Fireball fragmentation and rapidity correlations of protons

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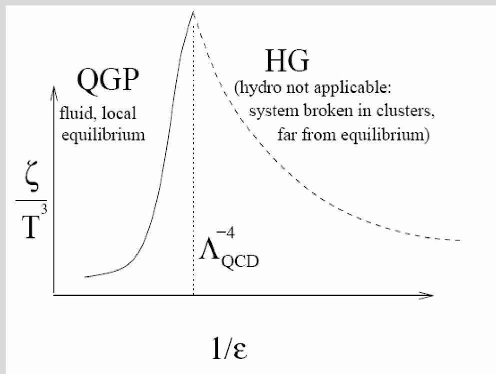
For first order phase transition the fireball fragmentation is possible by means of spinodal decomposition.

Fragmentation in case of smooth but rapid crossover [1]

Sudden rise of **bulk** viscosity at critical temperature [2,3]

1. QGP droplets expand easily
2. Bulk viscosity singular at critical temperature
3. System become rigid
4. Inertia may win and fireball can fragment
5. Fragments emit hadrons



Three-dimensional correlation function in relative rapidity

Lorentz factor for relative motion: $m_1 m_2 \gamma_{12} = E_1 E_2 - \vec{p}_1 \cdot \vec{p}_2$

Three-dimensional relative rapidity: $y_{12} = \ln\left(\gamma_{12} + \sqrt{\gamma_{12}^2 - 1}\right)$

Correlation function: $C_{3D}(y_{12}) = \frac{P_{3D}(y_{12})}{P_{3D}^0(y_{12})} - 1$

Correlation functions have been fitted by Gaussians: $C(y_{12}) - 1 = A\exp\left(-\frac{y_{12}^2}{2\sigma^2}\right)$

How to probe fireball fragmentation?

- For the droplets detection we use suitable observables – **correlation functions**
- Rapidities of hadrons stemming from the same droplet are **similar**
- Rapidities of hadrons not stemming from the same droplet are **random**
- Each particle emitted from the droplet has two components of momentum . One from the droplet motion, second from the chaotic thermal motion.
  - **heavier** particles – **worse** statistics, **slow** chaotic thermal motion
  - **lighter** particles - **better** statistics, **fast** chaotic thermal motion
- **Compromise – we will consider protons or antiprotons** [5,6]

DRAGON: MC generator of particles emitted from droplets [4]

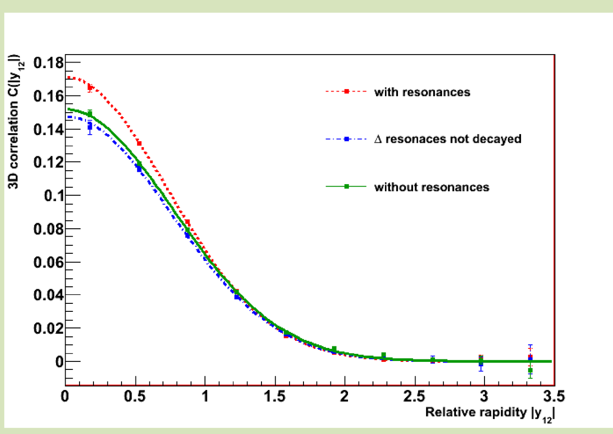
Used in generating the results shown here

- availability to emit particles from droplets (fragments)
- resonances decays included
- droplets are generated from blast-wave source (tunable parameters)
- droplets decay exponentially in time
- tunable size of droplets: Gamma distribution or fixed
- no overlap of droplets
- chemical composition: equilibrium with tunable parameters
- also directly emitted particles (tunable amount)
- rapidity distribution: uniform or Gaussian
- possible OSCAR output

Results

Influence of resonances on the correlation function RHIC parameter settings

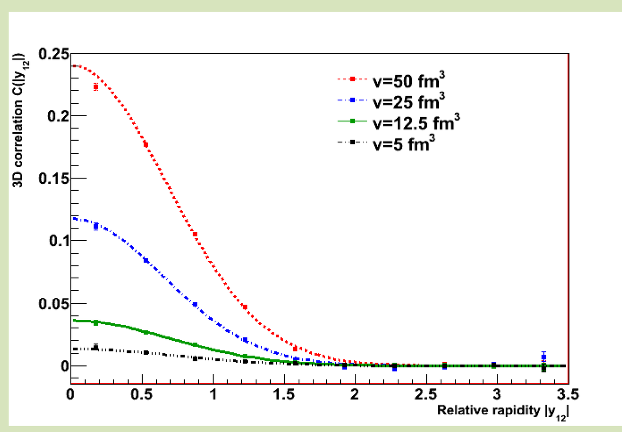
average droplet size v = 25 fm³
all hadrons from droplets



