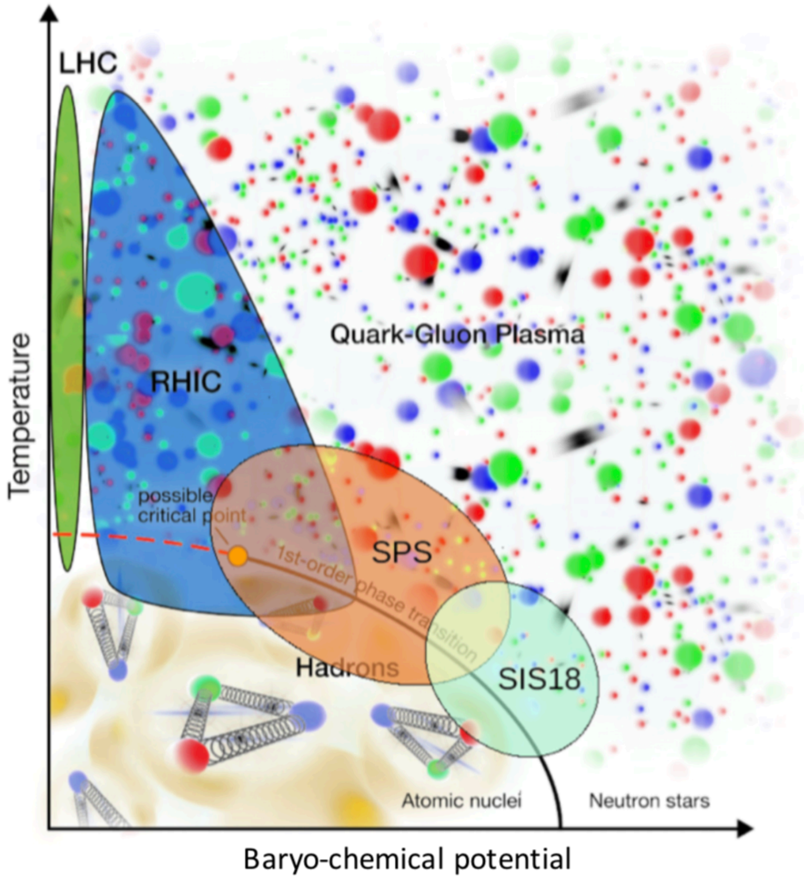
Fluctuations study in MC model of interacting quark-gluon strings

Daria Prokhorova

St. Petersburg State University

19. ZIMÁNYI SCHOOL
WINTER WORKSHOP ON HEAVY ION PYSICS

QCD phase diagram



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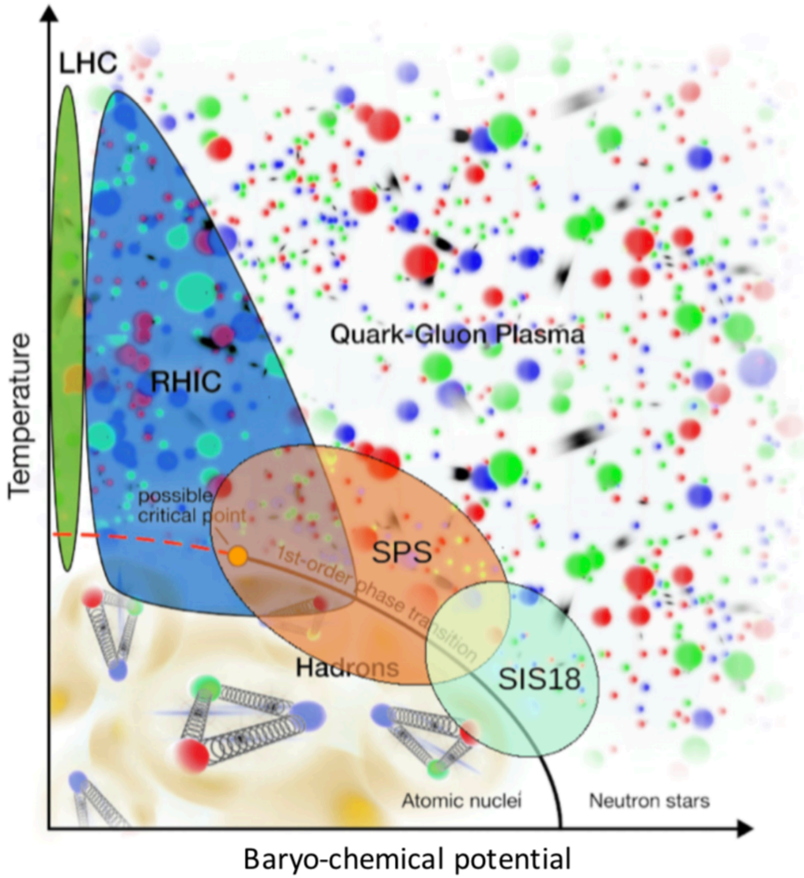

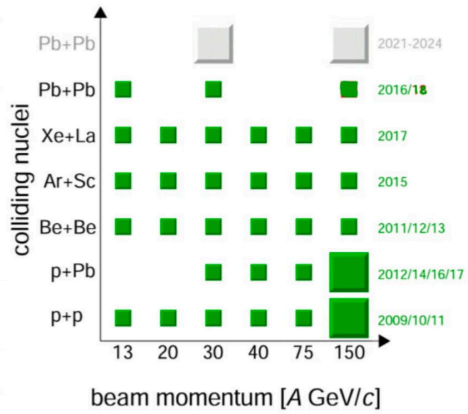

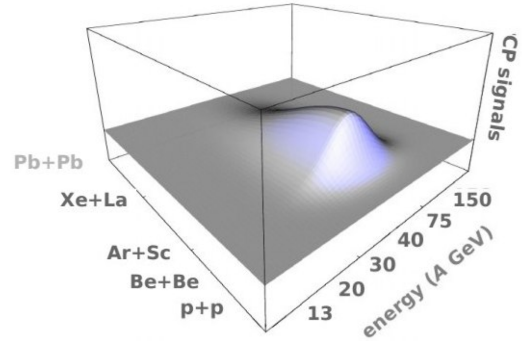

[Gazdzicki, M. and Seyboth, P. *Acta Phys. Pol. B* **47**, 1201 (2016)]

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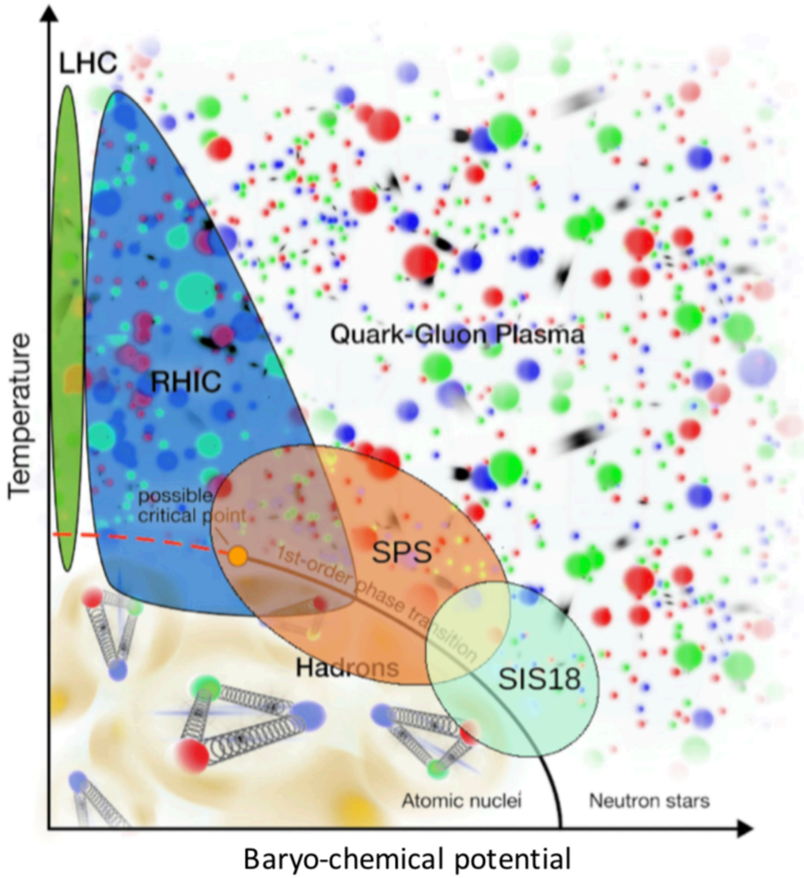

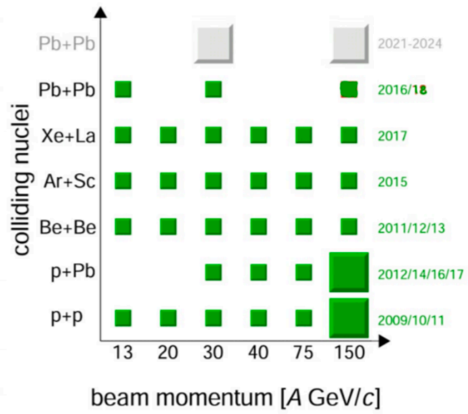

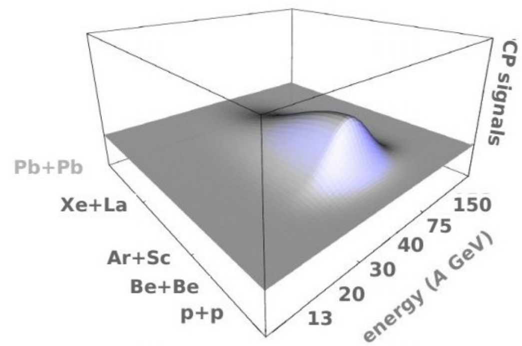

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System size - energy scan to spot the critical point by signal of enhanced fluctuations

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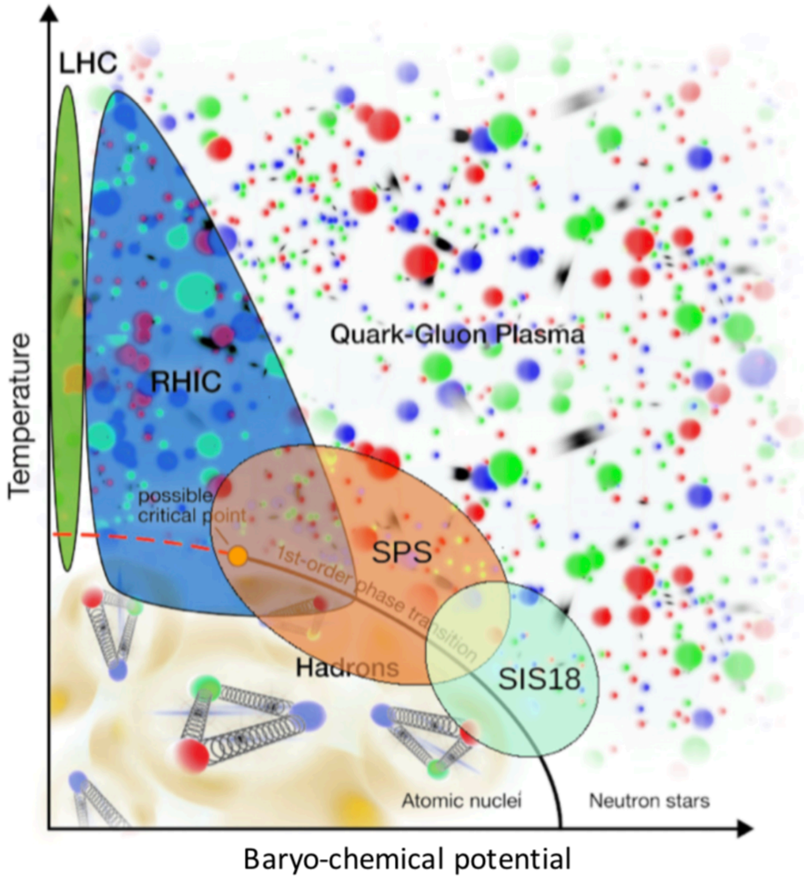

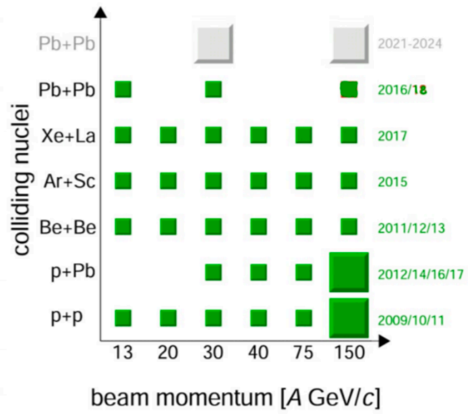

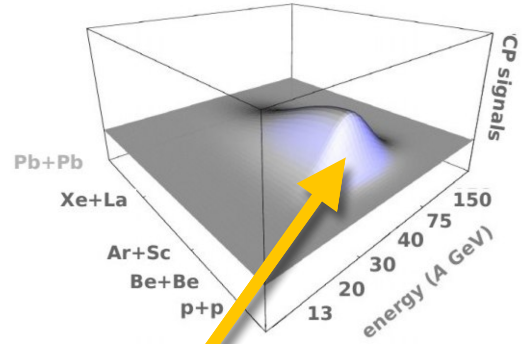

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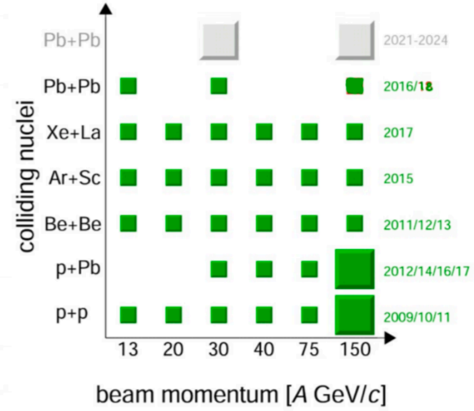

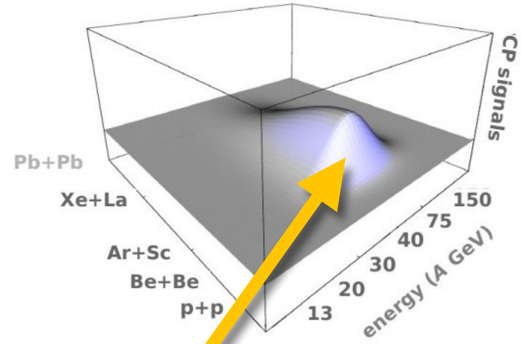

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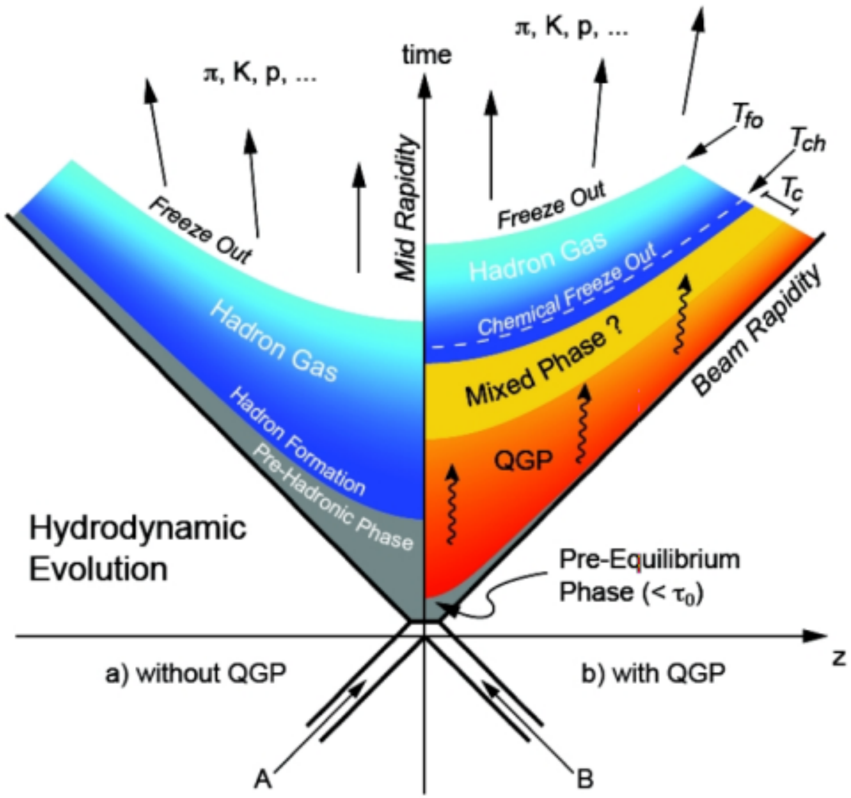

