Changing the PARADIGM – Corona Effect and Formation Time at RHIC and LHC in high p_t particle production.

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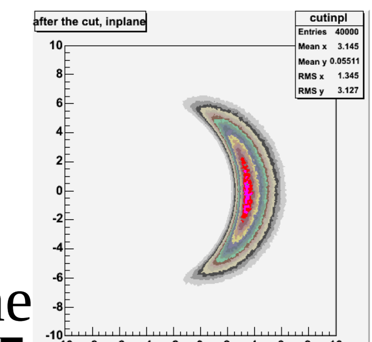
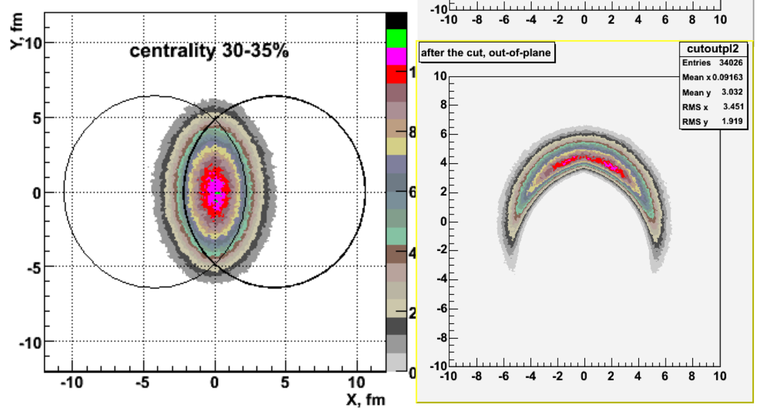
We argue that the observed large azimuthal parameter V_2 and R_{aa} for high p_t particles naturally lead to a finite formation time of the produced matter which extends corona region of interaction zone. At RHIC in peripheral corona it reaches 2 fm/c and ~0.7 fm/c in the central region. Following percolation scenario at LHC this time should be ~1.2 fm/c. At LHC in addition to the yield from corona region we see punch through high p_t particles from the core with fixed energy loss of about 7 GeV.

The primary idea came up 13 years ago in attempt to explain large "flow" parameter V_2 for high p_t particles at RHIC.
1. Observer can see only part of interaction zone, in-plane or out-of-plane.
2. Attempts to estimate the thickness of surface zone which will explain V_2 data by $\int \rho dx$ or $\int \rho x dx$ failed.
3. **Surprisingly, simple geometry cut, *L*=2.3 fm, can explain V_2 and Raa**
JETP Lett. 85 (2007) 104, arxiv:0509207[hep-ph]
4. It is very attractive to attribute this value to **formation time, T,** of color matter in **corona peripheral** region. After this time – black body.

X-Y plane of interaction zone





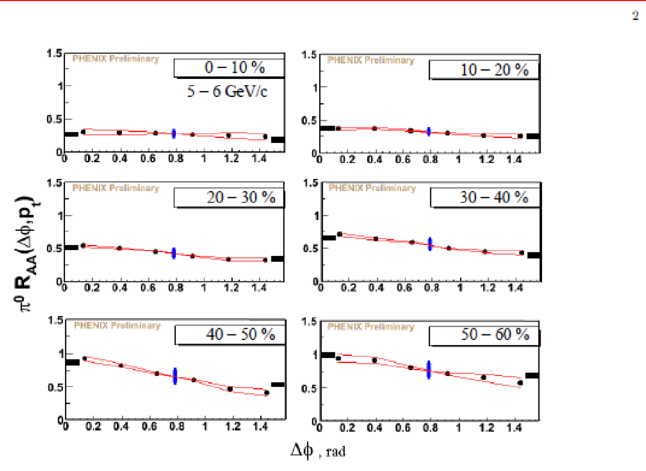
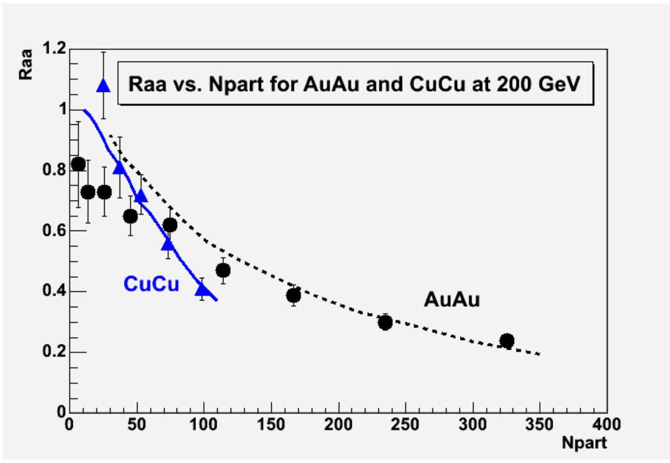
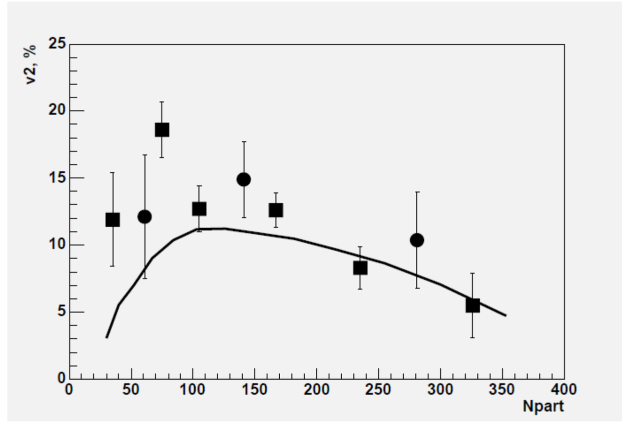


