POLYTECH
Peter the Great
St.Petersburg Polytechnic
University

PHENIX

Petersburg Nuclear Physics
Institute (PNPI), Gatchina
NRC "Kurchatov Institute"

PHENIX results on leading particles and jets measured in Cu+Au collisions at RHIC

Dmitry Kotov for the PHENIX collaboration

(NRC KI PNPI & SPbPU, Russia)

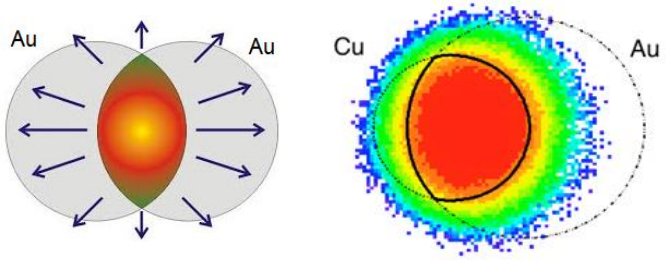
New Trends in High-Energy Physics,
Becici, Budva, Montenegro, 2-8 October 2016

Outline

- Motivation
- RHIC collider and PHENIX Detector
- Neutral pion and jet reconstruction methods
- Results: p_T spectra and R_{AA}
- Model comparison

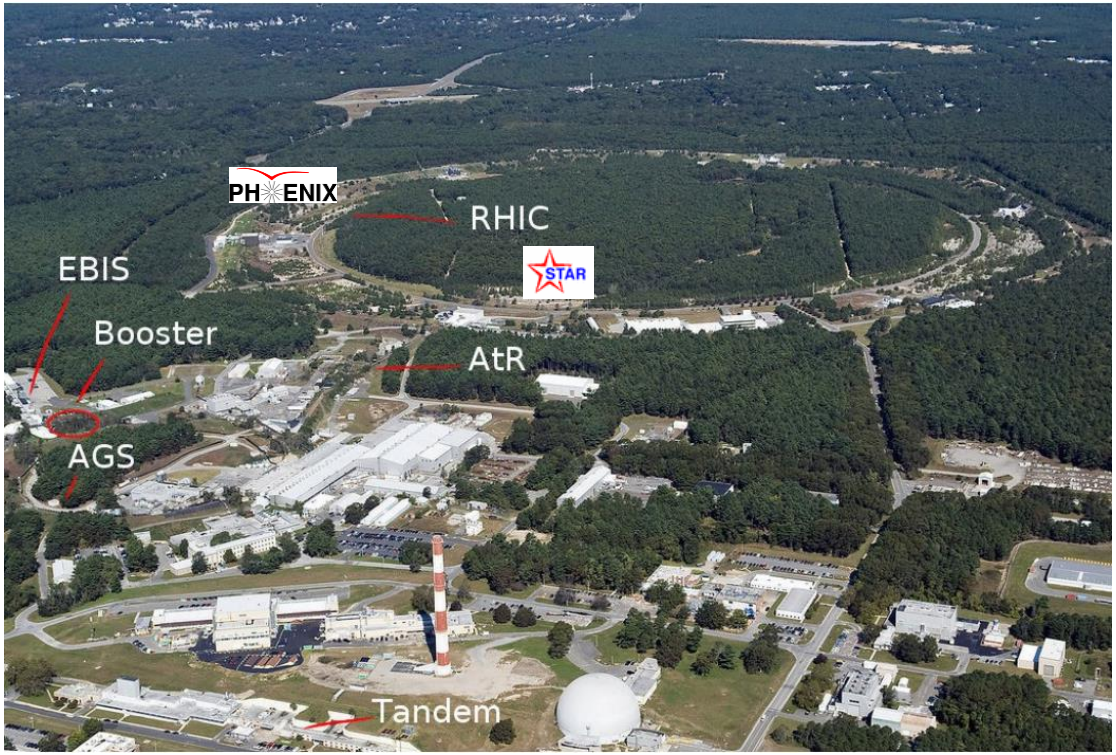
Motivation

- Jet quenching is one of the evidences of QGP formation in central heavy ion collisions;
- Experimentally jet-quenching at RHIC and LHC is observed as suppression of leading particles such as π^0 and jets, which are directly associated with partons, formed in the medium;
- RHIC results from Au+Au & Cu+Cu collisions showed suppression of high p_T particles as expected from parton energy loss in a hot and dense medium;
- An additional insight into the mechanism of particle production and parton energy loss can be gained from interactions of asymmetric Cu+Au collisions;
- Configuration of two different nuclei (Cu+Au) opens an opportunity to study particle production in different initial collision geometries;



- In 2012 RHIC delivered successful Cu+Au run at 200 GeV.

RHIC at Brookhaven National Lab



System	$\sqrt{s_{NN}}$, GeV
p+p	22.4, 62.4, 200, 500, 510
p+Al	200
p+Au	200
d+Au	20, 39, 62, 200
He^3+Au	200
Cu+Cu	22, 62, 200
Cu+Au	200
Au+Au	7, 15, 9, 19, 39, 62, 130, 200
U+U	193

- RHIC is a flexible and reliable accelerator complex with an extensive experimental program;
- A lot of operational time is devoted to beam energy scan and switching between colliding nuclei;
- Beam luminosity is being continuously increased;
- During 16 Runs, RHIC provided 11 energies and 9 combination of nuclei.

