Initial state nuclear effects for jet production measured in $\sqrt{s_{NN}}$ = 200 GeV d+Au collisions by STAR

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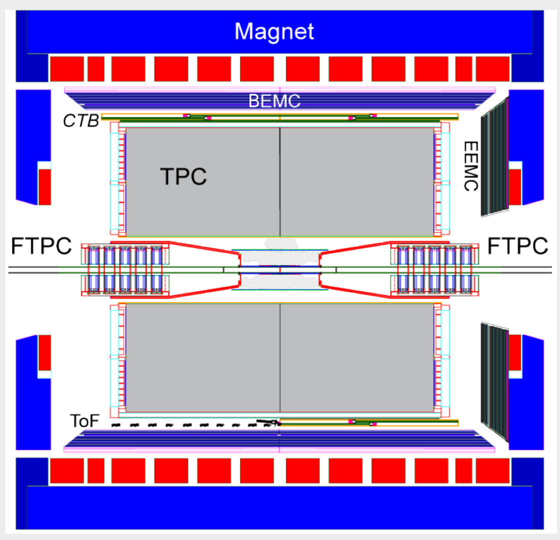
Abstract

Full jet reconstruction in heavy-ion collisions is a promising tool for quantitative study of properties of the dense medium produced at RHIC. Measurements of d+Au collisions are important to disentangle initial state nuclear effects from medium-induced k_T broadening and jet quenching. Therefore study of jet properties in d+Au system is an important baseline measurement needed to better understand heavy-ion results. Jet reconstruction also enables study of underlying event structure in d+Au collisions. The large acceptance of the Time Projection Chamber (TPC) and the Barrel Electromagnetic Calorimeter (BEMC) detectors makes the STAR experiment well suited for full jet reconstruction. Utilizing the high luminosity delivered by RHIC in run 8, a large data sample of 200 GeV d+Au collisions has been collected. Apart from minimally biased trigger, several fast online BEMC triggers have been used to enrich the rate of recorded jets. We report measurements of the inclusive jet spectrum, jet structure and di-jet correlations in d+Au that are sensitive to initial state nuclear effects, and compare to similar measurements in p+p collisions and di-hadron correlation measurements. In order to assess the systematic uncertainties on jet reconstruction, we apply several modern jet reconstruction algorithms [1,2]. To understand trigger bias, systematic study of reconstructed jets in the BEMC triggered data samples is compared to minimum bias data.

STAR experiment

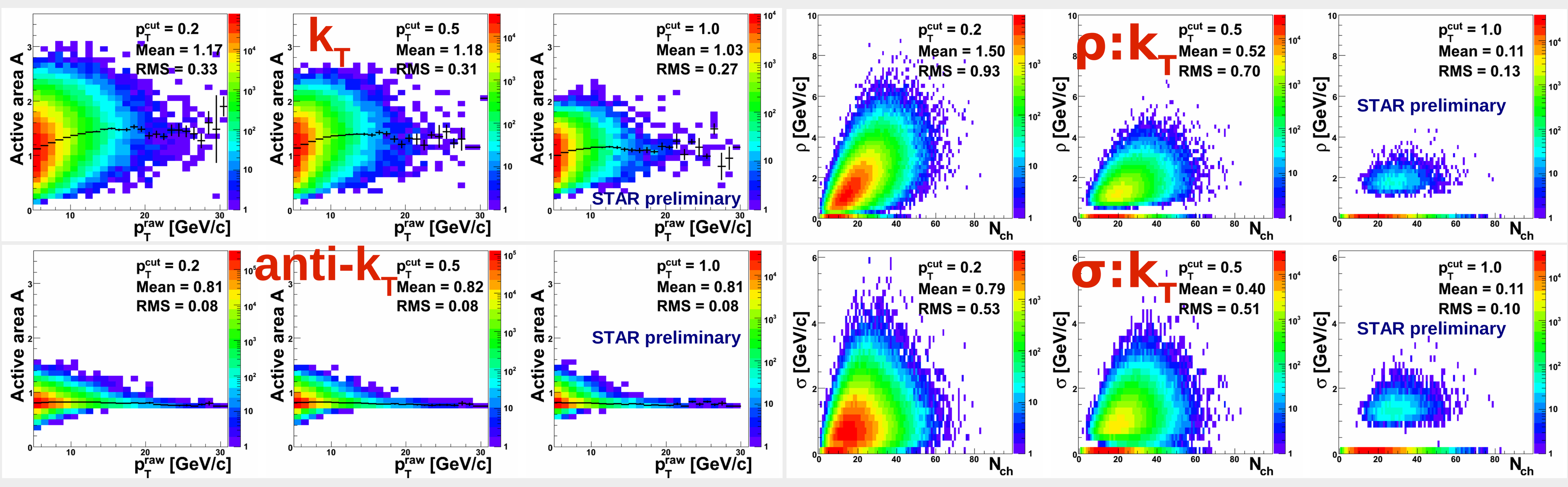
- Data sample:
  - 20% highest multiplicity d+Au collisions (run 8)
  - 7.5M minimum bias triggered events: MB
  - 0.6M (46k) high-tower E_T>4.3 (8.4) GeV triggered events: HT2 (HT4)
- charged energy: tracks from the Time Projection Chamber (TPC), p_T<15 GeV/c
- neutral energy: towers from the Barrel Electromagnetic Calorimeter (BEMC)
- electron+hadronic correction: 100% of associated charged track p_T subtracted off tower E_T
- acceptance: pseudo-rapidity $|\eta|$ < 0.9, full azimuth



