentative geometric acceptance (edge), but they shows that the  $\xi$  dependent  $\theta_X$  and  $\theta_Y$  should be considered.

Simulation

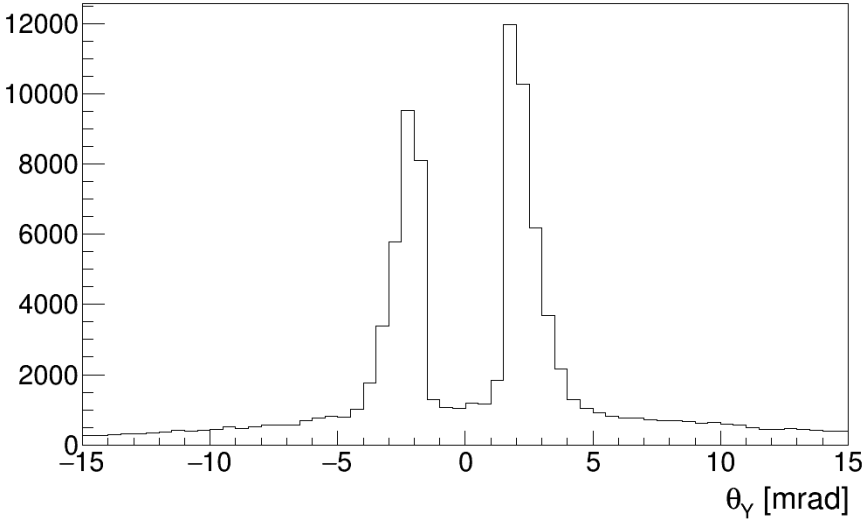
Data



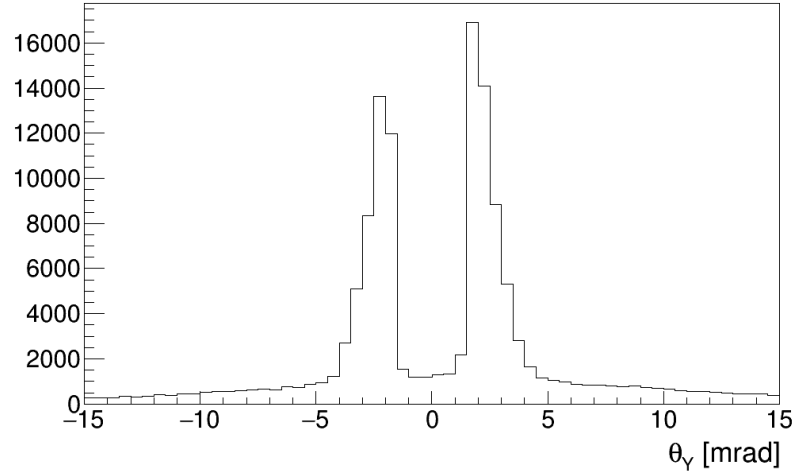
# West RP $\theta_Y$

We can consider the west RP  $\theta_Y$  cut:  $1.5 < |\theta_Y| < 3 \text{ mrad}$  for all  $\xi$

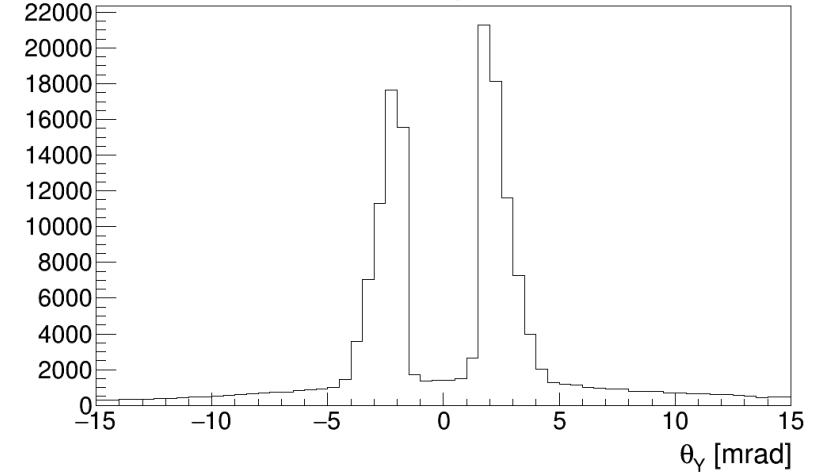
West Roman Pot  $\theta_Y$  ( $0.10 < \xi < 0.15$ )



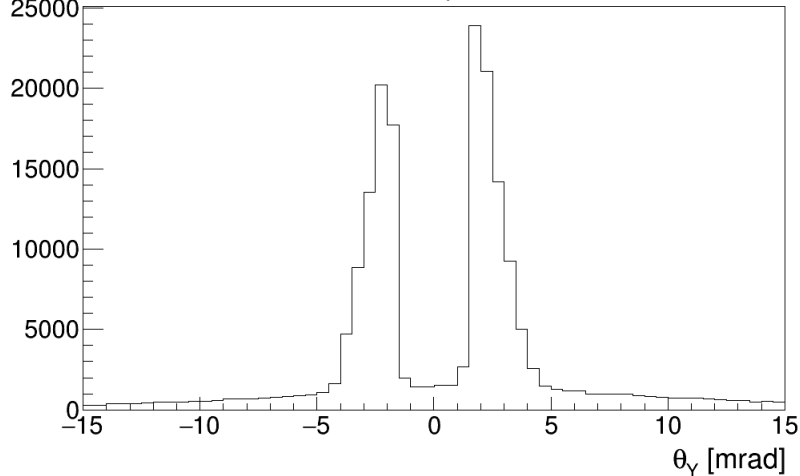
West Roman Pot  $\theta_Y$  ( $0.15 < \xi < 0.20$ )



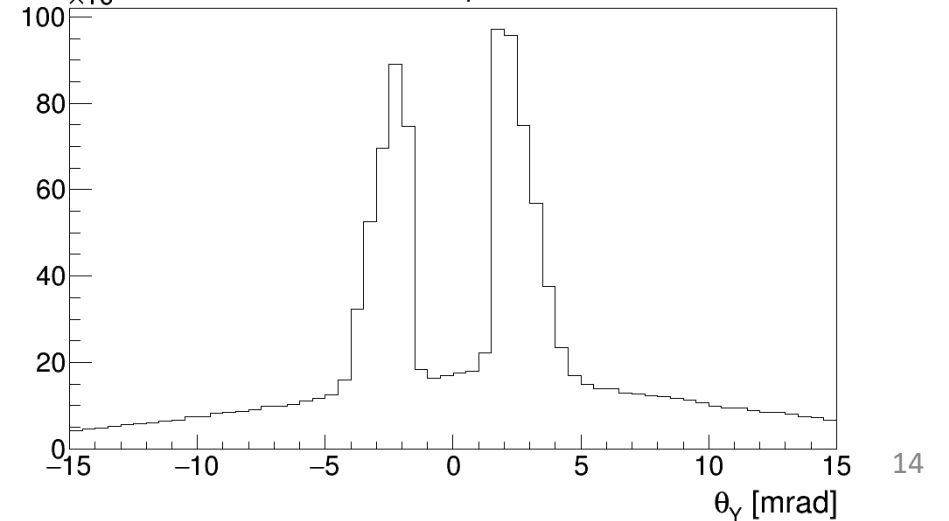
West Roman Pot  $\theta_Y$  ( $0.20 < \xi < 0.25$ )



West Roman Pot  $\theta_Y$  ( $0.25 < \xi < 0.30$ )



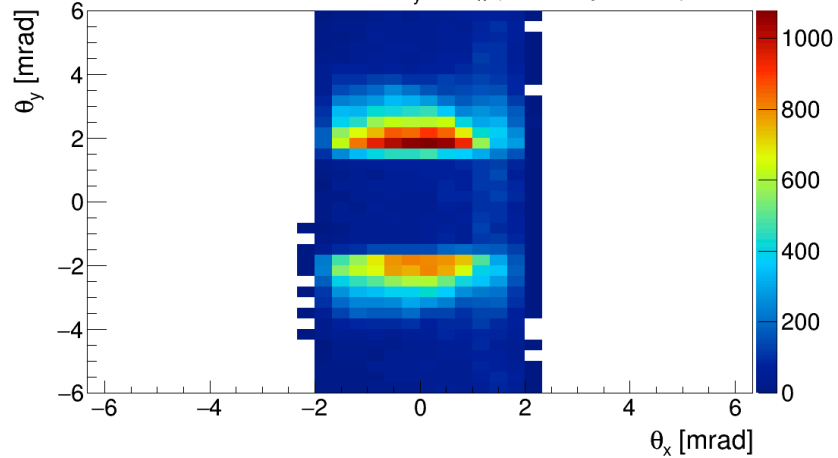
West Roman Pot  $\theta_Y$  ( $0.30 < \xi < 0.50$ )



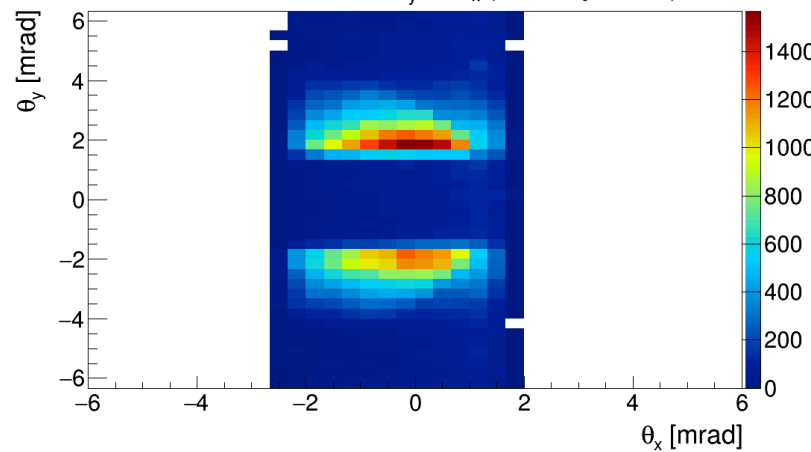
# West RP track $\theta_Y$ vs $\theta_X$ with different $\xi$ ranges

