Exploring experimental heavy-ion centrality dependence of particle production in MC Glauber model

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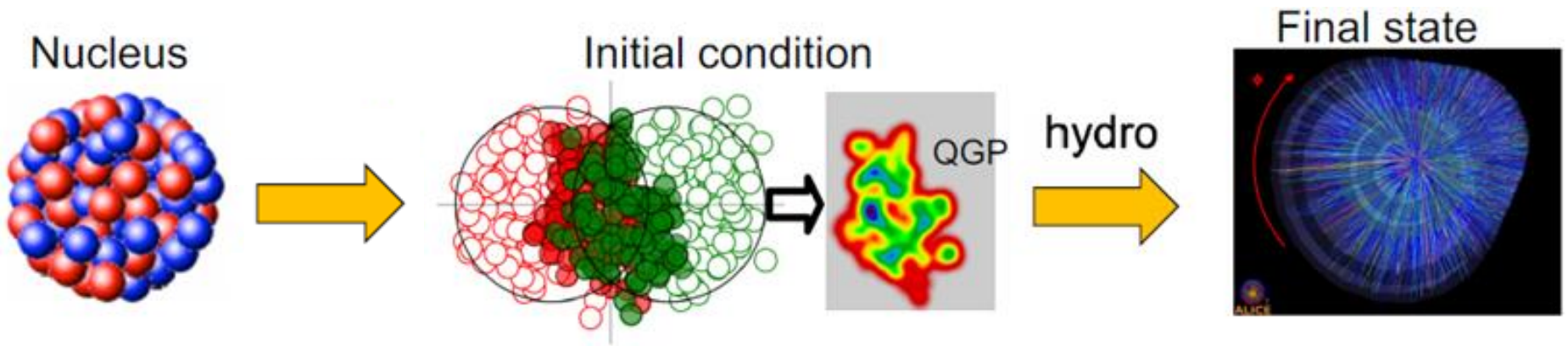
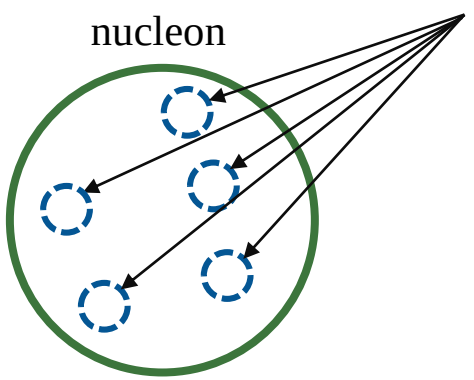
Heavy Ion Collision



Monte-Carlo Glauber

- Study of heavy ion collision initial state with nucleon and sub-nucleon Monte-Carlo Glauber model
- Analysis of charged particle yield from different emission sources for various nuclei (Au+Au, Pb+Pb, Xe+Xe) and collision energies from RHIC to LHC

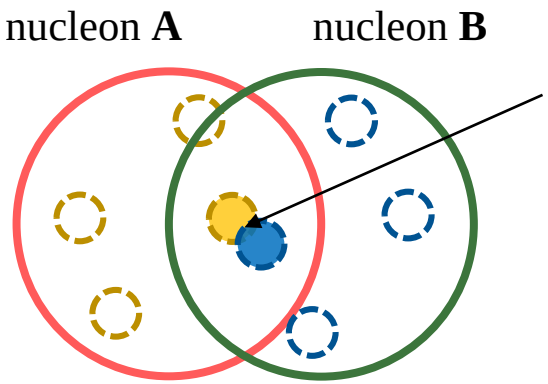
Monte-Carlo Glauber model [1]



$\boldsymbol{n_c}$ constituents, distributed by

$$\rho_c(r) = \exp(-\frac{r}{R_n})$$

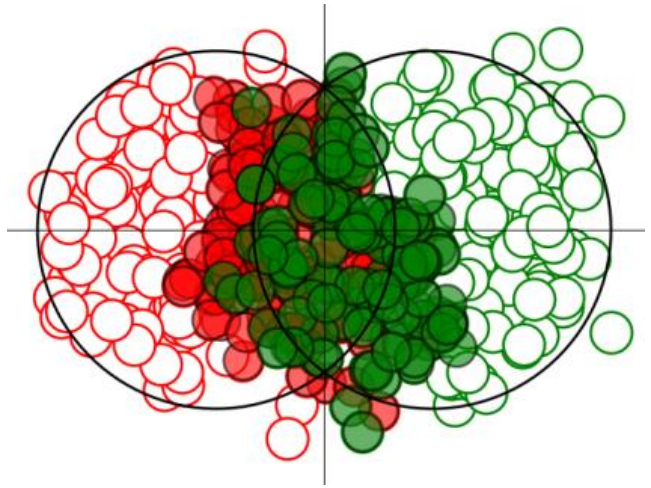
relative to the nucleon center + recentering



