Multiplicity correlations with strongly intensive quantities

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WPCF-2019, Dubna, Russia
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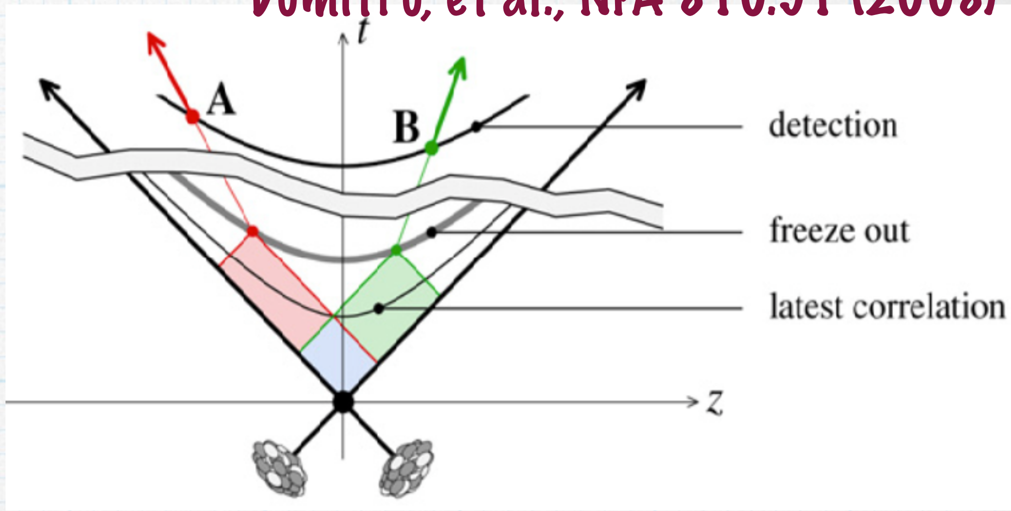
Outline

* Forward-backward multiplicity correlations
* Strongly intensive quantity Σ
* Independent quark-gluon strings model calculations for LHC energies
* Collectivity/string fusion
* ALICE Pb-Pb results vs. event generators
* LHC->RHIC->SPS->NICA

Forward-backward multiplicity correlations

Dumitru, et al., NPA 810:91 (2008)



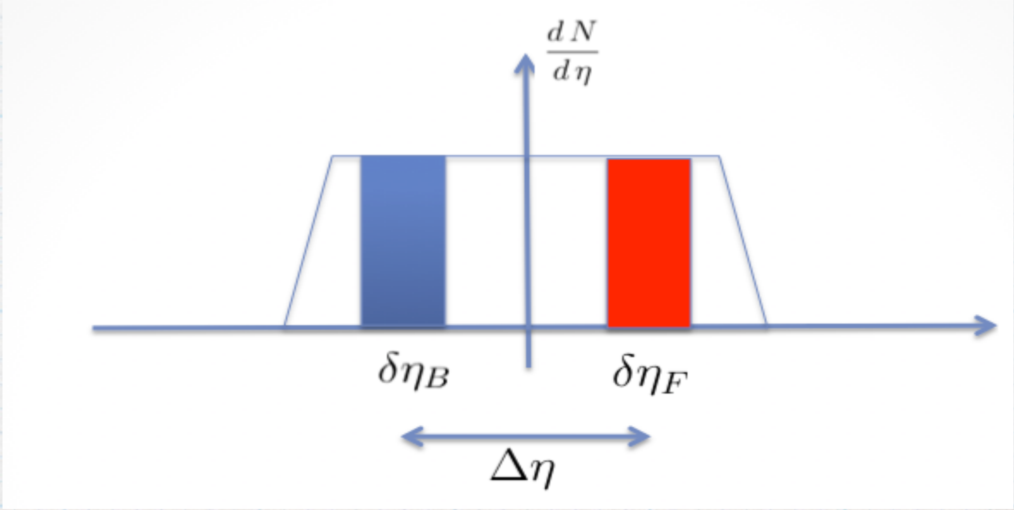
Causality requires appearance of long-range rapidity correlations at early stages of evolution.

Long-range correlations originate from fluctuations in the number of particle sources (initial stage)+ other effects (jets, etc)

Quantified by the correlation coefficient:

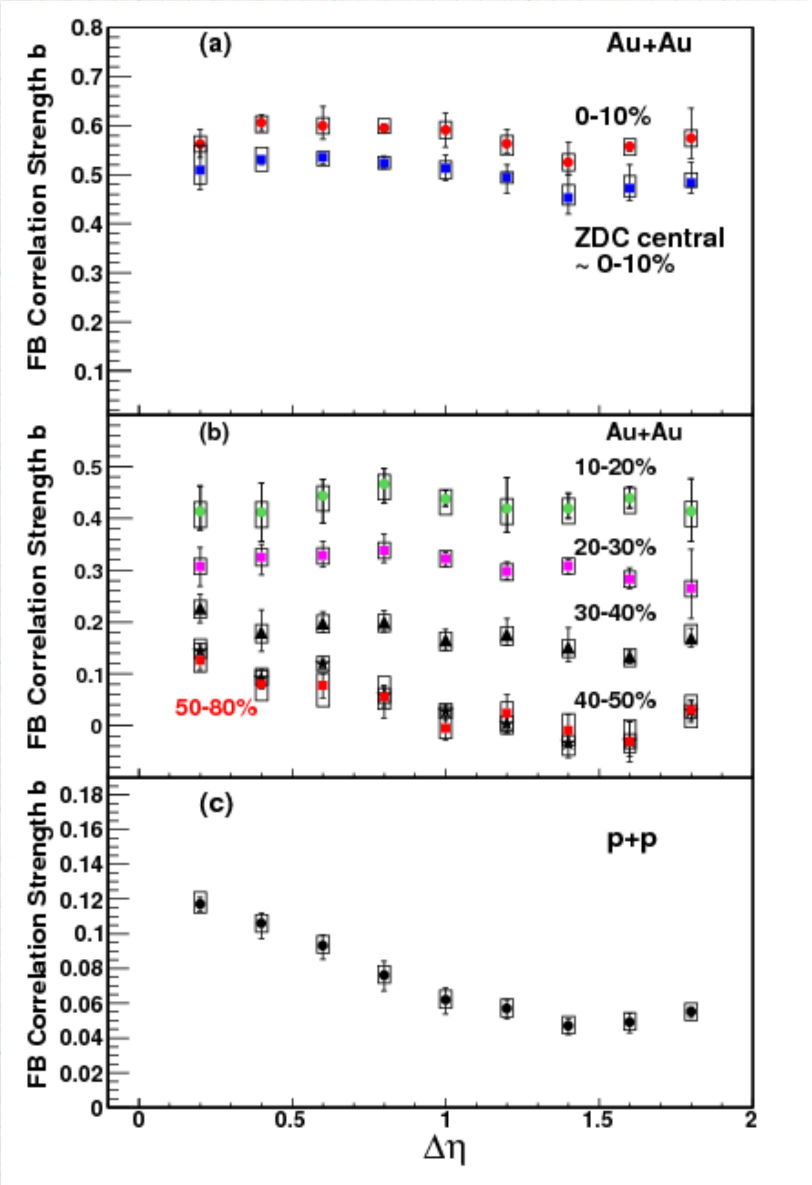
$$b_{corr} = \frac{\langle B \cdot F \rangle - \langle B \rangle \cdot \langle F \rangle}{\langle F^2 \rangle - \langle F \rangle^2}$$

Choose as B and F multiplicities in two separated rapidity intervals

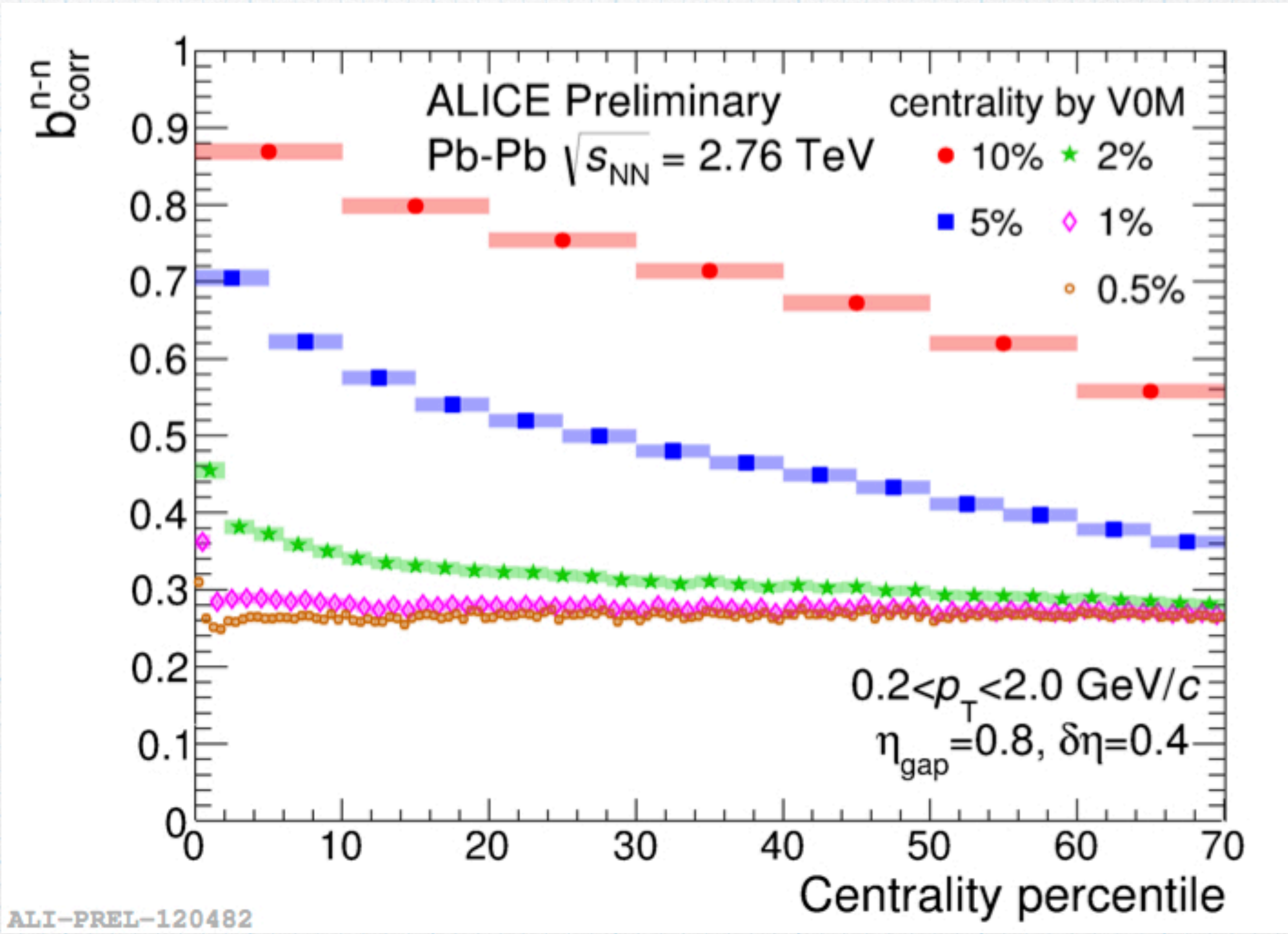


Forward-backward multiplicity correlations

Huge sensitivity to centrality selection/volume fluctuations



STAR, PRL 103: 172301 (2009)



I.Altsybeev(for ALICE), KnE Energy&Physics 3:304 (2018)

Strongly intensive quantity

For a pair of extensive (proportional to volume) observables A and B:

$$\Sigma[A,B] = \frac{\langle B\rangle\omega[A] + \langle A\rangle\omega[B] - cov(A,B)}{C_\Sigma}$$

M. Gorenstein, M. Gazdzicki, PRC 84:014904 (2011)

* Independent of <W> and ω[W] in the Wounded Nucleon Model
* Σ=1 for independent particle production model
* Σ=0 in case of absence of fluctuations

Can be applied for F-B multiplicity correlations!

