Event Structure at RHIC from p-p to Au-Au

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Agenda

- p-p *minbias* minijets probe A-A bulk medium
- $\langle p_t \rangle$ fluctuations: minijets as velocity structures
- Minijet *deformation* on (η,ϕ): parton-medium coupling
- Minijet dissipation: two-particle fragmentation function
- Net-charge correlations: 2D hadronization geometry

A summary of results from the
STAR Event Structure Working Group

p-p 1D Two-component Model

per-event p_t distribution

factorization hypothesis

soft hard

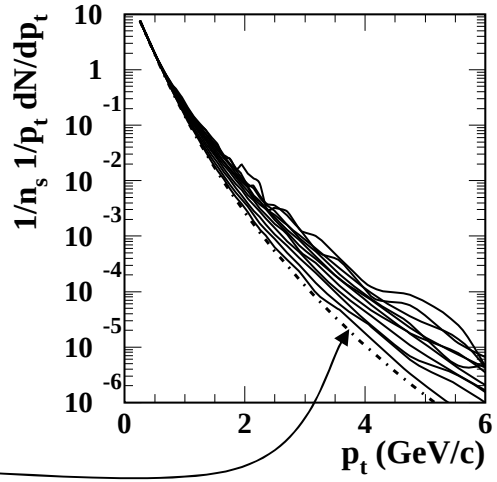
$$1/\,p_t\,dN/dp_t(p_t,n_{ch}) = n_s(n_{ch})\,S_0(p_t) + n_h(n_{ch})\,H_0(p_t)$$

integrates to n_{ch}

each integrates to 1

five-parameter model

normalized p_t distributions



$$n_{ch} = n_s(n_{ch}) + n_h(n_{ch})$$

linearity assumption:

$$n_h(n_{ch})/n_{ch} = \alpha(n_{ch} - n_0)$$

normalized p_t distribution

$$1/n_s(n_{ch}) \cdot 1/\,p_t\,dN/dp_t(p_t,n_{ch}) = S_0(p_t) + n_h(n_{ch})/n_s(n_{ch}) \cdot H_0(p_t)$$

p-p 1D Differential Analysis

full p_t distributions

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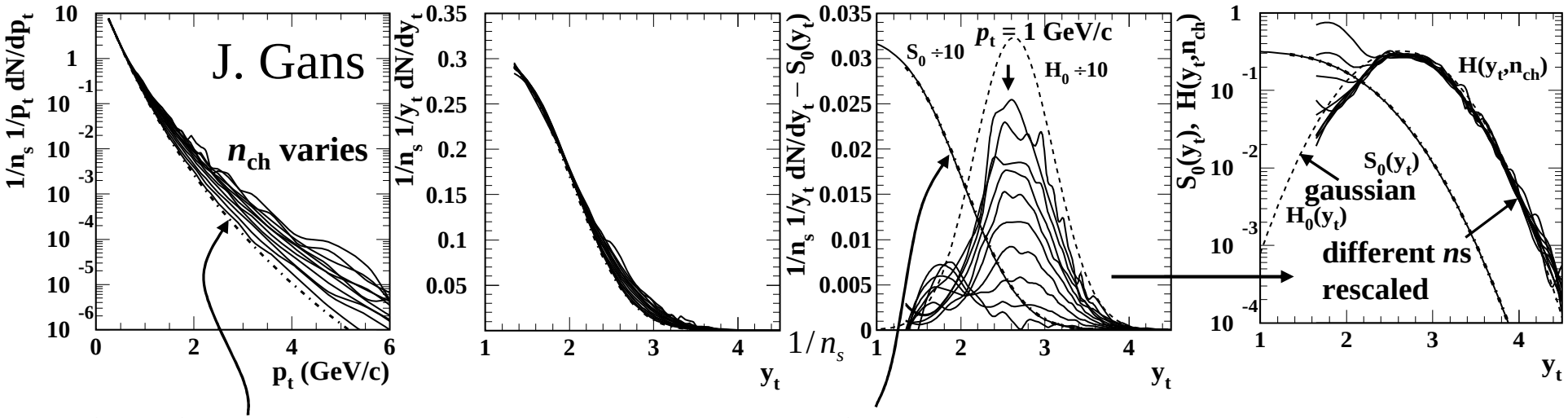
total – soft = hard (minijets)



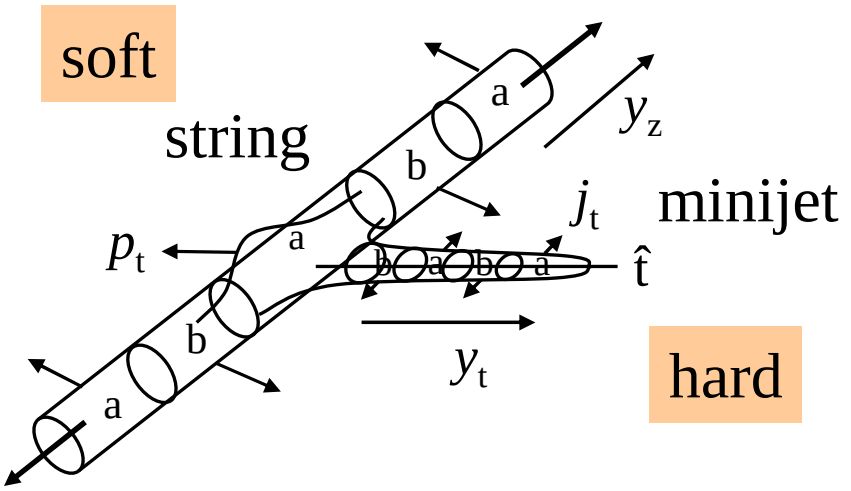
Soft reference S_0: Lévy on $m_t \rightarrow$ error function on y_t!

Lévy S_0:

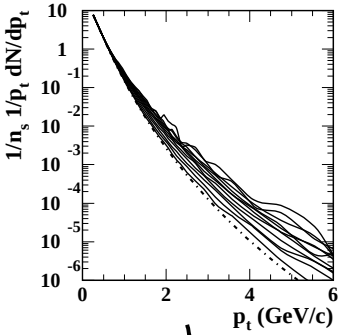
$$1/m_t\ dN/dm_t \equiv A/\{1+\beta_0(m_t-m_0)/n\}^n$$

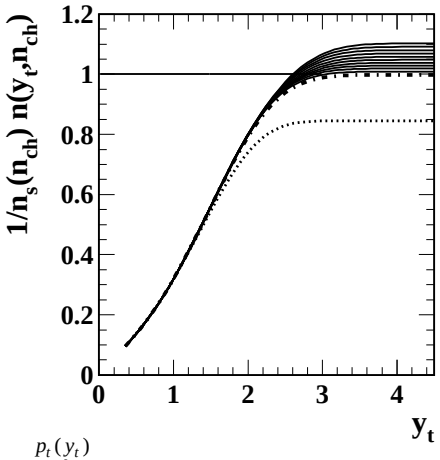
$$y_t \equiv \ln\left\{\sqrt{1+(p_t/m_0)^2}+p_t/m_0\right\}$$

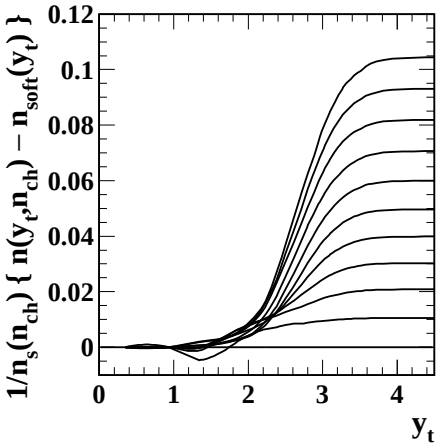
$$p_t/m_0 \equiv \gamma\beta_t$$

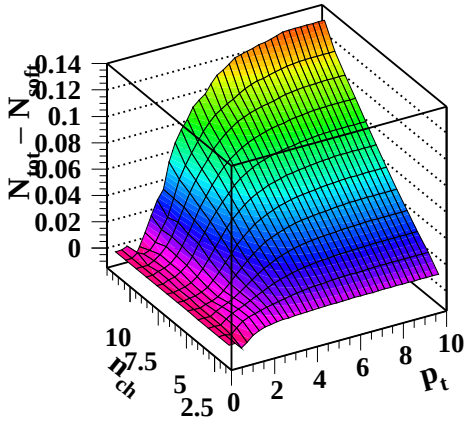


p-p 1D Direct Integration









$$1/n_s\ n(y_t,n_{ch}) = 1/n_s \int_0^{p_t(y_t)} dp_t'\ p_t' \cdot 1/p_t\, dN/dp_t(p_t',n_{ch})$$

$$1/n_s\ \{n(y_t,n_{ch}) - n_0(y_t)\} = n_h/n_s \int_0^{y_t} dy_t'\ y_t'\ H(y_t',n_{ch})$$

$$= \int_0^{y_t} dy_t'\ y_t' \cdot \{S_0(y_t') + n_h/n_s\ H(y_t',n_{ch})\}$$

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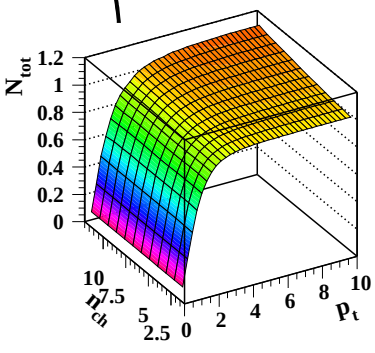
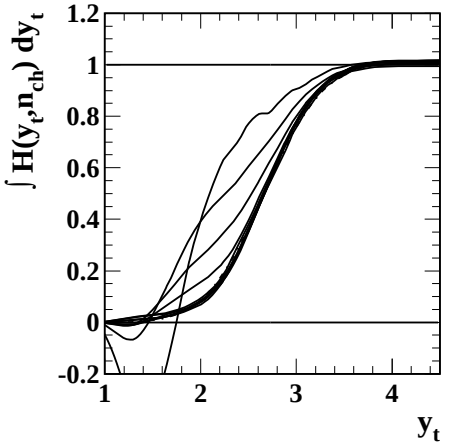
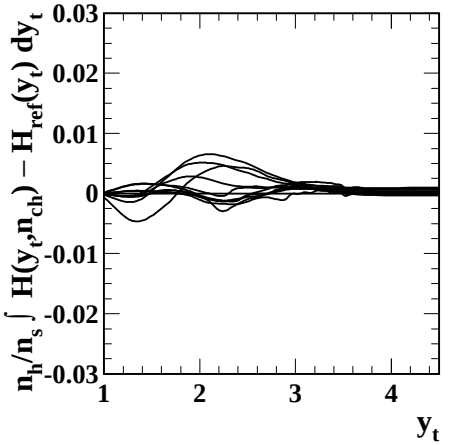