constituents from different nuclei collide if

$$d < \sqrt{\frac{\sigma_{cc}}{\pi}}$$

Number of wounded quarks – $\boldsymbol{N_{c-part}}$

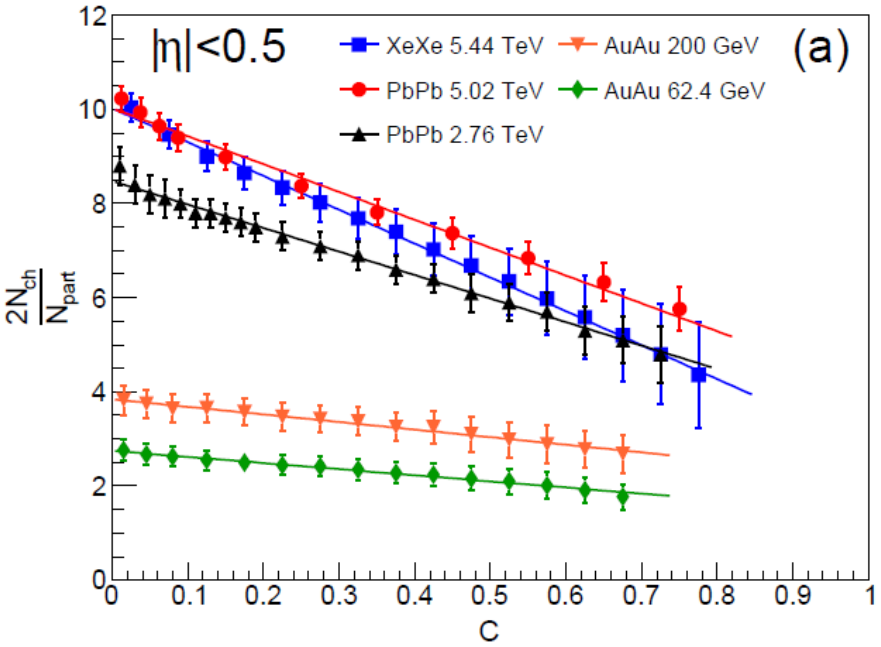


Number of wounded nucleons – $\boldsymbol{N_{part}}$

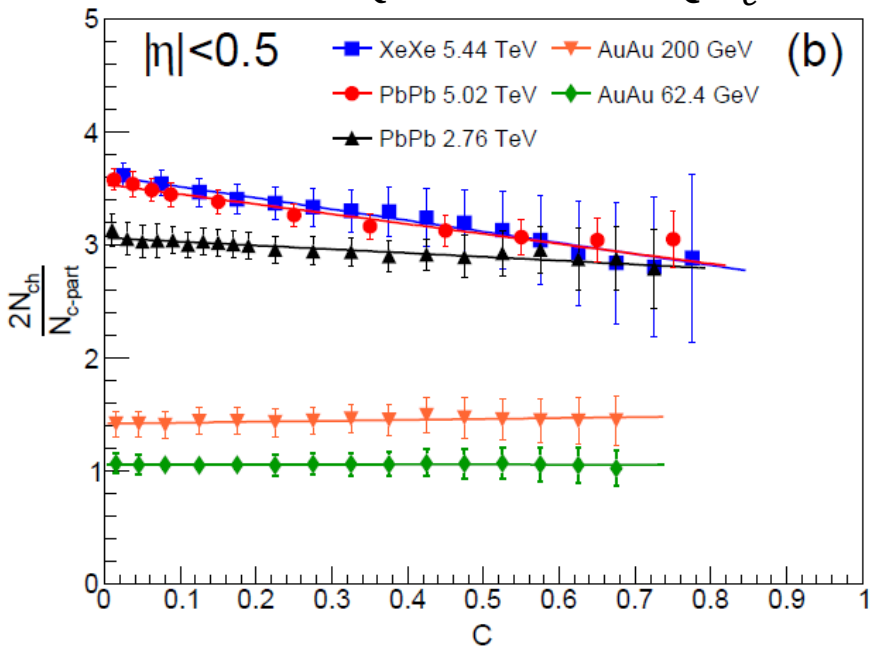
[1] *Loizides C. // Phys.Rev. C 94, 024914 (2016)*

Charged particle yield per wounded source

Wounded Nucleon model **WN**



Wounded Quark model **WQ** $n_c = 3$



Data was fitted with $const \times (1 + k \cdot C)$

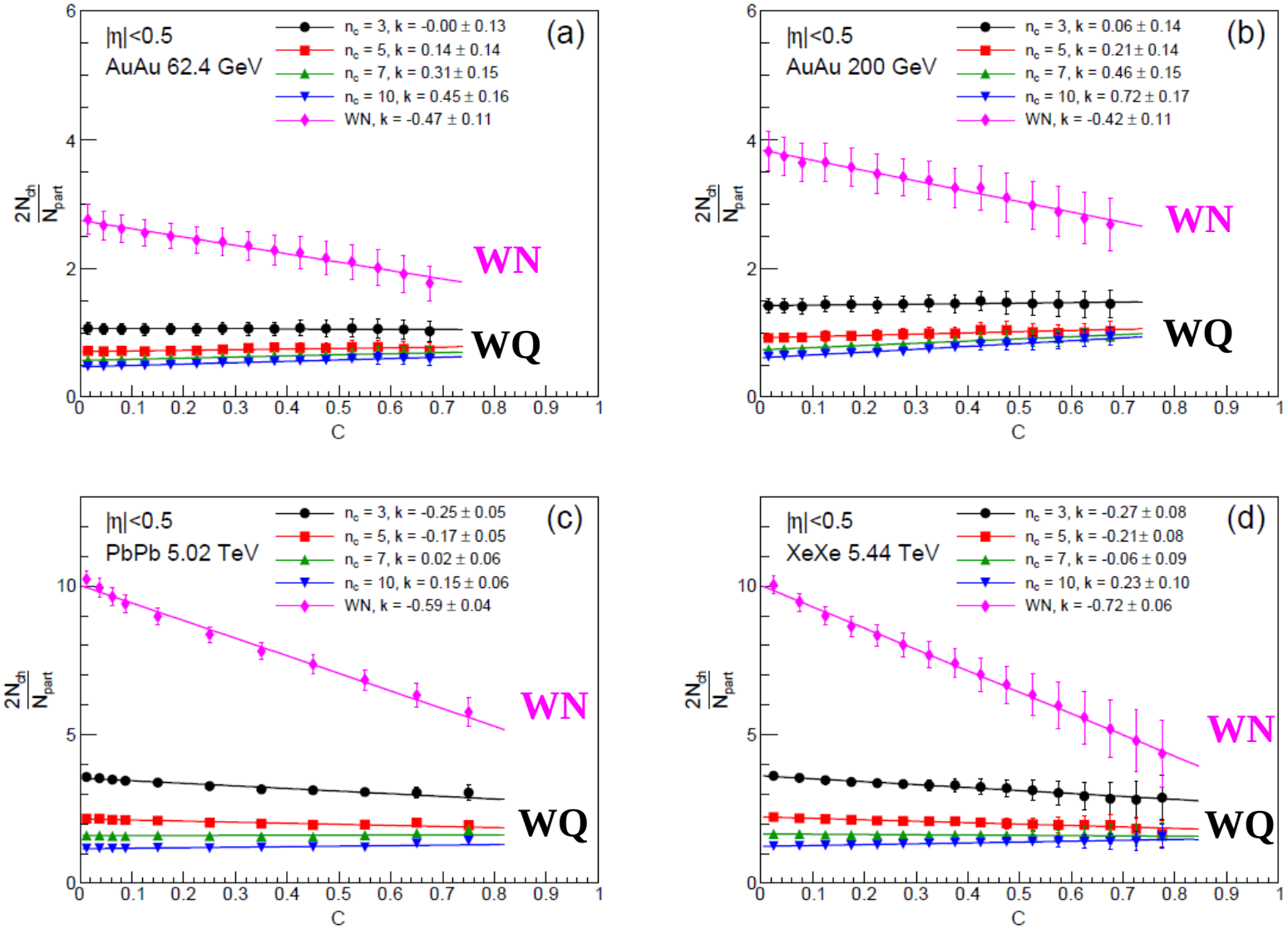
- Slopes of linear fit increase with energy

