PHENIX overview

Gabor David
Stony Brook University

ZIMÁNYI SCHOOL 2024

L. Kassák: Image architecture

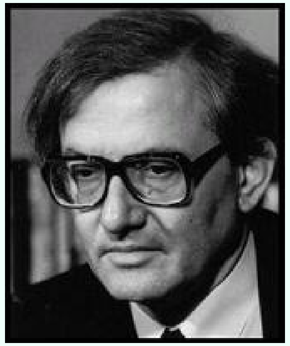
24th ZIMÁNYI SCHOOL

WINTER WORKSHOP

ON HEAVY ION PHYSICS

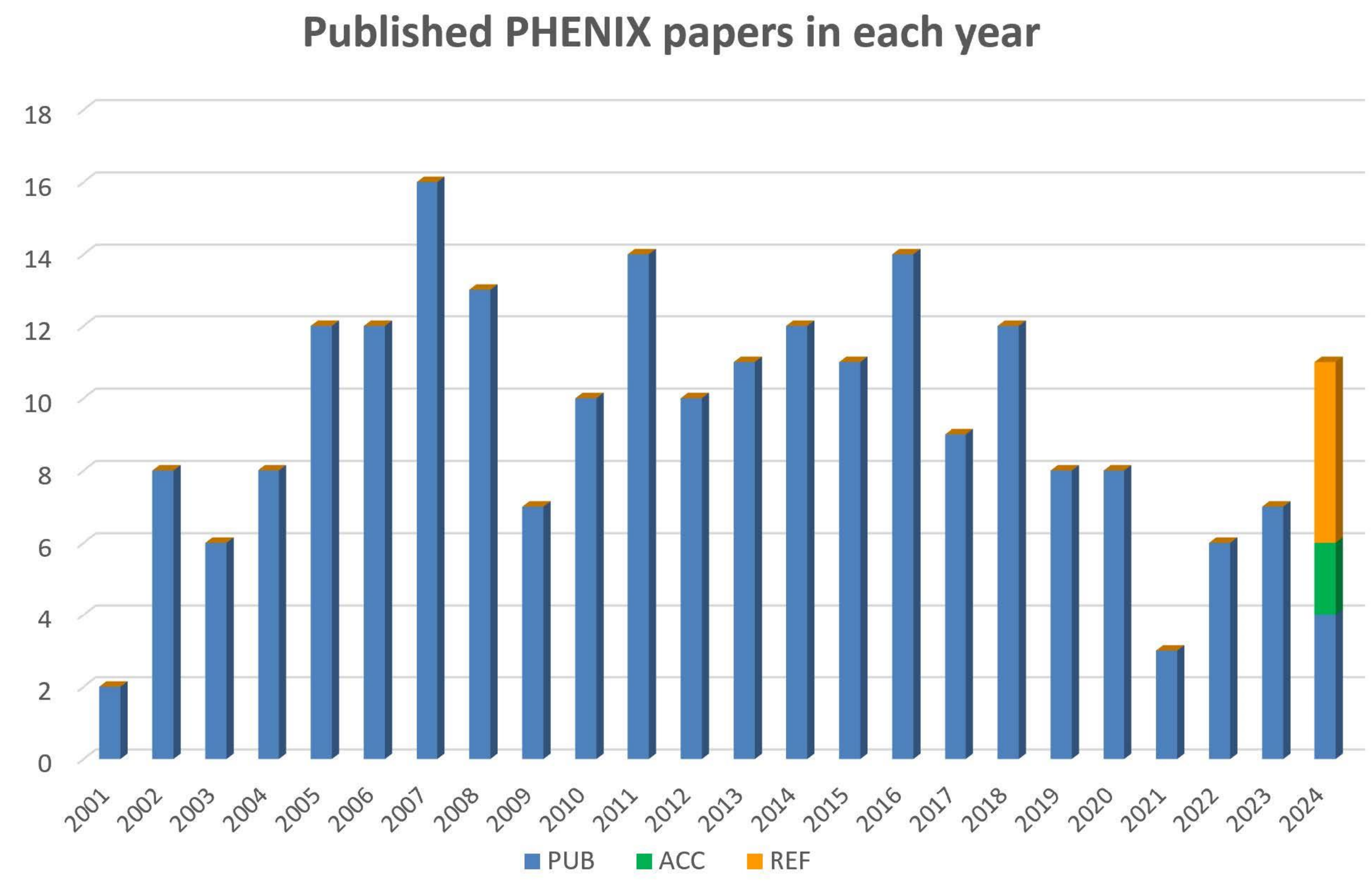
December 2-6, 2024

Budapest, Hungary



József Zimányi (1931 - 2006)

PHENIX publications



Two-pion BE correlations – η’ mass – 2407.08586

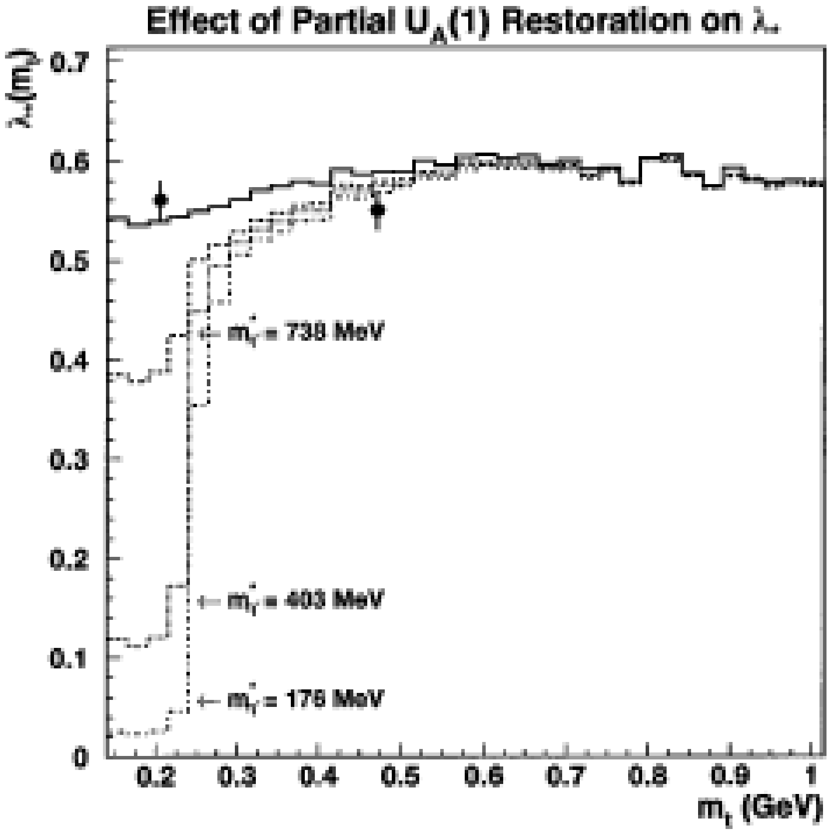
Sandor Lokos, Tue 14:20

Issues: $U_A(1)$ symmetry restoration?

VOLUME 81, NUMBER 11 PHYSICAL REVIEW LETTERS 14 SEPTEMBER 1998

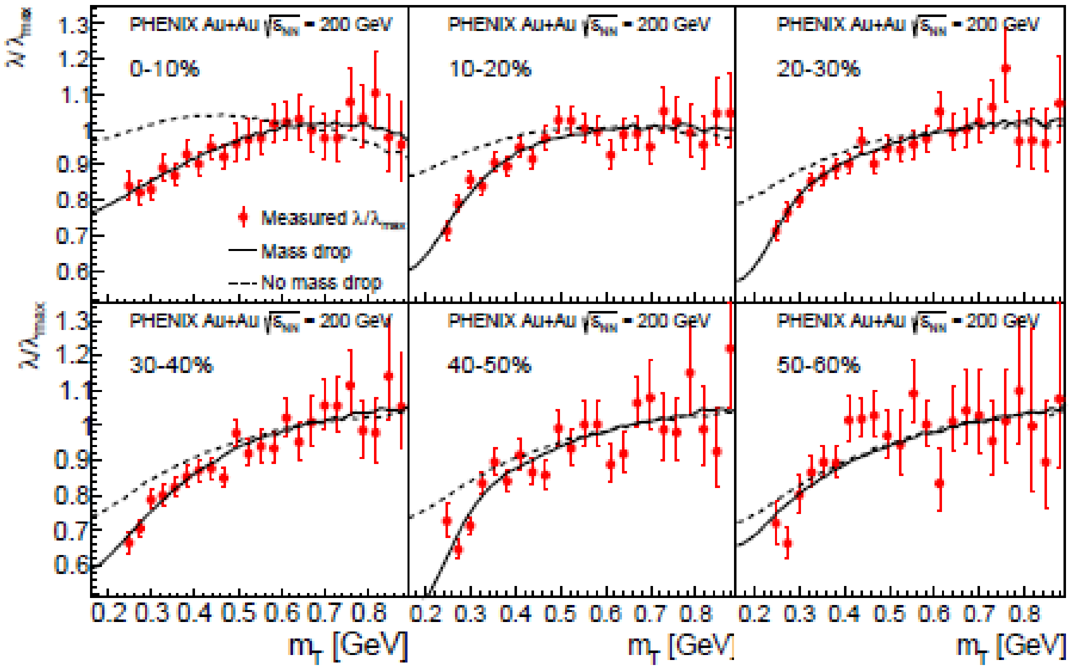
Observation of Partial $U_A(1)$ Restoration from Two-Pion Bose-Einstein Correlations

S. E. Vance,[1] T. Csörgö,[1,2] and D. Kharzeev[3]



26 years ago…

PRC Editor’s choice!



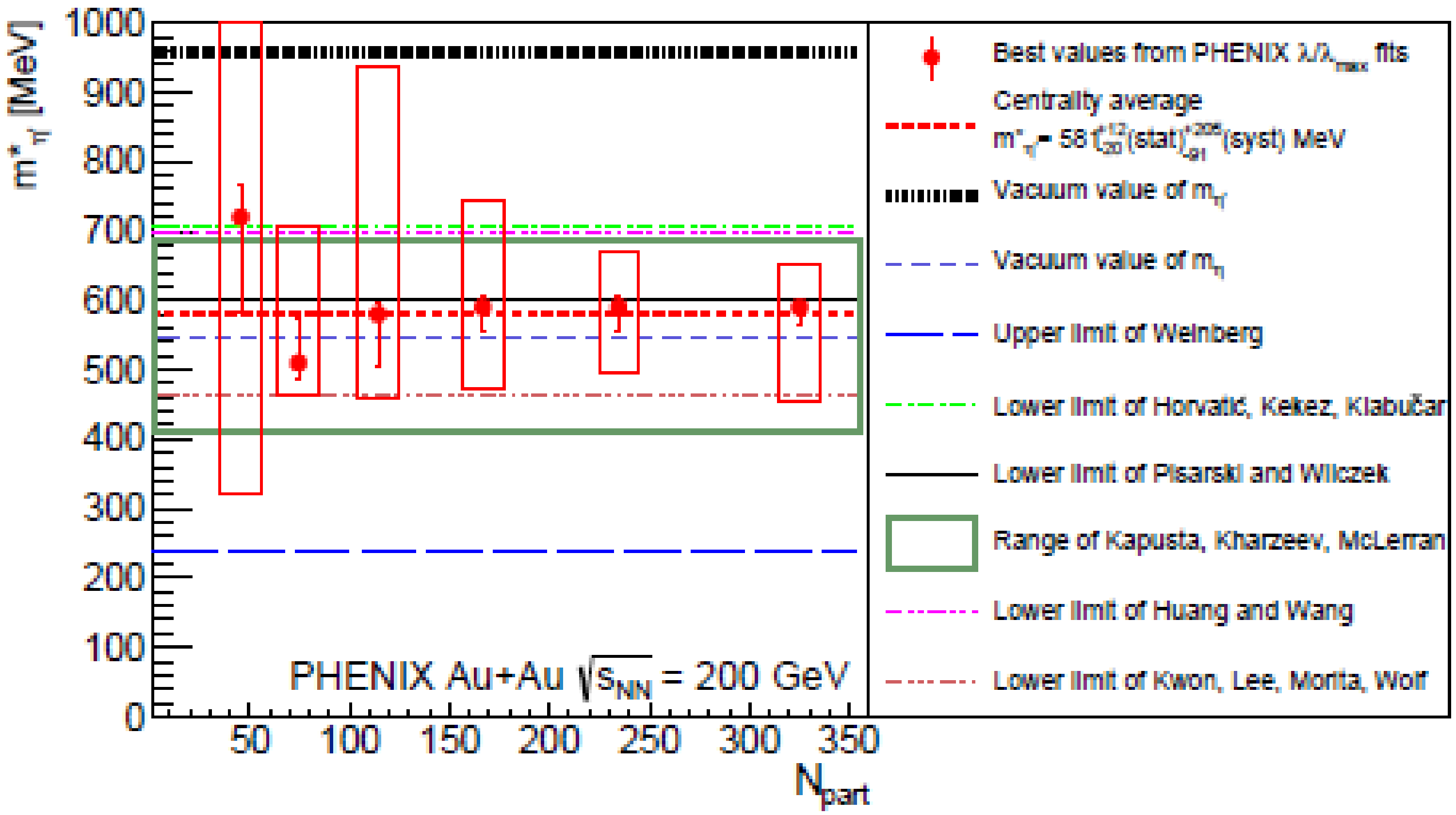
… and today

Consistent with dropping η’ mass

Two-pion BE correlations – η' mass – 2407.08586

Issues: $U_A(1)$ symmetry restoration?