PHENIX detector

1. Track reconstruction

Drift Chambers (DC): $\delta p/p = 0.7\% + 1.1\% \cdot p$

Pad Chambers (PC): $\sigma = \pm 1.7$ mm in z direction

2. Energy and coordinates of electrons and γ

- ✓ EMCal PbSc: $\delta E/E = 2.1\% + 8.1\%/\sqrt{E}$
- ✓ EMCal PbGl: $\delta E/E = 0.8\% + 5.9\%/\sqrt{E}$

3. Particle identification

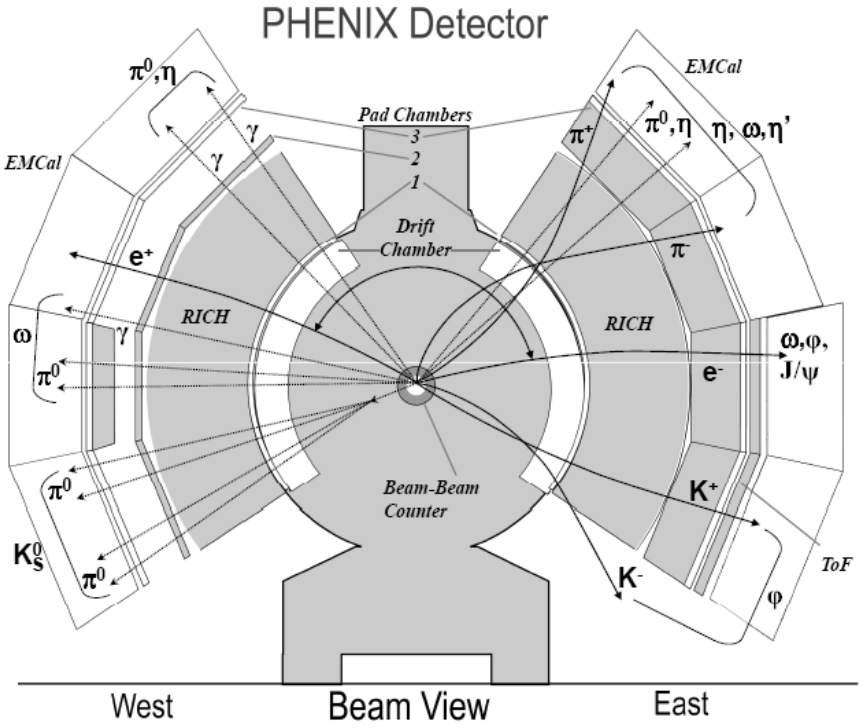
Time of flight in both arms (TOF.E, TOF.W):

- ✓ $\sigma_\tau \sim 100$ ps;
- ✓ π/K up to 2.5 GeV/c, K/p up to 4.0 GeV/c

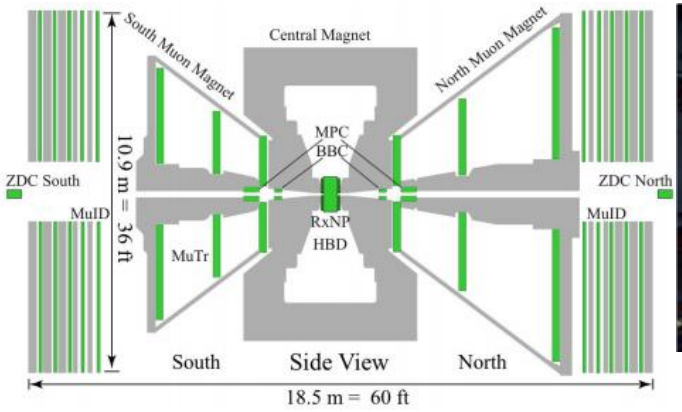
EMCal timing: $\sigma_\tau \sim 300$ ps

Forward Arms:

- ✓ $1.2 < |\eta| < 2.2$
- ✓ Muon Tracker / Muon ID



Acceptance: $-0.35 < \eta < 0.35$, $\Delta\varphi$ – 2 x 90°



Methods

❖ **$\pi^0 \rightarrow \gamma\gamma$ measurement:**

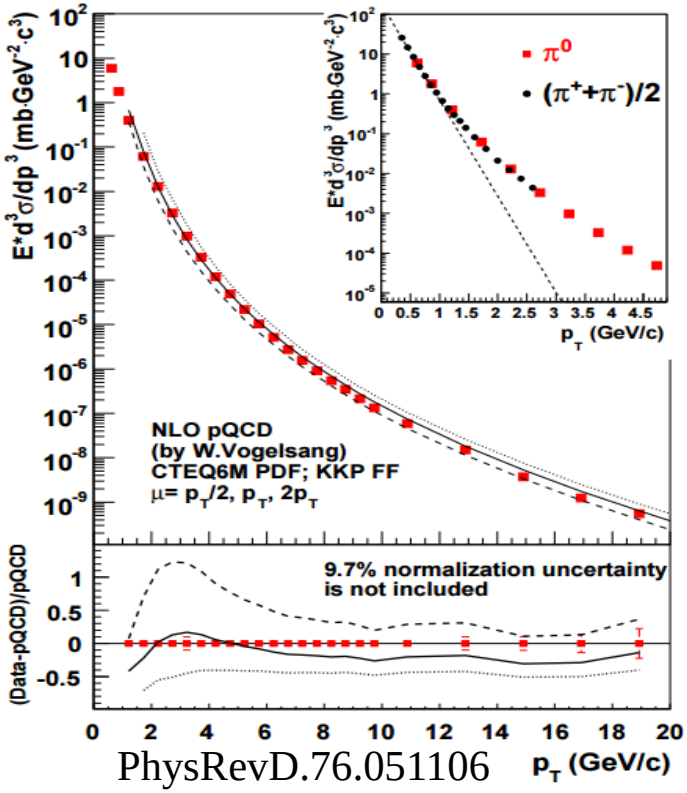
- ✓ EMCal (PbSc / PbGl) for γ clusters measurement;
- ✓ $\gamma\gamma$ inv. mass distributions to extract π^0 yields in different p_T and centrality bins;
- ✓ Good S/B ratio with lots of statistics: measure yields at high p_T;

