PHENIX Overview

PIC 2024

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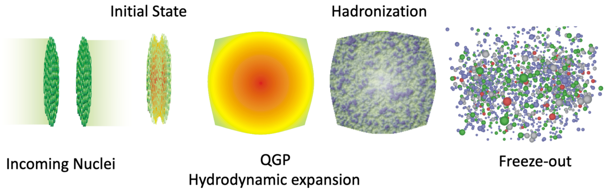
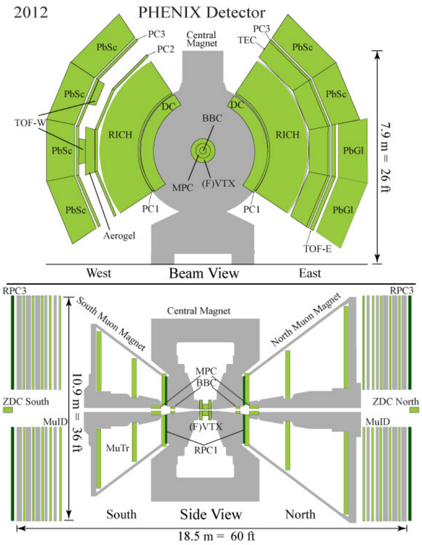
1. PHENIX stopped data taking after 2016
2. Ongoing analyses of large data sets taken in 2014, 2015, and 2016
3. Data and Analysis Preservation



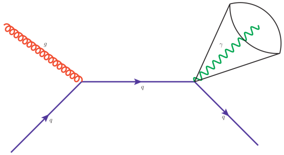


- Polarized p+p
  $\sqrt{s_{NN}}$=510 GeV
- Small systems
  p+Al, p+Au, d+Au, ^{3}He+Au
  $\sqrt{s_{NN}}$=200 GeV
- Large system Au+Au
  $\sqrt{s_{NN}}$=200 GeV

$\sqrt{s_{NN}}$ [GeV]		Al	Au	Au	Au	Cu Cu	Cu Au	Au Au	U U
510	✓								
200	✓	✓	✓	✓	✓	✓	✓	✓	✓
130								✓	
62.4	✓			✓		✓		✓	
39				✓				✓	
27								✓	
20				✓		✓		✓	
14.5								✓	
7.7								✓	

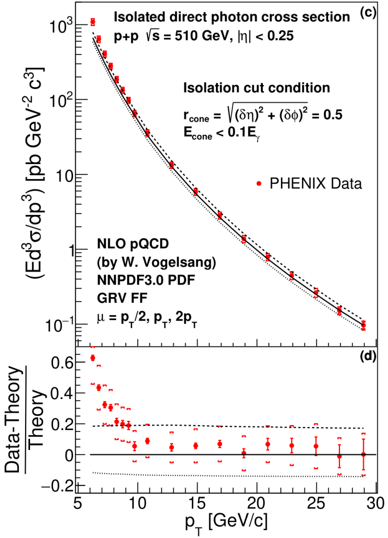
9 collision species and 9 collision energies

The quark-gluon Compton process sensitive to polarized gluon distribution



$r_{\rm cone} = \sqrt{(\delta\eta)^2 + (\delta\phi)^2} = 0.5$

Isolation cut requirement:
$\sum E_{\rm neutral} + \sum E_{\rm charged} < 0.1 E_\gamma$



in proton-proton collisions at RHIC is the dominant contributor to the **direct photons** with $p_T > 5$ GeV.

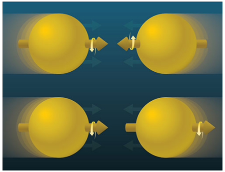
The cross sections were measured for the same and opposite helicity proton-proton collisions.

