Dynamical core-corona initialization model and its application to hadron chemistry

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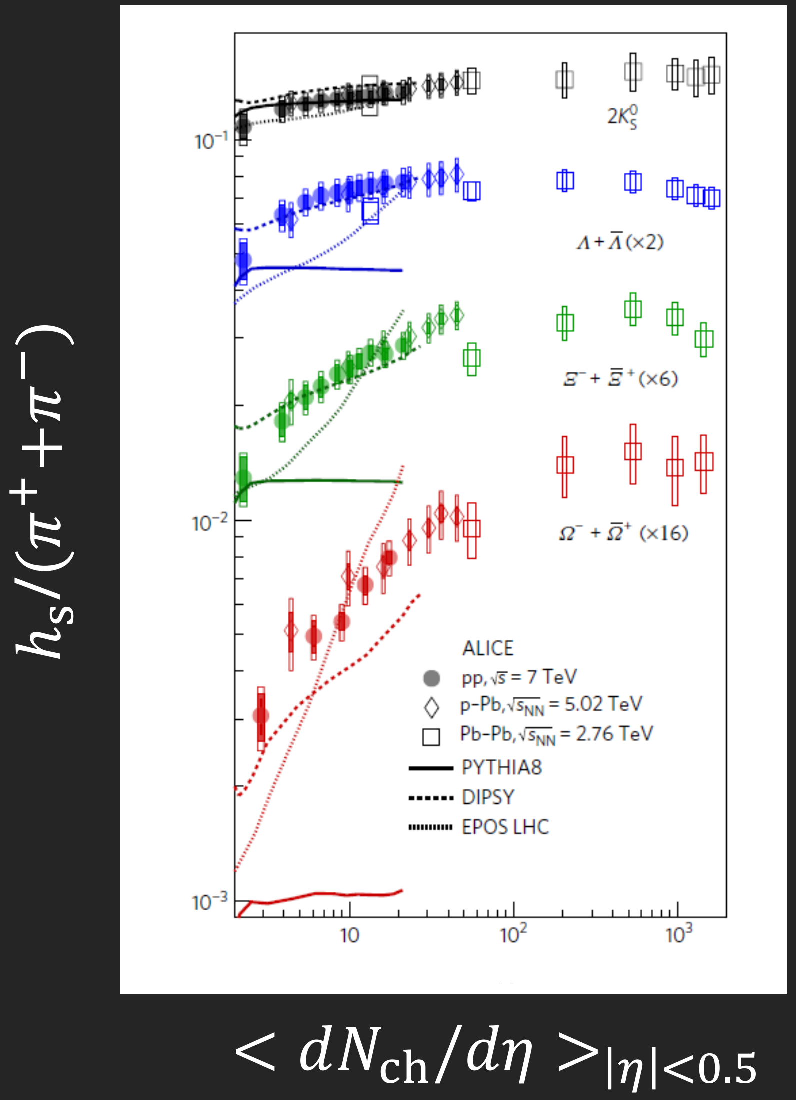
Y. Kanakubo, M. Okai, Y. Tachibana, T. Hirano, PTEP 2018 (2018) no.12, 121D01

Introduction



ALICE Collaboration: Nat. Phys. 13, (2017) 535.

Strangeness enhancement as a function of multiplicity

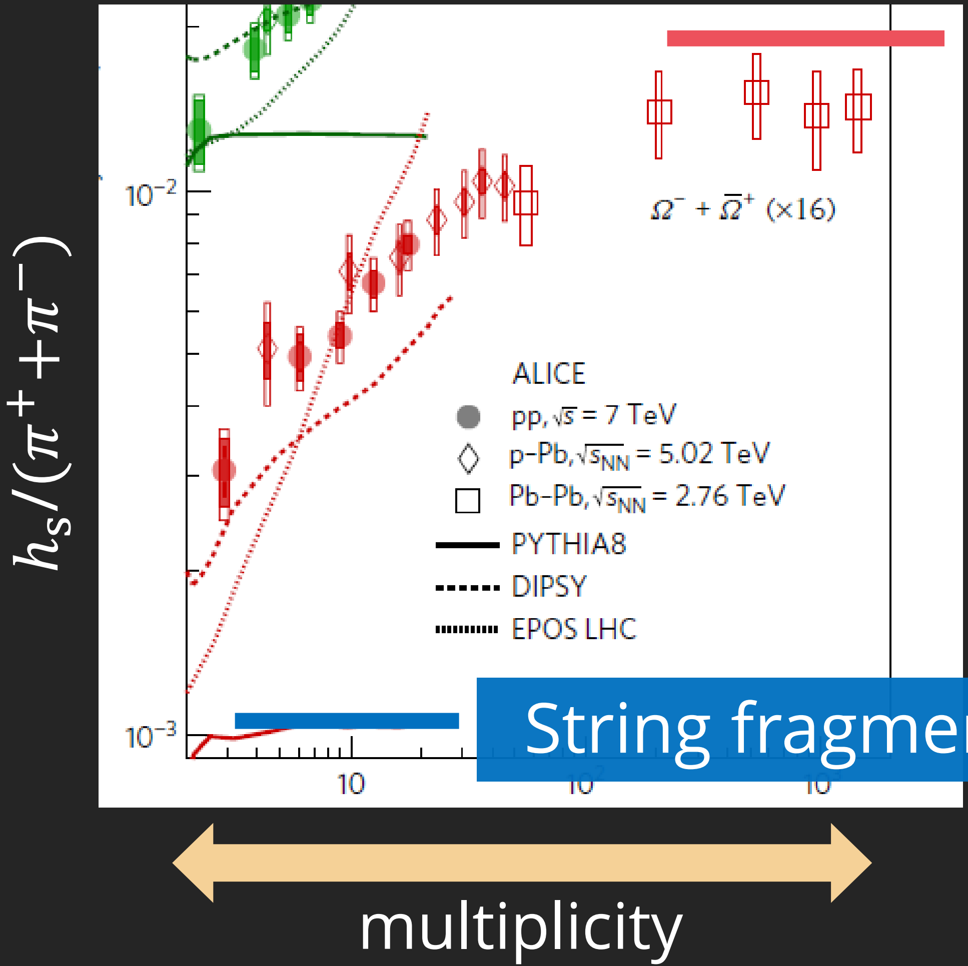
Rapid enhancement of multi-strange hadron ratios in small systems

Continuous growing up to the ratio in Pb+Pb as a function of multiplicity

How can we describe the continuous change of yield ratio?

