

HIJING code of Geant4

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HIJING: Heavy Ion Jet Interaction Generator

Xin-Nian Wang and Miklos Gyulassy, *Physical Rev. D* **44**, 3501(1991)

- A microscopic transport model
- Build to work at RHIC and LHC energy
- A two component model
- Jet Production ($p_T > p_0$) (Main source of hadrons at LHC energies)
- String interactions ($p_T < p_0$) (FRITIOF)

HIJING uses

- Eikonal formalism to determine the number of primary interacting nucleons
- PYTHIA 5.3 to generate kinetic variables for each scattering.
- JETSET 7.2 for string and jet fragmentation.

Parameters of HIJING code

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- The jet cross section σ_{jet} .
 - Cut off parameter p_0 .
- The soft parton cross section σ_{soft} .
- ▶ **Nuclear Shadowing.**

- σ_{soft} , p_0 are determined by
 - $p + p$ inelastic and total cross sections.
- For $A + A$ collisions, one needs **Exact nuclear shadowing**

Results of the improved HIJING code at RHIC energies

Cascade and Nucleon shadowing in ImHIJING

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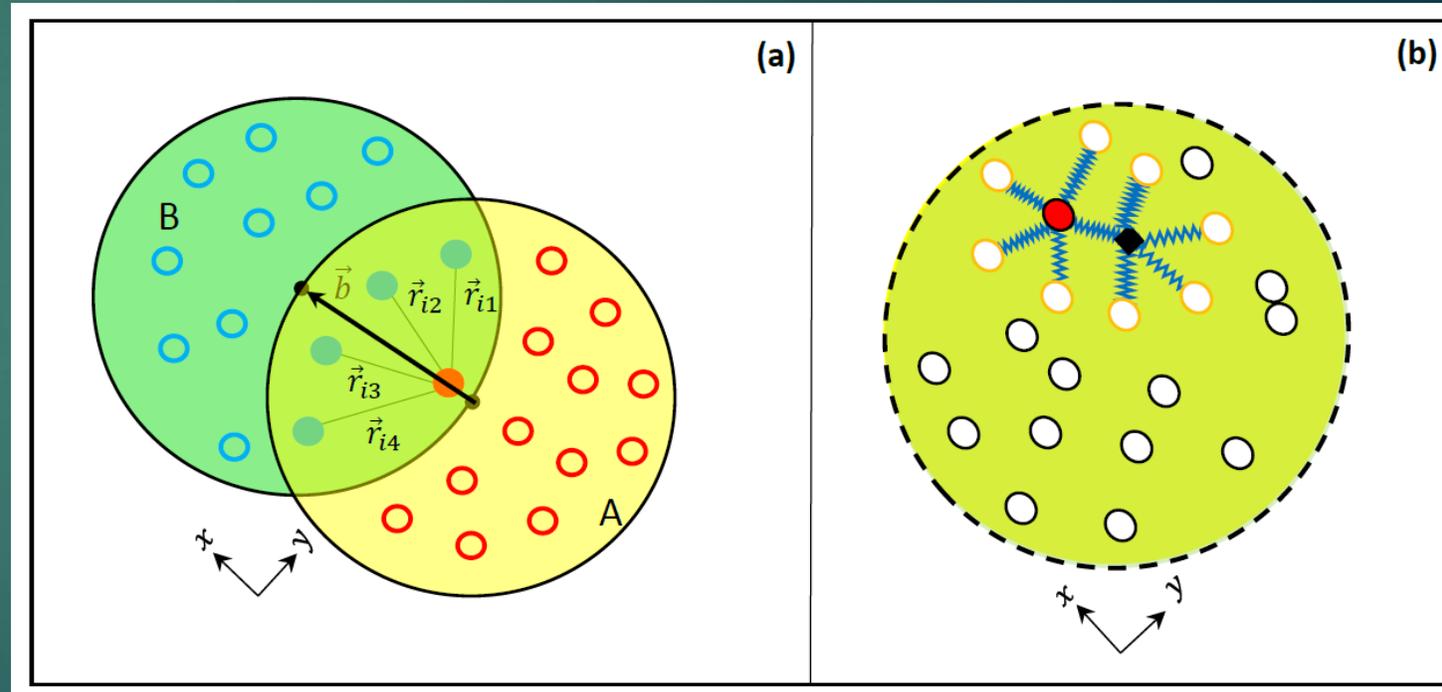
$$P(x'_i) \propto \prod_{i=1}^{N_A} \exp\left(-\frac{\left(x'_i - \frac{1}{N_A}\right)^2}{d^2}\right) \delta\left(1 - \sum_{i=1}^{N_A} x'_i\right) dx'_i$$

$$d = \frac{\gamma}{N_A}$$

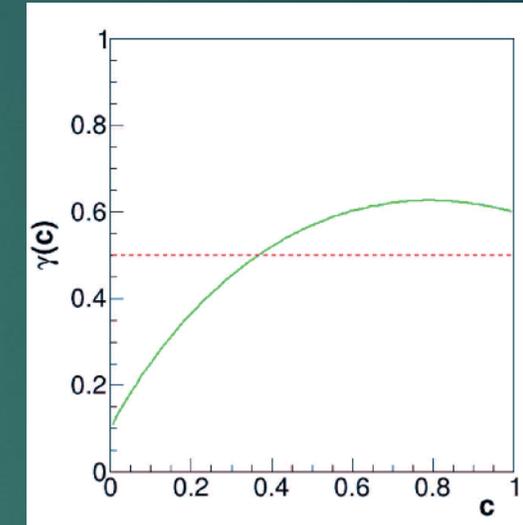
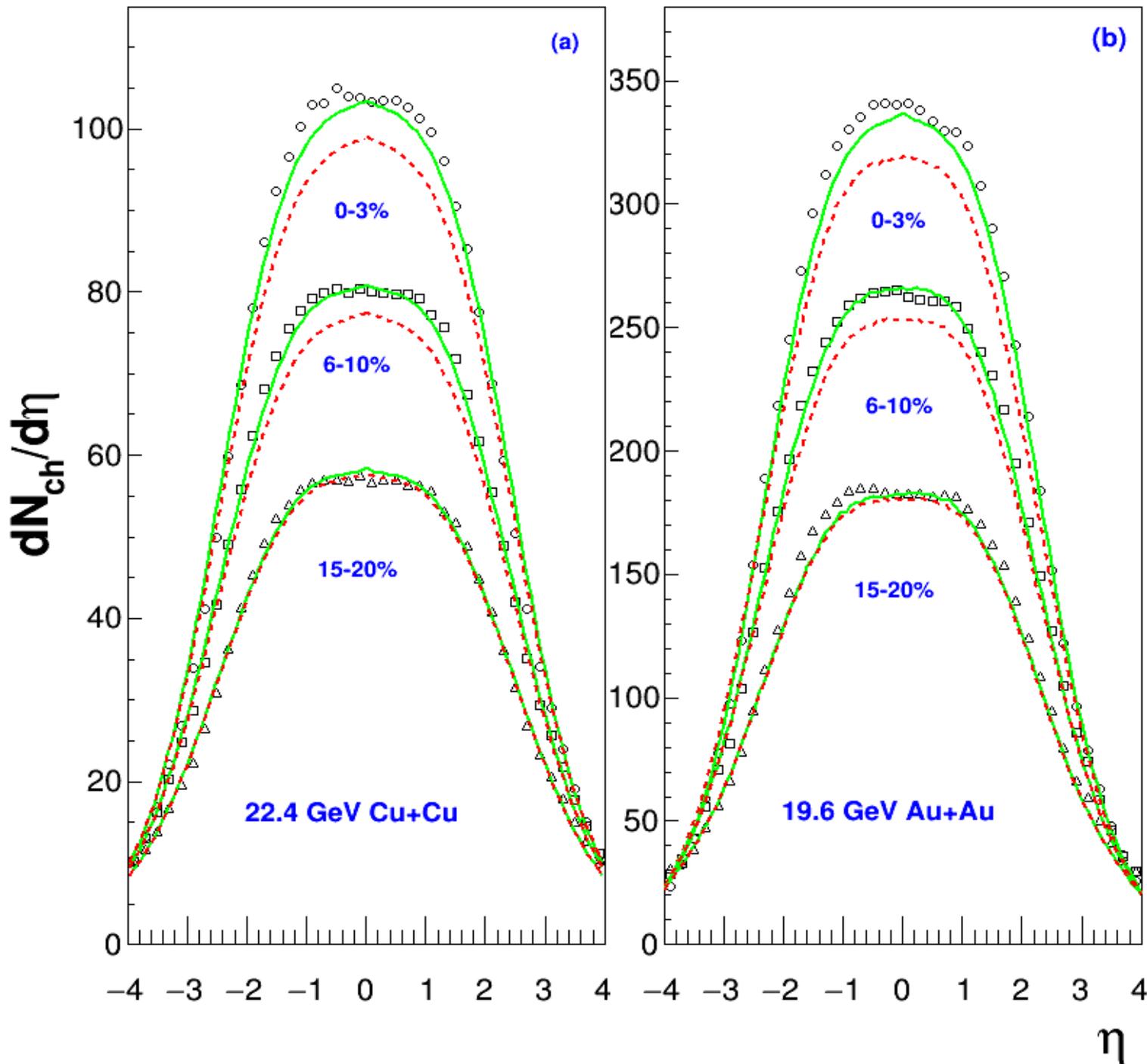
$$\gamma(c) = 0.1 + 2c\left(1 - \frac{3}{4}\sqrt{c}\right) \star \text{new}$$