E.A., TMPh 185:383 (2015)

$$\Sigma[n_F,n_B] = \frac{\langle n_B\rangle\omega[n_F] + \langle n_F\rangle\omega[n_B] - cov(n_F,n_B)}{\langle n_F\rangle + \langle n_B\rangle}$$

Independent strings model

1) The number of strings, N, fluctuates around the mean value <N> with the scaled variance $\omega[N] = \frac{\langle N^2 \rangle - \langle N \rangle^2}{\langle N \rangle}$

2) The fragmentation of each string contributes event-by-event to the forward and backward rapidity windows the μ_F and μ_B charged particles

3) $P(\mu_F, \mu_B)$ is identical for all strings

$\Sigma[n_F, n_B] = \Sigma[\mu_F, \mu_B]$ for independent sources

E.A., TMPh 185:383 (2015)

Independent strings model
Two-particle correlation function

$$C_2(\eta_1,\eta_2) = \frac{\rho_2(\eta_1,\eta_2)}{\rho(\eta_1)\rho(\eta_2)} - 1 \qquad \rho(\eta) = \frac{dn_{ch}}{d\eta} \qquad \rho_2(\eta_1,\eta_2) = \frac{d^2 n_{ch}}{d\eta_1 d\eta_2}$$

For string:

$$\Lambda(\eta_1,\eta_2) = \frac{\lambda_2(\eta_1,\eta_2)}{\lambda(\eta_1)\lambda(\eta_2)} - 1 \qquad C_2(\eta_1,\eta_2) = \frac{\omega[N] + \Lambda(\eta_1,\eta_2)}{\langle N \rangle}$$

V. Vechernin, NPA 939:21 (2015)

Translational invariance assumption:

$$\lambda(\eta) = \mu_0 \qquad \lambda_2(\eta_1,\eta_2) = \lambda_2(\eta_1 - \eta_2) = \lambda_2(\Delta\eta)$$

For small symmetric observation windows ($\delta\eta \ll \eta_{corr}$):

$$\Sigma[n_F, n_B](\Delta\eta) = 1 + \mu_0 \delta\eta (\Lambda(0) - \Lambda(\Delta\eta))$$

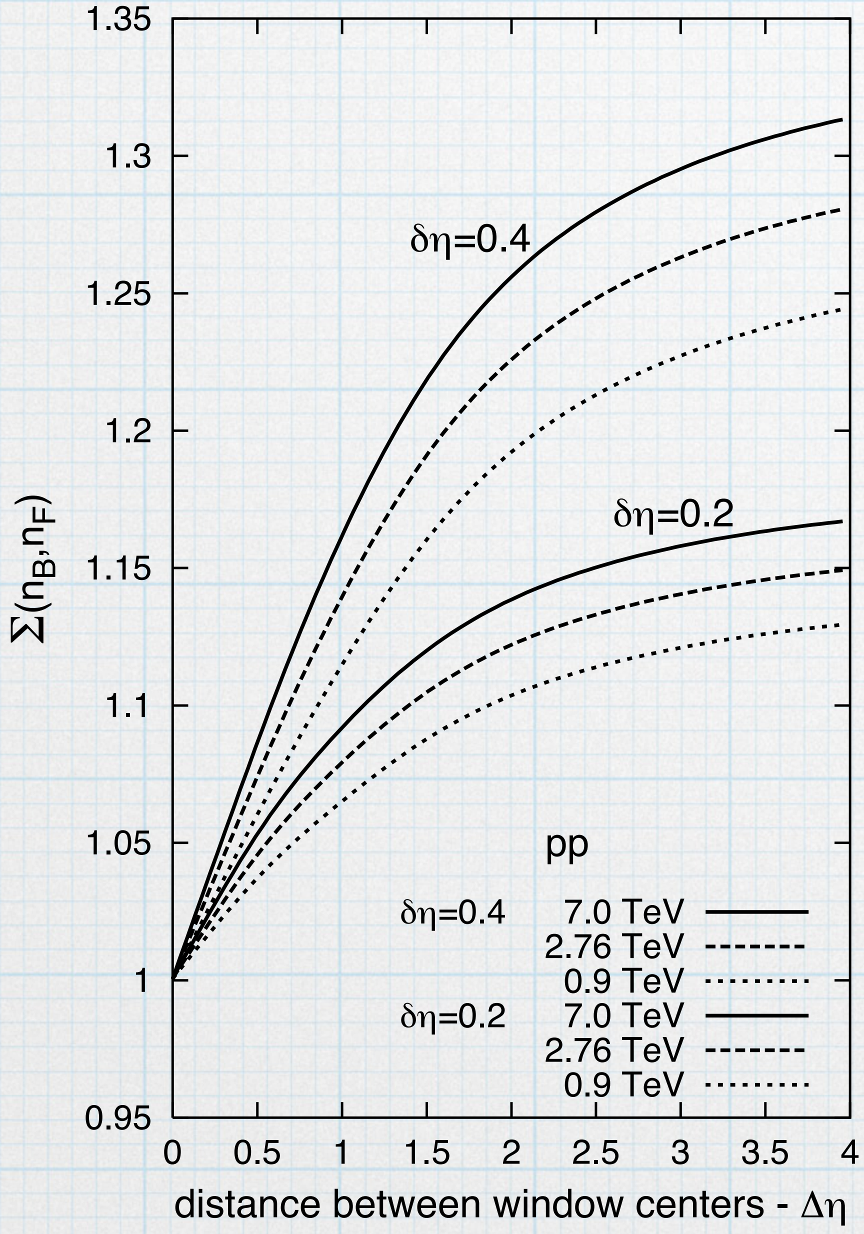
V. Vechernin, WPCF2017
E.A., V. Vechernin, EPJA 55(1):14 (2019)

Strongly intensive quantity is entirely described by string two-particle correlation function

LUHEP SPb SU

Strongly intensive quantity

With parametrisation of $\Lambda(\Delta\eta)$ from V. Vechernin, NPA 939:21 (2015)



E.A., V. Vechernin, EPJA 55(1):14 (2019)

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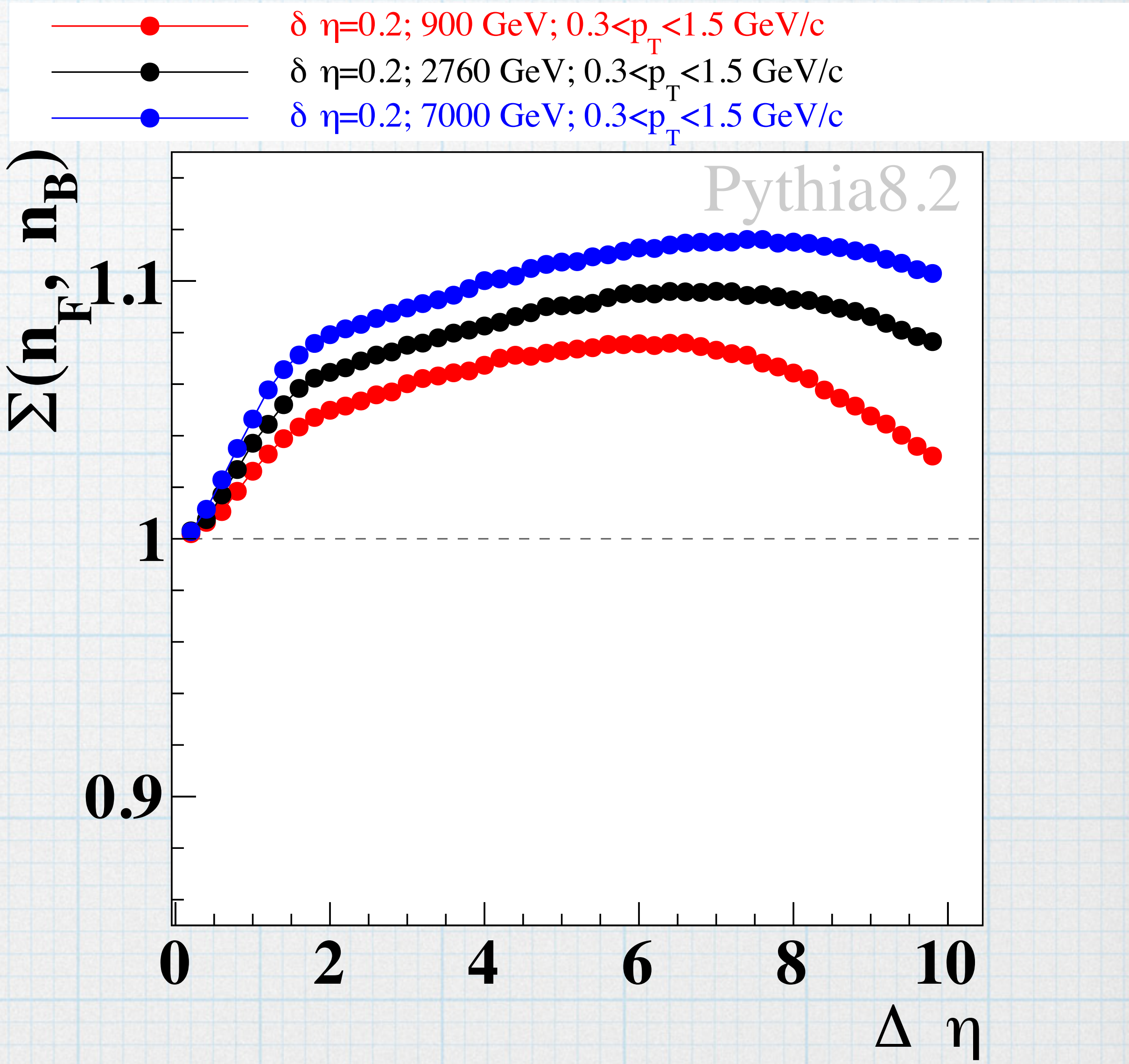