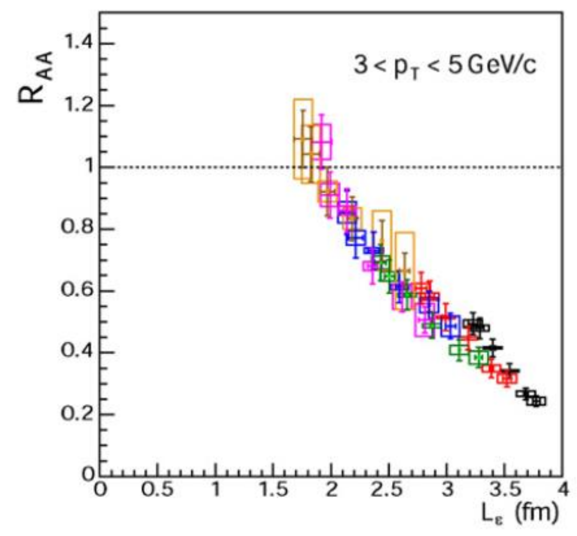
Рис. 1: PHENIX preliminary R_{AA} results for π^0 at momenta 5-6 GeV/c versus angle ϕ relative to the reaction plane for different centralities in Au+Au collisions at RHIC [4]. Points are experimental data, thin lines show systematic errors from the reaction plain resolution, vertical bars in the middle show avaraged over the reaction plane R_{AA} value and it's error. Black horizontal bars are predictions of the model.





Calculated ellipticity parameter v_2 for Au+Au collisons, solid line, versus the number of participant nucleons, N_{part}. Data for π^0 with error bars are: cicles for 4.59 GeV/c, squares for 5-7 GeV/c. PHENIX preliminary data [4, 7].

PHENIX analysis on Raa vs reaction plane also gets similar 2 fm:



Phys.Rev.C76:034904,2007

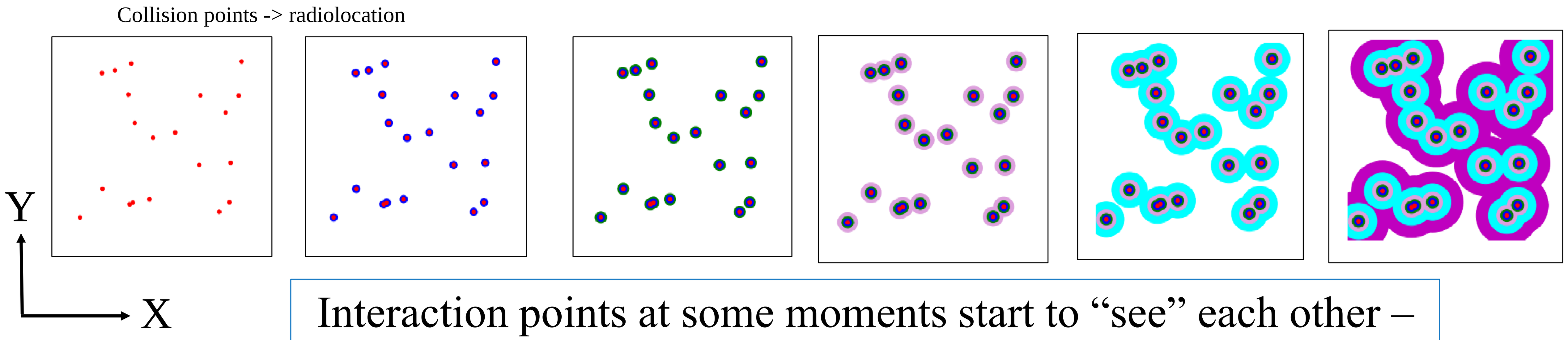
At very early time left side of the collision zone does not "know" about right side.
Even more, interaction points do not "see" each for quite some time