- Lower edge of  $\theta_Y$  in positive value could come from beam halo.
- The  $\theta_X$  cuts should be varied by different  $\xi$

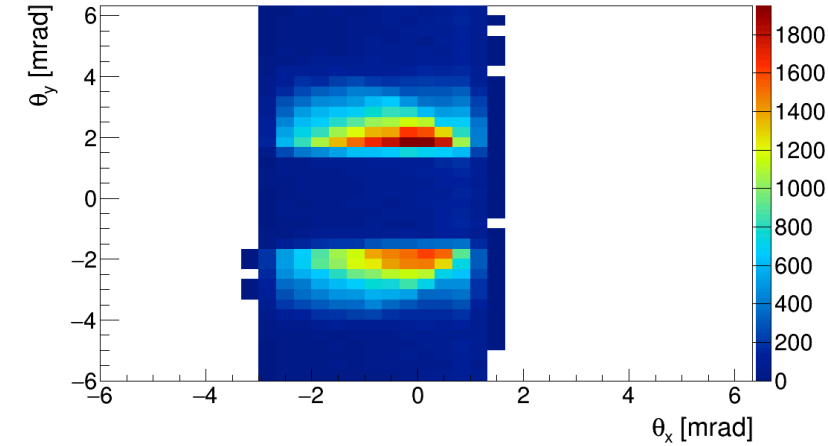
West Roman Pot trk  $\theta_y$  vs  $\theta_x$  ( $0.10 < \xi < 0.15$ )



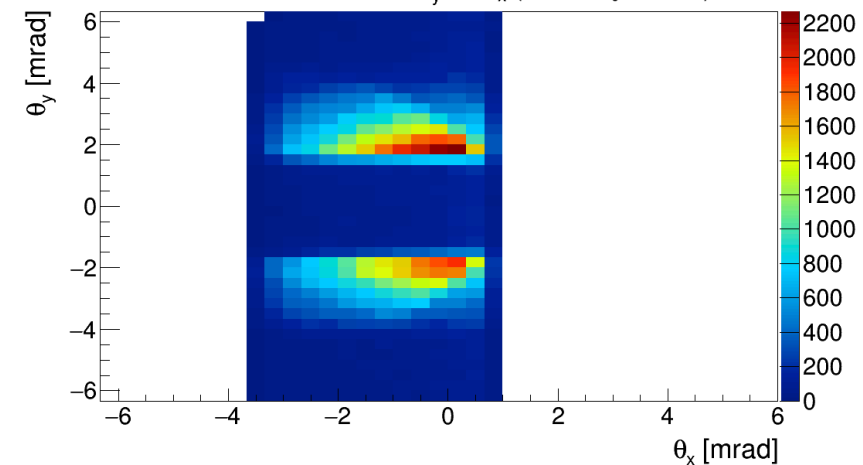
West Roman Pot trk  $\theta_y$  vs  $\theta_x$  ( $0.15 < \xi < 0.20$ )



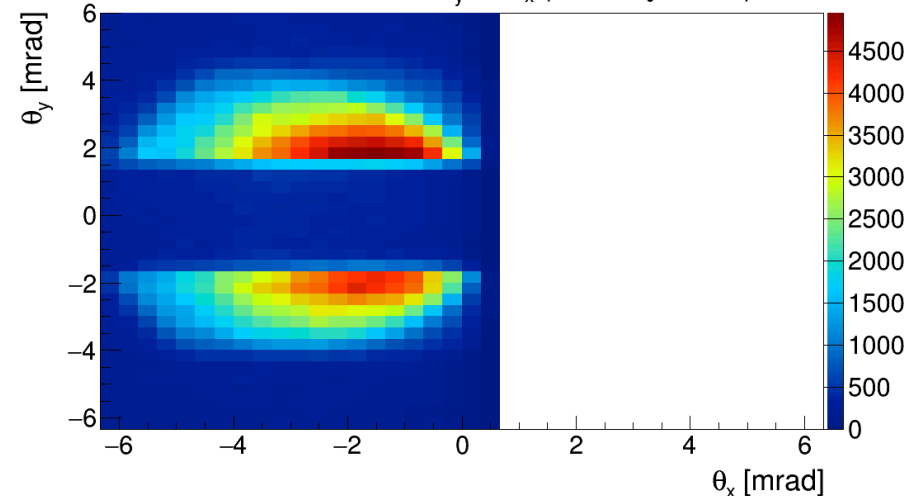
West Roman Pot trk  $\theta_y$  vs  $\theta_x$  ( $0.20 < \xi < 0.25$ )



West Roman Pot trk  $\theta_y$  vs  $\theta_x$  ( $0.25 < \xi < 0.30$ )



West Roman Pot trk  $\theta_y$  vs  $\theta_x$  ( $0.30 < \xi < 0.50$ )

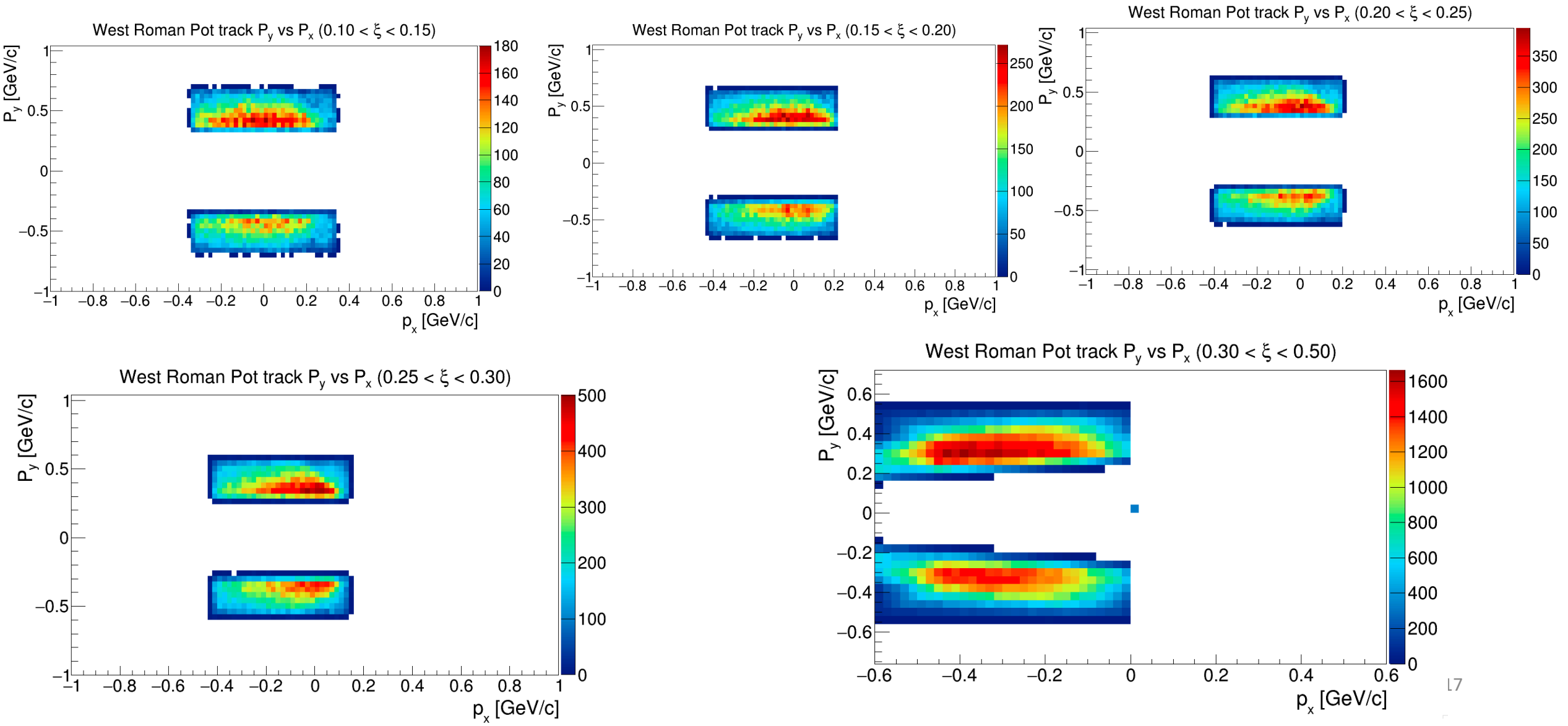


Consider the cut on the **west** RP track  $\theta_X$  and  $\theta_Y$

- We can consider the west RP  $\theta_Y$  cut:  $1.5 < |\theta_Y| < 3 \text{ mrad}$
- The west RP  $\theta_X$  cut can be applied with  $\xi$  dependent.
- $0.1 < \xi < 0.15$ :  $-1.5 < \theta_X < 1.5 \text{ mrad}$
- $0.15 < \xi < 0.2$ :  $-2 < \theta_X < 1 \text{ mrad}$
- $0.2 < \xi < 0.25$ :  $-2 < \theta_X < 1 \text{ mrad}$
- $0.25 < \xi < 0.3$ :  $-2.25 < \theta_X < 0.75 \text{ mrad}$
- $0.3 < \xi < 0.5$ :  $-3.5 < \theta_X < 0 \text{ mrad}$

