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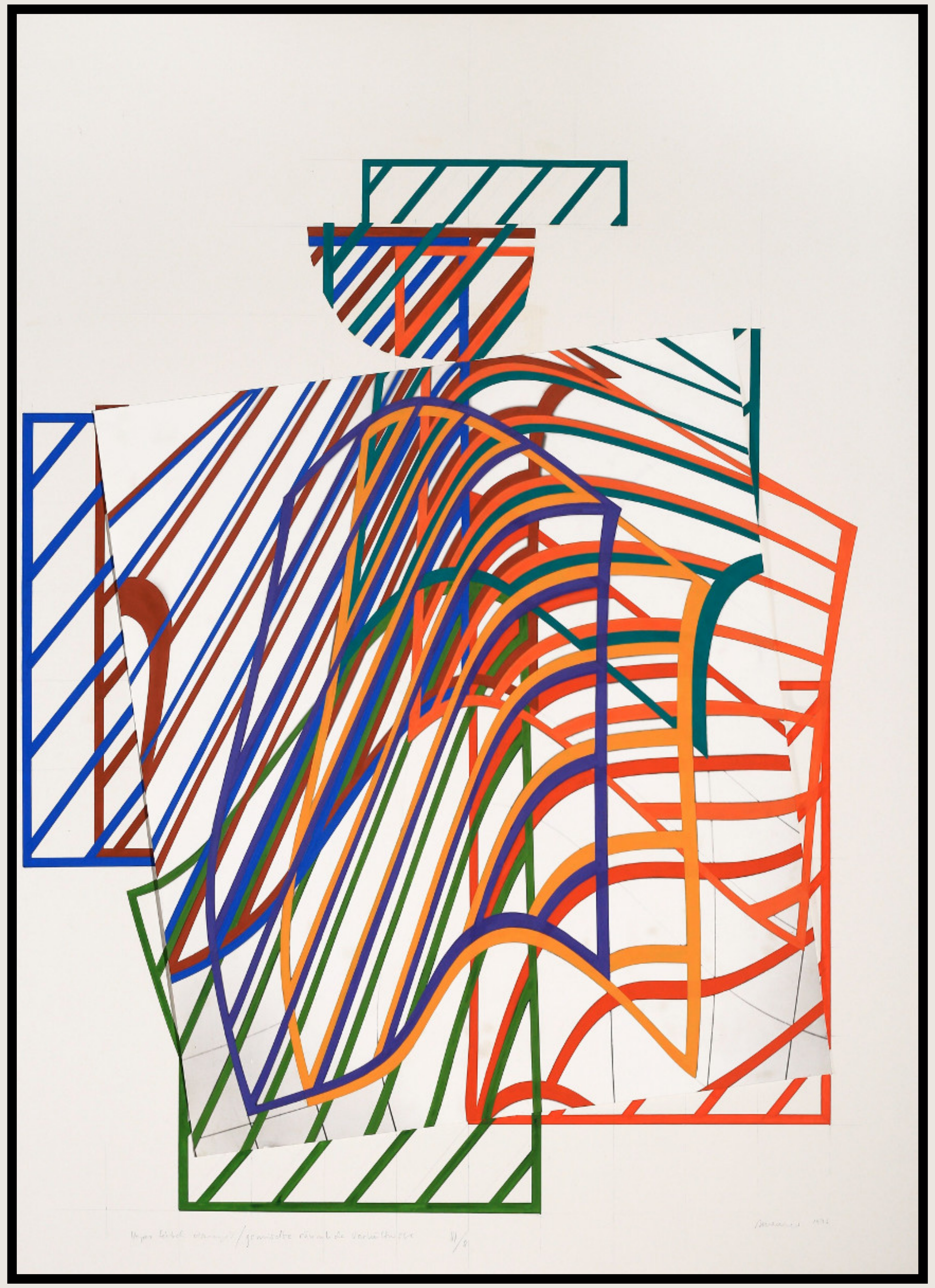
Office of Science

ZIMÁNYI SCHOOL
WINTER WORKSHOP ON HEAVY ION PHYSICS



Dóra Maurer, Space Painting

Highly recommend to visit:
https://awarewomenartists.com/en/

Particle vs antiparticle flow at STAR experiment

For the STAR Collaboration

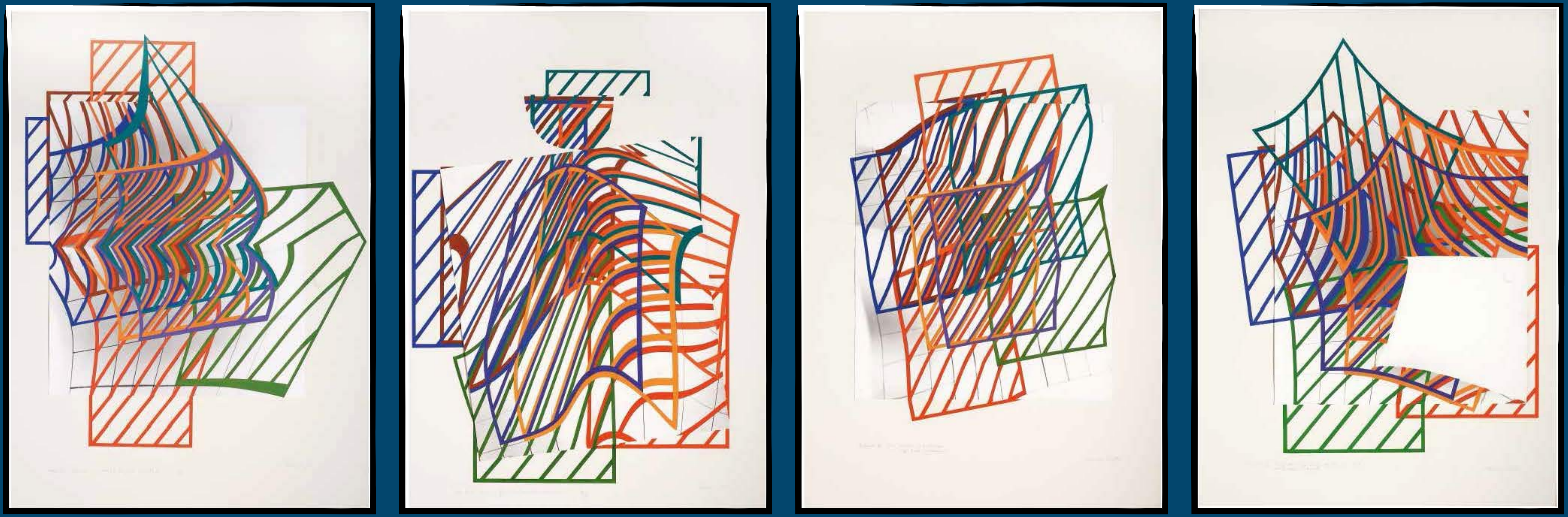
Maria Stefaniak

STAR

Faculty of Physics
WARSAW UNIVERSITY OF TECHNOLOGY

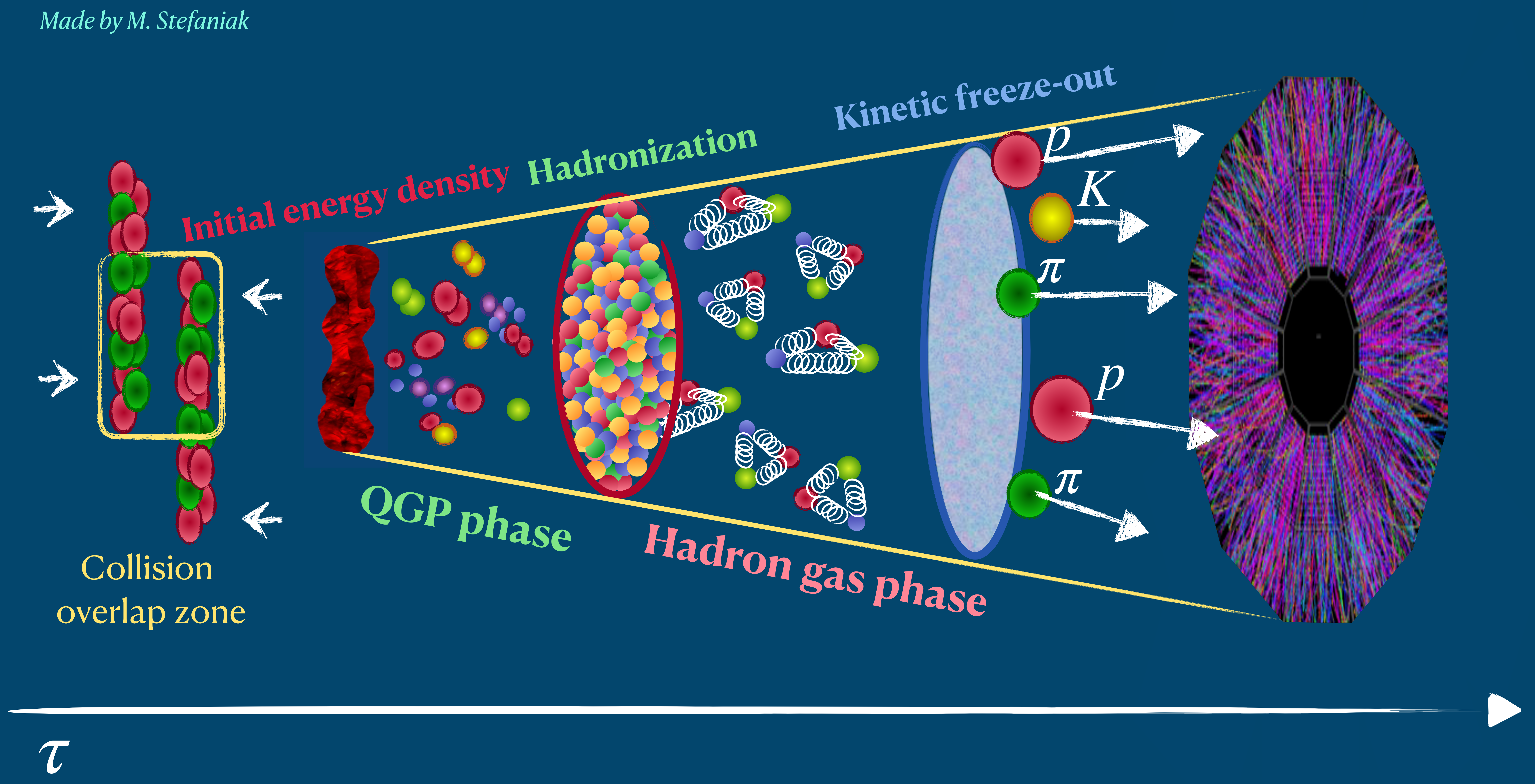
GSI

Why we are even interested ?