H. Satz, Nucl. Phys. A **642**, 130 (1998); hep-ph/9805418.

Percolation and formation or latent time

Time after collision

Collision points -> radiolocation



Interaction points at some moments start to "see" each other – and then – color medium forms !

Formation time is proportional to the mean distance between interaction points or ~$1/\sqrt{\rho(x,y)}$. Thus, projecting to the center of collision zone we get 0.7-0.8 fm/c

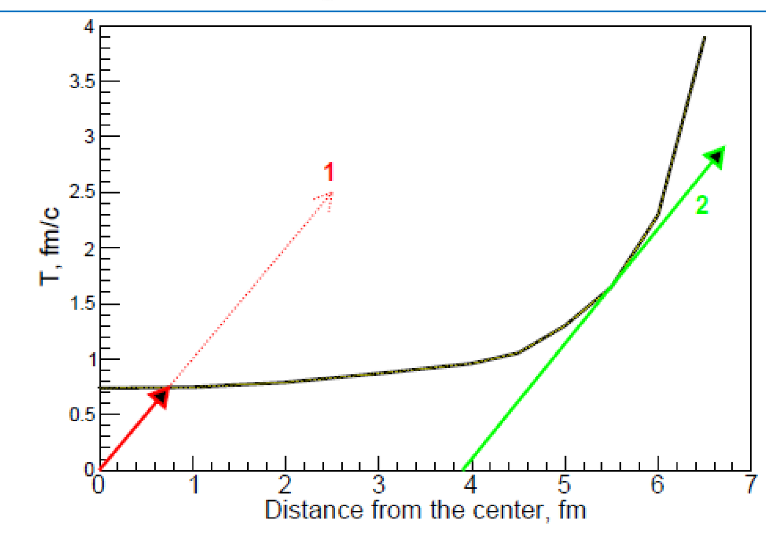


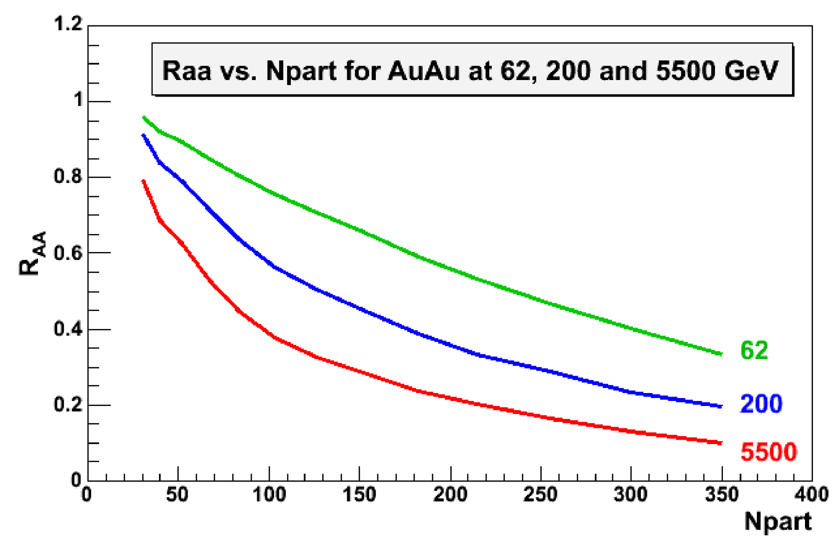
Figure 1: The value of formation time versus distance from the center of the colliding region, solid line, in most central AuAu collisions at RHIC. The arrows demonstrate world lines for two fast partons moving with the speed of light. The first parton was produced right in the center, the second – near the surface.

