Global Spin Alignment Update

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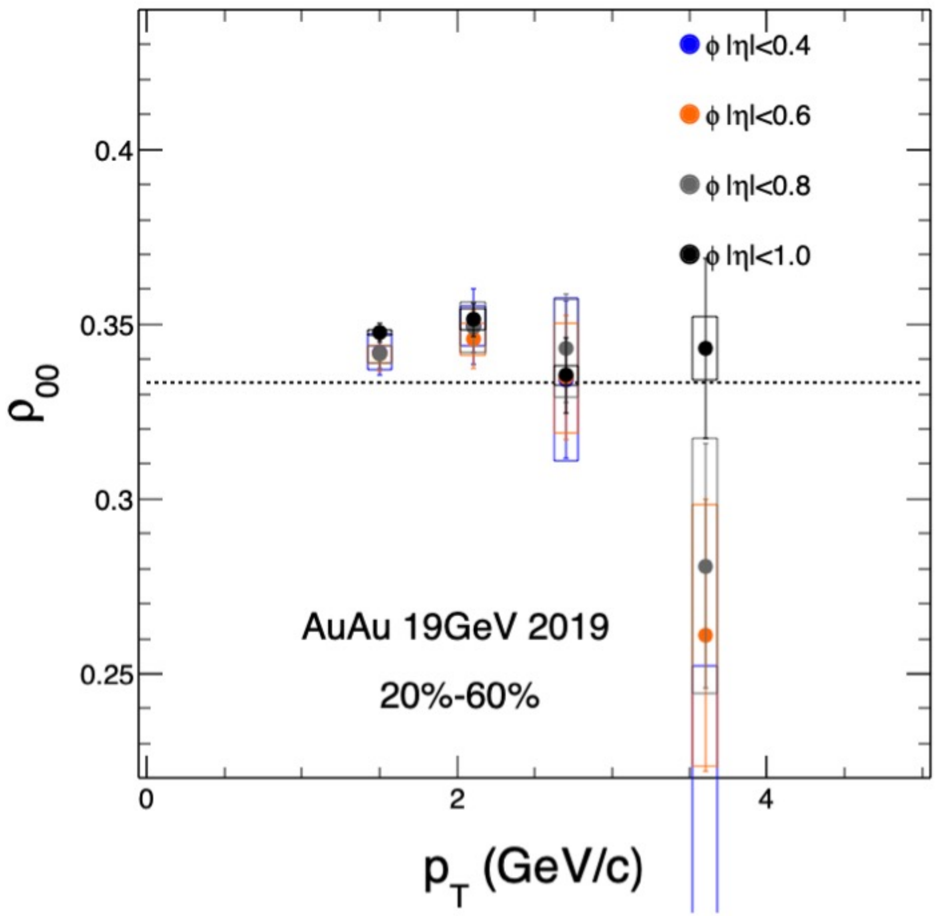
Reminder of last meeting

- We found that v2 caused differences between input and output ρ_{00} in simulation.
  - Effect is large in rapidity bins near the edge of the acceptance.
- Diyu noticed that <cos2β> was non-zero in simulation.
- This presentation includes studies that explore these two points.
- First, I will go over an error I found in my code.

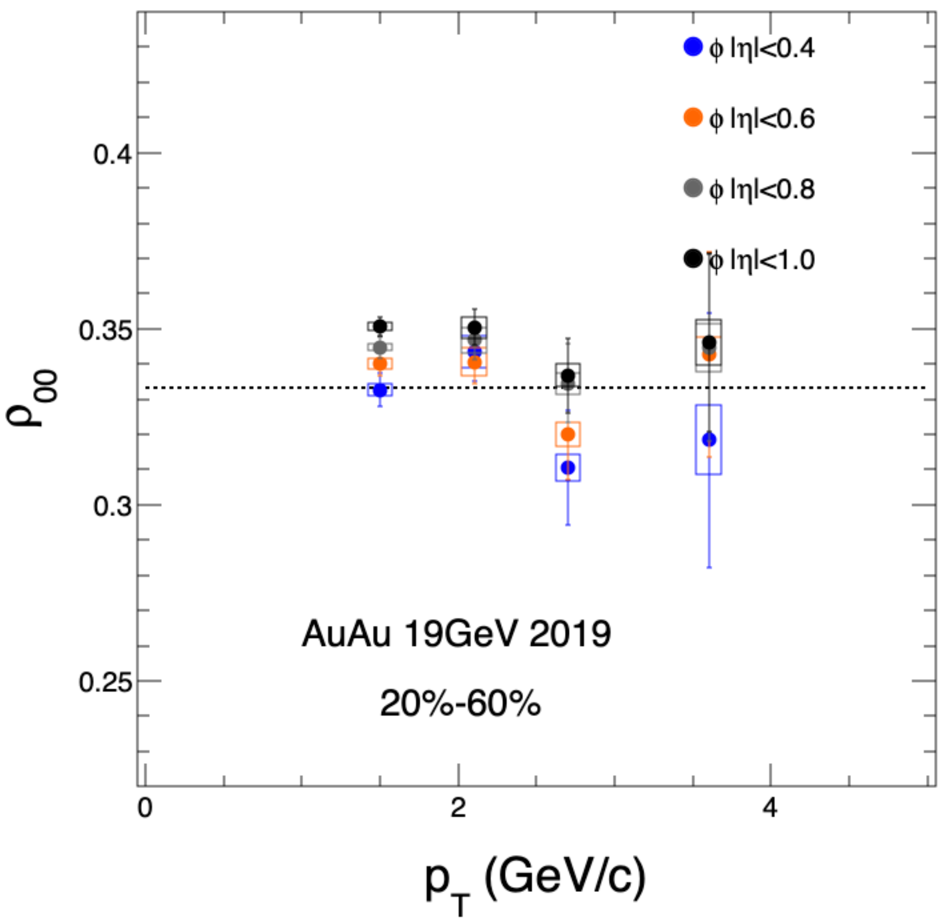
ϕ-meson global spin alignment

- Self-subtraction of Kaon daughters from Event plane Q-vector was not working properly in previous results.
- Difference between |η| cuts now.

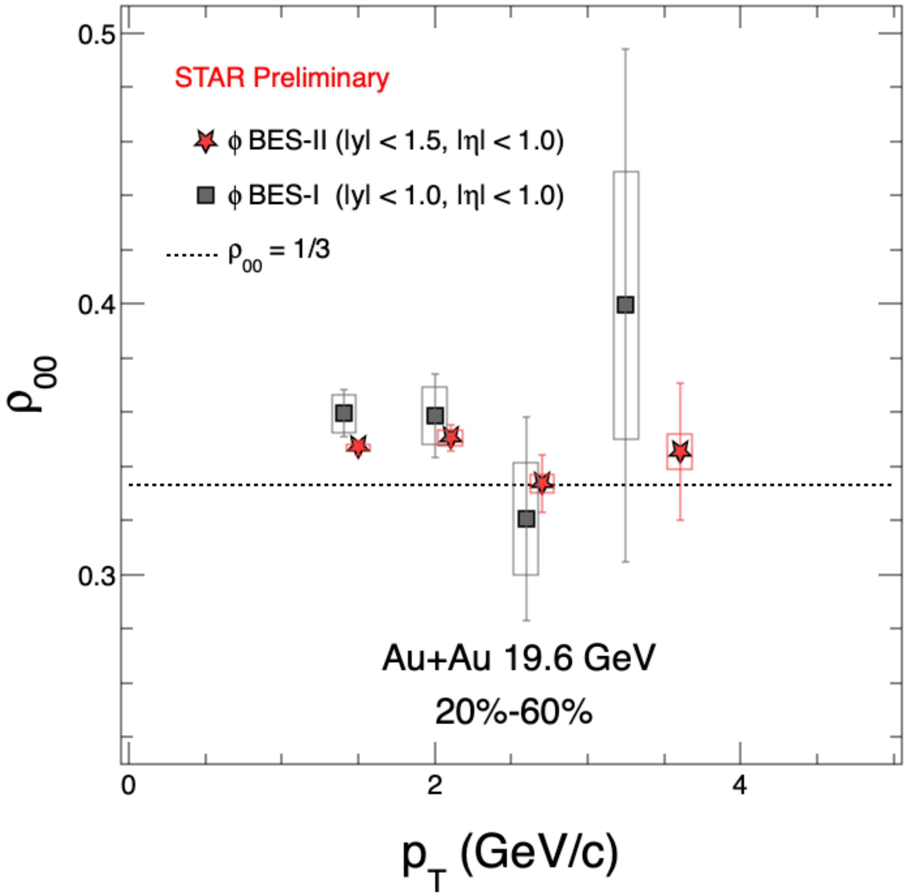
Before Fix



After Fix



- I just want to make the point that these results to agree with BES-I for the |η| < 1.0 cut.




```
Final corrected rho00 = 0.3472 +/- 0.0023 (stat) +/- 0.0013 (sys)
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sigma from 1/3 = 5.30
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sigma from BES-I = 1.065492
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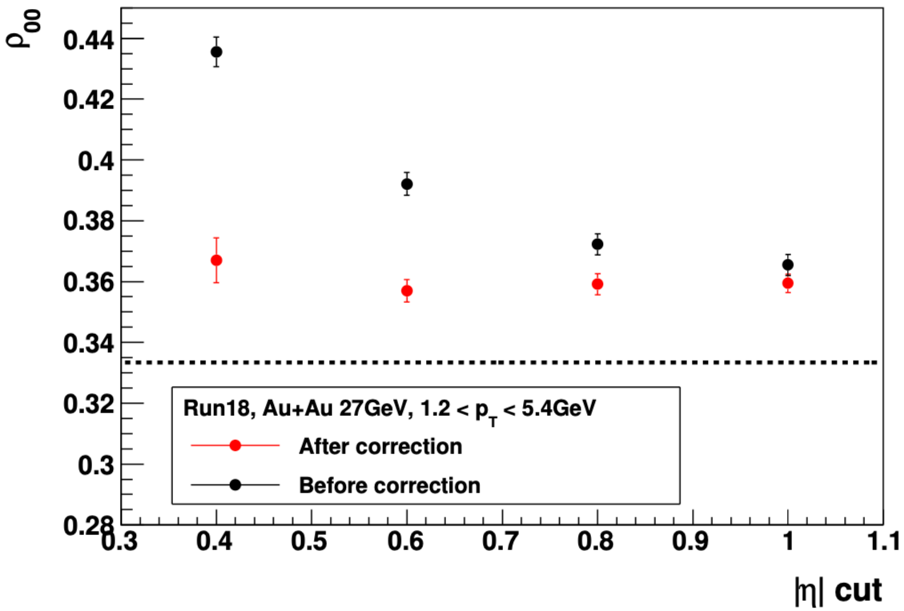
From Nature Paper analysis note



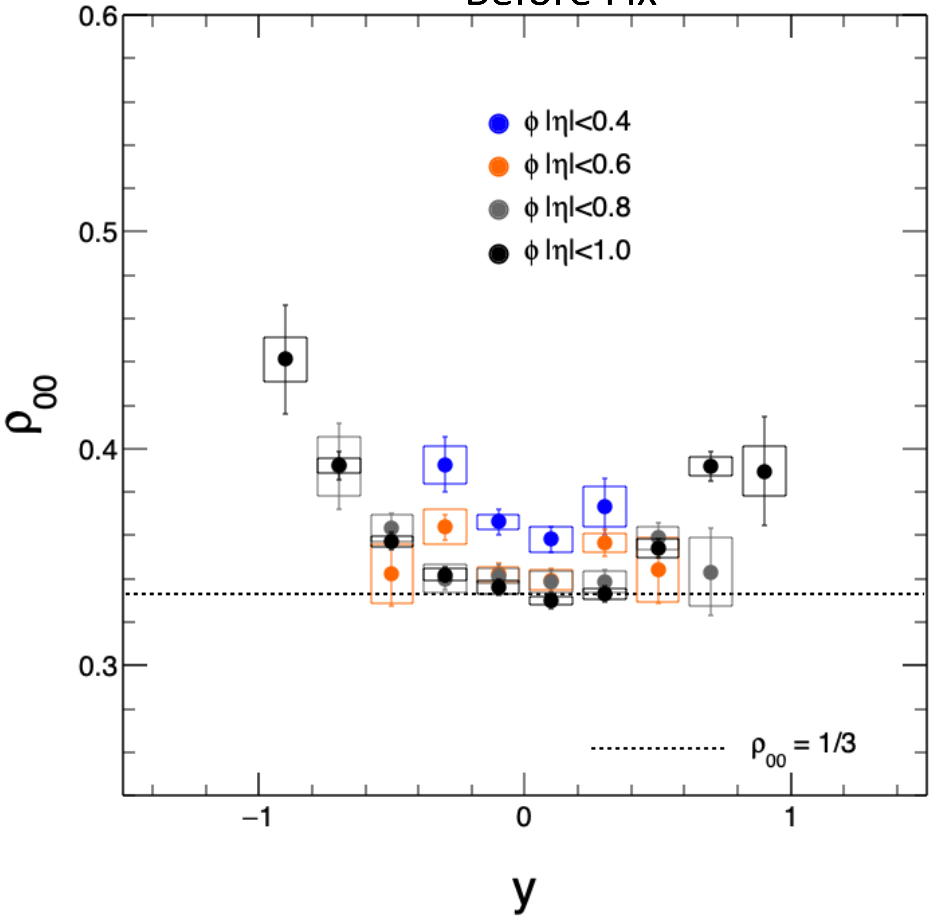
This contradicts our results, but I am unsure if this was updated to the acceptance correction with v2 included. (This was an issue in the original acceptance simulation)

- I will repeat this with no v2 in acceptance correction.

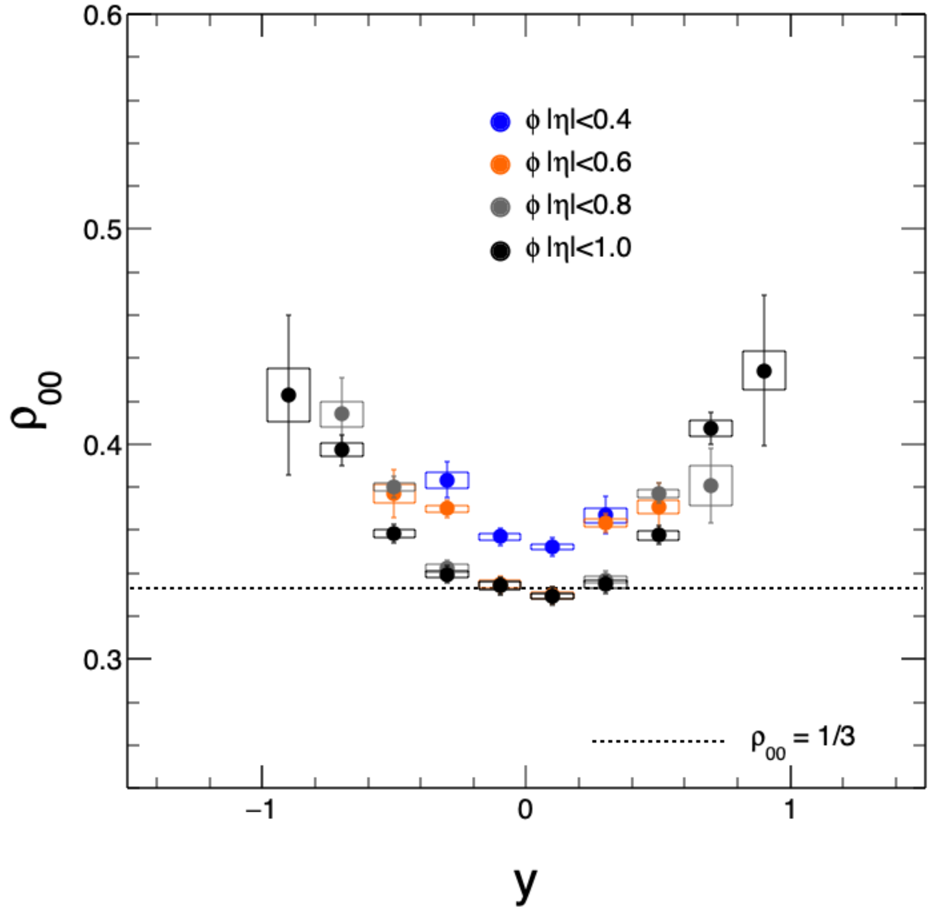
ϕ-meson global spin alignment

- Self-subtraction of Kaon daughters from Event plane Q-vector was not working properly in previous results.
- Rapidity dependent η cut still has issue.

