Correlation structure of STAR events

CINPP, Kolkata, India.

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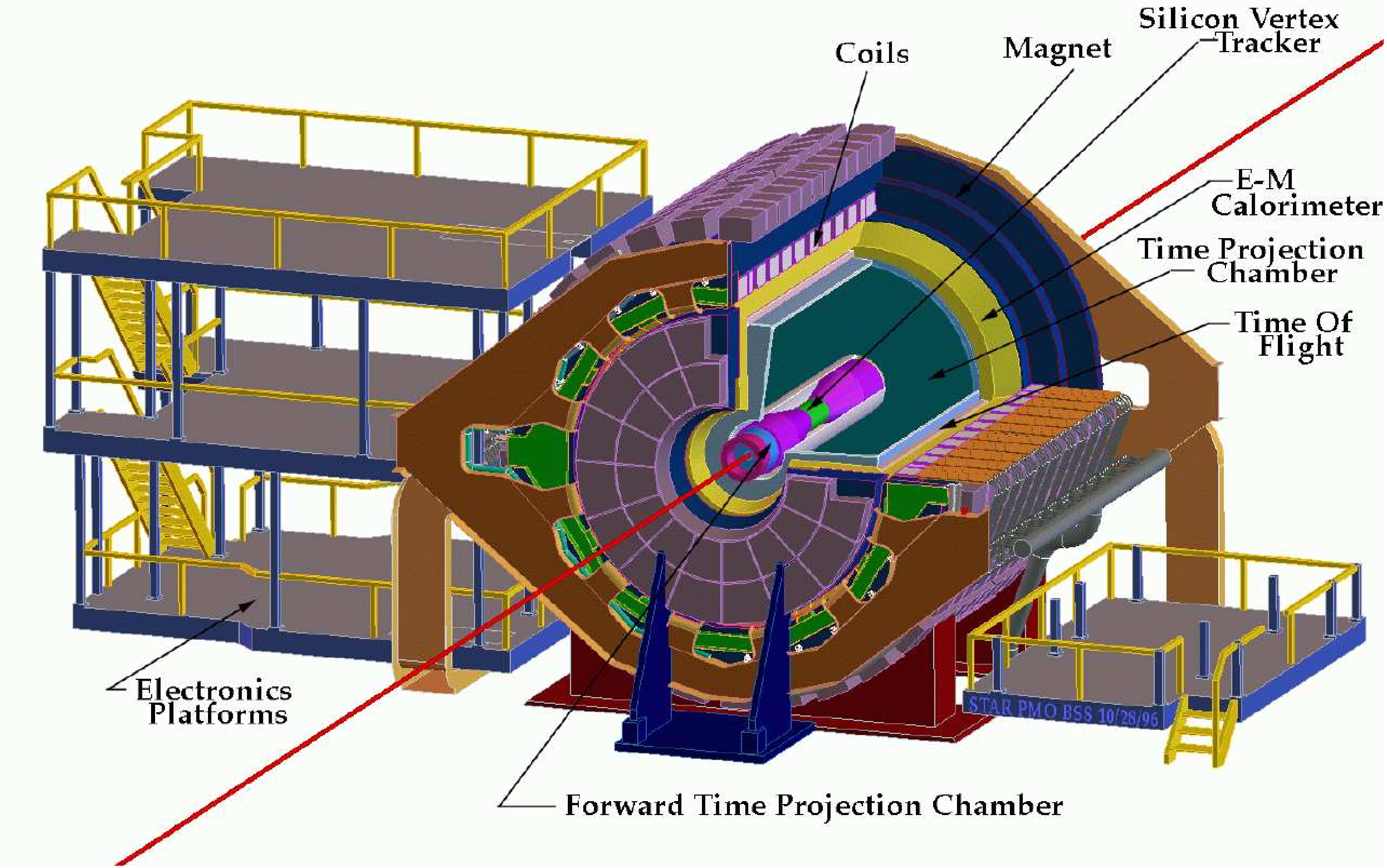
Kent State University

http://www.star.bnl.gov/~kopytin/

February 4, 2005

STAR Detector



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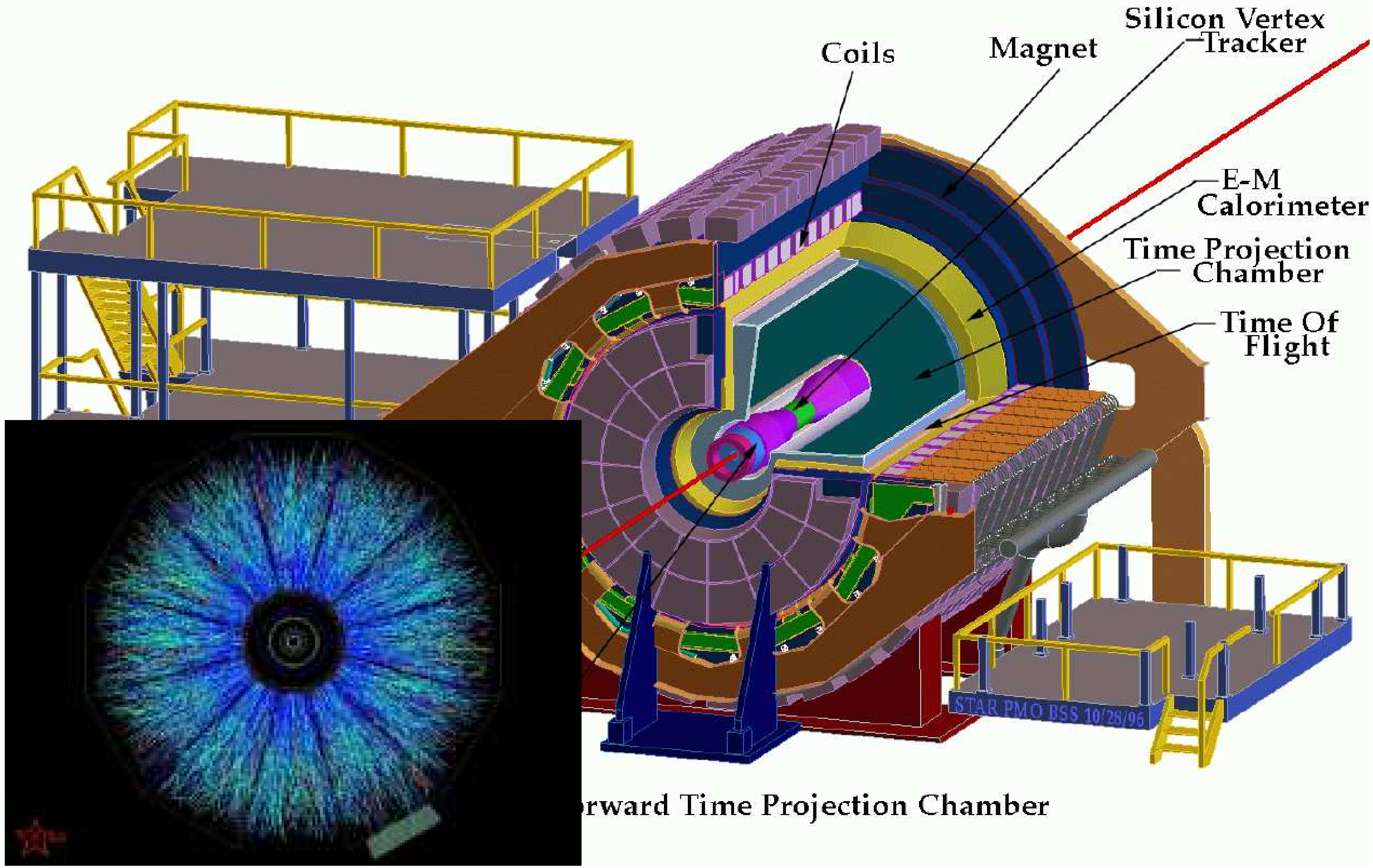

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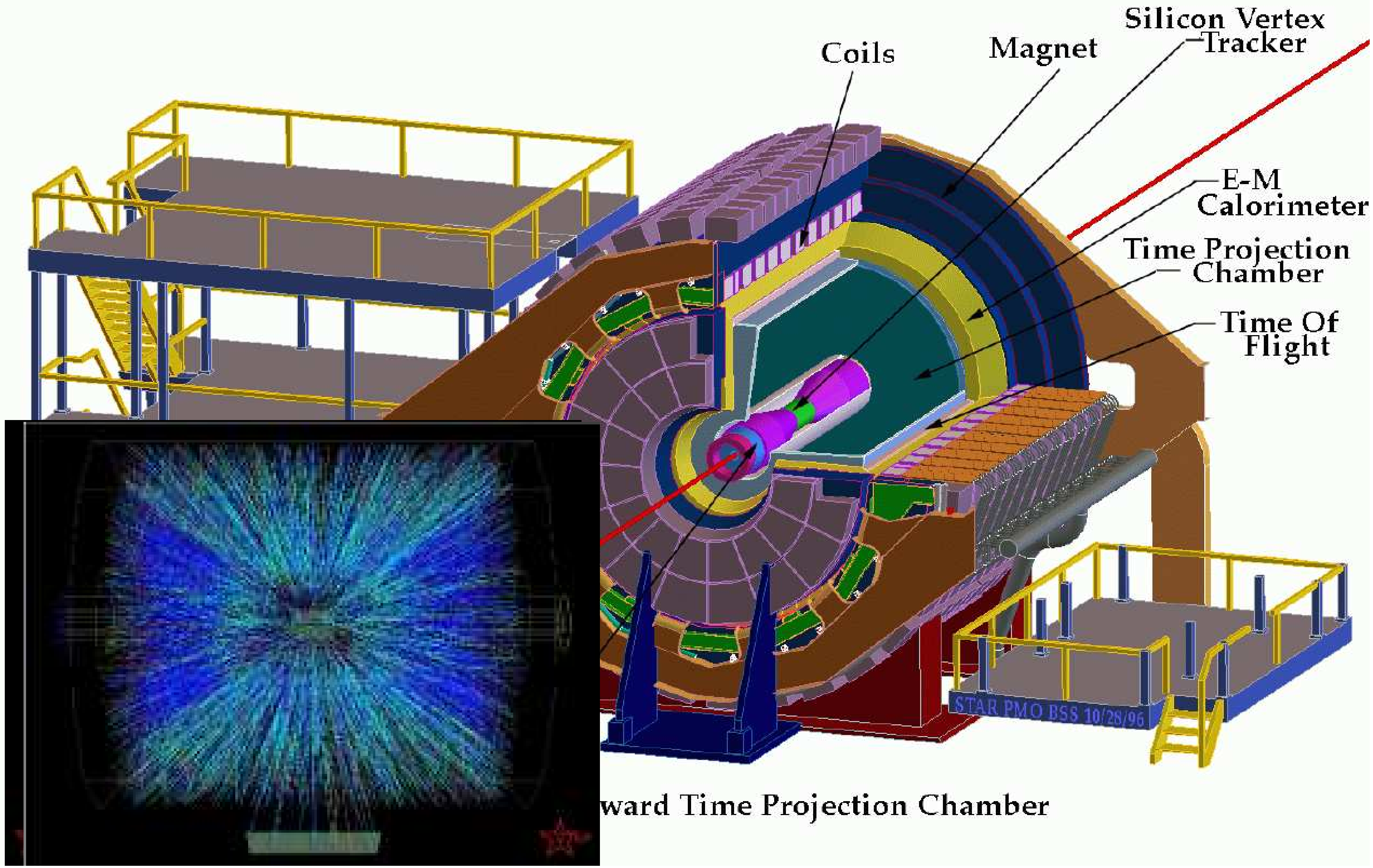

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- Conclusions

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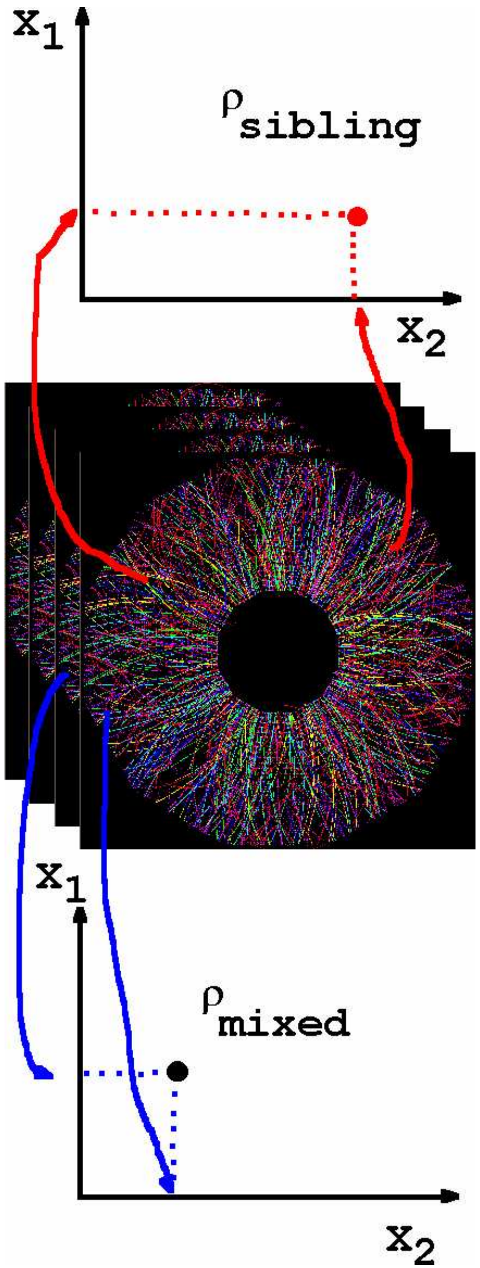

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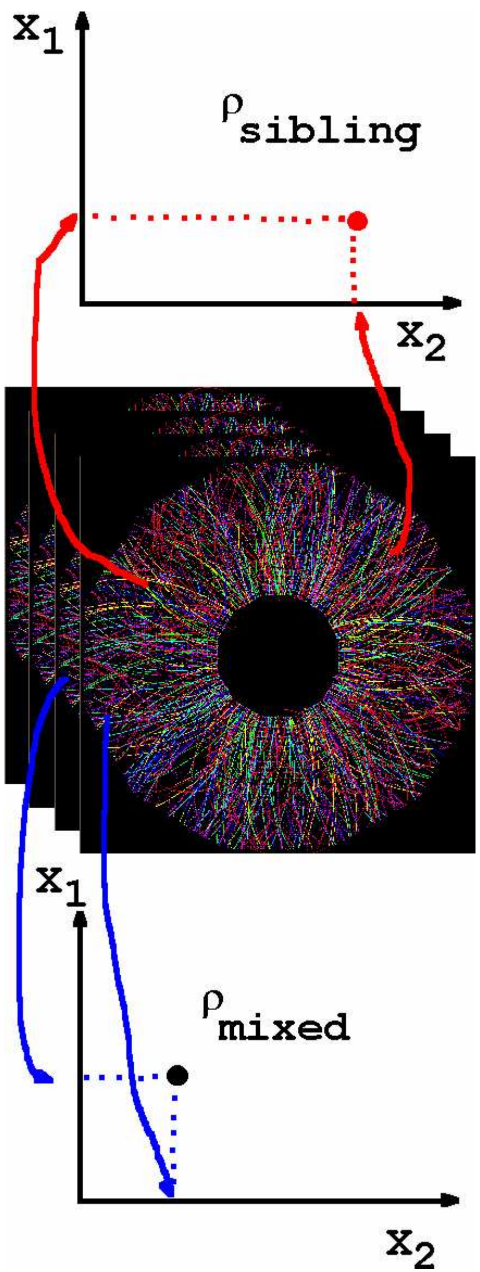

$$\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} \rightarrow \begin{pmatrix} x_\Sigma \equiv x_1 + x_2 \\ x_\Delta \equiv x_1 - x_2 \end{pmatrix},$$

always a lossless transformation of data. **Autocorrelation** A is a projection of a two-point distribution onto difference variable(s) x_Δ, lossless for x_Σ-invariant (homogenous, stationary) problems.

$$\Delta R(x_1, x_2) = \frac{\rho(x_1, x_2)}{\rho_{\mathrm{ref}}(x_1, x_2)} - 1$$

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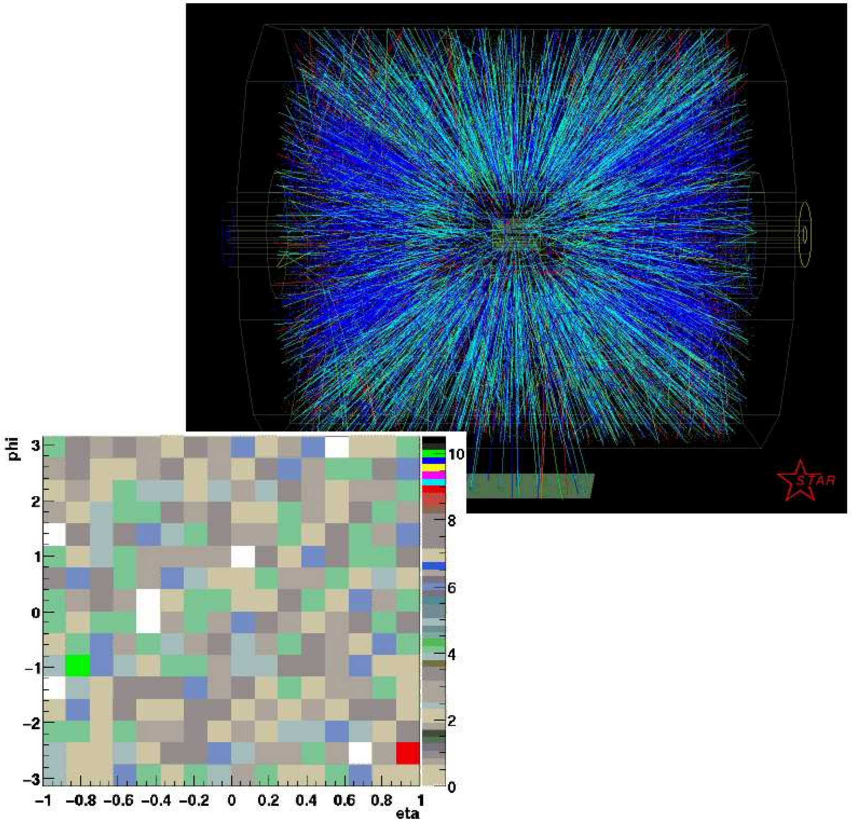

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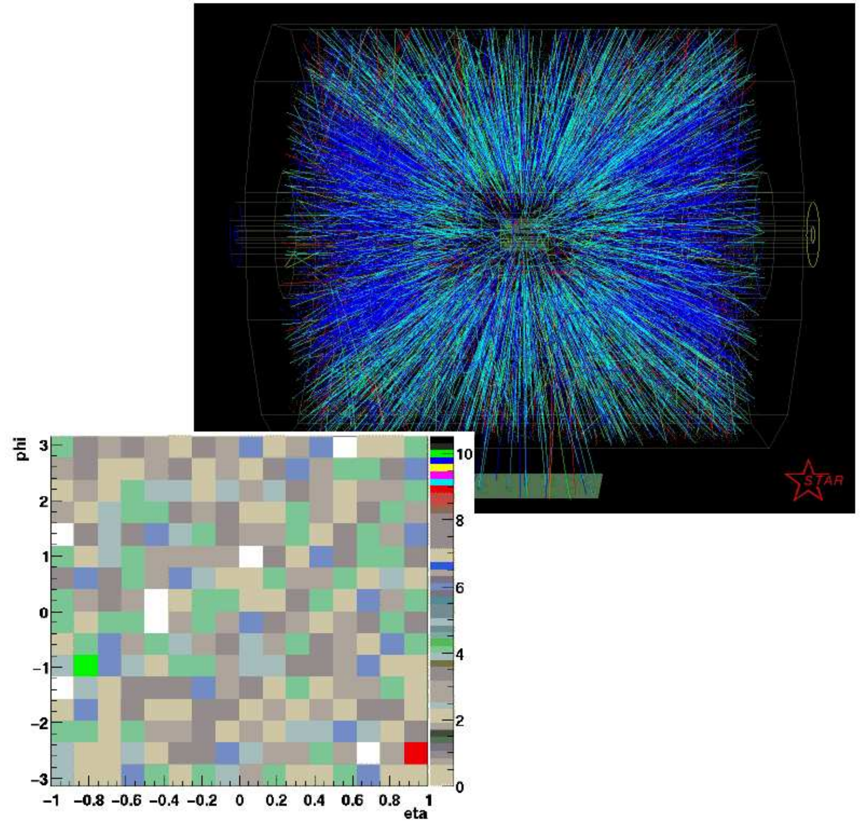

