International Symposium on Cosmic Rays and Astrophysics (ISCRA-2019),
Moscow, Russia, 25-28 June 2019

Analysis of models of A-A-interactions used in EAS simulations

A.G. Bogdanov, A.A. Petrukhin

National Research Nuclear University MEPhI, Moscow, Russia

Motivation

The interest to nucleus-nucleus interactions at very high energies (more than 10^{15} eV in cosmic rays and more than 1 TeV at LHC) is explained at least by two reasons.

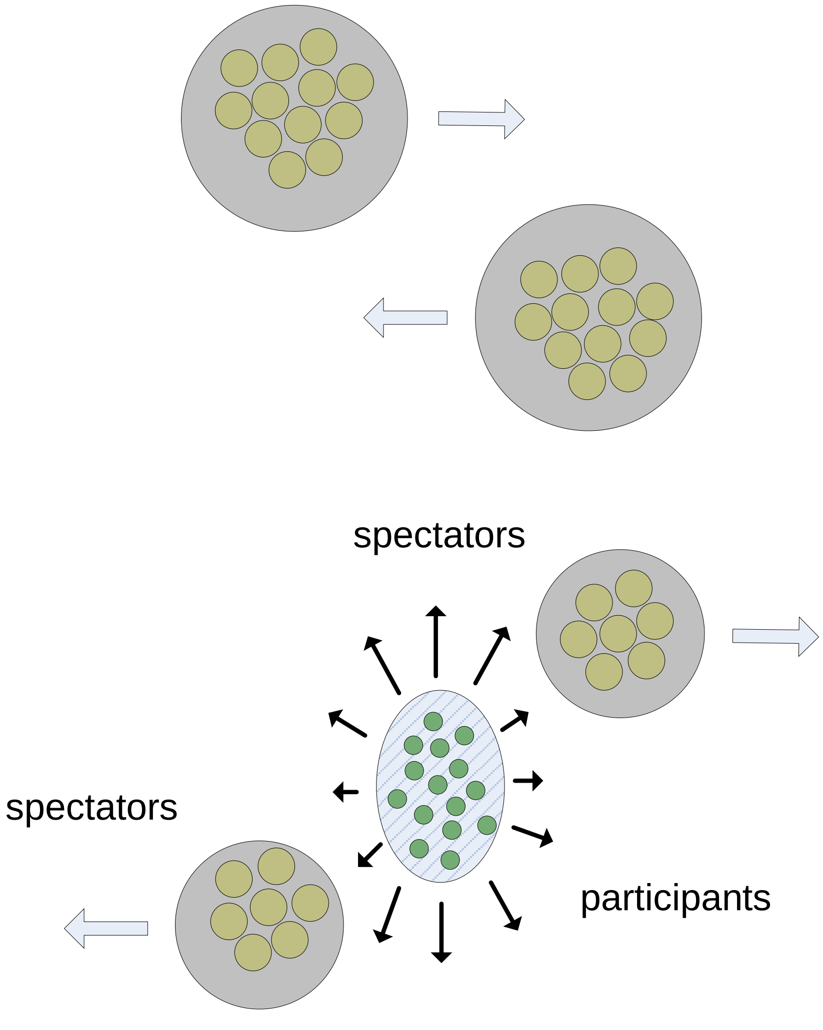
The first is an increase of the mean mass of primary cosmic rays at energies higher the “knee” which requires good knowledges about models of interaction of different nuclei presented in cosmic rays.

The second is the observation of various unusual phenomena in nucleus-nucleus collisions at PeV energies and above (alignment, penetrating cascades, long-flying particles etc.).

