D^0 re-analysis for Run 11 Au+Au collisions at $\sqrt{s} = 200$ GeV

Xiaolong Chen, Xin Dong, Guannan Xie, Yifei Zhang and Long Zhou

Contents

1 INTRODUCTION **2**

2 ANALYSIS FOR CROSS-CHECK **2**

2.1 The main issues 2

2.2 Raw yields 3

2.3 Efficiency comparisons 6

2.4 Corrected results 8

2.5 Systematic uncertainties 11

3 OTHER MATERIALS **11**

1. INTRODUCTION

Since at $p_T < 2$ GeV/c a discrepancy was observed in the D^0 p_T spectrum between new data from Run14 with HFT and published data from Run10+Run11. A re-analysis on Run11 data was performed to check if anything was incorrect. This document is for the re-analysis details.

2. ANALYSIS FOR CROSS-CHECK

The re-analysis was done by Xiaolong Chen, Long Zhou and Yifei Zhang independently but based on the same original code for published data. Cross-checks for raw yields, efficiencies, results comparisons were made between us. The analysis cuts are the same as in previous analysis note [1], also listed in Xiaolong 's analysis, see Ref. [2] Sec. 8. The only difference is varying DCA cut with < 1 cm or < 2 cm.

2.1. The main issues

In early days, there was no vertex detector, we had to use random combination of decay products to reconstruct D^0 meson in hadronic channel, which suffered from huge combinatorial background. The way to improve the significance was to enrich the kaon and pion PID probability and enhance the statistics as much as possible at the same time. Thus we developed a hybrid method: In low momentum region (p $<$ 1.6 GeV/c), we always required good TOF matching and TOF PID, those tracks without good TOF matching or failed to pass TOF PID were rejected. At high momentum (p $>$ 1.6 GeV/c) beyond the TOF identification capability, candidates were always required to pass the TPC dE/dx cut and the TOF $1/\beta$ cut was only required for those tracks with good TOF matching. (In order to have as much statistics as possible, we do not reject tracks passed TPC PID. But in the candidates passed TPC PID, a large overlap between kaons and pions still exists, the mis-identification probability of kaon and pion is large. What we did is to add additional constraint, TOF PID to enhance the purity of pion and kaon. We keep all of them but pion and kaon probability enhanced.) The details are list below:

A good TOF matching means tracks satisfy TOFMatchFlag $>$ 0 && beta $>$ 0.

At low momentum, p $<$ 1.6 GeV/c, the correct algorithm to ensure the purity of kaons and pions is:

GoodTOFMatching && TPC PID && TOF PID

At high momentum, p > 1.6 GeV/c , if there was a good TOF matching, we applied TPC PID + TOF PID, otherwise we used TPC PID only to enhance the PID efficiency:

If (GoodTOFMatching) TPC PID + TOF PID else TPC PID

Two main issues were found in the code: 1) The condition to reject those tracks without matching to TOF at low momentum was different from above algorithm and also different from what we used to calculate the efficiency. We found that those tracks with TOFMatchFlag > 0 but with beta < 0 were not correctly rejected, which results in higher yield obtained than expected. This introduces about 15% difference at low p_T but does not affect high $p_T$much.

2) We applied an additional DCA_{XY} cut efficiency in previous analysis. This cut was used in TOF matching algorithm (in TOFMatchMaker) to require tracks with a distance of closest approach to the beam line in xy plane within 1 cm. This efficiency was studied in early days and found there was about up to 20% of tracks at low p_T rejected with this cut, see Fig.5. However, when we studied TOF matching efficiency, we used a data driven method and this efficiency should be already included. Thus we double counting this efficiency.