T. Sjöstrand, et al., Comp.Phys.Comm. 191:159 (2015)

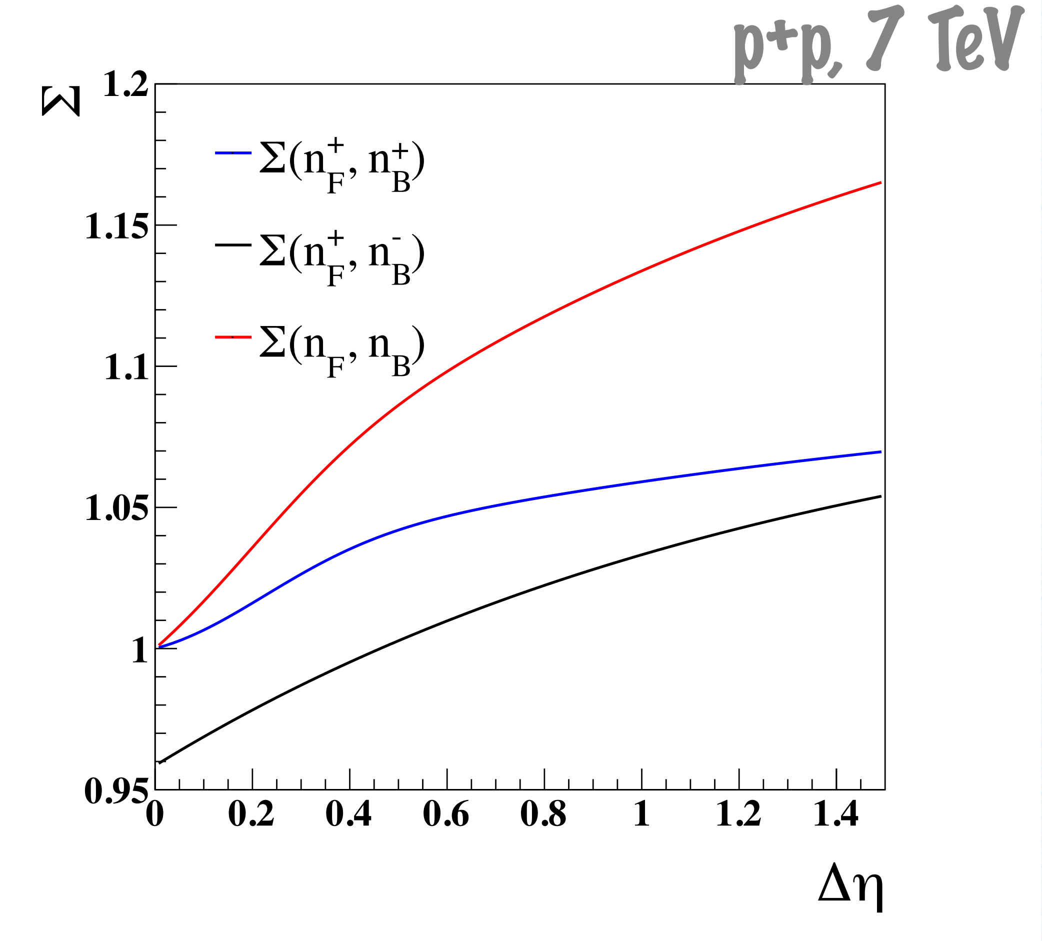
Electric charge

$$\Sigma[n_F, n_B] = \Sigma[n_F^+, n_B^+] + \Sigma[n_F^-, n_B^+] - \Sigma[n_F^+, n_F^-]$$

By fitting balance functions from ALICE, PRL 110:152301 (2013)
we find parametrisation for $\Lambda^{++}(\Delta\eta), \Lambda^{+-}(\Delta\eta)$

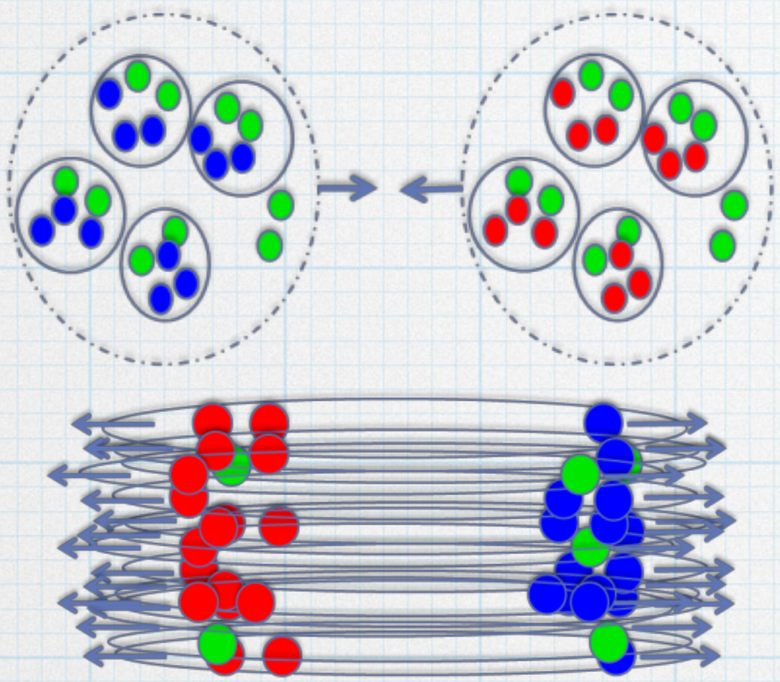
Oversimplified approach

Should be modified by taking into account short-range correlations of particles originating from different strings

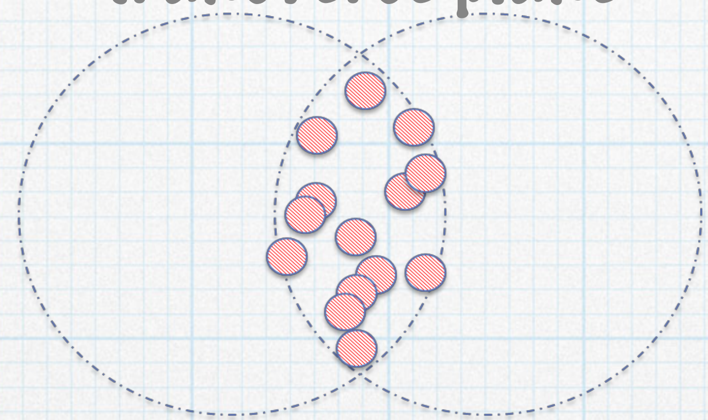


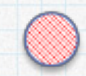
E.A., V. Vechernin, EPJA 55(1):14 (2019)

Interaction of strings



Transverse plane





Single string

$$\Sigma[n_F, n_B](\Delta\eta) = 1 + \mu_0 \delta\eta(\Lambda(0) - \Lambda(\Delta\eta))$$

Cluster of k strings

$$\Sigma_k[n_F, n_B](\Delta\eta) = 1 + \mu_{0k} \delta\eta(\Lambda_k(0) - \Lambda_k(\Delta\eta))$$

Set of string clusters

$$\Sigma[n_F, n_B](\Delta\eta) = \sum_{k=1}^{\infty} \alpha_k \Sigma_k[n_F, n_B](\Delta\eta)$$

$$\alpha_k = \frac{\langle n \rangle_k}{\langle n \rangle}$$

$$\mu_{0k} > \mu_0$$

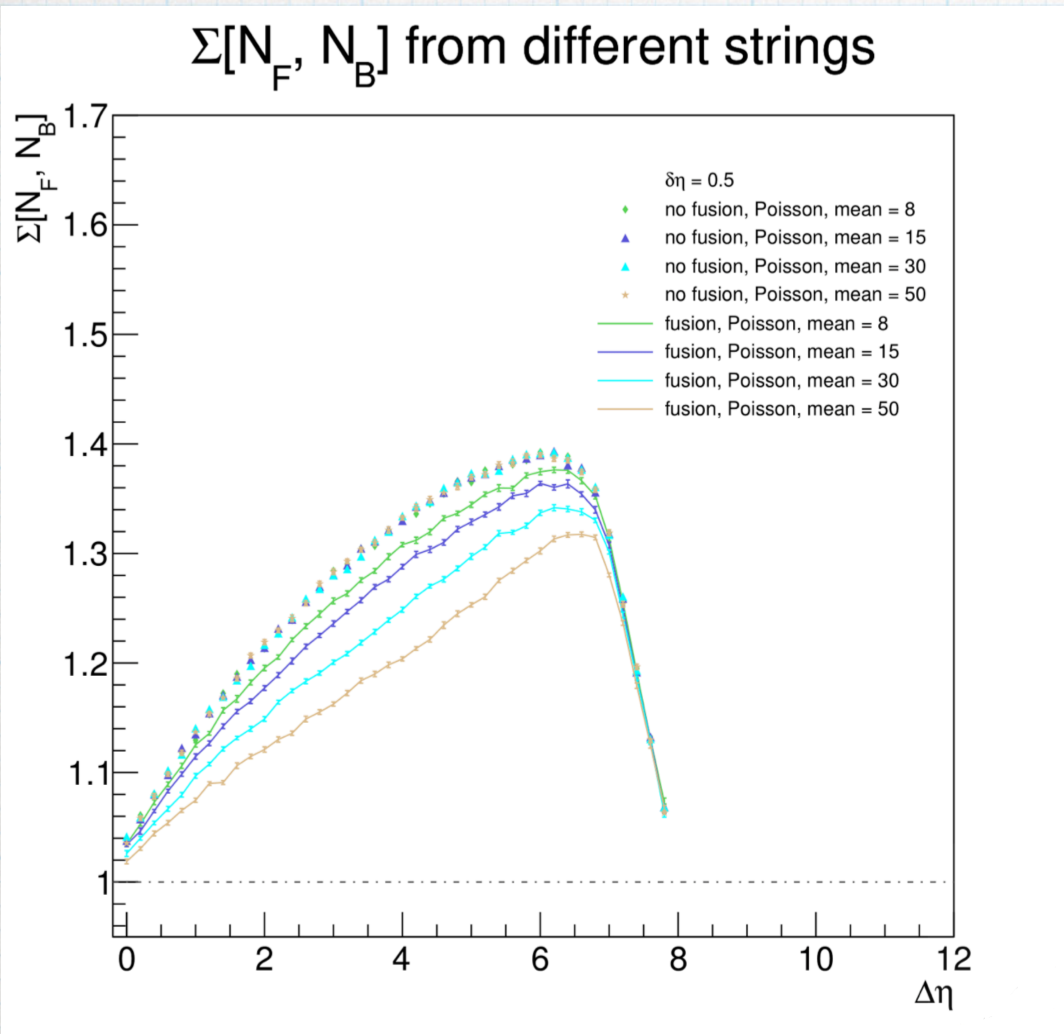
$$\eta_{corr,k} < \eta_{corr}$$

$$\Sigma^{fusion}[n_F, n_B](\Delta\eta) > \Sigma^{no-fusion}[n_F, n_B](\Delta\eta)$$