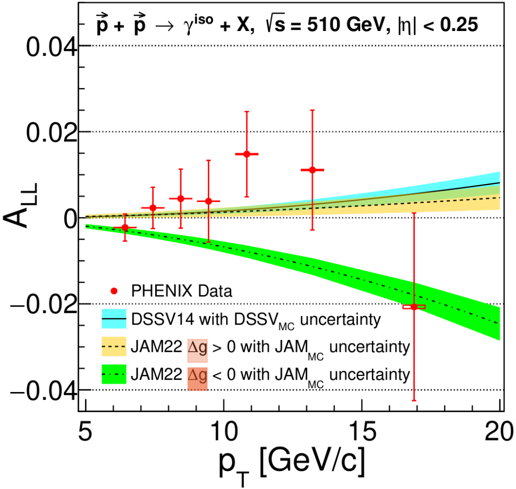
PHENIX, PRL 130, 251901 (2023)

Golden channel to access the gluon spin, the double-helicity asymmetry is defined as:

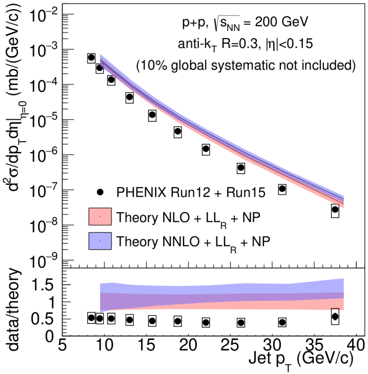
$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$$

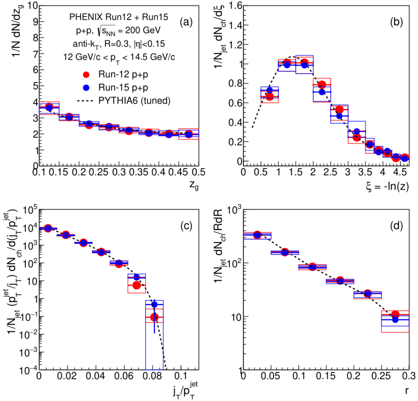
Our data are well consistent with the **positive gluon-spin contributions** and strongly disfavor the negative gluon-spin scenario, that the previously published data were unable to resolve.





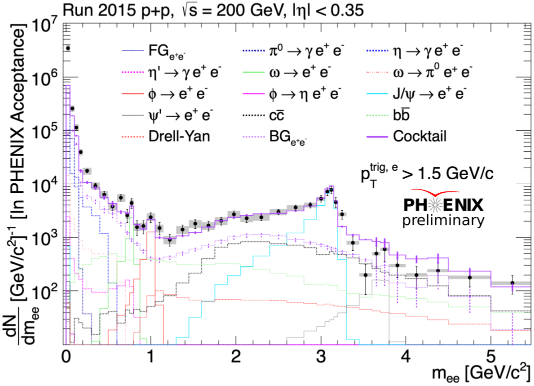
Jet substructure in Run12 and 15.





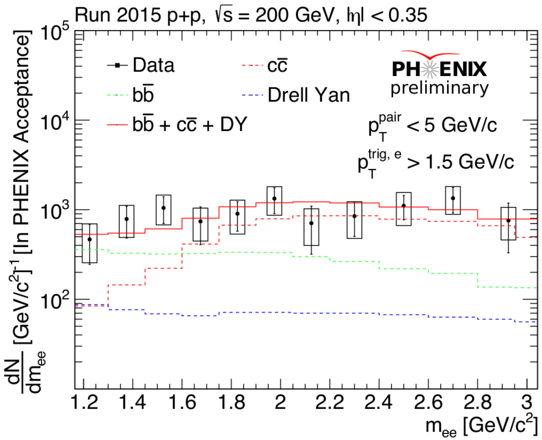
arXiv:2408.11144

Jets are reconstructed from charged-particle tracks and electromagnetic calorimeter clusters, NLO/NNLO predictions are higher than the measured jet cross section at RHIC.

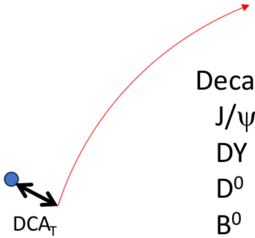


- Large statistics proof of principle study for the measurement of prompt and non-prompt $e^{+}e^{-}$ pair production in pp 2015

- Extend this measurement to large AuAu data, to isolate the prompt thermal dileptons (thermometer) in the intermediate mass region from non-prompt pairs from heavy flavor decays.
- Main physics signal originates from semileptonic decays of charm and bottom $q\bar{q}$ pairs
- Non-prompt component is identified by distance of closest approach (DCA) method with the VTX.
- Good agreement of the coctail calculation