Sandor Lokos, Tue 14:20

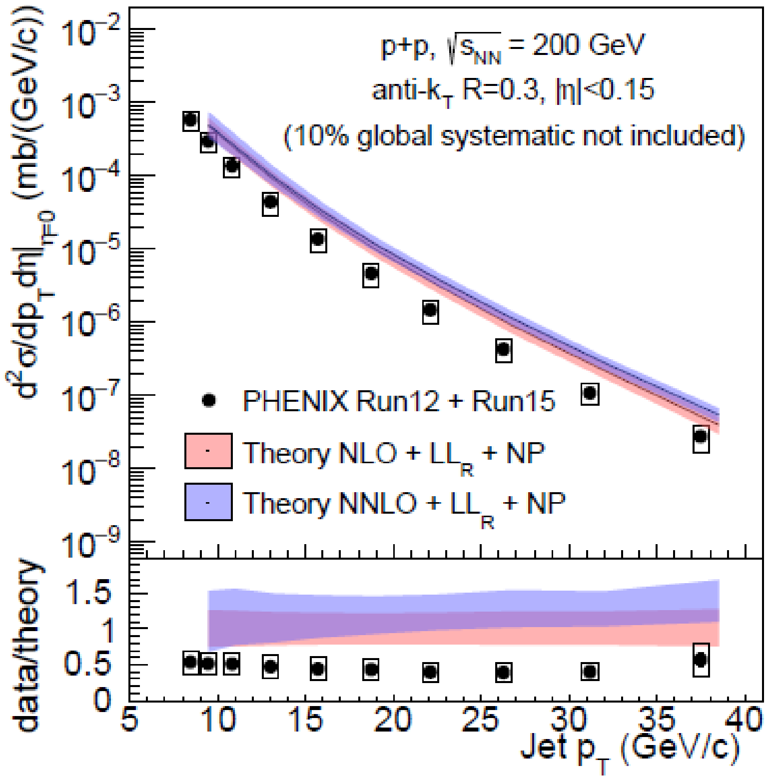


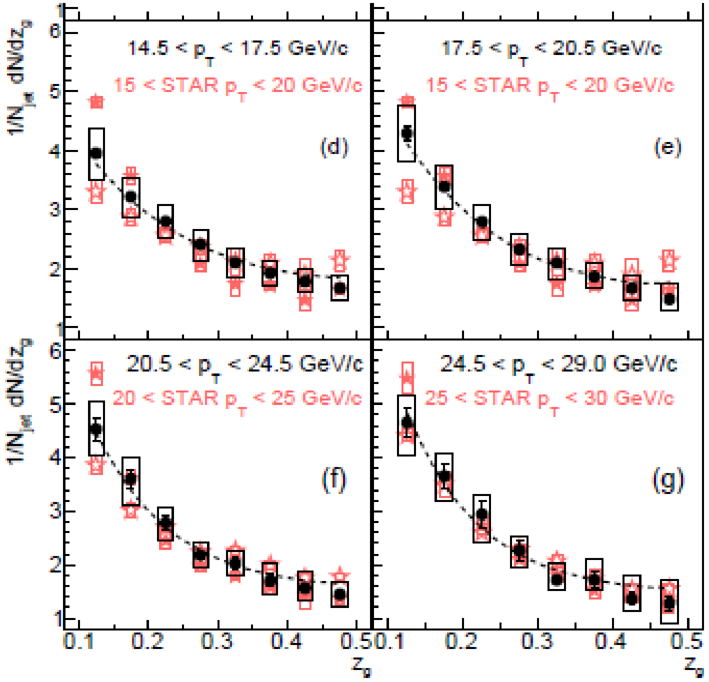
Consistent with dropping η' mass

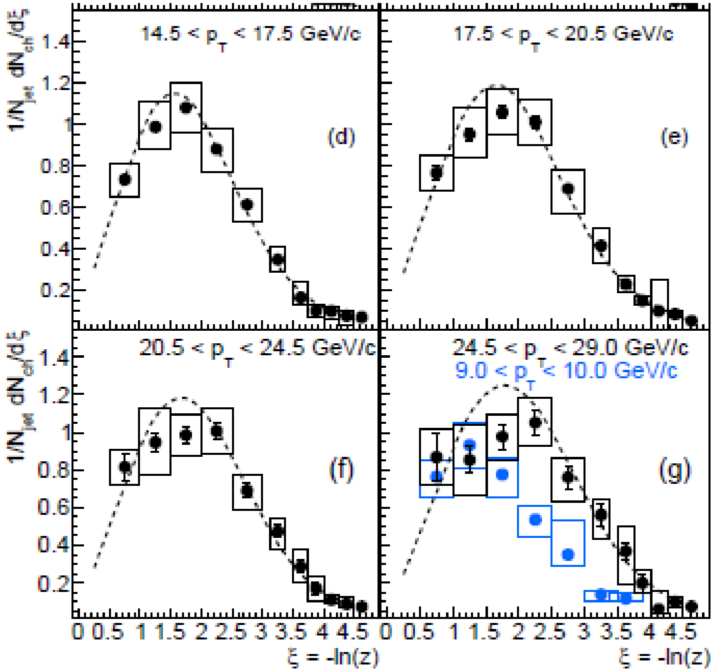
Jets – p+p, 2408.11144

Takao Sakaguchi, Tue 11:25

Issues: cross-section overestimated, shape characterization







R=0.3 → theory overestimates jet cross section

Soft-Drop z_g steeper with p_T consistent with STAR

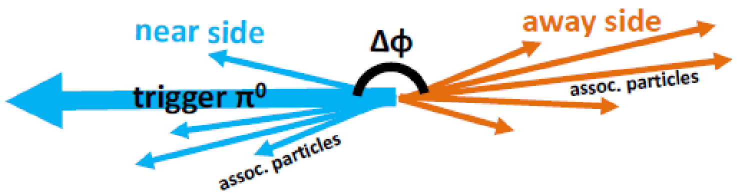
- ξ **= -ln(z)** fragmentation
- softer as p_T increases

Shift to lower z_g (higher ζ) with higher p_T

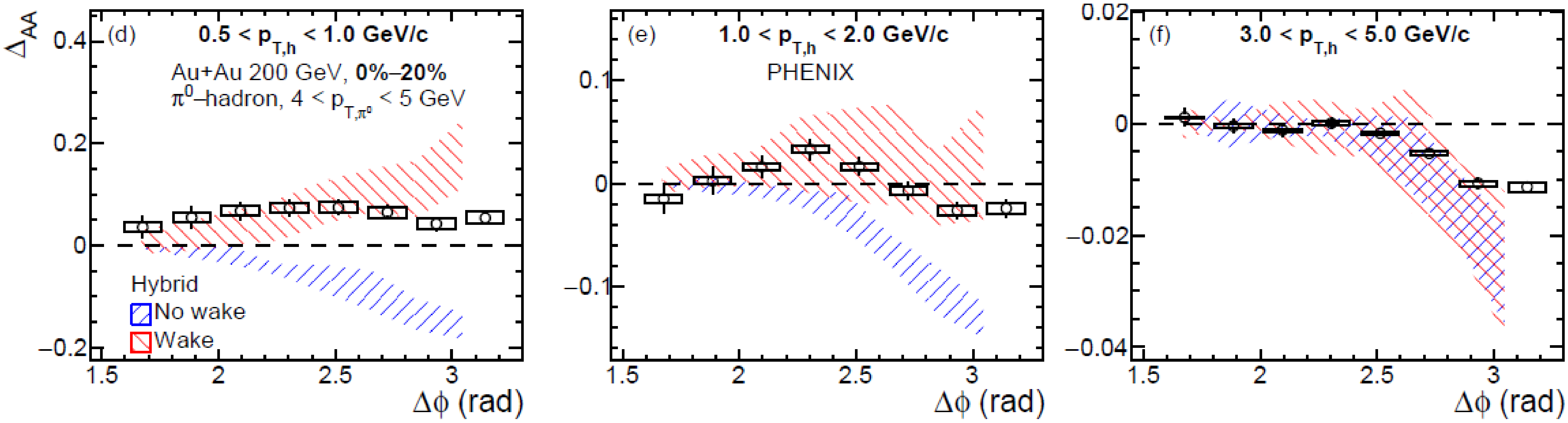
Jets (via π^0-hadron) – Au+Au PRC 110 (2024) 044901

Takao Sakaguchi, Tue 11:25

Issues: hybrid model that includes medium response



$$\Delta_{AA}(\Delta\phi) = \frac{dN^{\rm AuAu}_{\pi^0-h}}{d\Delta\phi} - \frac{dN^{pp}_{\pi^0-h}}{d\Delta\phi}.$$



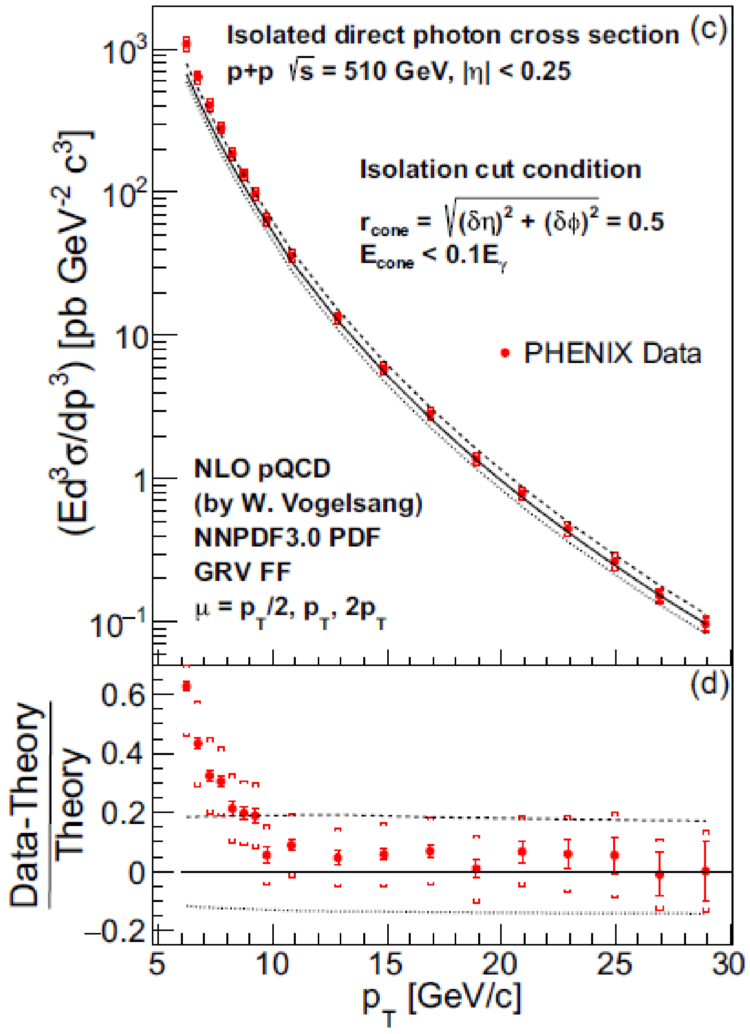
Hybrid (strong/weak, JHEP 10, 019 (2014) model) with wake → lost energy is treated as hydrodynamic "wake"

