Paper Proposal

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Measurements of inclusive $\boldsymbol{D^0}$-meson production in Isobar collisions at $\sqrt{\boldsymbol{s_{NN}}} = \mathbf{200}$ GeV

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Abstract

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We report the first measurements of D^0-meson production at mid-rapidity ($|y| < 1$) in Isobar collisions (^{96}Ru + ^{96}Ru and ^{96}Zr + ^{96}Zr) at $\sqrt{s_{NN}} = 200$ GeV with the STAR experiment. D^0 p_T differential invariant yield with transverse momentum $p_T < 8$ GeV/c are reported at 0-10%, 10-40% and 40-80% centrality bins. The N_{bin}-scale effect of the D^0 p_T spectra between Isobar and Au + Au collision system is observed by using $N_{bin}^{Isobar}/N_{bin}^{AuAu}$ to scale D^0 p_T spectra in Au + Au collisions at 200 GeV. The strong suppression D^0 nuclear modification factor R_{AA} is also observed for $p_T > 3$ GeV/c in the central Isobar collisions, demonstrating that charm quarks suffer significant energy loss in the bulk QCD medium. For $p_T > 4$ GeV/c, integrated D^0 cross section per nucleon-nucleon collision at mid-rapidity and integrated nuclear modification factor are respectively less than the corresponding results in Au + Au collisions at the same mean number of participating nucleons $\langle N_{part} \rangle$ within 1σ effect, indicating charm quarks may have a stronger energy loss in Isobar collisions than in Au + Au collisions for the same $\langle N_{part} \rangle$. Model calculations reproduce the features of our measured R_{AA} for $p_T > 4$ GeV/c.

D^0 signal Reconstruction

hadronic modes:

$D^0 \rightarrow K^- + \pi^+; \overline{D}^0 \rightarrow K^+ + \pi^- \ (\Gamma_i/\Gamma \sim 3.9\%)$

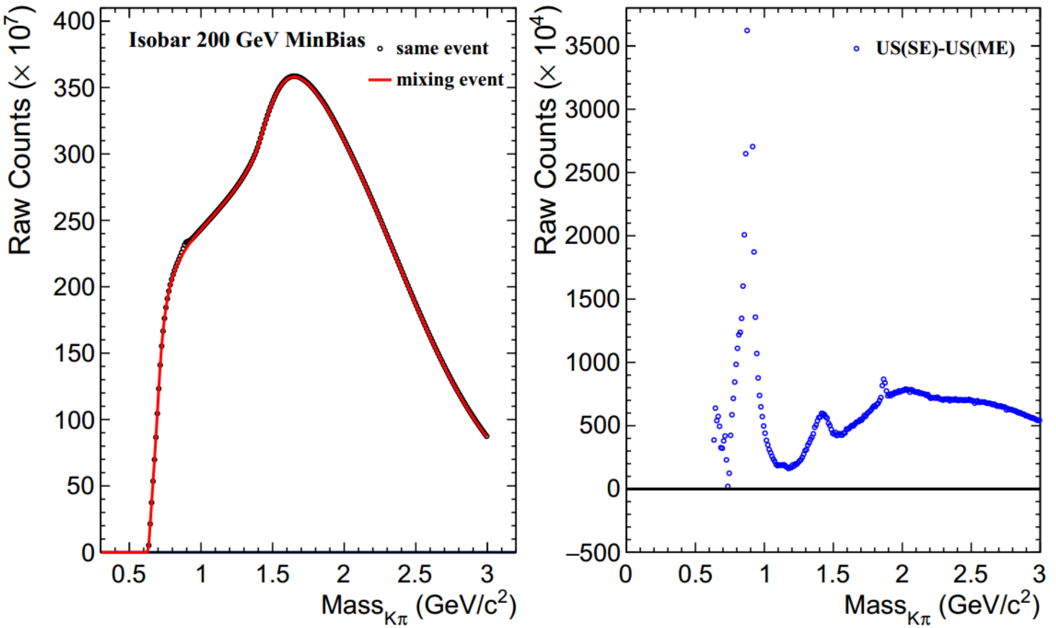


Fig.1. The K, π invariant mass distribution with centrality 0-80% and p_T range 0-8 GeV/c at midrapidity (left). Open circle depict the unlike-sign distribution under the same event, and red line shows that the mix-event method can well reproduce the combination background. The invariant mass distribution after removing the combination background (right).

