Influence of quark content and collision geometry on proton production in heavy ion collisions

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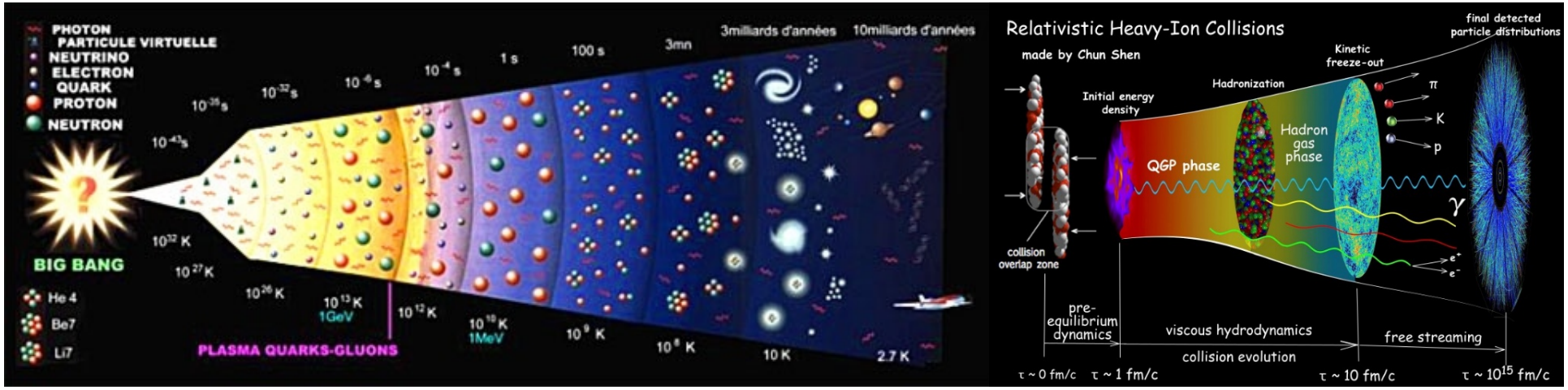
Introduction

QGP
T ≈ 170 MeV
Energy Density ≈ 1 GeV/fm^3

QCD

Heavy Ion Collisions

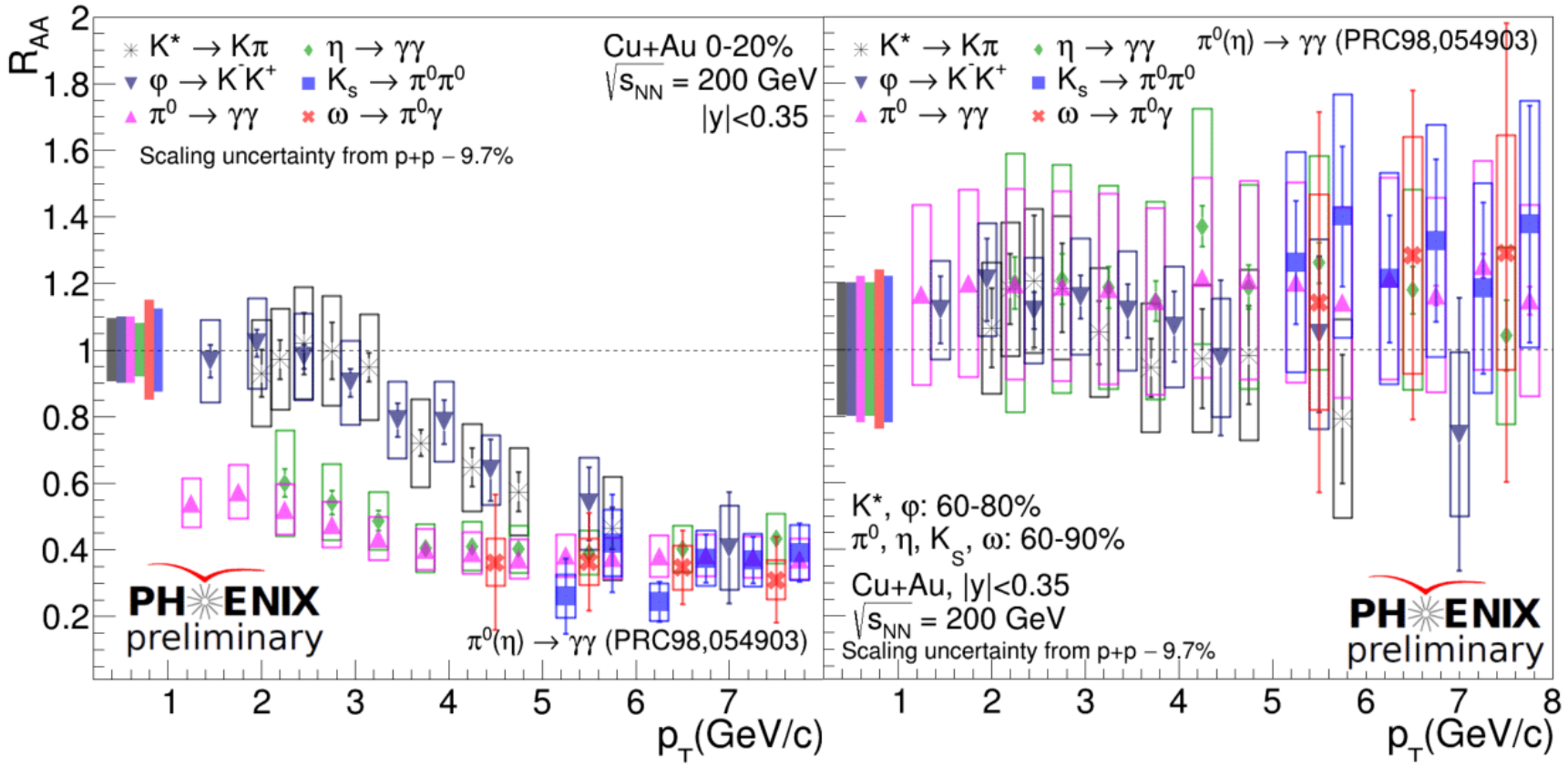
QGP – is a state of matter which exists at extremely high temperature and/or density. This state is thought to consist of asymptotically free strong-interacting quarks and gluons, which are ordinarily confined inside atomic nuclei or other hadrons.