❖ **Reconstructed jets:**

- ✓ DC/PC – charged track reconstruction, EMCal (PbSc / PbGl) – neutral clusters;
- ✓ anti-k_T algorithm with radius R = 0.3 in p+p and R = 0.2 in Cu+Au due to larger contribution of underlying event.

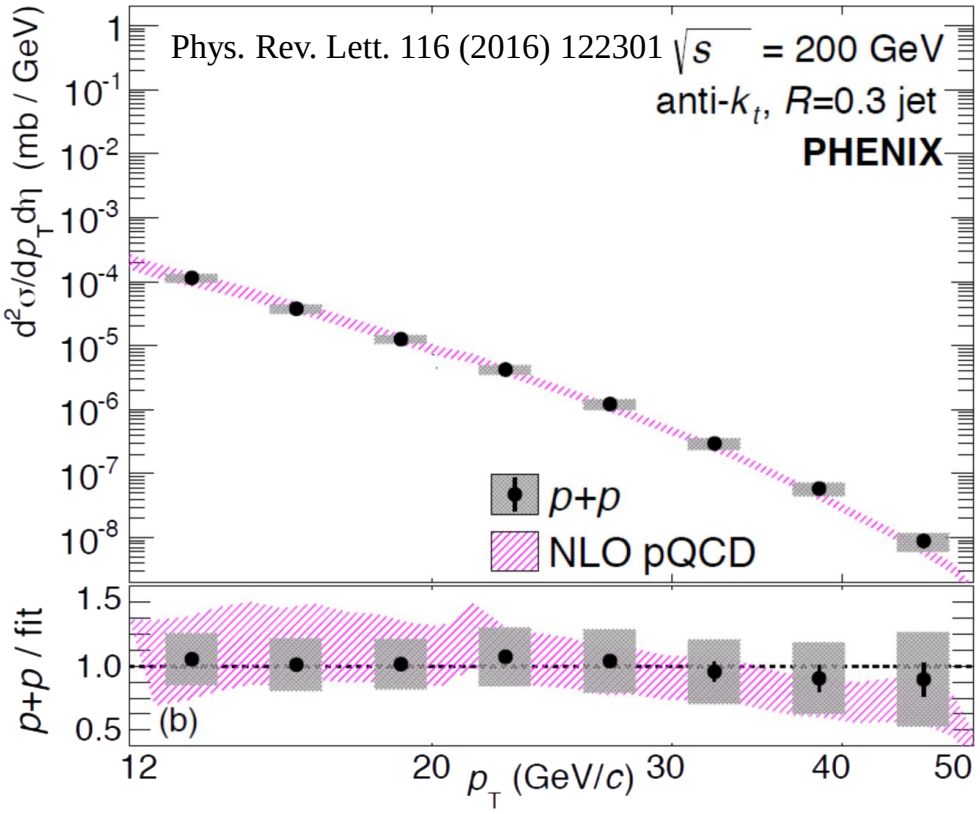
π^0 and jets in p+p @ 200 GeV

π^0-mesons



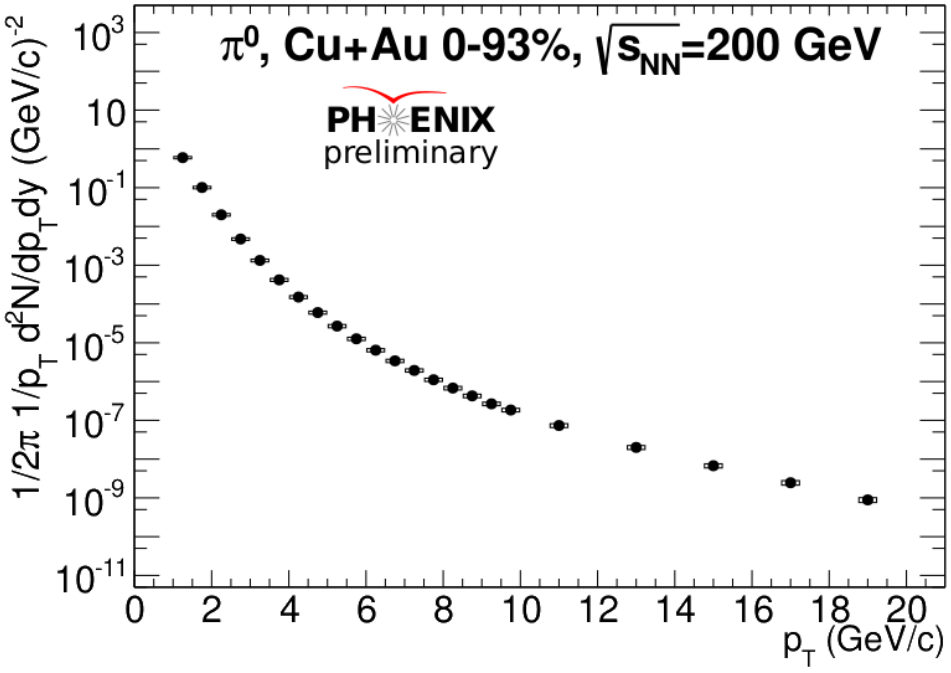
PhysRevD.76.051106

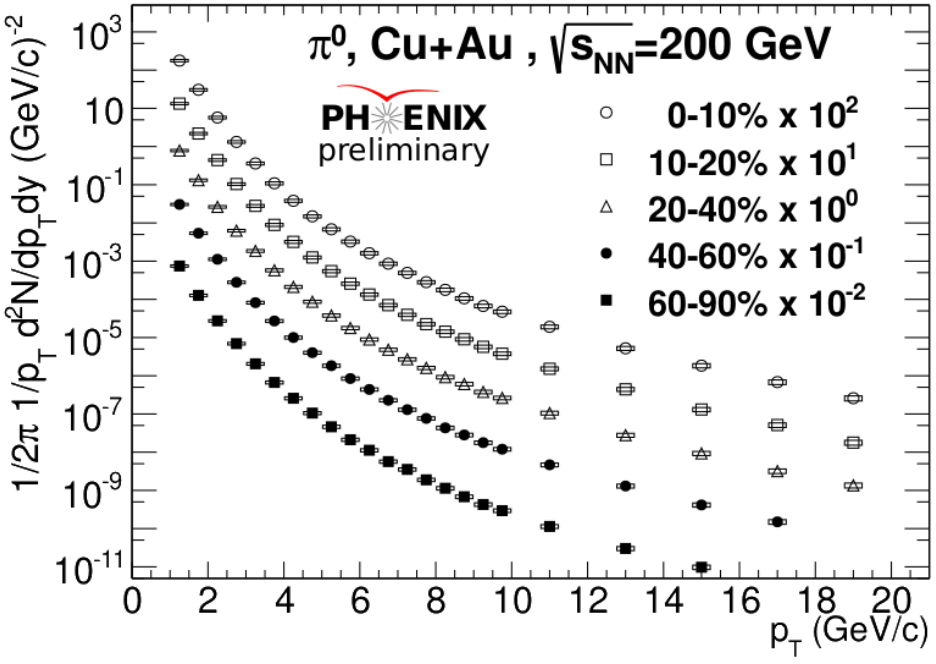
Reconstructed jets



- π^0 and reconstructed jets spectra in p+p collisions are measured in wide p_T ranges:
  - ✓ agrees with NLO pQCD calculations, which validates π^0/jet reconstruction procedure in PHENIX & explains π^0/jet production in elementary collisions;
  - ✓ used as a baseline to compare with more heavy colliding systems such as A+B.

π^0 spectra in Cu+Au @ 200 GeV





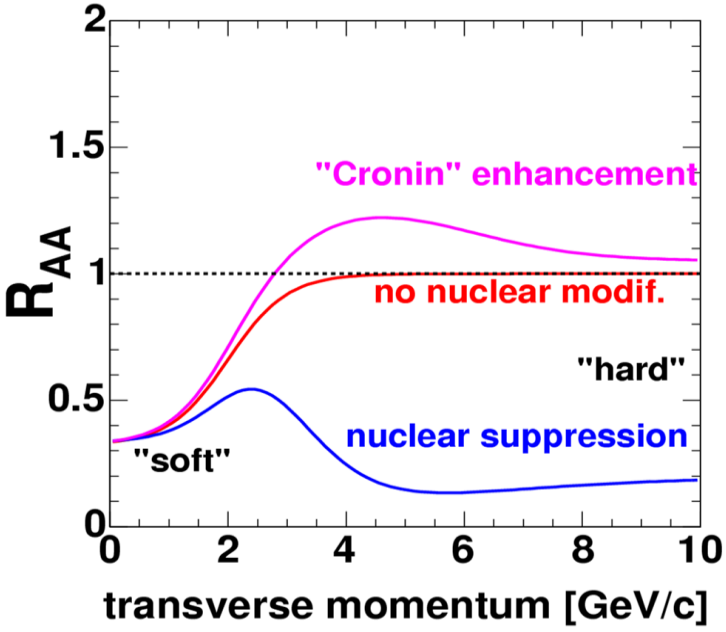
- Measured in a wide p_T range up to 20 GeV/c in different centrality bins;
- Used to calculate nuclear modification factors R_{AB} for heavy ion colliding systems;

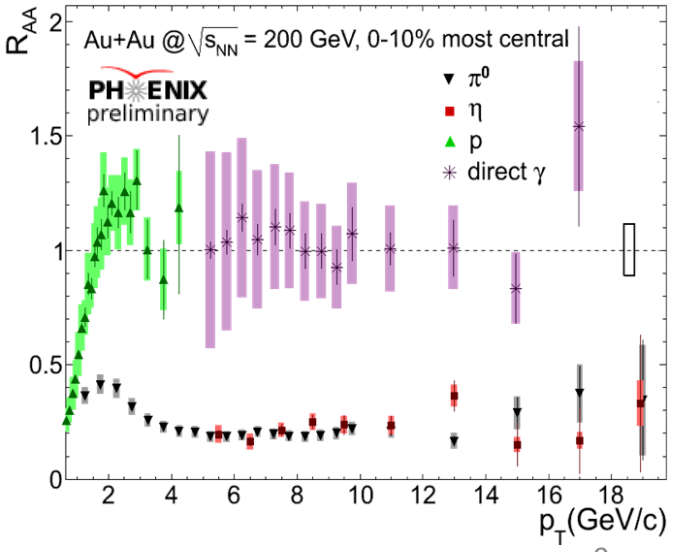
Hard processes, R_{AB}

- Hard processes scale with N_{coll}
  - ✓ Small cross section
  - ✓ Non-correlated superposition
- Nuclear modification factors