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- Phys. Rev. C 91, 034908 (2015).
- Phys. Rev. C 93, 024910 (2016).
- J. Phys. G 45, 025104(2018).



$$r_{ij} = \sqrt{(b_x + x_i - x_j)^2 + (b_y + y_i - y_j)^2}$$



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J. Phys. G 45, 025104(2018)

Cascade effects

----- $\gamma(c)$ with $C = 0$

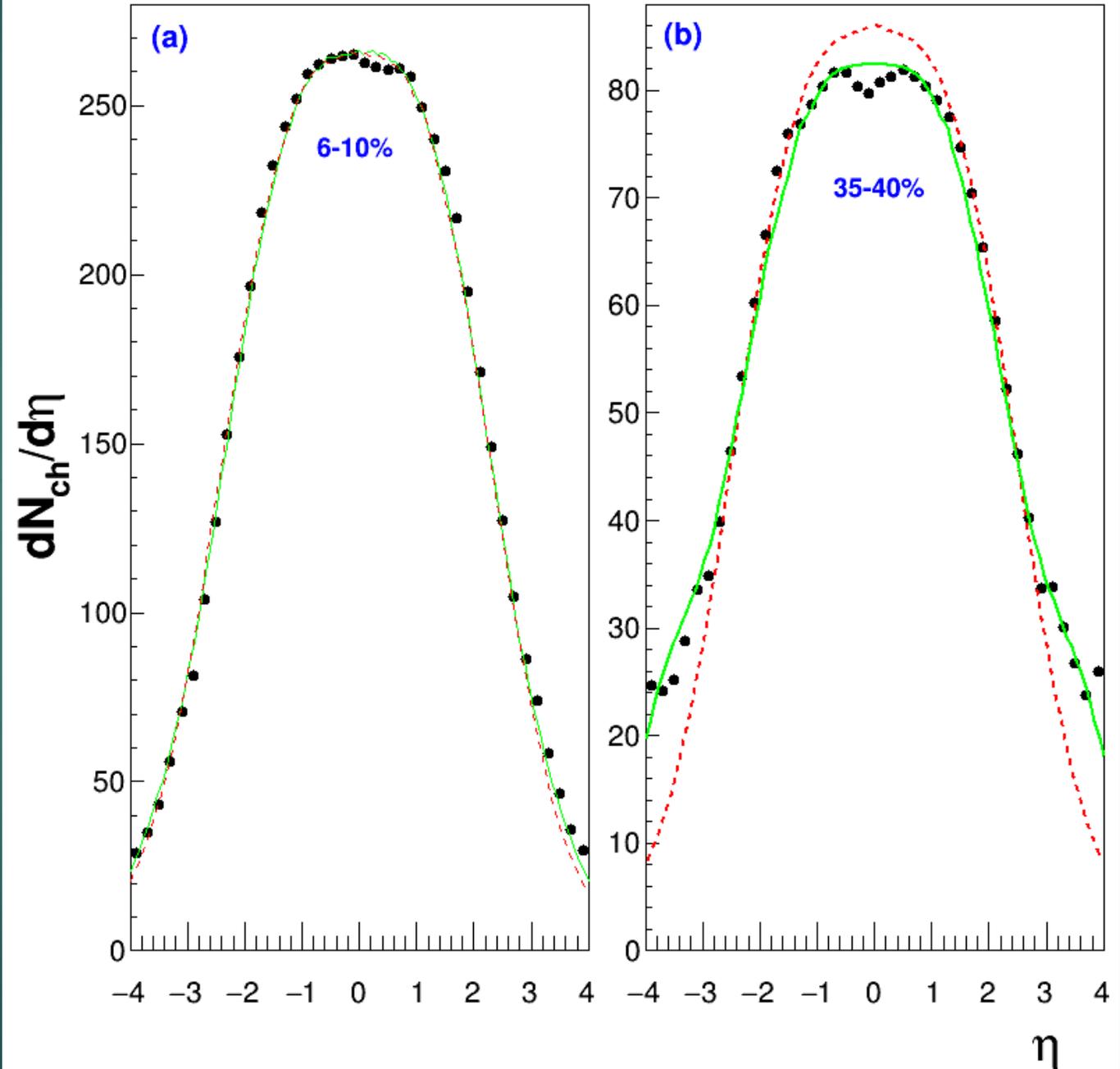
----- $\gamma(c)$ with $C = 0.5$

