Jet properties in *p+p* and their possible modification in cold nuclear matter in STAR

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Abract : The intrinsic transverse momentum of partons and the possible initial and initial state gluon radiation associated with hard scatterings give rise to an acoplanarity of di-jets which depends on both the Q^2 of hard scatterings and the center of mass energy of the colliding beams. Multiple scatterings of the hard scattered partons in cold nuclear matter may also alter the measured acoplanarity when compared to those in p+p. Studies in d+Au collisions are therefore vital to disentangle medium-induced k_t broadening from initial state nuclear effects and any potential broadening due to jet quenching in the medium produced in heavy-ion collisions. While full jet reconstruction is a direct way to study such acoplanarities, di-hadron correlations with respect to a high momentum leading particle can also be utilized as a complementary tool.

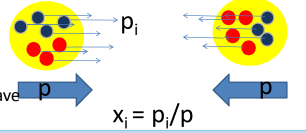
Two quantities commonly used to characterize the properties of jets are jt, the transverse momentum of the jet fragments relative to the jet axis, and kt, the transverse component of the momentum of the hard scattered partons. Measurements of the jet parameters, $\sqrt{\langle j_t^2\rangle}$ and $\sqrt{\langle k_t^2\rangle}$ at STAR in p+p collisions at $\sqrt{s}$ = 62.4, 200 and 500 GeV extracted from di-hadron correlations are presented. π^0 (Et = 6.5 to18.5 GeV) and charged tracks (pt = 3.0-8.5 GeV/c) are used as trigger particles in these analyses. The results extracted at $\sqrt{s}$ = 200 GeV will be compared to those using full jet reconstruction and contrasted to measurements made for several d+Au centralities.

Historical Background

$$E_c \frac{d\sigma}{d^3 p_c}(AB \to C+x) = \sum_{a,b,c,d} \int dx_a dx_b dz_c G_{a/A}(x_a) G_{b/B}(x_b) D_{C/c}(z_c) \frac{\hat{s}}{z_c^2} \frac{d\sigma}{d\hat{t}}(ab \to cd)\, \delta\left(\hat{s}+\hat{t}+\hat{u}\right)$$

Particle production in 2→2 (AB→CX) hard scattering formalism

Parton distribution function in DIS provide us the longitudinal information of partons momentum in terms of pdf, $f(x,Q^2)$



p_i

$x_i = p_i/p$

Due to confinement of partons inside hadrons there should have an intrinsic transverse momentum of partons ($\langle k_t\rangle$ ~300 MeV)

$$dx_a G_{a/A}(x_a, Q^2) \to dx_a d^2k_{ta} f(k_{ta}) G_{a/A}(x_a, Q^2)$$

$$f(k_{ta}) = \frac{e^{-k_t^2/\langle k_t^2\rangle}}{\pi \langle k_t^2\rangle}$$

Large initial p_t-kick to hard-scattered partons is need to Explain particle production at high p_t.

$\langle k_t\rangle = \langle k_t\rangle_{intrinsic} + \langle k_t\rangle_{NLO} + \langle k_t\rangle_{Soft}$

Smearing of the intrinsic k_t due to ISR and FSR increases $\langle k_t\rangle$

SPS the partons need $\langle k_t\rangle$ ~ 1 GeV/c to explain the data of photon production at large p_t

Multiple scattering in presence of nuclear matter : how significant is $\langle k_t\rangle$ broadening in presence of Nuclear matter $A^{1/3}$ dependency

Aim of the Study

How does $\langle k_t\rangle$ behave with : (1) center of mass energy of collisions (STAR $\sqrt{s}$ = 62.4, 200 and 500 GeV)
(2) Q^2 of hard scatterings

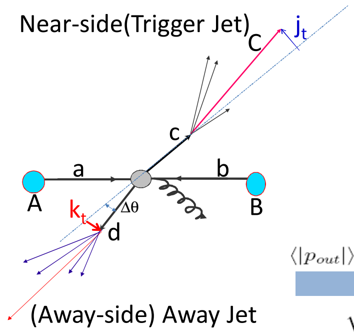
How does $\sqrt{\langle k_t^2\rangle}$ changes in d+Au collisions in comparison to pp collisions at 200 GeV

How width and acoplanarity depends on the centrality in d+Au collisions

Method of extraction of j_t and k_t

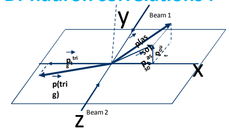
Jet transverse Momentum (j_t) : Average momentum of particles fragmenting from a jet perpendicular to the jet axis

Dijet acoplanarity vector (k_t) : Resultant vector of the two hard scattered plarons in the transverse plane



Jet reconstruction : reconstruction of partons ***c*** and ***d*** and obtain the vector, $k_t = p_{t,\,jet} \sin(\Delta\theta)$