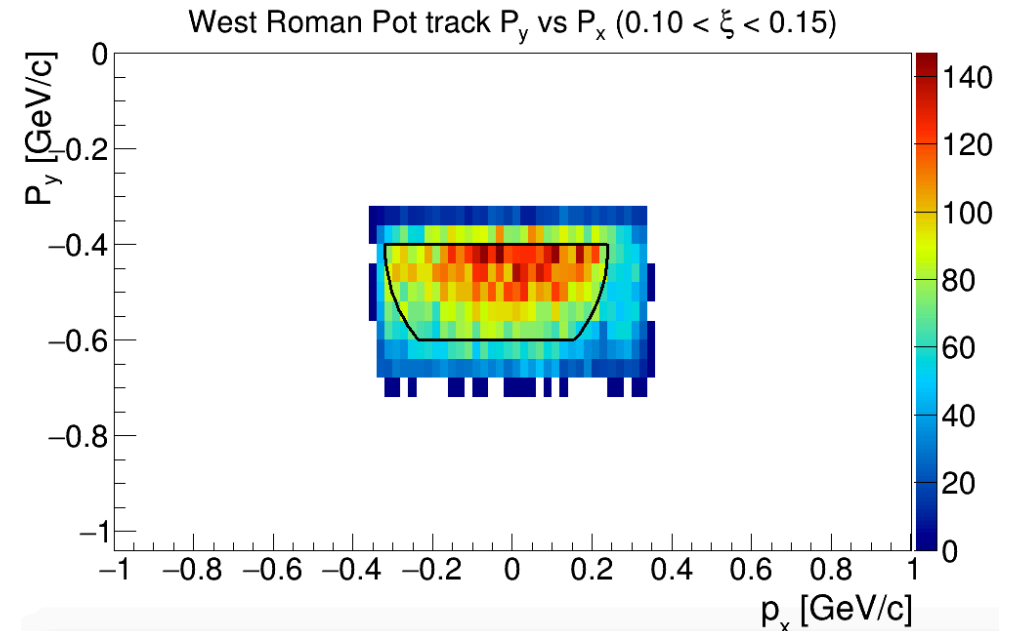
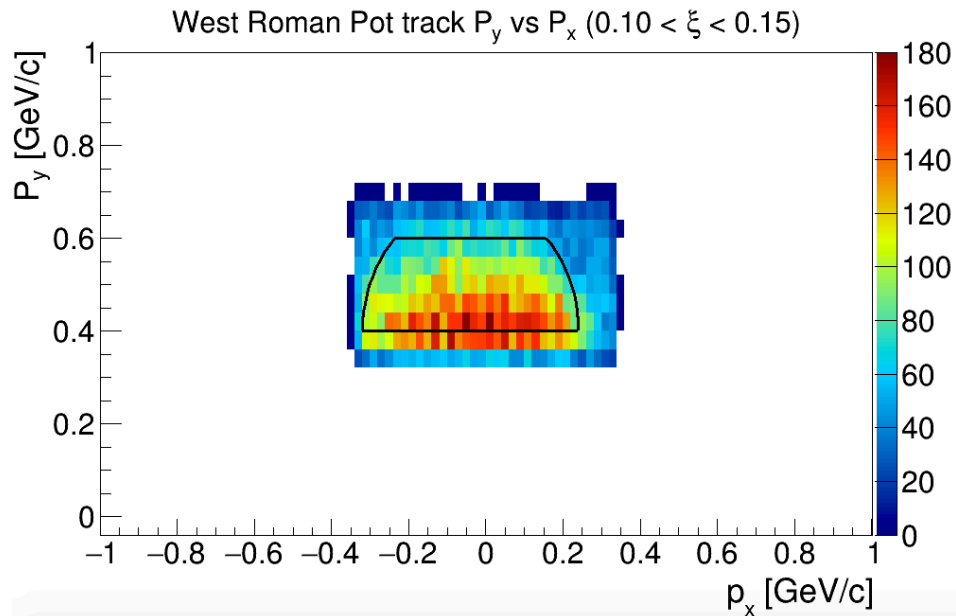


# West RP track $P_X$ and $P_Y$ after the RP track $\theta_X$ and $\theta_Y$ cut and small BBC west cut



# Determine West RP track $P_Y$ vs $P_X$ cuts

- $0.1 < \xi < 0.15$
- Event selection applied at this stage: small west BBC ADC sum  $< 80$
- The RP track  $\theta_X$  and  $\theta_Y$  cuts are applied.
- Additional RP track  $P_X$  and  $P_Y$  cut :  $(P_X + 0.04)^2 + (|P_Y| - 0.4)^2 < 0.28^2$  and  $0.4 < |P_Y| < 0.6$  (black curve region)
- Similar idea for the other  $\xi$  ranges for RP track  $P_X$  and  $P_Y$  cut (back up)



# List of west RP track $P_X$ and $P_Y$ cuts

- $0.1 < \xi < 0.15$ :  $(P_X + 0.04)^2 + (|P_Y| - 0.4)^2 < 0.28^2$  and  $0.4 < |P_Y| < 0.6$
- $0.15 < \xi < 0.2$ :  $(P_X + 0.09)^2 + (|P_Y| - 0.35)^2 < 0.29^2$  and  $0.35 < |P_Y| < 0.5$
- $0.2 < \xi < 0.25$ :  $(P_X + 0.12)^2 + (|P_Y| - 0.35)^2 < 0.23^2$  and  $0.35 < |P_Y| < 0.5$
- $0.25 < \xi < 0.3$ :  $(P_X + 0.1)^2 + (|P_Y| - 0.3)^2 < 0.2^2$  and  $0.3 < |P_Y| < 0.45$
- $0.3 < \xi < 0.45$ :  $(P_X + 0.3)^2 + (|P_Y| - 0.25)^2 < 0.2^2$  and  $0.25 < |P_Y| < 0.4$

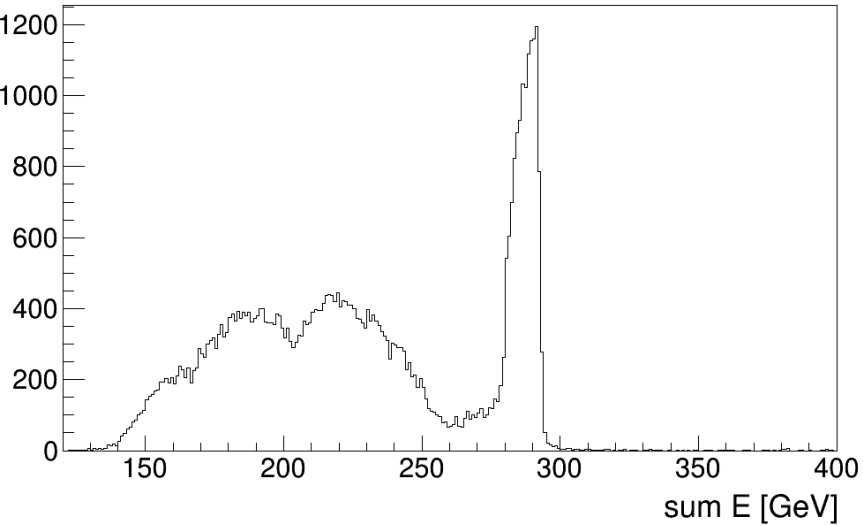
# Summary for the cuts

- Number of RP tracks for each case (this presentation, slide 4):
  - Case 2: only 1 west RP track
  - Case 3: only 1 east RP track and only 1 west RP track
- The RP track must hit at least 7 SSD planes.
- RP track  $\theta_X$  and  $\theta_Y$  cuts (slide 16)
- RP track  $P_X$  and  $P_Y$  cuts (slide 19)
- **FMS**
  - 9 Triggers, veto on FMS-LED
  - 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
- **BBC cuts: small BBC west ADC  $< 80$**

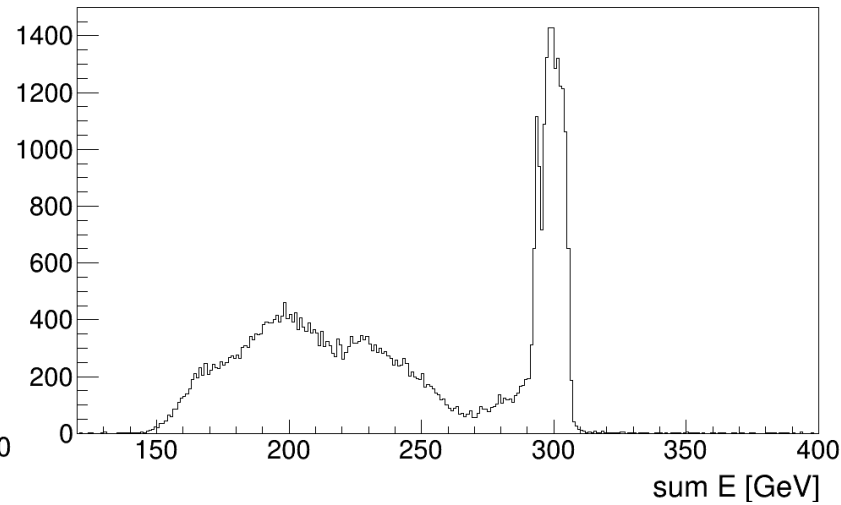
# Check the sum energy plot

- Sum energy:  $E(\text{west RP track}) + E(\text{EM-jet})$
- Similar situation for signal peak shifting with different EM-jet  $X_F$

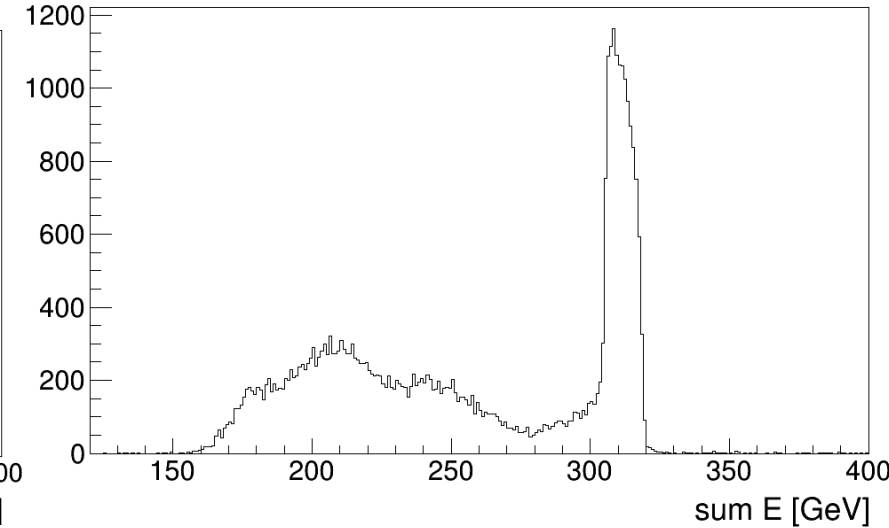
sum of west side RP track energy and EM Jet energy ( $0.1 < x_F < 0.15$ )



