ϕ-meson ρ_{00} acceptance QA

Gavin Wilks

University of Illinois at Chicago

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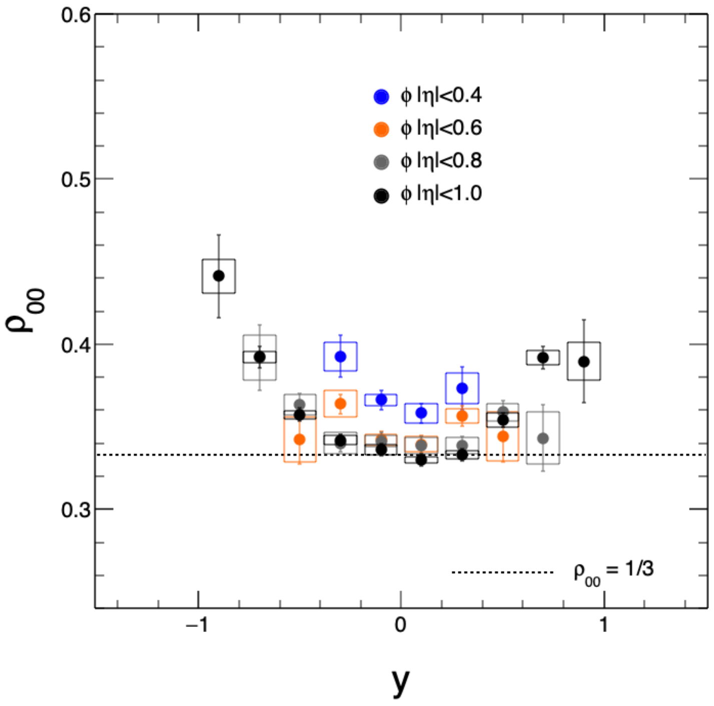
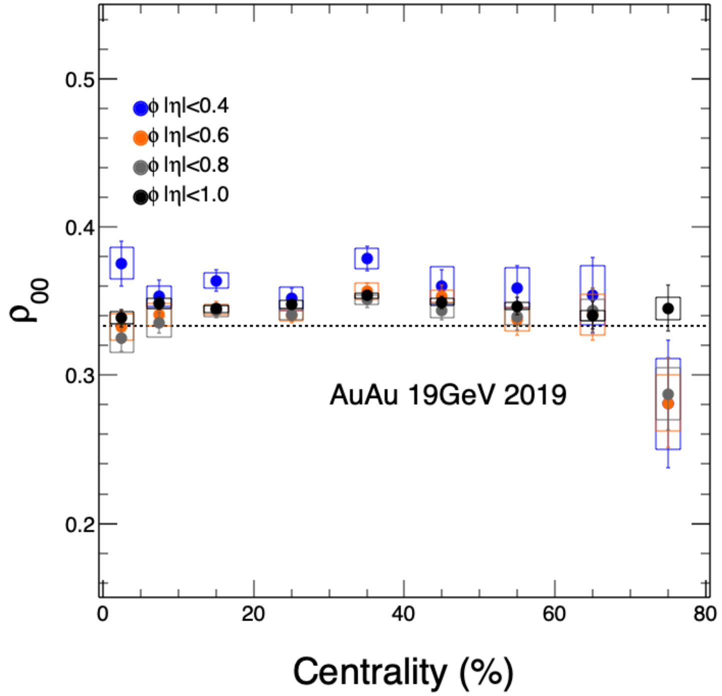
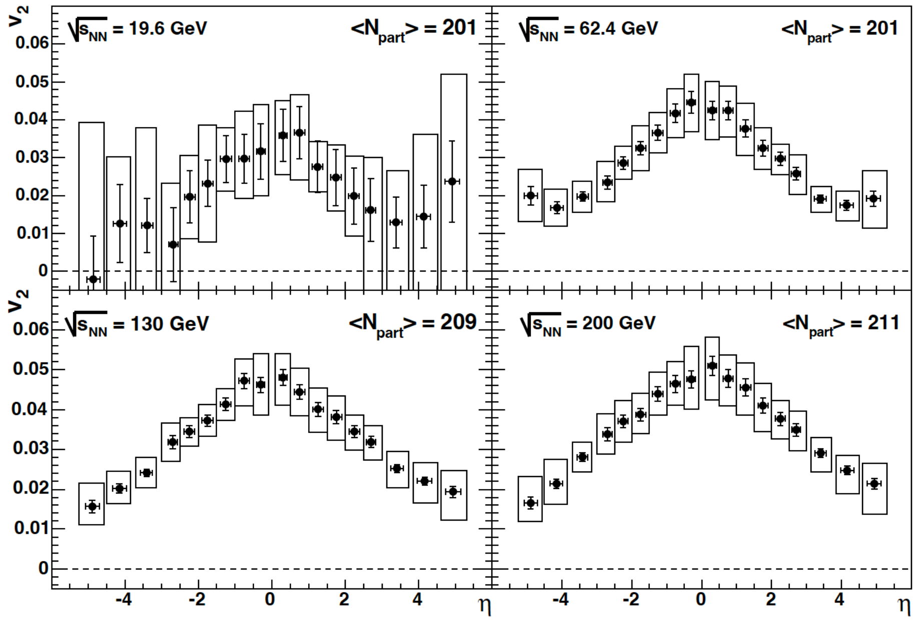
Motivation for this study

- We performed the rapidity and centrality dependent studies with various |η| cuts.
- Artificial increase in ρ_{00} after all corrections as |η| cut decreases.
- Perhaps v_2 is the cause of these inconsistent results.
- v_2 for charged particles has been measured as a function of η and it decreases as |η| increases.
- Could the ϕ-meson v_2 depend more heavily on η? We are using |η| < 1 input v_2 for all |η| cuts.







https://www.bnl.gov/userscenter/thesis/past-competitions/2007/files/hamblen_thesis.pdf

Acceptance + Resolution Method

- Assume RP = 0 rad
- Generate ϕ-meson input p_T with known spectra.
- All ϕ-meson rapidity inputs are sampled from a uniform distribution.
- v_2 can be turned on or off.
  - On: use known $v_2(p_T)$ distribution and randomly sample $\varphi-\Psi_2$ generated with the v_2 at a specific p_T.
  - Off: ϕ-meson φ angle is randomly sampled from uniform distribution.
- Cut on cos(θ*) w.r.t. RP using input ρ_{00}.
  - Shapes cos(θ*) distribution to the corresponding ρ_{00}.
- Using input 2nd order EP Resolution R_2 find χ from distribution:

$$R_2 = \frac{1}{2}\sqrt{\frac{\pi}{2}}\chi e^{-\frac{\chi^2}{4}}\left[I_0\left(\frac{\chi^2}{4}\right) + I_1\left(\frac{\chi^2}{4}\right)\right] \qquad \text{Eq. 1}$$

Acceptance + Resolution Method

- Using χ generate Δ to simulate R_2:

$$P(\Delta) = \frac{1}{2\pi}\left[e^{\frac{-\chi^2}{2}} + \sqrt{\frac{\pi}{2}}\chi\cos(2\Delta)\, e^{\frac{-\chi^2}{2}\sin^2(2\Delta)}\left(1+\mathrm{erf}\left(\frac{\chi}{\sqrt{2}}\cos(2\Delta)\right)\right)\right] \quad \text{Eq. 2}$$

- Now we can calculate cos(θ*’) w.r.t. EP using (primed frame):

$$\Psi_2{}' = \Psi_2 + \Delta \quad \text{Eq. 3}$$

- We cut on |η| of the Kaon daughters we therefore have two yield vs. cos(θ*) histograms: before |η| cut and after |η| cut.
- We divide: (after |η| cut) / (before |η| cut)
- For the ρ_{00}=0.33 case for each study. We fit this ratio histogram for the reaction plane cos(θ*) using a 4^{th} order function (slide 11, Eqn. 4), which provides us with F* and G*.

Acceptance + Resolution Method

- To reconstruct ρ_{00} for various input ρ_{00}, we fit the yield vs cos(θ*’) after |η| cut.
  - The inputs to this fit are F*, G* and the EP Resolution, which are fixed in the fitting function found on slide 12, Eqns. 5-8.
  - This function is consistent with the function from PHYSICAL REVIEW C 98, 044907 (2018) if we assume the G* = 0 (the 4th order fit coefficient). See slide 13.

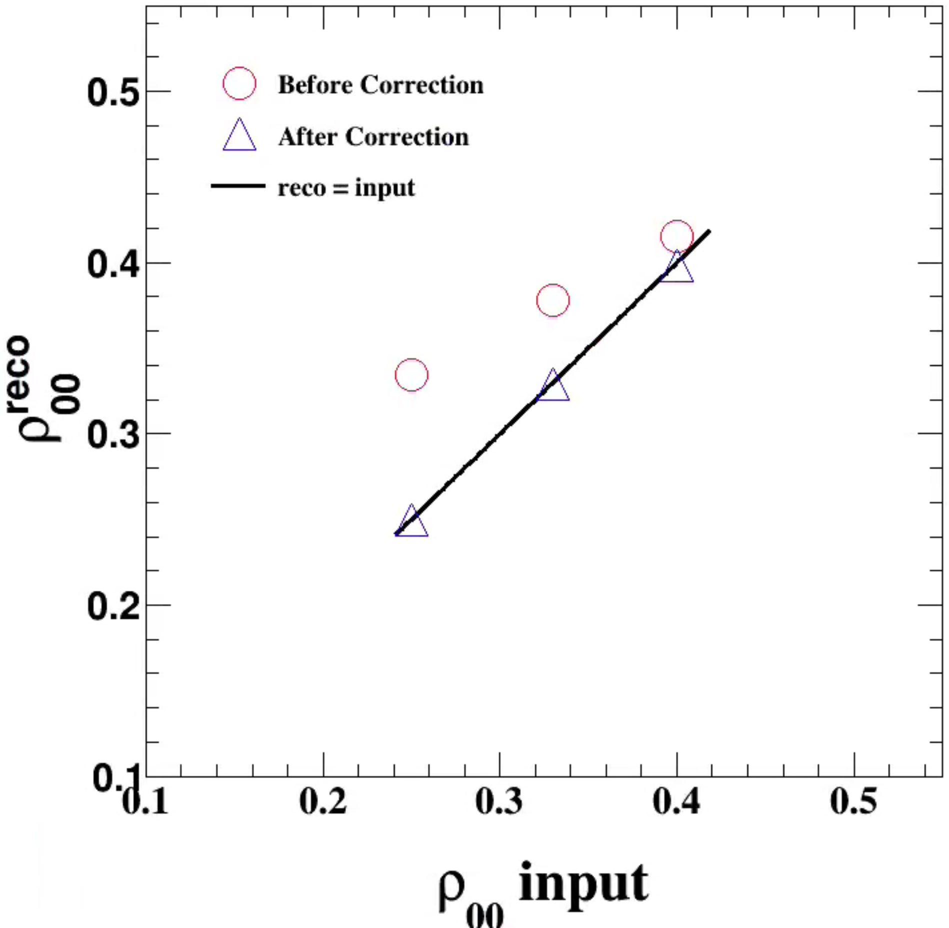
Now we will show results from these simulations with various input ρ_{00}={0.25,0.33,0.40}.