Motivation (1/3)

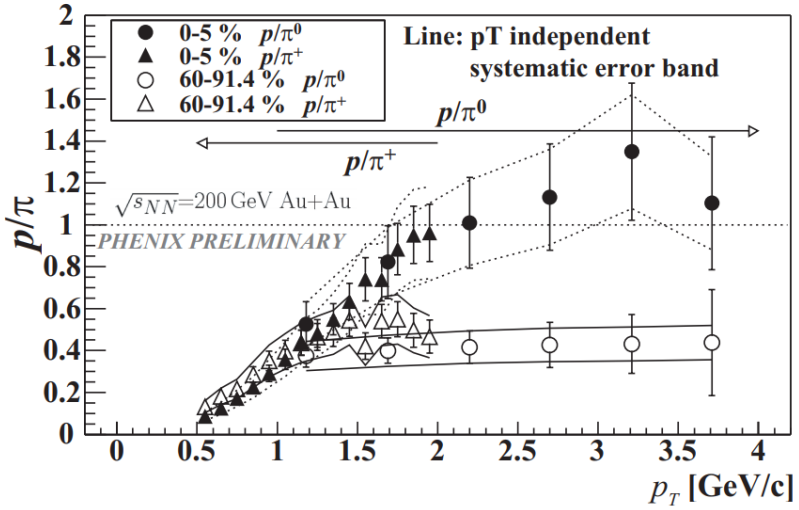
✓ Measurments of light mesons (φ, K*, π, η, Ks, ω) production.

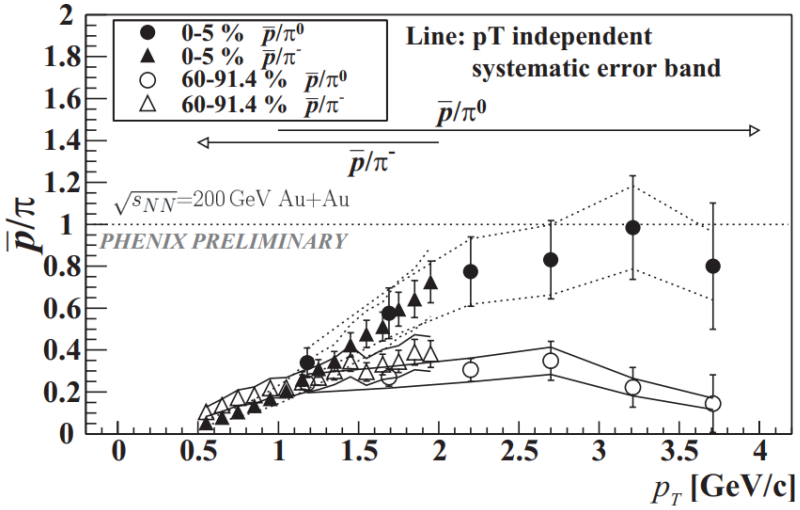
Study the QGP properties depending on the number and flavor of quarks.



Motivation (2/3)

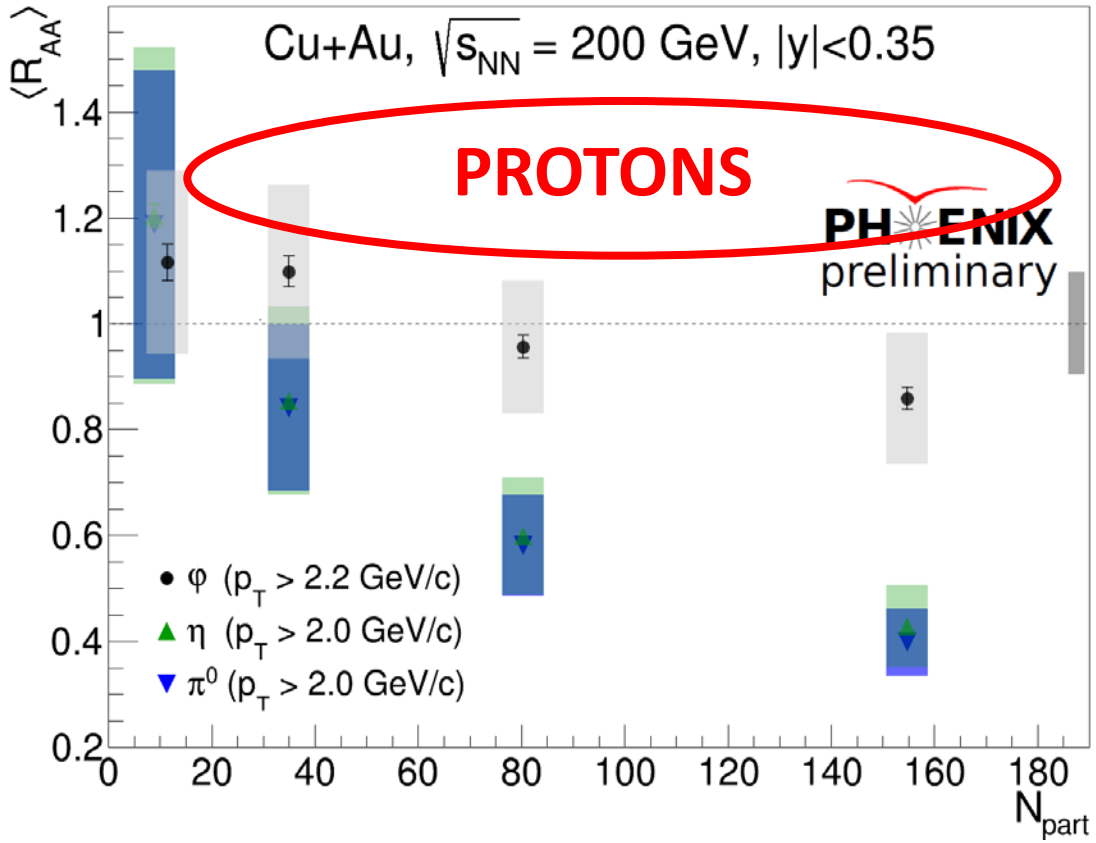
- ✓ Anomaly large ratio of protons (3 quarks) to π-mesons (2 quarks) yields in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV discovered by PHENIX





Motivation (3/3)