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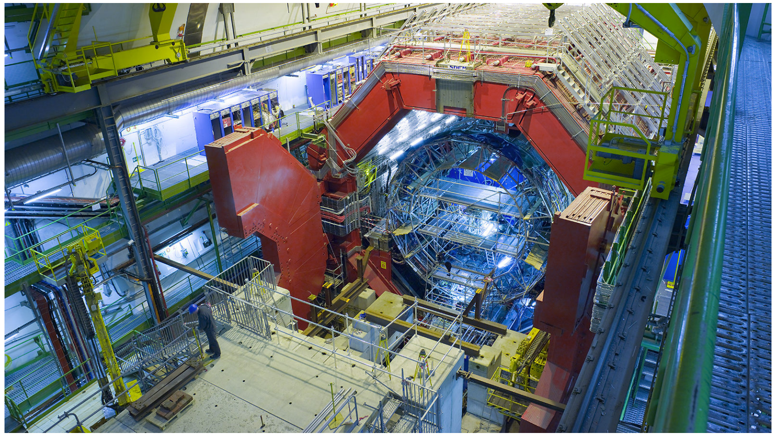
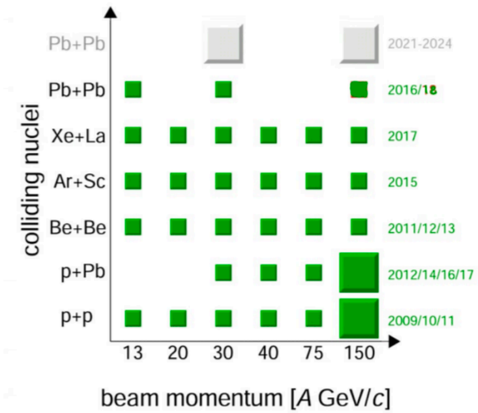
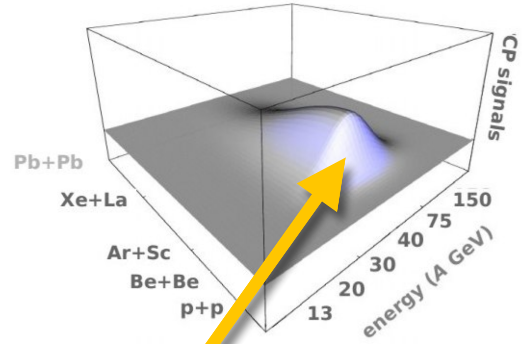
Mona Schweizer, CERN







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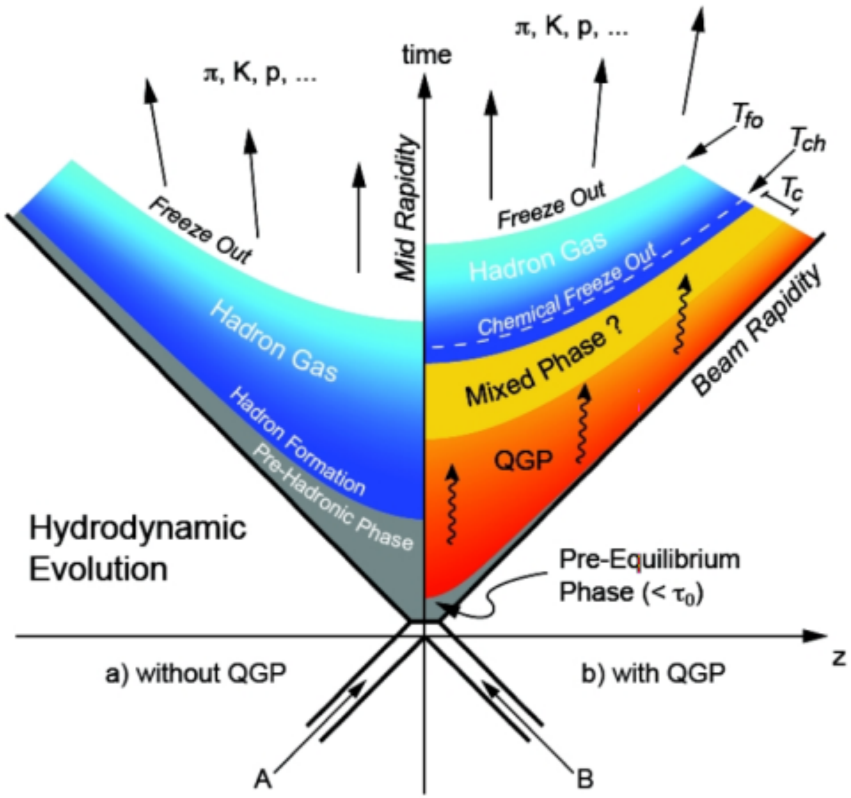

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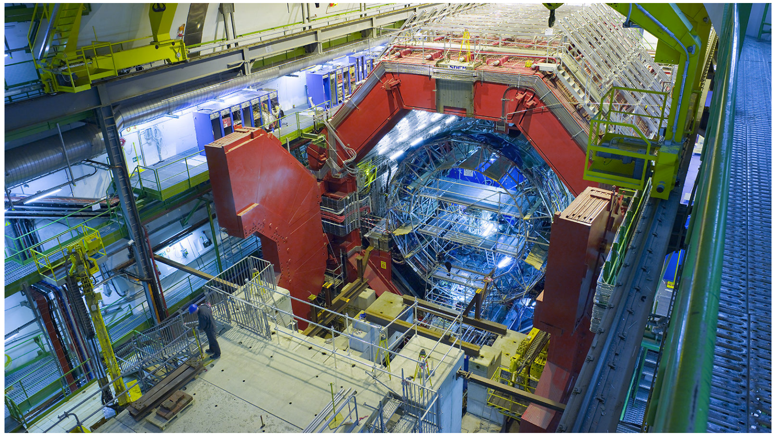

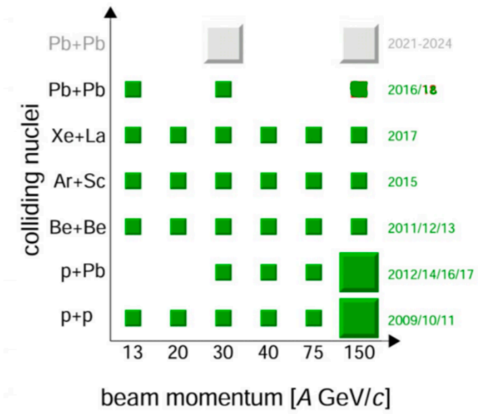

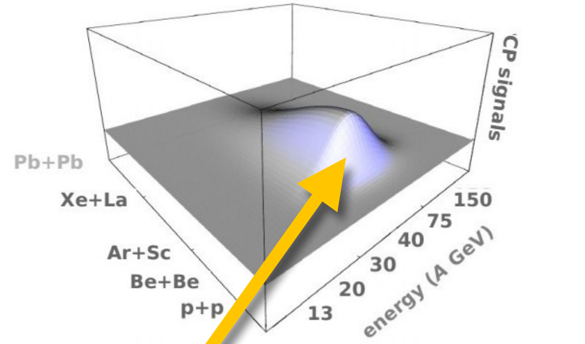

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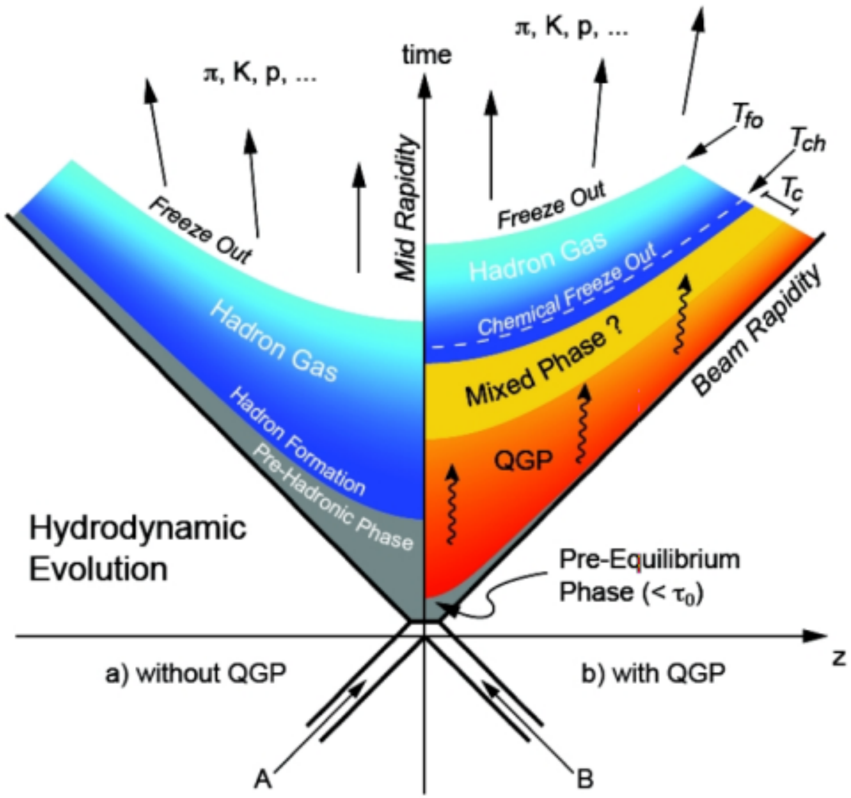

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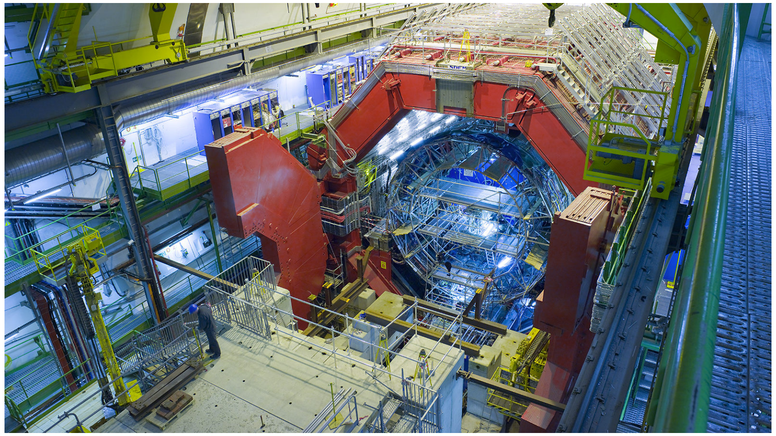

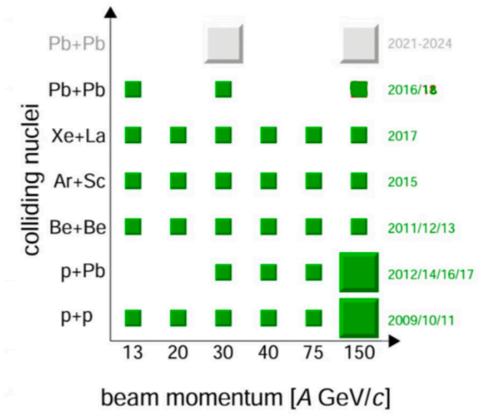

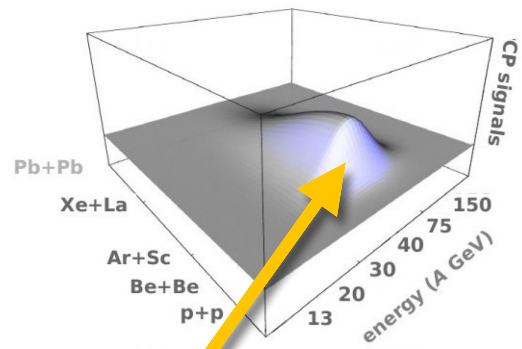

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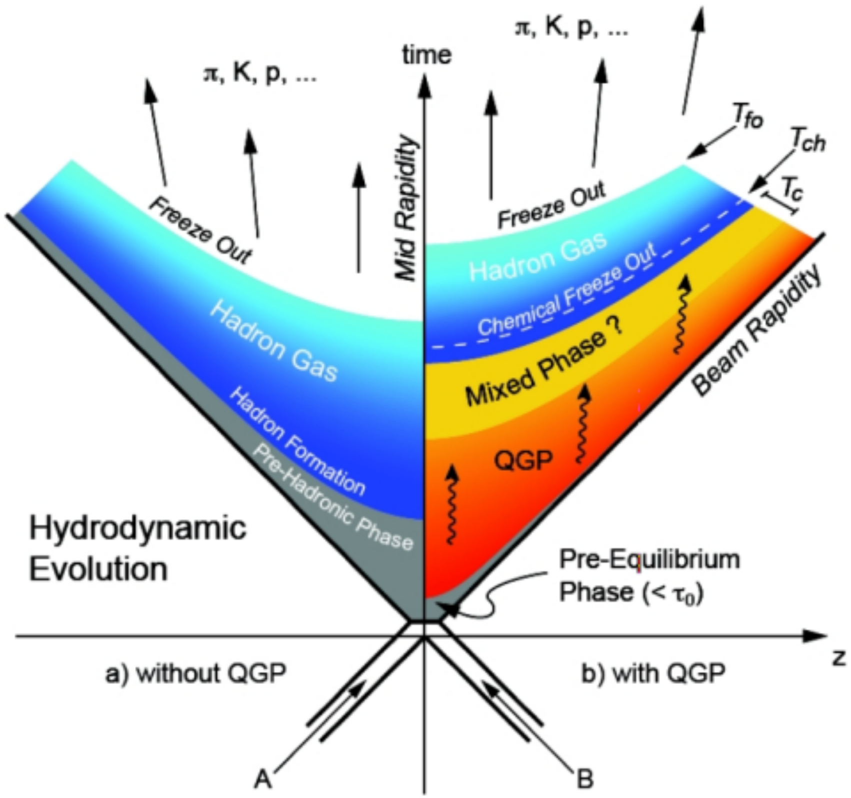

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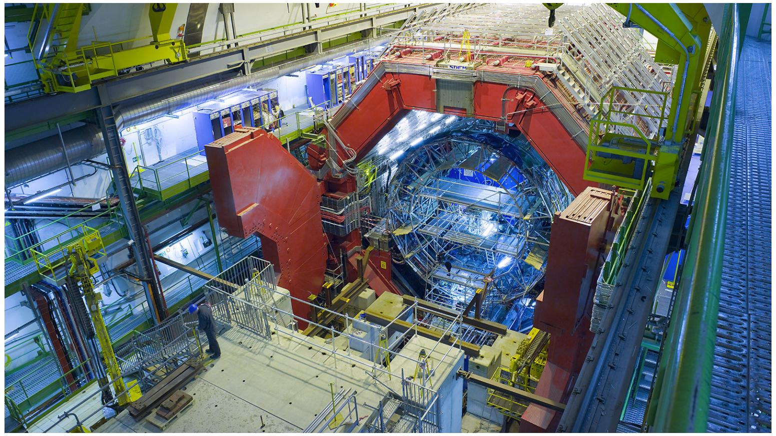

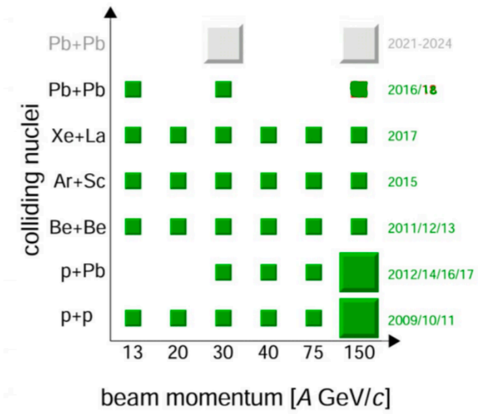

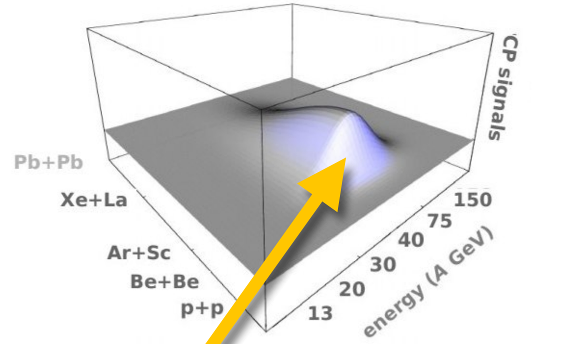

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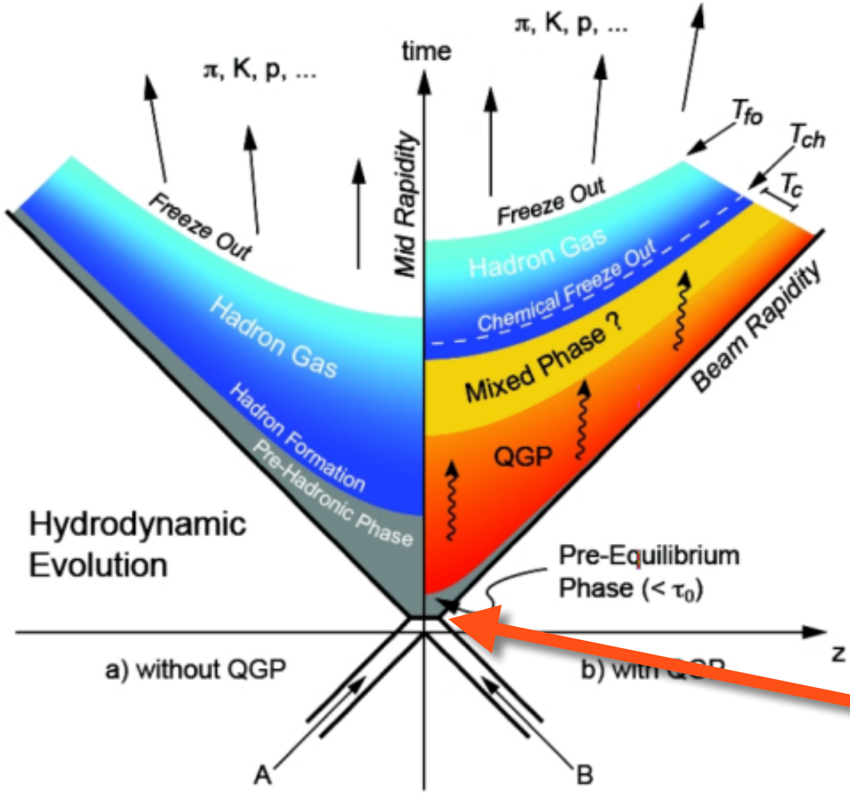

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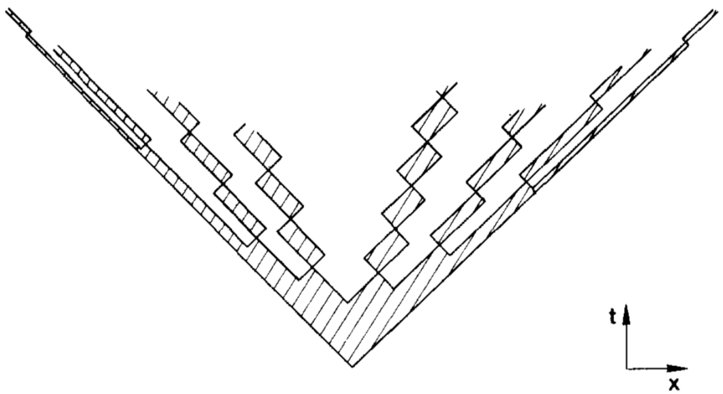
Look for the origin from initial stages!

