Forward-backward correlations between intensive observables

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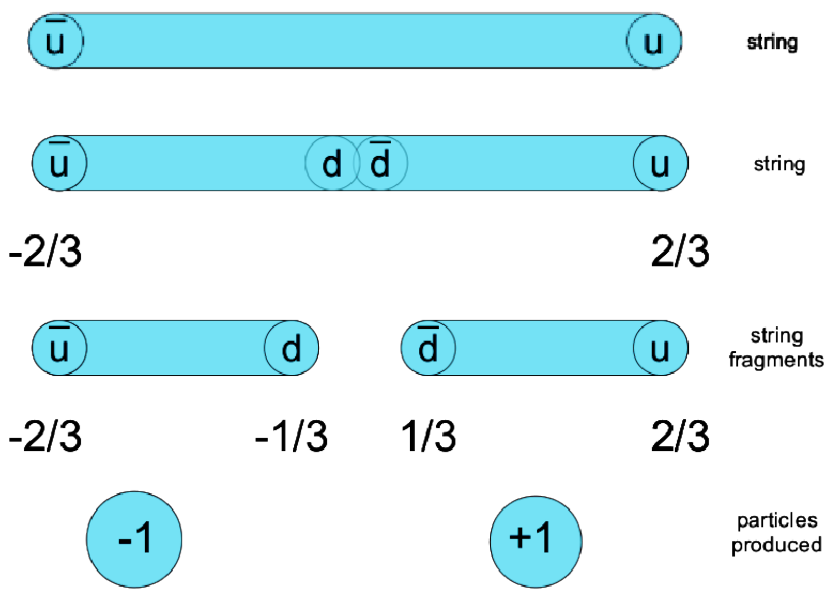
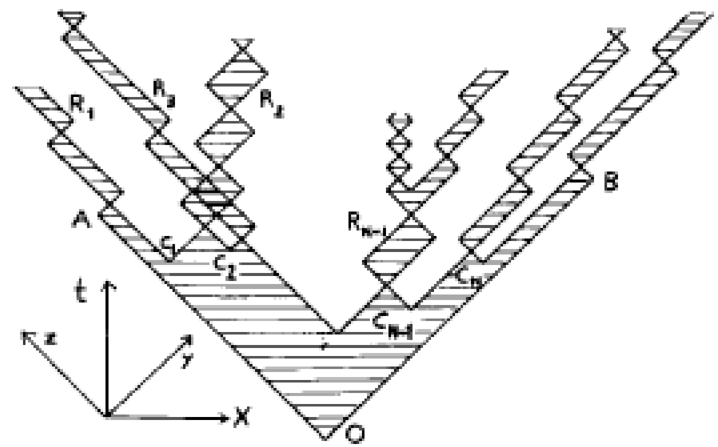
Centro de Congressos, Instituto Superior Técnico, Alameda Campus

String models

- The soft QCD processes is not described by usual perturbation theory
- The model of quark-gluon strings, stretched between projectile and target partons – semiphenomenological approach to the multiparticle production



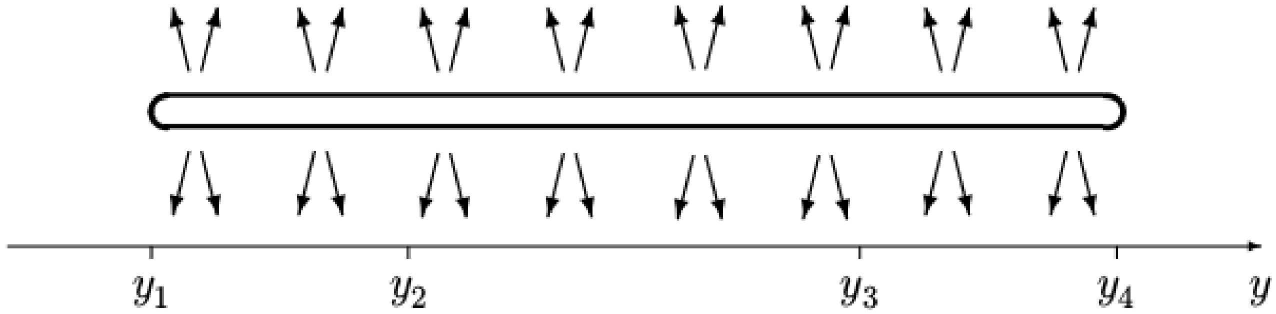


X. Artru and G. Mennessier, Nucl Phys B 70 (1974) 93 "String Model and Multiproduction",

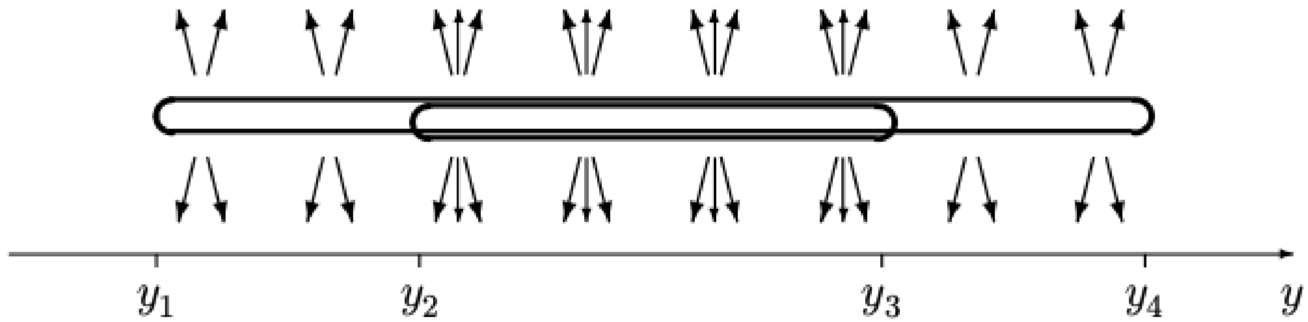
- Correlations play crucial role:
  – causality requires appearance of long-range correlations – if they exist – at the very early stages between particles detected in separated rapidity intervals

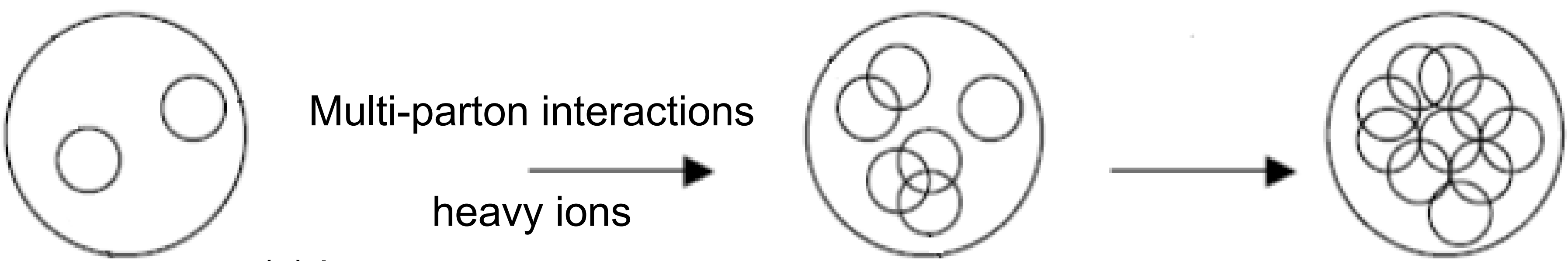
String in rapidity space

- Uniform and independent distribution of particles on rapidity from y_{min} to y_{max}



- Can study string overlaps:





—->>> sqrt(s) increases -->>> —->>> —->>>

String fusion

$$Q^2(n) = \left(\sum_{i=1}^{n} \vec{Q}_i(1) \right)^2 = \sum_{i=1}^{n} Q_i^2(1) + \sum_{i \neq j} \vec{Q}_i(1) \cdot \vec{Q}_j(1)$$

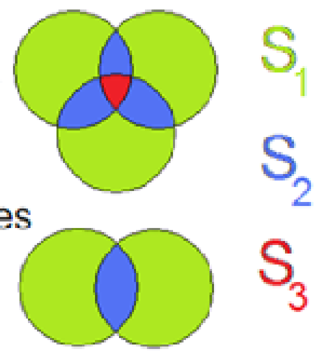
$$\langle Q^2(n) \rangle = n Q^2(1)$$

overlaps

SFM

$C = \{S_1, S_2, \ldots\}$

S_k – area covered k-times



String fusion mechanism predicts:

– decrease of multiplicity
– increase of p_T
– growth of p_T with multiplicit
in pp, pA and AA collisions
– growth of strange particle yields