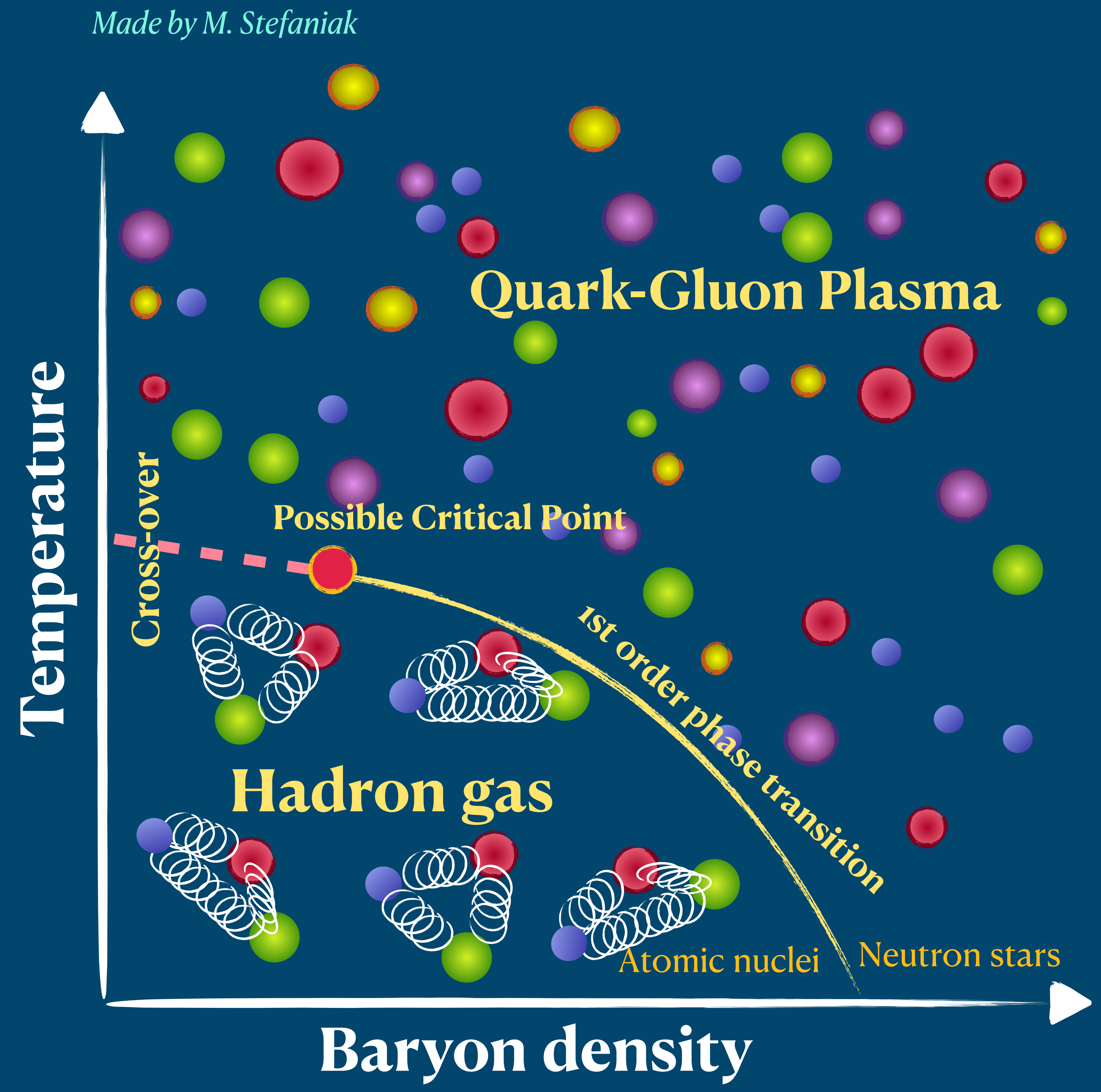


Dóra Maurer, Space Painting

Understand the properties of the elementary matter

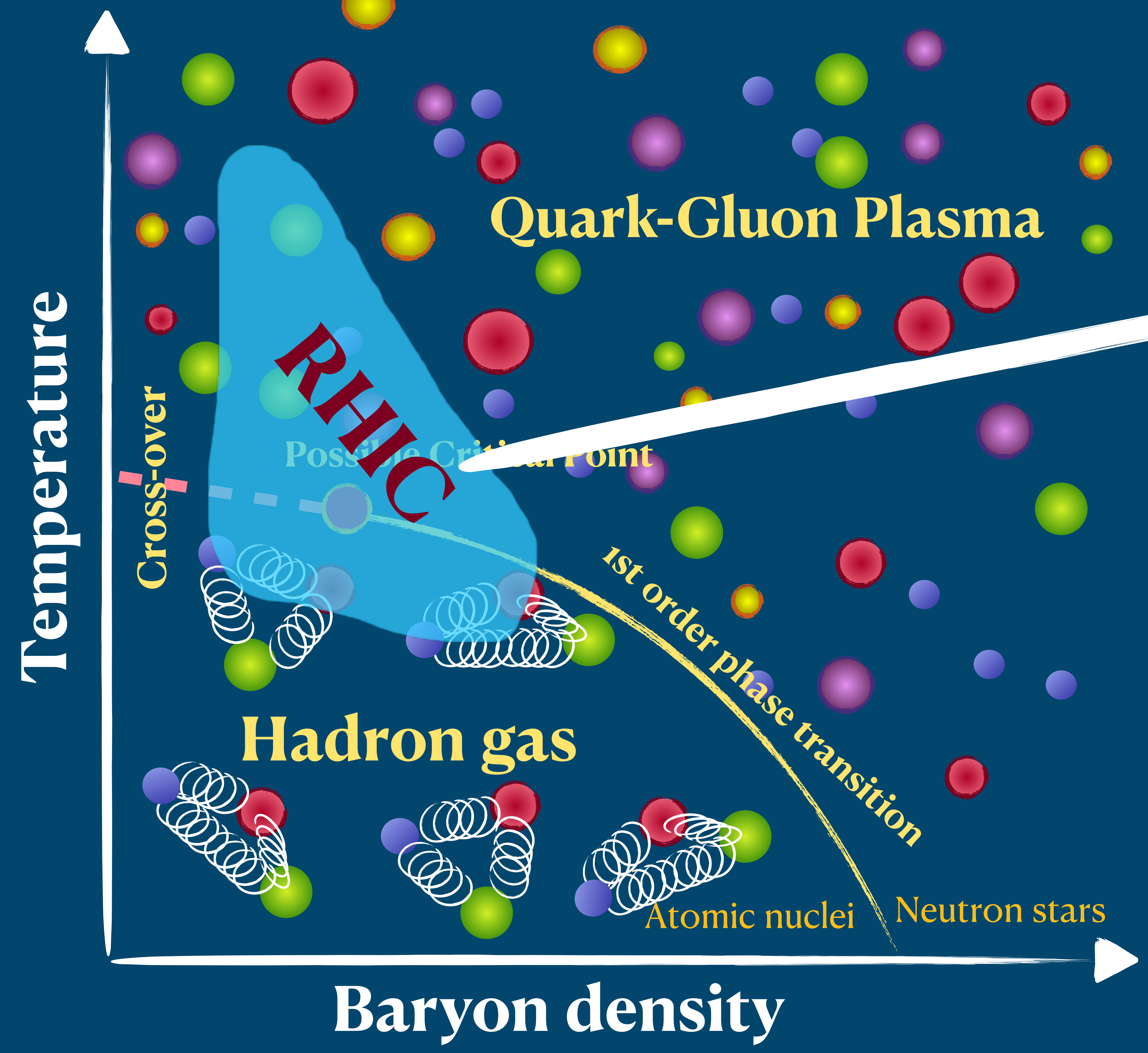


Understand the properties of the elementary matter

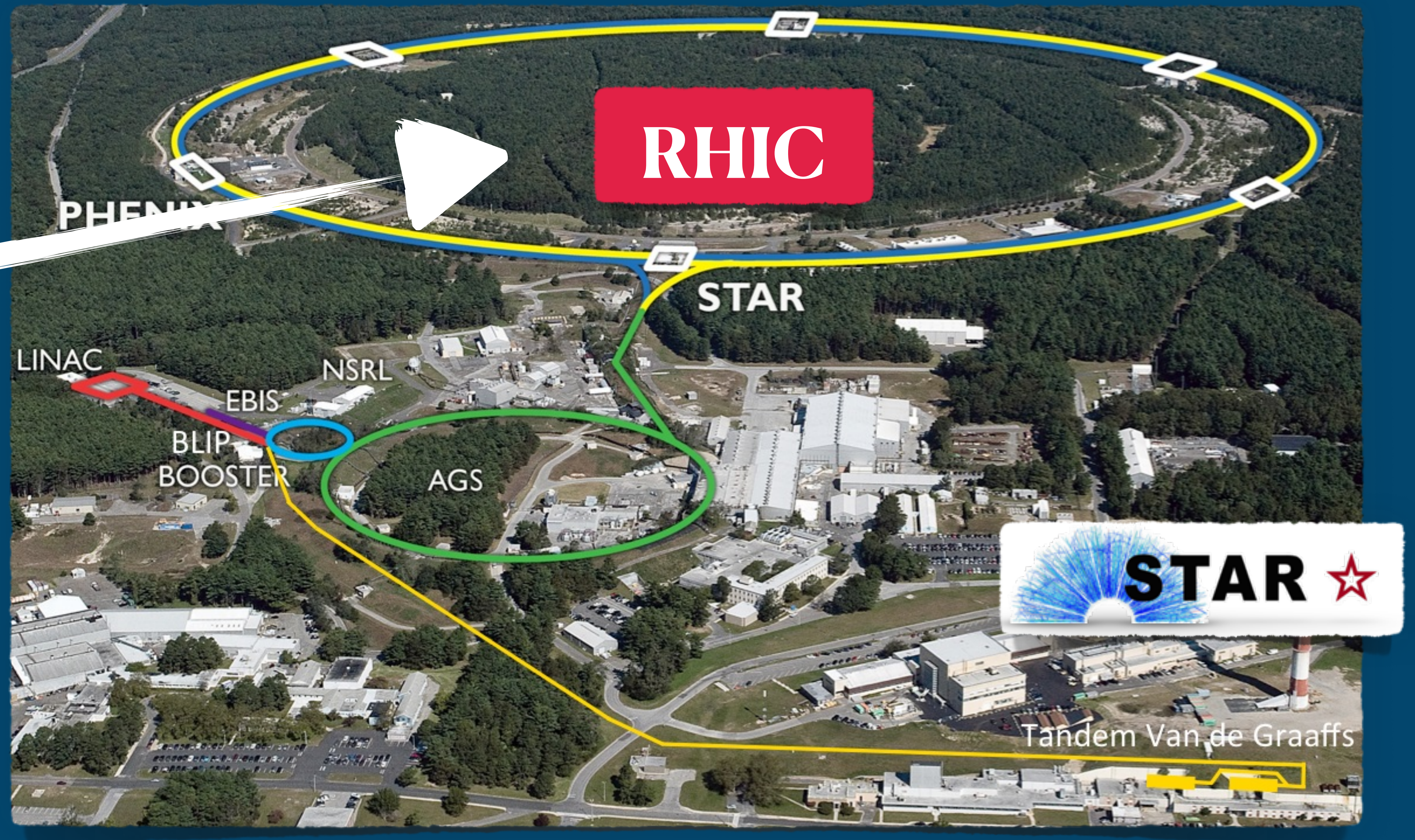


Understand the properties of the elementary matter

Made by M. Stefaniak



Brookhaven National Laboratory



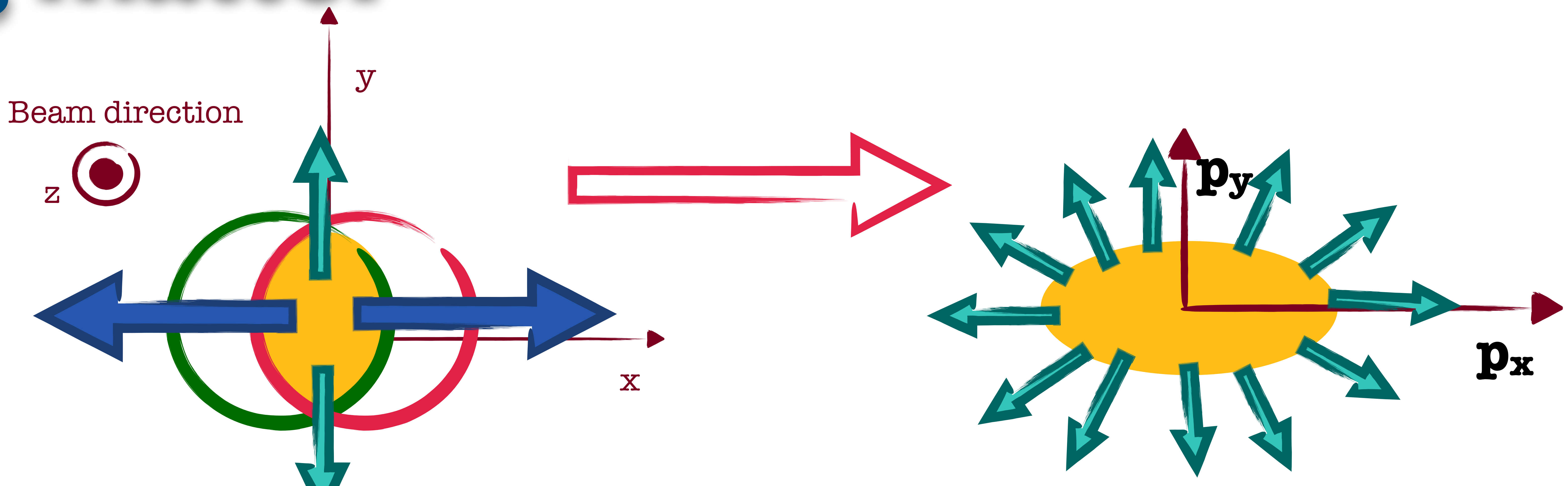
https://science.osti.gov/np/Facilities/User-Facilities/RHIC

Enhancement of in-plane expansion

Uniform expansion

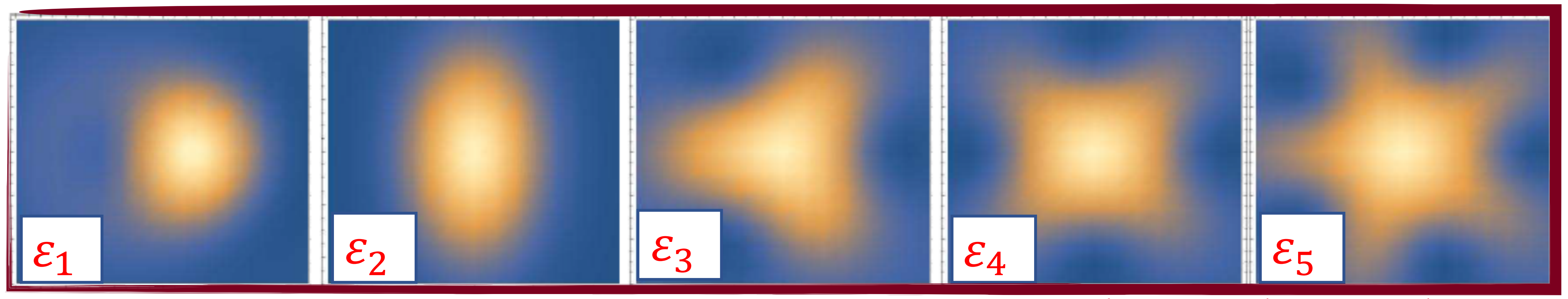
https://www.youtube.com/watch?v=xrL2ELkQOiE

Flowing matter



This thesis

Anisotropy in initial geometry ⇒ **Final-state momentum anisotropy**



https://indico.cern.ch /event/854124/contributions/4135473/,2021

Anisotropic flow measurements are sensitive to:

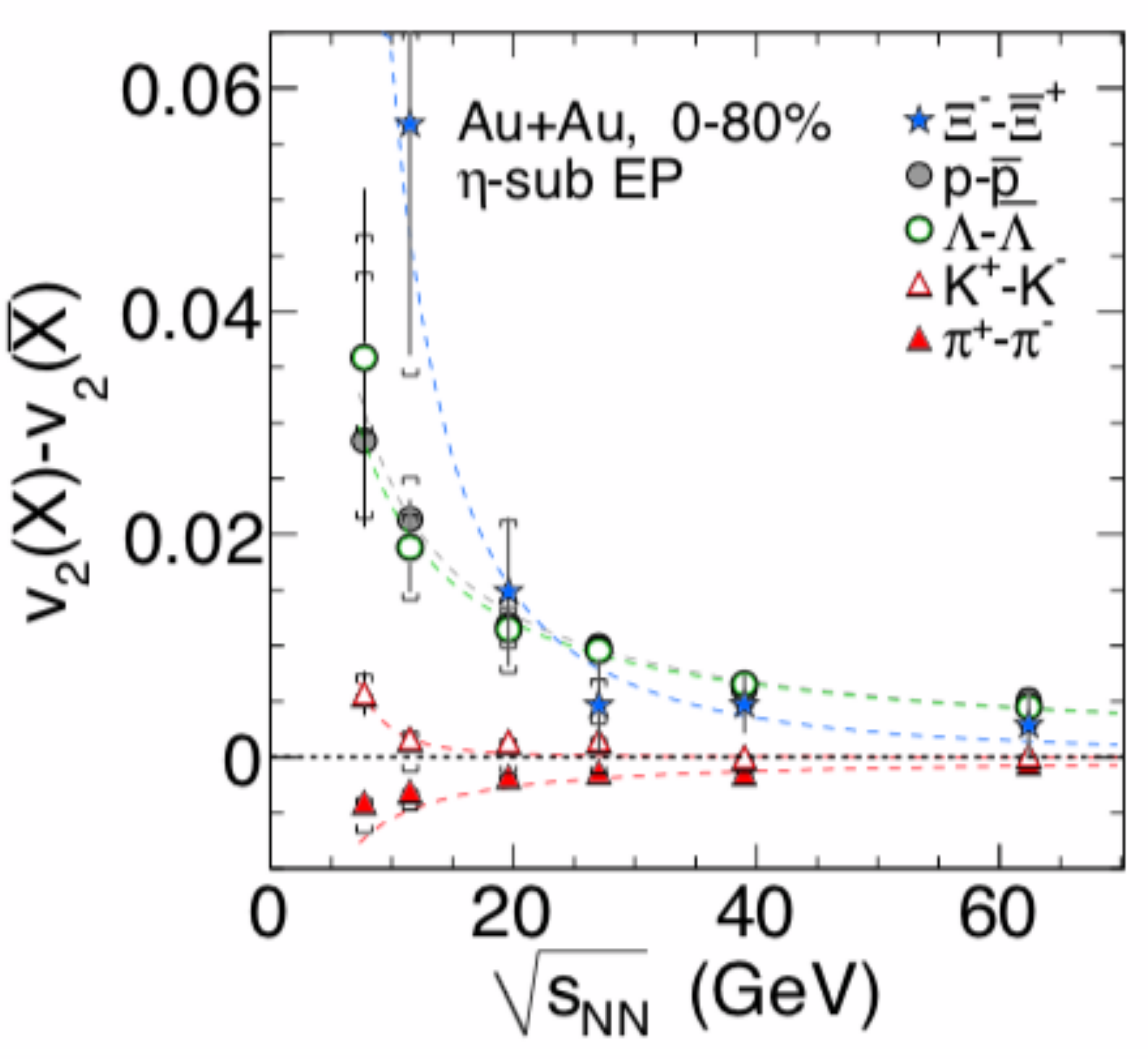
- Initial-state spatial anisotropy
- Flow fluctuations and correlations
- Transport properties (i.e., $\frac{\eta}{s}, \frac{\zeta}{s}, \frac{\hat{q}}{T^3}$,...)

What are the respective roles of ε_n and its fluctuations, flow correlations and transport properties on the v_n?

Motivation - differences between p vs $\bar{p}$

Differences between particle's and antiparticle's elliptic flow were observed by the STAR collaboration.

STAR Collaboration: Phys. Rev. C 88 (2013) 14902



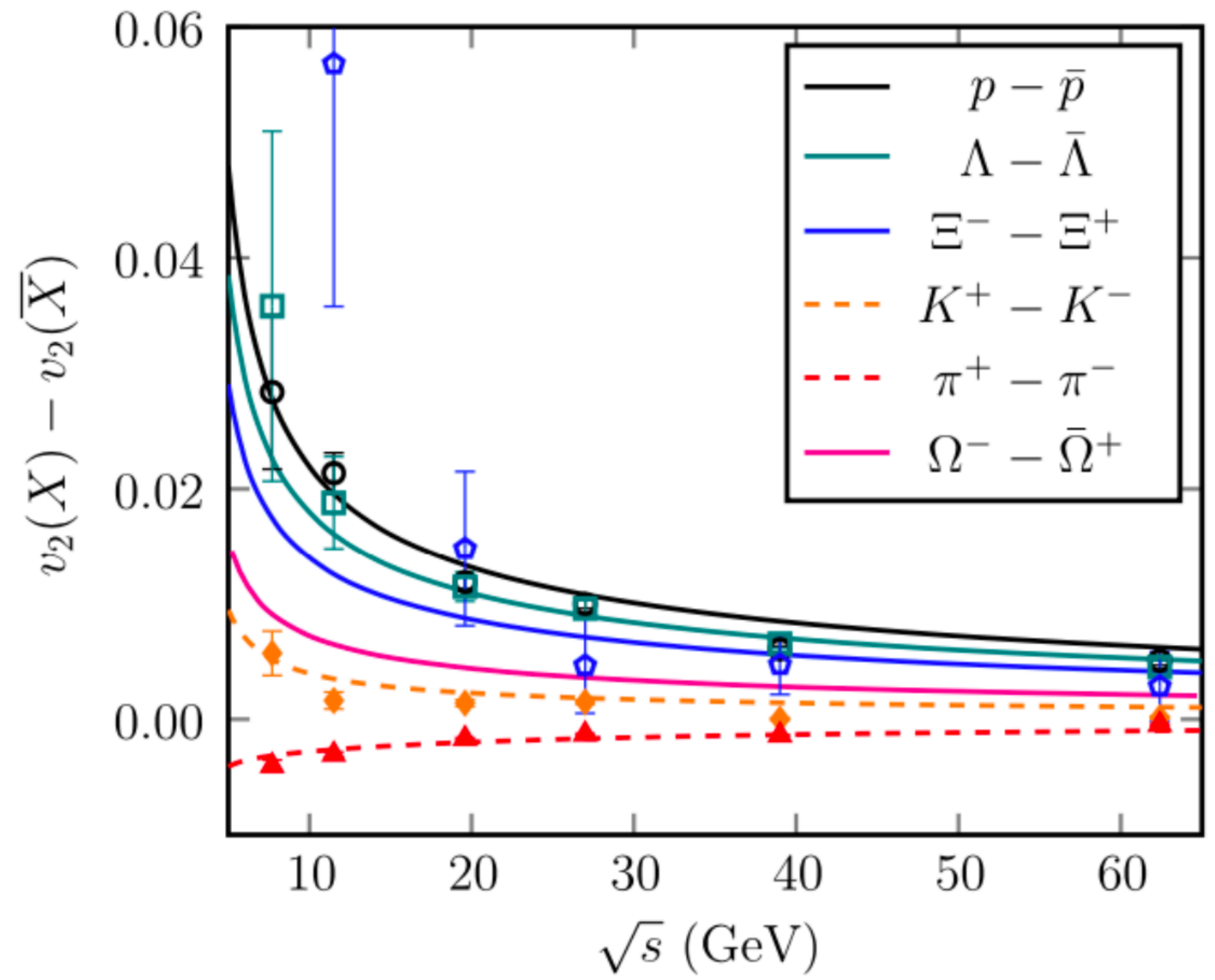
- Difference of protons - antiprotons elliptic flow increases with decreasing collision energy

Various theoretical scenarios of possible sources of this observations are available

- The new **viscous corrections** to v_n (enhanced at higher n_B)
  Phys.Rev.D 92 (2015) 11, 114010
- Mean field: impacts oppositely the quarks and antiquarks.
  Phys. Rev. Lett. 112, 012301 (2014)
- Transported vs. produced protons
  Biao Tu: Chin.Phys. C43 (2019) no.5, 054106

I Scenario: Viscous corrections

Yoshitaka Hatta, Akihiko Monnai, and Bo-Wen Xiao: Phys.Rev.D 92 (2015) 11, 114010



- New viscous corrections to v_n at finite μ_B obtained by solving the equations of viscous hydrodynamics coupled with conserved currents assuming conformal and boost-invariant symmetries.
- Enhanced at higher baryon density and give the leading order contribution to the differences in v_n between particles and antiparticles.

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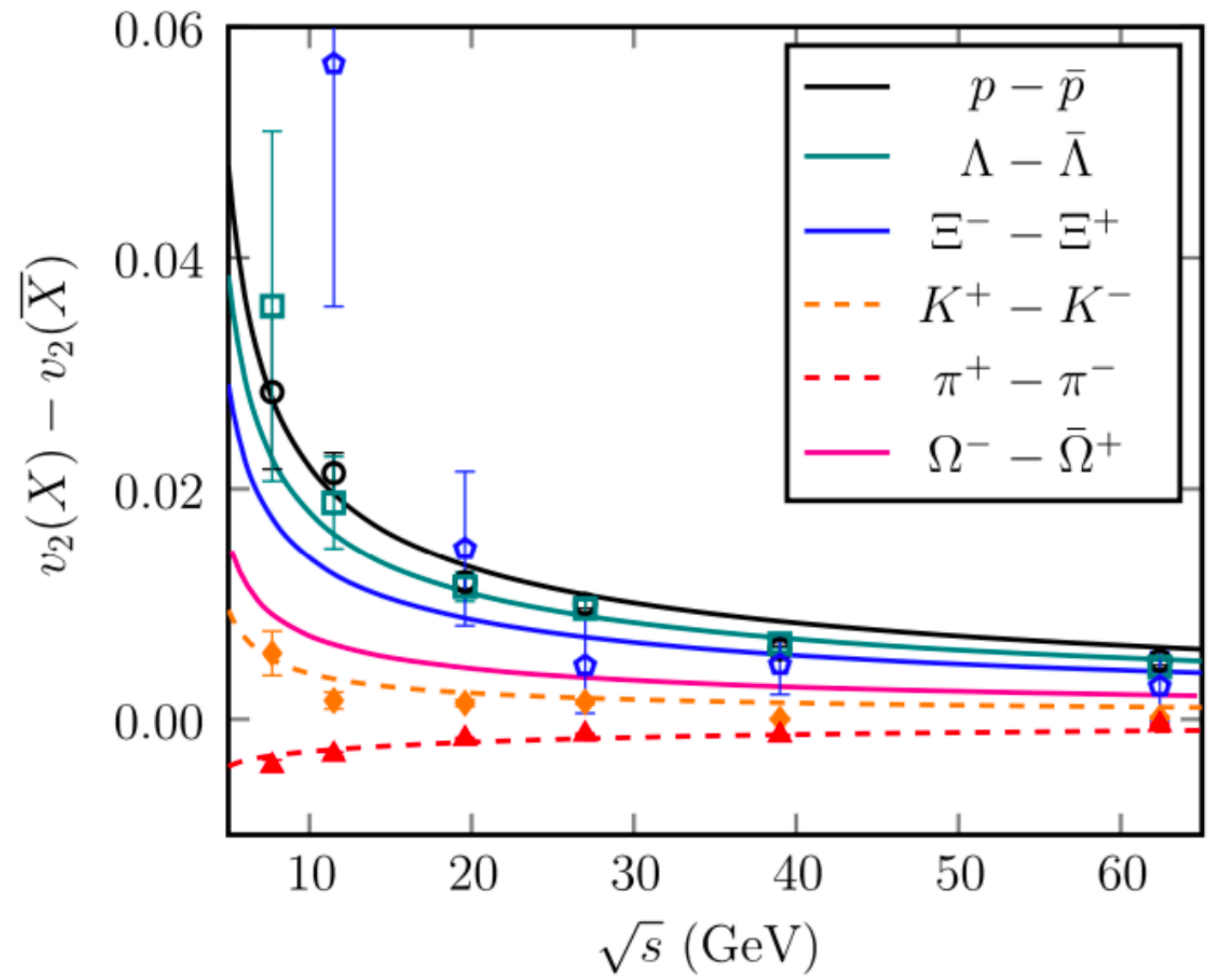

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I Scenario: Viscous corrections

STAR Collaboration: Phys. Rev. Lett. 122, 172301 (2019)

„The viscous attenuation of v_n/ε_n can also be understood within an acoustic model framework, akin to that for viscous relativistic hydrodynamics:

$$ln(v_n/\varepsilon_n) \propto -n^2 \langle \frac{\eta}{s}(T) \rangle \langle N_{ch} \rangle^{-1/3}$$

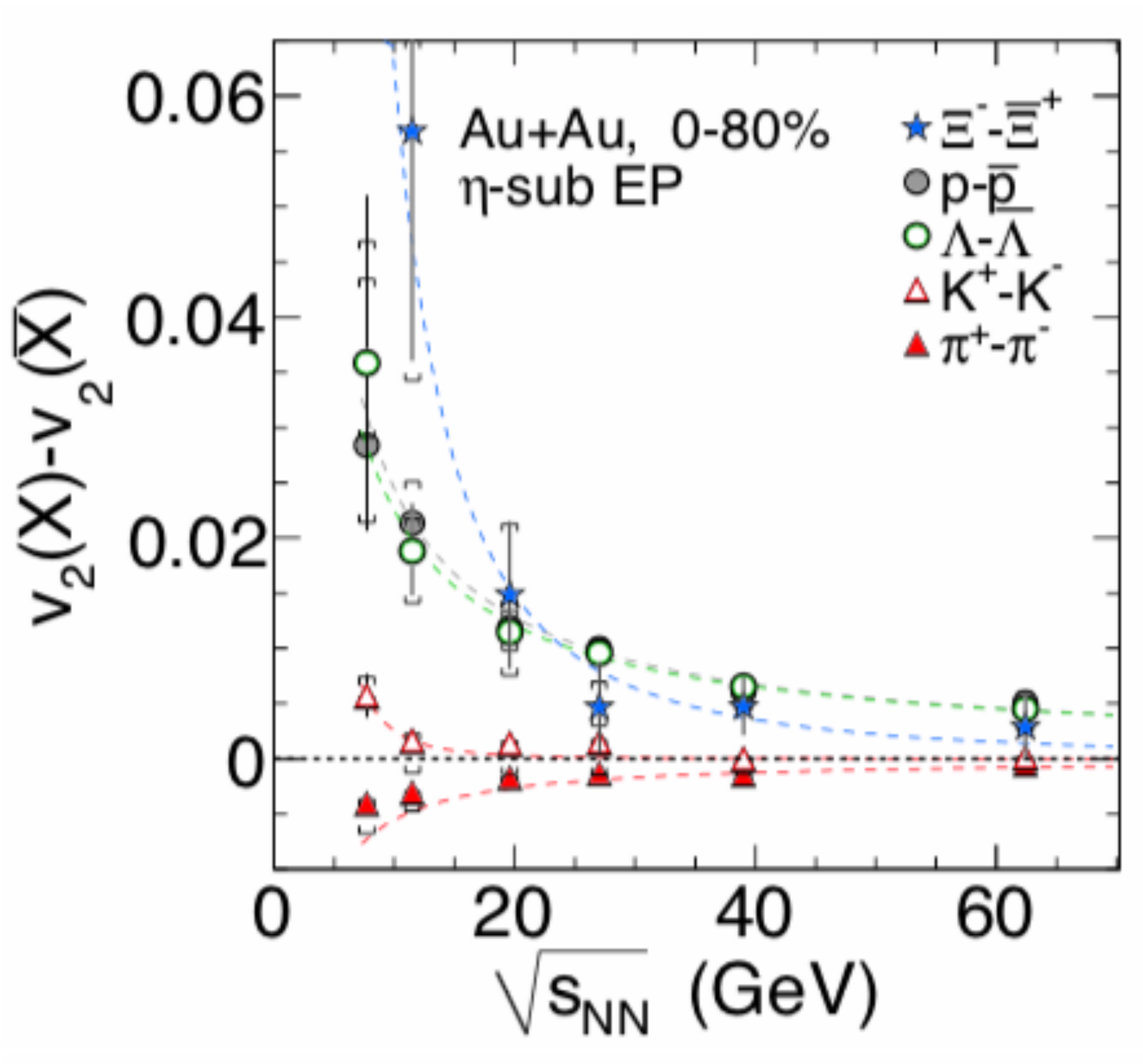
Where N_{ch} is the charged particle multiplicity and $\langle N_{ch} \rangle^{-1/3}$ is a proxy for the dimensionless size of the system"