2.2. Raw yields

The raw signals as a function of p_T from part of Run11 data with 85% of full statistics (roughly half of total Run10 + Run11 data) were extracted as Fig.1,

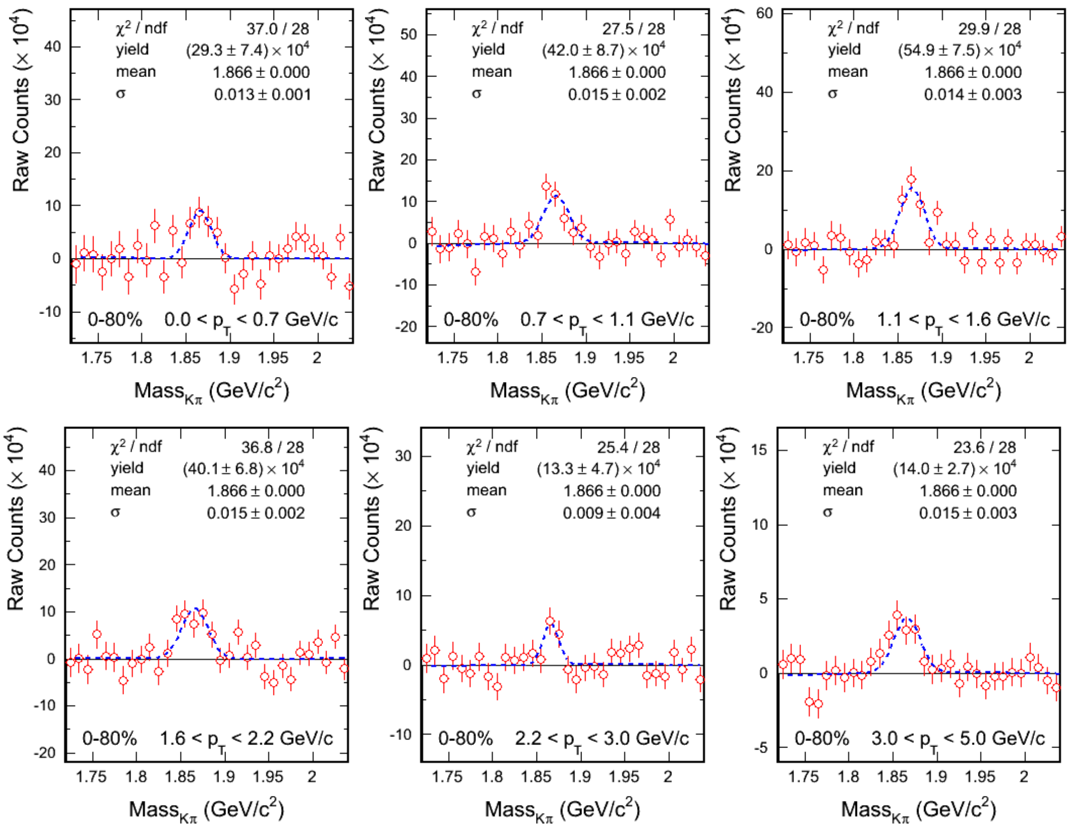

Figure 1. p_T dependence of D^0 signals in 0-80% from partial Run11 data.

The fit is with fixed mean value from PDG book. The comparison between fits with fixed mean and free mean is shown in Fig. 2, the difference is about 6.5%. This is only for raw yield checking, which is not used for final results.

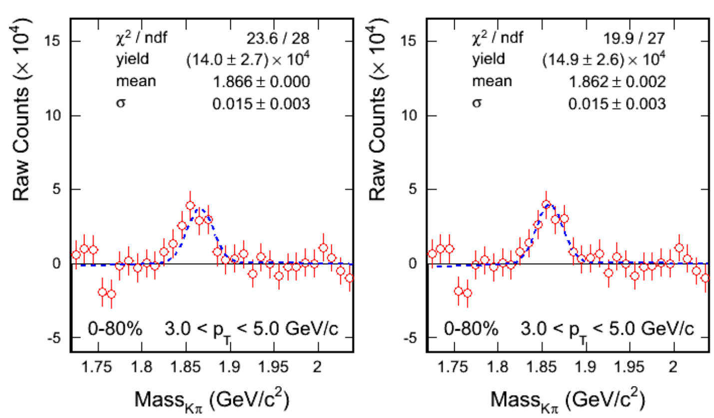

Figure 2. D^0 signal at p_T = 3-5 GeV/c. Left panel: fit with fixed mean. Right panel: fit with free mean.