– results are in a good agreement with the experiment

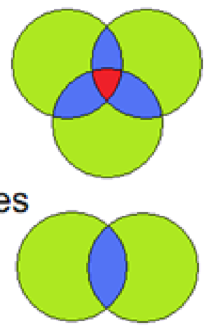
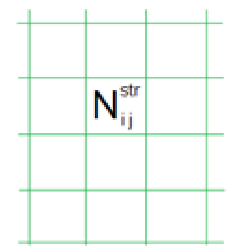
$$\langle \mu \rangle_k = \mu_0 \sqrt{k} \frac{S_k}{\sigma_0} \qquad \langle p_t^2 \rangle_k = p_0^2 \sqrt{k} \qquad \langle p_t \rangle_k = p_0 \sqrt[4]{k}$$

S_k – area, where k strings are overlapping, σ_0 single string transverse area,
μ_0 and p_0 – mean multiplicity and transverse momentum from one string

M. A. Braun, C. Pajares, Nucl. Phys. B 390 (1993) 542.
M. A. Braun, R. S. Kolevatov, C. Pajares, V. V. Vechernin, Eur. Phys. J. C 32 (2004) 535.
N.S. Amelin, N. Armesto, C. Pajares, D. Sousa, Eur.Phys.J.C22:149-163 (2001), arXiv:hep-ph/0103060
G. Ferreiro and C Pajares J. Phys. G: Nucl. Part. Phys. 23 1961 (1997)

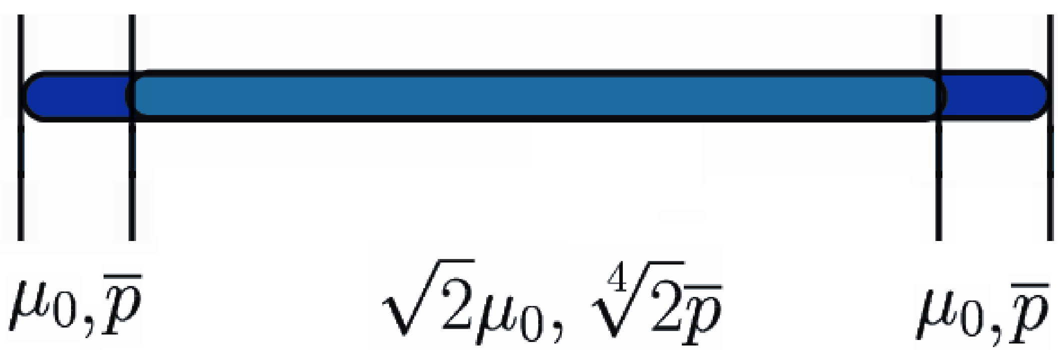
String fusion

- Lattice realization of string fusion model

	"overlaps" (local fusion)		"overlaps" (local fusion)
SFM	○ $C=\{S_1,S_2,\ldots\}$ S_k – area covered k-times  S_1 S_2 S_3	cellular analog of SFM	□ $C=\{N_{ij}^{str}\}$  $k_{ij}=N_{ij}^{str}$ – "occupation" numbers

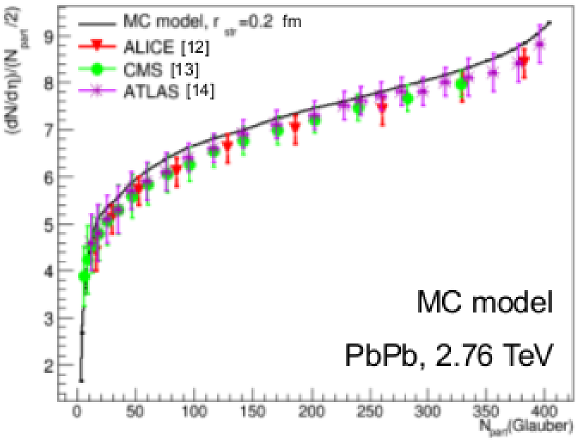
V. V. Vechernin and R. S. Kolevatov, Vestn. SPb. Univ., Ser. Fiz. Khim., No. 2, 12 (2004); hep-` ph/0304295.
V. V. Vechernin and R. S. Kolevatov, Vestn. SPb. Univ., Ser. Fiz. Khim., No. 4, 11 (2004); hep-ph/0305136.
I. A. Lakomov, V. V. Vechernin, PoS (Baldin ISHEPP XXI) 072 (2012).

- Fusion of finite rapidity strings



Monte Carlo model

•Partonic dipole-based picture of nucleons interaction.



•Energy and angular momentum conservation in the initial state of a nucleon.

•The probability of dipoles are defined by heir transverse coordinates [7-8]:

$$f = \frac{\alpha_s^2}{2} \ln^2 \frac{|\vec{r}_1 - \vec{r}_1'||\vec{r}_2 - \vec{r}_2'|}{|\vec{r}_1 - \vec{r}_2'||\vec{r}_2 - \vec{r}_1'|}$$

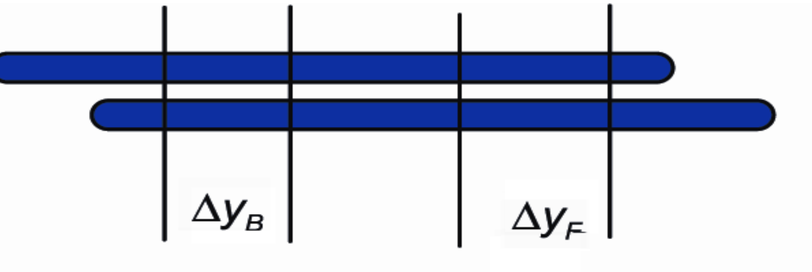
Multiplicity and transverse momentum are obtained in the approach of colour strings, stretched between projectile and target partons

•The interaction of strings is realized in the accordance with the **string fusion** model

•Multiplicity from one string is distributed according to Poisson

V. N. Kovalenko.. Phys. Atom. Nucl. 76, 1189 (2013), arXiv:1211.6209 [hep-ph]
V. Kovalenko, V. Vechernin., PoS (Baldin ISHEPP XXI) 077, arXiv:1212.2590 [nucl-th], 2012

Forward-backward correlations



Select 2 variables in windows:

F, B:

n – number of charged particles in the window

$$p_t = \frac{1}{n}\sum_{i=1}^{n} p_{ti}$$ – mean (in the event!) transverse momentum of charged particles in the given window

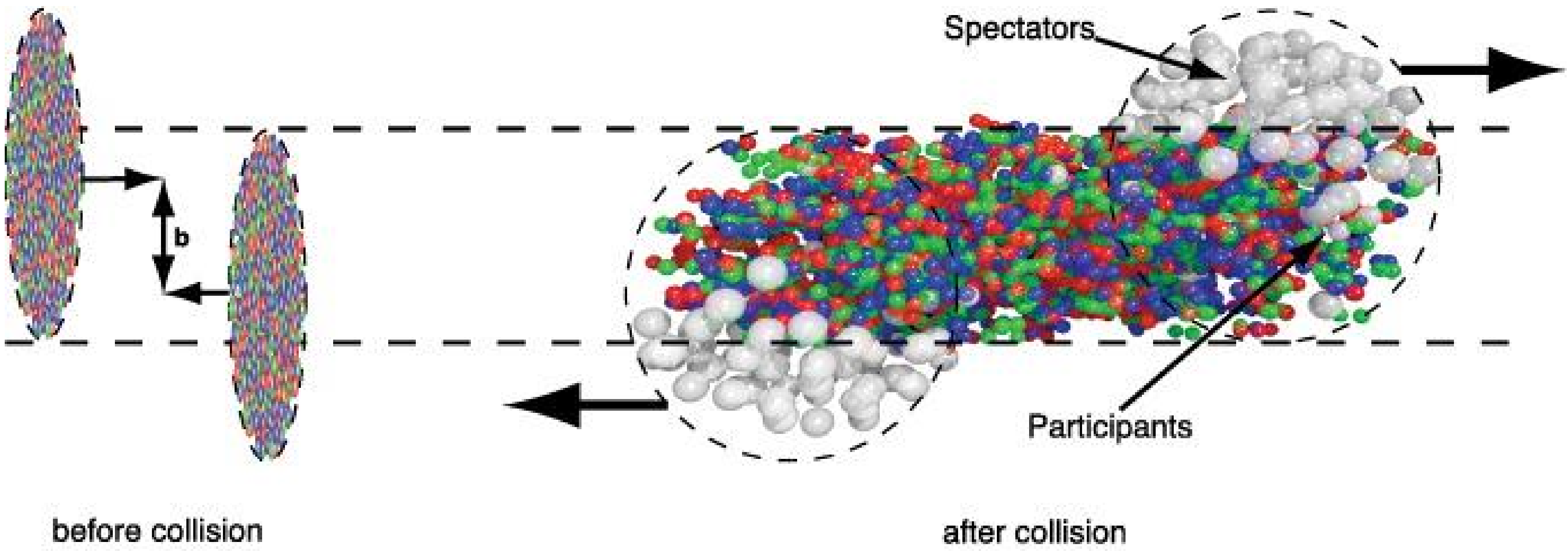
correlation coefficient

$$b = \frac{\langle F\,B\rangle - \langle F\rangle\langle B\rangle}{\langle F^2\rangle - \langle F\rangle^2}$$

