Fractional momentum loss of high-p_T hadrons in QGP at RHIC-PHENIX

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Outline

- Introduction
- Purpose
- Analysis method($S_{\mathrm{loss}}, S'_{\mathrm{loss}}, L, L^2, \Delta L^2$)
- Result
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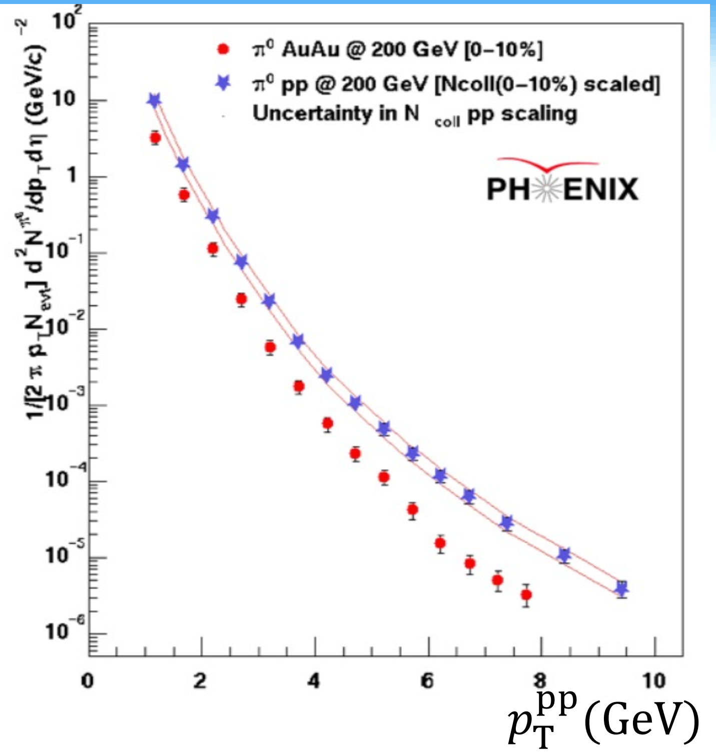
  - S'_{loss} vs. p_{T}
  - S_{loss}vs. L^2
  - S'_{loss} vs. ΔL^2
- Summary
- Outlook

Introduction

- PHENIX
  - One of the relativistic heavy ion collider (RHIC) experiments at Brookhaven National Laboratory
- Main evidence of QGP generation at RHIC
  1. High-p_T hadron yield suppression
  2. A large azimuthal anisotropy, v_2



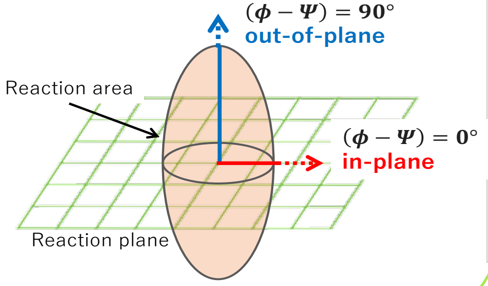
a crucial observable : Parton energy loss during passage in QGP