D^0 signals

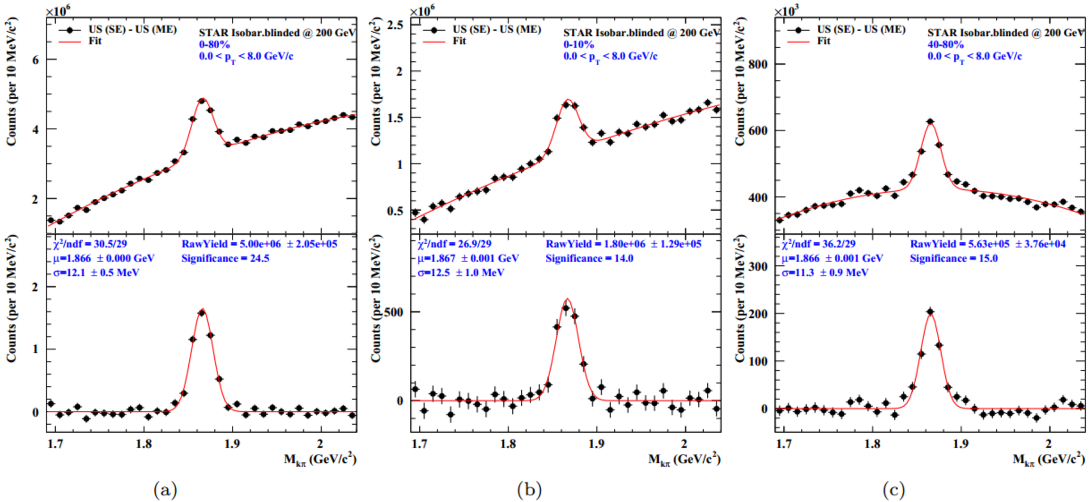


Fig.2. D^0 signal at 0-80%(a), 0-10%(b) and 40-80%(c) centrality bins with transverse momentum range 0-8 GeV/c at midrapidity. On the top panel, solid points show the invariant mass distribution after removing the combination background, and red line represents a Gauss + pol2 fitting. On the bottom panel, solid points show the D^0 signal after the redundant background is removed, and the red line is the Gaussian function fitting to the signal.

Efficiency correction procedures

$$\frac{d^2 N}{2\pi p_T dp_T dy} = \frac{\Delta N^{raw}/\epsilon_{D^0}^{reco}/2}{2\pi p_T \Delta p_T \Delta y \times N_{events} \times B.R.}$$

$$\epsilon_{D^0}^{reco} = \epsilon_{Accept} \times \epsilon_{TPC} \times \epsilon_{PID}$$

$$\epsilon_{PID} = \epsilon_{n\sigma_X} \cdot \epsilon_{TOF} \cdot \epsilon_{n\sigma_X^{TOF}} + \epsilon_{n\sigma_X} \cdot (1 - \epsilon_{TOF})$$

- ΔN^{raw} : the raw yield measured in the bin $\Delta p_T \Delta y$;
- $\epsilon_{Accept} \times \epsilon_{TPC}$: TPC acceptance and tracking efficiency (embedding);
- ϵ_{PID} : particle identification efficiency (data).

