Why mean p_T is interesting

Michal Praszalowicz

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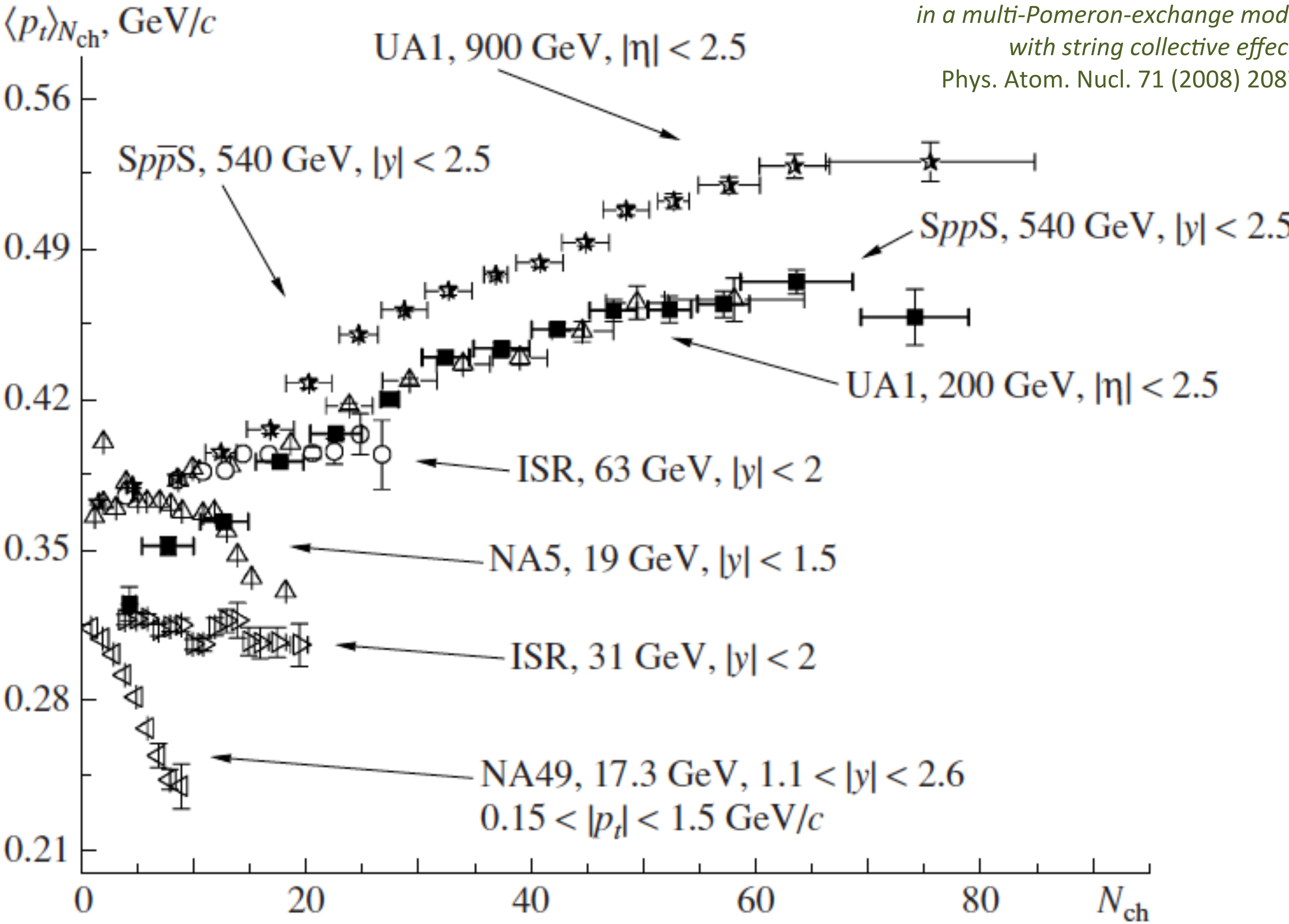
- $<p_T>(N_{ch})$ – correlations are sensitive to the fine details of dynamics

N. Armesto, D.A. Derkach and G.A. Feofilov,
p(t)-multiplicity correlations
in a multi-Pomeron-exchange model
with string collective effects
Phys. Atom. Nucl. 71 (2008) 2087.



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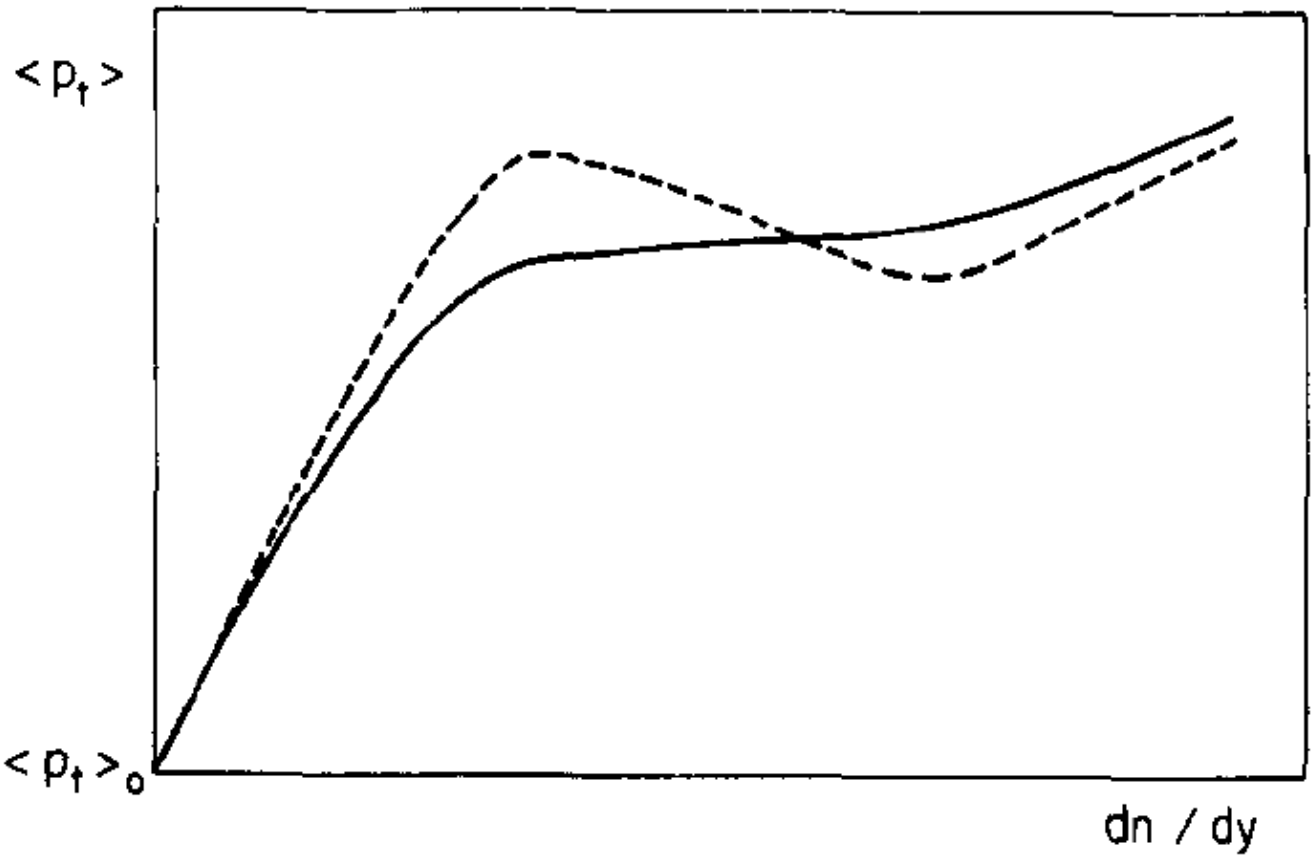
- complete change of behavior from small to large energies

MULTIPLICITY DEPENDENCE OF p_t SPECTRUM AS A POSSIBLE SIGNAL FOR A PHASE TRANSITION IN HADRONIC COLLISIONS

L. VAN HOVE
CERN, Geneva, Switzerland

Received 25 August 1982

Phys. Lett. B 118 (1982) 139



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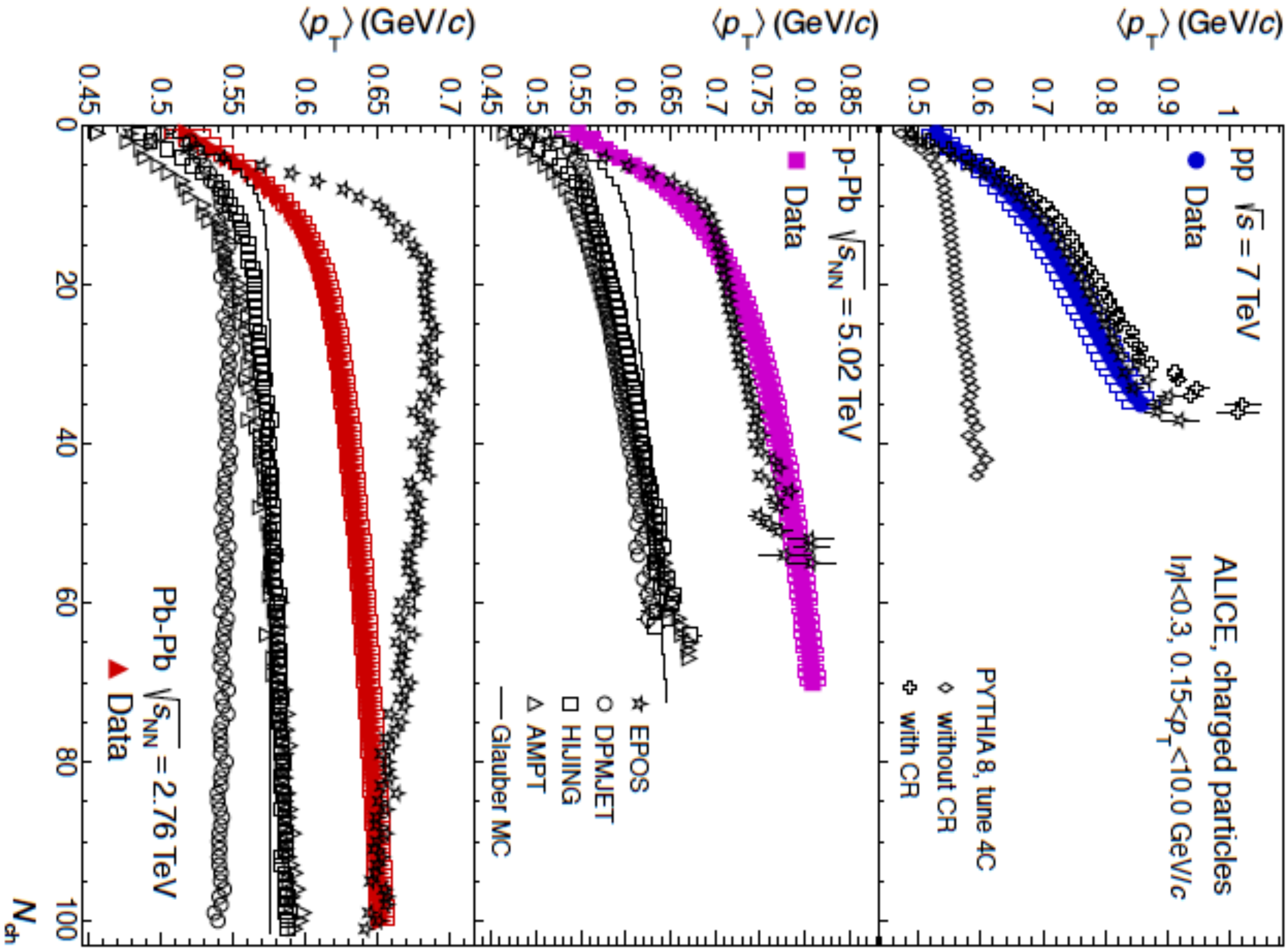
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-PH-EP-2013-111
July 2, 2013

