Charged-hadron production in the three-sources RDM at LHC energies

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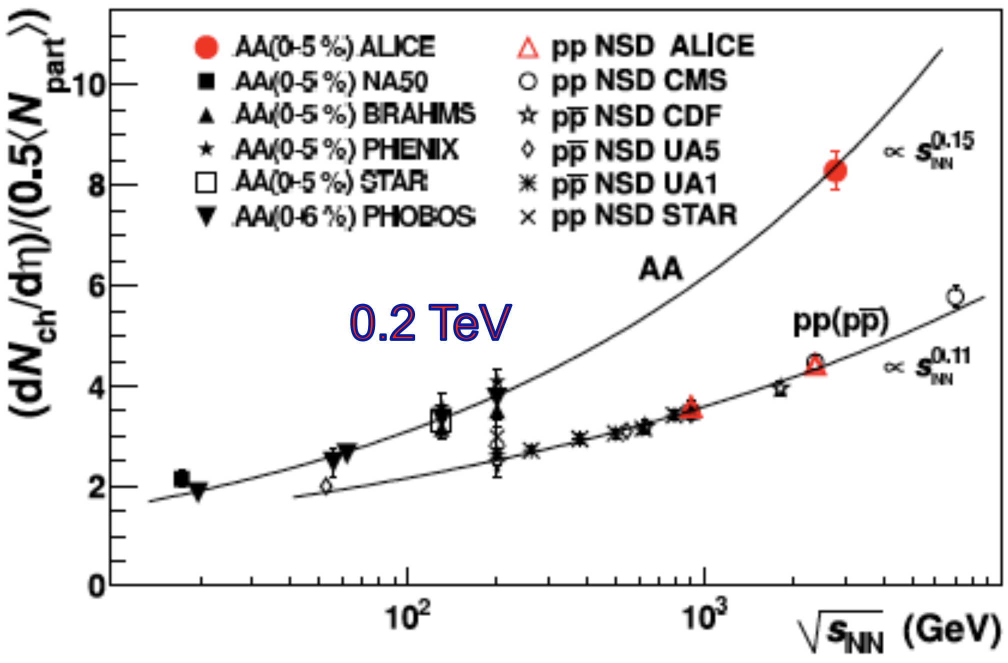
Topics

1. Introduction: PbPb @ LHC
2. Charged-hadron pseudorapidity distributions in a nonequilibrium-statistical approach (RDM)
3. Comparison with RHIC and LHC data
4. Conclusion

1. Intro: ALICE PbPb results @ LHC energy 2.76 TeV



$N_p \approx 382$

$$\eta = -\ln[\tan(\theta/2)]$$

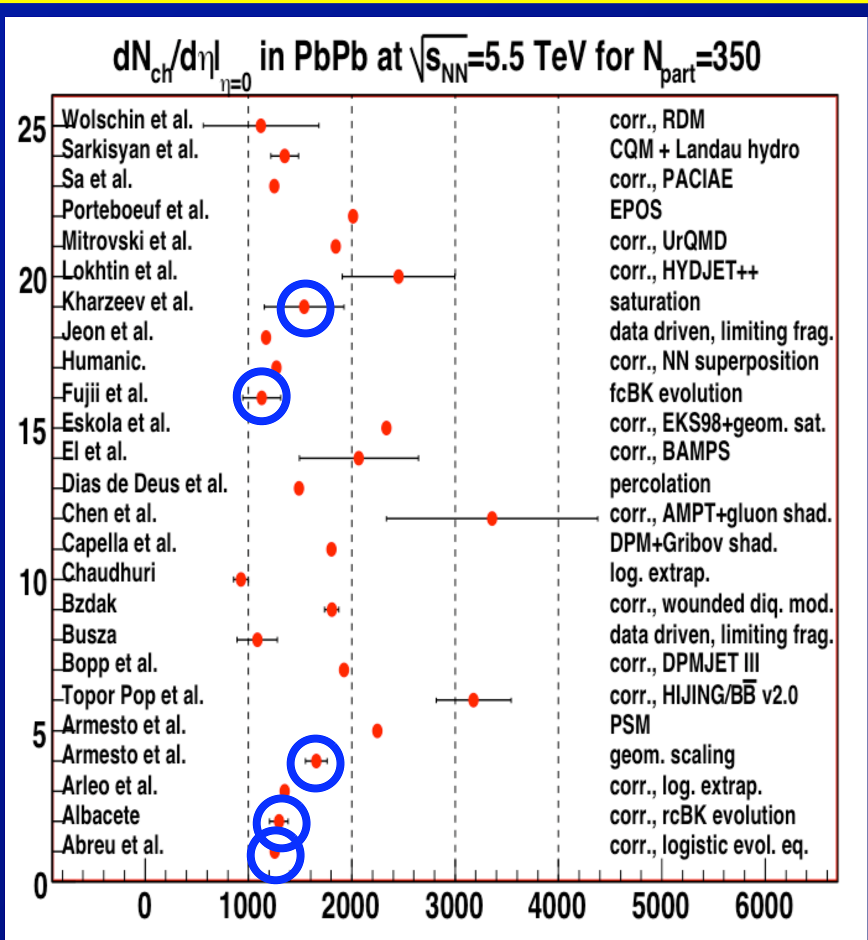
Talk by P. Christagoklou on June 12

FIG. 3. Charged particle pseudo-rapidity density per participant pair for central nucleus–nucleus [16–24] and non-single diffractive pp/p$\bar{\text{p}}$ collisions [25–31], as a function of $\sqrt{s_{NN}}$. The energy dependence can be described by $s_{NN}^{0.15}$ for nucleus–nucleus, and $s_{NN}^{0.11}$ for pp/p$\bar{\text{p}}$collisions.