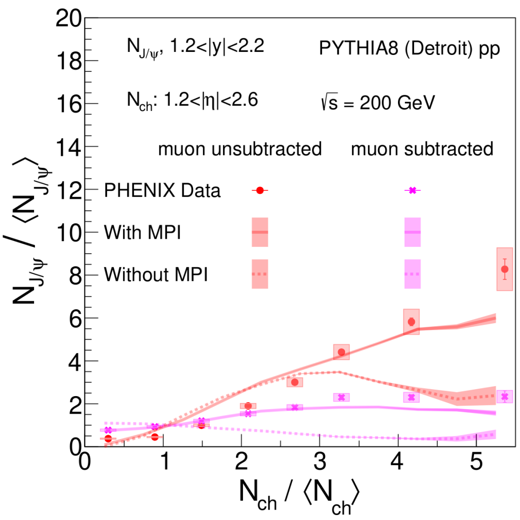
- IMR ($m_\phi < m_{ee} < m_{J/\Psi}$) pp 2015
- PYTHIA8 simulation of $c\bar{c}$, $b\bar{b}$ and Drell-Yan contributions for PHENIX acceptance



Decay length:

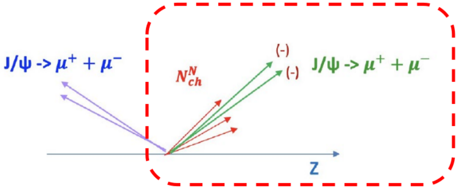
J/ψ ~ 0 μm
DY ~ 0 μm
D^0 ~ 120 μm
B^0 ~ 450 μm

Next step: separate open HF from others using DCA

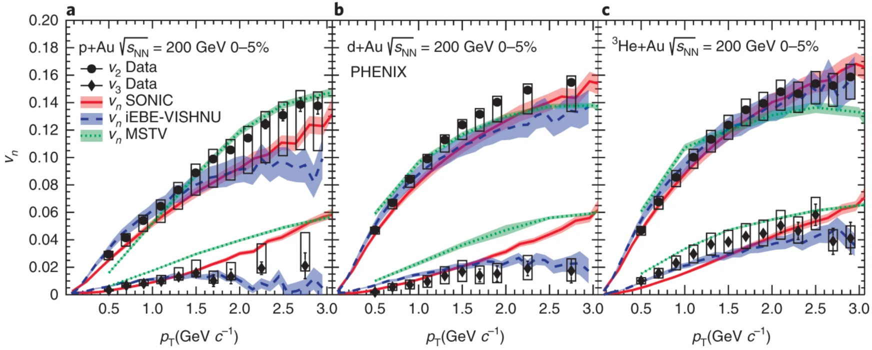


- J/Ψ and charged particles going to the same rapidity window – J/Ψ inside Jet
- J/Ψ yield increasing with multiplicity
- less increasing by removing the $\mu + \mu-$ from the multiplicity
- data described by PYTHIA with MPI

arXiv:2409.03728



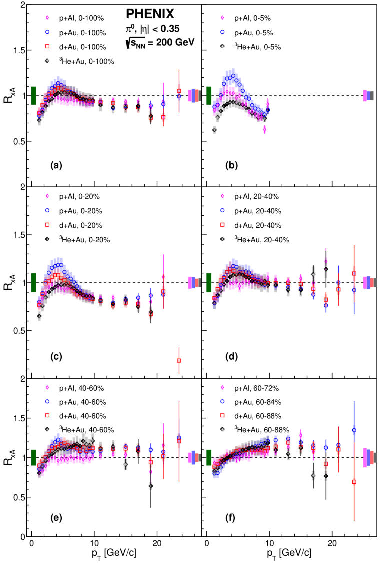
v_2: p+Au < d+Au ∼ ^{3}He+Au v_3: p+Au ∼ d+Au < ^{3}He+Au

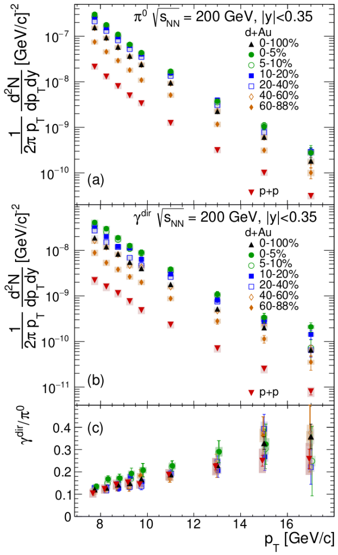


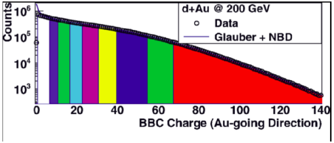
Anisotropy of charged particle production **consistent with hydrodynamic** expansion.
Nature Phys. 15 (2019) 214 – QGP droplets even is small systems?