D^0 Efficiency

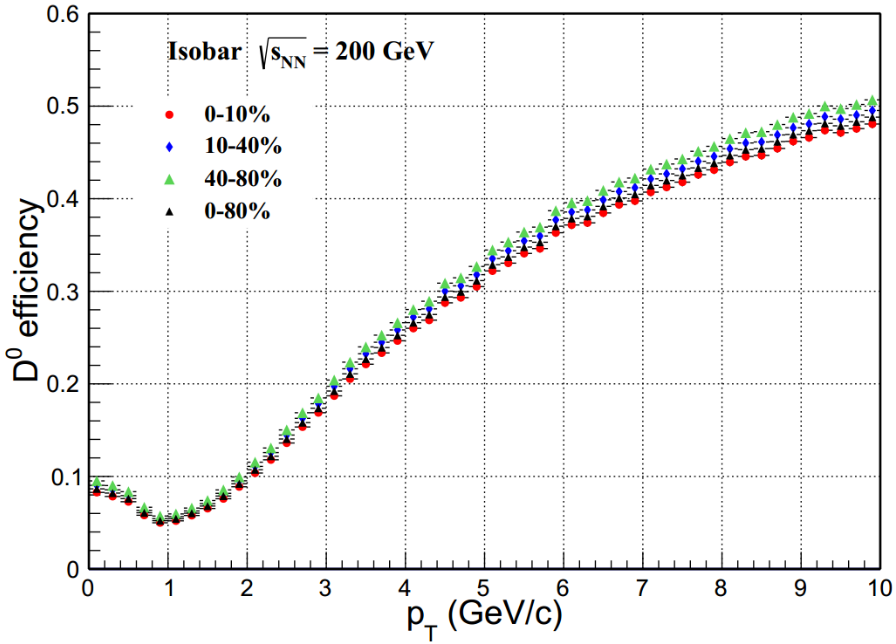


Fig.3. D^0 efficiency as a function of D^0 transverse momentum at 0-10%, 10-40%, 40-80% and 0-80% centrality bins.

Systematic uncertainties

- Signal extraction
  - The difference between the fitting and counting methods;
  - The order of polynomial function to depict the residual background;
  - Signal fit range;
  - p_T cut variation for daughter particles;
  - Mix-event like-sign normalization factor;
  - Double counting estimation
- TPC tracking
  - DCA: 2cm (default);
  - nHitsFit: 20 (default)

$$R(nHitsFit) = \frac{N_{data}(nHitsFit > 15)/N_{data}(nHitsFit \geq 20)}{N_{emb}^{MC}(nHitsFit > 15)/N_{emb}^{MC}(nHitsFit \geq 20)}$$

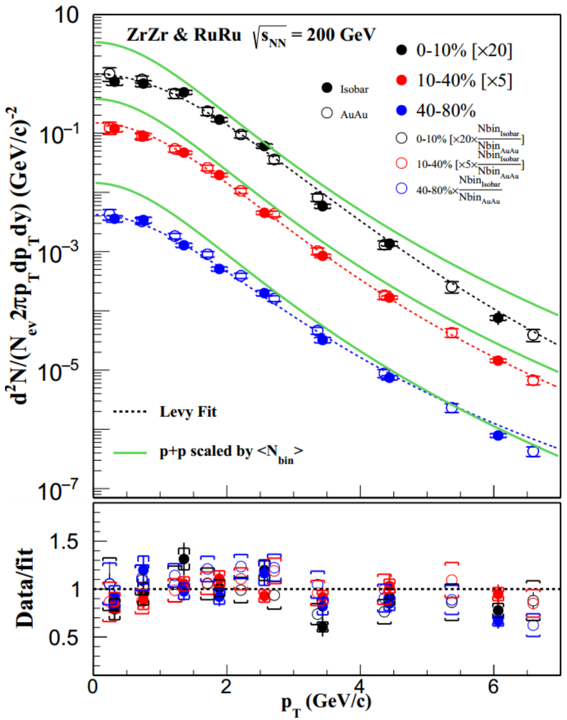
- PID cuts 3%
- B.R. 0.5%
- p + p inelastic scattering cross section 8%