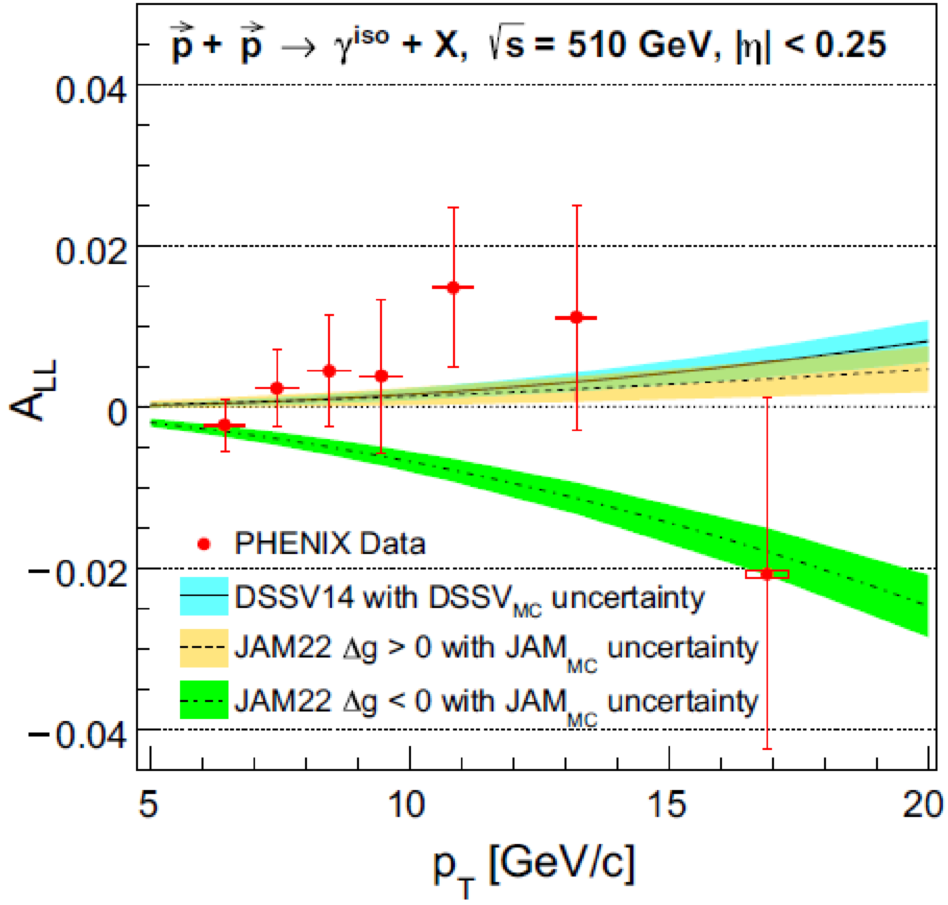
Wake preferred

Direct photons in polarized p+p – PRL 130, 251901 (2023)

Issues: NLO, "proton spin puzzle"

$$A_{LL} = \frac{\Delta\sigma}{\sigma} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}},$$



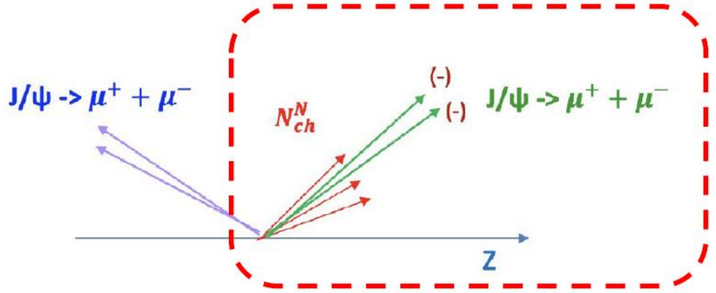


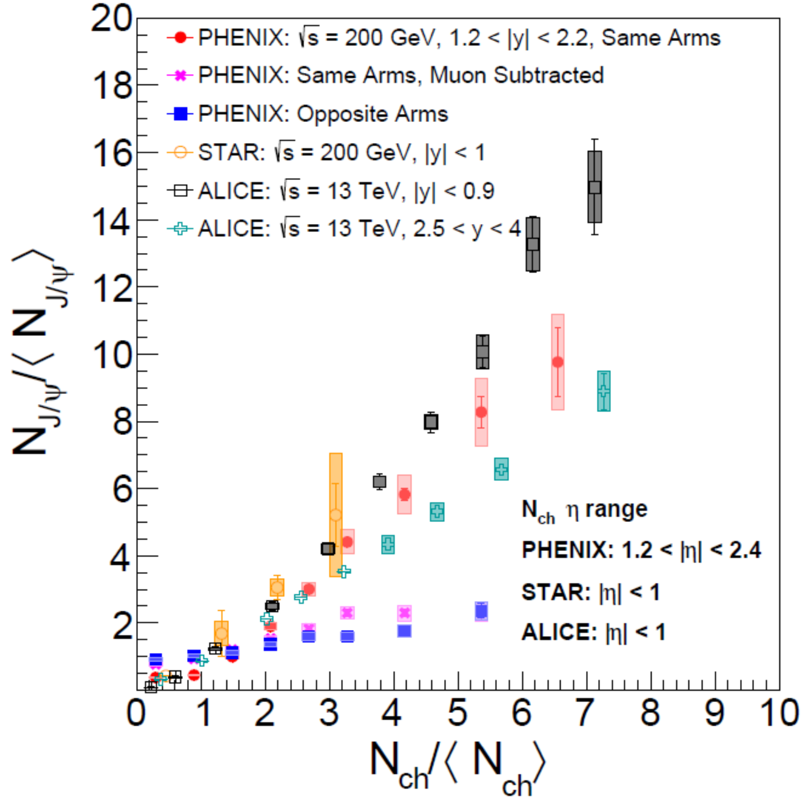
Isolated photons
Good agreement with theory at high $\mathbf{p_T}$

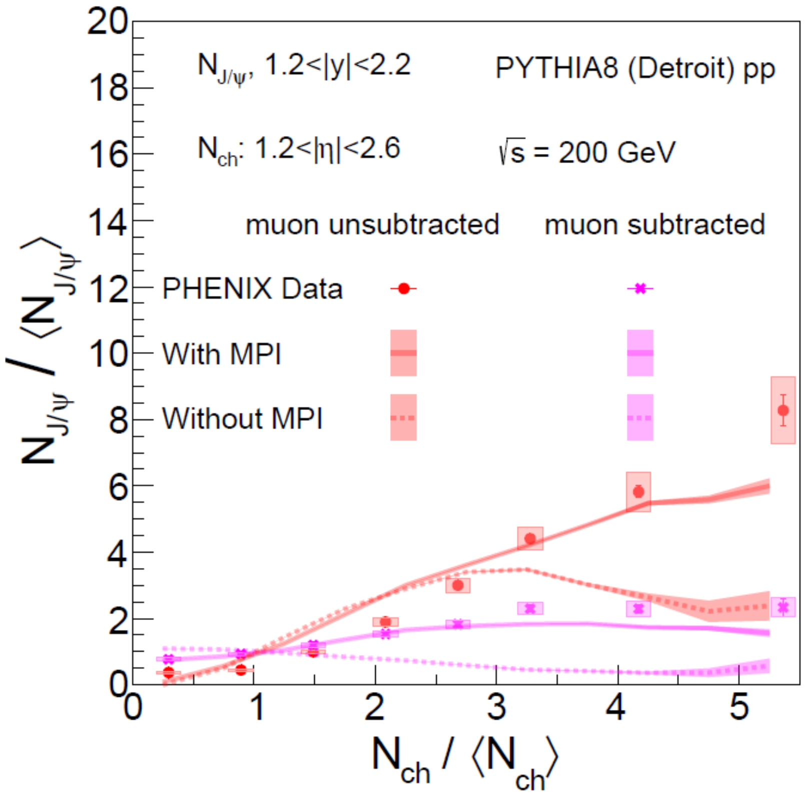
Small, positive contribution from gluons to proton spin

Charmonium vs multiplicity in p+p – 2409.03728

Issues: MPI, auto-correlations, self-normalized **J/ψ** and multiplicity







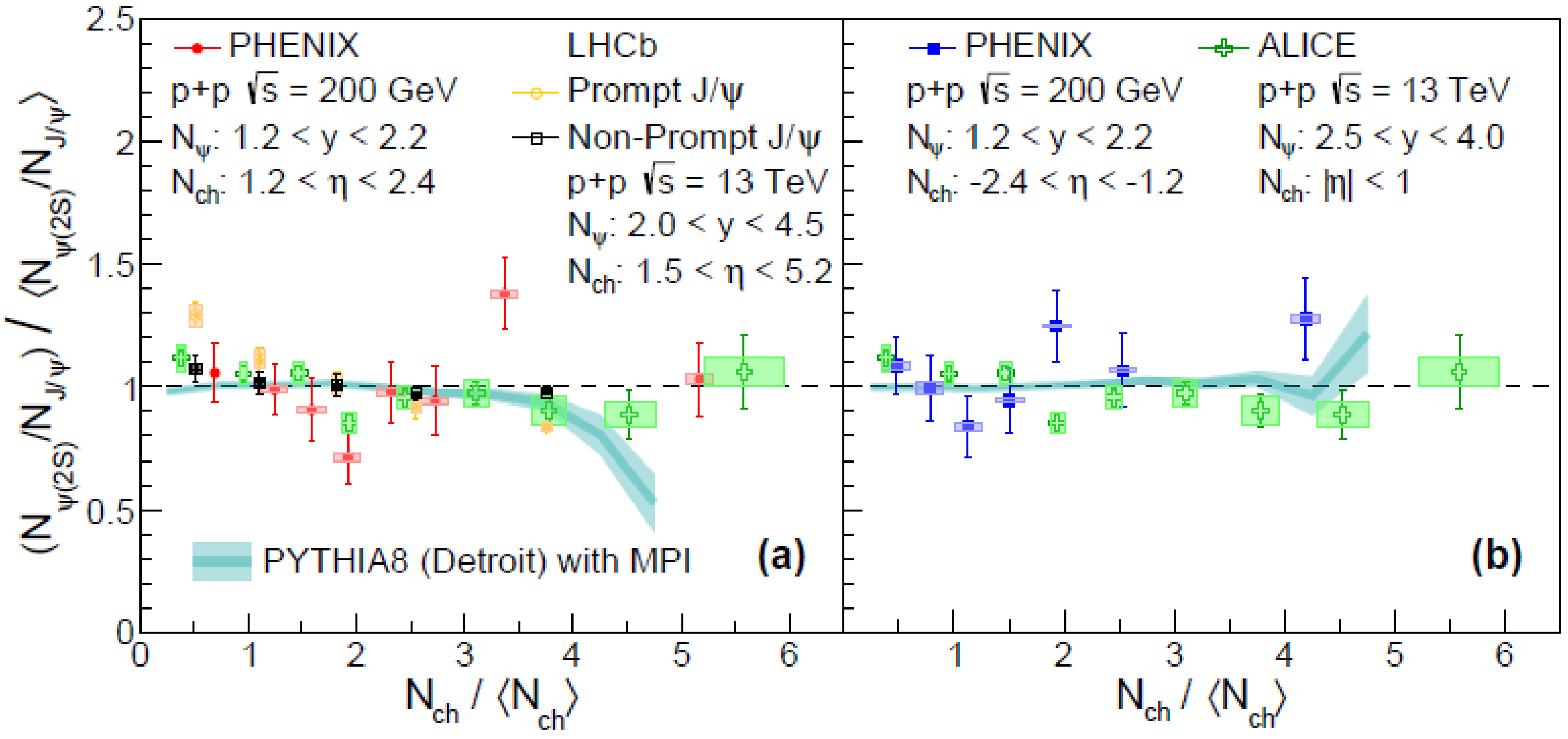
Both the muon subtracted and unsubtracted data consistent with the corresponding PYTHIA8 **with MPI**

MPI needed to describe data

ψ(2S) / J/ψ vs multiplicity in p+p – 2409.03728

Issue: any visible changes from hot (QGP) or cold (CNM) effects?

N_{ch} in **same** rapidity window



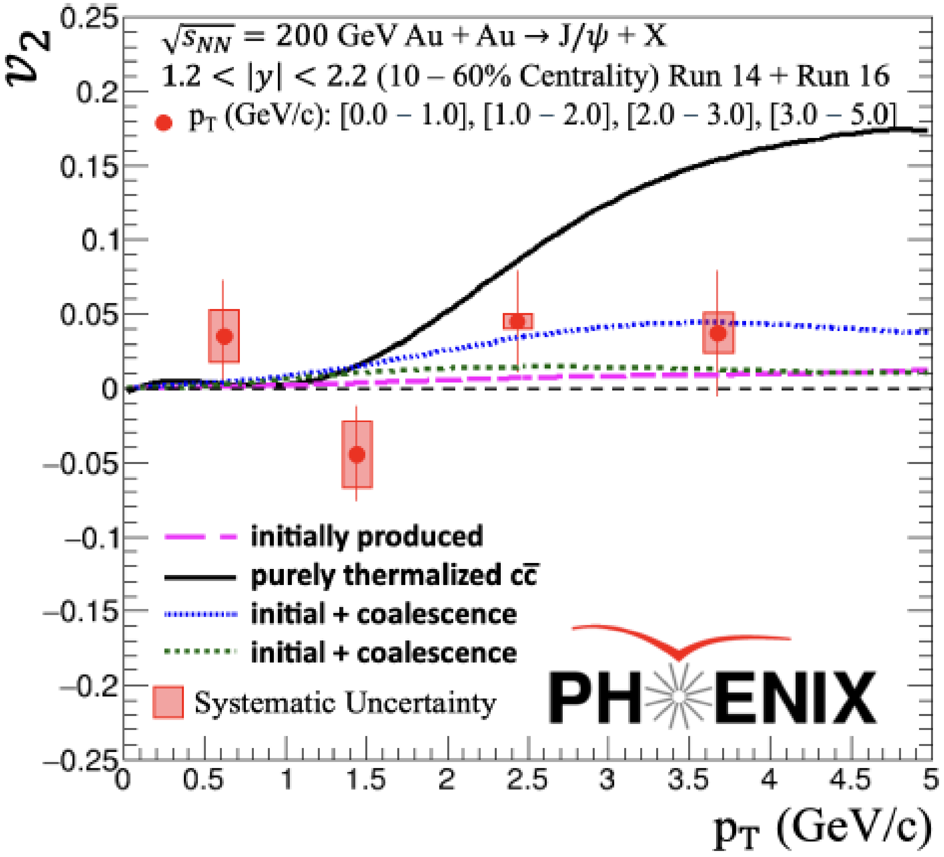
N_{ch} in **opposite** rapidity window

No change with multiplicity;
consistent with ALICE and LHCb
and with PYTHIA8 with MPI, no FSI