1. **$p_T > 8$ GeV/c** constant for the same centrality selection from different collision systems
2. **Central** the Cronin peaks height value shows a clear system size dependence
   p $\rightarrow$ d $\rightarrow$ ^{3}He
   Al $\leftrightarrow$ Au
3. **Peripheral** 15 % enhancement - unexplained.
   Potential bias in centrality determination?

PRC 105 (2022) 064902



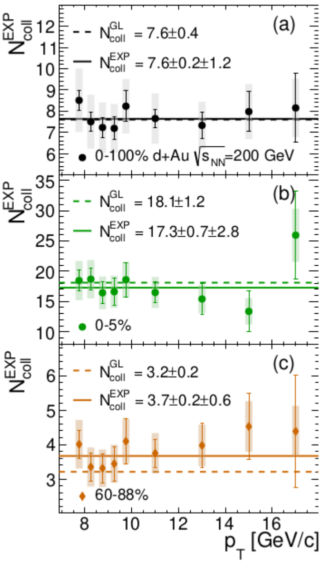


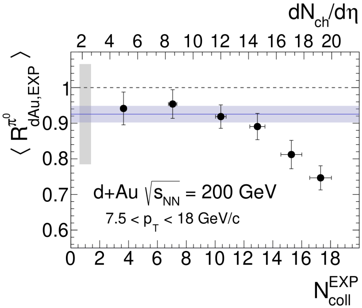


Since γ^{dir} produced by initial hard scattering, N_{coll} can be redefined by γ^{dir} ratio of d+Au to p+p:

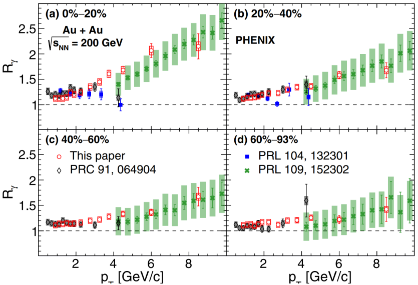
$$N_{coll}^{EXP}(p_T) = \frac{Y_{dAU}^{\gamma^{dir}}(p_T)}{Y_{pp}^{\gamma^{dir}}(p_T)}$$

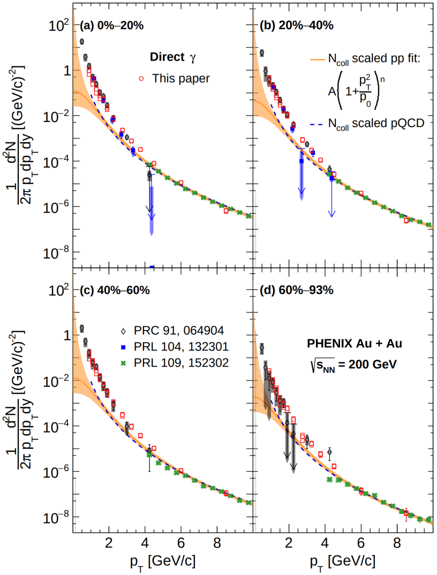
High p_T direct photons are used to experimentally estimate the number of binary collisions.





