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

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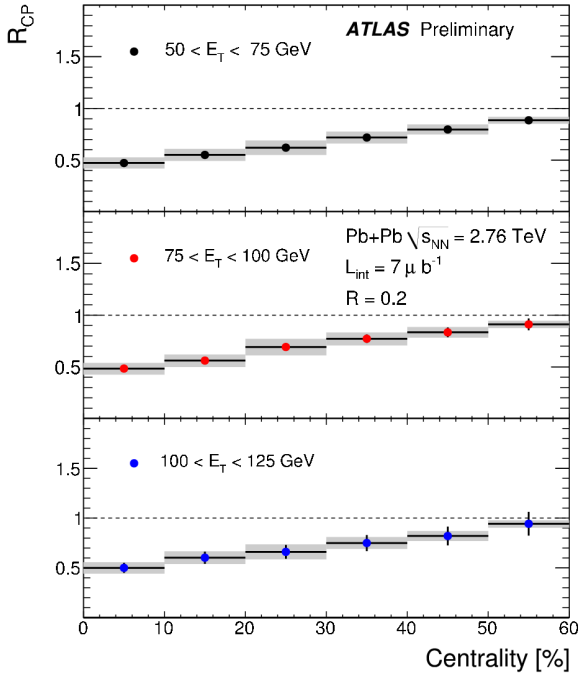
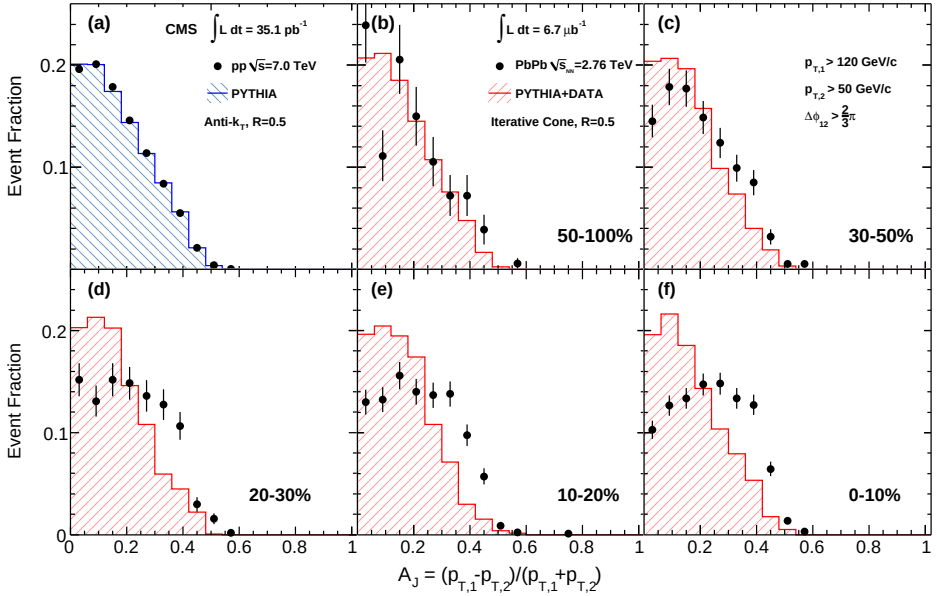
Jets in Heavy Ion Collisions





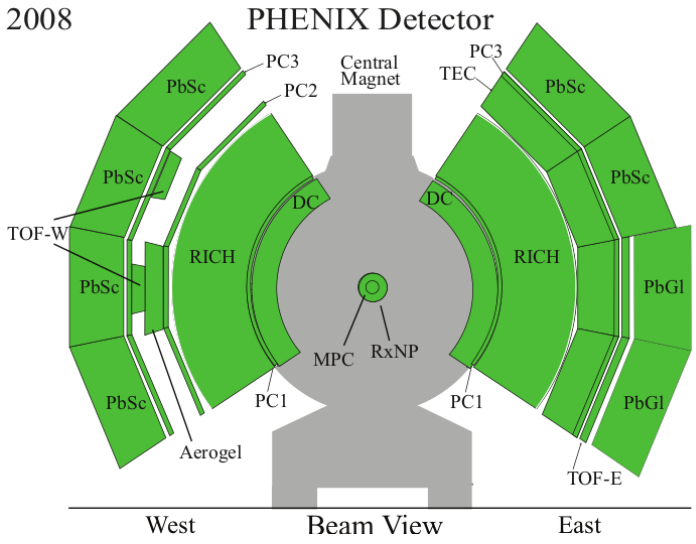
- Jet reconstruction is being done in heavy ion collisions at RHIC and the LHC:
  - Reconstruct full fragmenting parton kinematics at LO.
  - Sensitive probe of suppression/quenching effects.

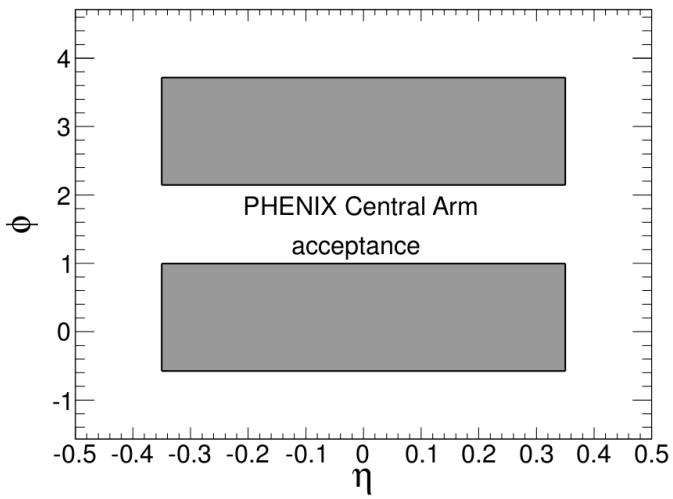
Why Jets at RHIC?

