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Correlations & Fluctuations for LHCB

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Support:
U.S. DOE Office of Sci: DE-FG02-03ER41259
U.S. NSF CDI program: NSF PHY-1513864

What kind of correlations?

Conservation laws: Charge, momentum, energy
Not HBT/femtoscopy
Stick to 2-body: $C(p_1,p_2)$

What do you learn?

Susceptibilities, fluctuations: connection to lattice
Equilibration & stopping dynamics
Jet dynamics

Conservation ⇒ Correlation

$$\delta\rho(r) \equiv \rho(r) - \overline{\rho}(r)$$

Any coordinate, e.g. rapidity

$$C(R,r) = \langle \delta\rho(R)\delta\rho(R+r) \rangle$$

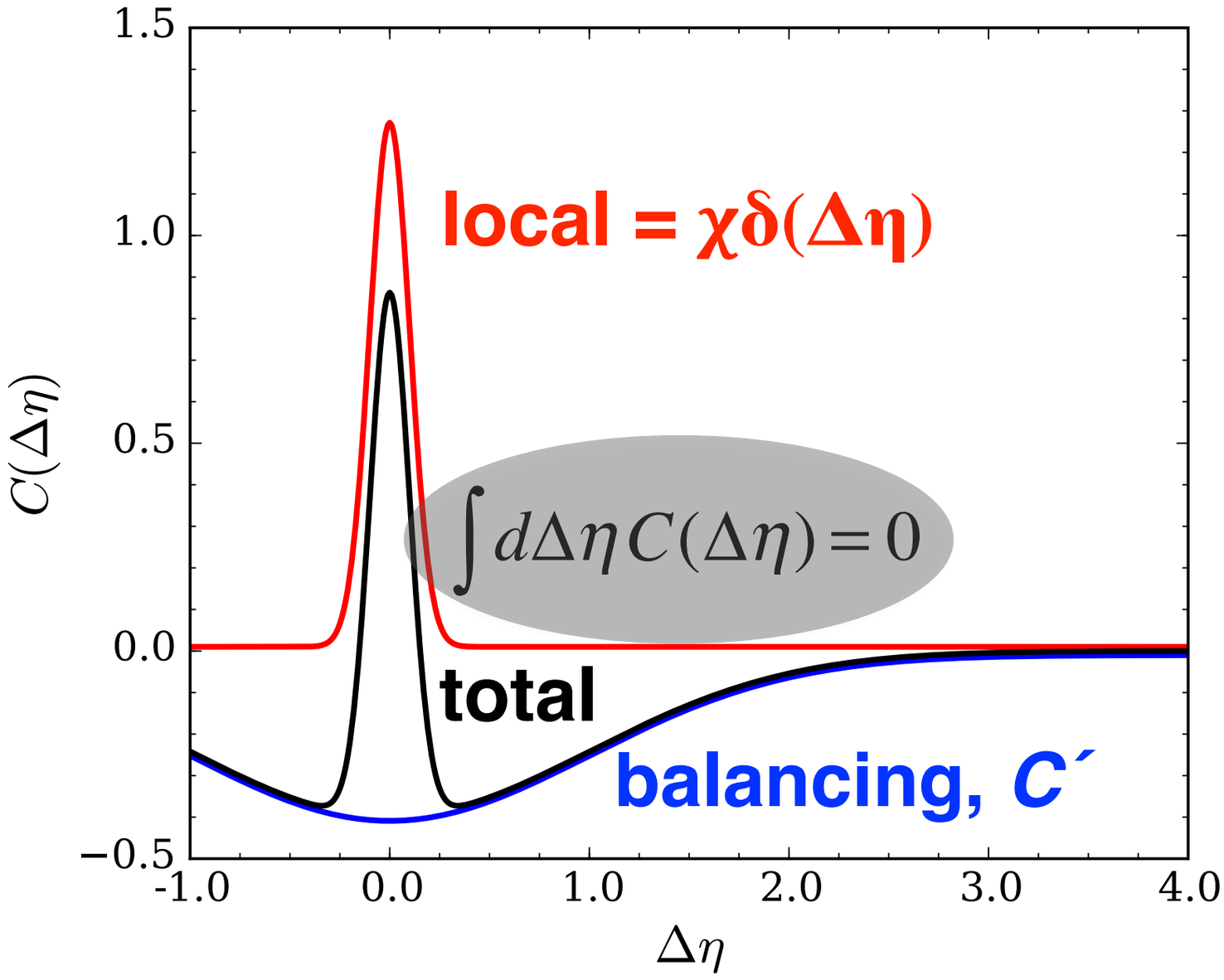
$$\int dr\, C(R,r) = 0$$

Example:

$$C(\eta,\Delta\eta) = \langle (N_+(\eta) - N_-(\eta))(N_+(\eta+\Delta\eta - N_-(\eta+\Delta\eta)) \rangle$$
$$- \langle (N_+(\eta) - N_-(\eta)) \rangle \cdot \langle (N_+(\eta+\Delta\eta - N_-(\eta+\Delta\eta)) \rangle$$

