Studying the effect of the hadronic phase in nuclear collisions

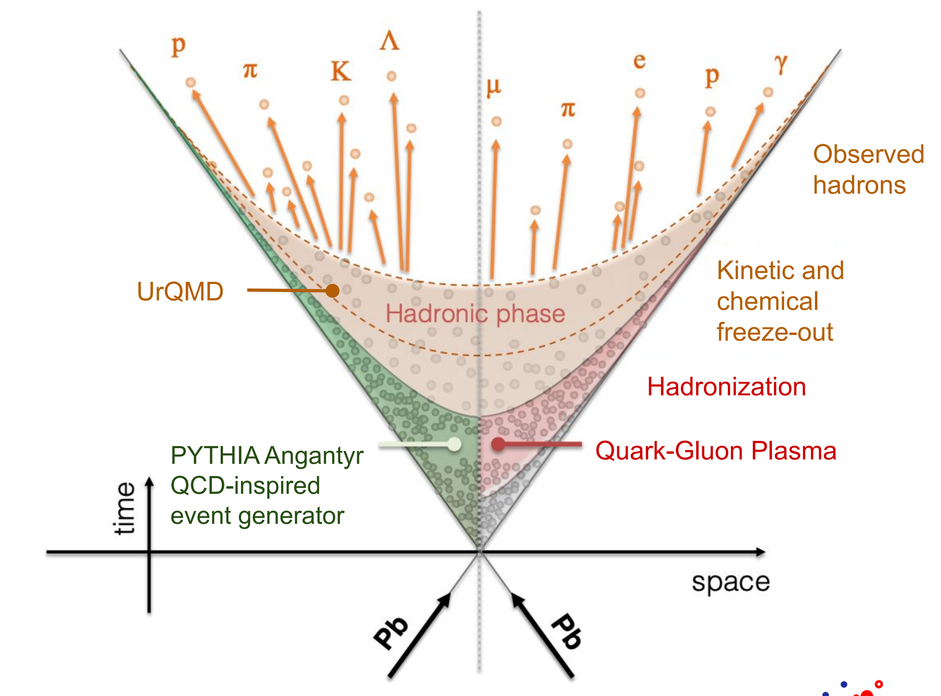
André V. da Silva
Universidade Estadual de Campinas, São Paulo, Brazil

Abstract

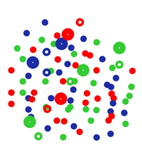
The goal of ultra-relativistic heavy-ion collisions is to study the properties of strongly interacting matter under extreme conditions. In these collisions, large energy densities are expected to be achieved and a state of matter where quarks and gluons are no longer confined in to hadrons, the quark-gluon plasma (QGP), is formed. The presence of such a system leads to some experimental signatures such as collective behaviour and the suppression of high momentum particles that are expected and measured in the experiments at the LHC. These signatures are only measured indirectly after hadronization take place and the system evolution in which inelastic and elastic interactions may still happen. Therefore, understanding the effects of this hadronic phase is of paramount importance to infer on the properties of the QGP. In this work, we couple the PYTHIA Angantyr event generator for heavy-ion collisions at LHC energies with the hadronic cascade simulator UrQMD to study the effect of the hadronic phase on observables such as charged-particle multiplicity densities, transverse momentum spectra, identified particle ratios, nuclear modification factor and anisotropic flow. In addition, the fact that PYTHIA is a perturbative QCD-inspired model that does not assume a thermalized QGP phase also makes these results a crucial baseline for hybrid models that include a QGP phase.

Introduction

The stages of a heavy-ion collision



- Quark-Gluon Plasma (QGP): A state of matter in which quarks and gluons are deconfined.



