E-BY-E FLUCTUATIONS OF INITIAL CONDITIONS IN INTERACTIONS OF LIGHT, INTERMEDIATE AND HEAVY NUCLEI AT ENERGIES 4 – 200 GEV AT NUCLEON

A.A. Loktionov, A.Kh. Argynova, T.N. Kvochkina

Institute of Physics and Technology, Almaty, Kazakhstan

Institute of Nuclear Physics , Almaty, Kazakhstan

loction@sci.kz

Dynamics of multiparticle production

INTRODUCTION

Better understanding the fluctuating structure in the initial conditions of nuclear interactions is one of the most important heavy ion physics problems. Our primary goal is to reveal initial fluctuations based on the results of experimental measurements with minimal involvement of additional information.

In order to study an additional (for system size) system structure problems we have estimated the evolution of experimental fluctuation patterns in two directions:

- **In interactions of different nuclei at a given level of centrality, - "on vertically",**
- **In interactions of the same nuclei as a function of centrality, - "on horizontally".**

In the present report these problems are studied in the centrality selected interactions:
l-l - (C, O, Ne) + (C/N/O), m-l - (Si, S) + (C/N/O) and h-h - (Au, Pb) + (Ag/Br),
on the data of JINR-AGS-SPS target emulsion experiments.
The analyses have performed in variables of FULL multiplicity and pseudorapidity.

Independent and accurate measurement in each event FULL charged multiplicity and SUM OF ALL fast charged fragment-spectators: proton-spectators, alpha-particle-spectators and heavy mass fragment-spectators opens the way for effective estimation of the E-BY-E FLUCTUATIONS OF MULTIPLICITY. The study in each event the third and fourth statistical moments of FULL pseudorapidity distribution gives us a clear picture of E-BY-E FLUCTUATIONS FOR THE LONGITUDINAL EVENT SHAPE.

EXPERIMENTAL VARIABLES

In order to research the processes of multiparticle dynamics only events with high multiplicities were accepted:

$$Ns > 1/3\ (Ns)_{max}$$

The basic variables of the analyses are:

1. The normalized multiplicity of the produced charged particles - $Ns/(Ns)_{max}$, and the normalized sum of the mass of all charged fragment-spectators: $-A_f/A_{max}$.

A_{max} corresponds to the mass of projectile nucleus.

$(Ns)_{max}$ corresponds to the maximal multiplicity in the experiment.

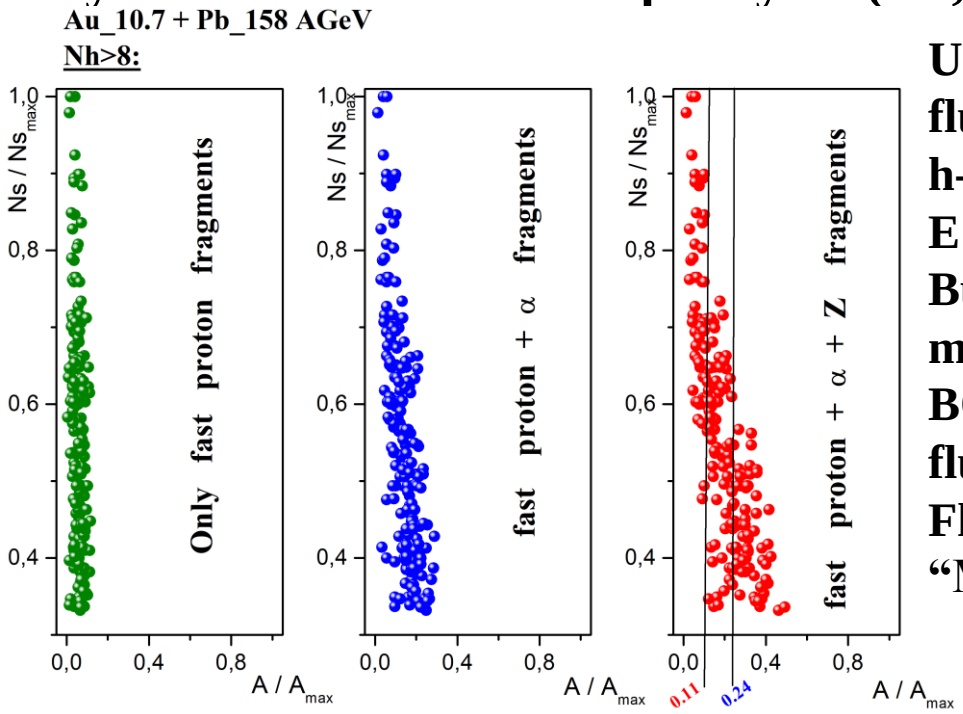
2. The third and fourth statistical moments of full pseudorapidity distribution for the study of E-by-E fluctuations for the longitudinal event shape.