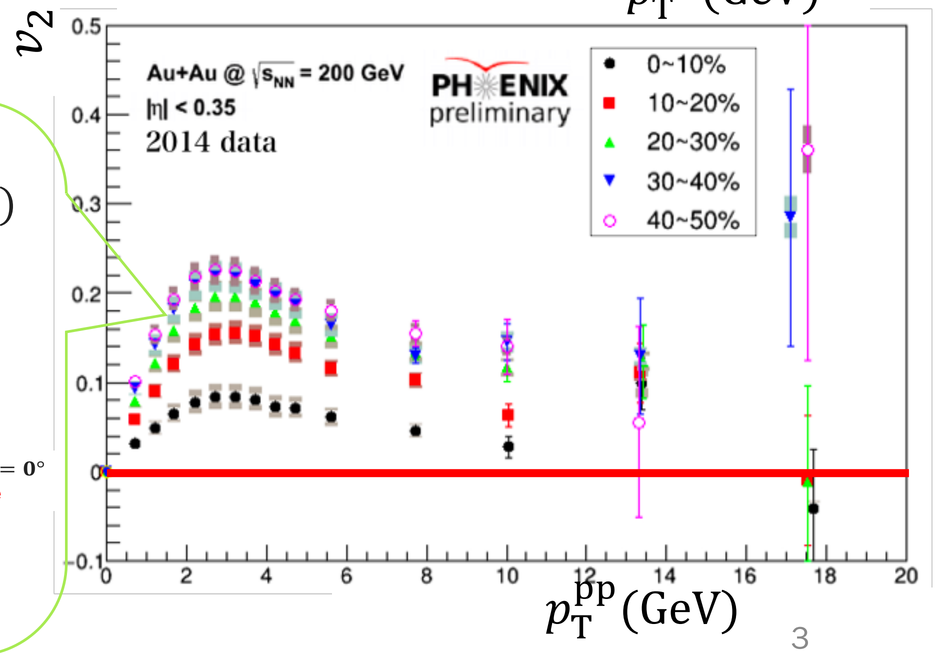
v_2: azimuthal anisotropy

$$\frac{dN}{d\phi} \propto (1 + 2v_2 cos[2(\phi - \Psi)])$$

Ψ: azimuthal of reaction plane

ϕ: azimuthal of generated particle



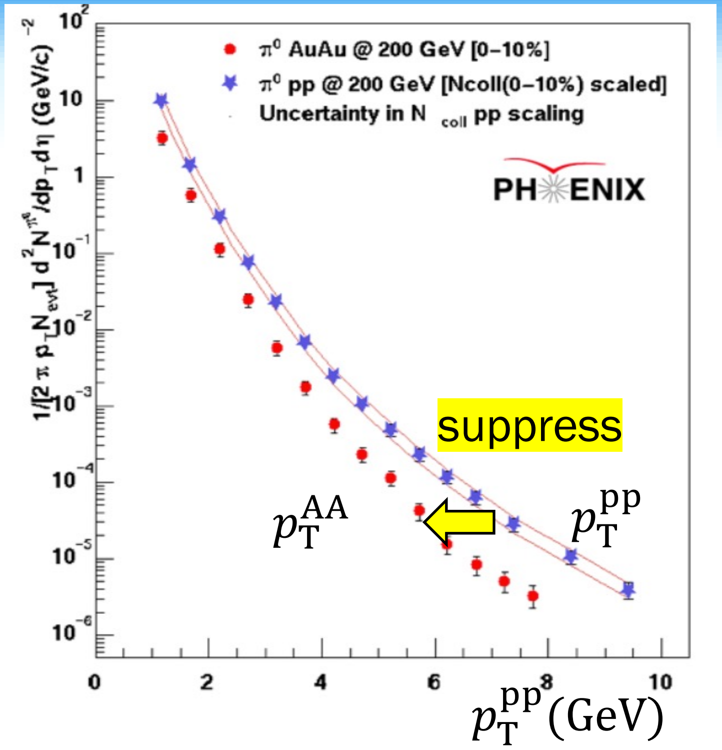


Introduction

crucial observable : Parton energy loss in QGP

- **S_{loss}: the fractional momentum loss of high-p_{T} hadrons**

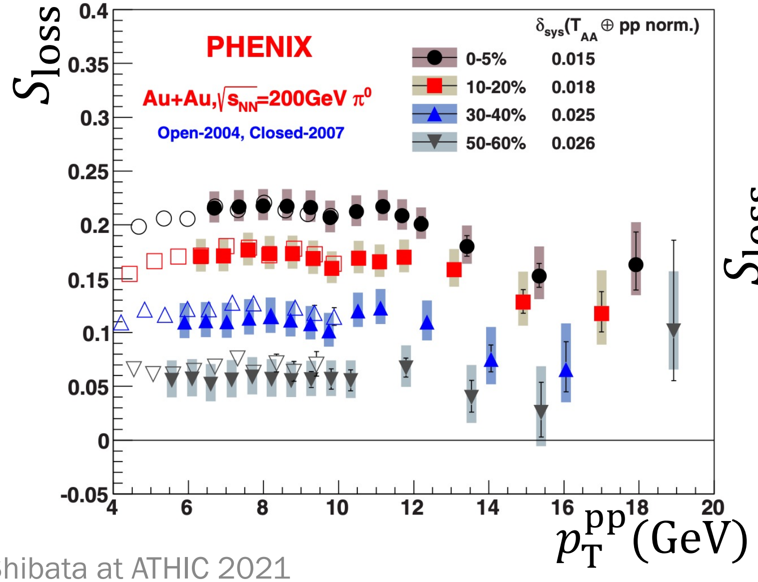
$$S_{\text{loss}} = \frac{p_{\text{T}}^{\text{pp}}(\text{scaled}) - p_{\text{T}}^{\text{AA}}}{p_{\text{T}}^{\text{pp}}(\text{scaled})}$$

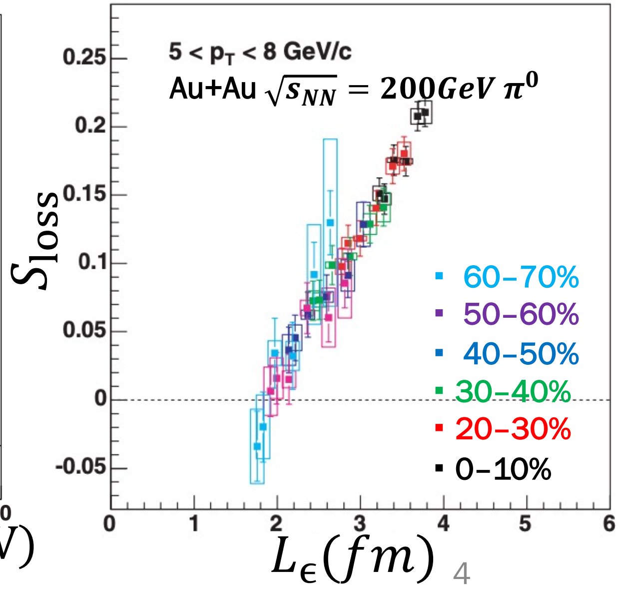


Phys. Rev. C.76.034904 (2007)

1. S_{loss} does not strongly depend on p_{T}, decreases as centrality increases. (Phys. Rev. C. 93. 024911 (2016))
2. S_{loss} increases with L_{ϵ}, an effective radius of the collision. (Phys. Rev. C. 76. 034904(2007))

Phys. Rev. C 93.024911 (2016)





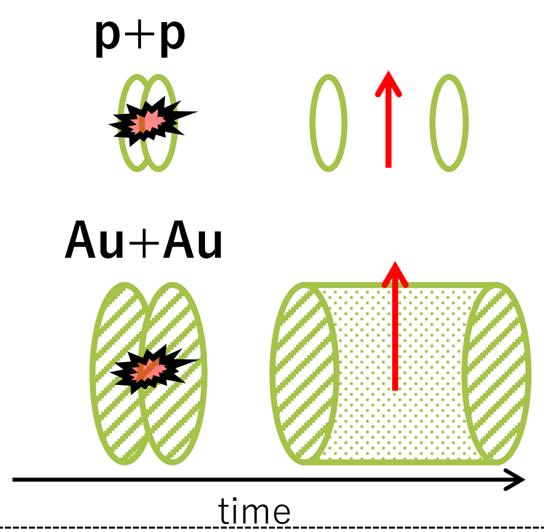
Purpose

- Estimation of the energy of parton in QGP from hadron spectra in various collision systems

Approach 1

Comparison particle yield in **A+A** and **p+p collisions**

$\boldsymbol{S}_{\mathbf{loss}}$: the fractional momentum loss of high-p_{T} hadrons

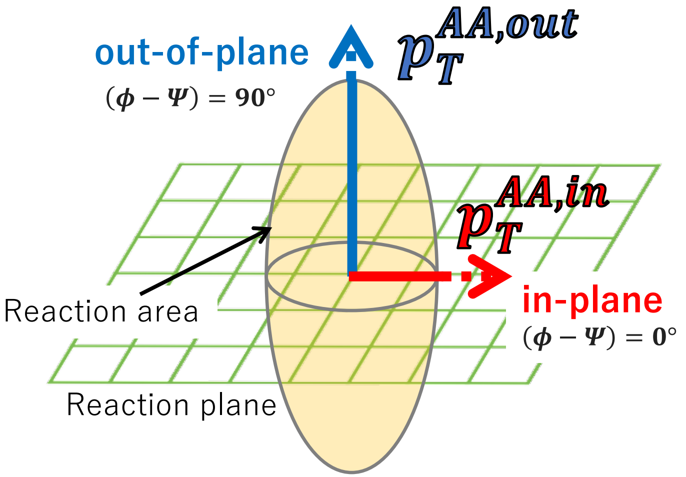


Approach 2

New!

Comparison particle yield **in-plane** and **out-of-plane in A+A collisions**

$\boldsymbol{S}'_{\mathbf{loss}}$: the fractional momentum loss of high-p_{T} hadrons considering **azimuthal anisotropy**