Before Fix



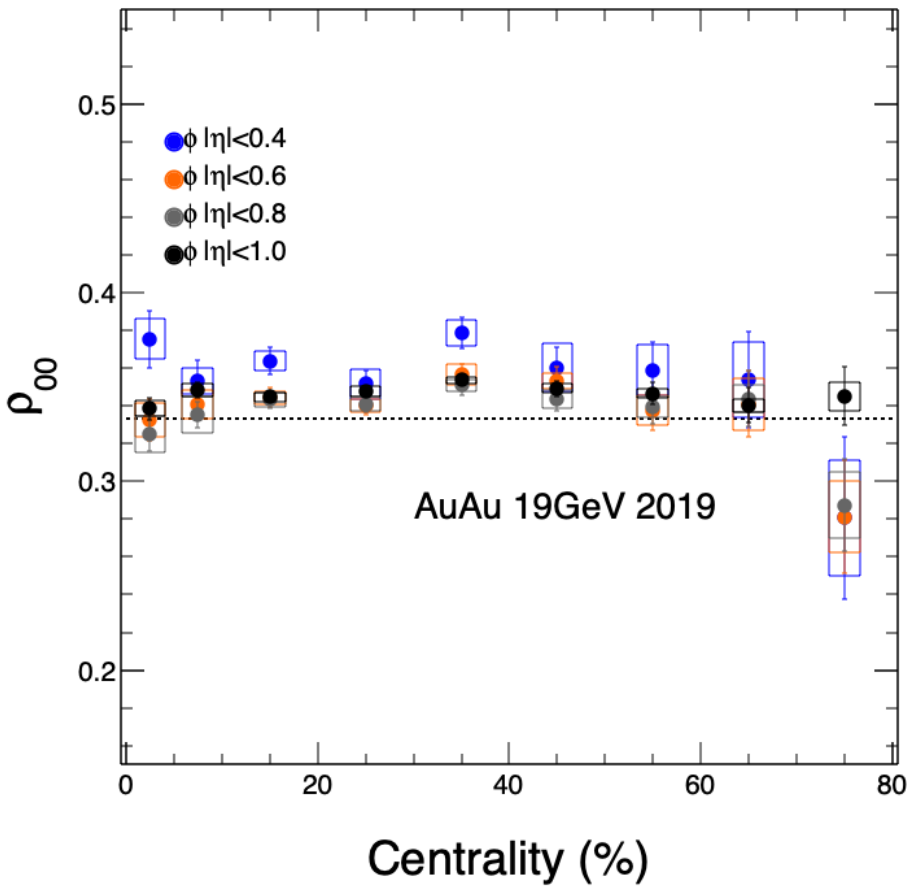
After Fix



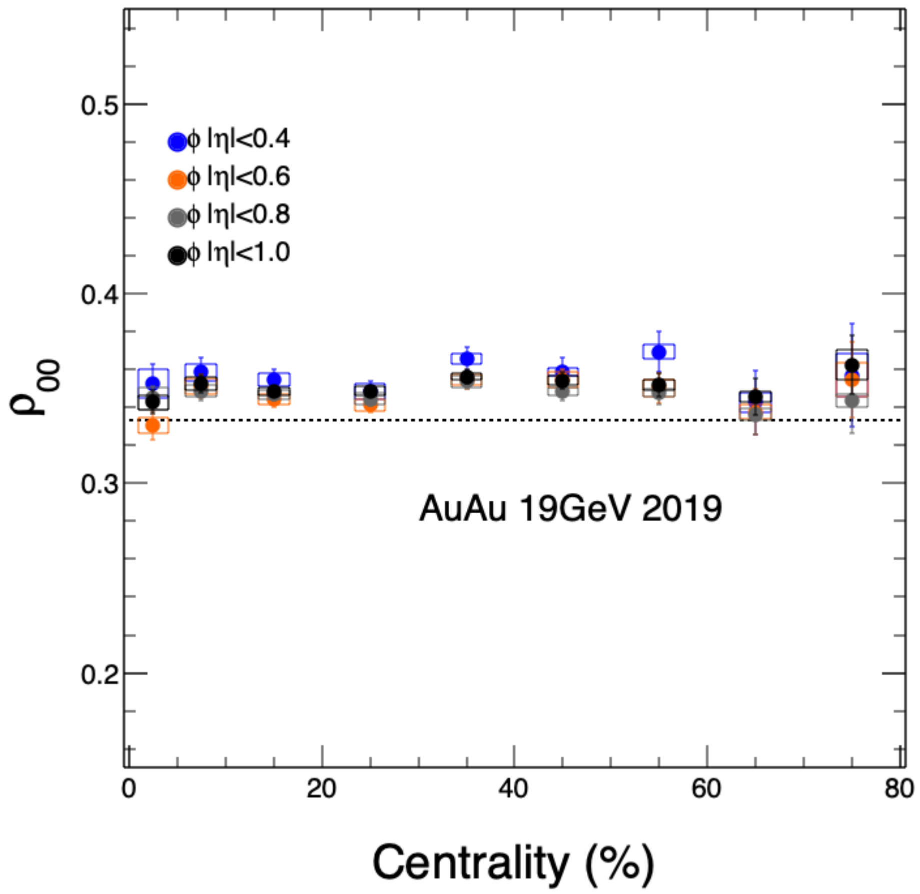
ϕ-meson global spin alignment

- Centrality dependent η cut still has issue. Blue smaller η cut points appear systematically larger by a small amount.

Before Fix



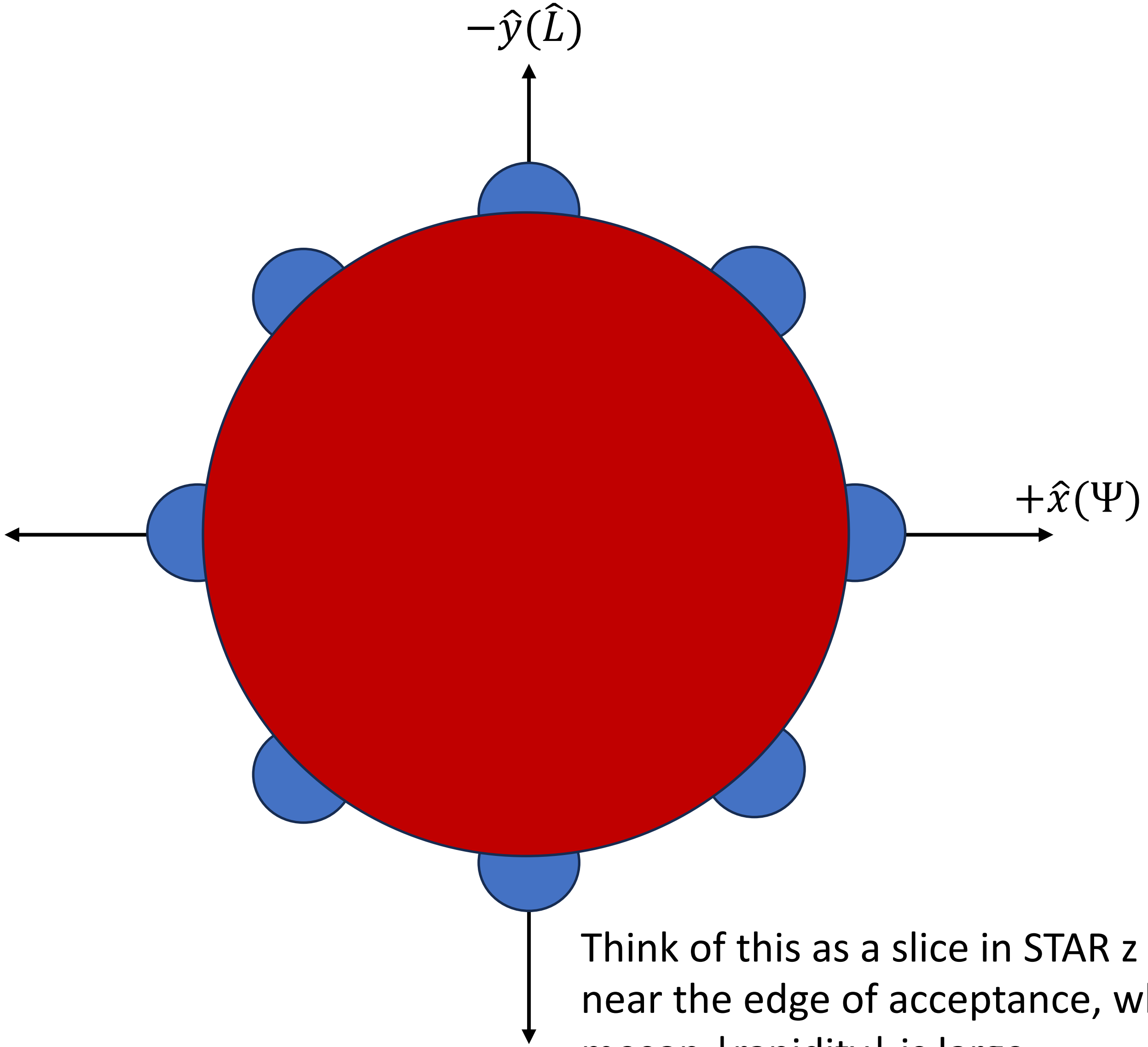
After Fix



v2 Studies

η cut leads to lower yield in |cosθ*| = 1 and higher yield in |cosθ*| = 0

- These contributions cancel out if there is no v2.
- When v2 is present:
  - Higher phi-meson yield along +x, meaning there is a lower yield in |cosθ*| = 0 and higher yield in |cosθ*| = 1.
  - This means there would be a positive contribution to ρ_{00} from v2.



η cut leads to lower yield in |cosθ*| = 0 and higher yield in |cosθ*| = 1

Think of this as a slice in STAR z position near the edge of acceptance, where ϕ-meson |rapidity| is large.

Standard correction method

- Take ratio of ϕ-meson yields as a function of **cos(θ*)** after/before η cuts on daughter kaons for ρ_{00}=1/3 input.
- Fit ratio with a 4th order polynomial to extract acceptance parameters F and G.
- Fix these parameters and EP resolution in fit which extracts ρ_{00} from the cos(θ*’) distribution (EP Smeared).

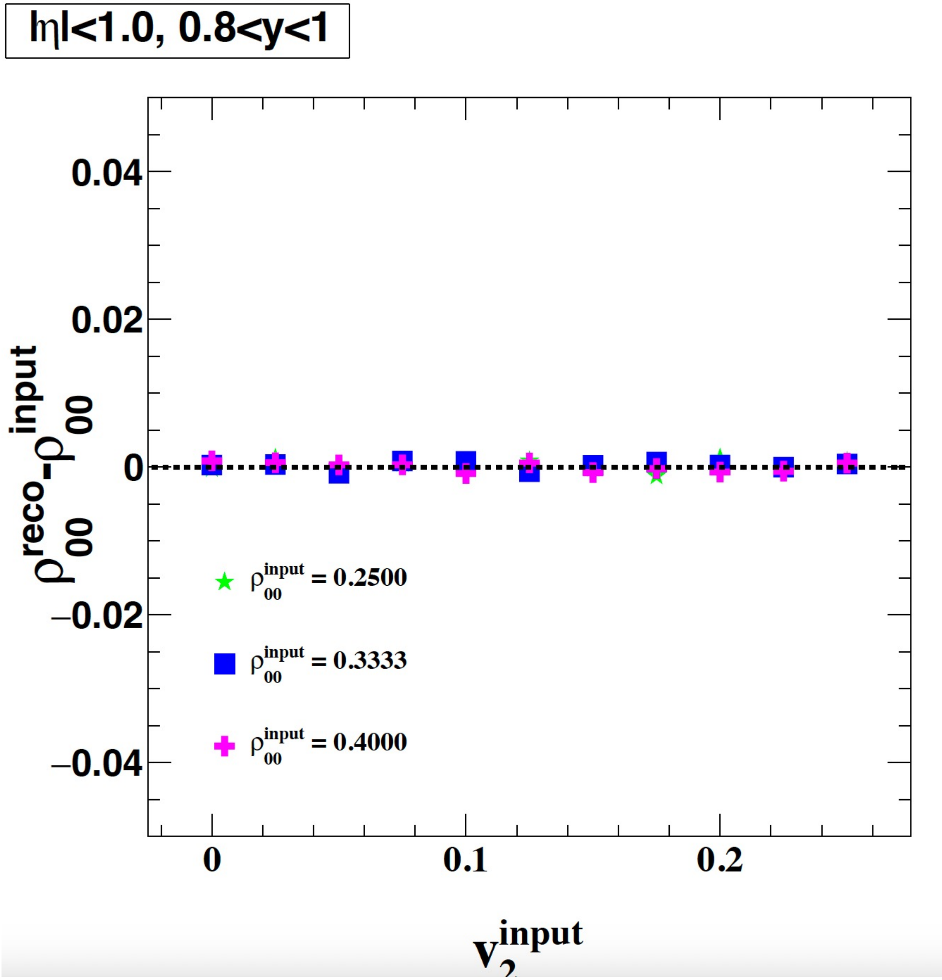
- We use pT = 1.5 and R = 0.4 for the following studies.

No |η| cut, EP Resolution Corrected

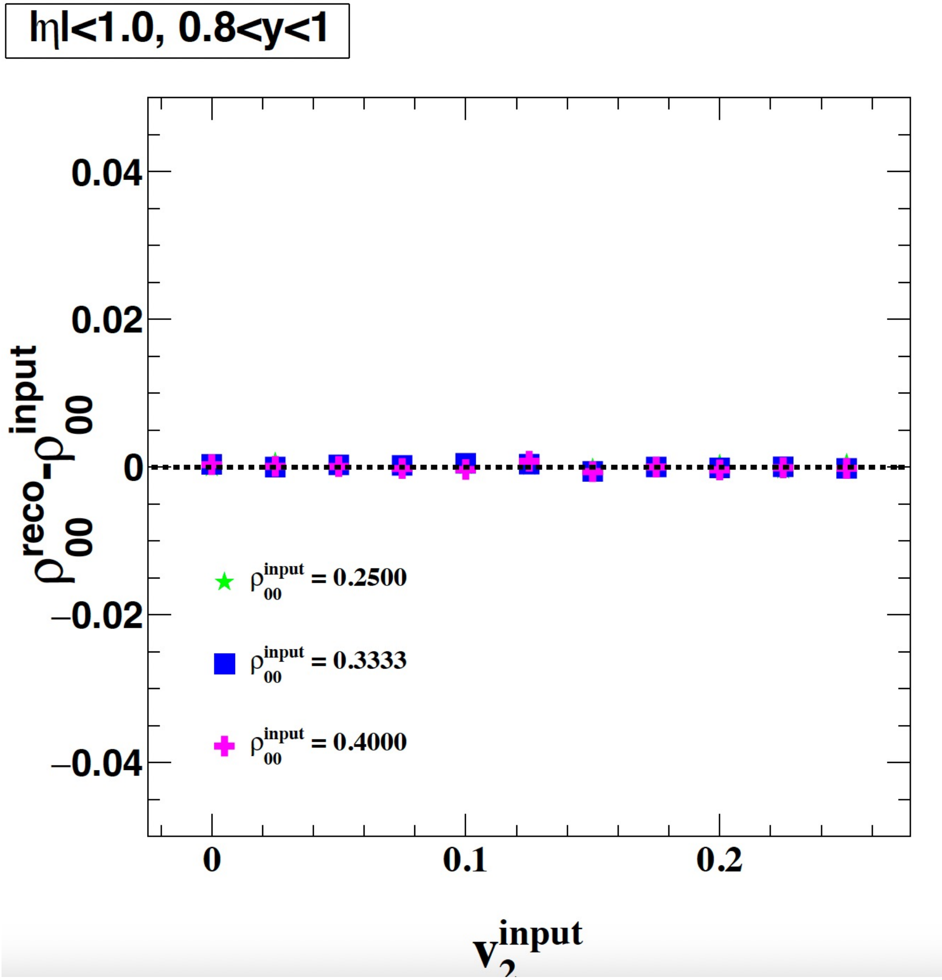
Acceptance parameters are derived from distributions with the **same** v2 input.

R = 0.4

EP Smearing



No EP Smearing

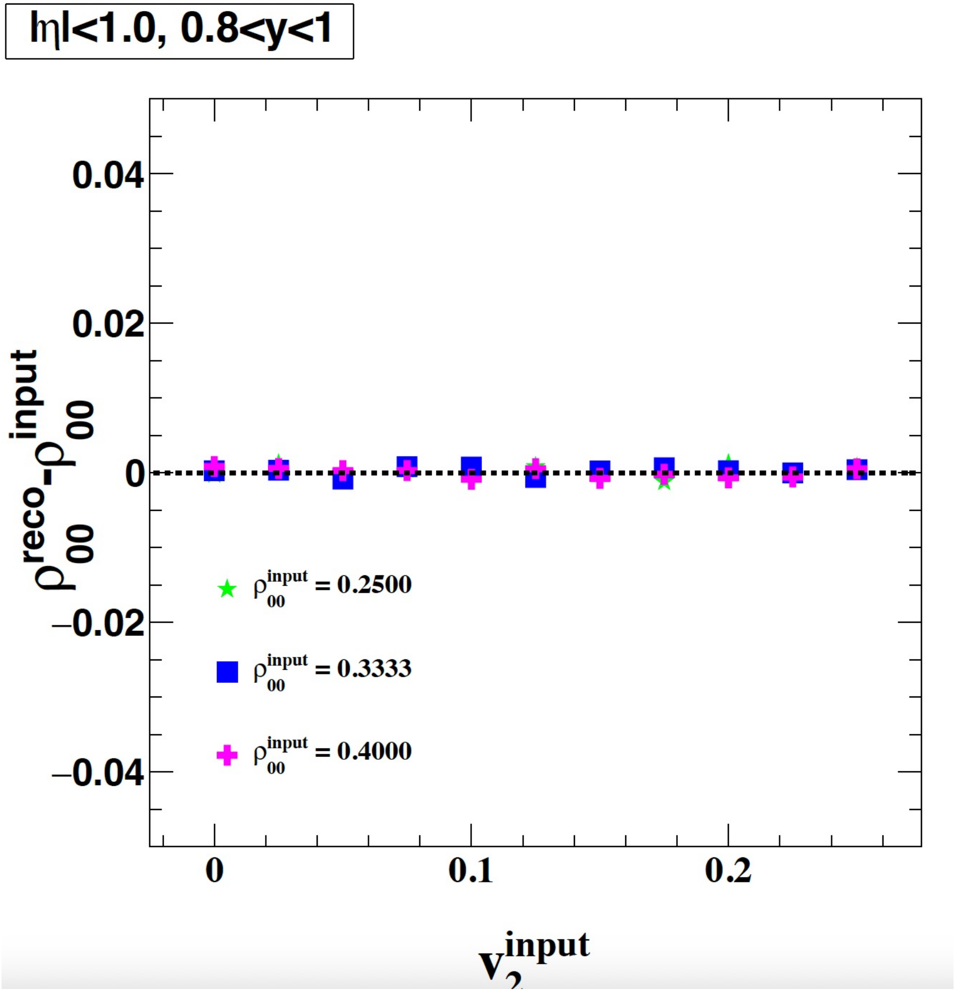


No |η| cut, EP Resolution Corrected

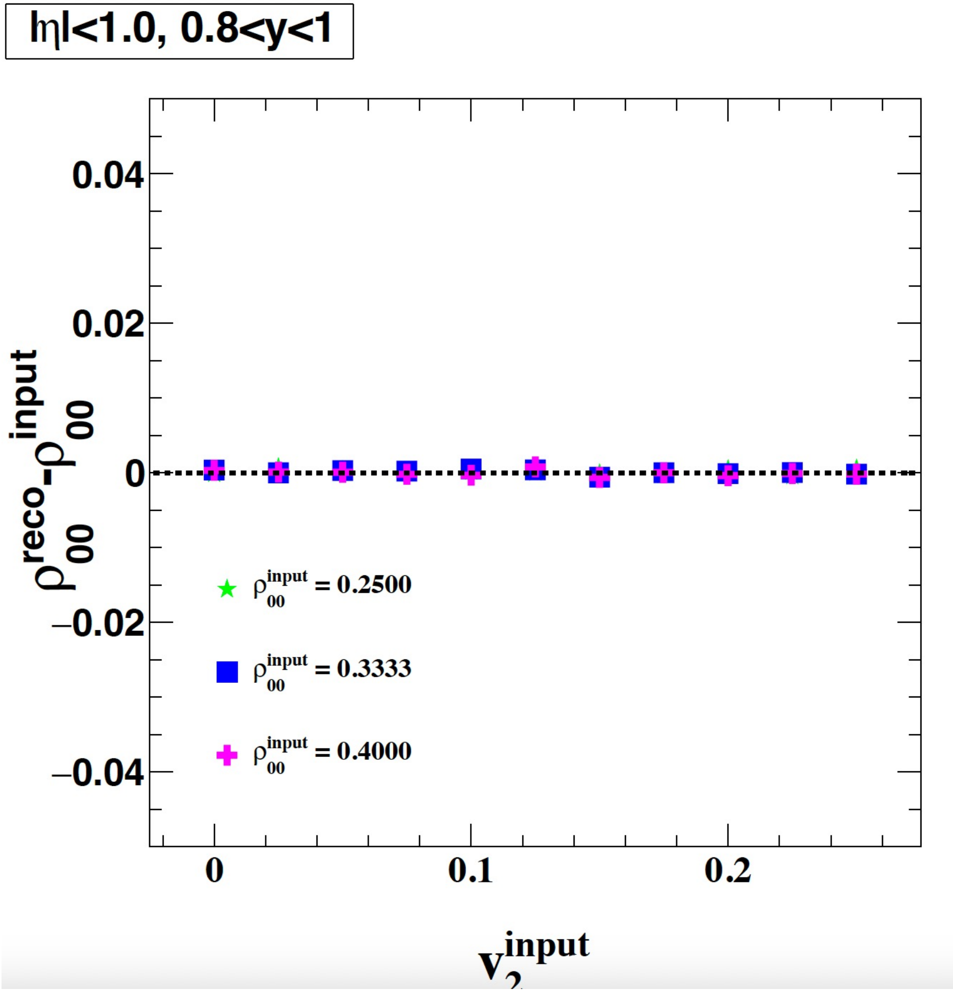
Acceptance parameters are derived from v2 = 0.

