Heavy Ion Jet Results from CMS

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High-\(p_T\) Probes of the Quark Gluon Plasma

- PbPb collisions (and pp reference) at 2.76 TeV
- High-\(p_T\) partons are produced in initial hard scatterings
- Partons are used as probes passing through the QGP
- Select a sample of back-to-back dijets
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Dijet asymmetry:
\[ A_J = \frac{(p_{T,1} - p_{T,2})}{(p_{T,1} + p_{T,2})} \]
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- Dijet asymmetry:
  \[ A_J = \frac{(p_{T,1}-p_{T,2})}{(p_{T,1}+p_{T,2})} \]

- Asymmetric dijets (large $A_J$) balancing distribution:
  - pp: more $p_T>4$ GeV
  - PbPb: mostly $p_T<2$ GeV
Angular Distribution of Missing-$p_T$

- Missing $p_T$ vs. radius parameter $\Delta = \sqrt{(\Delta \eta^2 + \Delta \phi^2)}$

Focus on unbalanced dijets

- **PbPb central:**
  soft excess to large $\Delta$

- **pp and peripheral:** more particles with $p_T > 4$ GeV
  (also to large angles)

$A_J > 0.22$

$5.3 \text{ pb}^{-1} (2.76 \text{ TeV})$

$p_{T,1} > 120; p_{T,2} > 50 \text{ GeV}$

$|\eta_1,|\eta_2| < 0.6; \Delta \phi_{1,2} > 5\pi/6$
Dijet Correlated Yield Studies

- Construct 2D $\Delta\eta$-$\Delta\phi$ correlations to leading and subleading jet axes
- Subtract combinatorial and long-range correlated background (measured on $1.5<|\Delta\eta|<2.5$ in “sideband” technique)
- Study each jet peak individually

“Sideband” region $1.5<|\Delta\eta|<2.5$
Jet Peak Modifications

- Measure jet shape from background-subtracted correlations:

\[ \rho(r) = \frac{1}{dr} \frac{1}{N_{\text{jet}}} \sum_{\text{jets}} \frac{\sum_{\text{tracks}}(r_a, r_b) p_T^{\text{track}}}{p_T^{\text{jet}}} \]

- Ratio \( \rho(\Delta r)_{\text{PbPb}}/\rho(\Delta r)_{\text{pp}} \) shows redistribution of \( p_T \) to large angles (carried by soft particles)
Per-Jet Particle Yields

- Look at modifications to distributions of charged particles by $p_T$

**Central PbPb:** enhancement of low-$p_T$ ($1<p_T<2$ GeV) particles
- Enhancement present in leading, larger for subleading jets
Per-Jet Particle Yields

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**Central PbPb:** enhancement of low-$p_T$ particles
- Present in leading, larger for subleading jets
- Integrate this excess: jet peak yield by track-$p_T$
Decomposing Hemisphere $p_T$ Balance

**Hemisphere $p_T$ balance by $\Delta \phi$**
- Low-$p_T$ excess in PbPb central collisions enhanced
- Less high-$p_T$ tracks relative to pp reference

**Now decompose into...**
- Leading jet peak
- Subleading jet peak
- Overall subleading-to-leading long range asymmetry (measured on $1.5<|\Delta \eta|<2.5$, $\Delta \eta$-independent)
Decomposing Energy Balance: Jet Peaks

Jet peak contributions for balanced dijets:

• Enhancement of momentum carried by low-\(p_T\) tracks about both leading and subleading jets

• Follows expectations from correlated yield studies
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PbPb – pp, subleading – leading gives contribution to hemisphere balance:
Decomposing Energy Balance: Long Range

- **In pp**: unbalanced dijets are accompanied by a long range excess of yield on the subleading side (momentum conservation/ 3-jet events)
- **In central PbPb**: disappearance of high-$p_T$ long range asymmetry, growth of low-$p_T$ long range asymmetry

"Sideband" region $1.5<|\Delta \eta|<2.5$
• **Three contributions to hemisphere momentum imbalance:**
  o Leading jet peak
  o Subleading jet peak
  o Long range $\Delta \eta$-independent asymmetry

• **Jet peaks:**
  o Excess momentum carried by soft particles ($p_T<$2 GeV) in central PbPb relative to pp
  o Suggests both leading and subleading jets are quenched

• **Long range asymmetry:**
  o pp: $\Delta \phi$-correlated excess of high-$p_T$ (4-8 GeV) associated particles, attributed to additional jets as required by momentum conservation in unbalanced dijet events
  o PbPb (central): unbalanced jet selection includes more quenched 2-jet events and as 3rd jets present in this selection are quenched