Di-jet Hadron Correlations in Au+Au Collisions at STAR at $\sqrt{s_{NN}} = 200$ GeV

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Jets

theory: $X \rightarrow q\bar{q}$ (or $g$)

experiment: collimated shower of hadrons

theory $\rightarrow$ jet finding $\rightarrow$ experiment

jets are calculable: pQCD

experimental agreement with theoretical predictions

FastJet


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Jets in the QGP

hard scattering happens early
internal probe of the QGP
partonic energy loss
broadening & softening

jet production  probes medium evolution
Jets in the QGP at STAR

Δφ

jet-hadron correlations

enhancement of recoil jet low $p_T$ constituents

suppression of recoil jet high $p_T$ constituents

how to measure jet-by-jet energy loss?
Hard core jets at STAR

in a heavy ion background

large background energy density
Hard core jets at STAR

in a heavy ion background

$p_T^{\text{const}}>2 \text{ GeV/c cut}$ removes almost all background
Hard core jets at STAR

in a heavy ion background

\( p_T^{\text{Cut}} = 2 \text{ GeV/c} \)
\( p_T^{\text{Lead}} > 20 \text{ GeV/c} \)
\( p_T^{\text{SubLead}} > 10 \text{ GeV/c} \)
\( |\Delta \phi - \pi| < 0.4 \)
\( \text{anti-kt } R=0.4 \)

\( p_T^{\text{const}} > 2 \text{ GeV/c cut} \)
removes almost all background

geometric matching
no combinatoric jets, recover all constituents

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Di-jet imbalance at STAR

Hard core di-jets imbalanced with respect to p+p

When soft constituents are included: balance restored to the level of p+p in R=0.4

More differential di-jet hadron correlations
Di-jet hadron correlations

di-jet definition
\[ p_T^{\text{Cut}} = 2 \text{ GeV/c} \]
\[ p_T^{\text{Lead}} > 20 \text{ GeV/c} \]
\[ p_T^{\text{SubLead}} > 10 \text{ GeV/c} \]
\[ |\Delta \phi - \pi| < 0.4 \]
anti-\( k_T \) \( R = 0.4 \)

correlations
\[ \Delta \eta = \eta^{\text{jet}} - \eta^{\text{track}} \]
\[ \Delta \phi = \phi^{\text{jet}} - \phi^{\text{track}} \]

Au+Au
0-20% central
\( 1.0 < p_T^{\text{assoc}} < 2.0 \text{ GeV/c} \)

systematic uncertainties
- tracking efficiency (±5%)
- relative jet energy scale
- relative tracking efficiency (±7%)
- relative tower energy scale (±2%)

jetfinding correlations & yields

detector level
particle level

Trigger jet
Recoil jet

STAR Preliminary
Correlations in $\Delta \eta$

project onto $\Delta \eta$

jet signal centered at (0,0)

underlying event

fit with a constant+gaussian
constant subtracted as background
Correlations in $\Delta\eta$ for $1.0 < p_{T,assoc} < 2.0$ GeV/c

$|\Delta\phi| < 0.71$

projection range

yield contained within jet radius $R=0.4$
Correlations in $\Delta \eta$

3.0 < $p_T^{assoc}$ < 4.0 GeV/c

projection range

$|\Delta \phi| < 0.71$

yield contained within jet radius R=0.4
Correlations in $\Delta \phi$

- Project onto $\Delta \phi$
- Jet signal centered at (0,0)
- Underlying event
- Modulation in $\Delta \phi$
Correlations in $\Delta \phi$

use sideband subtraction to account for flow in underlying event
Correlations in $\Delta\phi$

$1.0 < p_T^{\text{assoc}} < 2.0 \text{ GeV/c}$

projection range

$|\Delta\eta| < 0.45$

yield contained within jet radius $R=0.4$

similar to $\Delta\eta$

~ circular jets

STAR Preliminary

$1.0 < p_T^{\text{assoc}} < 2.0 \text{ GeV/c}$

$p+p$ eff. corrected to $Au+Au$ 0-20%

$|\Delta\eta|<0.45$

trigger jet

recoil jet
Correlations in $\Delta \phi$

$3.0 < p_T^{assoc} < 4.0$ GeV/c

**trigger jet**

3.0 < $p_T^{assoc}$ < 4.0 GeV/c

$p+p$ eff. corrected to Au+Au 0-20%

$|\Delta \eta| < 0.45$

projection range

$1/N \cdot dN/d\Delta \phi$

$1/\langle N_{dijets} \rangle$

 STAR Preliminary

- Au+Au HT 0-20%
- $p+p$ HT
- tracking unc. Au+Au
- tracking unc. $p+p$
- relative JES unc.

**recoil jet**

3.0 < $p_T^{assoc}$ < 4.0 GeV/c

$p+p$ eff. corrected to Au+Au 0-20%

$|\Delta \eta| < 0.45$

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 STAR Preliminary

- Au+Au HT 0-20%
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yield contained within jet radius R=0.4

similar to $\Delta \eta$

~ circular jets

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Jet constituent Yields

yields consistent between $\Delta \phi$ & $\Delta \eta$

yield contained within $R=0.4$

trigger jet: unmodified

"surface bias"

recoil jet: hint of modification for $p_T^{assoc}<2.0$ GeV/c
Consistent with $A_J$?

How is the energy distributed?

minimal modification at high $p_T$ for both trigger & recoil jets

possible enhancement at low $p_T$ in recoil jet

$A_J$ enhances sensitivity to modification

effect is diluted in ensemble measurements like di-jet hadron correlations

Why a small effect?

Conclusions

“Hard-Core" di-jets at STAR:

- energy recovered within $R=0.4$
- hint of modification of $A_J$ jets on recoil side

Towards the future:

- large new data set
- systematically explore di-jet cuts to constrain path length of jet in medium
- “jet geometry engineering”
Thank you :)

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Event mixing

flattened triangle in signal effect of pair acceptance

Division

Mixed Events Au+Au HT 0-20% Trigger jet-hadron

Corrected Signal Au+Au HT 0-20% Trigger jet-hadron

Max bin in $\Delta \eta$ projection normalized to unity

Correlation signal Au+Au HT 0-20% Trigger jet-hadron

$1.0 < p_{T}^{assoc} < 2.0$ GeV/c

STAR Preliminary
Event mixing

$|\eta^{\text{assoc}}| < 1.0$

$|\eta^{\text{trigger}}| < 1.0 - R$

dexample:
jet-hadron

event mixing

$|\eta^{\text{assoc}}| < 1.0$

$|\eta^{\text{trigger}}| < 1.0$

dexample:
hadron-hadron

event mixing