- 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

$\Rightarrow$ hard probes analyses from $Cu{+}Au$ and $U{+}U$ in progress!

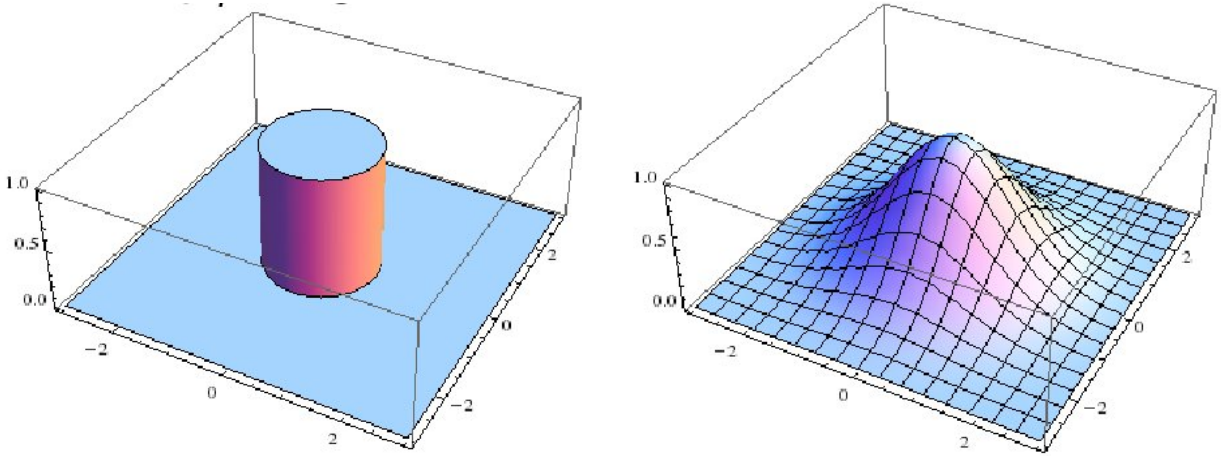
PHENIX detector





- Drift Chamber (DC), Pad Chambers (PC) and Ring Imaging Čerenkov Detector (RICH) measure charged hadrons and electrons
- Electromagnetic Calorimeter (EMCal) clusters photons, π^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

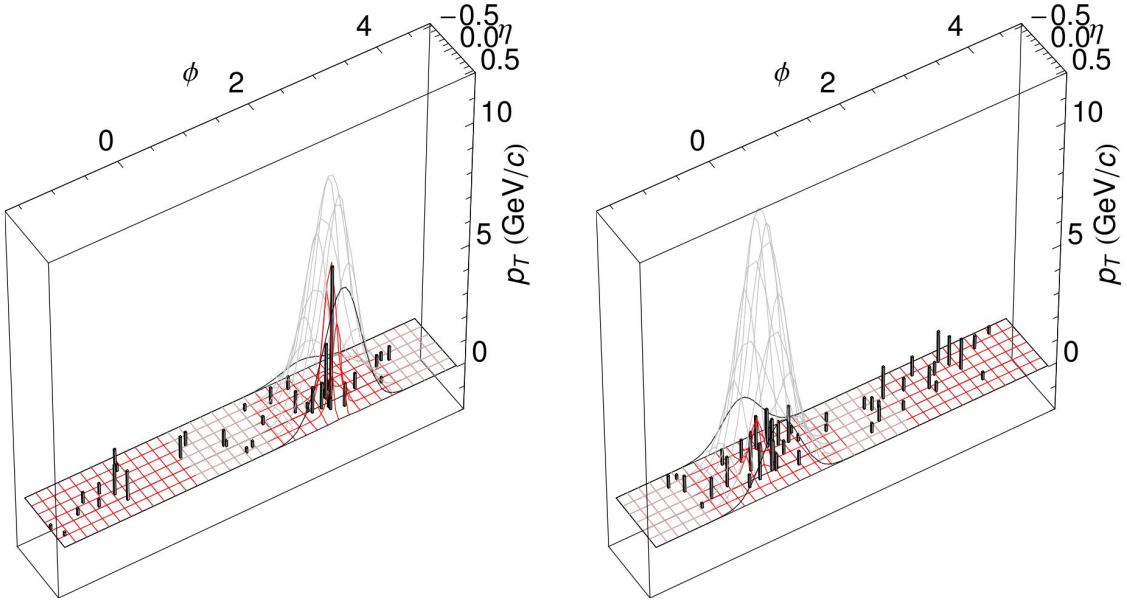


- Seedless, cone-like algorithm with a Gaussian angular weighting (`nucl-ex/0806.1499`)

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

- 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



9.6 GeV/c jet passing fake rejection Rejected 10.8 GeV/c background fluctuation

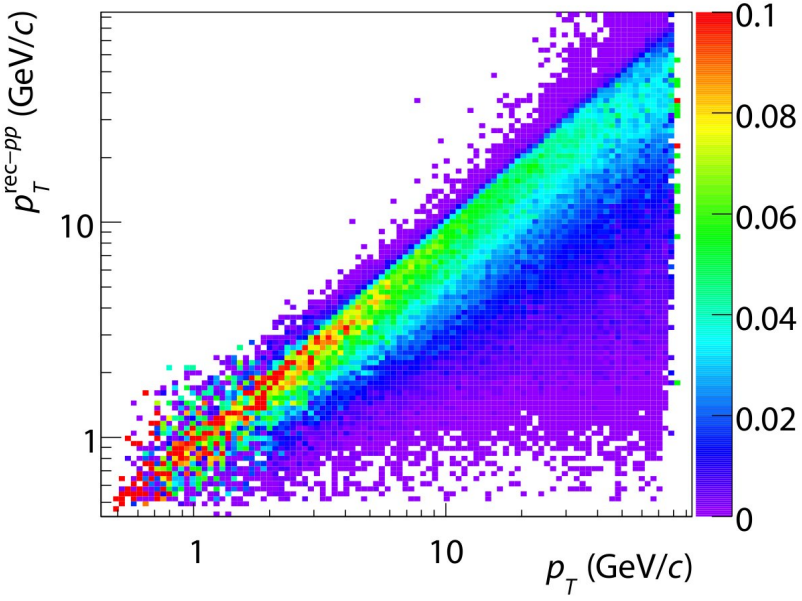
- Technique to separate low-p_{T} jets from underlying event fluctuations in HI collisions on a *jet by jet basis*.
- Similar to "angularly-weighted" p_{T} which rewards jets with a tight core of energy and punishes diffuse jets.