- Slopes decreased in the quark model

- At the first time a wide energy region (RHIC to LHC) is considered in the same standard approach
- Wounded quark model enhances the scaling on collision centrality for all data

Учен. зап. физ. фак-та Моск. ун-та. 2022. № 2, 2220201

Comparison of nucleon **WN** and quark **WQ** models



Wounded quark scaling ($\boldsymbol{n_c = 3}$) at **RHIC** energies

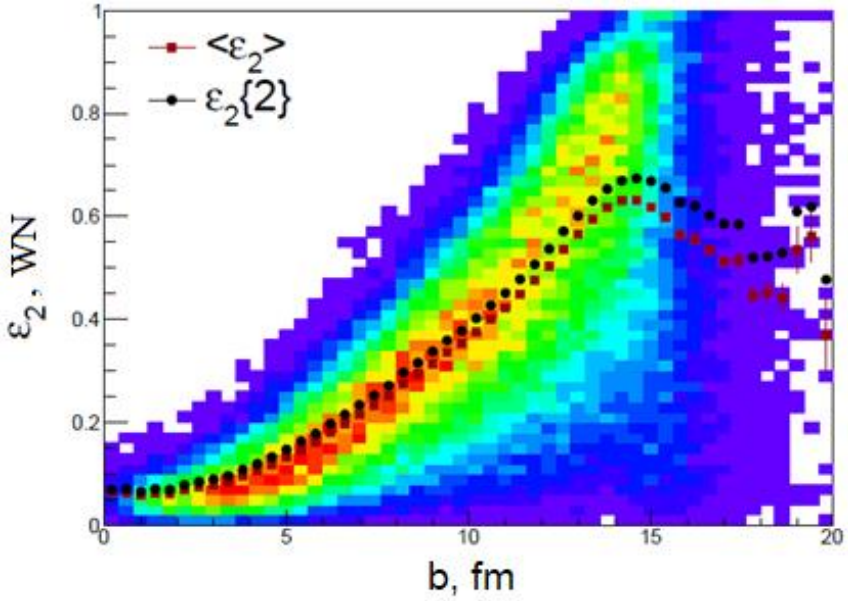
Wounded constituent scaling ($\boldsymbol{n_c = 7}$) at **LHC** energies

PHOBOS data: *Phys.Rev. C 83, 024913 (2011)*
ALICE data: *Phys.Rev.Lett. 116, 222302 (2016)*
CMS data: *Phys.Lett. B 799, 135049 (2019)*

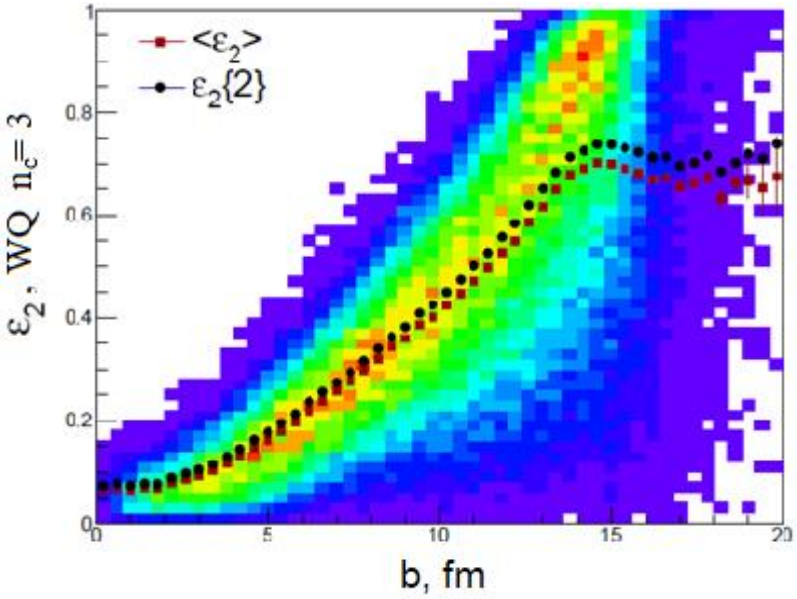
Initial state eccentricity ε_2 fluctuations in MC Glauber model

Pb+Pb 5.02 TeV

Wounded nucleon



Wounded quark



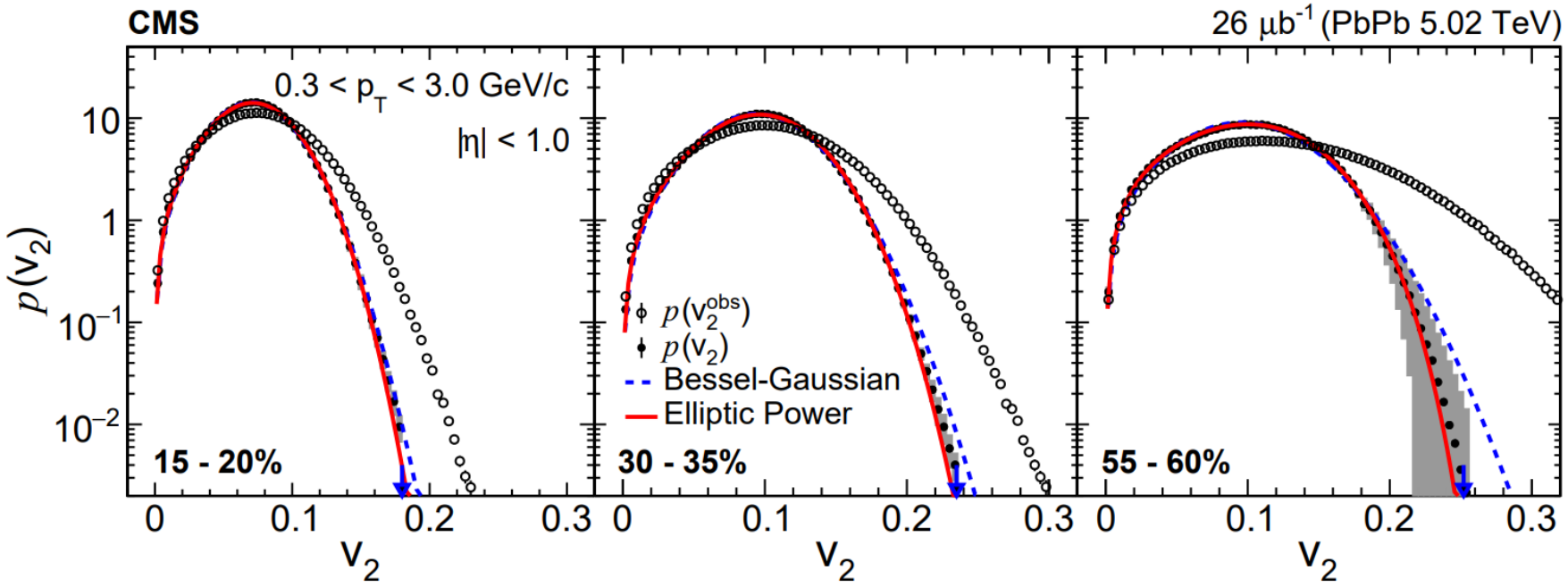
- Fluctuations increase with bigger impact parameter
- $\langle\varepsilon_2\rangle \lesssim \varepsilon_2\ \{2\}$ in both models
- $\langle\varepsilon_2\rangle_{WN} < \langle\varepsilon_2\rangle_{WQ}$