Usually consider *C(Δη)*

Susceptibilities & Correlations

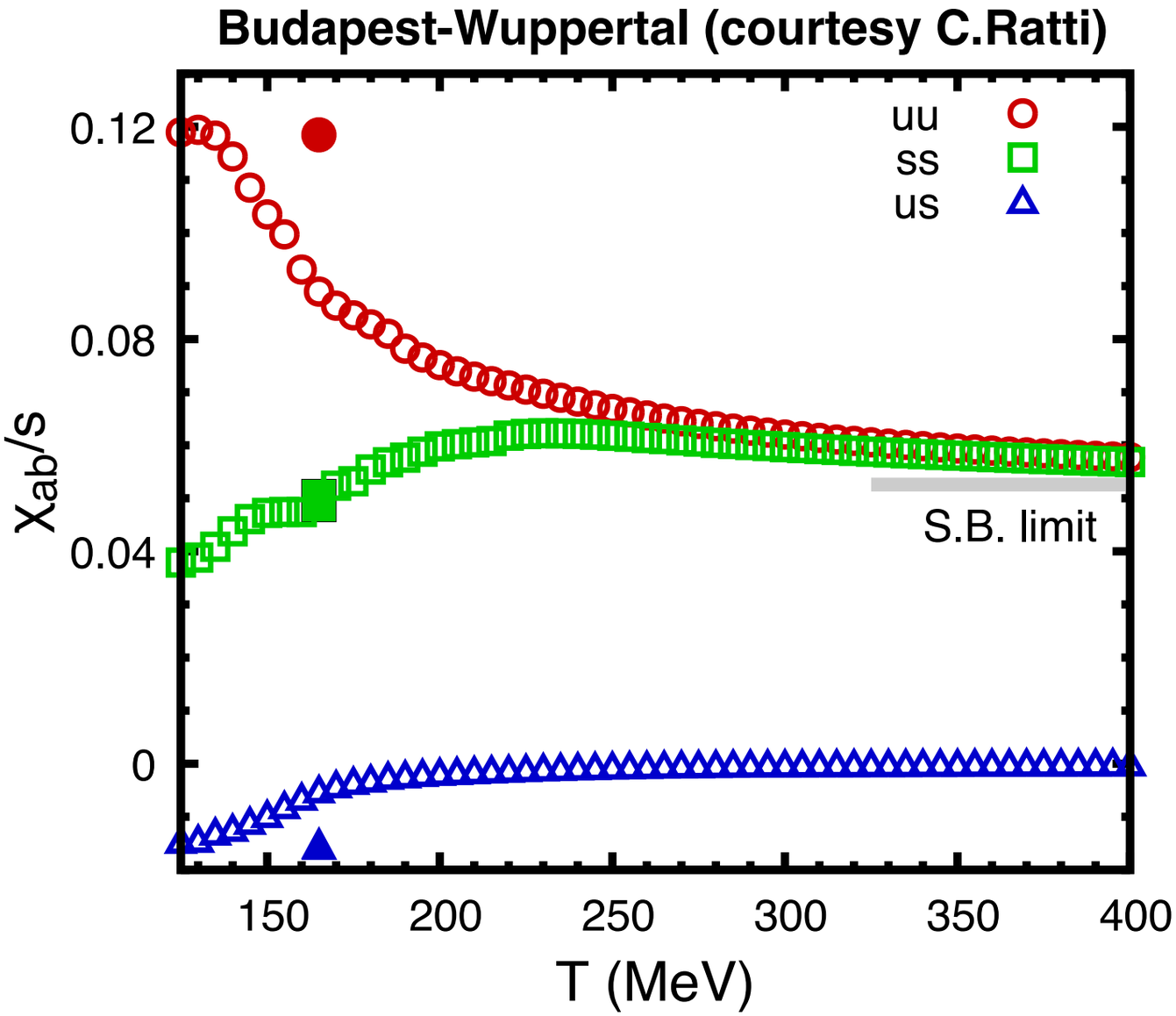


In equilibrated system (lattice) χ is charge fluctuation

$$\chi = \frac{1}{V}\langle (Q-\bar{Q})(Q-\bar{Q})\rangle$$

In collision fluctuation is zero!