Multiplicity dependence of the average transverse momentum in pp, p–Pb, and Pb–Pb collisions at the LHC

The ALICE Collaboration*



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Basics of geometrical scaling

for $y \sim 0$ (central rapidity) *i.e.* for $x_1 \sim x_2 = x$ and for symmetric systems

$$\frac{dN}{dy d^2 p_{\mathrm{T}}} = S_{\perp} \mathcal{F}(\tau) \quad \tau = \frac{p_{\mathrm{T}}^2}{Q_s^2(x)} \quad Q_s(x) = Q_0 \left(\frac{x_0}{x} \right)^{\lambda/2}$$

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saturation scale = gluon density
per transverse area

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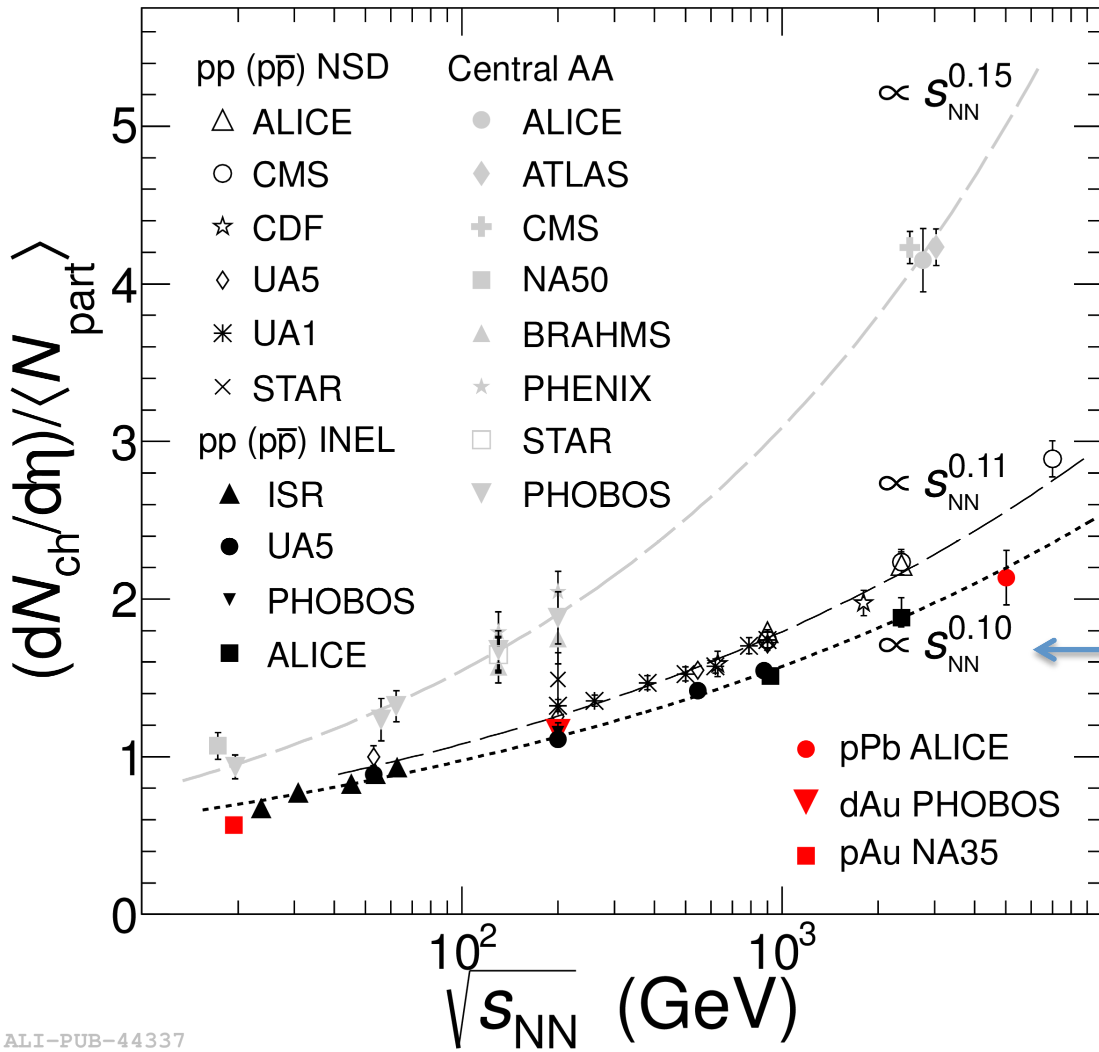
parton – hadron duality: power-like growth of particle multiplicity

saturation scale = gluon density per transverse area

Power-like growth of multiplicity

http://th-www.if.uj.edu.pl/school/2014/talks/braun-munzinger_1.pdf



plot: P. Braun-Munzinger, 54 Cracow School of Theoretical Physics (from ALICE-PUB-44337)

$$\frac{dN_{ch}}{dy} \sim S_\perp \bar{Q}_s^2(W)$$

$$\sim S_\perp Q_0^2 \left(\frac{W^2}{Q_0^2}\right)^{\lambda/(2+\lambda)}$$

inelastic

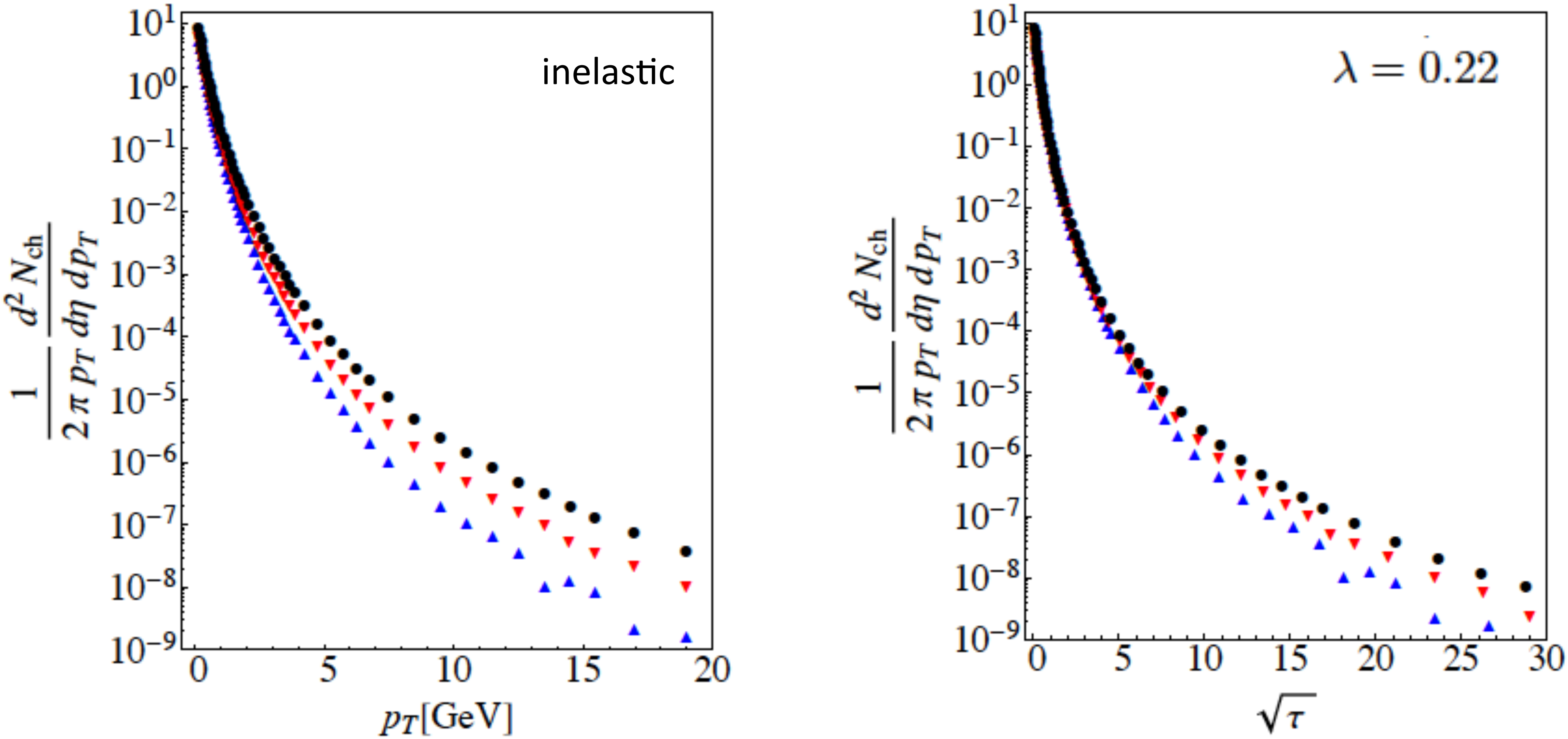
transverse area is energy indpendent

is power correct?