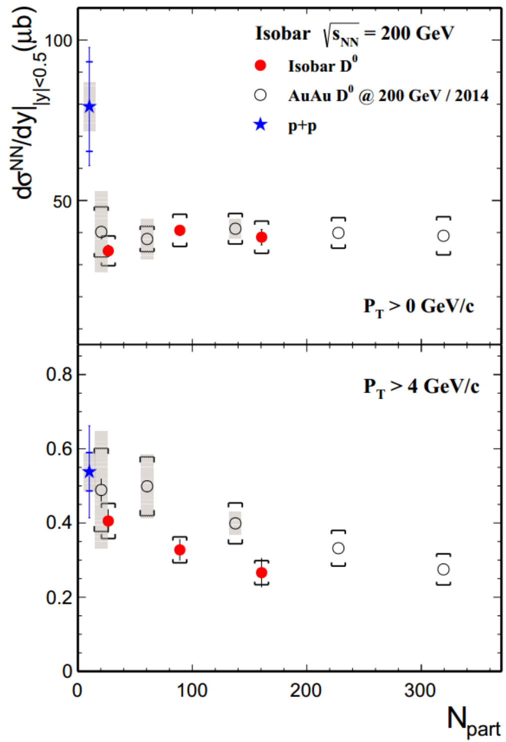
Systematic uncertainties

Table 4: Systematic uncertainties in D^0 analysis

		0-10%	10-40%	40-80%	Correlation in pT
spectra	Raw yield	8.6-14.1%	6.9-12.3%	7.9-12.7%	uncorrelated
	Double counting	0.7%	0.8%	0.9%	uncorrelated
	PID	3%	3%	3%	Largely correlated
	TPC	2-6%	2-6%	2-6%	Largely correlated
	B.R.	0.5%	0.5%	0.5%	global
RAA	<Nbin>	1.6%	0.6%	0.4%	global
	ppbase	20.6-71.8%	20.6-71.8%	20.6-71.8%	partially correlated
Rcp (/40-80%)		0-10%		10-40%	
	Raw yield		11.1-18.2%	9.8-17.1%	uncorrelated
	Double counting	negligible		negligible	uncorrelated
	B.R.	0		0	global
	TPC	negligible		negligible	Largely correlated
Integrated cross section		pt>0		pt >4 GeV/c	
	Total	12.3-13.6%		10.7-12.2%	

