Yale | Wright **Lab**oratory

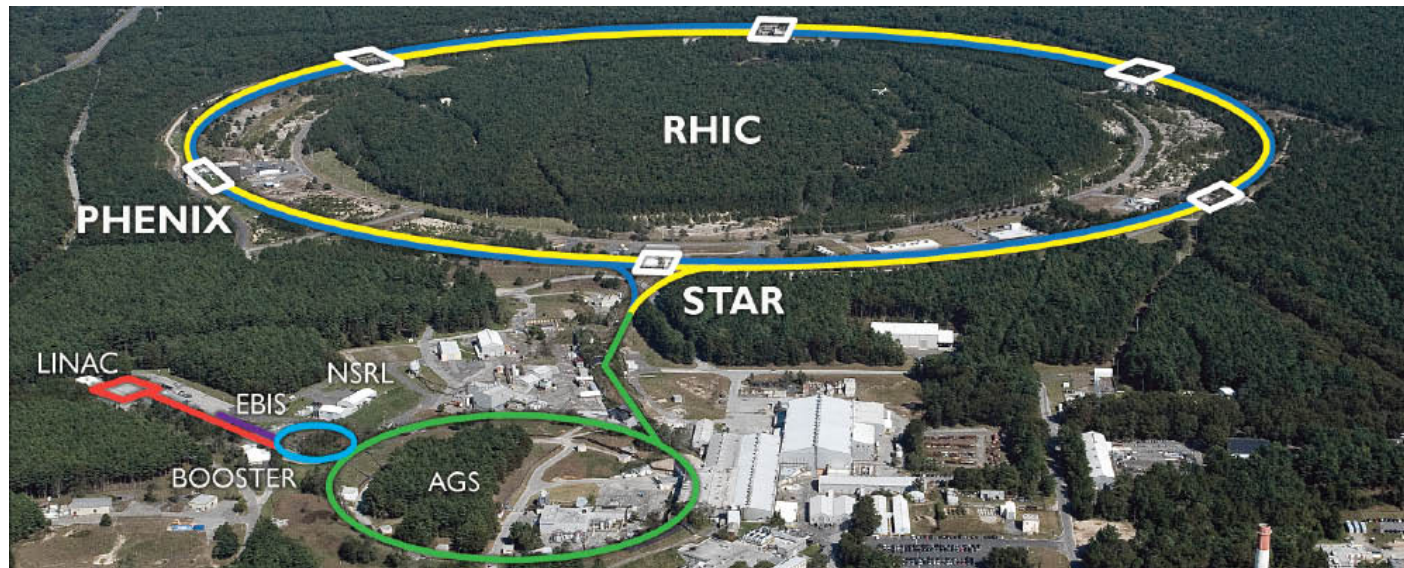LPC applications — Particules pLasmas Univers — Laboratoire de Physique de Clermont

Probing the system-size dependence of parton energy loss at RHIC

Assemblée générale du GdR QCD
8-10 Mars 2021

Audrey Francisco

Laboratoire de Physique de Clermont/Yale University

The Relativistic Heavy Ion Collider

Brookhaven Lab, Long Island New York, USA

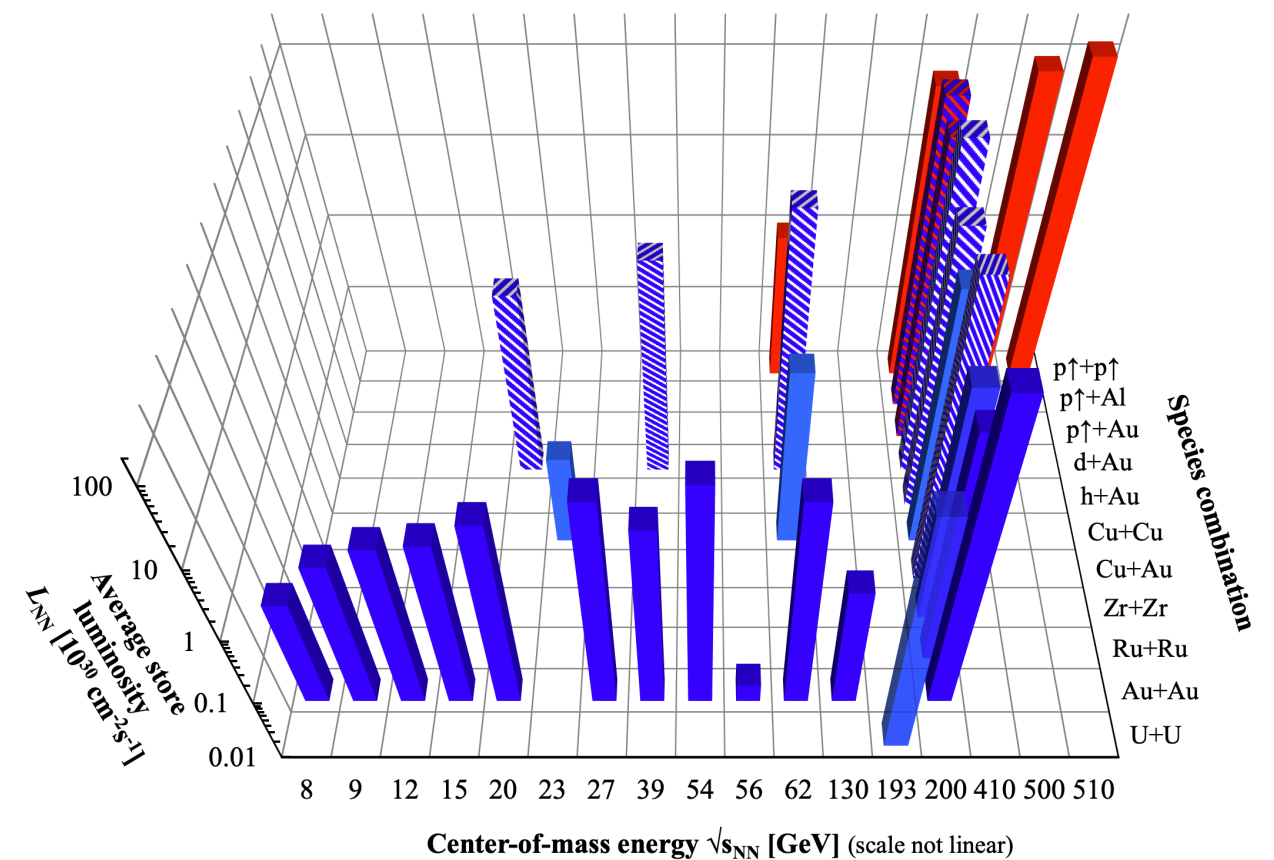RHIC energies, species combinations and luminosities (Run-1 to 20)

Past experiences : PHENIX, PHOBOS, BRAHMS, pp2pp, AnDY, RHICf

Still operating : STAR (since 2000)