R = 0.4

EP Smearing



No EP Smearing

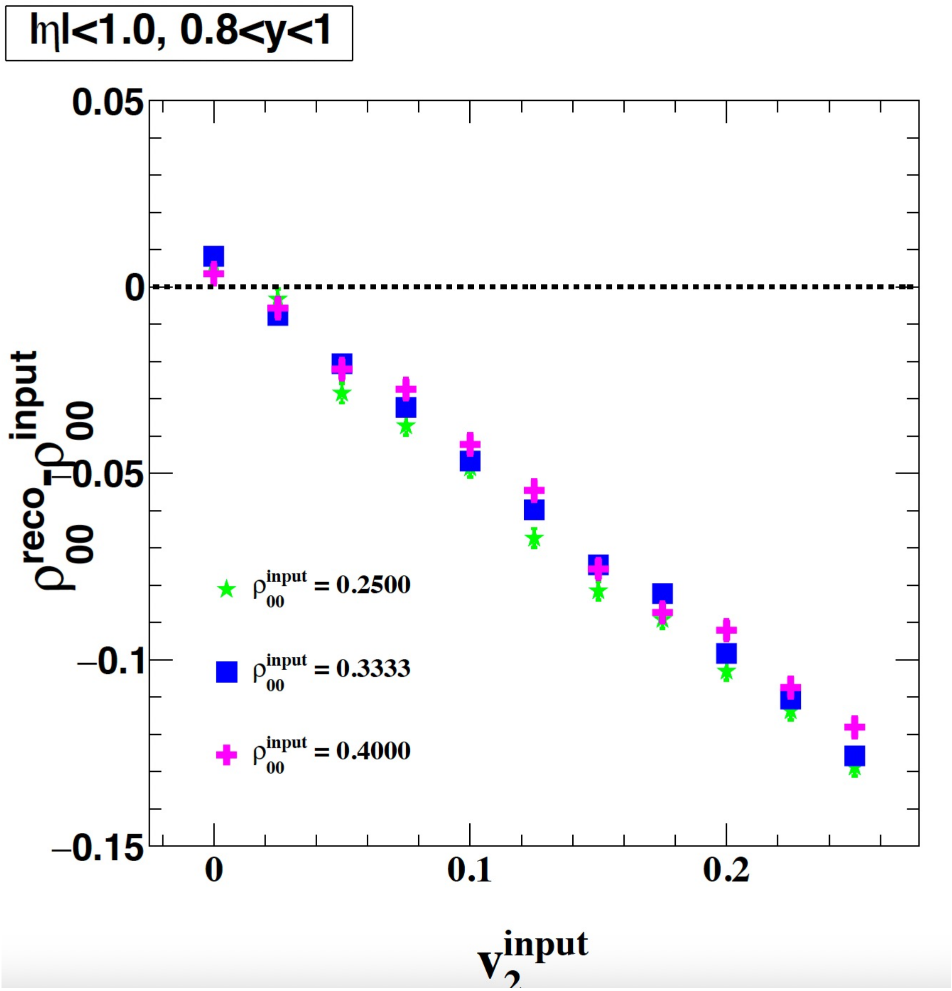


With |η| cut, Acceptance + EP Resolution Corrected

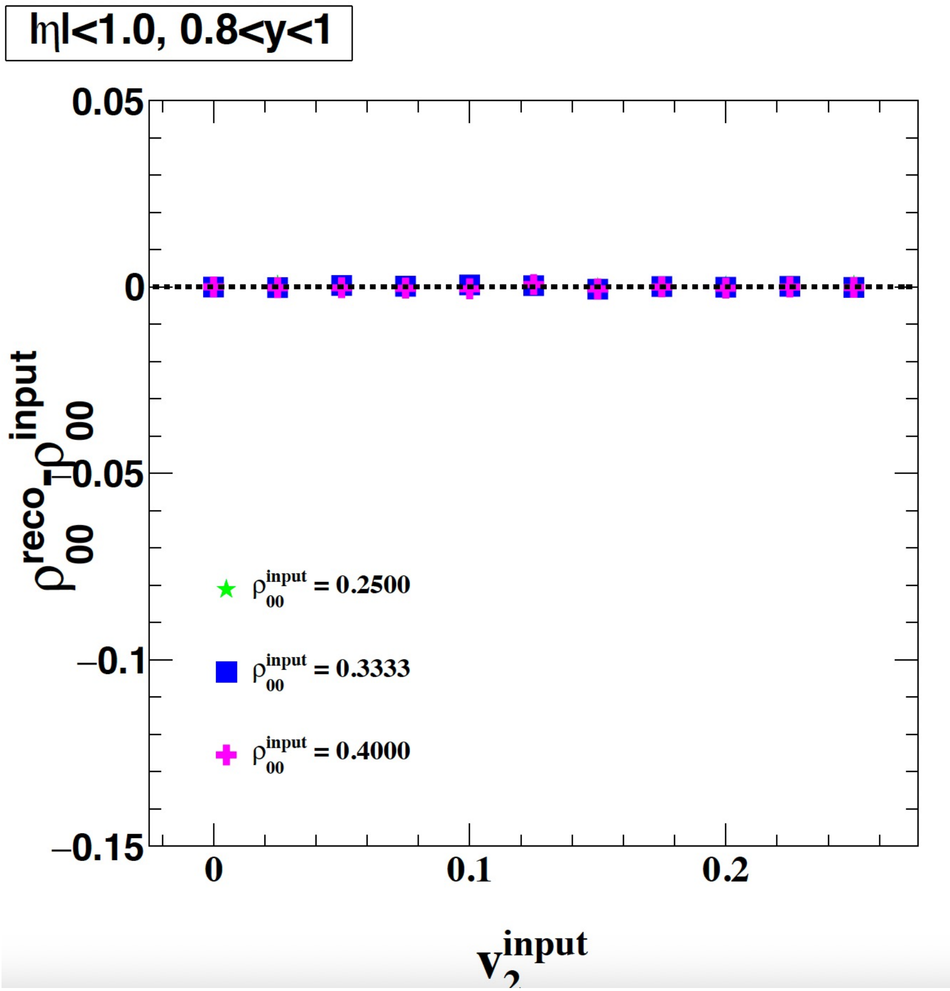
Acceptance parameters are derived from distributions with the **same** v2 input.

R = 0.4

EP Smearing



No EP Smearing

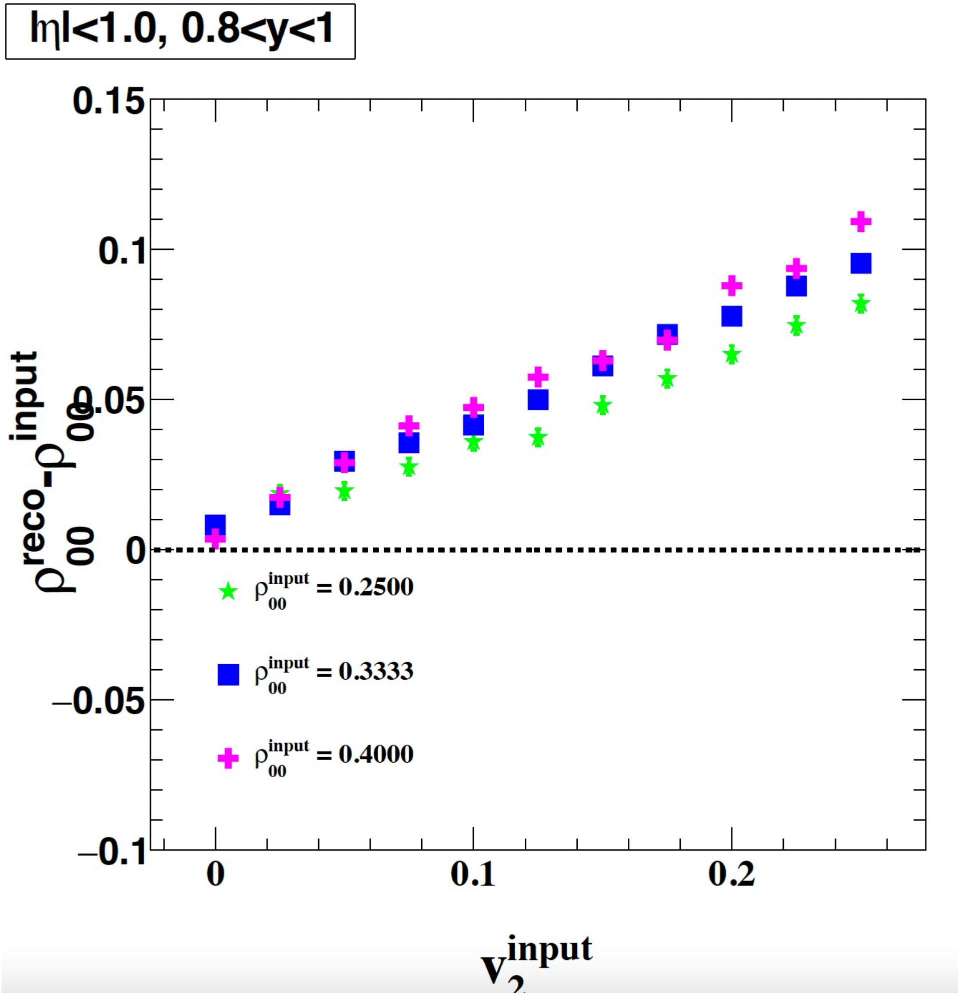


With |η| cut, Acceptance + EP Resolution Corrected

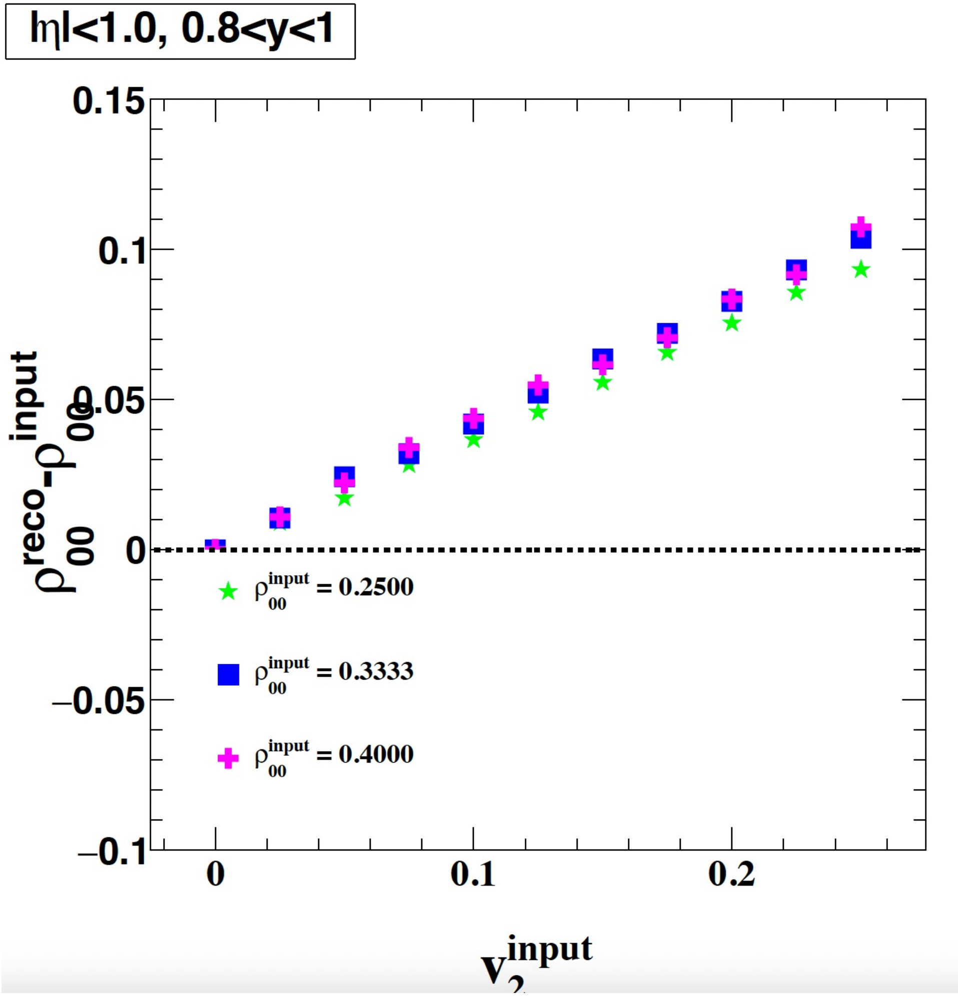
Acceptance parameters are derived from v2 = 0.

R = 0.4

EP Smearing



No EP Smearing



Summary

Acceptance parameters are derived from distributions with the **same** v2 input.

	No EP Smearing	With EP Smearing
No |η| cut	reco = input	reco = input
With |η| cut	reco = input	reco != input **Close agreement** when v2 = 0. reco – input **decreases** when v2 **increases**.

Acceptance parameters are derived from v2 = 0.

	No EP Smearing	With EP Smearing
No |η| cut	reco = input	reco = input
With |η| cut	reco != input **Agreement** when v2 = 0. reco – input **increases** when v2 **increases**.	reco != input **Close agreement** when v2 = 0. reco – input **increases** when v2 **increases**.

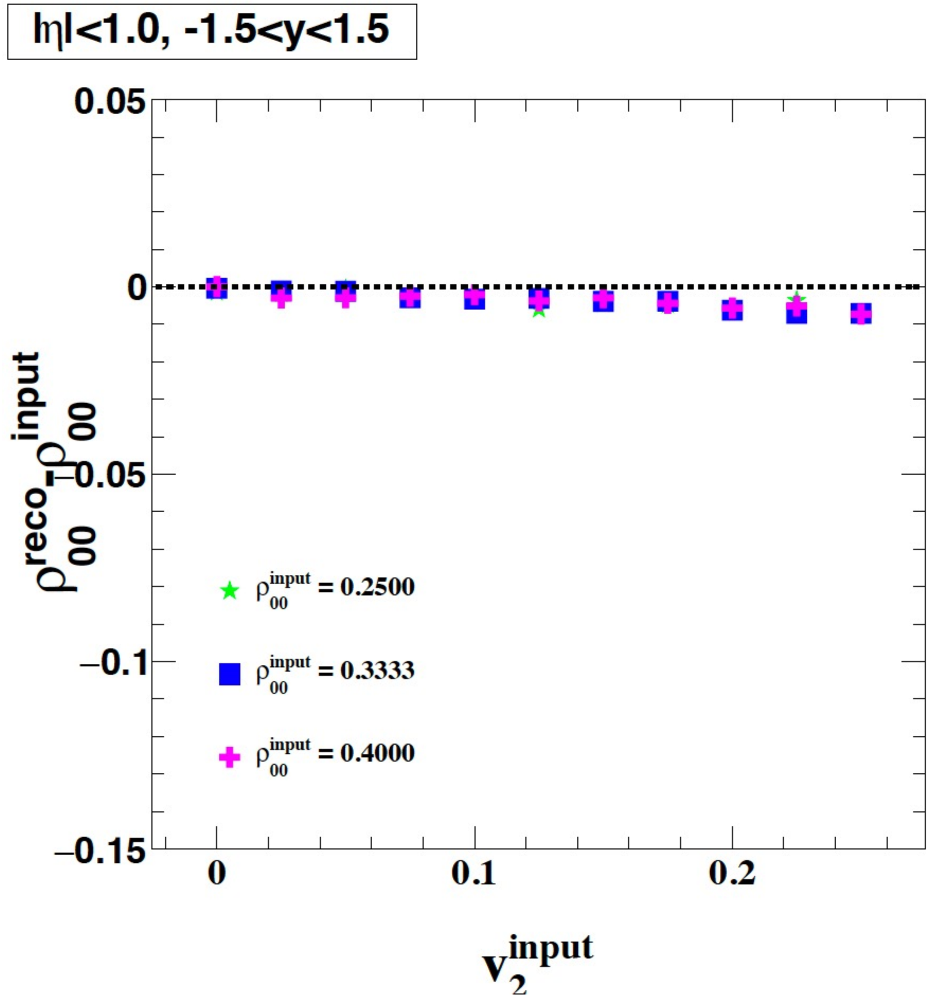
Let's look at the |η| cut dependence for a wide rapidity input with v2.

