Study on the Correspondence Between the Hadron and Its Quark Component in the Nuclear Modification Factor

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OUTLINE

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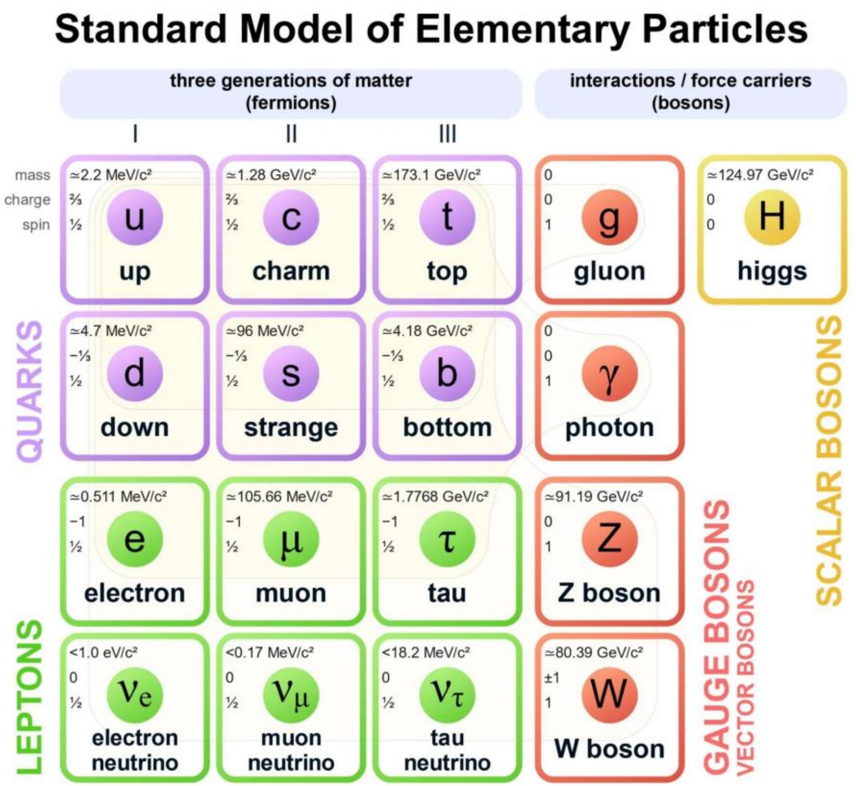
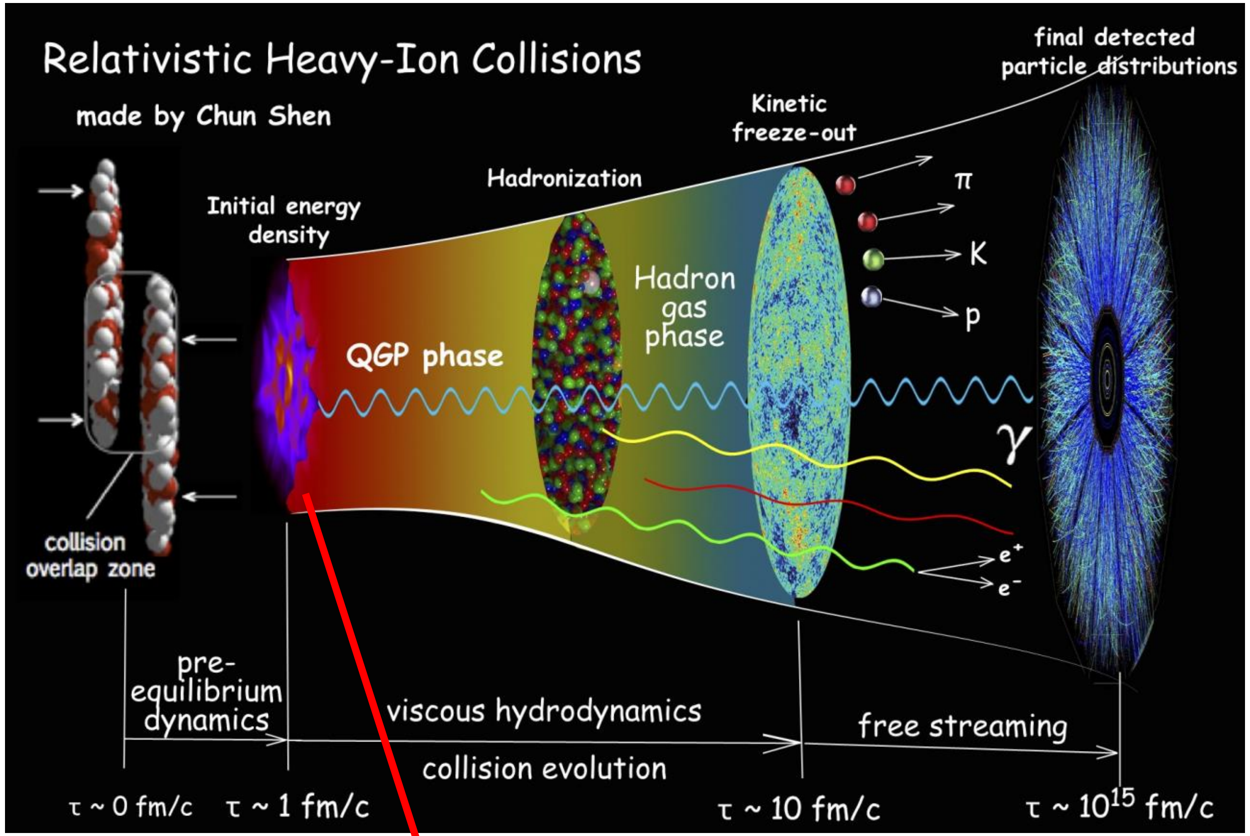
Introduction

Heavy-ion collisions





- **Color confinement**
- **Asymptotic freedom**

deconfinement

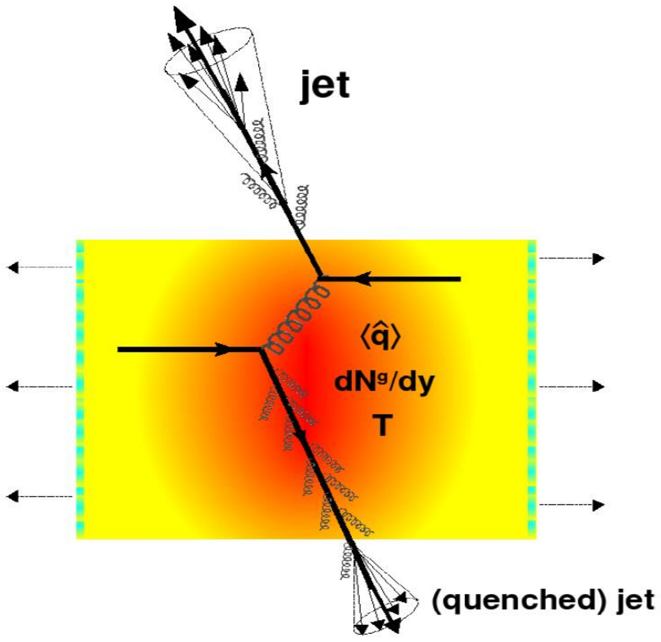
The nuclear modification factor R_{AA}

The ratio of p_T spectrum in AA to that in pp collisions:

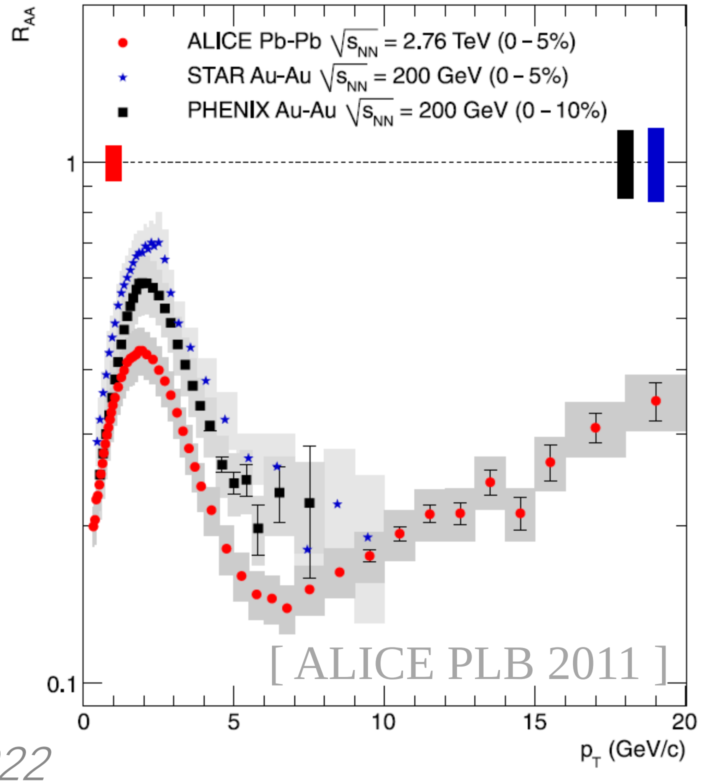
$$R_{AA}(p_T) = \frac{1}{\langle N_{coll} \rangle} \frac{dN^{AA}/dp_T}{dN^{pp}/dp_T}$$

= 1, *AA* collision is simple superposition of *pp* collisions

≠ 1, hot / cold medium effects, others...