Future experiment: sPHENIX (2022)
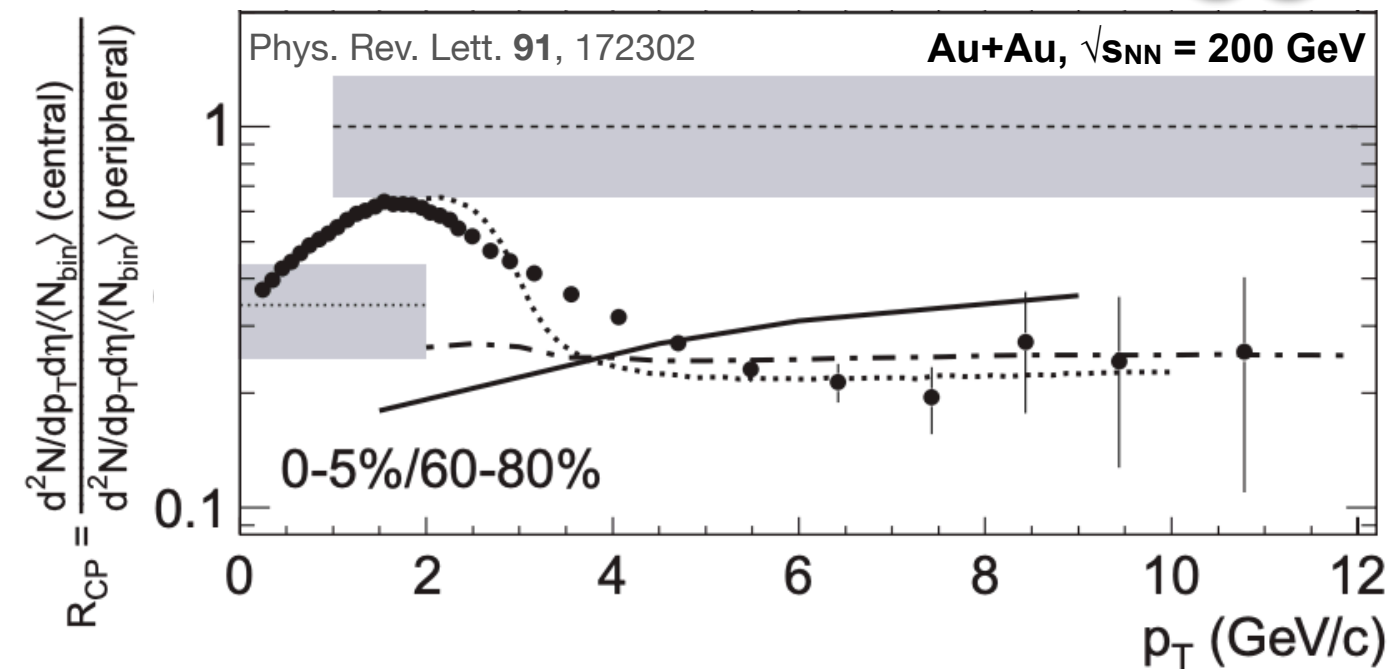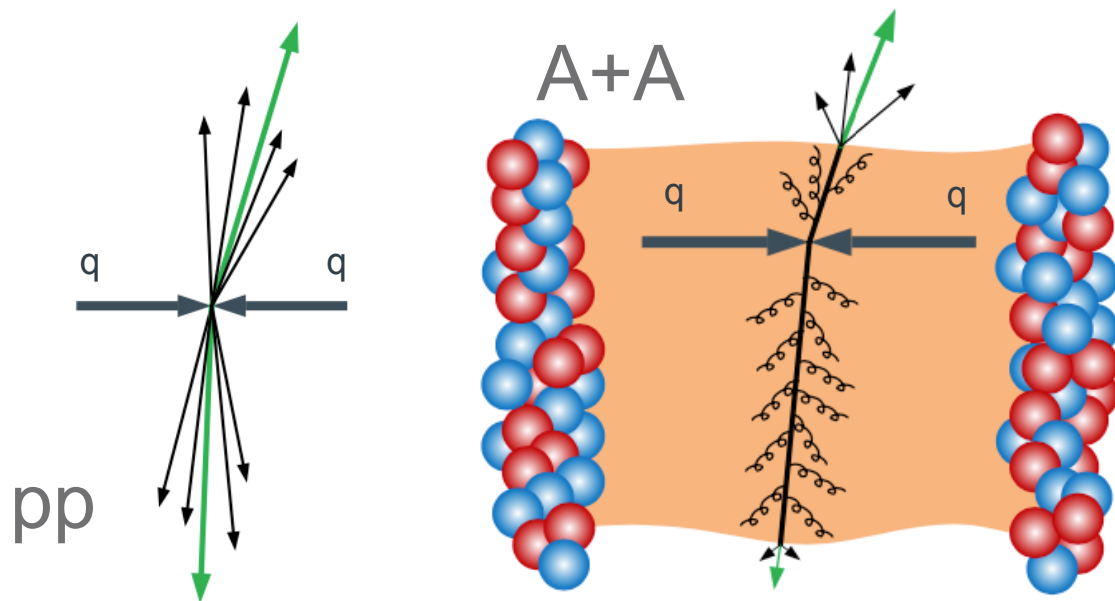
Site for the future Electron-ion Collider (2030)

Motivations for intermediate systems

- High-p_T hadrons are created during hard processes at early stages of the collision

- Suppression is observed in central heavy-ion collisions

- Interpreted as partonic energy loss through the formed QGP

$$R_{CP} = \frac{\bigcirc}{\bigcirc\bigcirc}$$

- Energy loss depends on:

  ‣ partonic flavor

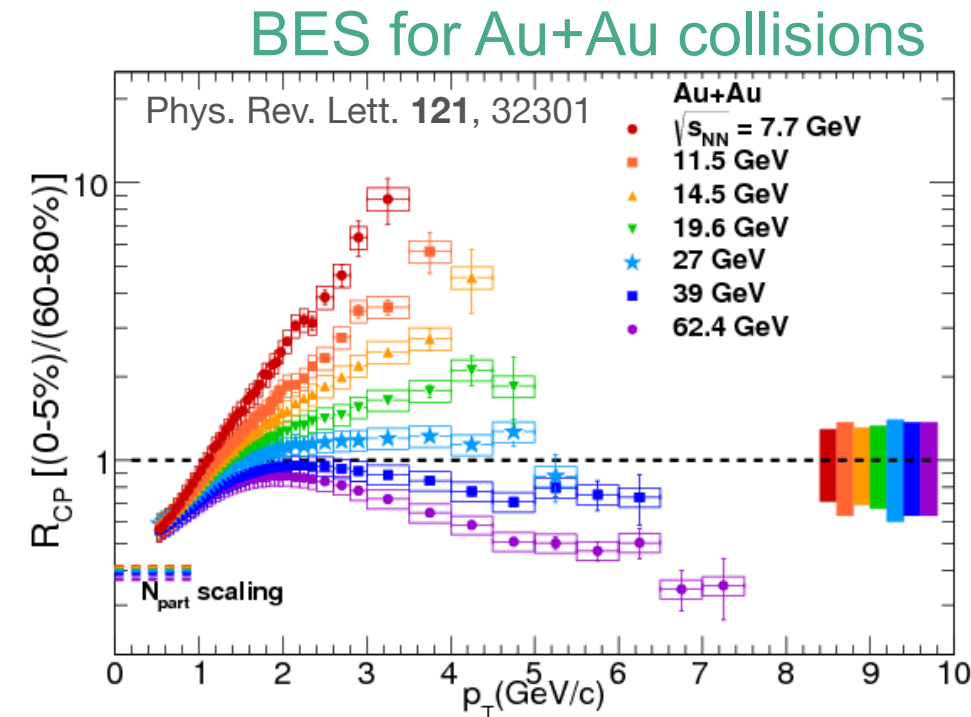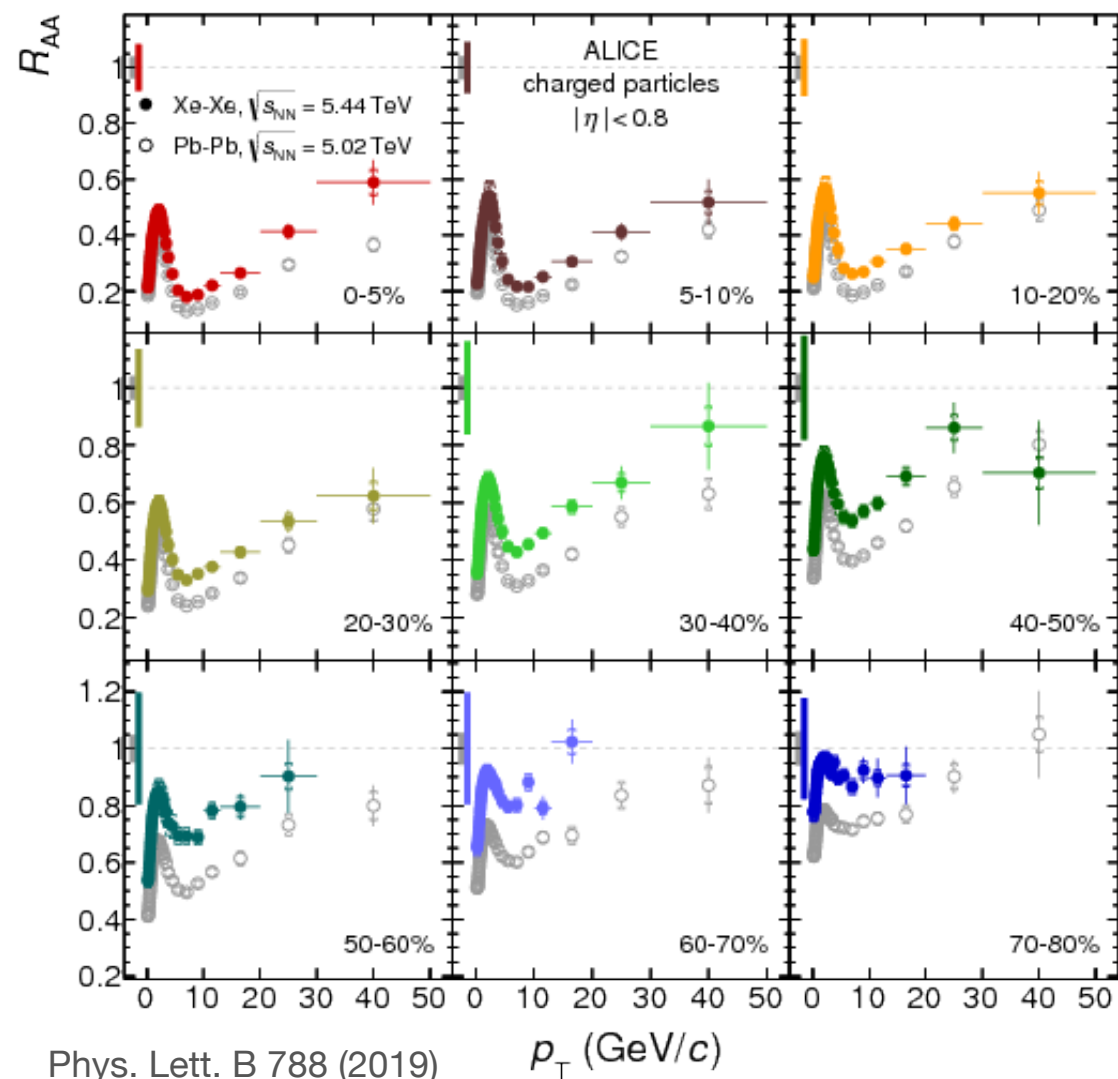 ‣ path length in medium

  ‣ energy density of the medium

How does energy loss depend on the system properties?

  ‣ Effect of varying the collision energy?

  ‣ Effect of varying the system size?

Motivations for intermediate systems

- Study of different collision energies: compare results from RHIC and the LHC + Beam Energy Scan at RHIC

- Study of different system sizes: vary the centrality or compare different (heavy-ion) collision systems
  - →more statistics, overlap regions, nuclei properties, etc...

BES for Au+Au collisions

Phys. Rev. Lett. **121**, 32301

Au+Au
$\sqrt{s_{NN}}$ = 7.7 GeV
11.5 GeV
14.5 GeV
19.6 GeV
27 GeV
39 GeV
62.4 GeV

N_{part} scaling

R_{CP} [(0-5%)/(60-80%)]

p_T (GeV/c)

ALICE charged particles
$|\eta| < 0.8$

Xe-Xe, $\sqrt{s_{NN}}$ = 5.44 TeV
Pb-Pb, $\sqrt{s_{NN}}$ = 5.02 TeV

R_{AA}

p_T (GeV/c)

Phys. Lett. B 788 (2019)
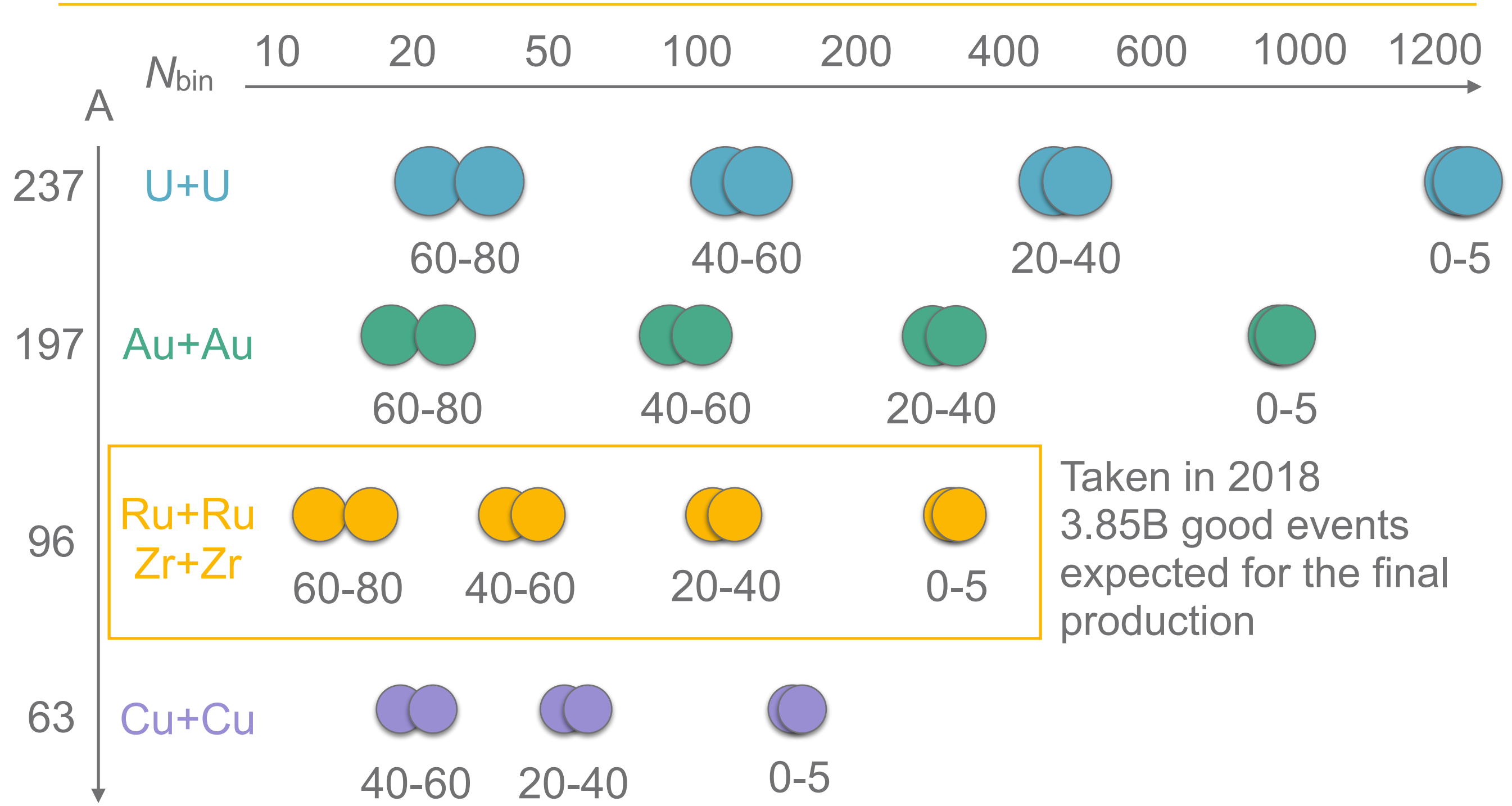
At the LHC:
Xe+Xe collisions at 5.44 TeV
vs Pb+Pb collisions at 5.02 TeV