The mean shift is not so clear for this particular p_T bin in previous analysis with full statistics. The raw yields for published data were extracted from fitting with fixed mean and the difference between fixed mean and free mean was taken into account as systematic uncertainties. The raw yields from previous analysis are still kept for the new results. The only change is corrected the raw yields with new efficiencies. The raw yields in each p_T bin and centrality bin can be found at [1] (P.12 - P.22).

For peripheral collision 40-80%, the R_{AA} drops at p_T 2 GeV/c, we provide the signal extraction plot for that data point Au+Au collisions as shown in Ref. [1] (P.16, P.20). The mass signals for p+p in similar p_T bin can be found in p+p analysis note at: [3] (p.13).

The raw signals were compared with Xiaolong 's independent analysis and found to be consistent, shown in left panel of Fig.3. The slight lower yield in Xiaolong 's analysis is due to the tight DCA cut $<$ 1 cm, while the DCA cut applied here is $<$ 2 cm. The raw spectrum is also compared with previous analysis and consistent within errors shown in right panel of Fig.3.

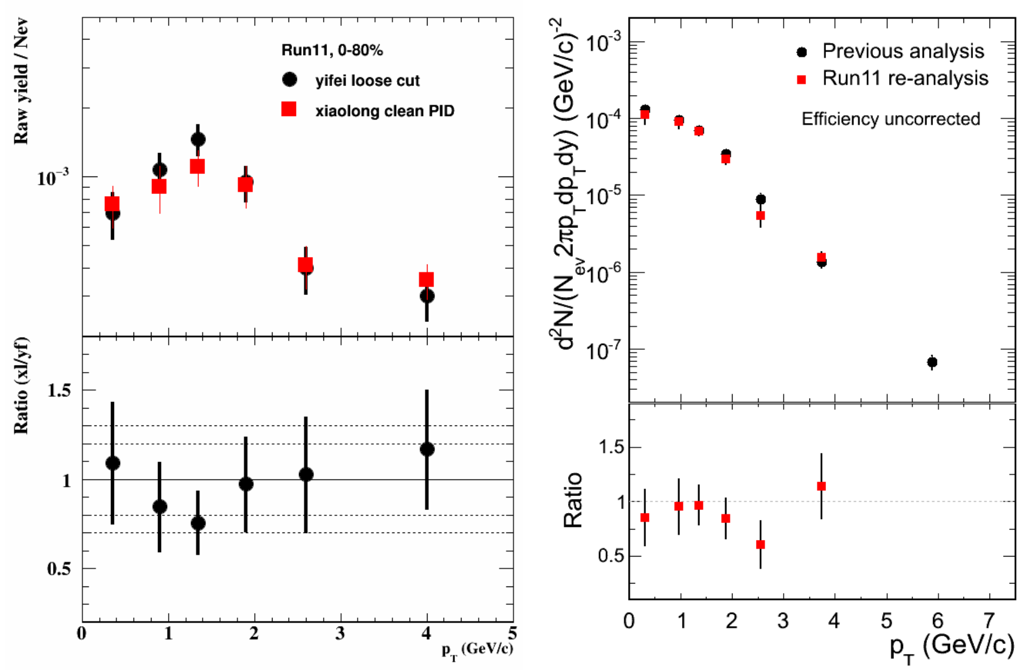

Figure 3. Left panel: Raw signals comparison with Xiaolong 's. Right panel: Raw spectrum compared with previous analysis.

2.3. Efficiency comparisons

Long Zhou calculated new efficiency with the same algorithm as used in data analysis by folding in the TOF matching efficiency obtained from data for single track, see left panel of Fig. 4. Fig. 4 right panel shows the comparison between Long 's new efficiency and the previous one.