v_2 OFF

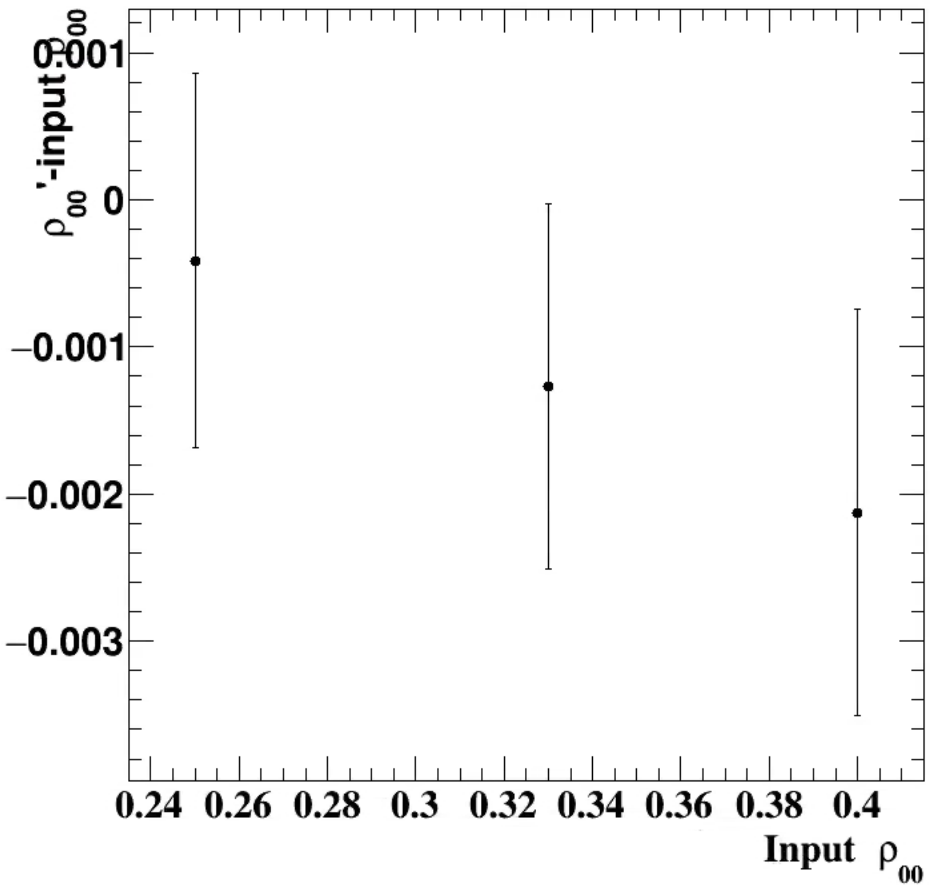
$1.2 < p_T < 1.8$

$-1 < y < 1$

$|\eta| < 0.4$



ρ_{00} reco - ρ_{00} input

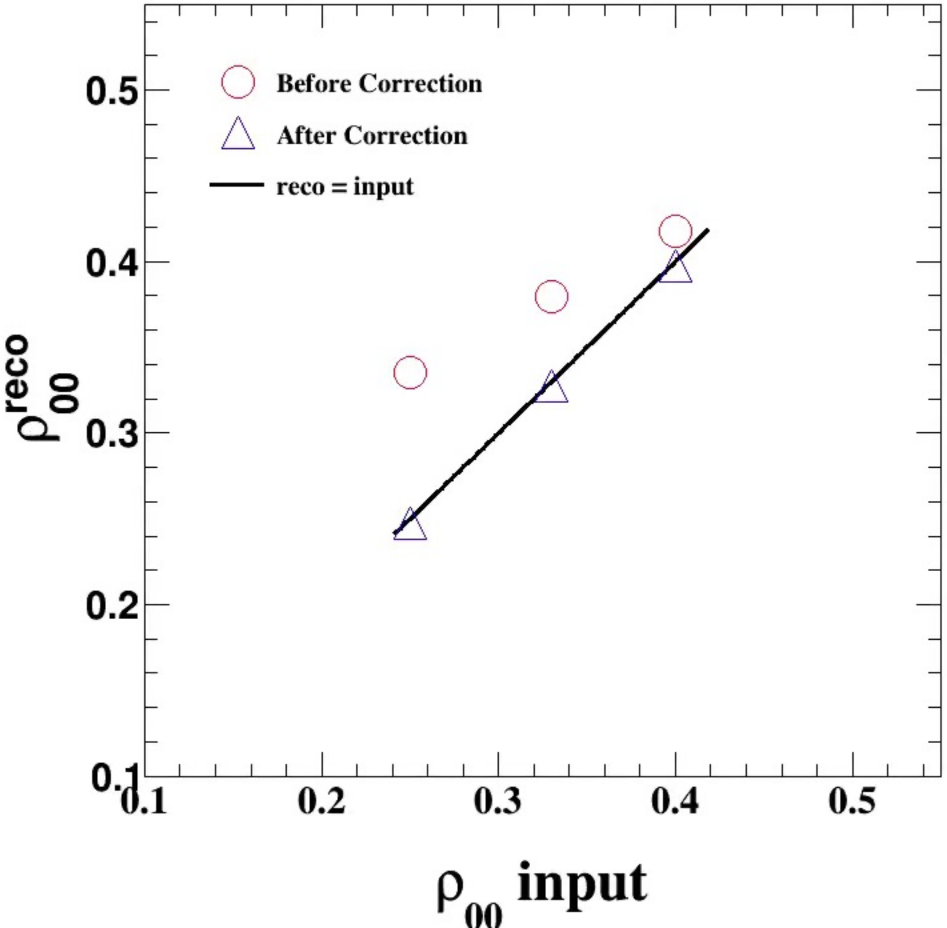


v_2 ON

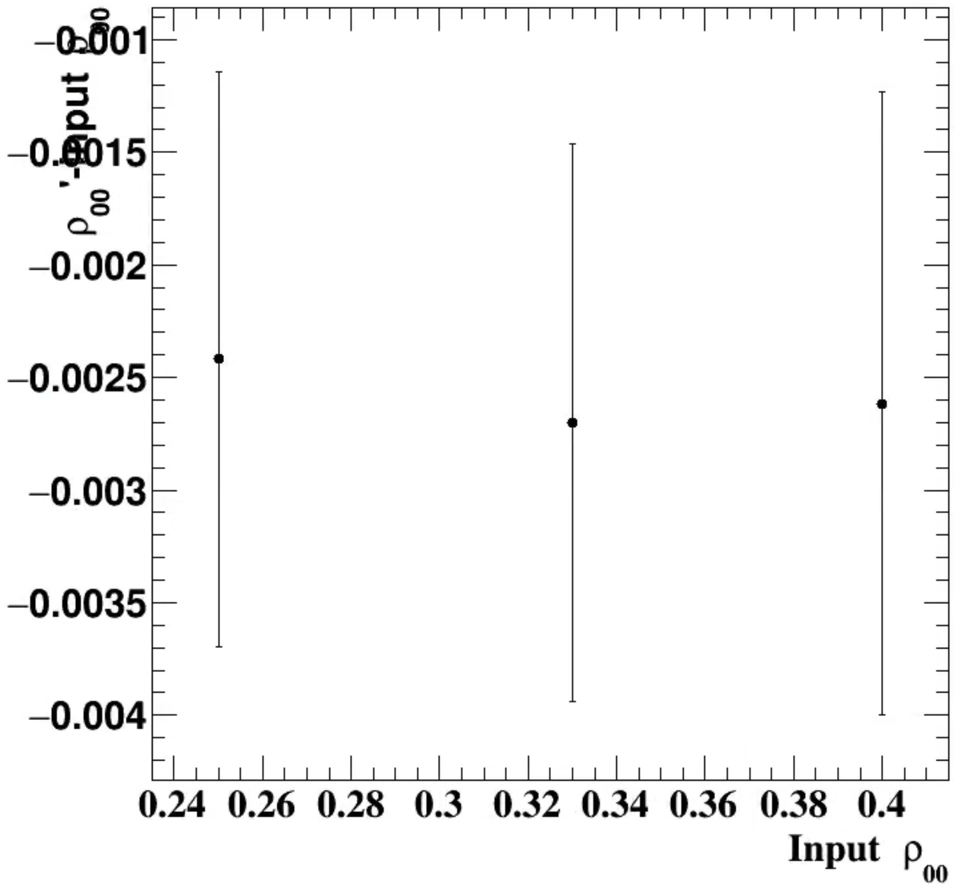
$1.2 < p_T < 1.8$

$-1 < y < 1$

$|\eta| < 0.4$



ρ_{00} reco - ρ_{00} input

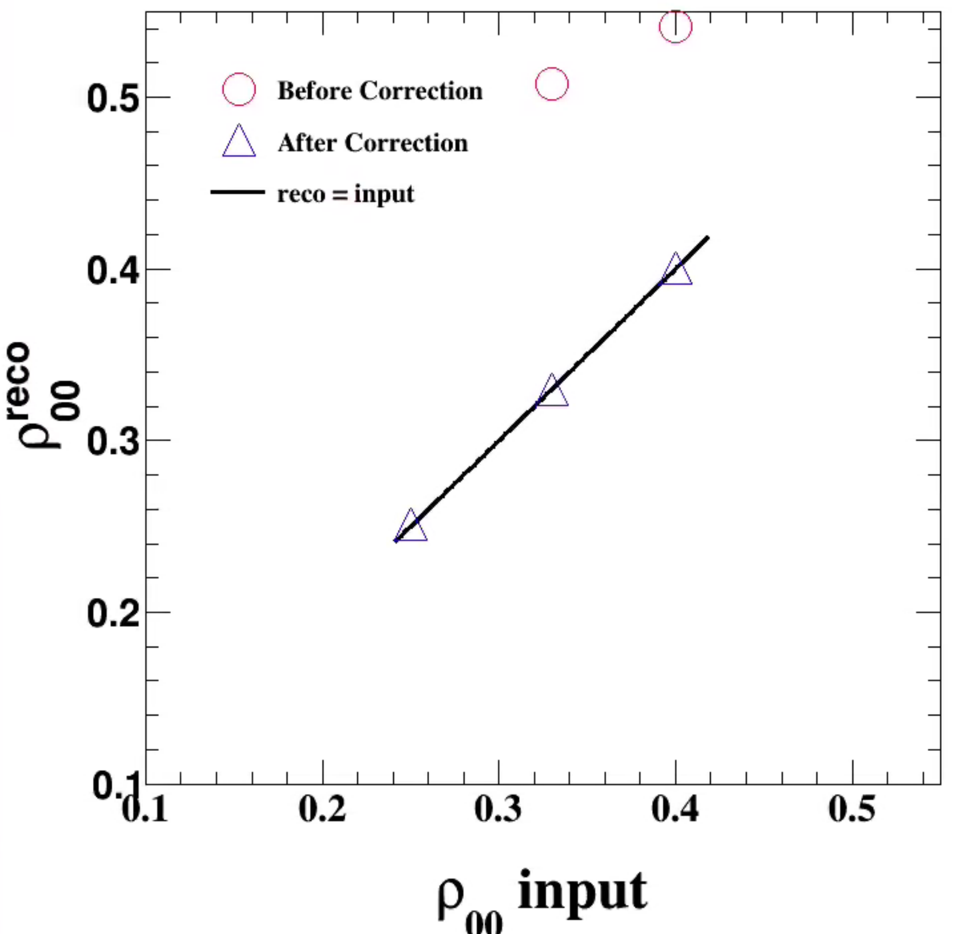


v_2 OFF

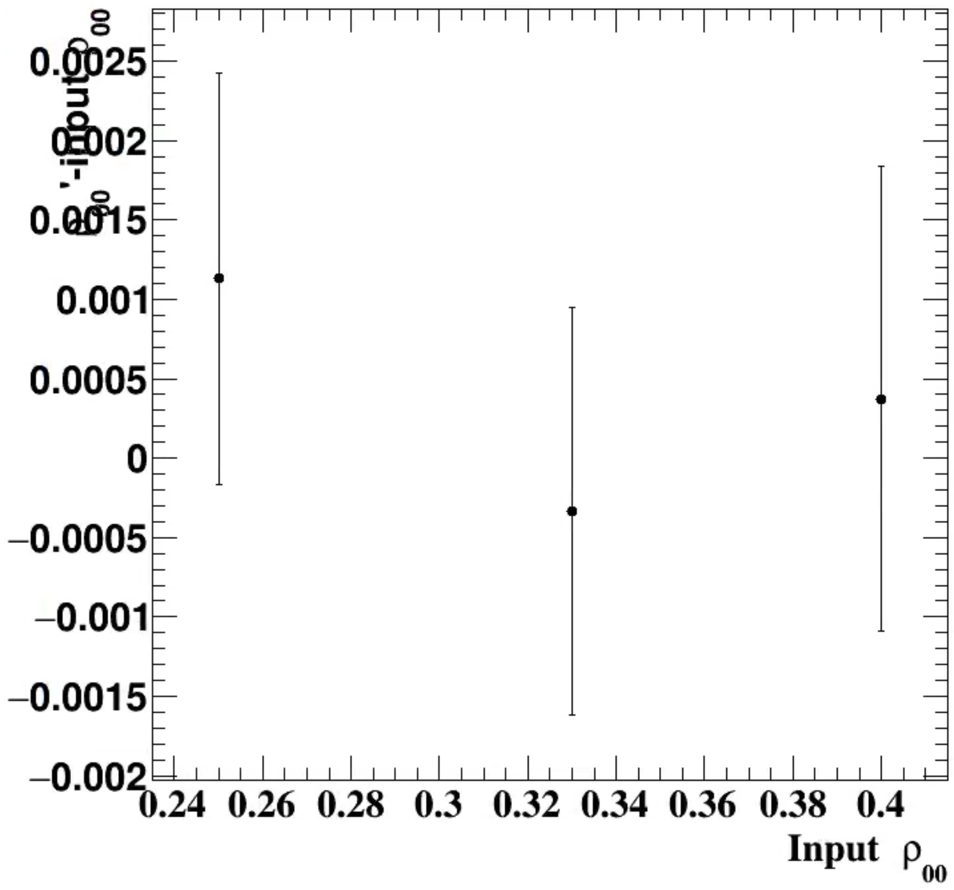
$1.2 < p_T < 1.8$

$0.2 < y < 0.4$

$|\eta| < 0.4$



ρ00 reco - ρ00 input

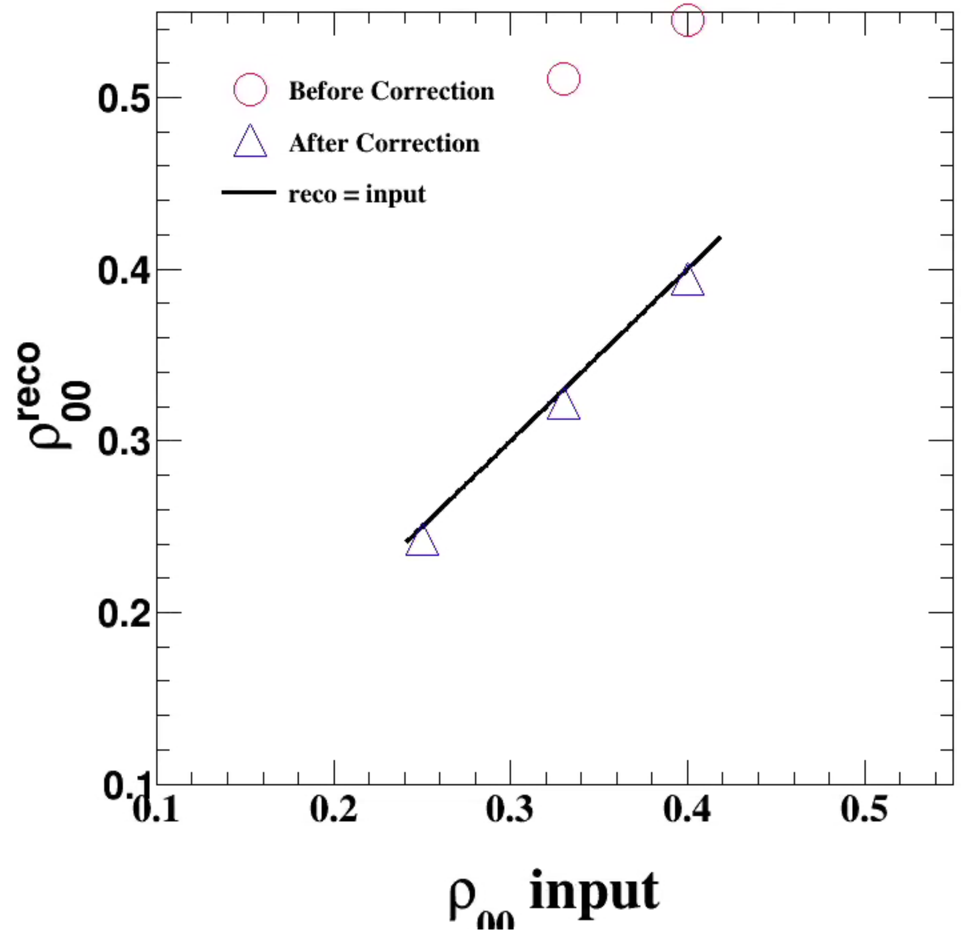