Jet reconstruction

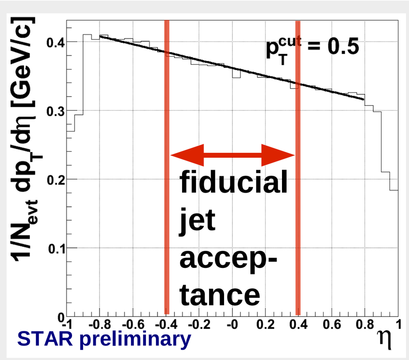
- k_T and anti-k_T sequential recombination jet finding algorithms, as implemented in Fastjet package [1,2]
- resolution parameter R=0.5 used for jet algorithms: fiducial jet acceptance $|\eta|$ < 0.4
- neutral energy fraction in reconstructed jets required in 0.1 – 0.9
- study influence of background with three different p_T cuts (on track/towers): $p_T > p_T^{cut}$, p_T^{cut} = 0.2,0.5,1.0 GeV/c

- subtraction of underlying event background [3] corresponding to active jet area (A) for measured jet momenta p_T^{raw}:
  $p_T = p_T^{raw} - A*\rho \pm \sqrt{A} * \sigma$
- ρ is background energy density, obtained on per-event basis: ρ = median $\{r^i\}$, $r^i = p_T^i/A^i$
- σ is the background fluctuation within event
- k_T algorithm is used to measure ρ and σ
- one (five) random sets of ghosts with size 0.01 used to determine A for anti-k_T (k_T) jet algorithm



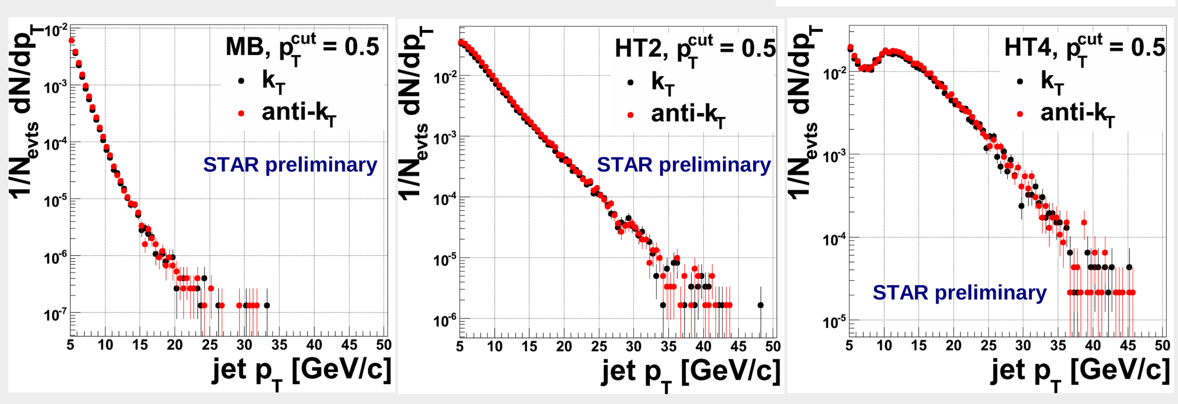
Pseudo-rapidity dependence of background:

- inherent asymmetry of d+Au system -> background depends on pseudo-rapidity
- η dependence of charged+neutral transverse energy is measured and fit
- ρ is weighted according to jet pseudo-rapidity
- overall effect of η dependence is negligible for jets in $|\eta|$<0.4