(Concept of normalized variables allows to unite the results of experiments at energies from JINR to SPS with sufficient accuracy.)

(The transfer from *Z* to *A* for projectile nucleus was performed on the basis of cosmic ray data for high energy primary nuclei.)

RESULTS

E-by-E fluctuations of multiplicity in (Au, Pb) + (Ag/Br) interactions.

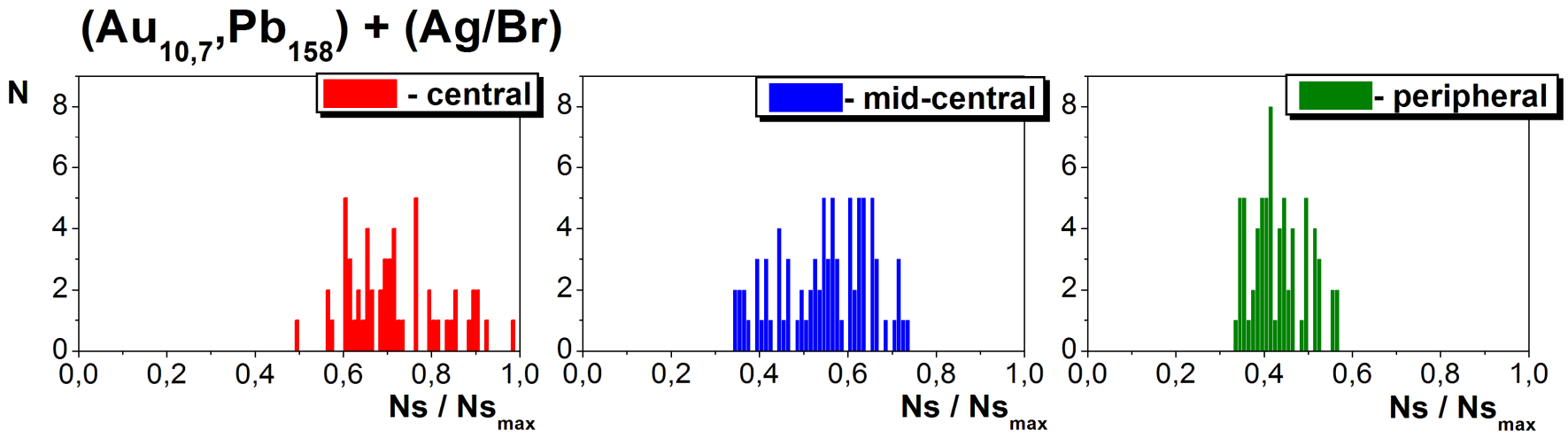


UPPER: E-by-E centrality selected fluctuations for multiplicity. Fluctuations in h-h interactions are the Weakest from E-by-E fluctuations!

But ATTENTION: the greatest multiplicities in these events .