Di-hadron correlations :



$$\langle |p_{out}|\rangle^2 = x_E^2 [2\langle |k_{Ty}|\rangle^2 + \langle |j_{Ty}|\rangle^2] + \langle |j_{Ty}|\rangle^2$$

S.S. Adler et al., Phys. Rev. D74 072002(2006).

$$\sqrt{\langle j_t^2\rangle} = \sqrt{2}\frac{p_t^{asso} p_t^{trig}}{\sqrt{(p_t^{asso})^2 + (p_t^{trig})^2}} \sigma_N{}^2$$

$$\sqrt{\langle k s_t^2\rangle} = \frac{\langle z_t(k_t, x_h)\rangle \sqrt{\langle k_t^2\rangle}}{\hat{x}_h(k_t, x_h)} = \frac{1}{x_h}\sqrt{\langle p_{out}^2\rangle - \langle j_{ty}^2\rangle(1+x_h^2)}$$

$\hat{x}_h = \frac{\hat{p}_t^{asso}}{\hat{p}_t^{trig}}$ and $\langle z_t\rangle = \frac{p_t^{trig}}{\hat{p}_t^{trig}}$ is calculated using PYTHIA simulations

Results

Datasets

Trigger : Neutral clusters from BEMC

- For E_t^{trig} of π^0 > 6.5 GeV/c both the decay-photons fall within single tower
- Tower are rejected if a charge track with p_t > 1 GeV is projected in it
- |Z_vertex| < 30 cm
- $|\eta|$(trigger) < 0.7

Associated particles : tracks from TPC with

- $|\eta|$ < 1.0, dca < 1.0 cm and number of fit points >=20

dAu(2003) and pp (2006) at $\sqrt{s_{NN}}$ = 200 GeV) is used

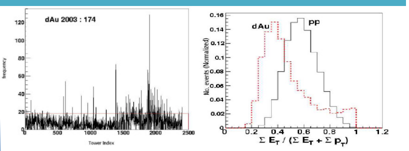
π^0-ch correlations : HT-2 datasets

Trigger particles are mostly π^0 (6.5 < E_t^{trig} < 18.5 GeV/c)

ch-ch correlations : MB datasets

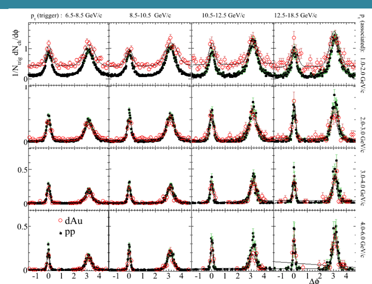
Trigger particles charged particles(4 < p_t^{trig} < 8.5 GeV/c)

Event Selection

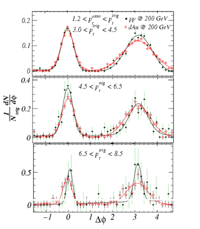


(A) Hot tower rejection : based on hit frequency distribution of BEMC towers. Hot Towers - 6.8%(dAu) 2.8%(pp)

(B) Neutral by charge energy deposition in the c entral region (-1 < η< 1)



$$f(\Delta\phi) = Y_{near}\frac{e^{-(\Delta\phi)^2/2\sigma_{near}^2}}{\sqrt{2\pi}\sigma_{near}} + Y_{away}\frac{e^{-(\Delta\phi-\pi)^2/2\sigma_{away}^2}}{\sqrt{2\pi}\sigma_{away}} + B$$

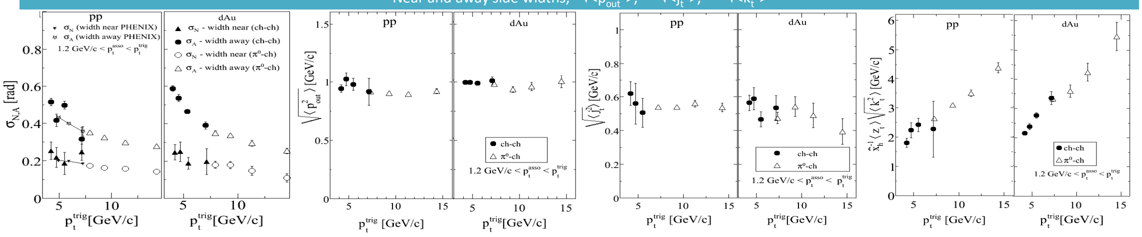


Di-hadron Correlation functions

: fitted with 2-gaussian+pol2

With/Without Background

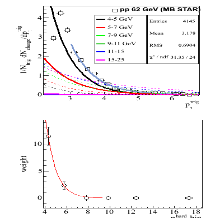
Near and away side widths, $\sqrt{\langle p_{out}^2\rangle}$, $\sqrt{\langle j_t^2\rangle}$, $\sqrt{\langle k_t^2\rangle}$