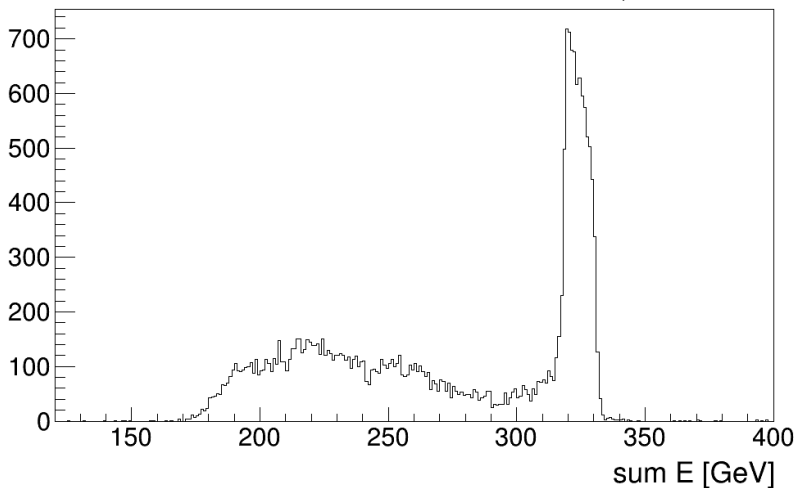
sum of west side RP track energy and EM Jet energy ( $0.15 < x_F < 0.2$ )



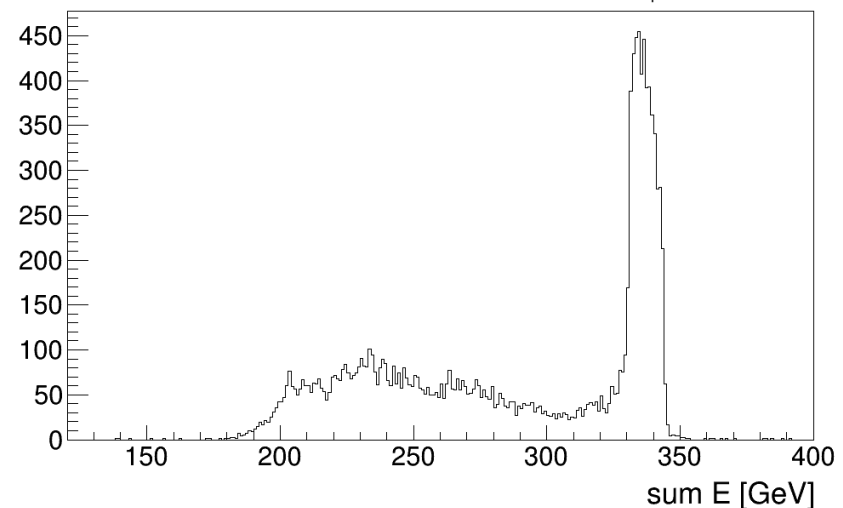
sum of west side RP track energy and EM Jet energy ( $0.2 < x_F < 0.25$ )



sum of west side RP track energy and EM Jet energy ( $0.25 < x_F < 0.3$ )



sum of west side RP track energy and EM Jet energy ( $0.3 < x_F < 0.35$ )



We still plan to apply the similar approach to determine the cuts for sum energy as before.

# Timeline for run 15 inclusive/diffractive EM-jet $A_N$ at forward rapidity

- General plan: we plan to merge the 2 analysis for publication. However, the paper proposal is still preparing and we are waiting for run 15 diffractive EM-jet  $A_N$  analysis to be completed.
- Status for the analyses:
  - Run 15 inclusive EM-jet  $A_N$  using FMS: The analysis is completed and the paper write-up is ongoing.
  - Run 15 diffractive EM-jet  $A_N$  using FMS: We are doing the final cross check with the RP track cuts and east RP coincidence study with simulation.
- Timeline for paper:
  - We will plan to finalize the analysis and have paper proposal by the end of this year.
  - Paper write-up will be done in the beginning of next year.

# Conclusion and Outlook

- We study the west RP track for run 17 data. The  $\xi$  dependent  $P_X, P_Y, \theta_X, \theta_Y$  cuts are more reasonable.
- Similar situation for signal peak shifting with different EM-jet  $X_F$  for the sum energy plots. We can continue to use the “mix event” method for zero-bias events to estimate the background shape.
- Next to do:
  - Check the ZDC distribution to see if we need the ZDC cuts.
  - Study the case 1 for the east RP track cuts, and consider proper cuts (RP cuts, BBC cuts, ZDC cuts, TOF cuts) for extracting the diffractive EM-jet  $A_N$
  - At the same time, final check the run 15 analysis for the RP cuts.

Back up



# Data set

- Data set: run 17 pp transverse  $\sqrt{s} = 510$  GeV ,**fms stream**
  - (pp500\_production\_2017)
- 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

# Part 1: West Roman Pot track $P_Y$ vs $P_X$

- Plot the west Roman Pot track  $P_Y$  vs  $P_X$  for different  $\xi$

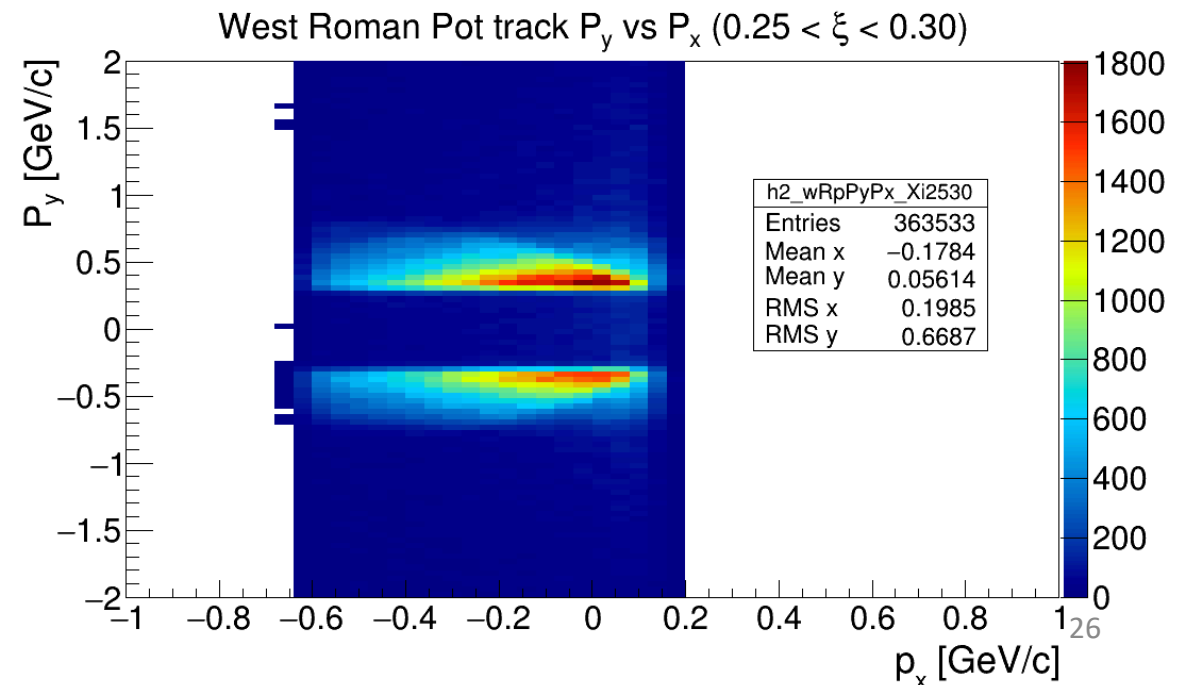
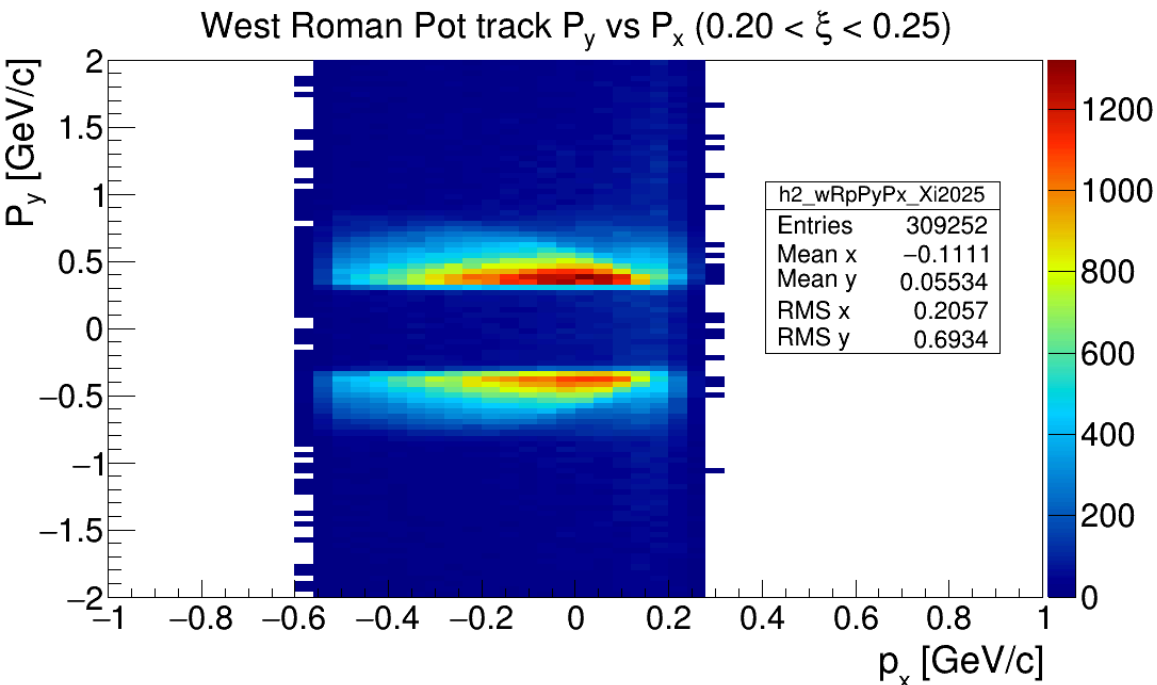
- $\xi = \frac{P_{beam} - P_{RP}}{P_{beam}}$