Determination of lambda

$$\frac{dN_{\rm ch}}{dy d^2 p_{\rm T}} = S_\perp \mathcal{F}(\tau) \qquad \tau = \frac{p_{\rm T}^2}{Q_{\rm sat}^2(p_{\rm T}/\sqrt{s})} = \frac{p_{\rm T}^2}{1\,{\rm GeV}^2}\left(\frac{p_{\rm T}}{\sqrt{s}\times 10^{-3}}\right)^\lambda$$

ALICE 1307.1093 [nucl-ex], Eur.Phys.J C73 (2013) 2662



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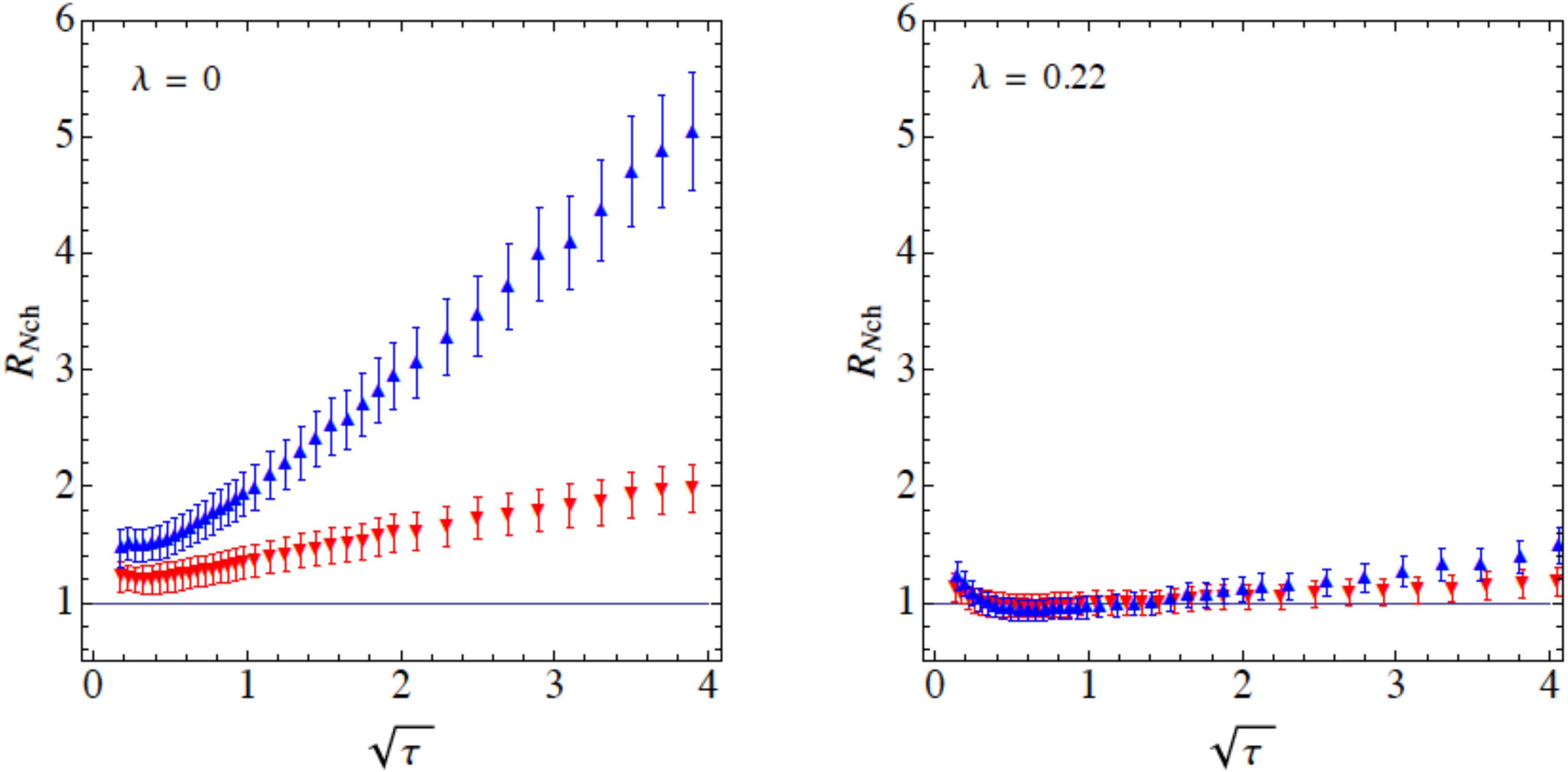

Power-like growth of multiplicity

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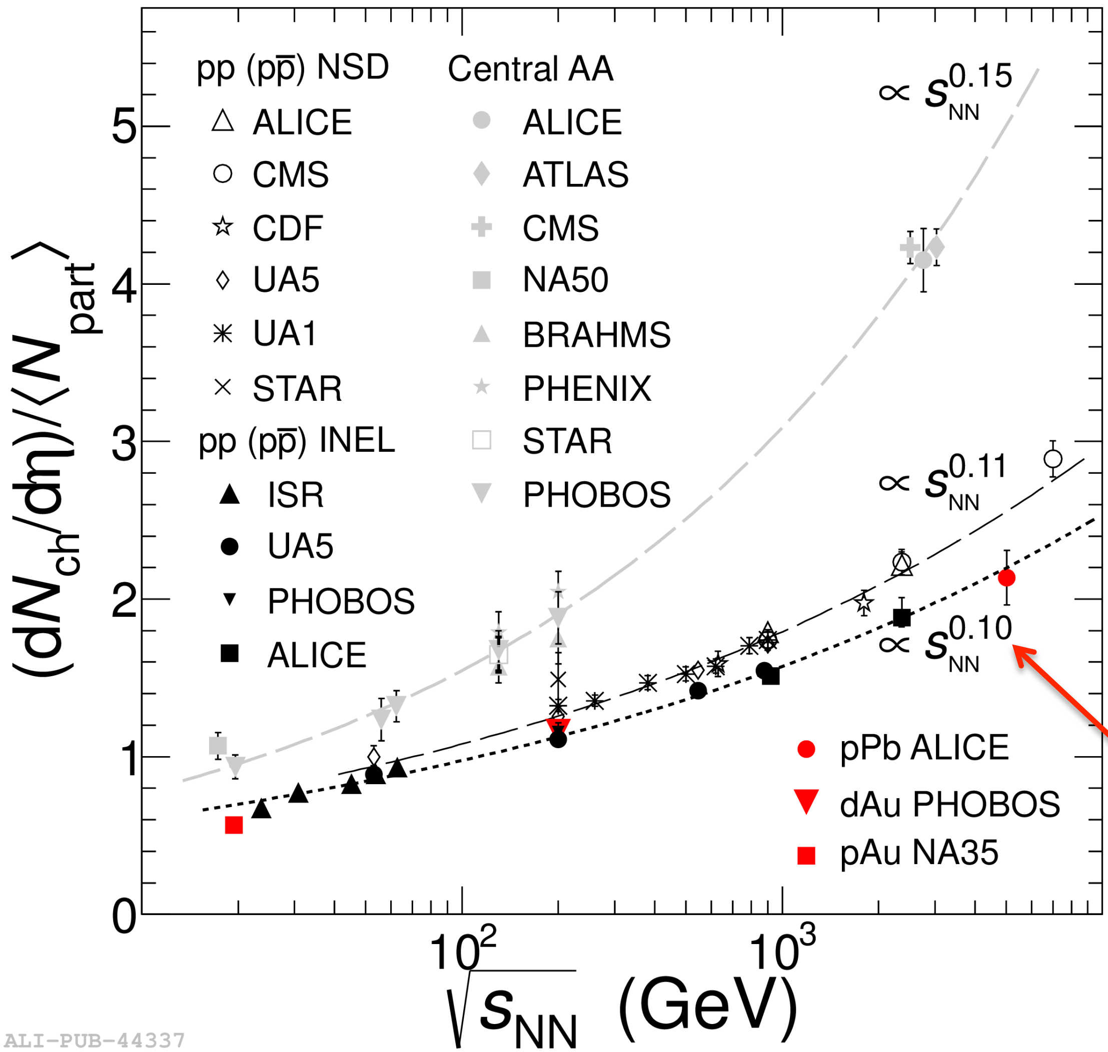

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transverse area is energy indpendent

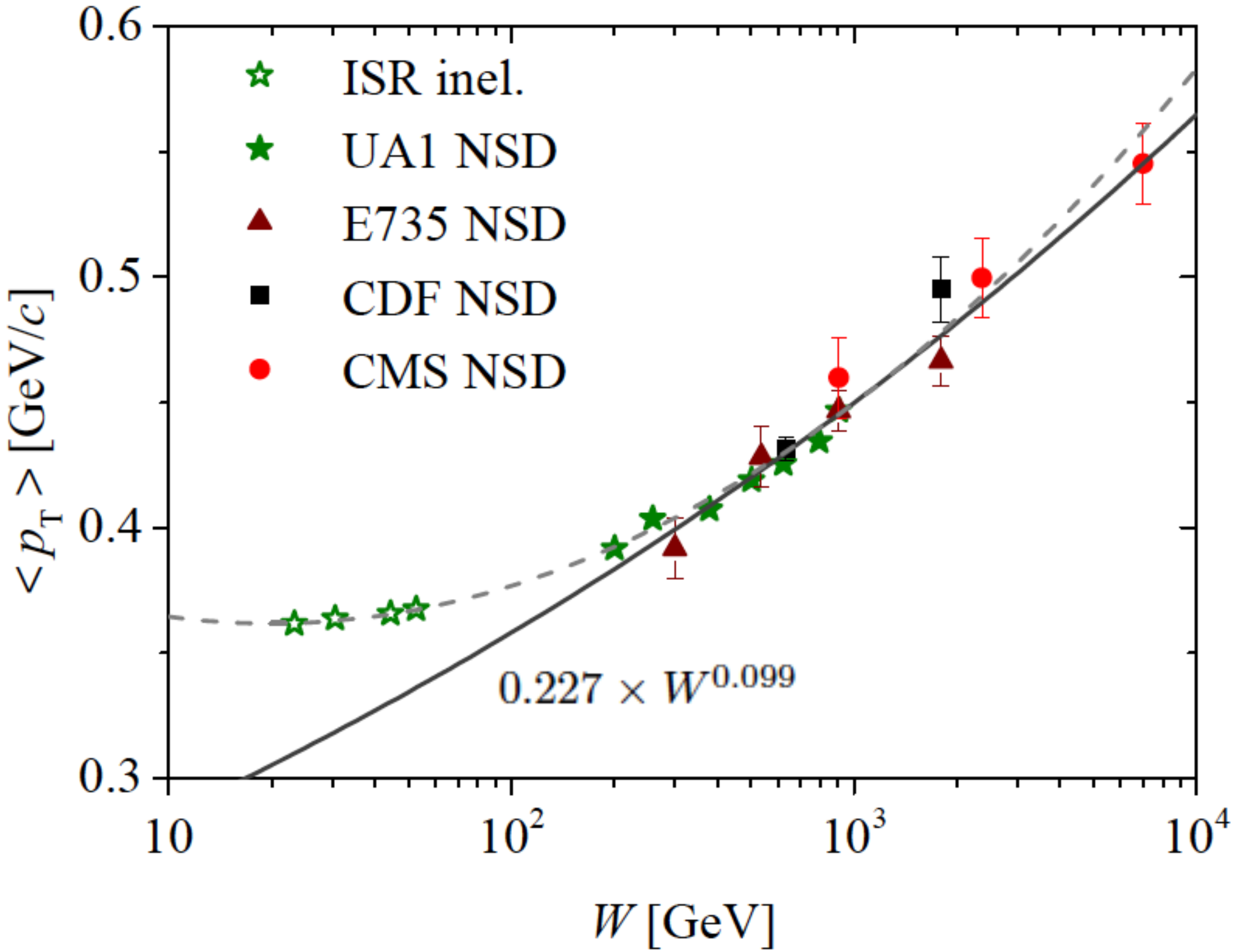
$$\lambda/(2+\lambda) \simeq 0.099$$

Average transverse momentum

$$\frac{dN_{\rm ch}}{dy d^2 p_{\rm T}} = S_\perp \mathcal{F}(\tau)$$

$$\langle p_{\rm T} \rangle = \frac{\int p_T \frac{dN_{\rm g}}{dy d^2 p_{\rm T}} d^2 p_T}{\int \frac{dN_{\rm g}}{dy d^2 p_{\rm T}} d^2 p_T} \sim \bar{Q}_{\rm s}(W) \sim Q_0 \left(\frac{W}{Q_0} \right)^{\lambda/(2+\lambda)}$$

