Angular correlations with charmed hadrons in the Monte-Carlo model with string repulsion

ICPPA-2017

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October 2-5, 2017, Moscow

Introduction

Color flux tubes (quark-gluon strings), formed at early stages of hadron-hadron collision, may overlap in case of sufficiently high densities and interact by repelling or attracting each other, depending on the direction of the color fluxes [1]. Thus, in the hypothesis of repulsive interaction, strings may acquire, before the hadronization, an additional transverse boost. This produces additional transverse momenta to the particles formed in string decays over a wide range of rapidity, thus leading to modification of observables and to azimuthal asymmetry of two-particle correlations. Monte Carlo implementation of the model is described in [2].

Recent experimental results revealed large elliptic flow of the charmed hadrons at LHC energies. These measurements are often interpreted using transport models, which incorporate dissociation and recombination mechanisms for charm quark. For this report, azimuthal correlations with charmed hadrons are calculated in MC model with string repulsion, assuming that strings can break into c-cbar pairs. It is shown that string repulsion mechanism may provide significant angular correlations and, if contribution from hard scattering is properly added to the model, may qualitatively describe experimental data.

The MC model with string repulsion

Stage 1. Simulation of strings configuration

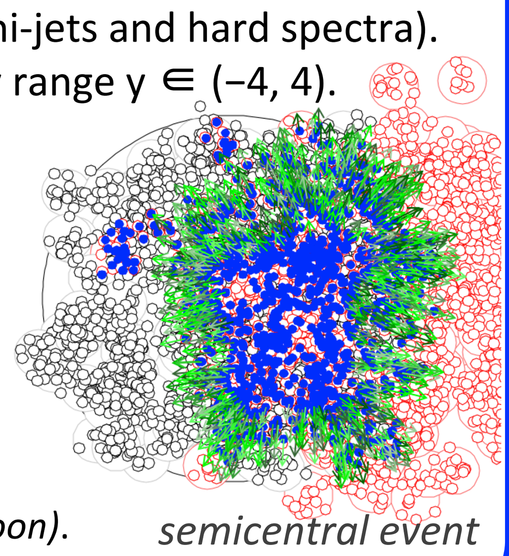
- Nuclei: Pb^{208}, the Woods-Saxon radius is 6.62 fm, a = 0.546 fm
- Inside each nucleon partons are distributed in transverse (xy) plane with 2D-Gauss law, with σ_{xy} = 0.4 fm.
- The mean number of partons inside nucleons depends on a collision energy and is a model parameter.
- Partons can interact and form a string, if the distance between partons in xy plane is less then some parton interaction distance dp.
- There is a ~3% probability to have "hard scattering" of partons (to emulate mini-jets and hard spectra).
- All strings are considered to be "soft" and "long" in rapidity, occupying rapidity range y ∈ (−4, 4).

Stage 2. Repulsion of the strings

- Strings have *effective interaction radius* R_{string}
- Strings overlaps which leads to repulsion, string boost is adjusted to $\langle\beta_{string}\rangle \approx 0.65$ in central Pb-Pb collisions

Stage 3. String hadronization

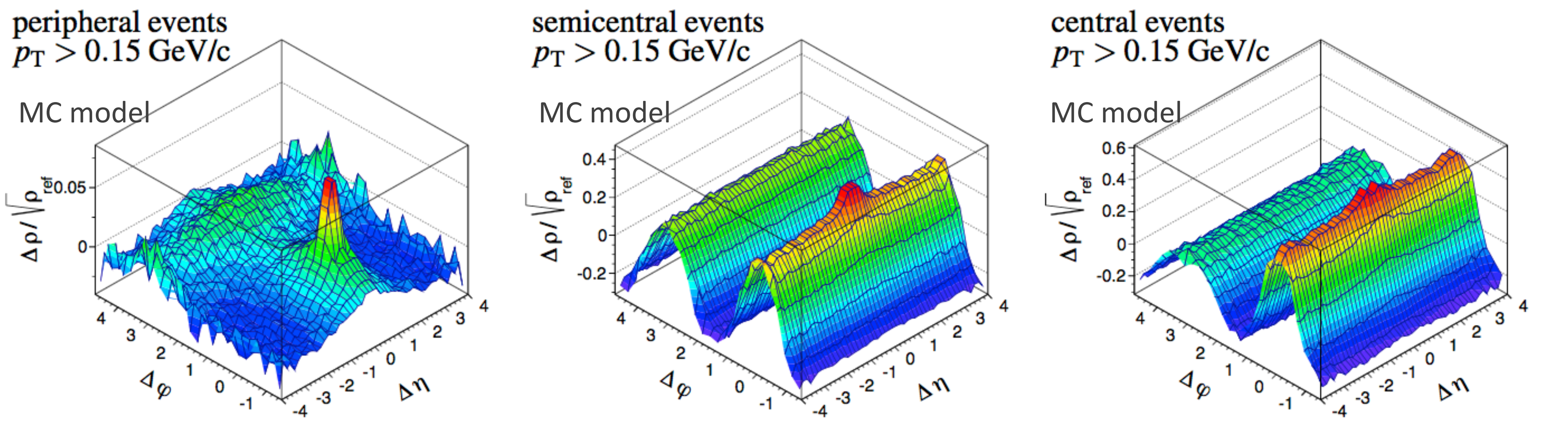
- Each string breaks into quark-antiquark pairs in several places, forming a number of mesons (pions and $\rho \rightarrow \pi\pi$)
- Transverse Lorentz boost β_{string} is applied for each particle *(green arrows on cartoon)*.