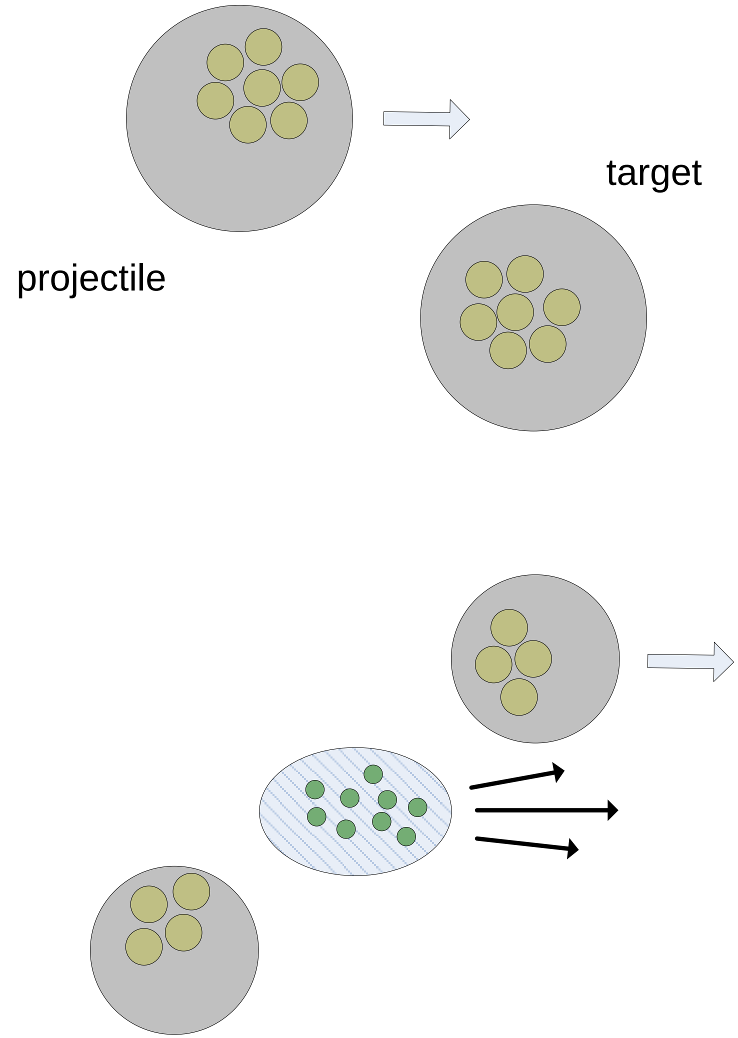
In this work comparison of various models of nucleus-nucleus interactions which are used in CORSIKA code is done. In particular, yield of baryons after the first interactions of primary nuclei with atomic nuclei of the atmosphere is analyzed. It may be important for the correct understanding of the further development of air showers.

Sketch of heavy ion collision at high energy

colliders



cosmic rays



CORSIKA – an air shower simulation program

www.ikp.kit.edu/corsika

The CORSIKA (COsmic Ray SImulations for KAscade) is a detailed Monte Carlo program that allows to simulate interactions and decays of nuclei, hadrons, muons, electrons, and photons in the atmosphere and to study the evolution of extensive air showers initiated by high energy cosmic ray particles.
It widely used for interpretation of data of many cosmic ray experiments.

The hadronic interactions at high energies may be described by several reaction models alternatively: DPMJET, EPOS, HDPM, NEXUS, QGSJET, SIBYLL, VENUS.

Steering of the simulation (1st interaction)

The simulation of air showers is steered by commands (keywords). A command consists of a keyword and one or more arguments.

Stack Output File Name
OUTFILE FILOUT
FILOUT : File name to define the name and directory of the output file which will contain the parameters of the secondary particles produced in the first interaction.
The first line of the file contains (format free after a leading blank) the number of secondaries and the primary energy (GeV). The following lines contain the current particle number, the particle type, the energy (GeV), the longitudinal momentum, and the two transverse momenta (GeV/c).

First Interaction Definition
FIXHEI FIXHEI N1STTR
FIXHEI : Fixes the height (in cm) of the first interaction of hadronic primaries. If FIXHEI = 0., the height of the first interaction is varied at random according to the appropriate mean free path.
N1STTR : Fixes the target of the first interaction: 1 = Nitrogen, 2 = Oxygen, 3 = Argon, else = random selection according to the atmospheric abundances.

Simulation details

CORSIKA 7.6900 (December 20, 2018).