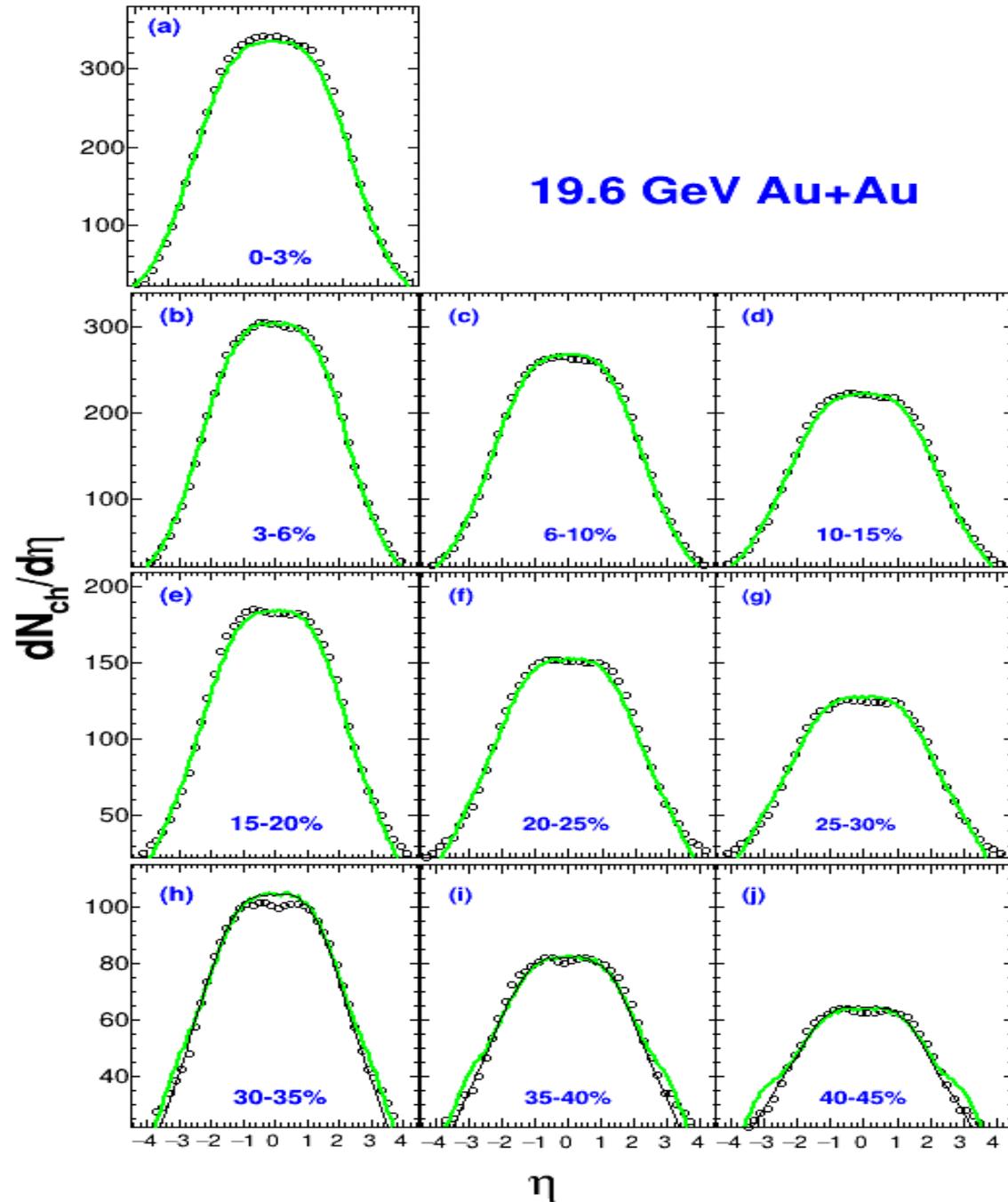
PHOBOS data,
Phys. Rev. C 83, 024913(2011)

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J. Phys. G 45, 025104(2018)

19.6 GeV Au+Au Collisions





— $\gamma(c)$ with $C = 0.5$

— $\gamma(c)$ with $C = 0.25$

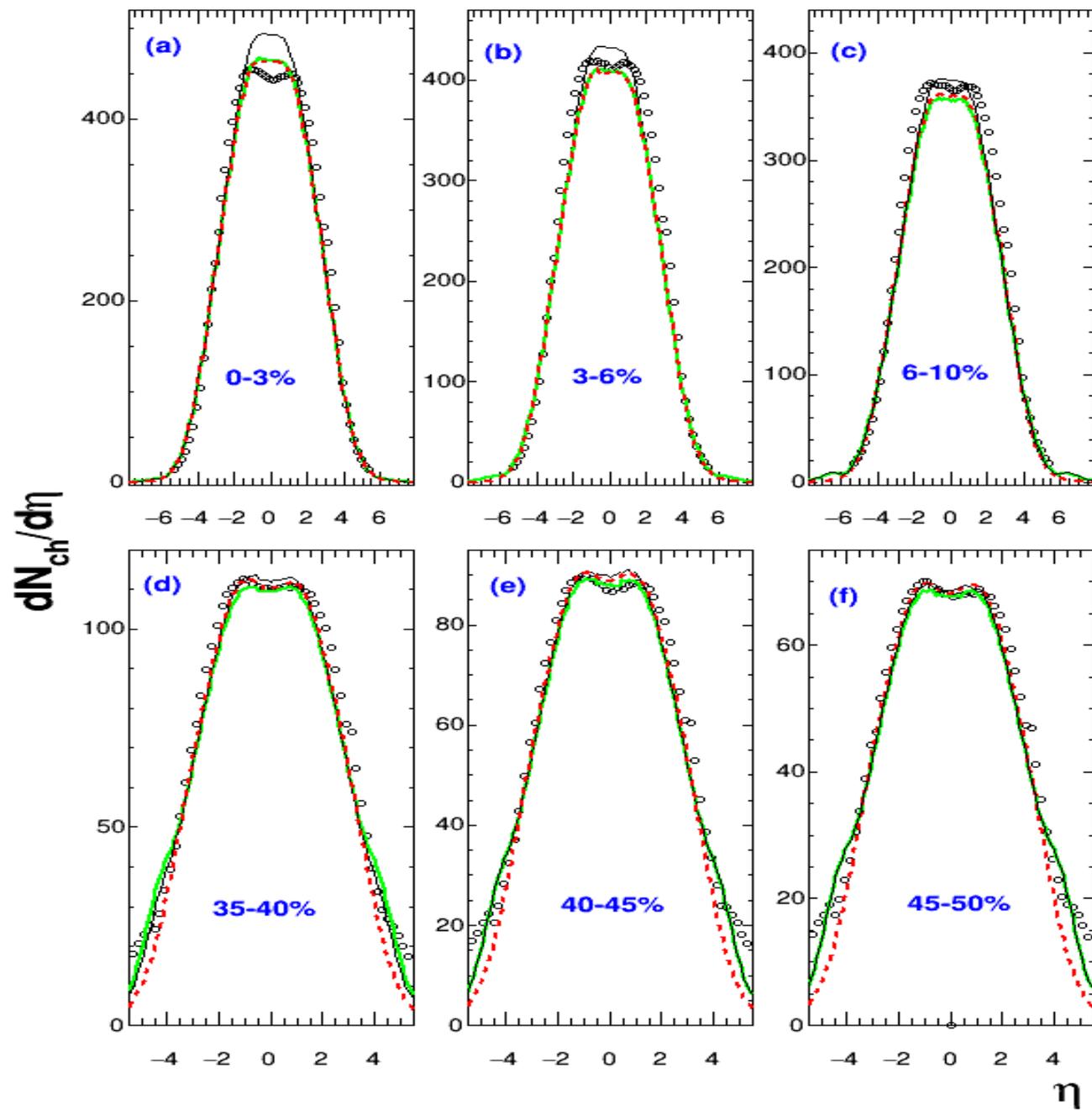
PHOBOS data,
Phys. Rev. C 83, 024913(2011)

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J. Phys. G 45, 025104(2018)

Au+Au (62.4 GeV)