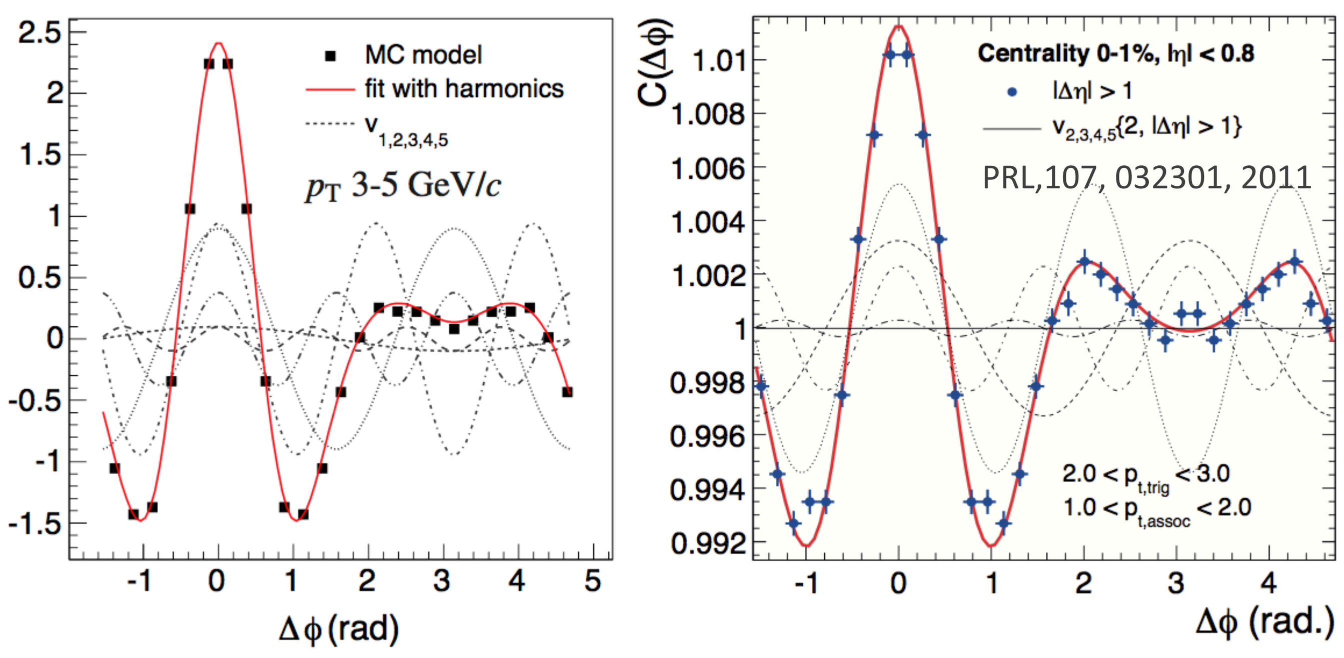


semicentral event

Two-particle Δη-Δφ correlations

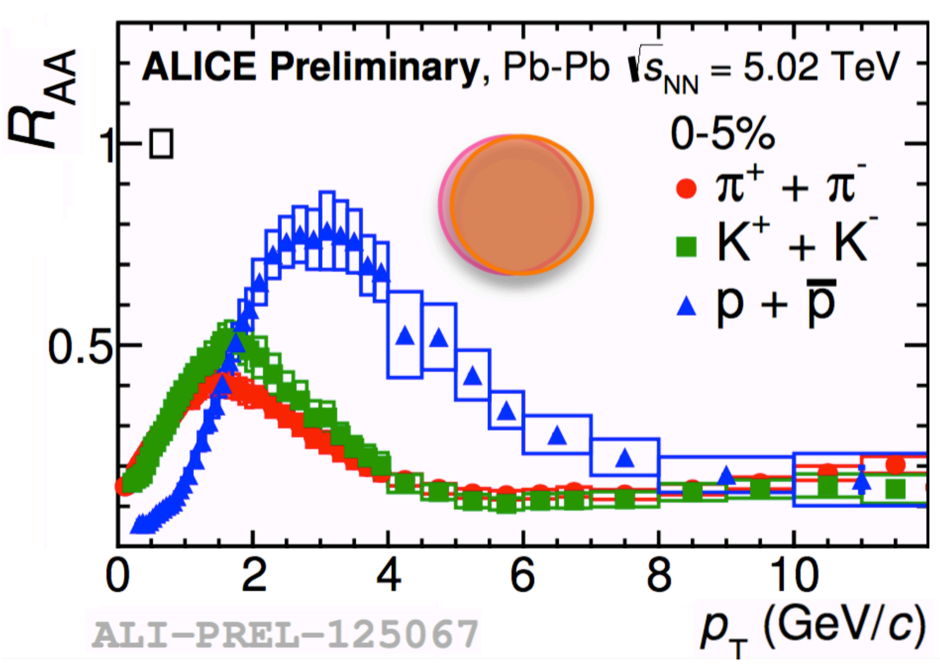
Due to string-string interactions, initial configuration of quark-gluon strings could be transferred into the azimuthal flow [3]. Two-particle correlation functions obtained in the toy model for peripheral (left), semi-central (middle) and central (right) events are shown in the Figure below for charged particles with p_T > 0.15 GeV/*c*, with string effective interaction radius 2 fm. The pads in the Figure illustrate the onset of collectivity when passing from peripheral to central A-A collisions. In peripheral events, a structure along Δϕ is visible, which is due to the ρ_0 decays into pions.