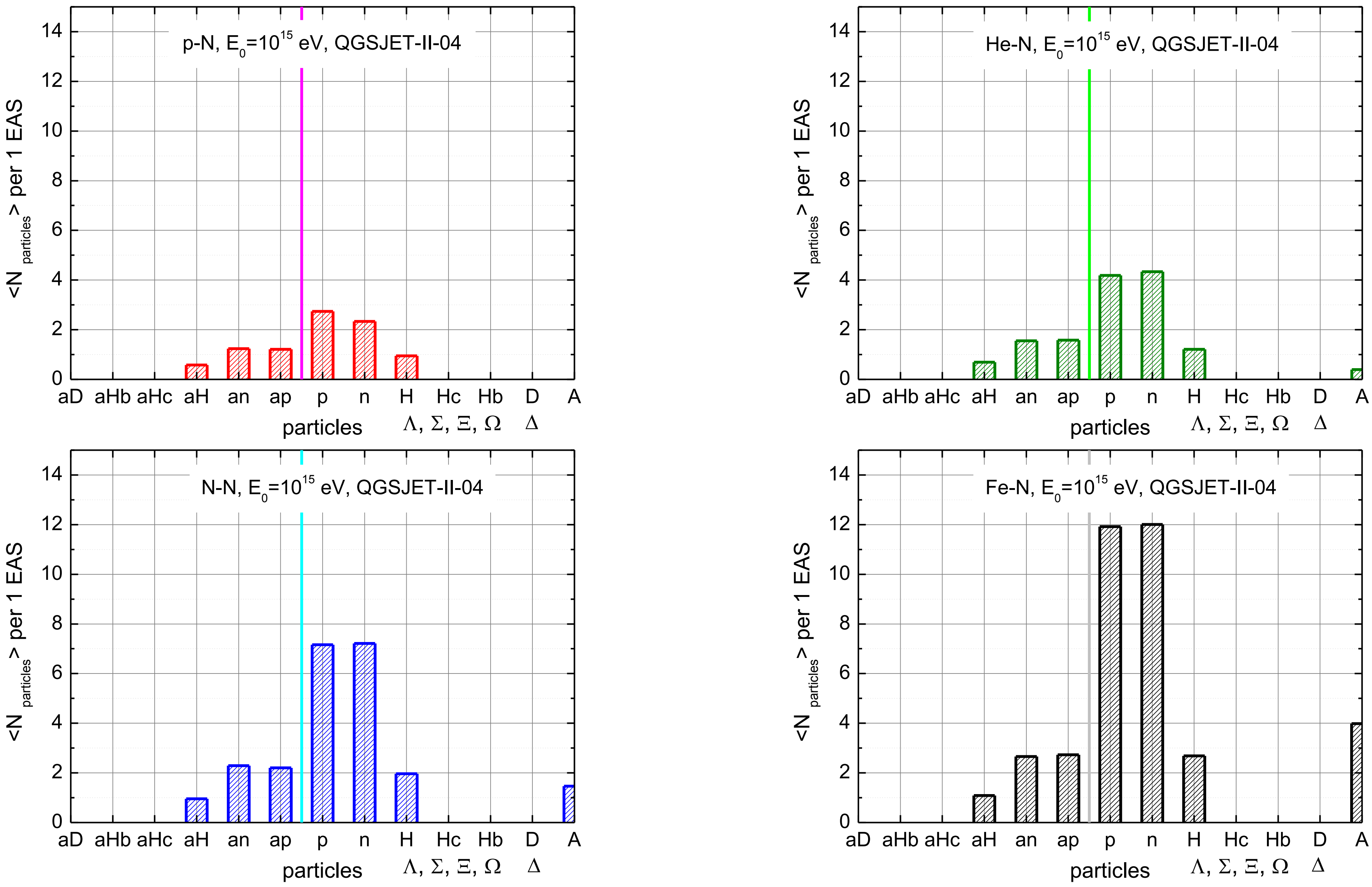
recent high-energy hadronic interaction models:
QGSJET-II-04, EPOS-LHC, SIBYLL-2.3c