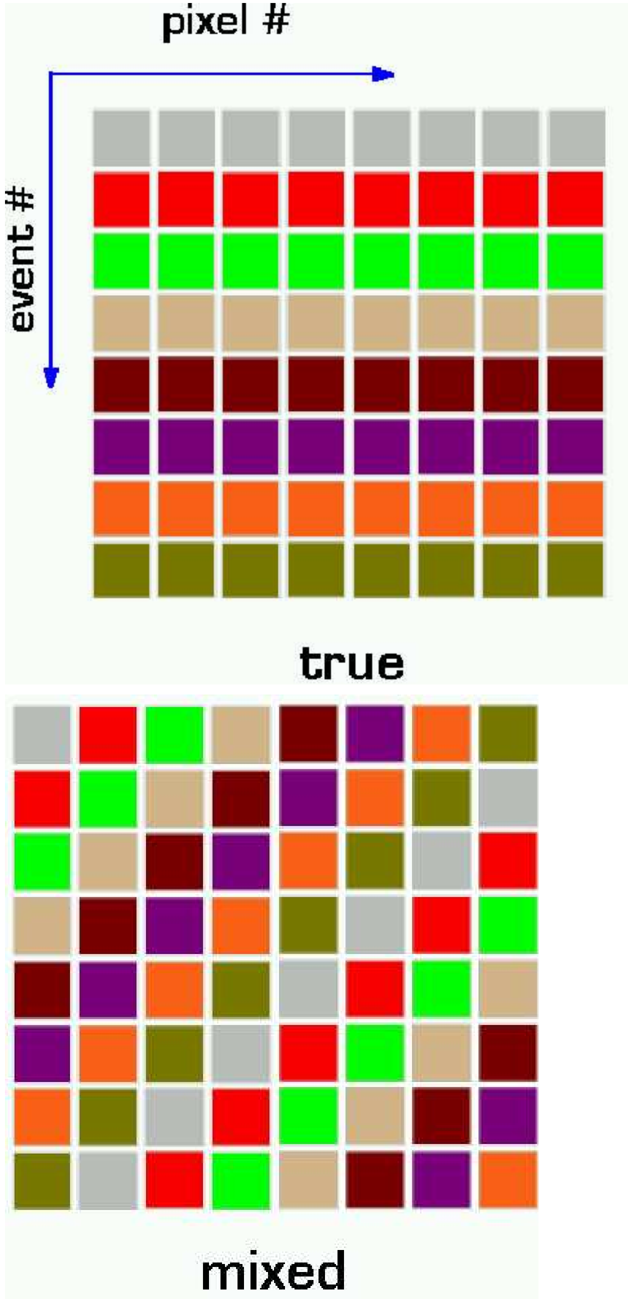

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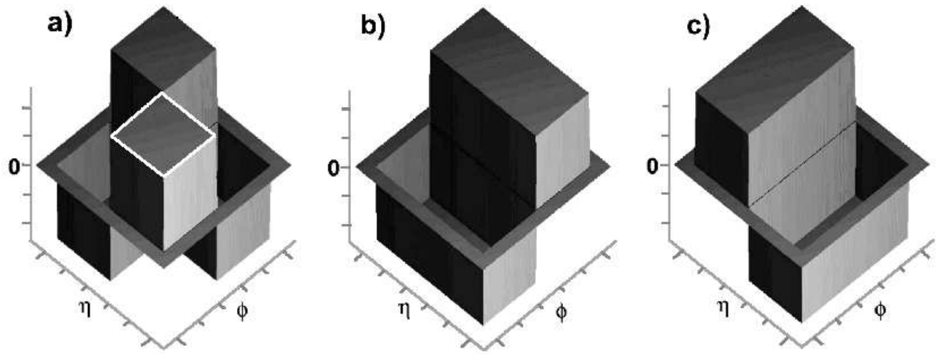

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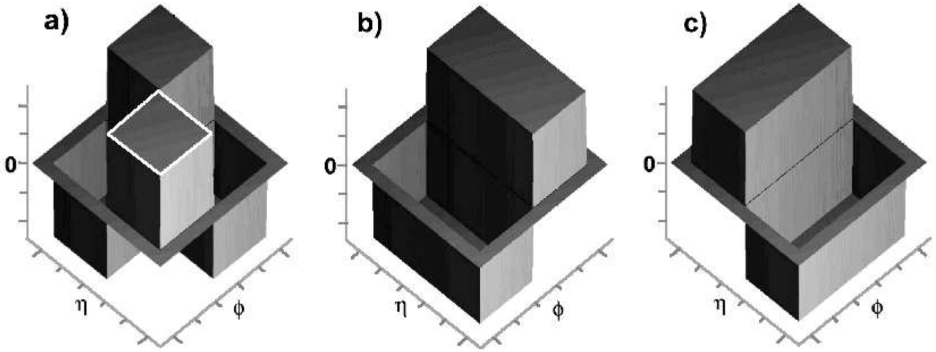

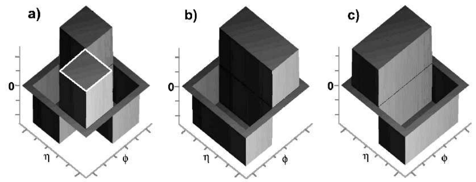

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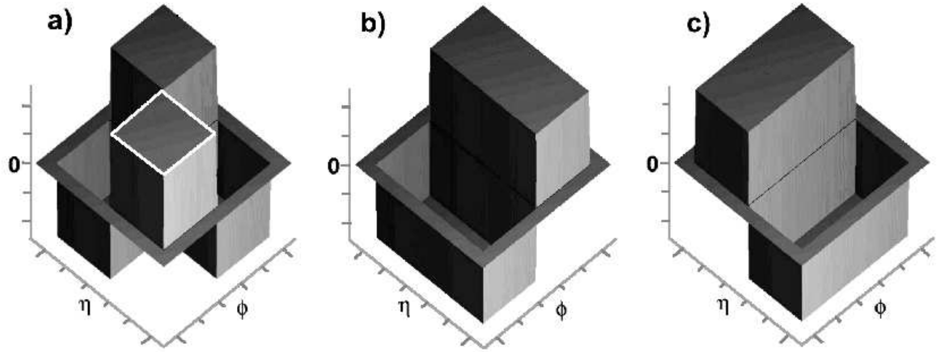

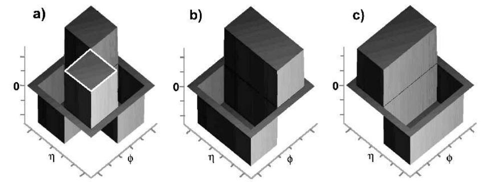

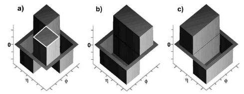

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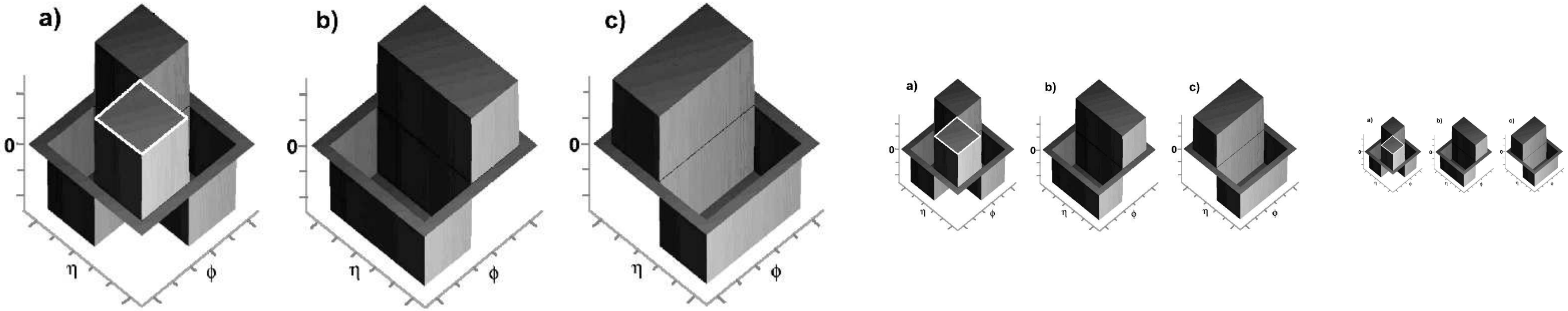

$F^{\lambda}_{m,l,k}(\phi,\eta)$–Haar wavelet **orthonormal basis** in (ϕ,η). scale fineness (m), directional modes of sensitivity (λ), track density $\rho(\eta,\phi,p_t)$, locations in 2D (l,k). **DWT is an expansion in this basis.**

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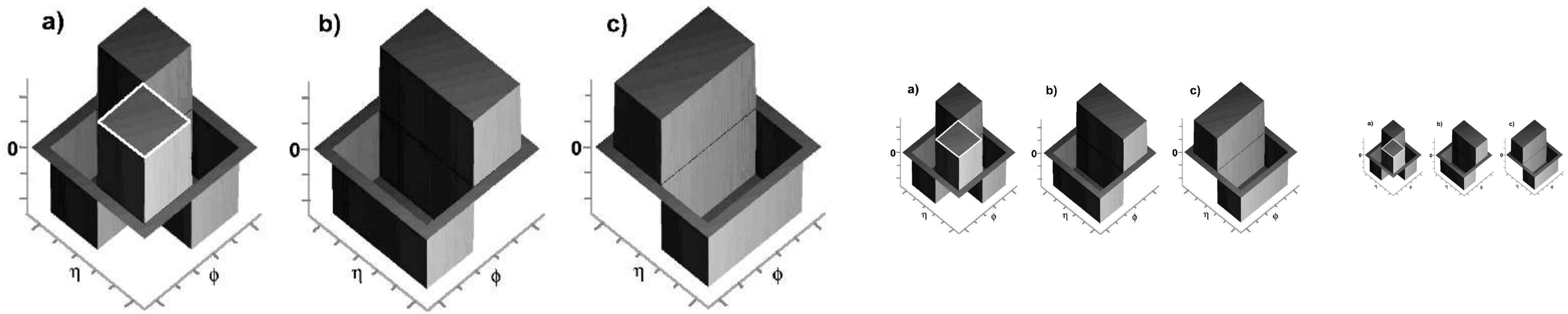

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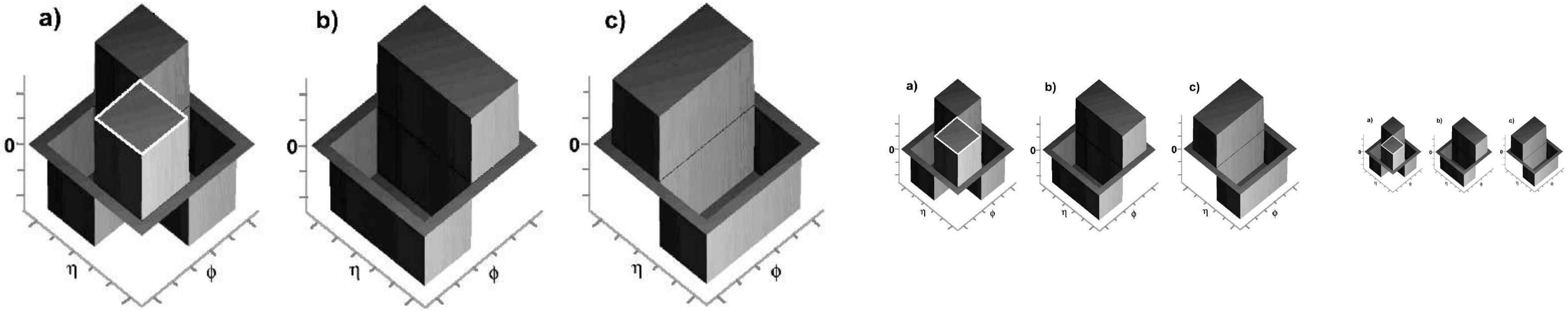

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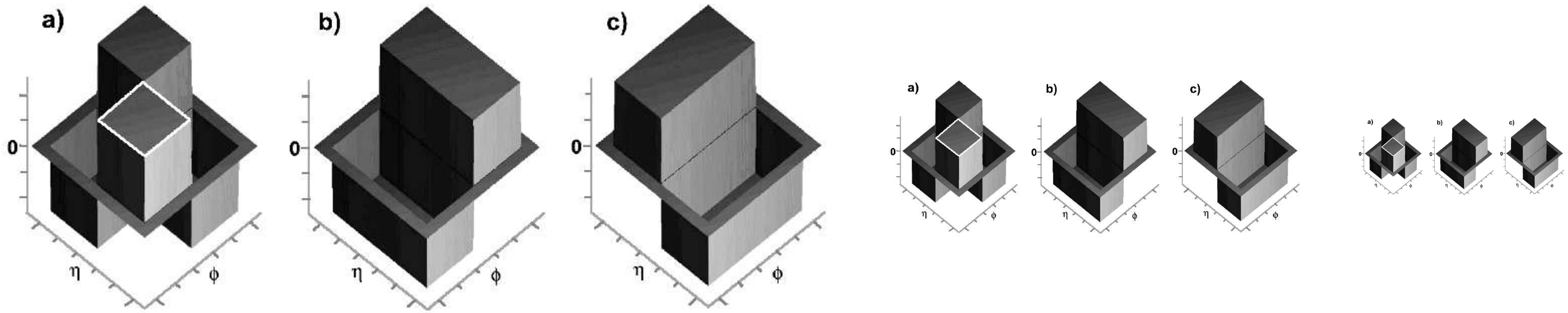

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Normalized:

$$P^{\lambda}_{\text{dyn}}(m)/P^{\lambda}_{\text{mix}}(m)/n(p_t) \qquad (3)$$

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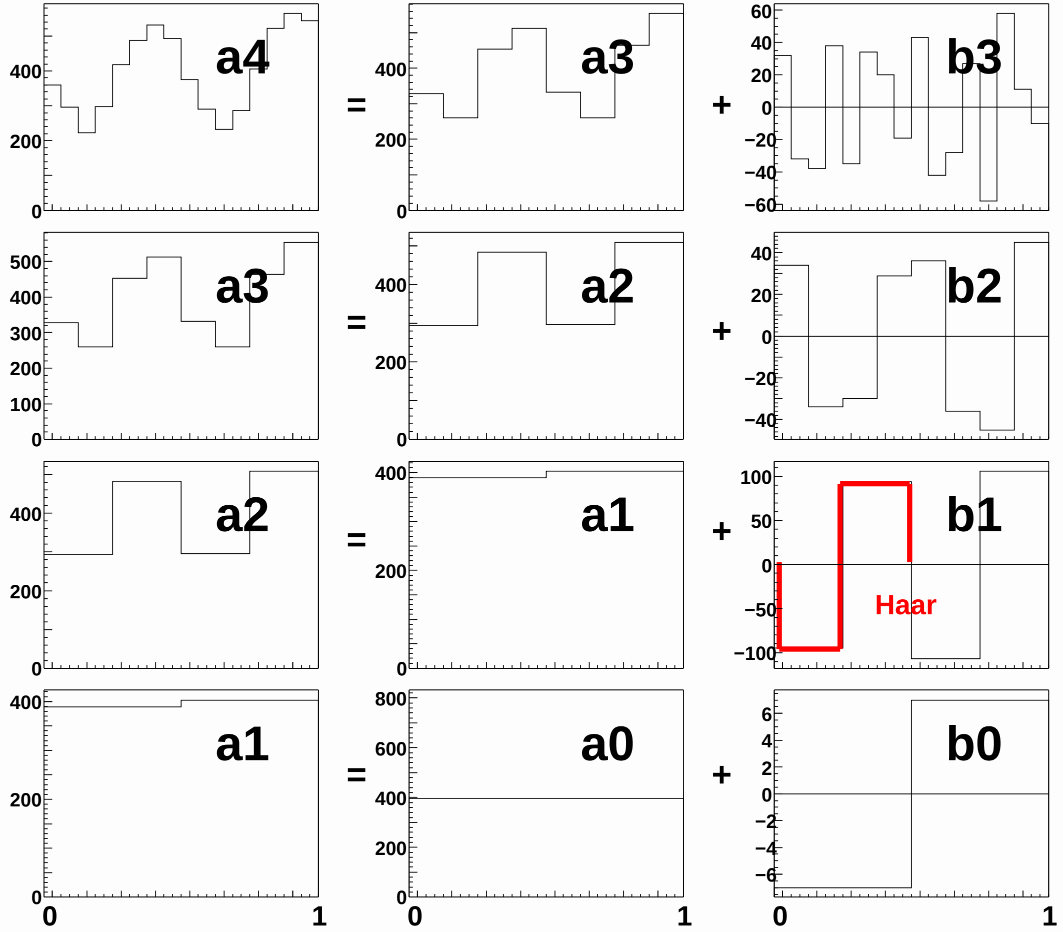
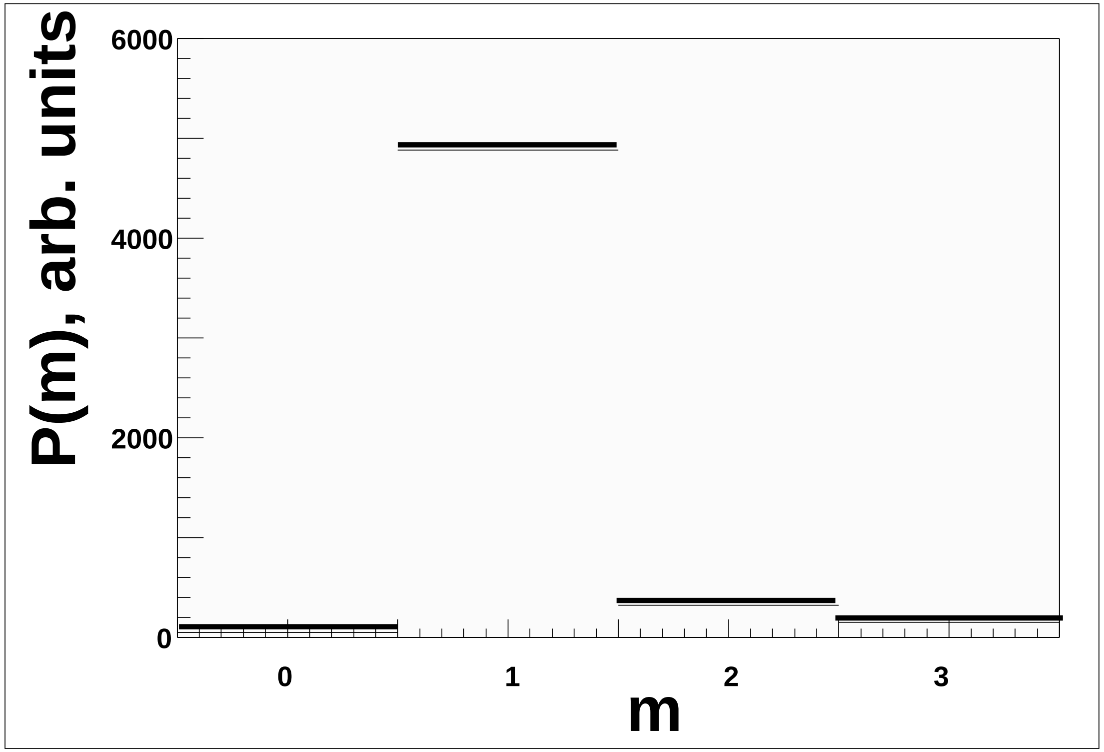


5 A flow-like example

Elliptic flow-inspired example: x axis – an angle in "natural units" $(2\pi = 1)$, y axis – multiplicity. The multiresolution theorem: **a4 = a0+b0+b1+b2+b3**, can have better fineness.

6 Example of a DWT power spectrum



Power spectrum of that flow event as a function of "fineness" m. The dominant contrubution is $m = 1$ (the "v_2" harmonic, **b1**). Statistical fluctuations also contribute.

$P(m) = 2^{-m} \sum_i \langle \rho, F_{m,i} \rangle^2$.

Computational complexity $O(N)$!