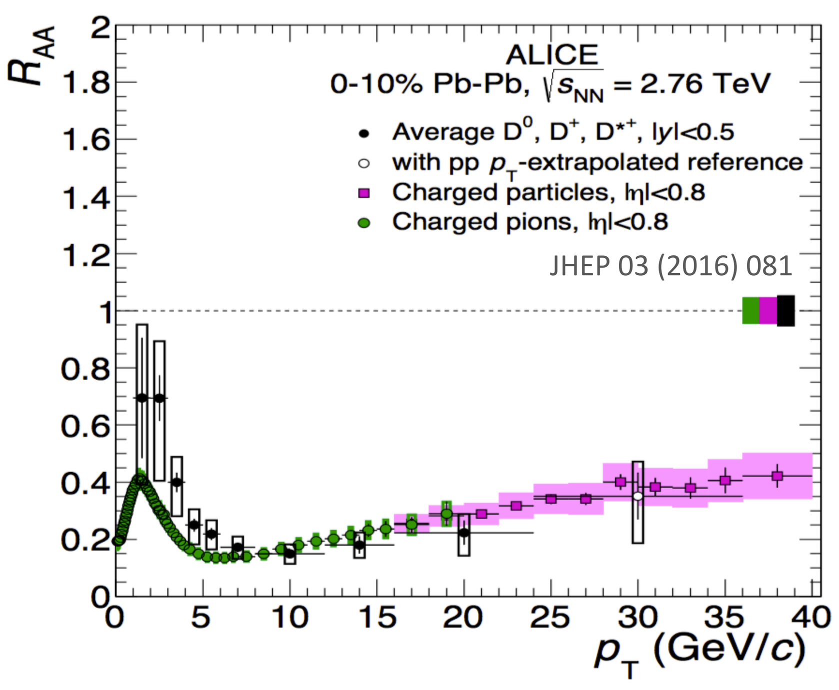




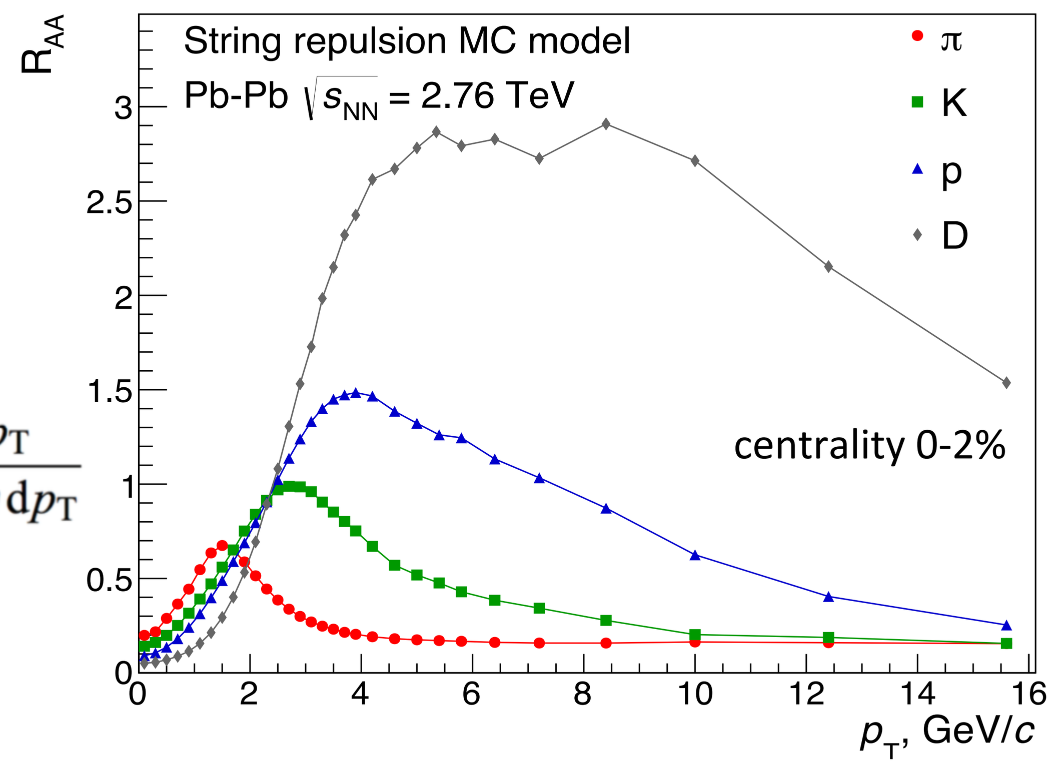
The "harmonic decomposition" of the azimuthal profile of the correlation function for most central for charged particles with p_T ∈ [3, 5] GeV/*c*. *Right*: comparison with ALICE..