v_2	$n^2 = 4$
v_3	$n^2 = 9$

I Scenario: Viscous corrections

Elliptic flow n = 2

STAR Collaboration: Phys. Rev. C 88 (2013) 14902



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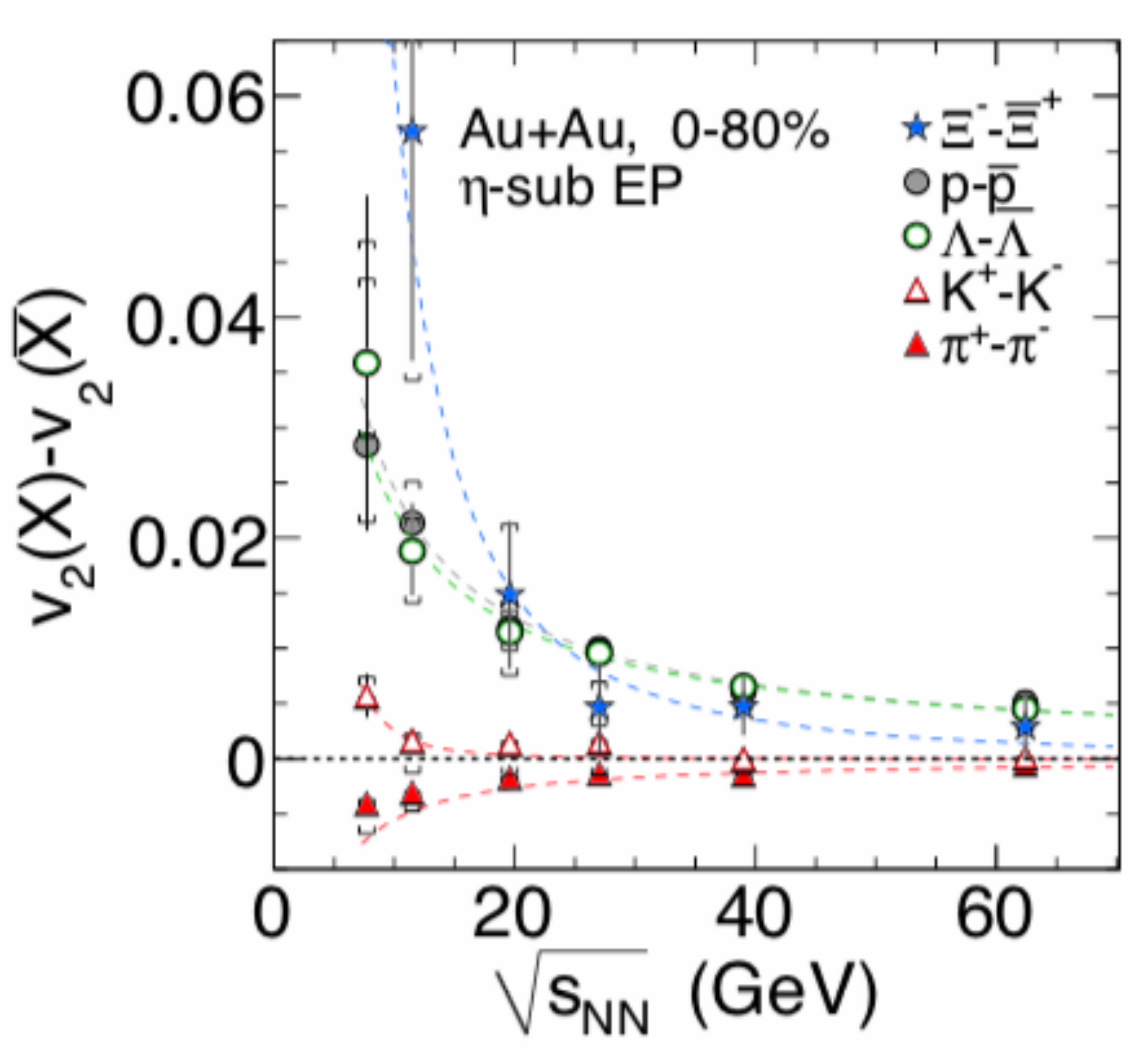
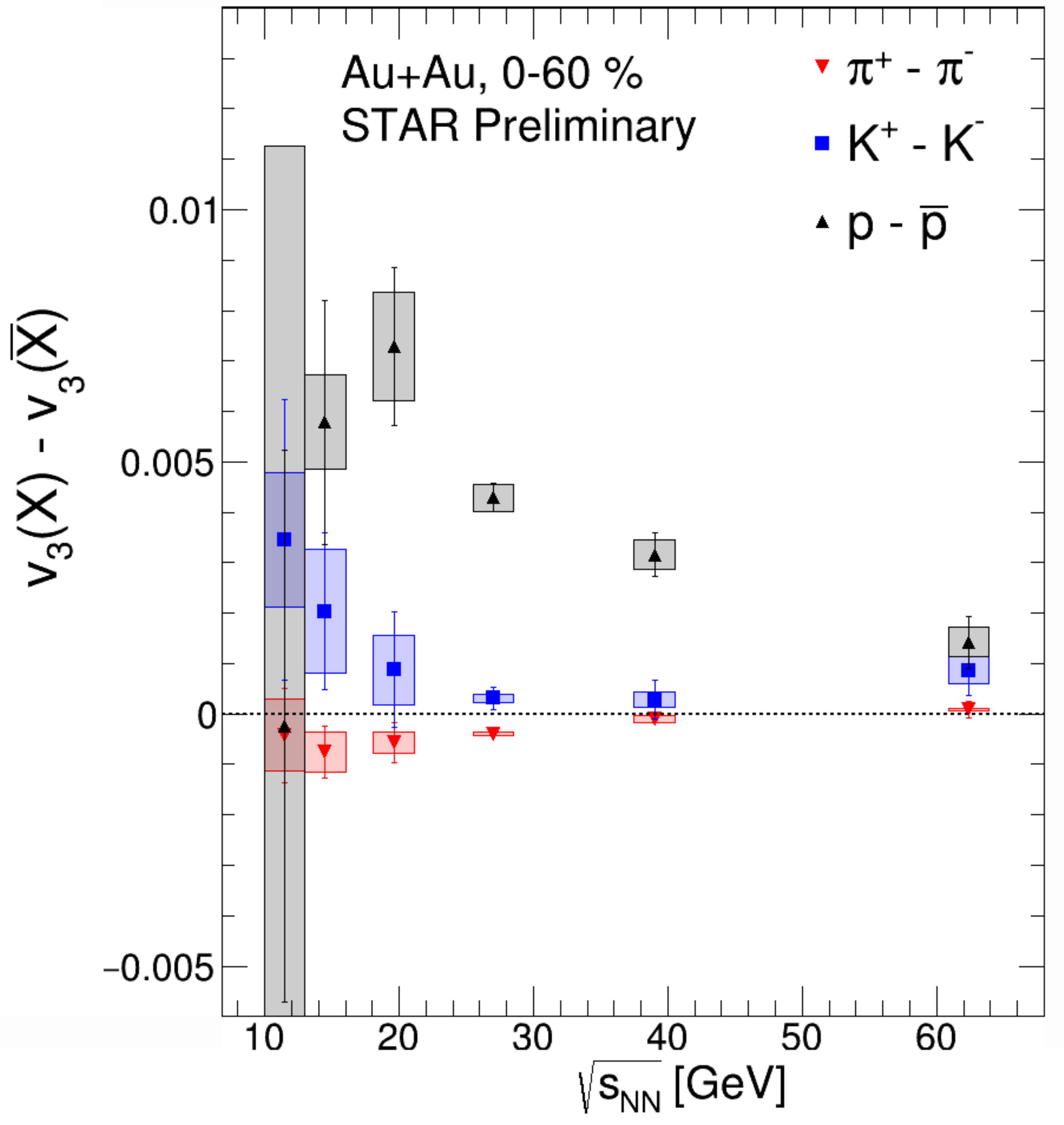


Triangular flow n = 3

STAR Collaboration: J. Phys.: Conf. Ser. 1690 012128



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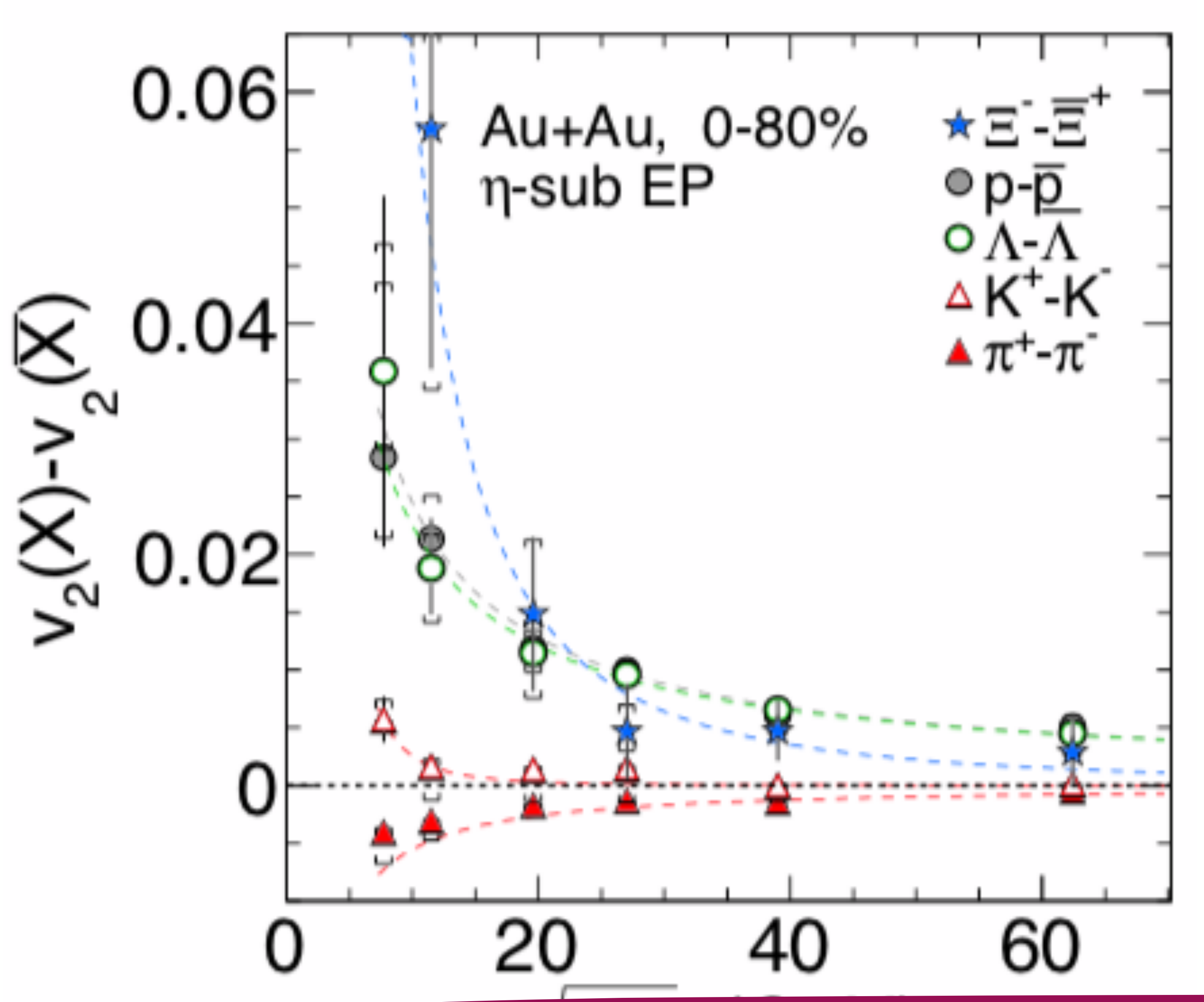

