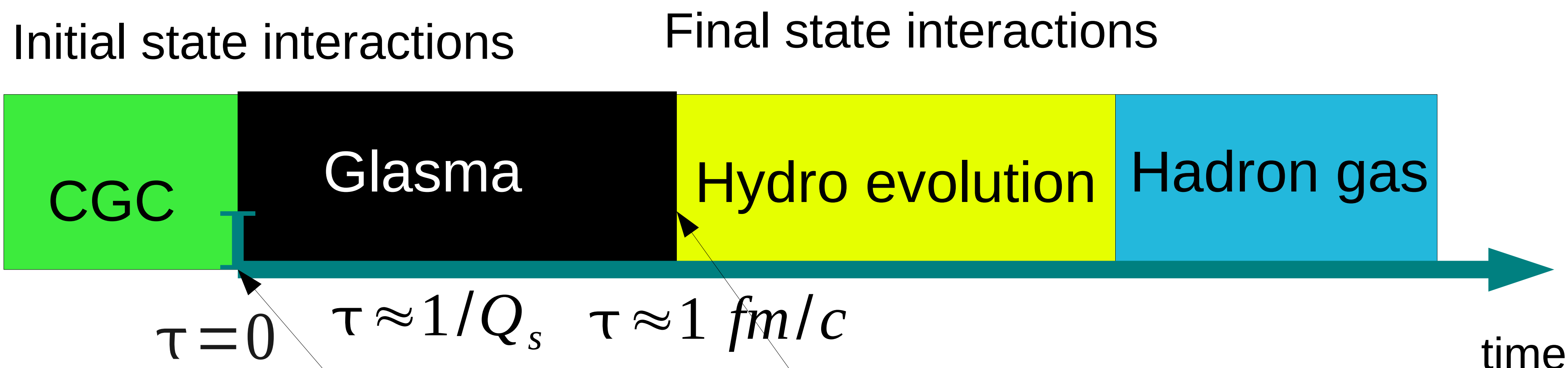
Extension of Pythia8 to high energy nuclear collisions

Yasushi Nara (Akita International Univ.)

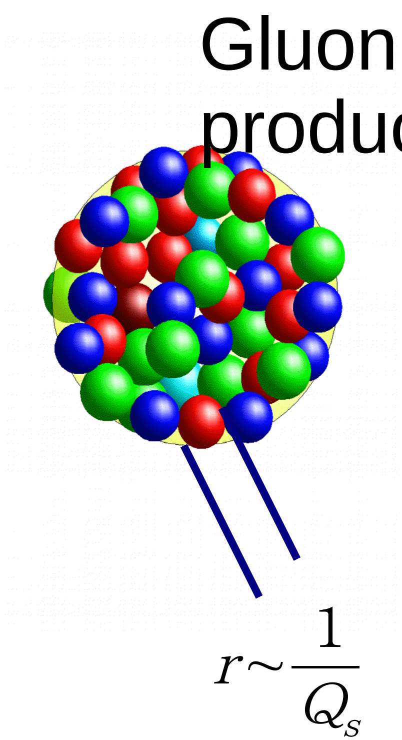
- Introduction
- How to use Pythia8 for nuclear collisions
- Comparisons with data at SPS, RHIC and LHC
- Comparisons with LHCf data
- Summary

Workshop on forward physics and high-energy scattering at zero degrees2017 , Oct 26 h-29 2017

High energy heavy ion collisions



Initial condition for hydro



p+A collision is important:

Initial condition for non-equilibrium evolution

Testing QCD at small Bjorken x

Event generators for high energy nuclear collisions

Useful tool to know baseline without QGP.
(some models includes partonic interactions or hydrodynamics.)

- HIJING
- FRITIOF
- FRITIOFP8
- EPOS
- DPMJET
- QGSJET II

Mainly for high energies Ecm>20-200GeV

Transport theoretical approaches

- UrQMD
- PHSD
- AMPT
- GiBUU
- JAM

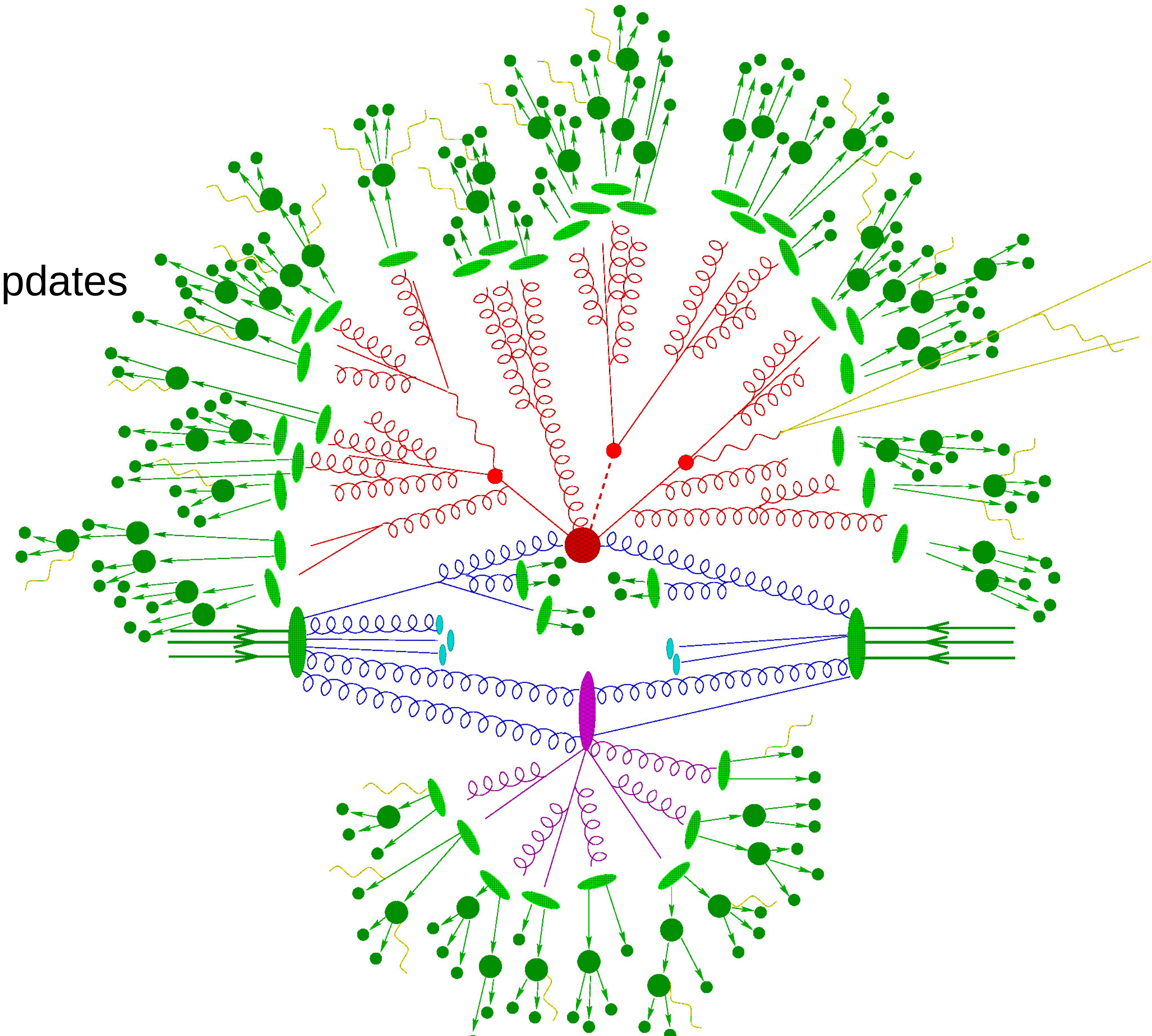
Mainly for low energies

Some of above models use Pythia to generate kinematics of pQCD scatterings, and/or hadronization by Lund string model. But their modeling and formalism are different from Pythia.

General purpose Event generators for pp

- Pythia 8
- Herwig++
- Sherpa

There are many new features and updates



- PQCD hard scattering
- Multiple scattering
- Initial state raiation
- Final state radiation
- Soft physics
- hadronization

Gluon production based on CGC

- x-evolution + Solving classical Yang-Mills equation

CYM + IP-sat model, Schenke, Tribedy, Venugopalan
CYM+JIMWLK evolution, Lappi, Phys.Lett.B703(2011)325,
B.Schenke,.Schlichting, PRC94(2016)