v_2 ON

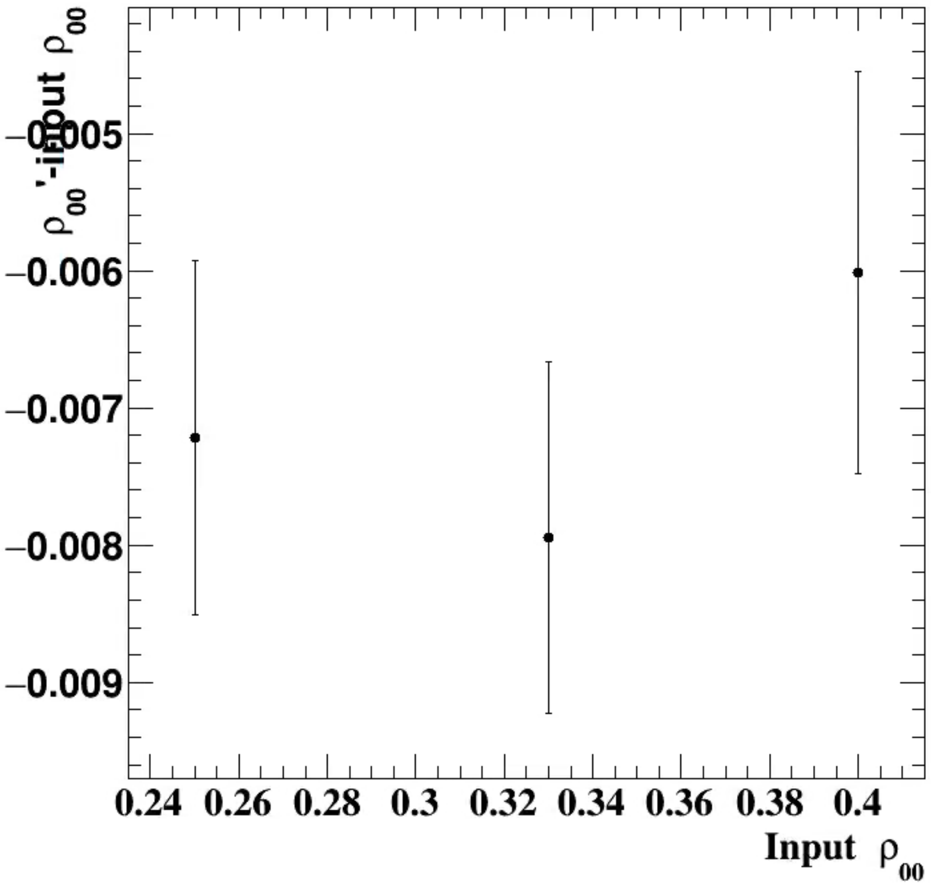
$1.2 < p_T < 1.8$

$0.2 < y < 0.4$

$|\eta| < 0.4$



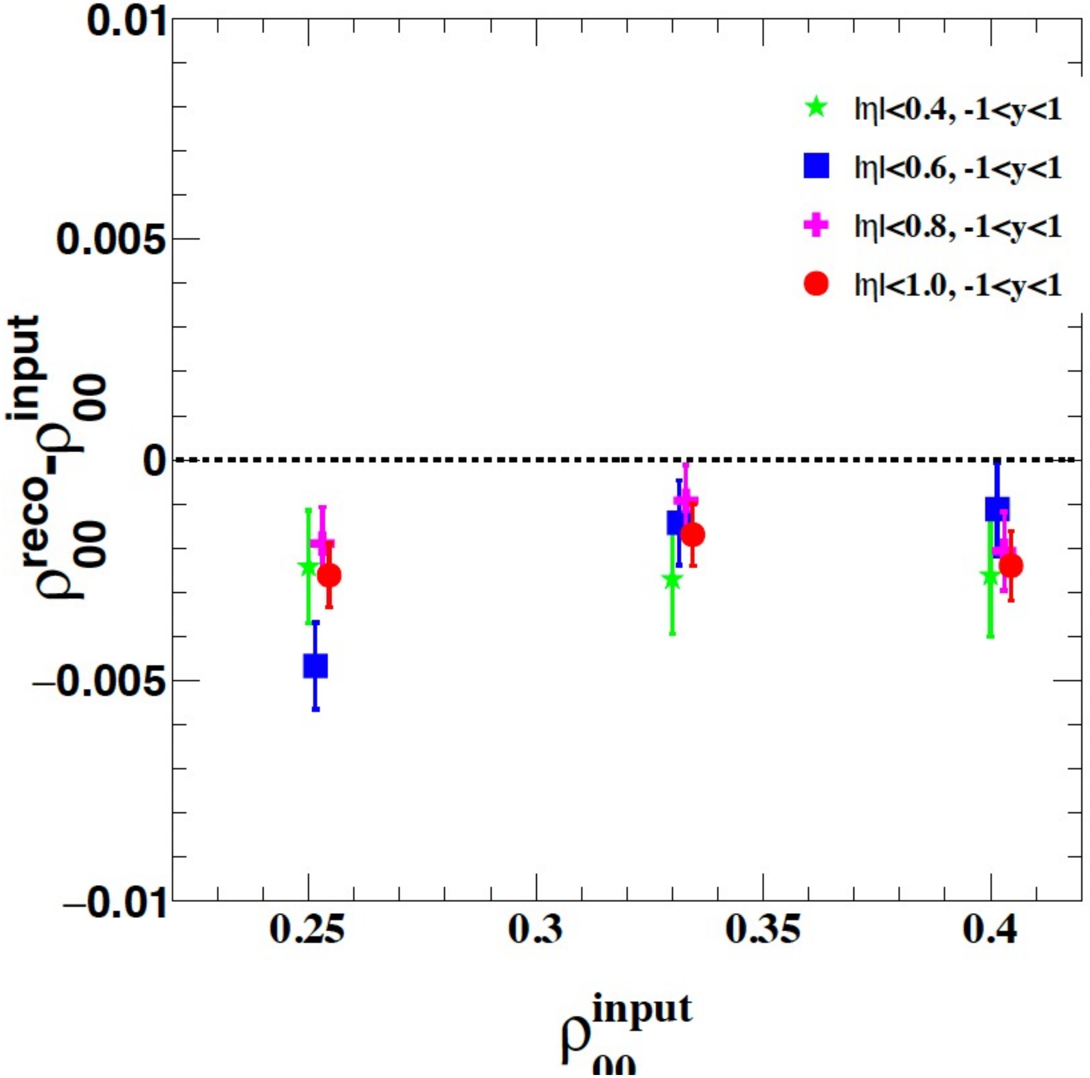
ρ00 reco - ρ00 input

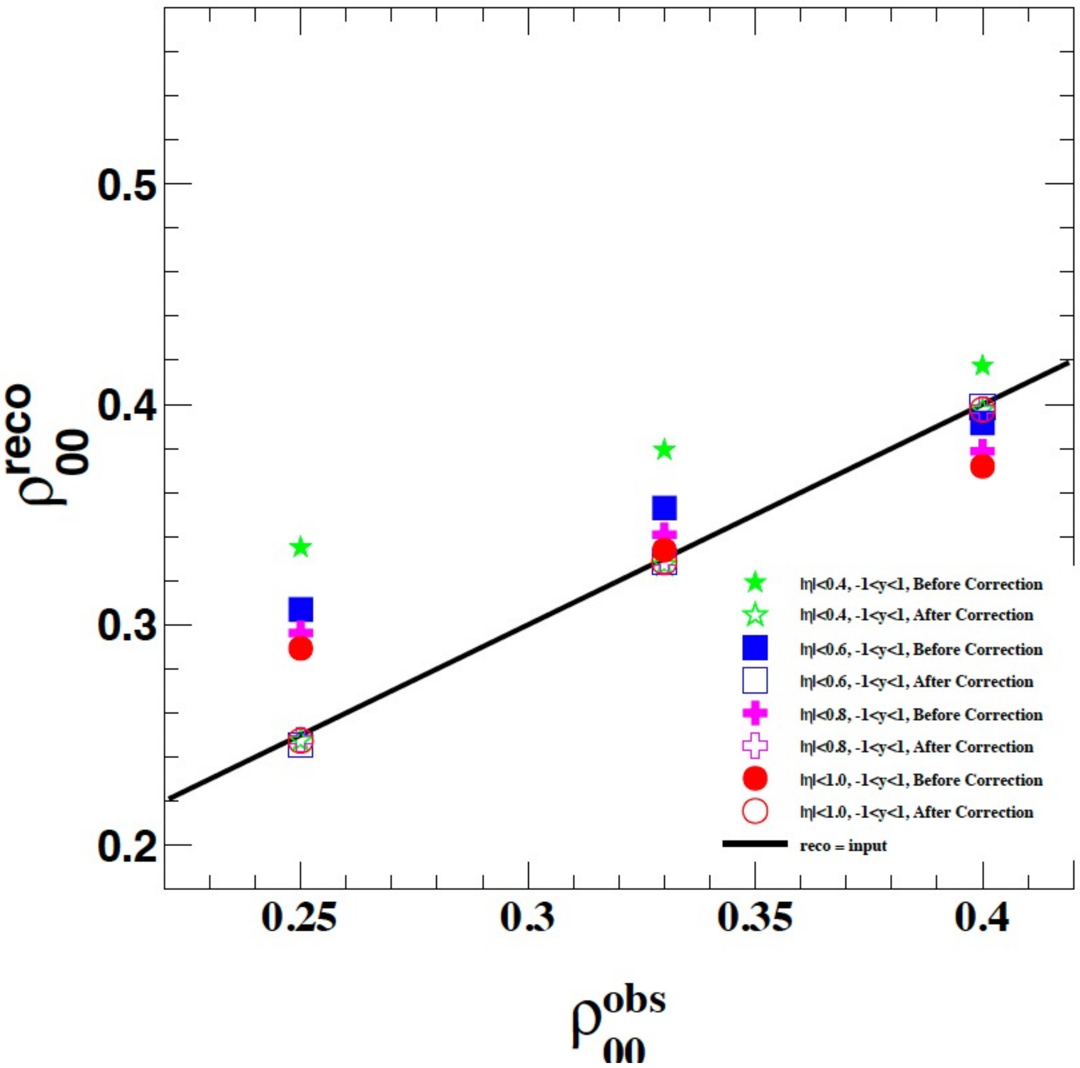


Summary and Next Steps (04/13/2023)

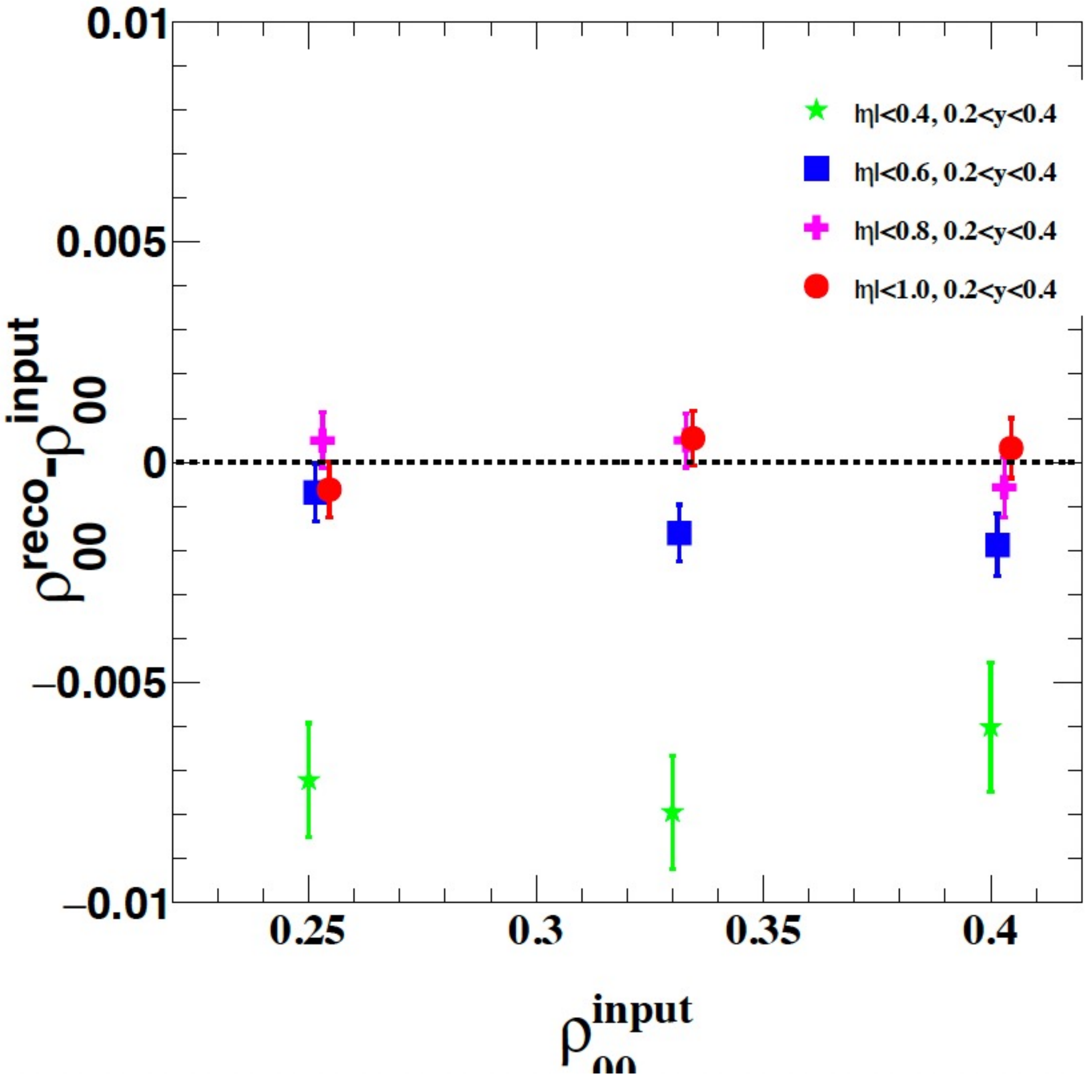
- We found that including v_2 in the acceptance + Resolution simulation causes the reconstructed ρ_{00} to differ from the input $\rho_{00.}$
  - Larger effect when dealing with individual rapidity bins.
  - Reconstructed ρ_{00} is always lower than input.
- We should see what happens when we vary $|\eta|$ cut for the same input kinematics with and without v_2.
- Try scaling v_2 for smaller $|\eta|$ cut to generate $\cos(\theta^{*\prime})$ distribution, but use the F* and G* from $|\eta| < 1$. See if this explains the trend we see for rapidity dependence on slide 2.
- Possible solution: calculate v_2 vs p_T ourselves for different $|\eta|$ cuts and these distributions in the simulation.