[David d'Enterria 2009]



[ALICE PLB 2011]

The nuclear modification factor R_{AA}

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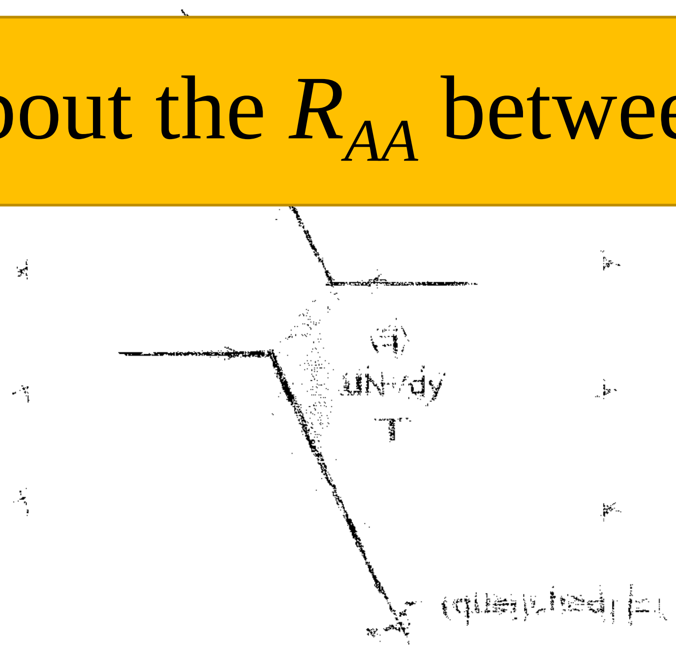
≠ 1, hot / cold medium effects, others...

How about the R_{AA} between the hadron and its quark component ?



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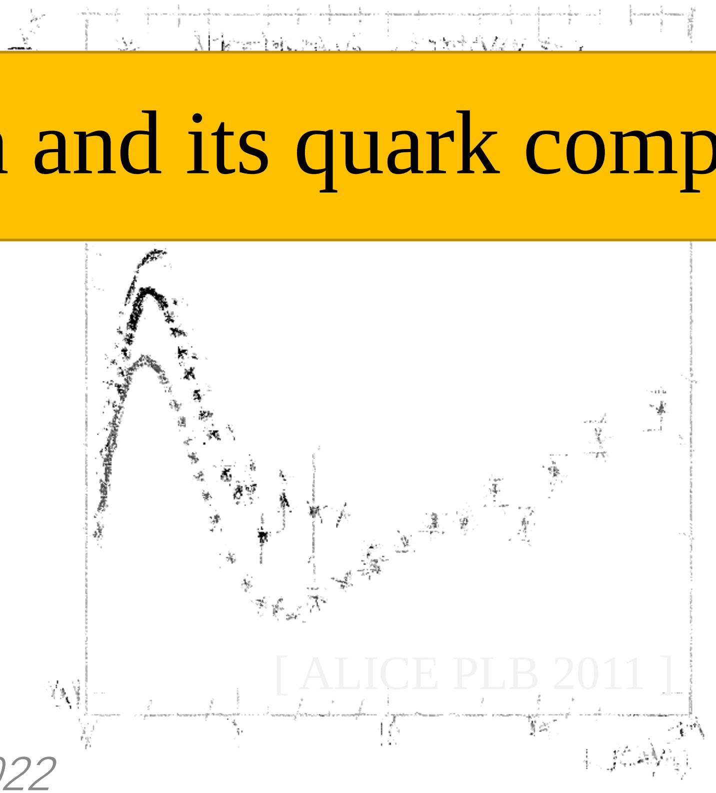

[ALICE PLB 2011]

R_{AA} of the hadron's quark component 華中師範大學

The hadron (h) normalized p_T distribution:

$$\frac{1}{N_h} dN_h/dp_T$$

Its quark (q) component normalized p_T distribution:

$$\frac{1}{n_{h-q}} \sum_q \frac{1}{N_q} dN_q/dp_T$$

n_{h-q}: the number of constituent quarks in a hadron h

$N_h(N_q)$: the multiplicity of the hadron (quark)

R_{AA} of the hadron's quark component

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The hadron (h) un-normalized p_T distribution:

$$\frac{1}{N_h} dN_h/dp_T \quad \rightarrow \quad dN_h/dp_T$$

Its quark (q) component un-normalized p_T distribution:

$$\frac{1}{n_{h-q}} \sum_q \frac{1}{N_q} dN_q/dp_T \quad \rightarrow \quad \frac{1}{n_{h-q}} \sum_q \frac{N_h}{N_q} dN_q/dp_T$$

n_{h-q}: the number of constituent quarks in a hadron h

$N_h(N_q)$: the multiplicity of the hadron (quark)

R_{AA} of the hadron's quark component

The hadron R_{AA}^{h} :

$$R_{AA}^{h}(p_T) = \frac{1}{\langle N_{coll} \rangle} \frac{dN_h^{AA}/dp_T}{dN_h^{pp}/dp_T}$$

Its quark component R_{AA}^{h-q} :

$$R_{AA}^{h-q}(p_T) = \frac{1}{\langle N_{coll} \rangle} \frac{\sum_q w_q^{AA}\, dN_q^{AA}/dp_T}{\sum_q w_q^{pp}\, dN_q^{pp}/dp_T}$$

$w_q = N_h/N_q$: a weight factor

PACIAE model

PACIAE model

PACIAE: a microscopic parton and hadron transport model (based on PYTHIA6)

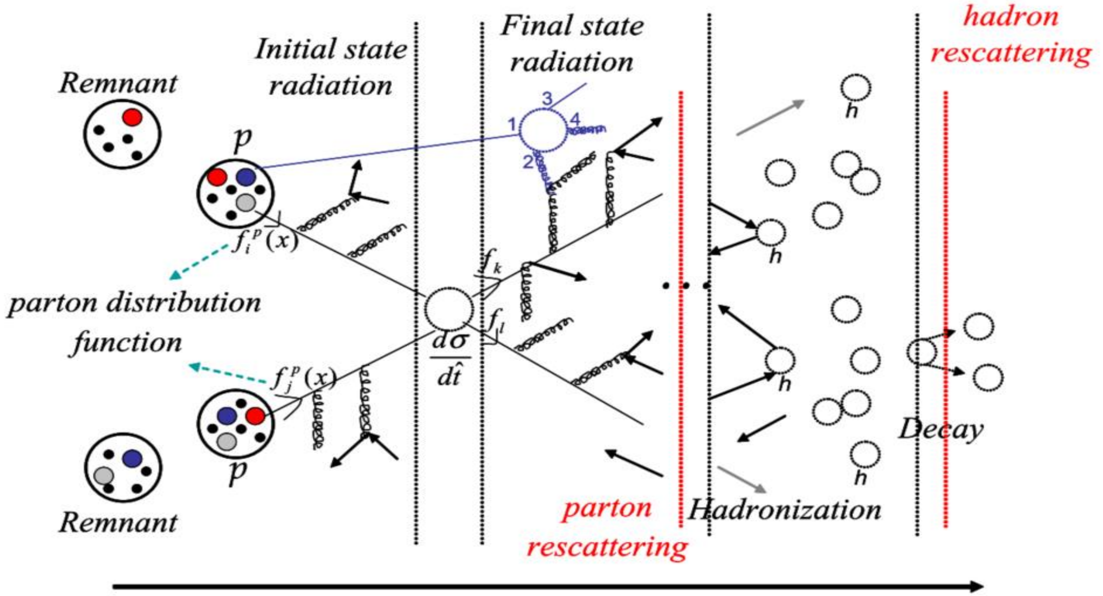
parton initialization

parton rescatterring

hadronization

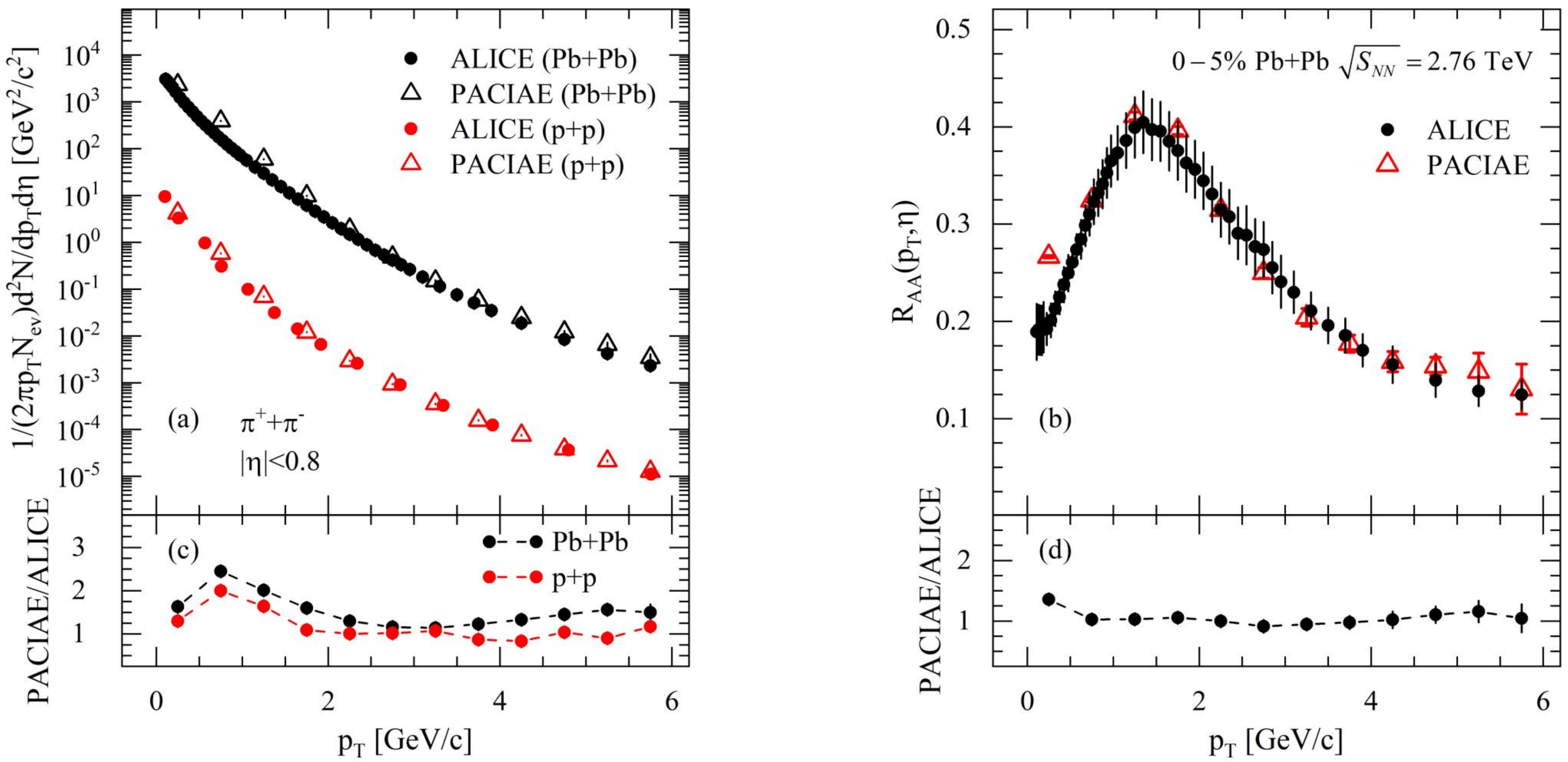
hadron rescatterring

Sketch for pp dynamic simulation (PYTHIA & PACIAE)