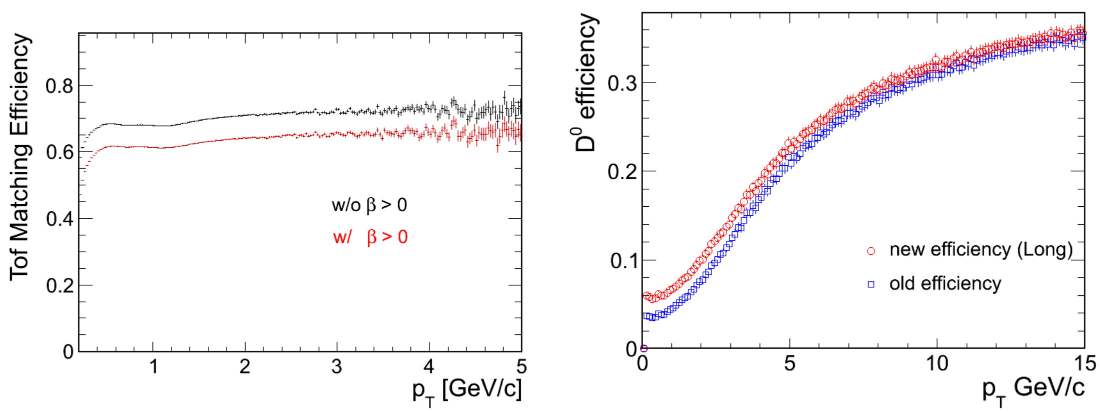

Figure 4. Left panel: Single pion Tof matching efficiency with or without $\beta > 0$ cut. Right panel: New D^0 efficiency compared with old one.

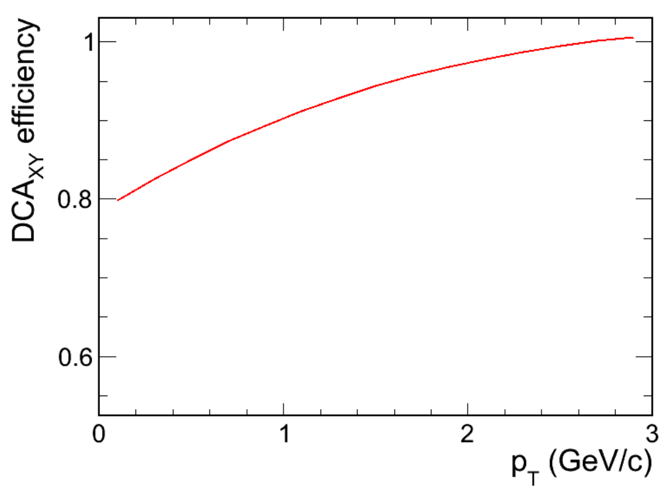

Figure 5. DCA_{XY} efficiency for single track.

The old efficiency was calculated by requiring $\beta > 0$ when applying TOF matching. The new efficiency was calculated with the same cuts (no $\beta > 0$ cut) as used in data analysis. And the TOF matching efficiency was then folded in the D^0 efficiency calculation. The ratio between old and new efficiencies for D^0 can be found as the blue one in Fig. 6. The red one is the ratio between old and new efficiency while the old one additionally counted the DCA_{XY} efficiency.

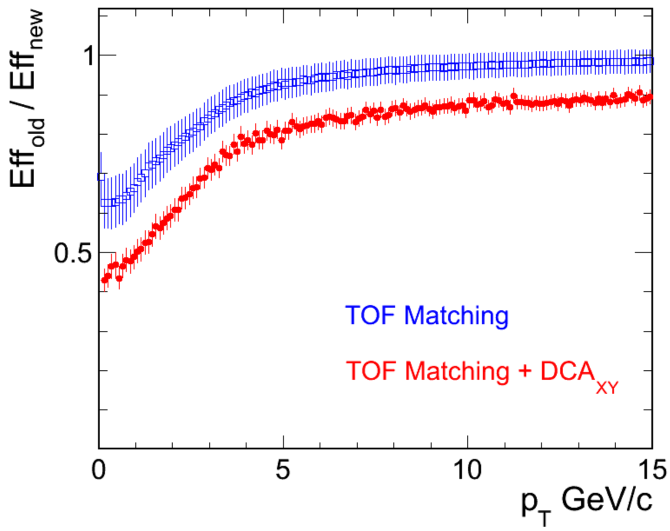

Figure 6. Ratio between old and new efficiencies for D^0.