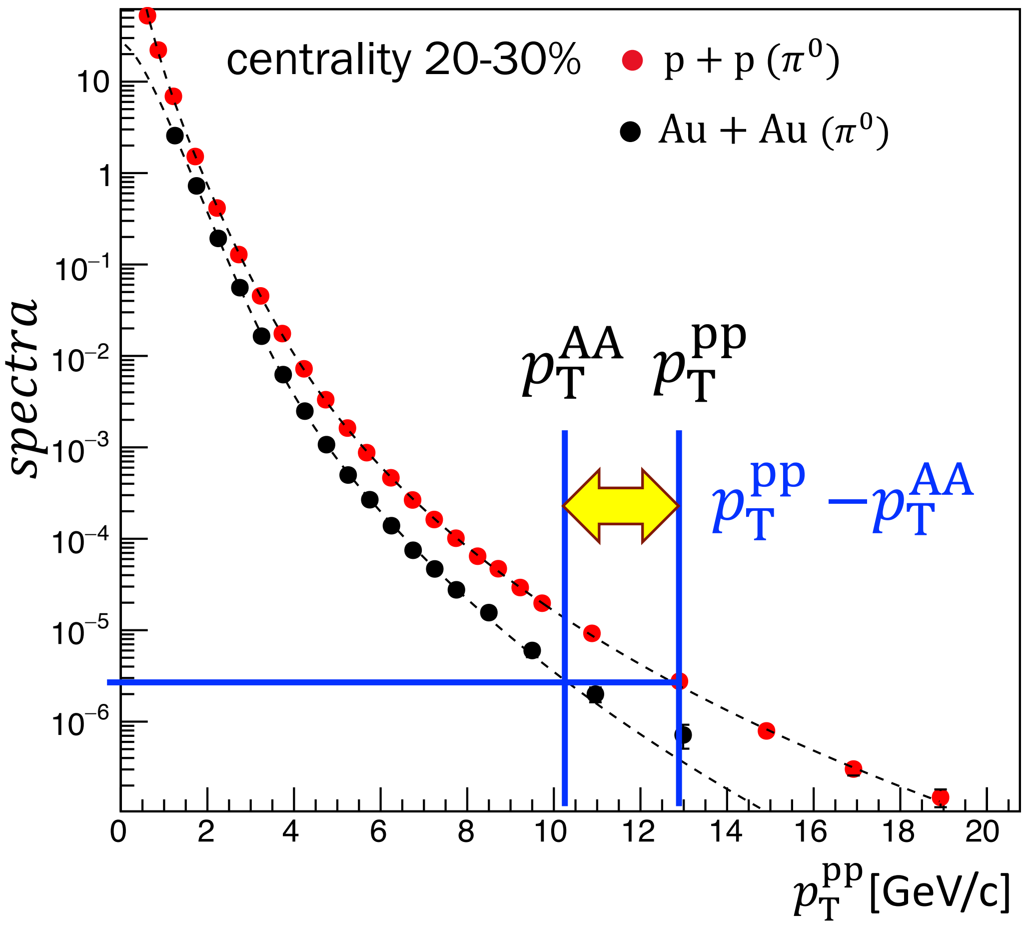
Analysis method for S_{loss}

S_{loss}: the fractional momentum loss of high-p_T hadrons

***Same as previous method, Phys. Rev. C 93, 024911 (2016)*

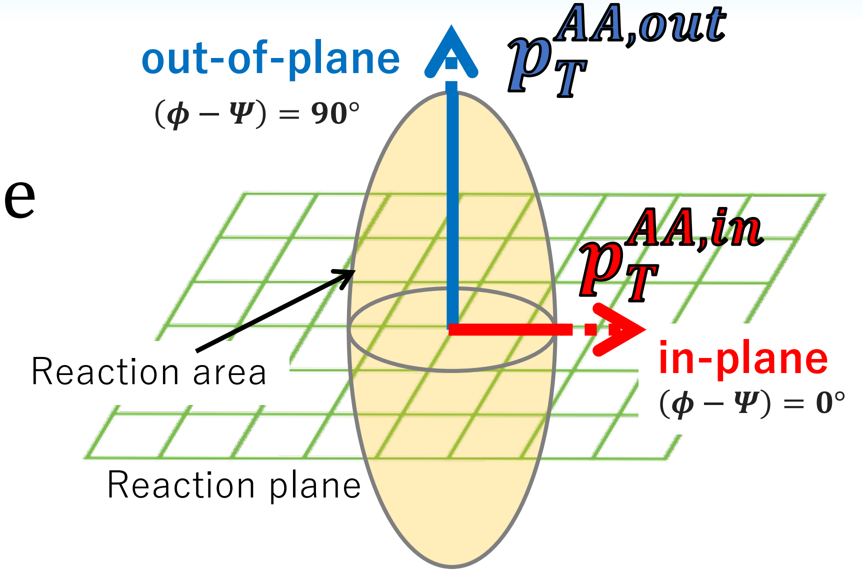
1. Scale spectra in p+p collisions by the number of binary collisions.
2. Calculate S_{loss}.

$$S_{\text{loss}} = \frac{p_T^{pp}(\text{scaled}) - p_T^{AA}}{p_T^{pp}(\text{scaled})}$$



Analysis method for S'_{loss}

S'_{loss}: the fractional momentum loss of high-p_{T} hadrons considering **azimuthal anisotropy**



1. Divide spectra in A+A collisions into in-plane and out-of-plane.

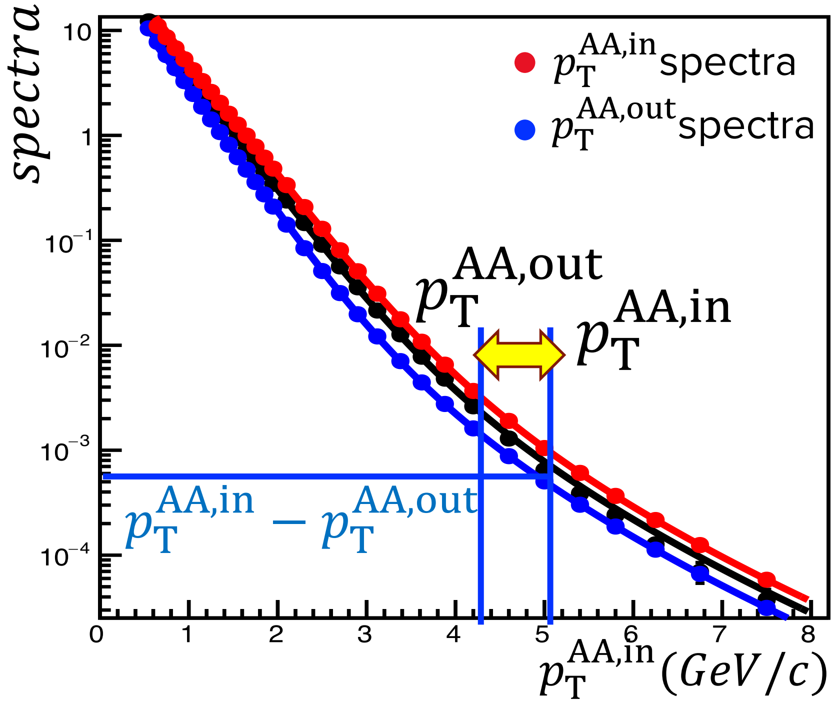
$\frac{dN}{dp_{\mathrm{T}}}$: inclusive particle yield , $\left.\frac{dN}{dp_{\mathrm{T}}}\right|_{\mathrm{in}}$: yield in-plane , $\left.\frac{dN}{dp_{\mathrm{T}}}\right|_{\mathrm{out}}$: yield out-of-plane

$$\left.\frac{dN}{dp_{\mathrm{T}}}\right|_{\mathrm{in}} = \frac{dN}{dp_{\mathrm{T}}} \times (2v_2 + 1)\ (\phi - \Psi = 0°)$$

$$\left.\frac{dN}{dp_{\mathrm{T}}}\right|_{\mathrm{out}} = \frac{dN}{dp_{\mathrm{T}}} \times (2v_2 - 1)\ (\phi - \Psi = 90°)$$

2. Calculate S'_{loss}.

$$S'_{\mathrm{loss}} = \frac{p_{\mathrm{T}}^{\mathrm{AA,in}} - p_{\mathrm{T}}^{\mathrm{AA,out}}}{p_{\mathrm{T}}^{\mathrm{AA,in}}}$$