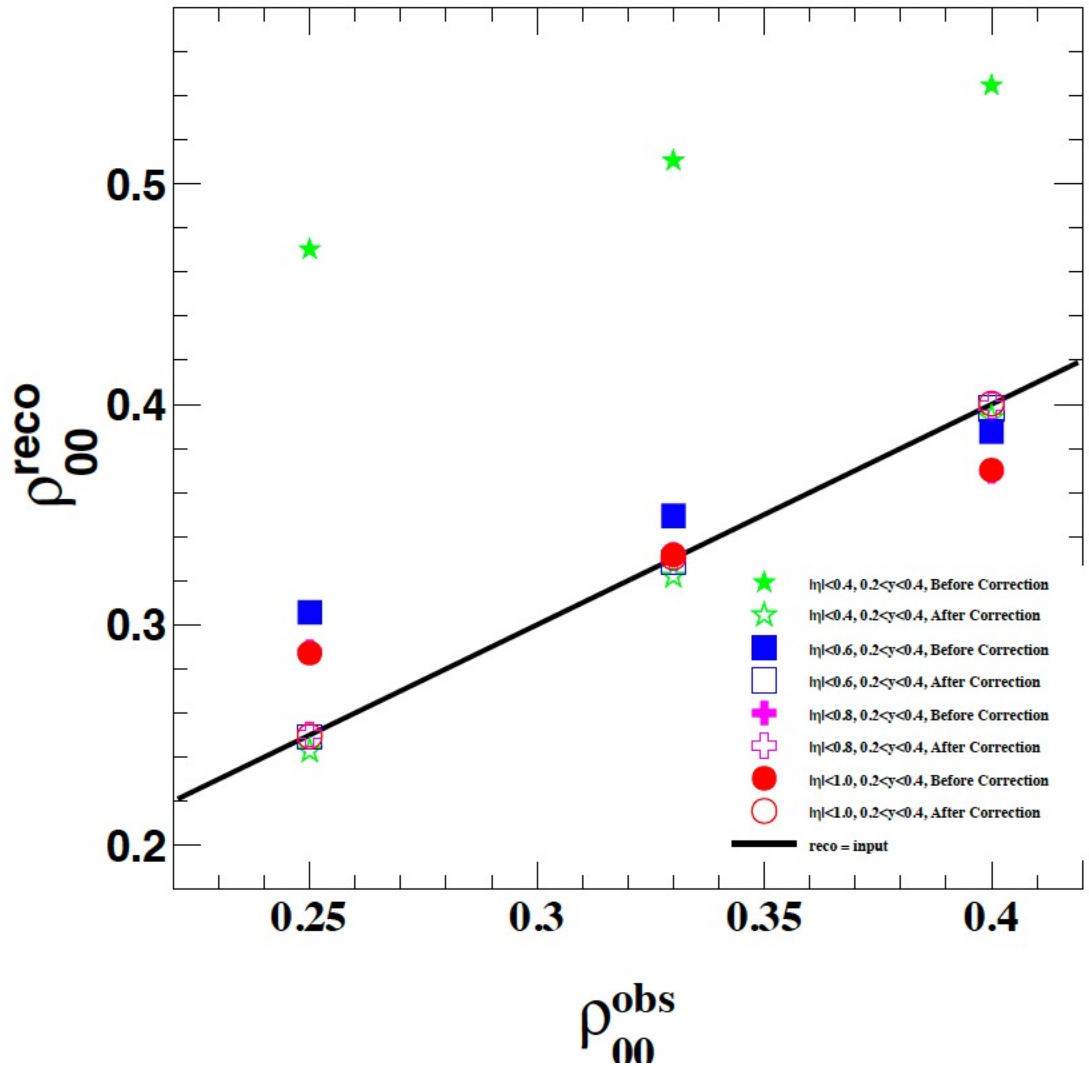
- -1 < y < 1
- v2 on
- 1.2 < pT < 1.8 GeV/c



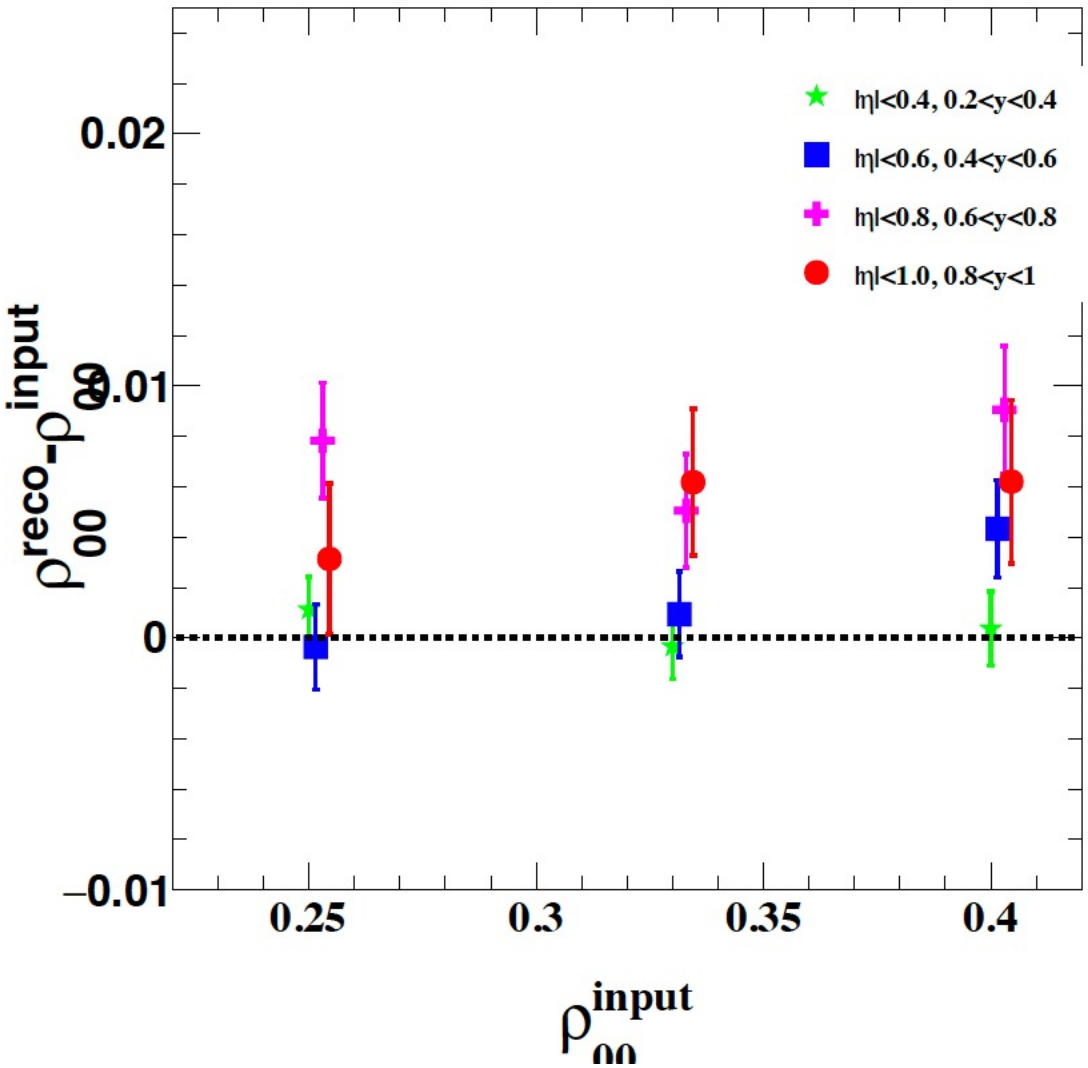


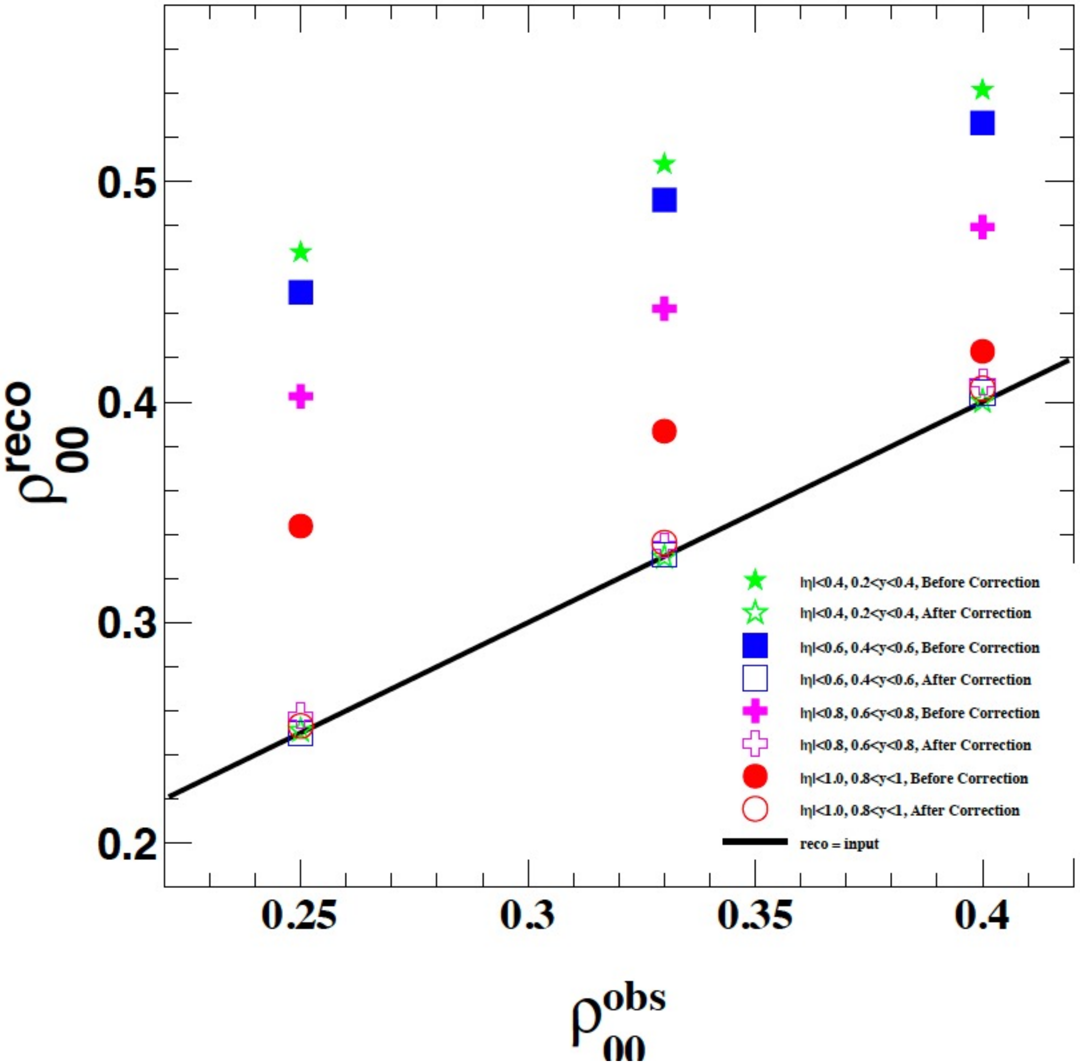
- 0.2 < y < 0.4
- v2 on
- 1.2 < pT < 1.8 GeV/c