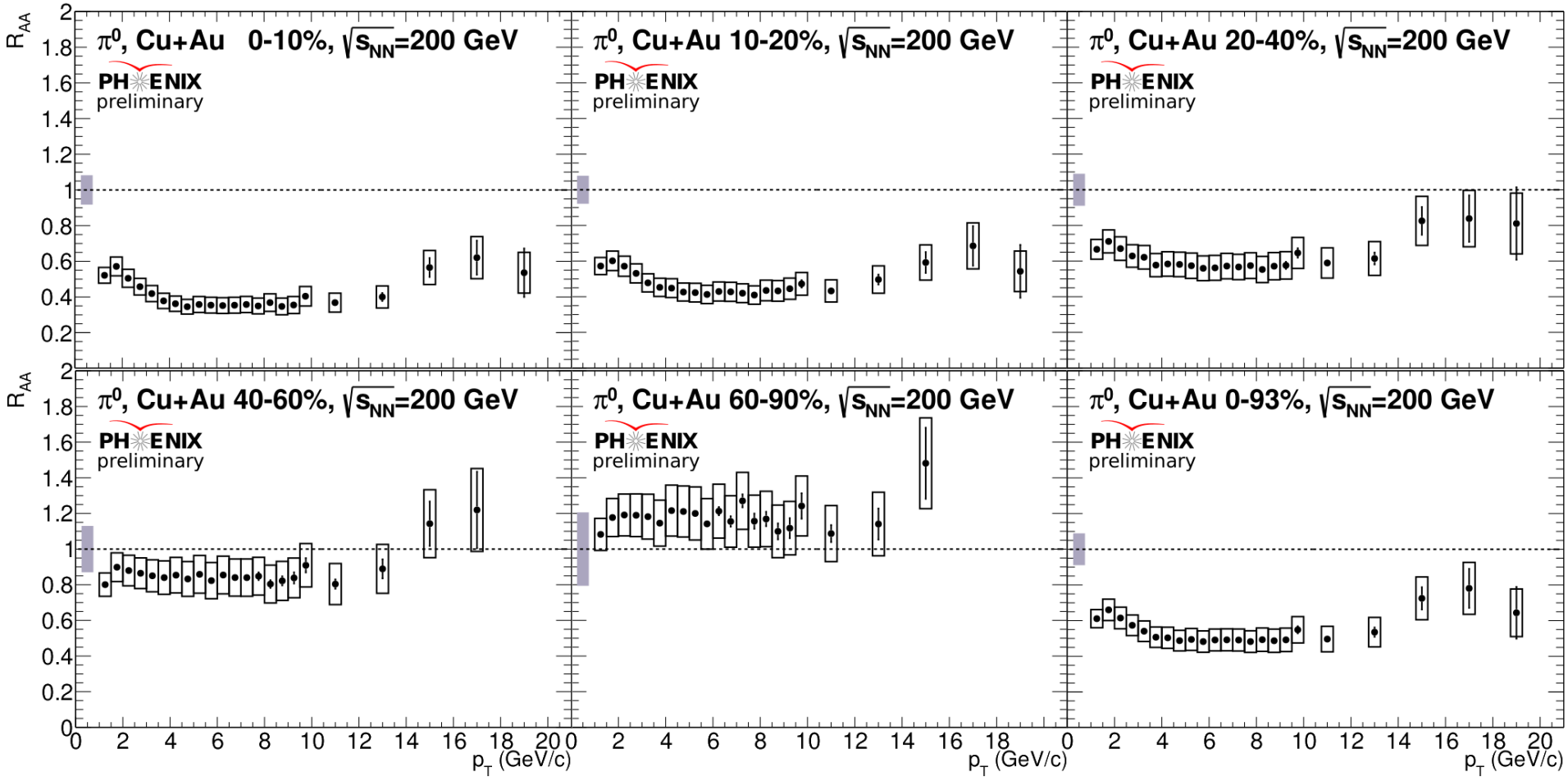
$$R_{\mathrm{AB}}(p_T) = dN_{\mathrm{AB}}/(\langle N_{\mathrm{coll}}\rangle \times dN_{pp})$$

- R_{AB}=1 – no medium effects
- R_{AB}≠1 – collective effects:
  - ✓ R_{AB}<1 – suppression
  - ✓ R_{AB}>1 – enhancement