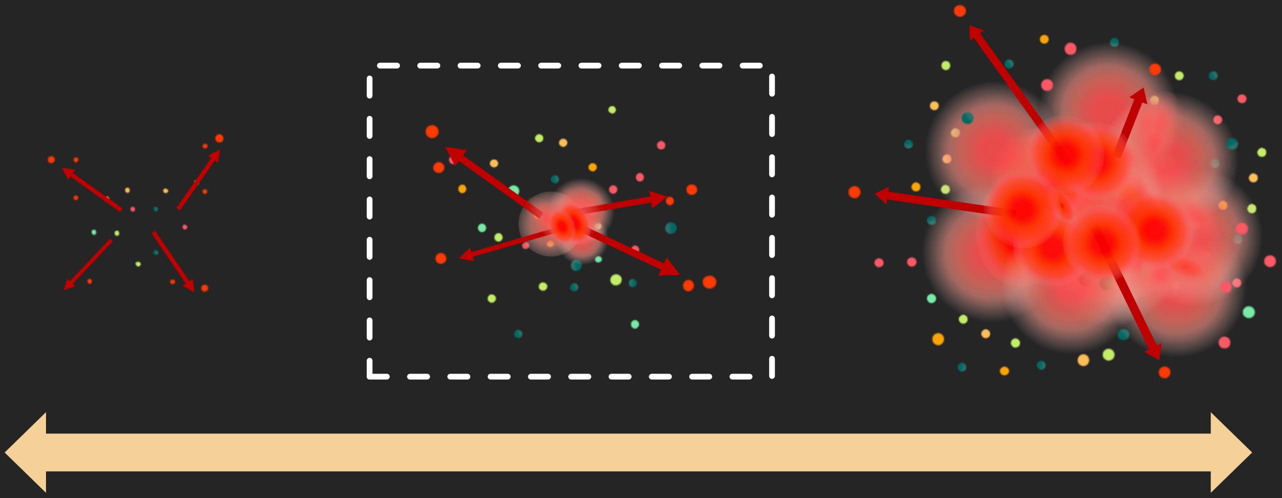
Introduction (cont'd)

Change of strangeness ratio → Two different hadronization mechanisms



Chemical equilibrium

String fragmentation



ALICE Collaboration: Nat. Phys. 13, (2017) 535.

→ Competition between string fragmentation and QGP formation

Purpose

Different hadronization mechanisms between "core" and "corona"

Dynamical initialization

M. Okai *et al.*

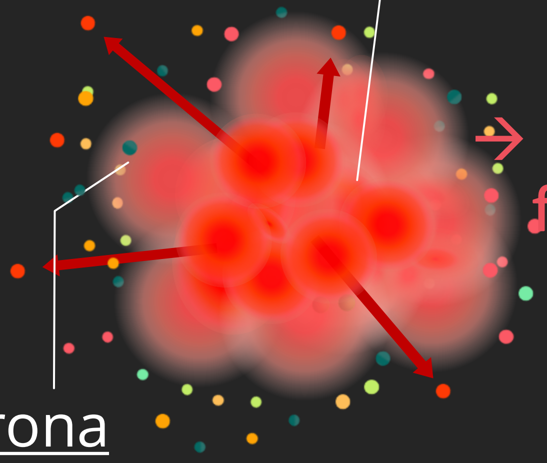
← **Core-corona picture**

P. Bozek *et al.*, J. Aichelin *et al.*,
F. Becattini *et al.*, T. Pierog *et al.*

New!