Estimation of Path-length $(L, L^2, \Delta L^2)$

1. Glauber Monte Carlo simulation
2. For each parton-parton collision, calculate L_{in} and L_{out}.
   - L_{in} : the length in the direction of **in-plane**
   - L_{out}: the length in the direction of **out-of-plane**
3. Calculate path-length for a given centrality class.
   - **L: mean path-length for S_{loss}**

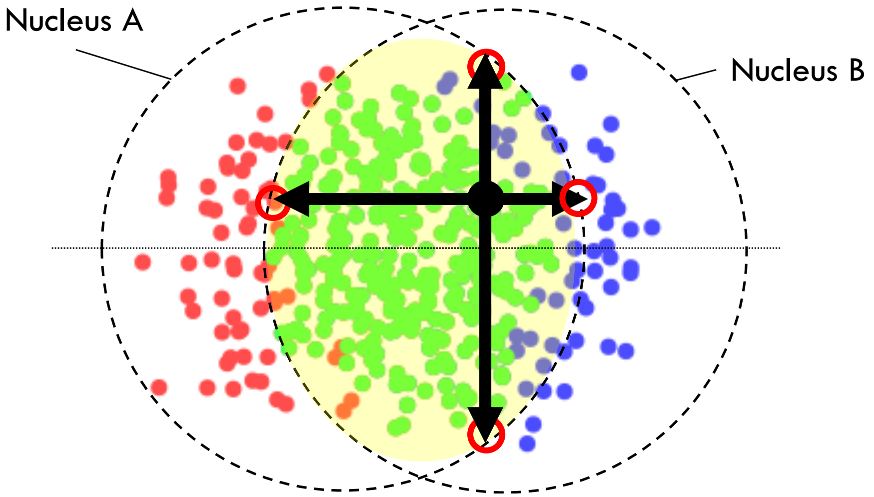
$$L = \frac{\overline{L_{\text{in}}} + \overline{L_{\text{out}}}}{2}$$

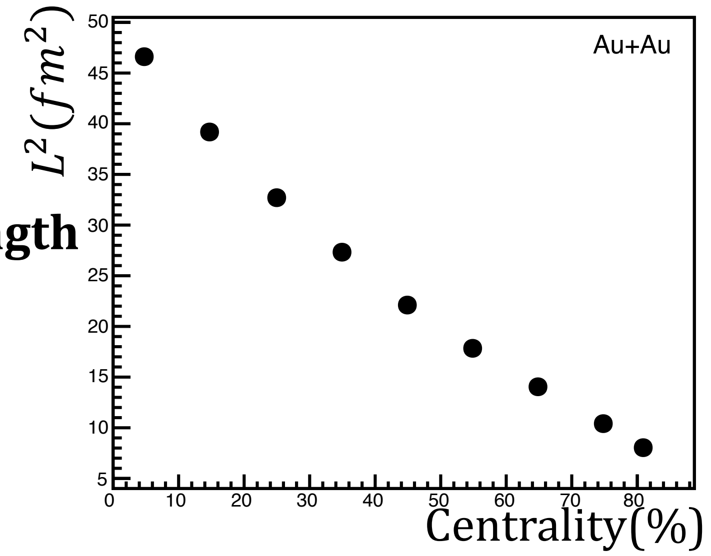
   - **L^2: squared path-length for S_{loss}**

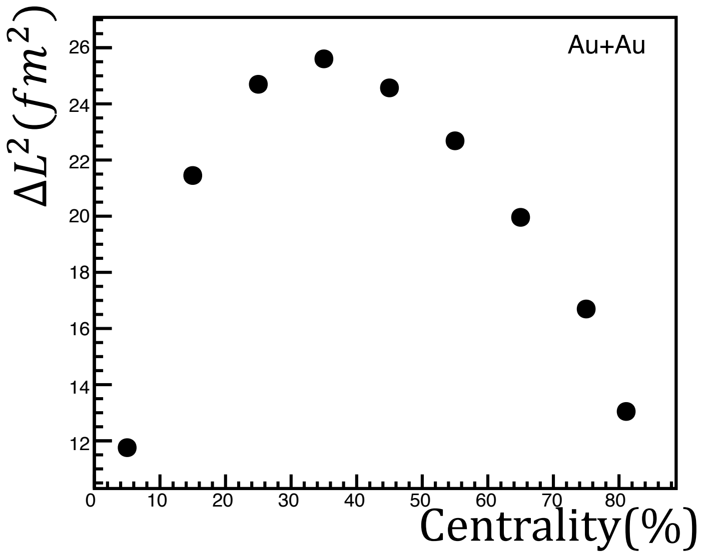
$$L^2 = \left(\frac{\overline{L_{\text{in}}} + \overline{L_{\text{out}}}}{2}\right)^2$$

   - **ΔL^2: a difference of squared path-length between in-plane and out-plane for S'_{loss}**