Nuclear modification factor for central A-A collisions





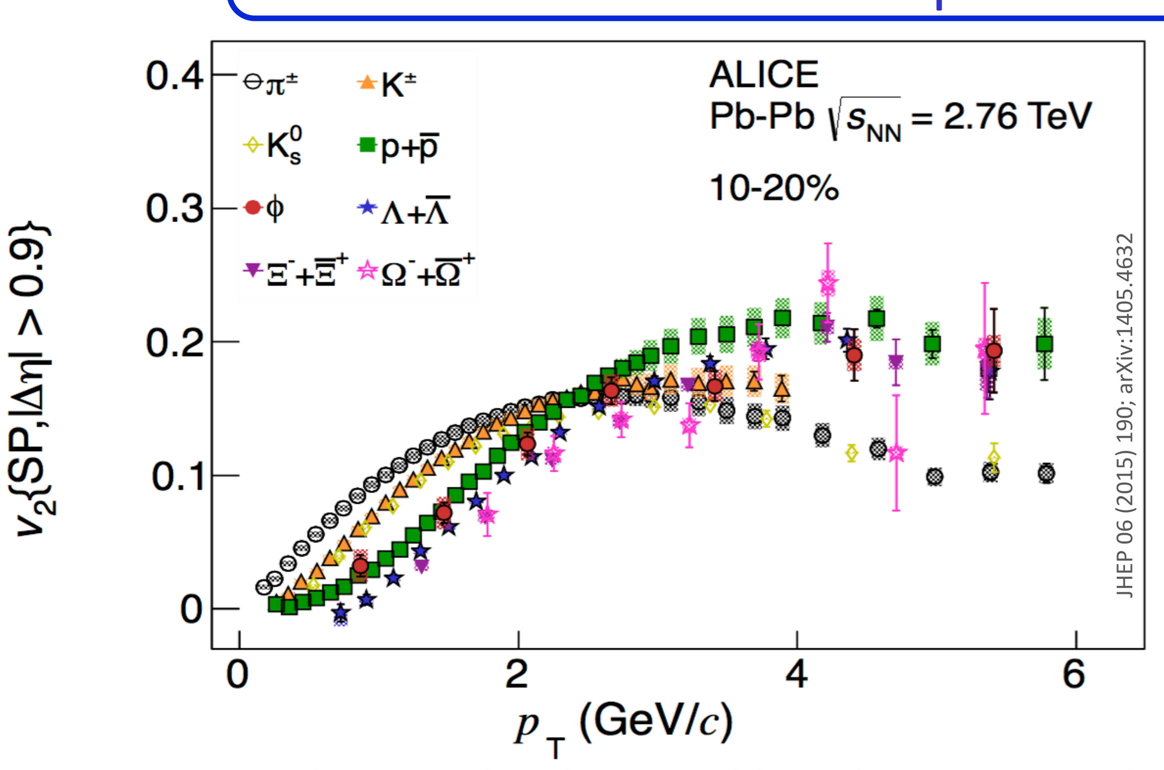
$$R_{AA}(p_T) = \frac{d^2N^{AA}_{ch}/d\eta dp_T}{\langle T_{AA}\rangle d^2\sigma^{pp}_{ch}/d\eta dp_T}$$