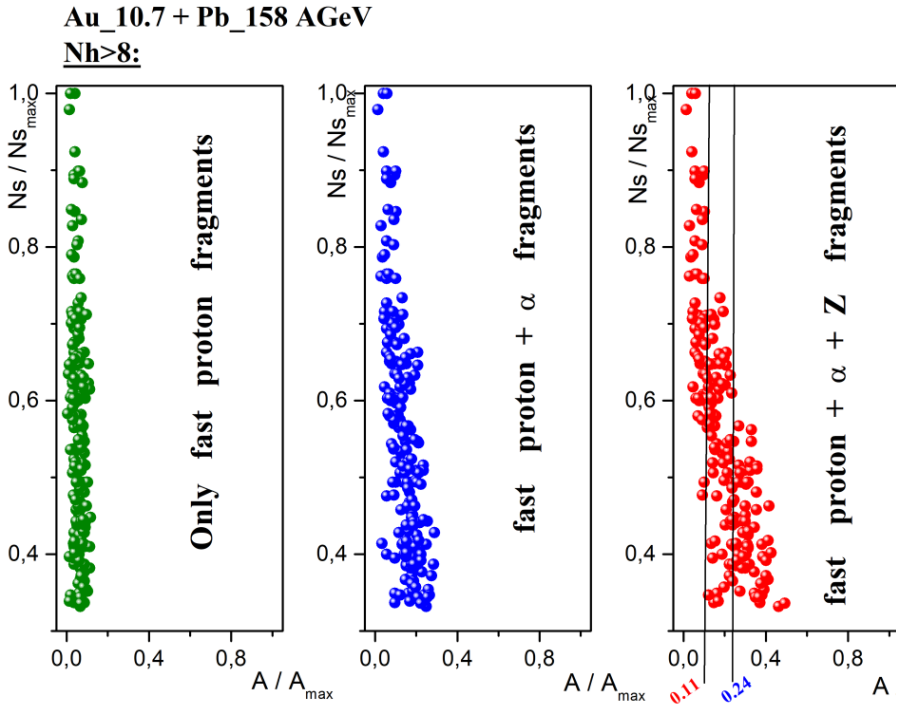
BOTTOM: Projection of E-by-E multiplicity fluctuations on *Ns/(Ns)$_{max}$*.

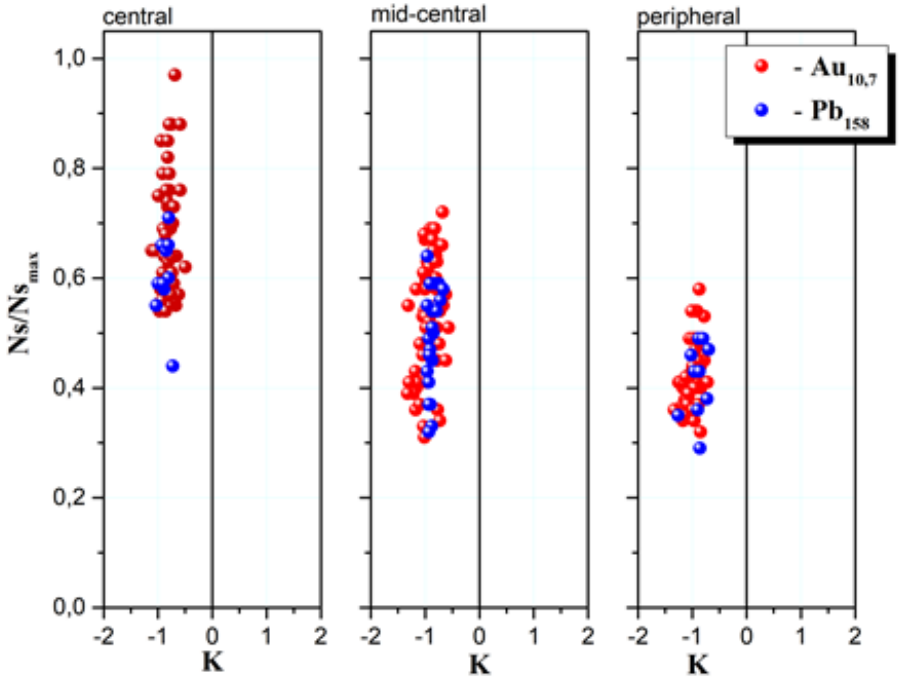
Fluctuations in "Central" are more than in "Mid-central" and in "Peripheral"!