At RHIC:
several systems at 200 GeV

Au+Au   Cu+Au
U+U   Zr+Zr
Cu+Cu   Ru+Ru

Previous results from RHIC

Phys. Rev. C **98**, 054903

π^0 at $\sqrt{s_{NN}}=200$ GeV — PHENIX

- Cu+Au 0-10% (N_{part}=177.20)
- Au+Au 20-30% (N_{part}=166.6)

π^0 at $\sqrt{s_{NN}}=200$ GeV — PHENIX

- Cu+Au 20-40% (N_{part}=80.37)
- Au+Au 40-50% (N_{part}=74.4)
- Cu+Cu 0-10% (N_{part}=98.3)

$\langle N_{part} \rangle$ = 160

J.Phys.Conf.Ser. 1602 (2020) 1, 012020

U+U, $\sqrt{s_{NN}}$ = 192 GeV, |y| < 0.35, (SET1)
20-40%

- $K^* \to (K\pi)^\pm$
- $\varphi \to K^+K^-$
- $K_S \to \pi^0\pi^0$
- $\pi^0 \to \gamma\gamma$
- $\eta \to \gamma\gamma$
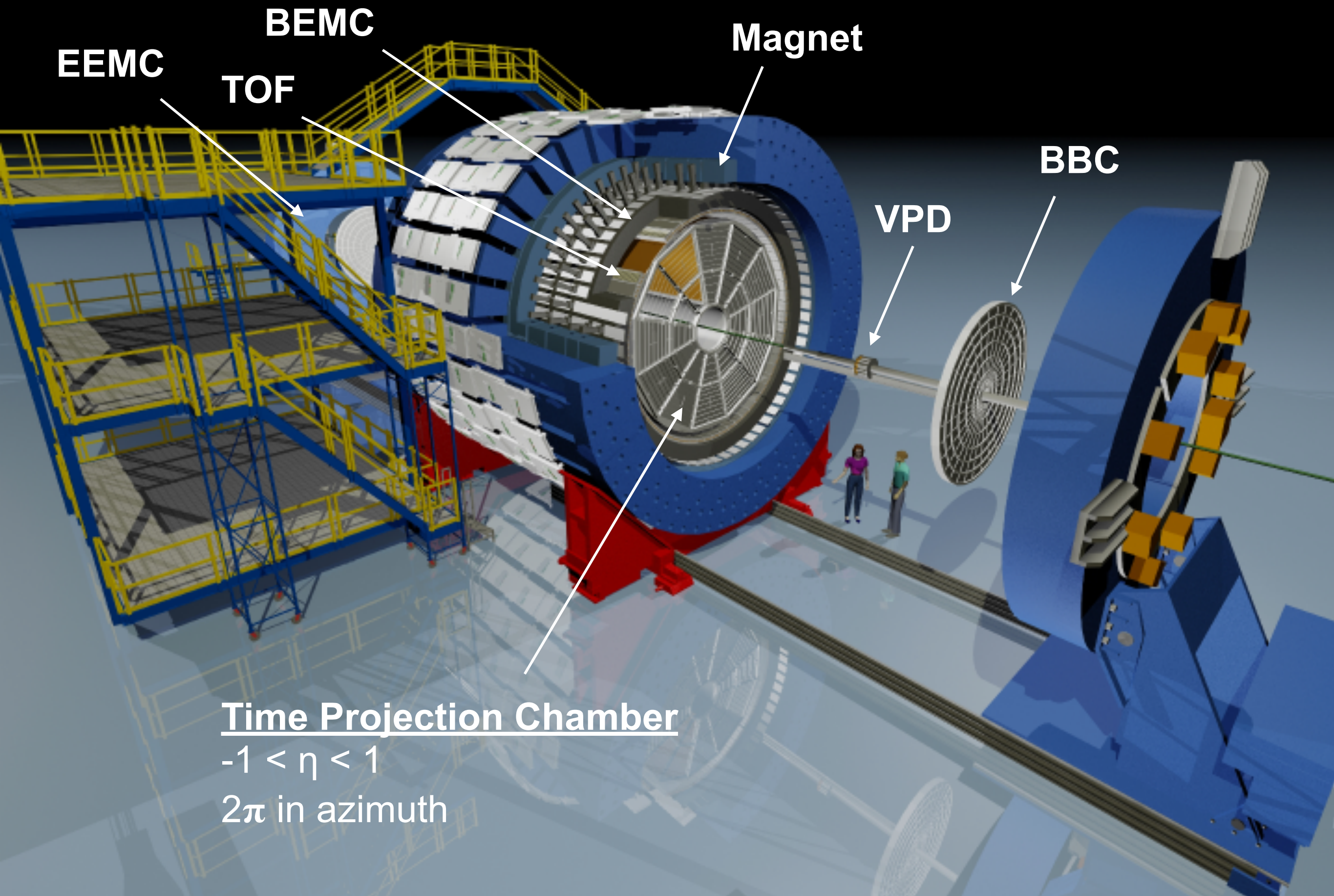
PH*ENIX preliminary