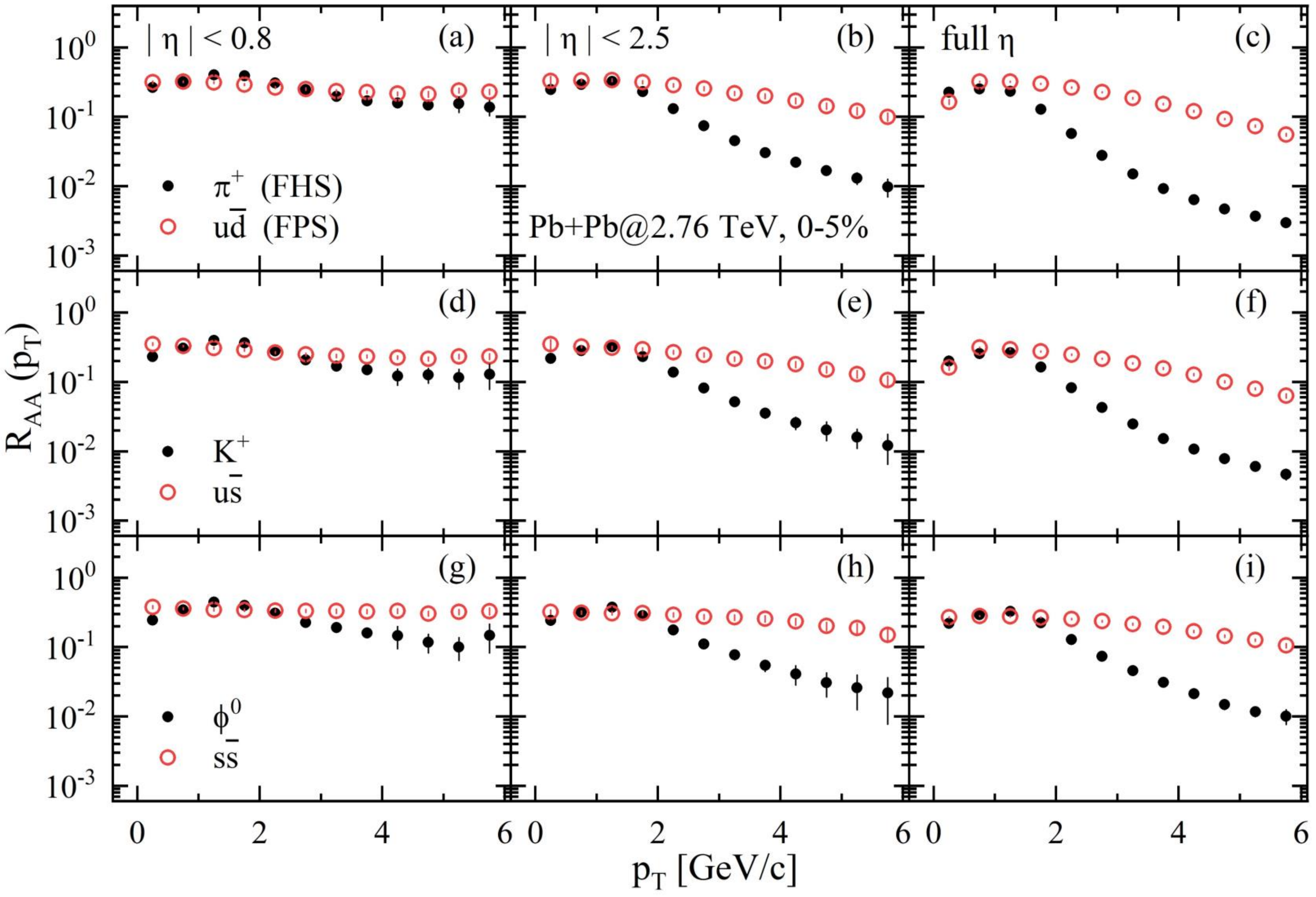
π, K, p, n, ρ(ω), Δ, Λ, Σ, Ξ, Ω, J/Ψ

PACIAE model



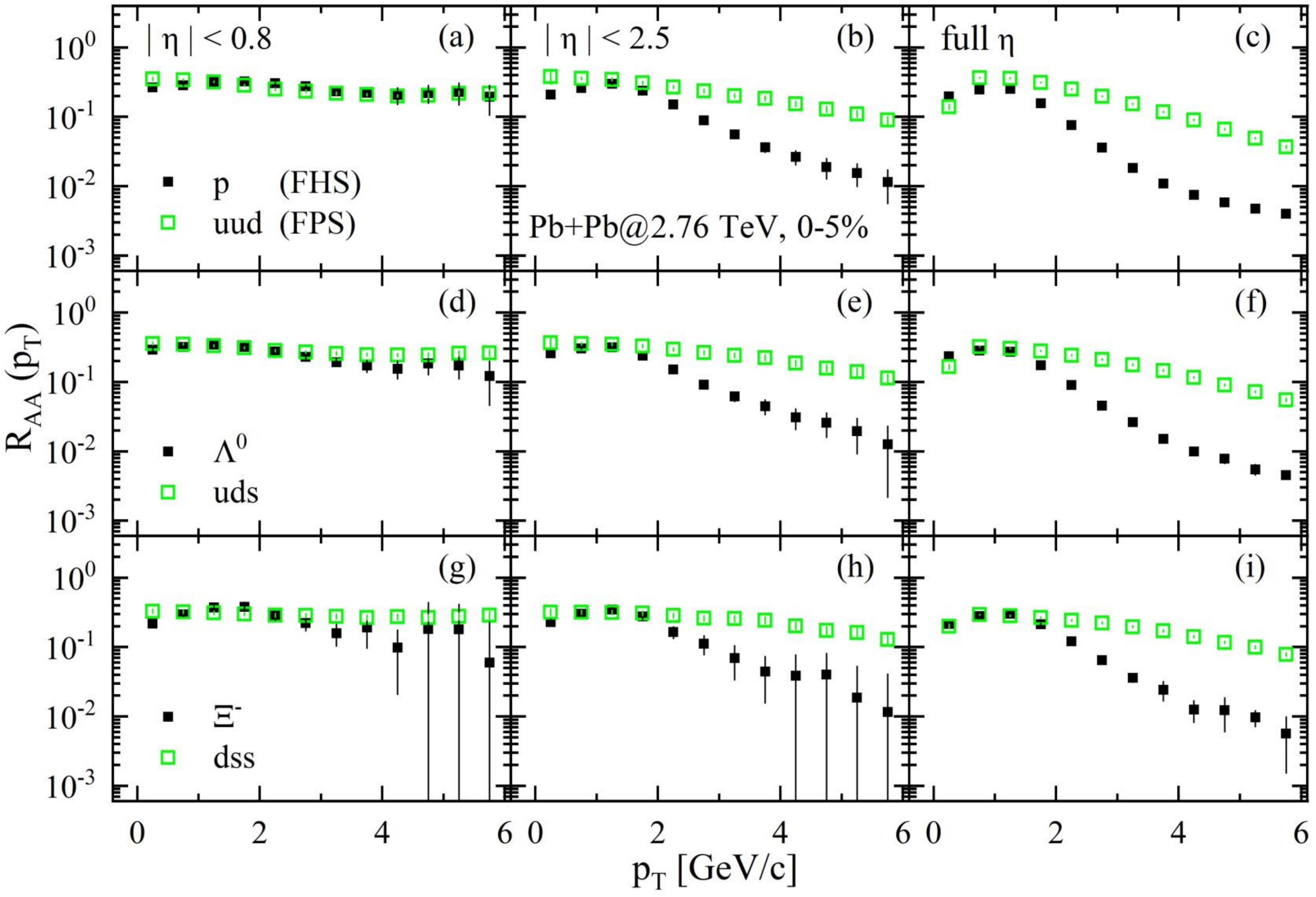
Results

Results: rapidity dependence



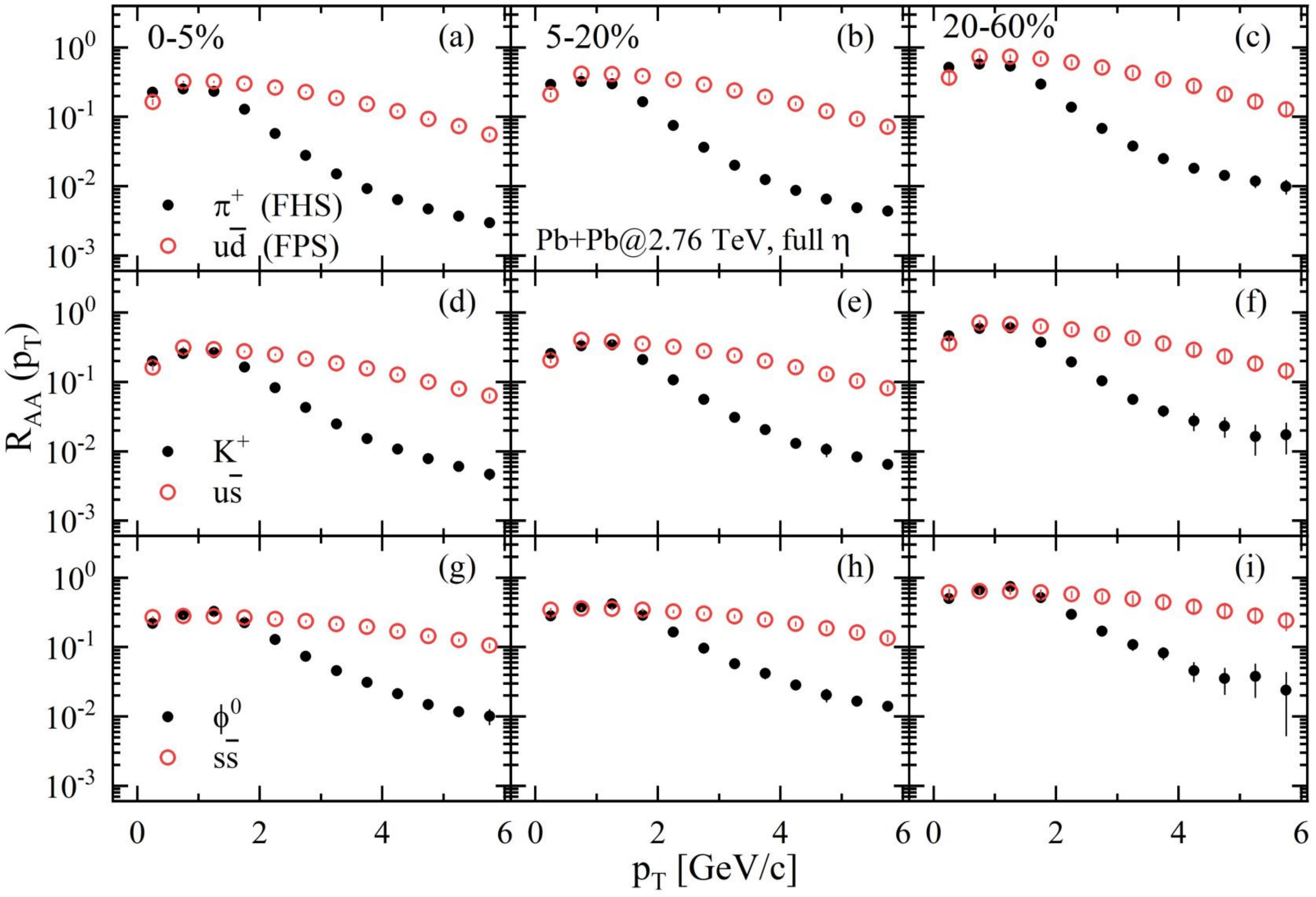
- $R_{AA}^{h-q} > R_{AA}^{h}$ above $p_T \sim 2$ GeV/c.
- Kept well in different η ranges.
- More significant discrepancy in the larger η range which includes more particles and energy loss.

Results: rapidity dependence



- $R_{AA}^{h-q} > R_{AA}^{h}$ above p_T ~ 2 GeV/c.