ALICE collab., PRL 105, 252301 (2010)(see also Eur. Phys. J. C 65, 111 (2010) for p + p)

dN/dη(η=0) = 1584 ± 4 (stat.) ± 76 (sys.): 8.3 ± 0.4 per part. nucleon pair

LHC dN/dη Predictions



- Many different predictions for LHC Pb+Pb central dN/dη
  - @ 5.5 TeV
- Saturation (motivated) predictions at low end of range
  - 1200-1600

From: N. Armesto et al., J.Phys. G35, 05400 (2008); cf also B. Cole, ICHEP Paris 2010

Predictions vs. ALICE PbPb data of dN/dη (η≈0) @ 2.76 TeV

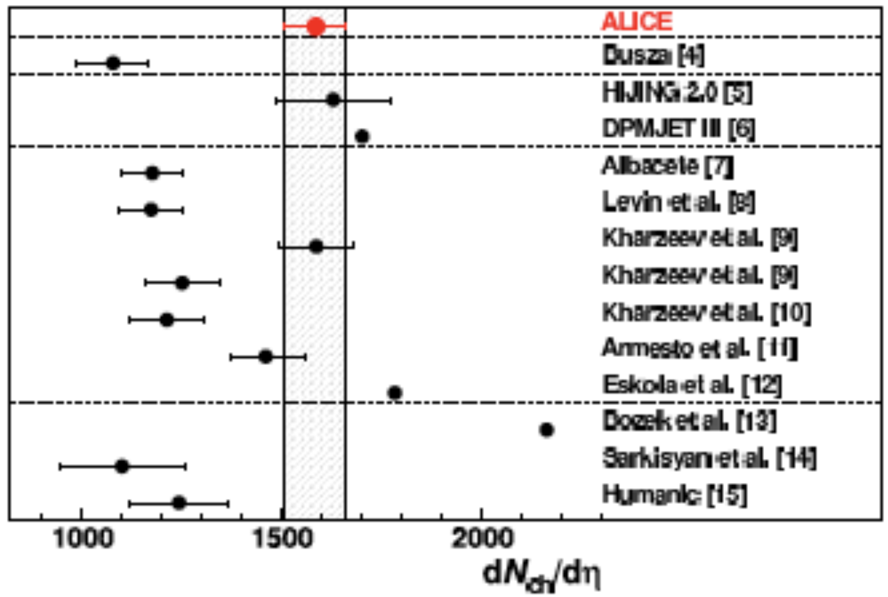


FIG. 4. Comparison of this measurement with model predictions. Dashed lines group similar theoretical approaches.

from: ALICE collab., PRL 105, 252301 (2010).

More interesting than the midrapidity value is the distribution function.

2. Relativistic Diffusion Model (RDM)

$$\frac{\partial}{\partial t}R(y,t) = -\frac{\partial}{\partial y}\Big[J(y)R(y,t)\Big] + D_y\frac{\partial^2}{\partial y^2}[R(y,t)]^{2-q}$$

R (y,t) Rapidity distribution function. The standard linear Fokker-Planck equation corresponds to q = 1, and a linear drift function. For the three components k = 1,2,3 of the rapidity distribution,

$$\frac{\partial}{\partial t}R_k(y,t) = -\frac{1}{\tau_y}\frac{\partial}{\partial y}\Big[(y_{eq}-y)\cdot R_k(y,t)\Big] + D_y^k\frac{\partial^2}{\partial y^2}R_k(y,t)$$

Linear drift term with relaxation time τ_y Diffusion term, D_y=const.

Relaxation time and diffusion coefficient are related through a dissipation-fluctuation theorem. The broadening is enhanced due to collective expansion.

$$< y_{1,2}(t) >= y_{eq}[1-\exp(-t/\tau_y)] \mp y_{max}\exp(-t/\tau_y)$$ mean value

$$\sigma^2_{1,2,eq}(t) = D_y^{1,2,eq}\tau_y[1-\exp(-2t/\tau_y)]$$ variance

Linear Model: G. Wolschin, Eur. Phys. J. A5, 85 (1999); with 3 sources: Phys. Lett. B 569, 67 (2003); PLB 698, 411 (2011); M. Biyajima, M. Ide, M. Kaneyama, T. Mizoguchi, and N. Suzuki, Prog. Theor. Phys. Suppl. 153, 344 (2004)

Pseudorapidity distributions are then obtained through the Jacobian transformation

$$\frac{dN}{d\eta} = \frac{dN}{dy}\frac{dy}{d\eta} = \frac{p}{E}\frac{dN}{dy} \simeq J(\eta, \langle m\rangle/\langle p_T\rangle)\frac{dN}{dy}$$

$$J(\eta, \langle m\rangle/\langle p_T\rangle) = \cosh(\eta)\cdot$$
$$[1 + (\langle m\rangle/\langle p_T\rangle)^2 + \sinh^2(\eta)]^{-1/2}.$$

- Consider pions, kaons, protons
- Determine $J_{y=0}$ at y = η = 0 with the experimental values for dN/dy(π,K,p) and dN/dη (charged hadrons)
- Compute J using $<m>=m_\pi$ and $<p_T> = <p_{T,eff}>$ with

$$< p_{T,eff} >= m_\pi J_{y=0}/\sqrt{1 - J^2_{y=0}}$$

with the rapidity distribution

$$\frac{dN_{ch}(y, t = \tau_{int})}{dy} = N^1_{ch}R_1(y, \tau_{int})$$
$$+N^2_{ch}R_2(y, \tau_{int}) + N^{eq}_{ch}R_{eq}(y, \tau_{int}).$$