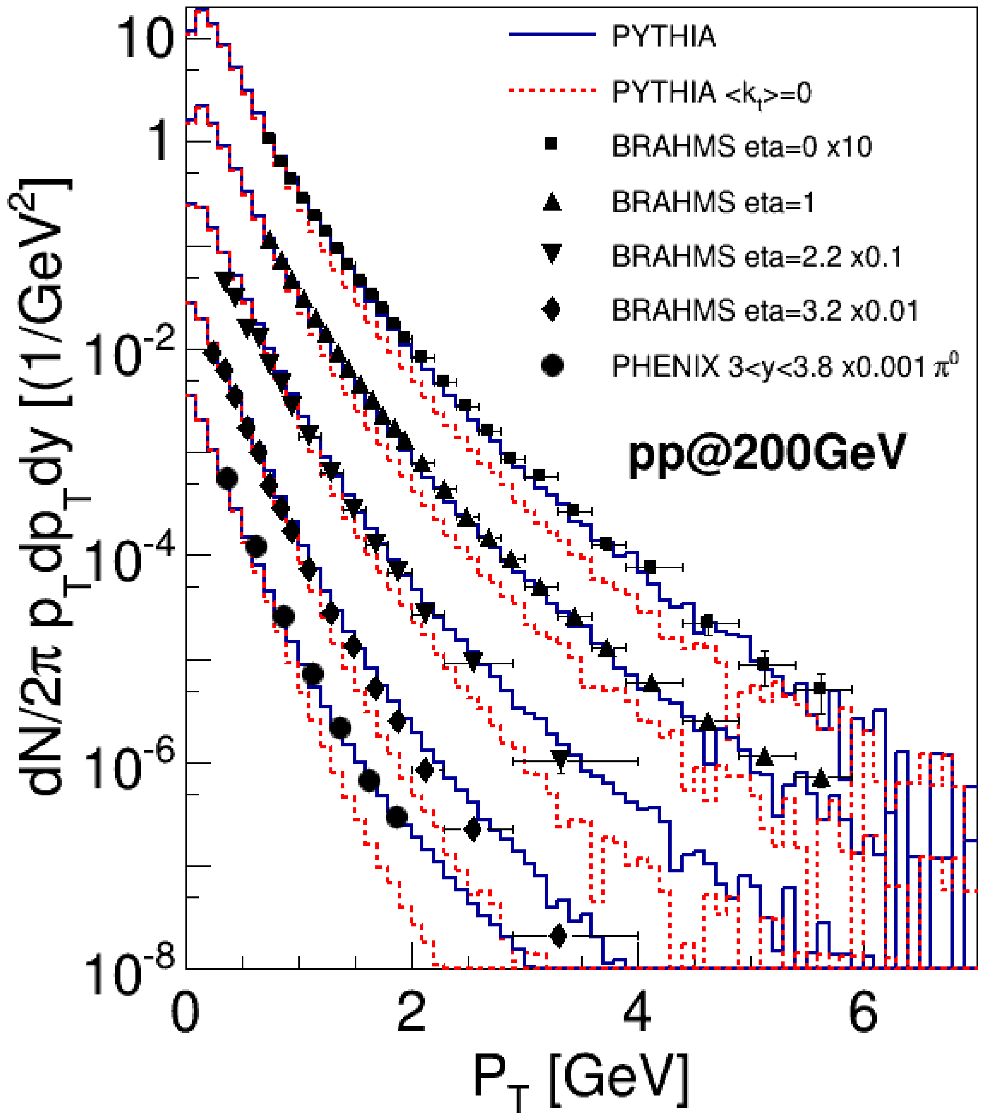
- rcBK evolution + Based on kt-factorization formula

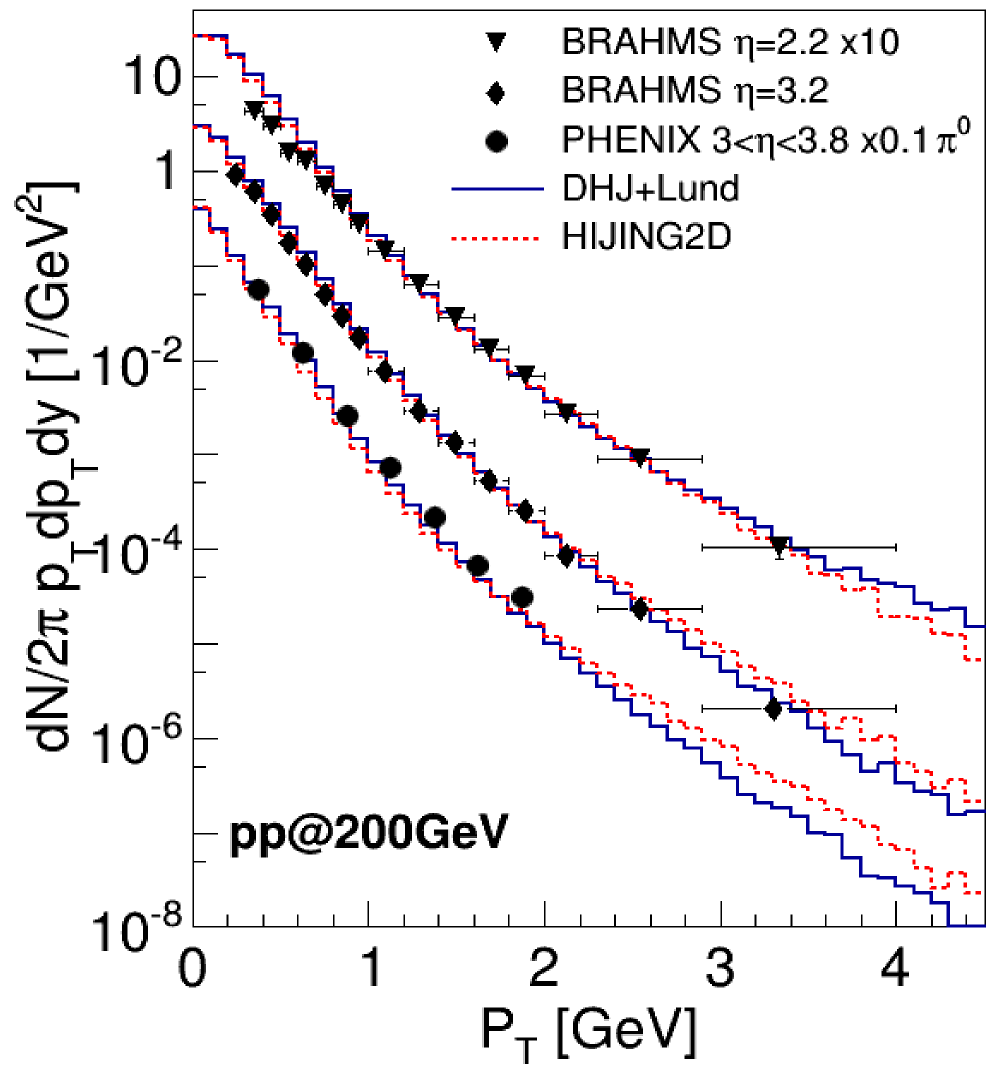
$$\frac{dN_g}{d^2 x_t dy} = \frac{4\pi N_c}{N_c^2 - 1} \int \frac{d^2 p_t}{p_t^2} \int d^2 k_t \alpha_s \phi(x_{1,} k_t^2) \phi(x_{2,} (p_t - k_t)^2)$$

Forward particle production: Dumitru Hayashigaki Jalilian-Marian (DHJ)
Albacete, Armesto,Mihano, Salgado 2009 for HERA fit

$$\frac{dN}{d^2 p_t dy} = \frac{K}{(2\pi)^2} \sum_i \int_{x_F}^1 \frac{dz}{z^2} x_1 f(x_{1,} p_t^2) N_i(x_{2,} p_t / z) D_{h/i}(z, p_t^2)$$

P + P@200GeV negative hadrons





Motivation and Purpose

Application of MC such as Pythia8,
Herwig++, Sherpa to nuclear collisions.

Prupose: MC-EG truly based on Pythia8

- Application of state of art MC in hadron-hadron collisions to nuclear collisions.
- What can we learn from a “straightforward” application of pythia8 to nuclear collision?
- A new initial condition for high energy heavy ion collisions.
- Fluctuations are naturally included.

How to generate NN collisions? Coherent scattering?
How to connect partons for hadronization?

Initial state nuclear effects

Final state nuclear effects → collective effect
is not included for now

How to simulate NN collision?

1) nucleon-nucleon collisions will occur if

$$(x_i - x_j)^2 + (y_i - y_j)^2 \leq \frac{\sigma_{NN}}{\pi}$$

2) In the case of nucleon with Gaussian shape:

$$T_p(r) = \frac{1}{2\pi B} \exp[-r^2/(2B)]$$

NN collision probability $P(b) = 1 - \exp[-kT_{pp}(b)]$

$$T_{pp}(b) = \int d^2 s T_p(s) T_p(s - b)$$

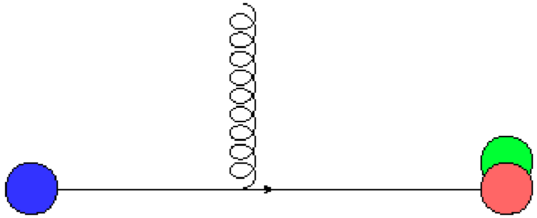
k is fixed by the relation $\sigma_{in} = \int d^2 b \, (1 - \exp[-kT_{pp}(b)])$

How to simulate NN collision II

Test two simple methods:

a) Each collision produces strings and hard partons until "nucleons" pass through nucleus.

FRITIOF, HIJING,…

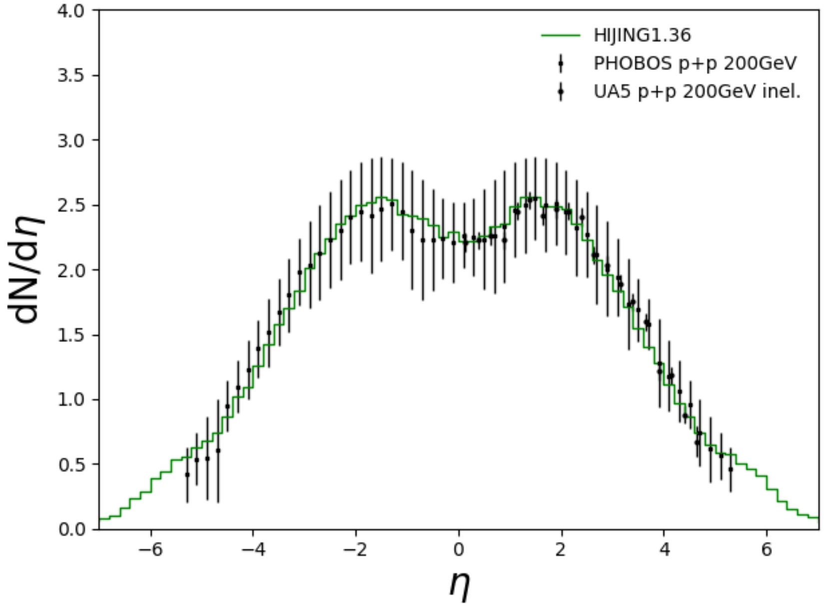


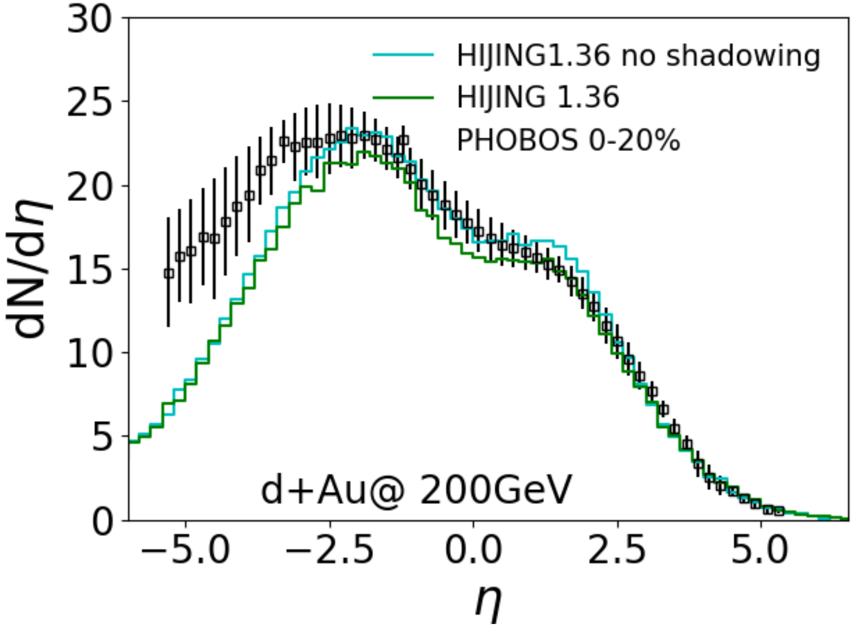
should work for high energies ecm > 20 GeV