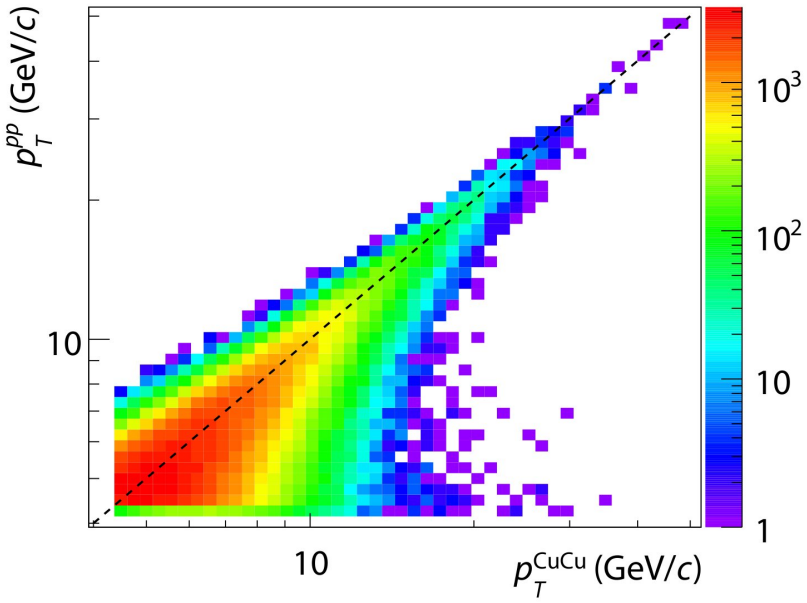
  $\Rightarrow$ efficient saturation with reconstructed p_{T}

  $\Rightarrow$ trade reconstruction efficiency for sample purity

  $\Rightarrow$ data-driven approaches set threshold

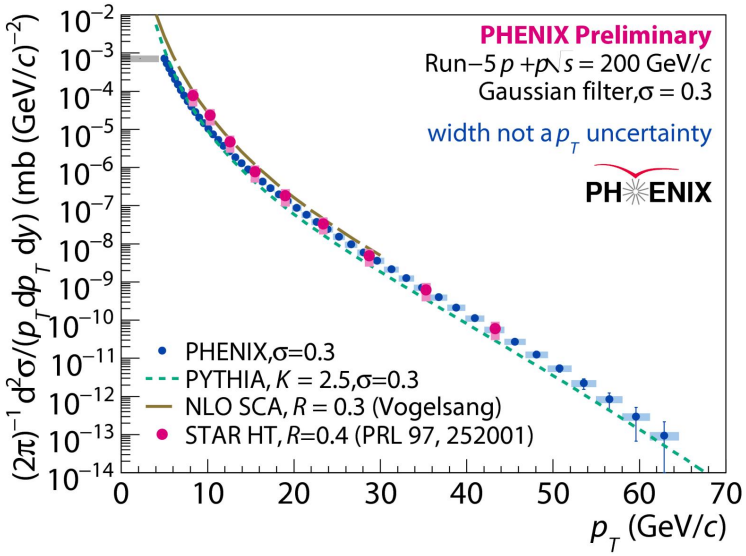
Energy Scale

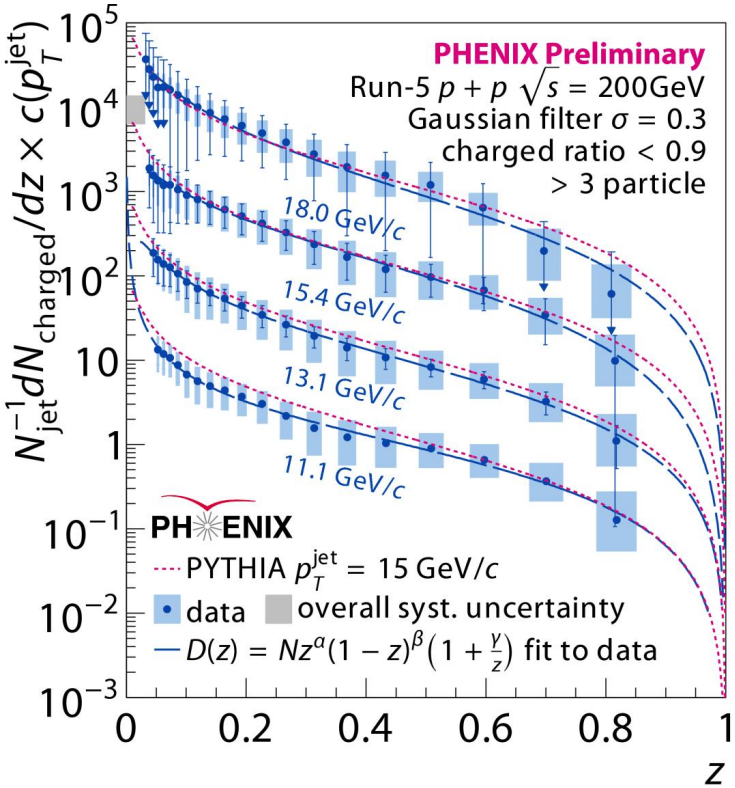




- In PHENIX, energy "resolution" driven by tracking inefficiency, loss of n, K_L^0 neutral energy, edge of acceptance effects.
- PYTHIA Tune A $2 \rightarrow 2$ QCD events from $Q^2 = 0.5$ to 64 GeV.
  - $\Rightarrow$ Cross-checks with HERWIG, other PYTHIA tunes
  - $\Rightarrow$ Embedding into real heavy ion background.
- NLO calculation + hadronization correction in progress that will allow proper comparison to data.