With |η| cut, Acceptance + EP Resolution Corrected

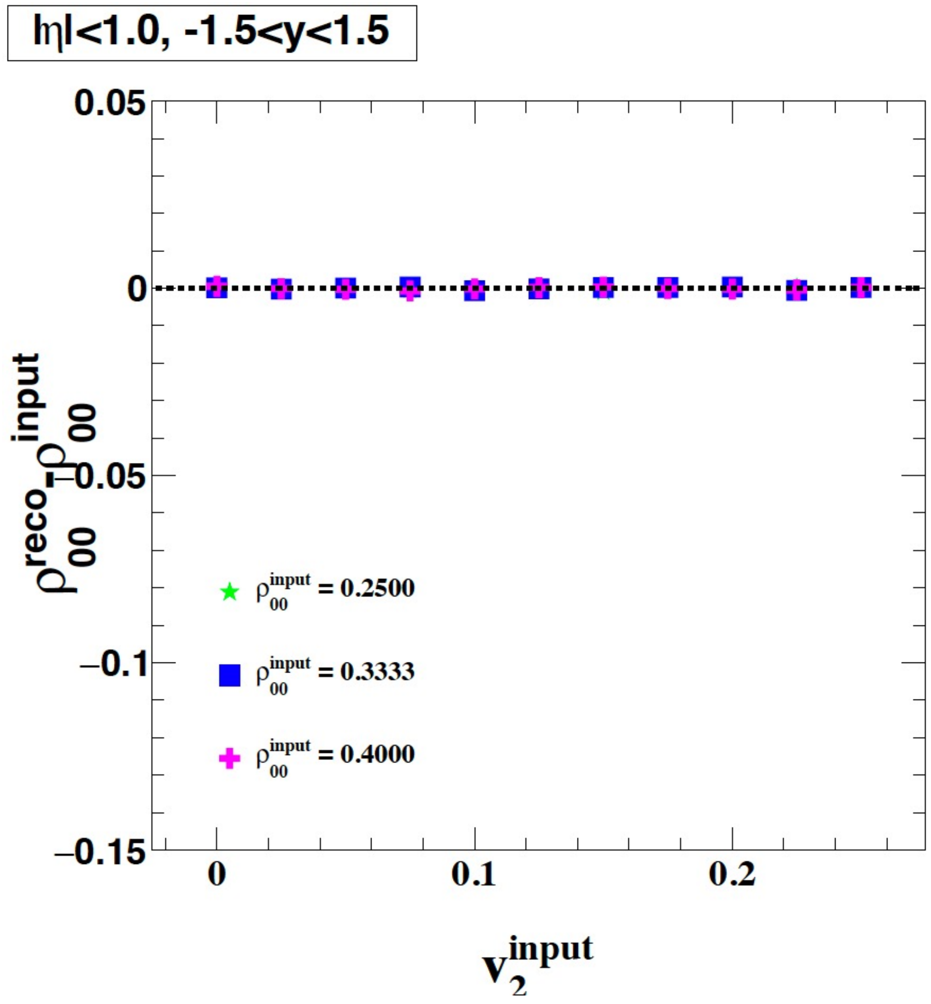
Acceptance parameters are derived from distributions with the **same** v2 input.

R = 0.4

EP Smearing



No EP Smearing

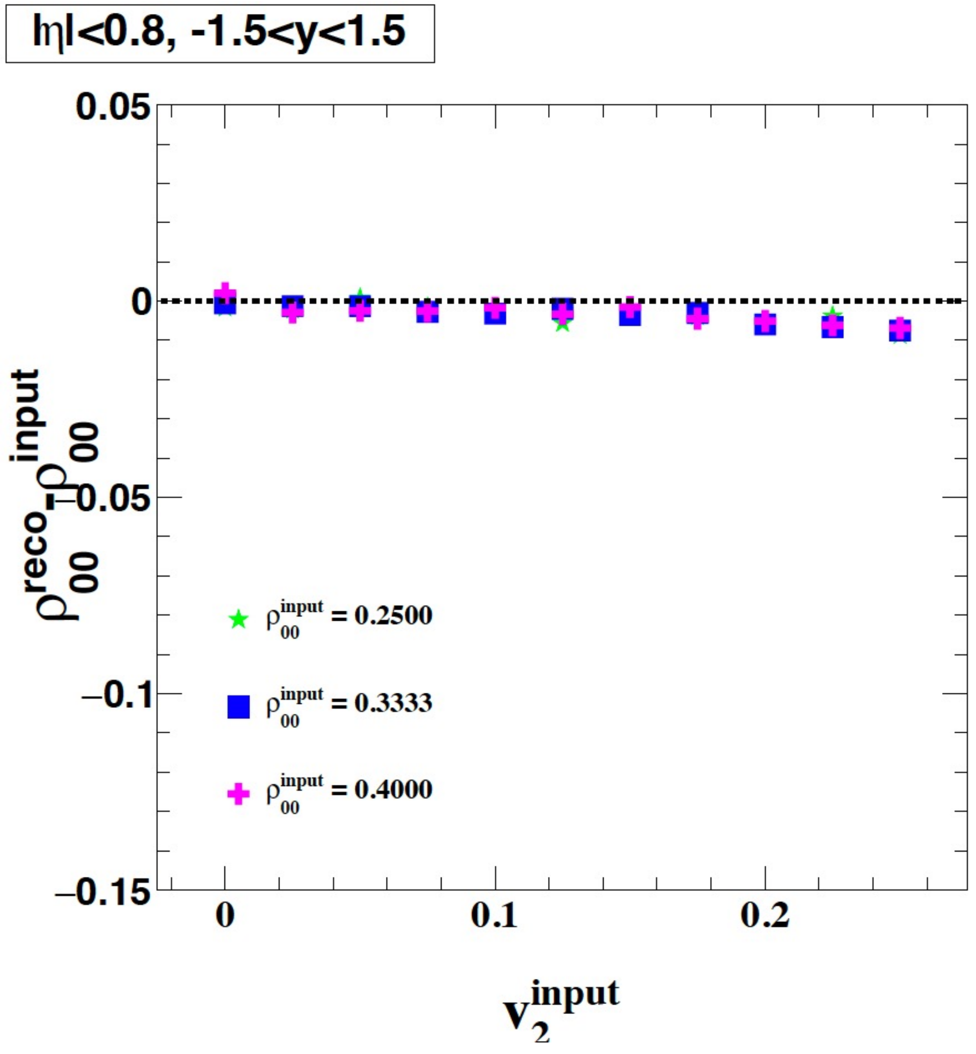


With |η| cut, Acceptance + EP Resolution Corrected

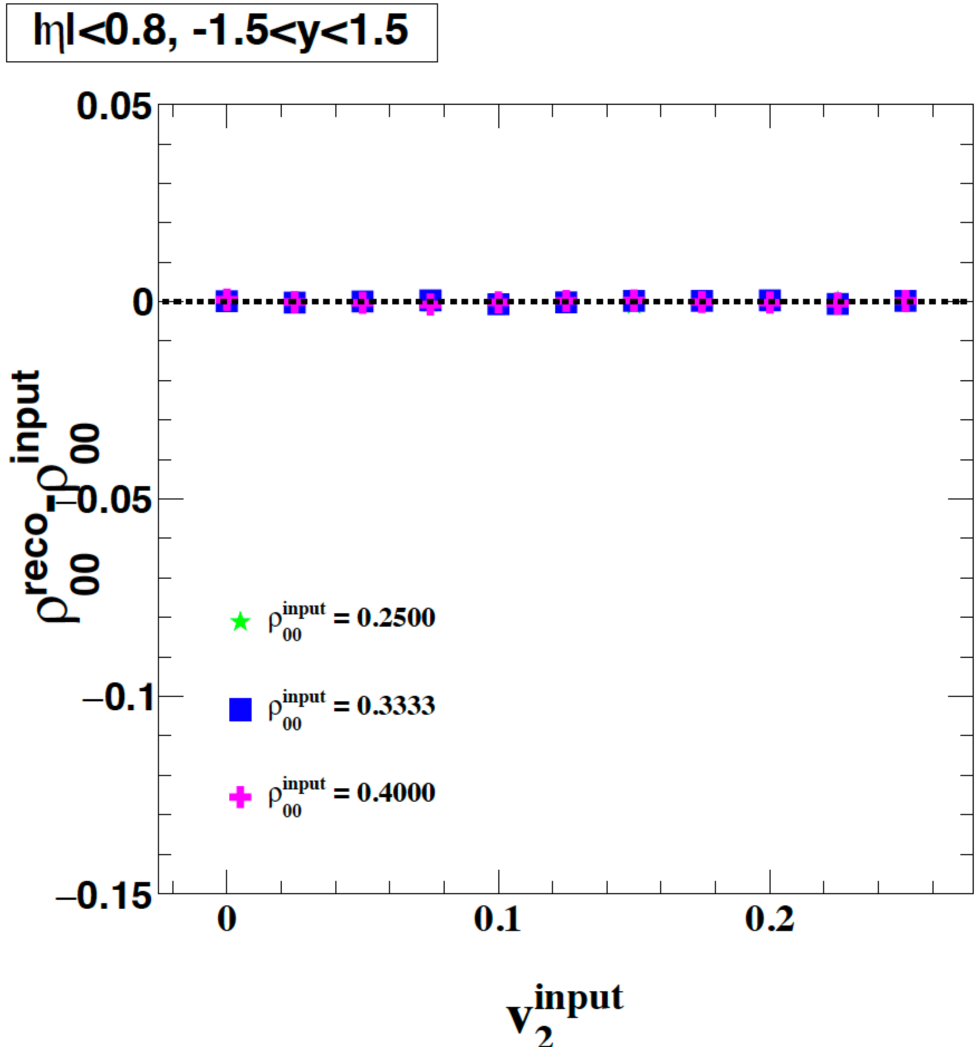
Acceptance parameters are derived from distributions with the **same** v2 input.

R = 0.4

EP Smearing



No EP Smearing

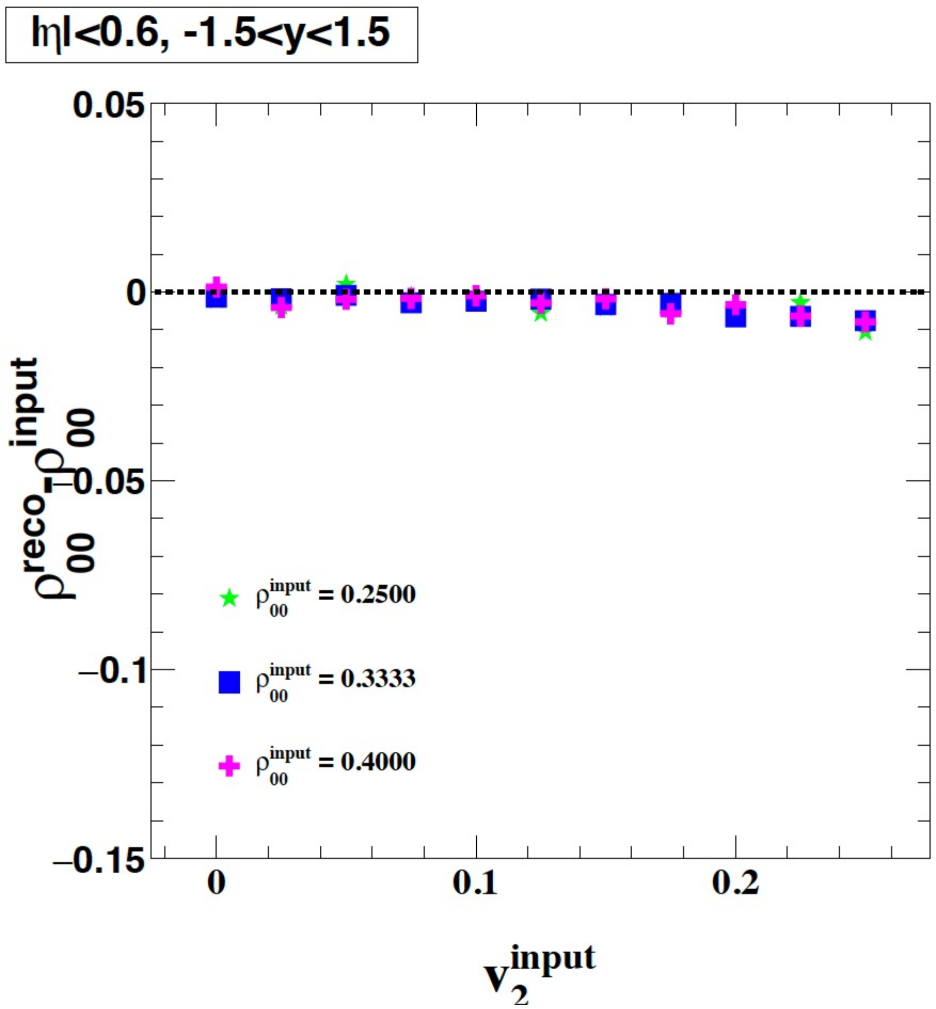


With |η| cut, Acceptance + EP Resolution Corrected

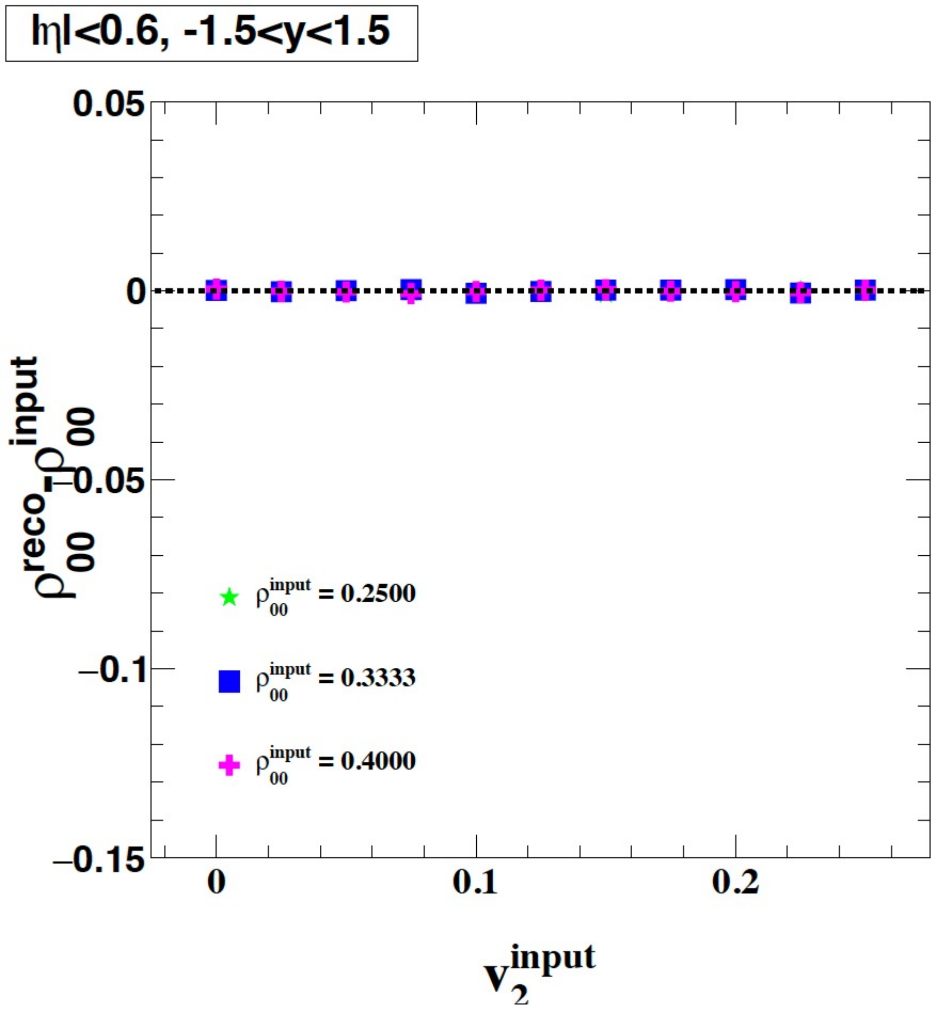
Acceptance parameters are derived from distributions with the **same** v2 input.

R = 0.4

EP Smearing



No EP Smearing

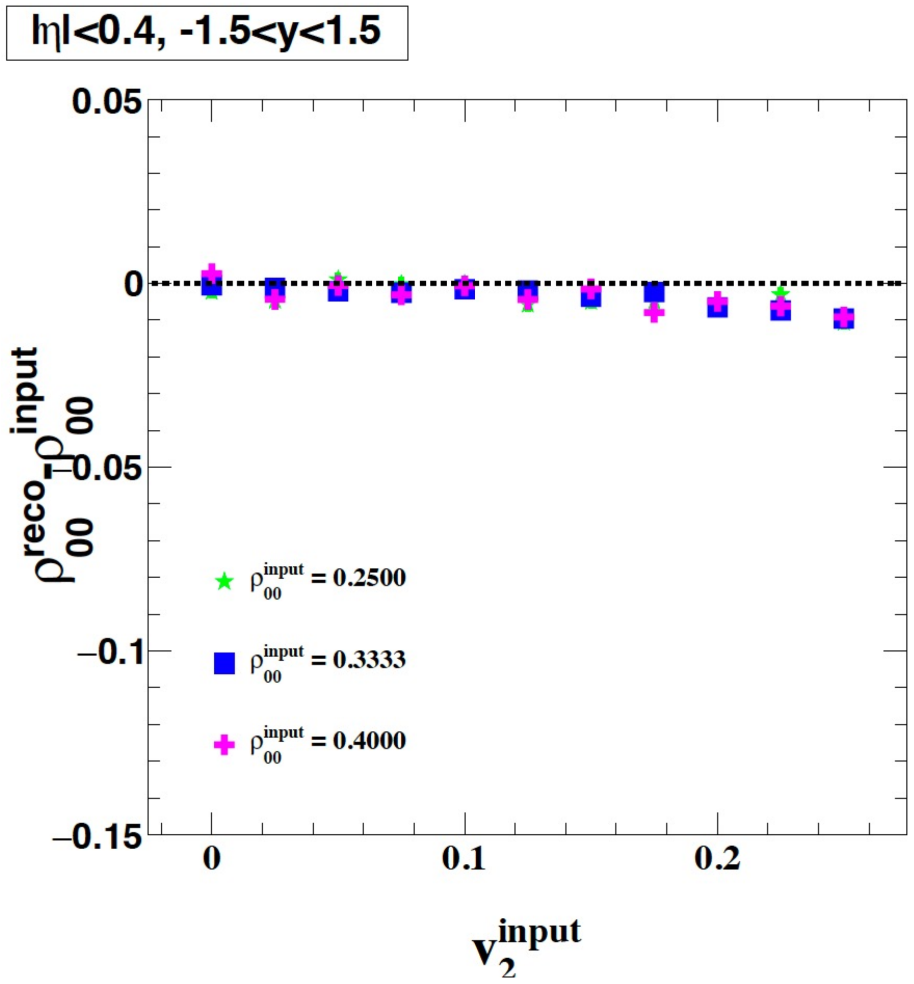


With |η| cut, Acceptance + EP Resolution Corrected

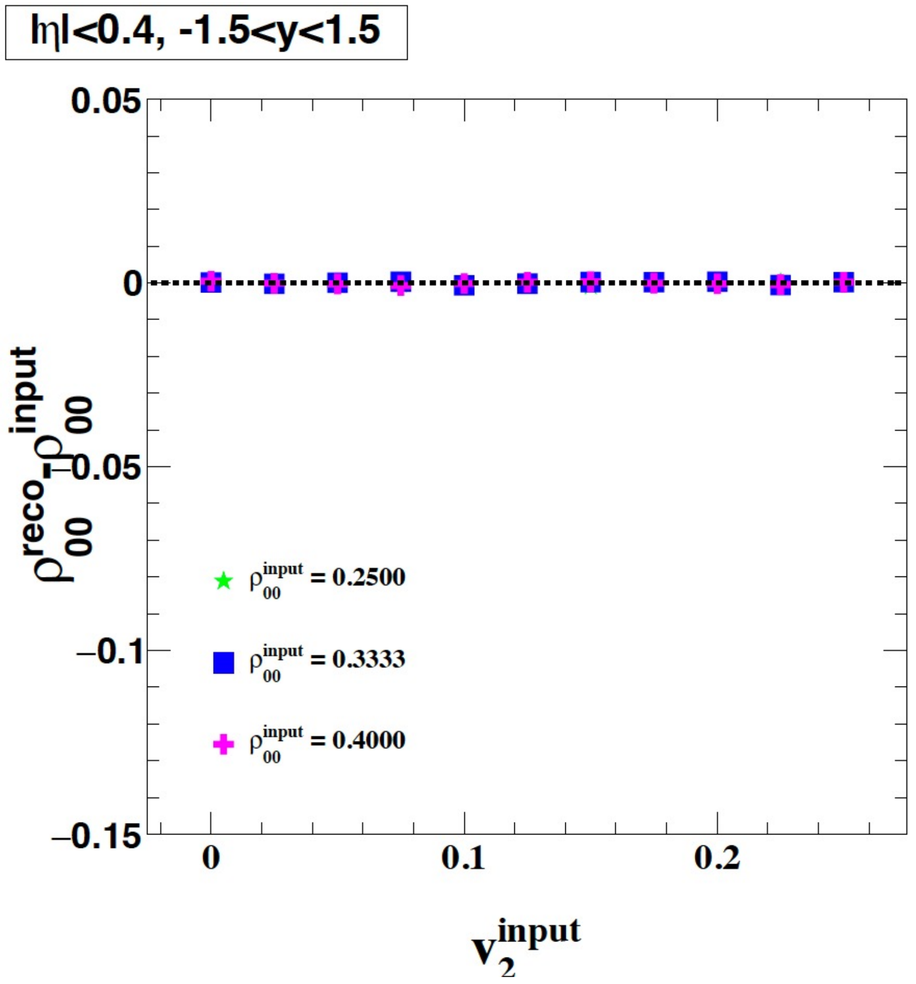
Acceptance parameters are derived from distributions with the **same** v2 input.