- Kept well in different η ranges.
- More significant discrepancy in the larger η range which includes more particles and energy loss.

Results: centrality dependence



- Show the correspondence from central to peripheral collisions.
- R_{AA}: peripheral > central, stemming from the stronger hot medium effect.

Results: centrality dependence

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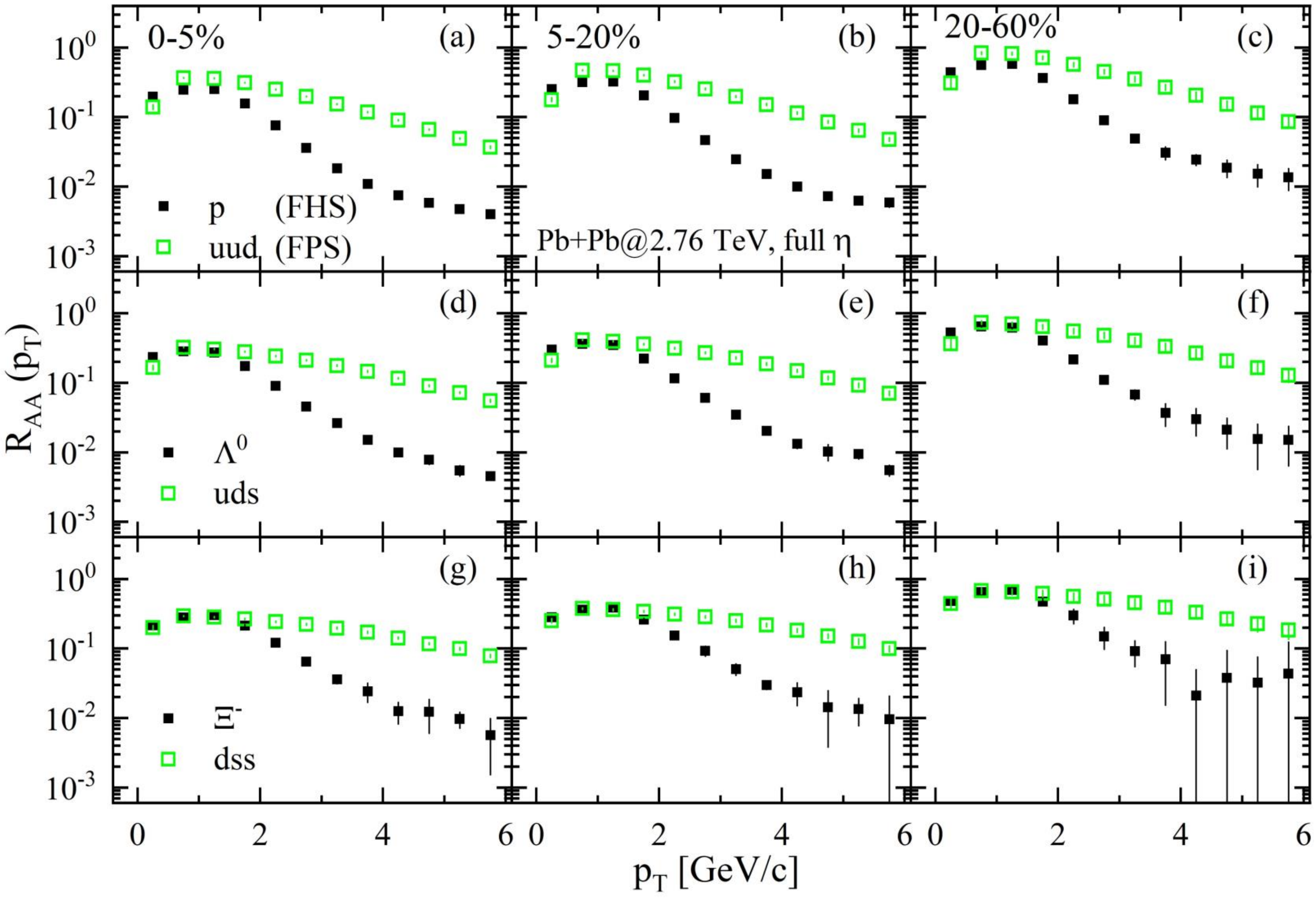
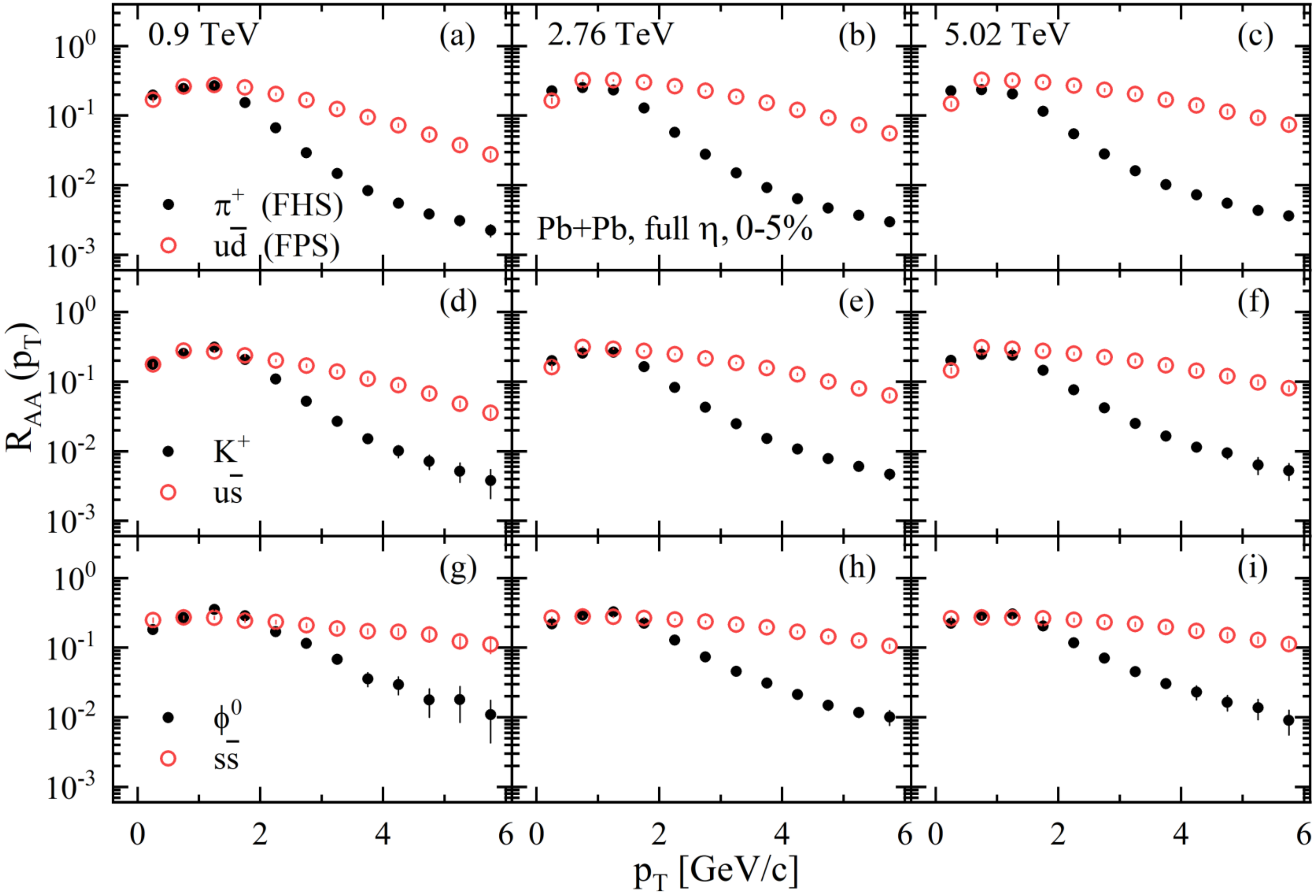