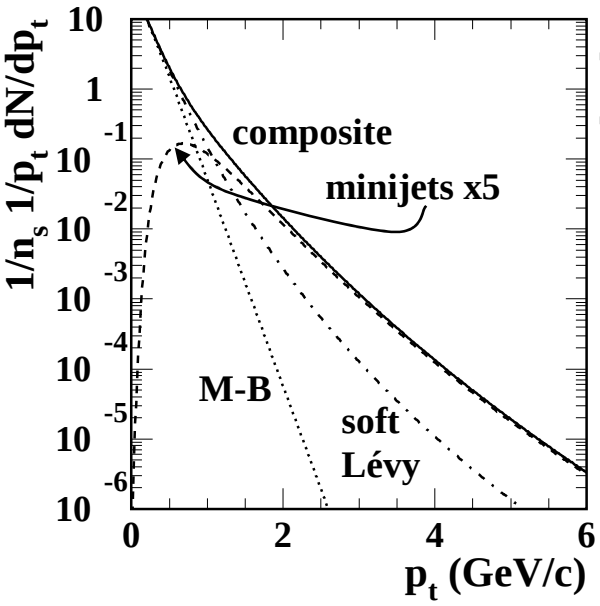
third component < 1% of S_0

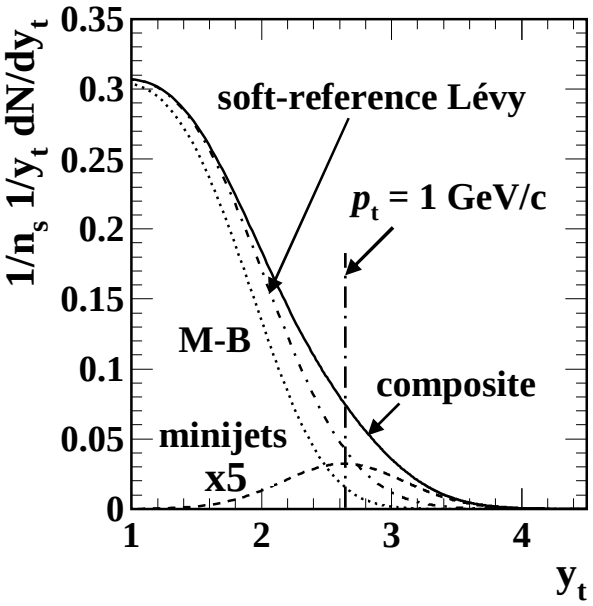
$$1/n_h\ \{n(y_t,n_{ch}) - n_0(y_t)\} = \int_0^{y_t} dy_t'\ y_t'\ H(y_t',n_{ch}) \approx \int_0^{y_t} dy_t'\ y_t'\ H_o(y_t')$$

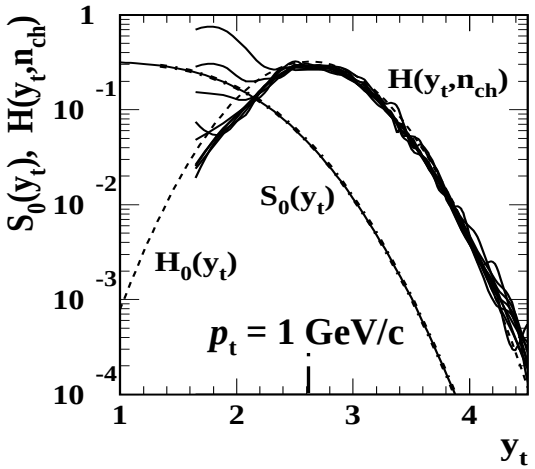
$$\int_0^{y_t} dy_t'\ y_t'\ \{S(y_t',n_{ch}) - S_0(y_t')\} = n_h/n_s \int_0^{y_t} dy_t'\ y_t'\ \{H(y_t',n_{ch}) - H_0(y_t')\}$$

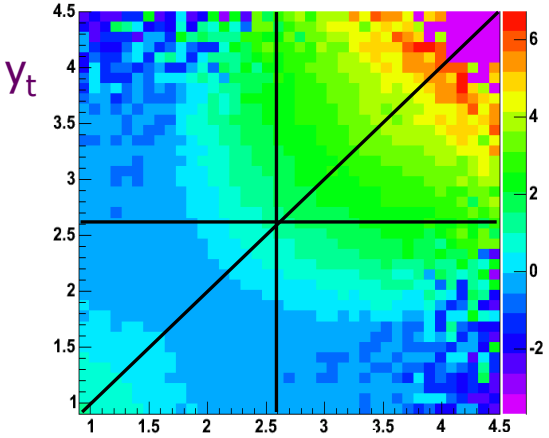
Minijet Fragments on p_t, y_t and $y_t \otimes y_t$

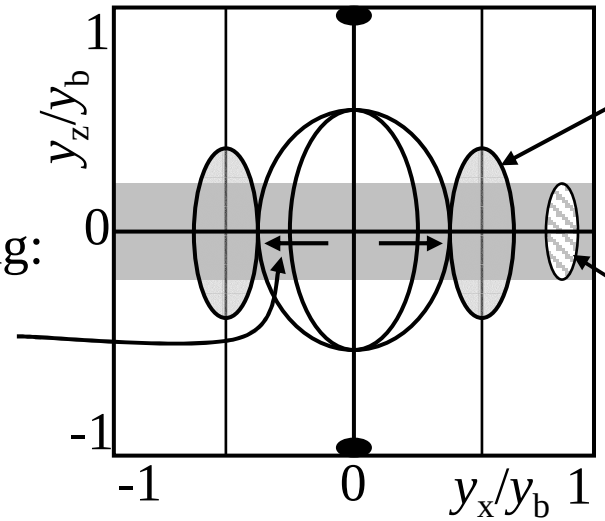
decomposing the p-p p_t distribution











minimum-bias minijets

STAR y_z acceptance

'high p_t'

p_t broadening: multiple soft-parton scattering

fragment correlations
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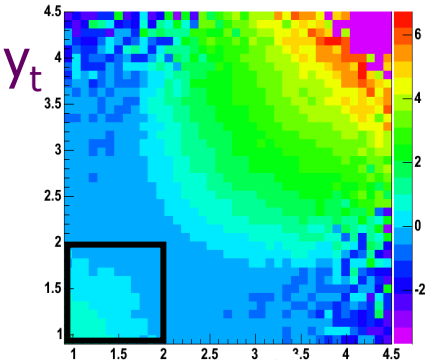
p-p Soft-sector n_{ch} Dependence

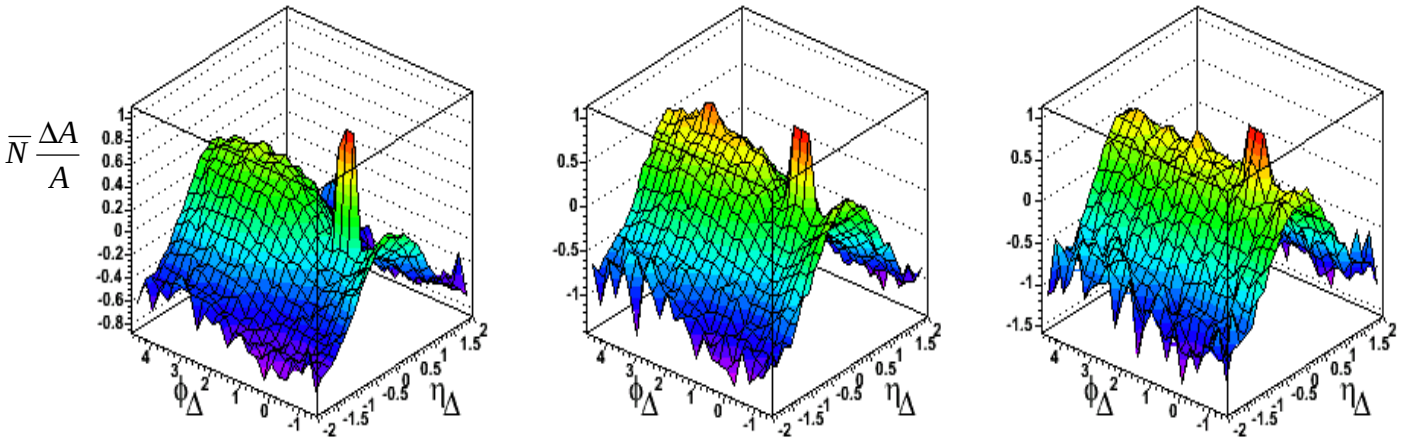
two-particle correlations



$p_t < 0.5$ GeV/c

accept only low-p_t particles

unlike-sign pairs



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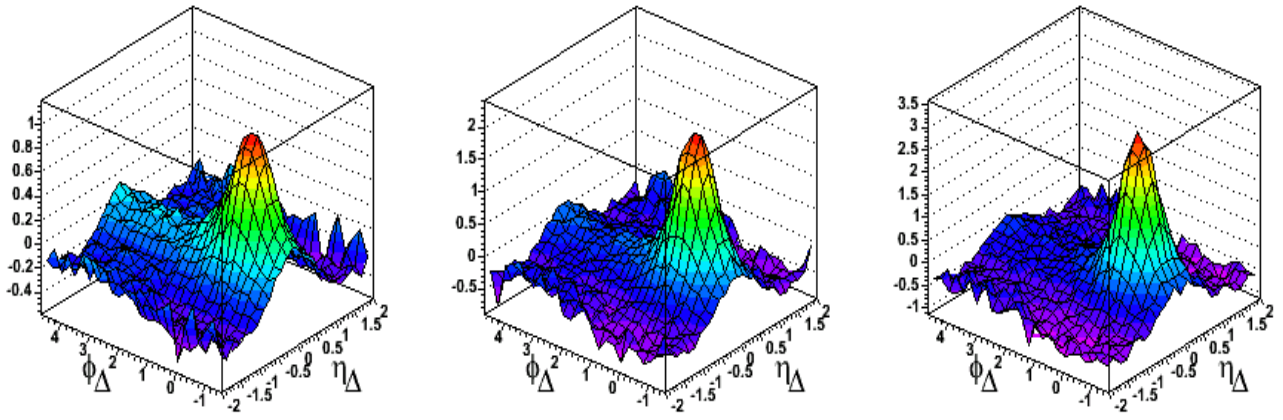
like-sign pairs



increasing N_{ch} ➔

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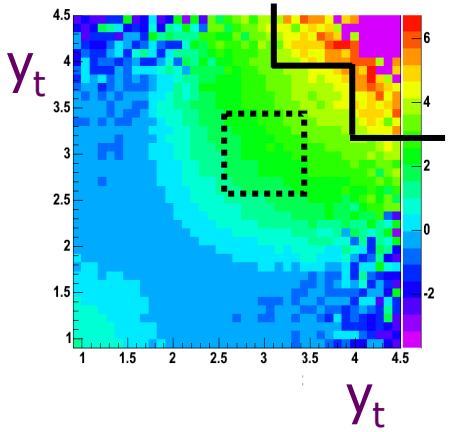
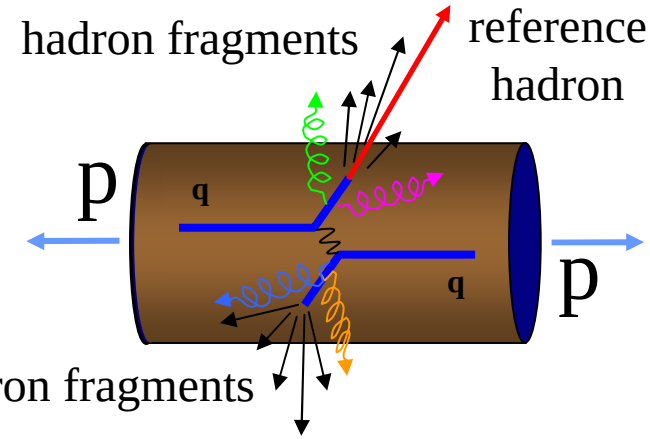
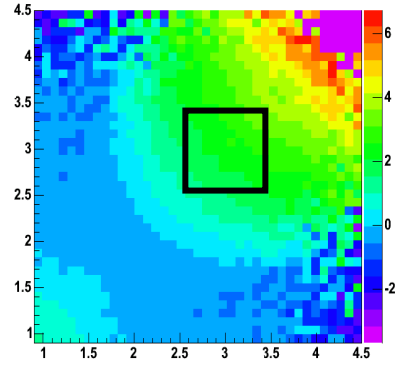
p-p Minijet Fragments