$$\varepsilon_2 = \frac{\sqrt{\langle r^2 cos2\varphi\rangle^2 + \langle r^2 sin2\varphi\rangle^2}}{\langle r^2\rangle}$$

$$\langle\varepsilon_2\rangle_{MC} = \int \varepsilon_2 P(\varepsilon_2) d\varepsilon_2$$

$$\langle\varepsilon_2^2\ \{2\}\rangle_{MC} = \int \varepsilon_2^2 P(\varepsilon_2) d\varepsilon_2$$

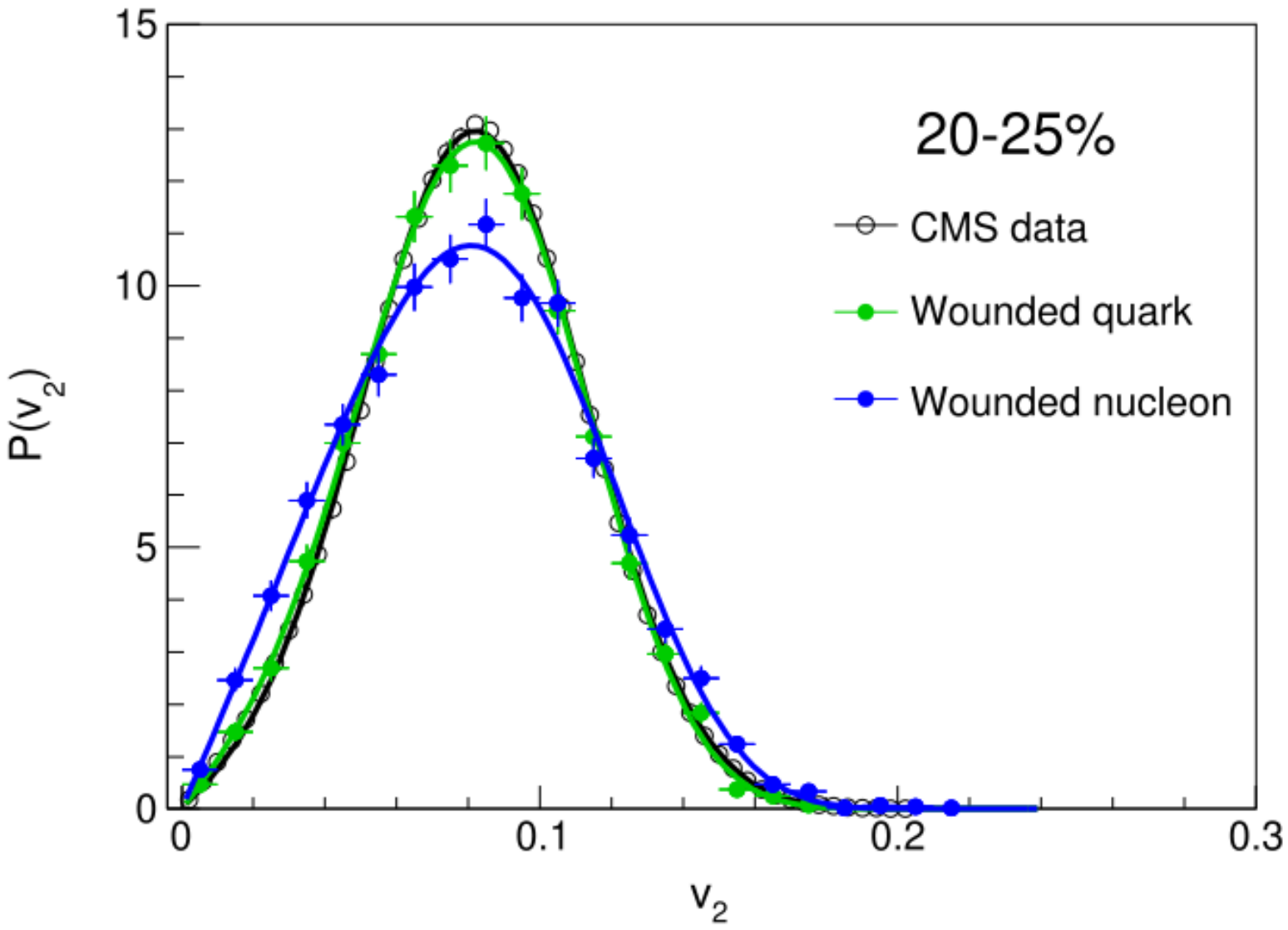
Probability density distribution of v_2 in CMS data



- Elliptic Power describes $p(v_2)$ better than Bessel-Gaussian
- We also use Elliptic Power parametrization

CMS // Phys.Lett. B 789 (2019) 643-665
Li Yan // Phys.Rev. C 90, 024903
James R. Castle // Nuclear Physics A 967 (2017) 401–404

Probability density distribution of v_2 in MC Glauber



$$k_2 = \frac{v_2\{2\}_{CMS}}{\varepsilon_2\{2\}_{MC}}$$

$$P(v_2) = \frac{d\varepsilon_2}{dv_2} P(\varepsilon_2) = \frac{1}{k_2} P\left(\frac{v_2}{k_2}\right)$$