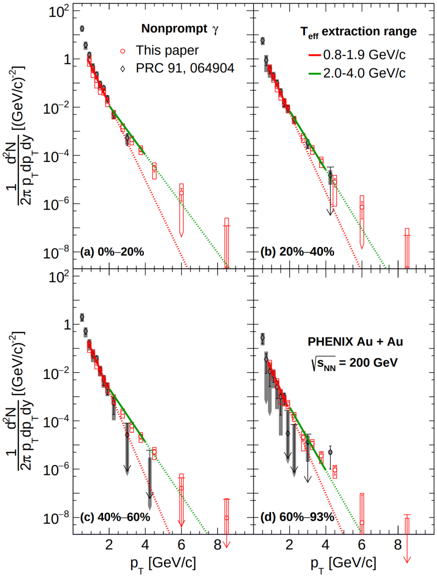
Further studies of the system size dependence with p+Au, d+Au, and 3He+Au collisions: droplets of QGP in small systems or system size effect.
arXiv:2303.12899 accepted to PRL

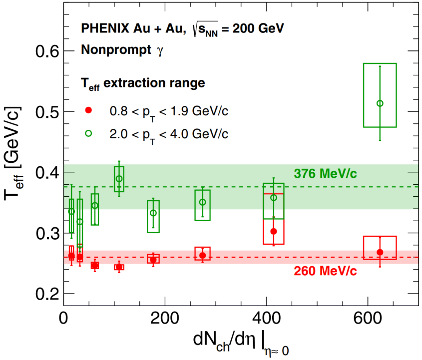




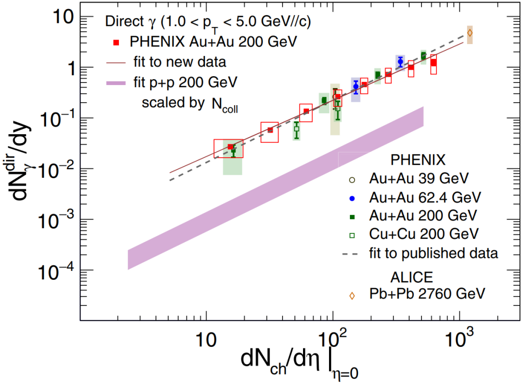
Internal PRL 104 132301
External HBD PRL 91 064904
Calorimeter PRL 109 152302
External VTX PRC 109, 044912

AuAu follows the N_{coll} scaled pp above 4 GeV, pp consistent with QCD.





T_{eff} from the p_T inverse slope, no dependence on centrality (8 bins!).



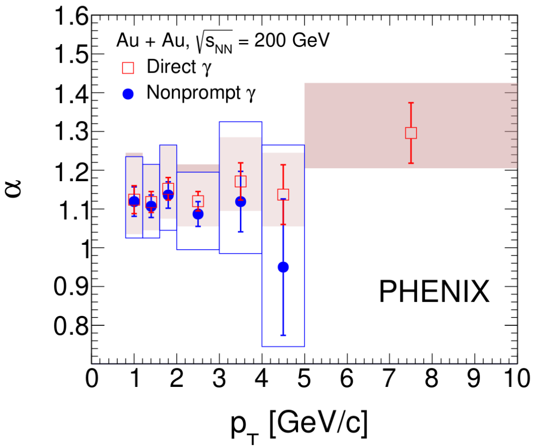
$$\frac{dN_\gamma}{dy} = A \times (\frac{dN_{ch}}{dy})^\alpha$$

Integrated direct-photon yield (1–5 GeV/c) versus charged-particle multiplicity at midrapidity.

Dashed line is from fitting previously published PHENIX data ($\alpha = 1.23$), solid line is the new fit (1.11).

HG phase scale with α close to 1.2, QGP phase exhibit closer to 2

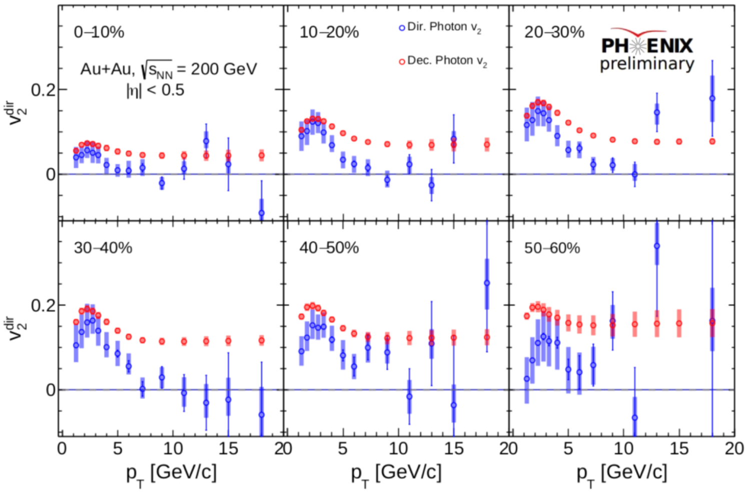
PRC 109, 044912 (2024)
PRC 107 024914 (2023)
PLB 754 235-248 (2016) Alice