Quark-gluon string approach

Non-perturbative Regge approach to describe the soft particle spectra (< 1 GeV/c)



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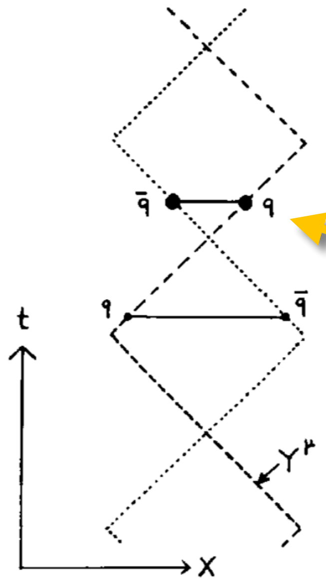
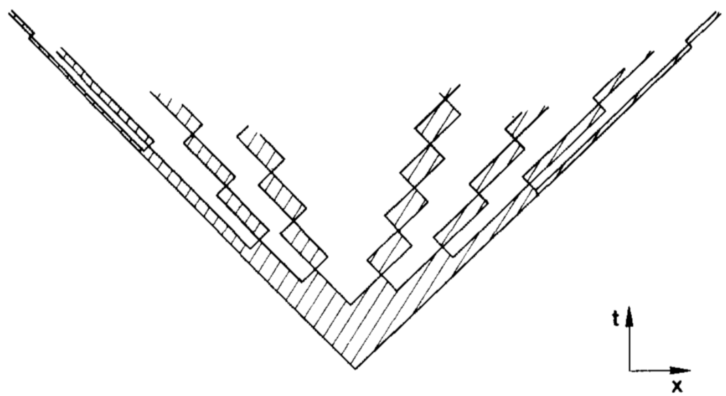


Colorless hadron represented by
the oscillating Jo-Jo solution

[X. Artru and G. Menessier Nuclear Physics B70 (1974) 93 - 115]



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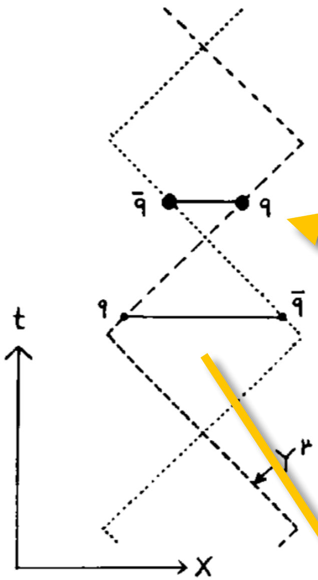

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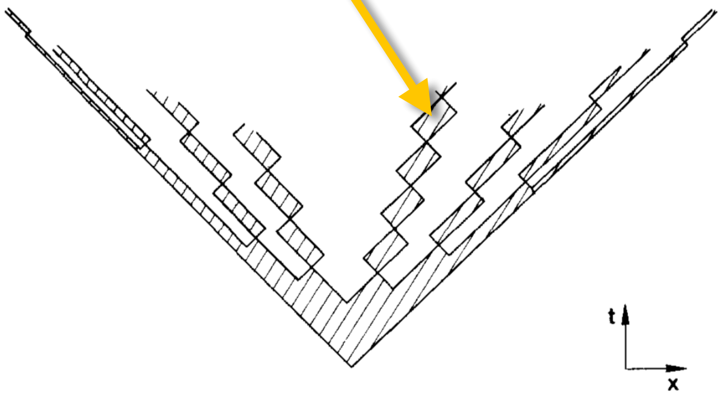

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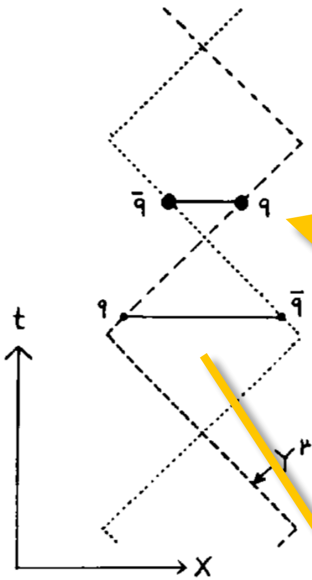

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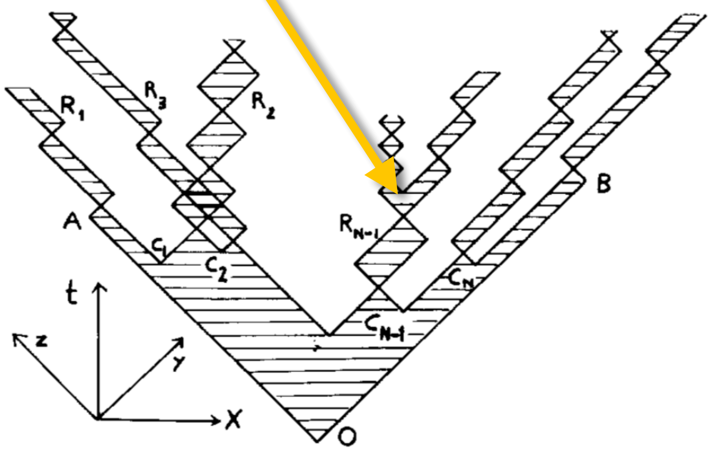

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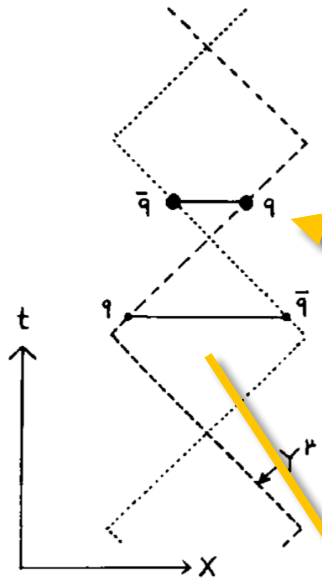

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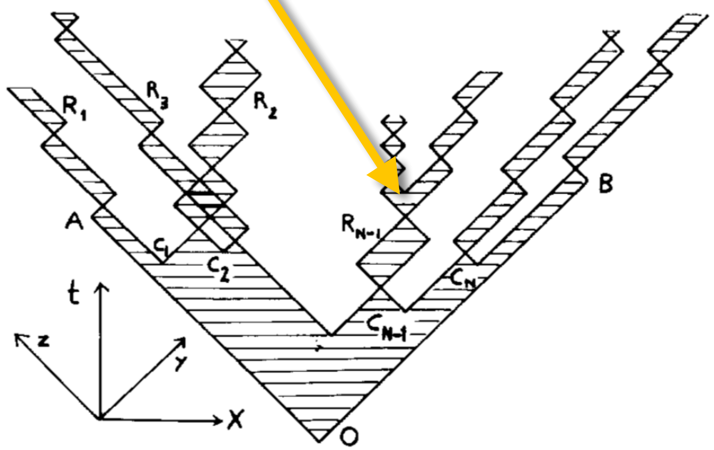

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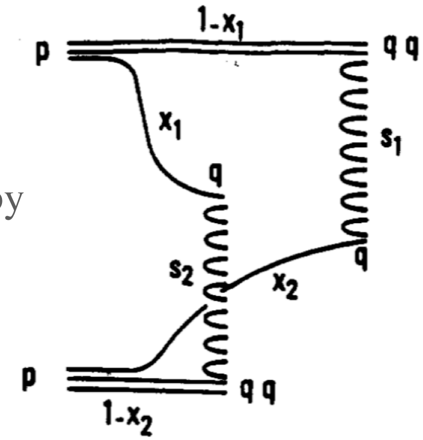

Unitarity cut of the cylindrical Pomeron results in two-chain diagram

[Capella A. et al Physics Reports 236, Nos. 4 & 5 (1994) 225 - 329]

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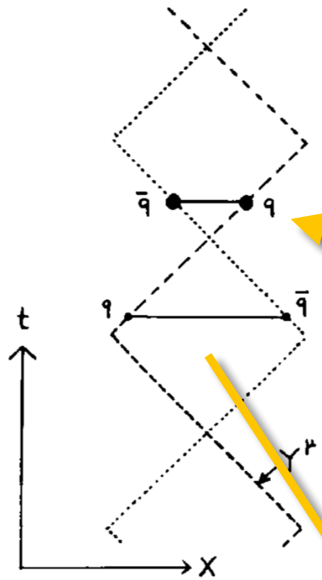

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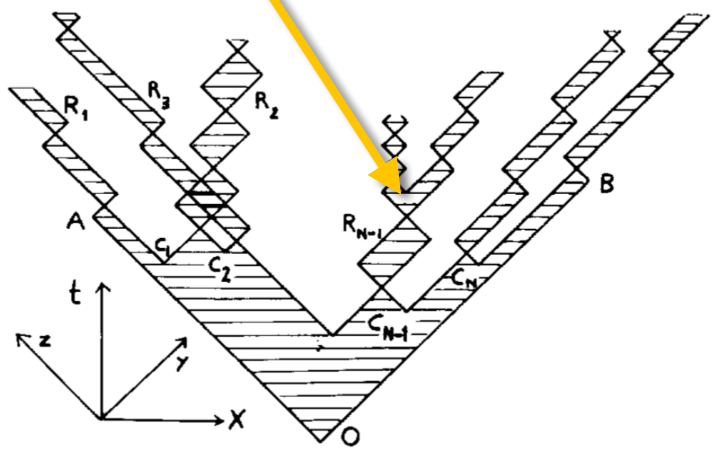

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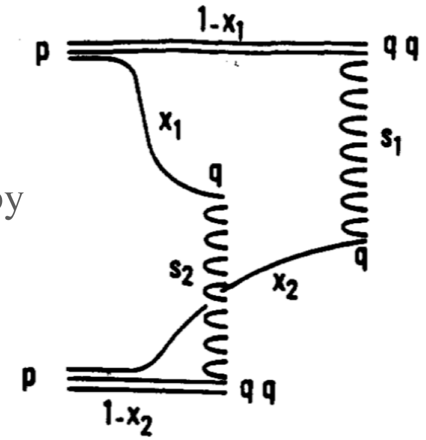

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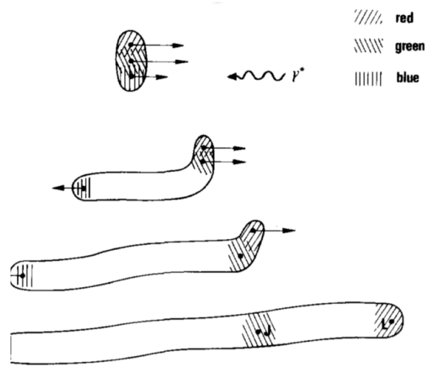

Lund model: longitudinally extended object stretched between the flying outwards wounded quarks and formed by the colour field lines gathered together due to the gluon self-interaction

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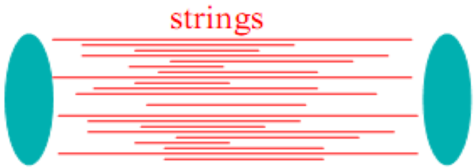
Interacting quark-gluon strings



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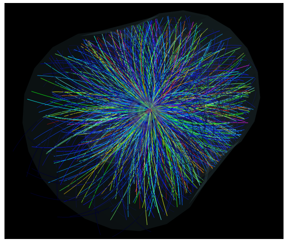

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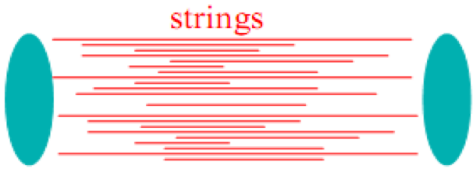
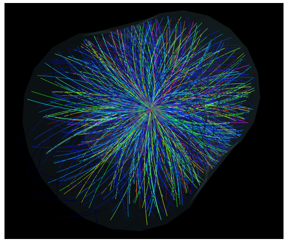
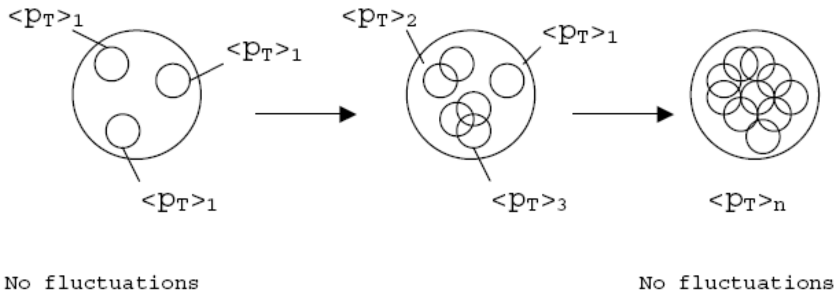




The string transverse position fluctuations changes the type of particle emitting sources

[Pajares, C. *Eur. Phys. J. C* **43**, 9–14 (2005)]



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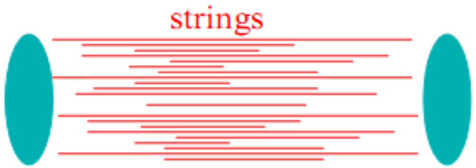

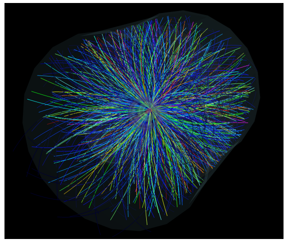

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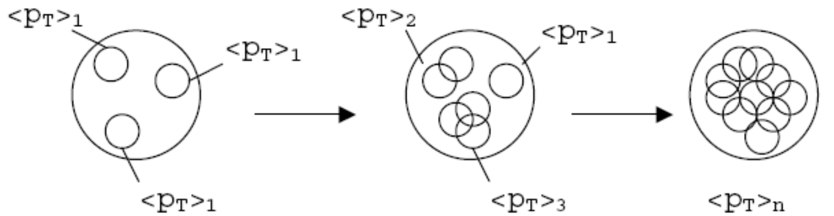
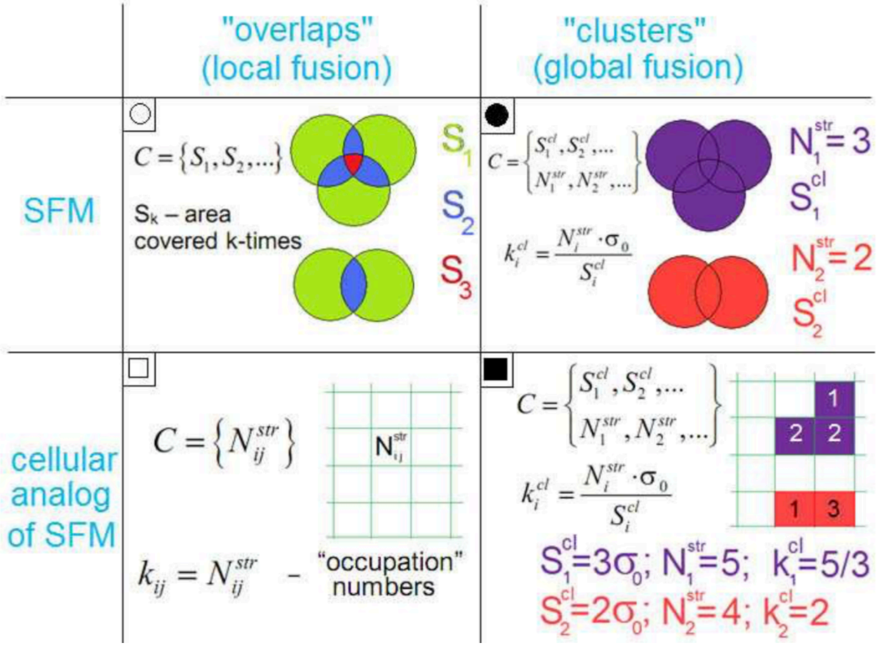


No fluctuations **2D picture** No fluctuations

Simplification of the transverse picture

[V. Vechernin, I. Lakomov PoS(Baldin ISHEPP XXI)072 (2012)]



String fusion modifies the color field density

[Braun, M. A., Kolevatov, R. S., Pajares, C. Vechernin, V. V. EPJ C, **32**, 535–546 (2004)]

This affects the mean multiplicity by the string and the mean transverse momentum of produced particles

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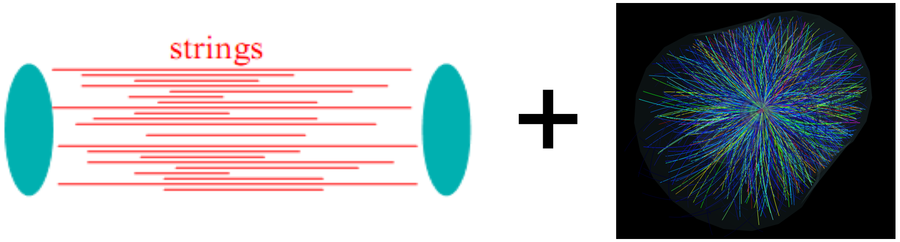