- Baryon puzzle

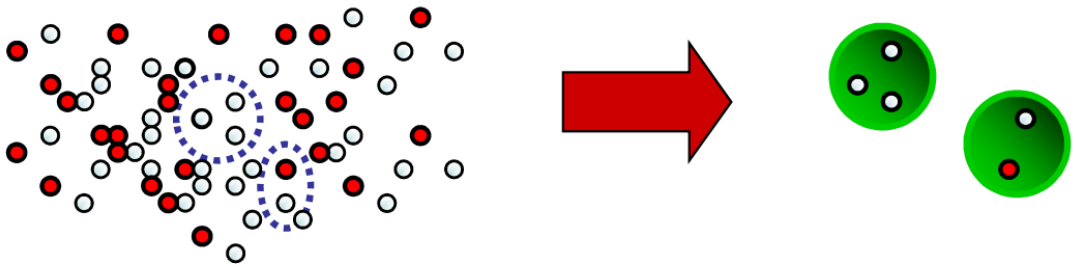


Hadronization

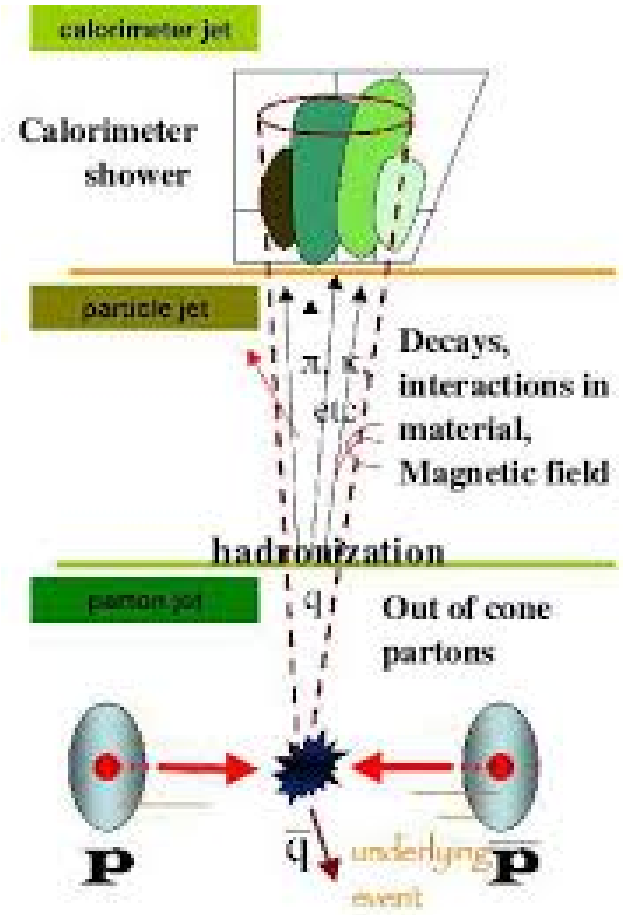
Recombination

Phase space at the hadronization is filled with partons

- Single parton description may not be valid anymore
- No need to create qq pairs via splitting / string breaking
- Partons that are “close” to each other in phase space (position and momentum) can simply recombine into hadrons
- According to the recombination model, quarks in QGP are more likely combine into baryons than into mesons