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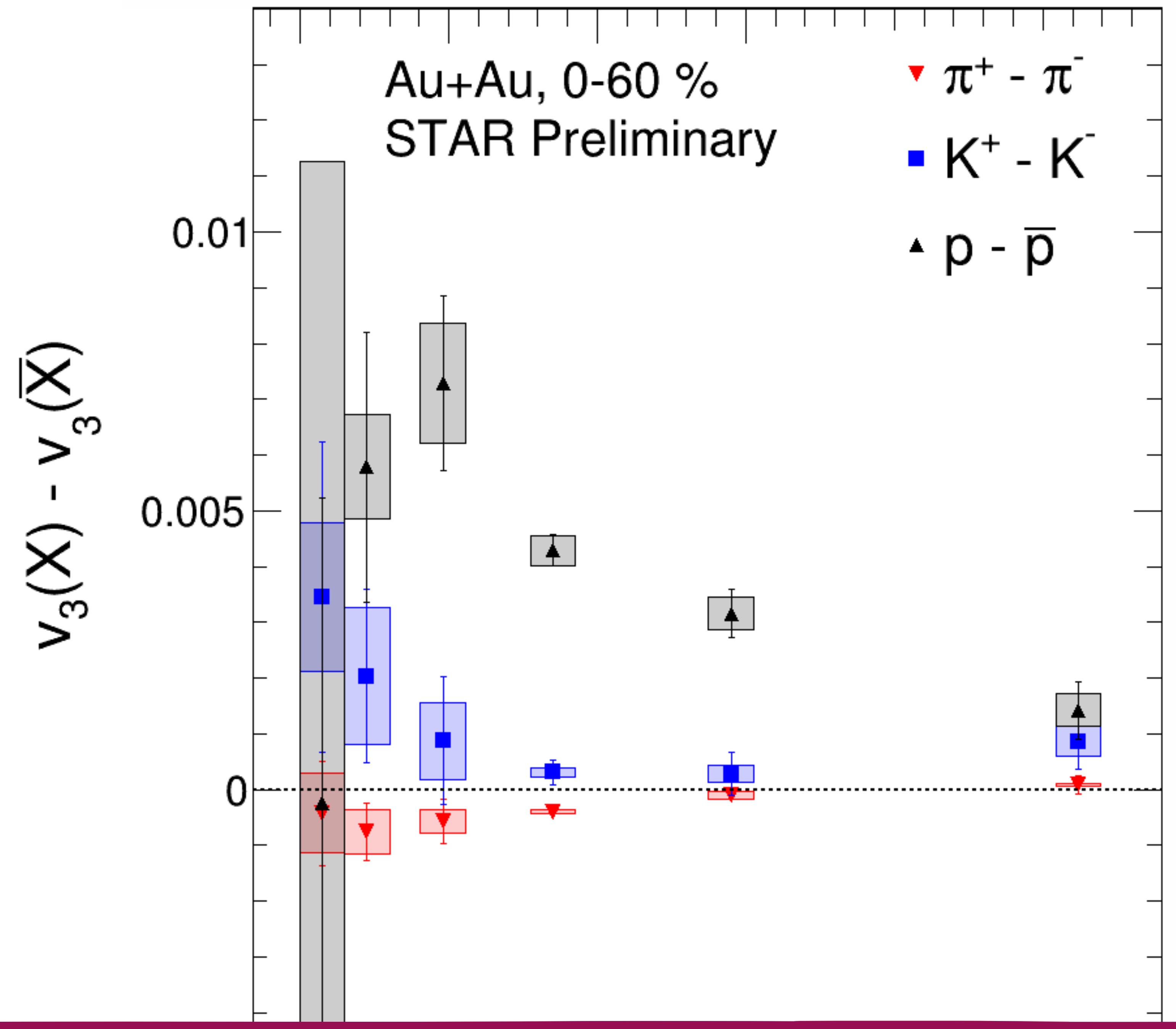
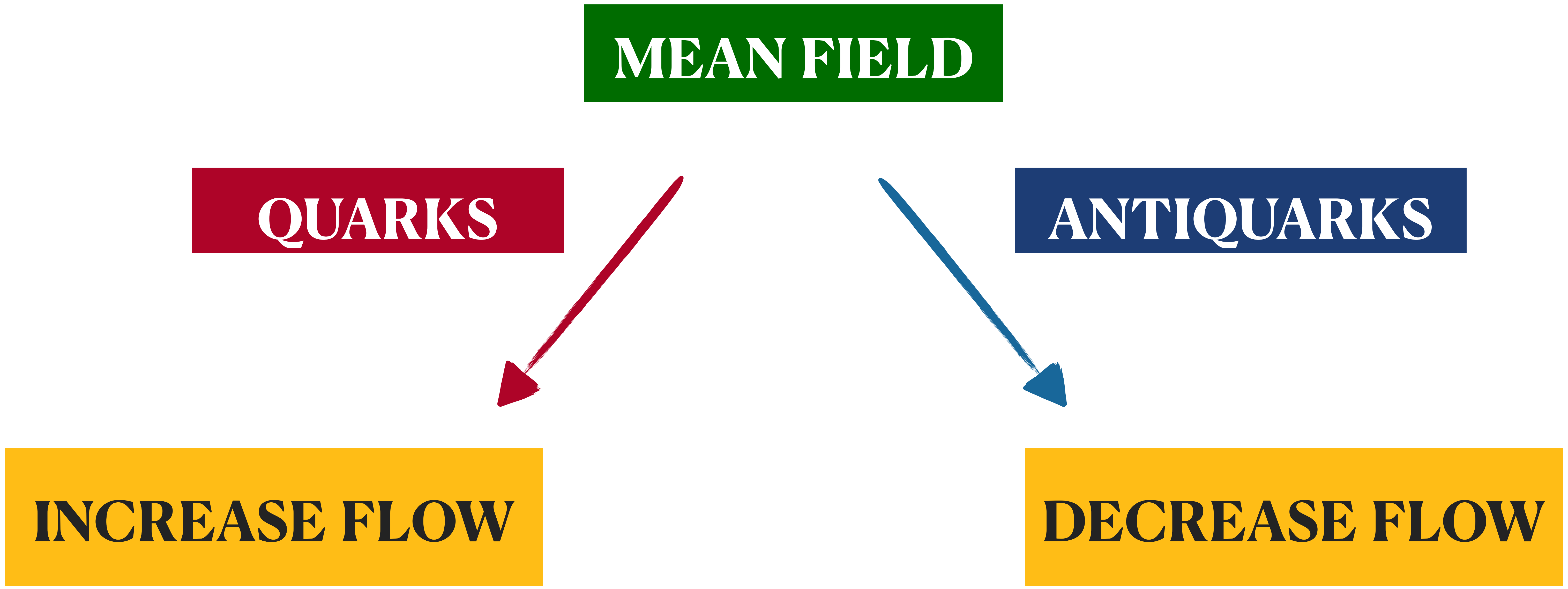


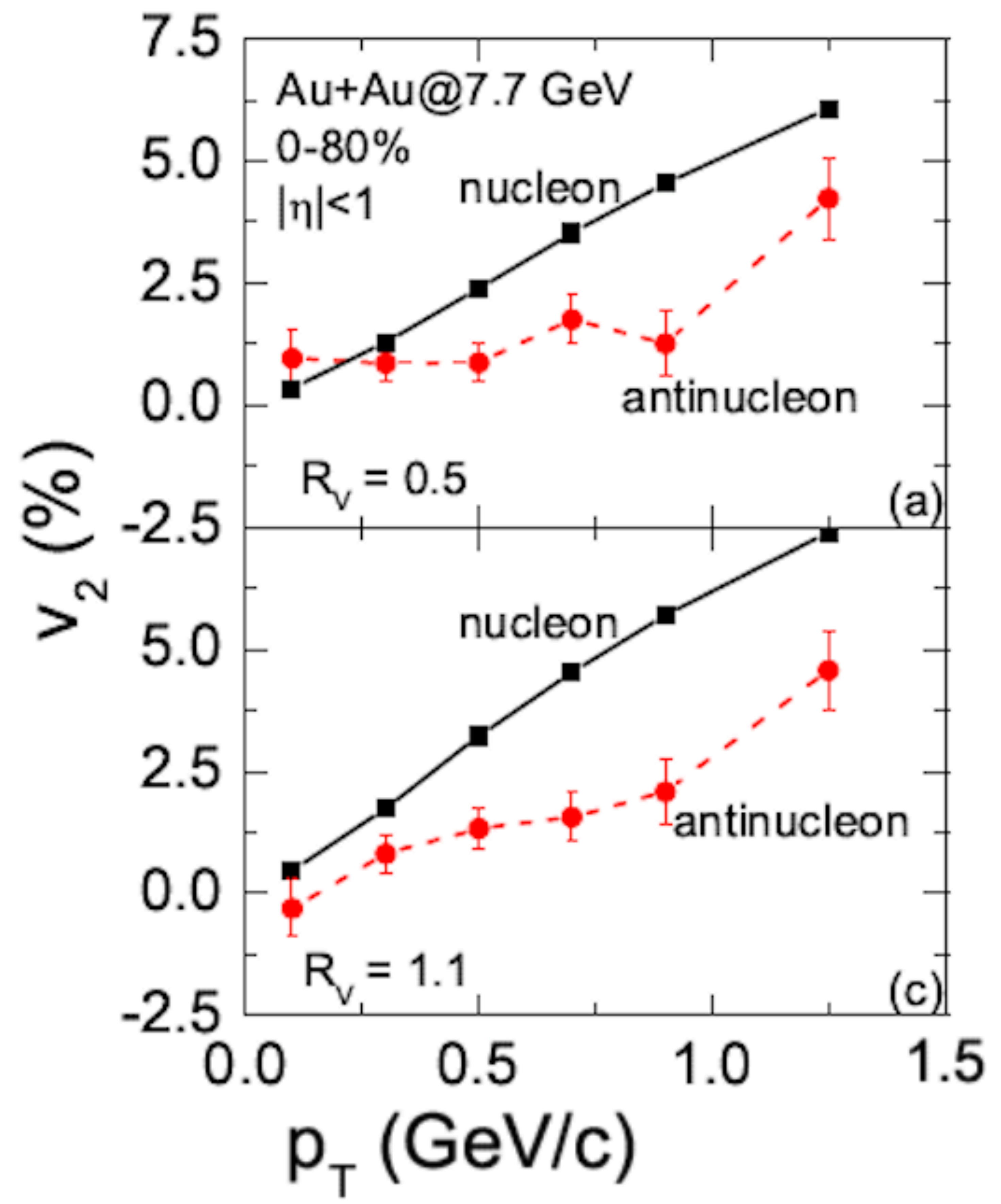
How the proposed corrections fit the v_n where n = 3?

II Scenario: Mean field

Jun Xu, Taesoo Song, Che Ming Ko, and Feng Li: Phys. Rev. Lett. 112, 012301 (2014), Nucl. Phys. Rev 32:146, 2015

- **Mean field**: impacts oppositely the quarks and antiquarks.





model used: AMPT and 3-flavor Nambu-Jona-Lasinio model

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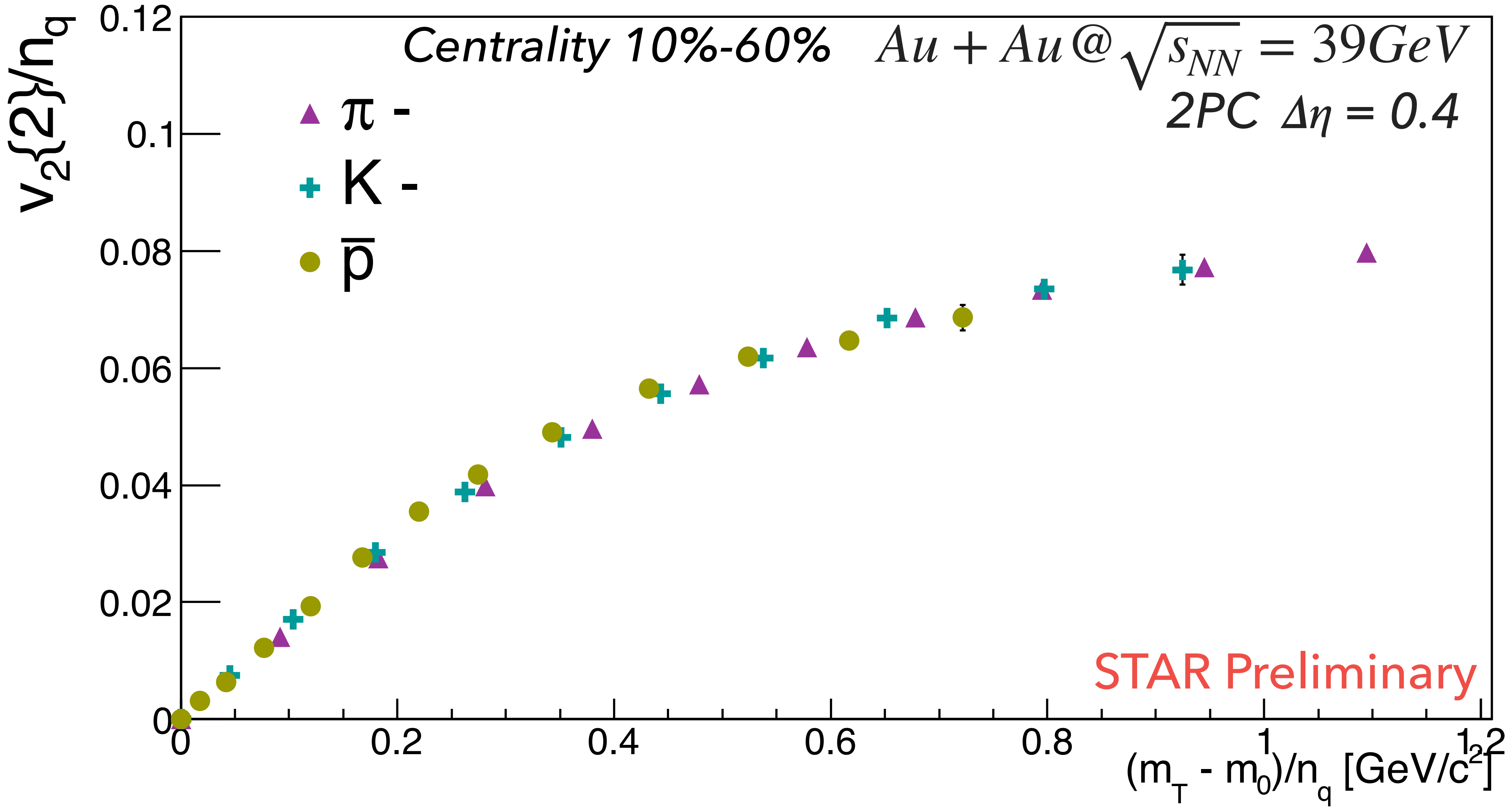
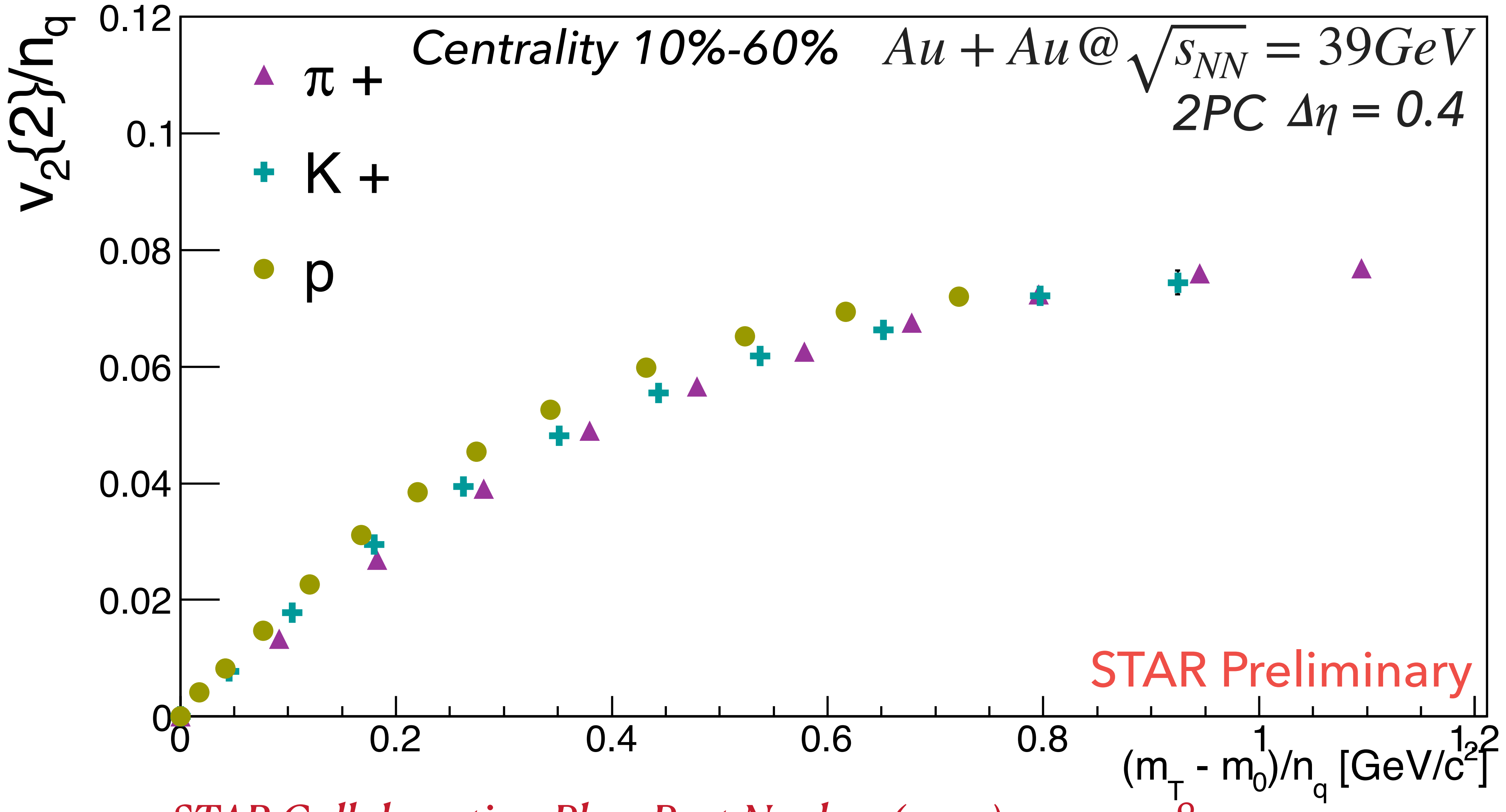