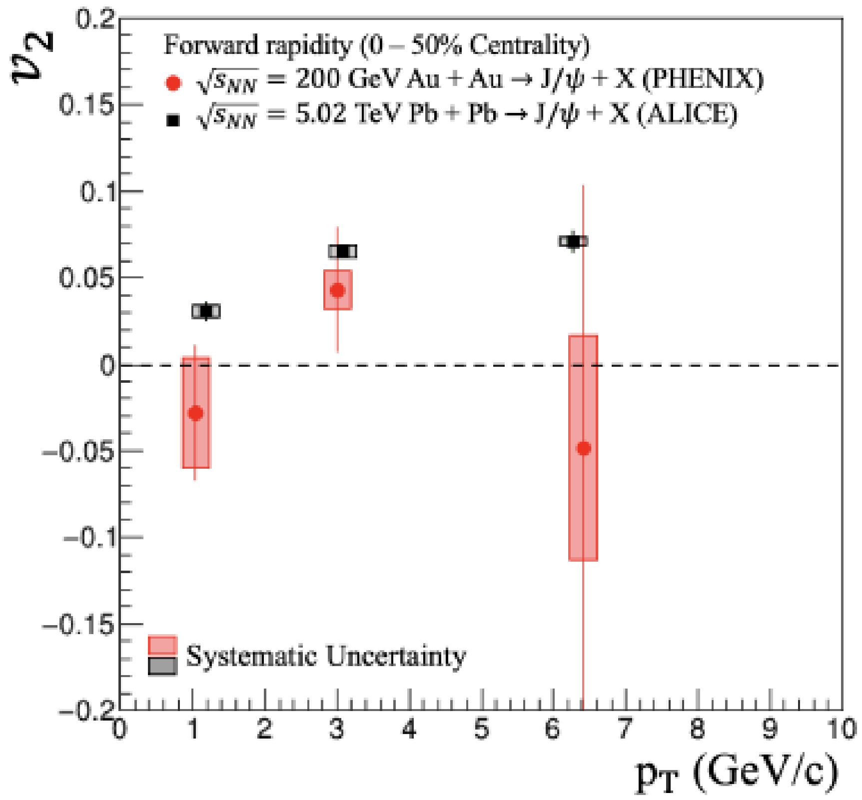
No significant final-state effects

J/ψ flow at forward rapidity in Au+Au – 2409.12756

Issue: charm thermalization, coalescence



Consistent with no flow or coalescence from partial thermalization

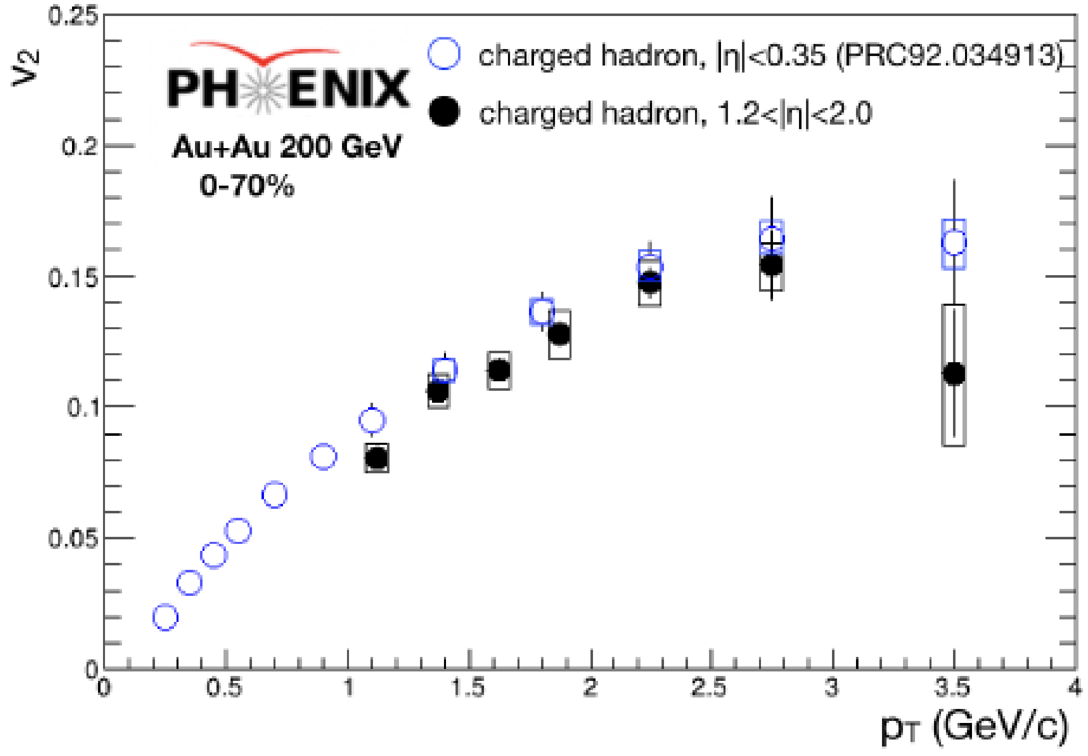


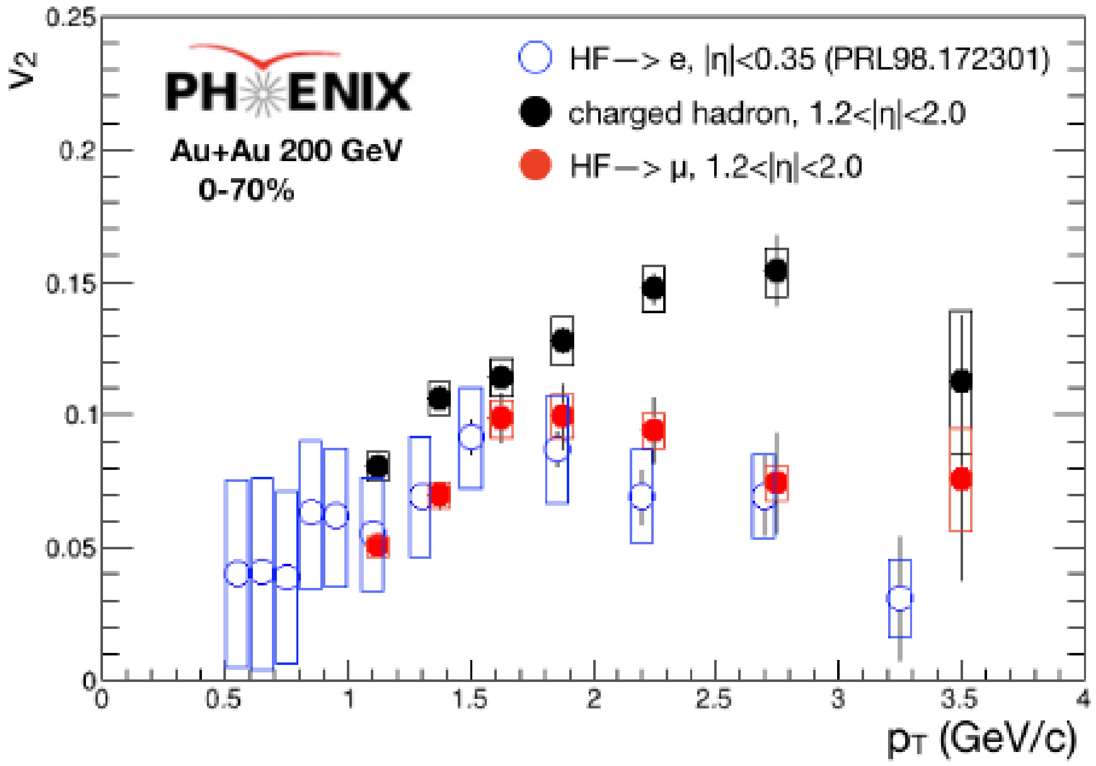
Tension with the flow (unambiguous) seen by ALICE

Full thermalization of charm disfavored

Hadron and open HF flow in Au+Au – 2409.12715

Issues: rapidity-dependence of flow, difference between light and heavy flavor





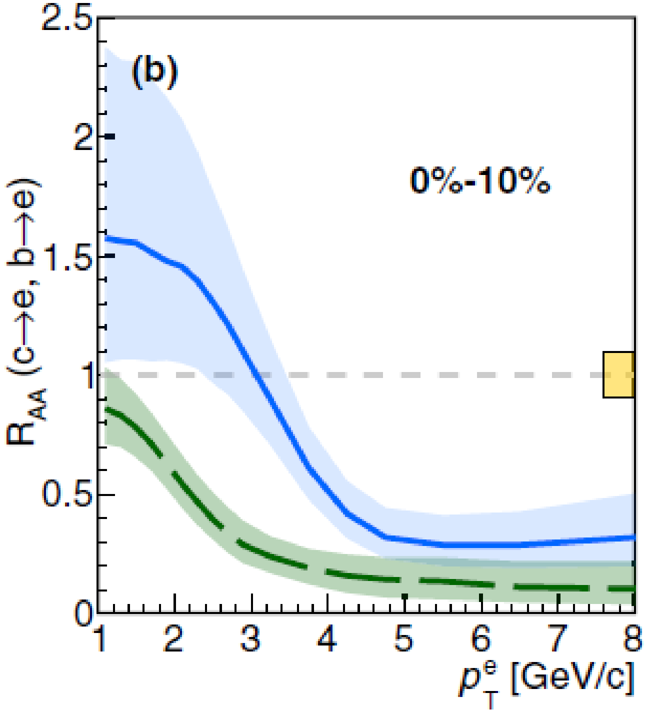
Comparable flow for charged hadrons at mid- and forward-rapidity (hint of some difference)

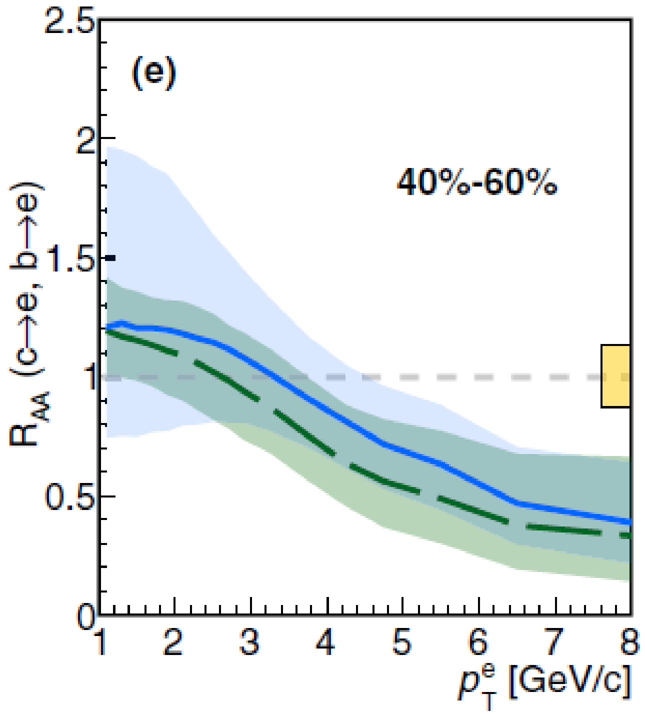
Comparable flow for HF muons (electrons) at mid- and forward-rapidity

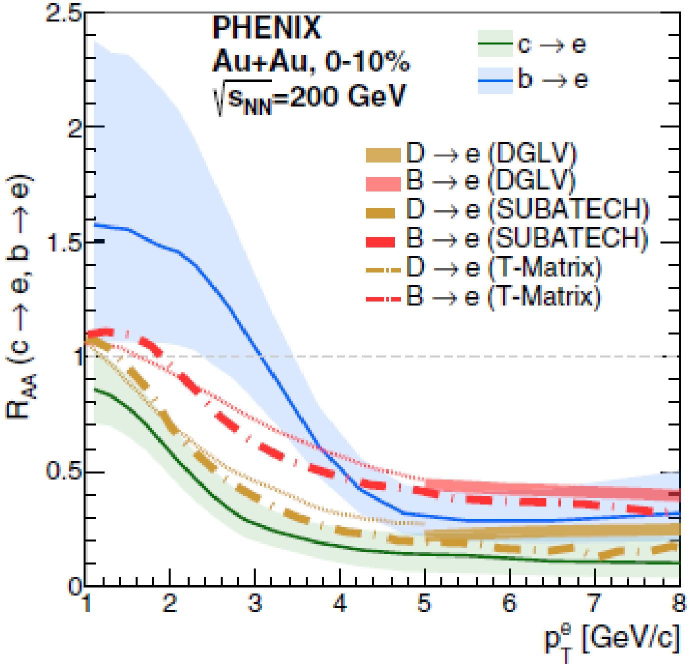
Light and heavy flavor flow very different
Quark-mass dependence of interactions with QGP