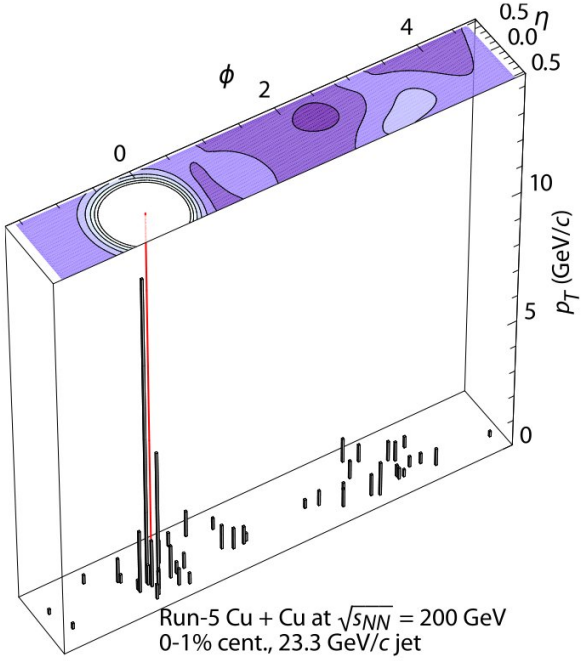
Jets in p+p at $\sqrt{s} = 200$ GeV

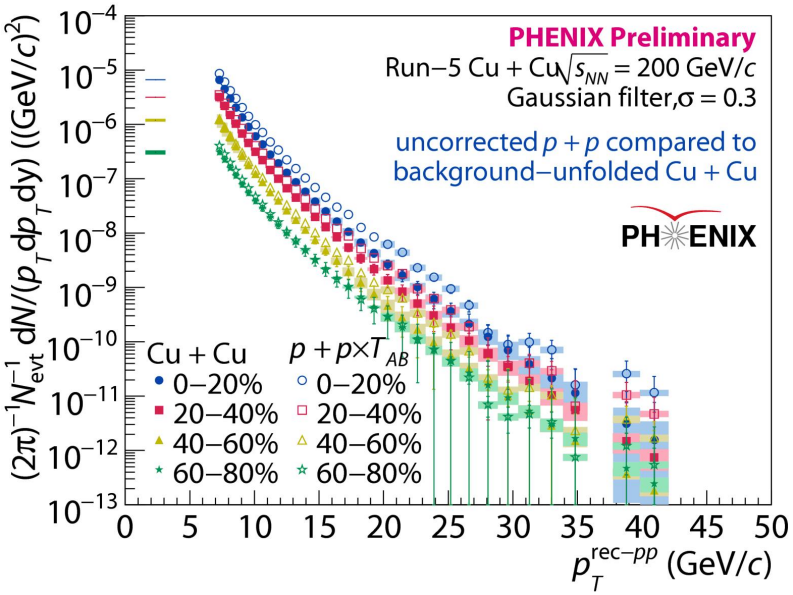




- Demonstration of PHENIX jet reconstruction and gaussian filter algorithm capability:
  - comparison with NLO pQCD across ten orders of magnitude.
- Fragmentation function ($z = p_{||}^{\mathrm{particle}}/p^{\mathrm{jet}}$) measurement:
  - required development of n-dimensional generalization of SVD unfolding in `GURU`!

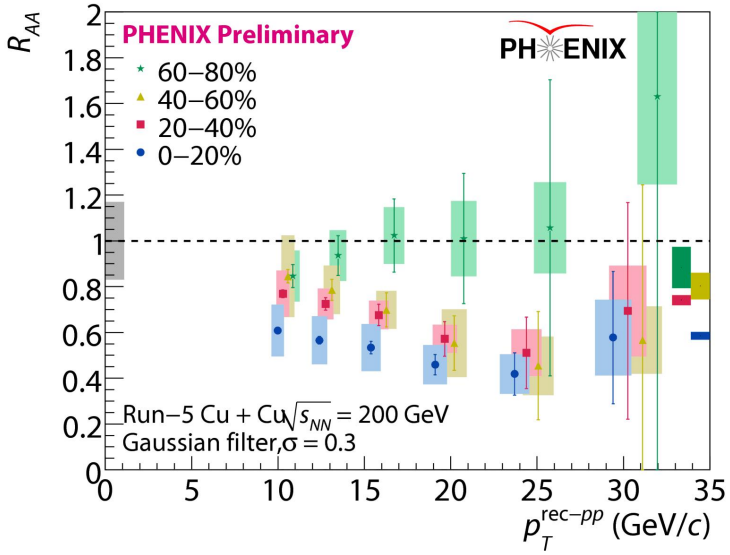
Jets in $Cu{+}Cu$ at $\sqrt{s} = 200$ GeV