- Applying the cut on small BBC west  $< 250$  (just to see more clear  $P_Y$  vs  $P_X$  distribution)

Therefore, we can consider the cuts for RP track:

$-0.3 < P_X < 0.15$  GeV/c ;  $-0.5 < P_Y < -0.3$  GeV/c or

$0.3 < P_Y < 0.5$  GeV/c



# West Roman Pot track $P_Y$ vs $P_X$

- Plot the west Roman Pot track  $P_Y$  vs  $P_X$  for different  $\xi$

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

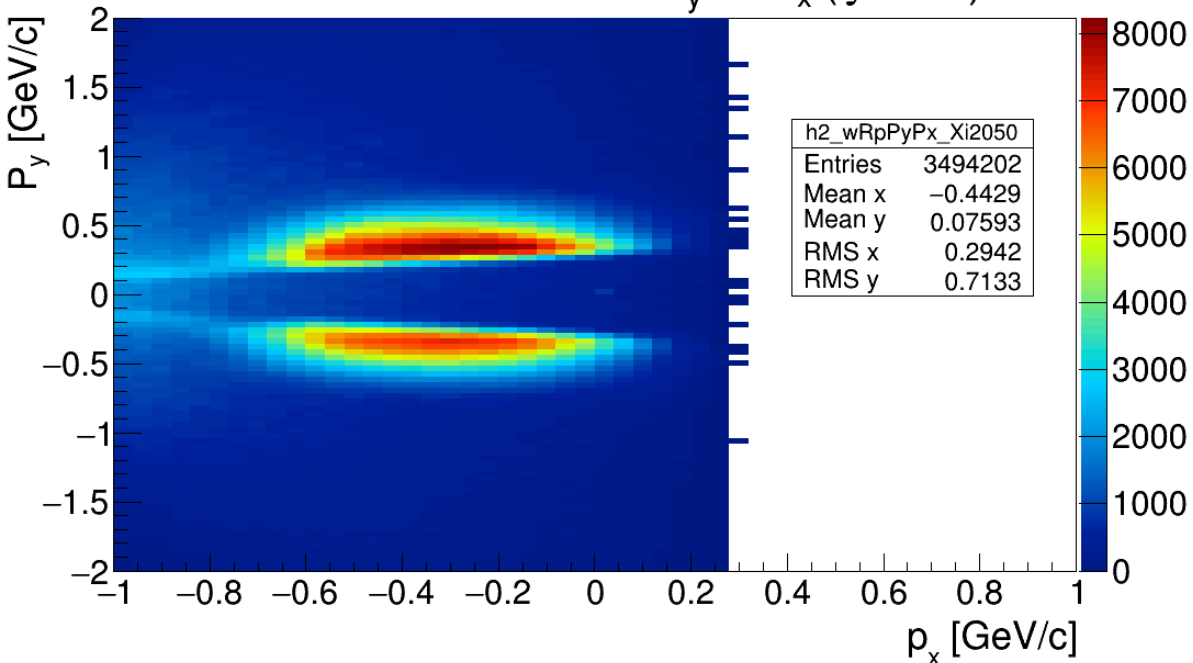
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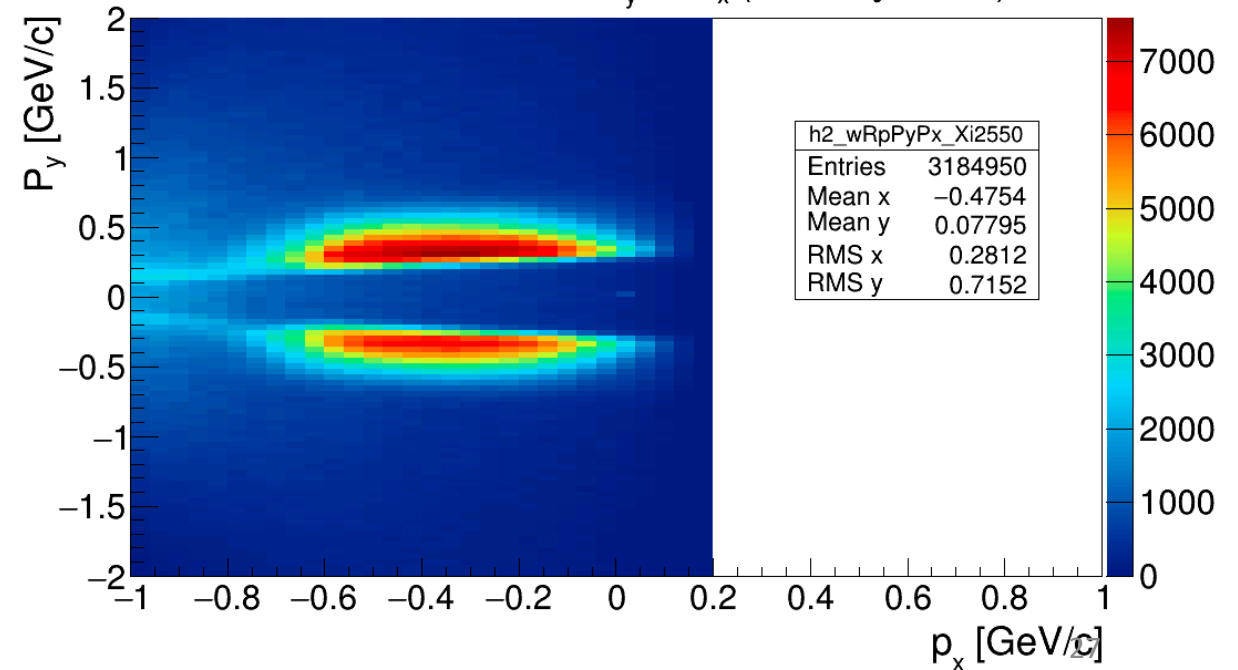
$$-0.6 < P_X < 0 \text{ GeV/c} ; -0.5 < P_Y < -0.3 \text{ GeV/c or}$$

$$0.2 < P_Y < 0.5 \text{ GeV/c}$$

West Roman Pot track  $P_Y$  vs  $P_X$  ( $\xi > 0.2$ )

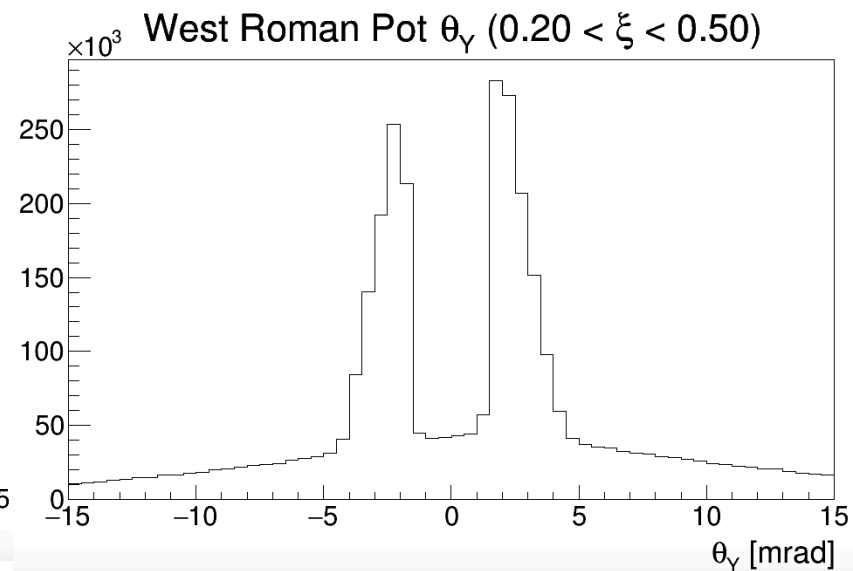
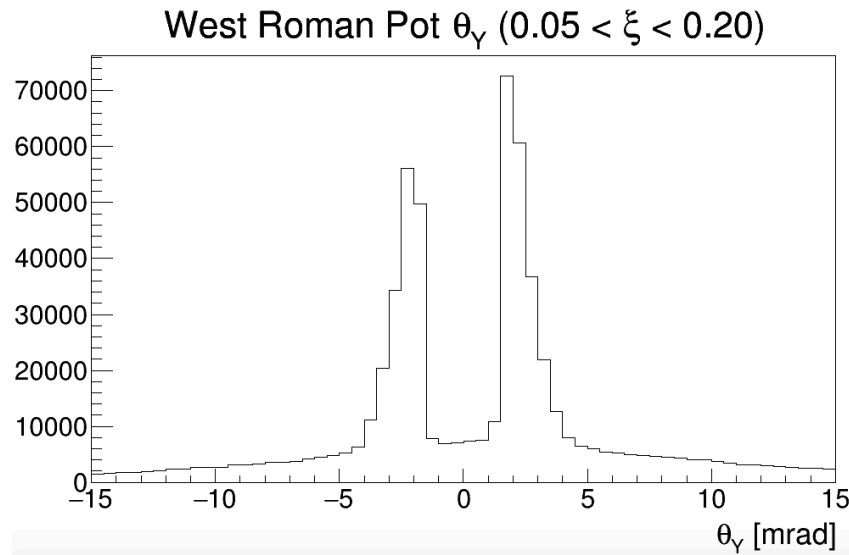
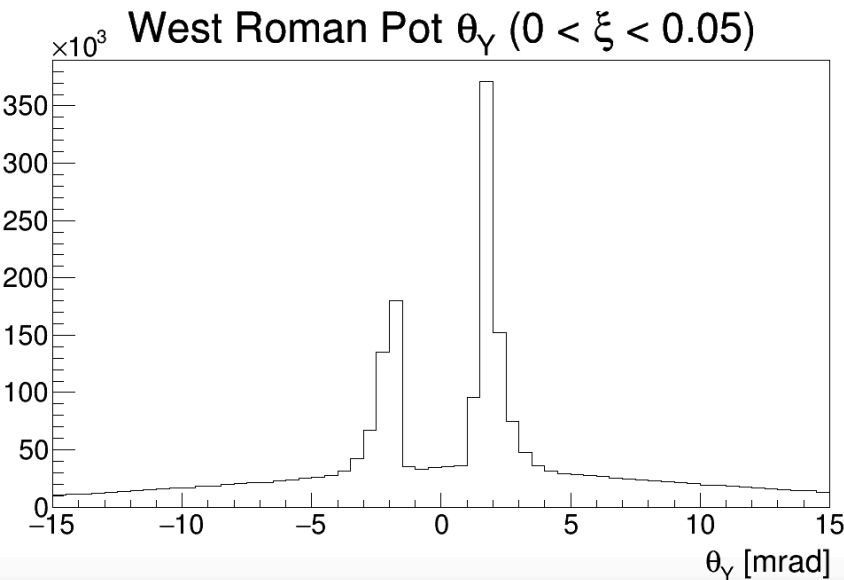