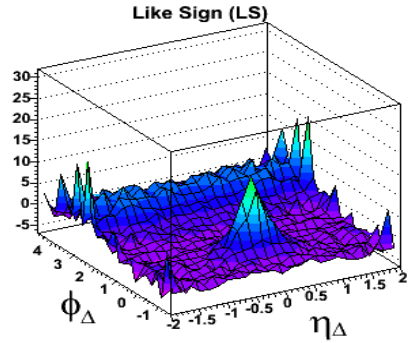


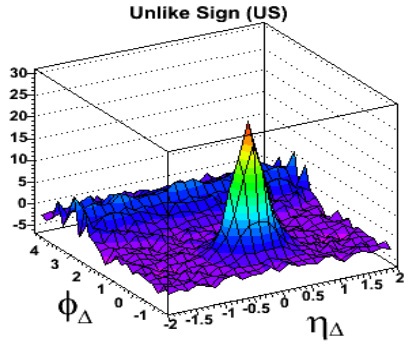
accept only high-p_t particles

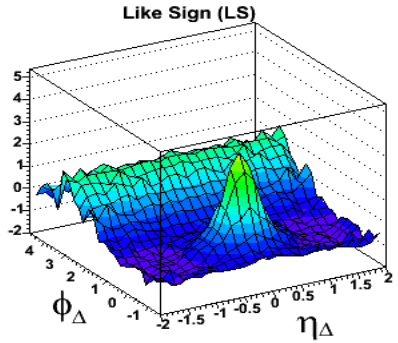


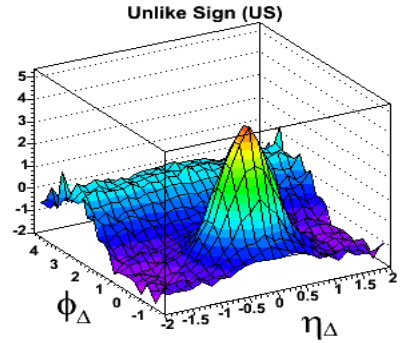


accept only medium-p_t particles









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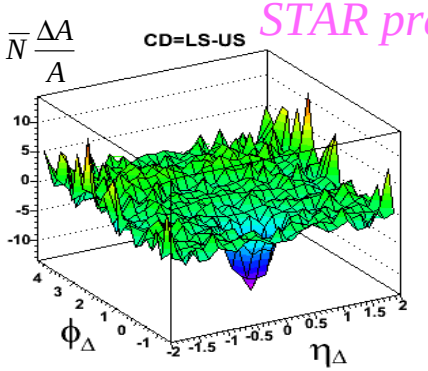
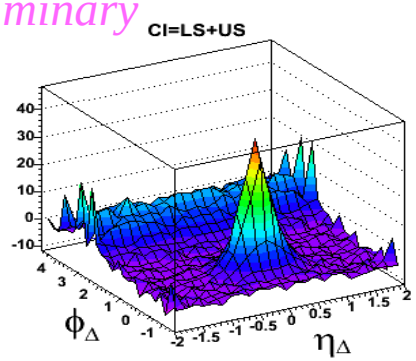
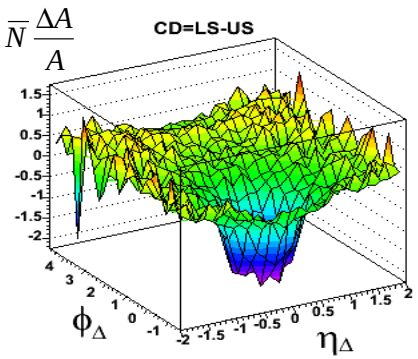
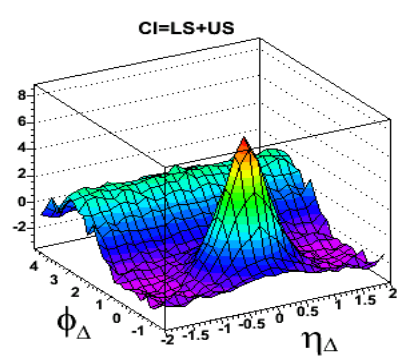
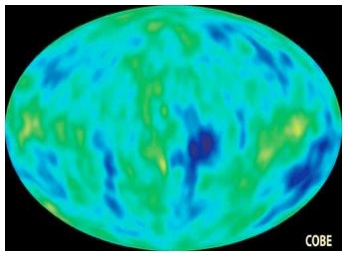






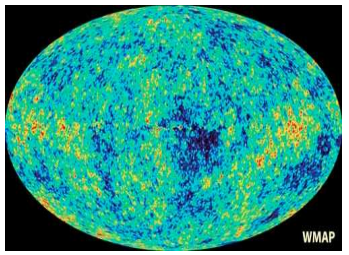


COBE

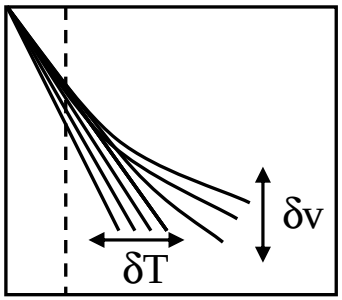


Au-Au $\langle p_t \rangle$ Fluctuations

WMAP

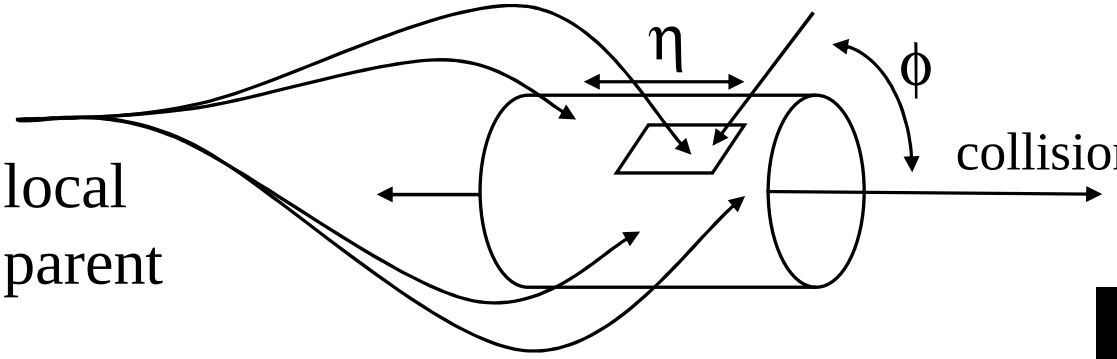


minijets in Au-Au collisions



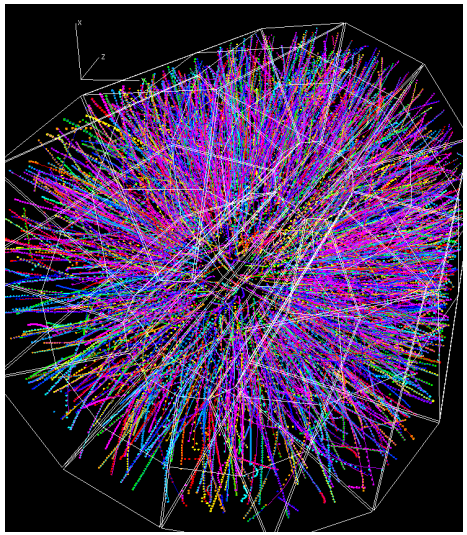
local parent

bin-wise fluctuation

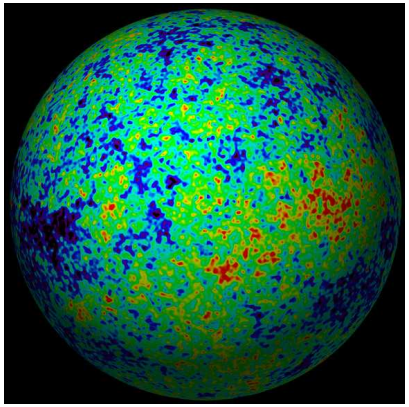


hadron p_t is drawn from *local parent*

1) local temperature variation δT
2) local velocity variation δv

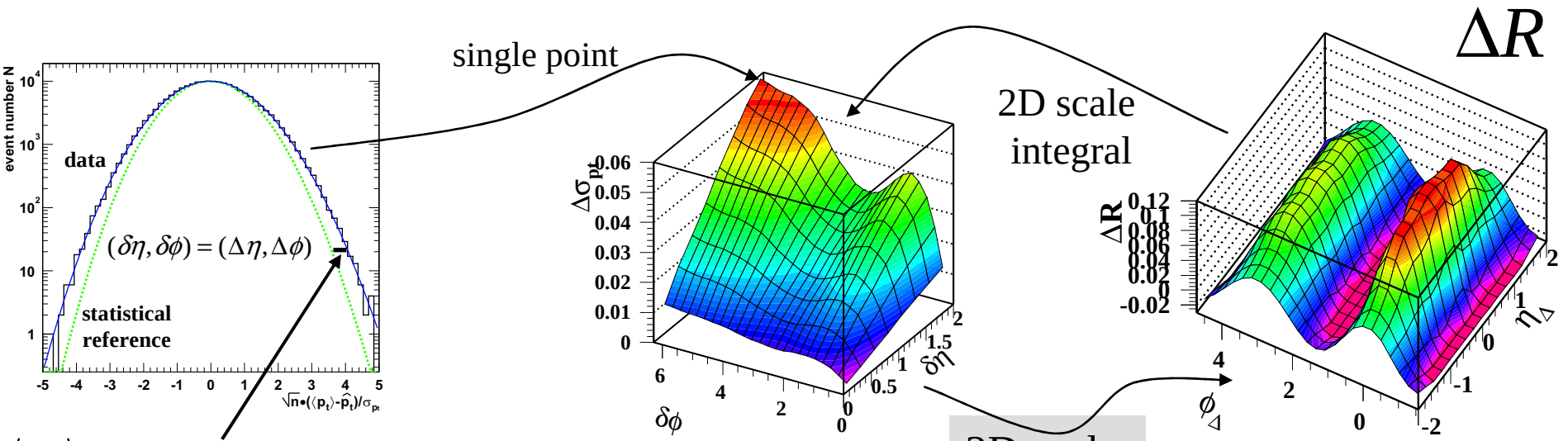


one Au-Au event



one bang

Fluctuations and Autocorrelations



$\langle p_t \rangle$ fluctuation excess

measure variance difference: $\Delta\sigma^2_{p_t:n} \equiv \overline{(p_k(\delta x) - n_k(\delta x)\hat{p})^2 / n_k} - \sigma^2_{\hat{p}_t}$