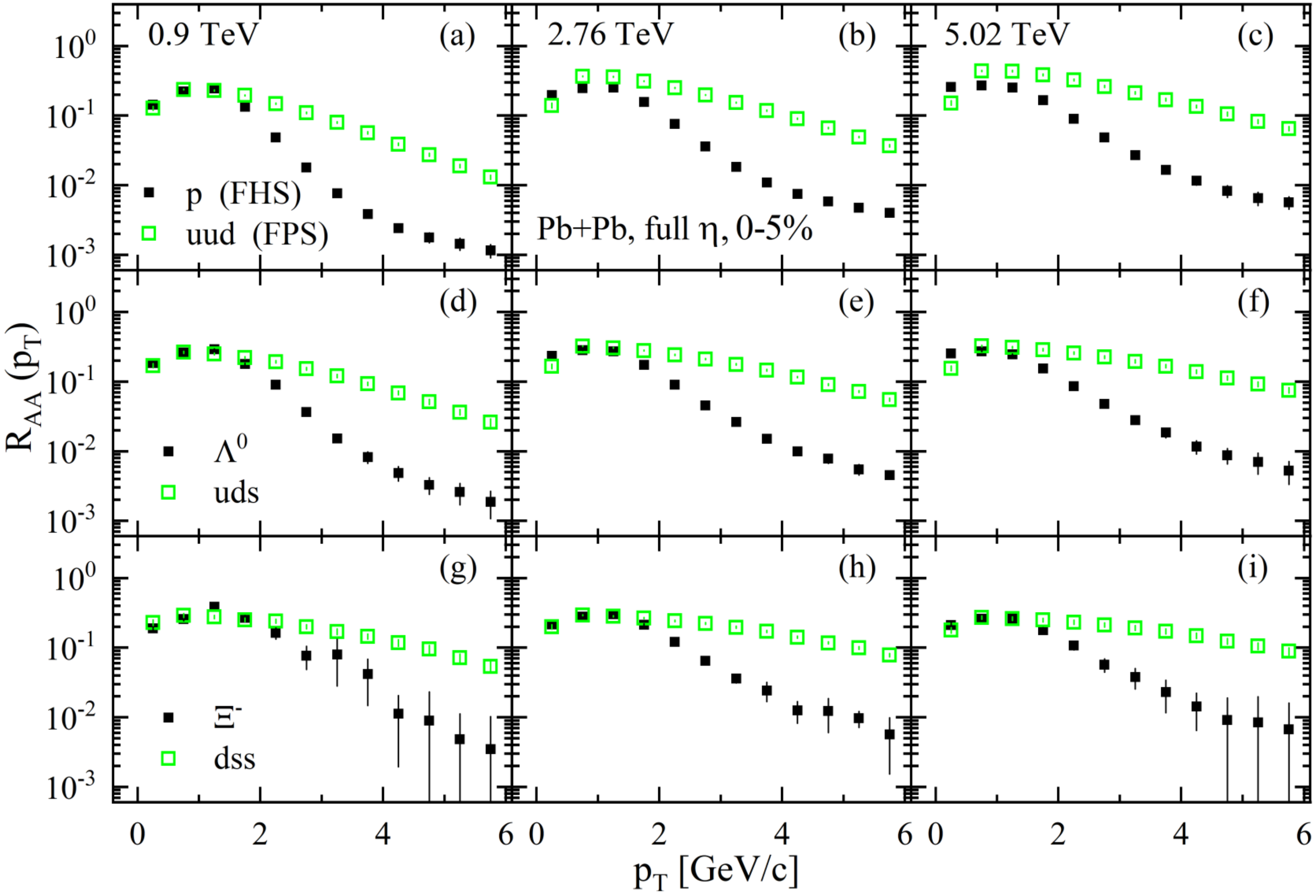
- Show the correspondence from central to peripheral collisions.
- R_{AA}: peripheral > central, stemming from the stronger hot medium effect.

Results: energy dependence



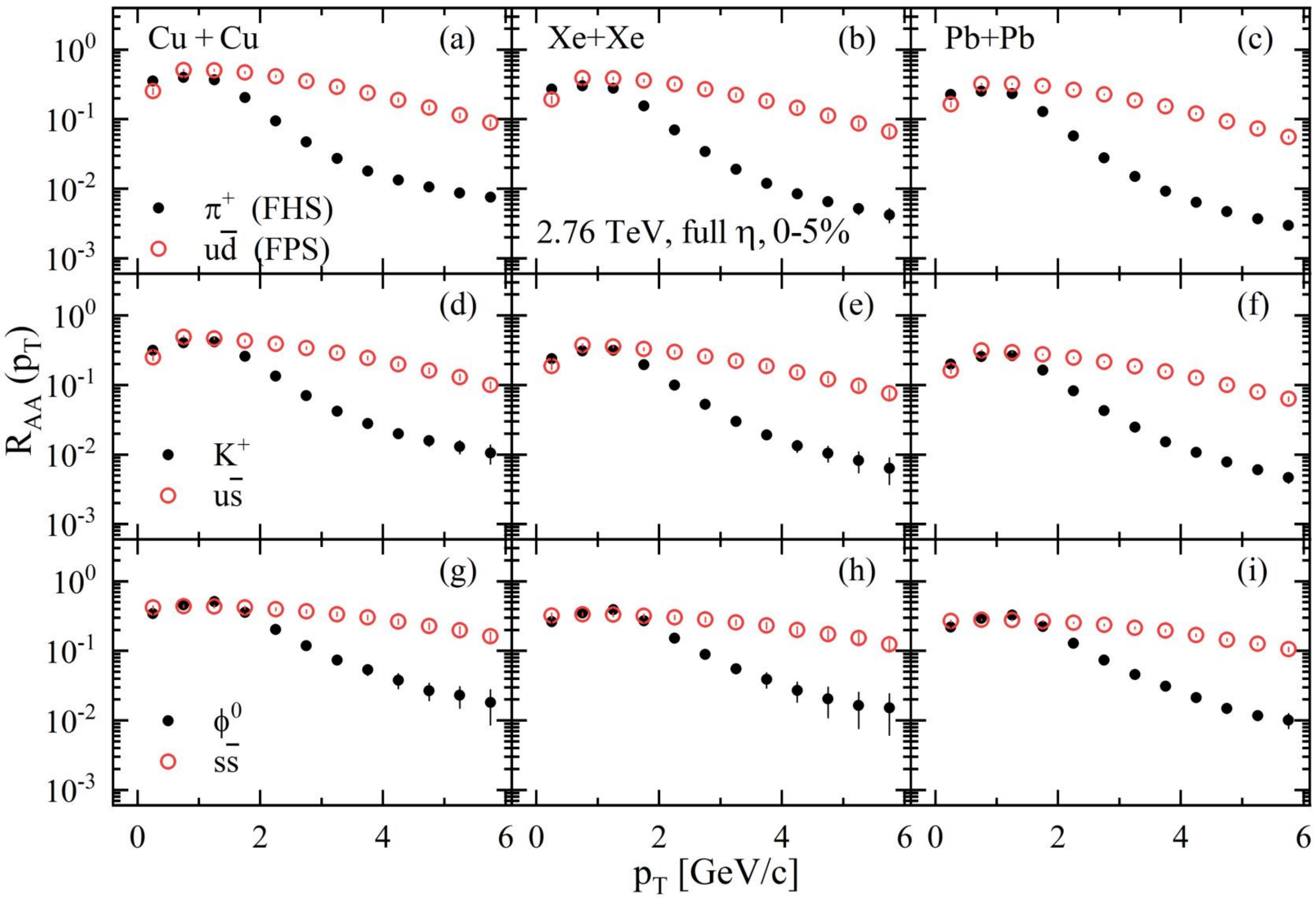
- $R_{AA}^{h-q} > R_{AA}^{h}$ above $p_T \sim$ 2 GeV/c.
- The correspondence is kept well from higher to "lower" energies.

