Bulk-medium Properties in Relativistic Nuclear Collisions

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Correlation measurements with hadron $p_t < 2$ GeV/c in Au-Au collisions at 130 GeV has provided qualitatively new information about heavy ion collisions [1]. We now present a broad survey of two-particle number and transverse-momentum correlations from Au-Au collisions at 62, 130 and 200 GeV which probe dynamical properties of the dissipative bulk medium. Charge-independent number correlations on transverse rapidity reveal the temperature/velocity structure resulting from parton dissipation.

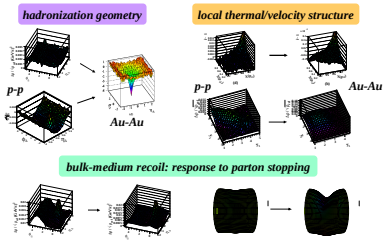
Transverse-momentum correlations on pseudorapidity and azimuth suggest that the bulk medium recoils collectively in response to parton stopping. Charge-dependent number correlations reveal qualitative change of hadronization geometry with centrality: from 1D string fragmentation in p-p to 2D bulk fragmentation in Au-Au collisions.

[1] J. Adams et al. (STAR Collaboration), nucl-ex/0406035, nucl-ex/0408012, nucl-ex/0411003.

Properties of the Bulk Medium

we consider three aspects of bulk-medium dynamics

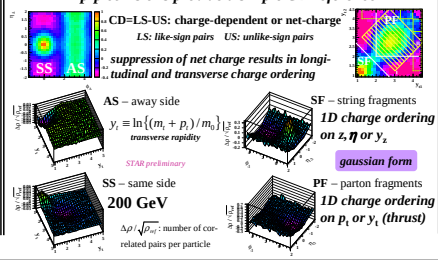
hadronization geometry — local thermal/velocity structure



bulk-medium recoil: response to parton stopping

hadronization geometry — p-p CD Correlations – 200 GeV

p-p collisions provide a simple CD reference



CD=LS-US: charge-dependent or net-charge
LS: like-sign pairs US: unlike-sign pairs

suppression of net charge results in longitudinal and transverse charge ordering

AS – away side

$y_t \equiv \ln\{(m_t + p_t)/m_0\}$ *transverse rapidity*

SS – same side

$\Delta\rho/\sqrt{\rho_{ref}}$: number of correlated pairs per particle

SF – string fragments

1D charge ordering on z, η or y_z

gaussian form

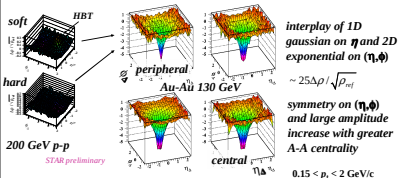
PF – parton fragments

1D charge ordering on p_t or y_t (thrust)

Au-Au CD Correlations – 130 GeV

Au-Au collisions reveal dramatic CD changes

large amplitude increase, change to symmetric angular correlations suggest change of hadronization geometry to 2D charge ordering



interplay of 1D gaussian on η and 2D exponential on (η,φ)

$\sim 25\Delta\rho/\sqrt{\rho_{ref}}$

symmetry on (η,φ) and large amplitude increase with greater A-A centrality

$0.15 < p_t < 2$ GeV/c

exponential form suggests hadron attenuation in an opaque medium

J. Adams et al. (STAR), *nucl-ex/0406035*

Dynamical properties of the bulk medium are studied with number and p_t correlations

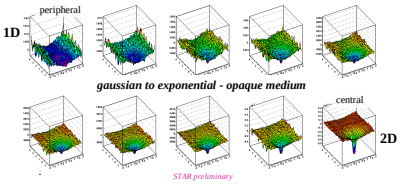
what is the geometry of the hadronization process? what is the local velocity structure of the medium in response to parton dissipation (bremsstrahlung)?

what is the collective response of the medium to parton stopping? each question can be addressed with two-particle number or p_t correlations

Au-Au CD Correlations – 62 GeV

1D string fragmentation evolves to 2D hadronization

net-charge fluctuations integrate these negatuve autocorrelations



gaussian to exponential - opaque medium

correlation attenuation by rescattering: exponential peak

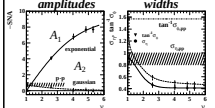
Compare to predictions of strong 'suppression' of net-charge fluctuations

hadronization geometry — Interpretation

Au-Au results inconsistent with p-p superposition

Au-Au CD correlations dominated by hadronization of a bulk medium

amplitudes *widths*

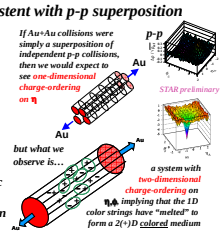


dramatic width reduction

A_1: *2D exponential – large amplitude dominates central Au-Au collisions*

A_2: *1D gaussian – small amplitude disappears in central collisions*

If Au+Au collisions were simply a superposition of independent p-p collisions, then we would expect to see one-dimensional charge-ordering on η



hadronization geometry: 1D for longitudinal string fragments → 2D for A-A bulk medium

Low-Q^2 partons probe the Au-Au Medium

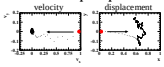
what is the local velocity structure of the QCD medium?

Brownian probe in dissipative medium: observable, yet sensitive to medium structure

Langevin equation

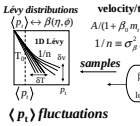
$$\dot{\vec{v}}(t) = -\frac{1}{\tau}\vec{v}(t) + \vec{a}_{stoch}(t) + \vec{a}_{mcs}(t)$$

classical point particle



local thermal/velocity structure: response to QCD probe dissipation

Lévy distributions $\langle p_t \rangle \leftrightarrow \beta(\eta,\phi)$



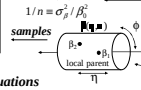
velocity/temp distribution $\beta(\eta,\phi)$

$A/(1+\beta_0 m_t/n)^n$

$1/n = \sigma_\beta^2/\beta_0^2$

1D β distribution

samples



two-point β correlations?