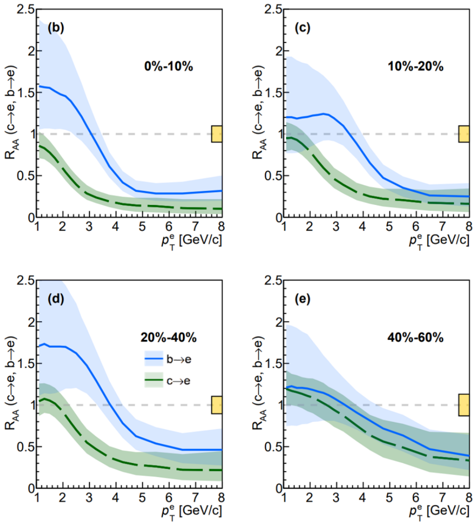
$$\frac{dN_\gamma}{dy} = A \times \left(\frac{dN_{ch}}{dy}\right)^\alpha$$

needs further theoretical understanding:

- yield
- α p_{T} dependence
- source: pre-equilibrium, QGP, HG



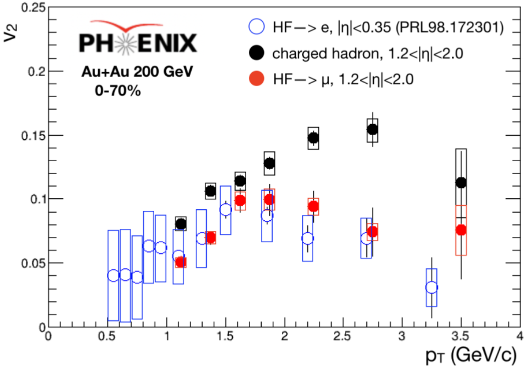
Significant flow for low p_T, clear centrality dependence.



PRC 109, 044907 (2024)

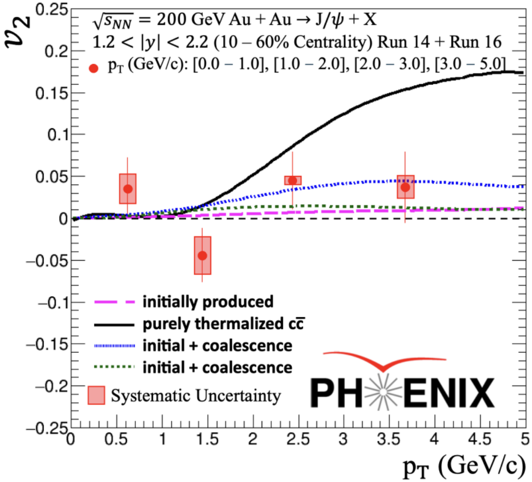
HF quarks early production, interact with the QGP → probe the medium
AuAu 200GeV

- Significant suppression at high p_T in all centrality classes
- Charm electrons show a stronger suppression than bottom electrons for $2 < p_T < 5$ GeV/c from 0 to 40%.
- In 40-60%, bottom and charm are similar



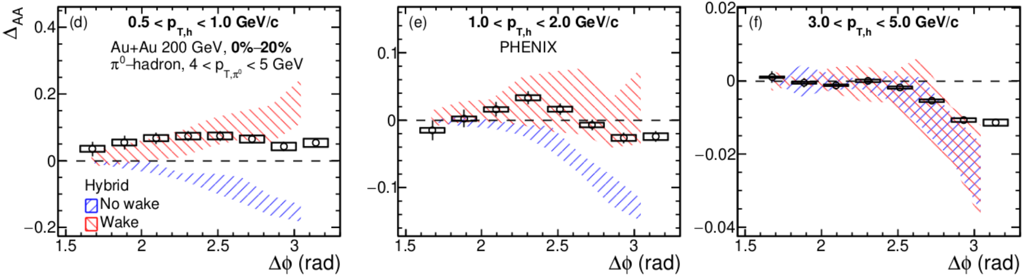
arXiv:2409.12715

- Largest Au+Au data set collected by PHENIX
  heavy-flavor decay ↔ light-hadron decay
- First observation of significant heavy flavor v_2 at the forward rapidity
- Despite the shift, the heavy-flavor electron and muon v_2 have similar magnitude and shape
- Smaller than charged hadron v_2 → HF particles flow with the QGP, but less than charged hadrons