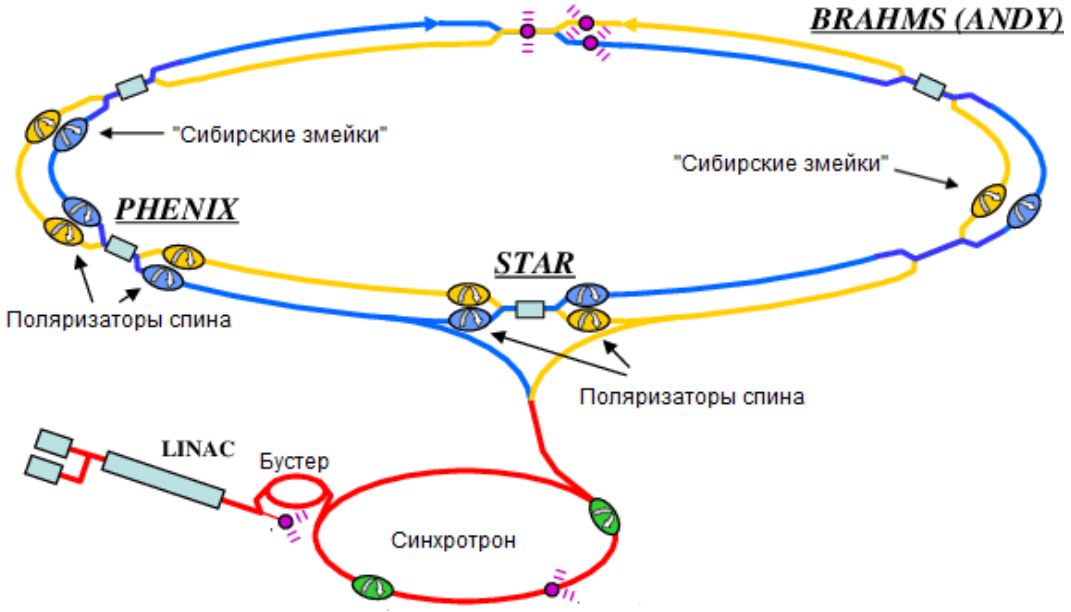
Fragmentation

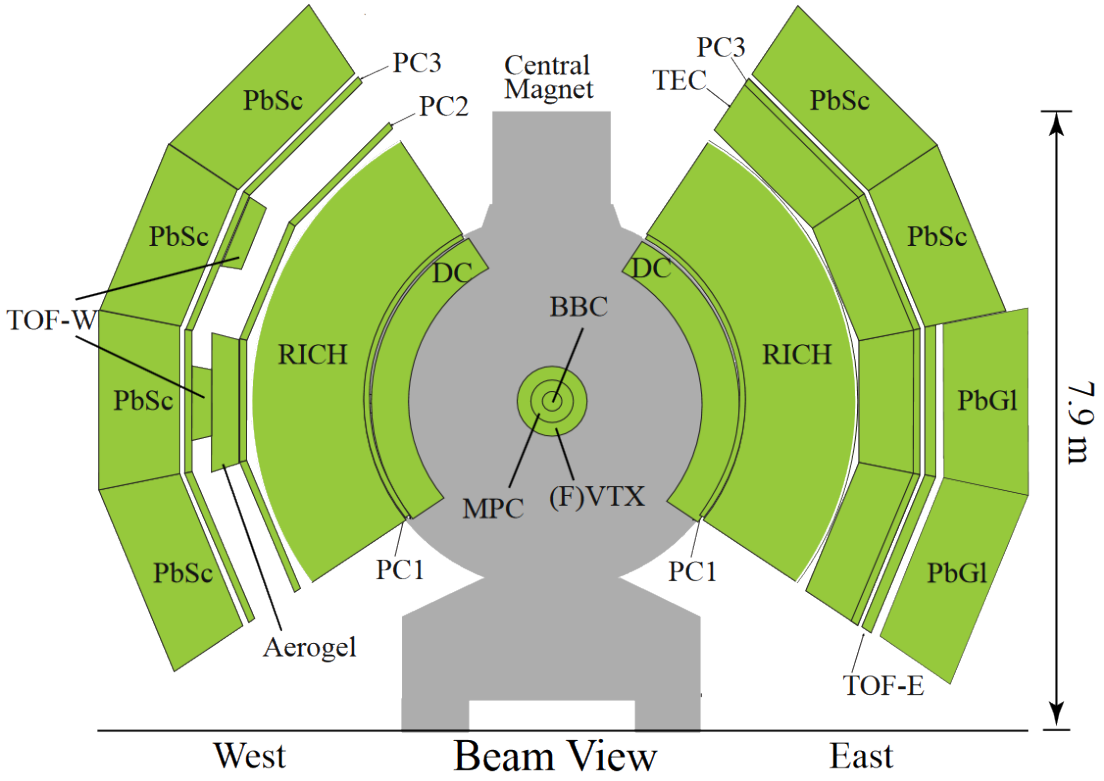


POLYTECH

PHENIX

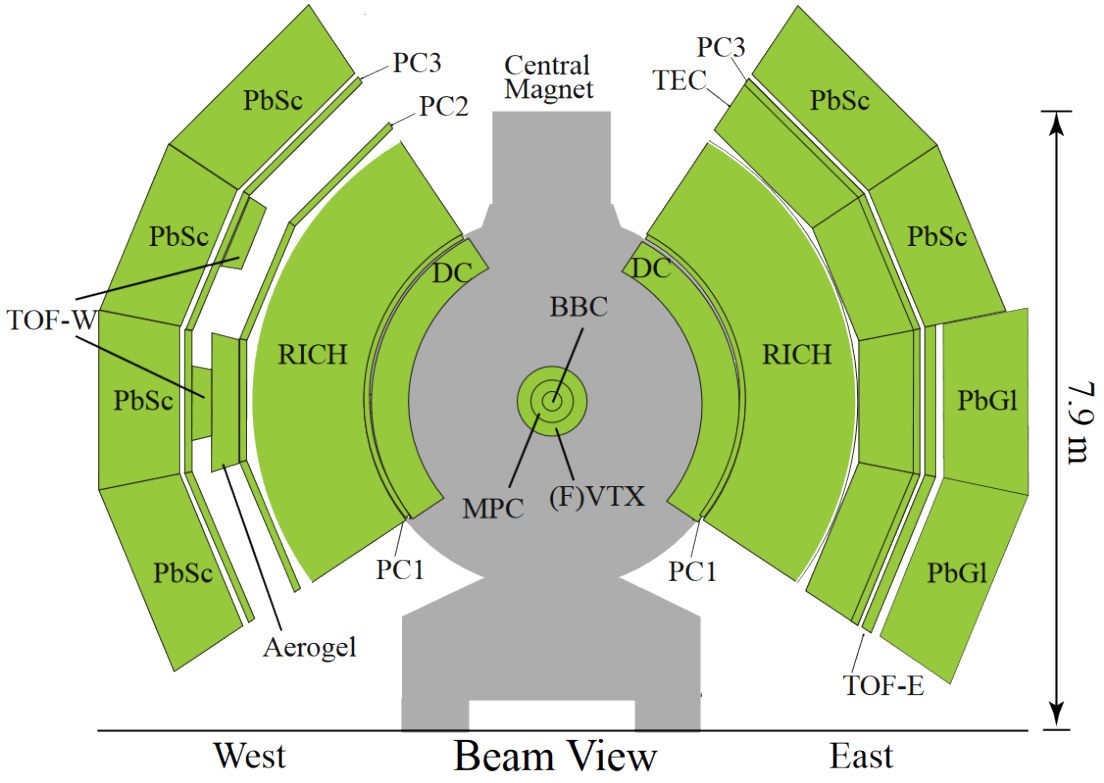
(Pioneering High Energy Nuclear Interaction eXperiment)