interactions: p-N, He-N, N-N, Fe-N

primary energy (E_0): 10^{14} – 10^{19} eV

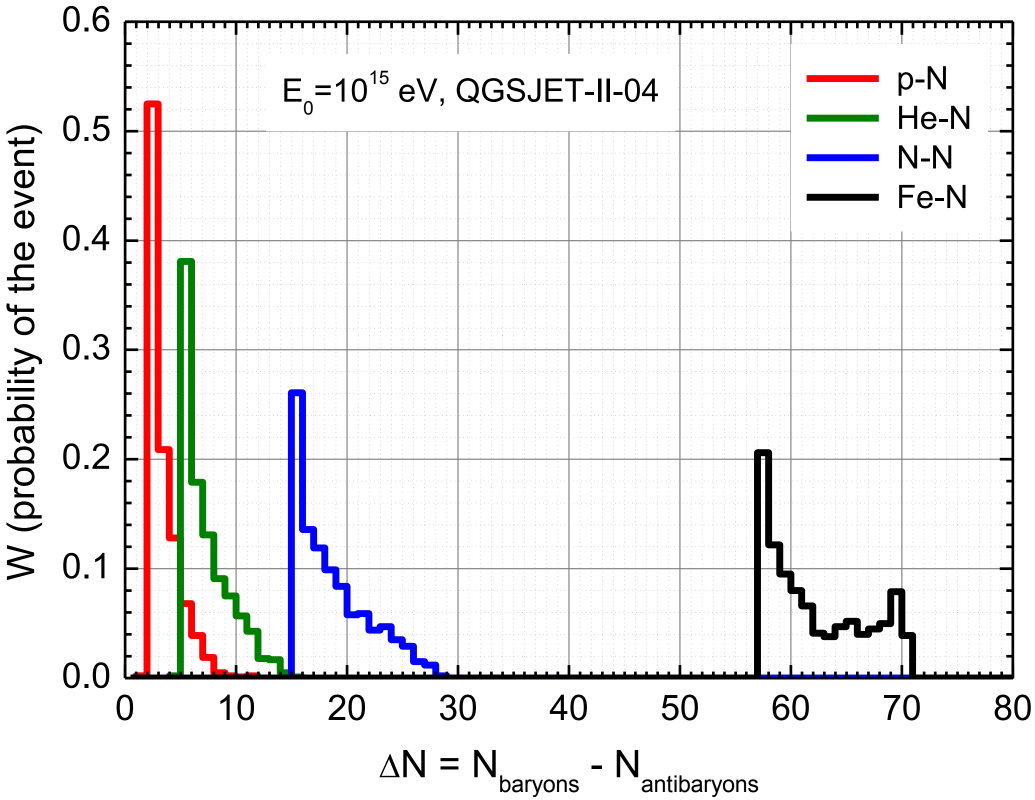
statistics (for each set of parameters): 1000 EAS

Secondary baryons formed as a result of the first interaction



the mean number of baryons increases with increasing mass of the primary nucleus and new nuclei appear