Nucleon and Parton shadowing effects

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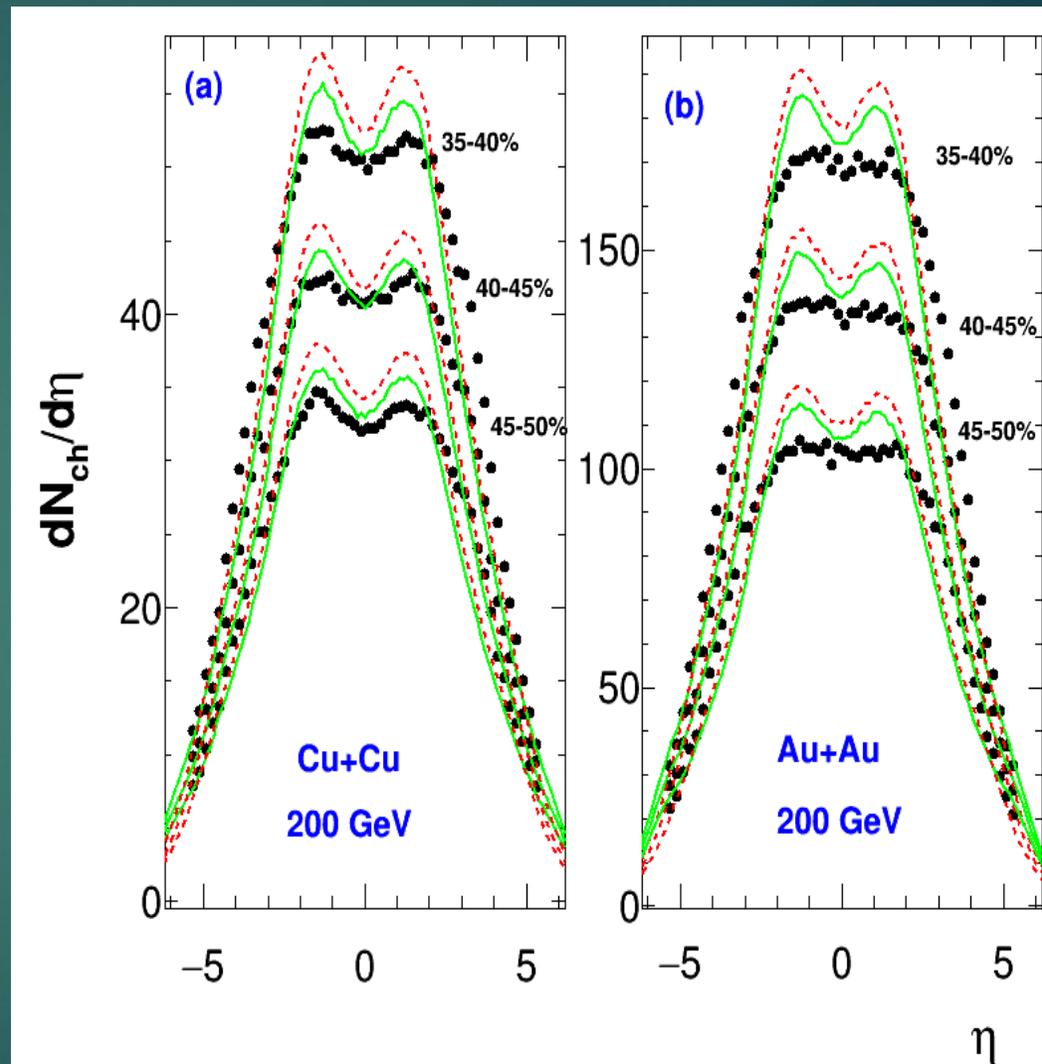
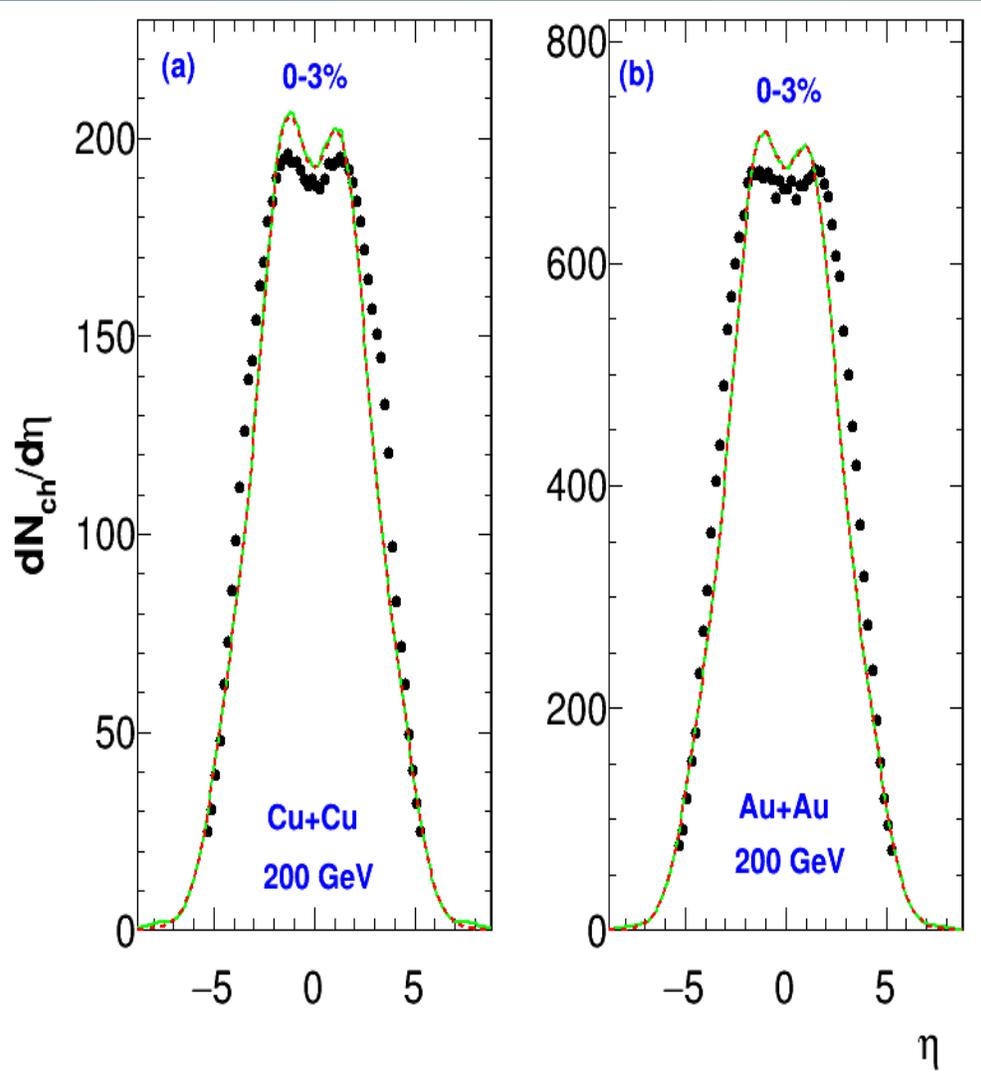
Parton shadowing

— off
- - on

Nucleon shadowing

— On
- - Off

Impact parameter dependent nucleon shadowing



..... off
—— on

Results of the improved HIJING code at LHC energies

HIJING 1.383

- The Duke-Owen (1984) parameterizations of parton distribution functions are used.

- QCD Coupling

$$\alpha_s = \frac{12\pi}{25} \log\left(\frac{Q^2}{\Lambda^2}\right)$$

$$\Lambda = 0.2 \text{ GeV}$$

- Parton Shadowing

$$S_g(r_i) = S_g \frac{5}{3} \left(1 - \frac{r_i^2}{R_A^2}\right)$$

Improved HIJING

- Martin-Stirling-Throne-Watt (2009) of parton distribution functions are used.
- QCD coupling (A. Vogt, Comp. Phys. Comm.170, 65 (2005))