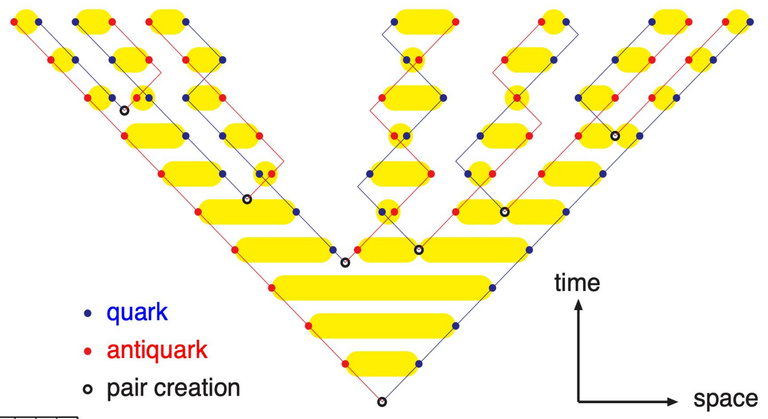
QGP phase

A new alternative: PYTHIA + UrQMD

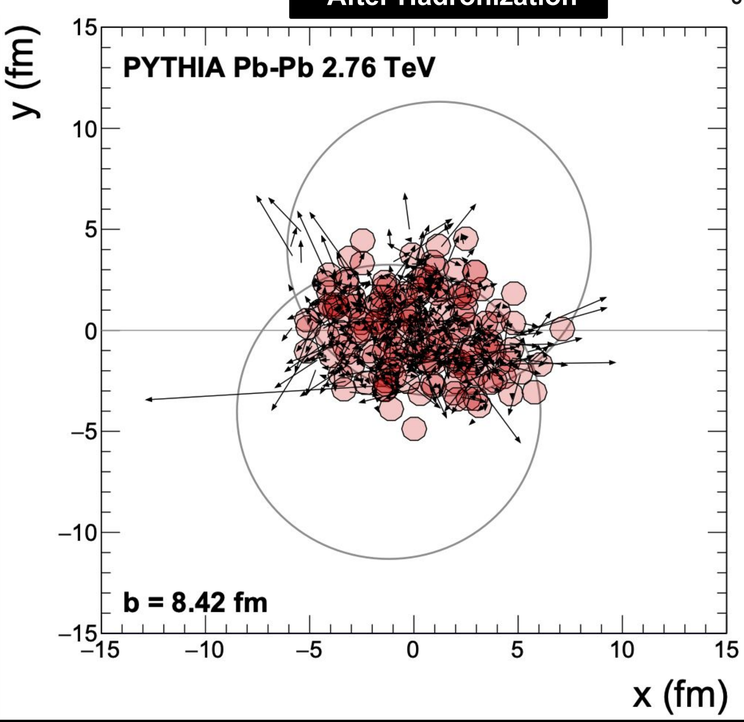
- PYTHIA Angantyr [1]:
  - Does not assume the QGP phase.
  - Baseline for a heavy-ion collisions.
- UrQMD - Hadronic cascade simulator [2]:
  - Propagation, rescattering and resonance decays.

PYTHIA: Lund string model with the hadron vertex model

- Lund string model provides a powerful picture of hadron production.
- Using the hadron vertex model [3] we can get the hadron positions after hadronization.



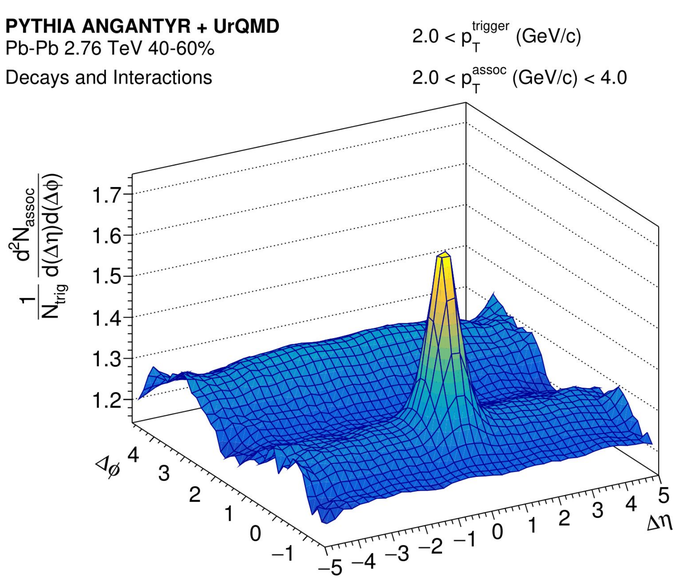
After Hadronization



- Produced hadrons after hadronization serve as input to UrQMD.
- UrQMD: Heavy flavors, leptons and photons not treated by UrQMD:
  - Heavy flavors decayed by PYTHIA;
  - Leptons and photons removed for now.
- The PYTHIA + UrQMD simulation chain provides us with a complete QGP-free simulator of a heavy-ion collision that can be compared to experimental data.