Conservation of baryon number



ΔN includes the part of the nucleons of the primary nucleus that

were not involved in the 1st interaction and the resulting secondary baryons

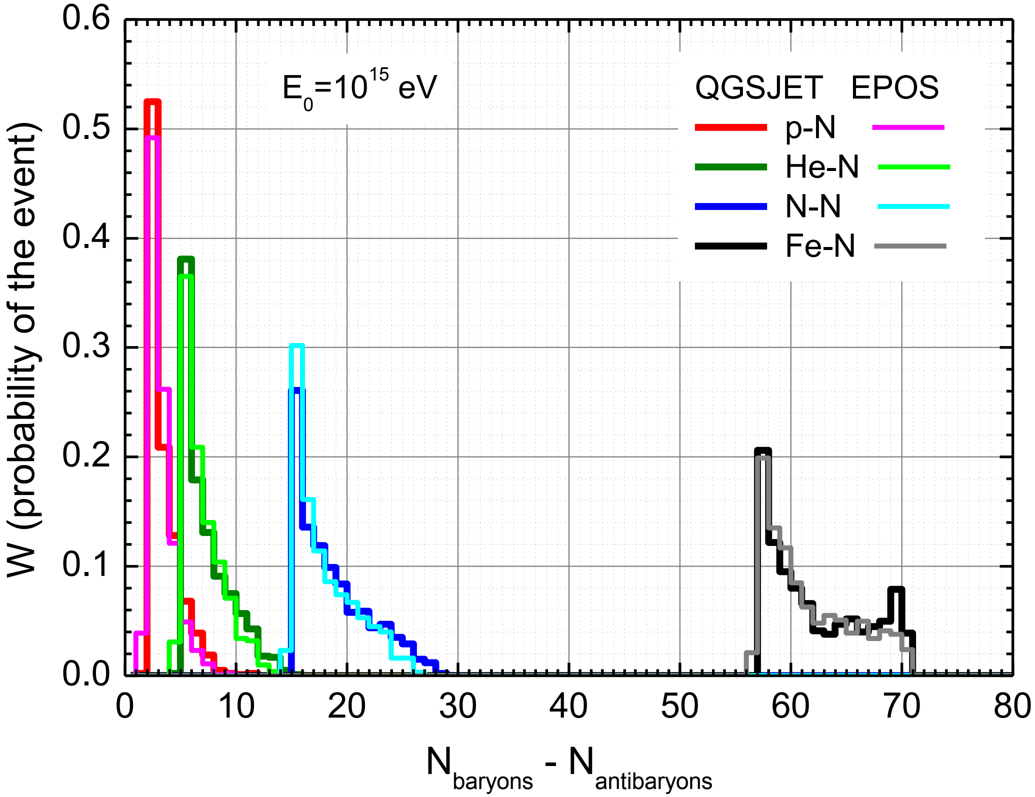
for example, for NN interaction:

$\Delta N = 14$ means that there was no interaction

$\Delta N_{min} = 1+14=15$ (14 nucleons of projectile and 1 nucleon of target interacted)

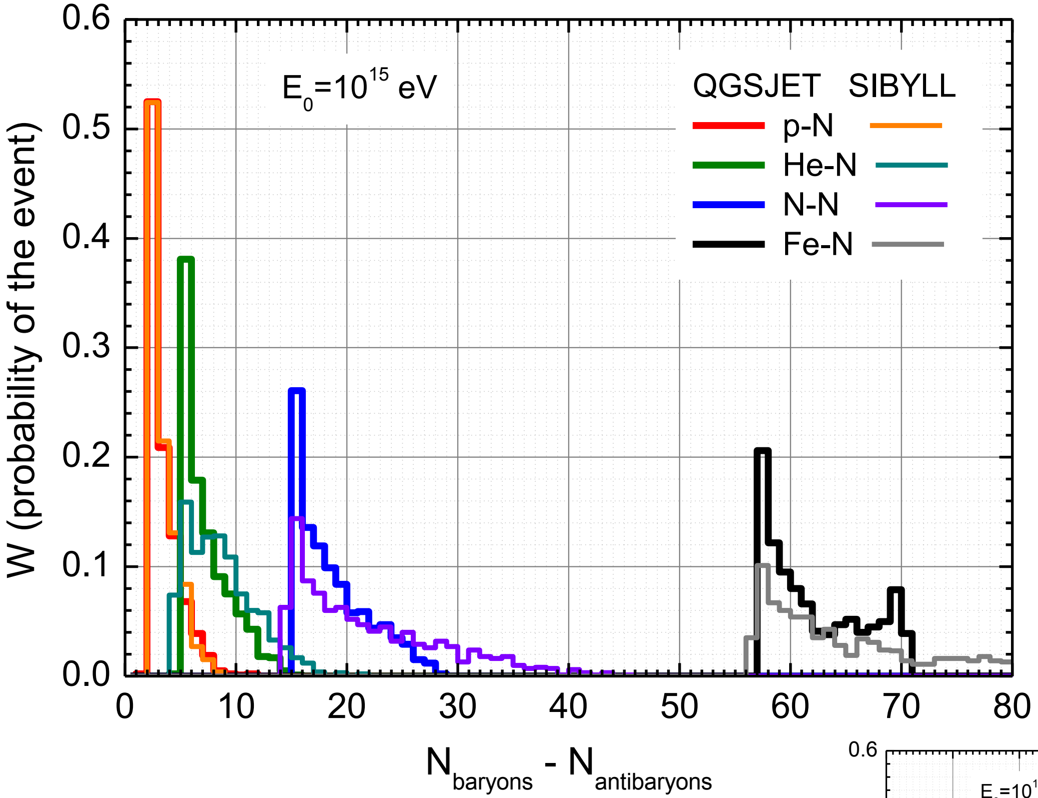
$\Delta N_{max} = 14+14=28$ (14 nucleons of projectile and 14 nucleons of target)