20-40%

Scaling uncertainty from p+p — 9.7%

(b)
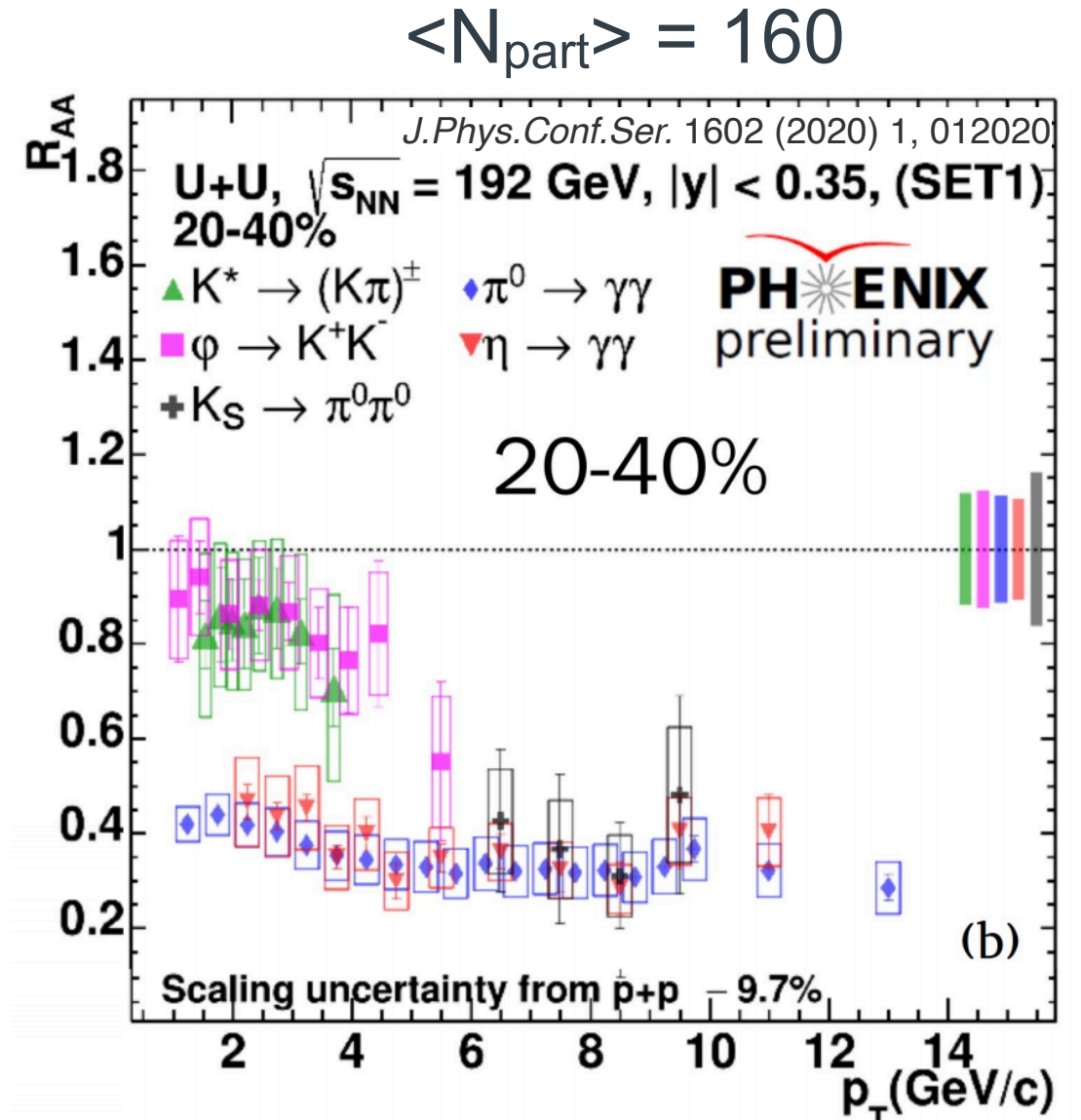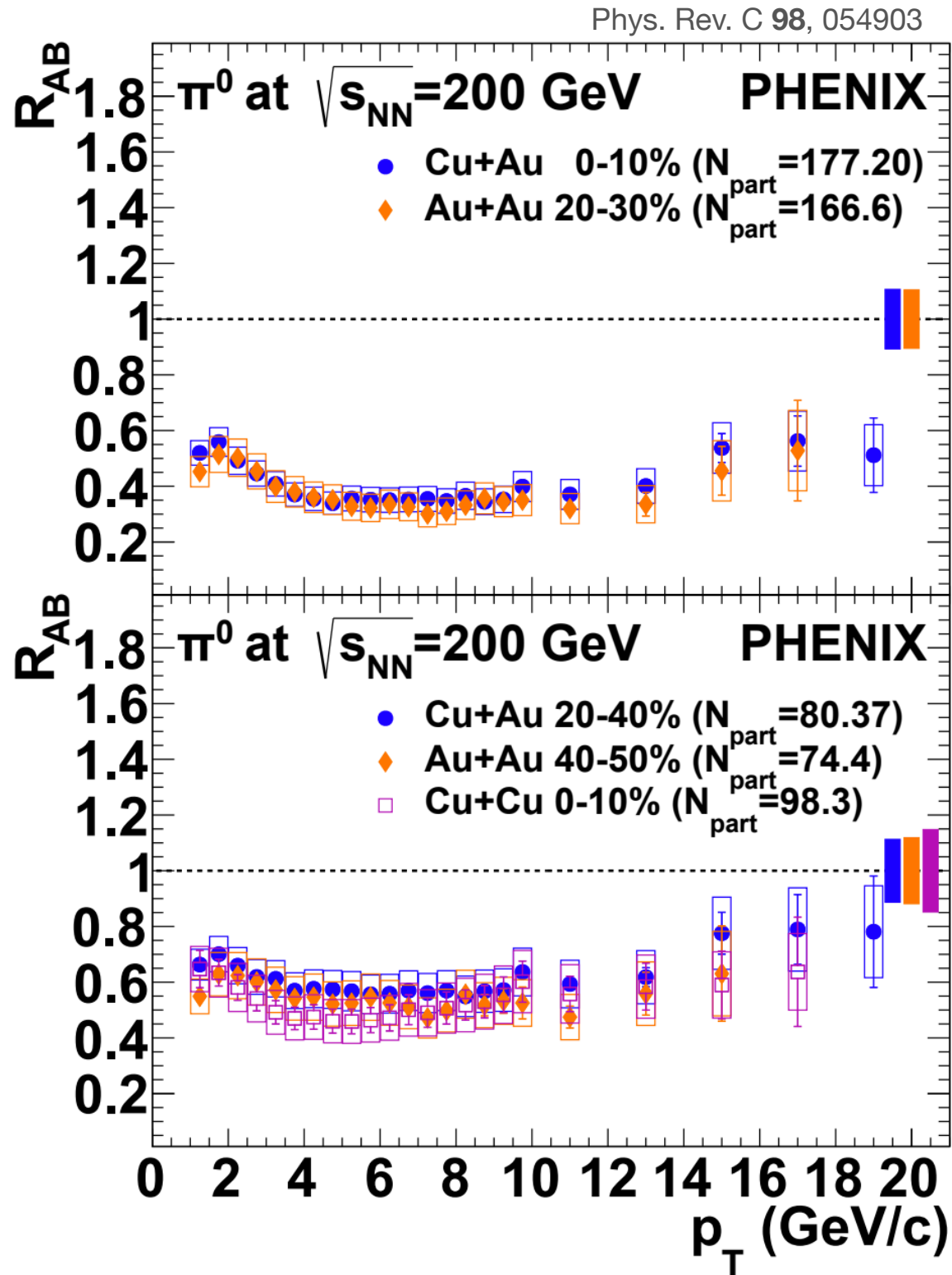
R_{AA} results show a similar suppression for π^0 across