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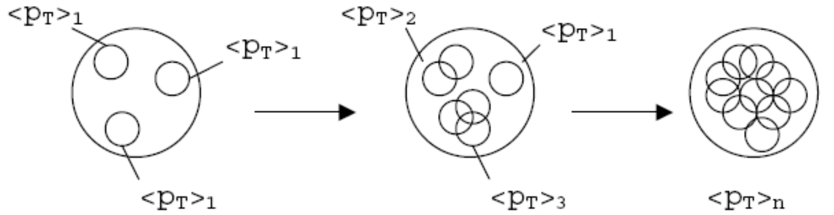

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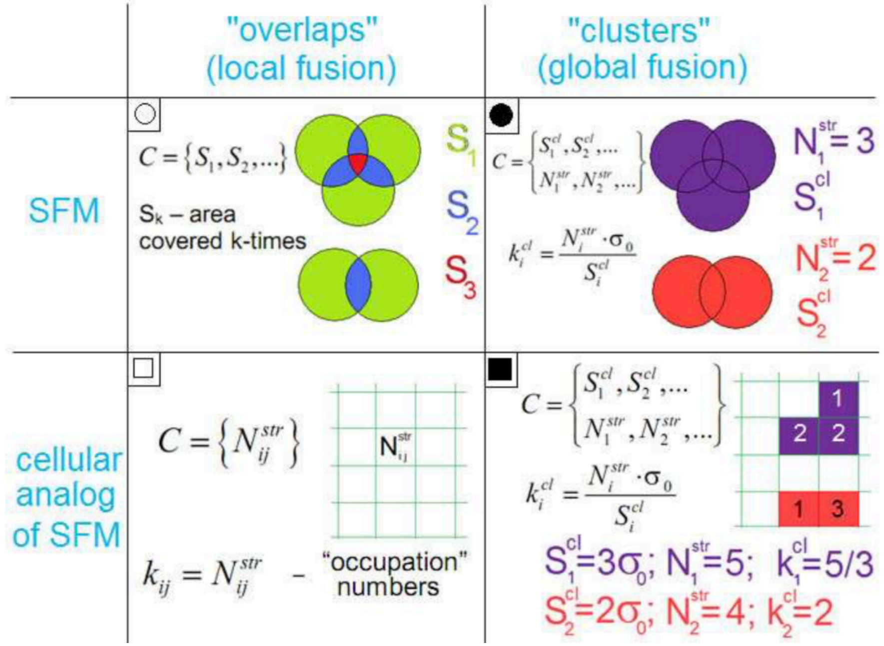

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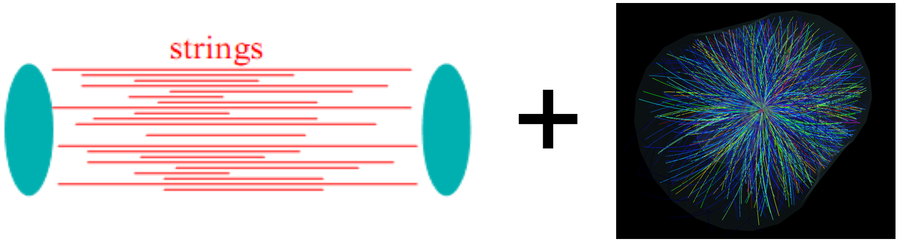

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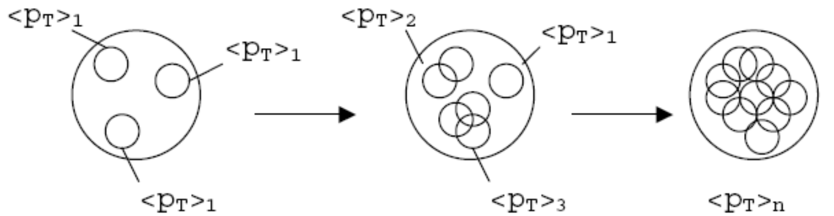

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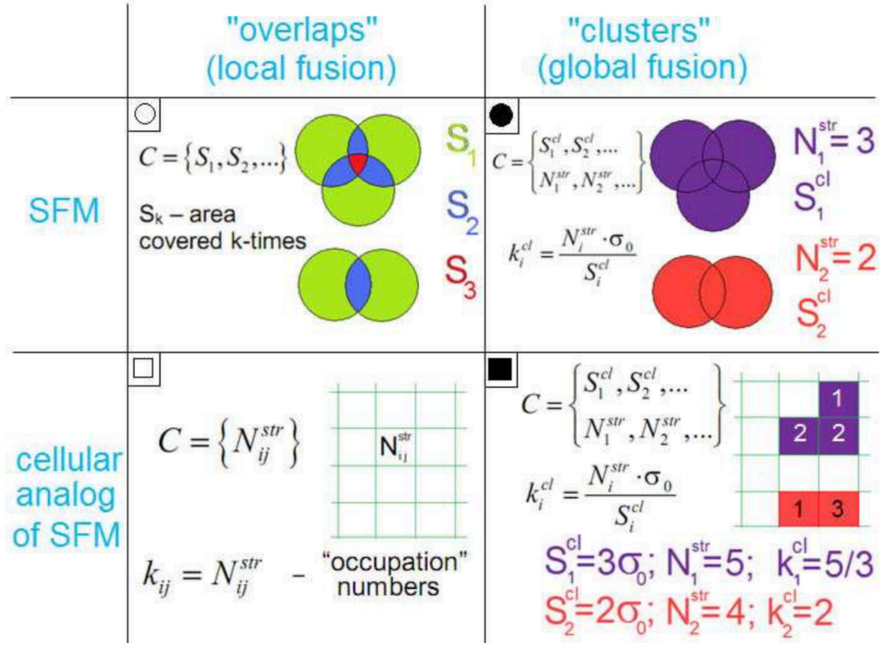

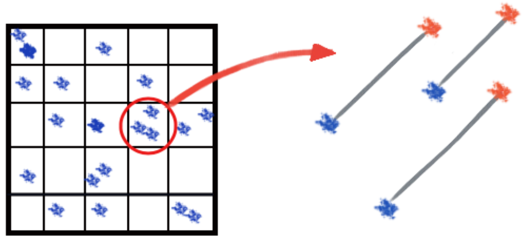

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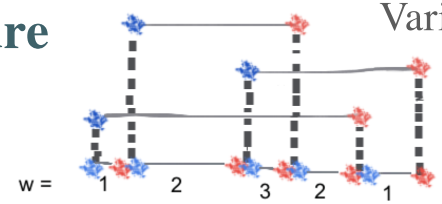
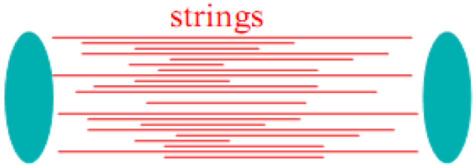
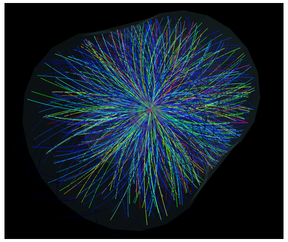


Variations in the string length and locations introduces the additional fluctuations

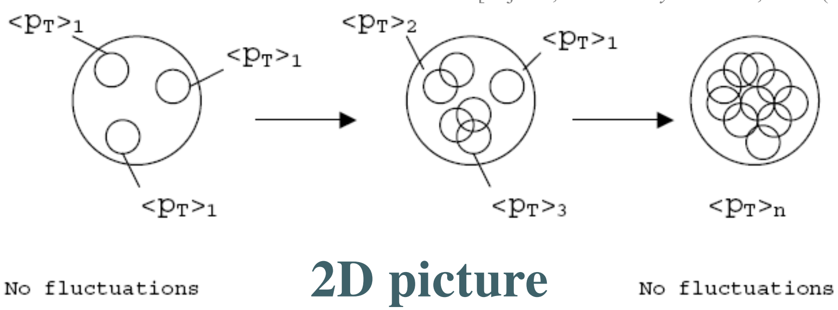


+



The string transverse position fluctuations changes the type of particle emitting sources

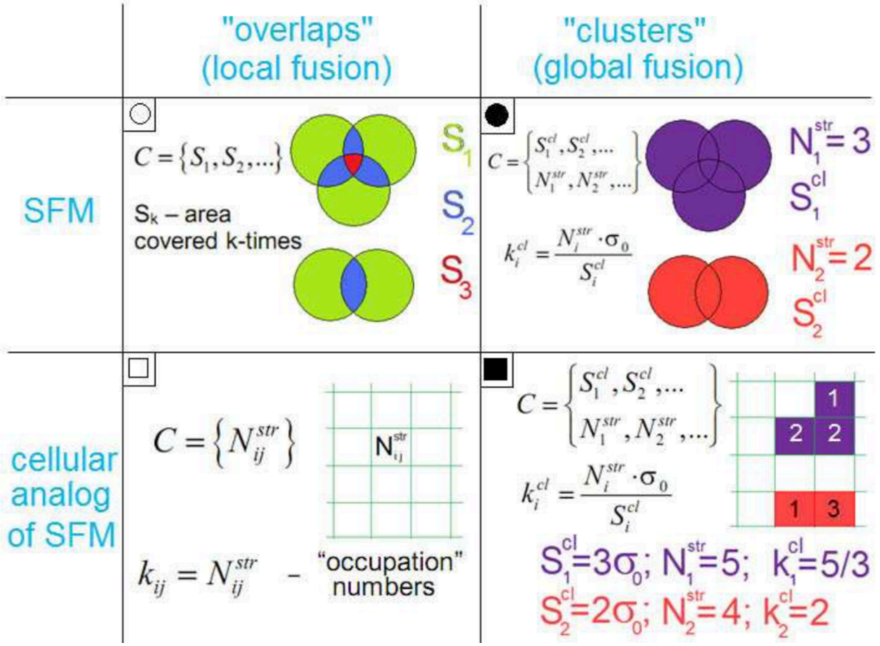
[Pajares, C. *Eur. Phys. J. C* **43**, 9–14 (2005)]

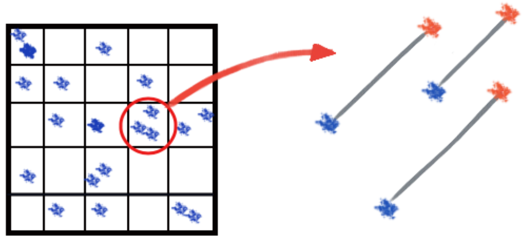


2D picture

Simplification of the transverse picture

[V. Vechernin, I. Lakomov PoS(Baldin ISHEPP XXI)072 (2012)]





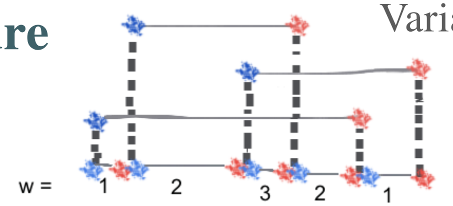
$$\langle\mu\rangle_k = \mu_0\sqrt{k}$$
$$\langle p_T^2\rangle_k = p_0^2\sqrt{k},$$

String fusion modifies the color field density

[Braun, M. A., Kolevatov, R. S., Pajares, C. Vechernin, V. V. EPJ C, **32**, 535–546 (2004)]

This affects the mean multiplicity by the string and the mean transverse momentum of produced particles

3D picture



Variations in the string length and locations introduces the additional fluctuations

Can check commonly used measures for robustness!

Fluctuations study

Strongly intensive quantities - independent both of the volume and its event-by-event fluctuations for the Ideal Boltsman gas in Grand Canonical Ensemble

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Strongly intensive quantities - independent both of the volume and its event-by-event fluctuations for the Ideal Boltsman gas in Grand Canonical Ensemble

[M. I. Gorenstein and M. Gaździcki, Physical Review C **84**, 014904 (2011)]

$$\Delta[A, B] = \frac{1}{C_\Delta}\left[\langle B\rangle\omega[A] - \langle A\rangle\omega[B]\right]$$

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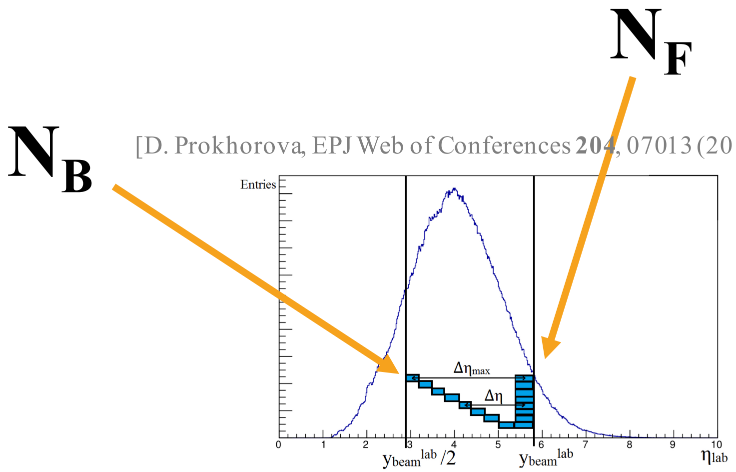
[D. Prokhorova, EPJ Web of Conferences **204**, 07013 (2019)]



In two kinematically separated regions:

$$\Sigma[\mathrm{N_F},\mathrm{N_B}] = \frac{1}{\mathrm{C}_\Sigma}\left[\langle \mathrm{N_B}\rangle\omega[\mathrm{N_F}] + \langle \mathrm{N_F}\rangle\omega[\mathrm{N_B}] - 2\cdot(\langle \mathrm{N_F}\cdot \mathrm{N_B}\rangle - \langle \mathrm{N_F}\rangle\langle \mathrm{N_B}\rangle)\right]$$

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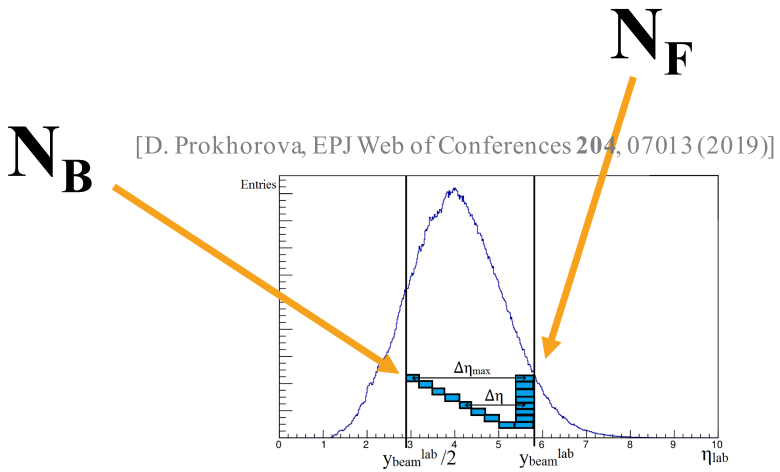

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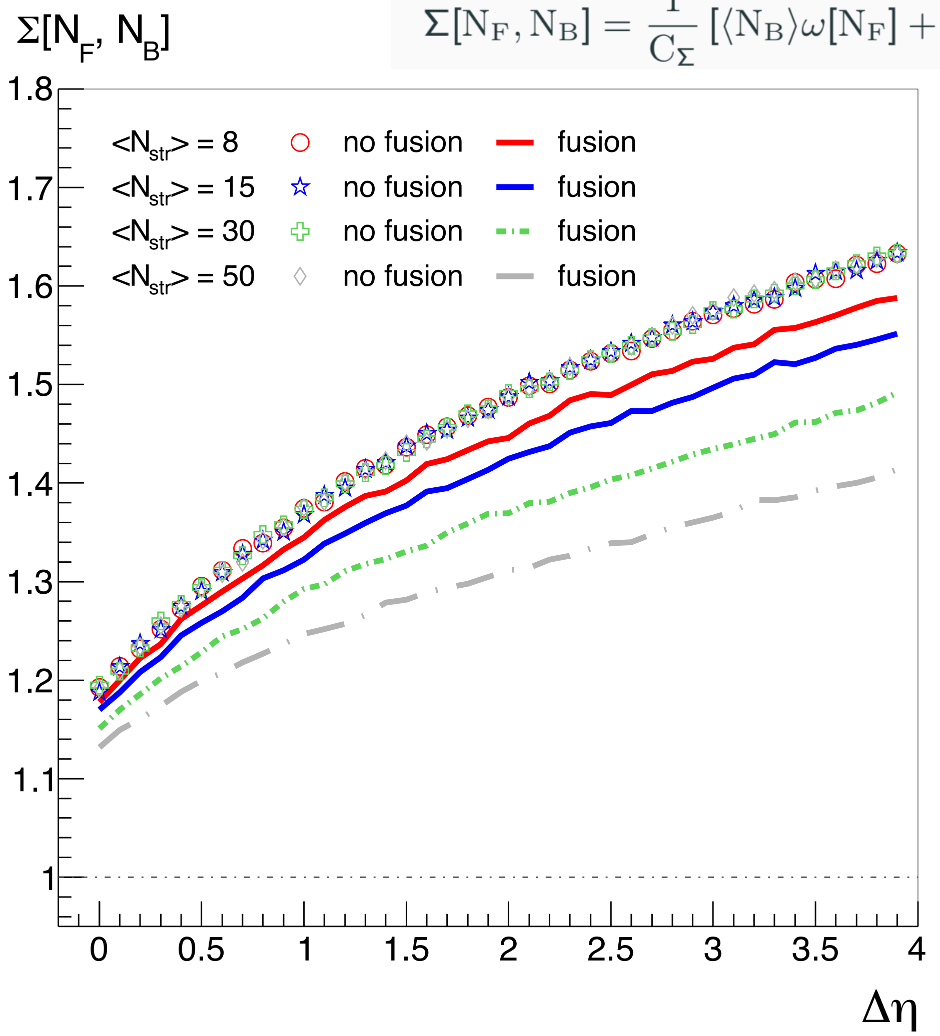
[E. V. Andronov, Theoretical and Mathematical Physics **185**, 1383 (2015)]