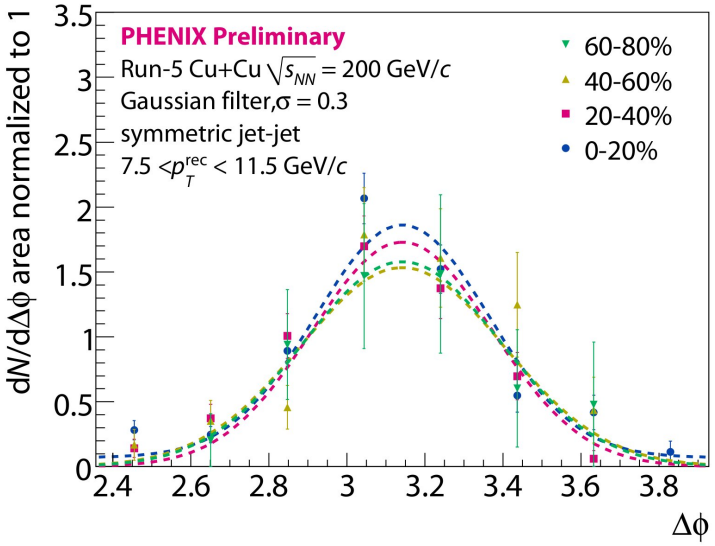




- p_{T}-feeding from underlying event:
  - subtraction of centrality- and z-vertex parameterized average background
- p_{T}-smearing from UE fluctuations:
  - evaluated through embedding $p{+}p$ jets into $Cu{+}Cu$ minimum bias events
  - results shown here unfolded to $p{+}p$ reconstructed scale

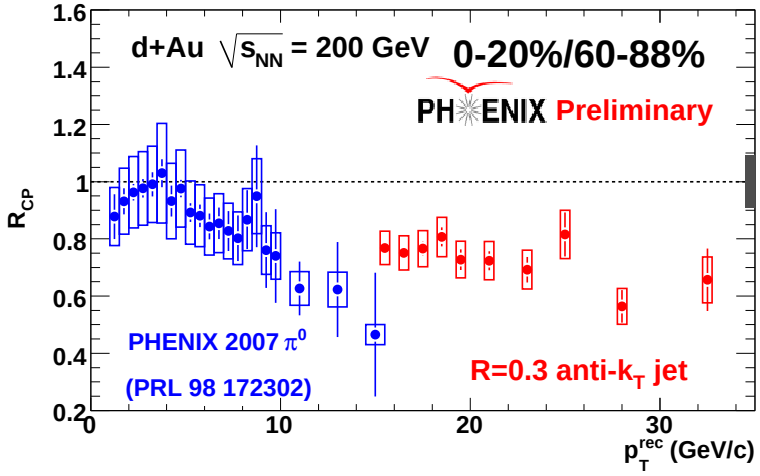
Suppression without de-correlation in *Cu+Cu*

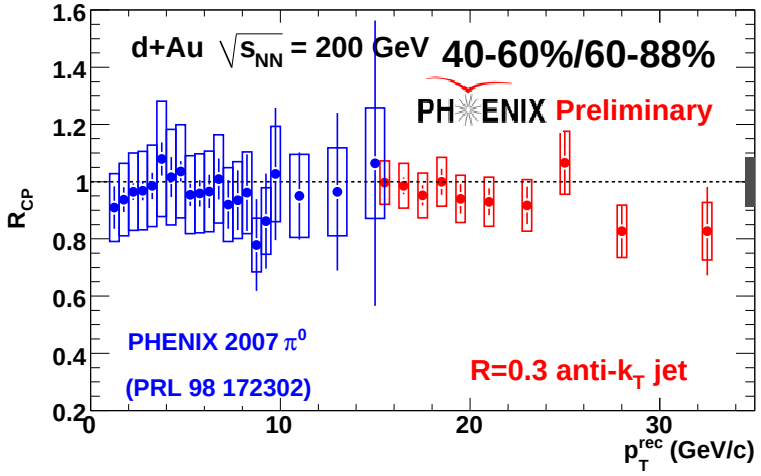




- Suppression of reconstructed jet R_{AA}:
  - ⇒ over a wide p_{T} range
  - ⇒ increasing suppression in more central collisions
- Reconstructed di-jet $\Delta\phi$ distributions unmodified:
  - ⇒ no angular de-correlation in central collisions!