Cu+Au, Au+Au, Cu+Cu and U+U systems for similar numbers of participants
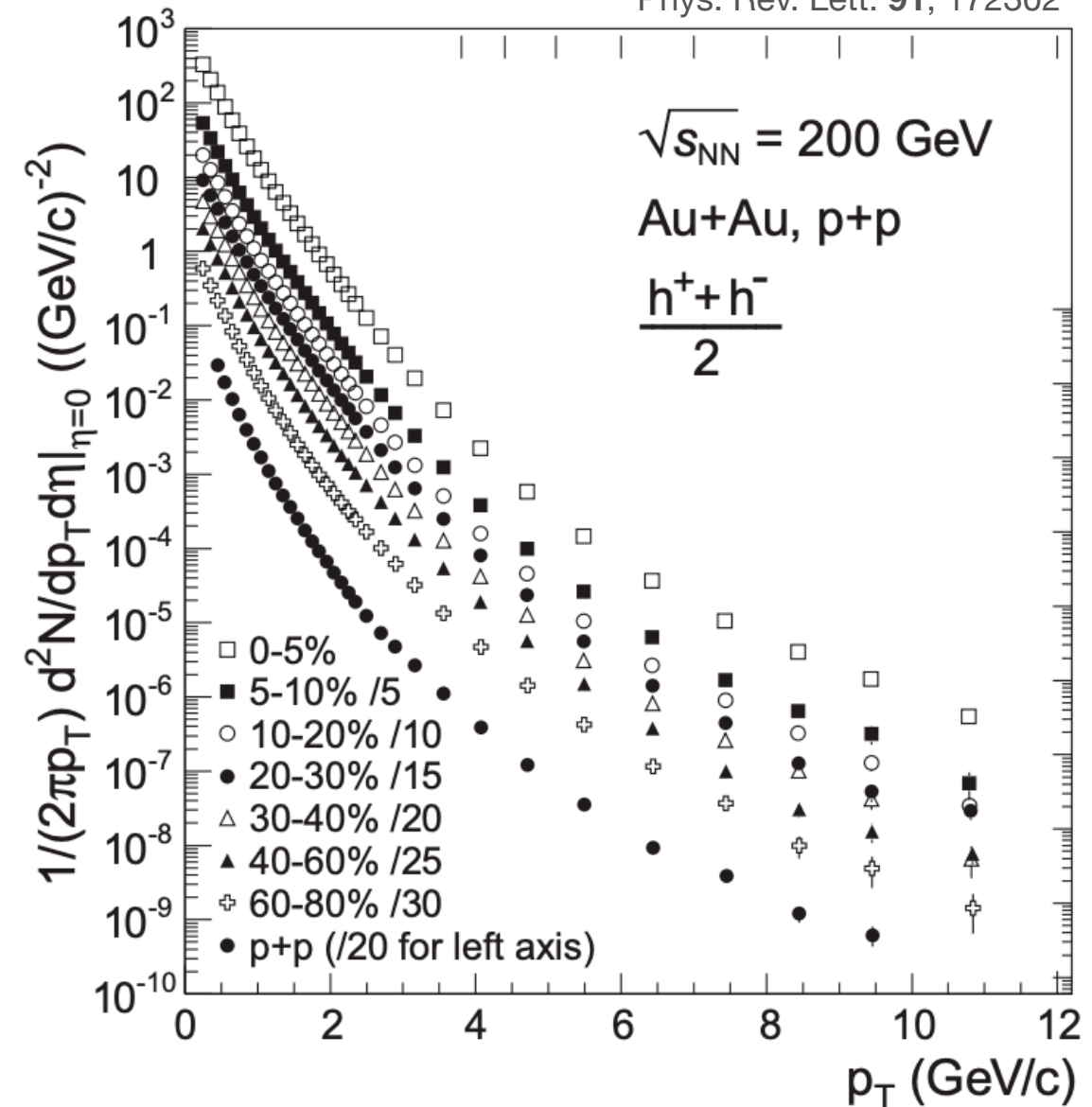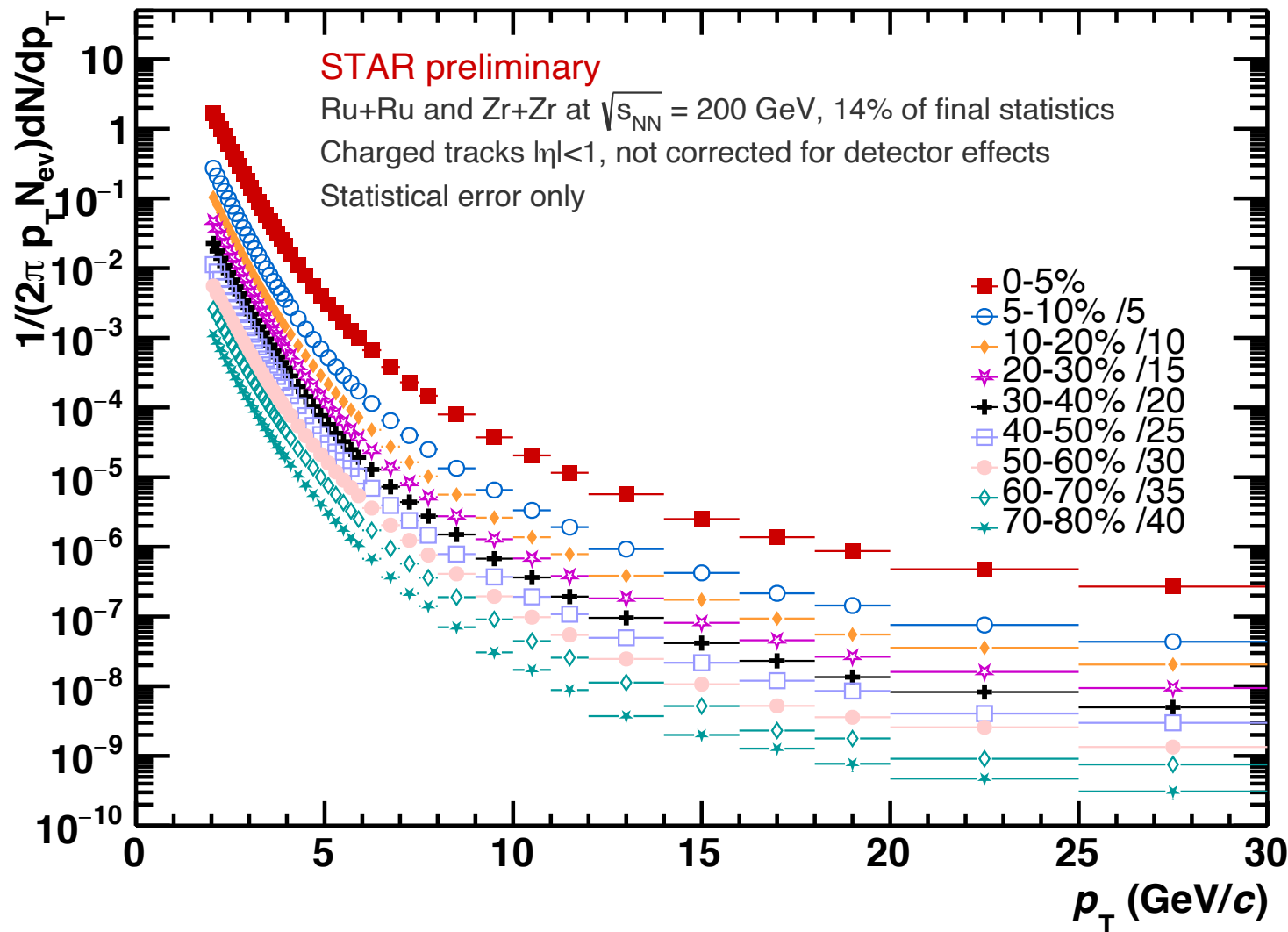
The Solenoid Tracker At RHIC