Extraction of (x_h^{-1} and $\langle Z_t\rangle$) factor from PYTHIA

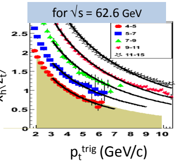
$$f = (f_1 \times x_1 + f_2 \times x_2 + f_3 \times x_3 + ..)/(x_1 + x_2 + x_3 + ..)$$

$$\text{“}f\text{”} = \langle x_h\rangle^{-1} \times \langle z_t(k_t, x_h)\rangle$$



Distribution of p_t^{trig} of data Is matched with simulation

for $\sqrt{s}$ = 62.6 GeV

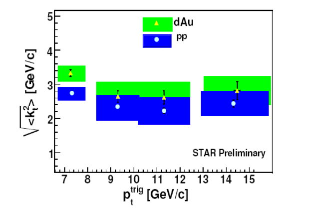


$\hat{x}_h = \frac{\hat{p}_t^{asso}}{\hat{p}_t^{trig}}$ $\langle z_t\rangle = \frac{p_t^{trig}}{\hat{p}_t^{trig}}$

for $\sqrt{s}$ = 200 GeV

p_t^{trig}	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5
f	2.02	1.63	1.32	1.09	0.93	0.81	0.72	0.65	0.61	0.57	0.55	0.54
$f(sys)$	0.096	0.052	0.056	0.076	0.097	0.113	0.123	0.125	0.119	0.106	0.083	0.052

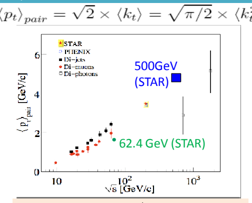
$\sqrt{\langle j_t^2\rangle}$ and $\sqrt{\langle k_t^2\rangle}$ for $\sqrt{s}$ = 200 GeV



$\sqrt{\langle k_t^2\rangle}$ is independent with p_t^{trig}

$\langle p_t\rangle_{pair}$ at $\sqrt{s}$ = 62.4, 200GeV, 500GeV

$$\langle p_t\rangle_{pair} = \sqrt{2} \times \langle k_t\rangle = \sqrt{\pi/2} \times \langle k_t^2\rangle$$

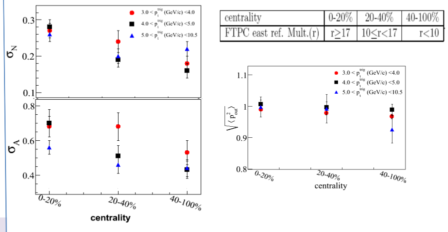


3.5<p_t^{trig}<8.5 for $\sqrt{s}$ =62.4 GeV
6.5<p_t^{trig}<18.5 for $\sqrt{s}$ =200 GeV

$\langle p_t\rangle_{pair}$ increases with $\sqrt{s}$
Consistent with earlier measurement

Width, $\sqrt{\langle p_{out}^2\rangle}$ with centralities for d+Au ($\sqrt{s}$=200GeV)

MinimumBias datasets : charged-charged correlation



Shows a trend of centrality dependence

Summary

(A) for $\sqrt{s}$ = 200 GeV (6.5<p_t^{trig} (π^0)<18.5)

System	$\sqrt{\langle j_t^2\rangle}$ (π^0 -ch) MeV/c	$\sqrt{\langle j_t^2\rangle}$ (ch -ch) MeV/c	$\sqrt{\langle k_t^2\rangle}$ (π^0-ch) MeV/c
p+p	576±11	598±28	2.80 ± 0.04(stat) ± 0.27(sys)
d+Au	576±42	576±44	3.41 ± 0.03(stat)±0.31(sys)

$\sqrt{\langle k_t^2\rangle}$ is independent with p_t^{trig}

(B) $\sqrt{\langle k_t^2\rangle}$ ($\langle p_t\rangle_{pair}$) increases with $\sqrt{s}$

(C) Width and $\sqrt{\langle p_{out}^2\rangle}$ for d+ Au collisions shows a trend of centrality dependence

Using direct jet reconstruction (Poster : 428)
$\sqrt{\langle k_t^2\rangle}$ (p+p) = 2.8 ±0.1 GeV/c
$\sqrt{\langle k_t^2\rangle}$ (d+Au) = 3.0 ± 0.1 GeV/c

Discussions :

- Selection of well defined di-jet events might put bias on selection of events samples
- Di-hadron results contain larger uncertainty in calculating fragmentation correction factor

References :
[1] R.P Feynman, R.D. Field, and G.C. Fox, Phys. Rev. D18 3320(1978).
[2] S.S. Adler et al., Phys. Rev. D74 072002(2006).

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