E-by-E analysis of FOURTH statistical moment, - Kurtosis (K), for (Au, Pb) + (Ag/Br) interactions.

K measures the sharpness of the distribution relative to a Gaussian.
Negative K implies that the peak is broader than a Gaussian.



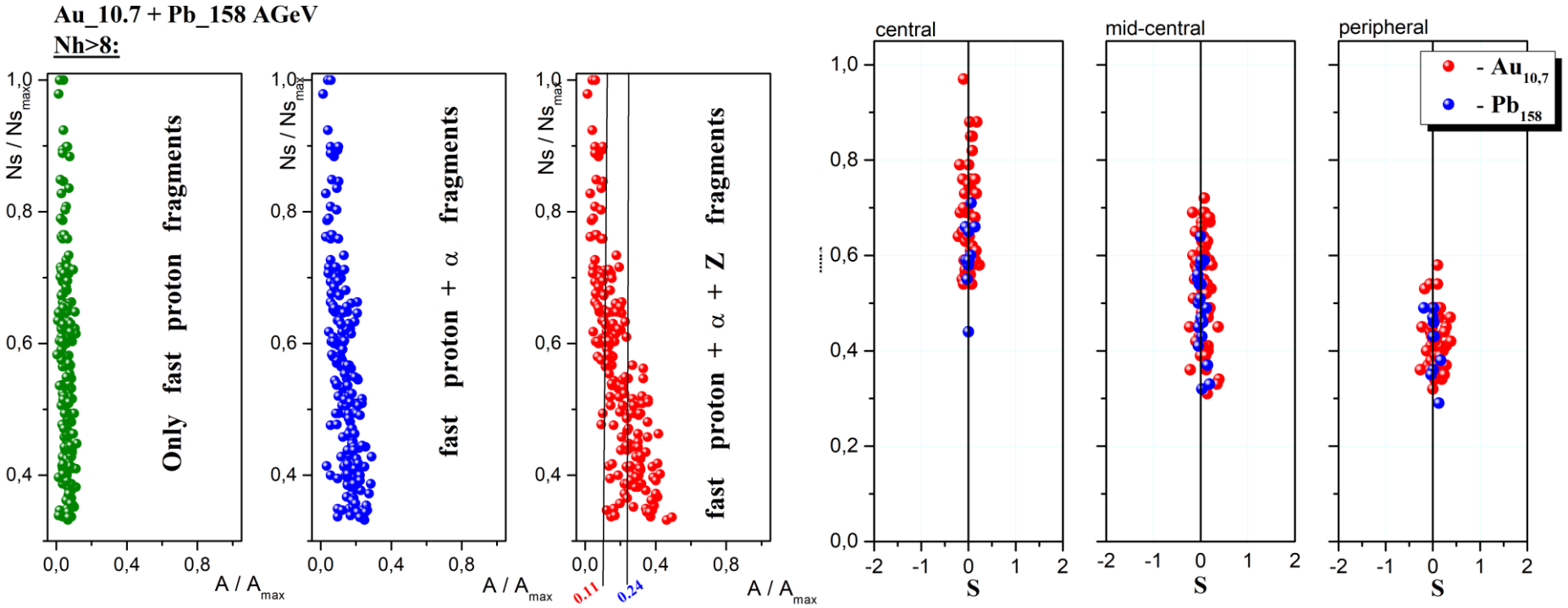


LEFT: E-by-E fluctuation for multiplicity. The Weakest E-by-E fluctuation!
VIP: But ATTENTION: the greatest multiplicities in this events .