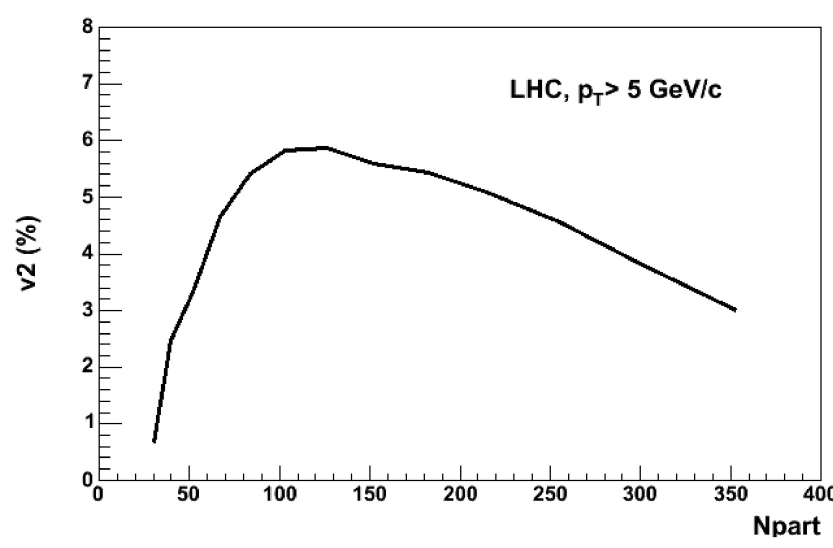
How to estimate **T** for different energies?
- Please remember that QCD color should be released in NN collision
- Thus, only part of total inelastic cross section (CS) should be considered, namely**, hard scattering**
- Please also remember - inelastic CS includes single and diffractive, plus soft NN scattering with just meson exchange
- Relativistic rise of CS is defined by parton **hard scattering** with color exchange
- At 200 GeV from 42 mb inelastic CS only 12 mb corresponds to **hard scattering**
- At LHC energies hard scattering CS is about 50 mb (subtracting diffractive and soft). It gives about factor 4 higher color density. Thus, following T ~$1/\sqrt{\rho(x,y)}$ we get T=2.3/ $\sqrt{4}$~ 1.2 fm/c

In 2007 there were our predictions for LHC ("Last call for predictions", *arxiv:0711.0974 [hep-ph], p119*)

Where with T=1.2 fm/c we get minimal and constant R_{aa}=0.1 and significant V_2, up to 6% at LHC

There assumptions were that:
- All high pt hadrons are produced in corona region **only**
- Central core is **opaque**, after time **T** all jets are stopped
- All considerations should be true for 'c' and probably 'b' quarks, including its V2





New LHC data show that Raa is not flat and rising with pt.
- So, there are two sources: from **corona** (see predictions) and from the **bulk**
- Let's calculate how much fast parton should loose to describe data and considering that at LHC hadron production follows power law ~p^{-6} .
- We found that corona and constant shift by Δp = 7 GeV describes data!

Predictions for V2 are valid at pt 10-15 GeV/c!
Because of delusion from the bulk V2 at higher p_t should go down with p_t, what is seen in experiment

How about Δp = 7 GeV and RHIC data?

At RHIC hadron production follows steep power law ~ p^{-8} .
Drop by Δp = 7 GeV here is too strong, this is why punch through hadrons start to be seen only at high p_t

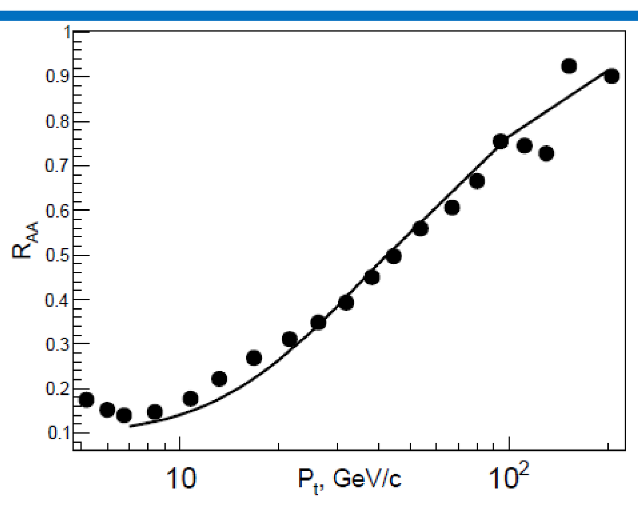


Figure 2: The dependence of single particle R_{AA} versus transverse momentum p_t. The points are data from the CMS collaboration for the most central 0-5% PbPb collisions [5]. The line is our estimation.