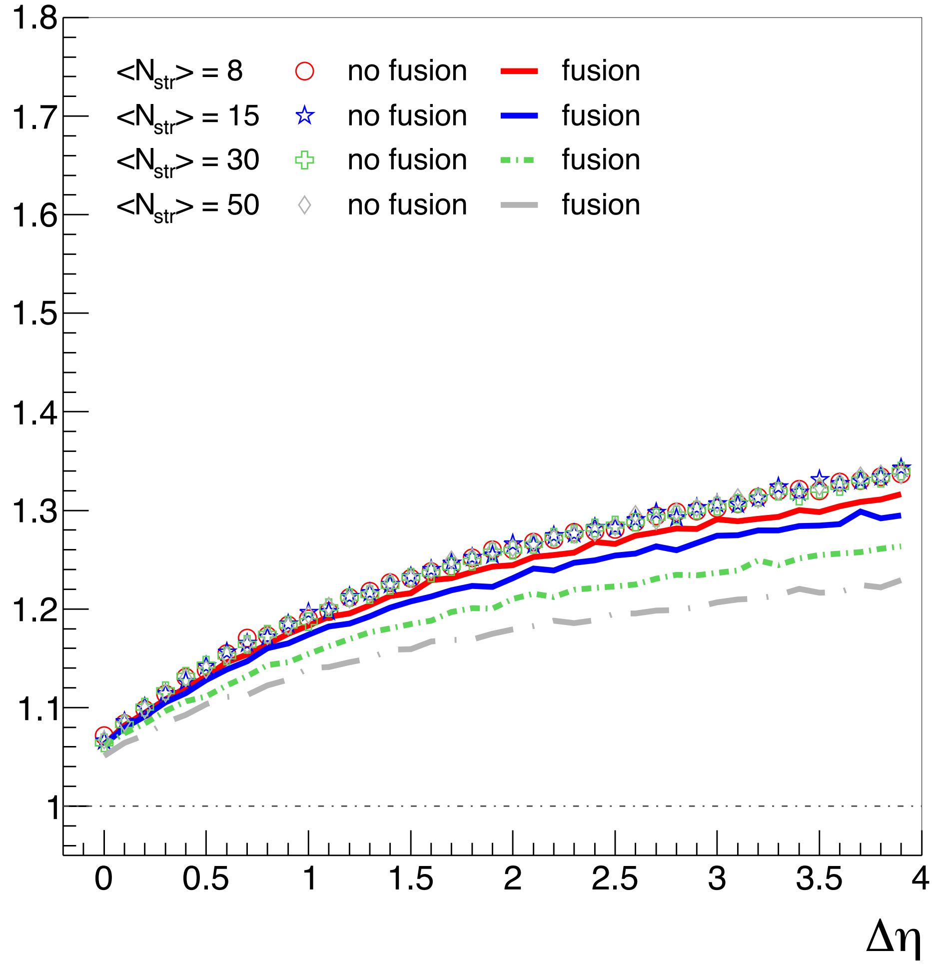
Interesting to have a look, because **in the model of interacting strings strongly intensive measures become dependent on the particle production sources composition** → one can probe by this study the physics of initial sources and type of their interaction

[E. Andronov and V. Vechernin, The European Physical Journal A **55**, 14 (2019)]

MC model results

$$\Sigma[\mathrm{N_F}, \mathrm{N_B}] = \frac{1}{\mathrm{C}_\Sigma}\left[\langle \mathrm{N_B}\rangle \omega[\mathrm{N_F}] + \langle \mathrm{N_F}\rangle \omega[\mathrm{N_B}] - 2\cdot(\langle \mathrm{N_F}\cdot \mathrm{N_B}\rangle - \langle \mathrm{N_F}\rangle\langle \mathrm{N_B}\rangle)\right]$$





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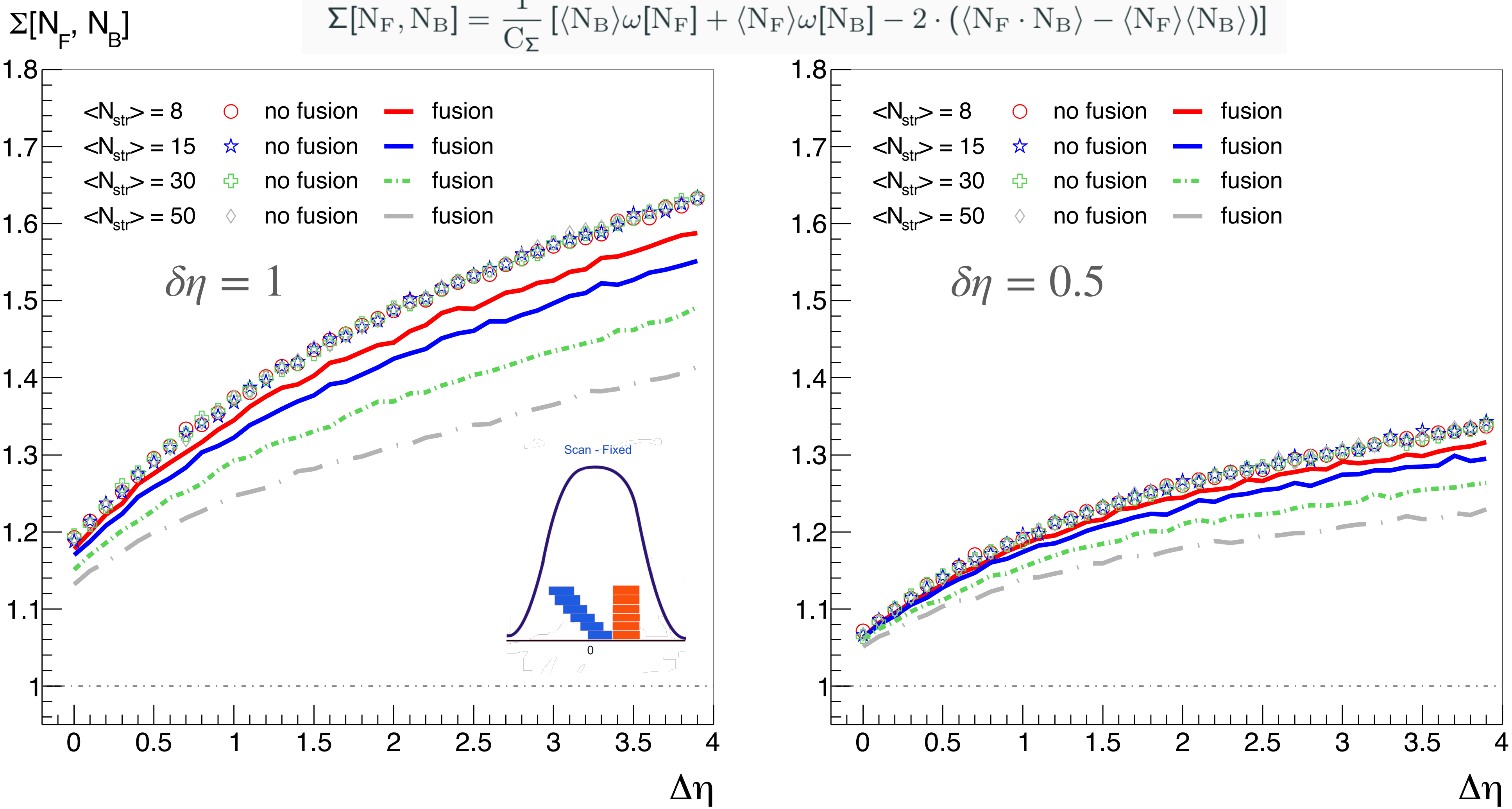

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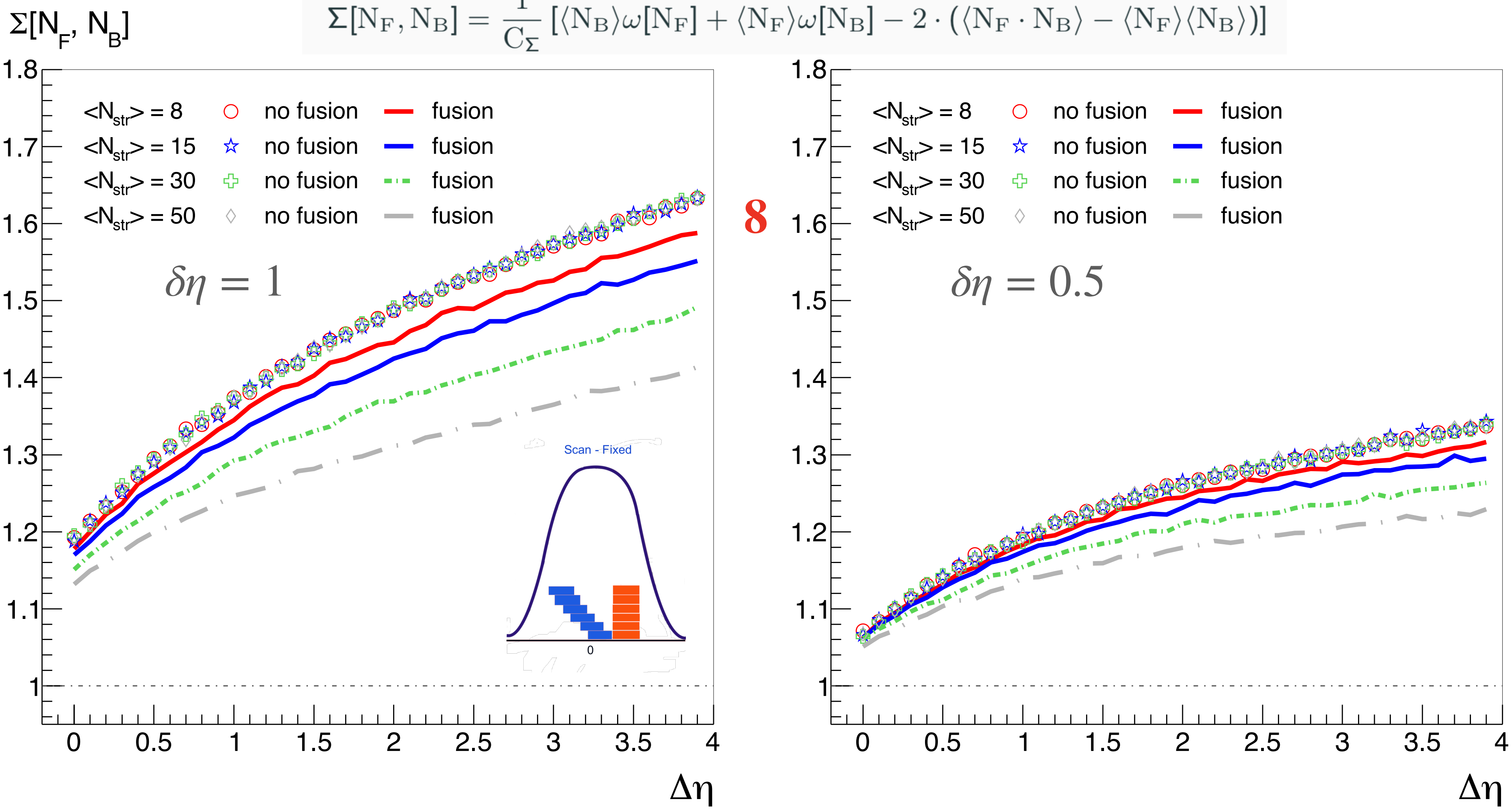

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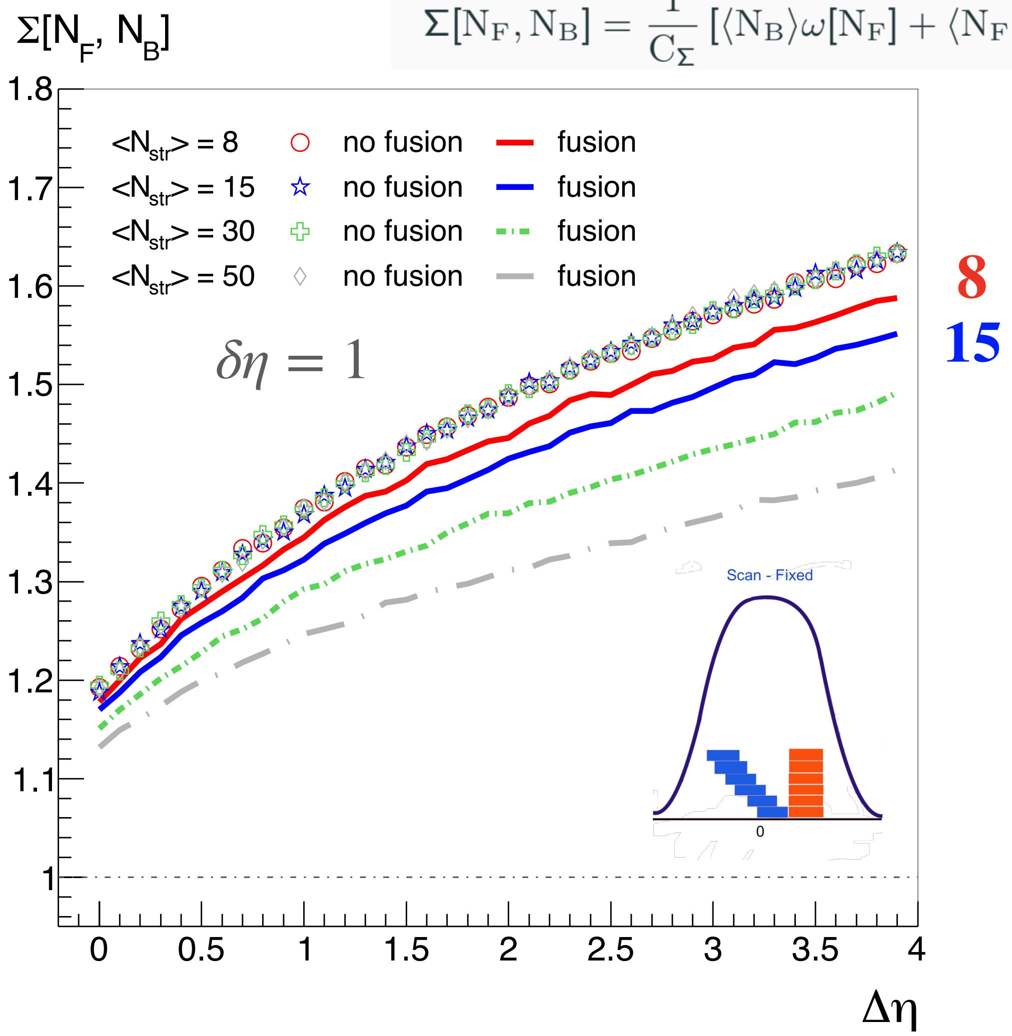