Conservation of baryon number (QGSJET-II-04 & EPOS-LHC)

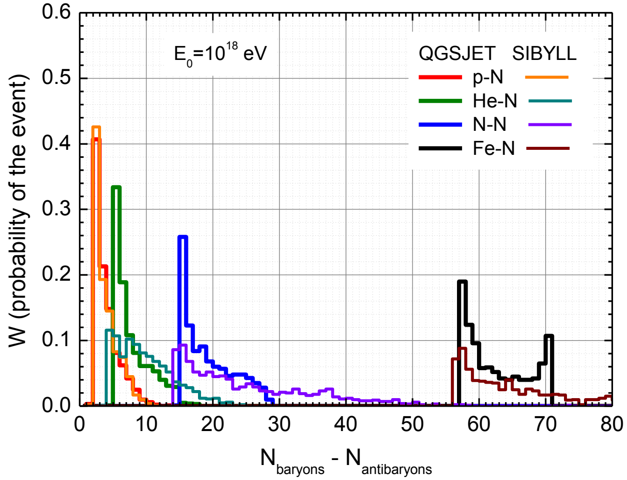


these models are not very different from each other

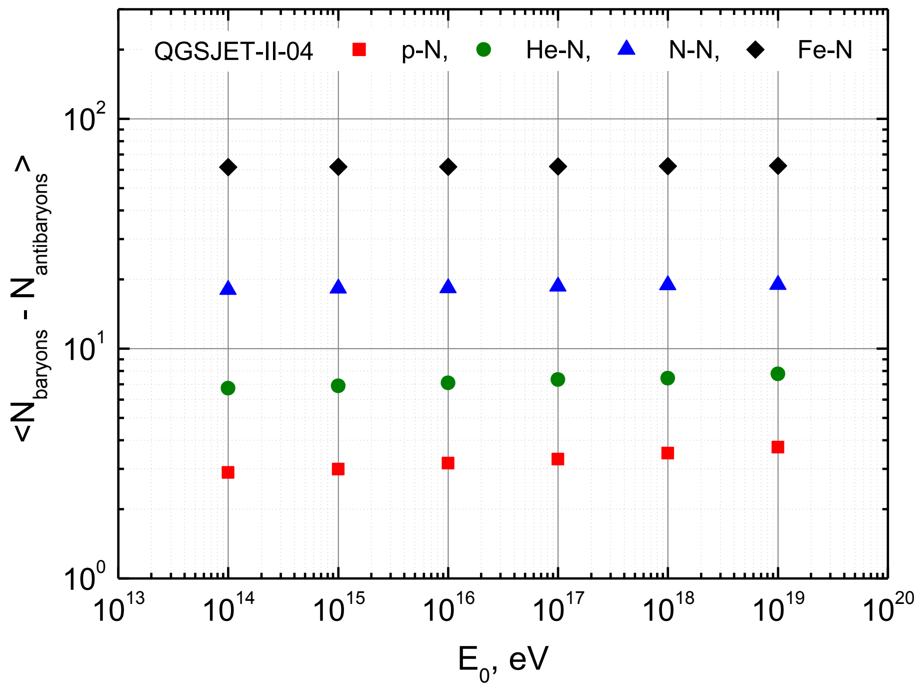
Conservation of baryon number (QGSJET-II-04 & SIBYLL-2.3c)



SIBYLL feature:
the difference in the number of baryons
and antibaryons is out of range



Dependence of the difference between baryons and antibaryons on the energy of the primary particle



E_0=1 PeV	$<N_{barions} - N_{antibaryons}>$
p-N	3.0
He-N	6.9
N-N	18.3
Fe-N	61.8

this can be useful for comparison with a simple geometric model

Thank you for your attention!