R = 0.4

EP Smearing



No EP Smearing



Let’s look at some cases where we use the smeared cos(θ*’) acceptance ratio to correct the the smeared cos(θ*’) distributions.

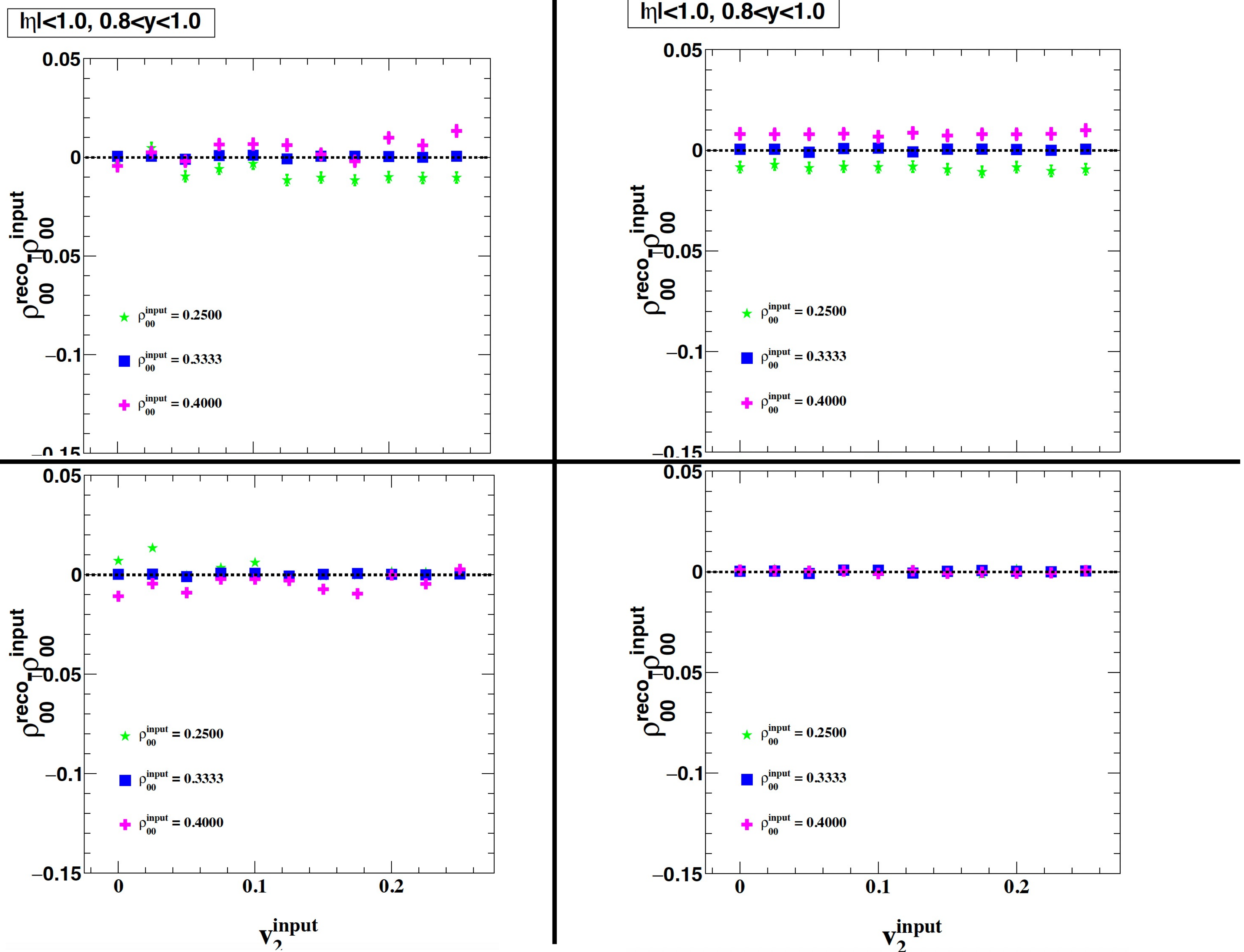
These results use EP Smearing and Corrections are derived from Smeared cos(θ*’)

Acceptance Correction from $\rho_{00} = 1/3$

Acceptance Correction from input ρ_{00}

Fit to Acceptance

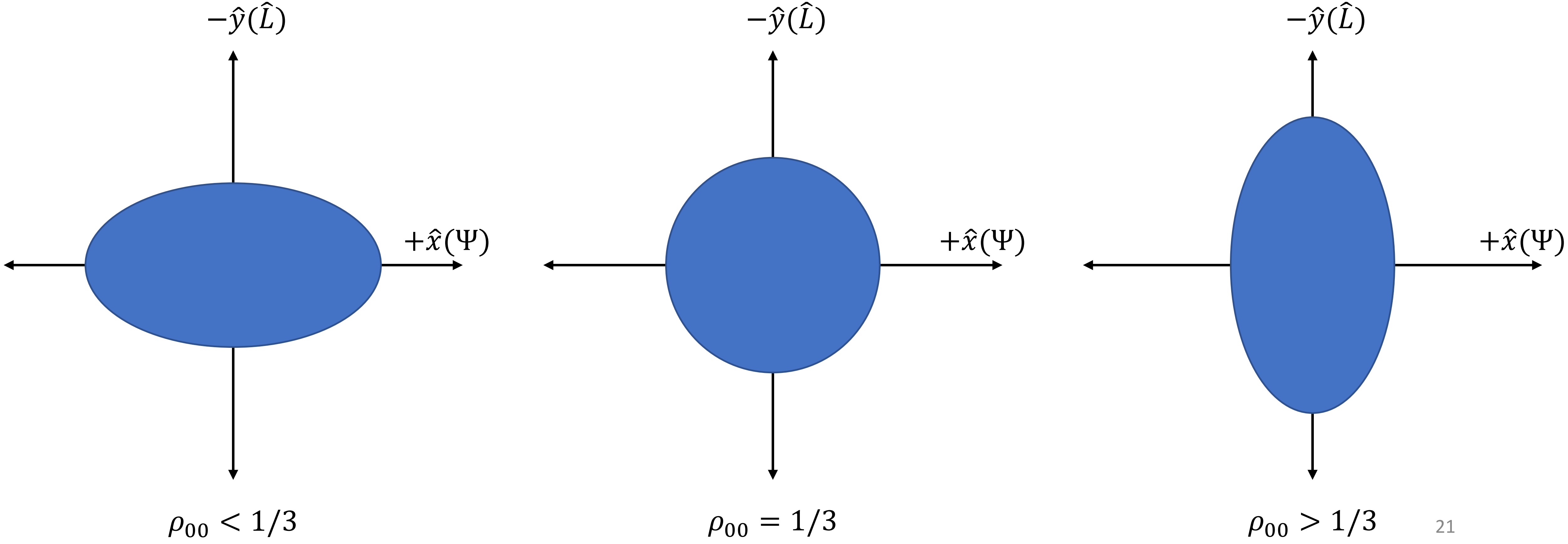
Divide Out Acceptance



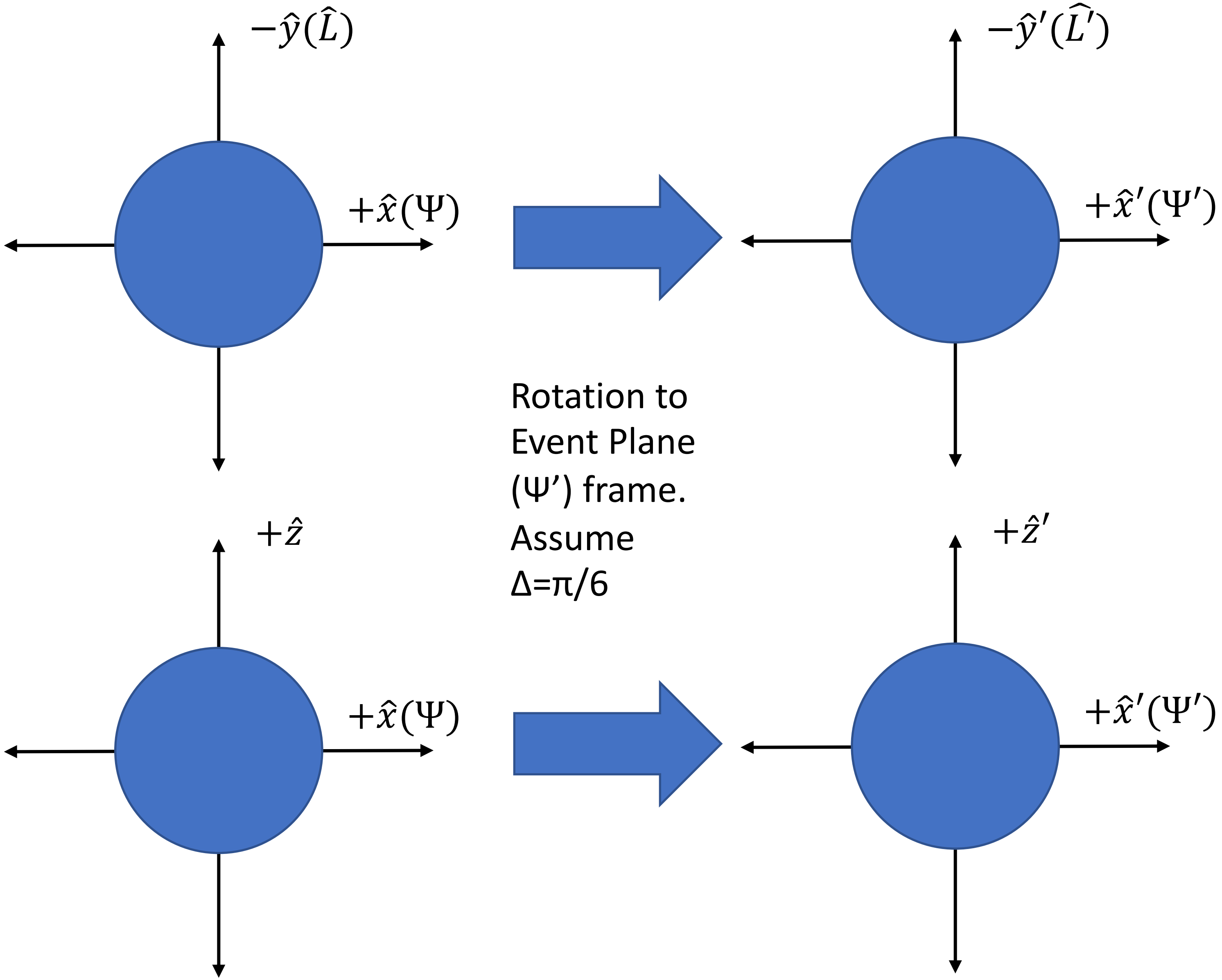
Effect of Event Plane Smearing on β angle

The following distributions are in the ϕ-meson rest frame. They represent the yield of ϕ-meson in 2D space for each of the input ρ_{00} values.

In reaction plane (Ψ) frame, the azimuthal angle (β) has a uniform distribution in xz-plane (circular).



Simple case ($\rho_{00} = 1/3$)

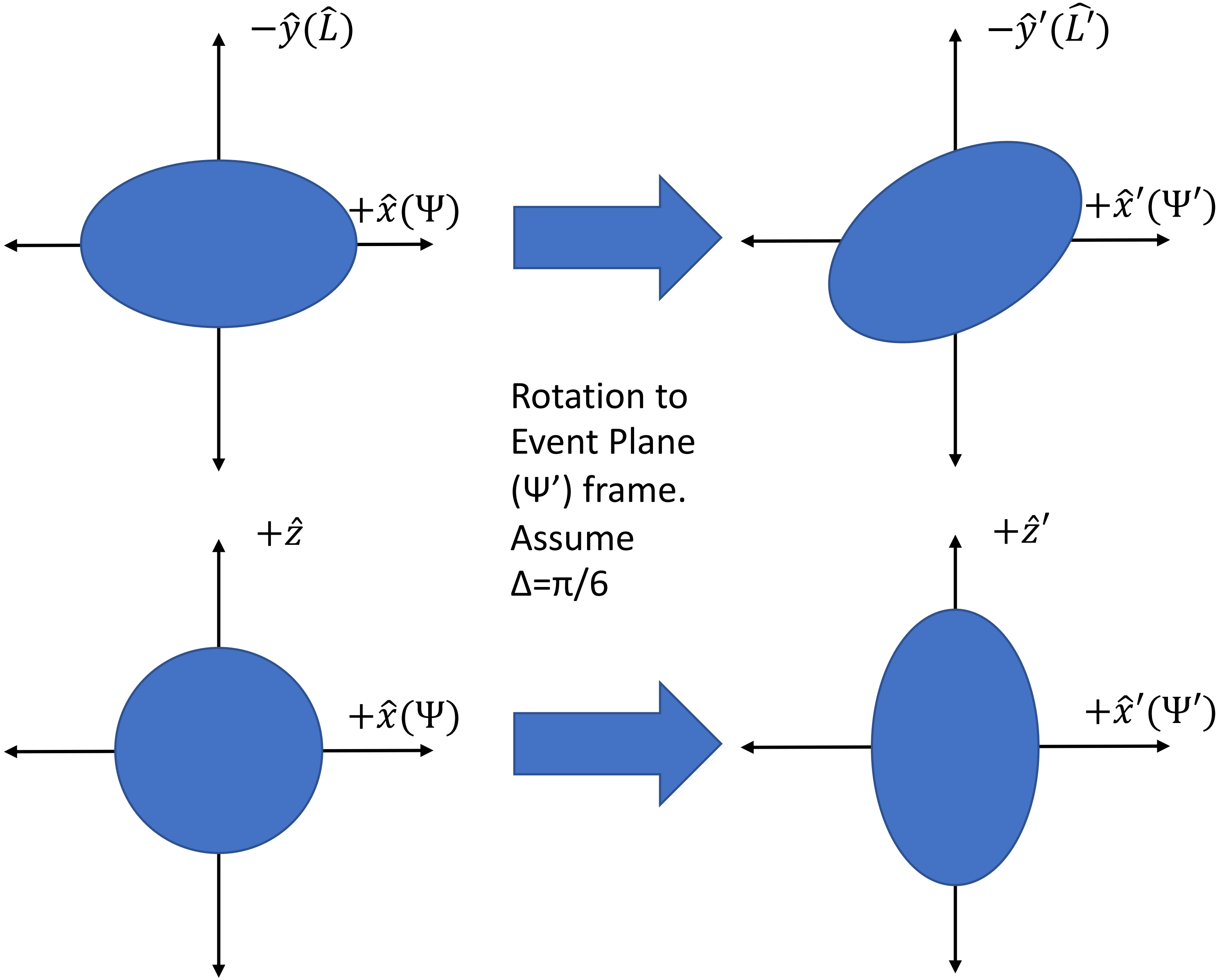


Rotating to the Ψ’ frame does not cause non-uniformity in the β’ angle.

$\therefore \langle \cos 2\beta \rangle = \langle \cos 2\beta' \rangle = 0$

The xz-plane and x’z’-plane projections are equivalent to cos(θ*) = 0 and cos(θ*’) = 0.

$(\rho_{00} < 1/3)$



Rotation to Event Plane (Ψ’) frame. Assume Δ=π/6

Rotating to the Ψ’ frame causes non-uniformity in the β’ angle.