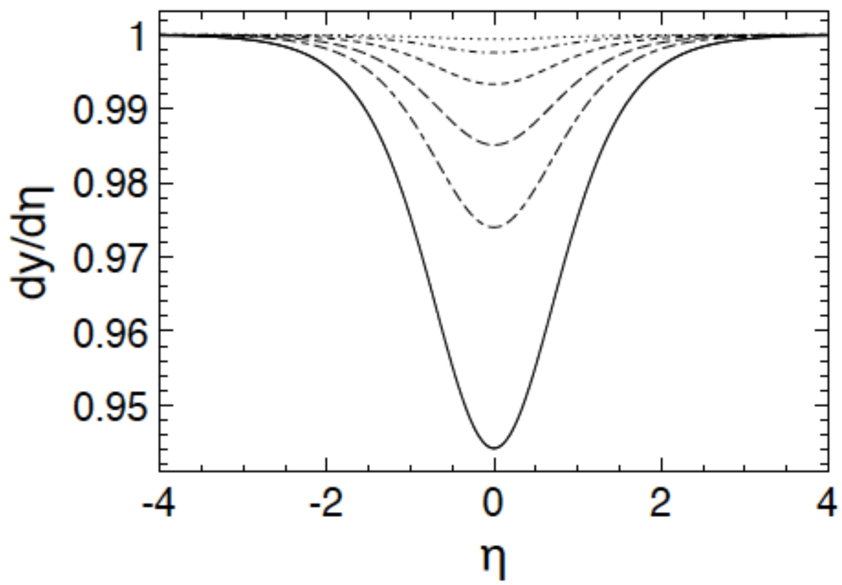
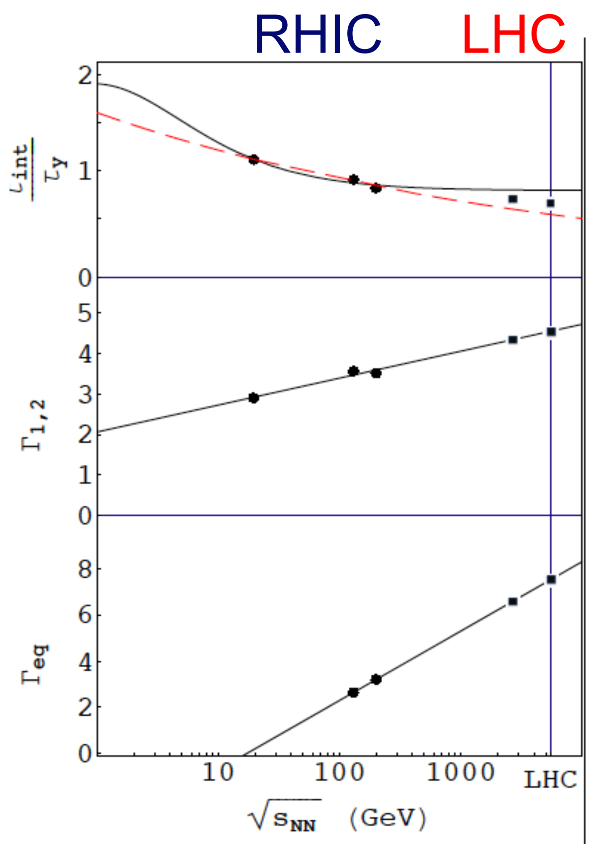


Figure 1: The Jacobian $dy/d\eta$ for $< m >= m_\pi$ and average transverse momenta (bottom to top) $< p_T >= 0.4, 0.6, 0.8, 1.2, 2$ and 4 GeV/c.

Energy dependence of the RDM parameters



From: R. Kuiper and G.Wolschin, Annalen Phys. 16, 67 (2006)

Dependence of the diffusion-model parameters for heavy systems at RHIC (dots) and LHC (squares) energies on ln $\sqrt{s_{NN}}$:

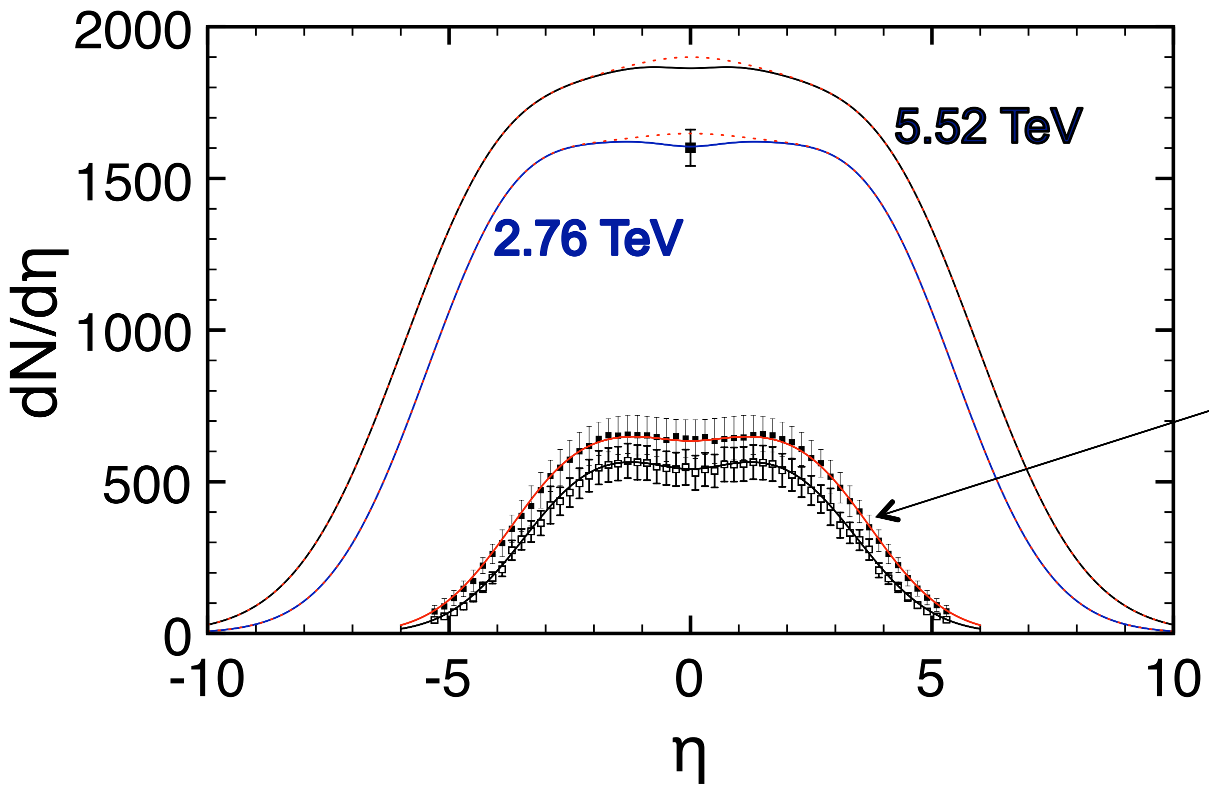
➢Quotient of interaction time and relaxation time for sinh- and exponential (dashed) extrapolation (upper frame);

➢Effective widths of the peripheral sources, including collective expansion (middle frame);

➢Effective width of the midrapidity source (lower frame).

The results are for charged-hadron pseudorapidity distributions.