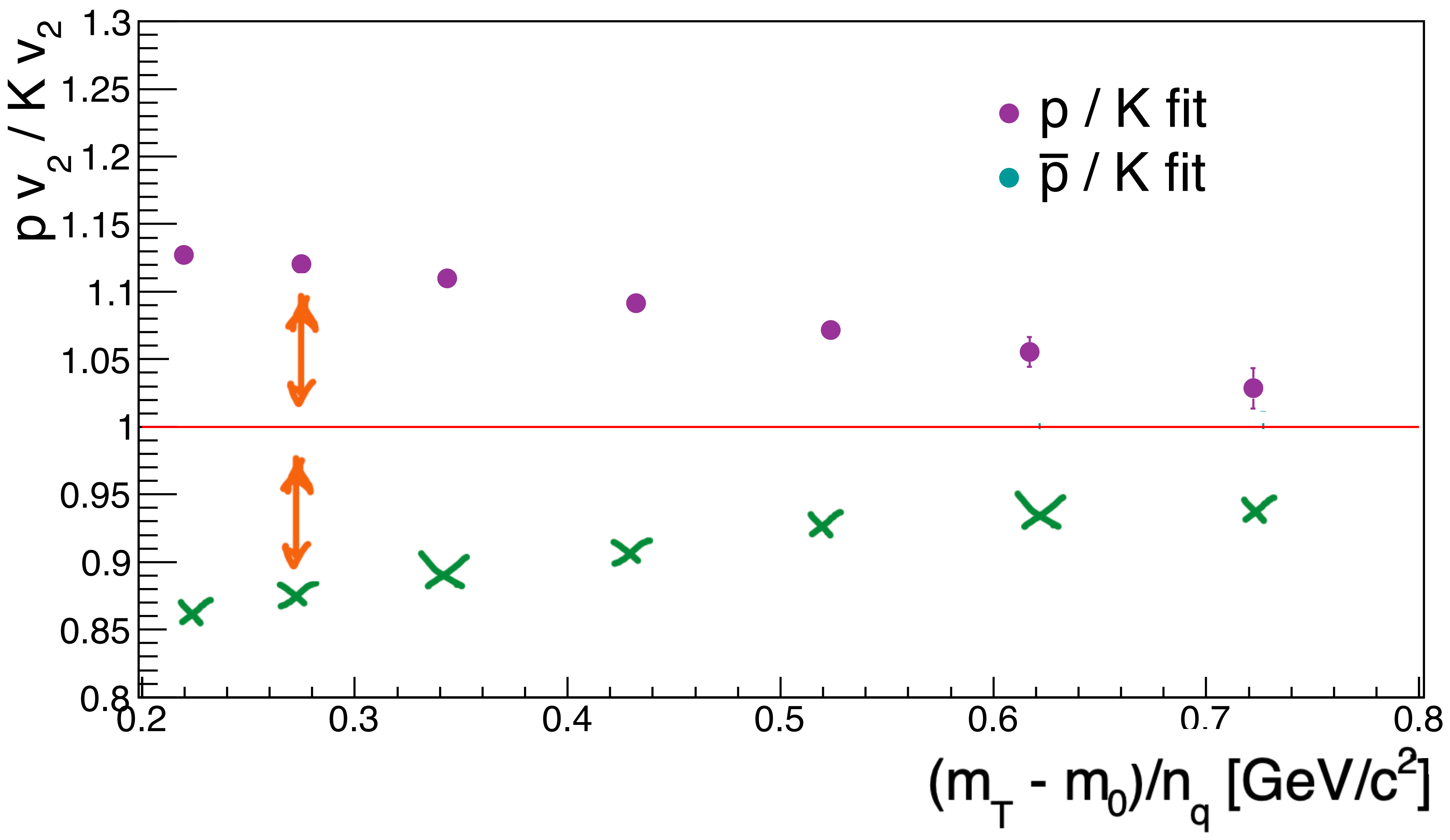


STAR Collaboration:Phys.Part.Nucl. 51 (2020) 3, 305-308

Mean field scenario:

- Expected proton and antiproton violate NCQ(KET) scaling in the same magnitude (but opposite sign)

SCRATCH!



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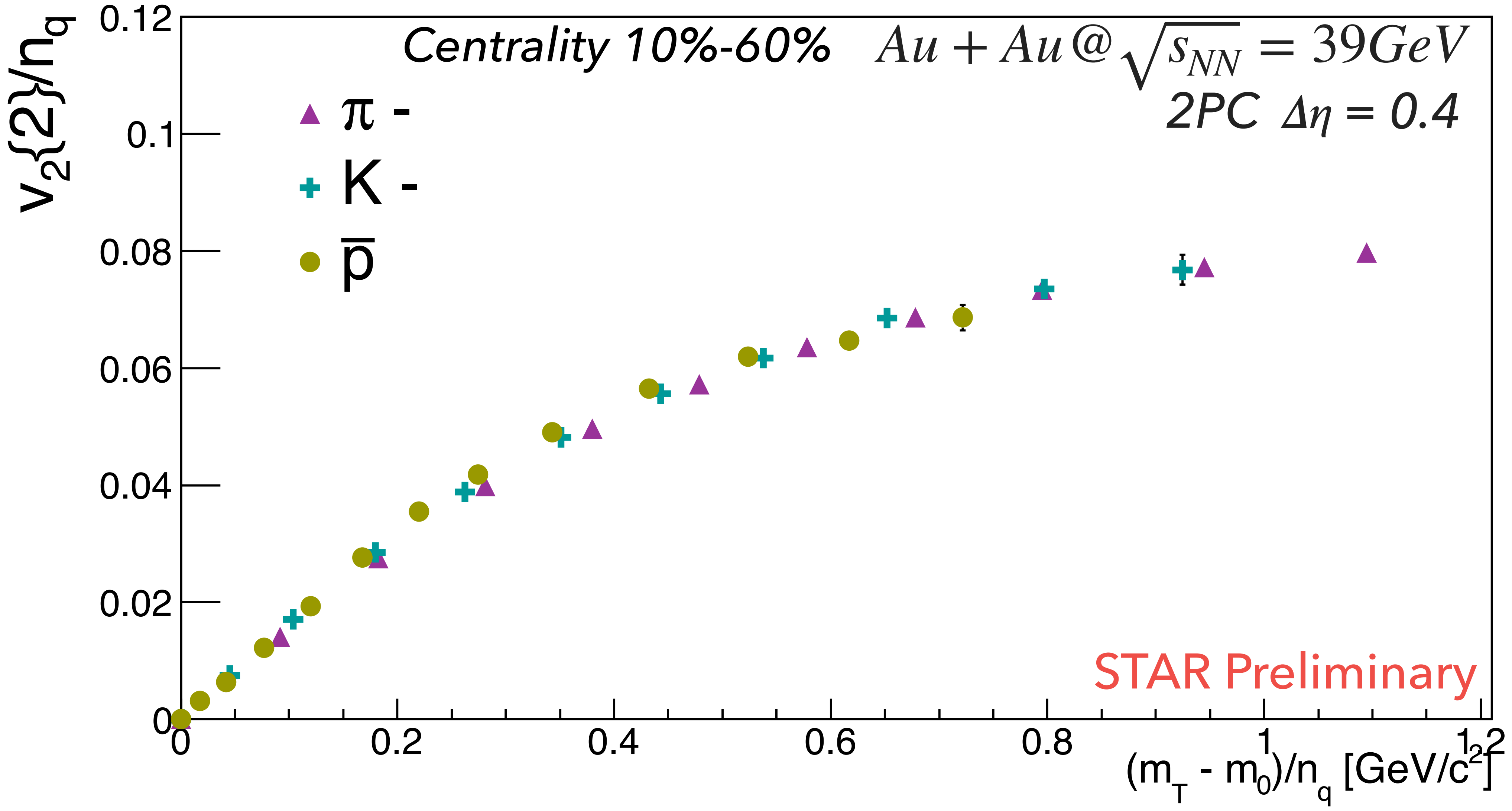