Several types of correlation coefficient:

n-n , pt-n, **pt-pt**

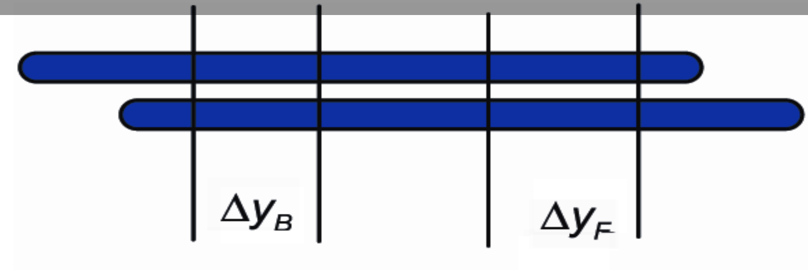
Centrality of AA collisions



- Nucleon-participants N_{part} - nucleons collided at least once
- Nucleon-spectators N_{spect} - nucleons, which didn't interact
- Number of nucleon-nucleon collisions N_{coll}
- Multiplicity of charge particles N_{ch}

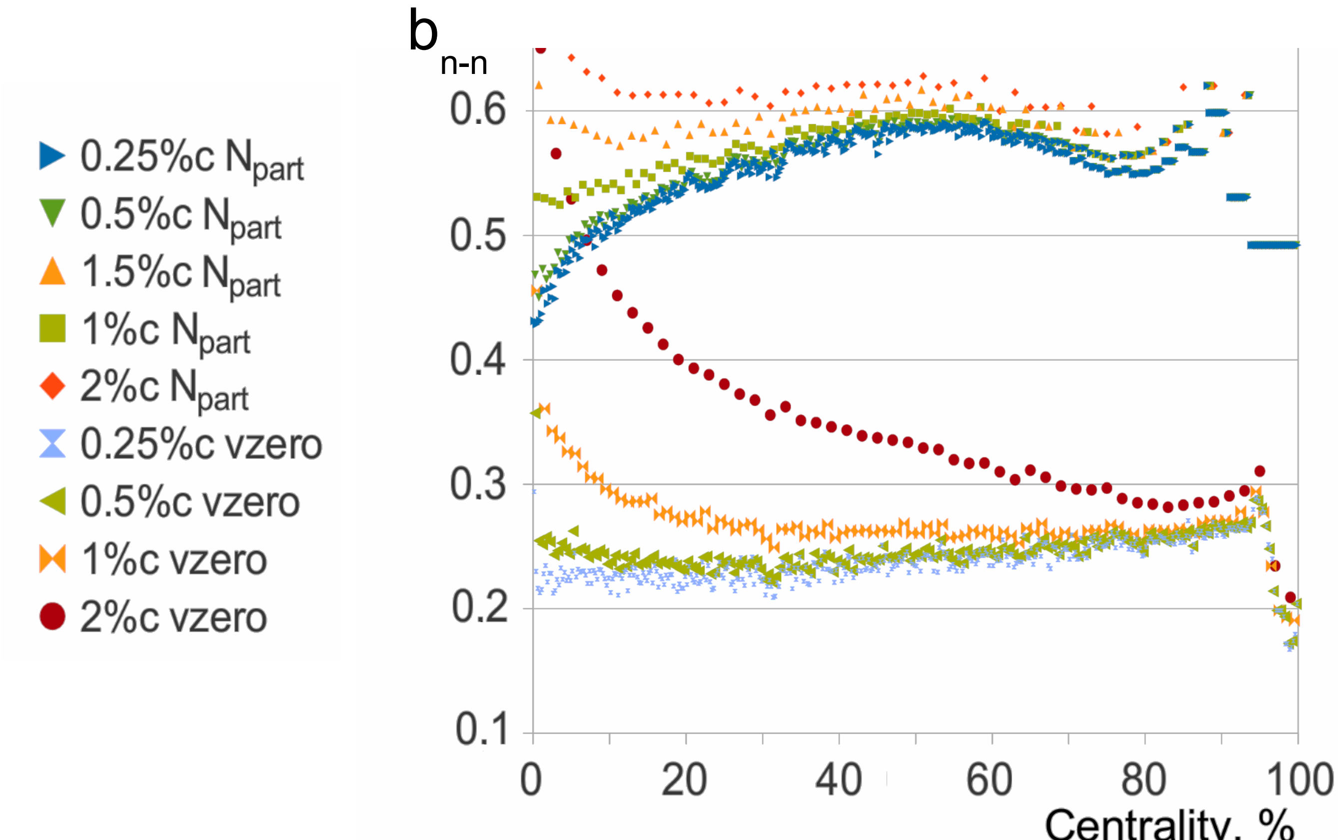
Forward-backward correlations in AA

multiplicity – extensive variable



n-n correlation coefficient

$$b = \frac{\langle F\, B\rangle - \langle F\rangle\langle B\rangle}{\langle F^2\rangle - \langle F\rangle^2}$$



Pb-Pb, 2.76 TeV

depends on

method of centrality determination

width of centrality class

V. Kovalenko, V. Vechernin. EPJ Web of Conferences 66, 04015 (2014), arXiv:1308.6618 [nucl-th]

Mean pt-pt correlations in SF model

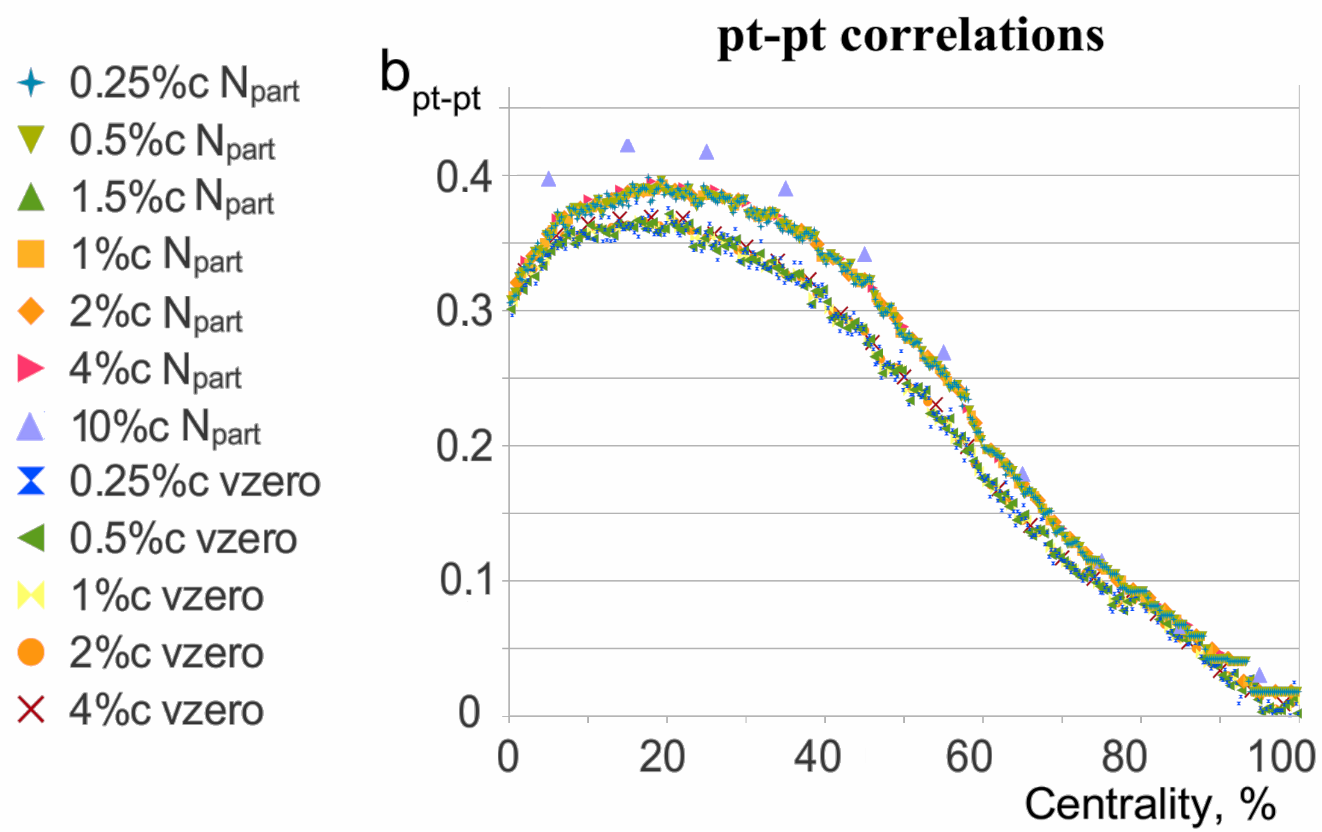
mean event transverse momentum – **intensive** variable