3. Comparison with RHIC and LHC data



LHC: PbPb 0-5% @ 5.52 TeV and 2.76 TeV central collisions, RDM-result adjusted to ALICE [2] dN/dη at η=0

RHIC: PHOBOS AuAu data 0-6% @ 0.13 and 0.2 TeV [3] with RDM-results (χ^2-minimization)

GW, Phys. Lett. B 698, 411 (2011)

dN/dη (η≈0) = 1584 ± 4 (stat.) ± 76 (sys.) [1]
1601±60 [2]

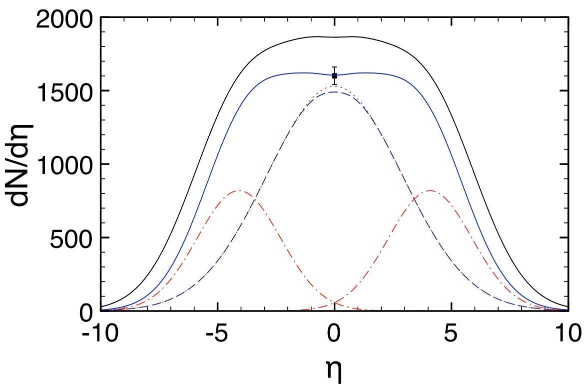
[1] ALICE collab., PRL 105, 252301 (2010)

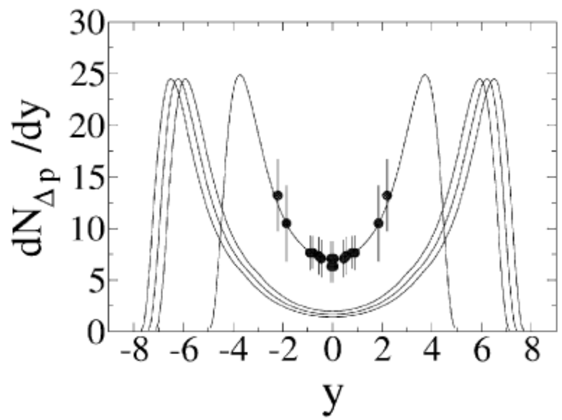
[2] ALICE collab., PRL 106, 032301 (2011)

[3] B.B. Back et al.,PHOBOS coll., PRL 87, 102303 (2001); PRL 91, 052303 (2003); PRC 83, 024913 (2011)

LHC: Small fragmentation-source contributions at midrapidity

Charged hadrons





Net protons

PbPb @ 2.76 TeV:

The smallness of the fragmentation sources at midrapidity is in qualitative agreement with results from our QCD-based microscopic model

Y. Mehtar-Tani and GW, Phys. Rev. Lett. 102,182301 (2009); PRC C80, 054905 (2009)

for net-baryon distributions, which indicates a midrapidity net-baryon yield dN/dy(y=0) ≈ 4, corresponding to 12 valence quarks, as cp. to 1248 valence quarks in the system (the net-baryon distribution has no gluon-gluon source)

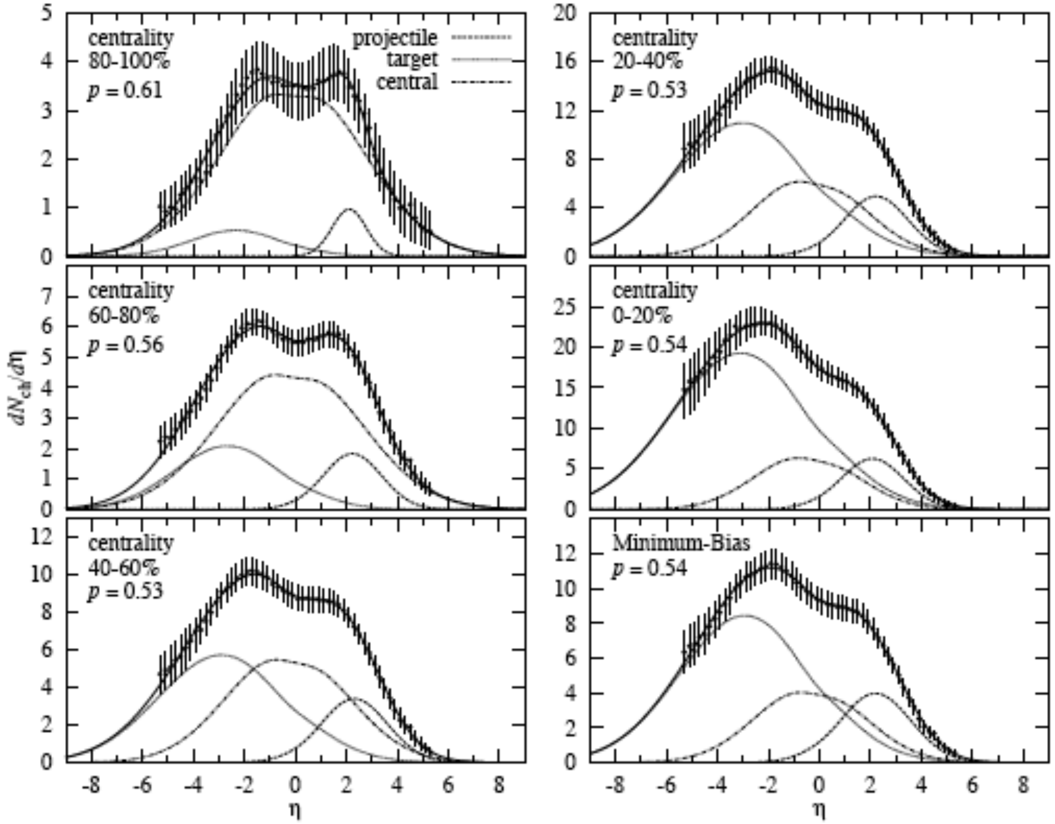
YMT&GW, Phys. Lett. B688, 174 (2010);
GW, Phys. Lett. B 698, 411 (2011)

Parameters of the 3-sources RDM at RHIC and LHC energies

Table 1: Three-sources RDM-parameters for 0–6% Au + Au at RHIC energies (upper two lines) and for 0–5% Pb + Pb at LHC energies (lower two lines). See Fig. 2 and text for the extrapolation of the time parameter τ_{int}/τ_y to LHC energies. Widths and particle numbers denoted by * are extrapolated linearly with $\log(\sqrt{s_{NN}})$. At RHIC energies the nonequilibrium sources from quark-gluon interactions with particle content $N_{ch}^{1,2}$ dominate. At LHC energies the local equilibrium source from gluon-gluon collisions with particle content N_{ch}^{eq} is the major origin of particle production at midrapidity. Experimental midrapidity values (last column) are from PHOBOS [22, 23] for $|\eta| < 1$ at RHIC energies and from ALICE [2] for $|\eta| < 0.5$ at 2.76 TeV.