$$\Delta\sigma^2_{p_t:n}(m\varepsilon_\eta, n\varepsilon_\phi) = 4\hat{p}^2 \sum_{k=1}^{m} \varepsilon_\eta \sum_{l=1}^{n} \varepsilon_\phi \left(1 - \frac{k-1/2}{m}\right)\left(1 - \frac{l-1/2}{n}\right) \overline{\left\{ \frac{d^2\bar{n}}{d\eta_\Delta d\varphi_\Delta} \frac{\Delta A}{A}_{kl} (\varepsilon_\eta, \varepsilon_\phi) \right\}}^{\Delta R}$$

integral equation: invert variance difference to get ΔR

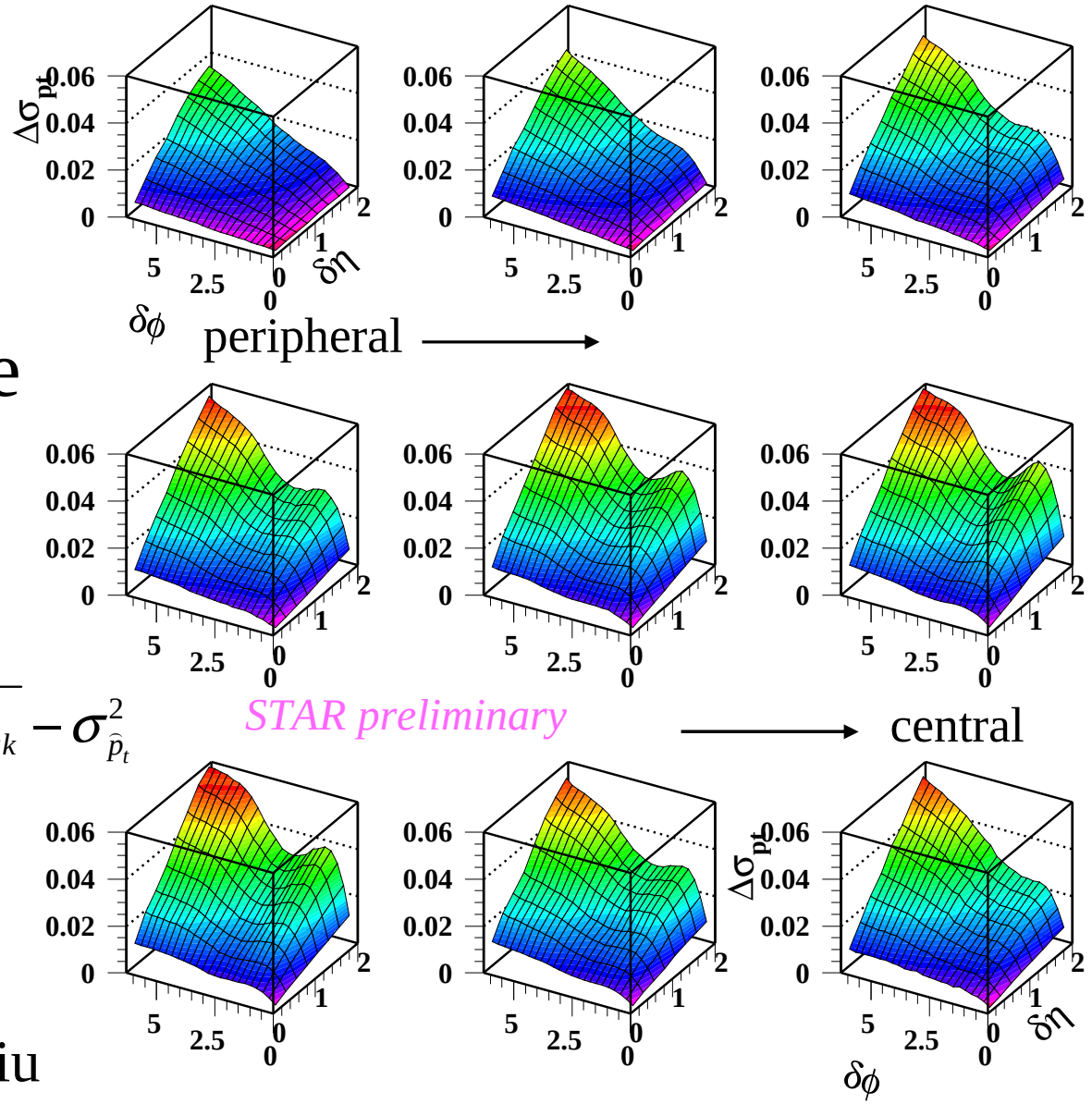
$\langle p_t \rangle$ Fluctuation Scaling

200 GeV Au-Au
centrality dependence

variance difference

$$\Delta\sigma^2_{p_t:n} \equiv \overline{(p_k(\delta x) - n_k(\delta x)\hat{p})^2 / n_k} - \sigma^2_{\hat{p}_t}$$

$$\equiv 2\sigma_{\hat{p}_t}\Delta\sigma_{p_t:n}$$

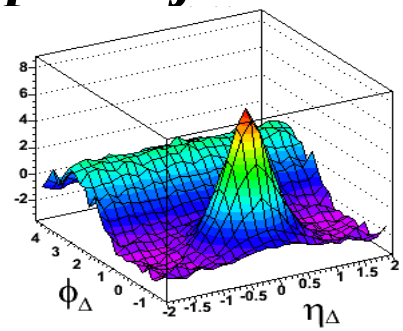


Q. J. Liu

p_t Autocorrelations

D. J. Prindle

p-p minijets

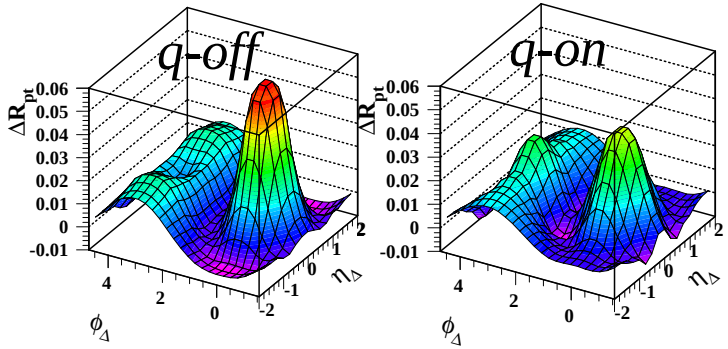


number autocorrelation

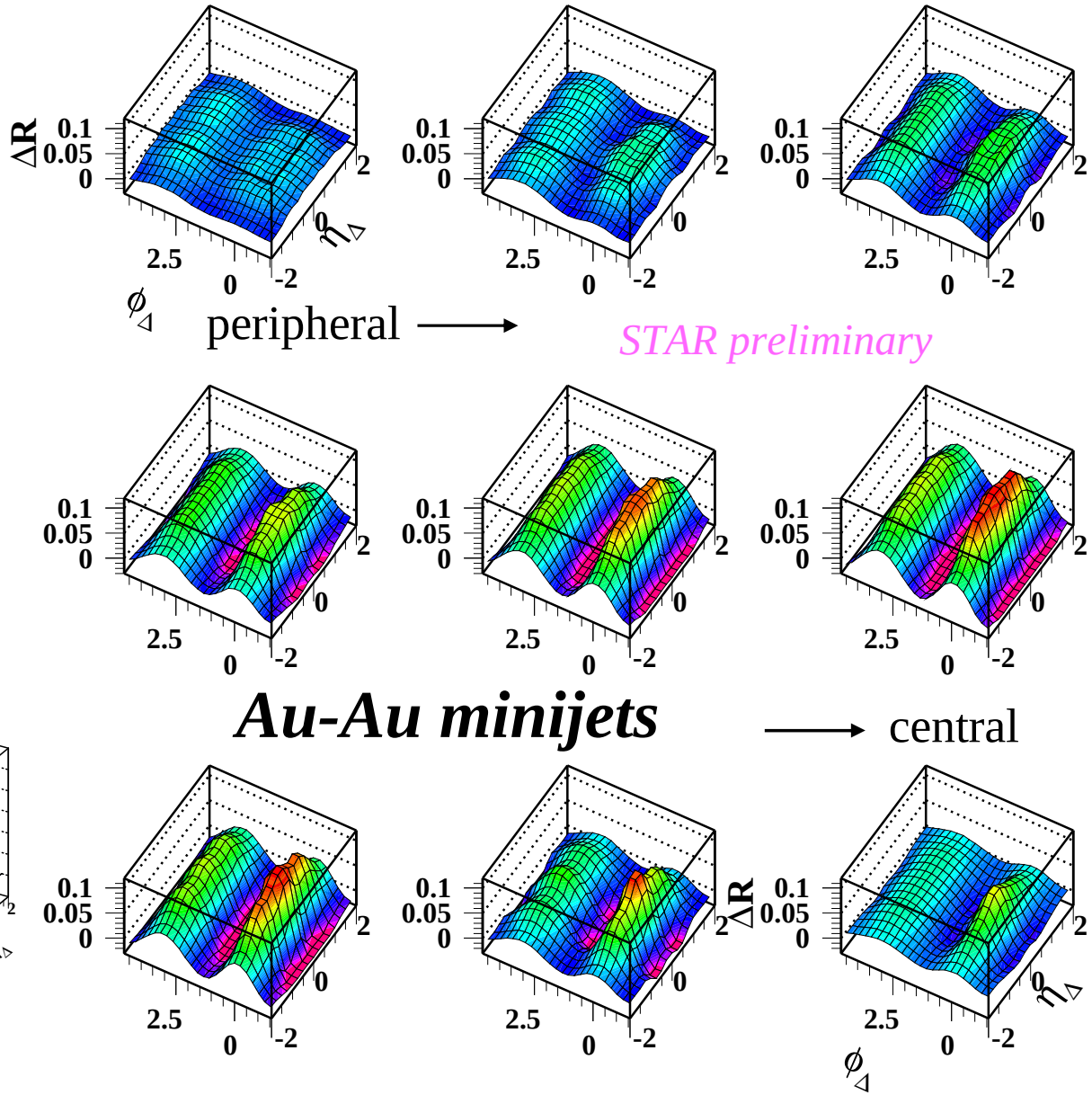
$p_t \in$ 1-2 GeV/c

inversion of integral equation

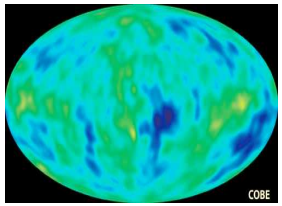
$$\Delta R = \left\{ \frac{d^2\bar{n}}{d\eta d\phi} \frac{\Delta A}{A}(\eta_\Delta, \phi_\Delta) \right\}$$