Lattice Susceptibilities



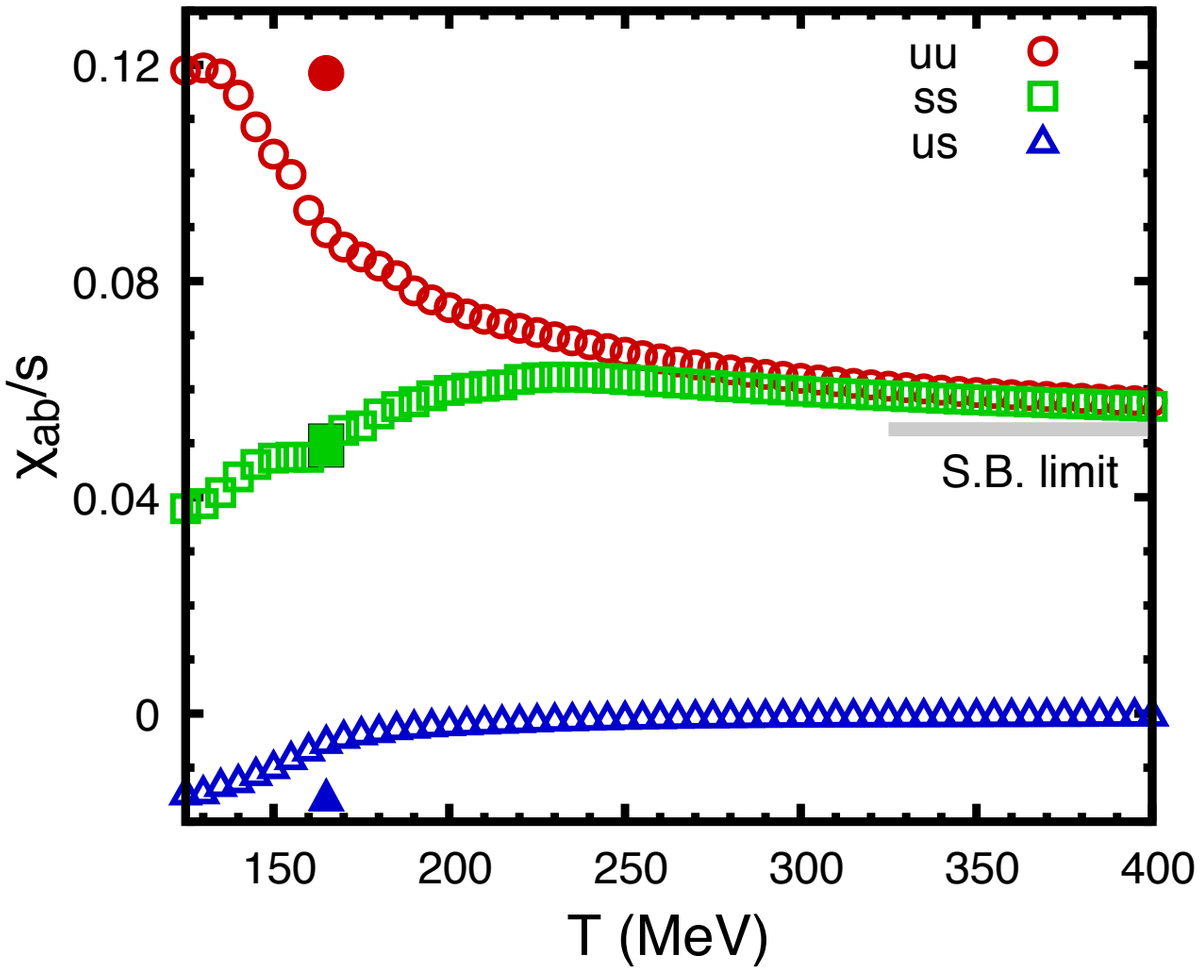
$T \gg T_c$: correlation between quark and itself