Abramovskii, et al., Pisma Zh.Eksp.Theor.Fiz. 47(6):281 (1988)
Braun,Pajares, PLB 287:154 (1992); NPB 390:542 (1993); PRL 85:4684 (2000)
Bierlich, NPA 982:499 (2019)
E.A., V. Vechernin, EPJA 55(1):14 (2019)

Interaction of strings

Suppression due to string fusion



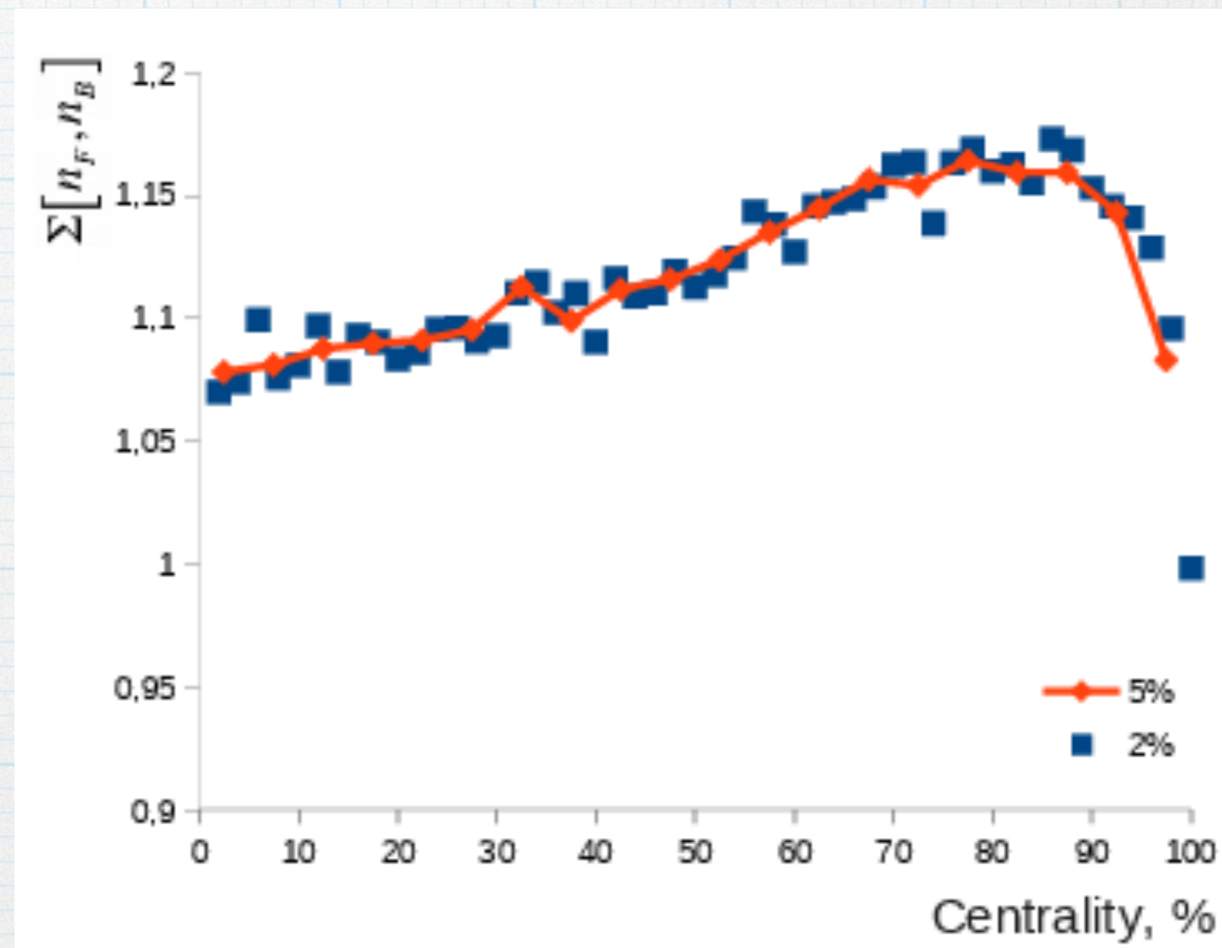
D. Prokhorova, this workshop

Pb+Pb

(-3.8;-3) and (3;3.8) windows

non-monotonic dependence

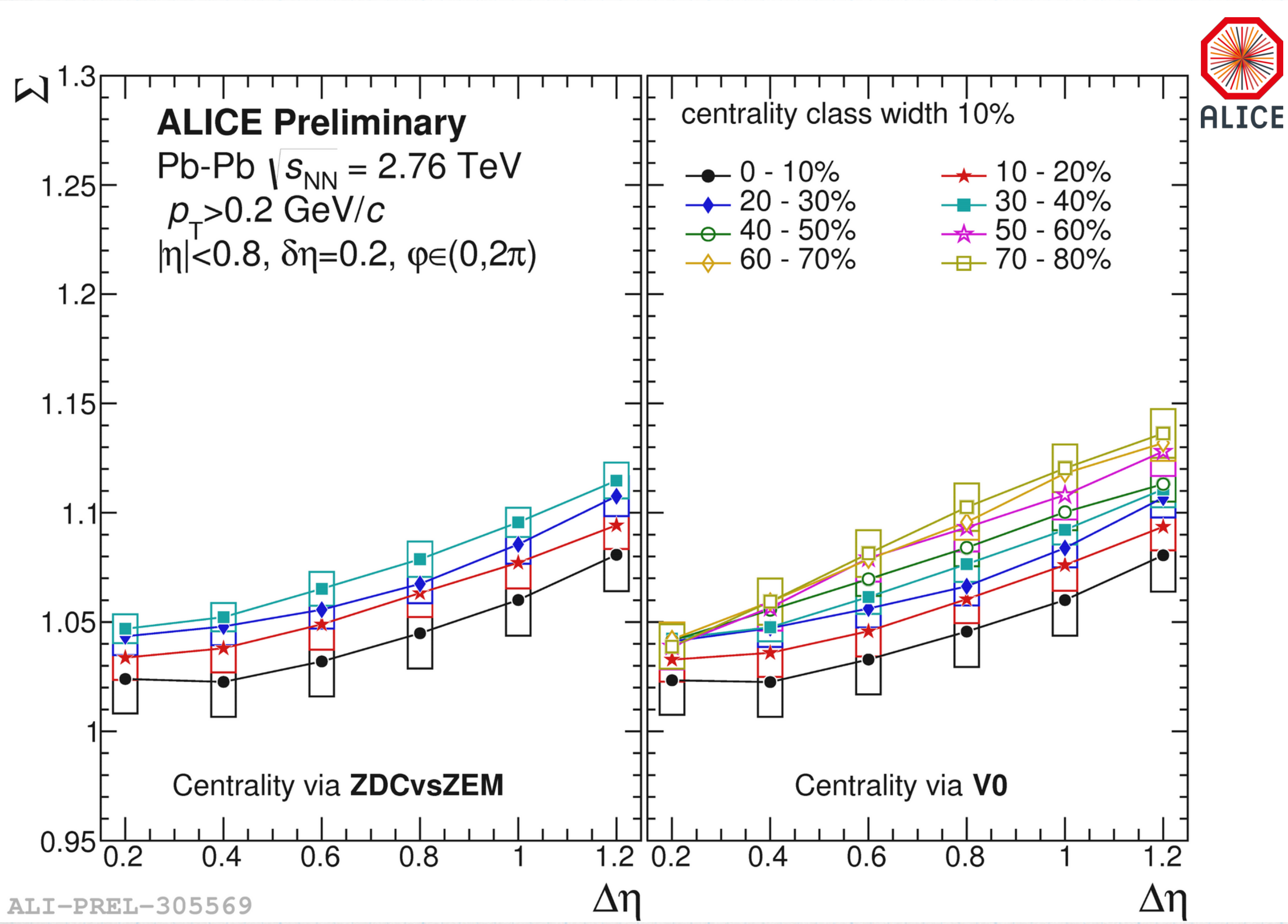
model with interacting strings from color dipoles



V. Kovalenko, EPJWConf 204:03006 (2019)

PbPb

I.Sputowska(for ALICE) MDPI Proc. 10(1):14 (2019)