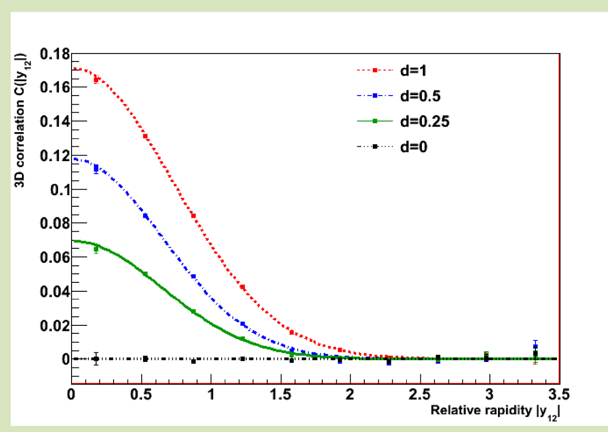
Resonances enhance the signal

Results for RHIC, resonanes included

One half of the hadrons from droplets
varying size

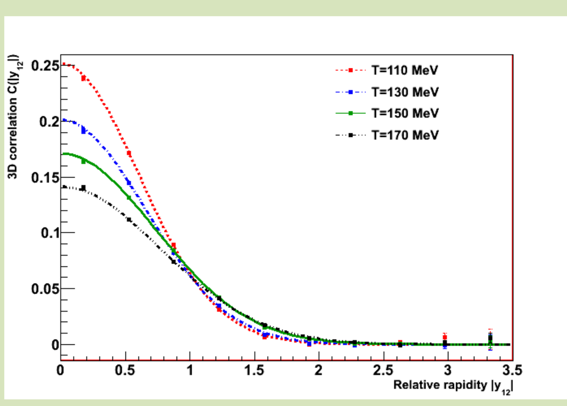


Average droplet size v = 25 fm³
varying part of hadrons from droplets



Influence of kinetic freeze-out temperature

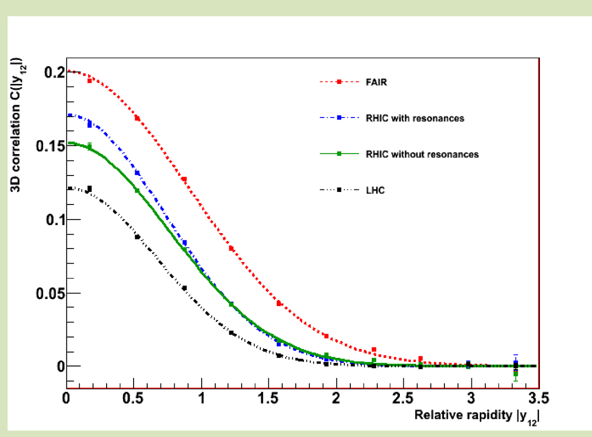
average droplet size v = 25 fm³
all hadrons from droplets



Less thermal smearing enhances the signal

Comparison of correlation functions for various experiments

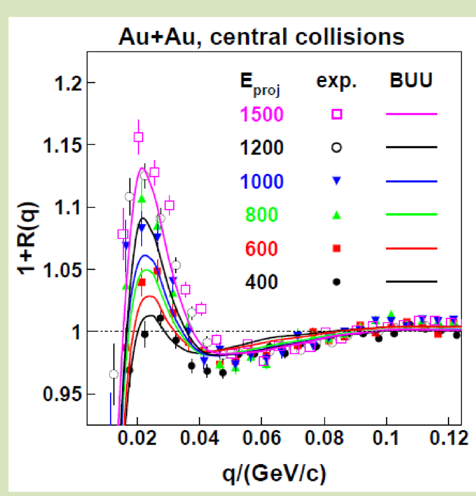
average droplet size v = 25 fm³
all hadrons from droplets



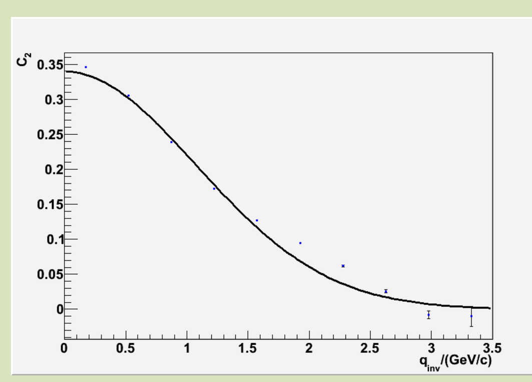
At FAIR strong signal due to narrow rapidity spectrum

Comparison between simulation and experiment (1st order phase transition)

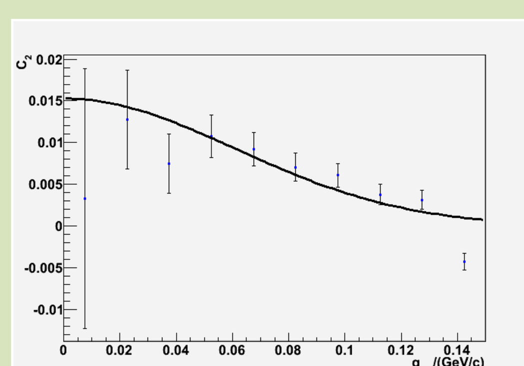
Simulated peak much wider than the range of measured data.



Correlation function of proton pairs from the FOPI collaboration [7]



Simulated correlation functions with FOPI settings, all hadrons from droplets



Simulated correlation function normalized to 1 at q_{inv} = 0.15 GeV

References:

[1] G. Torrieri, B. Tomášik, I.N. Mishustin, Phys. Rev. C **77** (2008), 034903
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[7] FOPI collaboration, EPJ A **23**, (2005), 271-278