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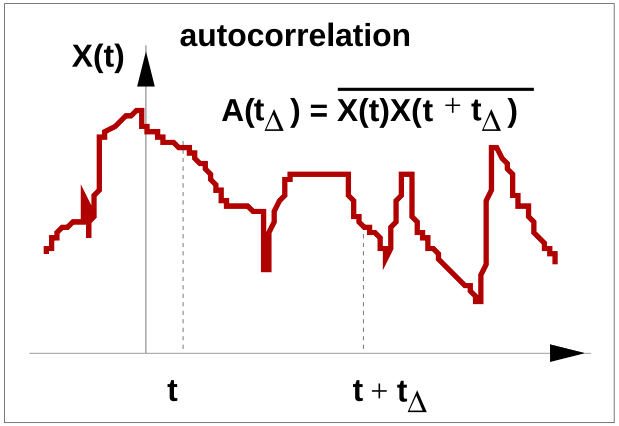

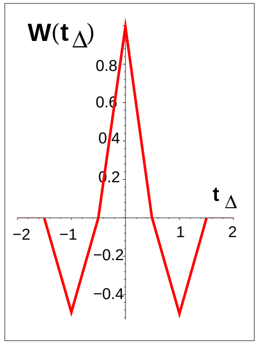

$$P(m) = \overline{\int_{-\infty}^{\infty} X(\tau/2)X(-\tau/2)W(\tau,m)\,d\tau},$$

where W is the weight function for the Haar wavelet. $P(m)$ reflects differential structure on scale m. See example:

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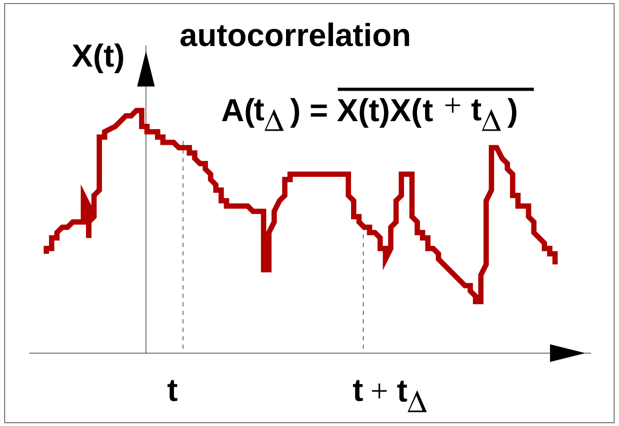

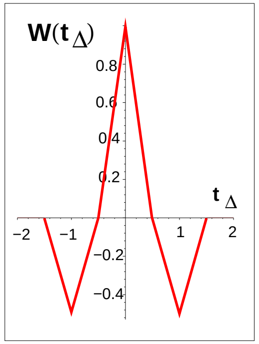

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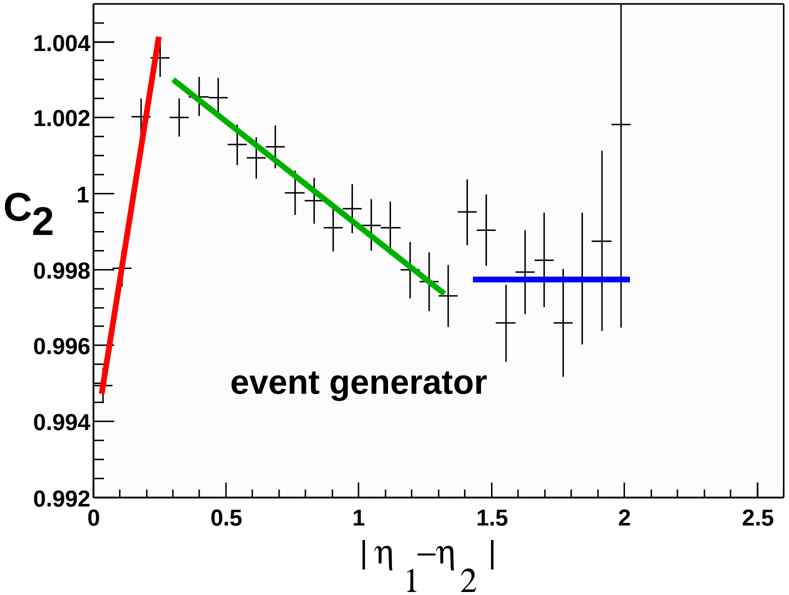

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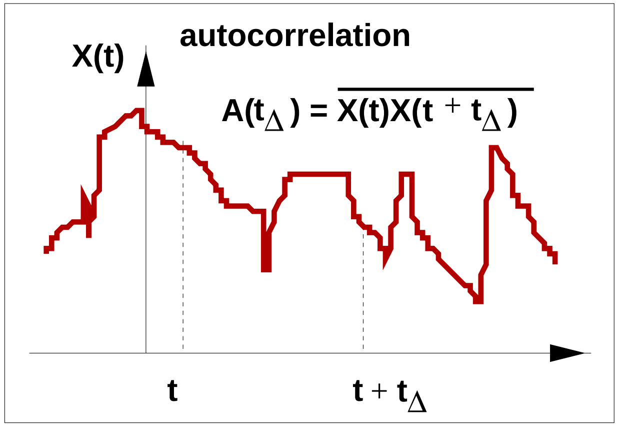

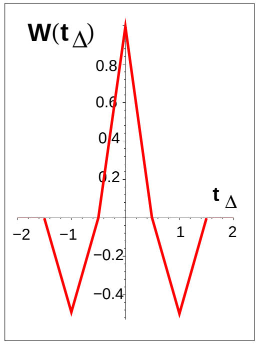

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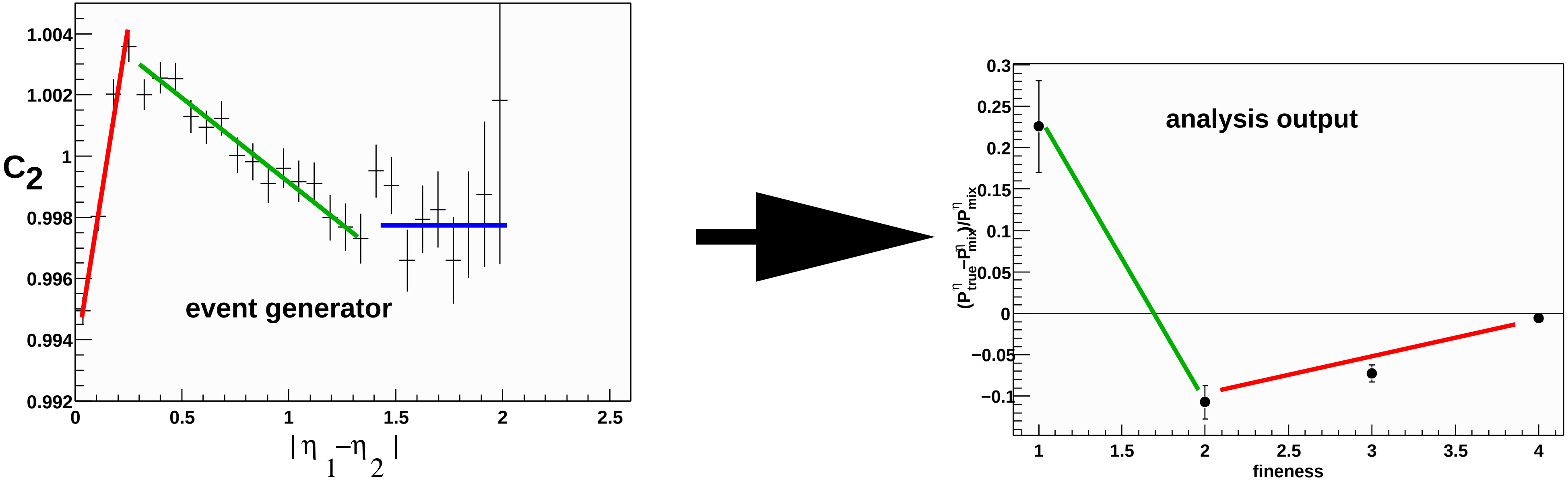
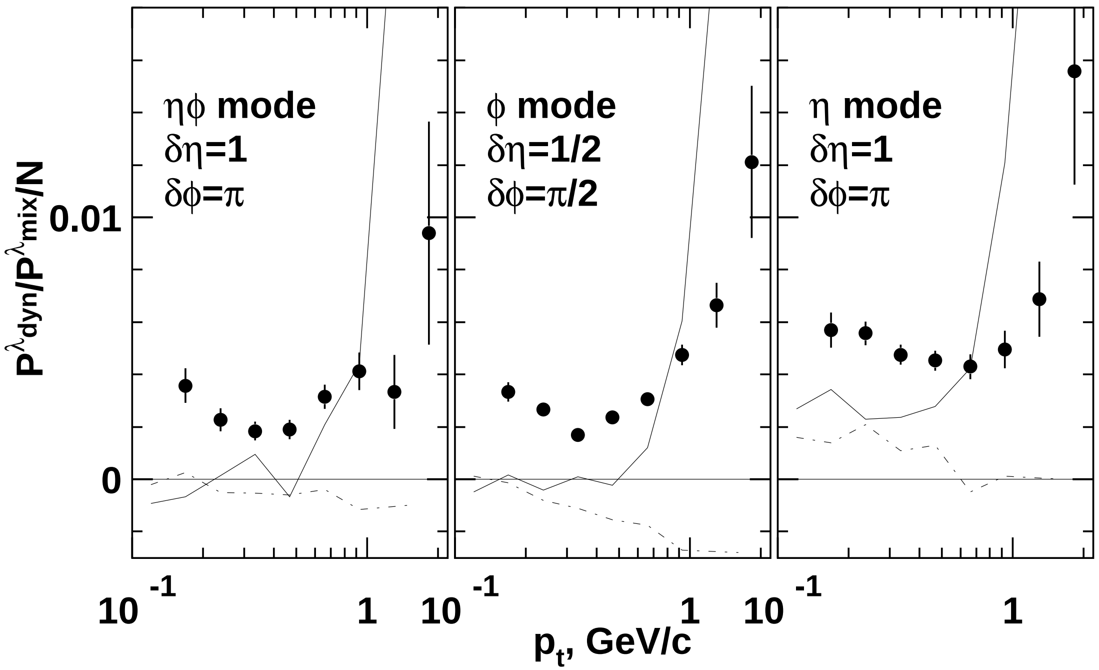


8 "Dynamic texture" p_t dependence: peripheral events, $\sqrt{s_{NN}} = 200$ GeV



Peripheral (60-84%) events: normalized dynamic texture for fineness scales $m = 0, 1, 0$ from left to right panels, respectively, as a function of p_t. • – STAR data; solid line – standard HIJING, dash-dotted line – HIJING without jets.

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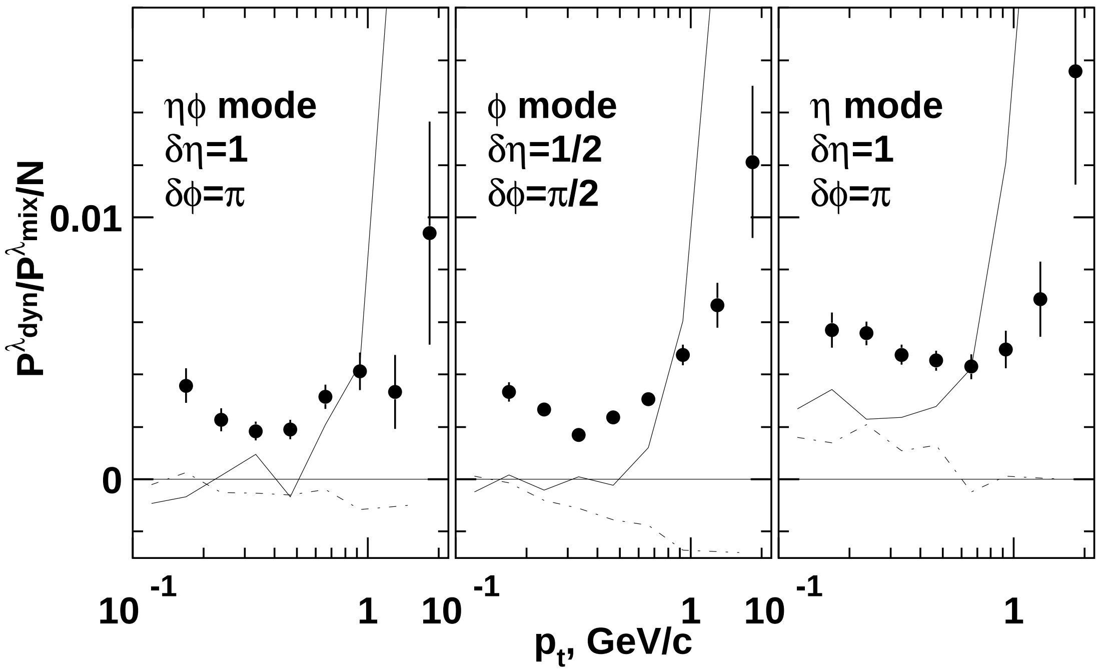

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Qualitative trends in peripheral data are as expected. What signal to expect in the central data, if correlation does not change ?

$$\left(\frac{P_{\rm true}}{P_{\rm mix}} - 1\right)\frac{1}{N}\bigg|_{\rm centr} = \left(\frac{P_{\rm true}}{P_{\rm mix}} - 1\right)\bigg|_{\rm periph}\frac{1}{N_{\rm centr}} \qquad (4)$$

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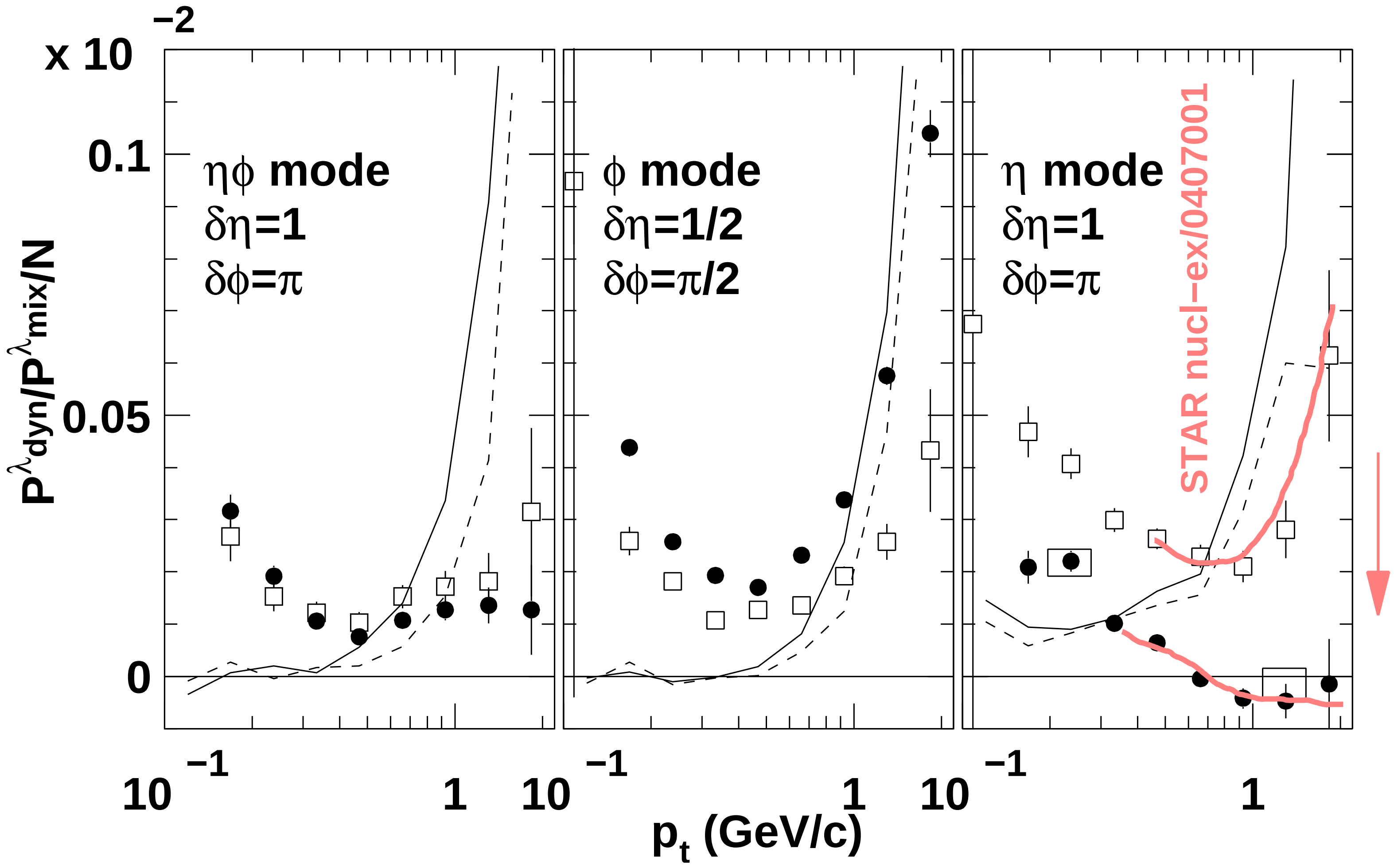

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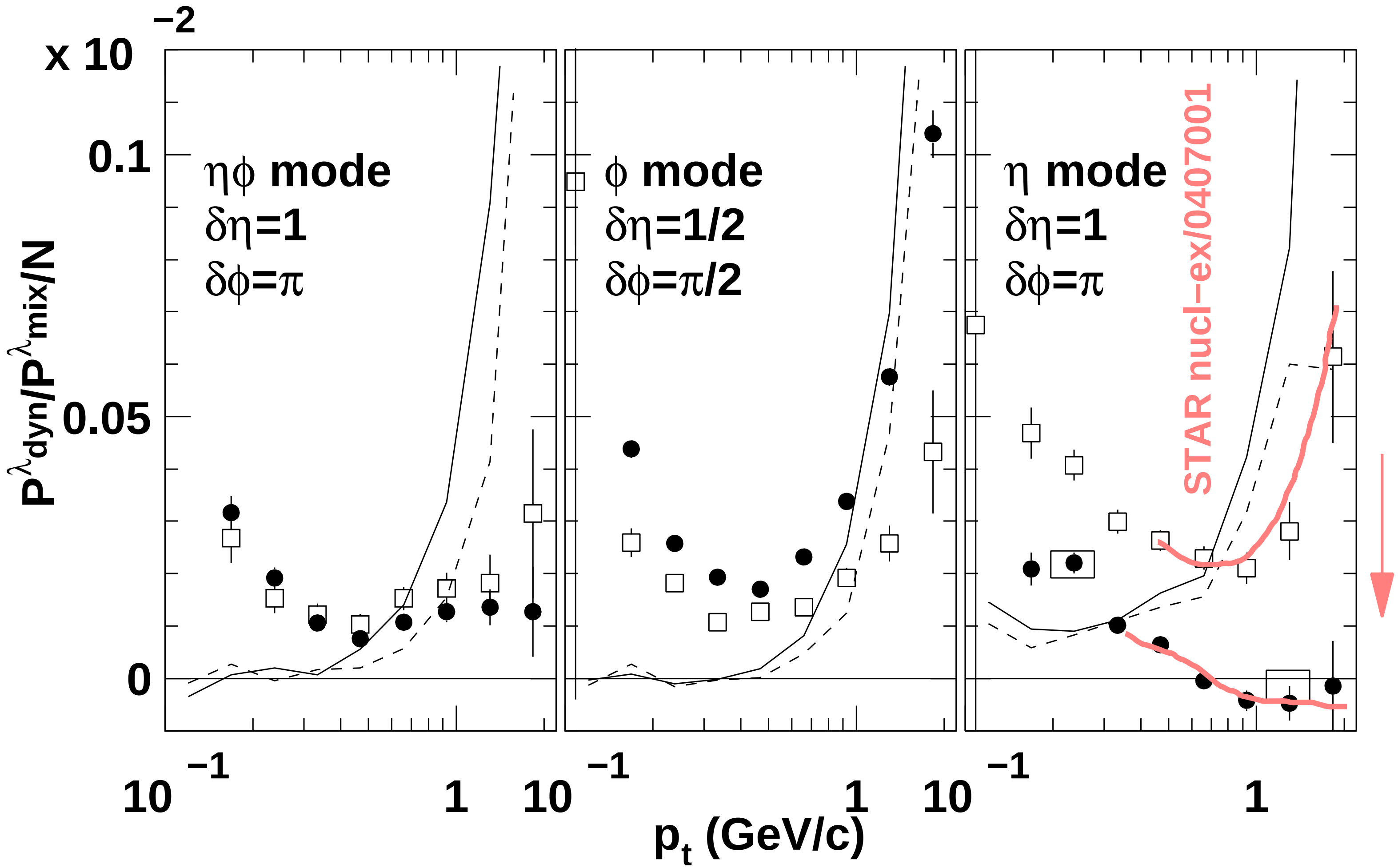

Central (top 4%) events: normalized dynamic texture for fineness scales $m = 0, 1, 0$ from left to right panels, respectively, as a function of p_t.