Dynamical core-corona initialization

Y. Kanakubo *et al.*

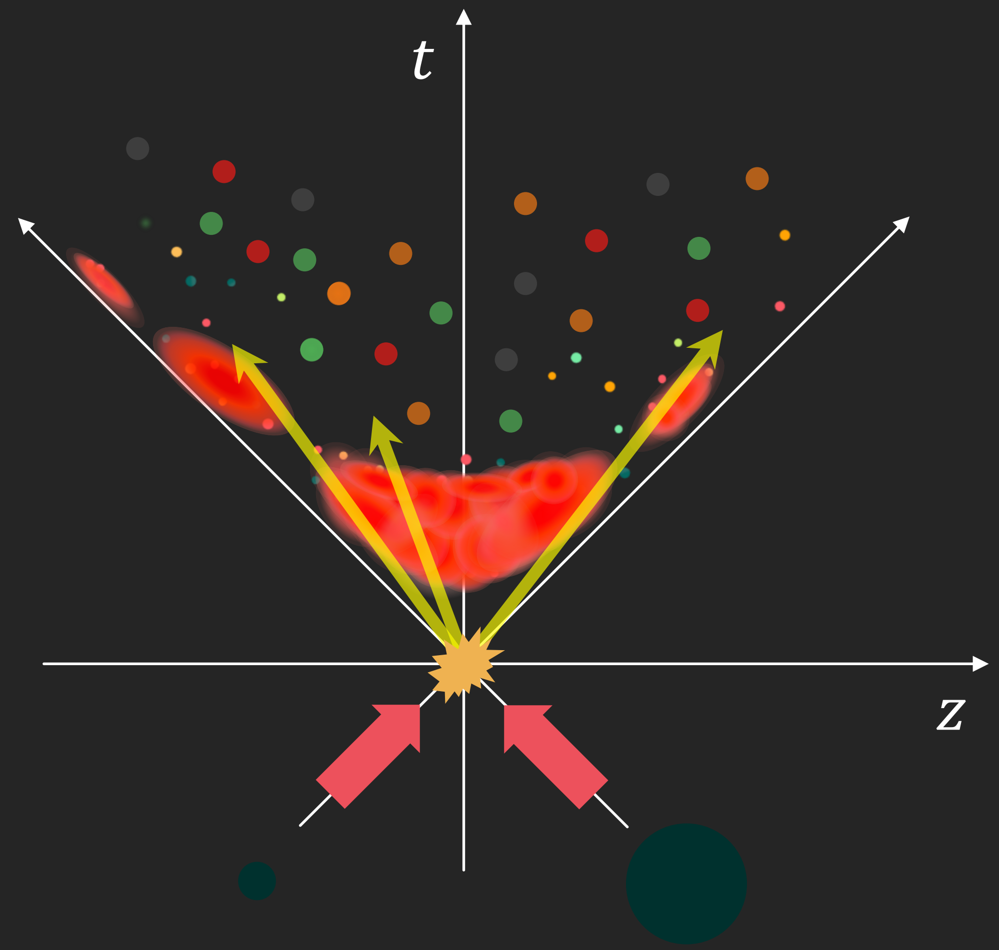


Core: Chemically equilibrated matter
→ Hadronization from QGP

Corona: Unscathed partons
→ **String fragmentation**

Universal description of hadron chemistry from small to large systems

Model



Hadronization

Corona → String fragmentation (PYTHIA)

Core → Freezeout at $T_{\mathrm{fo}} = 160\ \mathrm{MeV}$
with Cooper-Frye formula

F. Cooper and G. Frye, Phys. Rev. **D10**, 186 (1974).

\+ Resonance correction

A. Andronic *et al.*,
Nature 561 (2018) no.7723, 321-330 (2017).

Evolution of QGP fluids

Dynamical core-corona initialization

(3+1)-D ideal hydro, Lattice EoS

S. Borsanyi *et al.*,
Phys. Lett. **B730**, 155 (2014).

Parton generation

PYTHIA ver 8.230

T. Sjöstrand *et al.*, Comput. Phys. Commun. 191, 159 (2015).

Dynamical Initialization

M. Okai, K. Kawaguchi, Y. Tachibana, T .Hirano, Phys. Rev. C 95, no. 5, 054914 (2017).

Hydrodynamic eq. with source term:

$$\partial_\mu T^{\mu\nu} = J^\nu$$

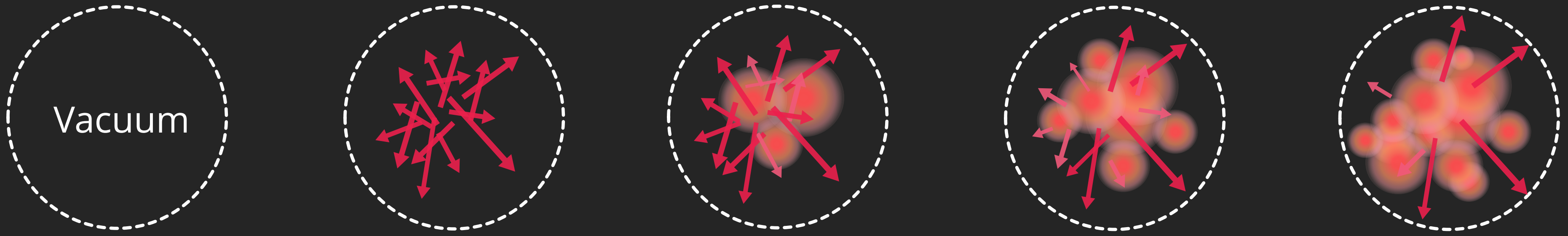
EM tensor of QGP fluids

Energy and momentum deposited from initial partons

$$J^\mu = -\sum_i \frac{d{p_i}^\mu(t)}{dt} G(\boldsymbol{x} - \boldsymbol{x}_i(t))$$

p_i^μ: Four-momentum of the i^{th} parton

G: Gaussian function



Formation time

Initial time of fluids

0 $\tau_{00} = 0.1\ \text{fm}$ $\tau_0 = 0.6\ \text{fm}$

Vacuum → QGP fluids

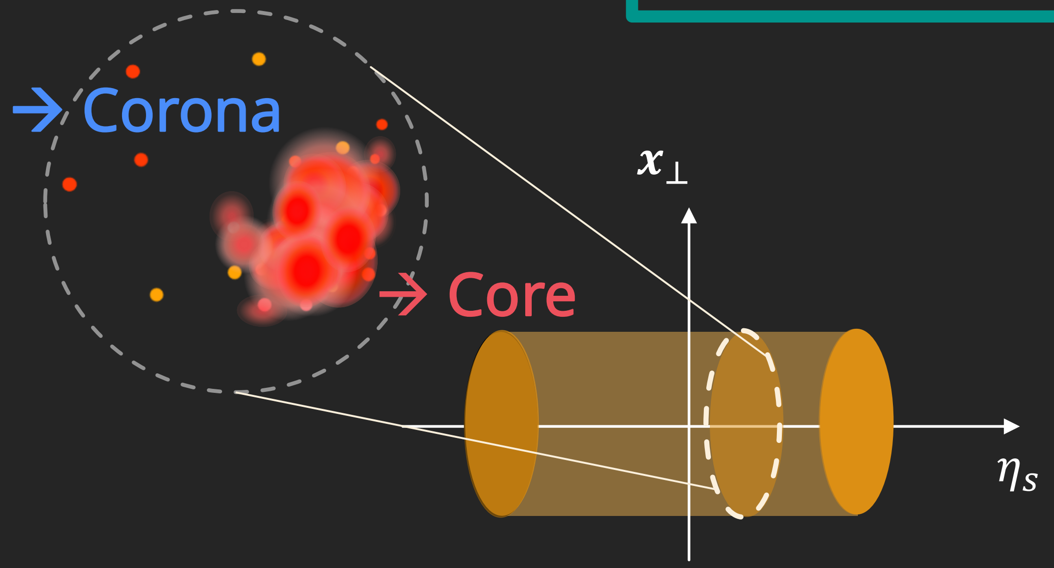
Energy & momentum

Partons → Survived partons

Fluidization rate with core-corona picture

Fluidization rate per parton:

$$\boxed{\frac{dp_i{}^{\mu}(t)}{dt} = -a_0 \frac{\rho_i\big(x_i(t)\big)}{p_{\mathrm{T},i}{}^2} p_i{}^{\mu}(t)}$$



$\rho_i(x_i(t))$: Density distribution of partons

$$\rho_i(x_i(t))d^3x = \sum_{j\neq i} G\left(\boldsymbol{x_i} - \boldsymbol{x}_j(t)\right)d^3x$$

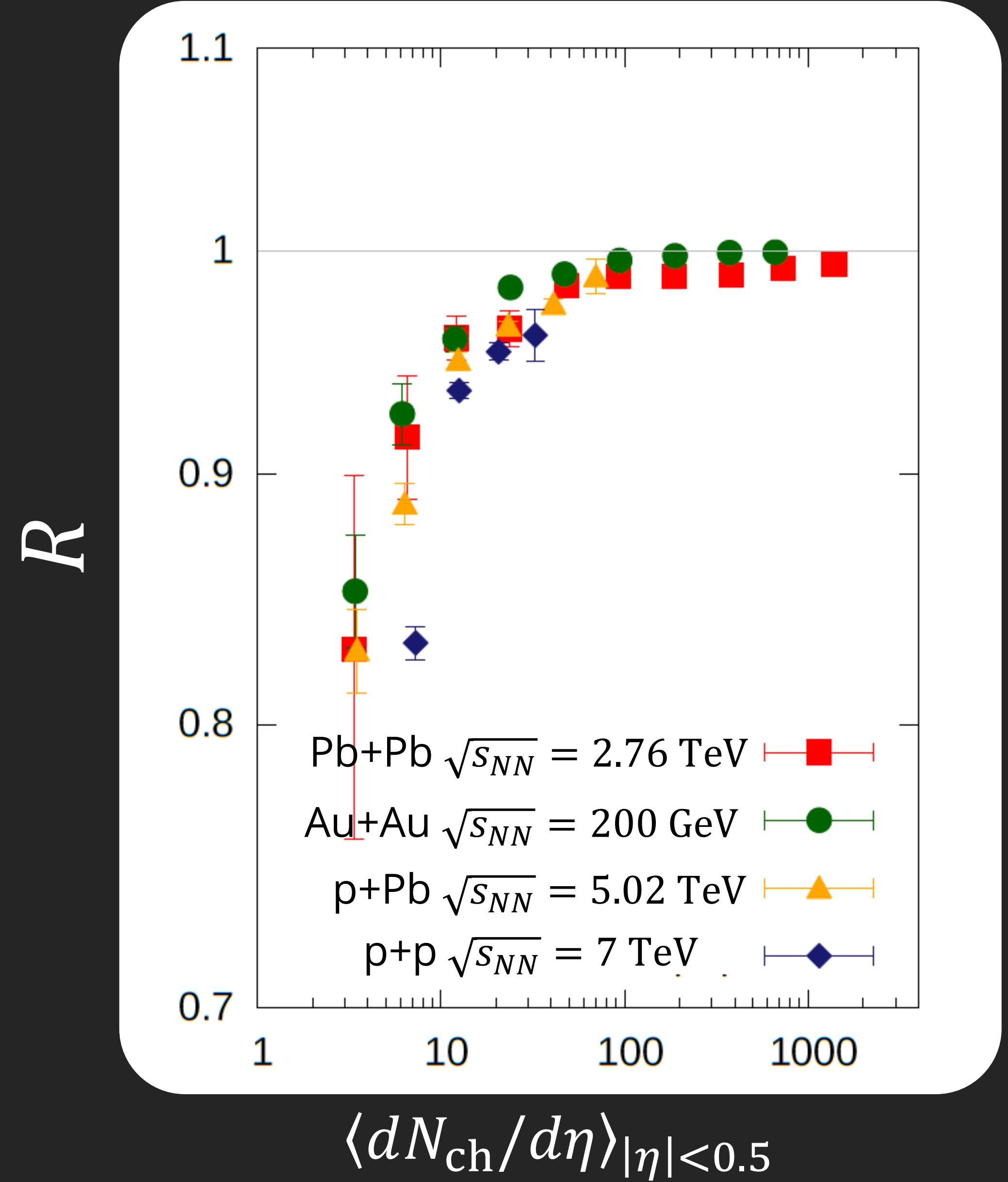
$a_0(= 10^2)$: Free parameter

Fluidization of partons → Interaction rate → Phenomenological "mean free path" $\frac{1}{\lambda_i} = \sigma_i\rho_i \approx \frac{a_0}{p_{T,i}{}^2}\rho_i$