Results: energy dependence



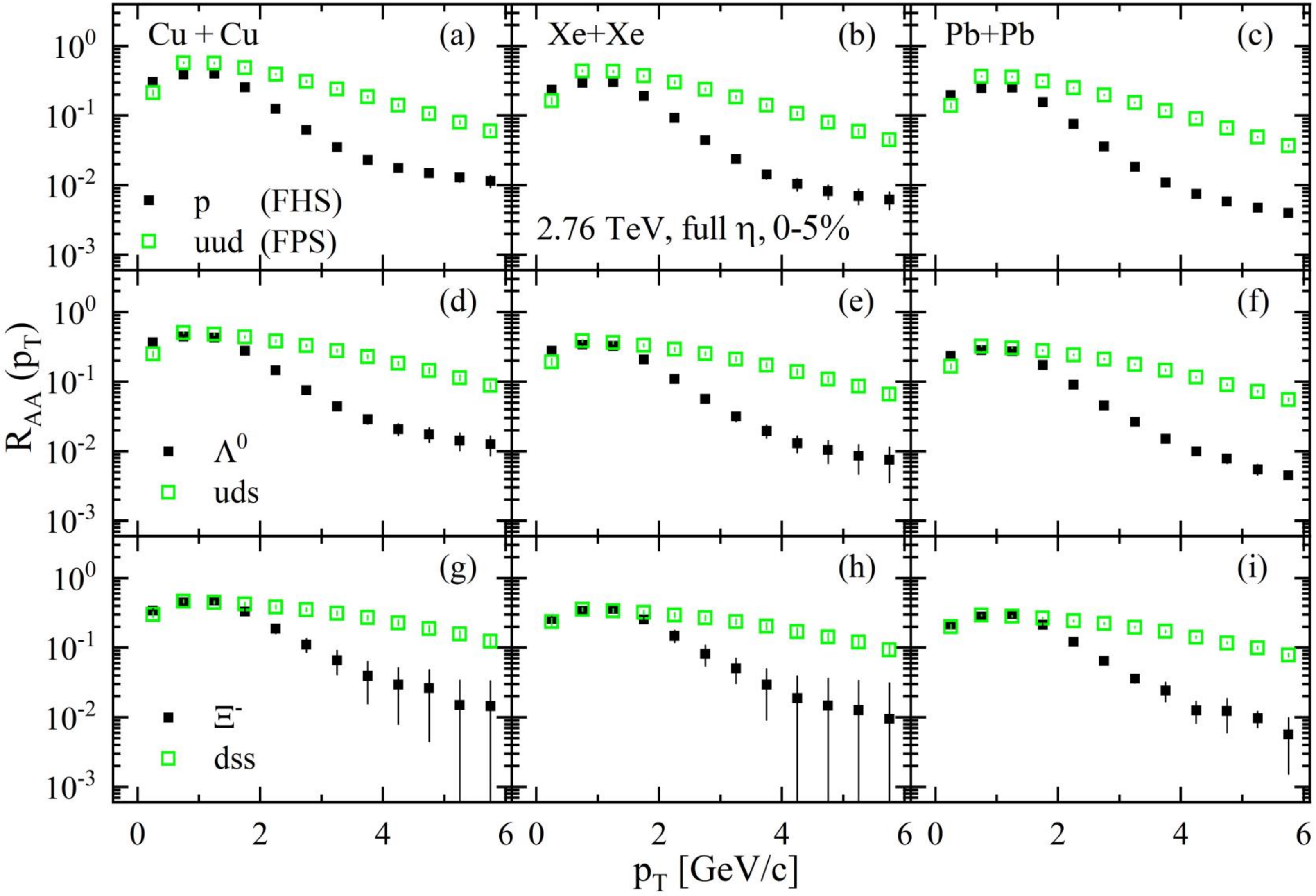
- $R_{AA}^{h-q} > R_{AA}^{h}$ above $p_T \sim$ 2 GeV/c.
- The correspondence is kept well from higher to “lower” energies.

Results: system dependence



- Still, $R_{AA}^{h-q} > R_{AA}^{h}$ above $p_T \sim 2$ GeV/c, irrespective of the collision system size.

Results: system dependence



- Still, $R_{AA}^{h-q} > R_{AA}^{h}$ above $p_T \sim 2$ GeV/c, irrespective of the collision system size.

Results: flavor (mass) ordering

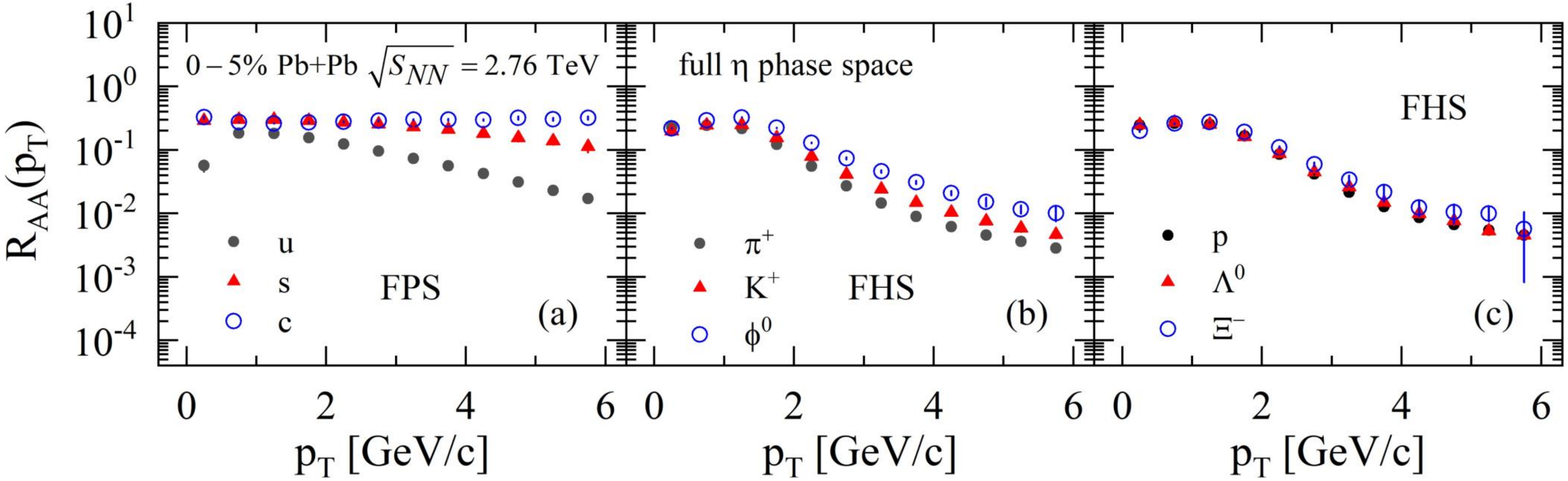
See Wei Dai's talk on 08/09/2022

The dead-cone effect: $\Theta \lesssim m/E$

The mass ordering in energy loss and R_{AA}:

$$\Delta E(g) > \Delta E(u) > \Delta E(s) > \Delta E(c) > \Delta E(b) > \Delta E(t)$$

