Reconstructed Jet Results in $p+p$, $d+Au$ and $Cu+Cu$ collisions at 200 GeV from PHENIX

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Jet reconstruction is being done in heavy ion collisions at RHIC and the LHC:

- Reconstruct full fragmenting parton kinematics at LO.
- Sensitive probe of suppression/quenching effects.
Why Jets at RHIC?

- Complementary set of measurements from two high statistics colliders!

- Can measure jet modification at:
  - lower energies due to smaller underlying event
  - different $x$ and $Q^2$ (different mixture of quark and gluon jets)

- Versatility of collision species provides:
  - ability to vary system size, energy density, geometry
  - control against cold nuclear matter effects

⇒ hard probes analyses from $Cu+Au$ and $U+U$ in progress!
PHENIX detector

- Drift Chamber (DC), Pad Chambers (PC) and Ring Imaging Čerenkov Detector (RICH) measure charged hadrons and electrons

- Electromagnetic Calorimeter (EMCal) clusters photons, $\pi^0$'s, (some) neutral hadrons

- EMCal/RICH Trigger (ERT) and the high PHENIX DAQ rate allow complementary Minimum Bias and high-$p_T$ triggered datasets
Gaussian Filter algorithm

- Seedless, cone-like algorithm with a Gaussian angular weighting (nucl-ex/0806.1499)

\[ p_{T}^{\text{jet}} \equiv \max \left\{ \int \int d\eta' d\phi' p_T (\eta', \phi') e^{-(\Delta \eta^2 + \Delta \phi^2)/2\sigma^2} \right\} \]

- Developed for use in heavy ion collisions.
- Focuses on the energetic core of the jet, optimizing $S/B$
- Stabilizes the jet axis in the presence of background
Fake jet rejection

- Technique to separate low-\(p_T\) jets from underlying event fluctuations in HI collisions on a jet by jet basis.
- Similar to “angularly-weighted” \(p_T\) which rewards jets with a tight core of energy and punishes diffuse jets.
  - \(\Rightarrow\) efficient saturation with reconstructed \(p_T\)
  - \(\Rightarrow\) trade reconstruction efficiency for sample purity
  - \(\Rightarrow\) data-driven approaches set threshold
In PHENIX, energy “resolution” driven by tracking inefficiency, loss of $n, K_L^0$ neutral energy, edge of acceptance effects.

- PYTHIA Tune A 2 $\rightarrow$ 2 QCD events from $Q^2 = 0.5$ to 64 GeV.
  - Cross-checks with HERWIG, other PYTHIA tunes
  - Embedding into real heavy ion background.

- NLO calculation + hadronization correction in progress that will allow proper comparison to data.
Demonstration of PHENIX jet reconstruction and gaussian filter algorithm capability:

- comparison with NLO pQCD across ten orders of magnitude.

Fragmentation function ($z = \frac{p_{\parallel}^{\text{particle}}}{p_{\parallel}^{\text{jet}}}$) measurement:

- required development of n-dimensional generalization of SVD unfolding in GURU!
Jets in $Cu+Cu$ at $\sqrt{s} = 200$ GeV

$\tau_T$-feeding from underlying event:
- subtraction of centrality- and $z$-vertex parameterized average background

$\tau_T$-smearing from UE fluctuations:
- evaluated through embedding $p+p$ jets into $Cu+Cu$ minimum bias events
- results shown here unfolded to $p+p$ reconstructed scale
Suppression without de-correlation in \textit{Cu+Cu}

- Suppression of reconstructed jet $R_{AA}$:
  - over a wide $p_T$ range
  - increasing suppression in more central collisions

- Reconstructed di-jet $\Delta\phi$ distributions unmodified:
  - no angular de-correlation in central collisions!
Jets in $d+Au$ at $\sqrt{s} = 200$ GeV

- anti-$k_T$ jet reconstruction with $R = 0.3, 0.5$
- Reconstructed jet $R_{CP}$ at the $p+p$ reconstructed scale.
  - relative to peripheral collision baseline
  - $p_T$-feeding from modest underlying event evaluated with embedding procedure and unfolded
- Suppression effect consistent with single-particle $\pi^0$ measurement.
  ⇒ cold nuclear matter energy loss?
  ⇒ impact parameter dependence of nPDFs?
Multiple cone sizes provide additional control against effects of underlying event

$R_{CP}$ exhibits increasing suppression with decreasing impact parameter

Ongoing improvements to analysis will produce:
- $R_{dA}$
- lower $p_T$ behavior
- results at $p_T^{truth}$ scale
nPDF effects in $d+Au \ R_{\text{CP}}$

- Nuclear PDF sets do not parameterize impact parameter dependence:
  - $\Rightarrow$ K. Eskola, Plenary 4B and I. Helenius, Parallel VC

- Leading-order toy study with EPS09 parameters (nucl-th/1011.4534):
  - $\Rightarrow$ quadratic $b$-dependence of Au nPDF from PHENIX $J/\psi$ data, (PRL 107, 142301 (2011))
  - $\Rightarrow$ suppression from nPDF effects underpredicts data
Outlook

- Jet reconstruction efforts at PHENIX are ongoing.
- Preliminary results from $d+Au$ jet reconstruction:
  - suppression effect at high-$p_T$
  - consequences for interpretation of $A+A$ results!
- PHENIX capability for jet measurements improving:
  - VTX (silicon vertex tracker) and FVTX (forward silicon vertex tracker)
Backup Plots I

PHENIX Au+Au, \( \sqrt{s_{NN}} = 200\text{ GeV}, 0-10\% \text{ most central} \)
- direct \( \gamma \) (arXiv:1205.5759)
- \( J/\psi \) 0-20\% cent. (PRL98, 232301)
- \( \pi^0 \) (PRL101, 232301)
- \( \eta \) (PRC82, 011902)
- \( \phi \) (PRC83, 024090)
- \( K^0 \) (PRC84, 044905)
- \( \rho \) (PRC83, 064903)

PHENIX d+Au, \( \sqrt{s_{NN}} = 200\text{ GeV} \)
- preliminary

Outlook
\[ g_{\sigma_{\text{dis}}} (\eta, \phi) \equiv \sum_{i \in \text{fragment}} (p_T)_i^2 \exp \left( \frac{- (\Delta \eta^2 + \Delta \phi^2)}{2 \sigma_{\text{dis}}^2} \right) \]
\( p_{\text{out}} \left( = \langle k_T \rangle \right) \equiv (p_T)_{\text{low}} \cdot \sin \Delta \phi \)}
PHENIX
Jet Results
(19/19)
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Introduction
Jets in PHENIX
Gaussian Filter
Analysis Techniques
p+p
Cu+Cu
d+Au
nPDF effects
Outlook

Backup Plots IV