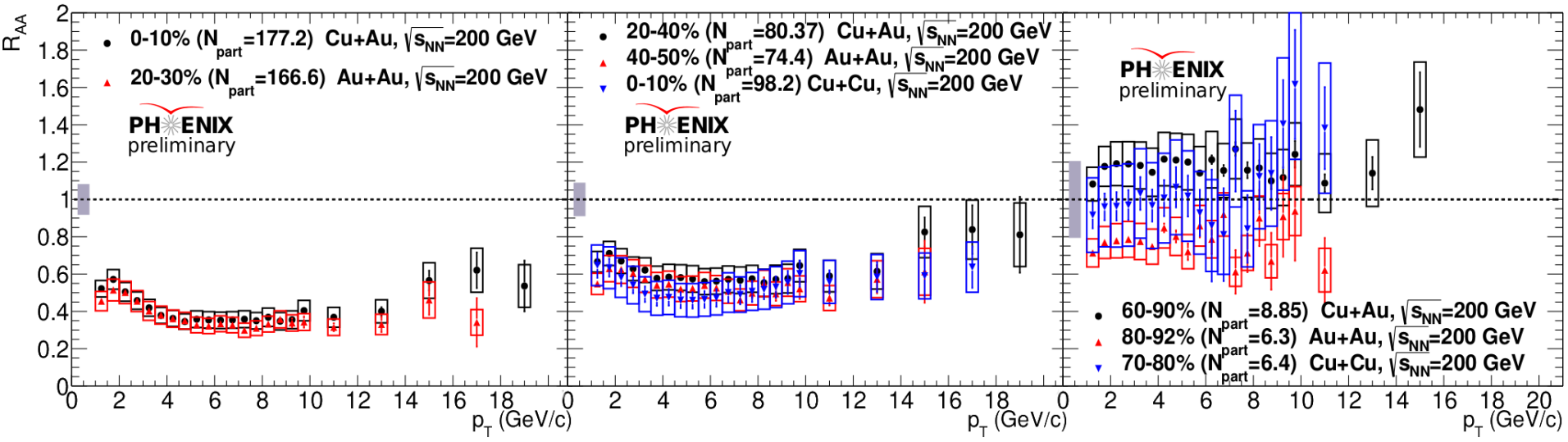


π^0 R_{AA} in Cu+Au



- Measured up to 20 GeV/c in different centrality bins;
- In central and semi central collisions π^0 production is suppressed;
- In peripheral collisions – a hint of enchancement of π^0 production.