Average transverse momentum



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Mean p_{T} as a function of N_{ch}

$$\langle p_{\mathrm{T}} \rangle \sim \bar{Q}_{\mathrm{s}}(W)$$

Mean p_T as a function of N_{ch}

$$\langle p_T \rangle \sim \bar{Q}_s(W) \sim \sqrt{\frac{dN/dy}{S_\perp}} \sim \frac{1}{R}\sqrt{\frac{dN}{dy}}$$

interaction radius

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interaction radius

phenomenological formula:

$$\langle p_T \rangle = \alpha + \beta\,\frac{1}{R}\sqrt{\frac{dN}{dy}}$$

nonperturbaitive
coefficient

α, β do not depend on energy, do depend on particle species

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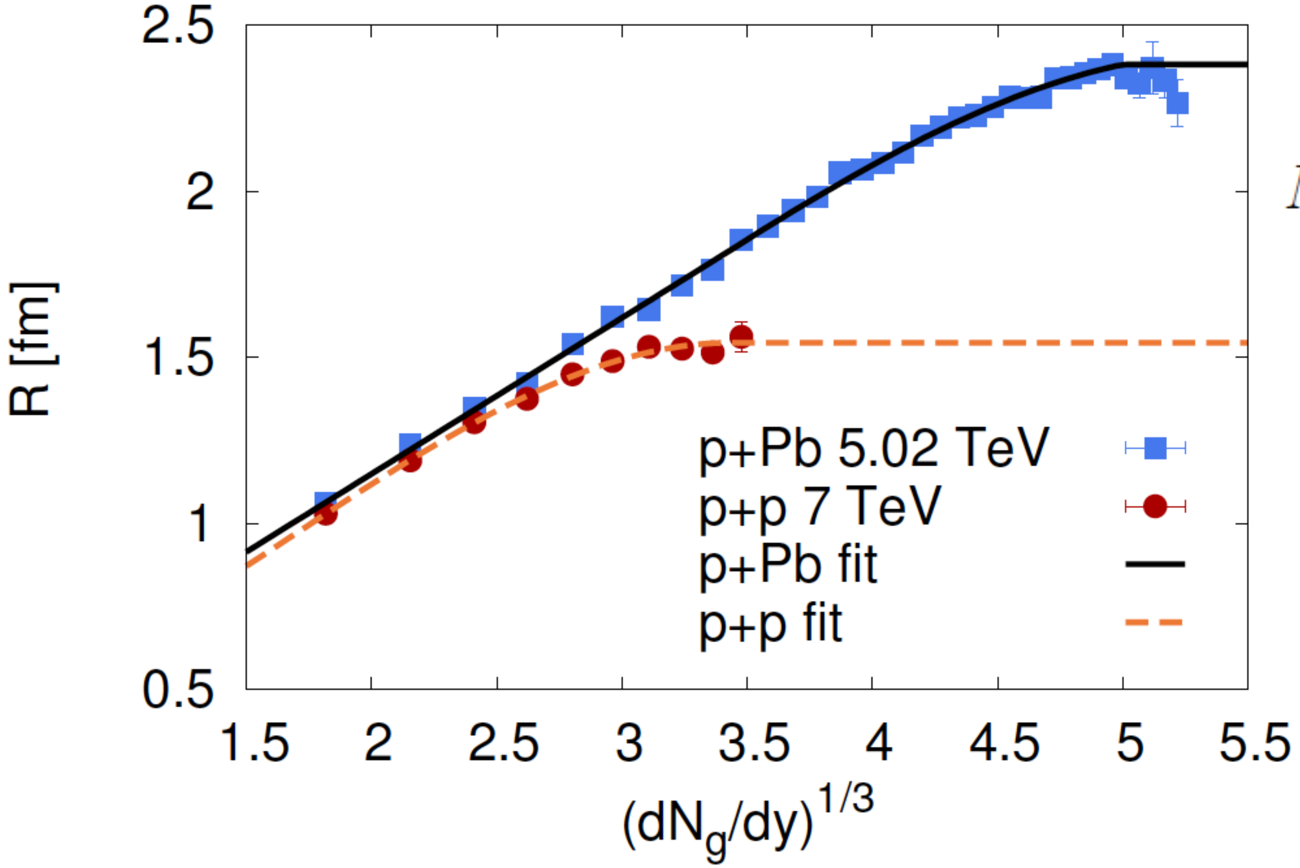
Interaction radius

A. Bzdak, B. Schenke, P. Tribedy and R. Venugopalan,
Initial state geometry and the role of hydrodynamics in proton-proton, proton-nucleus and deuteron-nucleus collisions,
Phys. Rev. C 87 (2013) 064906, [arXiv:1304.3403 [nucl-th]].



$$N_{\rm ch} = \frac{1}{\gamma \Delta y} \int_{\Delta y} \frac{dN_{\rm g}}{dy} dy$$

Scaling of mean p_T

$$\langle p_{\mathrm{T}} \rangle = \alpha + \beta \frac{\sqrt{N_{\mathrm{ch}}}}{R(\gamma N_{\mathrm{ch}})}$$

parton-hadron duality ↑

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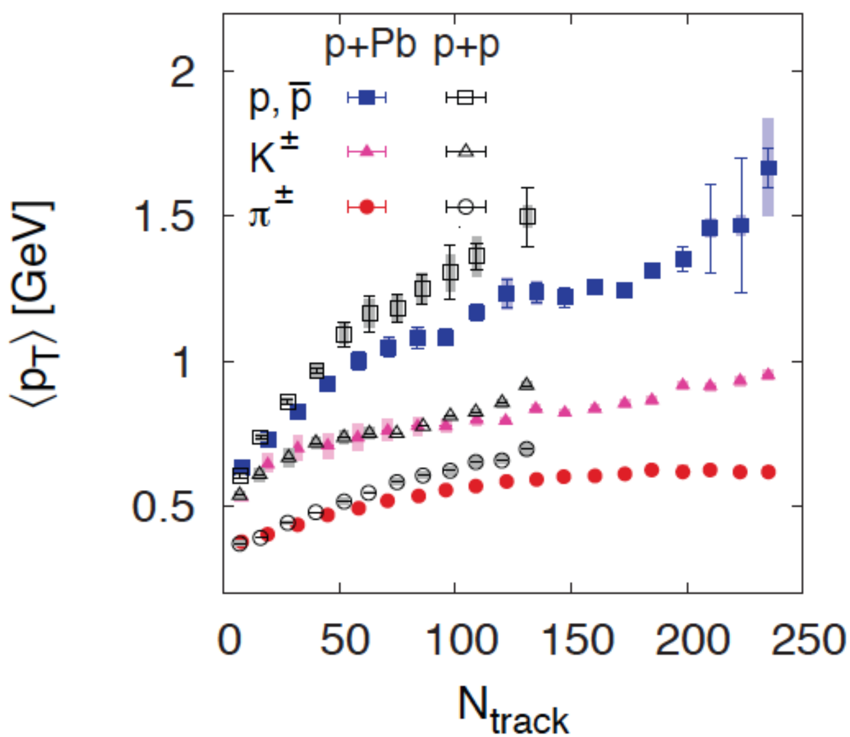
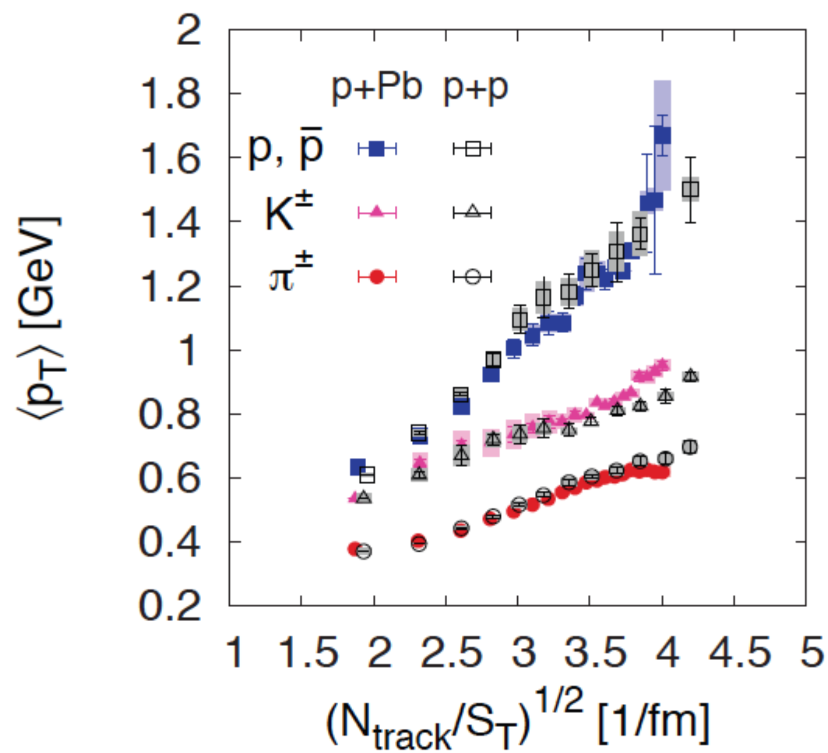
$$\langle p_T \rangle = \alpha + \beta \frac{\sqrt{N_{ch}}}{R(\gamma N_{ch})}$$