$$\frac{d\alpha_s(Q^2)}{d \ln(Q^2)} = \sum_{m=0}^n \beta_m \alpha_s^{m+2}$$

$$\beta_0 = 11 - \frac{2}{3} n_f$$

$$\beta_1 = 102 - \frac{38}{3} n_f$$

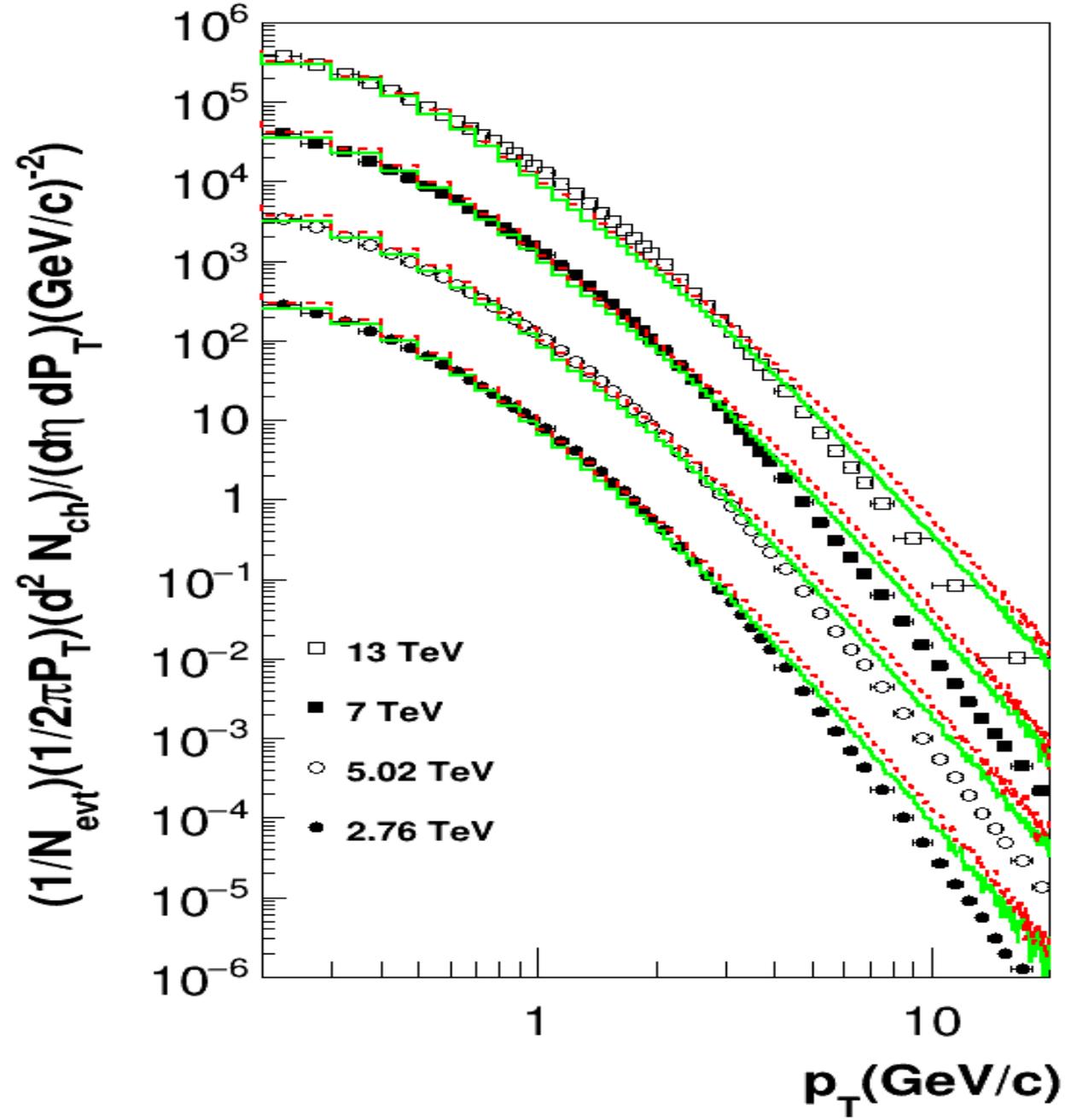
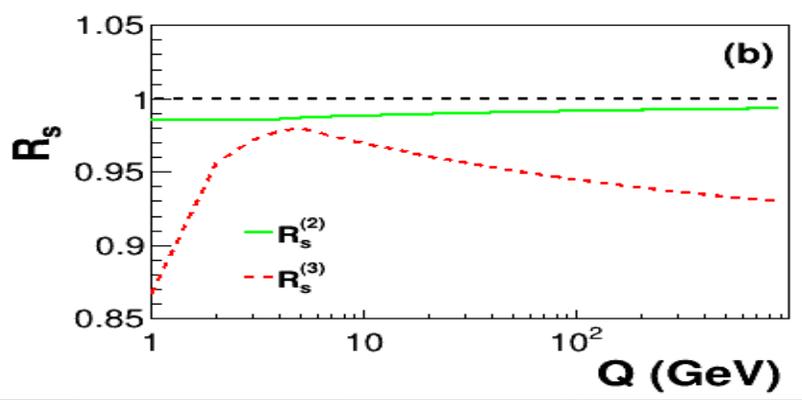
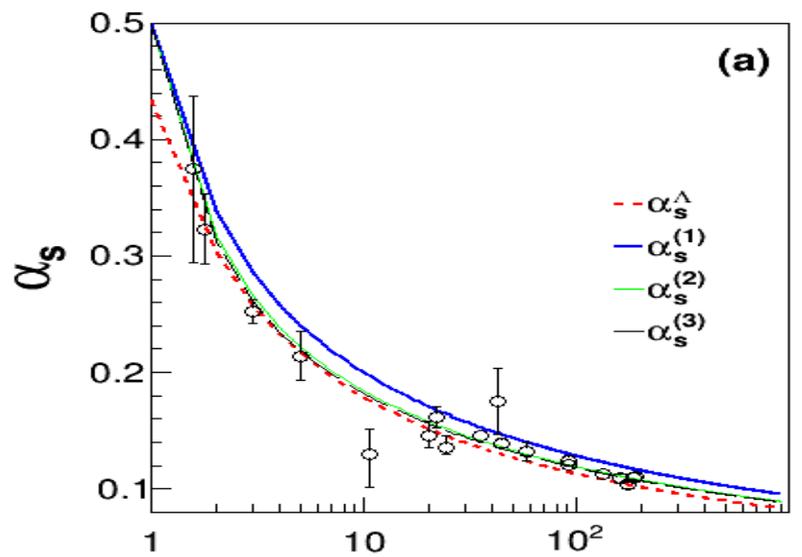
$$\beta_2 = 2857 - \frac{5033}{18} n_f + \frac{325}{54} n_f^2$$

- Cascade and Nucleon shadowing

- Surface medium effects

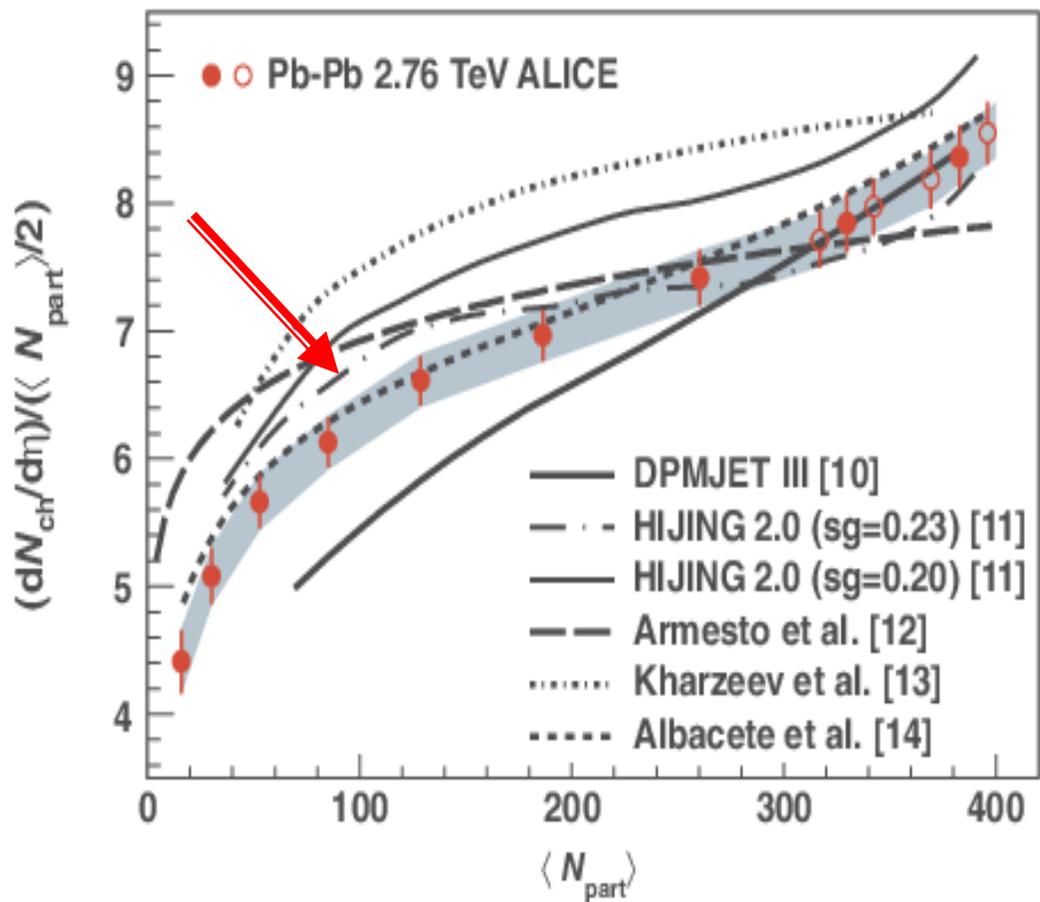
$$S_g(r_i) = S_g \frac{5}{3B} \frac{1}{1 - (1 - 1/B)^{5/2}} \left(1 - \frac{r_i^2}{BR_A^2}\right)$$