West Roman Pot track  $P_Y$  vs  $P_X$  ( $0.25 < \xi < 0.50$ )



# West Roman Pot track $\theta_Y$

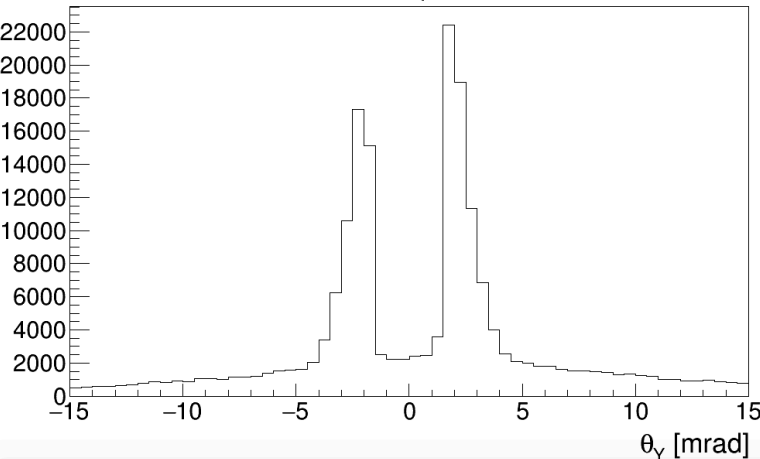
- Plot the west Roman Pot track  $\theta_Y$  for different  $\xi$ 
  - $\xi = \frac{P_{beam} - P_{RP}}{P_{beam}}$
- Applying the cut on small BBC west < 250 (just to see more clear  $\theta_Y$  distribution)
- The distribution for 3 different  $\xi$  ranges are similar. Therefore, we should consider similar  $\theta_Y$  cuts for different proton  $\xi$ .



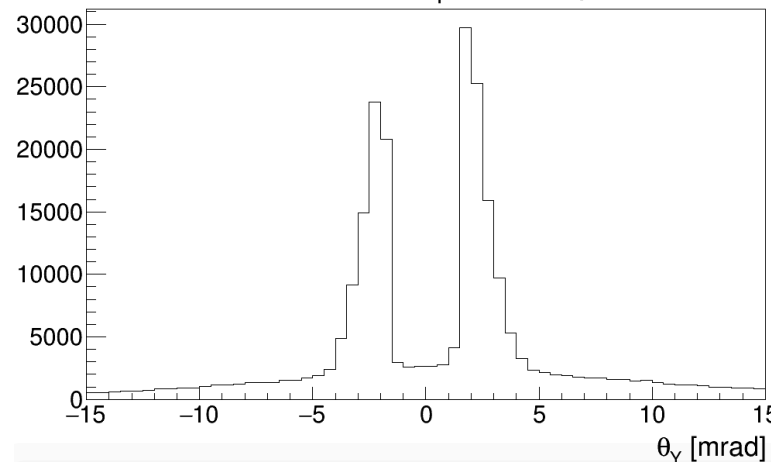
# West Roman Pot track $\theta_Y$

- West Roman Pot track  $\theta_Y$  distribution for different  $\xi$
- Applying the cut on small BBC east  $< 250$

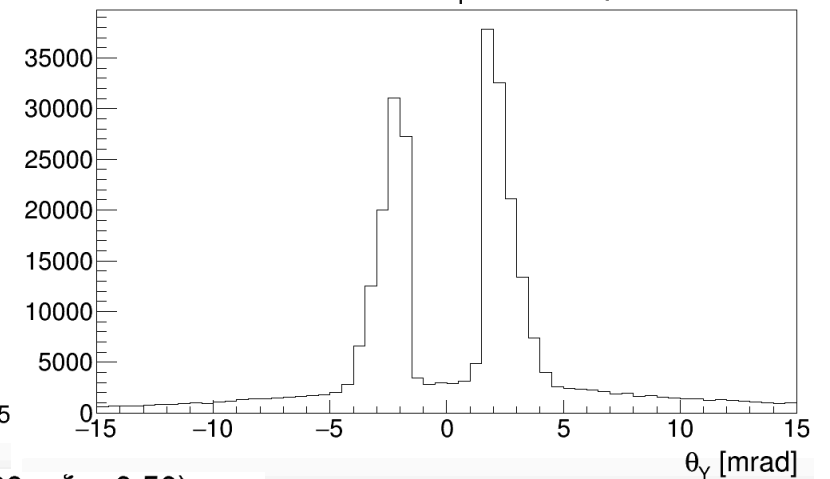
West Roman Pot  $\theta_Y$  ( $0.10 < \xi < 0.15$ )



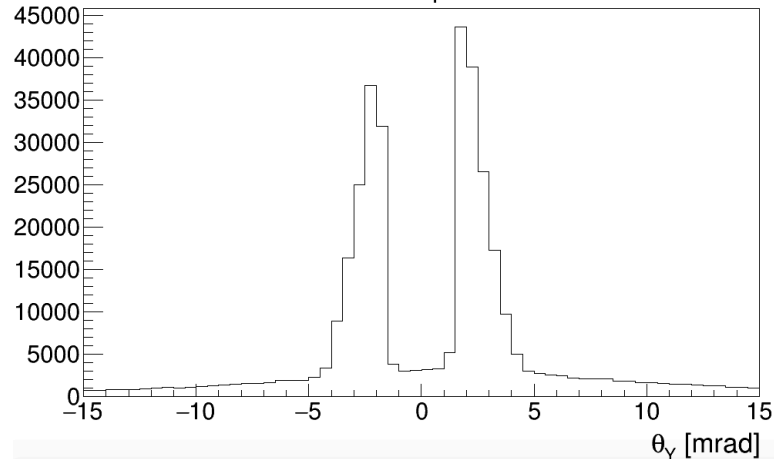
West Roman Pot  $\theta_Y$  ( $0.15 < \xi < 0.20$ )



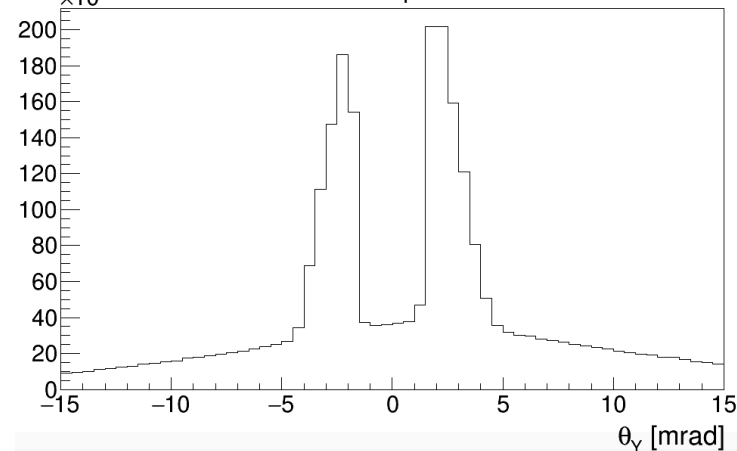
West Roman Pot  $\theta_Y$  ( $0.20 < \xi < 0.25$ )



West Roman Pot  $\theta_Y$  ( $0.25 < \xi < 0.30$ )