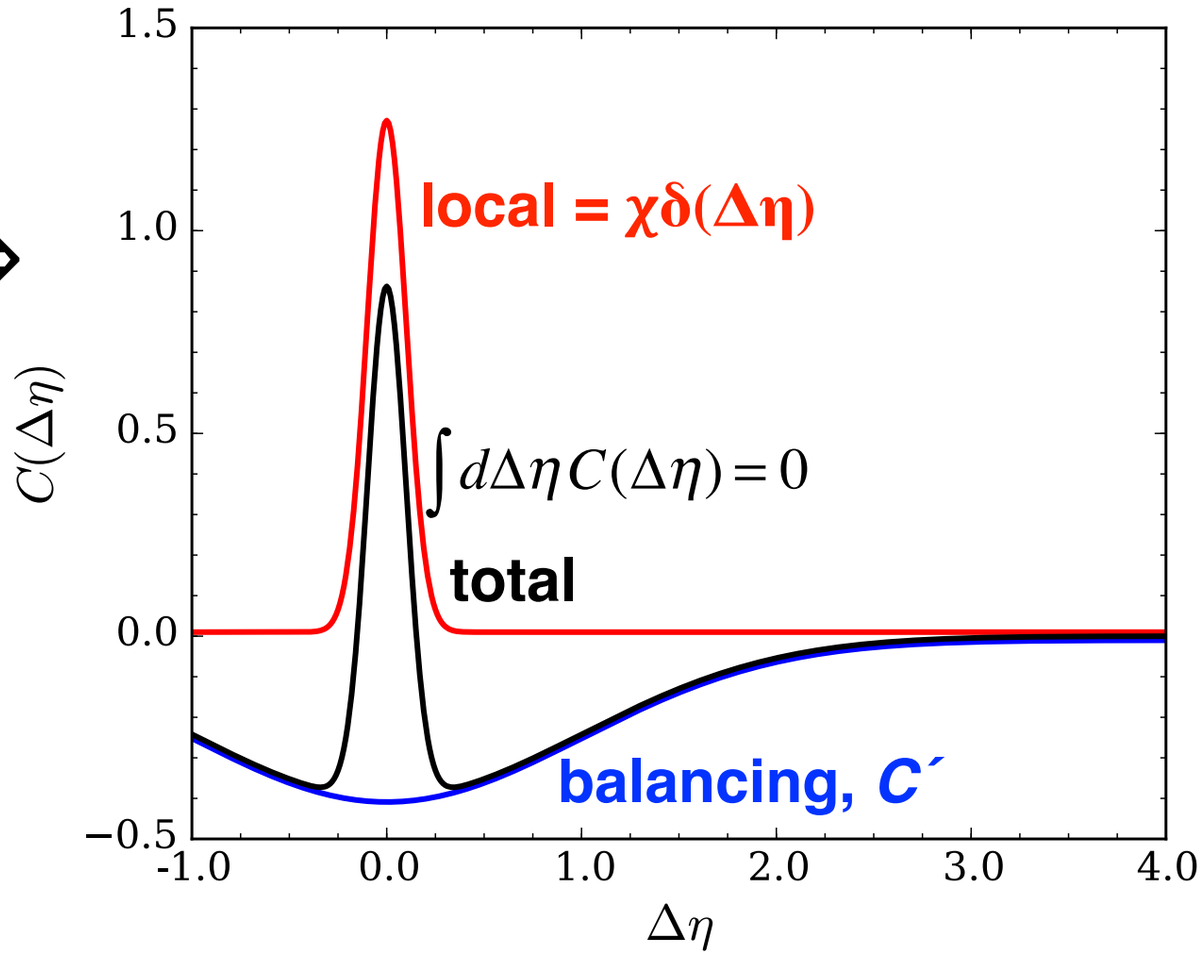
$$\chi_{uu} = n_u + n_{\bar{u}}$$

$T \ll T_c$: correlation within hadron

$$\chi_{uu} = \sum_h n_h q_{h,u}^2 \,,\; \chi_{us} = \sum_h n_h q_{h,u} q_{h,s} \;\cdots$$