Wounded quark model better describes **CMS** data

CMS data: *Phys.Lett. B 789 (2019) 643-665*

Summary

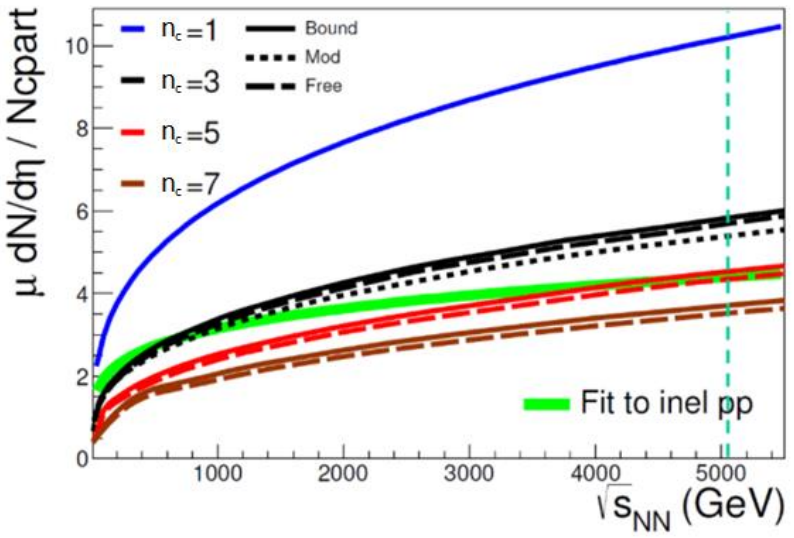
- Analysis of charged particles yield from single emission source favors the wounded parton model and confirms **wounded constituent scaling** at collision energies from RHIC to LHC

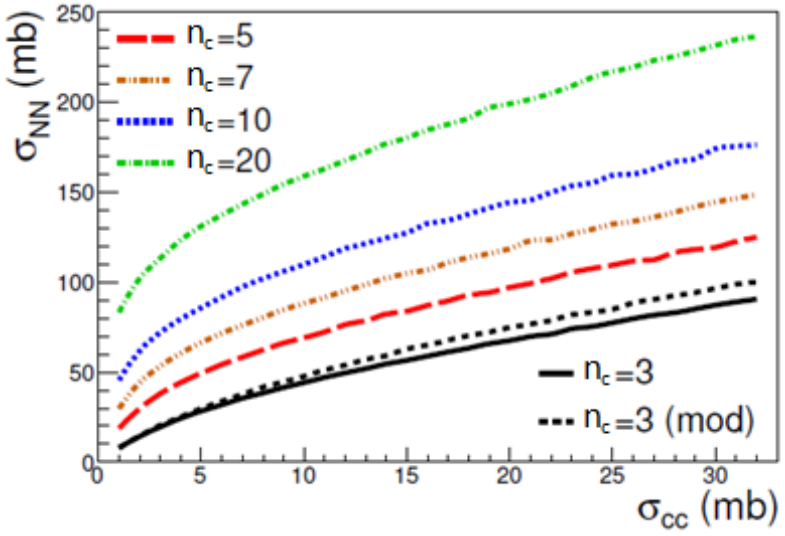
- At higher collision energies, **wounded constituent scaling** is fulfilled with larger $\boldsymbol{n_c}$

- **Wounded quark** model describes CMS **probability density distribution** data for centralities $< 35\%$

Thanks a lot for attention!

Monte-Carlo Glauber model parameters

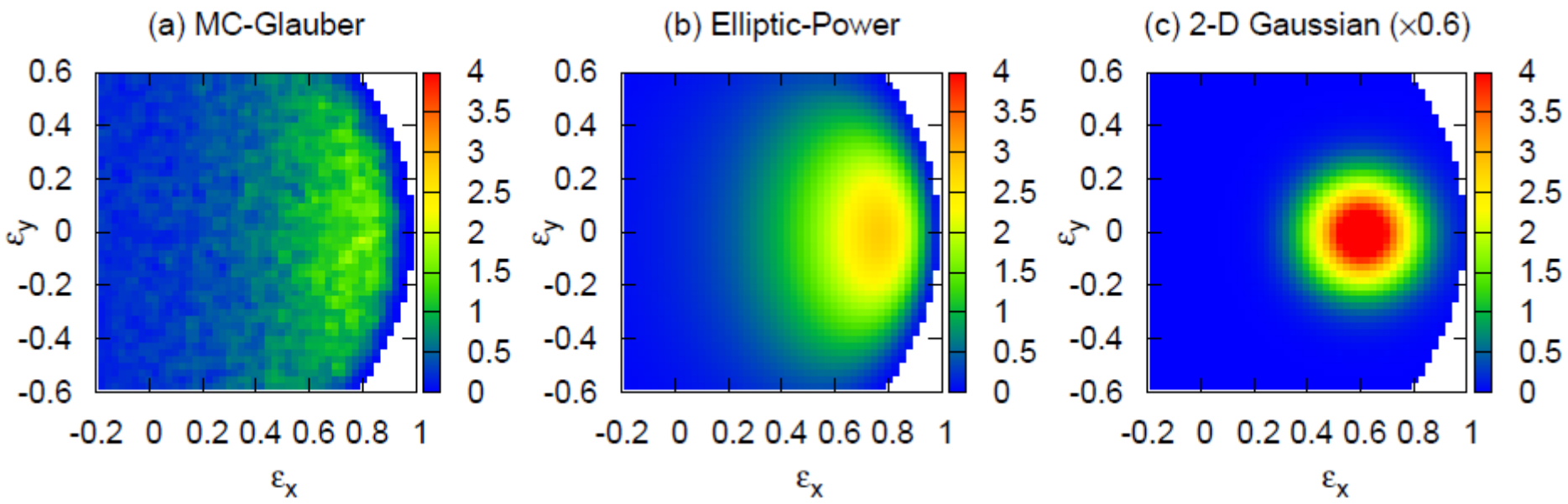




$\sqrt{s_{NN}}$, TeV	σ_{NN}, mb	σ_{cc}, mb			
		$n_c = 3$	$n_c = 5$	$n_c = 7$	$n_c = 10$
0.0624	35.2	6.3	2.7	1.4	0.7
0.2	42	8.3	3.7	1.8	0.8
2.76	64	15.6	8.4	4.4	2.1
5.02	70	18	10	5.5	3

Loizides C. // Phys.Rev. C 94, 024914 (2016)