$\sqrt{s_{NN}}$ (TeV)	y_{beam}	τ_{int}/τ_y	$< y_{1,2} >$	$\Gamma_{1,2}$	Γ_{gg}	N_{ch}^{tot}	n_{gg}	$\frac{dN}{d\eta}\vert_{\eta\simeq 0}$
0.13	∓4.93	0.89	∓2.02	3.43	2.46	4398	0.13	579±23[17]
0.20	∓5.36	0.82	∓2.40	3.48	3.28	5315	0.26	655±49 [17]
2.76	∓7.99	0.87	∓3.34	4.99	6.24	17327	0.56	1601±60 [2]
5.52	∓8.68	0.85*	∓3.70	5.16*	7.21*	21699*	0.67*	1940*

3-sources model (RDM): Centrality dependence of the asymmetric dAu system @ 0.2 TeV



200 GeV dAu

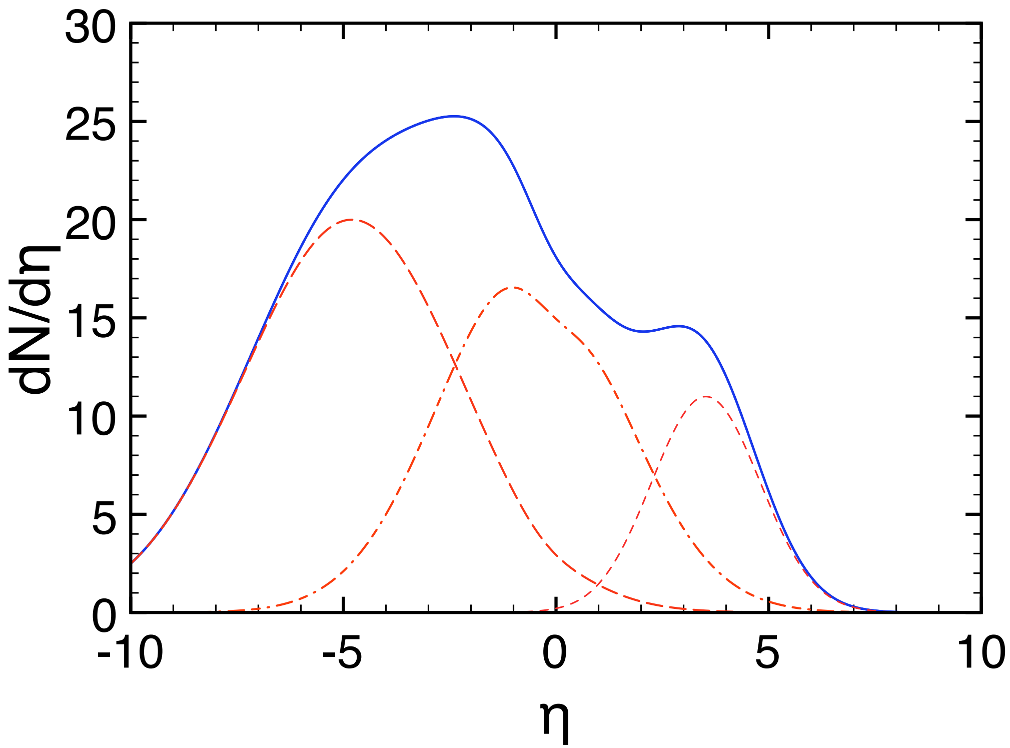
PHOBOS data Phys. Rev. C72, 031901 (2005)

G. Wolschin, M.Biyajima,T.Mizoguchi, N.Suzuki,
Annalen Phys. 15, 369 (2006)

Asymmetric systems are more sensitive to details of the nonequilibrium-statistical evolution than symmetric systems