arXiv:2409.12756

- Forward J/Ψ v_2 at RHIC is consistent with zero
- Our data exclude a scenario in which J/Ψ are produced entirely from coalescence of thermalized charm quarks
- Both initial production (high p_T) and coalescence (low p_T) must be included.

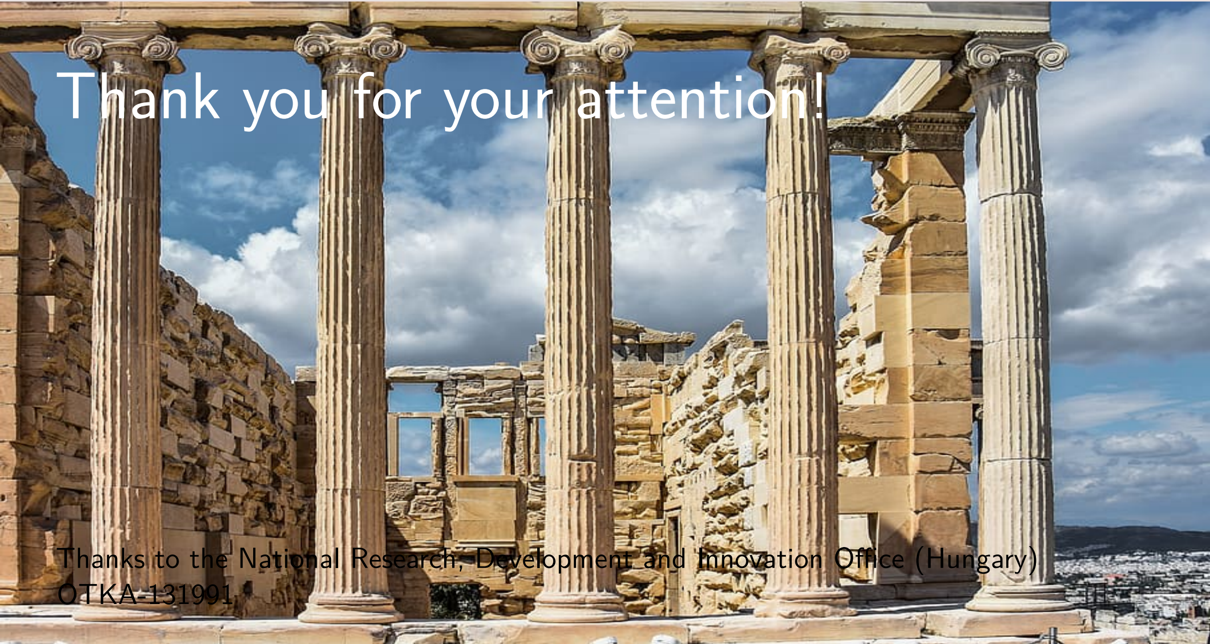


arXiv:2406.08301

- High-transverse-momentum neutral pions used as jet proxies, angular correlations between the π^0 and charged hadrons in the event (2014)
- $\Delta_{AA}(\Delta\Phi)$ difference between the yields in Au+Au and p+p
- Enhancement at low p_T + jet broadening and suppression for high p_T
- Hybrid model with medium response (Wake) consistent with PHENIX results

Summary

- Direct photon production: gluon spin likely to be positive
- Jet cross section and substructure
- New dilepton measurement with large statistics pp
- Forward J/Ψ multiplicity dependence, MPI
- System size dependence in $R_{p/d/^{3}\mathrm{He}Au}$, v_2 and v_3
- $R^{\pi^0}_{pAuEXP}$, in small systems
- Direct photon R_γ, T_{eff}, α
- $R_{AA}(c \to e,\ b \to e)$
- HF, J/Ψ v_2
- Jet modification



Thank you for your attention!

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