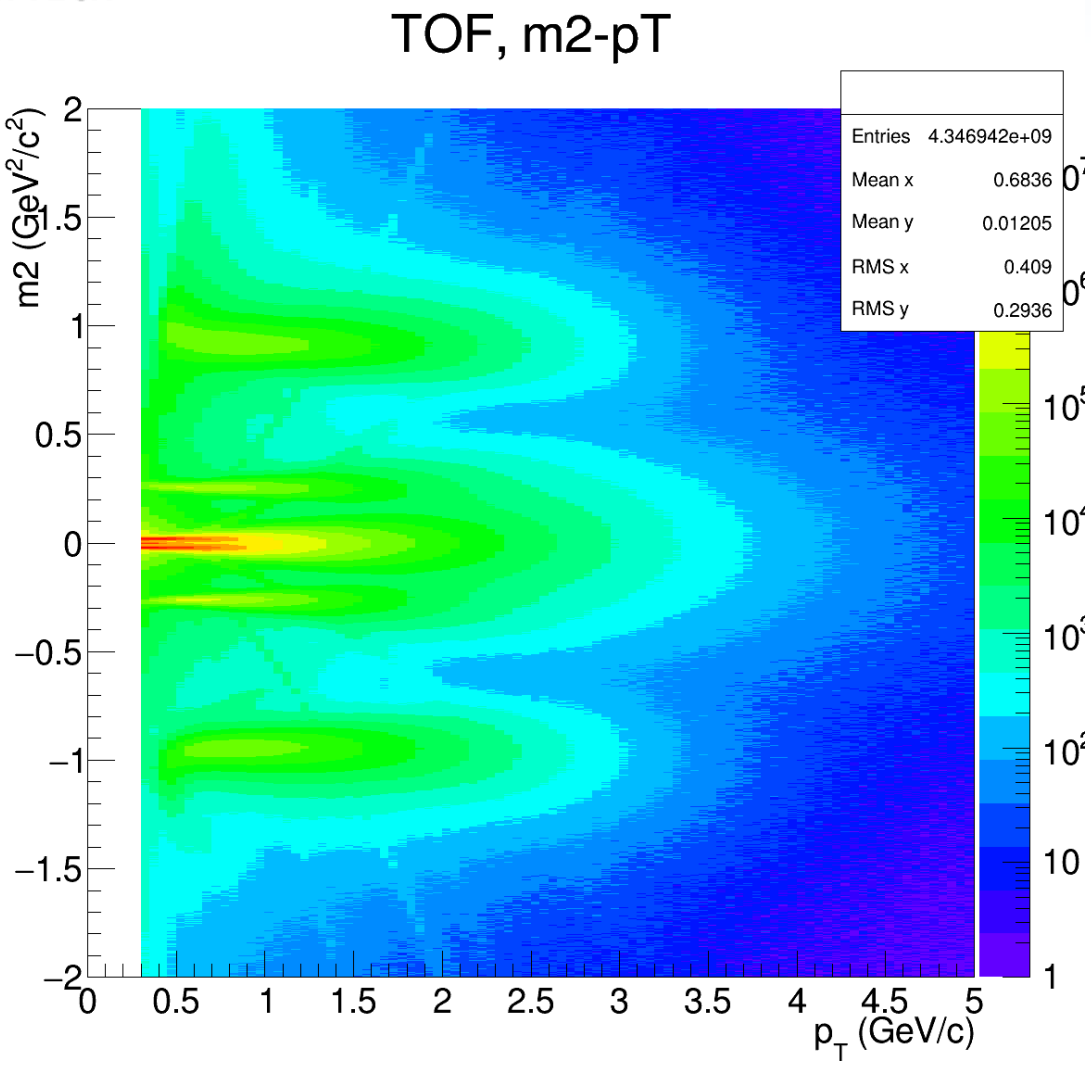


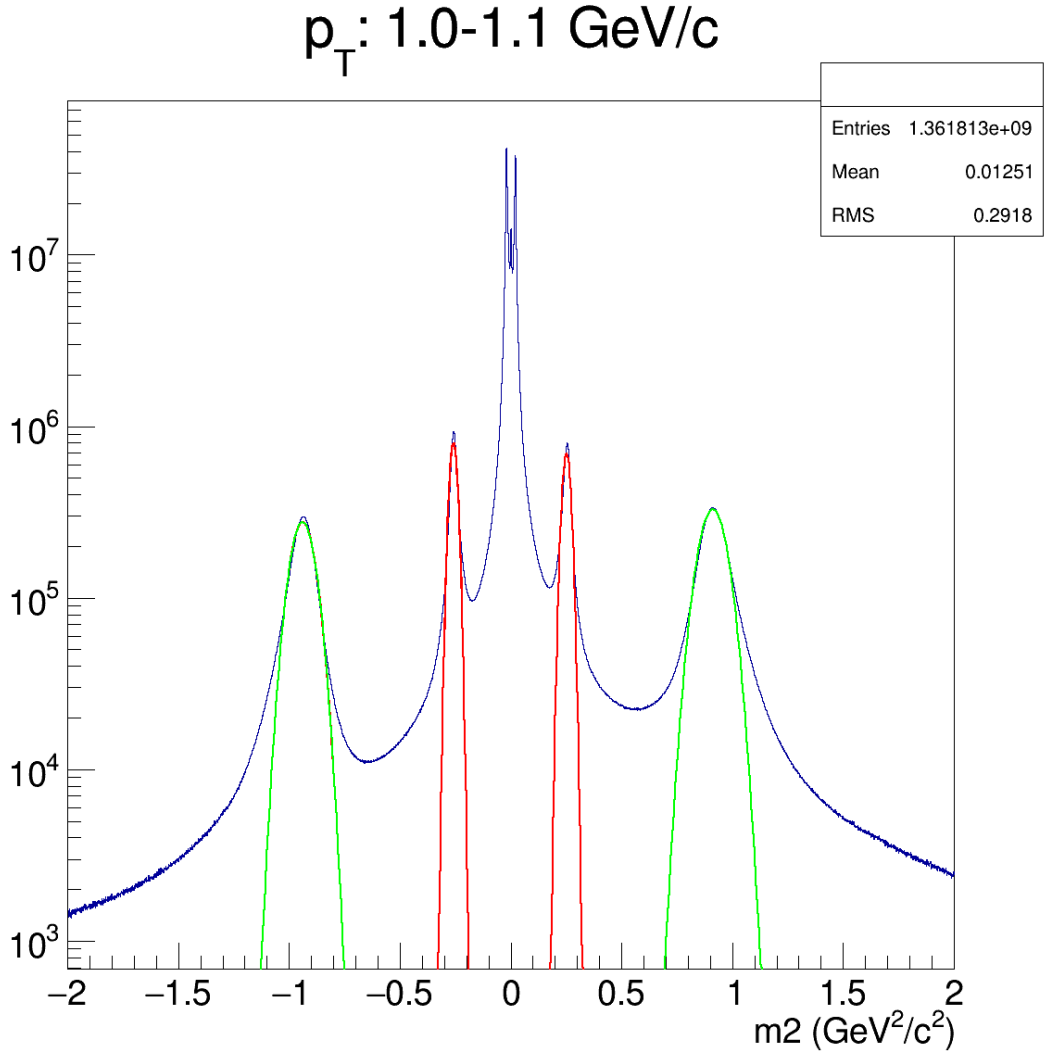
Detectors in the central spectrometer arms (|y| < 0. 35)

- Charged Particle Tracking:
  - Drift-Chambers (DC)
  - Pad-Chambers (PC)
- Identification of charged hadrons:
  - Tine-of-Flight (TOF) with start signal from the Beam-Counters (BBC)
- Centrality identification:
  - BBC detectors (beam-beam counters)