3-sources model (RDM): Preliminary calc. for central pPb @ 5.02 TeV

0-5% central 5.02 TeV pPb @ LHC



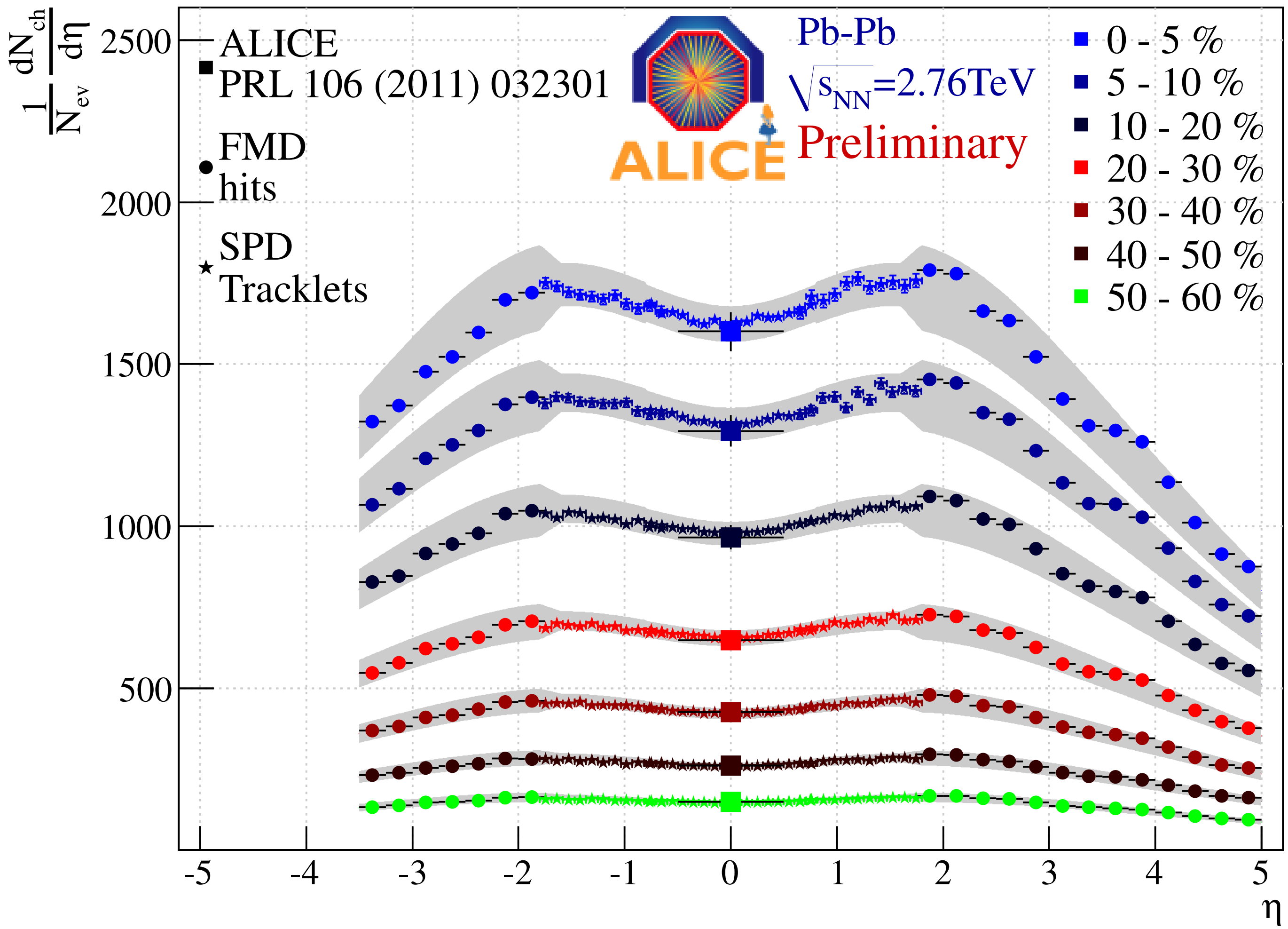
p_p= = 4 TeV/c

$$\sqrt{s_{NN}} = \sqrt{\frac{Z_1 * Z_2}{(A_1 * A_2)}} * 2p_p = 5.02\text{TeV}$$

$$y_{\text{beam}}^{cm} = \mp \ln(\sqrt{s_{NN}}/m_0) = \mp 8.586$$

(RDM parameters to be adjusted)