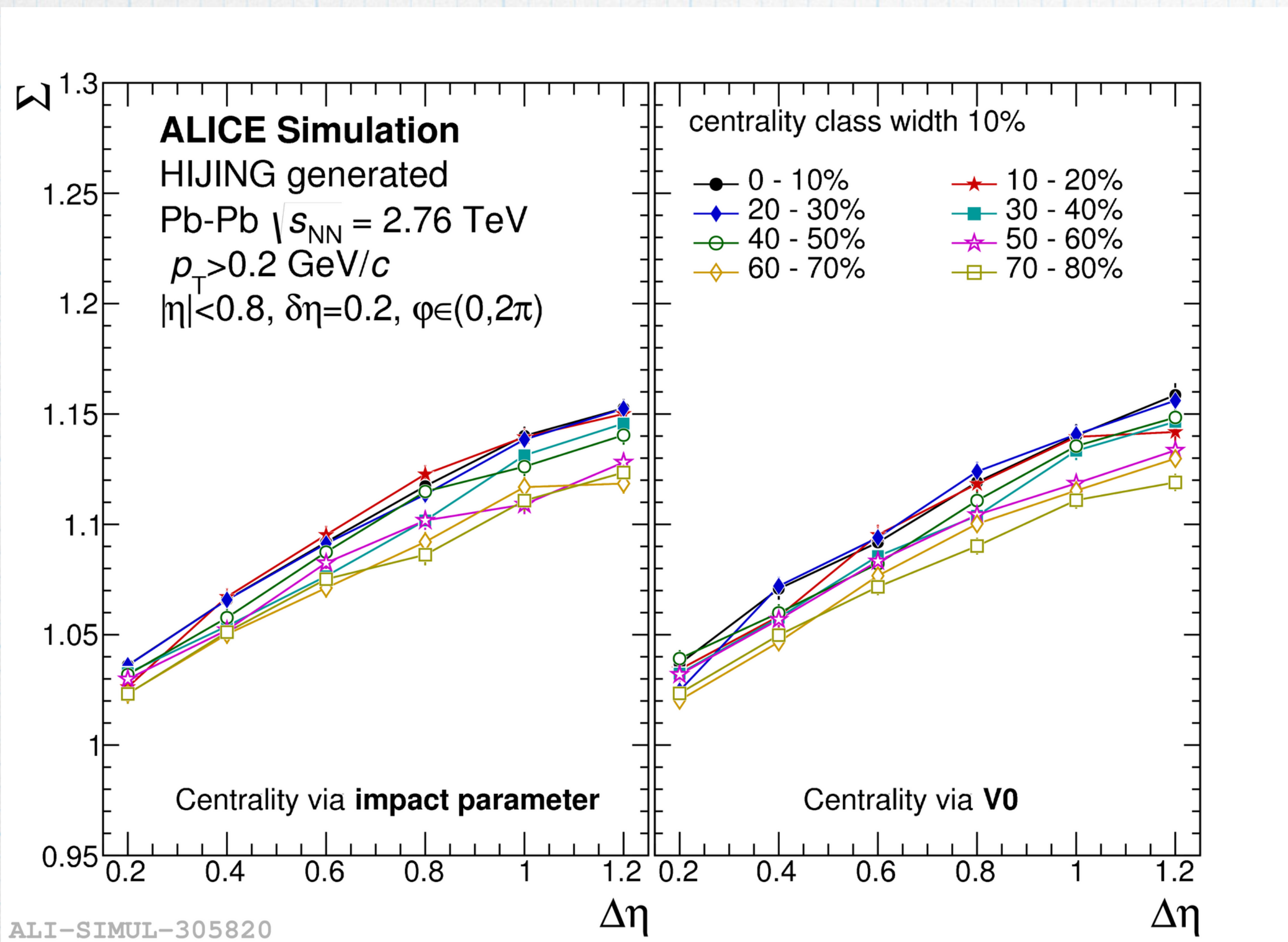


* almost no dependence on centrality selection procedure

* decreasing trend when going to more central collisions -> collectivity signal?

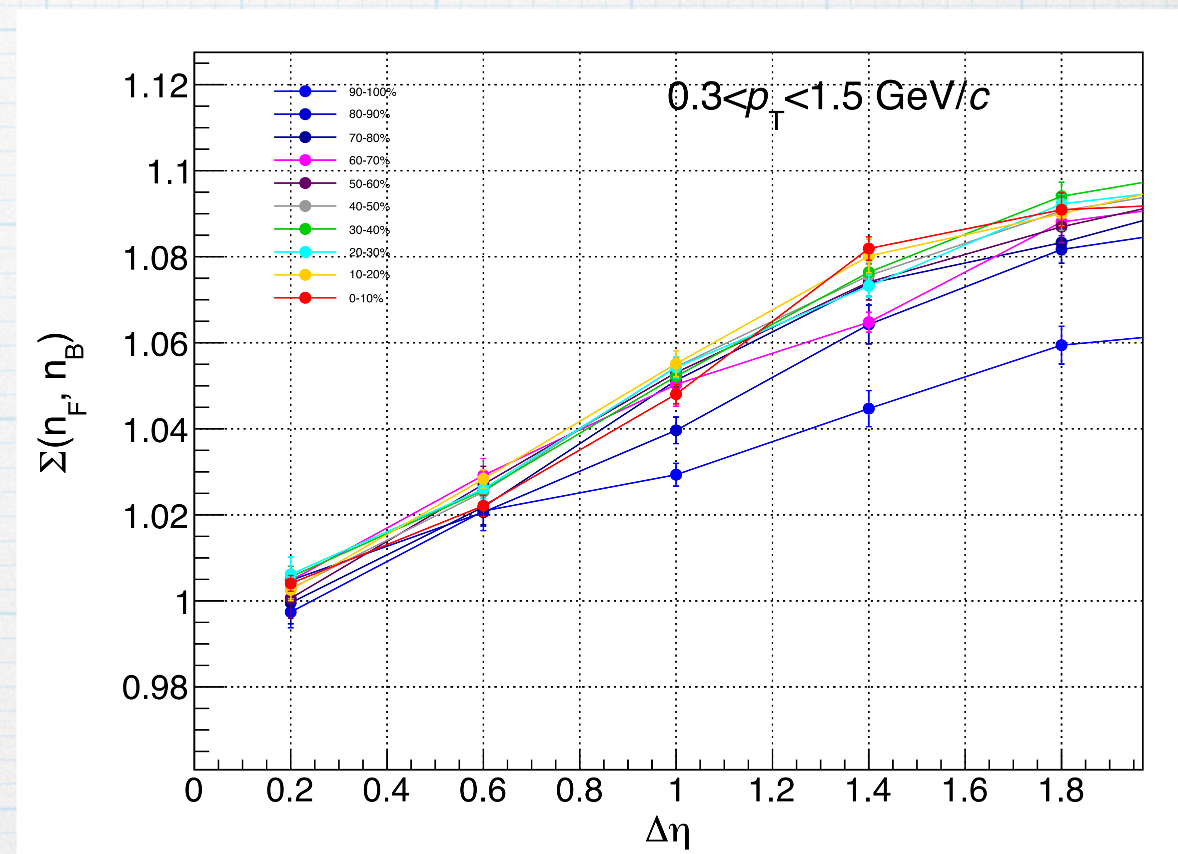
PbPb in models

HIJING
M.Gyulassy,X.-N.Wang, Comp.Phys.Comm. 83:307 (1994)



Increasing trend when going to more central collisions

Angantyr (PYTHIA extension for AA)
C.Bierlich, et al., JHEP 1810:134 (2018)



Almost independent on centrality

History lesson

Fluctuations of asymmetry parameter, C, have been studied at RHIC

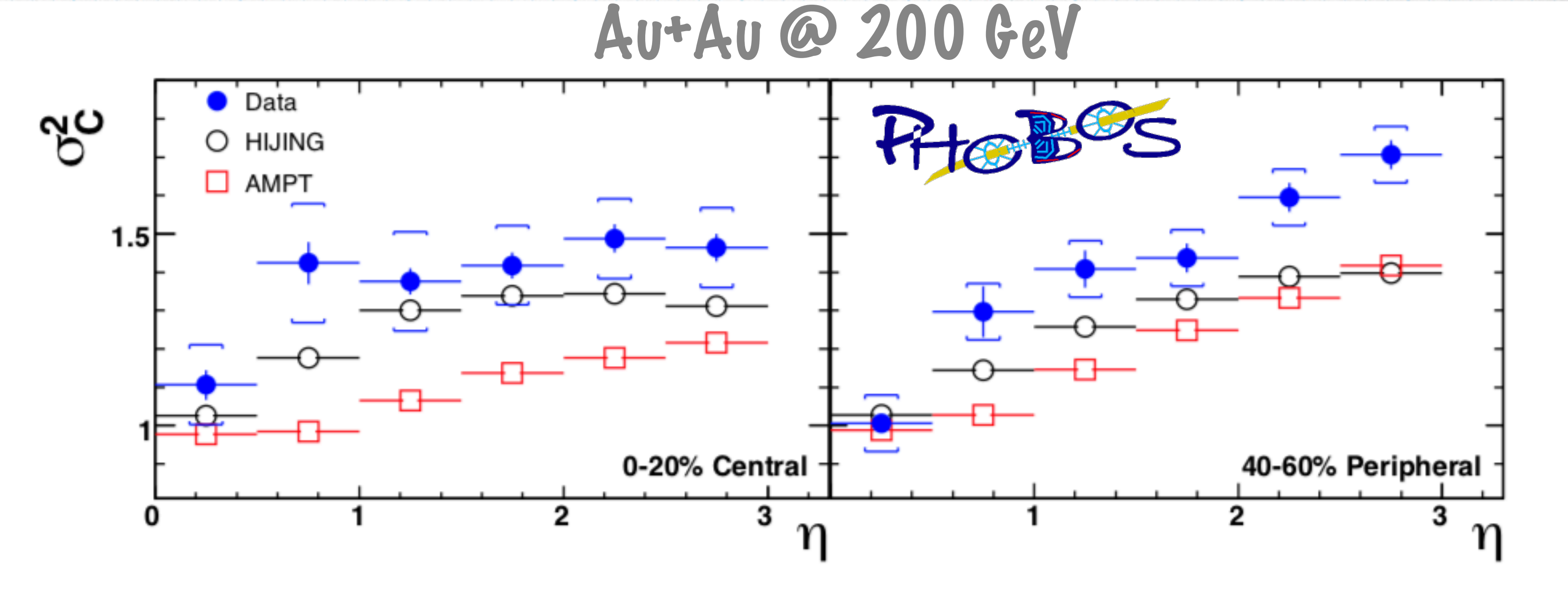
$$C = \frac{n_F - n_B}{\sqrt{n_F + n_B}} \qquad \sigma^2(C) = \langle \frac{(n_F - n_B)^2}{n_F + n_B} \rangle - \langle \frac{n_F - n_B}{\sqrt{n_F + n_B}} \rangle^2$$

$\sigma^2(C) \approx \Sigma[n_F, n_B]$ under assumptions:

$$\langle n_F \rangle = \langle n_B \rangle$$

$$\langle \frac{n_F - n_B}{\sqrt{n_F + n_B}} \rangle^2 = \frac{\langle n_F - n_B \rangle^2}{\langle n_F + n_B \rangle}$$

$$\langle \frac{(n_F - n_B)^2}{n_F + n_B} \rangle = \frac{\langle (n_F - n_B)^2 \rangle}{\langle n_F + n_B \rangle}$$



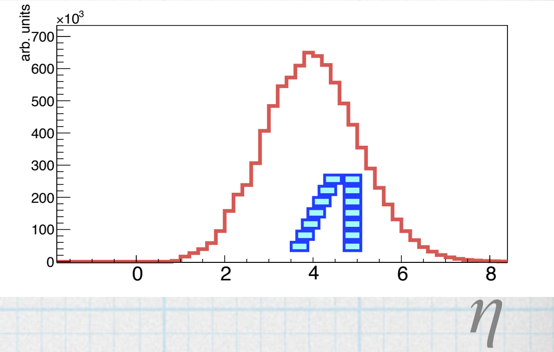
PHOBOS, PRC 74: 011901 (2006)

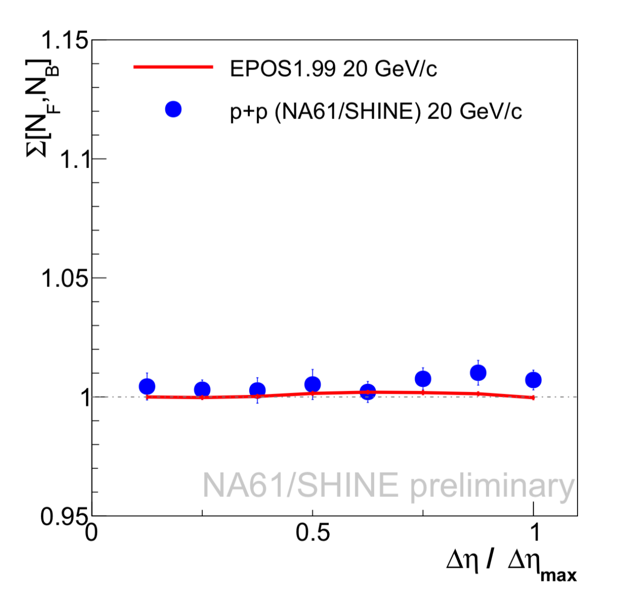
* Similar behaviour with Δη
* No centrality dependence visible