pt-pt correlation coefficient

$$b = \frac{\langle F B \rangle - \langle F \rangle \langle B \rangle}{\langle F^2 \rangle - \langle F \rangle^2}$$

$$B, F, \rightarrow p_t = \frac{1}{n} \sum_{i=1}^{n} p_{ti}$$

Pb-Pb, 2.76 TeV



robust

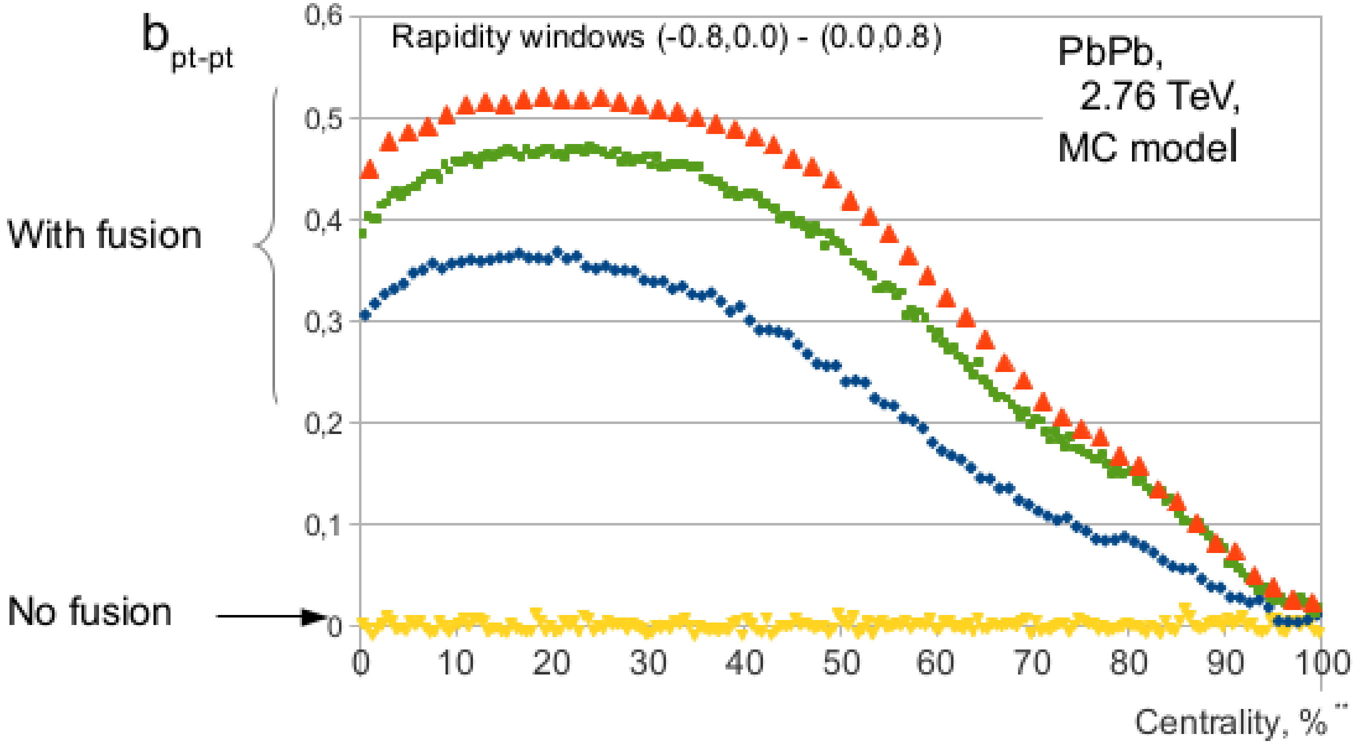
V. Kovalenko, V. Vechernin. EPJ Web of Conferences 66, 04015 (2014), arXiv:1308.6618 [nucl-th]

Mean pt-pt correlations in SF model

correlation coefficient $b = \dfrac{\langle F\,B\rangle - \langle F\rangle\langle B\rangle}{\langle F^2\rangle - \langle F\rangle^2}$