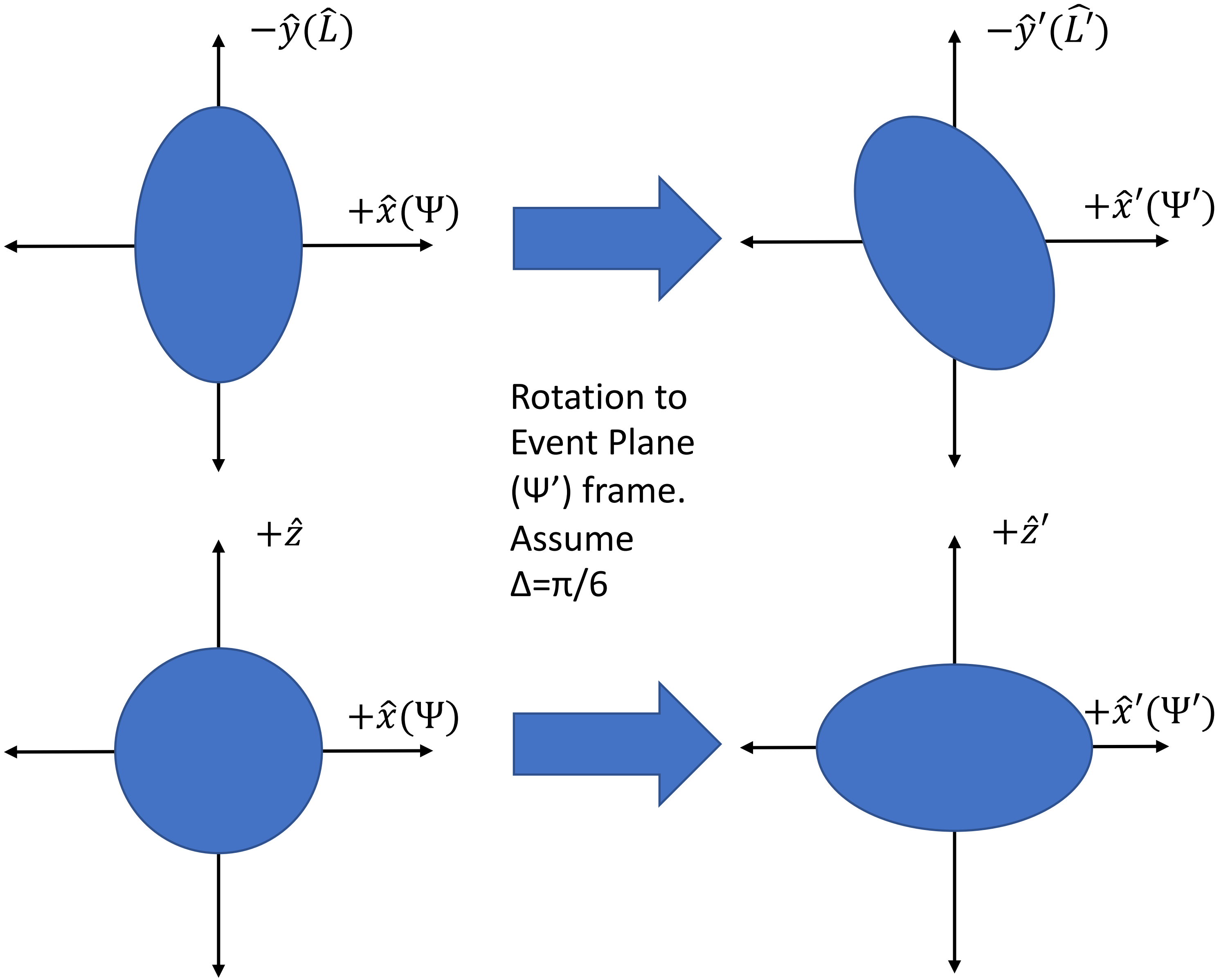
$\therefore \langle\cos 2\beta\rangle = 0$
$\langle\cos 2\beta'\rangle < 0$

The particle yield would be **smaller** at β'={0,π} than at β'={π/2,3π/2}

We expect $\langle\cos 2\beta'\rangle < 0$ since $\cos 2\beta'$ = 1 at β'={0,π} and $\cos 2\beta'$ = -1 at β'={π/2,3π/2}.

The xz-plane and x’z’-plane projections are equivalent to cos(θ*) = 0 and cos(θ*’) = 0.

$(\rho_{00} < 1/3)$



Rotating to the Ψ' frame causes non-uniformity in the β' angle.

$\therefore \langle \cos 2\beta \rangle = 0$
$\langle \cos 2\beta' \rangle > 0$

The particle yield would be **larger** at β'={0,π} than at β'={π/2,3π/2}

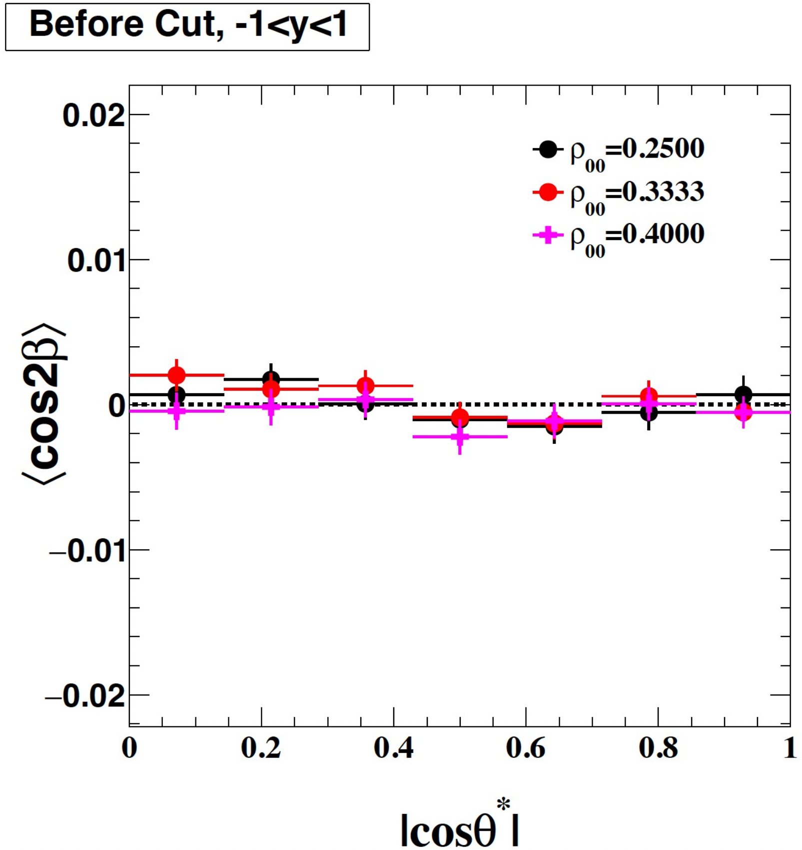
We expect $\langle \cos 2\beta' \rangle > 0$ since $\cos 2\beta'$ = 1 at β'={0,π} and $\cos 2\beta'$ = -1 at β'={π/2,3π/2}.

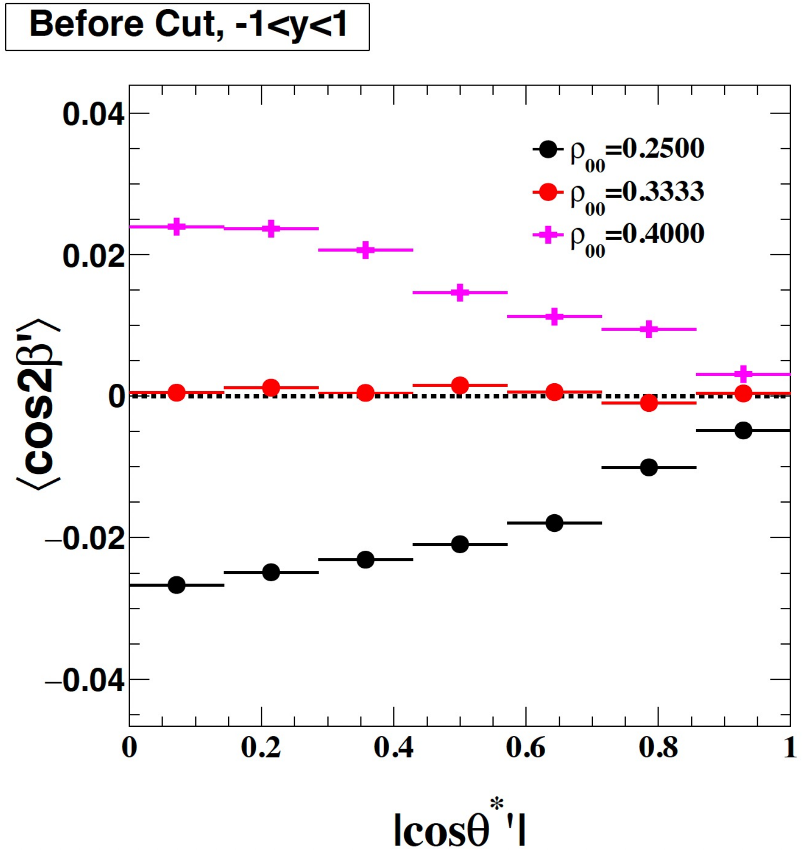
The xz-plane and x'z'-plane projections are equivalent to cos(θ*) = 0 and cos(θ*') = 0.

Conclusions from basic geometry examples at cos(θ*) = 0 and cos(θ*’) = 0 :

$$\rho_{00} < \frac{1}{3}: \quad \langle \cos 2\beta \rangle = 0$$
$$\rho_{00} = \frac{1}{3}: \quad \langle \cos 2\beta \rangle = 0$$
$$\rho_{00} > \frac{1}{3}: \quad \langle \cos 2\beta \rangle = 0$$

$$\rho_{00} < \frac{1}{3}: \quad \langle \cos 2\beta' \rangle < 0$$
$$\rho_{00} = \frac{1}{3}: \quad \langle \cos 2\beta' \rangle = 0$$
$$\rho_{00} > \frac{1}{3}: \quad \langle \cos 2\beta' \rangle > 0$$





By similar arguments, we would also expect other relevant terms $\langle \cos\beta' \rangle$ and $\langle \cos 4\beta' \rangle$ to be zero.

$$\rho_{00} < \frac{1}{3}: \quad \langle \cos\beta' \rangle = 0$$
$$\rho_{00} = \frac{1}{3}: \quad \langle \cos\beta' \rangle = 0$$
$$\rho_{00} > \frac{1}{3}: \quad \langle \cos\beta' \rangle = 0$$

$$\rho_{00} < \frac{1}{3}: \quad \langle \cos 4\beta' \rangle = 0$$
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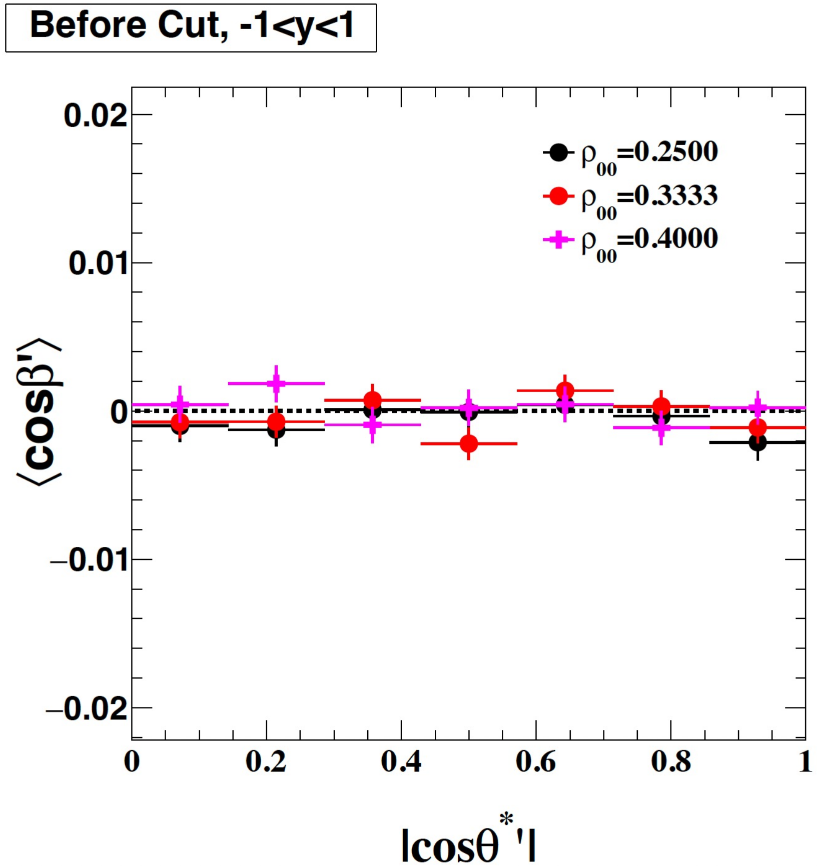
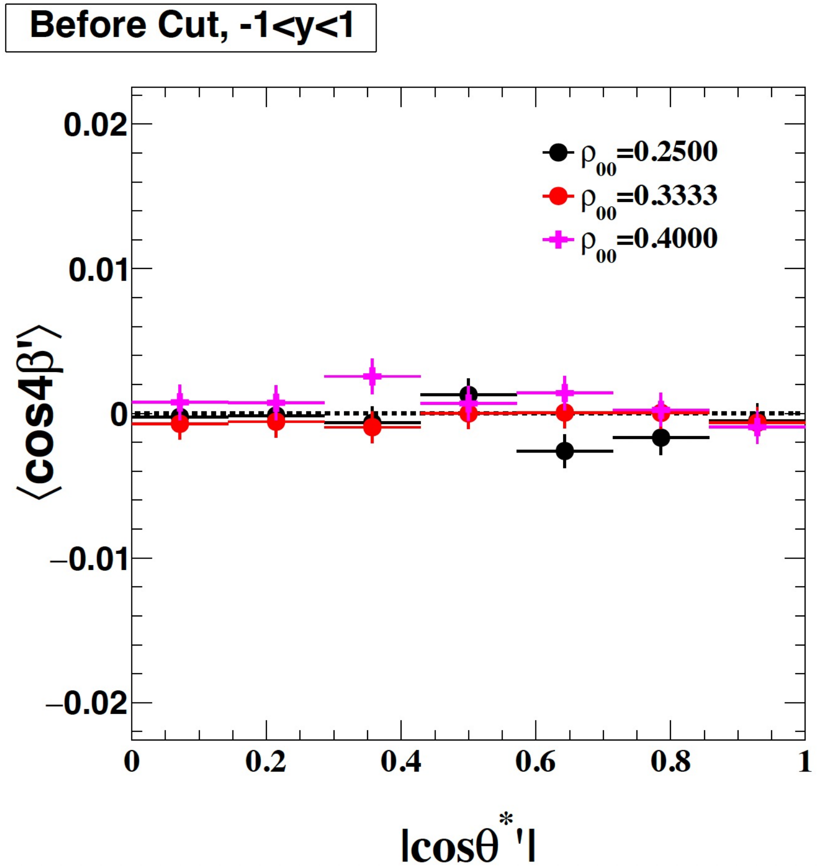
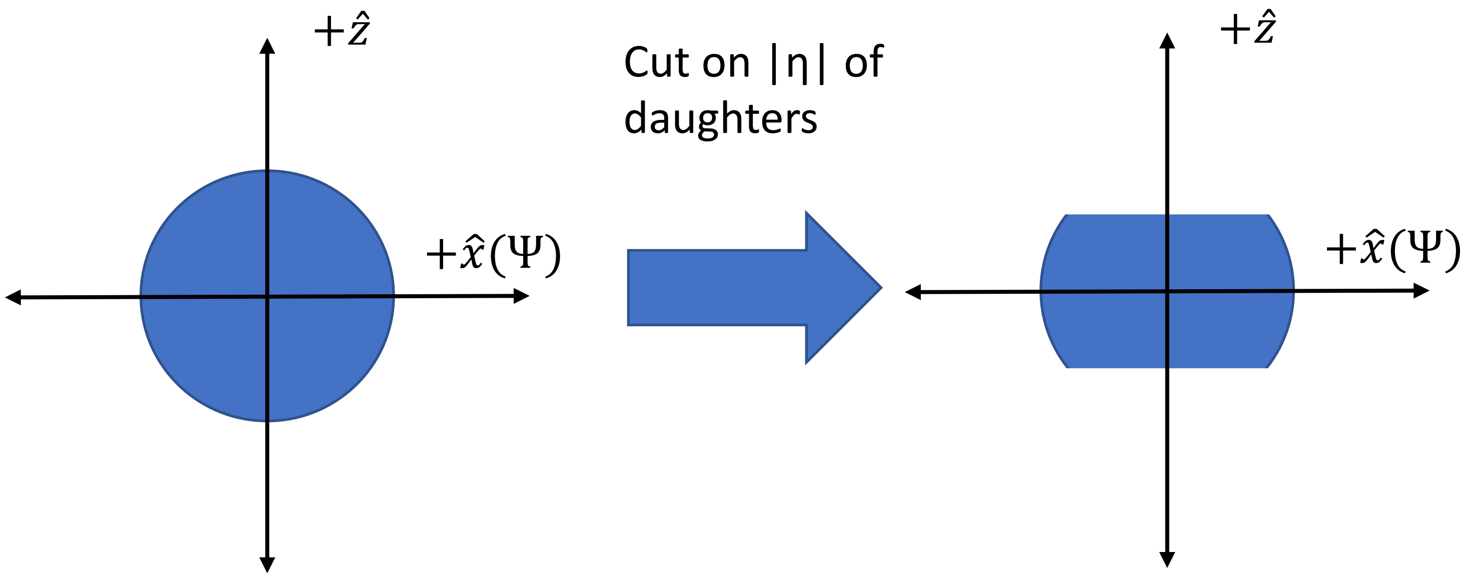




$(\rho_{00} = 1/3)$ |η| cut effect



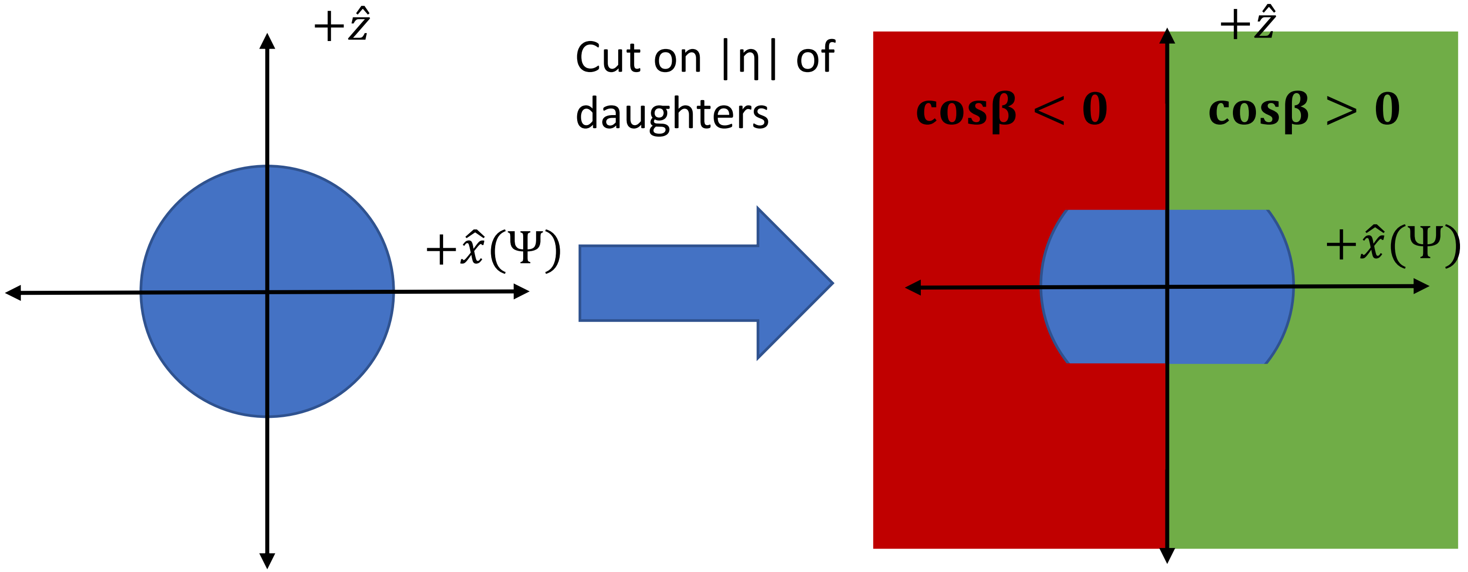
The particle yield would be **larger** at β={0,π} than at β={π/2,3π/2}

We expect $\langle\cos 2\beta\rangle > 0$ since
$\cos 2\beta$ = 1 at β={0,π} and
$\cos 2\beta$ = -1 at β={π/2,3π/2}.