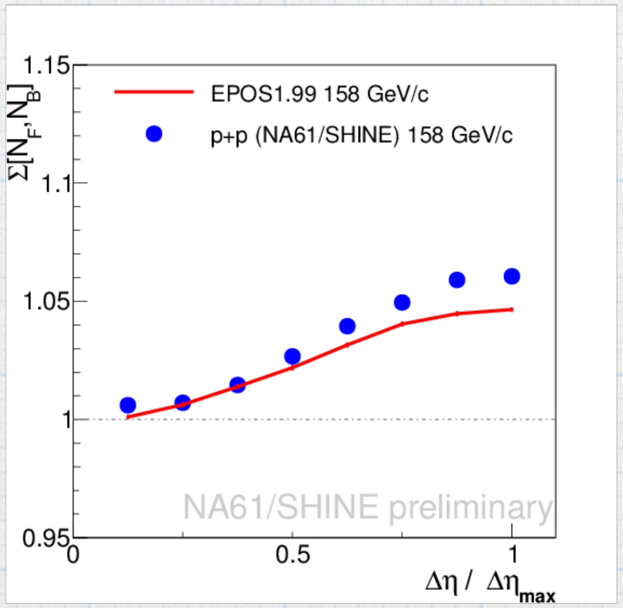
Going to lower energies

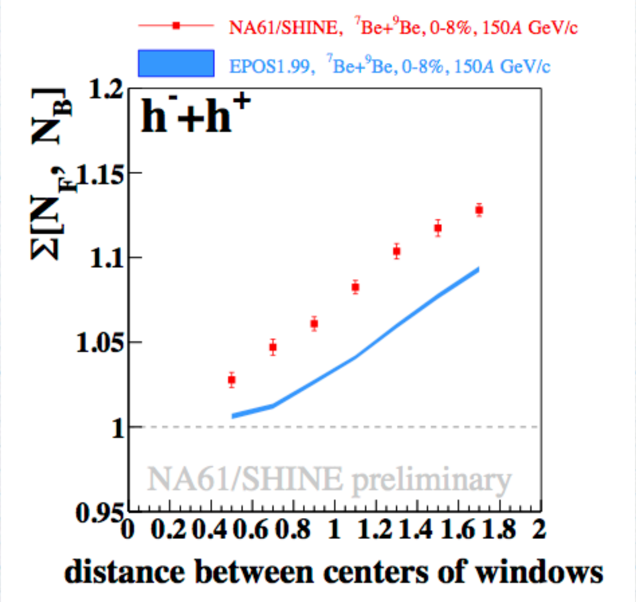
E.A., WPCF2017
E.A., EPJ Web Conf. 191:05002 (2018)
D.Prokhorova, EPJ Web Conf. 204:07013 (2019)
see also A. Seryakov, this workshop

* Fixed target experiment at the CERN SPS
* Have to take both rapidity windows in forward hemisphere
* Results for p+p and Be+Be collisions with the same increasing trend (consistent with EPOS)





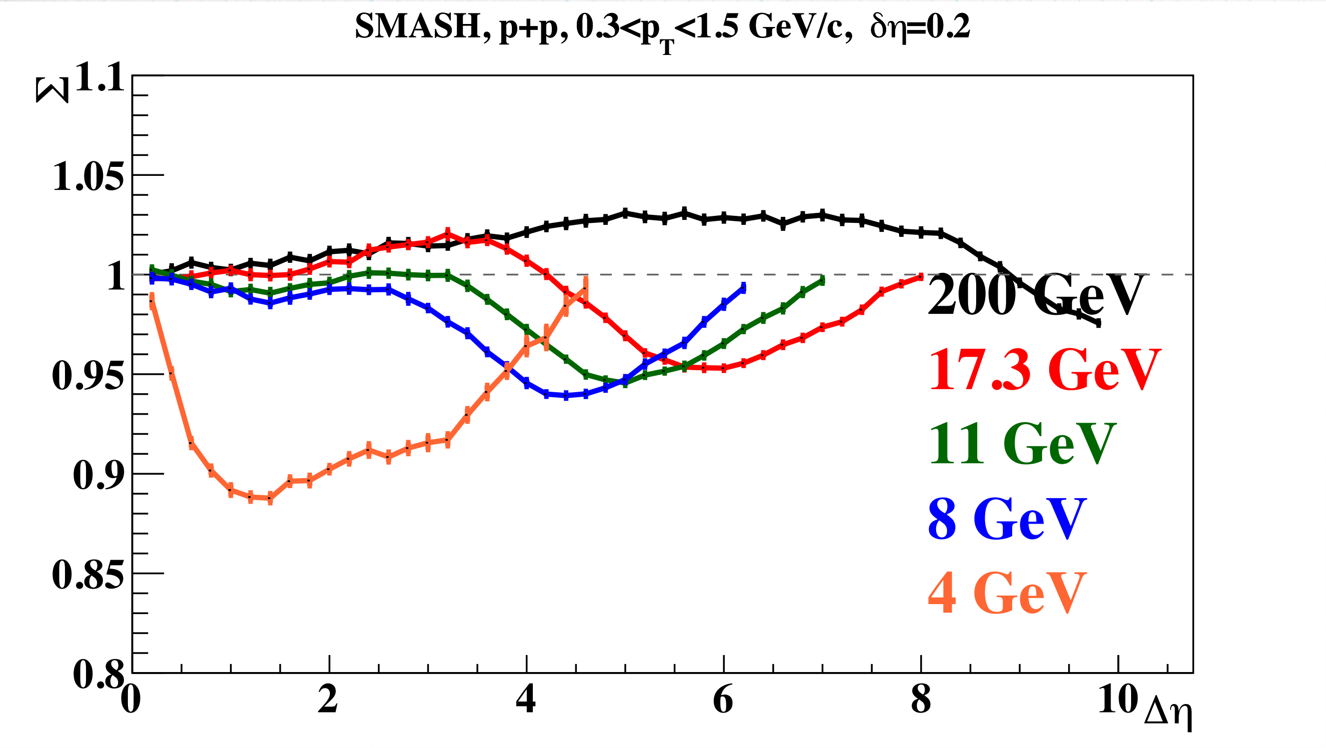




RHIC->SPS->NICA

smash
v.1.6

Test of strongly intensive quantity in SMASH event generator (transport code)



1M events for each energy

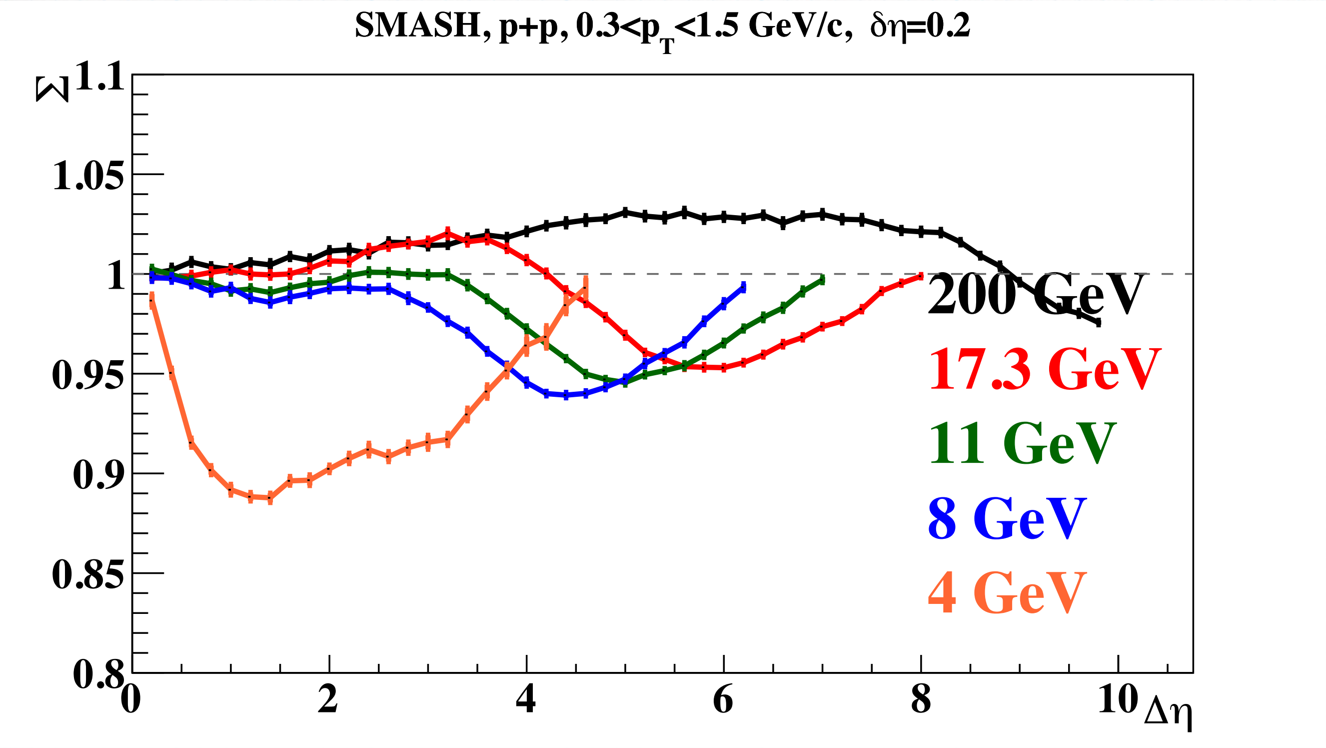
SMASH
J. Weil, et al., PRC 94: 054905 (2016)