Try to capture the "parton thermalization" in core-corona picture

Results ―Fraction of fluidized energy―

Y. Kanakubo *et al.*, (in preparation)



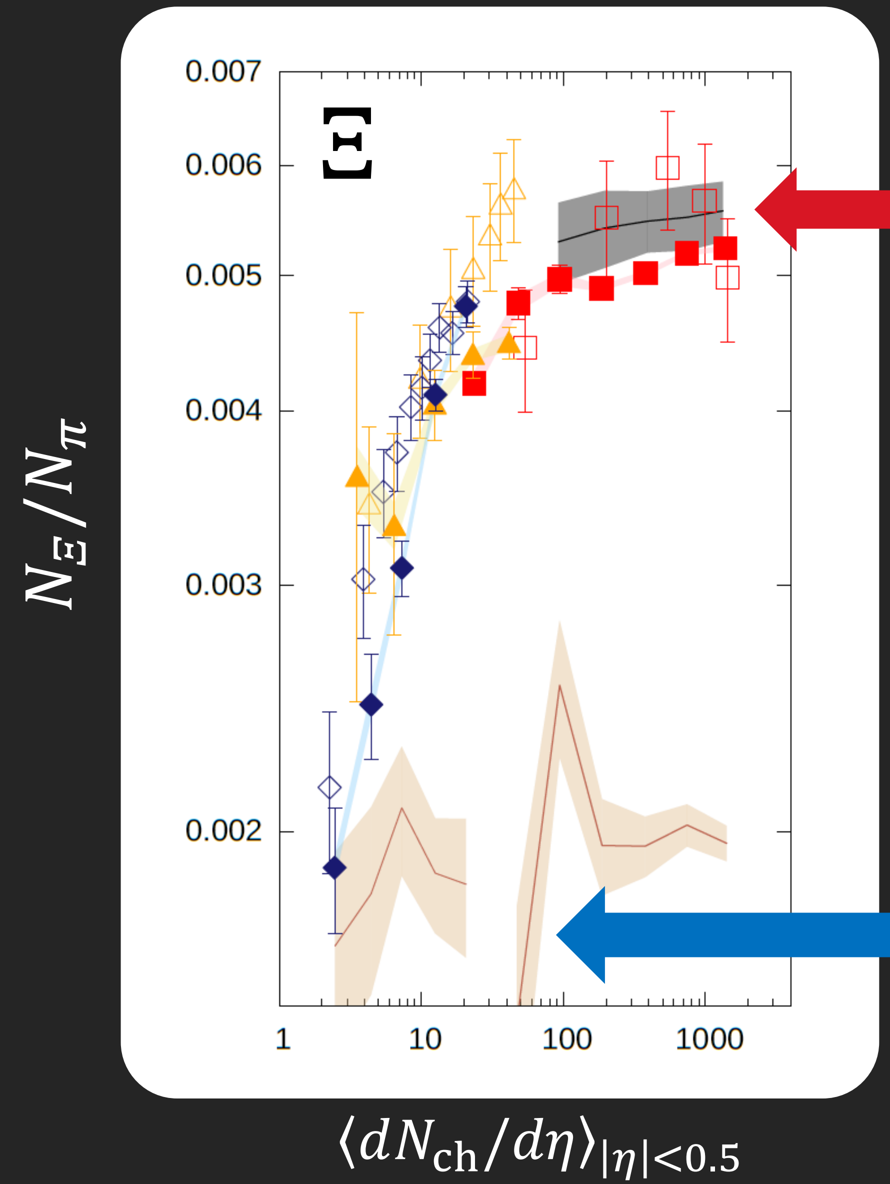
$$R = \left. \frac{dE_{\mathrm{core}}/d\eta}{dE_{\mathrm{tot}}/d\eta} \right|_{\eta_s = 0}$$

Estimation of energy turned to be fluids with dynamical core-corona initialization

Scale with multiplicity
→Almost no size (or energy) dependence

Results — Yield ratio Ξ/π —

Y. Kanakubo *et al.*, PTEP 2018 (2018) no.12, 121D01

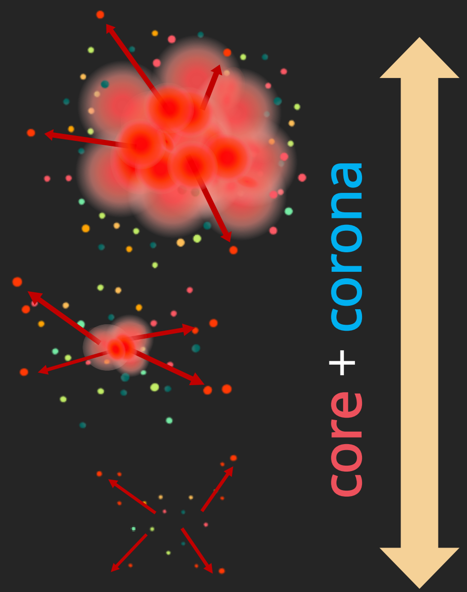


Continuous changes with multiplicity

→ Describe the behavior of experiment data

Hydro limit

Yield ratio from core (chemical equilibrium)