ALICE prel. results for pseudorapidity distributions of produced charged hadrons



H.H. Dalsgaard et al., ALICE Collab.; cf talk **June 12**

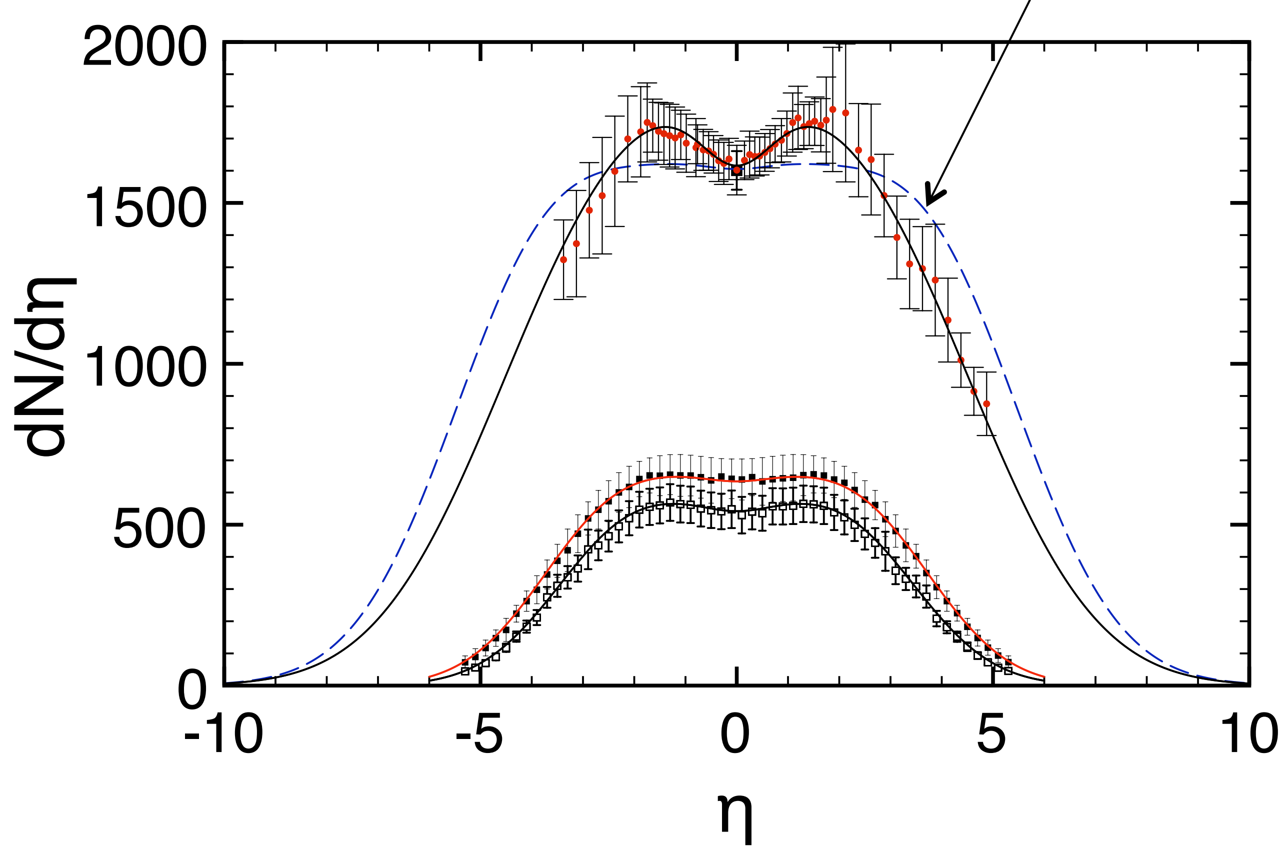
PRELIMINARY

- **Central dip is more pronounced than in the prediction**

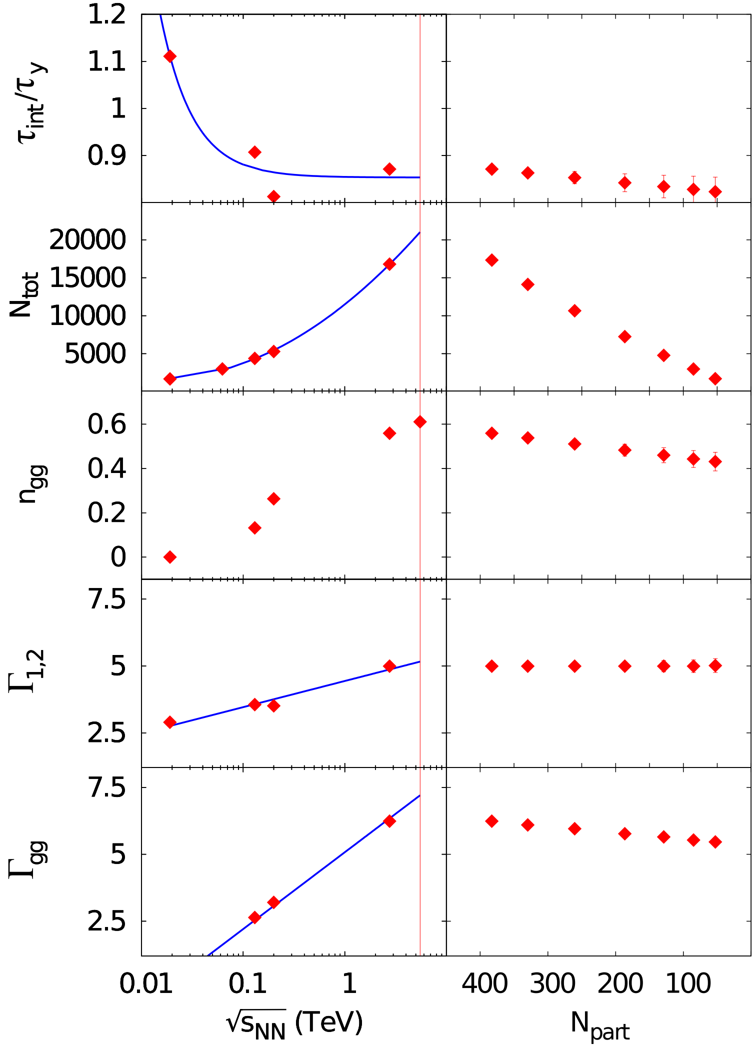
- **Peak at smaller eta values than expected**

Comparison with the RDM prediction

Central PbPb @ 2.76 TeV



Consequences for the RDM parameters

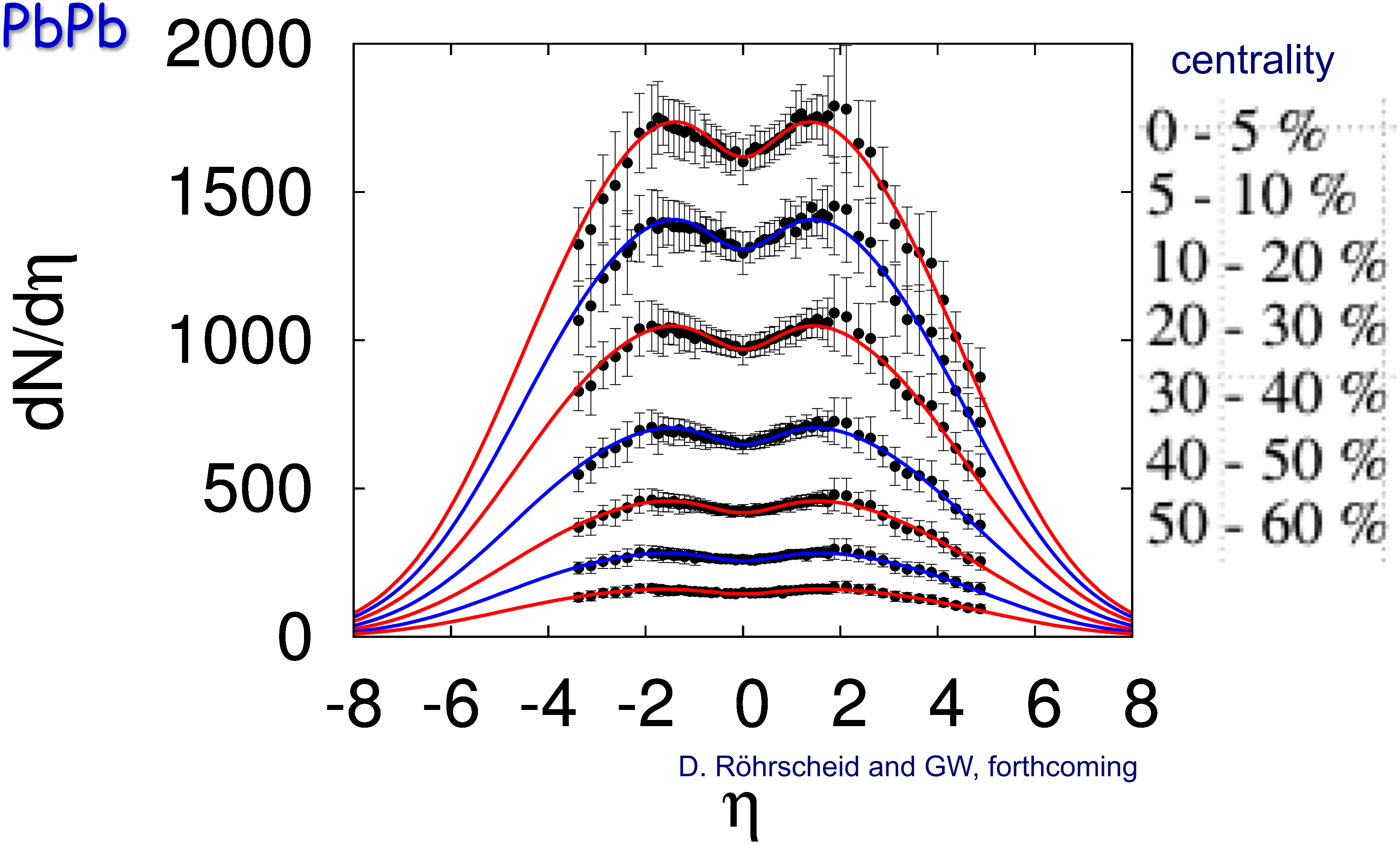


- The time parameter τ_{int}/τ_y is slightly larger than expected. It saturates at LHC energies because the rapidity relaxation time τ_y decreases (different from the original extrapolation!)

- The relative particle content in the gluon-gluon source is smaller than expected and hence, the midrapidity dip is more pronounced.