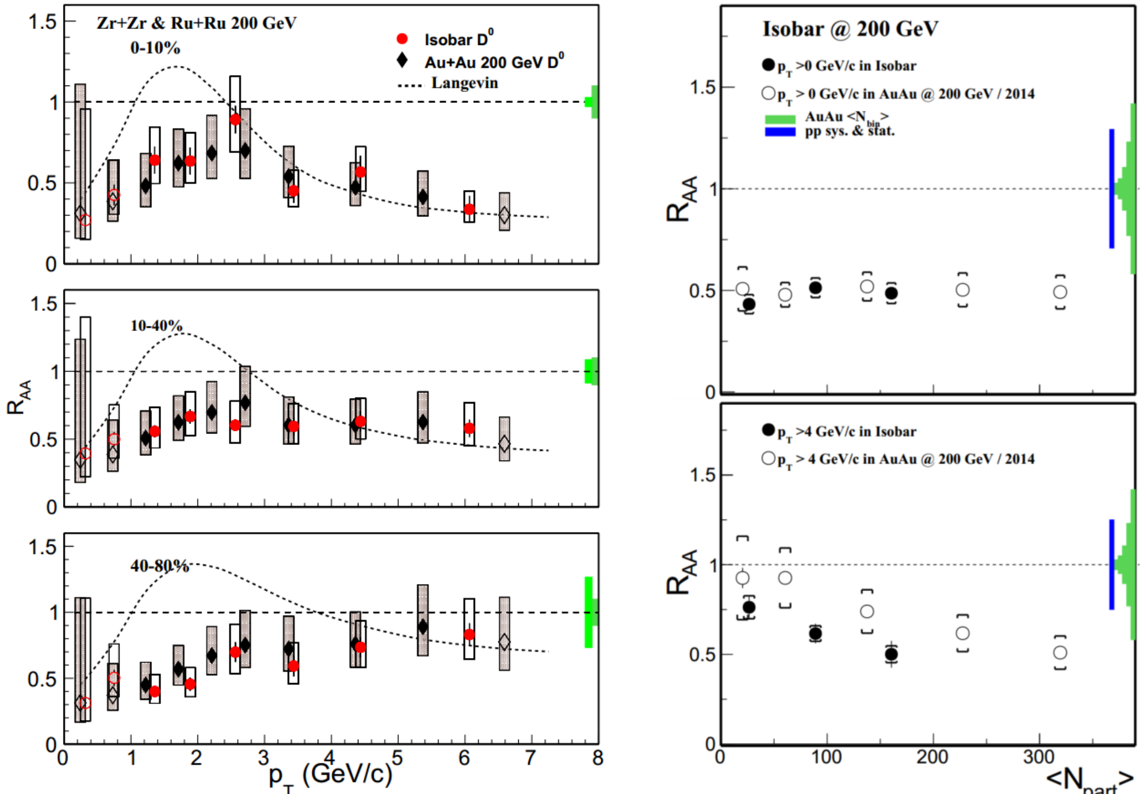
p_T Spectra and Integrated Yields





- Fig.4. D^0 invariant yields at mid-rapidity (|y|<1) vs. transverse momentum for different centrality classes in Isobar (solid) and Au + Au (open) collisions at $\sqrt{s_{NN}}$ = 200 GeV.
- Fig.5. D^0 integrated corss sections per nucleon-nucleon collision in Isobar.

R_{AA} and R_{AA} vs. N_{part}



- Fig.6. D^0 R_{AA} for different centrality classes in Isobar collisions compared to that of Au + Au results.
- Fig.7. D^0 integrated R_{AA} vs. $< N_{part} >$ for $p_T > 0$ and $p_T > 4$ GeV/c in Isobar and Au + Au collisions.