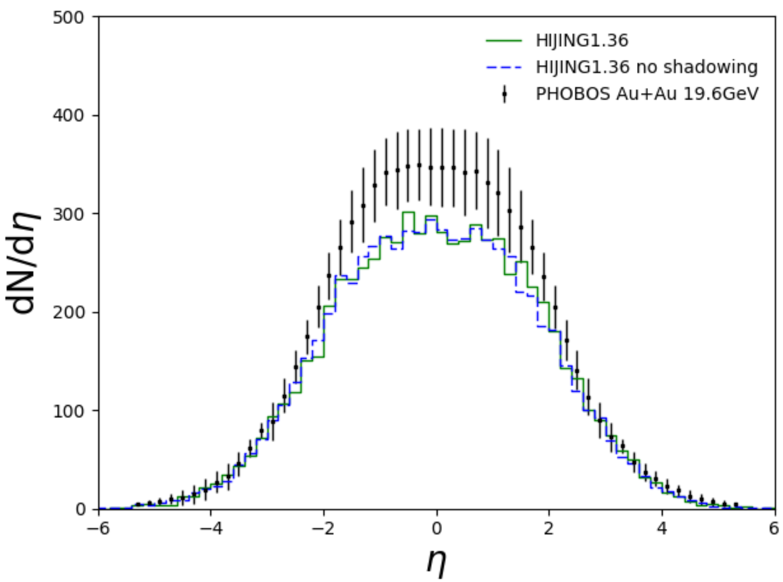
b) Hadronic cascade method:
At each collision, strings are immediately hadronized, and leading hadrons can interact again.

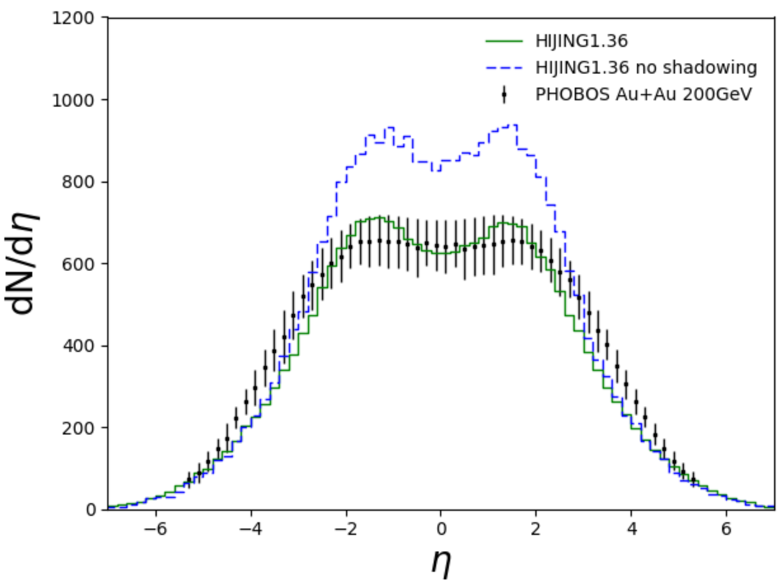
UrQMD, JAM…

HIJING results





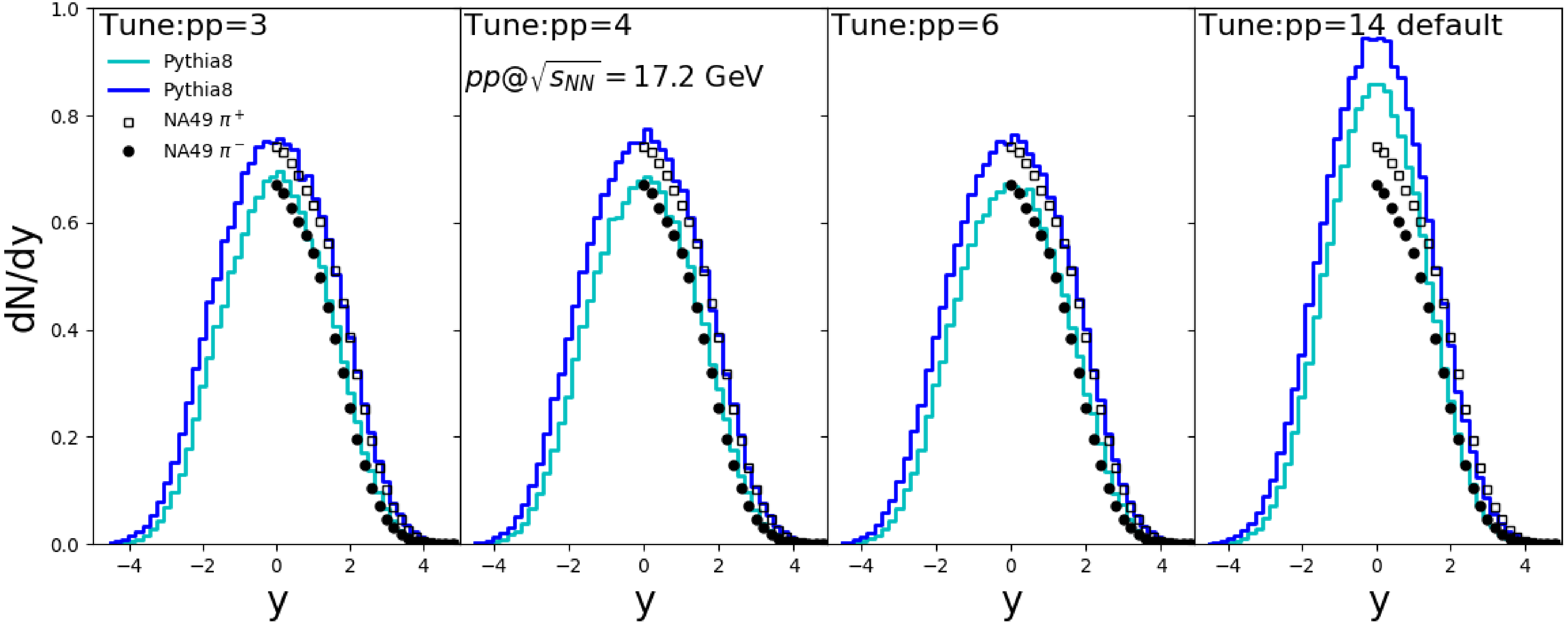




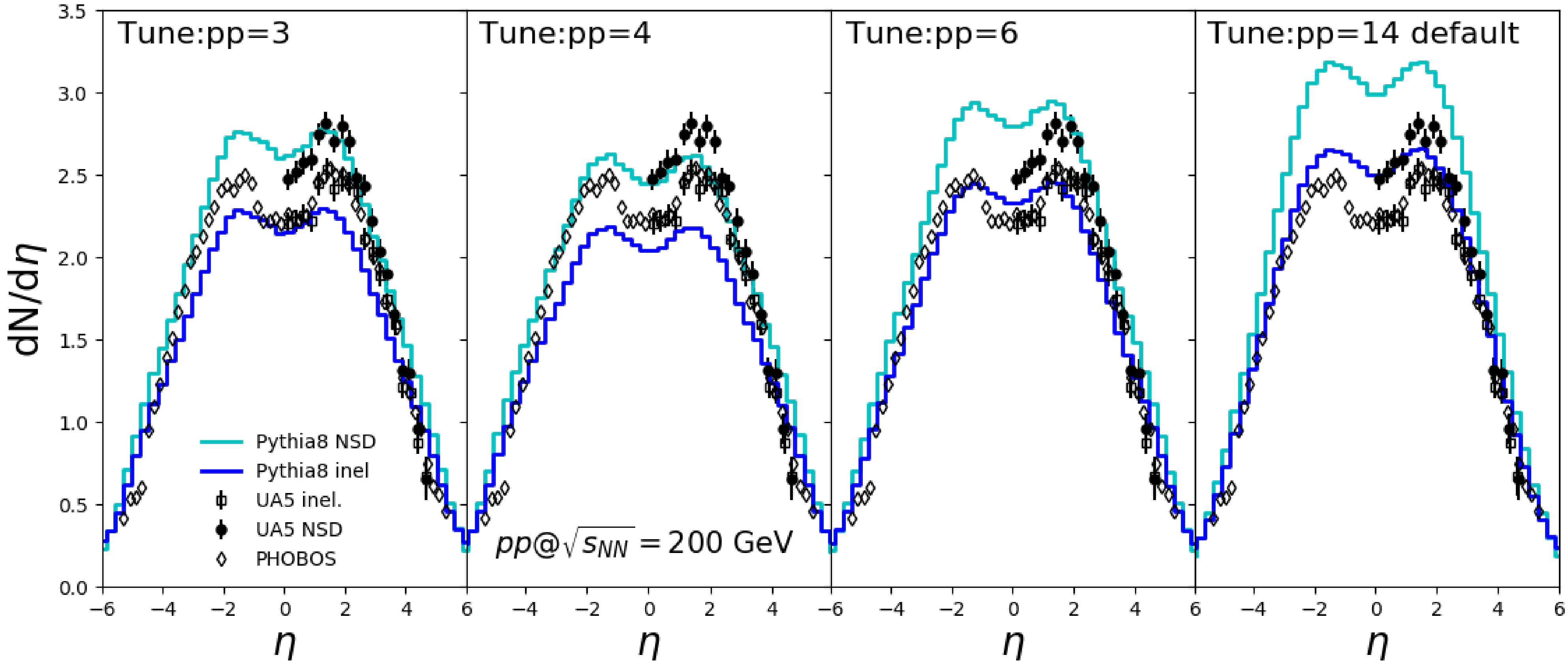
Initial nuclear effect is very important at RHIC, but not at SPS eneriges.