The smaller the |η| cut, the larger $\langle\cos 2\beta\rangle$ will become.

Naively, I would not expect $\langle\cos\beta\rangle$ or $\langle\cos 4\beta\rangle$ to deviate from zero, since the |η| cut effect is symmetric along z-axis.

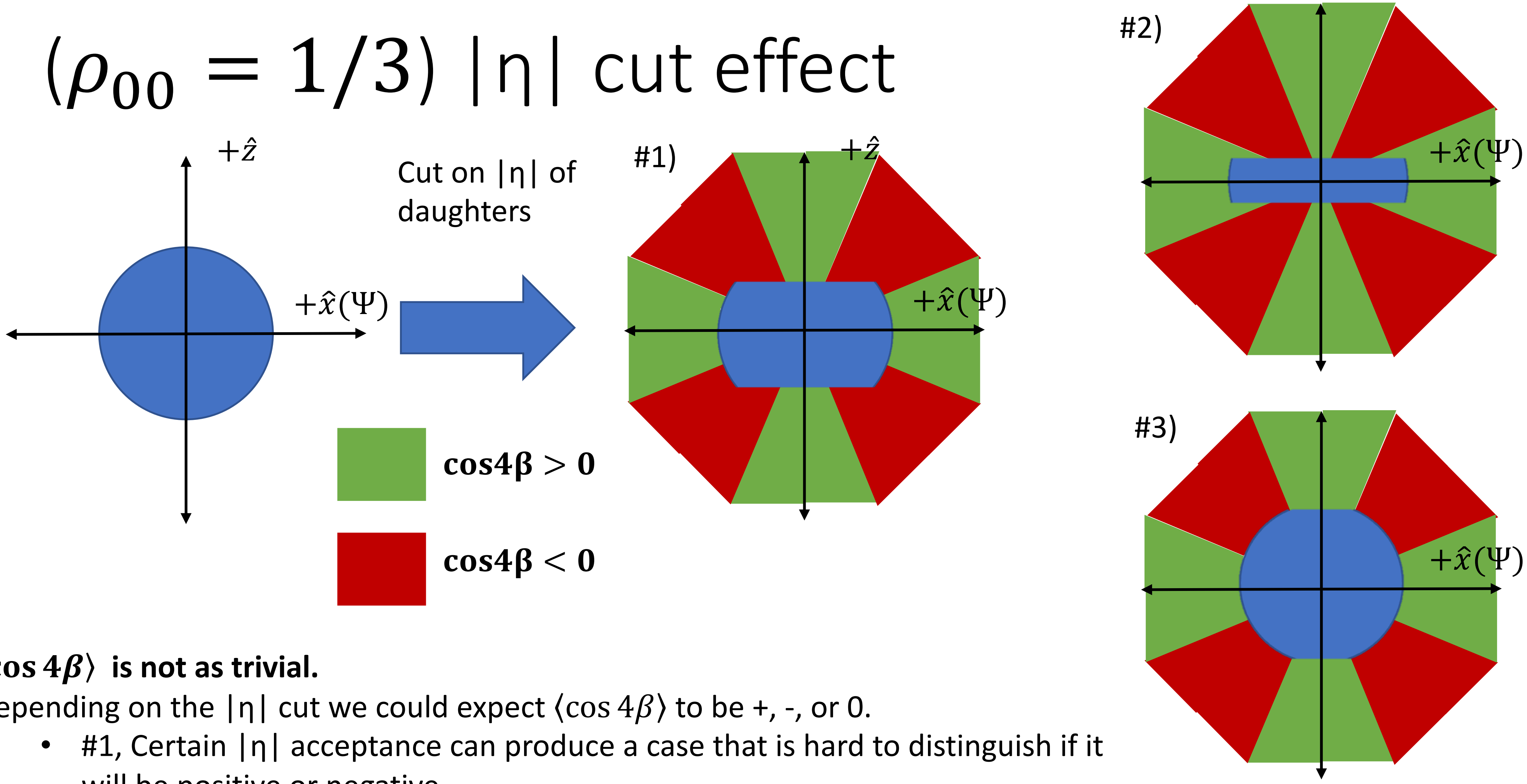
$(\rho_{00} = 1/3)$ |η| cut effect



We expect $\langle \cos \boldsymbol{\beta} \rangle = \mathbf{0}$ just looking at the example on the left.

There is symmetry of yield across the +z axis and a change of sign of cosβ across this axis.

$(\rho_{00} = 1/3)$ |η| cut effect



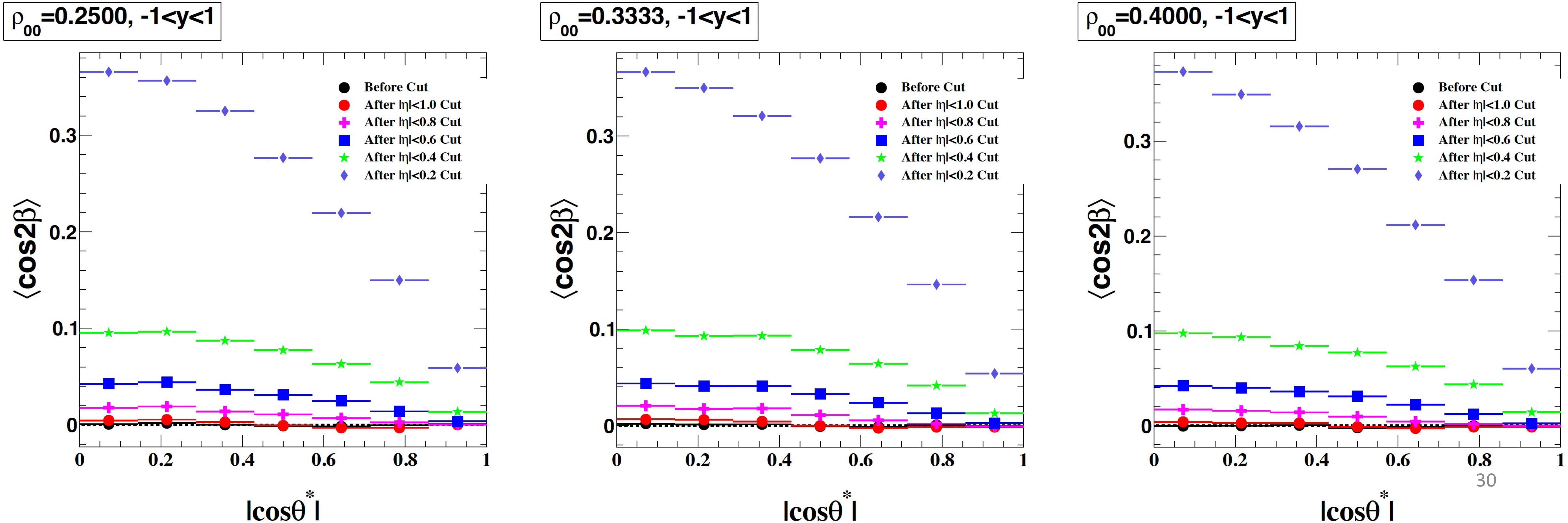
$\langle \cos 4\beta \rangle$ is not as trivial.

Depending on the |η| cut we could expect $\langle \cos 4\beta \rangle$ to be +, -, or 0.

- #1, Certain |η| acceptance can produce a case that is hard to distinguish if it will be positive or negative.
- #2, Small |η| acceptance can cause positive value.
- #3, Wide |η| acceptance can produce slightly negative.

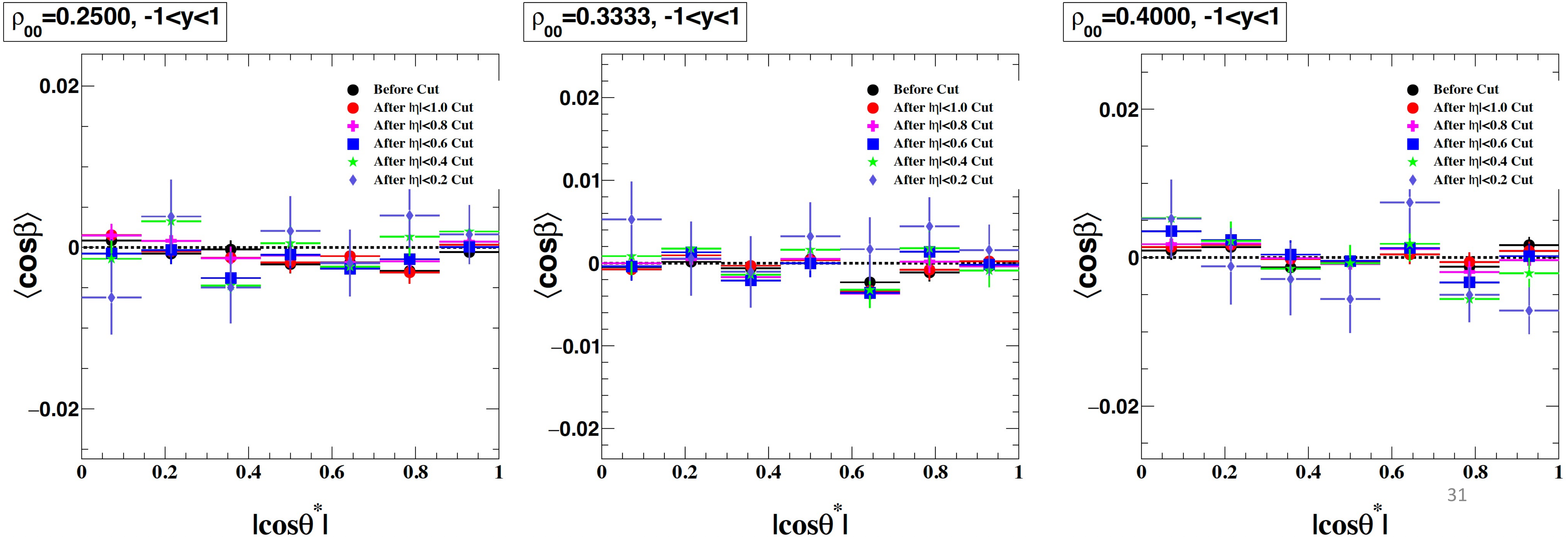
Check with simulation

- We see an increase in $\langle \cos 2\beta \rangle$ away from 0 when we introduce |η| cuts.
- Smaller |η| cut leads to larger deviation from 0.



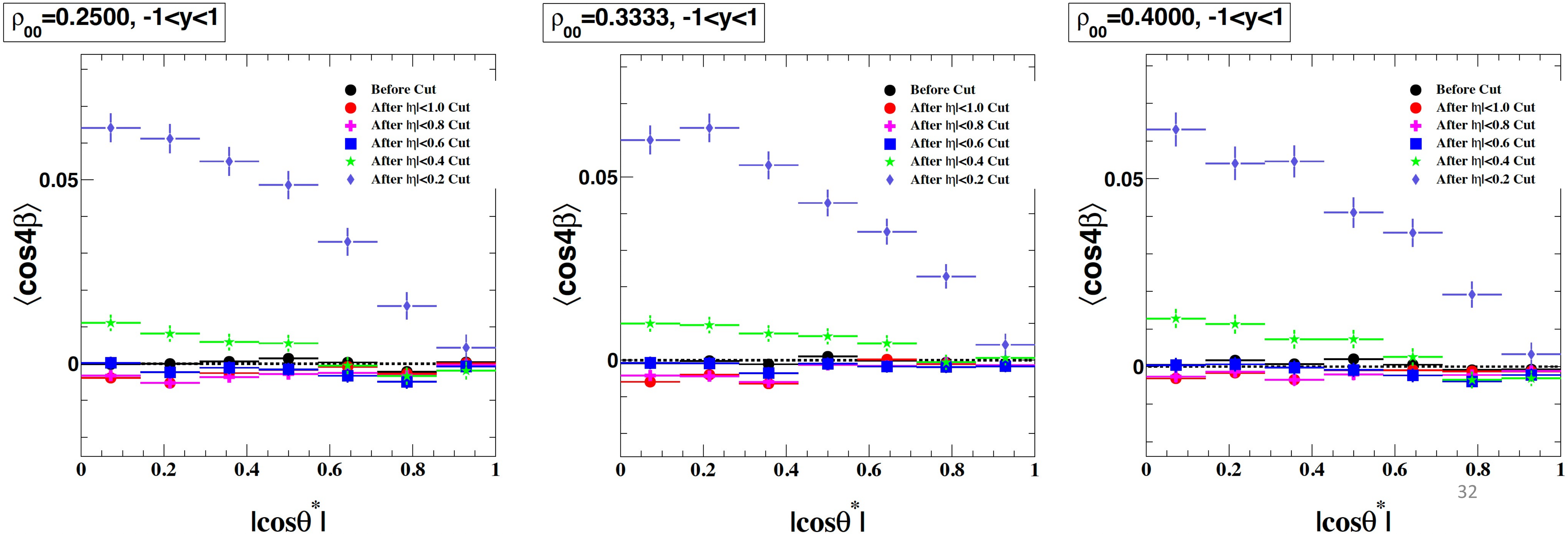
Check with simulation

- $\langle \cos \beta \rangle$ is consistently 0.



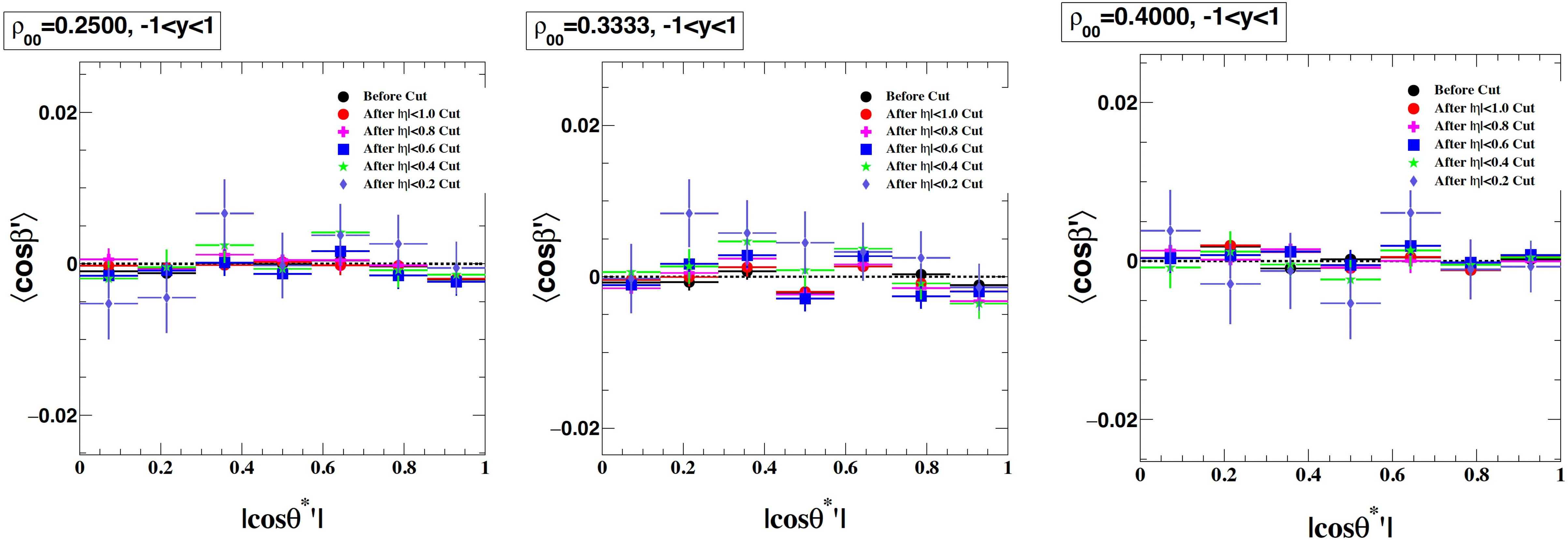
Check with simulation

- $\langle \cos 4\beta \rangle$ deviates significantly from 0 at very small |η| cut values.
- Sign change matches our expectation.



Combined effect of acceptance and EP Resolution on $\langle \cos \beta' \rangle$

- Naïve assumption: Effect on $\langle \cos \beta' \rangle$ from EP smearing and cutting on |η| will just be a sum of the deviation from zero from both effects.



Effect from these two sources was zero to begin with, so naïve assumption holds.