RIGHT: E-by-E fluctuations for the longitudinal event shape is weakest as well.
Fluctuations in Mid-central and Peripheral commensurate with ones in central.
See link to E. Bratkovskaya, HIC for FAIR, WS, Frankfurt, 2015.

E-by-E accuracy analysis via THIRD statistical moment, - Skewness (S) for (Au, Pb) + (Ag/Br) interactions.

In this context S "works" as an indicator of accuracy in the symmetrical collisions.

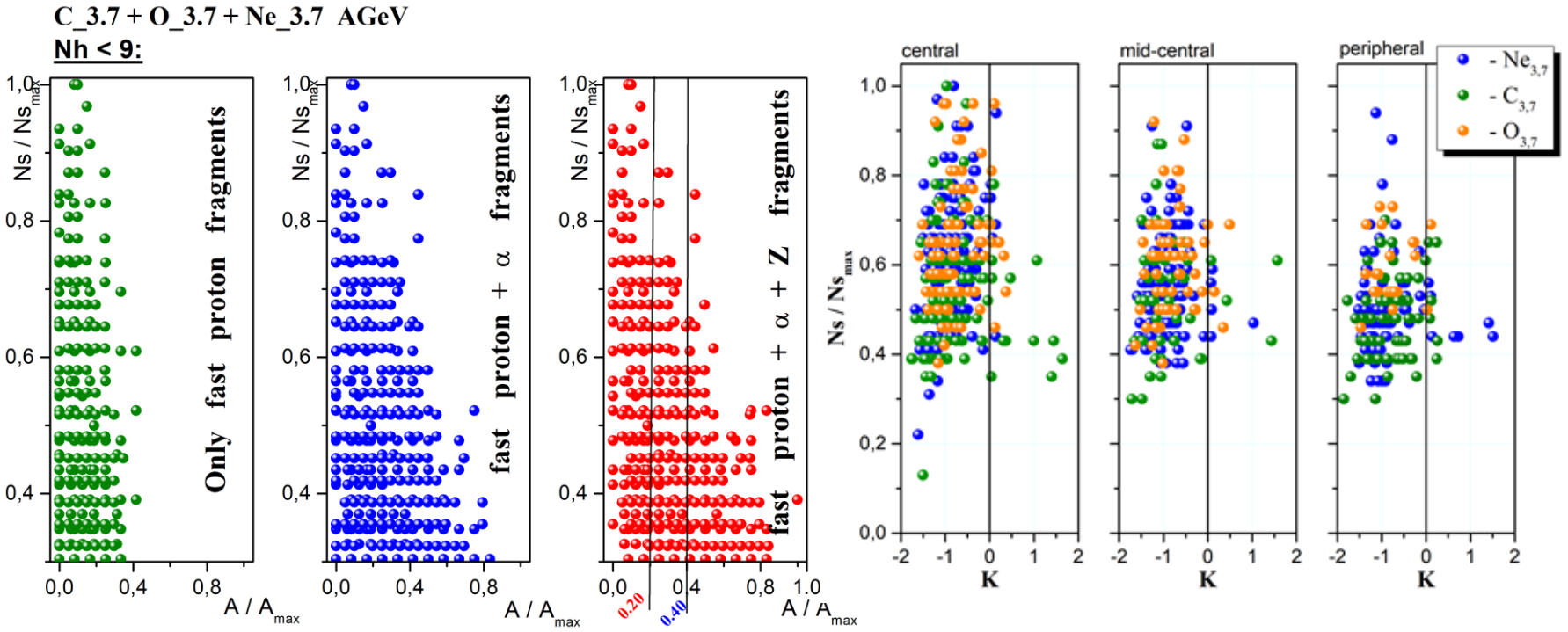


LEFT: E-by-E fluctuation for multiplicity. The Weakest E-by-E fluctuation!
VIP: But ATTENTION: the greatest multiplicities in this events .