Pythia 8.223 (default Monash2013) p+p at e.cm = 17.2 GeV

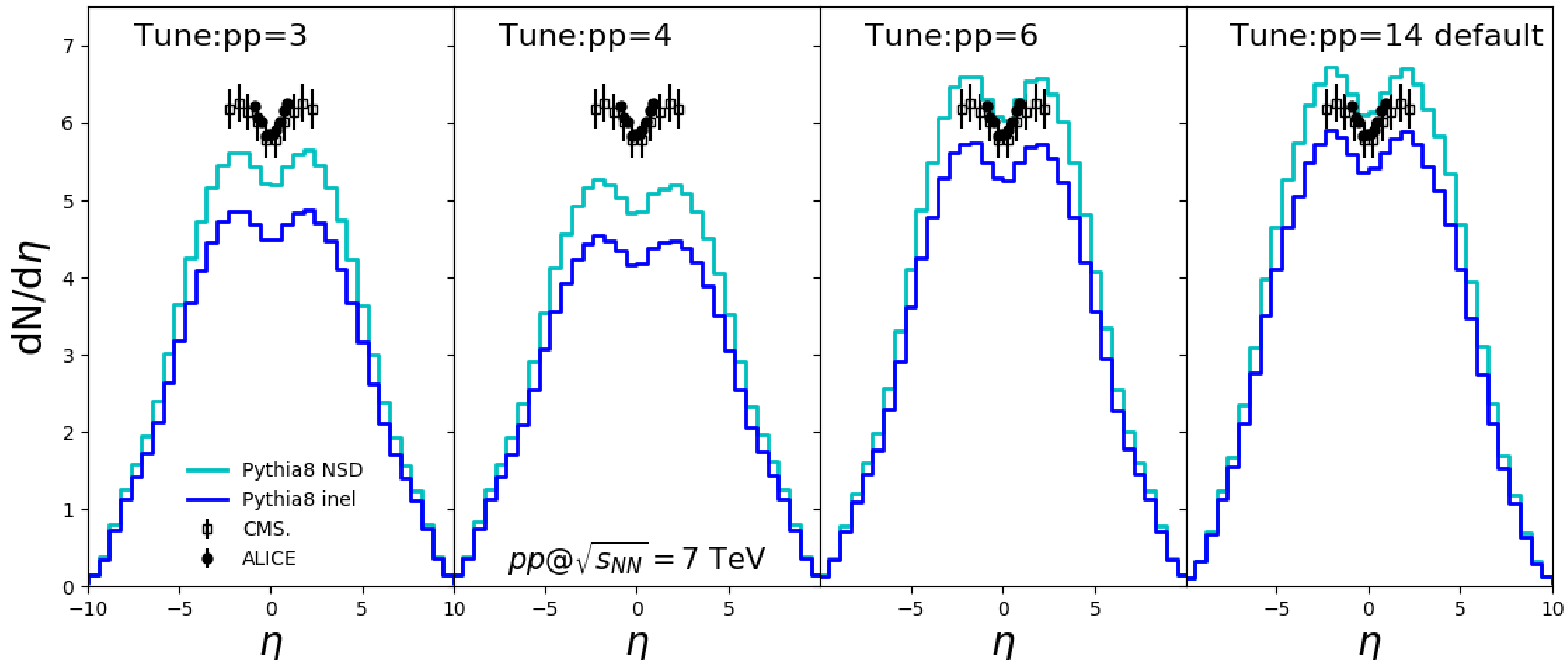
Tunes available in Pythia 8.223
Tune:ee: 1-7, (default 7)
Tunepp: 1-34 (default 14)