After corrected above two main issues, the corrected reconstruction efficiency can be found at Fig.7

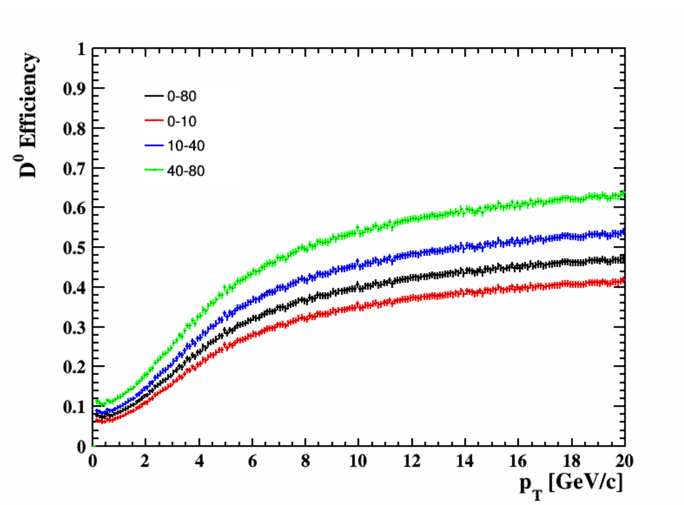

Figure 7. The reconstruction efficiency at each centrality bin

2.4. Corrected results

The main changes on the new data:

1) In Au+Au, corrected with new efficiency under knowing two mistakes below. - Hybrid PID algorithm in data analysis was different from efficiency calculation at low p_T. - Doubly counted DCA_{XY} cut efficiency.

2) Updated p+p reference with latest charm fragmentation ratios and the p_T dependence of D^*D^0. The details can be found in Guannan 's HFT analysis note [2] (P.75 77). We used the same p+p reference.

Fig. 8 shows the changes on p+p reference.

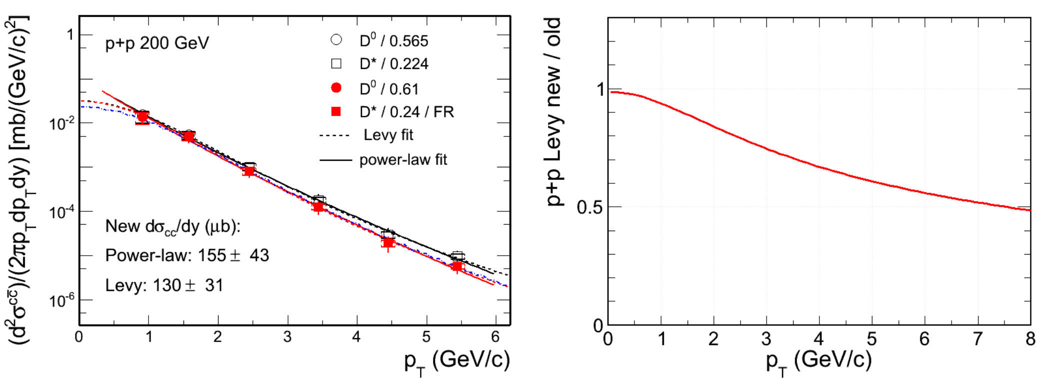

Figure 8. Left panel: The comparison between old and new p+p spectra. Right panel: The ratio between Levy fit for new and old p+p spectra.

The invariant yield changes in Au+Au collisions were shown in left panel of Fig. 9. The black solid circles are the ratio between new and old D^0 spectra. The red open circles represent the ratio between old and new efficiencies as the red one in Fig. 6.