scaling variable

parton-hadron duality

CMS Collaboration, Eur. Phys. J. C72 (2013) 2164, C74 (2014) 2847





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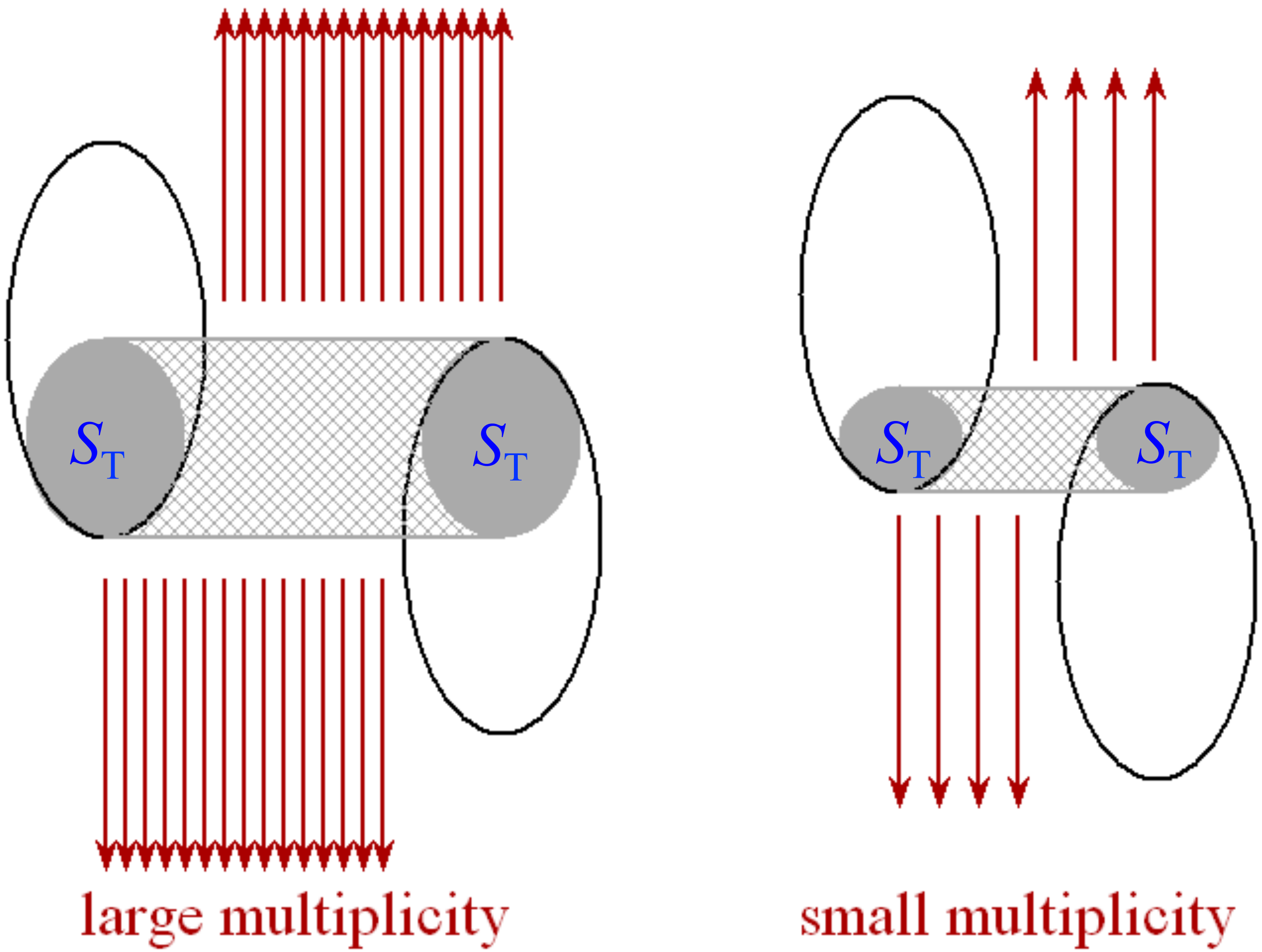
Interaction radius

Transverse size and expansion time (longitudinal size) are proportional for fixed multiplicity



similar effect in multipomeron model, where string tension is growing with multiplicity

M. A. Braun, C. Pajares
Phys. Lett. B 287, 154(1992)
Nucl. Phys. B 390 , 542, 559 (1993)
N. Armesto, D.A. Derkach, G.A. Feofilov
Phys. of At. Nuclei 71, 2087 (2008)

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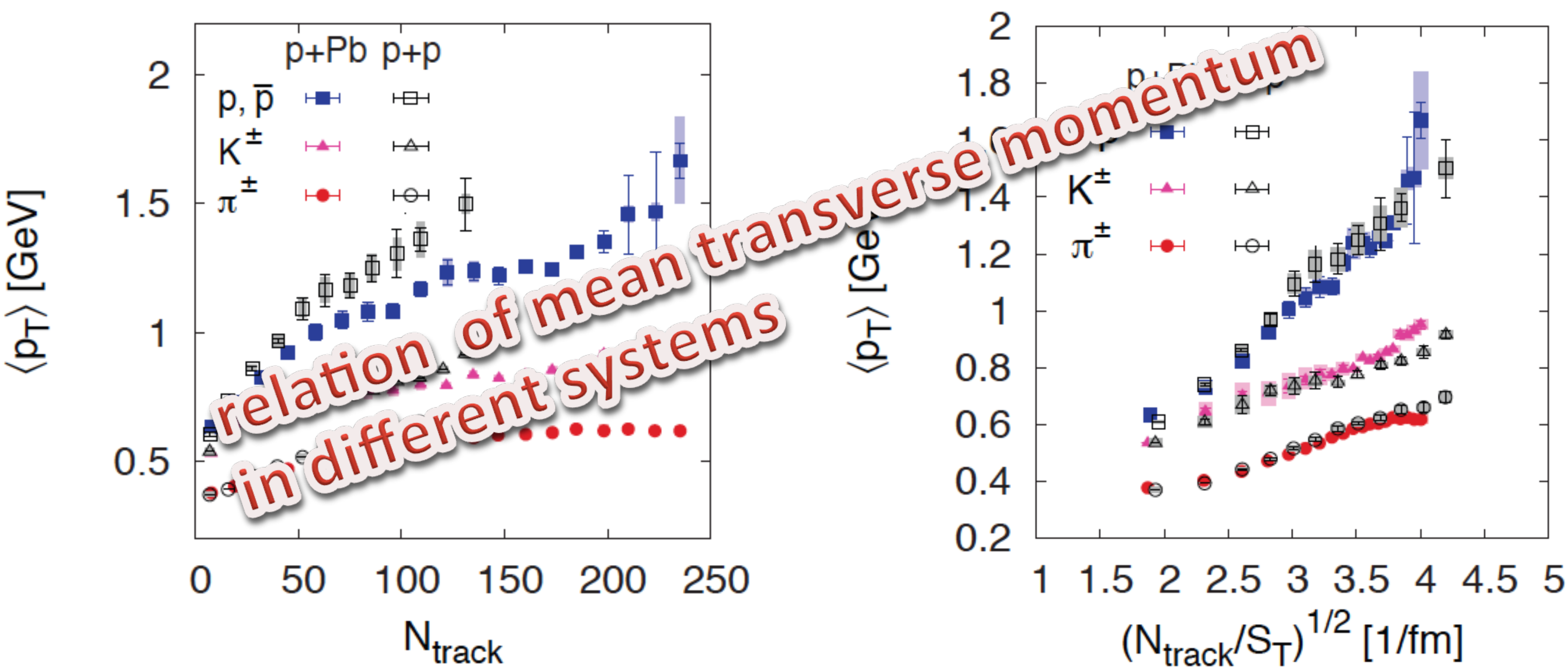
CMS Collaboration, Eur. Phys. J. C72 (2013) 2164, C74 (2014) 2847



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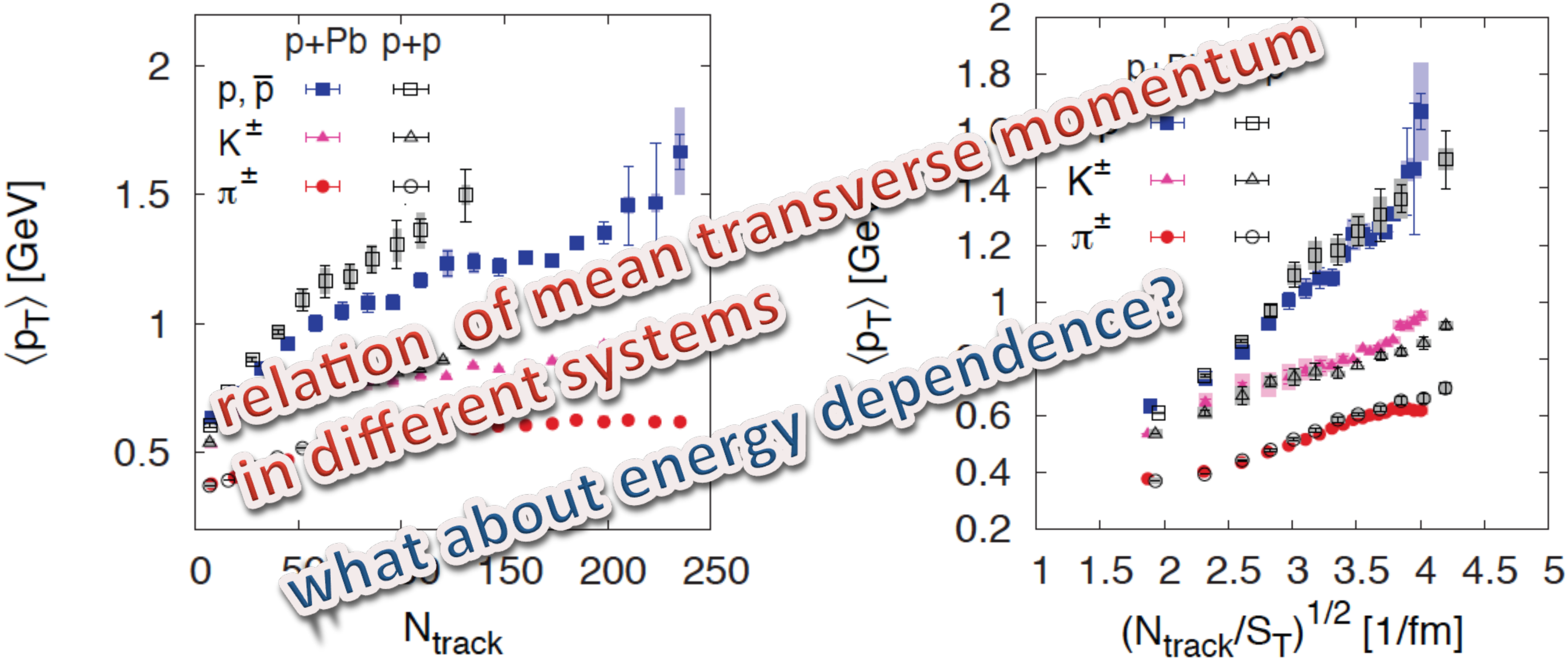

relation of mean transverse momentum in different systems

what about energy dependence?

Energy dependence of mean p_T - apparent paradox?