R_{CP}

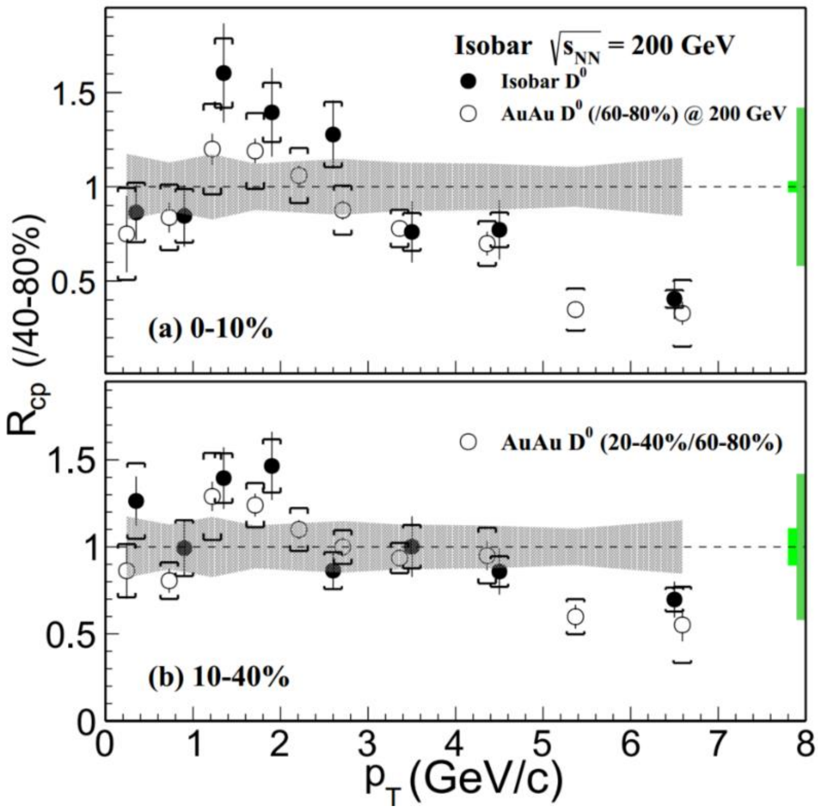
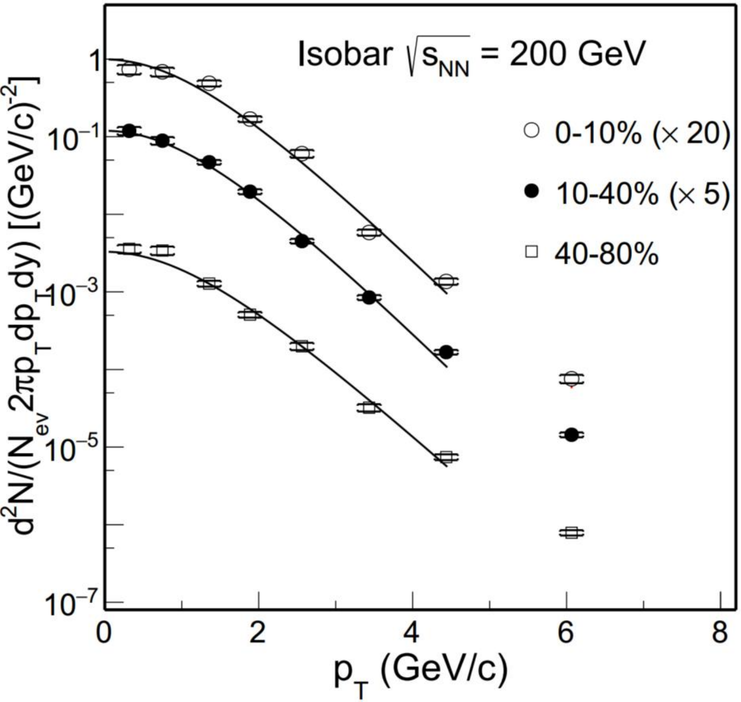
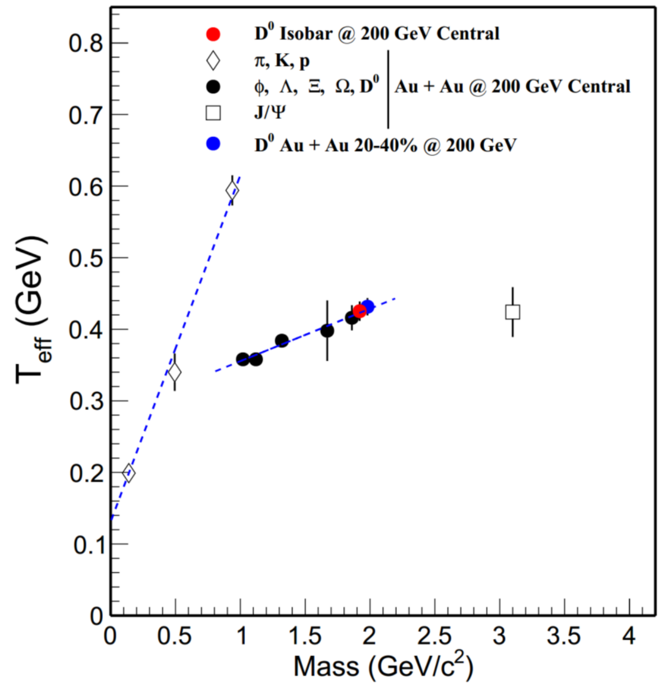


Fig.8. D^0 R_{cp} with the 40-80% spectrum as the reference for 0-10% and 10-40% centrality in Isobar collisions compared to that of Au + Au results.

m_T Spectra and Collectivity

$$\frac{d^2N}{2\pi p_T dp_T dy} = \frac{d^2N}{2\pi m_T dm_T dy} = \frac{dN/dy}{2\pi T_{\rm eff}\,(m_0 + T_{\rm eff})} e^{-(m_T - m_0)/T_{\rm eff}}$$