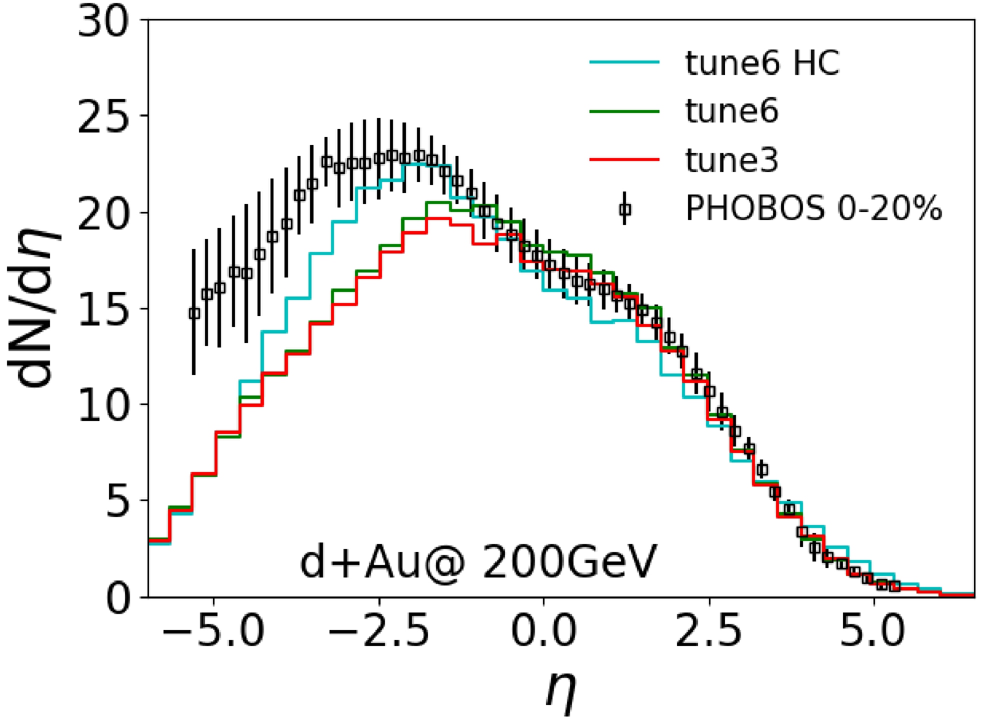
Pythia 8.223 results for 200GeV

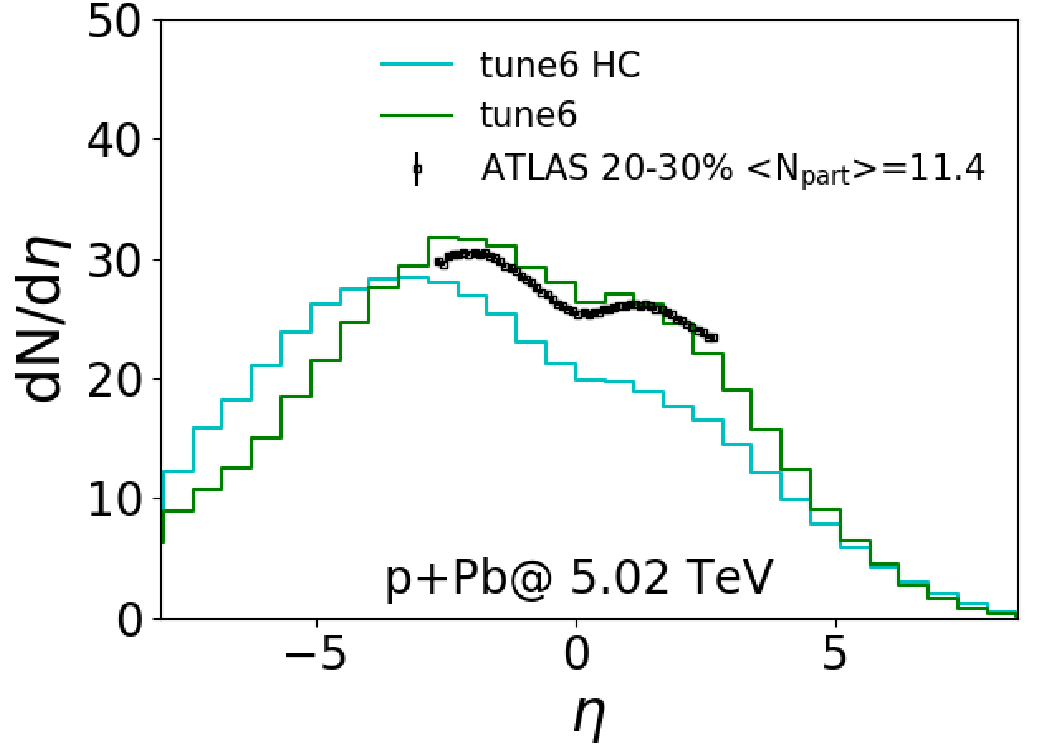


Pythia 8.223 results for 7 TeV

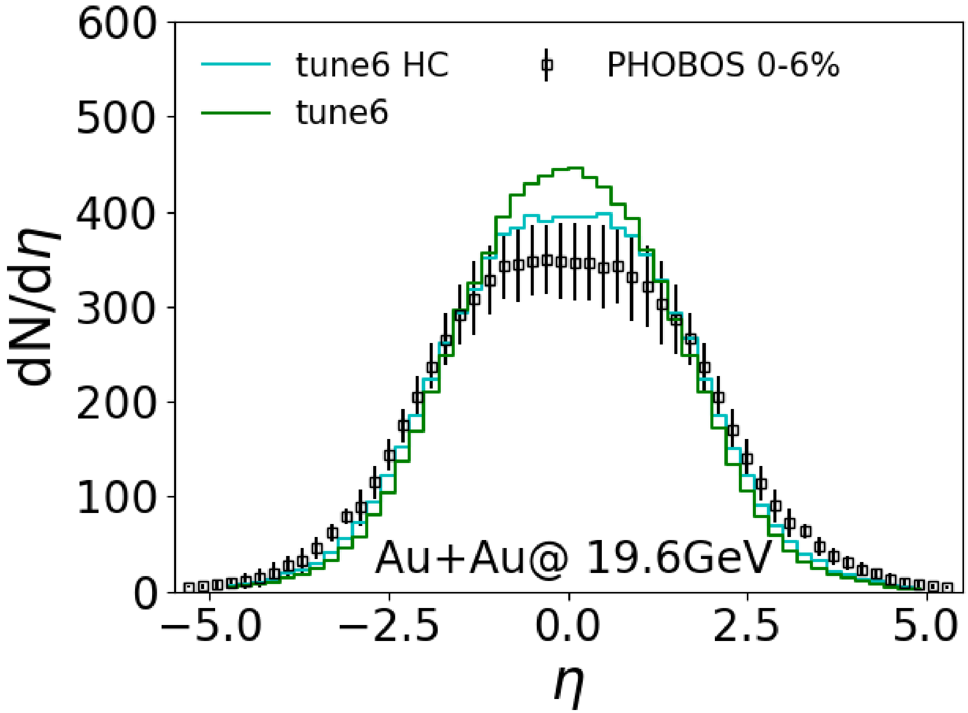


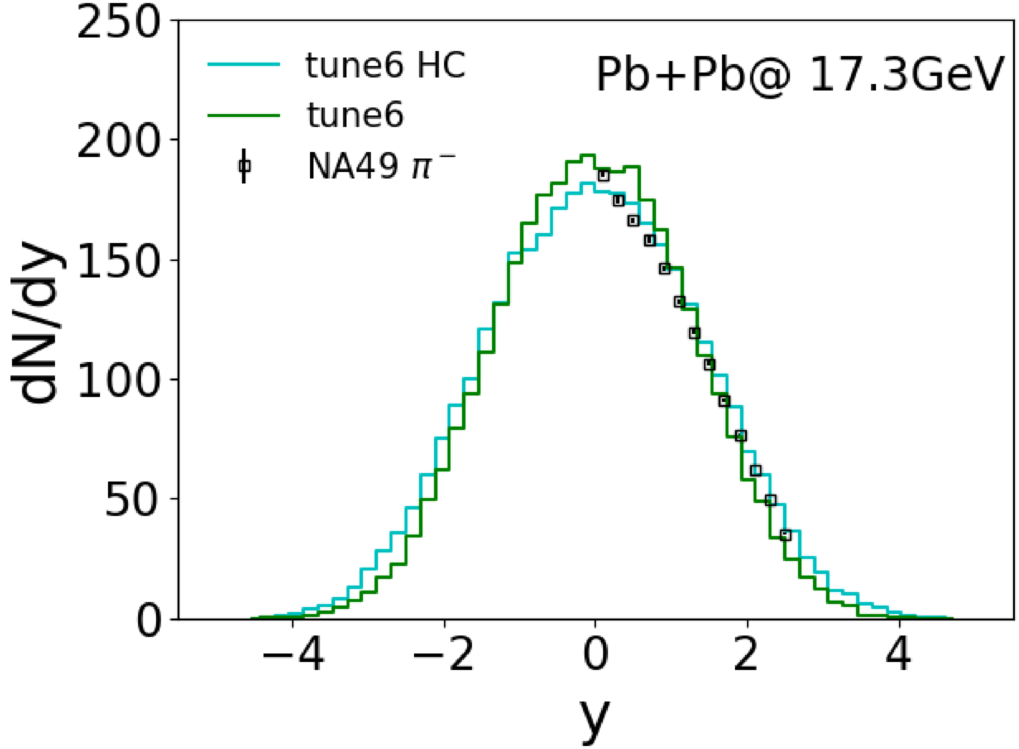
nPythia for d+Au and p+Pb



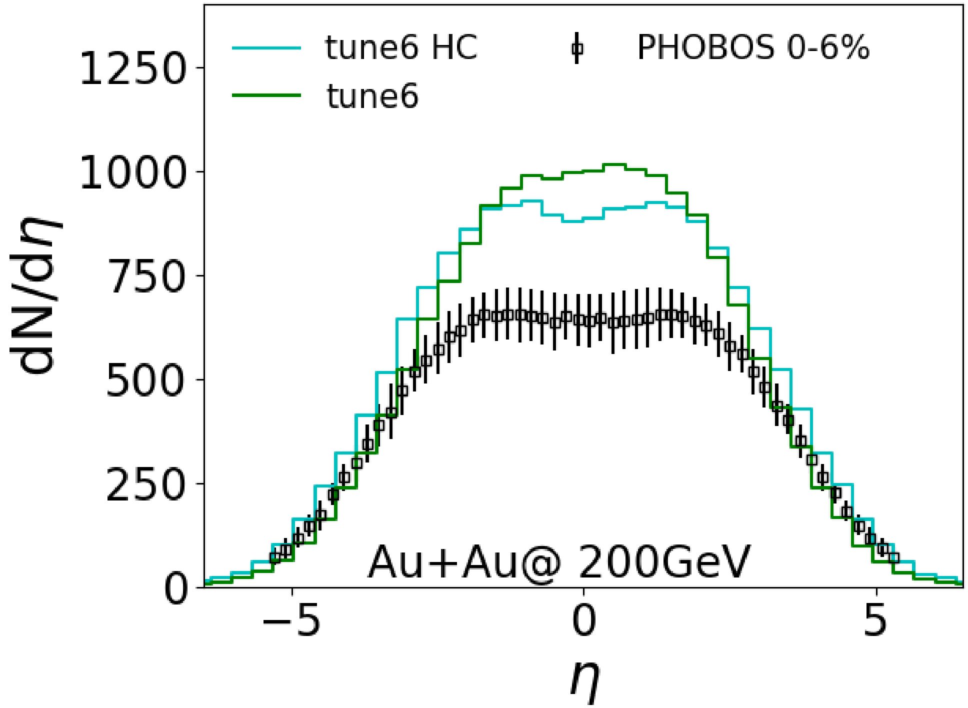


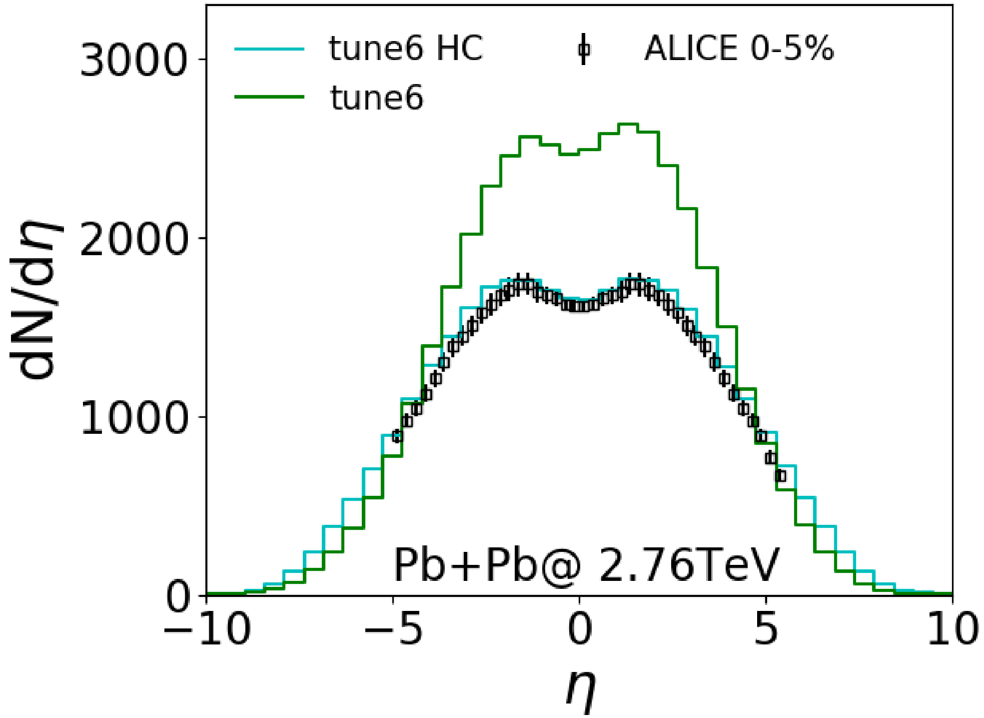
nPythia for A+A at SPS energies

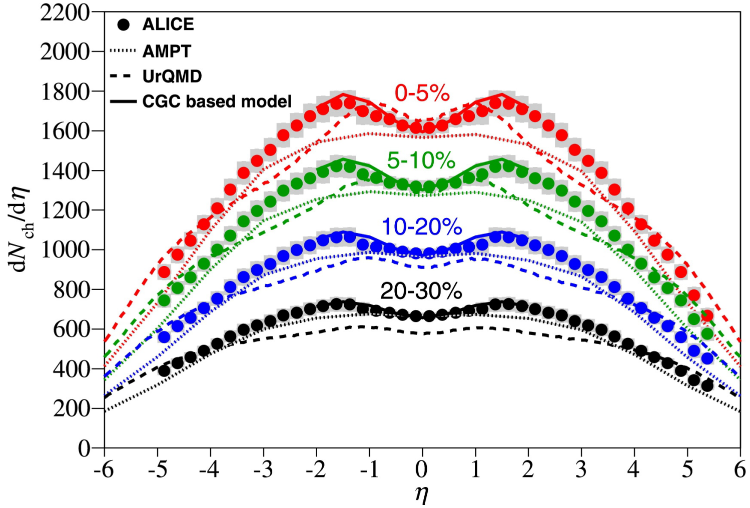




nPythia for A+A at RHIC and LHC



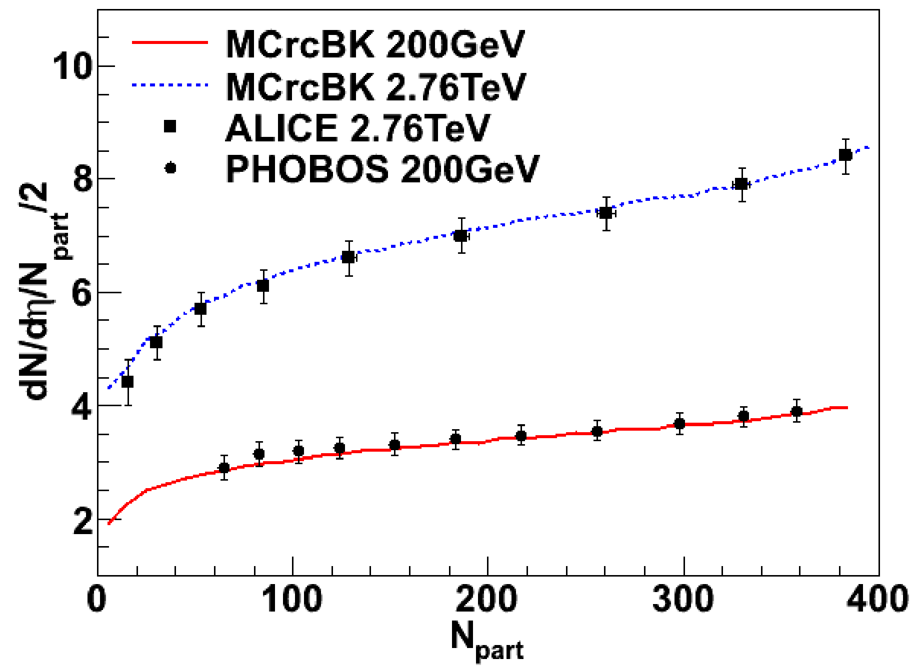




Alice:PLB726(2013)

Nuclear effect