Exact QCD running coupling calculations

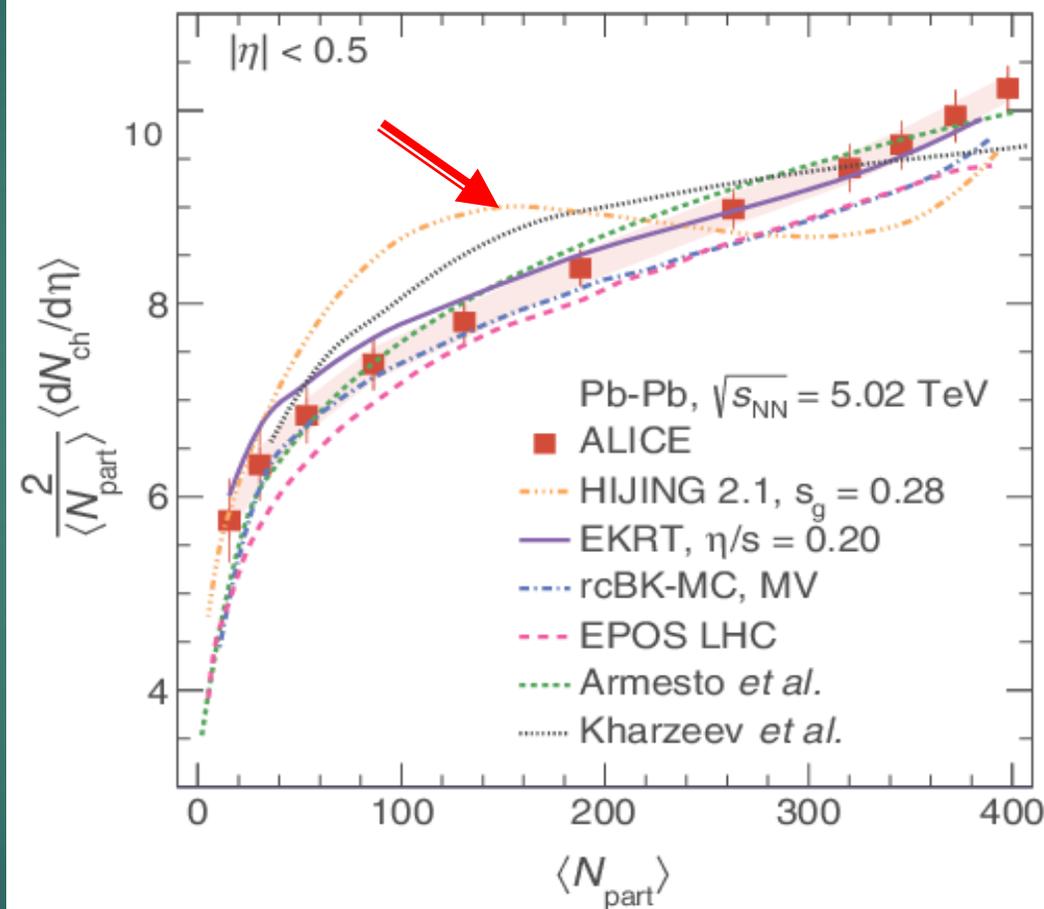


$p + p$
 $|\eta| < 0.8$

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to be published in Eur. Phys. Journal A (2018)



Phys. Rev. Lett. 106, 032301 (2011)



Phys. Rev. Lett. 116, 22302(2016)

The allowed Range of Parton Shadowing

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$$R_{q/A}^{(2)}(x) = \mathcal{R} - 0.1 \left(A^{\frac{1}{3}} - 1 \right)^{0.6} (1 - 3.5\sqrt{x})$$

$$\times \exp(-x^2/0.01)$$

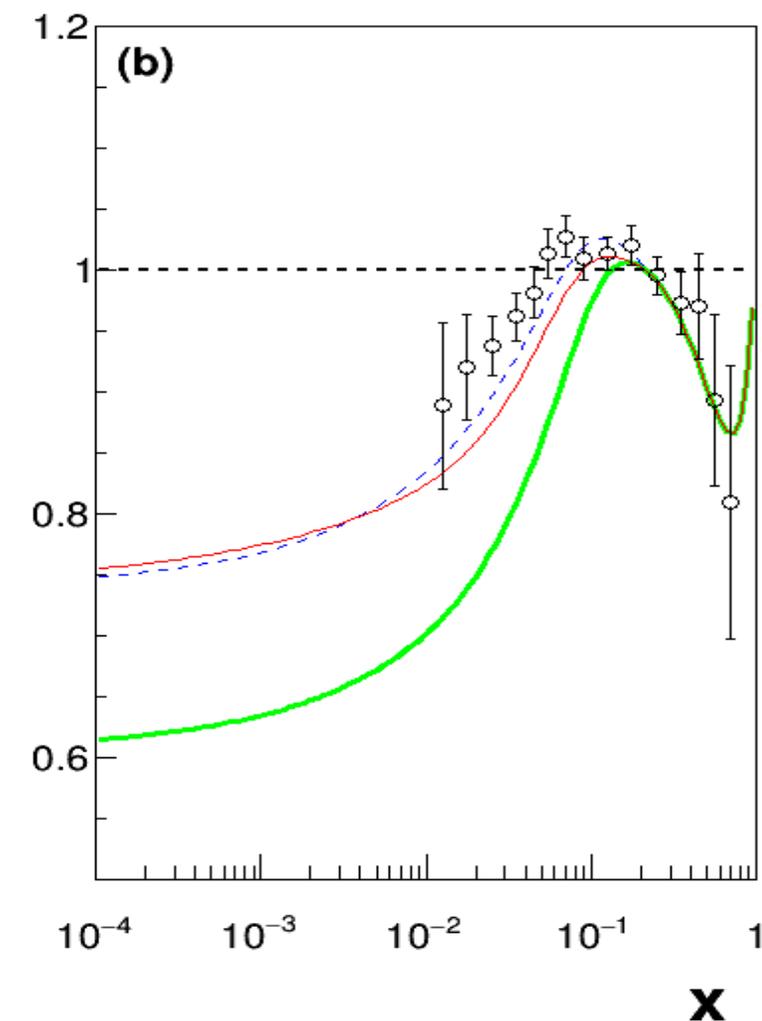
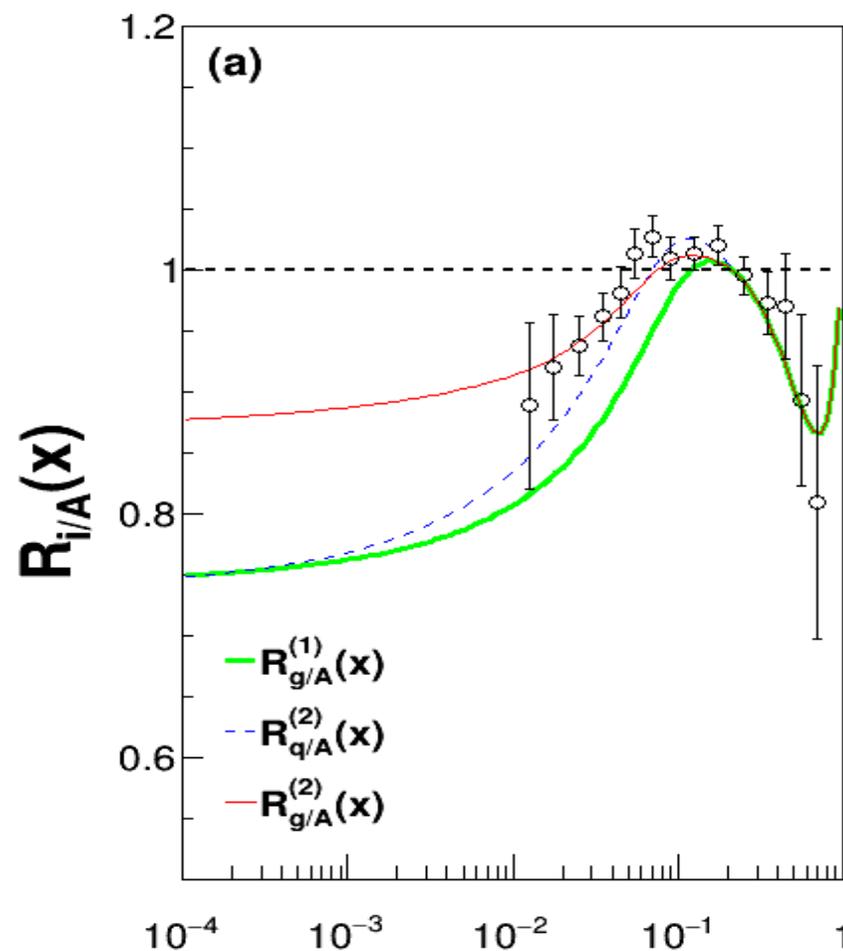
$$R_{g/A}^{(1)}(x) = \mathcal{R} - s_g^{(1)} \left(A^{\frac{1}{3}} - 1 \right)^{0.6} \left(1 - \frac{1.08}{\log(A+1)} \sqrt{x} \right)$$