● STAR data; solid line – Hijing without jet quenching; dashed line – Hijing with quenching; □ peripheral STAR data renormalized to compare.

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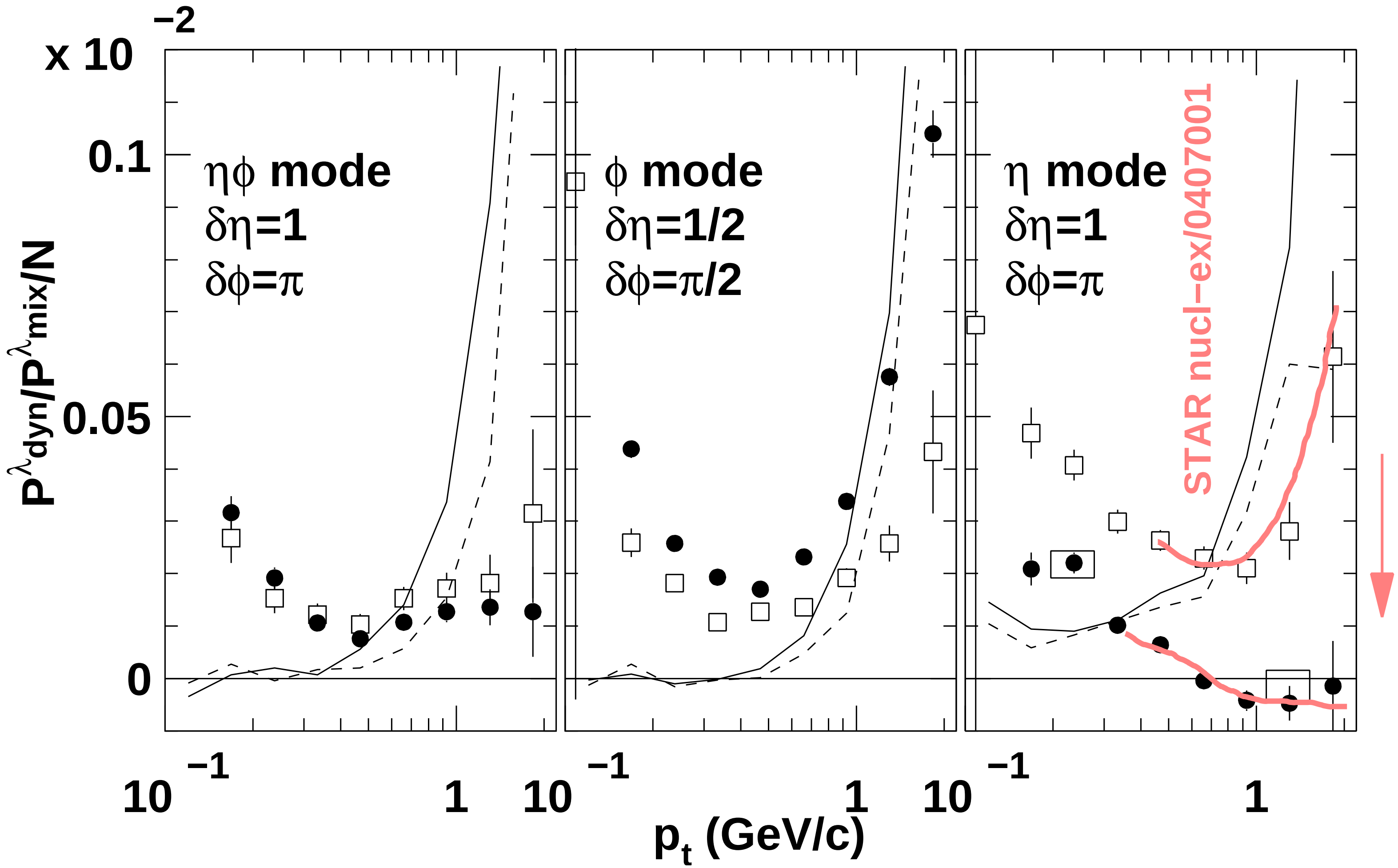

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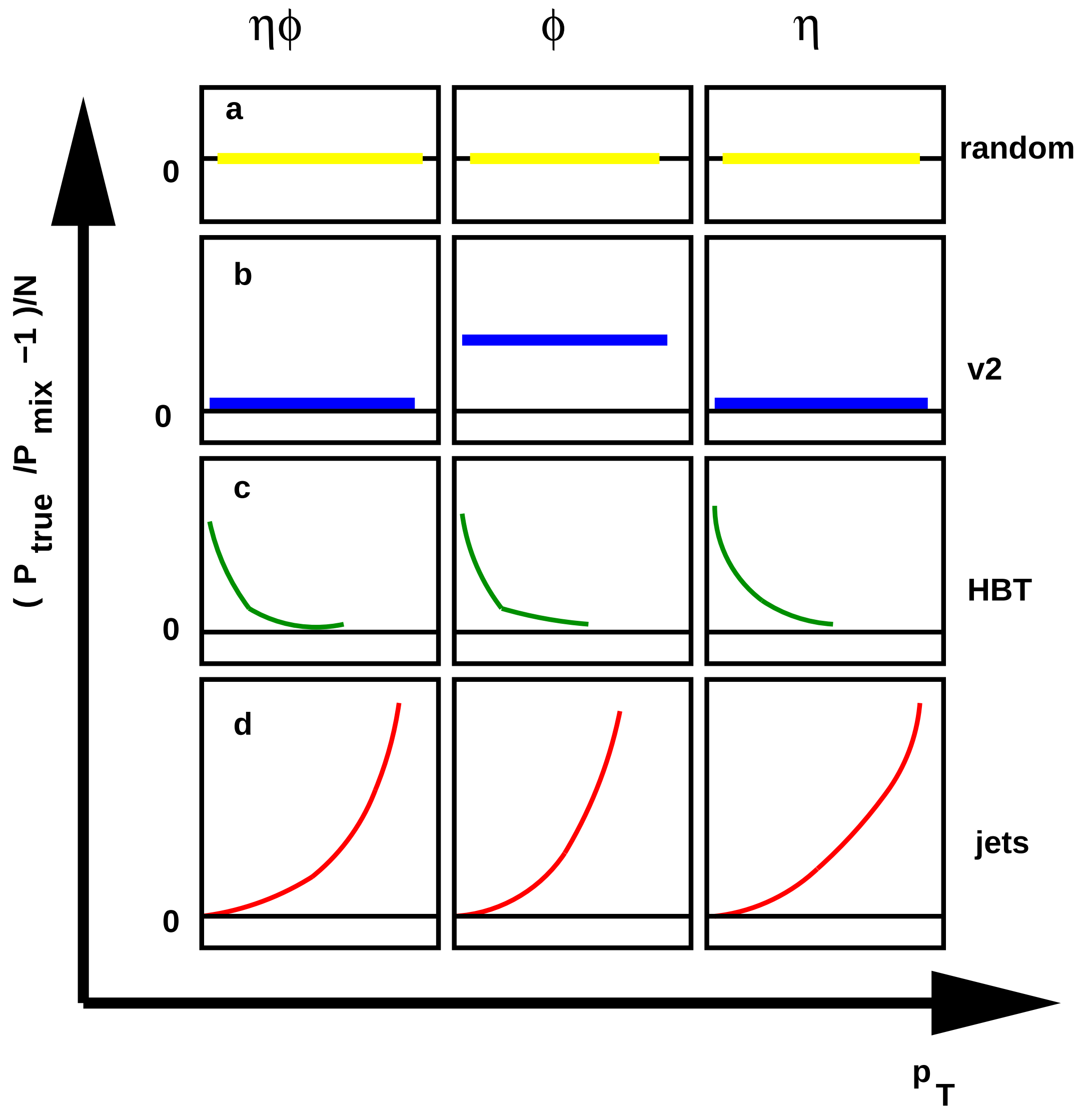
Minijet elongation ⇒ correlation broadening ⇔ reduced correlation gradient ⇔ reduced "texture"

10 "Dynamic texture" response



Dynamic texture response in various idealized situations (showing only one scale):

(a) events of random (uncorrelated) particles

(b) p_t-independent elliptic flow

(c) Correlations at low Q_{inv} (Bose-Einstein correlations and Coulomb effect)

(d) HIJING jets

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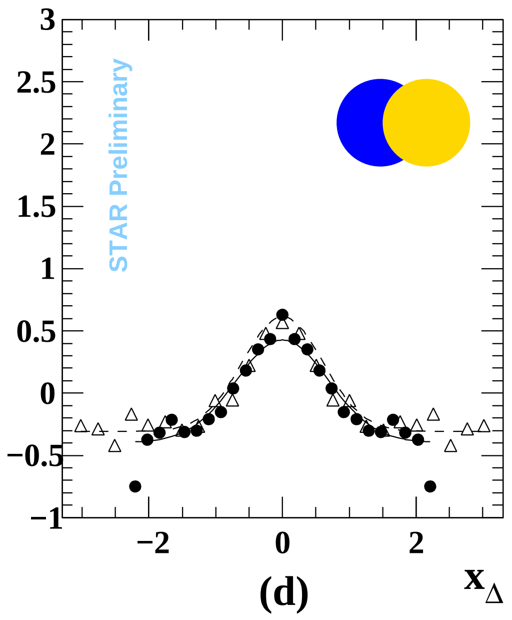

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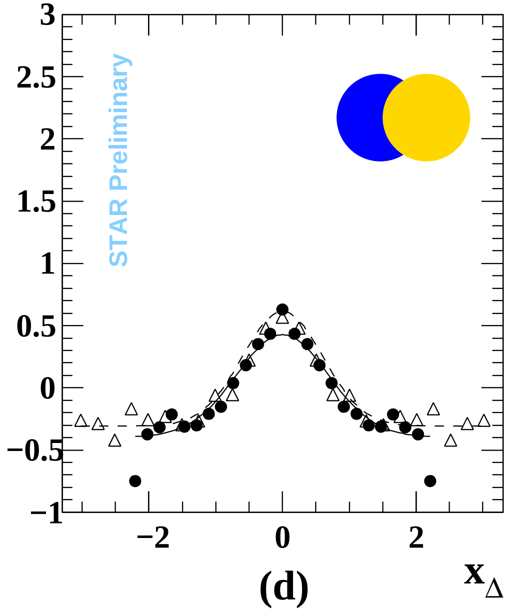

Projections of $\bar{N}[\rho(\eta_\Delta, \phi_\Delta)/\rho(\eta_\Delta, \phi_\Delta)_{\rm ref} - 1]|_{CI}$ on x_Δ which is ϕ_Δ (Δ) or η_Δ (●). v_1 and v_2 are subtracted.

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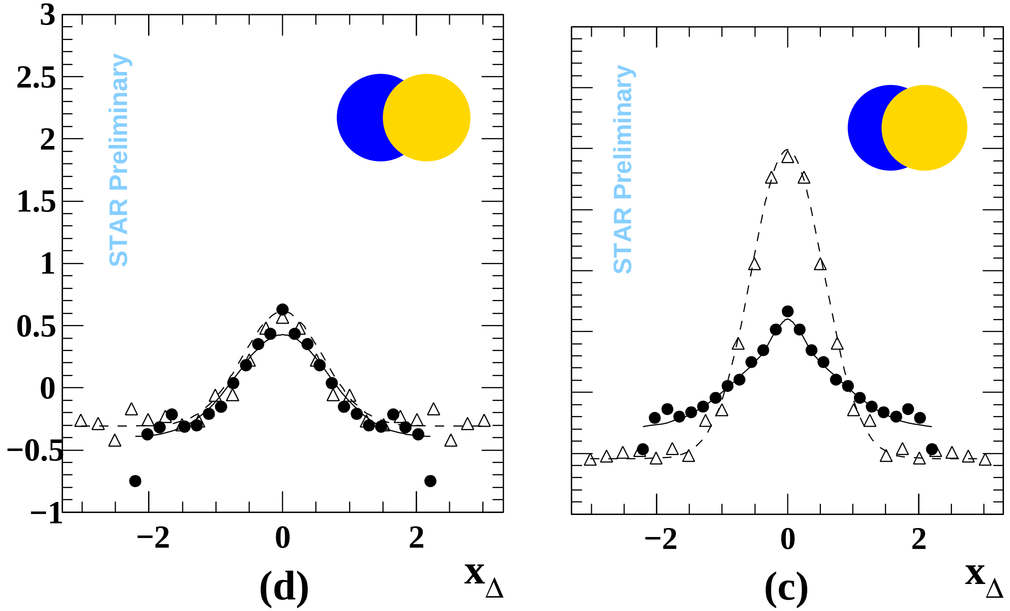

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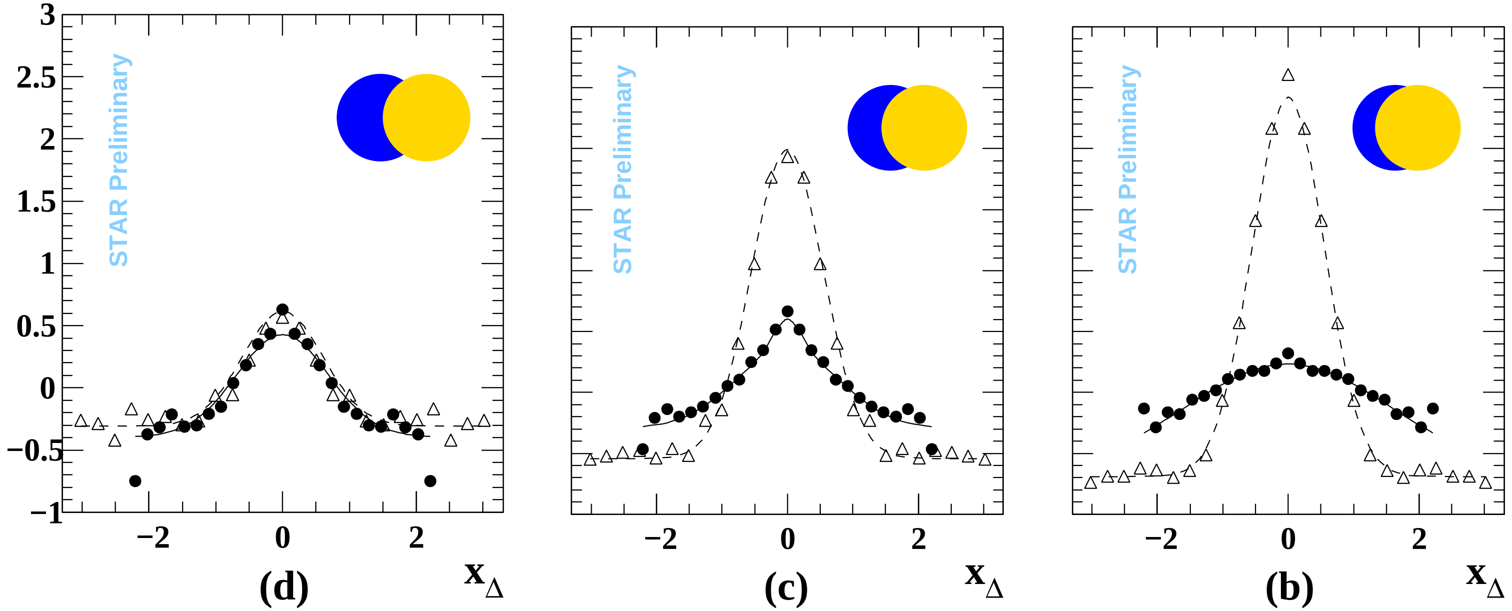

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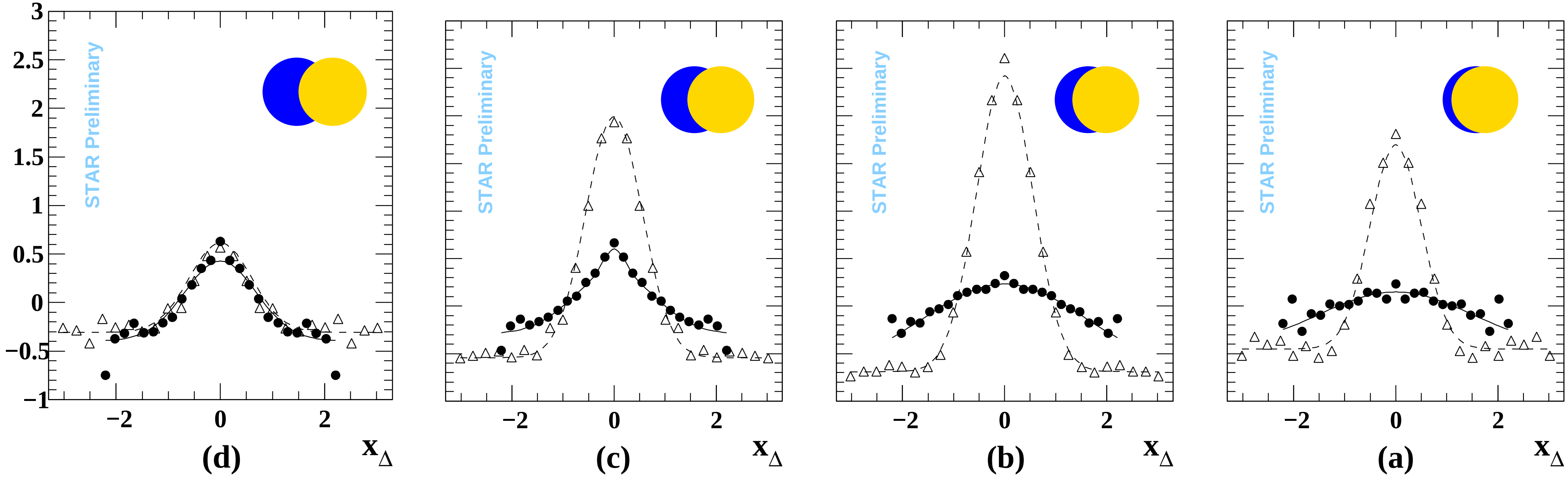

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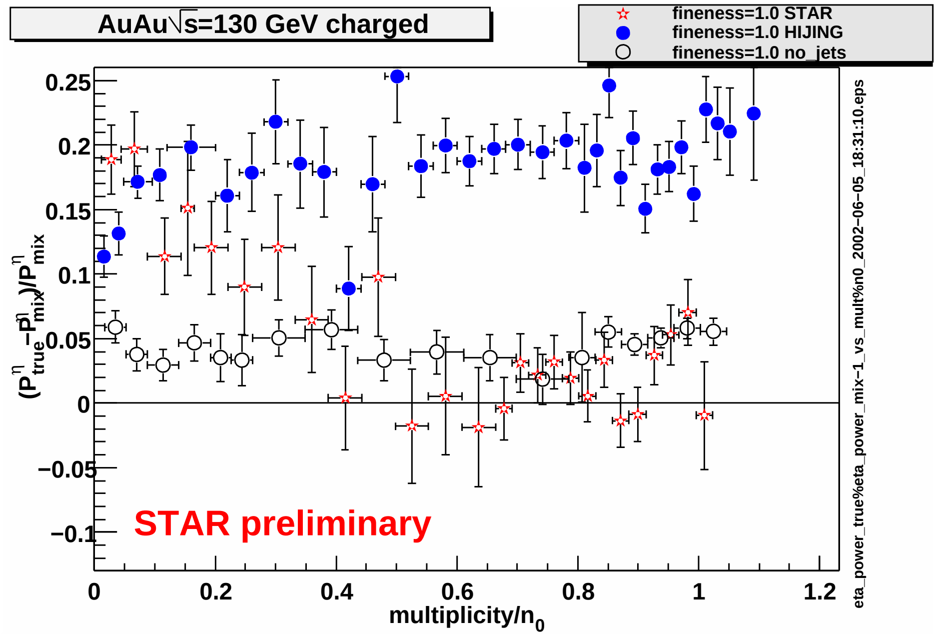
nucl-ex/0211015. STAR DWT analysis of charge-independent correlations, AuAu, $\sqrt{s_{NN}} = 130$ GeV