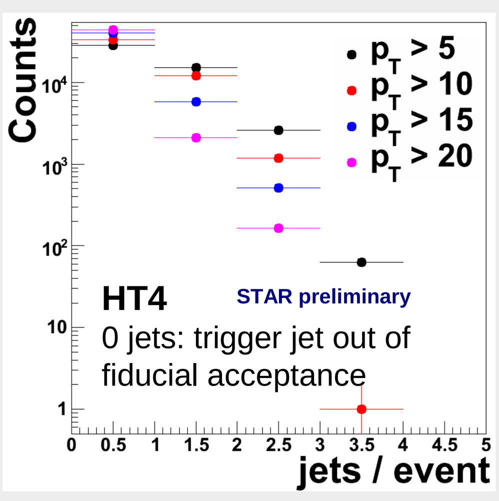
Background-subtracted jet p_T spectra:

- not corrected for detector effects
- k_T and anti-k_T give similar results
- anti-k_T slightly higher for lower p_T jets
- strong trigger bias visible in HT4
- p_T reach: 30 GeV/c (MB), 50 GeV/c (HT)



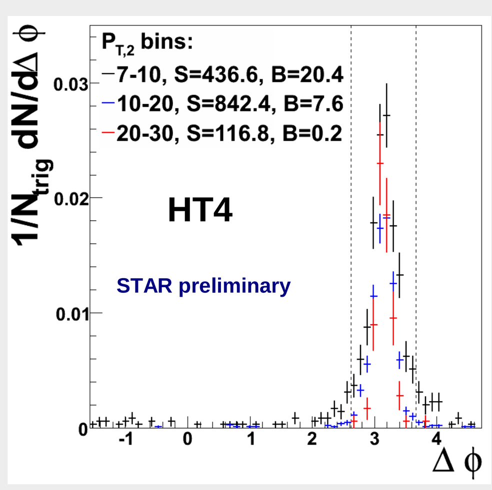
Di-jet analysis

- two highest energy jets in event: $p_{T,1} > p_{T,2}$
- three bins in $p_{T,2}$: 7-10, 10-20, 20-30 GeV/c
- anti-k_T algorithm, p_T^{cut}=0.5 GeV/c



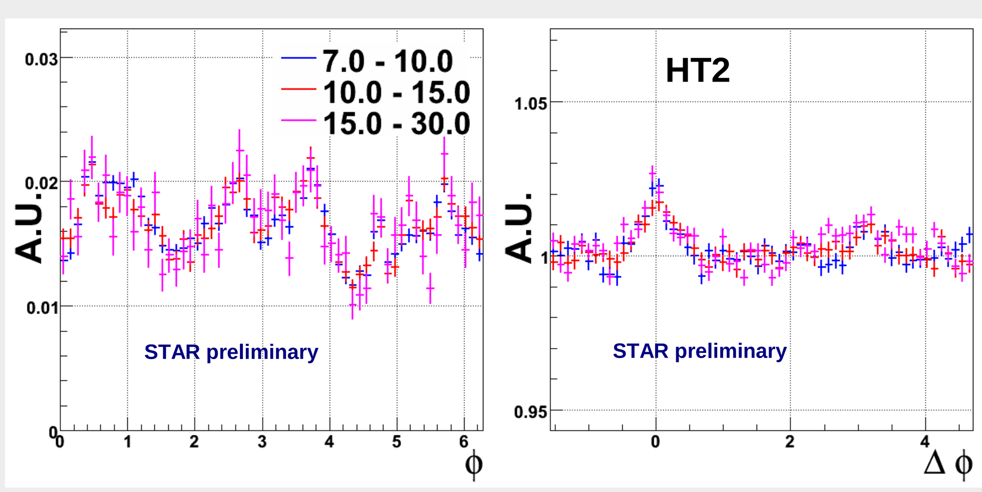
Δφ distributions for jet pairs:

- clear high-purity di-jet signal observed
- signal (S) and background (B) values correspond to the dashed-line region



Azimuthal acceptance of jets and di-jets:

- independent of jet p_T (shown for 3 p_T bins)
- non uniformities in track and tower acceptance enhanced in jet reconstruction
- resulting effect on di-jet acceptance is negligible