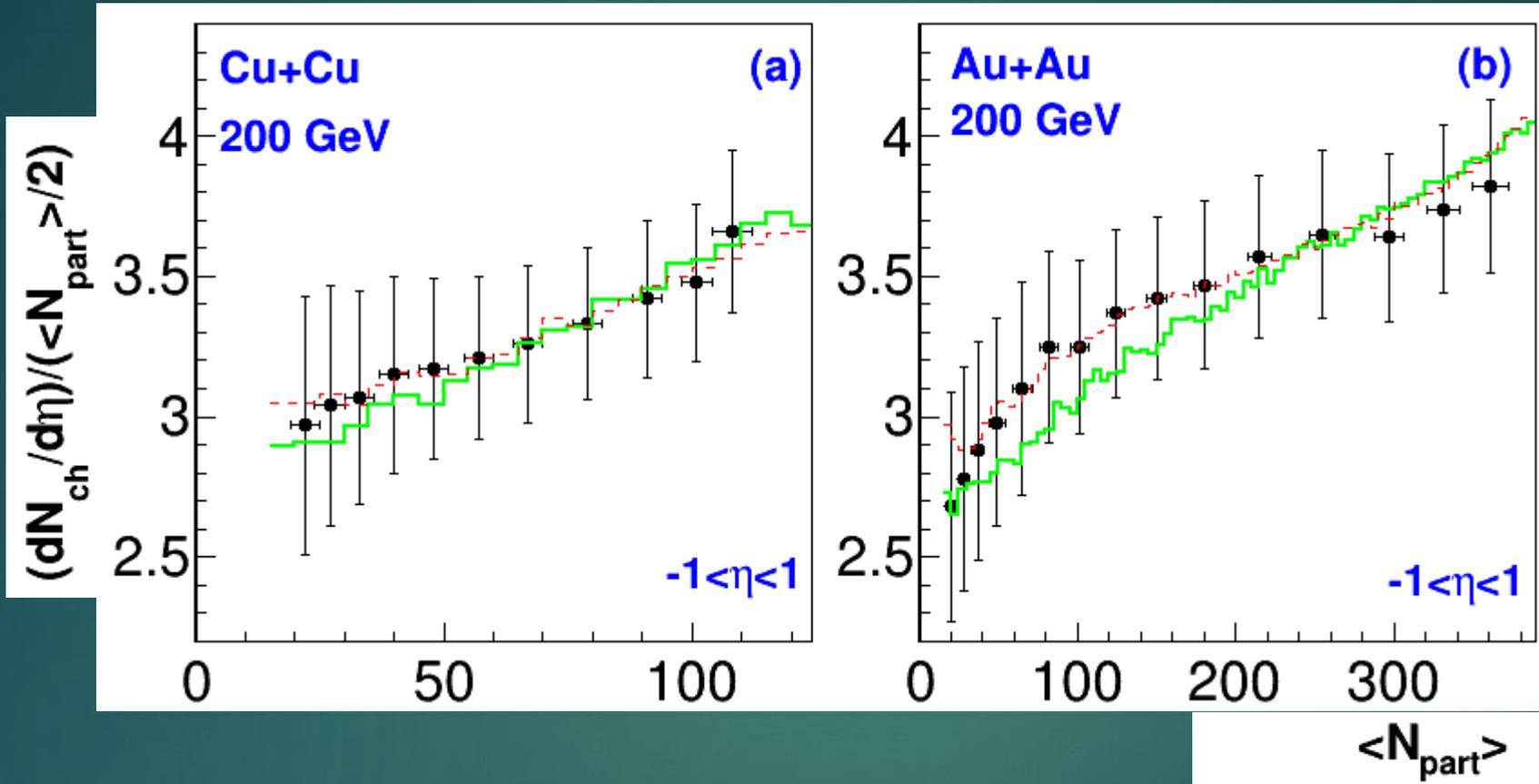
$$\times \exp(-x^2/0.01)$$

$$R_{g/A}^{(2)}(x) = \mathcal{R} - s_g^{(2)} \left(A^{\frac{1}{3}} - 1 \right)^{0.6} (1 - 1.5 x^{0.35})$$