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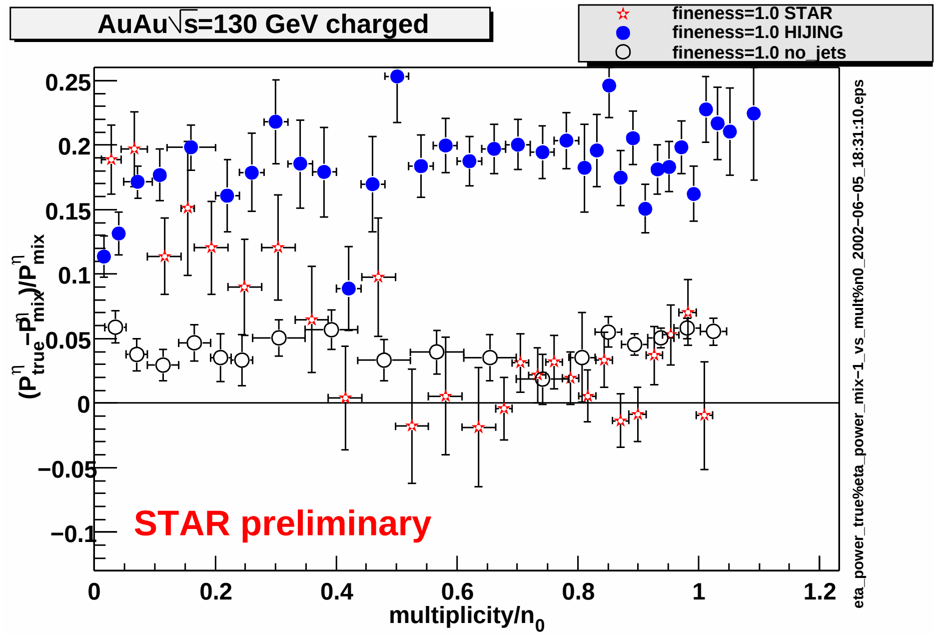

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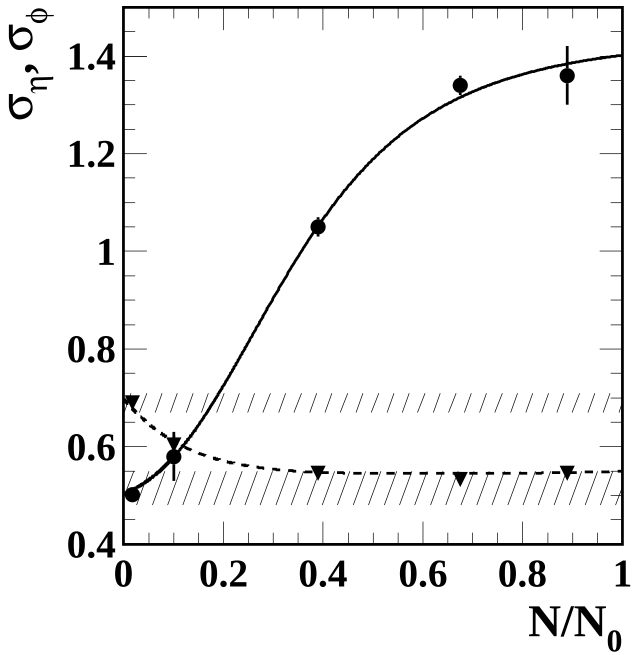

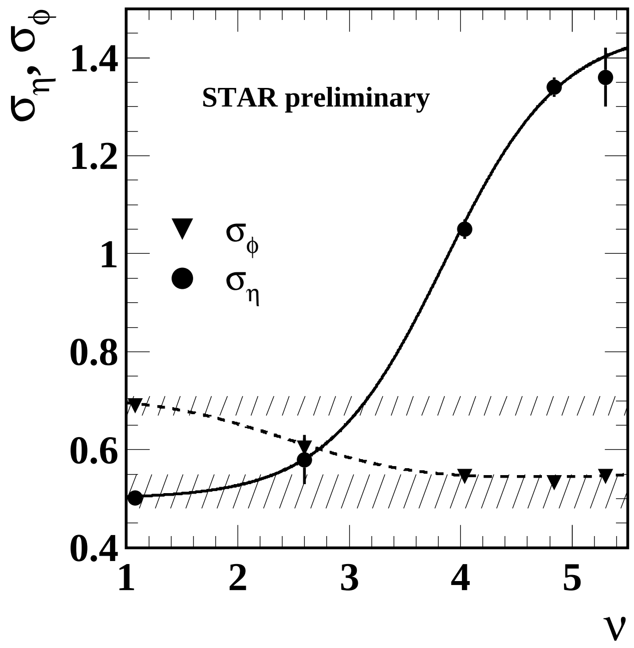

nucl-ex/0411003. STAR two-particle correlation analysis. The step-like character of the centrality dependence is elucidated using $\nu = (N_{\rm part}/2)^{\frac{1}{3}}$

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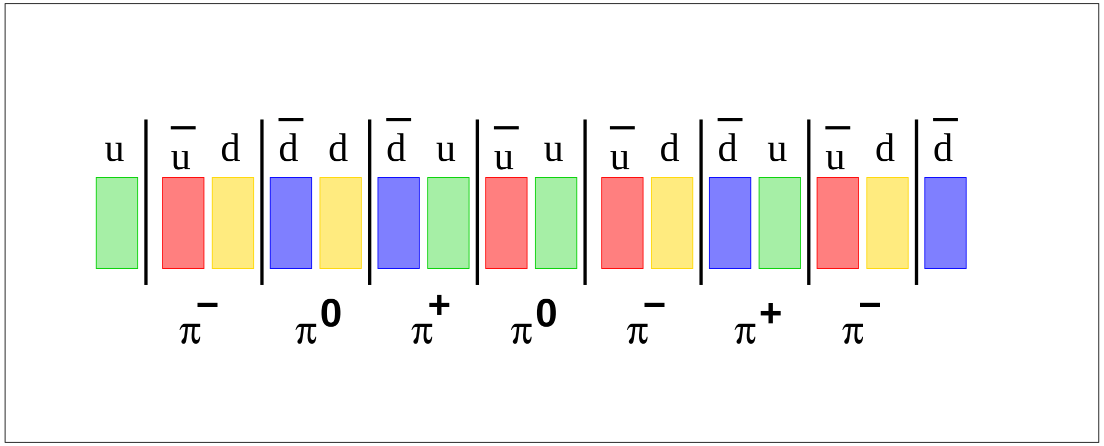

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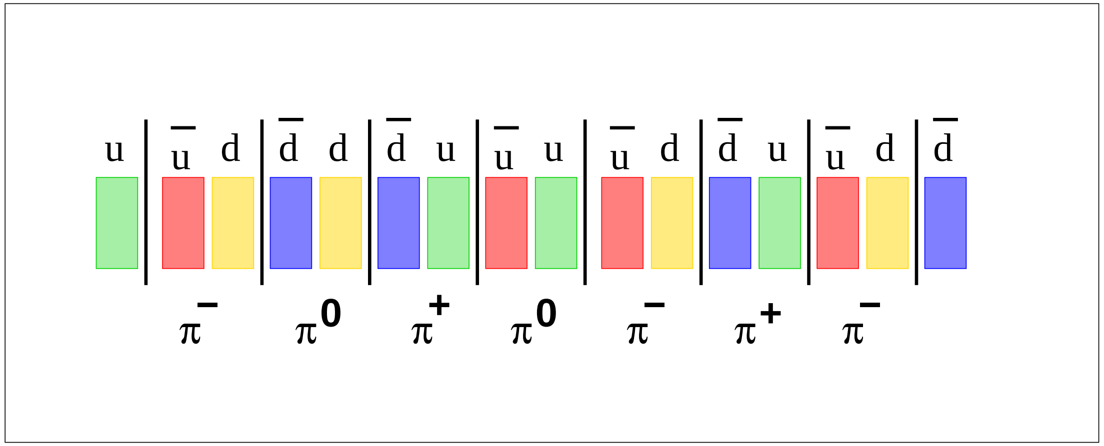

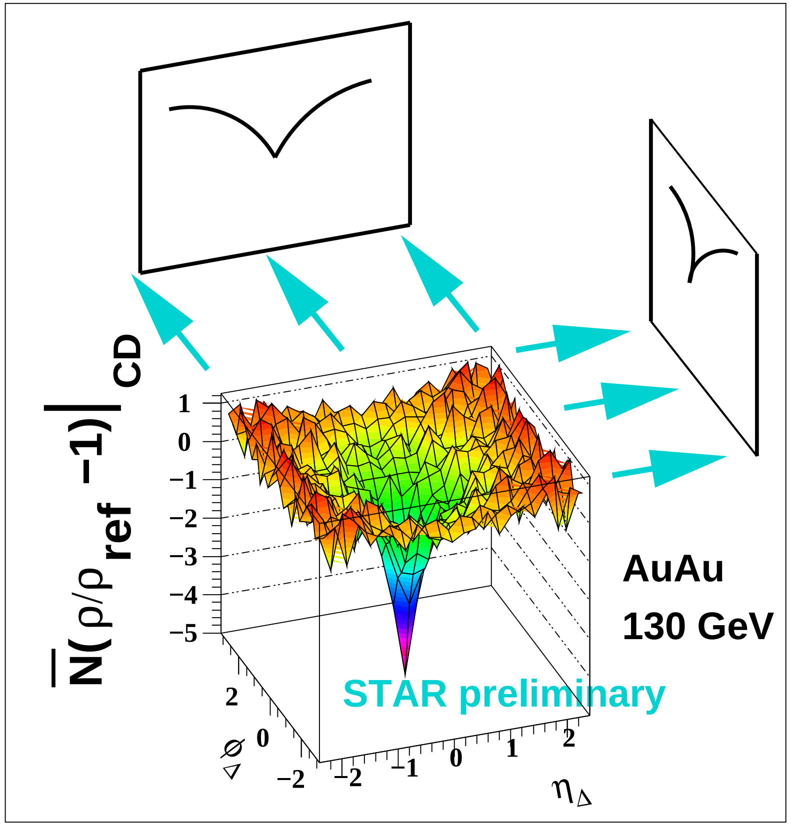

The driving physics: charge conservation in hadronization. Suppress short range correlations – BEC and conversion e^+e^- – by a kinematic pair cut. The $\bar{N}\times$ is good when number of correlation sources $\propto N$.

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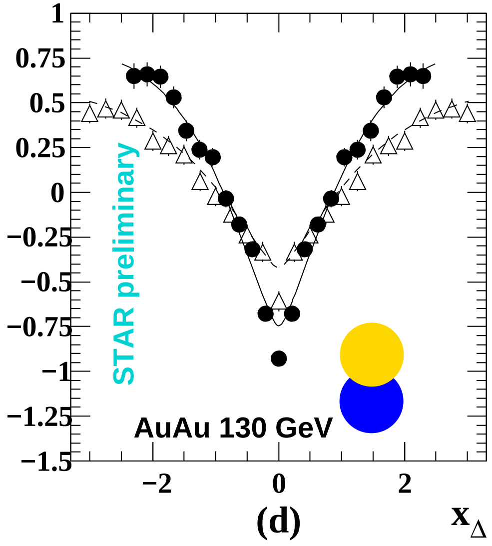

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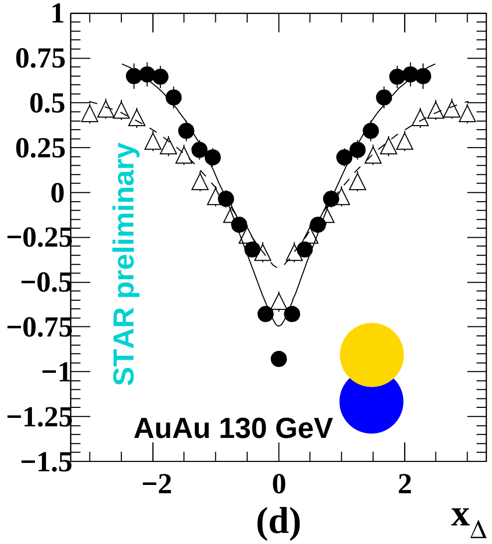

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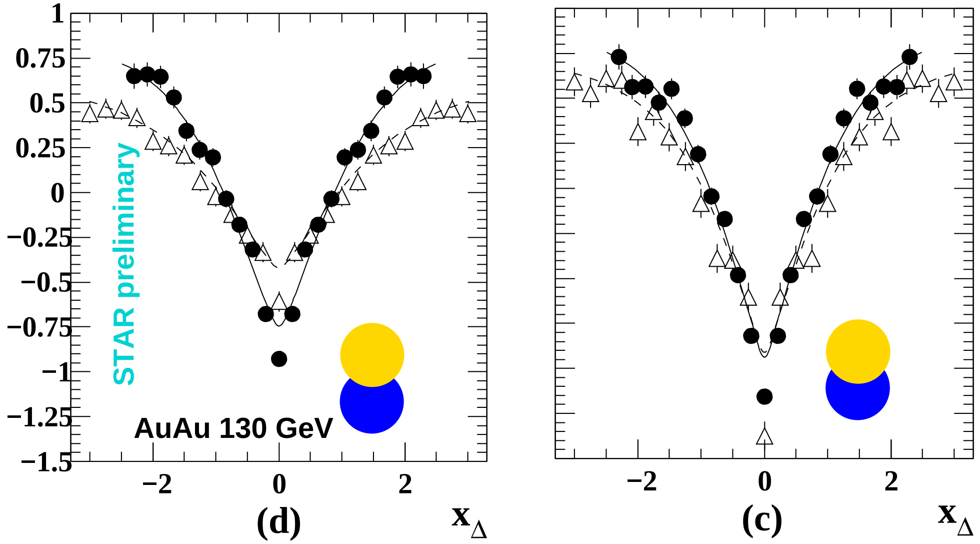

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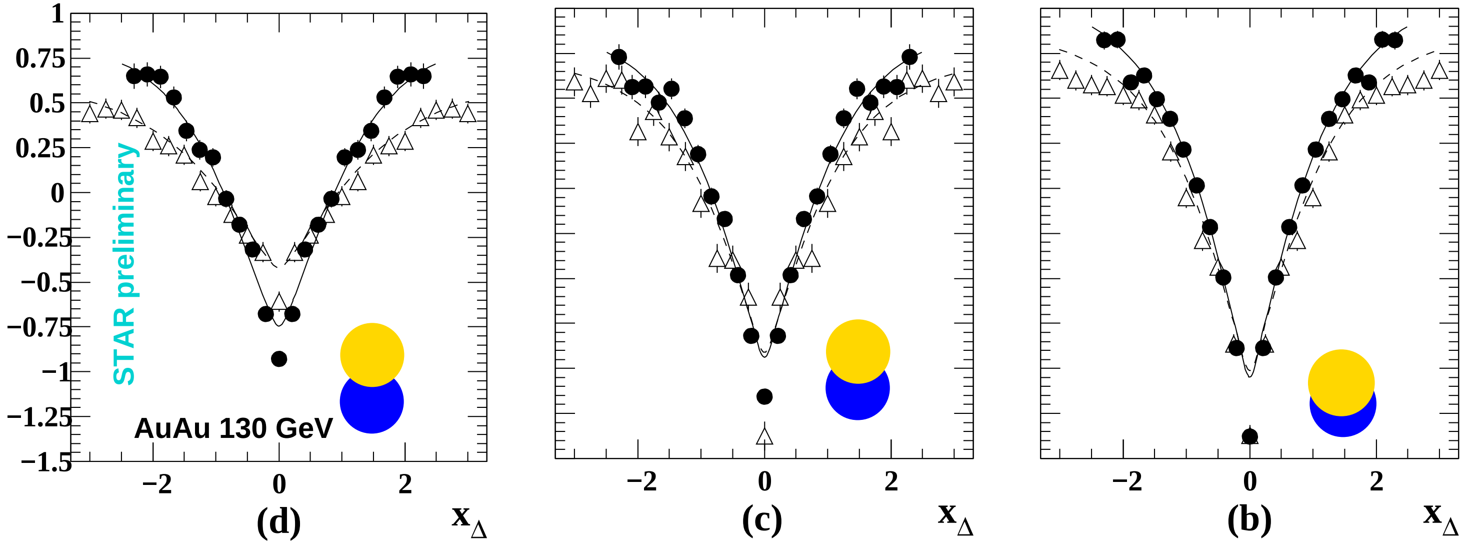

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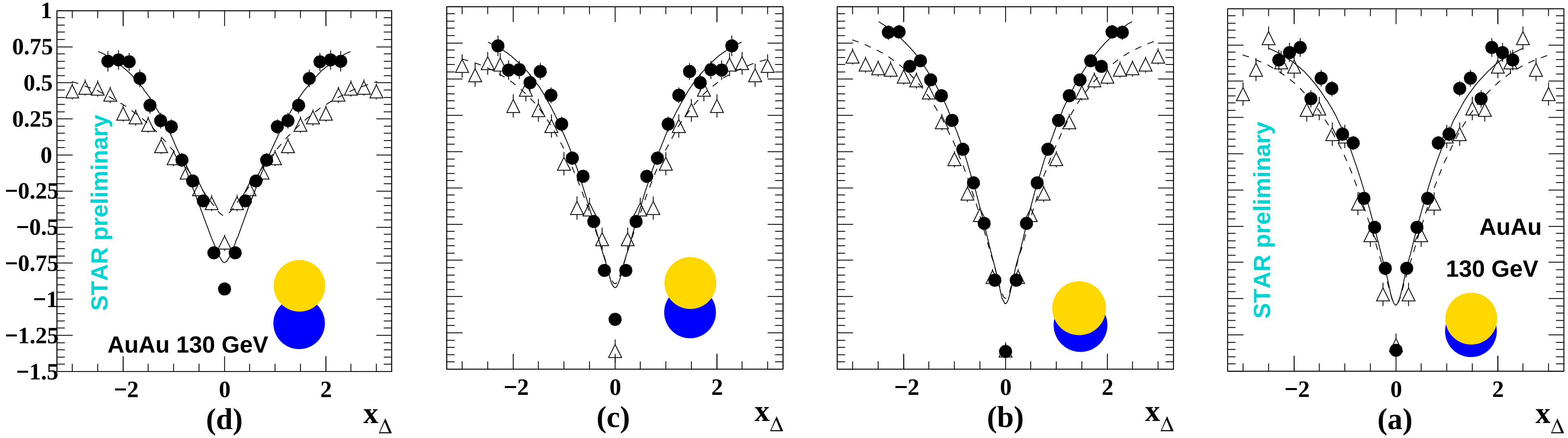

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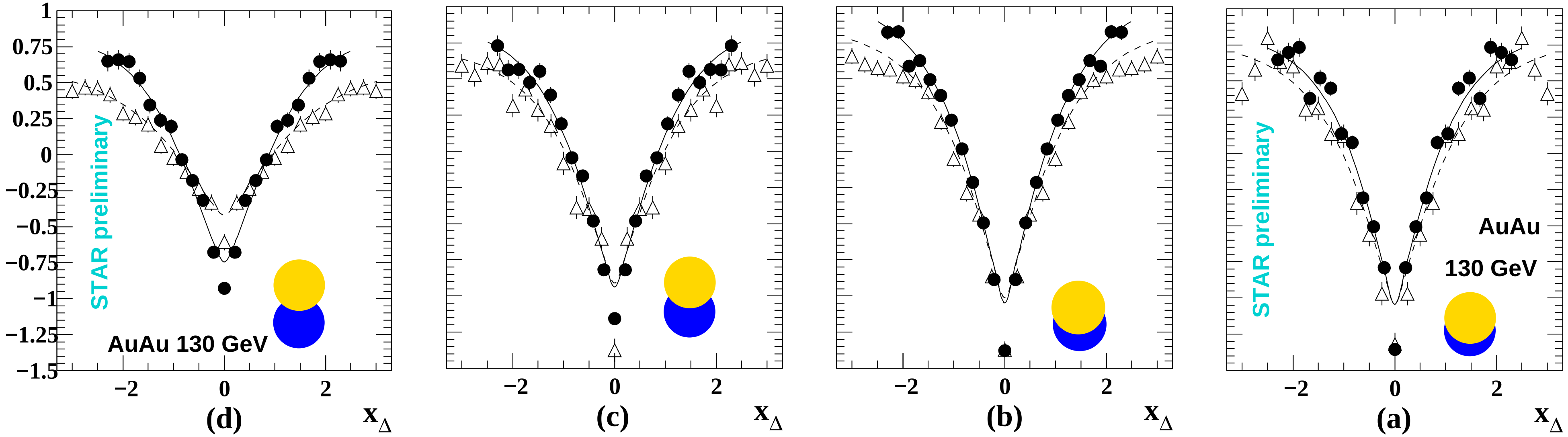