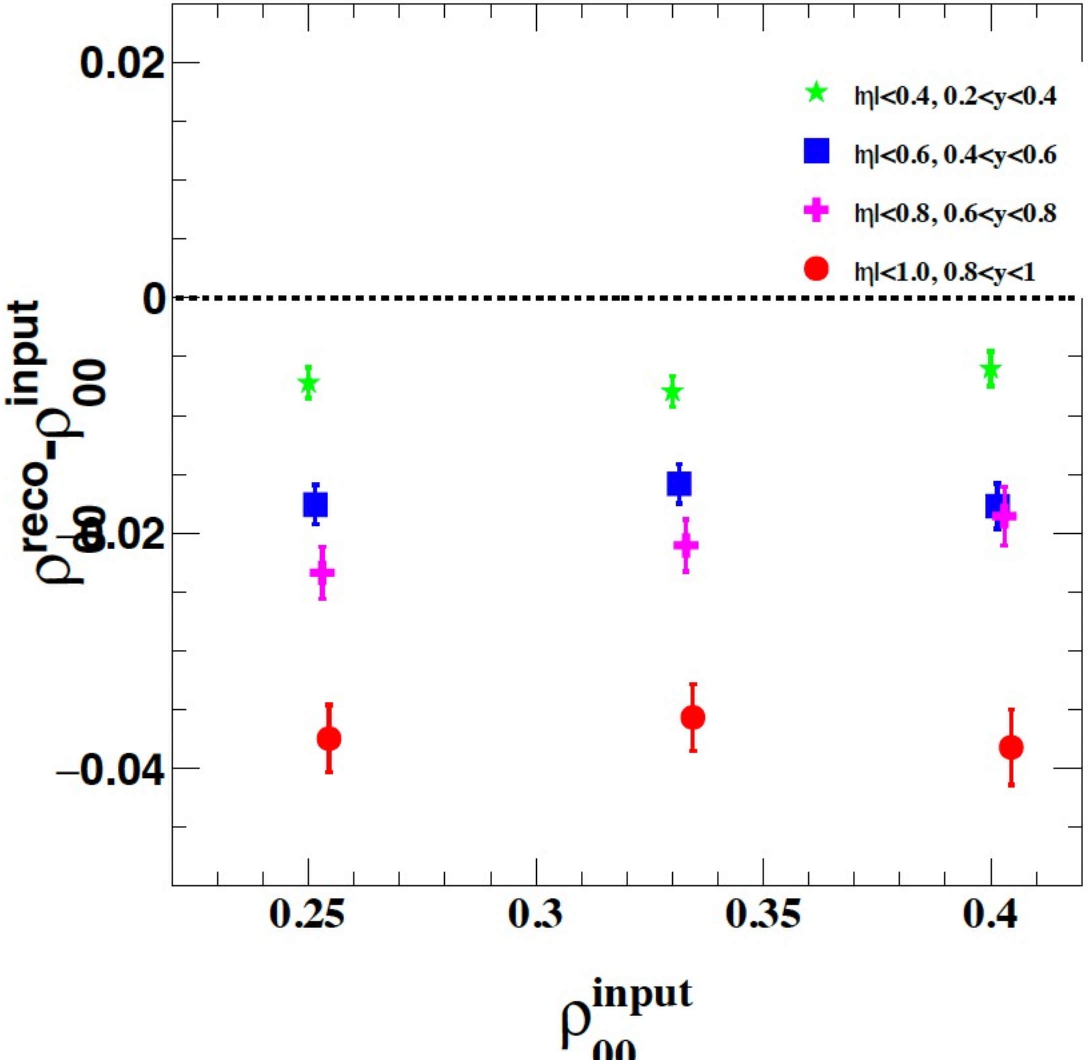


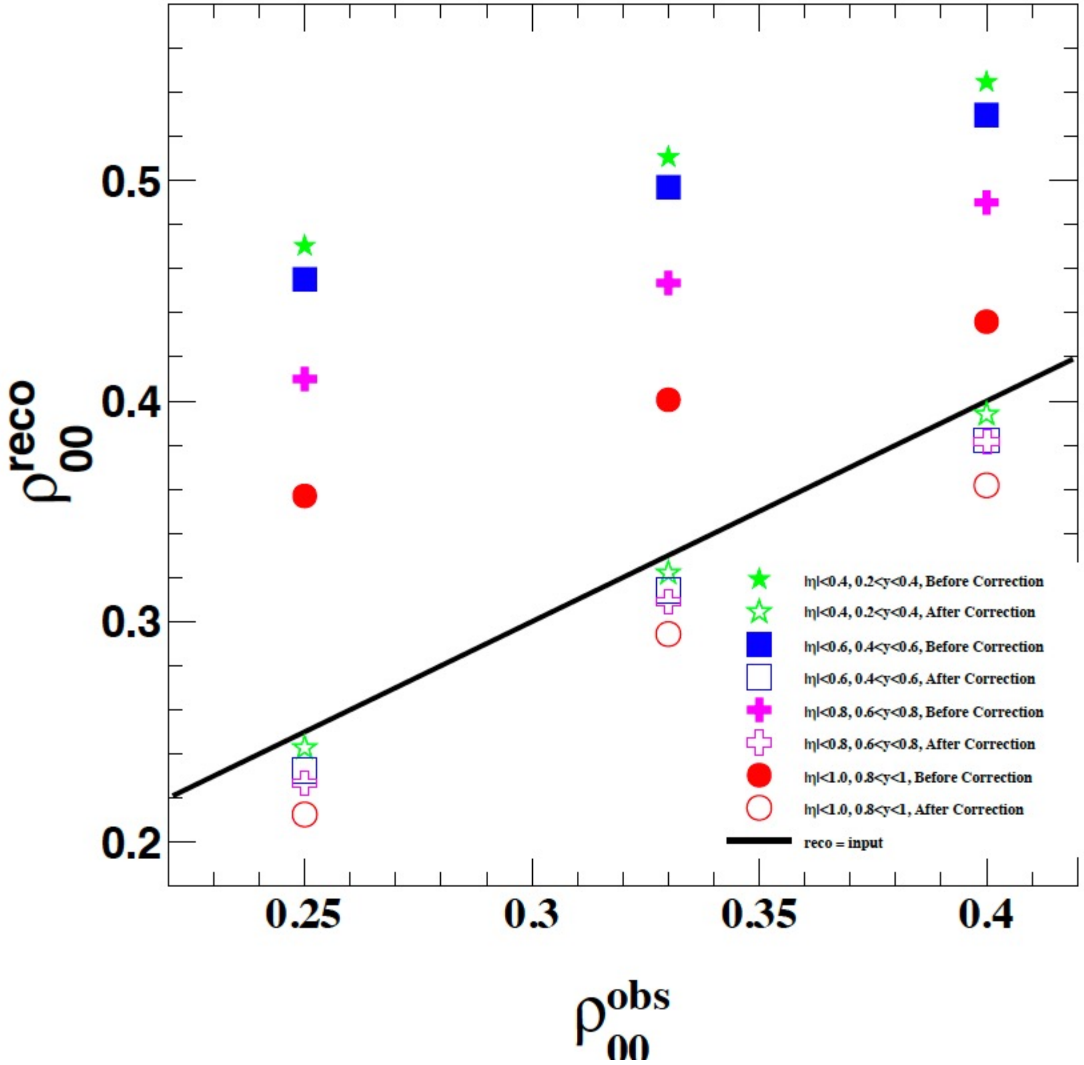
- Rapidity bins near edge of acceptance in pseudorapidity
- v2 off
- 1.2 < pT < 1.8 GeV/c