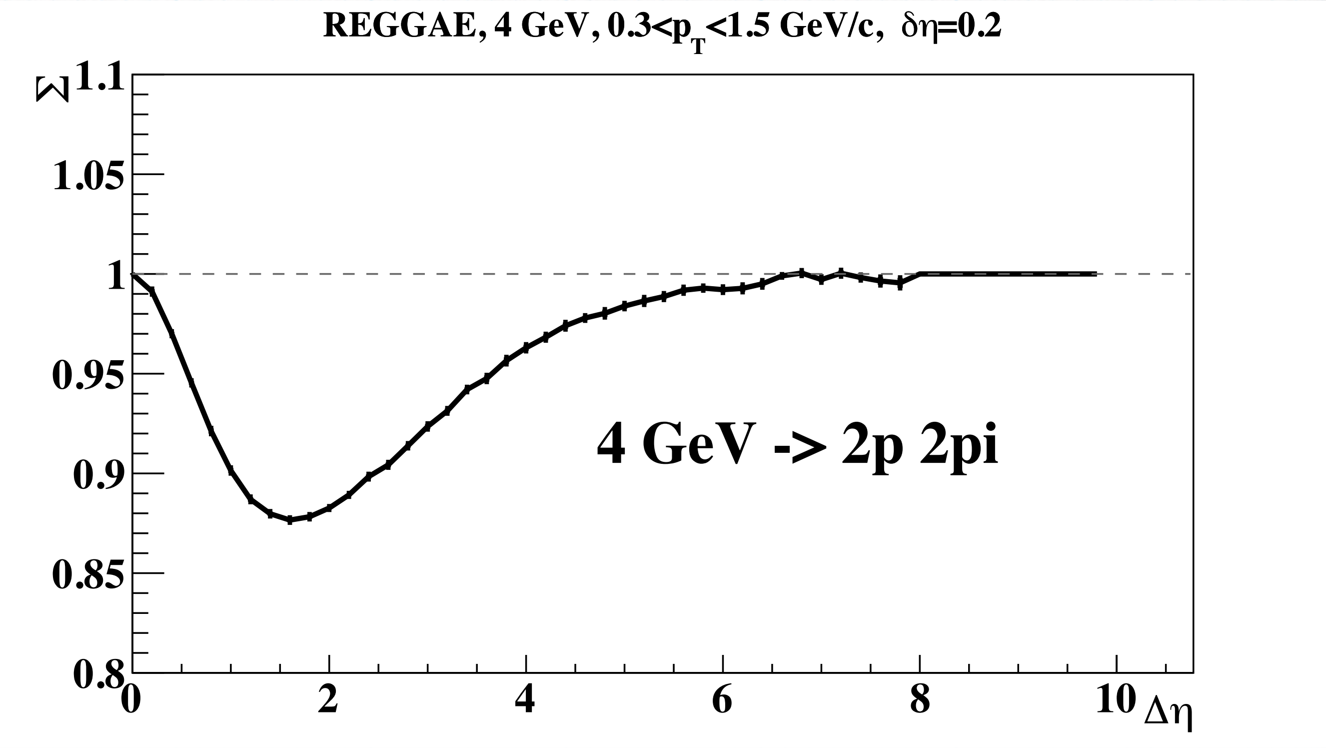
LUHEP SPb SU

RHIC->SPS->NICA

smash v.1.6

Test of strongly intensive quantity in SMASH event generator (transport code)





1M events for each energy

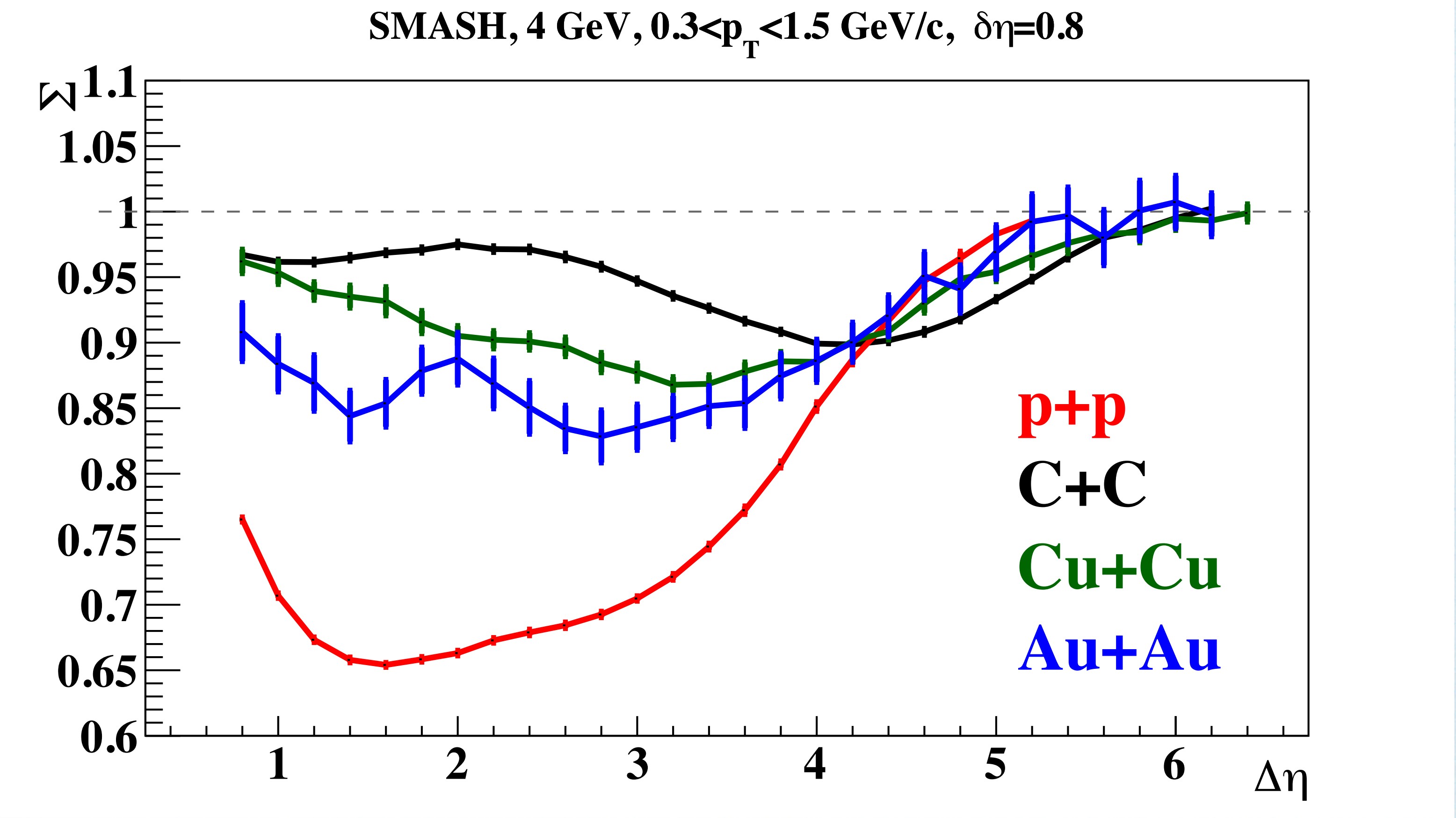
SMASH
J. Weil, et al., PRC 94: 054905 (2016)

Energy-momentum conservation code

REGGAE
M. Meres, et al., Comp.Phys.Comm. 182:2561 (2011)

NICA, system size scan?

smash
v.1.6



b=0fm
pp: 1M events
CC: 300k
CuCu: 30k
AuAu: 5k

nuclei deformation and clustered structure are not taken into account

SMASH
J. Weil, et al., PRC 94: 054905 (2016)

Conclusions and plans

* The string model enables to understand the main features of the behaviour of the strongly intensive observable $\Sigma(n_F,n_B)$ at LHC energies

* Collectivity (string fusion) leads to deviation from the baseline of the model with independent sources. Creation of homogeneous long-range sources increases $\Sigma(n_F,n_B)$. Inhomogeneity in rapidity leads to decrease of $\Sigma(n_F,n_B)$.

* Modification of the $\Sigma(n_F,n_B)$ behaviour at NICA collision energies (change from string decays to resonances decays). Role of global energy-momentum conservation.

* Plans - make use of MPDRoot, perform simulations in different event generators with the real detector geometry response


Proposed geometry of station 1 and 2
5 years ago

Thank you!

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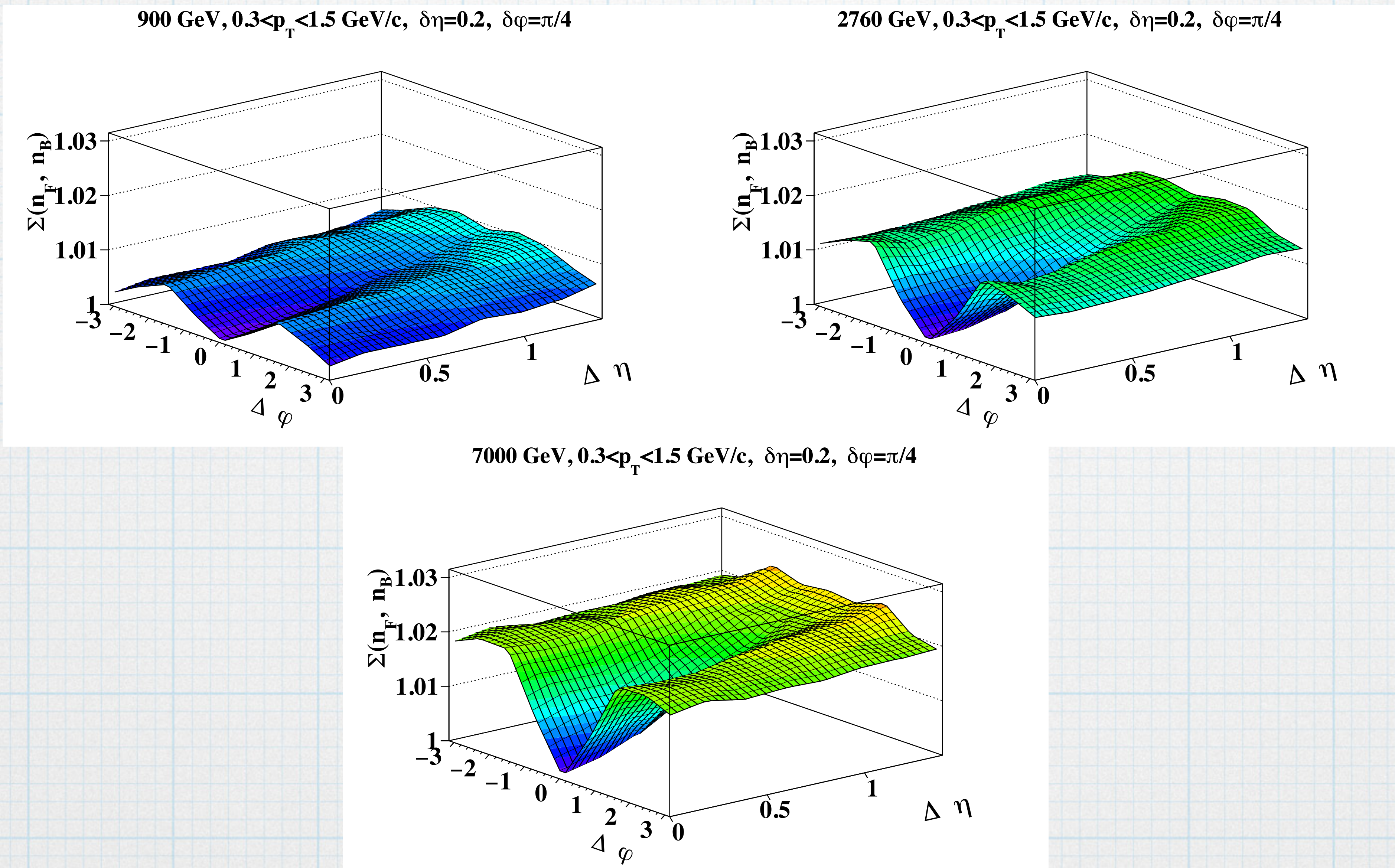
Back-up