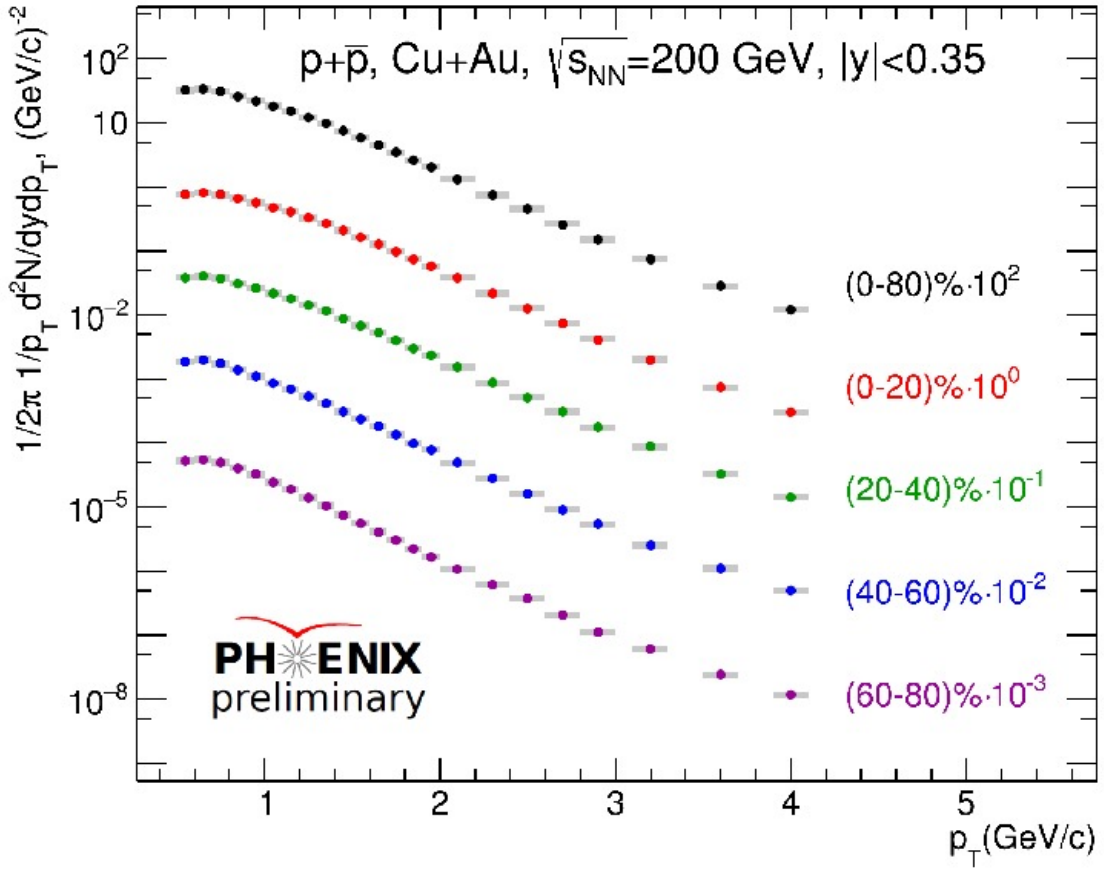


Particle identification





Invariant p_T spectra of $(p + \bar{p})/2$, Cu+Au@200 GeV



$$\frac{1}{2\pi p_T}\frac{d^2N}{dp_T dy} = \frac{N_p C_{bias}}{2\pi p_T N_{evt} \varepsilon_{rec} \Delta p_T \Delta y}$$

- N_{evt} is the number of events in a given centrality and p_T
- ε_{rec} is the efficiency of the protons identification
- N_p is the protons raw yield measured in the given centrality and p_T
- C_{bias} responsible for beam-beam trigger efficiencies for minimum bias and protons events respectively

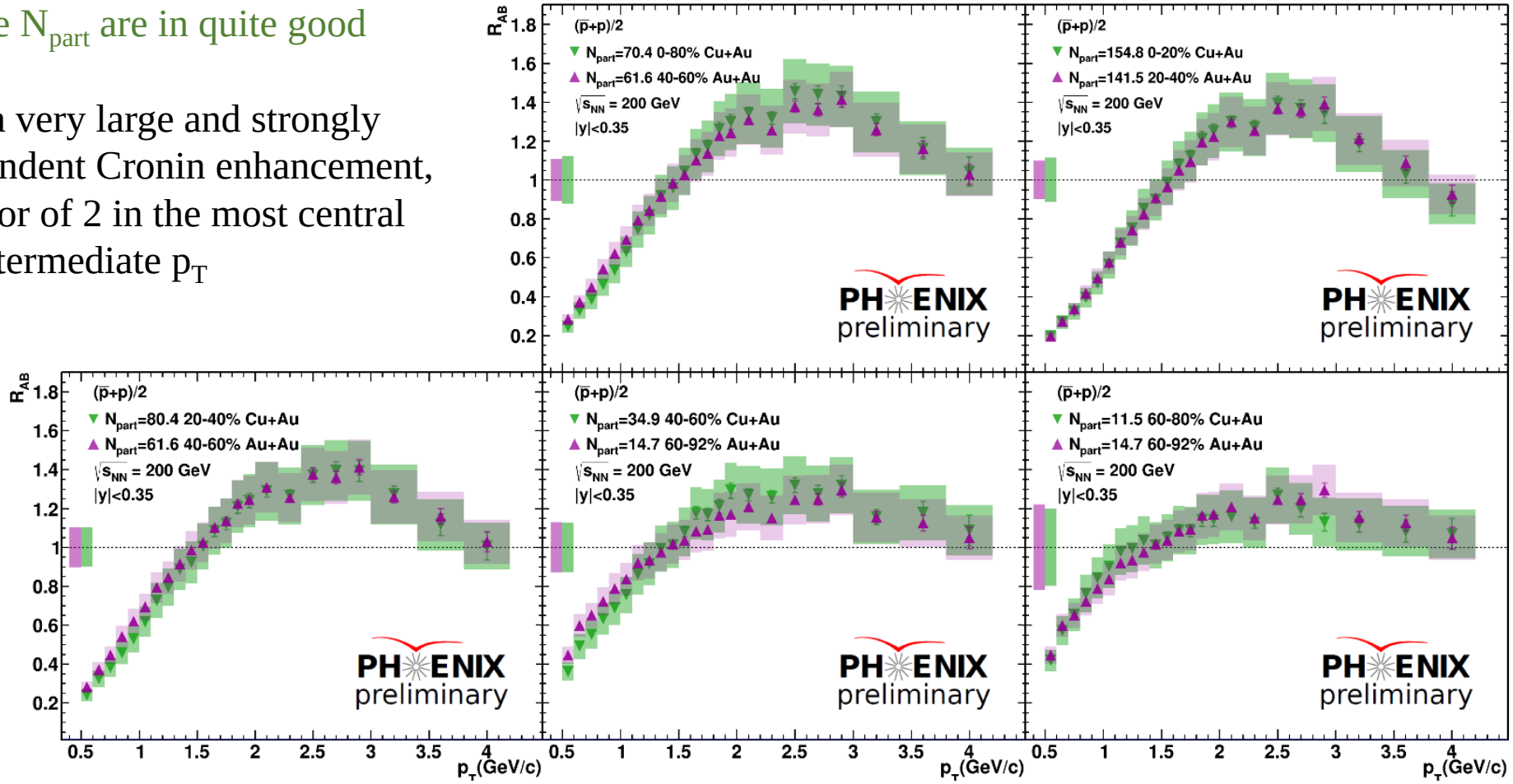
Nuclear modification factors

- Study of collective effects that affect particle invariant p_T spectra
- Calculated according to the formula:

$$R_{AB}(p_T) = \frac{1}{N_{coll}} \frac{d^2N_{AB}(p_T)/dydp_T}{d^2N_{pp}/dydp_T}$$