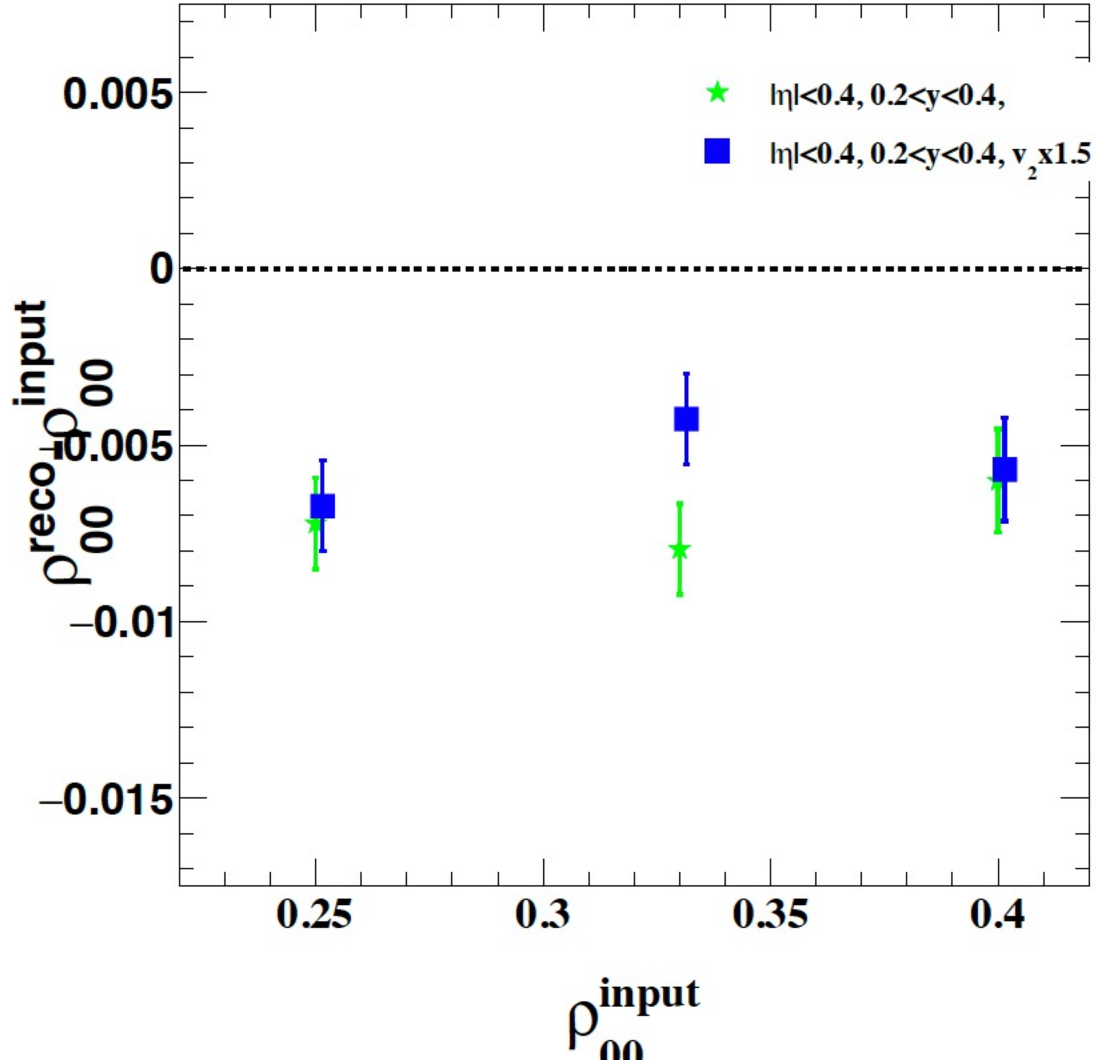


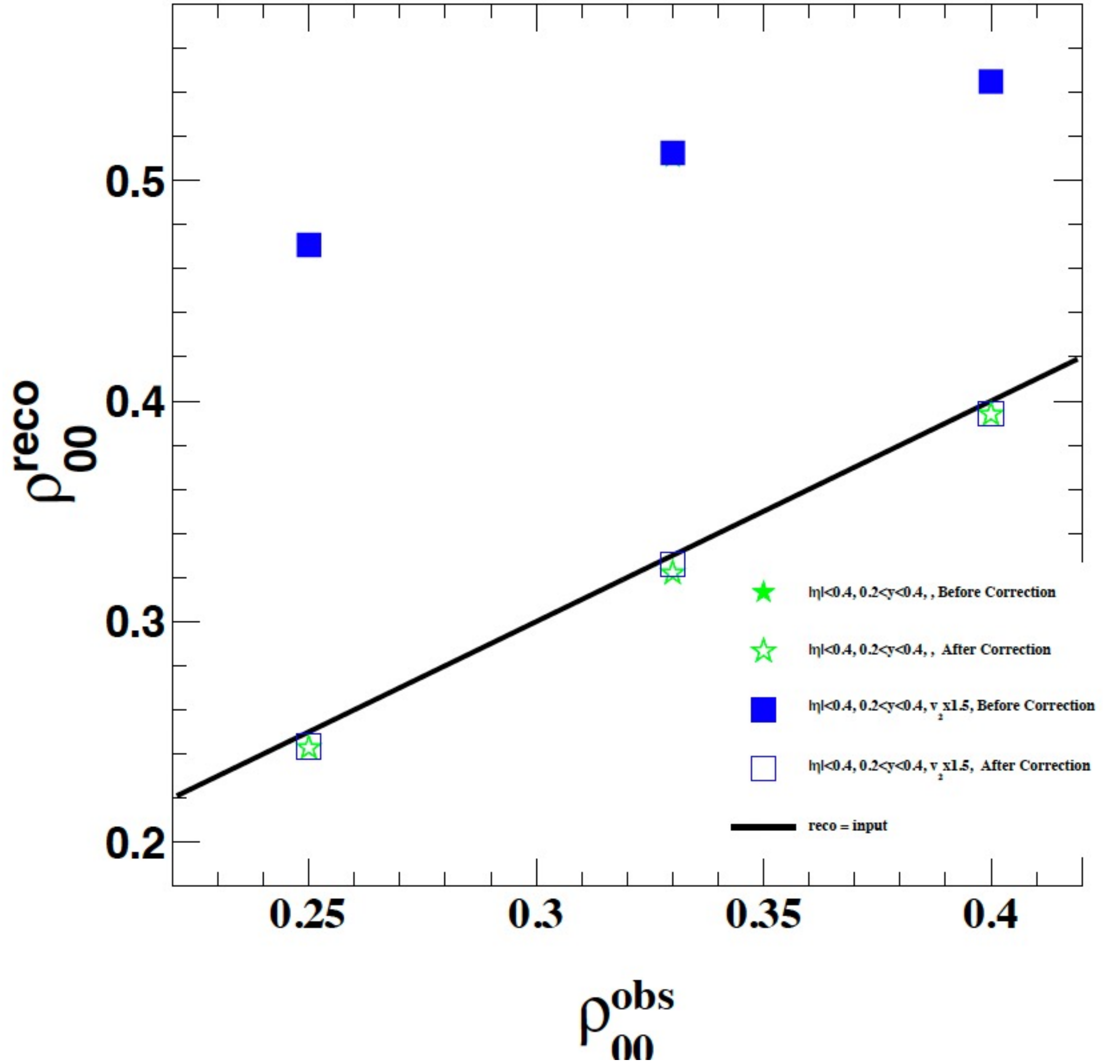
- Rapidity bins near edge of acceptance in pseudorapidity
- v2 on
- 1.2 < pT < 1.8 GeV/c





- Rapidity bins near edge of acceptance in pseudorapidity
- v2 on (with and without scaling)
- 1.2 < pT < 1.8 GeV/c
- All acceptance parameters from v2 without scaling and ρ00 = 0.33





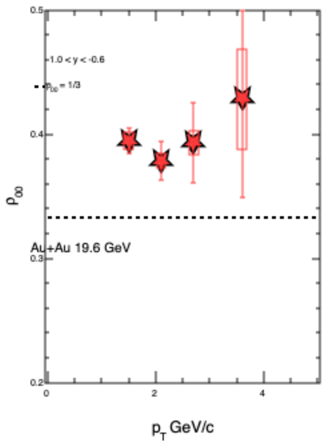
Summary (04/20/2023)

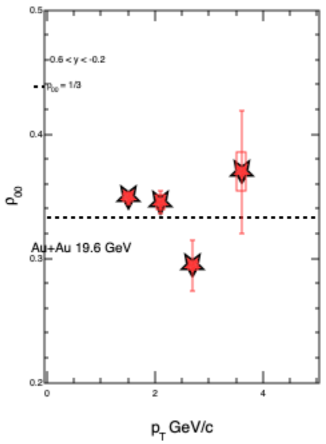
- $-1 < y < 1$: v2 leads to small difference between input and reco
- $0.2 < y < 0.4$: v2 leads to noticeable negative difference between input and reco
  - Specifically, for |η| cuts that significantly effect acceptance.
  - Opposite of expectation since we see a decrease in reco ρ_{00} rather than an increase which we see in the data.
- Edge of acceptance rapidity bins:
  - v2 off: small difference
  - v2 on: large difference
- v2 scaling effect:
  - for $0.2 < y < 0.4$ and $|\eta| < 0.4$ the v2 scaling did not change the results.
  - Try other cases for these rapidity bins near edge of acceptance.
  - If difference is negligible, then this does not explain the increase we see in data.

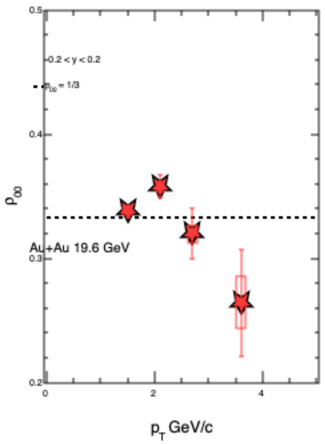
Outlook

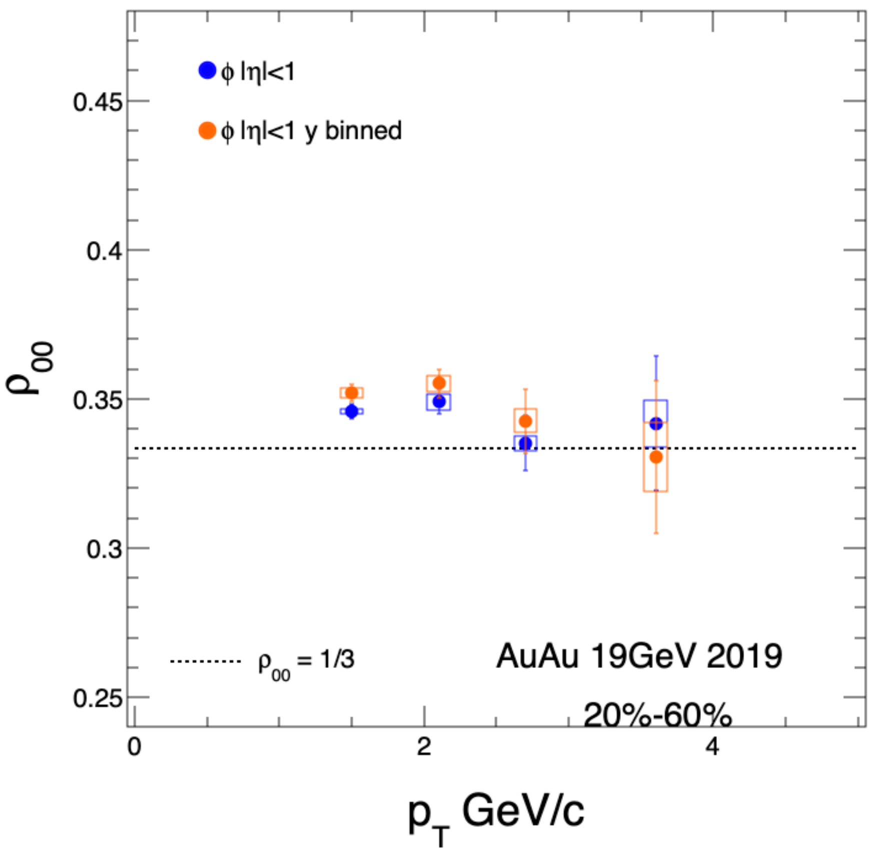
- Try other cases of v2 scaling.
- Why does v2 cause differences and how to address?