Susceptibilities to Correlations





You measure *C´(Δη,t→∞)*

***C´* has 2 contributions:**

1. Initial creation of QGP (τ<1 fm/c)

2. slow growth plus hadronization surge

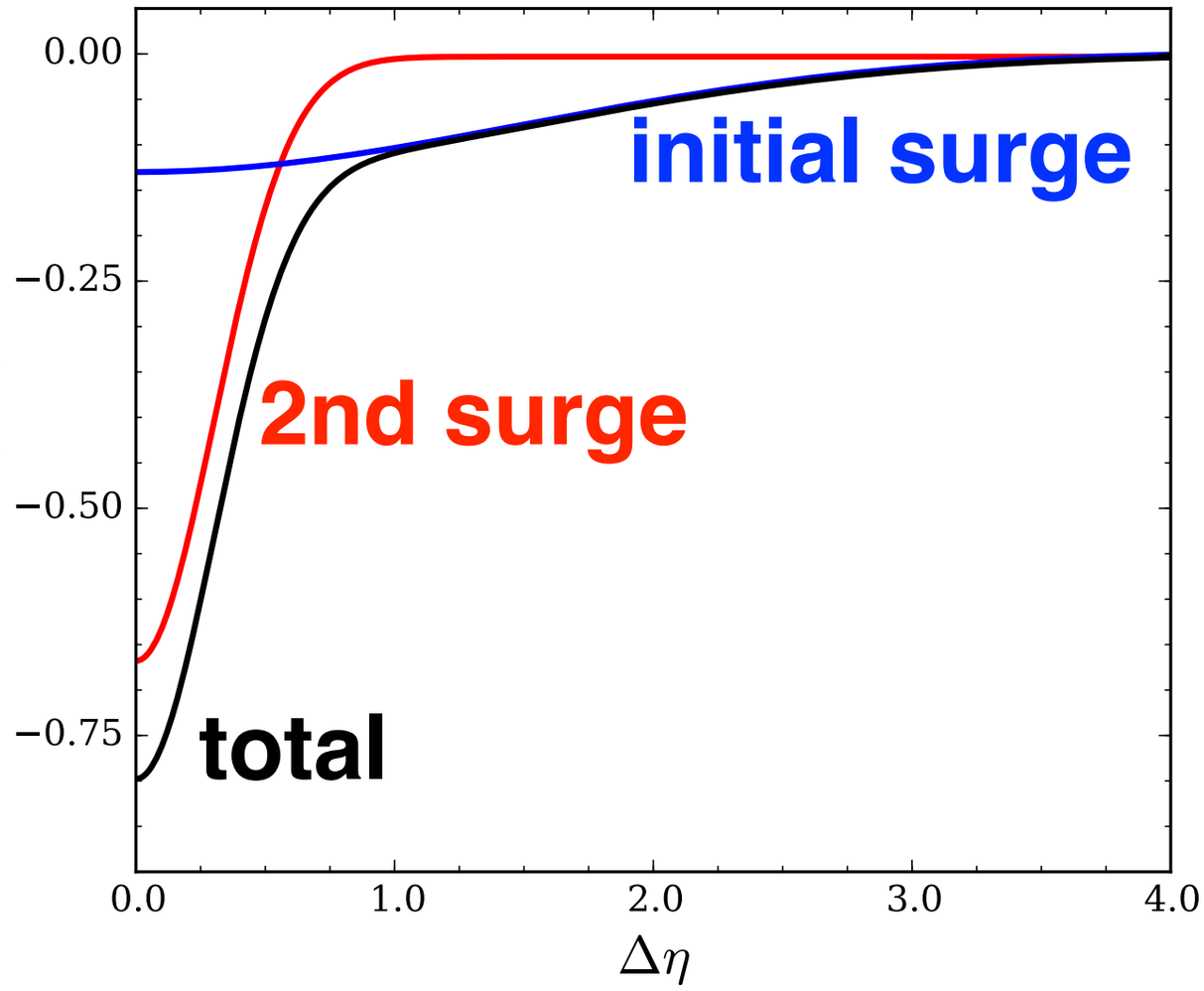
Strengths from lattice

Schematic Model

Assume 2 surges:

$$C'_{ab}(\Delta\eta,\tau_h) = -\chi_{ab}^{(\mathrm{QGP})}\frac{e^{-\Delta\eta^2/2\sigma^2_{(\mathrm{QGP})}}}{(2\pi\sigma^2_{(\mathrm{QGP})})^{1/2}}$$

$$-(\chi_{ab}^{(\mathrm{had})}-\chi_{ab}^{(\mathrm{QGP})})\frac{e^{-\Delta\eta^2/2\sigma^2_{(\mathrm{had})}}}{(2\pi\sigma^2_{(\mathrm{had})})^{1/2}}$$



Project to hadron species:

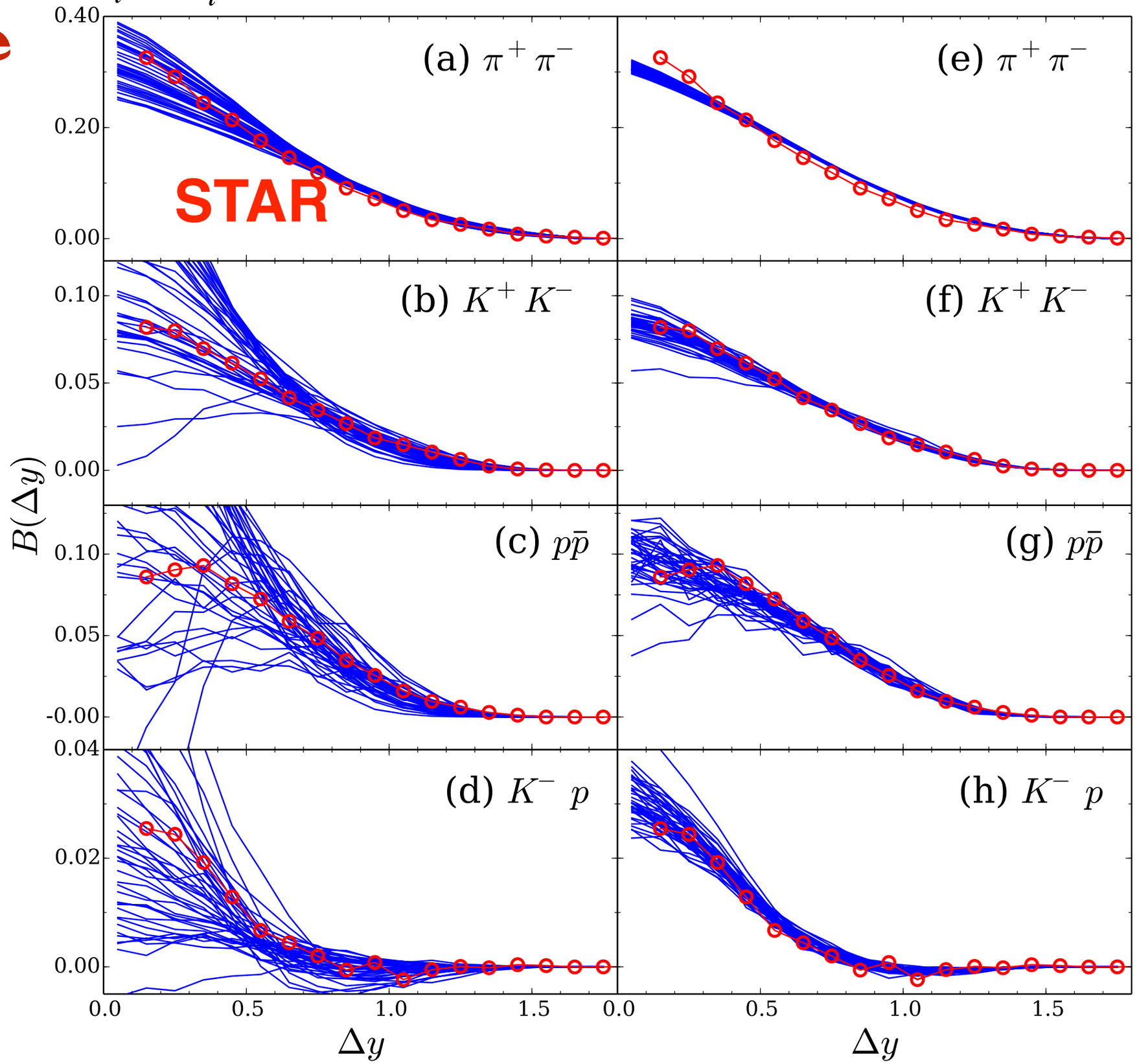
$$\delta n_h = \langle n_h \rangle \sum_b q_{ha}(\chi^{-1})_{ab}\delta\rho_b$$