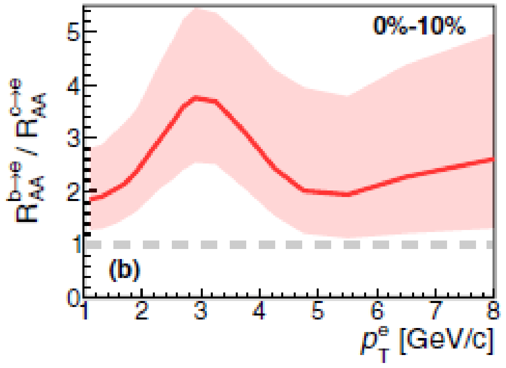
Charm and bottom R_{AA} in Au+Au – PRC 109, 044907 (2024)

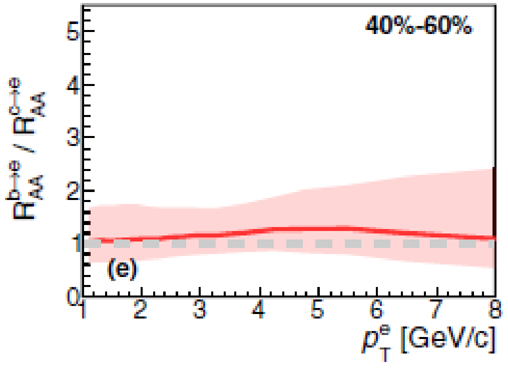
Issues: ordering, $\mathbf{p_T}$-dependence of energy loss mechanism











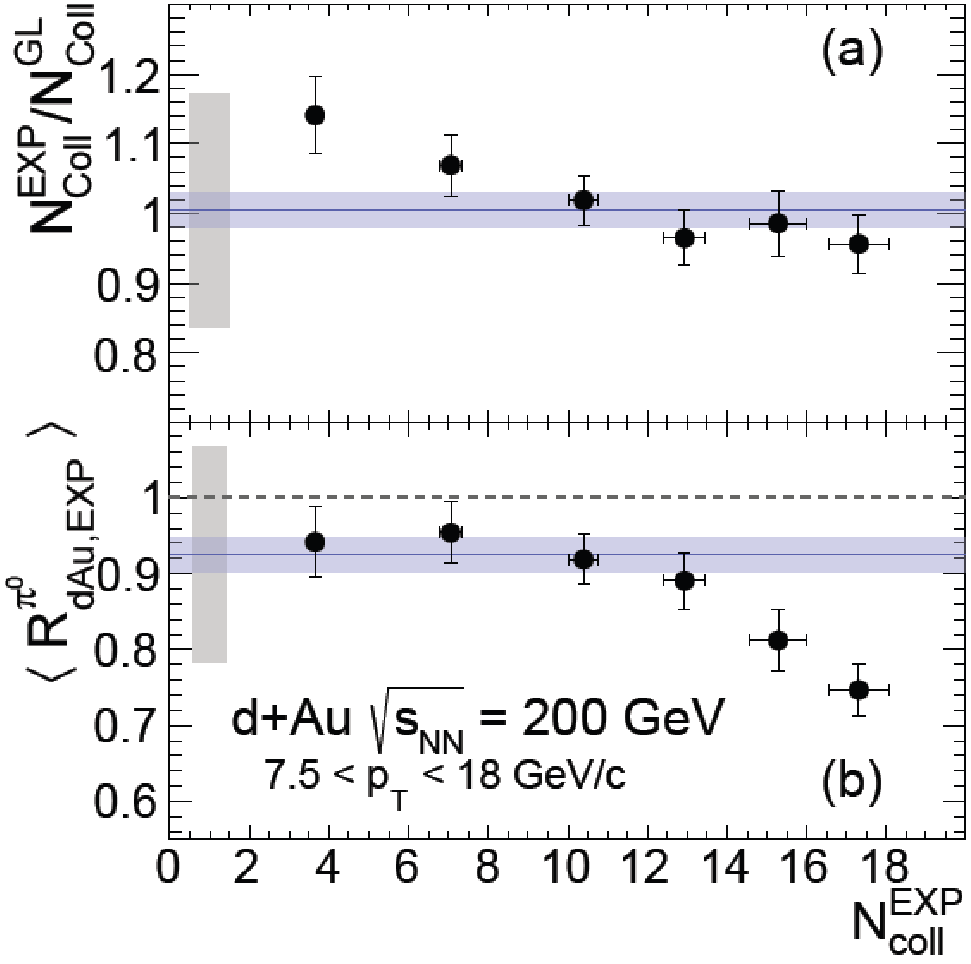
DGLV → rad + coll
SUBATECH → HTL
T-matrix → resonances

Quark-mass ordering of suppression

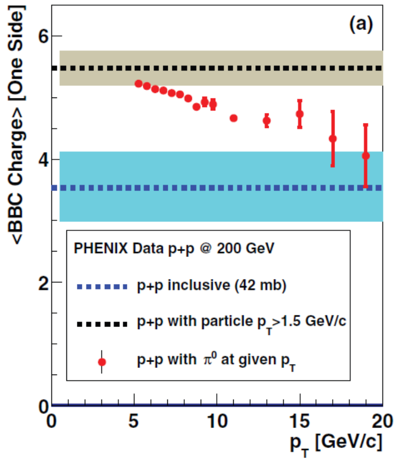
Small systems RAA, experimental Ncoll – 2303.12899

Issues: centrality bias, suppression in QGP droplets? Direct photon “standard candle”

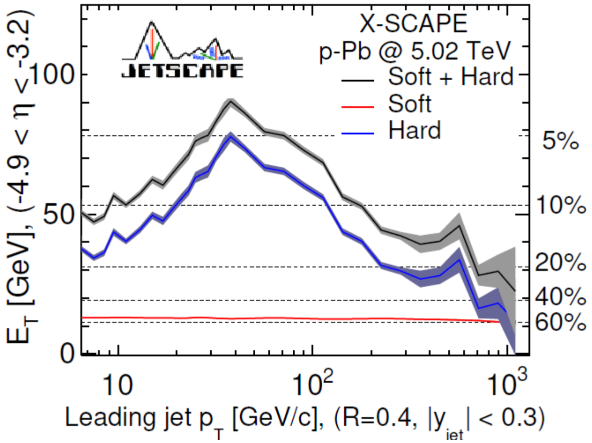
Zhandong Sun, Wed 16:35



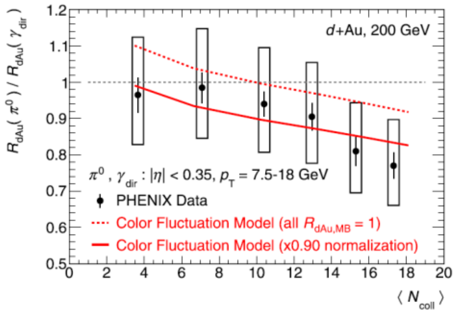
PRC 90, 034902 (2014)



2407.17443



PRC 110, L011901 (2024)



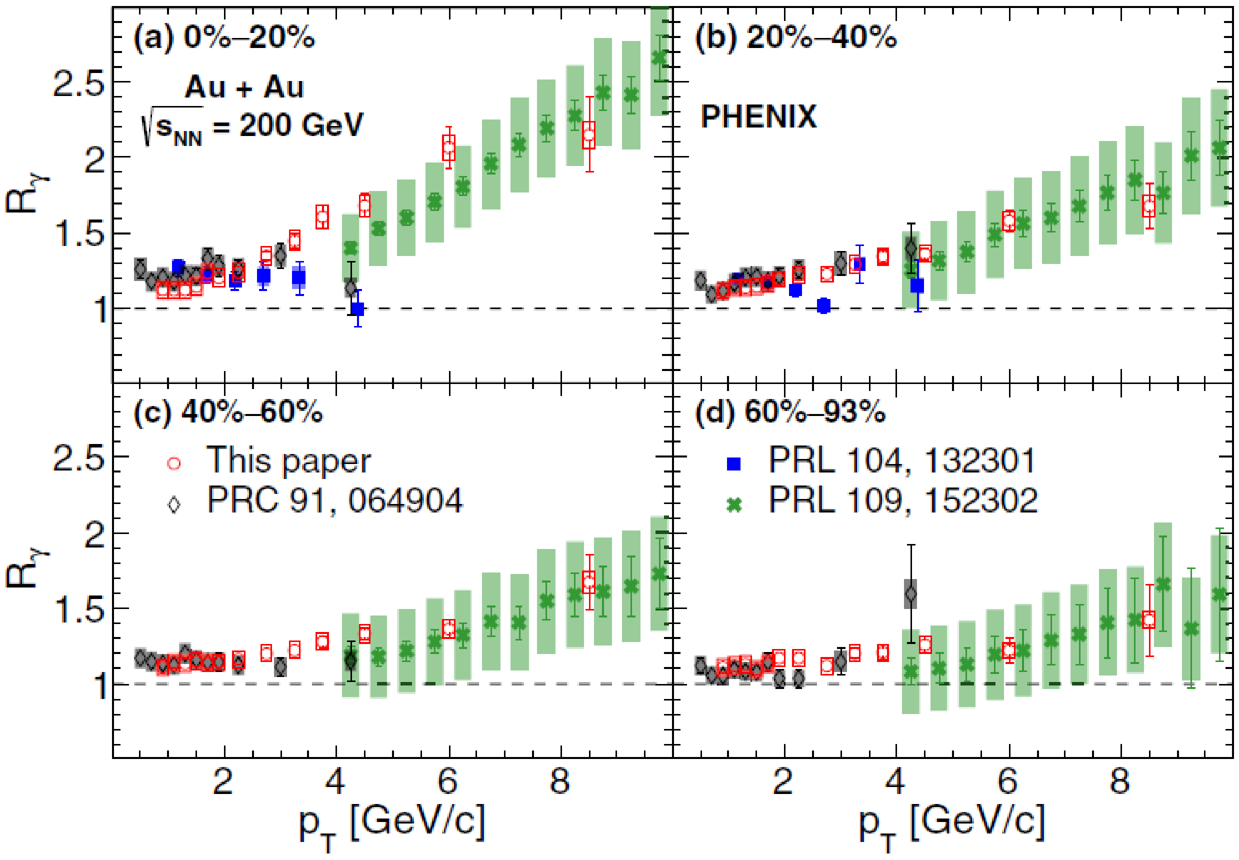
Genuine energy loss?
Energy conservation?
Shrinking proton?
Distinguishable?

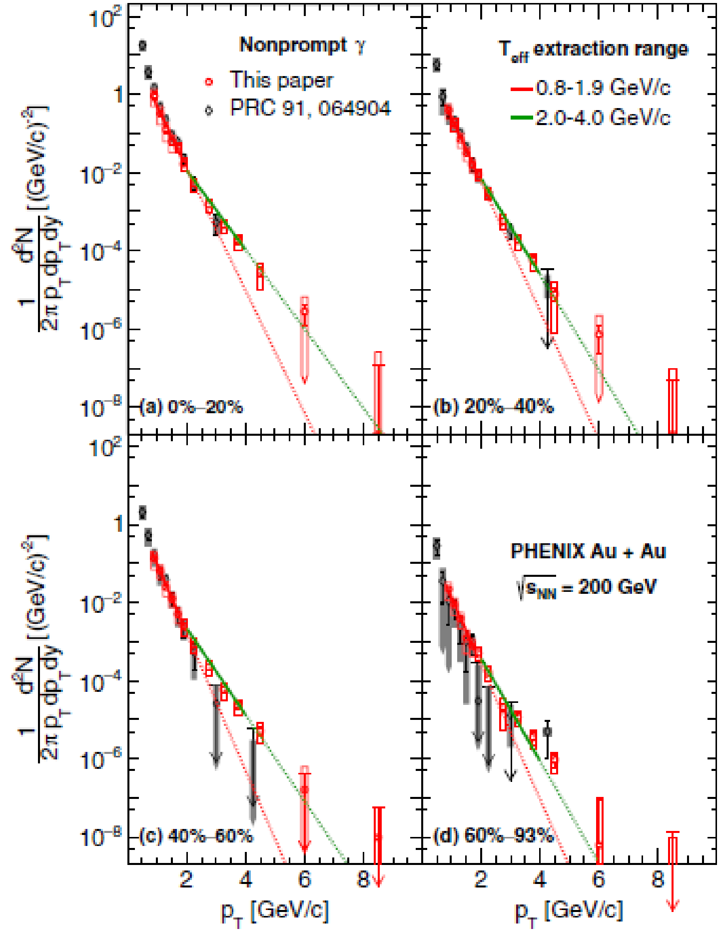
Suppression observed; system size scan important to prove origin

Normalize to direct photons
Still suppression in very central events
→ origin debatable

Low pT direct photon yield – PRC 109, 044912 (2024)

Issues: non-prompt photon yield, origins? (thermal, pre-equilibrium, hadronic…?)