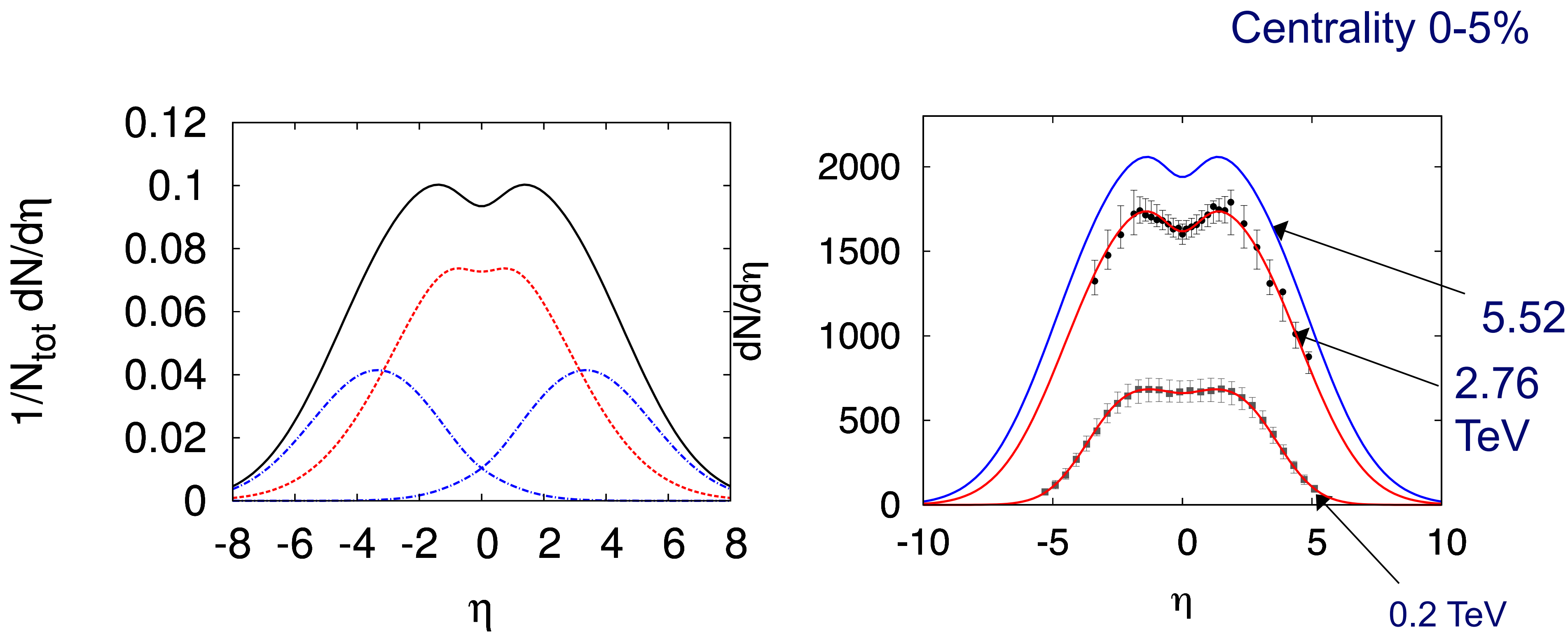
D. Röhrscheid and GW, preprint

RDM χ^2 fits to LHC/ALICE results for 2.76 TeV PbPb

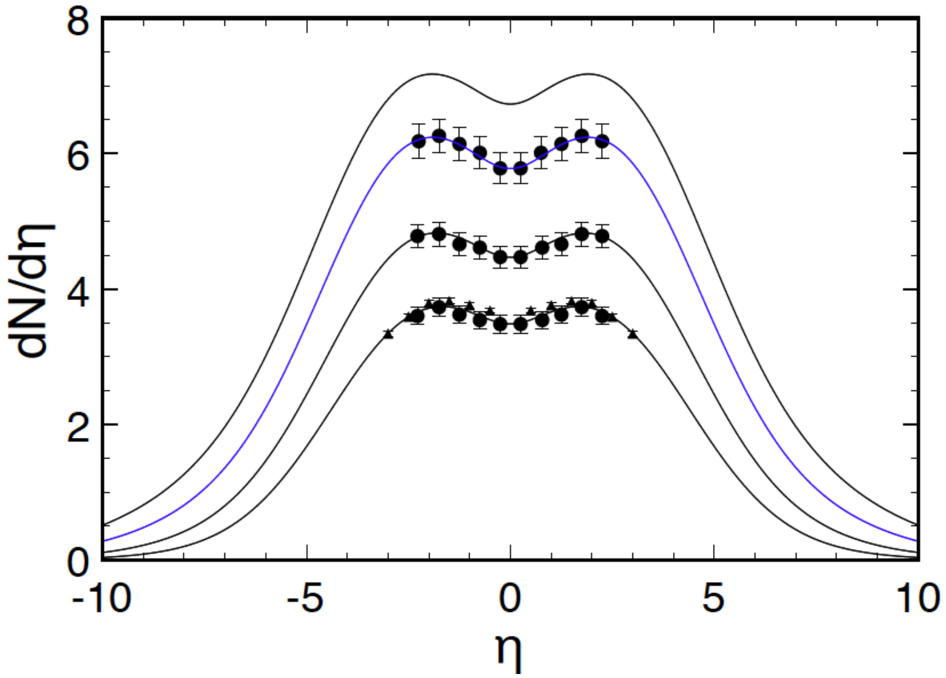


D. Röhrscheid and GW, forthcoming

3 sources, and prediction for 5.52 TeV PbPb



Charged-hadron distributions in pp: 3-sources relativistic diffusion model (RDM)



14 TeV pp

7 TeV

2.36 TeV

0.9 TeV (LHC injection energy / UA5)

Data: CMS collab., V. Khachatryan et al., J. High Energy Phys. 02, 041 (2010); Phys. Rev. Lett. 105, 022002 (2010); UA5 collab., R. Ansorge et al., Z. Phys. C 83, 357 (1989)

pp charged-hadron pseudorapidity data beyond η=2.5 needed

3-sources RDM calculation: see GW, EPL 95, 61001 (2011) [Europhys. Lett.]

4. Conclusion

- Charged-hadron production at RHIC and LHC energies has been described in a Relativistic Diffusion Model (RDM).

- Predictions of pseudorapidity distributions $dN/d\eta$ of produced charged hadrons for various centralities in the 3-sources RDM at LHC energies rely on the extrapolation of the diffusion-model parameters with $\ln(\sqrt{s_{NN}})$

- In agreement with a QCD-based microscopic model, the contribution of the fragmentation sources from quark-gluon collisions at LHC energies is very small at midrapidity, but substantial at larger values of pseudorapidity η.

- **The centrality dependence** of the three sources has been investigated in direct comparison with the preliminary **ALICE data.**