$$B, F, \rightarrow p_t = \frac{1}{n}\sum_{i=1}^{n} p_{ti}$$

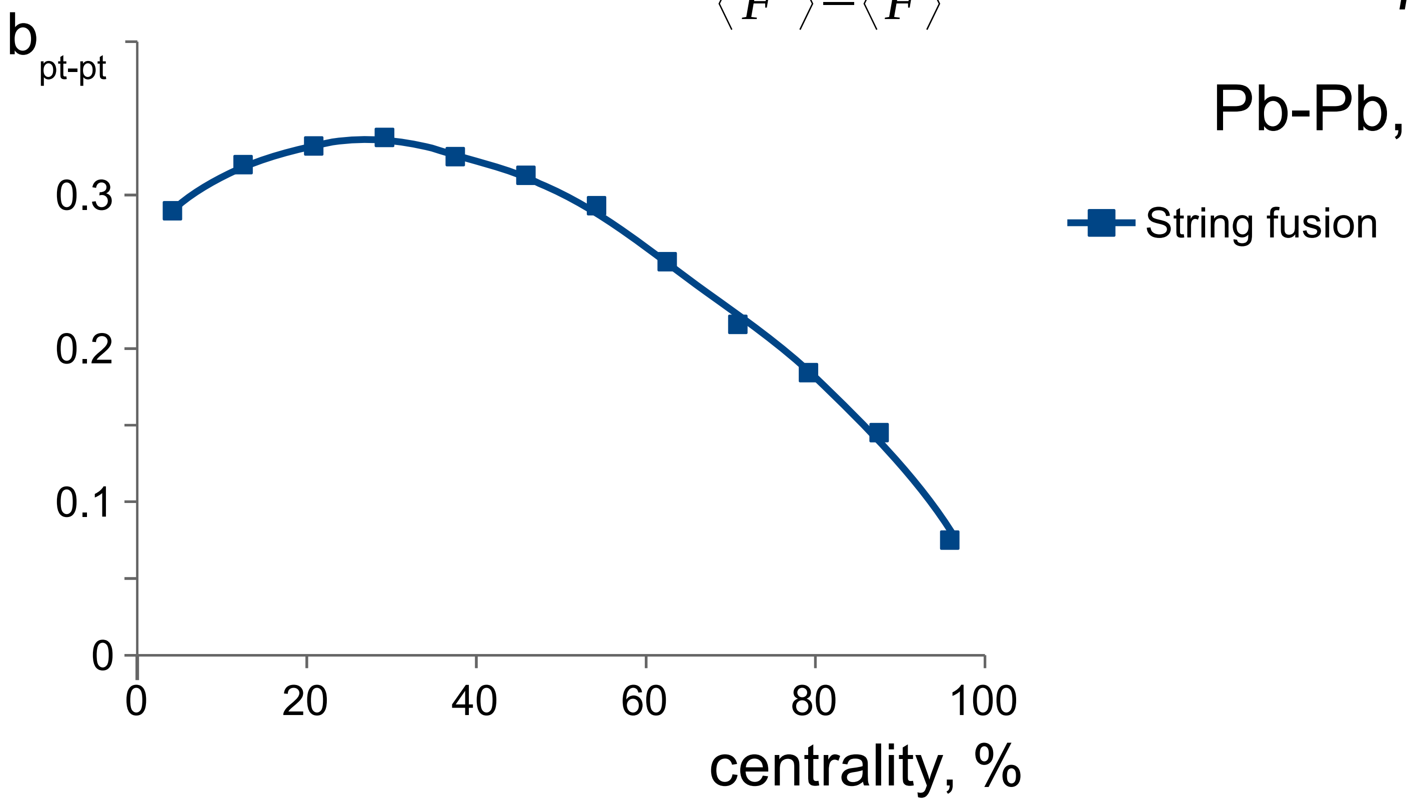
Pb-Pb, 2.76 TeV



V. Kovalenko, V. Vechernin. EPJ Web of Conferences 66, 04015 (2014), arXiv:1308.6618 [nucl-th]

Mean pt-pt correlations in different models

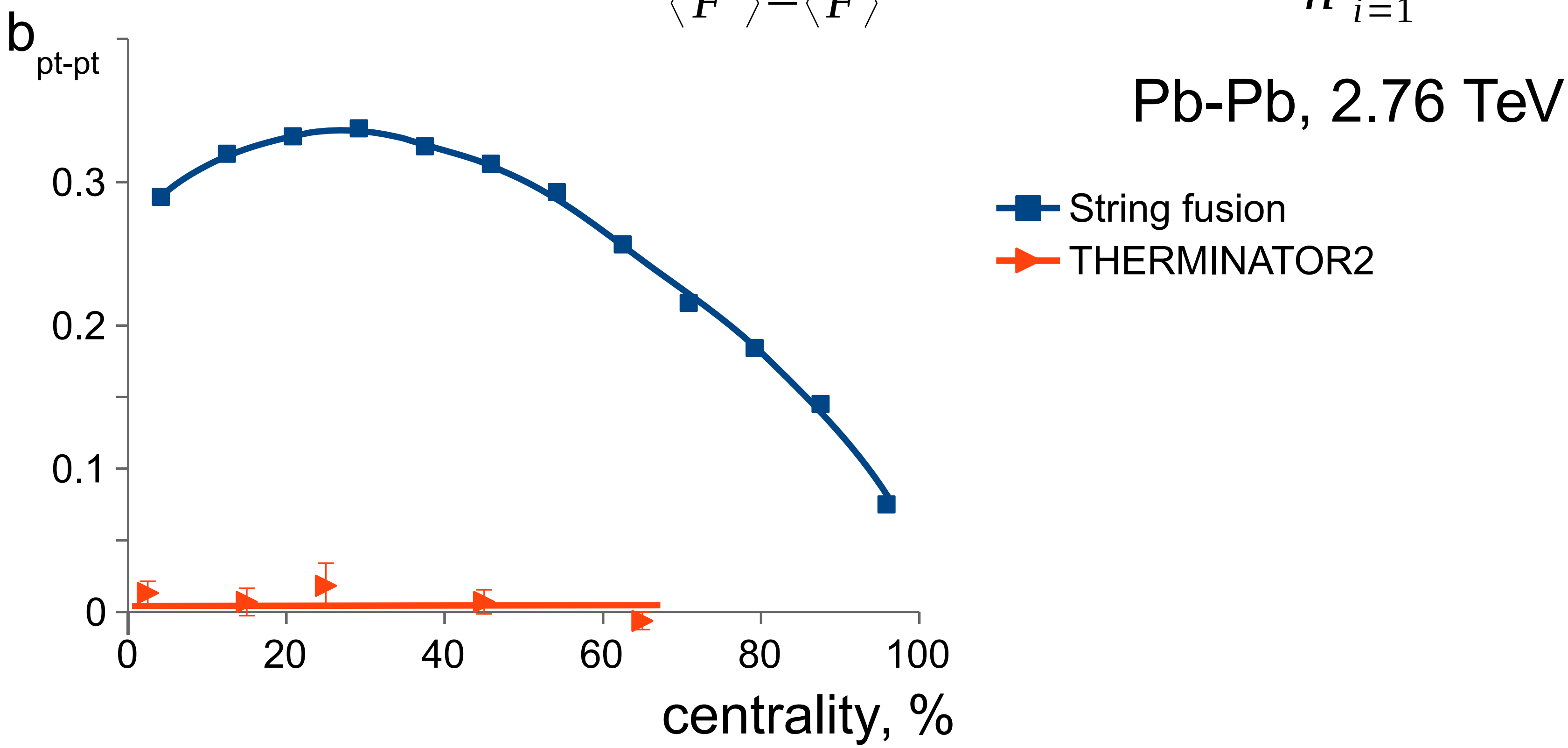
$$b = \frac{\langle F B \rangle - \langle F \rangle \langle B \rangle}{\langle F^2 \rangle - \langle F \rangle^2} \quad B, F, \rightarrow p_t = \frac{1}{n} \sum_{i=1}^{n} p_{ti}$$



Pb-Pb, 2.76 TeV, MC model with string fusion, r_{str}=0. 2fm, pseudorapidity windows (-0.8,-0.4), (0.4,0.8), no p_t cut

Mean pt-pt correlations in different models

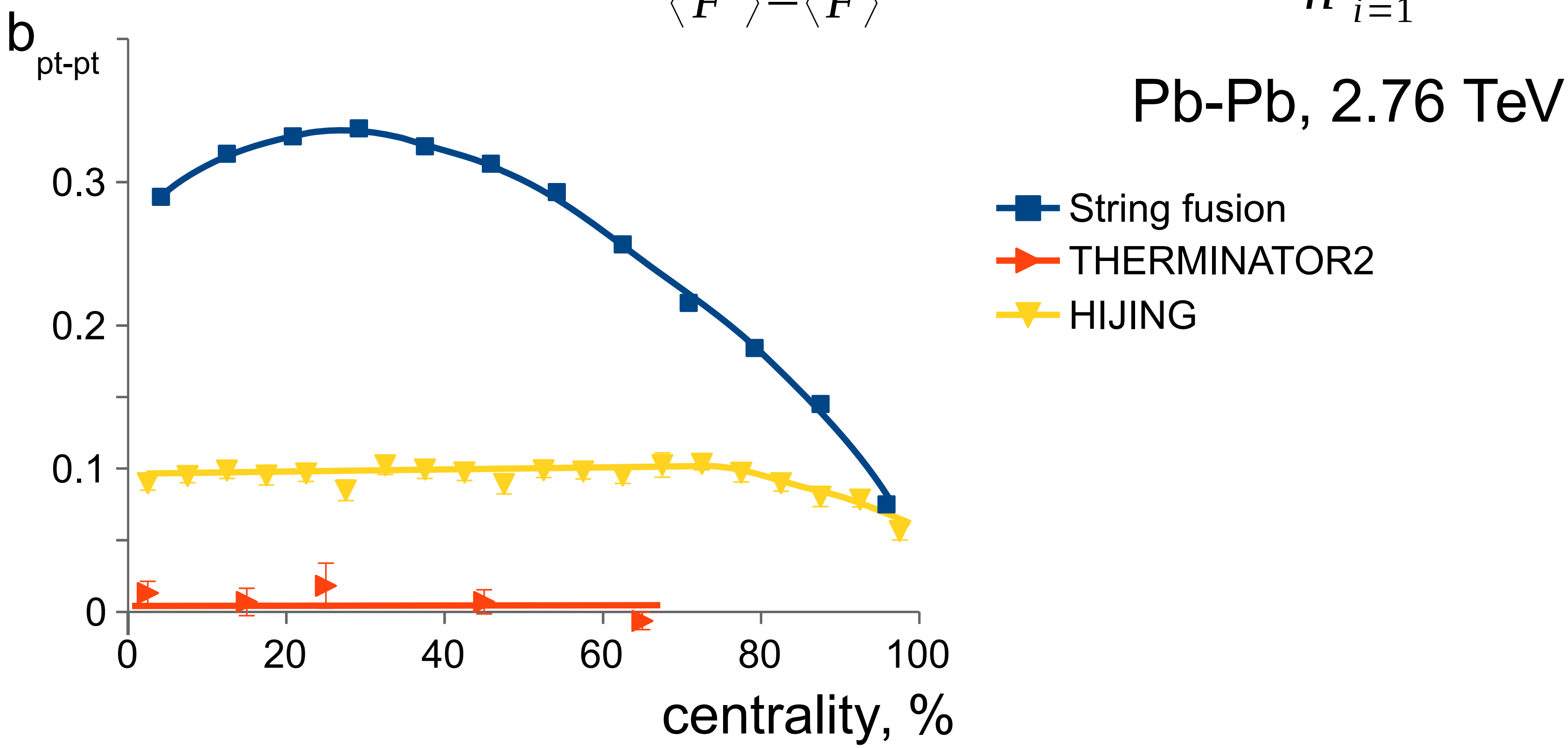
$$b = \frac{\langle F B\rangle - \langle F\rangle\langle B\rangle}{\langle F^2\rangle - \langle F\rangle^2} \qquad B, F, \rightarrow p_t = \frac{1}{n}\sum_{i=1}^{n} p_{ti}$$



THERMINATOR 2 (THERMal heavy IoN generATOR 2)
M. Chojnacki et al, Comput. Phys. Commun. 183, 746 (2012)
parametrized freeze-out hypersurface, Cooper-Frye + decays

Mean pt-pt correlations in different models

$$b = \frac{\langle F B\rangle - \langle F\rangle\langle B\rangle}{\langle F^2\rangle - \langle F\rangle^2} \qquad B, F, \rightarrow p_t = \frac{1}{n}\sum_{i=1}^{n} p_{ti}$$