$$\times \exp(-x^2/0.04)$$

$$\mathcal{R} = 1 + 1.19 \log^{\frac{1}{6}} A (x^3 - 1.2 x^2 + 0.21 x)$$



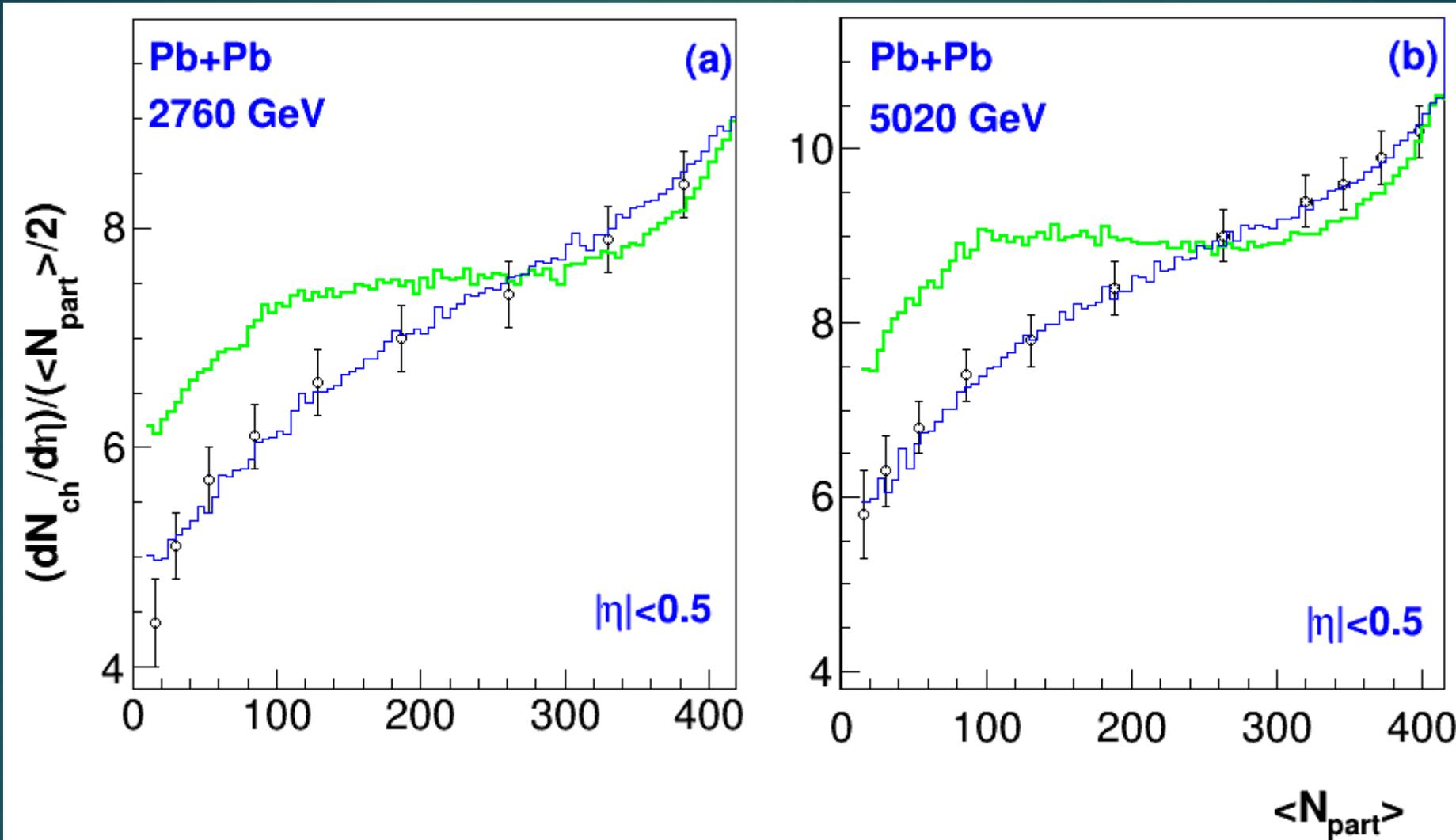


--- B=1
 — B=2

$$s_g^{(2)}(r_i) = S_g \frac{5}{3B} \frac{1}{1 - (1 - 1/B)^{5/2}} \left(1 - \frac{r_i^2}{BR_A^2} \right)$$

Surface effects at LHC energy

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— B=1
— B=2

$$s_g^{(2)}(r_i) = S_g \frac{5}{3B} \frac{1}{1 - (1 - 1/B)^{5/2}} \left(1 - \frac{r_i^2}{BR_A^2} \right)$$

Conclusions

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- ✓ Improvements of HIJING code are
 - ▶ Tabulated Martin-Stirling-Throne-Watt (2009) parton distribution functions are implemented.
 - ▶ Exact QCD running coupling is used.
 - ▶ Impact parameter dependent nucleon shadowing.
 - ▶ Surface effects are included.
- ✓ Transverse momentum spectra are reproduced for
 - ✓ $p + p$ collisions at $\sqrt{s_{NN}} = 2.76, 5.02, 7$ and 13 TeV
- ✓ Centrality dependence of charged particle yield are well accounted for
 - ✓ $Cu + Cu$ and $Au + Au$ collision data at RHIC energy.
 - ✓ $Pb+Pb$ collisions data at $\sqrt{s_{NN}} = 2.76$ TeV.
 - ✓ $Pb+Pb$ collisions data at $\sqrt{s_{NN}} = 5.02$ TeV

First Results with HIJING++ on High-energy Heavy Ion Collisions

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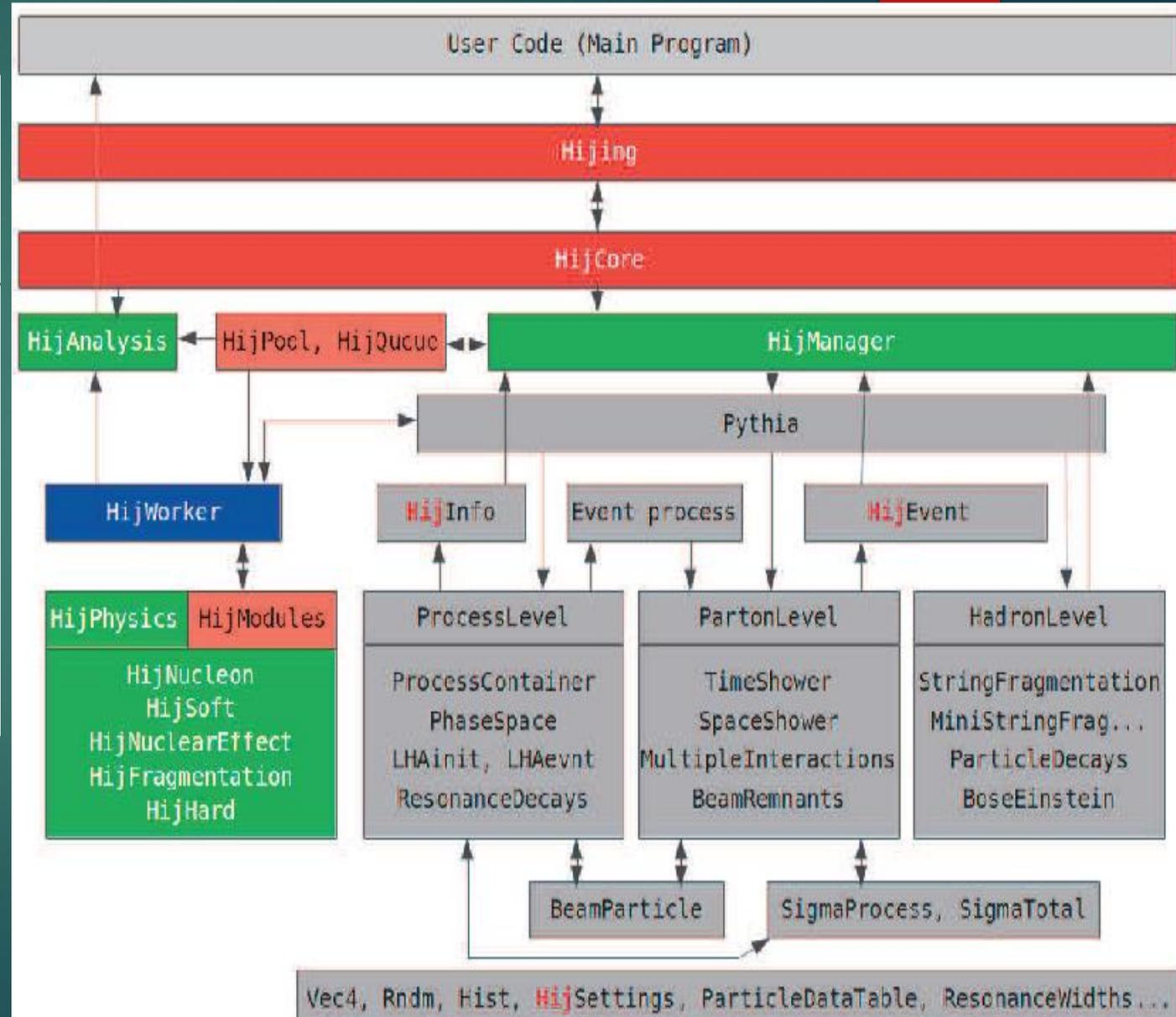
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Thanks