Jets in $d+Au$ at $\sqrt{s} = 200$ GeV



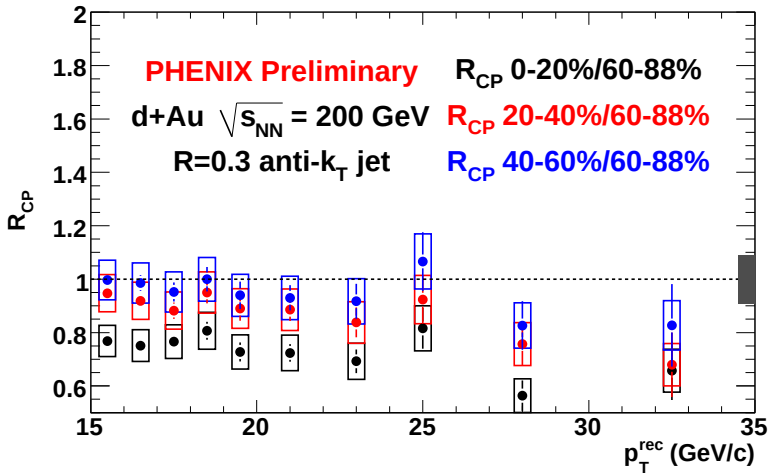


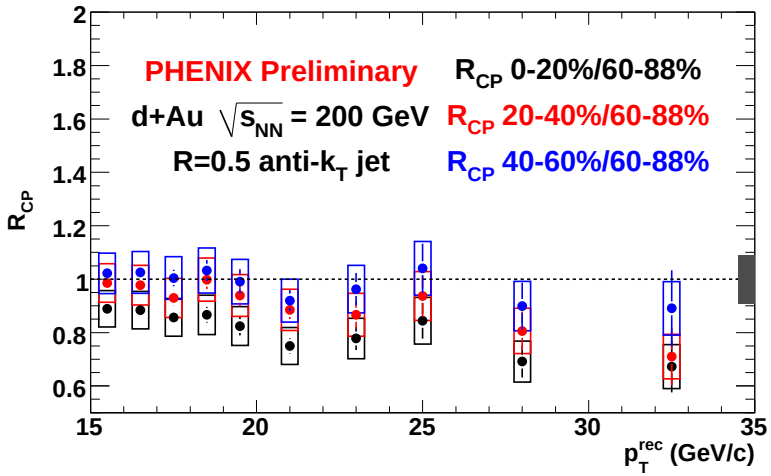
- anti-k_{T} jet reconstruction with $R = 0.3, 0.5$
- Reconstructed jet R_{CP} at the $p+p$ reconstructed scale.
  - relative to peripheral collision baseline
  - p_{T}-feeding from modest underlying event evaluated with embedding procedure and unfolded
- Suppression effect consistent with single-particle π^0 measurement.

$\Rightarrow$ cold nuclear matter energy loss?

$\Rightarrow$ impact parameter dependence of nPDFs?

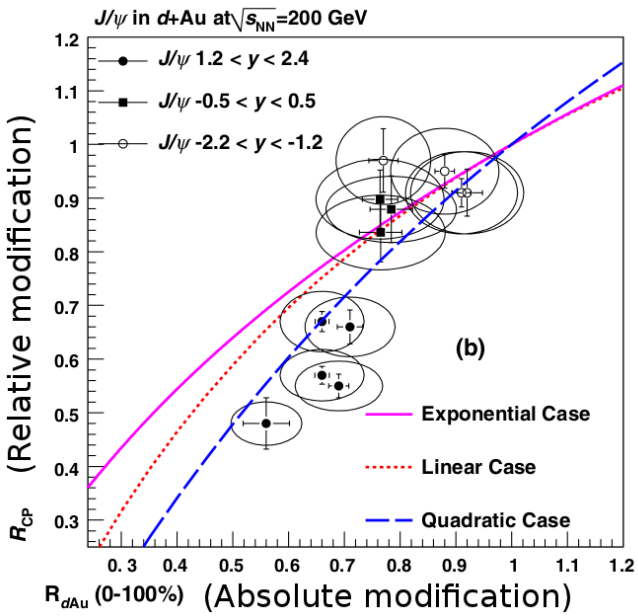
Jets in $d+Au$ at $\sqrt{s} = 200$ GeV

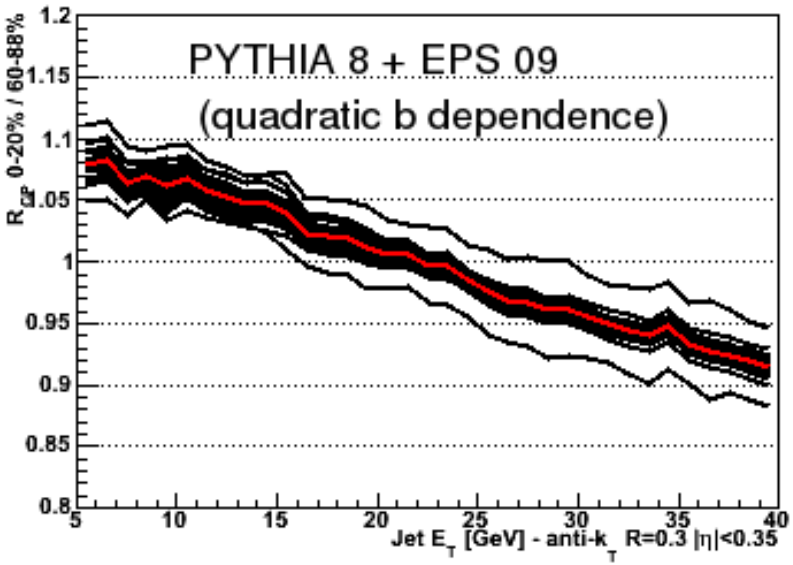




- Multiple cone sizes provide additional control against effects of underlying event
- R_{CP} exhibits increasing suppression with decreasing impact parameter
- Ongoing improvements to analysis will produce:
  - R_{dA}
  - lower p_{T} behavior
  - results at p_{T}^{truth} scale