Initial state saturation:
CGC (kt-fact.)

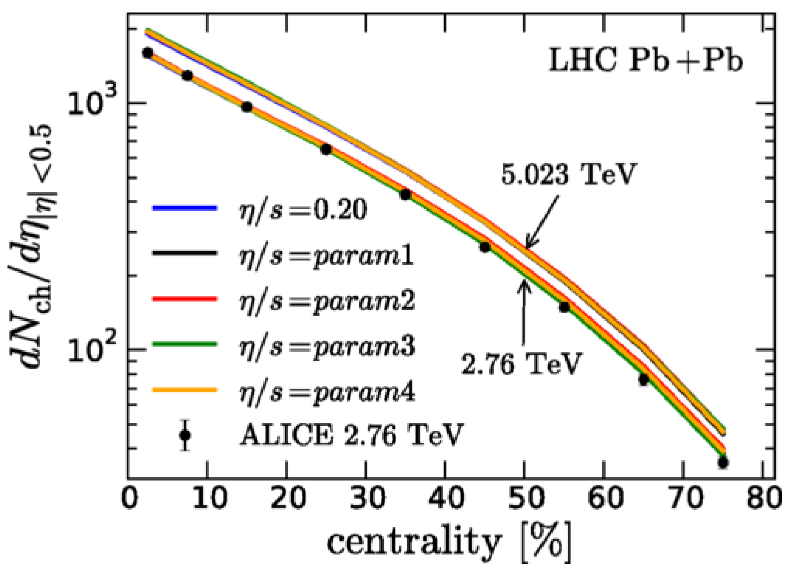


$$\frac{dN_g}{d^2 x_t\, dy} = \frac{4\pi N_c}{N_c^2 - 1} \int \frac{d^2 p_t}{p_t^2} \int d^2 k_t \alpha_s \phi(x_1, k_t^2) \phi(x_2, (p_t - k_t)^2)$$

$$\frac{dN}{d^2 \boldsymbol{x}_\perp dy} \sim \min\{N_{part,1}(\boldsymbol{x}_\perp), N_{part,2}(\boldsymbol{x}_\perp)\}$$

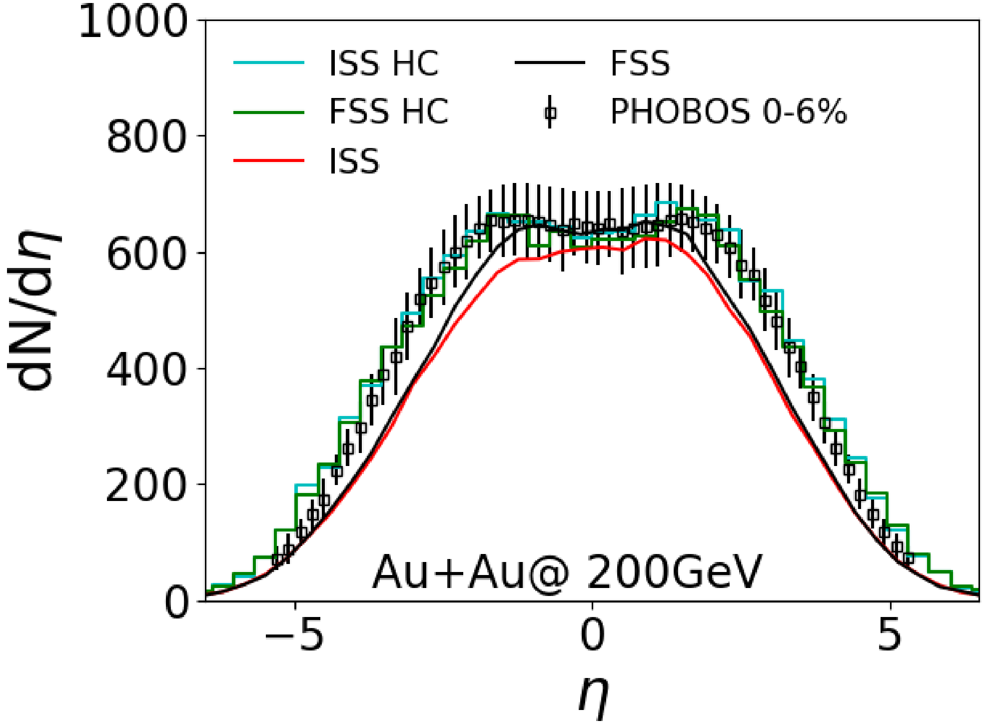
final state saturation
(EKRT: Finland group)

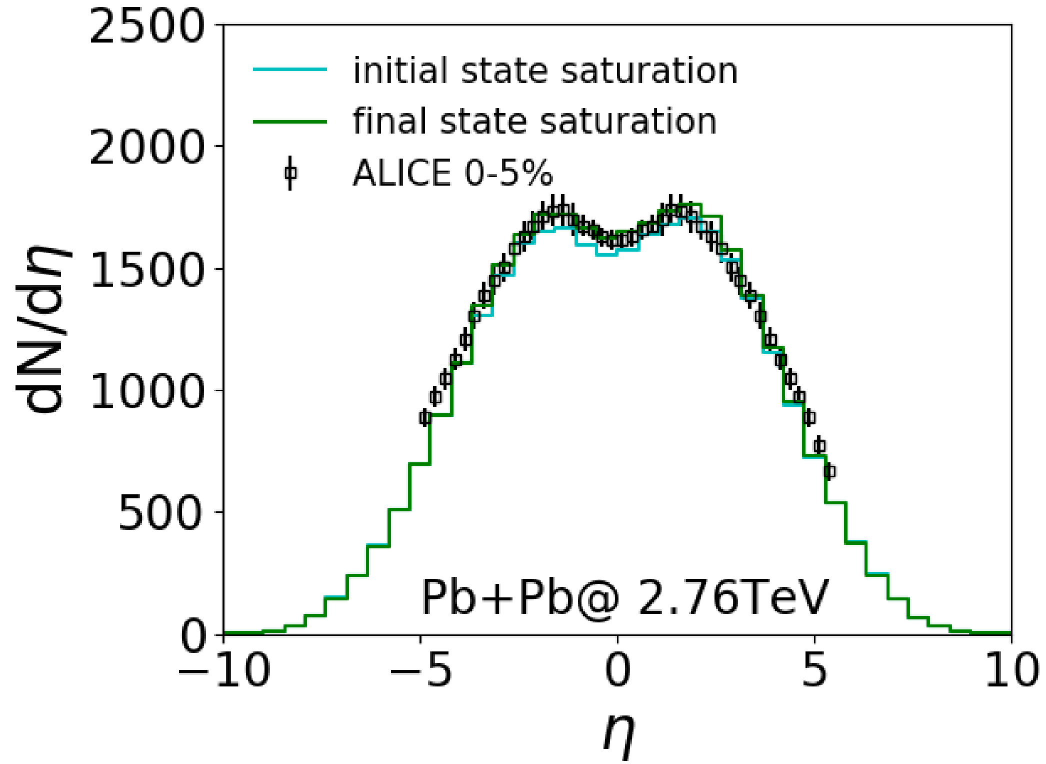
$$N_{coll} \sigma_{jet} \frac{\pi}{p^2} = \pi R^2$$