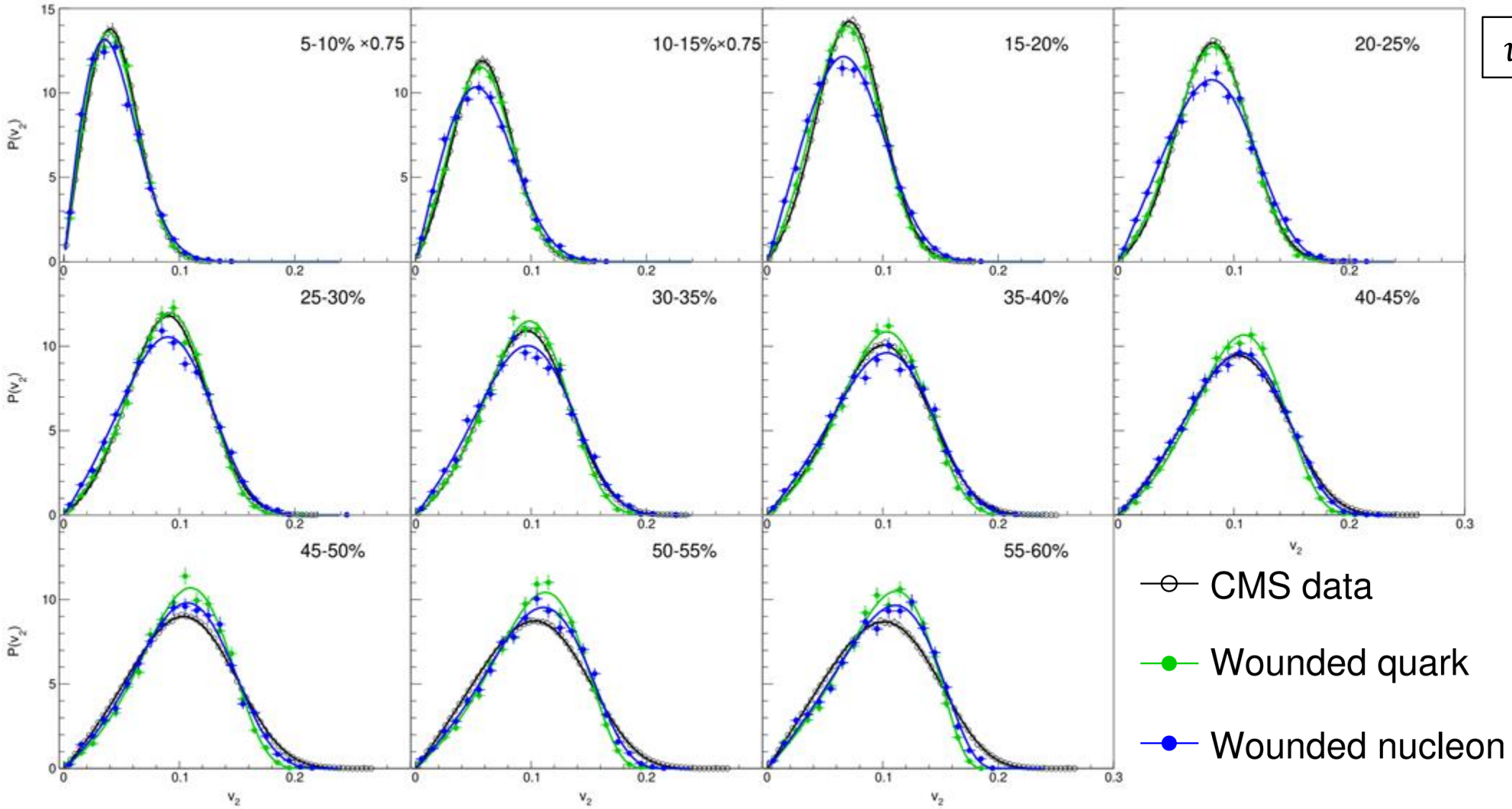
Elliptic Power distribution



$$p(\varepsilon_n) = \frac{2\alpha\varepsilon_n}{\pi}(1-\varepsilon_0^2)^{\alpha+\frac{1}{2}} \int_0^\pi \frac{(1-\varepsilon_n^2)^{\alpha-1} d\phi}{(1-\varepsilon_0\varepsilon_n\cos\phi)^{2\alpha+1}}$$