nPDF effects in $d+Au$ R_{CP}

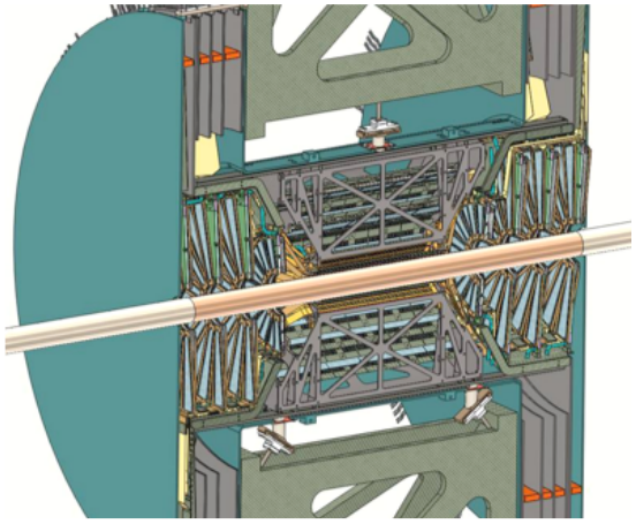


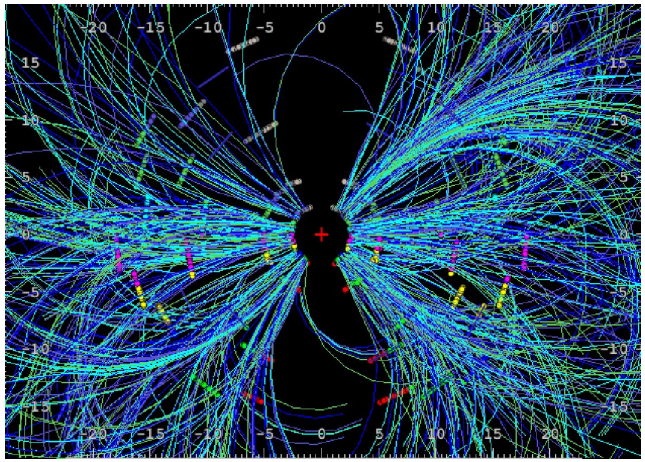


- ~~Nuclear PDF sets do not parameterize impact parameter dependence:~~
  - ⇒ K. Eskola, Plenary 4B and I. Helenius, Parallel VC
- Leading-order toy study with EPS09 parameters (`nucl-th/1011.4534`):
  - ⇒ quadratic b-dependence of Au nPDF from PHENIX J/ψ data, (PRL 107, 142301 (2011))
  - ⇒ suppression from nPDF effects underpredicts data

Outlook

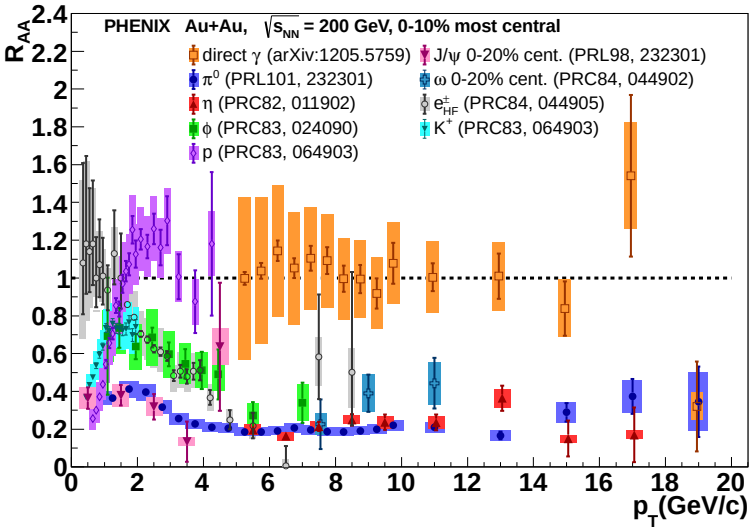
- Jet reconstruction efforts at PHENIX are ongoing.
- Preliminary results from $d+Au$ jet reconstruction:
  - $\Rightarrow$ suppression effect at high-p_{T}
  - $\Rightarrow$ consequences for interpreration of $A+A$ results!
- PHENIX capability for jet measurements improving:
  - $\Rightarrow$ VTX (silicon vertex tracker) and FVTX (forward silicon vertex tracker)