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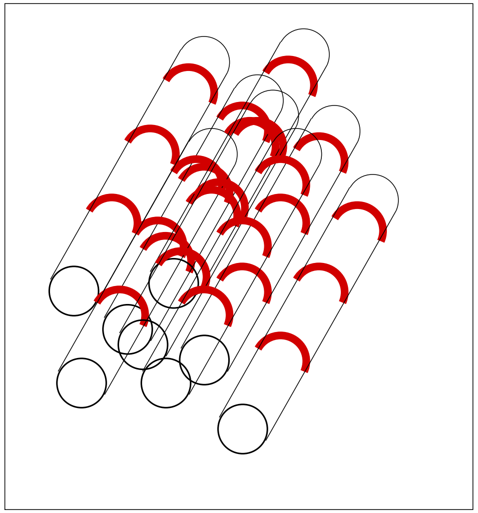

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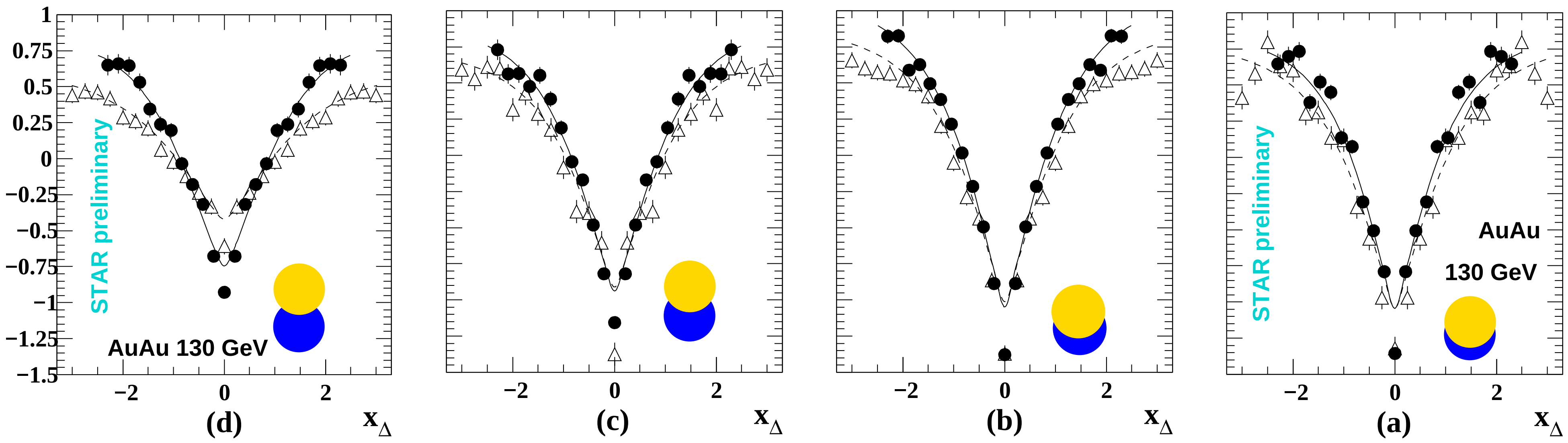

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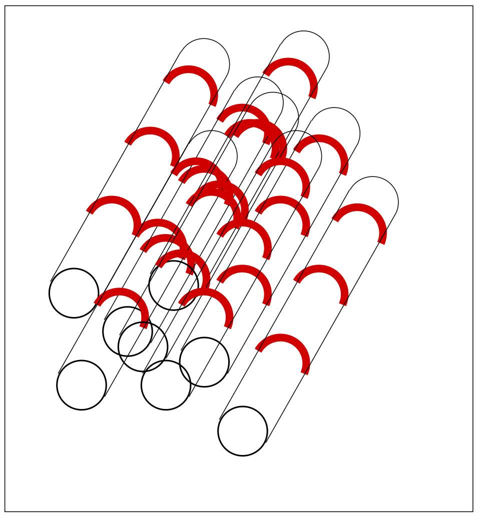

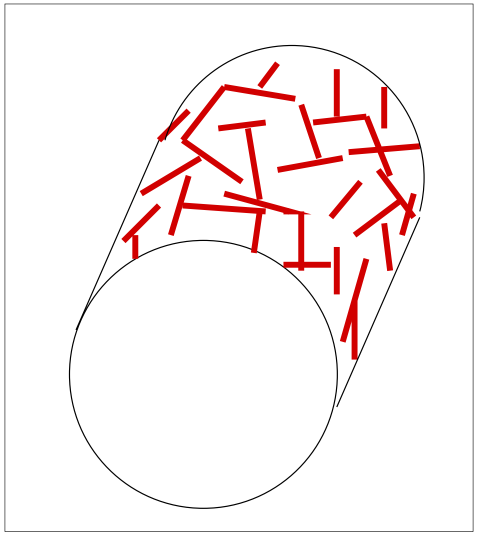

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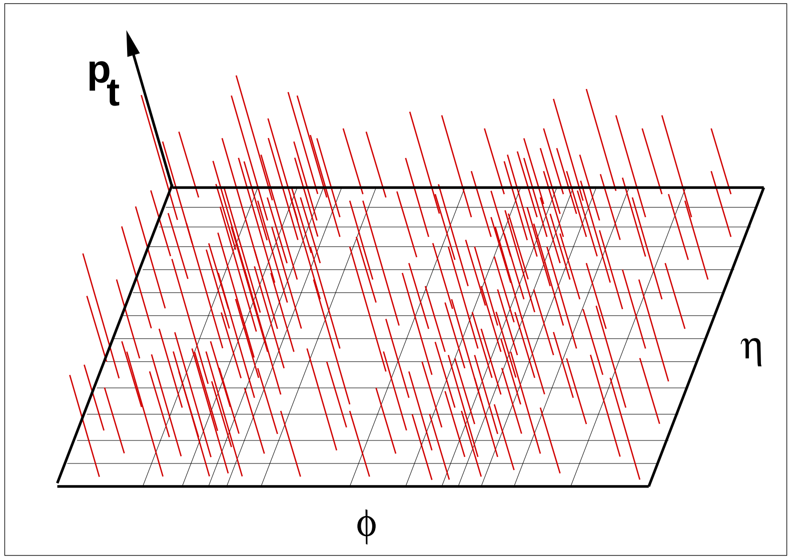

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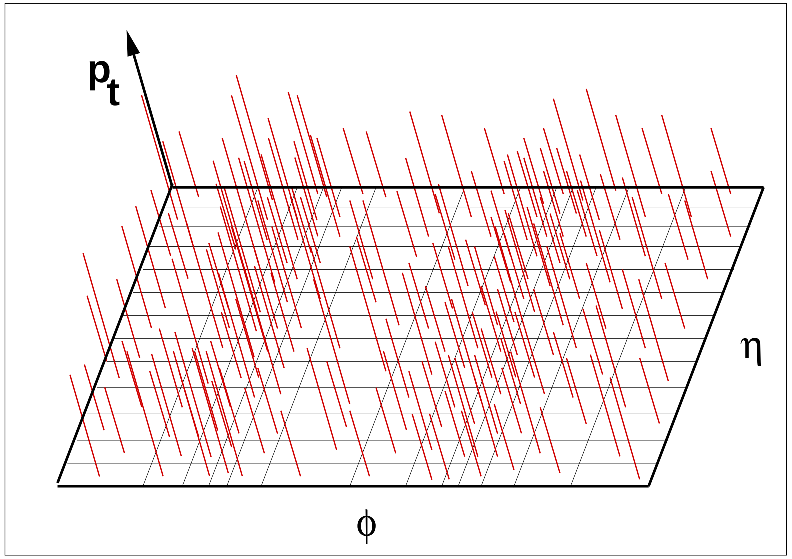

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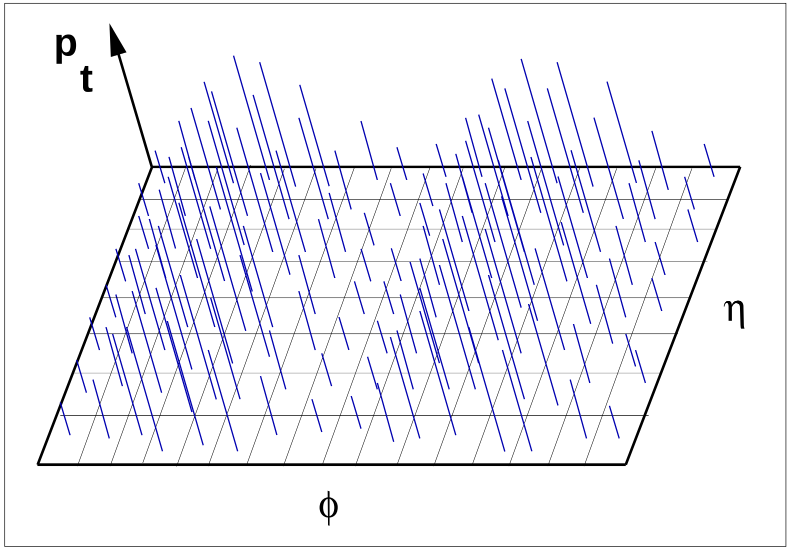

Also elliptic... flow (p_t effect) !
Pro: blast wave fits. Is there a **direct** measurement ?

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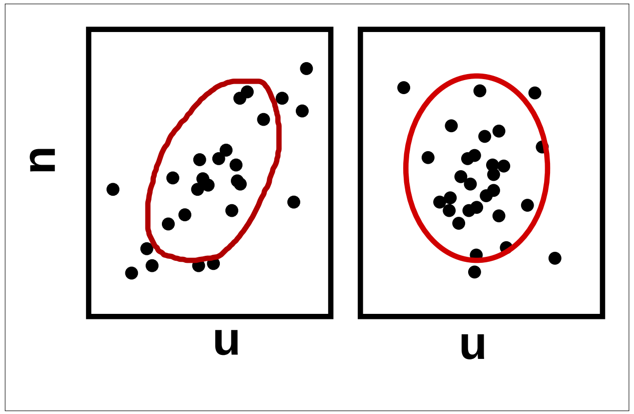

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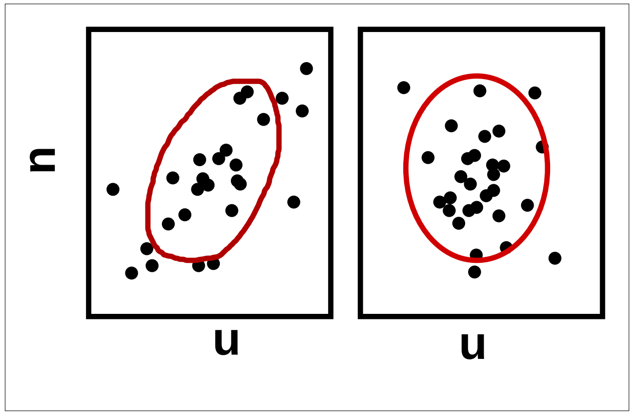

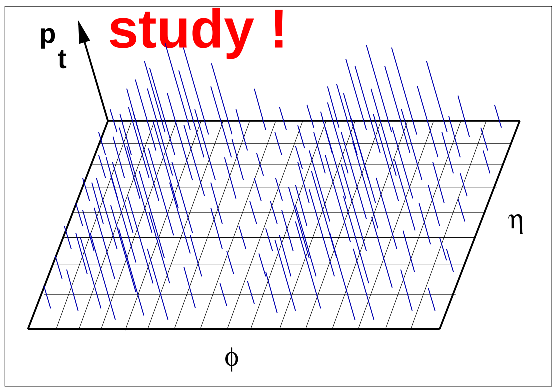

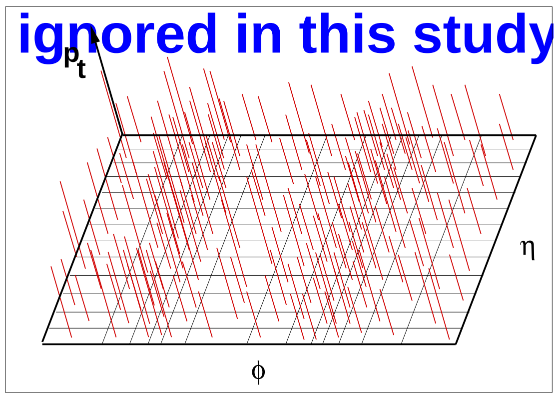

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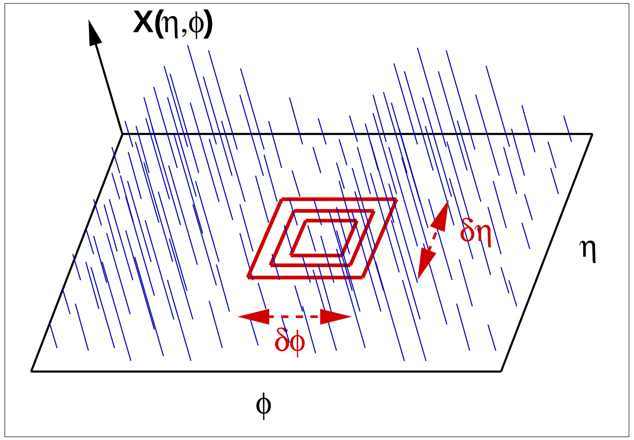

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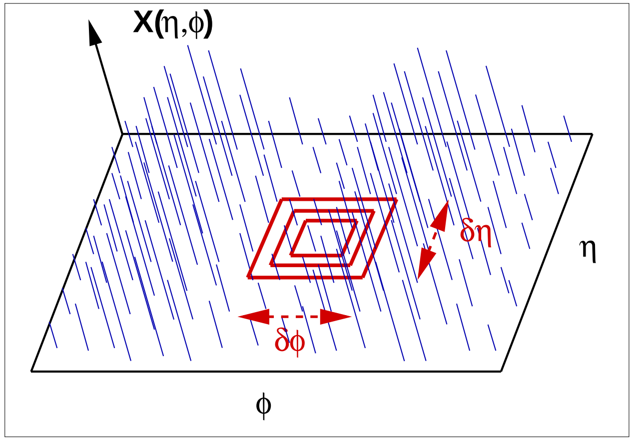

$$\mathrm{Var}[X;\delta\eta,\delta\phi] = \int_{-\delta\eta/2}^{\delta\eta/2} d\eta_1 \int_{-\delta\phi/2}^{\delta\phi/2} d\phi_1 \int_{-\delta\eta/2}^{\delta\eta/2} d\eta_2 \int_{-\delta\phi/2}^{\delta\phi/2} d\phi_2 \times[\overline{X(\eta_1,\phi_1)X(\eta_2,\phi_2)} - \overline{X(\eta_1,\phi_1)} \times \overline{X(\eta_2,\phi_2)}] \quad (8)$$

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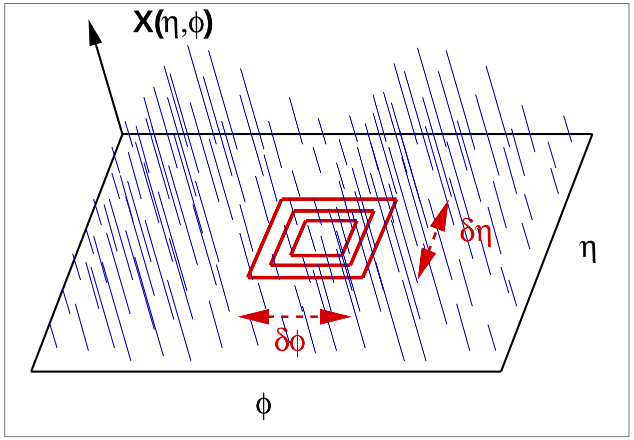

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$$\times[\overline{X(\eta_1,\phi_1)X(\eta_2,\phi_2)} - \overline{X(\eta_1,\phi_1)} \times \overline{X(\eta_2,\phi_2)}]$$

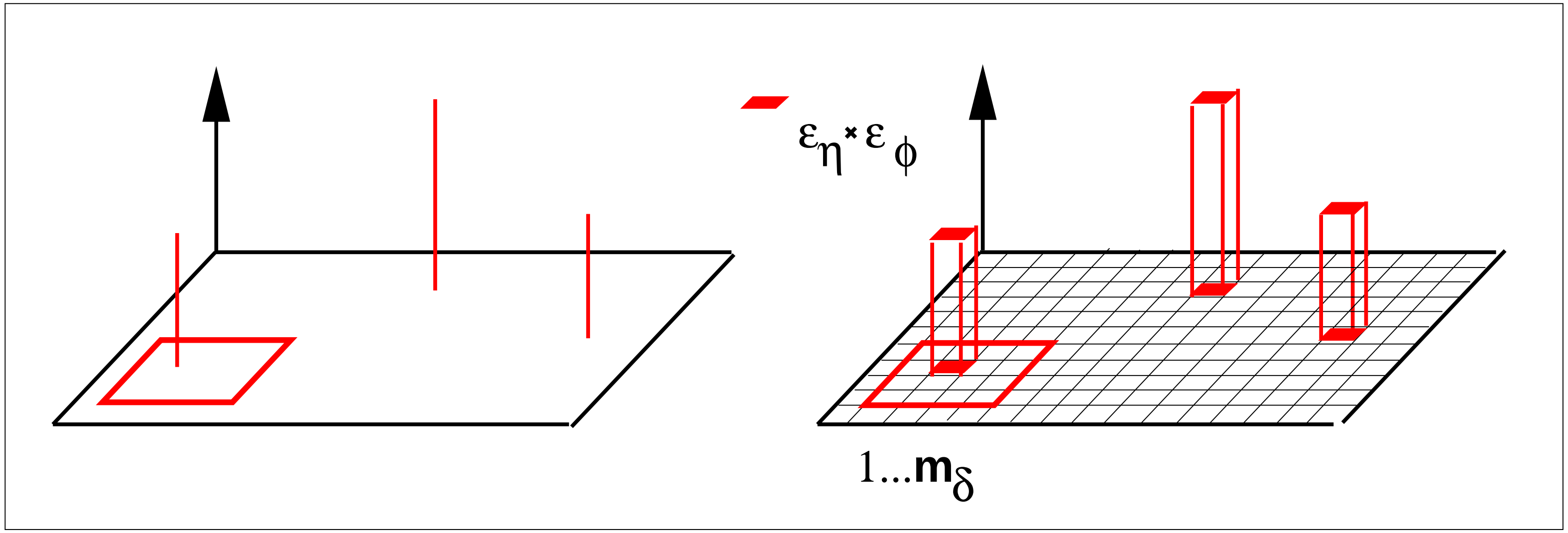
Compare with uncorrelated reference; recognize autocorrelation $\rho(X,t_\Delta) \equiv \overline{X(t)X(t+t_\Delta)}$ (t-average).

$$\Delta\sigma^2(X,\delta\eta,\delta\phi) = \quad (9)$$

$$\int_{-\delta\eta/2}^{\delta\eta/2} d\eta_1 \int_{-\delta\phi/2}^{\delta\phi/2} d\phi_1 \int_{-\delta\eta/2}^{\delta\eta/2} d\eta_2 \int_{-\delta\phi/2}^{\delta\phi/2} d\phi_2 \Delta\rho(X,\eta_1-\eta_2,\phi_1-\phi_2) \quad (10)$$

$$= 2\int_0^{\delta\eta} d\eta_\Delta 2\int_0^{\delta\phi} d\phi_\Delta(\delta\eta-\eta_\Delta)(\delta\phi-\phi_\Delta)\Delta\rho(X,\eta_\Delta,\phi_\Delta) \quad (11)$$