EEMC

BEMC

TOF

Magnet

BBC

VPD

Time Projection Chamber
-1 < η < 1
2π in azimuth

Charged particle spectra

STAR preliminary

Ru+Ru and Zr+Zr at $\sqrt{s_{NN}}$ = 200 GeV, 14% of final statistics

Charged tracks $|\eta|<1$, not corrected for detector effects

Statistical error only

- 0-5%
- 5-10% /5
- 10-20% /10
- 20-30% /15
- 30-40% /20
- 40-50% /25
- 50-60% /30
- 60-70% /35
- 70-80% /40

Phys. Rev. Lett. **91**, 172302

$\sqrt{s_{NN}}$ = 200 GeV

Au+Au, p+p

$\dfrac{h^+ + h^-}{2}$

- 0-5%
- 5-10% /5
- 10-20% /10
- 20-30% /15
- 30-40% /20
- 40-60% /25
- 60-80% /30
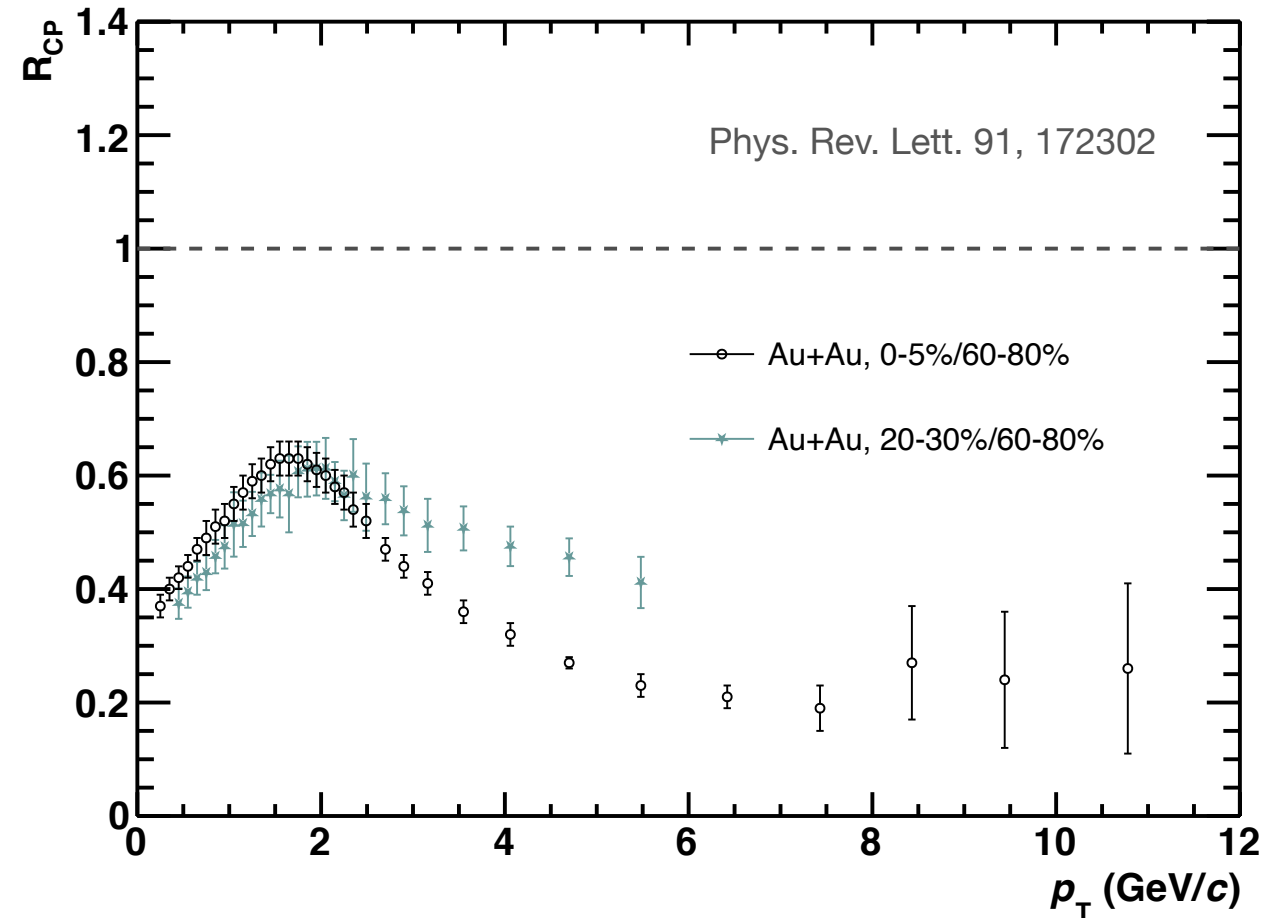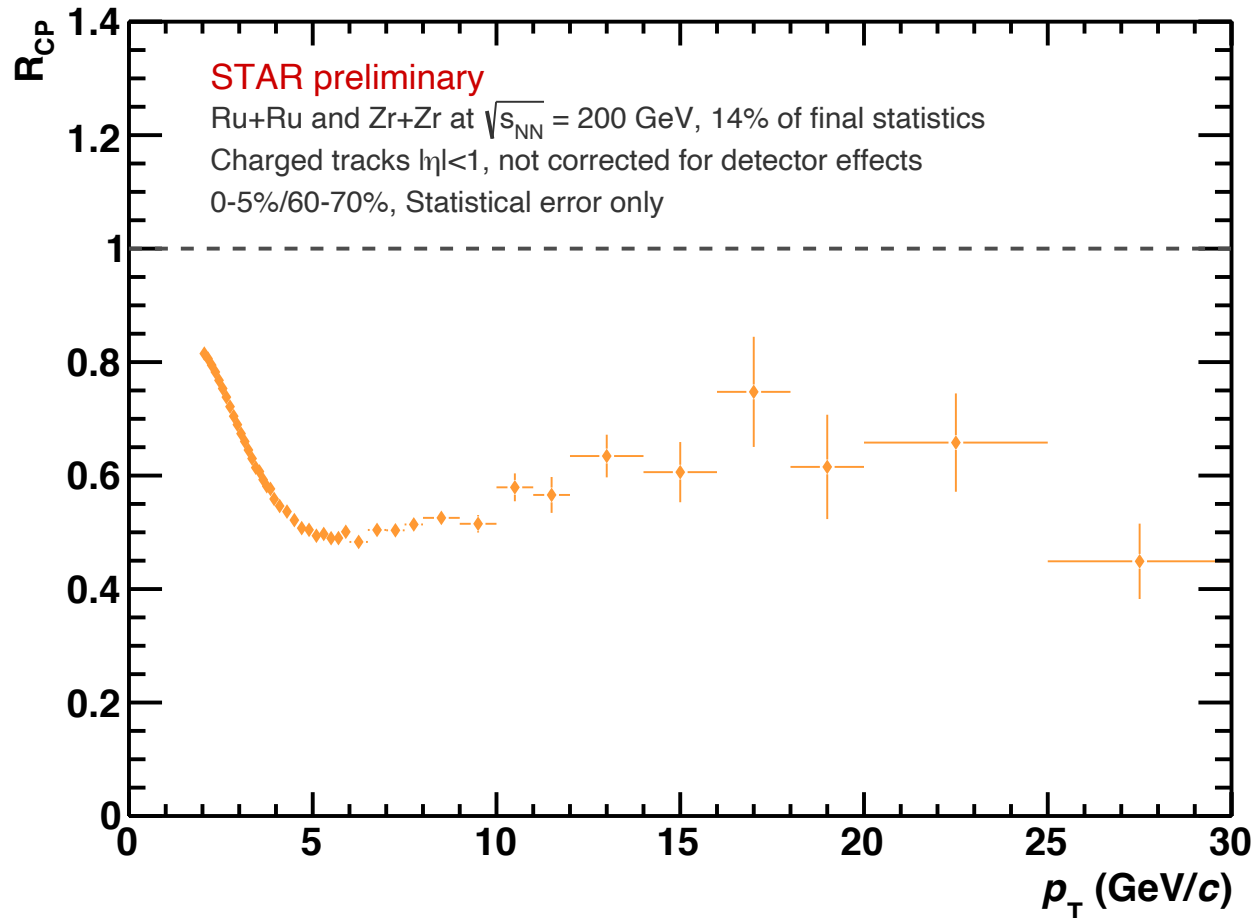- p+p (/20 for left axis)