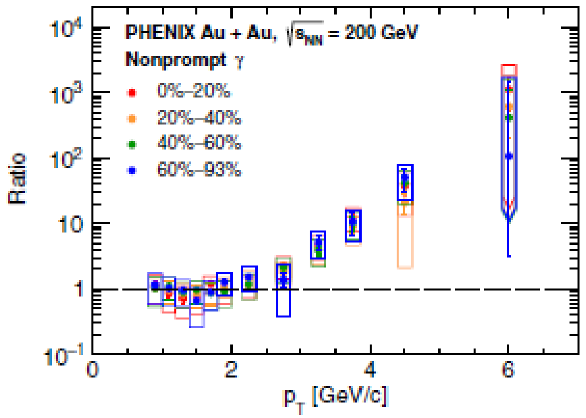
Rγ → inclusive / decay photon ratio
Consistent results with four different methods

T_{eff} varies with p_T

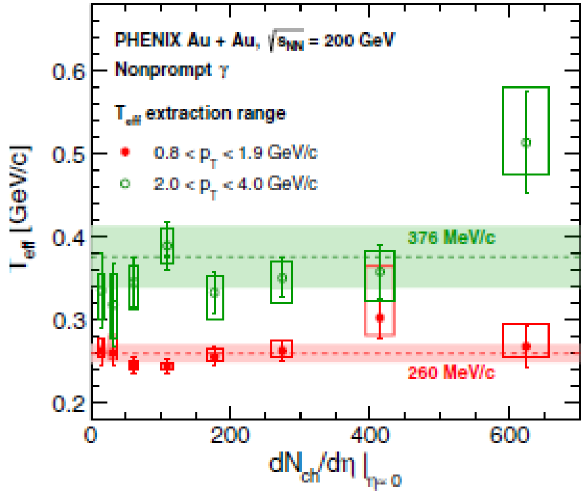
Low pT direct photon scaling, T_{eff} – PRC 109, 044912 (2024)

Issues: $\mathbf{T_{eff}}$ evolution, radial flow, centrality dependence

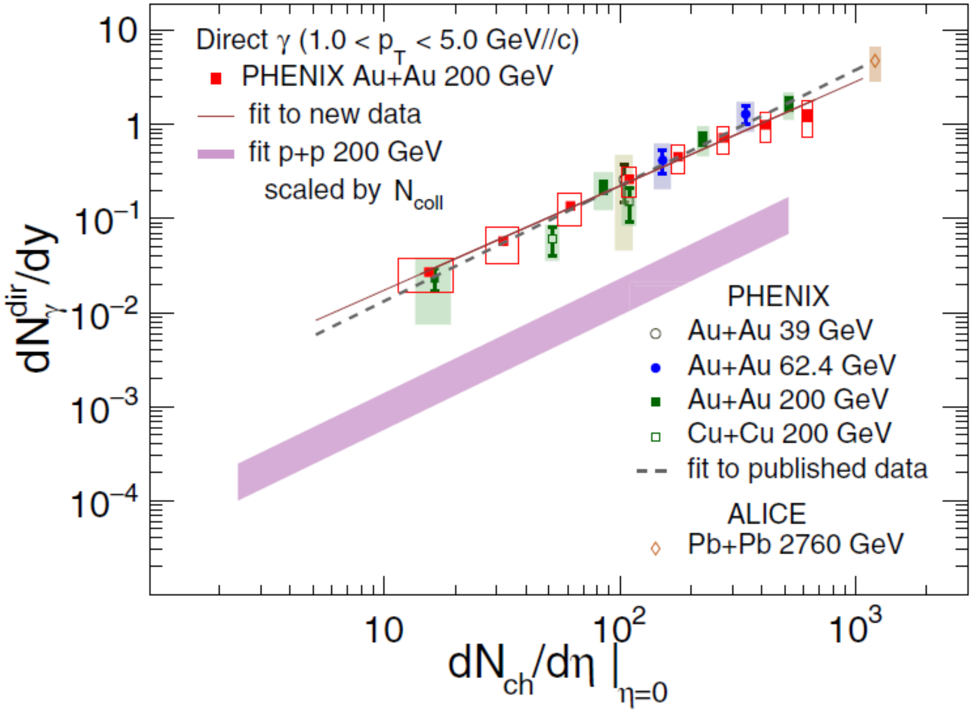
A glimpse into the joint effect of cooling and radial expansion (blueshift)



Ratio of $\mathbf{T_{eff}}$ vs $\mathbf{p_T}$
w.r.t. a fixed fit (260 MeV)



$\mathbf{T_{eff}}$ vs multiplicity at different $\mathbf{p_T}$ bins

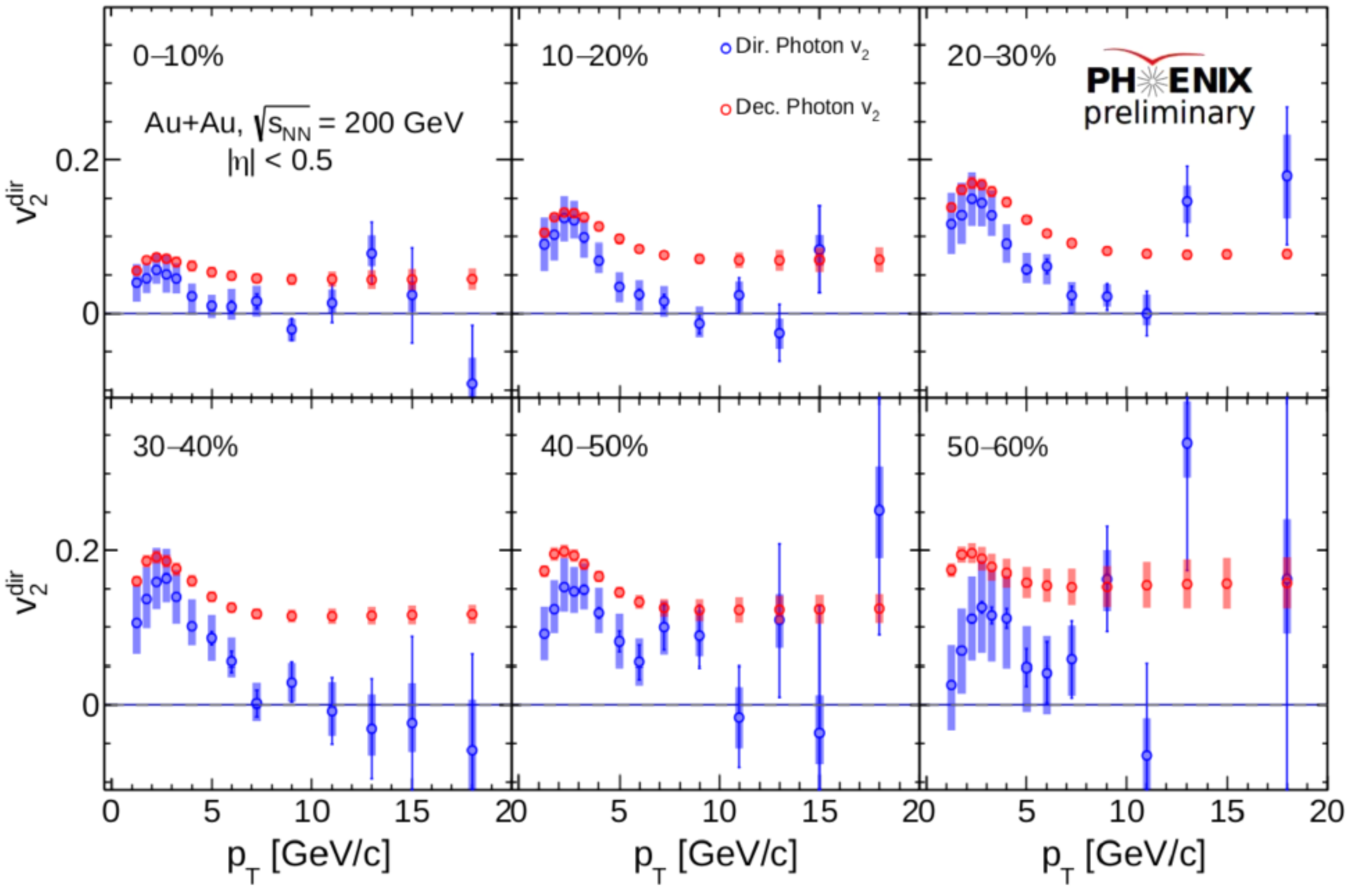


Integrated yield $1.0 < \mathbf{p_T} < 5.0$ GeV/c
Scaling with multiplicity only (different system sizes!)
Power α = 1.11 surprisingly small
Ongoing tension with STAR

T_{eff} varies with p_T but independent of centrality
Scaling with multiplicity for larger systems

Direct photon v_2

Issues: early emission → large yields, late emission → large $\mathbf{v_2}$ -- or paradigm change needed?



New $\mathbf{v_2}$ measurements, larger statistics, finer centrality bins

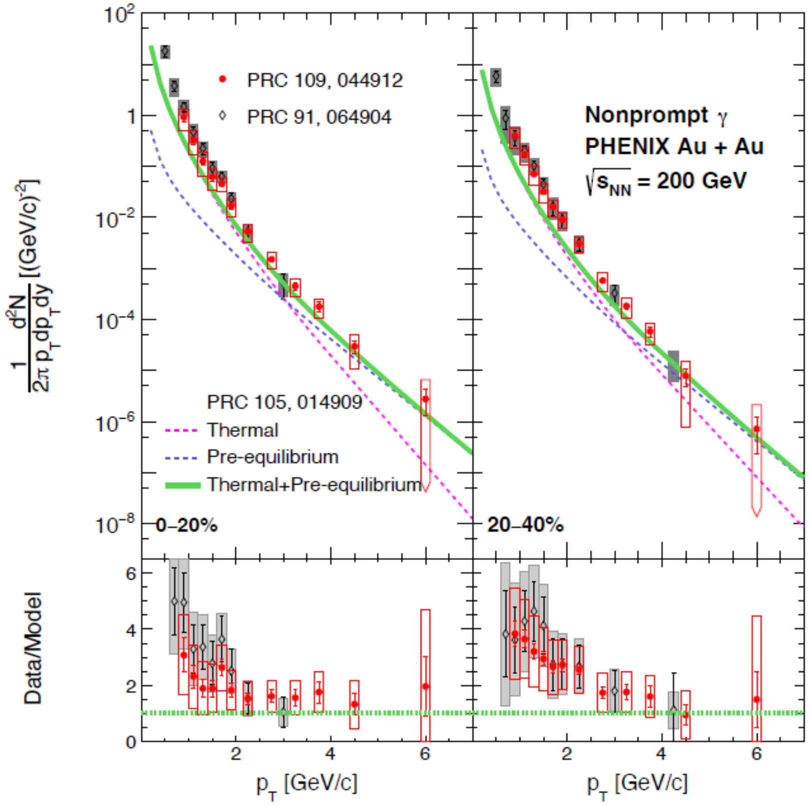
Photon $\mathbf{v_2}$ very close to hadron $\mathbf{v_2}$ although centroids systematically lower

At high $\mathbf{p_T}$ photon $\mathbf{v_2}$ about zero, as expected

Photon and hadron flow comparable

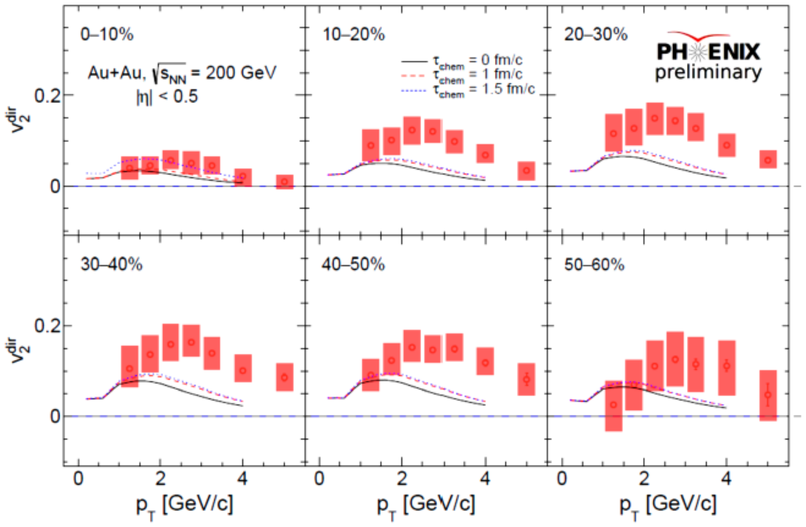
Low p_T photons – model calculations

Issues: early emission → large yields, late emission → large $\mathbf{v_2}$ -- or paradigm change needed?