$$\Delta L^2 = \overline{L_{\text{out}}}^2 - \overline{L_{\text{in}}}^2$$



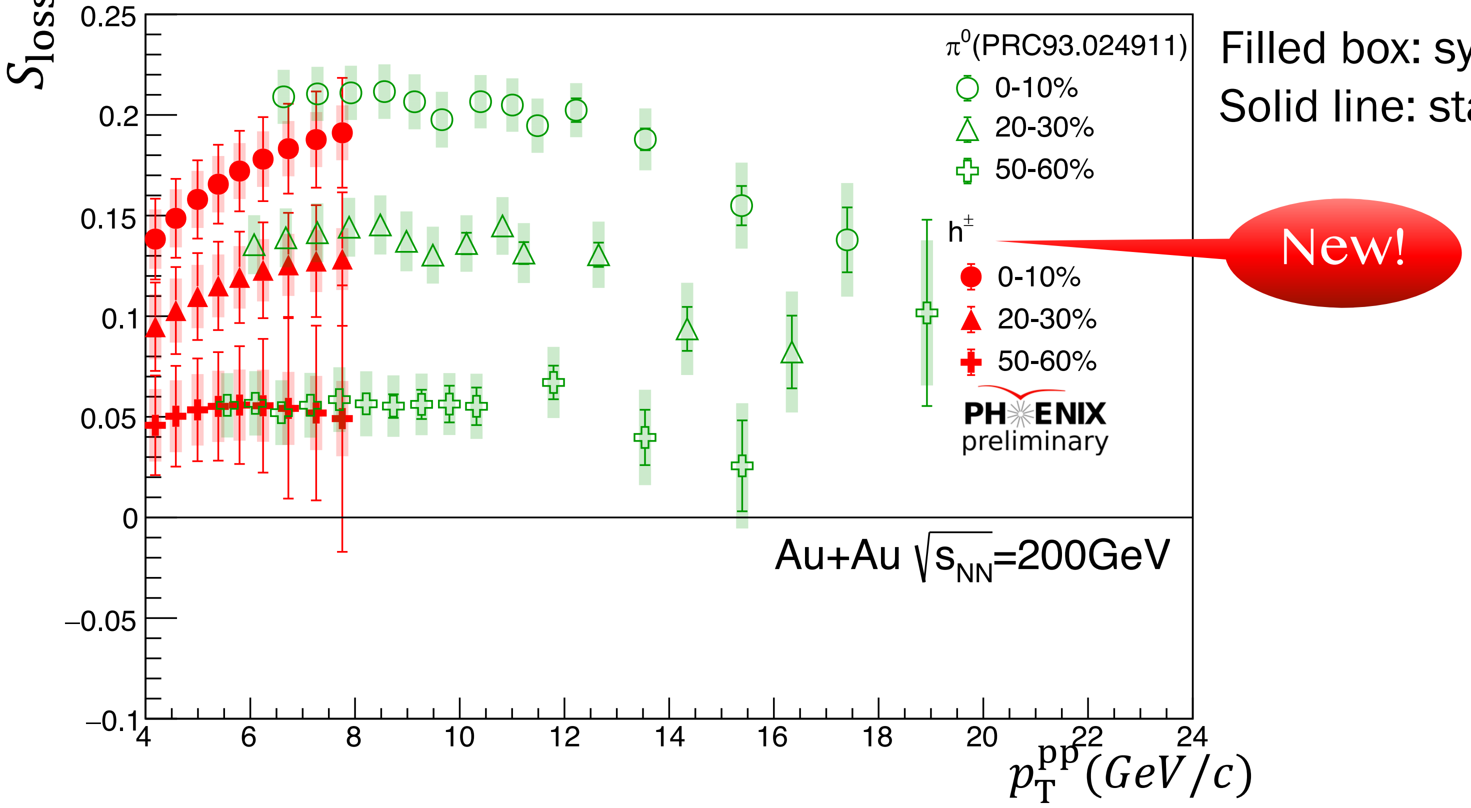




S_{loss} vs. p_{T} ($h^{\pm}$, Au+Au)

$$S_{\mathrm{loss}} = \frac{p_{\mathrm{T}}^{\mathrm{pp}}(\mathrm{scaled}) - p_{\mathrm{T}}^{\mathrm{AA}}}{p_{\mathrm{T}}^{\mathrm{pp}}(\mathrm{scaled})}$$

Phys. Rev. C 93.024911 (2016)



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- There is no significant difference between $h^{\pm}$s and π^0s within uncertainty.

S_{loss} vs. p_T (π^0, Cu+Au)

$$S_{\text{loss}} = \frac{p_T^{pp}(\text{scaled}) - p_T^{AA}}{p_T^{pp}(\text{scaled})}$$

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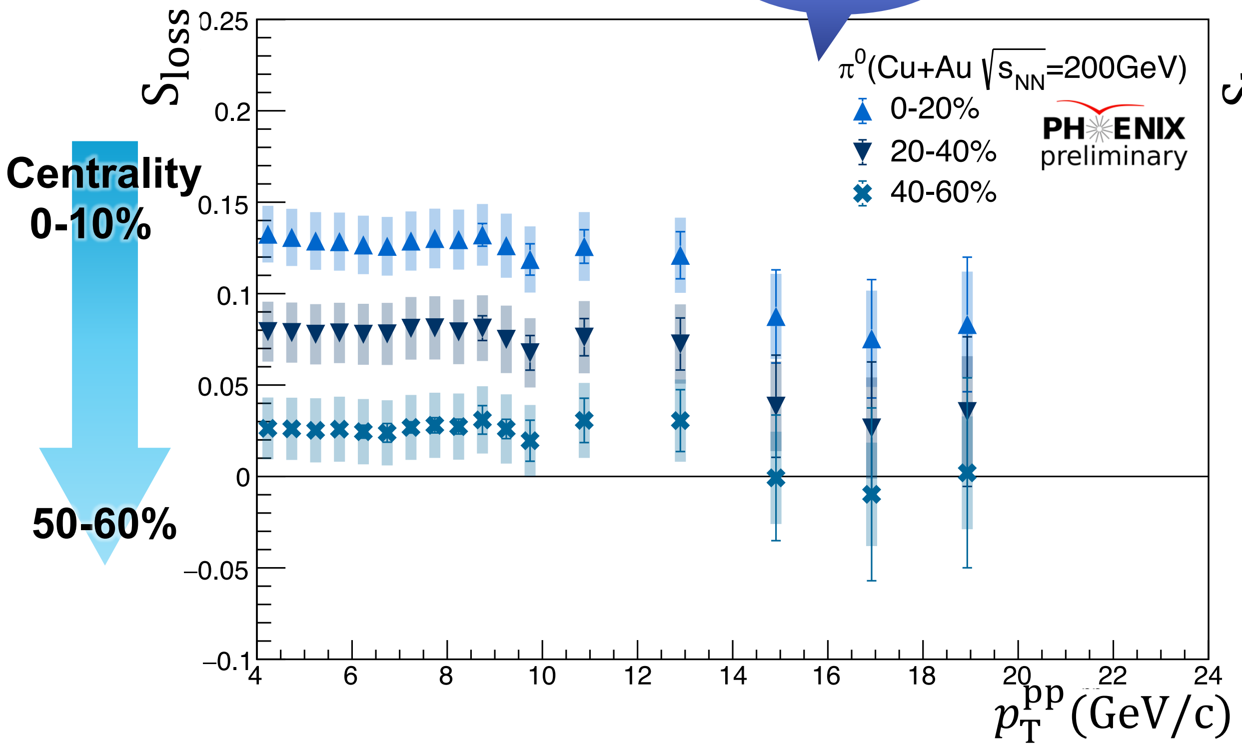
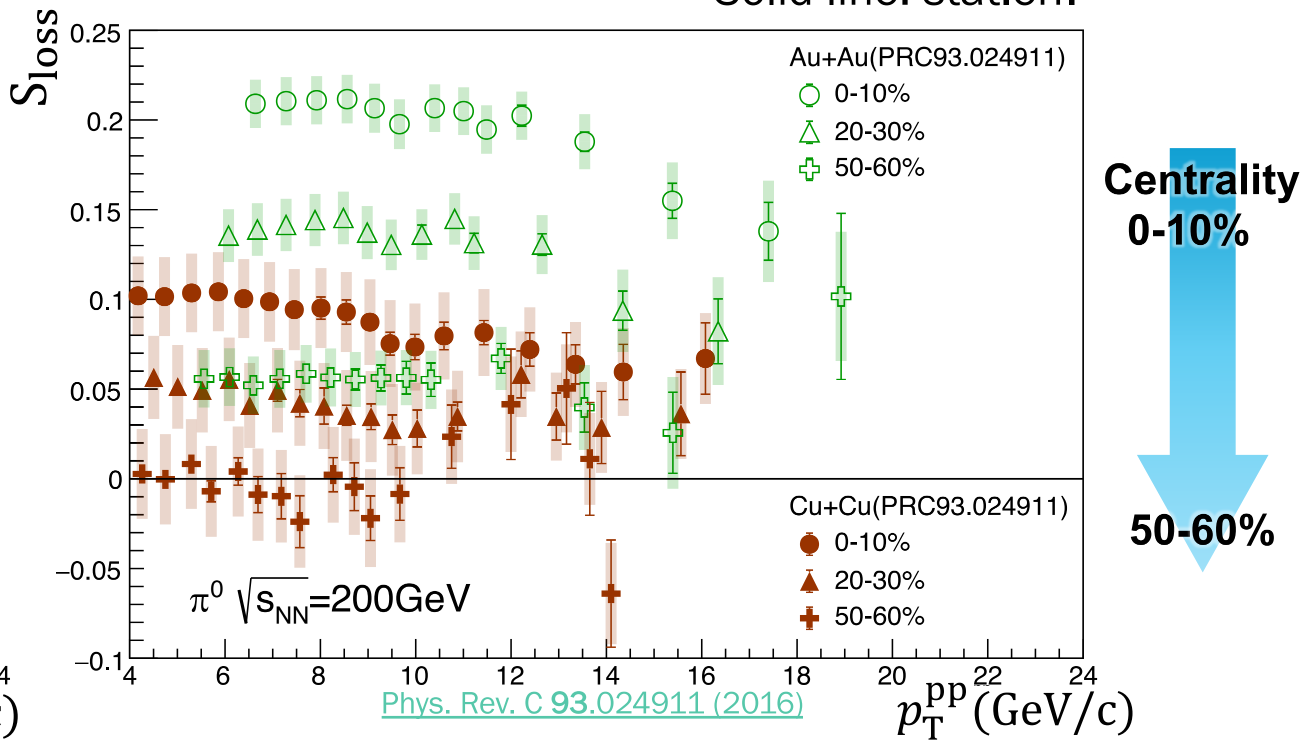
New!