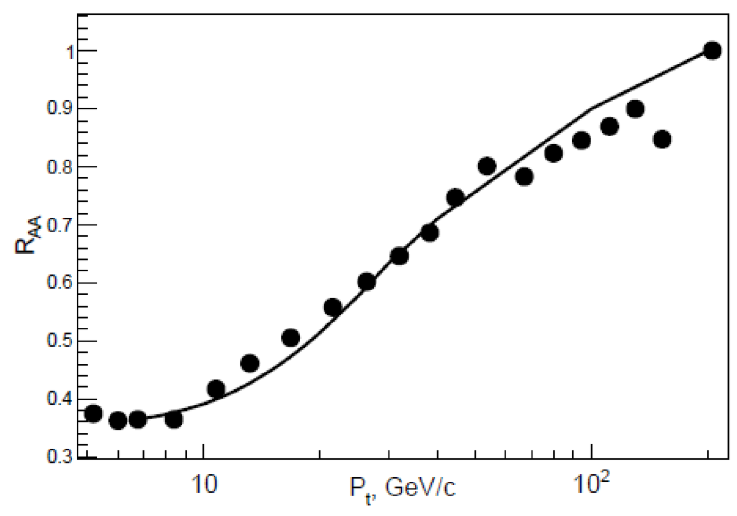


Figure 3: The same as Fig. 2 but for centrality 30-50%.

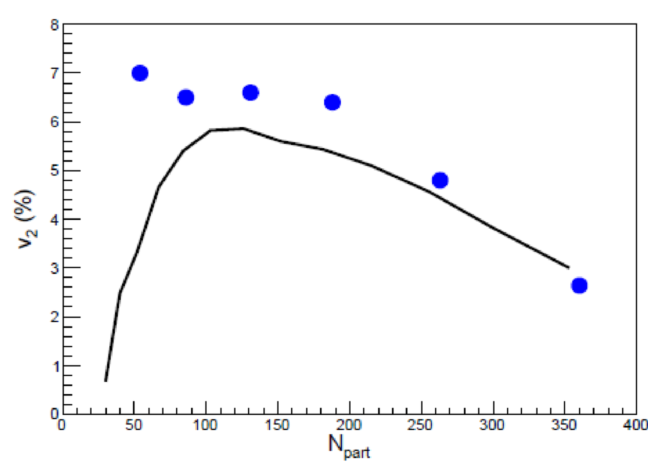


Figure 5: Dependence of azimuthal asymmetry parameter v_2 versus number of participant nucleons, N_{part}. Solid line is our prediction from ref. [3], points are CMS data at p_t=15 GeV/c [7].

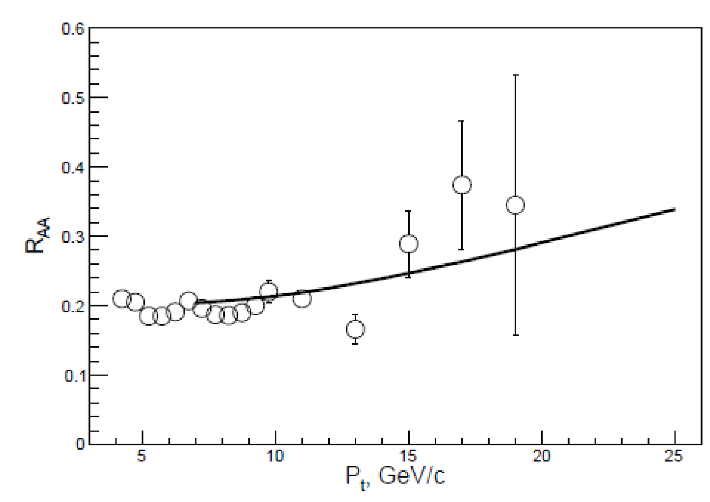


Figure 4: Re-estimation of PHENIX data for π^0 R_{AA} in 0-10% centrality bin [6] by using the same parton energy loss of 7 GeV as at LHC energy.

V.S. Pantuev, JETP Letters 105 (2017), 631 arXiv:1703.09021

Could value of 7 GeV be attributed to parton binding energy in QGP in analog to nucleon binding in nucleus?