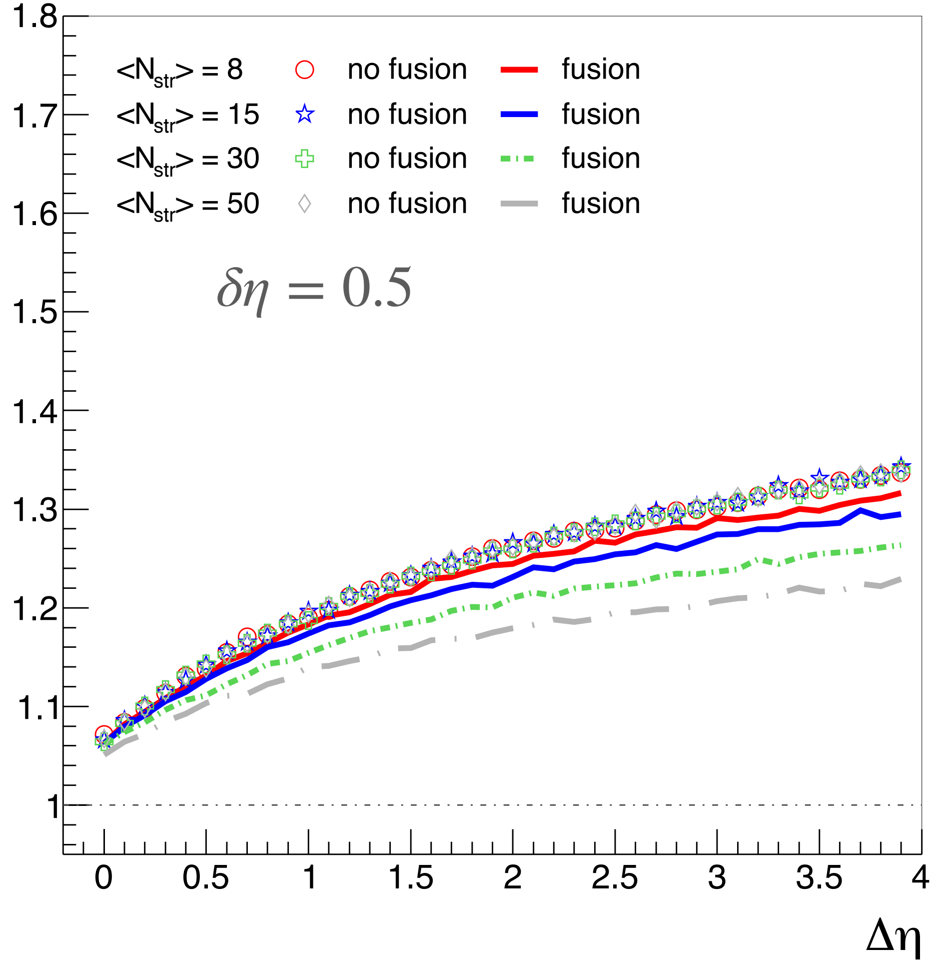

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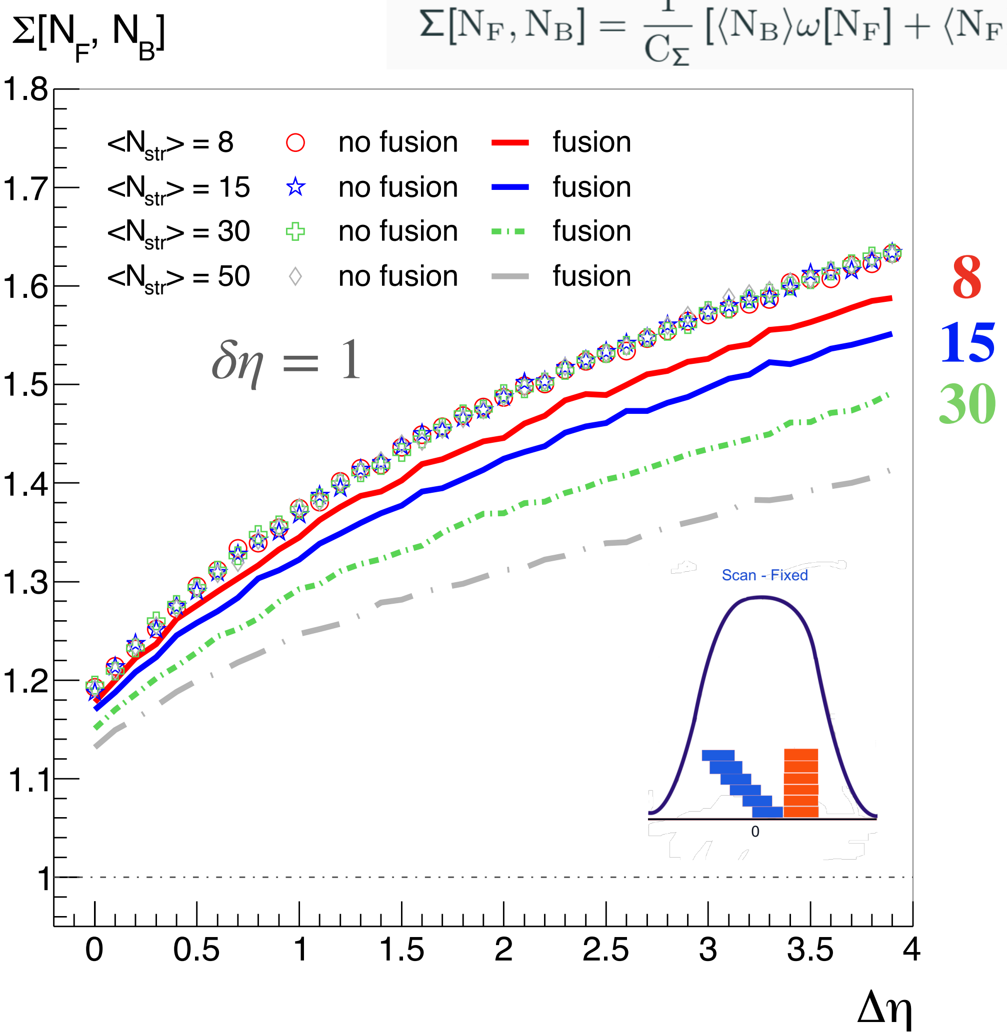

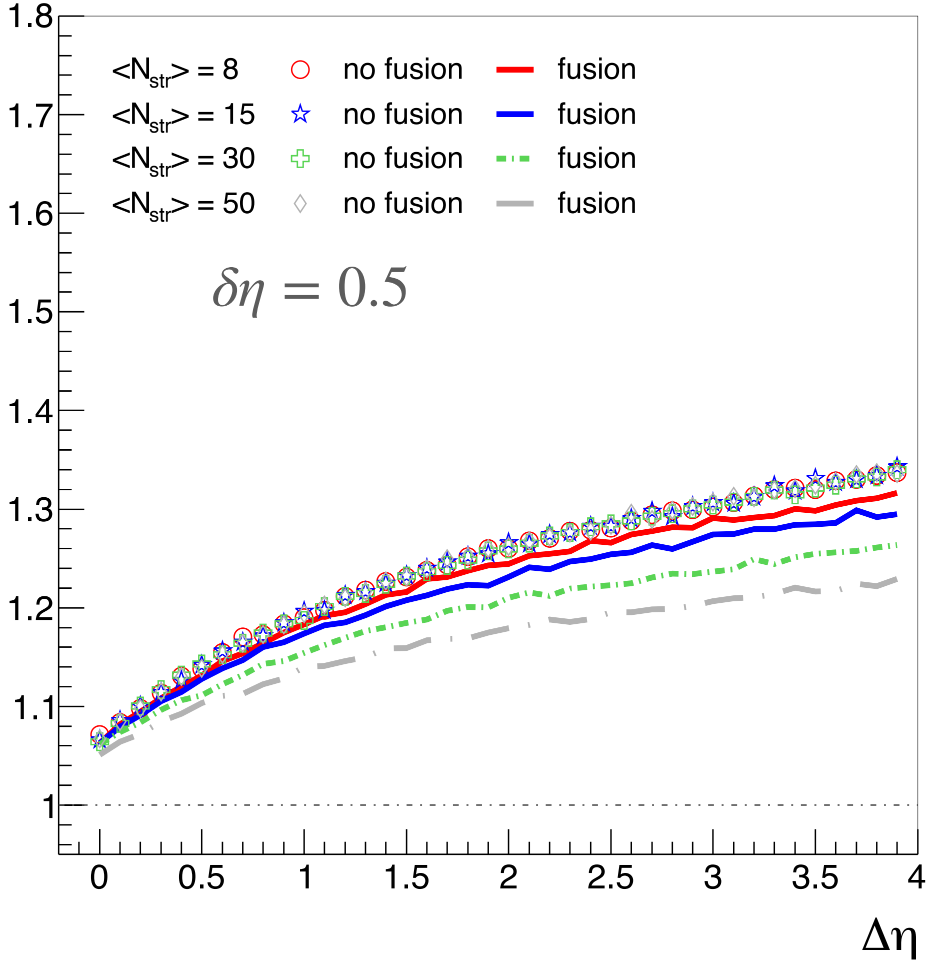

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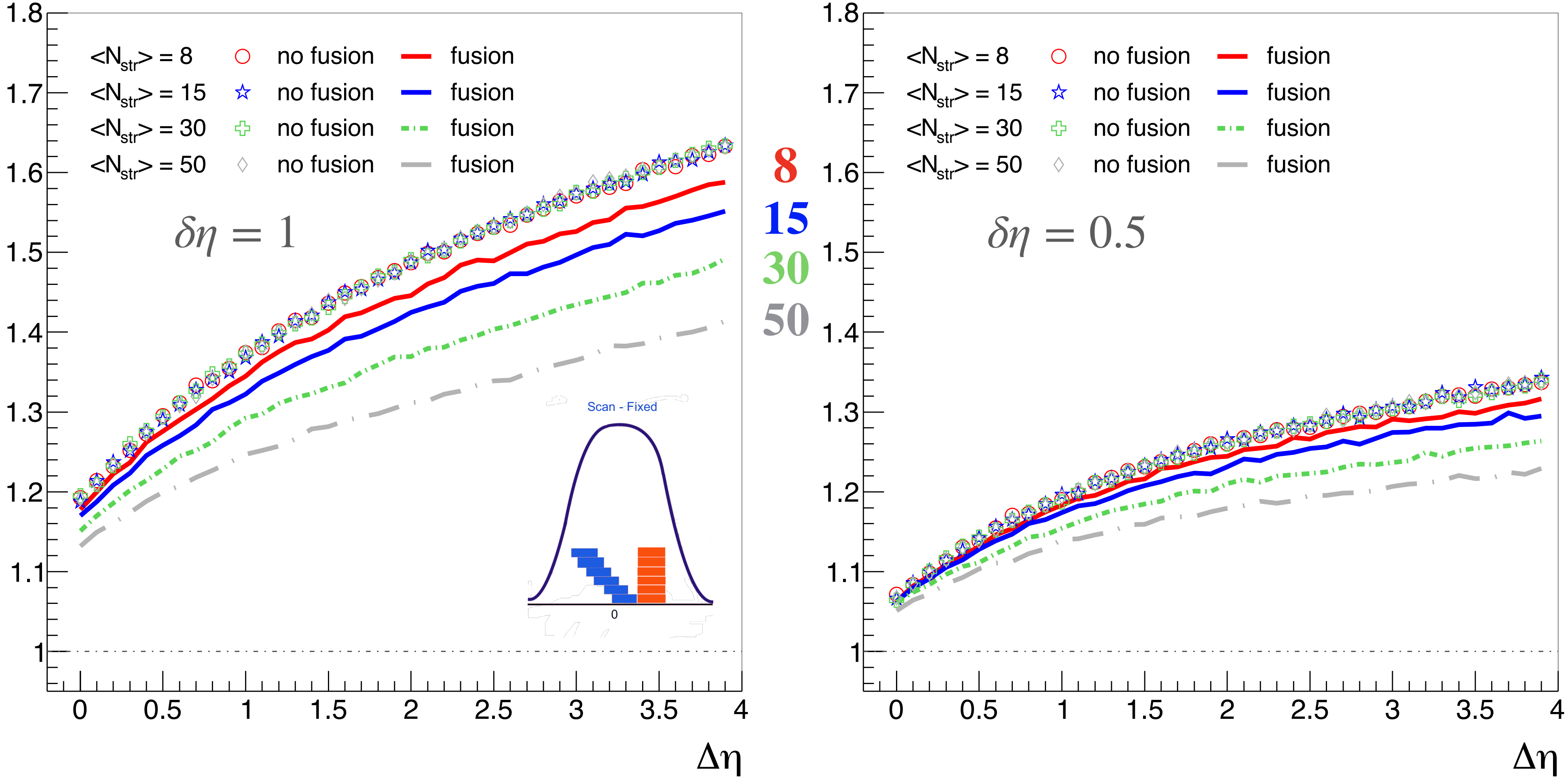

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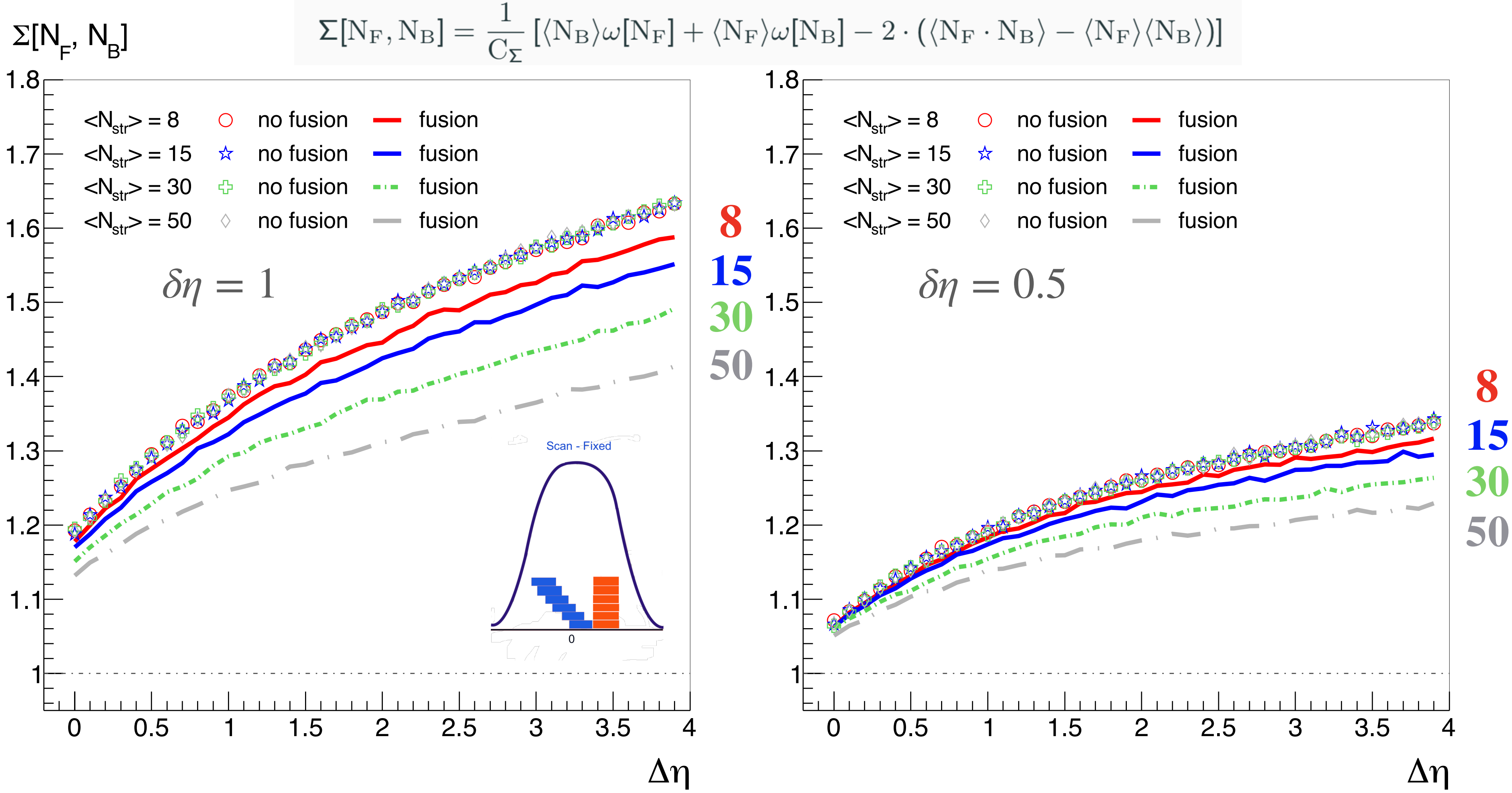

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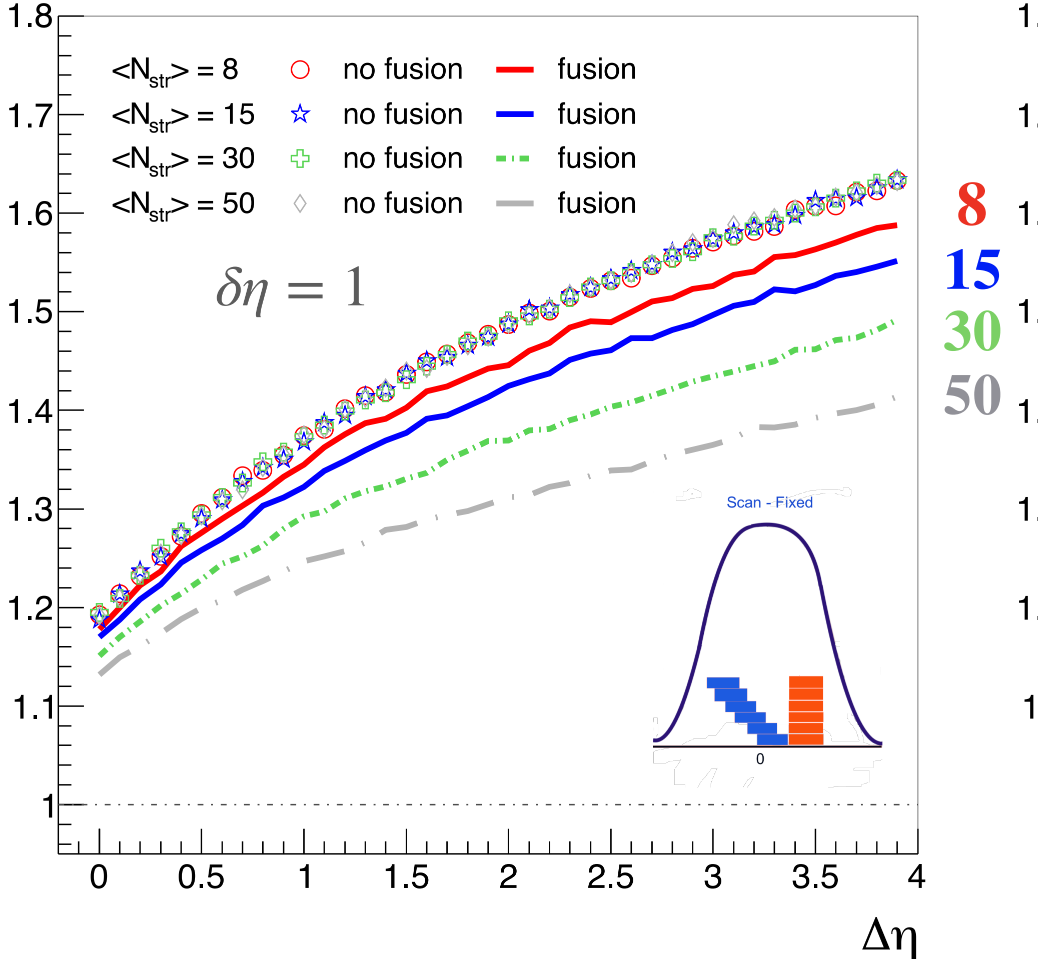