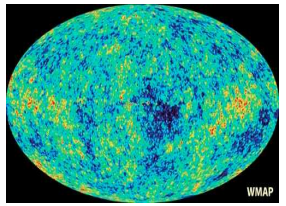


Hijing central 5%

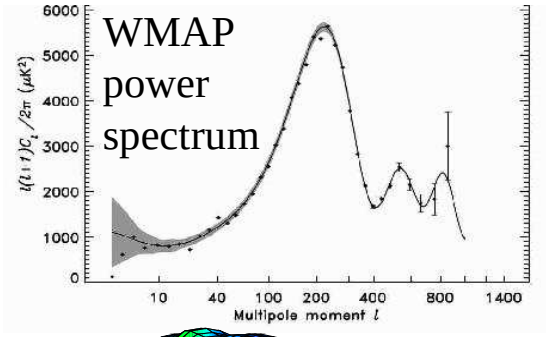


Minijets and Centrality

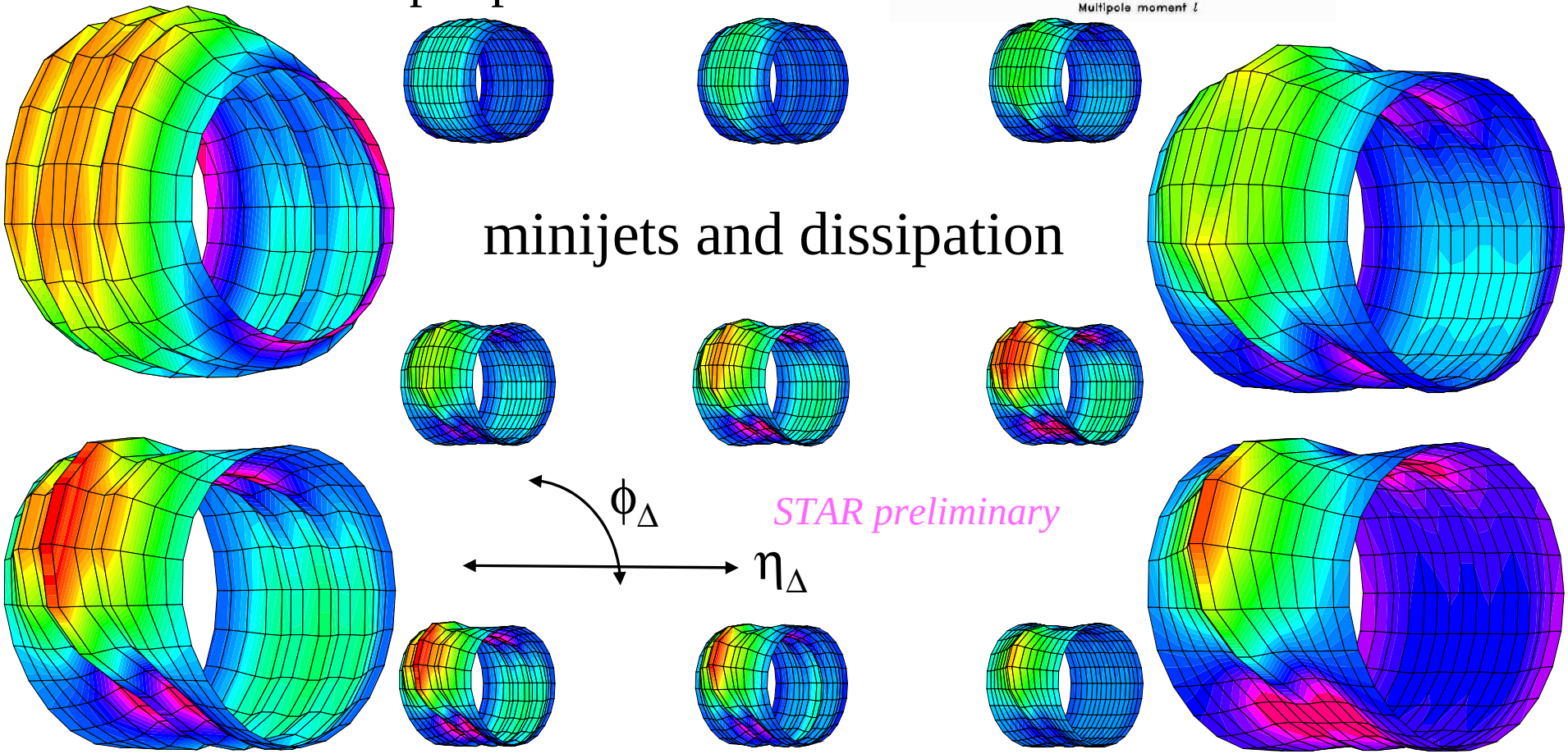




200 GeV Au-Au

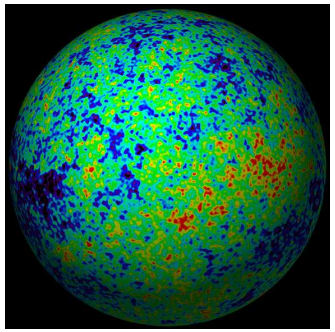


peripheral ⟶

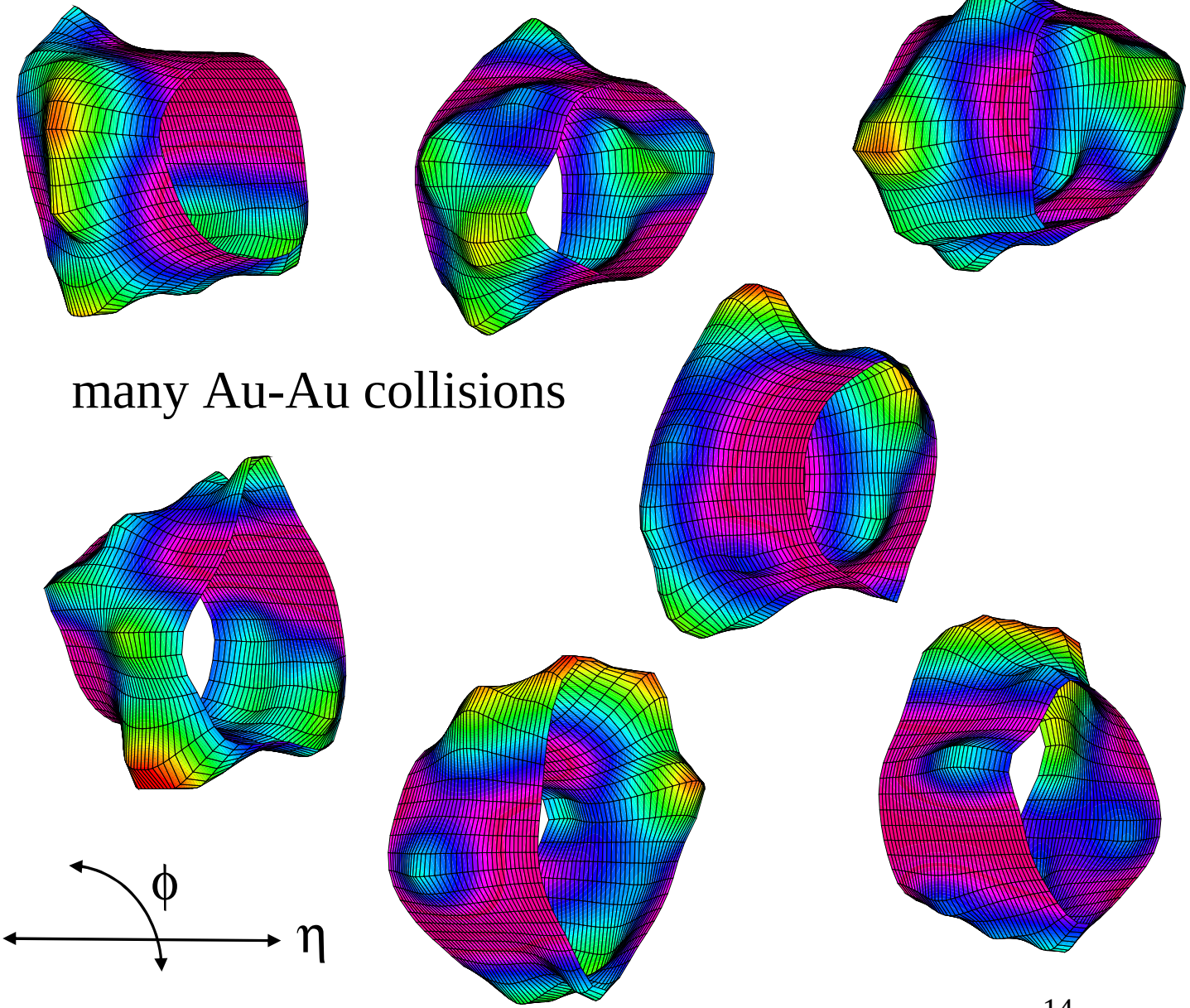


⟶ central

Event-wise Minijets



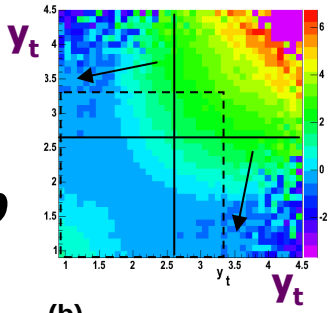
one bang



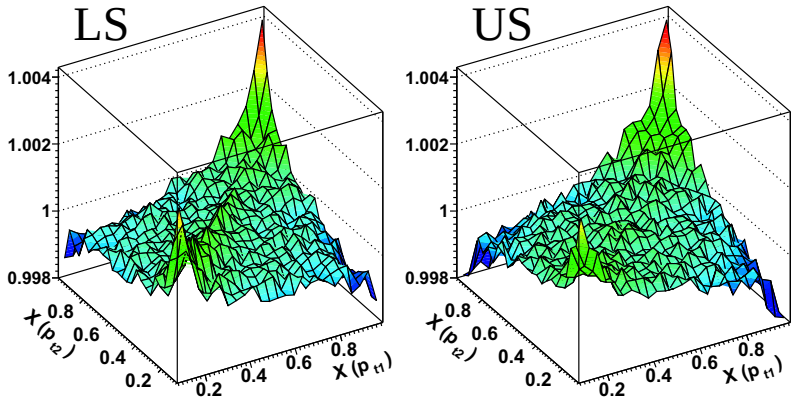
A. Ishihara

Lévy saddle

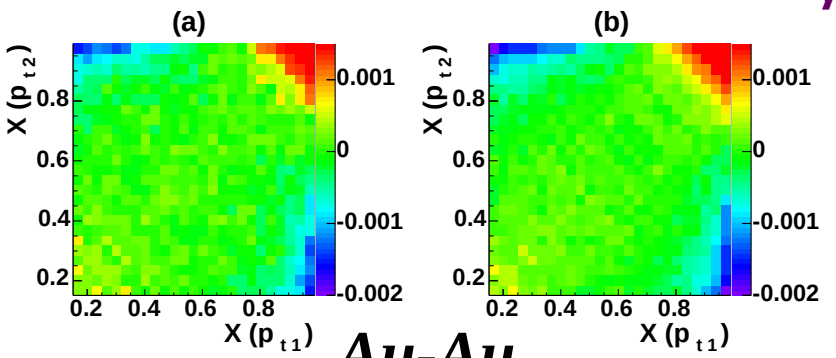
Au-Au Transverse CI



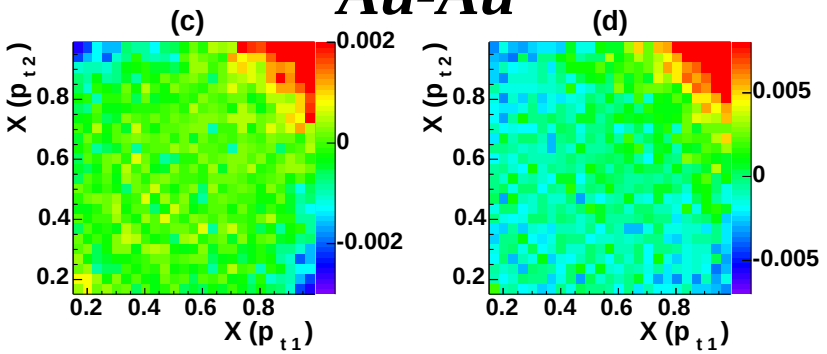
p-p



130 GeV Au-Au



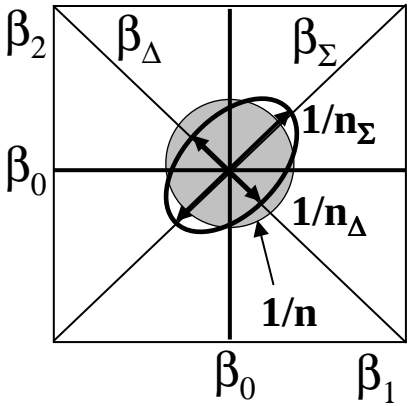
Au-Au

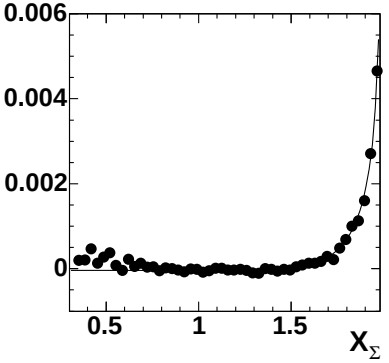


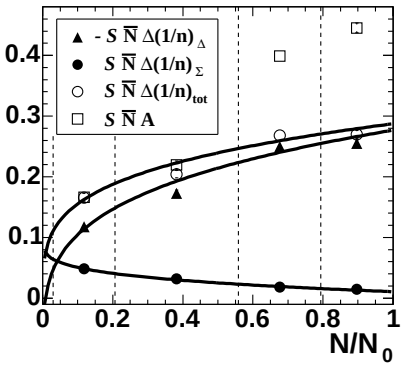
STAR preliminary