$\frac{dN_{\mathrm{ch}}}{d\eta} \gtrsim 100$ QGP formation dominance

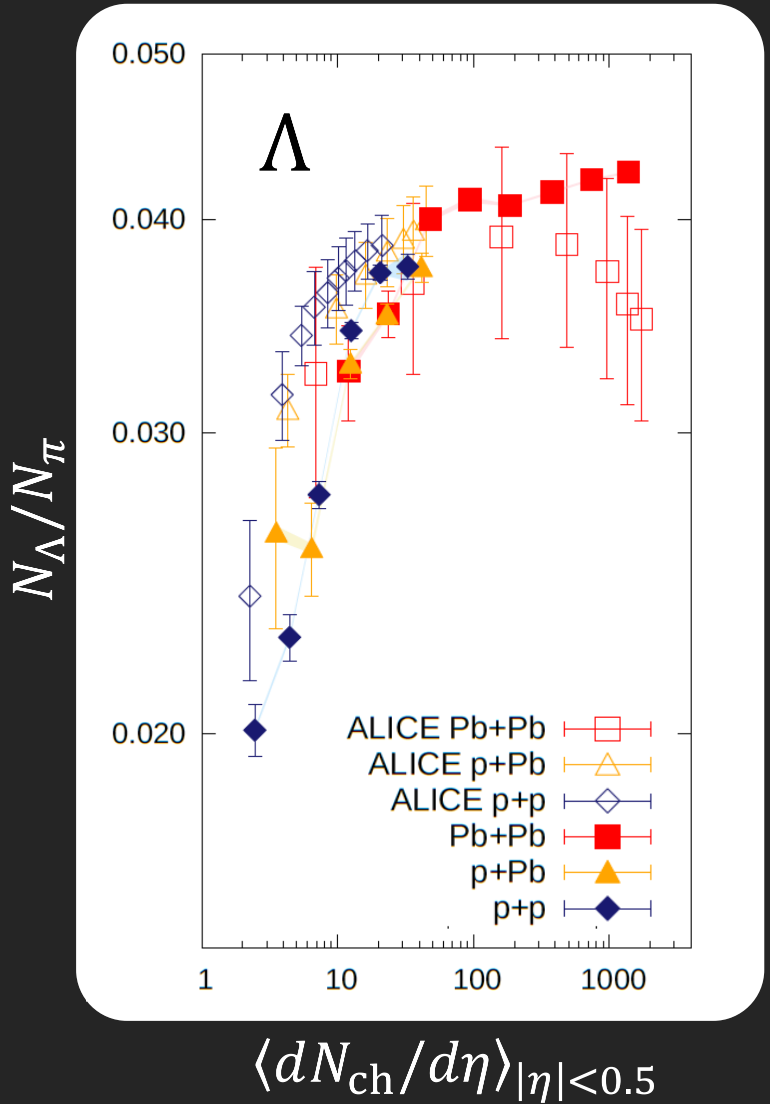
$\frac{dN_{\mathrm{ch}}}{d\eta} \lesssim 100$ Partial formation of QGP !

String fragmentation limit

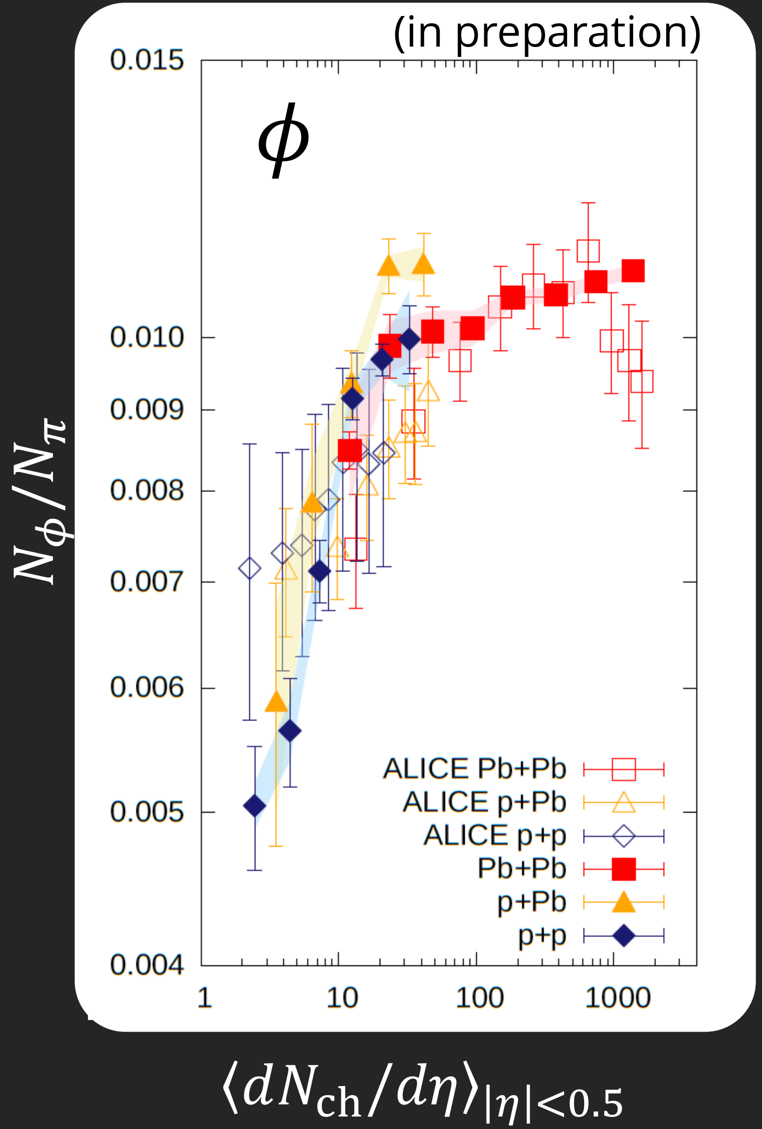
Yield ratio from corona (string fragmentation)