Monte Carlo thermal smearing (blast wave) and decays

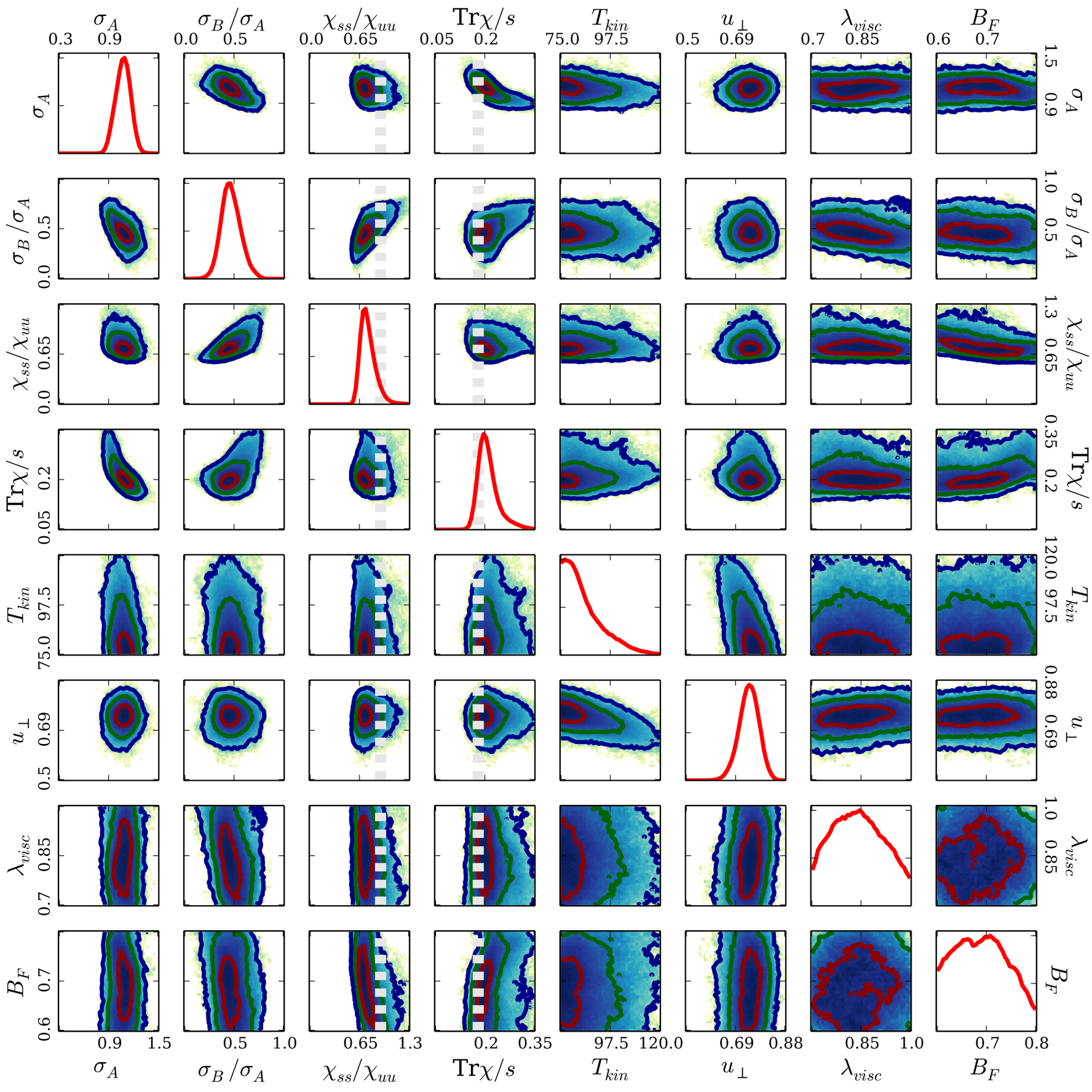
$$B_{ij}(\Delta y) = \frac{1}{n_i + n_{\bar{i}}} \left\langle [n_i(y) - n_{\bar{i}}(y)][n_h(y+\Delta y) - n_{\bar{h}}(y+\Delta y)] \right\rangle$$