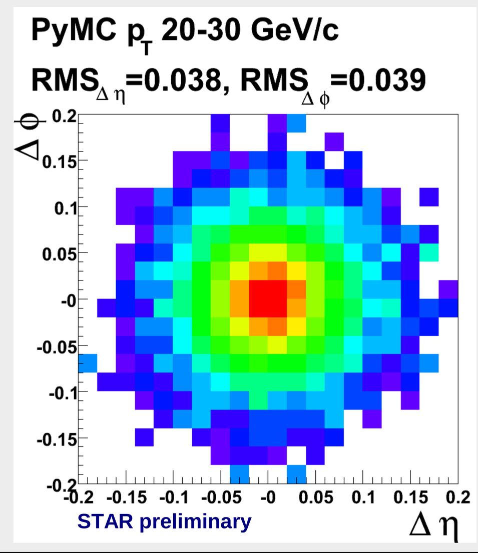


Corrections of detector resolution

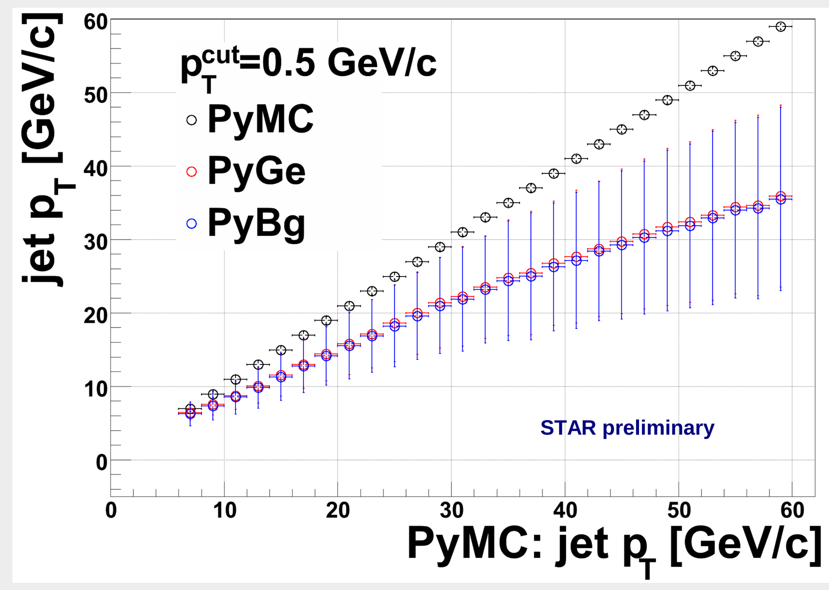
- Pythia 6.410 ("PyMC") + STAR detector response simulation ("PyGe")
- emulated response of HT2 / HT4 trigger
- Pythia mixed with d+Au minimum bias at reconstructed track/tower level ("PyBg") to check the background subtraction and it residual effect on reconstructed jet momenta
- matched to PyMC jets with p_T^{cut} = 0.2 GeV/c, plots shown for anti-k_T algorithm

jet matching to PyMC:

- matched PyBg jets: $\sqrt{(\Delta\eta^2 + \Delta\varphi^2)}$ < 0.2



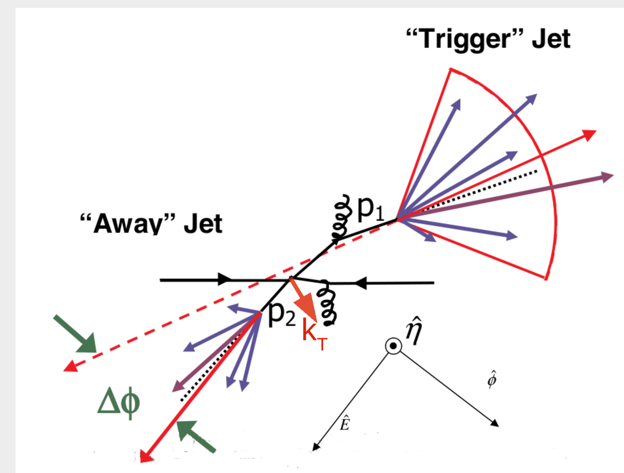
jet p_T resolution:



k_T measurement

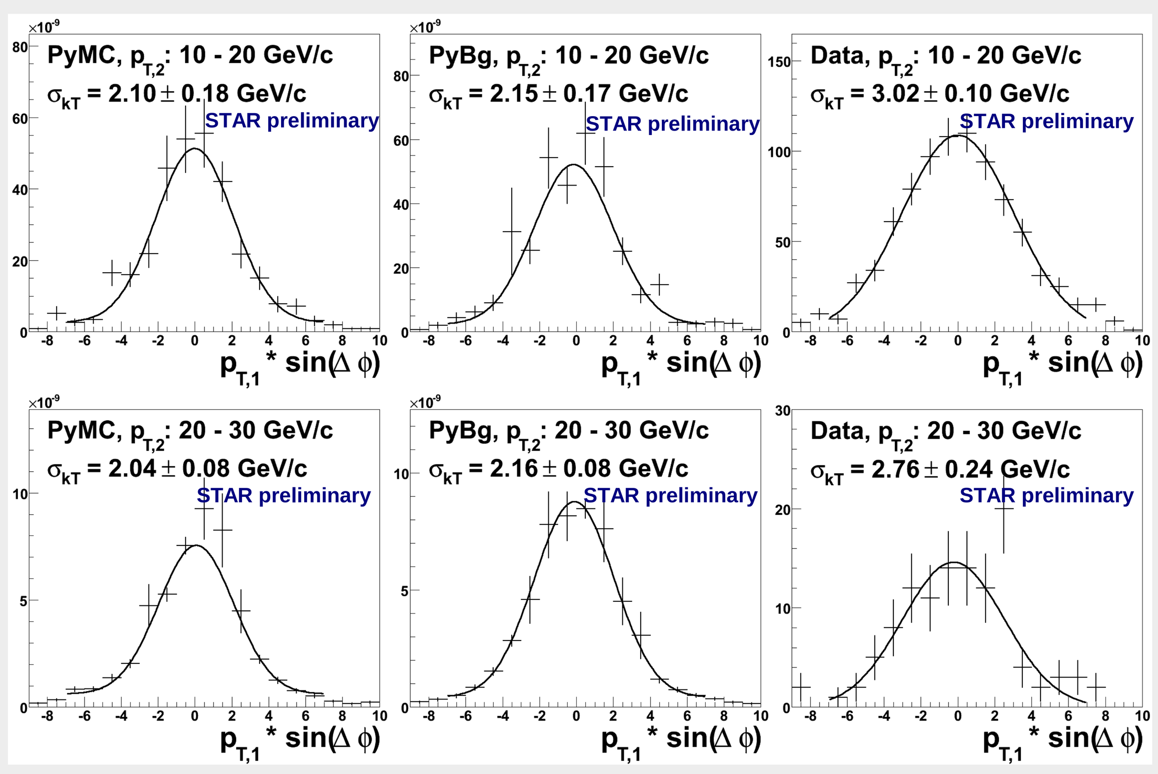
- previous STAR measurement at $\sqrt{s_{NN}}$=200 GeV (run 3) [4]:
  - p+p: σ_{kT} = 2.08 ± 0.12 ± 0.13 GeV/c (similar to Pythia)
  - d+Au: σ_{kT} = 2.2 ± 0.5 ± 0.5 GeV/c (without multiplicity cut)
- $k_T = p_{T,1} * \sin(\Delta\varphi)$ for di-jets, get sigma from Gaussian fit
- compare PyMC and PyBg to estimate detector effects
- using p_T^{cut} = 0.2 GeV/c (PyMC), 0.5 GeV/c (PyBg, Data)

- compare several different settings and datasets to estimate systematic uncertainty:
  - trigger: HT2, HT4
  - $p_{T,2}$ bins: 10-20, 20-30 GeV/c
  - jet algorithm: k_T, anti-k_T



partonic k_T projected to φ direction

k_T distributions for HT4 trigger, anti-k_T algorithm



Results:

- sigma fit parameter doesn't differ between PyMC and PyBg beyond its statistical errors and this difference shows no systematics
- resulting σ_{kT} value is therefore obtained directly from fit to Data
- average over different settings gives σ_{kT} = 3.0 ± 0.1 (stat) GeV/c
- total systematic uncertainty based on different behaviour of Gaussian fits to simulation and data is expected in the order 0.2 GeV/c
- detailed study of STAR TPC performance in high luminosity is ongoing, its systematic effect expected to be 0.3 GeV/c
- we estimate the total systematic uncertainty to be 0.4 GeV/c

Conclusions

- modern jet algorithms have been evaluated using d+Au collisions and pseudo-rapidity dependent background, influence of azimuthal acceptance for di-jets and detector effects have been studied
- sigma width of k_T distribution in 20% highest multiplicity d+Au collisions at $\sqrt{s_{NN}}$=200 GeV has been measured:
  σ_{kT} = 3.0 ± 0.1 (stat) ± 0.4 (syst) GeV/c
- systematic effects for this measurement are under study

References

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[3] M. Cacciari and G. Salam, Phys. Lett. B659, (2008) 119-126.
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