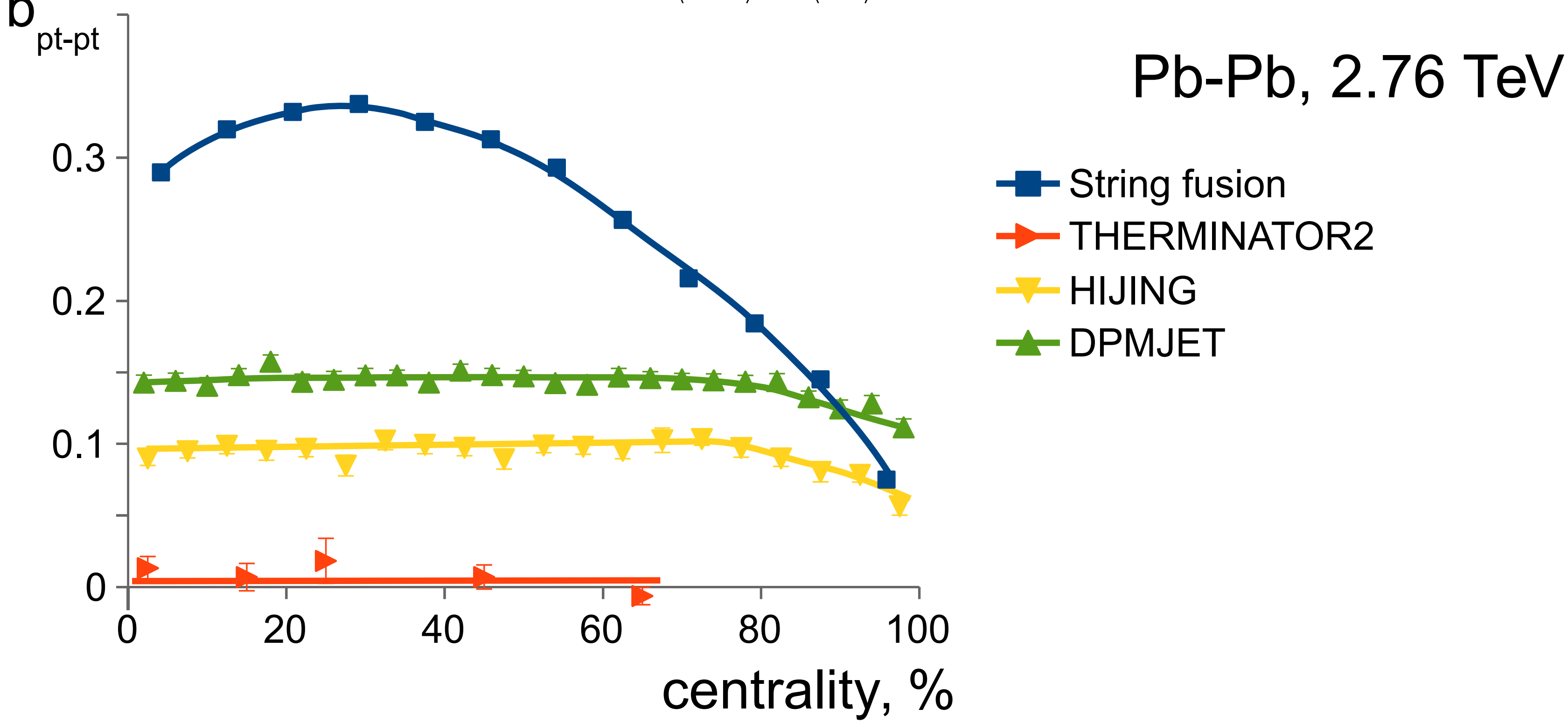
HIJING (Heavy Ion Jet INteraction Generator)

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

Gluon shadowing + Jet quenching

Mean pt-pt correlations in different models

$$b=\frac{\langle F\,B\rangle-\langle F\rangle\langle B\rangle}{\langle F^2\rangle-\langle F\rangle^2} \qquad B\,,F\,,\rightarrow p_t=\frac{1}{n}\sum_{i=1}^{n} p_{ti}$$



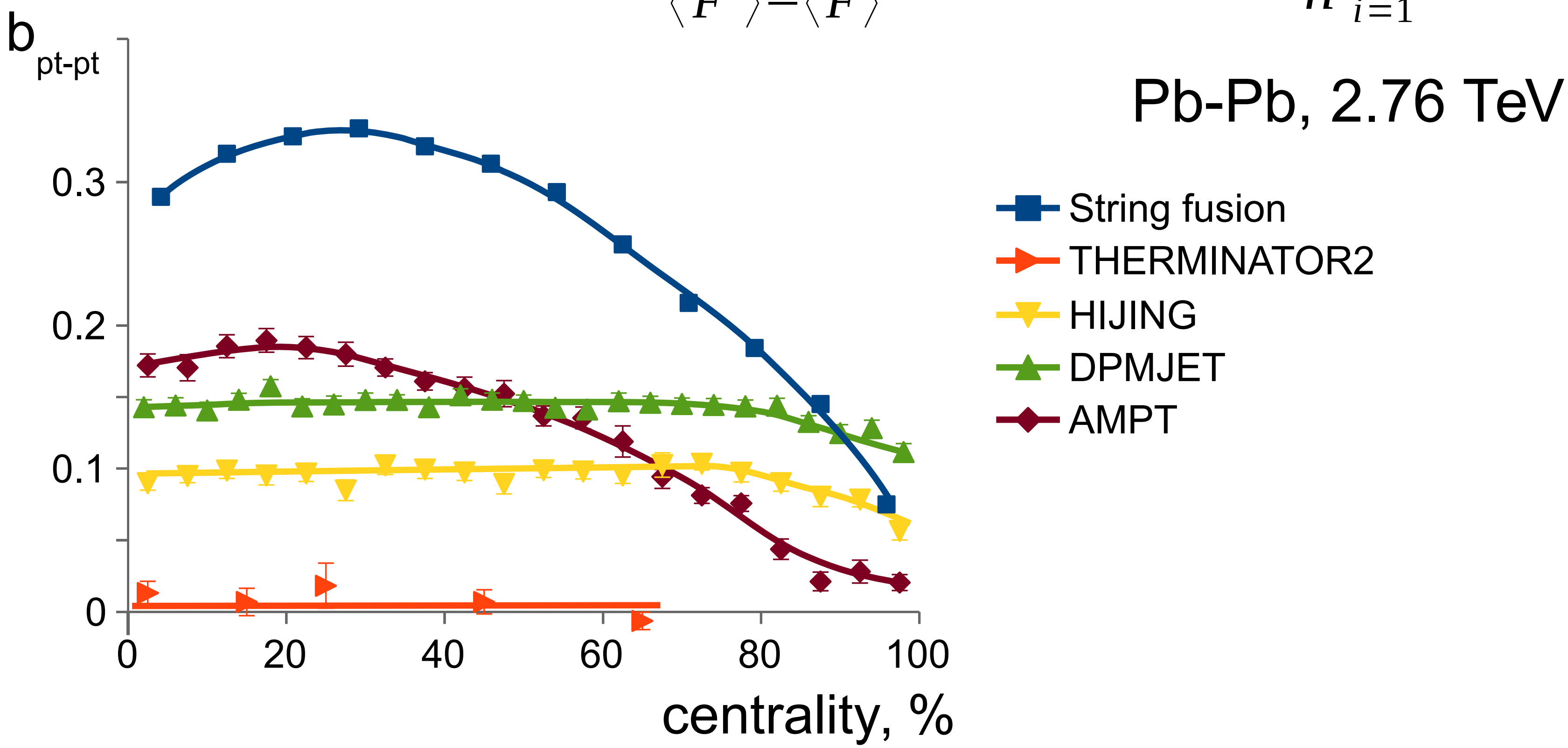
DPMJET, two-component Dual Parton Model, based on the Gribov-Glauber approach

S. Roesler, R. Engel, J. Ranft, arXiv:hep-ph/0012252

Soft + hard, fragmentation of partons by the Lund model

Mean pt-pt correlations in different models

$$b = \frac{\langle F B \rangle - \langle F \rangle \langle B \rangle}{\langle F^2 \rangle - \langle F \rangle^2} \quad B, F, \rightarrow p_t = \frac{1}{n} \sum_{i=1}^{n} p_{ti}$$



AMPT (A Multi-Phase Transport Model for Relativistic Heavy Ion Collisions)
Zi-Wei Lin, et al, Phys. Rev. C 72, 064901 (2005)
Shadowing, Zhang's Parton Cascade, string melting, A Relativistic Transport

Conclusions and outlook

- Centrality determination and a width of centrality class influences the value of fluctuational and correlational observables

- Correlations between intensive observables are robust against the volume fluctuations and the centrality determination methods

- Pt-pt forward-backward correlations provide clear observable sensitive to the properties of the initial state of AA collisions

- This type of correlation is promising for the observation of the signatures of string fusion in relativistic heavy ion collisions at LHC energies.