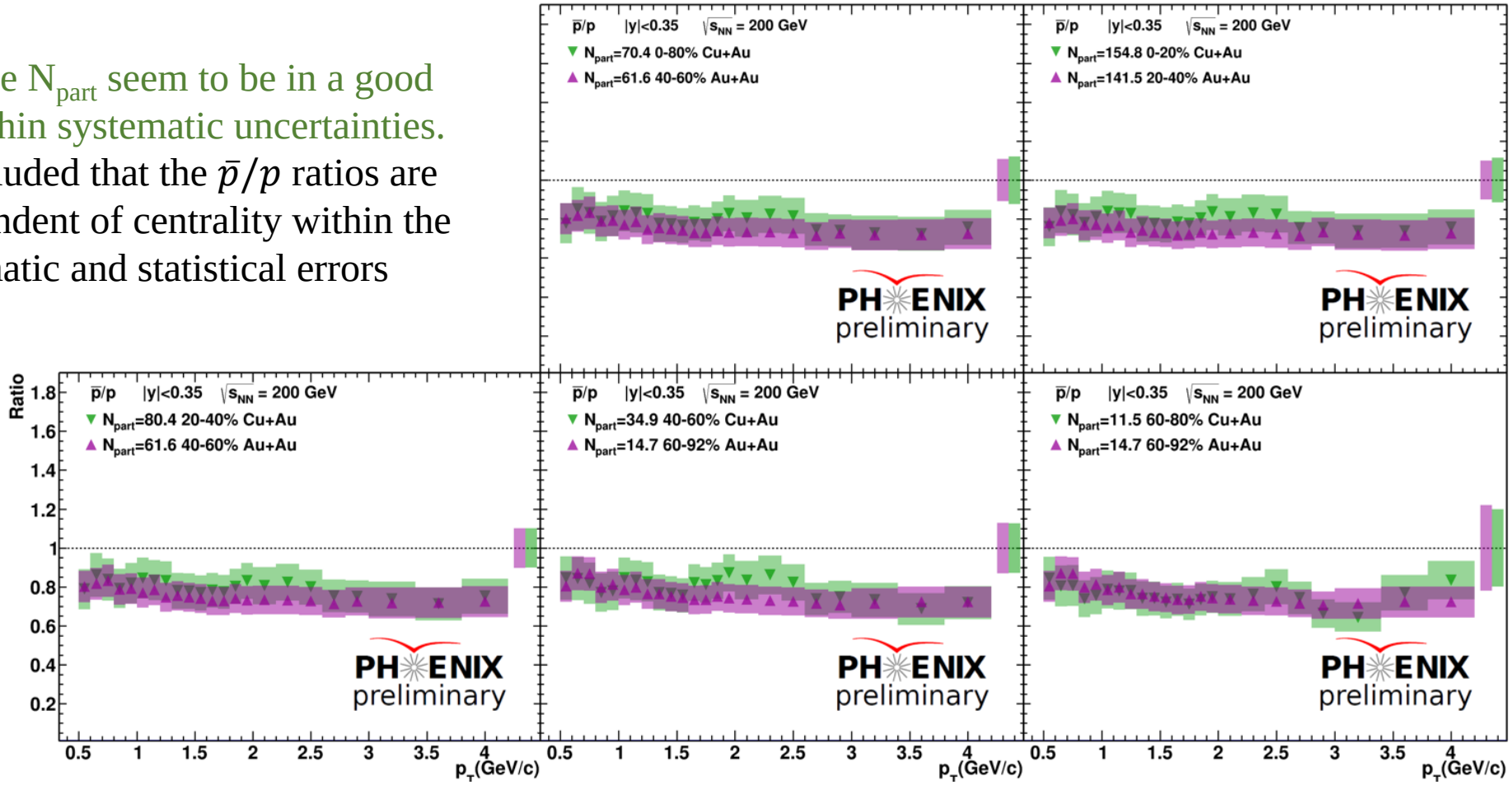
R_{AB} of $(p+\bar{p})/2$, Cu+Au@200 GeV

- Results at same N_{part} are in quite good agreement.
- Protons show a very large and strongly centrality dependent Cronin enhancement, reaching a factor of 2 in the most central collisions at intermediate p_T