Strongly intensive quantity

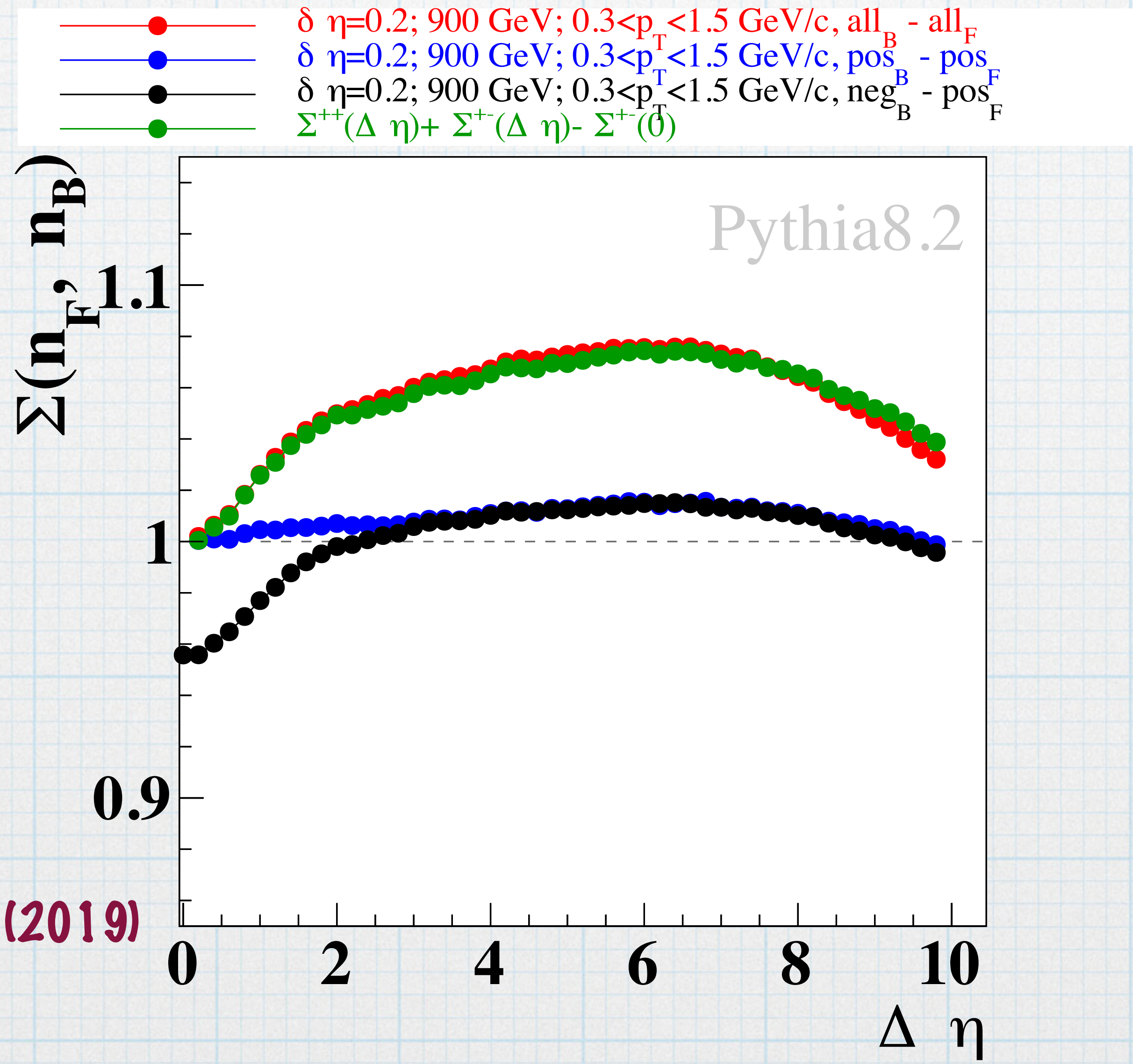
With parametrisation of $\Lambda(\Delta\eta, \Delta\phi)$ from V. Vechernin, NPA 939:21 (2015)



E.A., V. Vechernin, EPJA 55(1):14 (2019)

Electric charge

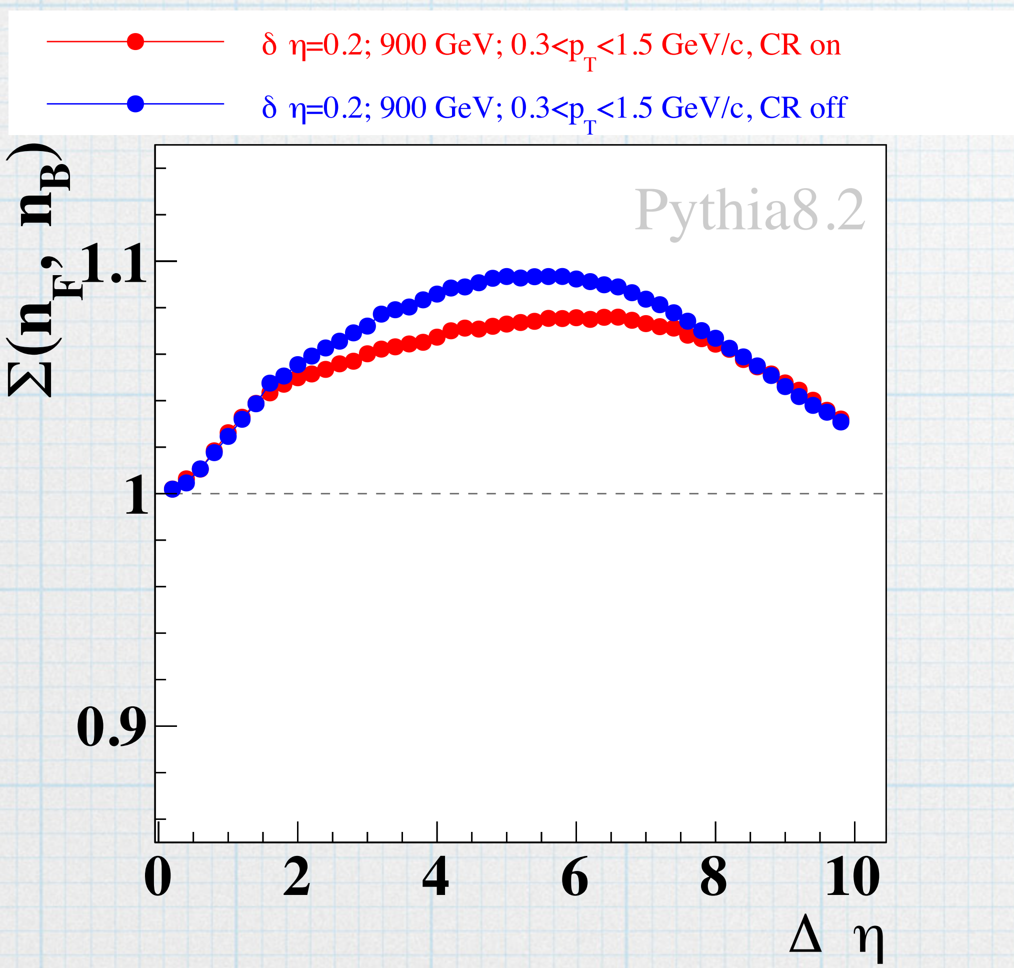
$$\Sigma[n_F, n_B] = \Sigma[n_F^+, n_B^+] + \Sigma[n_F^-, n_B^+] - \Sigma[n_F^+, n_F^-]$$

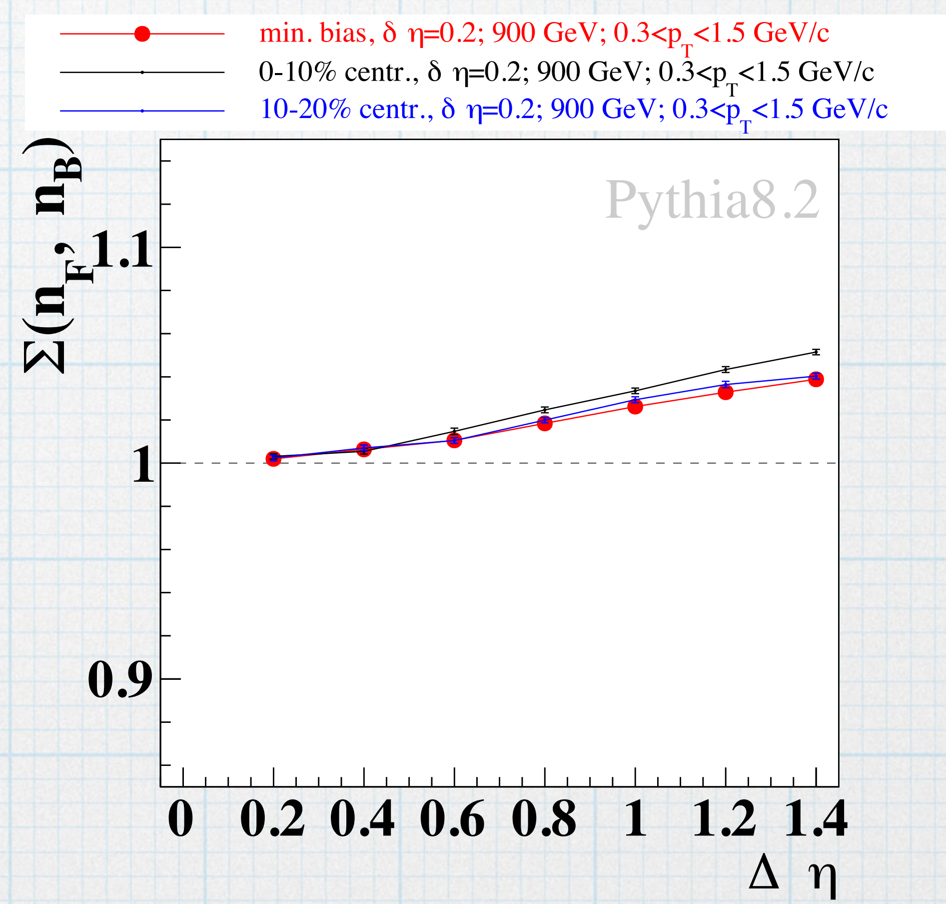


E.A., V. Vechernin, EPJA 55(1):14 (2019)

PYTHIA tests

v.8.235





T. Sjöstrand, et al., Comp.Phys.Comm. 191:159 (2015)