RIGHT: Accuracy indicator of E-by-E fluctuations for the longitudinal event shape well concentrates around zero with SMALL dispersion.
Accuracy in "Mid-central" and "Peripheral" commensurate with ones in "Central".

E-by-E analysis of FOURTH statistical moment, - Kurtosis (K), for (C, O, Ne) + (C/N/O) interactions.

K measures the sharpness of the distribution relative to a Gaussian.
Negative K implies that the peak is broader than a Gaussian.

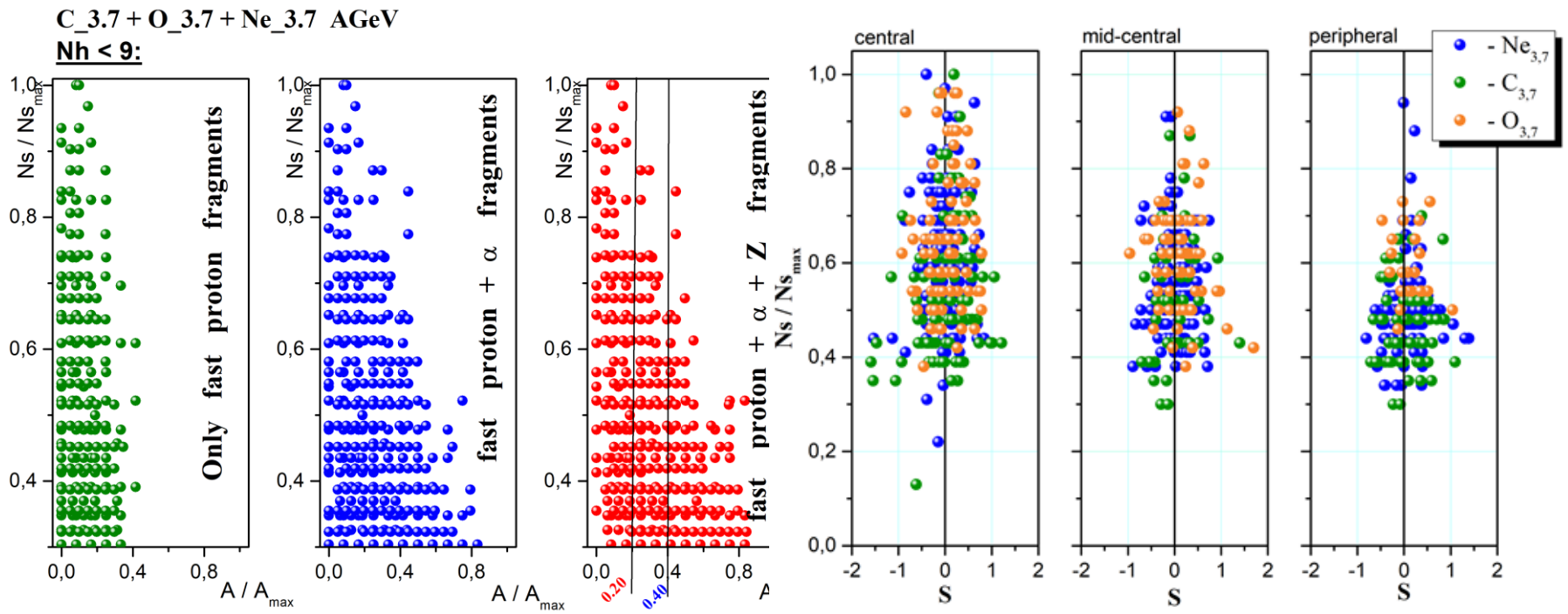


LEFT: E-by-E fluctuation for multiplicity. The Strongest E-by-E fluctuation!
VIP: But ATTENTION: the minimal multiplicities in this events .