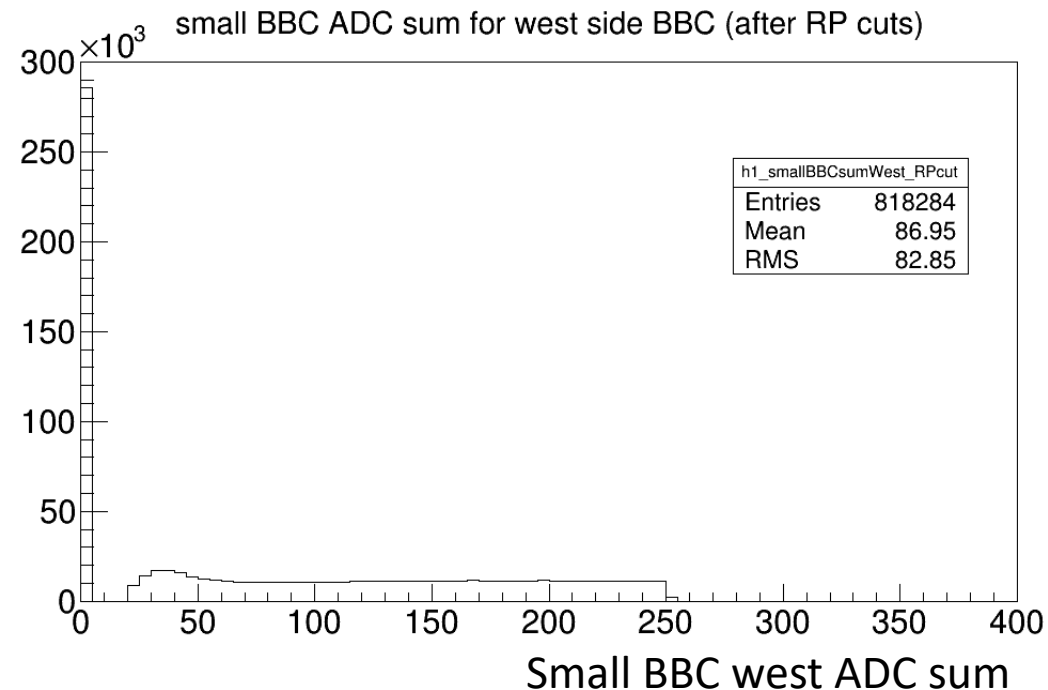
West Roman Pot  $\theta_Y$  ( $0.30 < \xi < 0.50$ )



# Part 3: Cross check on small BBC east/west ADC

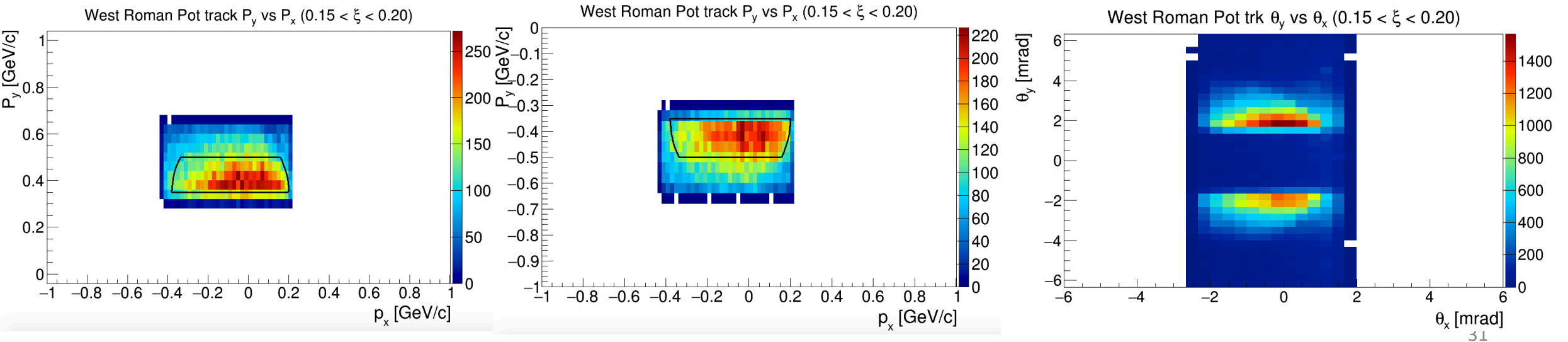
sum after the RP track  $\theta_x$  and  $\theta_y$  cut

- The small BBC east plot only counts the events with the east RP track passing the RP cut with corresponding  $\xi$  and east RP track  $\xi < 0.45$ .
  - Consider cuts: small BBC east  $< 70$  (same consideration)
- The small BBC west plot only counts the events with the west RP track passing the RP cut with corresponding  $\xi$  and west RP track  $0.1 < \xi < 0.45$ 
  - Consider cuts: small BBC west  $< 80$  (same consideration)



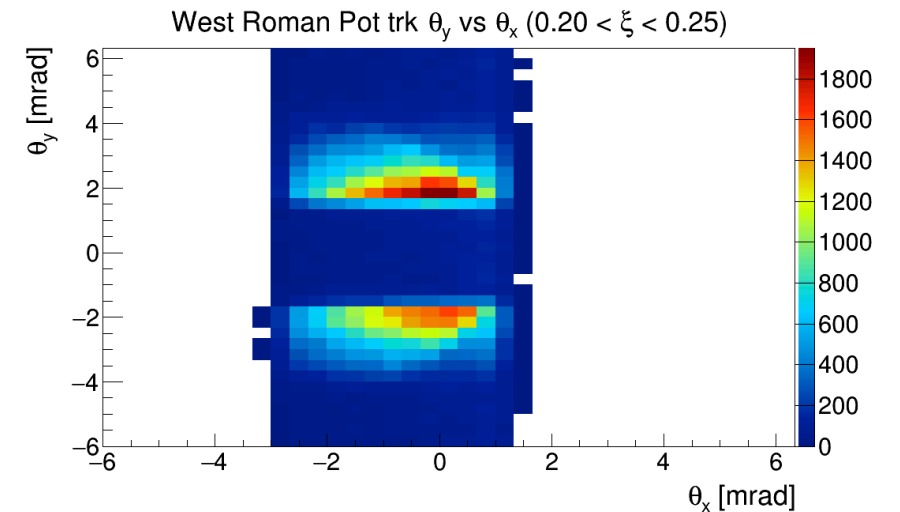
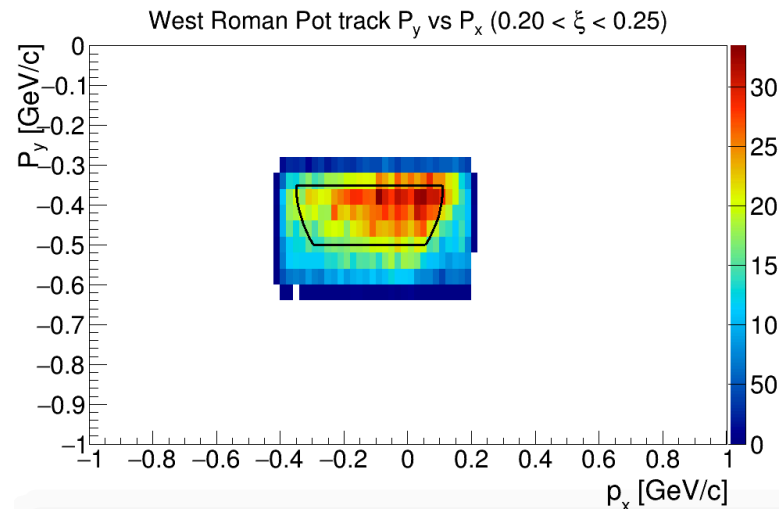
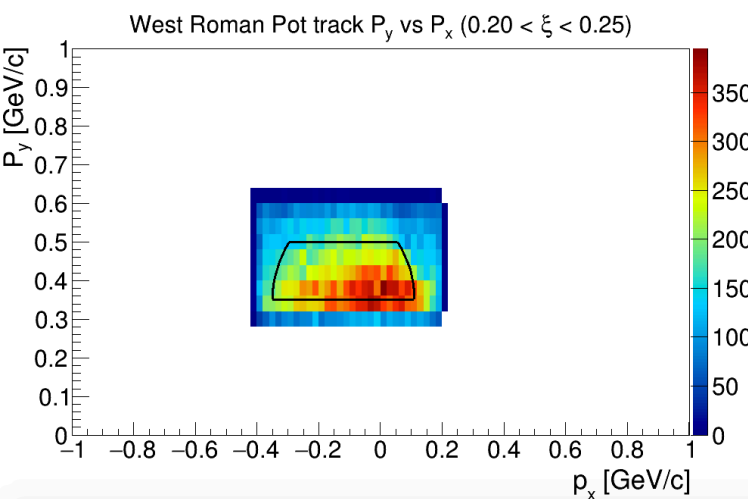
# Determine West RP track $P_Y$ vs $P_X$ cuts

- $0.15 < \xi < 0.2$
- Event selection applied at this stage: small west BBC ADC sum  $< 80$
- The RP track  $\theta_X$  and  $\theta_Y$  cuts are applied.
- Additional RP track  $P_X$  and  $P_Y$  cut :  $(P_X + 0.09)^2 + (|P_Y| - 0.35)^2 < 0.29^2$  and  $0.35 < |P_Y| < 0.5$  (black curve region)
- Similar idea for the other  $\xi$  ranges for RP track  $P_X$  and  $P_Y$  cut