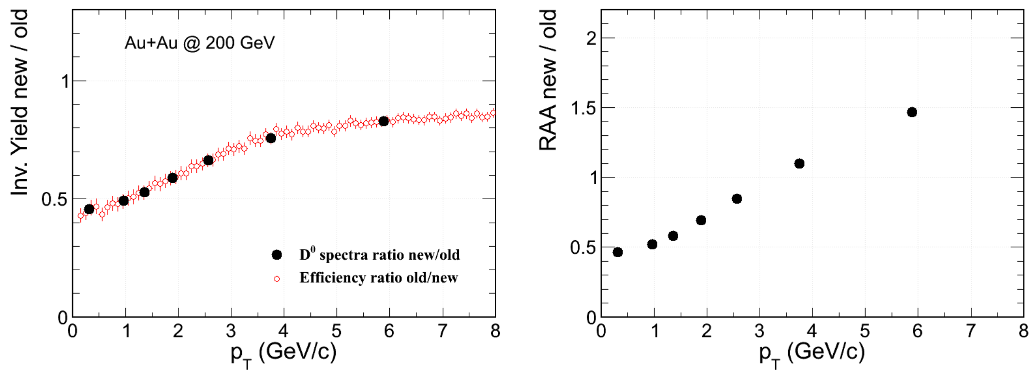

Figure 9. Left panel: Ratio between new invariant yield and old one in Au+Au collisions. Right panel: Ratio between new R_{AA} and old one.

The corrected D^0 p_T spectra are shown in Fig. 10.

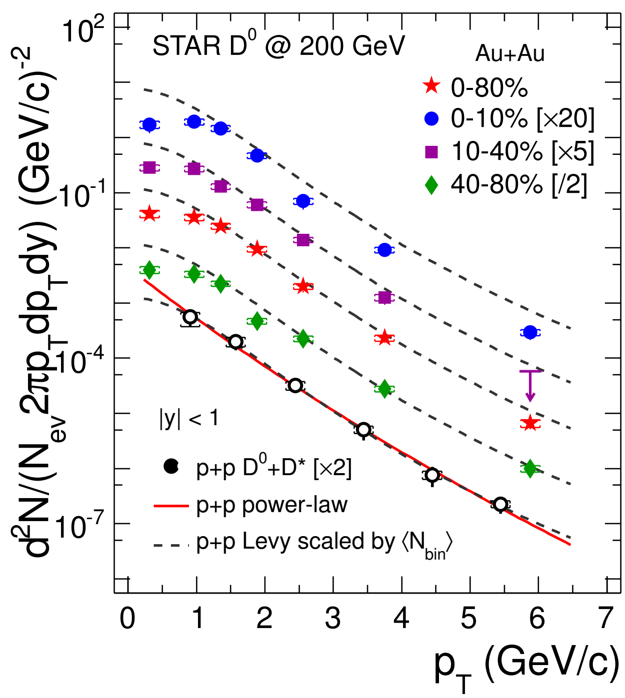

Figure 10. The Corrected D^0 spectra in each centrality class.

The final D^0 R_{AA} spectra are then corrected by efficiency ratio between the published reconstruction efficiency and the corrected reconstruction efficiency. The corrected D^0 R_{AA} is shown in Fig.11

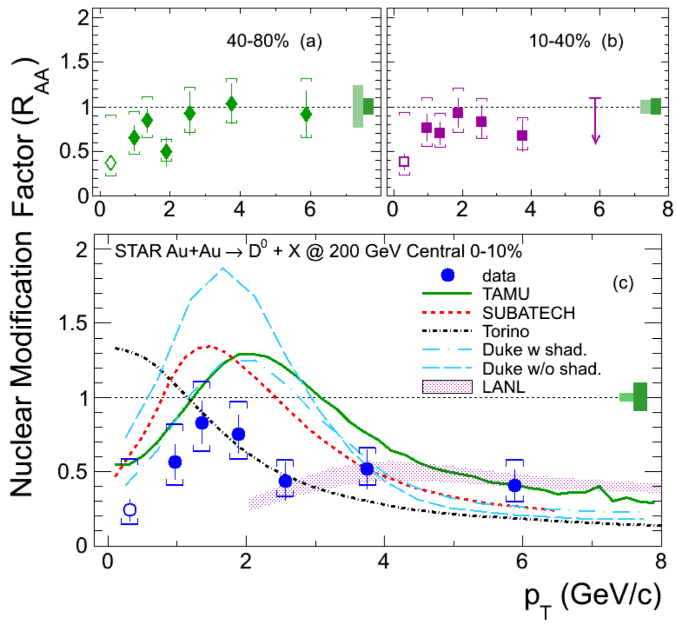

Figure 11. The Corrected D^0 R_{AA} in each centrality class, and compared with several model calculation

The ratio between new R_{AA} and old one can be found in right panel of Fig. 9.