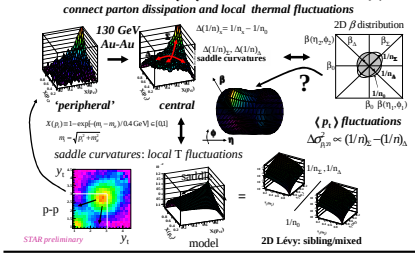
WMAP CMB survey

$\langle p_t \rangle$ *fluctuations*

Two-particle correlations on $p_t \otimes p_t$ and $y_t \otimes y_t$

saddle curvatures on $p_t \otimes p_t \leftrightarrow$ T/v correlations on (η,φ)

connect parton dissipation and local thermal fluctuations

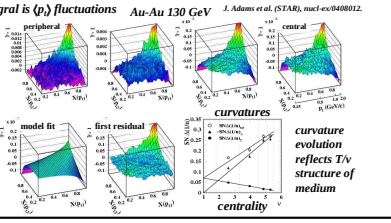


Number Correlations on $p_t \otimes p_t$

saddle curvatures track changing parton dissipation

transport from higher to lower p_t evolves with Au-Au centrality; saddle shape consistent with local temperature fluctuations

integral is $\langle p_t \rangle$ fluctuations Au-Au 130 GeV J. Adams et al. (STAR), *nucl-ex/0408012*.

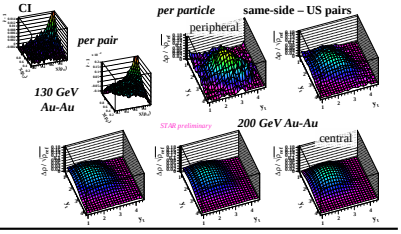


curvature evolution reflects T/v structure of medium

Number Correlations on $y_t \otimes y_t$

evolution of parton fragmentation with Au-Au centrality

first observation of two-particle fragment distributions in Au-Au

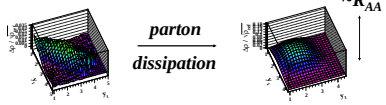


local thermal/velocity structure

Interpretation

saddle curvatures on $p_t \otimes p_t \leftrightarrow$ T/v correlations on (η,φ)

- Low-Q^2 partons as Brownian probes
- Temperature/velocity structure on (η,φ)
- Number correlations on $p_t \otimes p_t$, $y_t \otimes y_t$ in Au-Au reveal medium response to *parton dissipation*
- Structure evolves from parton fragmentation to local temperature variations (like CMB survey)



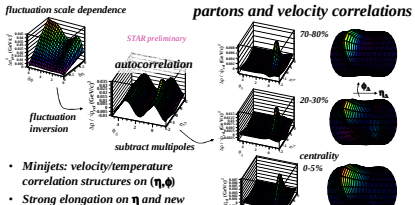
bulk-medium recoil

$\langle p_t \rangle$ Fluctuations and p_t Correlations

p_t autocorrelations from fluctuation scale dependence

inversion of $\langle p_t \rangle$ fluctuations → velocity structure resulting from low-Q^2 partons

fluctuation scale dependence *partons and velocity correlations*



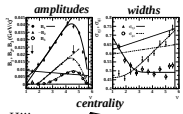
- *Minijets: velocity/temperature correlation structures on (η,φ)*
- *Strong elongation on η and new negative same-side structure*

p_t Correlations: Model Fits

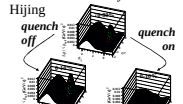
strong variation of amplitudes and widths with centrality

Hijing fails to describe structure, slowly-varying with centrality

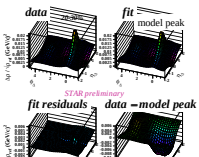
amplitudes *widths*



Hijing *quench off* *quench on*

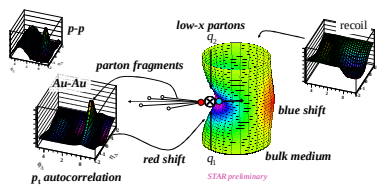


subtract same-side model peak to reveal negative structure beneath → red shift of local p_t spectra



Recoil Response to Parton Stopping

red shift: particle production from a recoiling source

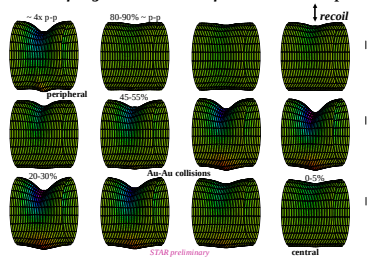


- *Medium response to minimum-bias parton stopping*
- *Momentum transfer to medium*
- *Velocity structure of medium*
- *Medium recoil observed via same-side p_t correlations*

bulk-medium recoil

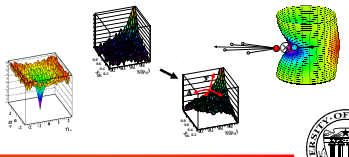
Same-side Medium Recoil

evolution of negative correlation follows same-side peak



Summary

- *Net-charge correlations reveal changing dimension of hadronization geometry – large-amplitude correlations*
- *Number correlations on p_t, y_t reveal medium response to parton dissipation – thermal/velocity structure on (η,φ)*
- *p_t correlations on (η,φ) inferred from $\langle p_t \rangle$ fluctuations reveal recoil response of the medium to parton stopping*



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