$$R_{AA}^{g} < R_{AA}^{u} < R_{AA}^{s} < R_{AA}^{c} < R_{AA}^{b} < R_{AA}^{t}$$

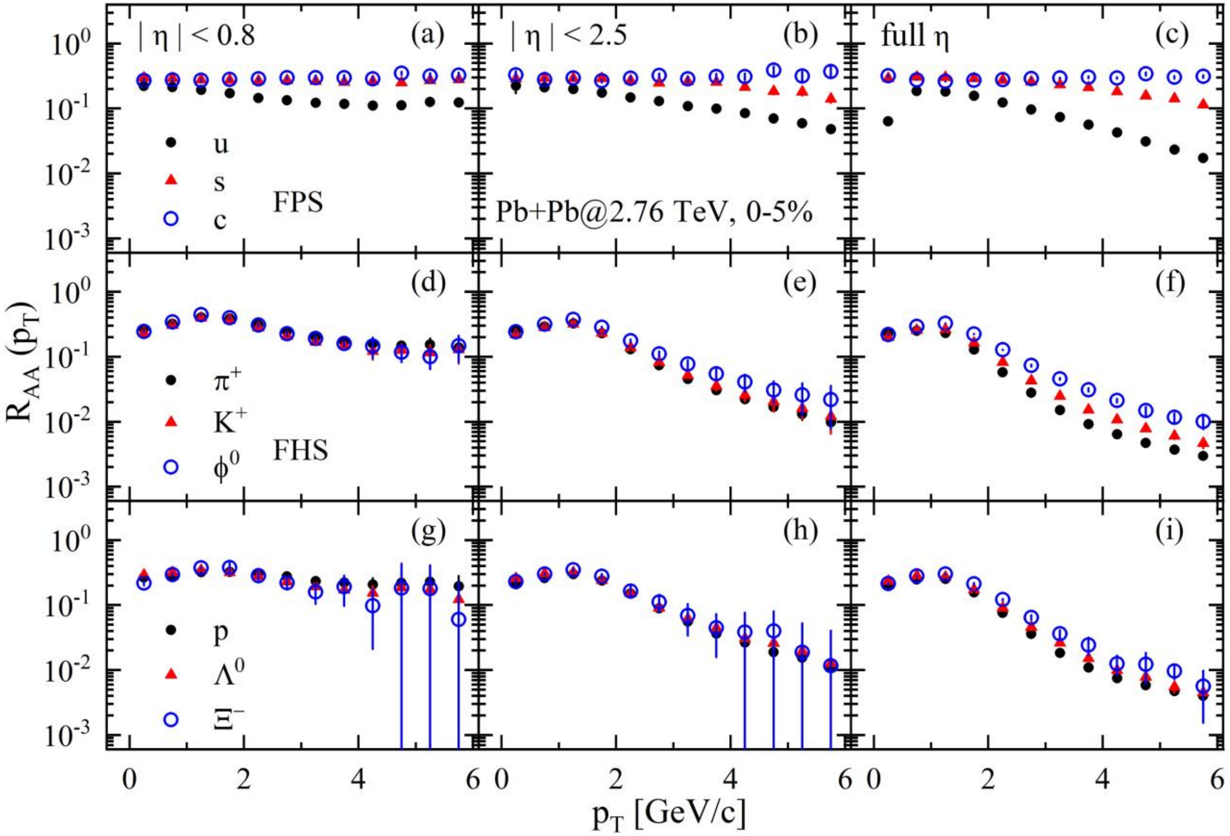


Summary

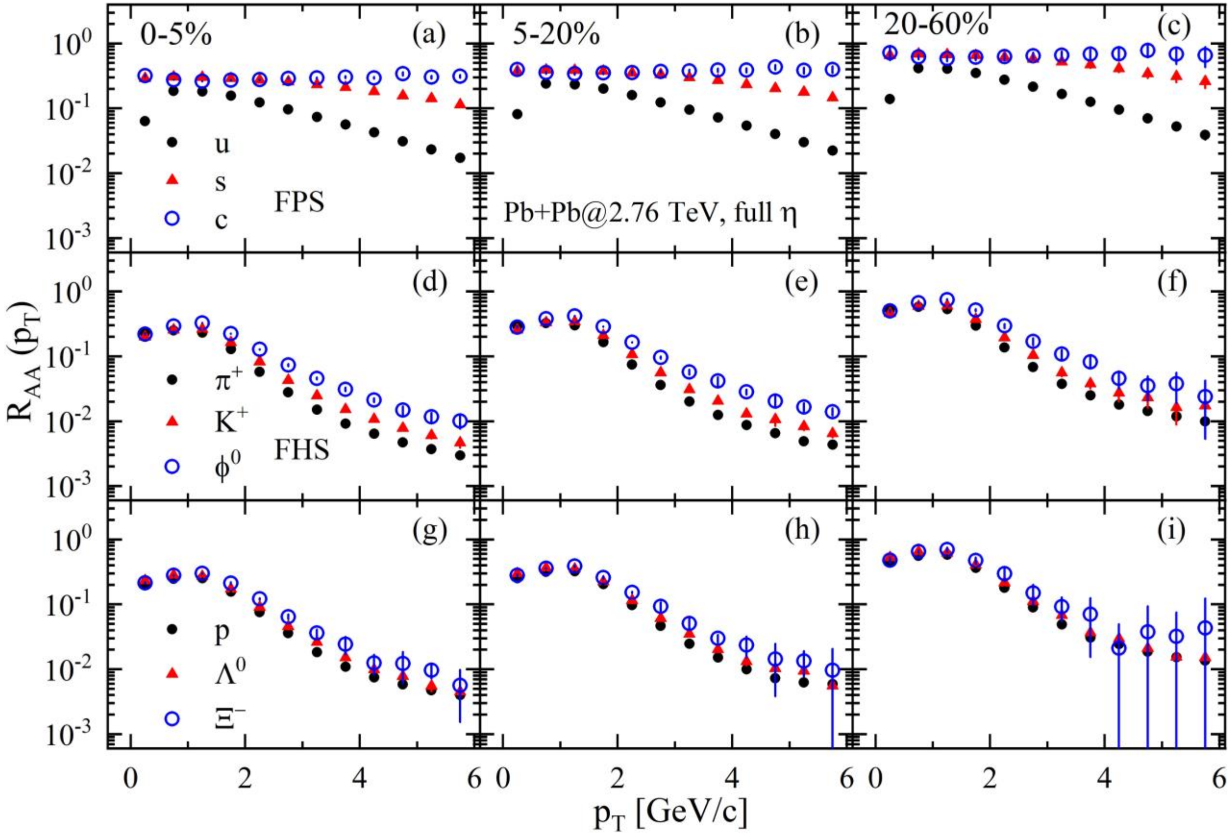
- We proposed a method connecting the $\boldsymbol{R_{AA}}$ between
  the hadron and its quark component (correspondence).
- A systematic study was given in the frame of PACIAE.
  η, centrality, energy and system…
- The correspondence and the mass ordering are held globally.
- The mass ordering in other observables ?
- More studies are still needed…

Thanks !

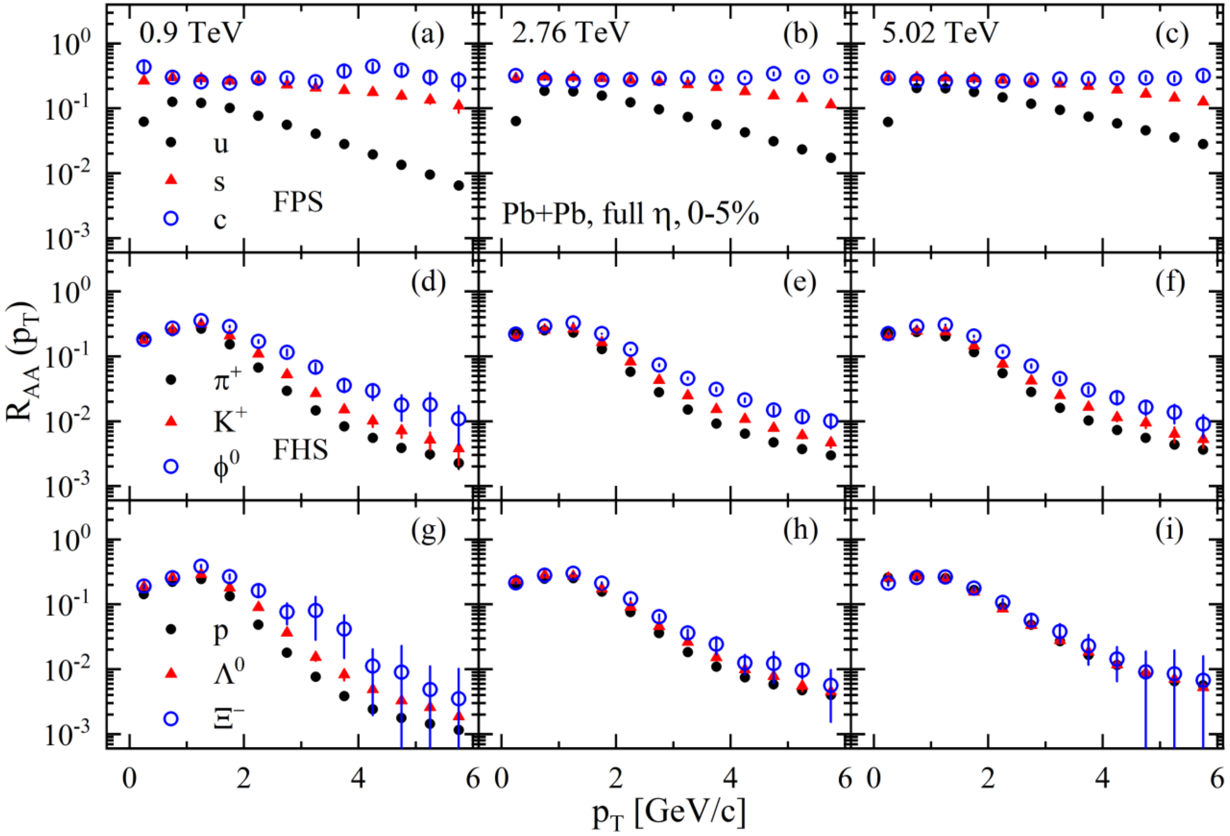
Results: flavor (mass) ordering

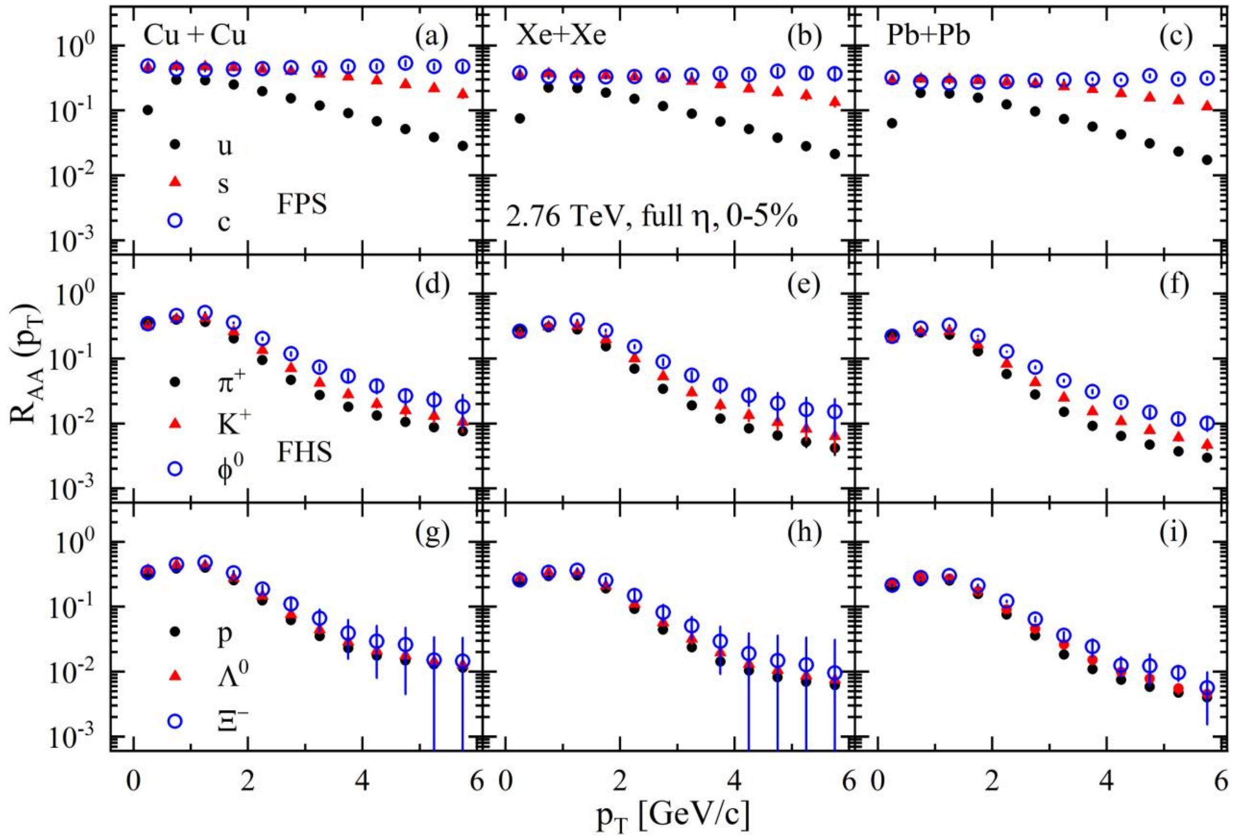


- The flavor (mass) ordering is kept well in hadrons, same as that in quarks, which inspired from "dead-cone effect".