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new scaling variable

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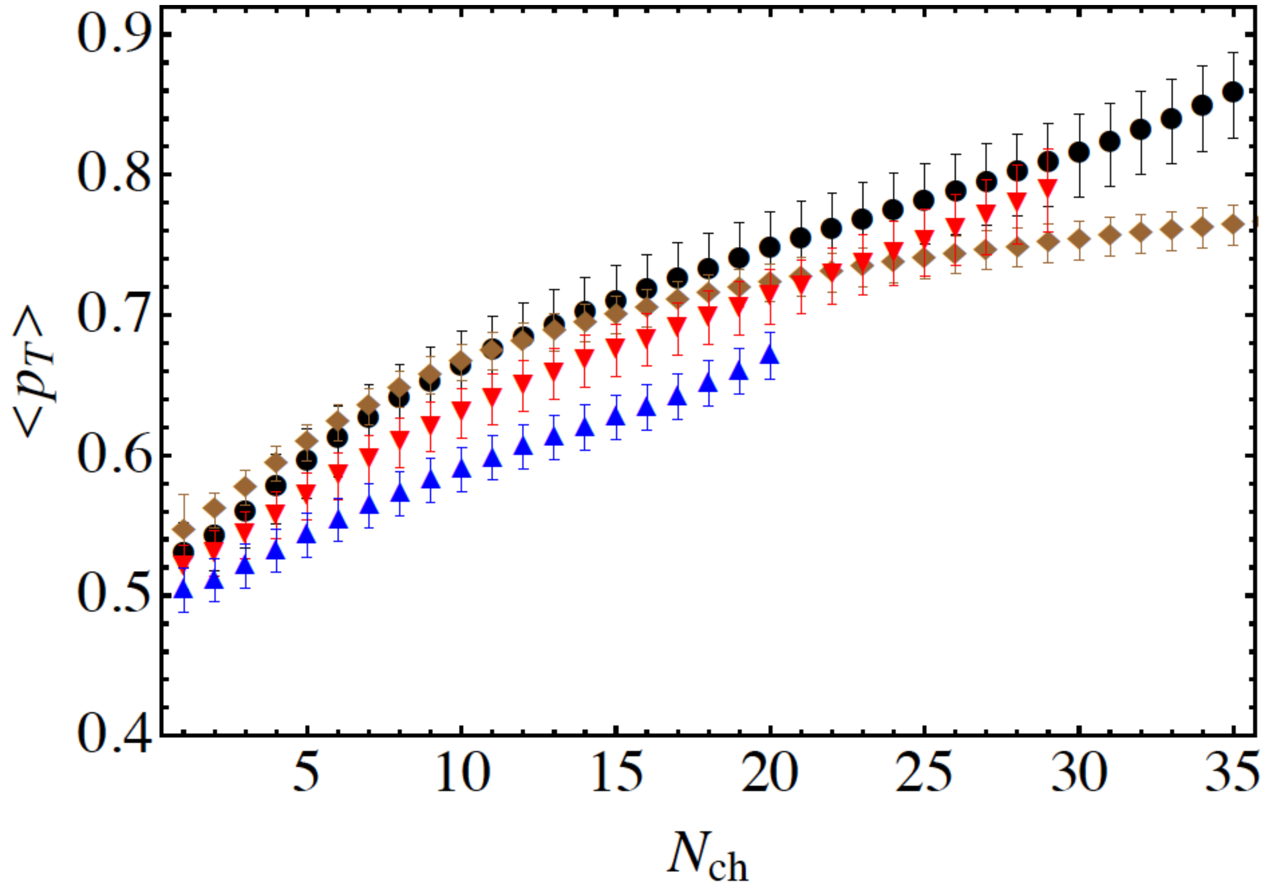
Mean p_T scaling

ALICE Collaboration, Phys. Lett. B727 (2013) 371 [arXiv:1307.1094 [nucl-ex]]



pp 7 TeV
pp 2.76 TeV
pPb 5.02 TeV
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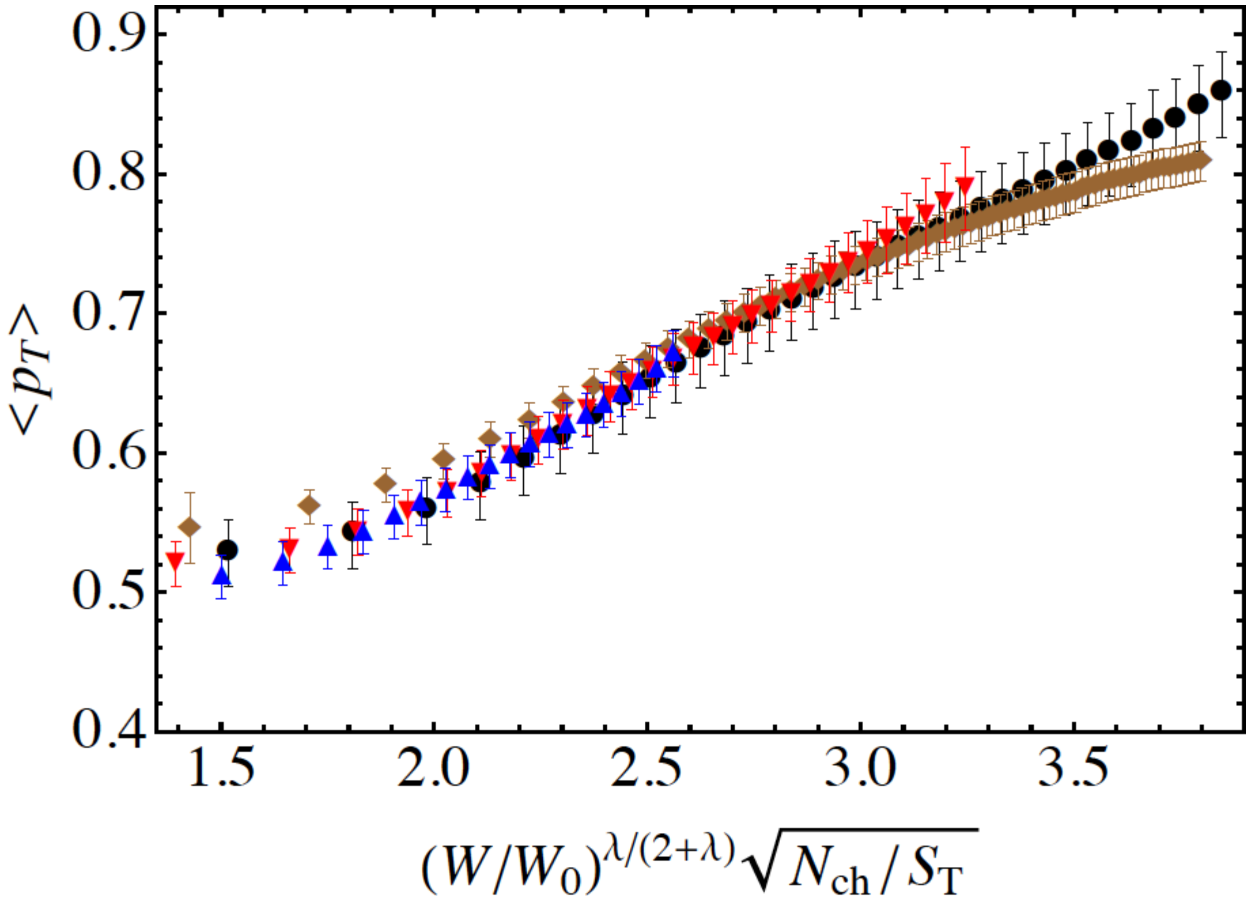
Mean p_T scaling

ALICE Collaboration, Phys. Lett. B727 (2013) 371 [arXiv:1307.1094 [nucl-ex]]