EKRT prediction: PRC93(2016)

nPythia for A+A at RHIC and LHC





$$T_A \cdot T_B > a \rightarrow \text{no nondiffractive}$$

$$\min(T_A, T_B) > a \rightarrow \text{no nondiffractive}$$

$$T_A = \frac{\text{number of nucleons}}{S}$$

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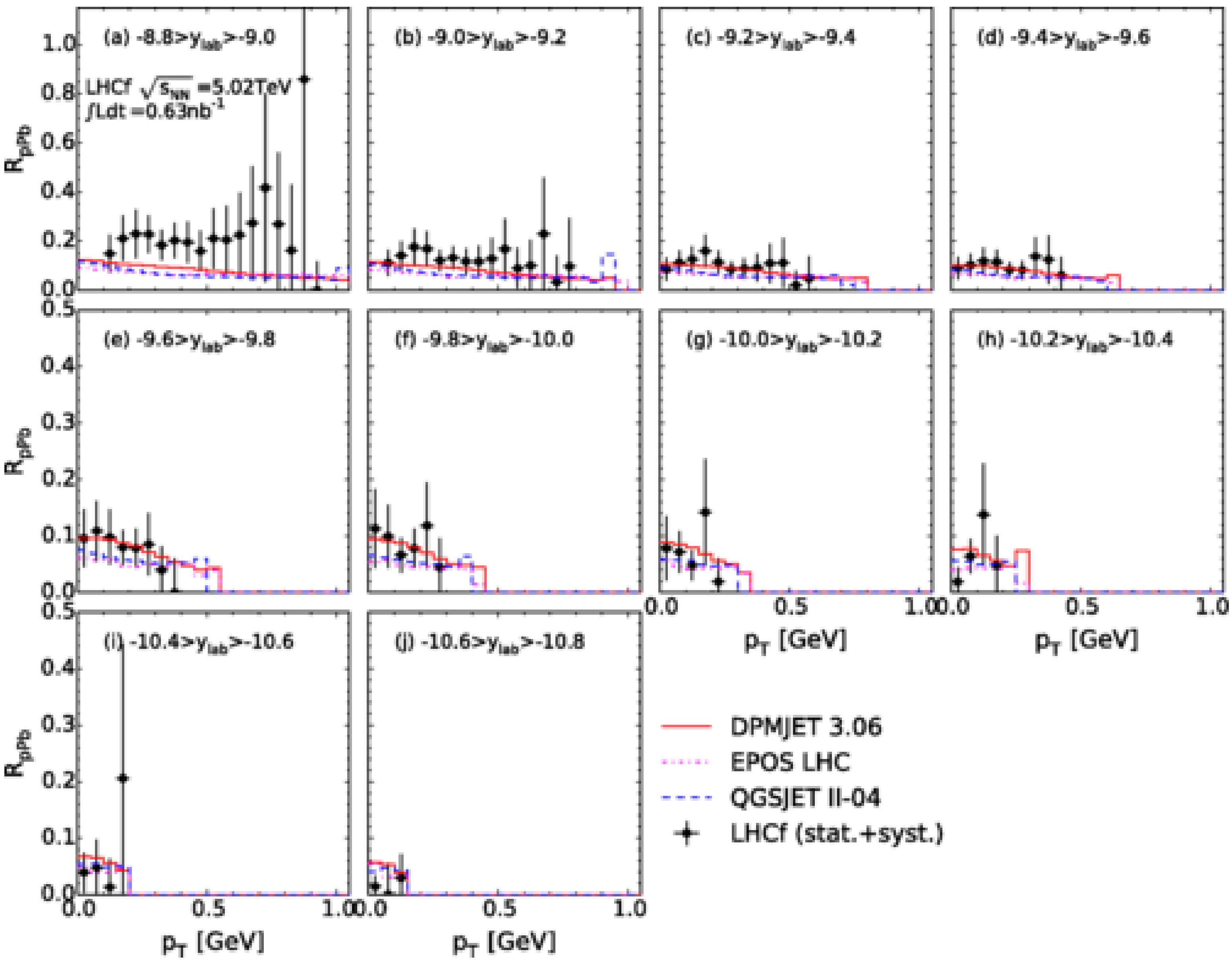
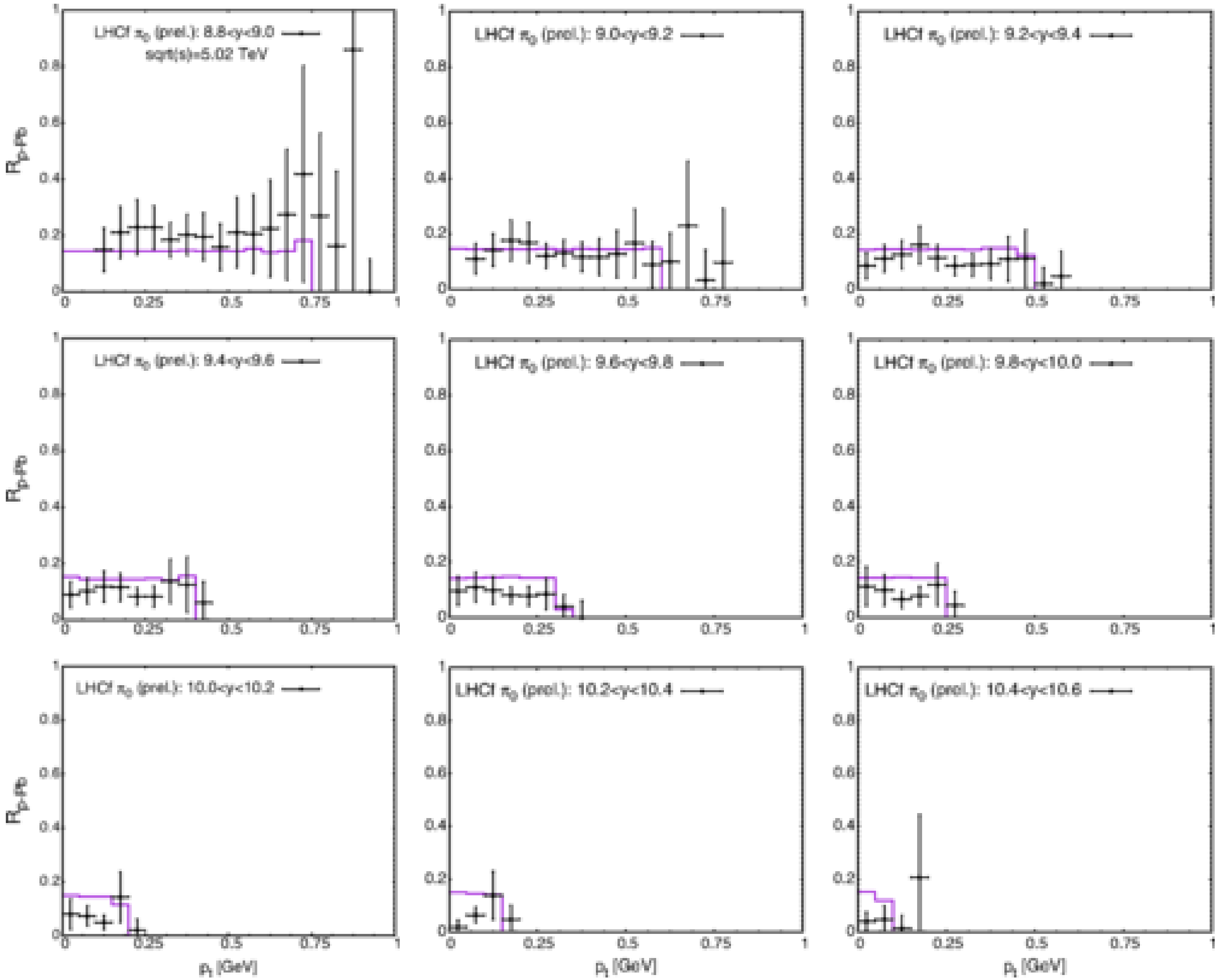
RpA at 5.02 GeV from LHCf