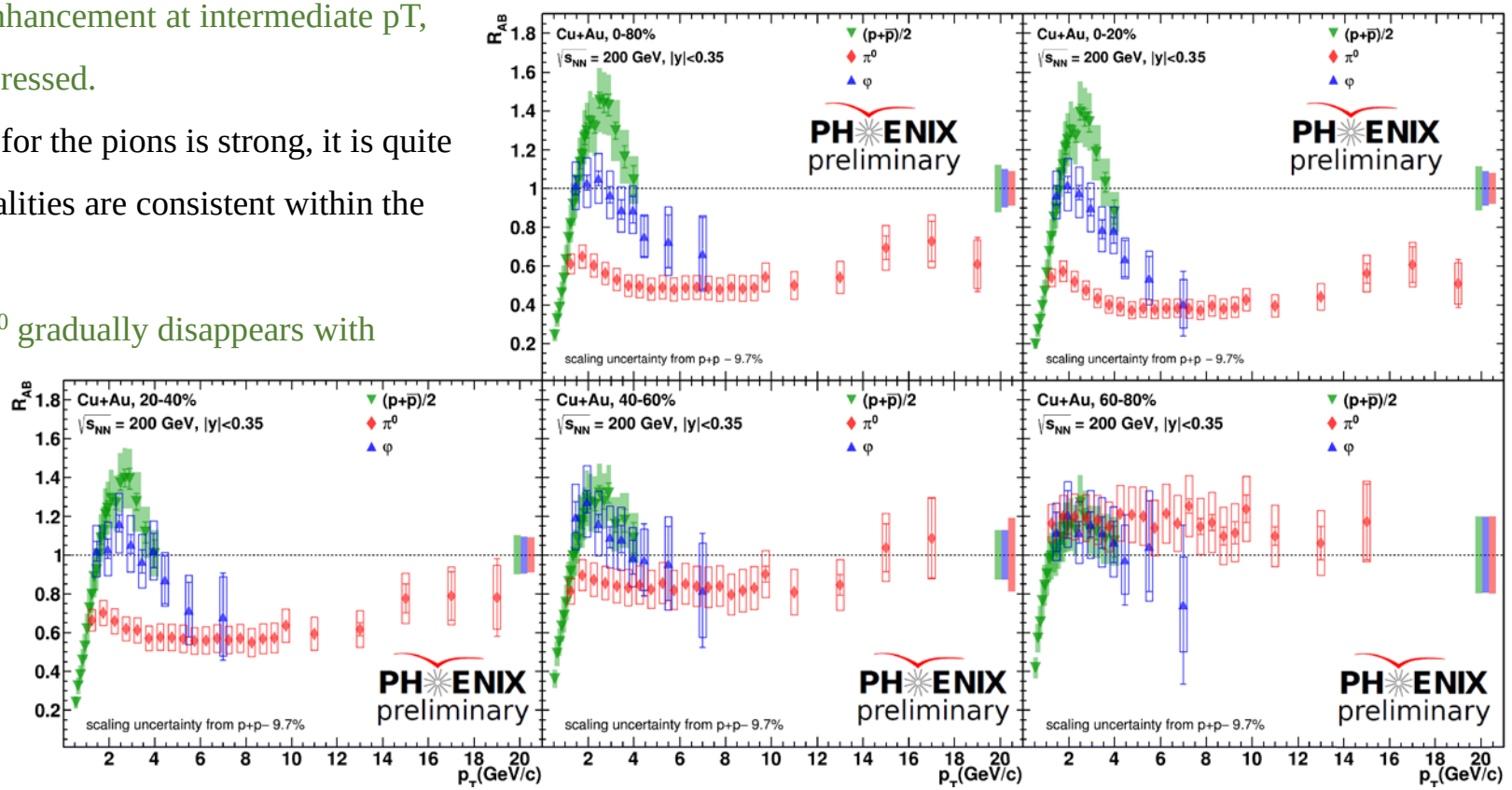
$\bar{p}/p$ ratio Cu+Au@200 GeV

- Results at same N_{part} seem to be in a good agreement within systematic uncertainties.
- It can be concluded that the $\bar{p}/p$ ratios are almost independent of centrality within the current systematic and statistical errors

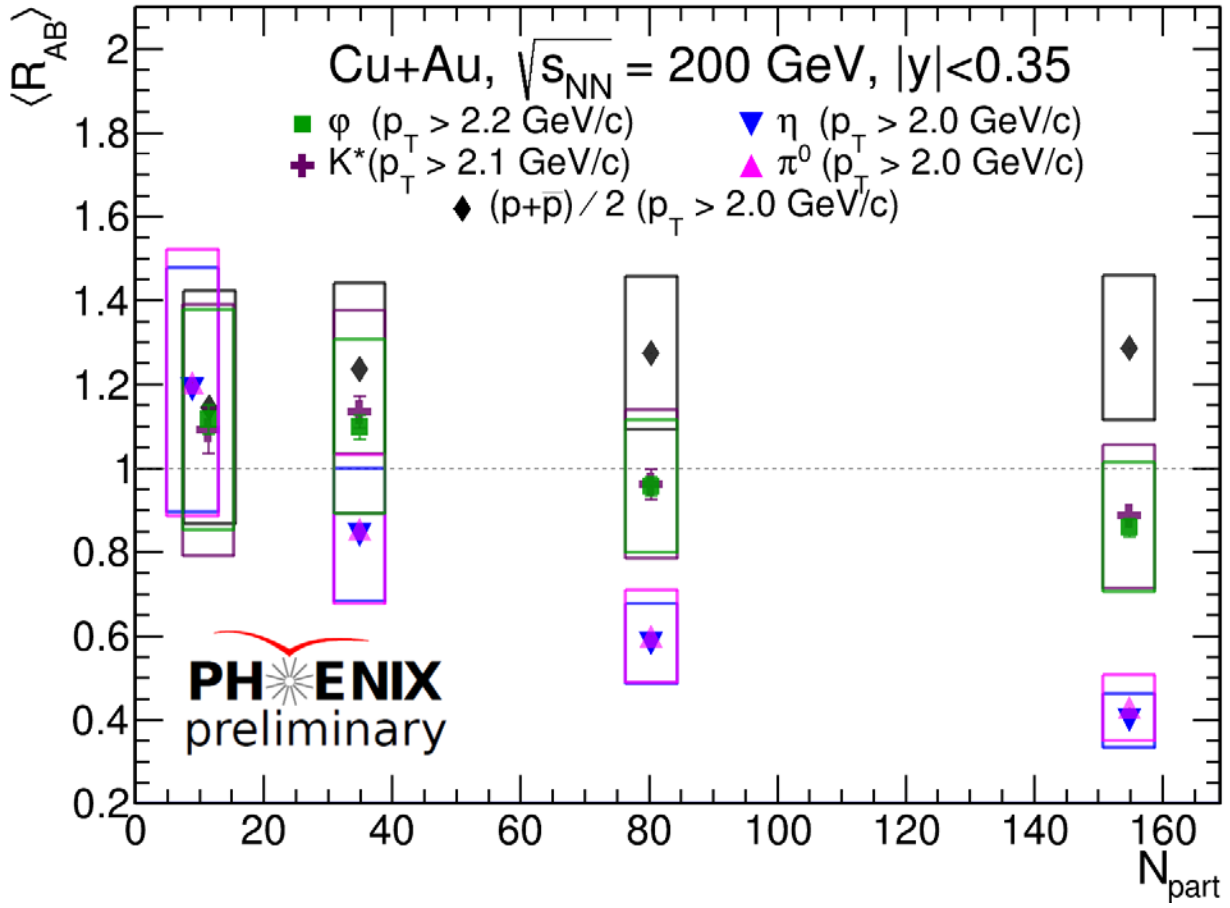


R_{AB} of $(p+\bar{p})/2, \pi^0 \& \varphi$ in Cu+Au@200 GeV

- p shows a different pattern compare to $\varphi \& \pi^0$;
- For central collisions, $(p+\bar{p})/2$ show an enhancement at intermediate pT, whereas the φ R_{AB}~1 & π^0 mesons are suppressed.
- While the centrality dependence of the R_{AB} for the pions is strong, it is quite weak for the protons and the different centralities are consistent within the systematic uncertainties.
- This difference between $(p+\bar{p})/2$, φ & π^0 gradually disappears with decreasing centrality.
- $R_{AB\,\varphi} < R_{AA\,p}$, $m_\varphi \approx m_p$
  This strongly suggests a baryon vs. meson dynamic, as opposed to a simple mass dependence



Integrated R_{AB} as a function of N_{part} in Cu+Au collisions



Conclusion

- Production and suppression of the $(p + \bar{p})/2$ seems to scale with the average size of the nuclear overlap region and not depend on the details of its shape;
- For the most central Cu+Au collisions proton yields are enhanced ($R_{AB} > 1$) at $p_T > 2$ GeV/c, while π^0-mesons yields are suppressed and φ –meson R_{AB} values are around 1. Observed difference in R_{AB} values for protons, φ and π^0-mesons disappears from central to peripheral collisions.
- The observation of these patterns in many collision systems can provide further constraints to quark recombination models.