The comparison between the new results with HFT results can be found at: [2] (P.76-77).

The integrated R_{AA} are shown in Fig. 12.

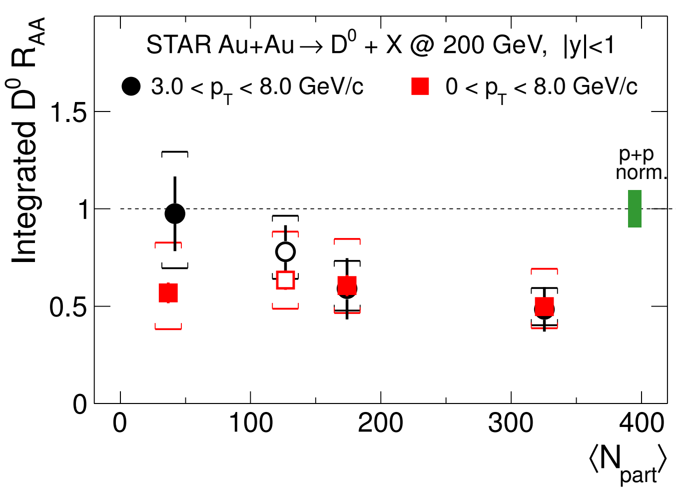

Figure 12. The integrated R_{AA} for full p_T range and for high p_T.

2.5. Systematic uncertainties

The systematic uncertainties for p+p and Au+Au spectra can be found in previous analysis note at Ref. [3][1]. The R_{AA} systematic uncertainty is updated with the same analytic method with HFT paper at Ref. [2][4]. The statistical uncertainties are only from Au+Au spectrum. The statistical and systematical uncertainties of the p+p reference are taken into account as the systematic uncertainty of the R_{AA}, which mainly comes from Levy fit to the p+p data with one standard deviation and the difference between Levy and power-law function fits. Partial systematic uncertainties for p+p and Au+Au were canceled when calculating R_{AA} errors, including 4% and 8% from DCA+nFitPts and dE/dx from TPC tracking. The overall normalization factor uncertainties are separately plotted at unity of the R_{AA}, which include the uncertainties of number-of-binary-collisions (24%, 7.7%, 2.8% for 40-80%, 10-40% and 0-10%, respectively), the pile-up effect on DCA for pion 8% and trigger correction uncertainty 5.2% in p+p analysis [1].

3. OTHER MATERIALS

More material can be found at here :

First GPC meeting: https://drupal.star.bnl.gov/STAR/system/files/GPC-04202018.pdf

Some checks provided by Long Zhou:

https://drupal.star.bnl.gov/STAR/system/files/D0_Eff_discussion_2016_11_7.pdf

https://drupal.star.bnl.gov/STAR/system/files/D0_Eff_discussion_2017_05_12.pdf

https://drupal.star.bnl.gov/STAR/system/files/D0_BNL170516_0.pdf

REFERENCES

1. Au+Au TPC analysis note:
   https://drupal.star.bnl.gov/STAR/system/files/dzeroAuAu_updated.pdf.
2. Au+Au HFT analysis note:
   https://drupal.star.bnl.gov/STAR/system/files/20180507_D0spectra_Note.pdf.
3. p+p analysis note:
   https://drupal.star.bnl.gov/STAR/system/files/dzero.pdf.
4. Analytic method for R_{AA} systematic uncertainties:
   https://www.star.bnl.gov/protected/heavy/xgn1992/paper/D0spectra/
   comments/180430_GPC_RAA_sys.pdf