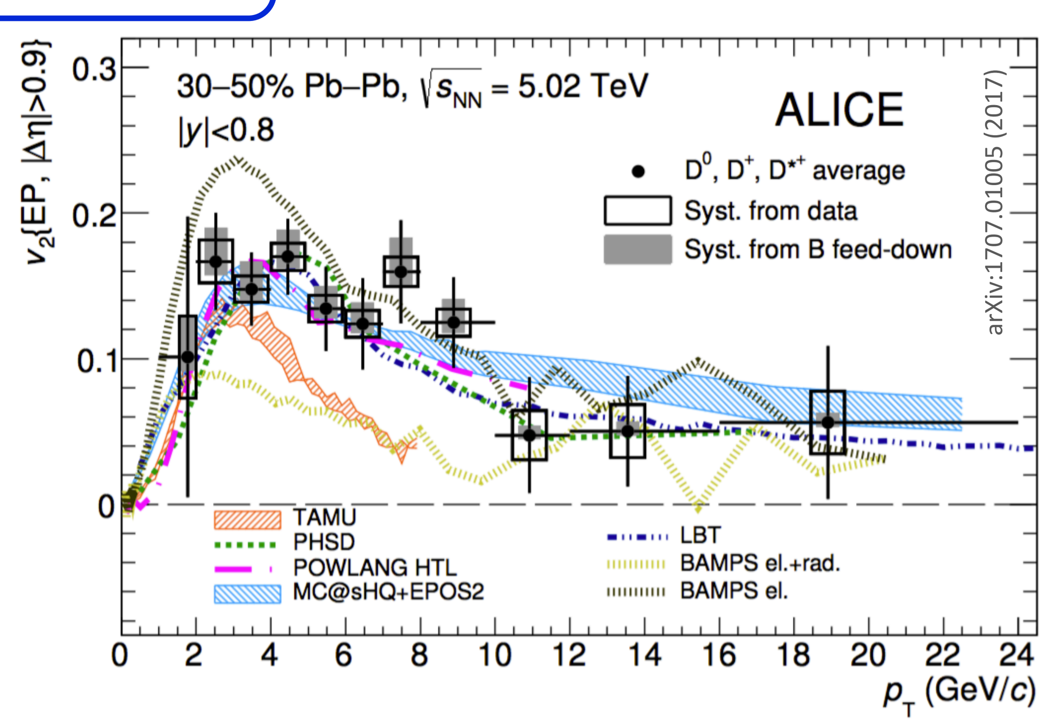


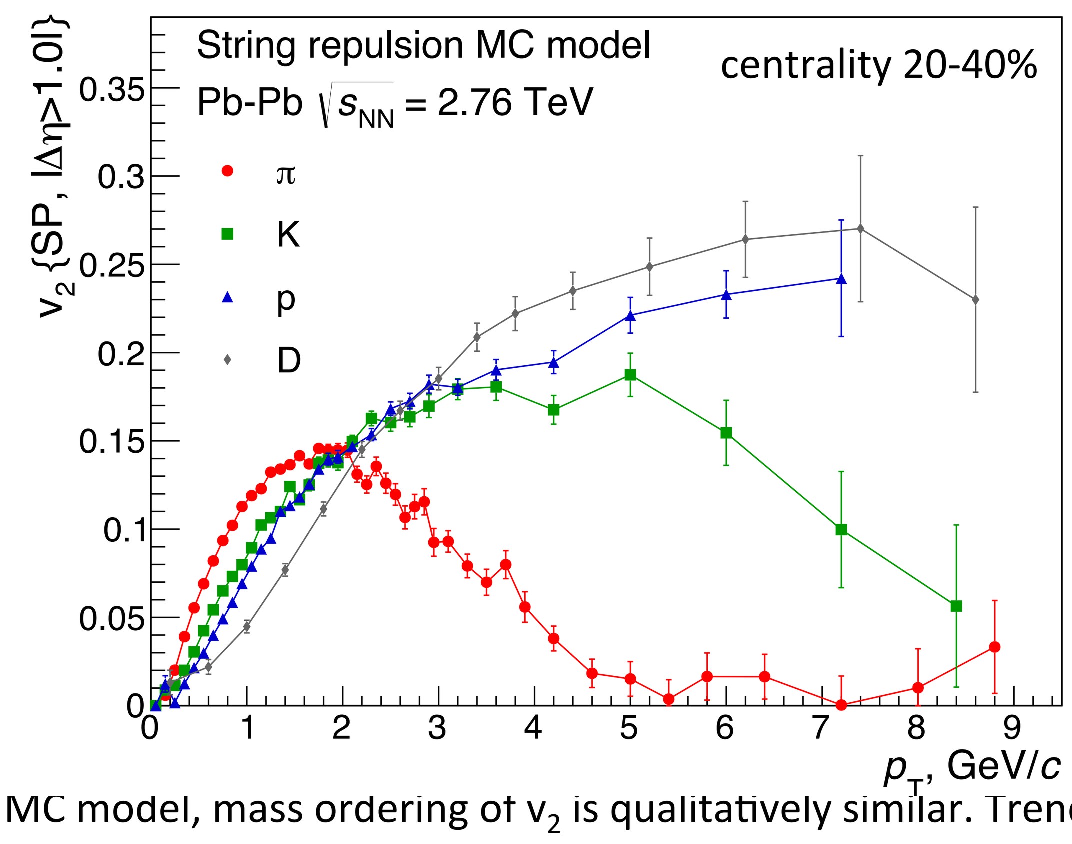
R_{AA} for most central collisions measured by ALICE is shown for π, K, p (*left plot*) and compared with D-mesons (*right*). So-called mass ordering is well visible at low p_T, while R_{AA} values of ~0.2 at high p_T range > 5 GeV/*c* are usually attributed to a suppression due to energy loss in medium.

Calculations with the MC model with string repulsion show qualitatively similar behaviour as in data. Quantitative discrepancies are due to (1) different treatment of $\langle N_{coll}\rangle$ in the MC model and (2) approximations in description of the "hard" contribution.

Differential elliptic flow







For v_2, mass ordering is also clearly visible in data, also seen for D meson. Theoretical calculations for D meson v_2 usually use in-vacuum fragmentation of heavy quarks for the high-momentum region, supplemented by hadronisation via recombination at low momentum, some models also include scattering of D mesons in the hadronic phase of the medium.

In the MC model, mass ordering of v_2 is qualitatively similar. Trend towards zero at high p_T is due to larger fraction of the "hard" contribution, which is not sensitive to the "collective" repulsive motion.

Conclusions

- It is shown that signatures of collectivity, observed experimentally in A-A collisions, can be obtained in the model with repulsing strings. Namely, the model qualitatively reproduces mass ordering of the nuclear modification factor and azimuthal flow for light flavours as well as for heavier hadrons, for instance, D mesons (assuming possibility for a string to hadronize into charmed hadrons).
- The main challenge for the model to get better quantitative agreement with data is to reproduce correctly an interplay between soft and hard contributions in intermediate p_T range (from 1 to 8 GeV/*c*, depending on particle species).
- To reproduce R_{AA}, normalisation on $\langle N_{coll}\rangle$ should be done in the same way as in data (Glauber approach without details at partonic level).

REFERENCES

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2. I. Altsybeev, AIP Conf.Proc. 1701 (2016).
3. I. Altsybeev, G. Feofilov, EPJ Web of Conferences 125, 04011 (2016), arXiv:1702.05281.

This work is supported by the Russian Science Foundation, grant 16-12-10176.