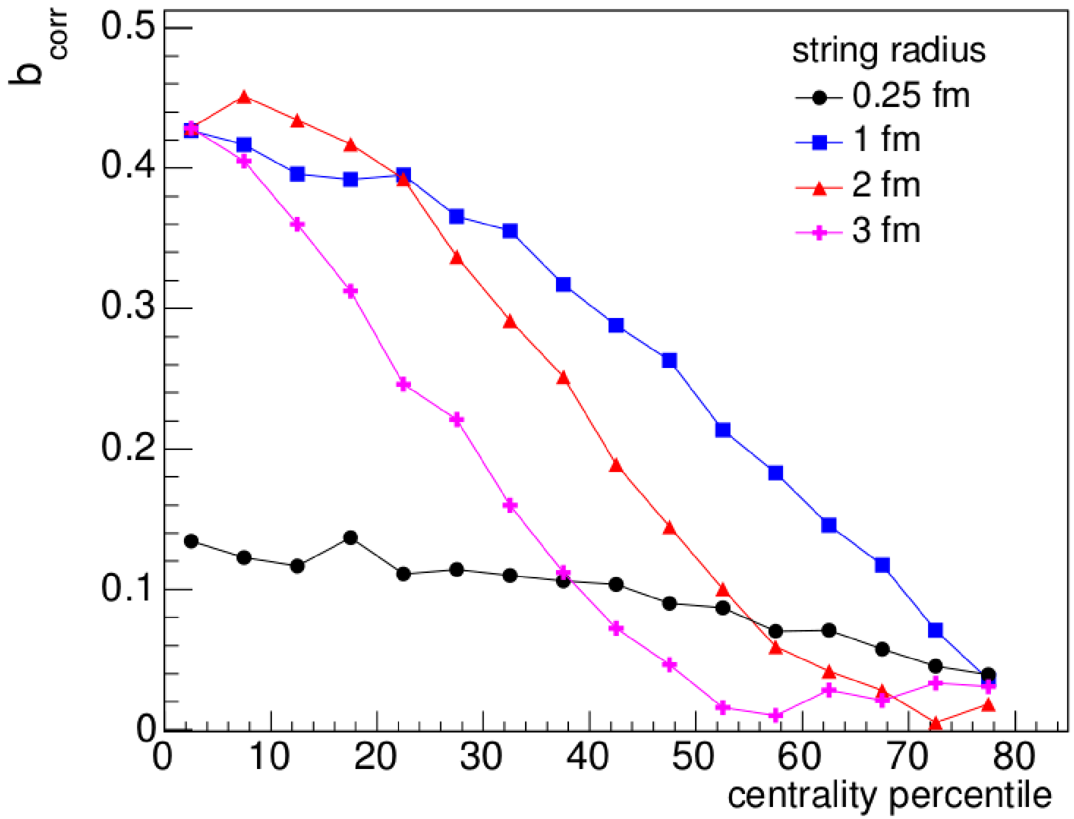
- Would be interesting to study pt-pt correlations in Event-by-event hydrodynamical models, like iEBE-VISHNU or EKRT.

Thank you!

Backup

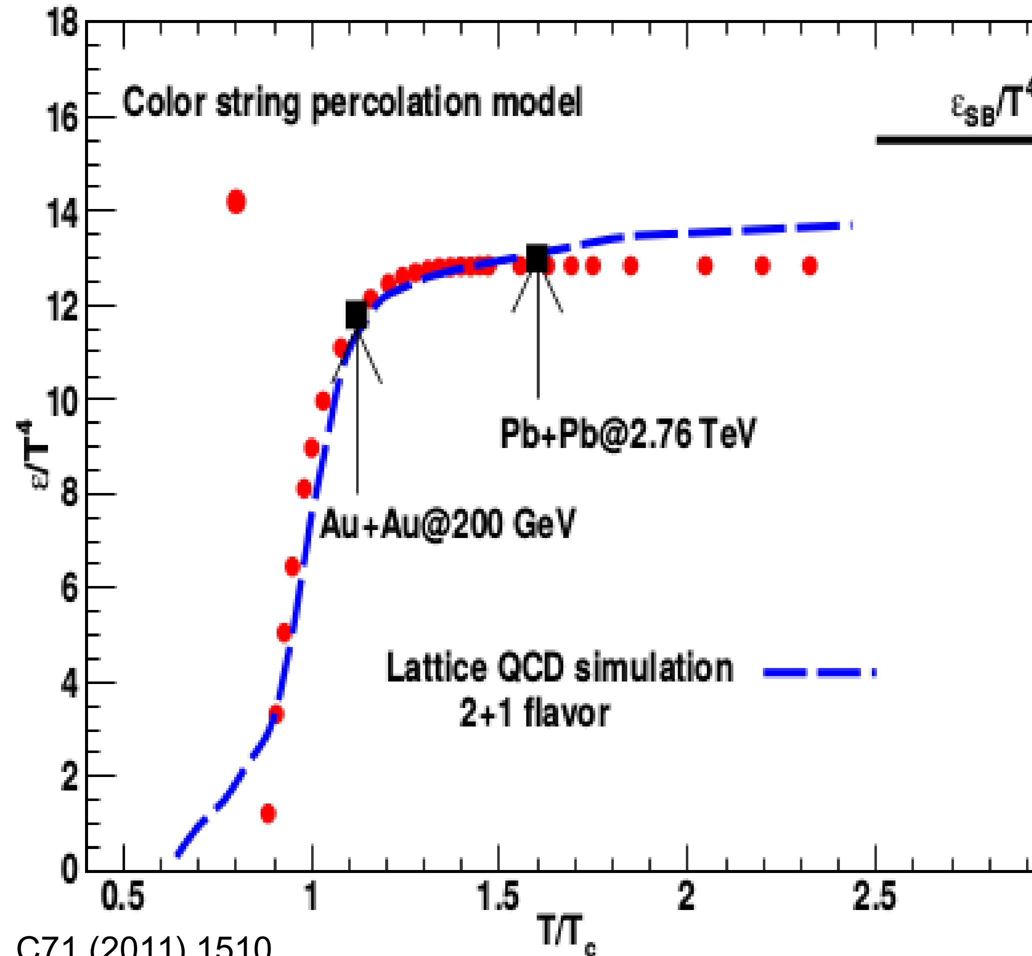
String fusion

Mean transverse momenta correlations
in MC toy model with repulsing strings



I. Altsybeev, AIP Conf.Proc. 1701, 100002 (2016) , arXiv:1502.03608 [hep-ph] .

String fusion



In the recent papers it was shown that the equation of state of QGP (ε/T^4 as a function of T) <u>at zero chemical potential</u>, obtained in the colour string percolation model is in a good agreement with the lattice results.

R.P. Scharenberg, B.K. Srivastava, A.S. Hirsch Eur.Phys.J. C71 (2011) 1510
J. Dias de Deus , C. Pajares, Phys.Lett. B642 (2006) 455-458
Brijesh K Srivastava, EP J Web of Conferences 70, 00032 (2014)

String fusion

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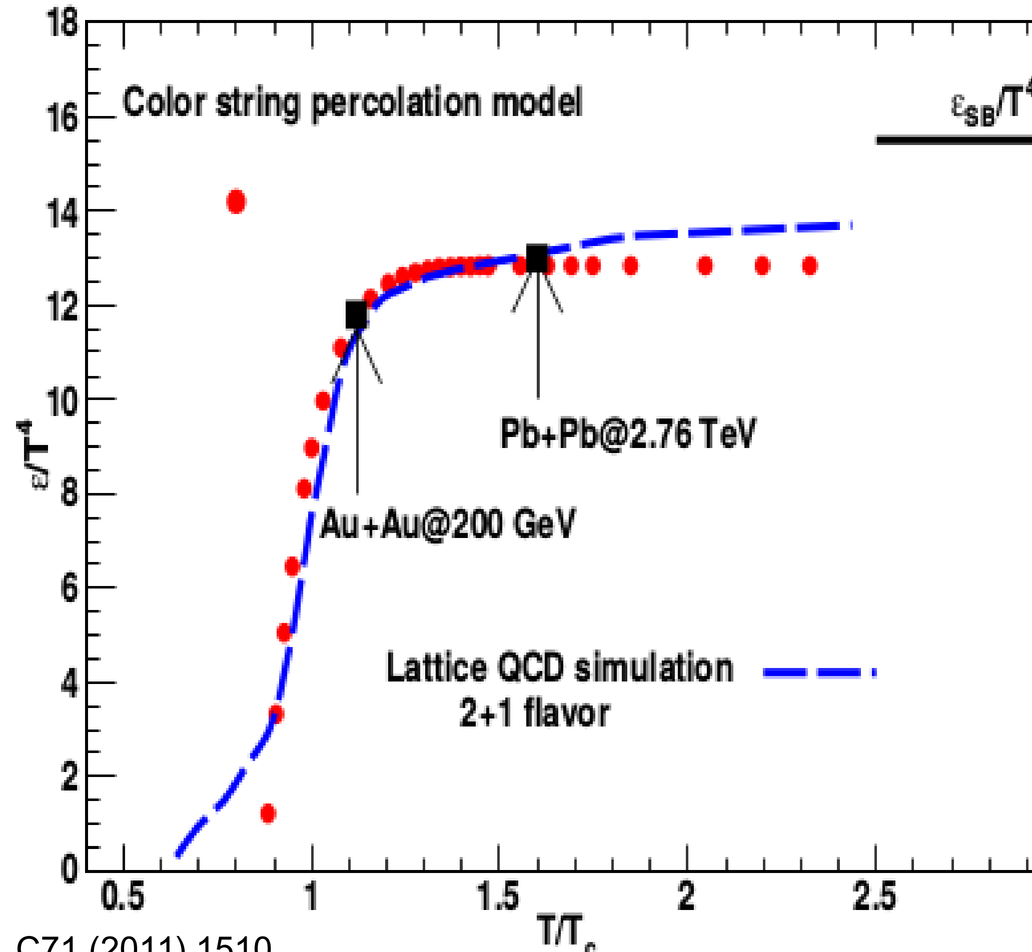