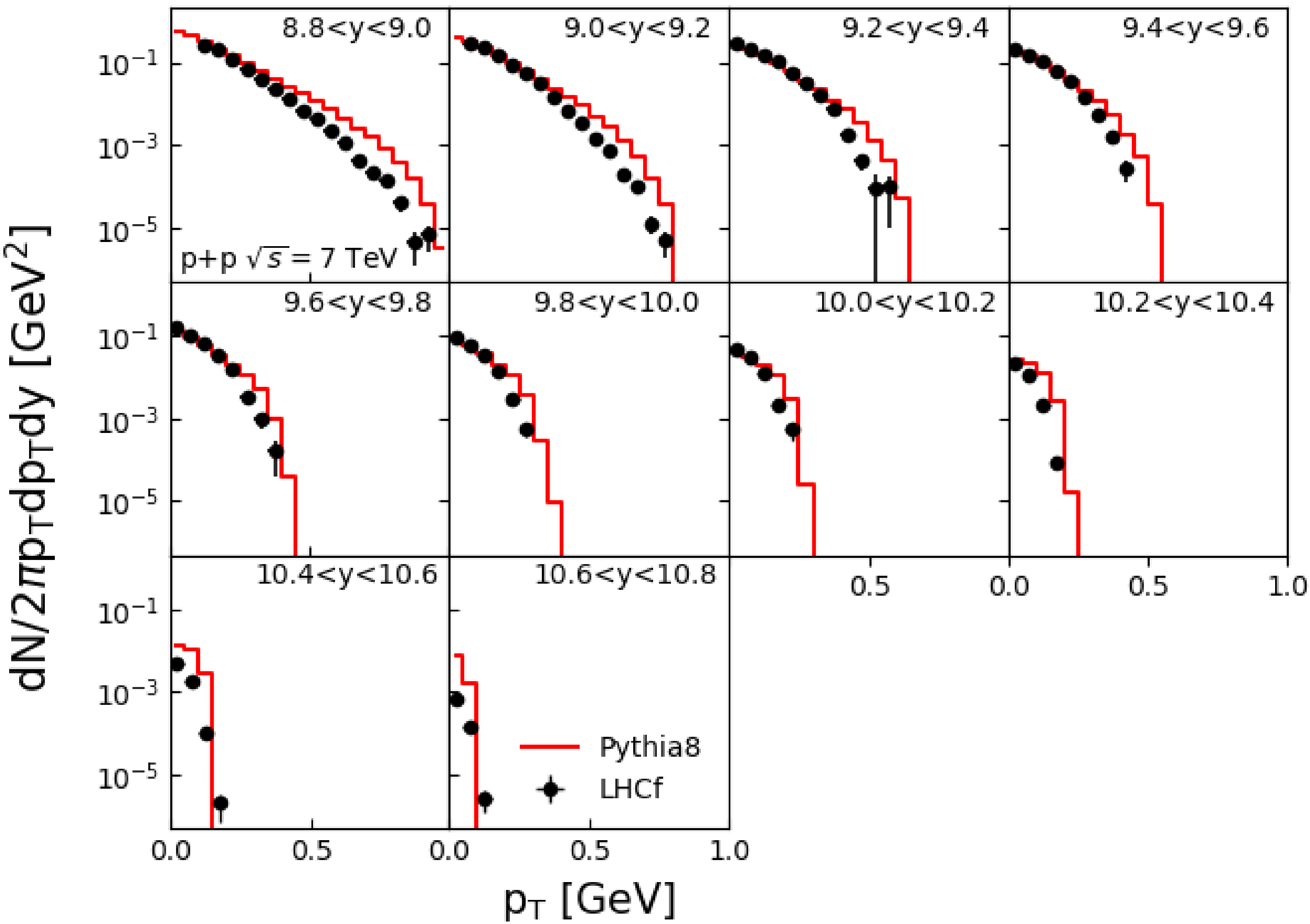


Phys.Rev. D94 (2016) no.5, 054004

RpA at 5.02 GeV from CGC

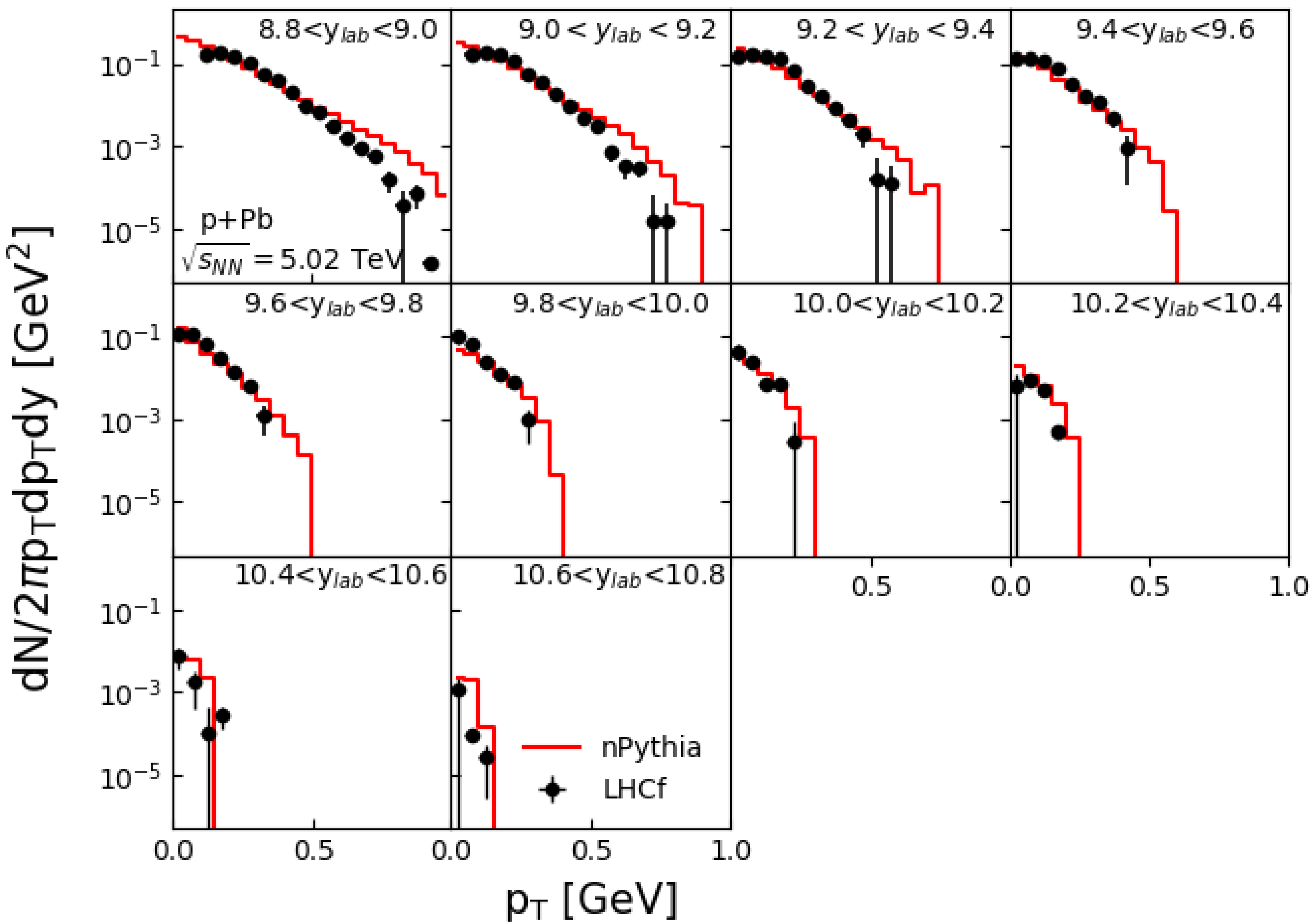


p+p at 7 GeV

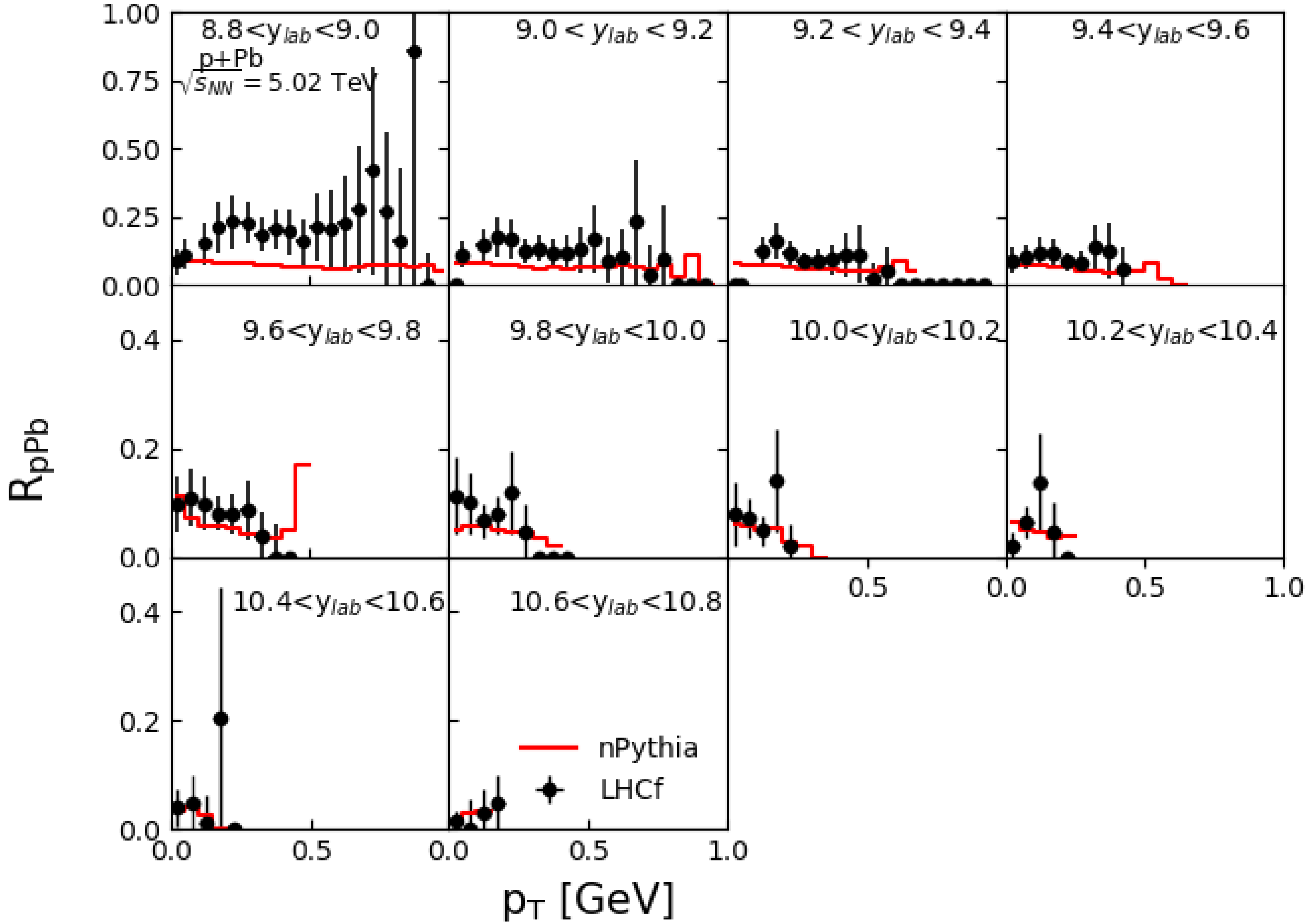


8.8<y<9.0
9.0<y<9.2
9.2<y<9.4
9.4<y<9.6
9.6<y<9.8
9.8<y<10.0
10.0<y<10.2
10.2<y<10.4
10.4<y<10.6
10.6<y<10.8
p+p √s = 7 TeV
10^{-1}
10^{-3}
10^{-5}
0.0
0.5
1.0
dN/2πp_T dp_T dy [GeV^2]
p_T [GeV]
Pythia8
LHCf

p+Pb at 5.02 GeV



Nuclear Modification factor at 5.02 GeV



summary

- Monte-Carlo Event Generator nPythia based on Pythia8 has been newly developed. (There are many things to do in the future).

- Nuclear suppression is not seen in
  A+A at SPS, d+Au at RHIC, p+PB at LHC

- Huge nuclear suppression is needed for A+A at RHIC and LHC.

- Implementation of nuclear PDF
- Test different assumptions of color connections.
- Systematic studies (centrality, baryons, pt distributions)