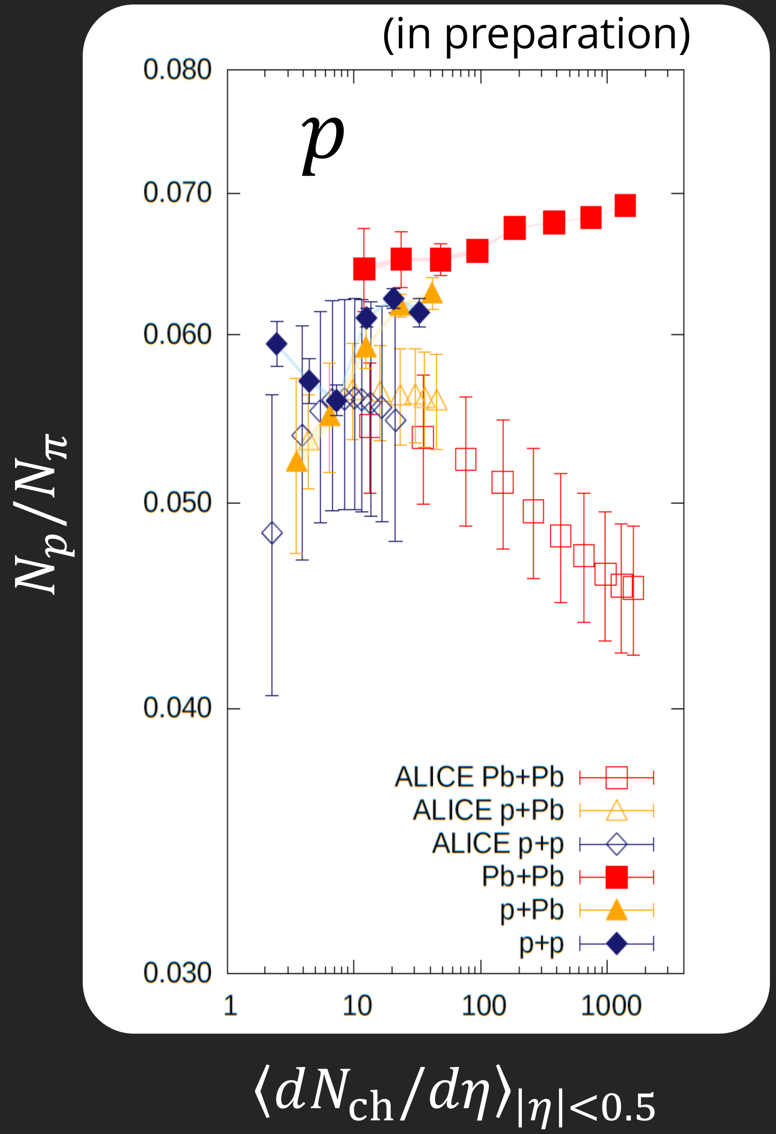
Results — Yield ratios Λ/π, ϕ/π, p/π —

Increase of particle ratios with multiplicity

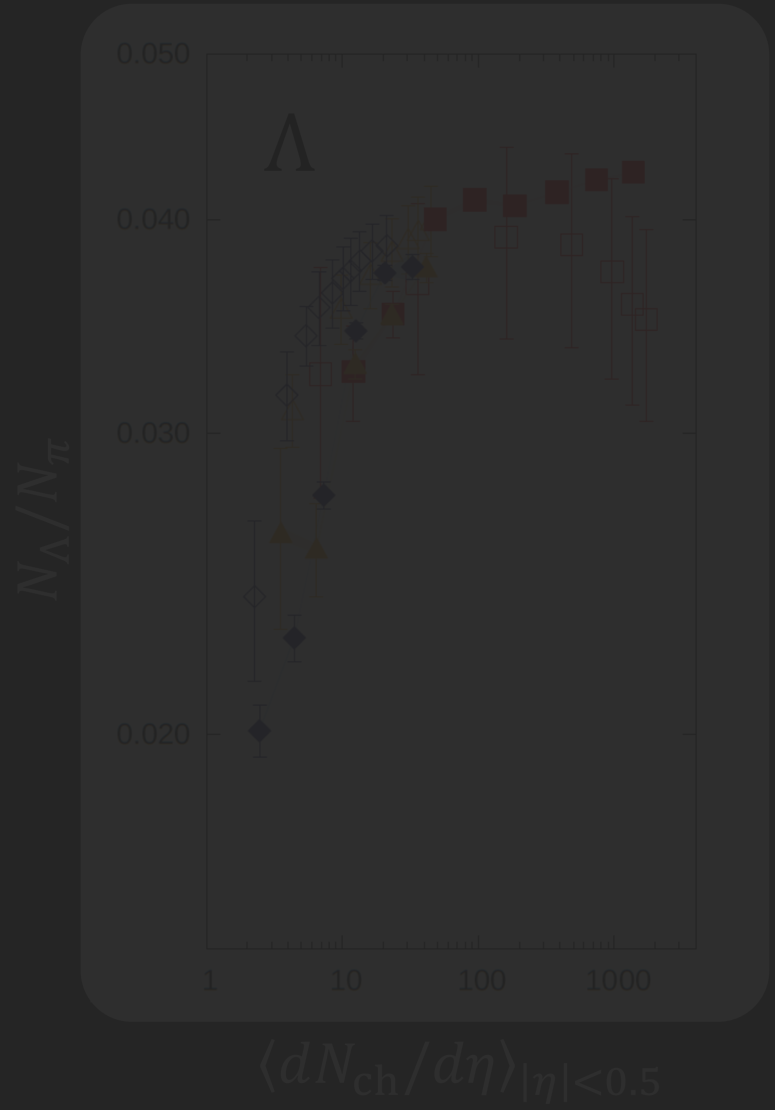


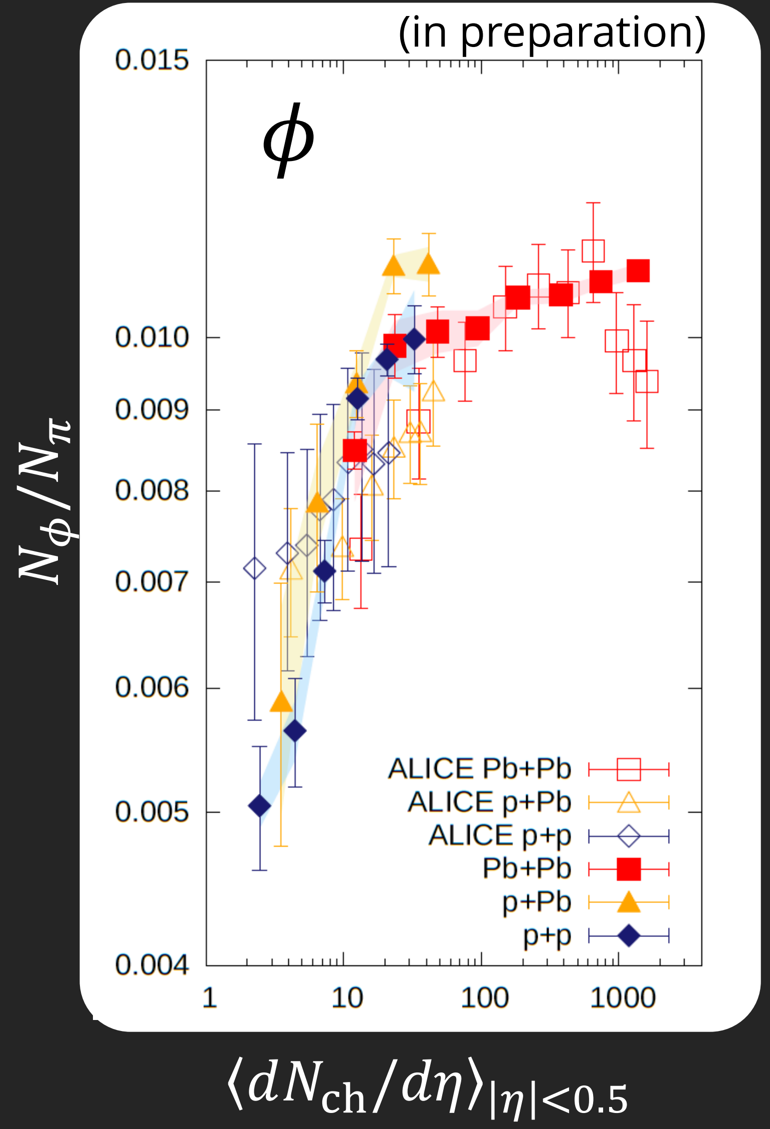
YK *et al.*, PTEP 2018 (2018) no.12, 121D01





Results —Yield ratios Λ/π, ϕ/π, p/π—





Increase behavior in exp. data

Phi meson ϕ $(S = 0)$
→Expected flat dependence with multiplicity from canonical suppression models

V. Vislavicius *et al.*, arXiv:1610.03001v3

✓ Reproduction of the increasing behavior with core-corona picture

Results −Yield ratios Λ/π, ϕ/π, p/π −

<u>Our result</u>

Core: $N_p/N_\pi \sim 0.068$

Corona: $N_p/N_\pi \sim 0.06 \pm 0.005$