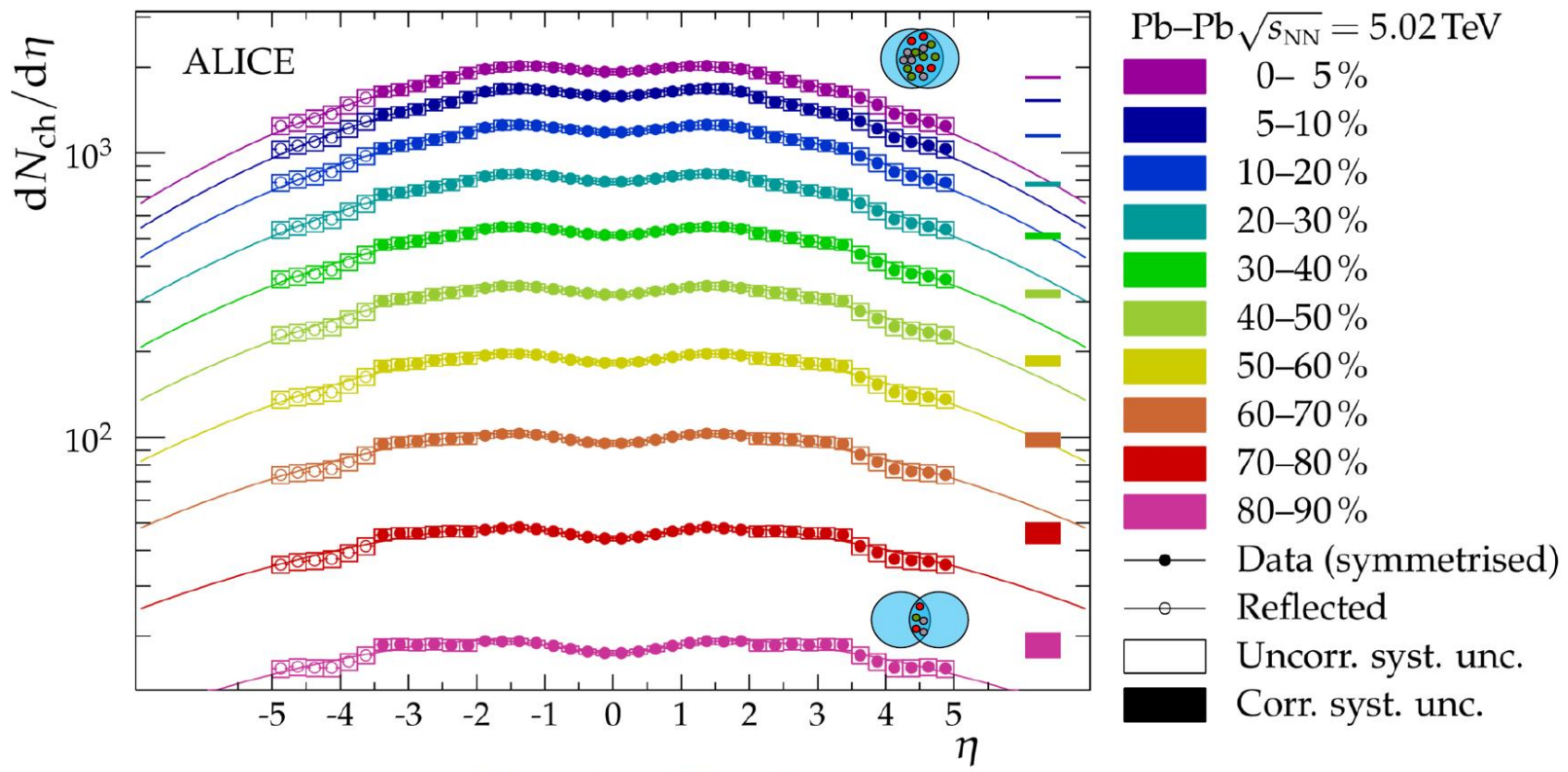
Probability density distribution of v_2

$$v_2\{2\} = k_2 \varepsilon_2\{2\}$$



Pseudorapidity density distribution for charged particles

$dN_{ch}/d\eta$ in 5.02 TeV Pb-Pb collisions at the LHC



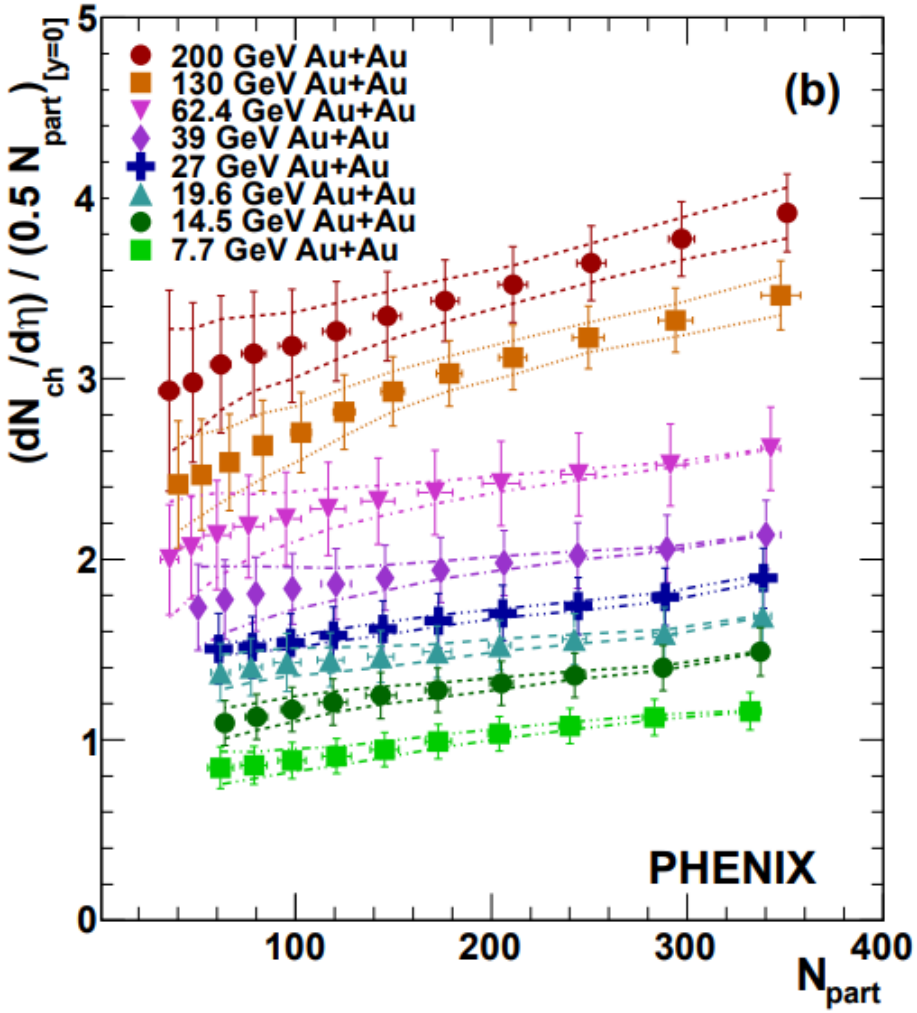
ALI-PUB-115086 [arXiv:1612.08966]

$dN_{ch}/d\eta \approx$ 1943 ± 54 at midrapidity.

→ Even at LHC energies, 95% of all particles are produced with p_T < 2 GeV/c in pp and Pb-Pb collisions.

→ Bulk particle production and the study of collective phenomena are associated with ***"soft" physics*** in the non-perturbative regime of QCD.