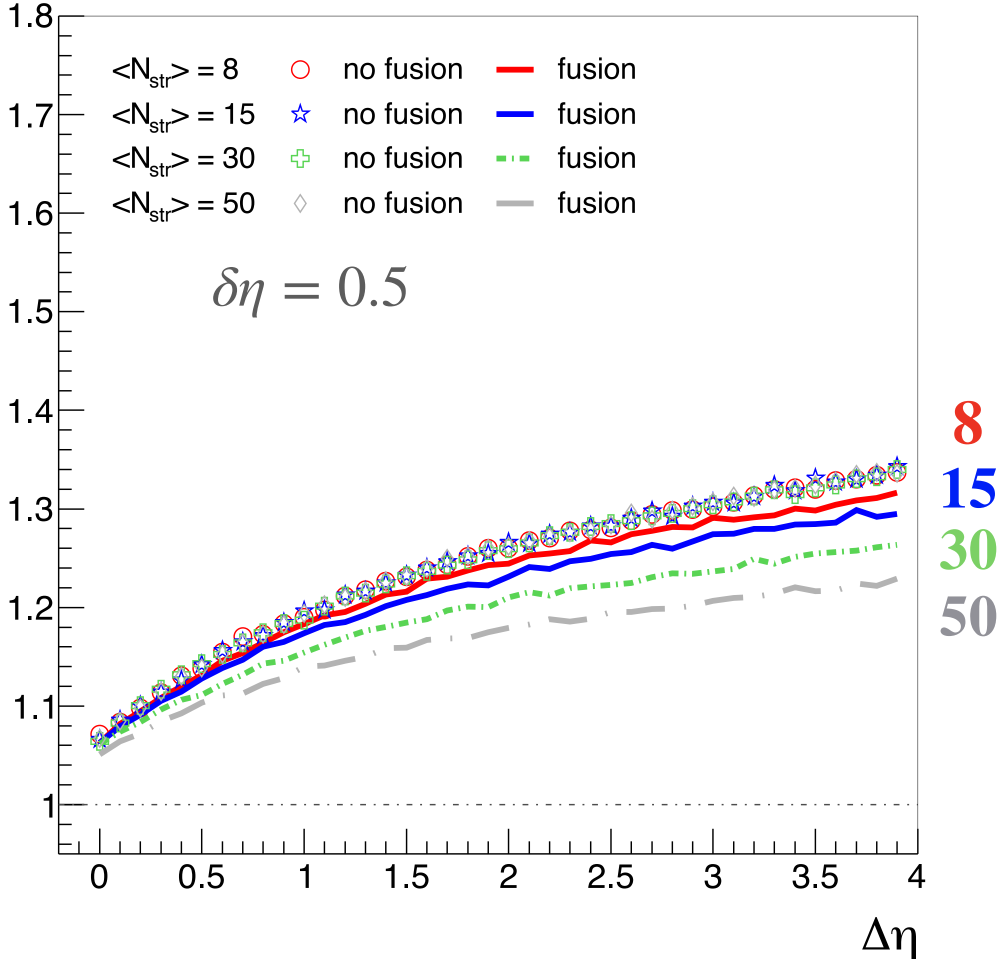

$\Sigma[N_F, N_B]$: grows with $\Delta\eta$

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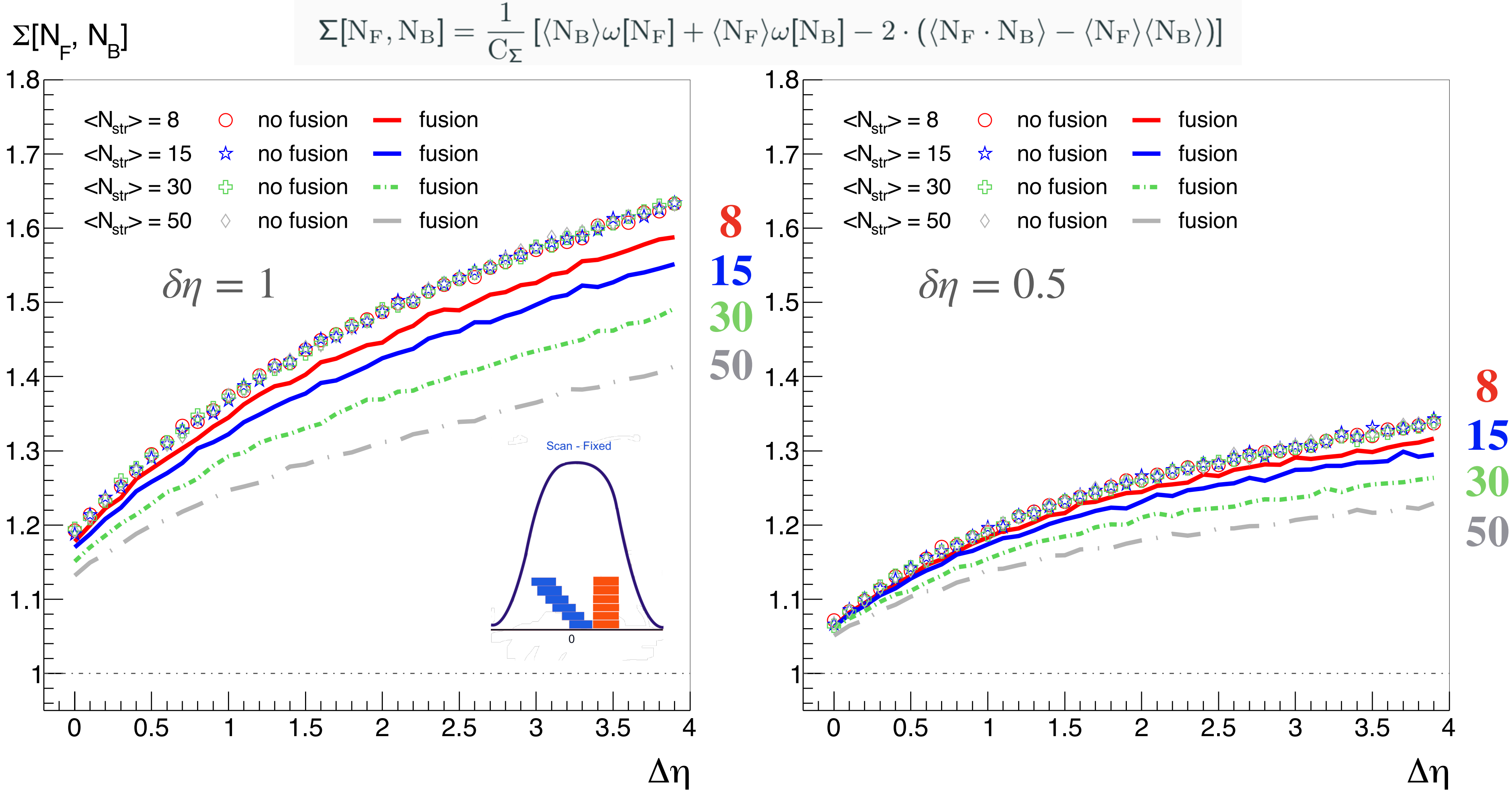

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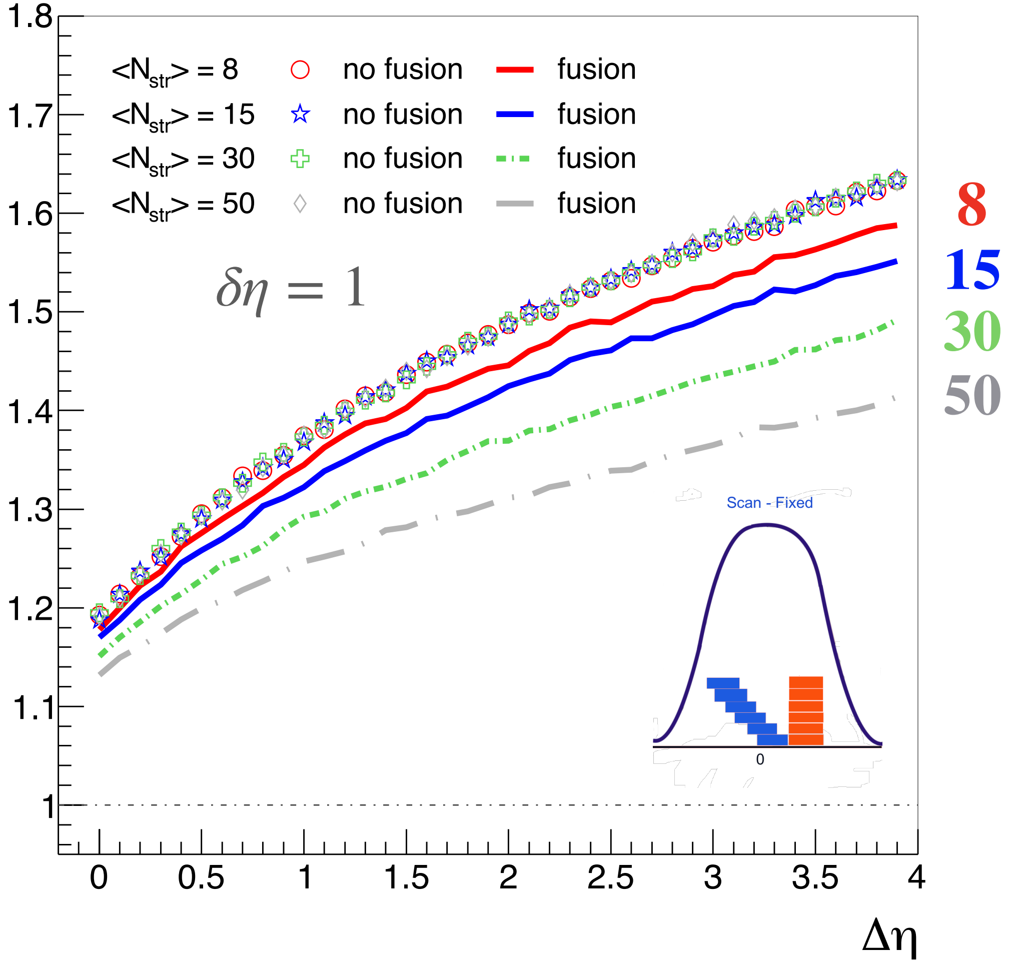
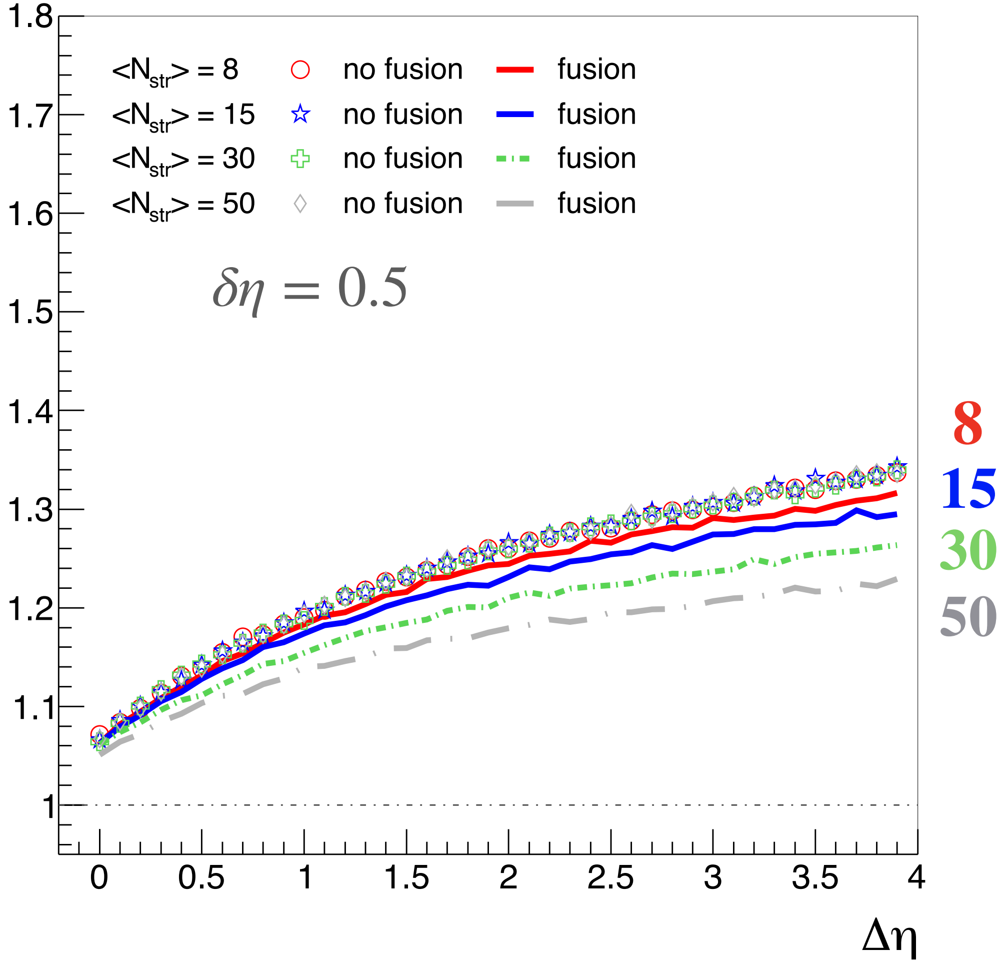




$\Sigma[N_F, N_B]$: grows with $\Delta\eta$

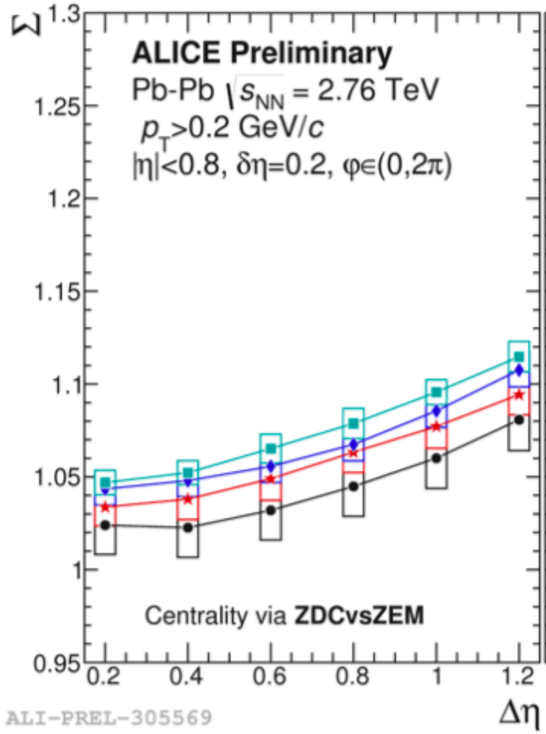
strongly **intensive** for the **independent** strings, **but**

decreases with the string density - is sensitive to the type of particle sources

ALICE 2.76 TeV results

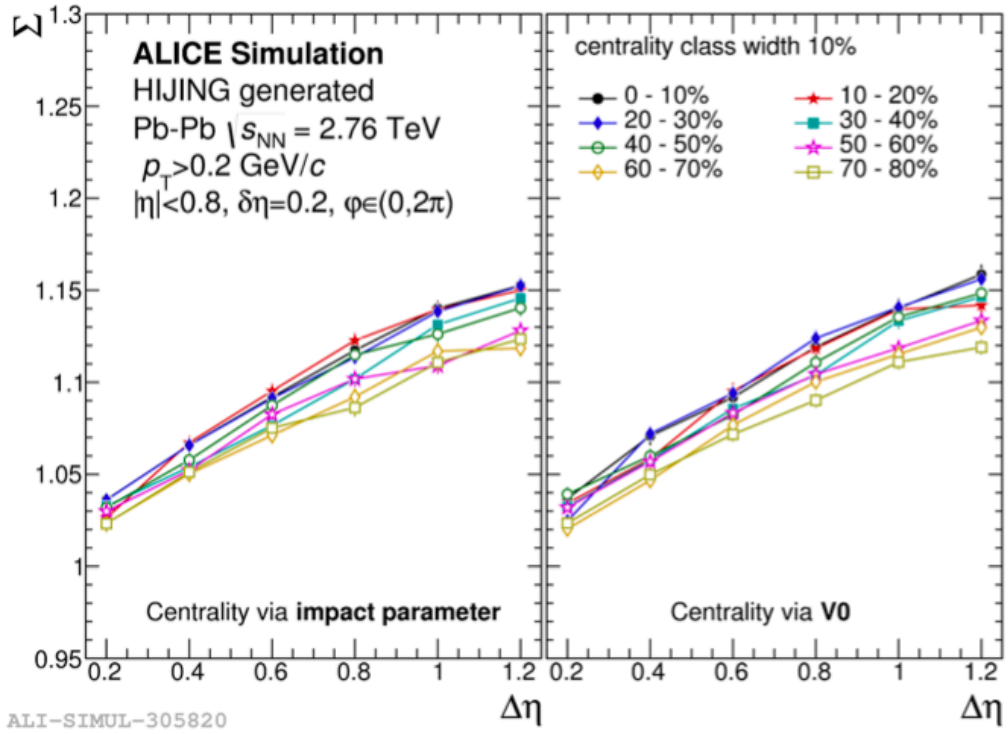
Centrality estimator: spectators in ZDC

Centrality estimator: charged particles in V0



Centrality determined using impact parameter

Centrality estimator: charged particles in V0



[presented at Hot Quarks 2018 by Iwona Sputowska for the ALICE Collaboration]