# Determine West RP track $P_Y$ vs $P_X$ cuts

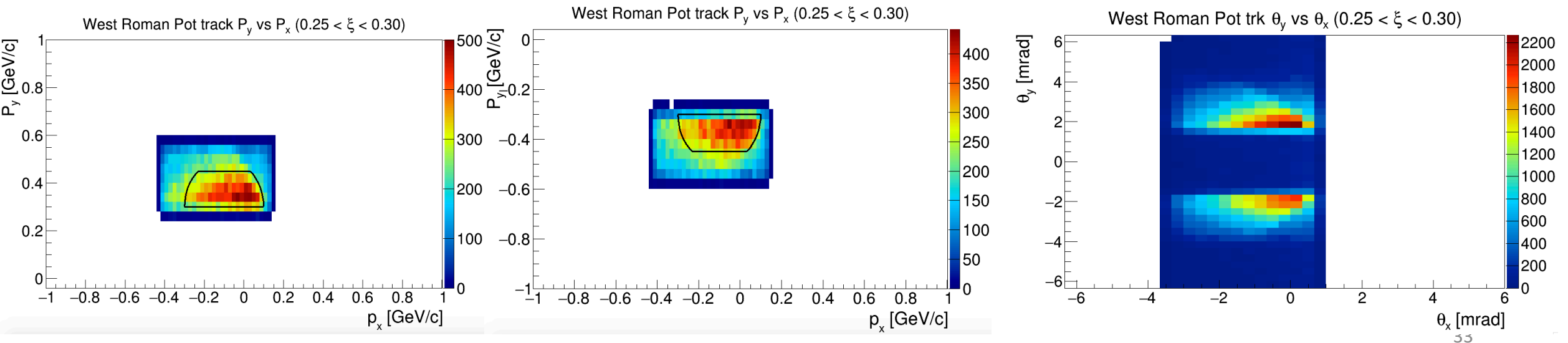
- $0.2 < \xi < 0.25$
- Event selection applied at this stage: small west BBC ADC sum  $< 80$
- The RP track  $\theta_X$  and  $\theta_Y$  cuts are applied.
- Additional RP track  $P_X$  and  $P_Y$  cut  $(P_X + 0.12)^2 + (|P_Y| - 0.35)^2 < 0.23^2$  and  $0.35 < |P_Y| < 0.5$  (black curve region)
- Similar idea for the other  $\xi$  ranges for RP track  $P_X$  and  $P_Y$  cut





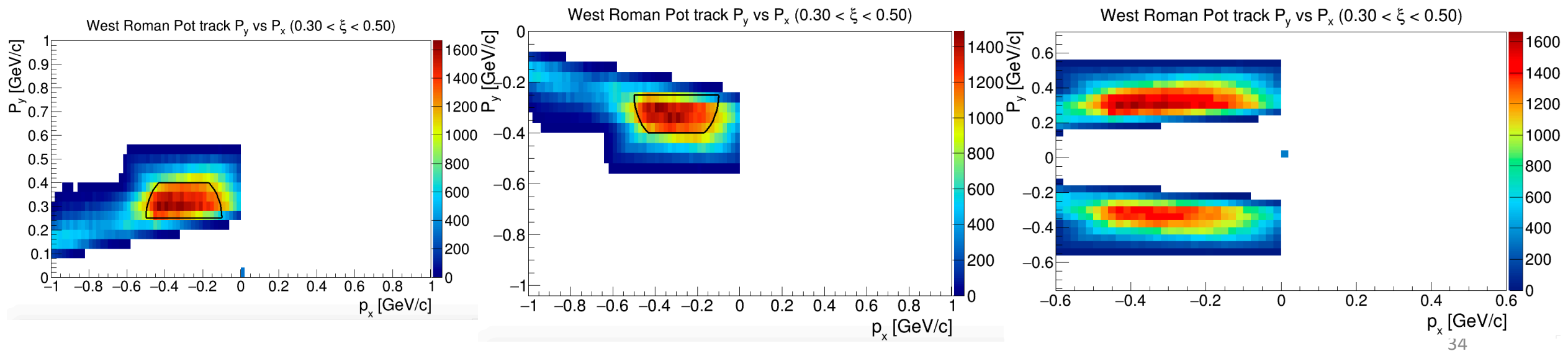
# Determine West RP track $P_Y$ vs $P_X$ cuts

- $0.25 < \xi < 0.3$
- Event selection applied at this stage: small west BBC ADC sum  $< 80$
- The RP track  $\theta_X$  and  $\theta_Y$  cuts are applied.
- Additional RP track  $P_X$  and  $P_Y$  cut  $(P_X + 0.1)^2 + (|P_Y| - 0.3)^2 < 0.2^2$  and  $0.3 < |P_Y| < 0.45$  (black curve region)
- Similar idea for the other  $\xi$  ranges for RP track  $P_X$  and  $P_Y$  cut



# Determine West RP track $P_Y$ vs $P_X$ cuts

- $0.3 < \xi < 0.45$
- Event selection applied at this stage: small west BBC ADC sum  $< 80$
- The RP track  $\theta_X$  and  $\theta_Y$  cuts are applied.
- Additional RP track  $P_X$  and  $P_Y$  cut  $(P_X + 0.3)^2 + (|P_Y| - 0.25)^2 < 0.2^2$  and  $0.25 < |P_Y| < 0.4$  (black curve region)
- Similar idea for the other  $\xi$  ranges for RP track  $P_X$  and  $P_Y$  cut

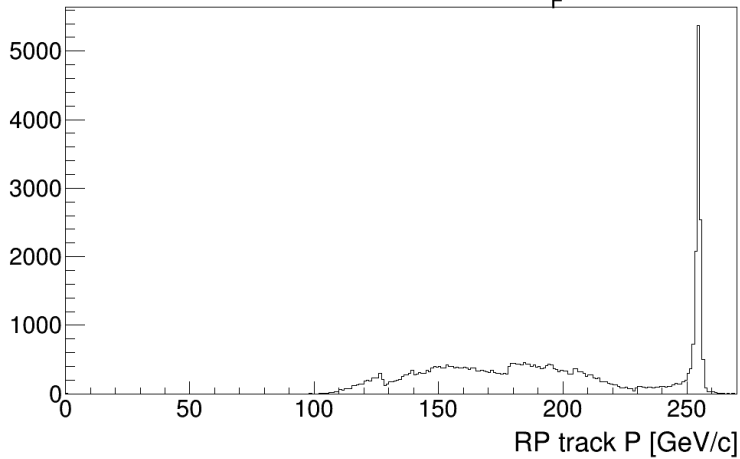


# The number of events after the small BBC cuts and RP cuts

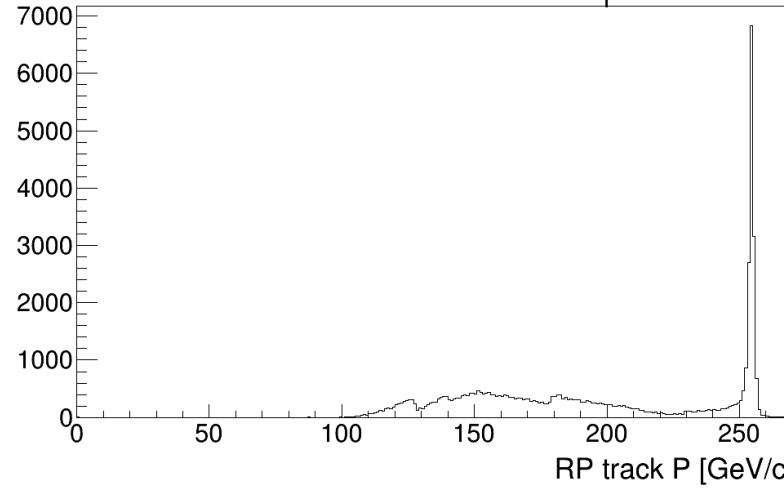
- Total number of events: 881.9 M
- Number of events after the west small BBC cuts: (west small BBC cut) 11.7 M
- Number of events with 1 west RP track, and  $\leq 1$  east RP track, and passing west small BBC cut: (N RP track cut) 1.81 M
- Number of events passing the west RP track cut, and passing west small BBC cut and N RP track cut : (west RP track cut) 0.18 M

# West RP track momentum for event with different EM-jet $x_F$

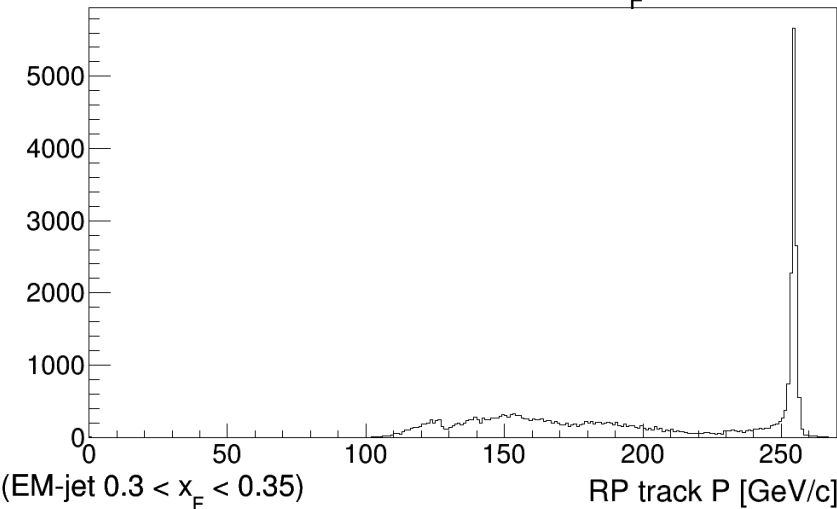
West RP trk P (EM-jet  $0.1 < x_F < 0.15$ )



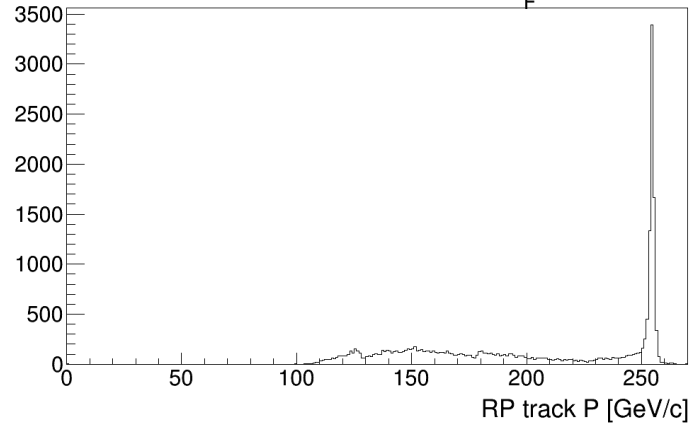
West RP trk P (EM-jet  $0.15 < x_F < 0.2$ )



West RP trk P (EM-jet  $0.2 < x_F < 0.25$ )



West RP trk P (EM-jet  $0.25 < x_F < 0.3$ )



West RP trk P (EM-jet  $0.3 < x_F < 0.35$ )