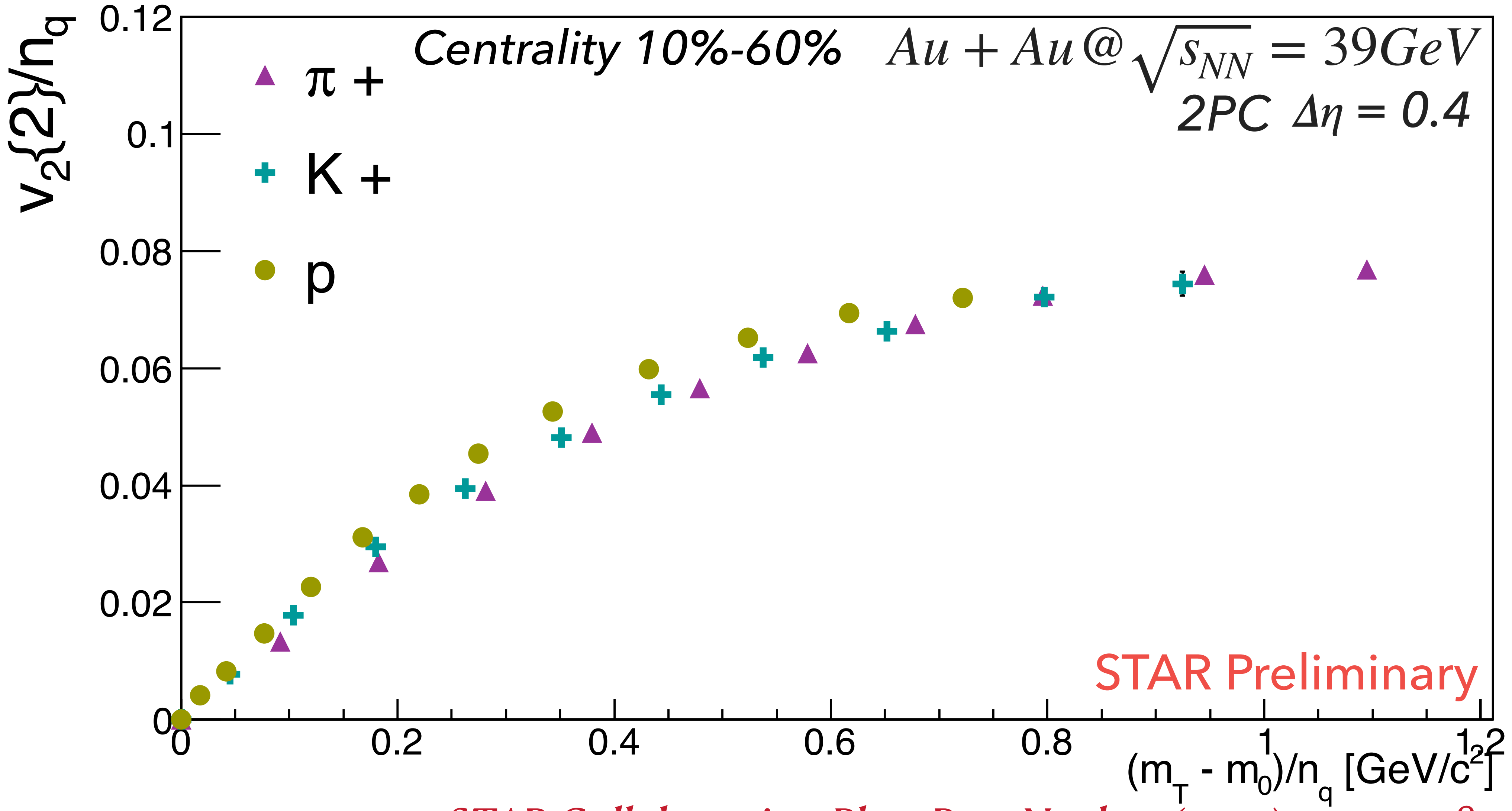

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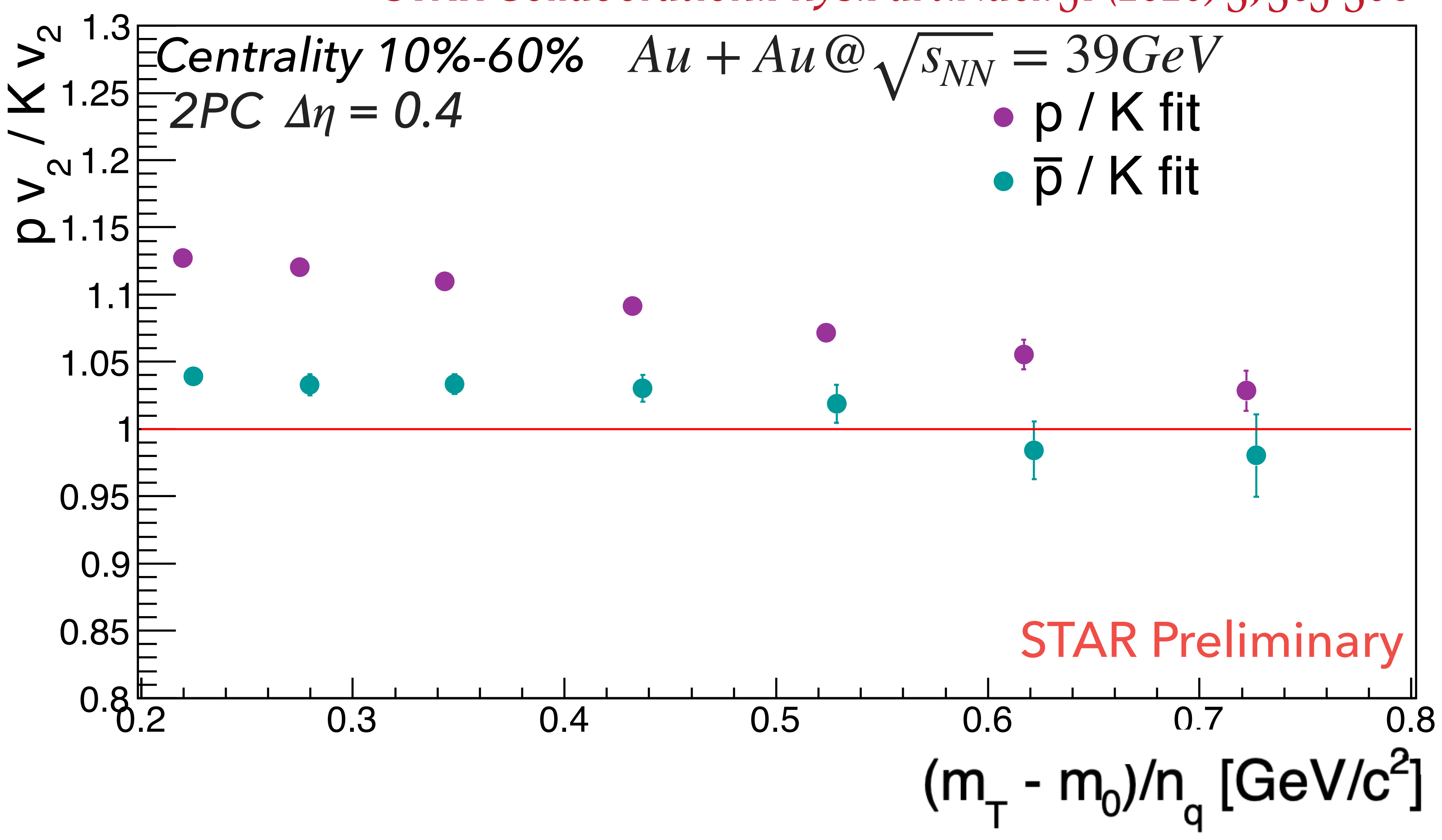


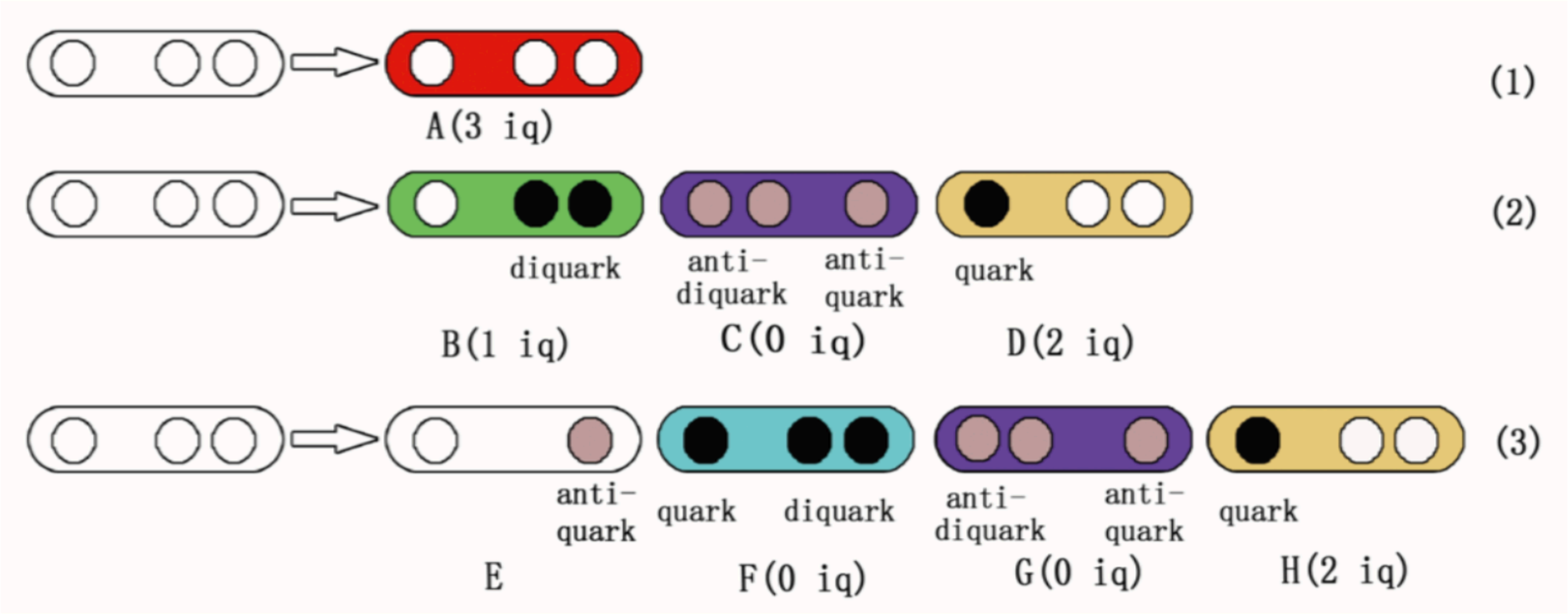
- Protons break the NCQ(KET) scaling

III Scenario: Transported vs produced protons

Biao Tu: Chin.Phys. C43 (2019) no.5, 054106

Transported vs. produced protons:

-



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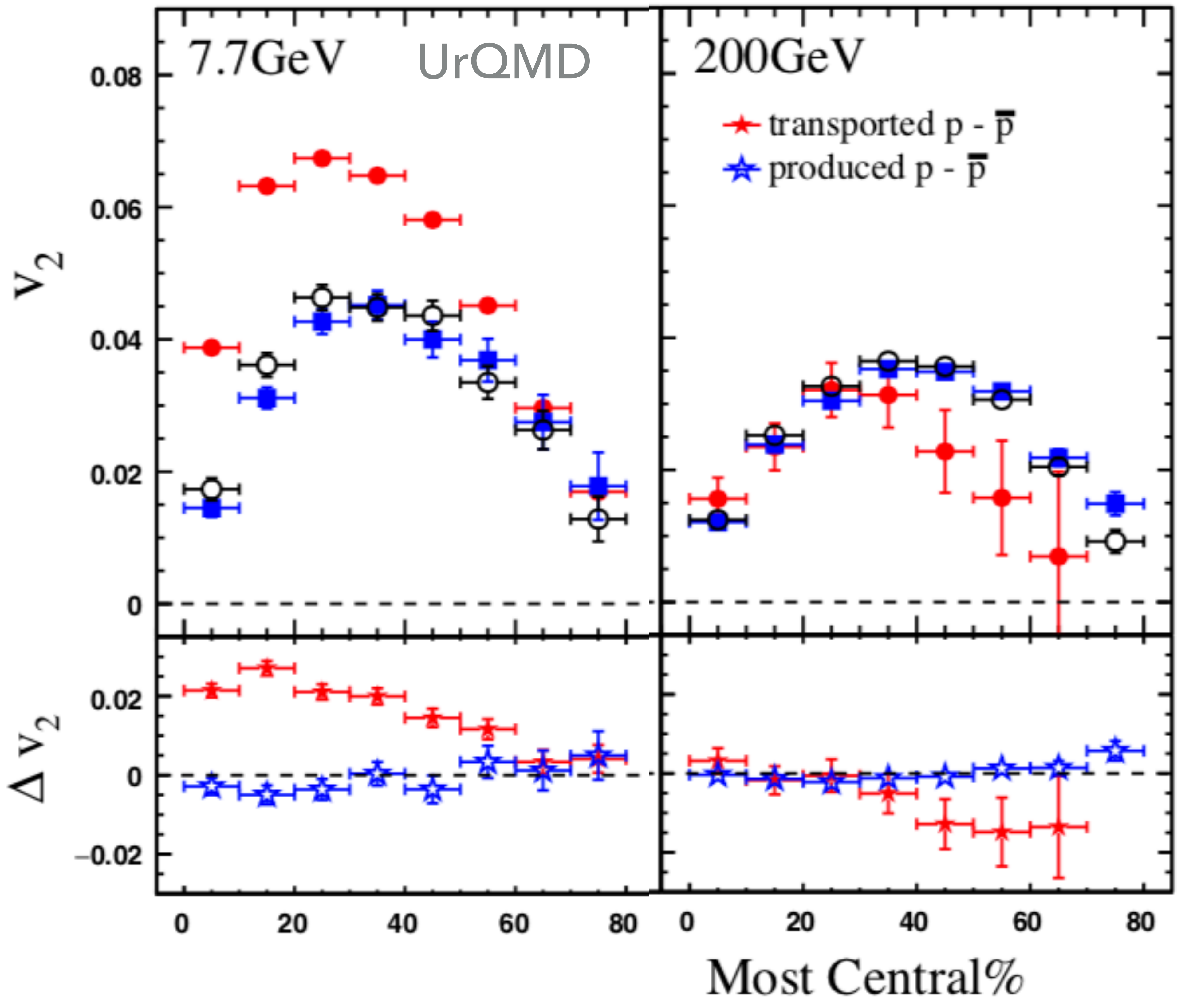
Transported vs. produced protons:

- Transported protons have stronger positive correlation than produced
- Both produced protons and antiprotons have similar flow - origin from same part of evolution
- Transported quarks go through all evolution process of transformation of initial geometry eccentricities to anisotropy in momentum, the produced go through only a part of this scenario
- Transported quarks suffer more scatterings
- Energy dependence can be explained by nuclear stopping



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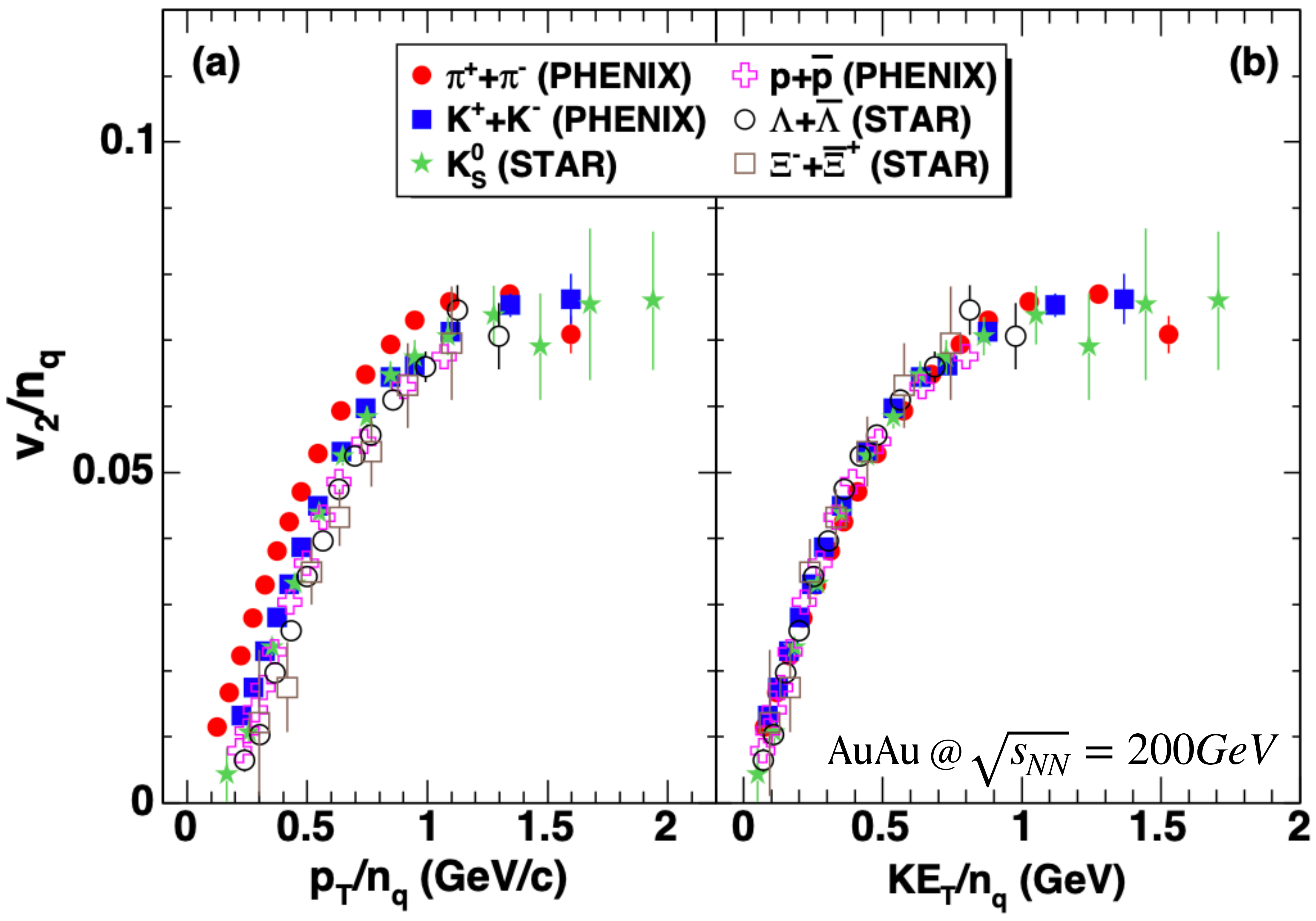

- It is claimed that the n_q scaling is the proof of the common origin of hadrons' flow

STAR Collaboration: Phys. Rev., 2013, C88, 014902.
PHENIX Collaboration: Phys. Rev. Lett., 2007, 98, 162301.