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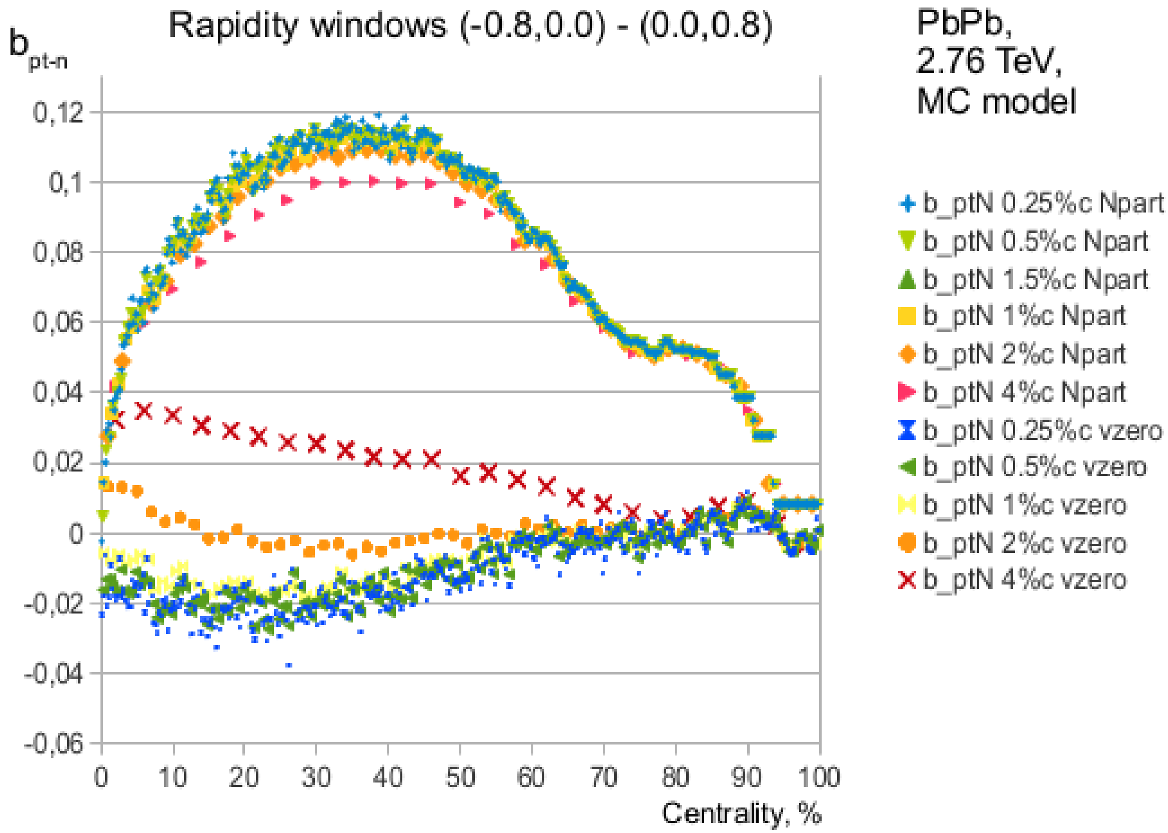
J. Dias de Deus , C. Pajares, Phys.Lett. B642 (2006) 455-458
Brijesh K Srivastava, EP J Web of Conferences 70, 00032 (2014)

Long-range correlations and fluctuations

pt-n correlation coefficient

$$b = \frac{\langle F\,B \rangle - \langle F \rangle \langle B \rangle}{\langle F^2 \rangle - \langle F \rangle^2}$$



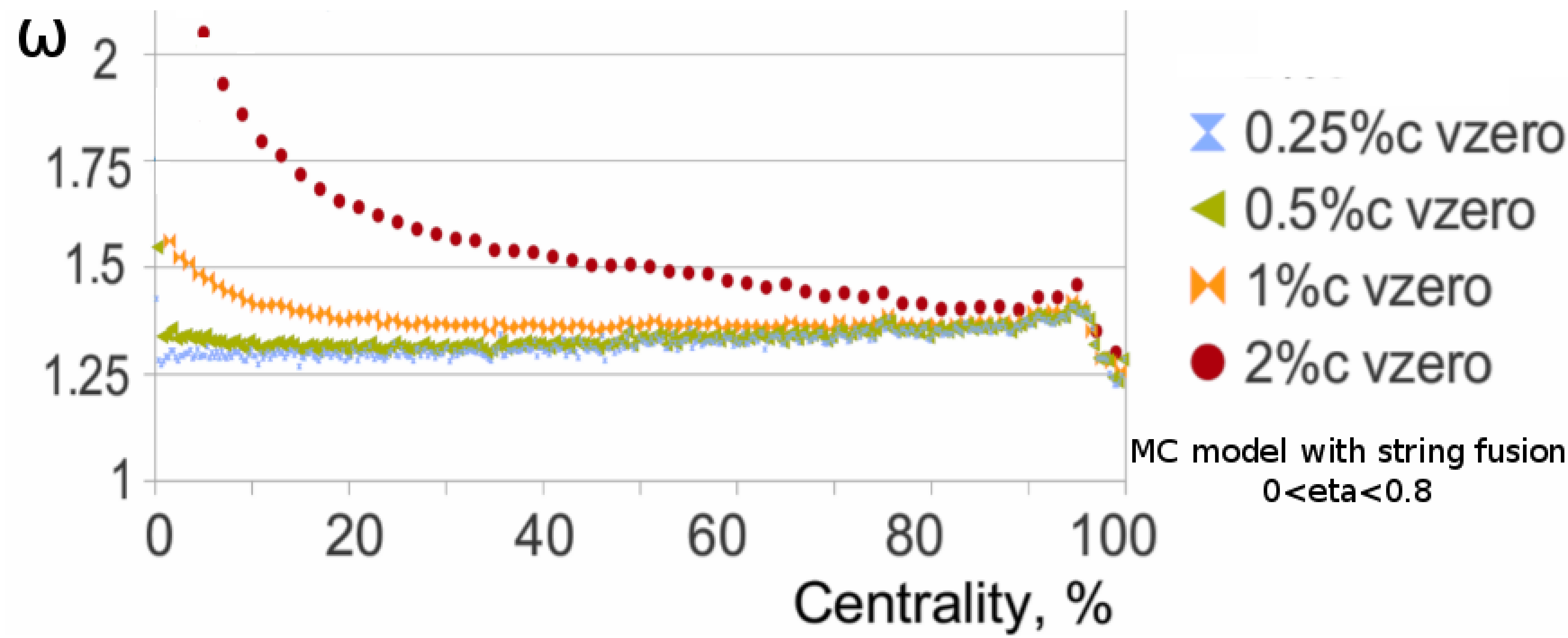
Pb-Pb, 2.76 TeV

V. Kovalenko, V. Vechernin. EPJ Web of Conferences 66, 04015 (2014), arXiv:1308.6618 [nucl-th]

Long-range correlations and fluctuations

scaled variance $$\omega = \frac{\langle n^2 \rangle - \langle n \rangle^2}{\langle n \rangle}$$

Pb-Pb, 2.76 TeV



V. Kovalenko, V. Vechernin. EPJ Web of Conferences 66, 04015 (2014), arXiv:1308.6618 [nucl-th]