Results: flavor (mass) ordering





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Backup

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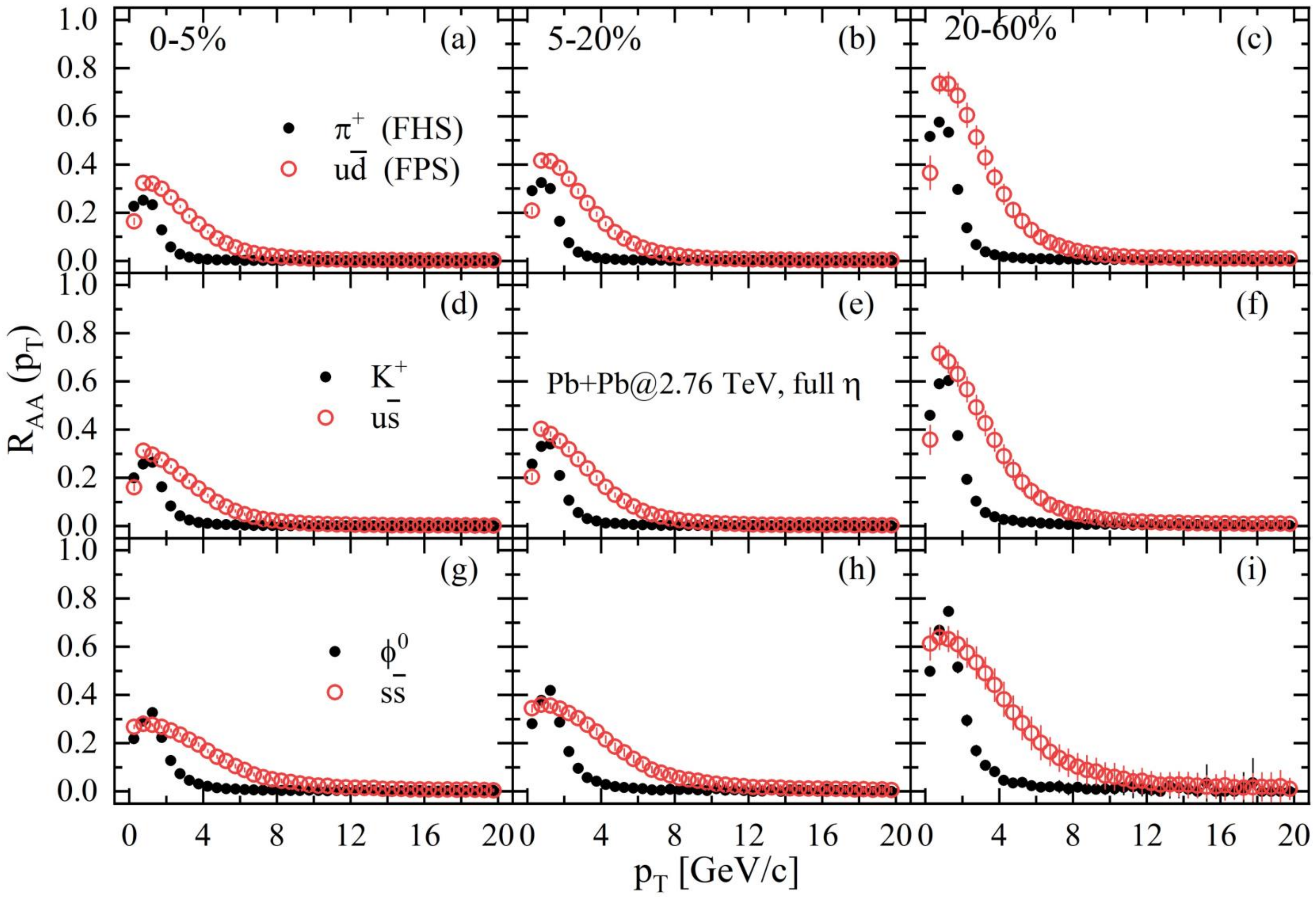

p_T 0~20 GeV/c

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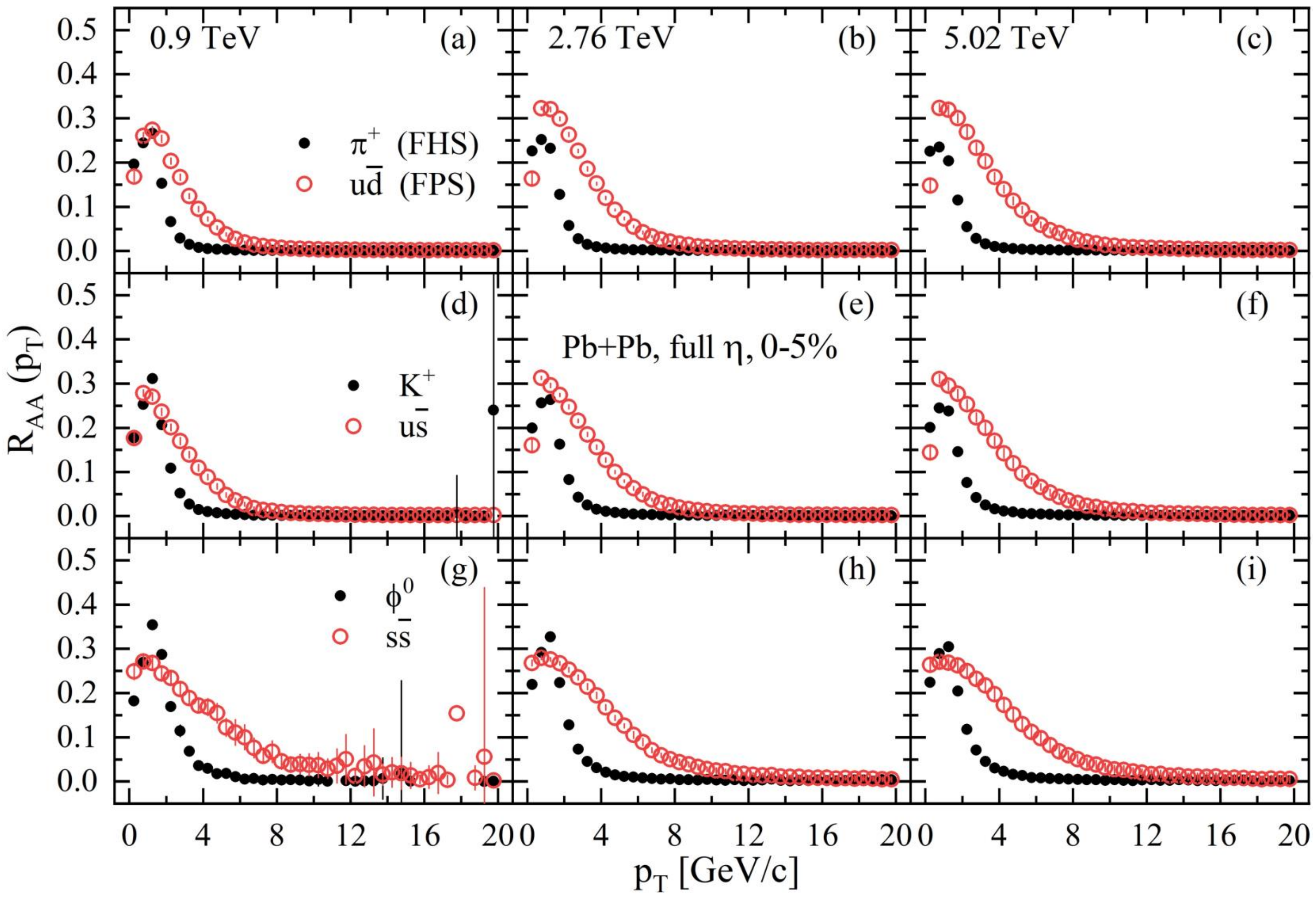

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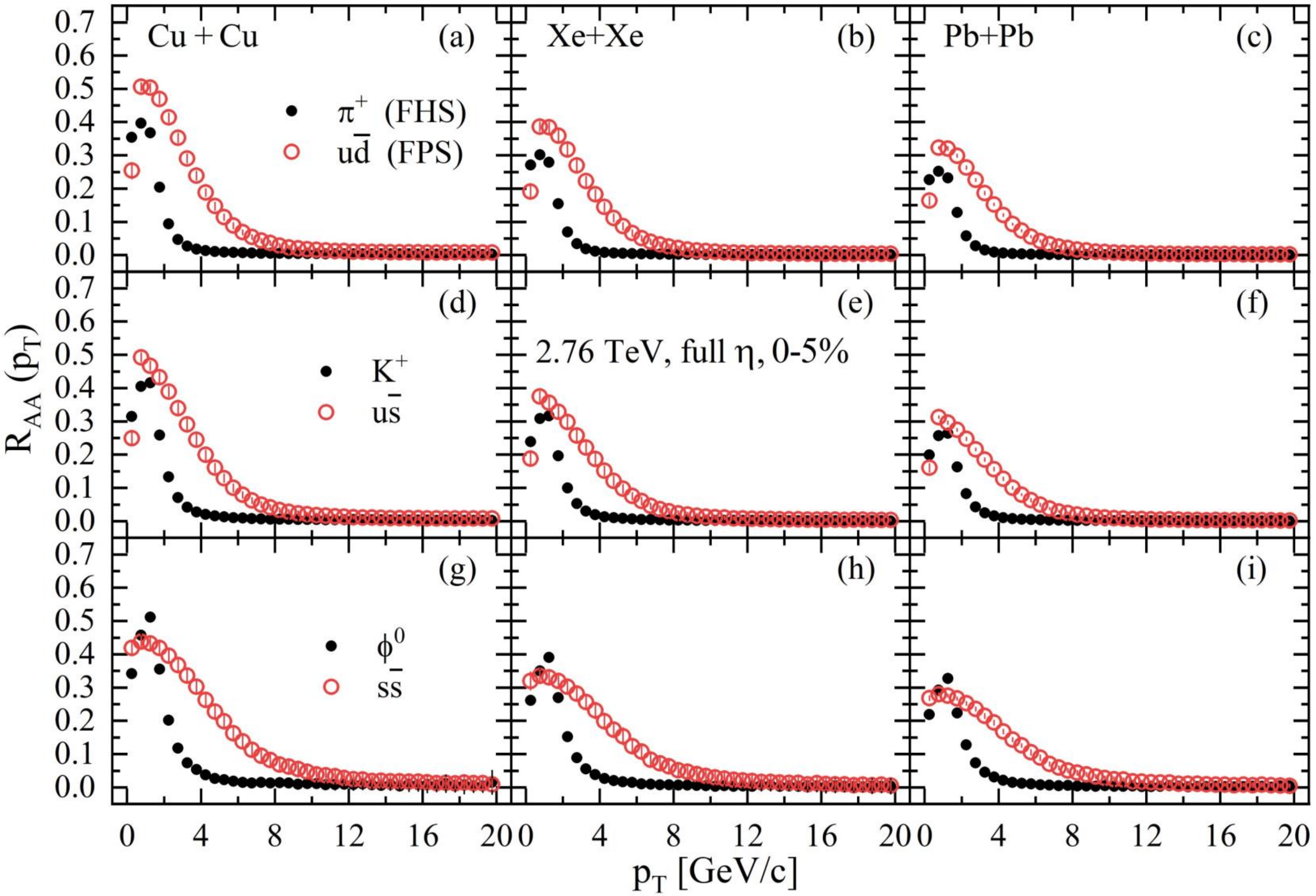

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