- S_{loss} for π^0s in Cu+Au is almost constant up to p_T ~12 GeV and decreases at higher p_T.
- S_{loss} decreases as centrality increases.
- S_{loss} vs. p_T shows the same tendency in Au+Au, Cu+Cu, and Cu+Au.

asymmetric collisions

S'_{loss} vs. p_T ($h^{\pm}, \pi^0$(Au+Au))

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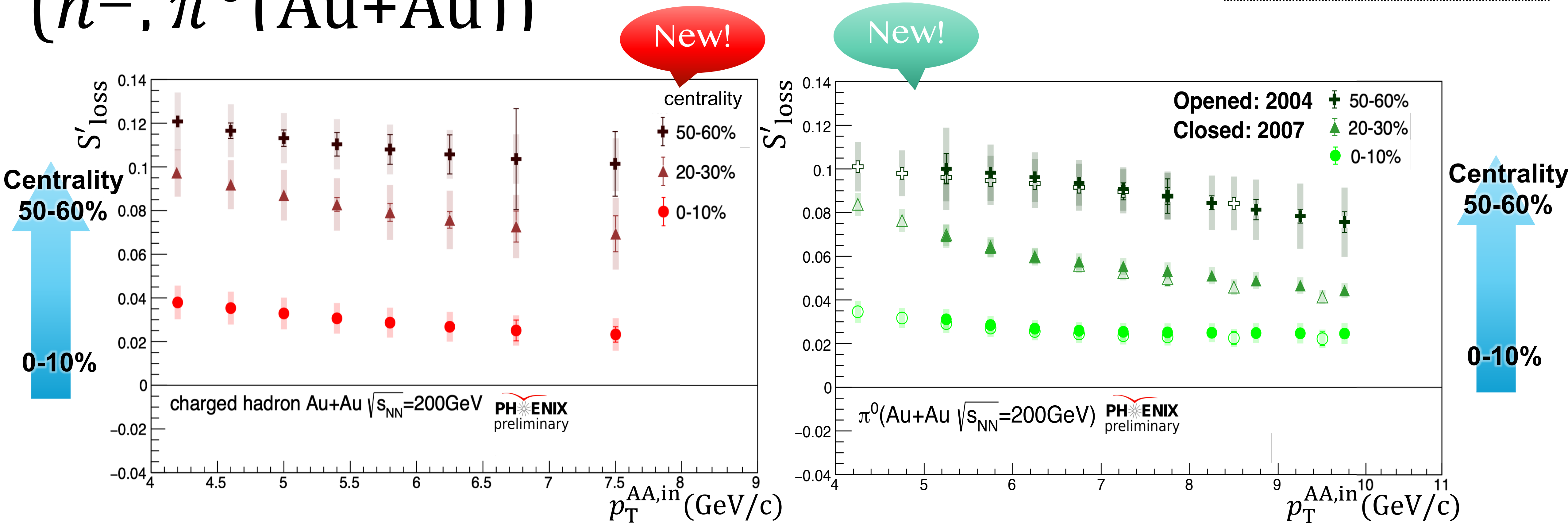
$$S'_{\text{loss}} = \frac{p_T^{\text{AA,in}} - p_T^{\text{AA,out}}}{p_T^{\text{AA,in}}}$$



- S'_{loss} for h$^{\pm}$s and π^0s slightly decrease up to p_T ~6 GeV and seems to be almost constant at higher p_T.
- S'_{loss} increases as centrality increases.
- There is no significant difference between $h^{\pm}s$ and π^0s.

S'_{loss} vs. p_T ($h^{\pm}, \pi^0$(Au+Au))

$$S'_{\text{loss}} = \frac{p_T^{\text{AA,in}} - p_T^{\text{AA,out}}}{p_T^{\text{AA,in}}}$$

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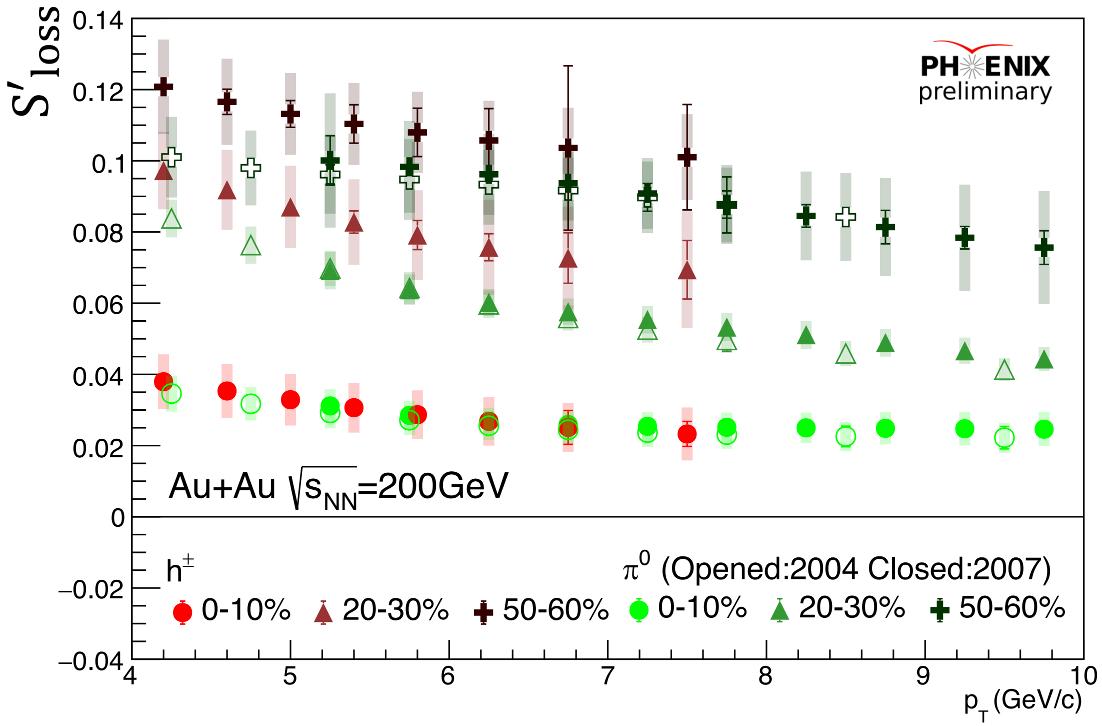