Combined effect of acceptance and EP Resolution on $\langle \cos 2\beta' \rangle$

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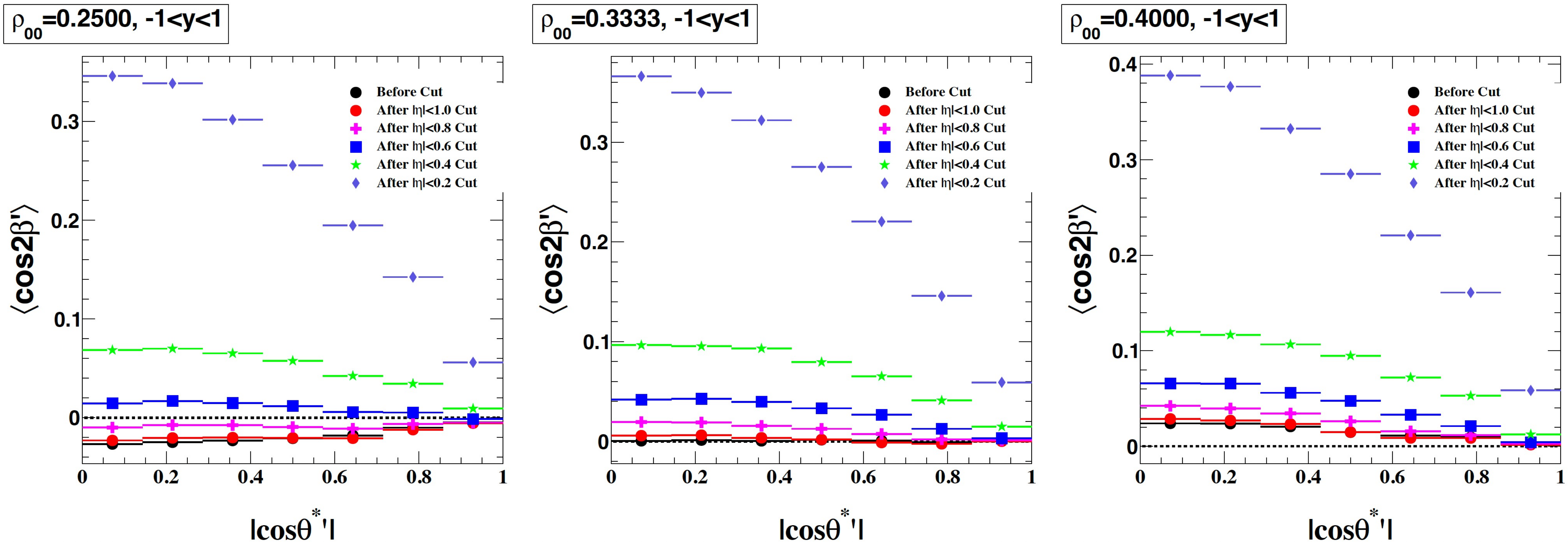
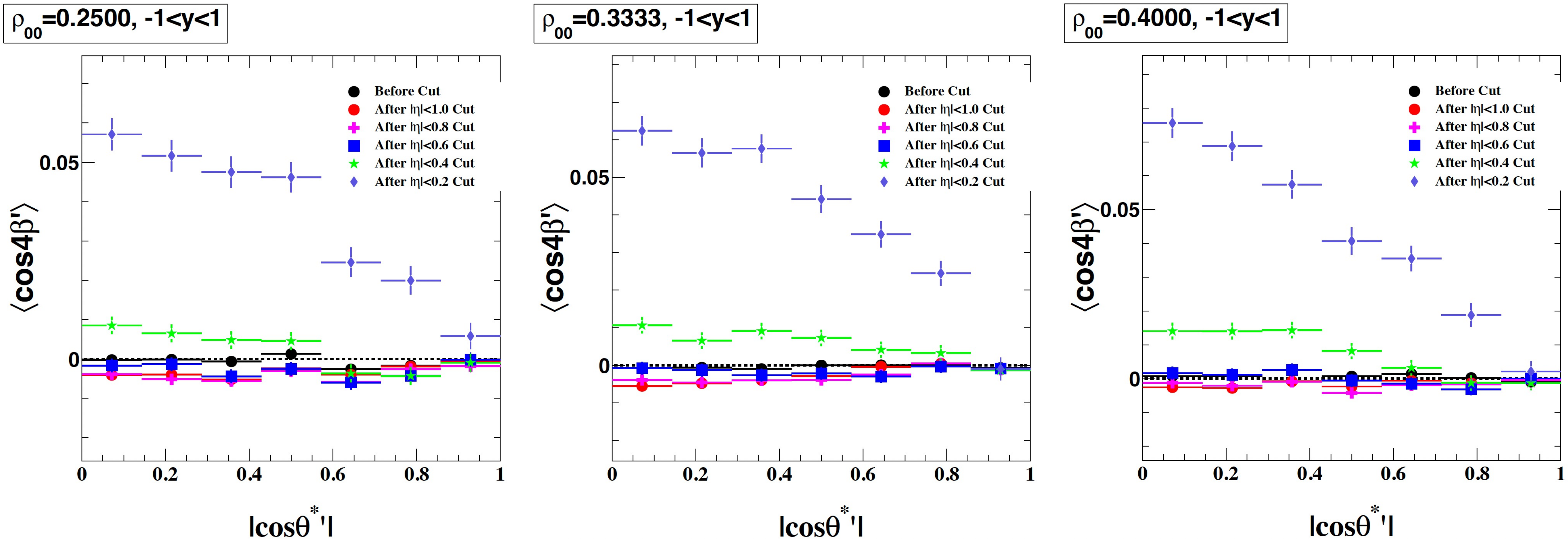


Simulation shows that this is assumption isn't too far off.

Combined effect of acceptance and EP Resolution on $\langle \cos 4\beta' \rangle$

- Naïve assumption: Effect on $\langle \cos 4\beta' \rangle$ from EP smearing and cutting on |η| will just be a sum of the deviation from zero from both effects.



Simulation shows that this assumption isn't too far off.

Summary

- There was an issue in the self-subtraction of the Kaon daughters, which has been fixed.
- We have learned from these studies that we need to have a precise measurement of v2 to properly correct our data.
  - I have been working on a rapidity and centrality dependent v2.
  - I have produced the yield histograms, but I need to rewrite some macros.
- Non-zero $\langle\cos(2\beta)\rangle$ and $\langle\cos(4\beta)\rangle$ from EP smearing/ Acceptance Cuts.

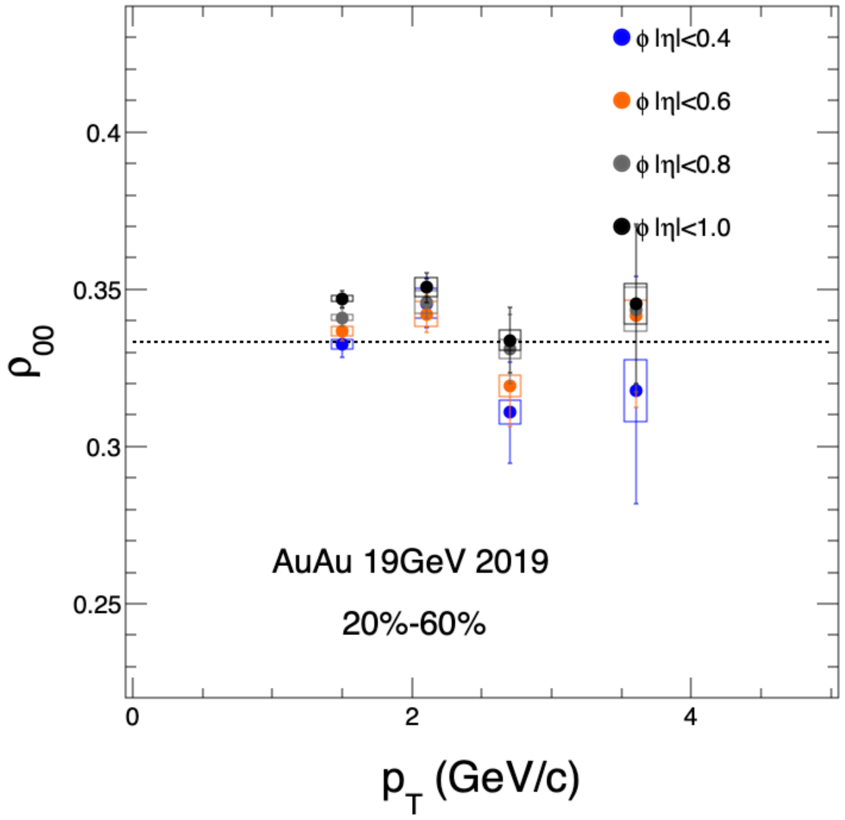
BACKUP

Other correction method

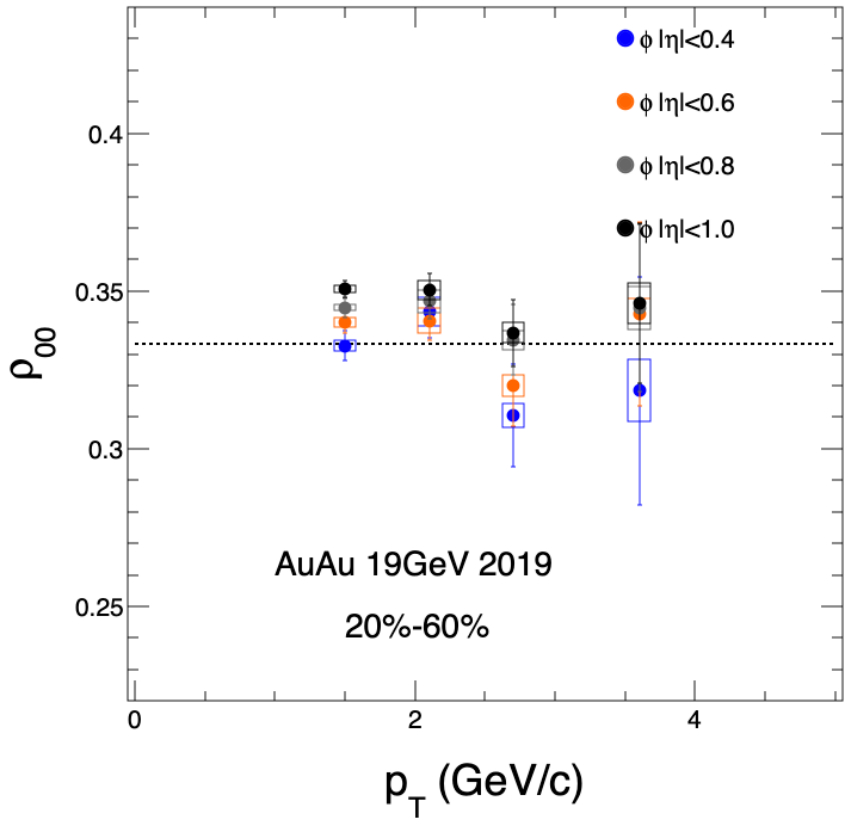
- Take ratio of ϕ-meson yields as a function of **cos(θ*’)** after/before η cuts on daughter kaons for ρ_{00}=1/3 input.
- Fit ratio with a 4th order polynomial to extract acceptance parameters F and G.
- Fix these parameters and EP resolution in fit which extracts ρ_{00} from the cos(θ*’) distribution (EP Smeared).

- We use pT = 1.5 and R = 0.4 for the following studies.

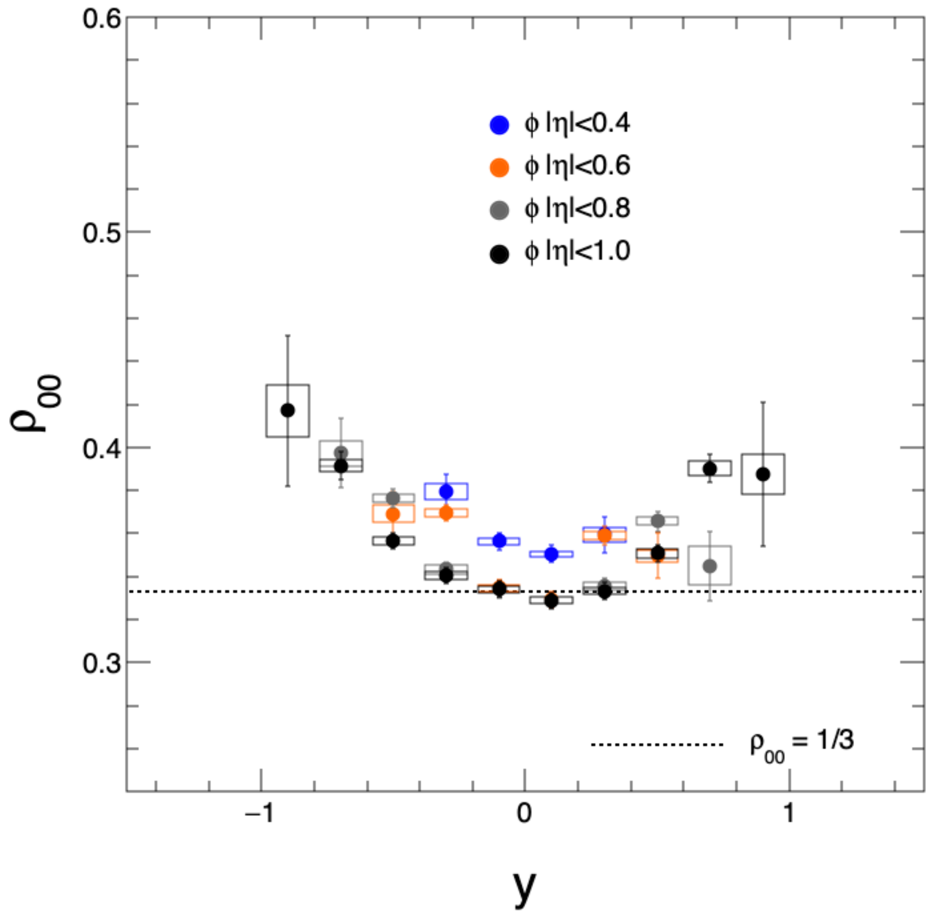
Division Acceptance Method with RP



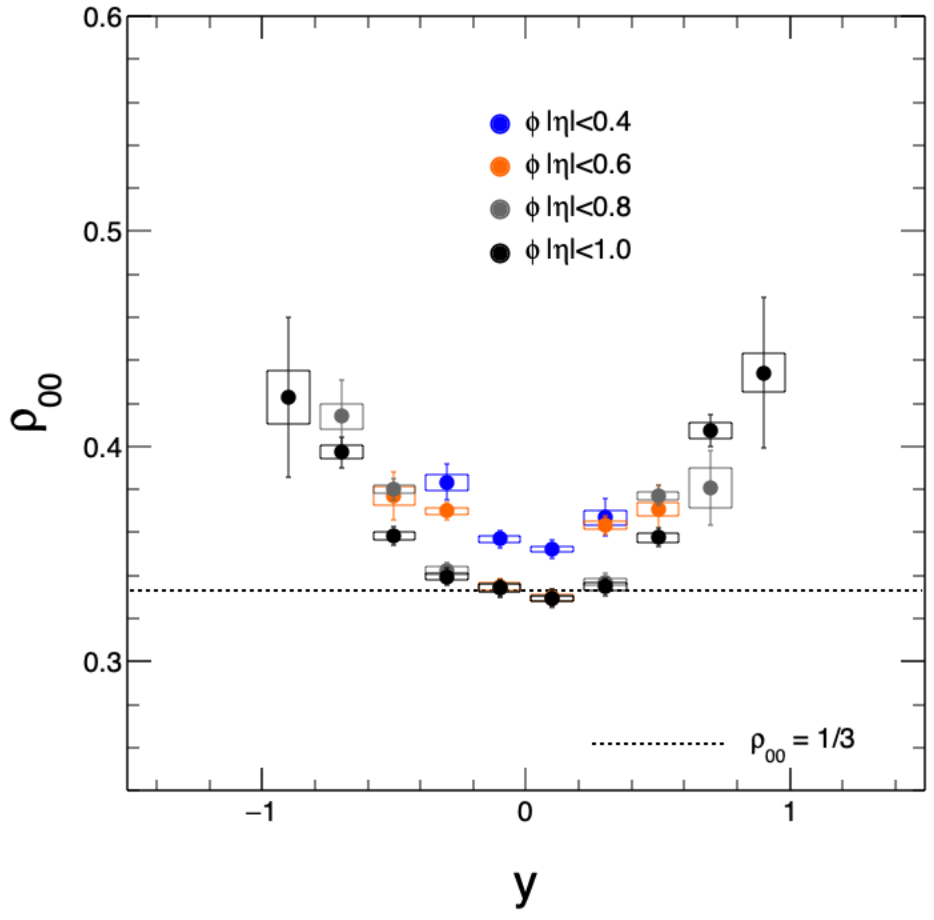
Division Acceptance Method with EP



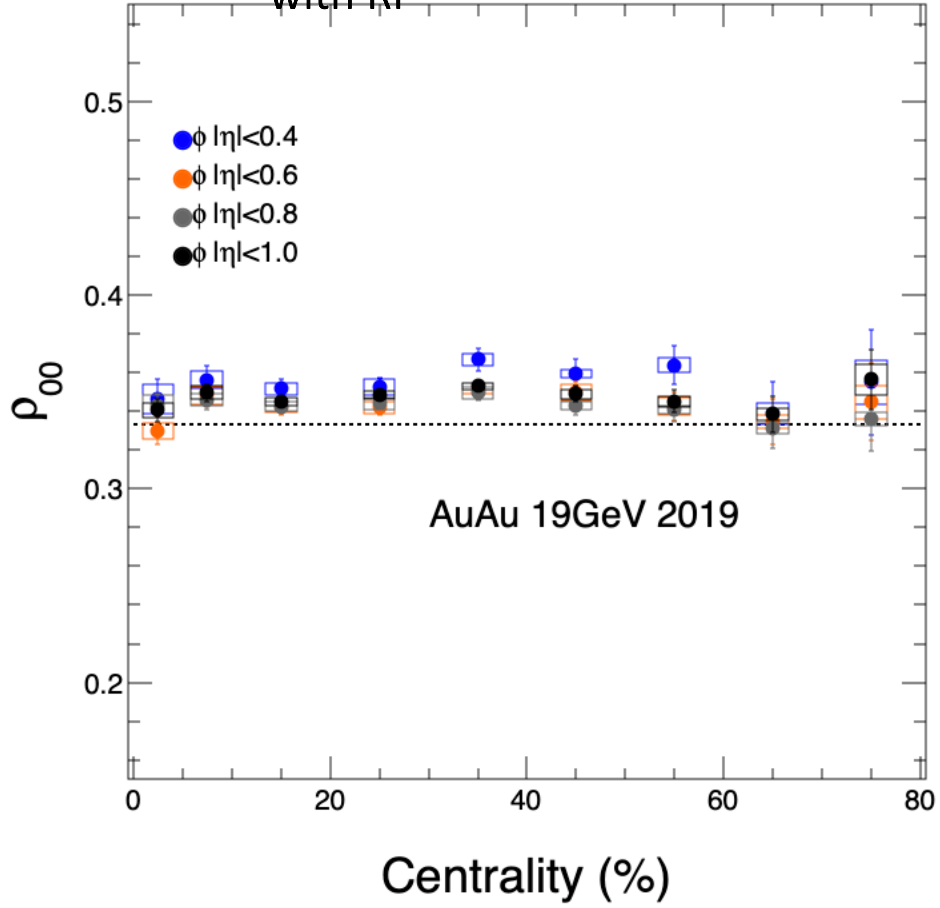
Division Acceptance Method with RP



Division Acceptance Method with EP



Division Acceptance Method with RP



Division Acceptance Method with EP