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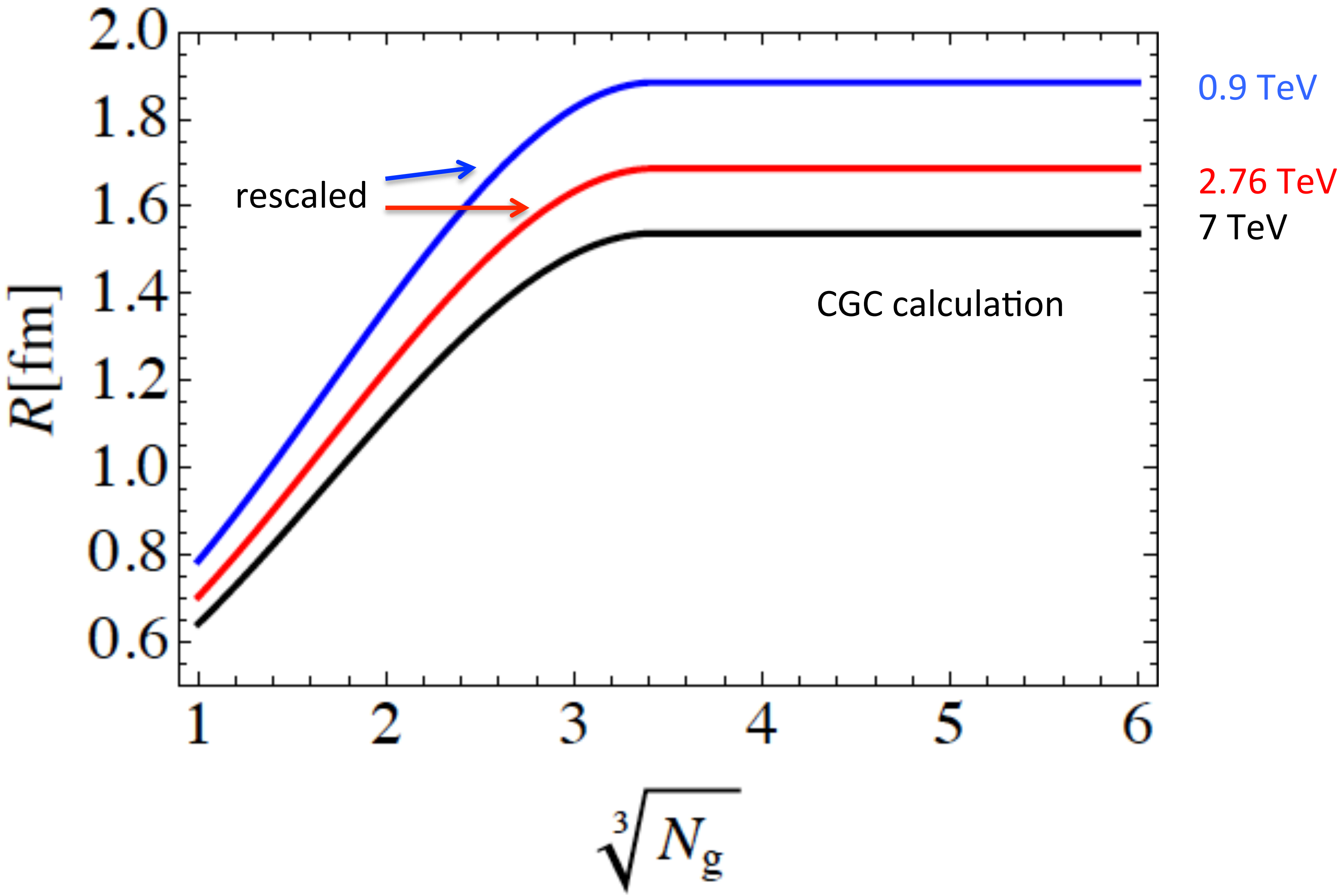
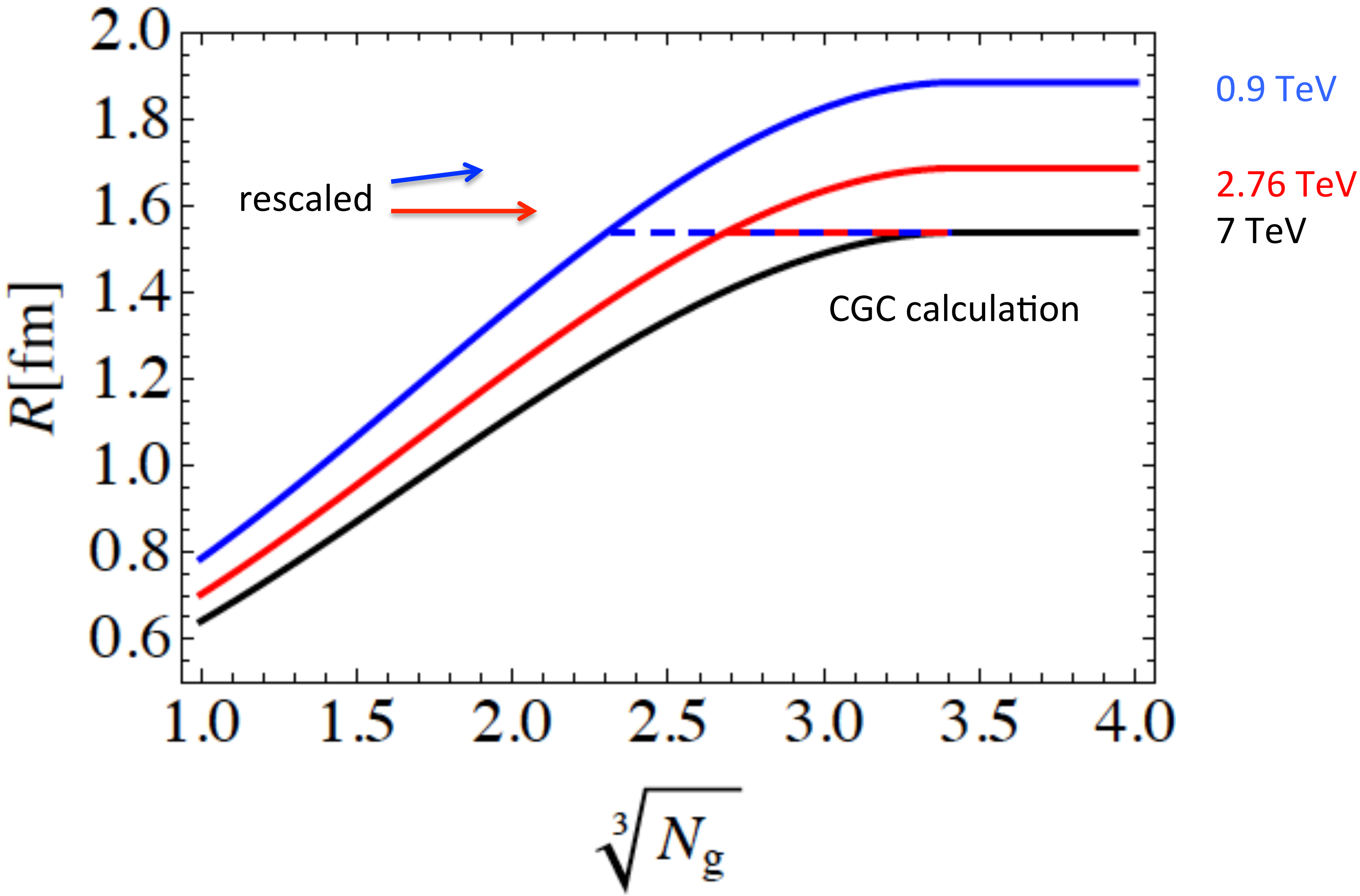
Effective R dependence on W



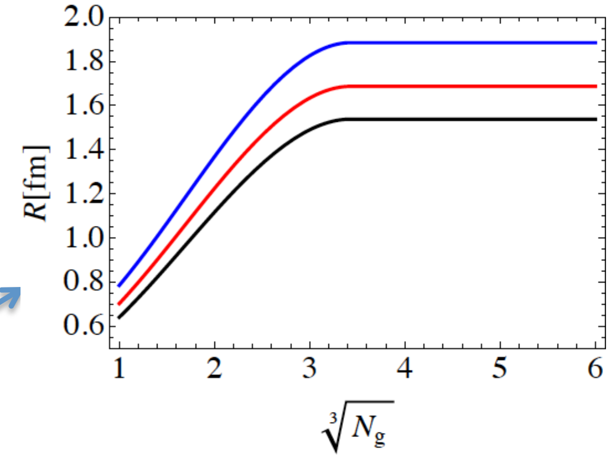
Effective *R* dependence on *W*



Mean p_T vs. interaction radius R

$$\langle p_T \rangle|_W = \alpha + \beta \frac{\sqrt{N_{ch}}}{R(\sqrt[3]{\gamma N_{ch}})|_W}$$

fit α, β and γ to 7 TeV and then use R from Fig.



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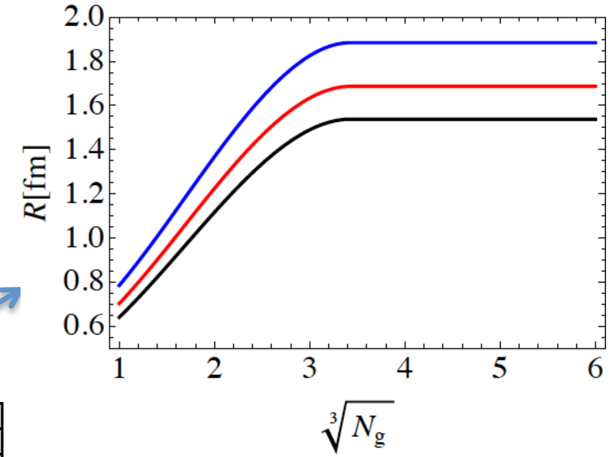