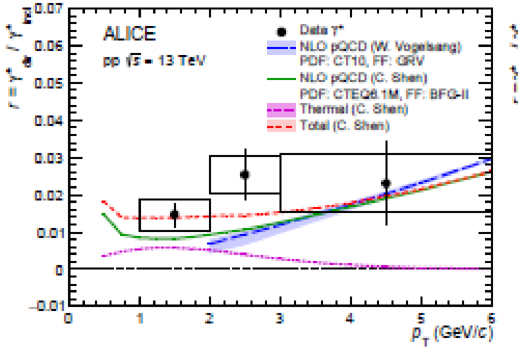
Discrepancy below 2 GeV/c

Phys. Rev. C 105 014909 (2022) C. Gale et. al.



Discrepancy above 2 GeV/c

Just off the press: 2411.14366
ALICE finds small but unambiguous low $\mathbf{p_T}$ photon yield in 13 TeV p+p at all multiplicities (not just the highest)

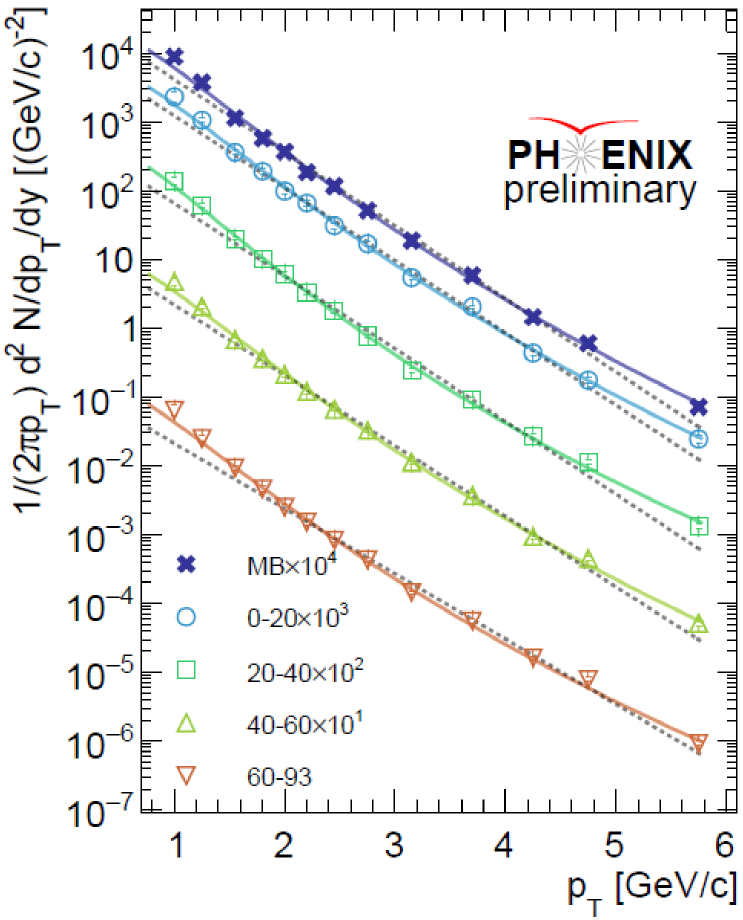


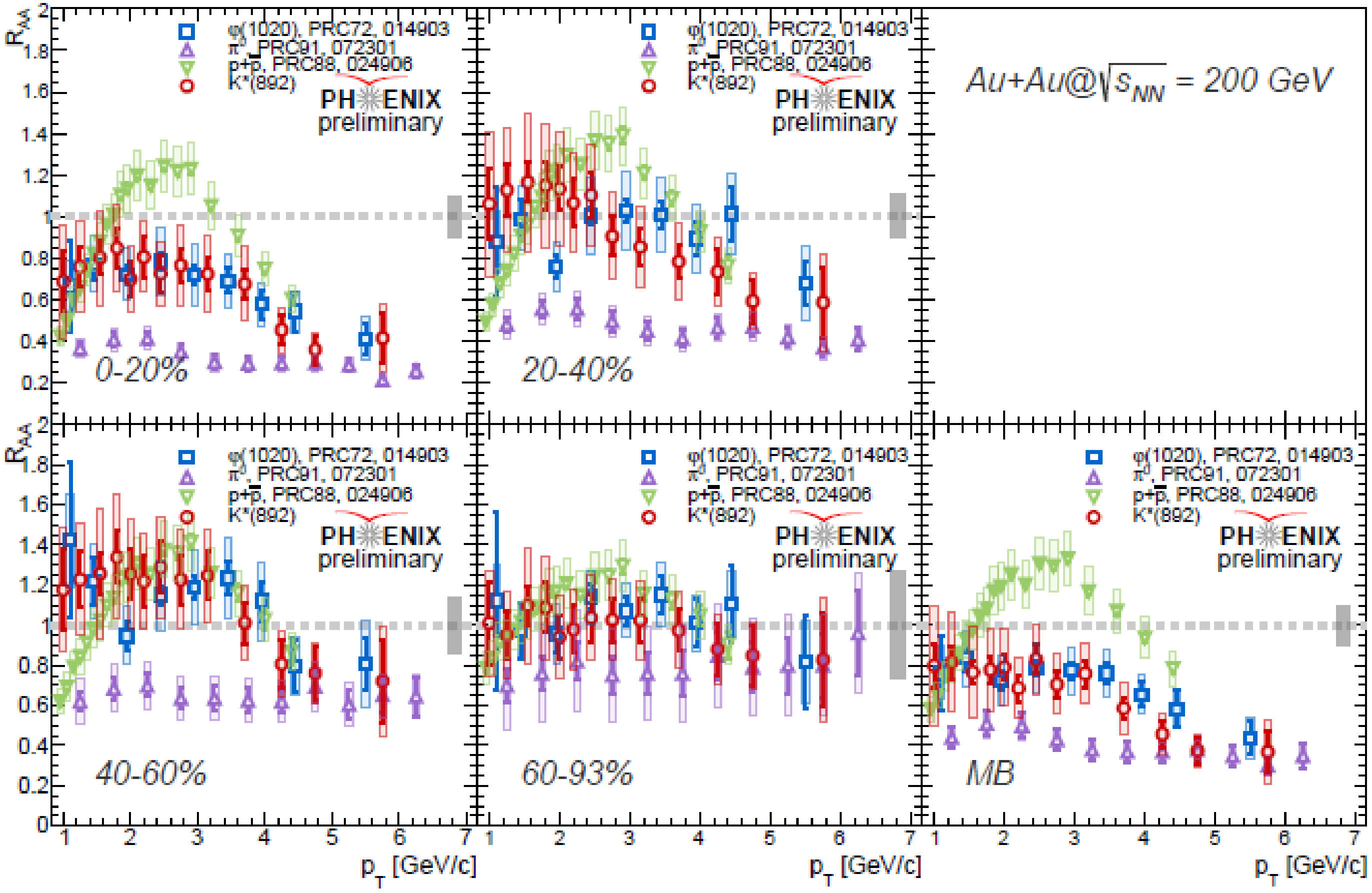
"Direct photon puzzle" alive and well…

Strangeness – K and φ (preliminary)*

Issues: strangeness in QGP

Melinda Orosz, Wed 16:50



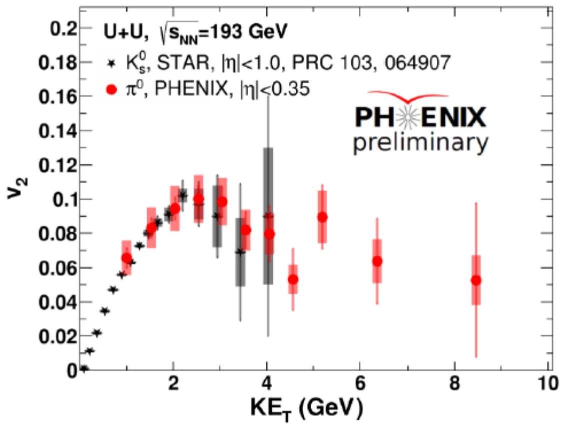


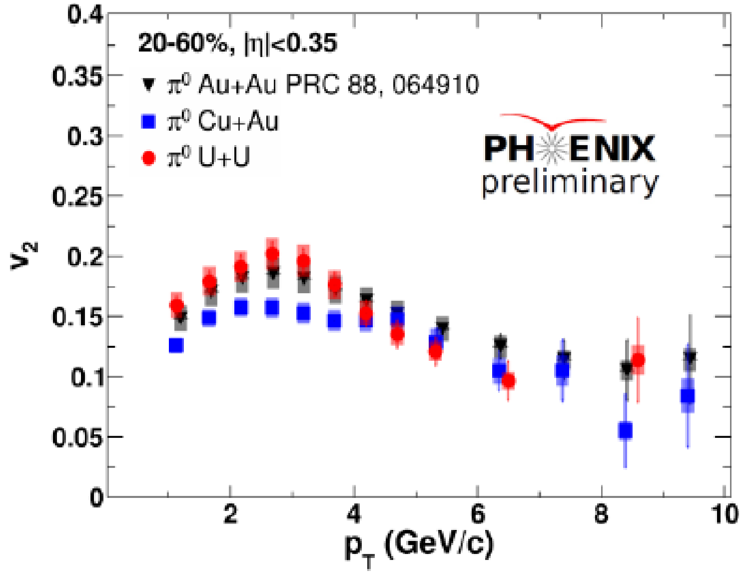
K* and φ R_{AA} compatible, above those from pure u, d mesons

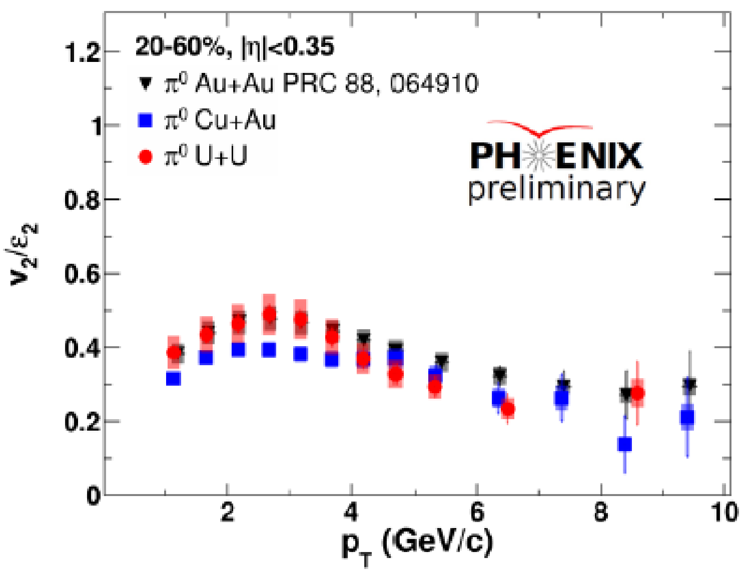
U+U – π^0 v_2 (preliminary)

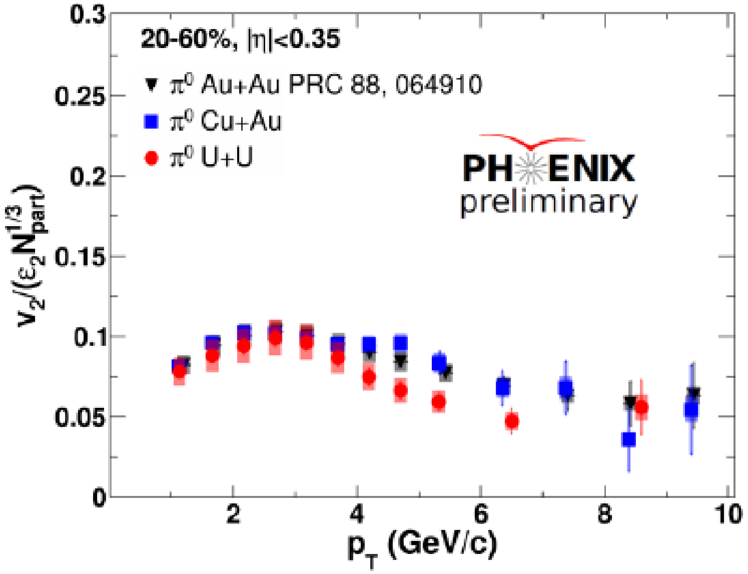
Issue: universal scaling with $\varepsilon_2 N^{1/3}_{part}$?