$$\frac{\left[1+\frac{m_{t,\Sigma}}{2n\,T_0}\right]^{2n}\cdot\left[1-\left(\frac{m_{t,\Delta}}{2n\,T_0+m_{t,\Sigma}}\right)\right]^{n}}{\left[1+\frac{m_{t,\Sigma}}{2n_\Sigma T_0}\right]^{2n_\Sigma}\cdot\left[1-\left(\frac{m_{t,\Delta}}{2n_\Sigma T_0+m_{t,\Sigma}}\right)\right]^{n_\Delta}}$$

model: ratio of 2D Lévys

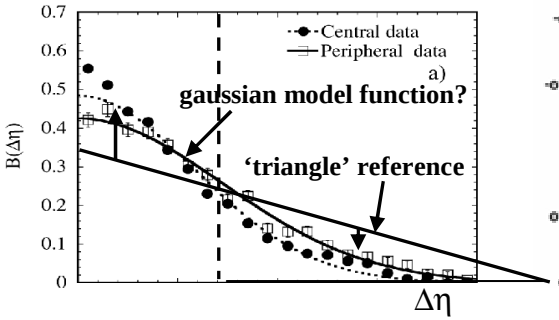


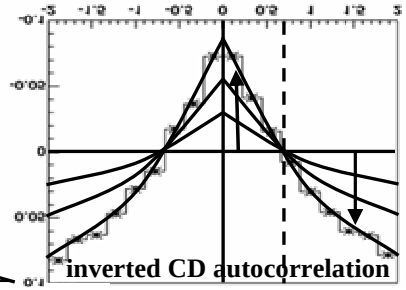




- Curvatures determine exponents
- Exponents measure T/v fluctuations
- Minijet dissipation in bulk medium

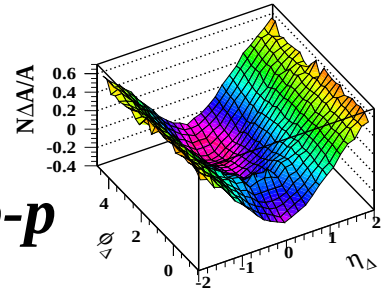
Au-Au Axial CD

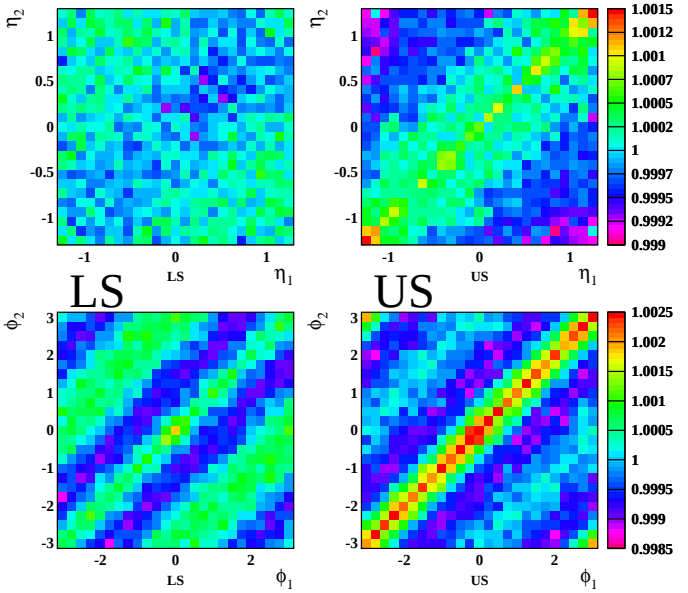


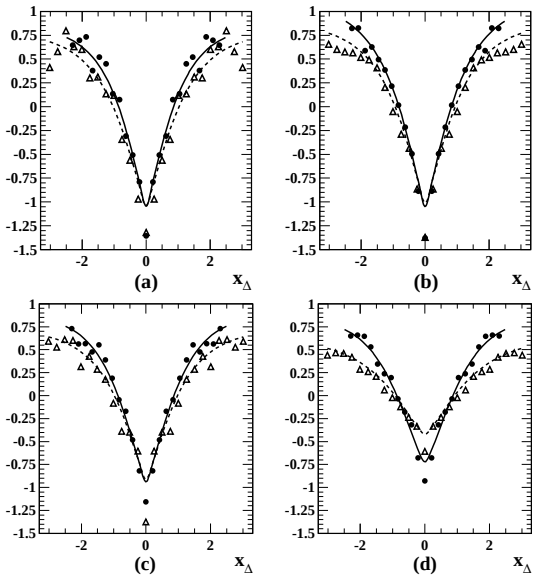


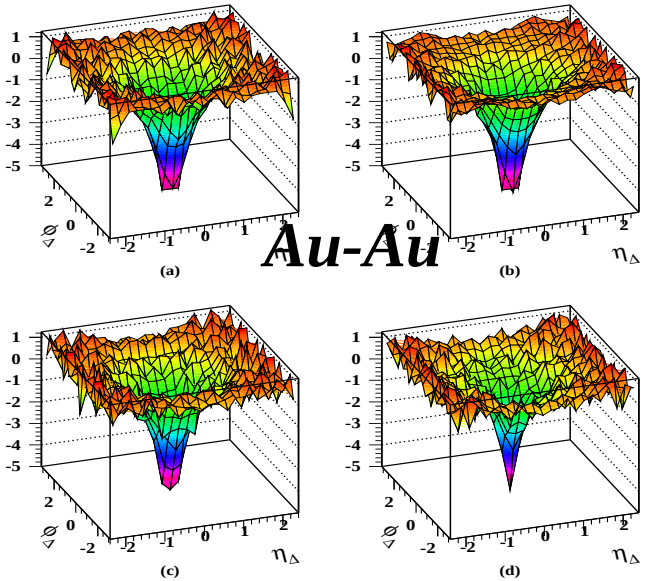
130 GeV

p-p



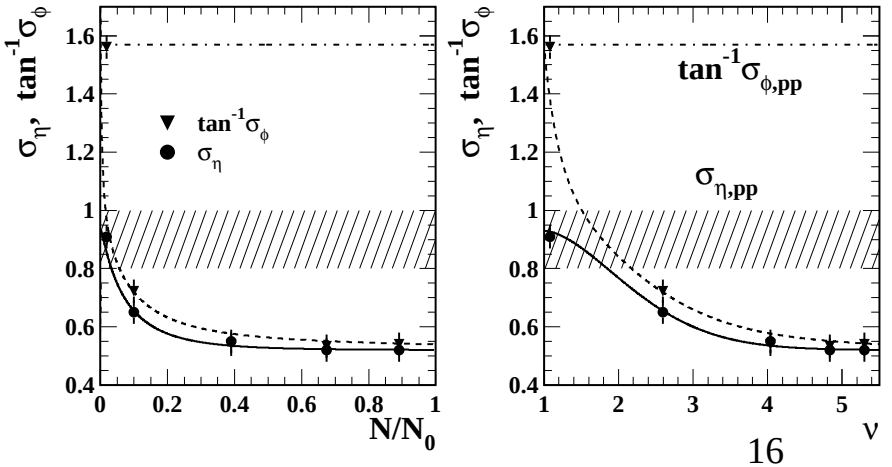






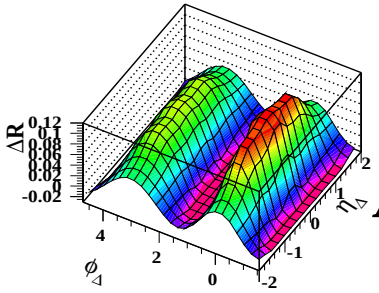
STAR preliminary

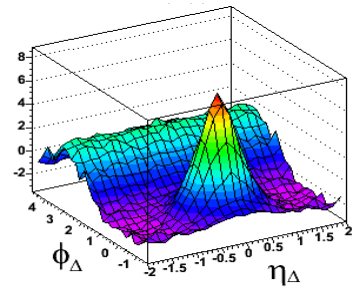
- Net-charge autocorrelation
- Hadronization geometry
- Transition from 1D to 2D
- Transition more peripheral