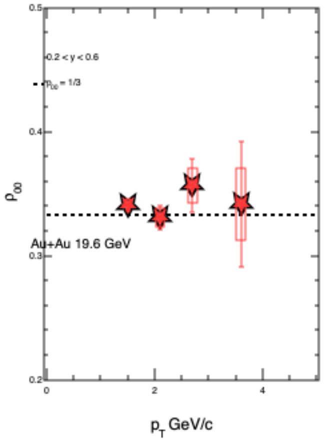
Backup

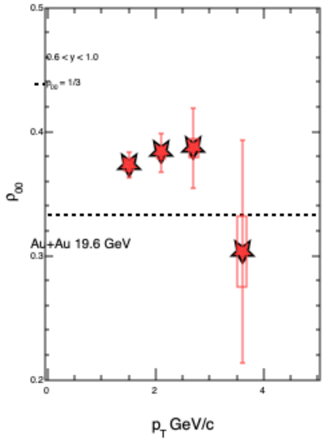

-1.0 < y < -0.6
ρ00 = 1/3
Au+Au 19.6 GeV
p_T GeV/c

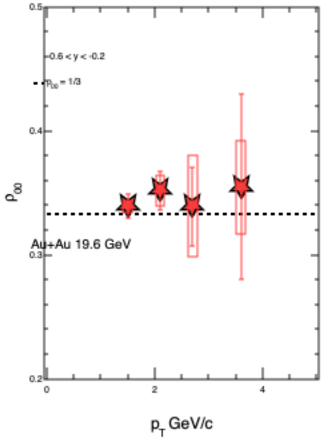

-0.6 < y < -0.2
ρ00 = 1/3
Au+Au 19.6 GeV
p_T GeV/c

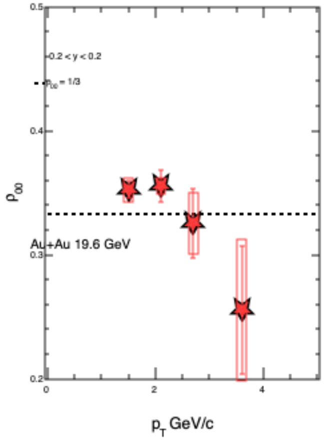

-0.2 < y < 0.2
ρ00 = 1/3
Au+Au 19.6 GeV
p_T GeV/c

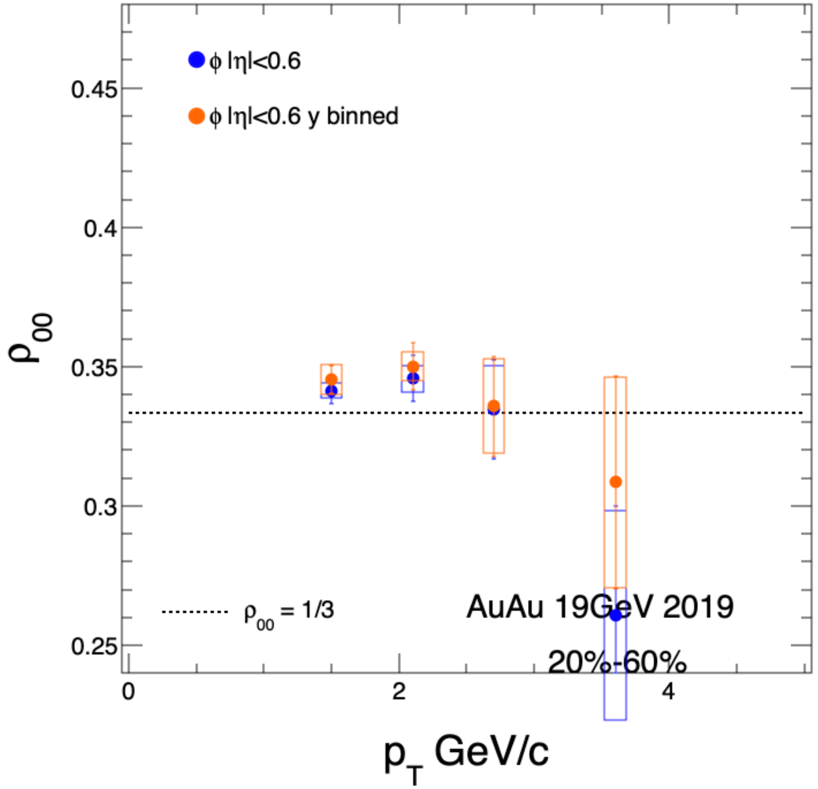

ϕ |η|<1
ϕ |η|<1 y binned
ρ00 = 1/3
AuAu 19GeV 2019
20%-60%
ρ00
p_T GeV/c

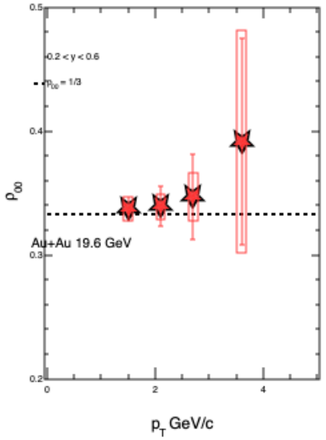

0.2 < y < 0.6
ρ00 = 1/3
Au+Au 19.6 GeV
p_T GeV/c


0.6 < y < 1.0
ρ00 = 1/3
Au+Au 19.6 GeV
p_T GeV/c


-0.6 < y < -0.2
ρ_{00} = 1/3
Au+Au 19.6 GeV
ρ_{00}
p_T GeV/c


-0.2 < y < 0.2
ρ_{00} = 1/3
Au+Au 19.6 GeV
ρ_{00}
p_T GeV/c


ϕ IηI<0.6
ϕ IηI<0.6 y binned
ρ_{00} = 1/3
AuAu 19GeV 2019
20%-60%
ρ_{00}
p_T GeV/c


0.2 < y < 0.6
ρ_{00} = 1/3
Au+Au 19.6 GeV
ρ_{00}
p_T GeV/c

p_T dependent study (1.2 < p_T < 4.2, 20-60%) binned in pT

|η| cut	integrated ρ_{00}	stat. error
|η| < 0.4	0.3424	0.0055
|η| < 0.6	0.3416	0.0041
|η| < 0.8	0.3427	0.0035
|η| < 1.0	0.3461	0.0020

p_T dependent study (1.2 < p_T < 4.2, 20-60%) binned in pT and rapidity

|η| cut	integrated ρ_{00}	stat. error
|η| < 0.6	0.3457	0.0041
|η| < 1.0	0.3522	0.0024

centrality dependent study (1.0 < p_T < 5.0, 20-60%) binned in centrality and pT

|η| cut	integrated ρ_{00}	stat. error
|η| < 0.4	0.3613	0.0046
|η| < 0.6	0.3466	0.0034
|η| < 0.8	0.3442	0.0029
|η| < 1.0	0.3496	0.0018

centrality dependent study (1.0 < p_T < 5.0, 0-80%) binned in centrality and pT

$\|\eta\|$ cut	integrated ρ_{00}	stat. error
$\|\eta\| < 0.4$	0.3632	0.0045
$\|\eta\| < 0.6$	0.3416	0.0032
$\|\eta\| < 0.8$	0.3378	0.0027
$\|\eta\| < 1.0$	0.3456	0.0017

rapidity dependent study (1.0 < p_T < 5.0, 0-80%) binned in rapidity, centrality and pT

$\|\eta\|$ cut	integrated ρ_{00}	stat. error
$\|\eta\| < 0.4$	0.3662	0.0038
$\|\eta\| < 0.6$	0.3489	0.0027
$\|\eta\| < 0.8$	0.3453	0.0023
$\|\eta\| < 1.0$	0.3504	0.0015

Deriving 4th Order Acceptance Correction

$$\left[\frac{dN}{d\cos\theta^* d\beta}\right]_{|\eta|} = \frac{dN}{d\cos\theta^* d\beta}\times g(\theta^*, \beta).$$

$$g(\theta^*, \beta) = 1 + F^* \cos^2\theta + G^* \cos^4\theta$$

$$= 1 + \left(\frac{4F^* + 3G^*}{8}\right) - \left(\frac{2F^* + 3G^*}{4}\right)\cos^2\theta^* + \frac{3G^*}{8}\cos^4\theta^*$$

$$- \frac{\cos 2\beta}{2}\left[F^*(1-\cos^2\theta^*) + G^*(1-\cos^2\theta^* + \cos^4\theta^*)\right]$$

$$+ \frac{G^*\cos 4\beta}{8}\left[1-\cos^2\theta^* + \cos^4\theta^*\right],$$

$$\int_0^{2\pi} d\beta\; g(\theta^*, \beta) = g(\theta^*) \propto 1 + \left(\frac{4F^*+3G^*}{8}\right) - \left(\frac{2F^*+3G^*}{4}\right)\cos^2\theta^* + \frac{3G^*}{8}\cos^4\theta^*. \qquad \text{Eq. 4}$$

Deriving 4th Order Acceptance Correction

$$\frac{dN}{d\cos\theta^{*\prime}\, d\beta'} \propto 1 + A'\cos^2\theta^{*\prime} + B'\sin^2\theta^{*\prime}\cos 2\beta' + C'\sin 2\theta^{*\prime}\cos\beta' \,.$$

$$\left[\frac{dN}{d\cos\theta^{*\prime}}\right]_{|\eta|} \propto 2 + F^* - \frac{B'F^*}{2} + \frac{3G^*}{4} - \frac{B'G^*}{2}$$

Eq. 5

$$+\left[2A' - F^*(1 - A' - B') - G^*\left(\frac{3}{2} - \frac{3A'}{4} - \frac{3B'}{2}\right)\right]\cos^2\theta^{*\prime}$$

$$+\left[-F^*\left(A' + \frac{B'}{2}\right) + G^*\left(\frac{3}{4} - \frac{3A'}{2} - \frac{3B'}{2}\right)\right]\cos^4\theta^{*\prime}$$

$$+\left[G^*\left(\frac{3A'}{4} + \frac{B'}{2}\right)\right]\cos^6\theta^{*\prime} \,.$$

$$A' = \frac{A(1+3R)}{4 + A(1-R)} \,, \qquad B' = \frac{A(1-R)}{4 + A(1-R)} \,, \qquad A = \frac{3\rho_{00} - 1}{1 - \rho_{00}}$$

Eq. 6-8

Deriving 4th Order Acceptance Correction

Now let's set $G = 0$ and $F^* = \frac{-2F}{1+F}$ to recover form of equation from PHYSICAL REVIEW C 98, 044907 (2018)

$$\left[\frac{dN}{d\cos\theta^{*\prime} d\beta'}\right]_{|\eta|} \propto 2 + \frac{-2F}{1+F}(1 - \frac{B'}{2}) + \left[2A' - \frac{-2F}{1+F}(1 - A' - B')\right]\cos^2\theta^{*\prime} + \left[-\frac{-2F}{1+F}\left(A' + \frac{B'}{2}\right)\right]\cos^4\theta^{*\prime}.$$

Pull out constant factor 2/(1+F).

$$\left[\frac{dN}{d\cos\theta^{*\prime} d\beta'}\right]_{|\eta|} \propto 1 + F - F\,(1 - \frac{B'}{2}) + [A'(1+F) + F\,(1 - A' - B')\,]\cos^2\theta^{*\prime} + \left[F\left(A' + \frac{B'}{2}\right)\right]\cos^4\theta^{*\prime}.$$

$$\left[\frac{dN}{d\cos\theta^{*\prime} d\beta'}\right]_{|\eta|} \propto 1 + \frac{B'F}{2} + [A' + F - B'F\,]\cos^2\theta^{*\prime} + \left[\left(A'F + \frac{B'F}{2}\right)\right]\cos^4\theta^{*\prime}.$$

THIS MATCHES THE SECOND ORDER ACCEPTANCE CORRECTION FORMULA