Compare to STAR

broader KK and pK peaks requires 2 surges



7-Parameter Fit



Compelling evidence of chemically equilibrated QGP

Compelling evidence of chemically equilibrated QGP

X_{ss}/s

$(X_{uu}+X_{dd}+X_{ss})/s$

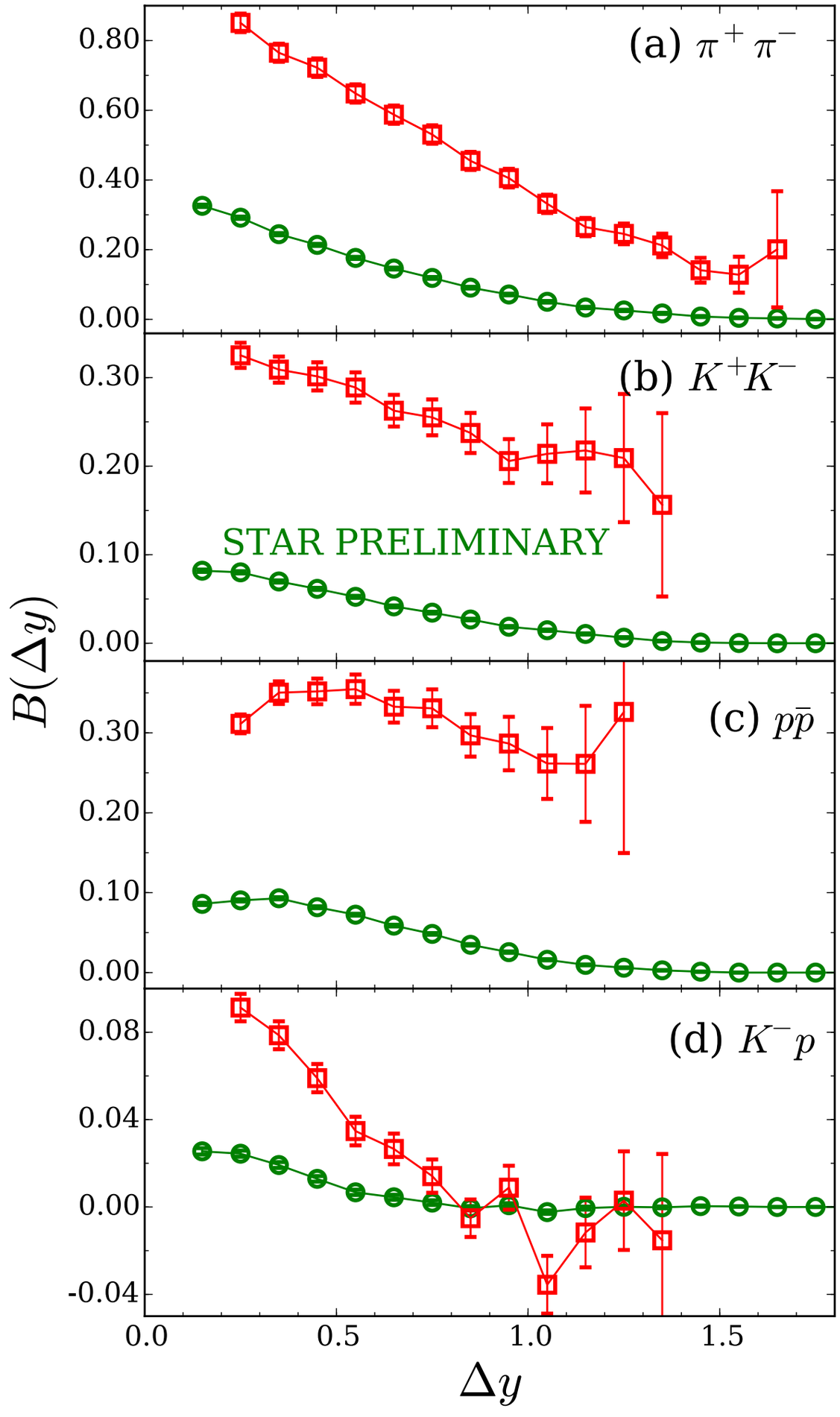
What we are working on

- **Microscopic model**
  - **— Local creation of balancing charge set by lattice**
  - **— Diffusion comes into play**
- **Extend to E_t, p_x,p_y**
- **More dynamical variables: ϕ,p_t, etc.**

What you can do

Acceptance
Acceptance
Acceptance!!!

For identified part.s
Δy max =
1.8 (STAR)
1.6 (ALICE)
2.5 (LHCB)



What you can do — and why

1. Measure for large Δy
   — understand early creation and diffusion
   —good even without particle ID
2. Measure for $\Delta\phi$, and correlate with Δy
   — determine diffusion constant

EXAMPLE

Consider pairs created early:
separation in Δ*y* from production mechanism & diffusion

separation in Δ*ϕ* only from diffusion.

1. **Isolate early created pairs by looking at large Δy**
   — **Plot B(Δ*ϕ*) to constrain diffusion**

2. **Analyze B(Δ*y*) for large Δ*y* to understand quark production**

What you can do — and why

1. Measure for large Δy
   — understand early creation and diffusion
   —good even without particle ID
2. Measure for $\Delta\phi$, and correlate with Δy
   — determine diffusion constant
3. **Compare $B(\Delta\phi)$ in-plane vs. out-of-plane**
   — "background" to CME effect
4. **Repeat 1-3 for *pp* and *pA***
   — look for differences in early creation
   — test baryon-stopping pictures
5. **Finite baryon number (low beam E)**
   — novel behavior of susceptibilities
6. **Extend paradigm to E_t-E_t, P_x-P_x and P_y-P_y**