- It is built during the QGP phase where quarks are deconfined, and they are boosted as separate particles. Subsequently, they are bounded into hadrons, but their flow is already established.
- Due to such an approach, breaking the scaling means that the flow of given particle specie does not originate completely from the QGP phase.

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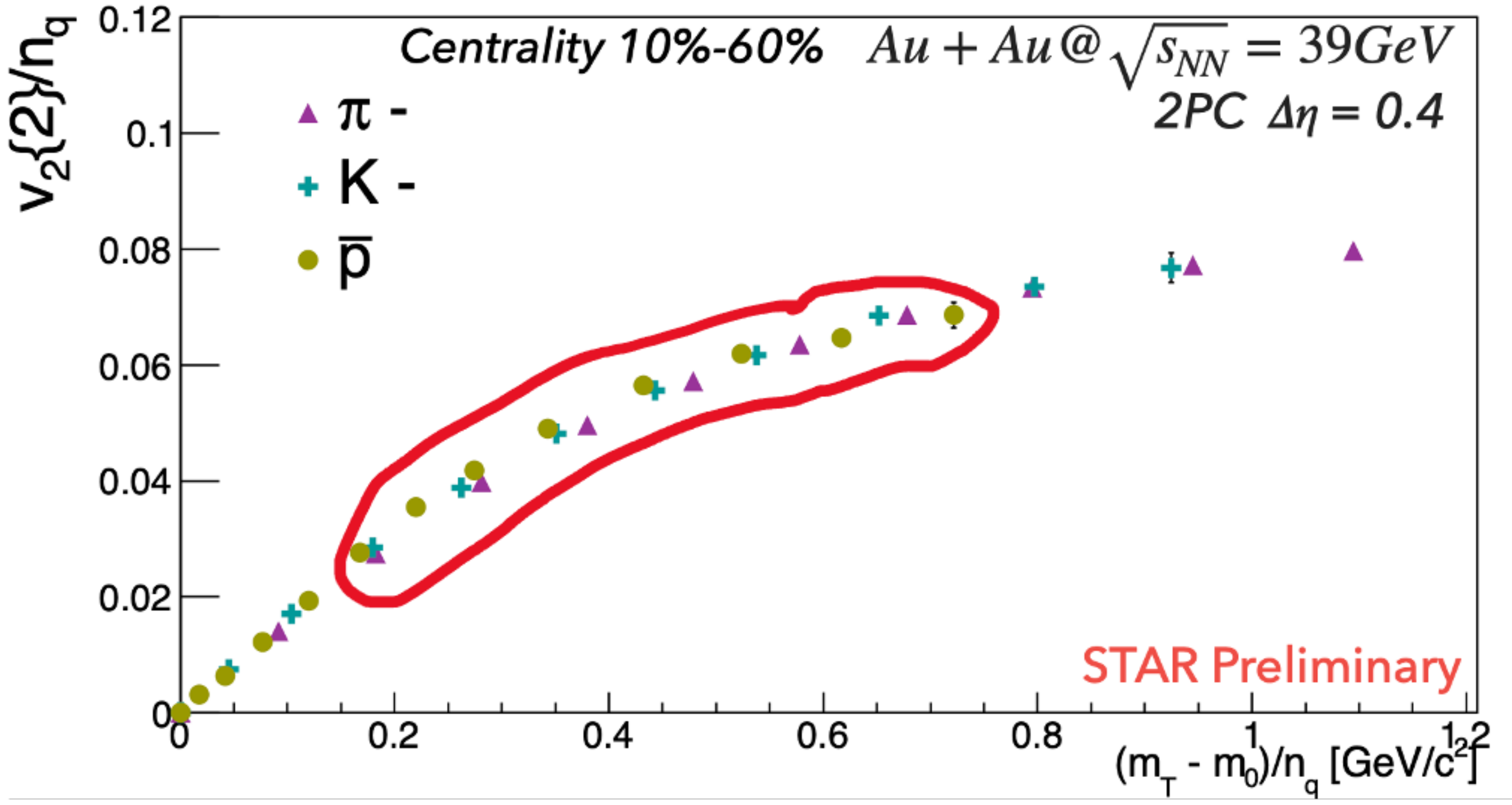

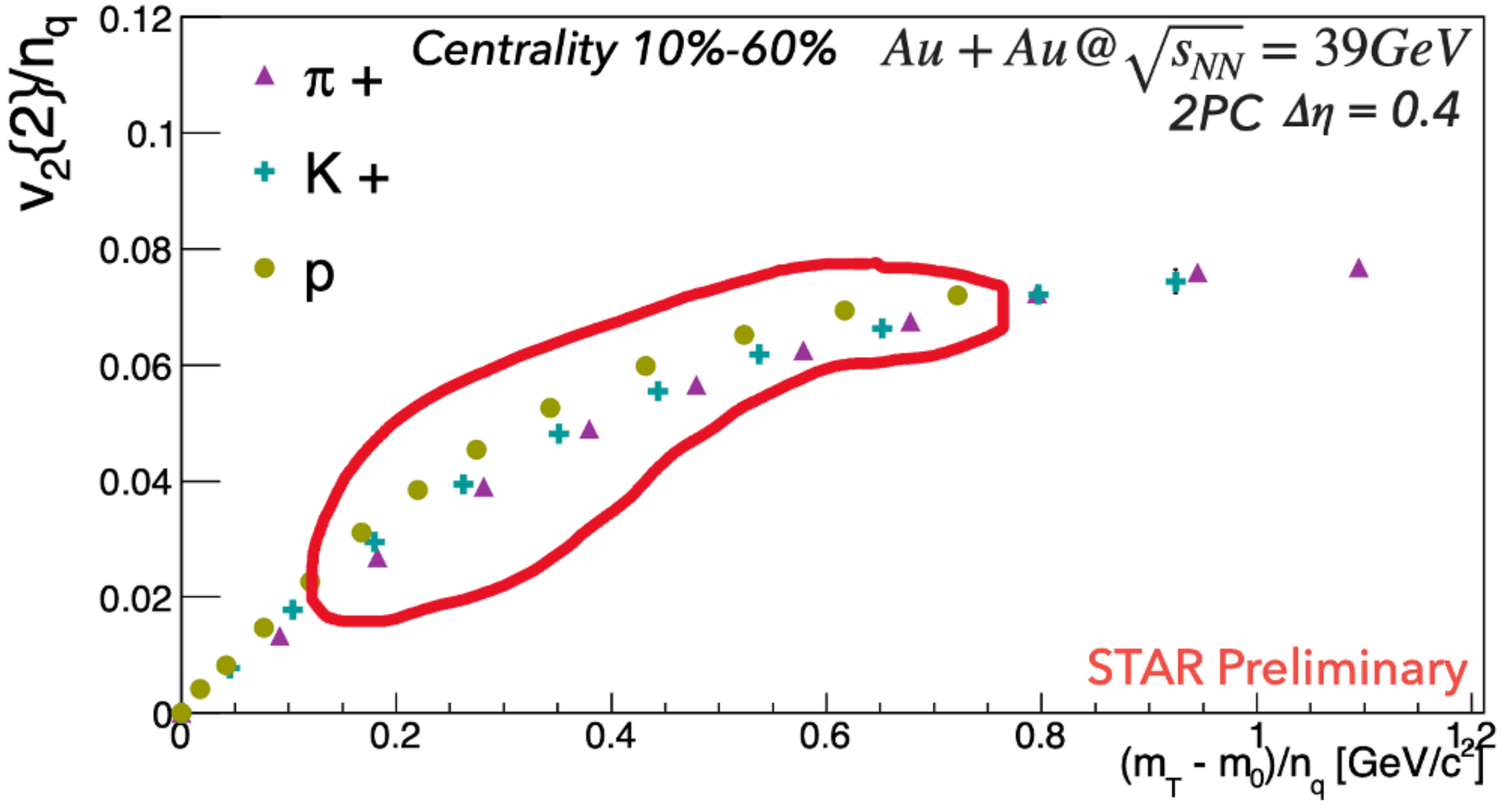

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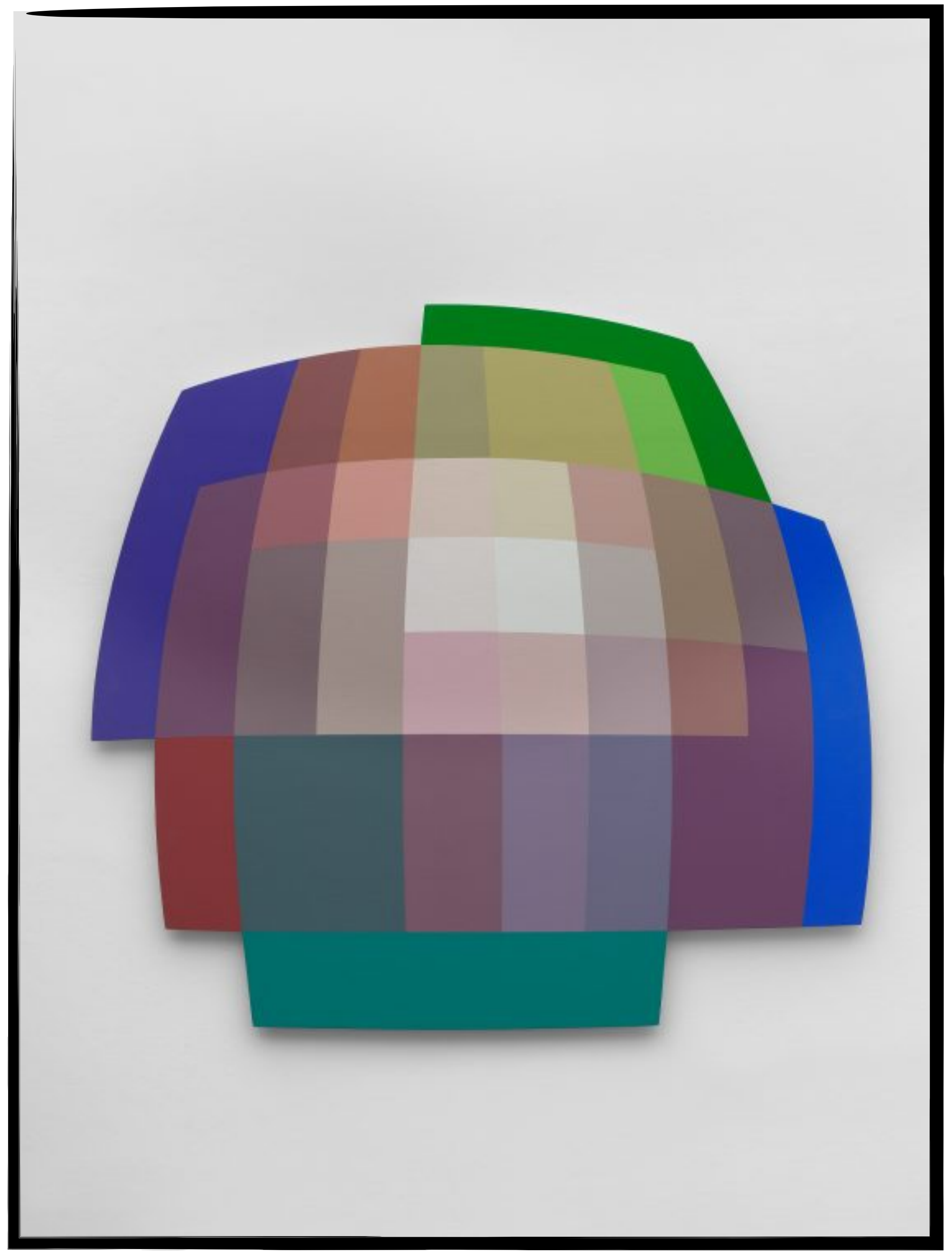
- Due to such an approach, breaking the scaling means that the flow of given particle specie does not originate completely from the QGP phase.

Protons break the scaling

OUTPUT and QUESTIONS

- We can do extensive studies of the dynamics of matter and antimatter with STAR experiment data.
- Worth to have a closer look into the **„new viscous corrections".**
- What we can say more about the **Transported vs Produced** matter?

THANK YOU!



Dóra Maurer, Overlappings12