Good agreement with STAR K^0_S





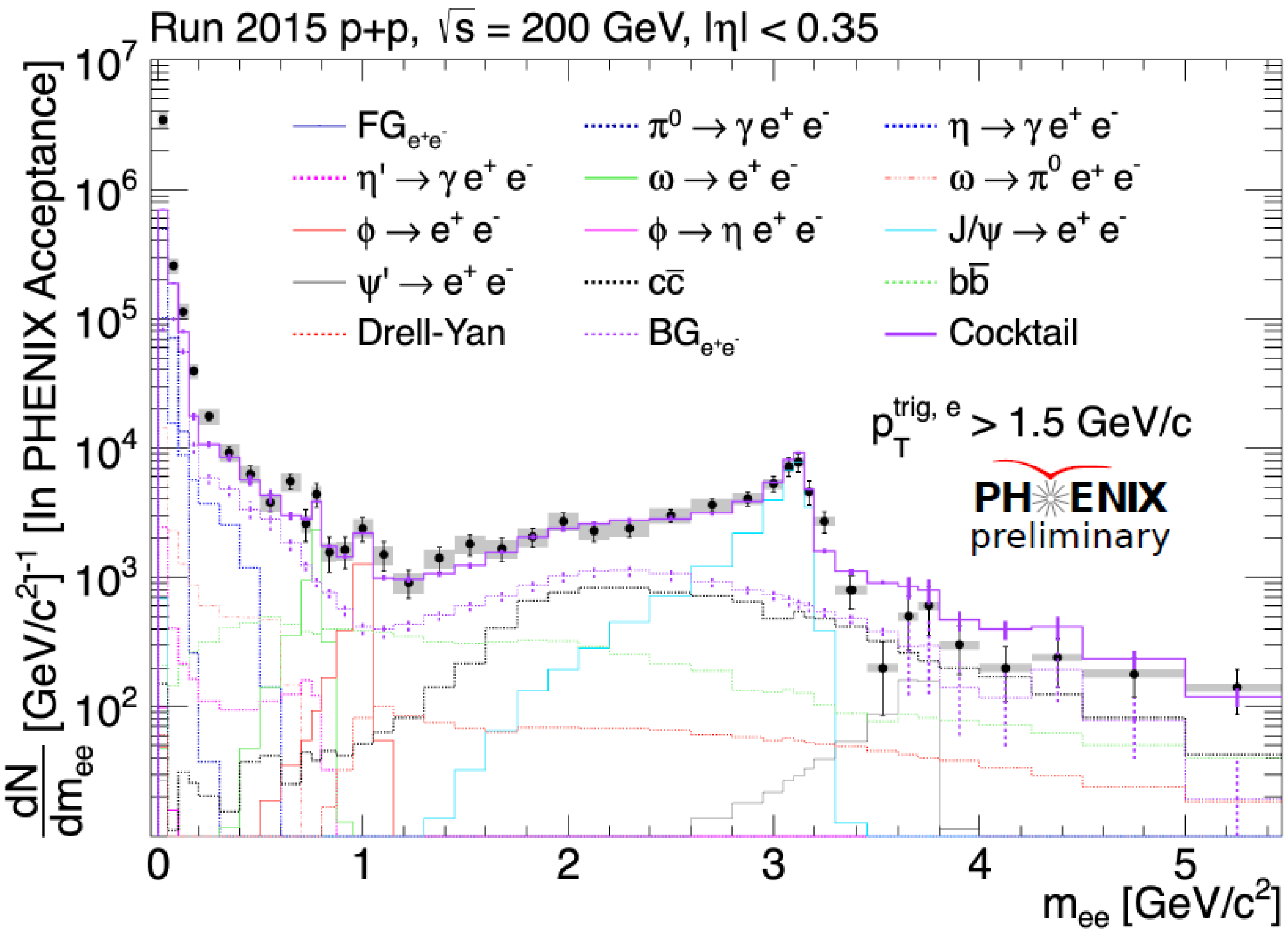


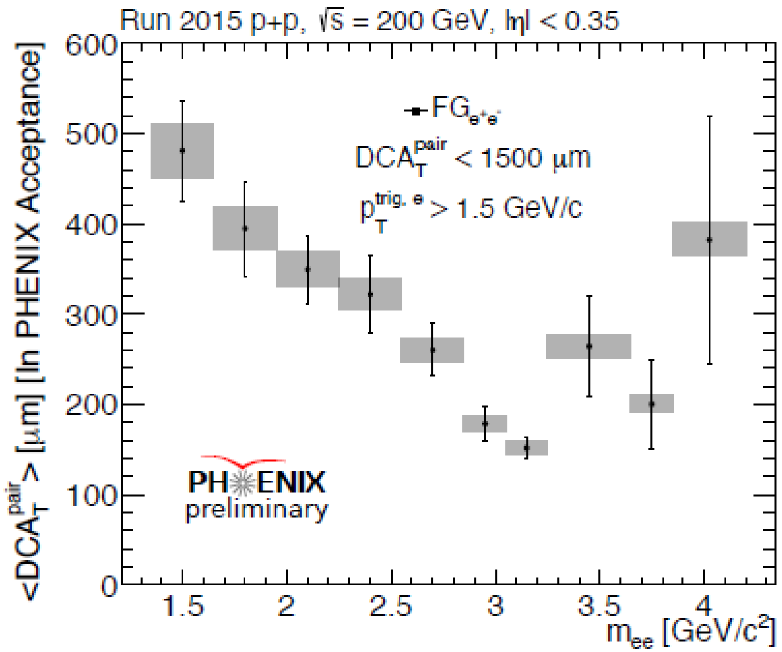


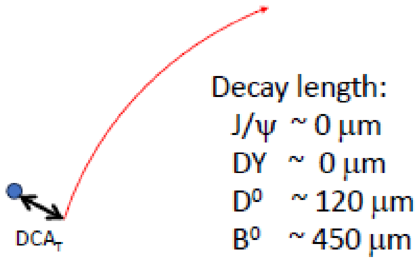
Reasonably good scaling with $\varepsilon_2 N^{1/3}_{part}$

Dileptons in p+p (preliminary)

Issues: charm-bottom separation, Drell-Yan, conversion rejection







Significantly improved cocktail

DAP – Data and Analysis Preservation

New (public) PHENIX homepage:
https://www.phenix.bnl.gov/

HEPData:
data tables for 210+ published papers

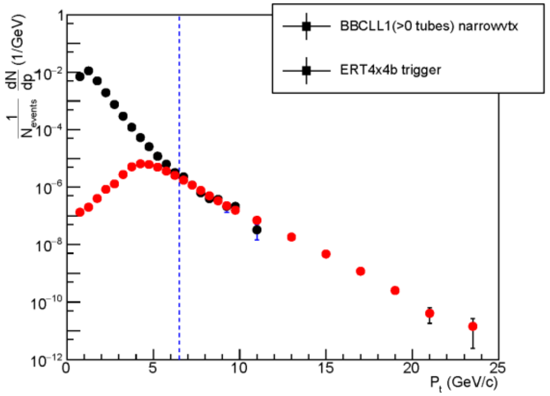
Zenodo:
>700 documents,
including all PHENIX theses
and talks since 2016

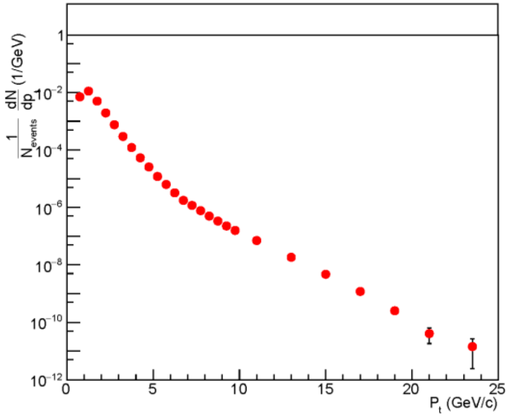
OPENData:
hands-on introduction to
photon and π^0 analysis

***REANA**: 2016 d+Au data*
π^0 MB spectrum reconstructed
by a non-PHENIX person (22/03/2023)

FIRST IMPLEMENTATION AT RHIC

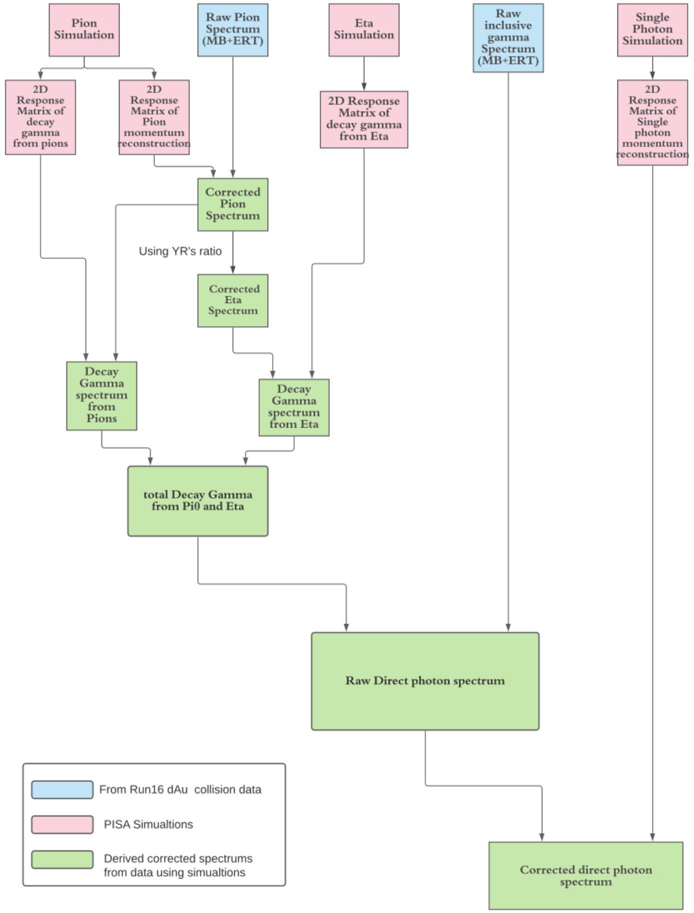
REANA





REANA

High p_T direct photon and π^0 analysis chain implemented



Why the previous slide?

Only 8 years since PHENIX stopped data taking

Many important analyses, including “archival papers” still in the pipeline

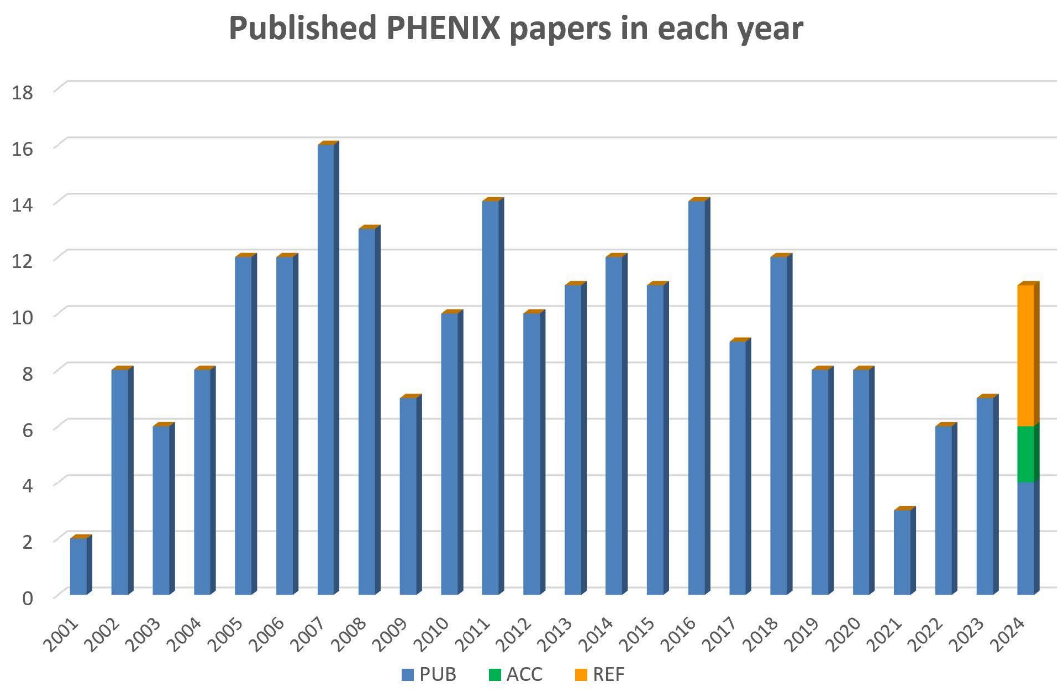
Still already fighting deterioration of “institutional memory”

Data on tape are unique, never will be repeated
Keeping them analyzable is a must (and DOE mandate…)

Good example: HERA H1 recently reanalyzed data taken 2006-2007 with modern methods

Right now there’s an opening (limited DOE funds) but the RHIC community – current and future collaborations – have to step up, forcefully

Trust me (involved since 2008/2019) this is not just PHENIX’s problem!



Full functionality DAP vital for good science

Summary (not the customary one)

Many new results and publications

PHENIX is relevant even in the recent “hottest” topics

RHIC data will never be outdated since they **are and will remain unique** (never repeated)

Corollary: preserving the capability to re-analyze them in the future is a must

Act today or face huge difficulties tomorrow and near-impossibility a few years from now

Thanks for your attention!

Backup