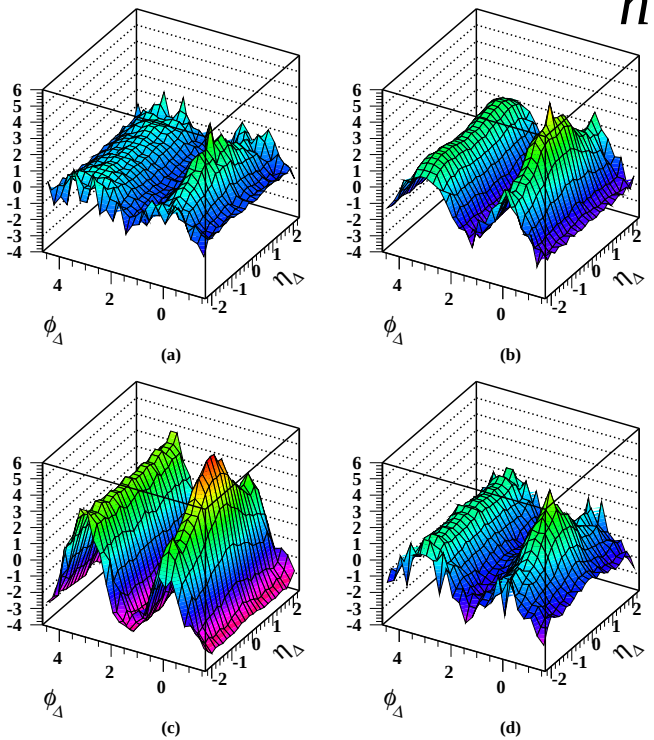


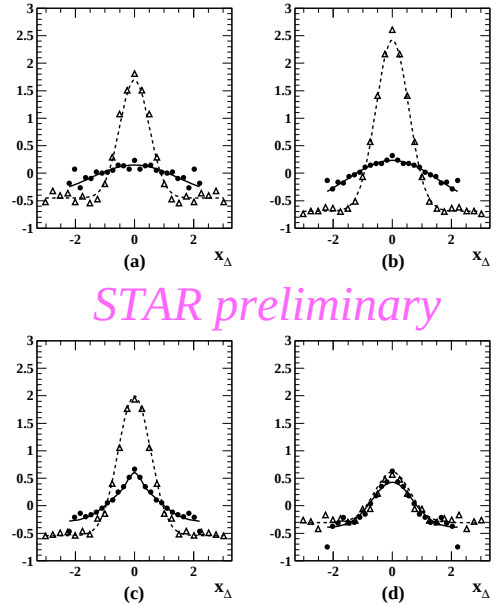
A. Ishihara

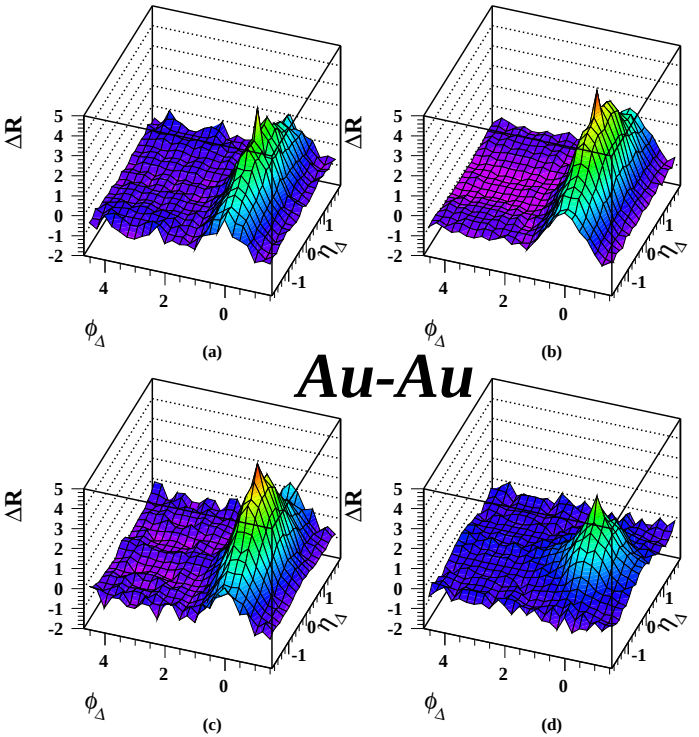
Au-Au Axial CI





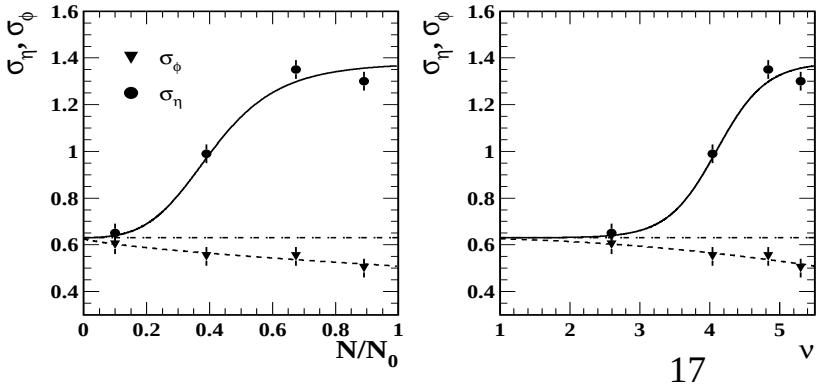




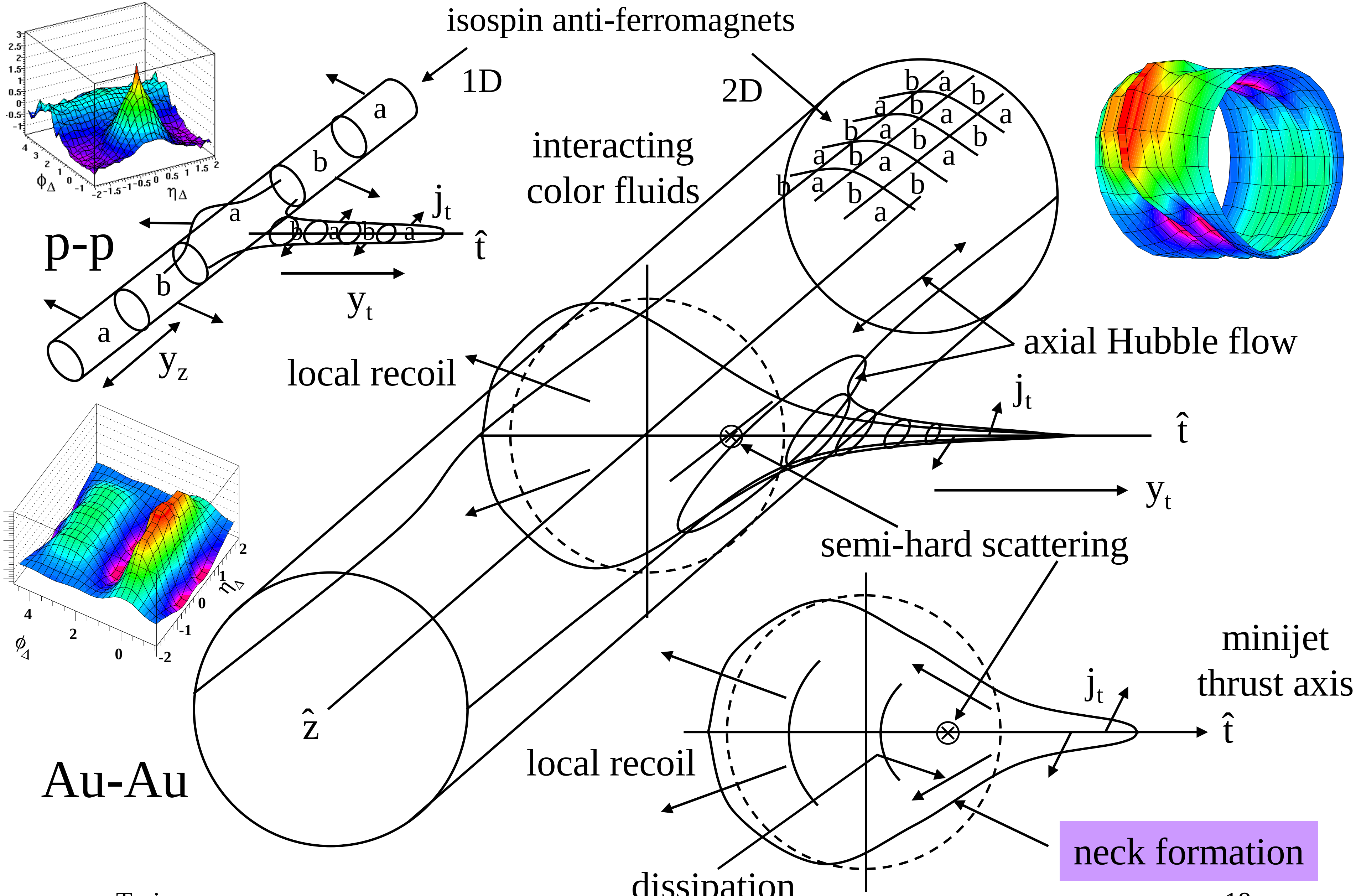


A. Ishihara

- Minijets deformed on (η,ϕ)
- Strong coupling to *axially-expanding* bulk medium
- Transition more central