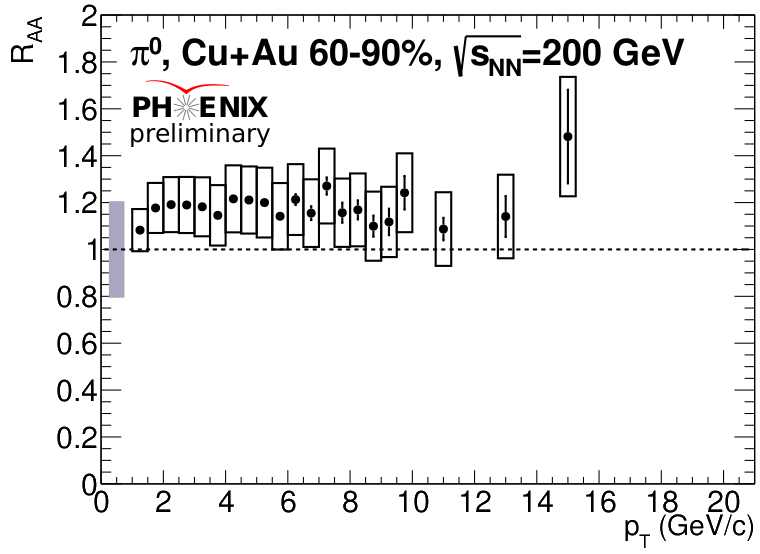
π^0 R_{AA} Cu+Au, Cu+Cu & Au+Au

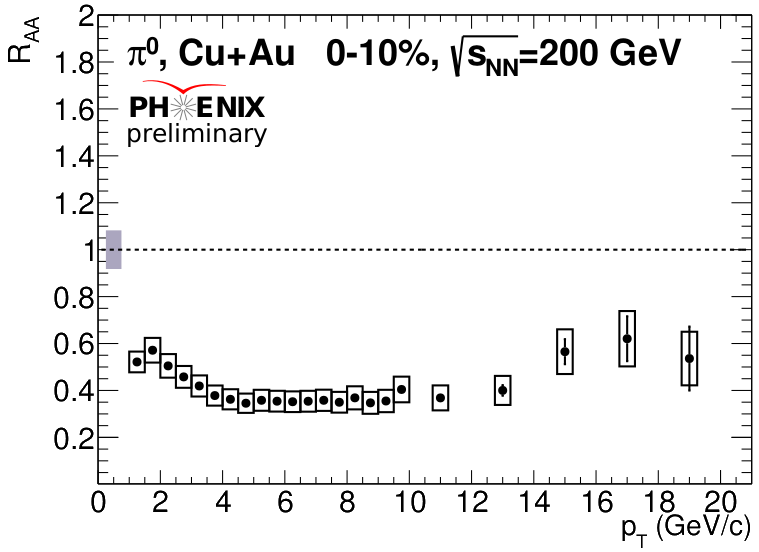


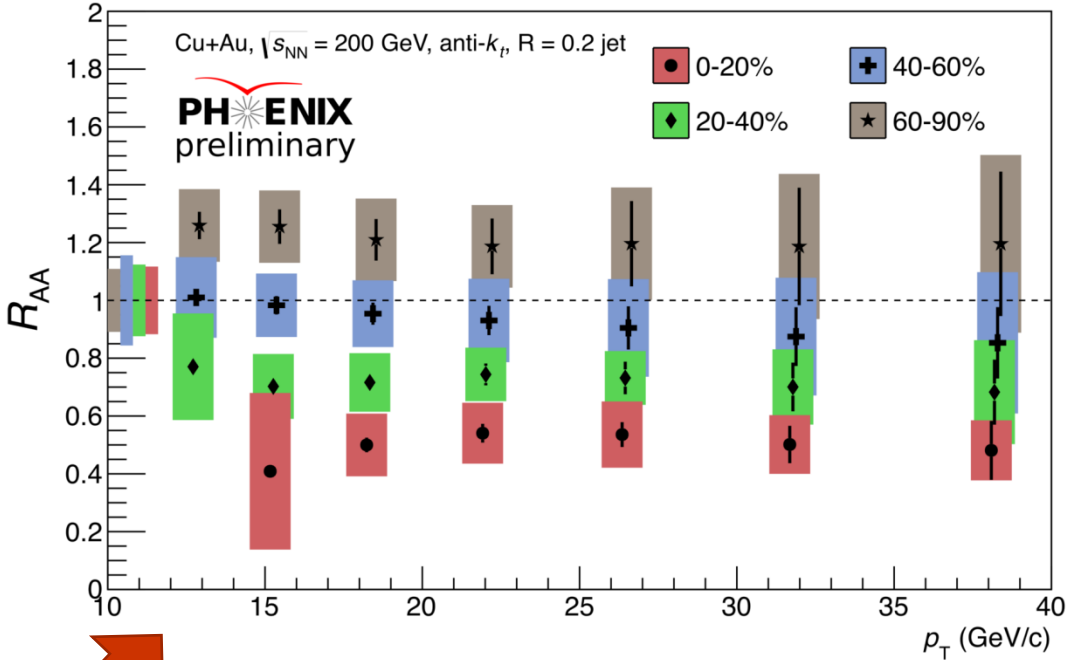
Phys. Rev. Lett. 101, 232301
Phys. Rev. Lett. 101, 162301

- In central and semi central Cu+Au collisions π^0 yields are suppressed similar to Cu+Cu and Au+Au:
  - ✓ π^0 production depends on the size of the nuclear overlap, but not on it's shape;
- In peripheral Cu+Au collisions π^0 yields show a hint of enhancement, while suppressed in Au+Au with Cu+Cu lying in the middle.

π^0 and jets R_{AA} in Cu+Au



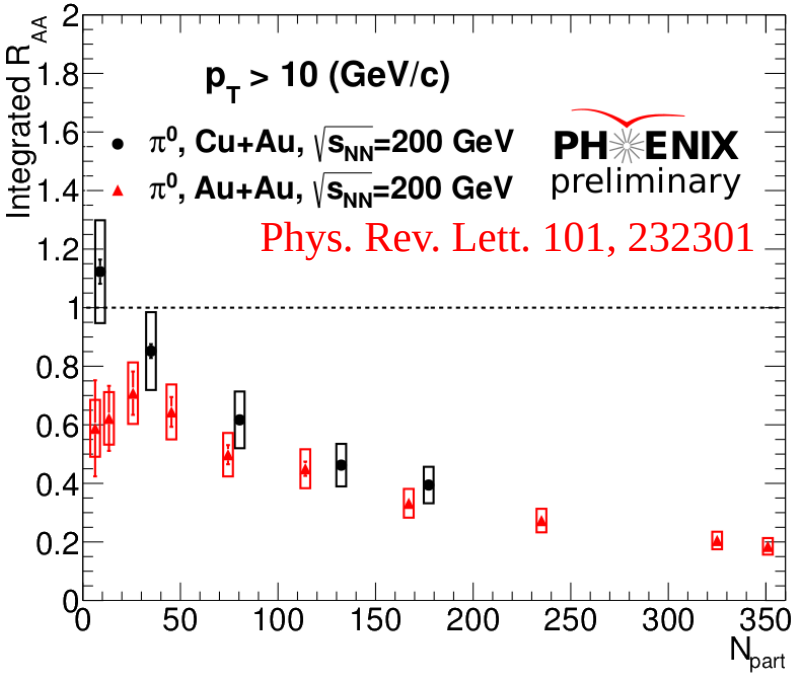


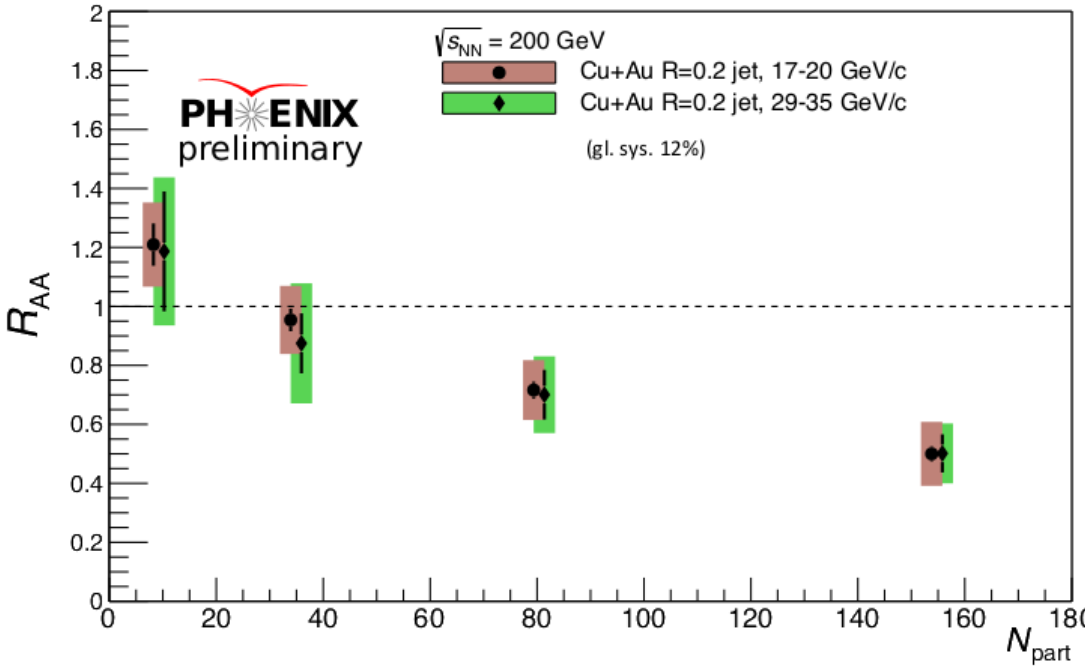


❖ π^0 suppression pattern is similar to the one observed for reconstructed jets:

✓ suppressed in central collisions and non-zero enhanced in peripheral collisons.