RIGHT: E-by-E fluctuations for the longitudinal event shape is strongest as well.
Fluctuations in Mid-central and Peripheral commensurate with ones in central.
See link to E. Bratkovskaya, HIC for FAIR, WS, Frankfurt, 2015.

E-by-E accuracy analysis via THIRD statistical moment, - Skewness (S) for (C, O, Ne) + (C/N/O) interactions.

In this context S "works" as an indicator of accuracy in the symmetrical collisions.



LEFT: E-by-E fluctuation for multiplicity. The Strongest E-by-E fluctuation!

VIP: But ATTENTION: the minimal multiplicities in this events .

RIGHT: Accuracy indicator of E-by-E fluctuations for the longitudinal event shape well concentrates around zero, but with LARGE dispersion.

Accuracy in "Mid-central" and "Peripheral" commensurate with ones in "Central".

SHORT DISCUSSION

1.

Independent and accurate measurement in each event FULL charged multiplicity and SUM OF ALL fast charged fragment-spectators: proton-spectators, alpha-particle-spectators and heavy mass fragment-spectators opens the way for effective estimation of the E-BY-E FLUCTUATIONS OF MULTIPLICITY.

The study in each event the third and fourth statistical moments of FULL pseudorapidity distribution gives us a clear picture of E-BY-E FLUCTUATIONS FOR THE LONGITUDINAL EVENT SHAPE.

The additional analyses "on vertically" and "on horizontally" in each event have improved understanding the fluctuating structures in the initial conditions.

These approaches complement previous results of our research group

[А.А. Локтионов, и др., Ядерная Физика, 2018, V 81, N 5, с. 569],

[A.Kh. Argynova, et al., Book of Abs., 2016 Baldin ISHEPP, p. 94, Dubna, 2016].

which showed that there is a clear trend to the E-by-E fluctuation increasing with system size decreasing for central interactions of light-light - (C, O, Ne) + (C/N/O), intermediate-light - (Si, S) + (C/N/O) and heavy-heavy - (Au, Pb) + (Ag/Br) nuclei.

The strong enhancement E-by-E fluctuations in multiplicity and pseudorapidity for the most central collisions of (C, O, Ne) + (C/N/O) was interpreted as the sign of intrinsic alpha-clustering in light nuclei.

2.

Comparison of our results with today modern experiments is the hard problem.

[A. Aduszkiewicz, Recent results from NA61/SHINE // Quark Matter 2017]: The broad system size studies have performed in the modern fixed target NA 61/SHINE experiments at SPS, as a part of the program of a systematic search for critical behavior of strongly interacting matter. Collisions of protons, light, intermediate and heavy mass nuclei (Be, Ar, Xe, Pb) in the whole SPS energy range (Beam = 400, 13A – 158A GeV/c) were studied.

NA 61 searches for the critical point by searching for non-monotonic dependences in fluctuations of hadron production properties. However, no hint for critical point so far. The study of system size dependences at collisions of p + p, Be + Be and Ar + Sc no indicate non-monotonic behavior so far as well.

[Maja Mackowiak-Pawlowska for the NA61/SHINE Collaboration:
News on fluctuations and correlations from the NA61/SHINE experiment],
ISMD 2018, Singapore:
NA61/SHINE seems to probe one of the most interesting part of the phase diagram - critical point, onset of fireball and onset of deconfinement:
Interpretation of data becomes a huge challenge.

SUMMARY

In order to make the reliable inference on the system size and structure dependence for multihadron production processes, the new physical approaches and experiments with high resolution and statistics are needed.

New project "NICA" opens the excellent possibilities for this goal.

Actual system size and structure problems can be studied on the first stage of NICA project – target experiment "Baryonic Matter at Nuclotron" ("BM@N").

It is very interesting to perform comparative analysis of multiparticle processes in p + p, C + C and Au + Au collisions at new interval of JINR energies at MPD.

Thank You for Your Attention