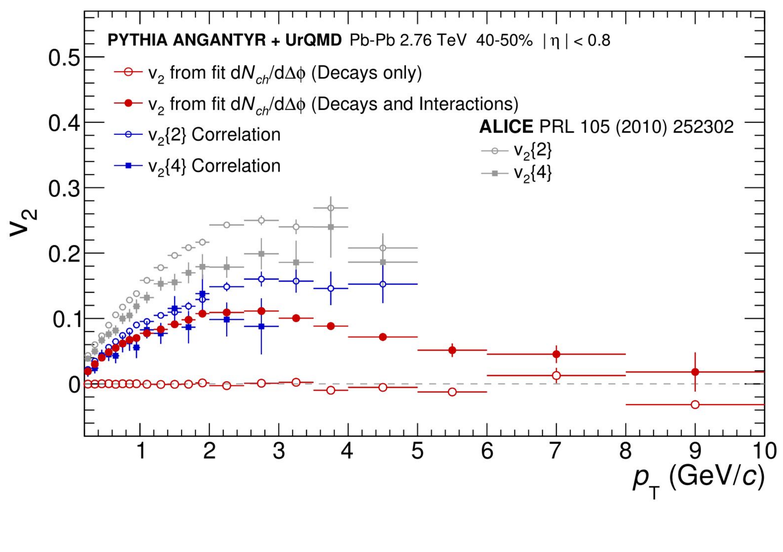
Results - flow / collective behaviour

Two-particle angular correlations - 2pc



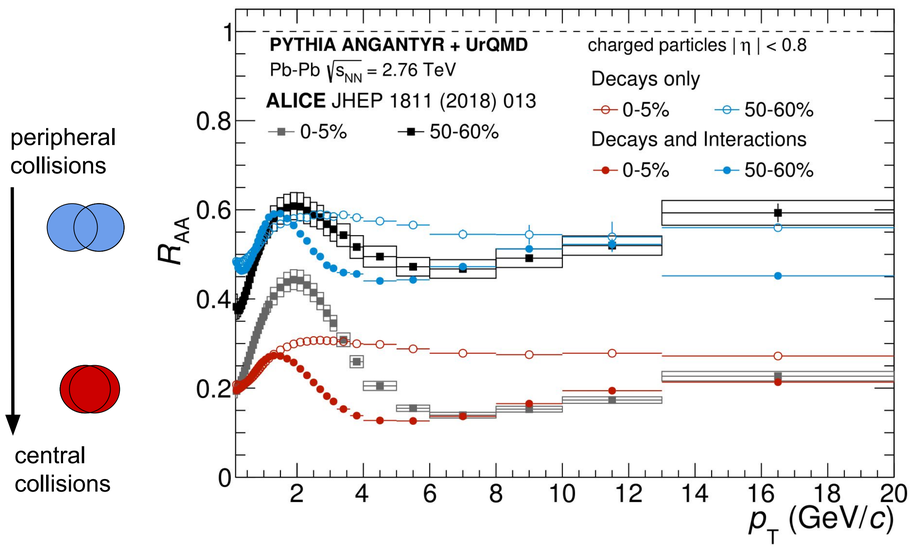
- Elliptic flow via 2pc technique shows that hadronic interactions produce long-range correlations in η (the double ridge).
- Consistent with simulation results obtained at lower energies [4].

Elliptic flow coefficient - v_2



- Rescattering generates an anisotropic flow with approximately 50 % of magnitude of the v_2 observed by ALICE.
- The p_T-dependence of the v_2 is qualitatively similar to the one observed in real data.

Results - nuclear modification factor R_{AA}



- R_{AA} compares the Pb-Pb p_T spectra with pp spectra rescaled by the number of binary collisions from a Glauber model.
- R_{AA} < 1 in Angantyr: nucleon-nucleon (binary) collisions are not independent, unlike in the Glauber model.
- High-p_T particles lose momentum interacting with low-p_T ones.
- R_{AA} vs centrality: stronger momentum loss in central collisions.

Conclusions

- We built a new machinery coupling PYTHIA Angantyr and UrQMD to simulate heavy-ion collisions without a quark-gluon plasma phase
- The new approach can generate a hadronic final state that can be directly compared to experimental data.
- The preliminary results show effects on spectra and flow:
  - **Spectra**: Rescatterings produce R_{AA}-like peak.
  - **Flow:** Hadronic interactions lead to v_2 that is half the one observed experimentally.
- New baseline leaves significantly less room for QGP effects!

References

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IFGW Instituto de Física Gleb Wataghin