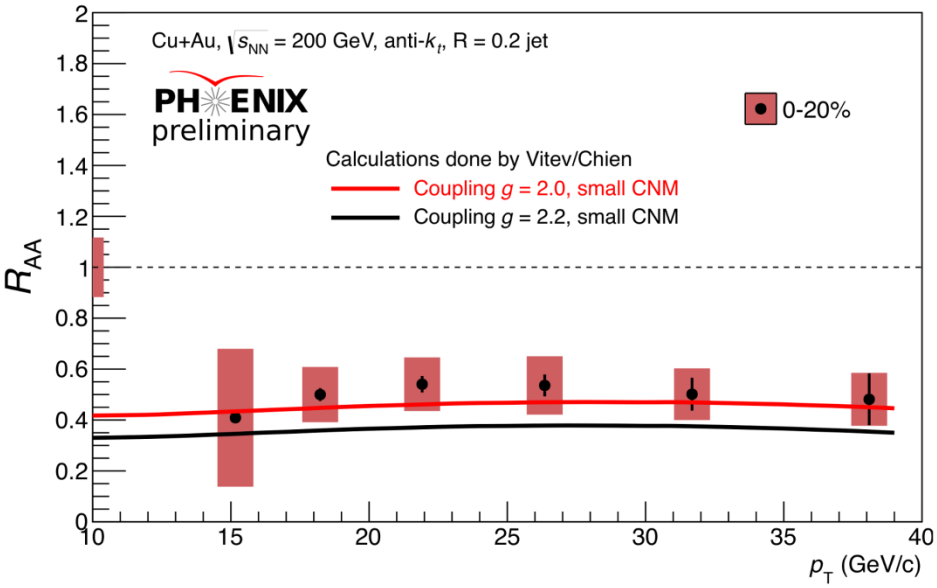
Integrated π^0 and jets R_{AA}

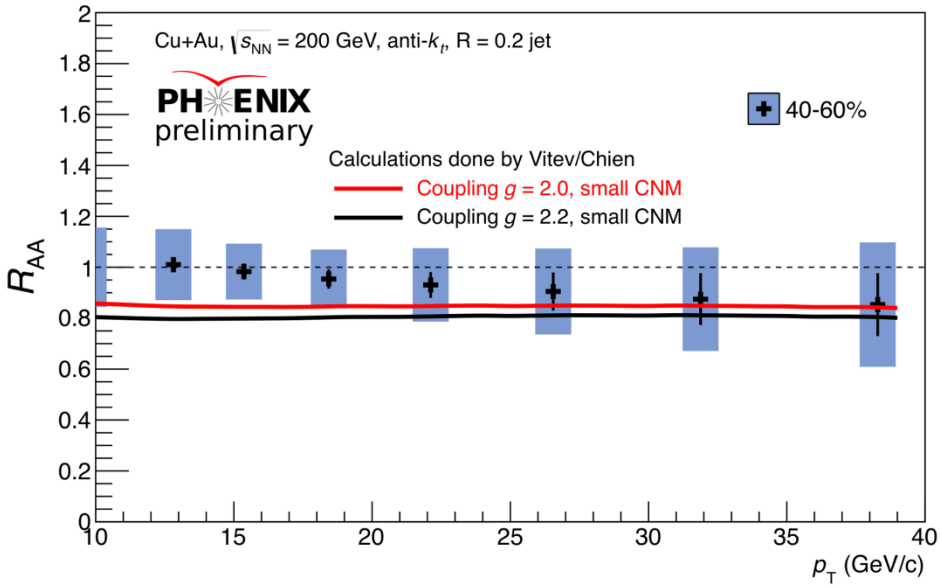




- π^0 suppression pattern is similar in Cu+Au and Au+Au collisions at $N_{part} > 50$;
- π^0 is less suppressed in Cu+Au than in Au+Au at $N_{part} < 50$;
- π^0 and jets show a hint of enhancement in peripheral Cu+Au collisions.

Model predictions for jets R_{AA} in Cu+Au





hep-ph/1509.07257
hep-ph/1509.02936

- Left: 0-20%; Right: 40-60%;
- $SCET_G$ model allows to describe jet propagation in matter:
  - ✓ Calculations were done for 2 input parameters g=2.0 and g=2.2 (couplings between the jet and the medium);
  - ✓ Quantitatively agrees with experimental results.

Conclusions

- PHENIX experiment has measured nuclear modification factors R_{AA} for π^0 and jets in Cu+Au collisions at 200 GeV;
- π^0 production is suppressed in central and semicentral Cu+Au collisions like in Au+Au and Cu+Cu collisions at similar N_{part}:
  - ✓ suppression level depends on overlap size and not on its geometry;
- In peripheral collisions there is a hint of π^0 and jet production enhancement;
- Jet nuclear modification factors are in agreement with $SCET_G$ calculations:
  - ✓ no predictions for π^0 R_{AA} available yet.