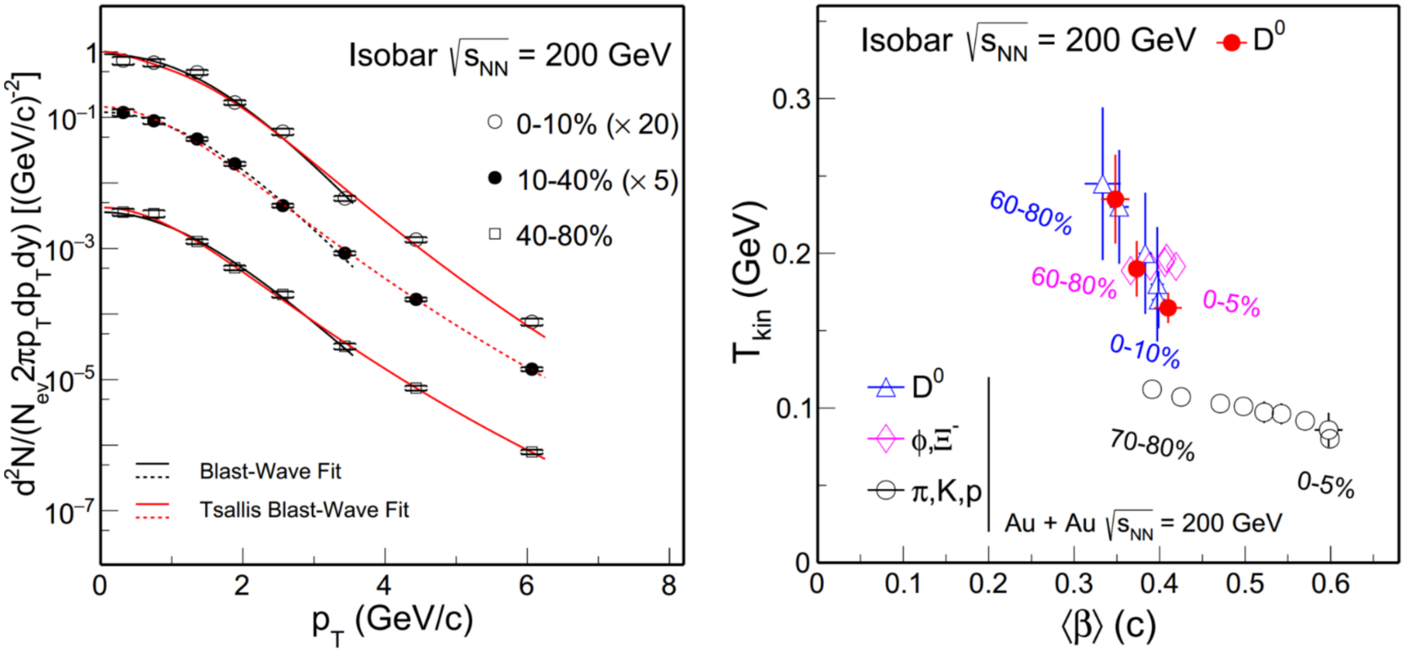




- Fig.9. D^0 invariant yield at mid − rapidity (|y|<1) vs. p_T for different centrality bins fitted with m_T distribution.
- Fig.10. T_{eff} for D^0 in central Isobar collisions is consistent with that of Au + Au results.

Blast – Wave Fits

$$\frac{dN}{p_{\mathrm{T}}dp_{\mathrm{T}}} = \frac{dN}{m_{\mathrm{T}}dm_{\mathrm{T}}} \propto \int_0^R r dr m_{\mathrm{T}} I_0\left(\frac{p_{\mathrm{T}}\sinh\rho}{T_{\mathrm{kin}}}\right) K_1\left(\frac{m_{\mathrm{T}}\cosh\rho}{T_{\mathrm{kin}}}\right)$$



- Fig.11. D^0 invariant yield at mid-rapidity (|y|<1) vs. p_T for different centrality bins fitted with blast-wave function
- Fig.12. D^0 freeze out temperature in Isobar collisions are consistent with that of in Au + Au collisions for the same centrality.