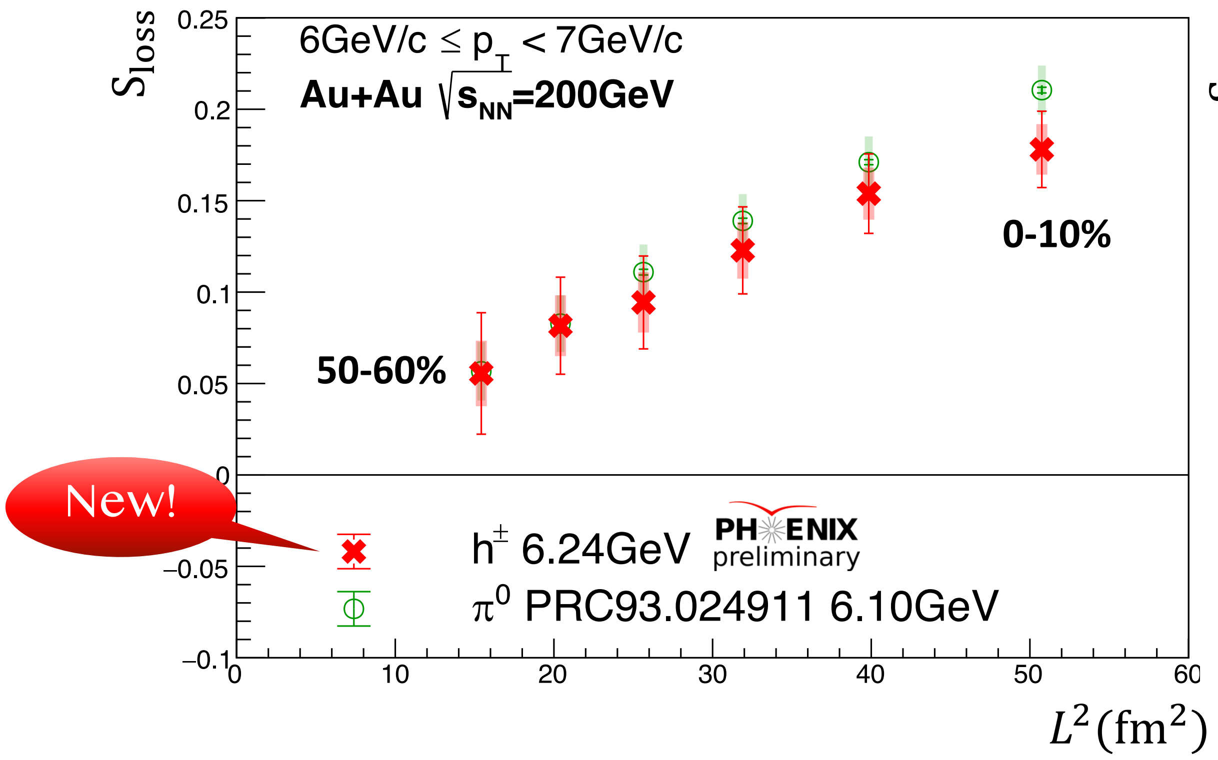
- S'_{loss} for h$^{\pm}$s and π^0s slightly decrease up to p_T ~6 GeV and seems to be almost constant at higher p_T.
- S'_{loss} increases as centrality increases.
- There is no significant difference between $h^{\pm}s$ and π^0s.

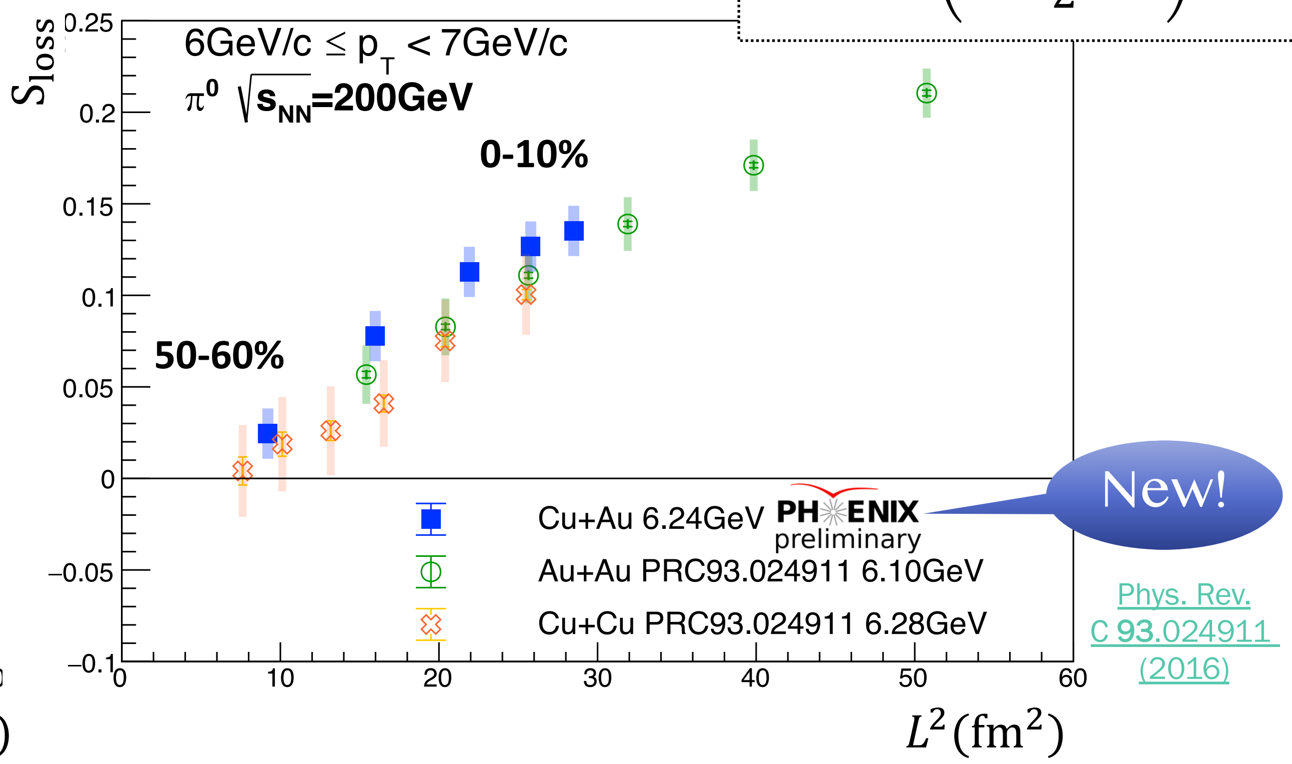
S_{loss} vs. L^2 ($h^{\pm}$(Au+Au), π^0(Cu+Au))