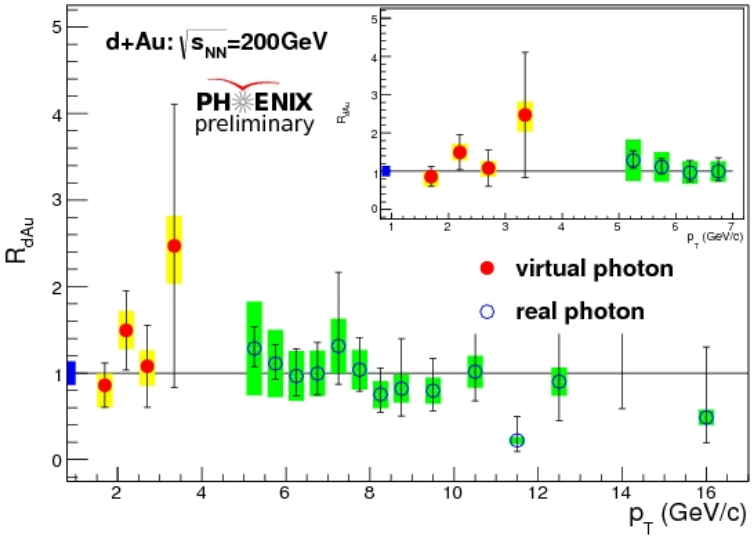




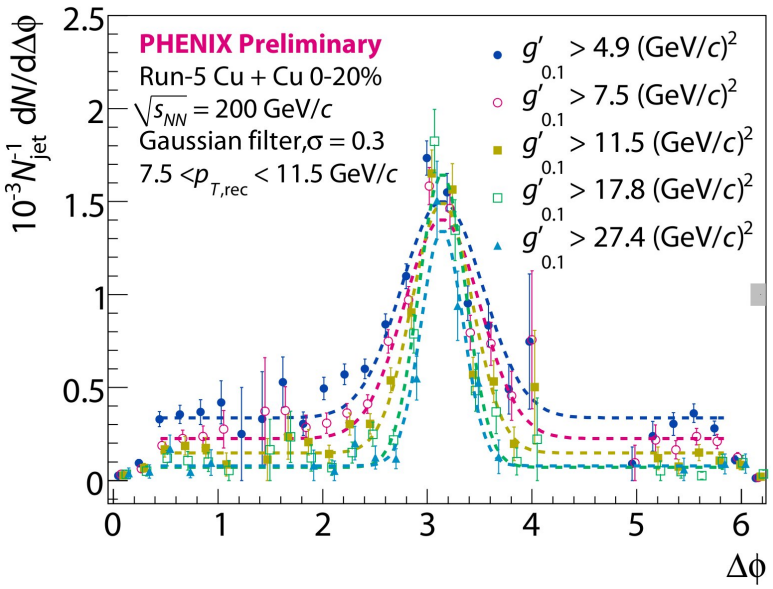
BACKUP

Backup Plots I



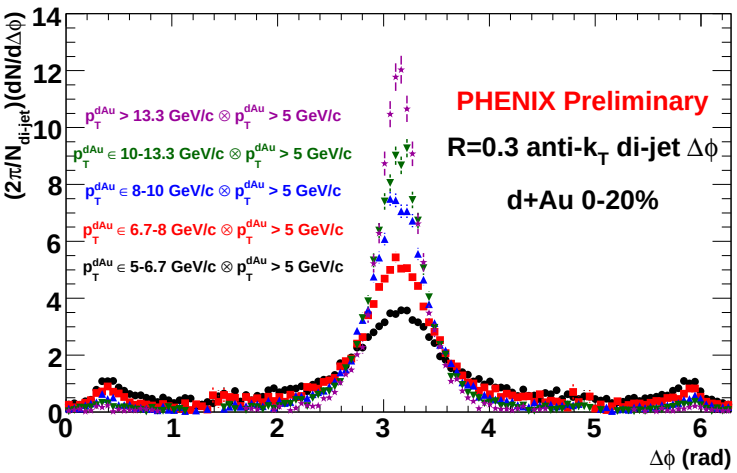


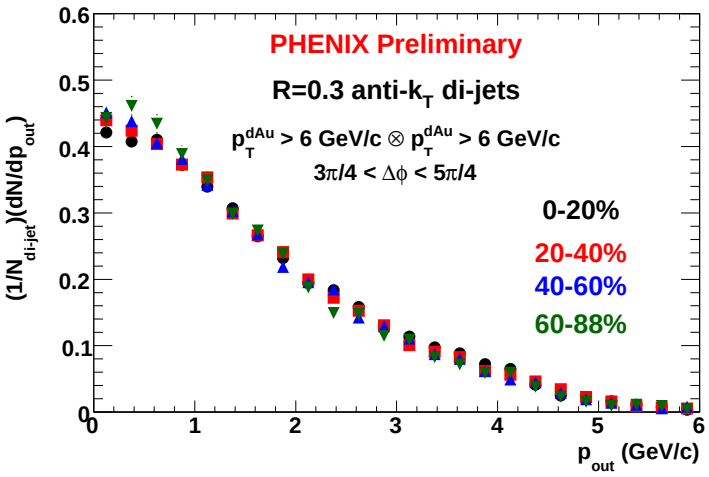
Backup Plots II



$$g_{\sigma_{\rm dis}}(\eta,\phi) \equiv \sum_{i\in \rm fragment} (p_T)_i^2 \exp\left(-(\Delta\eta^2+\Delta\phi^2)/2\sigma_{\rm dis}^2\right)$$

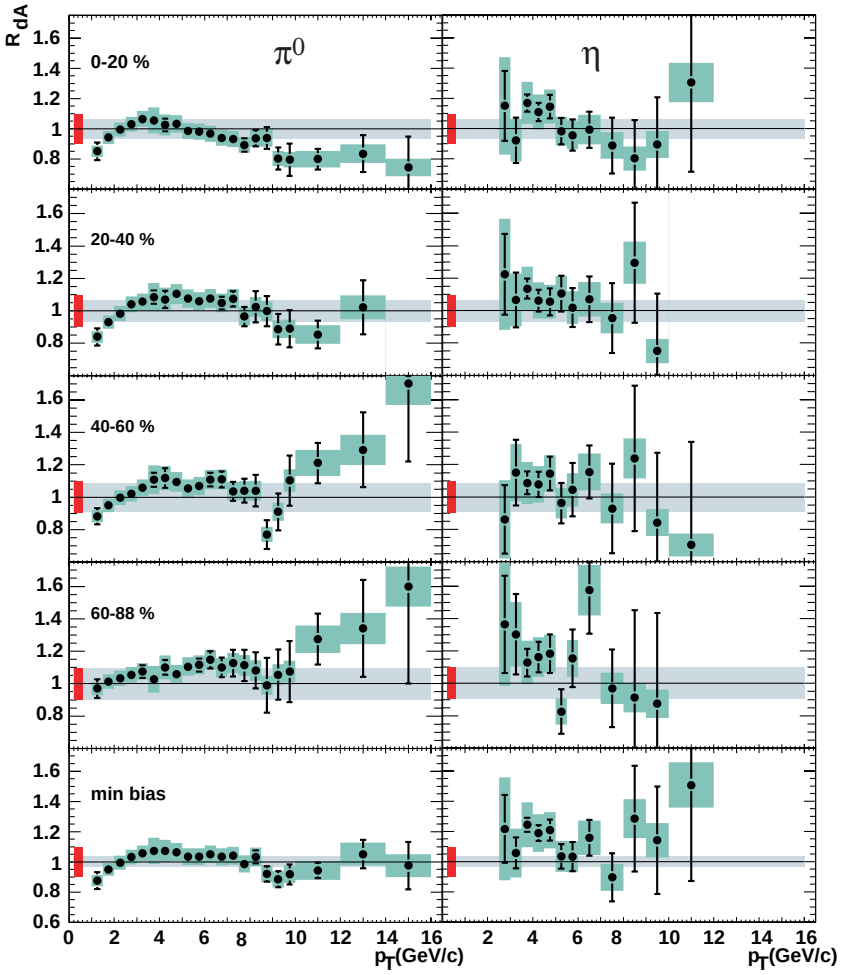
Backup Plots III





$$p_{\mathrm{out}}\,(=\langle k_T\rangle) \equiv (p_{\mathrm{T}})_{\mathrm{low}} \cdot \sin\Delta\phi$$

Backup Plots IV



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