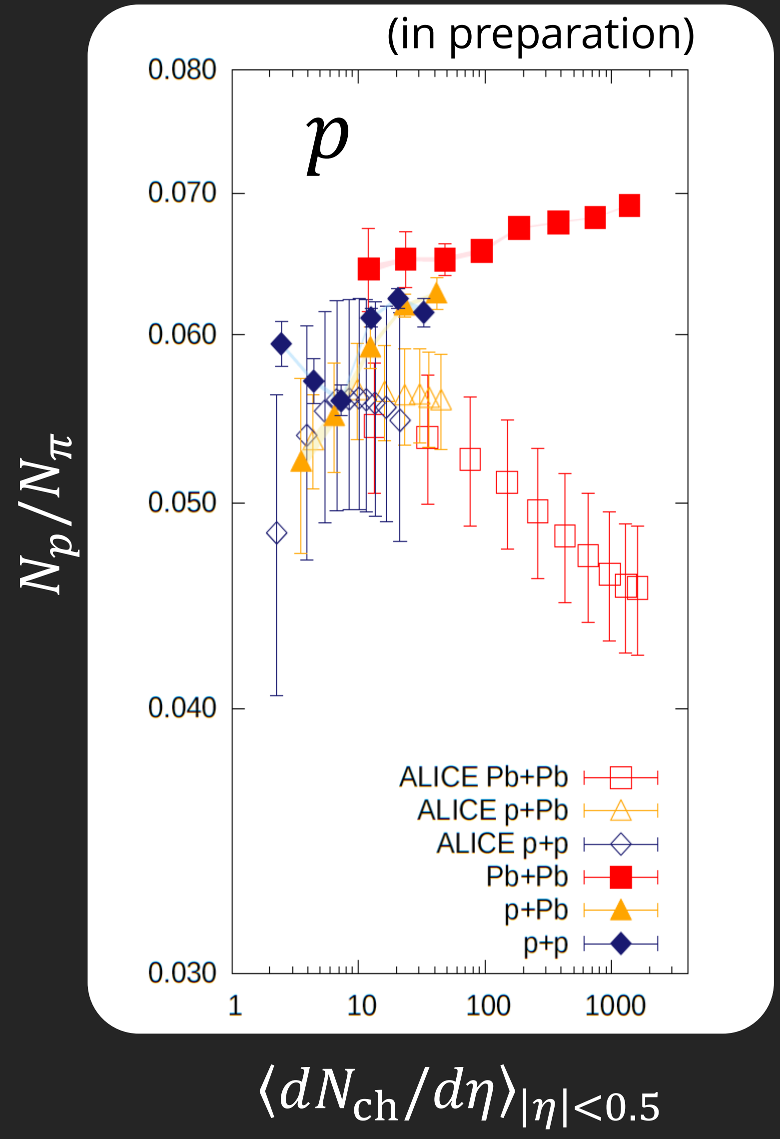
→Slight increase with multiplicity

Discrepancy?

<u>Experiment data</u>

→Suppression in high multiplicity

Need to consider effects of antibaryon-baryon annihilation from hadronic rescattering(?)



YK *et al.*, PTEP 2018 (2018) no.12, 121D01

Summary

Dynamical core-corona initialization

String fragmentation + hadronization from fluids
→ Reasonable agreement with the ALICE exp. data (Ξ/π, Λ/π, ϕ/π)
in p+p, p+Pb and Pb+Pb

*No suppression in p/π → Importance of the effect of hadronic rescattering

Universal description of QGP formation

Future work: Sophistication of our model

Collectivity, interplay between soft and hard physics ...