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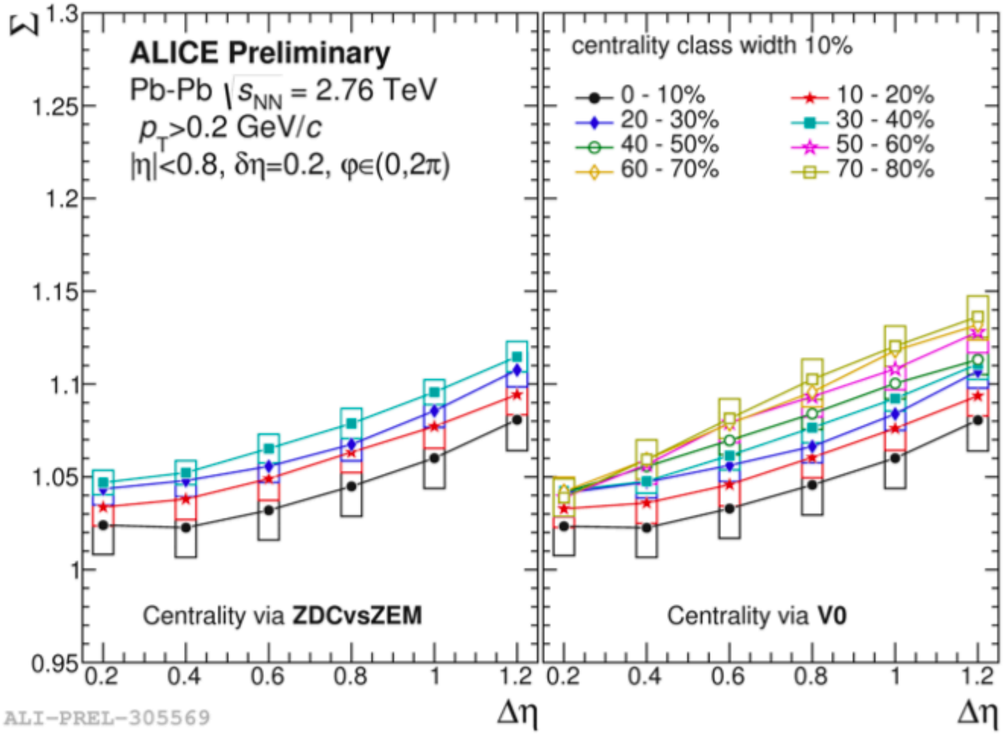

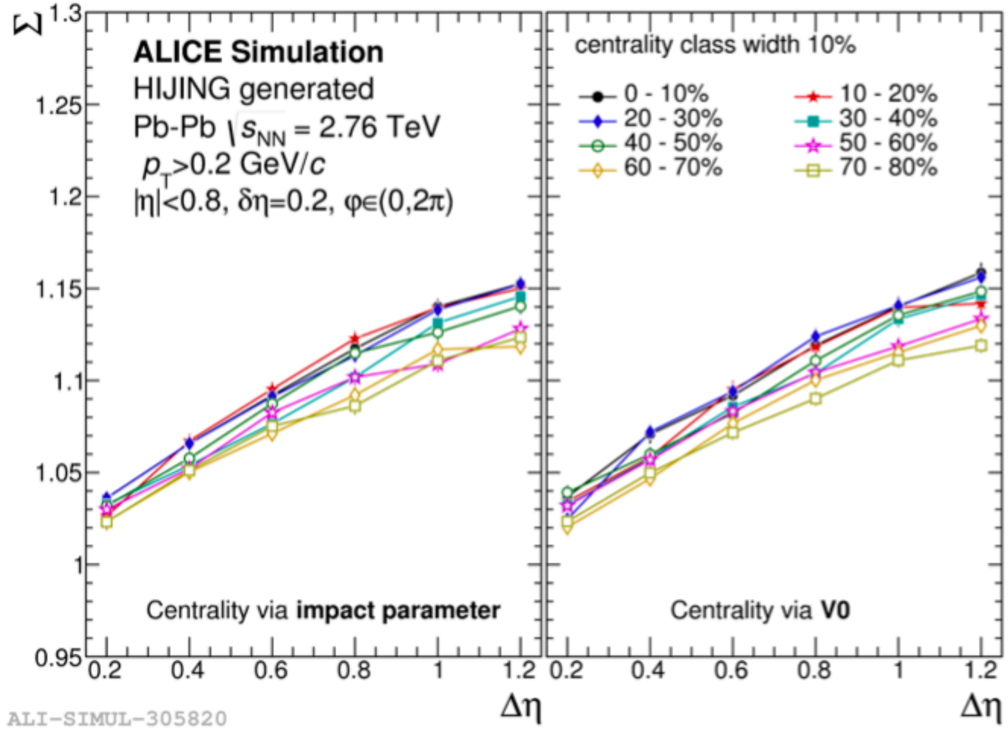

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decreases with the centrality in data

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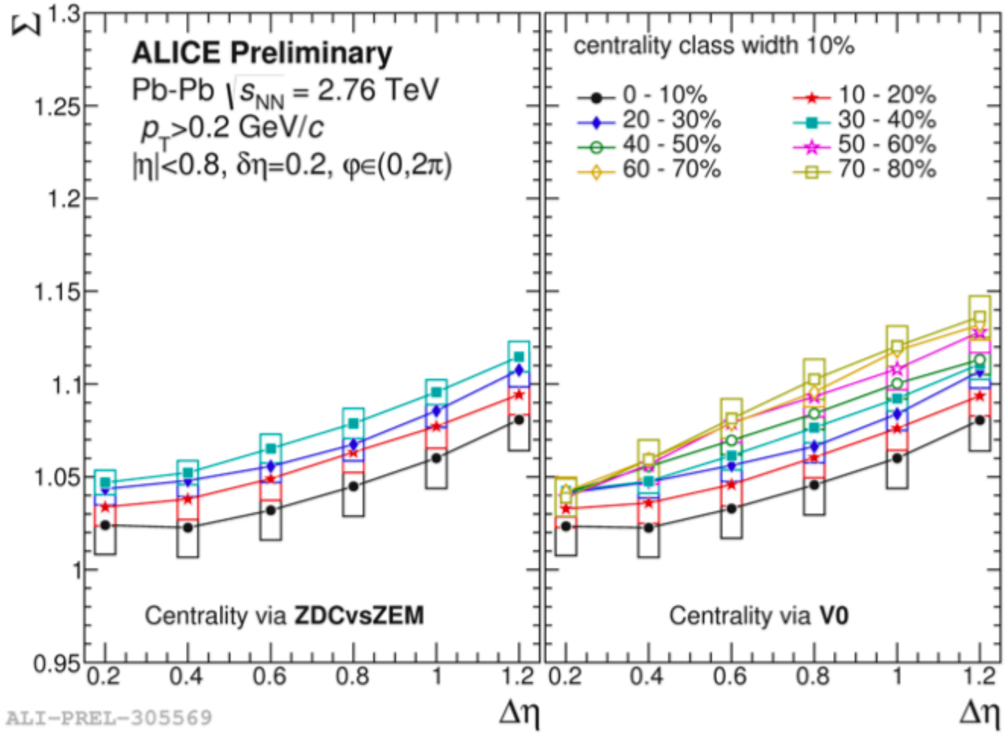

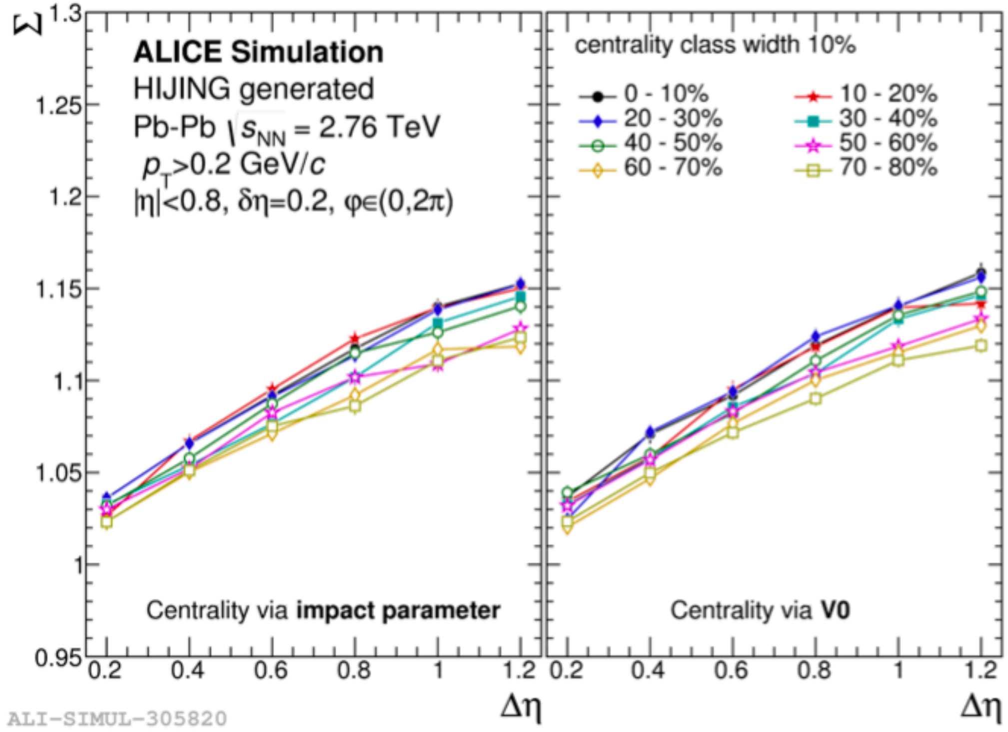

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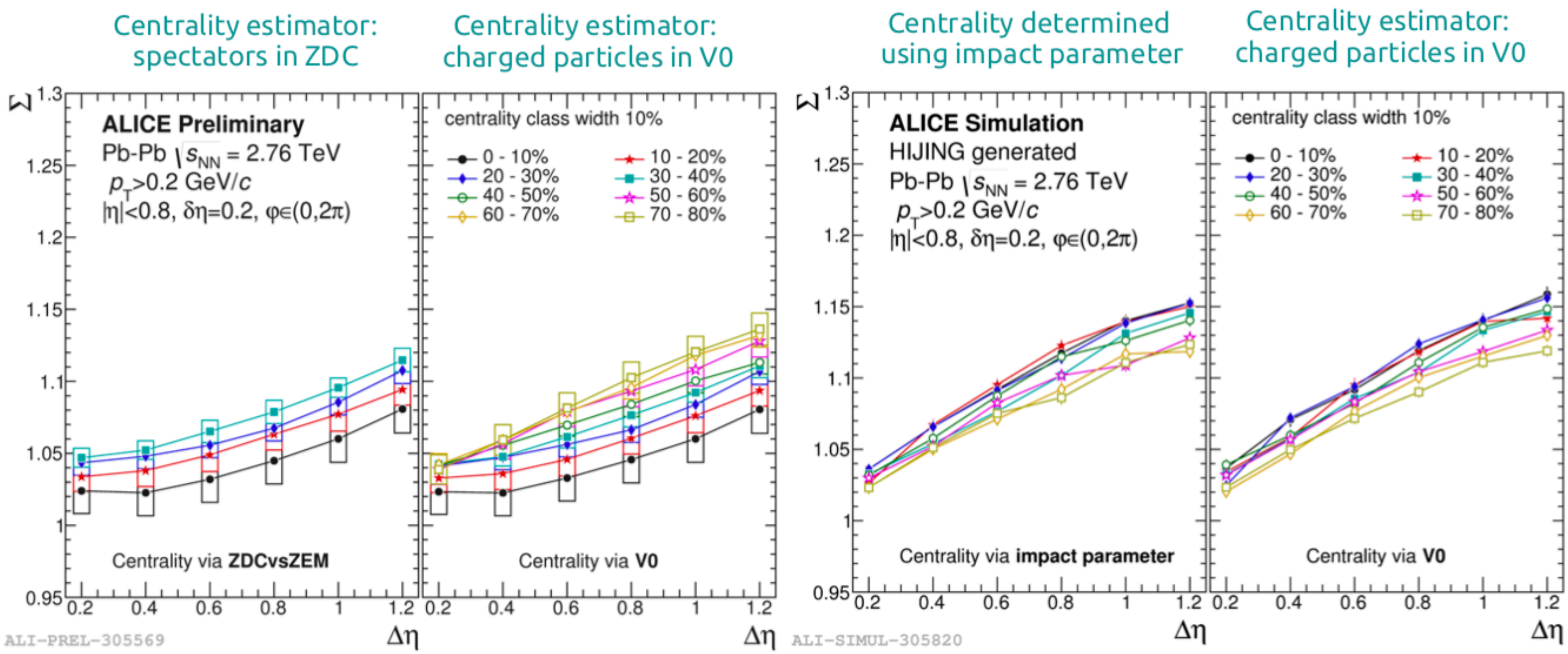

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the opposite behavior with centrality in HIJING

In qualitative agreement with string fusion model

FUTURE PLANS

- STUDY N-PT CORRELATIONS AND FLUCTUATIONS
- STUDY NET-BARYON CUMULANTS
- INTRODUCE EXPLICIT ENERGY DEPENDENCE OF STRING NUMBERS

This work is supported by the Russian Foundation for Basic Research, project 18-32-01055_mol_a

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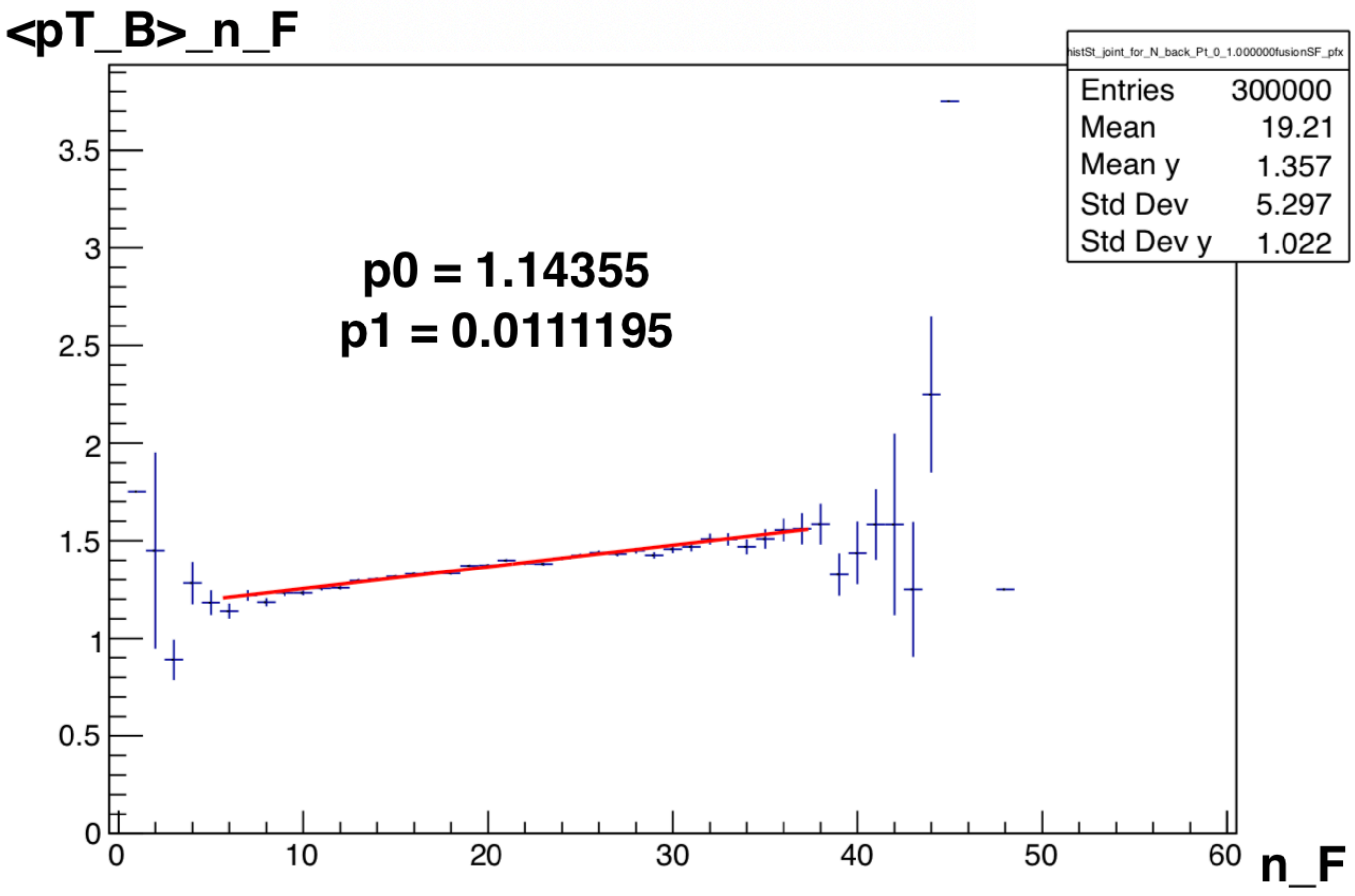
Thank you for your attention!

BACK UP

Correlations coefficient

$$b_{p_t - n} = \frac{< n_F >}{< p_{tB} >} \cdot \frac{d < p_{tB} >}{dn_F}|_{n_F = < n_F >}$$



Correlations coefficient

$$B \equiv \overline{p_{\mathrm{T}}}_B = \frac{\sum_{i=1}^{n_B} p_{\mathrm{T}}^{(i)}}{n_B} \qquad F \equiv \overline{p_{\mathrm{T}}}_F = \frac{\sum_{j=1}^{n_F} p_{\mathrm{T}}^{(j)}}{n_F}$$