Ru+Ru/Zr+Zr results are not corrected for detector effects

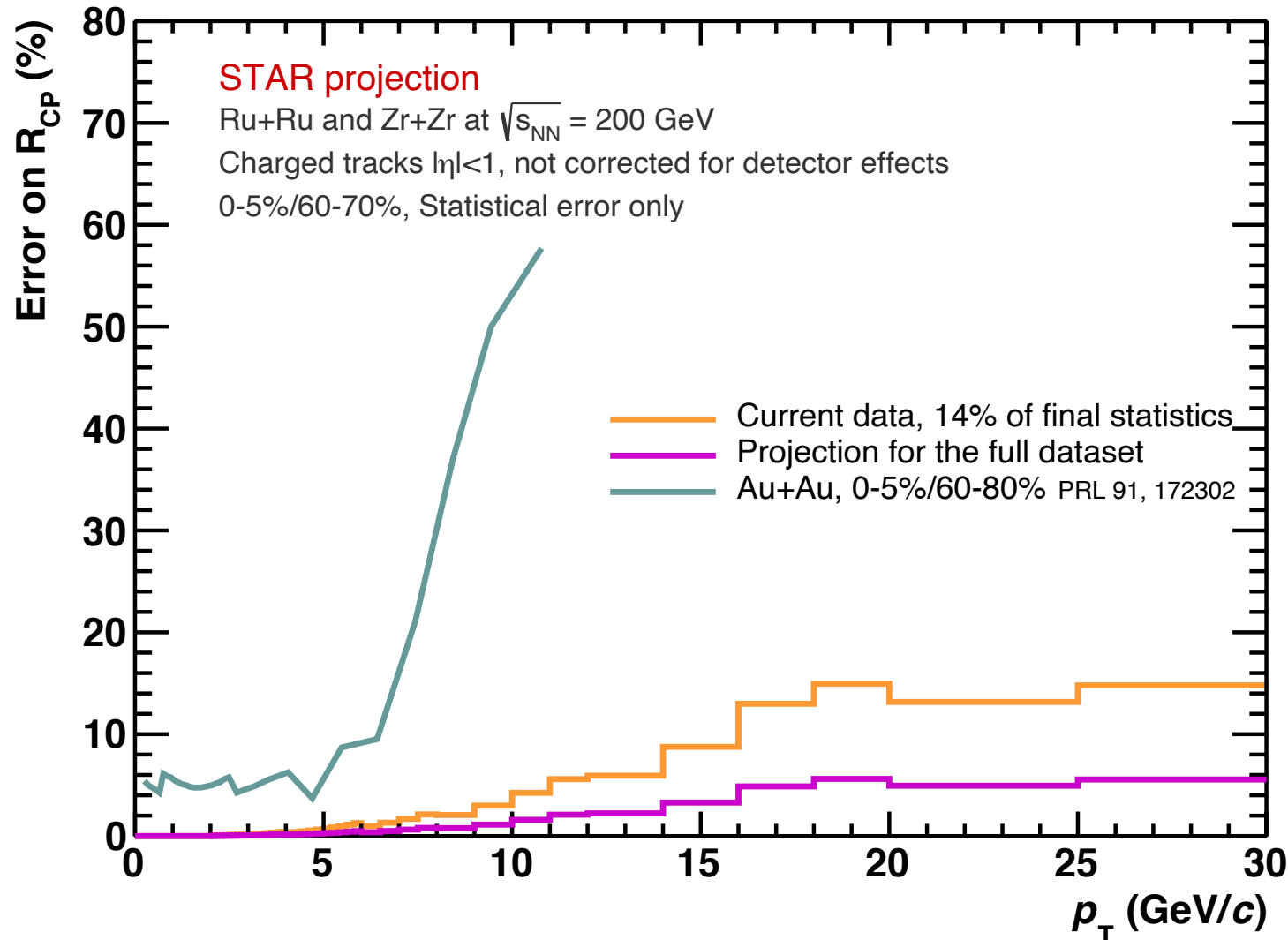Extended p_T reach for Ru+Ru/Zr+Zr

Nuclear modification factor R_{CP}

$$R_{CP} = \frac{N_{\text{bin,Peri}}}{N_{\text{bin,Cent}}} \times \frac{\left(\frac{d^2N}{\langle N_{\text{ev}}\rangle dp_T d\eta}\right)_{\text{Cent}}}{\left(\frac{d^2N}{\langle N_{\text{ev}}\rangle dp_T d\eta}\right)_{\text{Peri}}} = \frac{\text{Central}}{\text{Peripheral}}$$

STAR preliminary
Ru+Ru and Zr+Zr at $\sqrt{s_{NN}}$ = 200 GeV, 14% of final statistics
Charged tracks |η|<1, not corrected for detector effects
0-5%/60-70%, Statistical error only

Phys. Rev. Lett. 91, 172302

Au+Au, 0-5%/60-80%
Au+Au, 20-30%/60-80%

- Ratio of 0-5% to 60-70%, not corrected for detector efficiency (will enhance the final R_{CP} by a few %)

- Clear suppression is observed at all p_T, corrected data are required for comparing to Au+Au collisions

- Comparison to Au-Au:
  similar N_{part} regions : 0-5%(165.7) vs 20-30%(167.6), 60-70%(16.7) vs 60-80%(20.9)

Improved measurement precision

STAR projection

Ru+Ru and Zr+Zr at $\sqrt{s_{NN}}$ = 200 GeV

Charged tracks |η|<1, not corrected for detector effects

0-5%/60-70%, Statistical error only

Current data, 14% of final statistics
Projection for the full dataset
Au+Au, 0-5%/60-80% PRL 91, 172302

- Dramatically reduced statistical errors at high p_T

- Finer centrality bins (peripheral is 10% wide)

- Significantly extended p_T range up to 30 GeV/c

- Au+Au contains statistical + systematic uncertainties

‣ Very promising with the full dataset!
‣ Prospects for new differential measurements (event-plane, rapidity, etc…)

Conclusions

- New dataset at 200 GeV with intermediate number of nucleons: Ru+Ru and Zr+Zr

- No difference is expected between both datasets but will check

- New opportunity to investigate partonic energy loss and its dependence on the system-size and the initial energy density by comparing to Au+Au collisions

Future prospects

- Substantial statistics for Ru+Ru and Zr+Zr will allow:

    ‣ a finer centrality and p_T binning + increase the p_T reach to 30 GeV/c

    ‣ new differential measurements

- Run O+O at RHIC… and the LHC?

Thank you for your attention!

Back-up

Dataset status

**<100 runs
A fraction of events
Mixed dataset**

**2K runs
A fraction of events
Blinded dataset**

→ Data with partial statistics
Blinded but not mixed
(1 run = 1 coll. system)

**2K runs
All events
Unblinded dataset**

Estimated final dataset statistics:
1.85B + 2B