Filled box: syst.err.
Solid line: stat.err.

$$S_{loss} = \frac{p_T^{pp}(\text{scaled}) - p_T^{AA}}{p_T^{pp}(\text{scaled})}$$

$$L^2 = \left(\frac{L_{out} + L_{in}}{2}\right)^2$$





Phys. Rev. C 93.024911 (2016)

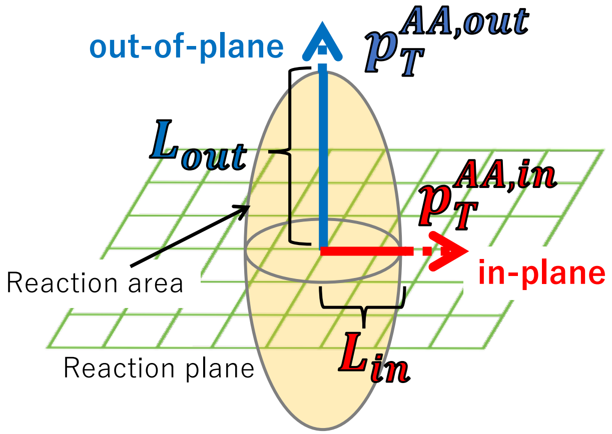
- S_{loss} is proportional to L^2 for both $h^{\pm}$s and π^0s, and it is common in Au+Au, Cu+Cu, and Cu+Au.
- It indicate that the gluon radiative loss seems to be dominant.

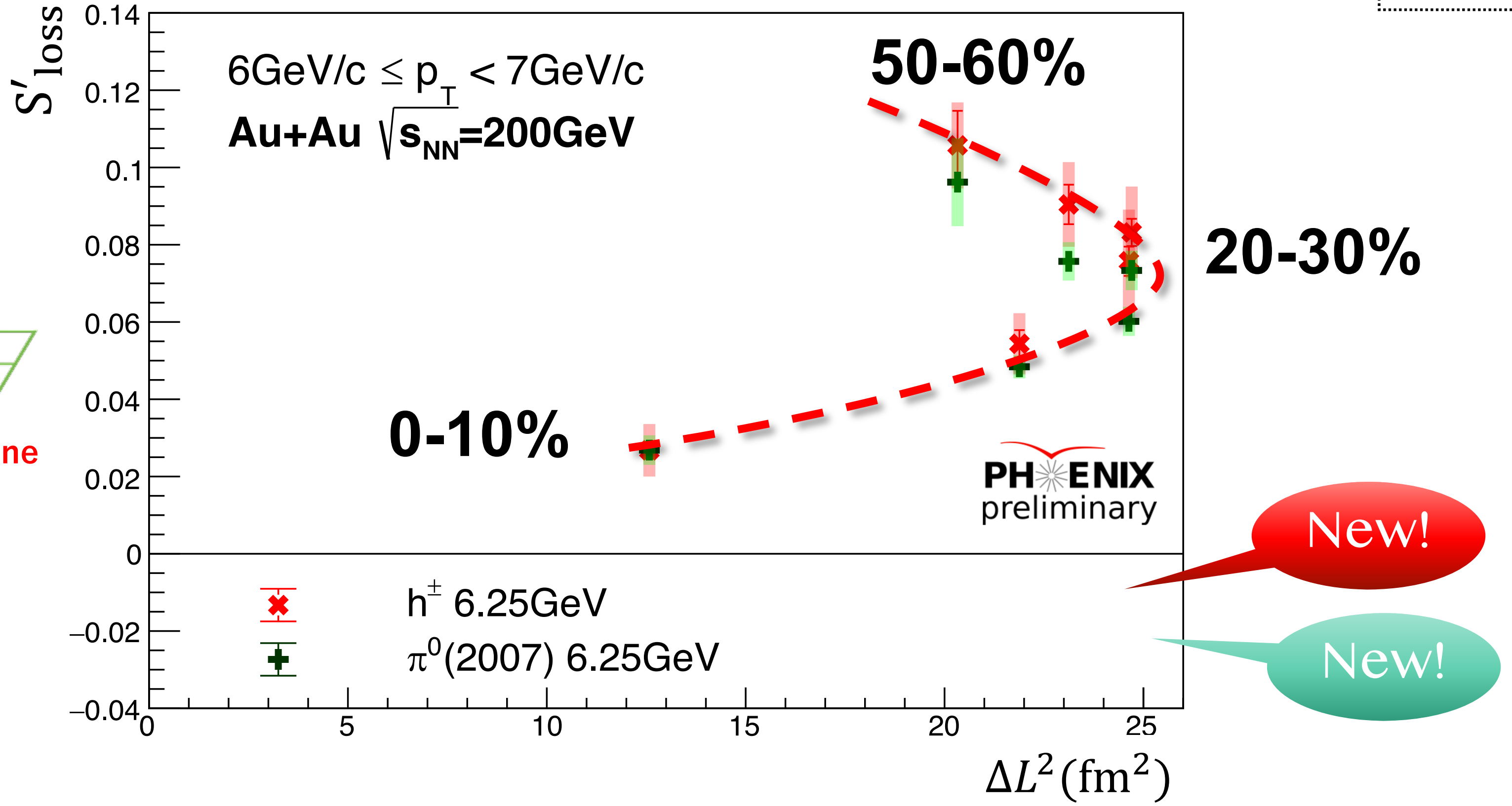
S'_{loss} vs. $\Delta L^2 (= \overline{L_{\mathrm{out}}}^2 - \overline{L_{\mathrm{in}}}^2)$ $(h^{\pm}, \pi^0 (\mathrm{Au+Au}))$

$$S'_{\mathrm{loss}} = \frac{p_T^{\mathrm{AA,in}} - p_T^{\mathrm{AA,out}}}{p_T^{\mathrm{AA,in}}}$$

$$\Delta L^2 = \overline{L_{\mathrm{out}}}^2 - \overline{L_{\mathrm{in}}}^2$$

Filled box: syst.err.
Solid line: stat.err.





- S'_{loss} is not proportional to ΔL^2.
- There is no significant difference between $h^{\pm}$s and π^0s within uncertainty.

S'_{loss} exhibits a different tendency from S_{loss}!

Summary

- We evaluated the energy loss of partons in QGP.
- We newly measured S_{loss} for π^0s in Cu+Au and $h^{\pm}s$ in Au+Au.
  - S_{loss} is proportional to L^2.
  - Throughout π^0s (Au+Au, Cu+Cu, and Au+Cu) and $h^{\pm}$s (Au+Au) cases, the S_{loss} vs. L^2 relation looks common within uncertainty.
- We newly measured S'_{loss} for $h^{\pm}$s and π^0s in Au+Au.
  - S'_{loss} vs. p_T relation is common for $h^{\pm}$s and π^0s in Au+Au within uncertainty.
  - S'_{loss} is not proportional to ΔL^2, different behavior from S_{loss}.
  - S'_{loss} vs. ΔL^2 is common for $h^{\pm}$s and π^0s in Au+Au within uncertainty.

Outlook

- We are working on comparison this measured result and simulation result.
  - We are generating v_2 and p_T spectra for π^0s in AuAu at 200GeV using Jetscape framework.