18 The actual analysis is discrete: $\int \to \sum$



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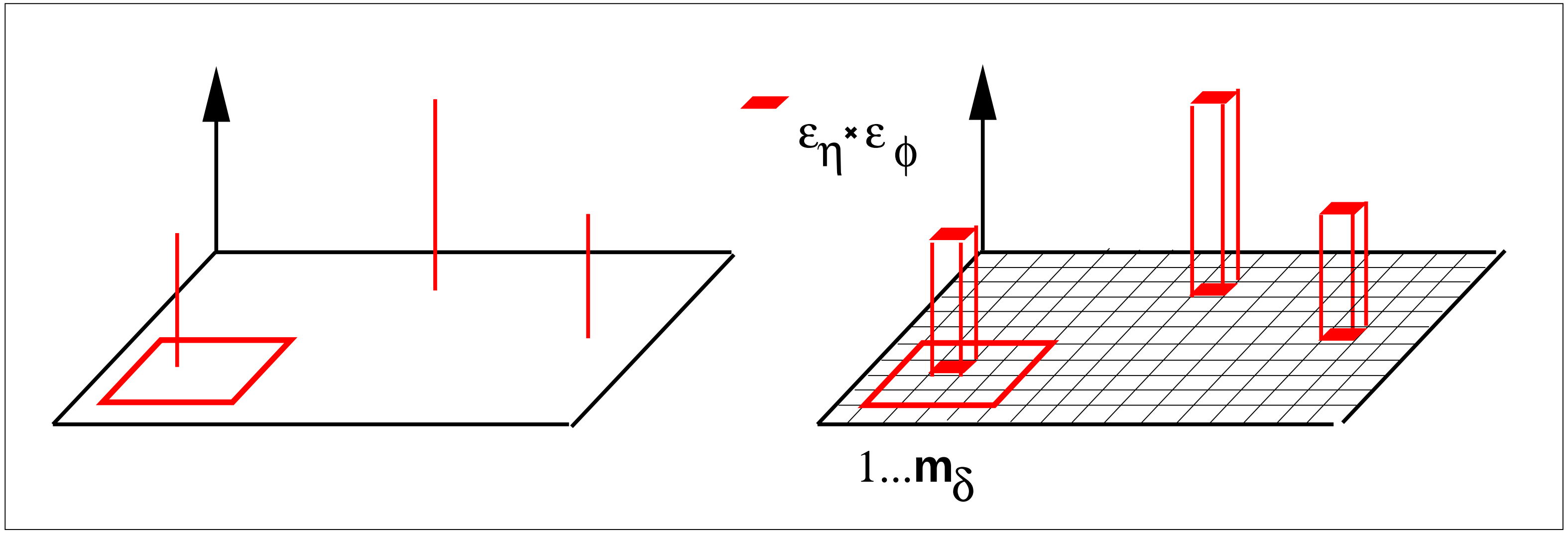

kernel K:

$$(\delta\eta - \eta_\Delta)(\delta\phi - \phi_\Delta) \rightarrow \varepsilon_\eta \varepsilon_\phi K_{m_\delta n_\delta : kl} \equiv \varepsilon_\eta \varepsilon_\phi (m_\delta - k + \frac{1}{2})(n_\delta - l + \frac{1}{2}) \qquad (12)$$

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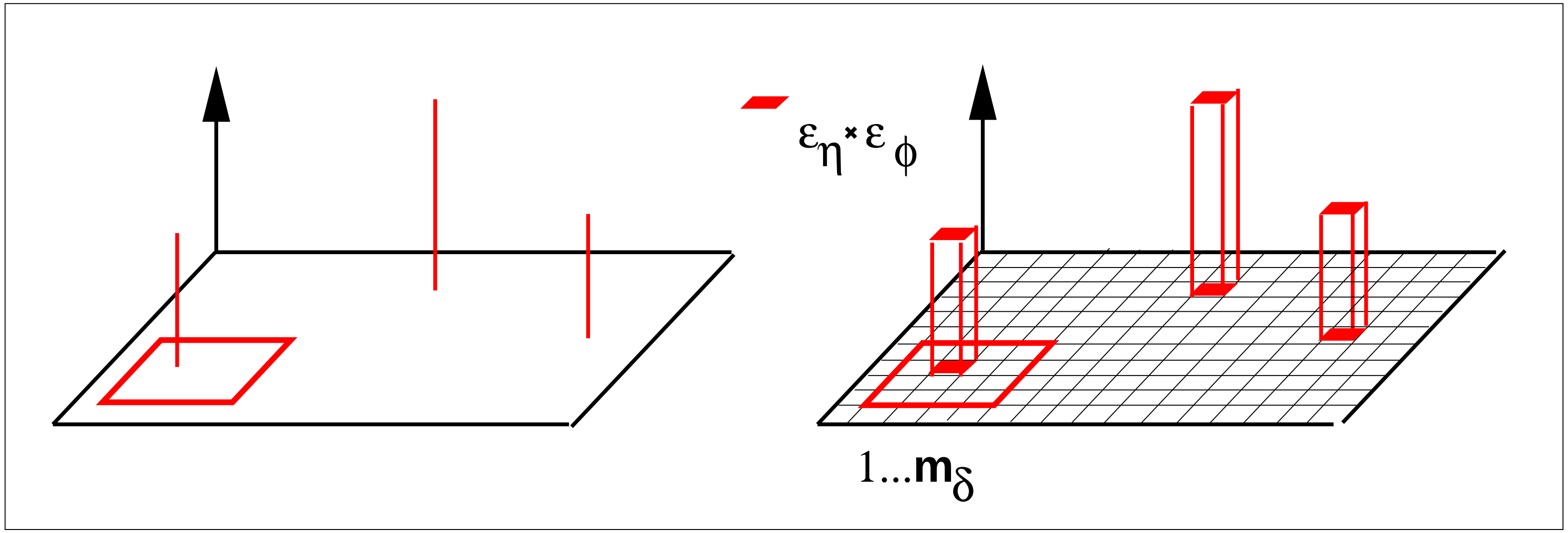

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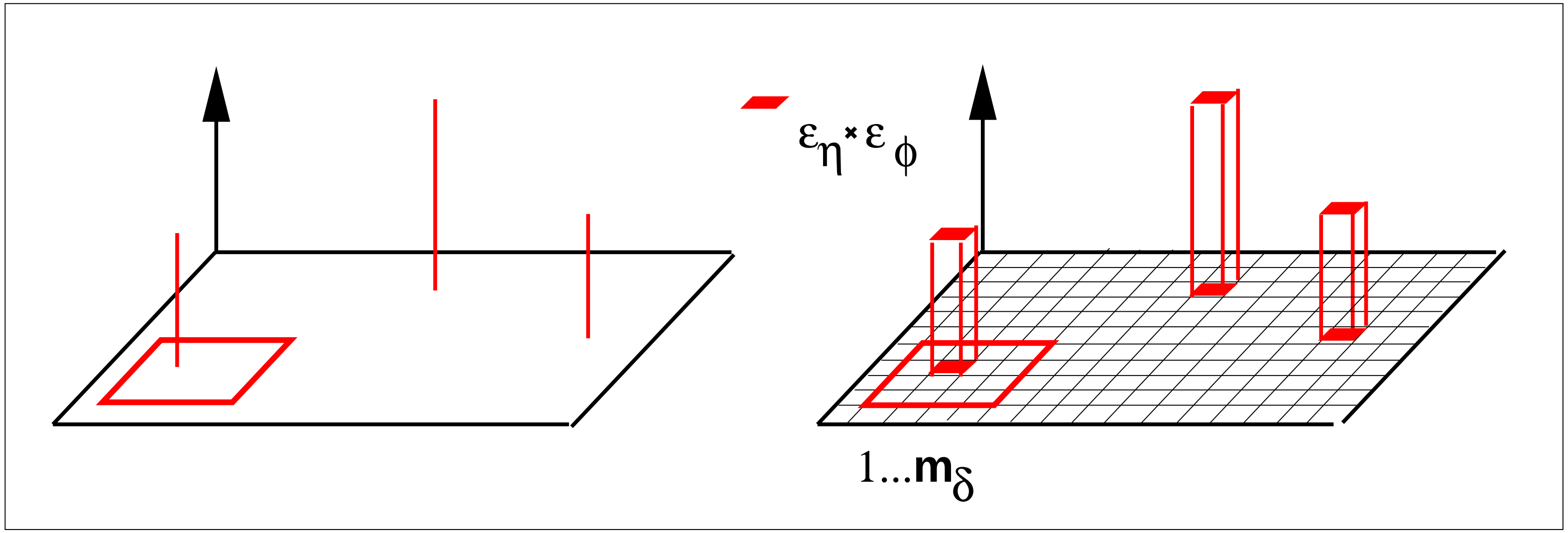

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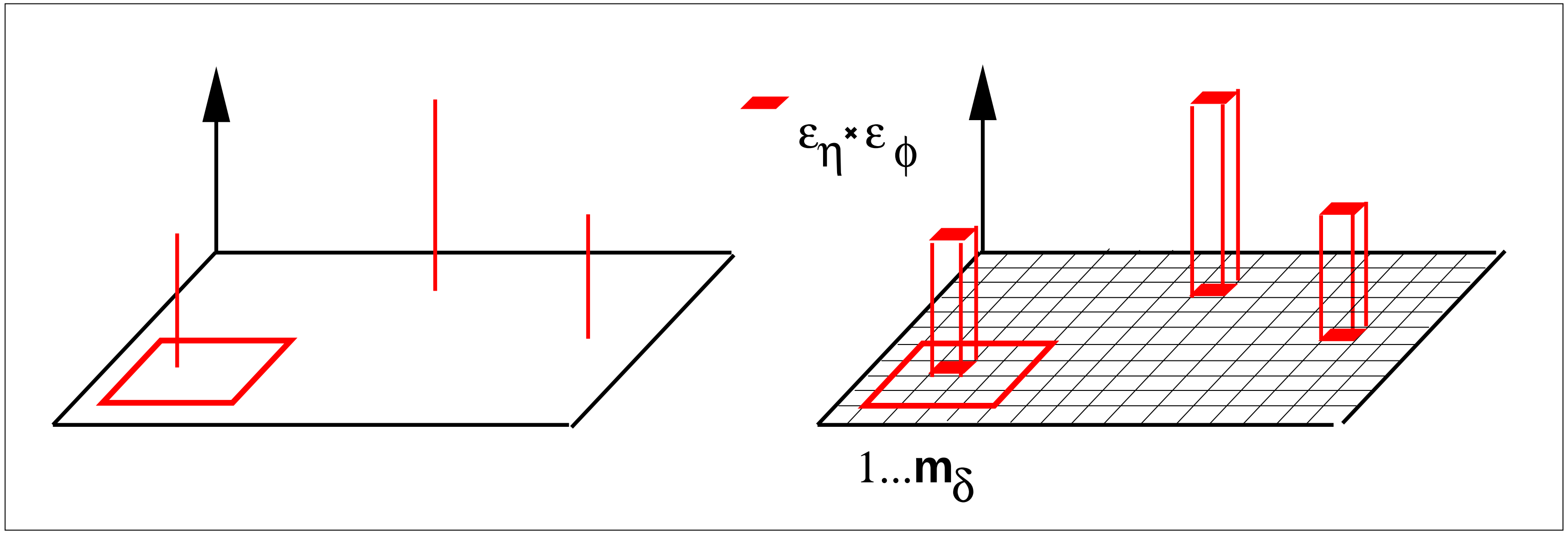

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Inverse problem: knowing $\Delta\sigma^2$, solve for $\Delta\rho/\sqrt{\rho_{\rm ref}} \Rightarrow$ save $O(N)$ in CPU time !

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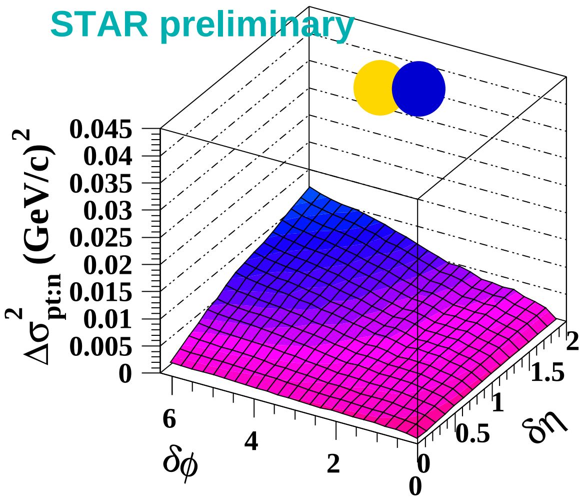

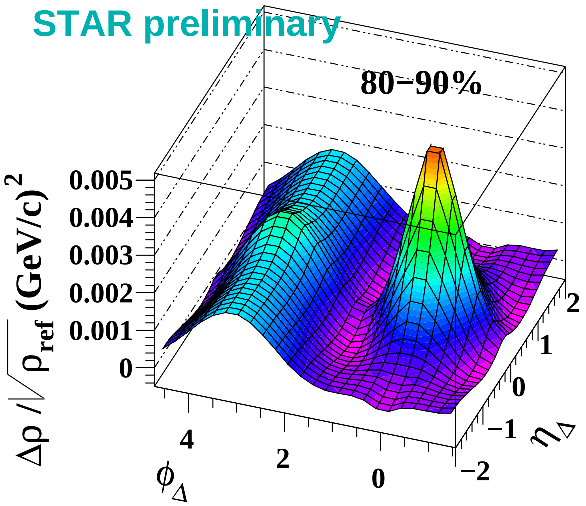

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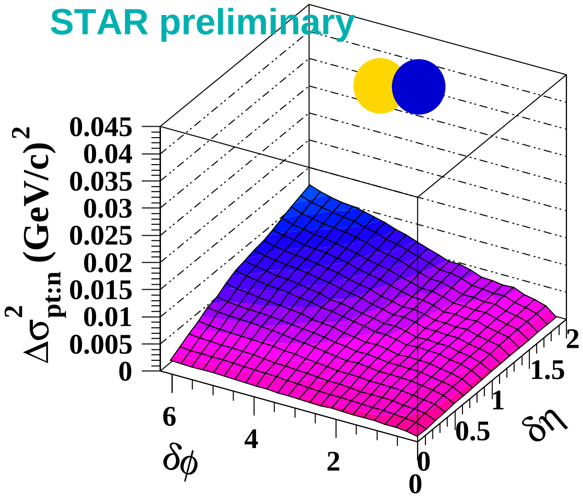

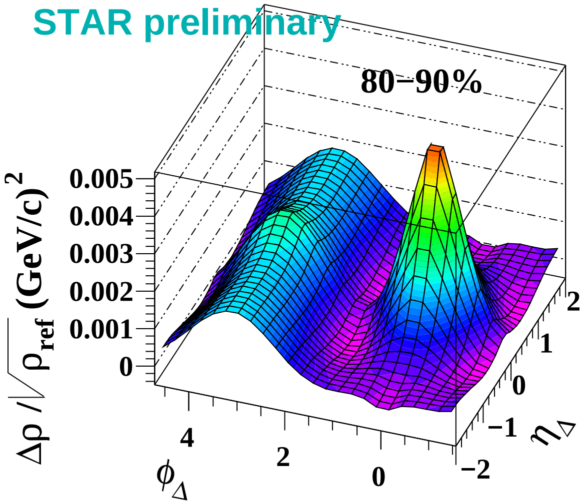

Top:

scale dependence of the "pure" p_t variance.

Bottom:

corresponding autocorrelation

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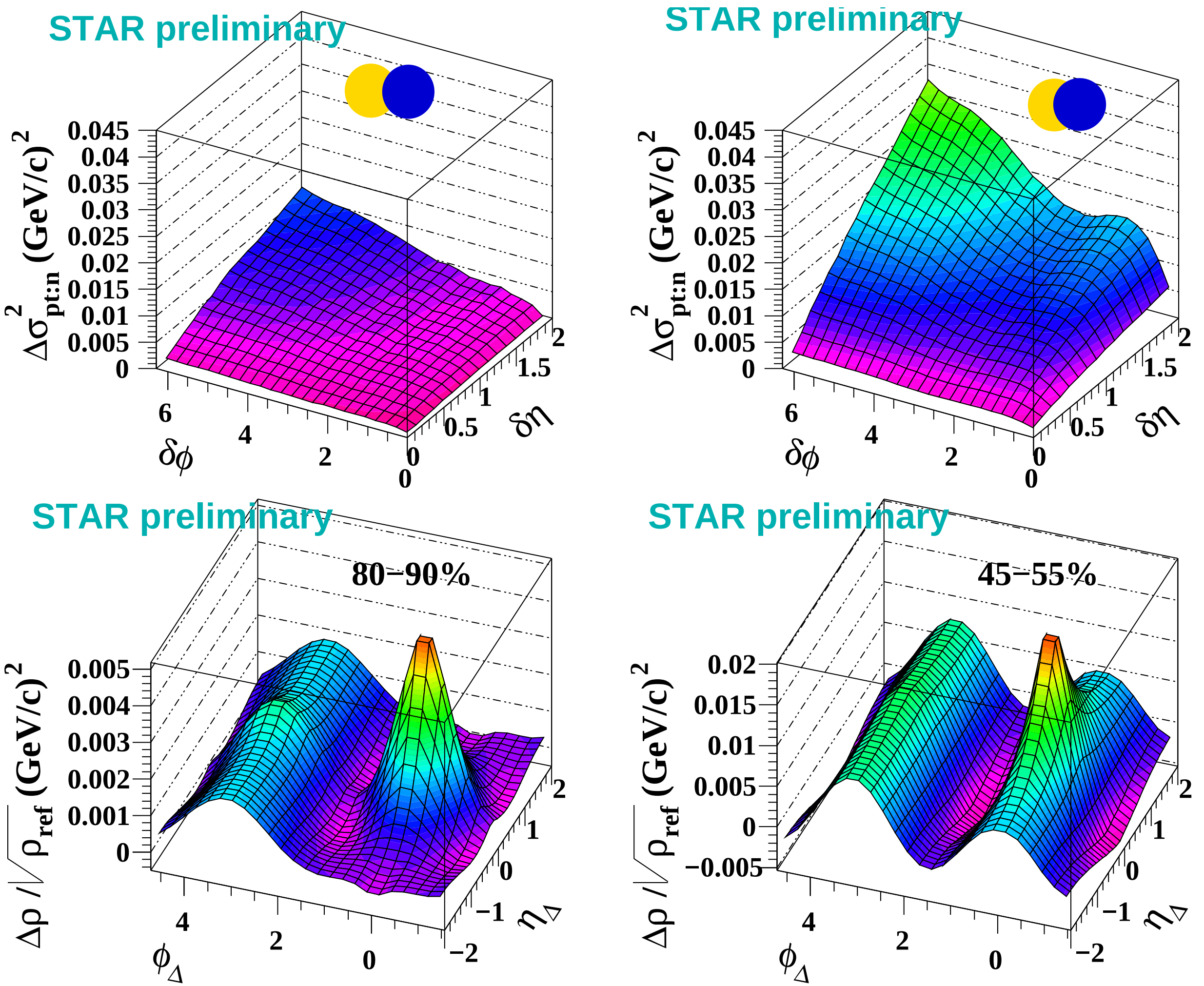

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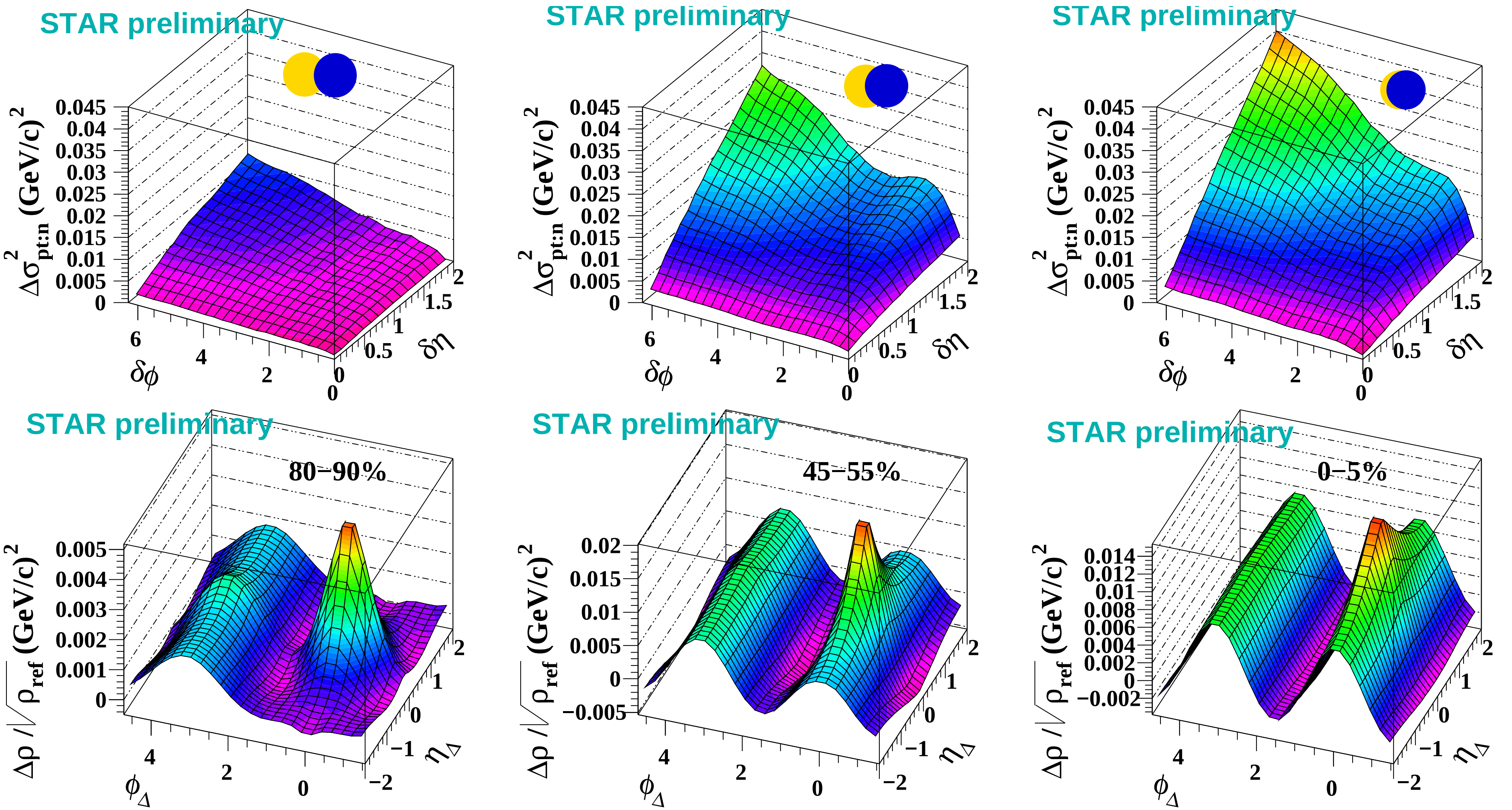

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First direct evidence of elliptic flow as a p_t blast. Next, subtract the flow contribution to look at minijets.