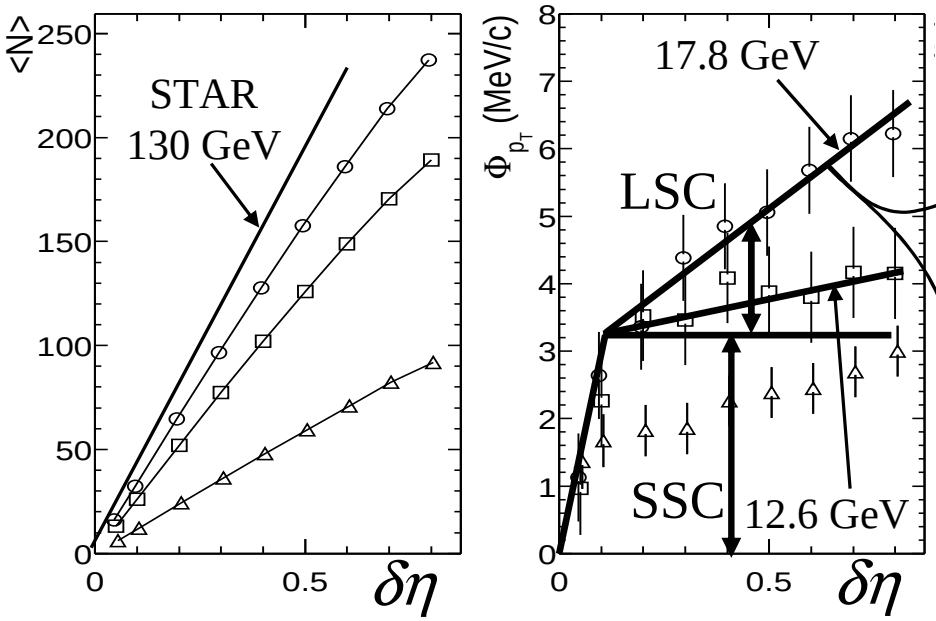
In-medium Au-Au Minijet Model



Energy Dependence – SPS & RHIC

fluctuations autocorrelation

SPS 17.8, 12.6 GeV 0-20% central

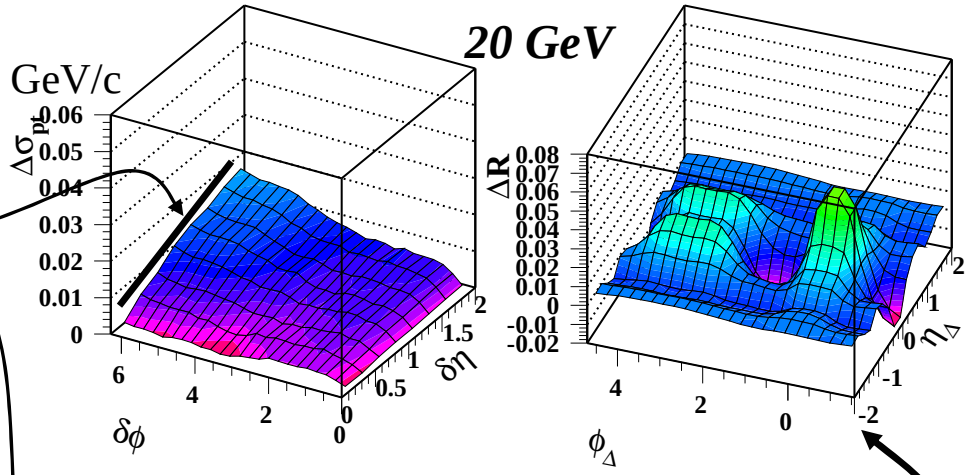


$\delta\phi \rightarrow 2\pi$ $\quad \Phi_{p_t} \approx \Delta\sigma_{p_t:n}$

CERES Fig. 2 nucl-ex/0305002

0-20% central

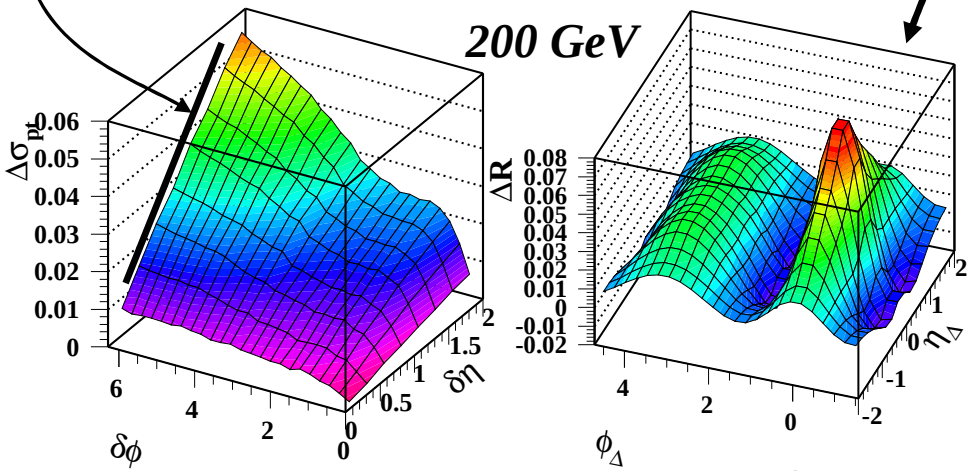
20 GeV



same detector and analysis method

STAR preliminary 0-5% central

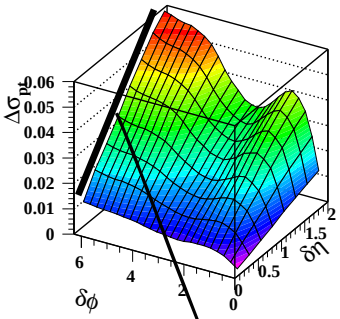
200 GeV

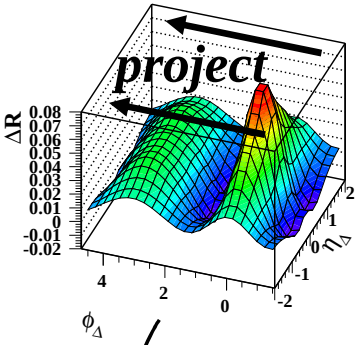


dramatic increase of correlation structure with √s

Q.J. Liu/D.J. Prindle

Comparisons of $\Delta\sigma_{pt}$, ΔR



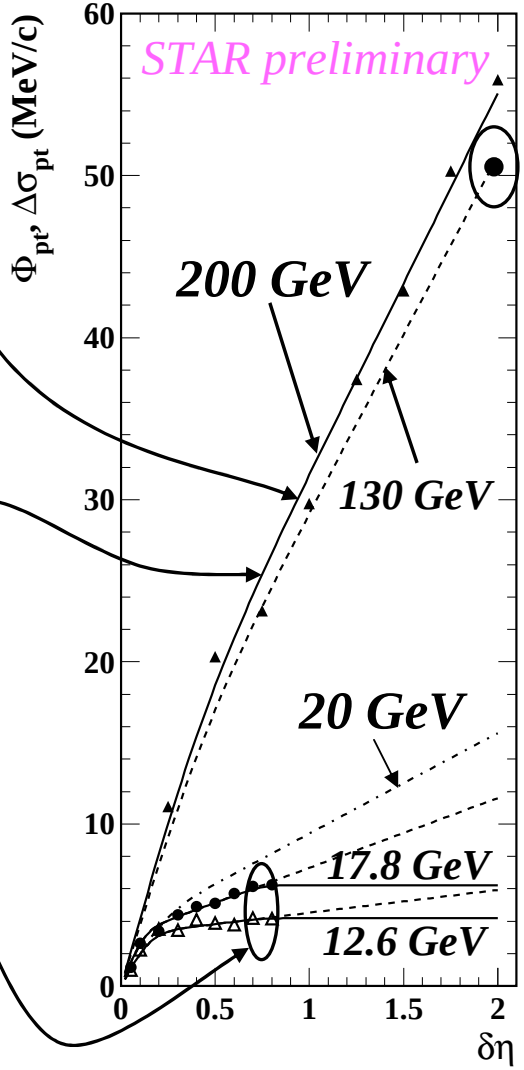


fluctuations

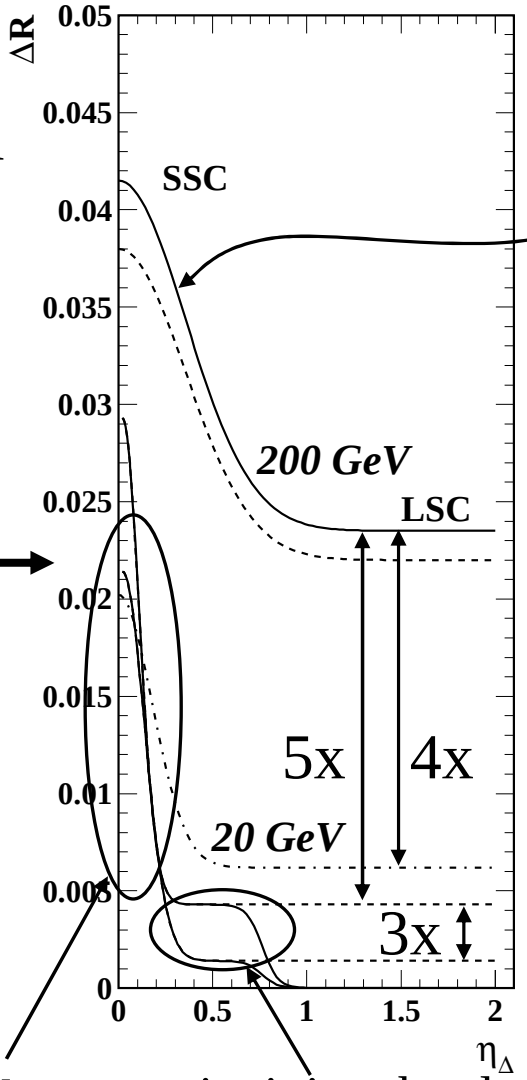
autocorrelations

$\delta\phi \to 2\pi$

integral of ΔR in right panel



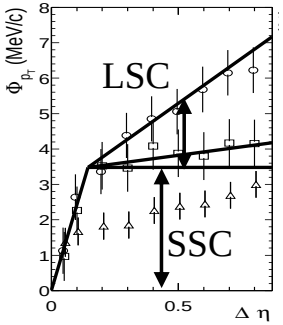
STAR PRL



integrate over ϕ_Δ

LSC: proper basis for RHIC/SPS comparison

LSC: *exact description* for global T fluctuations

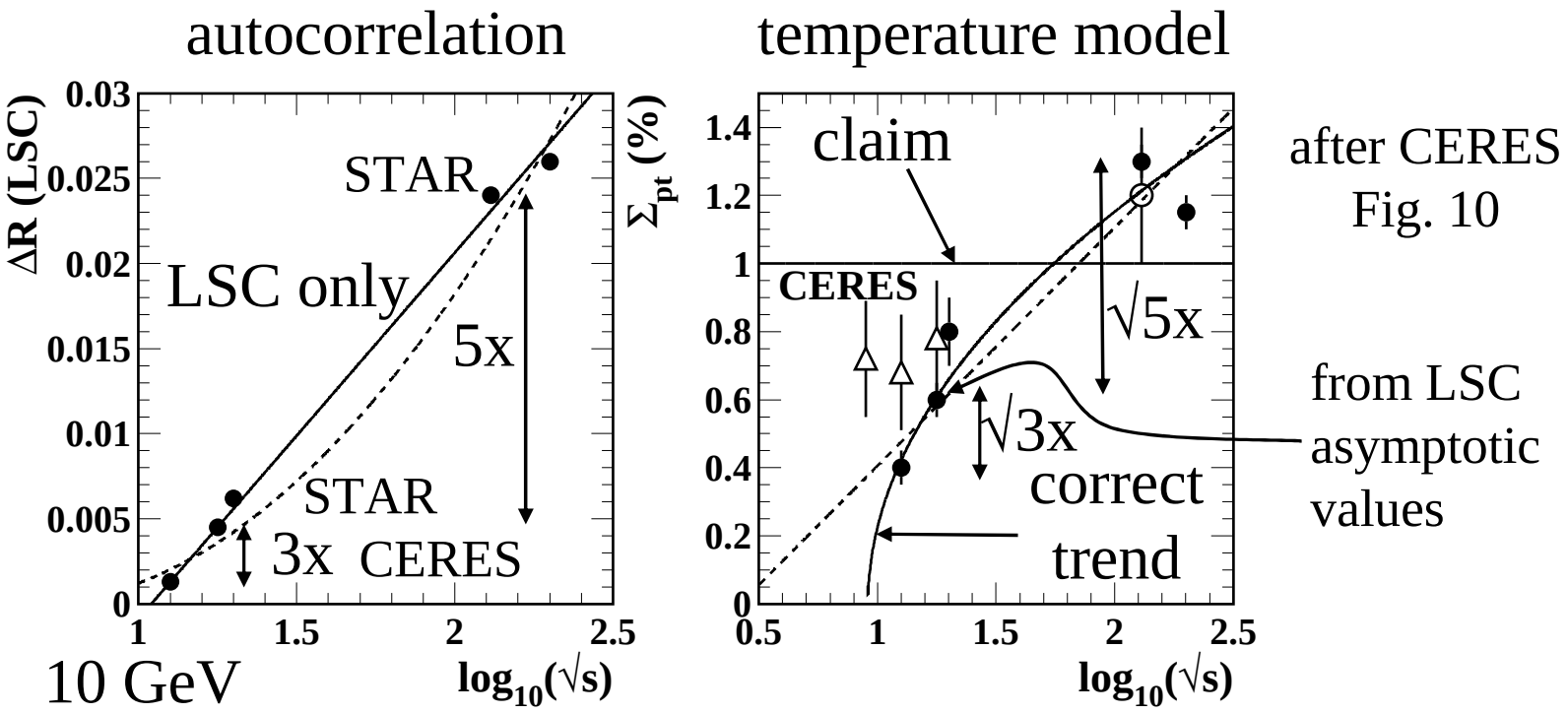


CERES

soft physics

incipient hard scattering

√s Dependence of LSC



Dramatic changes with $\sqrt{s_{NN}}$

Hard-scattering threshold at 10 GeV?

Summary

- Correlations and fluctuations: powerful new techniques
- Formal connection to cosmic microwave analysis
- New STAR results:
  - Minijet gaussian on y_t in p-p collisions
  - Minijet correlations on (η,ϕ) in p-p collisions
  - Minijet distortions on (η,ϕ) in Au-Au collisions
  - Dissipative bulk medium in Au-Au collisions
  - 2D isospin antiferromagnet in Au-Au collisions
- Bulk color-medium properties in HI collisions
- Strong $\sqrt{s}$ dependence of p_t fluctuations/correlations