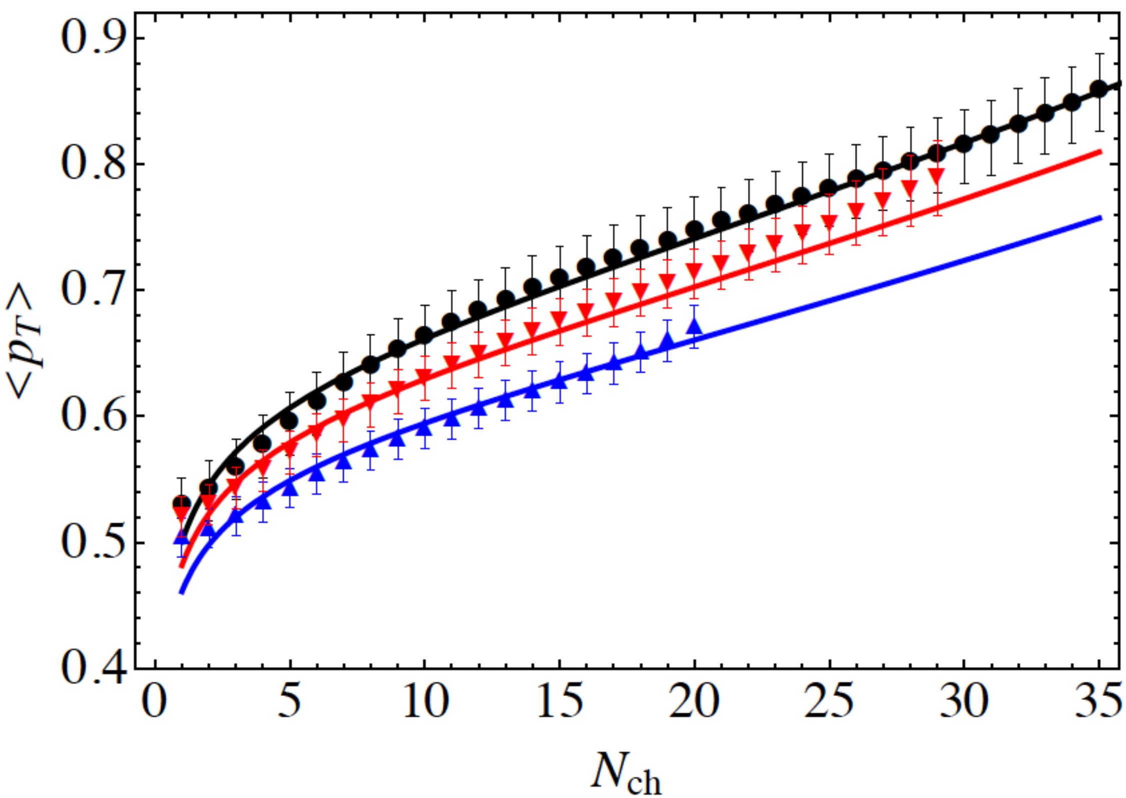

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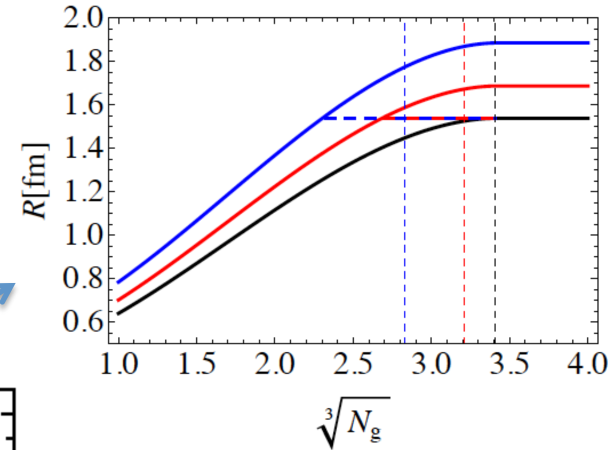
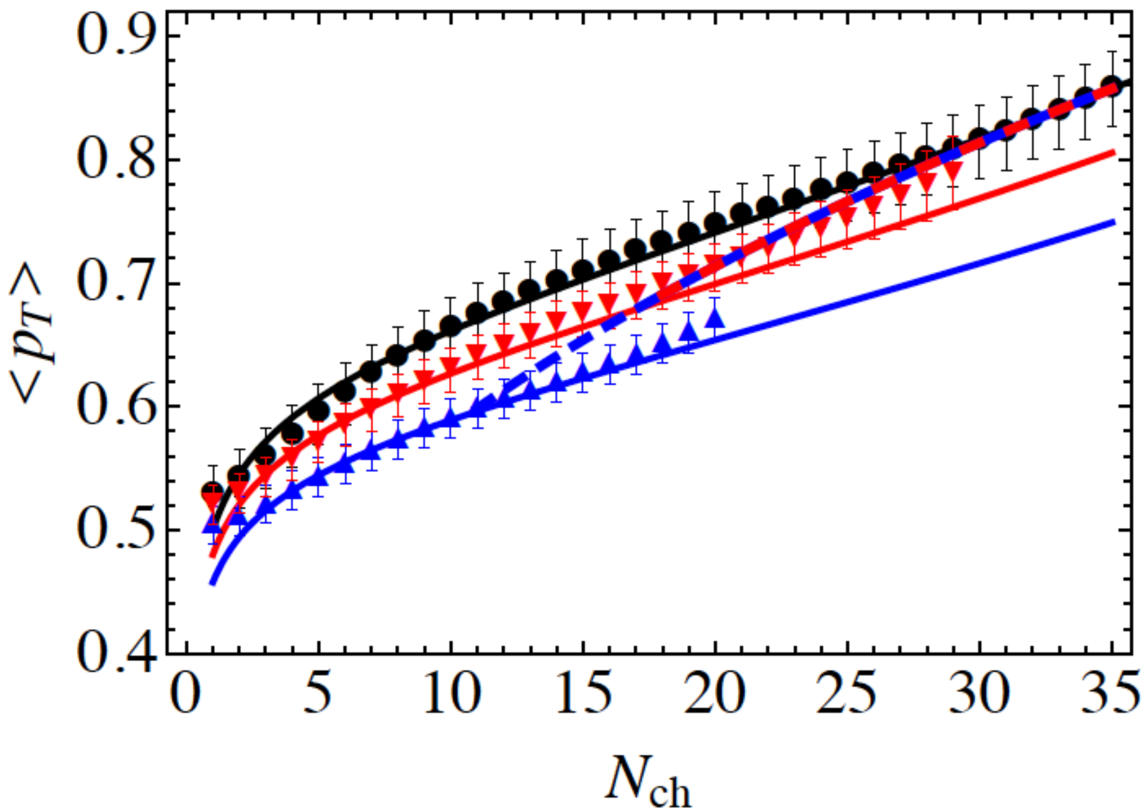
fit *α*, *β* and *γ* to 7 TeV and then use *R* from Fig.





pp 7 TeV

pp 2.76 TeV

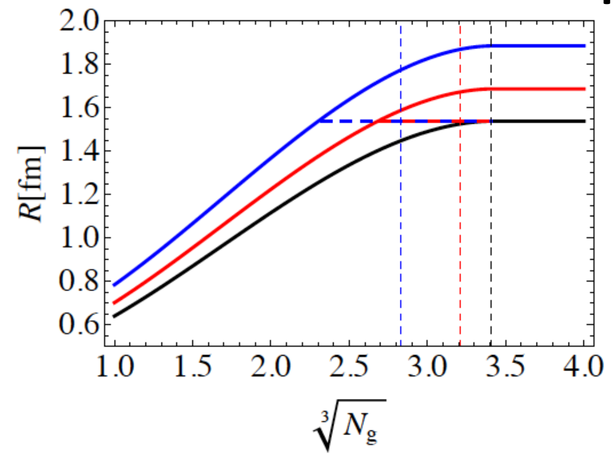
pp 0.9 TeV

Why mean p_T is interesting

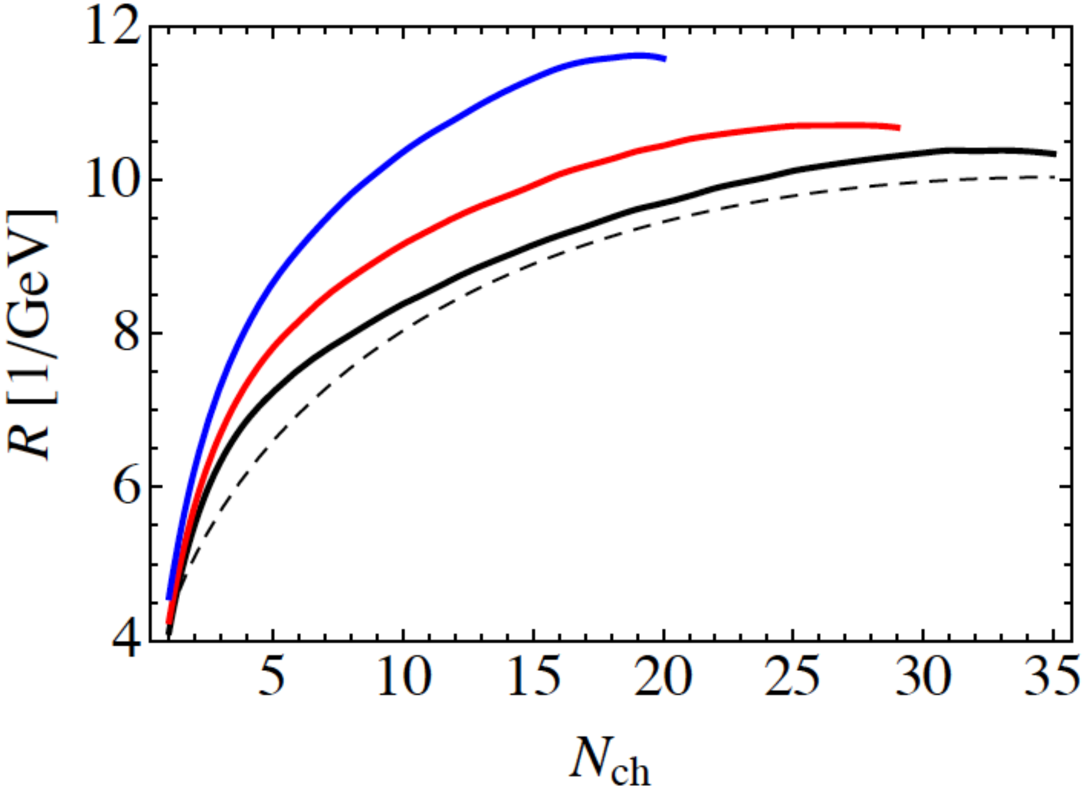
- $\langle p_T \rangle (N_{ch})$ – correlations are sensitive to the fine details of dynamics
- complete change of behavior from small to large energies
- possible sign of phase transition
- difficult to describe by untuned MonteCarlos
- saturation included in EPOS does a good job
- geometrical scaling predicts energy dependence of $\langle p_T \rangle$
- sensitivity to the interaction radius dependence on N_{ch}
- radii calculated from CGC describe well $\langle p_T \rangle$ in different systems
- longitudinal vs. transverse sizes – one scale problem
- induced energy dependence of S_T for fixed N_{ch}
- scaling of $\langle p_T \rangle (N_{ch})$ induced by energy dependence of Q_{sat}
- interaction radii cannot be too large, new saturation seen in data?

Interaction radius R from mean p_T

$$\langle p_T \rangle|_W = \alpha + \beta \frac{\sqrt{N_{ch}}}{R(\sqrt[3]{\gamma N_{ch}})|_W}$$



fix α assuming energy scaling for intermediate N_{ch}



extracted interaction radii at 2.76, 0.9 and 7 TeV

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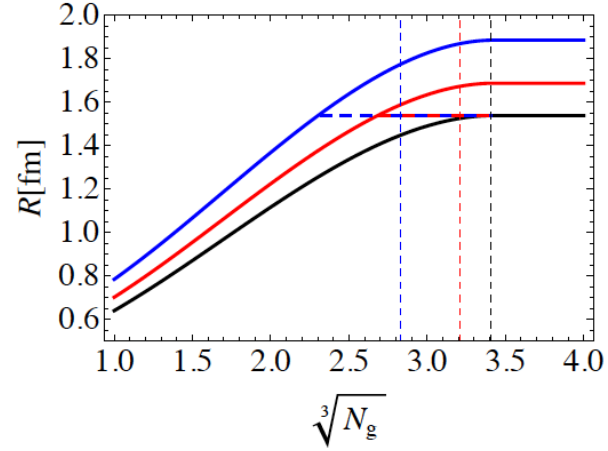

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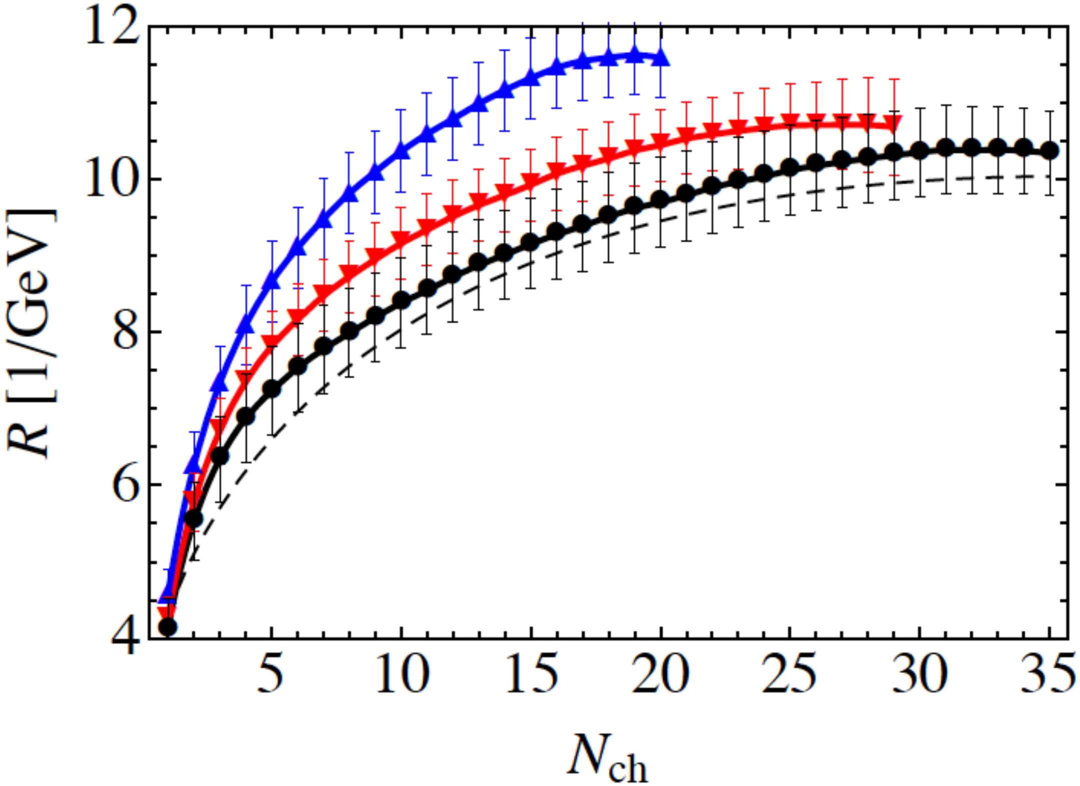

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