20 Localized p_t correlations: minijets

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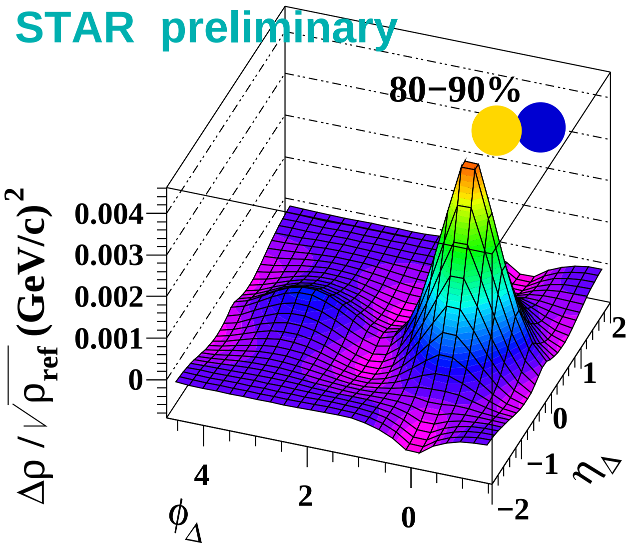
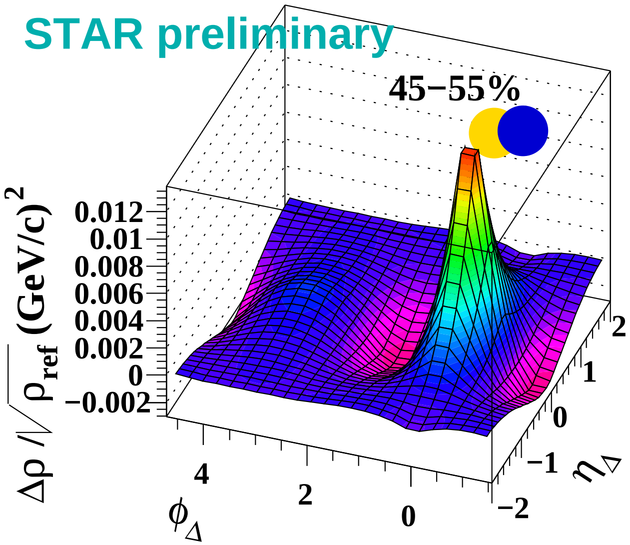
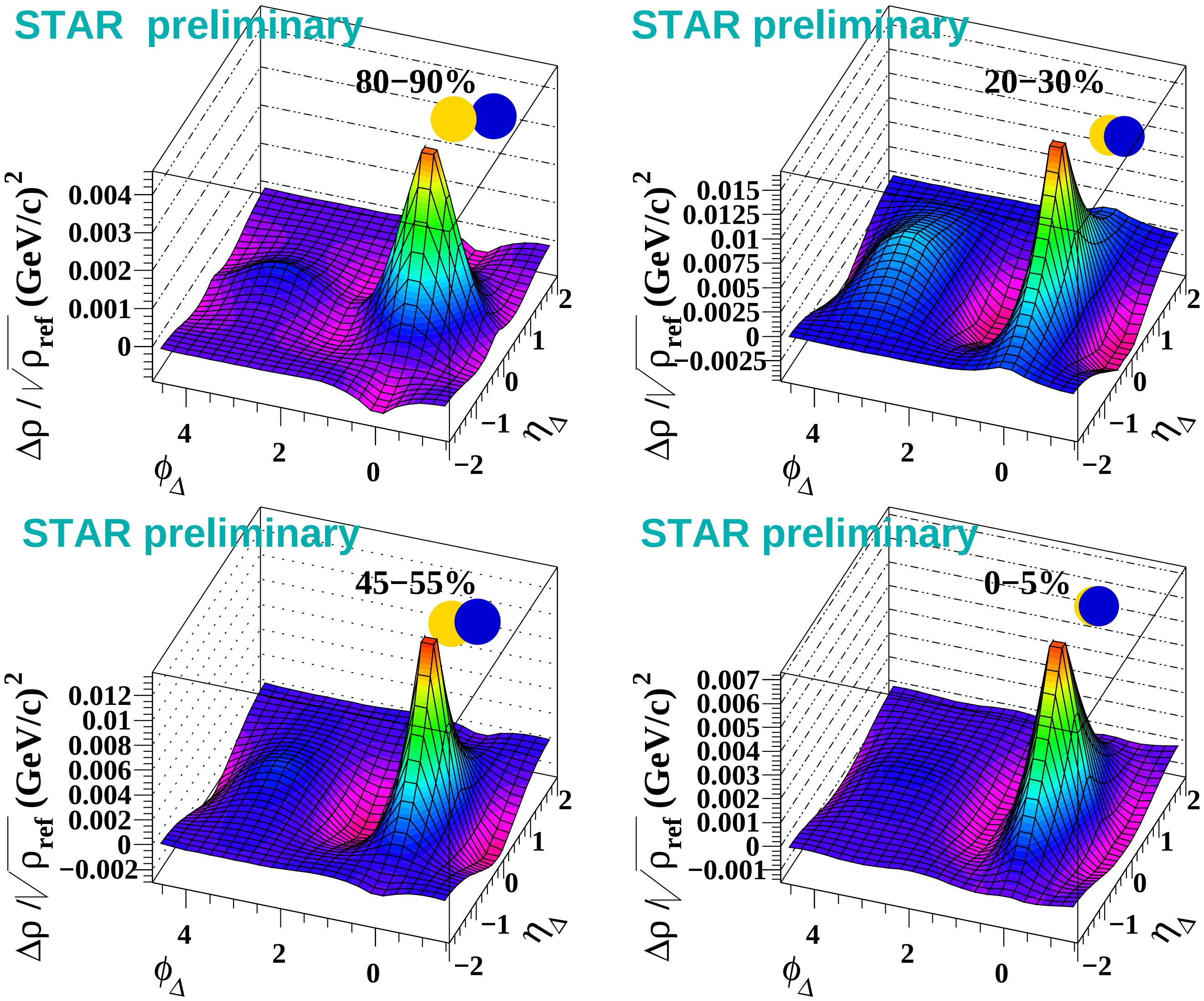
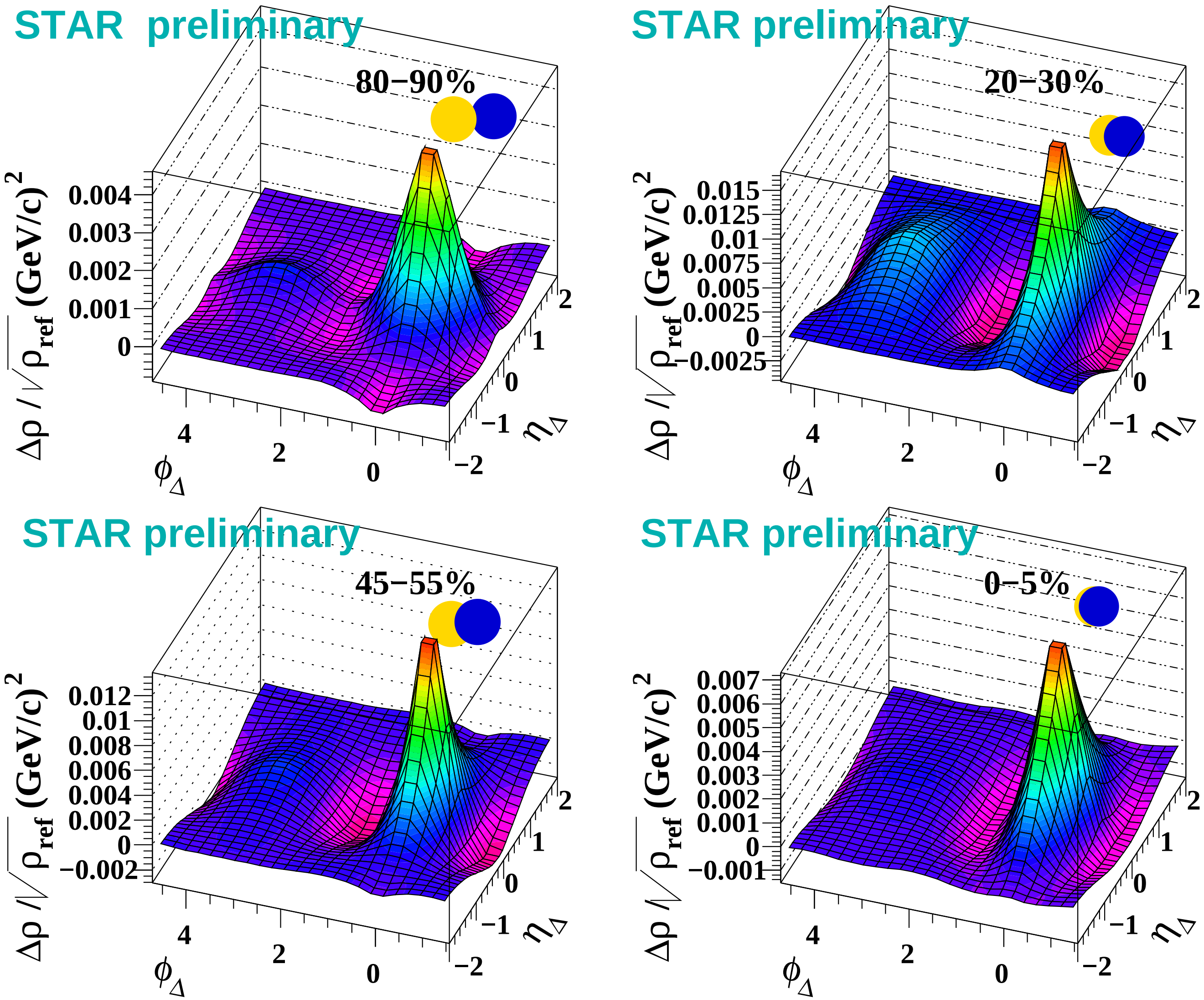




20 Localized p_t correlations: minijets



20 Localized p_t correlations: minijets



AuAu 200 GeV. In η, correlation broadens with centrality; in ϕ the trend is opposite. The surrounding background seems to recoil.

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- Increased symmetry of the charge-dependent correlation on (η,ϕ) in the central collisions may point to a change in the hadronization geometry in the medium

22 Extra slides

23 DWT of a photographic image

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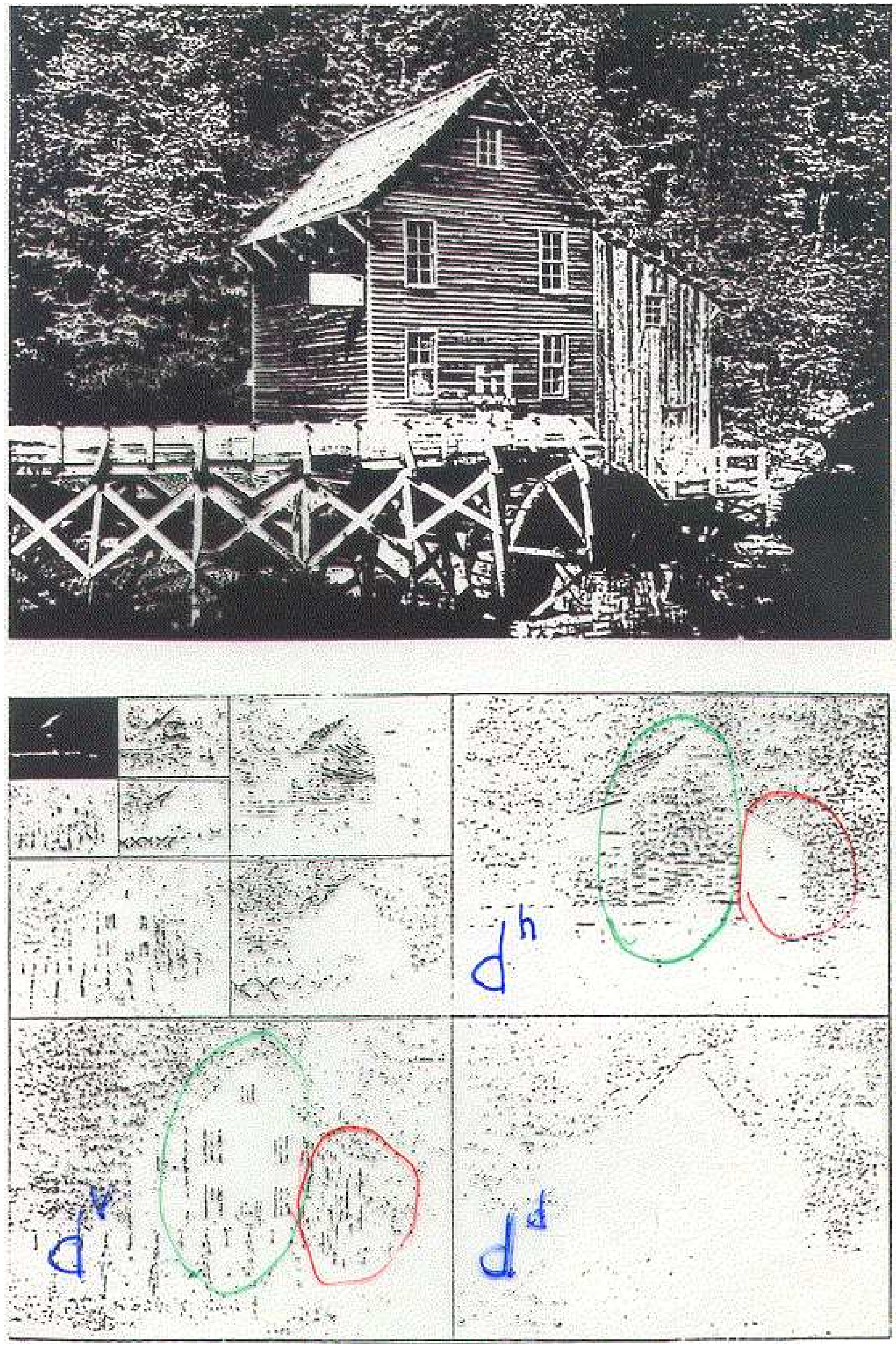
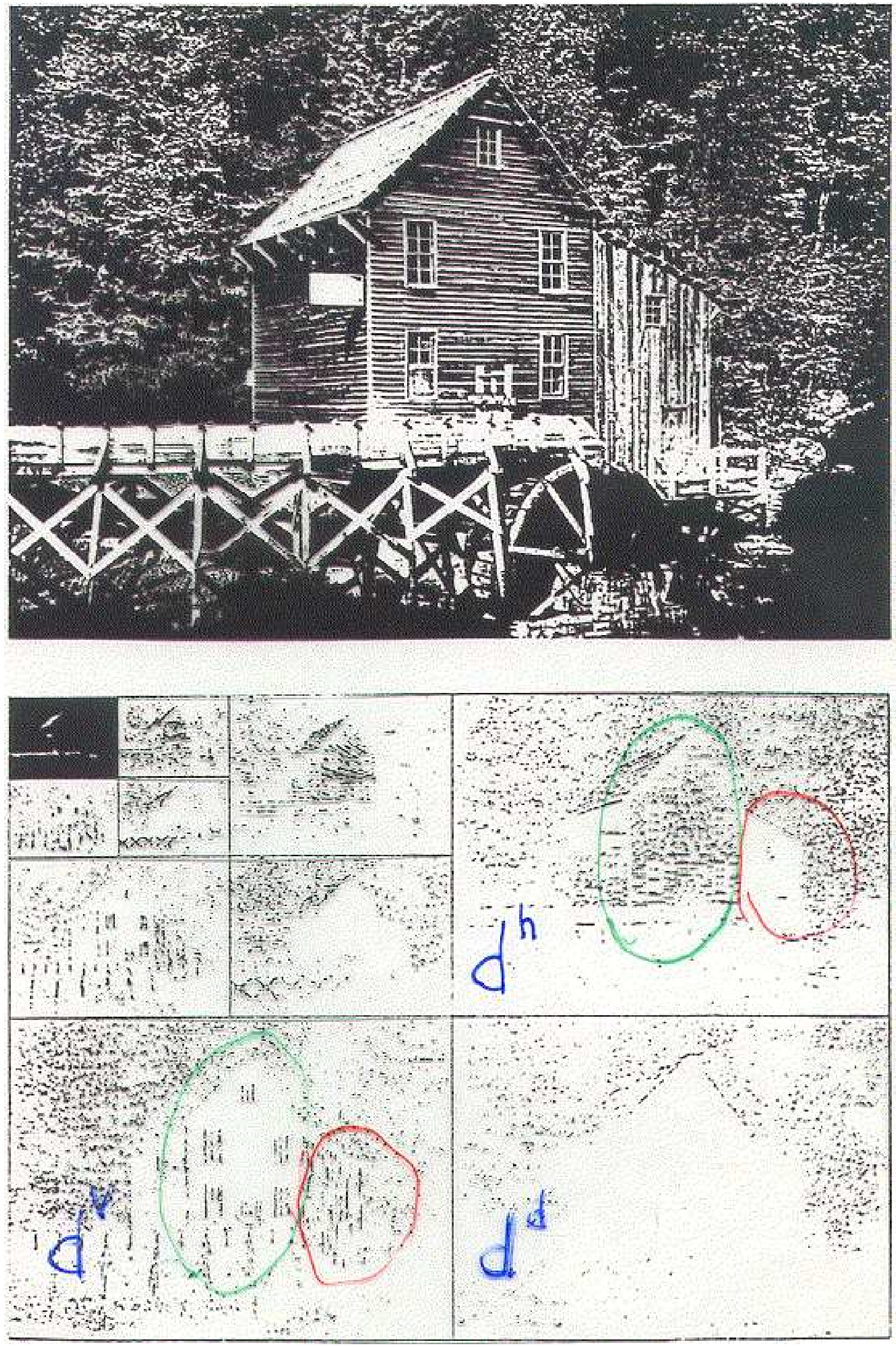


23 DWT of a photographic image



Reproduced from textbook: I.Daubechies, "Ten lectures on wavelets". The original caption: "A real image, and its wavelet decomposition into three multiresolution layers. On the wavelet components one clearly sees that the $d^{j,v}$,$d^{j,h}$,$d^{j,d}$ emphasize, respectively, vertical, horizontal, and diagonal edges. In this figure, the bottom picture has been overexposed to make details in the $d^{j,\lambda}$ more apparent. I would like to thank M.Barlaud for providing this figure." The colored marks are mine.