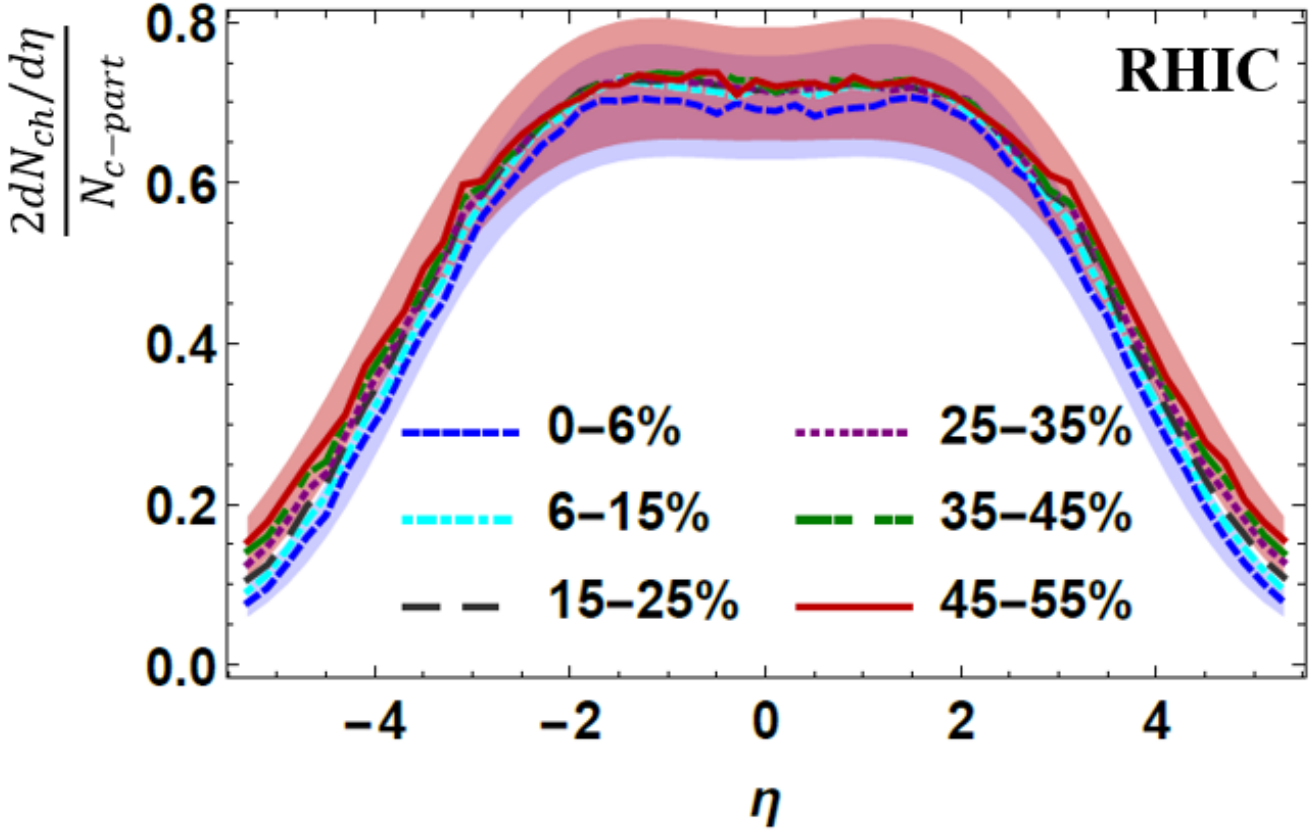
$\frac{dN_{ch}/d\eta}{N_{part}/2}$ at midrapidity (RHIC)

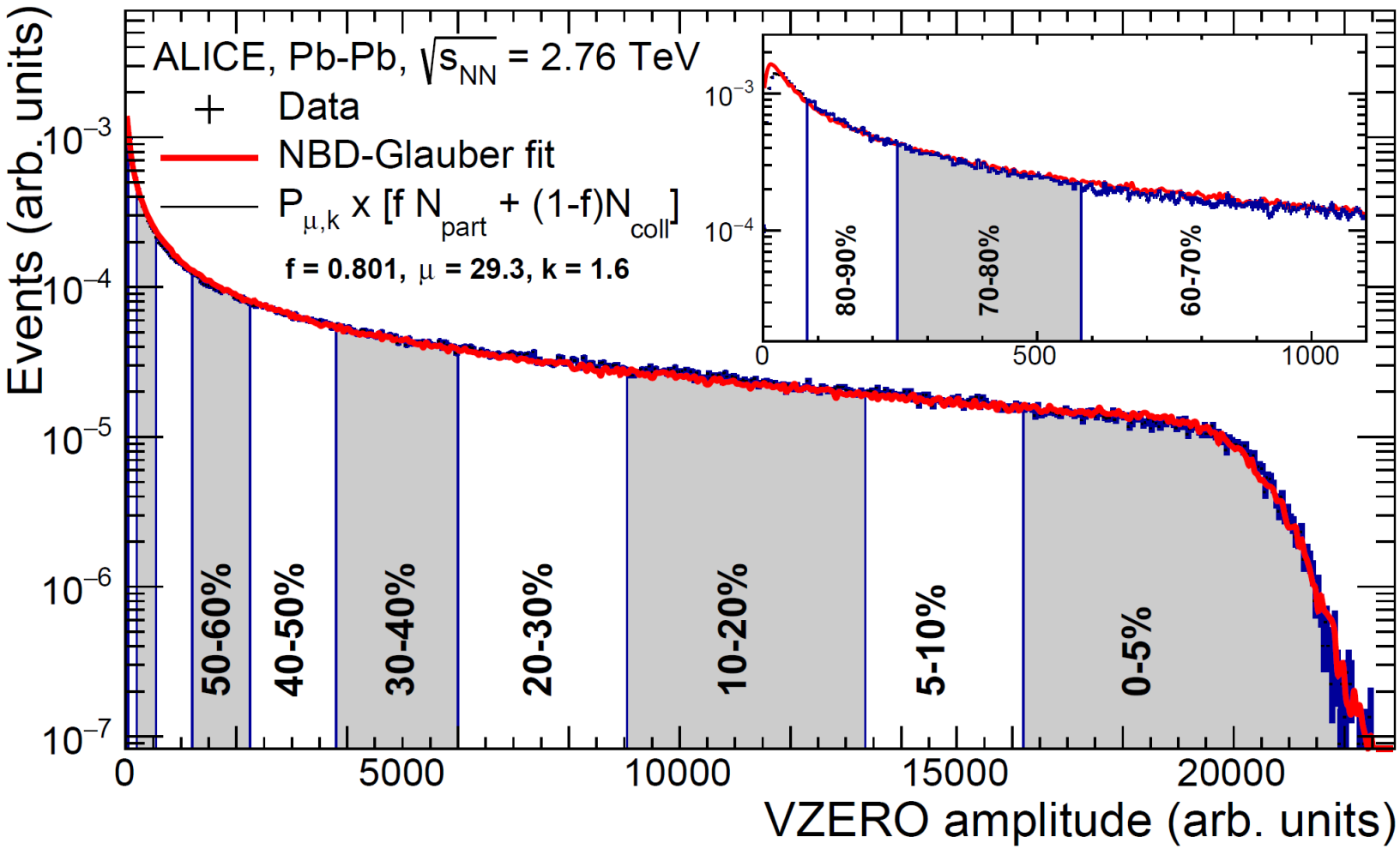


PHENIX Collaboration // arXiv:1509.06727

Wounded quark emission function

Au+Au 200 GeV



Rohrmoser, Broniowski // arXiv:1809.08666v2

Collision Centrality